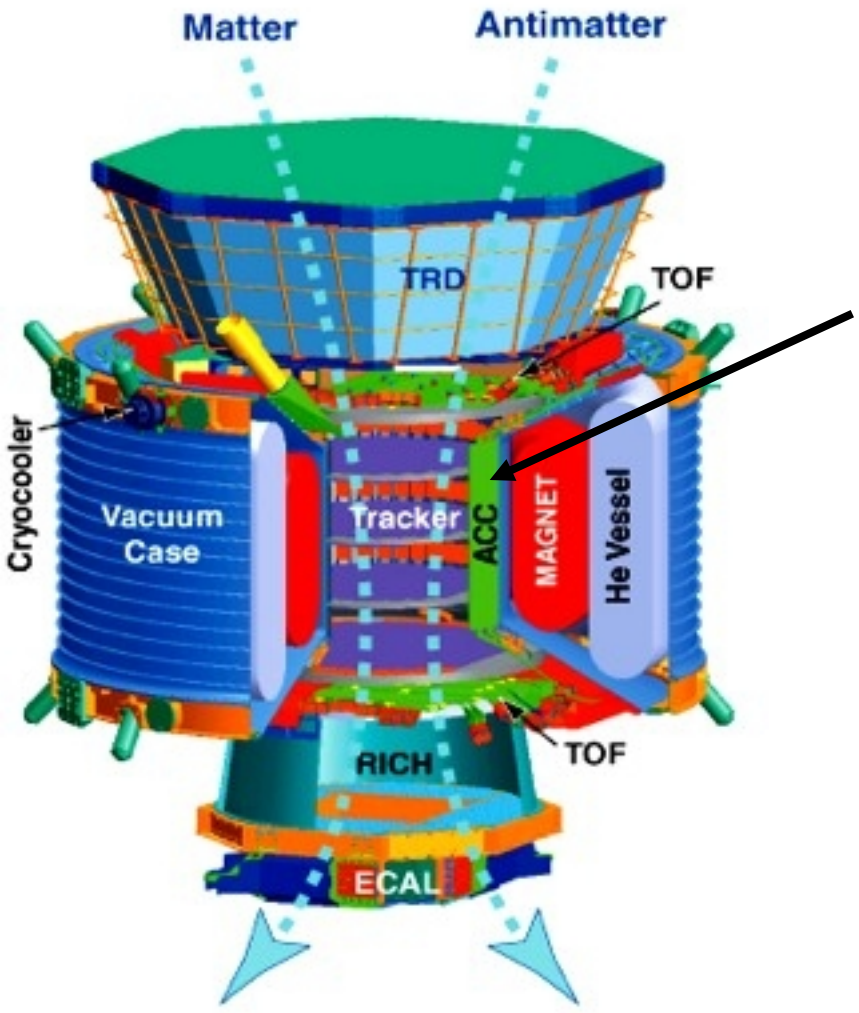
AMS-02 ACC

Thomas Kirn
RWTH Aachen University
CERN, November 28th

AMS-02 – Anti Coincidence Counter (ACC)



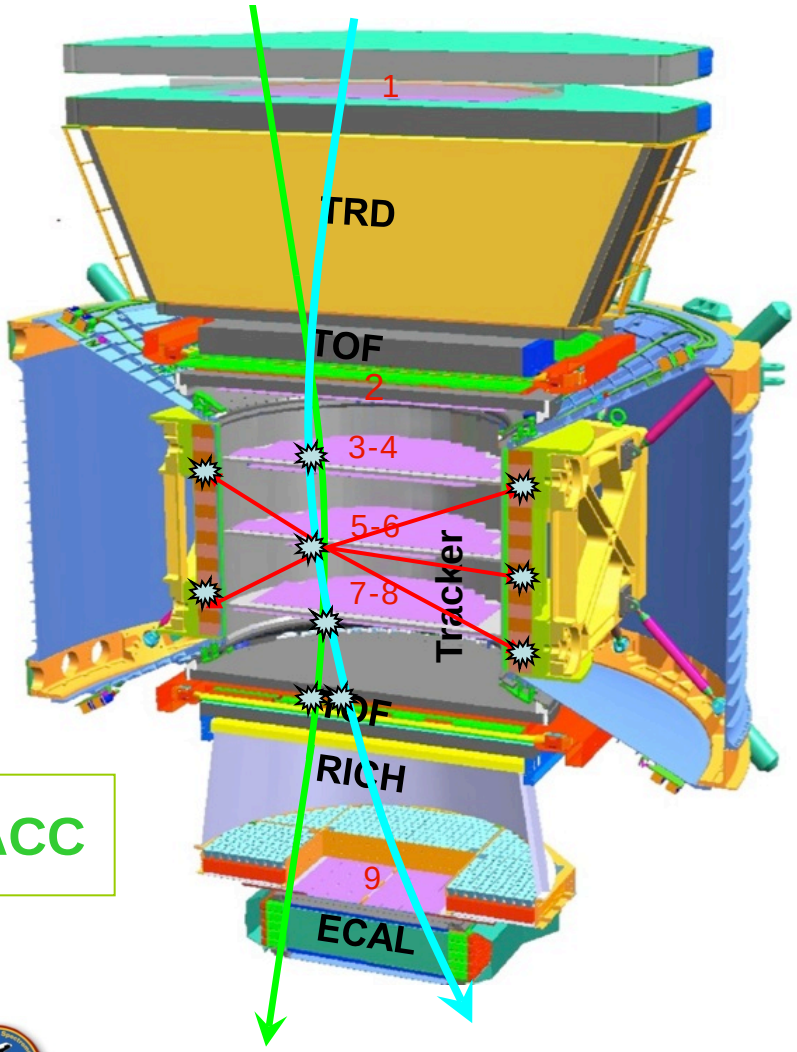
The ACC surrounds the silicon tracker inside the magnet.
It rejects particles that leave or enter AMS-02 through inner shell of the magnet → protection against misidentification of matter nuclei as antimatter nuclei.

Requirements:

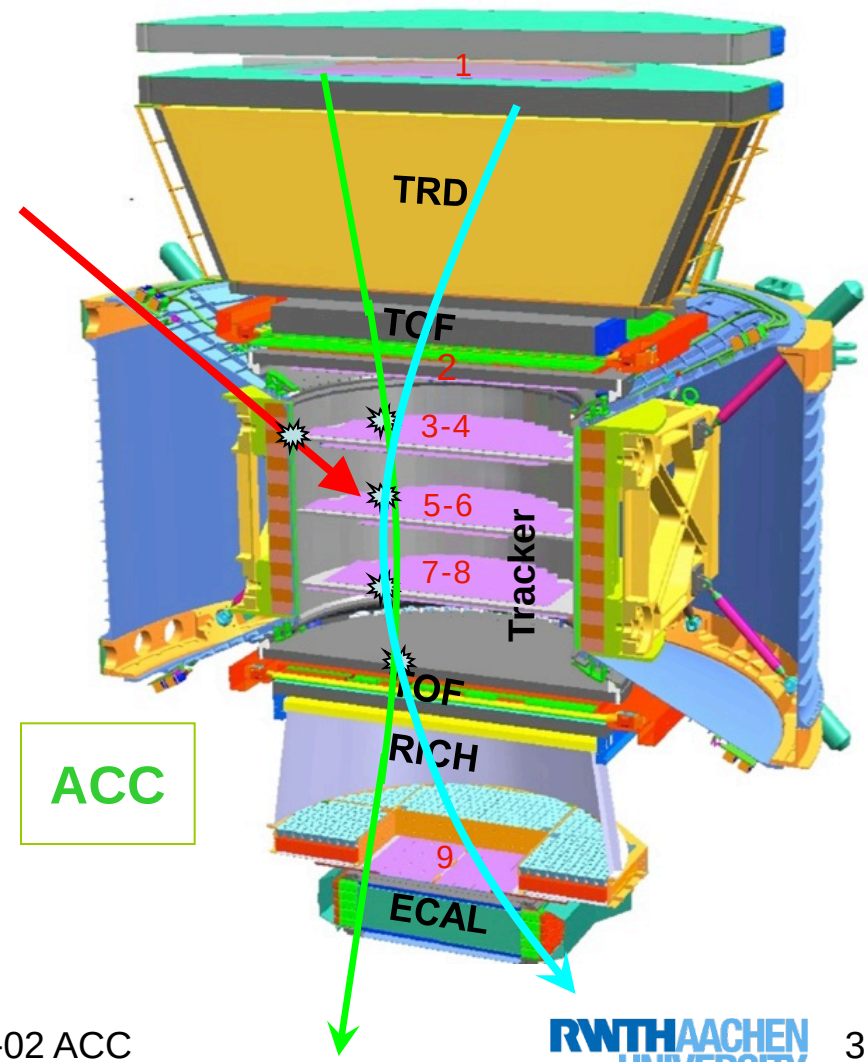
- **High detection efficiency (0.9999)**
- **operational in high magnetic field**
- **fast response for trigger**

AMS-02 – Anti Coincidence Counter (ACC)

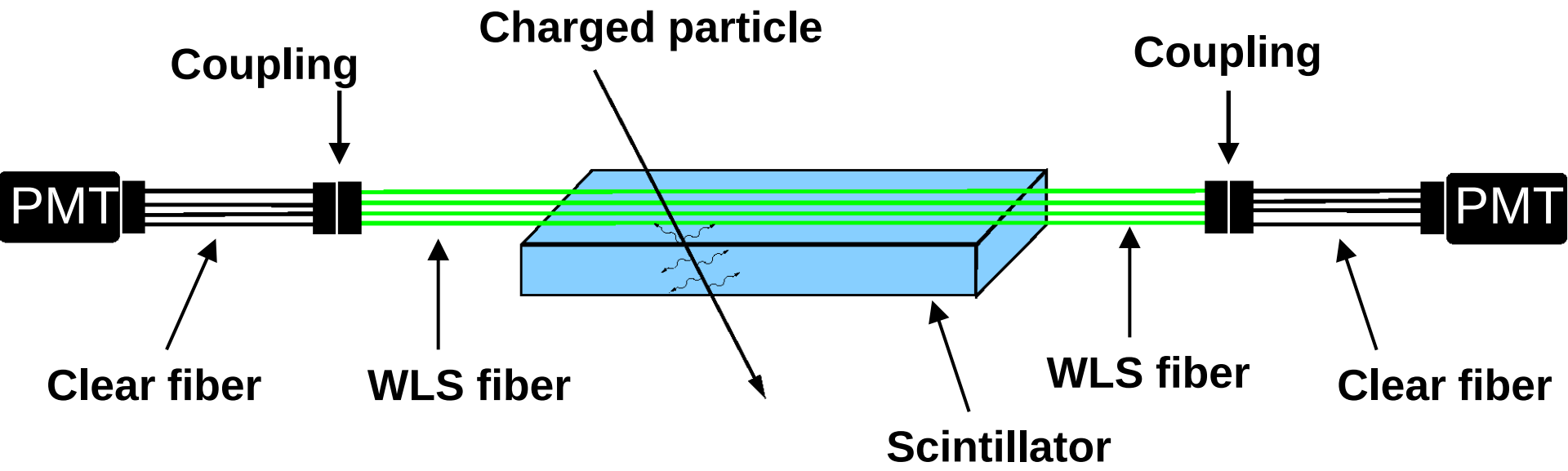
Rejection of internal events



Rejection of external events

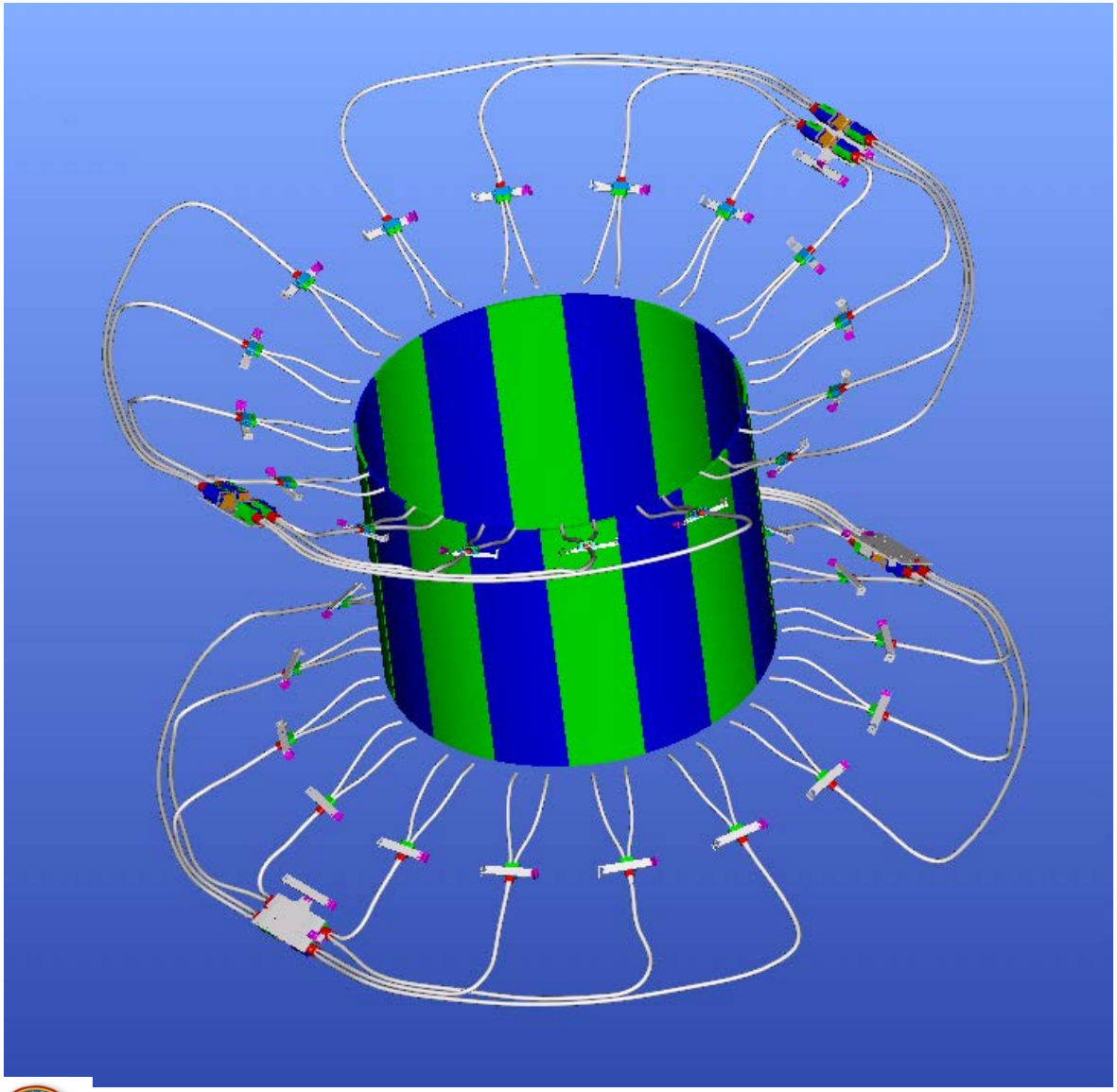


AMS-02 ACC Principle



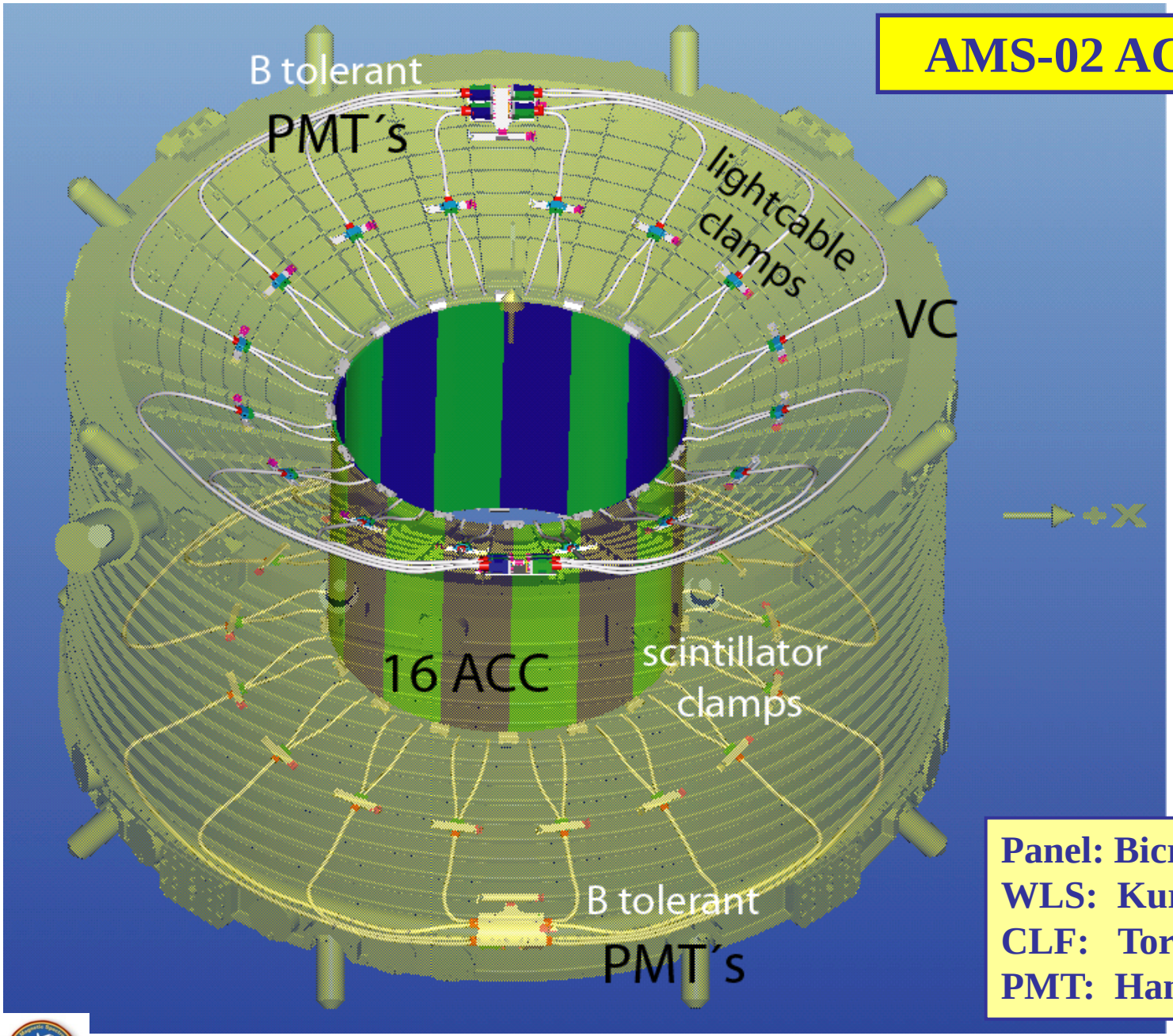
Scintillator Panel:	**Bicron BC414 (826.5 x 230 x 8 mm³)**
Wavelength Shifting Fiber (WLS):	**Kuraray Y-11(200)M**
Clear Fiber (CLF):	**Toray PJU-FB1000**
Photomultiplier (PMT):	**Hamamatsu R5946**

AMS-02 ACC without Vacuum Case



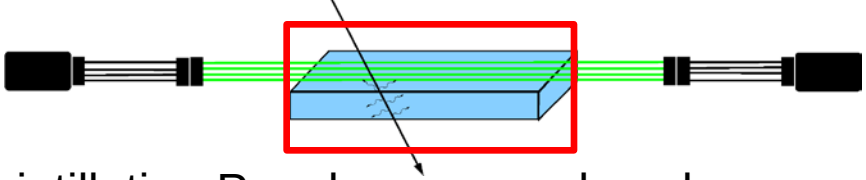
Panel: Bicron BC414
WLS: Kuraray Y-11(200)M
CLF: Toray PJU-FB1000
PMT: Hamamatsu R5946

AMS-02 ACC with VC



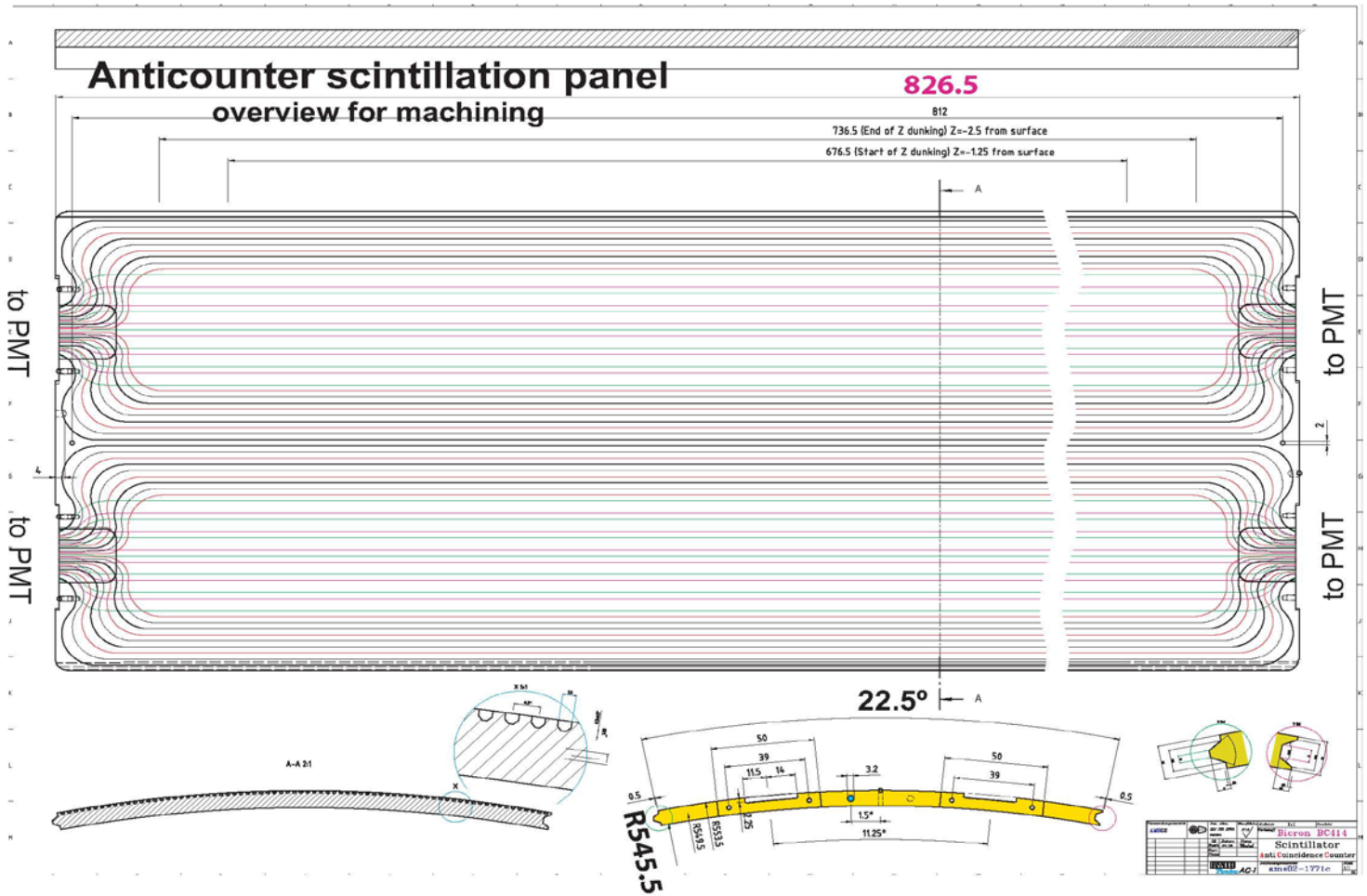
Panel: Bicron BC414
WLS: Kuraray Y-11(200)M
CLF: Toray PJU-FB1000
PMT: Hamamatsu R5946

AMS-02 ACC Scintillation panel



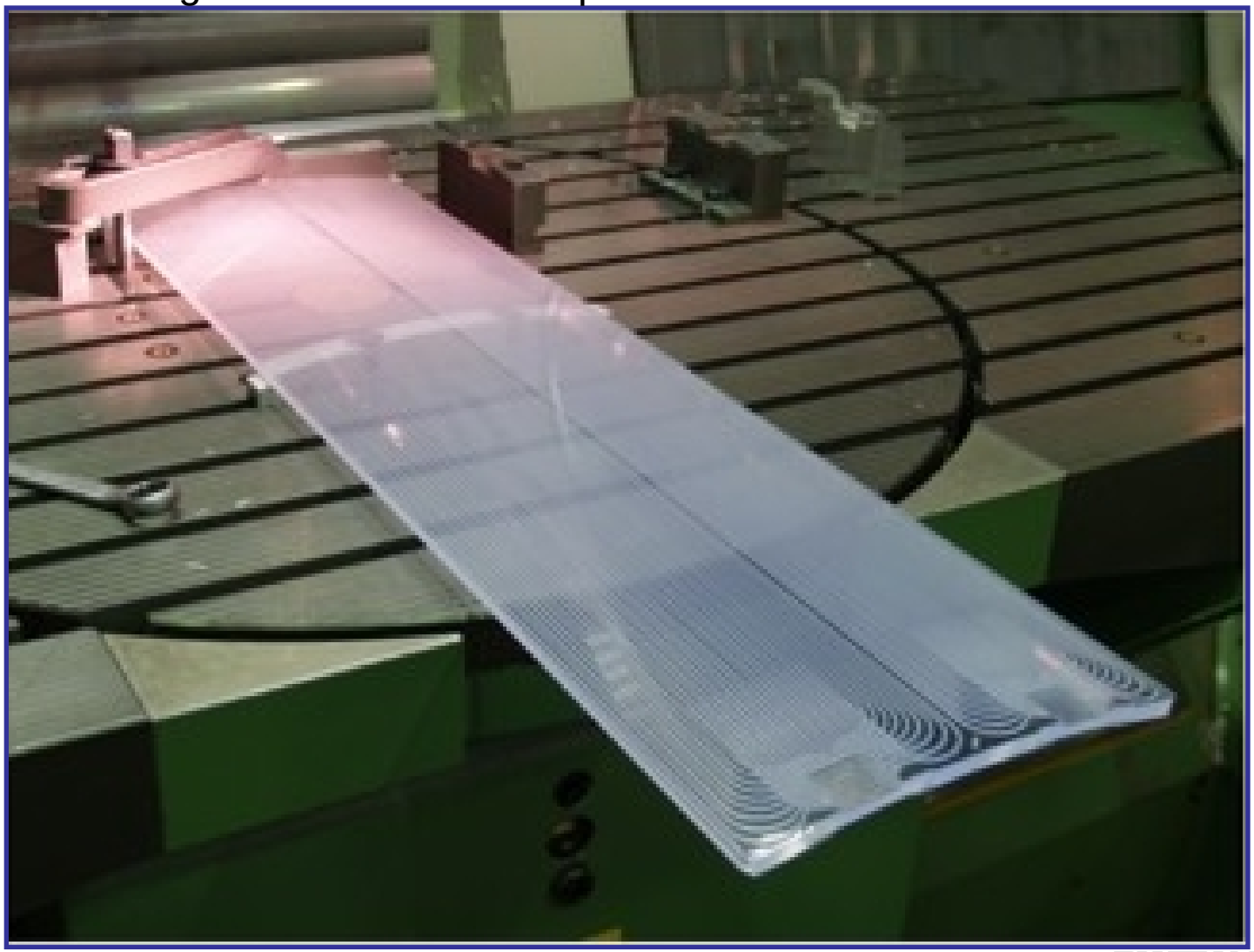
16 FM Scintillating Panels and 4 FM-Spare Scintillating Panels were produced following a procedure:

1.) 74 Grooves were milled into the scintillation panels:



AMS-02 ACC Scintillaton Panel machining

1.) Groove milling into the scintillation panels:



AMS-02 ACC Scintillaton Panel machining

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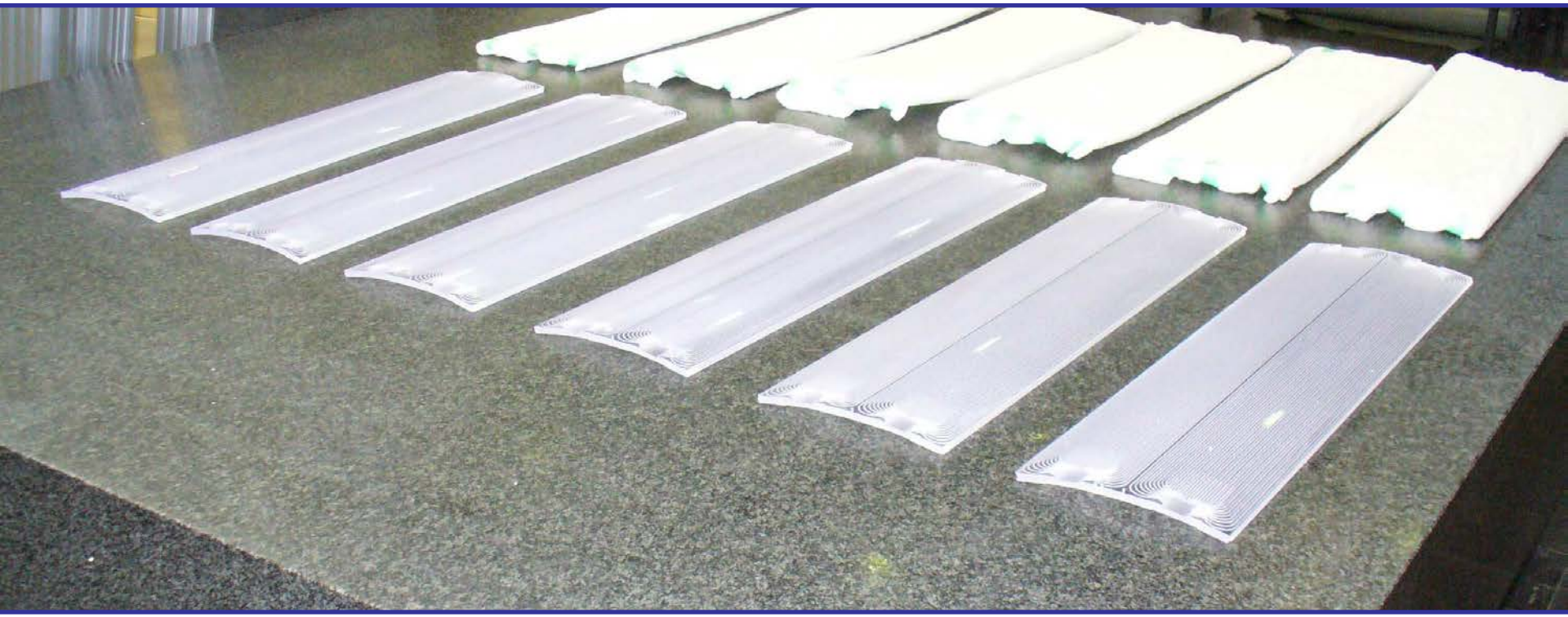
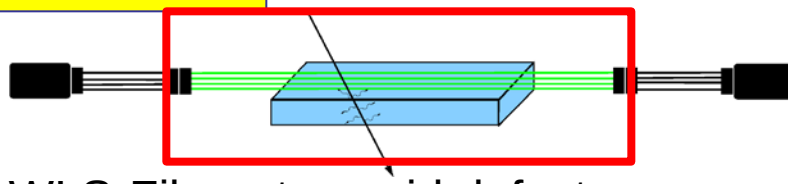


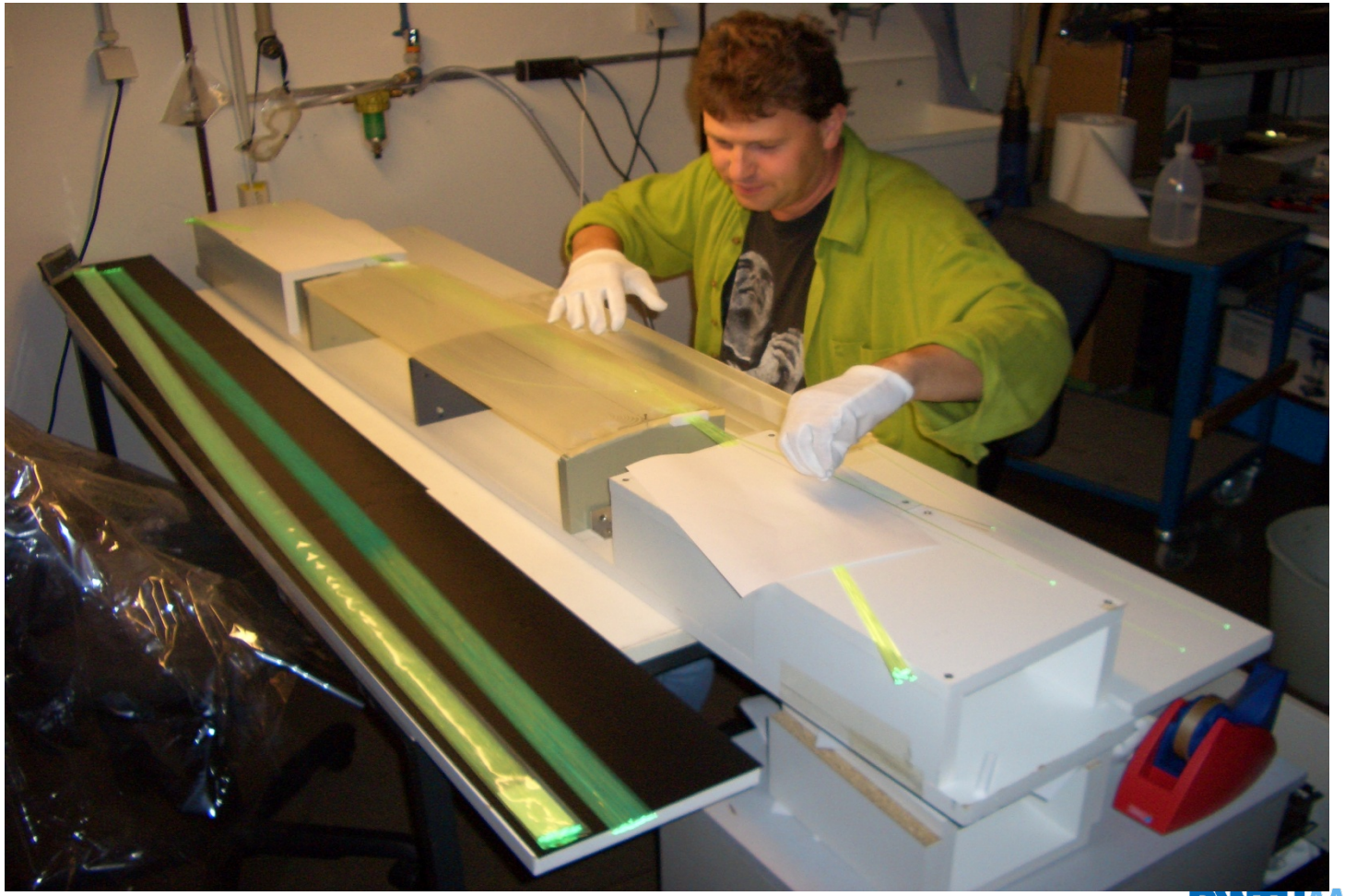
AMS-02 ACC Scintillator Module Production

2.) Optical inspection of scintillation panels

3.) Preparation of tongue, groove and frontfaces



4.) WLS-Fibers placed into grooves after warming WLS-Fibers to avoid defects



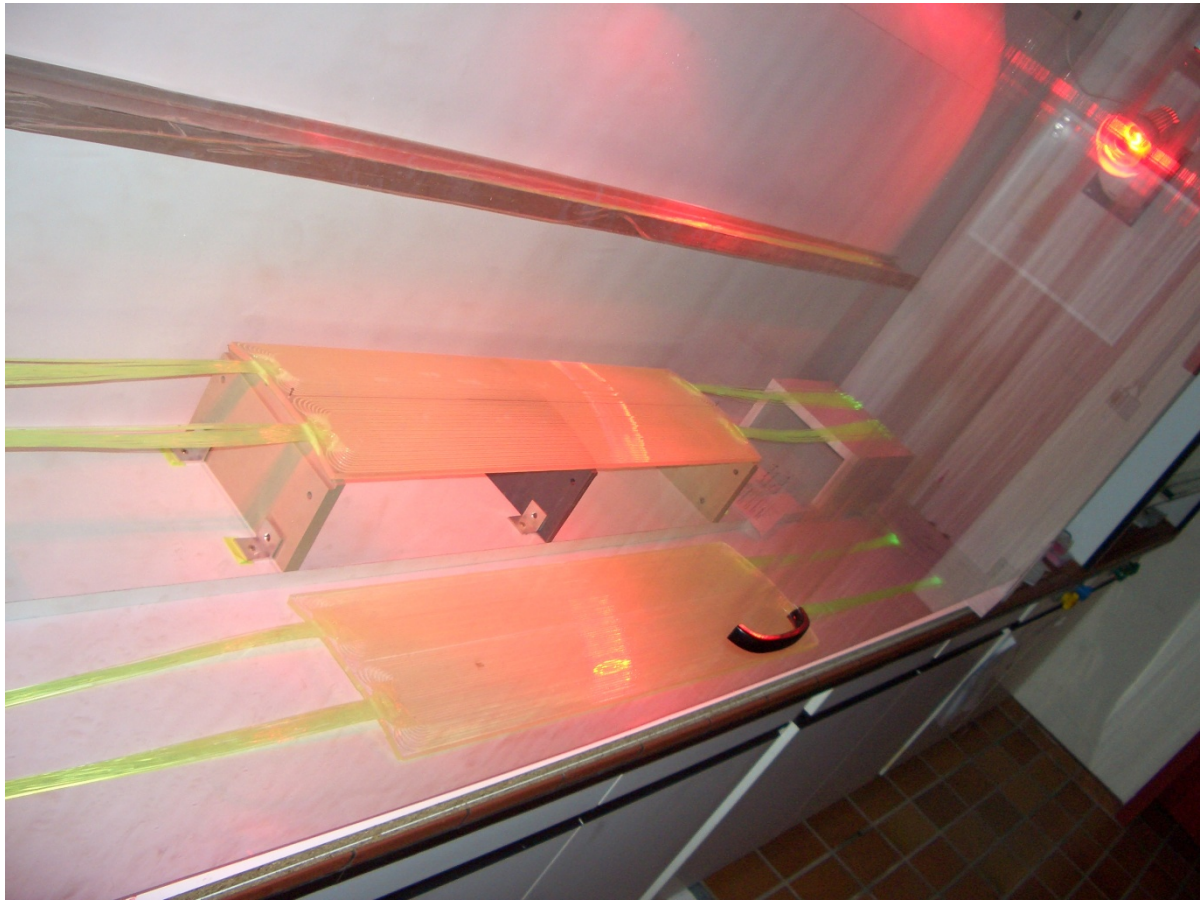
AMS-02 ACC Scintillator Module Production

5.) Optical inspection of WLS-fibers for defects after placing into grooves

6.) Storage for thermal equilibrium at chemical room

7.) Glueing of WLS-Fibers and Scintillating Panels with BC-600

8.) Curing of glue @higher temperature using infrared lamps



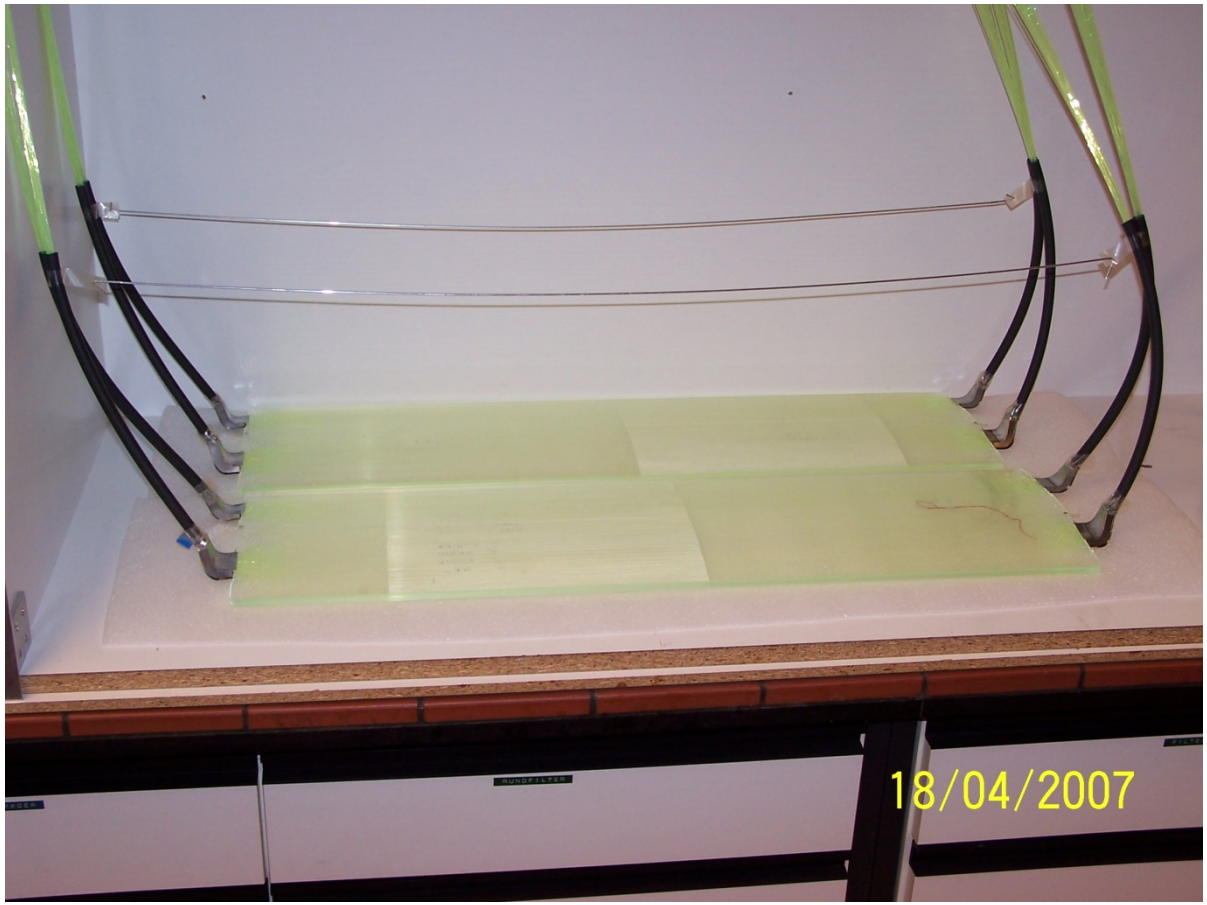
AMS-02 ACC Scintillator Module Production

9.) Bundling of WLS-Fibers into 2 Bundles at each side of scintillating panel

10.) Glueing of 2 UV-LEDs into scintillating panel

11.) Mounting of fiber bending protection

12.) Lighttight packaging of WLS-Fiber bundles in Viton tubes



AMS-02 ACC Scintillator Module Production

13.) Mounting of optical connector at end of WLS-Fiber bundles

14.) Wrapping of scintillator panel with reflective aluminized mylar foil

AMS-02 ACC Scintillator Module Production

15.) Lighttight wrapping of scintillating panel with black cloth

16.) Lighttight glueing of scintillating panel with Nusil glue

17.) Cutting of overlength and polishing of WLS-fibers

AMS-02 ACC Scintillator Modules: Lightyield-Measurement, Setup

Test with atmospheric muons & pulsed LED-signals

The 16 FM and 4 FM-Spare Scintillation Panels tested with atmospheric muons:

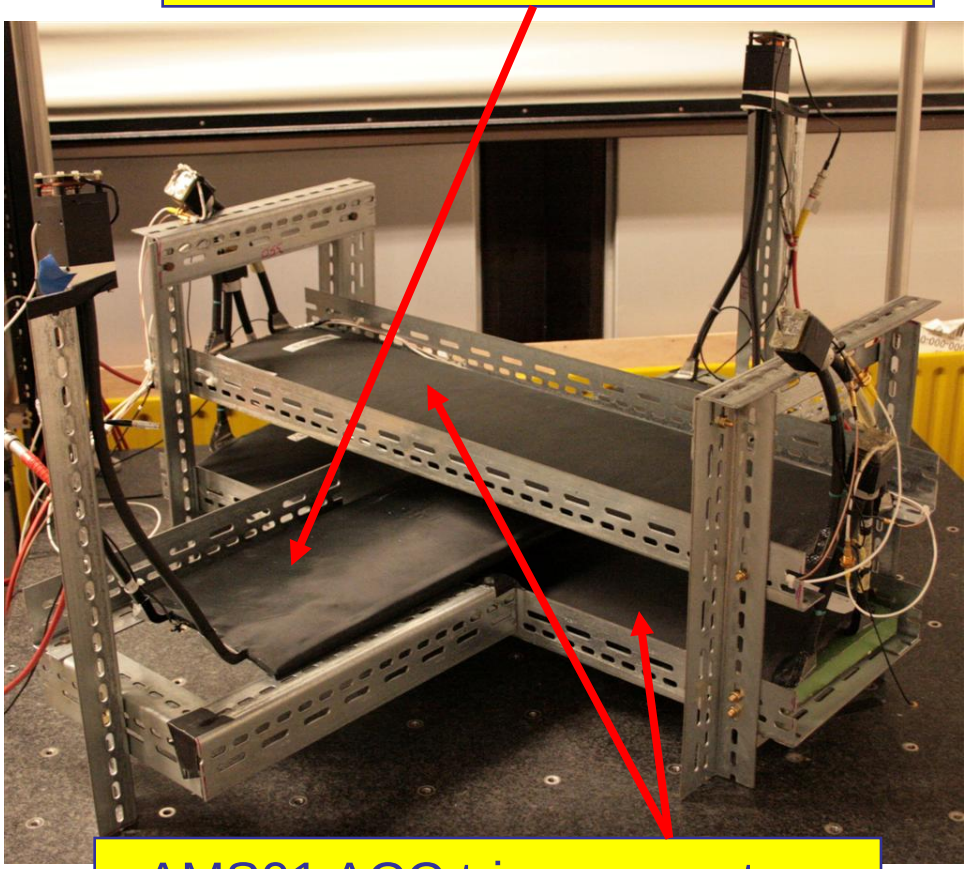
The Most-probable-value of the typical Landau-Distribution corresponds to the number of photo-electrons detected by two reference PMTs mounted to the AMS-02 counter.

All AMS-02 scintillation panels were tested with the same reference PMTs!

Calibration:

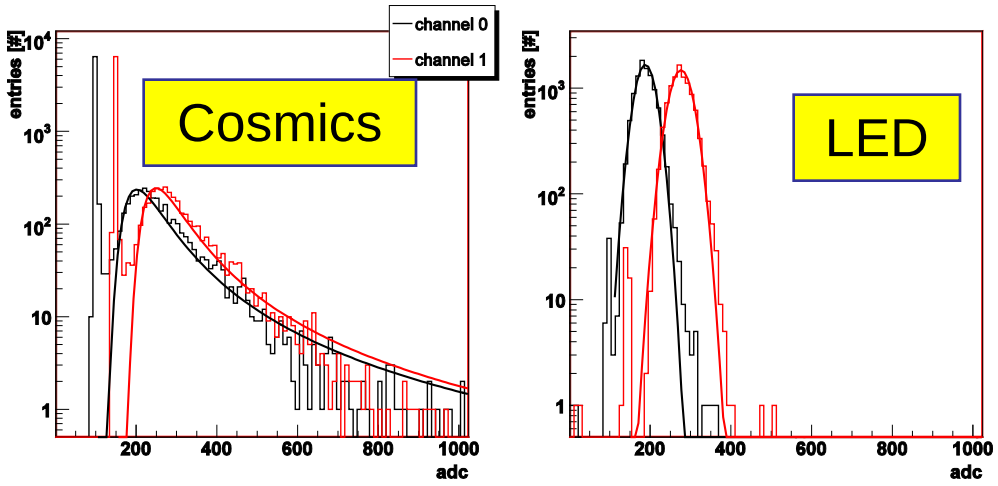
A LED-pulse create a typical Gaussian-distributed signal in the AMS-02 counter and can be used to calibrate the detected number of photo-electrons .

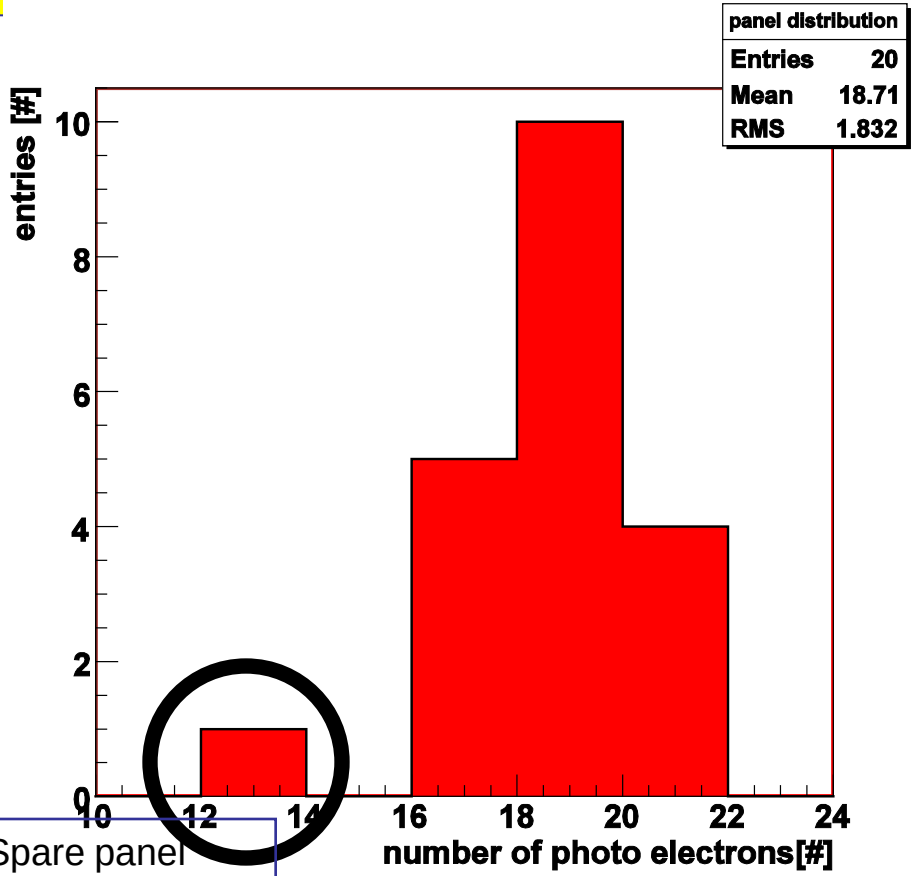
AMS02 ACC scintillation panel



AMS01 ACC trigger counters

AMS-02 ACC Scintillator Modules: Lightyield-Measurement, Calculation of photo electron number





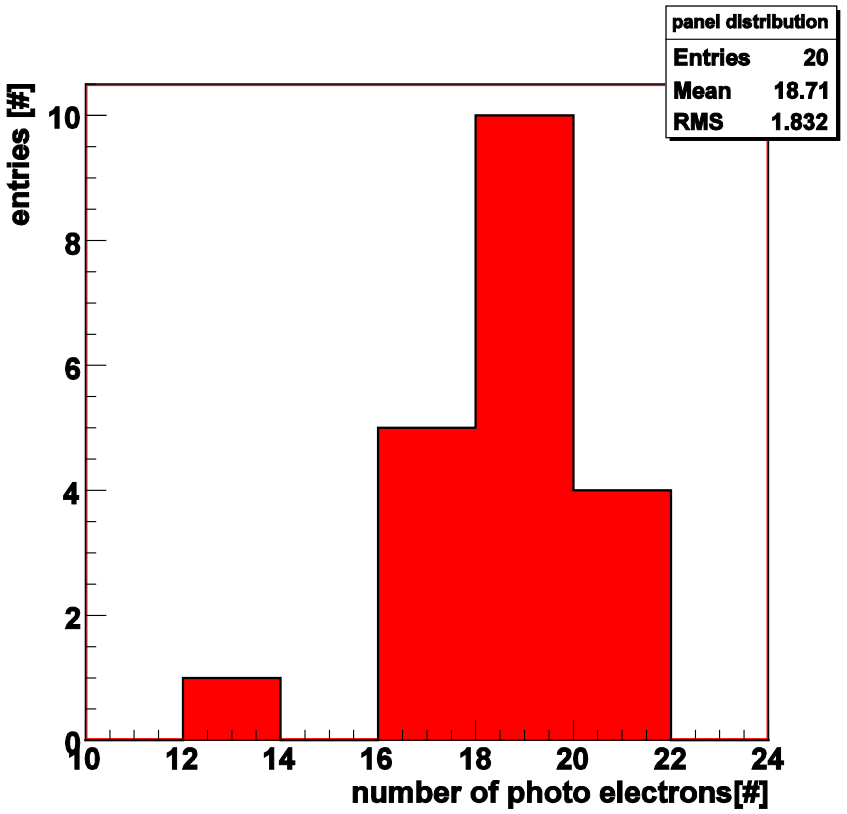
- Measurement of MOP with cosmics
- calibration with LEDs implemented in scintillation panels

Flight-Spare panel
(1st produced FM panel)

Calculation of photo electron number

$$N_{pe} = \frac{Q_C Q_{LED}}{\sigma^2_{LED}}$$

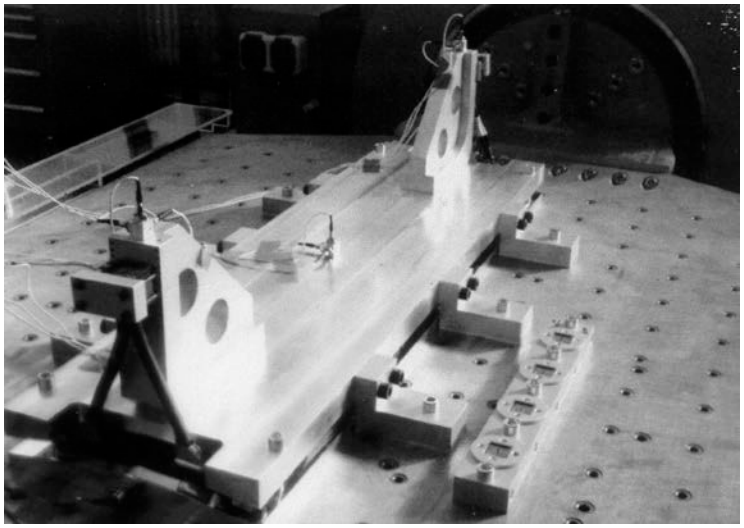
AMS-02 ACC Scintillator Modules: Lightyield-Measurement, Result of photo electron number measurement



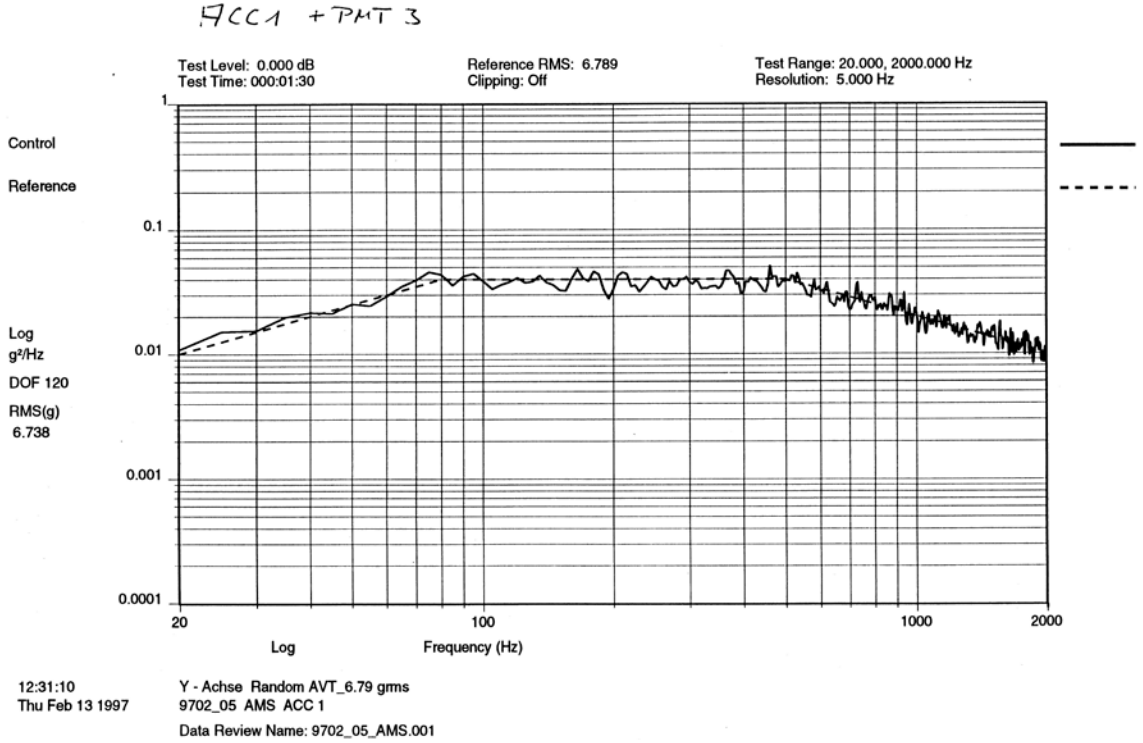
Panel No.	p.e.	Panel No.	p.e.
1	13	11	19
2	17	12	18
3	17	13	17
4	19	14	19
5	19	15	20
6	20	16	19
7	19	17	20
8	20	18	21
9	19	19	18
10	19	20	21

AMS-02 ACC Scintillator Modules: Space Qualification

The 16 FM and 4 FM-Spare Scintillation Counters are made out of the same material as the AMS-01 ACC scintillation counter. The space qualification was carried out for the AMS-01 ACC scintillation counters and is therefore done by similarity for the AMS-02 ACC scintillation counters.

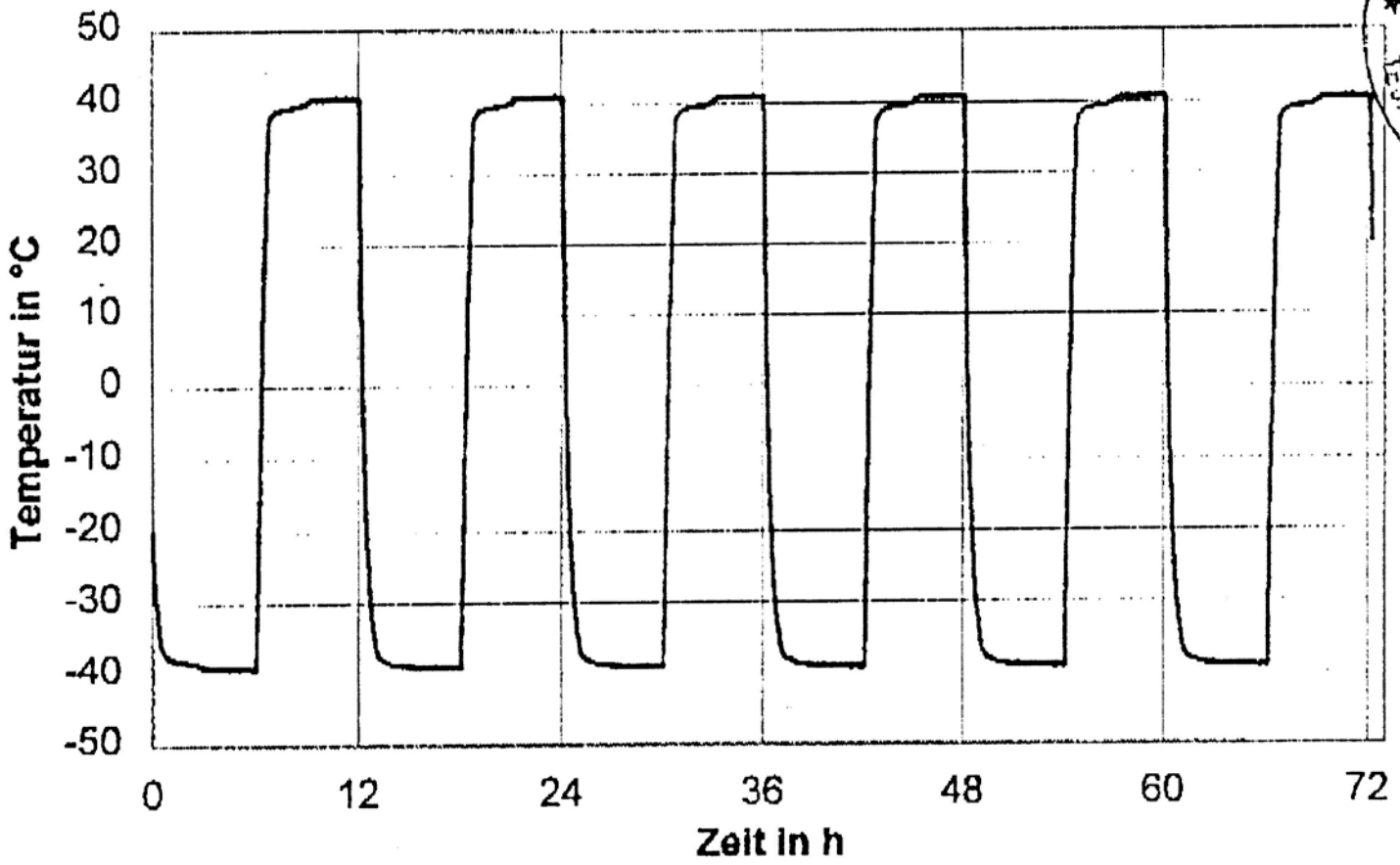


Vibration with 6.8g with AMS-01 ACC panels
AMS-01 ACC panels consist of the same Material as AMS-02 ACC panels



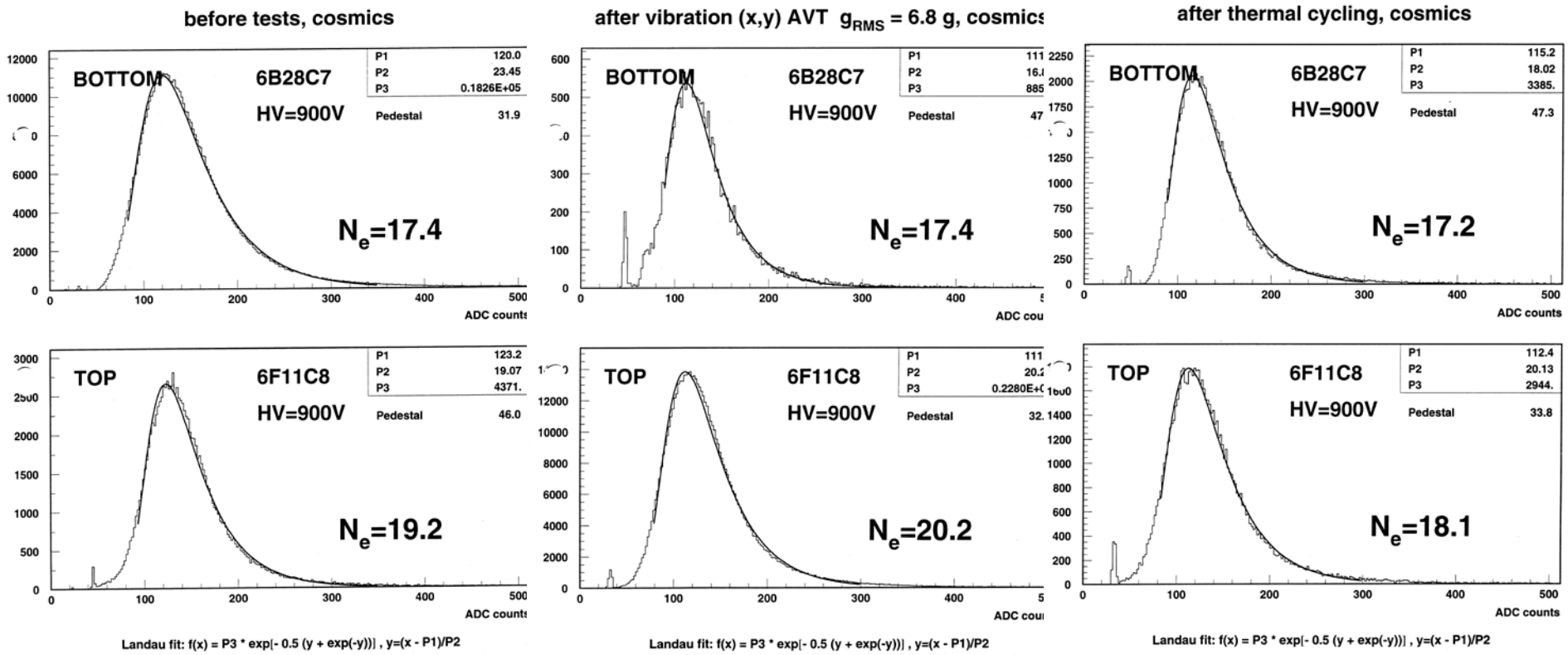
AMS-02 ACC Scintillator Modules: Space Qualification

Thermo-Vacuum-Test @ Institute for Bauforschung at RWTH Aachen with AMS-01 ACC panels which consist of the same Material as AMS-02 ACC panels



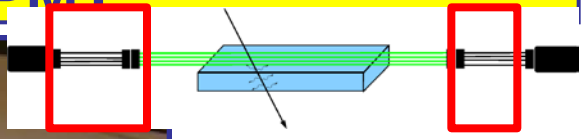
AMS-02 ACC Scintillator Modules: Space Qualification

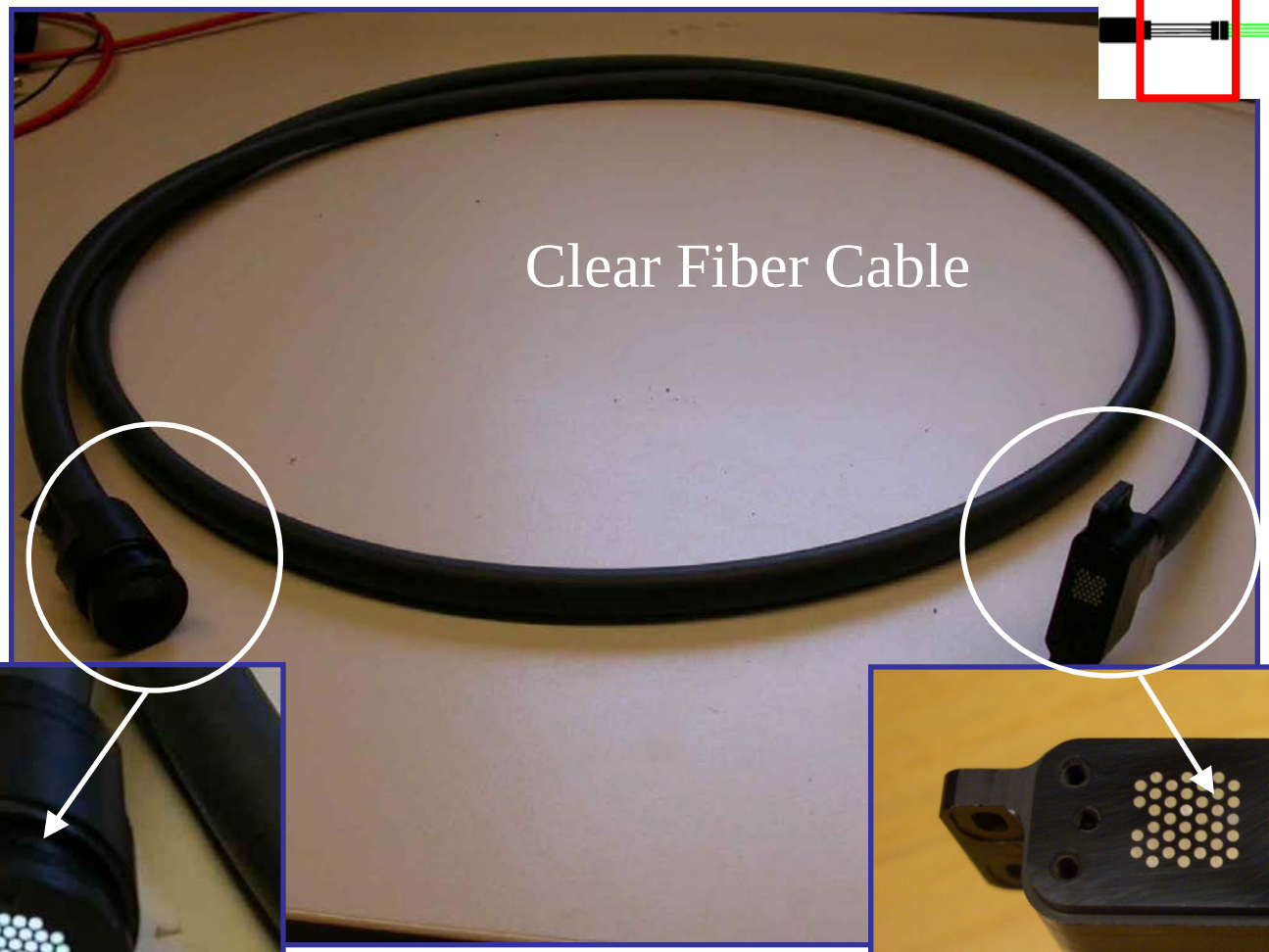
Lightyield-Measurement of AMS-01 ACC panels before and after space qualification tests. The AMS-01 ACC panels consist of the same material as AMS-02 ACC panels

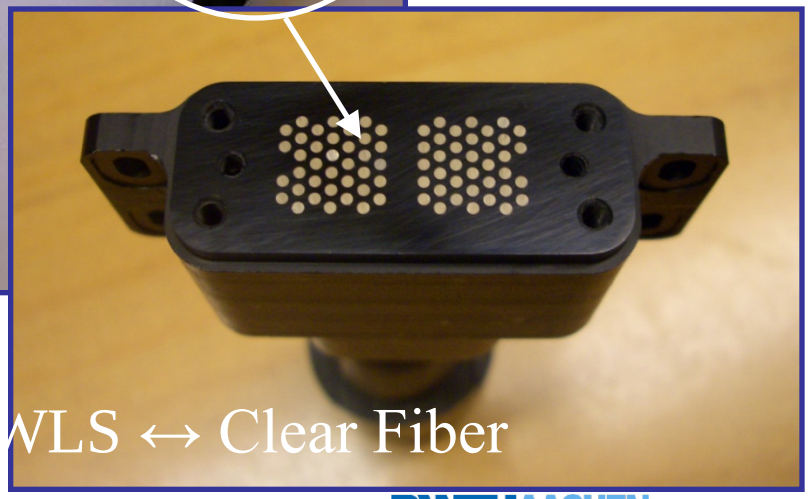


No significant differences between the light output performance before and after the space qualification tests.

AMS-02 ACC Optical Couplings: WLS Fiber ↔ Clear Fiber ↔ PMT

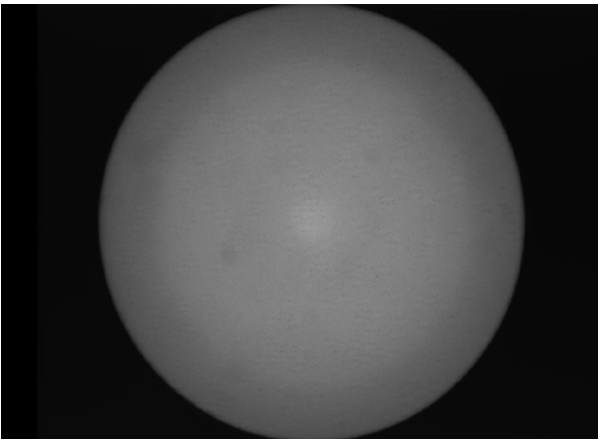




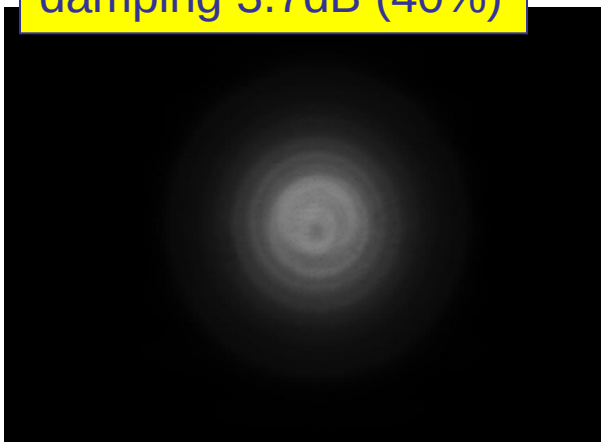


AMS-02 ACC WLS Fiber ↔ Clear Fiber; Farfield Measurement (POFAC FH Nürnberg)

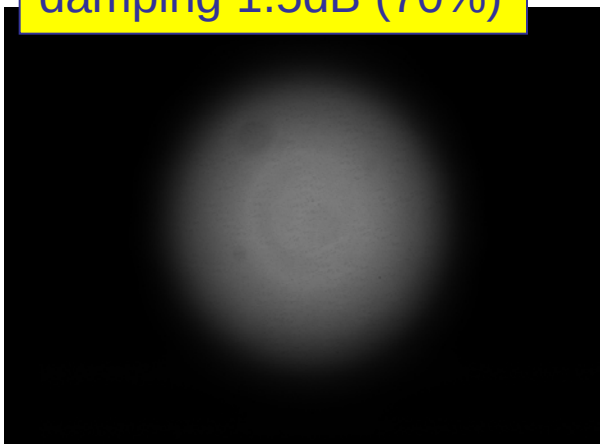
WLS Fiber Output

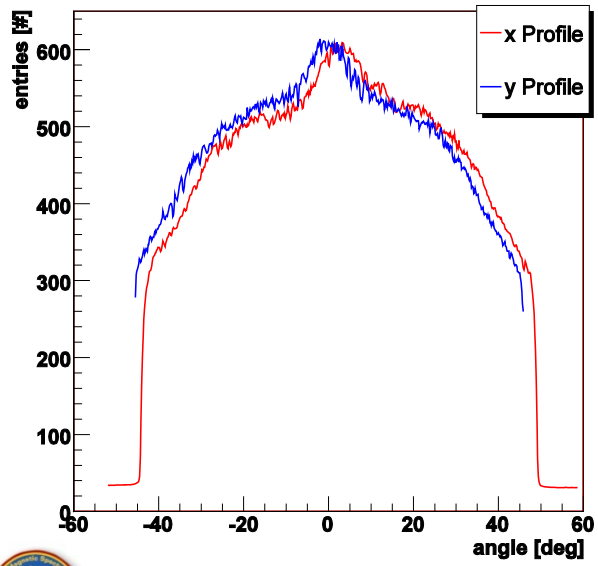


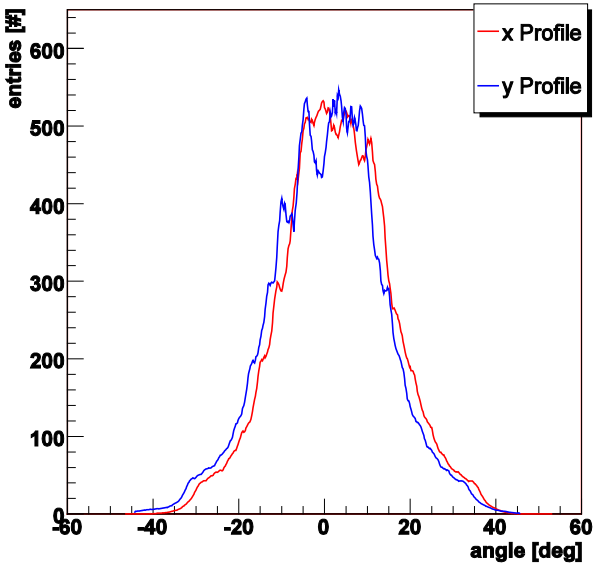
Clear Fiber: Bicron damping 3.7dB (40%)

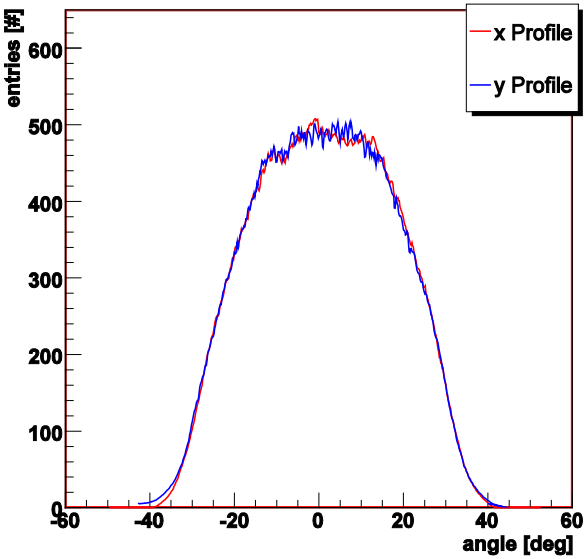


Clear Fiber: Toray damping 1.5dB (70%)

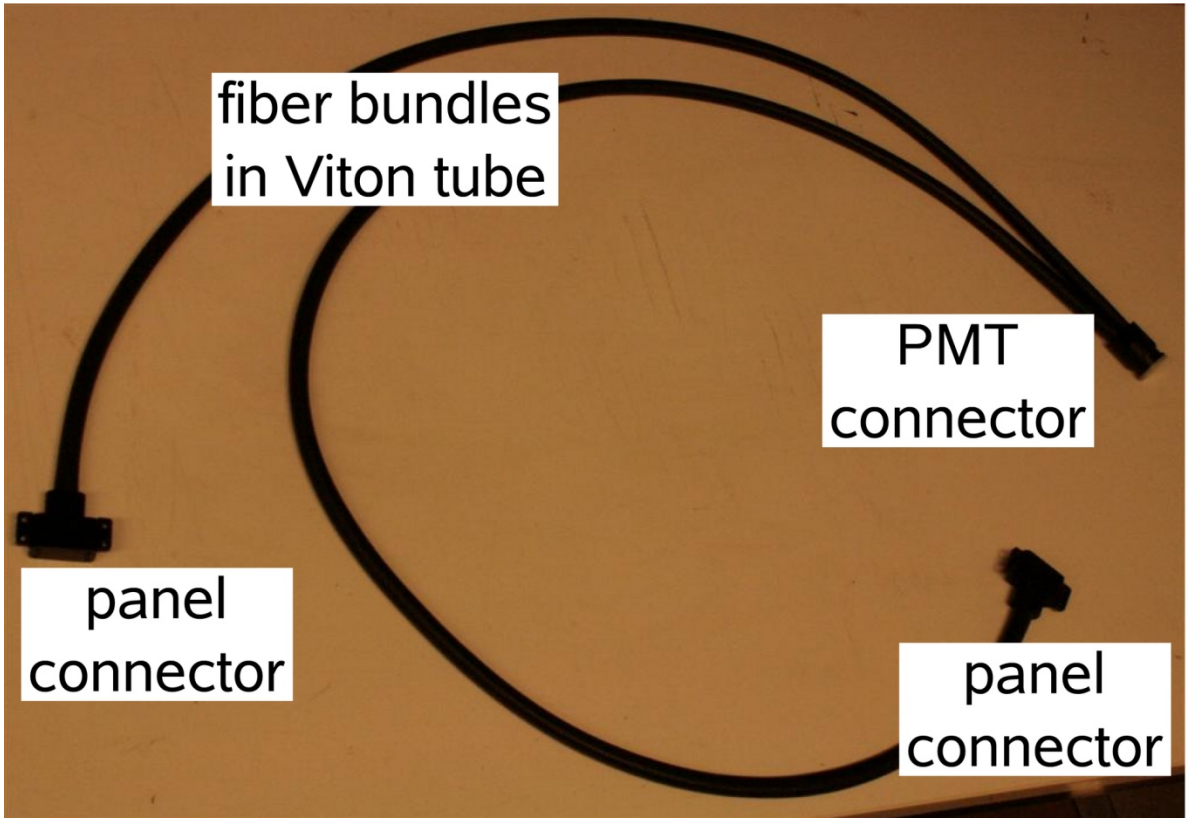


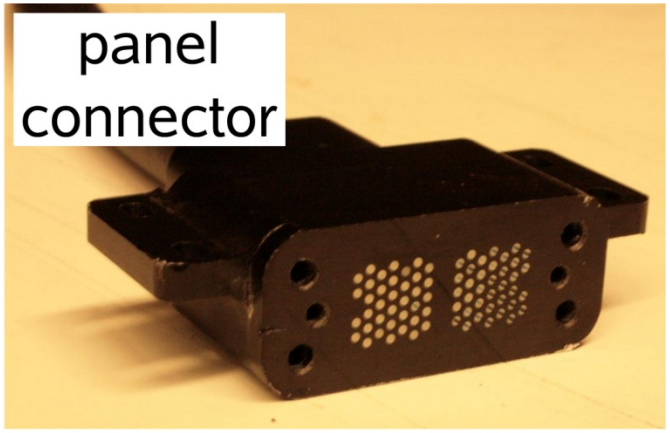




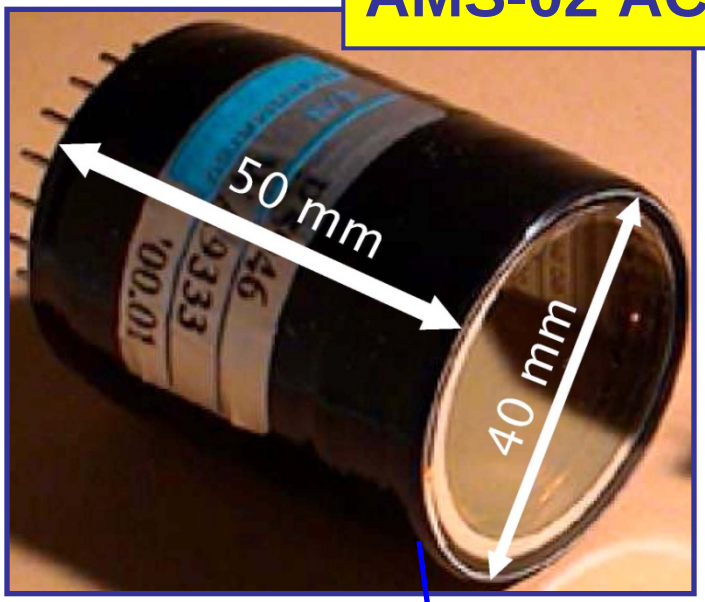


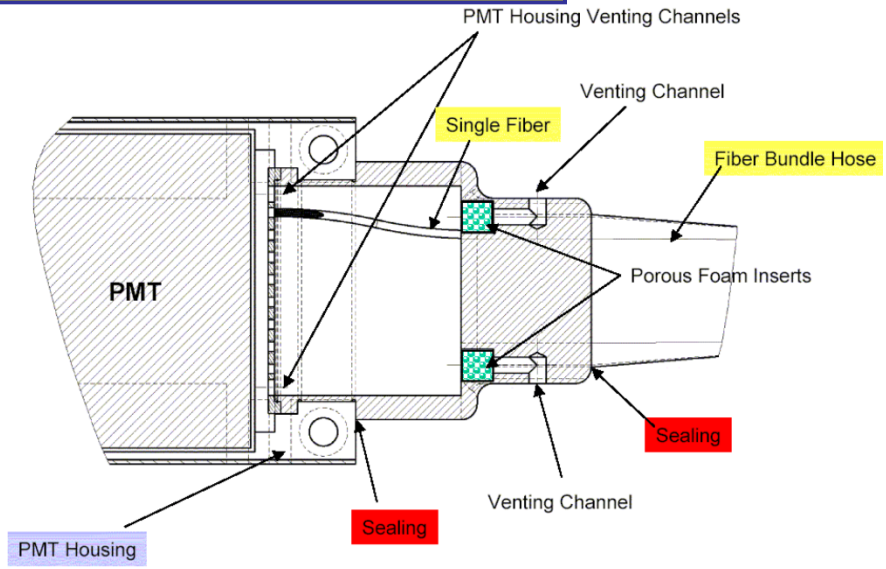
AMS-02 ACC Clear Fiber



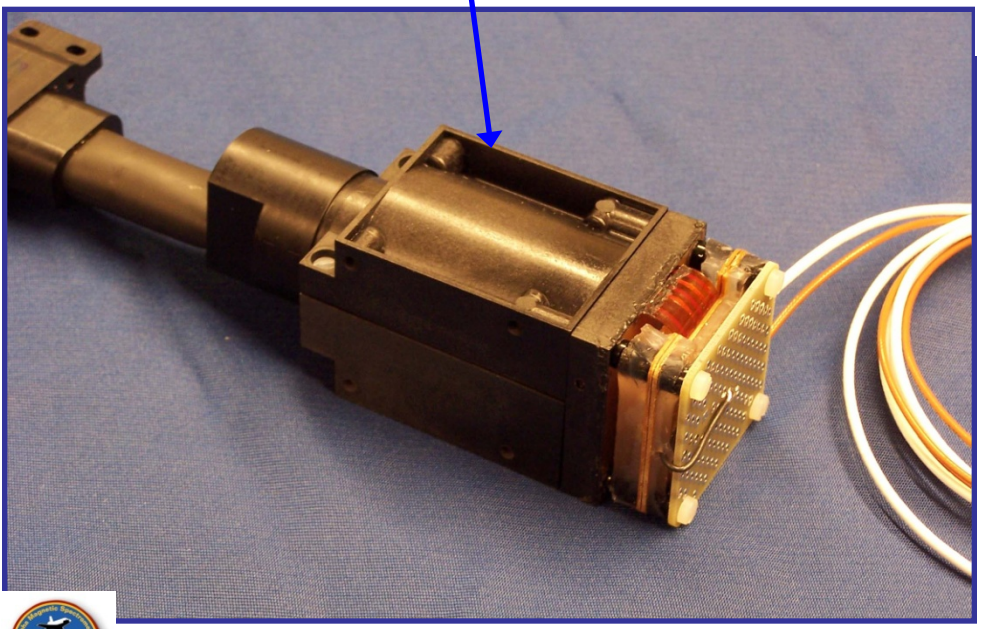


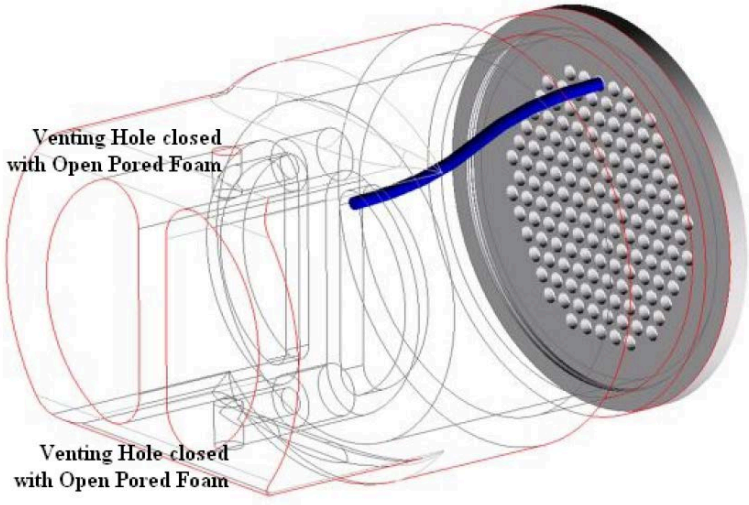
AMS-02 ACC PMT: Hamamatsu R5946



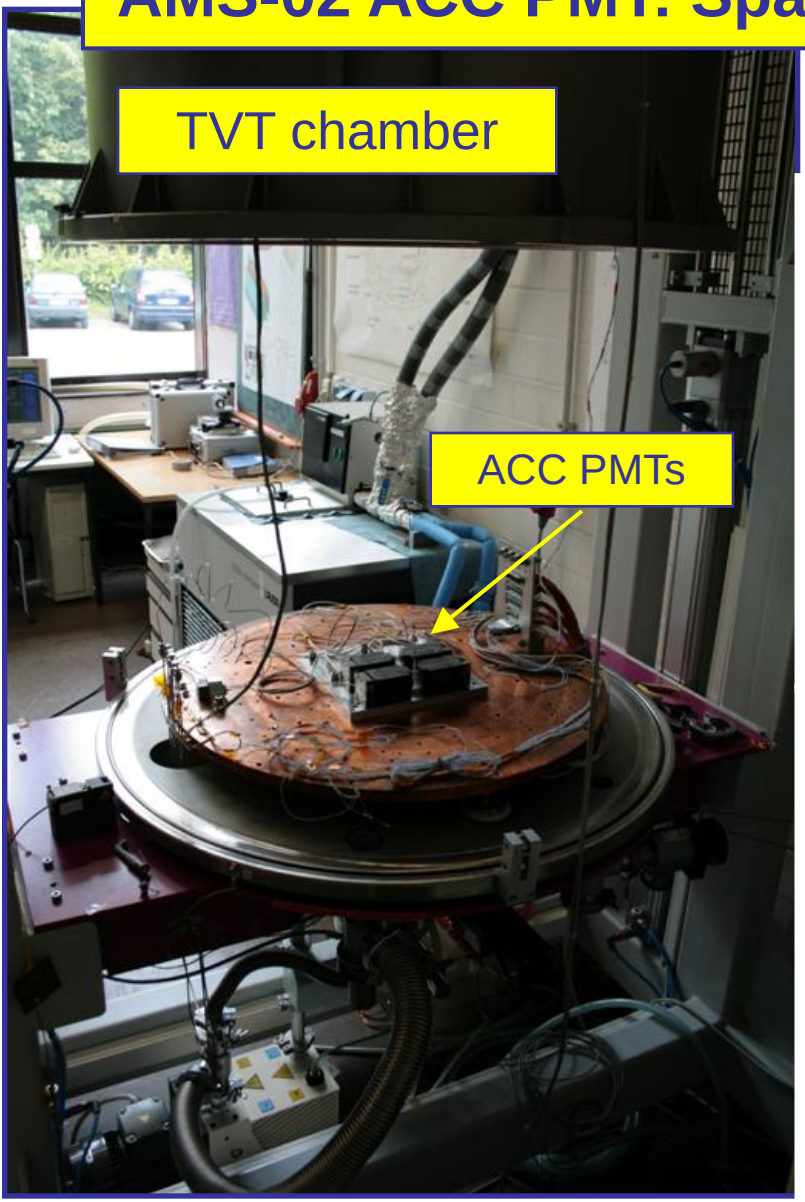


ACC PMT Construction Detail (Variance from TOF design)

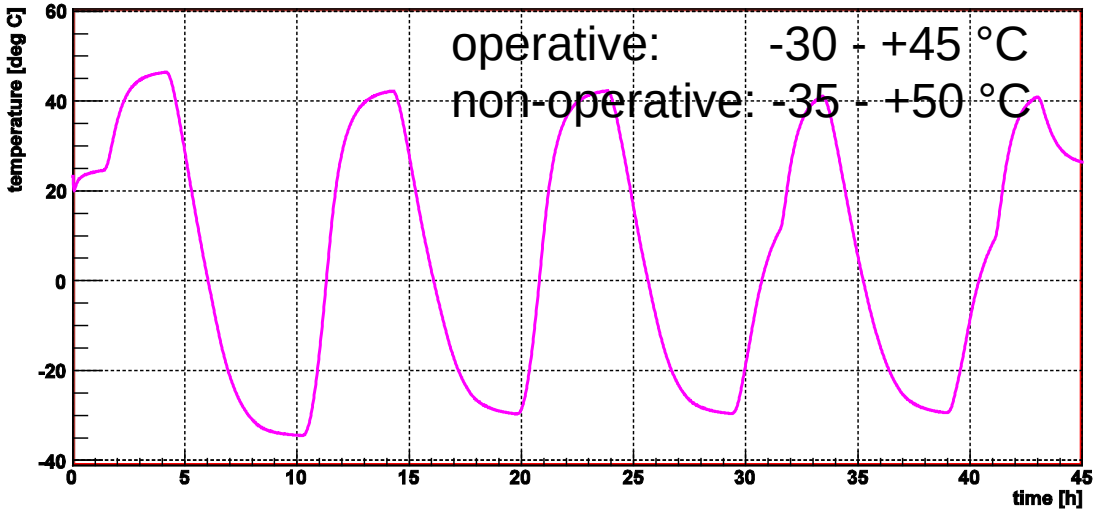




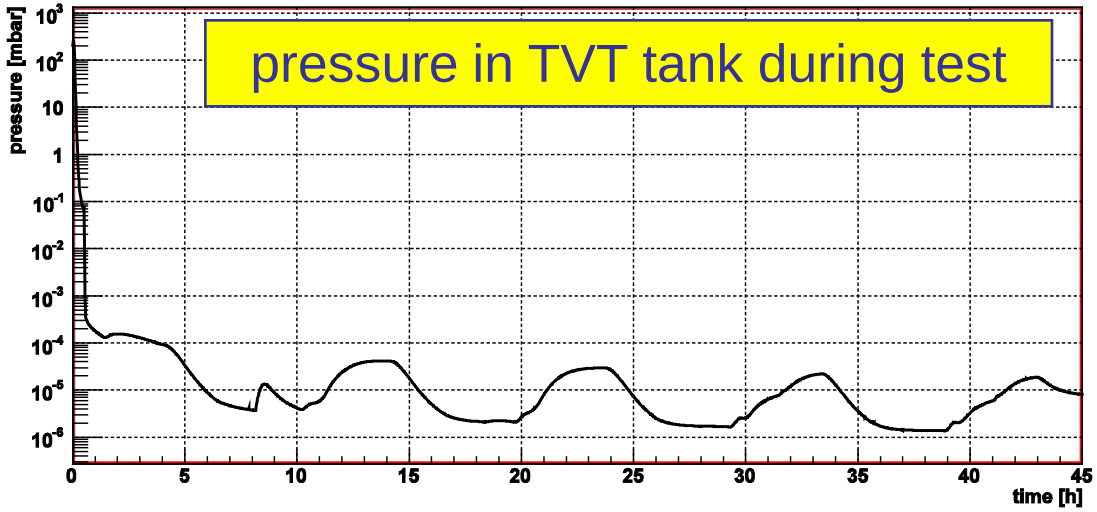
AMS-02 ACC PMT: Space Qualification @ RWTH Aachen



Temperature on voltage divider

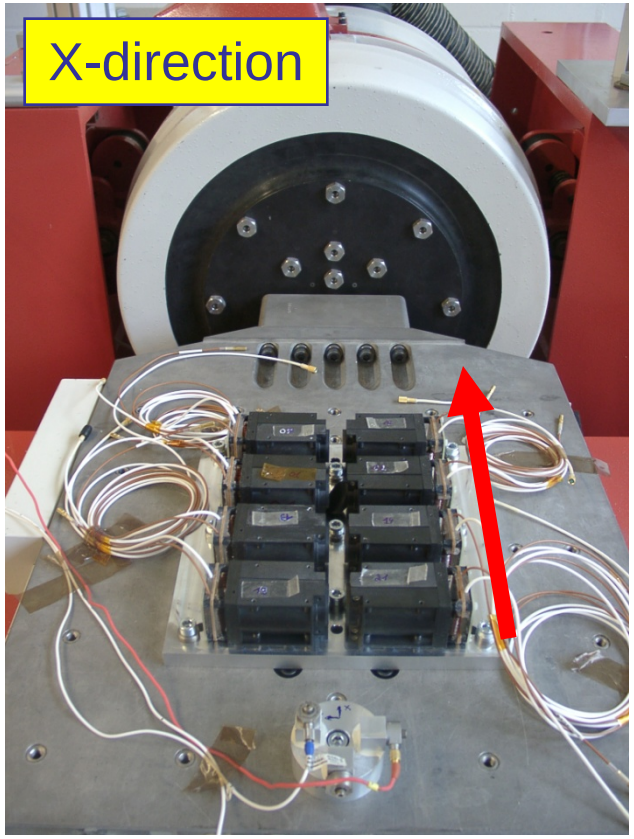


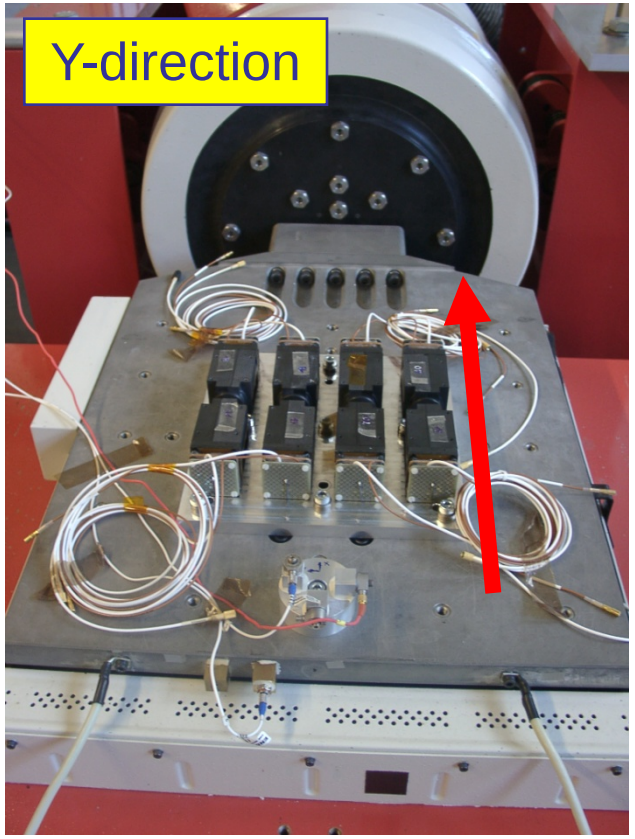
pressure in TVT tank during test

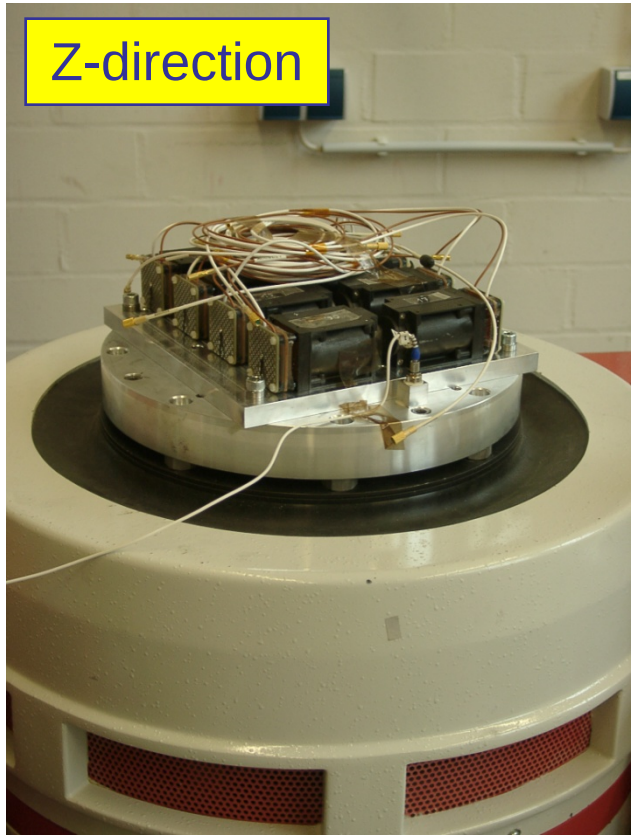


AMS-02 ACC PMT: Space Qualification @ RWTH Aachen

Vibration teststand

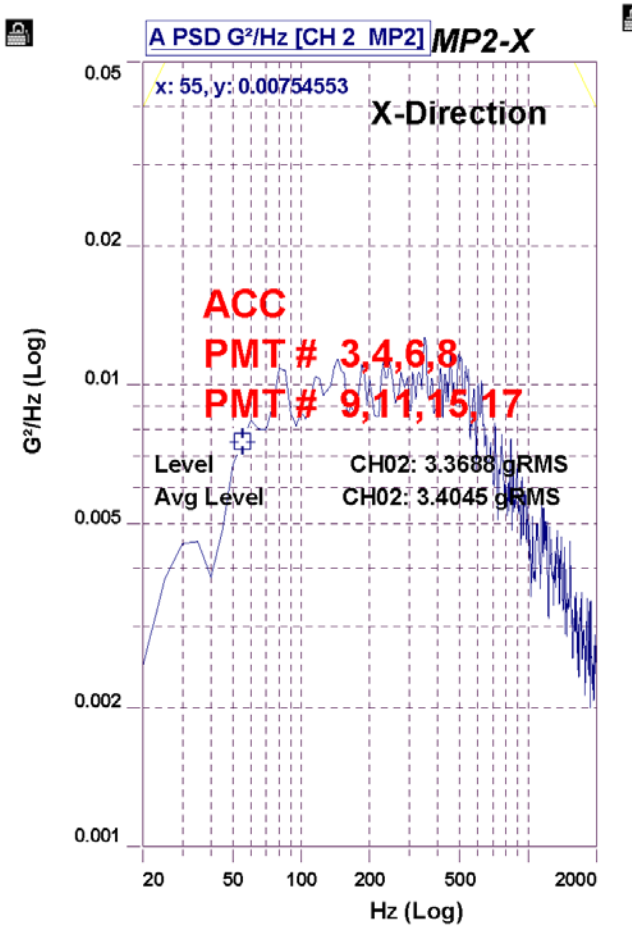


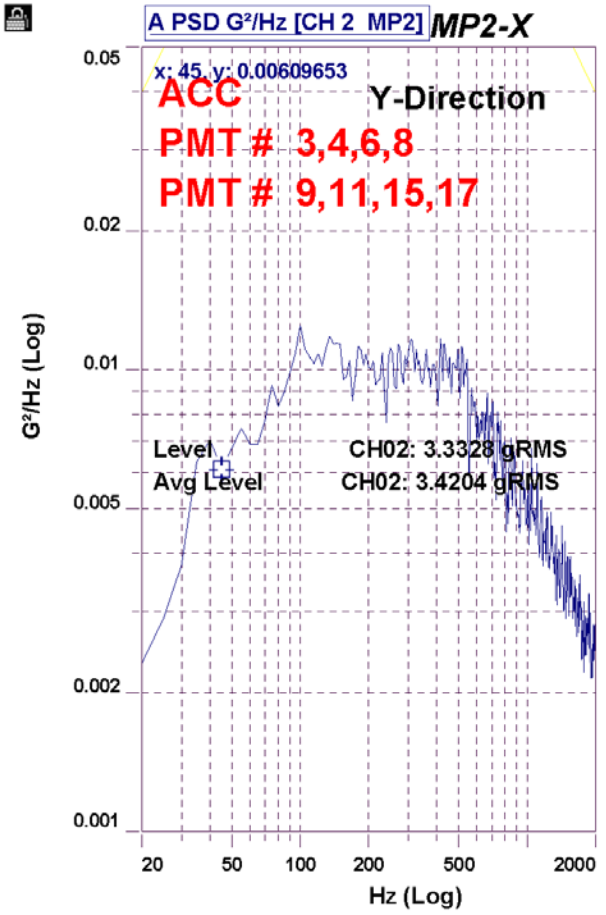


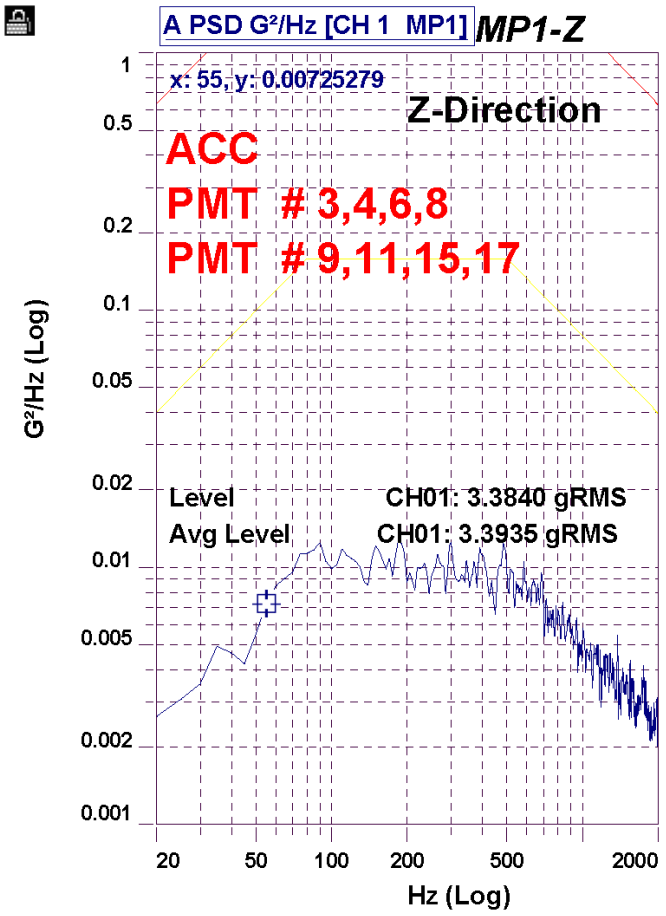


No significant changes observed !

AMS-02 ACC PMT: Space Qualification @ RWTH Aachen



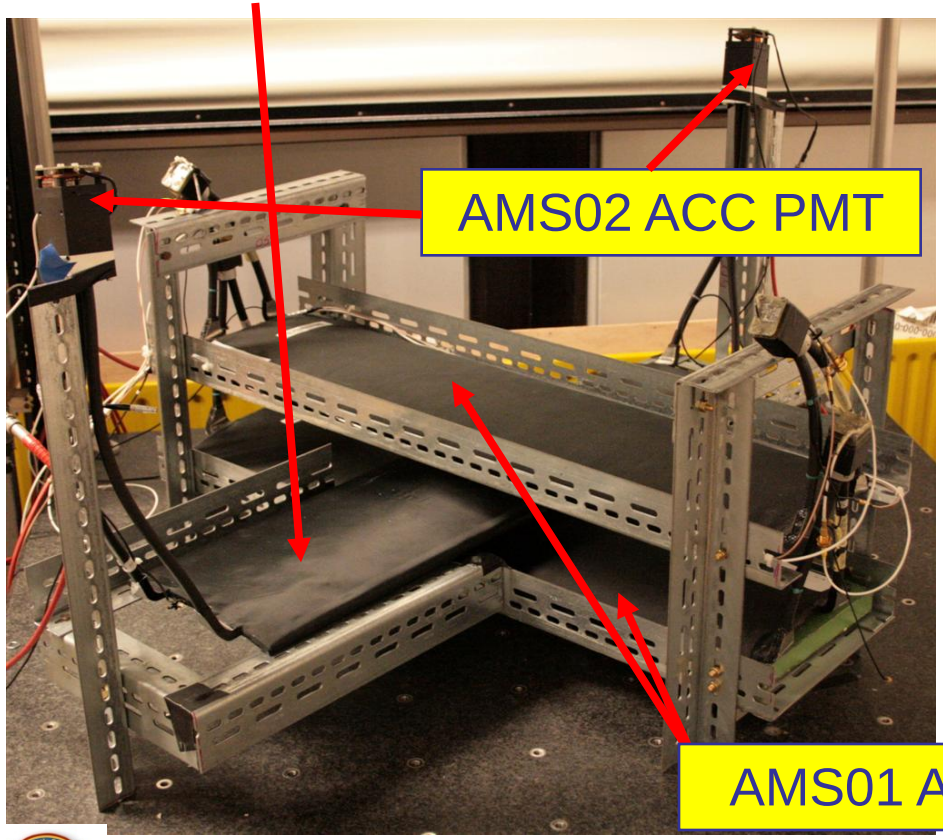


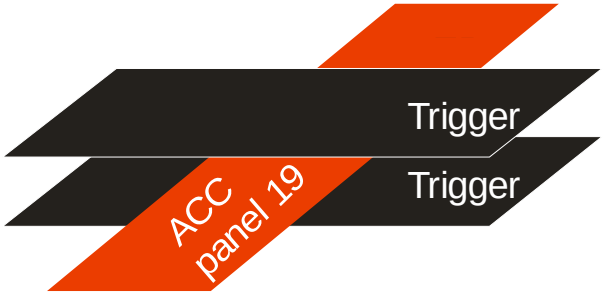


AMS02 ACC Photomultiplier (PMT): Space Qualification Tests, Measurement of # photo electrons

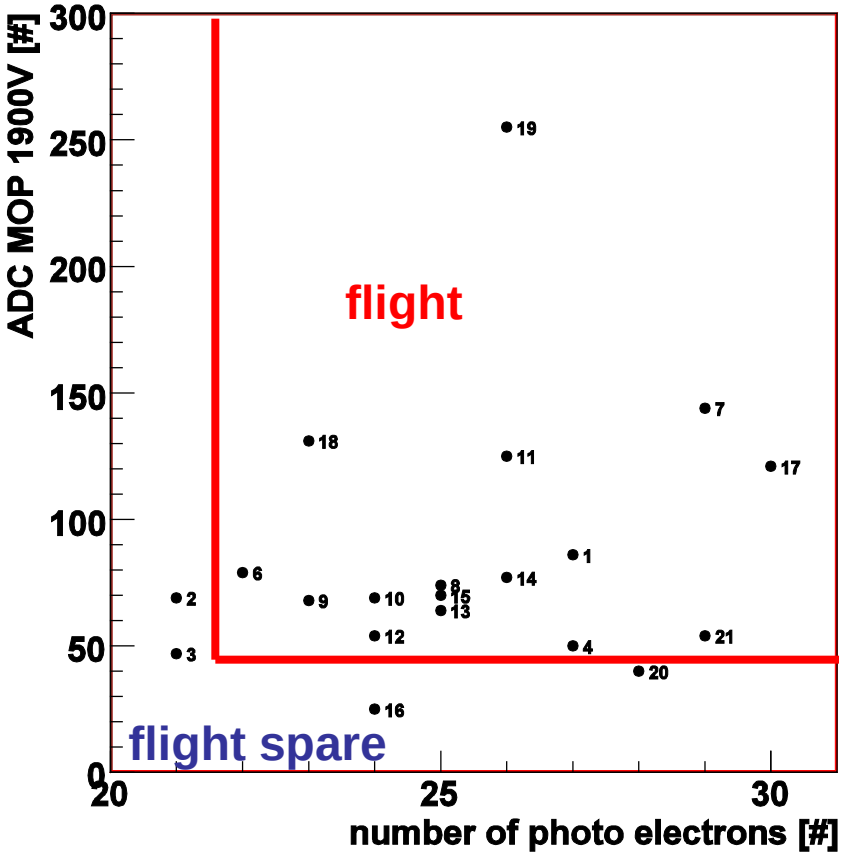
Test with atmospheric muons & pulsed LED-signals for 3 different PMT HVs

AMS02 ACC scintillation panel nr. 19





AMS02 ACC Photomultiplier (PMT): Results after Space Qualification Tests (TVT & Vibration)

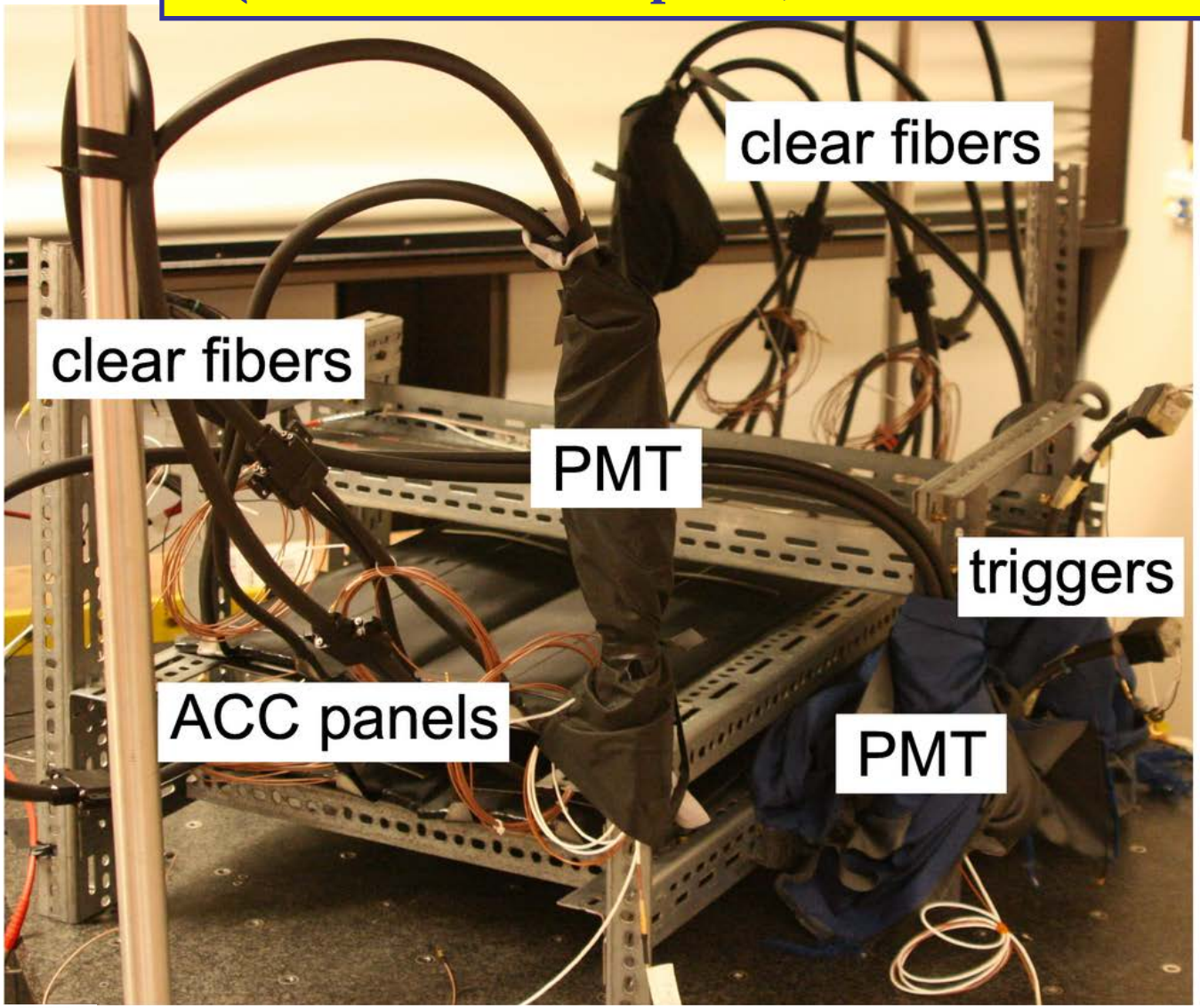


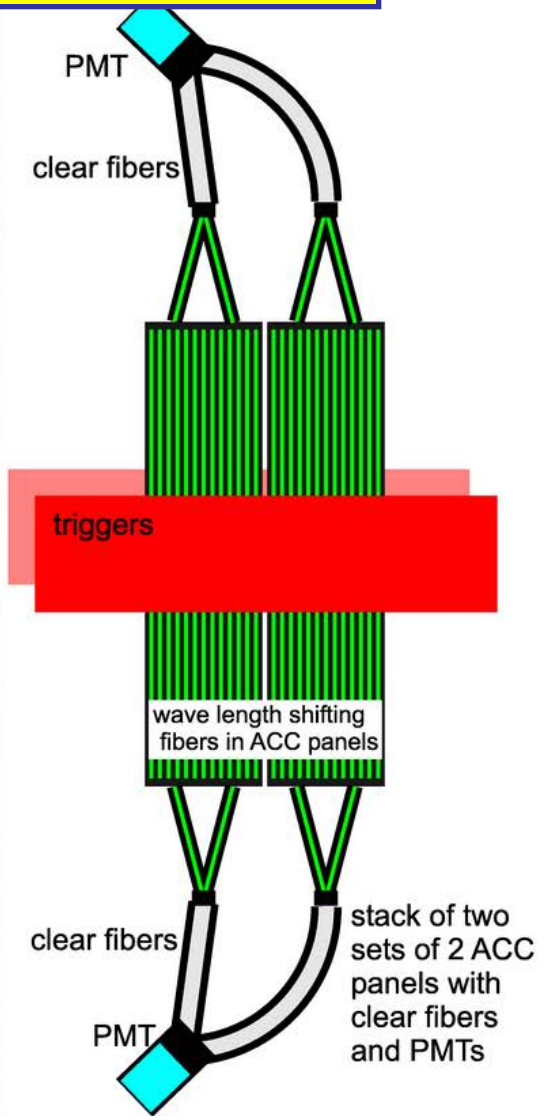
red: flight

blue: flight spare

PMT	MOP 1900V (adc counts)	number of photo electrons
1	86	27
2	69	21
3	47	21
4	50	27
6	79	22
7	144	29
8	74	25
9	68	23
10	69	24
11	125	26
12	54	24
13	64	25
14	77	26
15	70	25
16	25	24
17	121	30
18	131	23
19	255	26
20	40	28
21	54	29

AMS02-ACC System Test:
(FM scintillation panel, clear fiber cable and PMT)





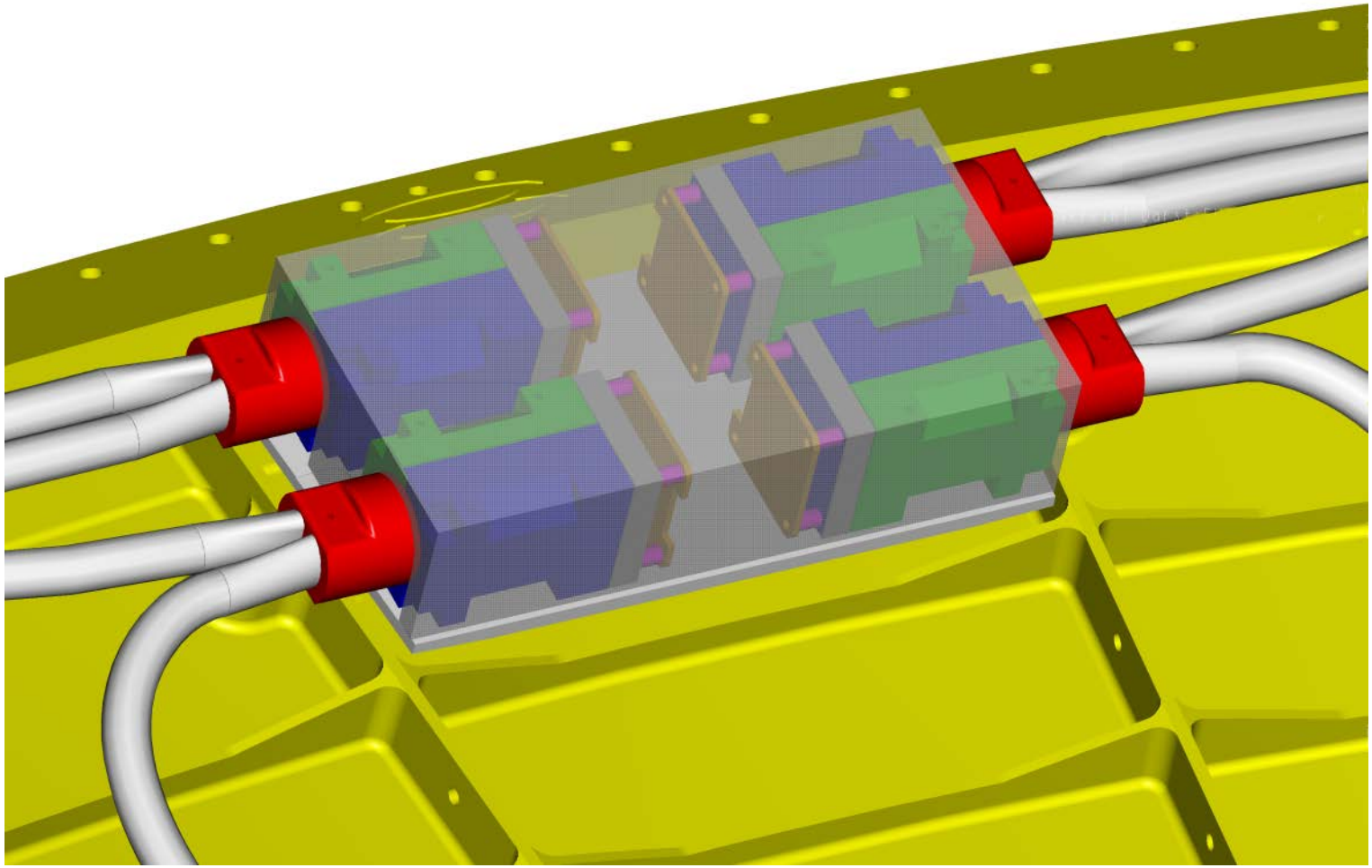
AMS02-ACC System Test Results: (FM scintillation panel, clear fiber cable and PMT)

Panel	Cable A	PMT A	MOP A 1900V (adc counts)	number of photo electrons A	Cable B	PMT B	MOP B 1900V (adc counts)	number of photo electrons B
13 12	18 short 18 long	19	127	15	7 short 7 long	7	70	13
19 16	2 short 2 long	18	76	14	11 short 11 long	11	60	16
5 4	1 short 1 long	1	46	17	17 short 17 long	17	69	18
9 7	8 short 8 long	8	44	16	6 short 6 long	6	53	14
11 14	15 short 15 long	15	44	16	3 short 3 long	14	45	16
10 6	10 short 10 long	10	44	16	9 short 9 long	9	41	15
8 15	13 short 13 long	13	43	17	14 short 14 long	21	33	17
18 20	12 short 12 long	12	37	17	4 short 4 long	4	36	17

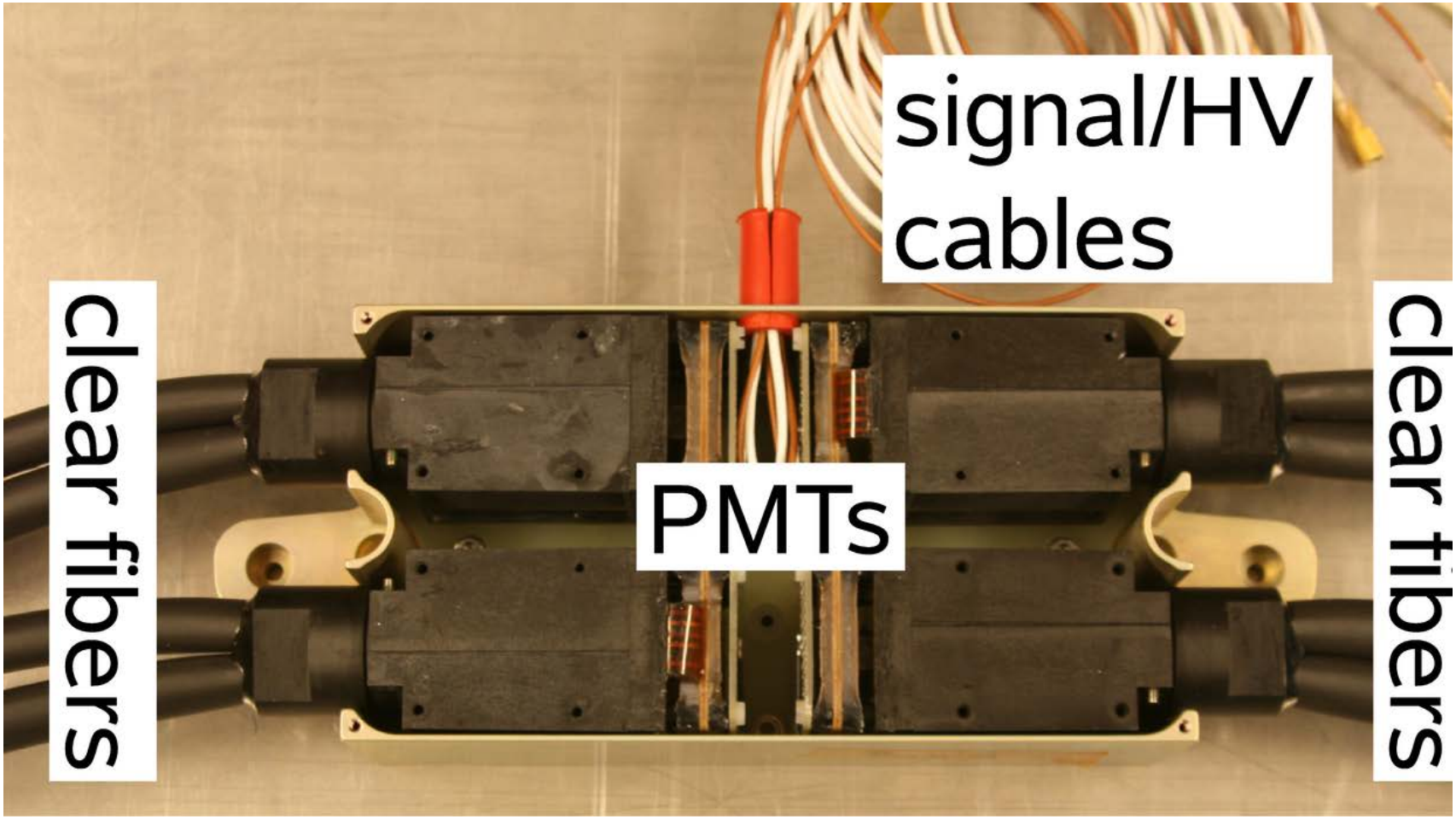
3 17	19 short 19 long	2	41	14	21 short 21 long	3	40	16

red: flight; blue: flight spare

ACC PMT: 4 Hamamatsu R5946 in Box

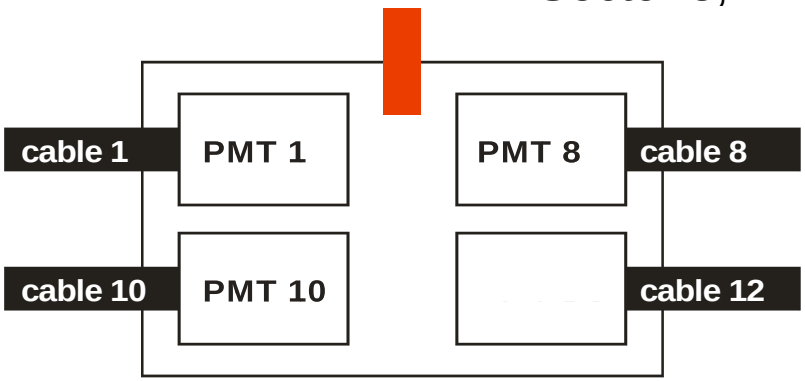


ACC PMT: 4 Hamamatsu R5946 in Box

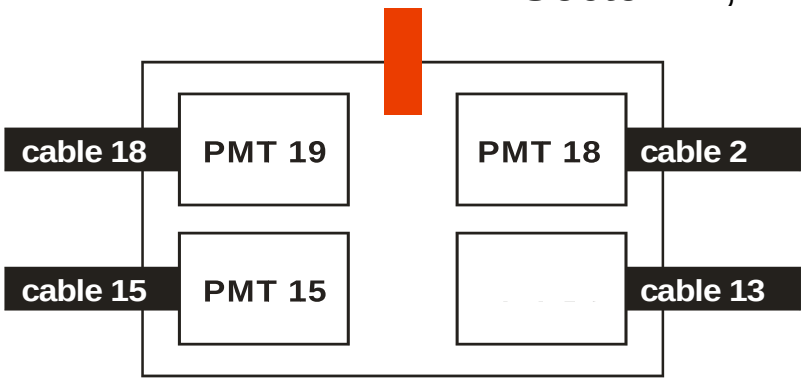


AMS02-ACC System Test Results: PMT Boxes: Order of PMTs and clear fiber cables

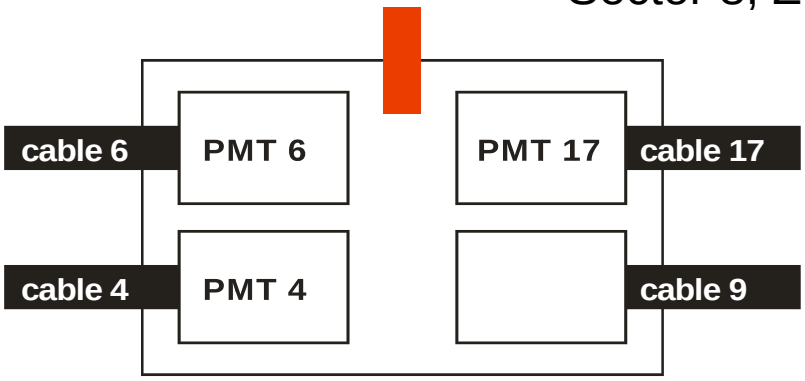
WAKE A TOP Sector 8, Z+



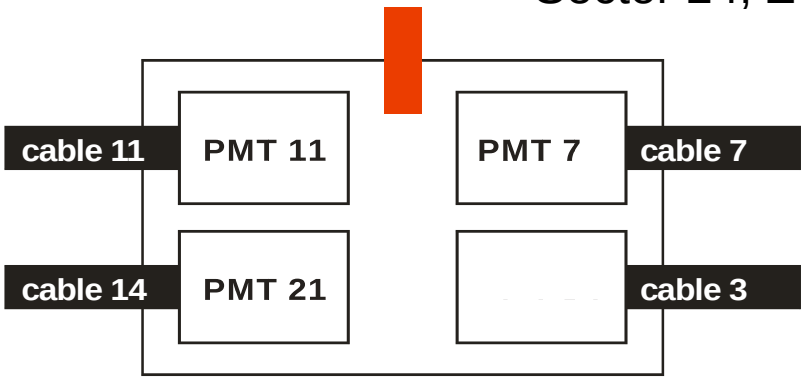
RAM A TOP Sector 24, Z+



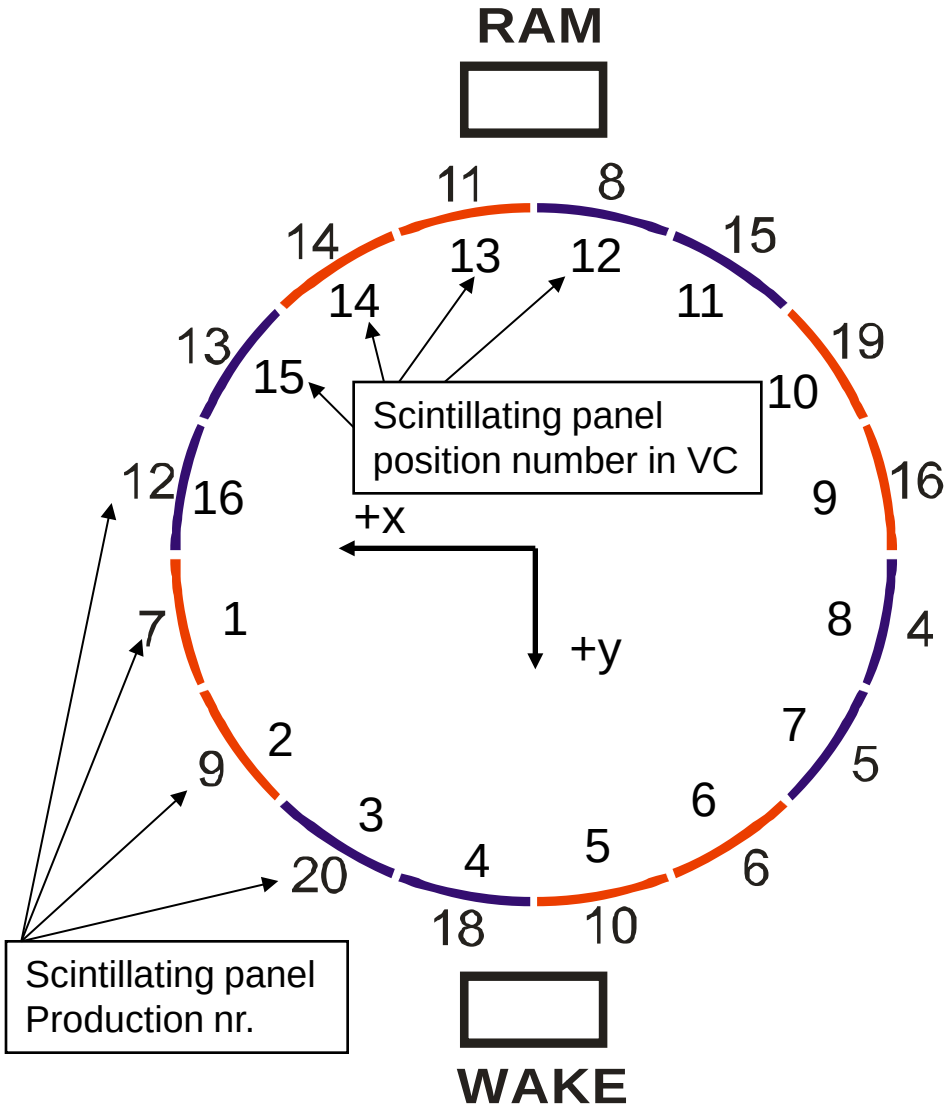
WAKE B BOTTOM Sector 8, Z-



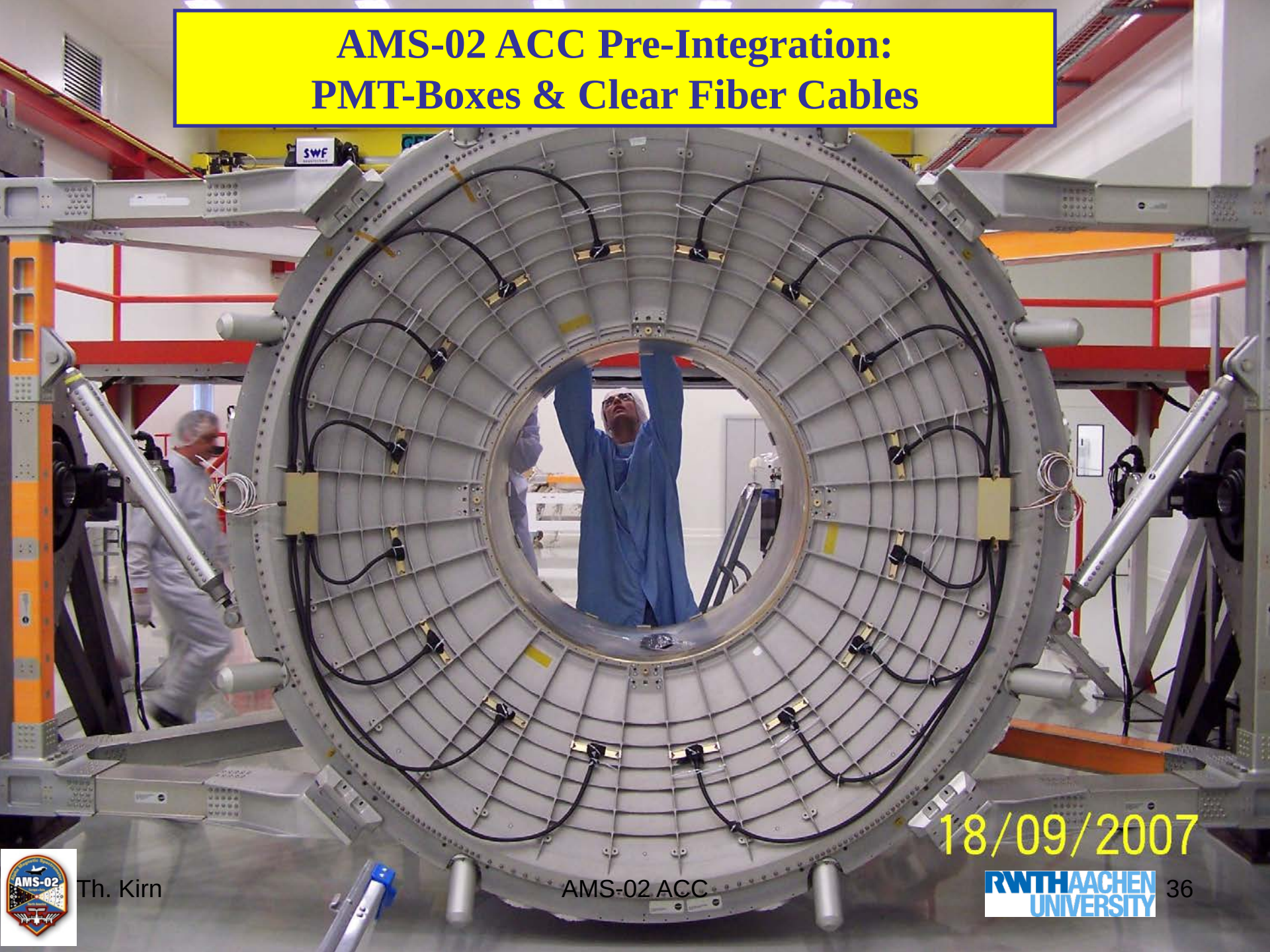
RAM B BOTTOM Sector 24, Z-



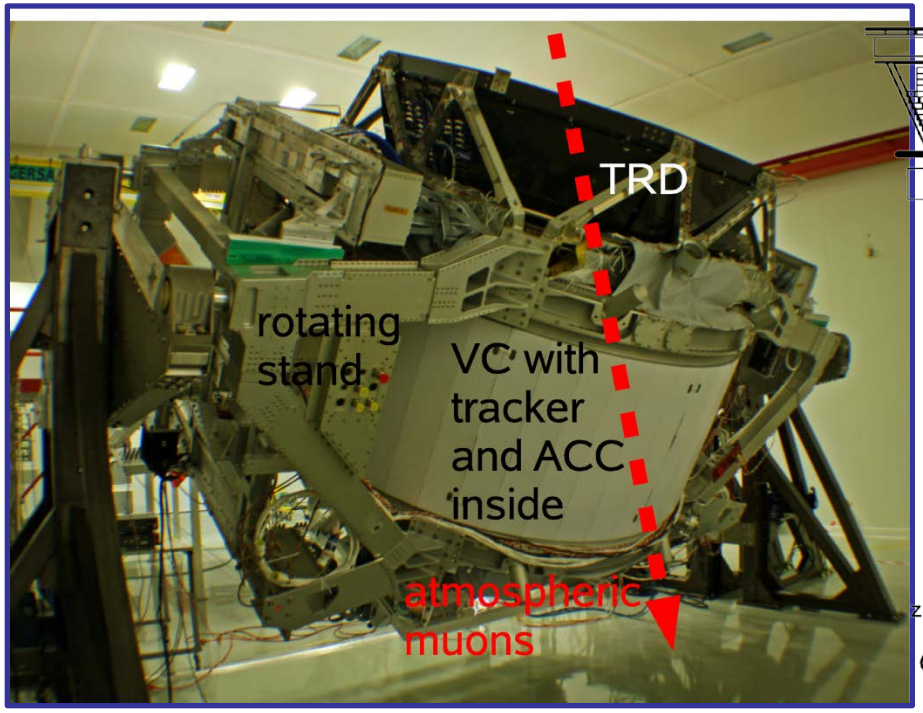
AMS02-ACC System Test Results: Positioning of scintillation panels

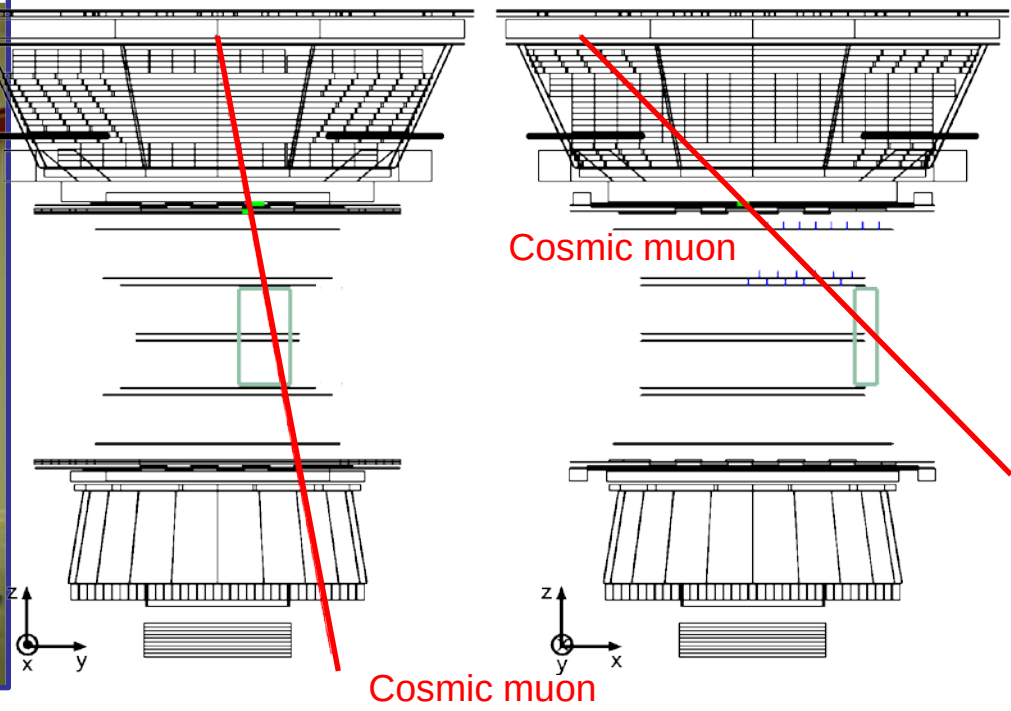


AMS-02 ACC Pre-Integration: PMT-Boxes & Clear Fiber Cables



AMS-02 Pre-integration Data-taking with Cosmic Muons



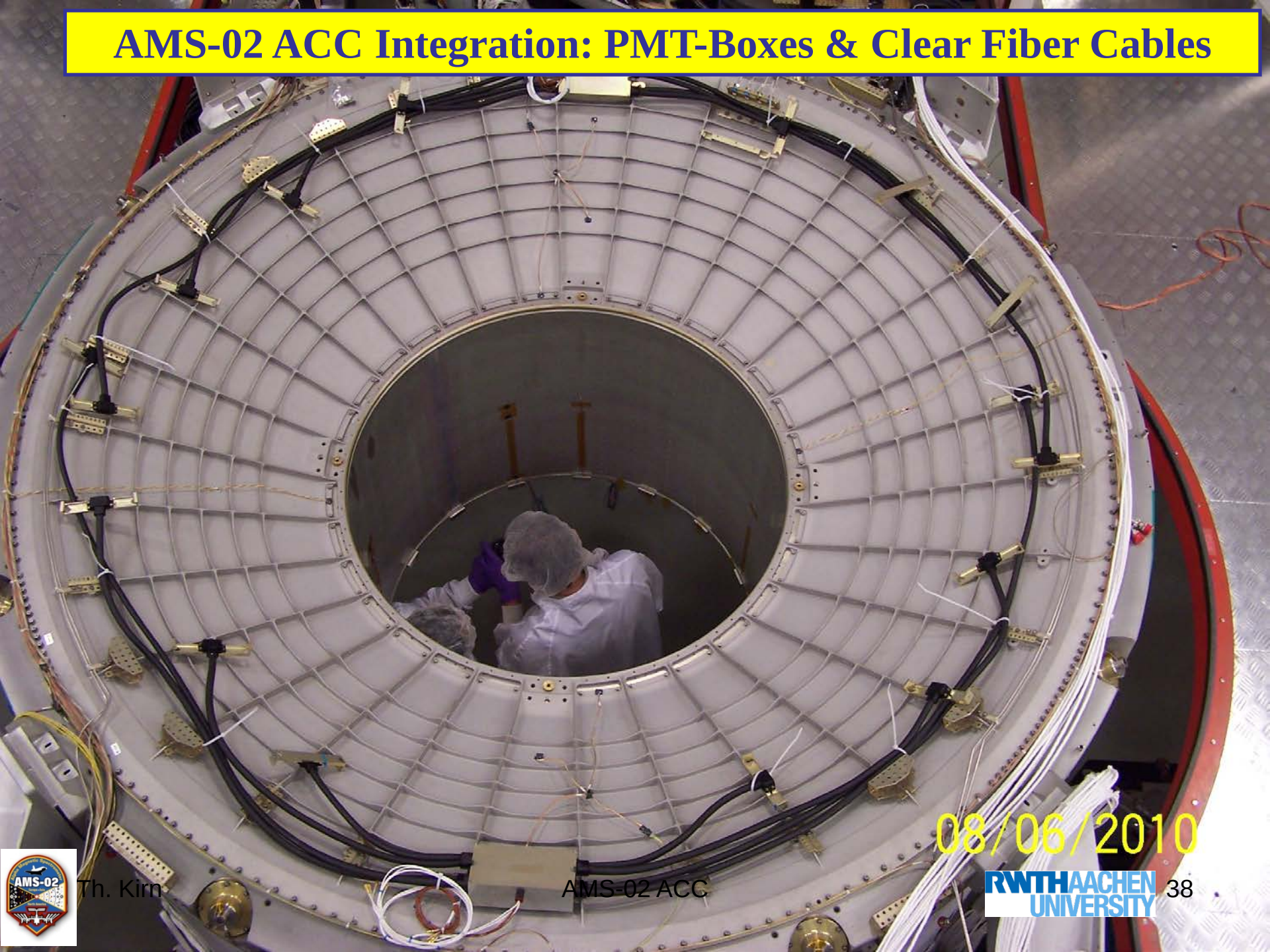


Inefficiency study of ACC with TRD and tracker tracks:

Extrapolate clean single tracks and determine ACC inefficiency as function of position!

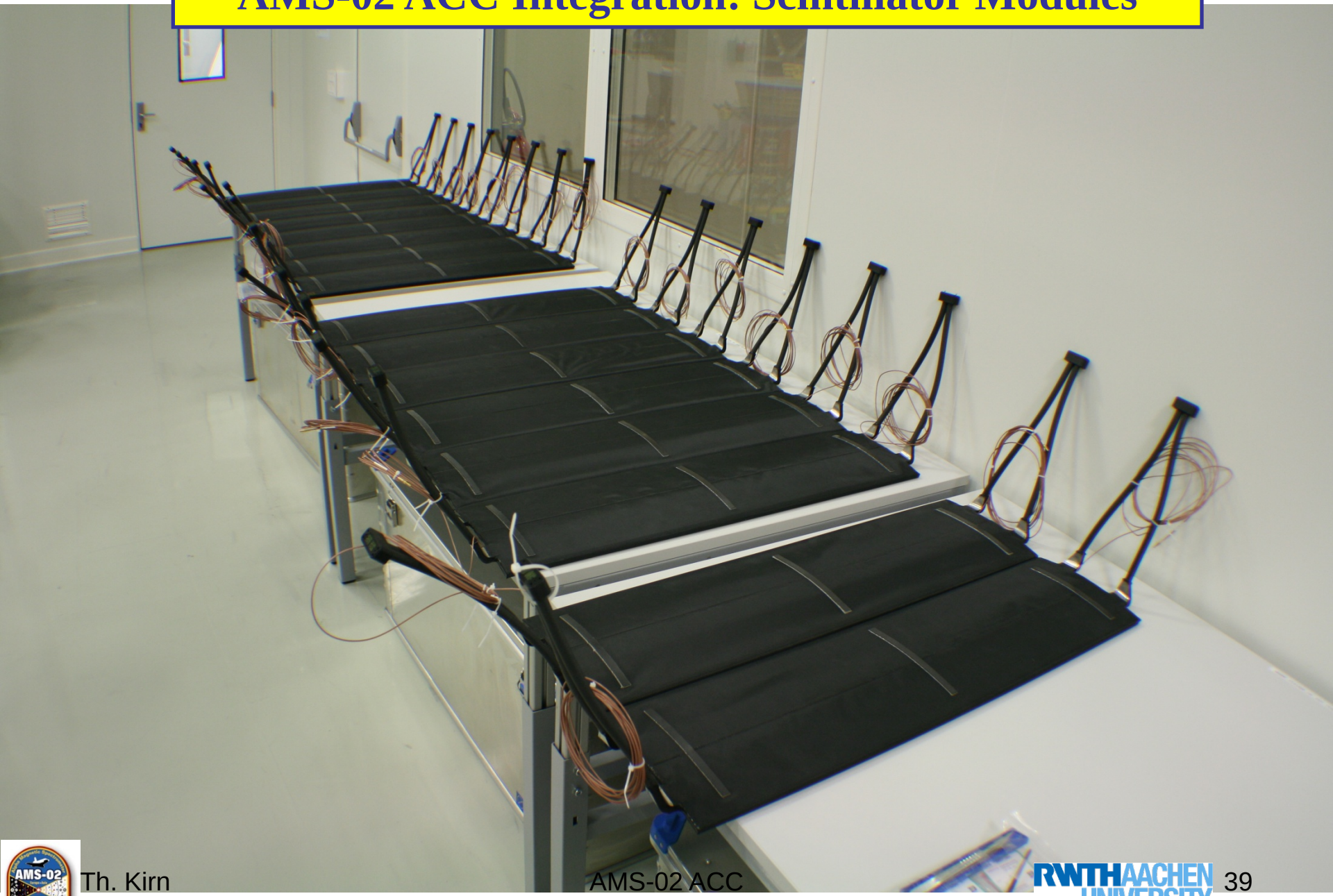
→ **Inefficiency = $1.5^{+2.3}_{-1.1} \cdot 10^{-5} < 0.9999$**

AMS-02 ACC Integration: PMT-Boxes & Clear Fiber Cables

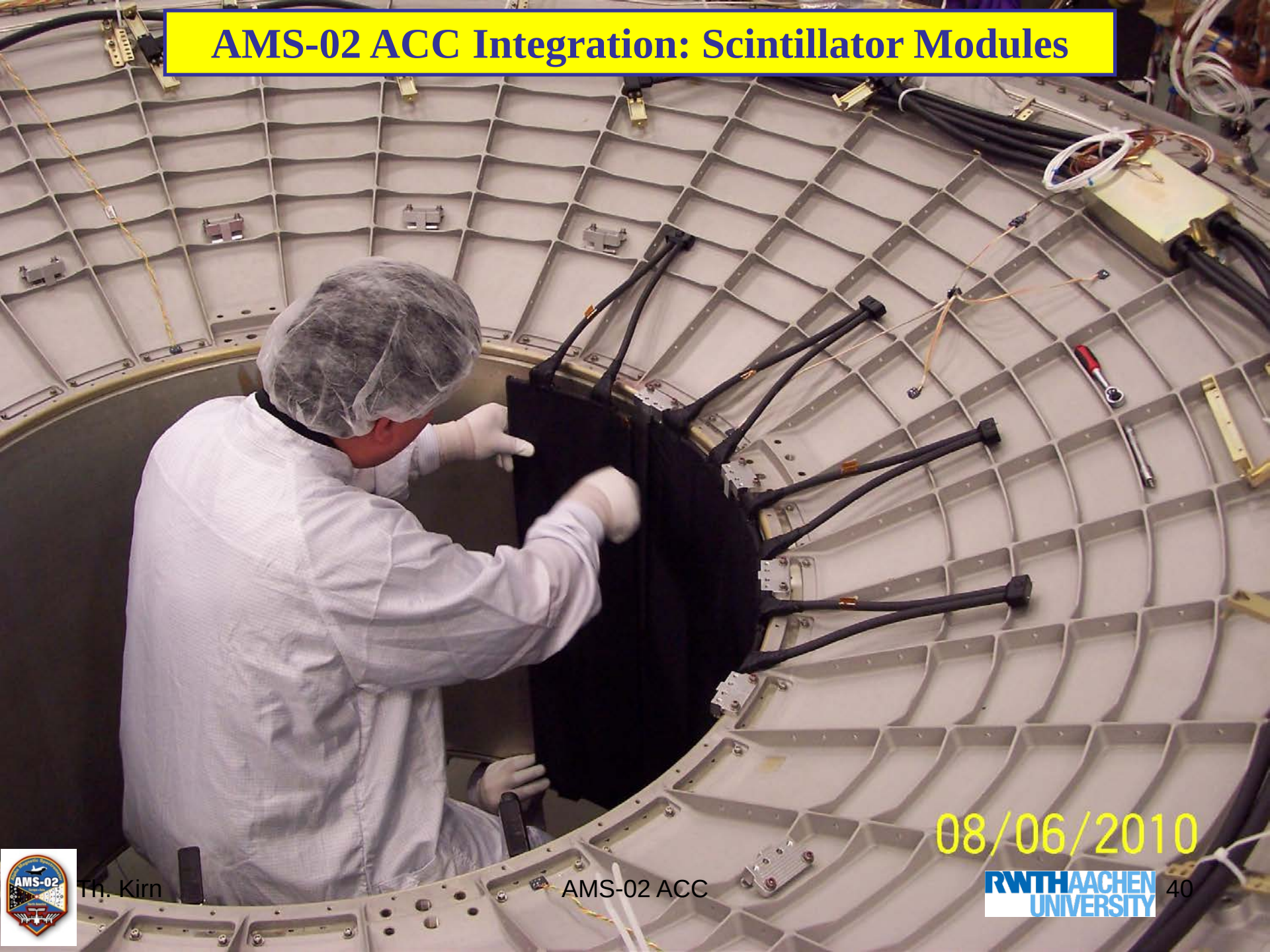


08/06/2010

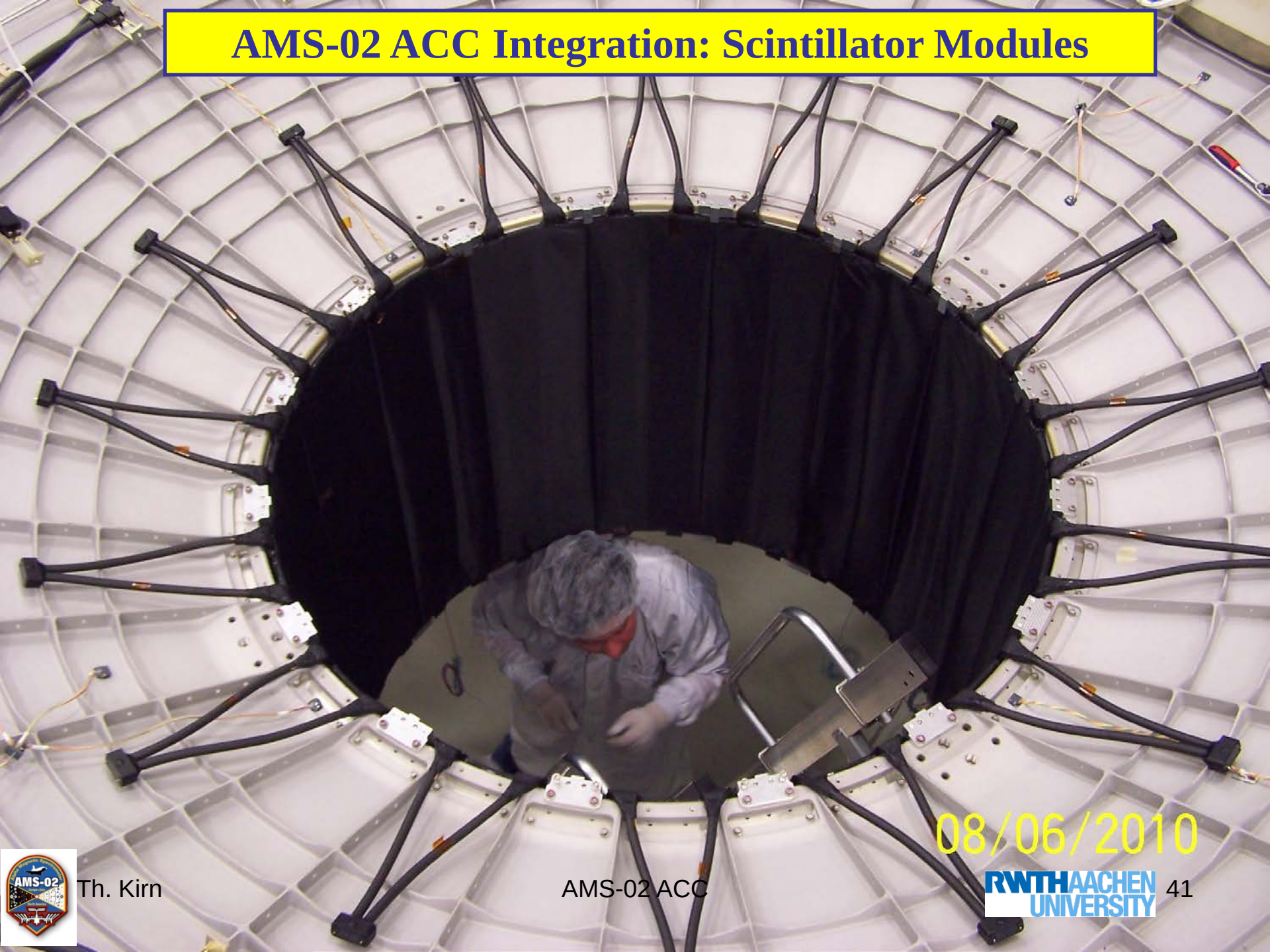
AMS-02 ACC Integration: Scintillator Modules



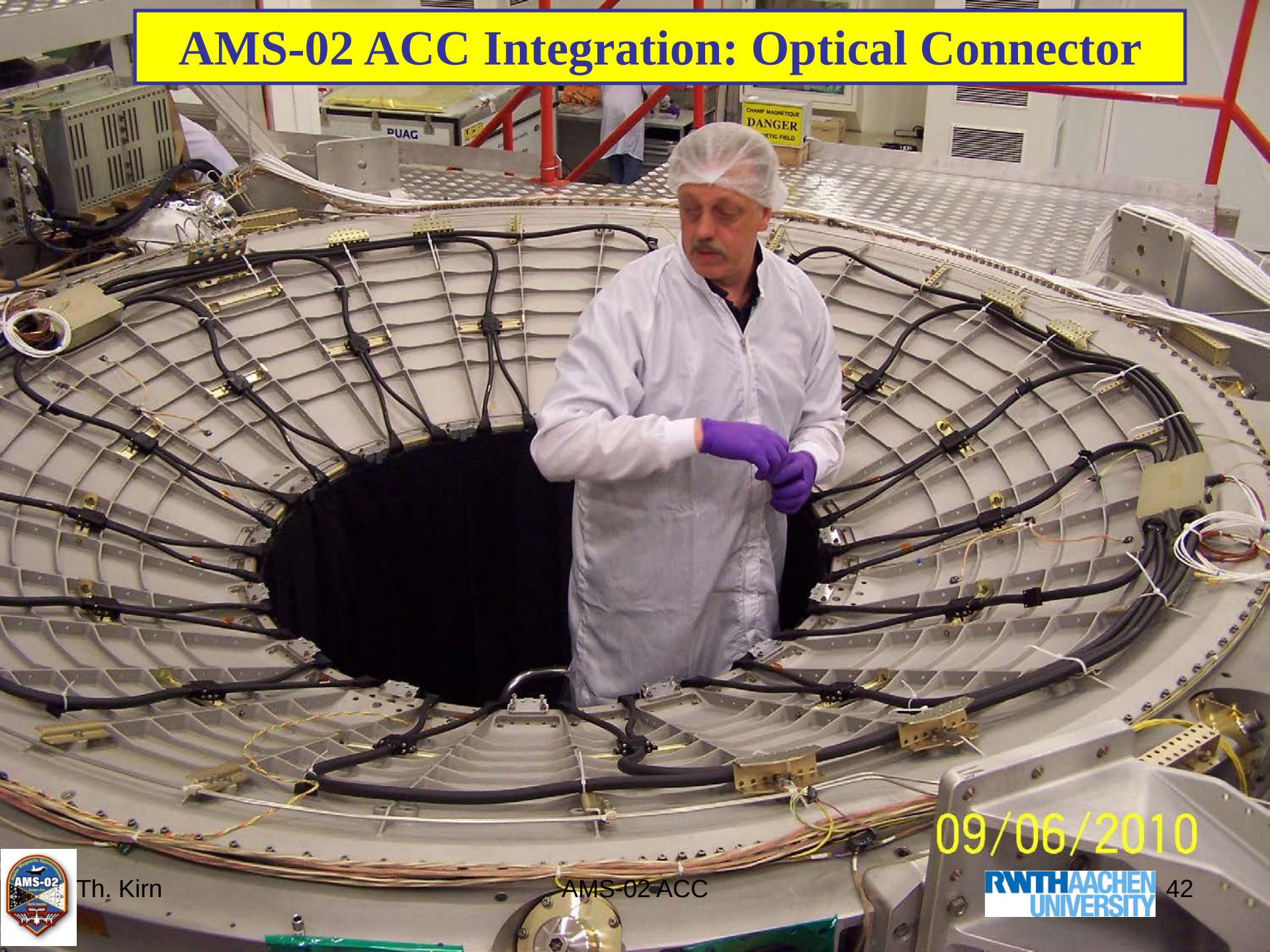
AMS-02 ACC Integration: Scintillator Modules



AMS-02 ACC Integration: Scintillator Modules

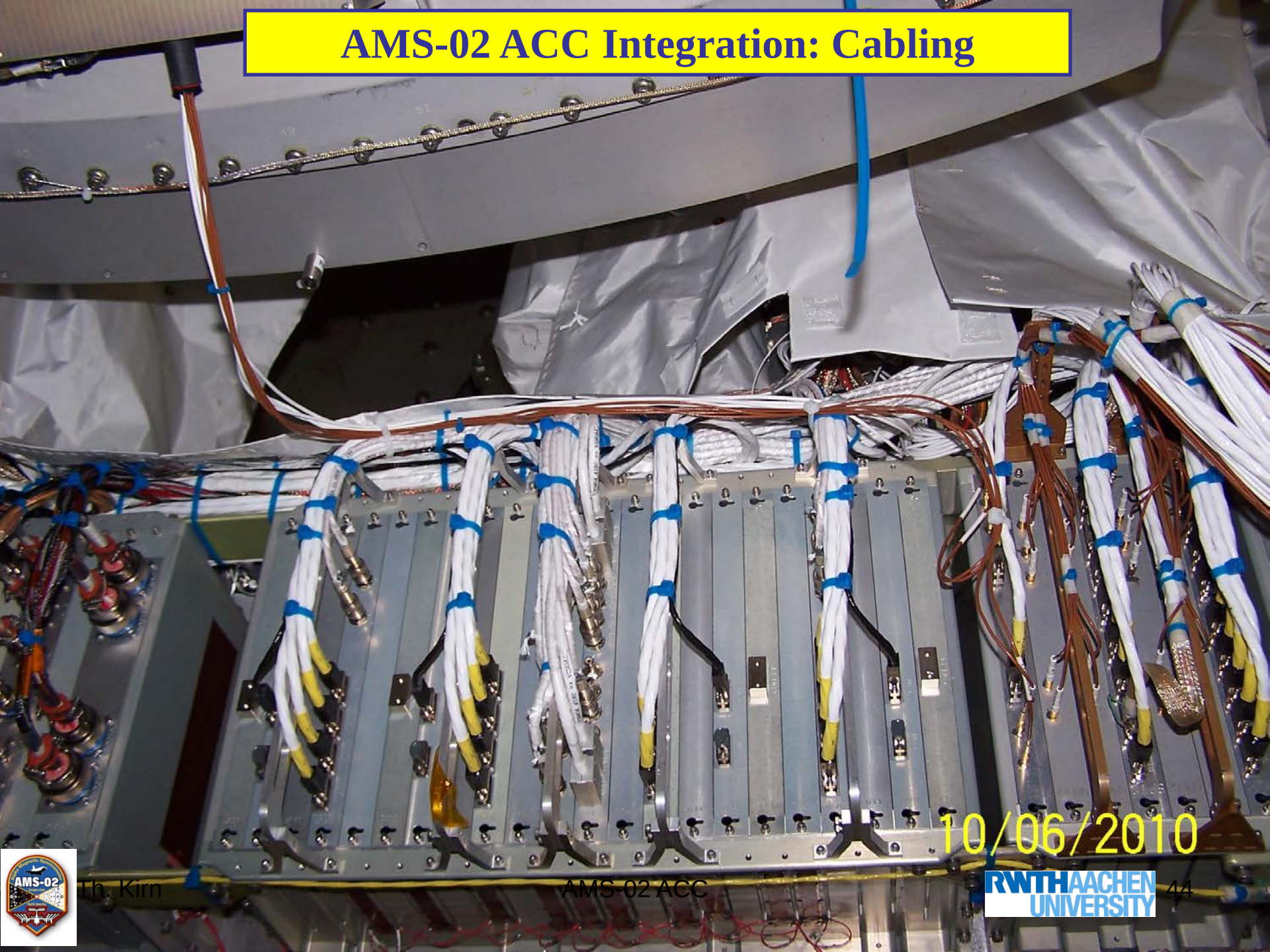


AMS-02 ACC Integration: Optical Connector

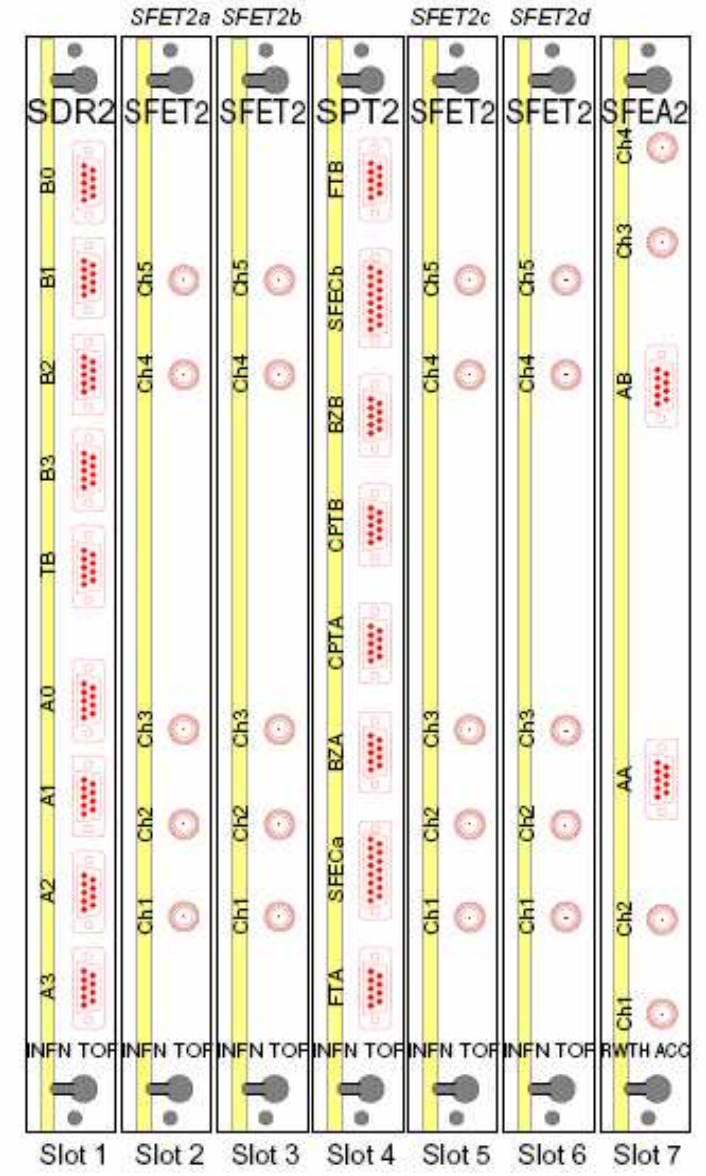


AMS-02 ACC Integration: Support Cylinder

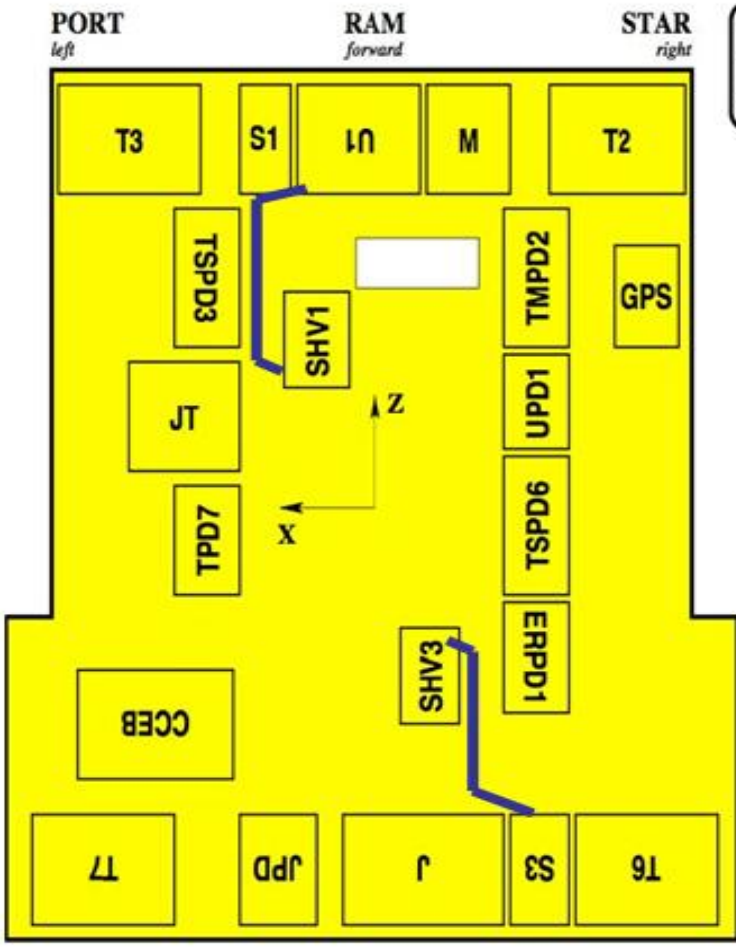
AMS-02 ACC Integration: Cabling

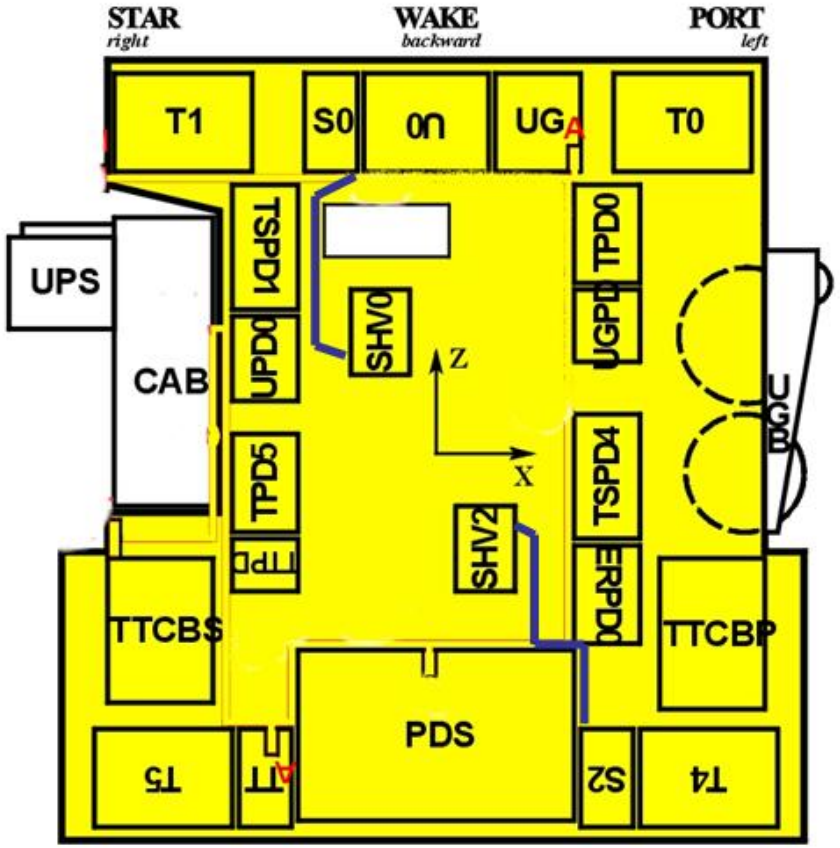


AMS-02 ACC Readout

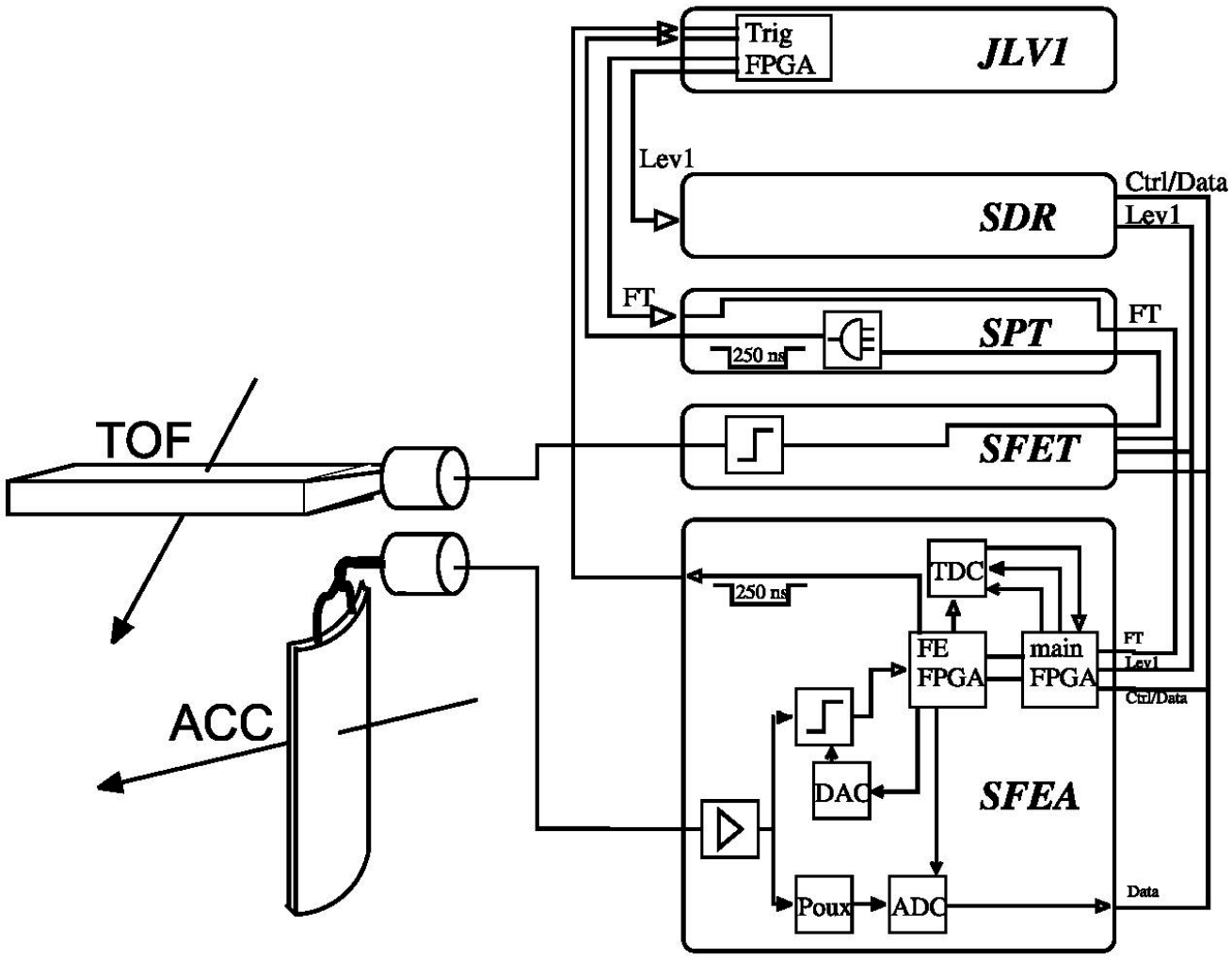


AMS-02 ACC Readout

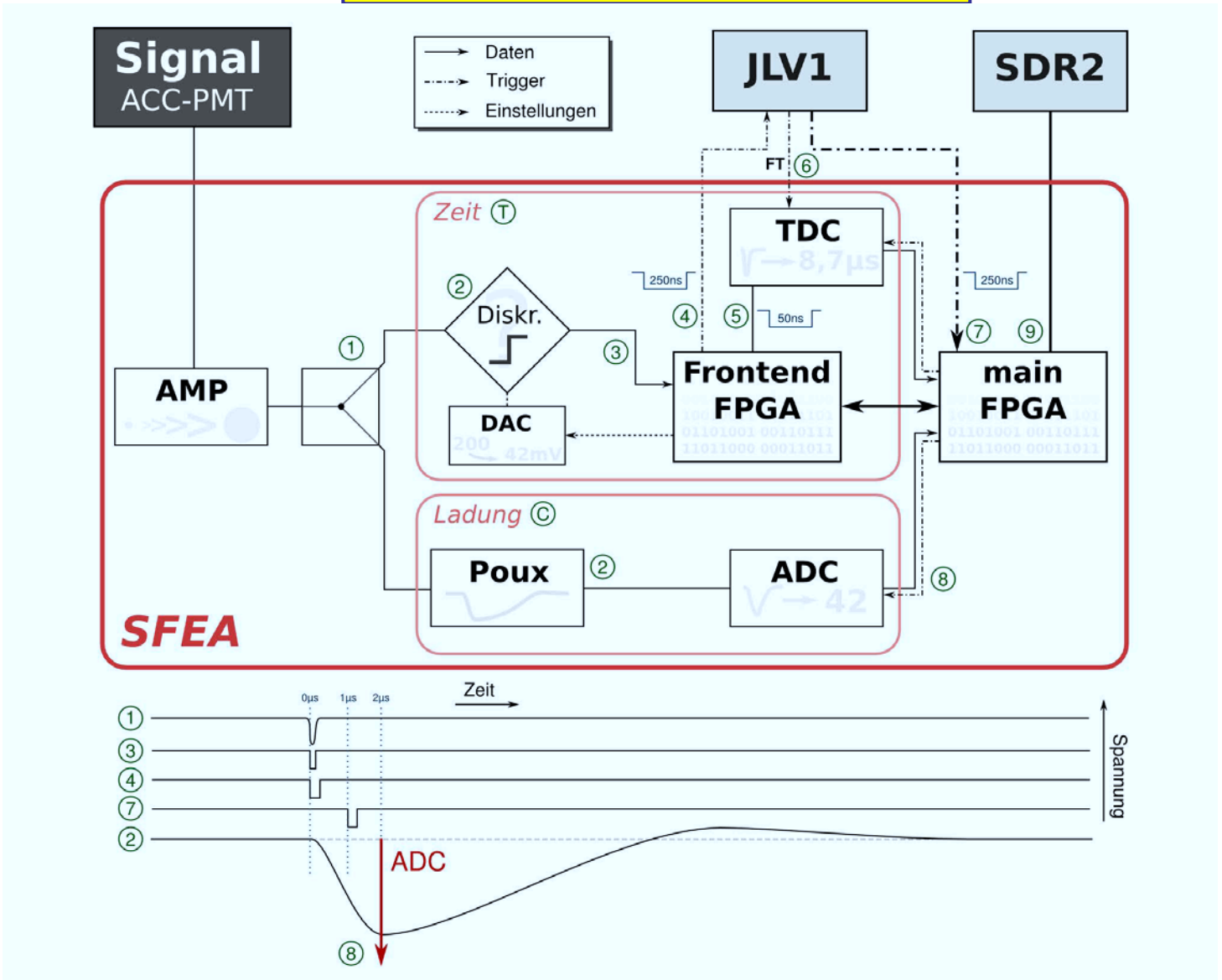




AMS-02 ACC Readout



AMS-02 ACC Readout

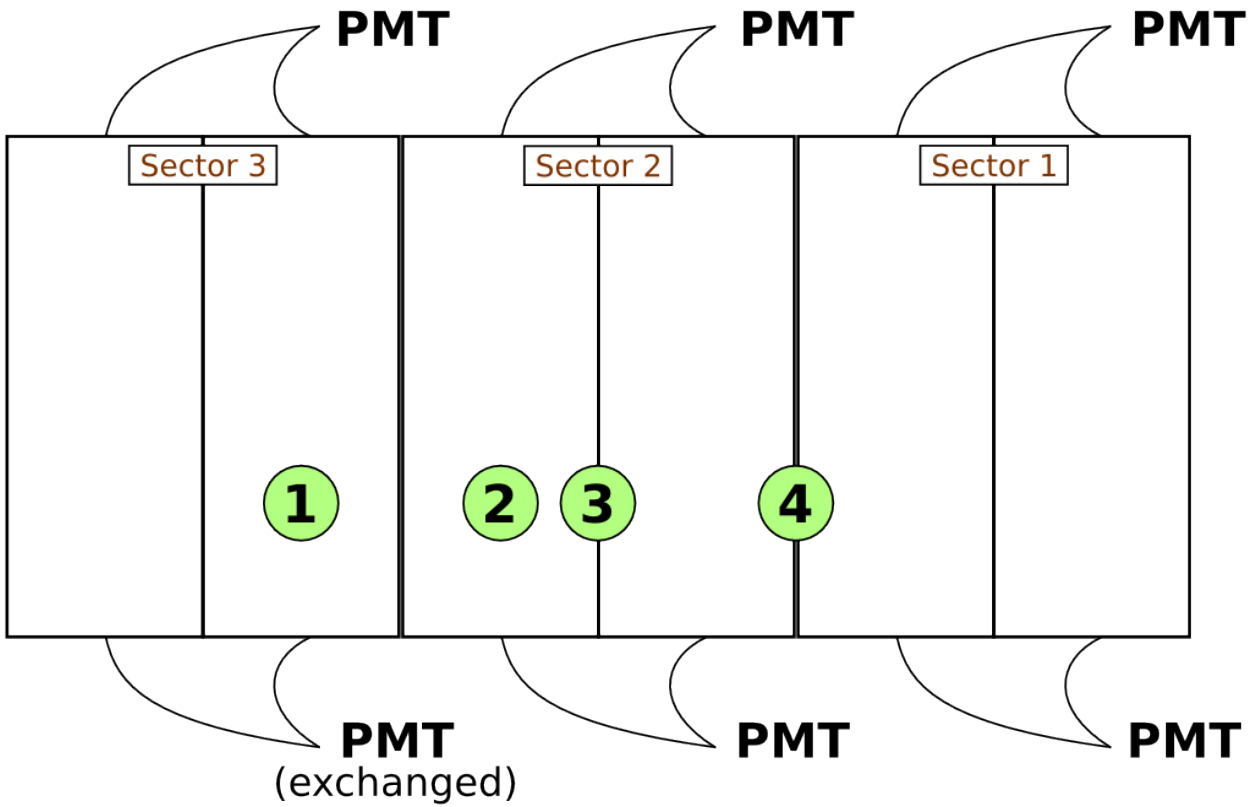


AMS-02 ACC Integration done

AMS-02 – Test Beam H8 CERN

AMS-02 ACC: Inefficiency Measurement in Test Beam

2010 August Testbeam Configuration



180 GeV proton-beam

Ø beamspot: ~ 3 cm

4 positions for ACC-test

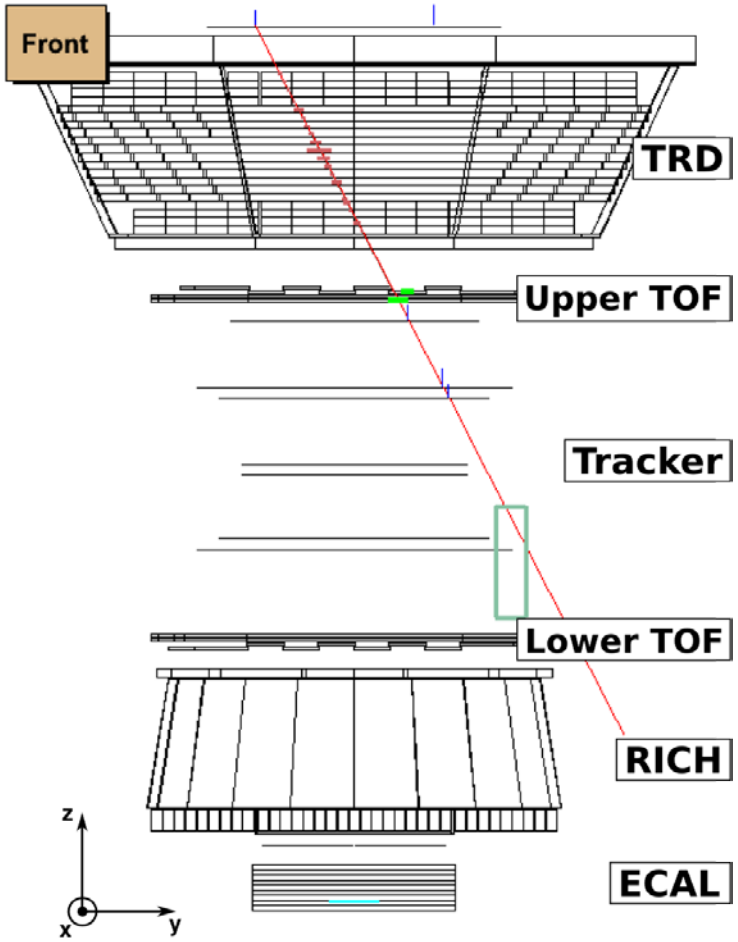
(1) panel (8mm thickness), exchanged PMT (3) slit region (2x4mm thickness), shared PMT

(2) panel (8mm thickness), original PMT (4) slit region (2x4mm thickness), separate PMT

AMS-02 ACC: Inefficiency Measurement in Test Beam

Event Selection

Requirements:	7661060
- Trigger from Upper TOF	5310522
- Single reconstructed TRD-Track	2994861
- TRD-Track matching beam config.	705926
- matching TOF-hit positions	**528643**
- min. 2 matching TrCluster-hits on first 3 layers below TRD	415966
- linear fit / check for chi²	324826
- track predicts ACC-hit	322884



→ **322,884 events** after all cuts

AMS-02 ACC: Inefficiency Measurement in Test Beam

Dimensions

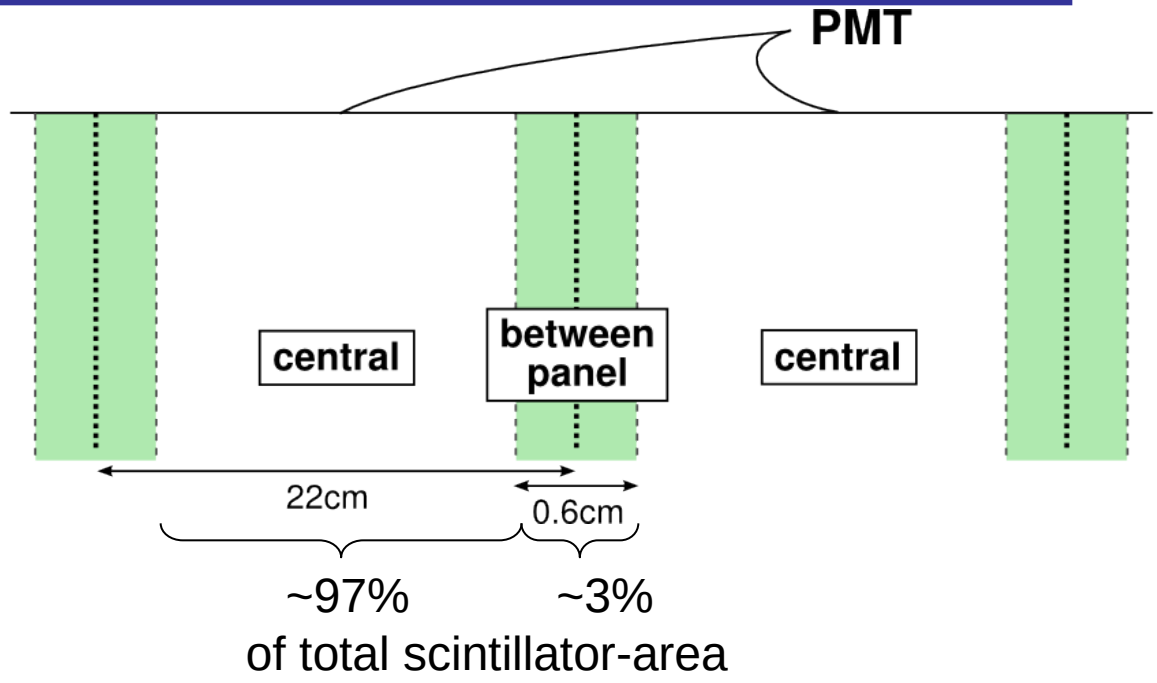
panel width: 22 cm

beamspot Ø: 3 cm

Slit region (nut & spring)

width of slit region

between panel: 0.6 cm



Inefficiencies

Panel (8 mm thickness):

$I < 1.90 \cdot 10^{-5}$

Slit region (2x4mm thickness), shared PMT:

$I < 3.17 \cdot 10^{-4}$

Slit region (2x4mm thickness), different PMT:

$I < 3.18 \cdot 10^{-4}$

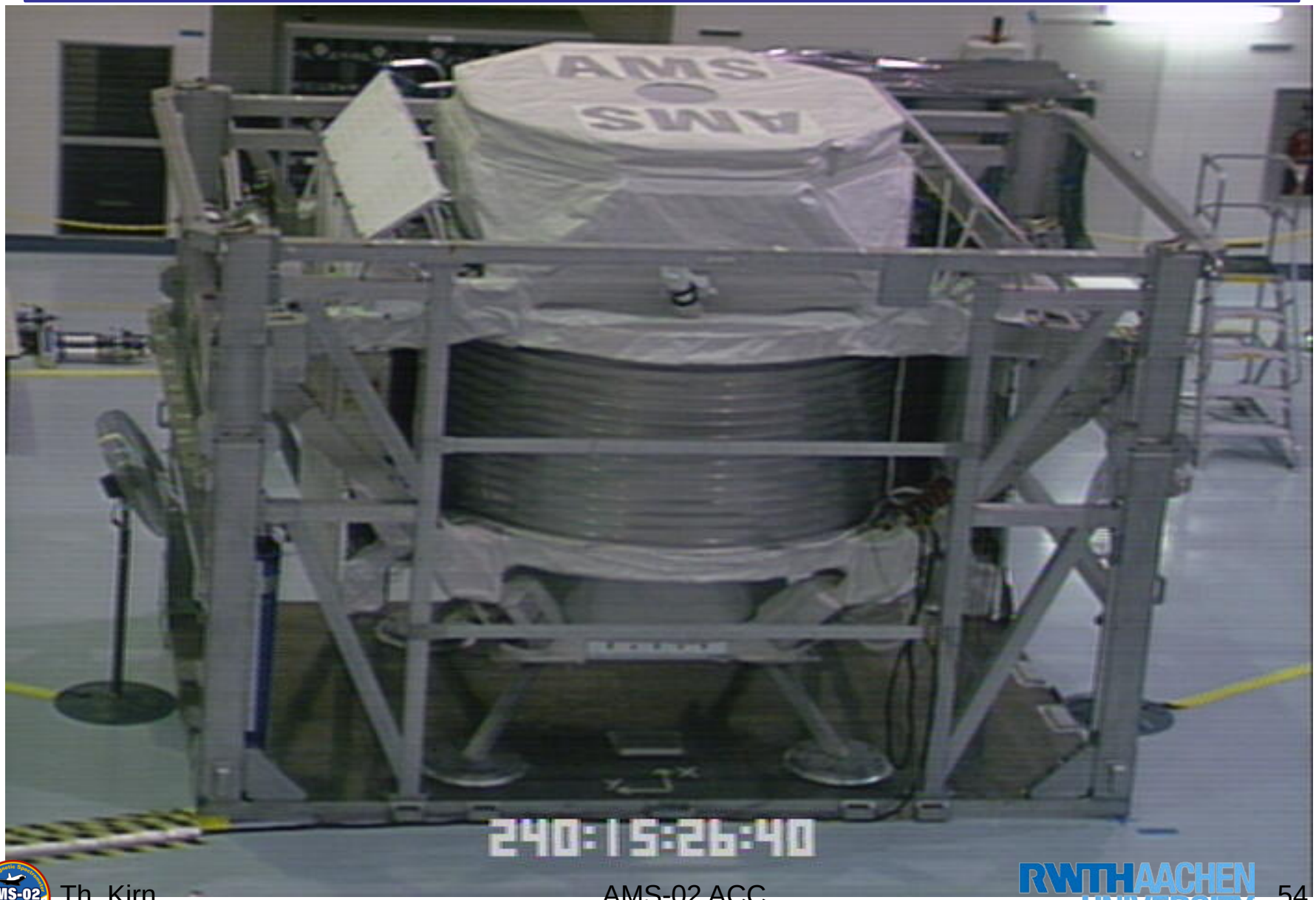
single inefficiencies weighted corresponding to area

ACC Inefficiency:

$I < 1.89 \cdot 10^{-5}$ (@ 95% CL)

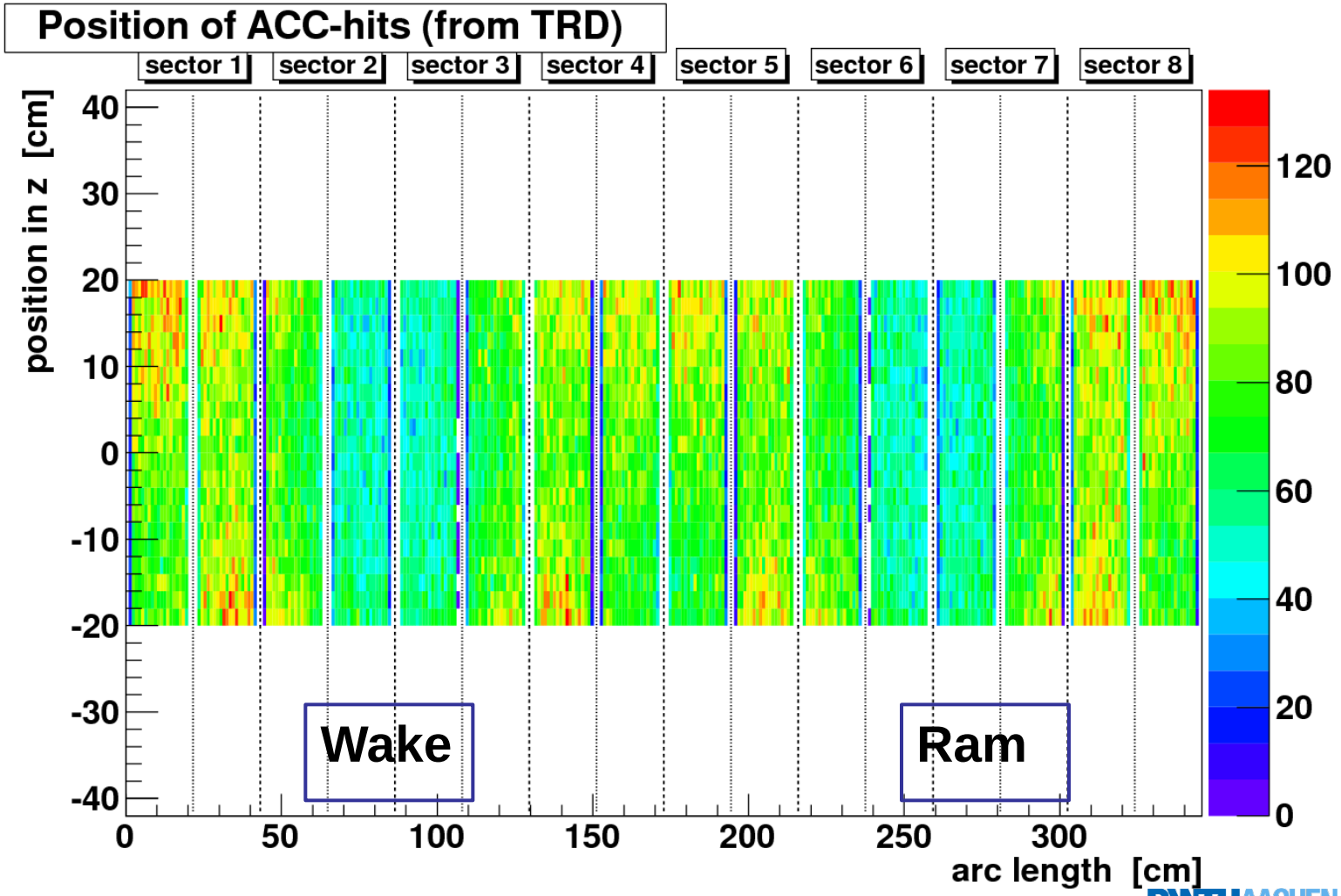
requirement: Idesign < 10-4

AMS-02: 2010 KSC Cosmic Data Period → ACC Stability

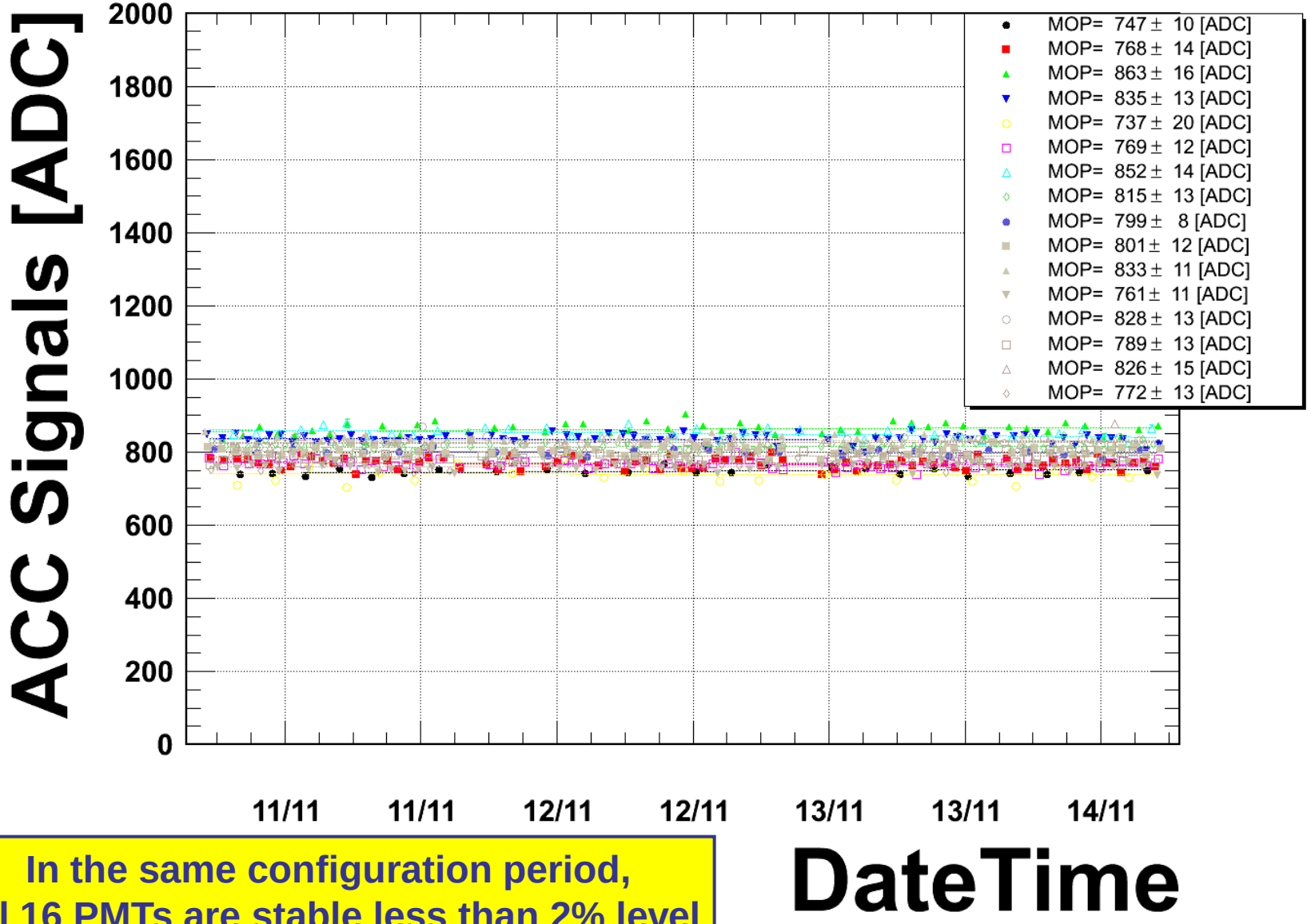


AMS-02 2010 KSC Cosmic Data Period

- TRD-track for prediction of ACC-hit
- only the center of panel is taken into account

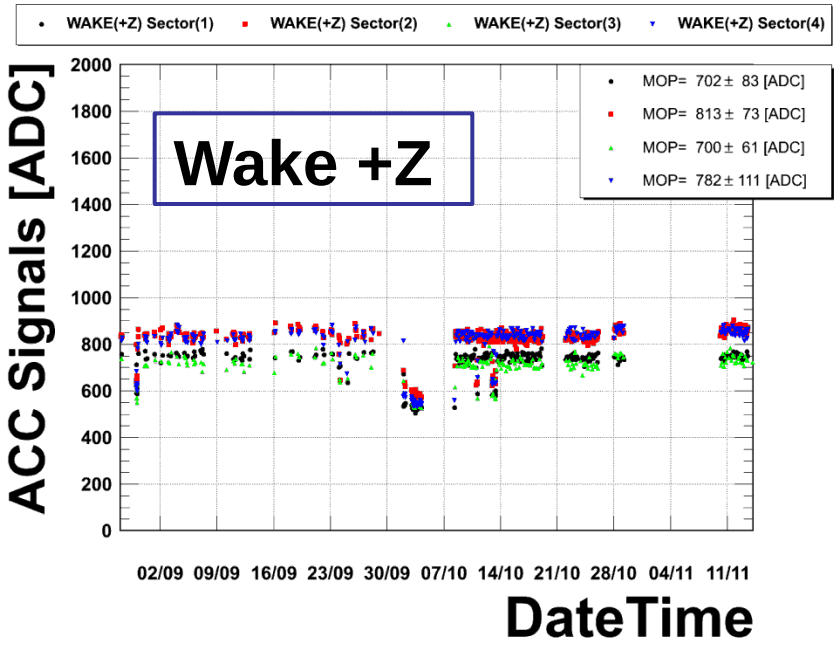


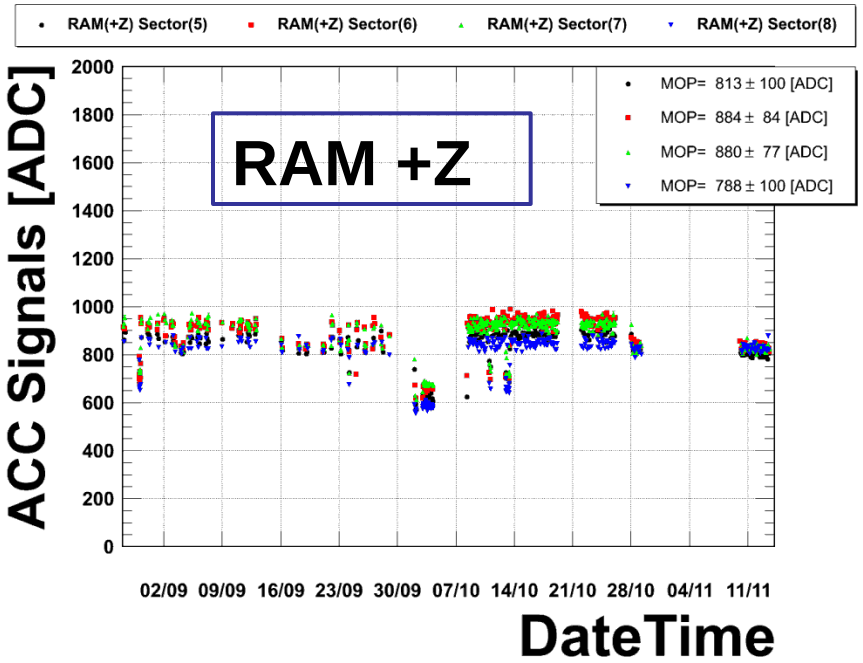
AMS-02 2010 KSC Cosmic Data Period

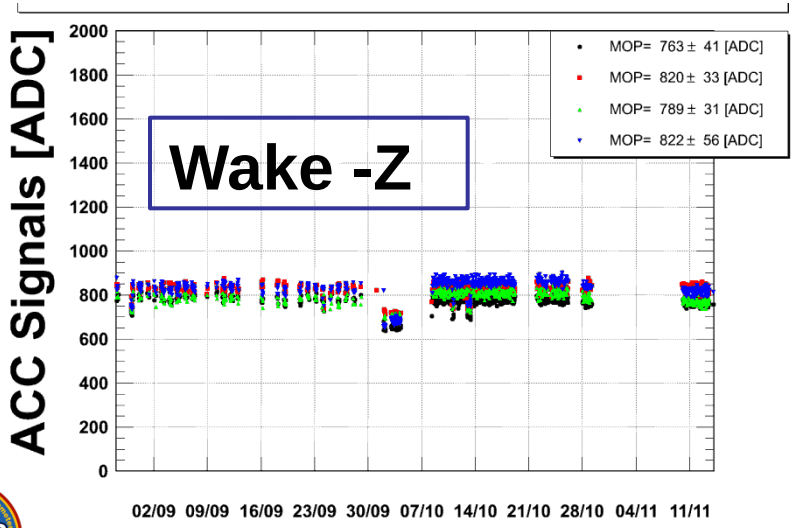


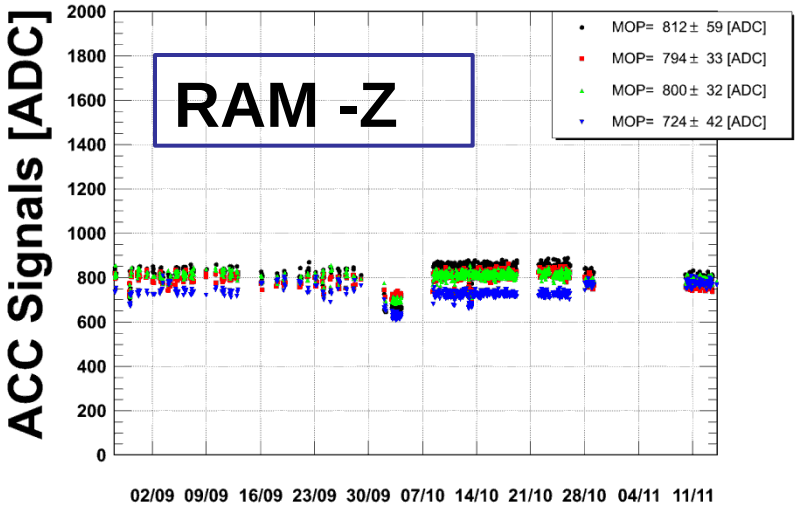
In the same configuration period, all 16 PMTs are stable less than 2% level

AMS-02 2010 KSC Cosmic Data Period





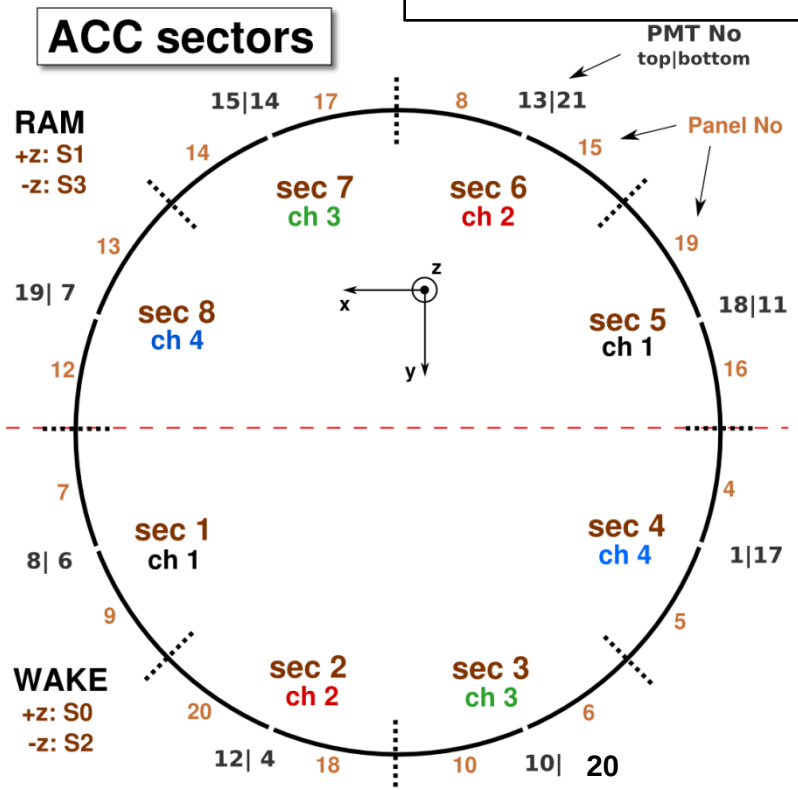




AMS-02 ACC
Slow Control and Data Monitoring

TRD/ACC/TAS-Standard Shift

ACC-System



- ACC is mounted inside PM surrounding inner tracker planes to serve as a veto.
- ACC consists of 8 cylindrical sectors with a radius of 55 cm from the center of Z-axis, 83 cm in height and readout by 16 PMTs. Each sector is composed of two scintillator panels optically linked to upper one and lower one PMT.
- Upper and Lower 4 x 4 PMTs are grouped and housed into 4 PMT boxes (2 x Wake ±Z, 2 x RAM ±Z) mounted on vacuum case.
- Charge threshold is set the same 25 ADC in all LT/HT/SHT values.
- Monitor calibration (pedestal and its width), configuration (HV, threshold, ..) and scaler from JLV1 status
- Monitor ADC and TDC during DAQ

TRD/ACC/TAS-Standard Shift

List of ACC Programms:

- ACC Status Monitor (ACC-S)
- ACC Slow Control Monitor (ACC-M)
- ACC Data Monitor (ACC-data-M)

TRD-ACC-TAS SHIFTER:
ACC Standard Monitoring Shift

- Check: ACC slow control data and data monitor (ACC-M, ACC-data_M)
- Check: ACC scaler rates, HV-settings, Temperatures in range (ACC-S)

Emergency Actions from Shifter **ASK for Commanding**

1. Temperature PMT-Box out of Range **LEAD: Turn ACC-HV off**
(Operational: -30 C

2. Scaler rate to high (>35000 outside SAA and polar regions)

3. Scaler rate zero -> HV off

-> cooperate with TOF-Shifter!

-> make an entry in E-Log: TOF
-> Phone ACC-expert!

ACC-Monitoring Program

1. ACC Status Monitoring (ACC-S)

Check HV, Temperature and Scaler with operating ranges

2. ACC Housekeeping Monitoring (ACC-M)

JLV1 Scaler, ACC Calibration (Ped, Width), ACC Configuration (HV, Trigger Threshold)

3. ACC Data Monitoring (ACC-data-M)

Charge signal mean and ist running median, TDC mean, Temperatures (SFEA2, PMT boxes, Veto trigger rate w.r.t LV1)

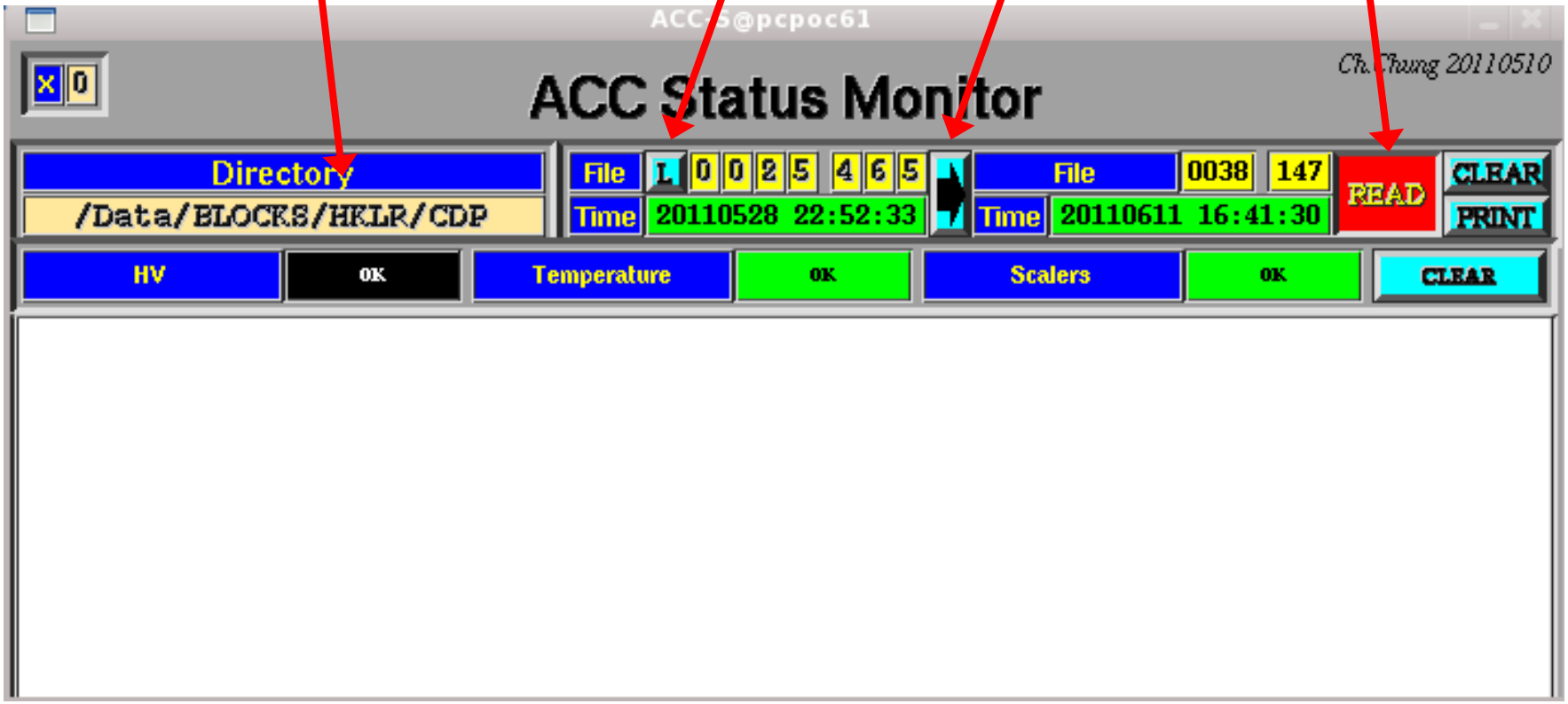
Configuration of ACC-S

Set Directory to
/Data/BLOCKS/HKLR/CDP

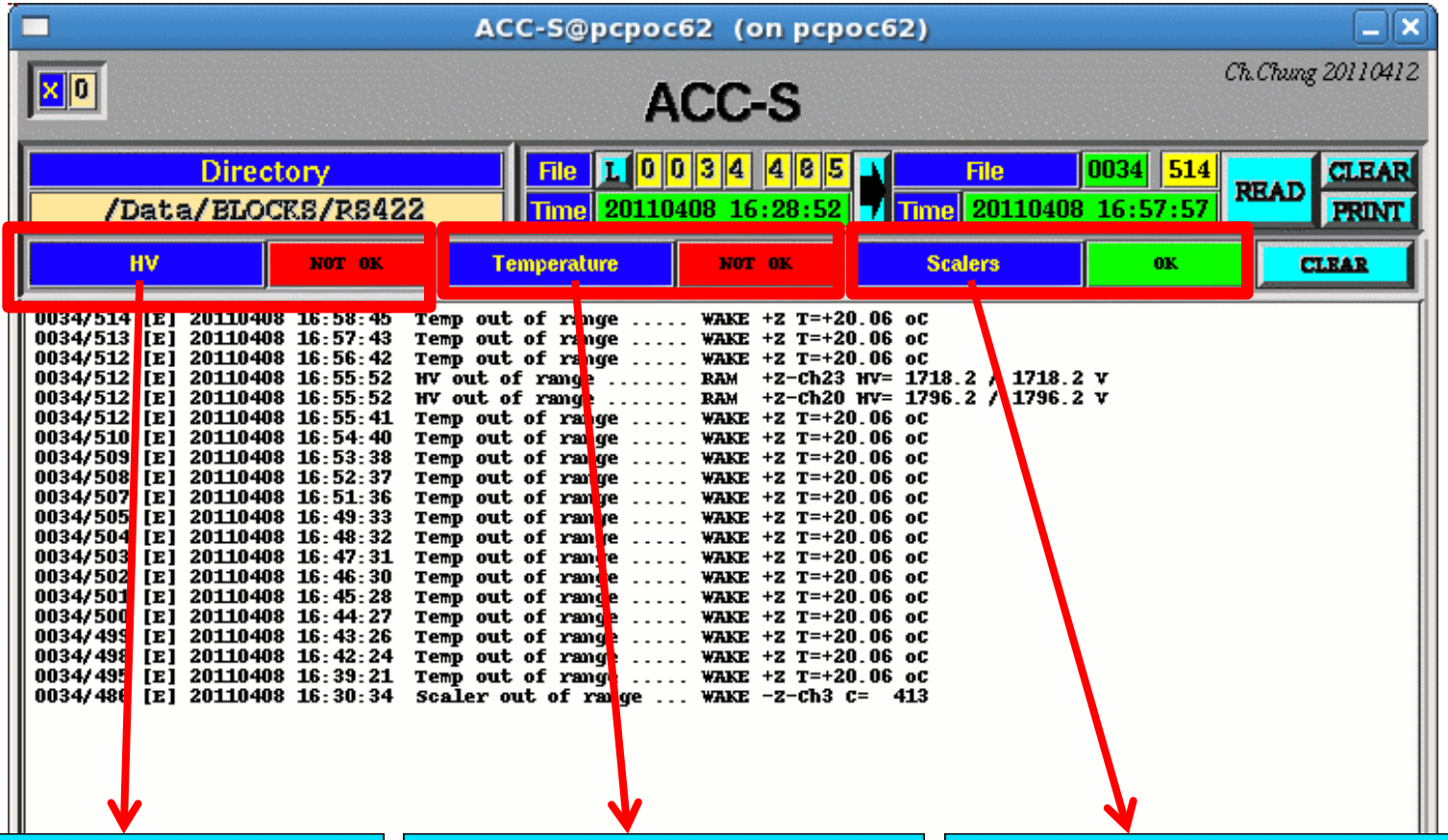
Find Last File
(left click on L)

Load for reading
(left click)

Read continously
(right click)



ACC-S



PMT HighVoltage
(16 PMTs)

Range = (1700 / 2300 V)

Temperature of PMT Box
(WAKE+,RAM+,W-,R-)

Range = (-30 / +45 °C)

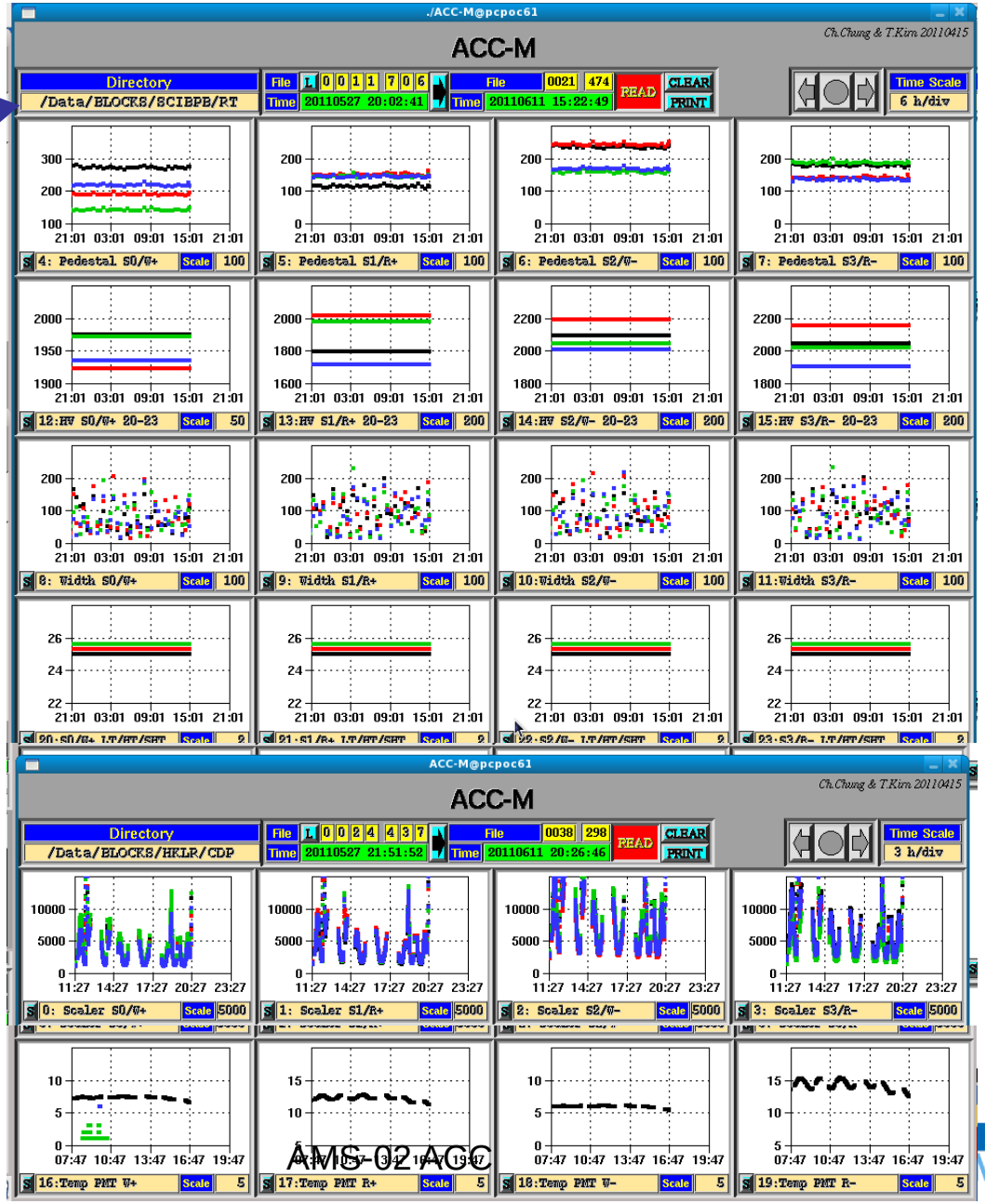
JLV1 Scaler
(16 PMTs)

Range = (10 / 400 cnt)

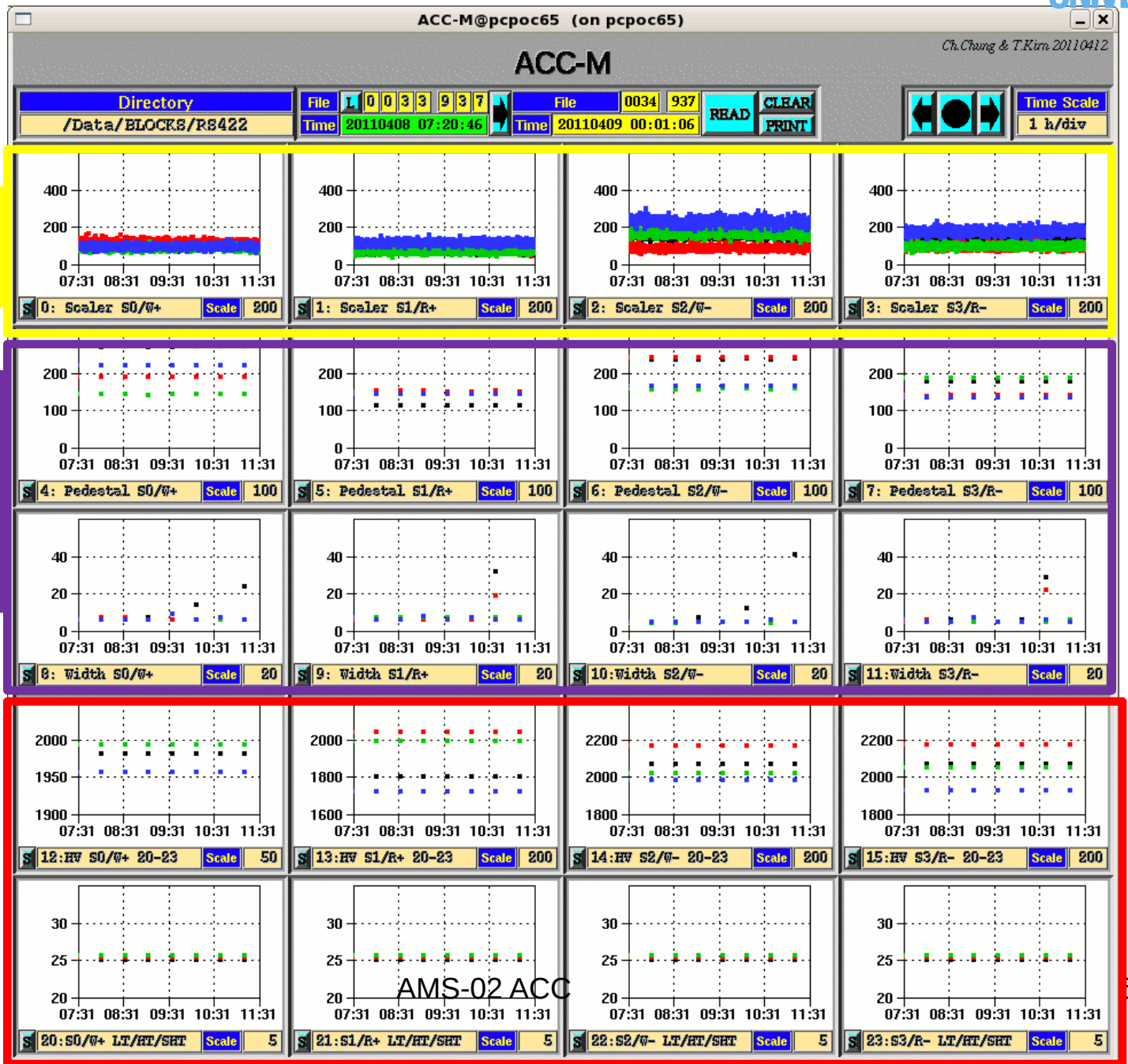
ACC-M

First ACC-M:
Set Directory to
/Data/BLOCKS/SCIBPB/RT

Second ACC-M:
Set Directory to
/Data/BLOCKS/HKLR/CDP



ACC-M



JLV1 Scaler
(DT=0x11)
DM

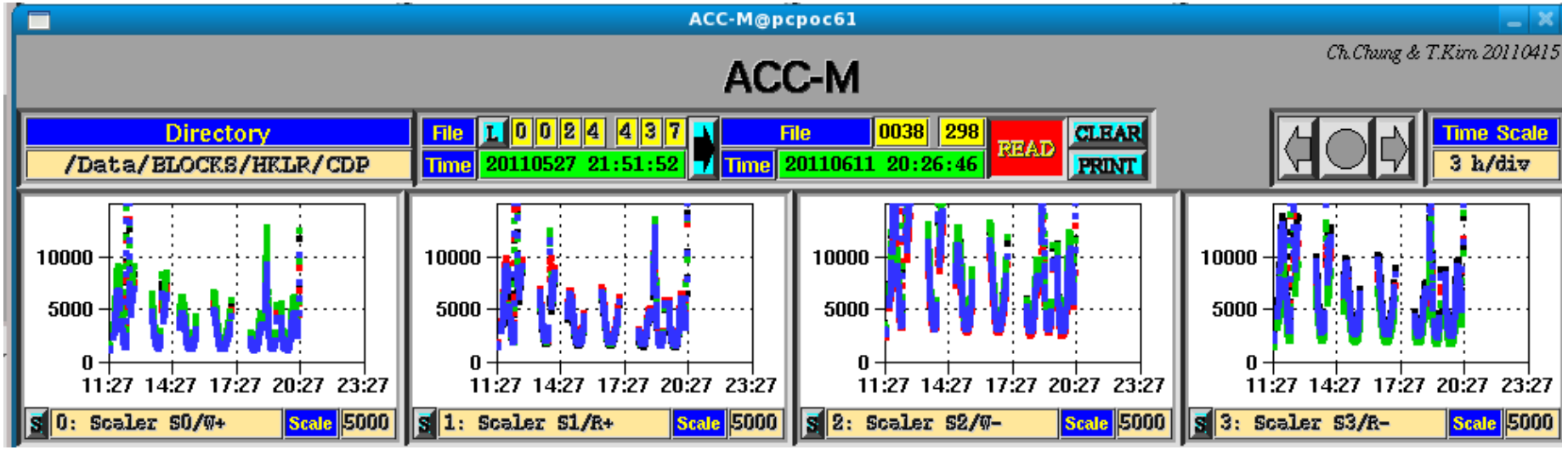
Calibration
(DT=0x13)
Pedestal / Width

SD Proc. Status
(DT=0x14)
SHV-LR

LT/HT/SHT
Threshold

ACC-M

Scalar rates of 16 ACC PMTs



S0
WAKE +Z

S1
RAM +Z

S2
WAKE -Z

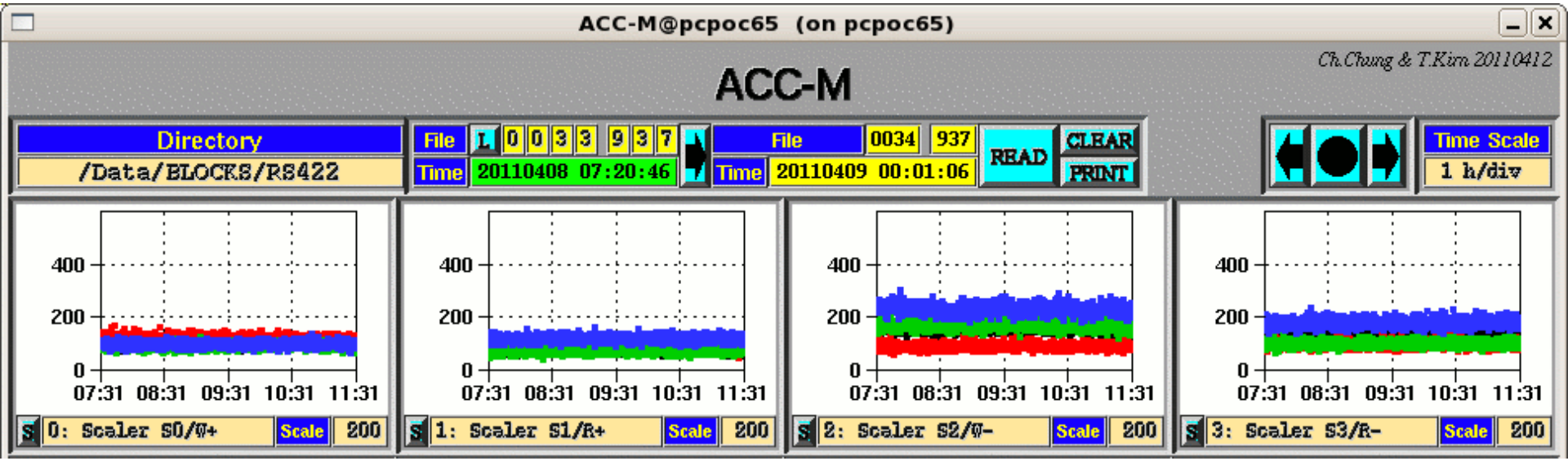
S3
RAM -Z

Black (SFEA input channel 0)
Green (SFEA input channel 2)

Red (SFEA input channel 1)
Blue (SFEA input channel 3)

ACC-M

Scalar rates of 16 ACC PMTs during Cosmic Data taking at KSC



S0
WAKE +Z

S1
RAM +Z

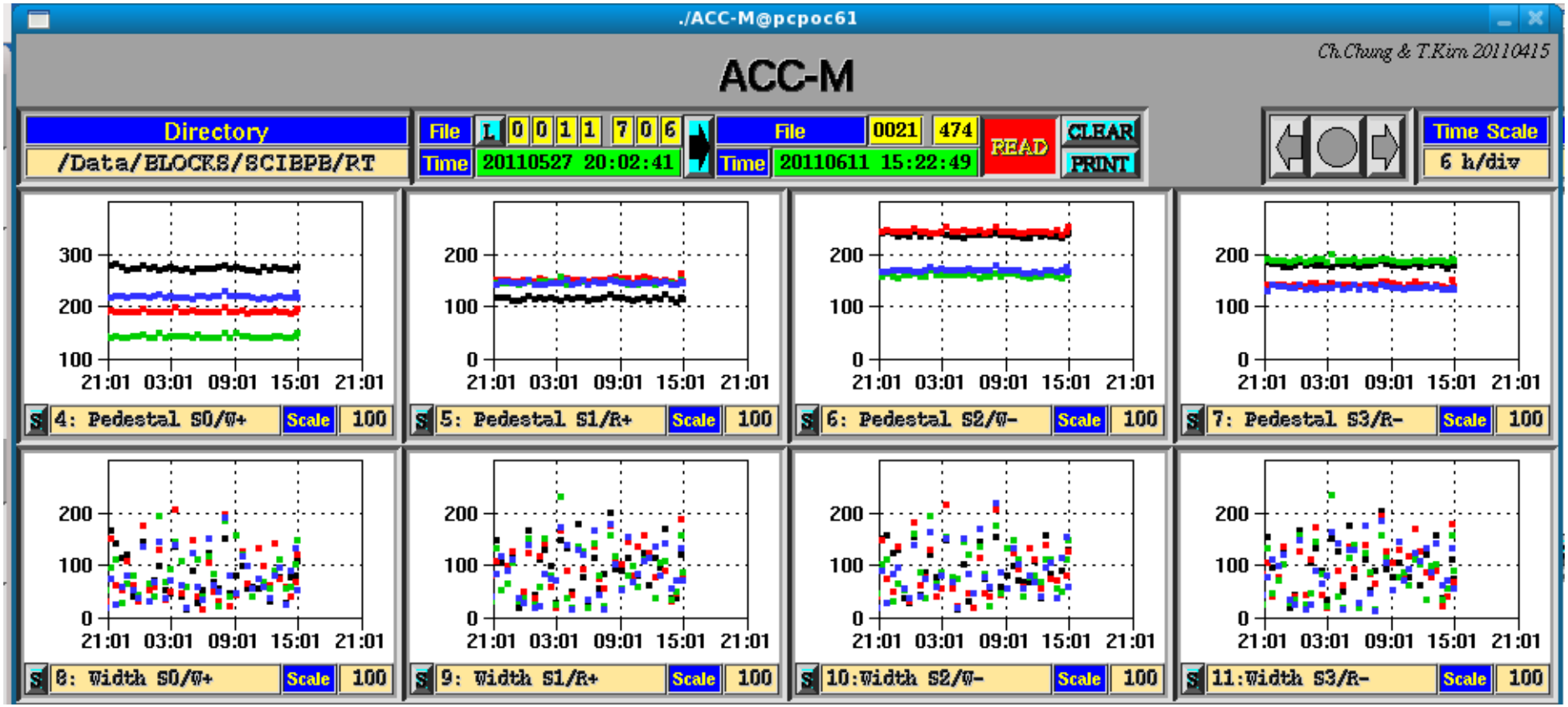
S2
WAKE -Z

S3
RAM -Z

Black (SFEA input channel 0) **Red (SFEA input channel 1)**
Green (SFEA input channel 2) **Blue (SFEA input channel 3)**

ACC-M

Calibration: Pedestal & Pedestal Width of 16 ACC PMTs



S0 **S1** **S2** **S3**

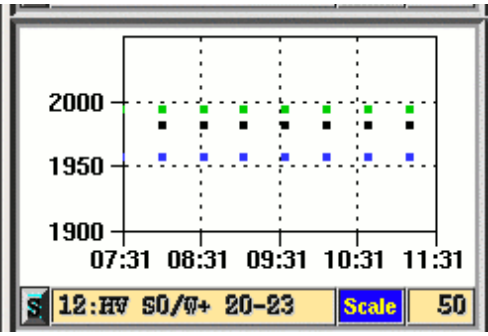
WAKE +Z **RAM +Z** **WAKE -Z** **RAM -Z**

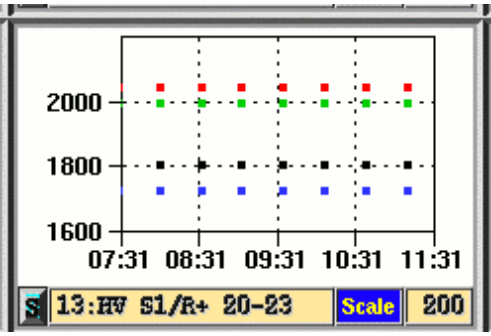
Black (SFEA input channel 0) **Red (SFEA input channel 1)**

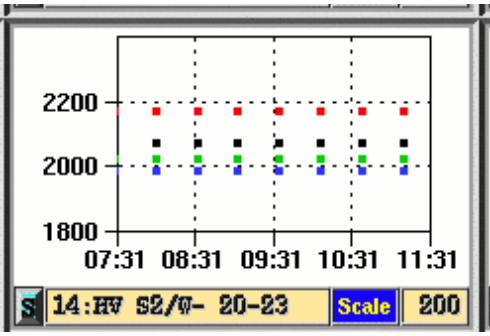
Green (SFEA input channel 2) **Blue (SFEA input channel 3)**

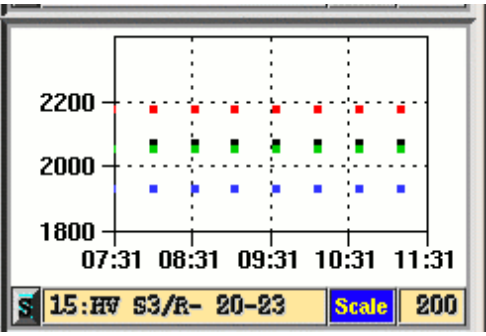
ACC-M

High voltage settings of 16 PMTs of S0, S1, S2 and S3-crate









S0
WAKE +Z

S1
RAM +Z

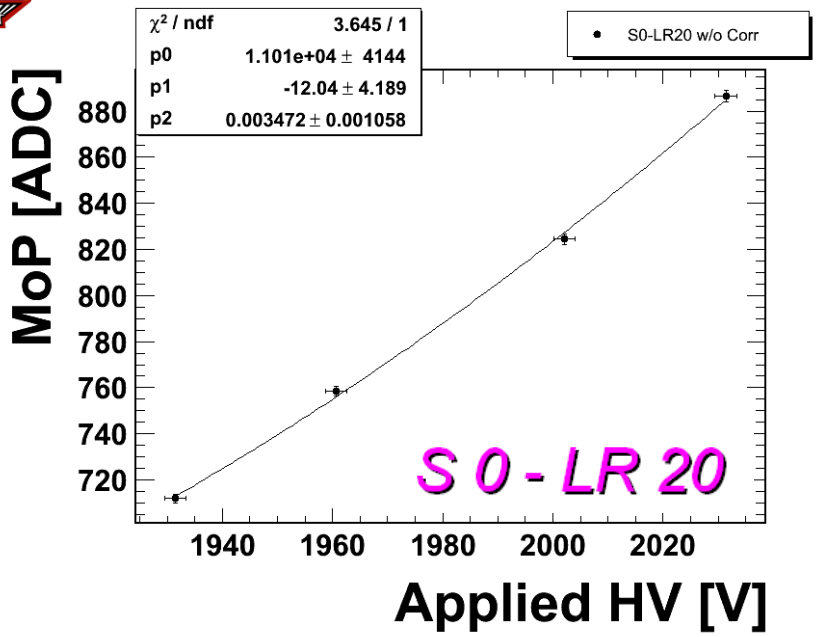
S2
WAKE -Z

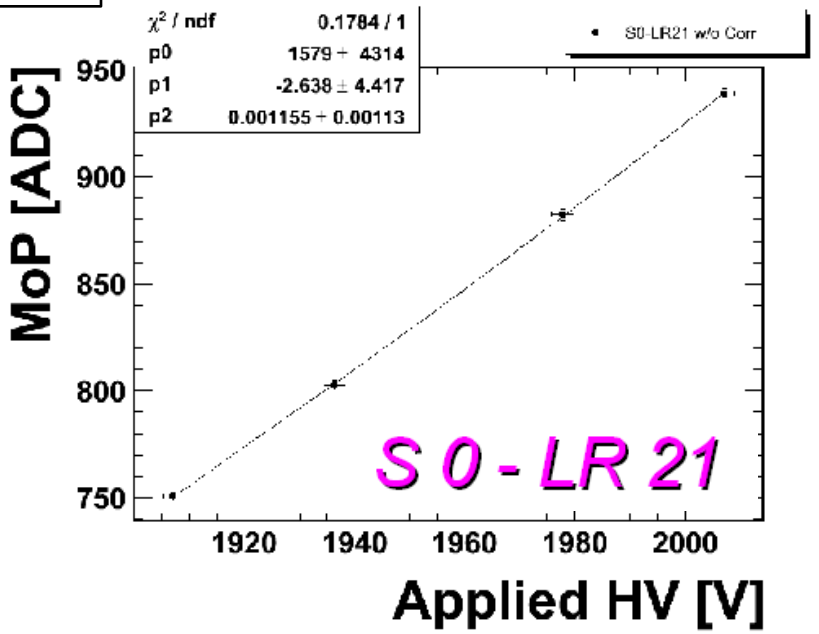
S3
RAM -Z

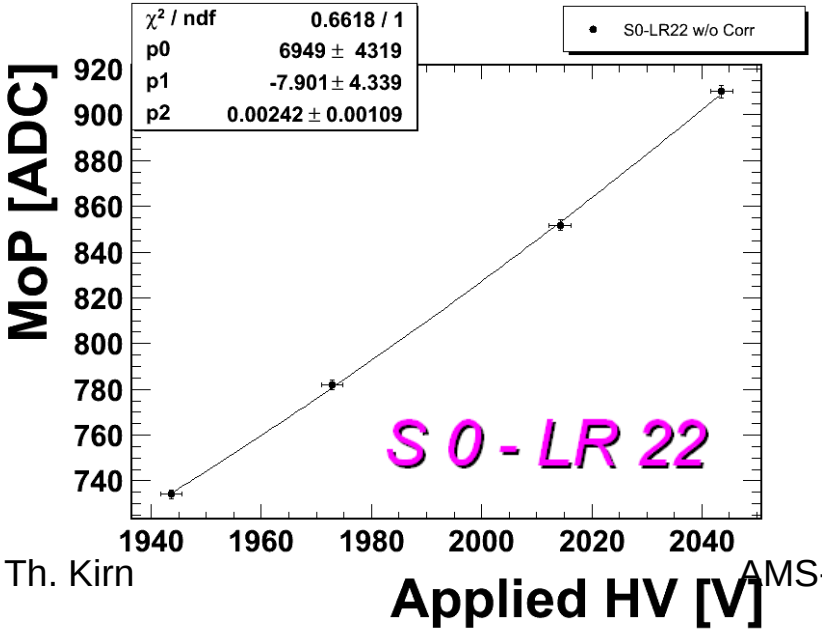
Black (SFEA input channel 0) **Red (SFEA input channel 1)**
Green (SFEA input channel 2) **Blue (SFEA input channel 3)**

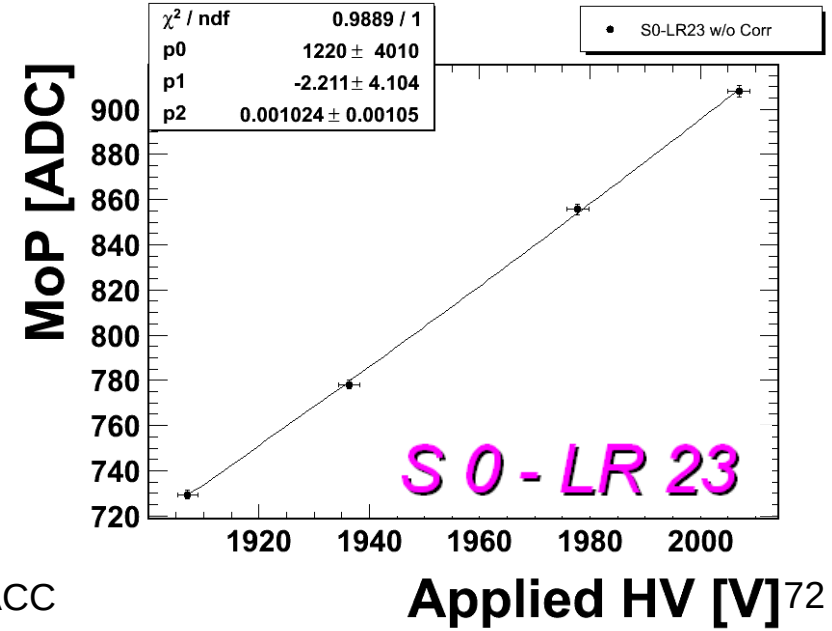
SHV-brick	S0	S1	S2	S3
Ch20	1975.4 V	1795.7 V	2093.2 V	2042.0 V
Ch21	1923.5 V	2014.6 V	2191.6 V	2157.1 V
Ch22	1972.4 V	1952 V	2048.5 V	2018.6 V
Ch23	1936.5 V	1719.4 V	2007.0 V	1900.8 V

ACC-High Voltage Scans

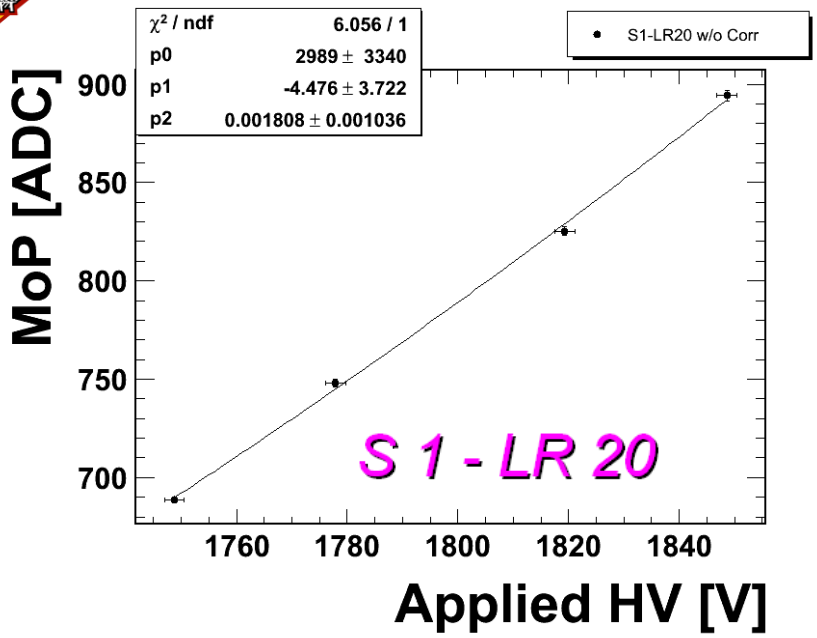


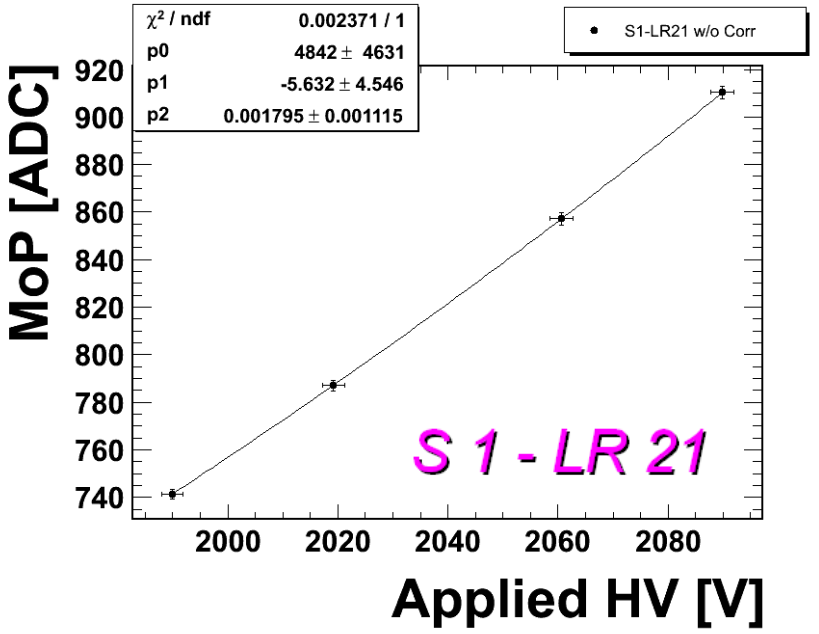


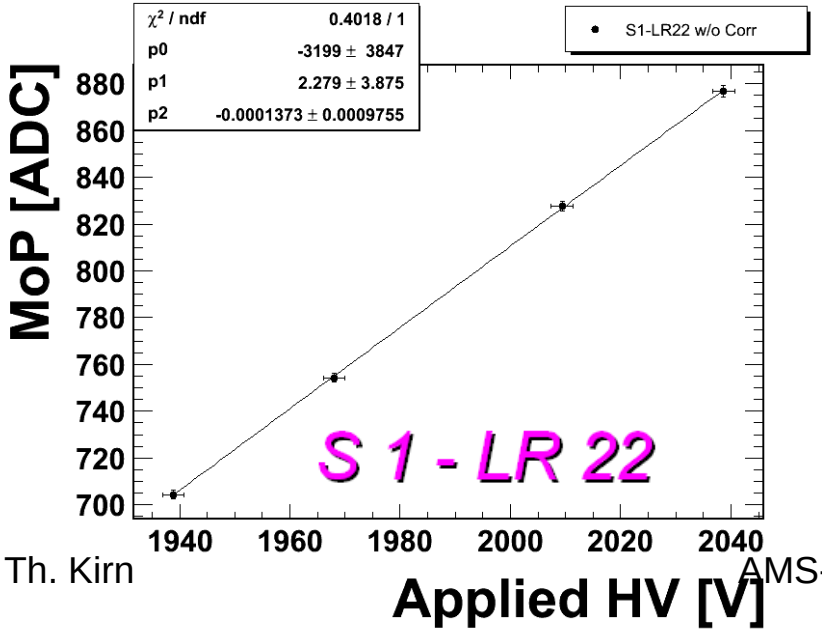


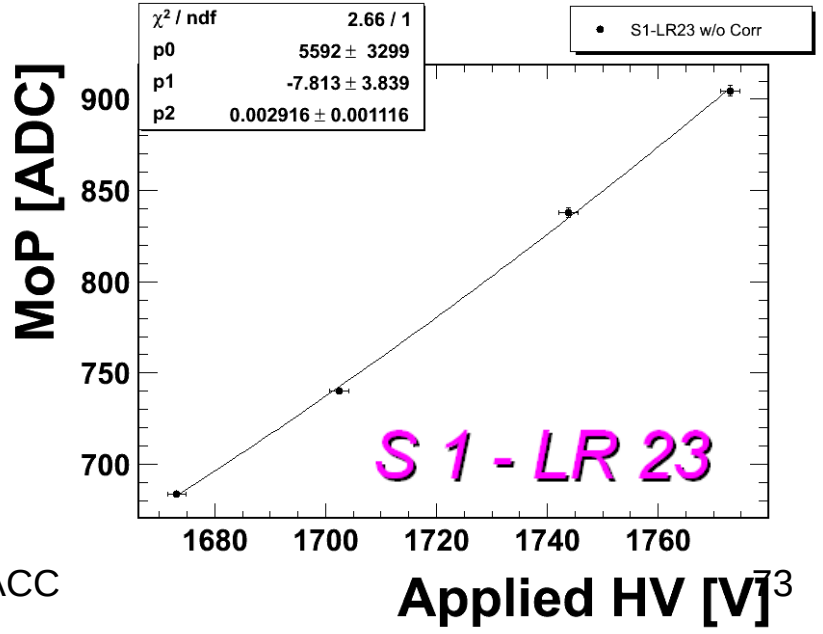


ACC-High Voltage Scans

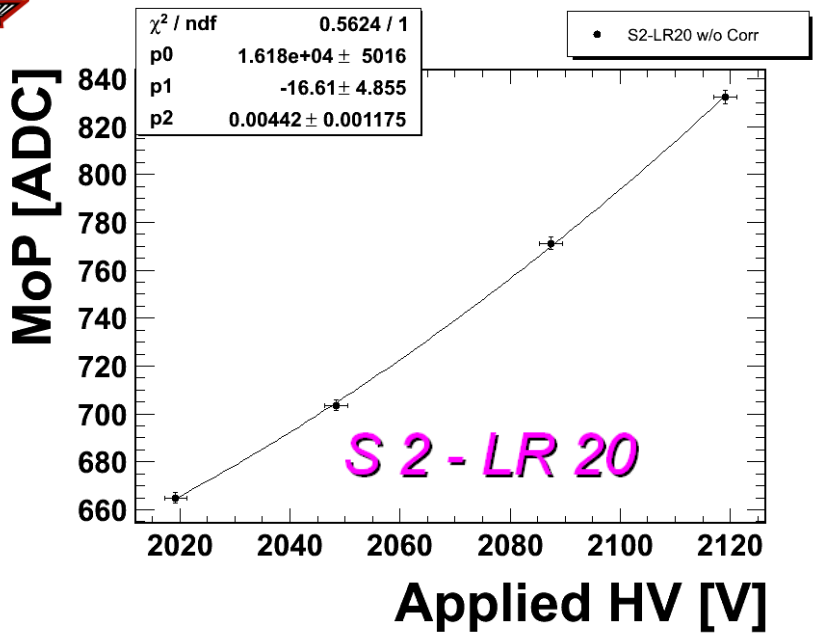


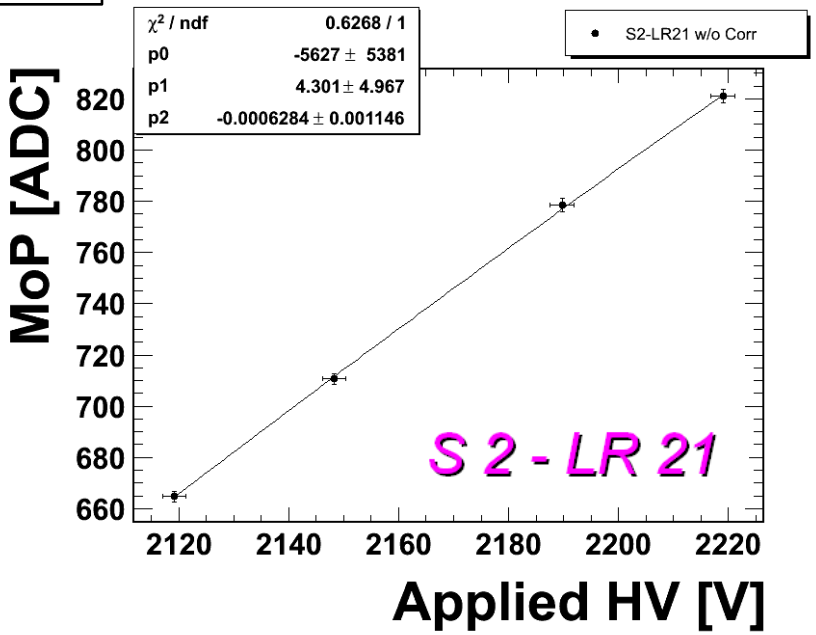


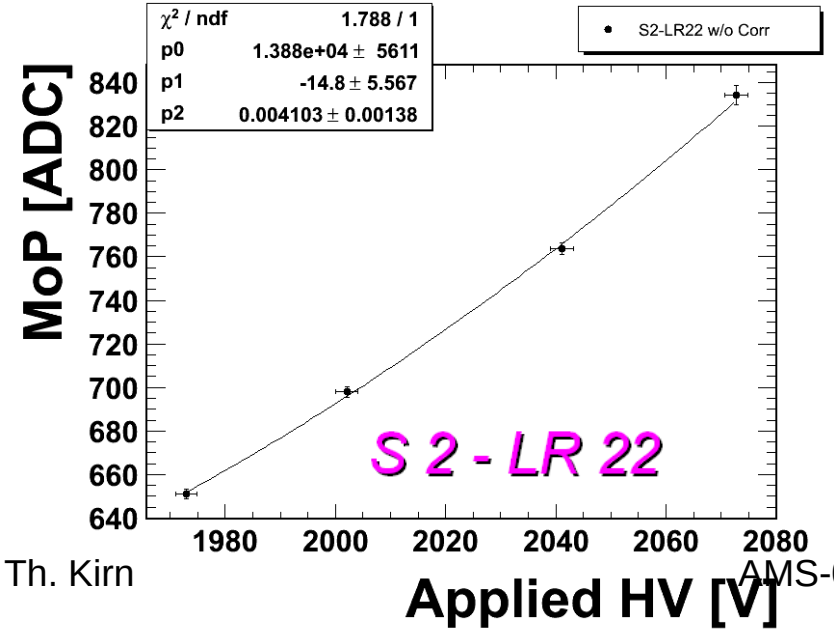


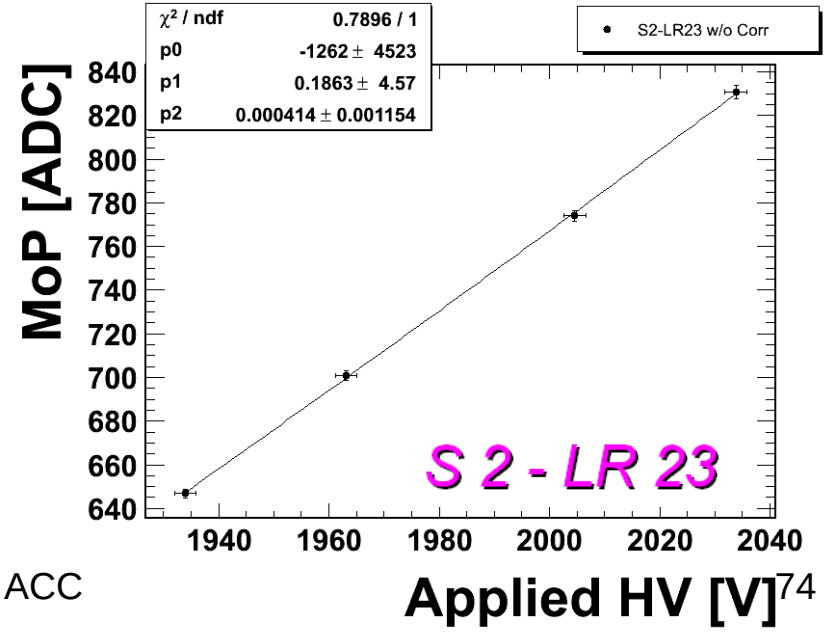


ACC-High Voltage Scans

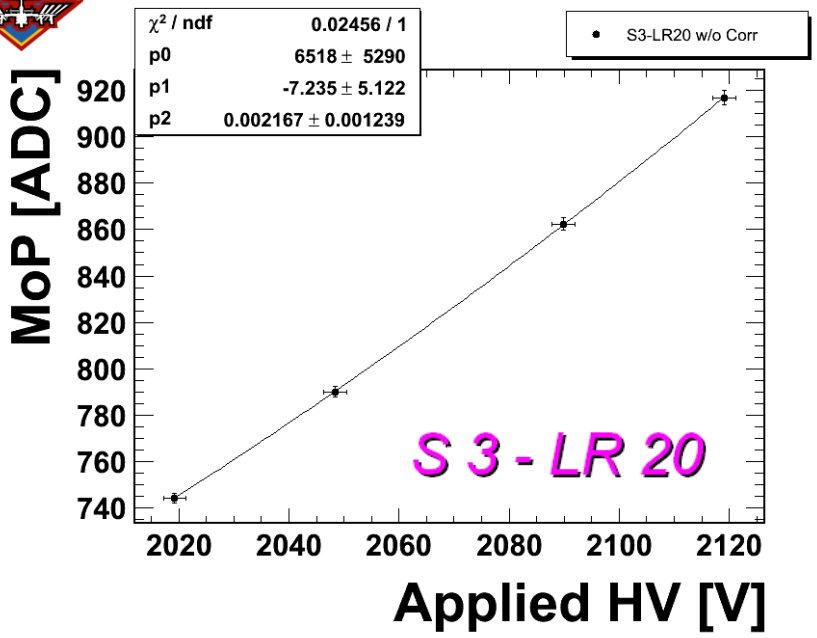


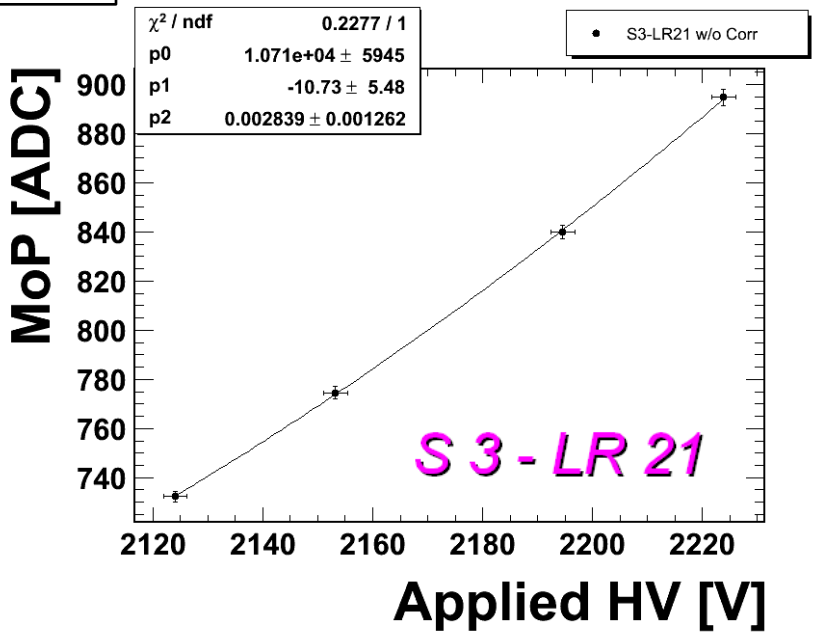


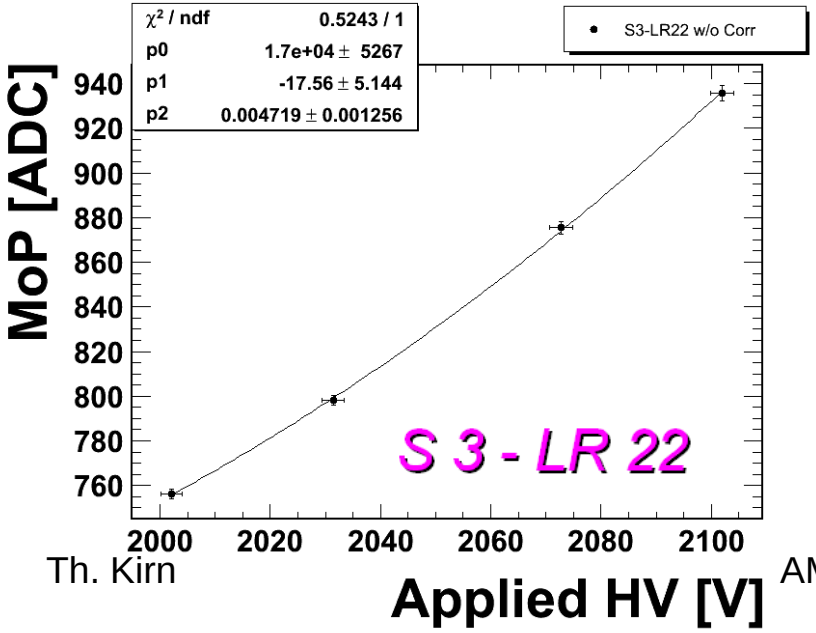


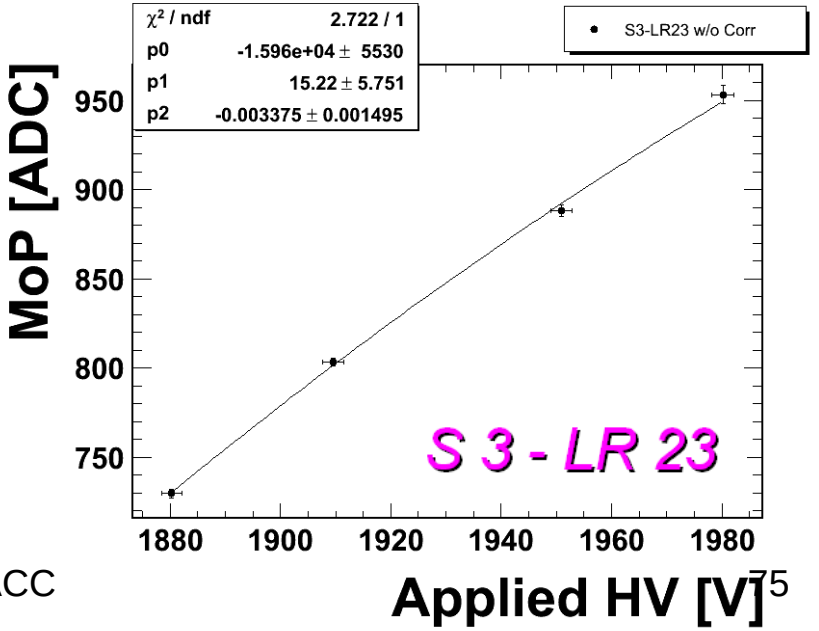


ACC-High Voltage Scans

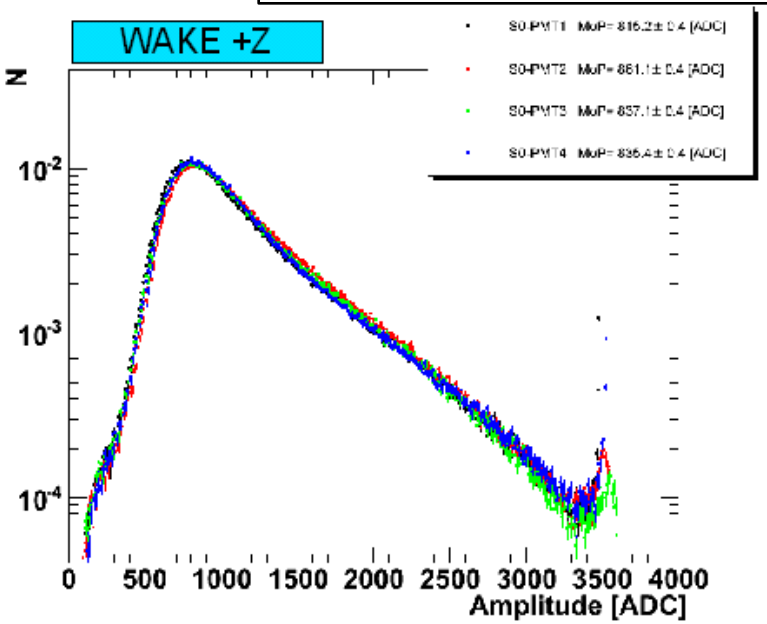


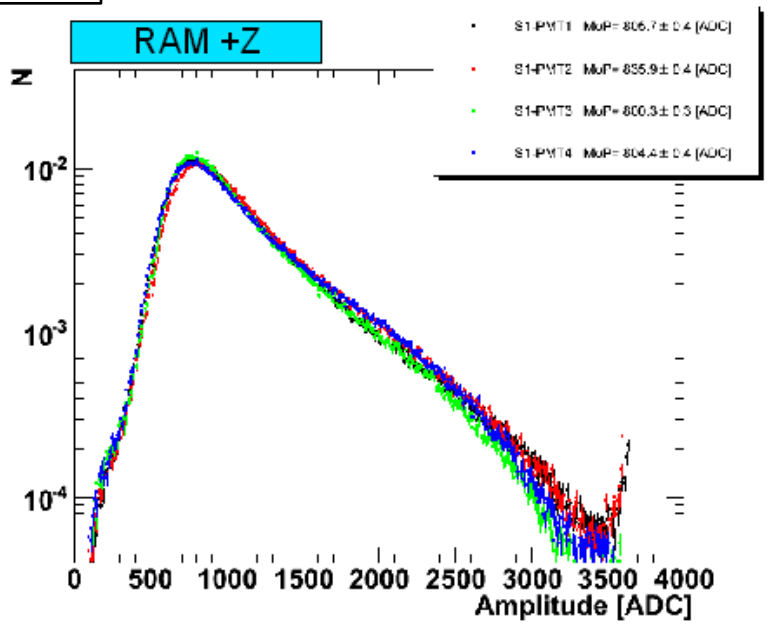


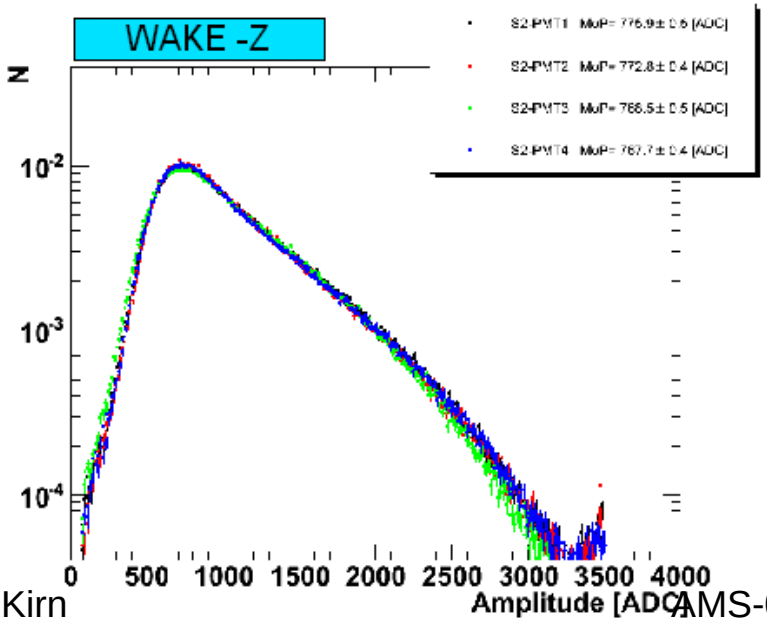


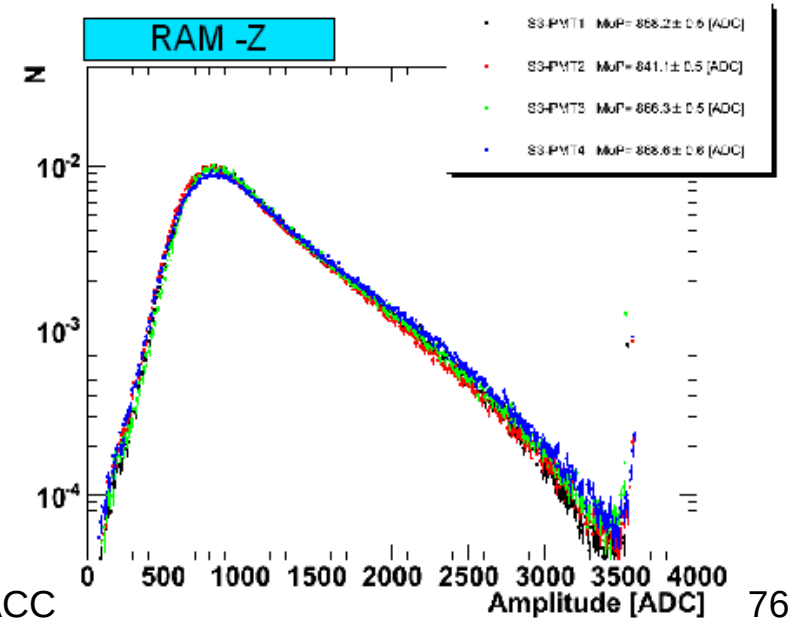


ACC-CR Spectra (Raw)

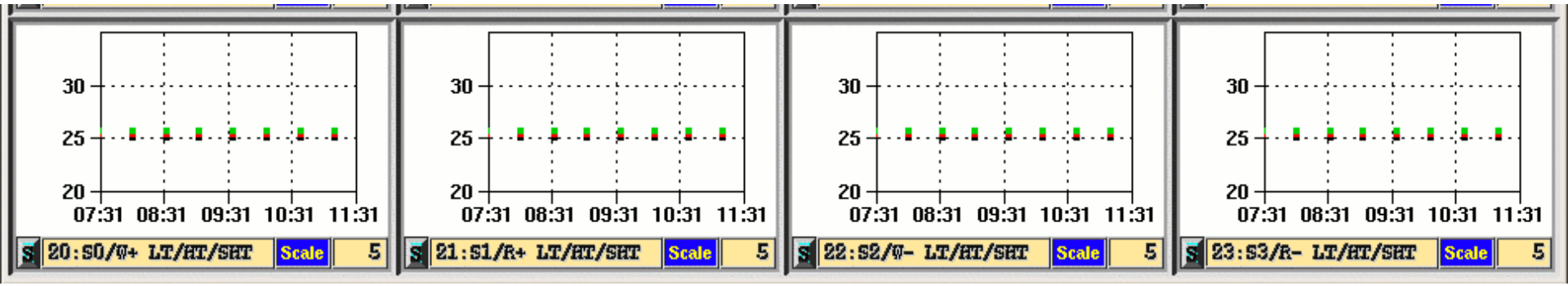








Discriminator threshold settings; all register values set to 25 (Maximum) (artificial spread to visualize 4 points)



S0
WAKE +Z

S1
RAM +Z

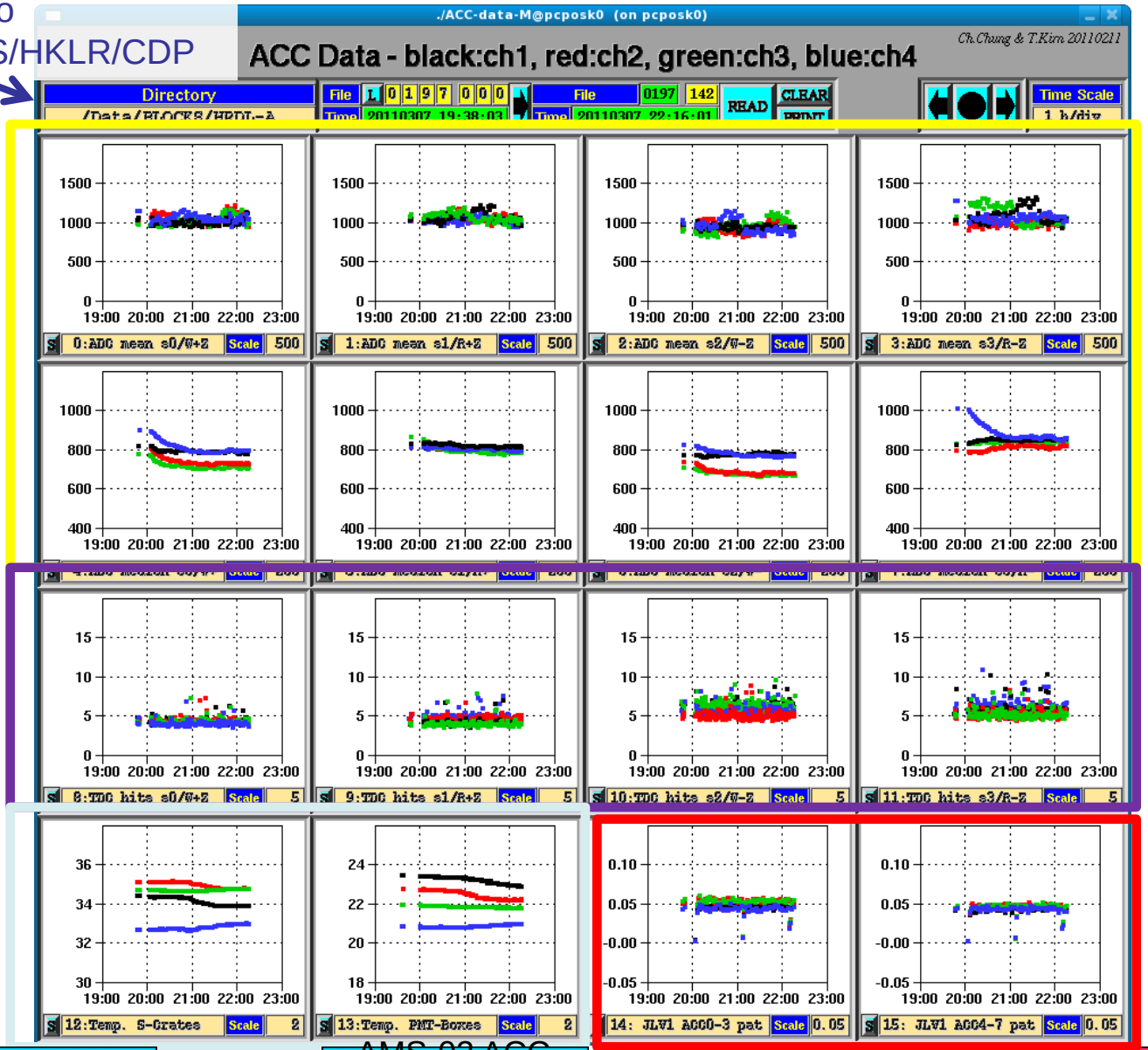
S2
WAKE -Z

S3
RAM -Z

Black (SFEA input channel 0)
Red (SFEA input channel 1)
Green (SFEA input channel 2)
Blue (SFEA input channel 3)

ACC-data-M

Set Directory to
/Data/BLOCKS/HKLR/CDP



Signal Amplitude
ADC (mean)

vs.

Dynamic ADC

TDC

Temperature

SDR2
SFEA2

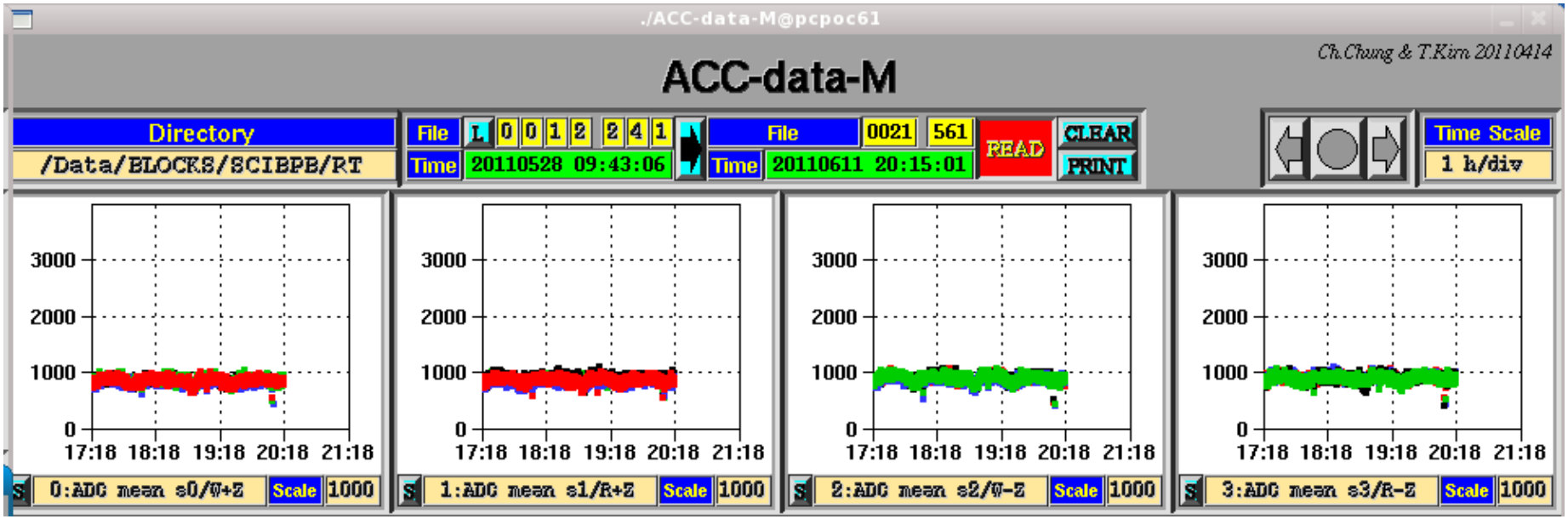
PMT Box
W+,R+,W-,R-

Veto cnt/ LV1 cnt
(W+,W-)

Veto cnt/ LV1 cnt
(R+,R-)

ACC-data-M

Mean ADC values for each of the 4 PMTs of S0, S1, S2 and S3 crate
Calculated out of 500 events, pedestal corrected



S0
WAKE +Z

S1
RAM +Z

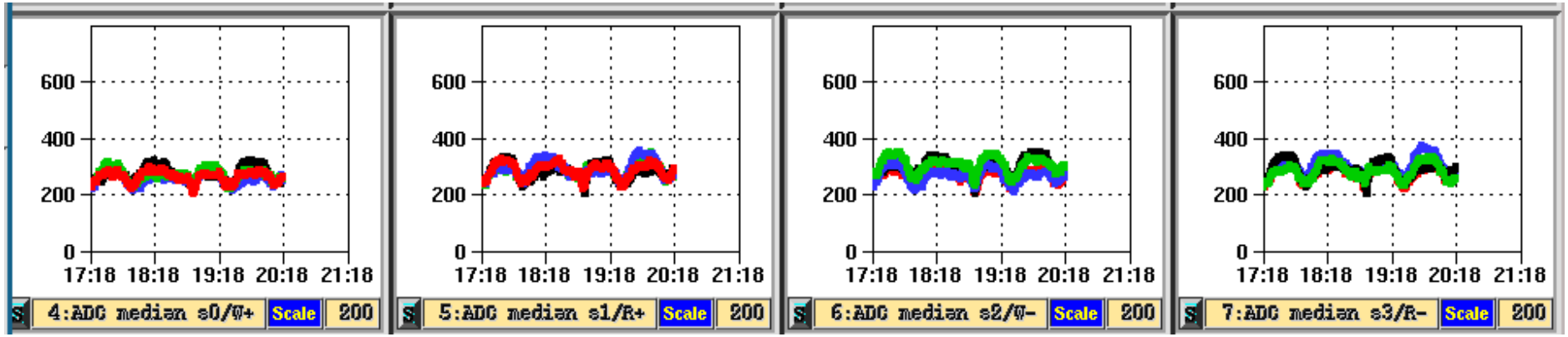
S2
WAKE -Z

S3
RAM -Z

Black (SFEA input channel 0) **Red (SFEA input channel 1)**
Green (SFEA input channel 2) **Blue (SFEA input channel 3)**

ACC-data-M

Median ADC values for each of the 4 PMTs of S0, S1, S2 and S3 crate
Median value range 700 – 1000, ADC value range 300 – 2000,
Running value: ADC value above median → median increase by 1/8
ADC value below median → median decrease by 1/8



S0
WAKE +Z

S1
RAM +Z

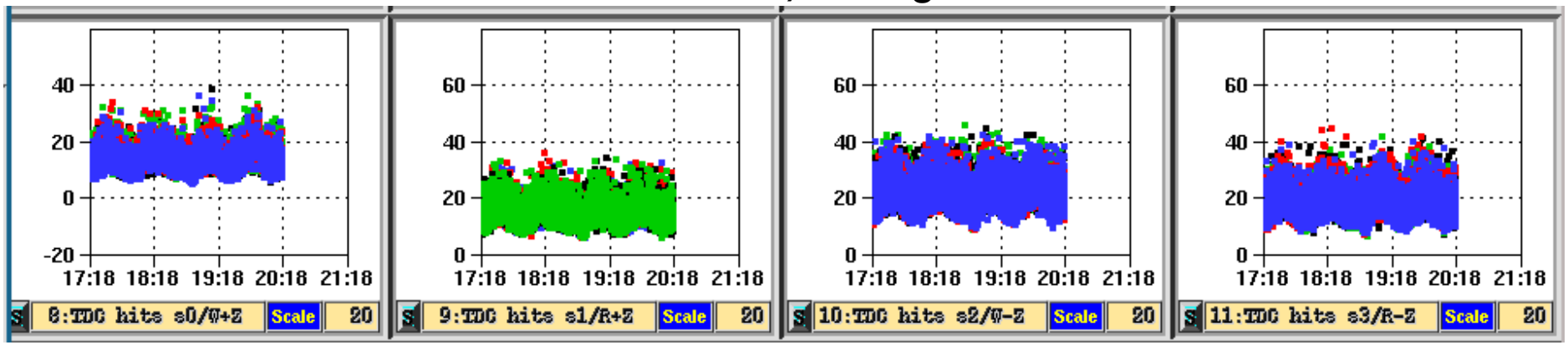
S2
WAKE -Z

S3
RAM -Z

Black (SFEA input channel 0) **Red (SFEA input channel 1)**
Green (SFEA input channel 2) **Blue (SFEA input channel 3)**

ACC-data-M

Mean number of TDC Hits, averaged over 1500 entries

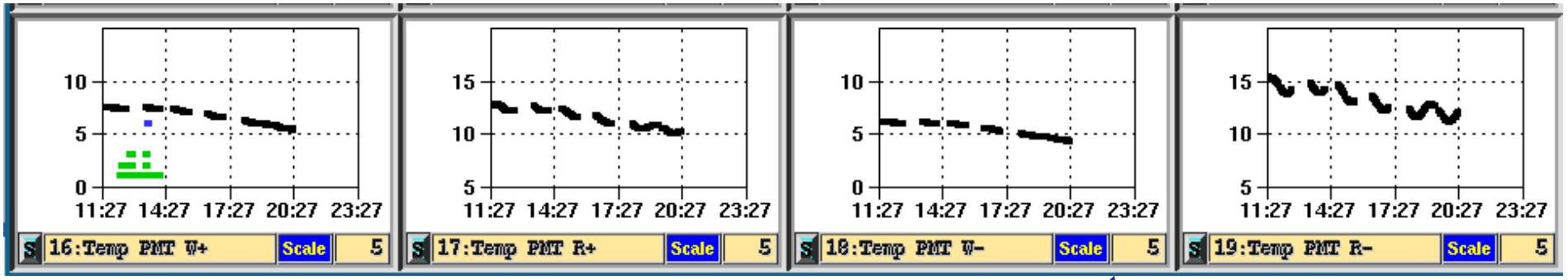


S0 WAKE +Z | **S1 RAM +Z** | **S2 WAKE -Z** | **S3 RAM -Z**

Black (SFEA input channel 0) **Red (SFEA input channel 1)**
Green (SFEA input channel 2) **Blue (SFEA input channel 3)**

ACC-data-M

Global DALLAS Temperature Sensor on each ACC PMT box



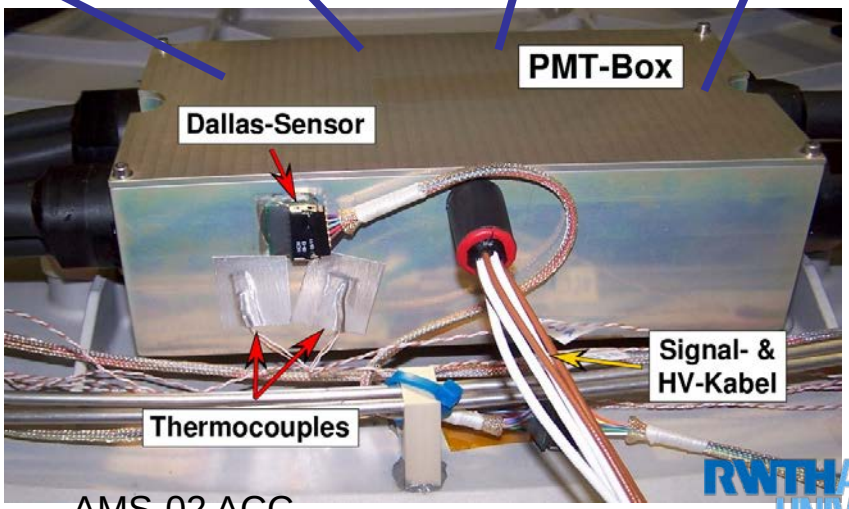
S0
WAKE +Z

S1
RAM +Z

S2
WAKE -Z

S3
RAM -Z

Operational:
-30°C … +45°C
Non-Operational:
-35°C … +50°C

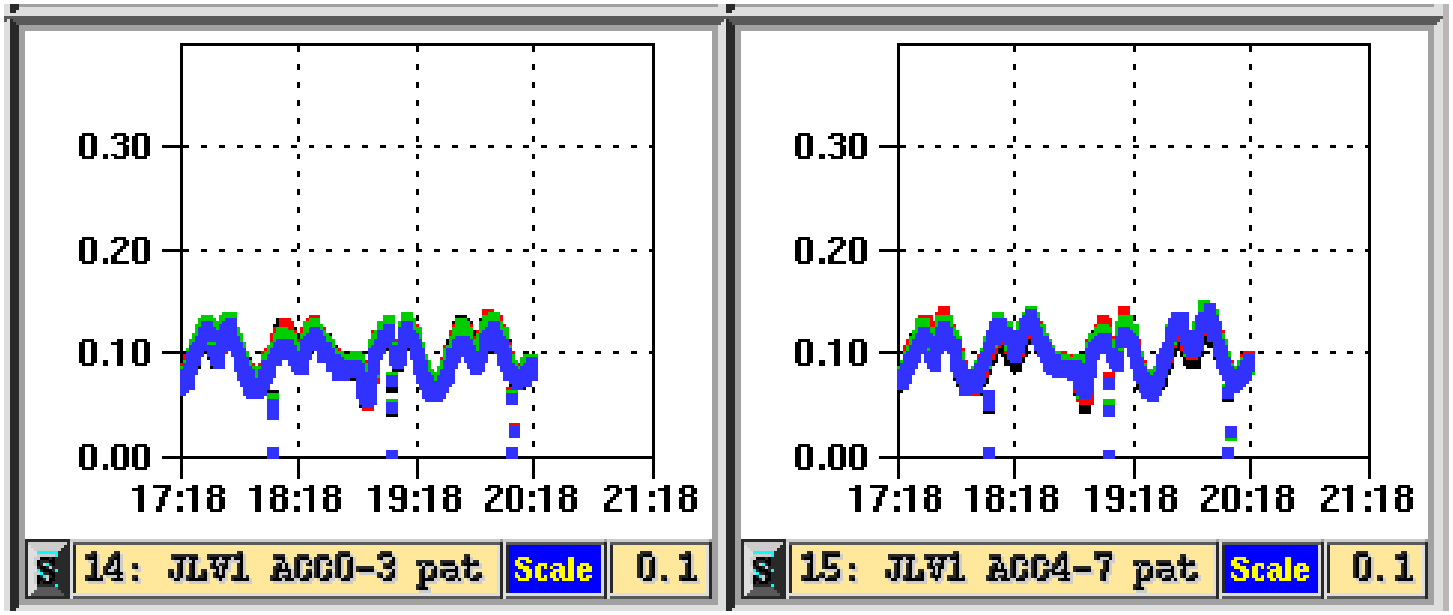


ACC-data-M

- **JLV1-trigger: Percentage of events which get a veto-flag**

  ACC Veto rate every 500 JLV1 trigger, depending on JLV1 trigger setting

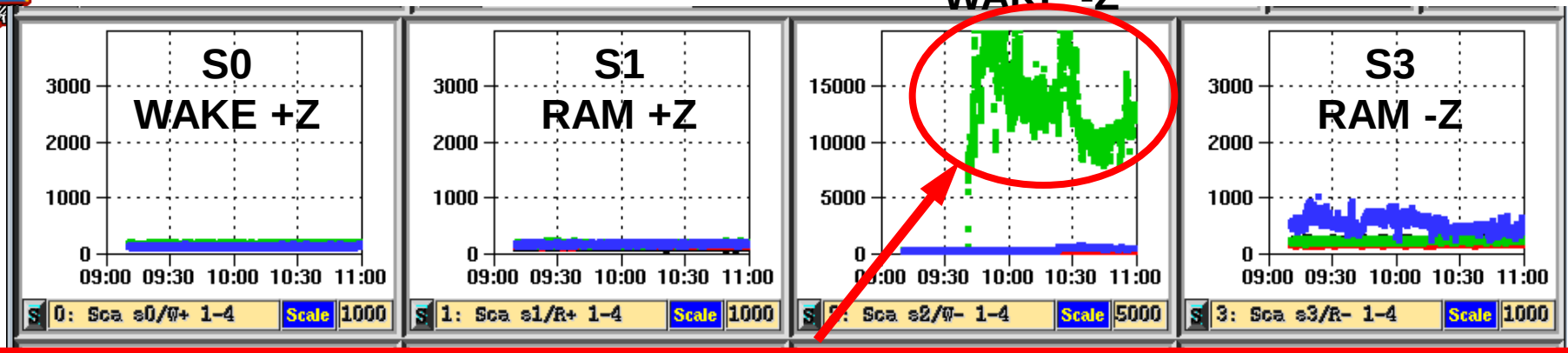
  (2 out of 4**, 3 out of 4 (standard),** 4 out of 4 or ECAL trigger)



Black (SFEA input channel 0) **Red (SFEA input channel 1)**

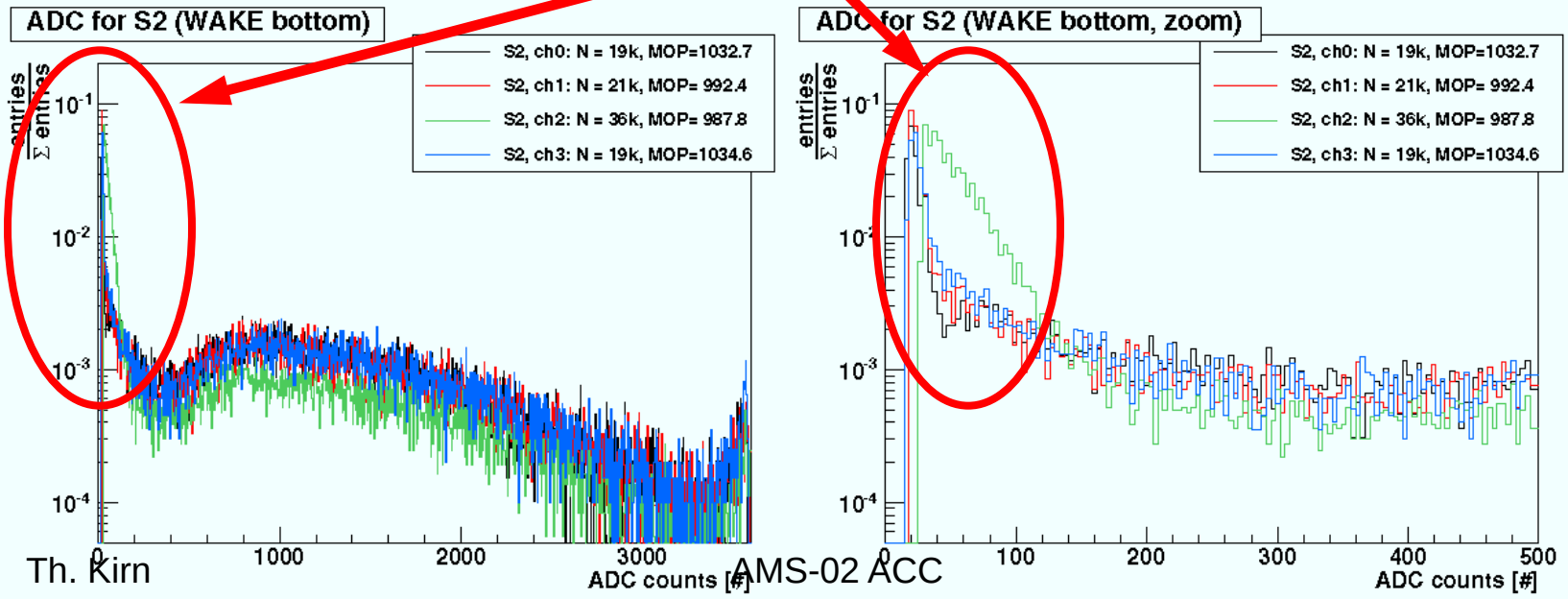
Green (SFEA input channel 2) **Blue (SFEA input channel 3)**

ACC-trouble shooting

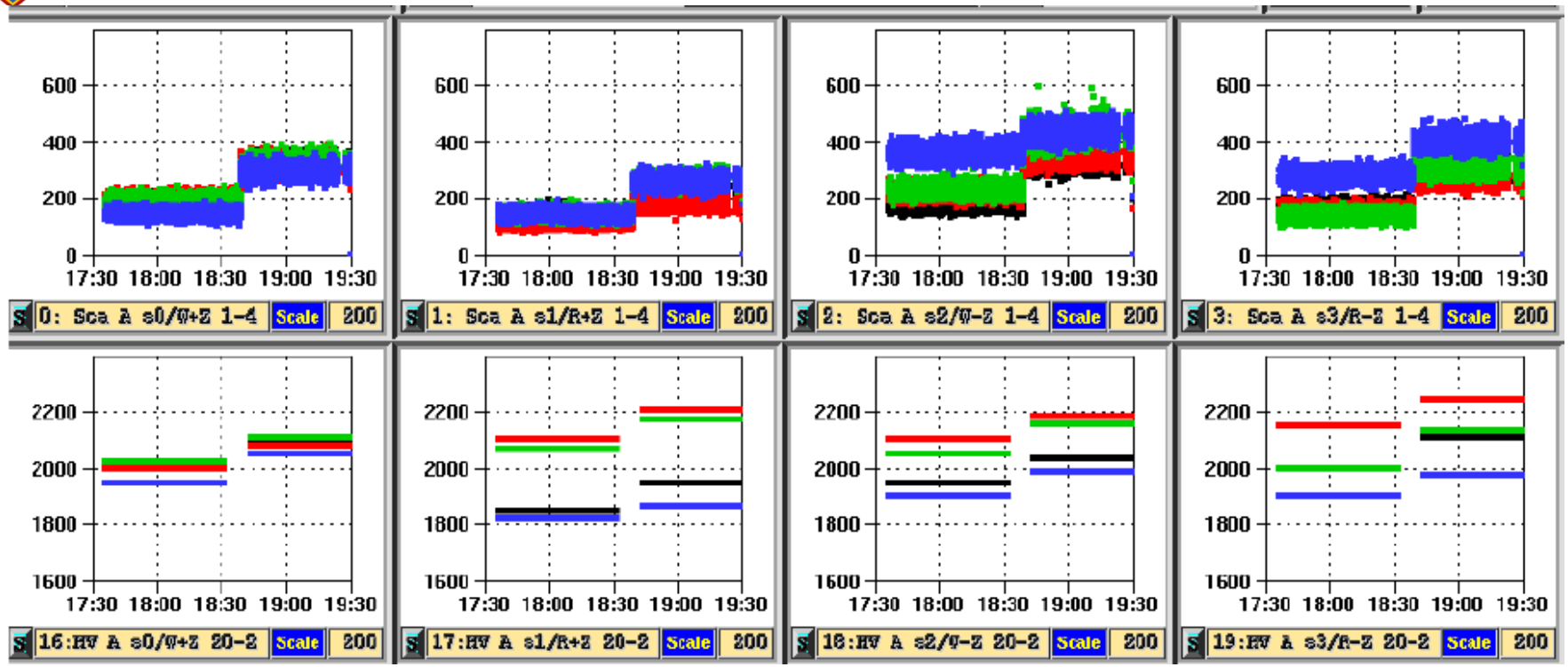


Scaler rising; Saturation at 32k, Check: HV, threshold, Trigger config.

Due to noisy PMT → check corresponding ADC spectrum! Lower HV if necessary



ACC-trouble shooting



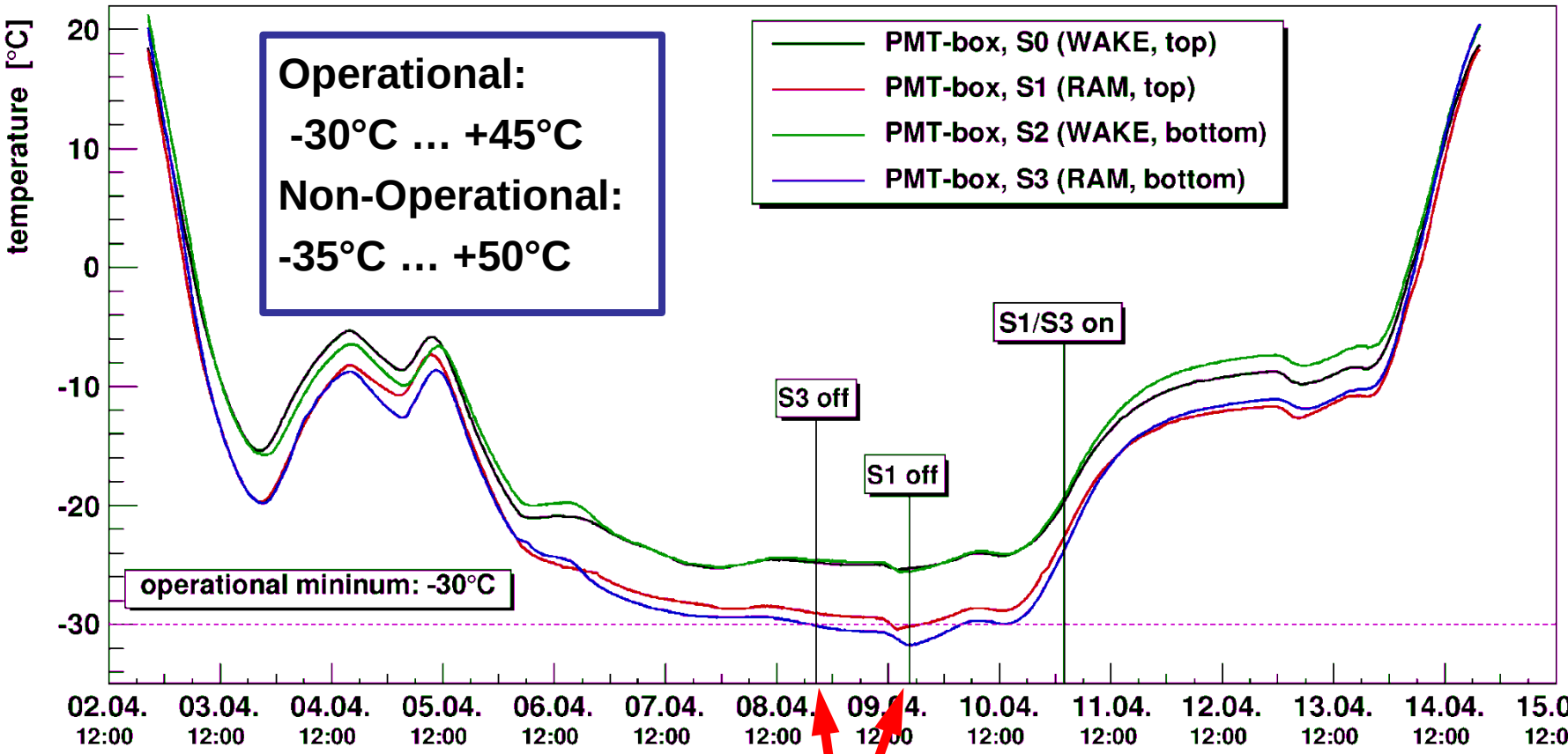
S0	S1	S2	S3
WAKE +Z	RAM +Z	WAKE -Z	RAM -Z

Scaler increase (stepwise) due to change of HV settings (or trigger config)

Scaler at zero → No data taking, HV off, PMT dead, cross check with ACC-S!

Contact ACC-Expert, AMS-LEAD, AMS-CMD

ACC-trouble shooting



Temperature below operational range → HV off!

Screen 3 Right!