The Performances of the Transition Radiation Detector of the AMS-02 Experiment

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for:

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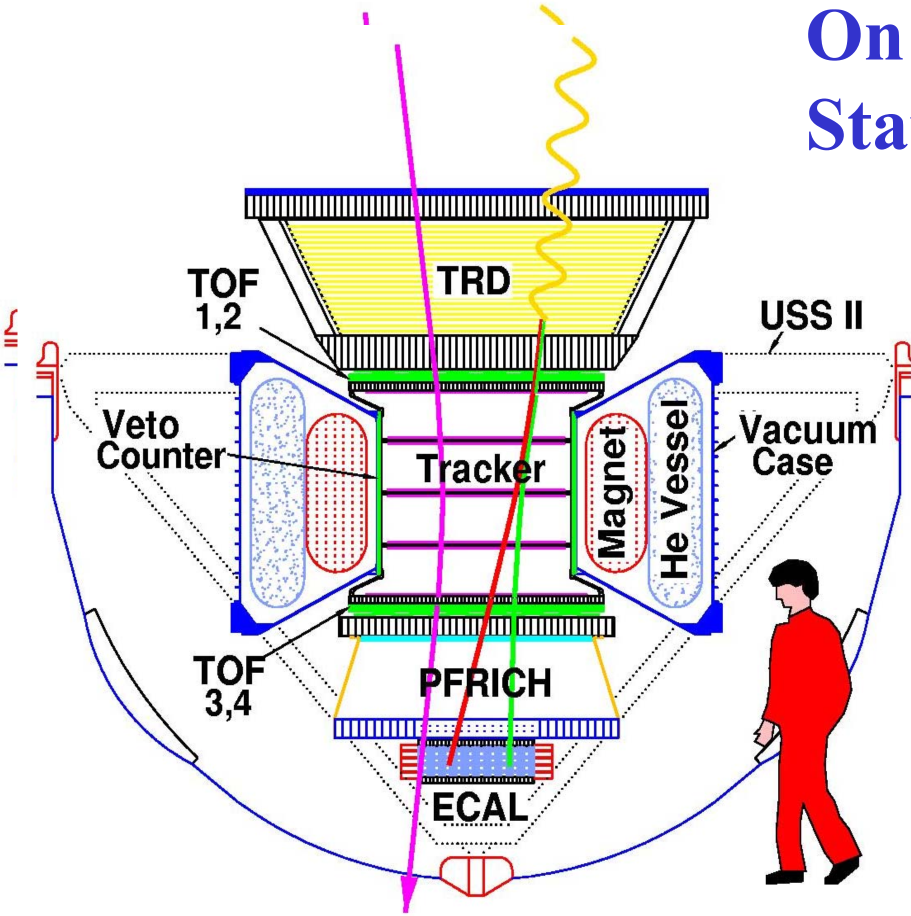
The Alpha Magnetic Spectrometer



On International Space Station from October 2006

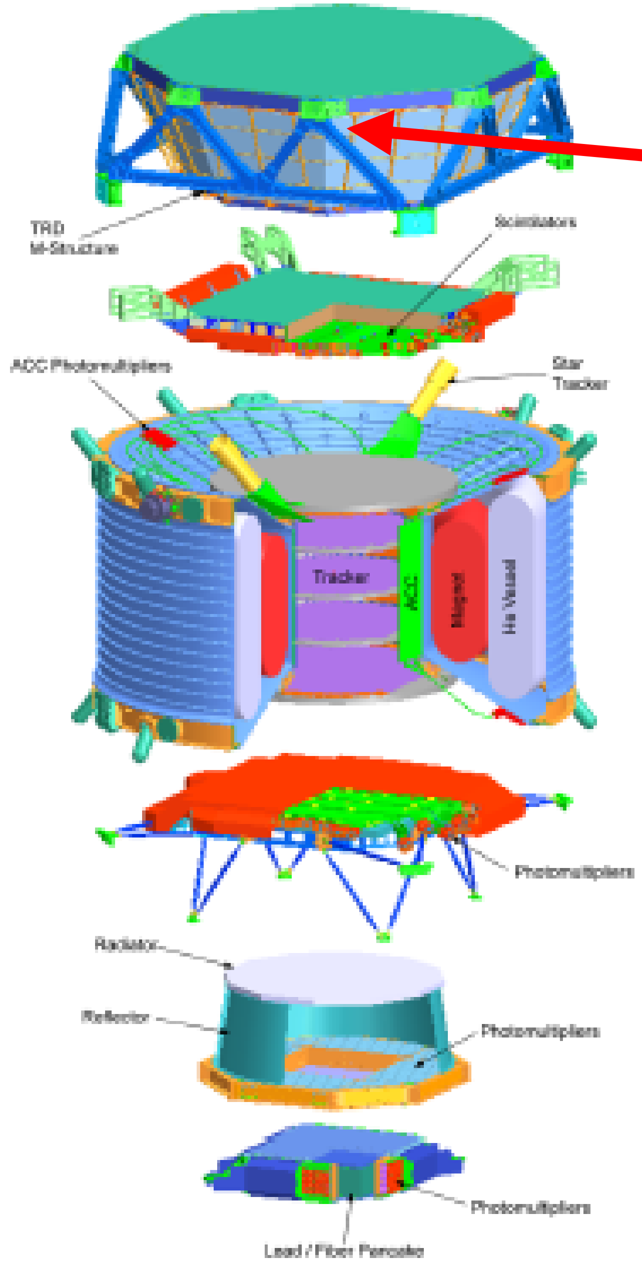
- Study of charged particles   and nuclei with rigidity 0.5 GV– few TV

- Direct search for antimatter (antihelium)

- Indirect search for Dark Matter

U. Becker N42-2
The AMS Experiment

Transition Radiation Detector (TRD)



TRD:
Transition
Radiation
Detector

TOF: (s1,s2)
Time of Flight
Detector

MG:
Magnet

TR:
Silicon Tracker

ACC:
Anticoincidence
Counter

AST:
Amiga Star
Tracker

TOF: (s1,s2)
Time of Flight
Detector

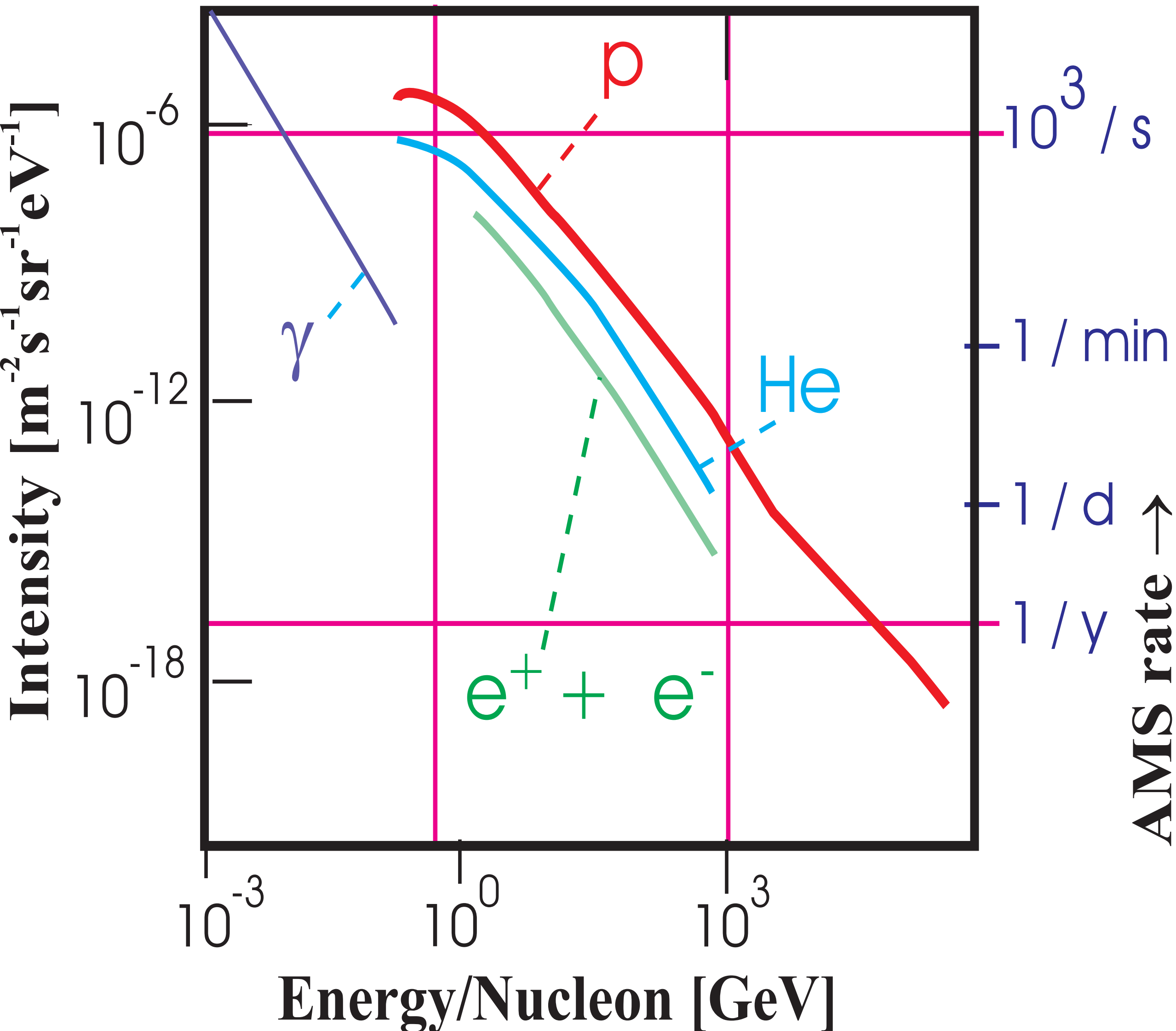
RICH:
Ring Image
Cherenkov Counter

EMC;
Electromagnetic
Calorimeter

<u>OUTLINE</u>

- The TRD as space experiment: requirements and status
- Operating principle and construction of the TRD
- Performance
- Summary

Positron identification necessary to dark matter search



The primary cosmic radiation is dominated by protons

$$\frac{\#p^+}{\#p^-} = \mathcal{O}\left(10^4\right)$$

Requirements for TRD in AMS-02

AMS02 p^+ rejection 10^6 for 90% detection efficiency for e^+

F.Hauler N35-2
The AMS02 TRD

Requirements for the rejection power of the subdetectors:

ECAL: $10^3 \ldots 10^4$

TRD: $10^2 \ldots 10^3$

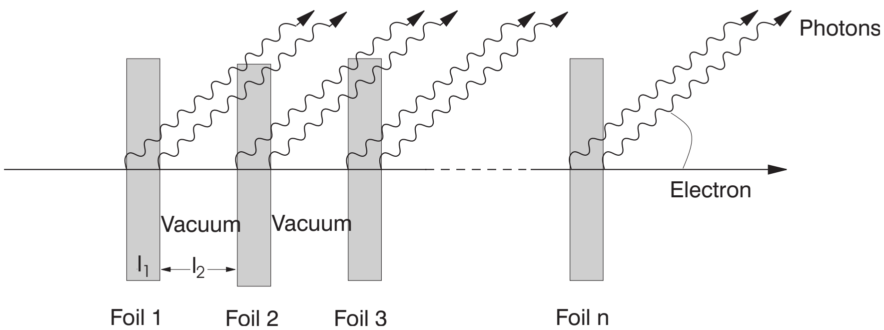
Tracker+ECAL

0.38 $m^2 sr$

Tracker +ECAL + TRD

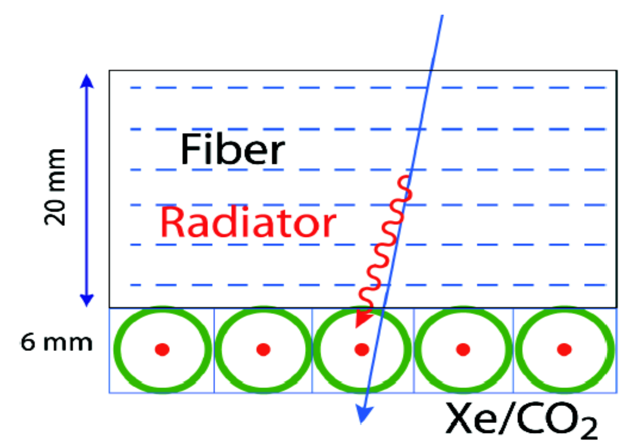
0.06 $m^2 sr$

Principle of operation of the TRD

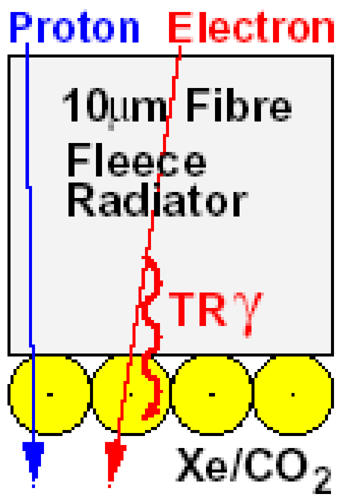


$$\gamma \geq 1000$$
$$N_{Ph} \;\mathcal{O}\; \alpha_{em} \times N_{tr}$$
$$E_{Ph} \sim \gamma(\,\mathcal{O}\,(keV))$$
$$\theta_{Ph} \sim 1/\gamma$$

- **highly relativistic charged particle generates photons at the boundary between media ($\varepsilon_{r1} \neq \varepsilon_{r2}$)**
- **Radiator: fleece**
- **Good photon (5 –30KeV) detection: gas with high atomic number Z**



Proton-Positron separation

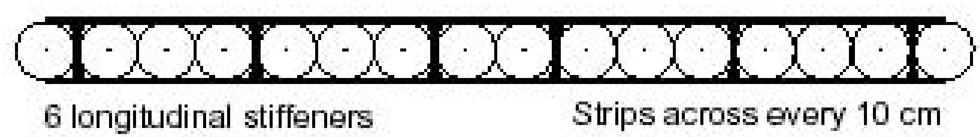


-20 layers 22 mm fleece-radiator

6mm straw-tubes Xe/CO2(80/20)

-Tubewall 72μm Kapton-Al sandwich

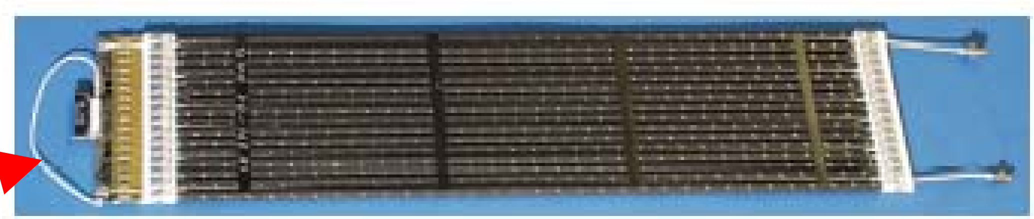
-Wire 30μm W/au tensioned with 100g



-Pressure 1250 mbar

-Gas flow 1liter/h

-Gain 3000

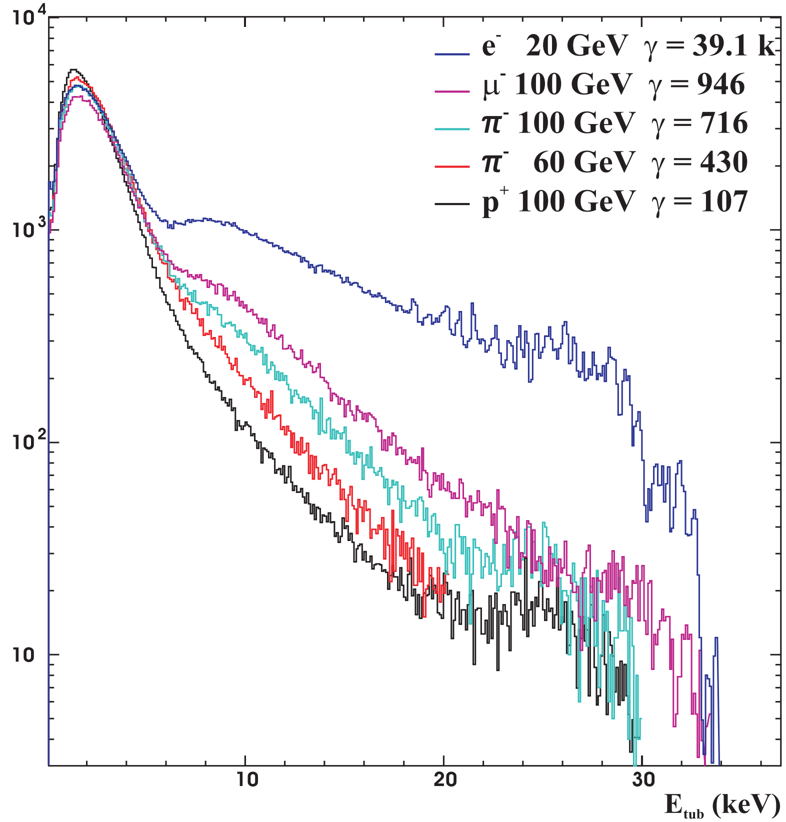


- Modules 16 tubes

-8 modules per gas-circuit

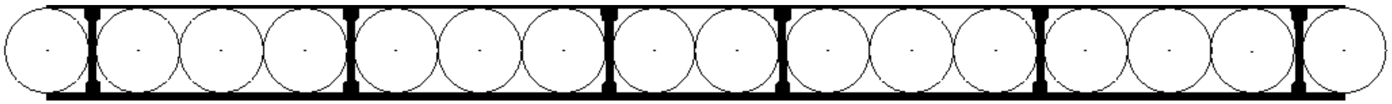
Energy deposit

Test beam results

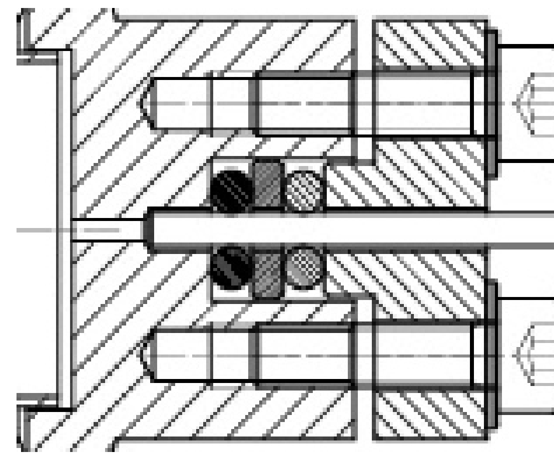


Gas tight Module

Chamber Body



16 straws with lengthwise and crosswise stiffeners

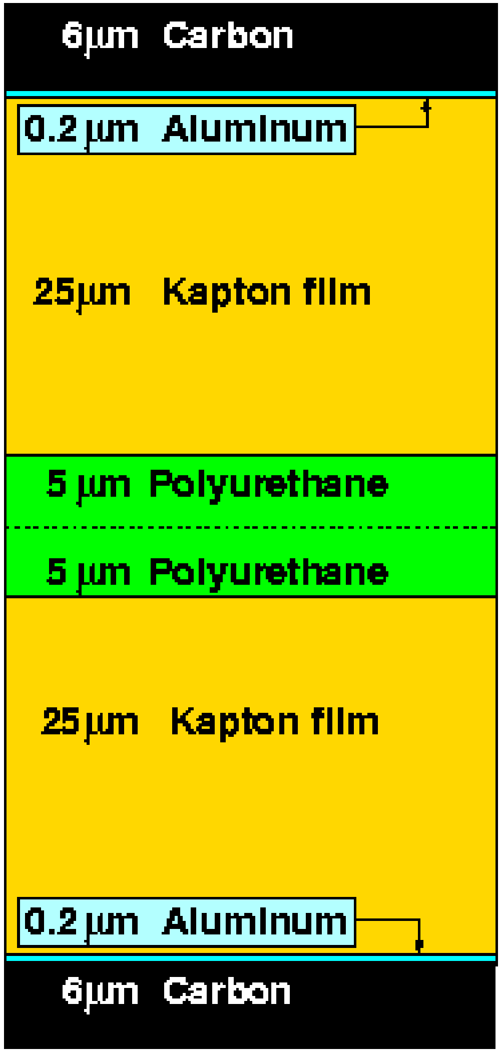


Polycarbonate endpieces
Plasma treated (O_2, 0.5 mbar, 20 min)
Glue AW 134 for potting
Copper-Tellurium Crimp Inserts

1.6mm SS Tubing

Double O-Ring
Gas Connector

Gastight Modules Require Gastight Straws



Laboratory Tests:

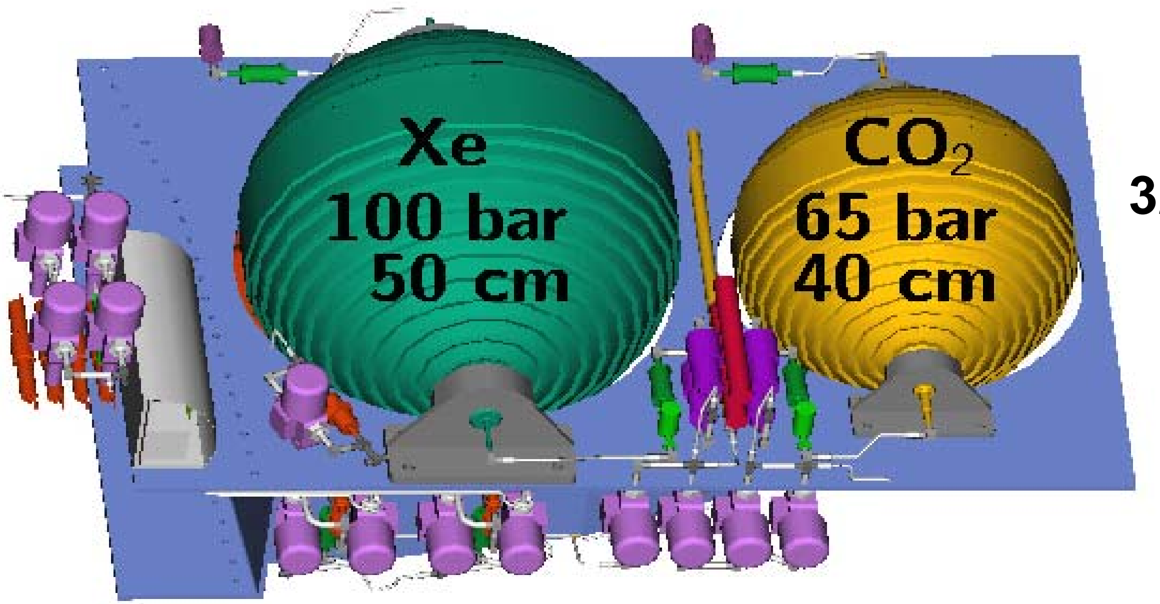
- -12h Gastightness
  2.8 bar He in Atmosphere
- - 60h Gastightness
  1.8 bar CO_2 in Vacuum

Max leakage for 3 years (10^8s)
5×10^{-4} mbar/s(safety factor 5)

-pA Leakage Current

-Ar/CO_2 ^{55}Fe Gas Gain Measurement

TRD Gas System

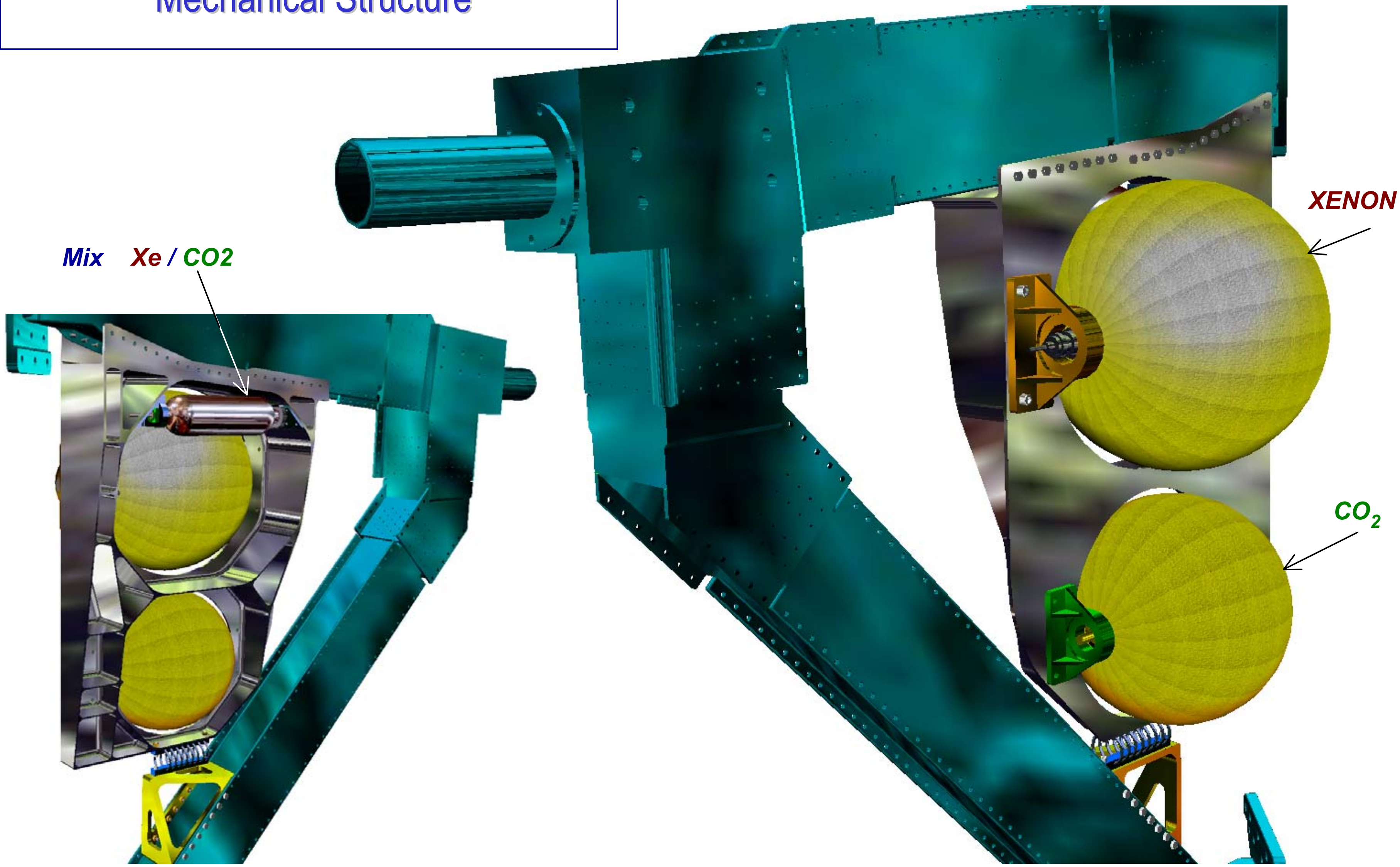


320 l @ 1 bar in 41 loops

46kg Xe (8100 l @ 1bar)
4 kg CO_2 (2000 l @1bar)

AMS TRD GAS SUPPLY SYSTEM
BOX_S
Mechanical Structure

AMS



B. Monreal N26-92

Gas Slow Control System

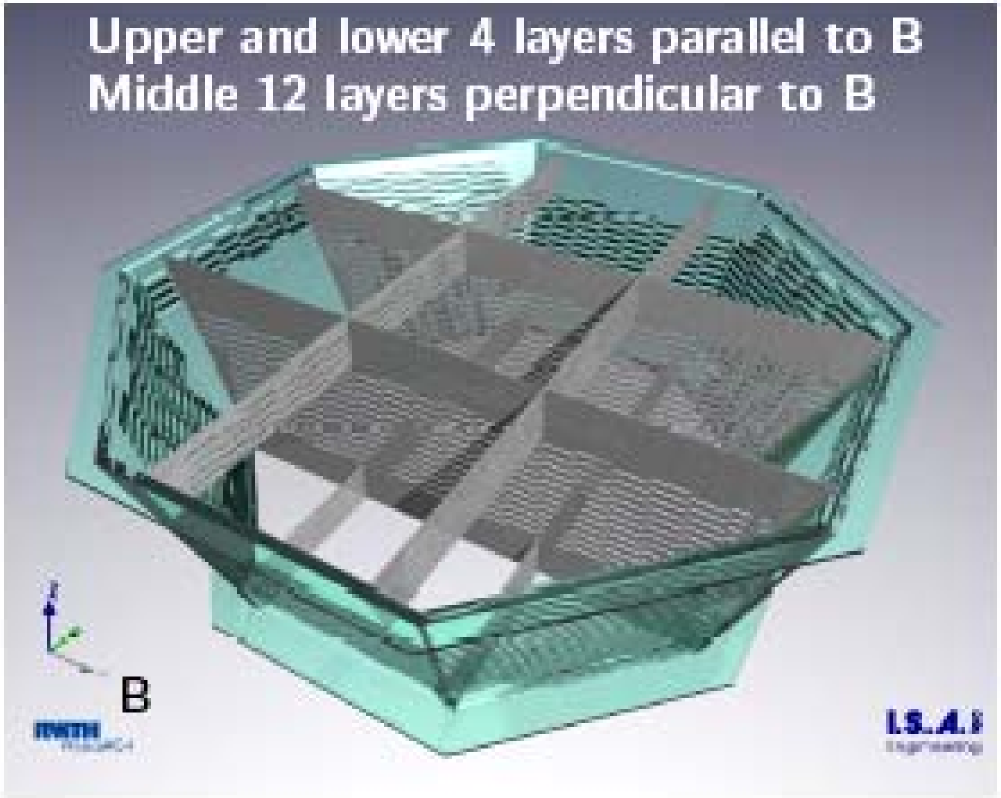
To reach the required positrons/proton rejection factor

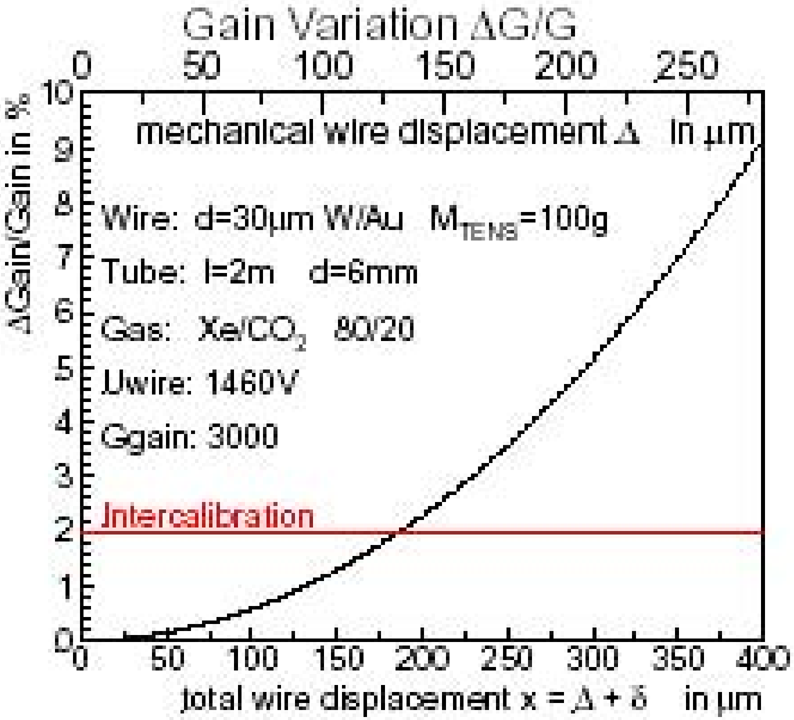
Gas gain controlled better than 5%.

→ ΔT controlled to 1°

Chamber Support in Carbon-Fibre / Honeycomb Octagon

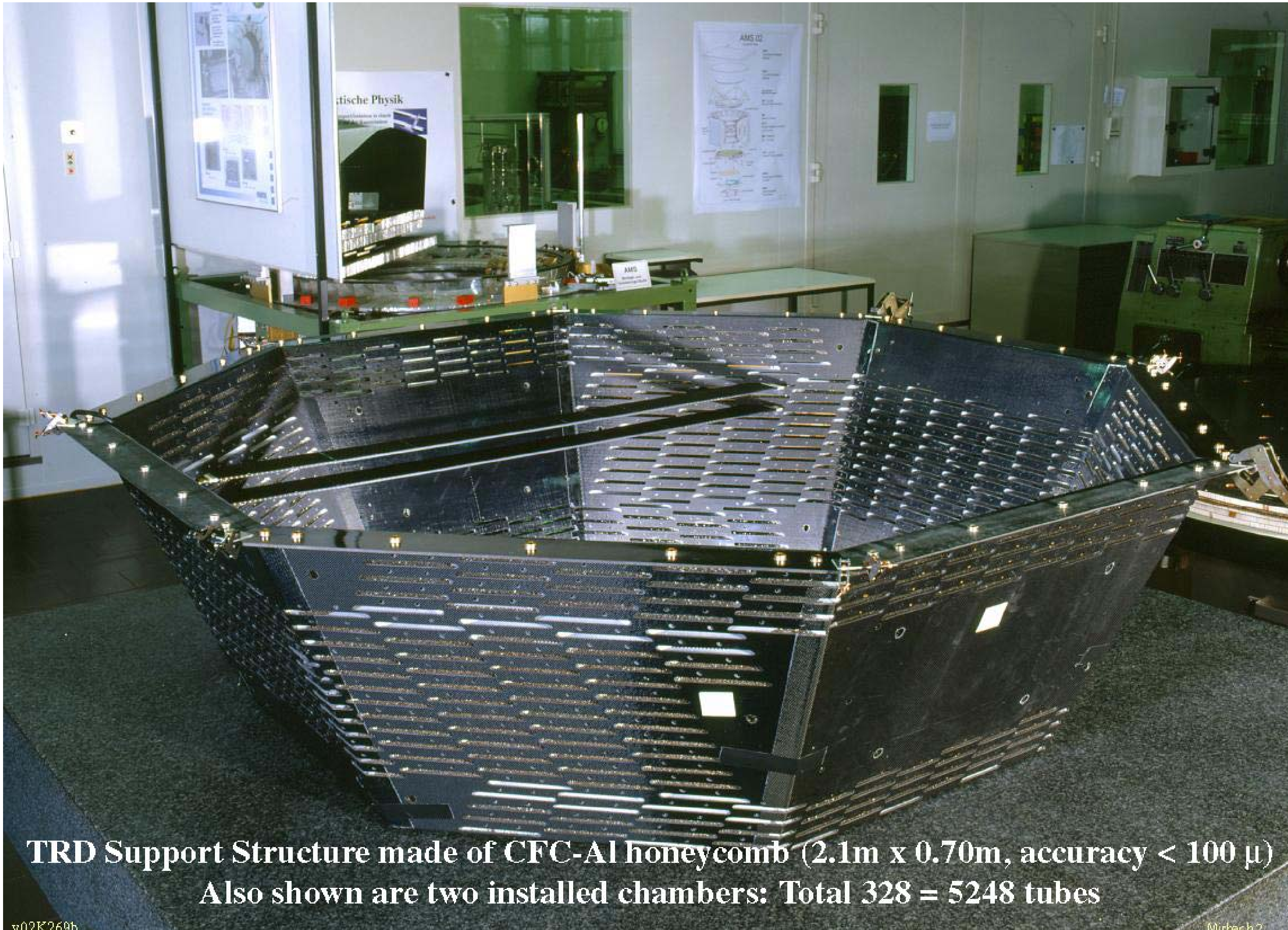
328 Modules in 20 layers





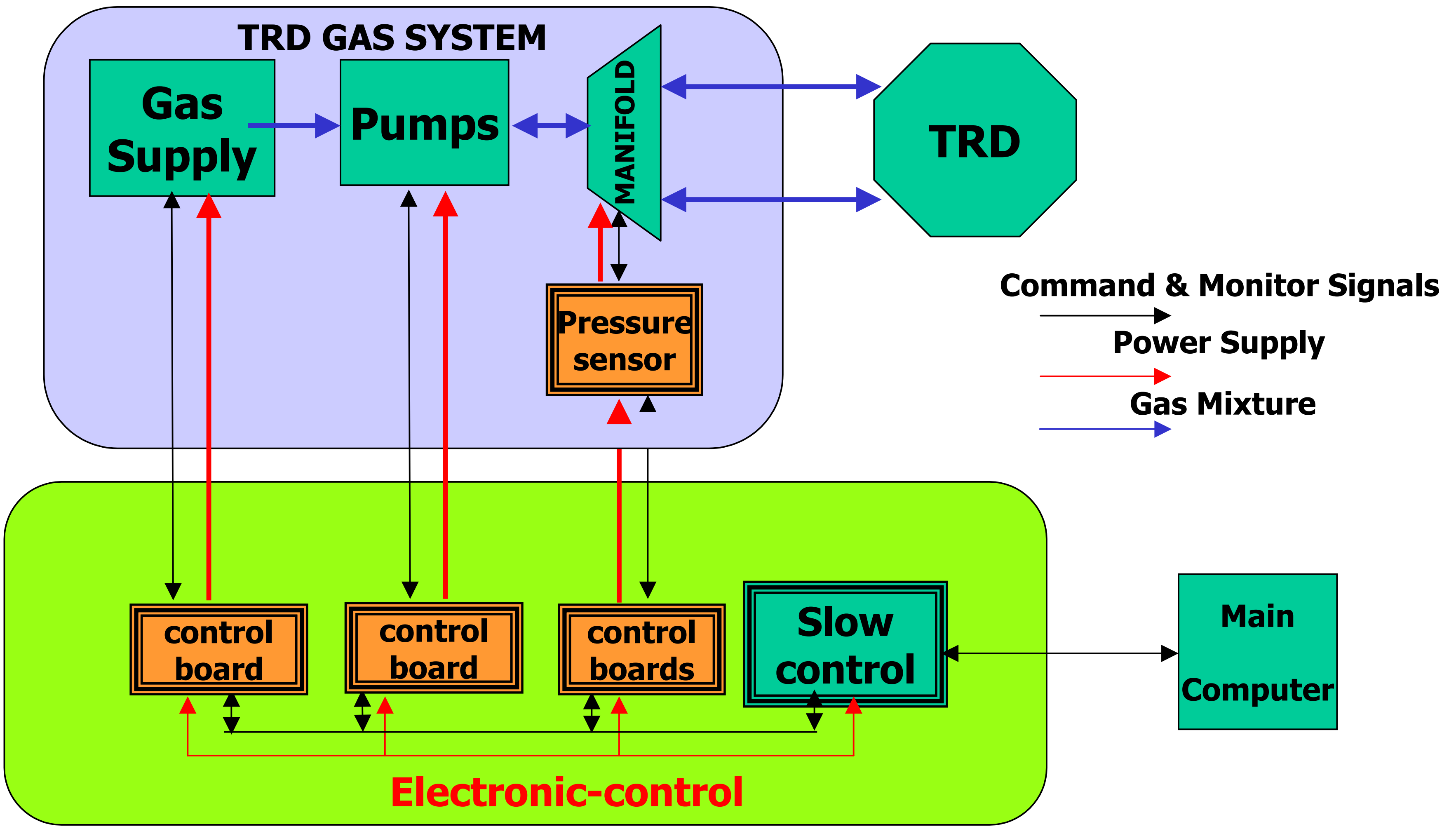
Mechanical precision < 100μm

Module lengths up to 2m

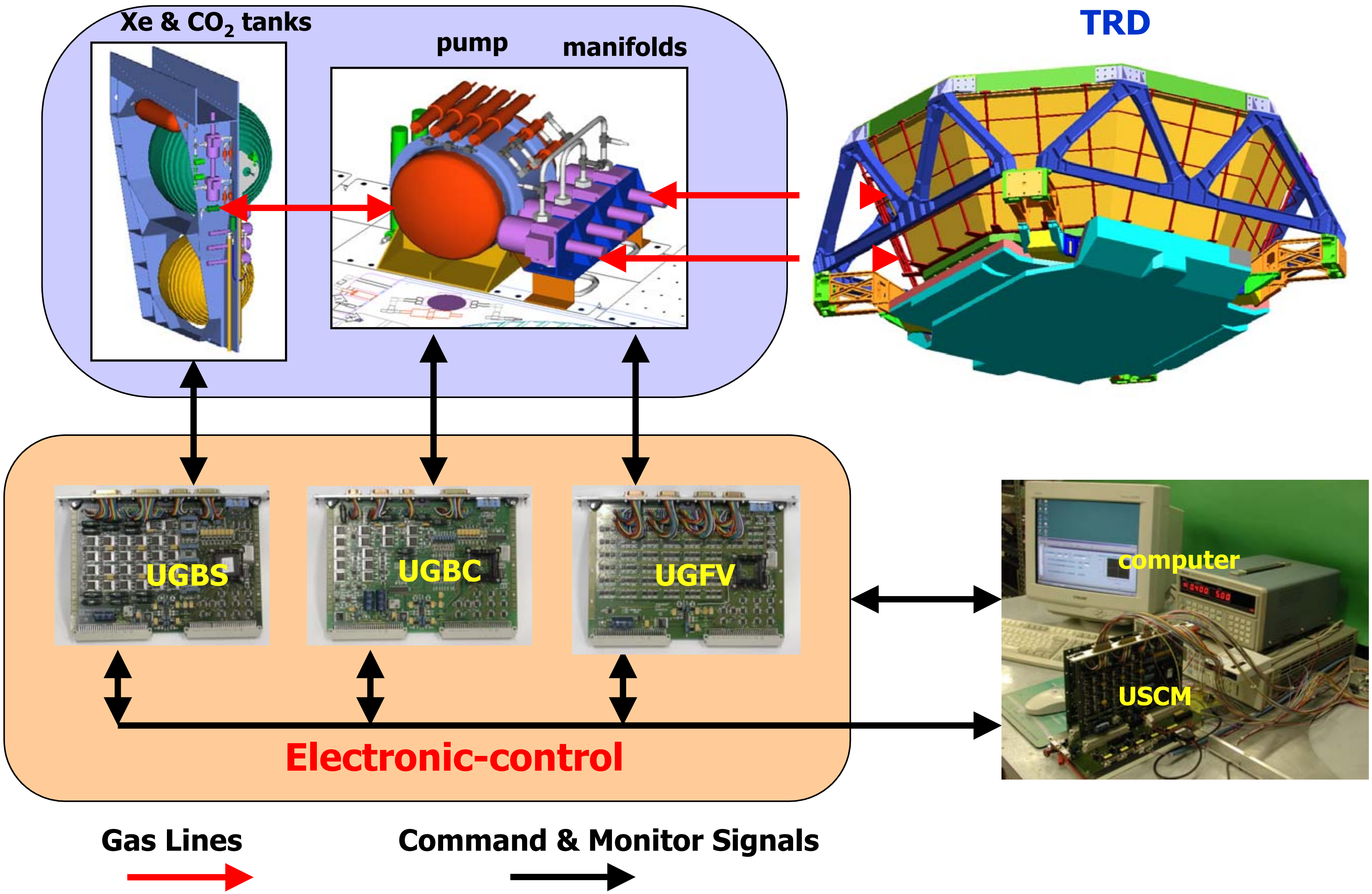


TRD Support Structure made of CFC-Al honeycomb (2.1m x 0.70m, accuracy < 100 µ)
Also shown are two installed chambers: Total 328 = 5248 tubes

AMS TRD GAS SYSTEM ELECTRONIC CONTROL

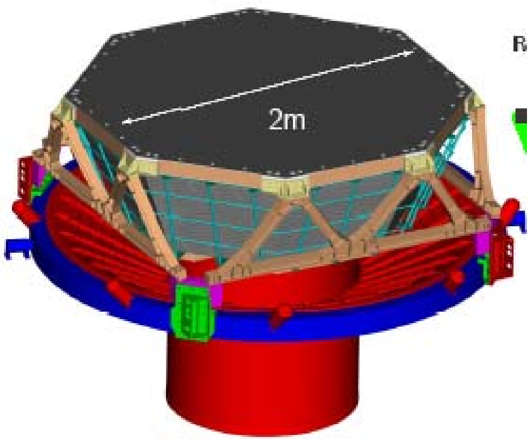


AMS TRD GAS SYSTEM ELECTRONIC CONTROL

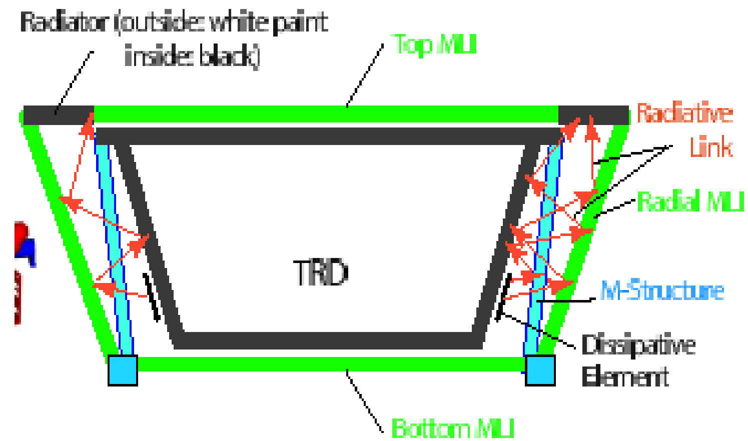


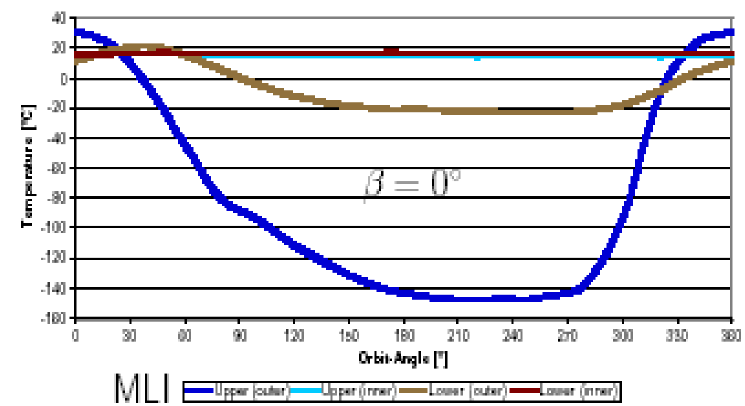
Mechanical Structure

TRD Octagon Support



Thermal Model





Other β: $+10C° < T_{inner} < +25C°$

Octagon of aluminum honeycomb with carbon fiber walls

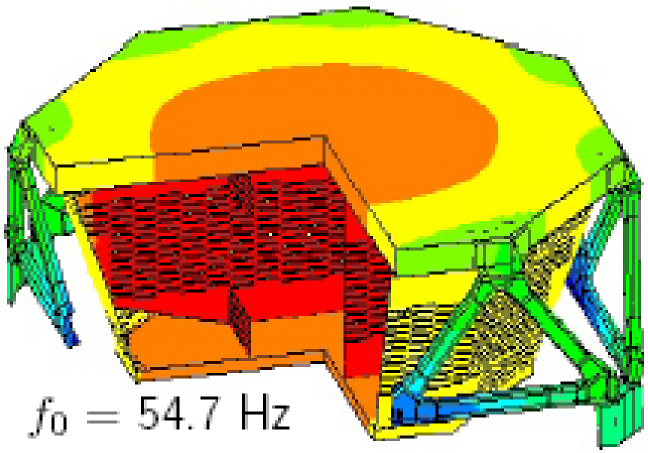
-Stable and light

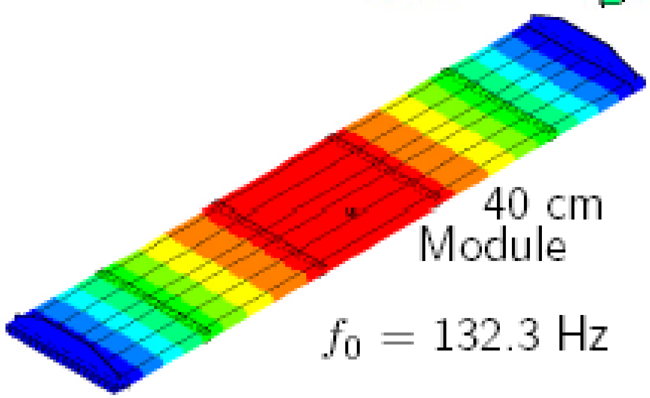
-Dimensions: height 62.3 cm, ∅ 201.8 cm (above)

-Weight: 207 kg (including external support)

-Thermal stability through multi-layer insulation (MLI)

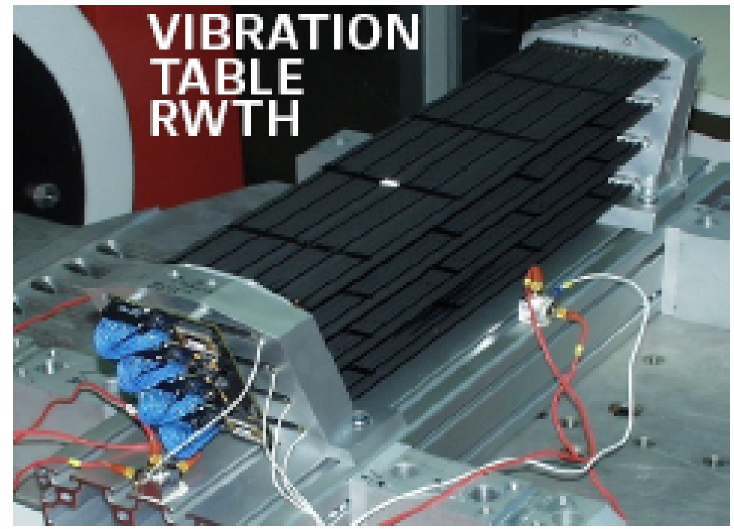
Structural Verification FEC sufficient for $f_0 > 50$ Hz

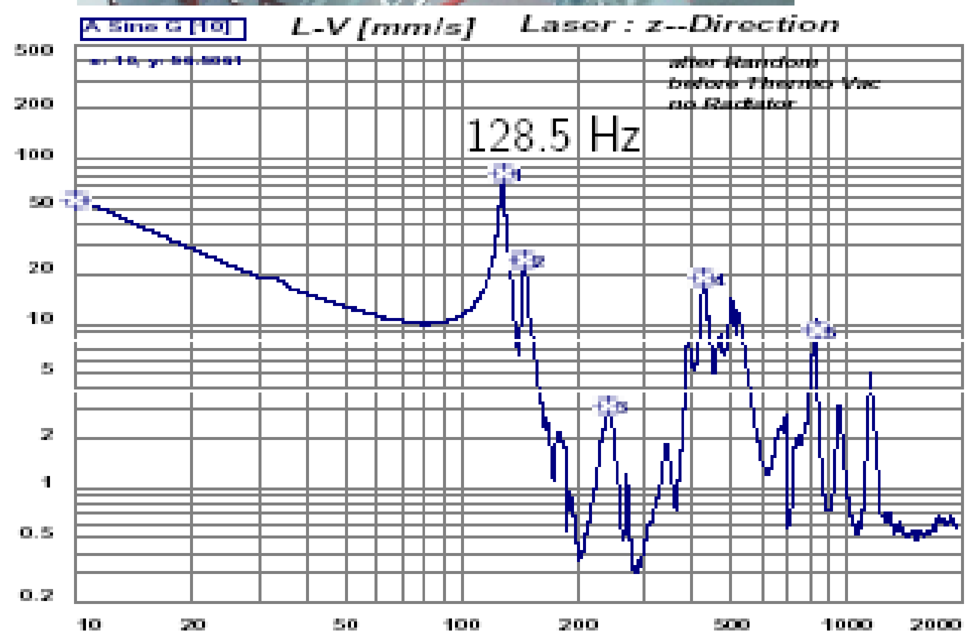


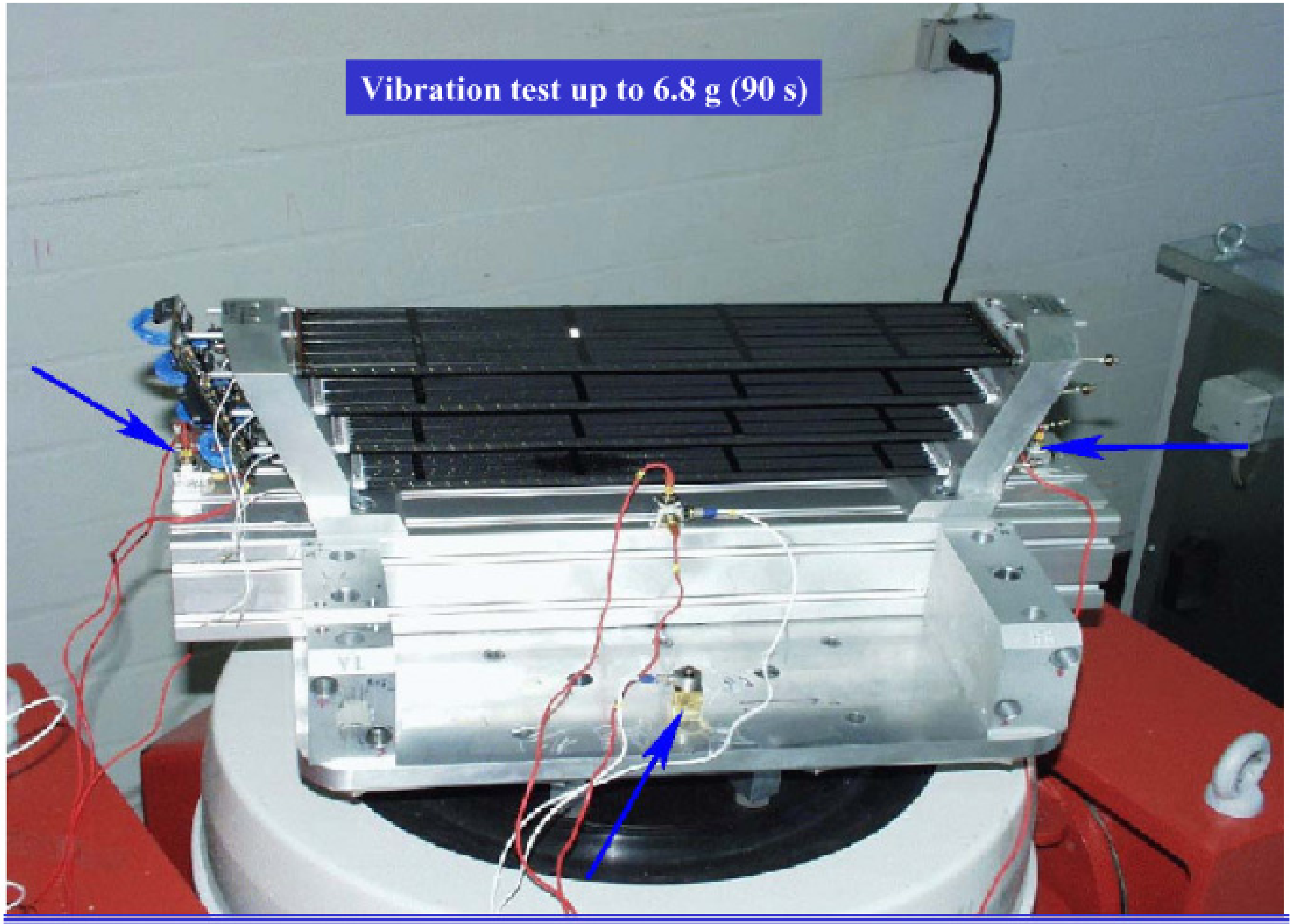


FEC coupled load modal analysis

Parameters from static measurements
Verify with component vibration tests



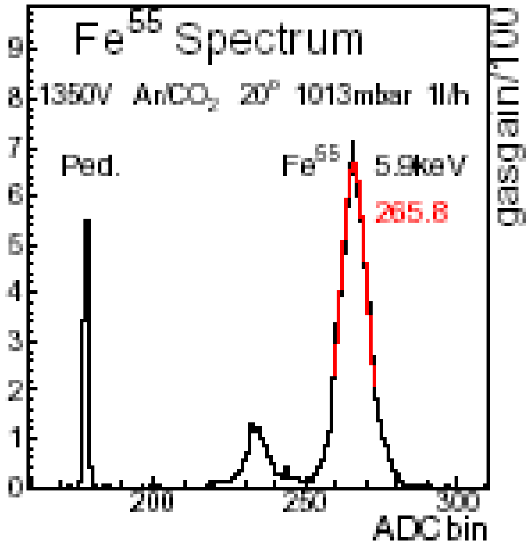


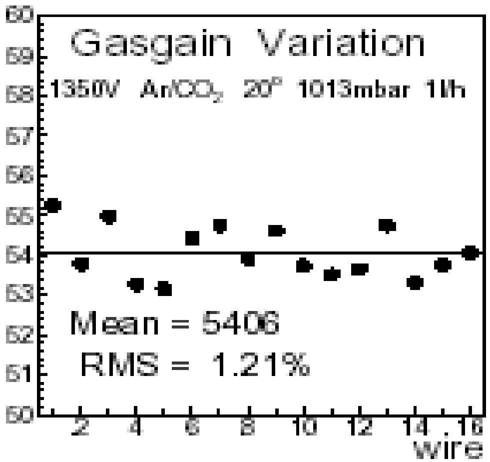


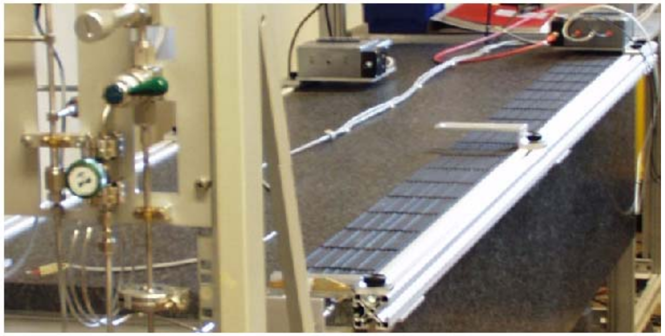
y02K248

Gas Gain Measurement

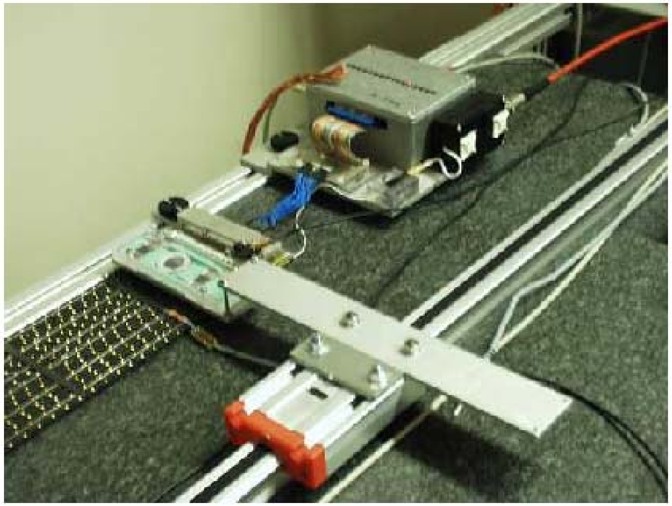
Laboratory





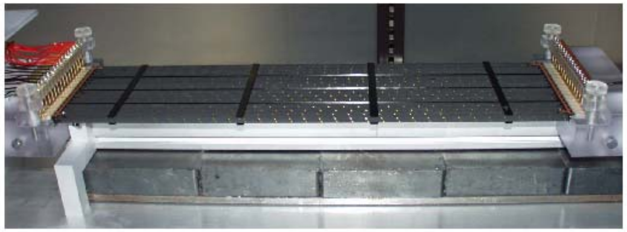


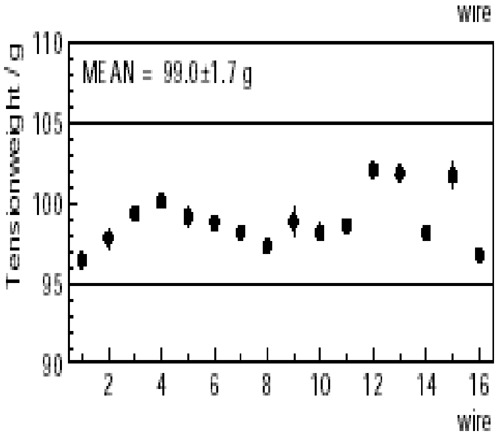
Gas gain precalibration
With **Ar/CO2**

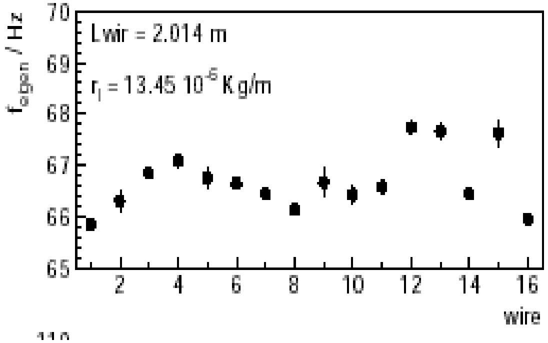


Wire Tensioning and Tension Measurement

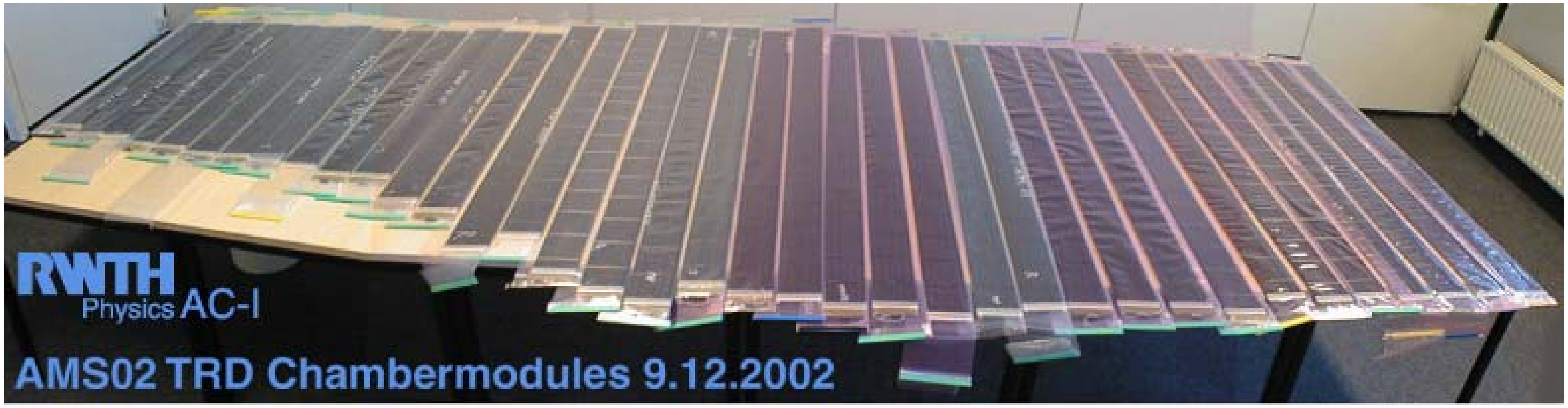
Requested wire tensioning measurents 100+/-5 gr







First natural frequency f_0

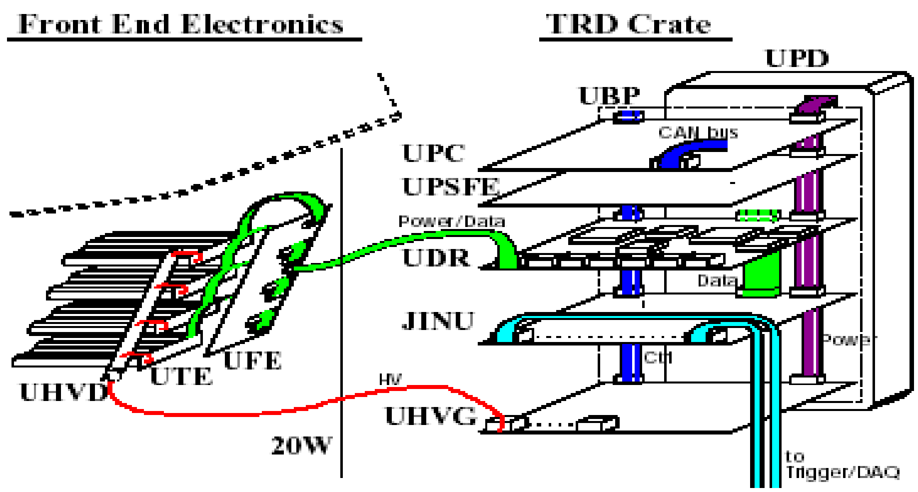


AMS02 TRD Chambermodules 9.12.2002


1.5m Chamber on assembly Gigg

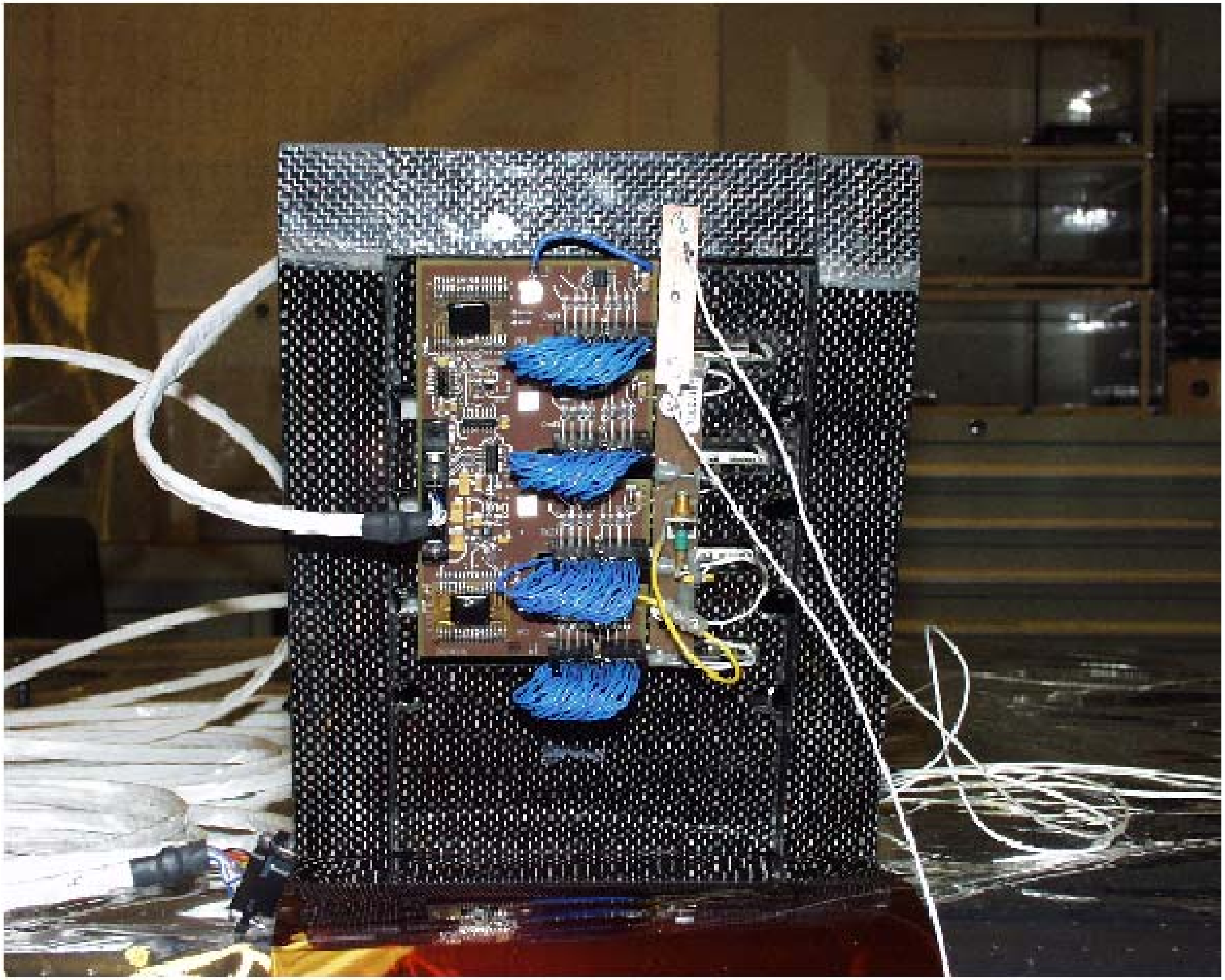
y02K266c

TRD Electronics



- 82 front-end units (FE), 2 crates (+ power supply)
- 5248 channels, double redundant throughout up to the front-end
- a 28V DC connection for each crate

Test Assembly of a Front End Electronic



Test of TRD prototype

➢Prototype:

• 20 layer , 2 x 16 tube modules each layer
• 16 layers horizontal , 4 layers vertical
Tubes and radiator identical to flight version (except length)
Gas Xe and CO_2 (80%:20%) at 1 bar

➢Test beam (CERN) :

•Protons, @ E= 15 –200 GeV
•e^-, μ^-, π^-, @ E= 20-100 GeV

➢ Data:

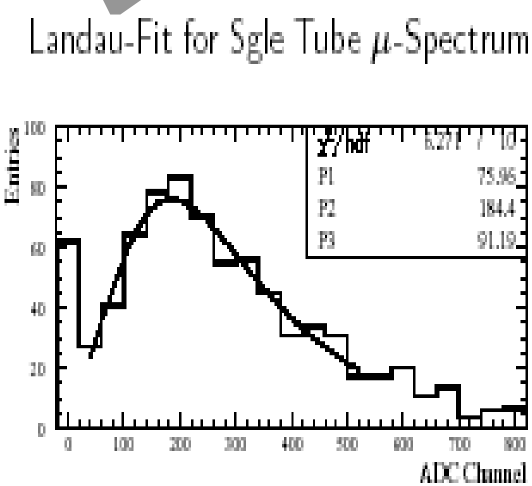
Over 3 milion events recorded

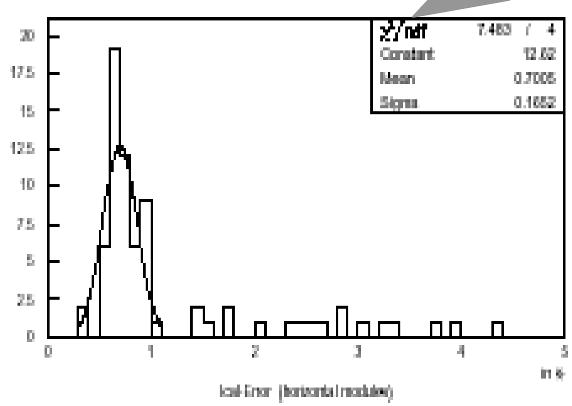
Calibration

Tube by tube **intercalibration** with protons and muons to correct differences in electronics and mechanical construction to **equalize the signals from each tube** to standard value.

- **Tube Intercalibration with muons**

Determine the **most probable value for tube's energy deposit spectrum**, using overlapping tubes determine **correction factors**



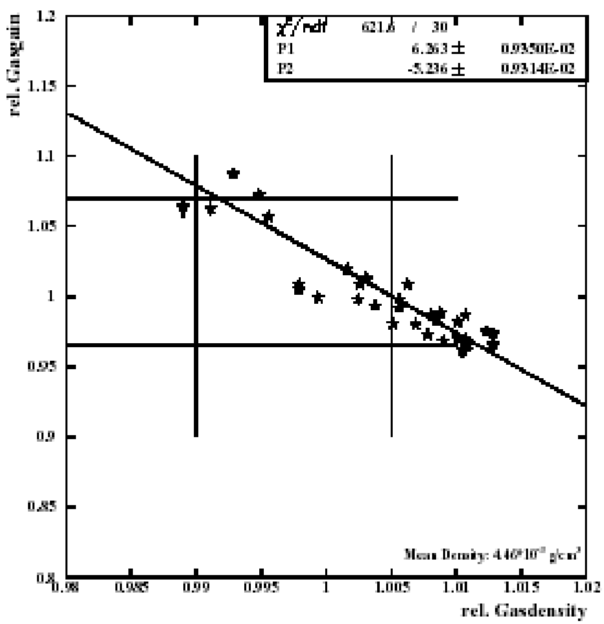


Intercalibration more accurate than 1%

Calibration

- **Gas gain Calibration**

Pressure and temperature monitored for gas density correction. At standard density $\rho = 4.46 \times 10^{-3}$ g/ cm^3 with HV at 1470 V for a gas gain of 5000 an increase of ρ = 1% leads to a decrease of gas amplification of 5.5%.



Correction accurate to 1.5%

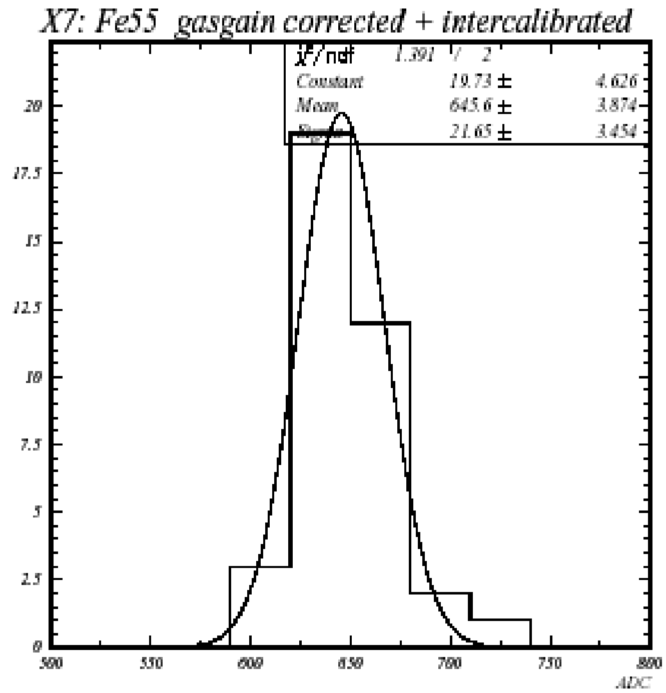
Gas –gain correction:

M’ =M*[1+(ρ / <ρ> –1)*5.24]

Calibration

- **ADC Calibration**

Fe[55]spectra were taken between runs on the first and last layers to **calibrate the energy deposition by photons to ADC scale** (12bit ADC).



Photon energy corrisponds:
9.09+- 0.05 eV/ADC-channel

In conclusion:
Good agreement for calibrations with protons and muons

Radiator tests

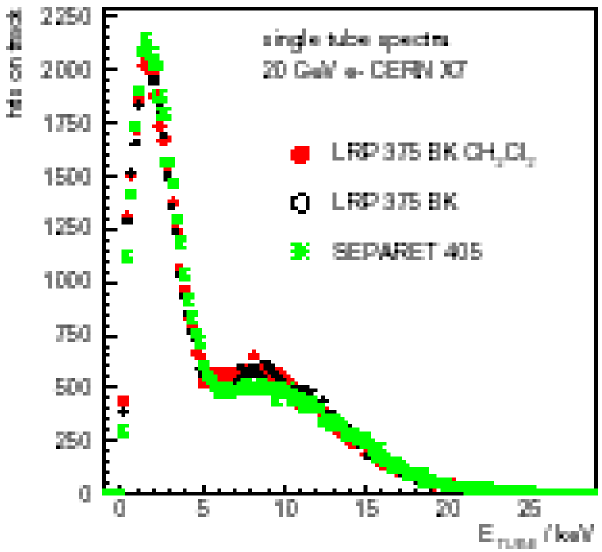
Tested materials from Freudenberg Vliesstoffe KG:

LRP 375 BK (ATLAS)	10 μm Polypropylene	60 g/l
Separet 405	14 μm Polyacryl	80 g/l

AMS TRD outgassing limit: $< 1.2 \cdot 10^{-12}$ g/s/cm^2

Separet 405 meets ASTM E 1559 requirements
LRP 375 BK needs CH_2Cl_2 cleaning (Soxhlett extraction)

TR-yield:



LRP 375 BK chosen for TR-yield and weight reasons

Event selection

•Single track event.

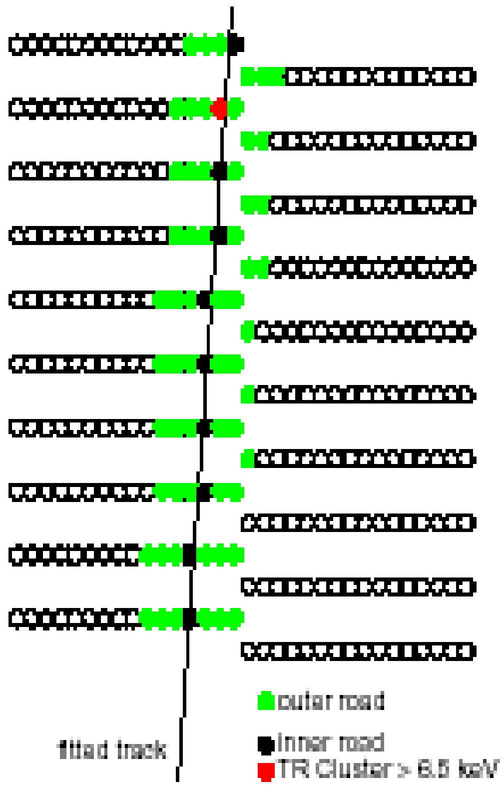
Secondary particles excluded.

Proton rejection

$$\frac{\text{Total number protons}}{\text{Selected protons}}$$

Electron efficiency

$$\frac{\text{Accepted electrons}}{\text{Total number of electrons}}$$



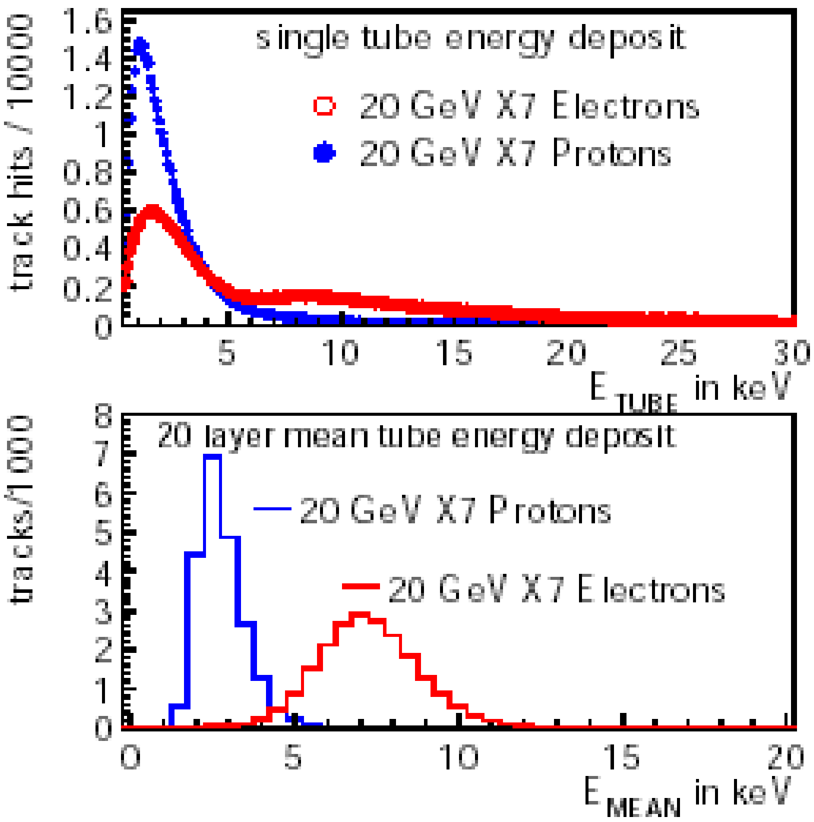
Measurent of proton rejection:

•Cluster counting Hit: $E_{hits} > 5\text{-}10$ KeV, $N_{hits} > 6$ ➡ electron

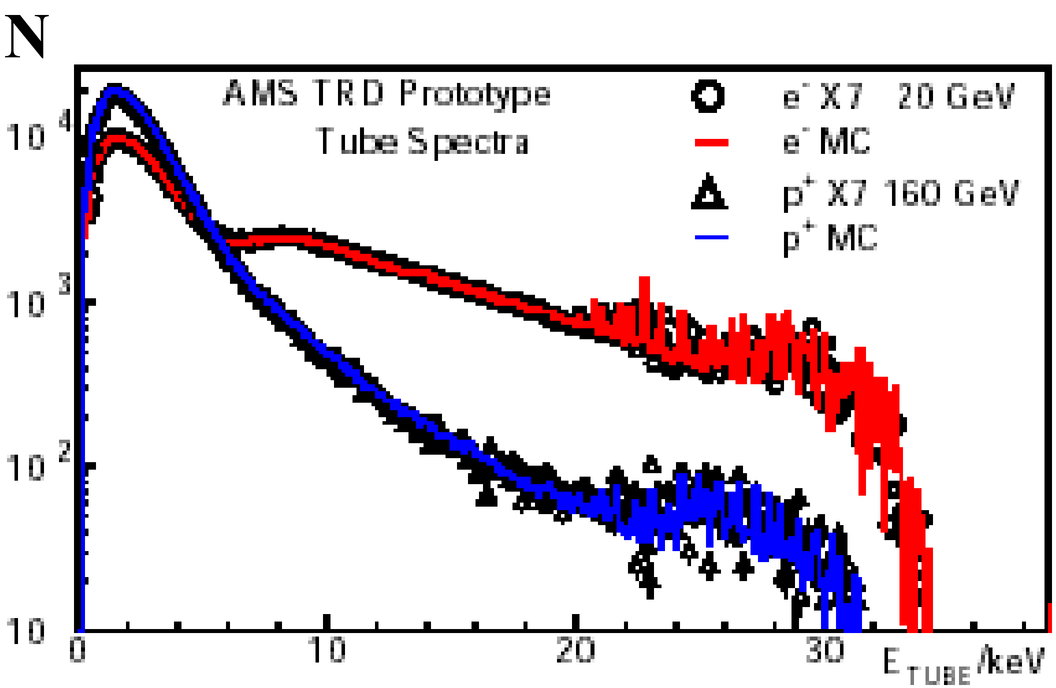
•Likelihood method energy deposit distribution normalized and for each hit ➡ $P^i_{e,p}(E_i)$ prob. density function

Combined probability $W_{e,p} = \prod^N_{i=1} P^i_{e,p}(E_i)$.

TRD beam test



TRD Beamtest Proton Rejection for 90% Electron efficiency

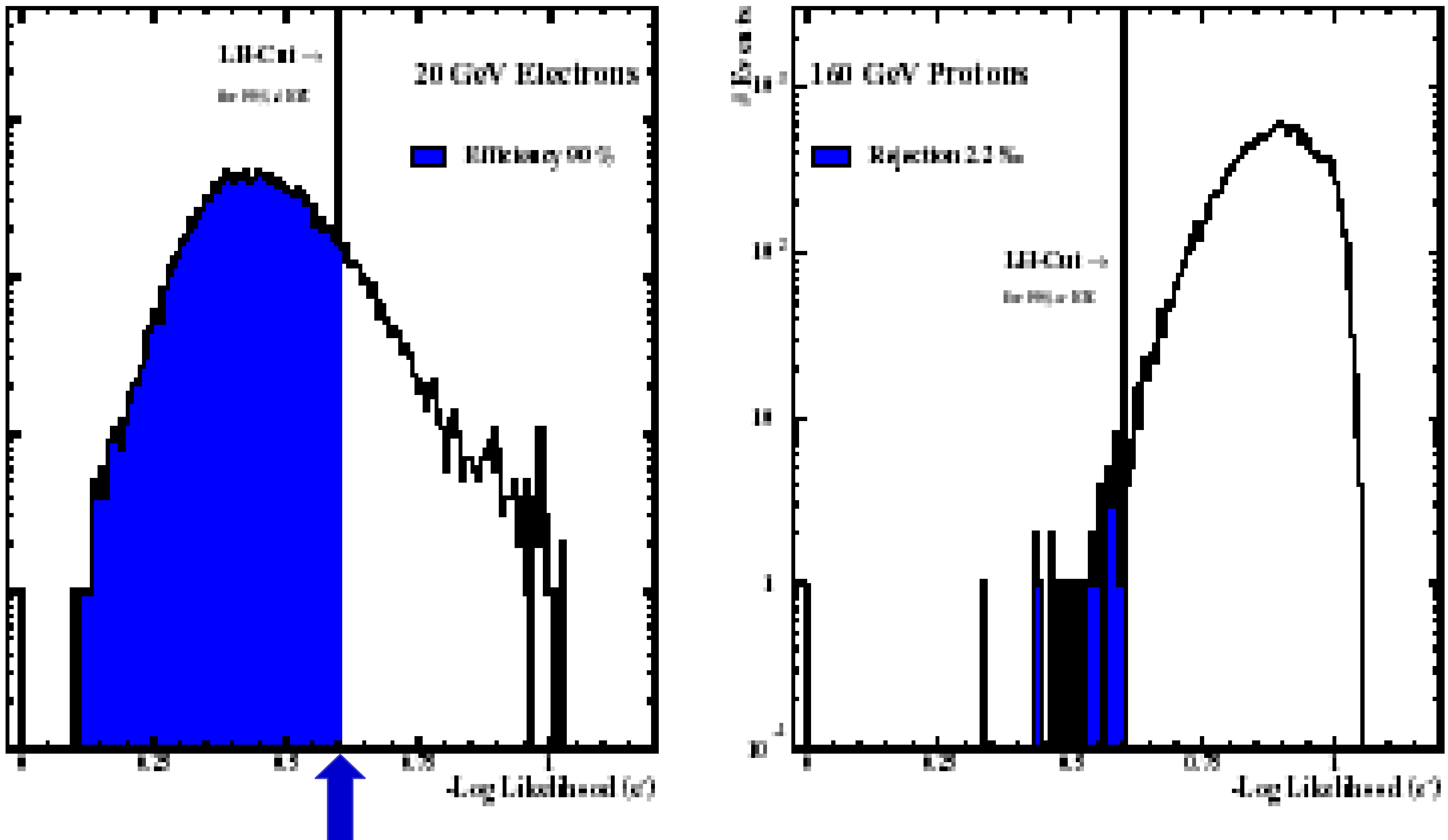


Single track preselection with MC 90% efficiency p^+/e^- likelihood separation with

$\mathcal{L} = W_e/(W_e + W_p)$

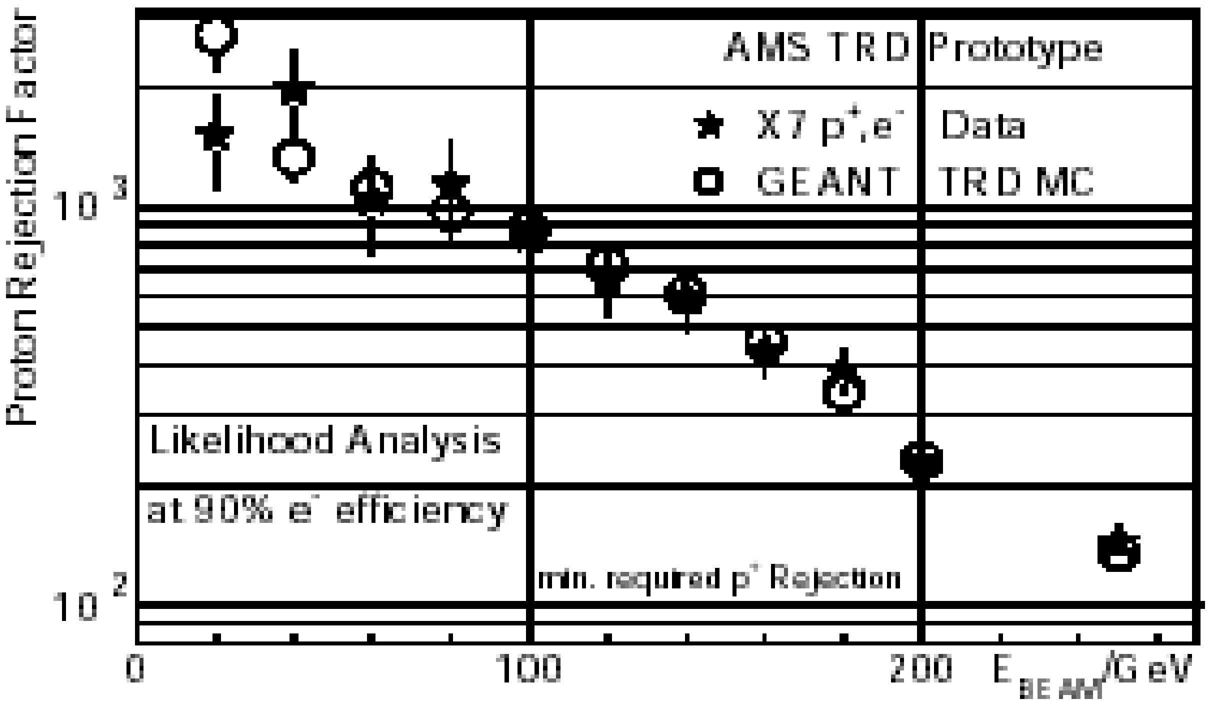
W_e, W_p
from single tube spectra

Likelihood cut



Events with $\mathcal{L} = W_e/(W_e + W_p) < 0.6$ are light particles

TRD Testbeam



20 layer prototype tested with e^-, μ^-, π^+, p^+

Proton rejection $>10^2$

reached up to 250GeV with 90% electron efficiency

Conclusion

- Required proton rejection of > 10^2 for 250 GeV has been reached

-Quality of the design (mechanical, electronic) demonstrated through calculations and tests.

-Limits kept for

- weight , power
- outgassing, leak tightness