TRDs for the 3^{rd} millennium

The AMS02 TRD
A detector designed for space

for the AMS-TRD Group
MIT, Roma, RWTH

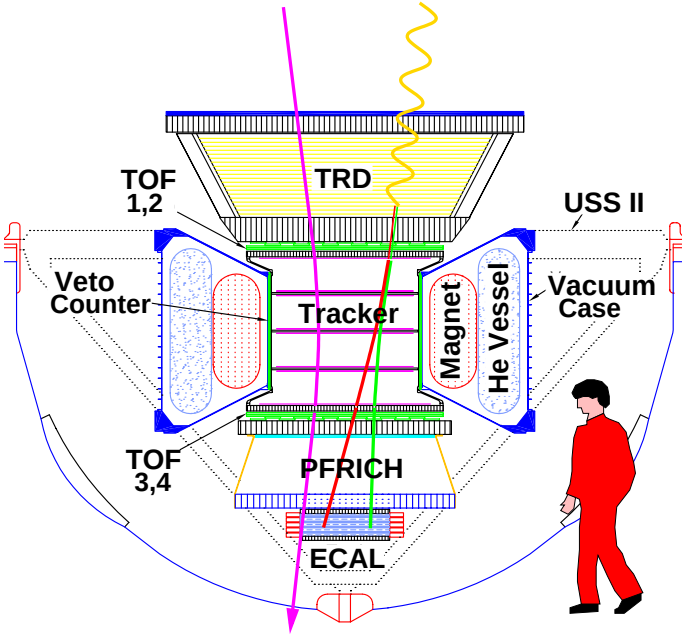
Th. Kirn
I. Phys. Institut RWTH Aachen

Bari, September 20^{th} 2001

RWTH Physics AC-I

The AMS02 TRD
A detector designed for space

- Cosmic Particle Spectroscopy
- AMS02 on ISS
- AMS01 Results
- TRD for particle identification
- TRD Design for space
- Conclusion

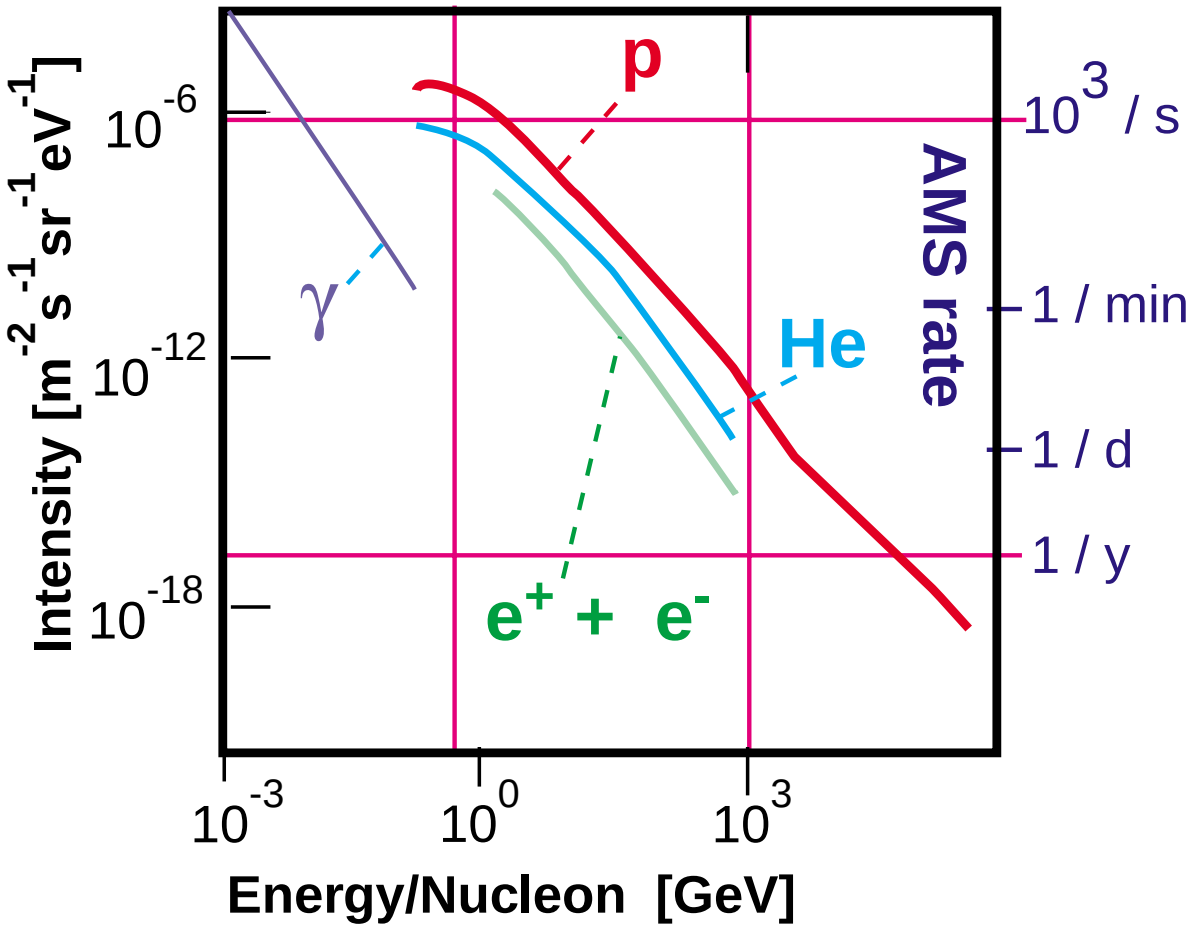


Iss - an experimental platform

What would we like to measure?

$\Downarrow$

Cosmic Particle Spectrum



flux ratio in orbit: $p^+/e^+ \approx 10^4$

$\Rightarrow$ p^+-rejection $< 10^{-6}$

Why would we like to measure it?

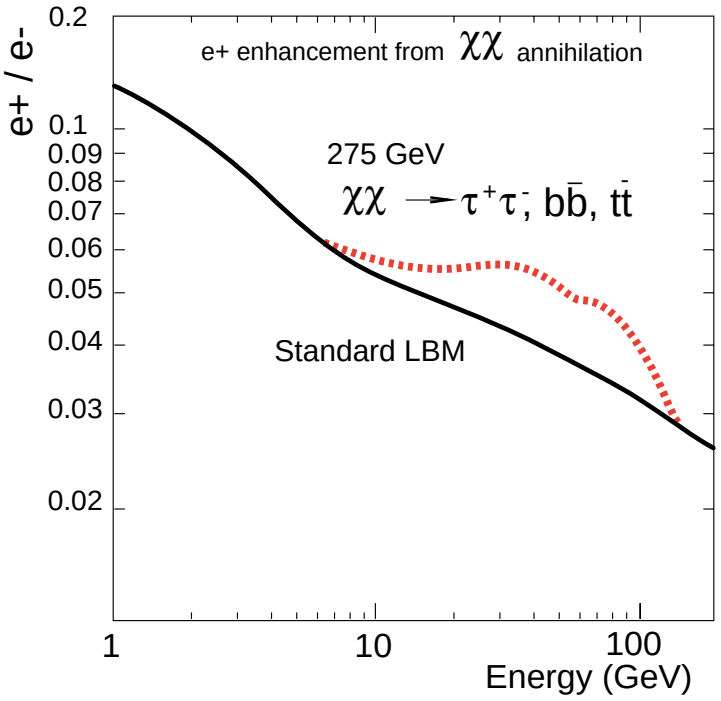
$\Downarrow$

- Baryon Symmetry $\Leftrightarrow$ **Antimatter Search**

$\overline{He}$: cosmic antimatter
$\overline{C}$: antimatter stars

$\Delta p/p < 30\%$ to 1000 GeV

- Dark Matter Search $\Rightarrow$ e^+-Spectroscopy



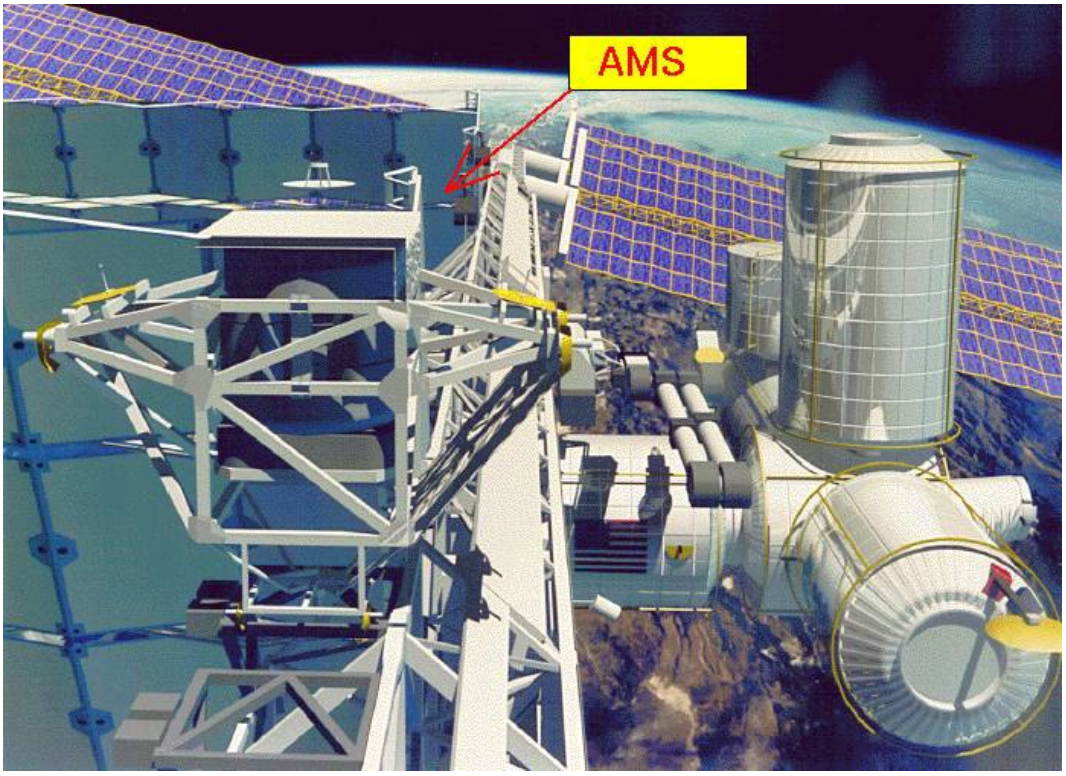
$\Longrightarrow$ Cosmic-ray spectroscopy with highest-precision in Particle identification

$p^+/e^+ < 10^{-6}$ to 300 GeV

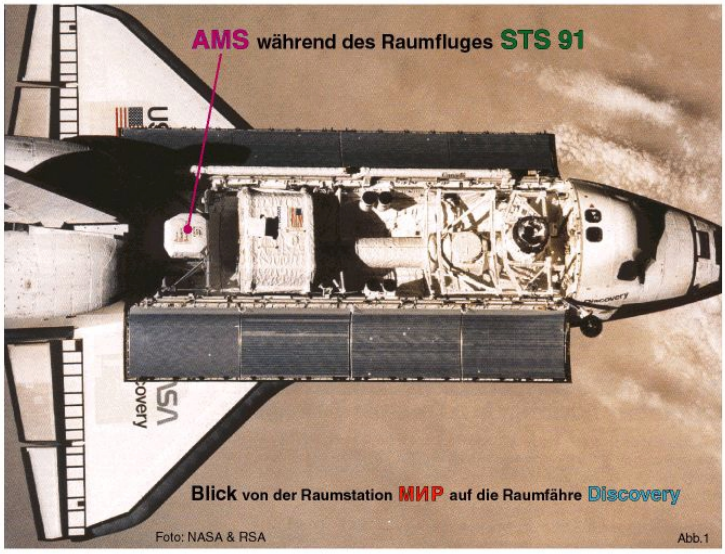
Experiments in space

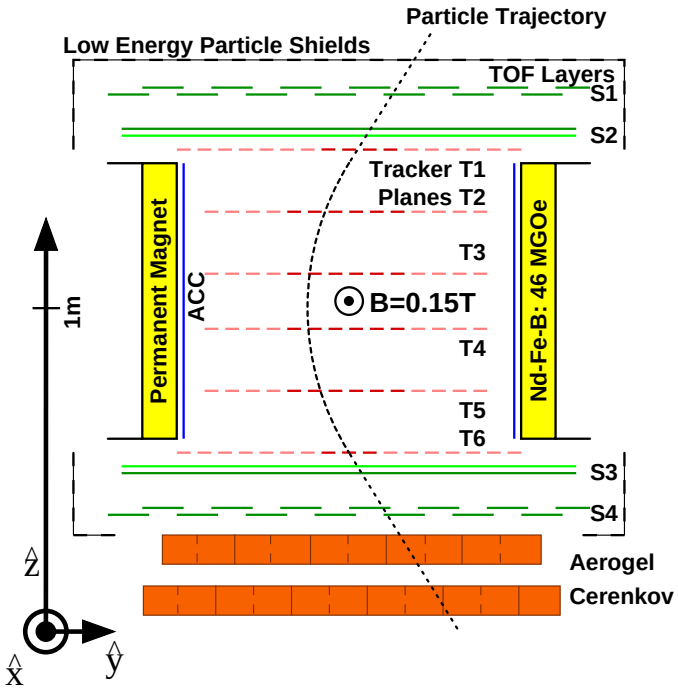
New environment for HEP experiments

- Operation in vacuum
- Acceleration during start and landing up to 9g
- Temperature variations -180 - $+50$ °C
- Deposition limits on ISS $< 10^{-14}$ g/s/cm^2
- Weight limited to 13500 lb
- Datarate 1 Mbyte/s via 1 datalink
- Power consumption limited to 2kW
- Powersupply at 120 V via 1 powercable

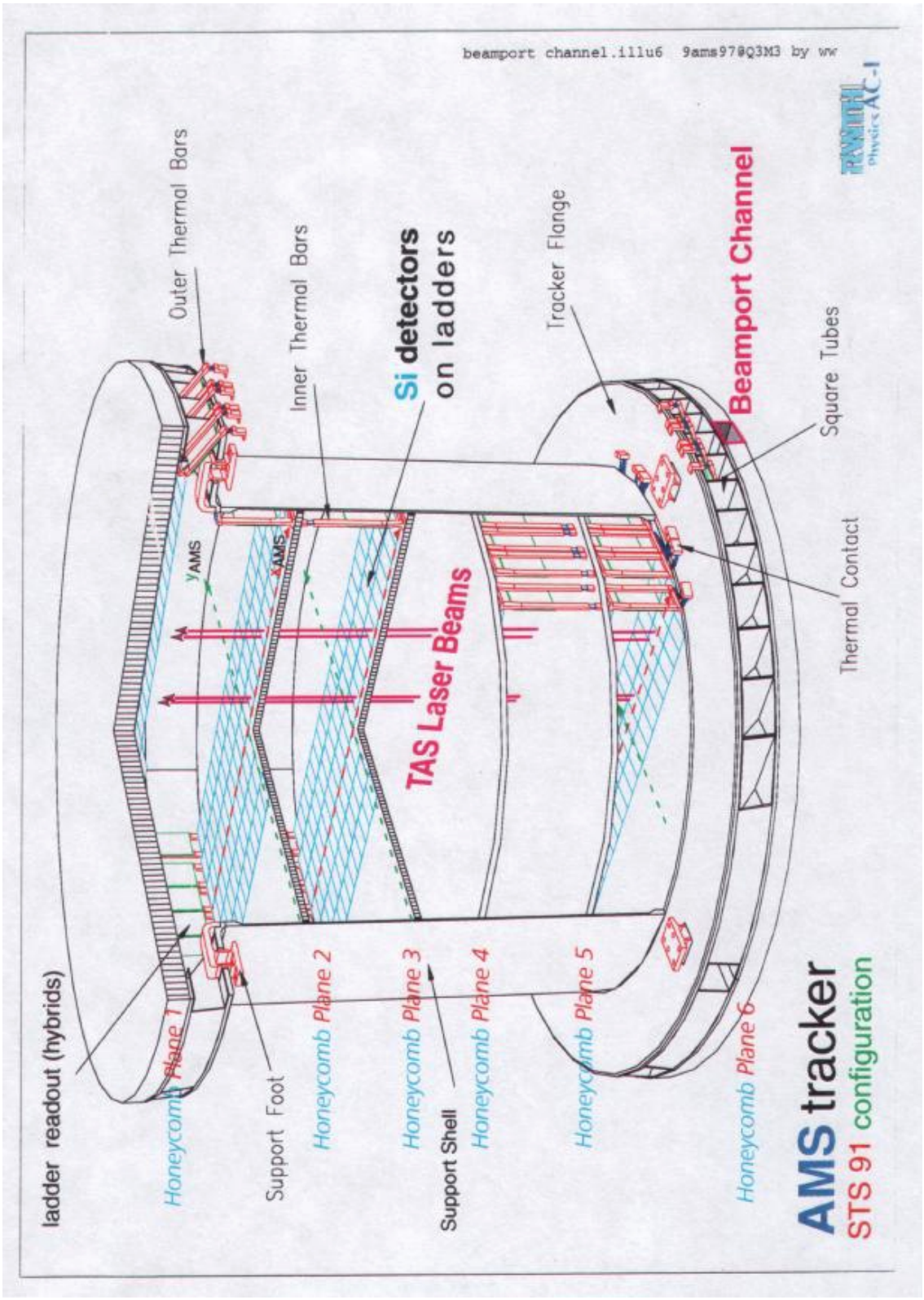


AMS01 STS-91 Precursor Flight



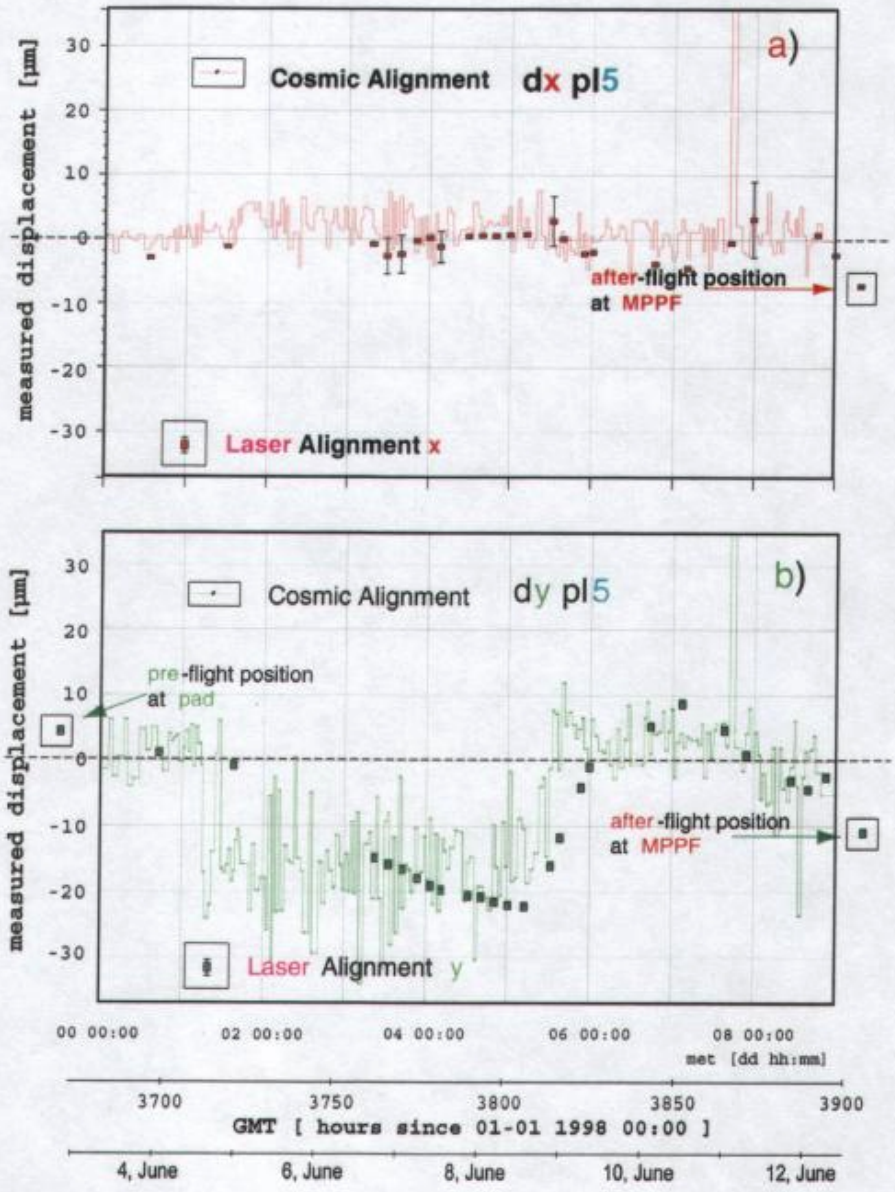


- 2-11 June 1998 aboard Shuttle Discovery
- Mean altitude 370 Km
- 90 min orbit inclined at 51.7°
- Trigger-rate 100-700 Hz
- Recorded 10^8 events in 100 h


beamport channel.illu6 9ams97@Q3M3 by ww
RWTH Physics AC-I
AMS tracker
STS 91 configuration
ladder readout (hybrids)
Honeycomb Plane 1
Support Foot
Honeycomb Plane 2
Honeycomb Plane 3
Support Shell
Honeycomb Plane 4
Honeycomb Plane 5
Honeycomb Plane 6
Outer Thermal Bars
Inner Thermal Bars
Si detectors
on ladders
TAS Laser Beams
Tracker Flange
Beamport Channel
Square Tubes
Thermal Contact
yAMS
xAMS

AMS-01

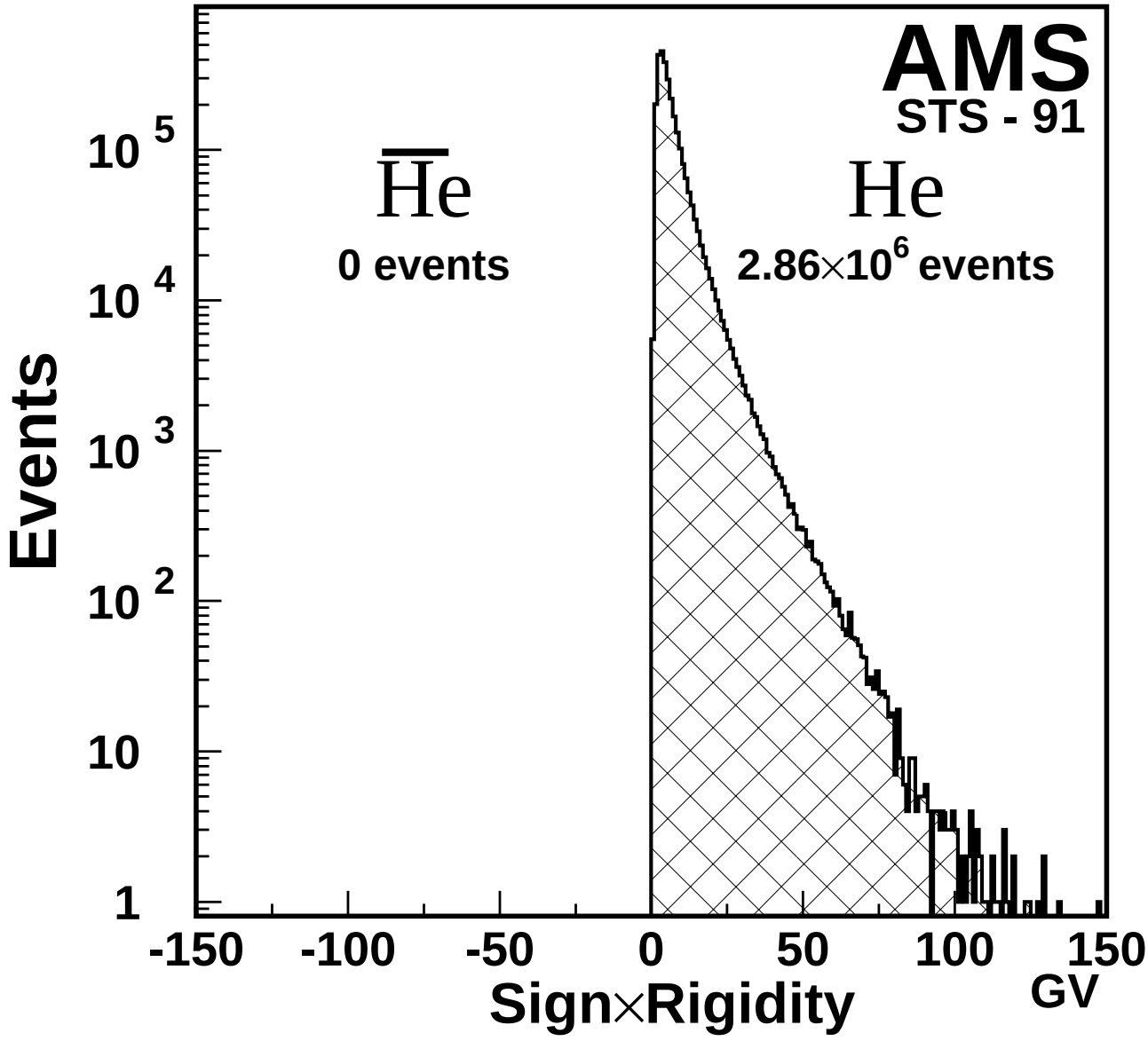
Laser and Cosmic Ray Alignment Control



Measured time evolution of plane 5 displacements.
x (y) parallel (orthogonal) to main B component.

The glitch in the early morning of June 11th is excluded from AMS physics data.

AMS01 Results



Assume $\overline{He}$ and He have the same spectrum up to 140 GV then $\overline{He}/He < 1.1 \cdot 10^{-6}$

AMS01 Results

Search for Antihelium in Cosmic Rays

Phys. Lett. B461 (1999) 387-396

Protons in Near Earth Orbit

Phys. Lett. B472 (2000) 215-226

Leptons in Near Earth Orbit

Phys. Lett. B484 (2000) 10-22

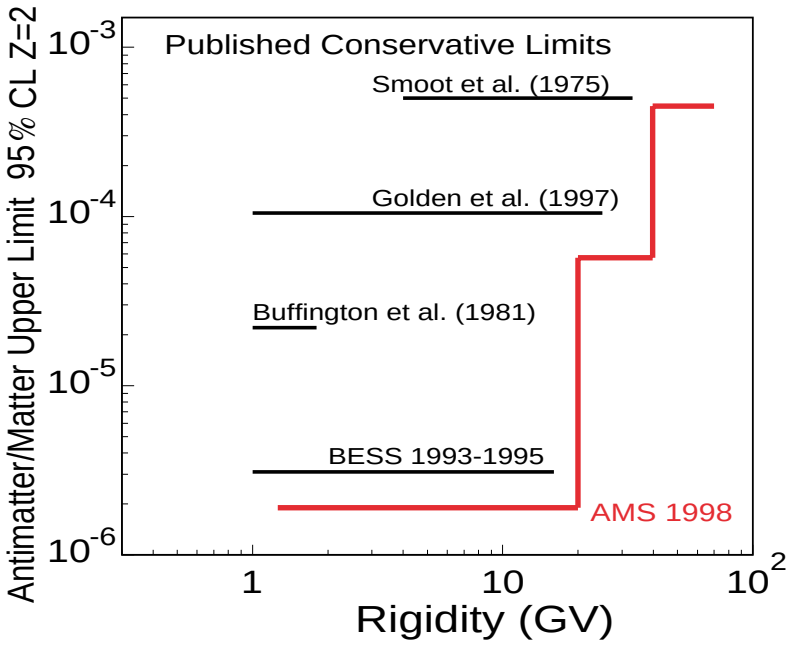
Cosmic Protons

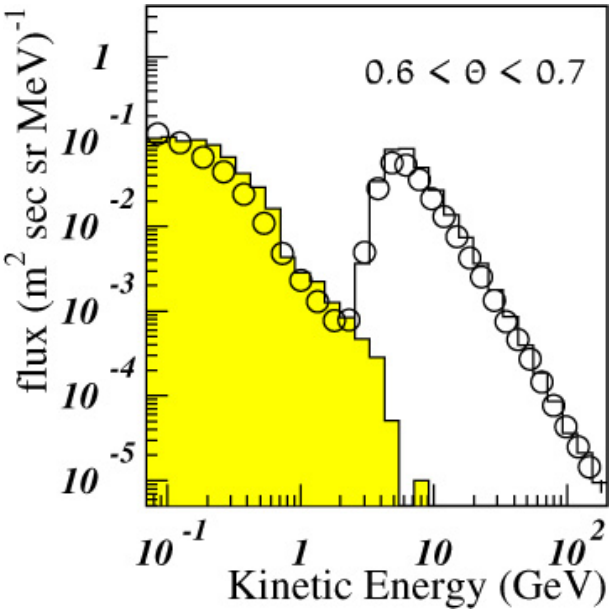
Phys. Lett. B490 (2000) 27-35

Helium in Near Earth Orbit

Phys. Lett. B494 (2000) 193-202

AMS01: 0 $\overline{He}$ / $2.86 \cdot 10^6$ He $<$ 100GV



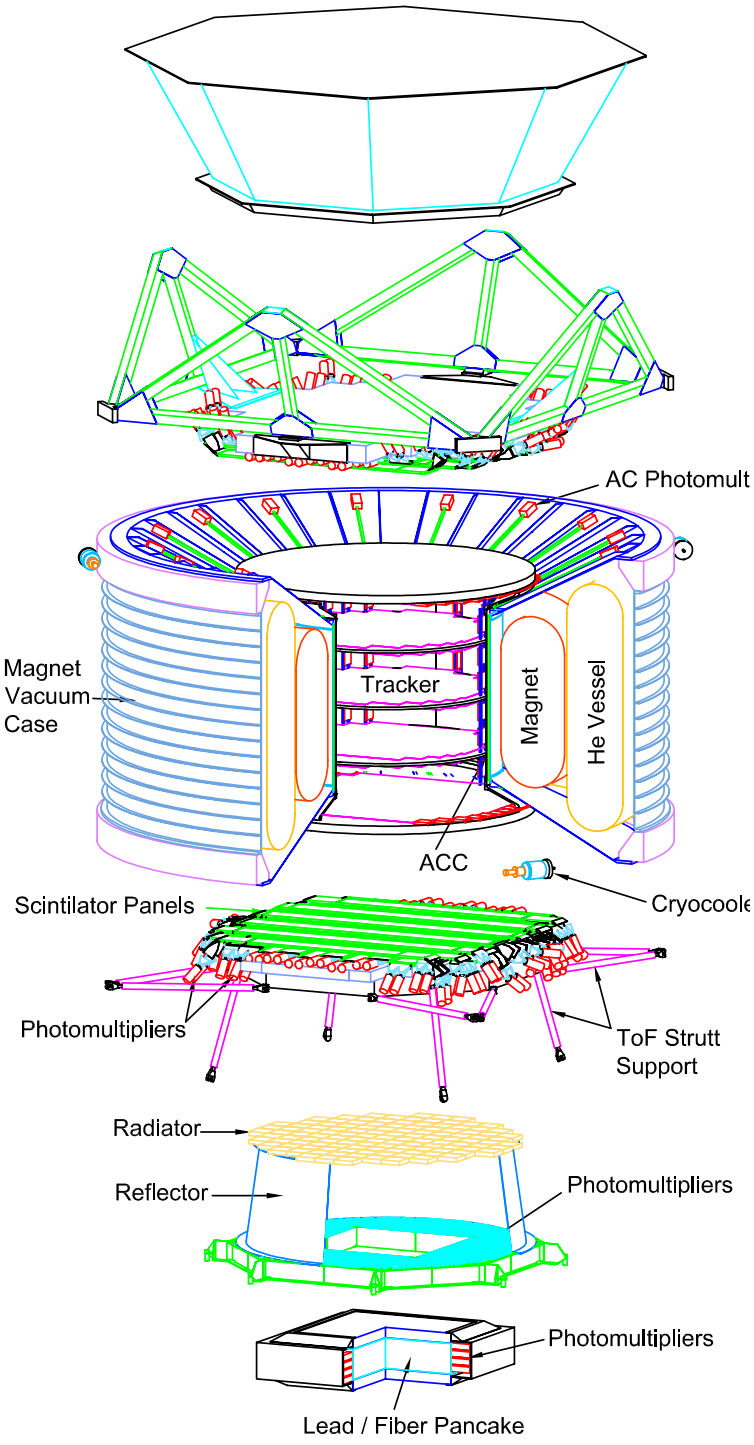


50 AMS01 related papers submitted to ICRC 2001

AMS02 – A Particle Spectrometer for ISS

How to suppress proton background to 10^{-6} and perform high statistic tracking up to 1 TV?

Large acceptance 0.5 m^2sr in orbit for 3 years



TRD Particle ID & 3D tracking
20 layers fleece + Xe/CO2
5248 channels 6mm straw-tubes

$p^+/e^+ < 10^{-2}$ (10 - 300 GeV)

TOF 1,2 Trigger $\sigma_t \approx$125ps

Anticoincidence (Veto) counter

Silicon strip tracker
with internal laser alignment
6 m^2 in 3 double + 2 single xy layers
1σ charge separation up to 1TV

Superconducting Magnet (ETH)
B = 0.9T V = 0.6m^3

TOF 3,4 1.3m distance to TOF 1,2
$p^+/e^+ > 3\sigma$ below 2 GeV

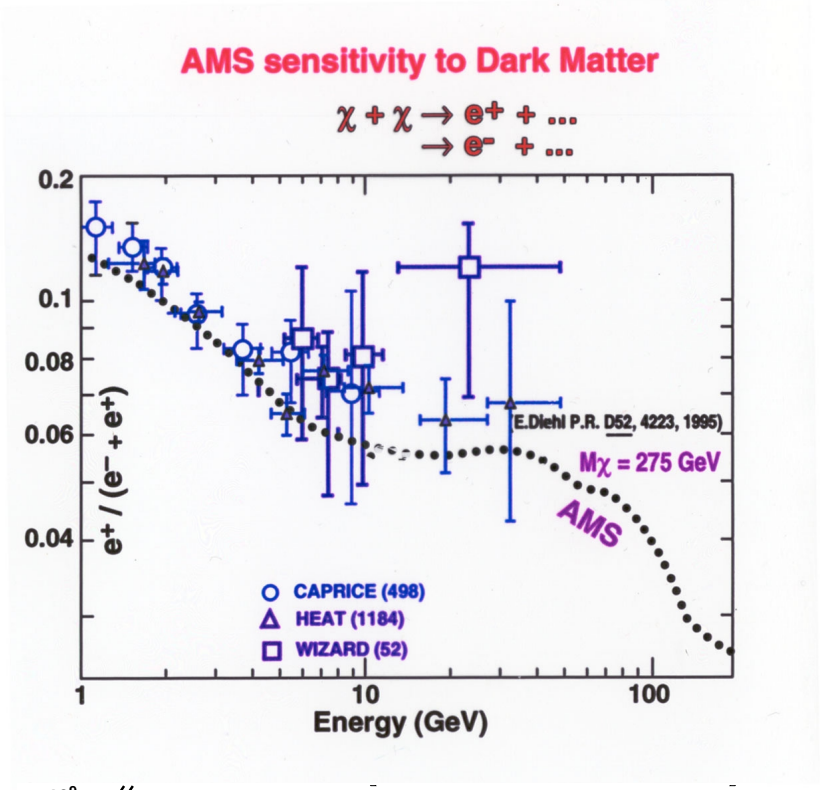
PFRICH AGL(+NaF) Radiator
for A$\leq$27 and Z$\leq$28
separation $> 3\sigma$ from 1-12 GeV

ECAL 3D sampling lead/scint.-fibre
with p-E matching and shower-shape

$p^+/e^+ < 10^{-4}$ (10 - 300 GeV)

AMS02 Expectations

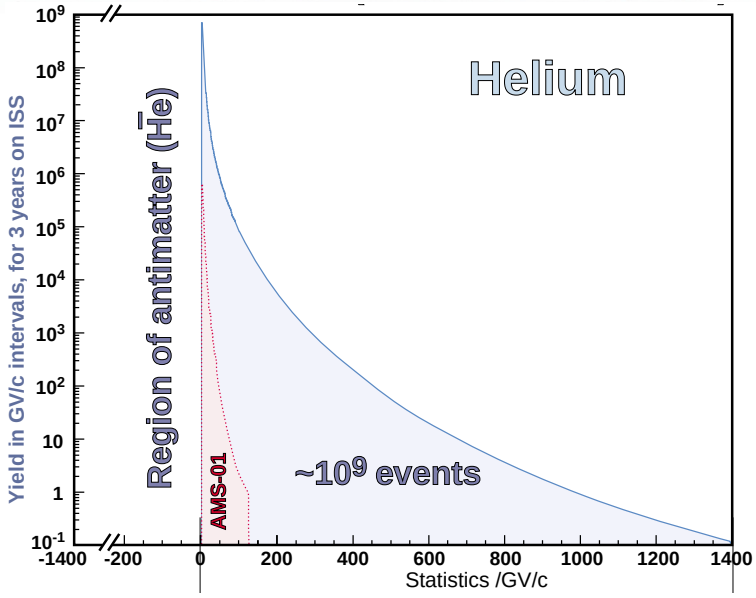
AMS01 statistics $\times 10^3$ momentum reach $\times 6$



Expected events:

$4 \cdot 10^6$ e^+ 5 - 300 GeV

$1 \cdot 10^6$ p^- 5 - 1000 GeV

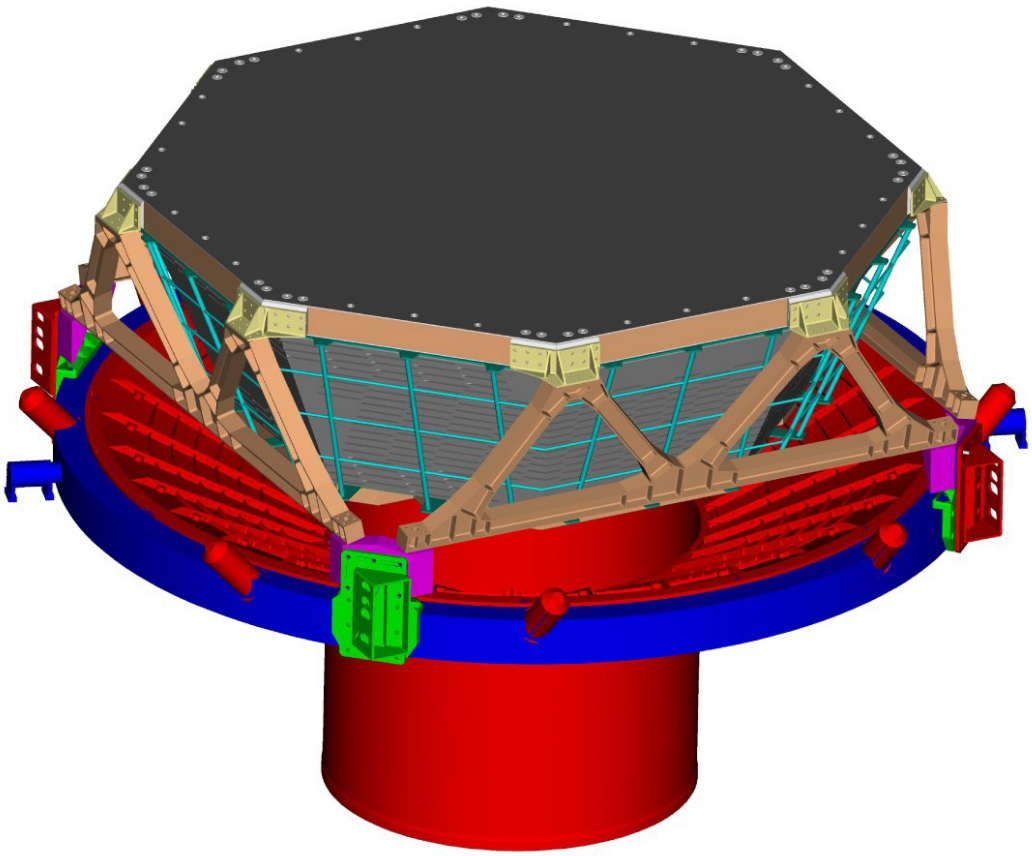


$1 \cdot 10^9$ He 1 - 1400 GV

$3 \cdot 10^6$ p^+ $>$ 1 TeV

$1 \cdot 10^7$ e^- $>$ 10 GeV

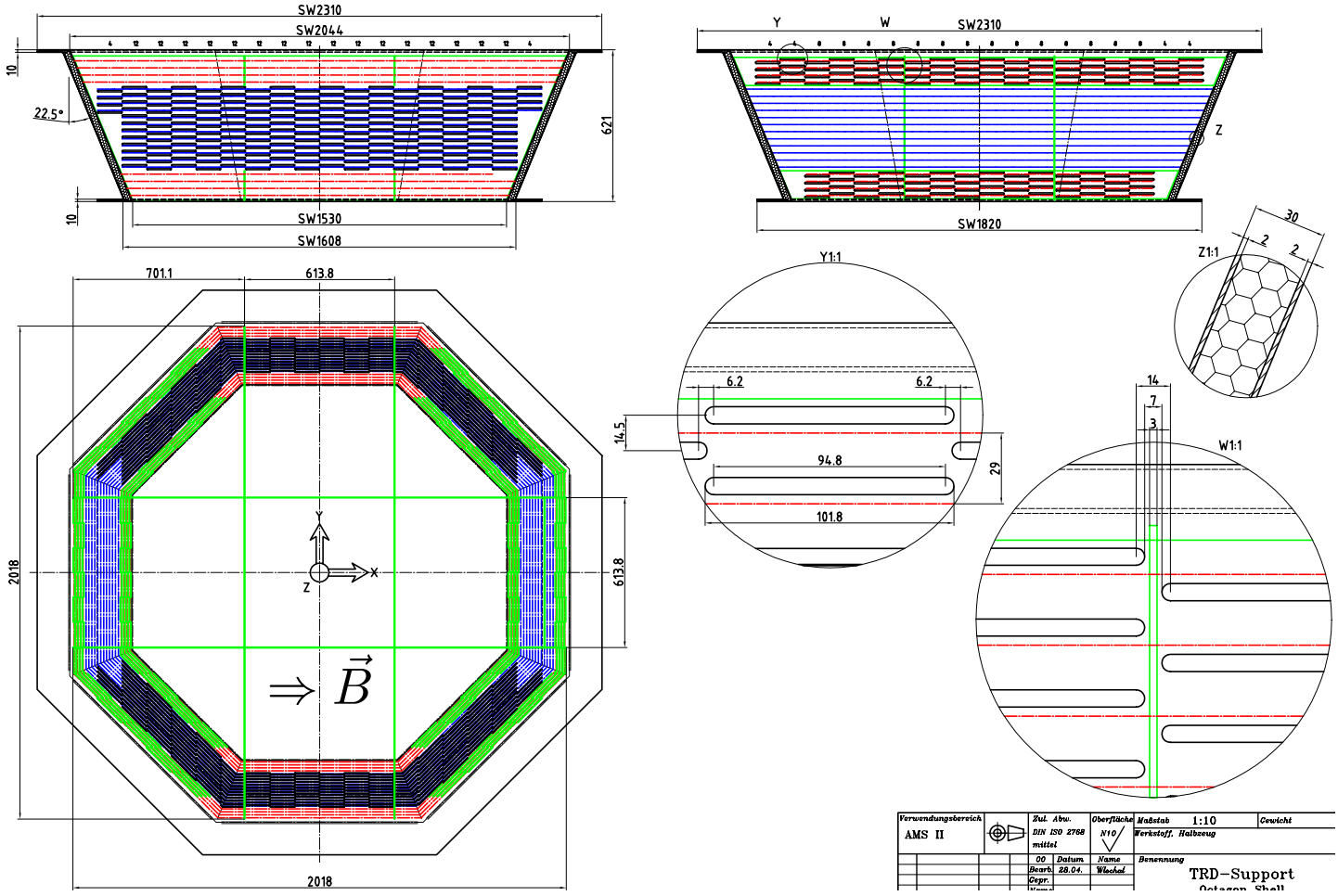
TRD Octagon Support



Component	kg
Radiator + Straws	118
Xe/CO_2	46
Octagon + Support + Shielding	207
Gas System	50
Electronics	53
TRD Total	474

TRD Octagon Construction

20 layers with 22mm radiator 6mm straw tube modules

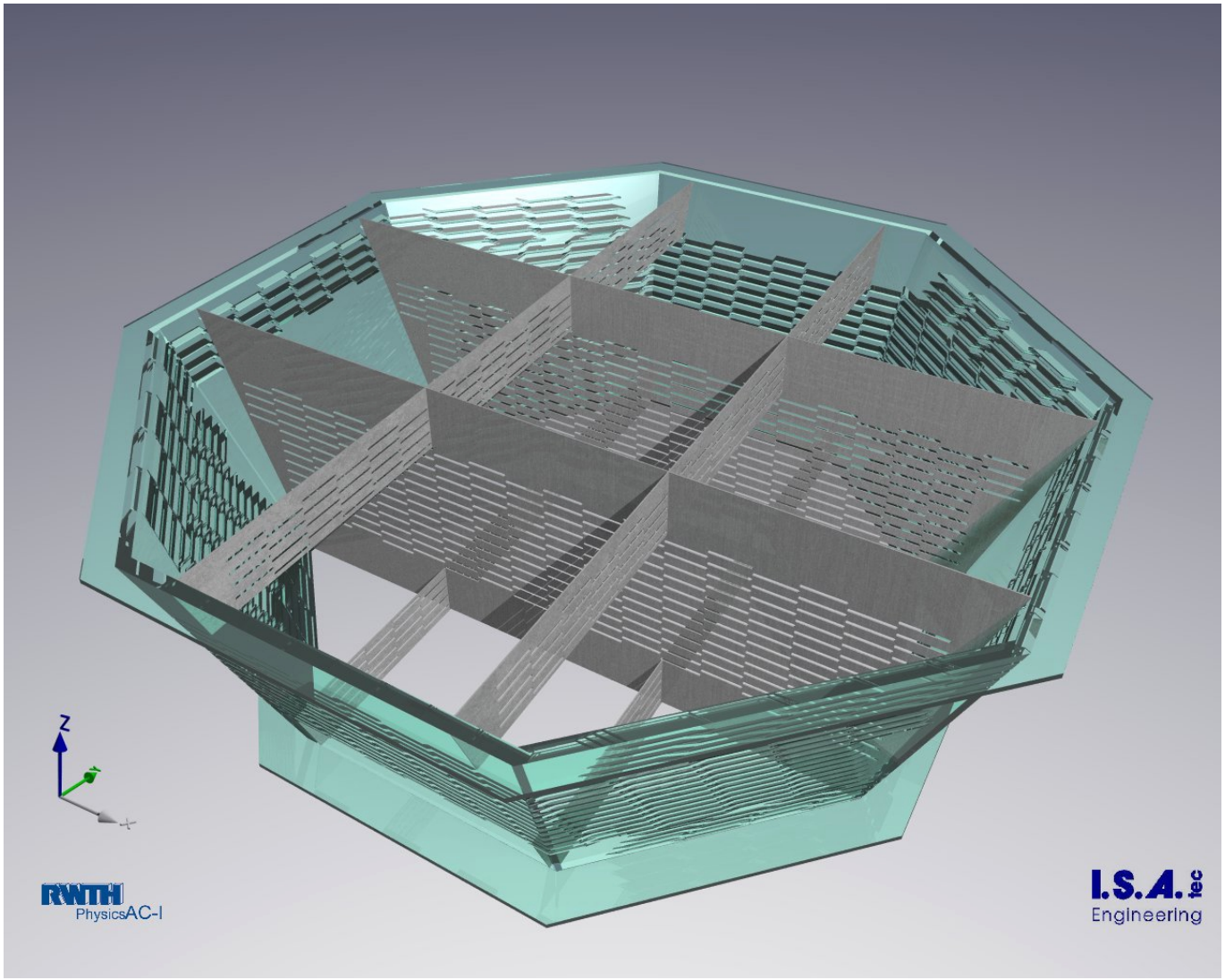


2018mm

Upper/lower 4 layers measure in bending plane
Middle 12 layers measure in perpendicular plane

328 Modules, supported with 100 μm mech. accuracy

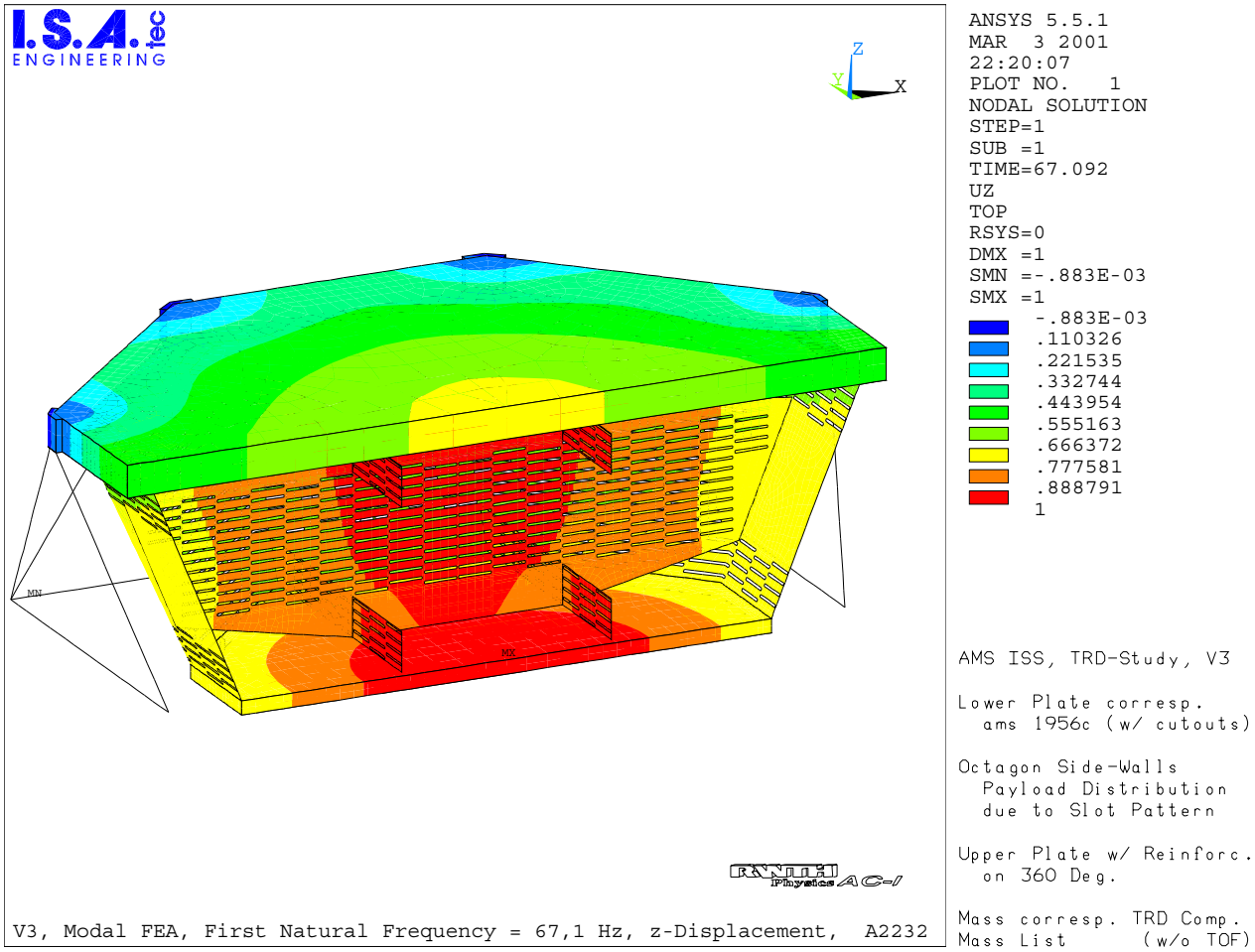
Chamber support in Octagon



Octagon + bulkheads support chambers from 86 to 201cm

Structural Verification (modal analysis)

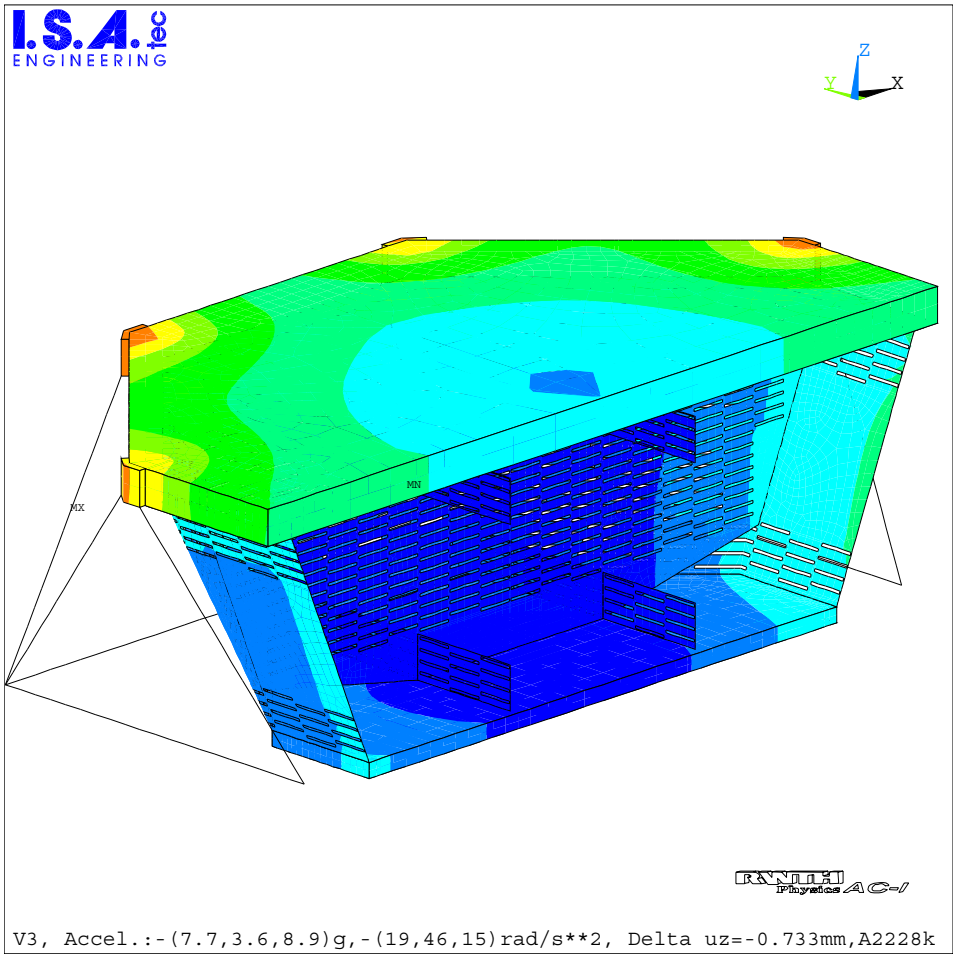
NASA requirement: $f_0 > 50$ Hz



Coupled load modal analysis FEC: $f_0 = 67.1$ Hz

Parameters from static elastic modulus measurements
Verification with componet vibration tests

Structural Verification (displacement)



ANSYS 5.6.1
MAR 16 2001
11:47:51
PLOT NO. 1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
UZ
TOP
RSYS=0
DMX =31.607
SMN =-.724748
SMX =.007766

-.724748
-.640632
-.556516
-.472399
-.388283
-.304167
-.22005
-.135934
-.051818
.032299

AMS ISS, TRD-Study, V3

Lower Plate corresp.
ams 1956c (w/ cutouts)

Octagon Side-Walls
Payload Distribution
due to Slot Pattern

Upper Plate w/ Reinforc.
on 360 Deg.

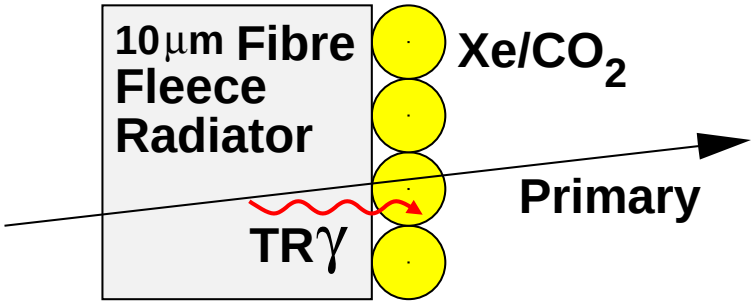
Mass corresp. TRD Comp.
Mass List (w/o TOF)

Main accelerations during shuttle start: 7.7g in x
and at landing: 8.9g in z

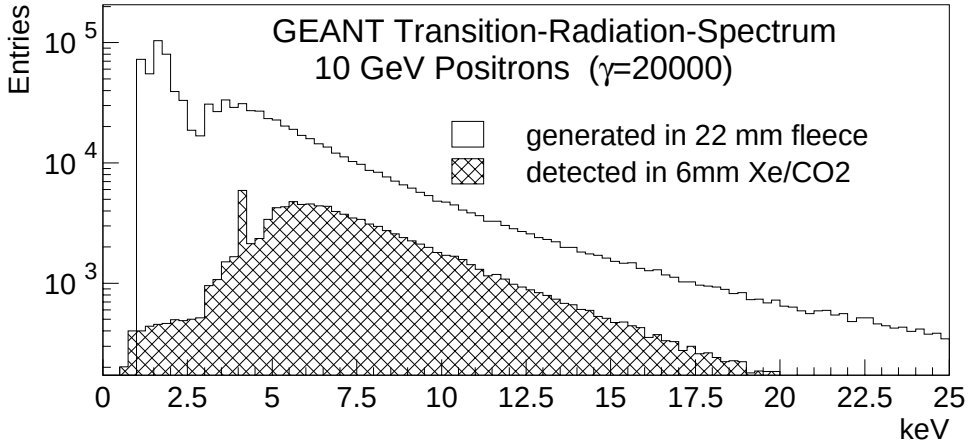
Max. displacement 0.73mm well within elastic limits

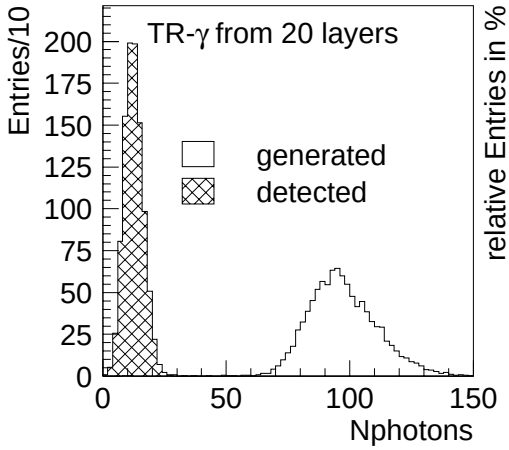
TRD-Principle

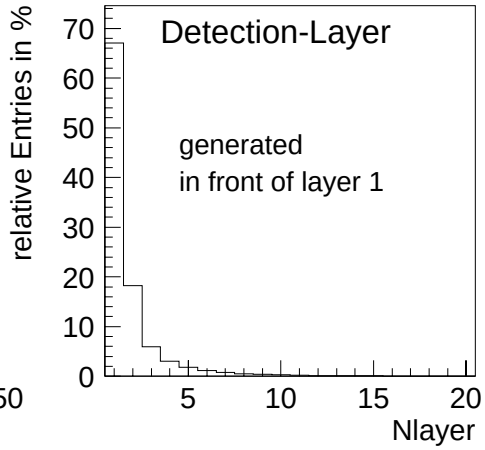
Realisation: HERAb/ATLAS straw-tubes and fleece



$$N_{Ph} \quad \mathcal{O} \quad \alpha_{em} \times N_{tr}$$
$$E_{Ph} \quad \sim \quad \gamma$$
$$\theta_{Ph} \quad \sim \quad 1/\gamma$$

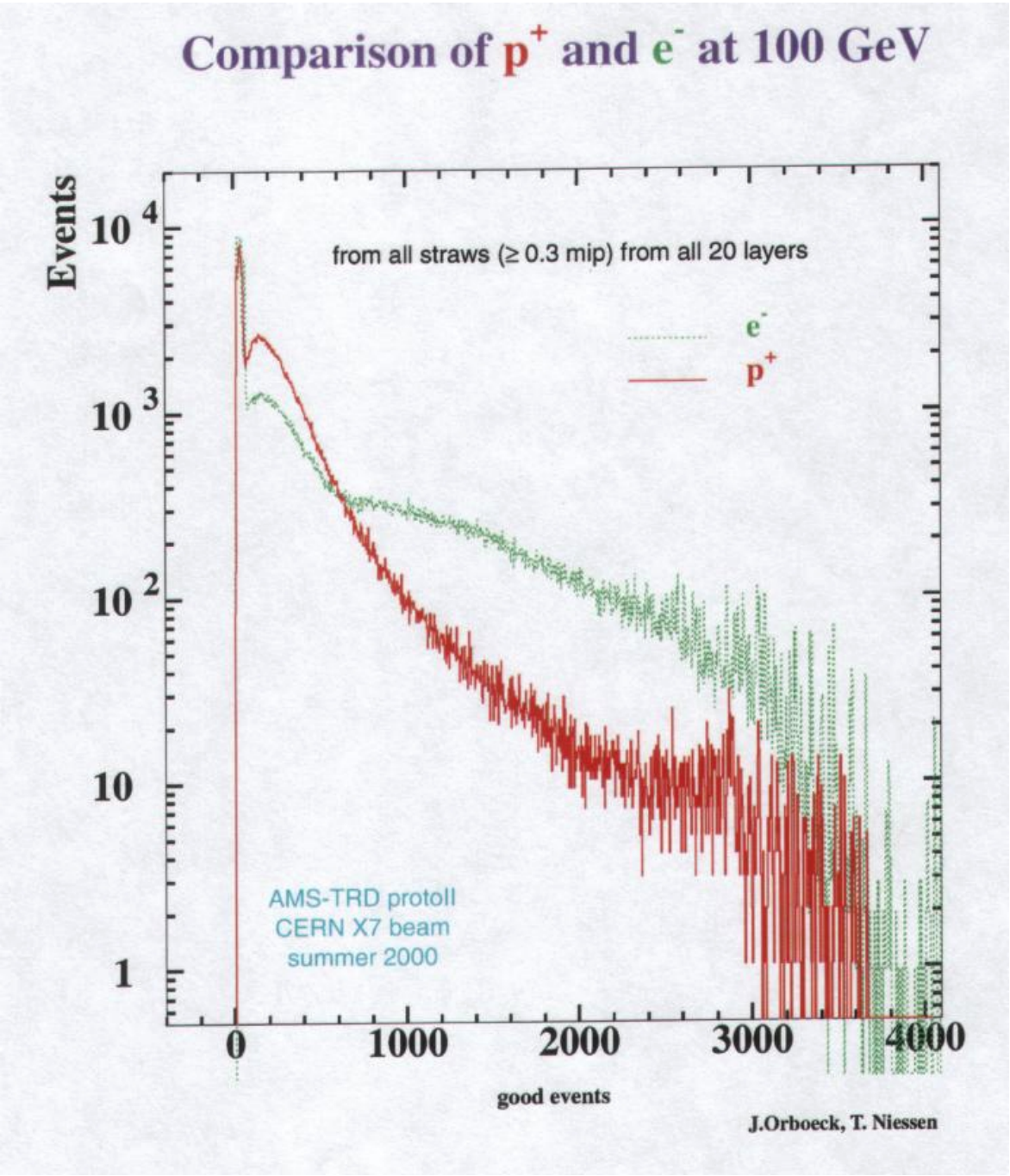






TRD Parameters

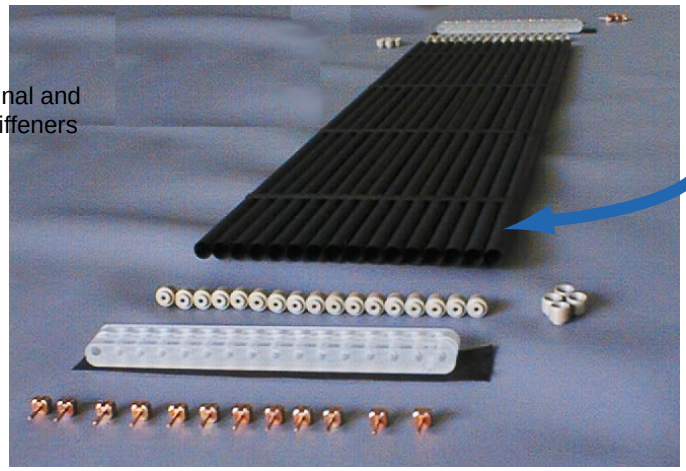
Chosen configuration: 20 layers with 22 mm fleece



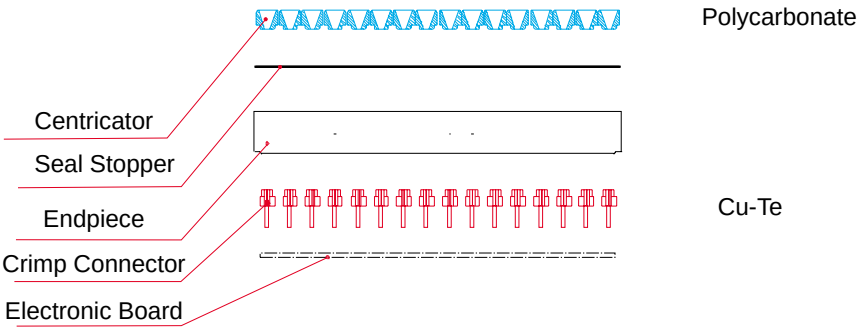
Straw Modules

Module: 16 tubes at 6mm ∅ with 30 μm W-Au wire

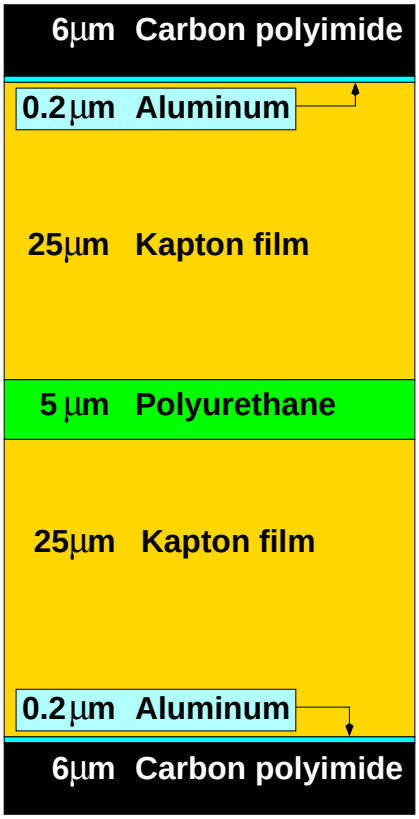
Multilayer Capton tubings

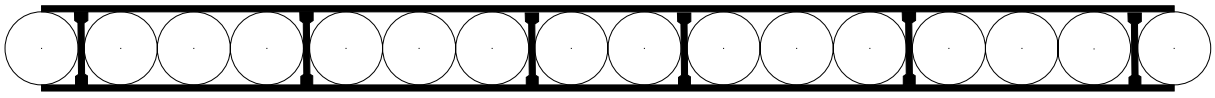


CFC longitudinal and transversal stiffeners



Capton wall



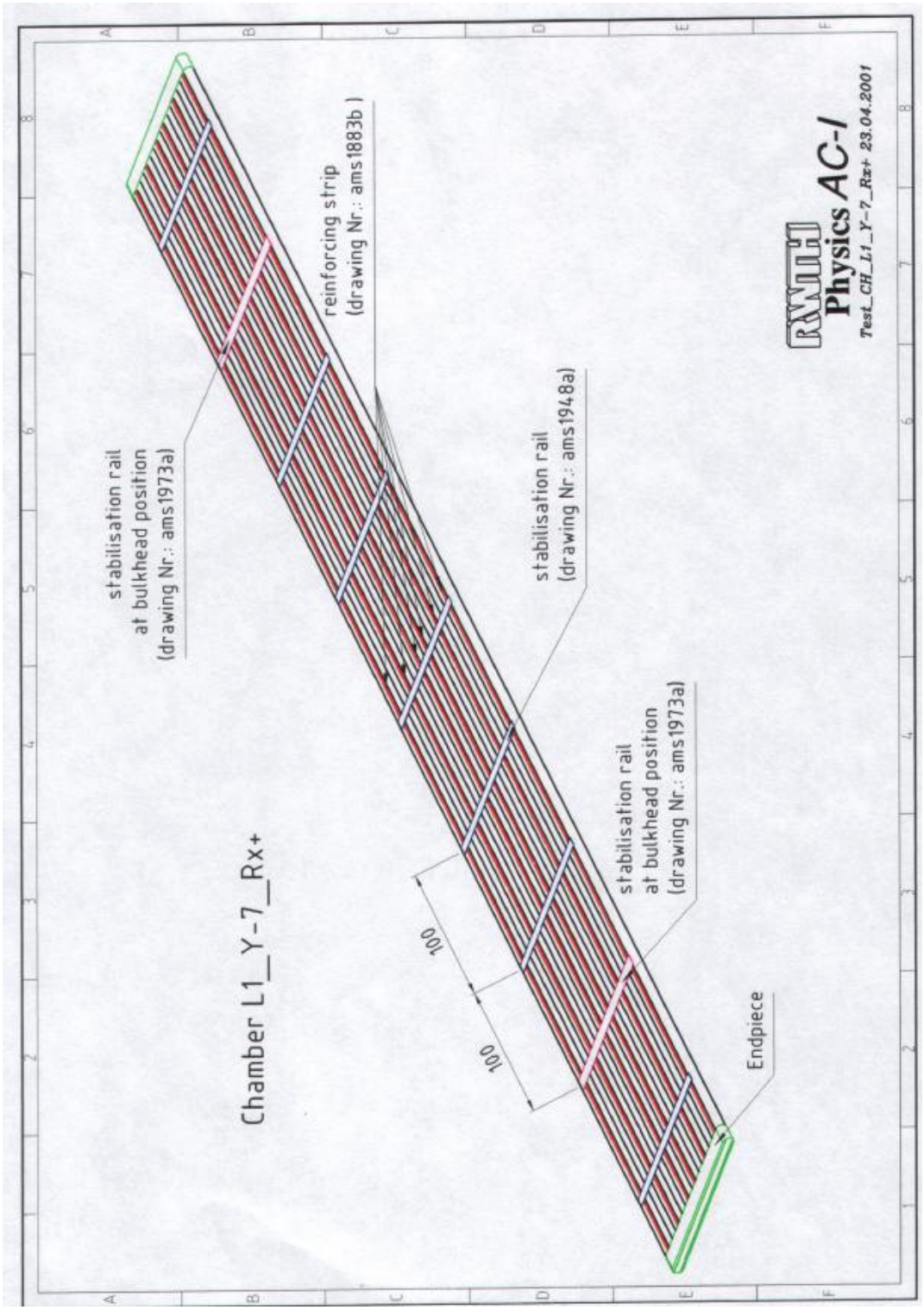


6 longitudinal stiffeners

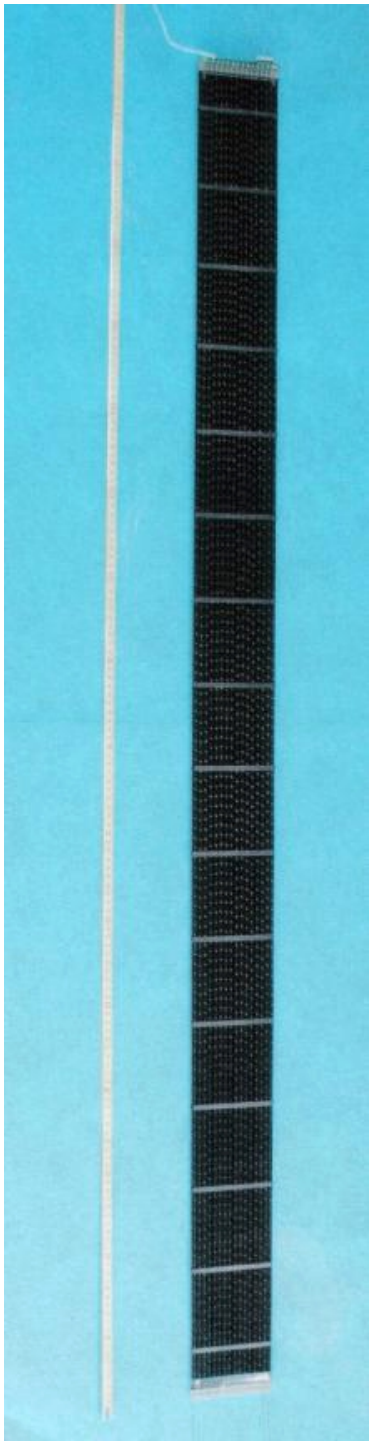
Strips across every 10 cm

Module lengths between 86 cm and 201 cm f_0 = 101 Hz

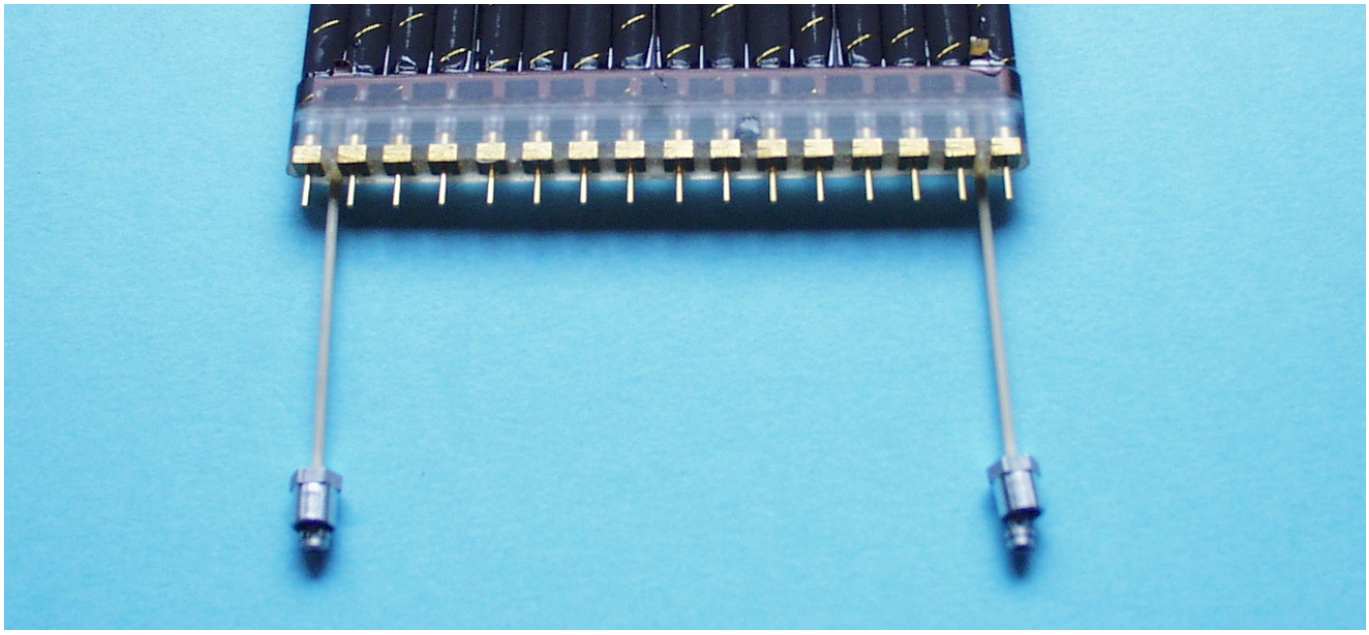
Straw Modules



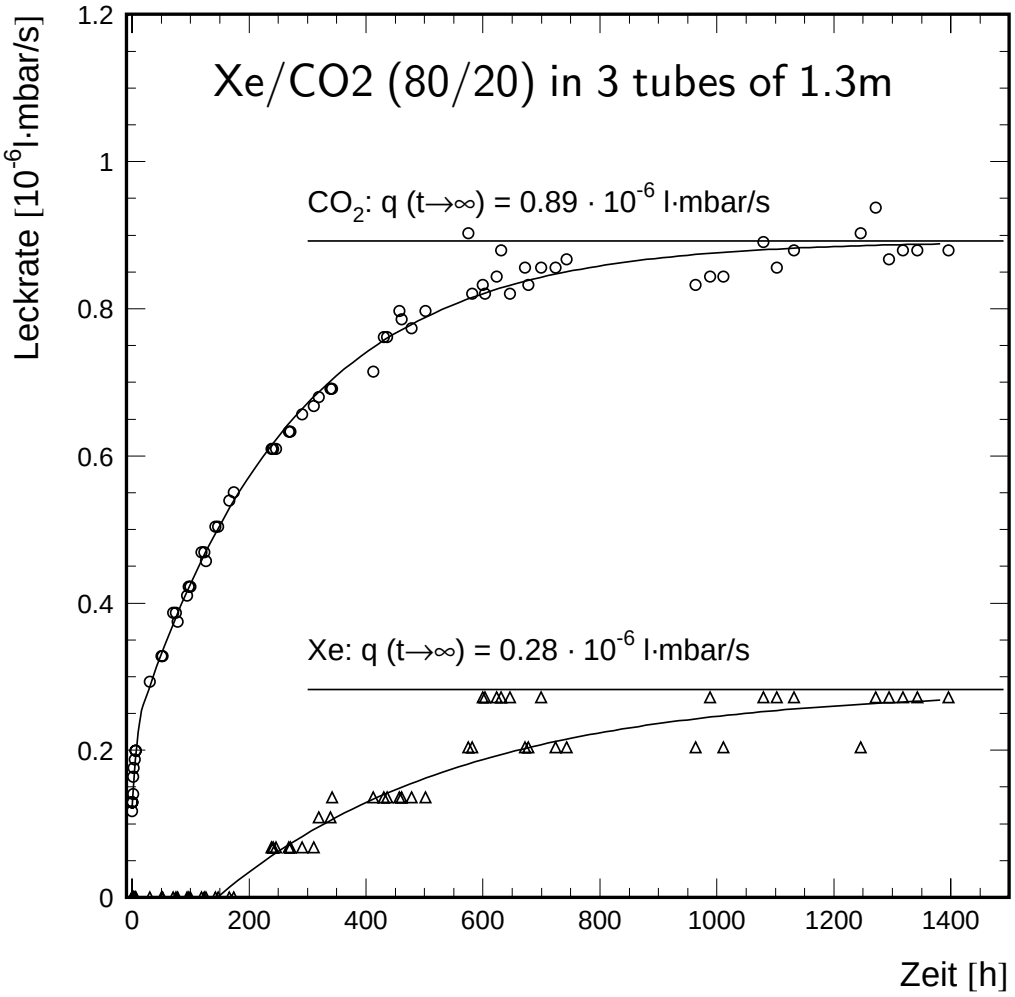
Straw Modules



Straw Modules



Diffusion Measurements



Gas leakage through straw wall

CO_2: $0.23 \cdot 10^{-6}$ l mbar / s / m $\equiv$ 0.17 l/d @ 1 bar

Xe: $0.07 \cdot 10^{-6}$ l mbar / s / m $\equiv$ 0.05 l/d @ 1 bar (for 230 l TRD)

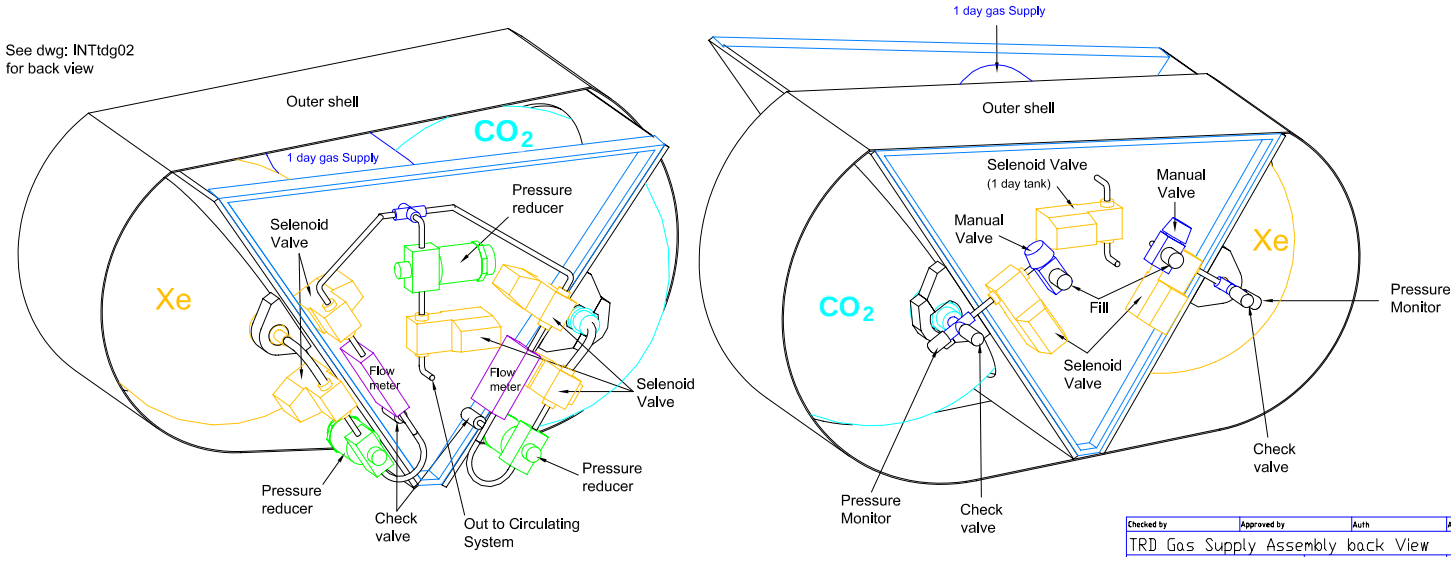
total: $1 \cdot 10^{-5}$ mbar/s at 1 bar

TRD Gas System (MIT)

Allowed leakage: $1{\cdot}10^{-4}$ mbar/s at 1 bar
Equiv. to 1760 l Xe and 440 l CO_2 in 1000 days

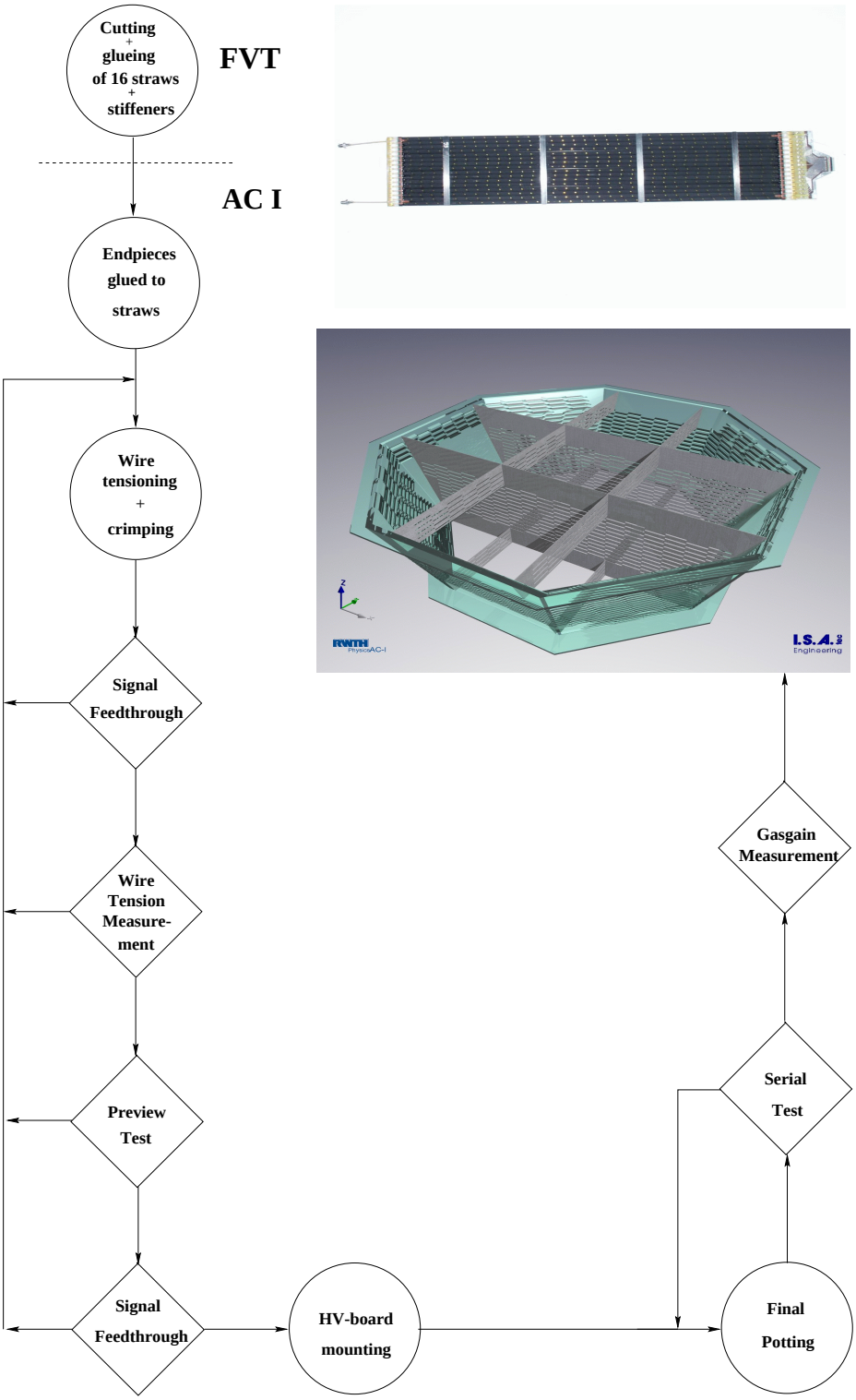
Storage:	44.3 kg Xe	3.7 kg CO_2 at 50 bar
Equiv. to	8100 l Xe	2000 l CO_2 at 1 bar

Extra safety factor of 5 for gas-refreshing



Circulating system serving 41 loops at 1 l/h
each with 8 modules in series

Straw Module Produktion



Chamber Body Glueing

Adjustable cutting/positioning jig built at AC I

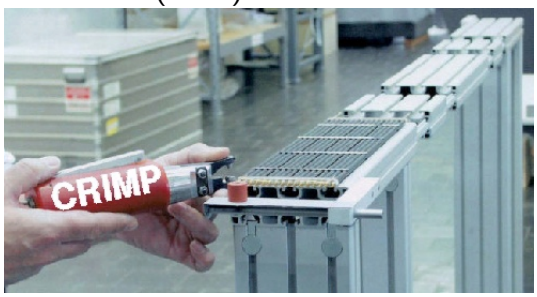
Carbon-fiber rod assures straightness
- straw to straw: 50 μm
- along straw: 10 μm

Glueing with automatic dispenser

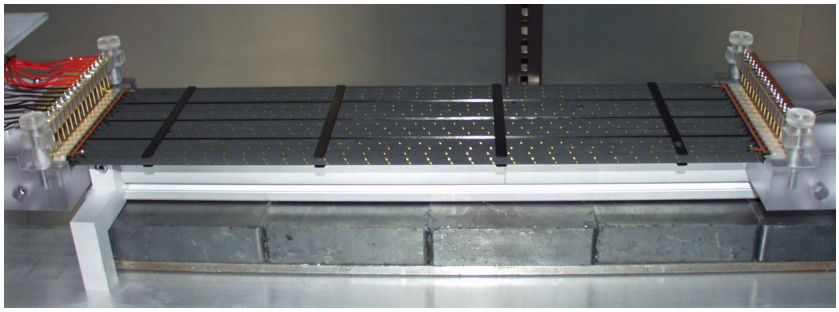
Wire Stringing

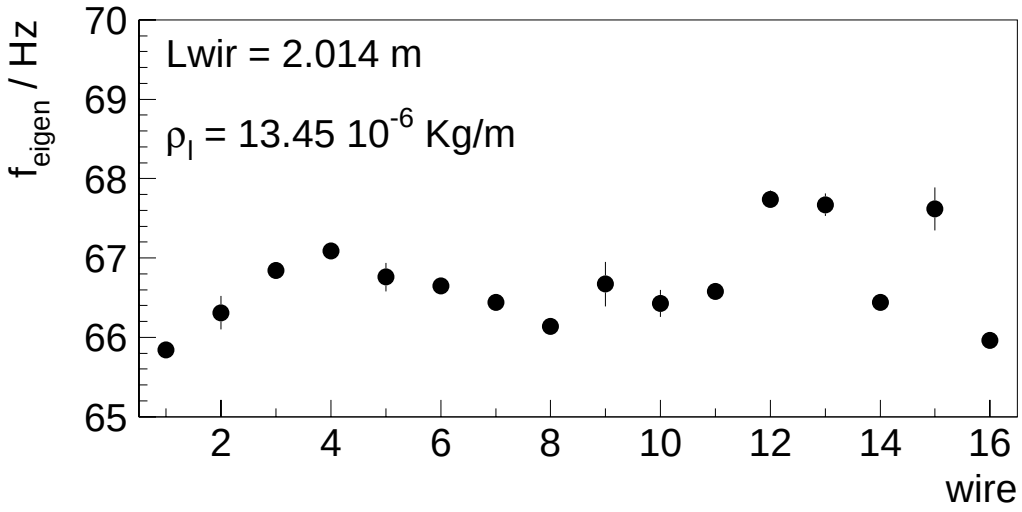
Stringing & crimping

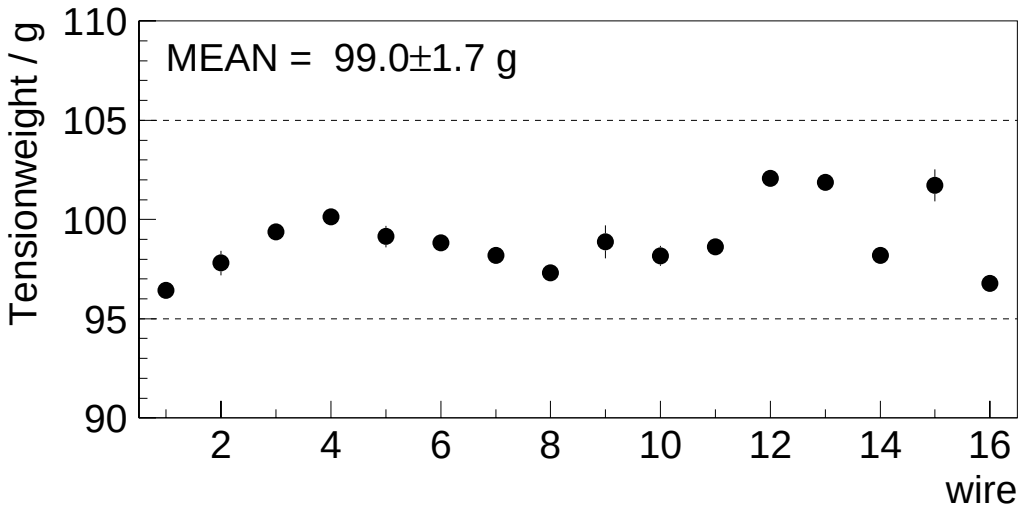
NIM A336 (1993) 128



Wiretension Measurement







T.S. 13/06/2001 20:20

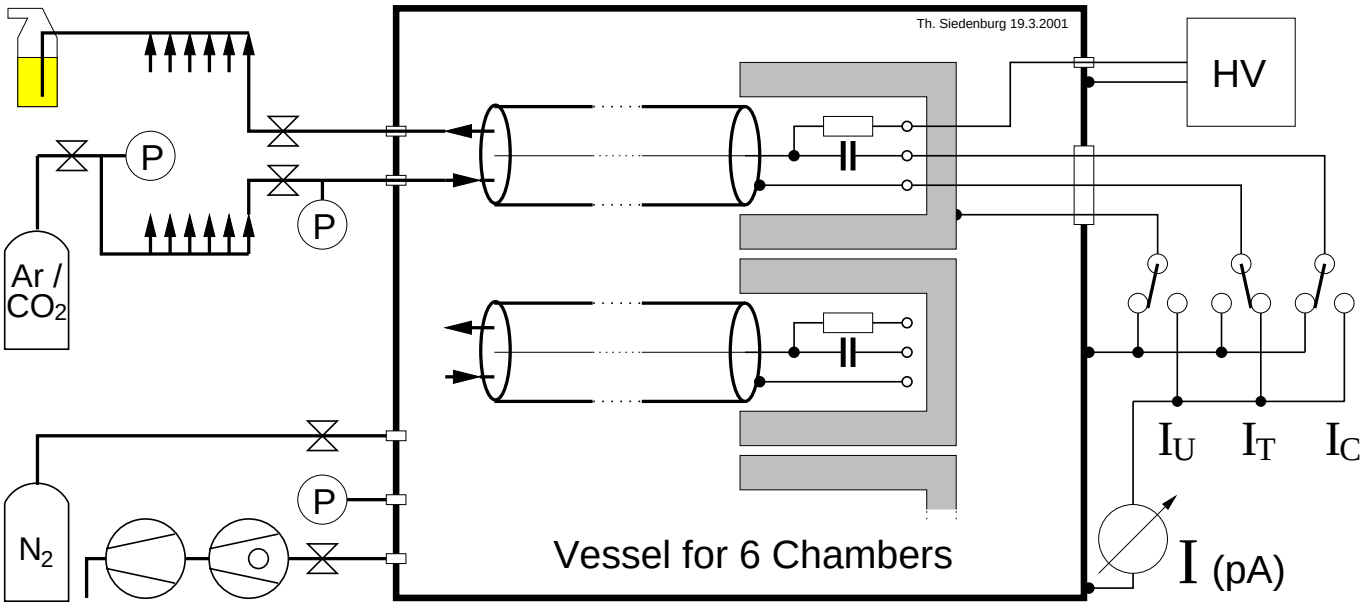
Serial Test

Operation at 1.25 bar
Burst test to 2.5 bar

Gastightness at 2 bar
$< 2{\cdot}10^{-4}$ mbar/s

Leakage < 1 nA through
coupling capacitor (I_C)
tube (I_T)
UTE corona (I_U)

Gas system panel by MIT

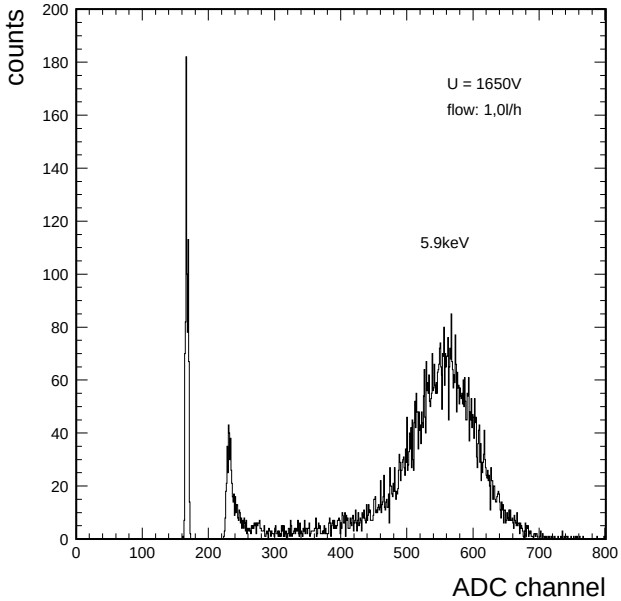


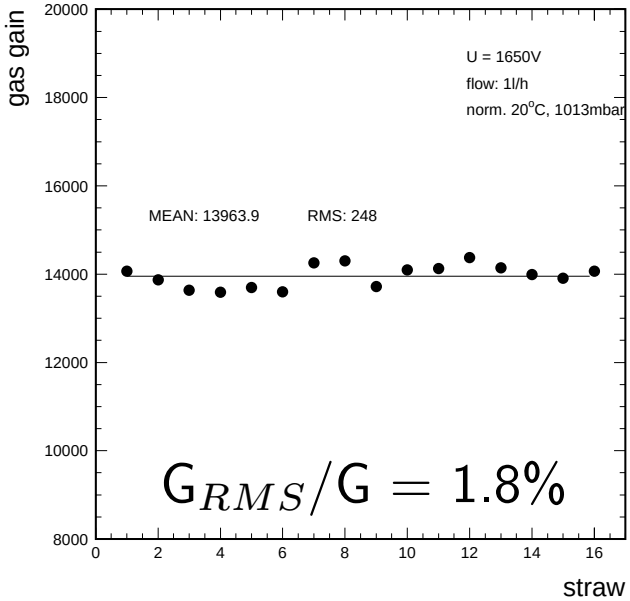
Xe/CO_2 Gasgain Pre-Calibration

Selftriggered Fe^{55} spectra on precision granite block
p and T corrected
$\Delta G/G \approx 5 \cdot \Delta\rho/\rho$

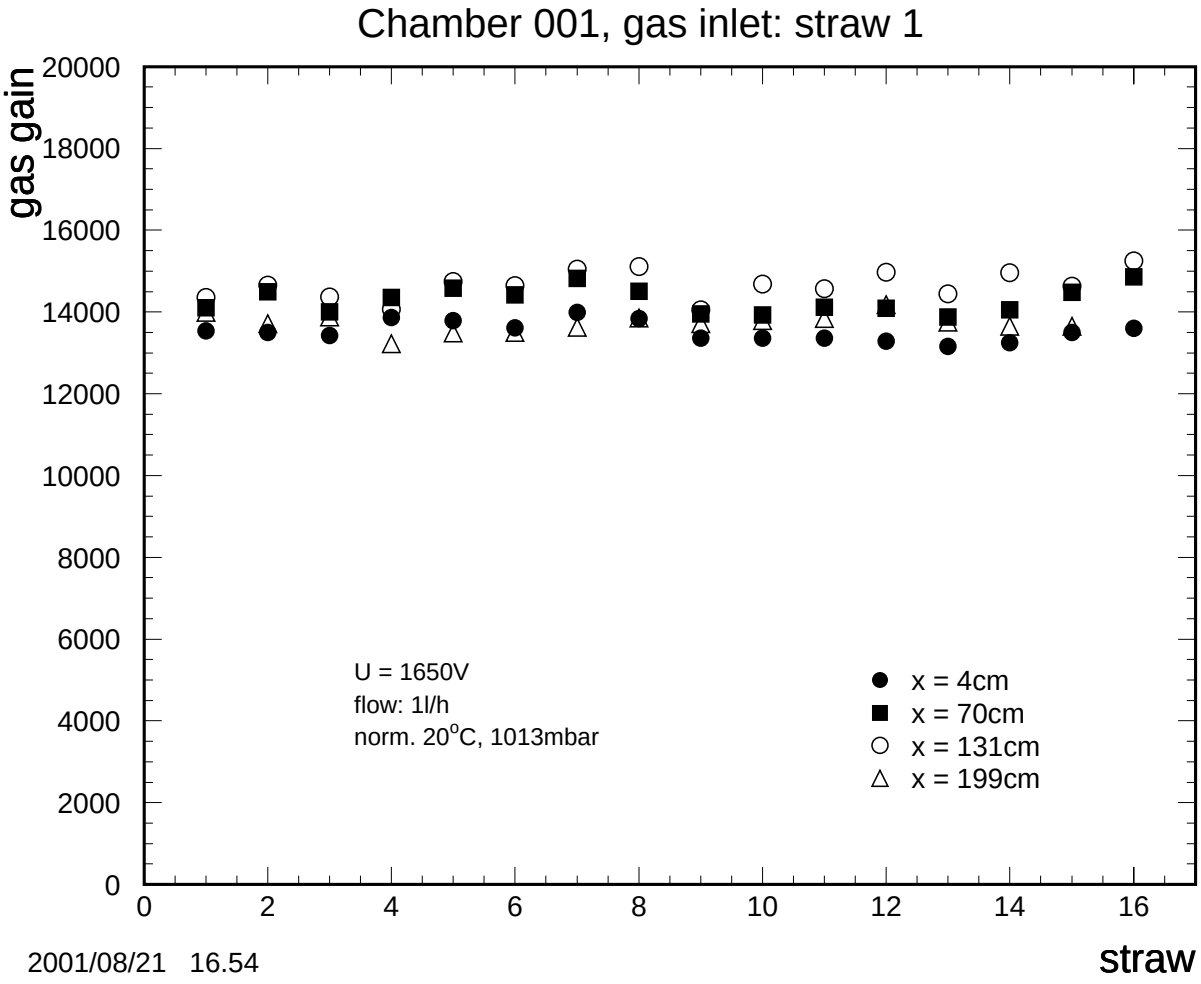
Gain at 1650V 1bar 20°C
homogenity $< 2\%$
G $= 14000 \pm 5\%$

Gas system panel by MIT

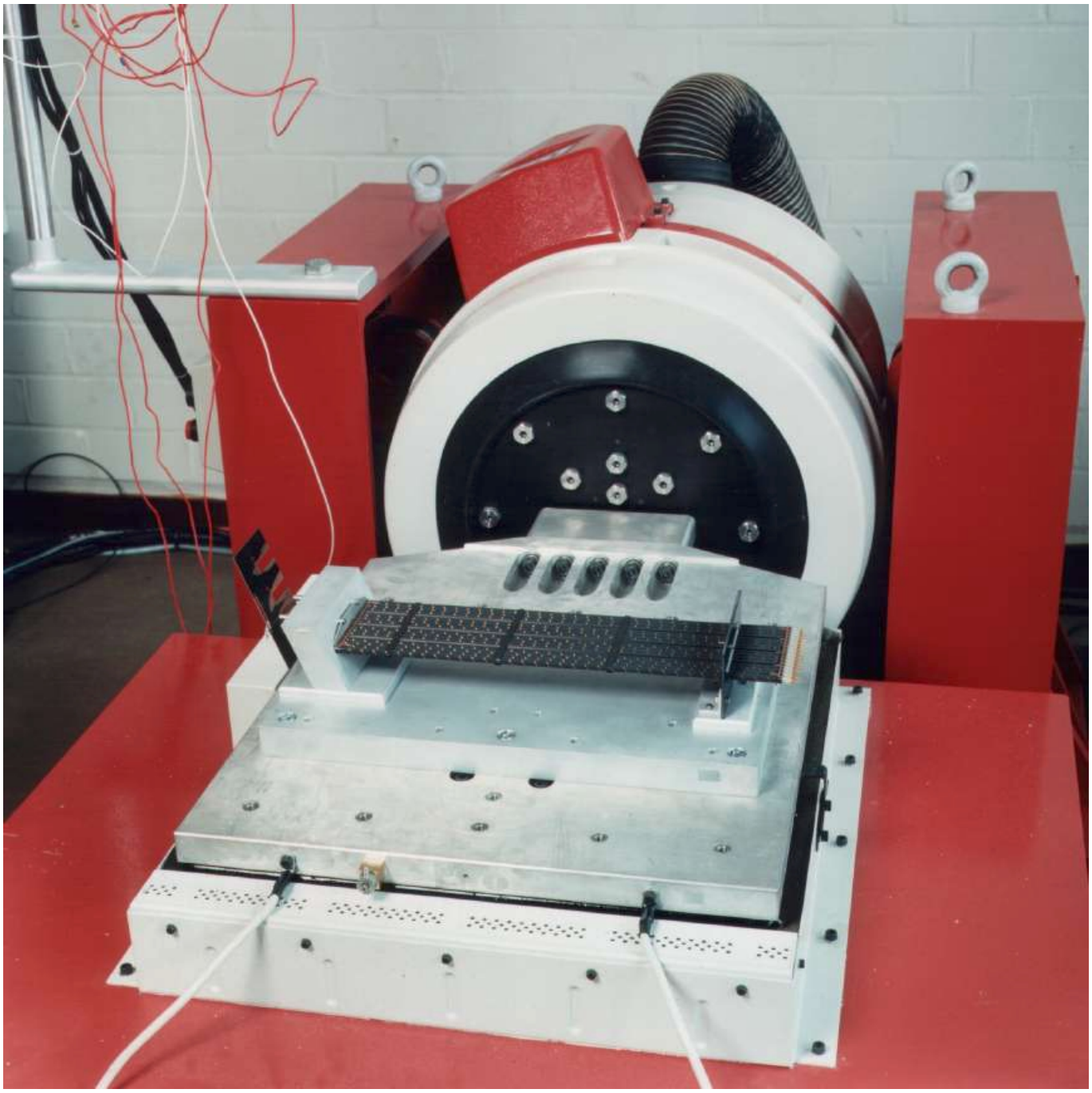




Xe/CO_2 Gasgain Pre-Calibration

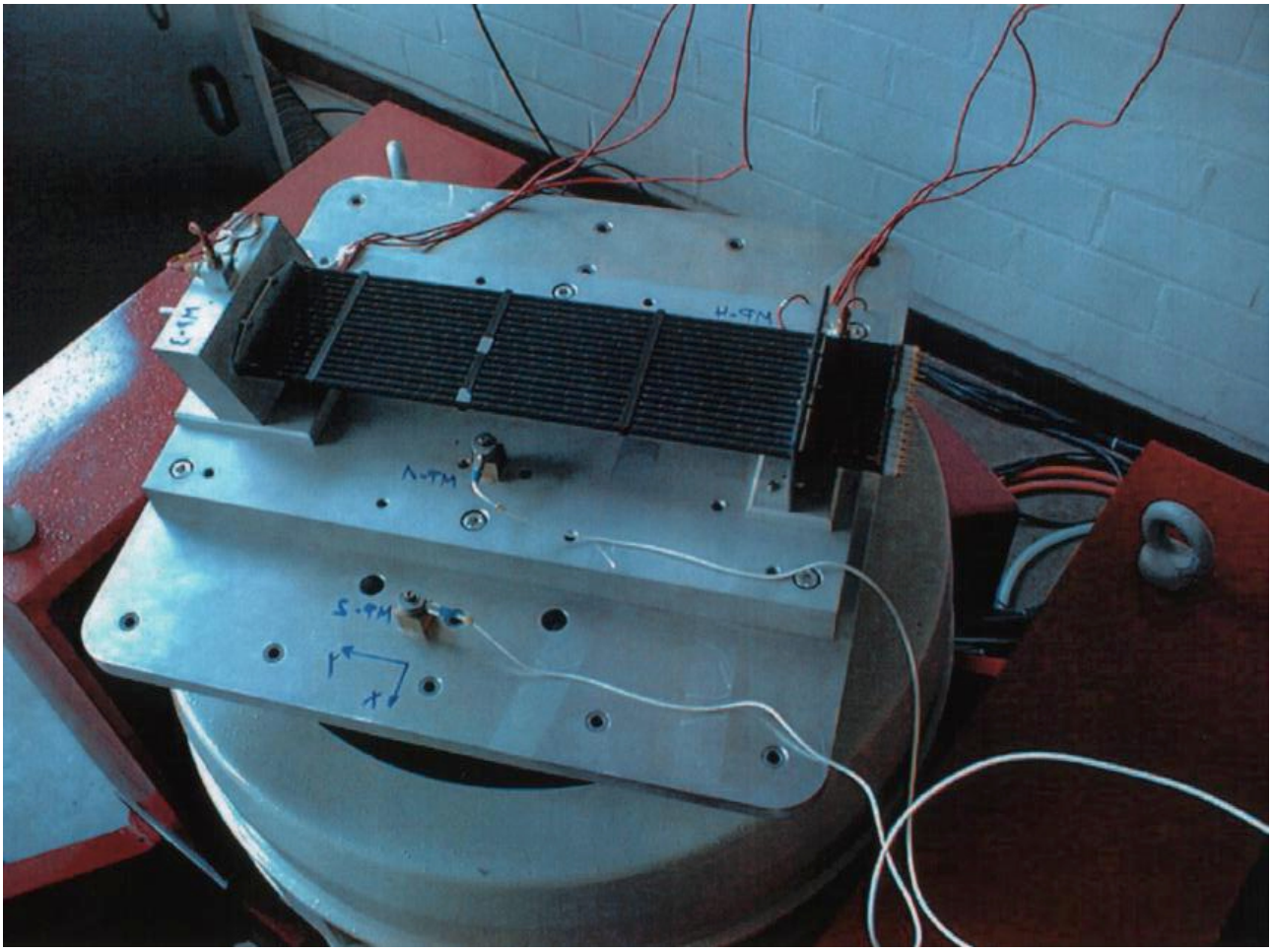


Vibration Tests at RWTH

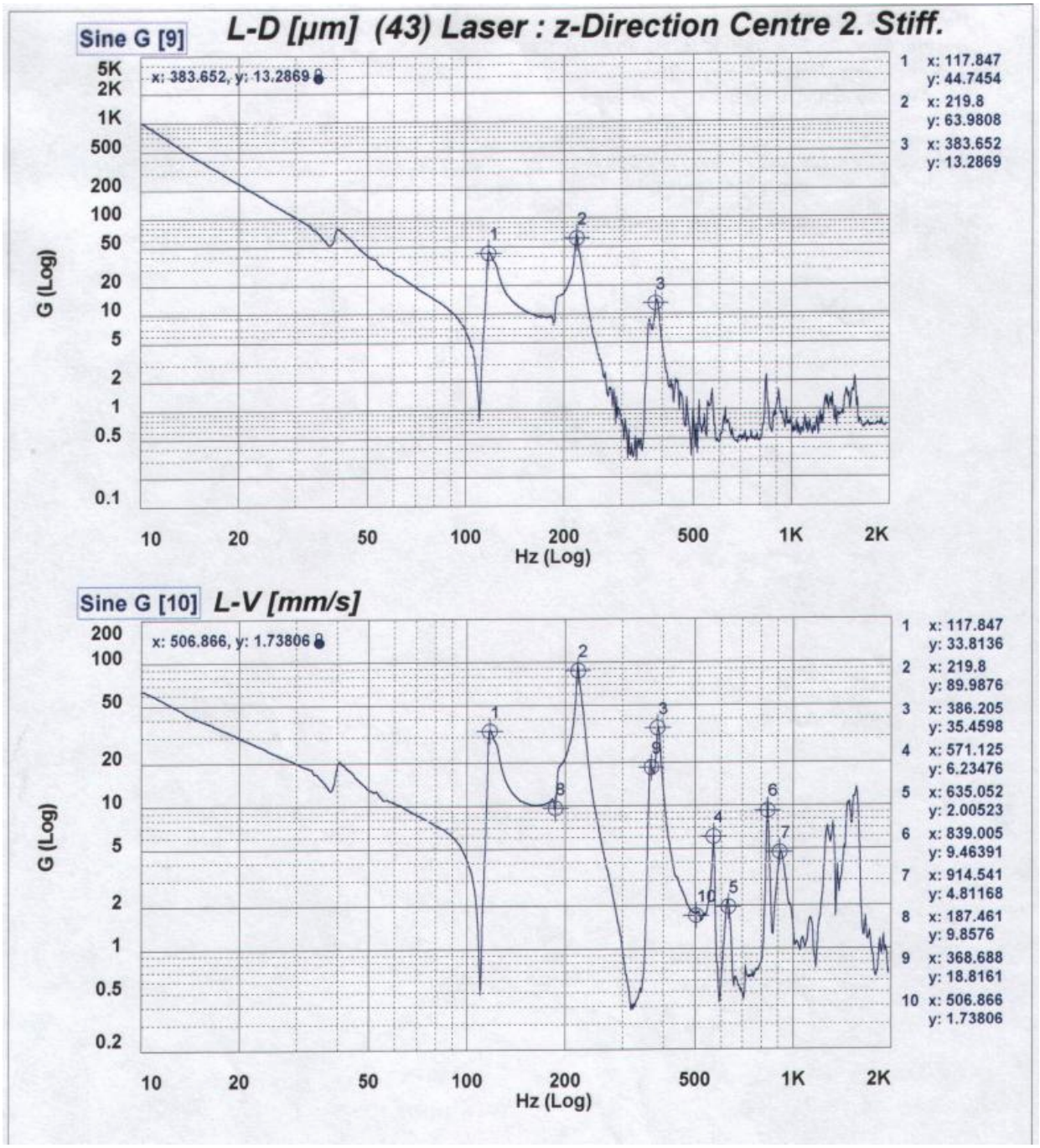


Vibration table at AC I for component testing and space qualification

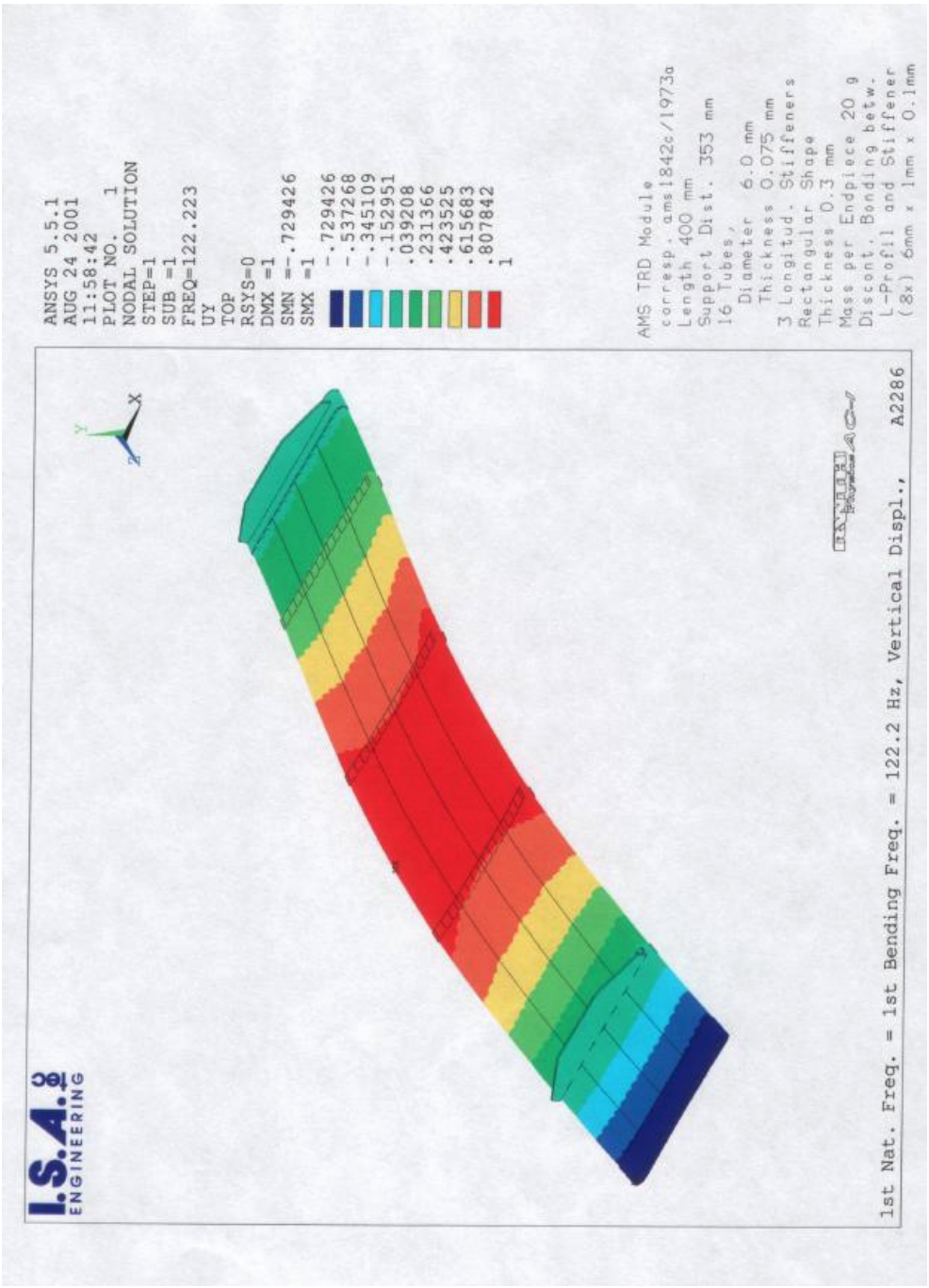
Vibration Tests at RWTH



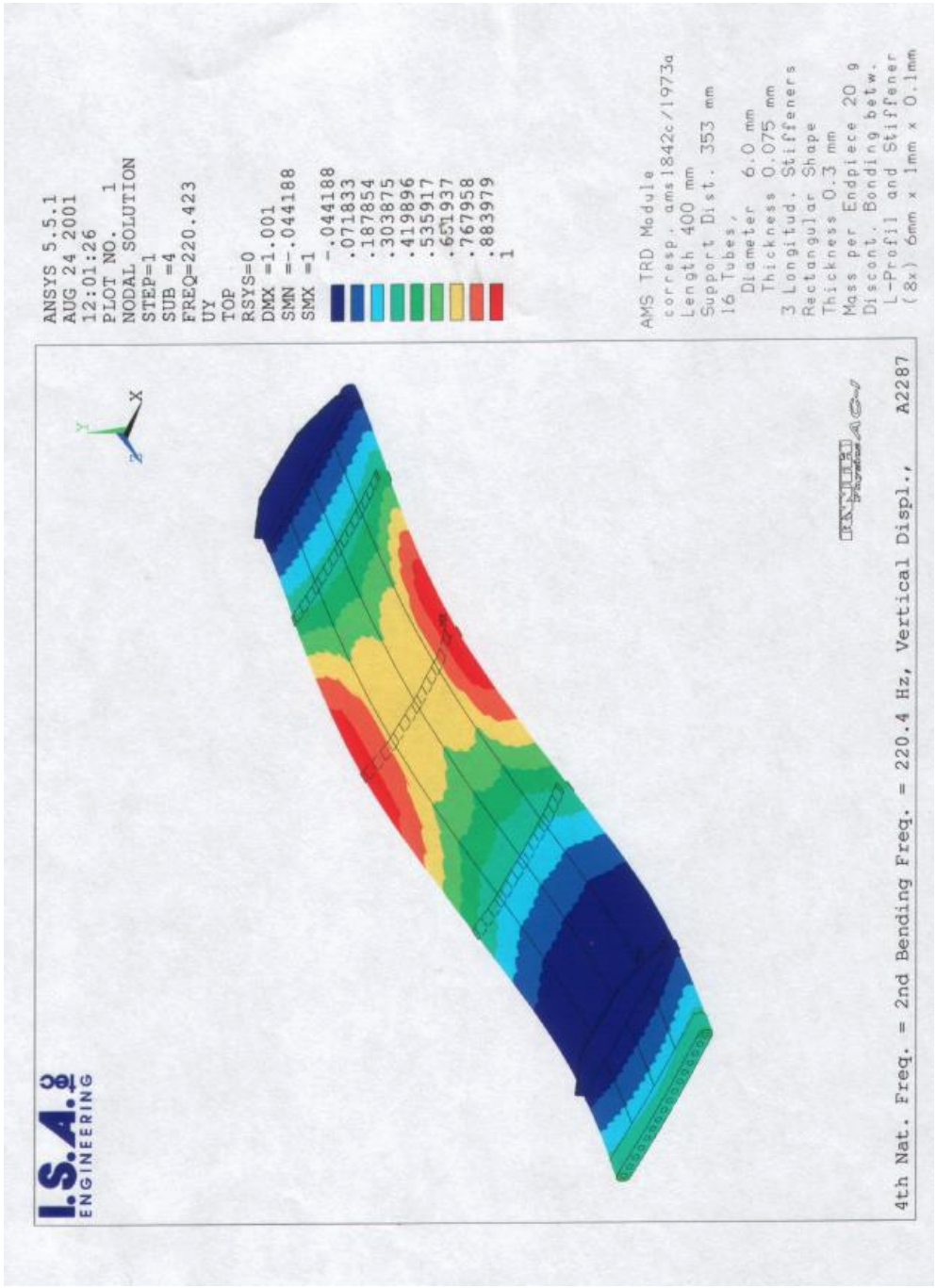
Vibration Tests at RWTH



Vibration Tests at RWTH

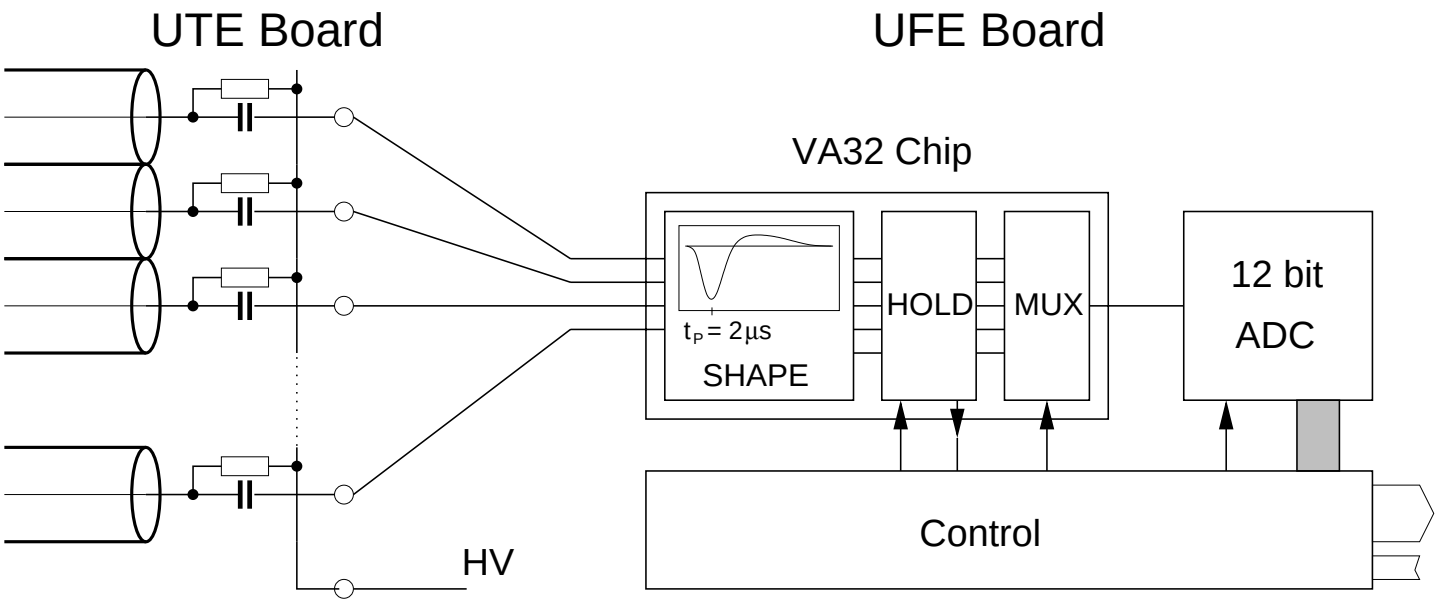


Vibration Tests at RWTH



Frontend Readout (RWTH)

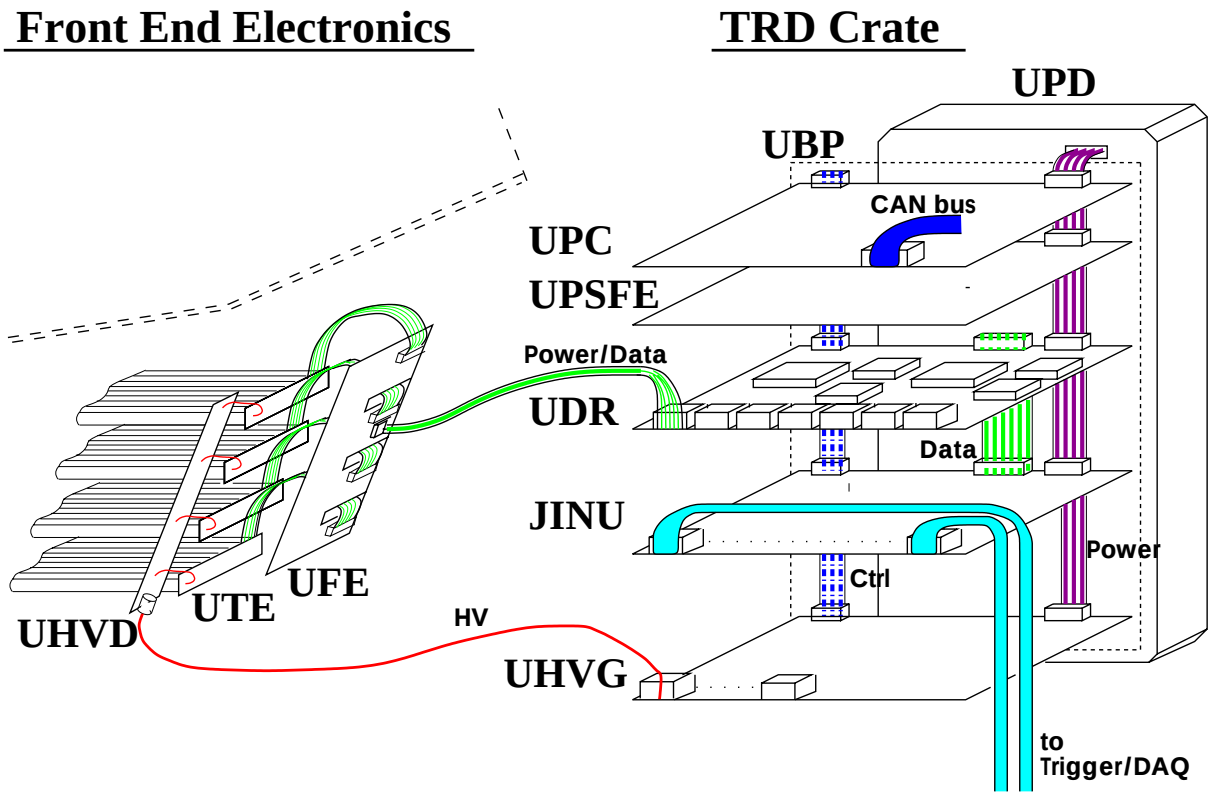
20 W for 5248 channels: Multiplexed pulseheights only



VA Inputrange: 1500 fC $\approx$ 50 MIPs (gasgain 3000)

Noise: $\approx$ 7000 e^- $\approx$ MIP/30

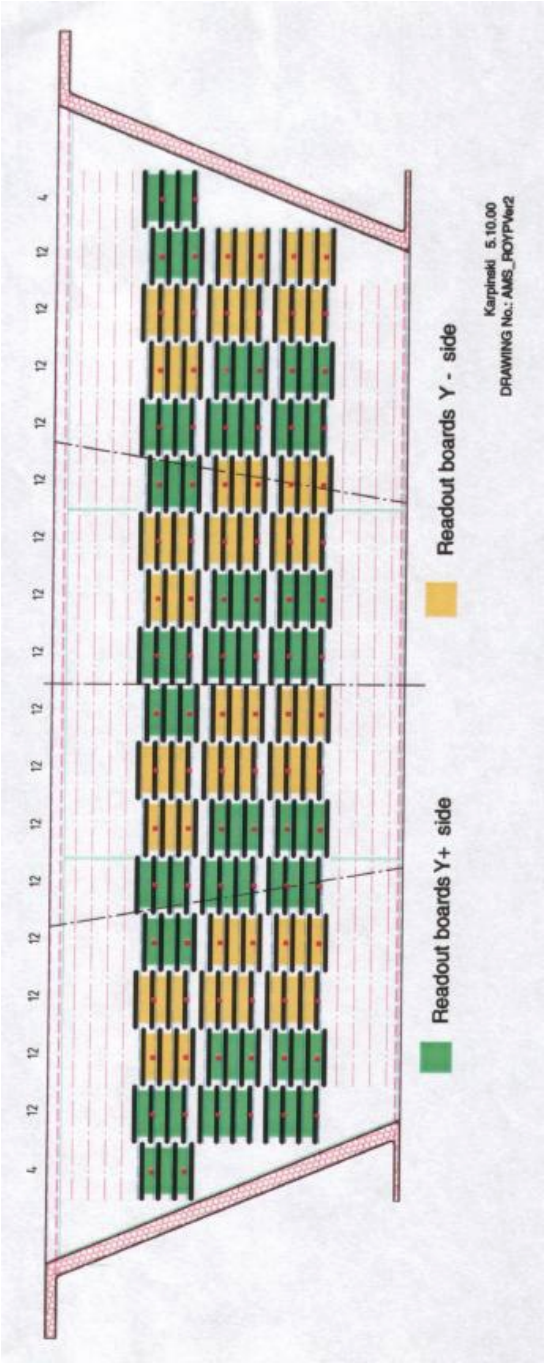
TRD DAQ



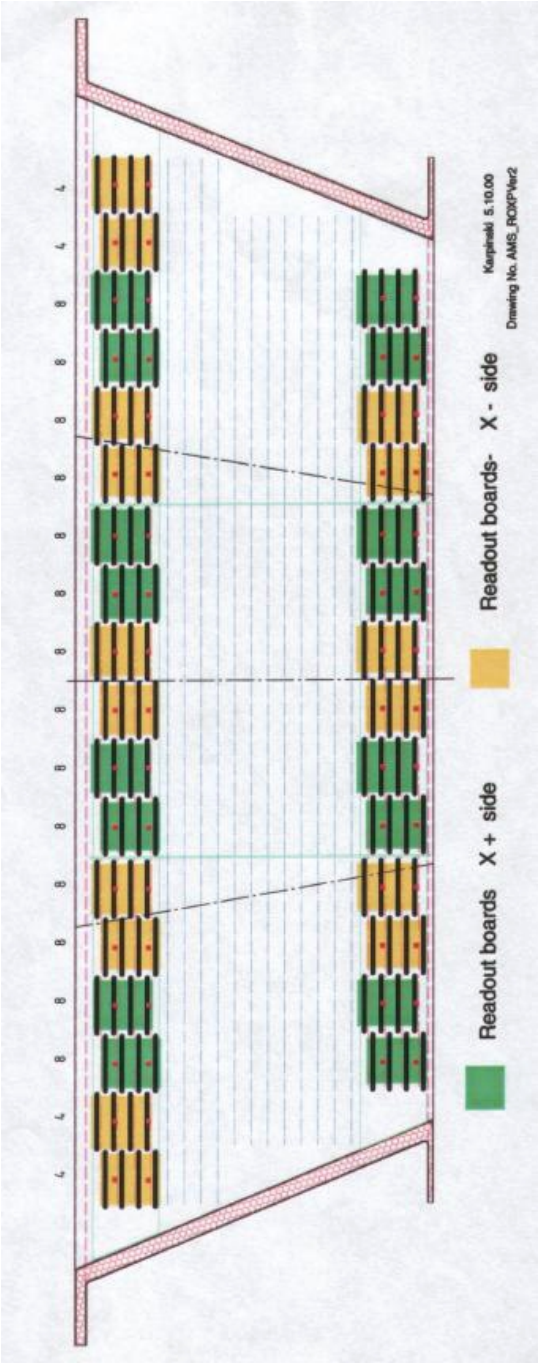
DAQ with 2x / 3x redundancy
UDR for data-reduction (1Mbyte/s limit)

R & D: C.A.E.N., Geneva, MIT, RWTH
Prod.: CSIST (Taiwan)

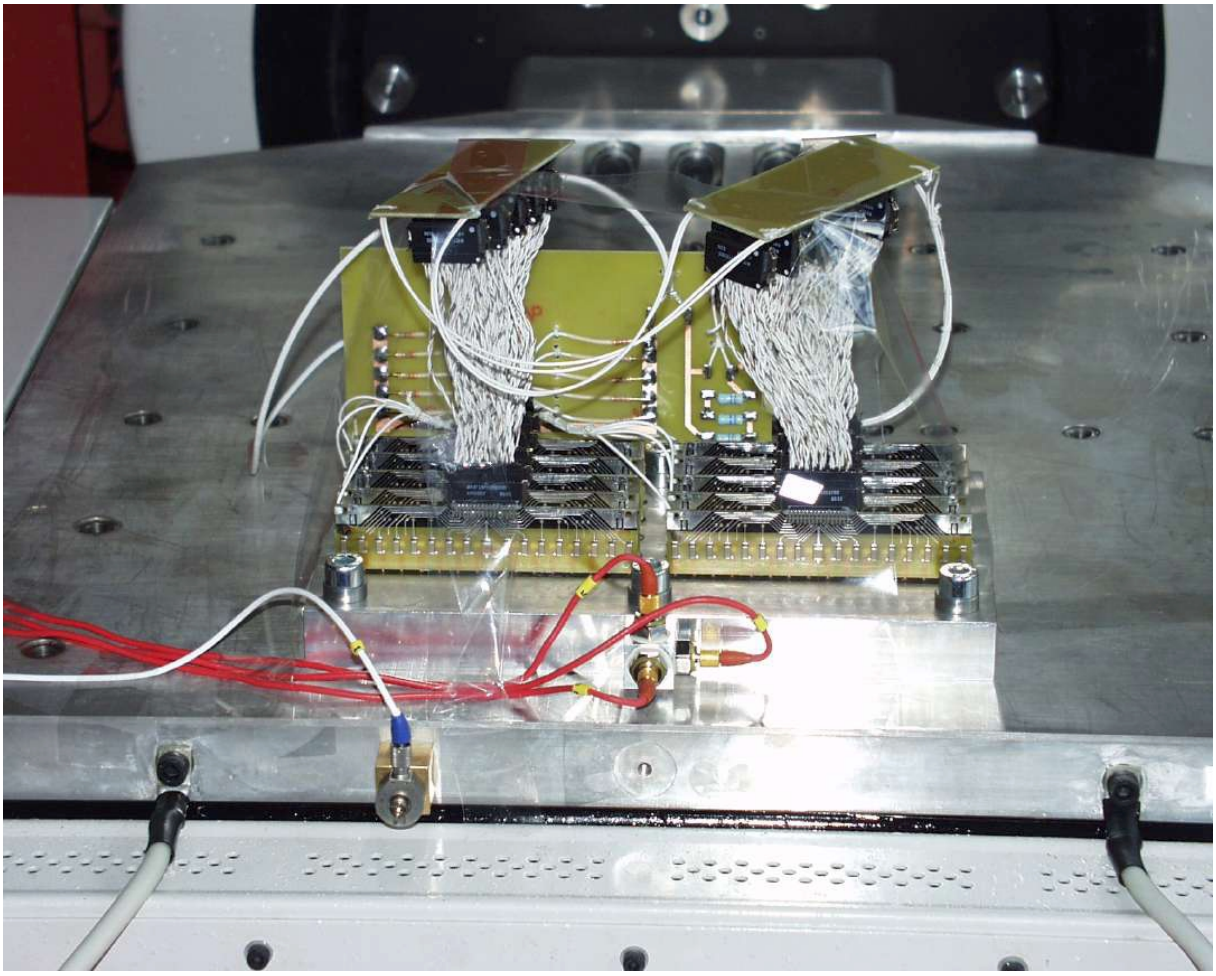
TRD Readout


Readout boards Y - side
Readout boards Y+ side
Karpinski 5.10.00
DRAWING No.: AMS_ROYPVer2

TRD Readout


Readout boards- X - side
Readout boards X + side
Kasprinski 5.10.00
Drawing No. AMS_ROXP.Ver2

Frontend Space Qualification



Vibration/thermovacuum qualification for electronics

Leakage currents 0.3nA unaffected

Radiator Tests

Deposition rate on nearby attached payloads at ISS

$$\boxed{\text{LIMIT: } 10^{-14}\ \frac{\mathrm{g}}{\mathrm{s}\cdot\mathrm{cm}^2}}$$

Radiator outgassing limit $\boxed{< 10^{-12}\ \frac{\mathrm{g}}{\mathrm{s}\cdot\mathrm{cm}^2}}$

1.) LRP 375 BK (ATLAS)

10 μm Polypropylene, $\quad \varrho = 0.06\ \frac{\mathrm{g}}{\mathrm{cm}^3}, \quad 26.00\ \frac{\mathrm{DM}}{\mathrm{m}^2}$

$\Longrightarrow$ not space qualified

2.) LRP 375 BK cleaned with CH_2Cl_2 ((Soxhlett extraction))

10 μm Polypropylene, $\quad \varrho = 0.06\ \frac{\mathrm{g}}{\mathrm{cm}^3}, \quad 126.00\ \frac{\mathrm{DM}}{\mathrm{m}^2}$

$\Longrightarrow$ space qualified

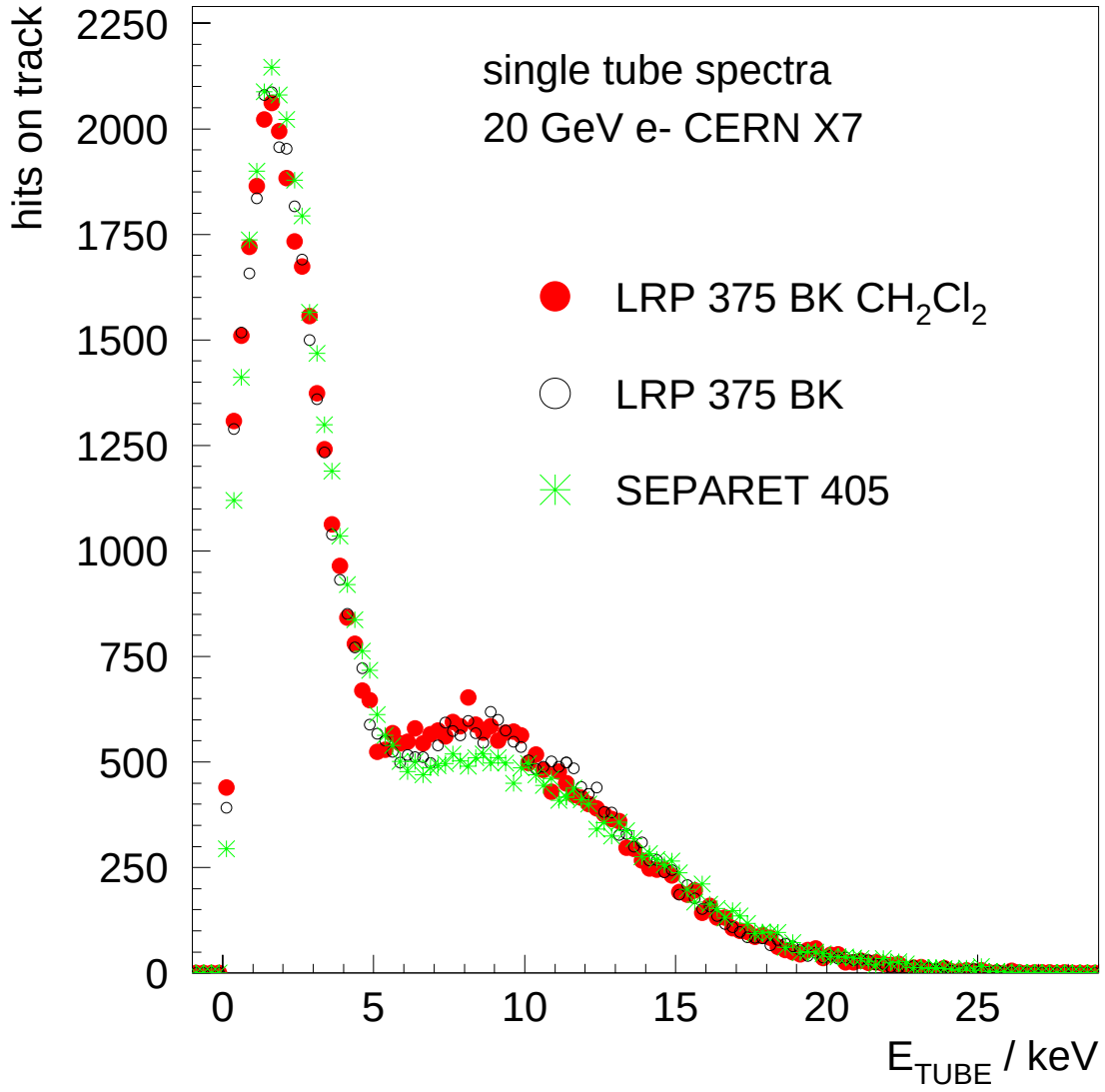
3) Separet 405

14 μm Polyacryl, $\quad \varrho = 0.08\ \frac{\mathrm{g}}{\mathrm{cm}^3}, \quad 5.00\ \frac{\mathrm{DM}}{\mathrm{m}^2}$

$\Longrightarrow$ space qualified

Tested materials manufactured by Freudenberg Vliessstoffe KG

Radiator Tests



TR-yield + weight $\Rightarrow$ **LRP 375 BK CH_2Cl_2**

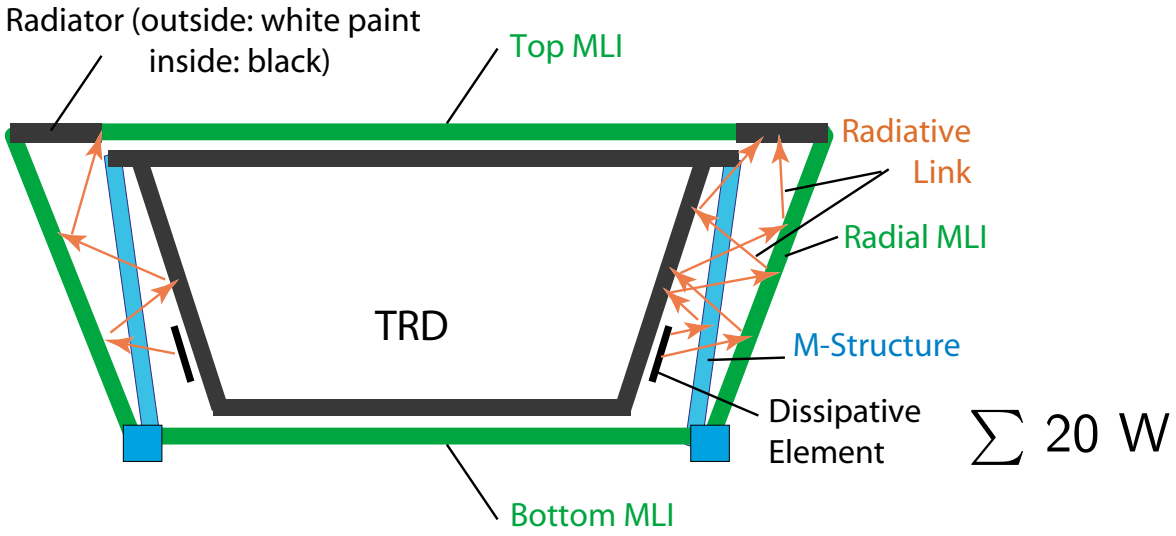
4000 pieces cut to individual shape

10 soxhlett extraction pipes (70cm) installed at RWTH Aachen Institute of Organic Chemistry

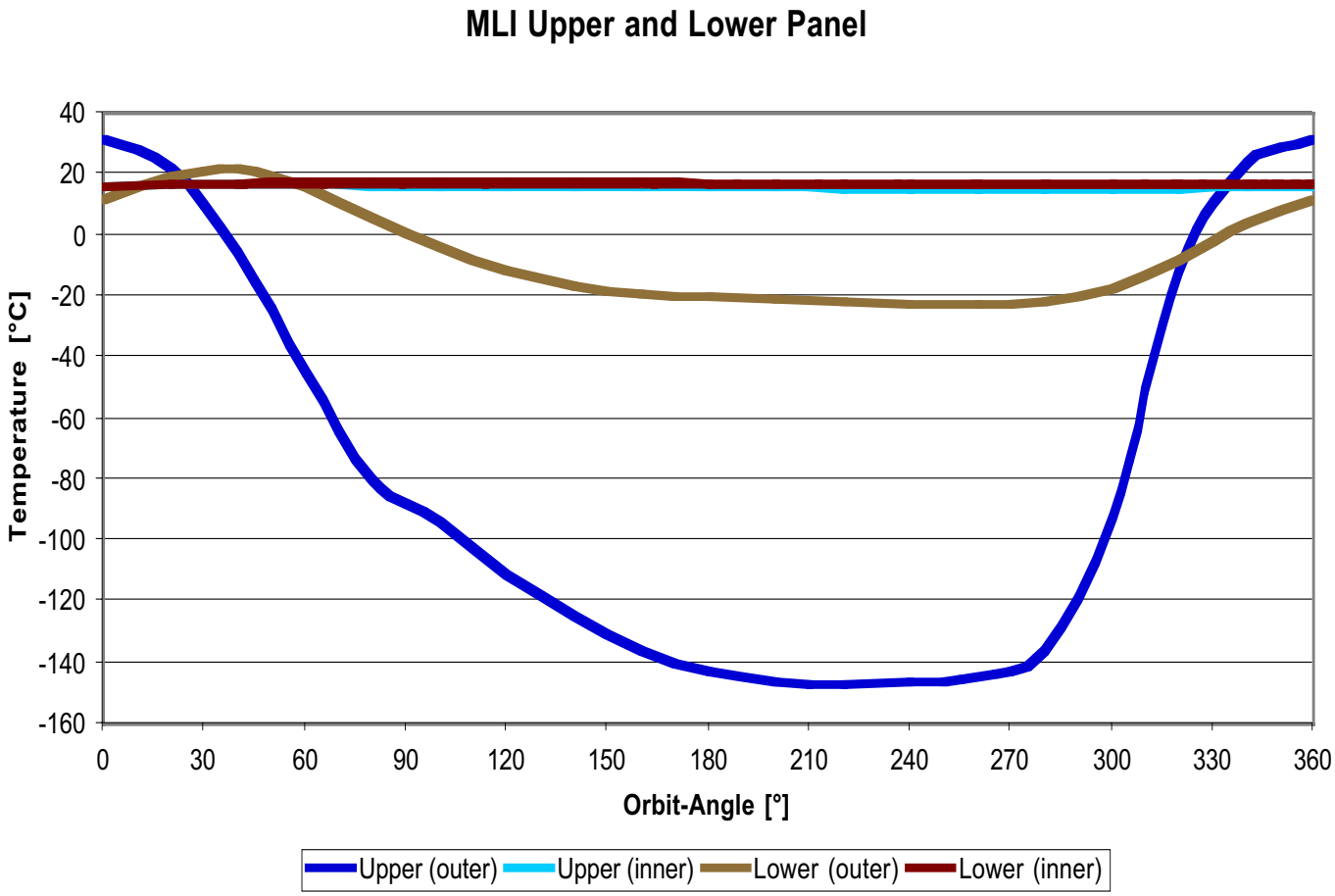
1000 modules of 22mm are sewn from 4 layers of 5.5mm

TRD thermal model

For gasgain stability: $\Delta T < 2°C$



$\sum$ 20 W



Conclusion and Outlook

- Space qualification requirements fulfilled
  - Eigenfrequency
  - Material stress
  - Radiator Outgassing
  - Gastightness
  - Weight and power
- End of TRD-construction $\rightarrow$ Sep. 2002
  $\hookrightarrow$ Cosmictest with full TRD
- Full TRD beamtest forseen for 2003
- AMS02 Assembly end of 2003
- Set for liftoff in Nov. 2004