9th Topical Seminar on Innovative Particle and Radiation Detectors

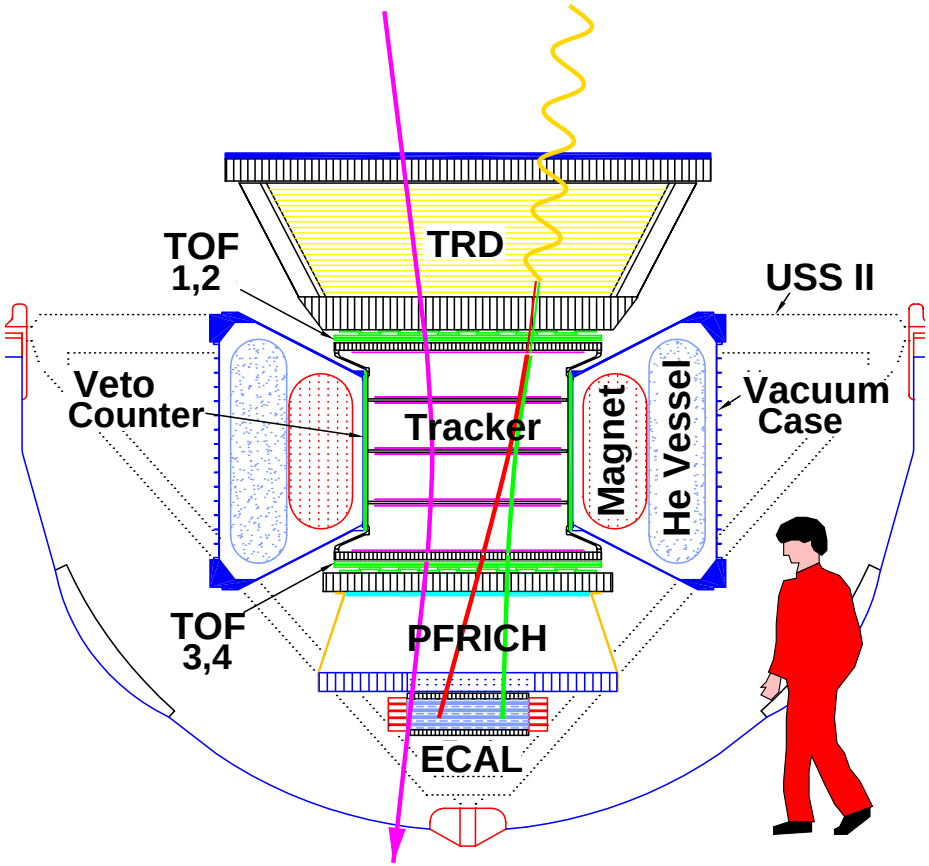
The AMS TRD
A gasdetector designed for operation in space

for the AMS-TRD Group (Karlsruhe, MIT, Roma, RWTH)

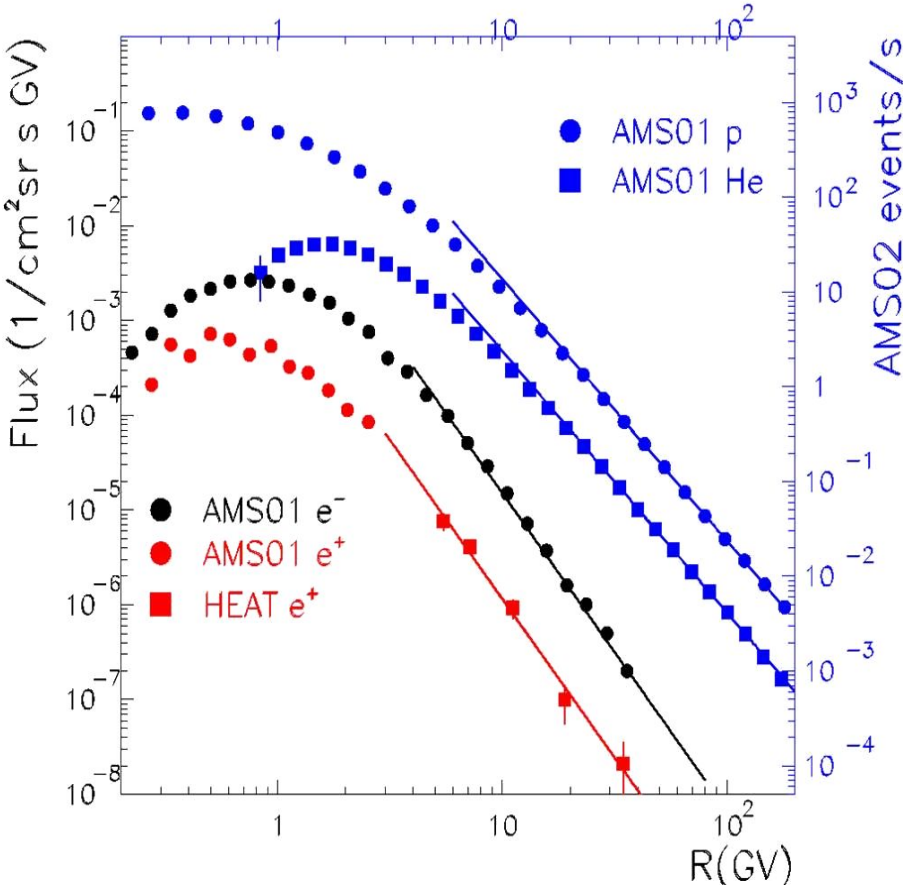
Th. Siedenburg, I. Phys. Institut RWTH Aachen

Siena, May 23^{rd} 2004

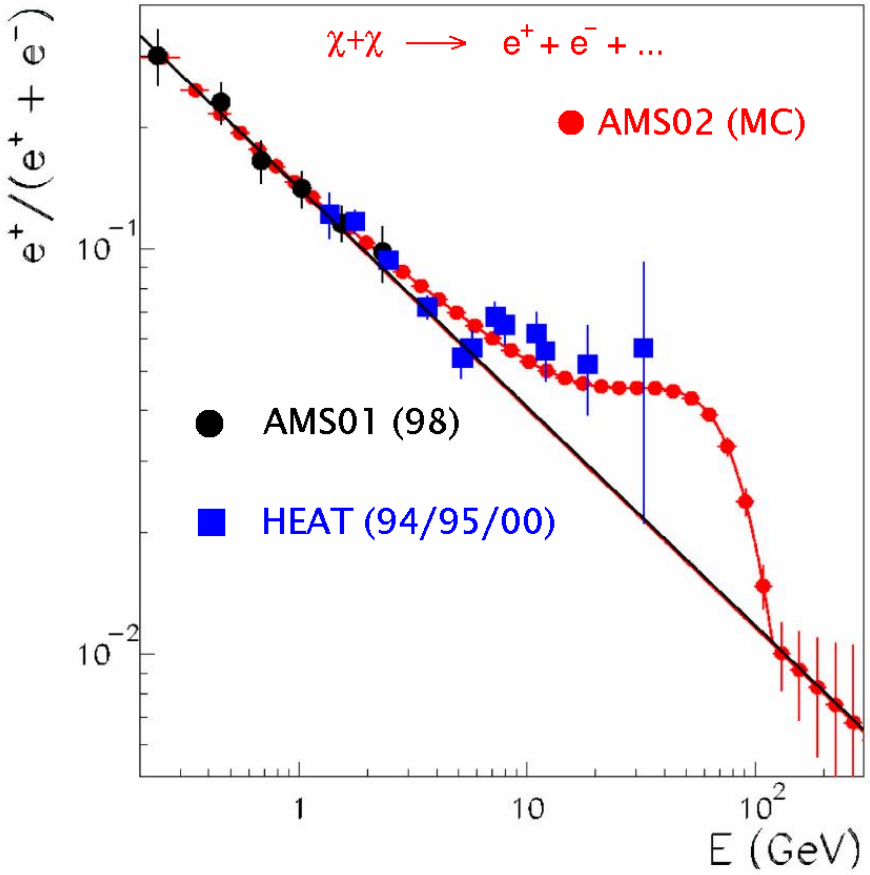
- TRD for particle identification
- TRD design for space
- Beamtest results and MC



Positron Spectroscopy to search for Dark Matter candidates



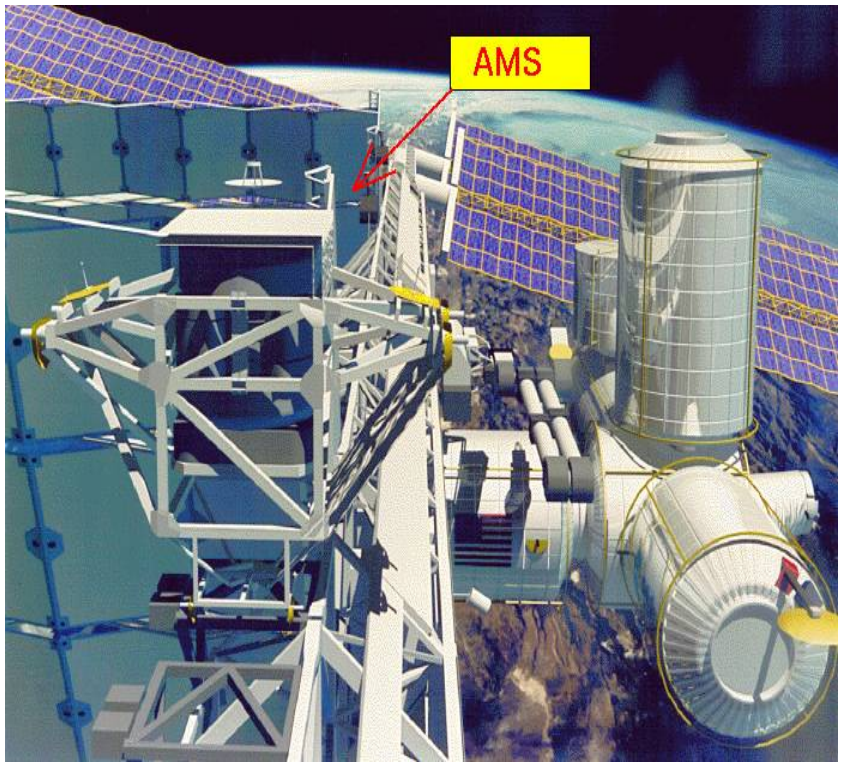
Neutralino Annihilation



Cosmic Flux: $p^+/e^+ \approx 10^4$

e^+ Fraction with p^+ Backgnd $< 10^{-2}$
$\rightarrow$ AMS02 p^+ Rejection $\approx 10^6$

Experimental Platform ISS

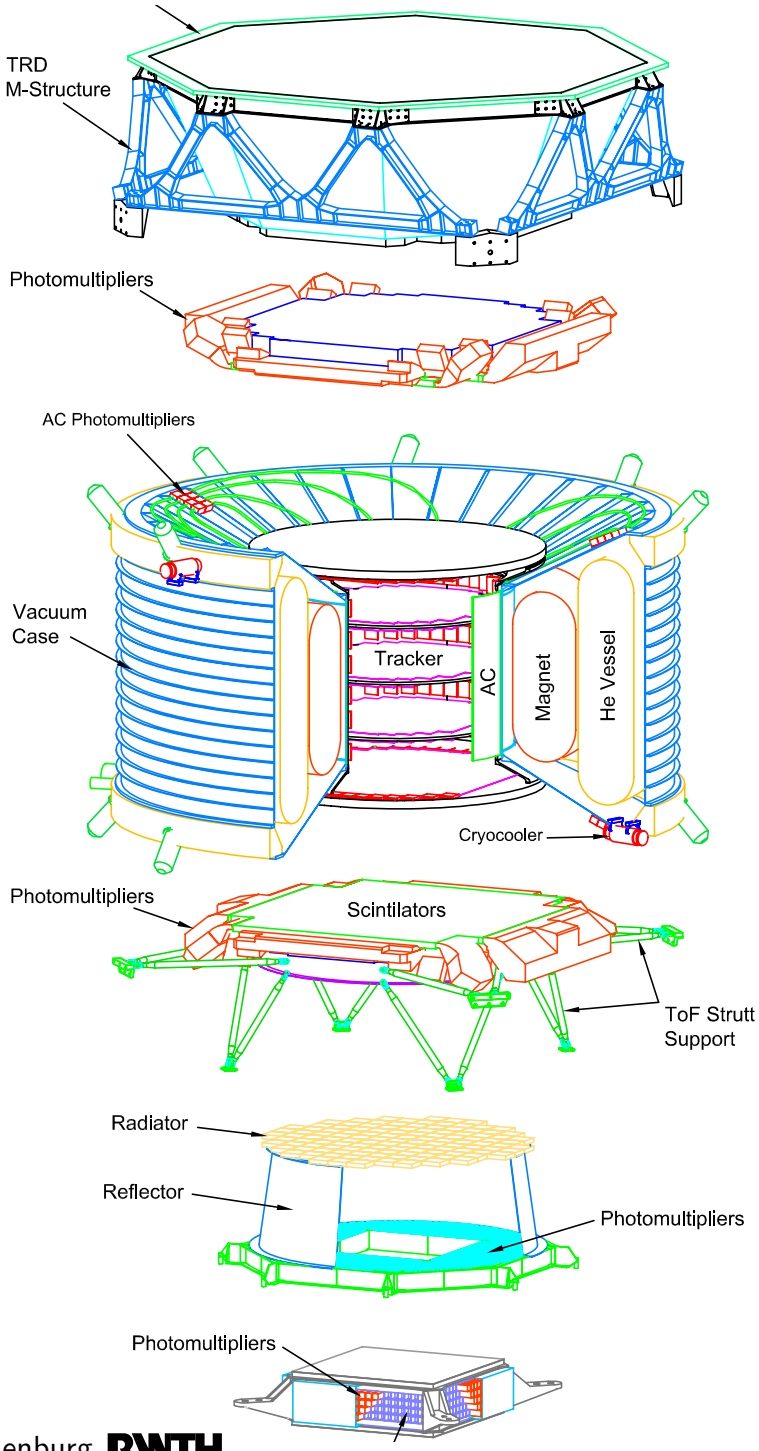


Detectors in space

New environment for HEP experiments

- Acceleration during start and landing up to 9g
- Weight limited to 14809 lb
- Power consumption limited to 2kW
- Deposition limits on ISS $< 10^{-14}$ g/s/cm^2
- Unattended longterm operation in vacuum
- Temperature variations -180 - $+50$ °C
- Single powerline at 120 V
- Single dataline at 1 Mbyte/s

AMS02 – A TeV Particle Spectrometer for the ISS



TRD Particle ID & 3D tracking
20 layers fleece + Xe/CO_2
5248 channels 6mm straw-tubes

p^+Rej 10^3-10^2 from 10-300 GeV for 0.5 m^2sr

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

Anticoincidence (Veto) counter

Silicon strip tracker ($2 \cdot 10^5$ Ch)
with internal laser alignment
6 m^2 in 3 double + 2 single xy layers
1σ charge separation up to 1TV

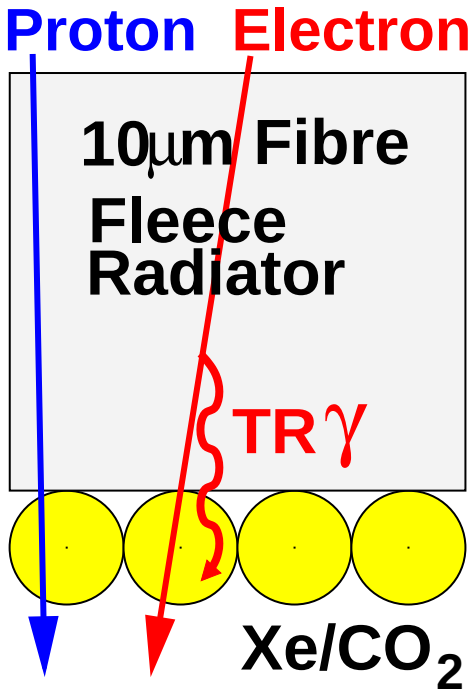
Superconducting Magnet (ETH)
B = 0.9T V = $0.6 m^3$

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 pancake
p^+Rej 10^3-10^4 from 10-300 GeV for 0.05 m^2sr
with p-E matching and shower-shape

Transition Radiation to separate Protons from Positrons



Realisation: HERA-B/ATLAS fleece-radiator + straw-tubes

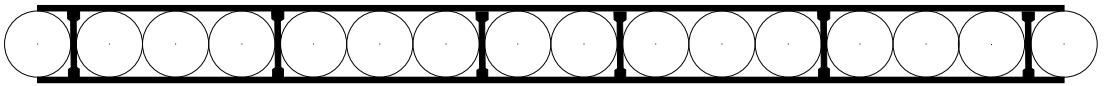
20 Layers 22mm fleece-radiator (Freudenberg LRP-375-BK)
6mm straw-tubes Xe/CO_2 (80/20)

Tubewall 72 μm Kapton-Al sandwich

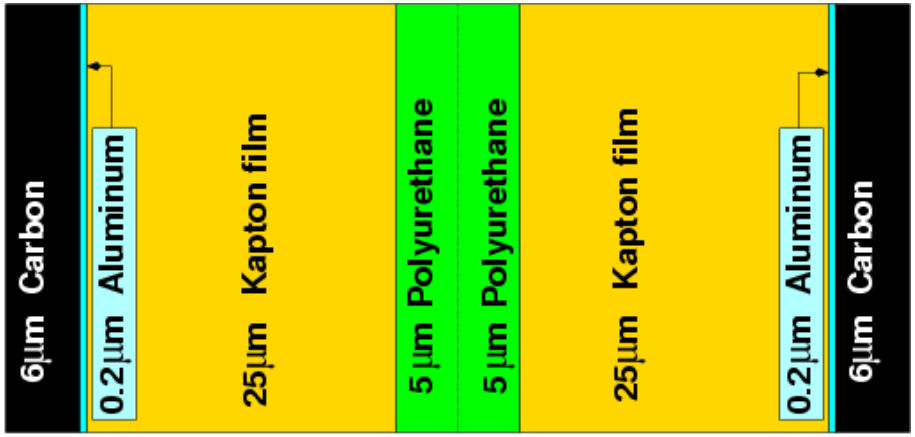
Wire 30 μm W/Au tensioned with 100g

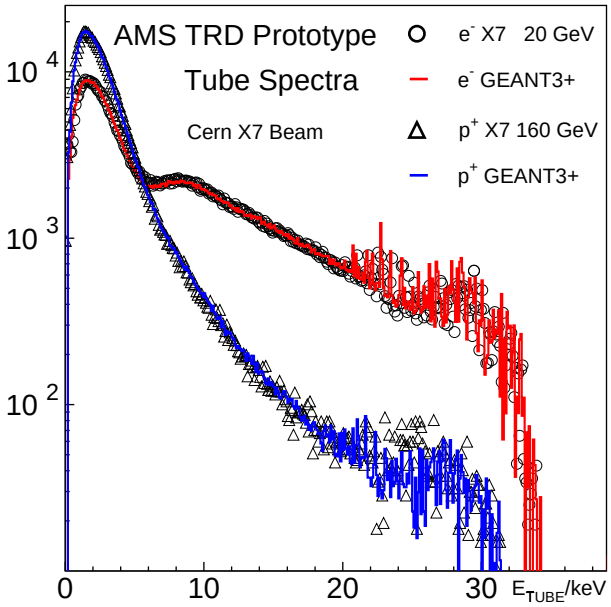
Pressure 1000 mbar flow 1 l/h gain 3000

Modules 16 tubes 8 modules per gas-circuit

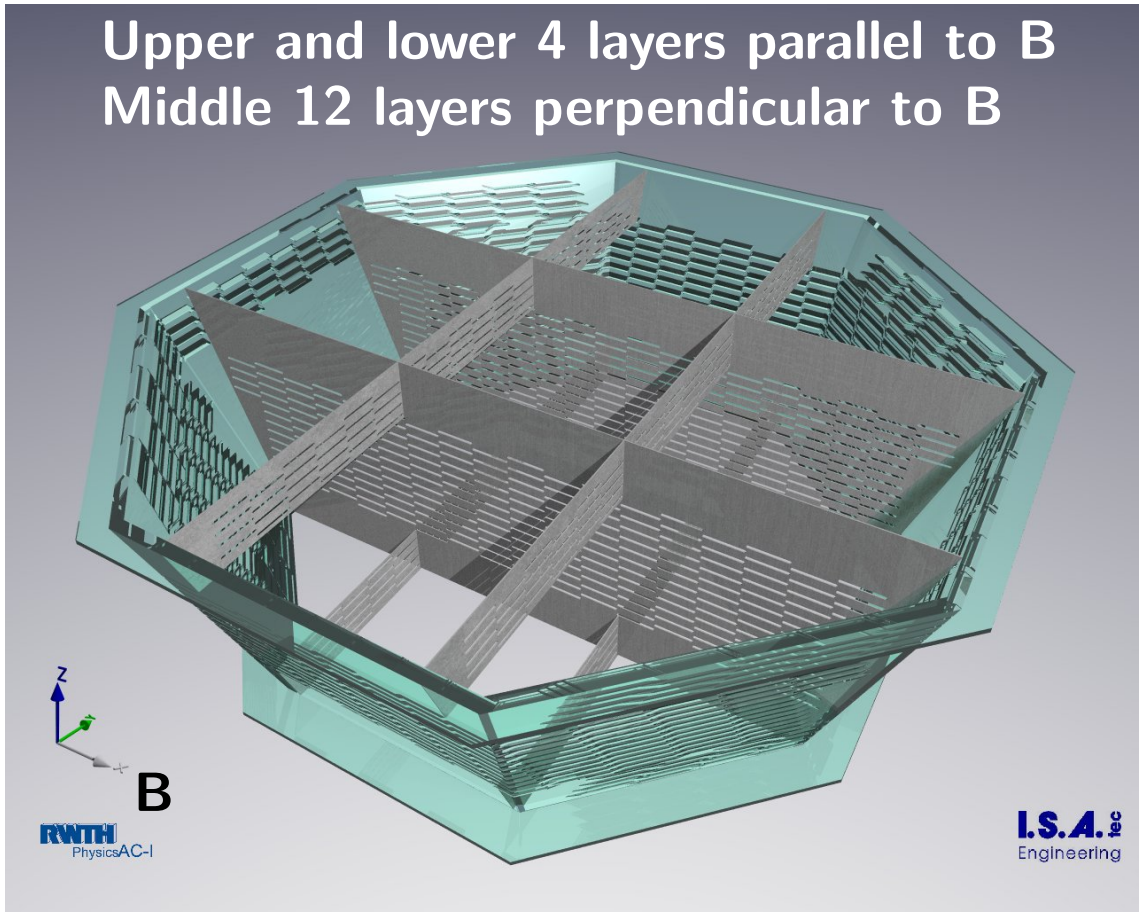


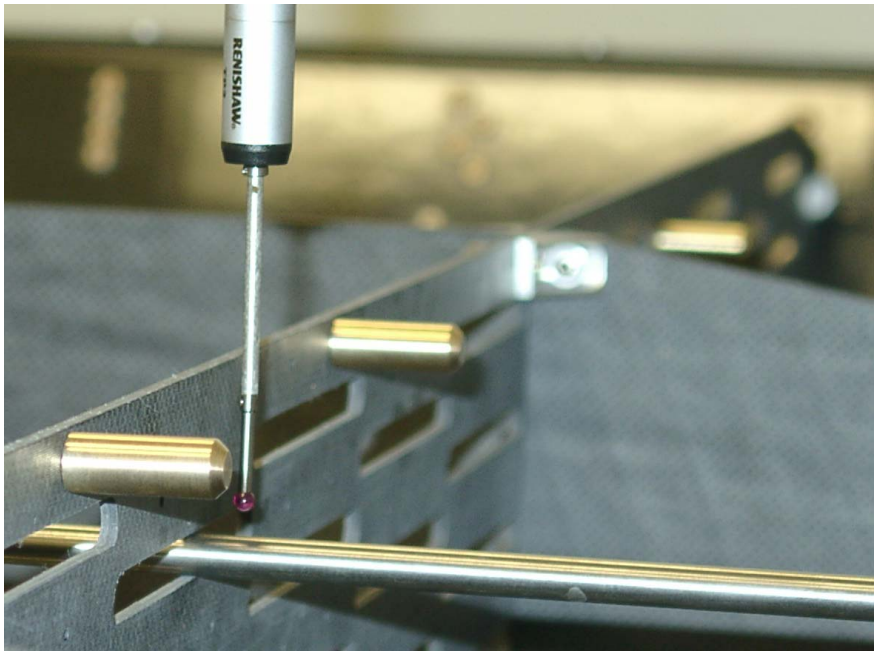
6 longitudinal stiffeners Strips across every 10 cm





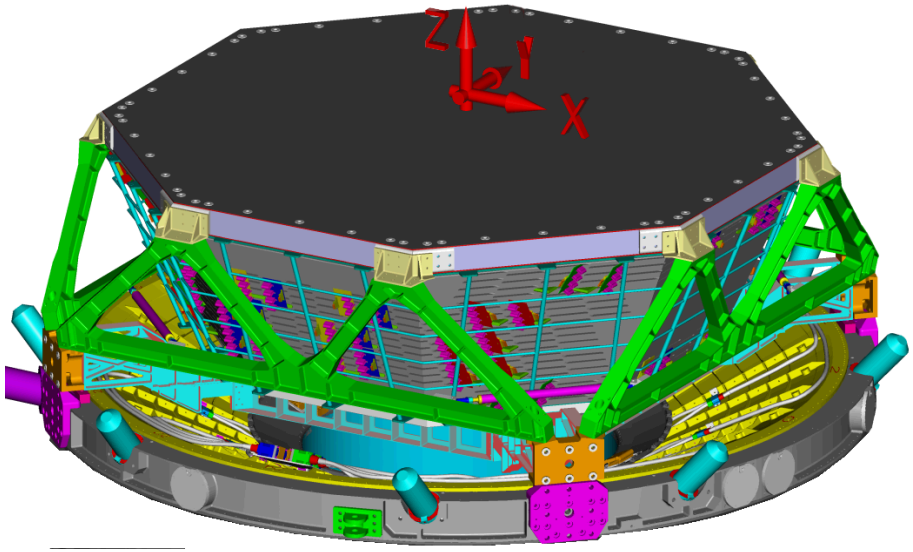
Chamber Support in Carbon-Fibre/Honeycomb Octagon





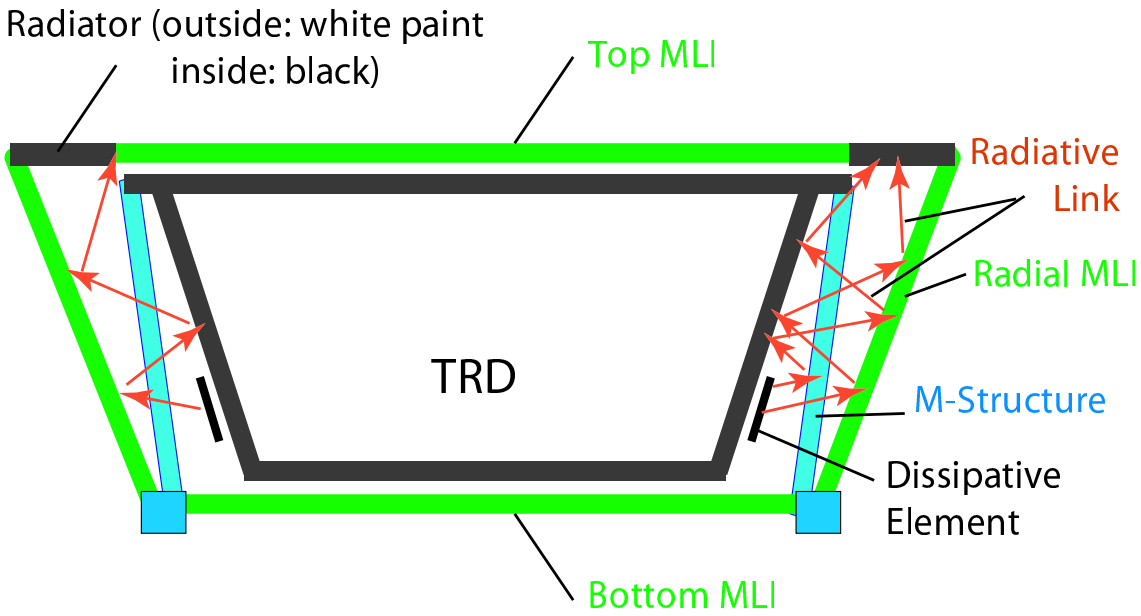
328 Modules in 20 layers
Module lengths up to 2m
Mechanical precision $< 100\mu$m
Gasgain Homogenity $\Delta G/G < 2\%$

TRD Mechanical Model

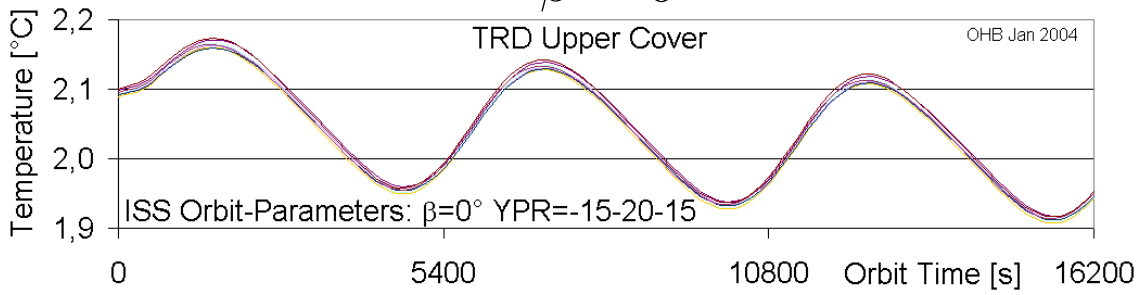


Component	kg
Radiator	60
Straw-Modules	54
Xe/CO_2	54
Octagon	114
Support + Shielding	100
Gas System	63
FE + Crate-Electron.	53

Thermal Model



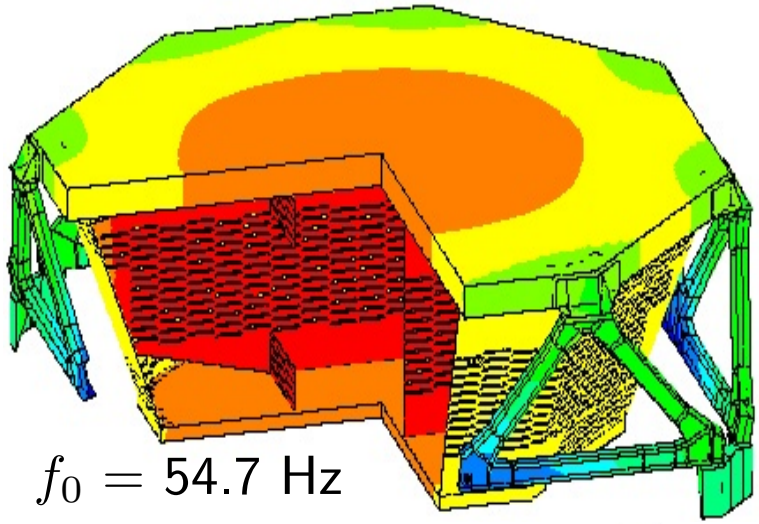
$\beta = 0°$



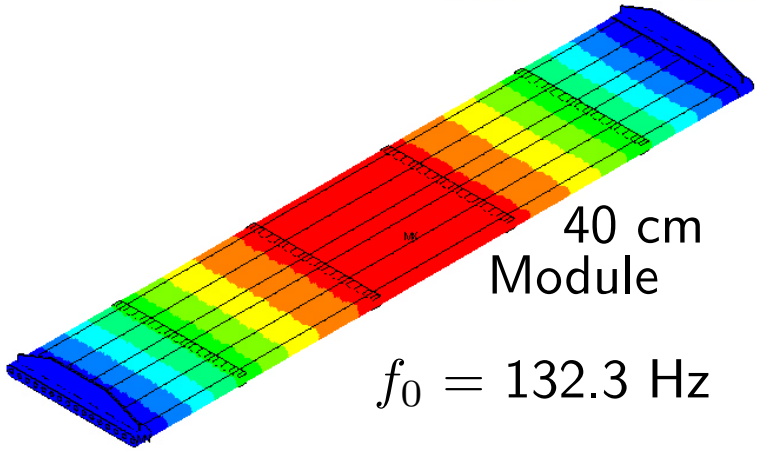
Other β: $-15C° < T_{inner} < +35C°$

Structural Verification

FEC sufficient for $f_0 > 50$ Hz

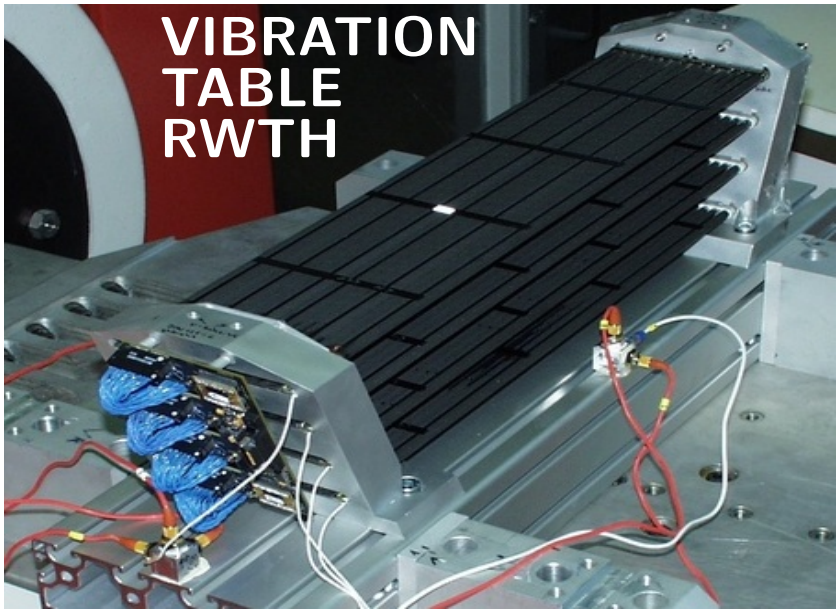


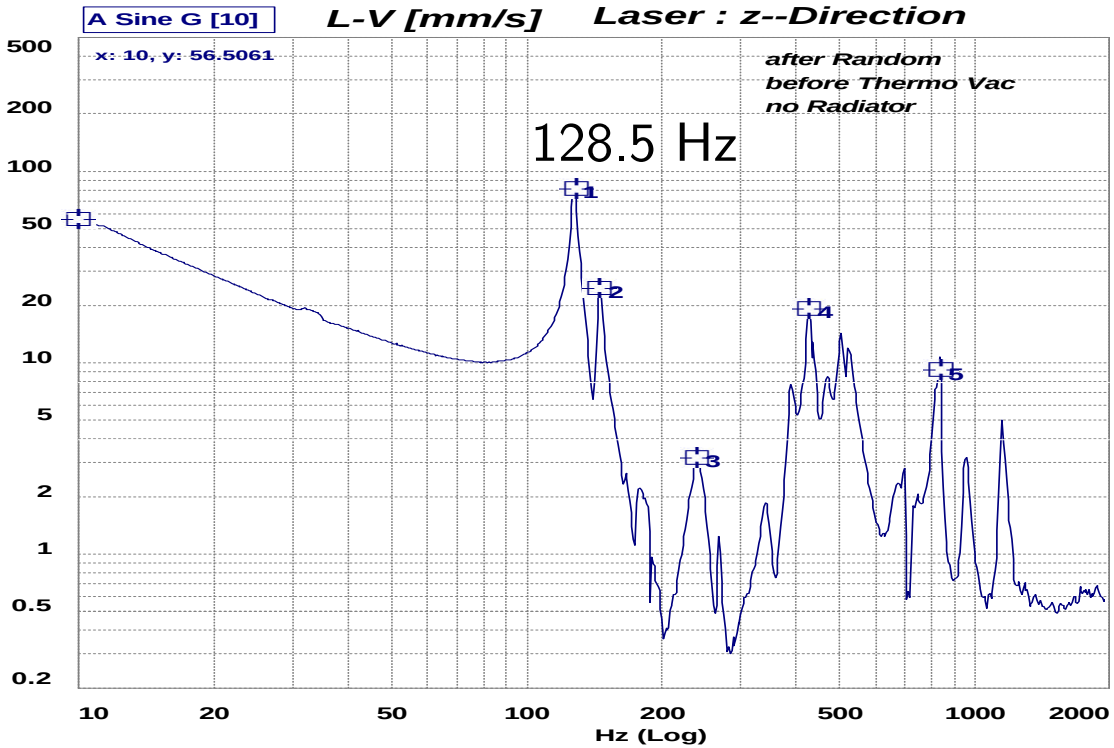
$f_0 = 54.7$ Hz



40 cm Module

$f_0 = 132.3$ Hz

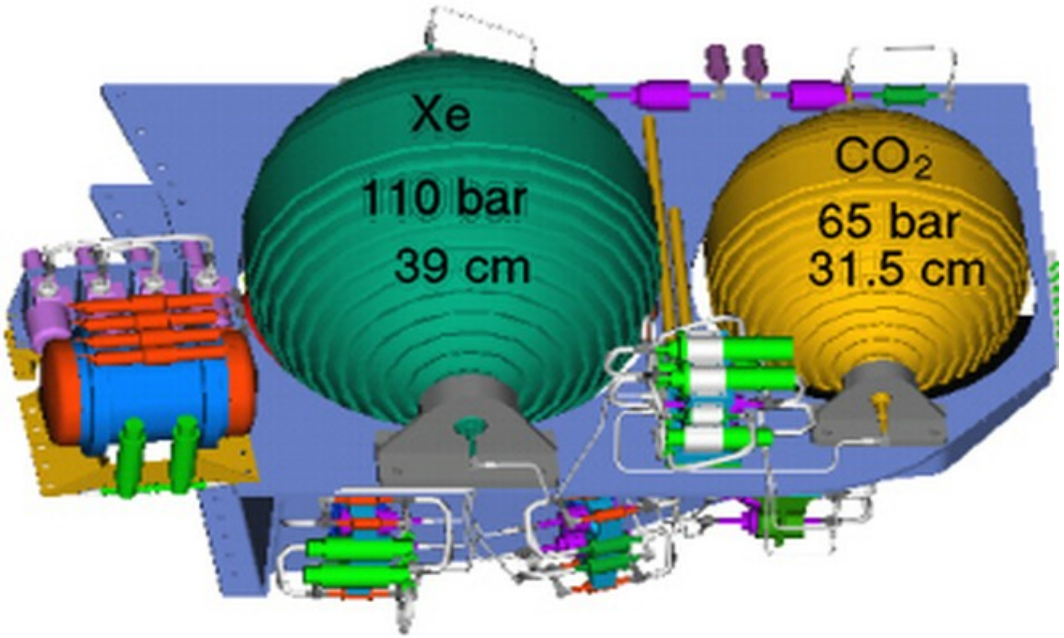




FEC coupled load modal analysis

Parameters from static measurements
Verify with component vibration tests

TRD Gassystem (MIT)

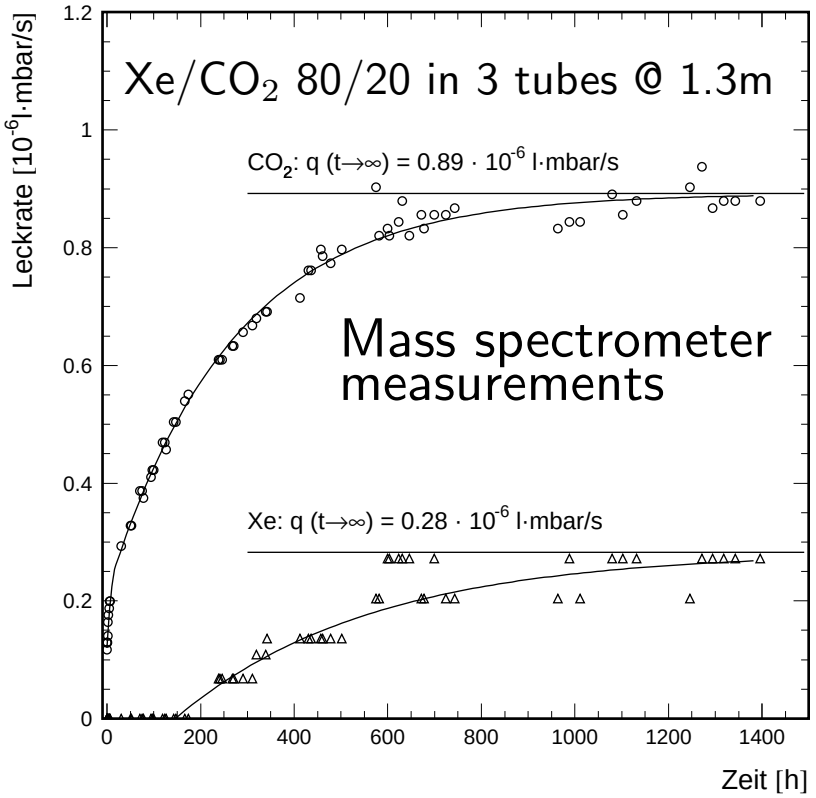


TRD 230 l in 41 loops (500 m_{CH})
Xe 50 kg (8100 l @ 1 bar)
CO_2 4 kg (2000 l @ 1 bar)

CO_2 Safety-Factor SF=1 for 10^8s
$23.5 \cdot 10^{-5}$ l mbar/s/m_{CH} @ 1 bar

Limit: SF = 4

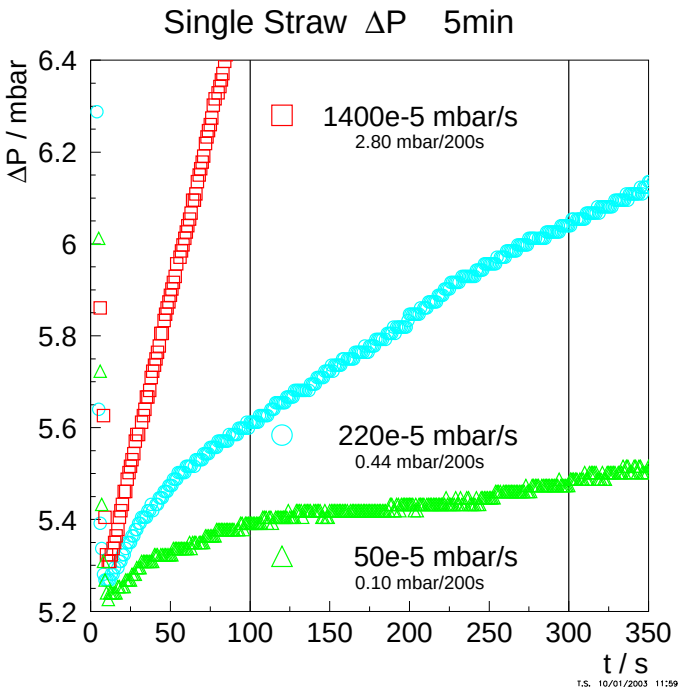
Gastightness - Diffusion limit

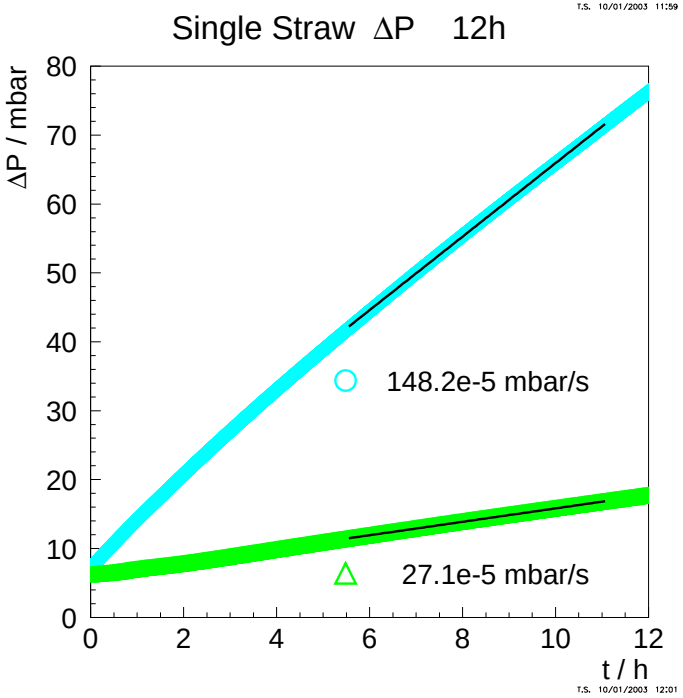


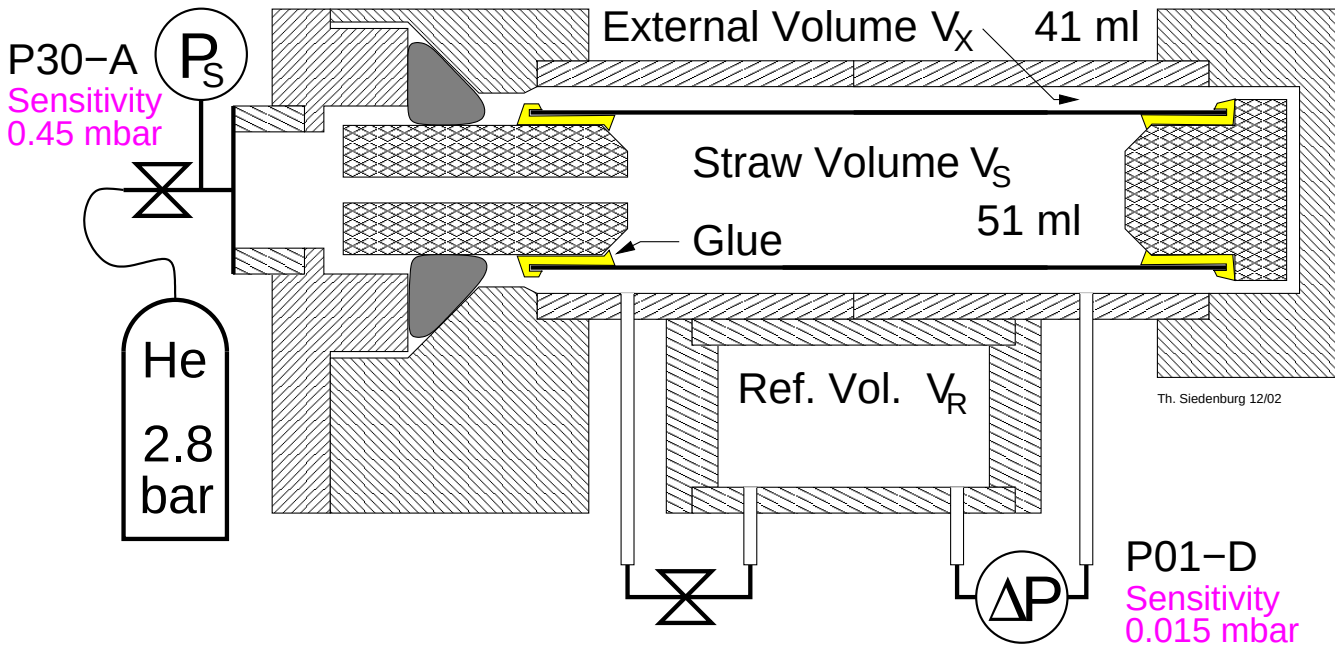
Xe $0.12 \cdot 10^{-5}$ l mbar/s/m_{CH} ≡ 0.3 g/d for TRD
CO_2 $0.37 \cdot 10^{-5}$ l mbar/s/m_{CH} ≡ 0.3 g/d for TRD

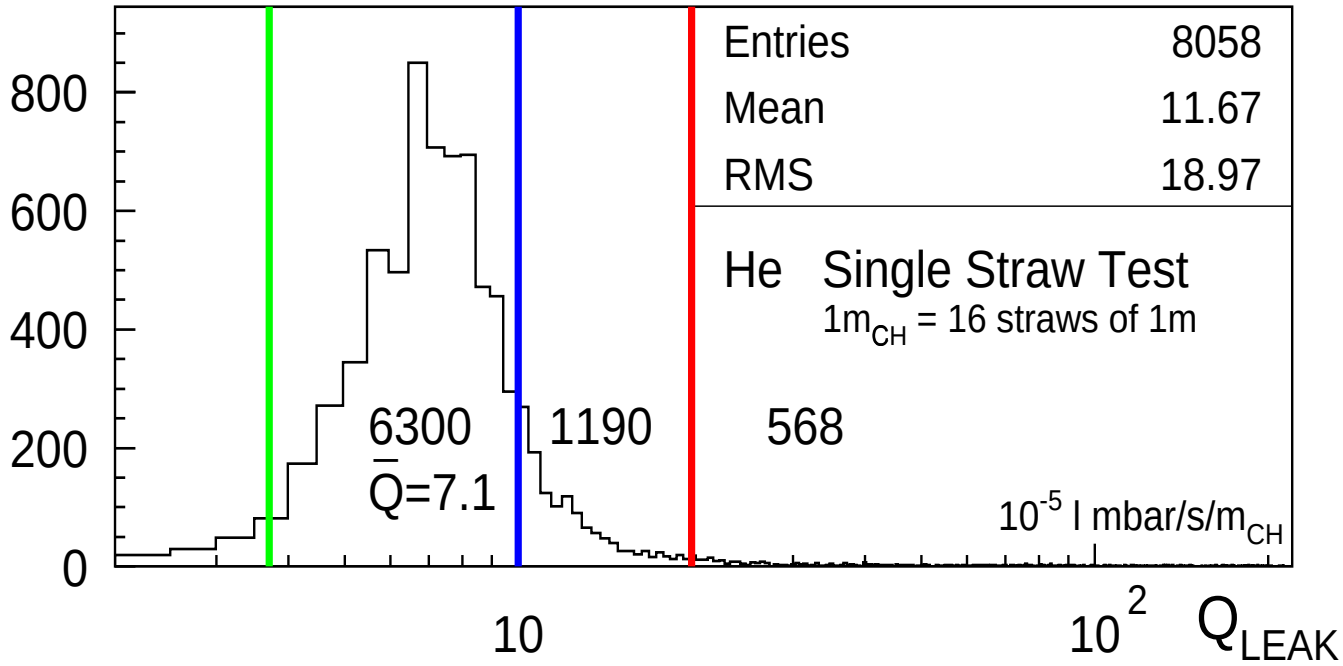
CO_2 Straws @ 1 bar: $1.85 \cdot 10^{-5}$ l mbar/s/m_{CH} ≡ SF 12.7
1.7m CH with Endpcs. $3.26 \cdot 10^{-5}$ l mbar/s/m_{CH} ≡ SF 7.2

Gastightness requires Single Straw Tests

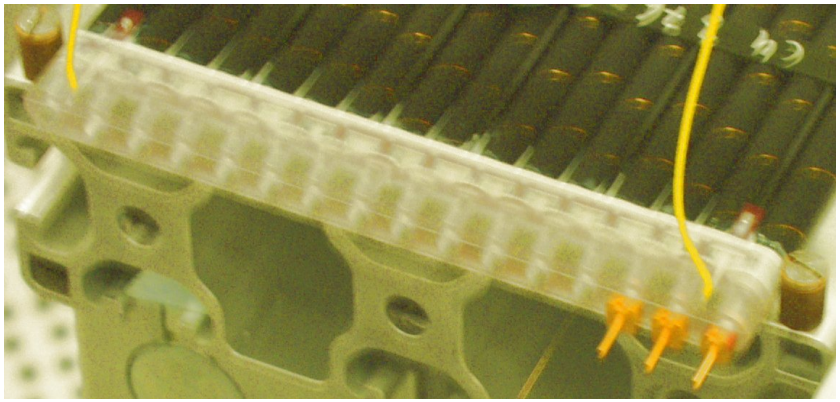


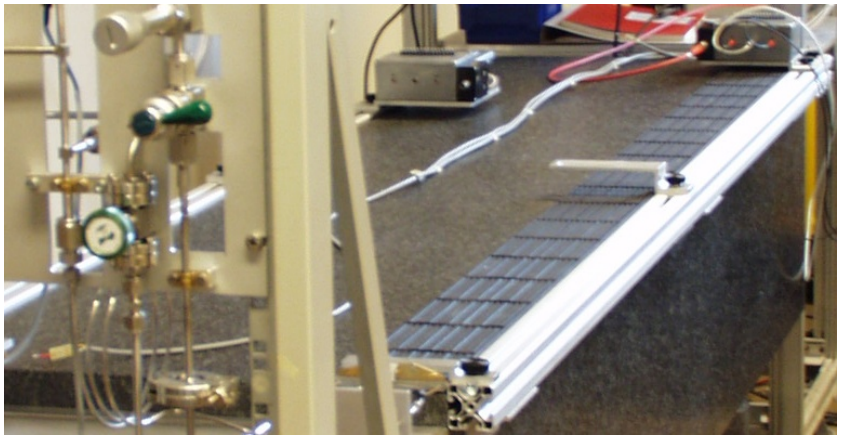






Chamber Production and Quality Control

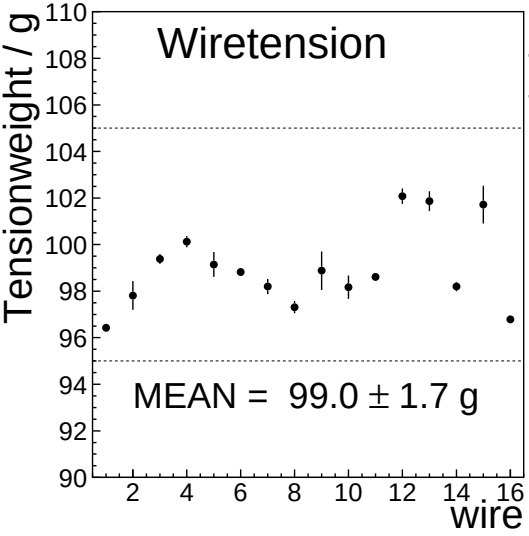


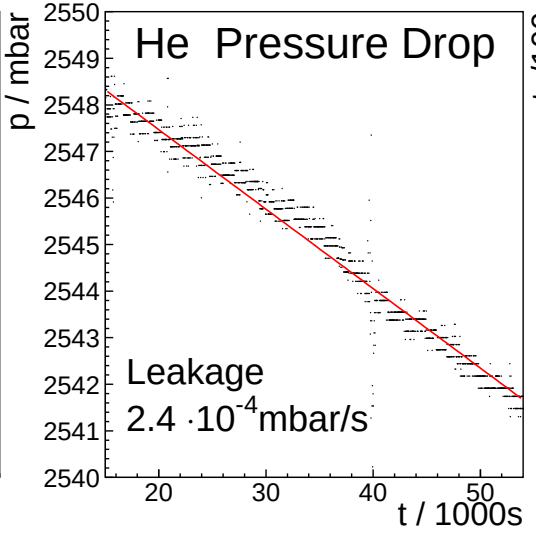


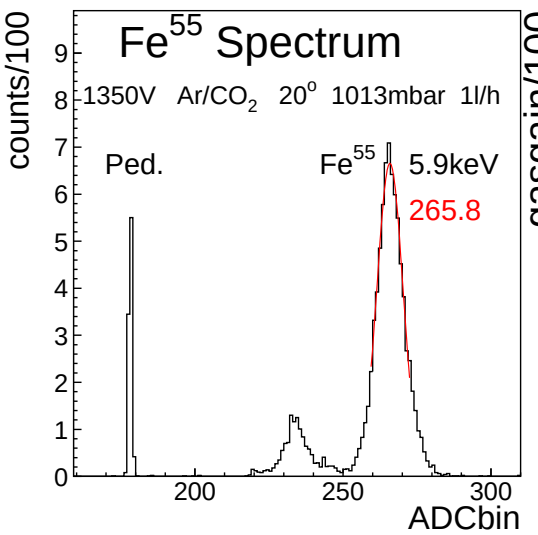
Chamberbody glueing at FVT Company
Endpieces O_2 plasma treated at TC-Kleben

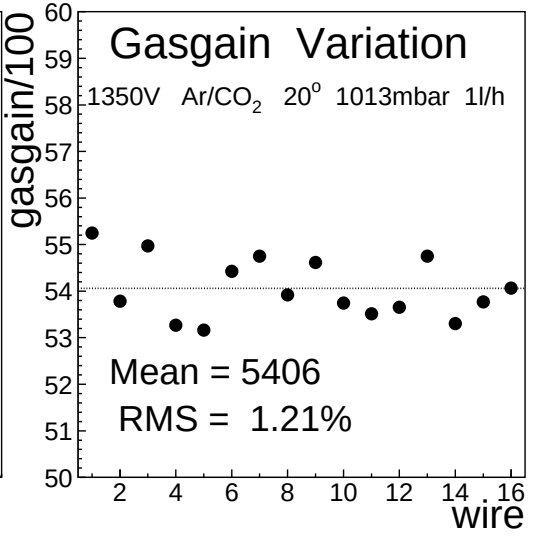
At RWTH:
Endpiece glueing
Wire stringing and crimping
HV board mounting / final potting

Wiretension measurement 100±5 g
Pressure burst test $\Delta P = 2.5$ bar
Gastightness (He) $< 3{\cdot}10^{-4}$ mbar/s
Leakage currents < 1 nA
Gasgain precalibration with Ar/CO_2

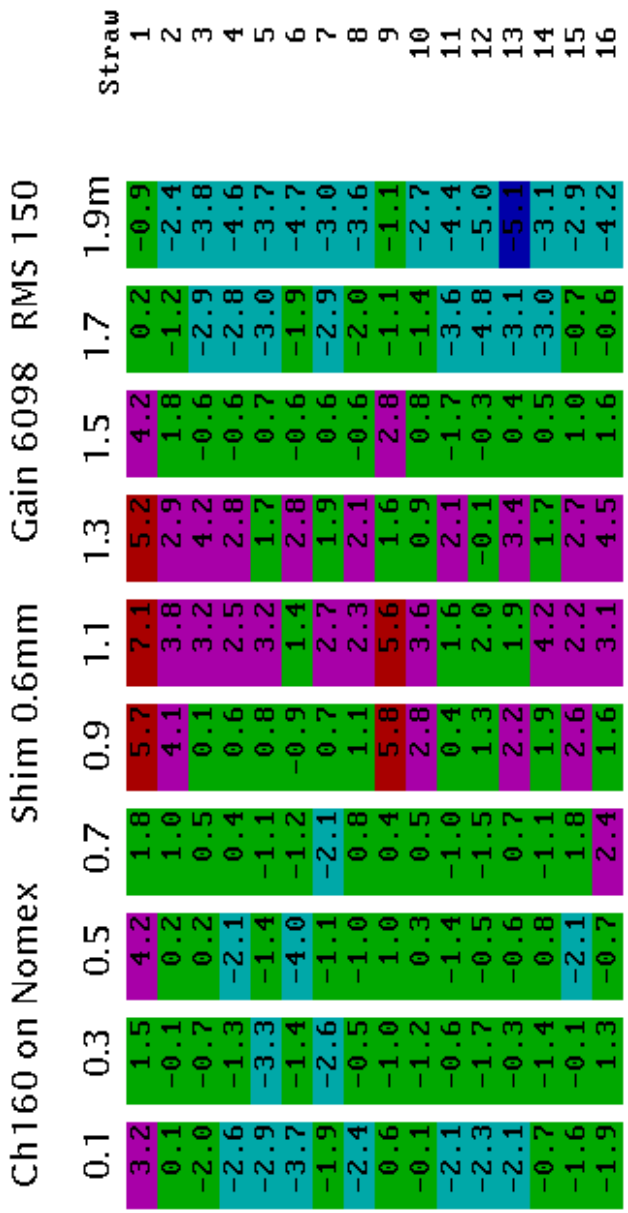




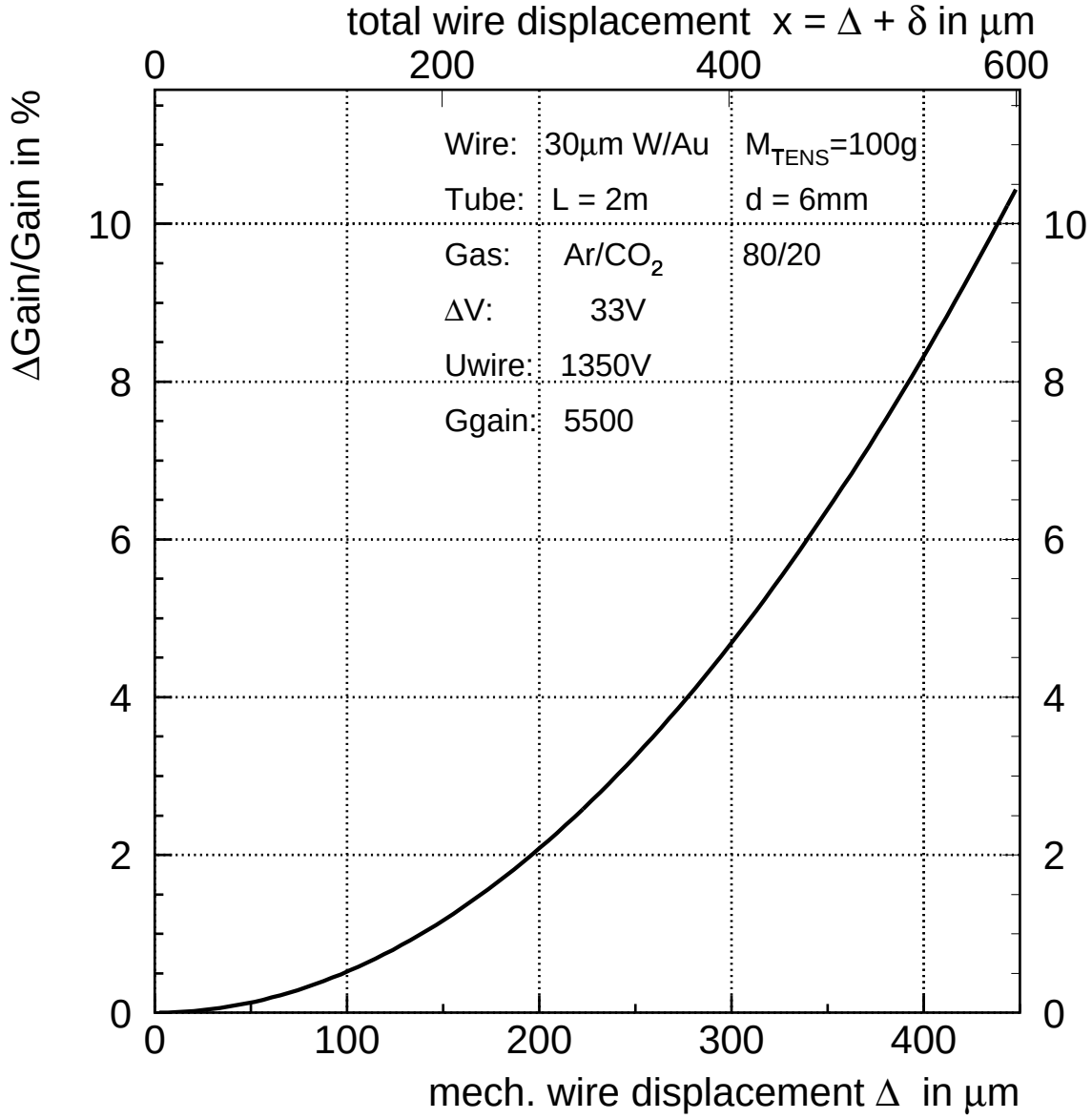




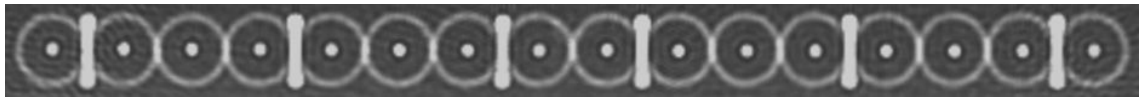
Gasgain Homogenity verifies Mechanical Precision

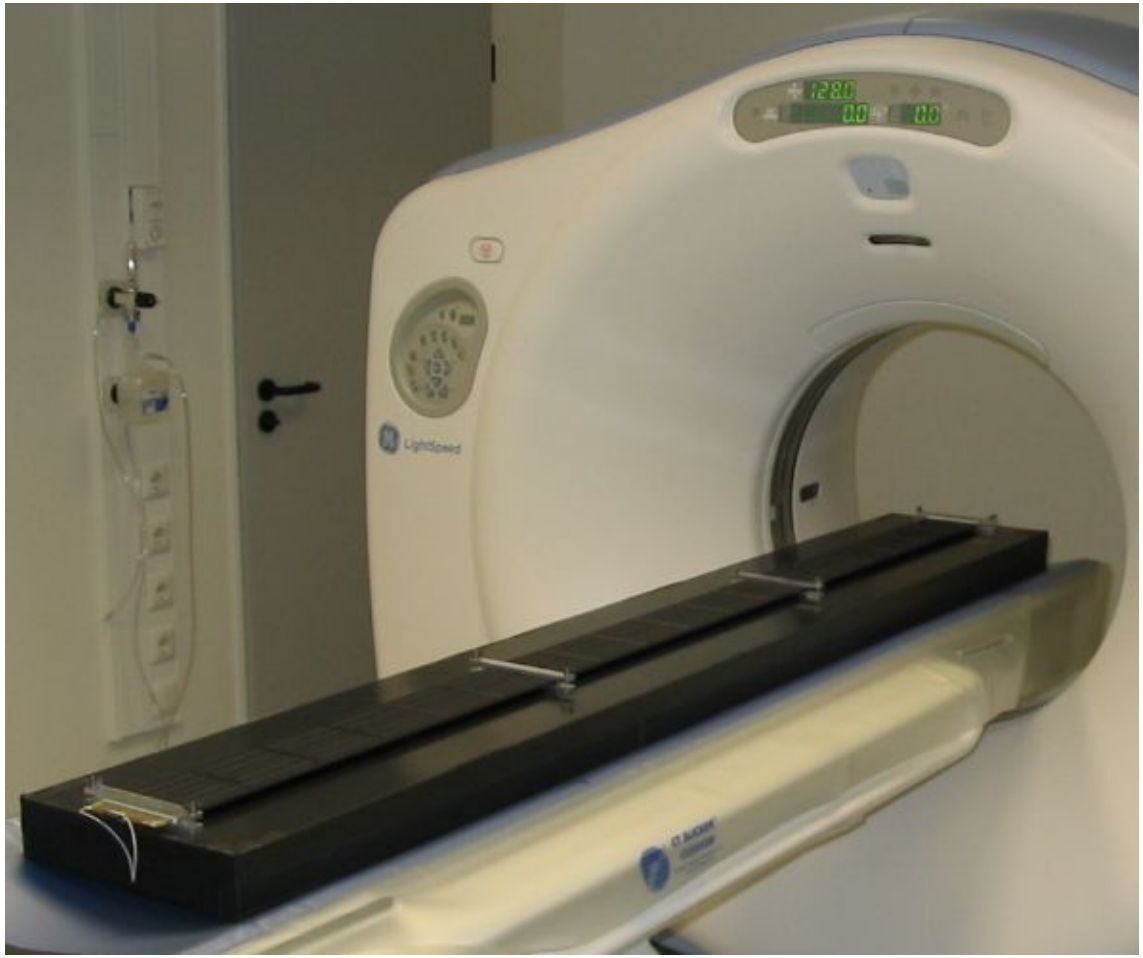


Gasamplification in off-center cyl. Capacitor

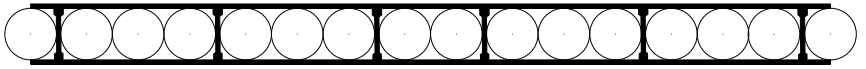


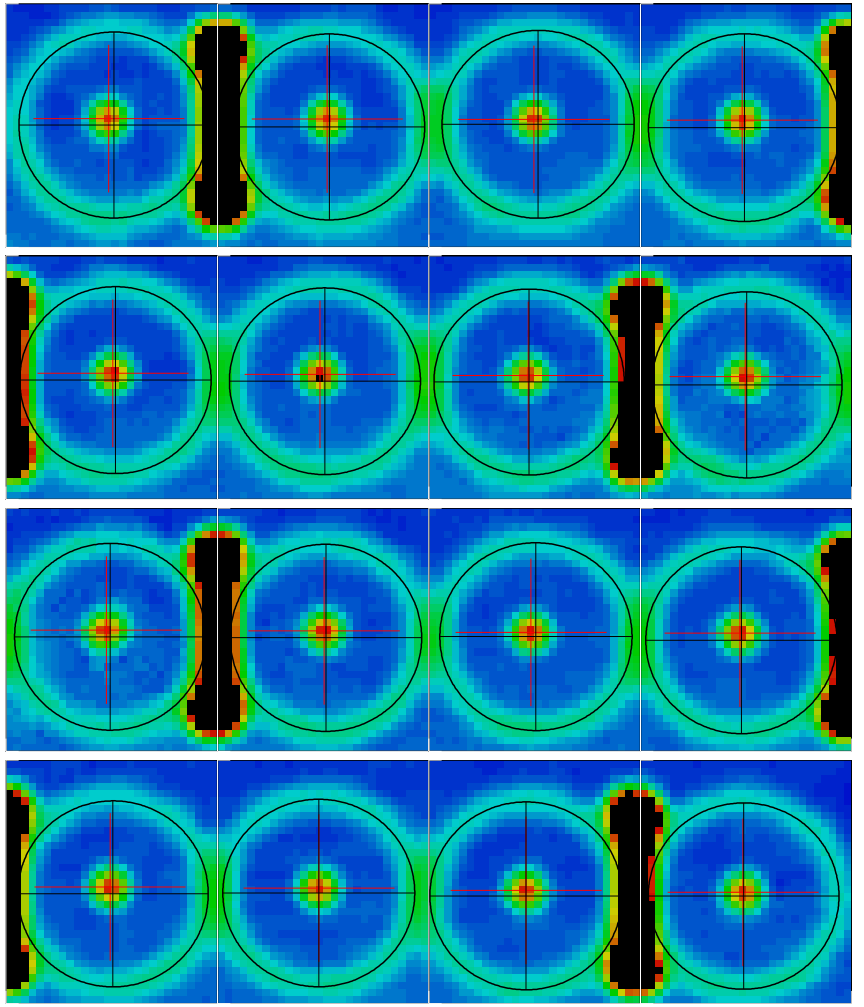
TRD Module Computer-Tomography X-Ray Scan





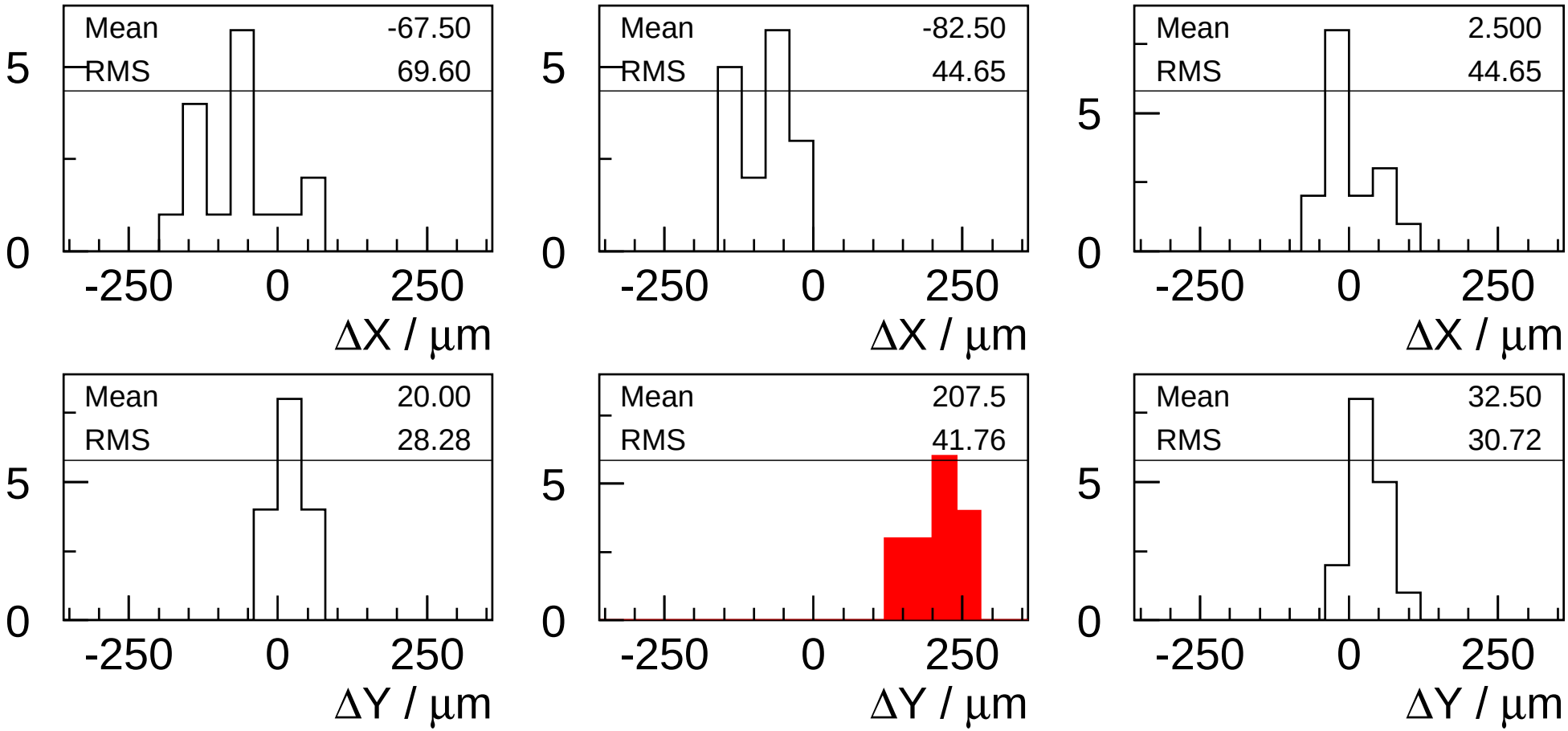
Luisenhospital Aachen (GE 16-Channel CT)



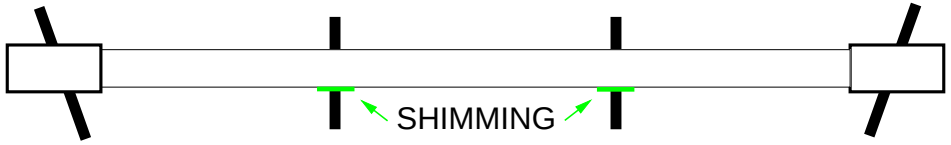


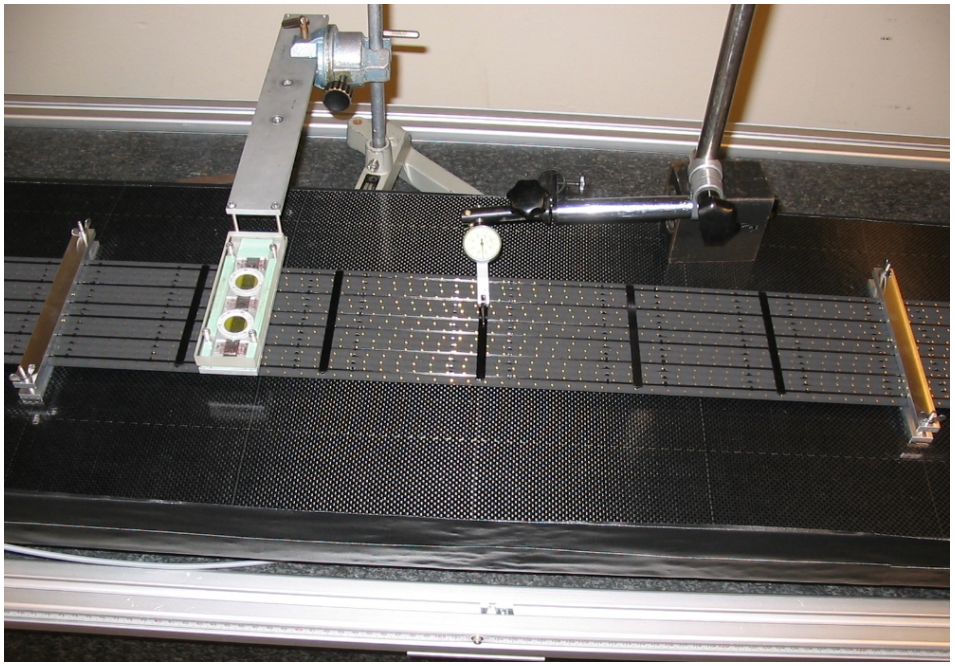
Wire- and Tube-xy-Fit ($\sigma \approx 10\mu$m)

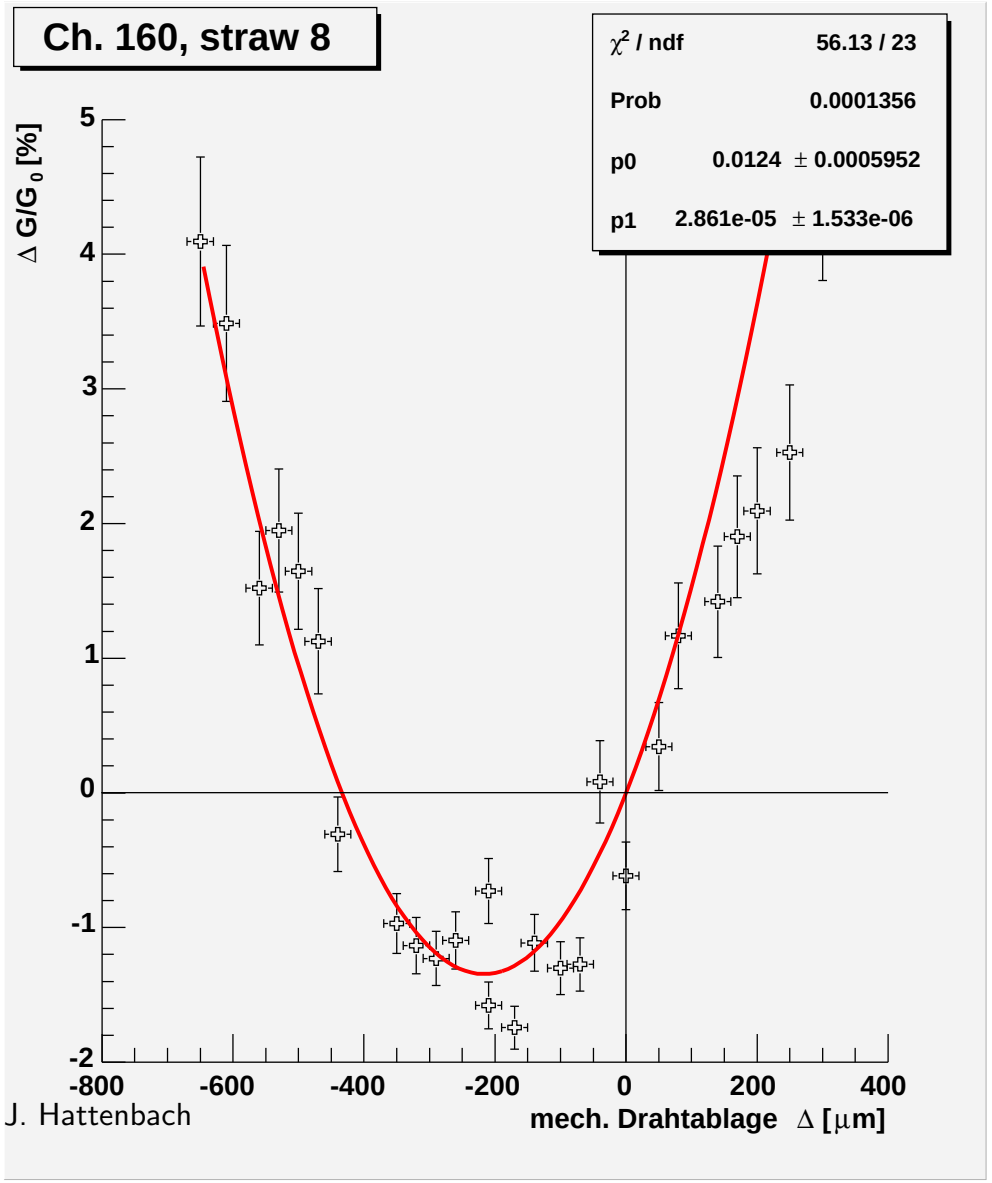
Chamber 160 Wire – Tube Offsets



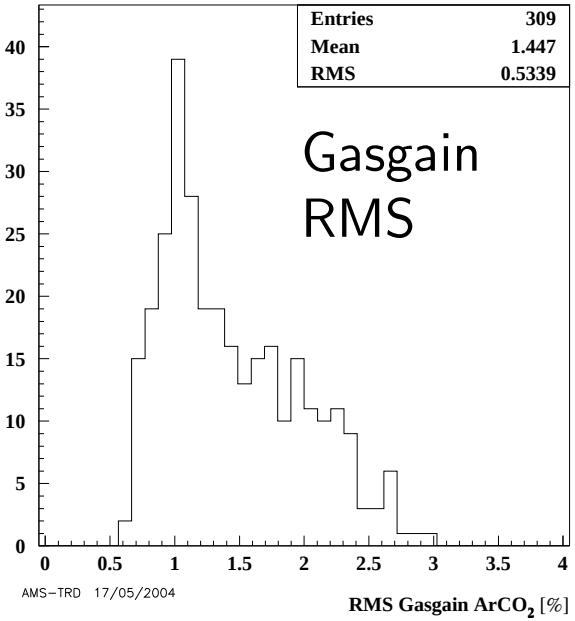
Gasgain Variation with Module-Support Shimming

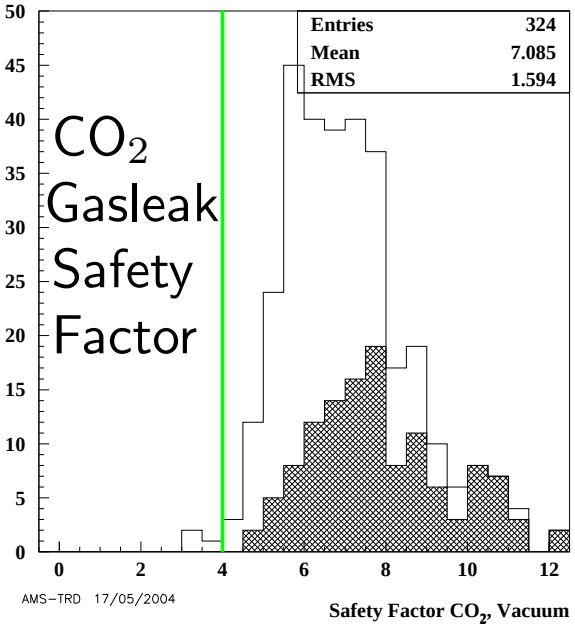


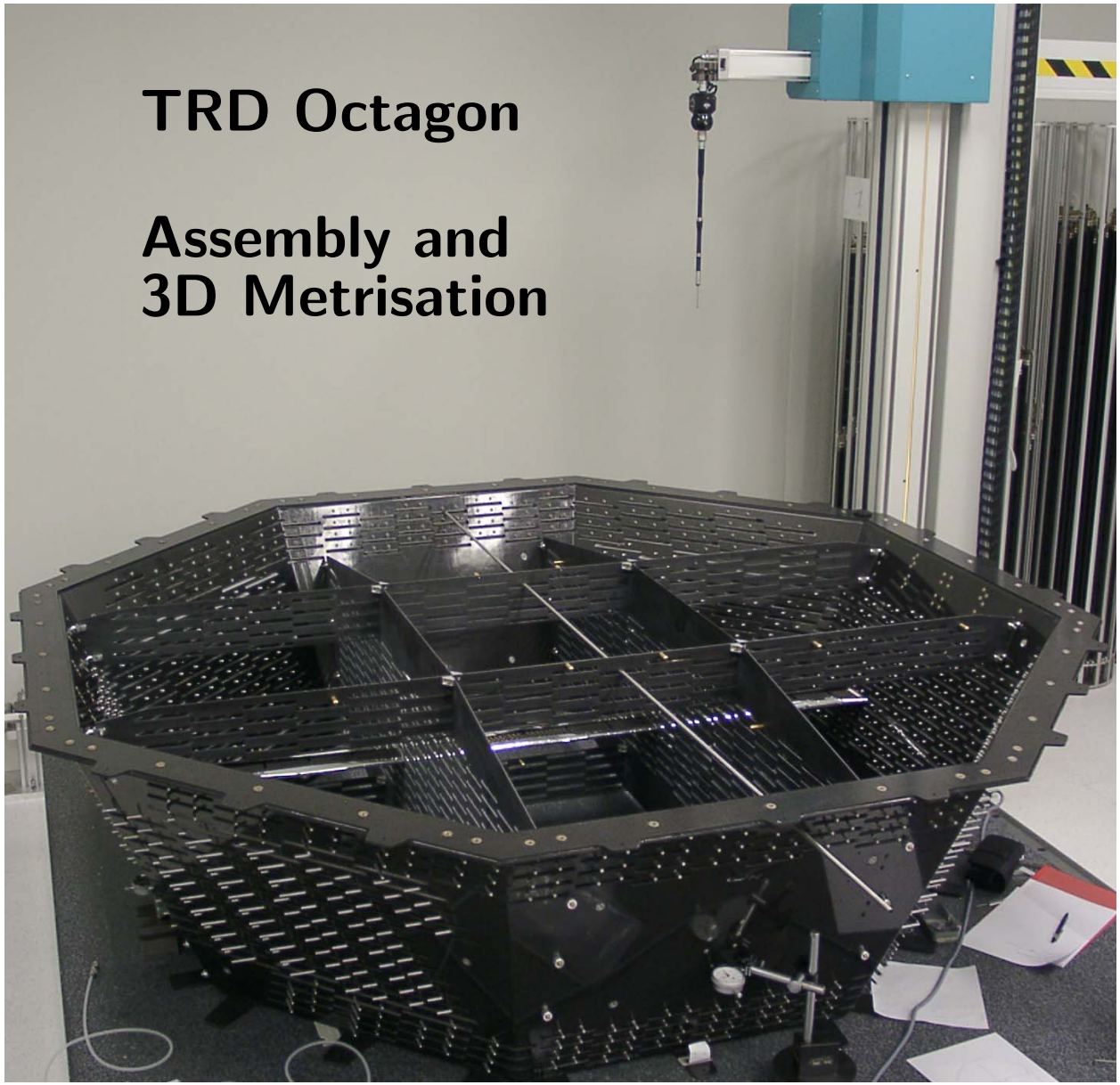




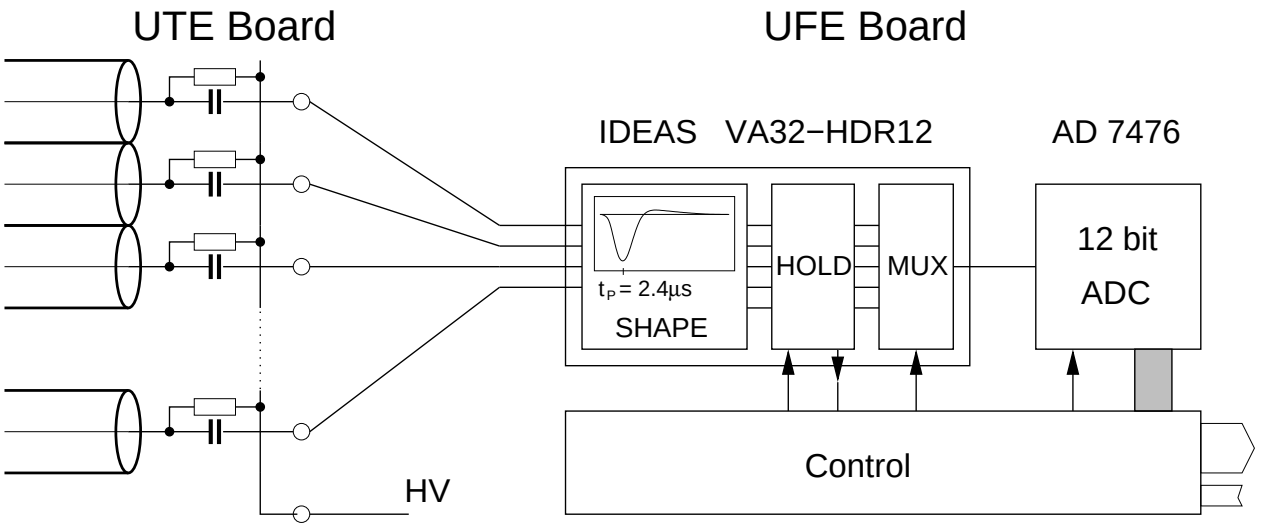
AMS TRD Construction Status

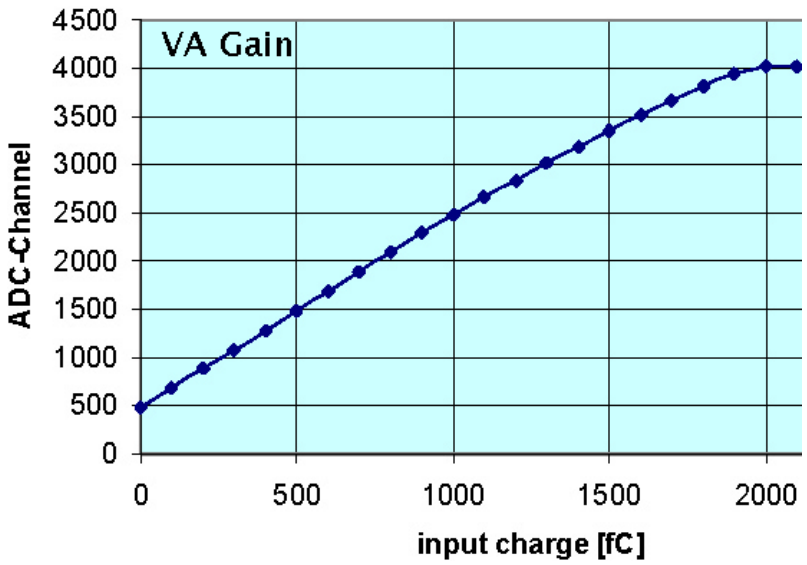






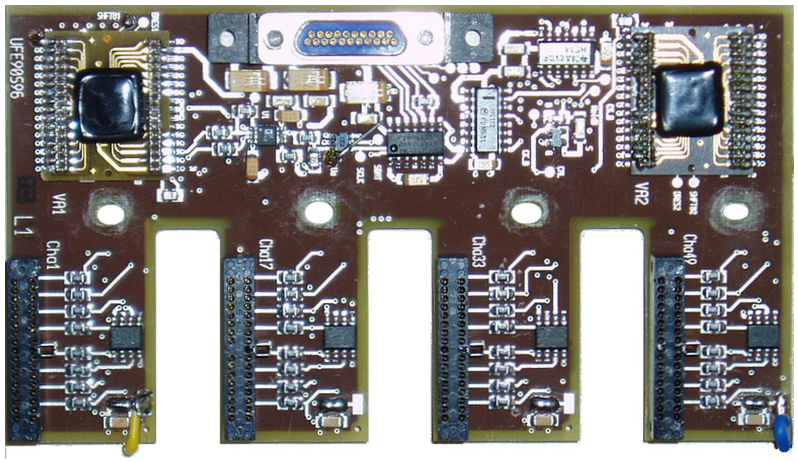
TRD FE VA-Chip Multiplexed Pulseheight Readout





Tube-End Board

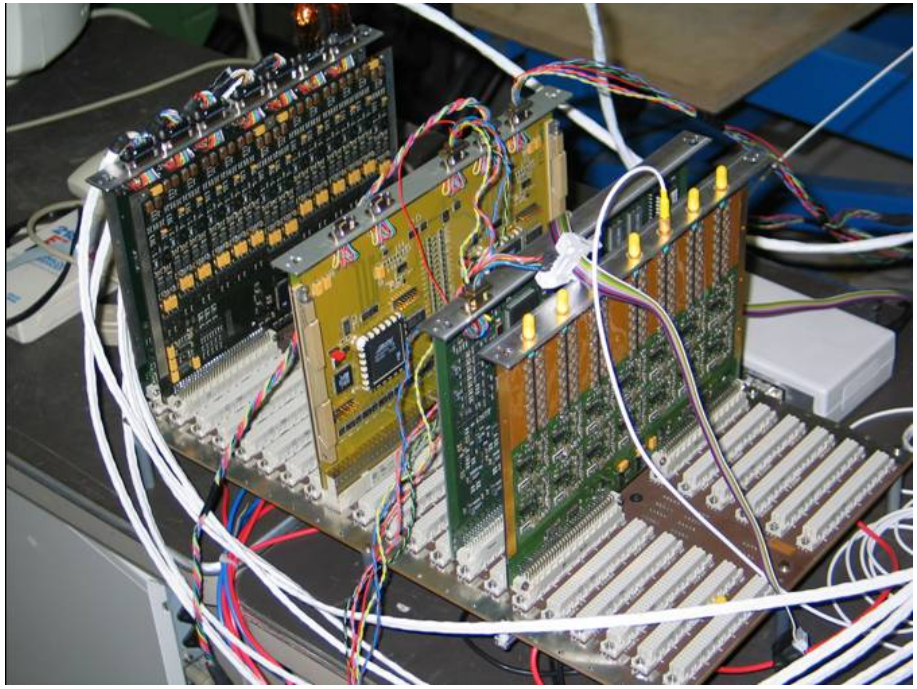
Front-End Board

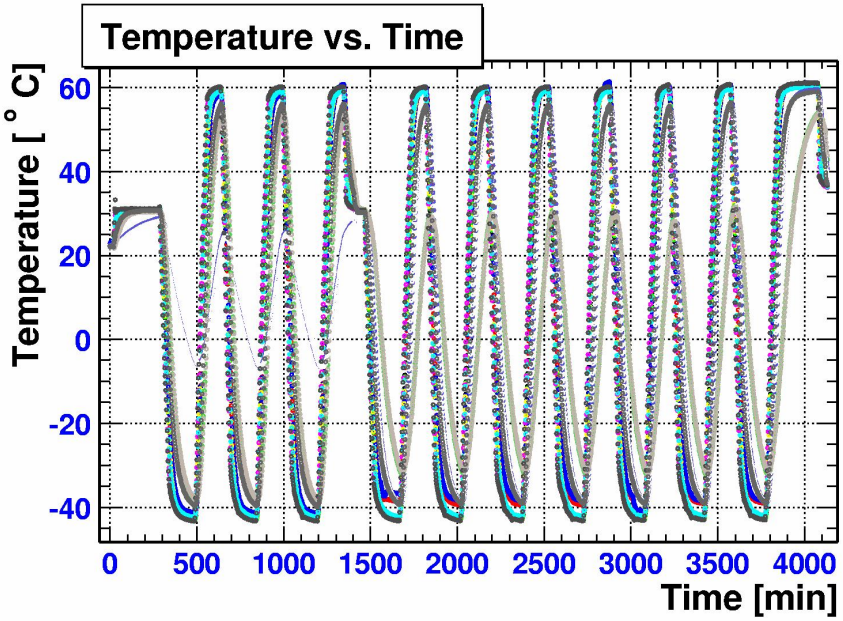


Power: 20W/5248 Channels

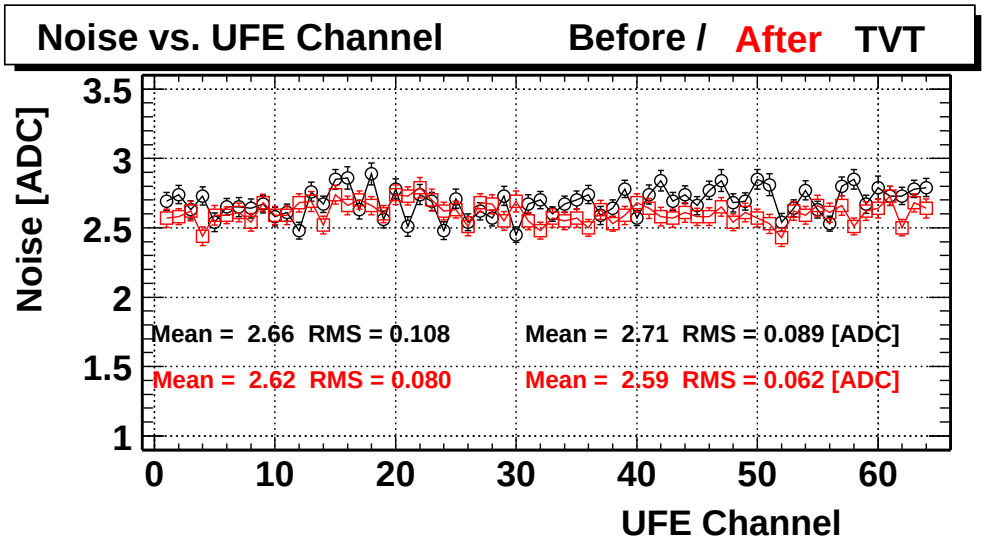
MIP MOP (G=3000)	30 fC 60 bins
MIP S/N	$>$ 60/2
Range	60 MIPs

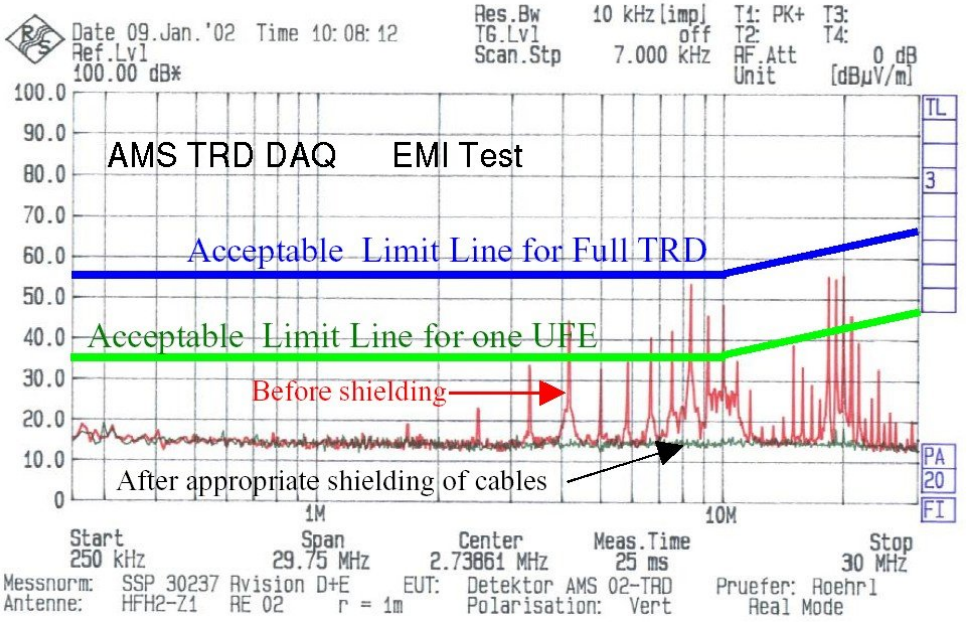
AMS TRD DAQ



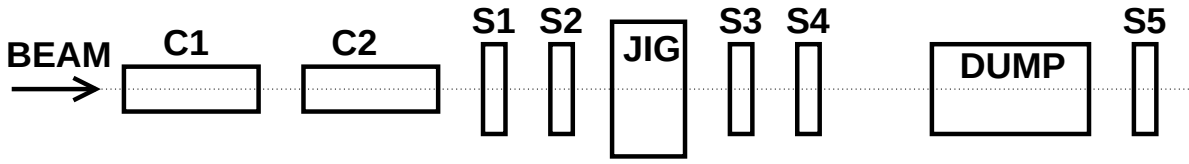


Space Qualification Tests



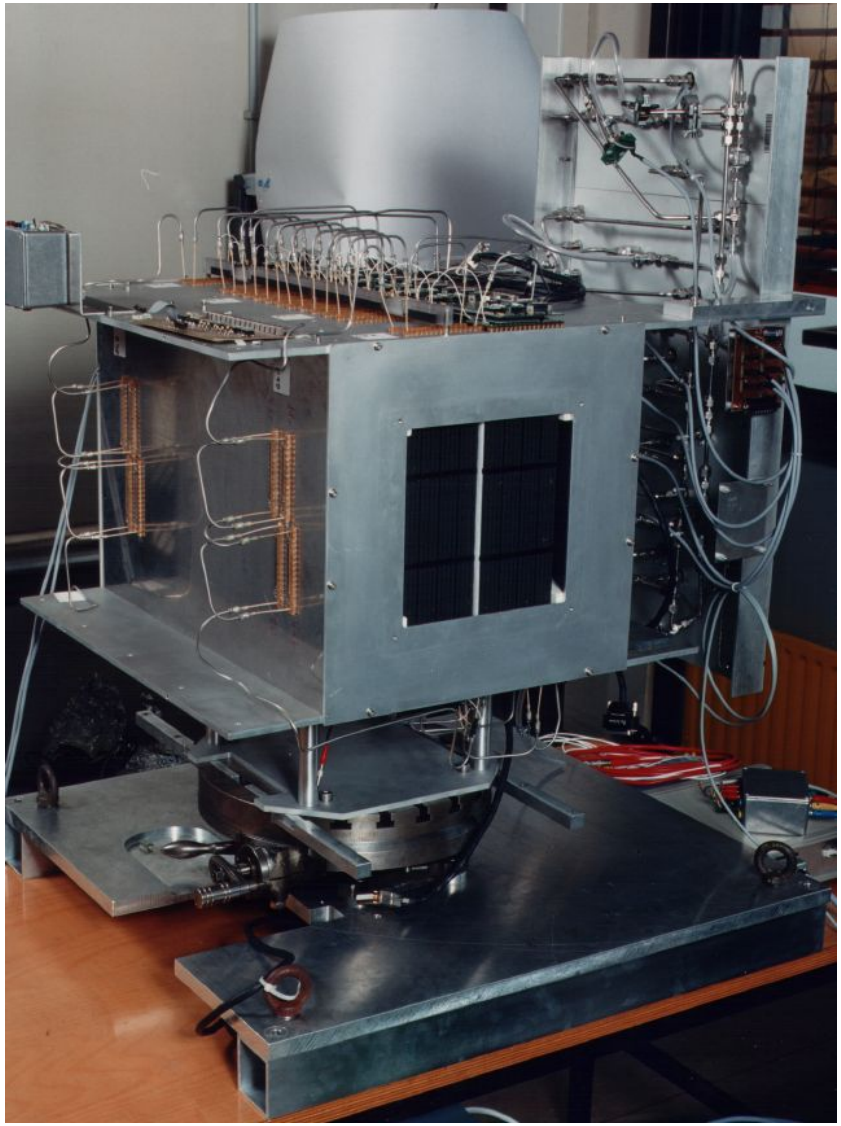


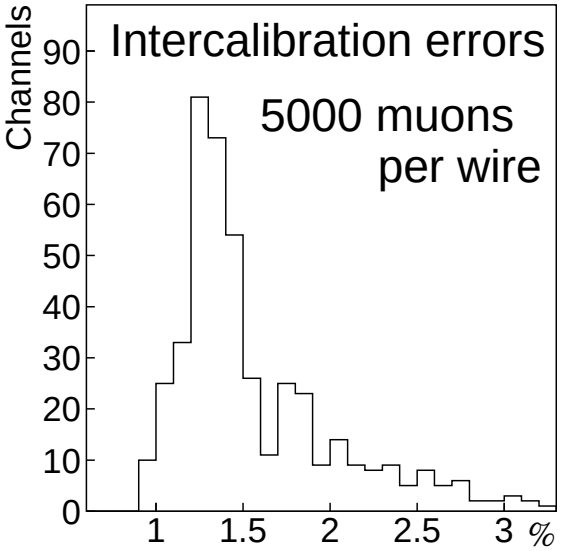
TRD Beamtest CERN X7,H6



20 layer prototype
40 Modules @ 40 cm length

TRD FE VA-Chip Multiplexed Pulseheight Readout
$3 \cdot 10^6$ Recorded events: $e^- \mu^- \pi^+$ 10 - 100 GeV
Protons 10 - 250 GeV

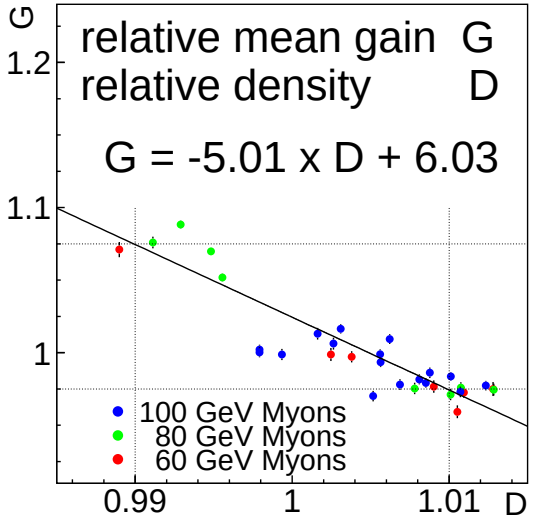


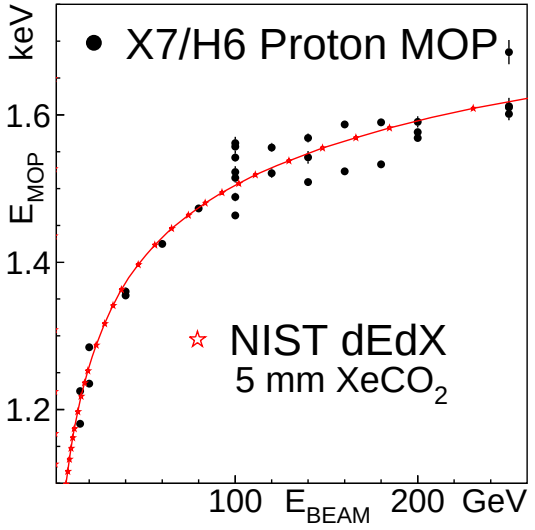


Tube intercalibration <2%

Gasgain density correction

Fe^{55} energy calibration

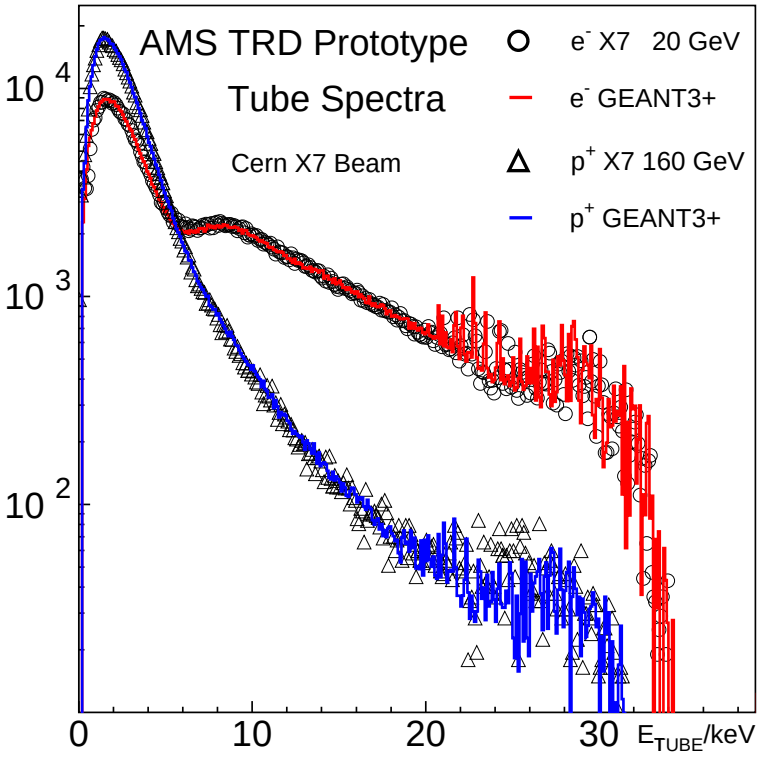




TRD Beamtest Proton Rejection for 90% Electron-Efficiency

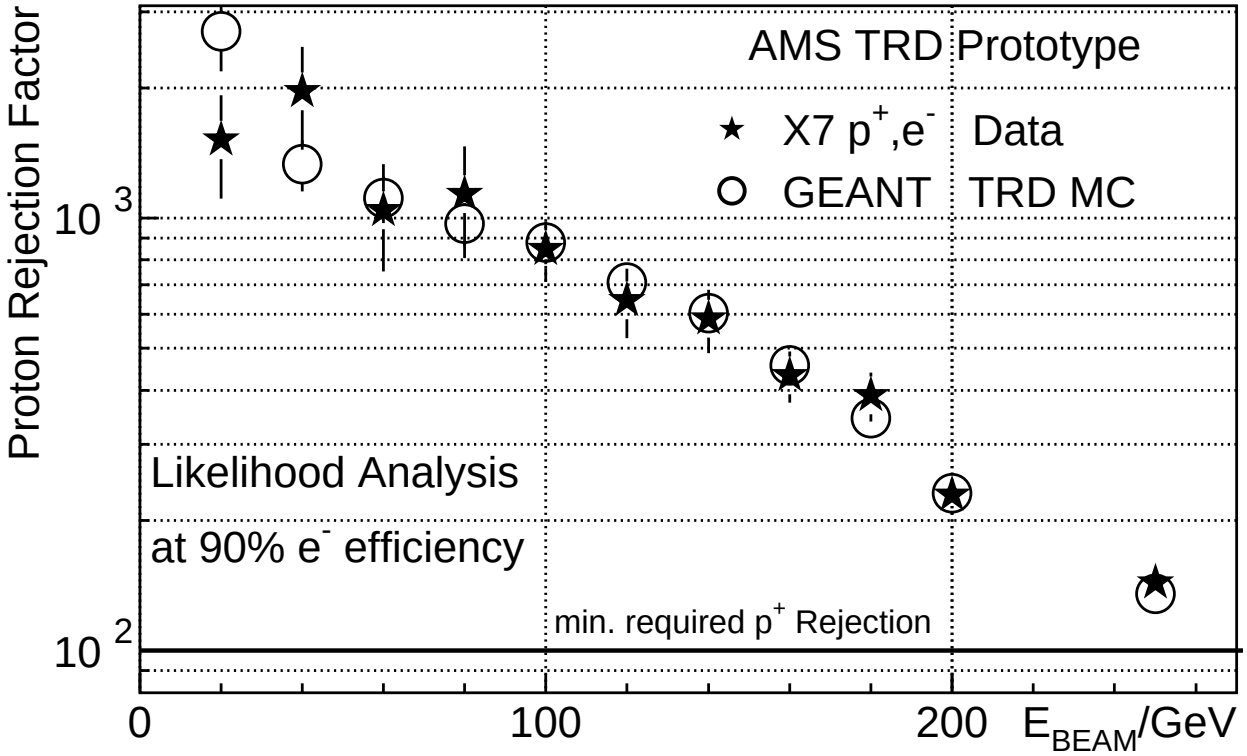
Analysis: single clean track preselection with 90% MC efficiency

p^+/e^- likelihood separation with $\mathcal{L} = \prod p_e \,/\, (\prod p_e + \prod p_p)$



p_e p_p from single tube spectra

GEANT-MC modified dEdX + TR



Upper limits due to remaining pion-contamination

Conclusion and outlook

- TRD Prototype performs as expected
  10-250 GeV Proton rejection 10^3-10^2
- Critical space qualification test passed
  Structural rigidity and thermal stability
  Gastightness and radiator outgassing
  Weight and power
- Construction on schedule within budget
  324/328 flight-modules gastight
  309/328 gasgain homogenity ok
  Octagon will give 100μm precision
- Chamber Integration on Cosmic Testsetup
  Jun. - Oct. 2004
- Gassystem and Electronics Integration Nov. 2004
- Full TRD System Test Dec. 2004
- AMS Integration and TVT in 2005