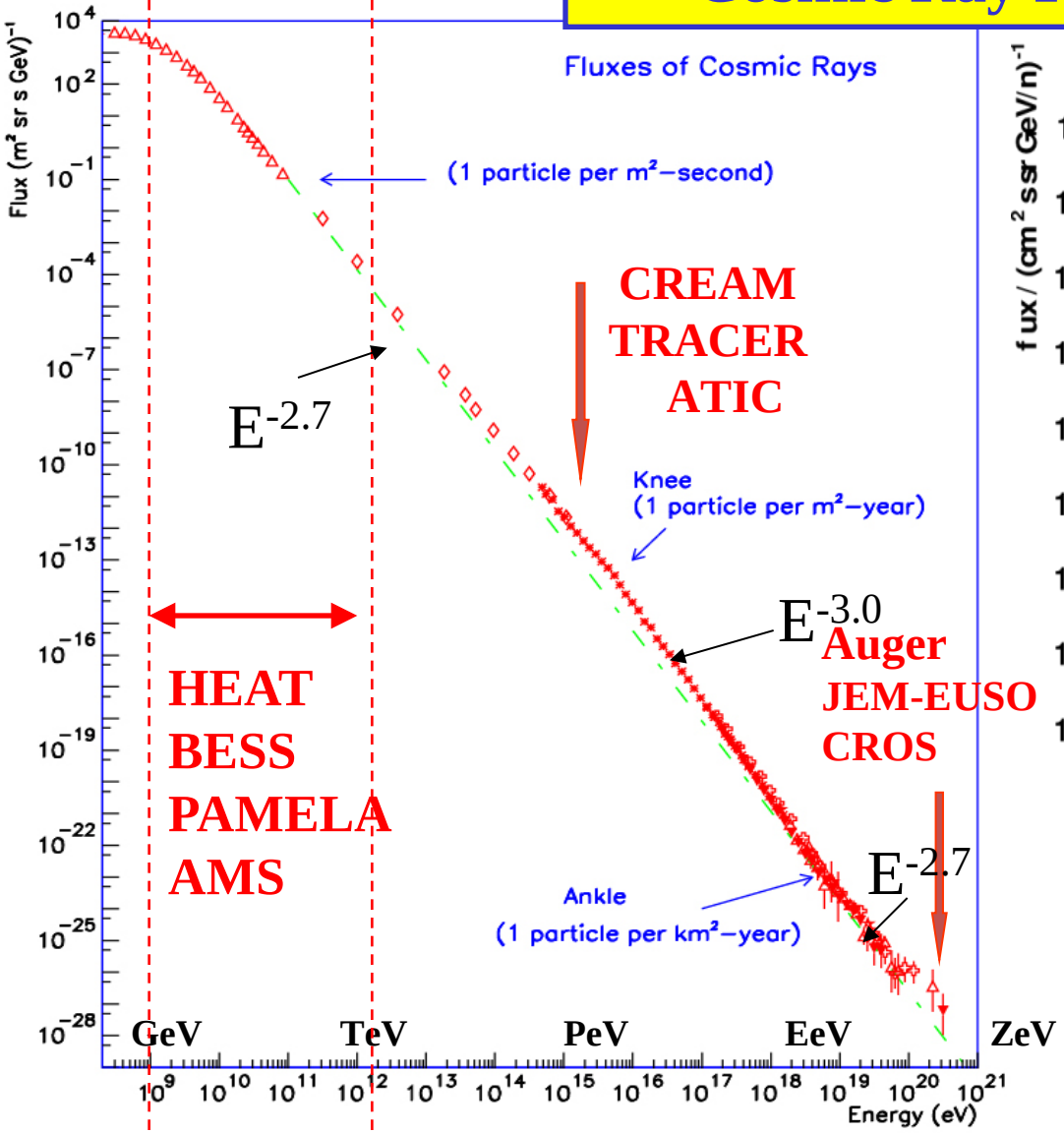
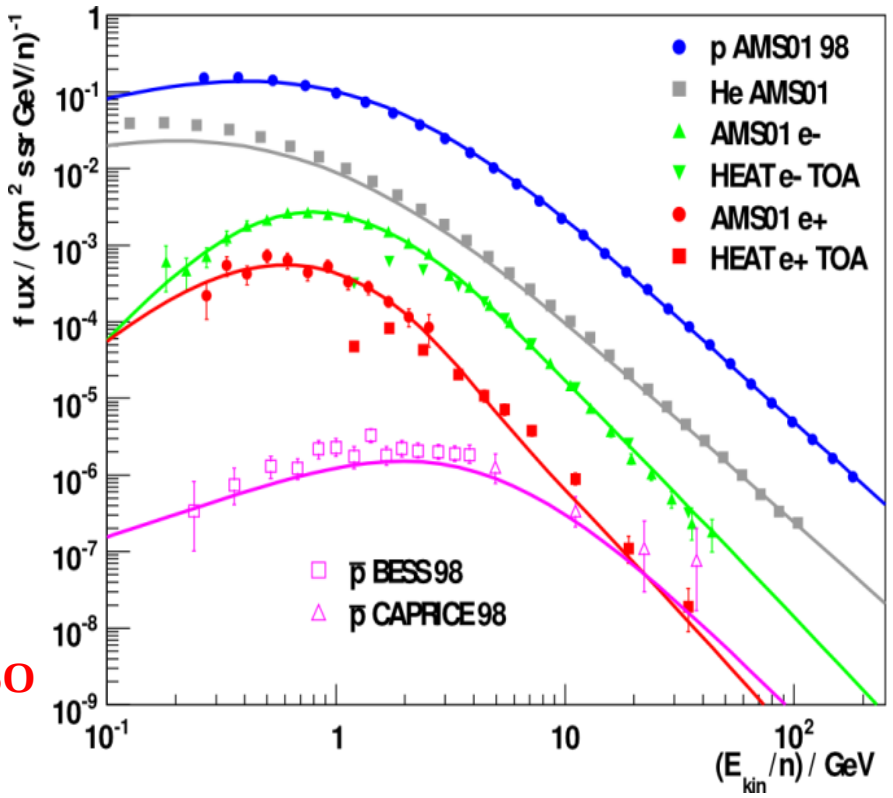
AMS-02 TRD

Thomas Kirn
RWTH Aachen University
CERN, November 28th

Cosmic Ray Fluxes

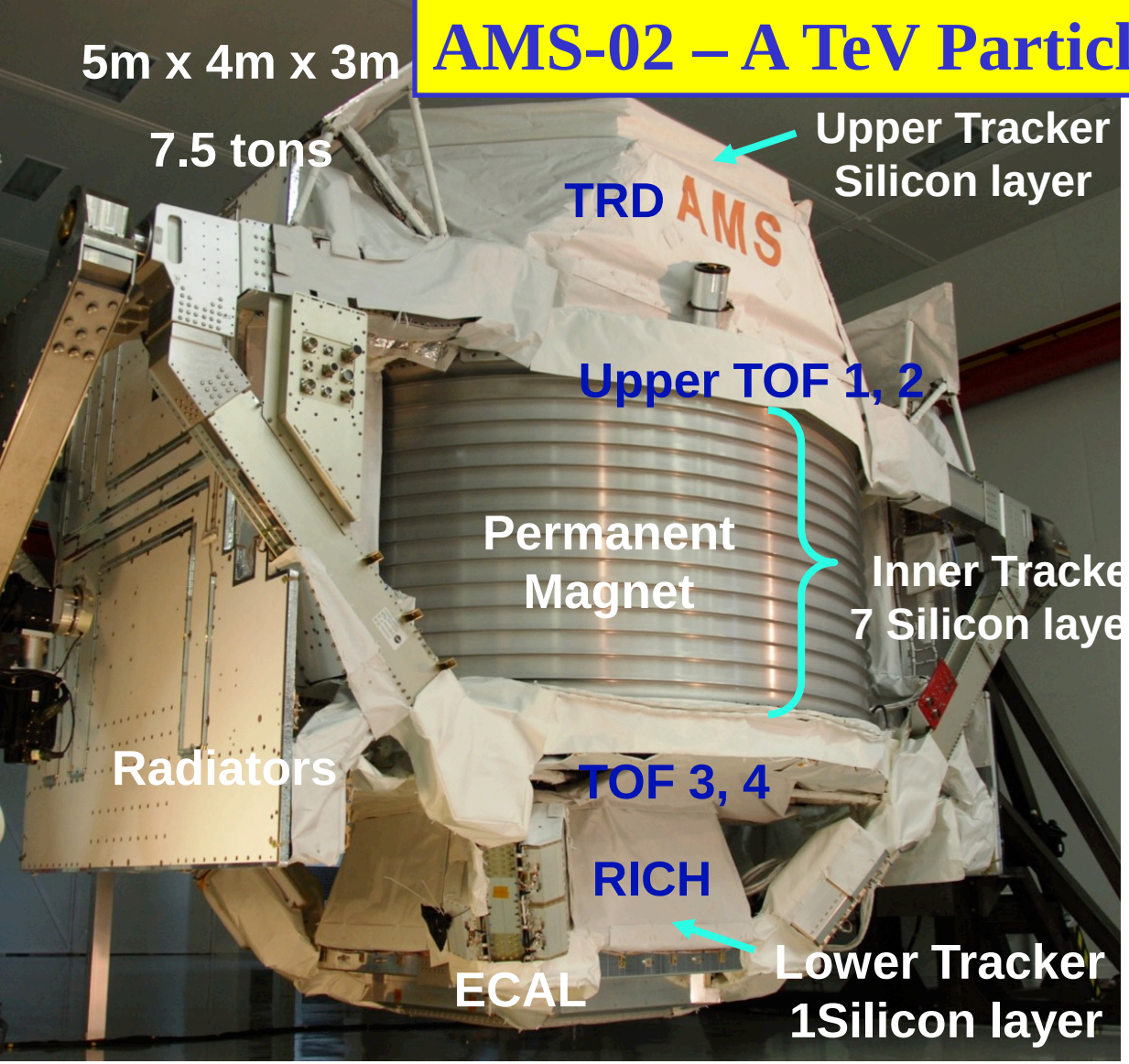


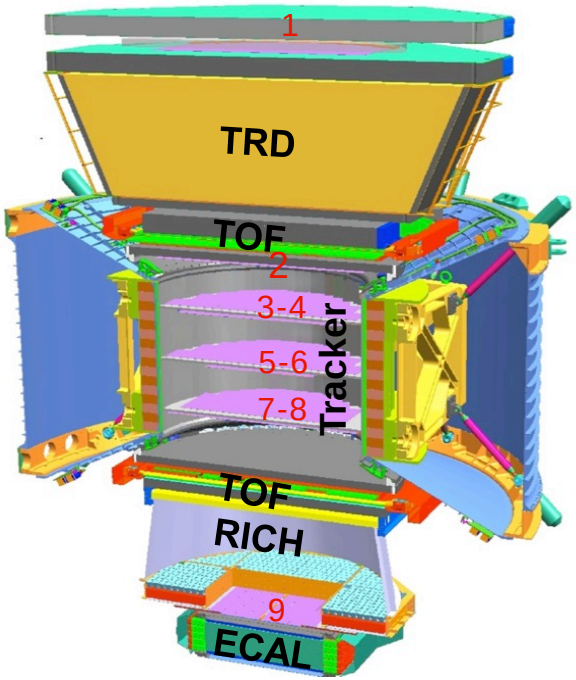


Cosmic Ray Composition:

Protons	88 %
Helium	10 %
e^-	1 %
e^+	0.1 %
Antiprotons	0.01 %

AMS-02 – A TeV Particle Spectrometer





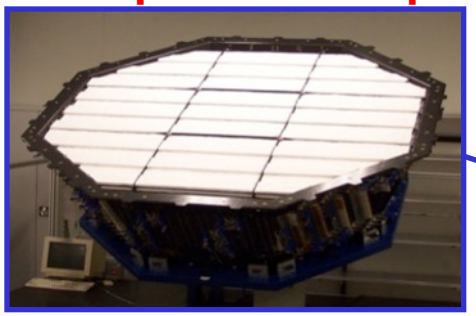
ISS Lifetime extended until at least 2020 / 2028 (March 2010)

→ Switch to AMS-01 permanent magnet (B=0.14T)
→Tracker reconfigured
→ 'external' layers

AMS-02 – A TeV Particle Spectrometer

TRD

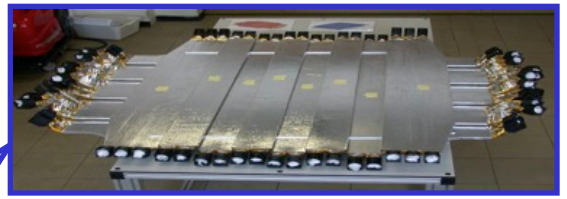
Separation $e^{\pm}$:p

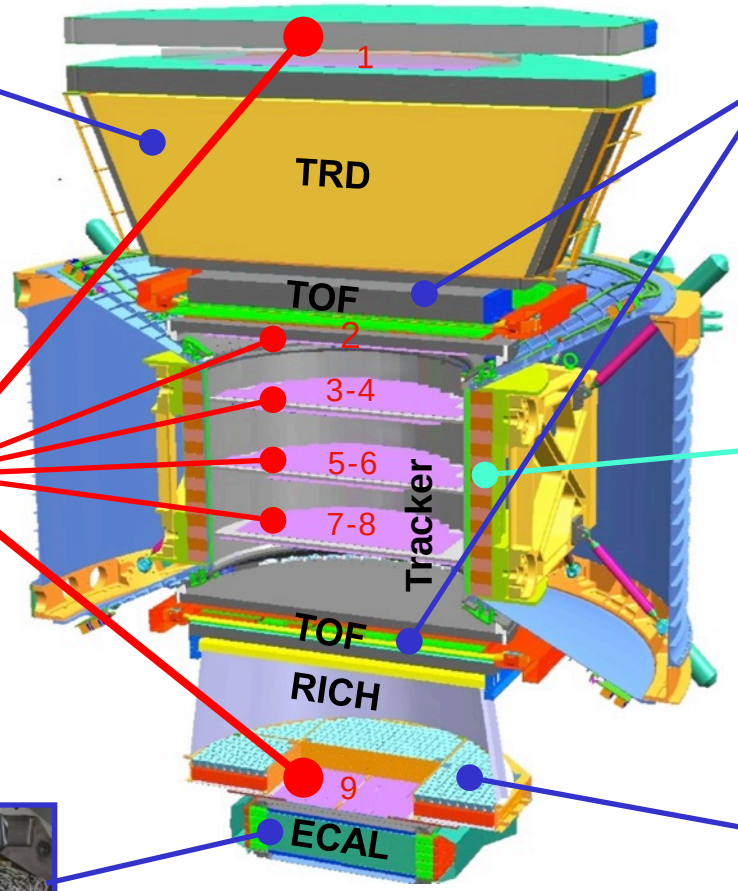


Particles and nuclei are defined by their charge (**Z**) and energy (**E ~ P**)

TOF

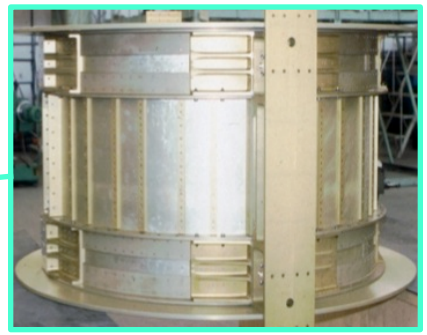
Z, E





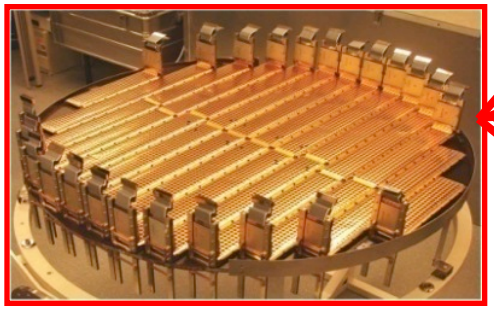
Magnet

± Z



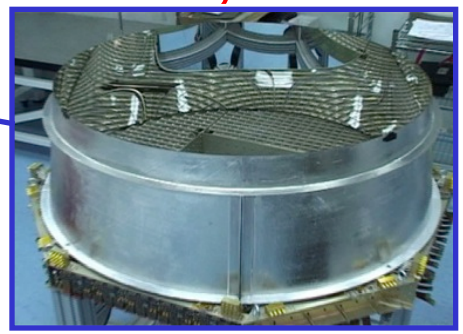
Silicon Tracker

Z, P



RICH

Z, E



ECAL

E of $e^{\pm}$, γ

***Z, P** are measured independently by the Tracker, RICH, TOF and ECAL*

AMS-02 – Transition Radiation Detector (TRD)

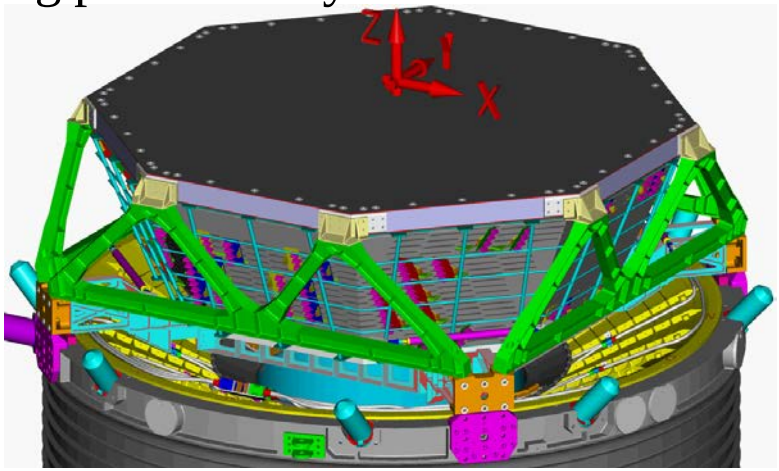
Choosen configuration for 60 cm height:

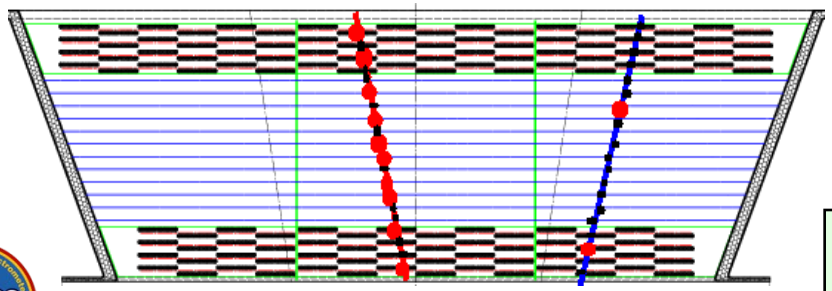
20 Layers each existing of:

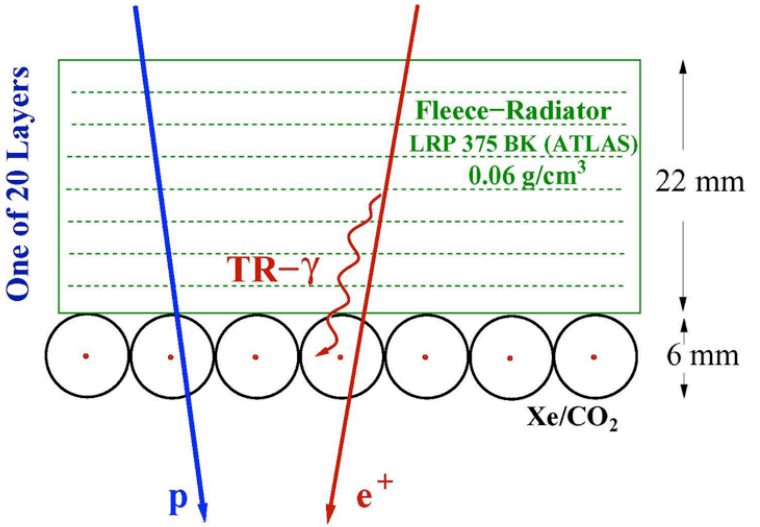
- 22 mm fibre fleece
- Ø 6 mm straw tubes (Xe/CO_2 80%/20%)

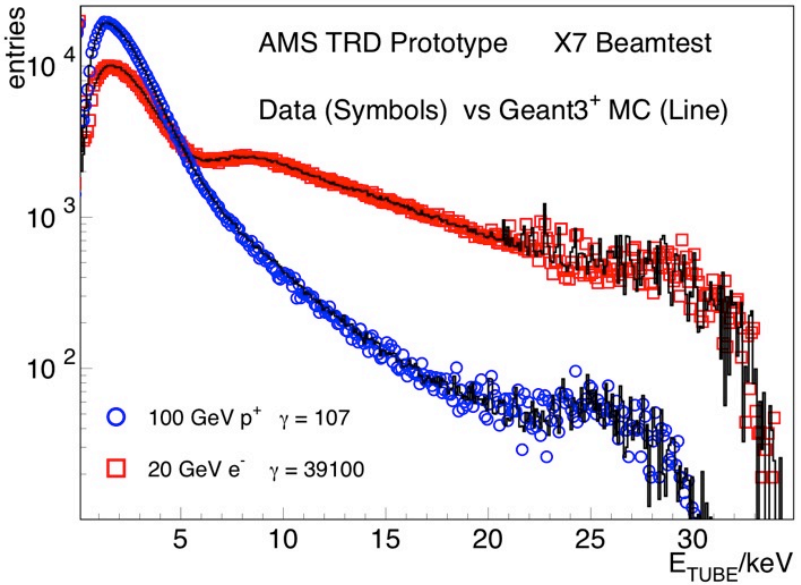
Non-bending plane: 2x4 layers

Bending plane: 12 layers



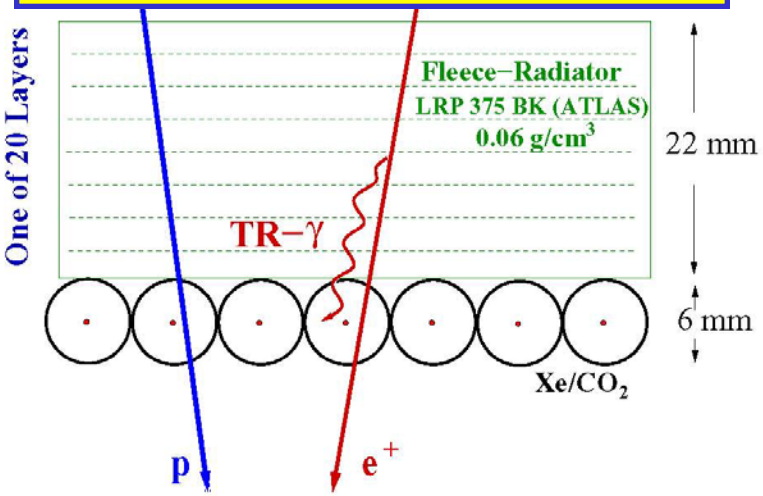


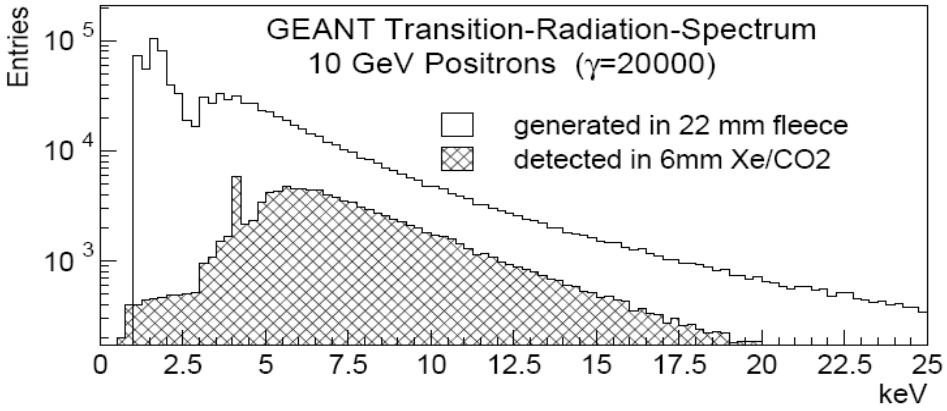


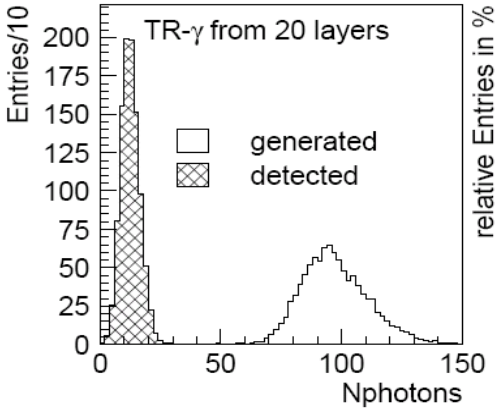


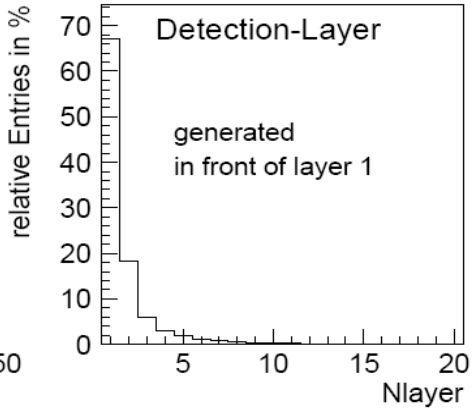
p^+ rejection $>10^2$ 1-300 GeV 0.5m^2sr

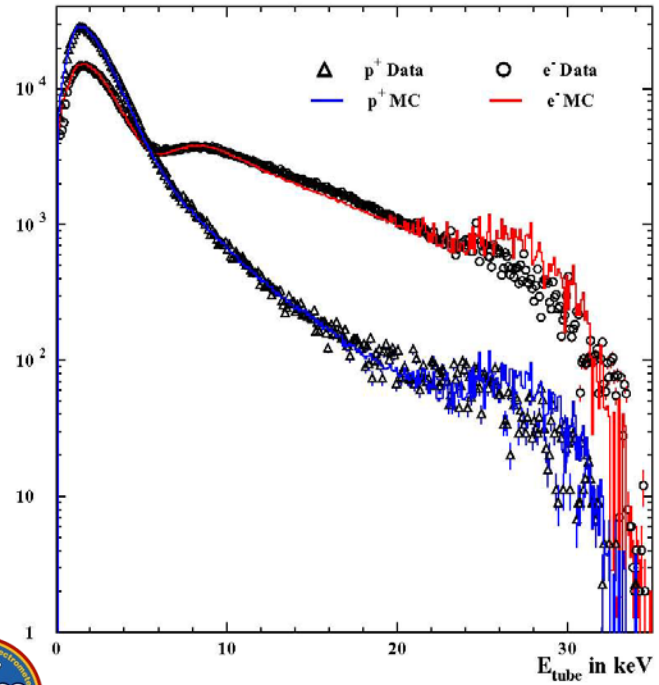
AMS-02 - TRD

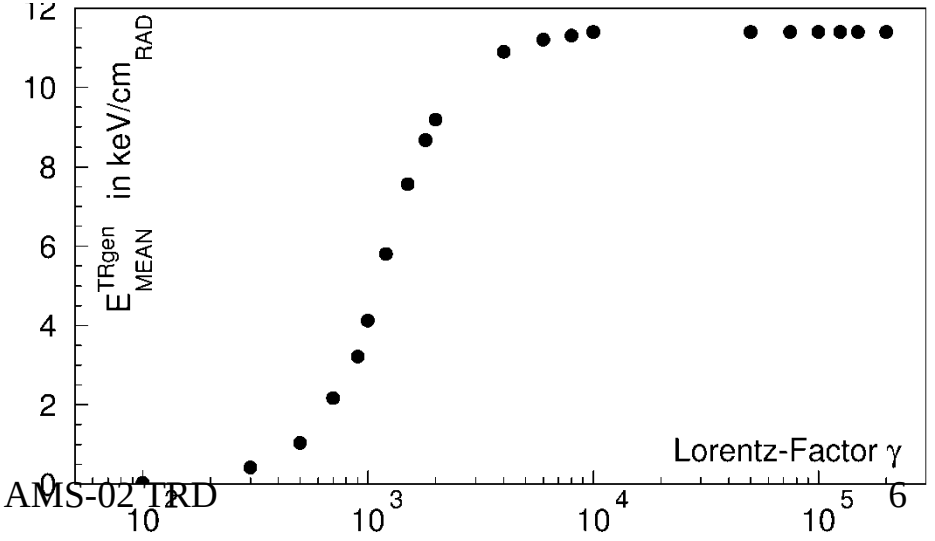

One of 20 Layers
Fleece−Radiator
LRP 375 BK (ATLAS)
0.06 g/cm3
22 mm
TR−γ
6 mm
Xe/CO2
p
e+


GEANT Transition-Radiation-Spectrum
10 GeV Positrons (γ=20000)
generated in 22 mm fleece
detected in 6mm Xe/CO2
Entries
keV

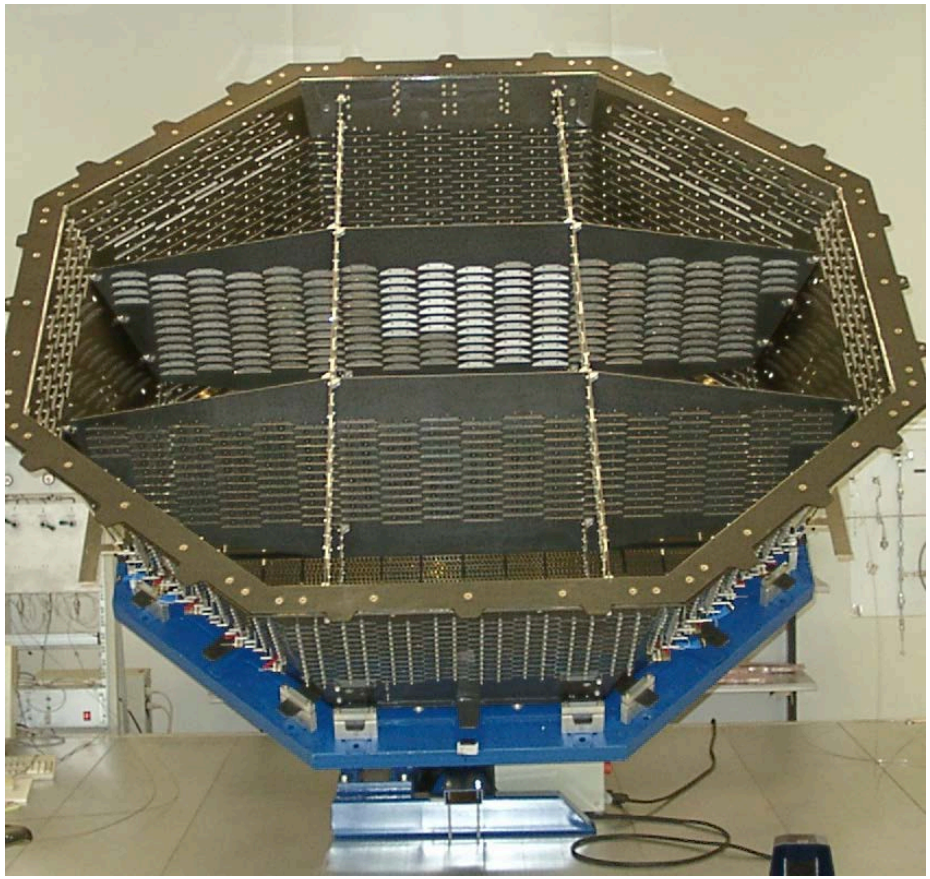

TR-γ from 20 layers
generated
detected
Entries/10
Nphotons

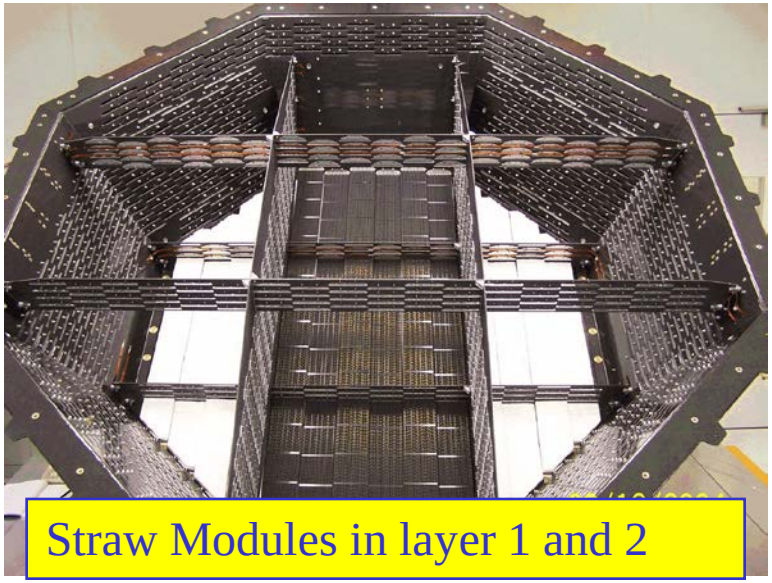

Detection-Layer
generated
in front of layer 1
relative Entries in %
Nlayer


p+ Data
p+ MC
e- Data
e- MC
Etube in keV


E TRgen MEAN in keV/cm RAD
Lorentz-Factor γ

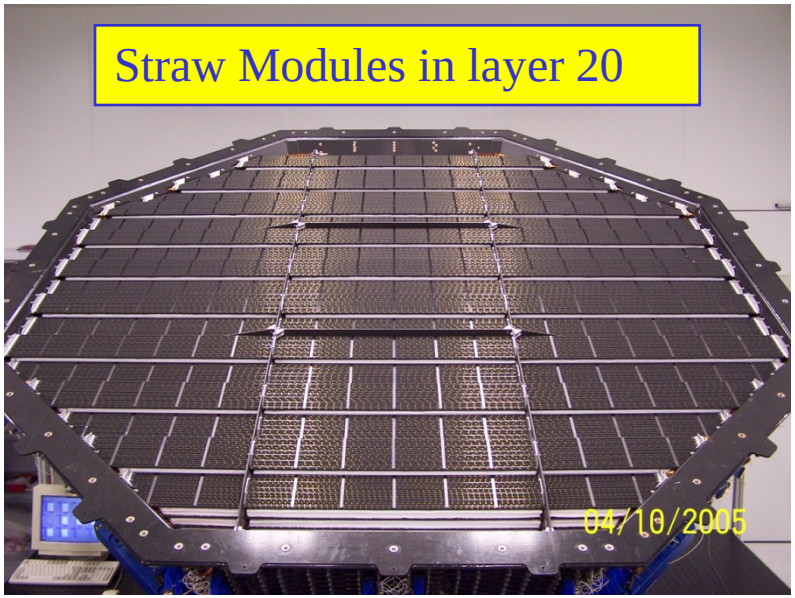
AMS-02 – Transition Radiation Detector (TRD)





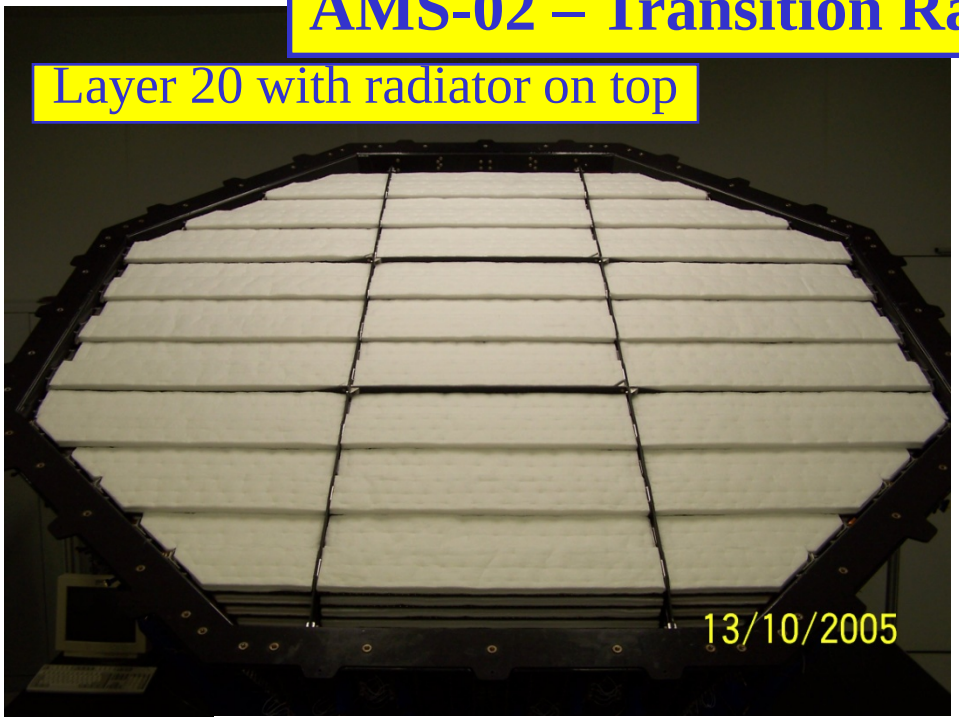
Straw Modules in layer 1 and 2

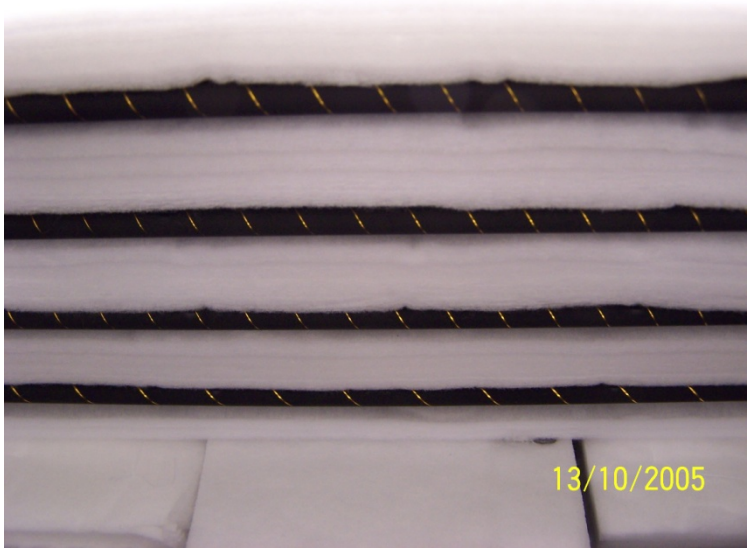
Straw Modules in layer 20

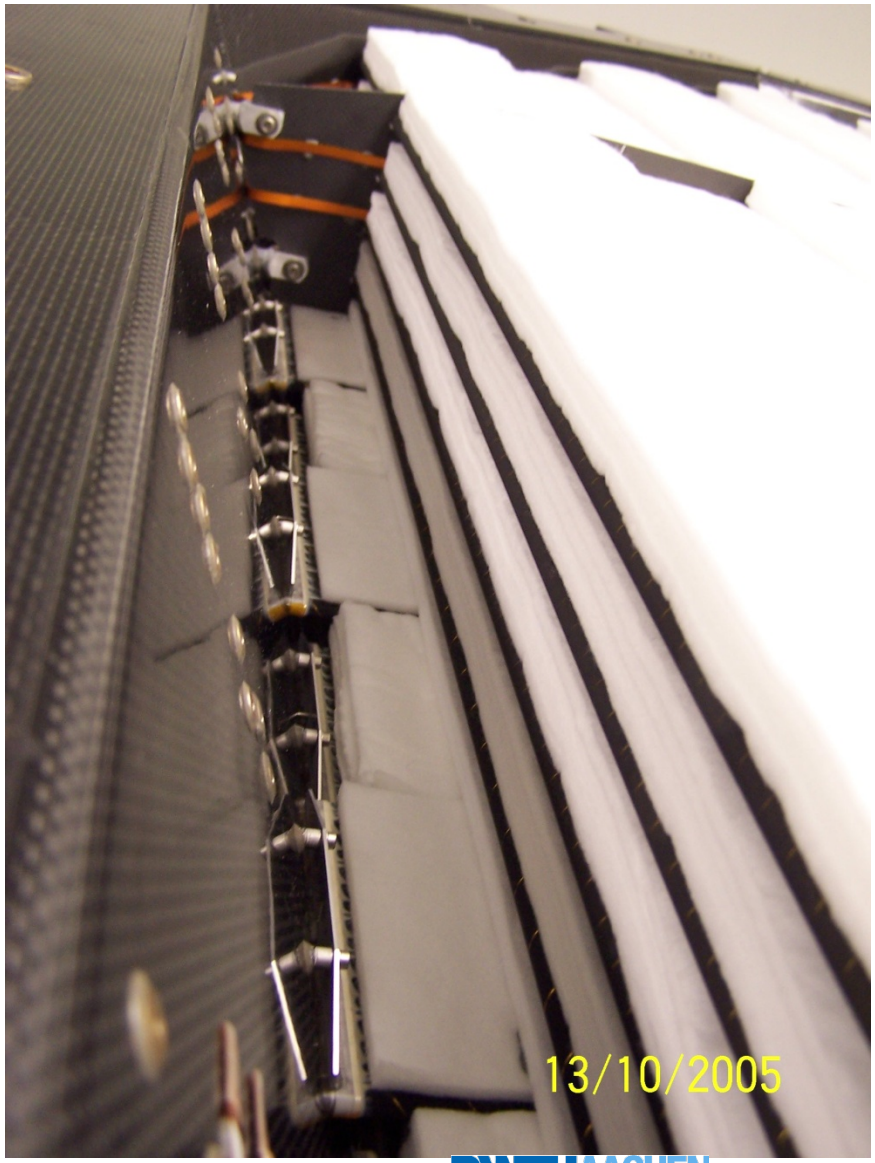


AMS-02 – Transition Radiation Detector (TRD)

Layer 20 with radiator on top



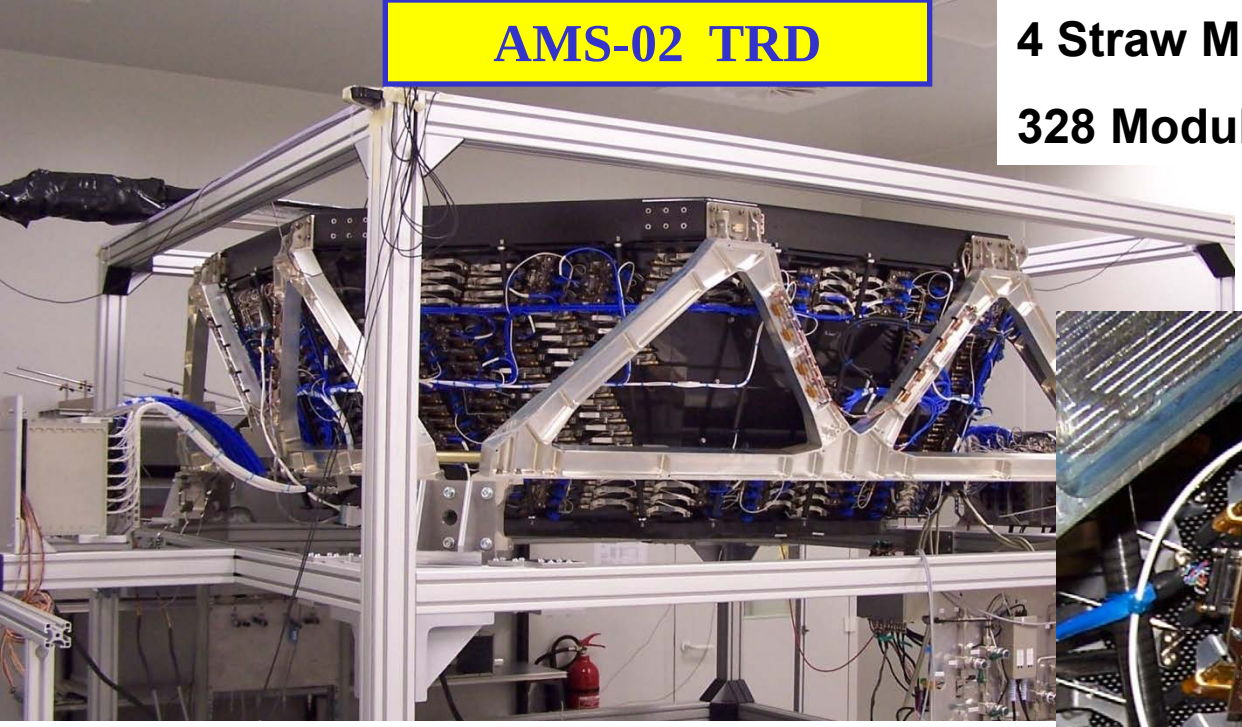


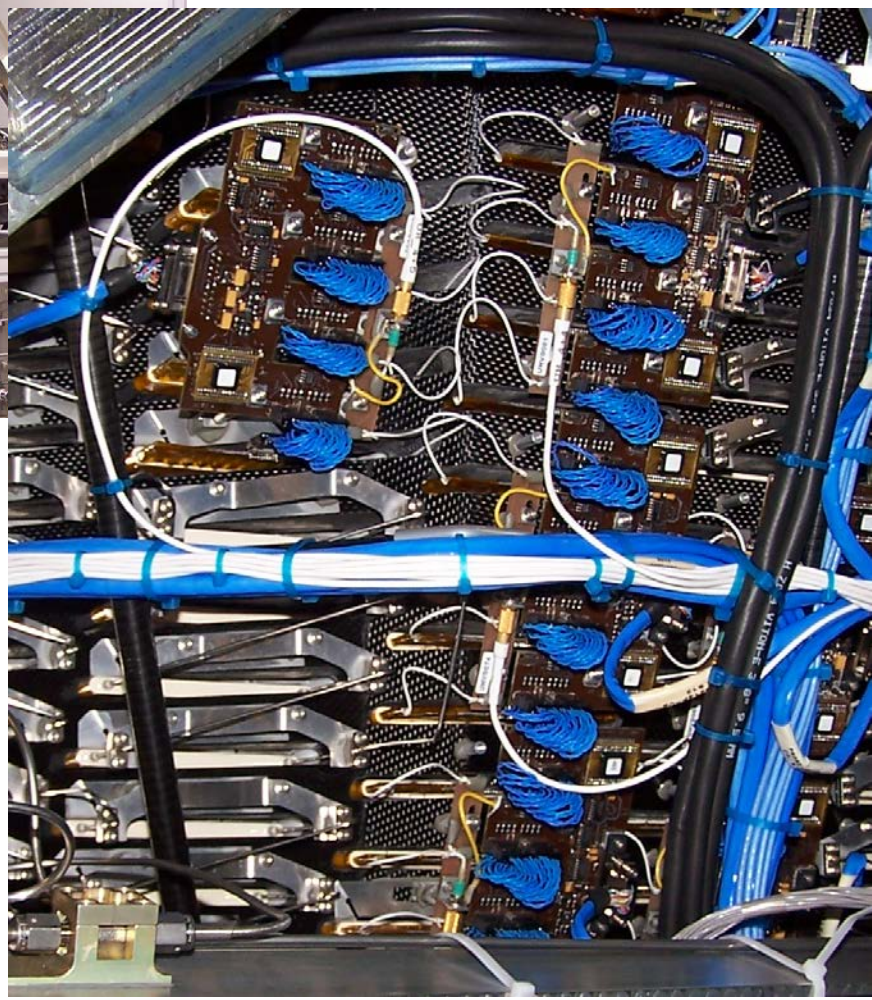


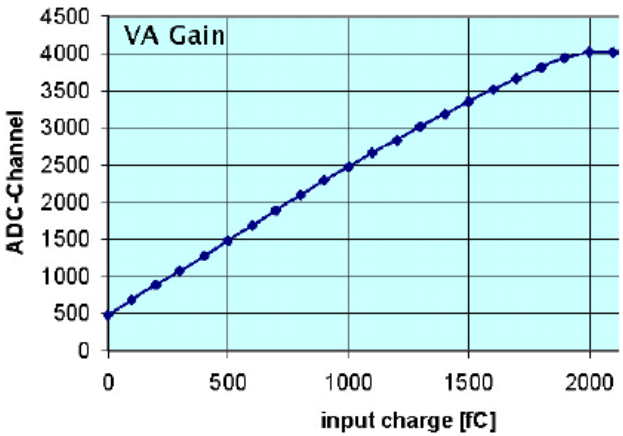
AMS-02 TRD

4 Straw Modules → 1 Readout Group

328 Modules → 82 Readout Groups



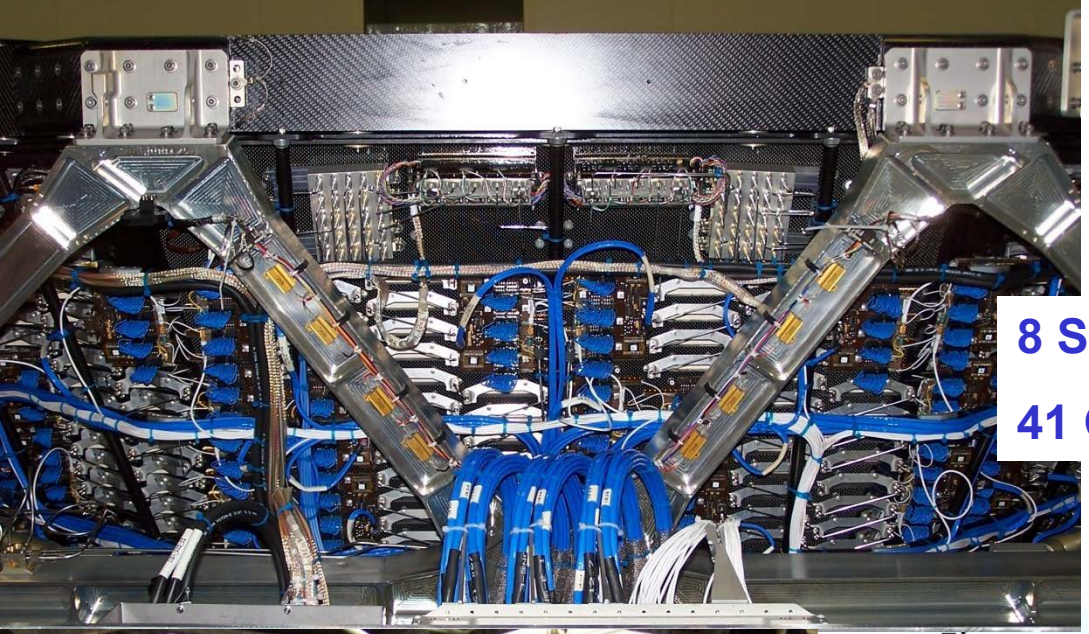




Power: 20W/5248 Channels

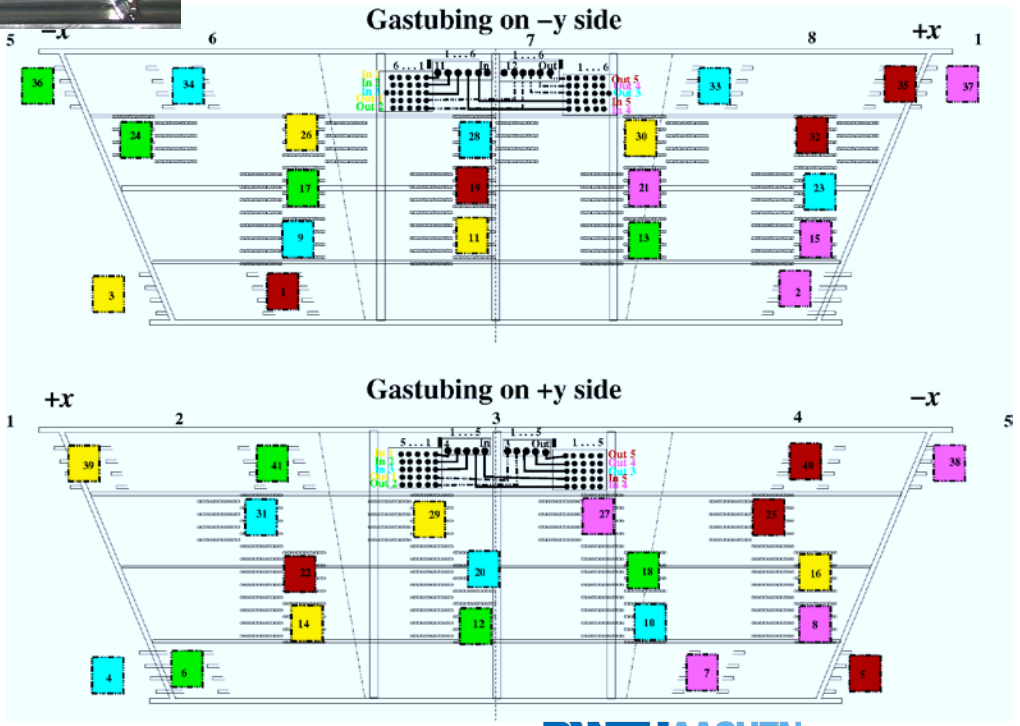
MIP MOP (G=3000)	30 fC 60 bins
MIP S/N	> 60/2
Range	60 MIPs

AMS-02 TRD



8 Straw Modules → 1 Gas Tower

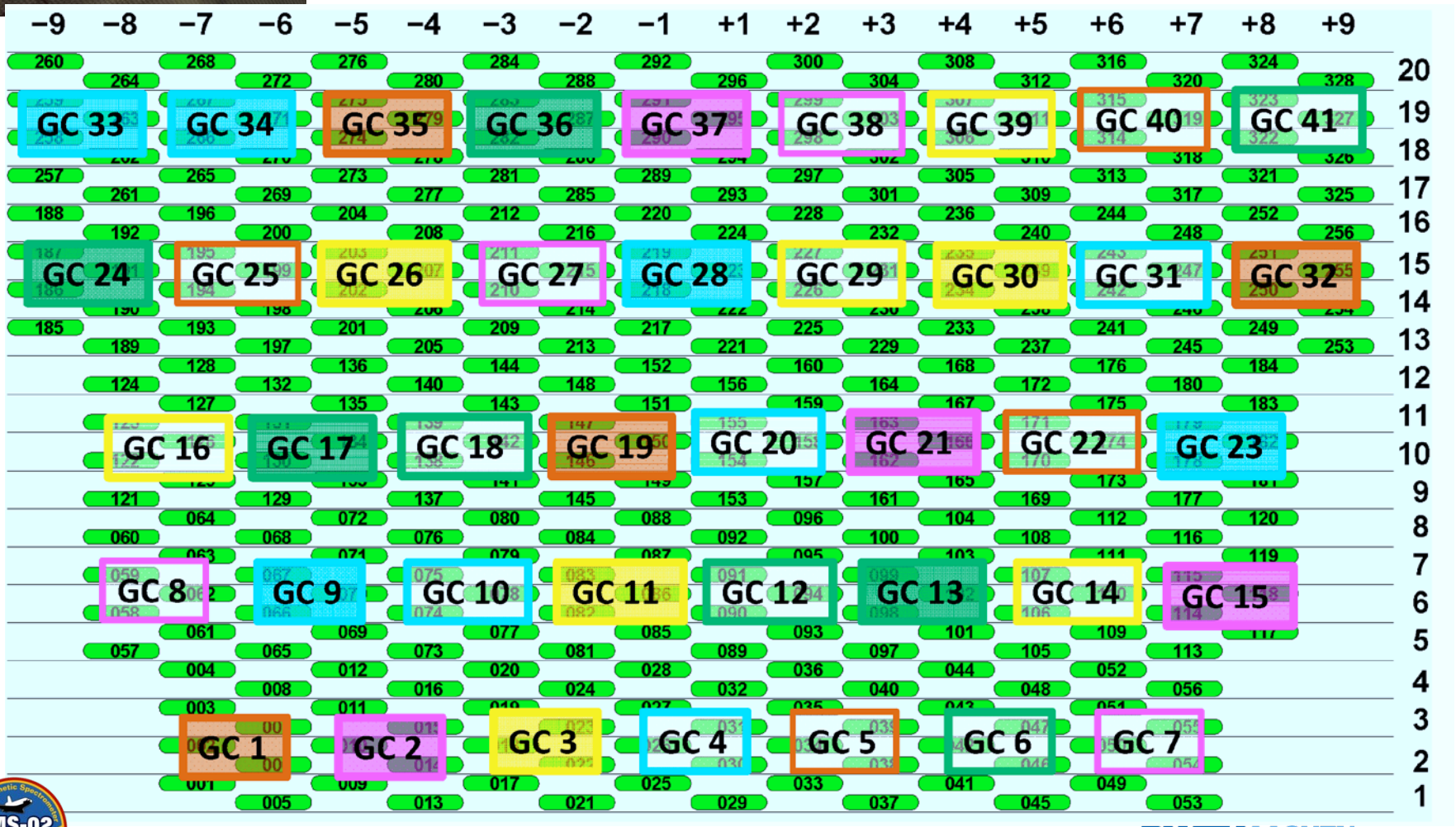
41 Gas Towers → 10 Gas Circuits



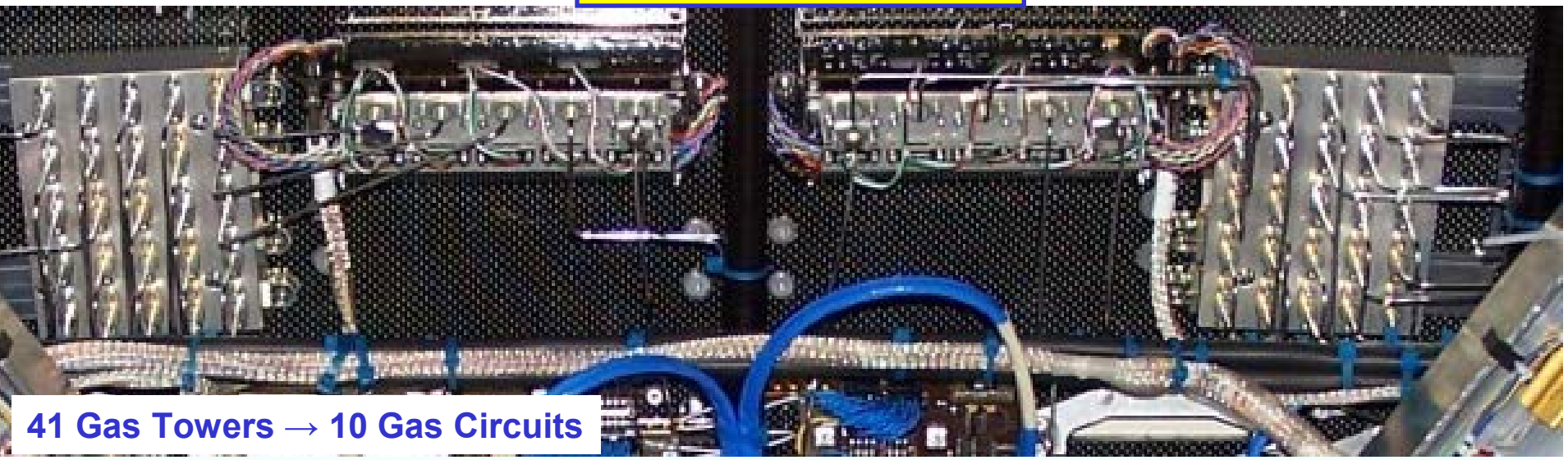
AMS-02 TRD: Gas System

AMS-02 TRD

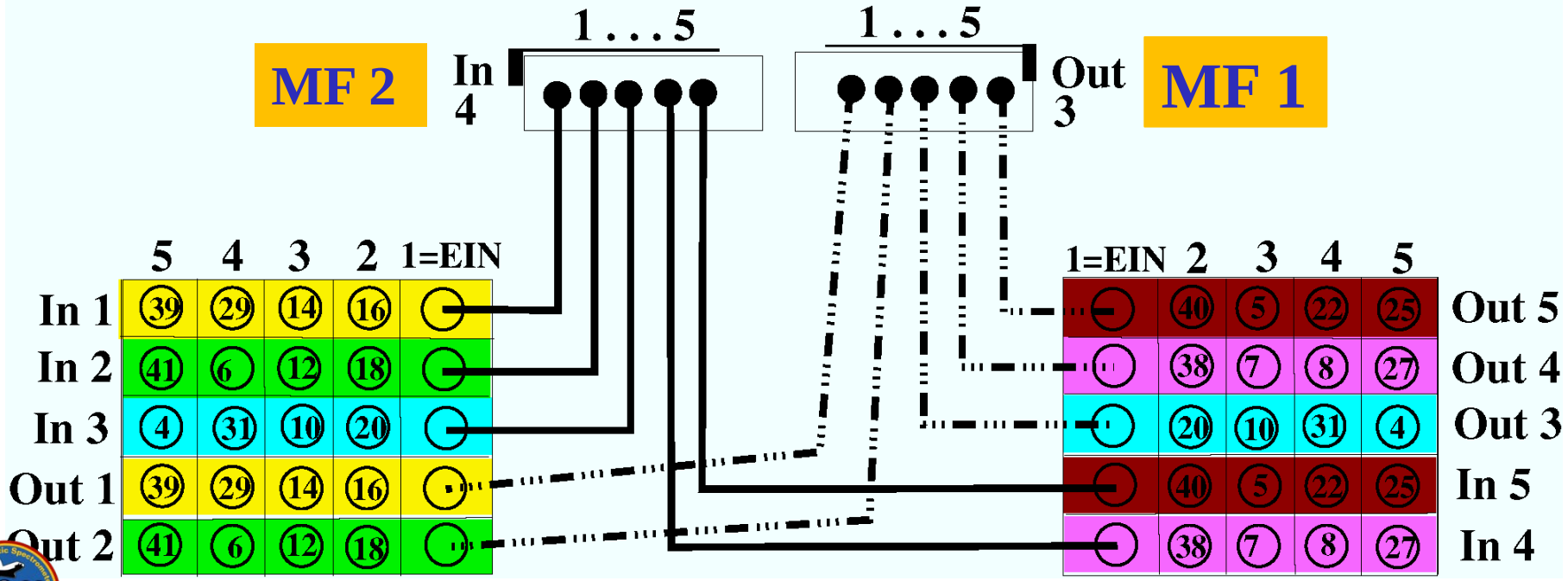
8 Straw Modules → 1 Gas Tower → 41 Gas Towers



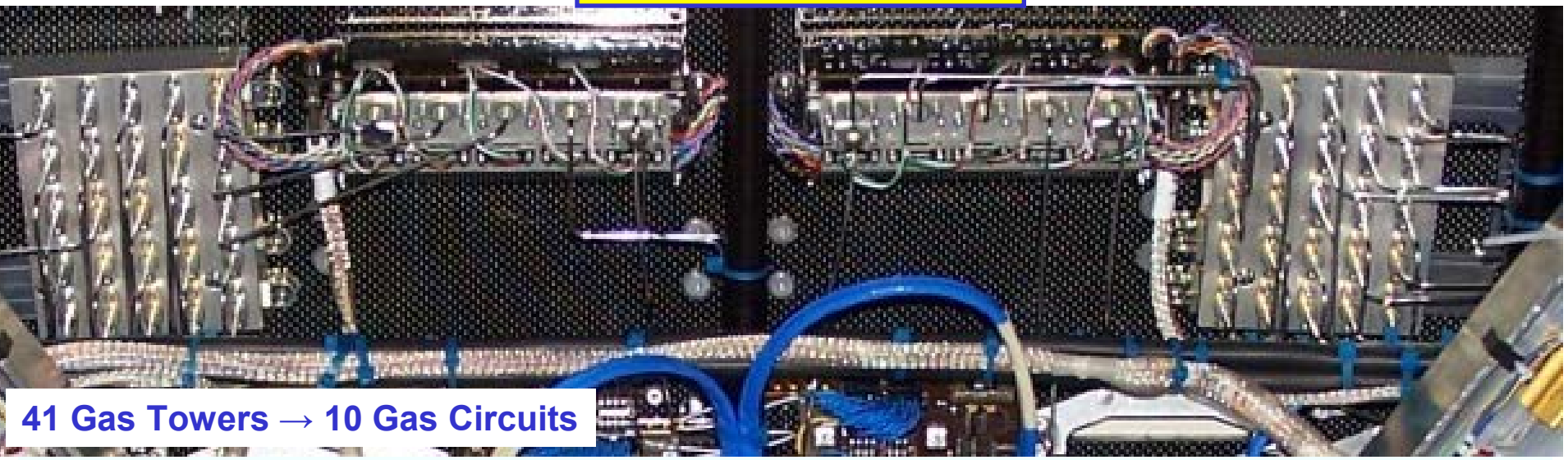
AMS-02 TRD



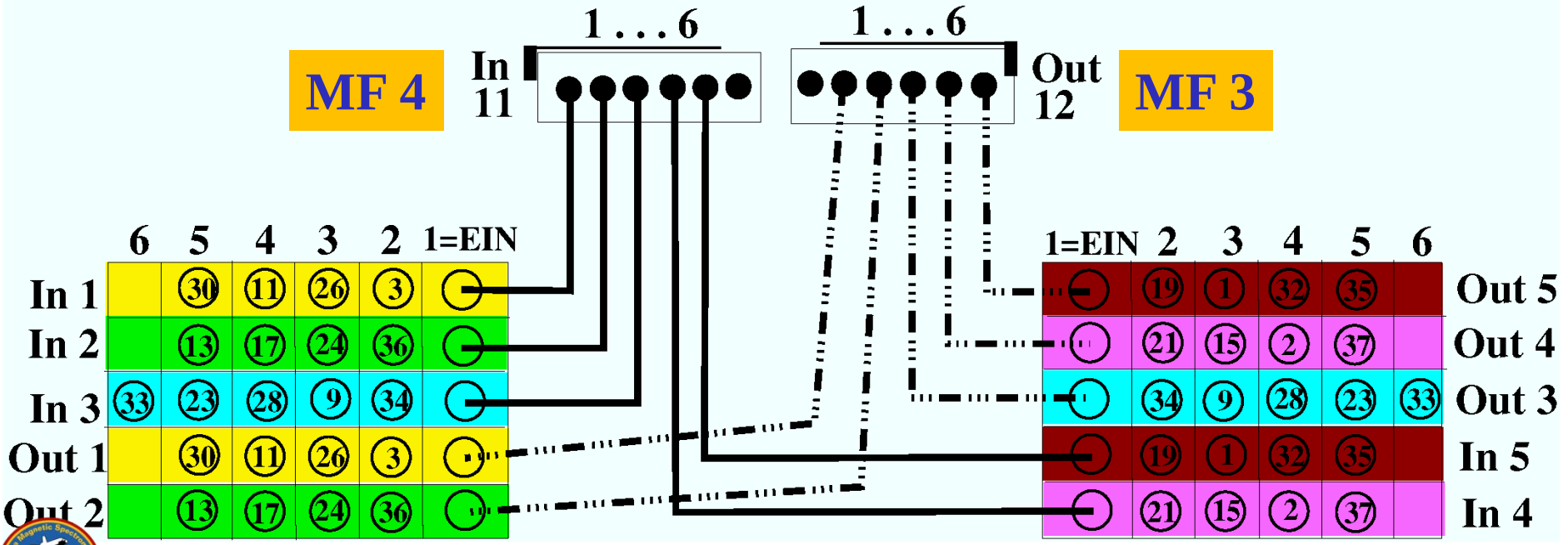
41 Gas Towers → 10 Gas Circuits



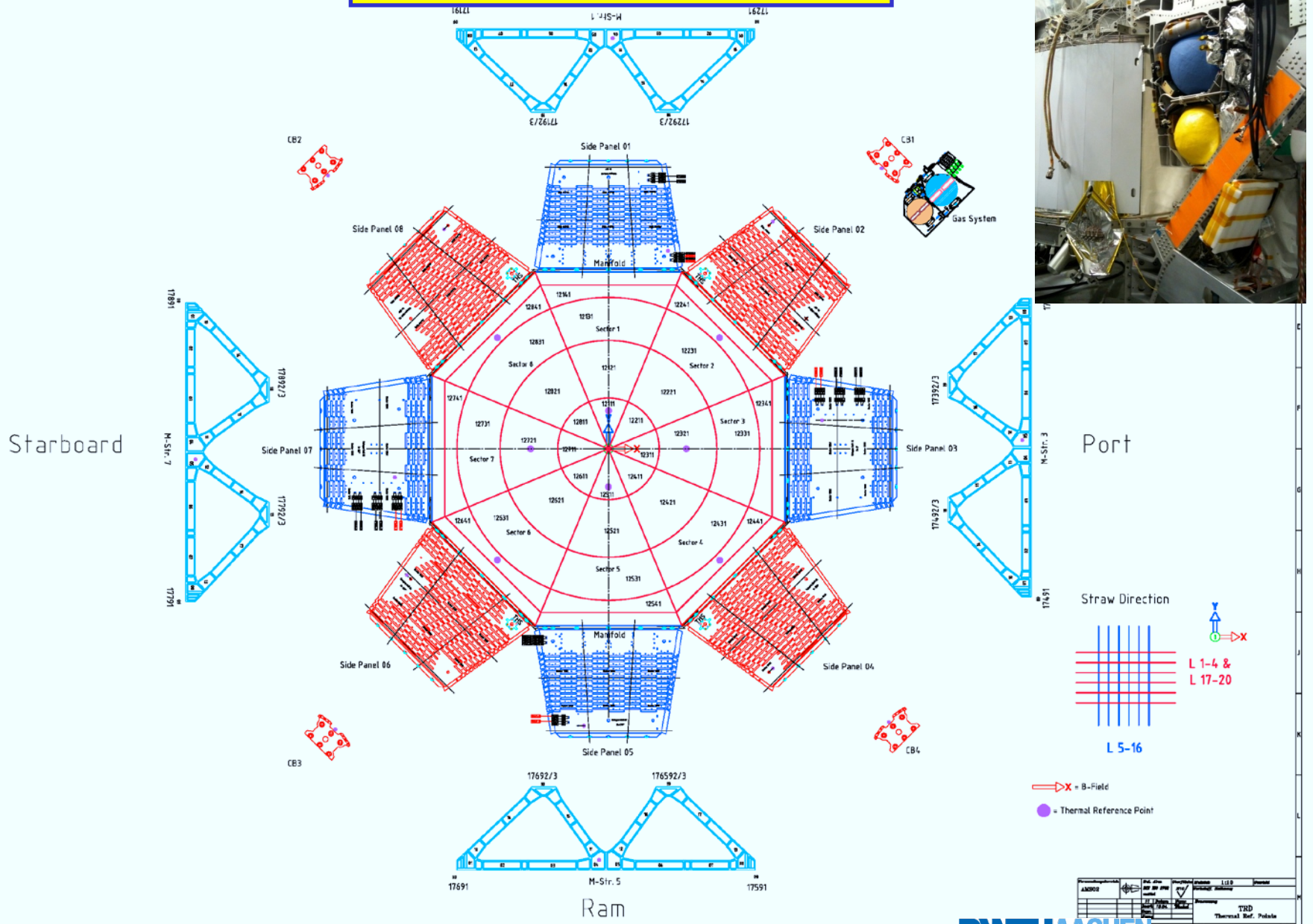
AMS-02 TRD



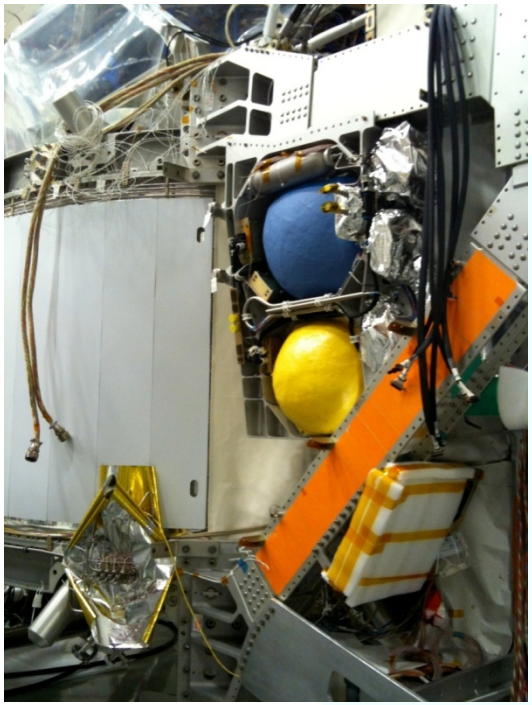
41 Gas Towers → 10 Gas Circuits

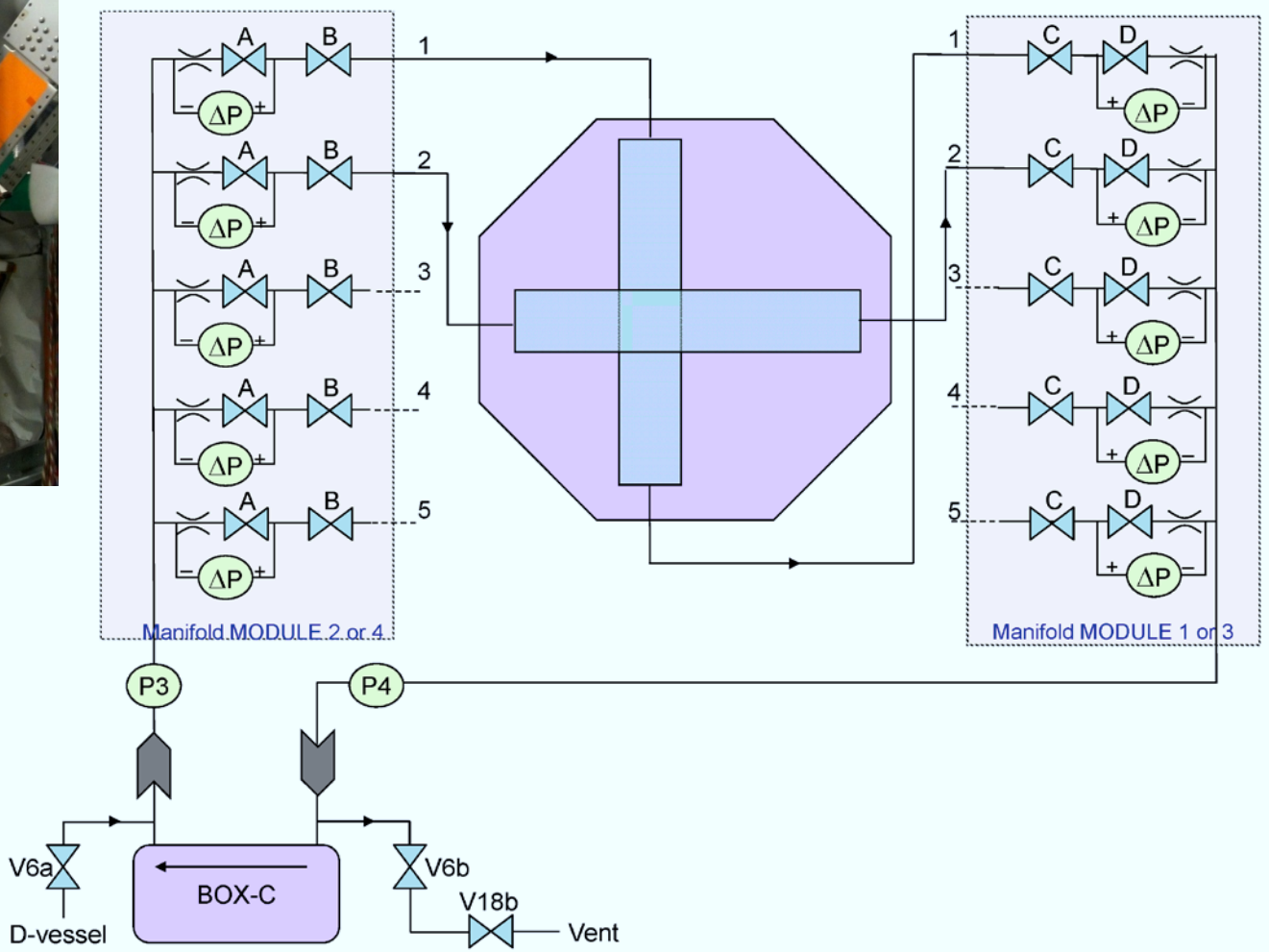


AMS-02 TRD Gassystem

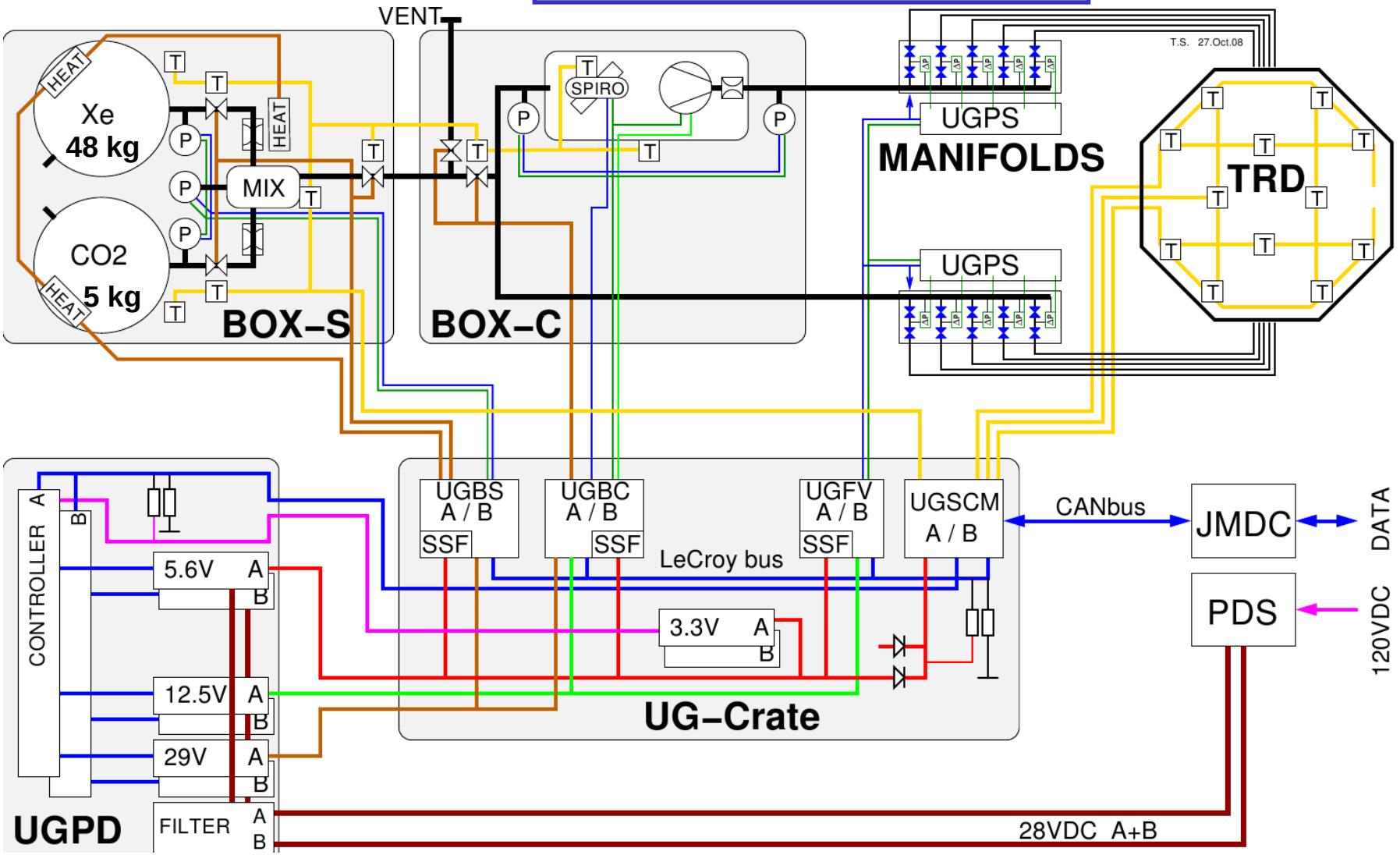


AMS-02 TRD Gassystem





AMS-02 TRD Gassystem



AMS-02 TRD: Radiator

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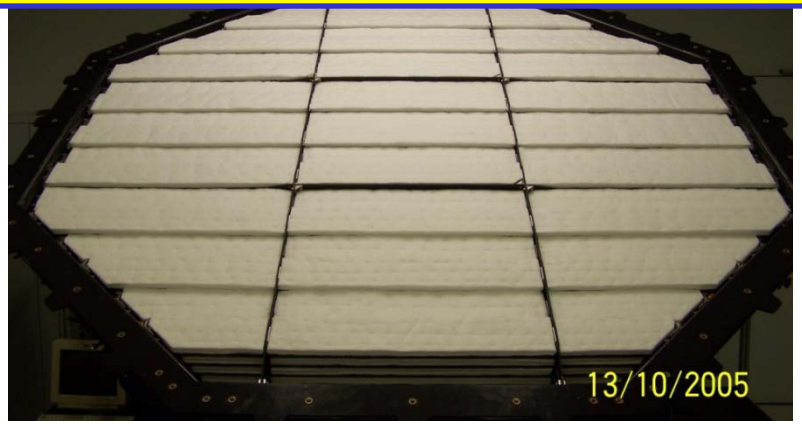


Radiator LRP 375 BK:

Polyethylene/Polypropylene fibers

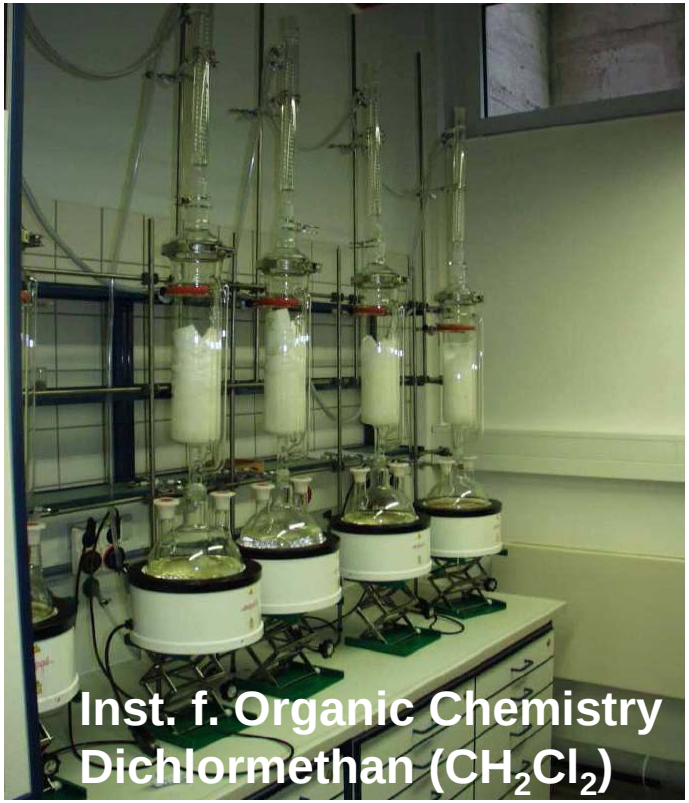
Effective fiber diameter: 10 μm

Radiator thickness: 22 mm

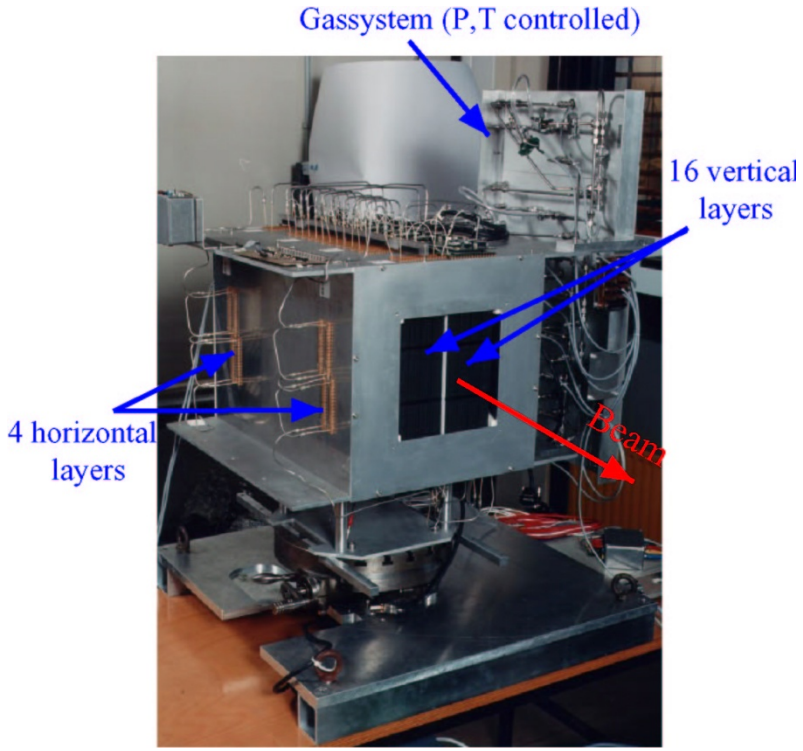
Density: 0.06 g/cm^3

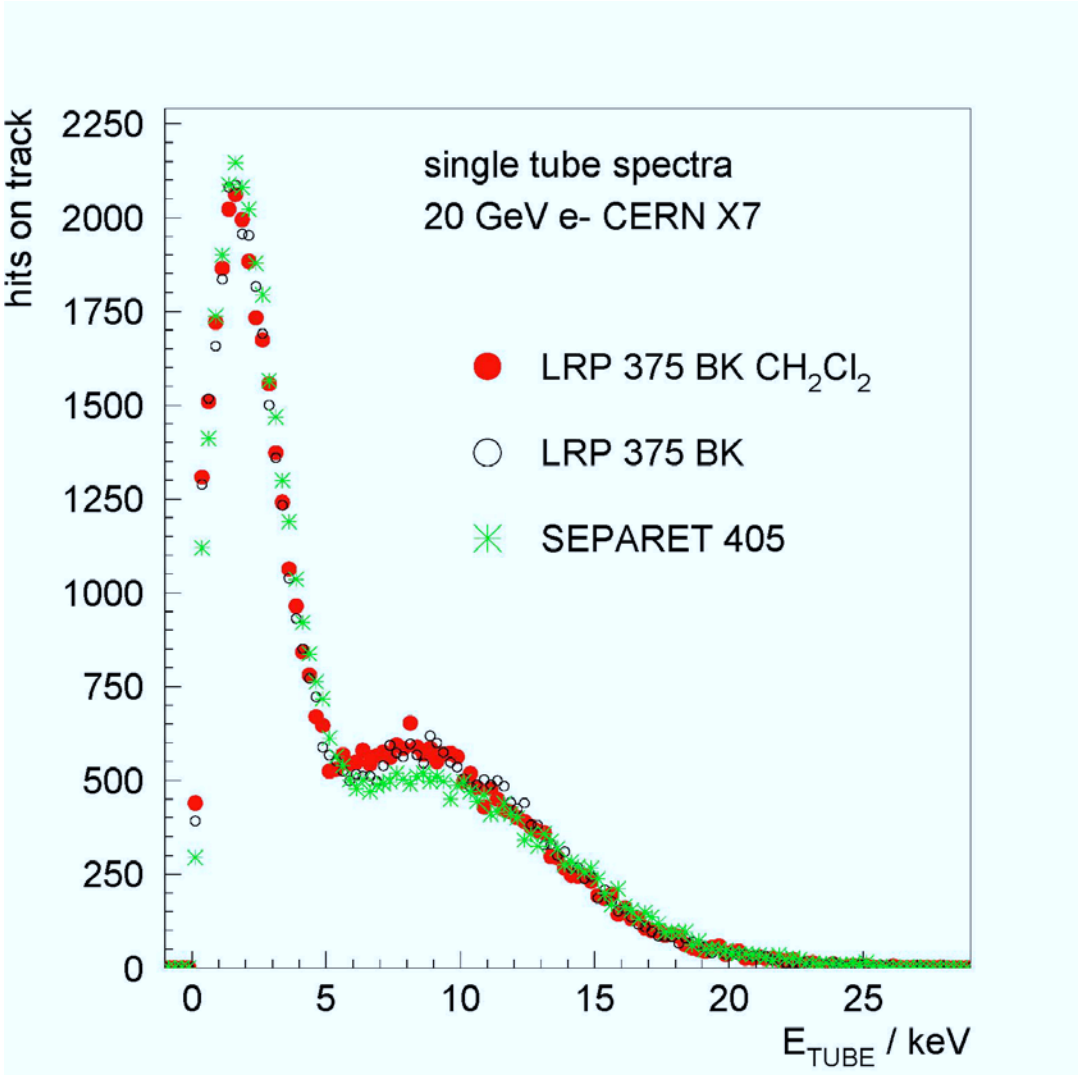
Cleaning with Dichlormethane CH_2Cl_2

→ dM/dt ≈ 10^{-12} g/s/cm^2



AMS-02 TRD: Radiator



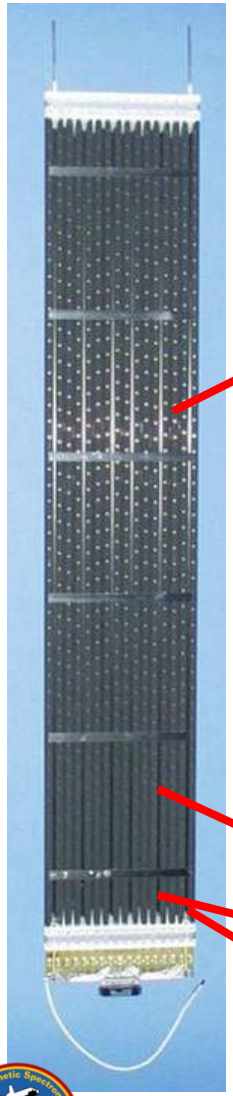


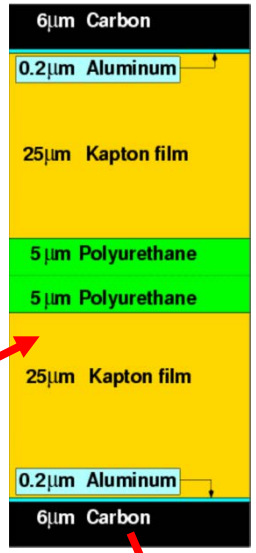
AMS-02 TRD: Straw Modules

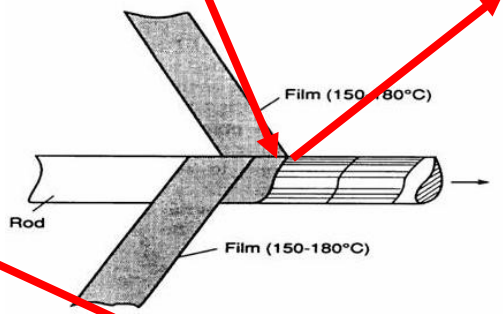
AMS-02 – TRD: Straw Modules

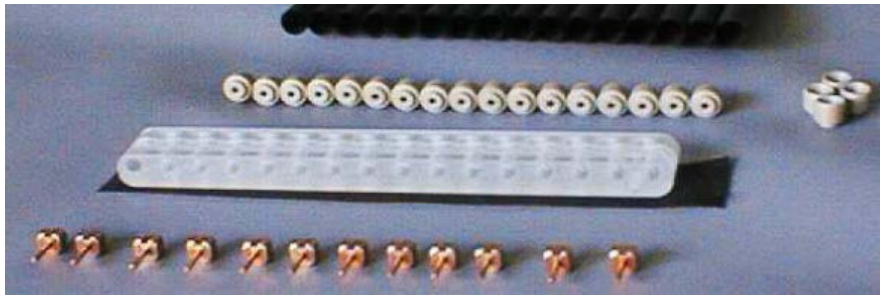
Straw tube proportional counter modules:

- Straw tubes: 72 μm multilayer aluminium kapton foil, Ø 6 mm , 0.8 2.0 m length
- Wire: tungsten anode wire, 30 μm Ø, tension ≈ 100 g
- Gas mixture: Xe / CO_2 (80% / 20%) → to be optimized
- Operating HV ~ 1460 V → Gasgain of ~ 3000
- 1 Module → 16 Straws, 100 μm mechanical accuracy
- 328 Modules → 5248 Straws

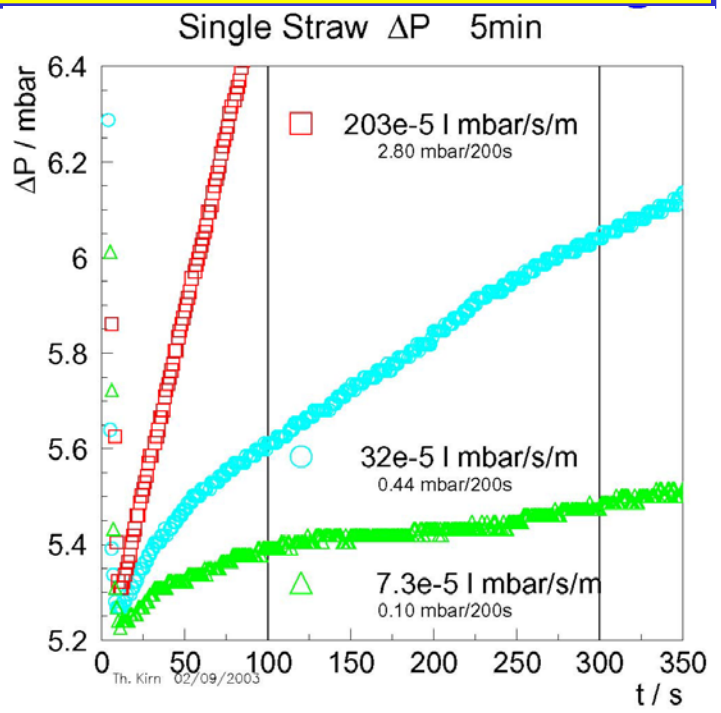


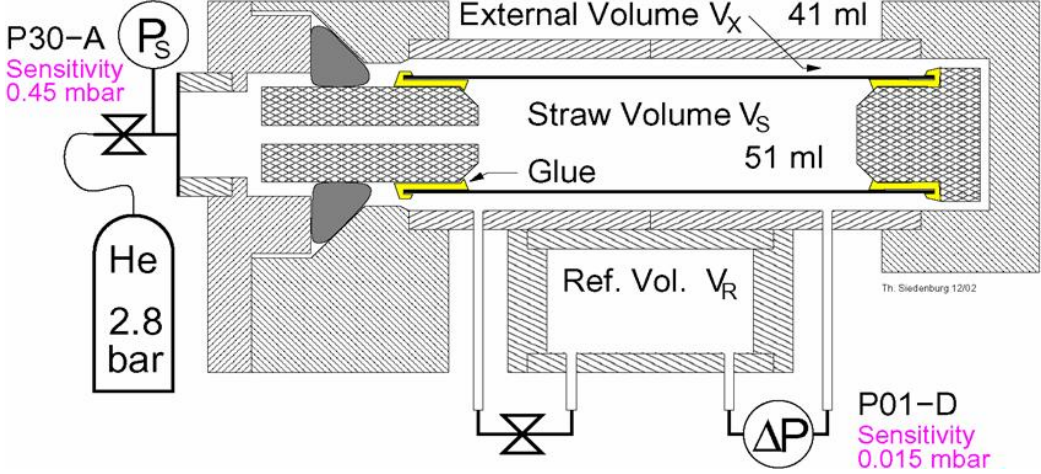


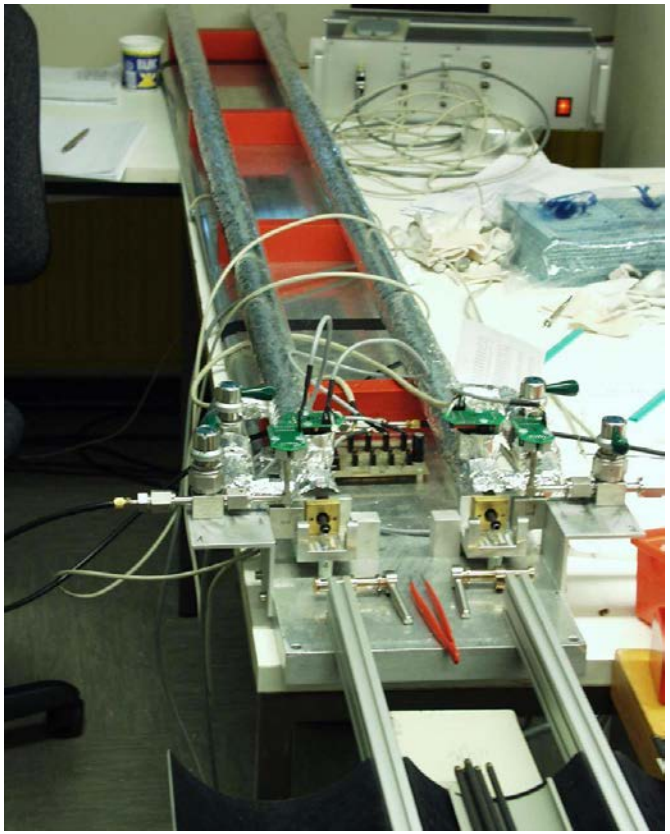


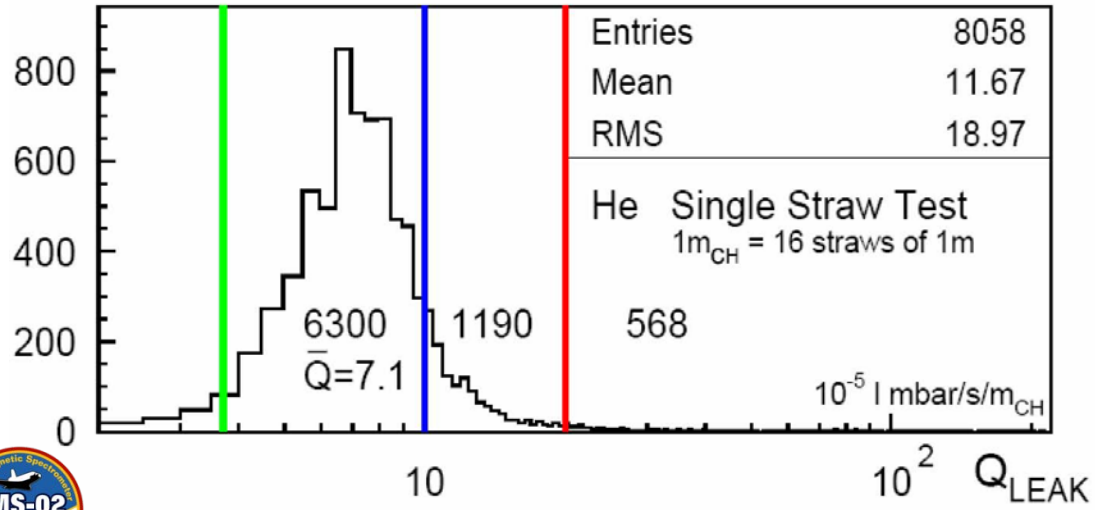


AMS-02 TRD:Gastightness

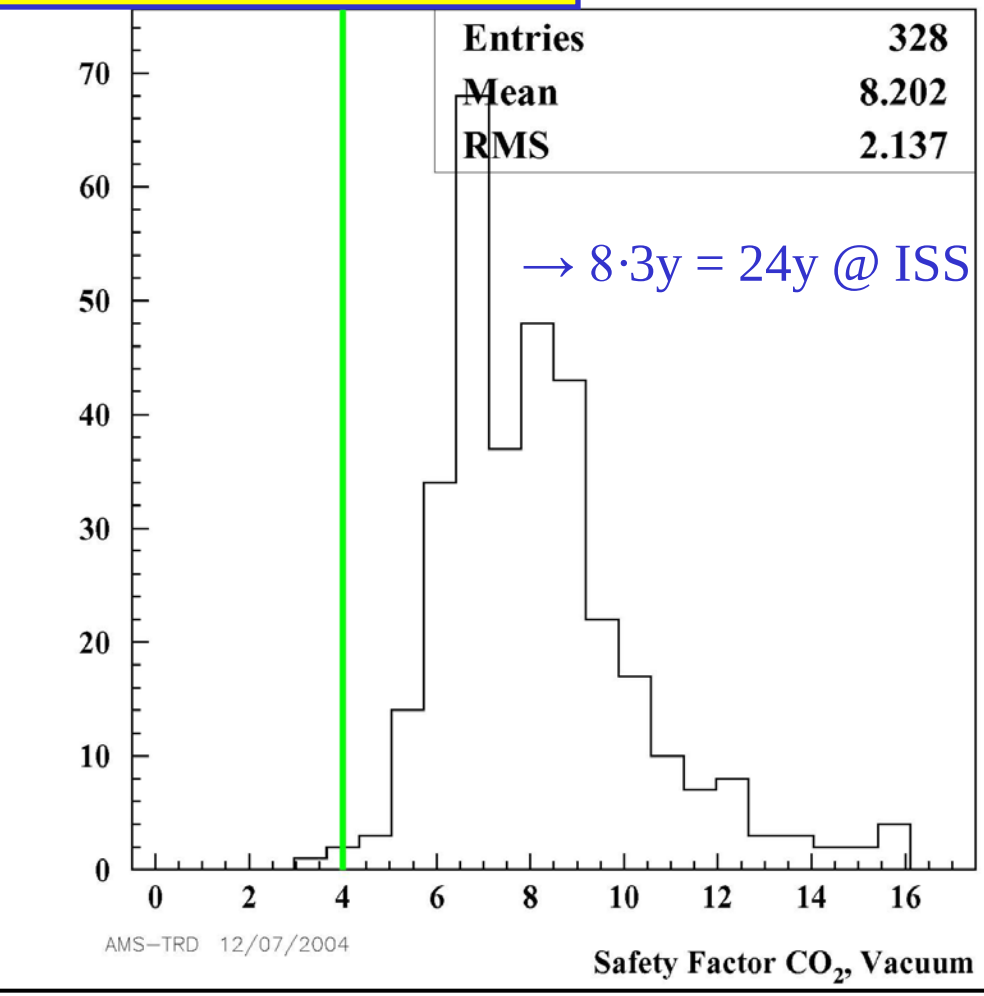








AMS-02 TRD: Straw Module Gastightness

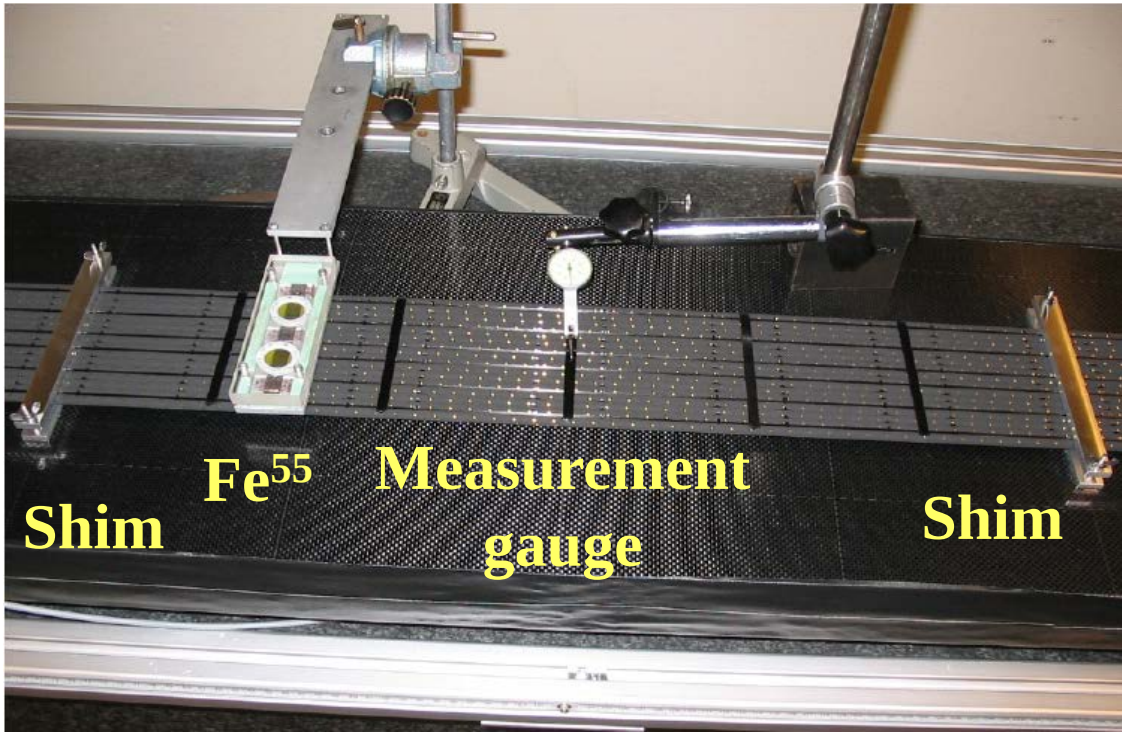


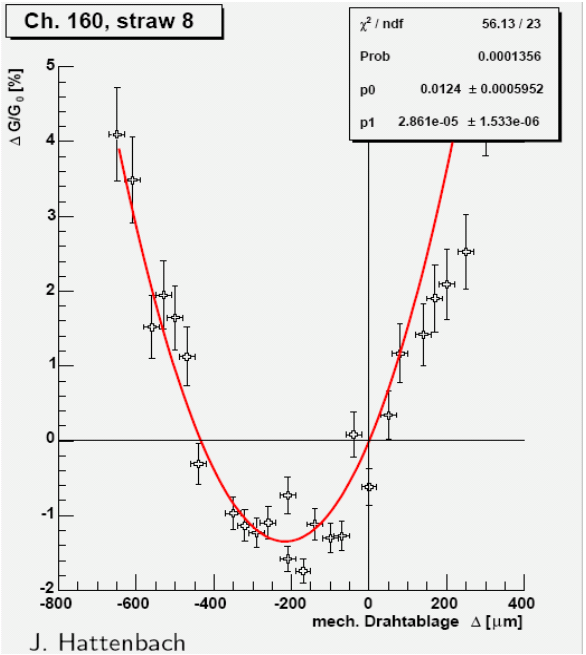
CO_2 Leaktest in Vacuum Straws @ 1bar

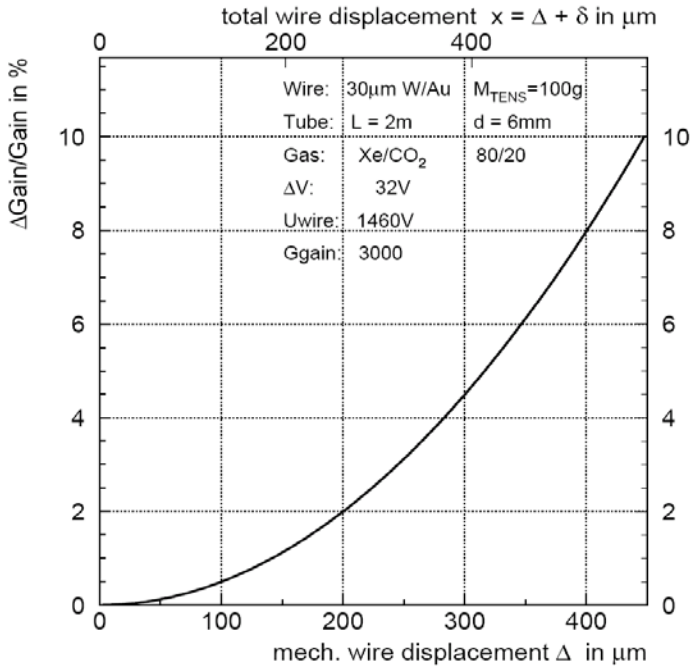
$1m_{CH}$ = 16 straws of 1m [+2 endpcs] Typ. Module [1.5m]: $3.1 \cdot 10^{-5}$ l mbar/s/m_{CH} ≡ SF 8.2

Gas Tightness measured in safety factors SF, SF=1 → $25.3 \cdot 10^{-5}$ l mbar/s/m_{CH}

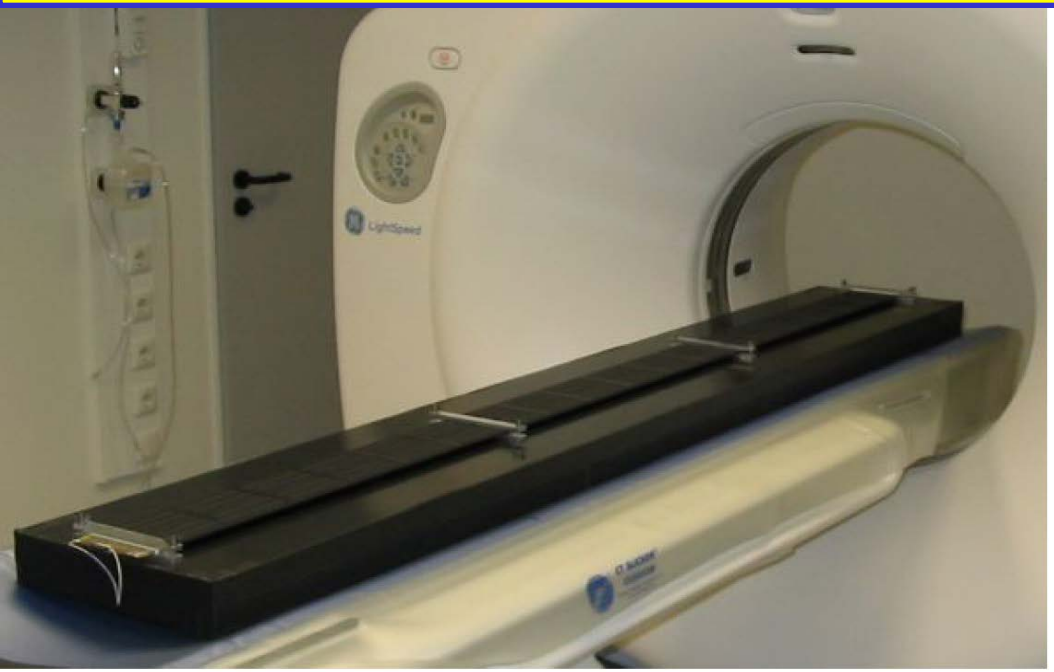
AMS-02 TRD: Straw Modules; Wire displacement detection by Fe^{55} – Gasgain-Measurement for controlled shimming



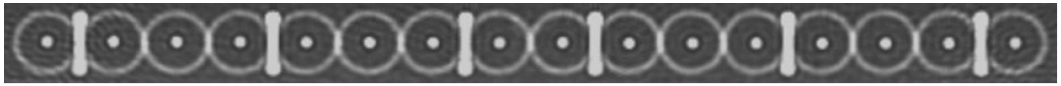




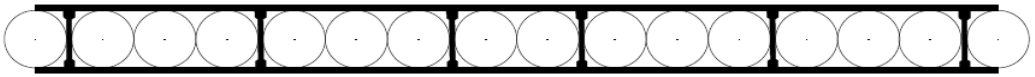
AMS-02 TRD: Straw Modules, Wire displacement detection, Computer Tomography X-Ray

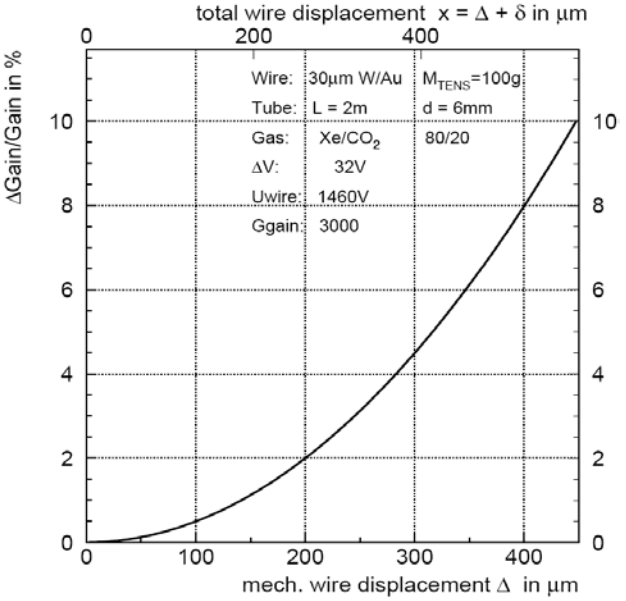


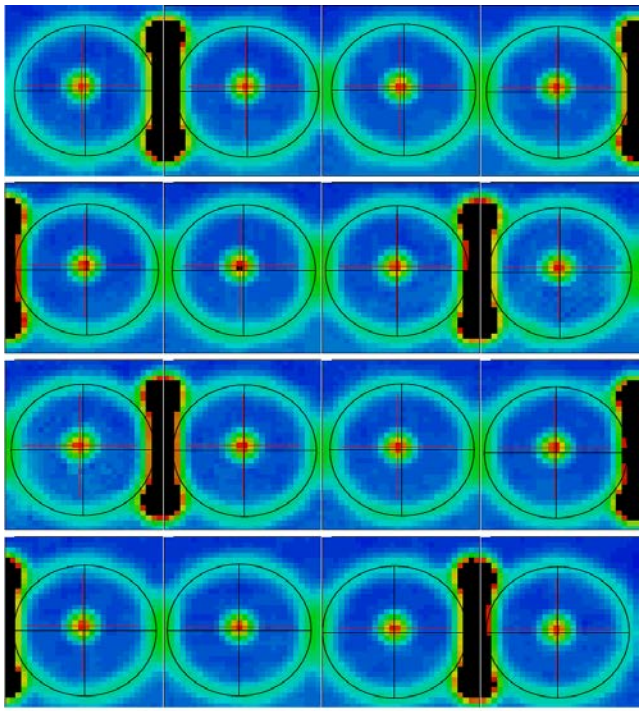
Luisenhospital Aachen (GE 16-Channel CT)



Dicom Image File



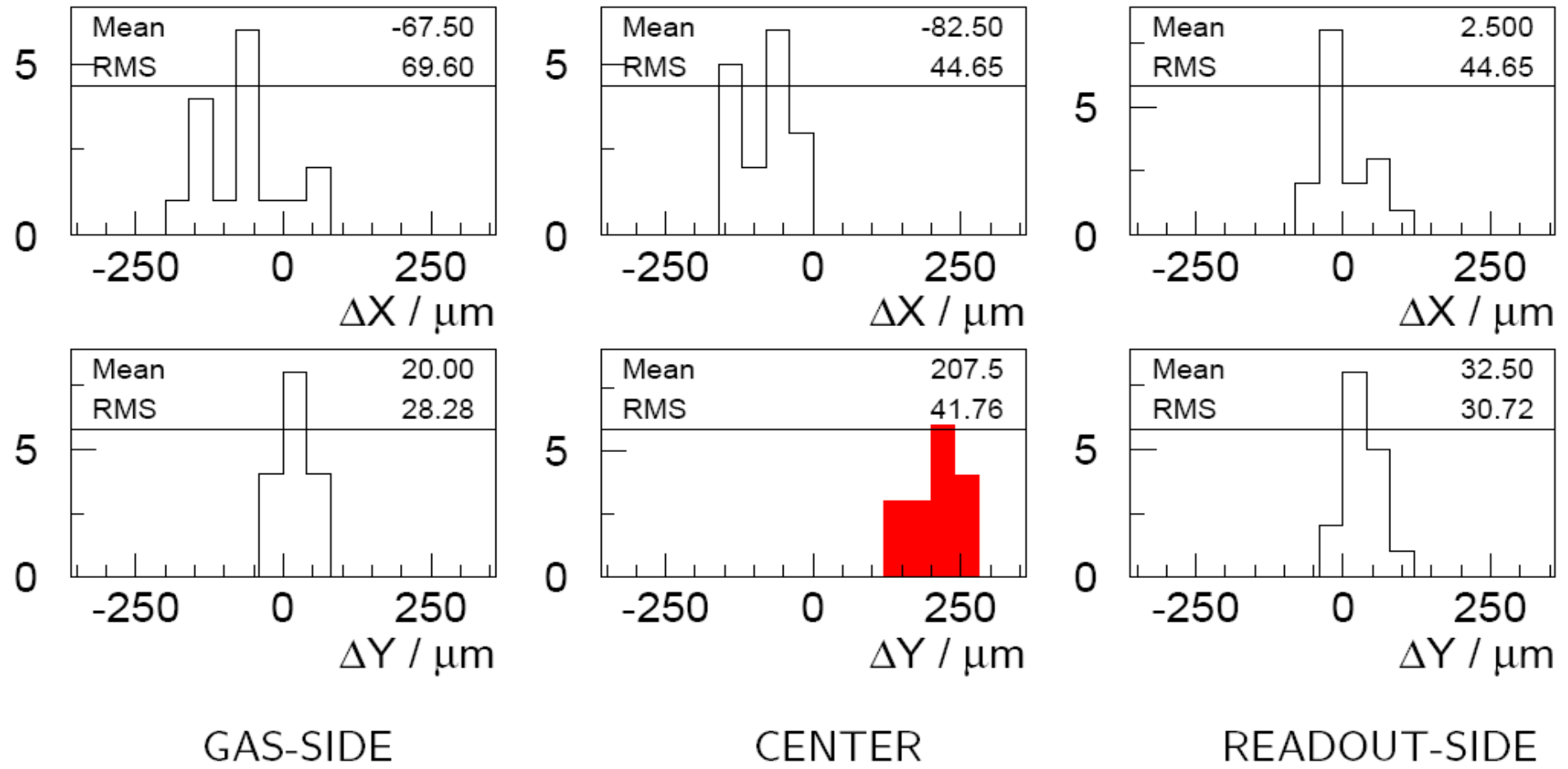




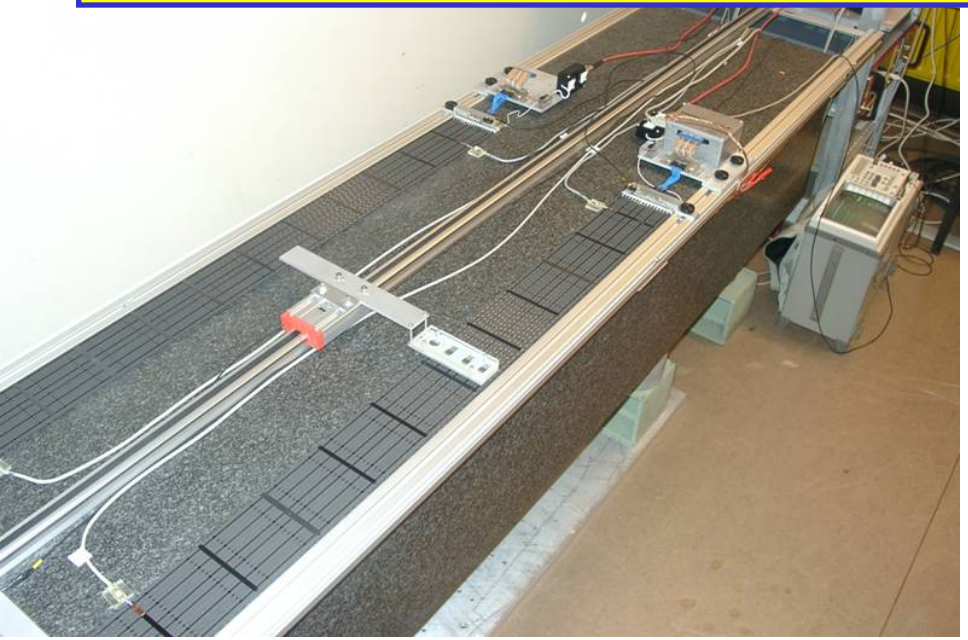
Wire- and Tube-xy-Fit ($\sigma \approx 10 \mu m$)

AMS-02 TRD: Straw Modules, Wire displacement detection by Computer Tomography X-Ray

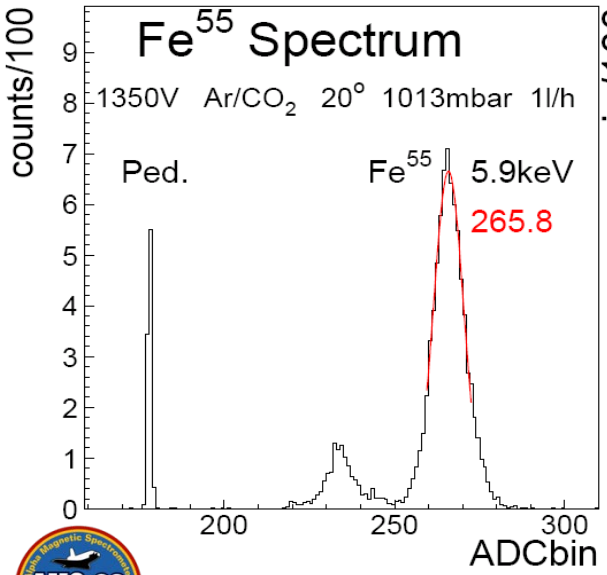
Controlled Shimming of +200µm y-direction in middle of module

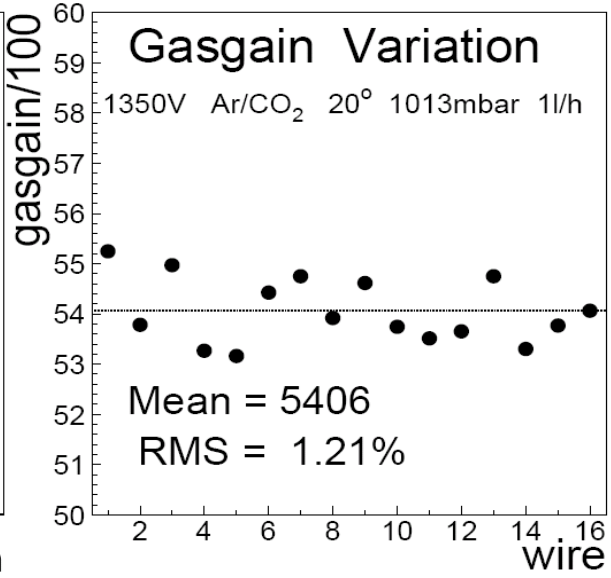


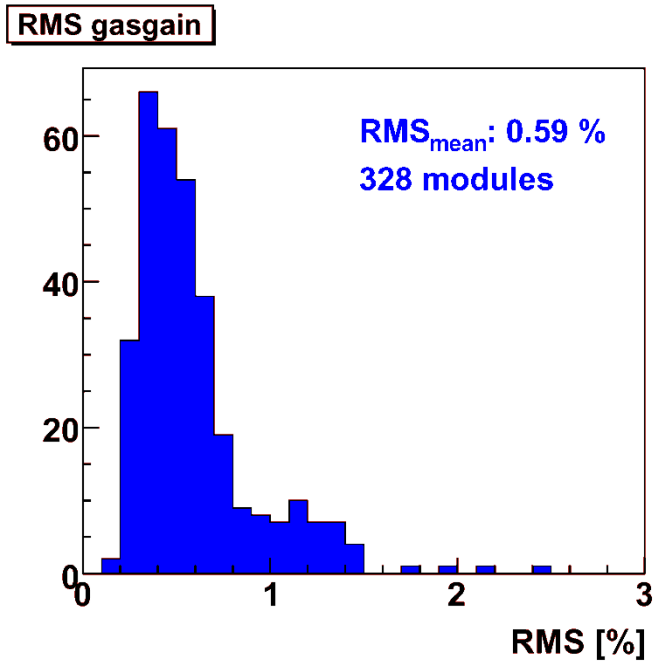
AMS-02 TRD: Fe^{55} – Gasgain-Measurements of 328 Flight Straw Modules



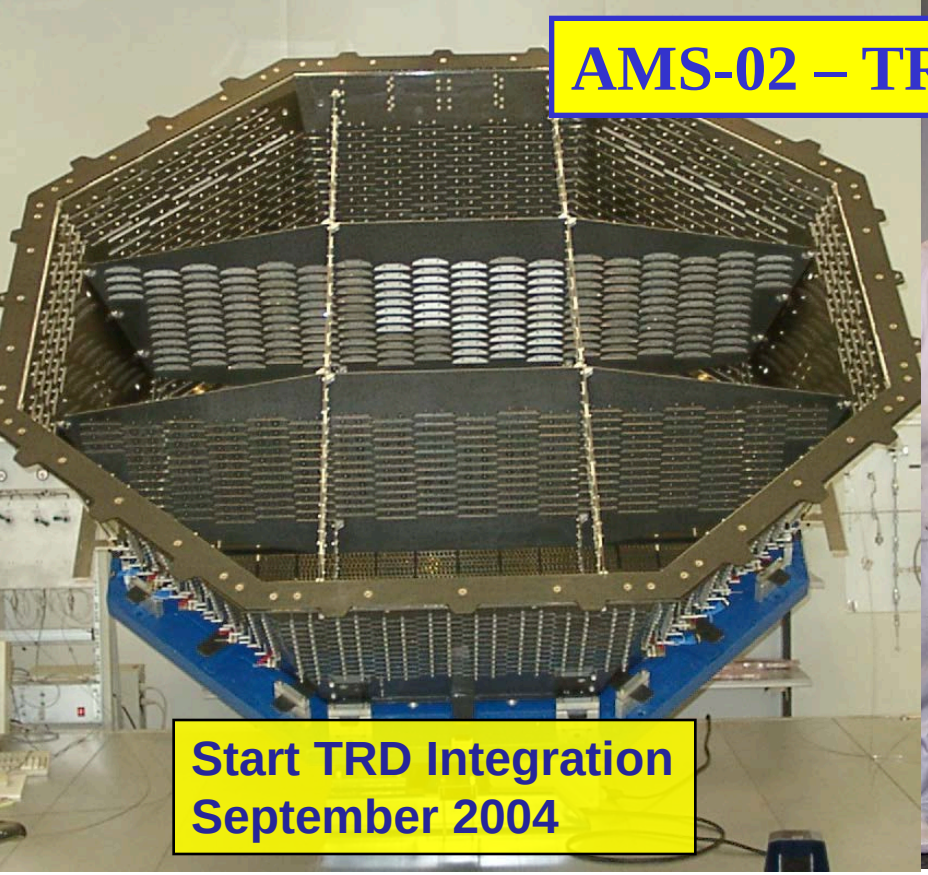
0.1	0.3	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9m	Straw
3.2	1.5	4.2	1.8	5.7	7.1	5.2	4.2	0.2	-0.9	1
0.1	-0.1	0.2	1.0	4.1	3.8	2.9	1.8	-1.2	-2.4	2
-2.0	-0.7	0.2	0.5	0.1	3.2	4.2	-0.6	-2.9	-3.8	3
-2.6	-1.3	-2.1	0.4	0.6	2.5	2.8	-0.6	-2.8	-4.6	4
-2.9	-3.3	-1.4	-1.1	0.8	3.2	1.7	0.7	-3.0	-3.7	5
-3.7	-1.4	-4.0	-1.2	-0.9	1.4	2.8	-0.6	-1.9	-4.7	6
-1.9	-2.6	-1.1	-2.1	0.7	2.7	1.9	0.6	-2.9	-3.0	7
-2.4	-0.5	-1.0	0.8	1.1	2.3	2.1	-0.6	-2.0	-3.6	8
0.6	-1.0	1.0	0.4	5.8	5.6	1.6	2.8	-1.1	-1.1	9
-0.1	-1.2	0.3	0.5	2.8	3.6	0.9	0.8	-1.4	-2.7	10
-2.1	-0.6	-1.4	-1.0	0.4	1.6	2.1	-1.7	-3.6	-4.4	11
-2.3	-1.7	-0.5	-1.5	1.3	2.0	-0.1	-0.3	-4.8	-5.0	12
-2.1	-0.3	-0.6	0.7	2.2	1.9	3.4	0.4	-3.1	-5.1	13
-0.7	-1.4	0.8	-1.1	1.9	4.2	1.7	0.5	-3.0	-3.1	14
-1.6	-0.1	-2.1	1.8	2.6	2.2	2.7	1.0	-0.7	-2.9	15
-1.9	1.3	-0.7	2.4	1.6	3.1	4.5	1.6	-0.6	-4.2	16



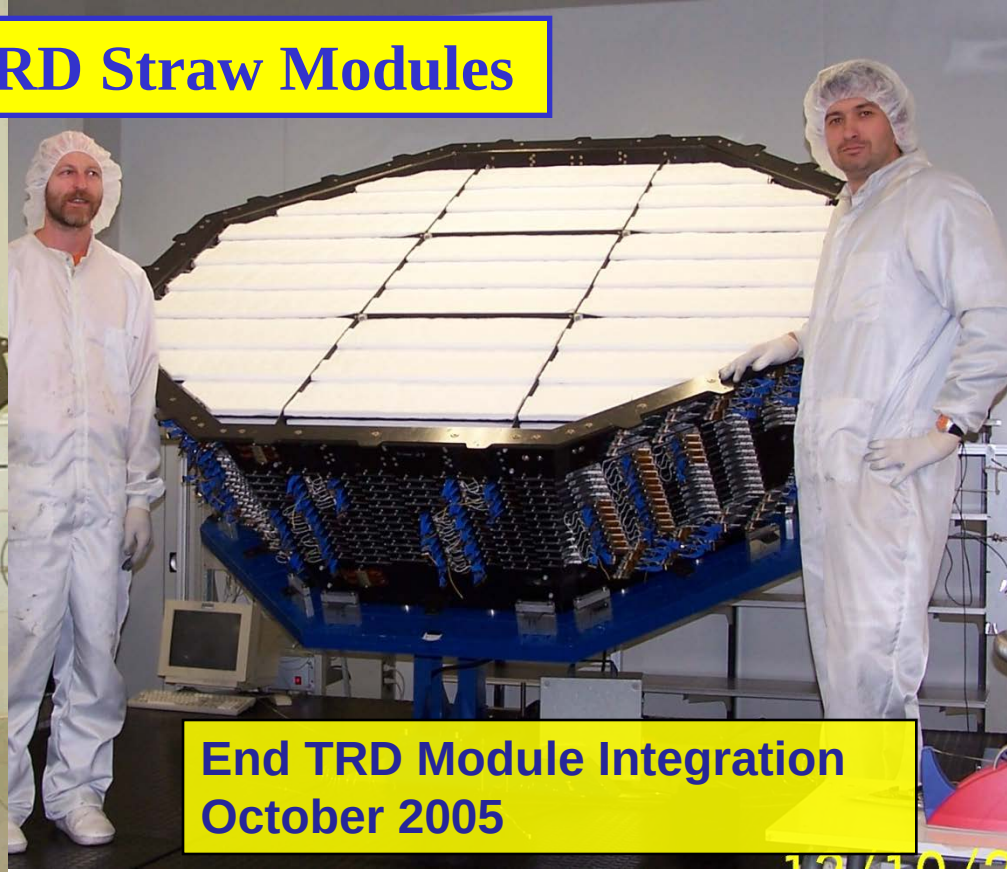




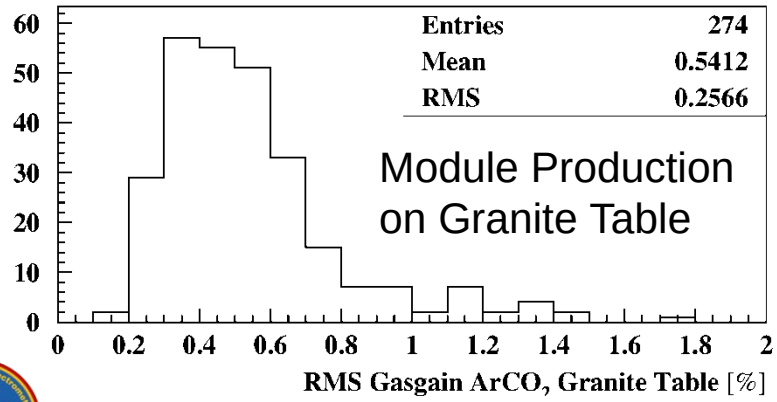
AMS-02 – TRD Straw Modules

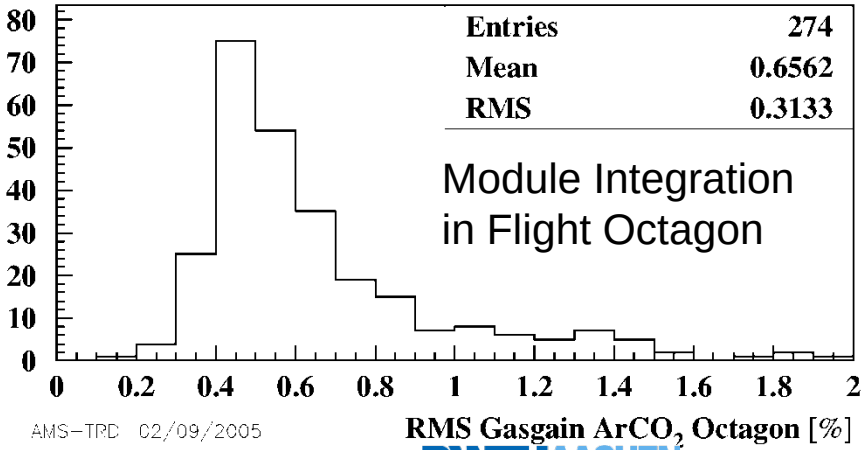


Start TRD Integration
September 2004

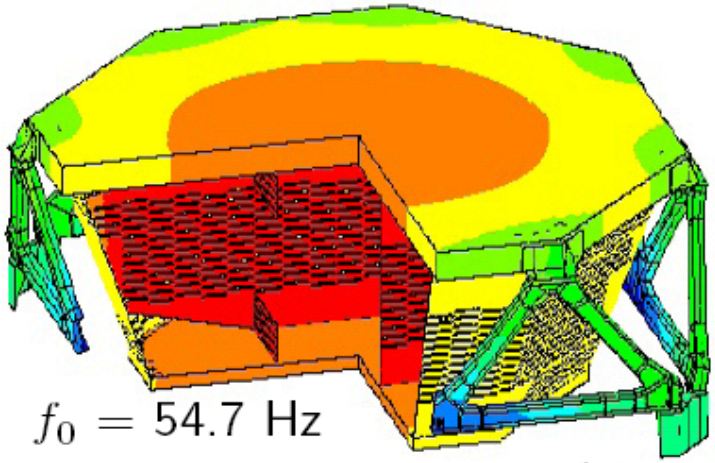


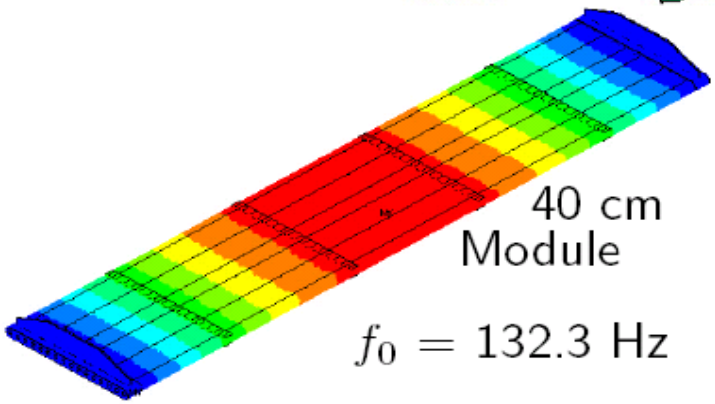
End TRD Module Integration
October 2005





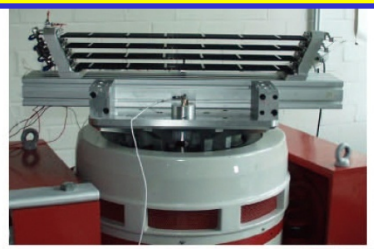
AMS-02 TRD: Straw Modules: Space Qualification Tests



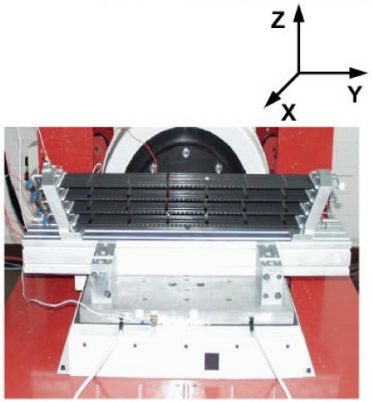


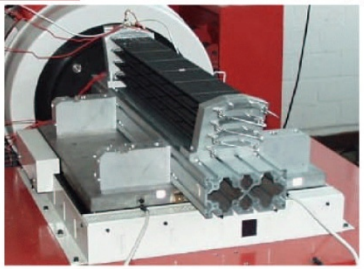
FEC coupled load modal analysis

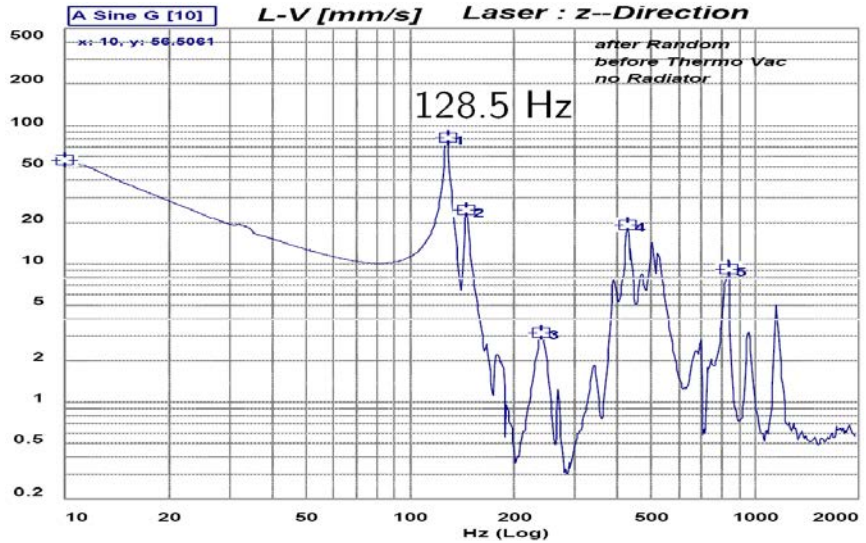
Parameters from static measurements
Verify with component vibration tests



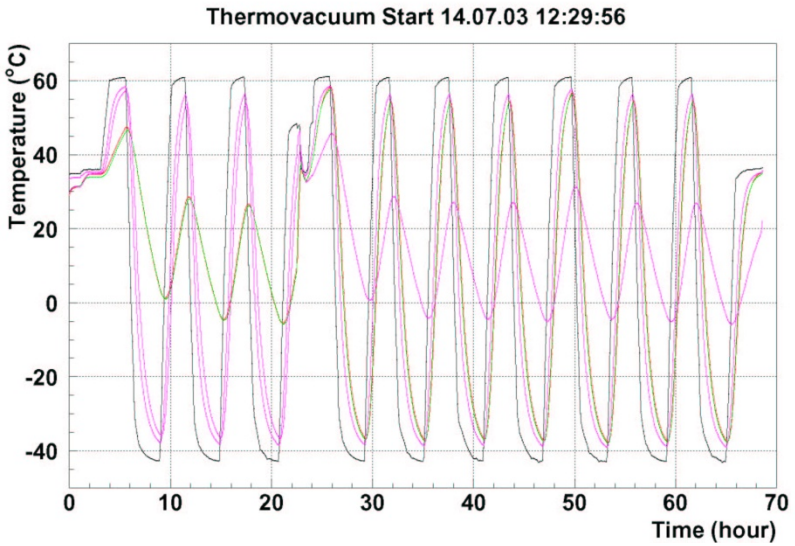
Vibration-Test-Cycle:
- Sine Sweep 0.5g (10-2000Hz)
- Random Spectrum $a_{RMS} = 6.8g$
- Sine Sweep 0.5g (10-2000Hz)

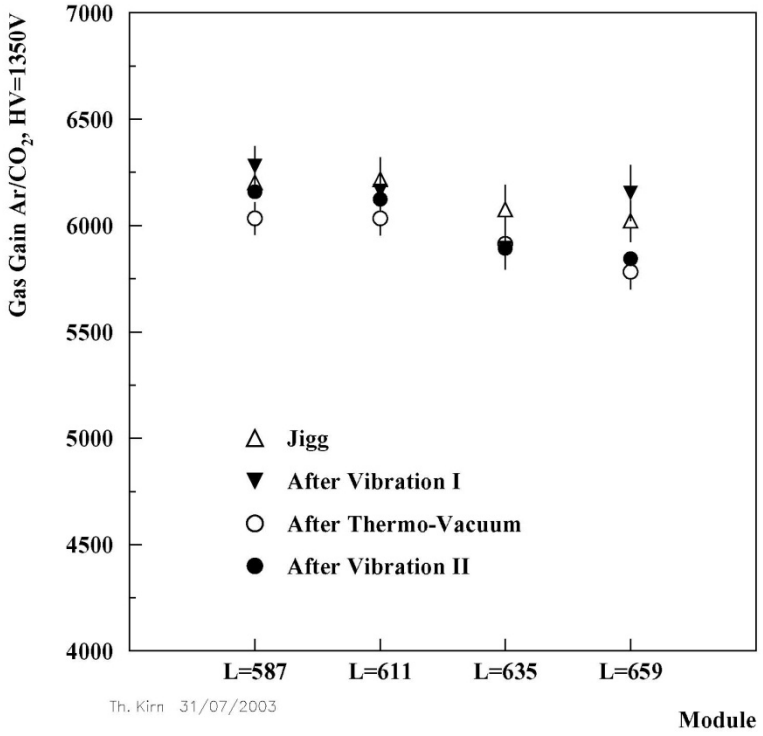






AMS-02 TRD: Space Qualification Tests



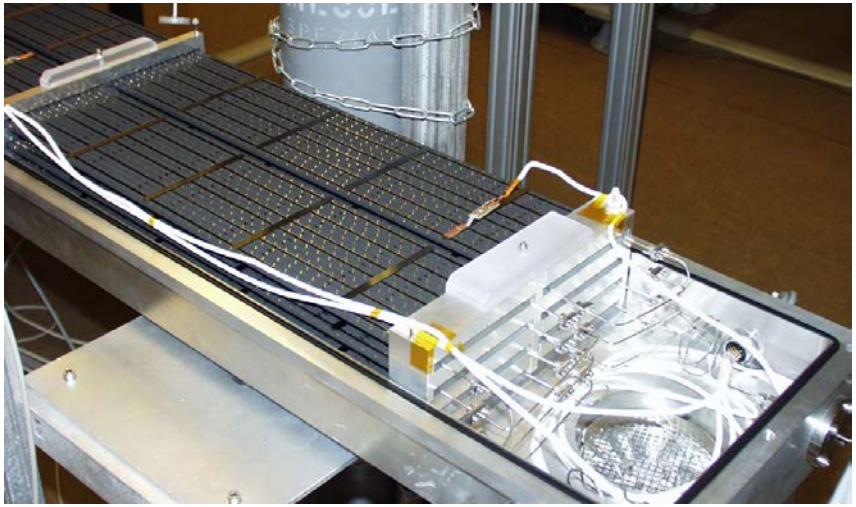


No significant changes in:

- Gasgain
- Gastightness

→ Straw Modules space qualified

AMS-02 TRD: Straw Module Longterm Tests

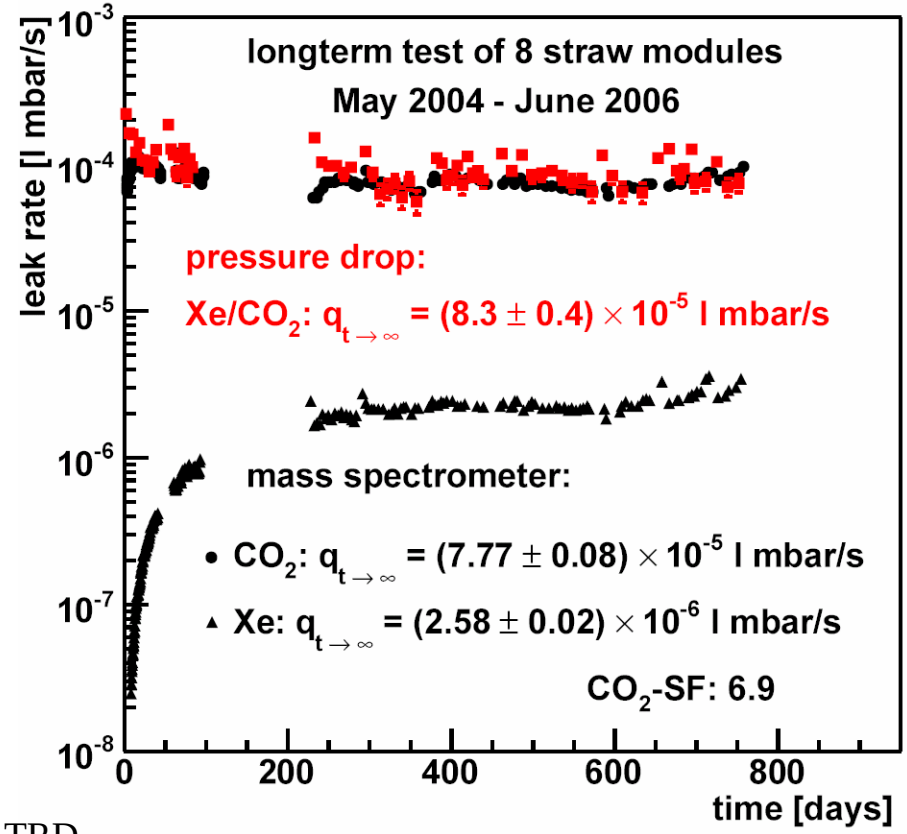


1 Gasgroup → 8 Modules

Fe^{55} – Monitoring

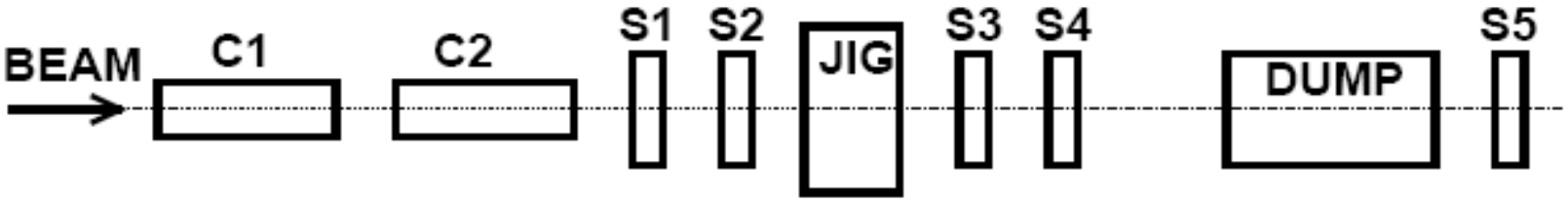
Pressure-Drop Measurements

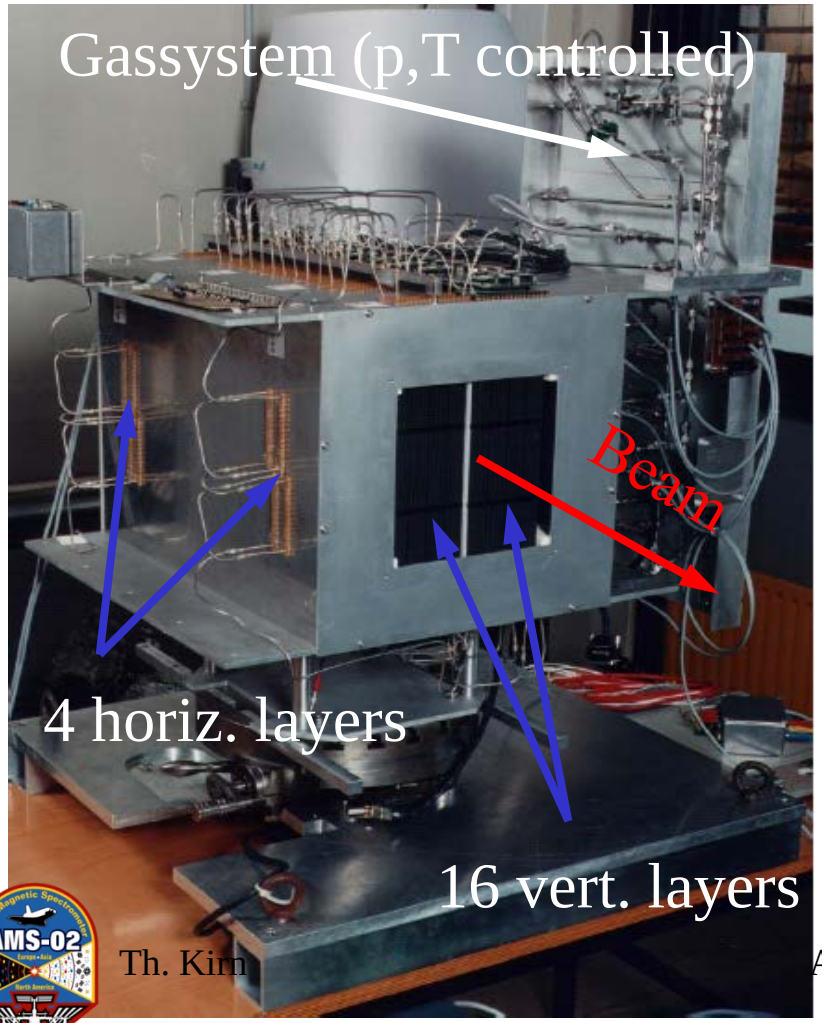
Mass-Spectrometer Measurements



Stable Operation for 2 years

AMS-02 – TRD: Performance, 20 Layer Prototype





Beamtest @ CERN 2000

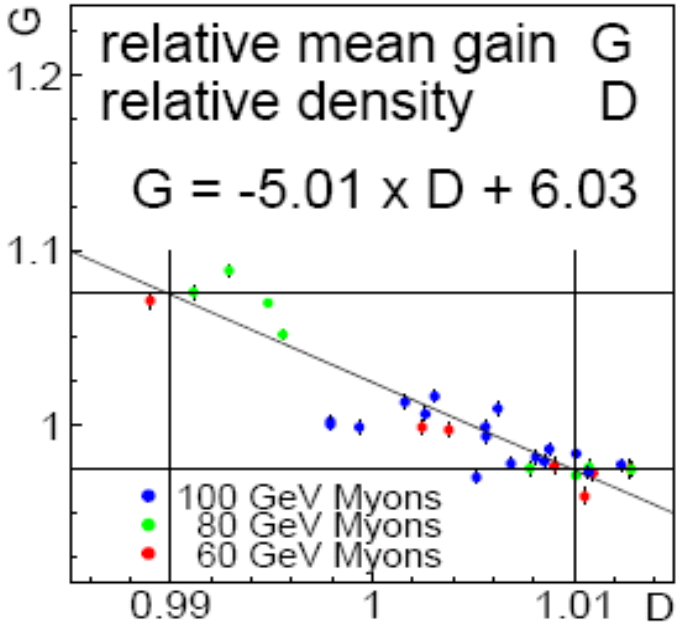
PS (T9) & SPS (X7, H6):

Recorded events: $3 \cdot 10^6$

Particles: e^-, μ^-, π^+ 10 - 100 GeV

Protons 10 - 250 GeV

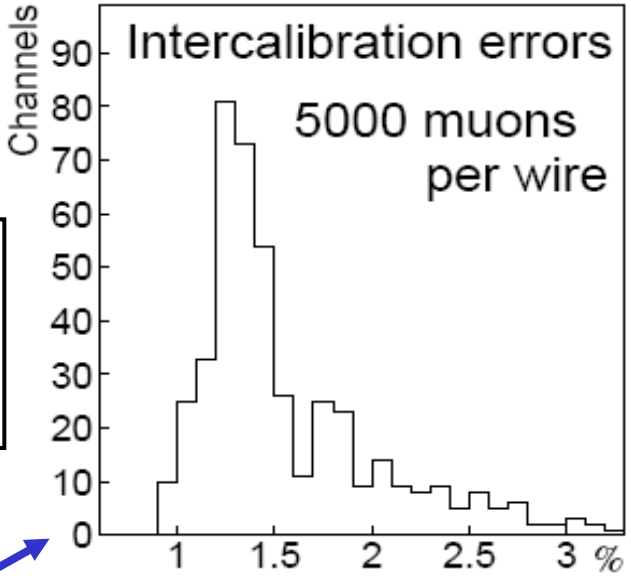
AMS-02 – TRD: Performance, 20 Layer Prototype

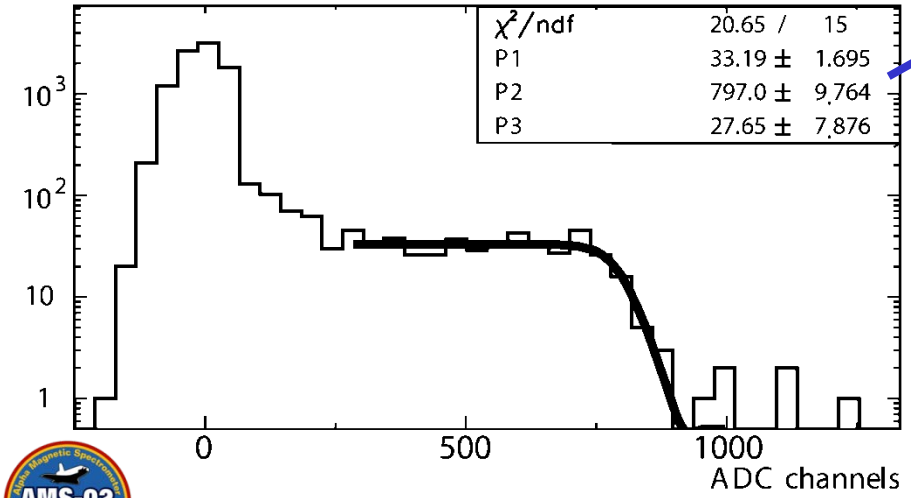


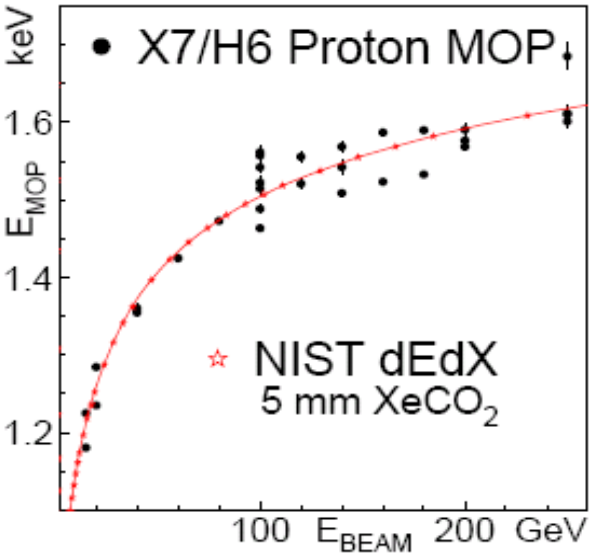
Tube Intercalibration

Gasgain-Density-Corr.

Fe^{55} Energy Calibration





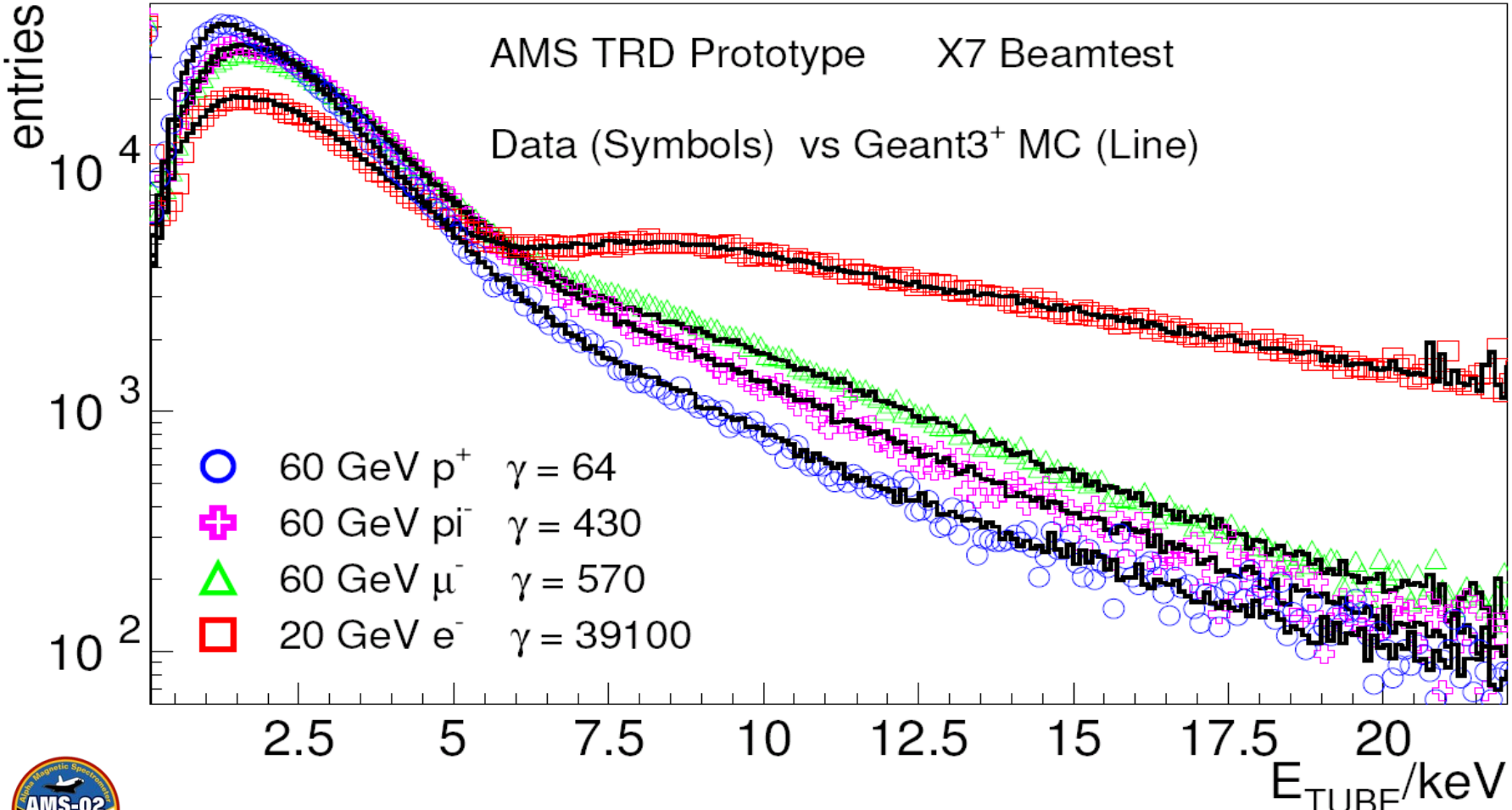


AMS-02 – TRD: TRD Spectra with Geant 3$^+$ MC

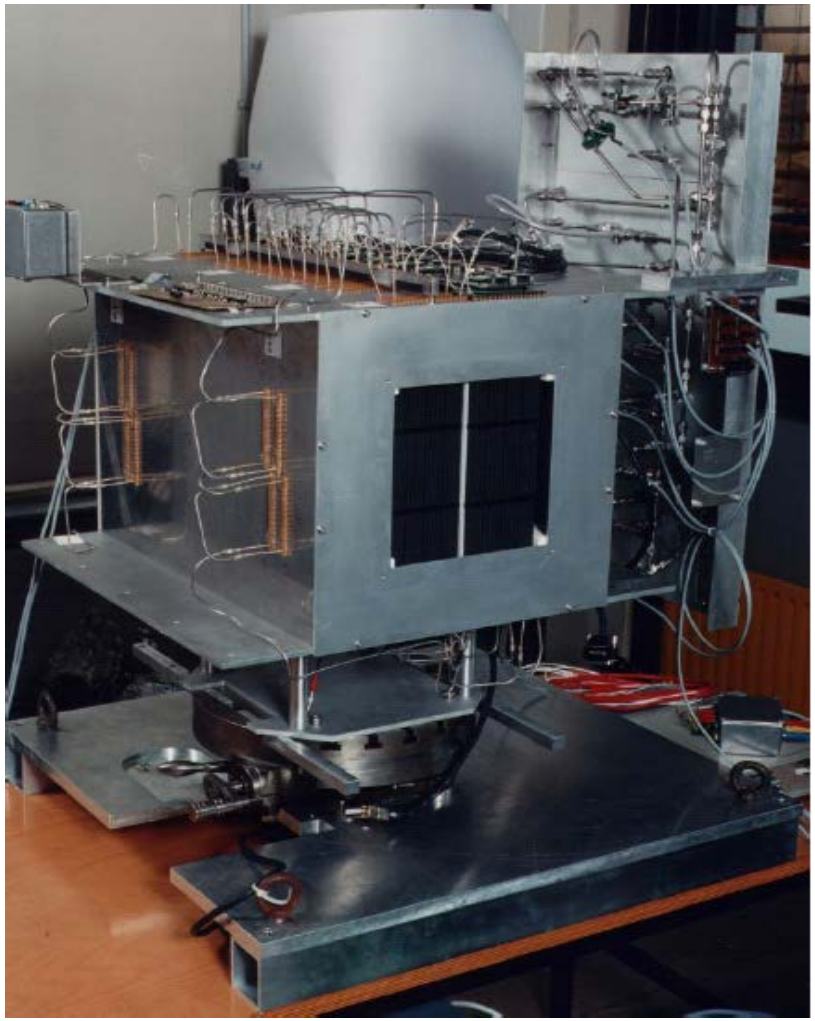
dE/dX in thin gas-layers V. Ermilova, NIM A **145** (1977) 555

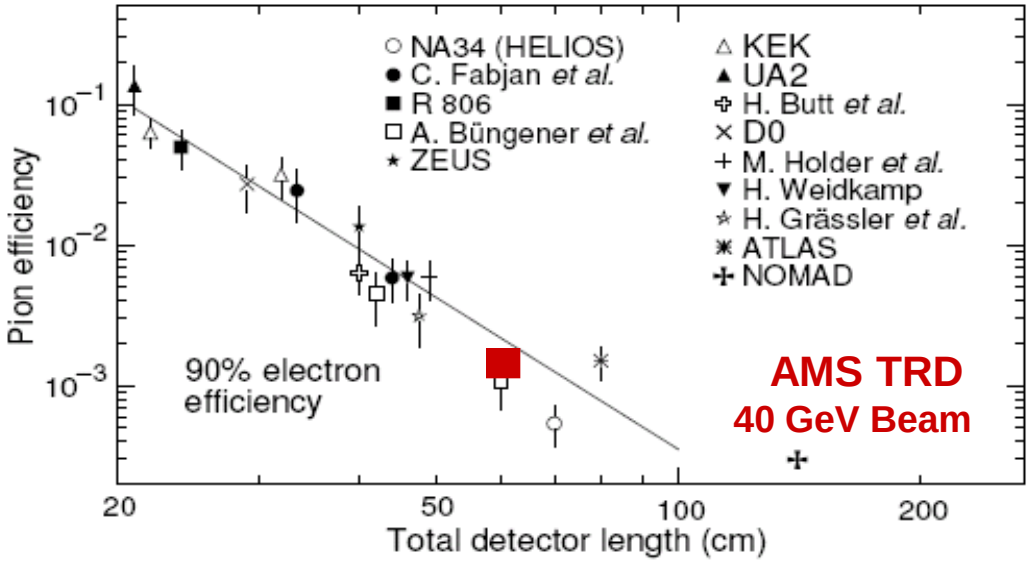
TR gener. and absorp. M. Cherry, Phys.Rev.Lett. D **10** (1974) 3594

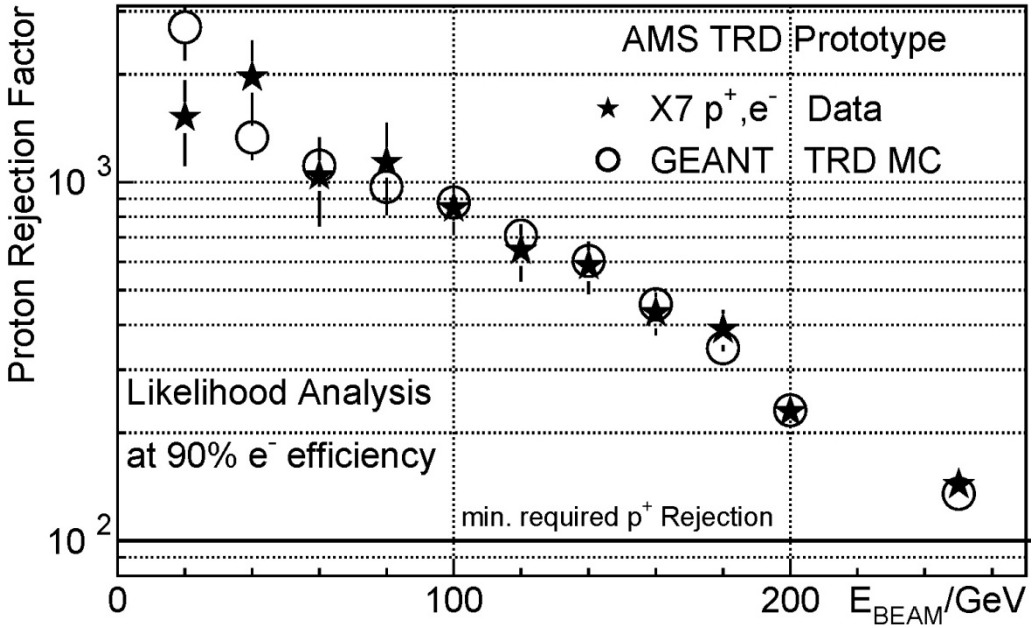
Implement. V. Saveliev (HERA-B) G.M. Garibian, NIM A **125** (1975) 133



AMS-02 – TRD: Performance, 20 Layer Prototype



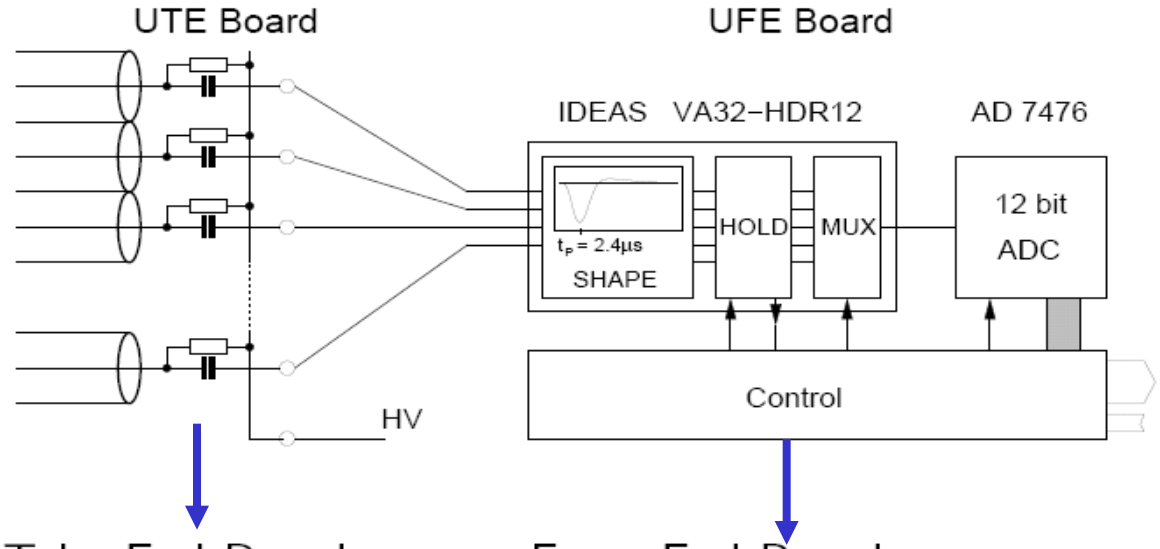


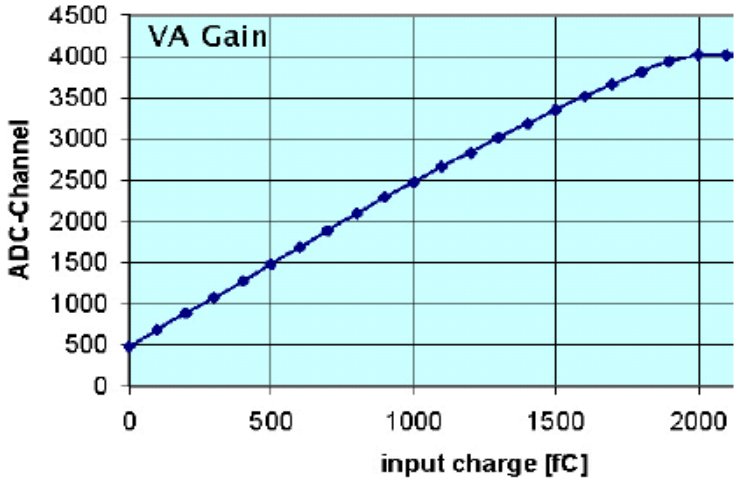


AMS-02 TRD: Frontend Electronic UFE-Boards

AMS-02 – TRD: Front End Electronic

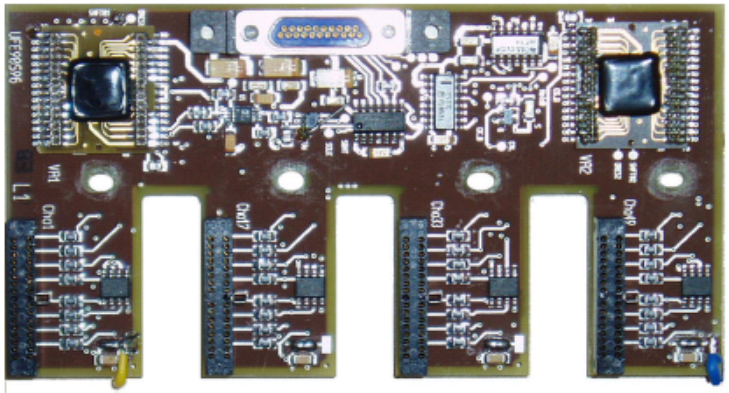
VA-Chip Multiplexed Pulsheight Readout





Tube-End Board

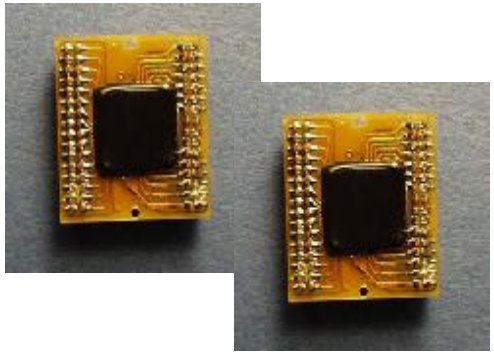
Front-End Board



Power: 20W/5248 Channels

MIP MOP (G=3000)	30 fC 60 bins
MIP S/N	> 60/2
Range	60 MIPs

AMS-02 – TRD: Production of UFE-board (FM)



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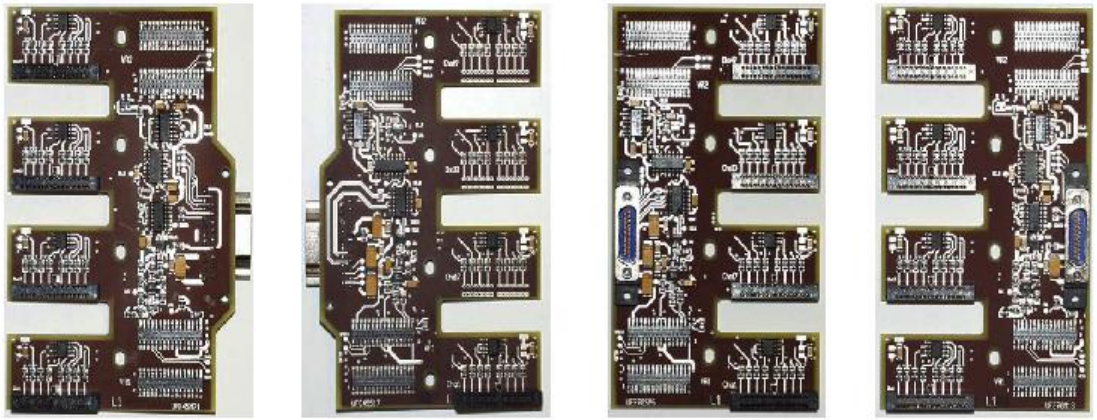
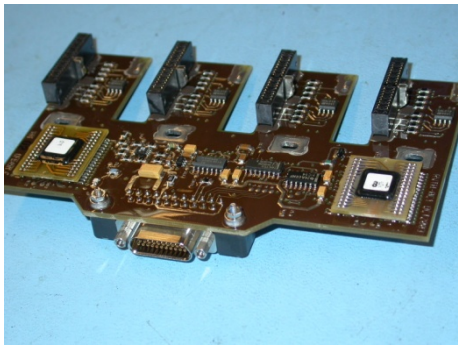
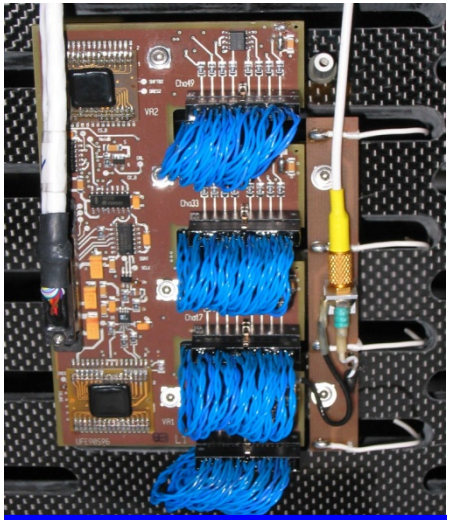


358 VA Chips Tests
Select 202 Chips

101 Production of 4 Types PCB



Series of Space Qualification Tests

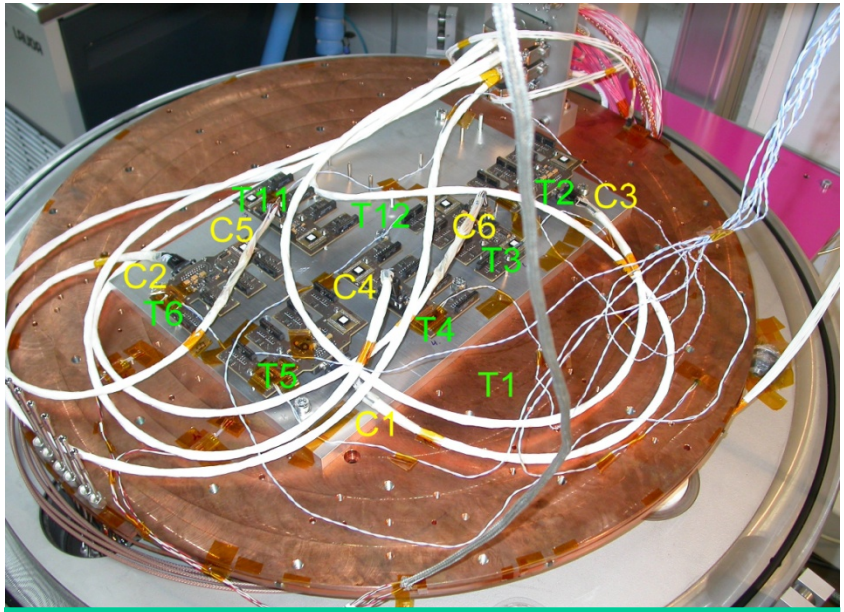


Functional Tests

TVT → 3D Vibration → Coating → TVT

Integration

AMS-02 – TRD: Space Qualification Tests of UFE-board (FM)

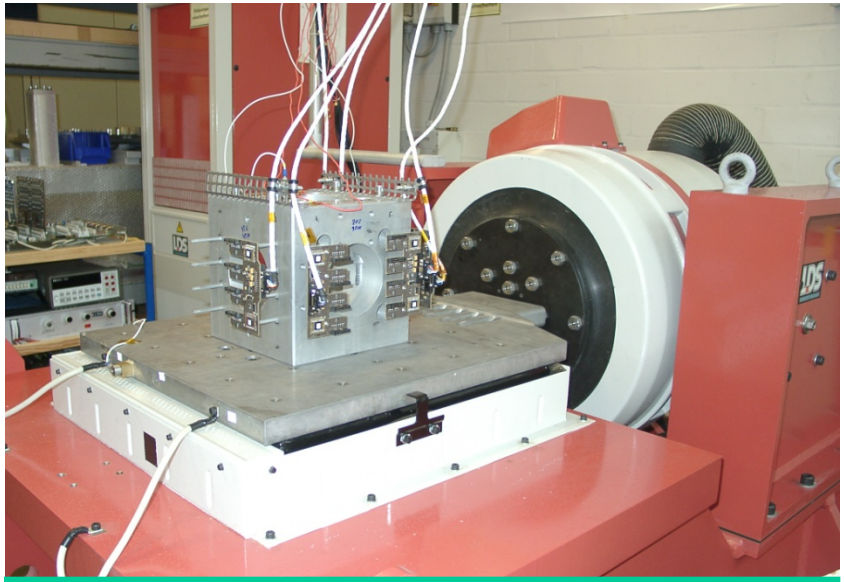


1st TVT

Temperature : -40°C … +80°C

Pressure : 1×10^{-5} mbar

Functional test without failure



Random Vibration

X,Y and Z-Direction

a_{RMS} = 6.8g, 20-2000 Hz for 120 sec

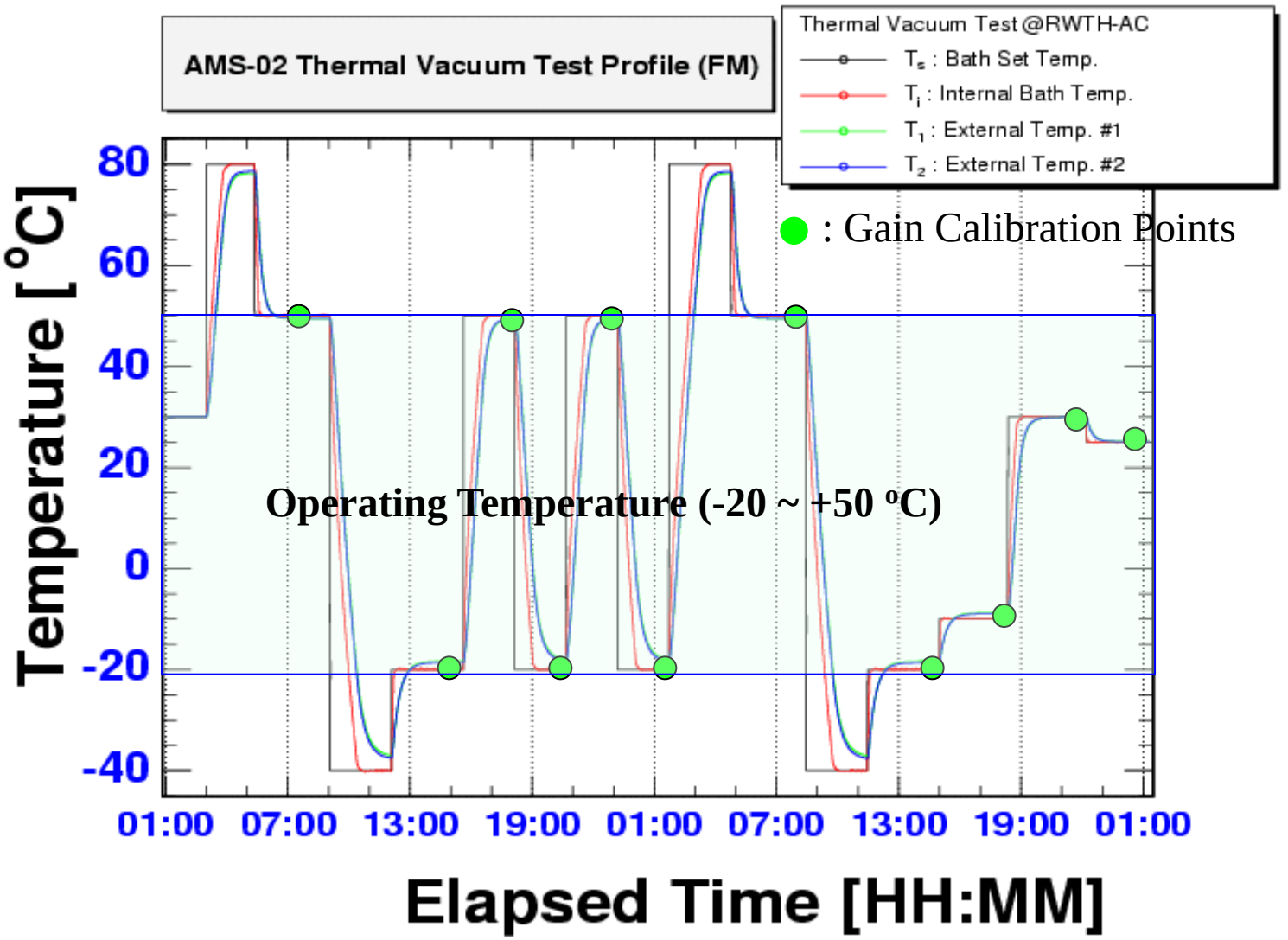
Functional test without failure

Conformal Coating

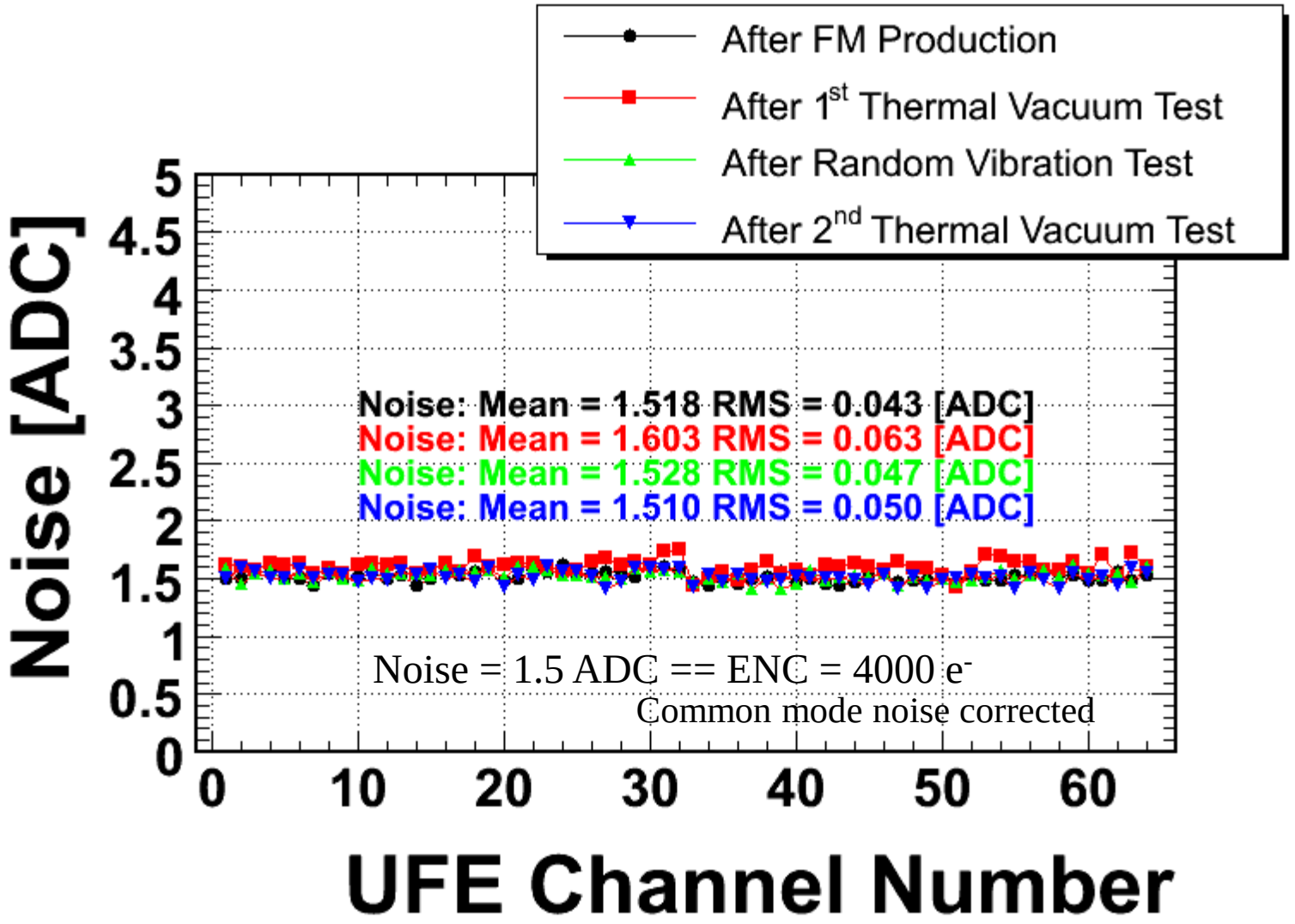
2nd TVT

Same as 1st TVT condition

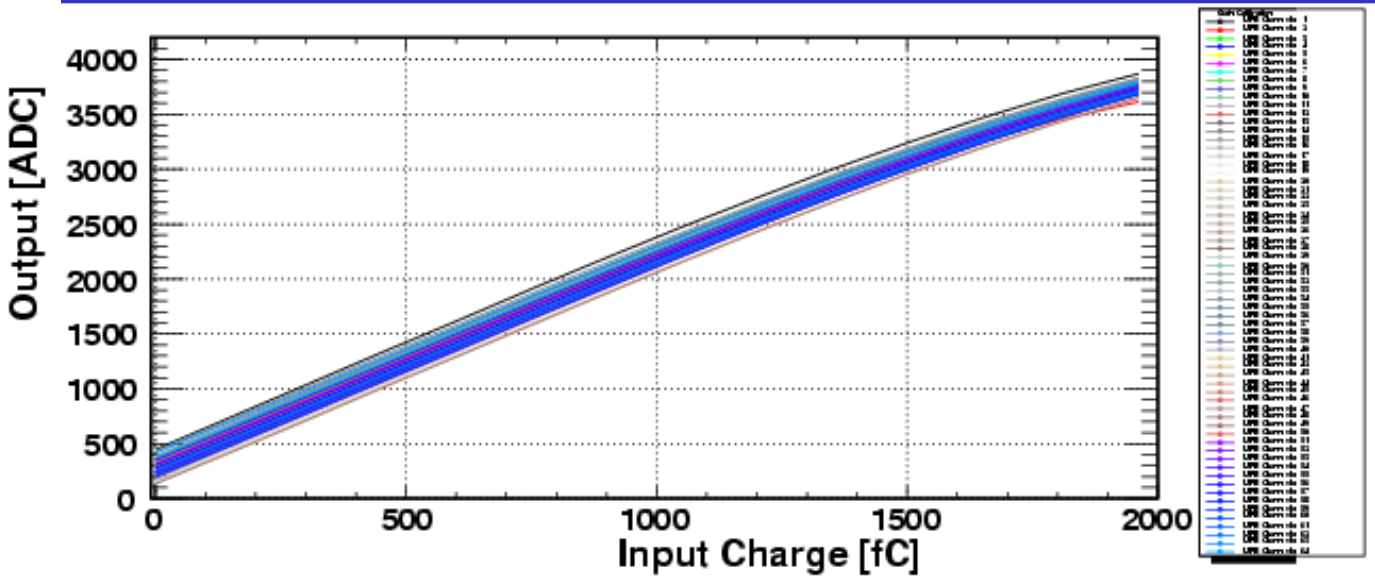
AMS-02 – TRD: Thermal Profile of TVT Test for FM-UFE-Boards

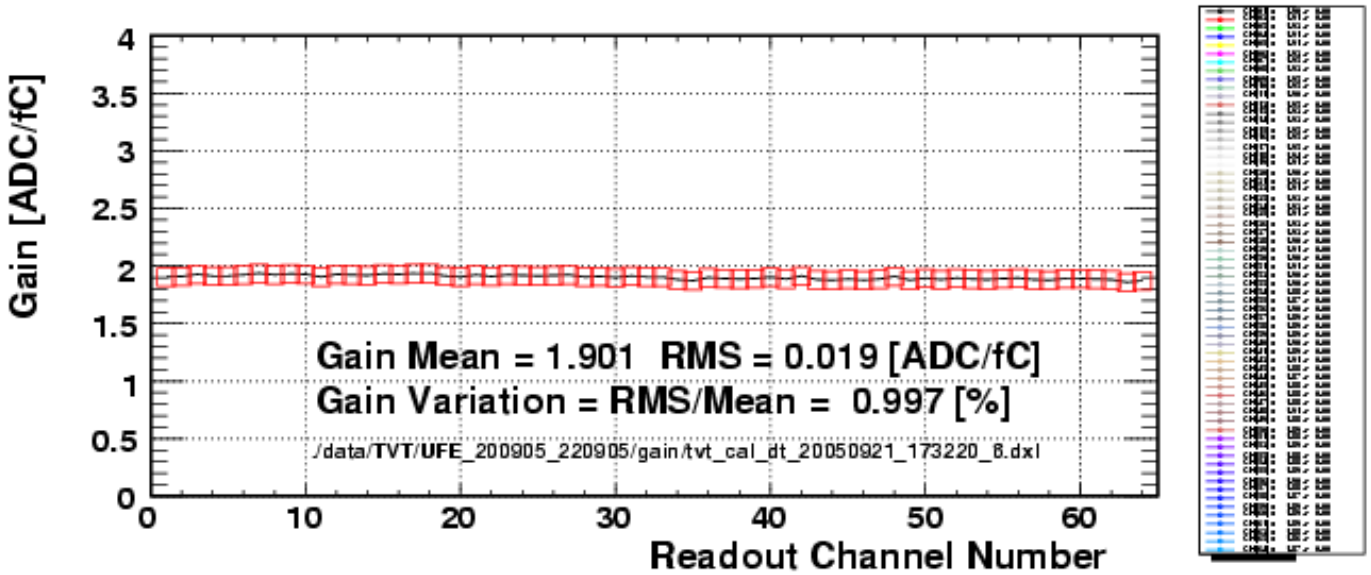


AMS-02 – TRD: UFE-Board Noise Measurement after TVT Test

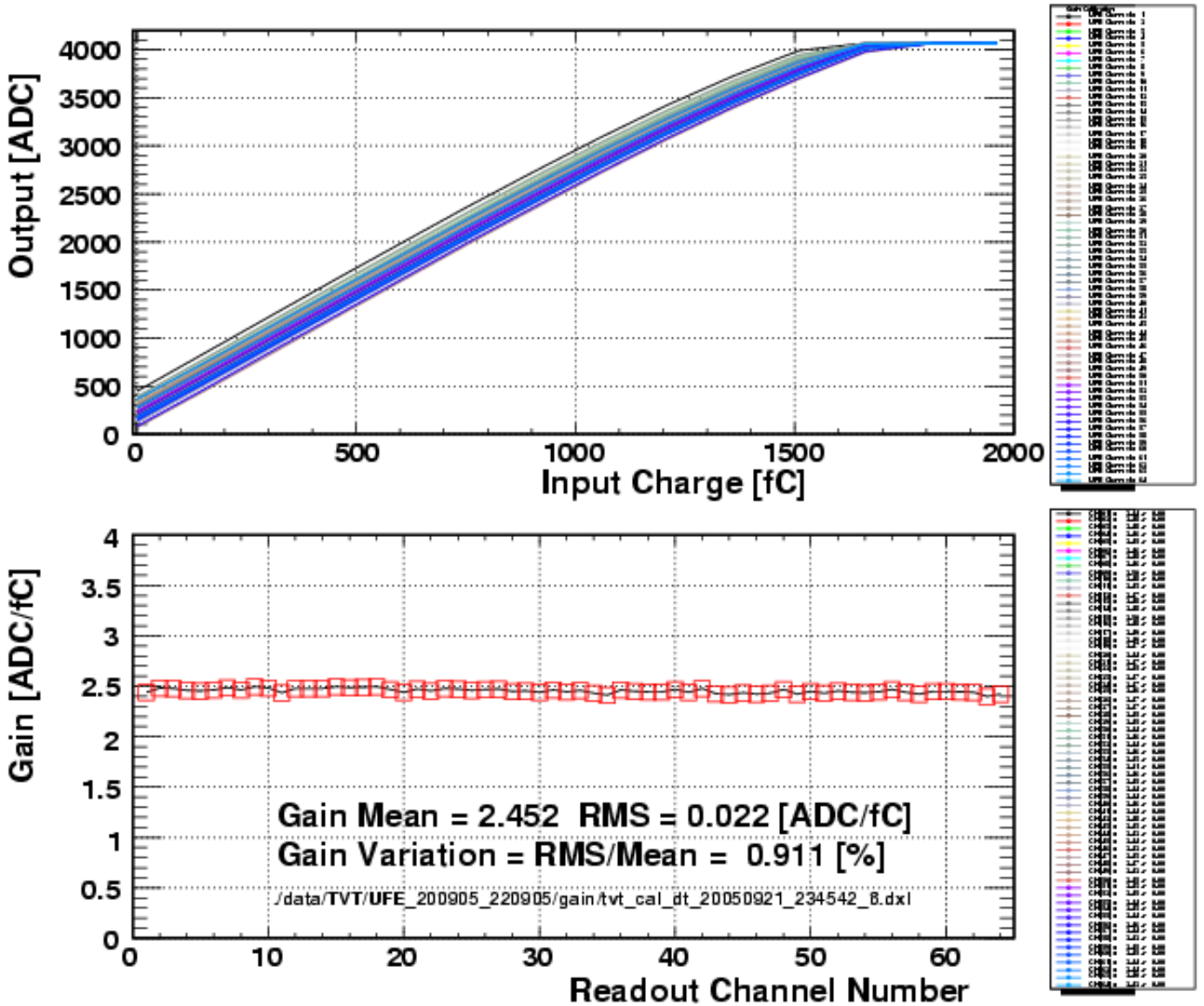


AMS-02 – TRD: UFE-Board Gain Calibration @ +50°C

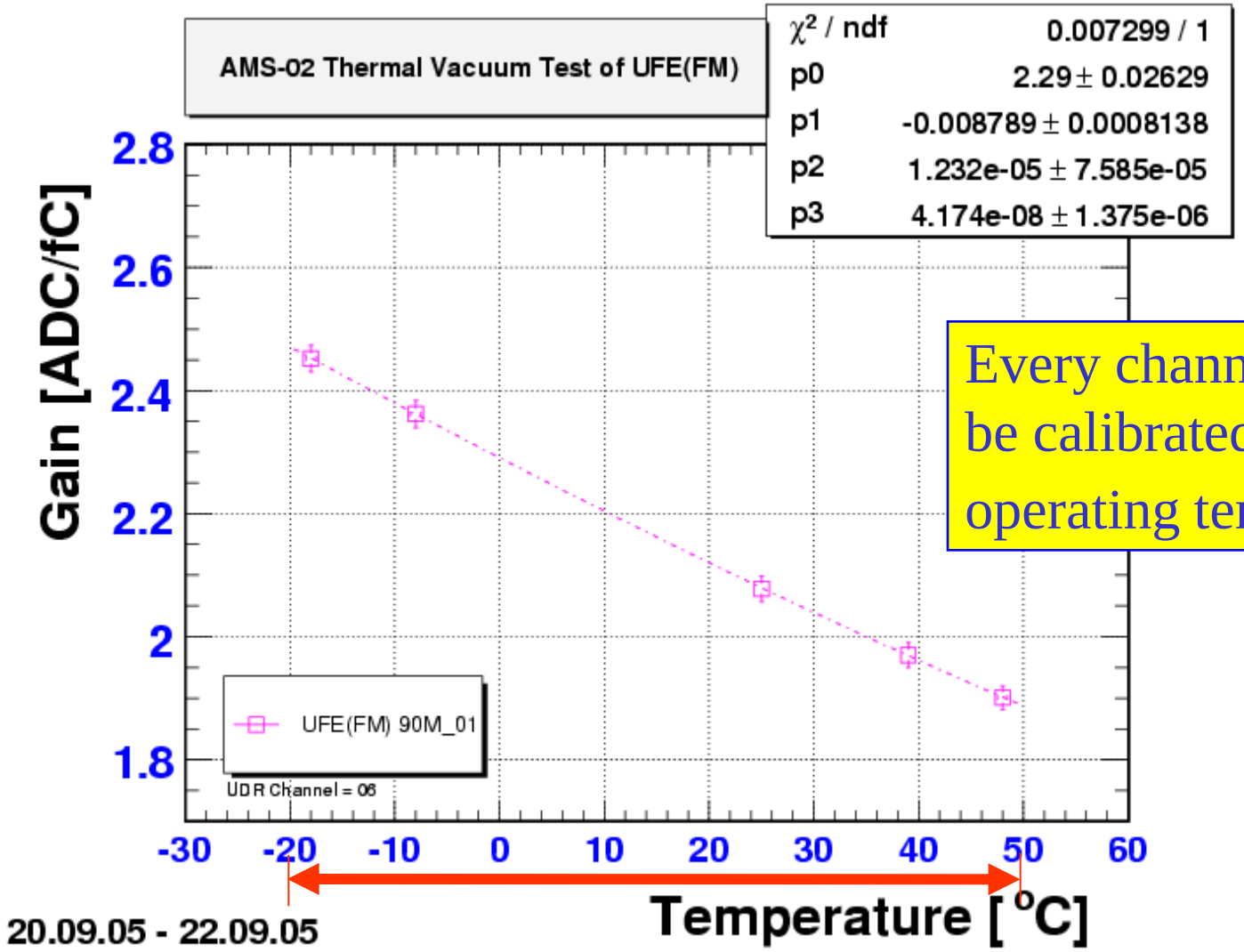




AMS-02 – TRD: UFE-Board Gain Calibration @ -50°C



AMS-02 – TRD: UFE-Board Gain versus Temperature

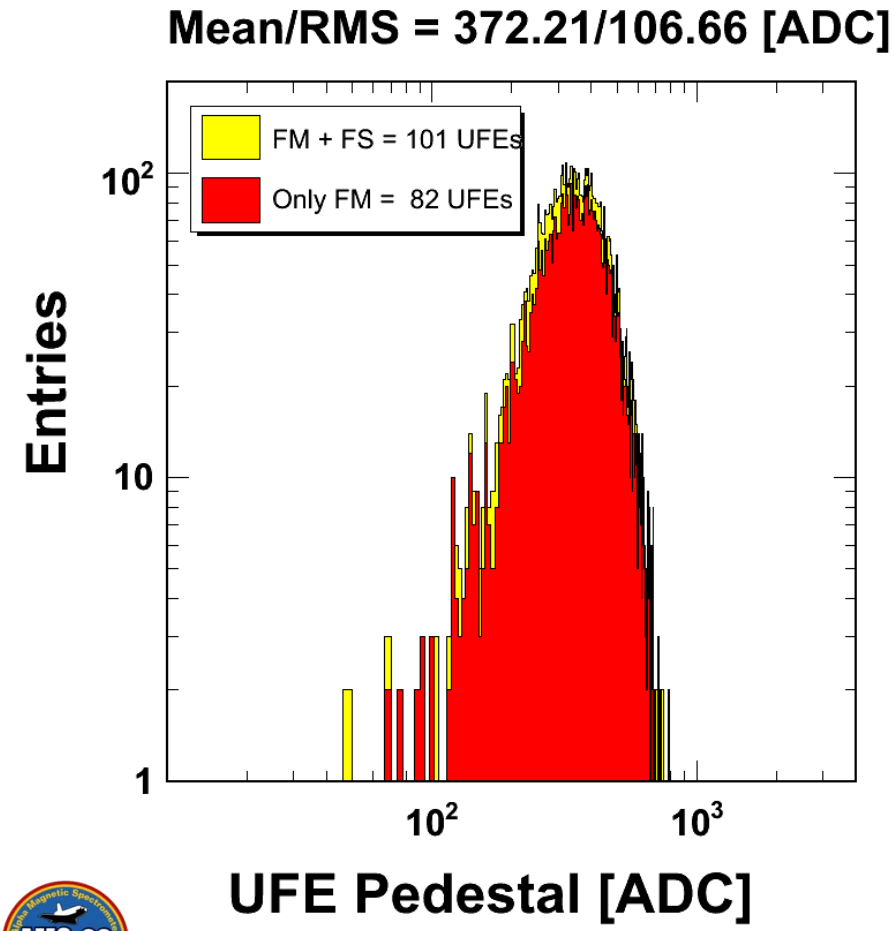


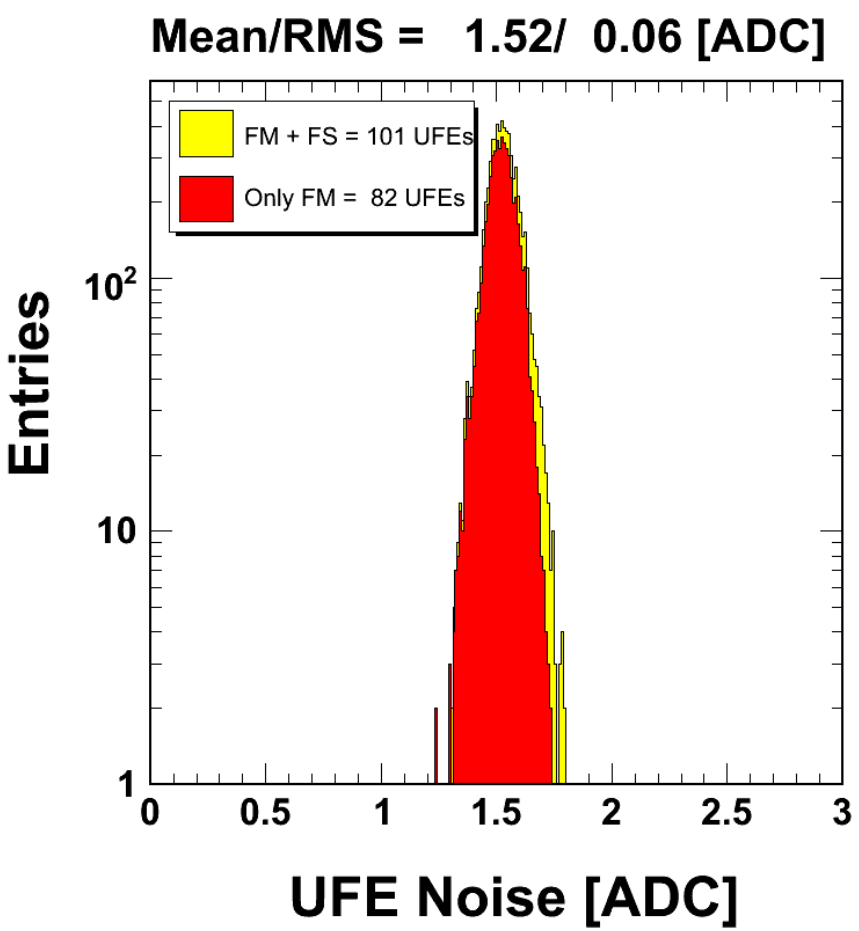
Every channel has to be calibrated within operating temperature.

AMS-02 – TRD: FM-UFE-Board Pedestal & Noise Distribution

Pedestal Distribution :
~ 10% of full range

Noise RMS Spread :
~ 4%

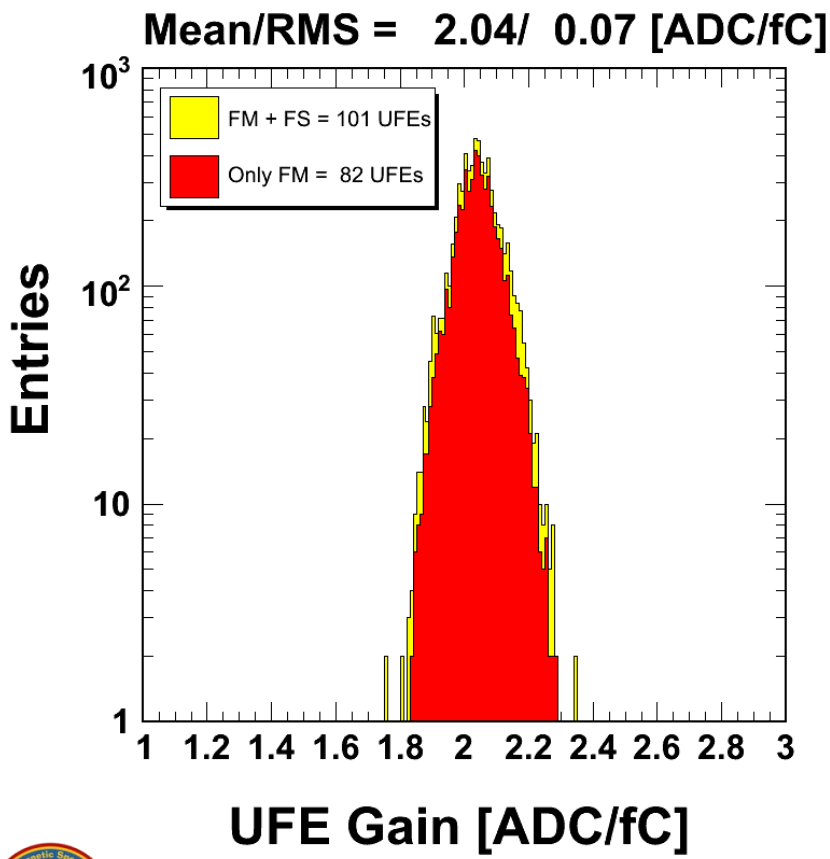


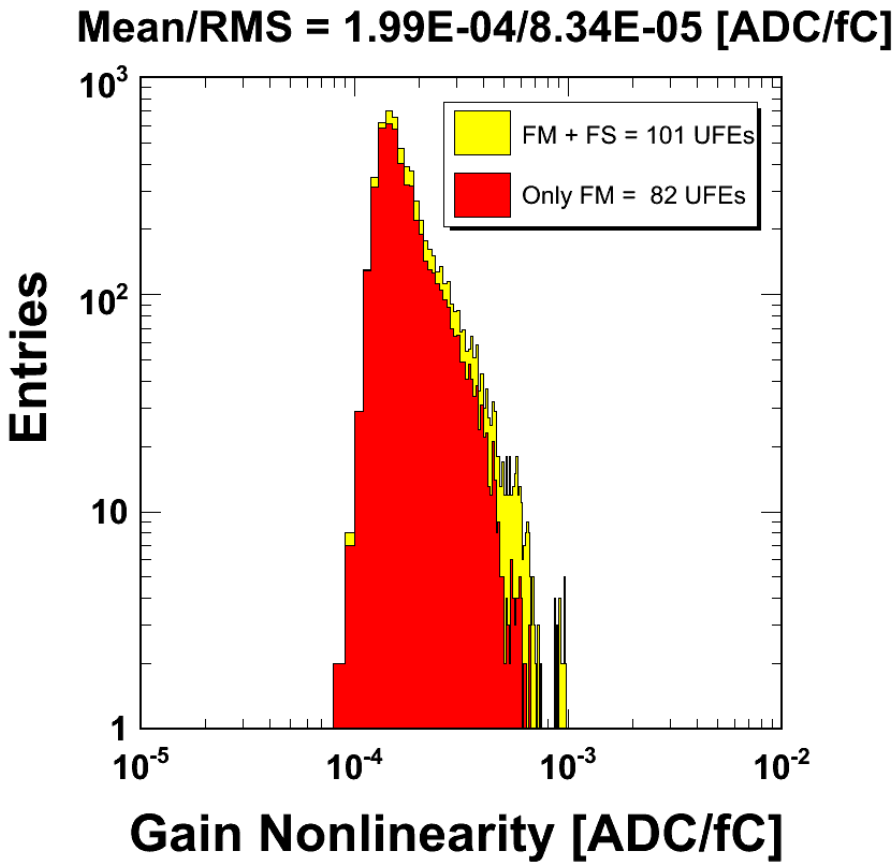


AMS-02 – TRD: FM-UFE-Board Gain & Nonlinearity Distribution

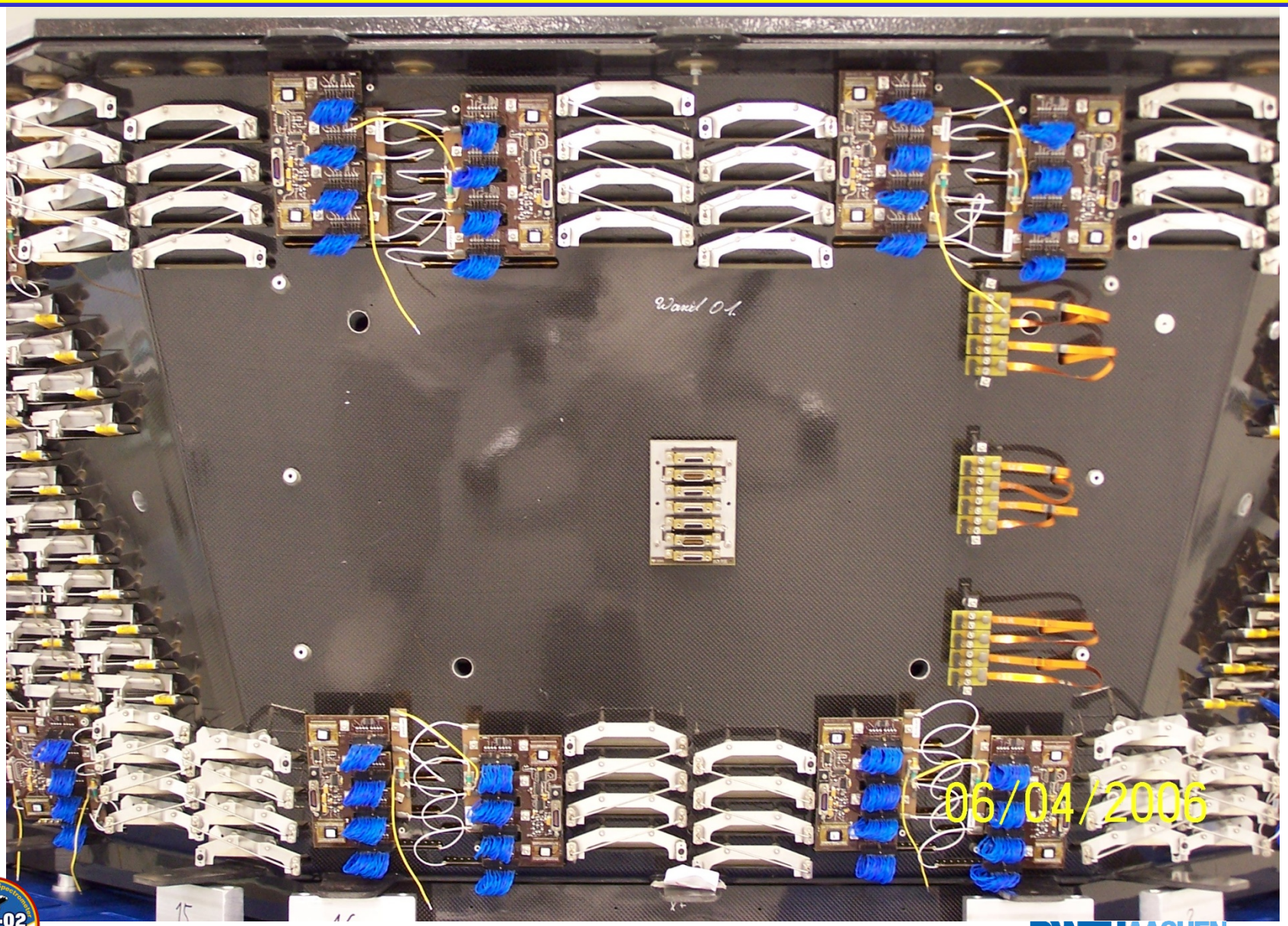
Gain RMS Spread :
~ 3%

Nonlinearity
~ 2E-04 [ADC/fC]

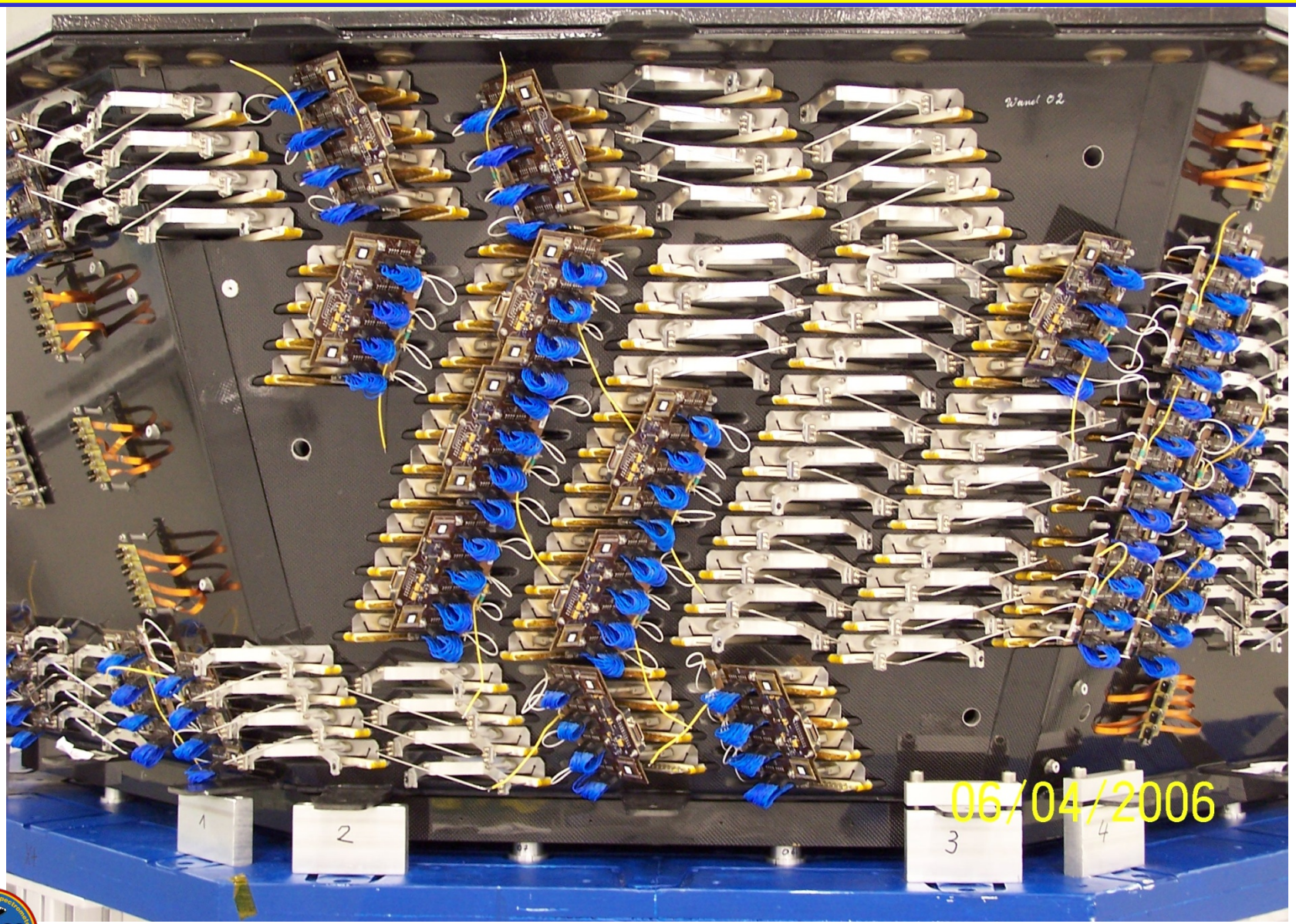




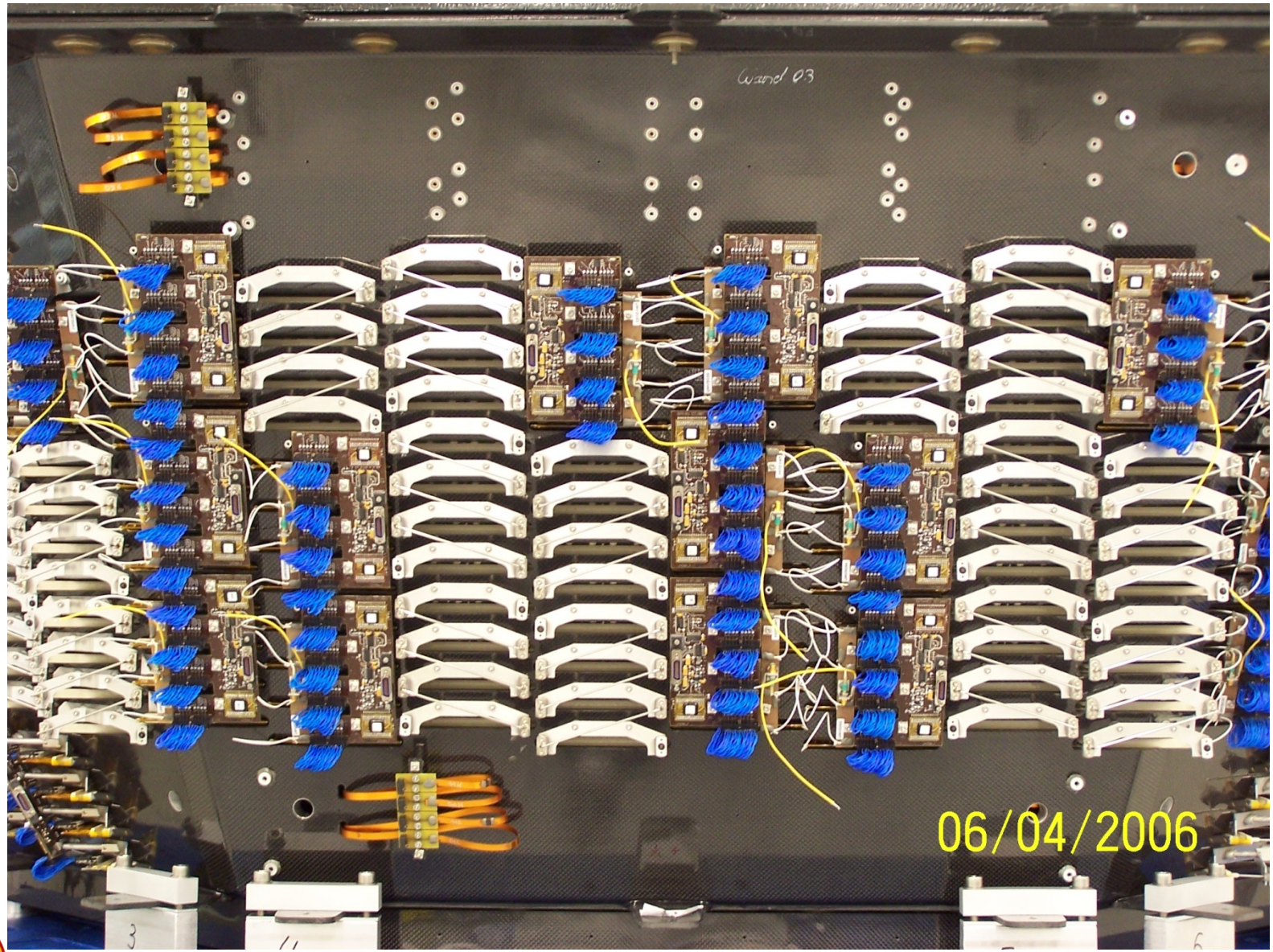
AMS-02 – TRD: Integration of FM-UFE-Boards on Octagon Wall 1



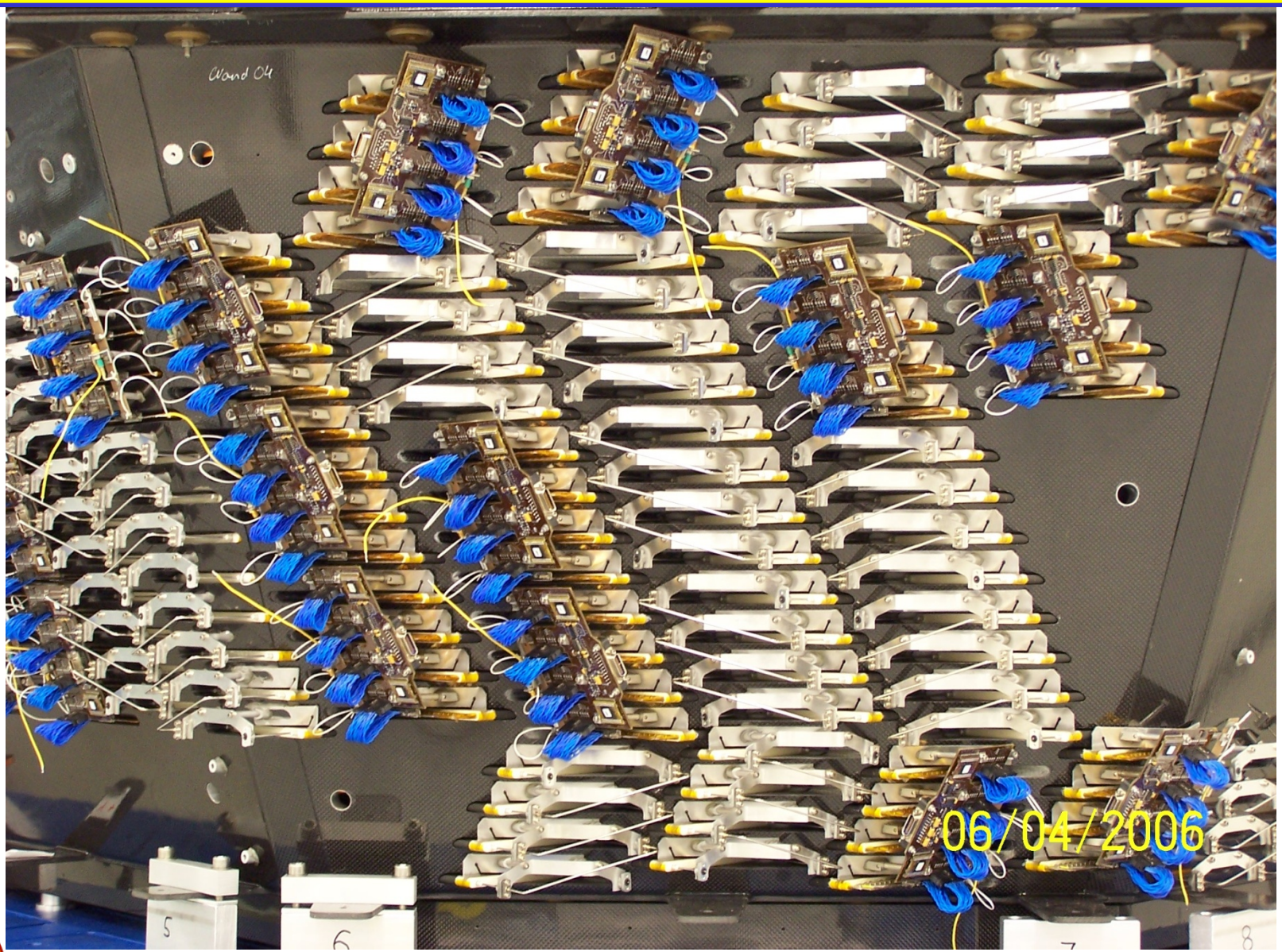
AMS-02 – TRD: Integration of FM-UFE-Boards on Octagon Wall 2



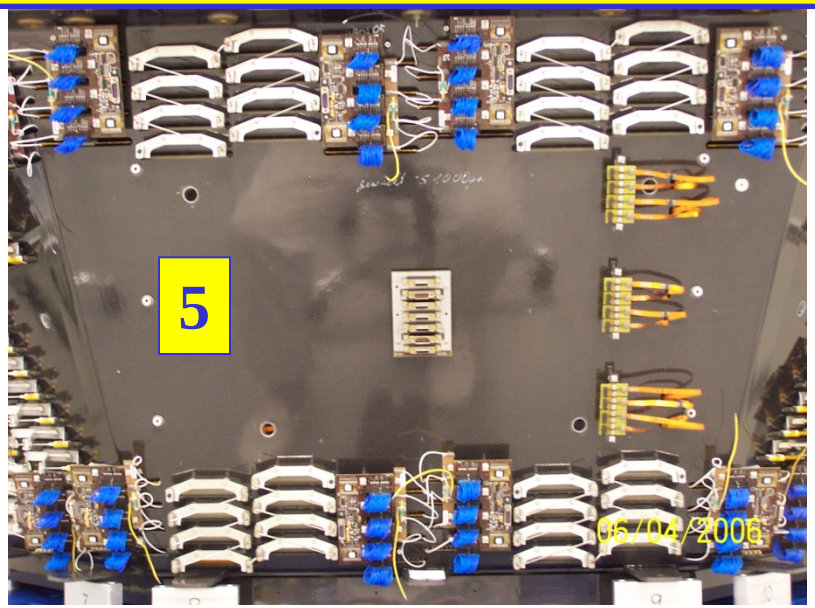
AMS-02 – TRD: Integration of FM-UFE-Boards on Octagon Wall 3

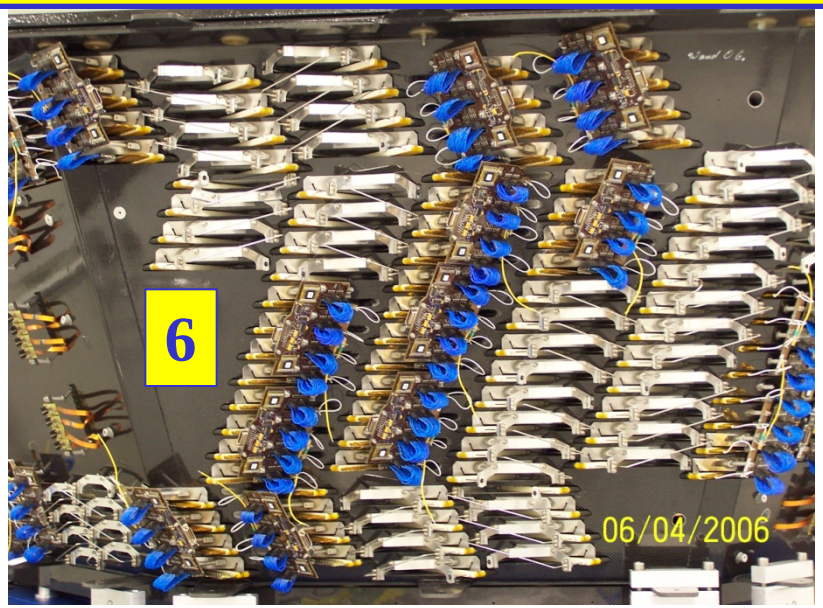


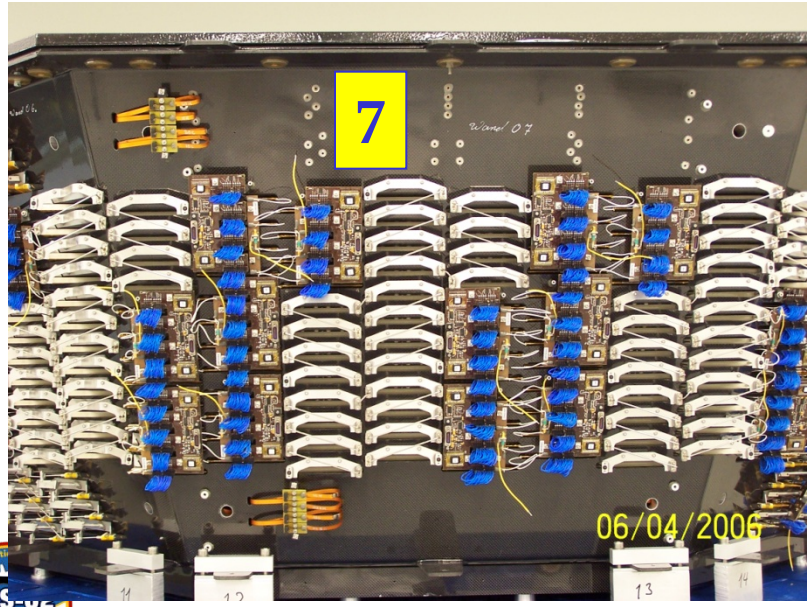
AMS-02 – TRD: Integration of FM-UFE-Boards on Octagon Wall 4

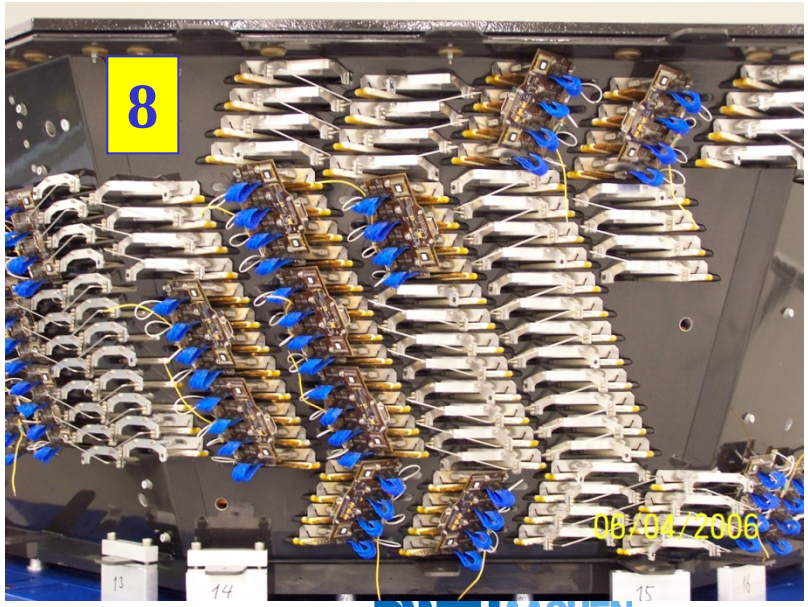


AMS-02 – TRD: Integration of FM-UFE-Boards on Octagon Walls

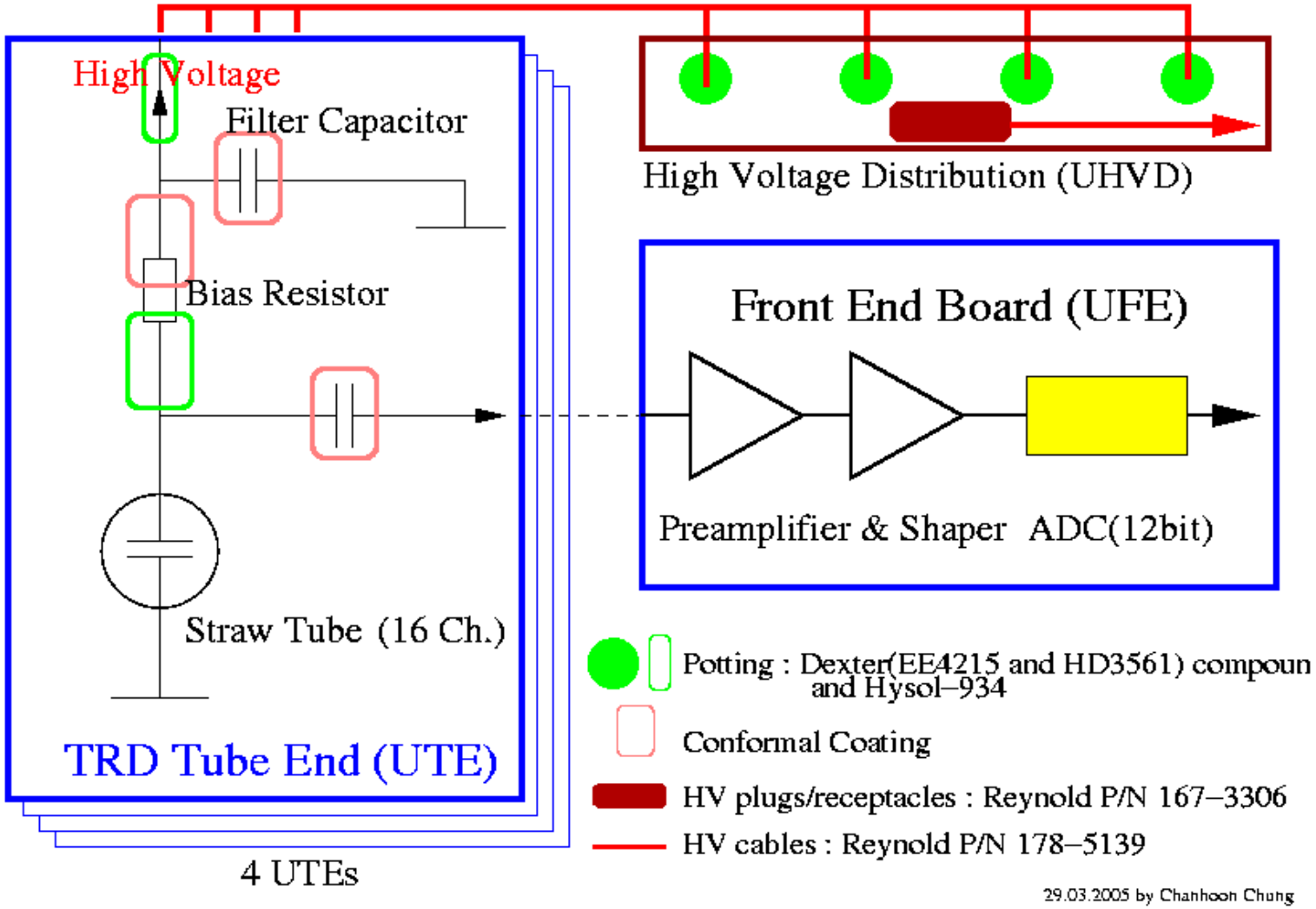






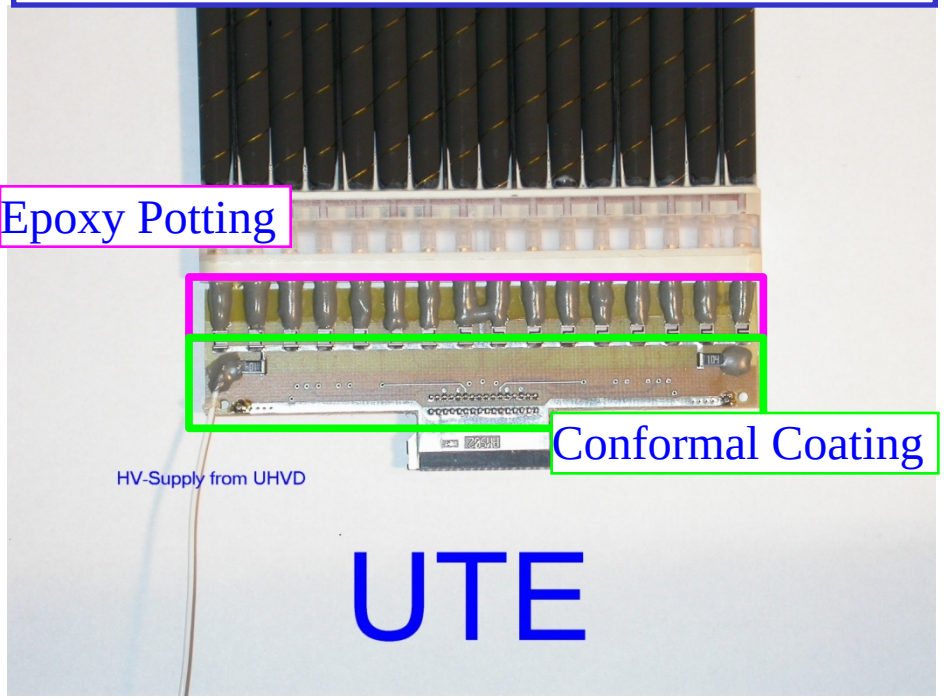


AMS-02 TRD: Straw Module+Frontend-Readout, Corona Discharges

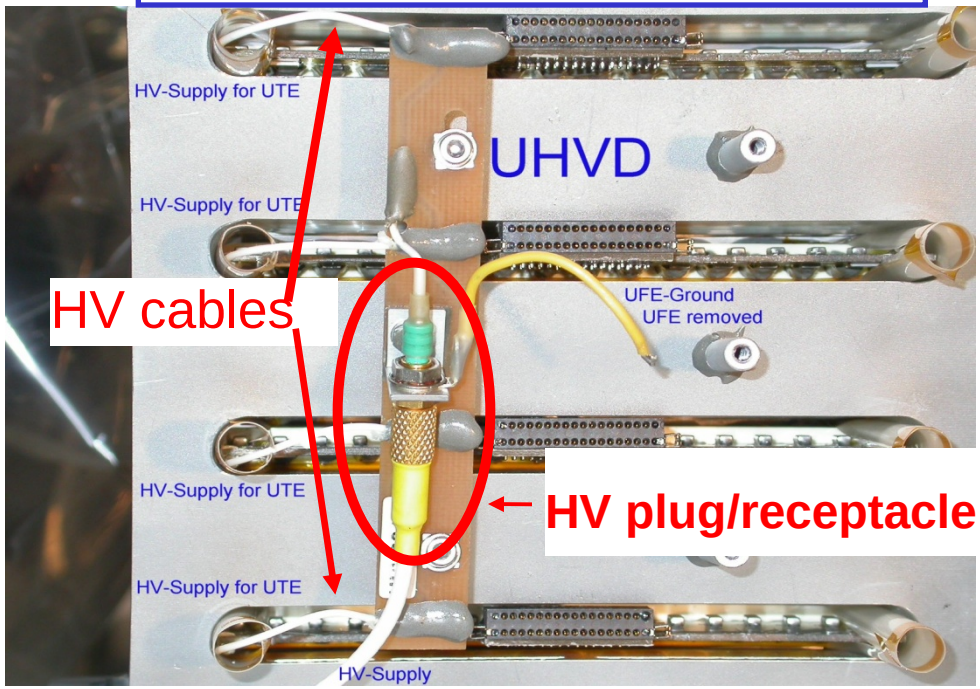


AMS-02 TRD: Corona Discharge Test

Straw Module UTE-board

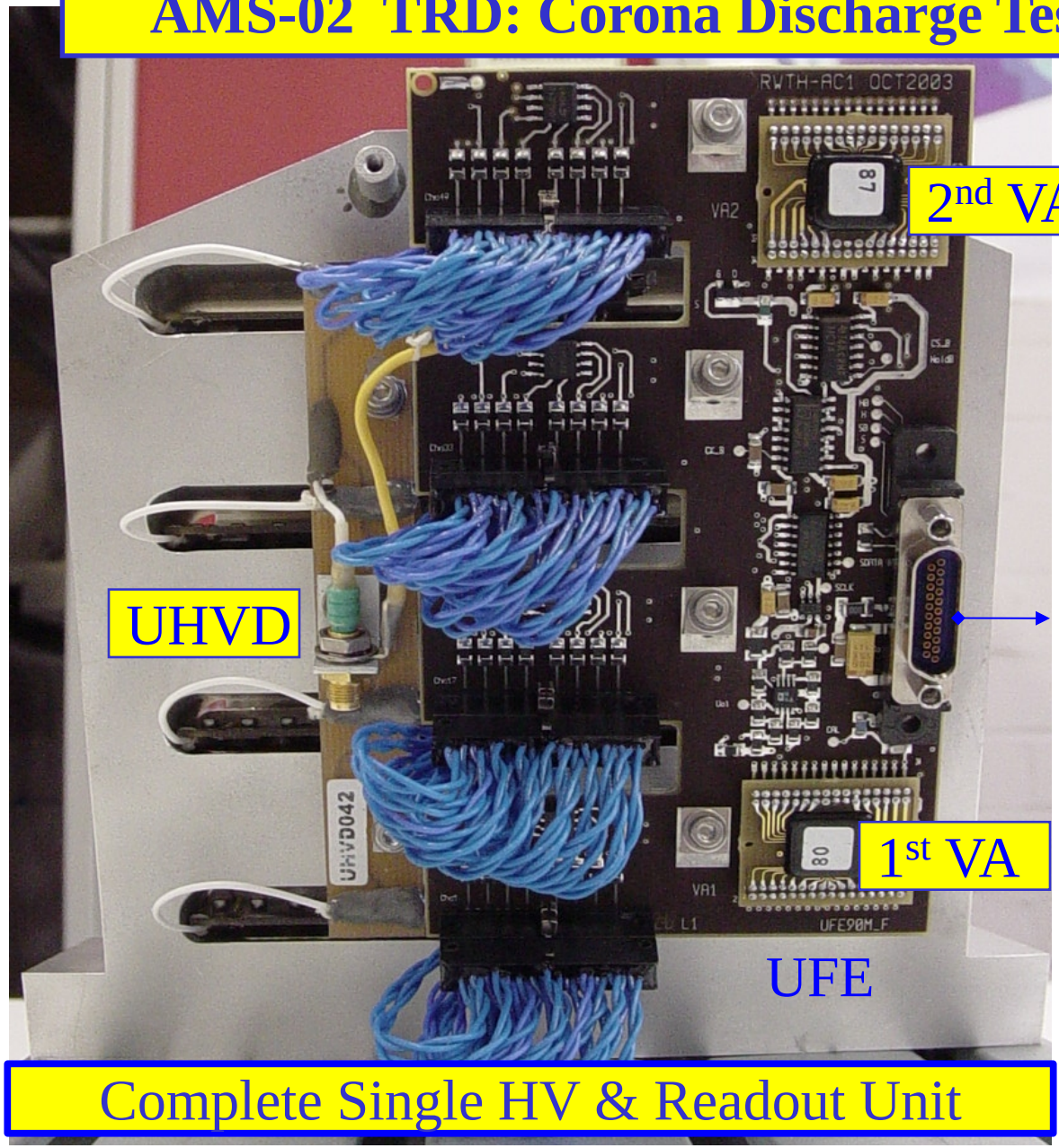


HV-Distribution (UHVD) board



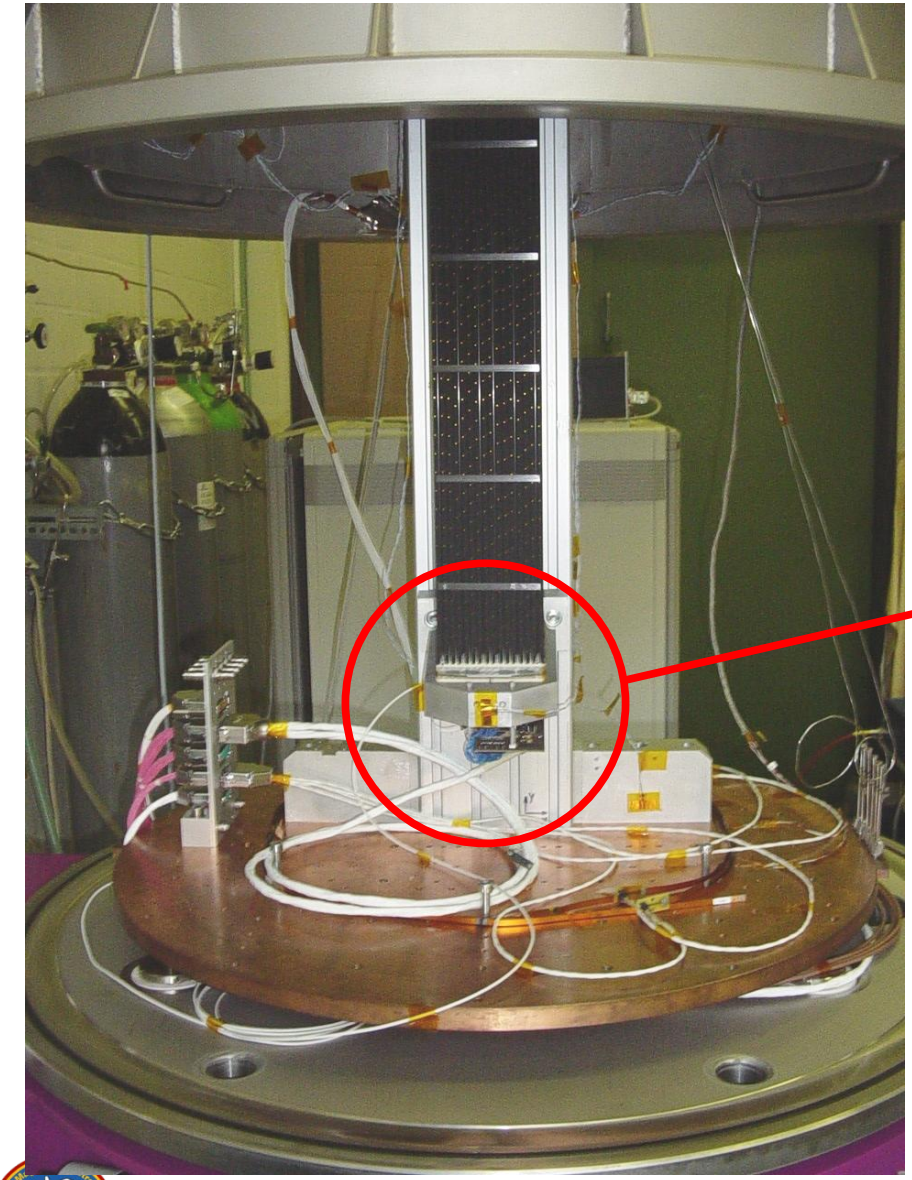
AMS-02 TRD: Corona Discharge Test

Octagon-Like Al. Panel

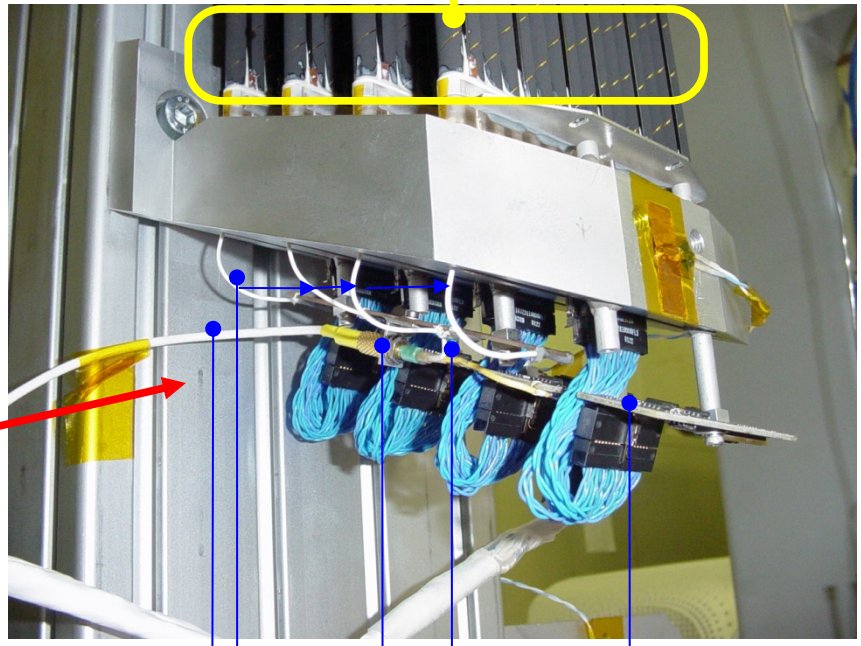


Complete Single HV & Readout Unit

AMS-02 TRD: Corona Discharge Test



TRD 4 layers straw modules



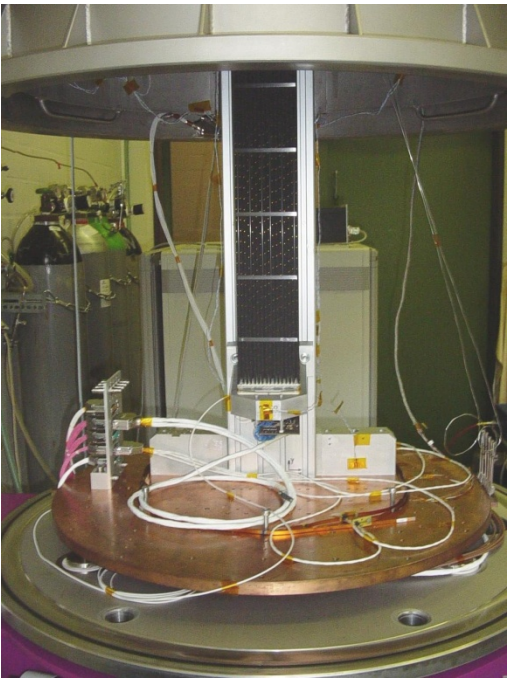
UHVD

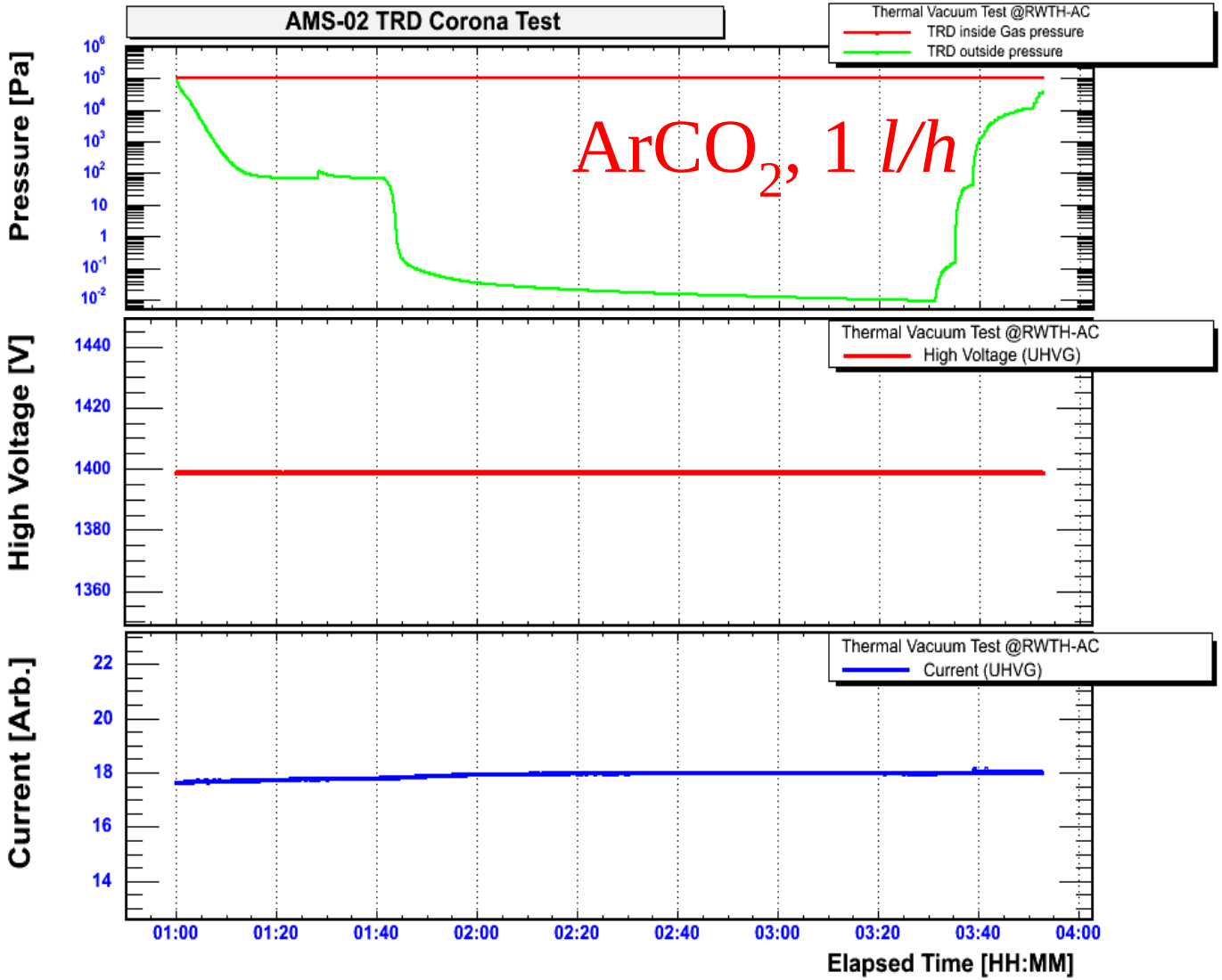
UFE

HV Plug/Receptacle

HV Cables

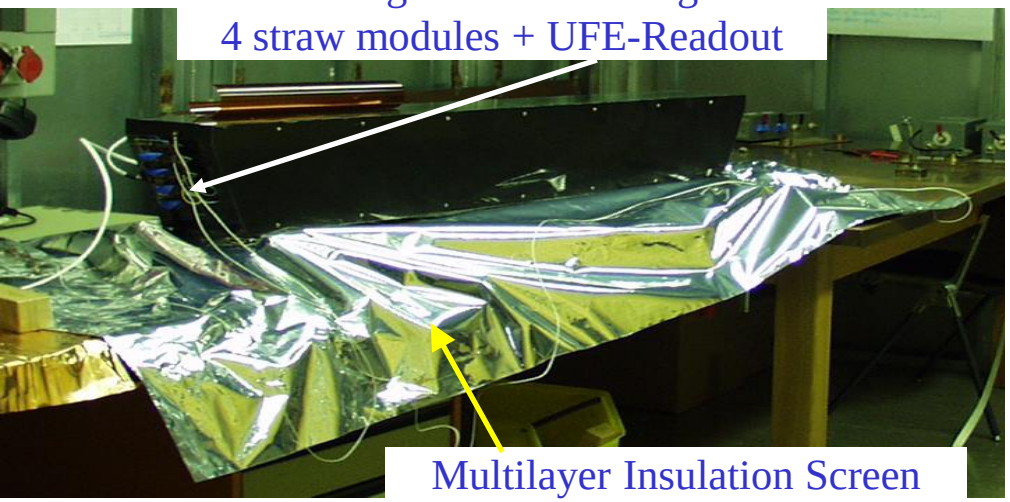
AMS-02 TRD: Corona Discharge Test





With Kapton Screening of UTE-boards no Corona discharges observed!

AMS-02 TRD: ElectroMagnetic Interference Test



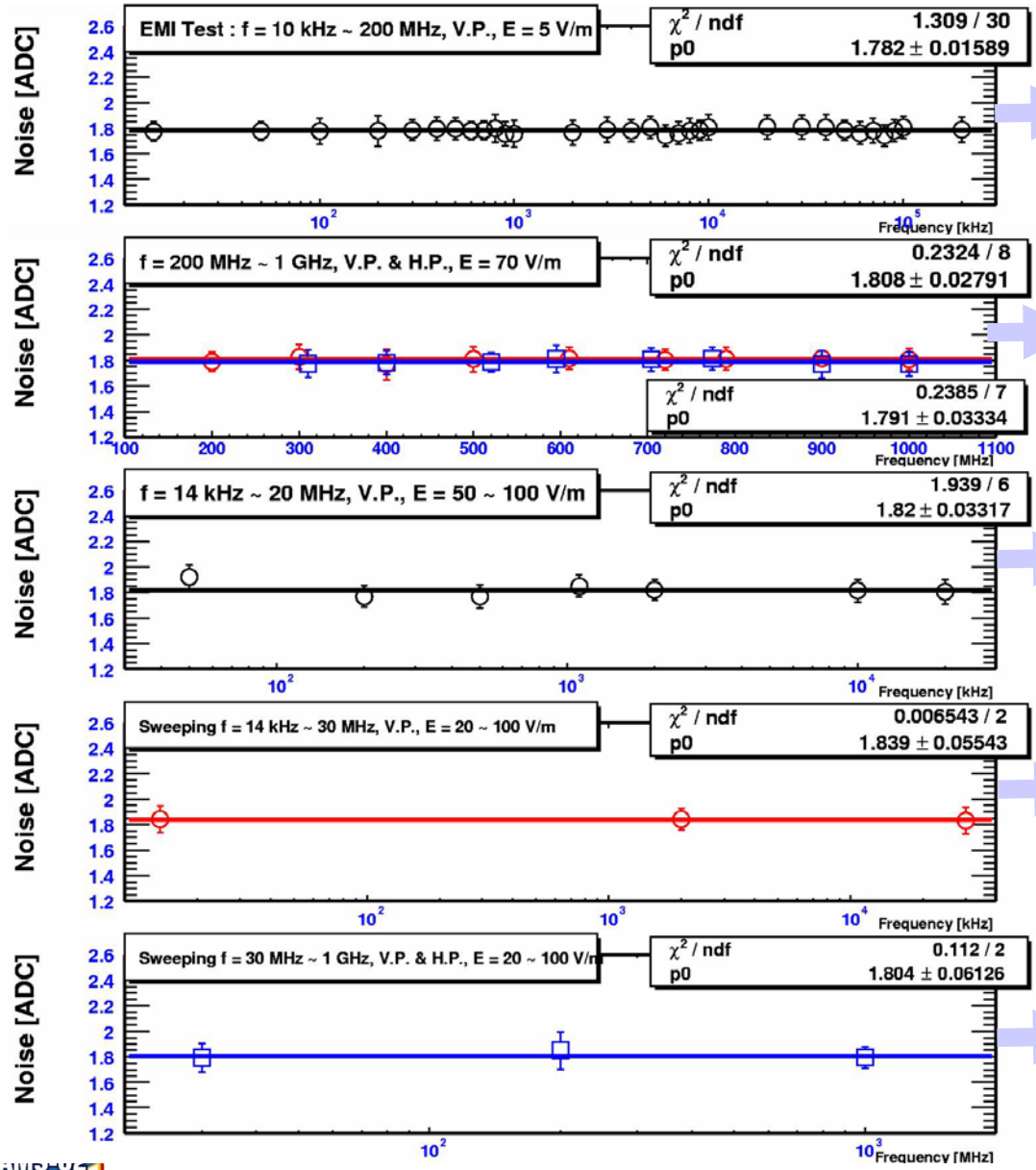
EMI Test @KMW Co. Munich

According to
"Space Station Electromagnetic Emission and Susceptibility Requirements for the Electromagnetic Compatibility"

SSP30237 paragraphs RS02, RS03, and RE02

Wave : Horizontal / Vertical Polar.
Frequency range : 10 kHz ~ 1 GHz
Electric Field : 5 ~ 100 [V/ m]

AMS-02 TRD: ElectroMagnetic Interference Test



Freq. =10 kHz ~ 200MHz
$|E|_{rms}$ = 5 [V/m] w. V.P.
Noise VP = 1.782 +- 0.0159[ADC]

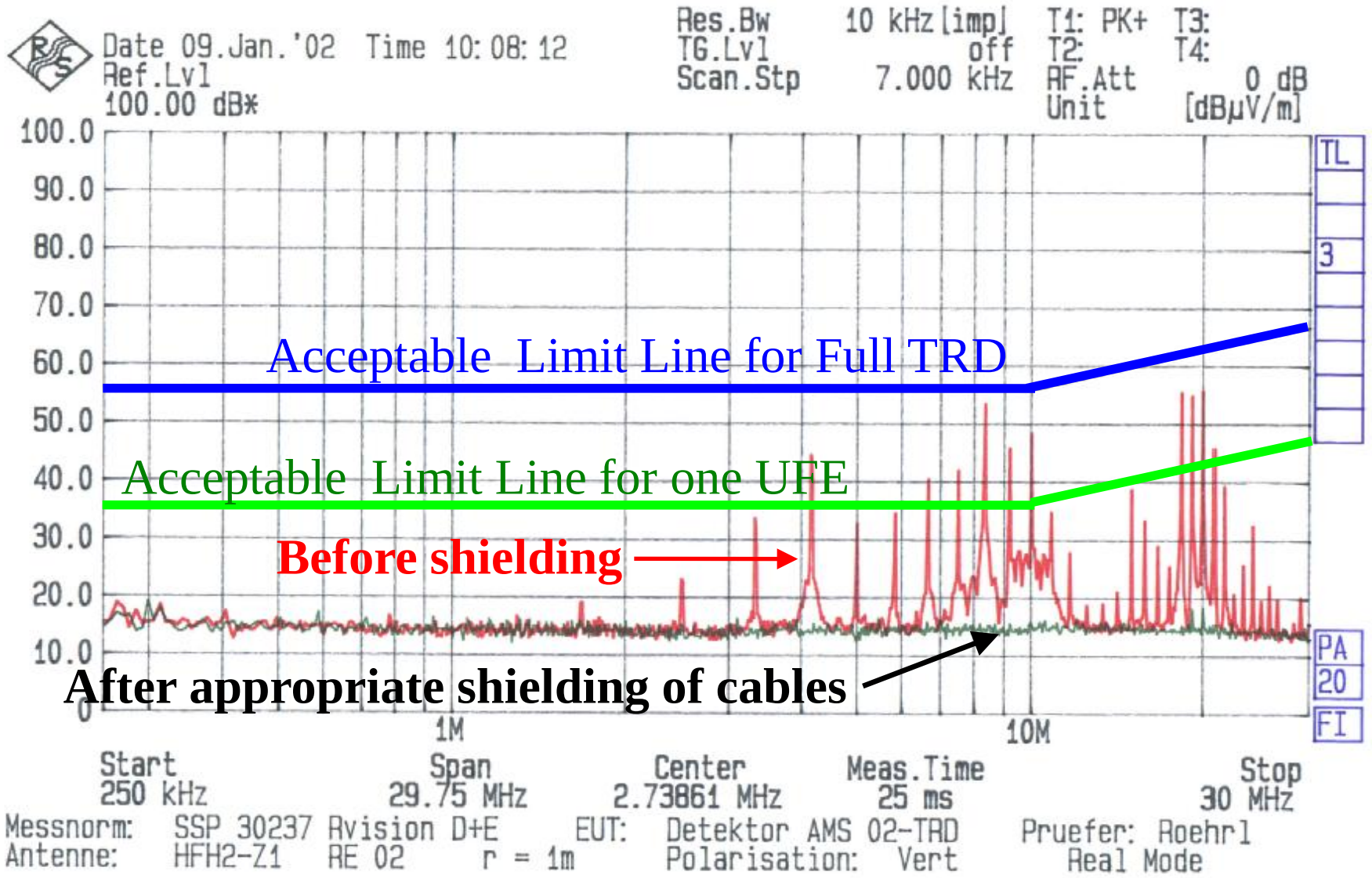
200MHz ~ 1GHz, 70 [V/m]
Noise VP = 1.808 +- 0.0279[ADC]
Noise HP = 1.781 +- 0.0333[ADC]

14kHz ~ 20MHz, 50~100[V/m]
Noise VP = 1.82 +- 0.0332[ADC]

Sweeping Freq. =14 kHz ~ 30MHz
$|E|_{rms}$ = 20 ~ 100[V/m] w. V.P.
Noise VP = 1.839 +- 0.0554[ADC]

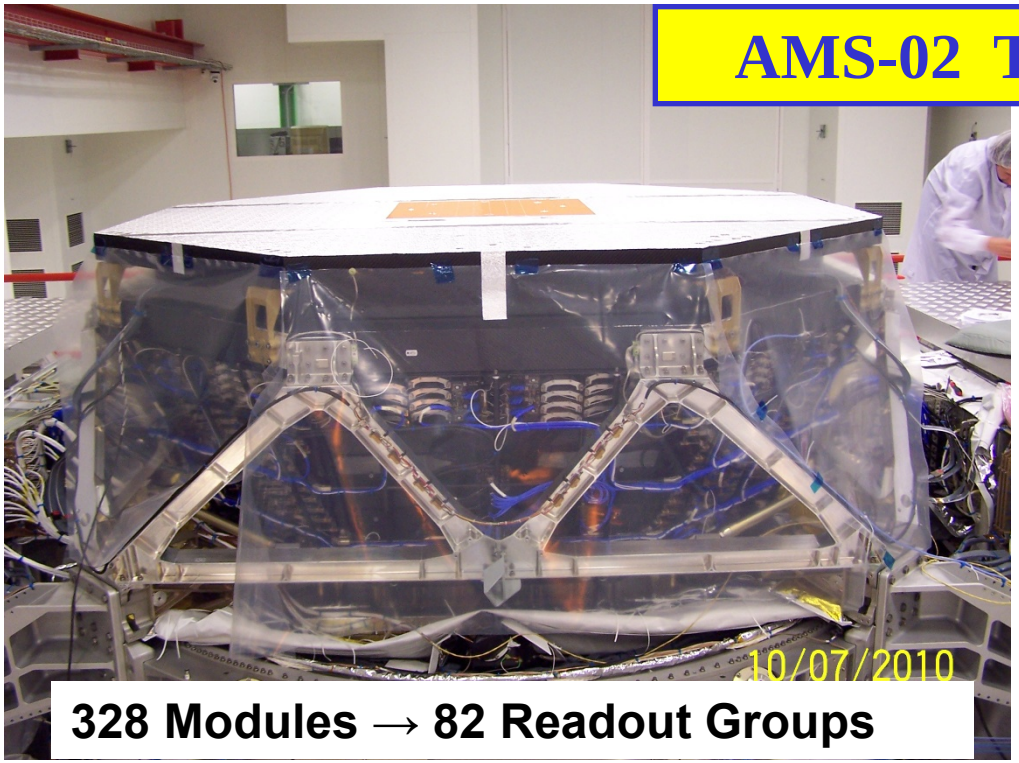
Sweeping Freq. =30MHz ~ 1GHz
$|E|_{rms}$ = 20 ~ 100[V/m] w. V(H).P.
Noise V&H = 1.804 +- 0.0613[ADC]

AMS-02 TRD: ElectroMagnetic Interference Test

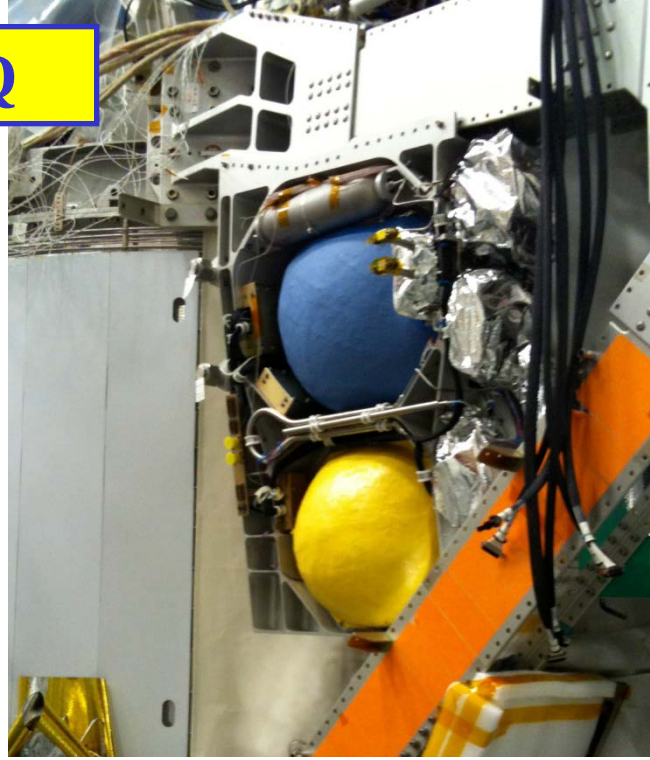


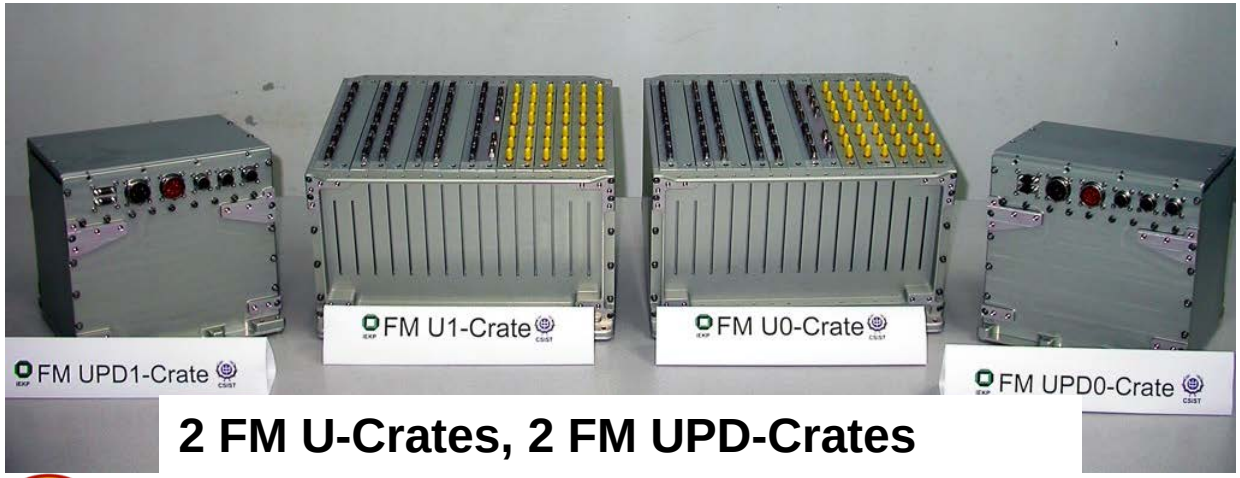
AMS-02 TRD DAQ

AMS-02 TRD DAQ

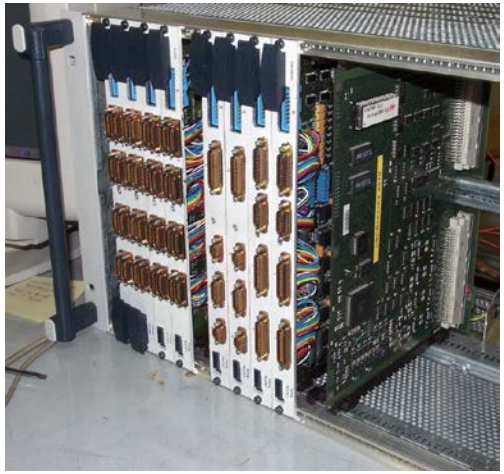


328 Modules → 82 Readout Groups





2 FM U-Crates, 2 FM UPD-Crates

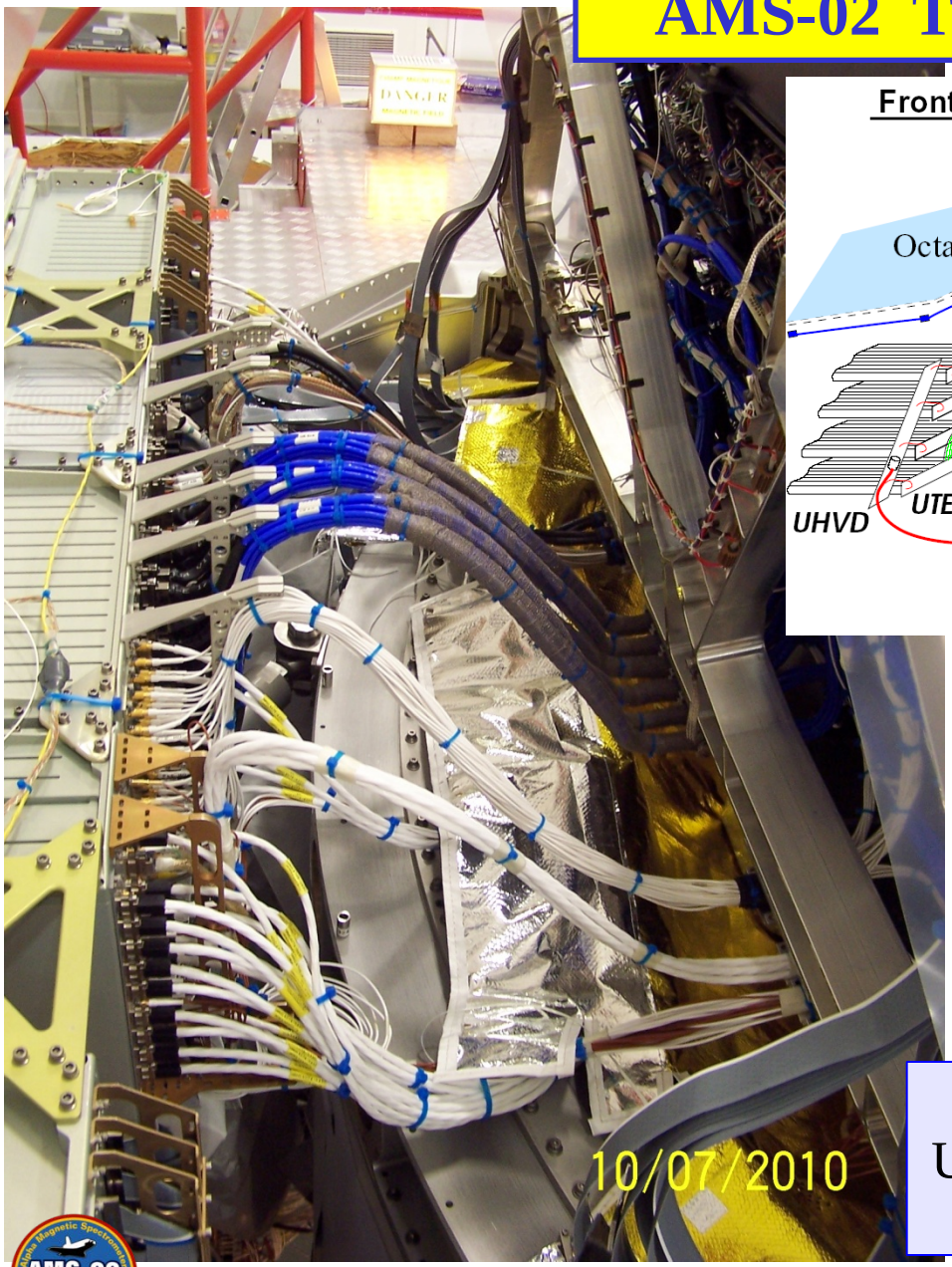


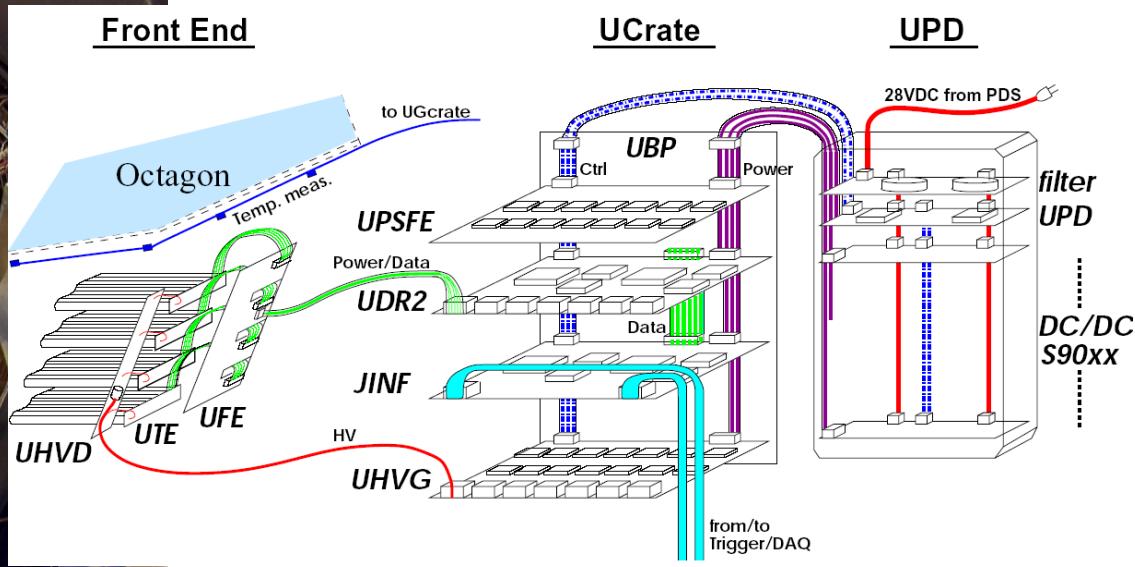
AMS-02 TRD DAQ

All AMS-02 electronics is mounted on two main radiators (RAM and WAKE) to dissipate about 1000W into space

TRD readout electronics (RAM side):
U-Crate and UPD

AMS-02 TRD DAQ





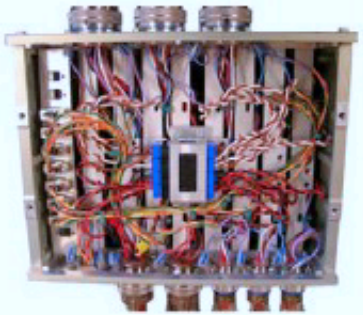
Space requirements issued by NASA :

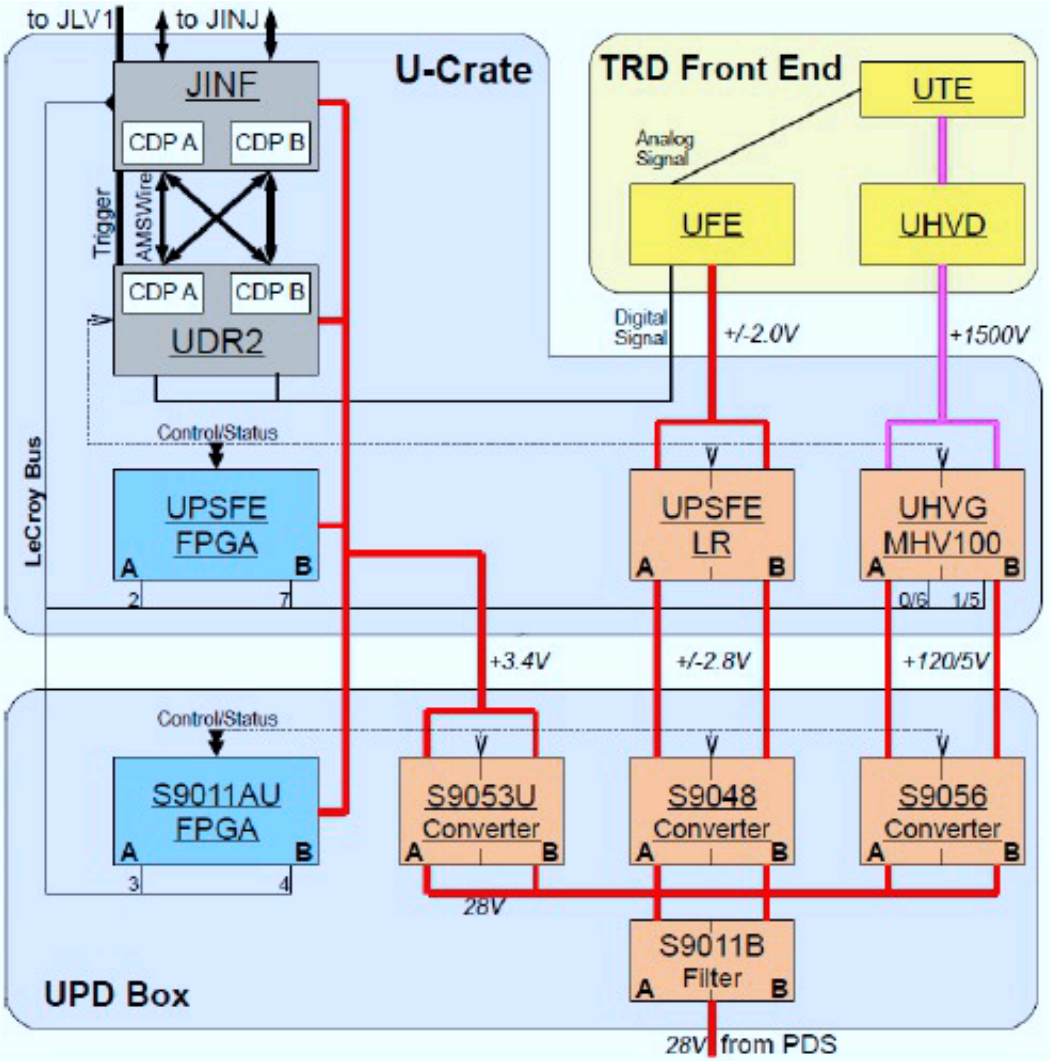
- **Electromagnetic Interference**
- **Electromagnetic Compatibility**
- **Mechanical Vibration**
- **Thermal Vacuum Test**

TRD Power Consumption
UFE (20W) + UCrate (41W) + UPD (36W)
≈ 100W

AMS-02 TRD DAQ

…space qualification:
- Space Debris impact
- Heavy ions radiation
+ redundancy!
+ testing!!!



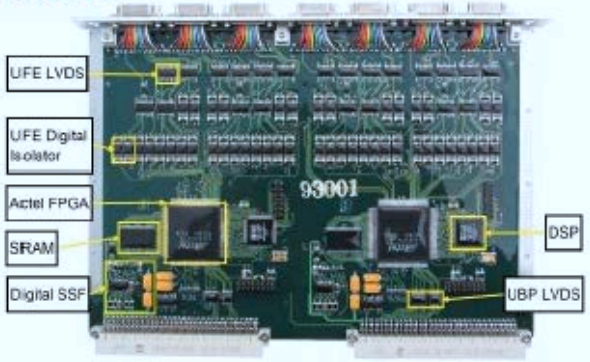


AMS-02 TRD DAQ

KIT - IEKP
Karlsruhe

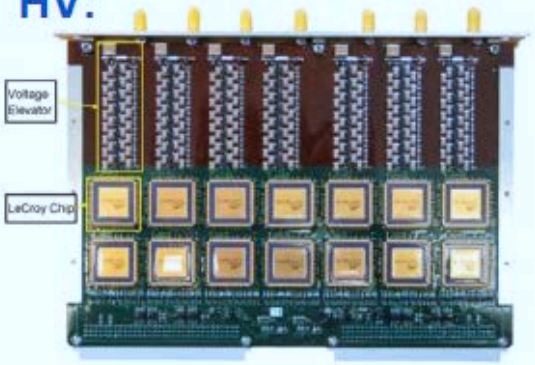
TRD Electronics Production

Readout:

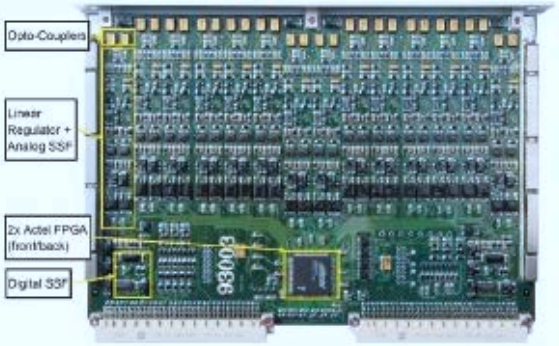


Phases:
EM = Engineering
QM = Qualification
QM2 = QM at production line
FM = Flight Model

HV:



Power:

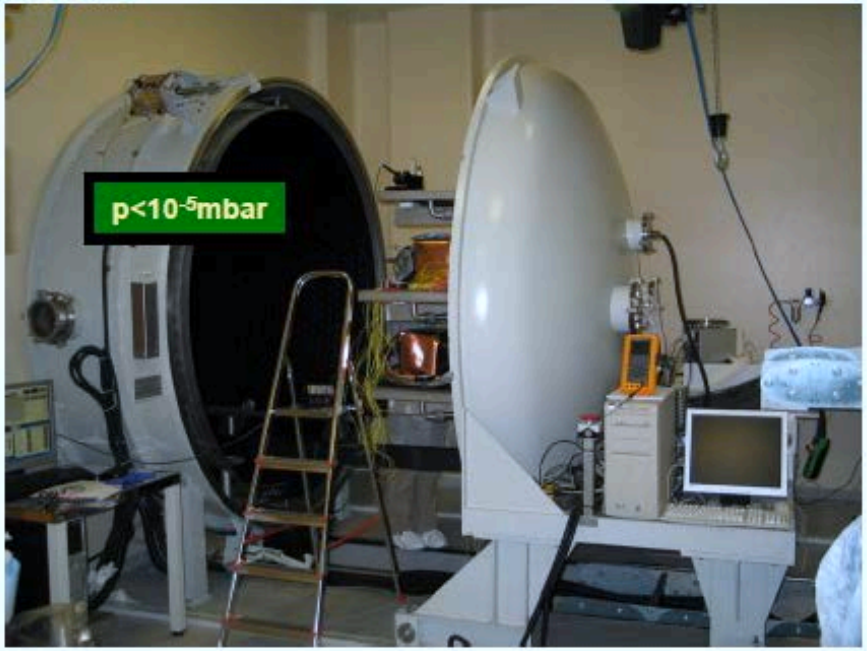


Production of qualification and flight model at CSIST in Taiwan

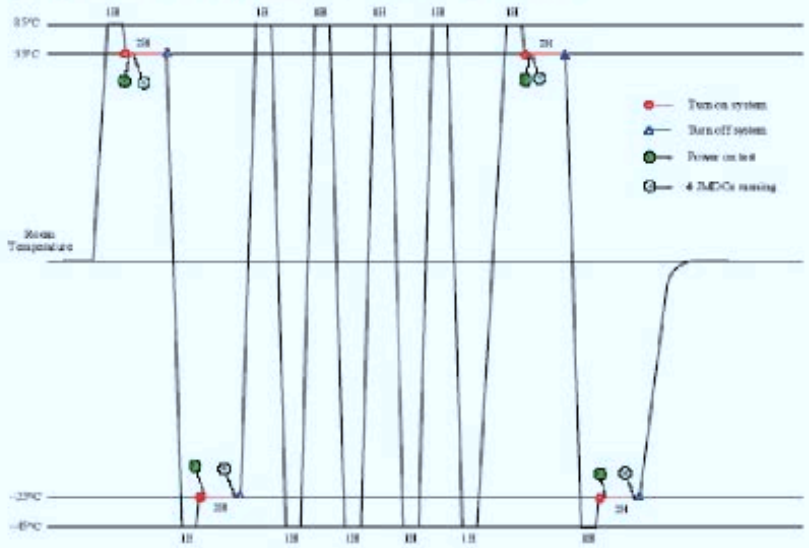
Board-level qualification and acceptance testing performed during production in Taiwan with specialized CSIST technicians and physicists.

KIT - IEKP Karlsruhe

QM/FM Thermal-Vacuum-Test



Repeated temperature profile



- Storage temperature cycles -45°C to +85°C
- Functional tests -25°C to +55°C
- Heat dissipated to cool plate only (on ISS this is the main radiator)

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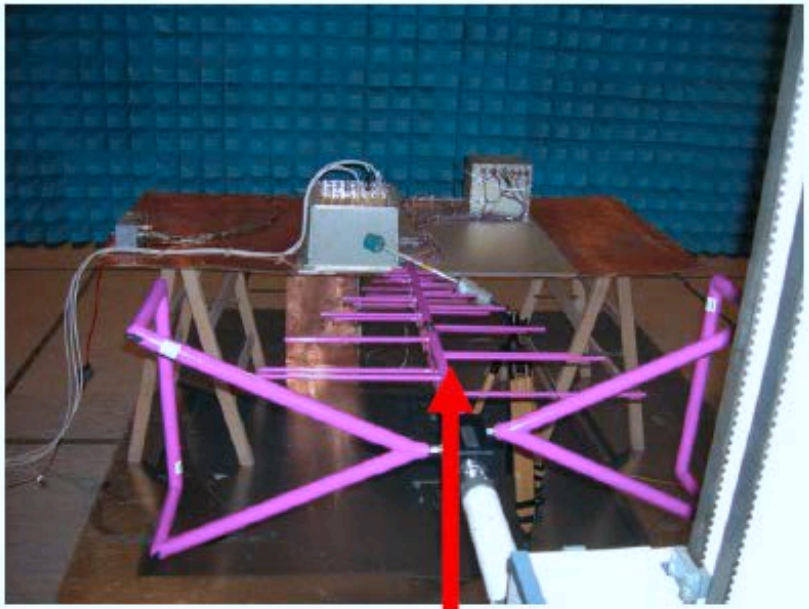
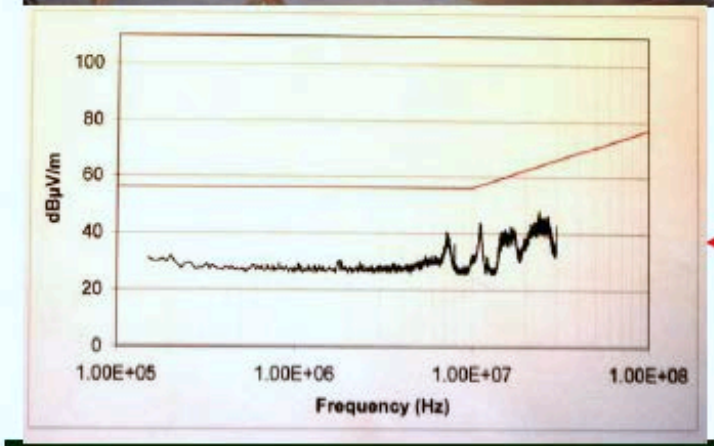
QM EMI/EMC Test





- *EMC*: operation during conducted or radiated disturbing pulses without failure
- *EMI*: test of radiated frequency spectrum in kHz to GHz range within NASA limits

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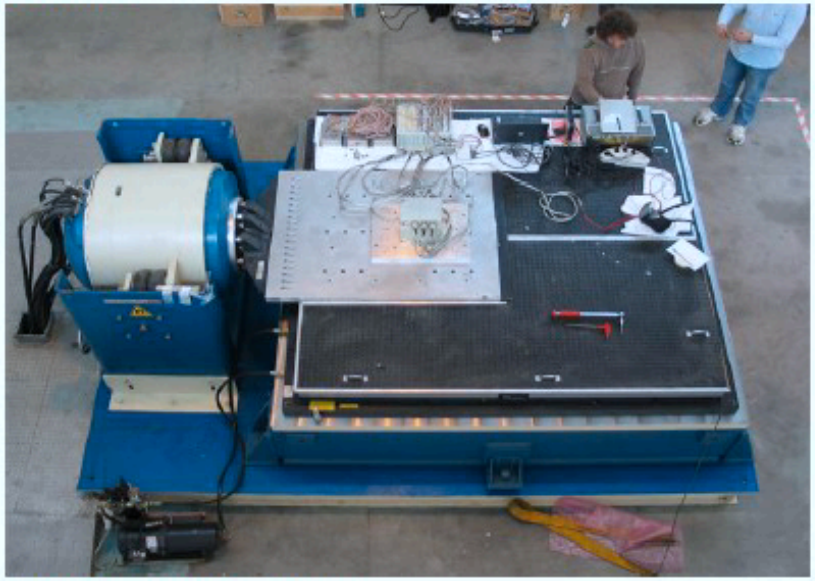
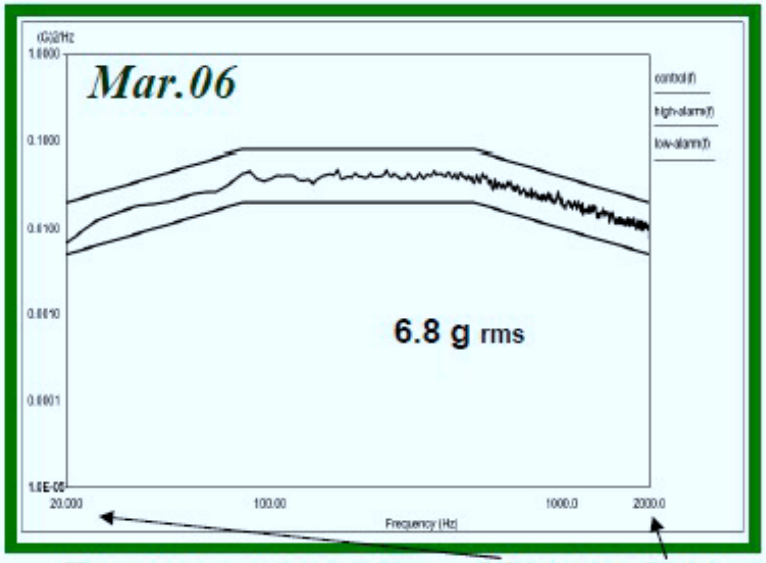
QM/FM Vibration test



S.E.R.M.S, Italy



Frequency spectrum 20Hz to 2kHz

- Simulation of vibration frequencies occuring during shuttle launch of up to 6.8g rms (duration about 10min – duration of shuttle launch about 4min)
- After test careful inspection for damage

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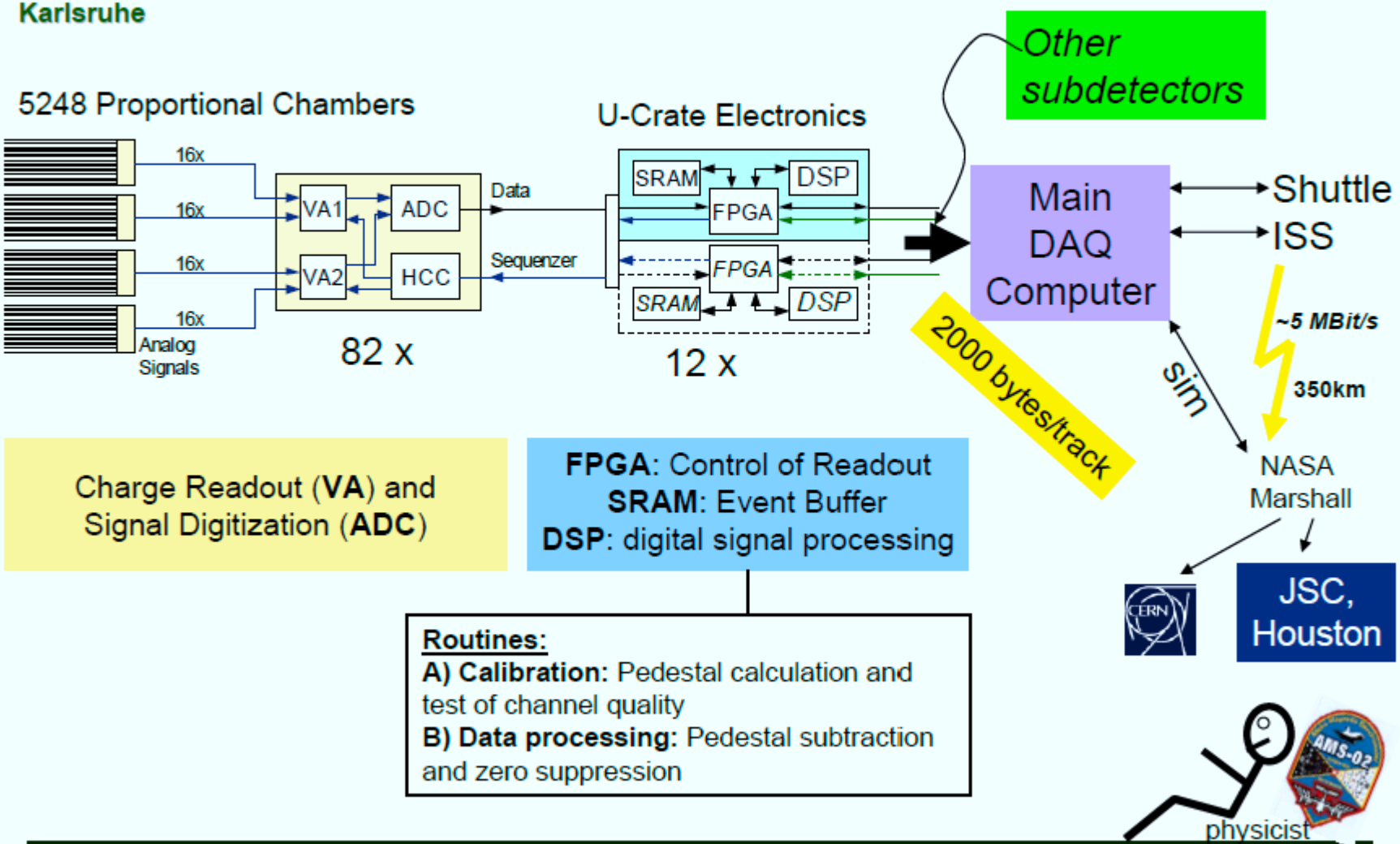
TRD Readout in AMS-02



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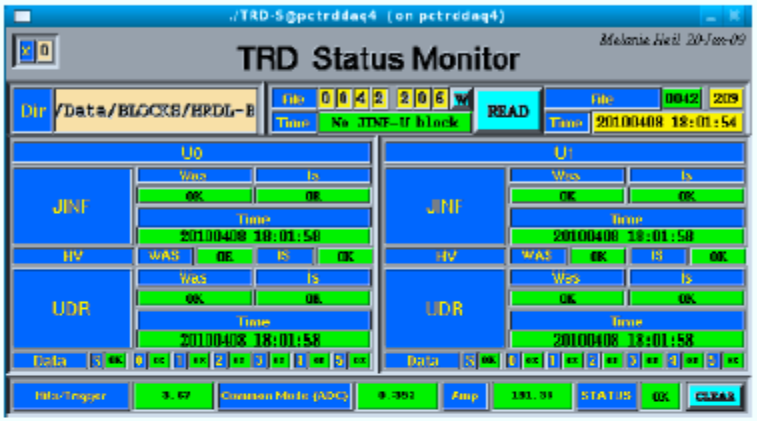
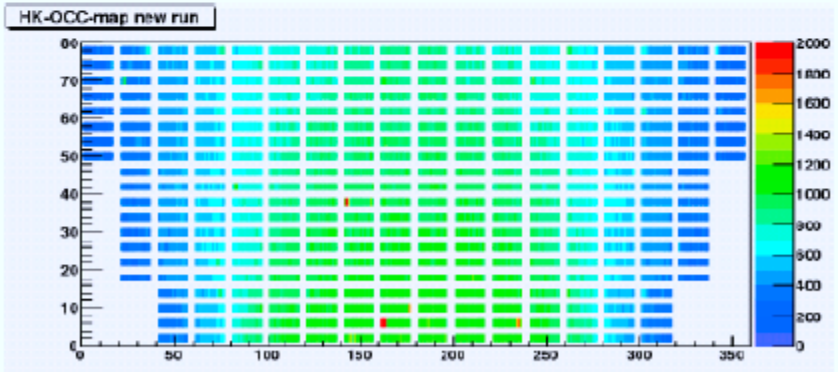
TRD Monitoring

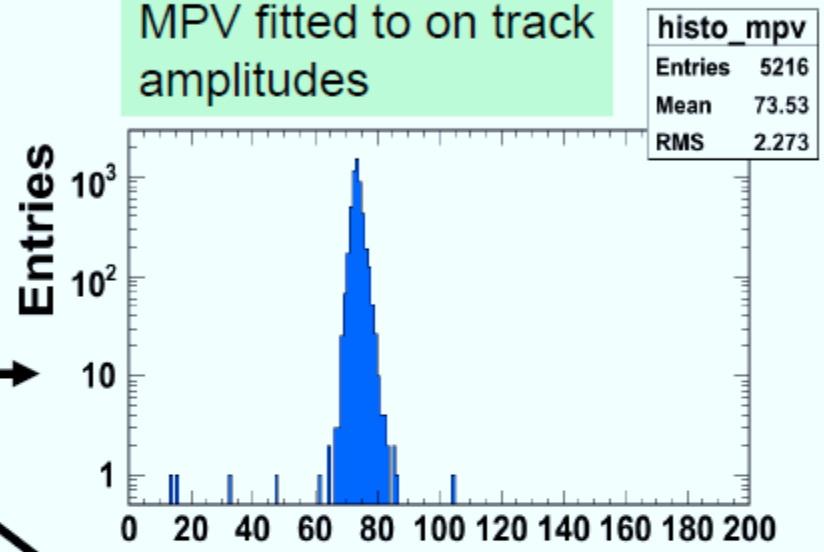


Extract from data stream, what instrument sends



map for occupancy

MPV fitted to on track amplitudes

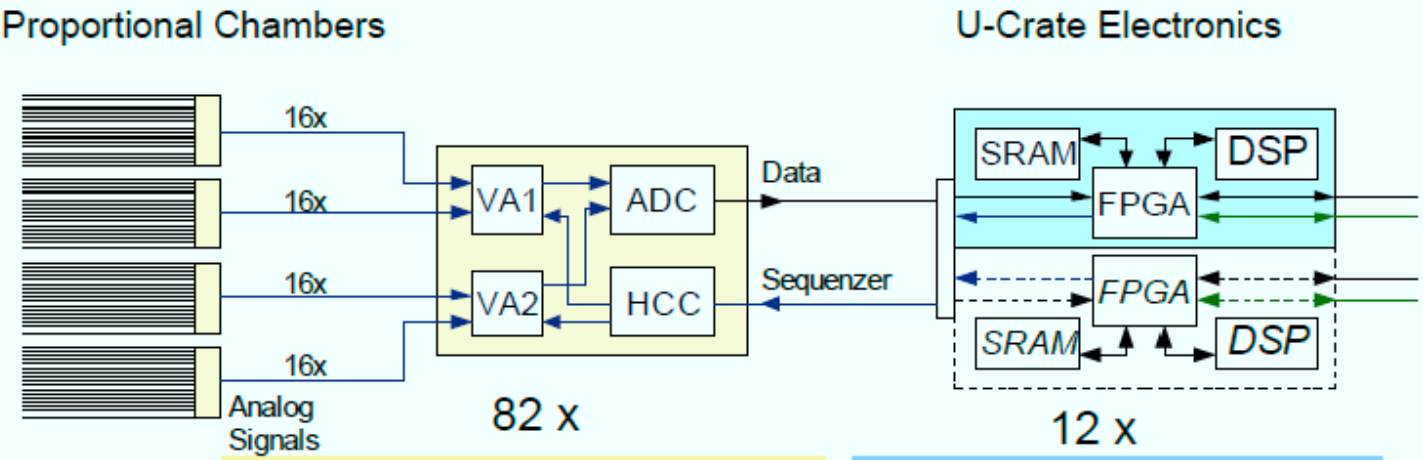


. . .

(status of power supplies, temperature, gas parameters, data acquisition, etc)

KIT - IEKP Karlsruhe

UDR DSP Code Description



Each UDR2 board reads and processes raw data of 448 strawtube channels. **Raw data** consists of 12-bit adc values.

AMS-02 TRD DAQ

Three main detector-specific parts:

a) **Data calibration:** pedestal calculation and test of channel quality

b) **Event processing:** pedestal substraction and zero-suppression, dynamic pedestal calculation

c) **DAQ monitoring:** Assembly of housekeeping data, calculation of average hit amplitude and occupancy

AMS-02 – TRD M-Structure, Heating

AMS-02 – TRD M-Structure Heating

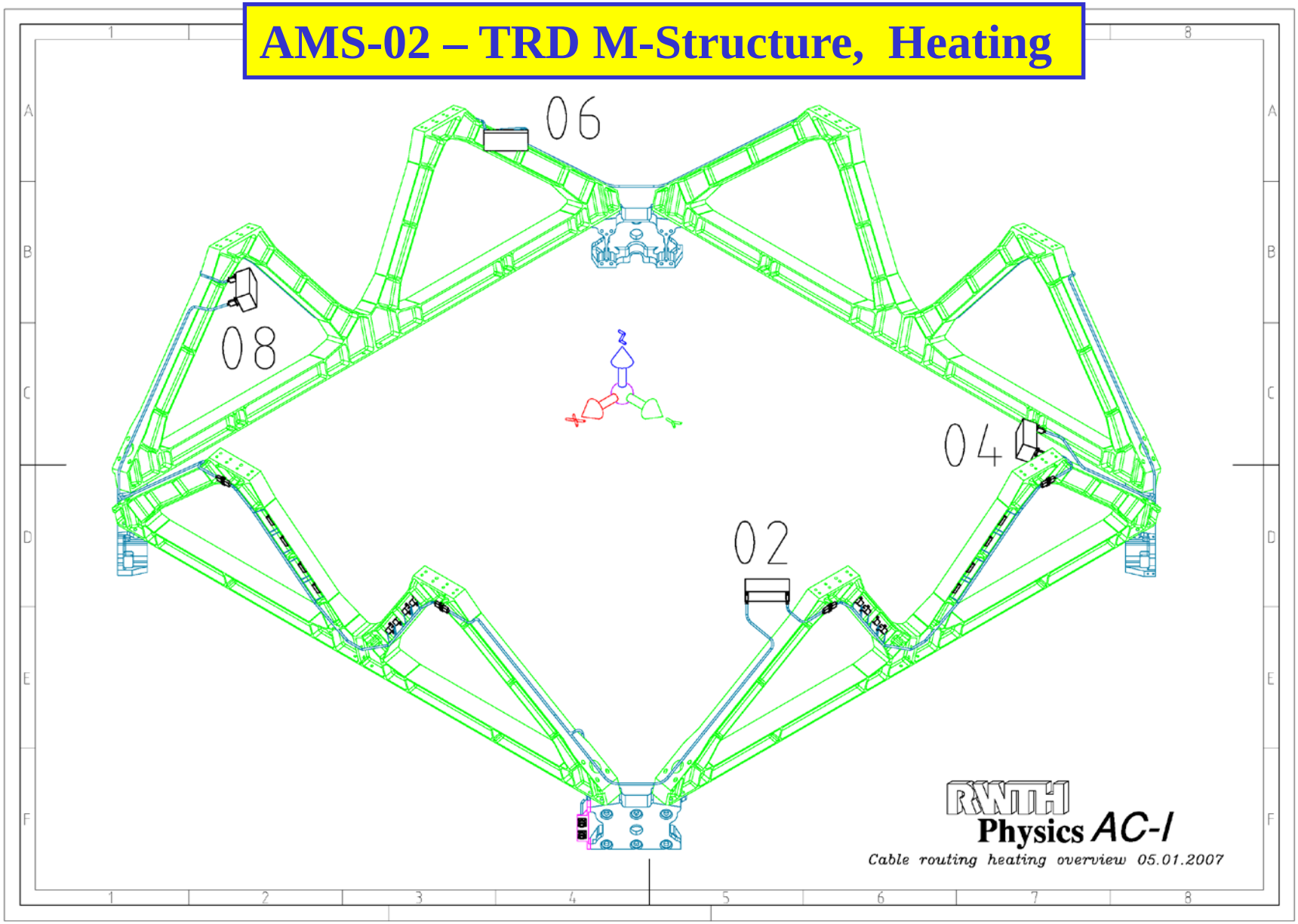
TRD Component Temperature Range

Item	Experim. Setup	Quantity tested	Temperature Range [°C]	Operative	Survival (no damage)	Comment
DOR-Connector	LN_2 (15 min)	8	-77	No	Yes	
DOR-Connector	TVT AC	20	T<-20	No	Yes	
			-20<T<+40	Yes	Yes	
Manifold FVs unswitched	TVT AC	1 x 5 channels potted, no Stycast	-20<T<+40	Yes	Yes	
			-25<T<-20	-	Yes	
FV Operation	TVT AC	2 x 2 FV	0<T<+40	Yes	Yes	
			-25<T<0	No	Yes	No switching
TRD Straw Module	TVT AC	4 SQ-Modules	-20<T<+45	Yes	Yes	With (Gas, HV, Power)
	TVT MPE		-45<T<+60	-	Yes	No (Gas, HV, Power)
UFE	TVT AC	82 FM(+19 FS)	-20<T<+50	Yes	Yes	
			-35<T<-20	-	Yes	
			+50<T<+80	-	Yes	
UHVD	TVT AC	5 QM	-45<T<+63	-	Yes	

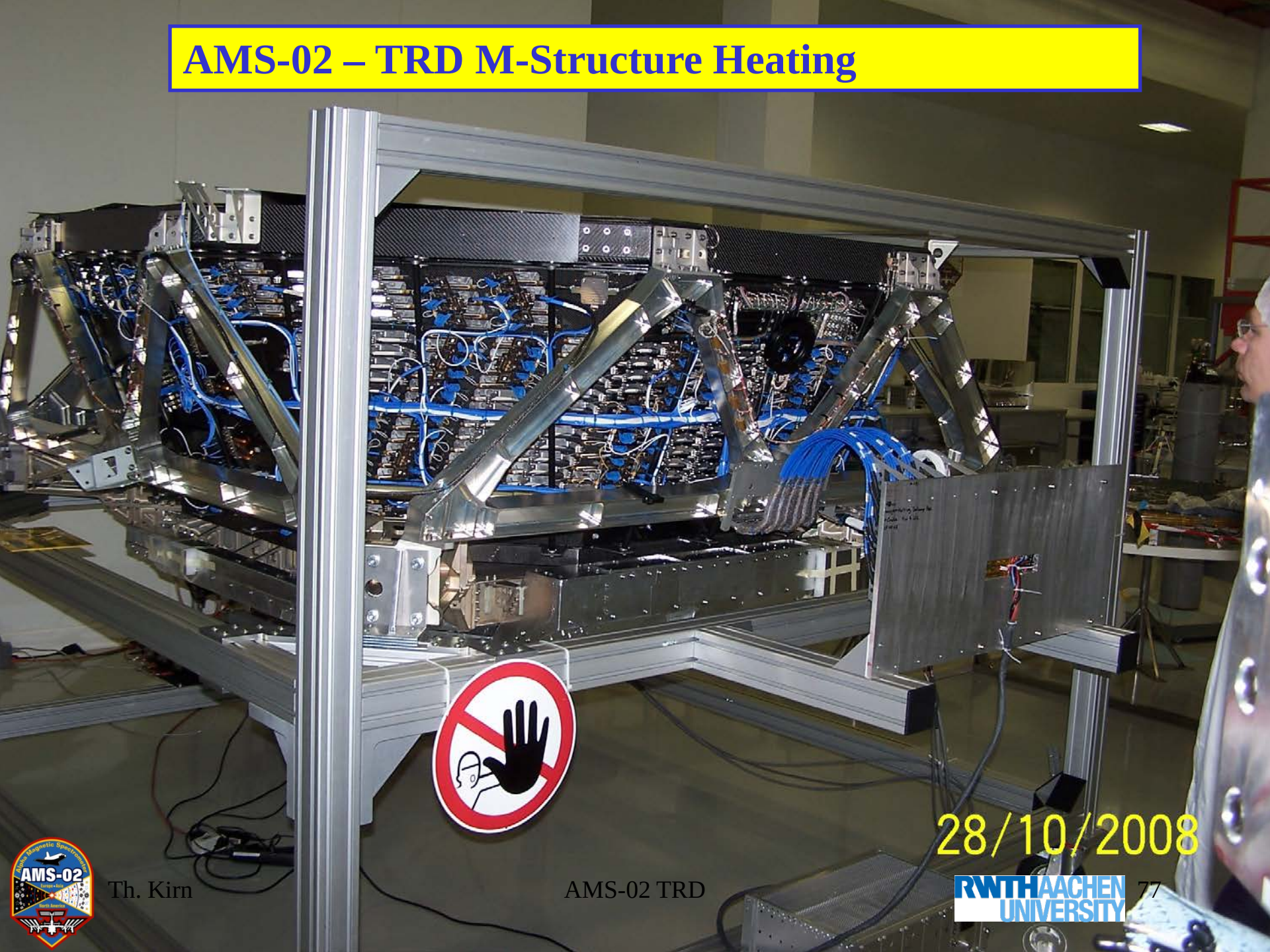
TRD Requirements ICD 27.01.2006	
Non Operative (Survival)	-20<T<40°C
Operative	-10<T<40°C

TRD Component Space Qualification:	
Non Operative (Survival)	-25<T<40°C
Operative	-20<T<40°C

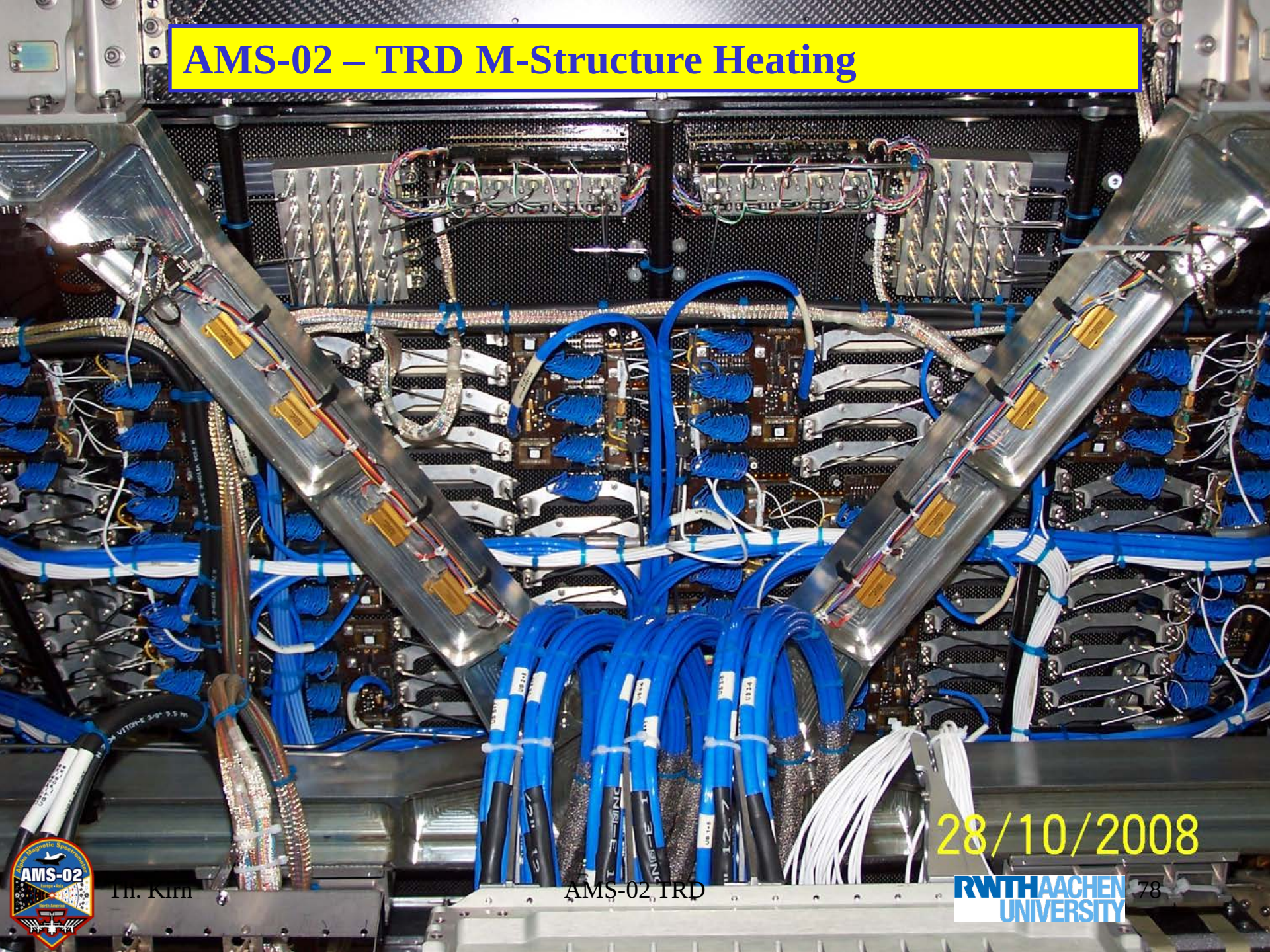
AMS-02 – TRD M-Structure, Heating



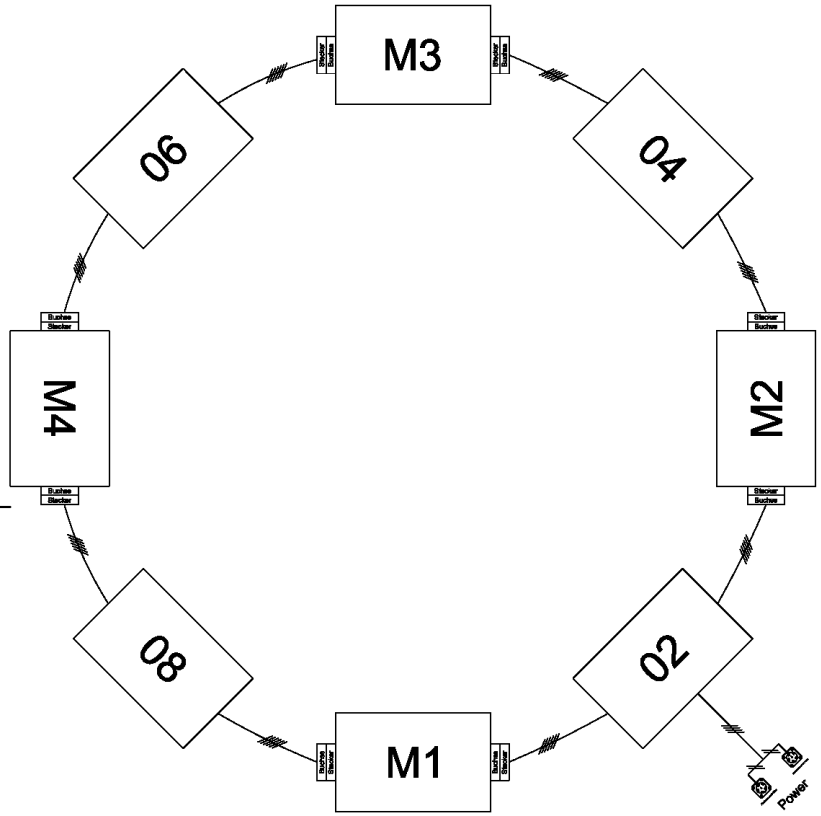
AMS-02 – TRD M-Structure Heating

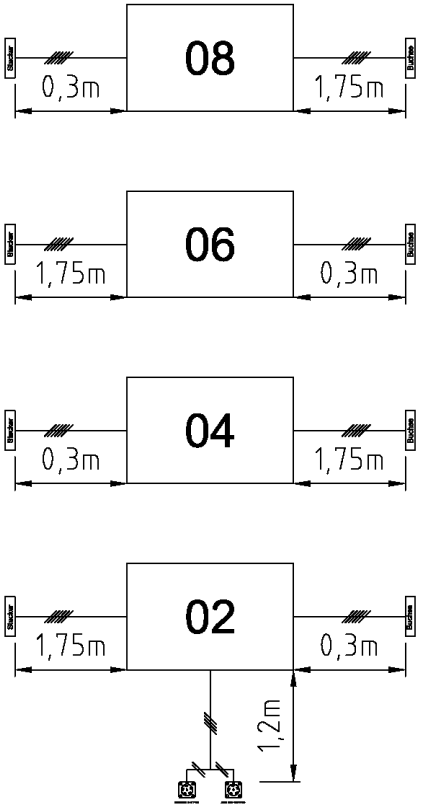


AMS-02 – TRD M-Structure Heating



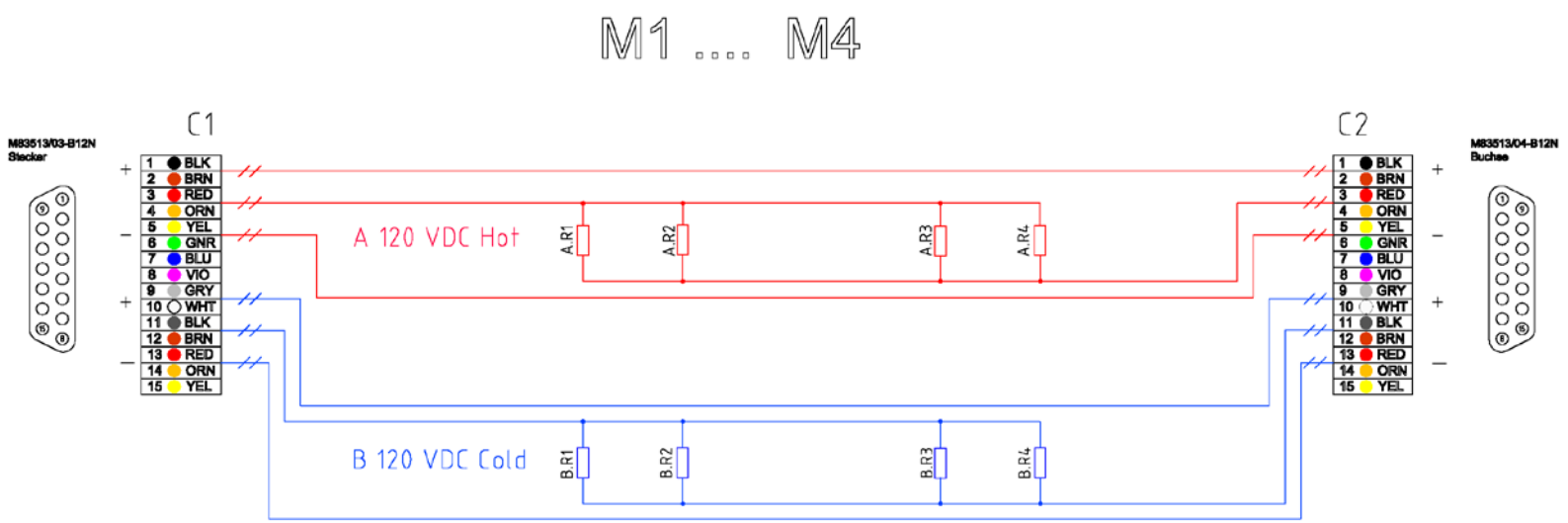
AMS-02 – TRD M-Structure Heating





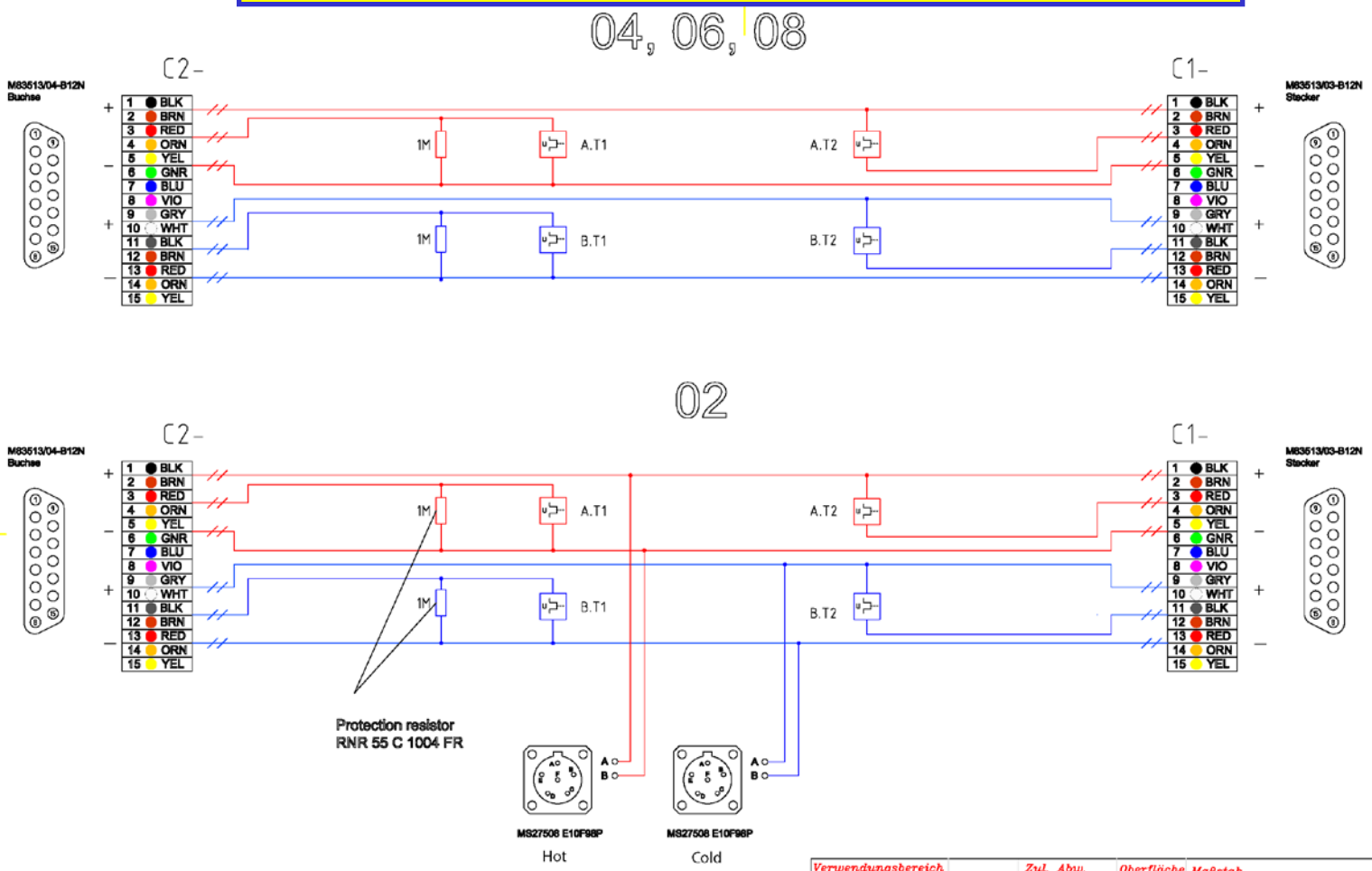
Verwendungsbereich		Zul. Abw.	Oberfläche	Maßstab	Gewicht
				Werkstoff, Halbzeug	
		2006 Datum	Name	Benennung	
		Bearb. 25.11	SSßer	M–Structure schematics	
		Gepr.		Thermostats & heaters	
		Name		RWTH Physics AC-I	Zeichnungsnummer / Blatt 3 / A3 Bl.
Rev.	Änderung	Revision	Name	Ers. f.:	Ers. d.: / Plot Datum:

AMS-02 – TRD M-Structure Heating

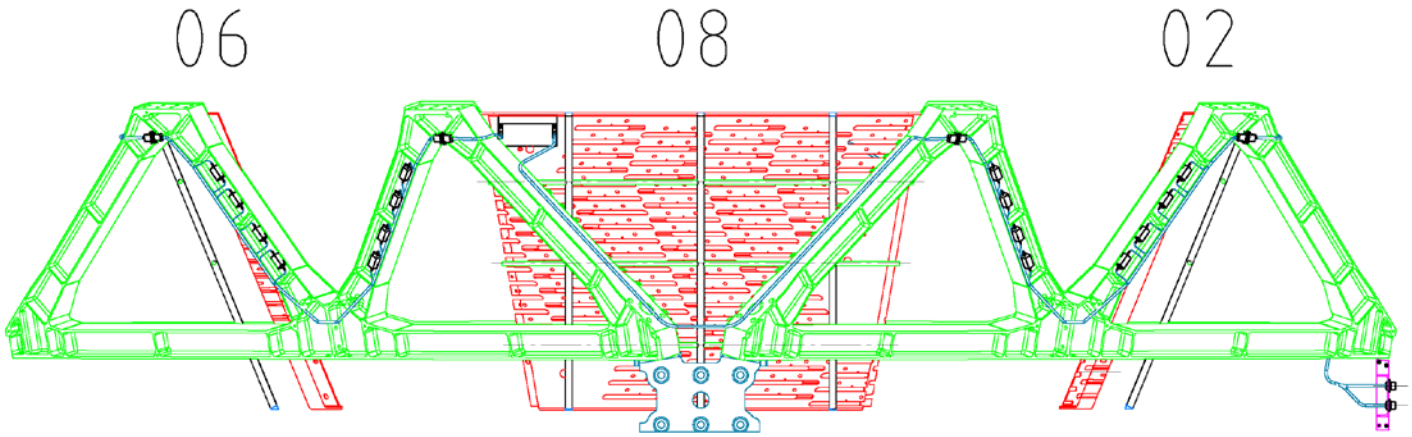


Verwendungsbereich		Zul. Abw.	Oberfläche	Maßstab	Gewicht
				Werkstoff, Halbzeug	
		2006 Datum	Name	Benennung	
		Bearb. 25.11.	Ößer	M-Structure schematics	
		Gepr.		Heaters	
		Name			
		RWTH Physics AC-I		Zeichnungsnummer	Blatt 2 Bl.
Rev. Änderung	Revision Name			Ers. f.: Ers. d.:	Plot Datum:

AMS-02 – TRD M-Structure Heating



AMS-02 – TRD M-Structure Heating

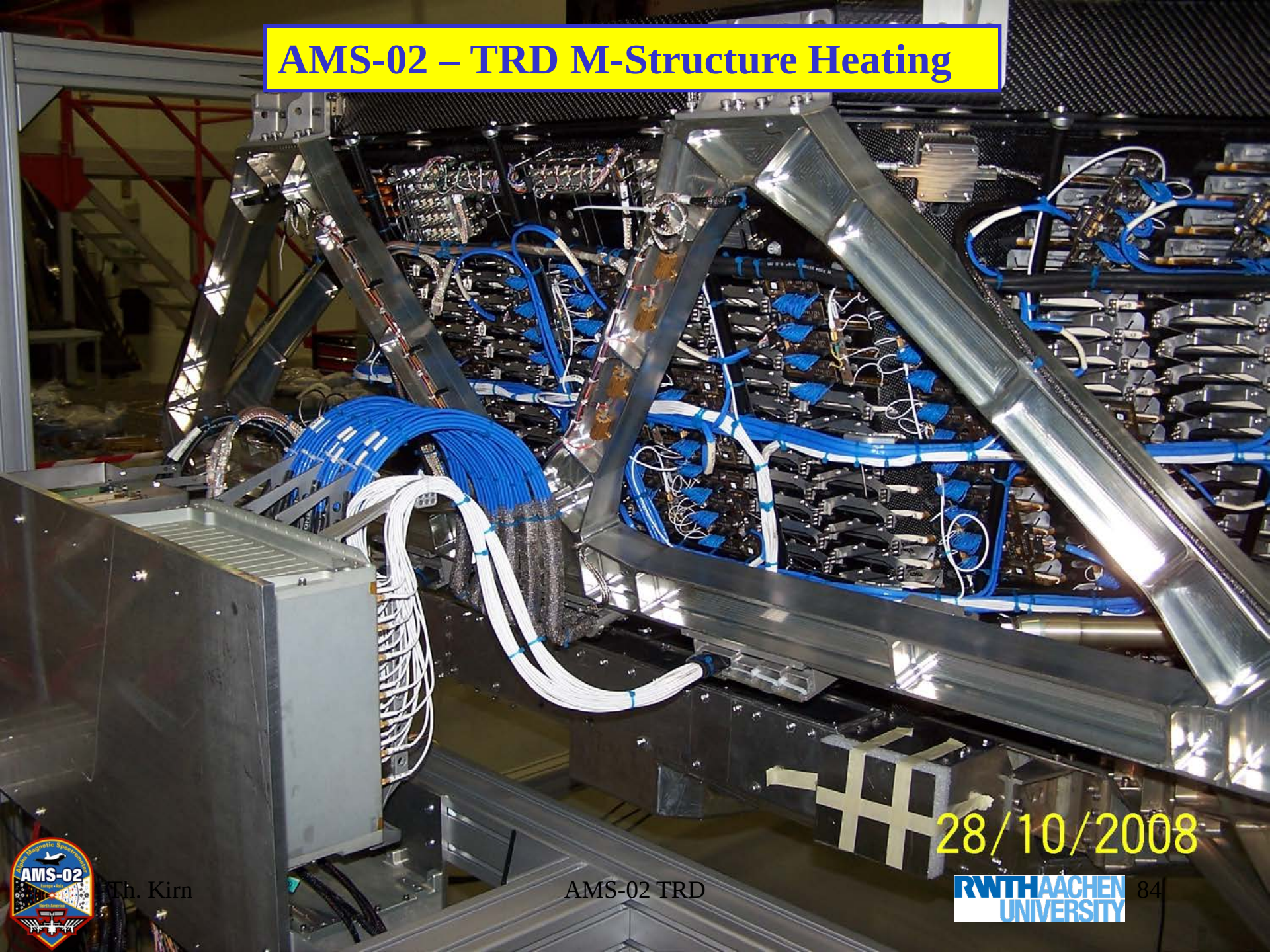


+X / −Y

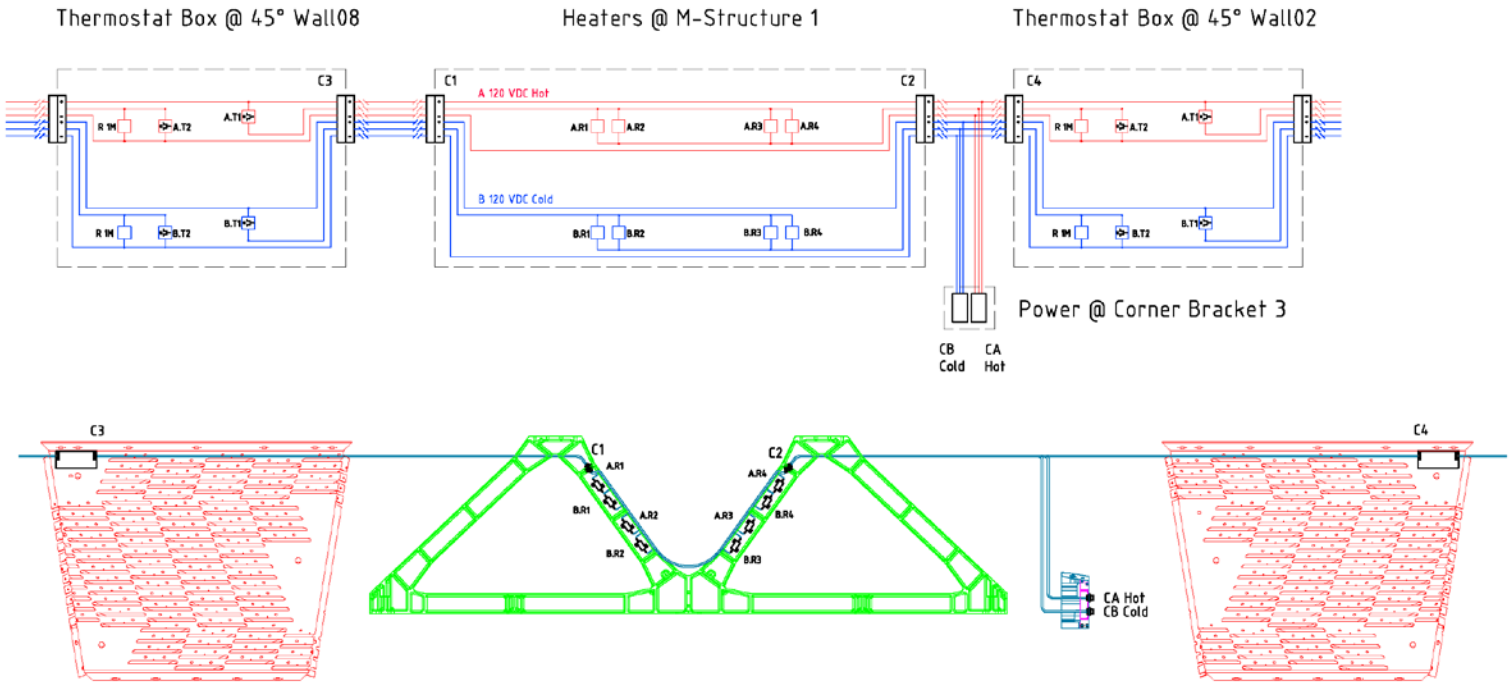
RWTH Physics AC-I
Cable routing Wall08 03.01.2007

AMS-02 – TRD M-Structure Heating

AMS-02 – TRD M-Structure Heating

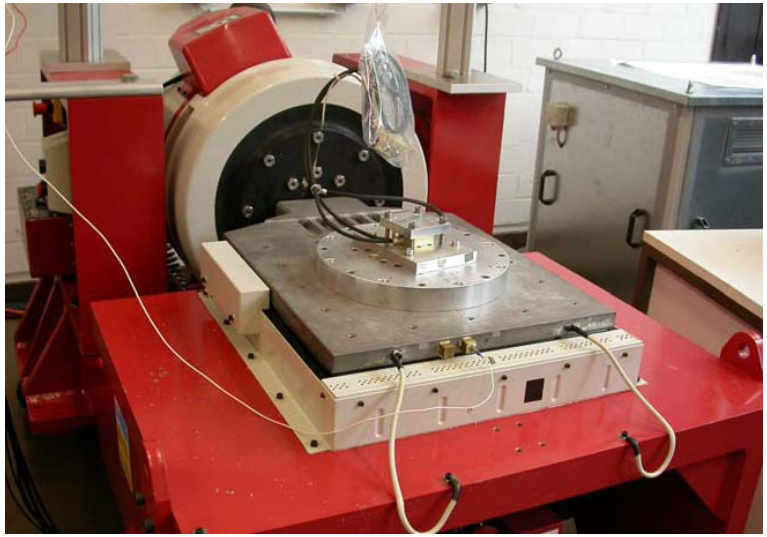


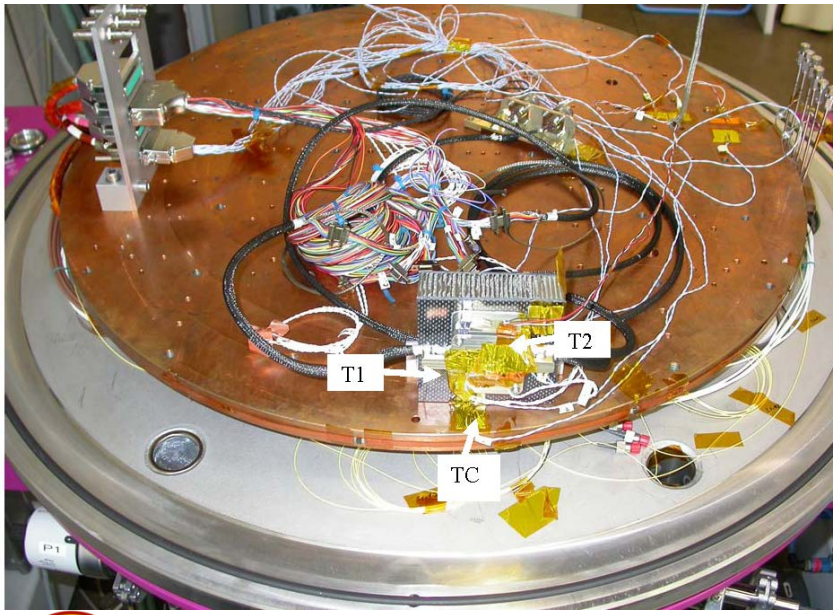
AMS-02 – TRD M-Structure Heating



Verwendungsbereich		Zul. Abw. DIN ISO 2768 mittel	Oberfläche N10	Maßstab 1:12	Gewicht
				Werkstoff, Halbzeug	
		2007 Datum	Name	Benennung	
		Bearb. 29.06.	Kosbow	M-Structure schematics	
		Gepr.		Thermostats & heaters	
		Name			
		RWTH Physics AC-I		Zeichnungsnummer ams02-06-4100g	Blatt 1/1 A3 Bl.
Rev. Änderung	Revision Name			Ers. f.:	Ers. d.: Plot Datum:

AMS-02 – TRD Thermostats Space Qualification





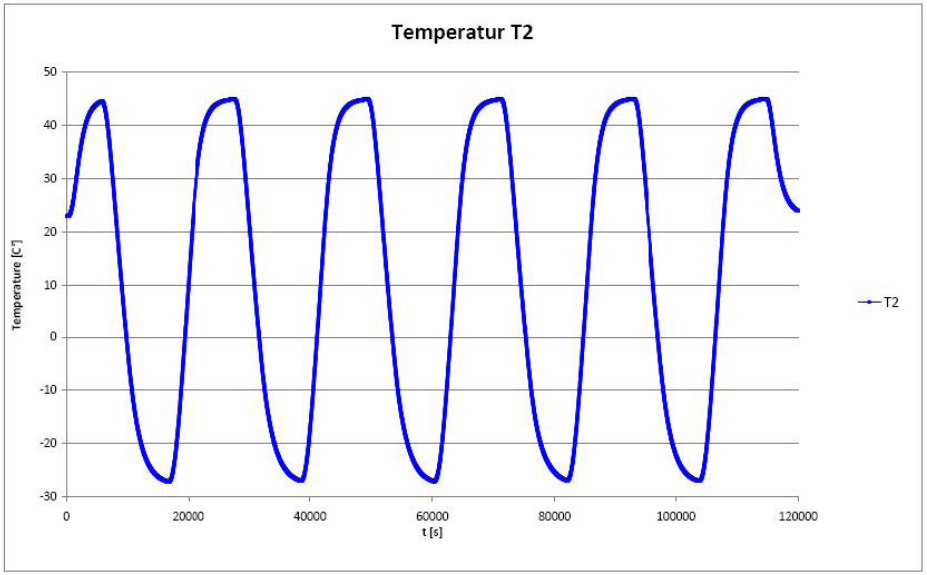
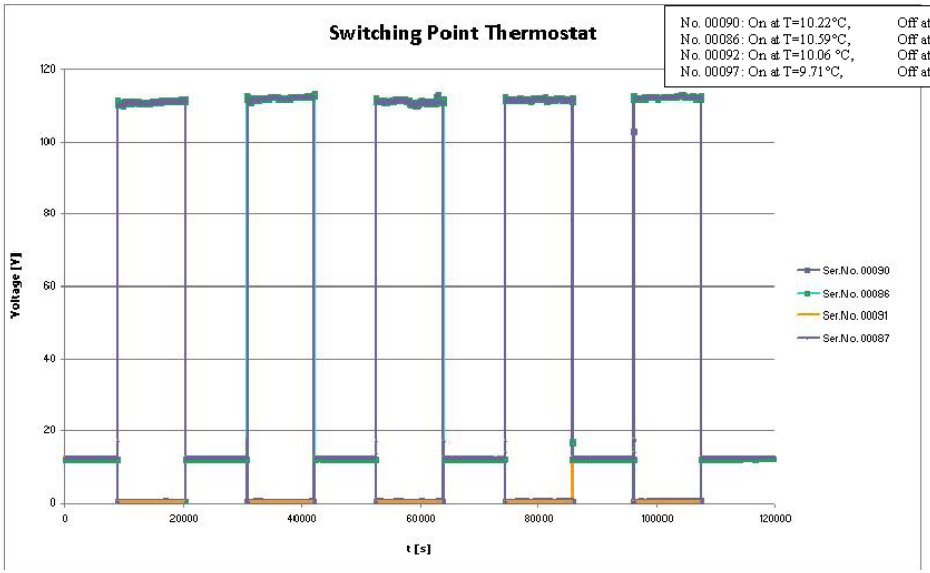
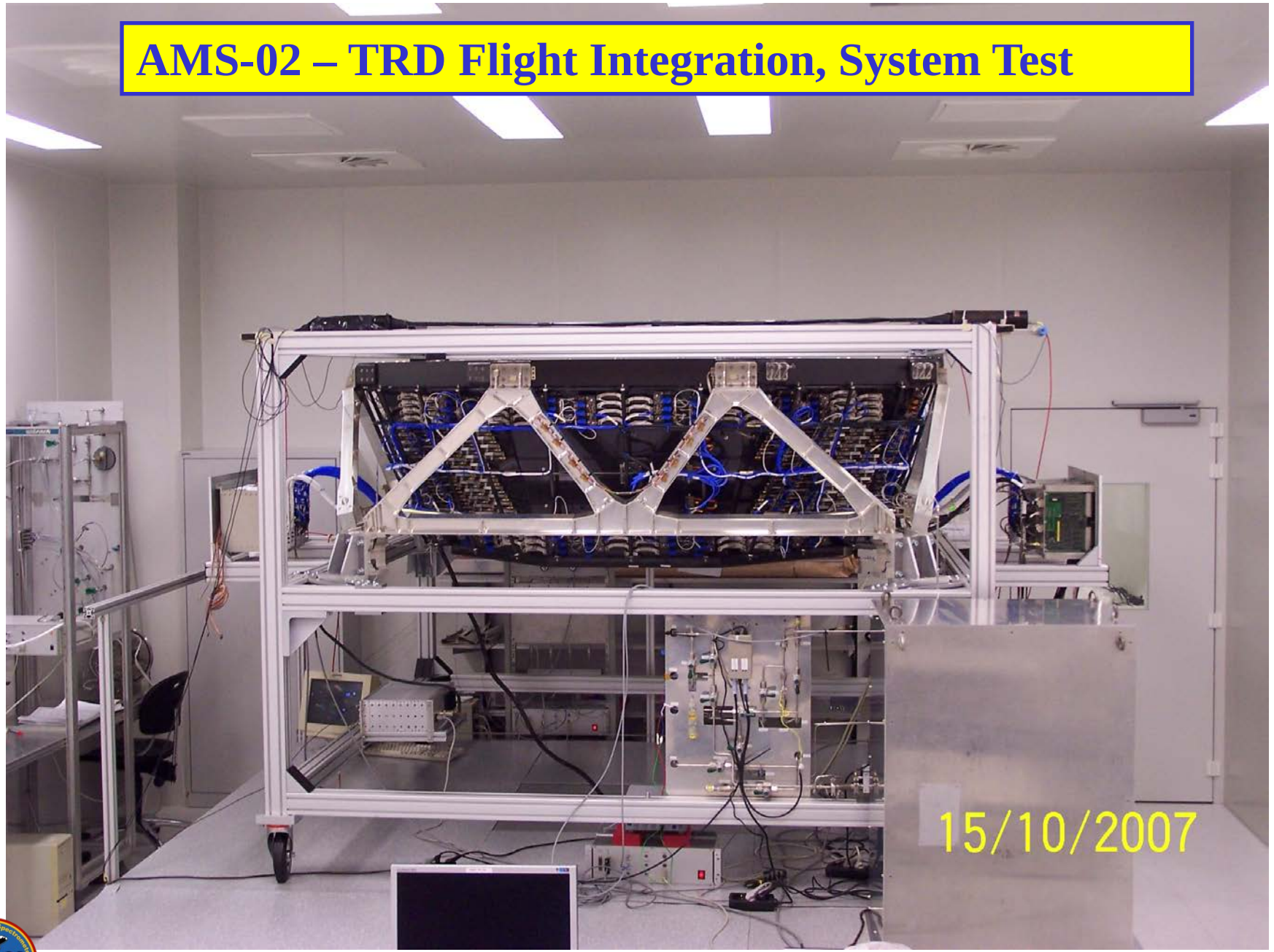


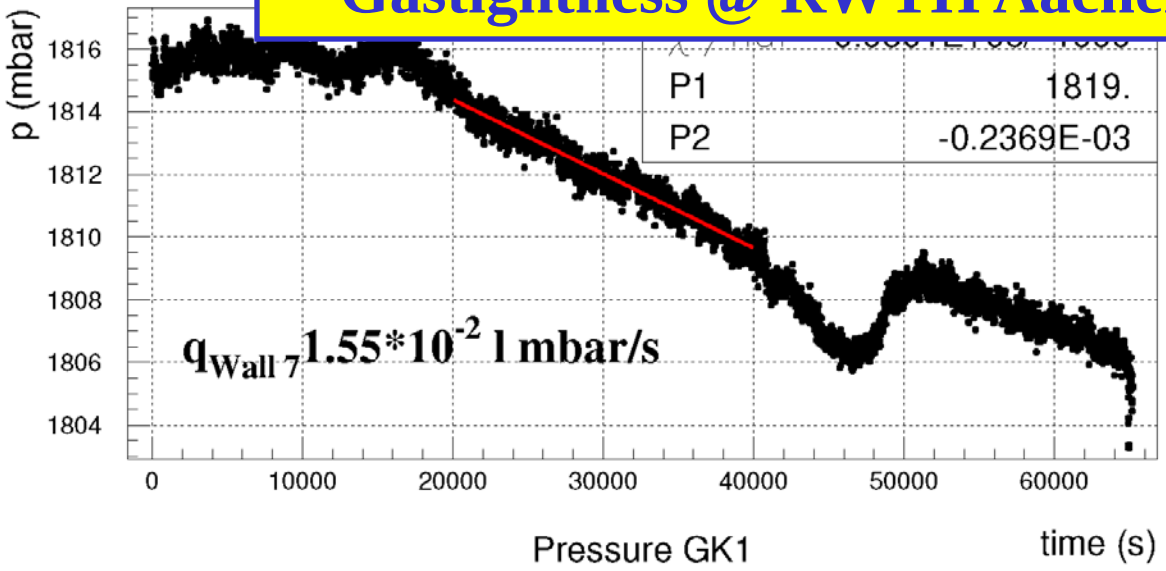
Fig. 5 Environment, Temperature sensor T2 on Thermostat Box 04

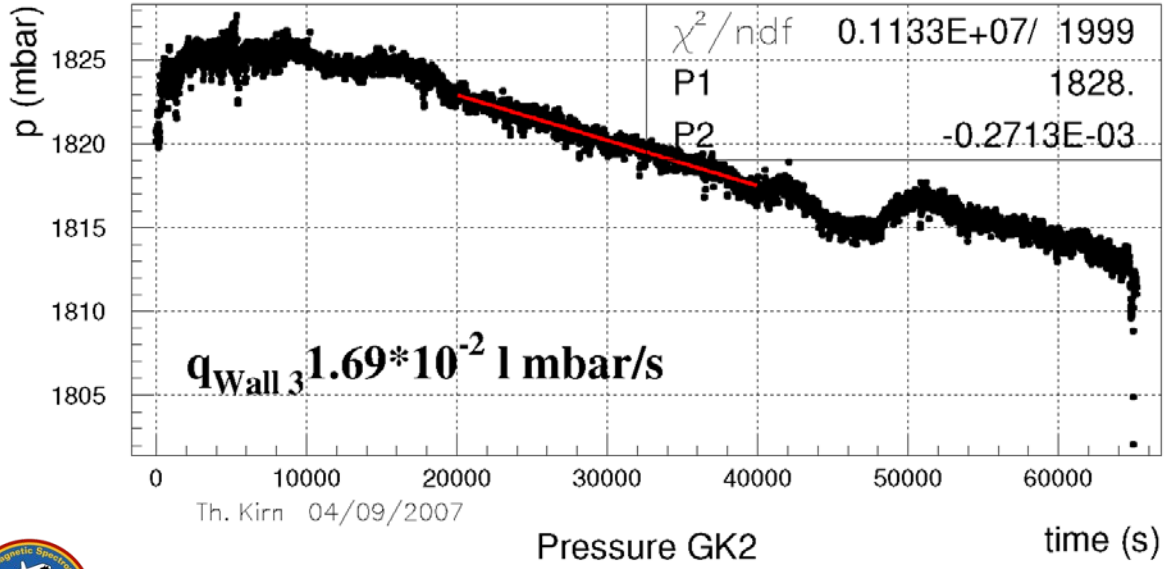


AMS-02 – TRD Flight Integration, System Test



AMS-02 – TRD Flight Integration, Gastightness @ RWTH Aachen Cleanroom





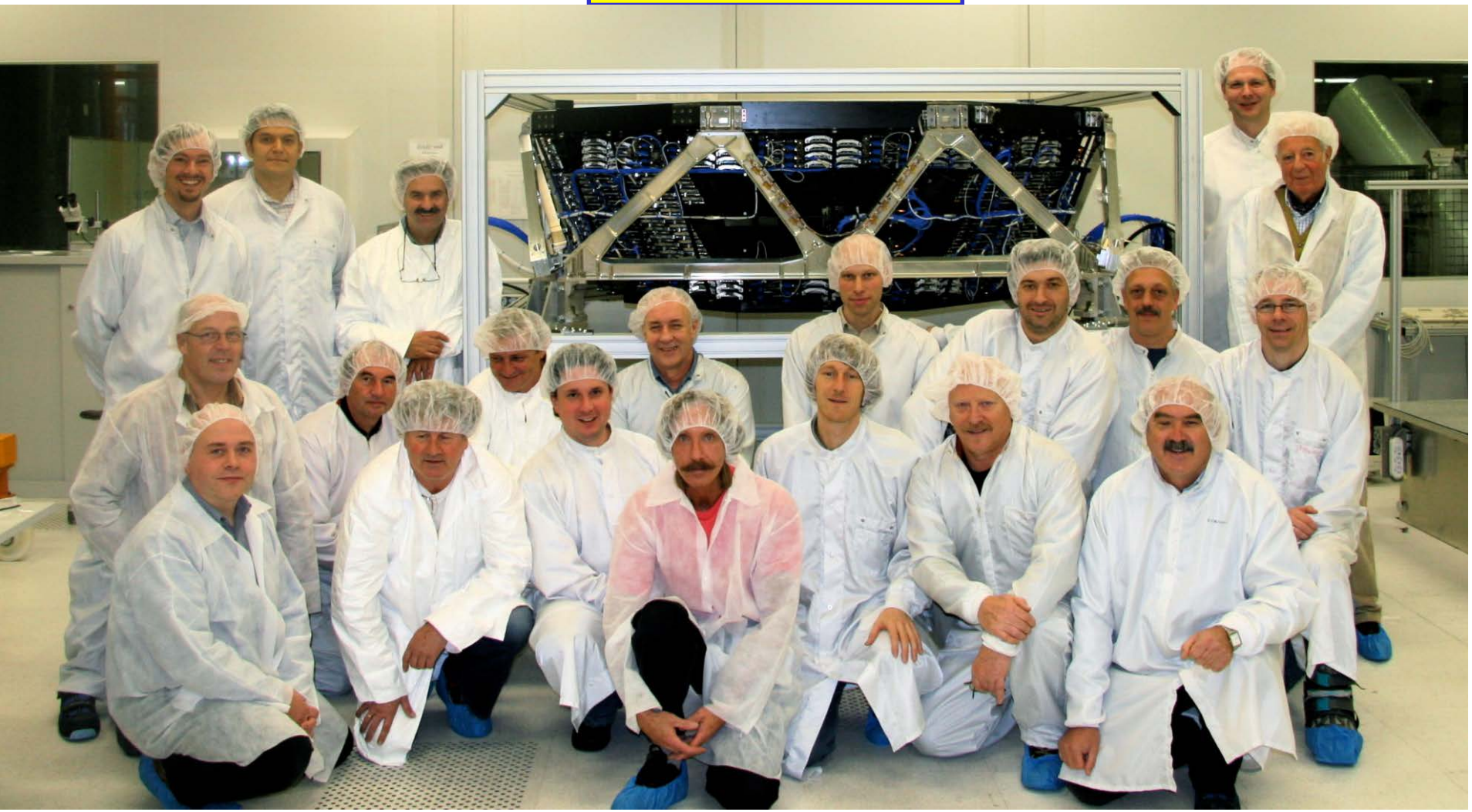
He-dp/dt-Measurements of individual straw modules during production:

$q_{Wall\ 7}$ = 1.56*10^{-2} l mbar/s

$q_{Wall\ 3}$= 1.53 * 10^{-2} l mbar/s

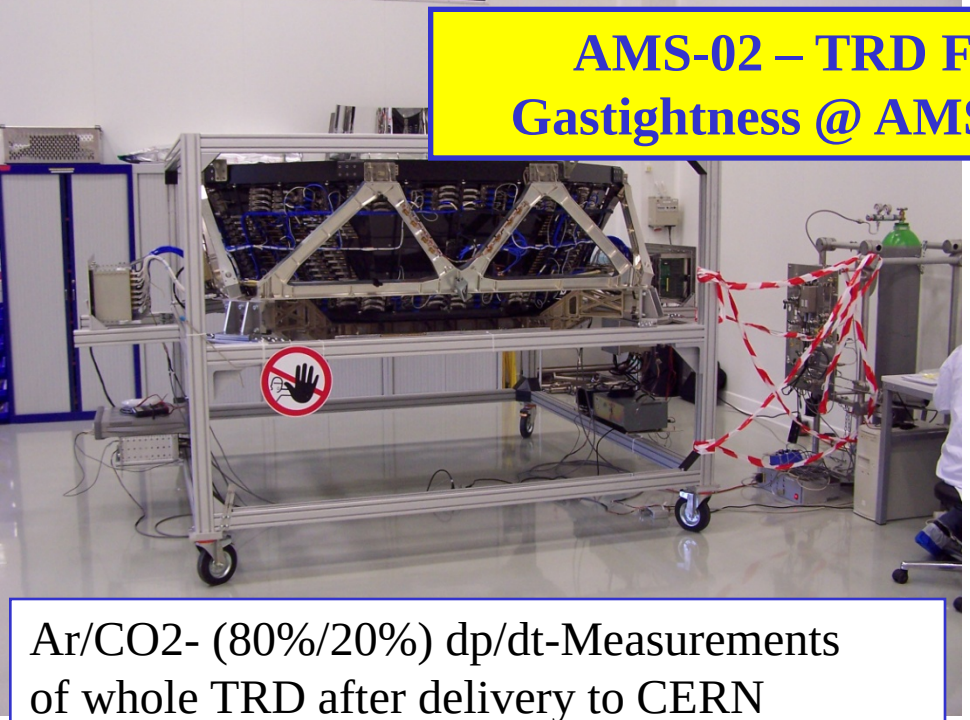
→ Safety Factor 8 for CO_2

AMS-02 – TRD



TRD Delivery to CERN October 2007

AMS-02 – TRD Flight Integration, Gastightness @ AMS Cleanroom CERN



Ar/CO2- (80%/20%) dp/dt-Measurements of whole TRD after delivery to CERN end of 2007:

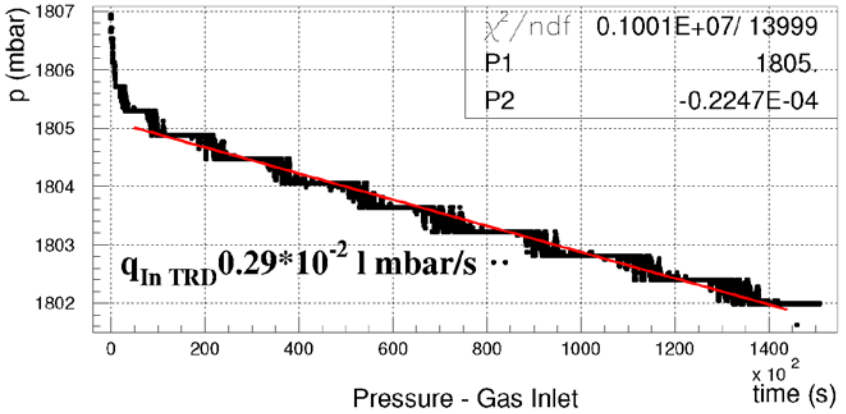
$q_{CO2} = 0.29 * 10^{-2}$ l mbar/s

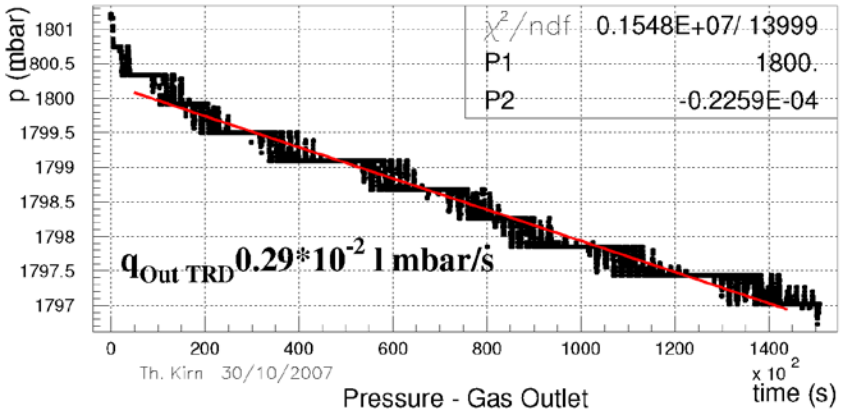
• Comparison Measurement dp/dt in air: He ↔ CO2 Factor of 2

• Factor 5 20% to 100 % CO2

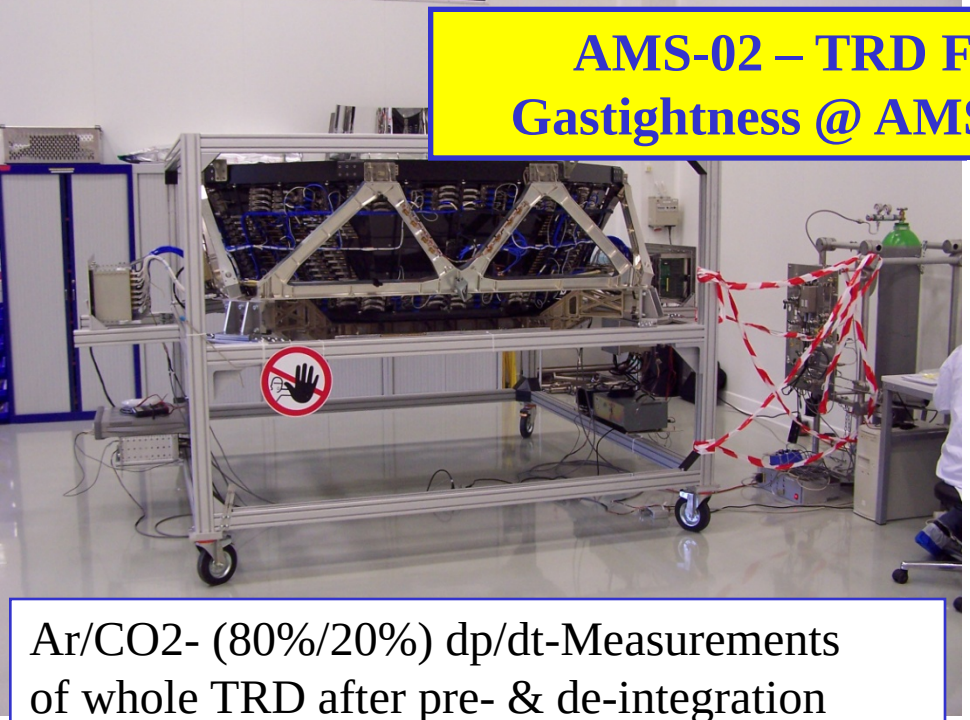
↳$q_{He} = 3.09*10^{-2}$ l mbar/s

→ TRD gastight





AMS-02 – TRD Flight Integration, Gastightness @ AMS Cleanroom CERN



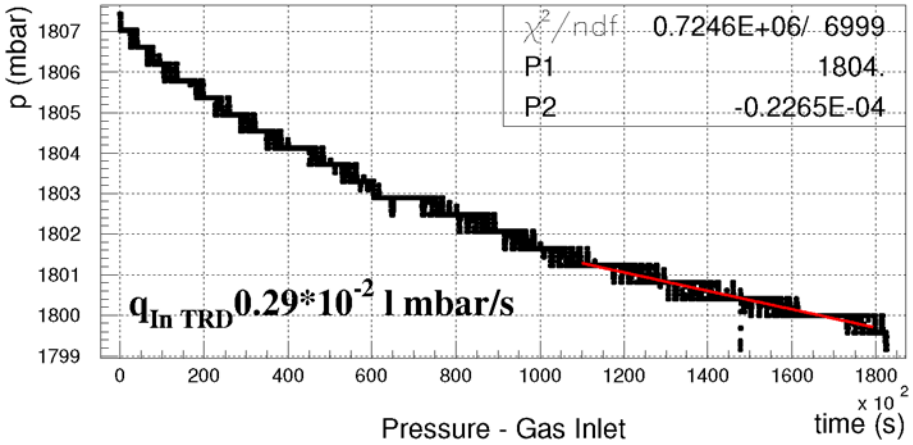
Ar/CO2- (80%/20%) dp/dt-Measurements of whole TRD after pre- & de-integration End of 2008:

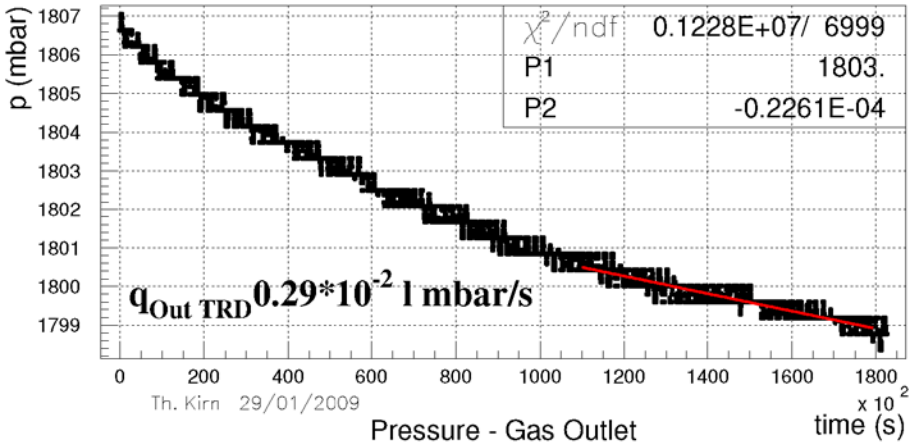
$q_{CO2} = 0.29 * 10^{-2}$ l mbar/s

• Comparison Measurement dp/dt in air:
He ↔ CO2 Factor of 2
• Factor 5 20% to 100 % CO2

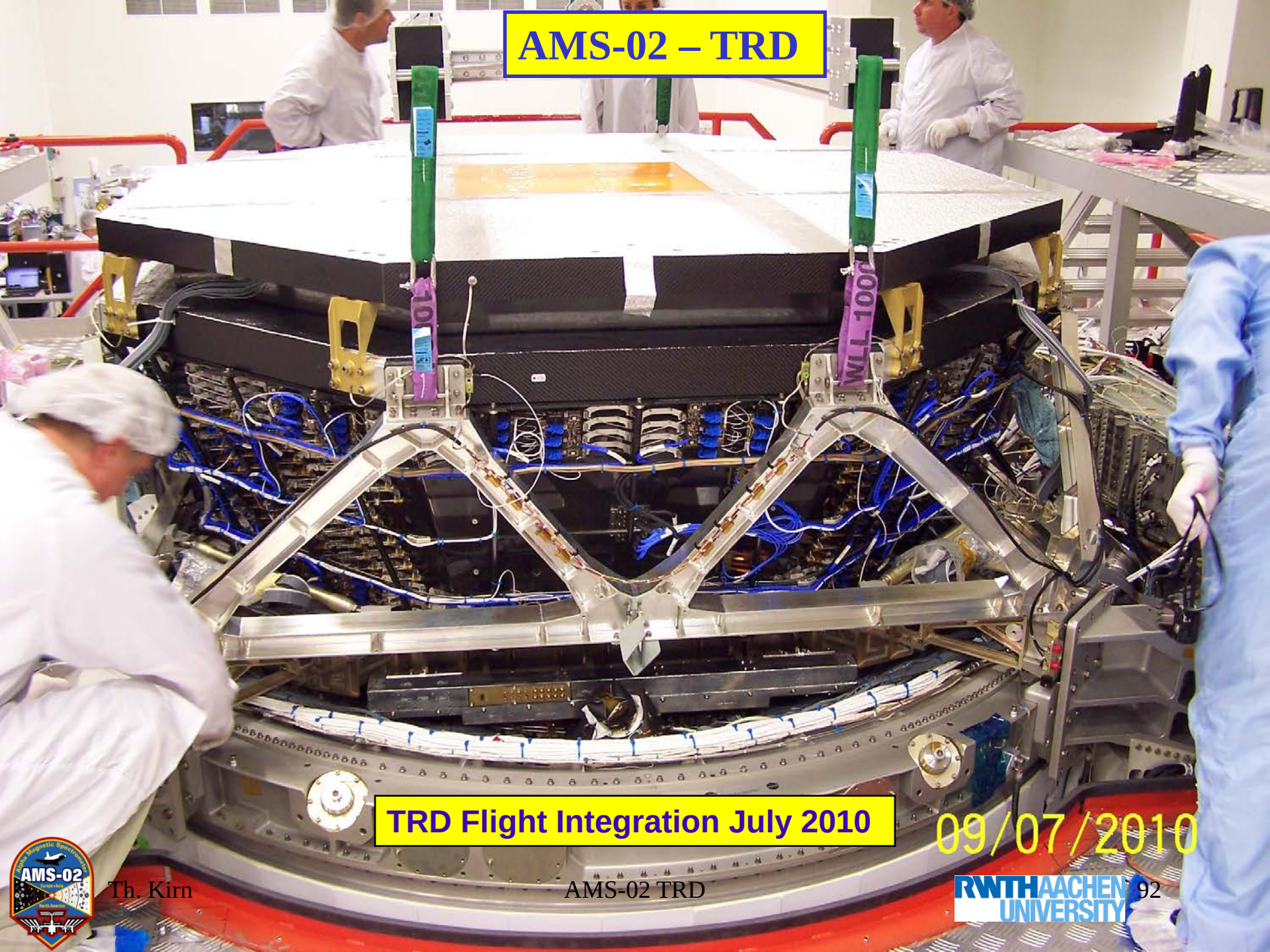
↳ $q_{He} = 3.09*10^{-2}$ l mbar/s

→ TRD gastight





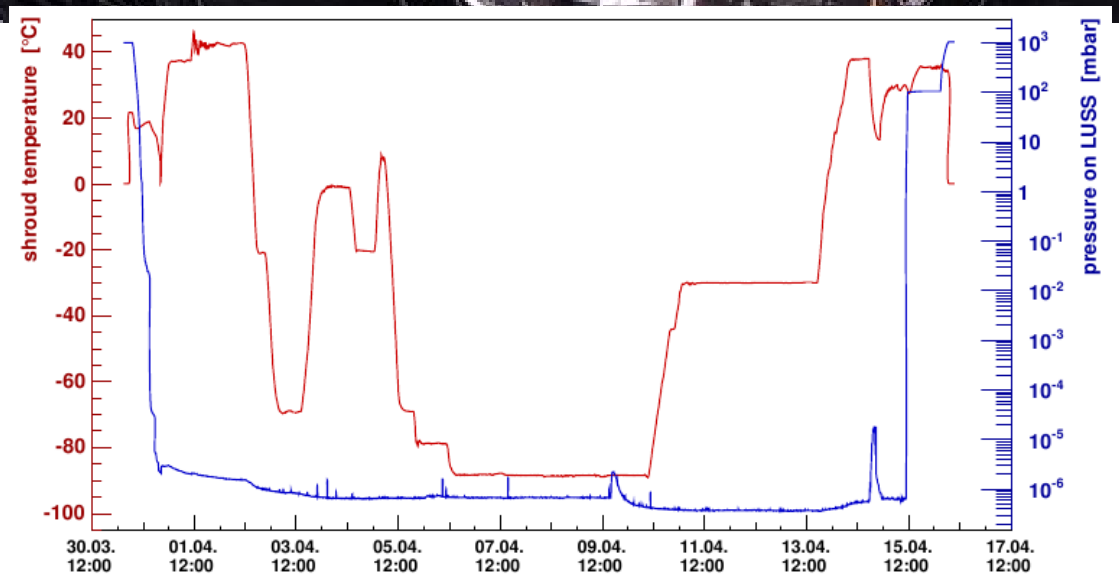
AMS-02 – TRD



AMS-02 @ CERN Cleanroom

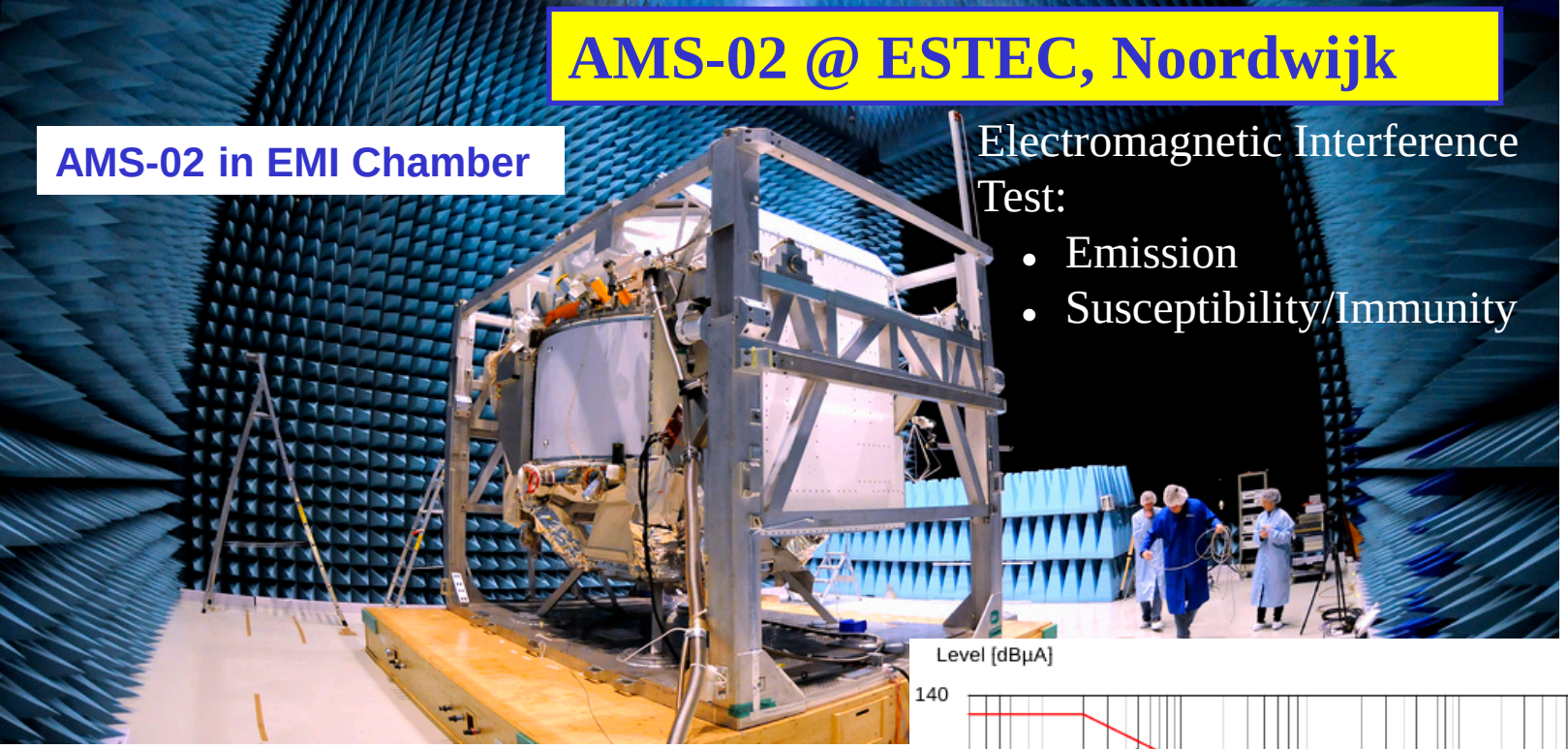
AMS-02 @ ESTEC, Noordwijk

AMS-02 inThermal Vacuum Chamber



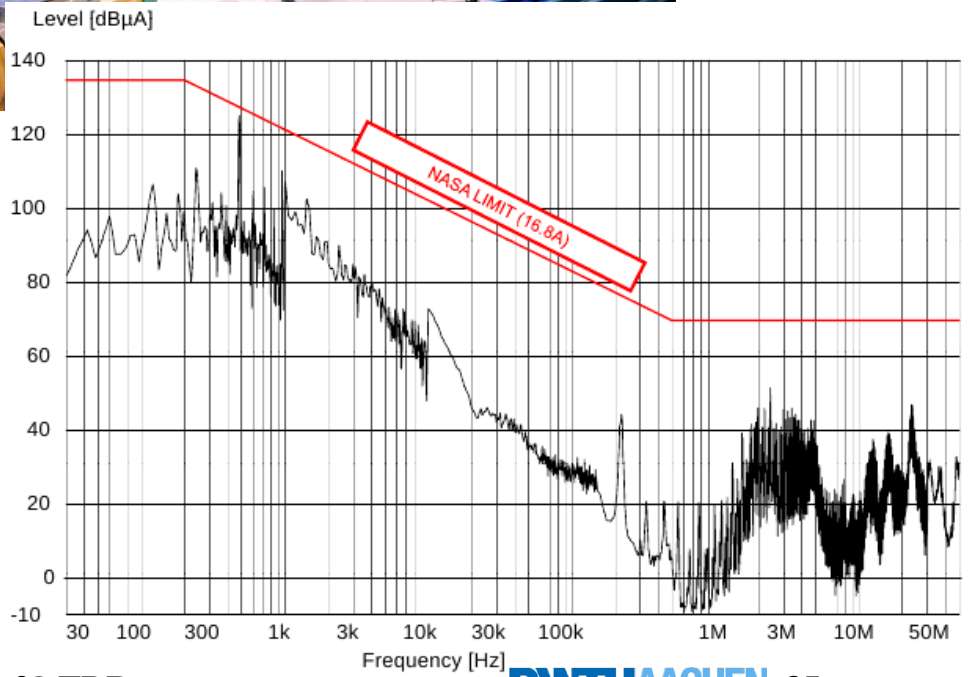
No major issues

AMS-02 @ ESTEC, Noordwijk



Electromagnetic Interference Test:

- Emission
- Susceptibility/Immunity



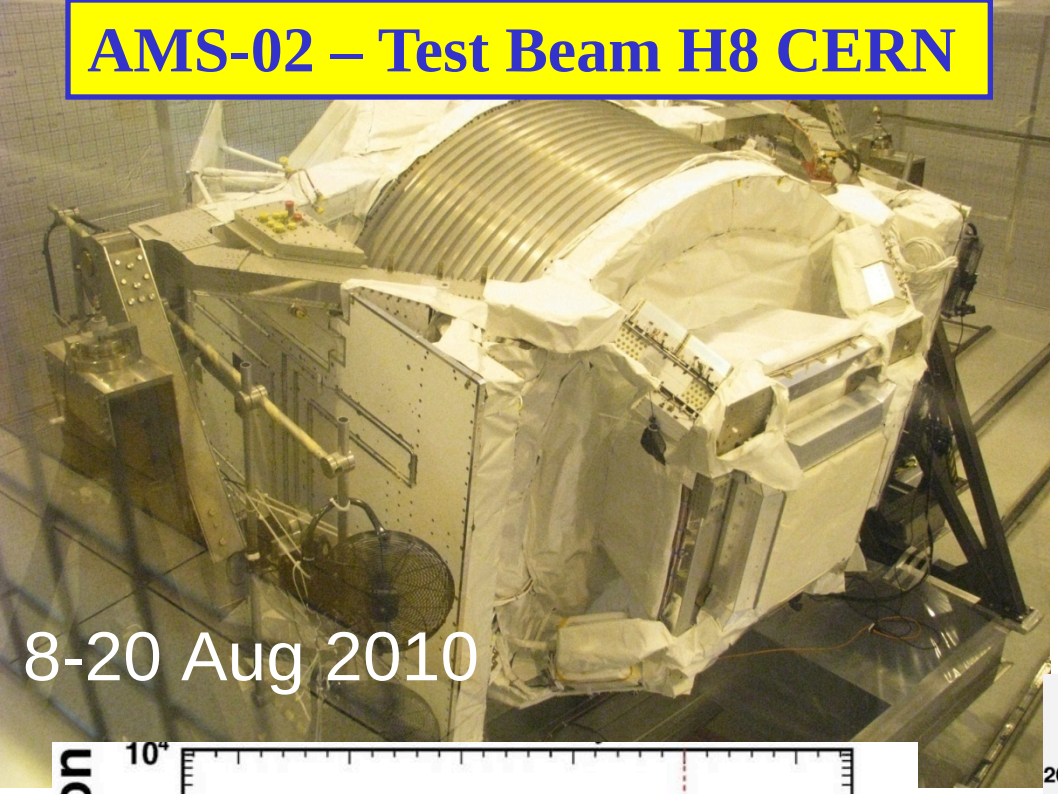
EMI emission profile:

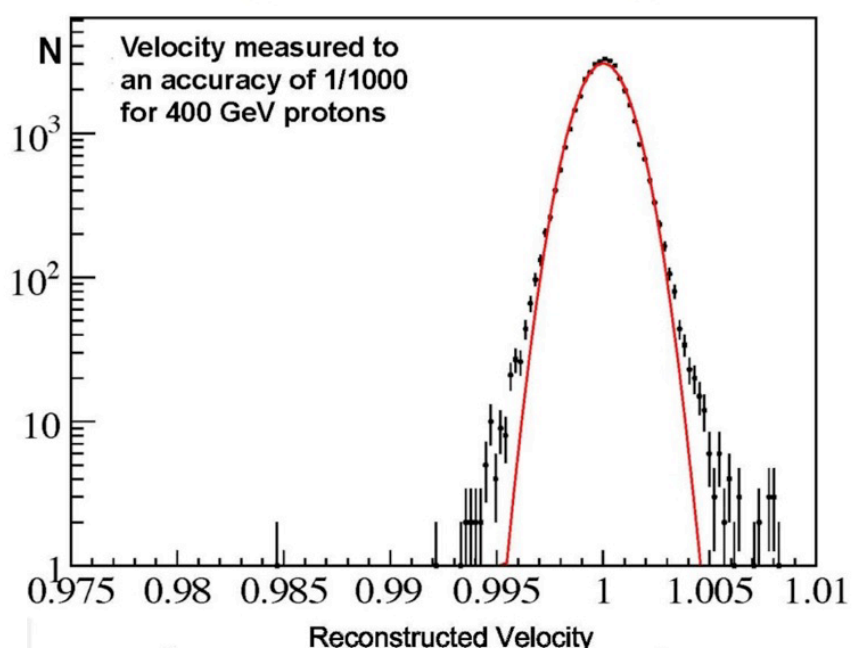
- Range 30 Hz – 50 MHz
- Limit set by Nasa not exceeded

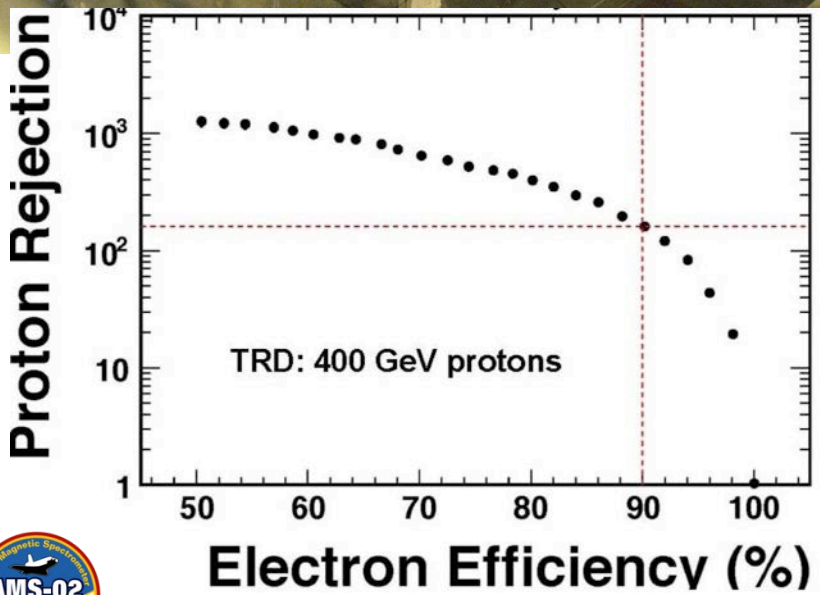
EMI susceptibility (not shown):

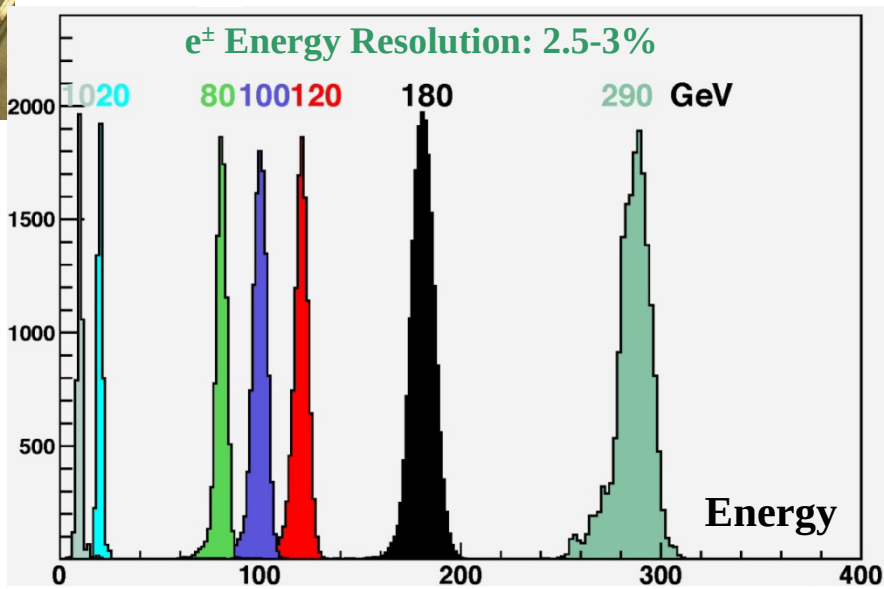
- Interference at 80 MHz (TDCs)
- No major issues

AMS-02 – Test Beam H8 CERN





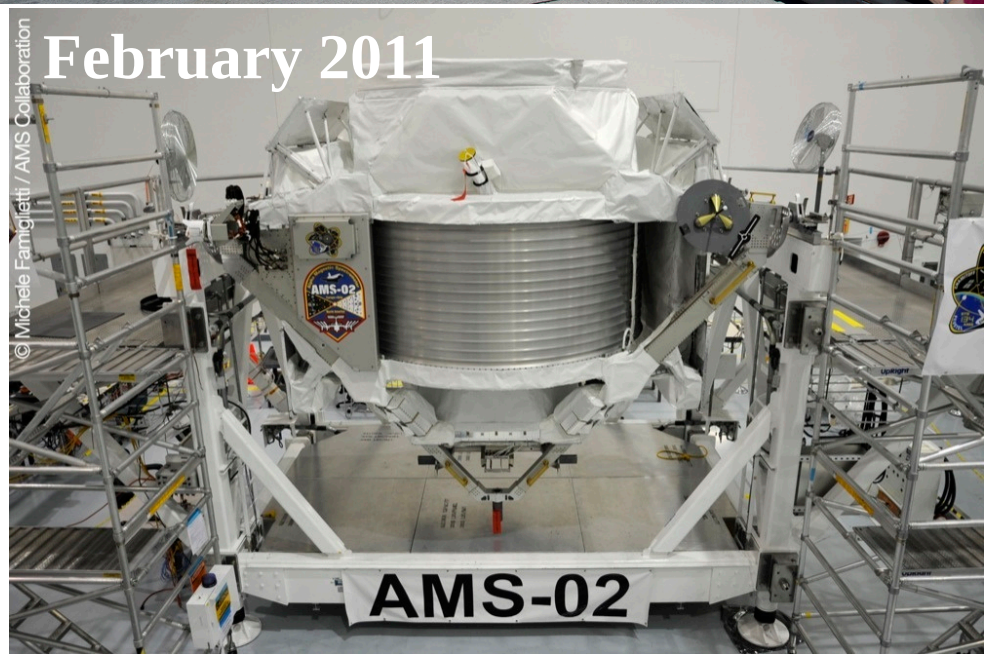




AMS-02 Transport CERN to KSC

Arrival of US Air Force C5 Galaxy

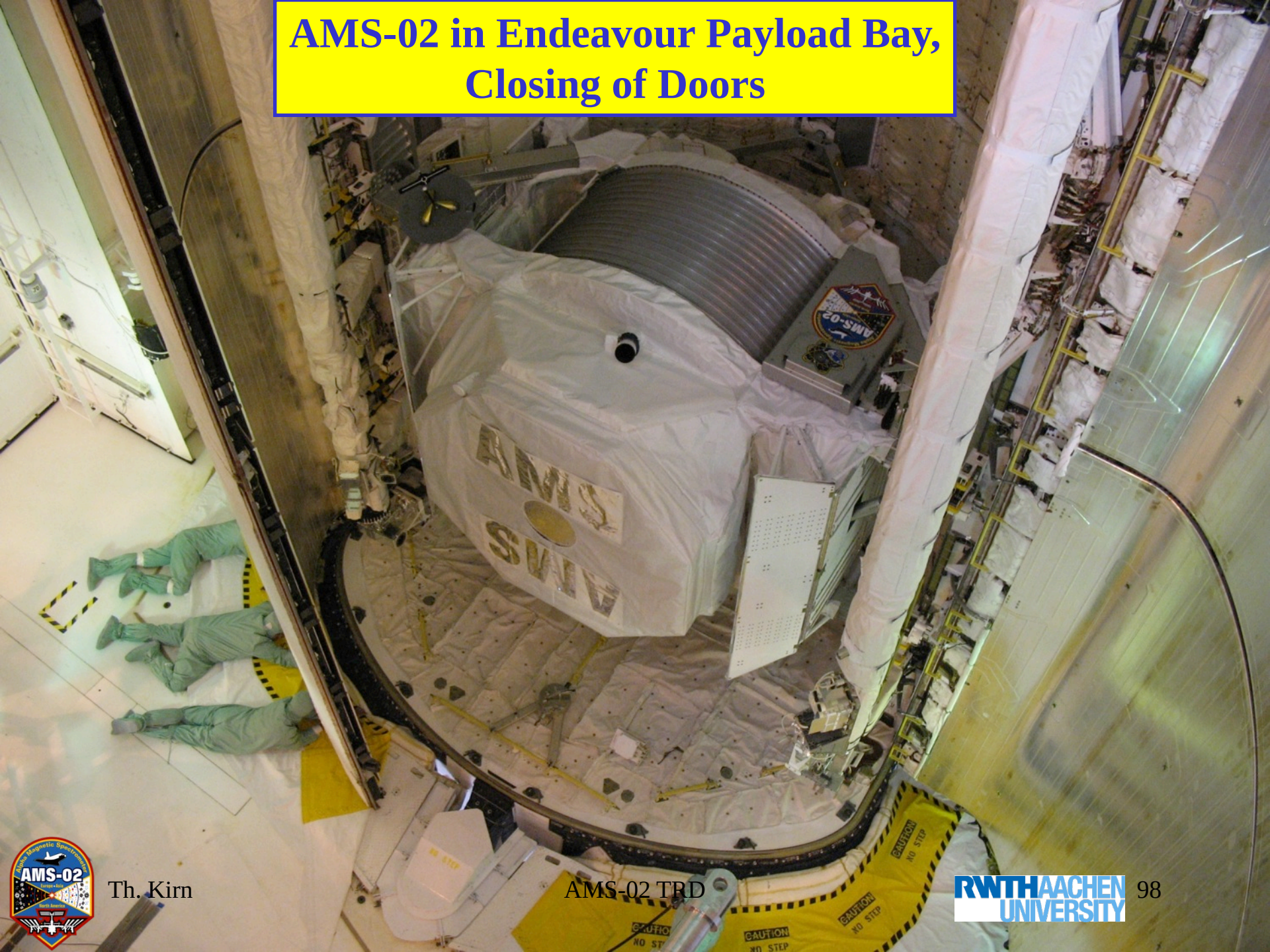
at Geneva – 25 Aug 2010



AMS-02 in the Space Station Processing Facility (SSPF), ready for installation into the Space Shuttle

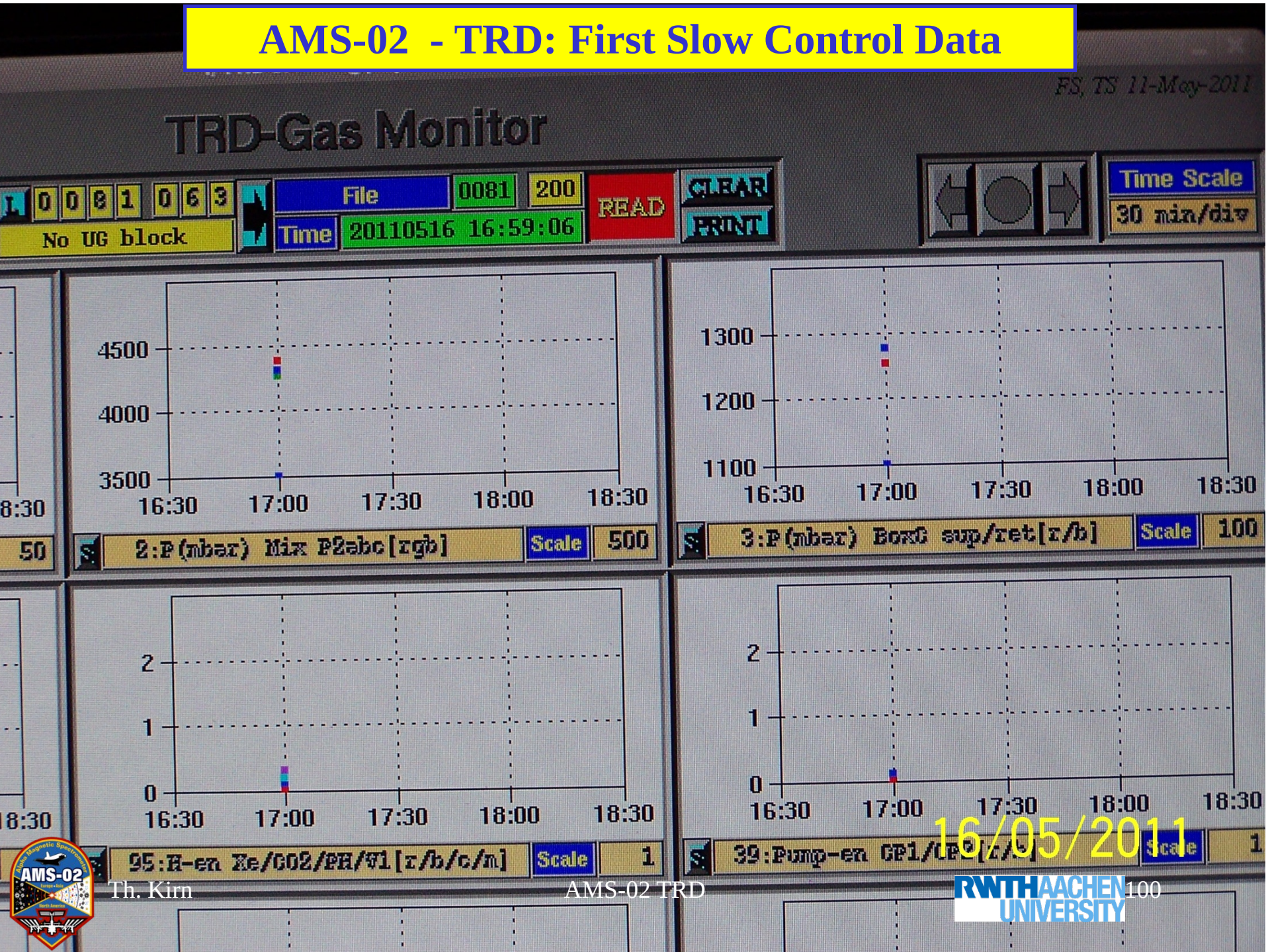
Extended data taking periods to verify detector performance

AMS-02 in Endeavour Payload Bay, Closing of Doors

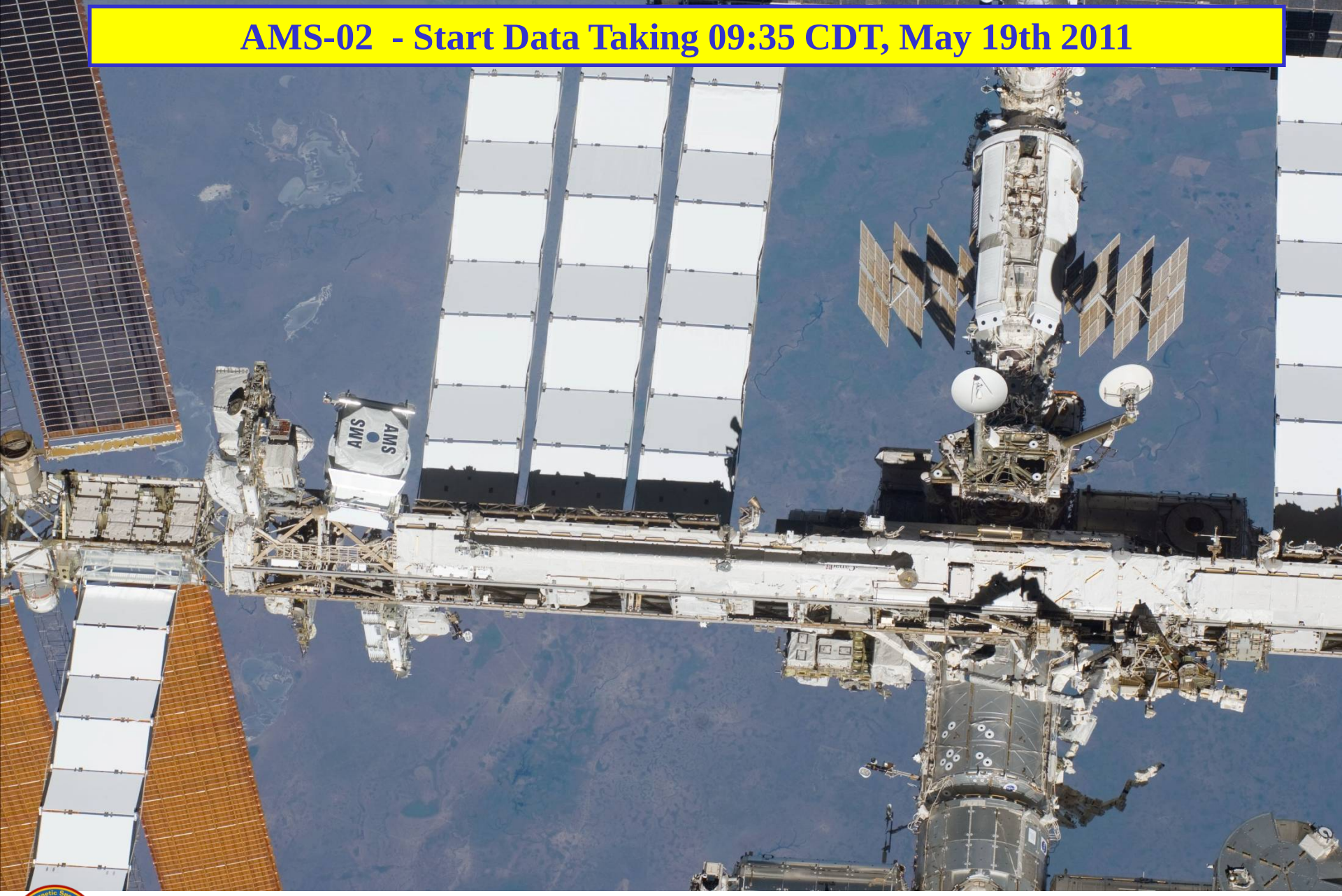


AMS-02 - STS 134 Launch
16th of May

AMS-02 - TRD: First Slow Control Data

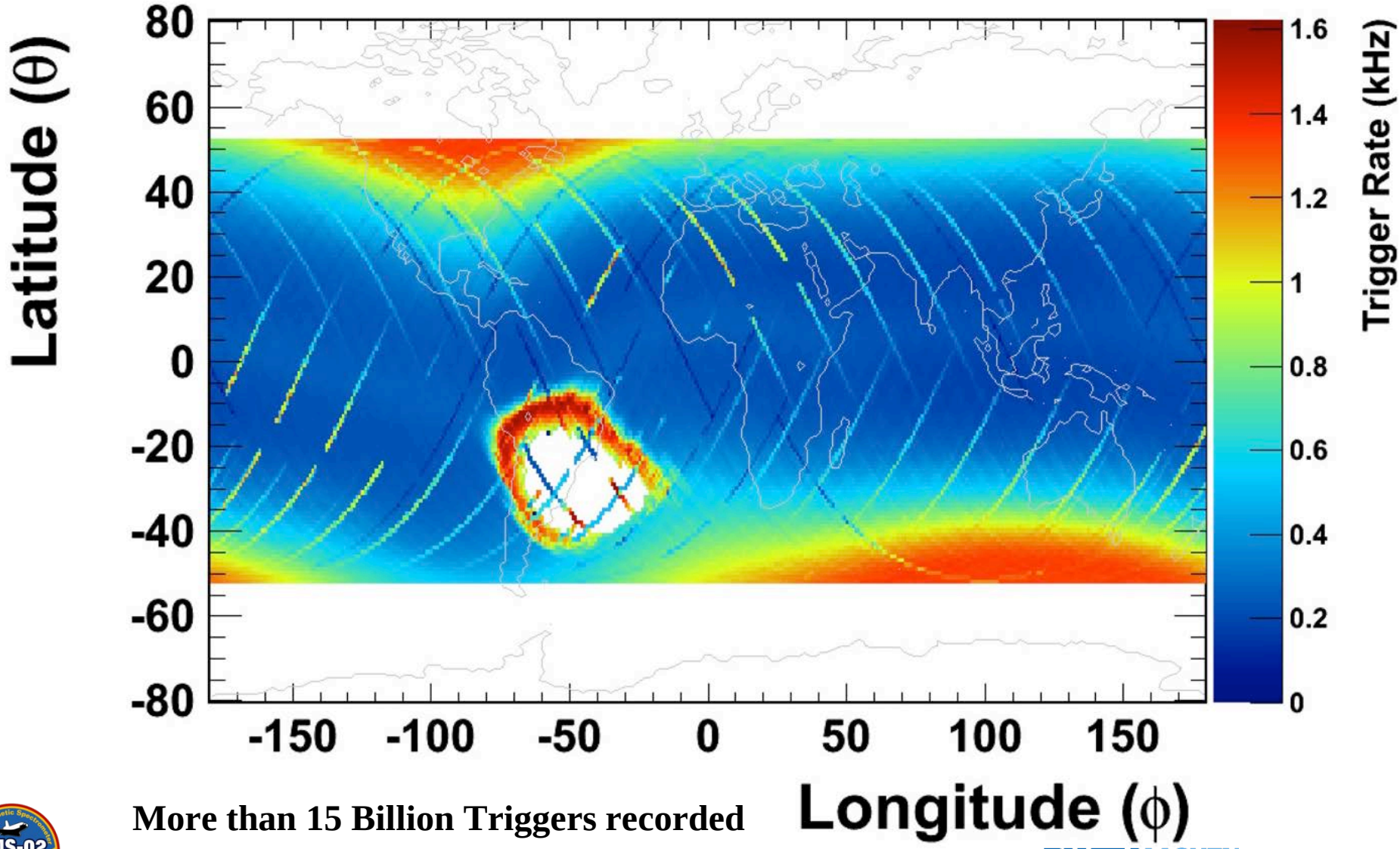


AMS-02 - Start Data Taking 09:35 CDT, May 19th 2011



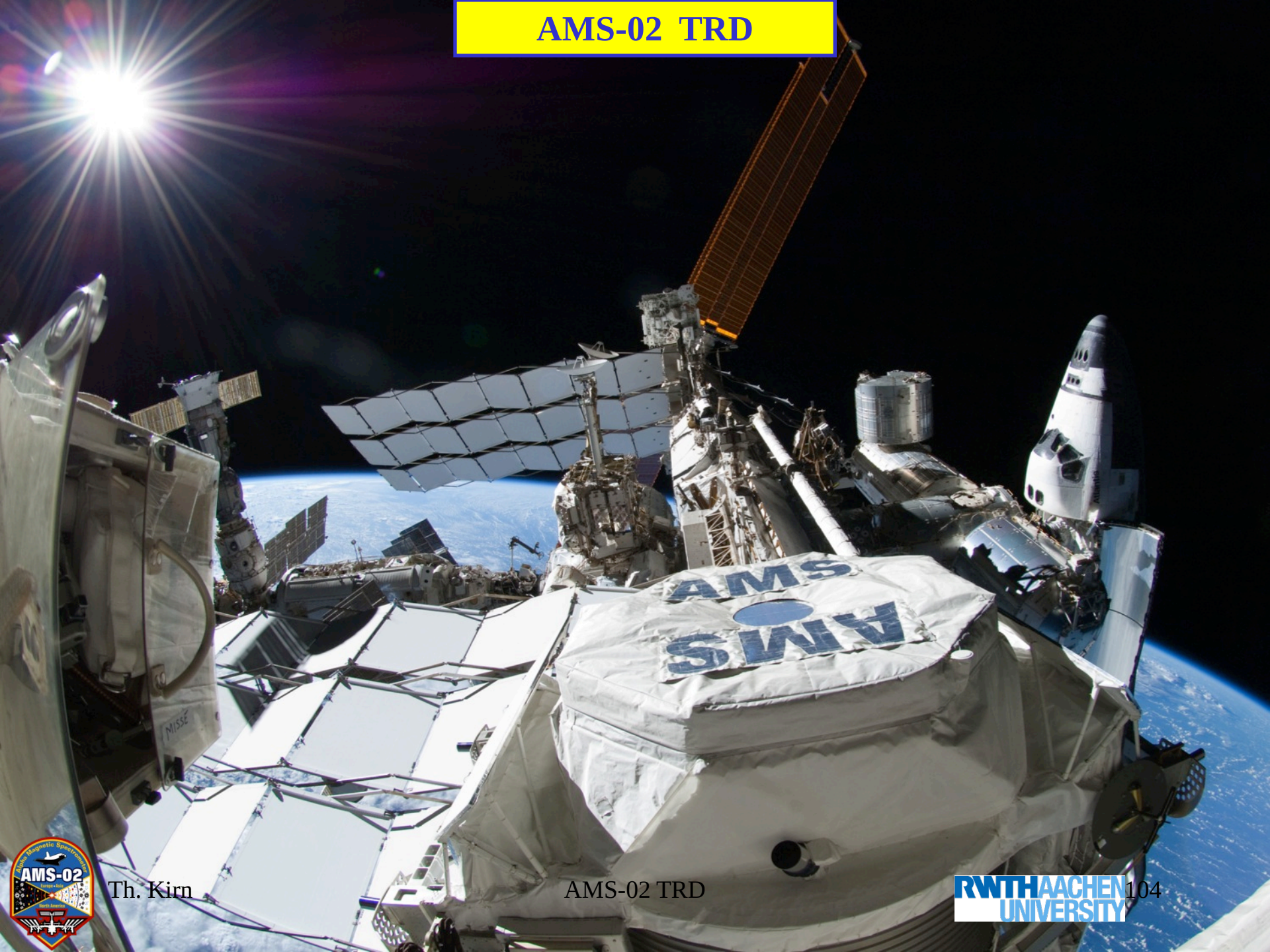
AMS-02 - Start Data Taking 09:35 CDT, May 19th 2011

AMS-02 - Trigger Rate

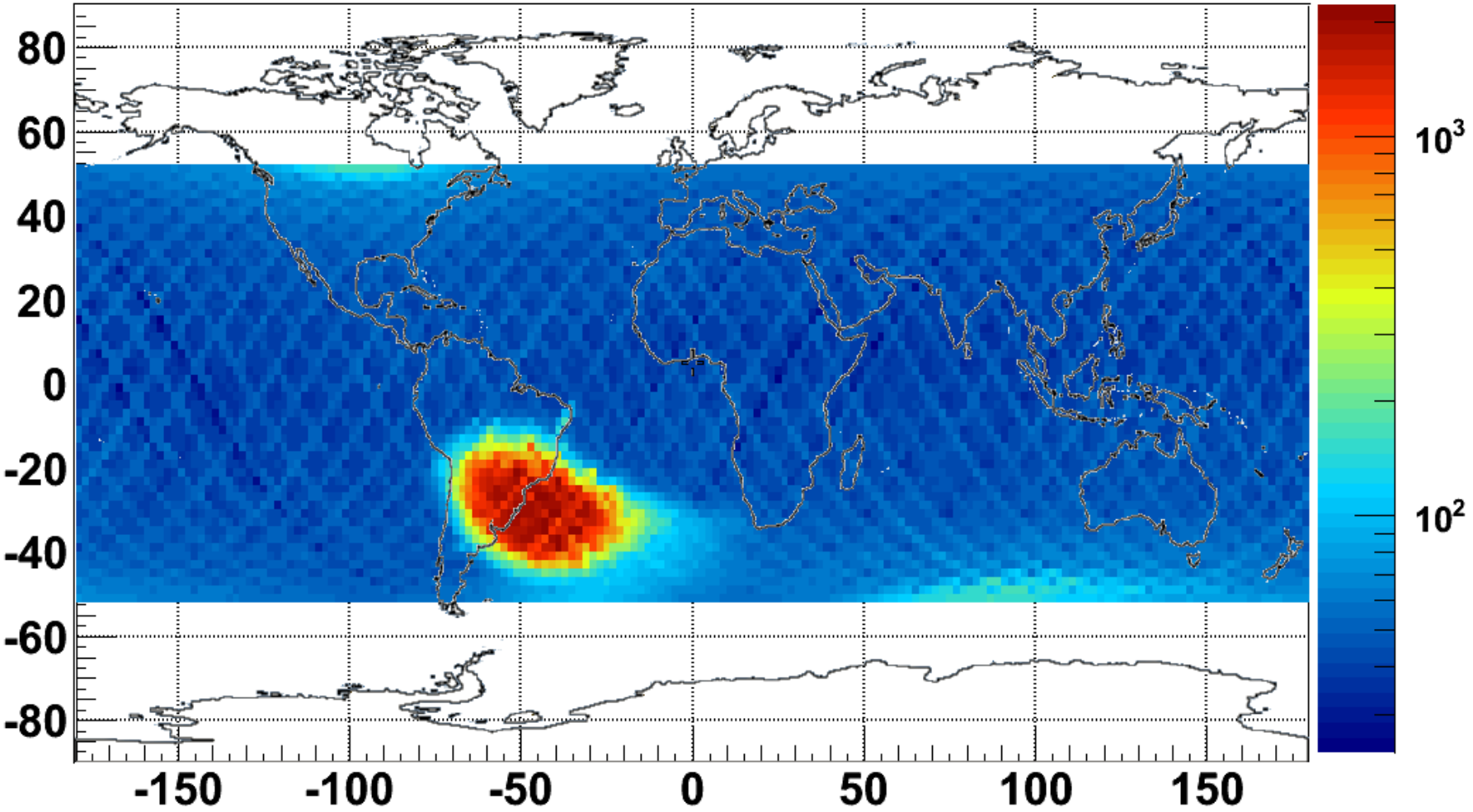


More than 15 Billion Triggers recorded

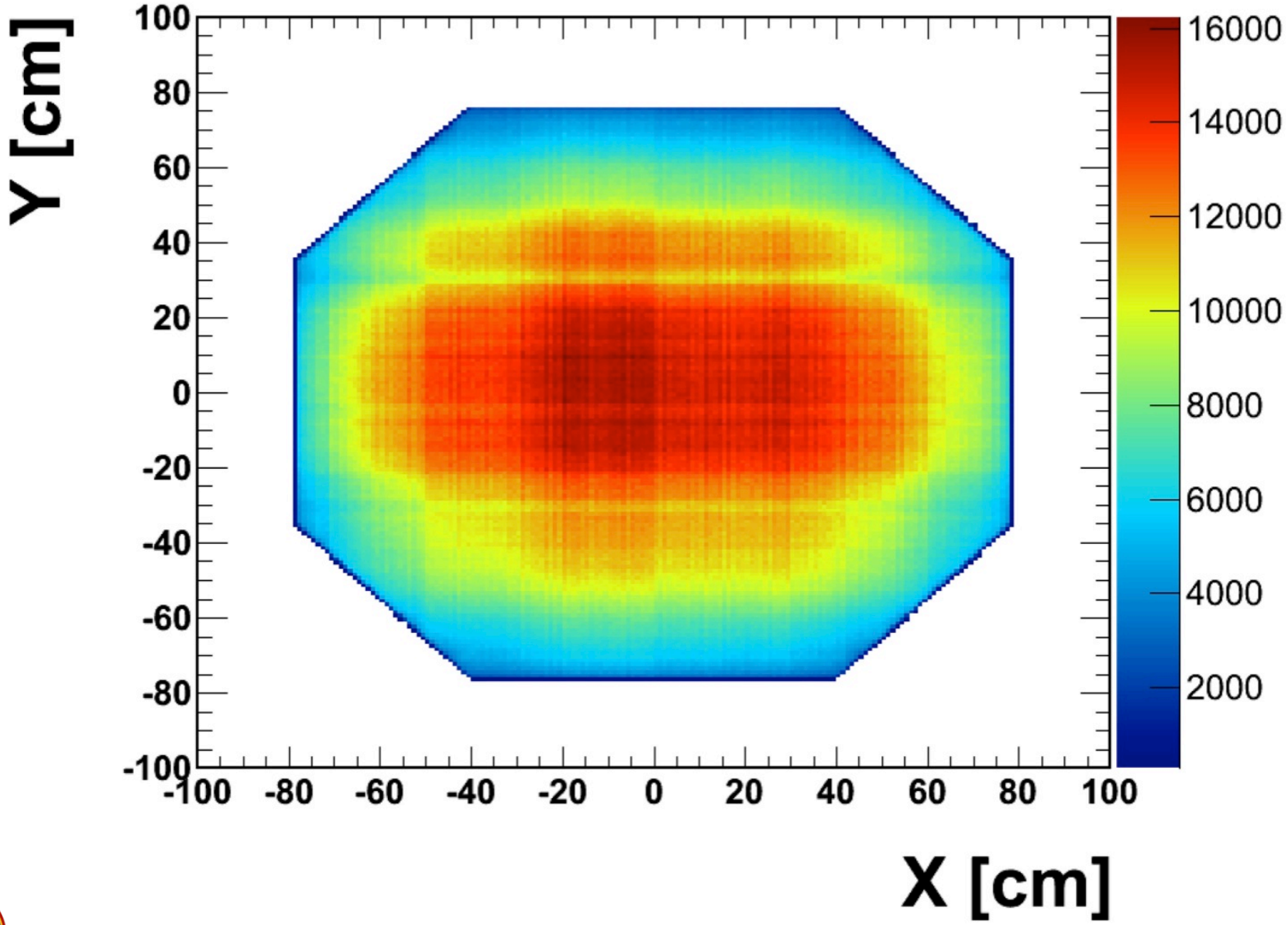
AMS-02 TRD



TRD Hits per event

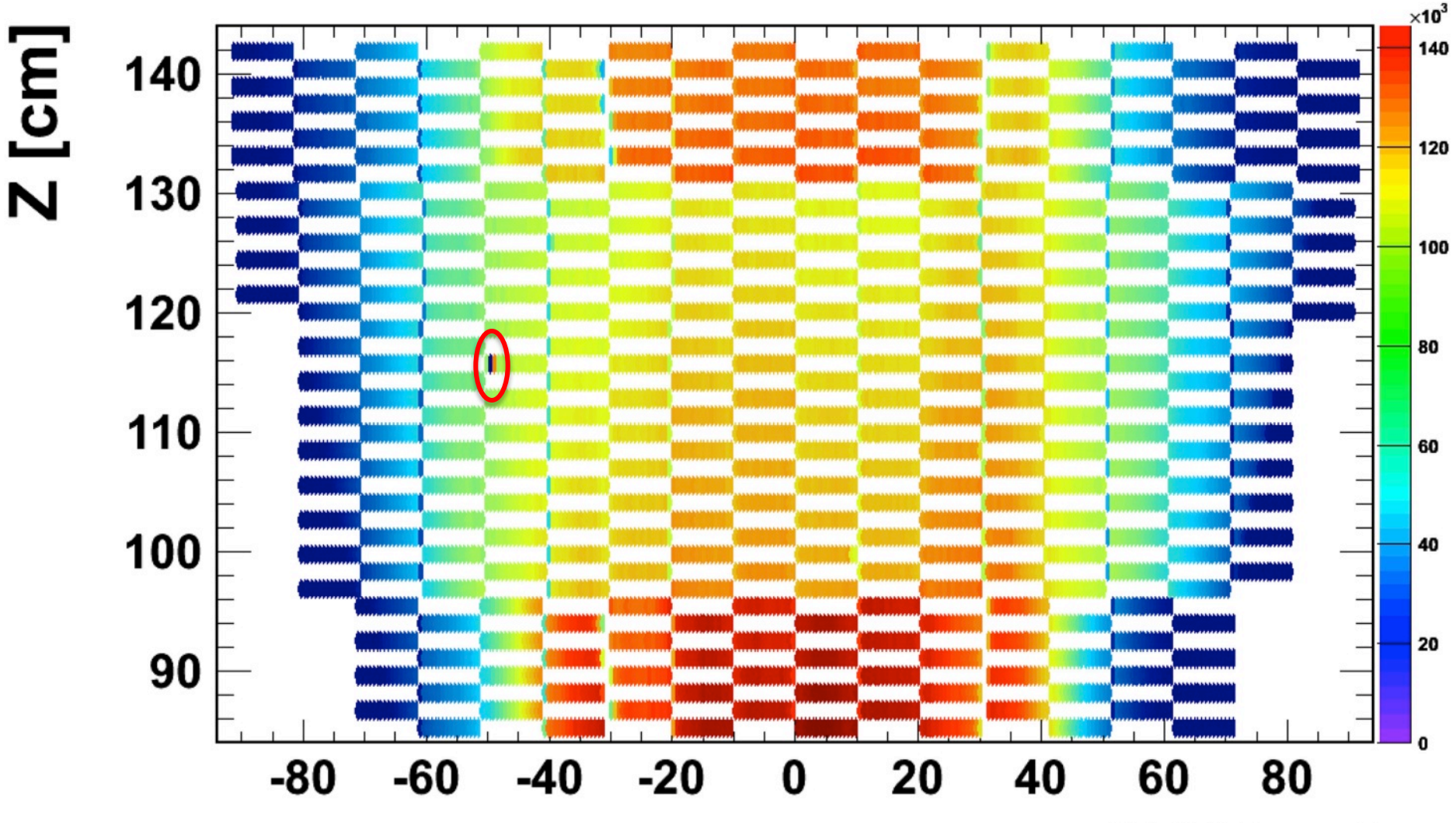


AMS-02 TRD - Occupancy



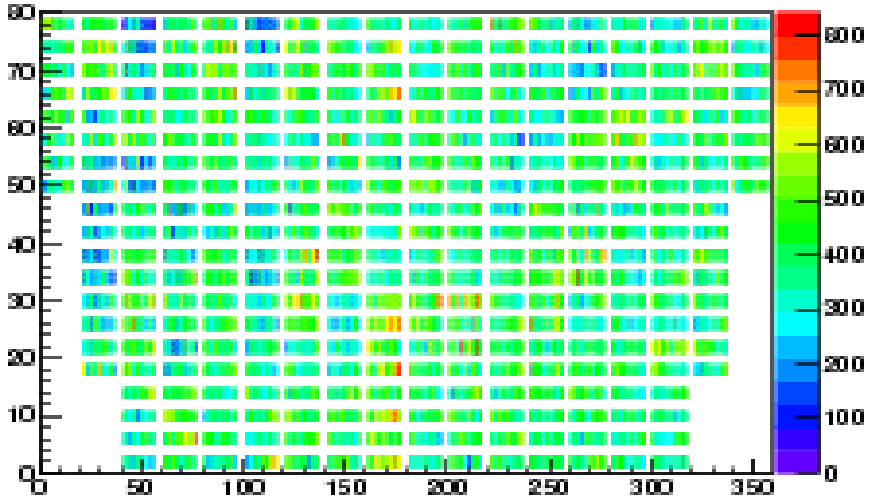
AMS-02 TRD - Occupancy

AMS TRD Occupancy
5246/5248 Channels within specification.

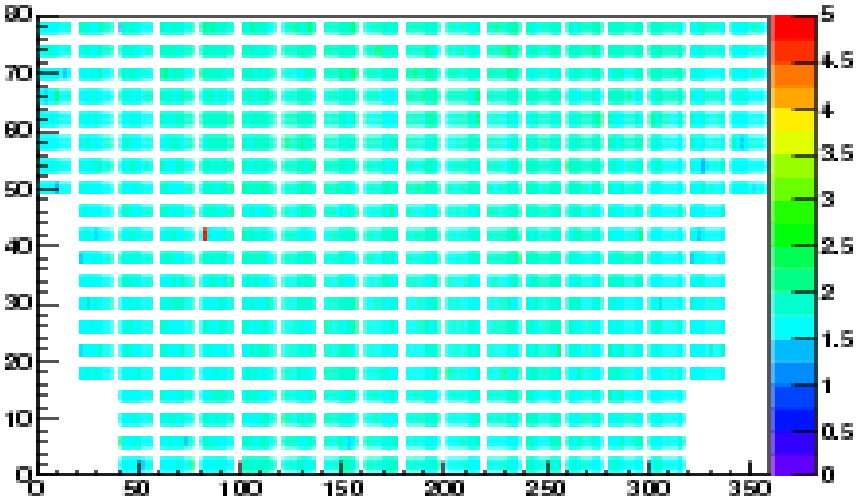


AMS-02 TRD – Amplitude/Noise

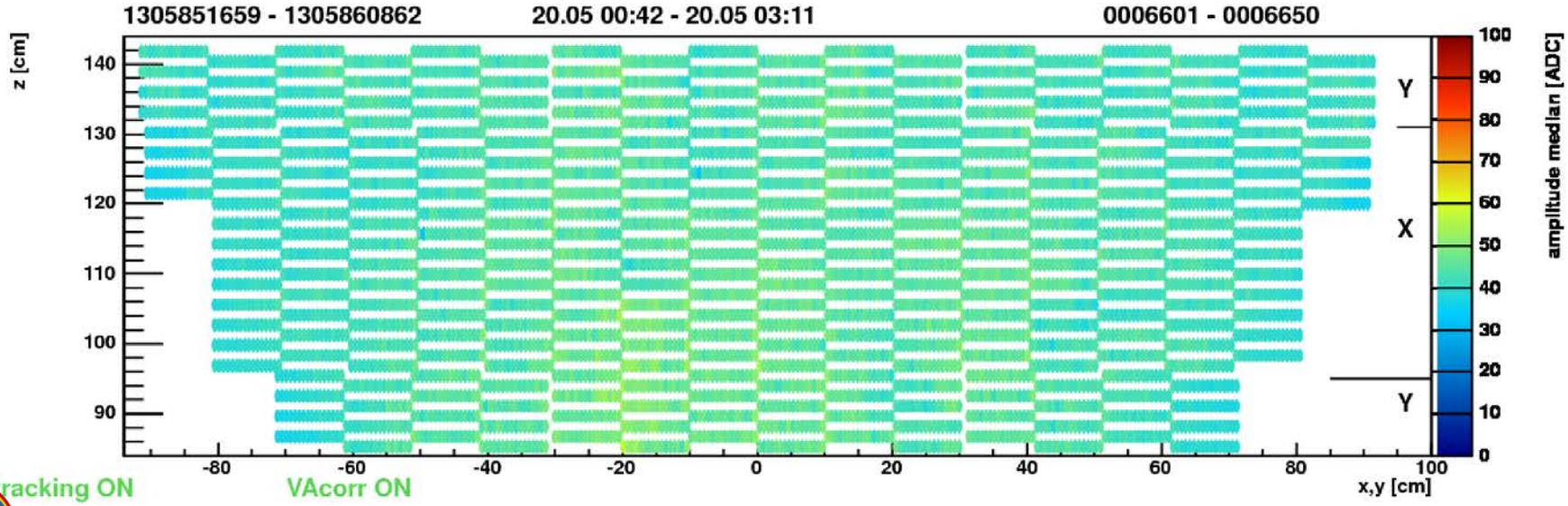
Pedestal



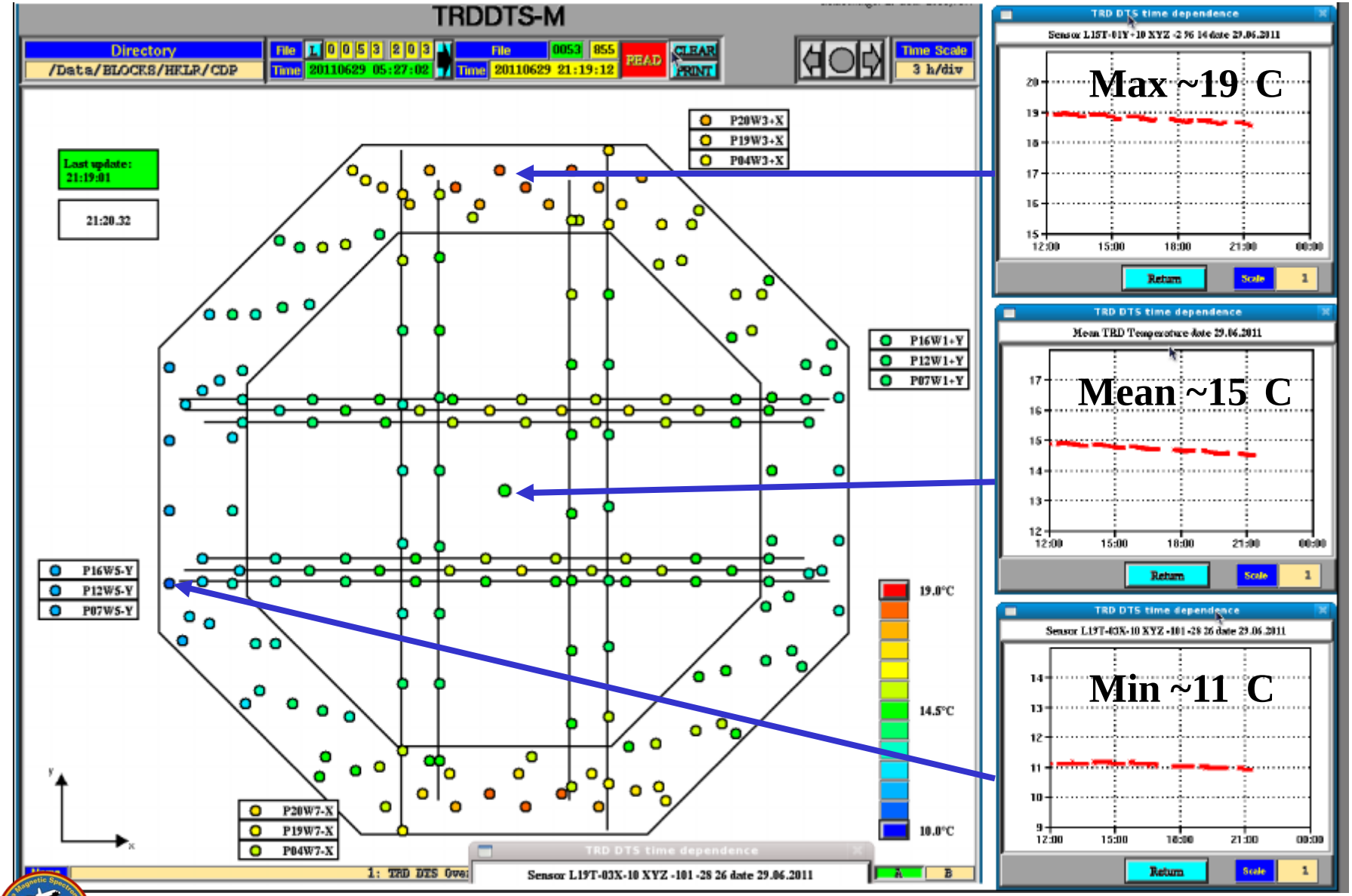
Noise



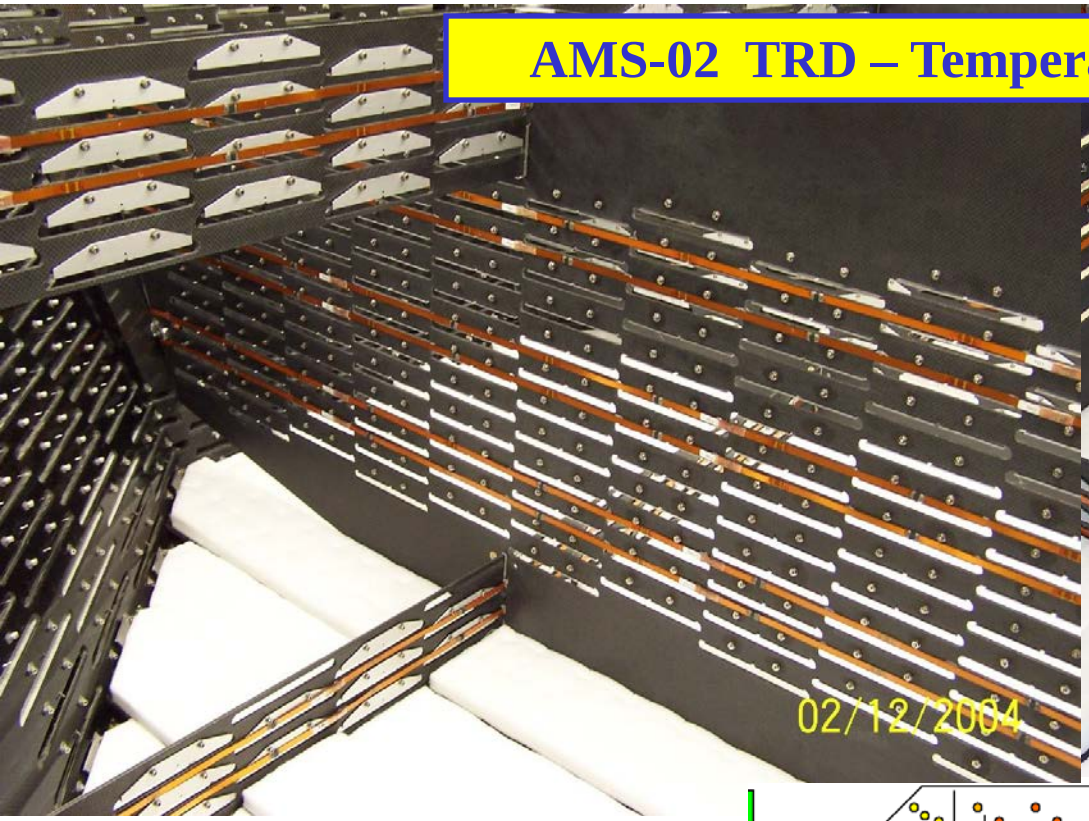
Amplitude on track

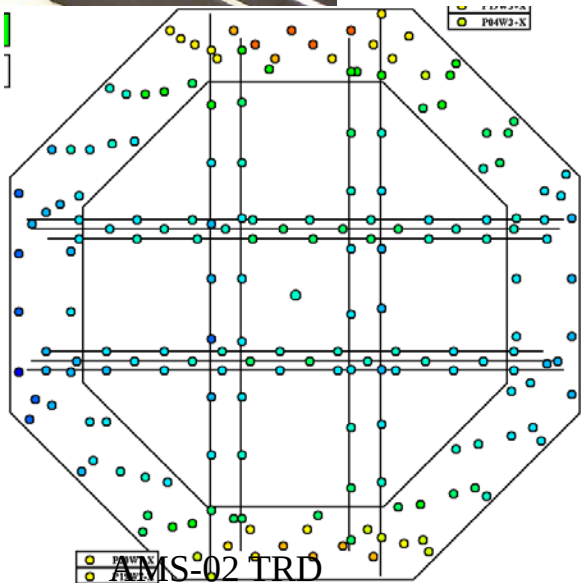


AMS-02 TRD – Temperature Monitoring

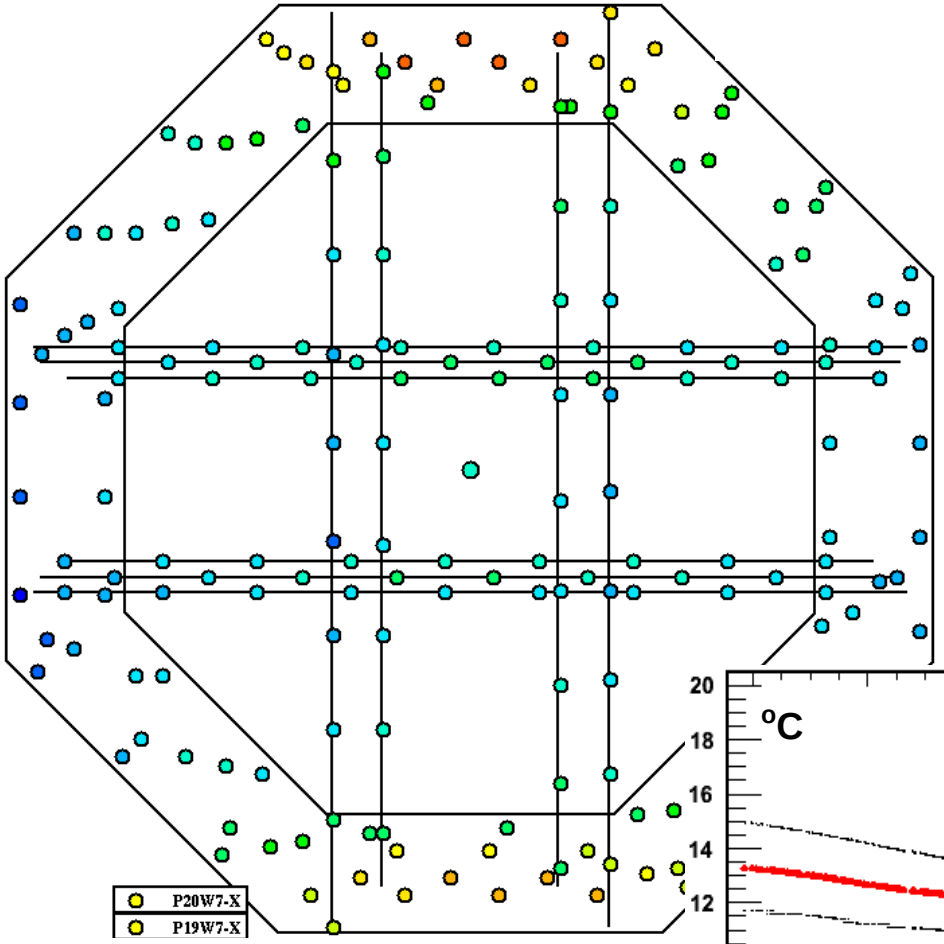


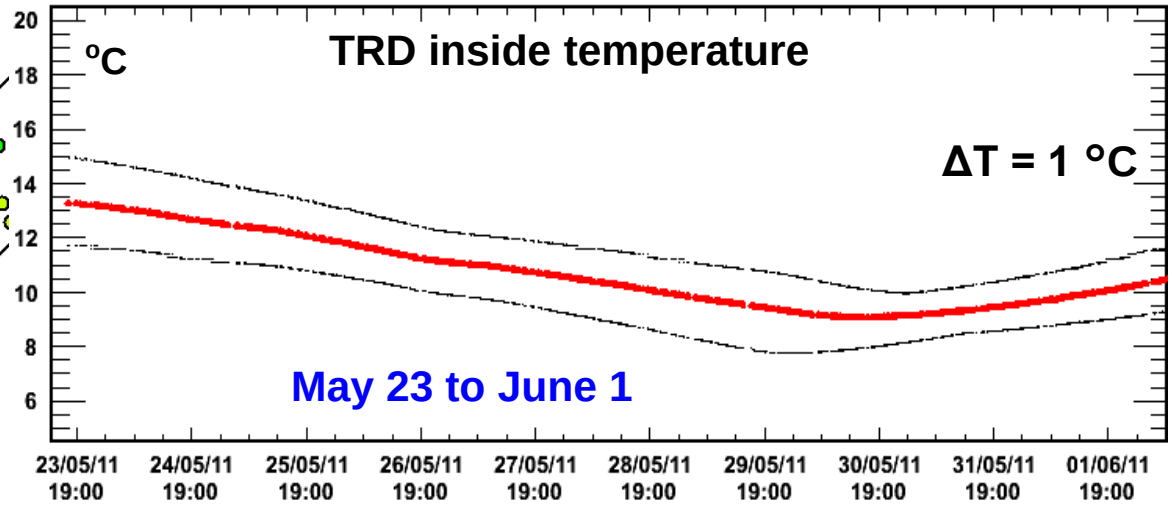
AMS-02 TRD – Temperature Monitoring



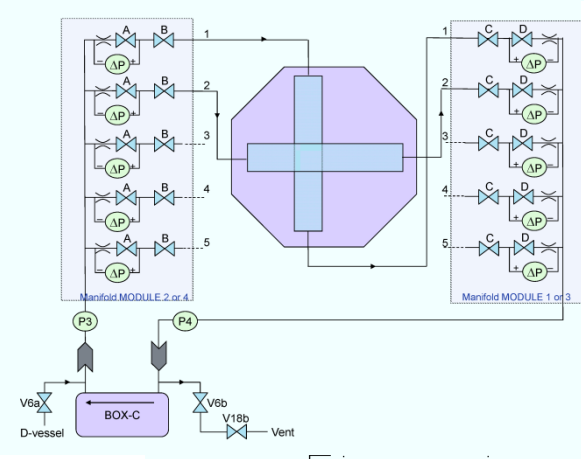


AMS-02 TRD – Temperature Monitoring





AMS-02 TRD – Pressure Monitor



Total leak rate of 4.2 mbar/day:

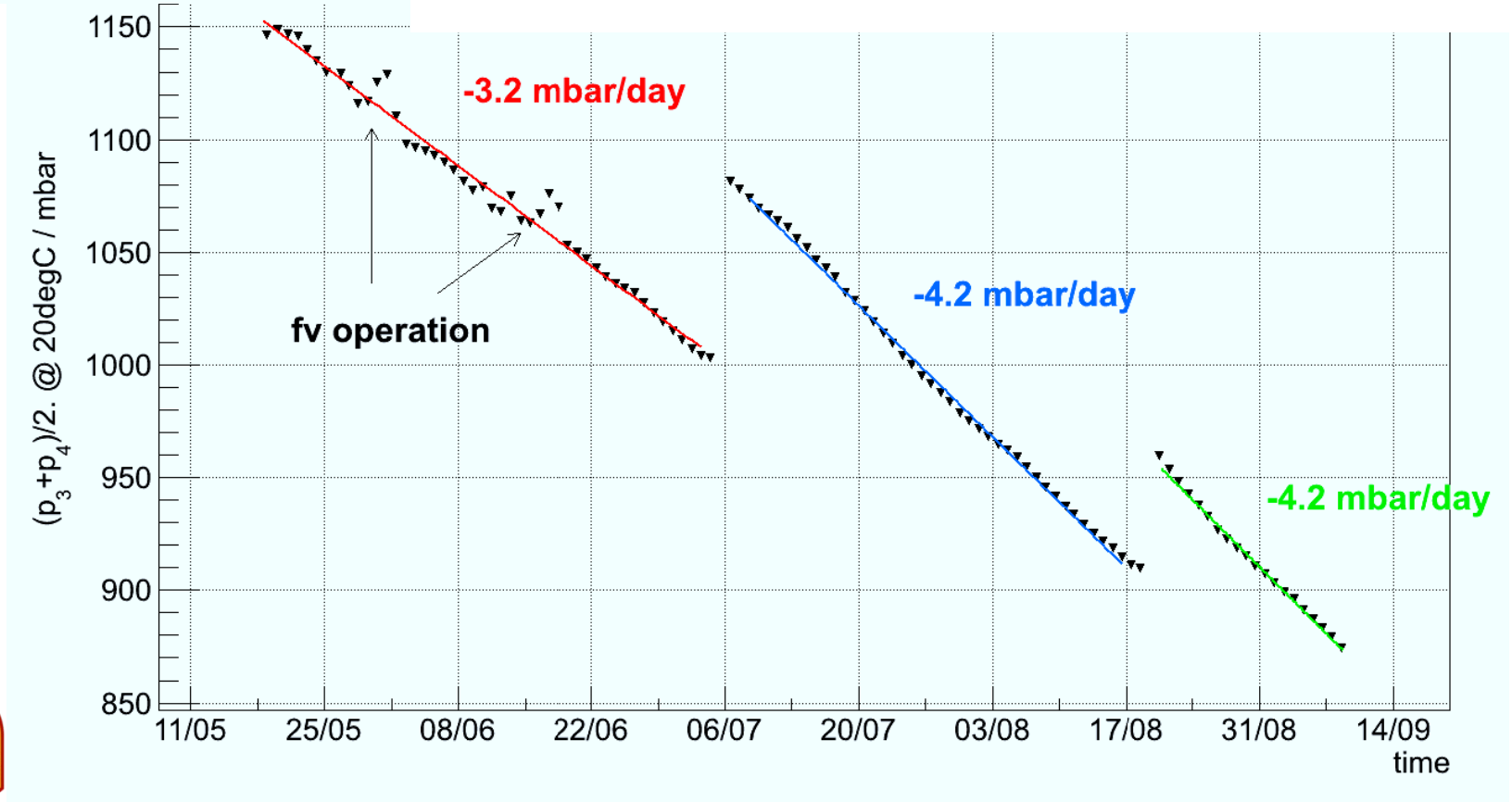
→ CO_2: (1.5 + 0.125*2.7) mbar/d = 1.84 mbar/day

Volume* leak rate = 230 l · 1.84 mbar/day = 422.6 l mbar / day

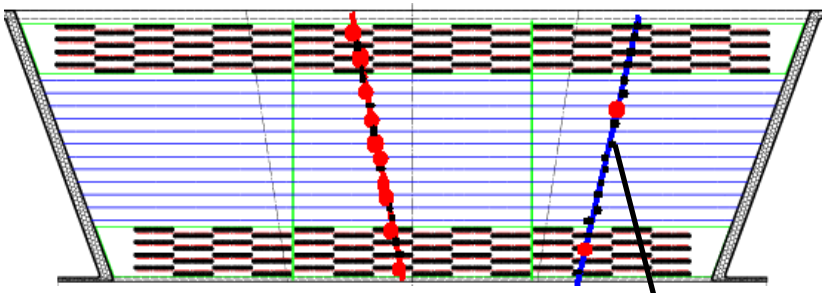
→ 0.764 g /day = 8.85 µg / s (before launch 6 µg / s)

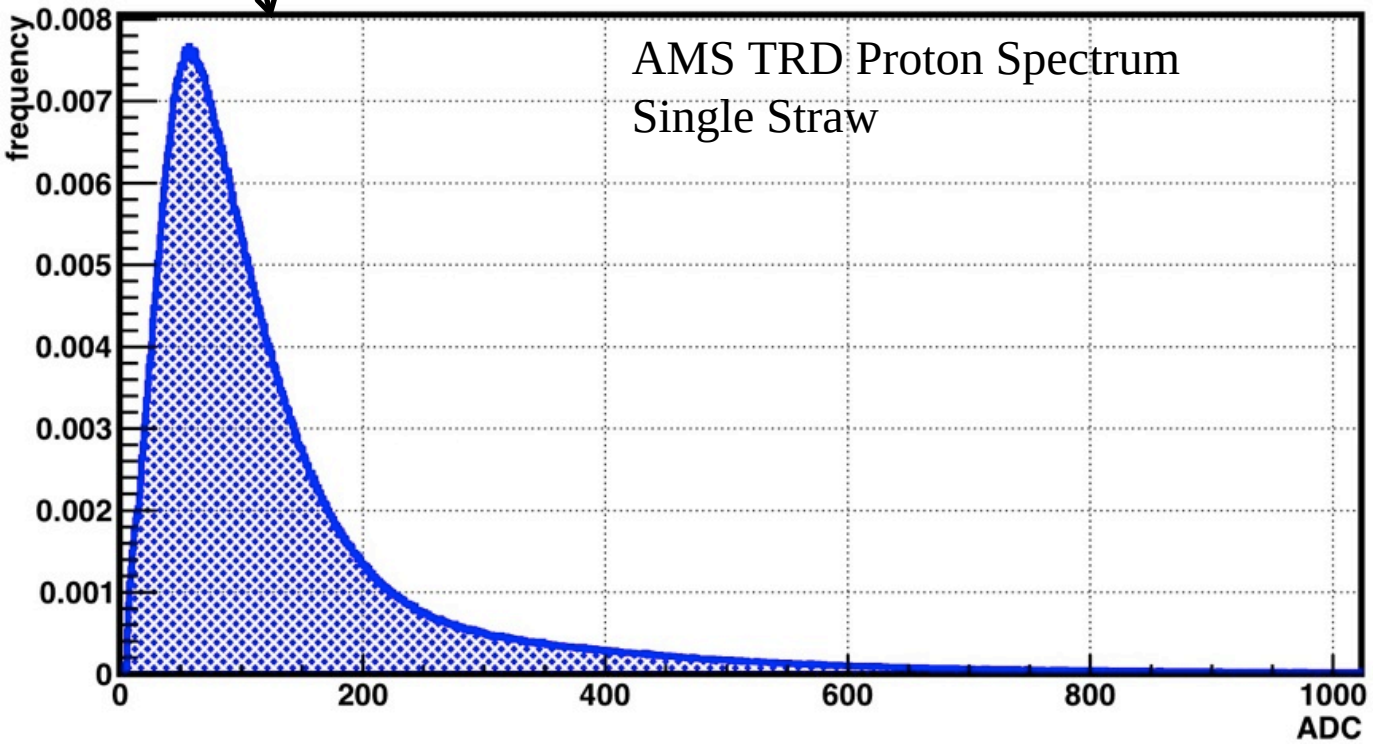
Total storage: 5kg

→ CO_2 lasts for 17.9 years > ISS Lifetime

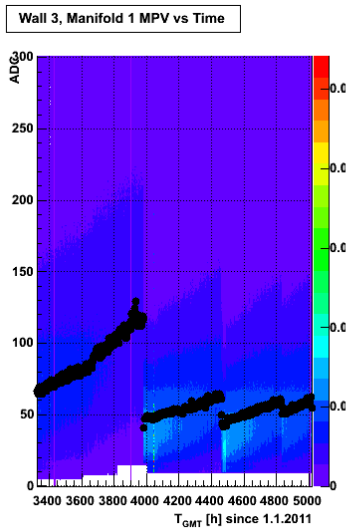


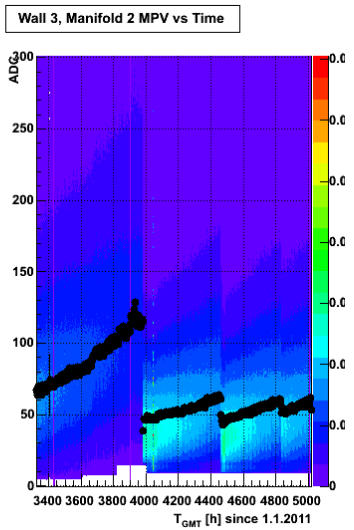
AMS-02 TRD Raw Data, before 1st Calibration

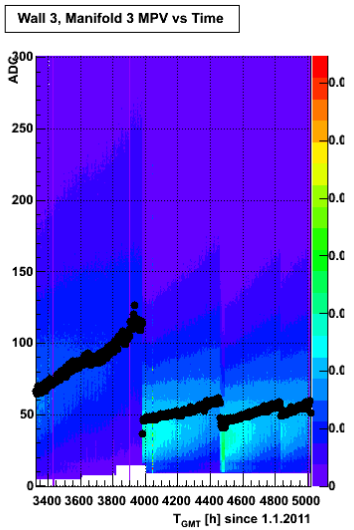


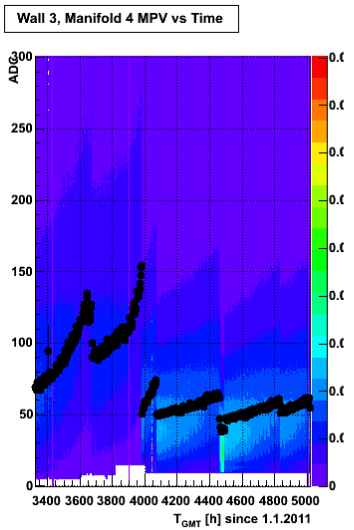


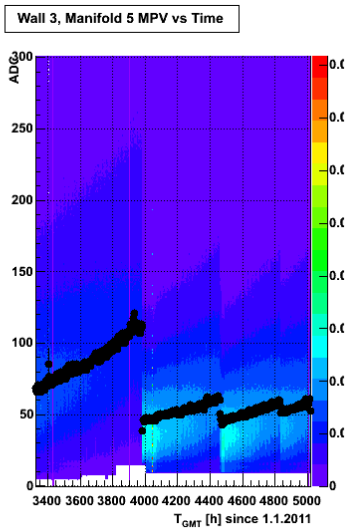
AMS-02 TRD Raw Data, before 1st Calibration

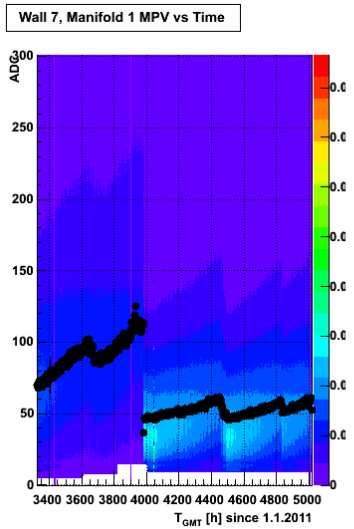


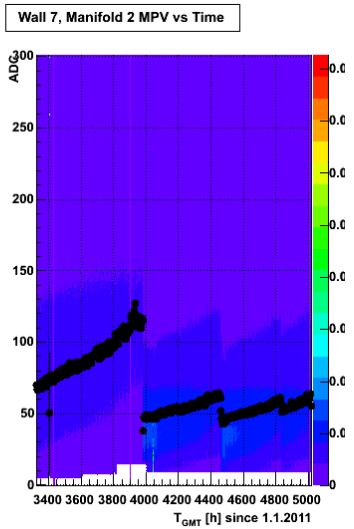


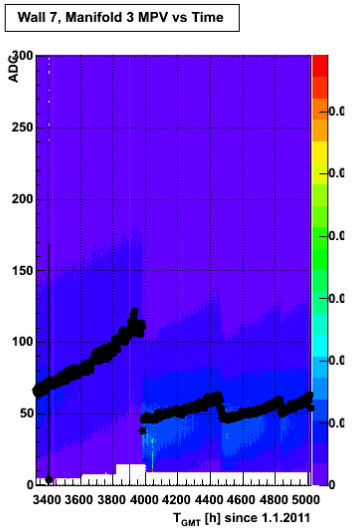


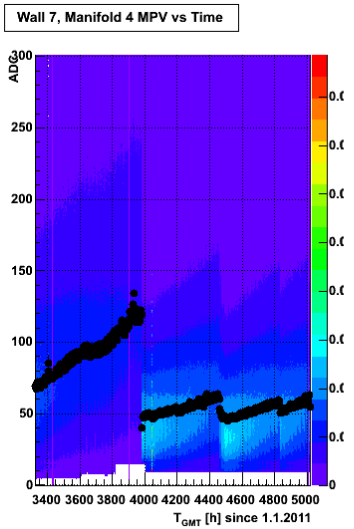


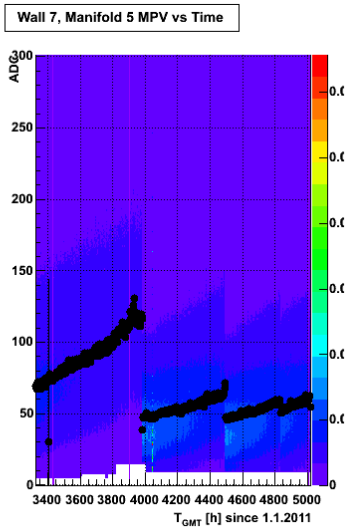




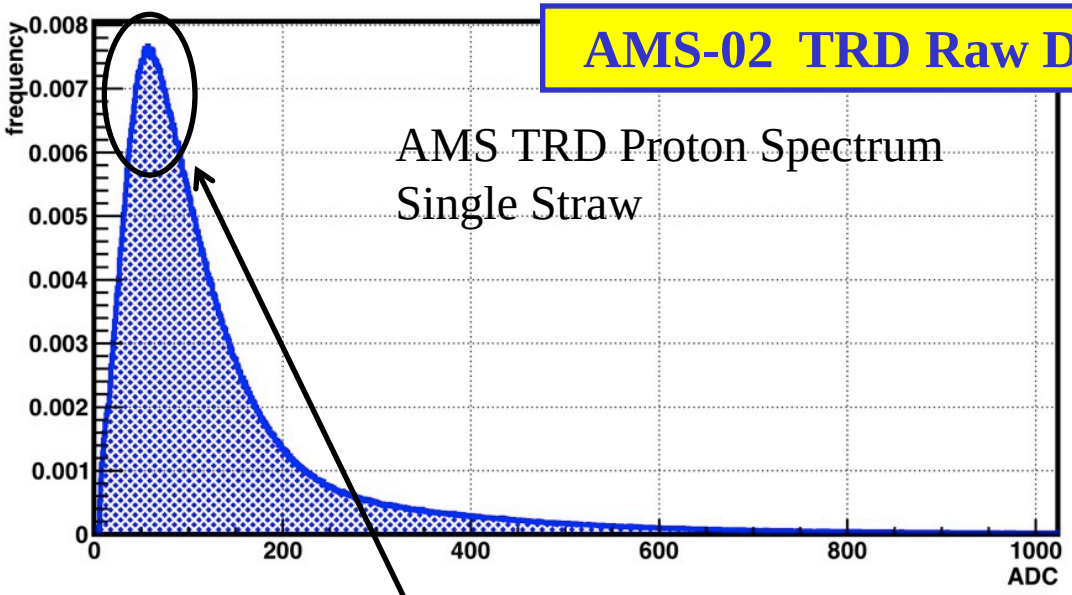


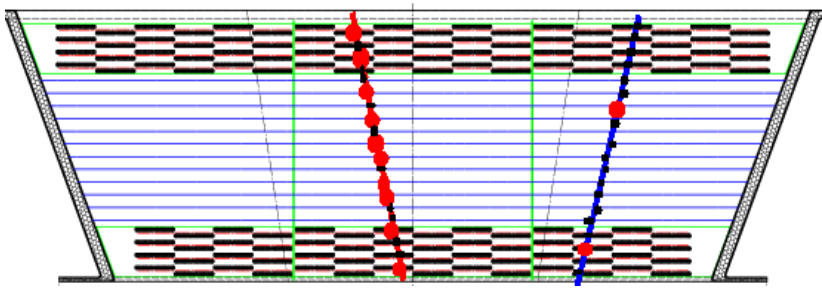


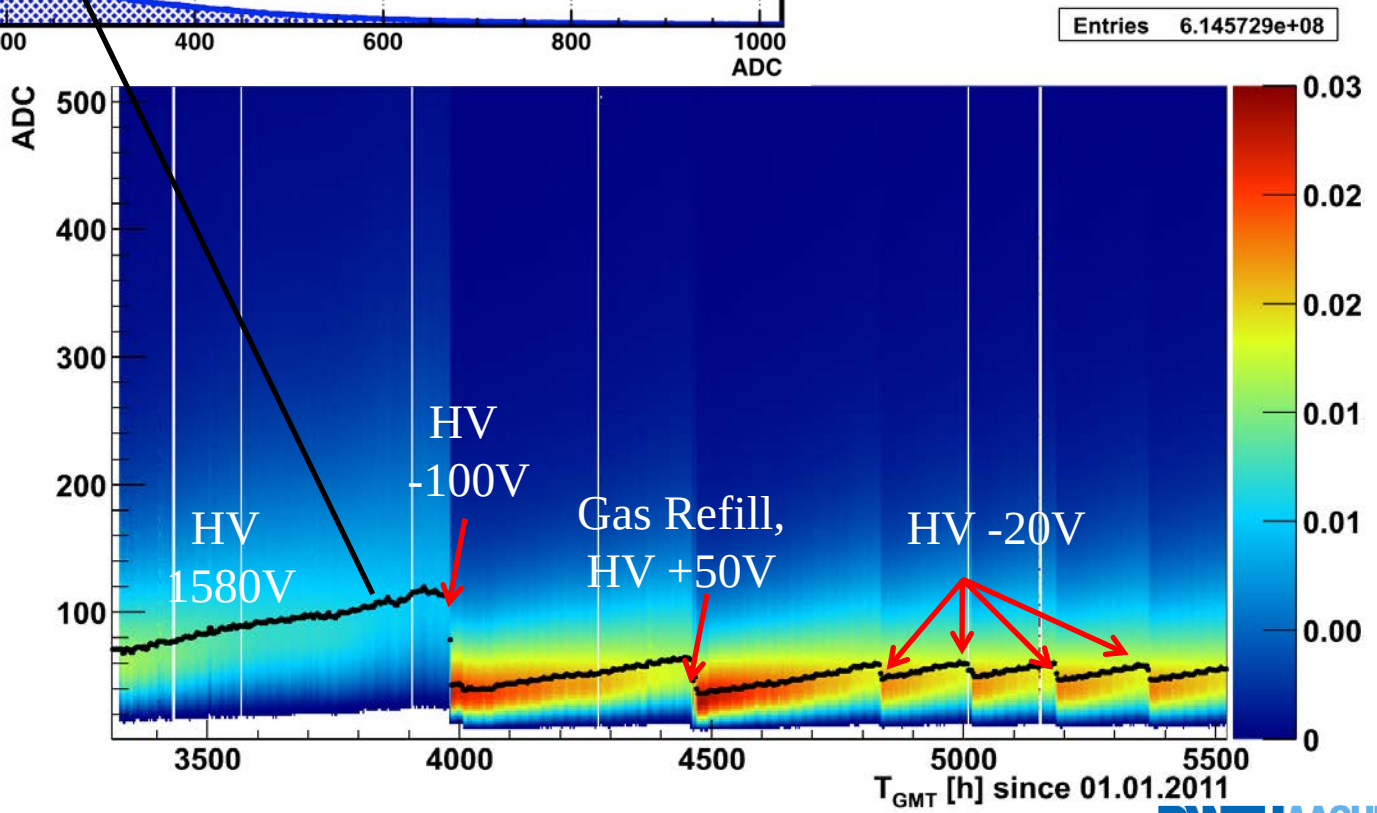




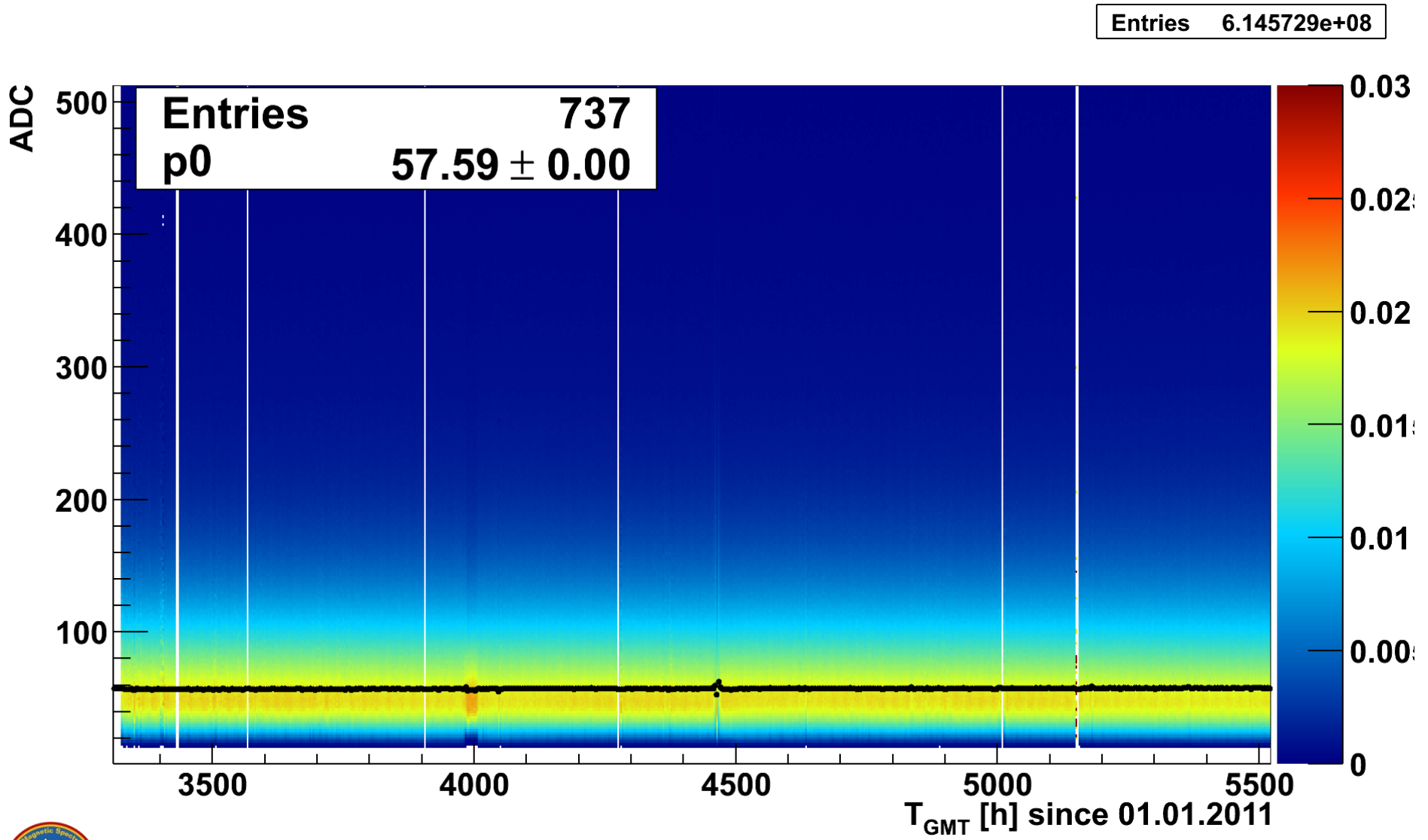
AMS-02 TRD Raw Data, before 1st Calibration





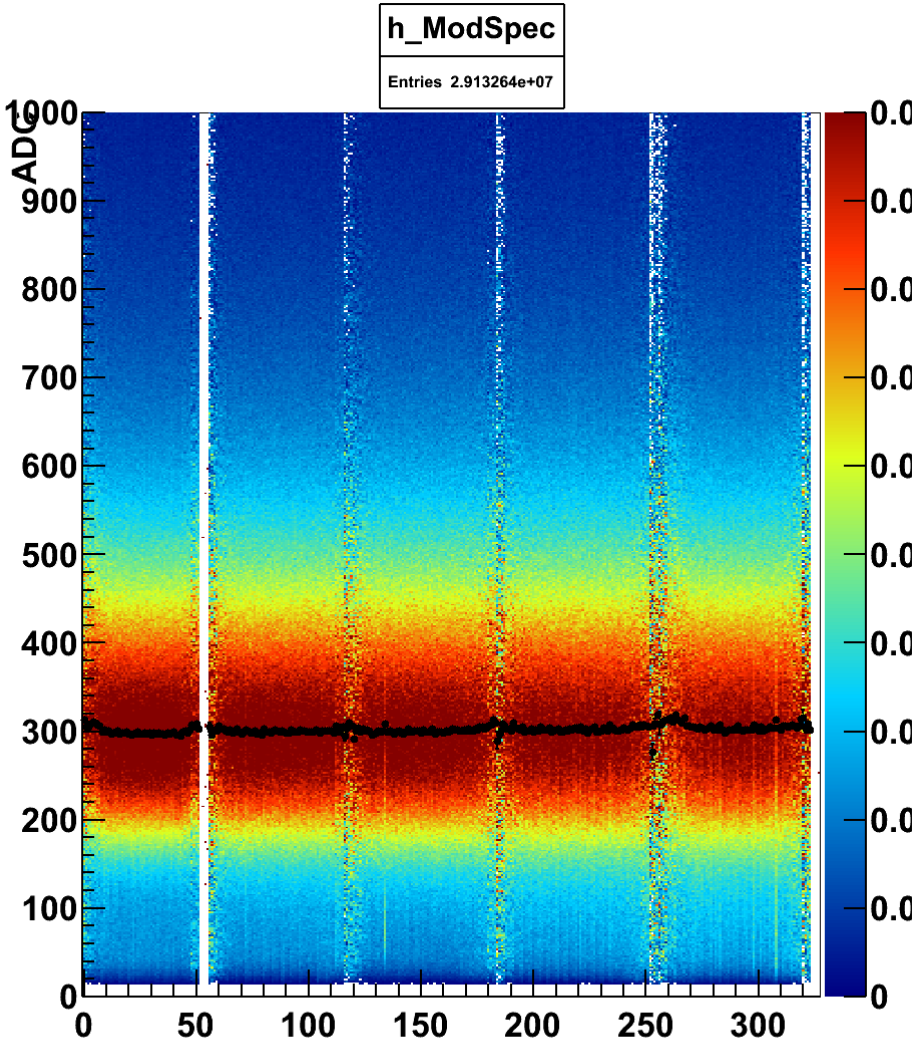


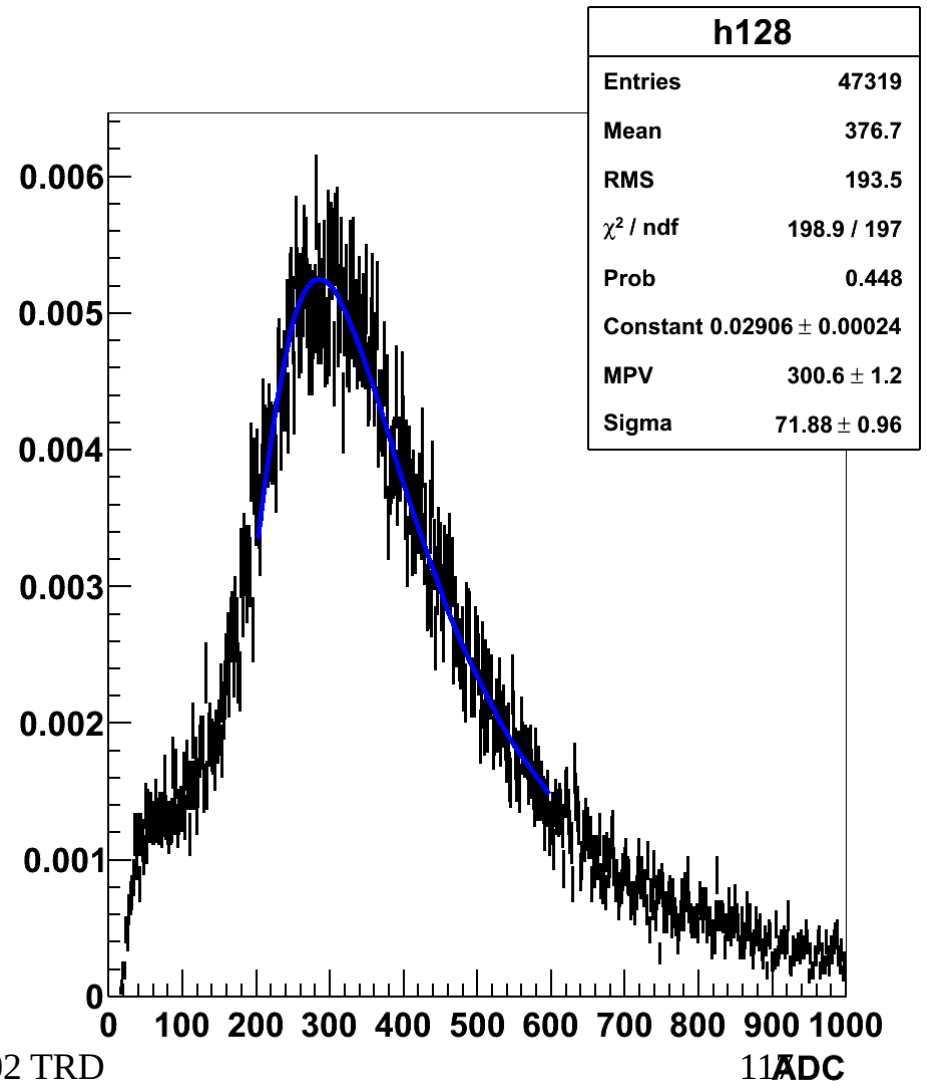
AMS-02 TRD after 1st Calibration

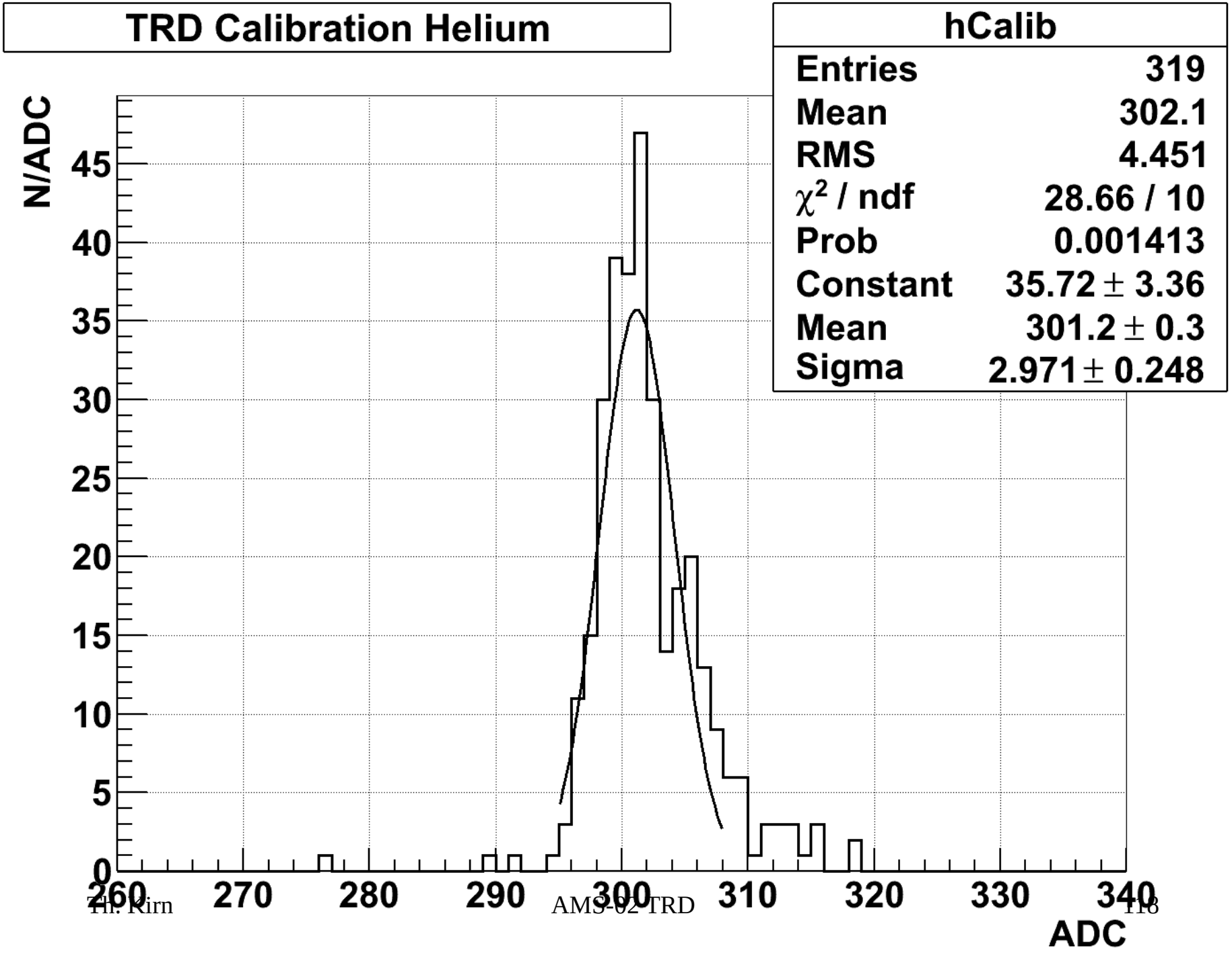


AMS-02 TRD after 1st Calibration, He-Sample

Helium (Z=+2, 10.0 GeV/c < P < 20 GeV/c)
Day 138 - 220

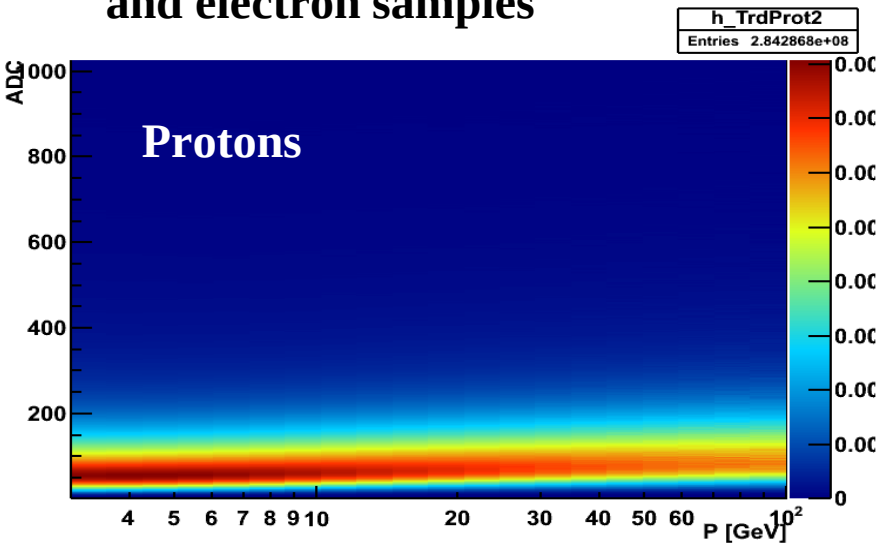


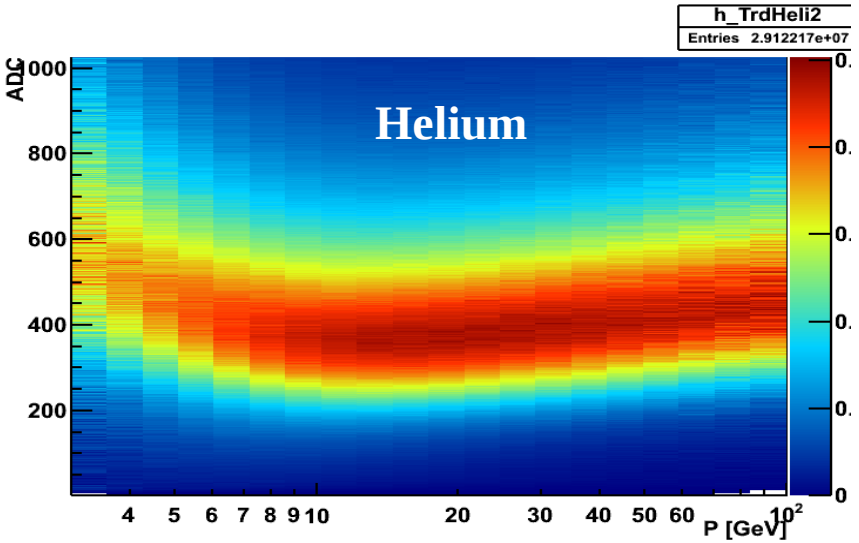


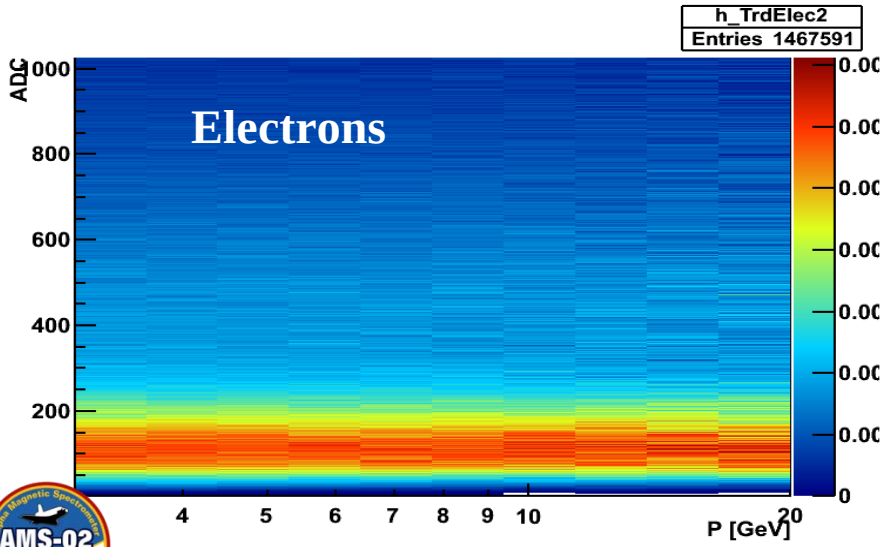

TRD Calibration Helium
hCalib
Entries 319
Mean 302.1
RMS 4.451
χ² / ndf 28.66 / 10
Prob 0.001413
Constant 35.72 ± 3.36
Mean 301.2 ± 0.3
Sigma 2.971 ± 0.248
N/ADC
0
5
10
15
20
25
30
35
40
45
260
270
280
290
300
310
320
330
340
ADC

AMS-02 TRD Response to Protons, Helium, Electrons

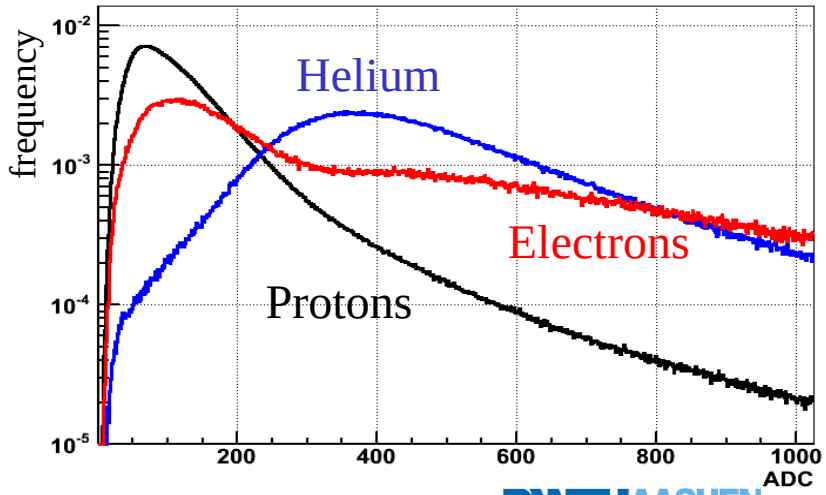
- **Use ToF, Tracker and ECAL to define clean single track proton, helium and electron samples**



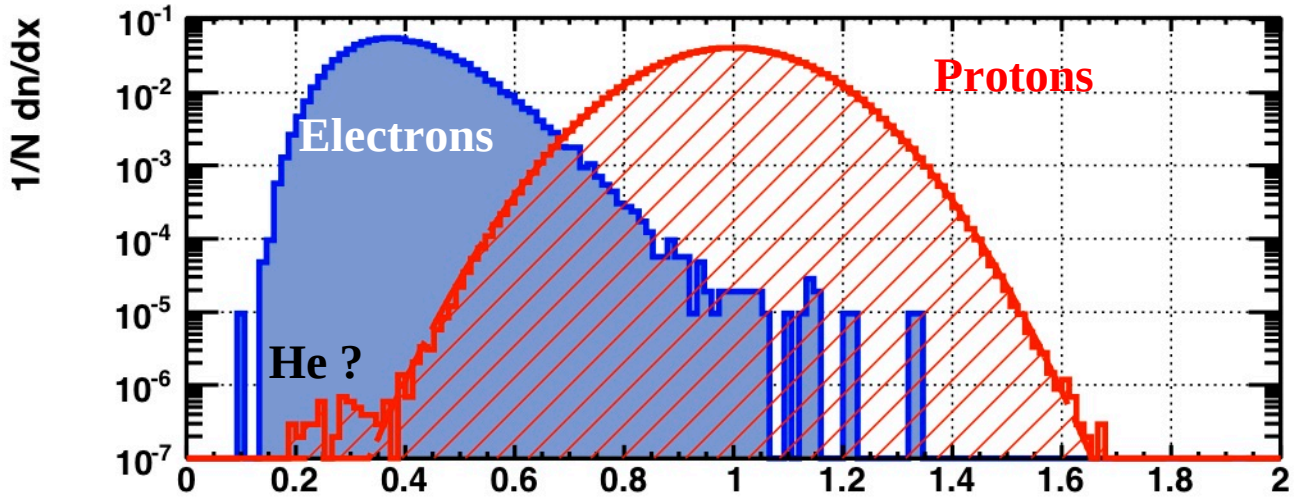




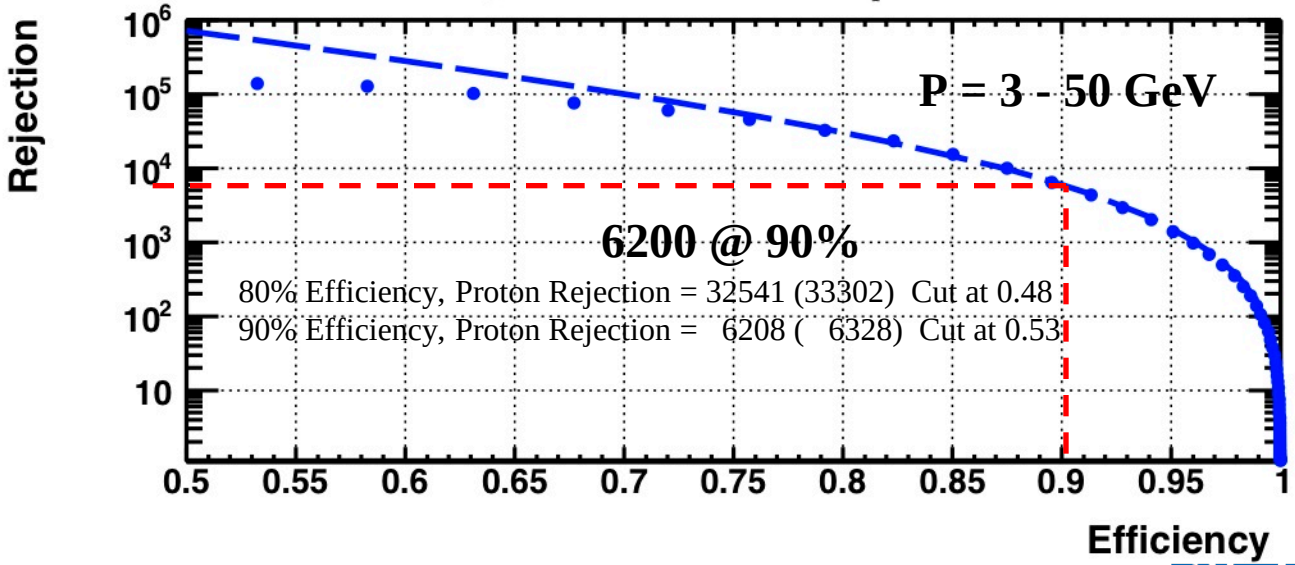
Single Straw Spectrum



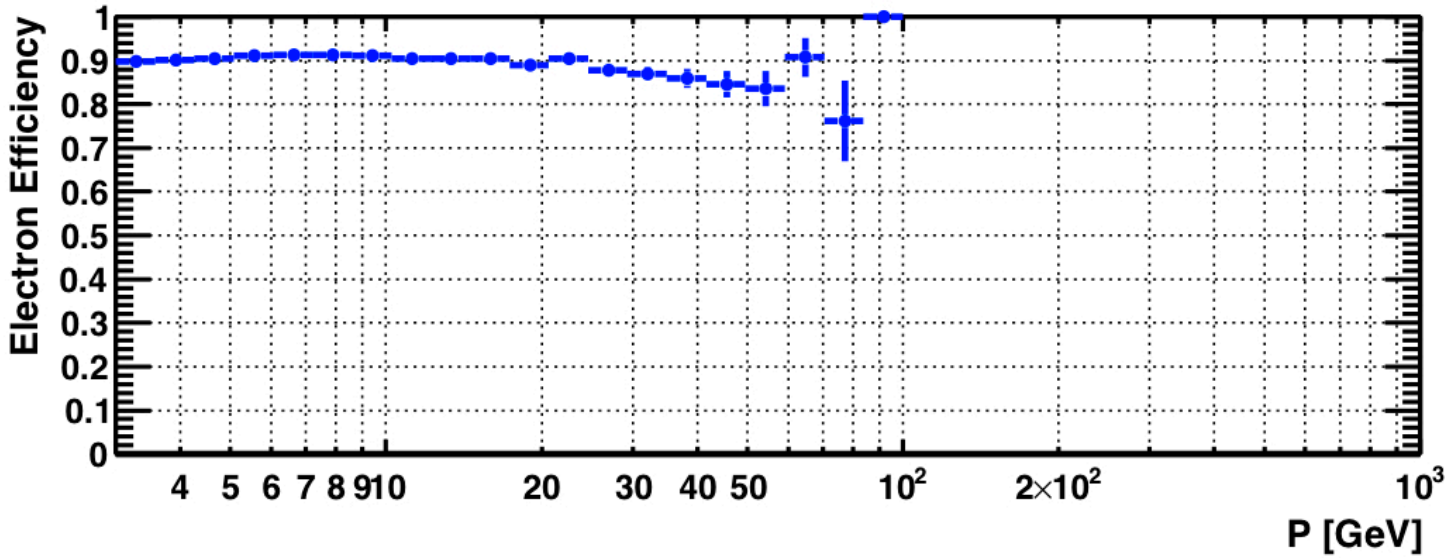
AMS-02 TRD Proton Rejection

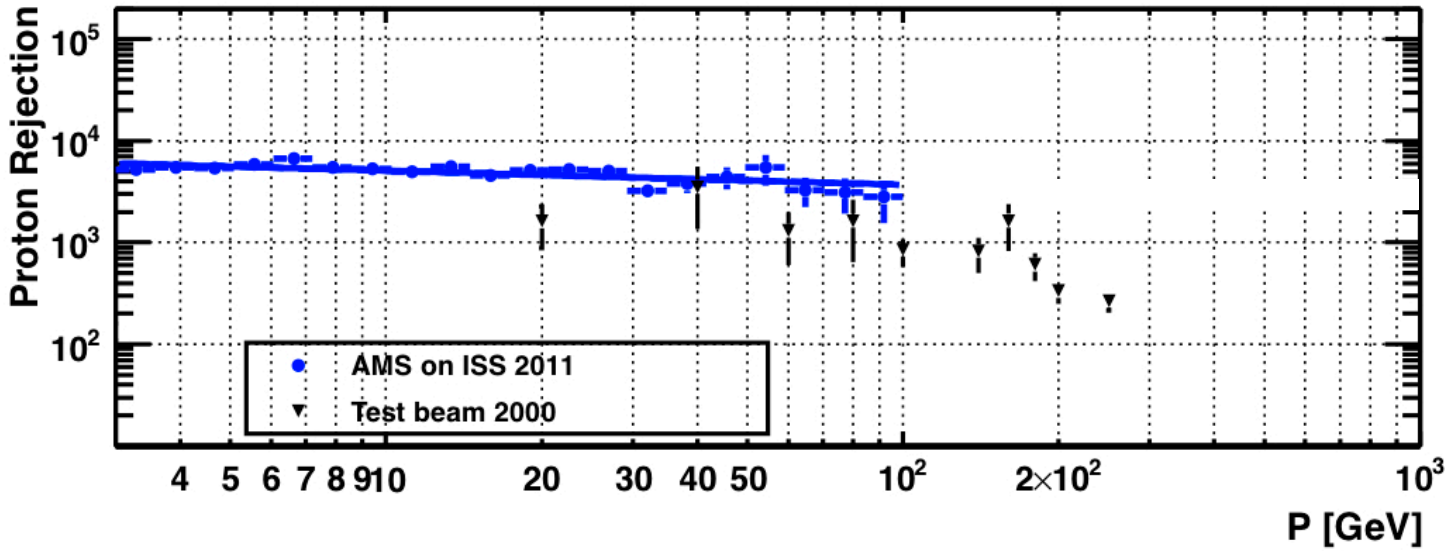


$$\bar{P}_{e/p} = \sqrt[n]{\prod_i^n P_{e/p}^{(i)}(E)} \qquad L = \frac{\bar{P}_e}{\bar{P}_p + \bar{P}_e}$$

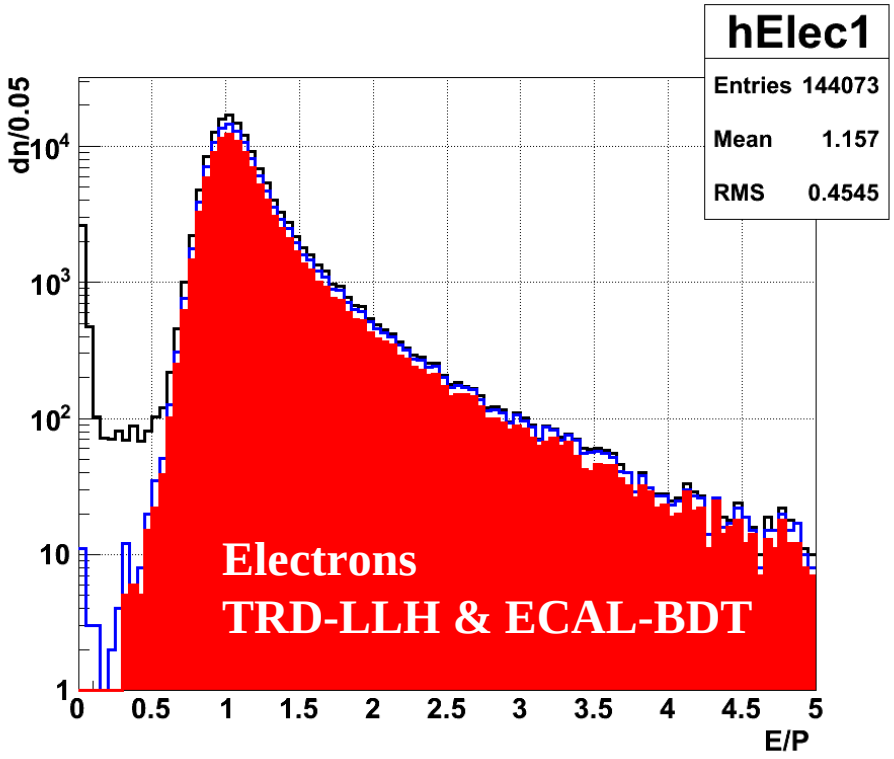


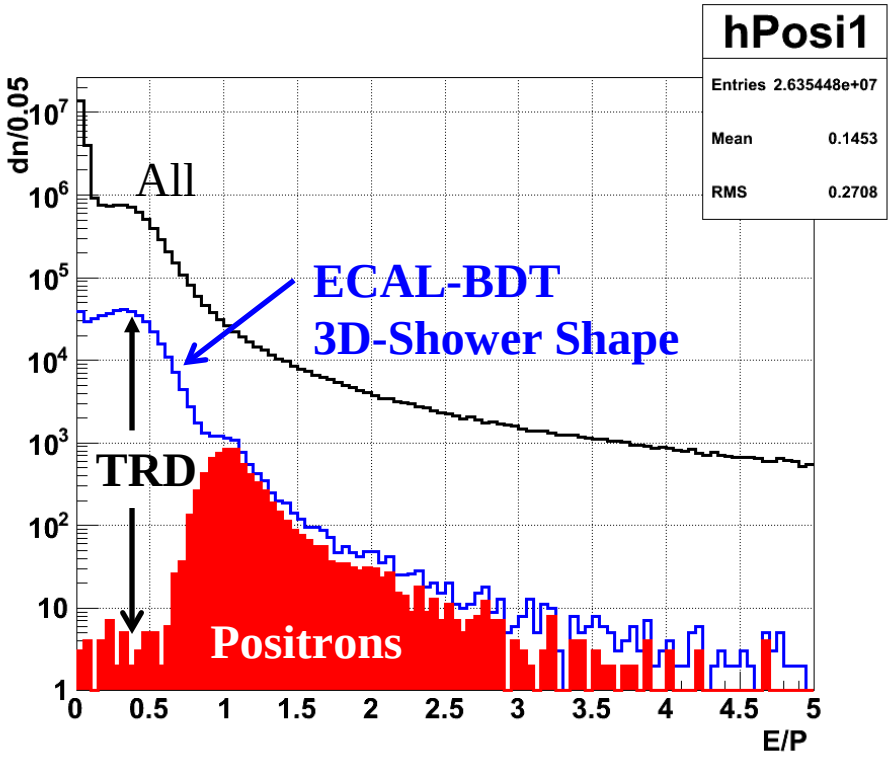
AMS-02 TRD Proton Rejection





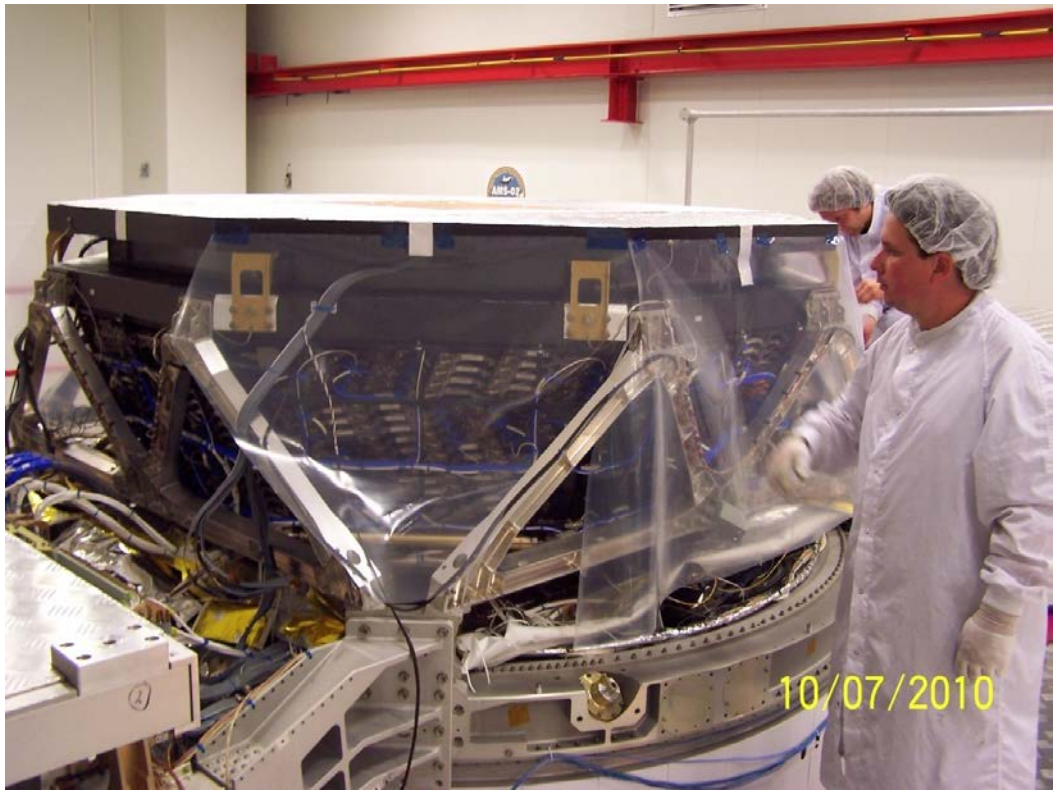
AMS-02 TRD Proton Rejection

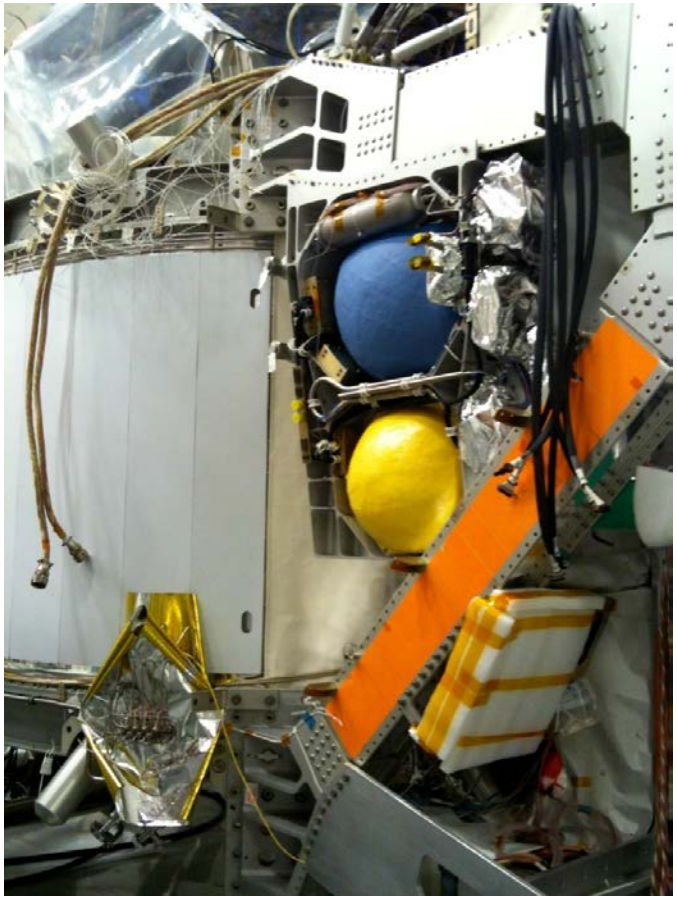




AMS-02 TRD
Slow Control and Data Monitoring

TRD/TRDGas-System Monitoring Programs





TRD/ACC/TAS-Standard Shift

List of TRD/TRDGas Programs

Electronics Monitoring:

- TRD Status Monitor (TRD-S)
- Pedes_Canvas
- UDR_HK_Canvas
- Read_block_files
- UHV Status Monitor (UHV-S)

Gas Monitoring:

- TRDGAS Monitor (TRDGAS-M)
- TRDGAS Status Monitor (TRDGAS-S)
- TRD Pressure Monitor (Pressure Monitor)

Detector Monitoring:

- TRD Data Monitor (TRD-M)
- TRD-DTS Monitor (TRDDTS-M)
- TRD-GainMonitor (TRD-GainMonitor)

TRD-ACC-TAS SHIFTER:
TRDGas Standard Monitoring Shift

Start-up of AMS-Activation:

AMS Power-Step-1 from CMD Post
- Initializes TRDGAS Crate (UG)
- Configures and starts UG CtrlTsk
- Activates UG Q-List items 7A/7B

HV ON: CMD asks if TRD Gas is ok

Standard Shift Activity:

- **No** TRDGAS commanding in standard shift

- **Adjust** TRD HV once per day by a 3V step (MOP-ADC value ≈ 60)
  details see pages 131-133

- Check: TRDGAS monitor data available
  All plots in TRDGAS-M update

- Check: Pressures and Temperatures in range
  TRDGAS-S is updating regularly

TRD-ACC-TAS SHIFTER:
TRDGas Emergency Actions

Emergency Actions from TRD Post CALL EXPERT	ASK for Commanding
- Xe/CO2 Vessel High Pressure (>175/100bar)	UG Heaters DISABLE
- Xe/CO2 Vessel High Temperature (>+60 C)	UG Heaters DISABLE
- Xe/CO2 Vessel Low Temperature (<-20 C)	HEAT VESSELS (UG-A)
- Xe/CO2 Vessel Low Temperature (<-40 C)	HEAT VESSELS (UG-B)
Requires UGPD-B powered and all DC/DC on	
- Xe/CO2 Vessel Low Temperature (<-50 C)	Turn AMS into sun
- Mixing Vessel High Pressure (>13bar)	VENT MIX
- Box-C High Pressure (>1500mbar)	VENT Box C
- TRD High Pressure (>1300mbar)	Flipper Valves CLOSE
- TRD Low Pressure (< 900mbar)	Flipper Valves CLOSE
	ask CMD: TRD HV OFF
-TRD-SidePanel High Temperature (>+40 C)	Flipper Valves CLOSE
Ask CMD to disable TRD 120V Heaters	(PDS 120V Heater #3)
- TRD-SidePanel High Temperature (>+50 C)	ask CMD: TRD StandBy
Option: ask CMD for AMS StandBy last Option:	Turn TRD away from sun
- TRD-SidePanel Low Temperature (<+5 C)	Flipper Valves CLOSE
Ask CMD to switch ON TRD 120V Heaters A & B	(PDS 120V Heater #3)
- TRD-SidePanel Low Temperature (<-20 C)	Turn AMS into sun

TRD-ACC-TAS SHIFTER:
TRD Standard Monitoring Shift

- Check: TRD data monitor (TRD-M, Pedes_Canvas.ps, UDR_HK_Canvas)
- Check: TRD Temperatures in range (TRDGAS-S and TRD Sidepanels)

Emergency Actions from TRD Post CALL EXPERT

-TRD HV Trip!

ASK for Commanding

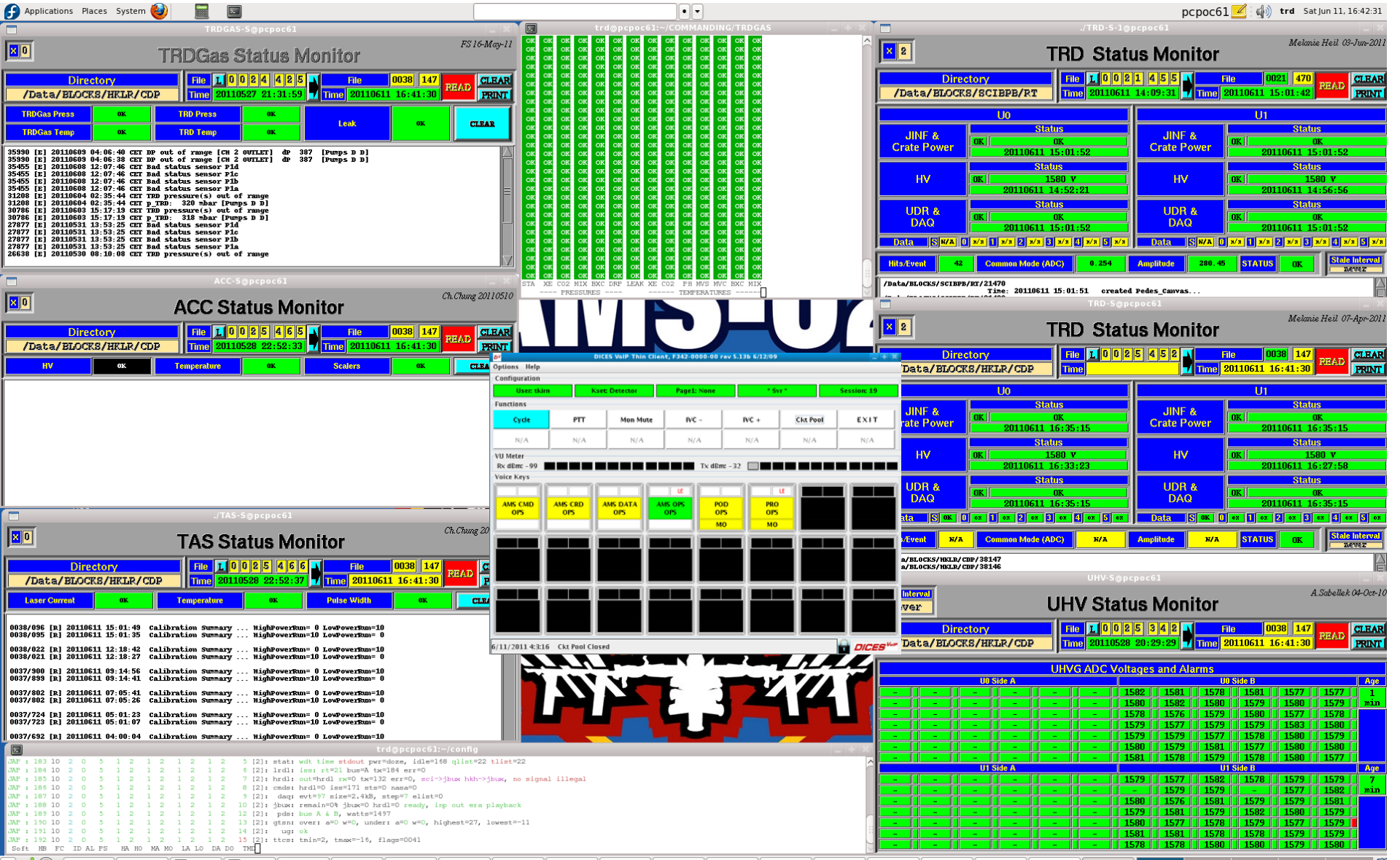
ASK Command to stop DAQ

Go to TRD-HV

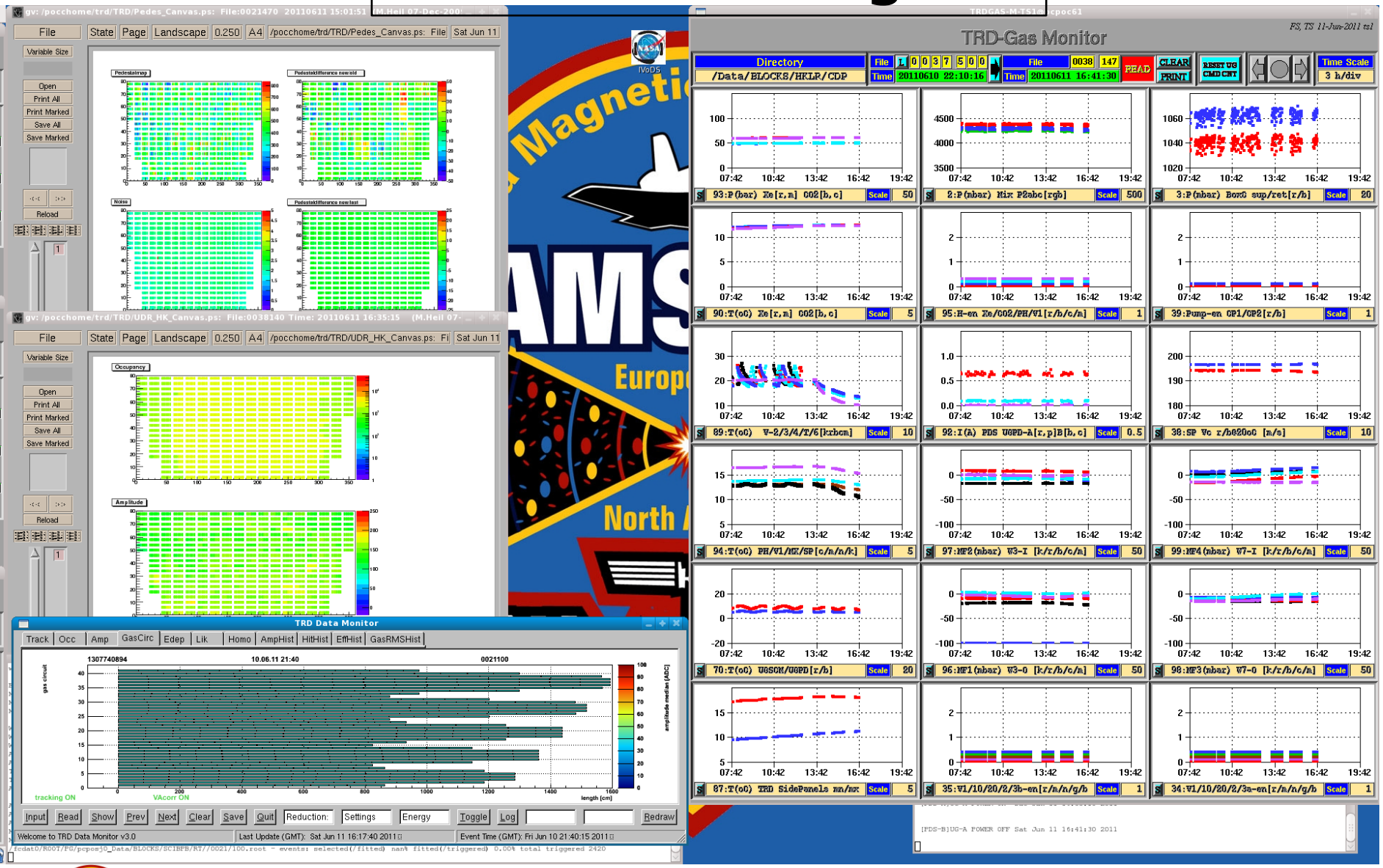
reset HV by pressing button `HV On´

TRD-ACC-TAS SHIFT SETUP

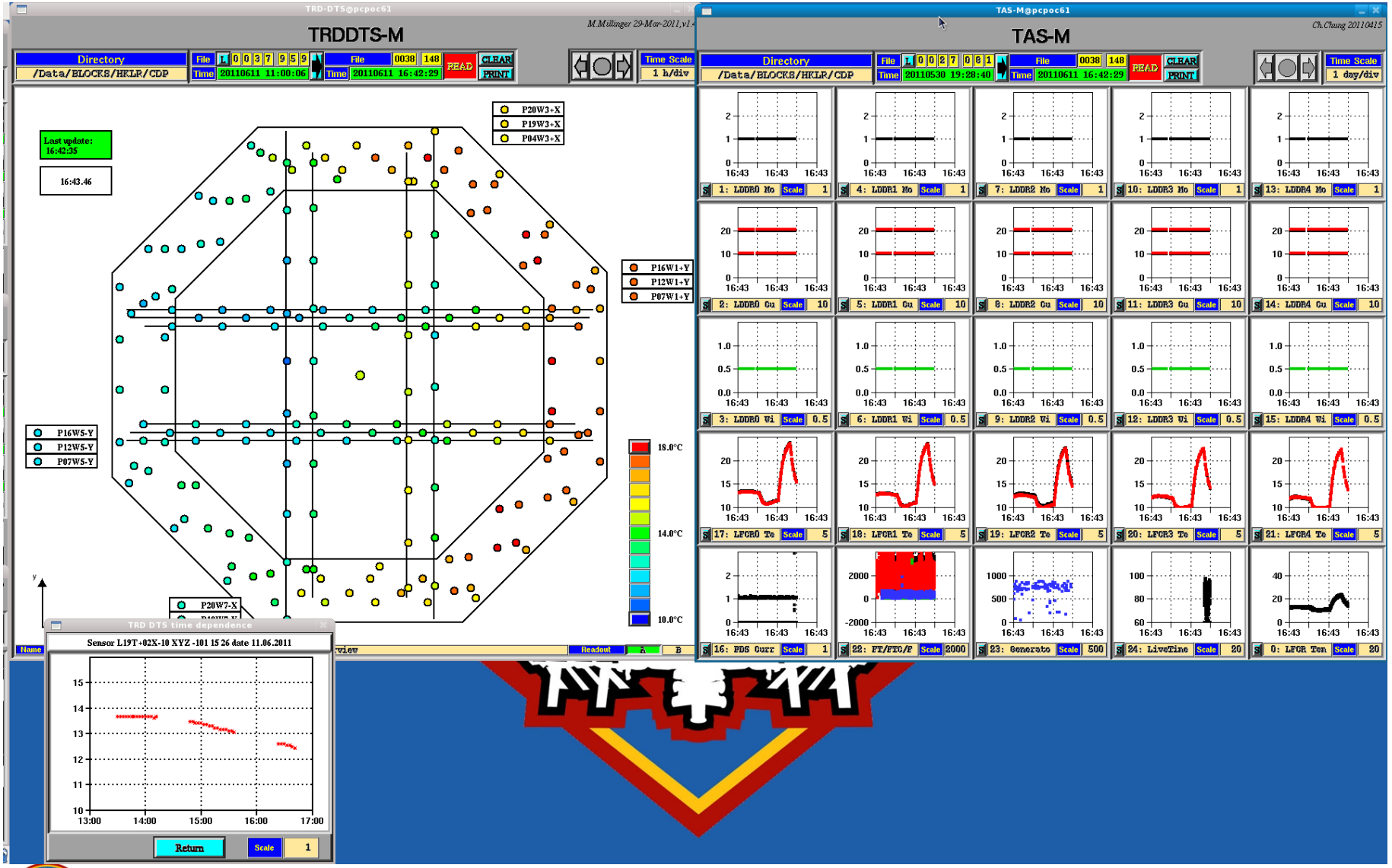
Screen 1 Left (TRD/GAS)



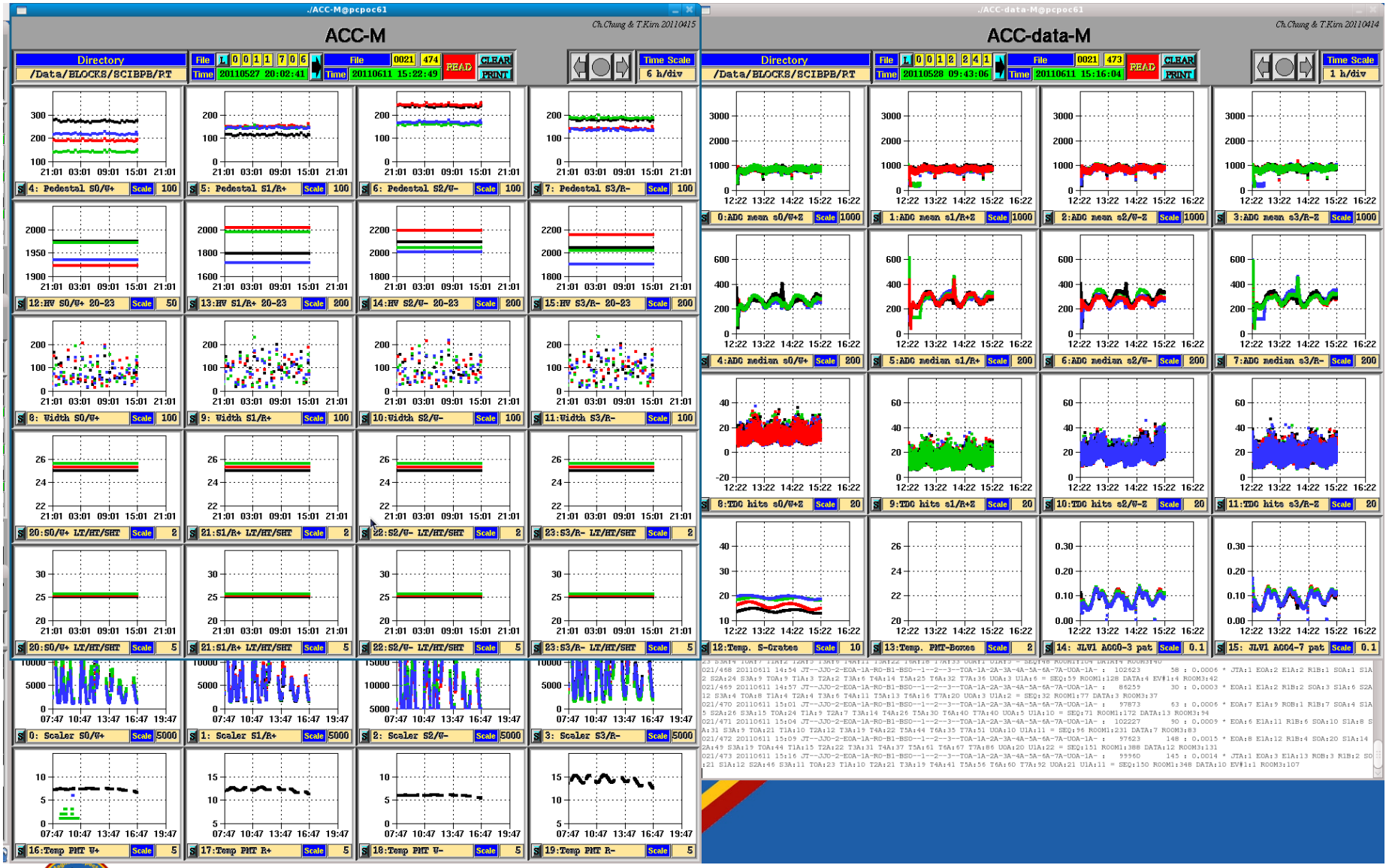
Screen 1 Right



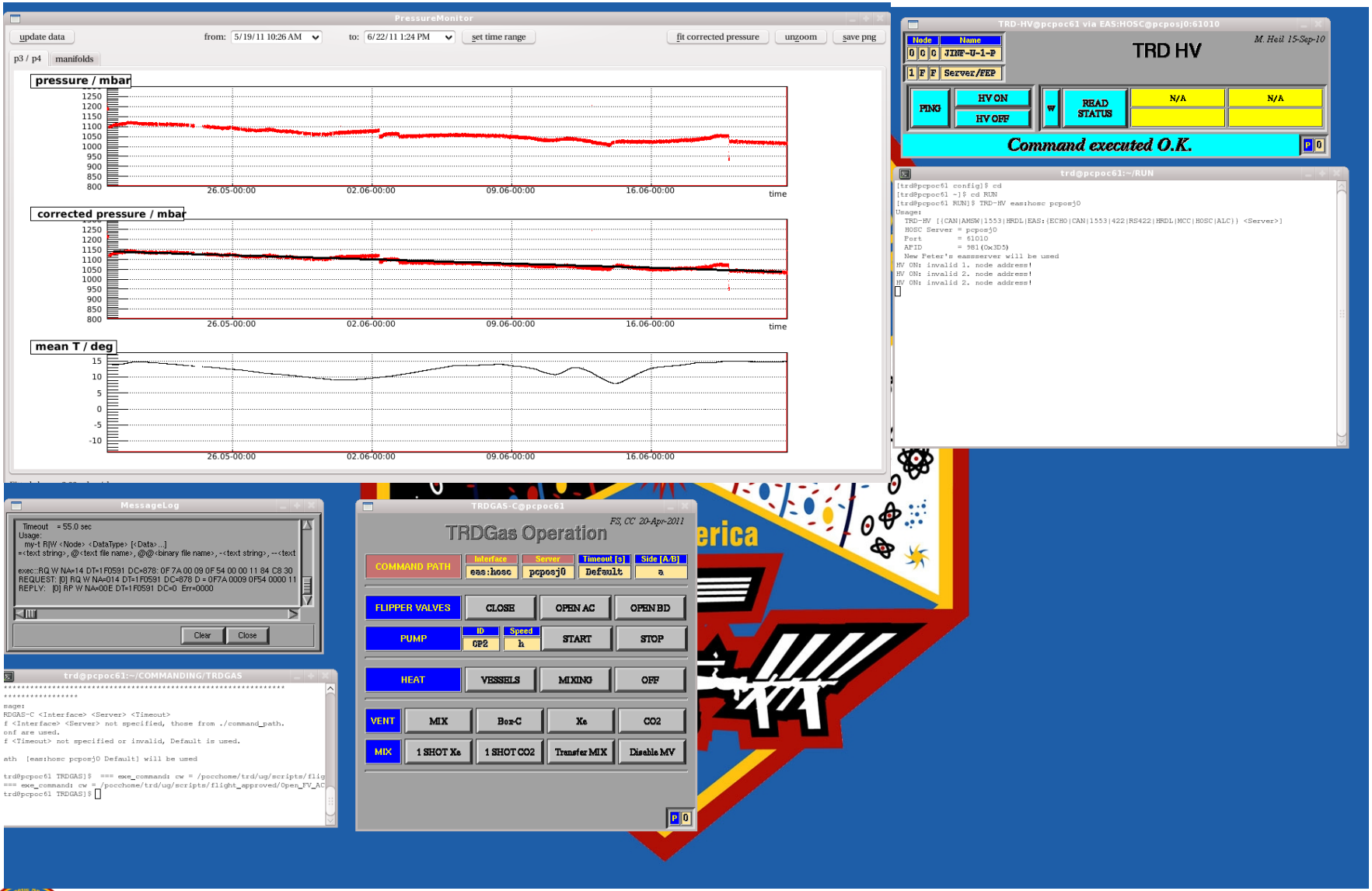
Screen 2 Right



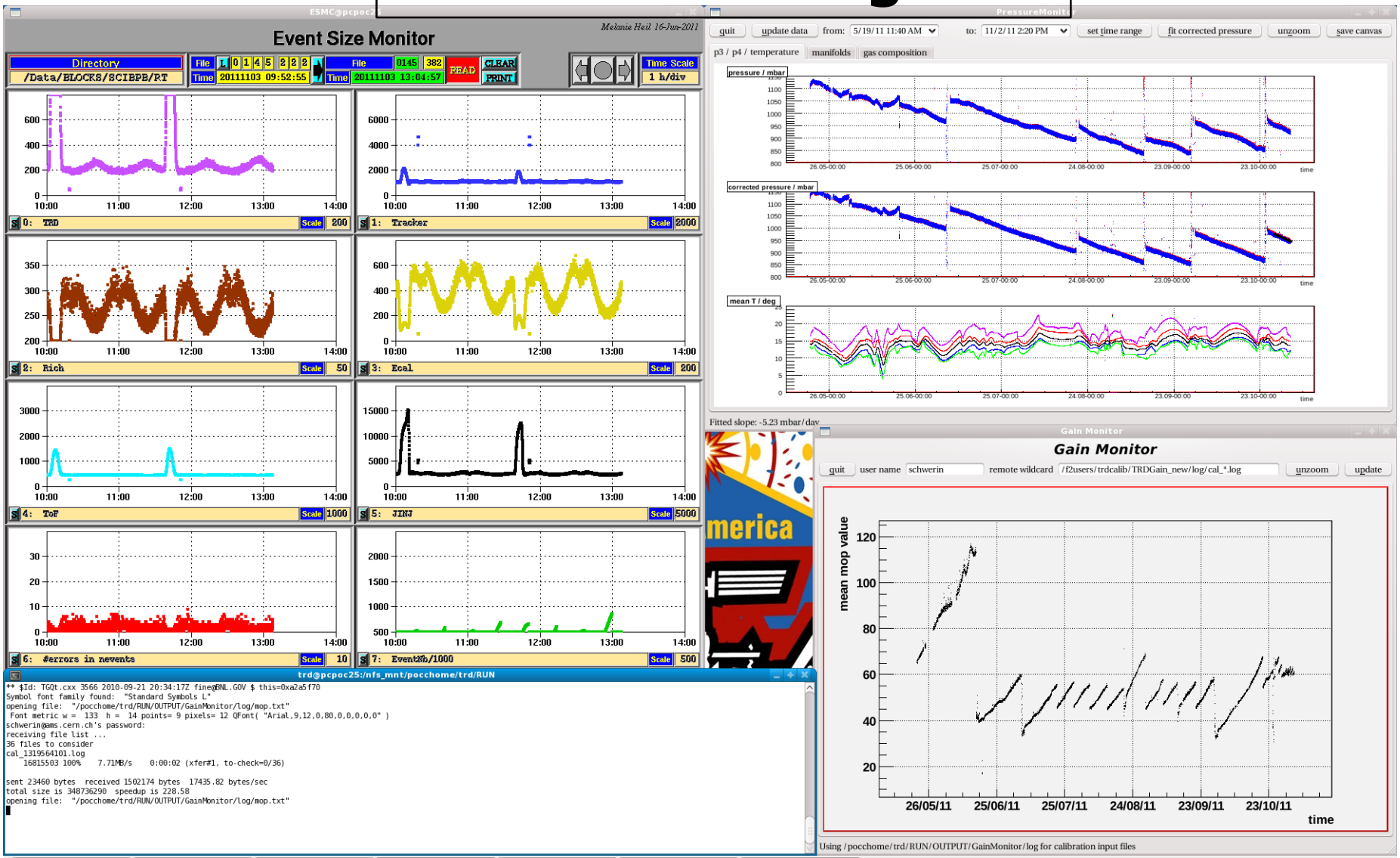
Screen 3 Right!



Screen 4 Right!



Screen 5 Right!



TRD Monitoring:

- TRD Status Monitor (TRD-S)
  - Pedes_Canvas
  - UDR_HK_Canvas
- Read_block_files
- TRD Data Monitor (TRD-M)
- TRD-DTS Monitor (TRDDTS-M)
- GainMonitor (GainMonitor)

Configuration of TRD-S

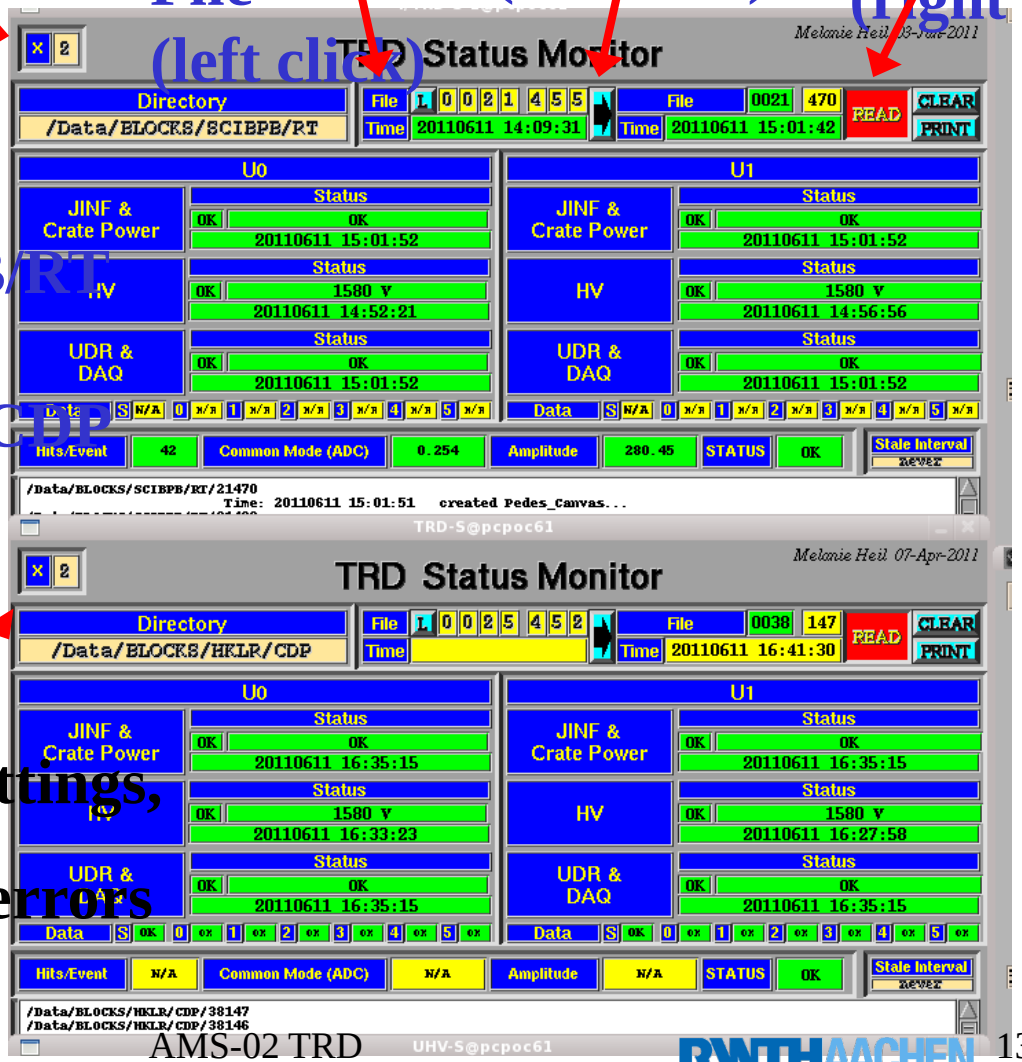
Set X to 2
left-click ↑ number
right-click ↓ number

Find Last File (left click)

Load for reading (left click)

Read continou (right click)

Set Directory to Data/BLOCKS/SCIBPB/RT and Data/BLOCKS/HKLR/CDP



Check:

- **Every box green,**
- **HV value match the settings,**
- **browser for warnings/errors**

TRD-S

JMDC QList

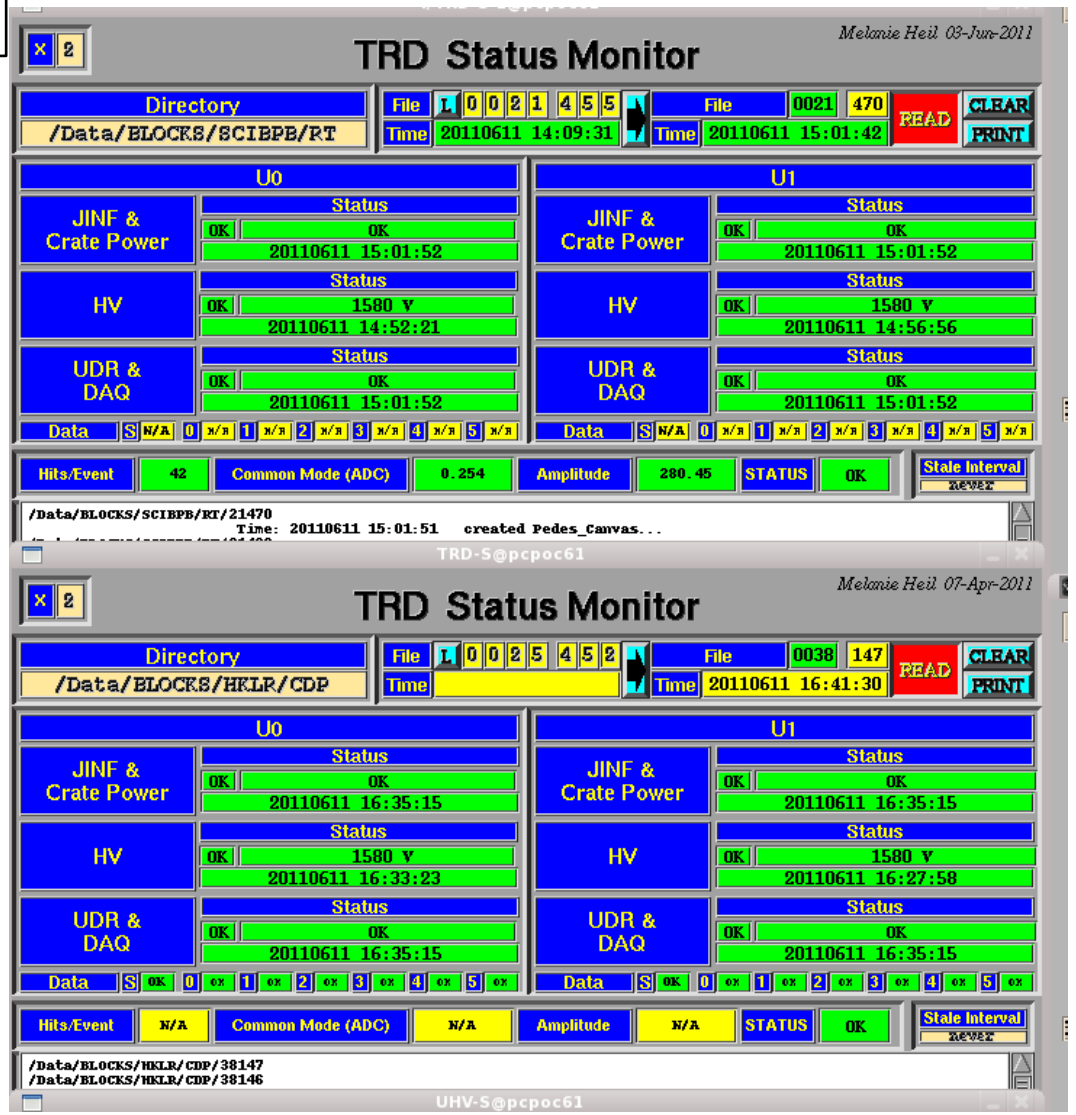
↓

BLOCK Files

↑

Commands from ground

DAQ and SC Status →



All information from TRD Readout is analyzed and summarized in overall status for shift taker

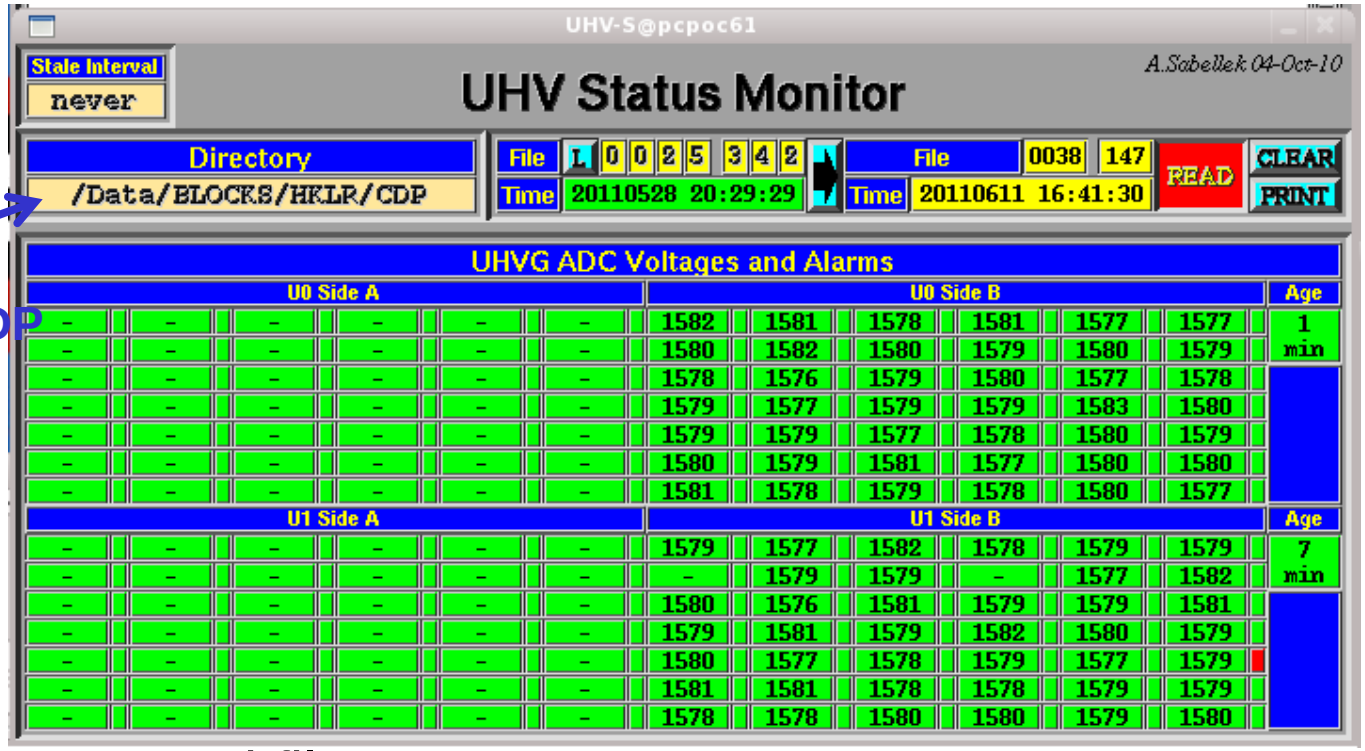
Screen-3: Additional Tools for TRD Experts

UHV Status Monitor:

Go to RUN directory and open programm:

```
cd ~/RUN
UHV-S &
```

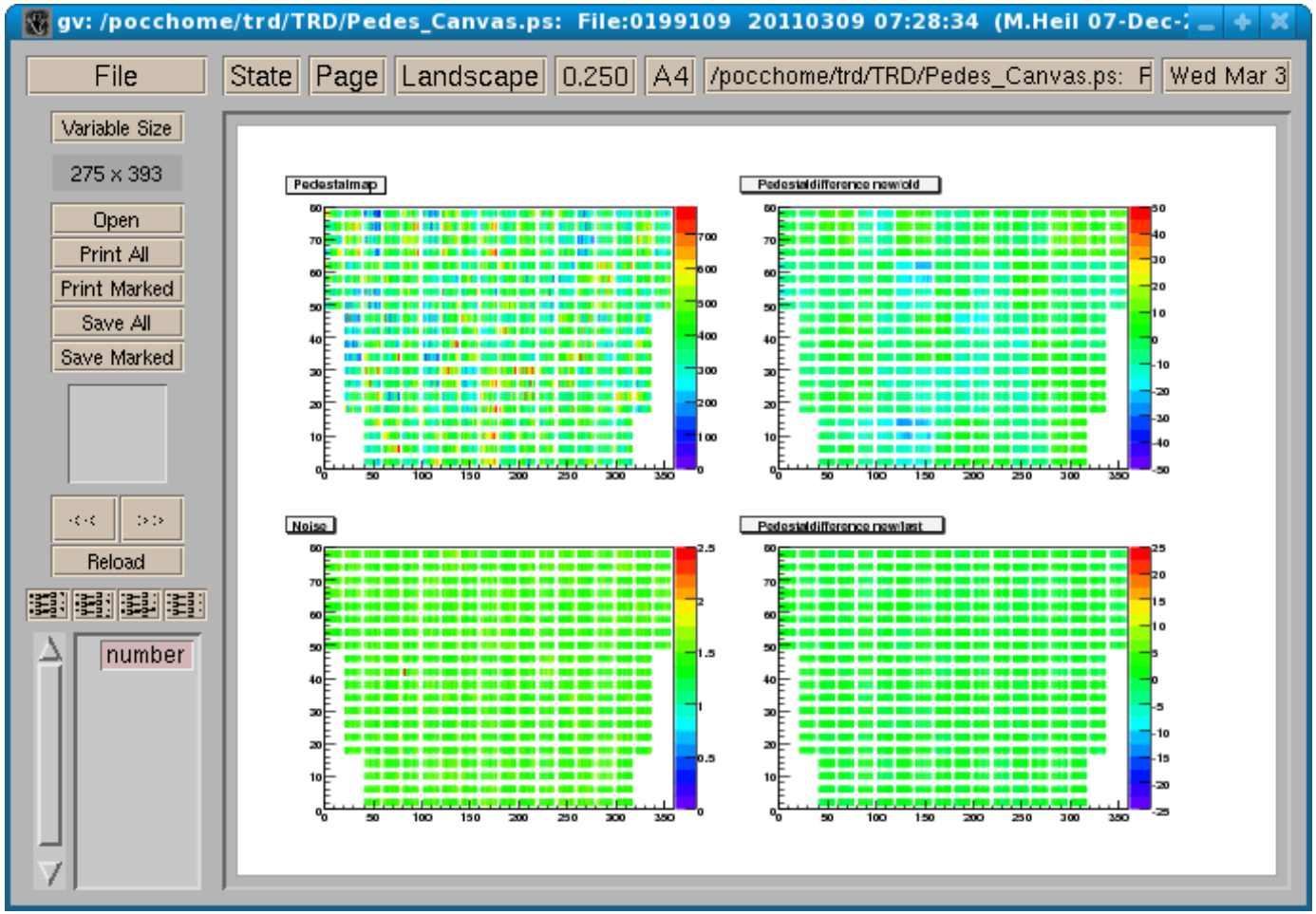
Set Directory to Data/BLOCKS/HKLR/CDP



Set to current directory and file

Use to check single channel HV values for A/B-Side

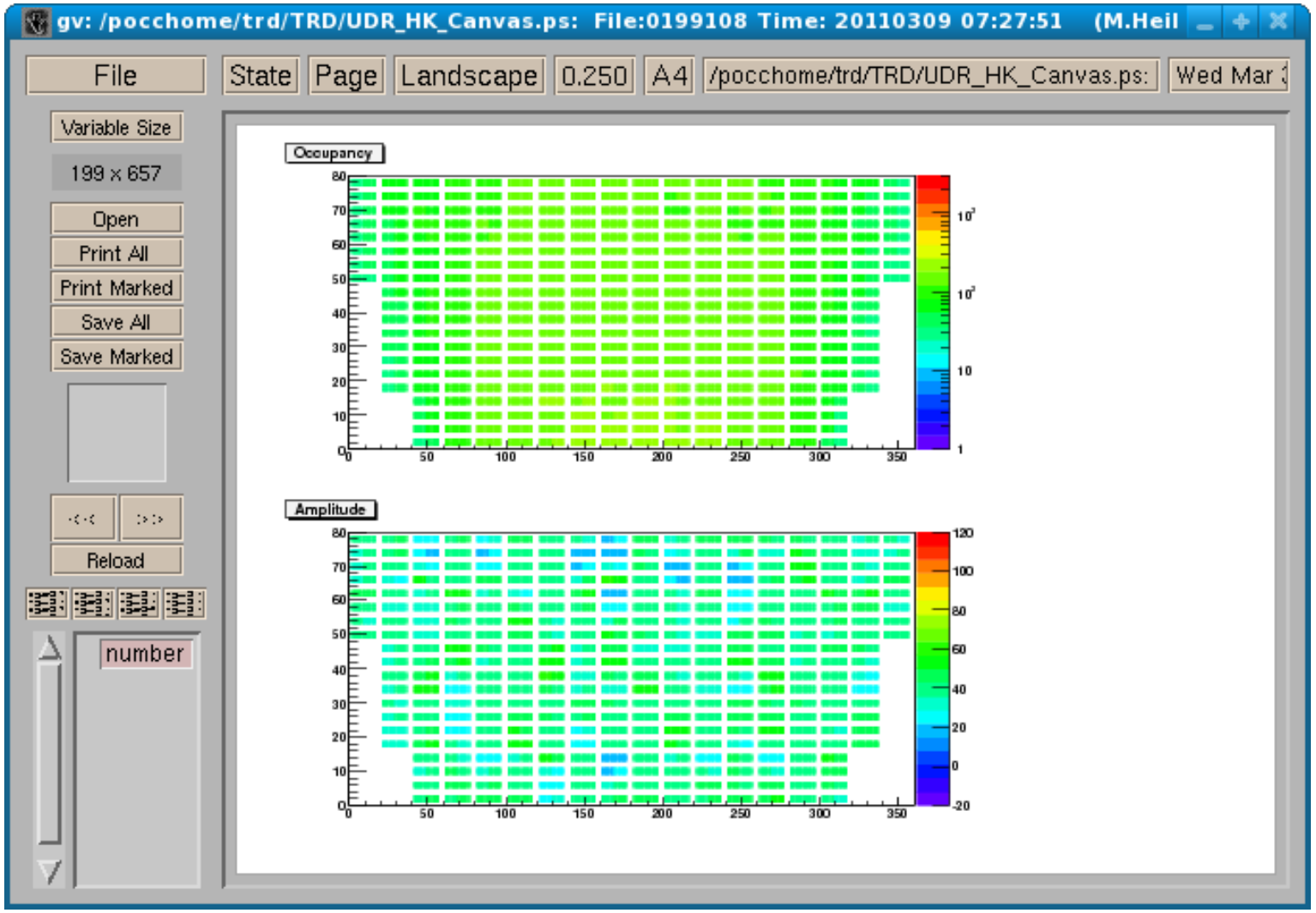
Pedes_Canvas.ps



Calibration of each of the 5248 Straw-Tubes
Upper left: Actual Pedestal values in ADC channels
Upper Right: Difference between actual and default Pedestal values
Lower Left: Actual Noise values in ADC channels
Lower Right: Difference between actual and last Pedestal values

Noise should show usual pattern
(all but 2 channels green for A-Side Power,
also slightly higher noises on end/front of segment for B-Side Power)

UDR_HK_Canvas.ps

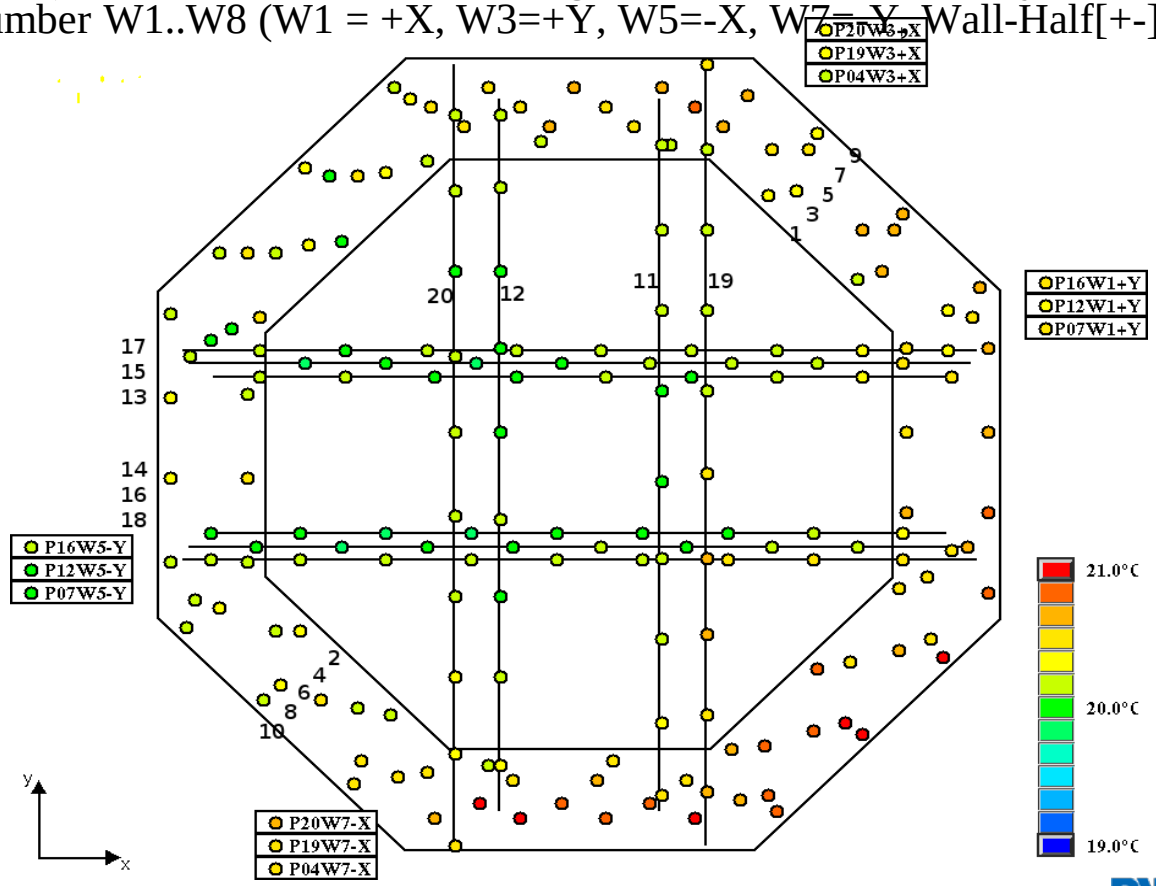


Upper: Actual Occupancy (number of hits in each of the 5248 straws)
Lower: Actual Amplitude (Median, Pedestal corrected) values in ADC channels for each of the 5248 straws

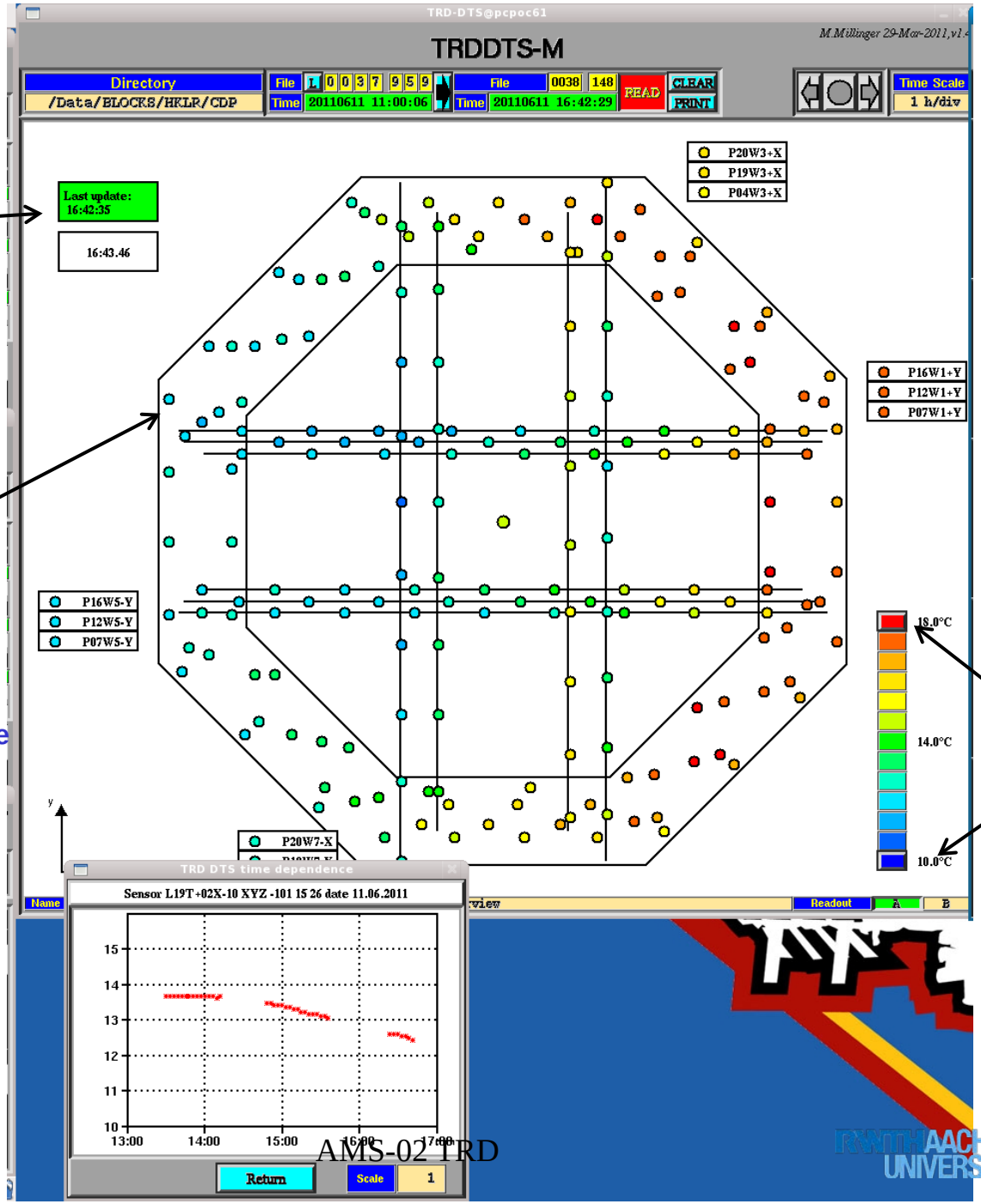
- **Occupancy plot should not show any unusual high or low channels**
- **Amplitudes should be fairly homogenous**

TRD-DTS Monitor – TRDDTS-M

- A total of 404 Dallas Sensors on 40 strips are read out by USCM-UG-A/B (202 sensors – 20 strips – 7 busses respectively)
- The Label contains Layer-Number L01..L20, Tower-Number T-9..T+9 and position along chamber in decimeters [XY]-10..[XY]+10
- Some sensors on the strips are located outside of the octagon volume (near the connector patch-panel). For those sensors the naming scheme is as follows: Layer-Number P01..L20, Wall-Number W1..W8 (W1 = +X, W3=+Y, W5=-X, W7=-Y, Wall-Half[+-][XY]



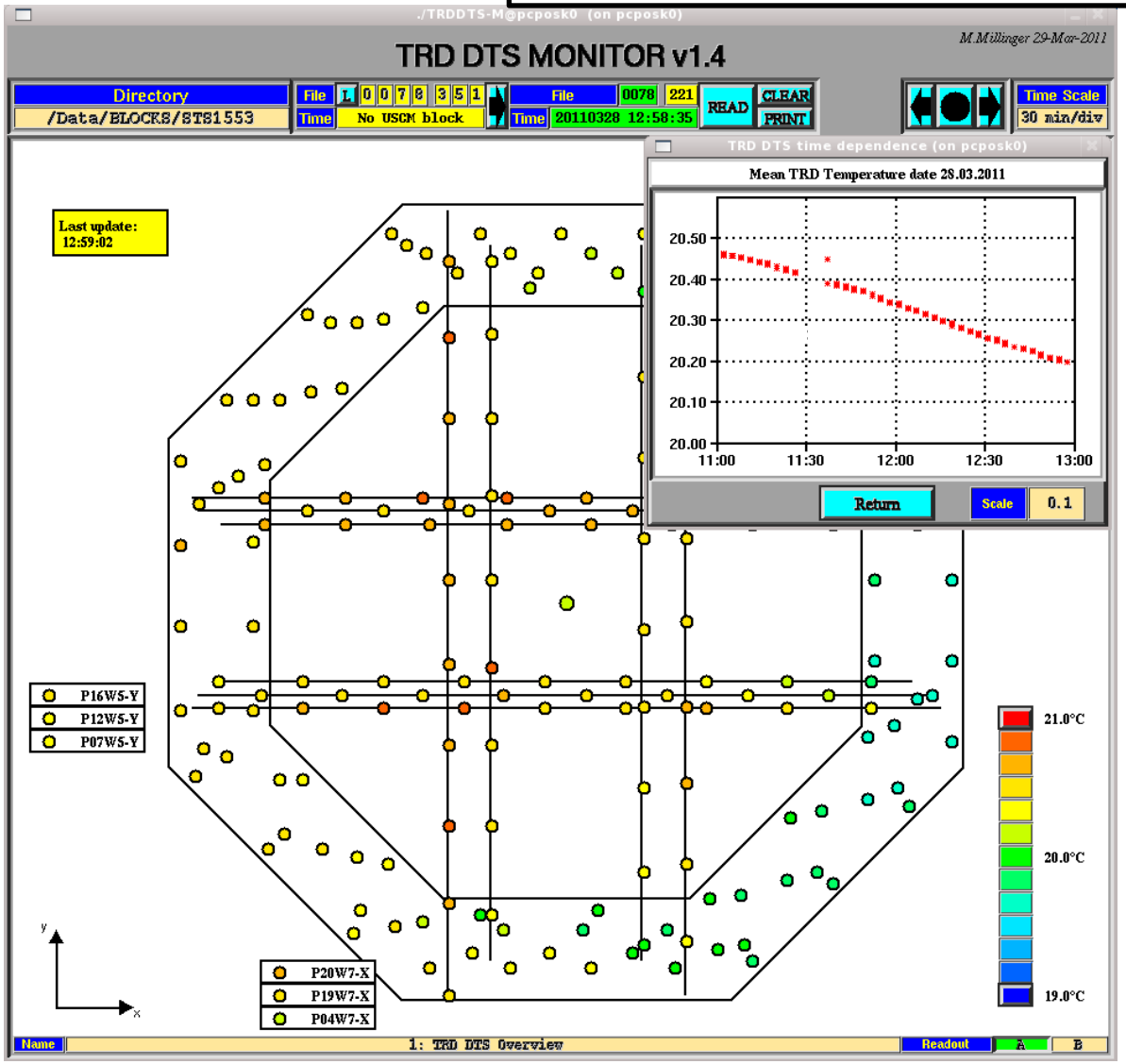
Time of last update



On any sensor:
Left click -> get sensor information
Right click-> get histogram of sensor temperature (close histogram again using the 'Return' button!)

Change color range

Usage: TRD-DTS Monitor– TRDDTS-M



- Each button represents the approx. location of 1A & 1B sensor
- A left-/right-click on a button shows detailed information/ Temp.history of the sensor
- ‘Last update’ supposed to stay green in ‘Read’-mode
- Color palette adjustable left-/right-click on maxor min button increases/decreases respective limit by 1
- On bottom right the active readout side is shown – in case both readouts are available one can select which one shall be displayed
- Different views available (click on ‘Name’ button on bottom)

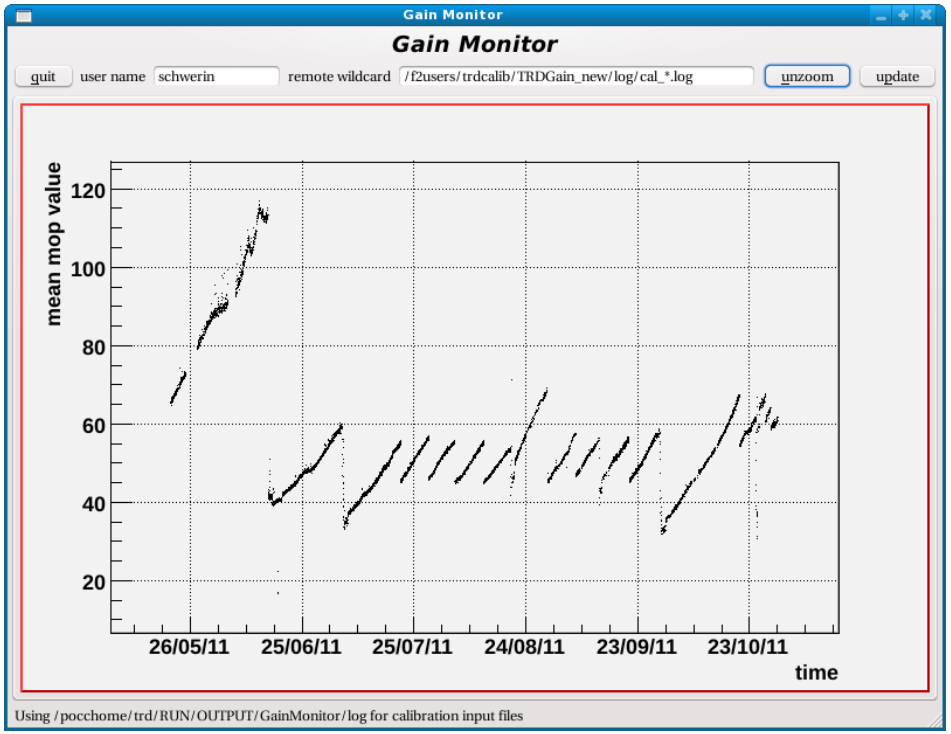
Gain Monitor:

The HV of the TRD has to be adjusted every day to minimize the gas gain variations.

The MOP should be at about 60 ADC counts.

For checking the evolution of the TRD signal gain, open a terminal, go to RUN directory and open program:

```
cd ~/RUN
TRD-GainMonitor &
```



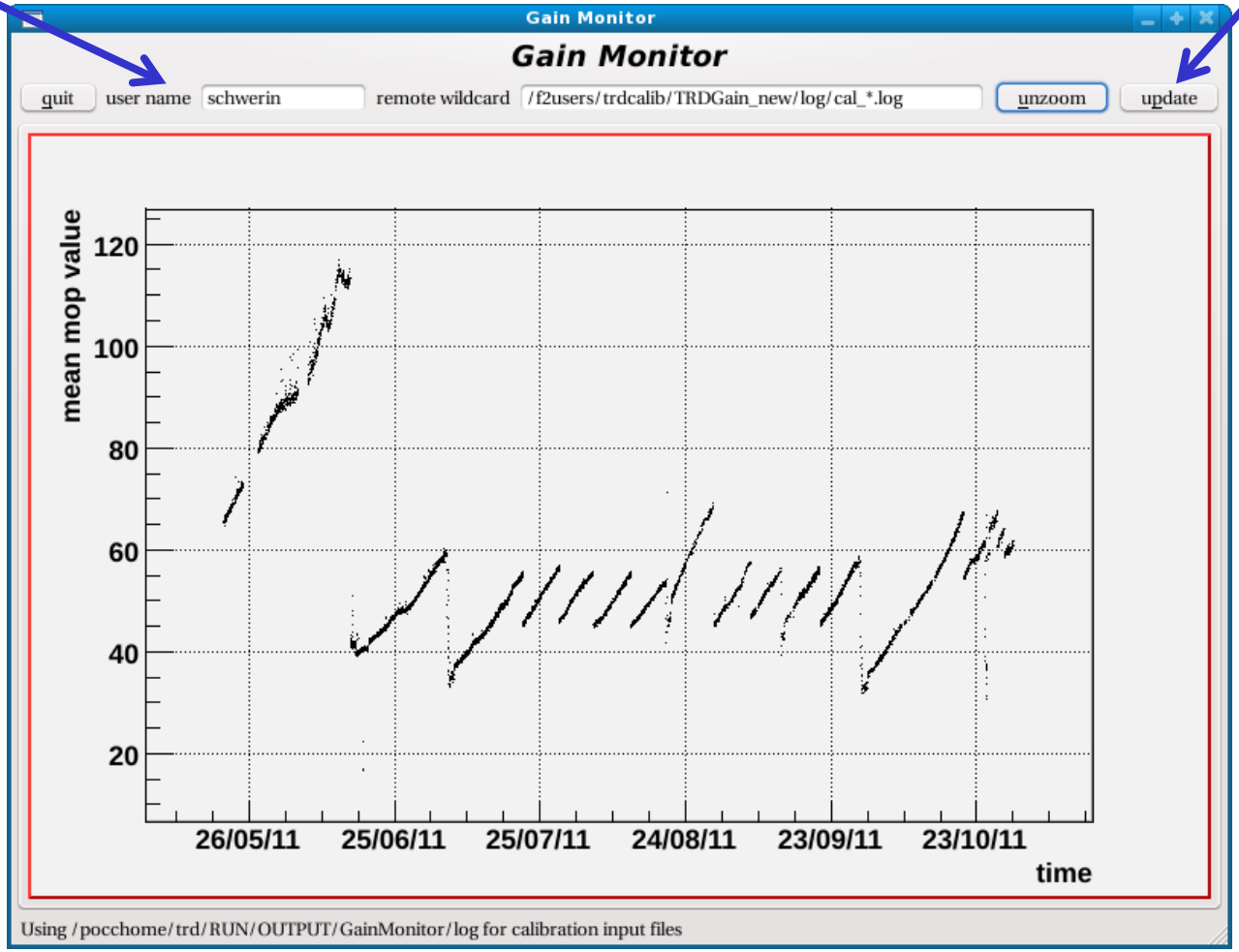
Take care that you do not hit any key afterwards (causes hang-up)

Be patient, especially when you ask for updating.

GainMonitor

Type in your CERN AFS user name

Click on update



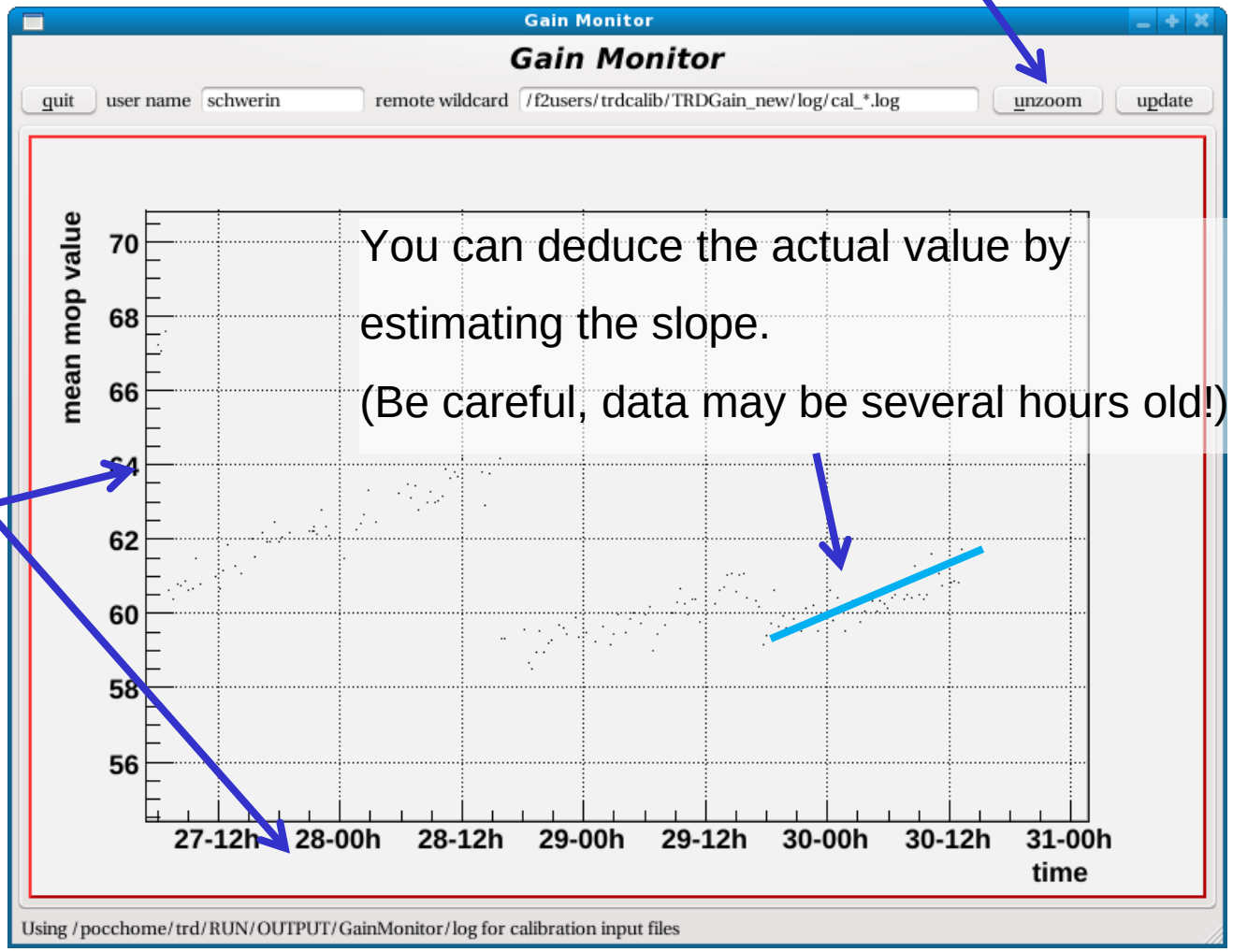
You are then prompted in the terminal window:

`Your_user_name@ams.cern.ch password:`

GainMonitor

Click on unzoom for returning to complete data set

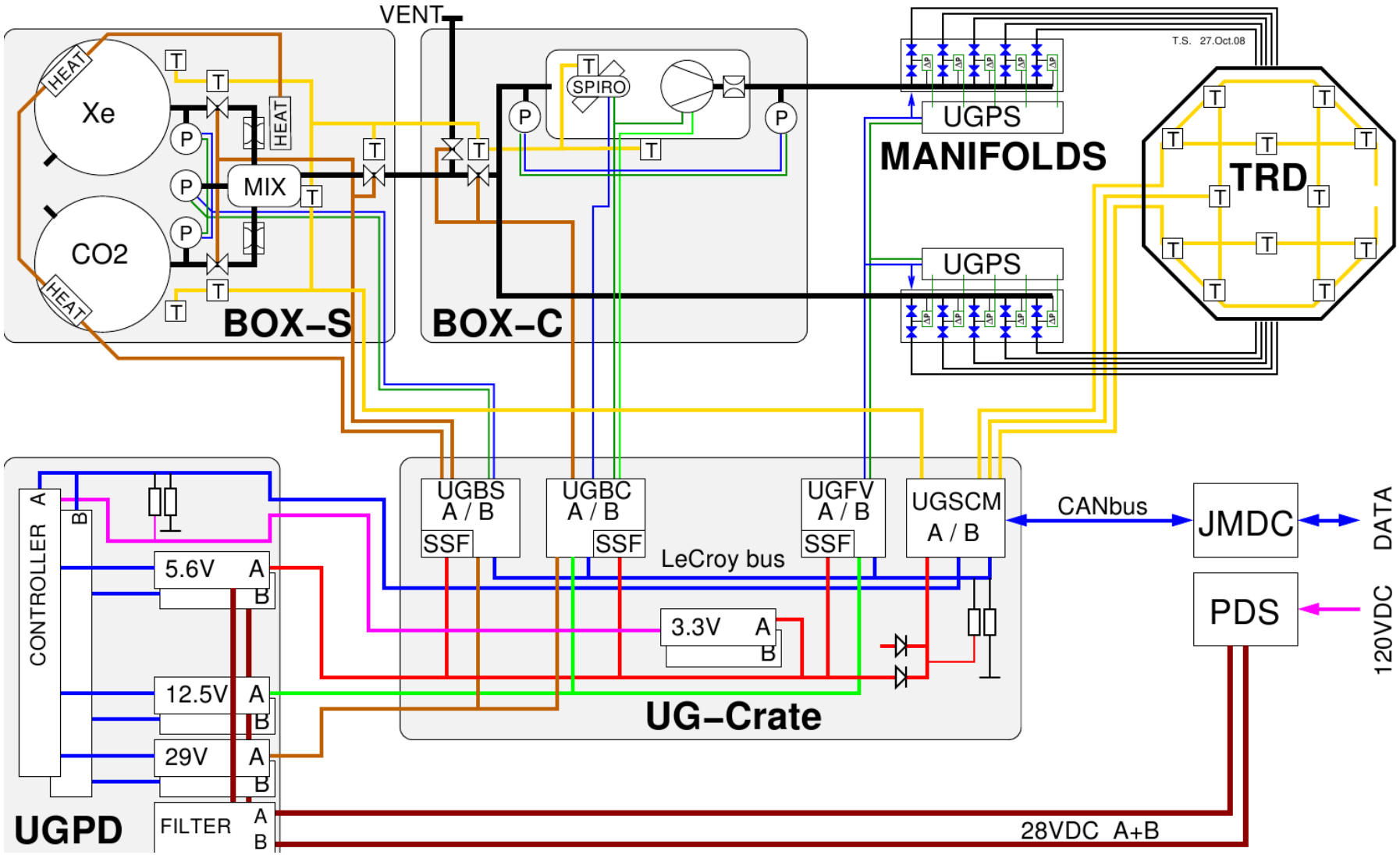
You can enlarge the scale by selecting an interval on each axis



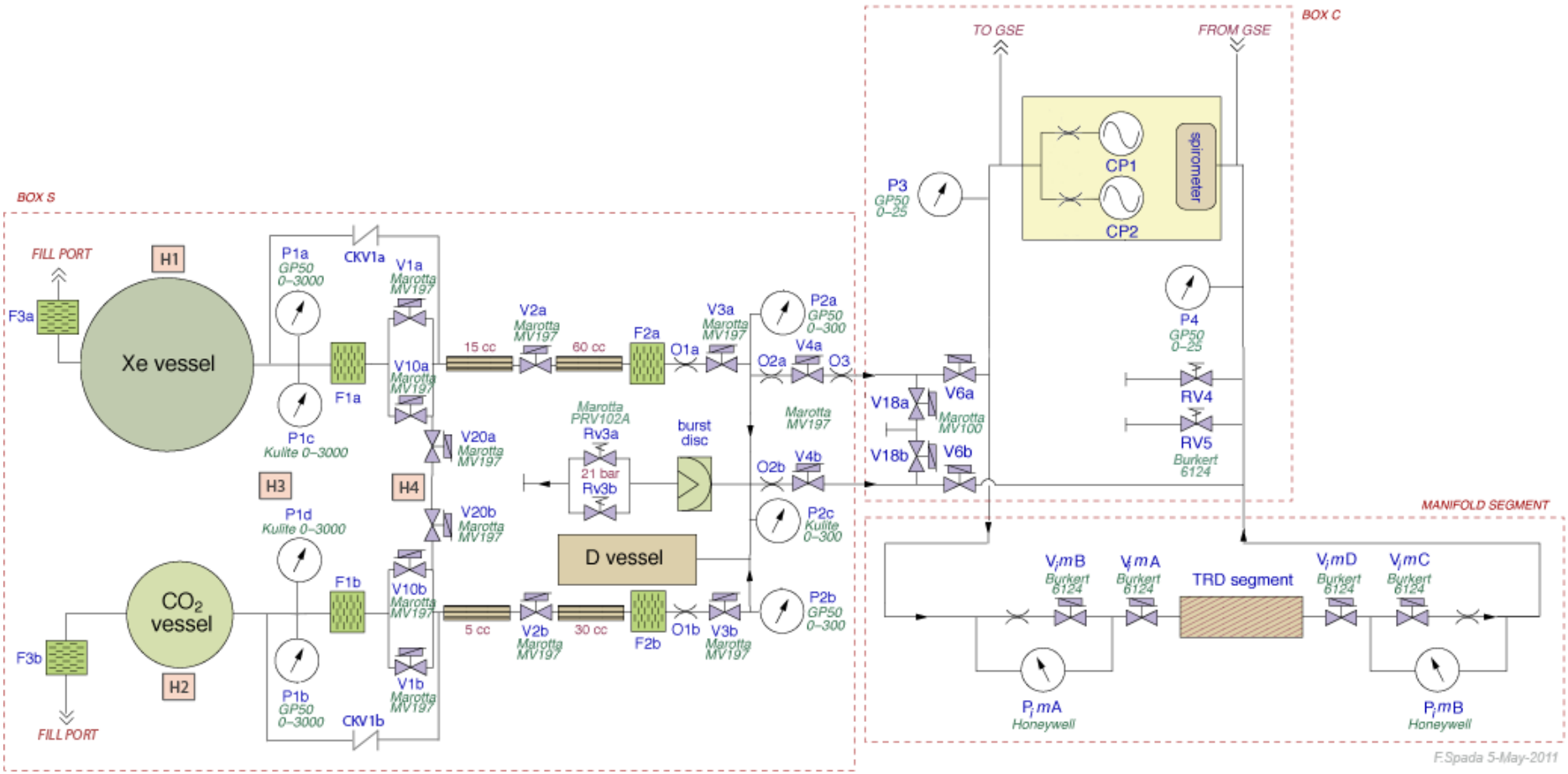
TRDGas Monitoring

- TRDGAS Status Monitor (TRDGAS-S)
- UG CHD (Critical Health Data)
- TRDGAS Monitor (TRDGAS-M)
- Pressure Monitor (Pressure Monitor)

TRD/TRDGas-System

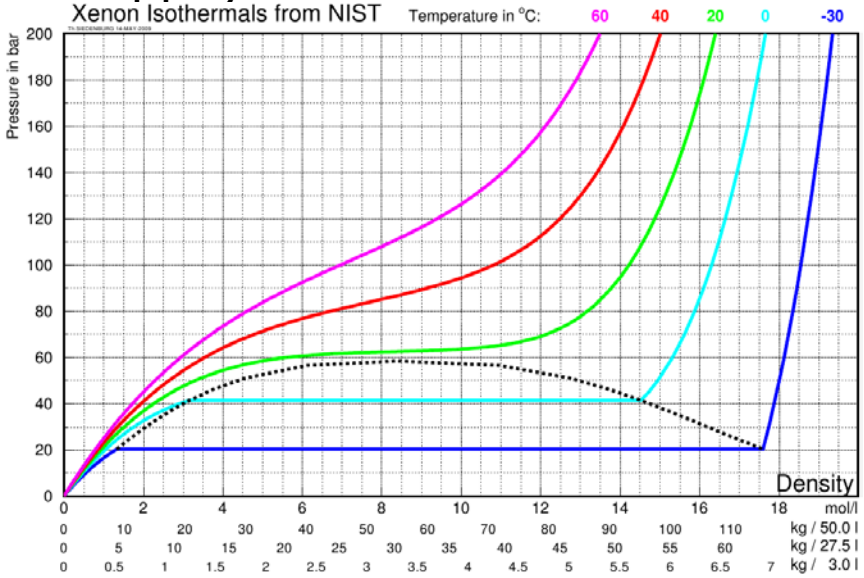


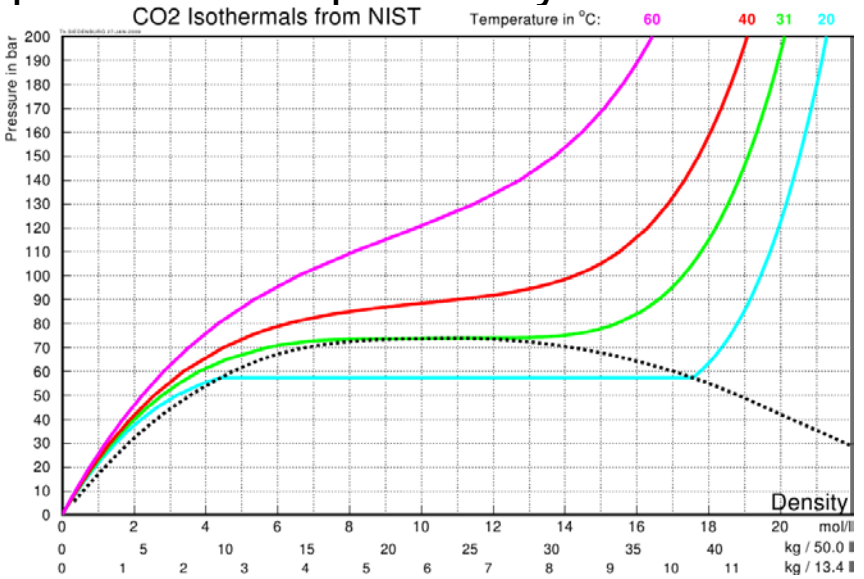
TRDGas-System



TRDGAS Supply Vessel Limits

Supply Vessels: Pressure-Temperature dependency





Vessel:	Xenon	CO2	MIX
100% Fill Level:	48kg	5kg	
Max.Op.Press.	175bar	100bar	**14bar**
Max.Des.Press.	**207bar**	**220bar**	20bar
Proof Press.	335Bar	330bar	40bar
Burst Press.	645Bar	440bar	80bar
Min.Des.Temp.	**-70°C**	-70°C	
Max.Des.Temp.	**+65°C**	**+65°C**	
Gas Freezing	-110°C	**-55°C**	

TRDGAS Sensor Value Limits

```
UG-Supply-Current [92]  Monitoring:       0.6A
                        Pump HalfSpeed: +0.1A
                        Heat Vessels:
                        Heat for Mix:   +1.0A
                        Marotta Valve:  +1.2A

BoxC Canister       Relief Valve at Inlet: 1.7bar

TRD Pressure:       900-1300 mbar
  Pump HalfSpeed:   Psup +320mbar   Pret -320mbar

MfdP [96..99]:      0 +- 20 mbar

Temp [89/94]:     -20°C .. +55°C
  NO BOX-S/C Marotta-Valve Operations below 0 °C
  NO Pump Operation below +5°C [94-SP blk]

Temp UGSCM/UGPD [70]   -15°C .. +45°C
```

Configuration of TRDGAS-S

Set Directory to Data/BLOCKS/HKLR/CDP

Find Last File (left click)

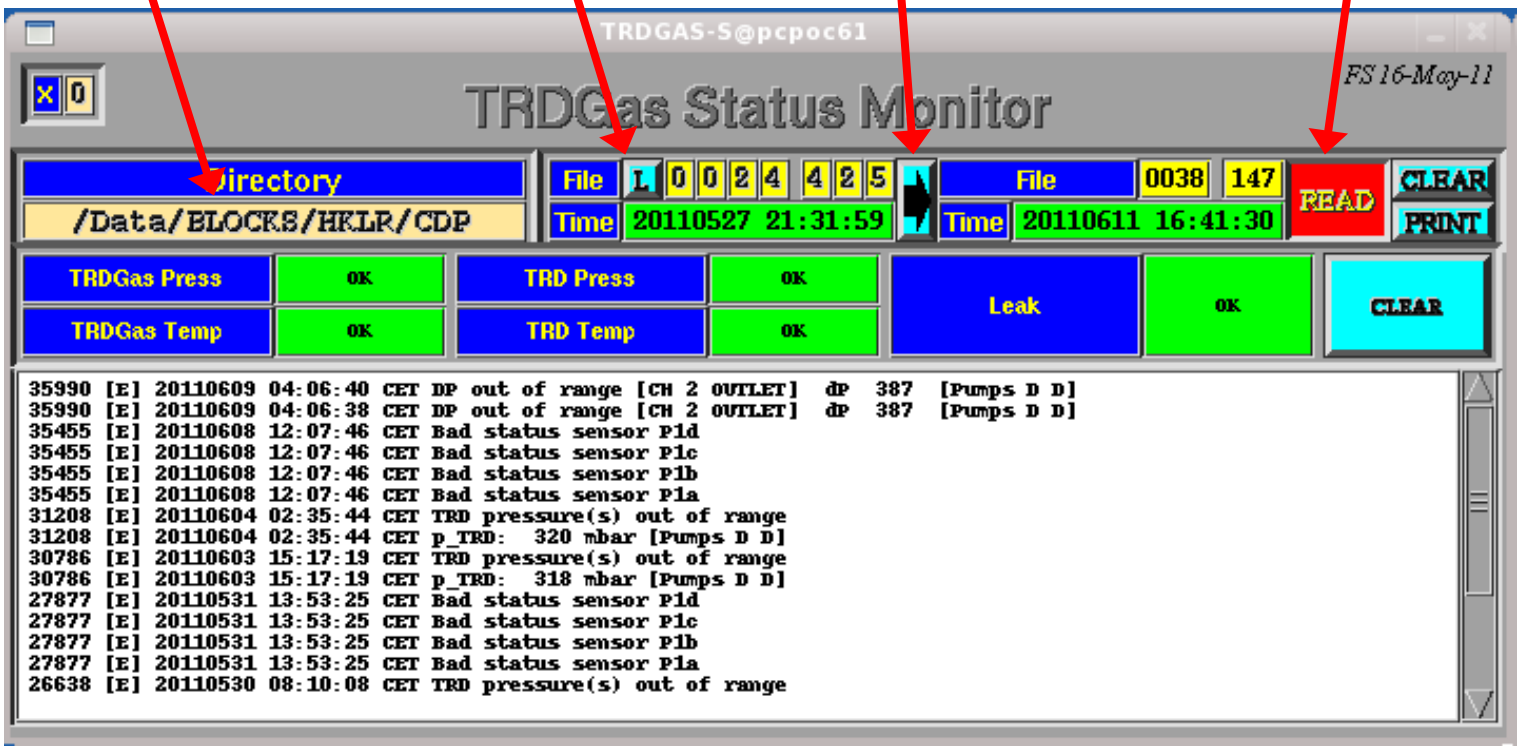
Load for reading (left click)

Read continously (right click)

Set X to 2

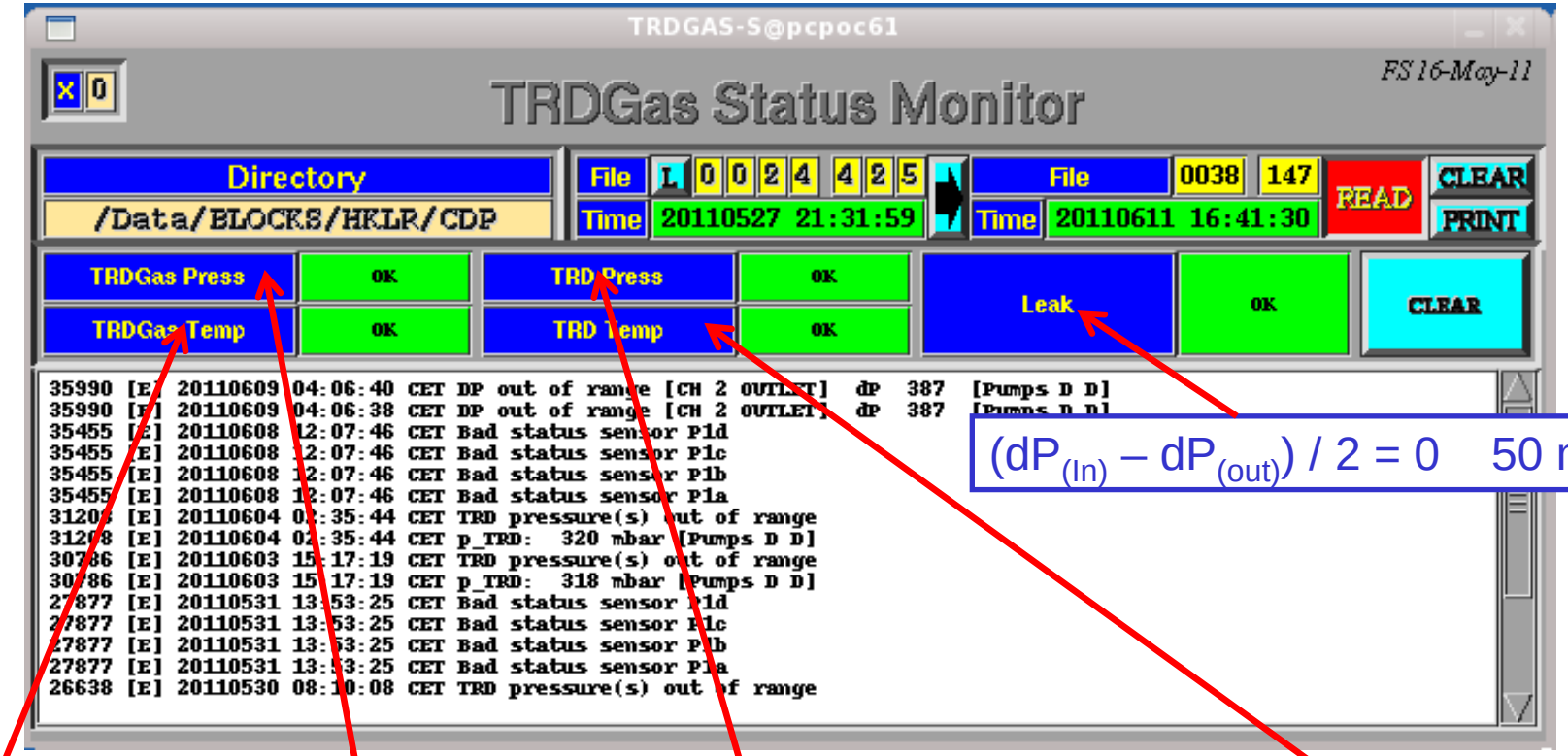
left-click ↑ number

right-click ↓ number



- **Every box should be green,**
- **Temperature and Pressure values should be in the operating ranges,**
- **check the browser for warnings or errors**

TRDGAS-S



$(dP_{(In)} - dP_{(out)}) / 2 = 0$ 50 mbar

Temperatures:
All TRDGas DTS-Sensors
Range:
-30 C to +50 C

Pressures TRDGas:
Xe/CO_2 / Mix. Vol.
Range:
Xe: <150 bar
CO_2 : < 80 bar
Mix.Vol.: < 4.6 bar

Pressures TRD:
BoxC
Range:
Pump off: 900 to 1500 mbar
Pump on half speed:
P3: 1220 to 1820 mbar
P4: 580 to 1180 mbar

SidePanel DTS-Sensors:
Ranges: +5 C to +40 C

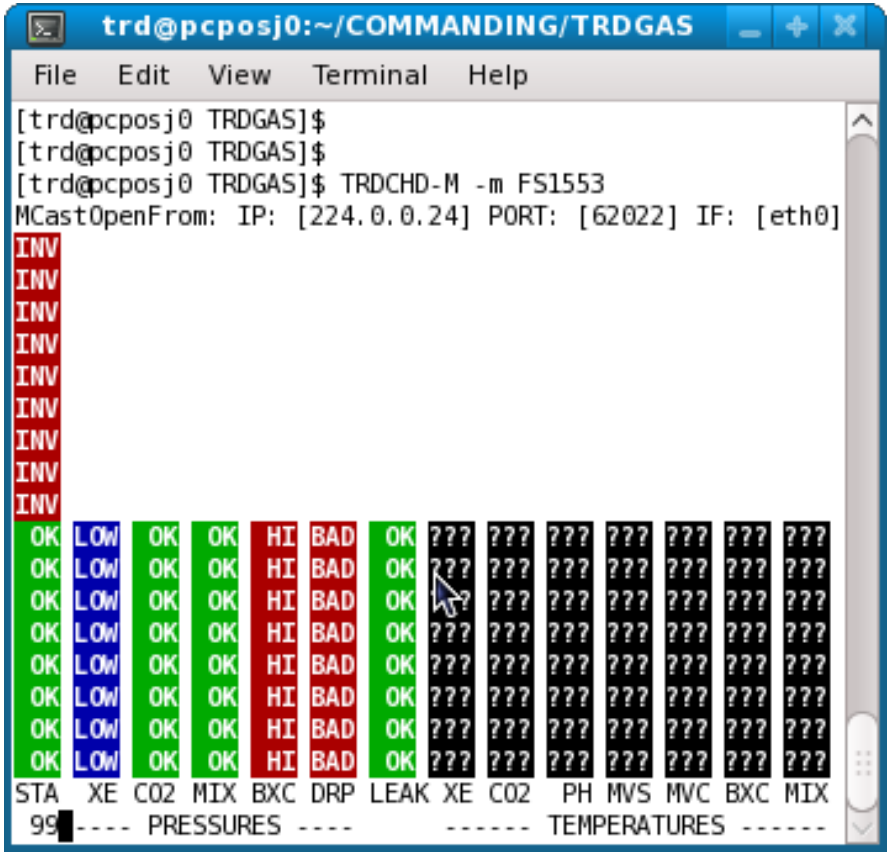
UG CHD (Critical Health Data)

Bit Definition:

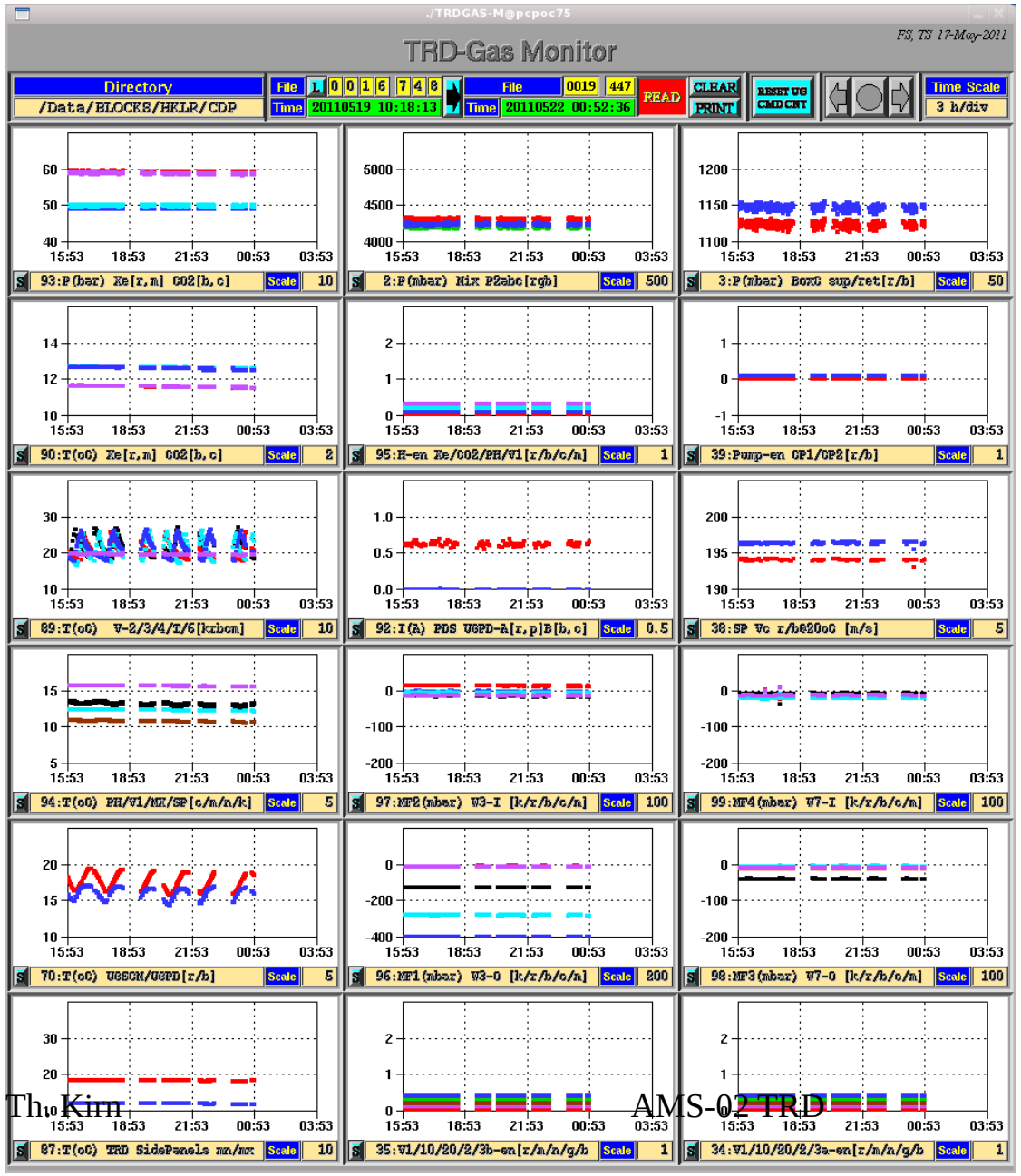
AMS-02 CHD Time-Mux Data ID=14
TRD Gas Status

Bit / Byte	7	6	5	4	3	2	1	0
6	P-TRD (1:low;2:high;3:inv)		P-Mix (1:low;2:high;3:inv)		P-CO2 (1:low;2:high;3:inv)		P-Xenon (1:low;2:high;3:inv)	
7	Pump off at over temperature	Valve disabled at over temperature	Heater off at over temperature	Gas closed by leak detection	Closed gas segment differeing from P3-P4		Gas circulation drop wrong	Data Invalid
8	T-V1/2/3 (1:low;2:high;3:inv)		T-PH (1:low;2:high;3:inv)		T-CO2 (1:low;2:high;3:inv)		T-Xenon (1:low;2:high;3:inv)	
9	T-UG/PD (1:low;2:high;3:inv)		T-BP/Mix (1:low;2:high;3:inv)		T-Can (1:low;2:high;3:inv)		T-V4/6/18 (1:low;2:high;3:inv)	

```
UG-CHD Bits from UG-CtrlTask

Monitor MultiCast Server:

$ TRDCHD-M -m MCC  (Shuttle)
           -m HOSC (ISS)


STA    INV – not updated
          -> UG-Task running ?

 XE  P   20.. 175bar
CO2  R   10.. 100bar
MIX  E    0..  13bar
BXC  S  800..1200mbar
DRP  S  Pin-Pout = 0 / 650mbar
        For CP    off  half

LEAK    detected by UG-CtrlTask

 XE  T  -30..+60degC
CO2  E  -50..+60degC
 PH  M  -15..+60degC
MVS  P  -15..+60degC
MVC  E  -15..+60degC
BXC  R   +5..+40degC
MIX  T  -15..+60degC
```



TRD-Gas Monitor Program: TRDGAS-M



Dir: selected interface
File: DDDD/NNN

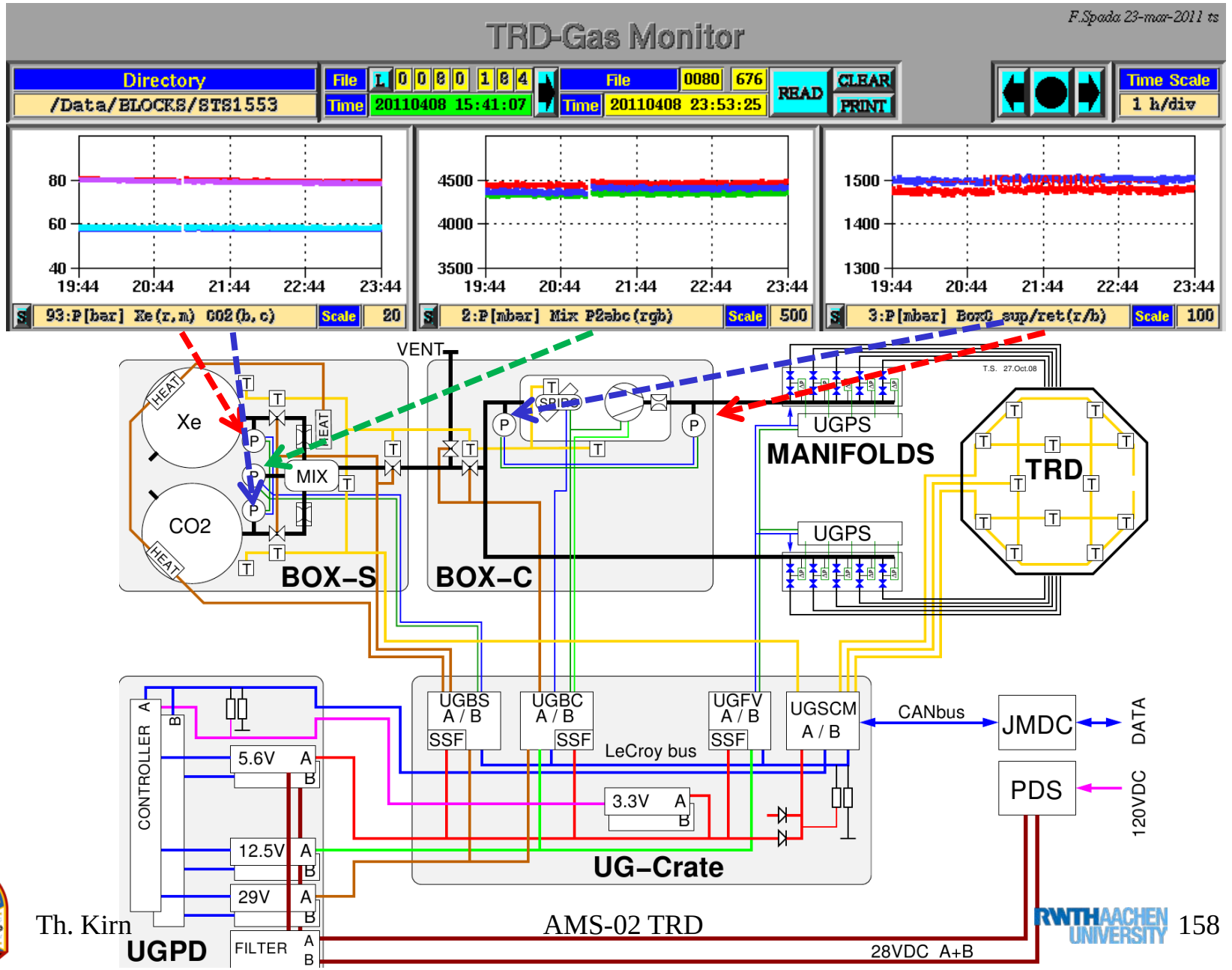
right-click READ

PDS-UGPD current from PDS

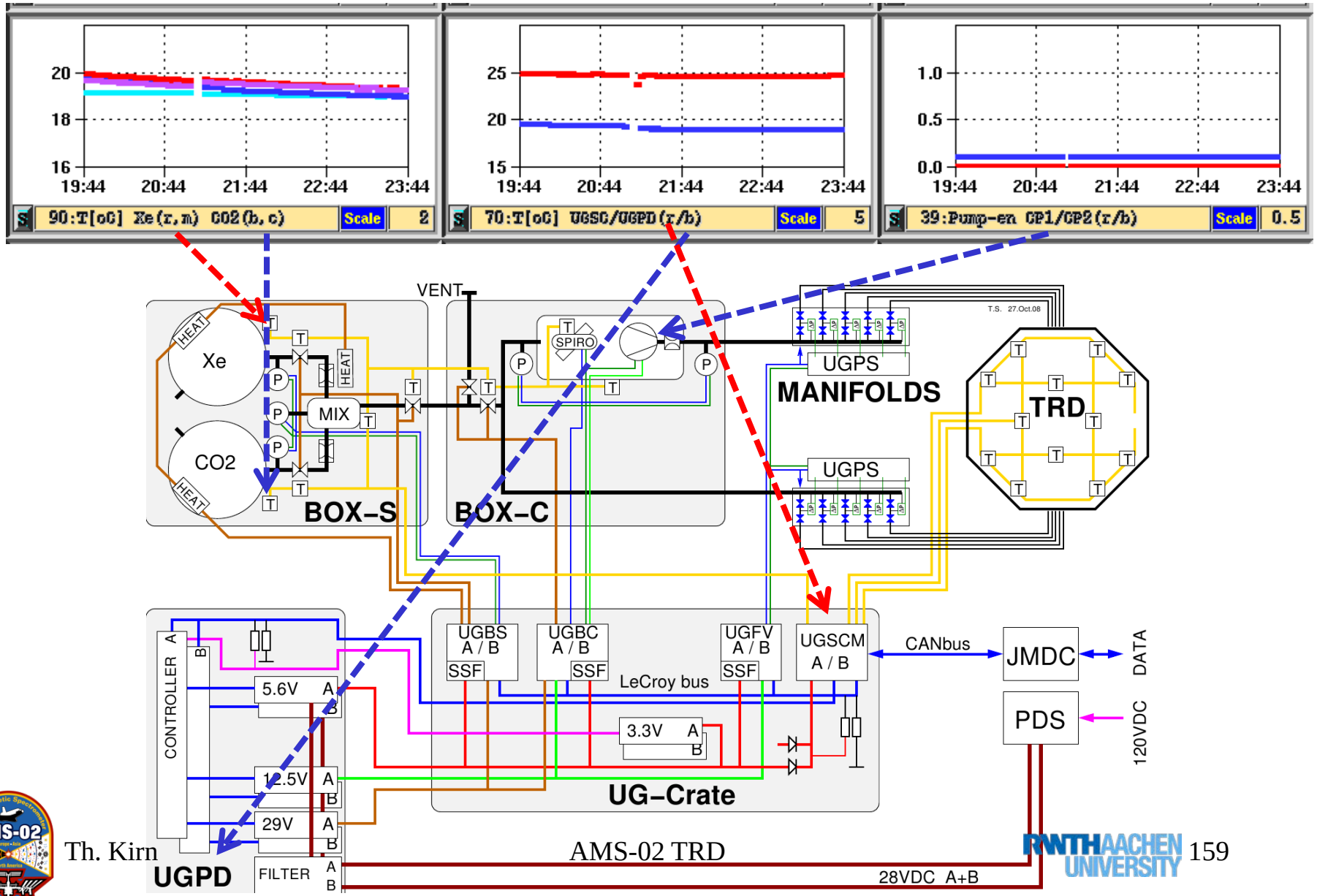
Other Data from UG
(1st DTSdata after 5min)

JMDC output in terminal

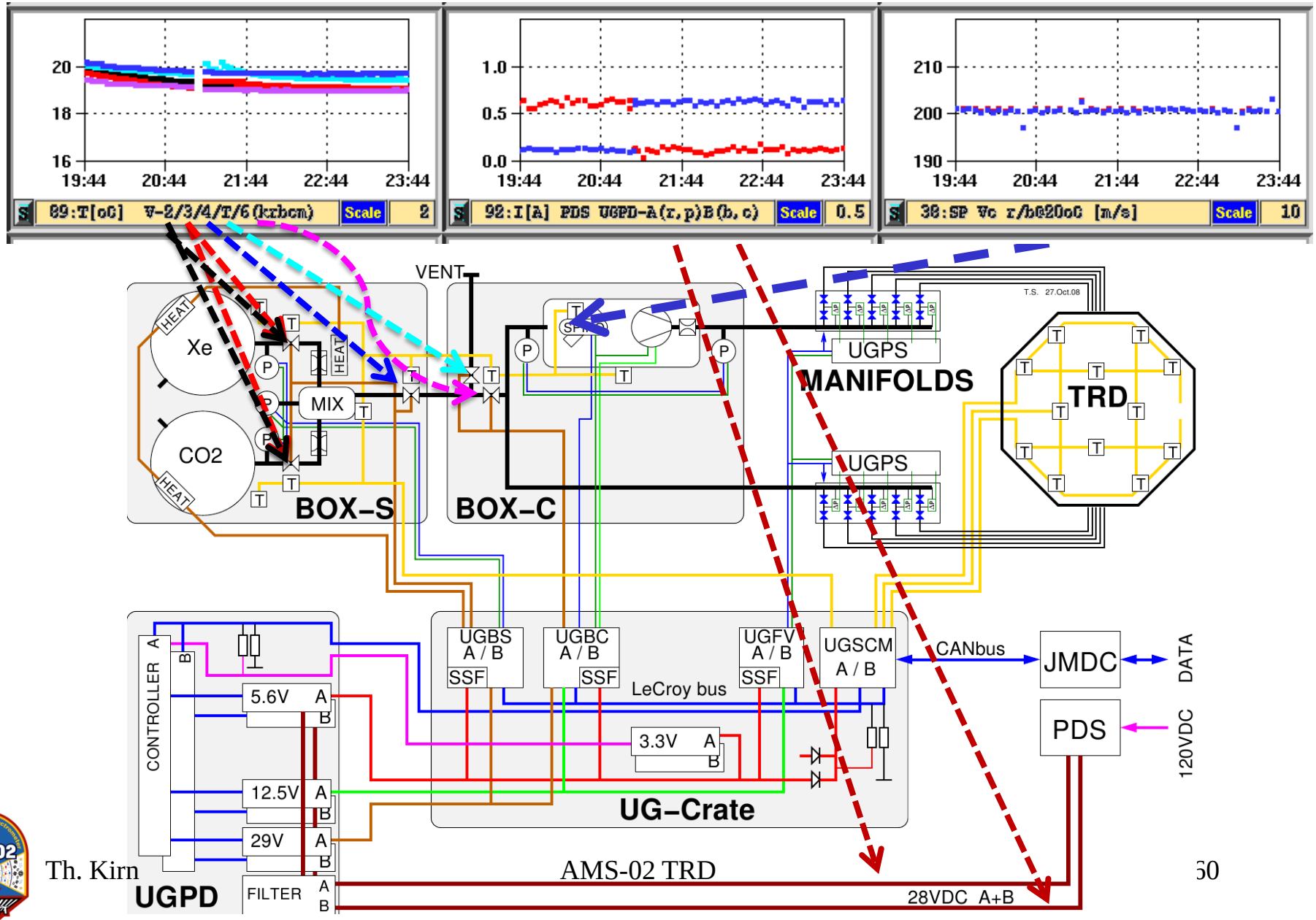
TRD-Gas Monitor Program: TRDGAS-M



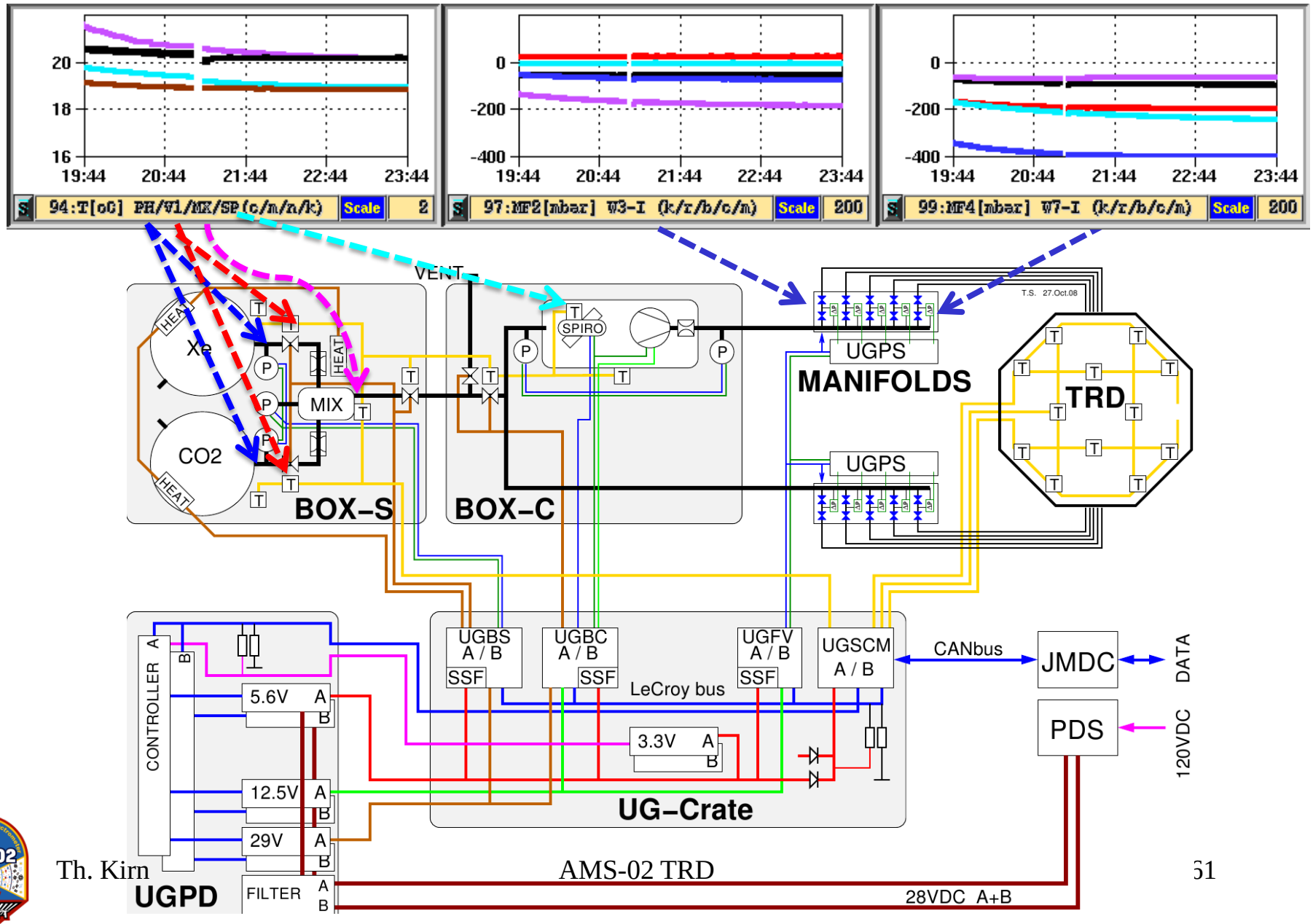
TRD-Gas Monitor Program: TRDGAS-M



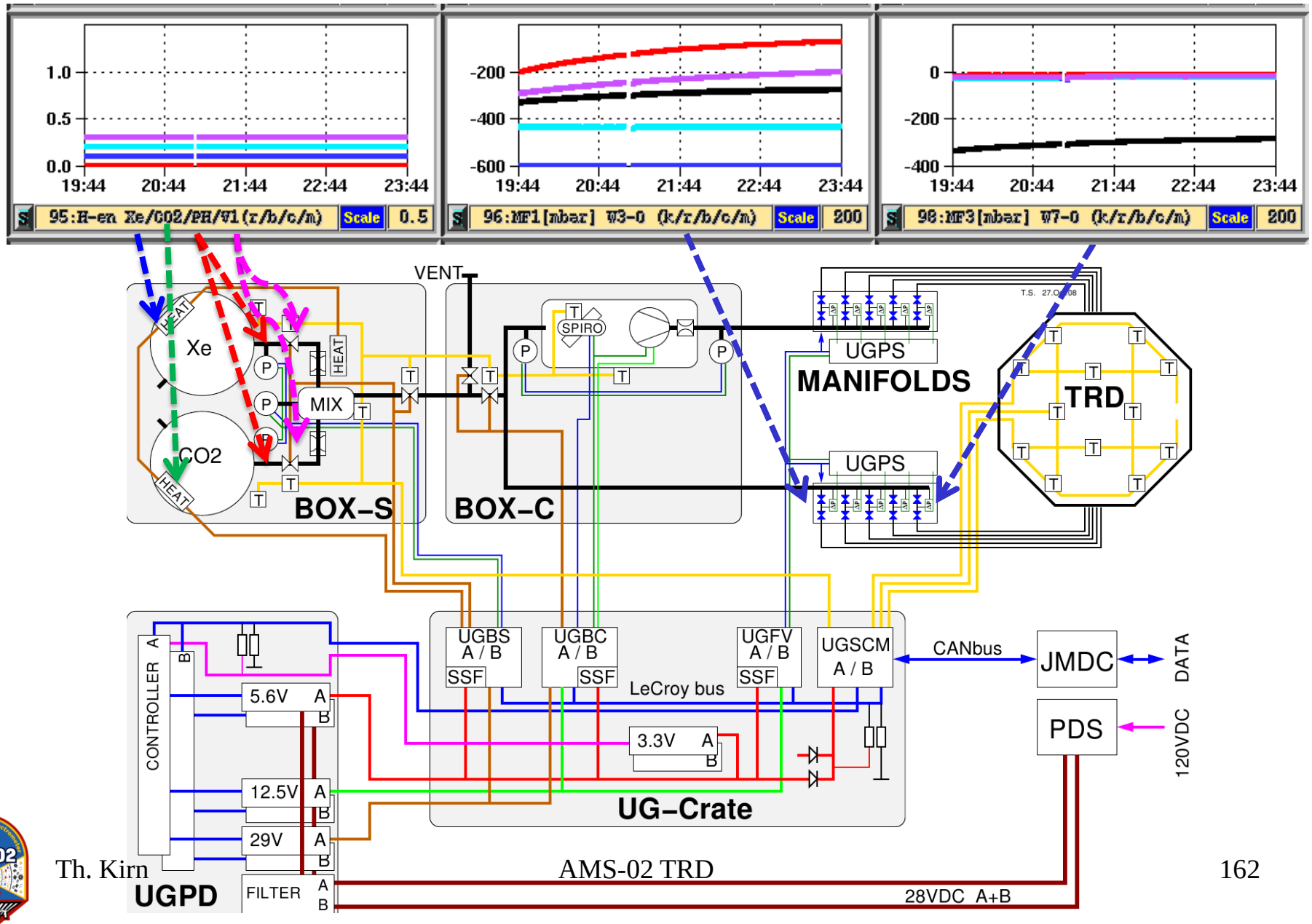
TRD-Gas Monitor Program: TRDGAS-M



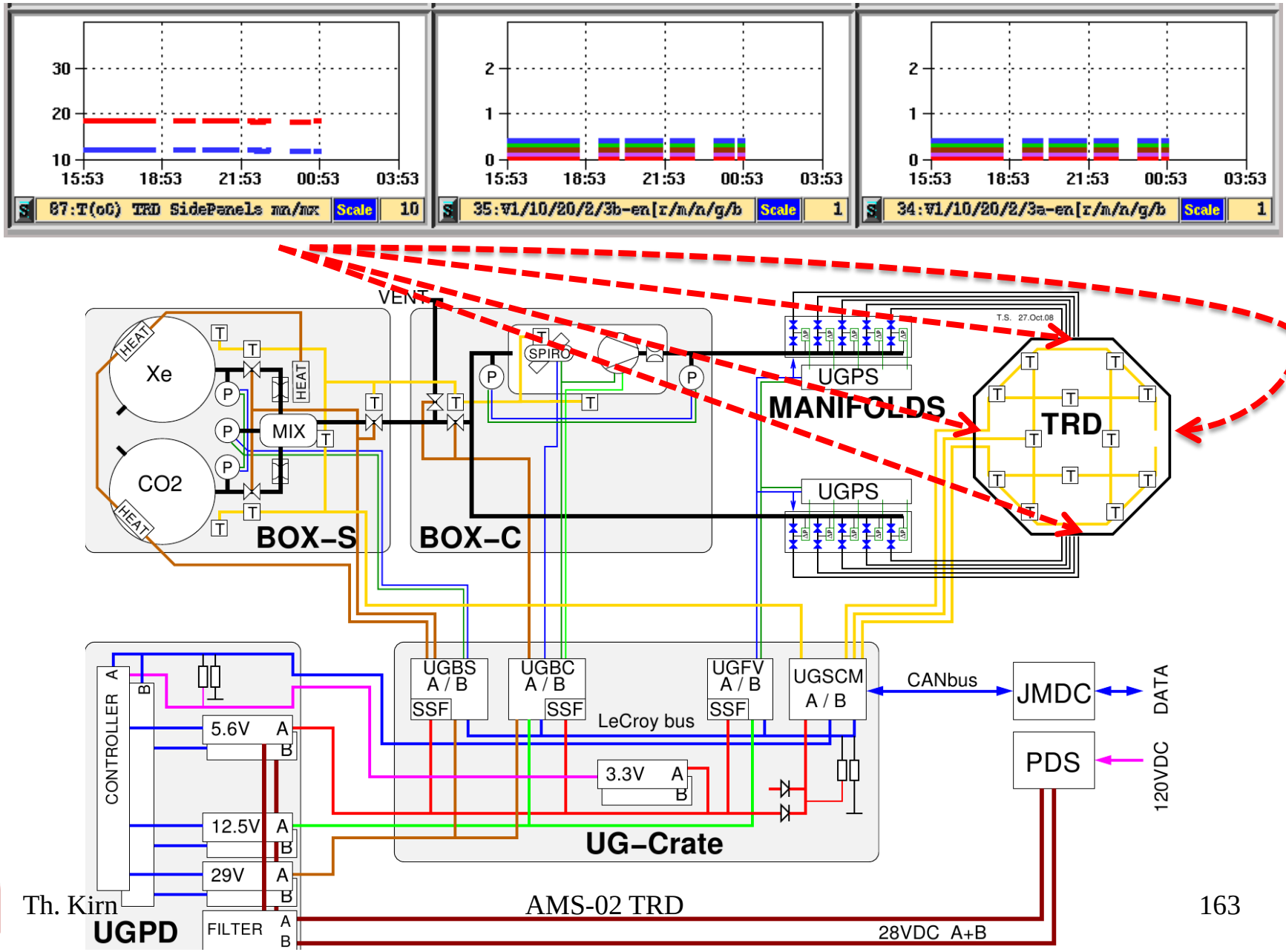
TRD-Gas Monitor Program: TRDGAS-M



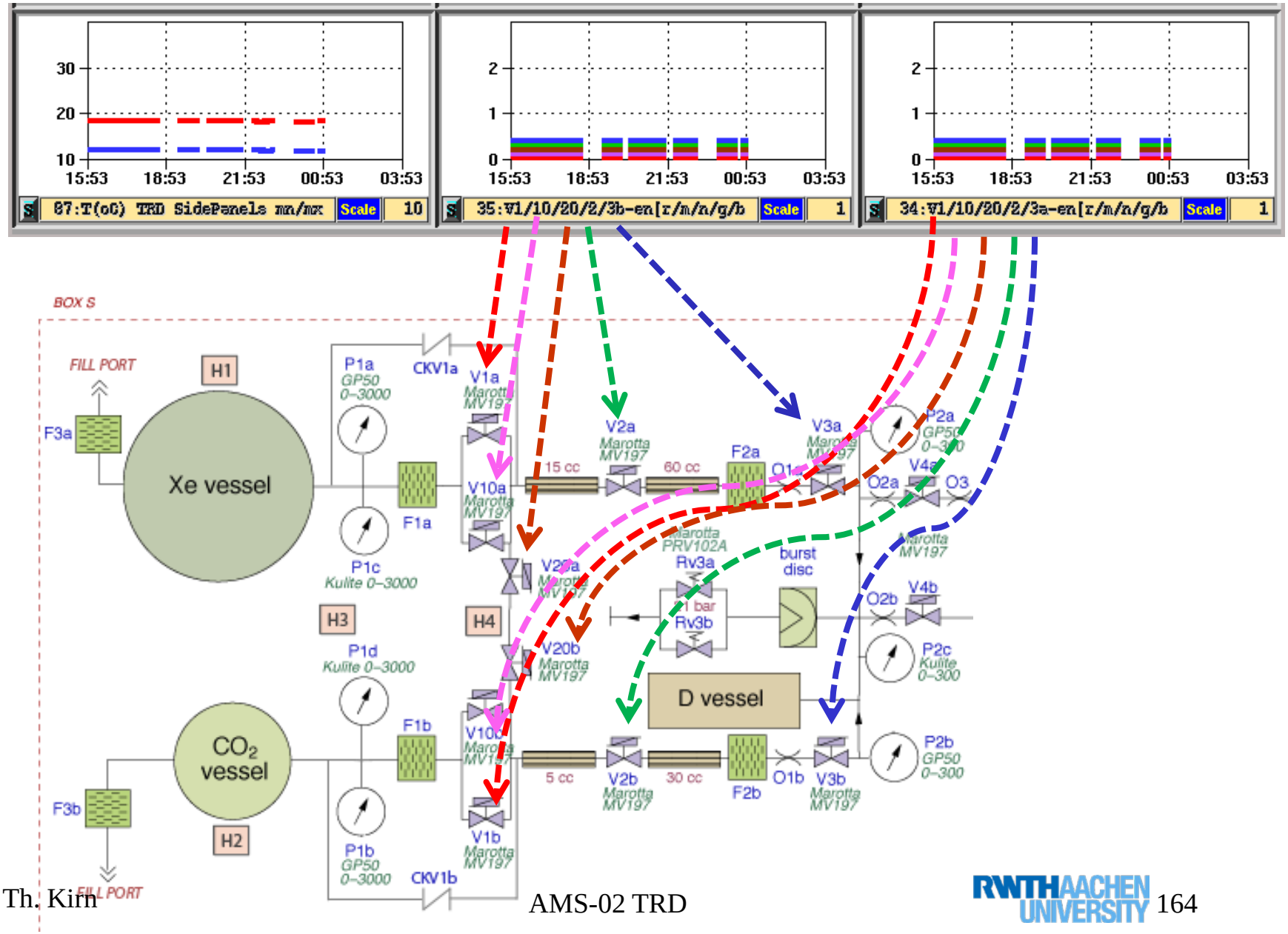
TRD-Gas Monitor Program: TRDGAS-M



TRD-Gas Monitor Program: TRDGAS-M



TRD-Gas Monitor Program: TRDGAS-M



TRD-Gas Monitor Program: PressureMonitor

Actualize data

Chose Time Range, Start (Calendar) End

Set chosen time range

Fit to temperature corrected pressure in chosen time range

Save 3 Canvas As png-file