TRDs for the 3^{rd} millennium

Status of the AMS TRD

for the AMS-TRD Group
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Status of the AMS TRD Straw Modules

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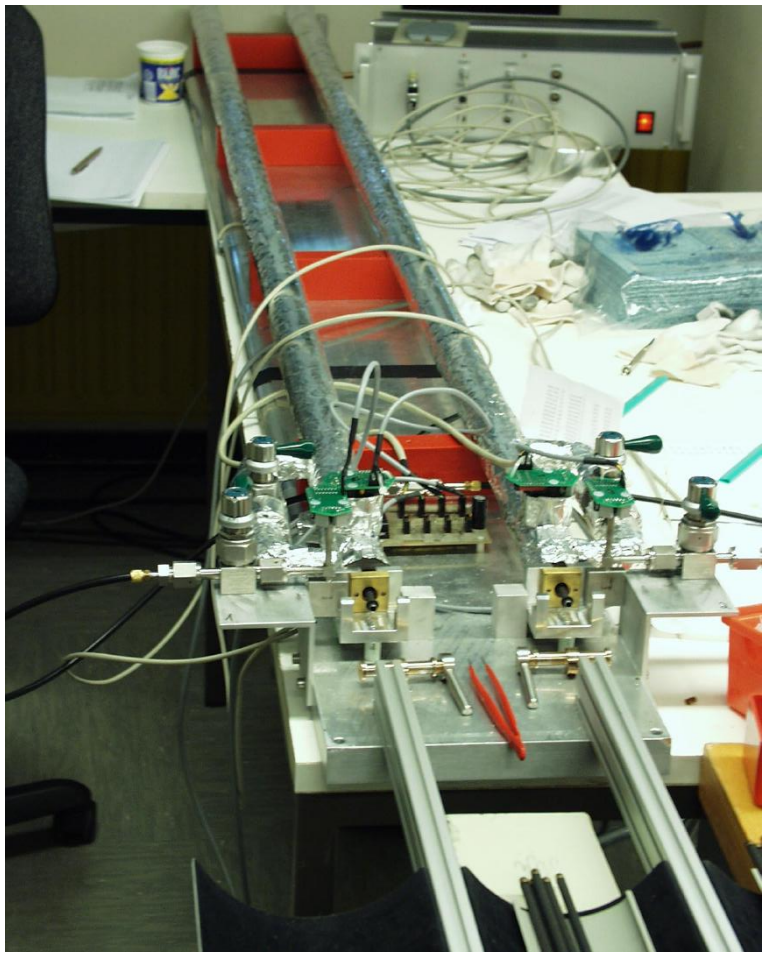
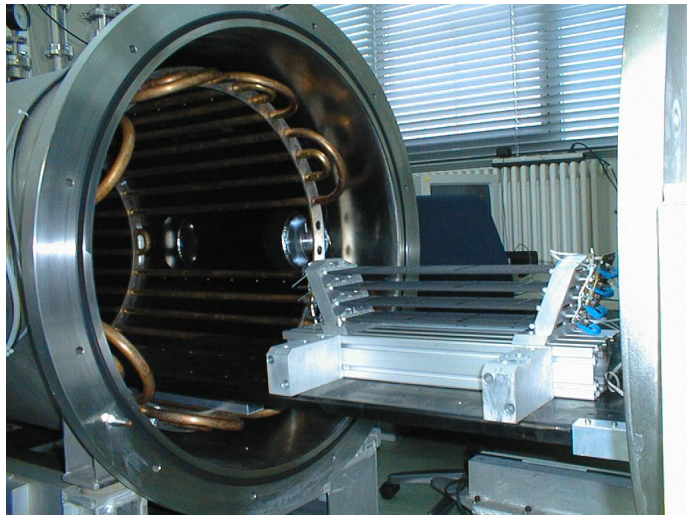
1.) Single Straw Test

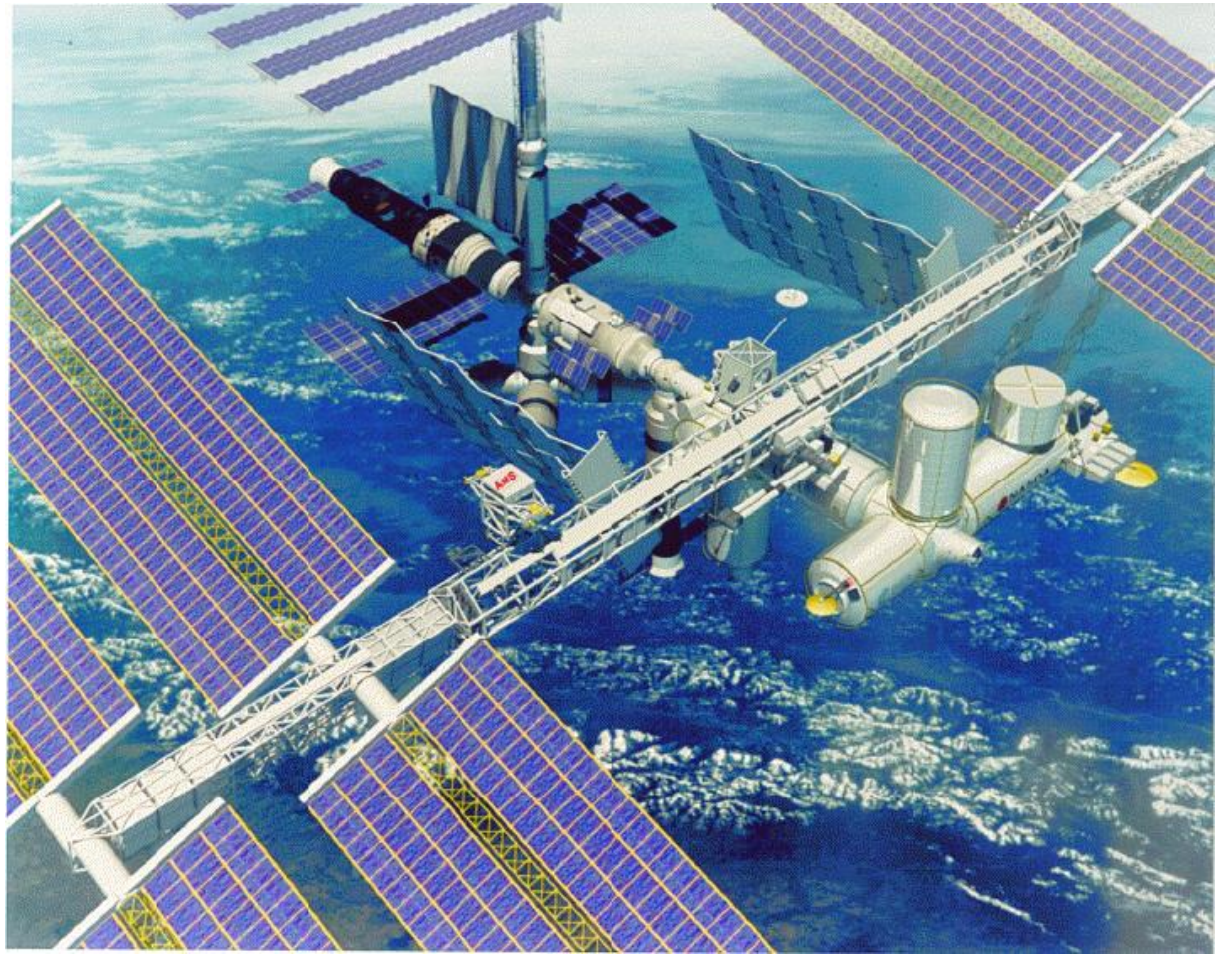


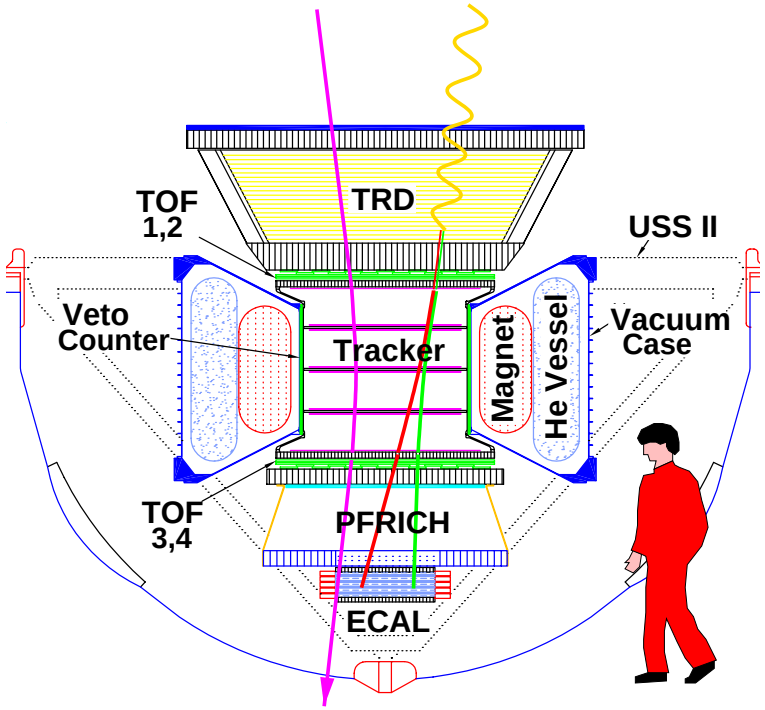
2.) Module Production

3.) Space Qualification



AMS02-Detector





Height: 3.50 m
Width: 2.30 m
Weight: 7 t

AMS02 on ISS

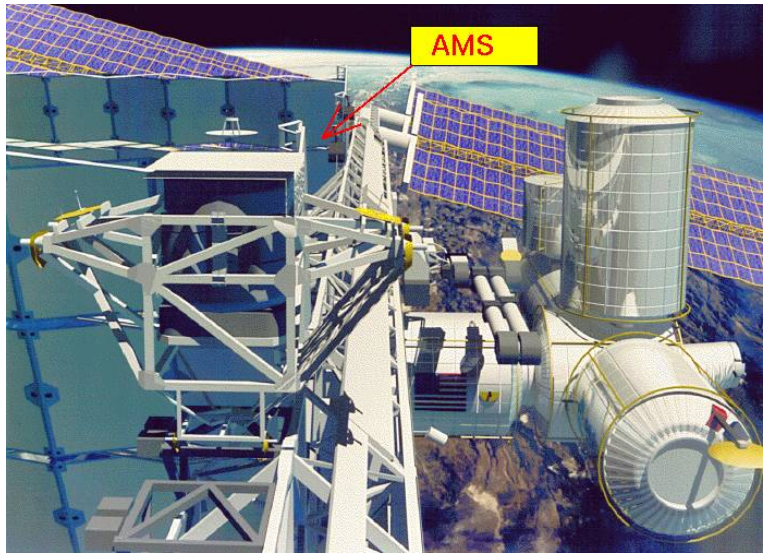
- Mean altitude 400 km
- in orbit for 3 years
- acceptance 0.5 m^2sr

$\Longrightarrow$ Cosmic Particle Spectroscopy

Space, a new environment for HEP experiments

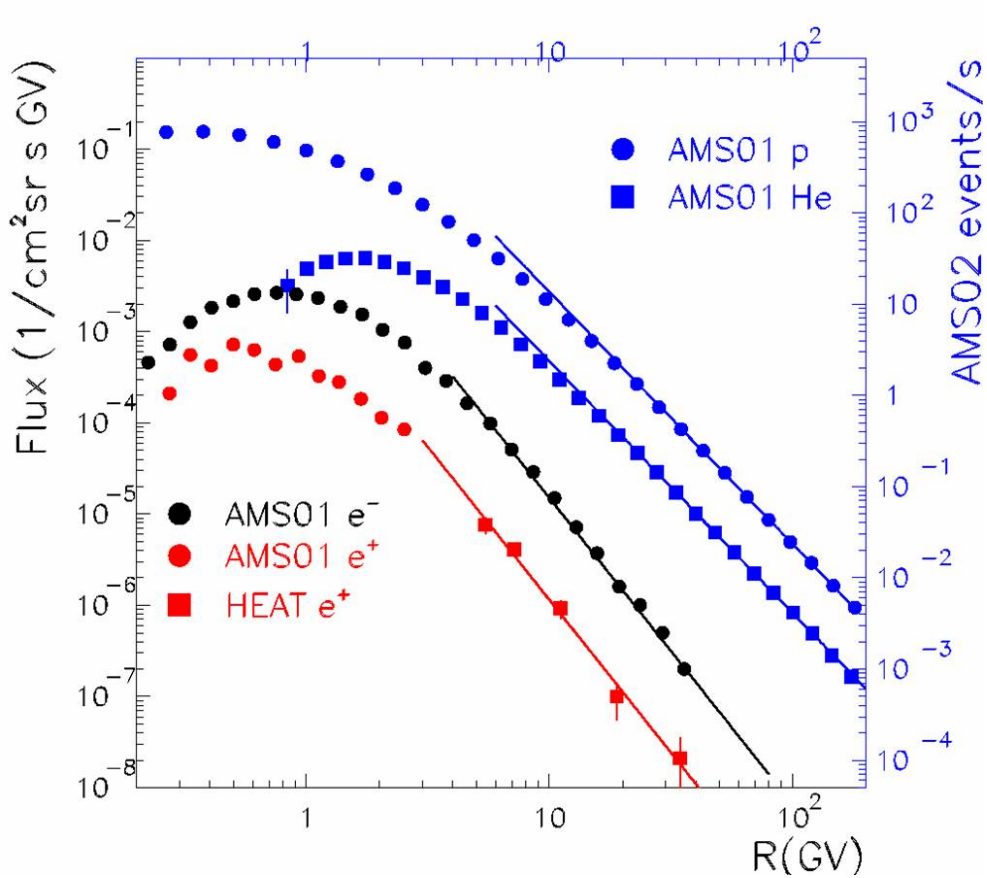
- Acceleration during start and landing
  Design Goal up to 9g

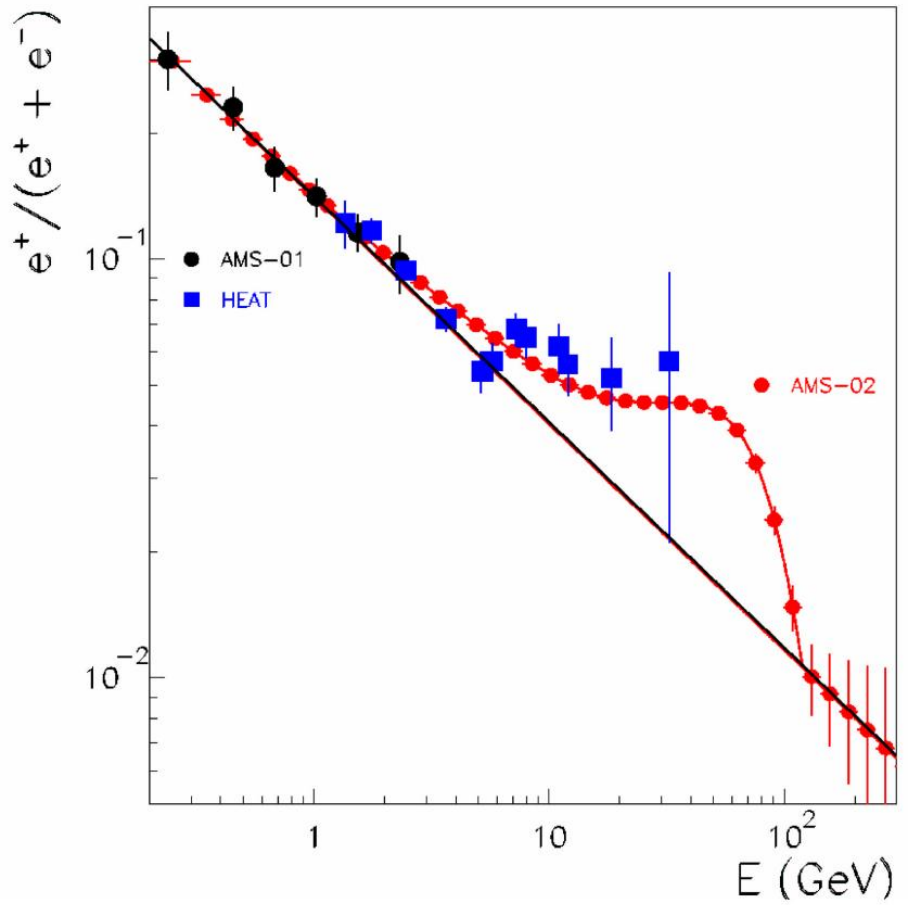
- Operation in vacuum
- Temperature variations: -150 - $+30$ °C
- Deposition limits on ISS:$< 10^{-14}$ g/s/cm^2
- Weight limited to 14000 lbs
- Power consumption limited to 2kW
- Single Powersupply at 120 V
- Datarate 1 Mbyte/s via 1 datalink



$\Longrightarrow$ Cosmic Particle Spectroscopy

Cosmic Particle Spectroscopy



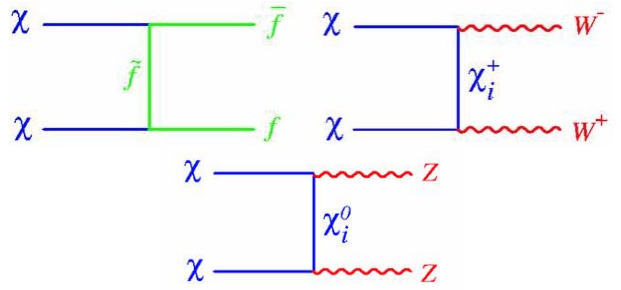


flux ratio in orbit:
$p^+/e^+ \approx 10^4$

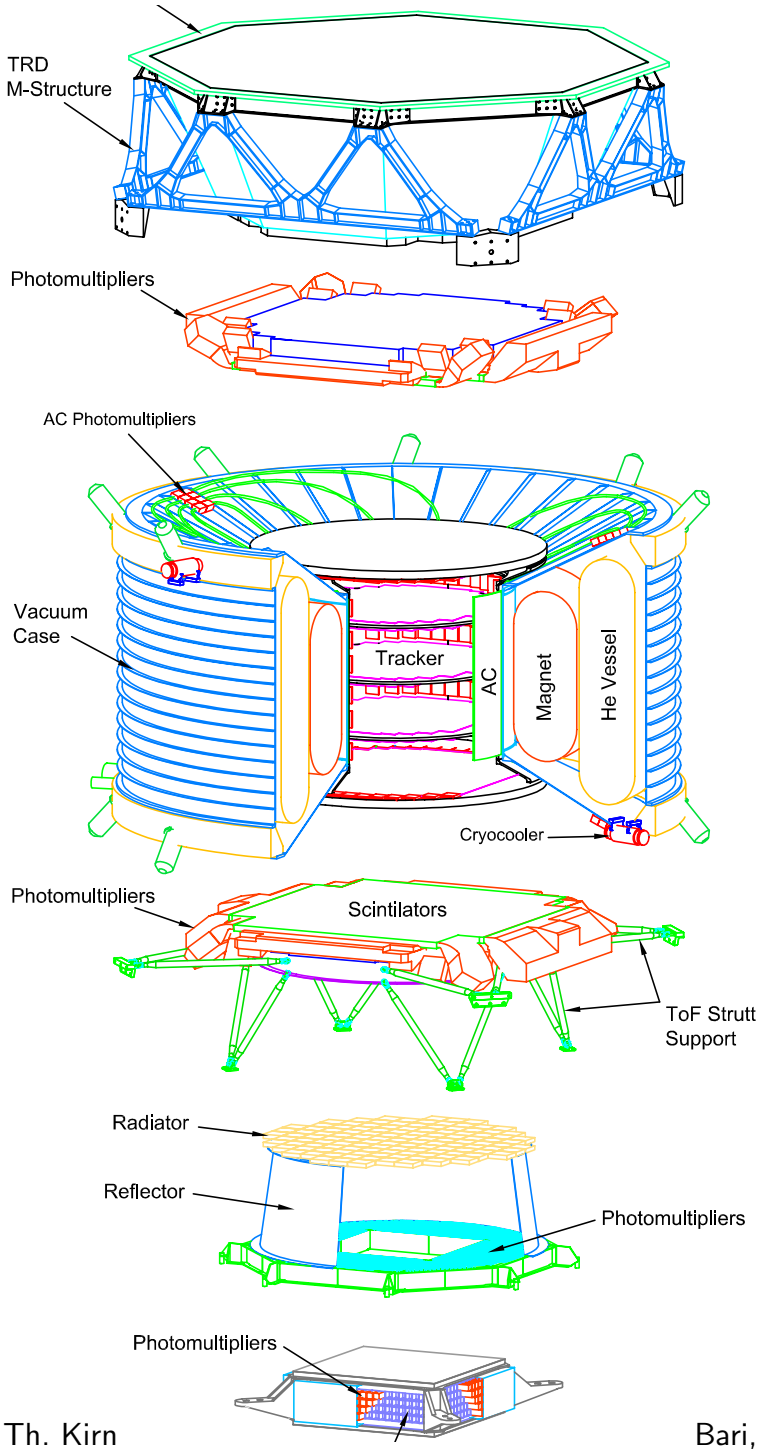
p^+-Contamination:
$\leq 10^{-2}$

$\Rightarrow p^+$-rejection $> 10^6$

$m(\chi) = 116$ GeV, $\tan\beta = 5$, $\Omega_M = 0.28$



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 $>$ 100 from 10-300 GeV

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 = 0.6m^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

p^+Rej $> 10^4$ from 10-300 GeV

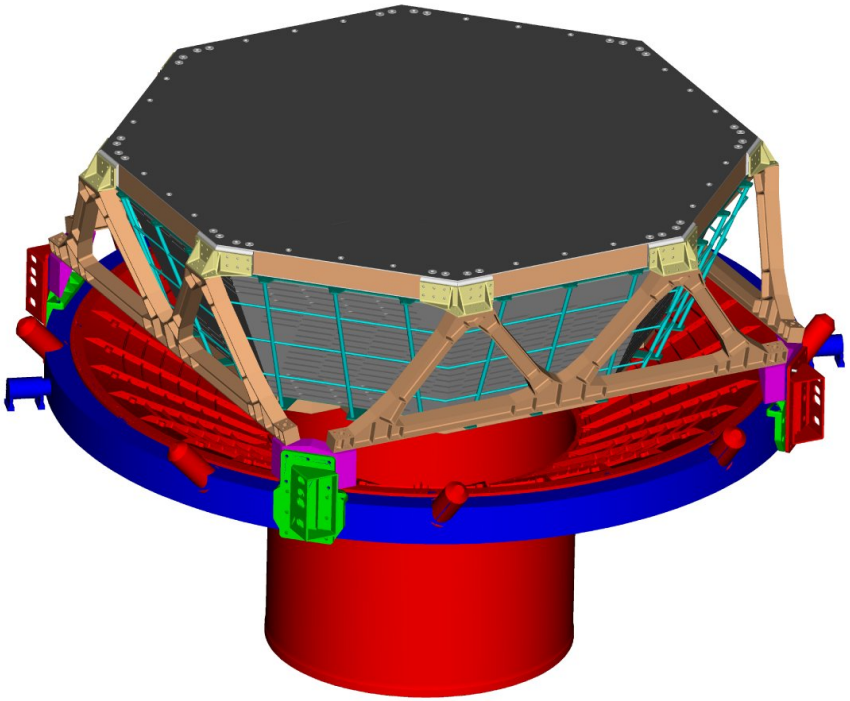
with p-E matching and shower-shape

p^+-rejection $> 10^2$ (10 - 300 GeV)

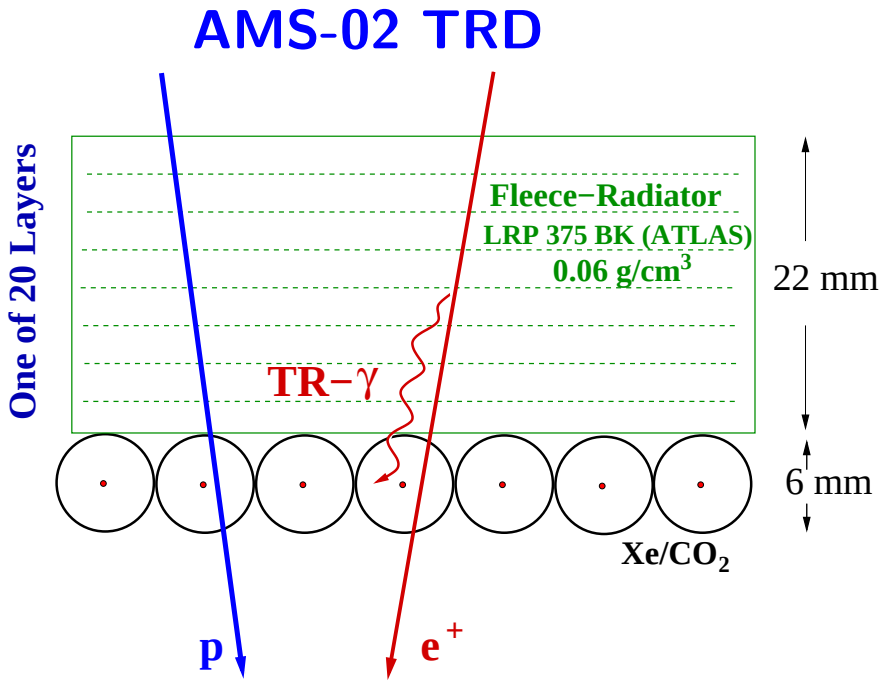
Chosen Configuration for 60 cm height:

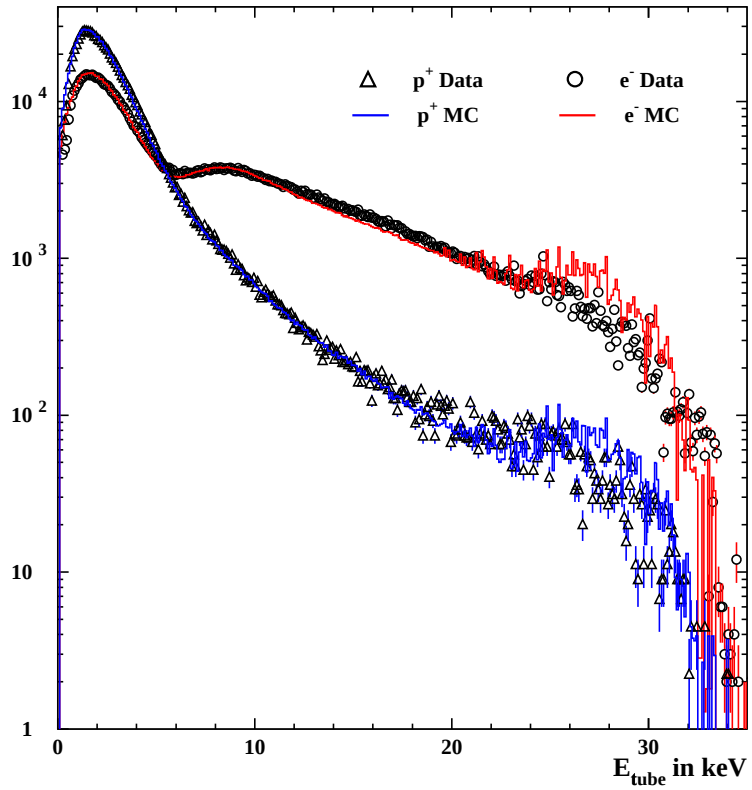
20 Layers each existing of

- 22 mm fleece
- $\varnothing$ 6 mm straw tubes (Xe/CO_2 (80/20))



Radiator + Straws + Xe/CO_2	168 kg
Octagon + Support + Shielding	207 kg
Gas System	50 kg
Electronics	53 kg
TRD Total	478 kg

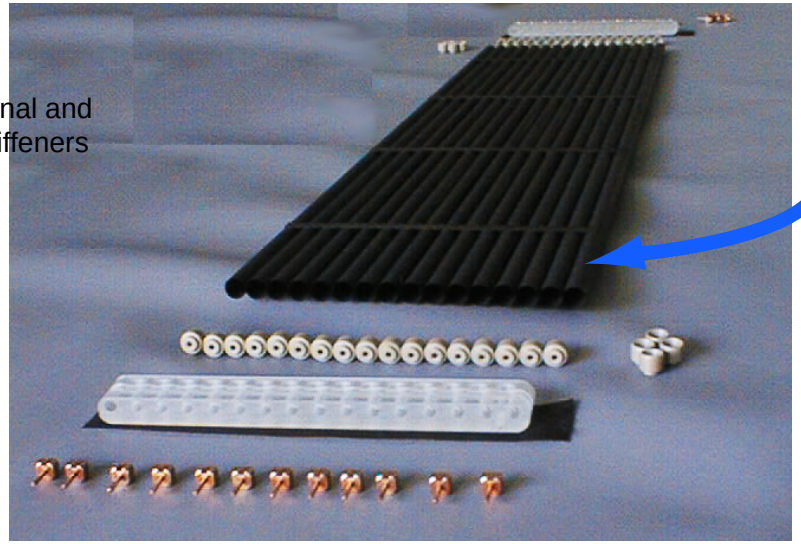




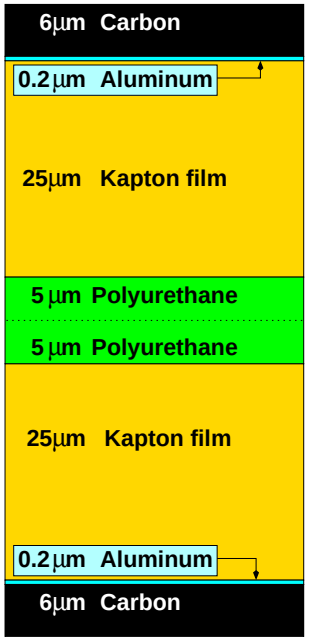
AMS-02 TRD Straw Modules: 16 straws at 6mm ∅ with 30 μm W-Au wire

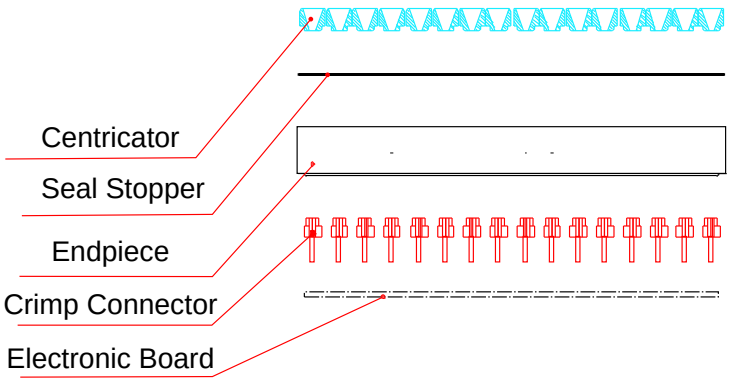
Multilayer Capton tubings

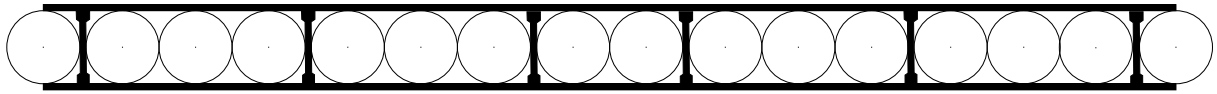
CFC longitudinal and transversal stiffeners



Capton wall



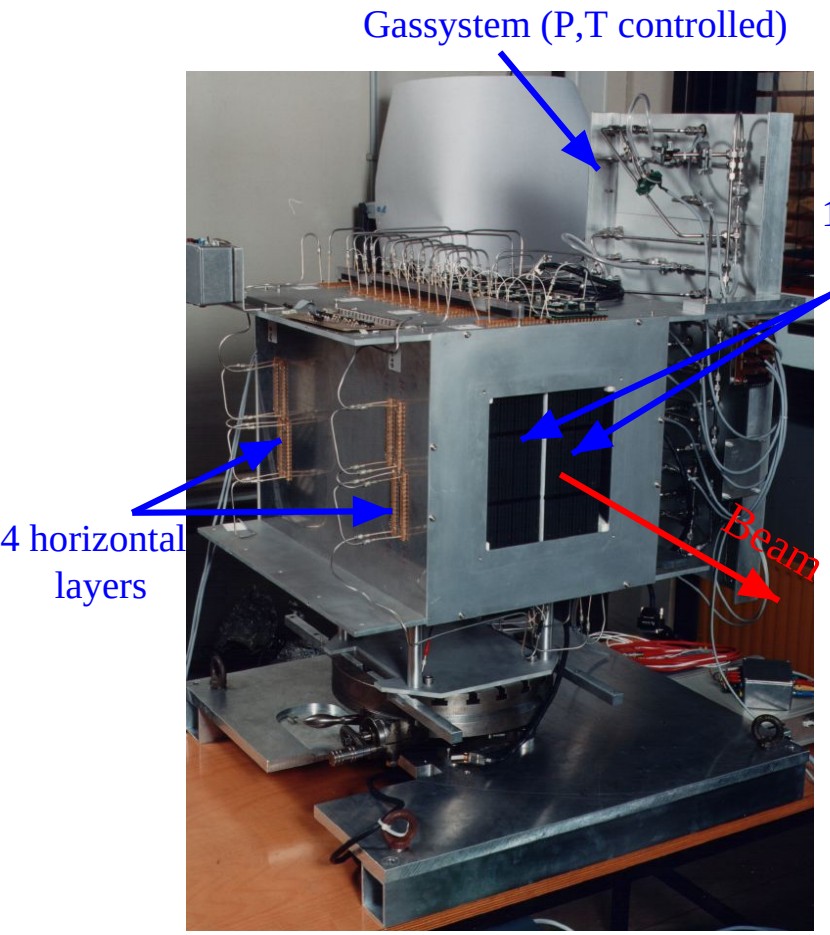


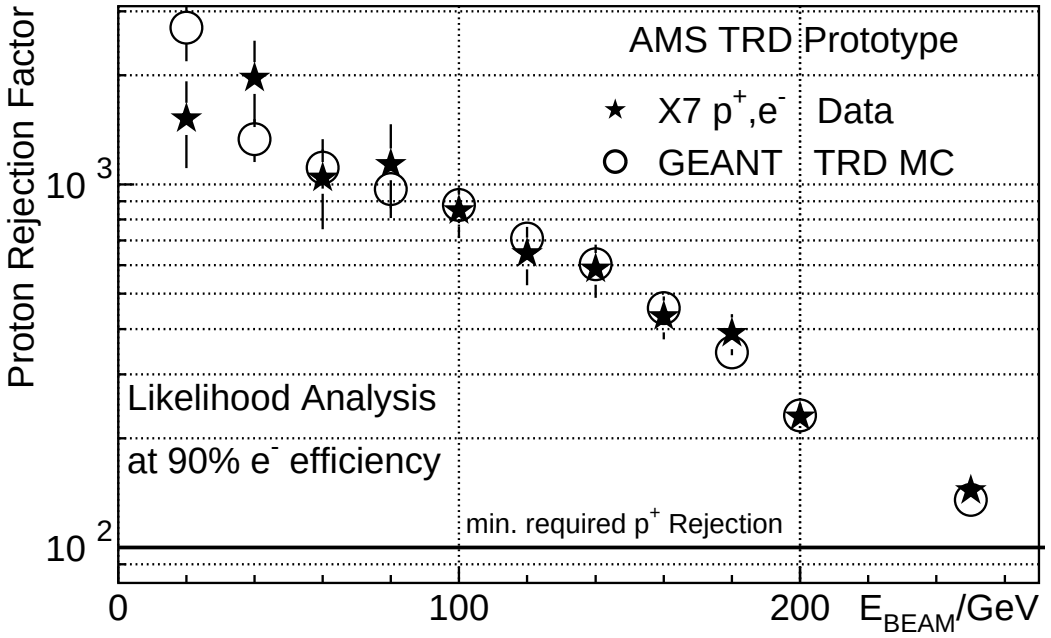


6 longitudinal stiffeners

Strips across every 10 cm

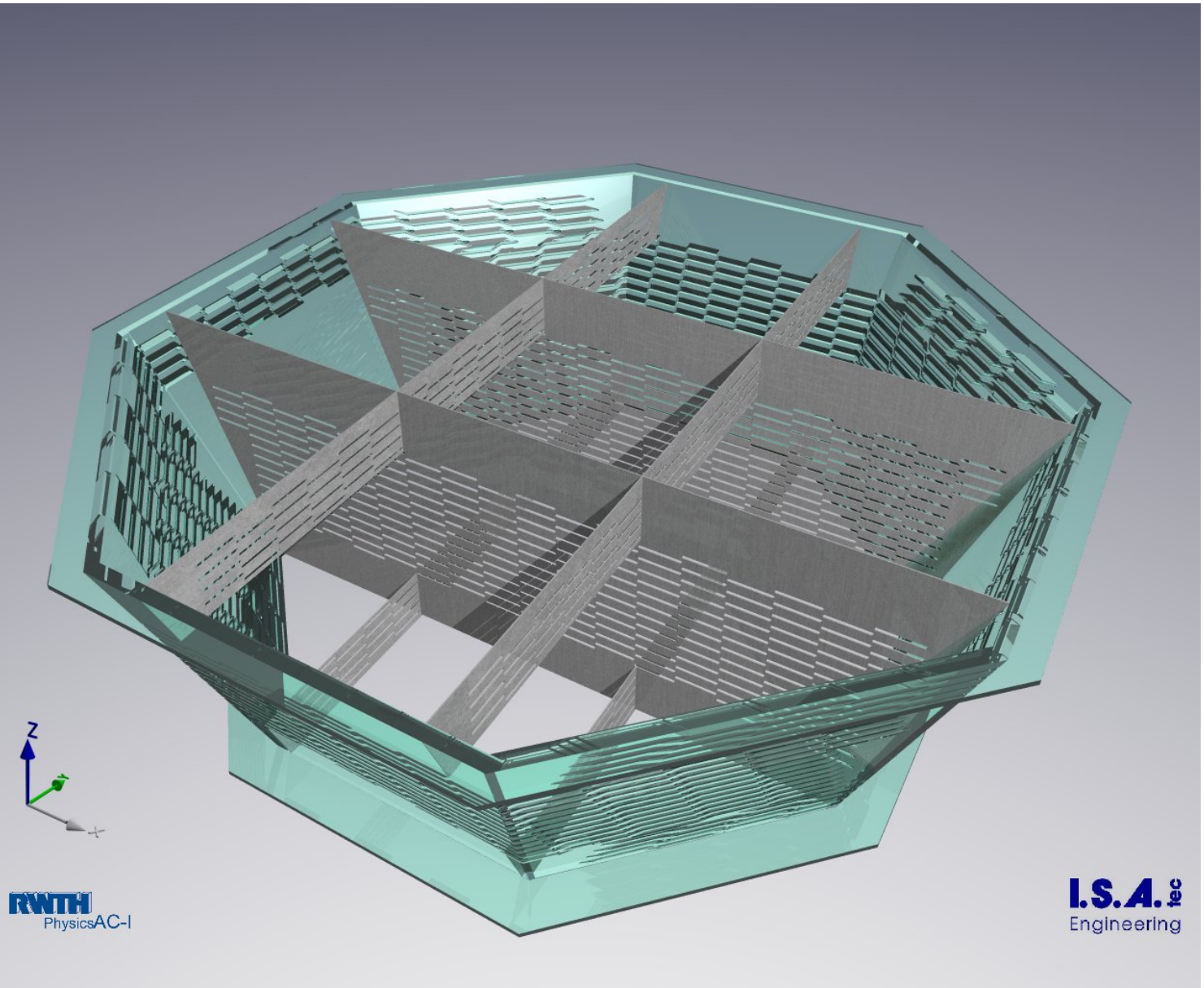
AMS-02 TRD:20 Layer Prototype Testbeam





AMS-02 TRD

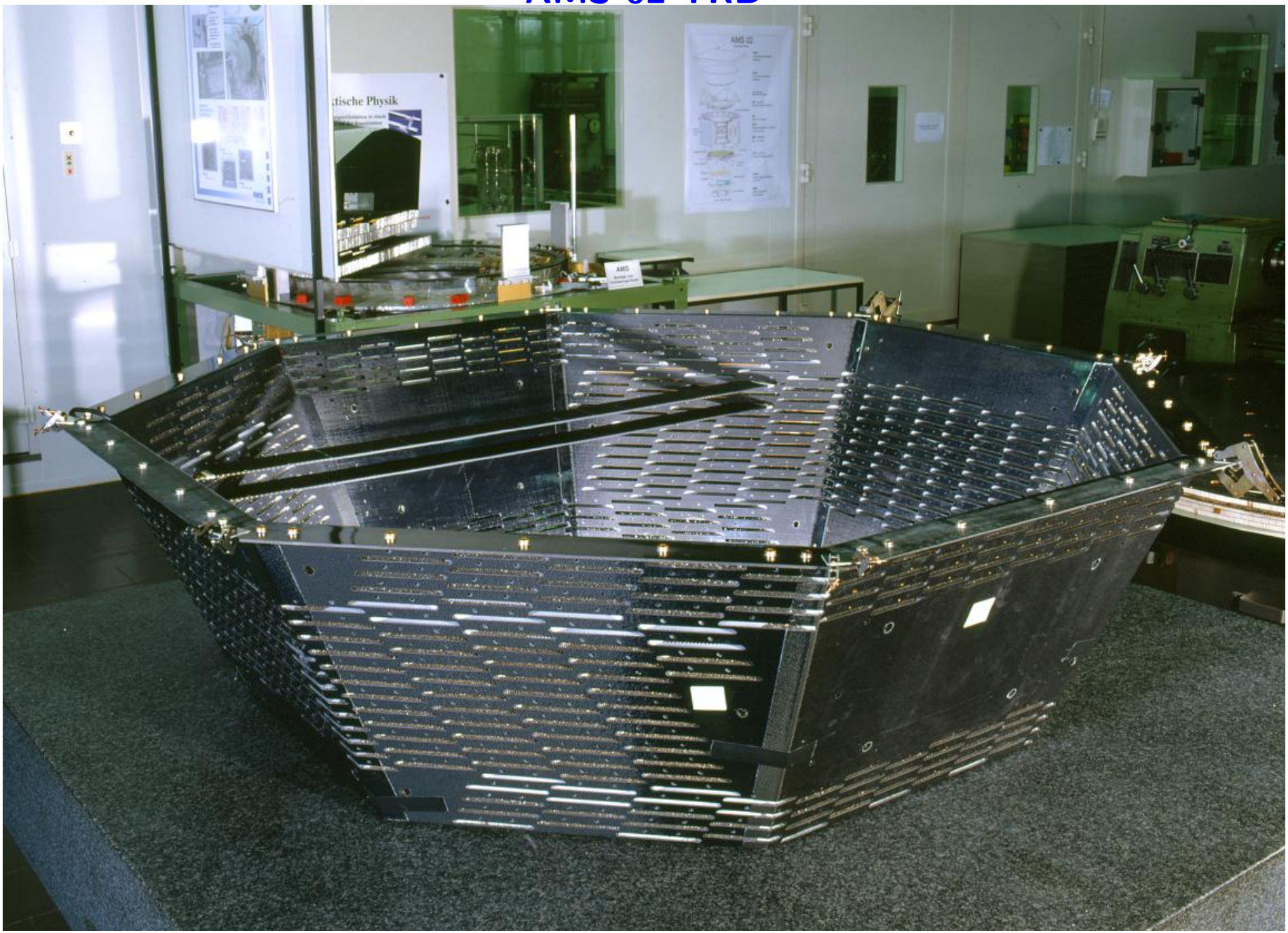
Octagon and Bulkheads support 328 Modules (5248 Straws)
(L=86 to 201 cm) with 100 μm mech. accuracy



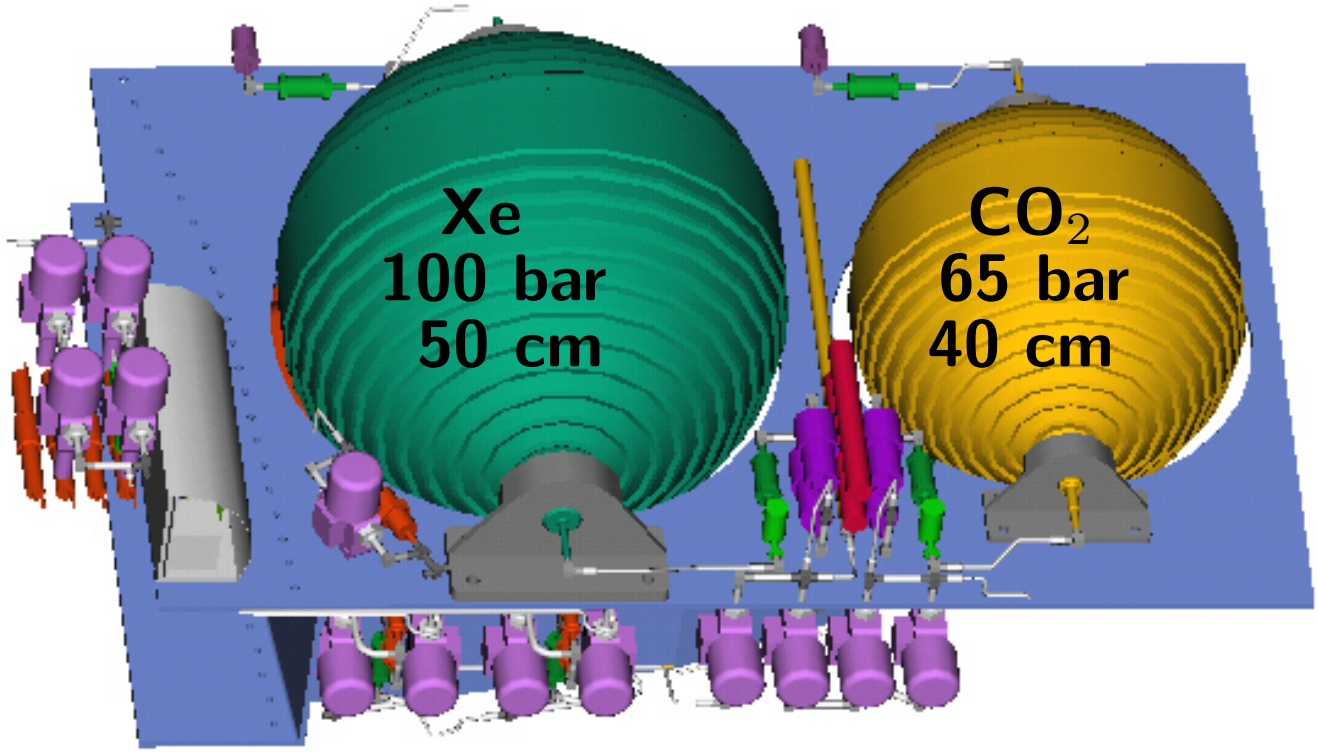
Upper/lower 4 layers
measure in bending plane

Middle 12 layers
measure in perpendicular plane

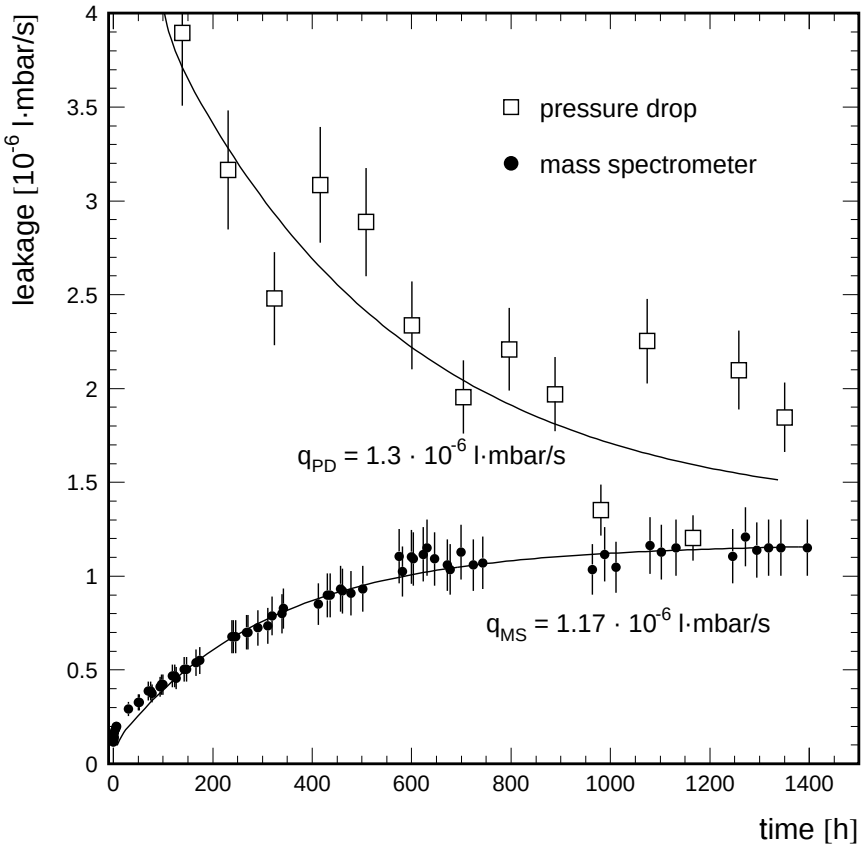
AMS-02 TRD

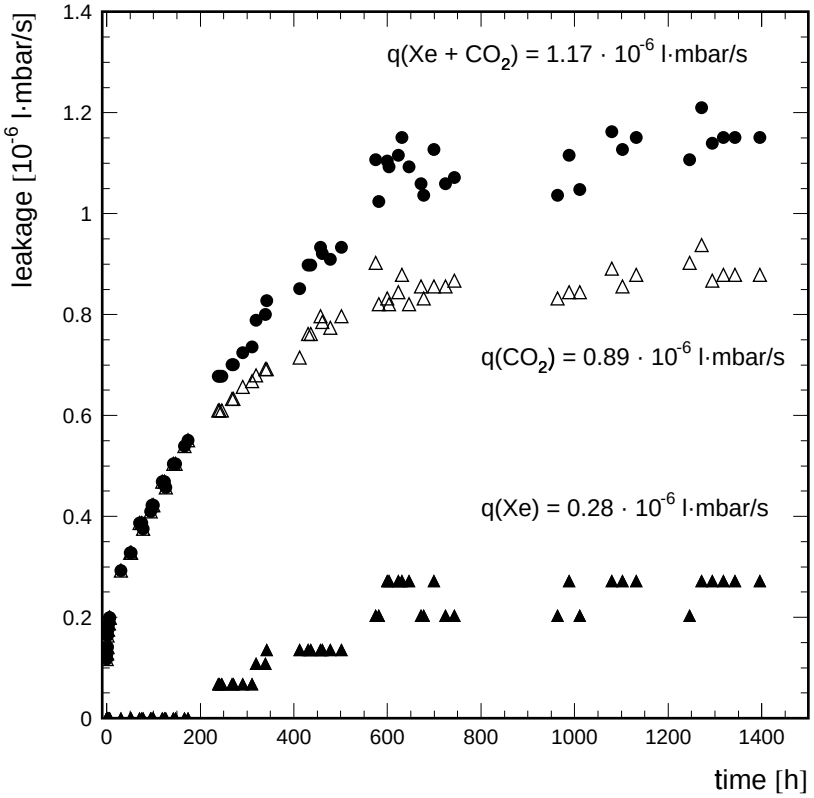


TRD Gassystem (MIT)



L_{TRD}^{Mod} = 500 m
V_{TRD} 230 l @ 1 bar (41 loops, each loop 8 Straw Modules in Series)
Xe 46 kg (8100 l @ 1 bar)
CO_2 4 kg (2000 l @ 1 bar)





- Xe/CO_2 (80/20) Leak rate 3 single Straw Tubes L=1.3 m

$$q_{Xe}(80\%, 16\text{straws}) = 0.12 \cdot 10^{-5} \frac{l \cdot mbar}{s \cdot m_{\text{Module}}},$$

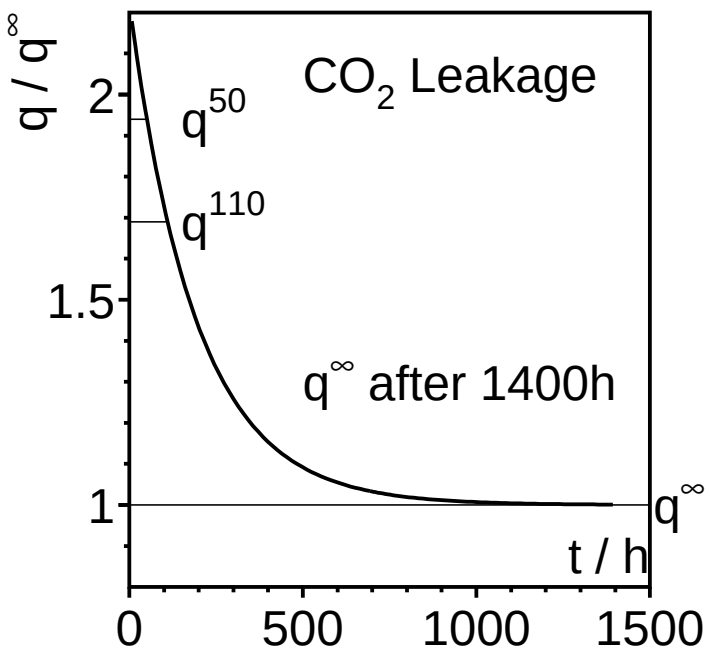
$$q_{Xe,max} = \frac{8100\ l \cdot 1013\ mbar}{1000 \cdot 86400\ s} \cdot \frac{1}{500\ m} = 19 \cdot 10^{-5}\ \frac{l \cdot mbar}{s \cdot m_{\text{Module}}} \quad \rightarrow \text{Safety factor :158}$$

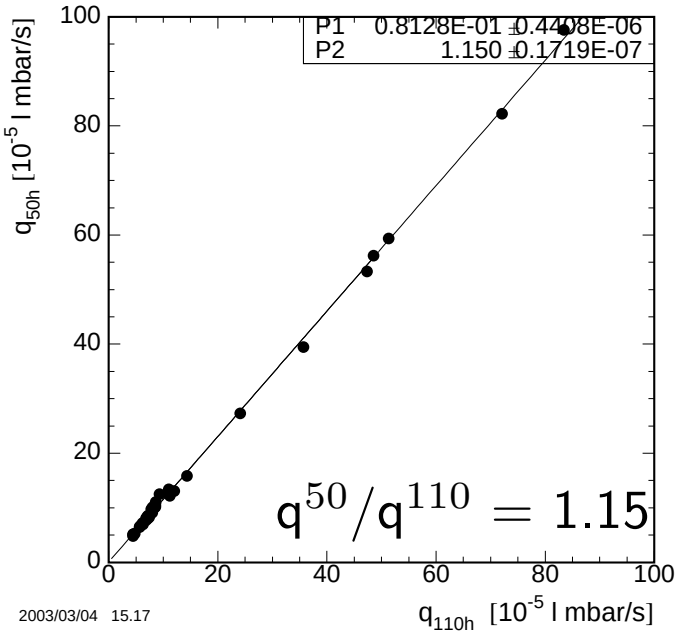
$$q_{CO_2}(20\%, 16\text{straws}) = 0.37 \cdot 10^{-5} \frac{l \cdot mbar}{s \cdot m_{\text{Module}}},$$

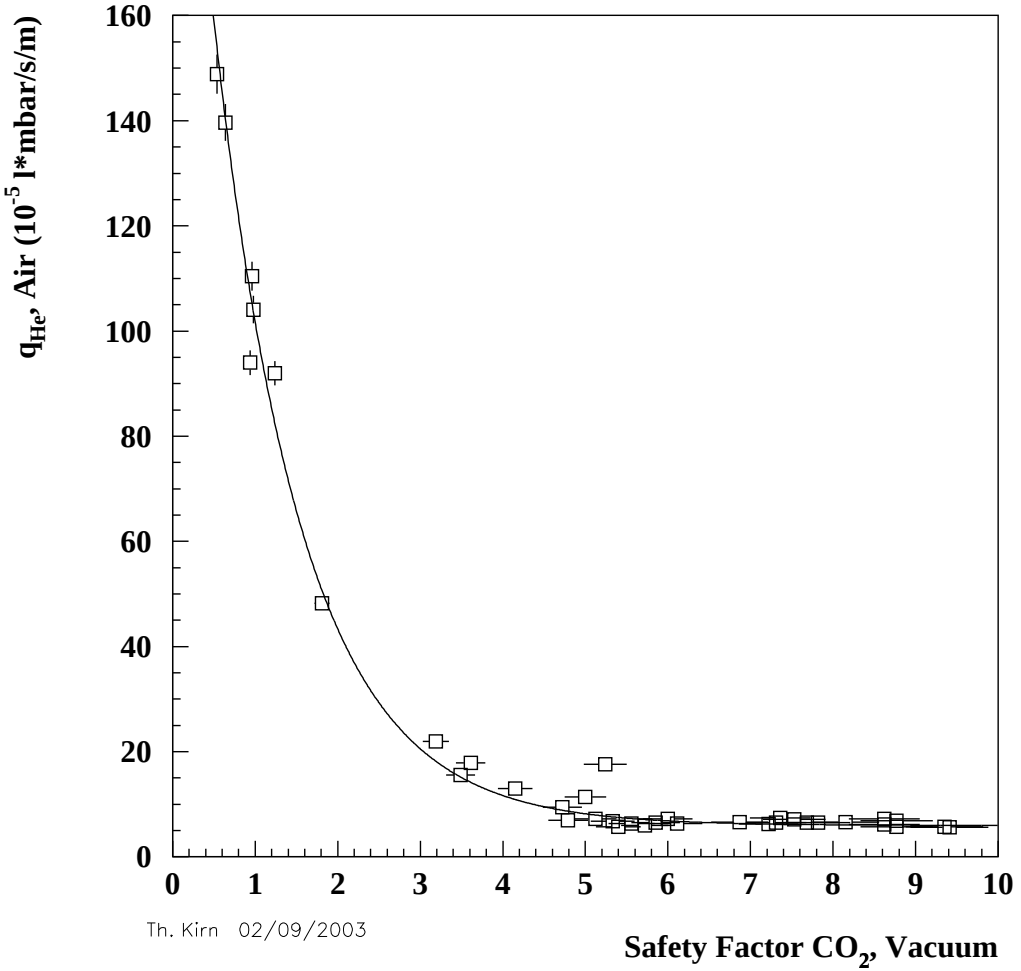
$$q_{CO_2,max} = \frac{2000\ l \cdot 1013\ mbar}{1000 \cdot 86400\ s} \cdot \frac{1}{500\ m} = 4.7 \cdot 10^{-5}\ \frac{l \cdot mbar}{s \cdot m_{\text{Module}}} \quad \rightarrow \text{Safety factor :12.7}$$

AIM: CO_2 Safety Faktor: 4

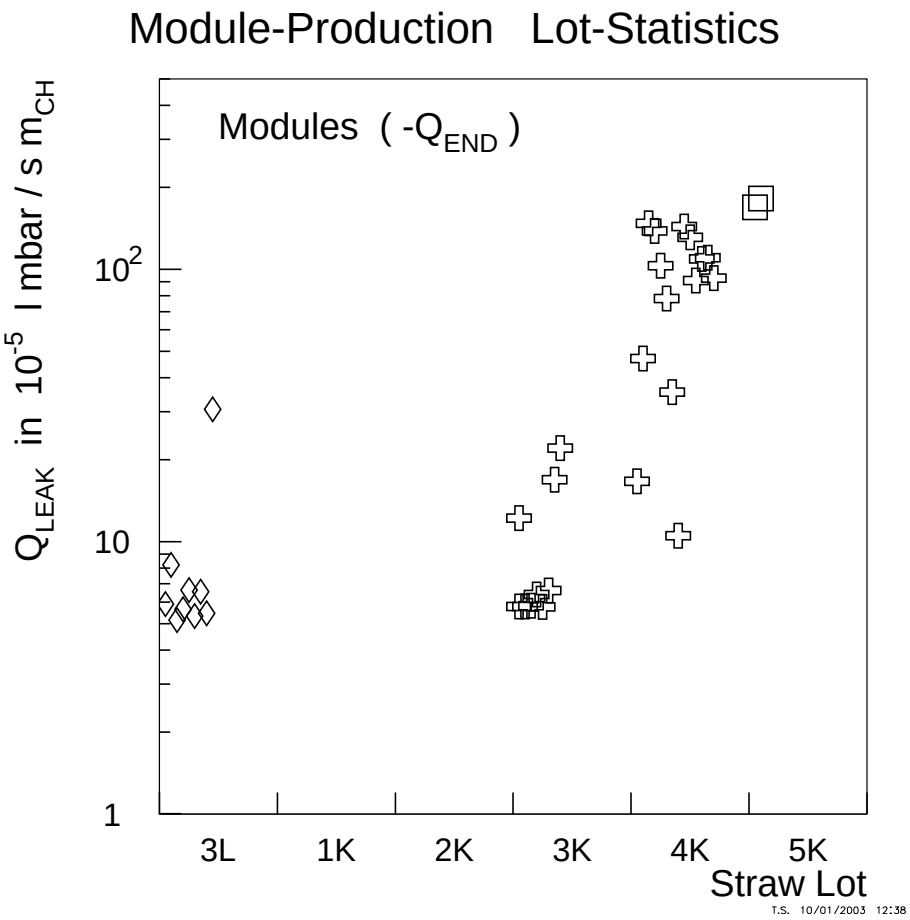
CO_2 Safetyfaktor using 50h CO_2 and 12h He Measurements

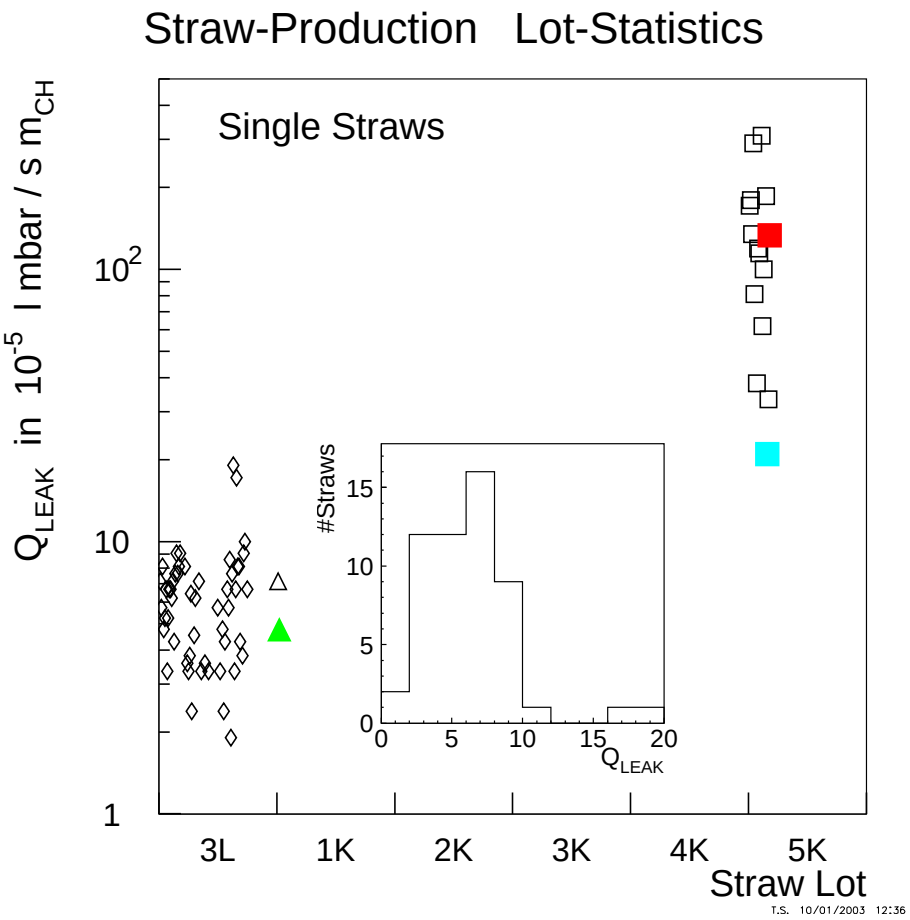






- He vs CO_2 good correlation,
  Advantage: He measurements faster
- Aim: Safety Factor of $> 4 \Leftrightarrow > 12$ years on ISS
  $\hookrightarrow$ He leak rate $10 \cdot 10^{-5} l \cdot mbar/s/m$

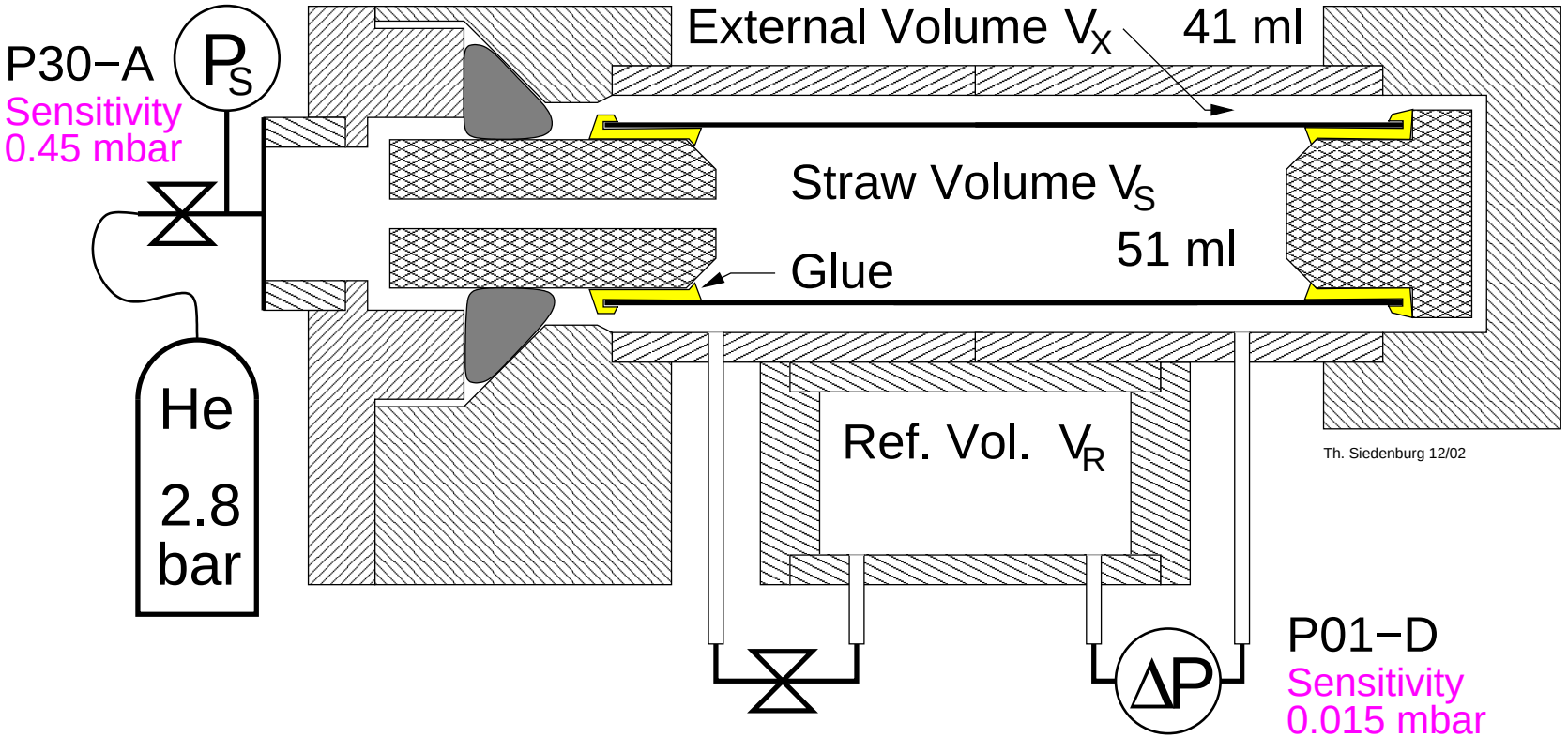


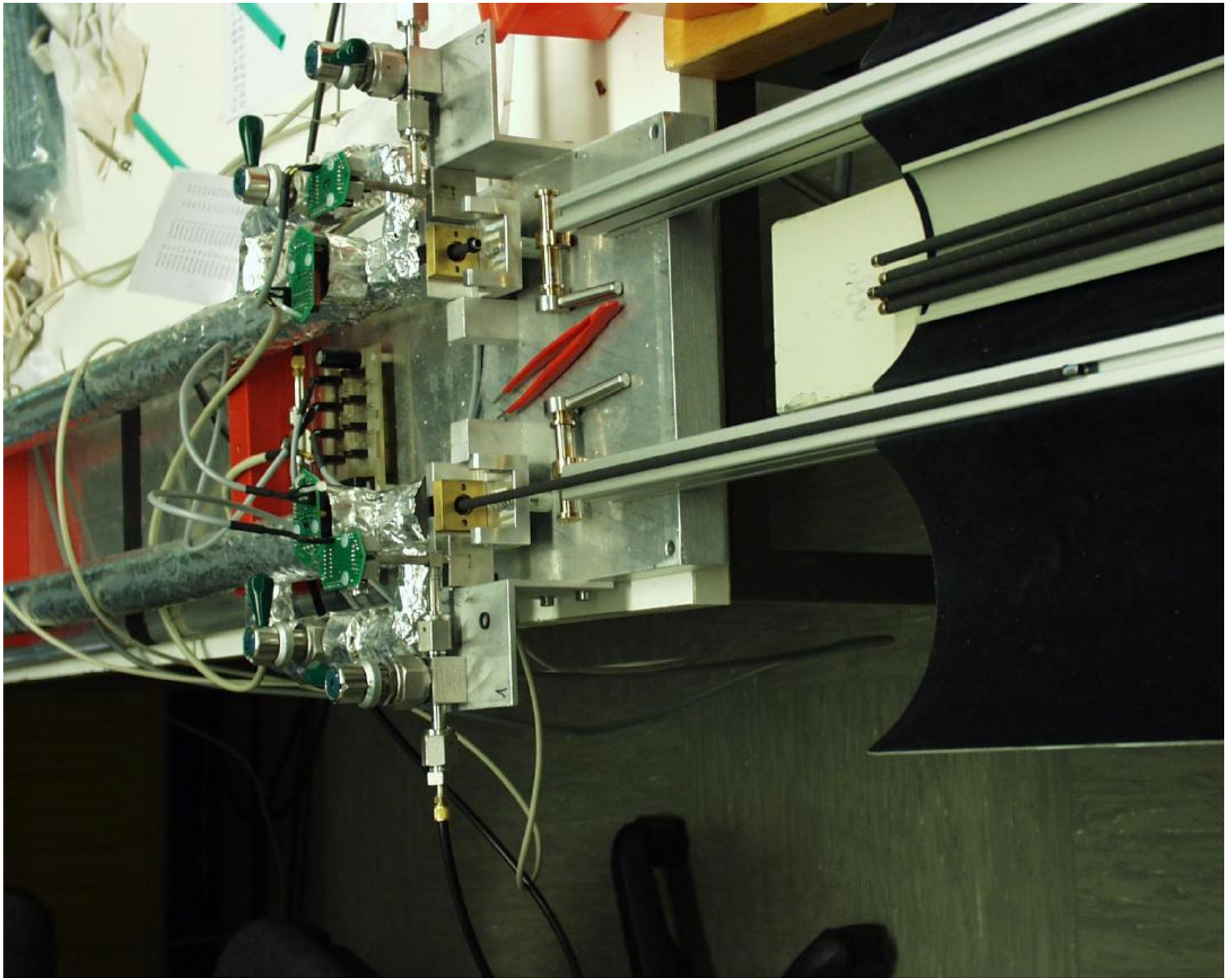


- Bad straws vs bad modules $\longrightarrow$ perfect correlation

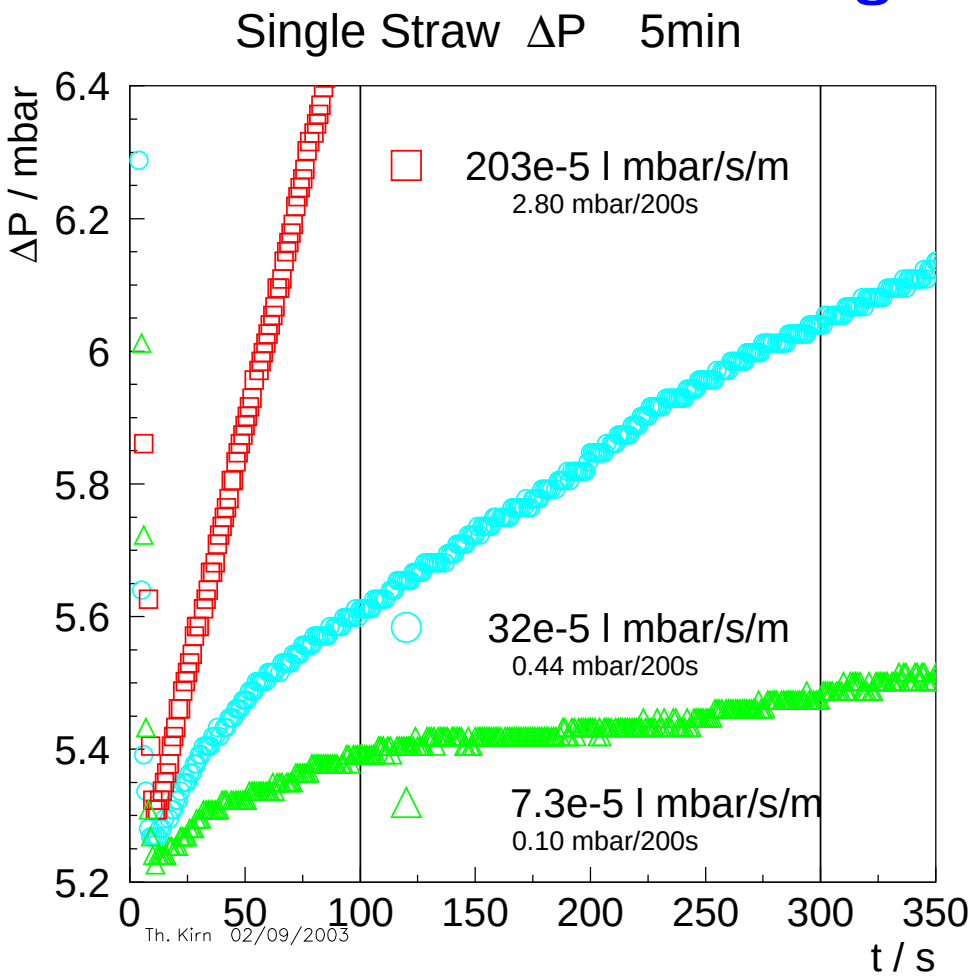
$\Longrightarrow$ Need to test each of 5248 straws $\longrightarrow$ need fast measurements

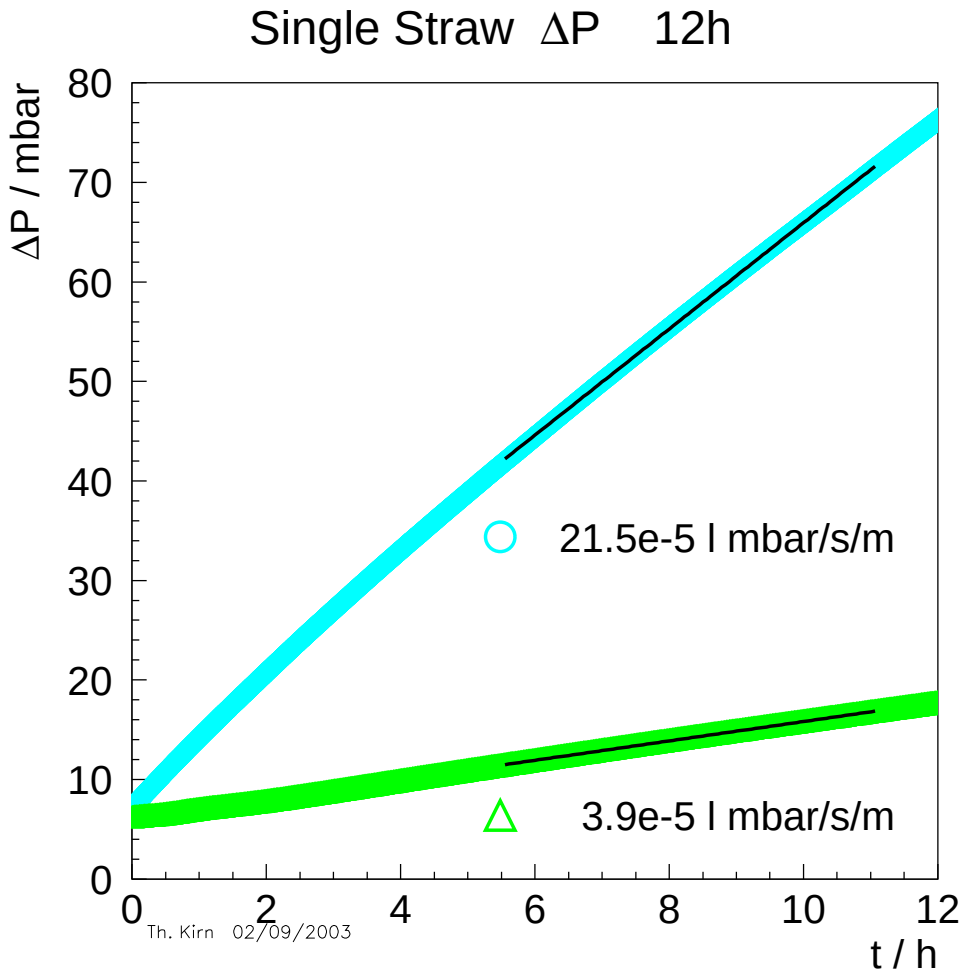
Single Straw Test





Single Straw Test

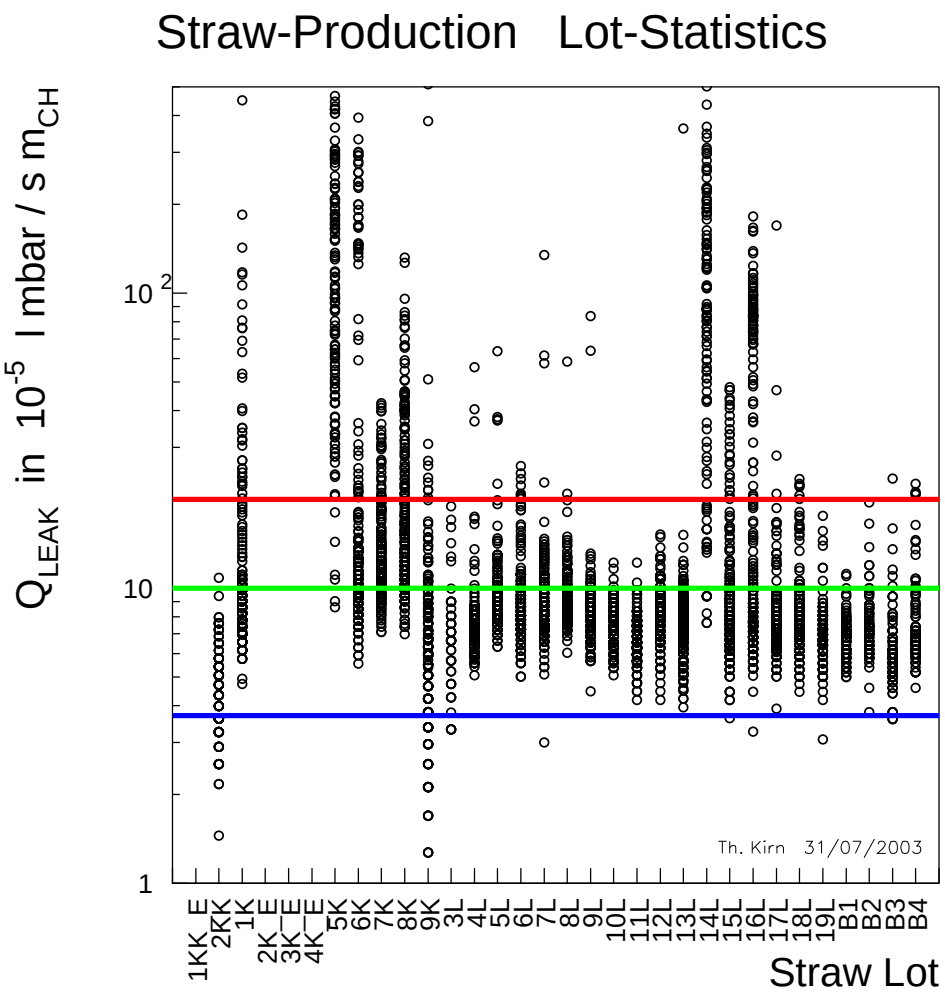


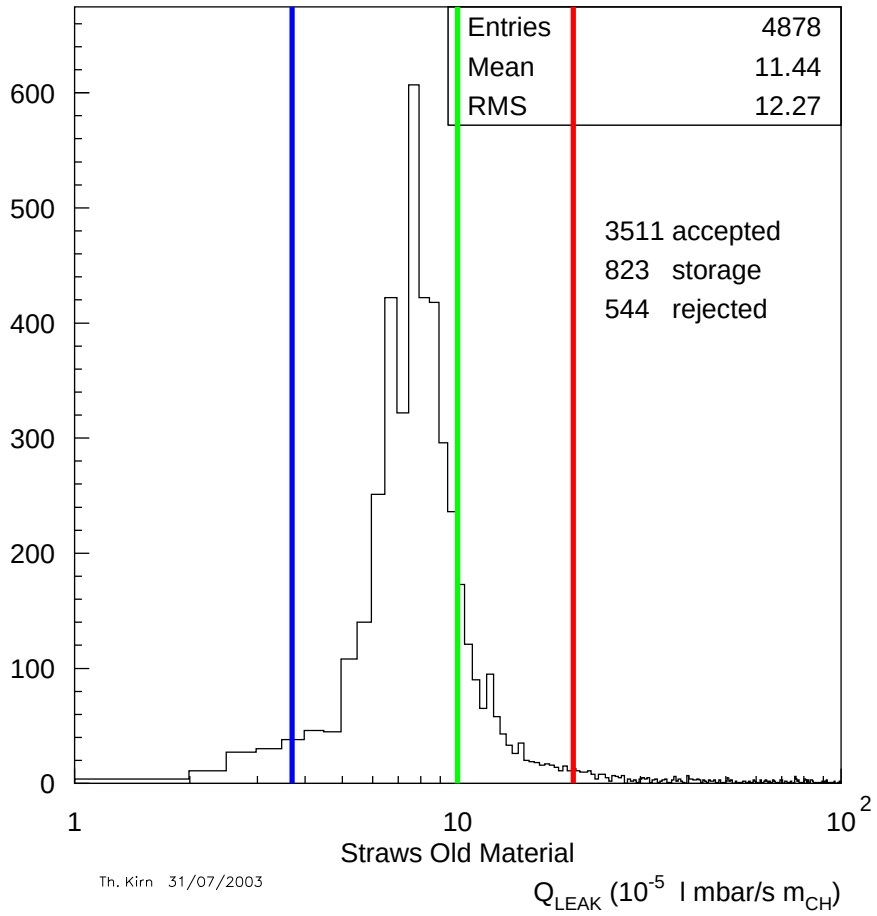


- 12h reference measurement over night

  → Δp-increase

Single Straw Test

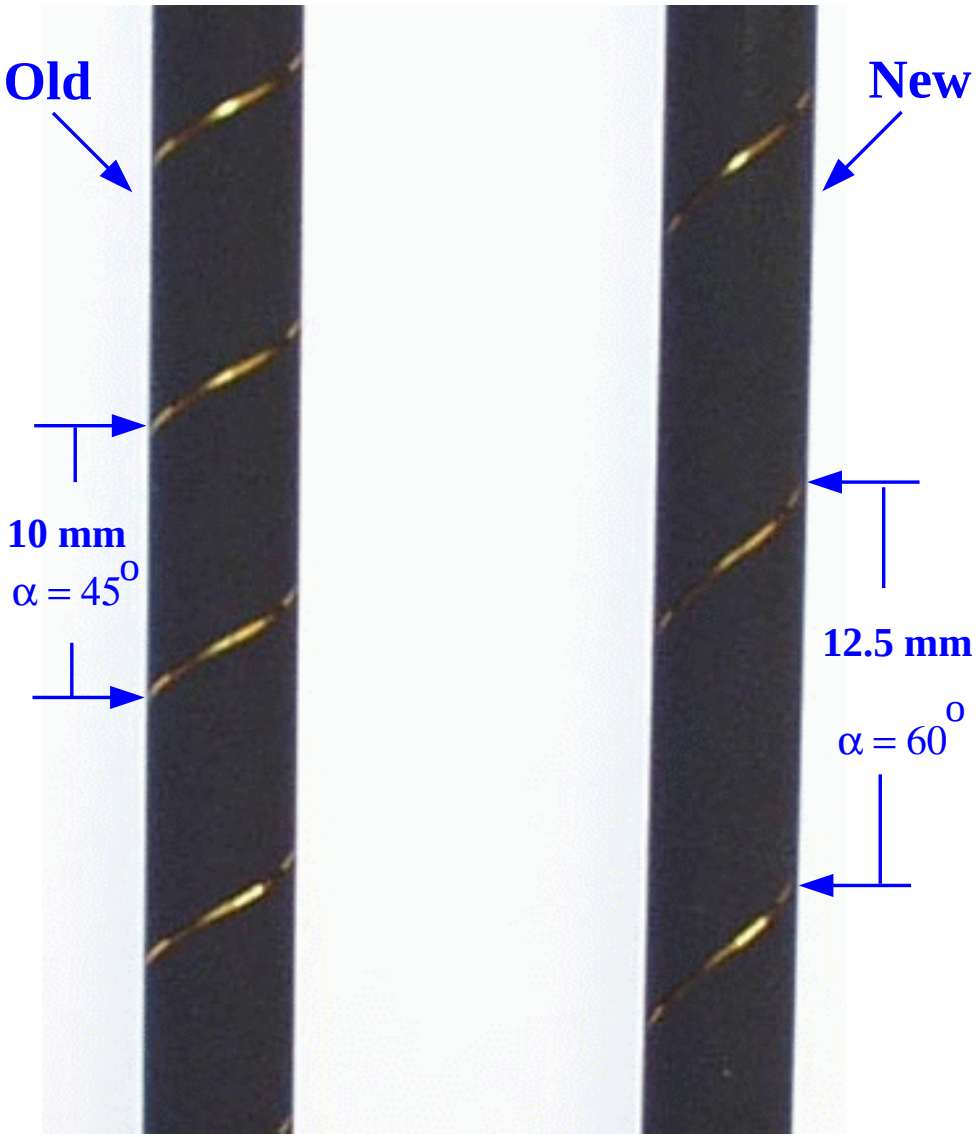


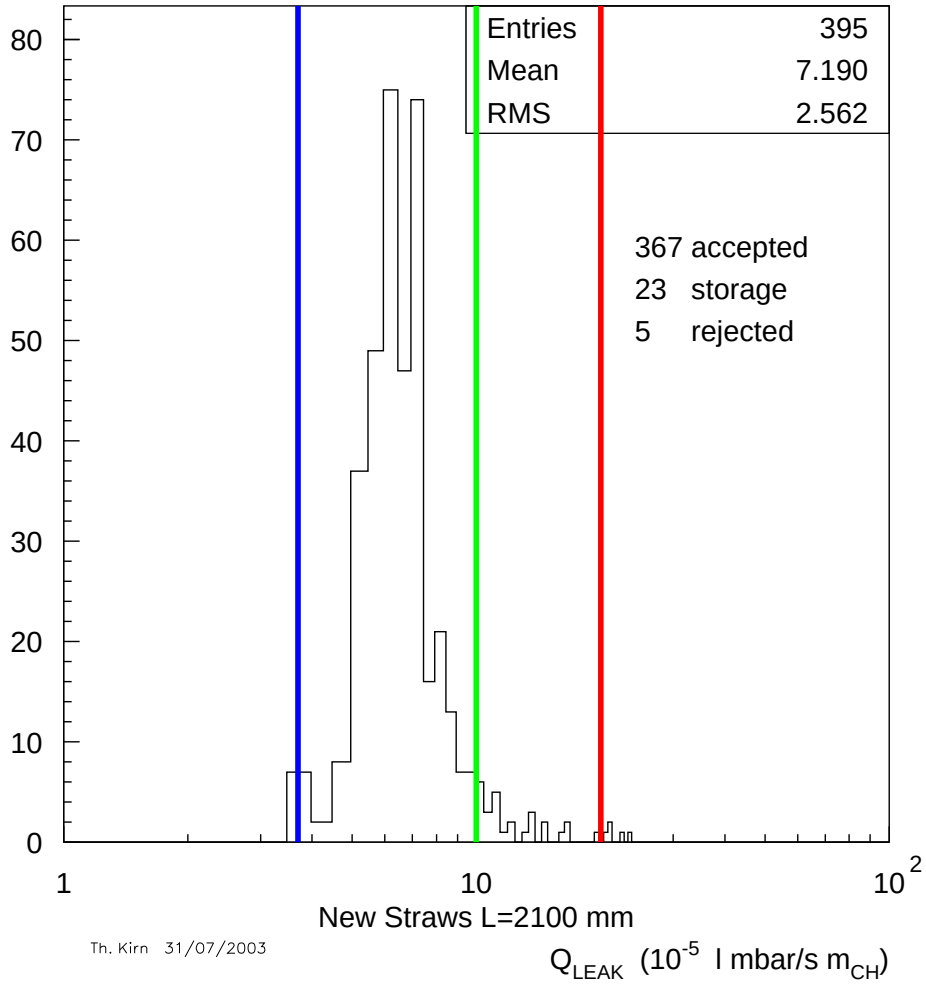


16 Straws/Module $\times$ 328 Modules $=$ 5248 Straws $\longrightarrow$ 1737 Straws missing

$\longrightarrow$ New Straws needed

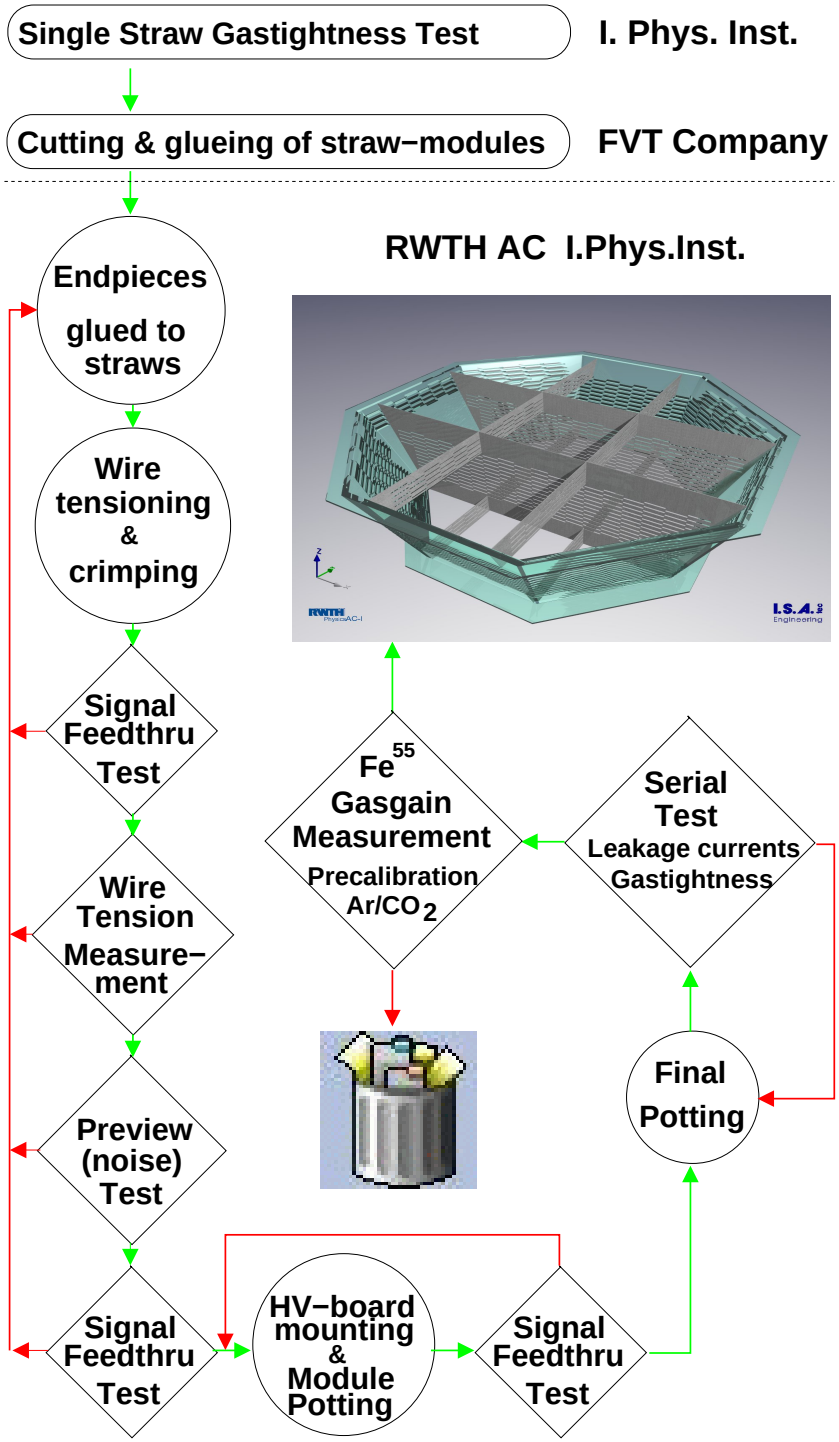
Single Straw Test





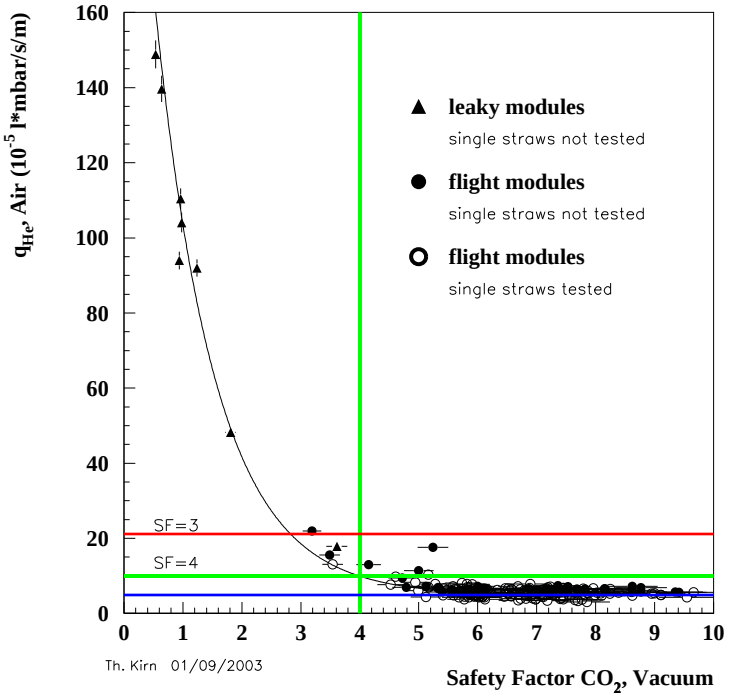
⟶ 1800 new straws ordered

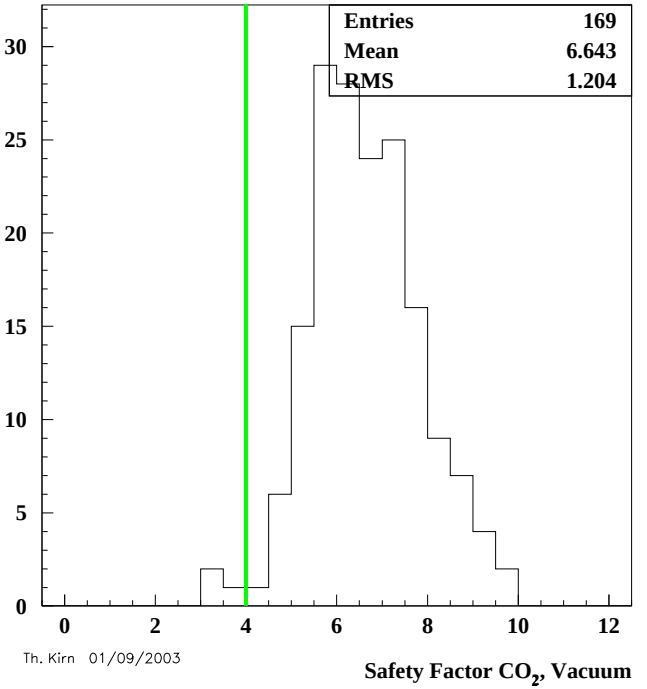
Module Production:



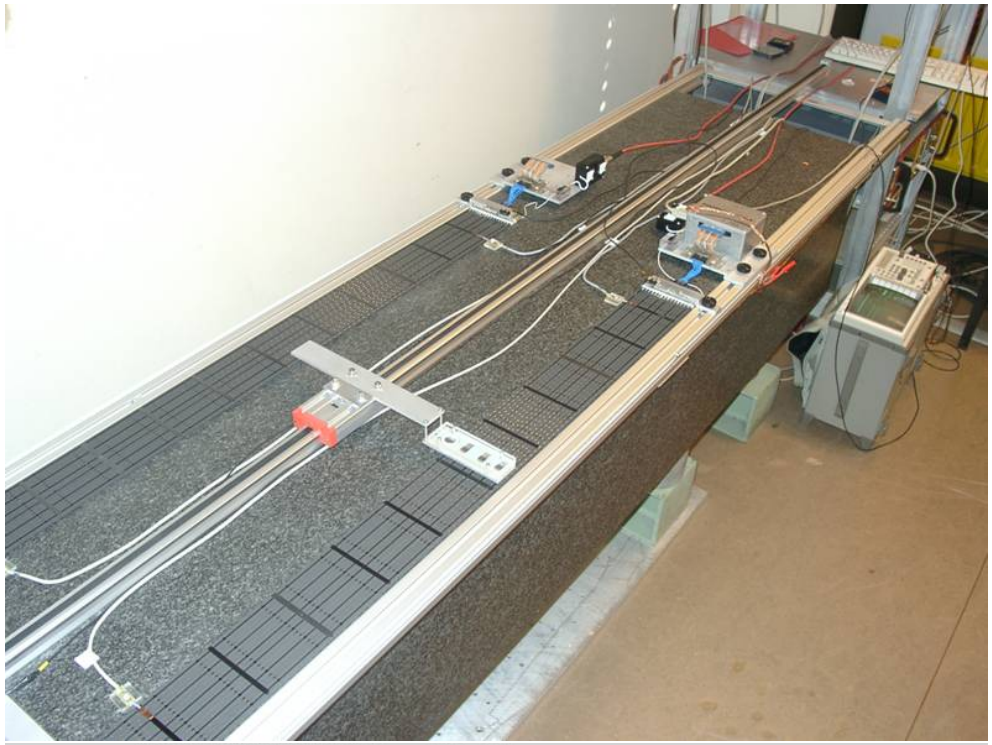
Module Production: Gastightness

169 Straw Modules:
Safety Factor for TRD: ~ 6.7
$6.7 \times 3\text{y} = 20$ years operation on ISS



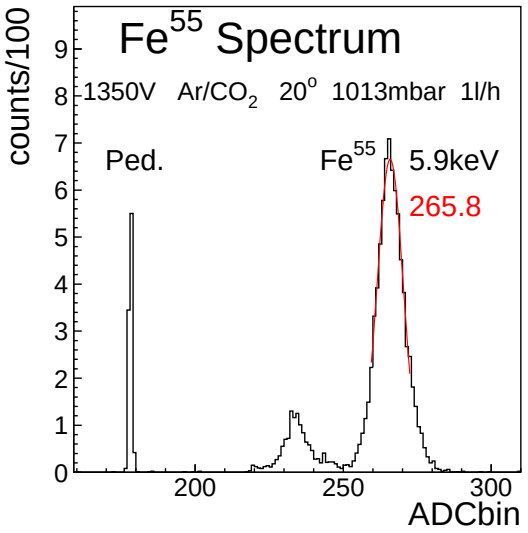


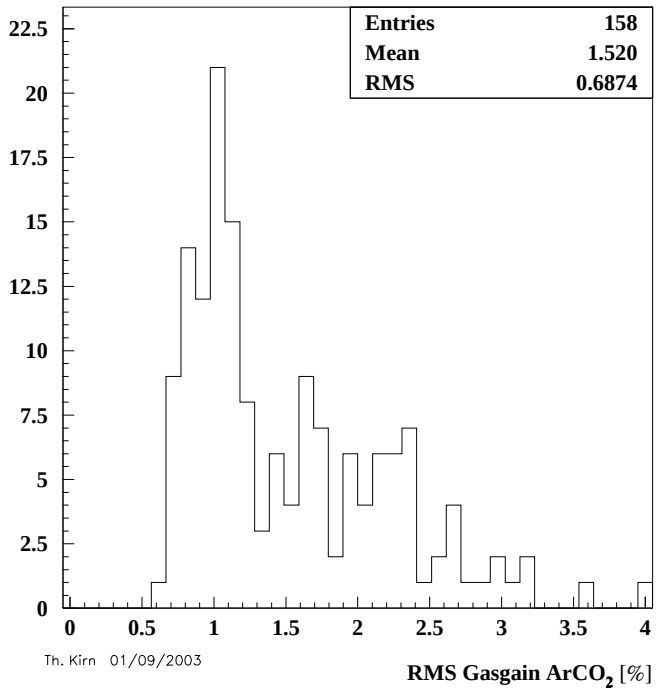
Measurement of Gas Gain with Fe^{55} source



Mean: 5720.69 RMS: 63.90
c:\ggdata\progs\027_3S.pas

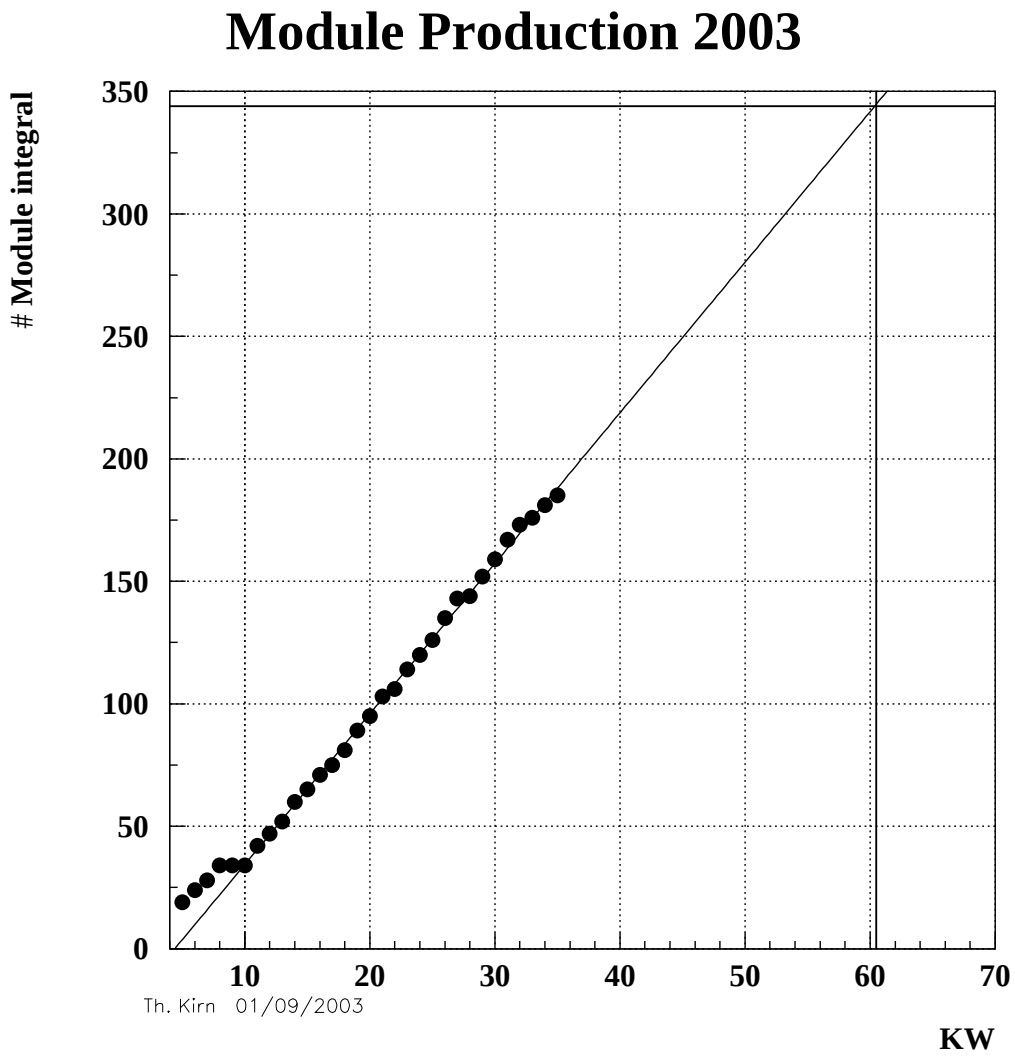
Straw										
1	2.1	1.6	-2.1	1.0	1.4	1.9	-0.3	0.5	1.6	0.5
2	-0.8	1.2	0.0	-0.7	1.2	1.0	1.7	-0.2	1.9	1.3
3	-0.4	-0.5	0.8	-1.3	-0.3	1.6	2.4	0.7	2.9	2.4
4	-0.4	-1.0	-0.7	-0.5	-1.6	-1.2	0.4	0.5	0.4	0.7
5	-0.3	0.2	-1.4	0.2	0.3	0.1	0.5	0.8	1.5	0.1
6	-0.4	0.7	-1.7	-0.1	0.4	-1.3	-0.2	1.4	-0.8	-1.2
7	-1.1	0.9	-1.9	-1.1	0.3	-0.3	-1.1	1.4	0.6	-0.0
8	-0.4	-0.1	-1.2	-0.8	-0.0	-2.0	0.4	1.4	-1.4	-1.2
9	-0.1	-0.3	-0.2	-0.7	-0.8	-1.4	0.2	1.4	-1.2	-0.2
10	-0.1	0.6	-2.5	-0.3	1.0	0.0	-0.5	0.6	1.2	-1.3
11	-1.7	-0.6	-1.1	-2.3	0.3	0.1	-0.6	-0.3	0.6	0.3
12	0.2	-0.9	-2.8	-0.7	-0.9	-0.5	-1.0	-0.5	-0.4	-1.3
13	-0.3	0.6	-2.3	-0.3	1.4	-0.5	-2.0	0.2	0.5	-1.1
14	-0.2	0.4	-0.3	0.2	0.3	0.6	-0.1	1.1	0.8	1.4
15	-2.2	-0.8	0.1	-0.6	-1.0	0.5	0.9	-0.8	2.0	1.9
16	0.8	1.3	-1.1	2.1	2.4	0.6	0.2	1.7	1.0	-1.2





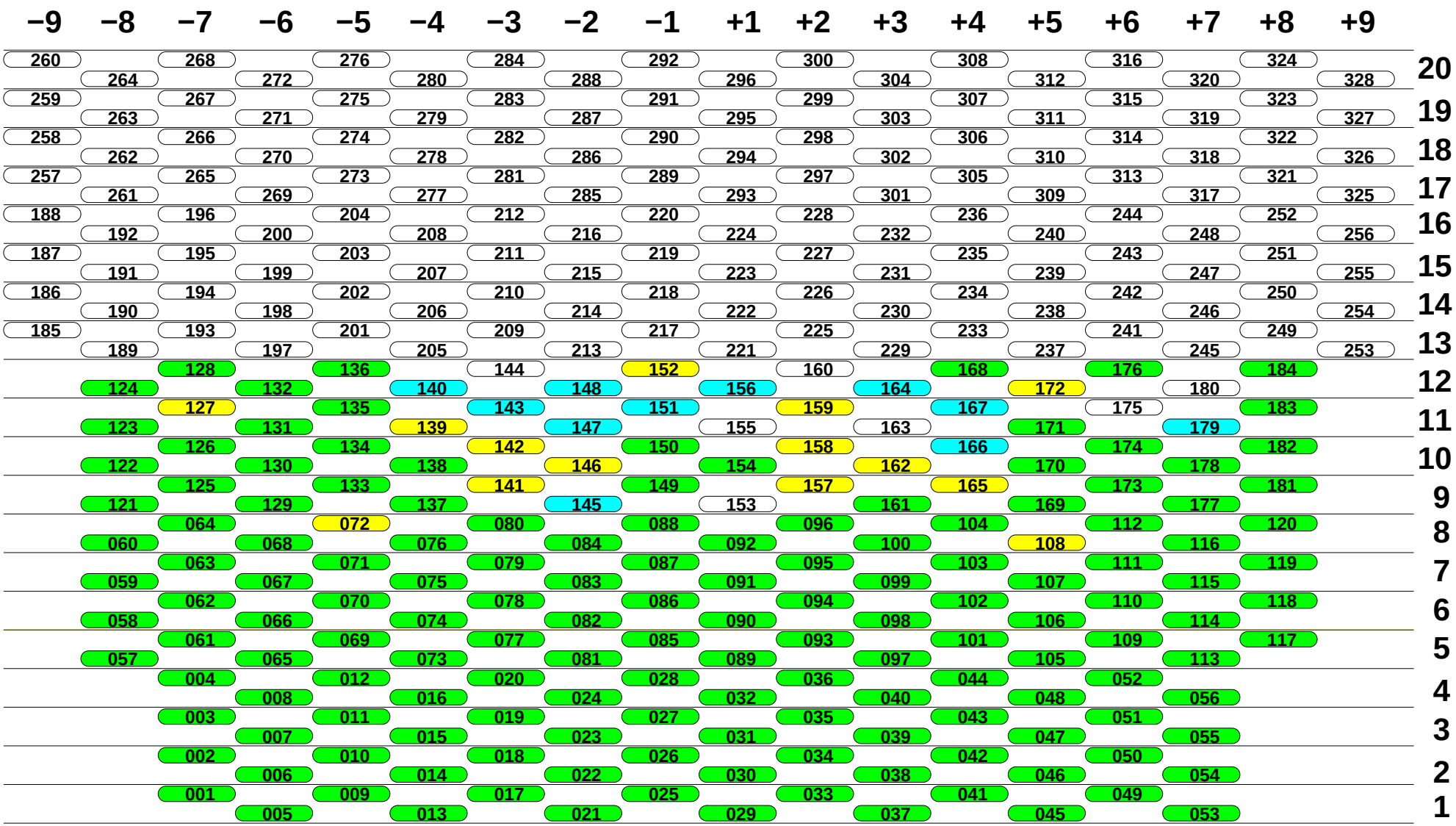
Average variation of gas gain: 1.5%

Module Production Status

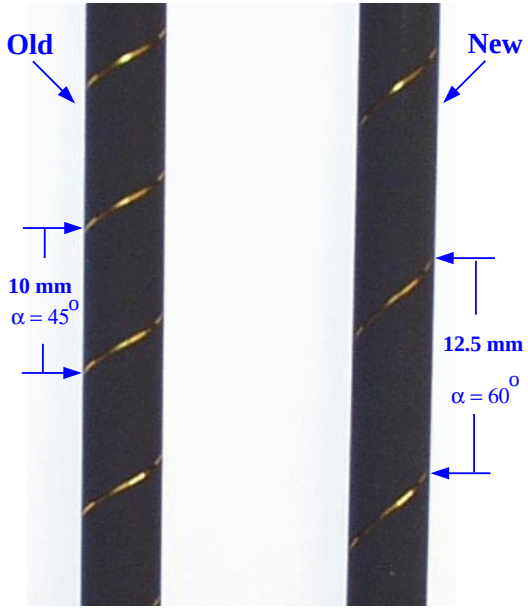


End of Module Production: March 2004

Module Production Status



Space Qualification

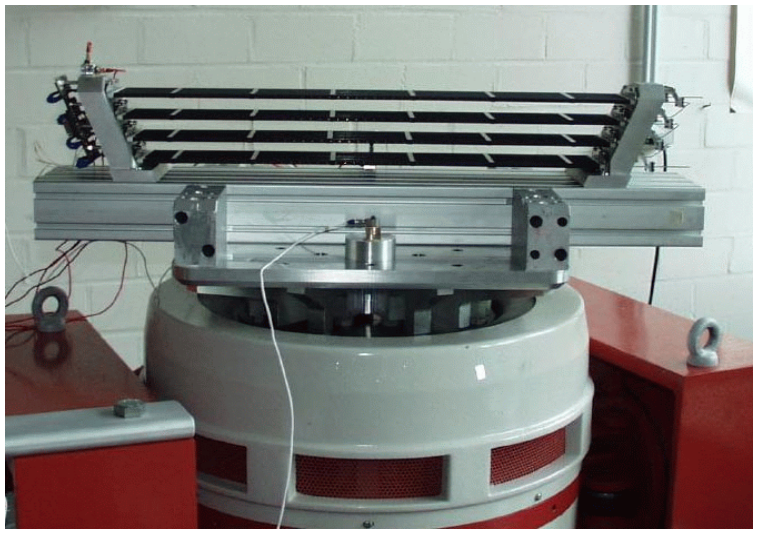


MOD 06 Length mm	Air q_{He} $10^{-5}\ \frac{l \cdot mbar}{s}$	Vacuum Safety Factor CO_2
587	5.7	4.1
611	7.0	4.2
635	4.5	5.6
659	3.8	5.9
$\sum$	20.9	

MOD 07 Length mm	Air q_{He} $10^{-5}\ \frac{l \cdot mbar}{s}$	Vacuum Safety Factor CO_2
587	2.6	5.1
611	2.7	5.8
635	8.3	3.5
659	4.0	5.0
$\sum$	17.6	

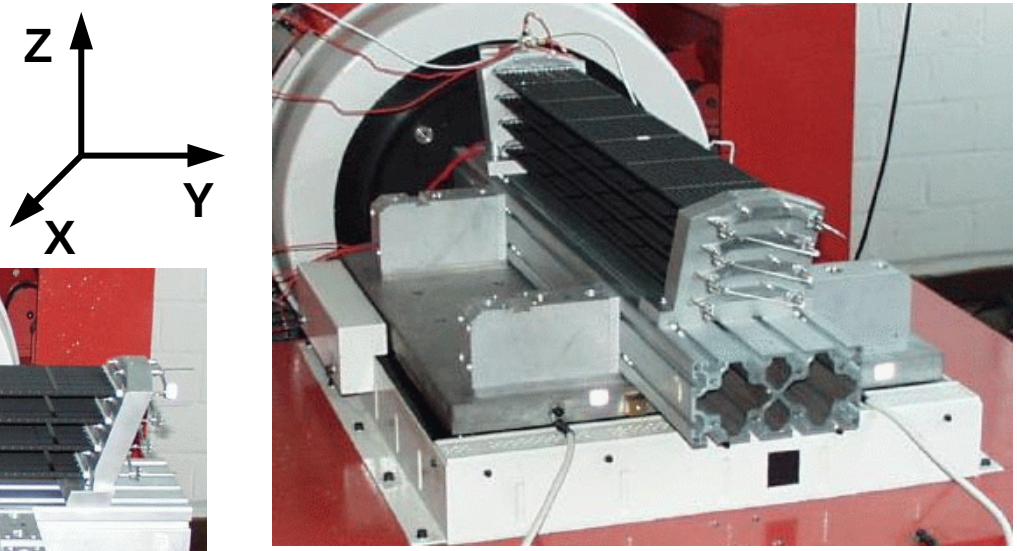
Vibration test, Thermo vacuum test $\rightarrow$ Eigenfrequencies, Leak Rate, Gas Gain

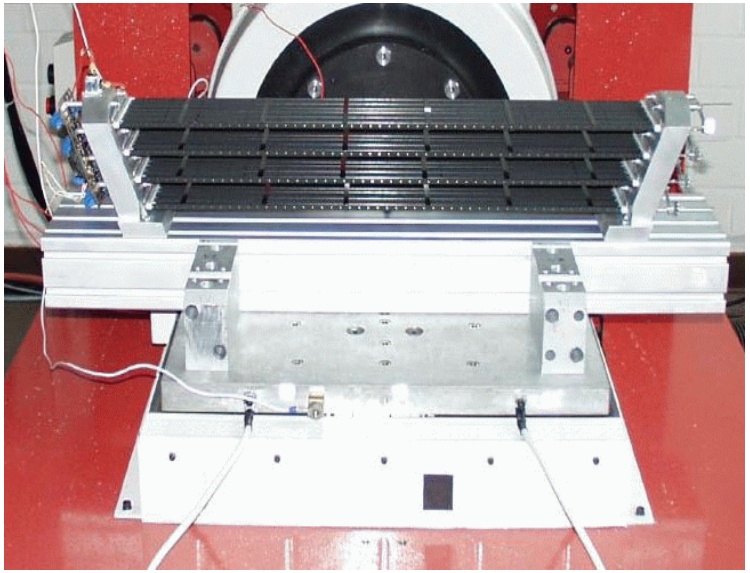
Space Qualification, Vibration Test I+II



Vibration-Test-Cycle:

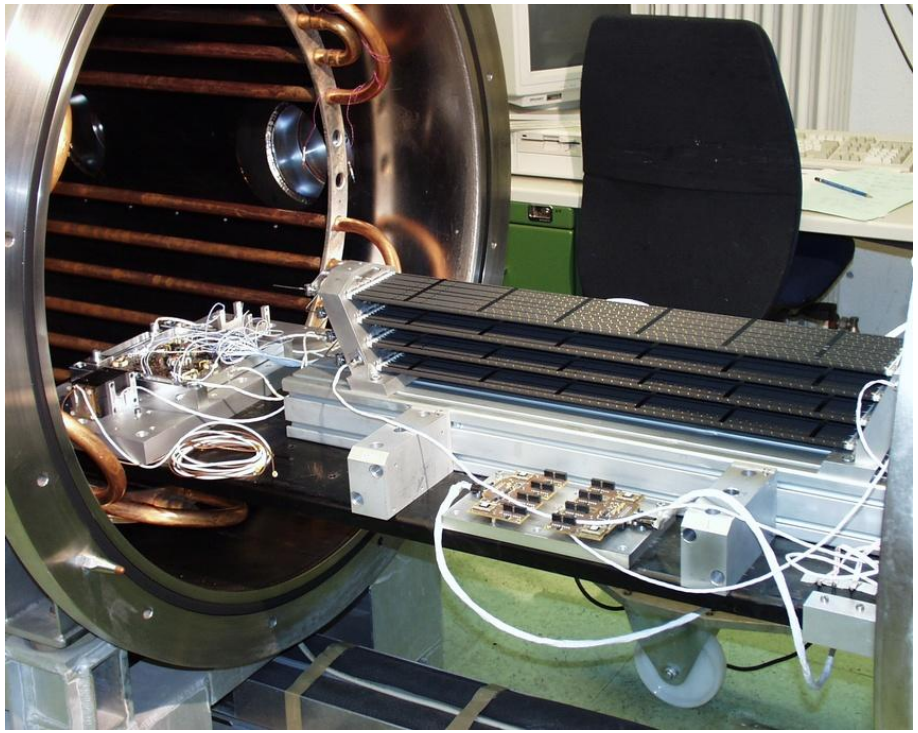
- Sine Sweep 0.5g (10-2000Hz)
- Random Spectrum $a_{\mathrm{RMS}} = 6.8g$
- Sine Sweep 0.5g (10-2000Hz)



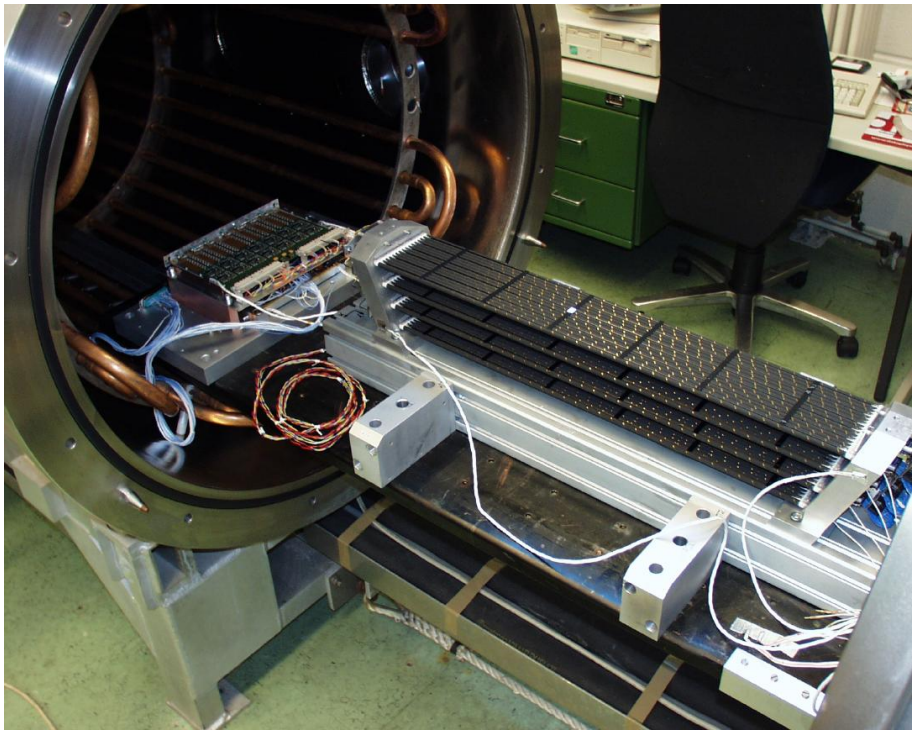


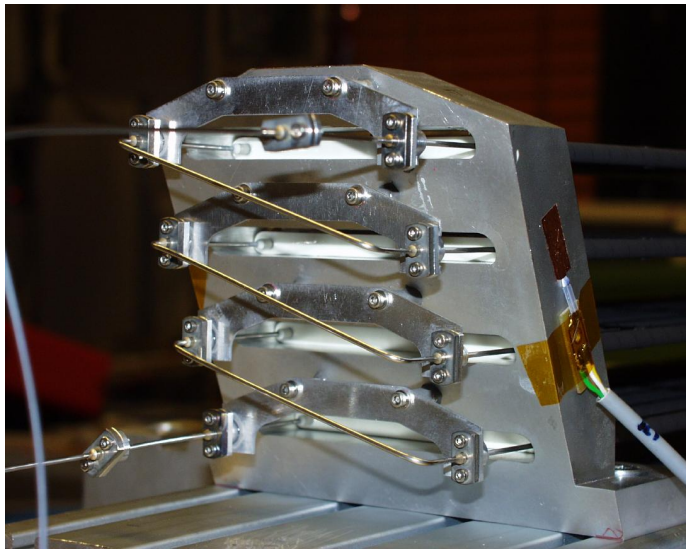
Space Qualification, Thermo Vacuum Test

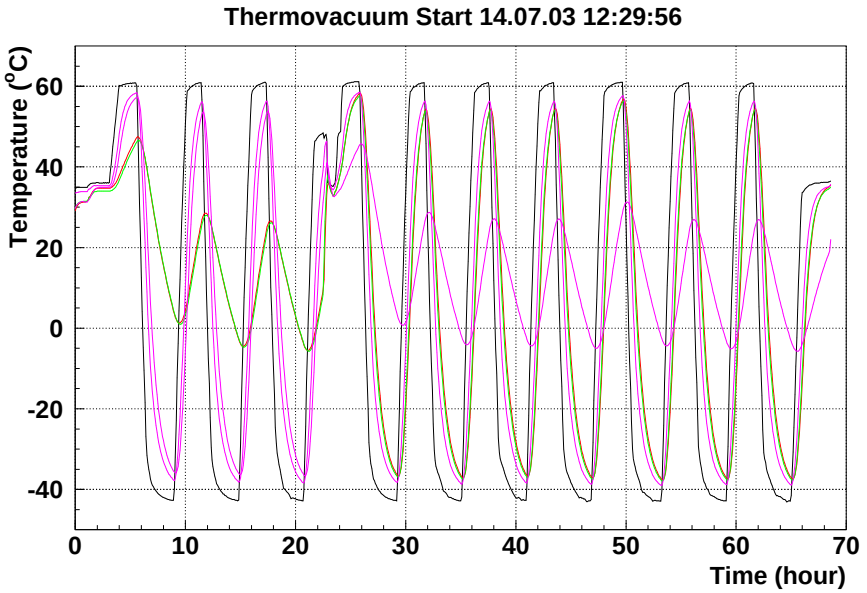
MOD06



MOD07



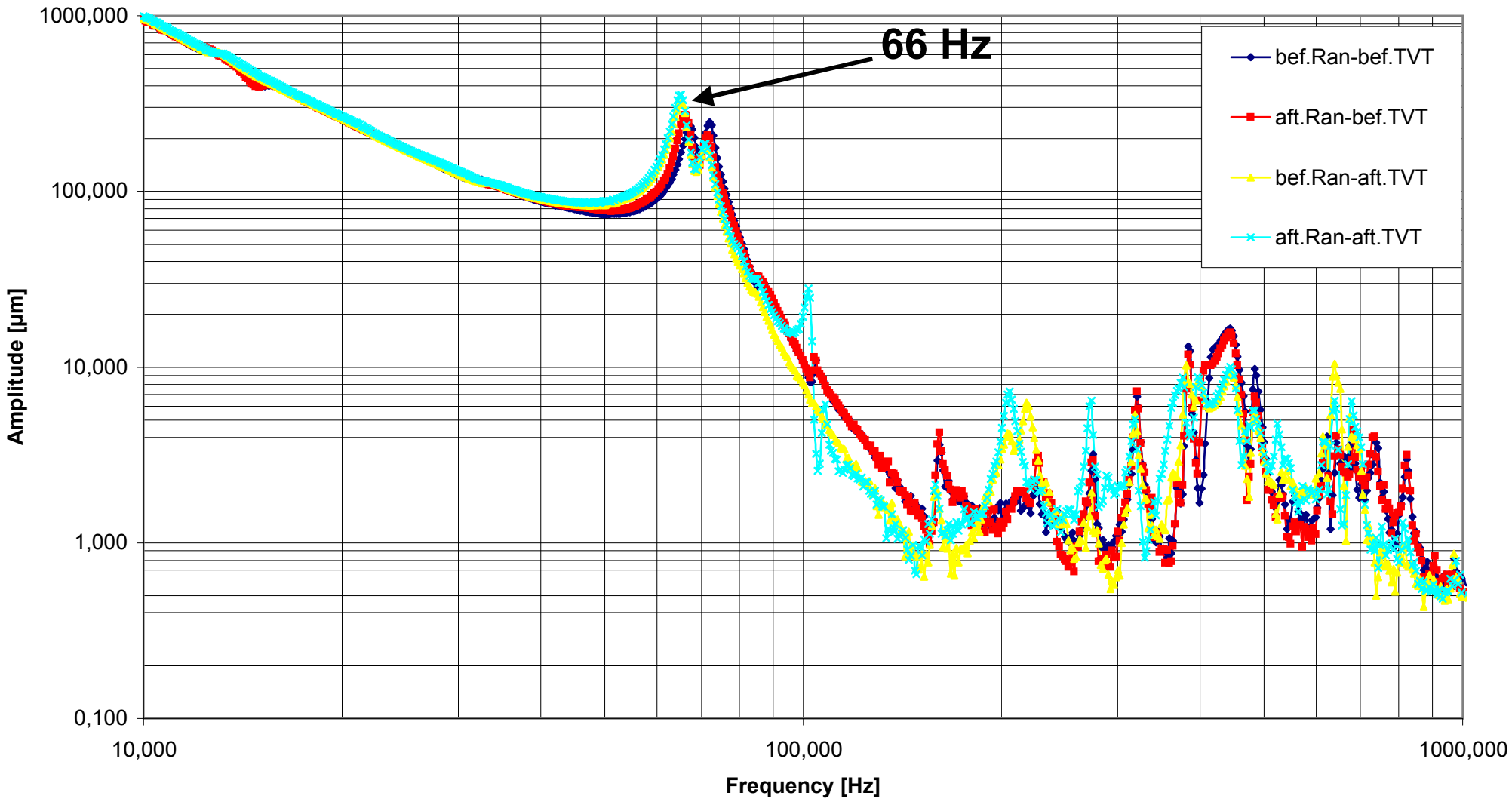




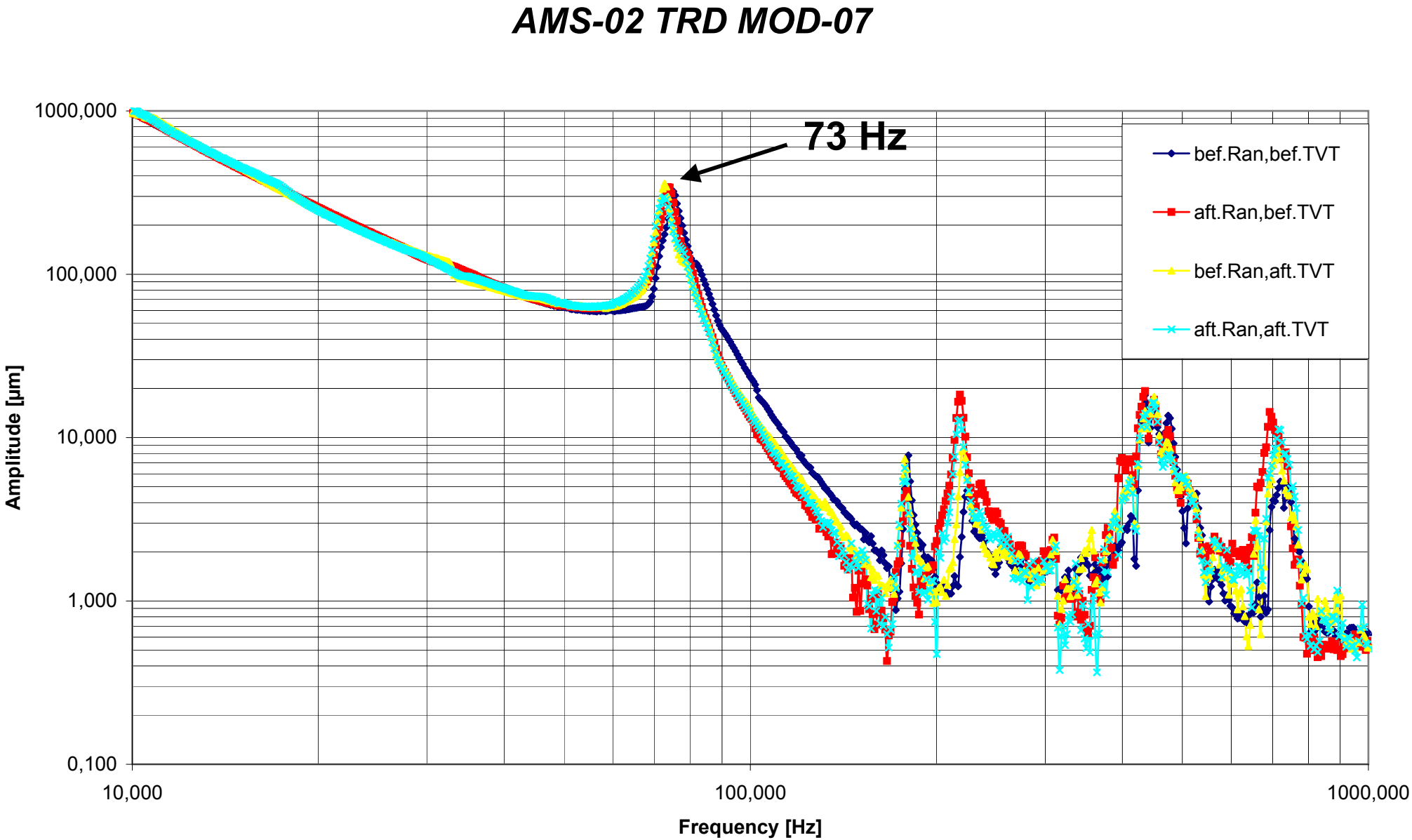
Space Qualification, Leak Rate

Mod. No.	$q_{He,Air}$ $10^{-5}\ \frac{l \cdot mbar}{s}$			
	before SQ	Vib I	TVT	Vib II
MOD06: Old Straw Material				
587	5.7			5.2
611	7.0			6.1
635	4.5			3.7
659	3.8			3.5
Jigg06	21.5	19.9	22.4	19.4
MOD07: New Straw Material				
587	2.6			3.1
611	2.7			3.2
635	8.3			7.7
659	4.0			3.4
Jigg07	13.5	12.7	18.4	14.0

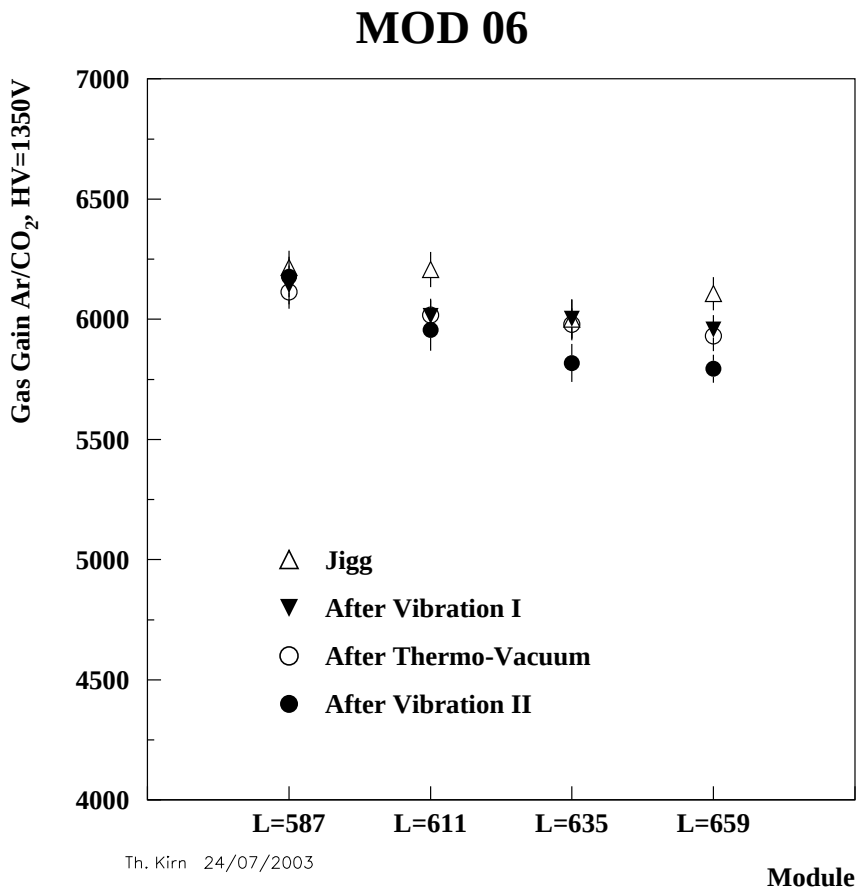
Space Qualification, Eigenfrequencies

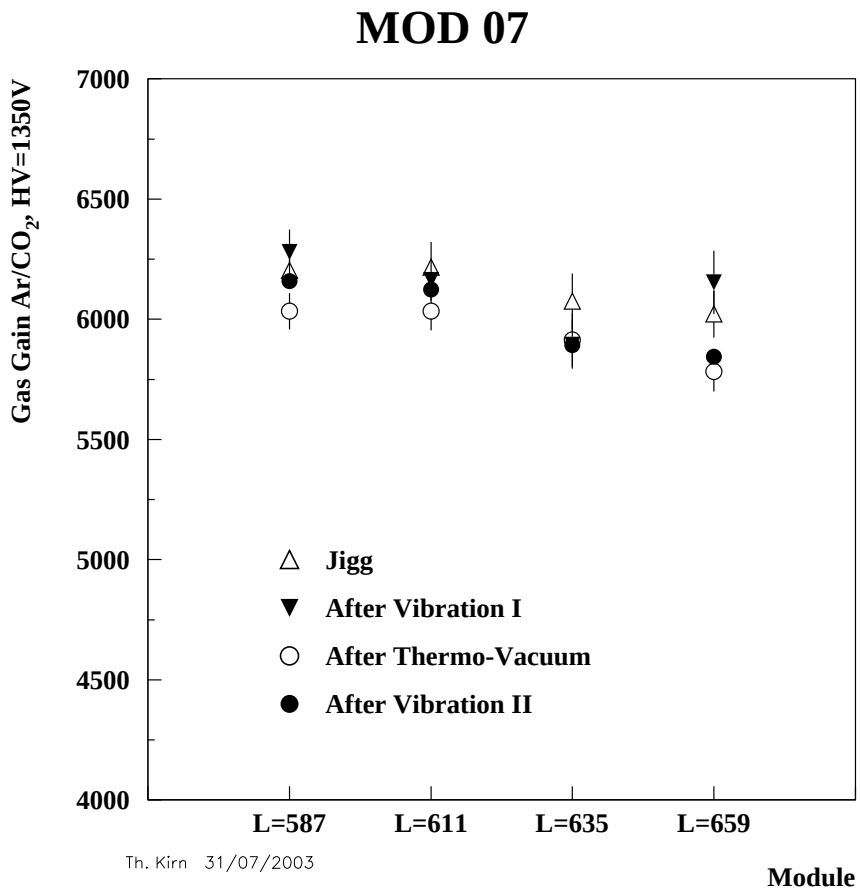


Space Qualification, Eigenfrequencies

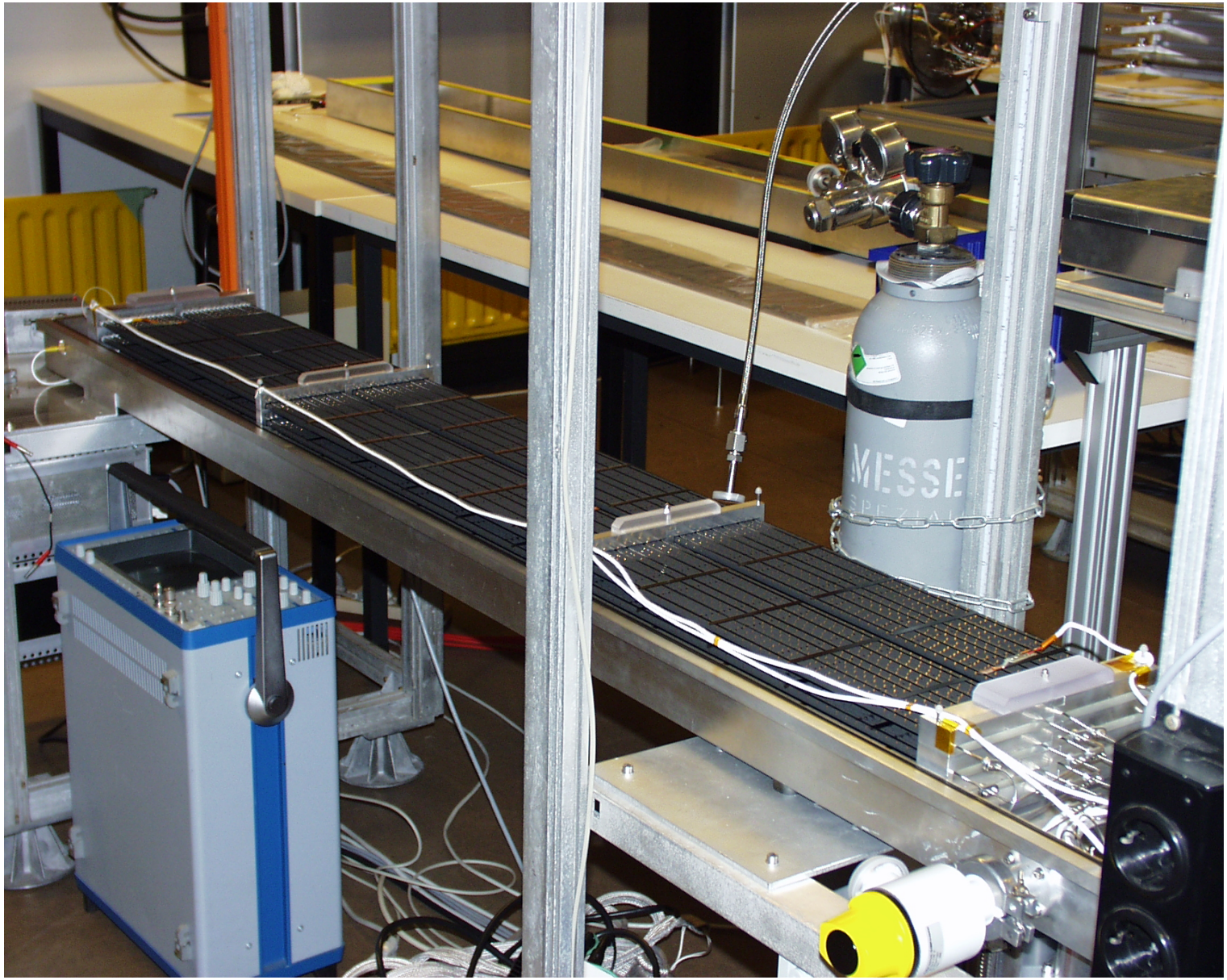


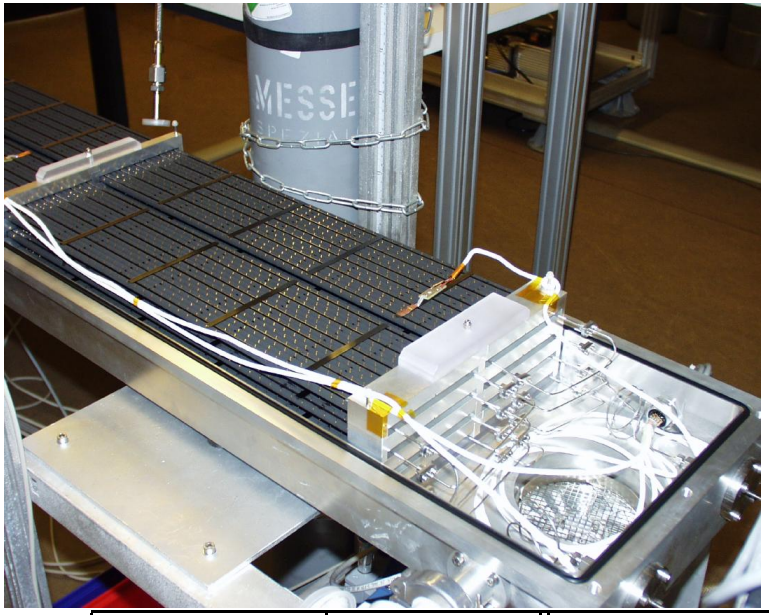
Space Qualification, Gas Gain

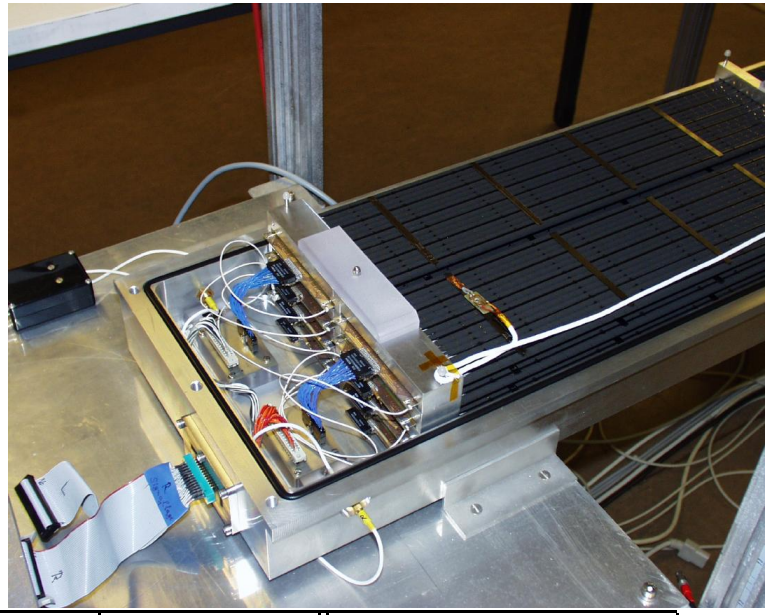




AMS02-TRD: Longterm-Vacuum-Test







Mod. No.	Length [mm]	Air q_{He} $[10^{-5}\ \frac{l \cdot mbar}{s}]$	Vacuum Safety-Factor CO_2	Gas Gain $ArCO_2$ U = 1350V Mean	RMS [%]
LZT I	1534.61	6.0	7.4	6018.6	1.65
LZT II	1534.61	5.7	7.8	5922.2	1.82
LZT III	1534.61	5.2	7.2	5891.4	1.70
LZT IV	1534.61	5.8	7.5	5756.6	2.17
LZT V	1534.61	6.3	6.9	5902.3	1.64
LZT VI	1534.61	5.1	7.7	5737.9	1.11
LZT VII	1534.61	4.7	7.9	5906.7	1.99
LZT VIII	1534.61	5.5	7.7	5867.4	1.25

Conclusion

- Single Straw Test $\rightarrow$ Selection of gastight Straws
- TRD: 328 Flight Modules
  - Flight Modules ready for installation: 158
  - Flight Modules produced: 177
  - Production ready March 2004
- Space Qualification successful
- Longterm-Test started
- TRD-Assembly + Cosmictest $\rightarrow$ autumn 2004
- AMS02-Assembly end of 2004