

TRDs for the 3rd millennium

Status of the AMS TRD



for the AMS-TRD Group

MIT Boston, INFN Rome, IEKP Karlsruhe, CHEP KNU Daegu, RWTH Aachen

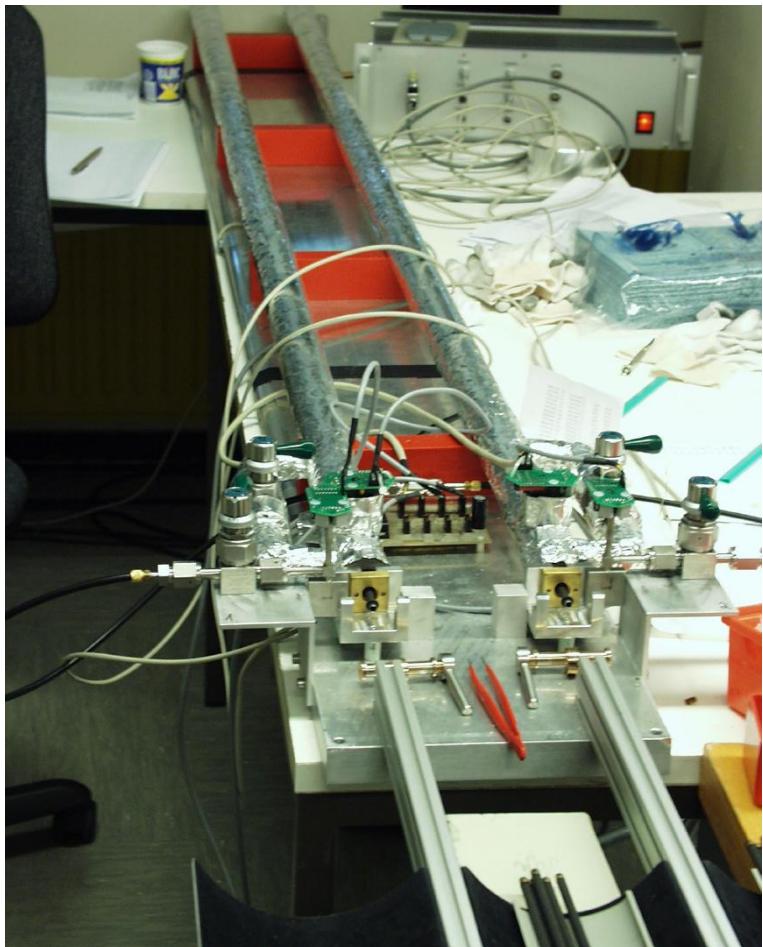
Th. Kirn
I. Phys. Institute RWTH Aachen

Bari, September 5th 2003

Status of the AMS TRD Straw Modules

C.H. Chung, S. Fopp, K. Lübelsmeyer, W. Karpinski, Th. Kirn, S. Schael
G. Schwering, Th. Siedenburg, R. Siedling, A. Schultz von Dratzig, M. Wlochal

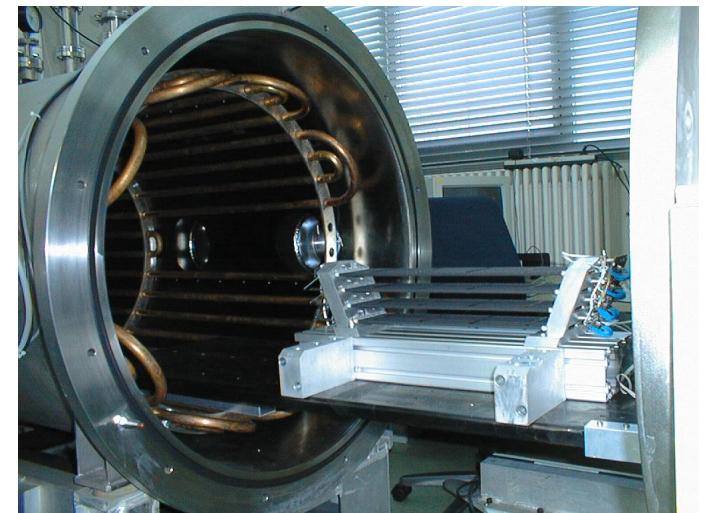
1.) Single Straw Test



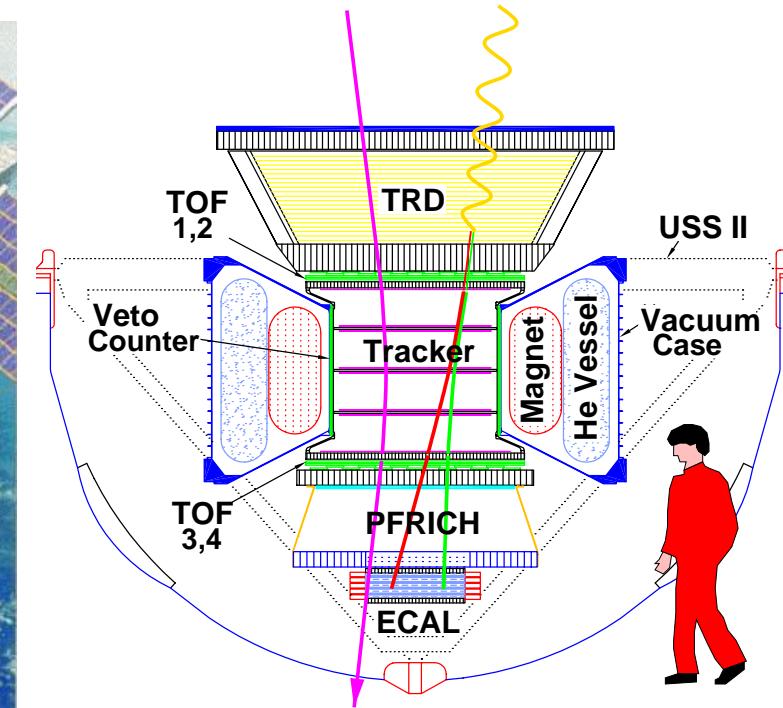
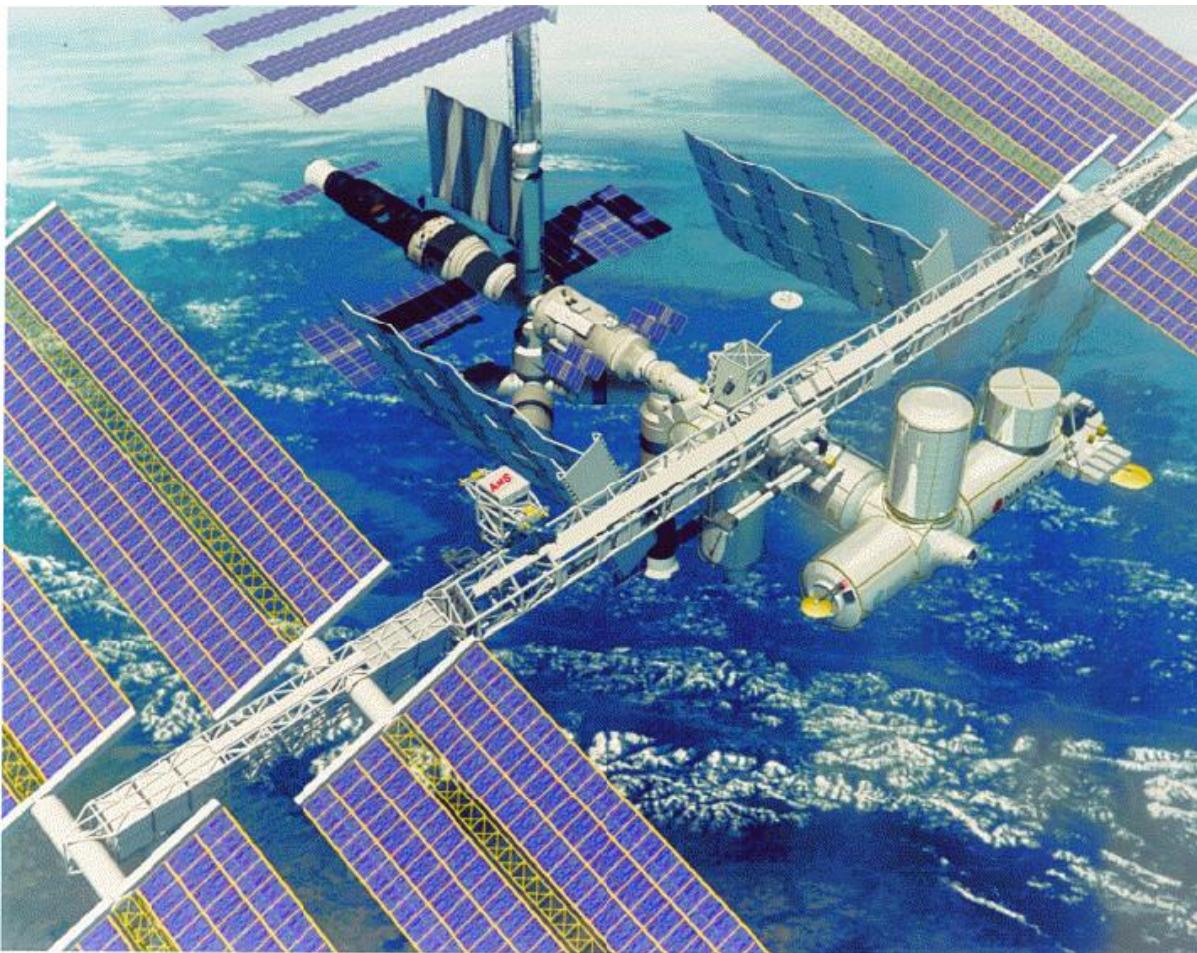
2.) Module Production



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 $0.5 \text{ m}^2\text{sr}$

}

⇒ Cosmic Particle Spectroscopy

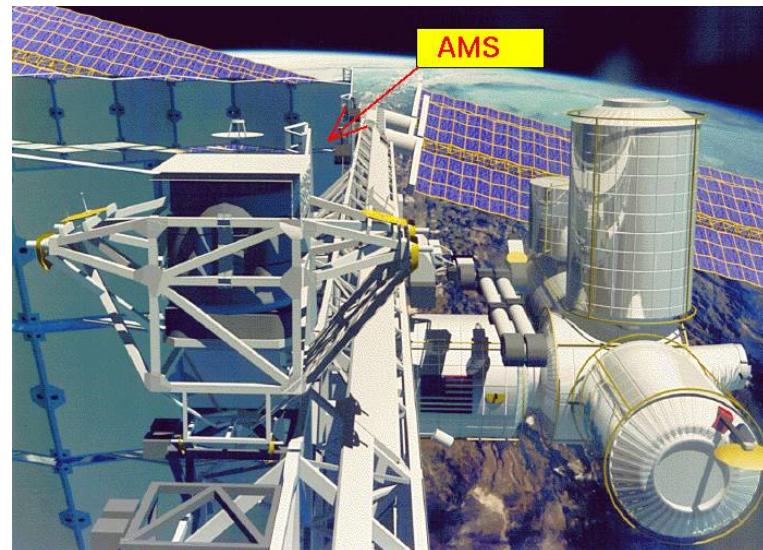
Space, a new environment for HEP experiments

- Acceleration during start and landing

Design Goal up to 9g

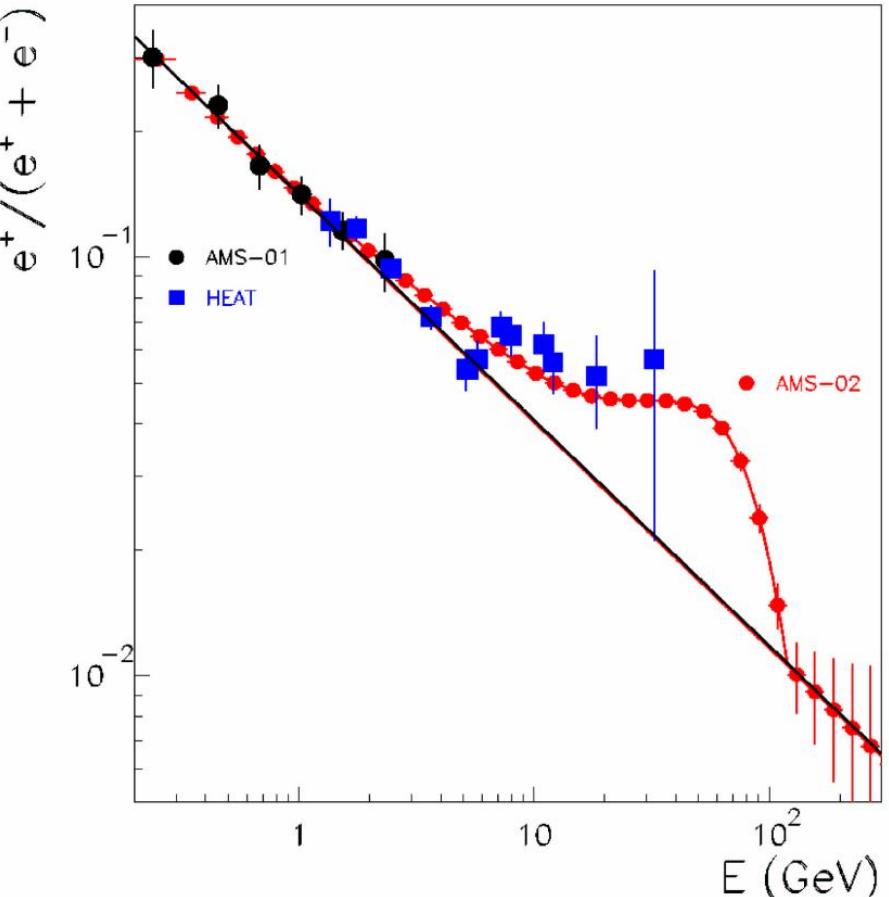
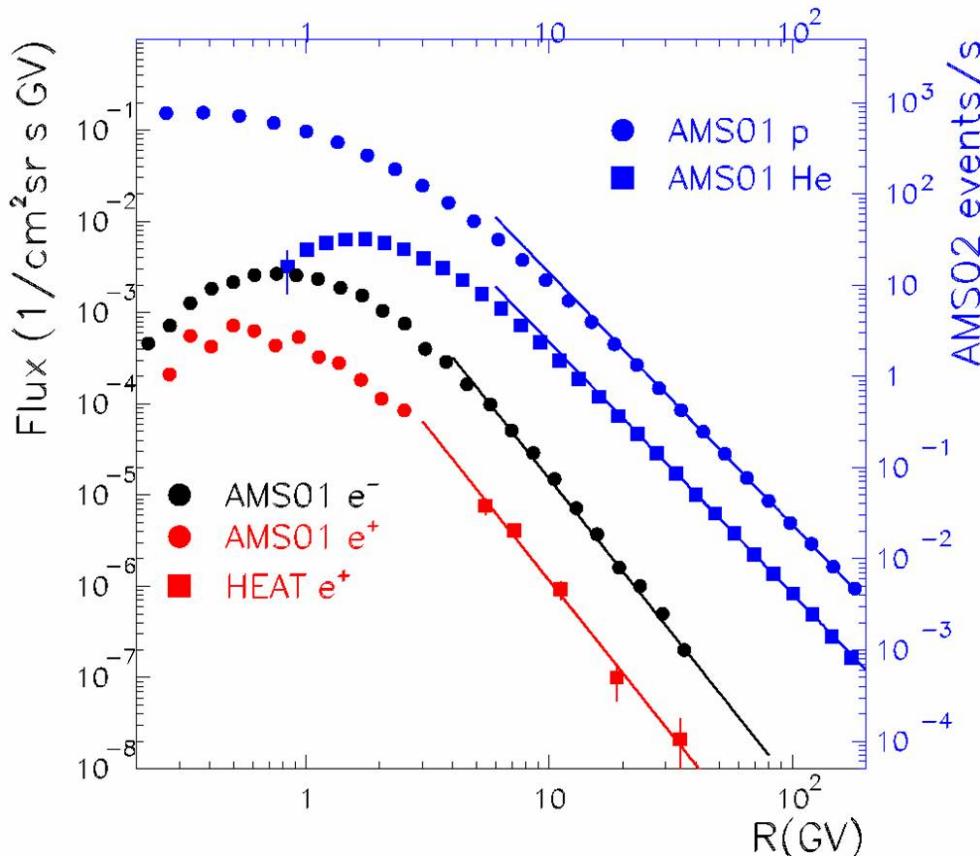


- Operation in vacuum
- Temperature variations: -150 - $+30$ °C
- Deposition limits on ISS: $< 10^{-14}$ g/s/cm²
- Weight limited to 14000 lbs
- Power consumption limited to 2kW
- Single Powersupply at 120 V
- Datarate 1 Mbyte/s via 1 datalink



⇒ Cosmic Particle Spectroscopy

Cosmic Particle Spectroscopy



flux ratio in orbit:

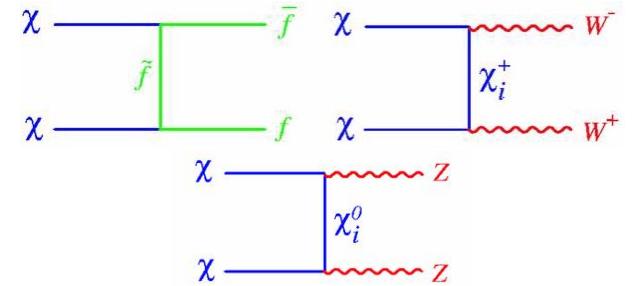
$$p^+/e^+ \approx 10^4$$

p^+ -Contamination:

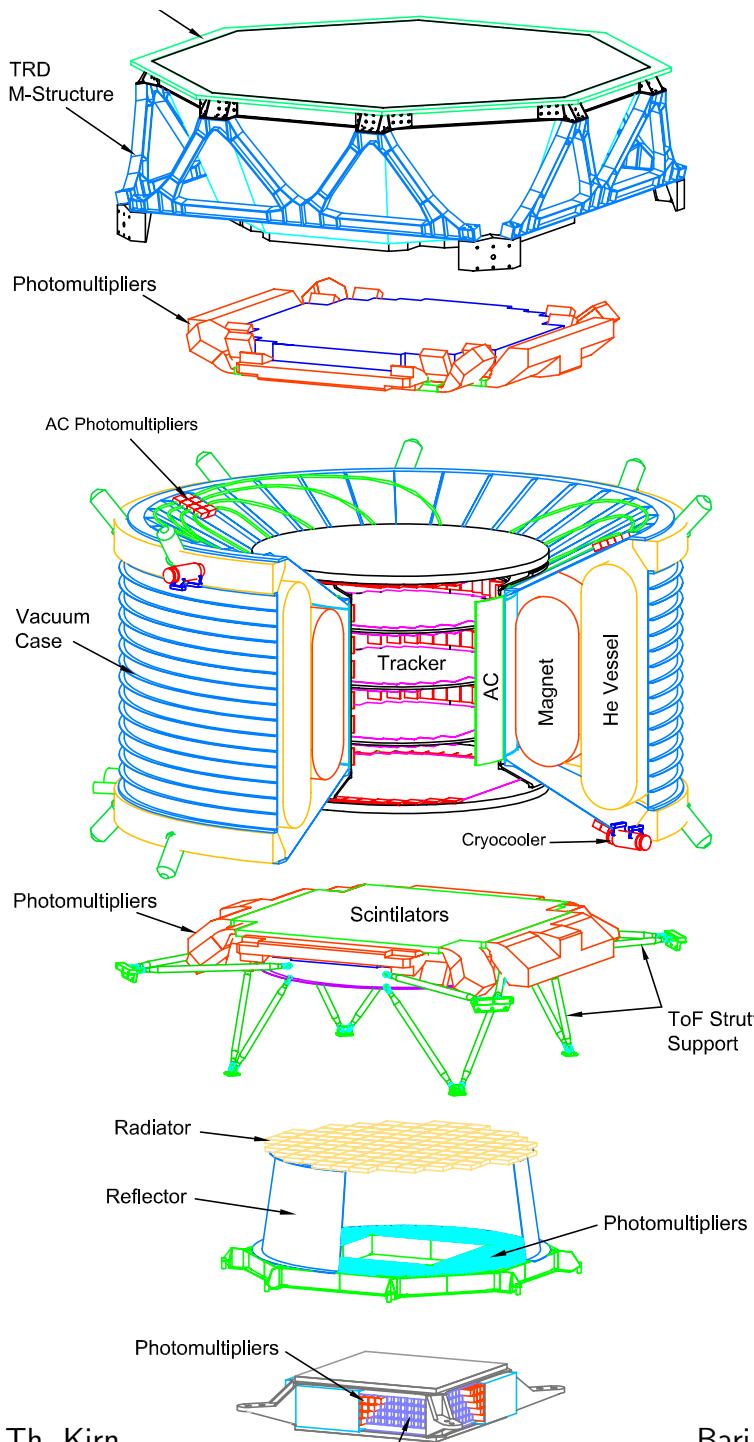
$$\leq 10^{-2}$$

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

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



AMS02 – A TeV Particle Spectrometer for the ISS



TRD Particle ID & 3D tracking

20 layers fleece + Xe/CO₂

5248 channels 6mm straw-tubes

$p^+ \text{Rej} > 100$ from 10-300 GeV

TOF 1,2 Trigger $\sigma_t \approx 125\text{ps}$

Anticoincidence (Veto) counter

Silicon strip tracker ($2 \cdot 10^5$ Ch)

with internal laser alignment

6 m² in 3 double + 2 single xy layers

1 σ charge separation up to 1TV

Superconducting Magnet (ETH)

B = 0.9T V = 0.6m³

TOF 3,4 1.3m distance to TOF 1,2

$p^+ / e^+ > 3\sigma$ below 2 GeV

PFRICH AGL(+NaF) Radiator

for A ≤ 27 and Z ≤ 28

separation $> 3\sigma$ from 1-12 GeV

ECAL 3D sampling lead/scint.-fibre

$p^+ \text{Rej} > 10^4$ from 10-300 GeV

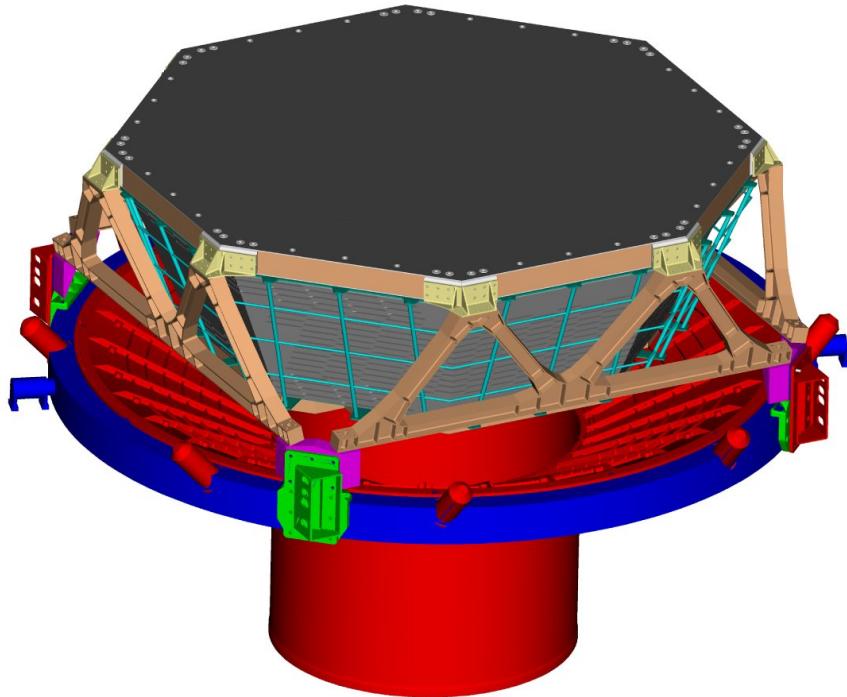
with p-E matching and shower-shape

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

Chosen Configuration for 60 cm height:

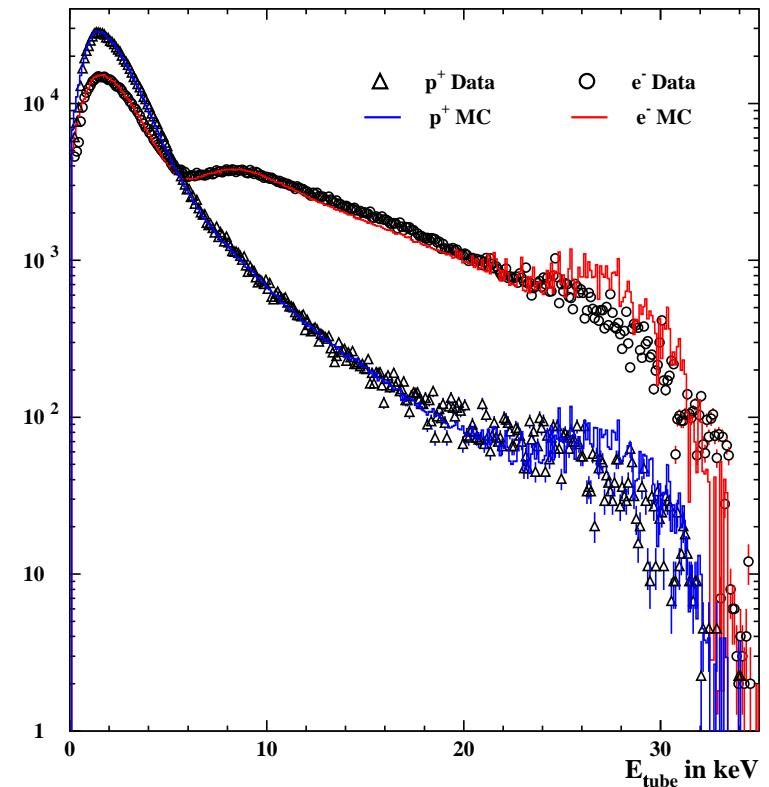
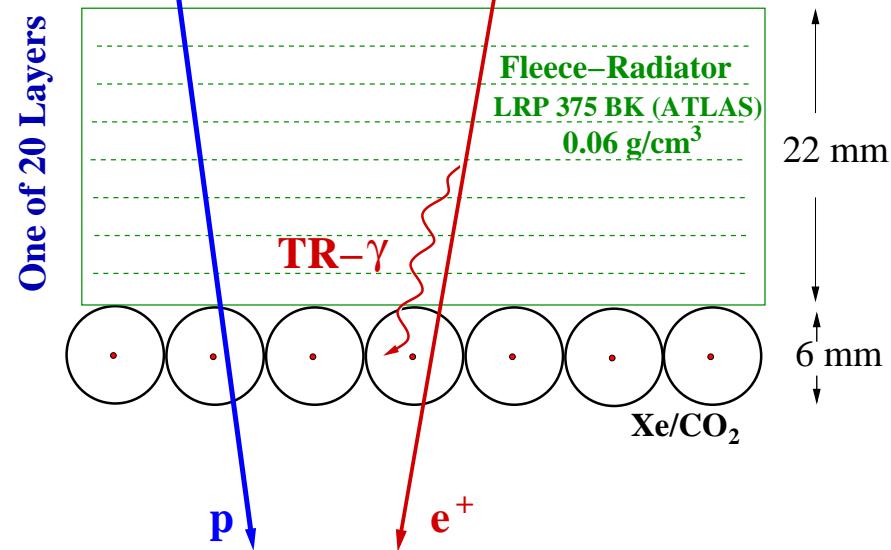
20 Layers each existing of

- 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 Th. Kirn	478 kg

AMS-02 TRD

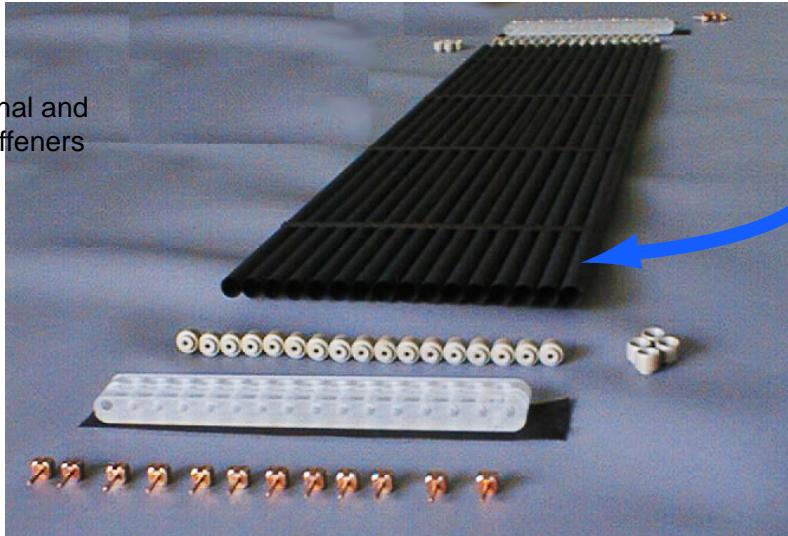


Bari, September 5th 2003

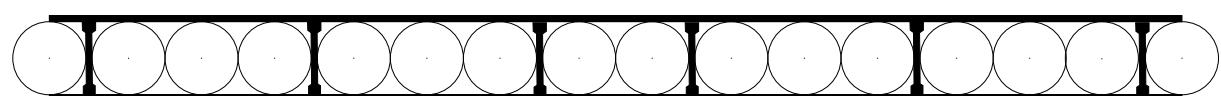
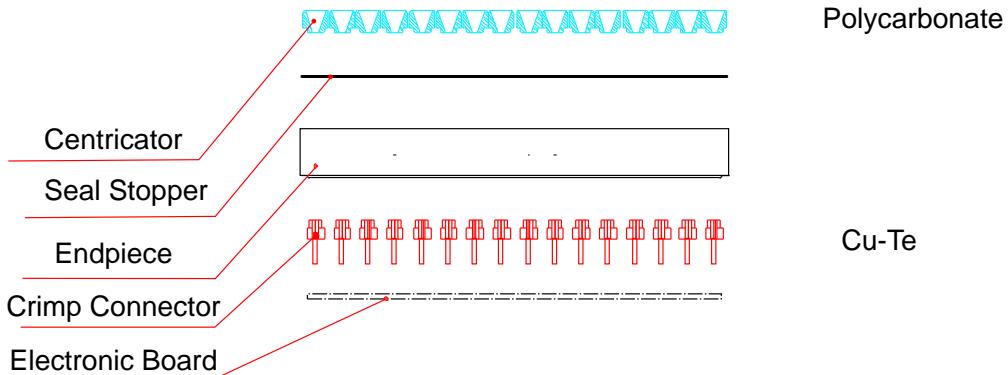
AMS-02 TRD Straw Modules: 16 straws at 6mm Ø with 30 μm W-Au wire

Multilayer Capton tubings

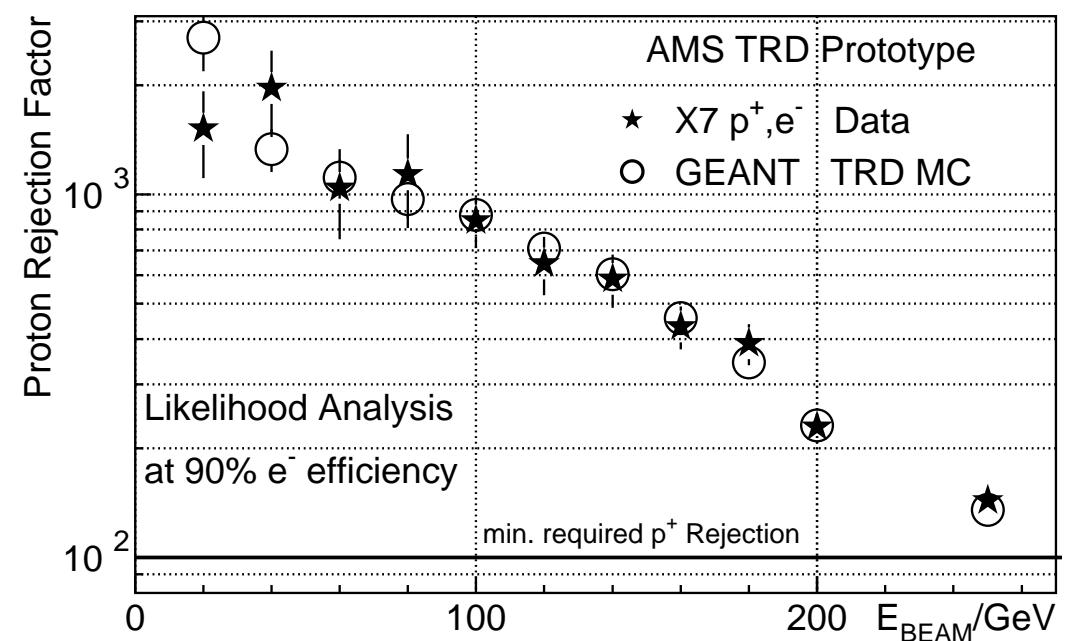
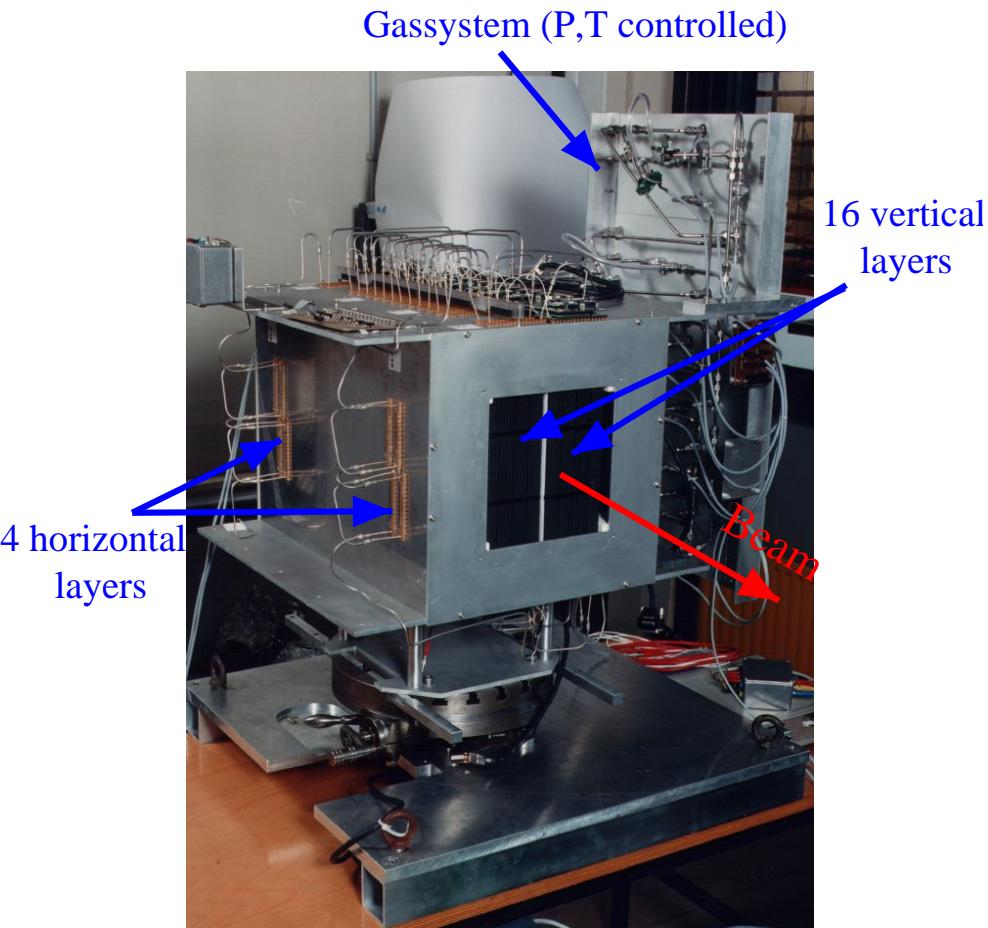
CFC longitudinal and transversal stiffeners



Capton wall

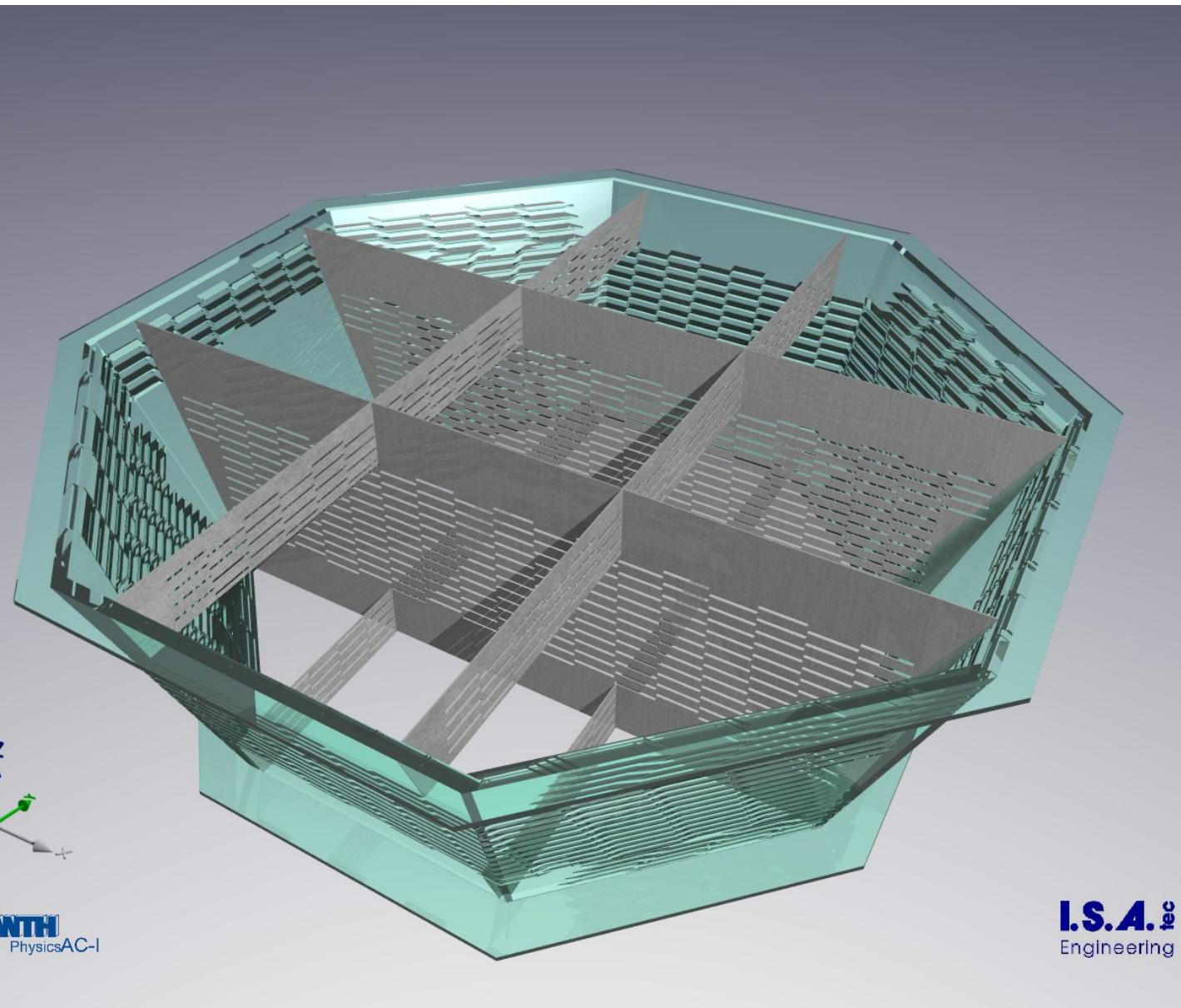


AMS-02 TRD:20 Layer Prototype Testbeam



AMS-02 TRD

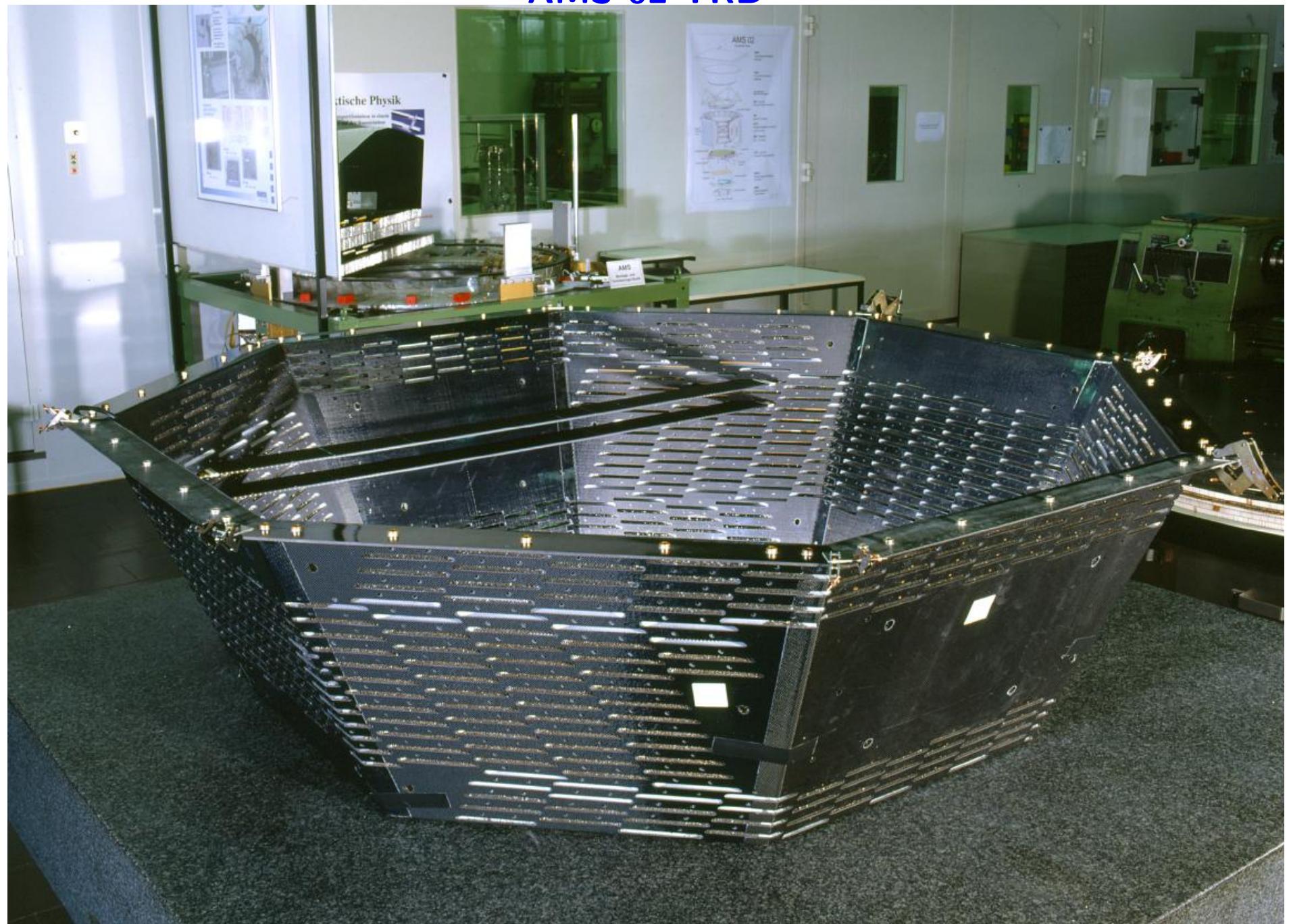
Octagon and Bulkheads support 328 Modules (5248 Straws)
(L=86 to 201 cm) with 100 μm mech. accuracy



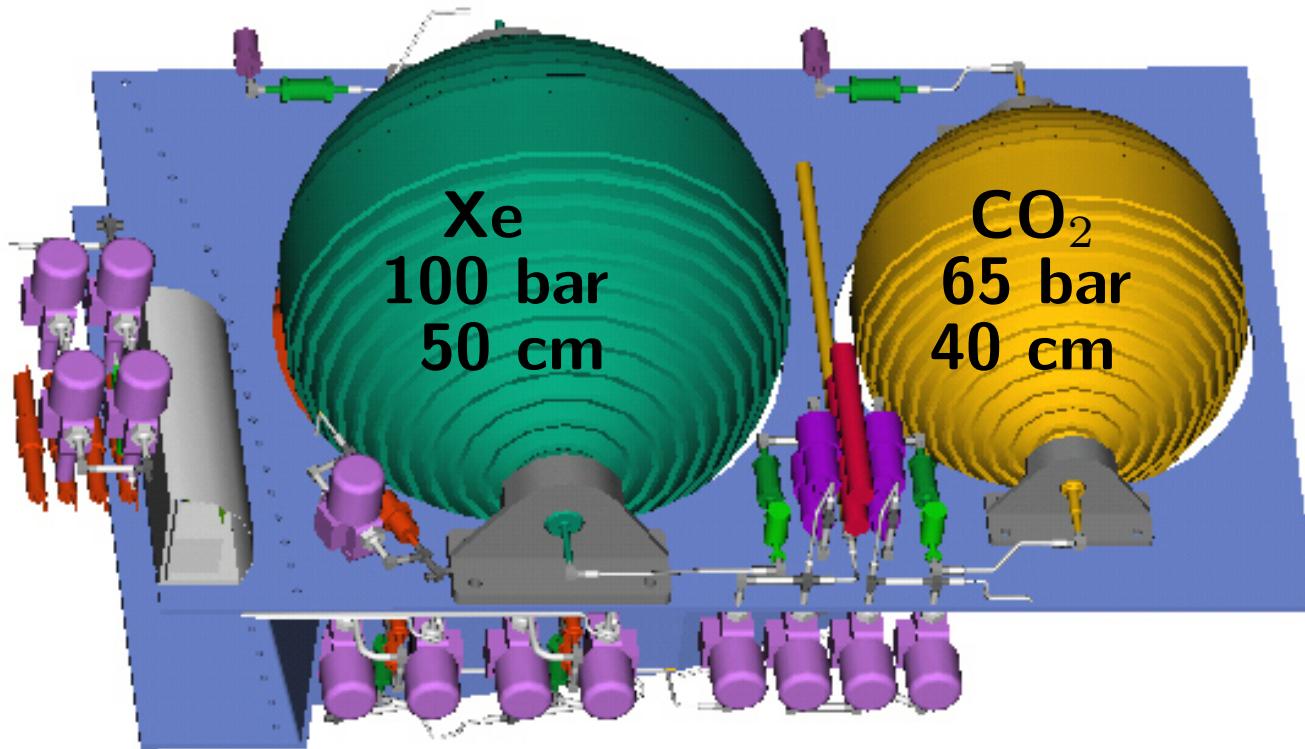
Upper/lower 4 layers
measure in bending plane

Middle 12 layers
measure in perpendicular
plane

AMS-02 TRD



TRD Gassystem (MIT)

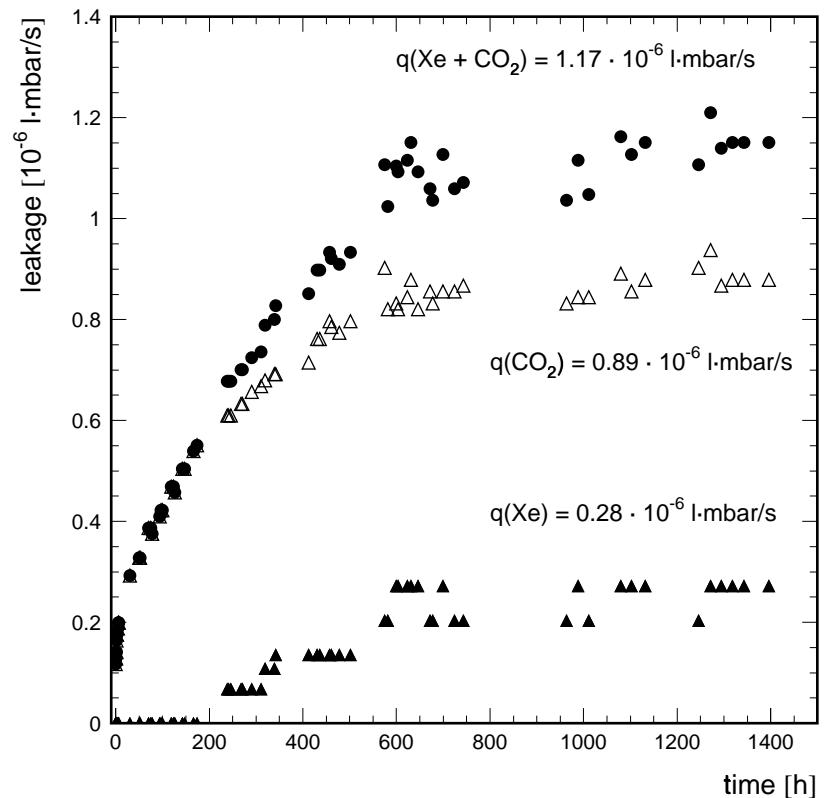
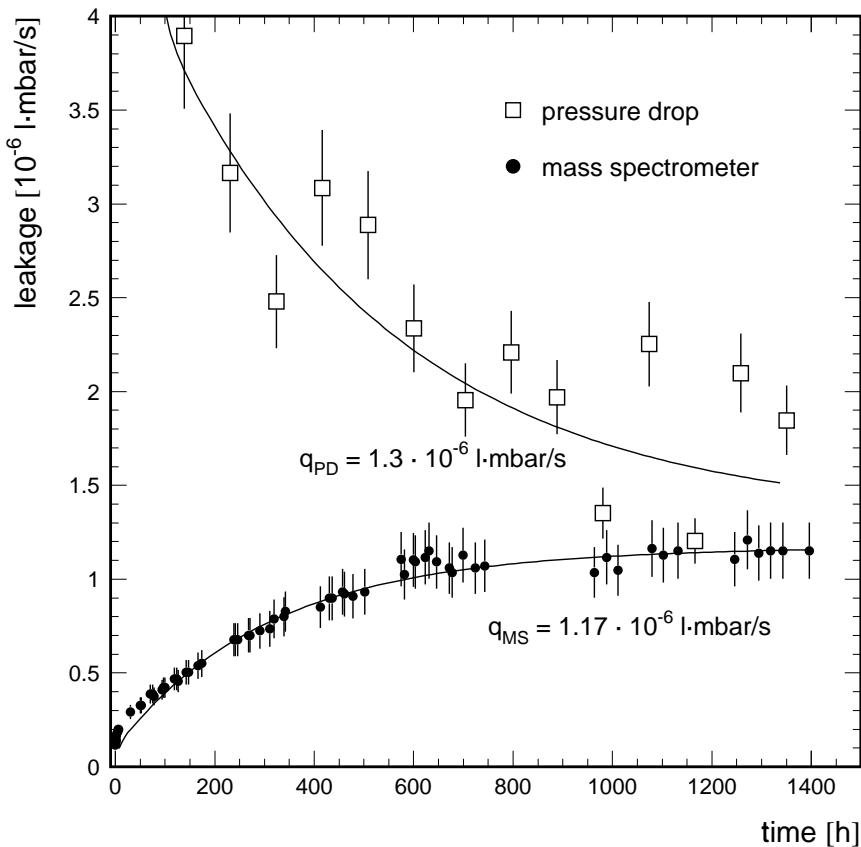


$$L_{\text{TRD}}^{\text{Mod}} = 500 \text{ m}$$

V_{TRD} 230 l @ 1 bar (41 loops, each loop 8 Straw Modules in Series)

Xe 46 kg (8100 l @ 1 bar)

CO₂ 4 kg (2000 l @ 1 bar)



- Xe/CO₂ (80/20) Leak rate 3 single Straw Tubes L=1.3 m

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

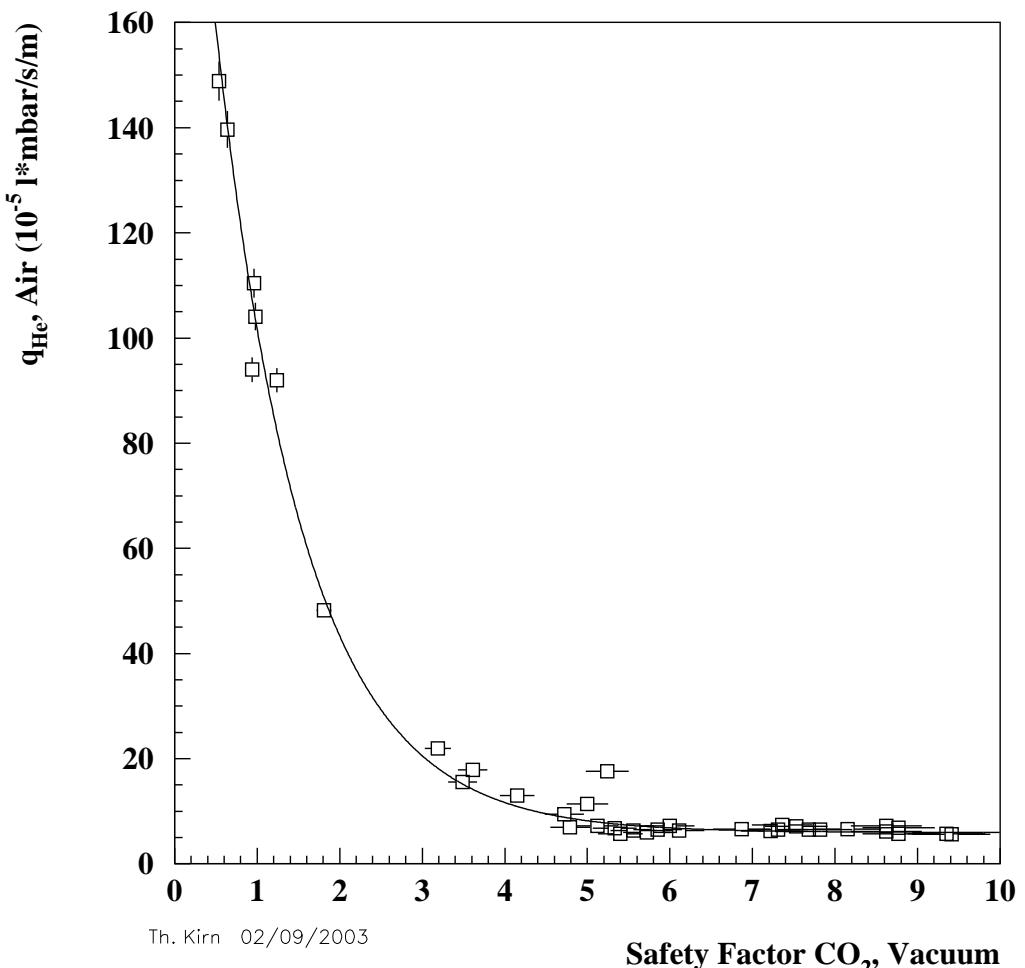
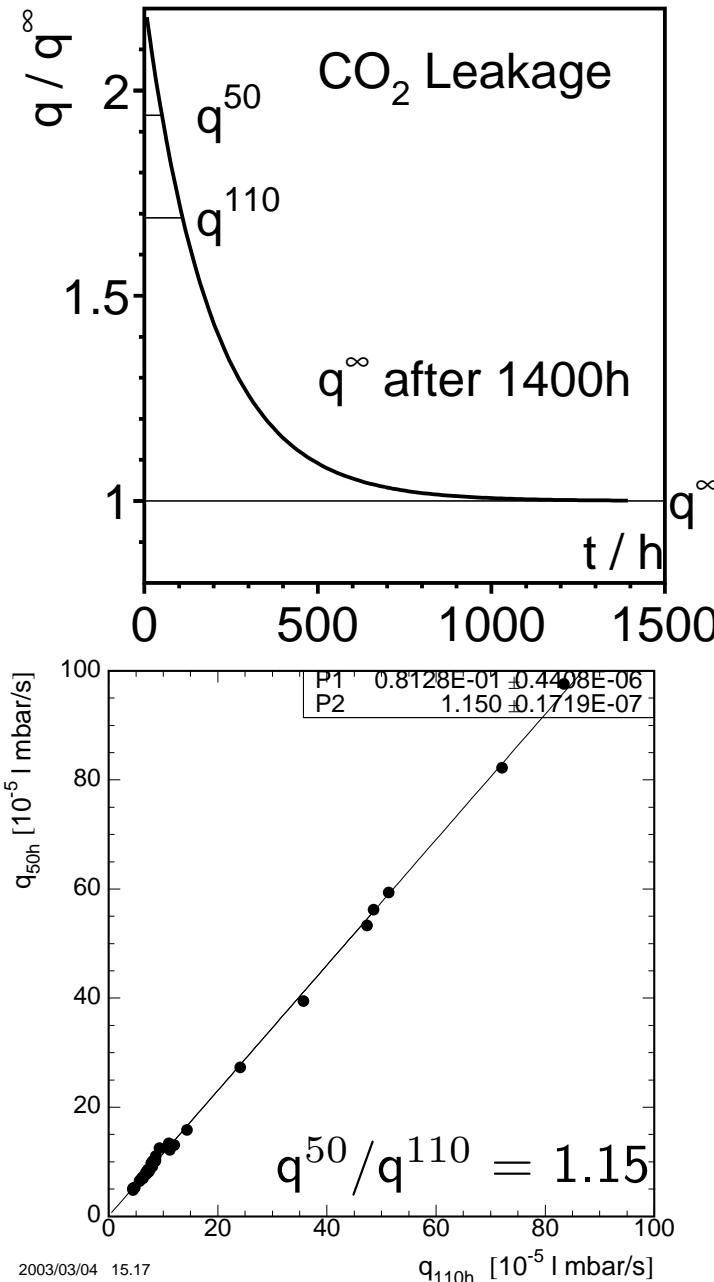
$$q_{Xe,max} = \frac{8100 \text{ } l \cdot 1013 \text{ } mbar}{1000 \cdot 86400 \text{ } s} \cdot \frac{1}{500 \text{ } m} = 19 \cdot 10^{-5} \frac{l \cdot \text{mbar}}{s \cdot m_{\text{Module}}} \rightarrow \text{Safety factor :} 158$$

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

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

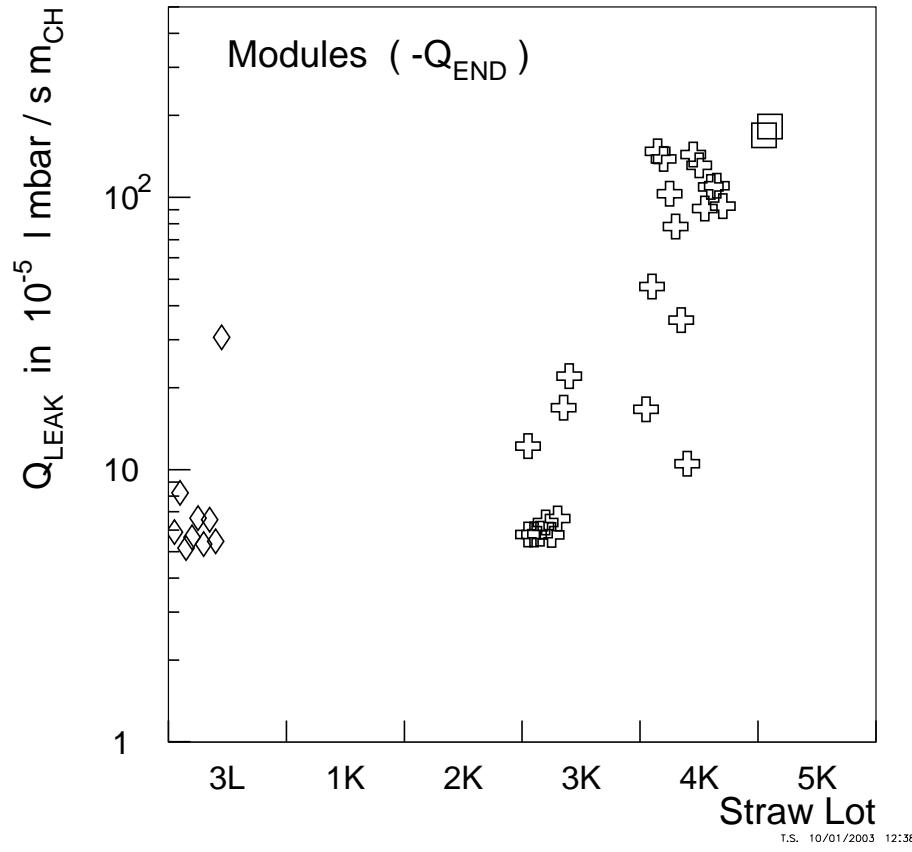
AIM: CO₂ Safety Faktor: 4

CO₂ Safetyfaktor using 50h CO₂ and 12h He Measurements

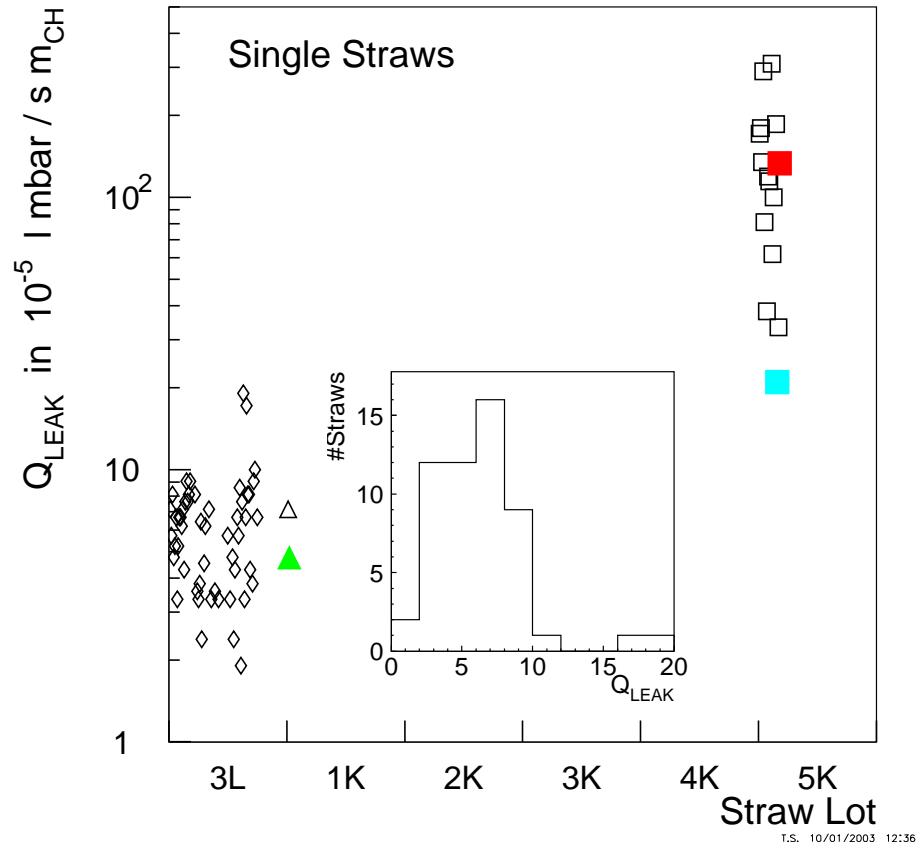


- He vs CO₂ good correlation,
Advantage: He measurements faster
- Aim: Safety Factor of $> 4 \Leftrightarrow > 12$ years on ISS
 \hookrightarrow He leak rate $10 \cdot 10^{-5} l \cdot mbar/s/m$

Module-Production Lot-Statistics



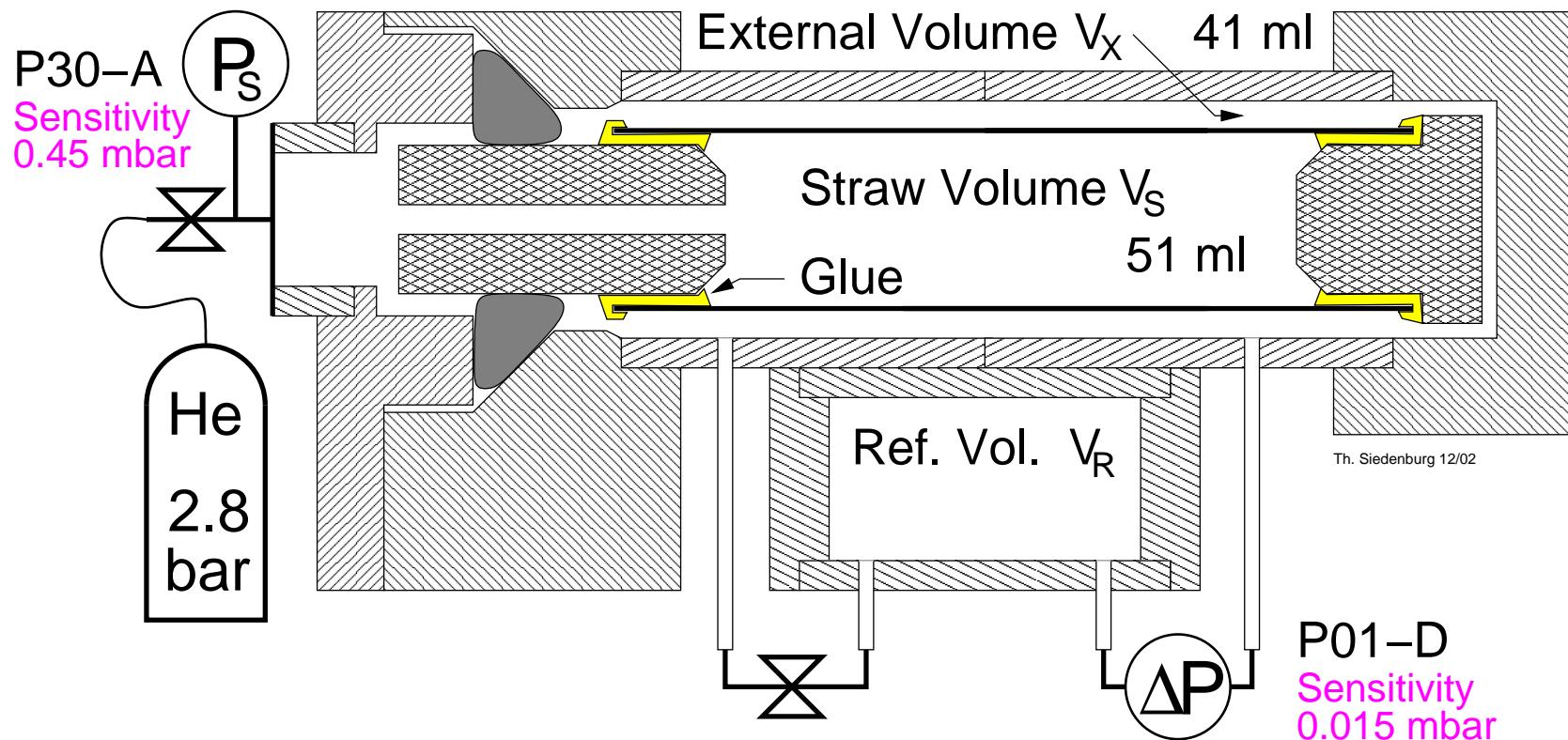
Straw-Production Lot-Statistics

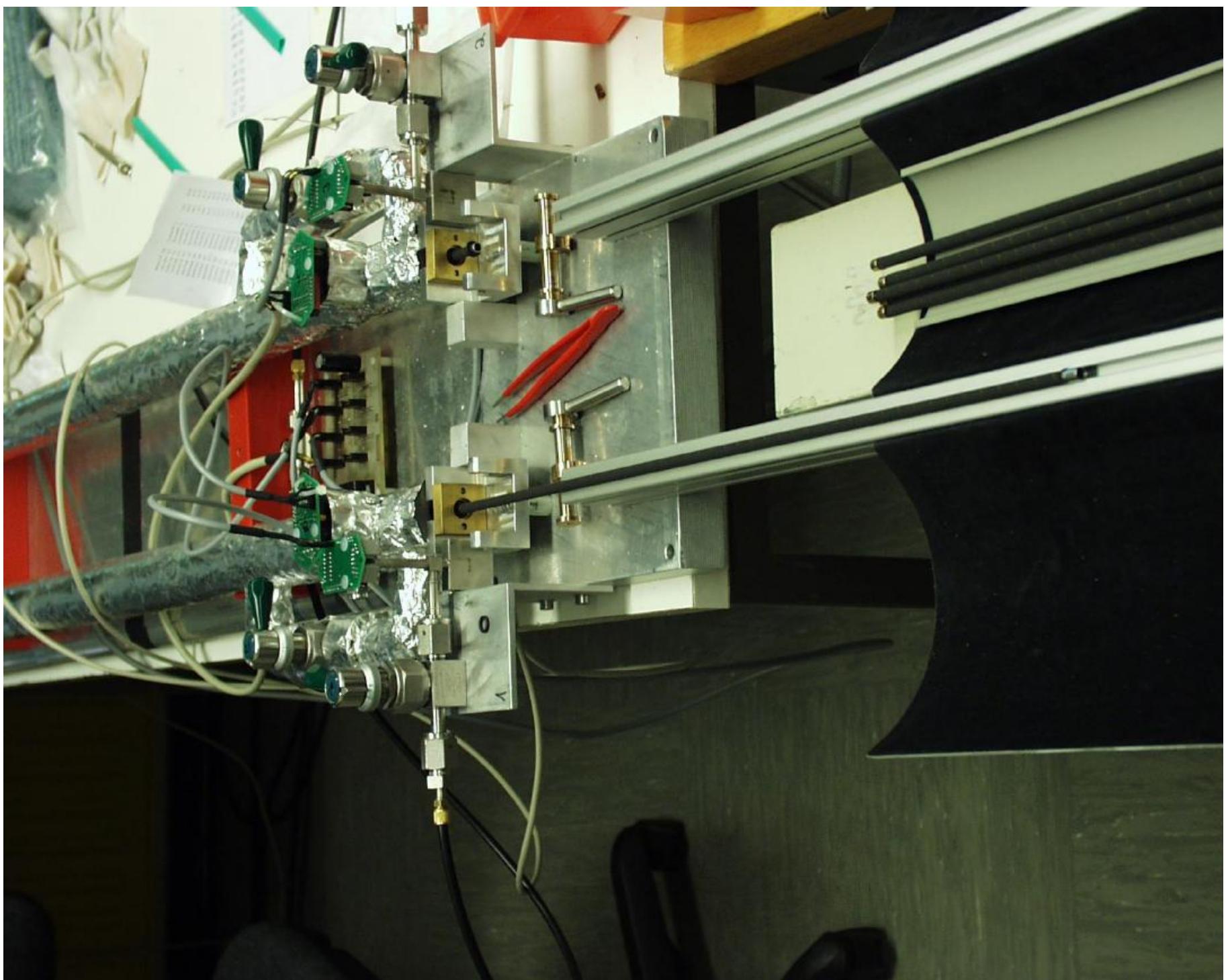


- Bad straws vs bad modules → perfect correlation

⇒ Need to test each of 5248 straws → need fast measurements

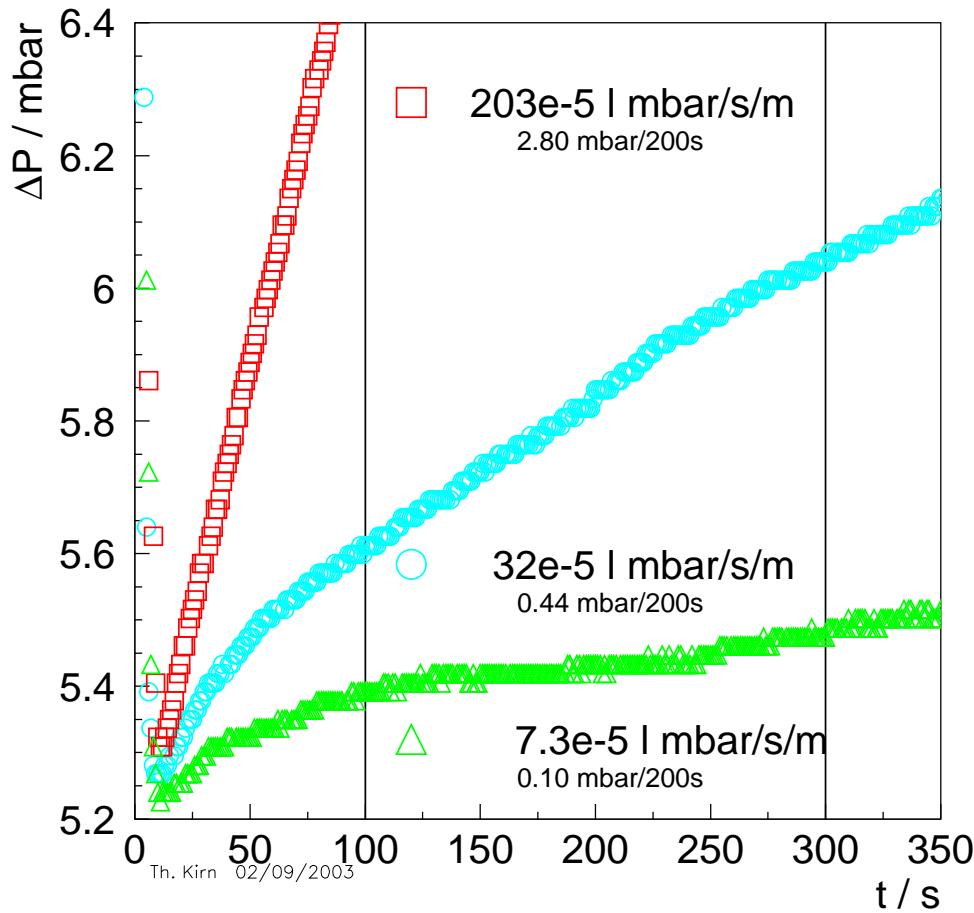
Single Straw Test



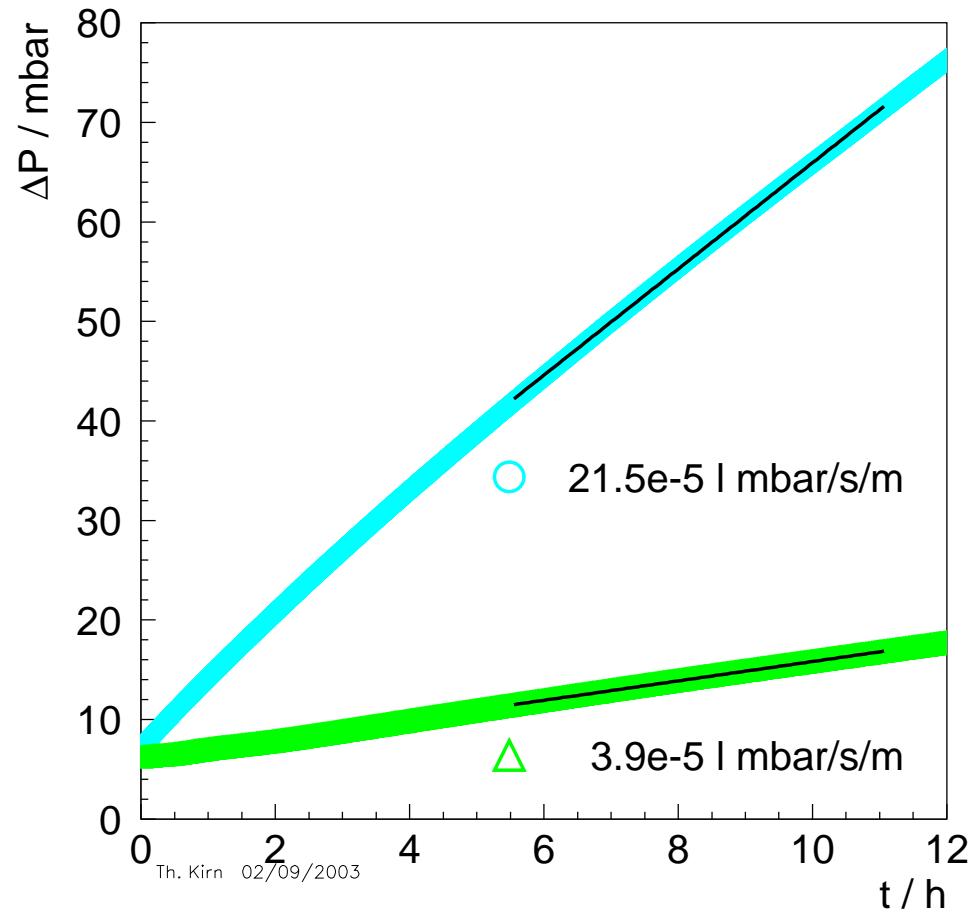


Single Straw Test

Single Straw ΔP 5min



Single Straw ΔP 12h

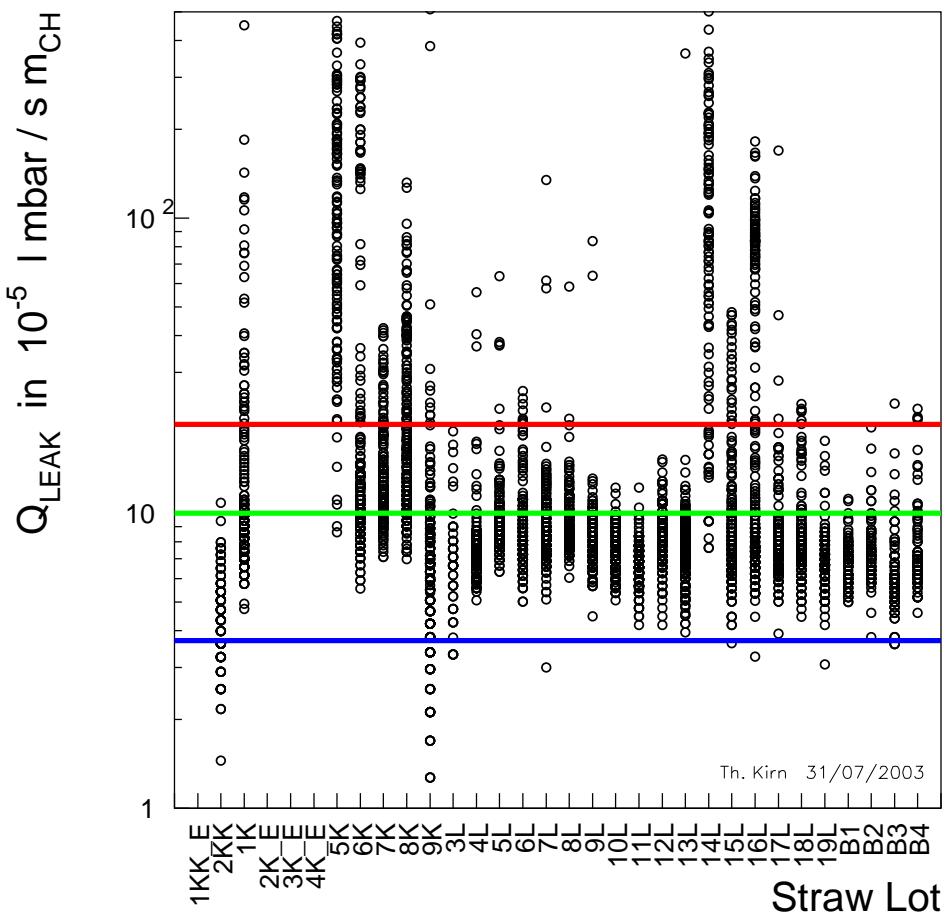


- 12h reference measurement over night

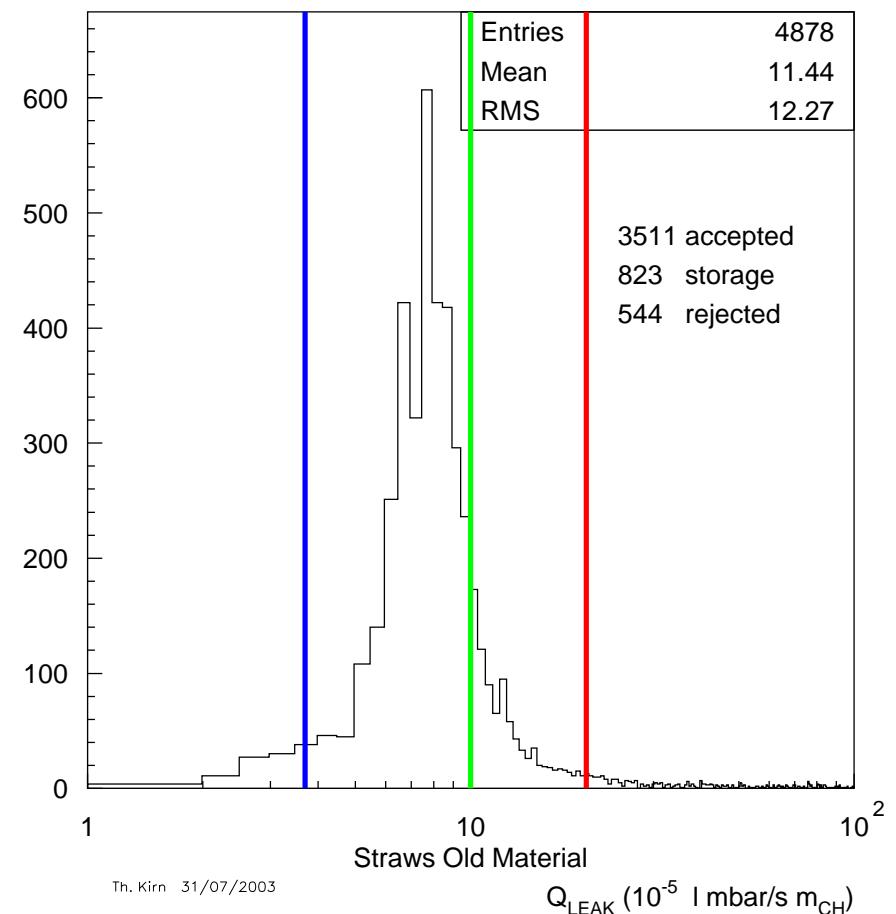
→ Δp -increase

Single Straw Test

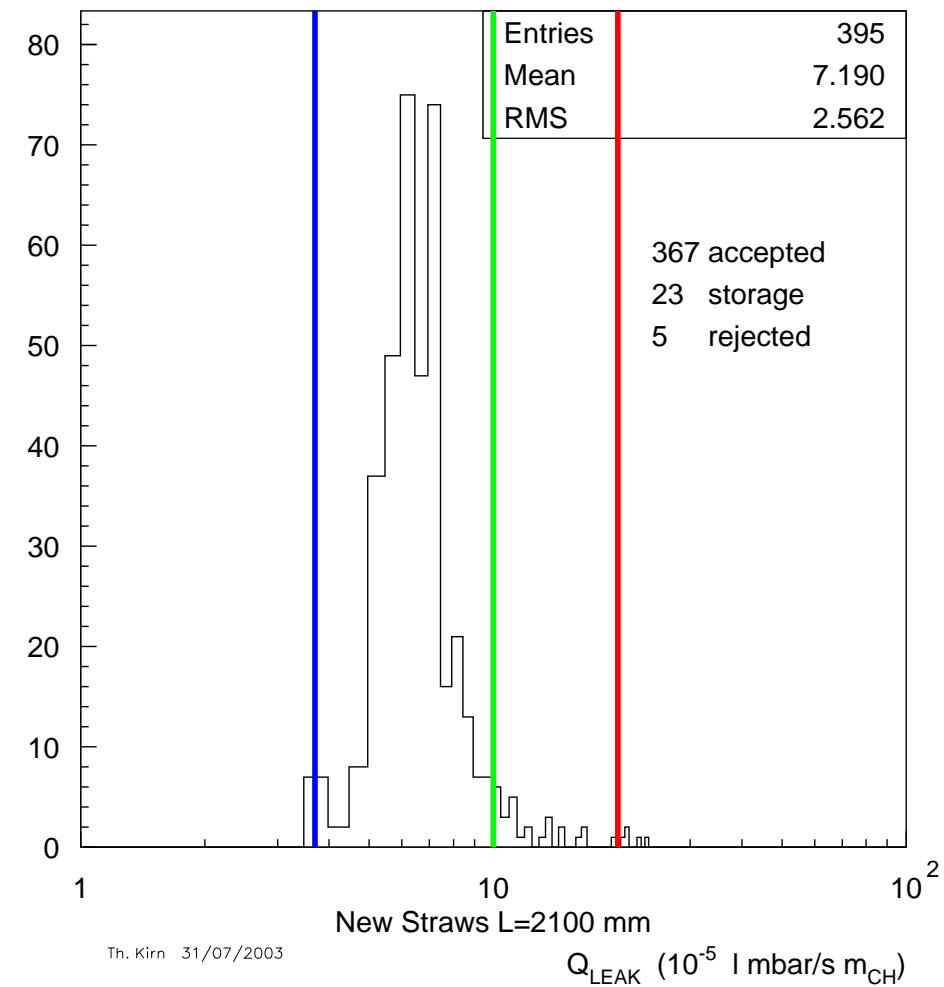
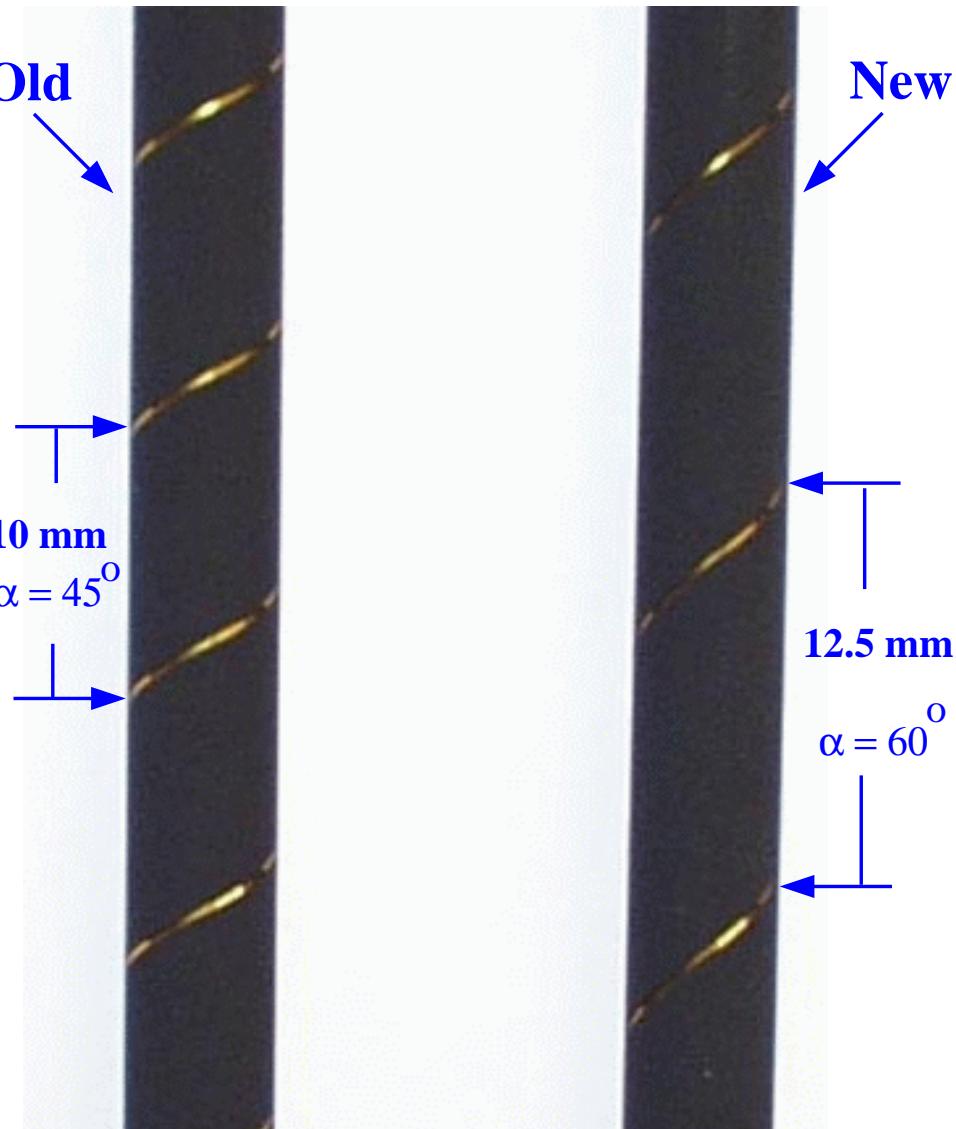
Straw-Production Lot-Statistics



$16 \text{ Straws/Module} \times 328 \text{ Modules} = 5248 \text{ Straws} \longrightarrow 1737 \text{ Straws missing}$
 $\longrightarrow \text{New Straws needed}$



Single Straw Test



→ 1800 new straws ordered

Module Production:

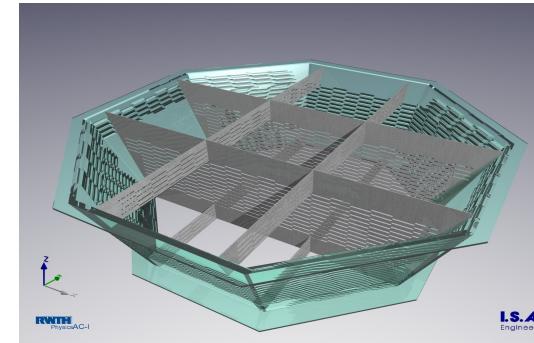
Single Straw Gastightness Test I. Phys. Inst.

Cutting & glueing of straw-modules FVT Company

Endpieces
glued to straws

Wire
tensioning
&
crimping

RWTH AC I.Phys.Inst.



Signal
Feedthru
Test

Wire
Tension
Measure
ment

Preview
(noise)
Test

Signal
Feedthru
Test

^{55}Fe
Gasgain
Measurement
Precalibration
 Ar/CO_2



Serial
Test
Leakage currents
Gastightness

Final
Potting

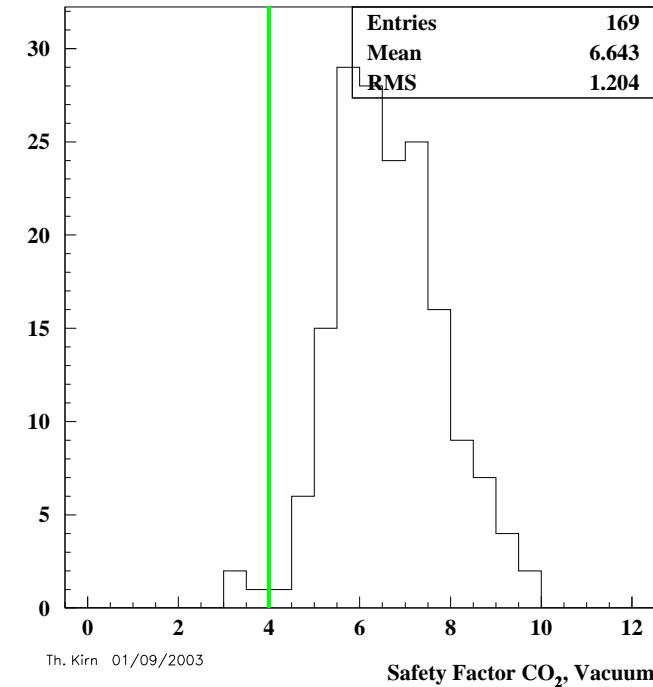
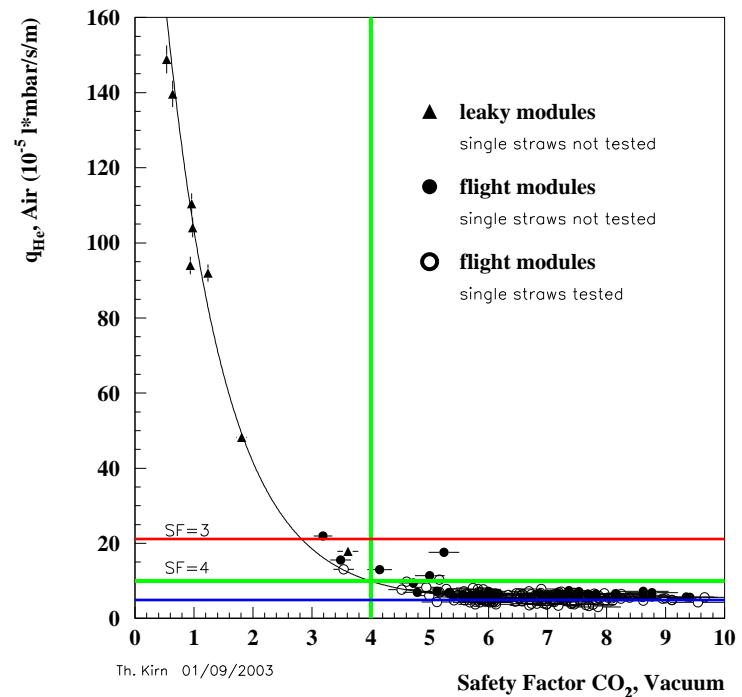
HV-board
mounting
&
Module
Potting

Signal
Feedthru
Test

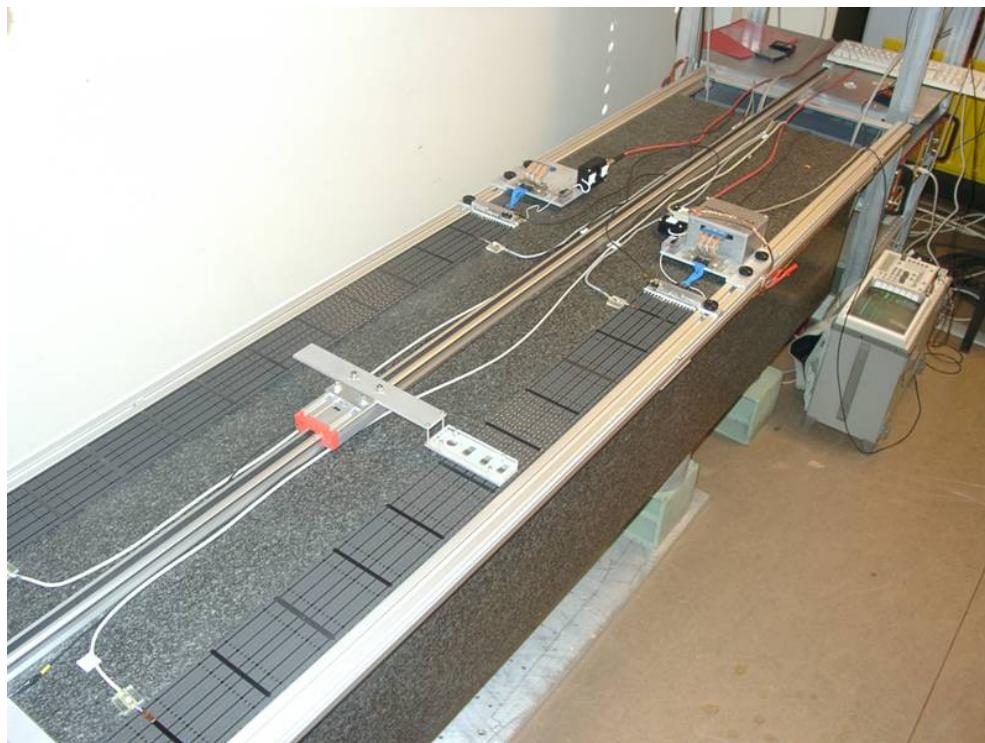
Module Production: Gastightness



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

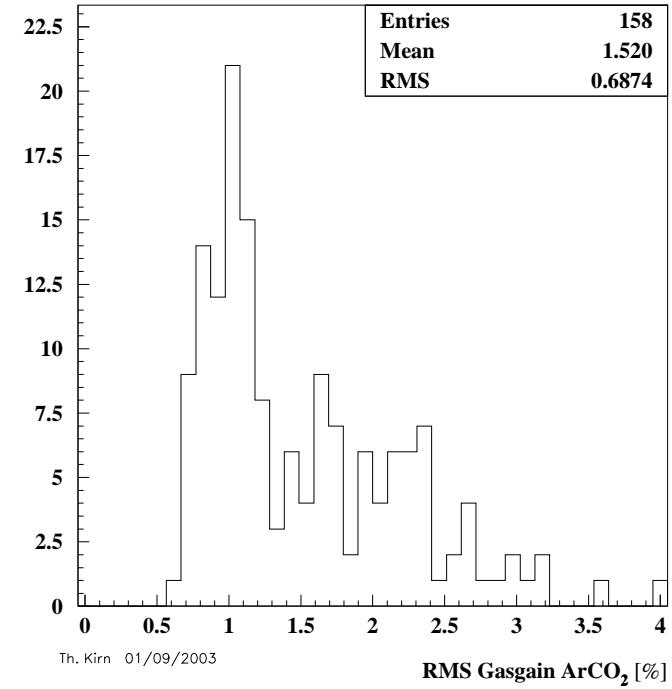
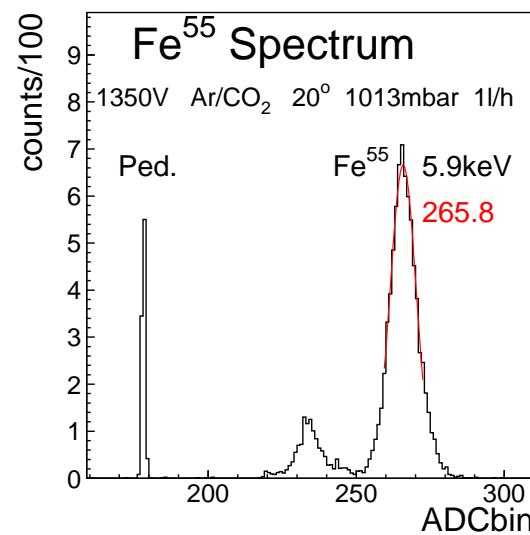


Measurement of Gas Gain with Fe⁵⁵ source



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

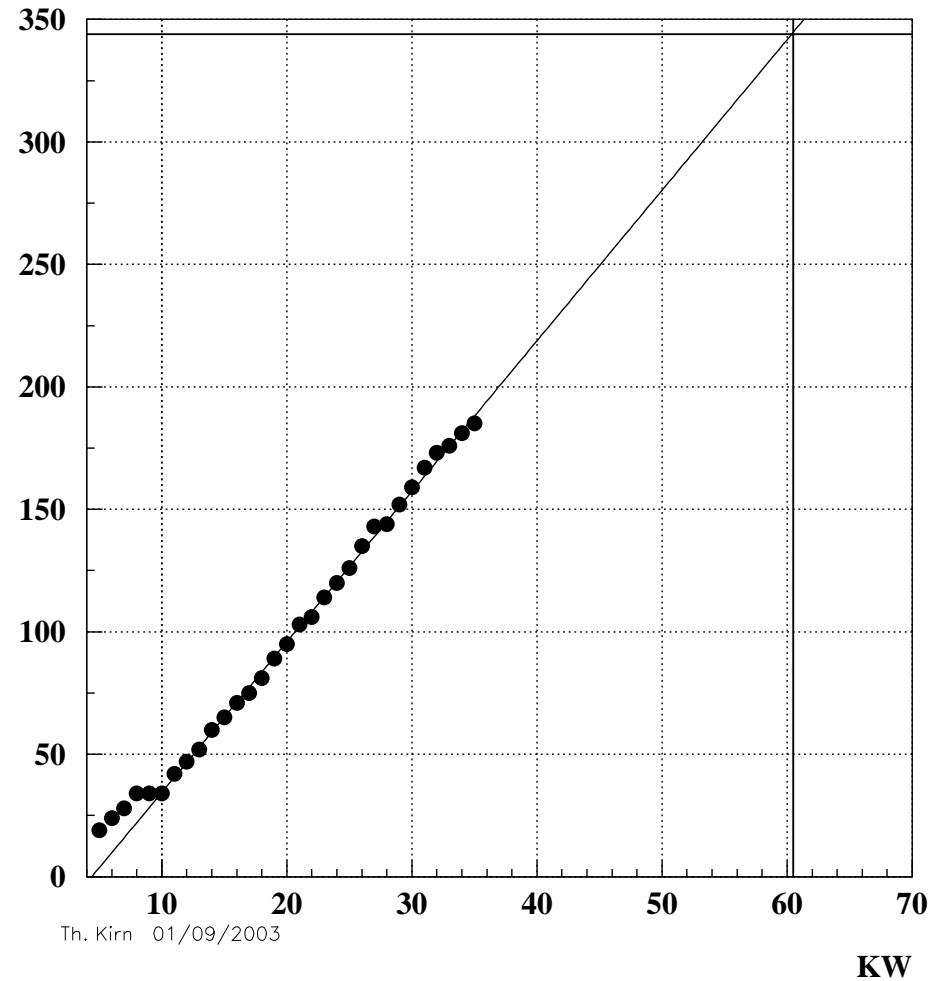


Average variation of gas gain: 1.5%

Module Production Status



Module Production 2003



End of Module Production: March 2004

Module Production Status

-9	-8	-7	-6	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	+6	+7	+8	+9	
260	268	276	284	292	300	308	316	324	20									
264	272	280	288	296	304	312	320	328										
259	267	275	283	291	299	307	315	323	19									
263	271	279	287	295	303	311	319	327										
258	266	274	282	290	298	306	314	322	18									
262	270	278	286	294	302	310	318	326										
257	265	273	281	289	297	305	313	321	17									
261	269	277	285	293	301	309	317	325										
188	196	204	212	220	228	236	244	252	16									
192	200	208	216	224	232	240	248	256										
187	195	203	211	219	227	235	243	251	15									
191	199	207	215	223	231	239	247	255										
186	194	202	210	218	226	234	242	250	14									
190	198	206	214	222	230	238	246	254										
185	193	201	209	217	225	233	241	249	13									
189	197	205	213	221	229	237	245	253										
	128	136	144	152	160	168	176	184	12									
124	132	140	148	156	164	172	180											
127	135	143	151	159	167	175	183		11									
123	131	139	147	155	163	171	179											
126	134	142	150	158	166	174	182		10									
122	130	138	146	154	162	170	178											
125	133	141	149	157	165	173	181		9									
121	129	137	145	153	161	169	177											
064	072	080	088	096	104	112	120		8									
060	068	076	084	092	100	108	116											
063	071	079	087	095	103	111	119		7									
059	067	075	083	091	099	107	115											
062	070	078	086	094	102	110	118		6									
058	066	074	082	090	098	106	114											
061	069	077	085	093	101	109	117		5									
057	065	073	081	089	097	105	113											
004	012	020	028	036	044	052			4									
008	016	024	032	040	048	056												
003	011	019	027	035	043	051			3									
007	015	023	031	039	047	055												
002	010	018	026	034	042	050			2									
006	014	022	030	038	046	054												
001	009	017	025	033	041	049			1									
005	013	021	029	037	045	053												

BODY

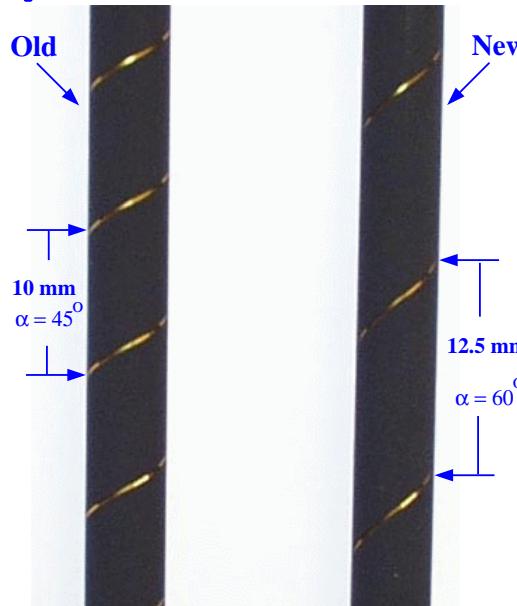
produced

MODULE

under test

ok

Space Qualification



MOD 06 Length <i>mm</i>	Air $q_{He} \cdot 10^{-5} \frac{l \cdot mbar}{s}$	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 <i>mm</i>	Air $q_{He} \cdot 10^{-5} \frac{l \cdot mbar}{s}$	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	

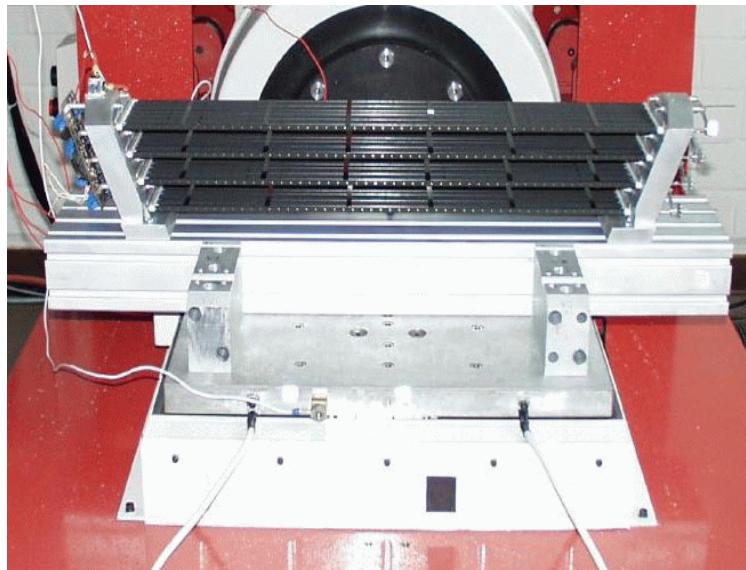
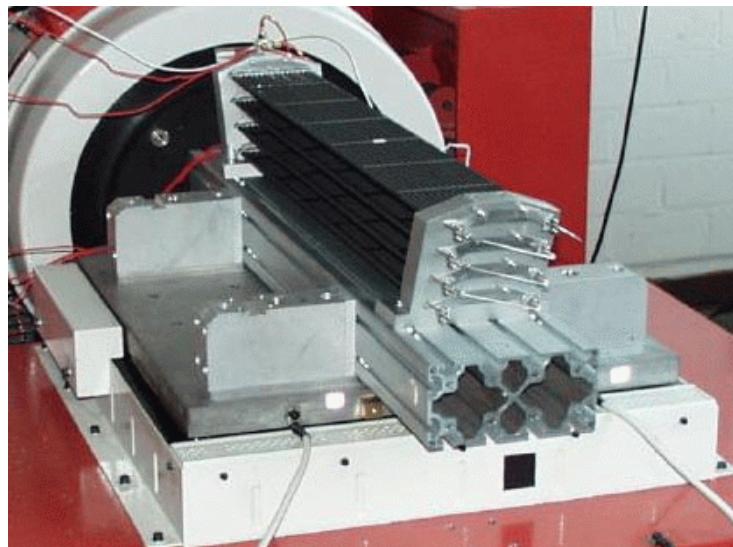
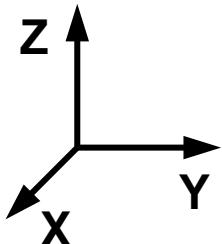
Vibration test, Thermo vacuum test → Eigenfrequencies, Leak Rate, Gas Gain

Space Qualification, Vibration Test I+II



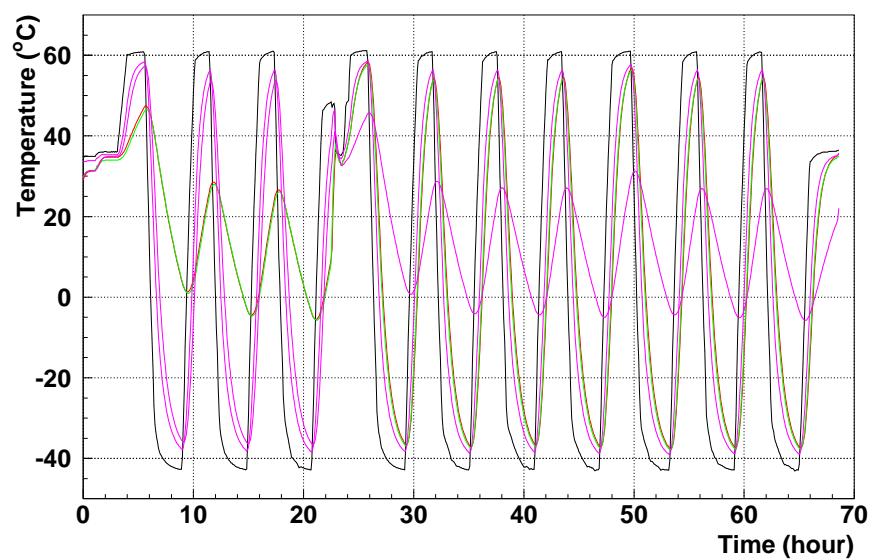
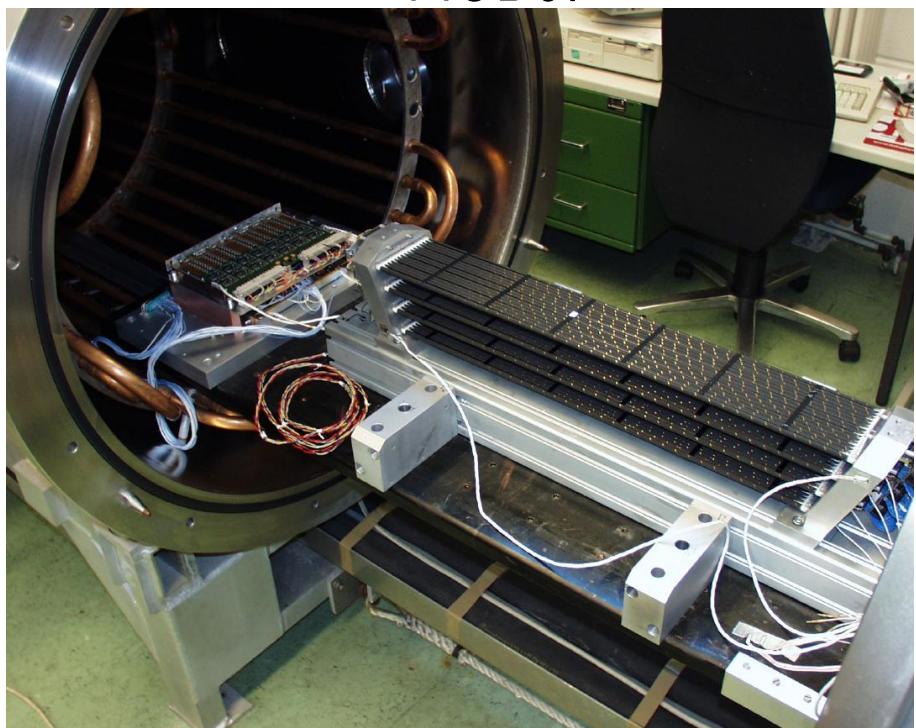
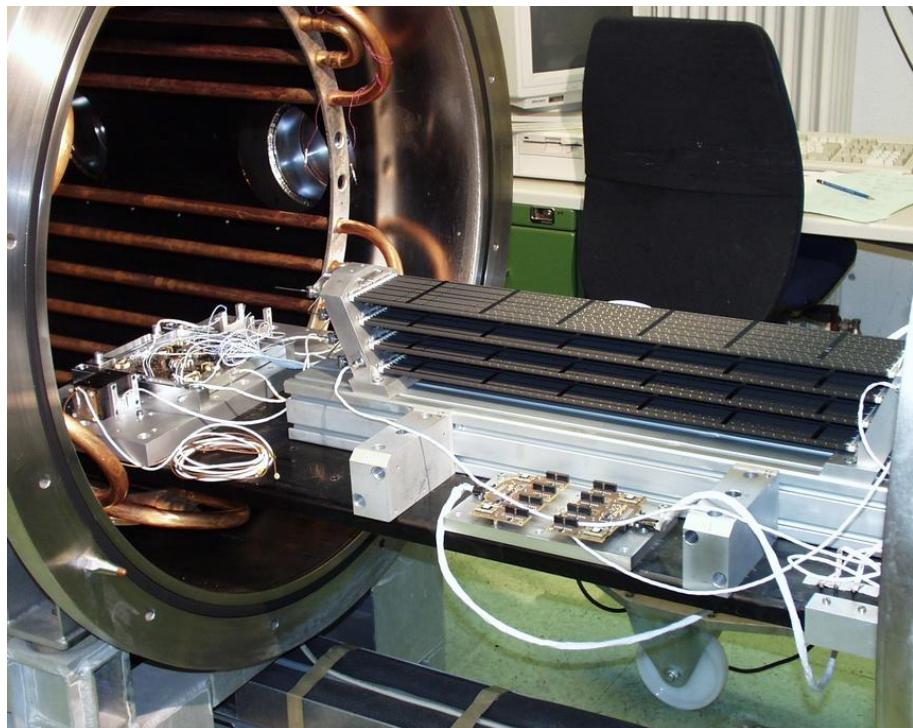
Vibration-Test-Cycle:

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

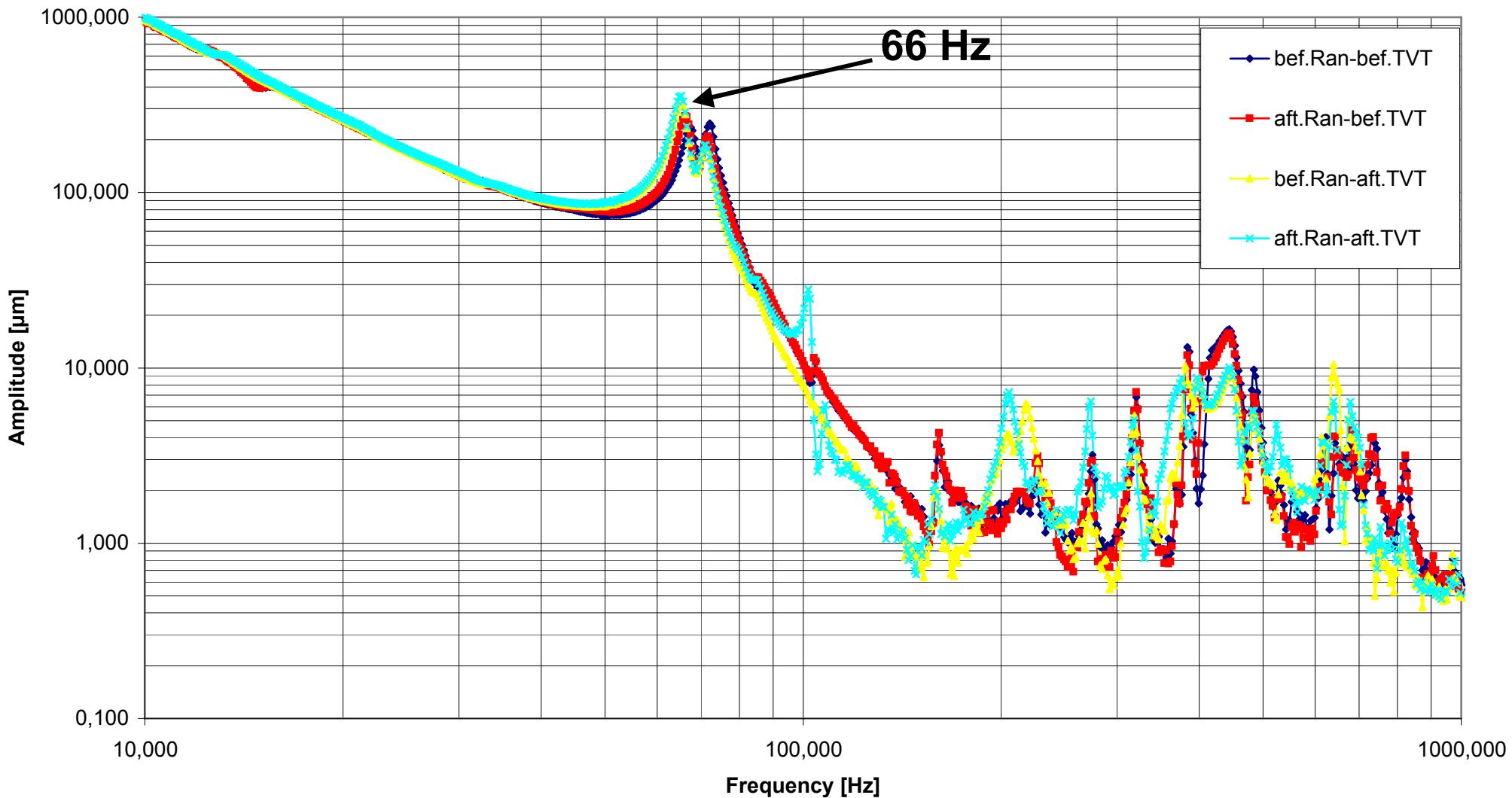
587	5.7			5.2
611	7.0			6.1
635	4.5			3.7
659	3.8			3.5
Jigg06	21.5	19.9	22.4	19.4

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

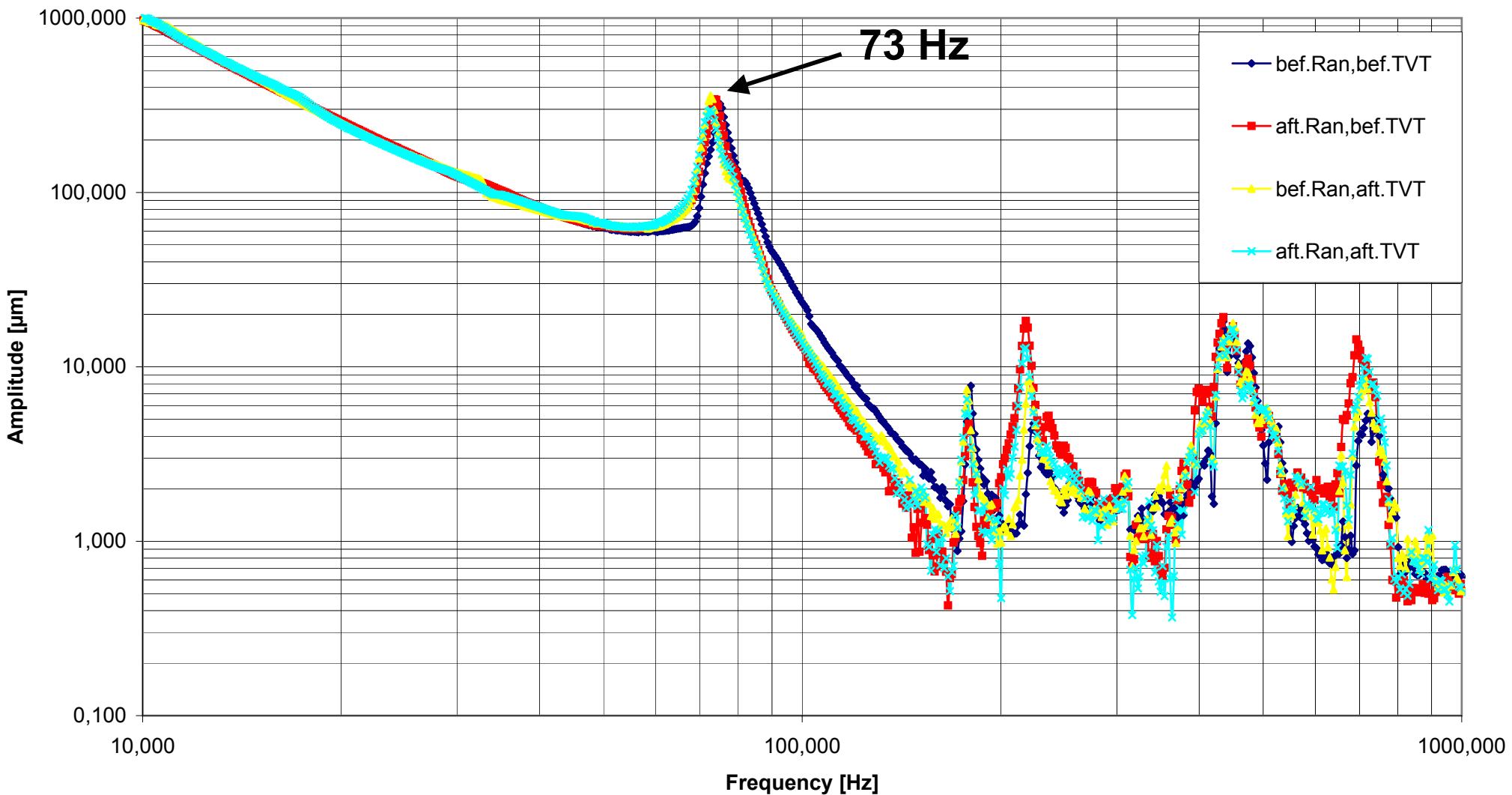
Space Qualification, Eigenfrequencies

AMS-02 TRD MOD-06

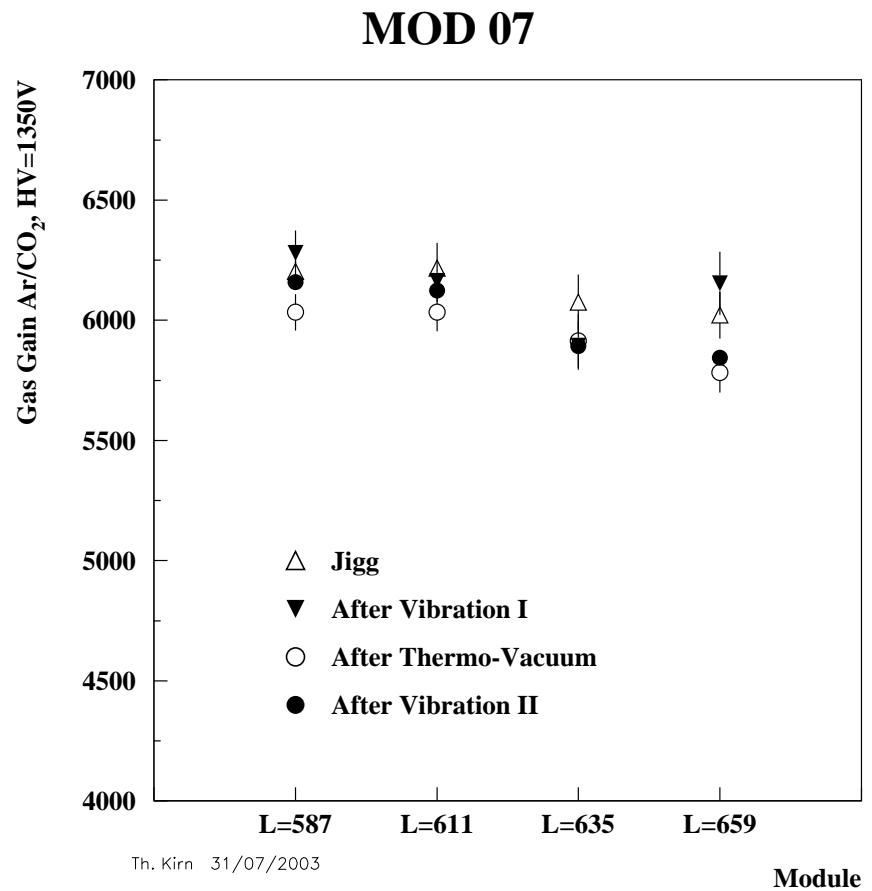
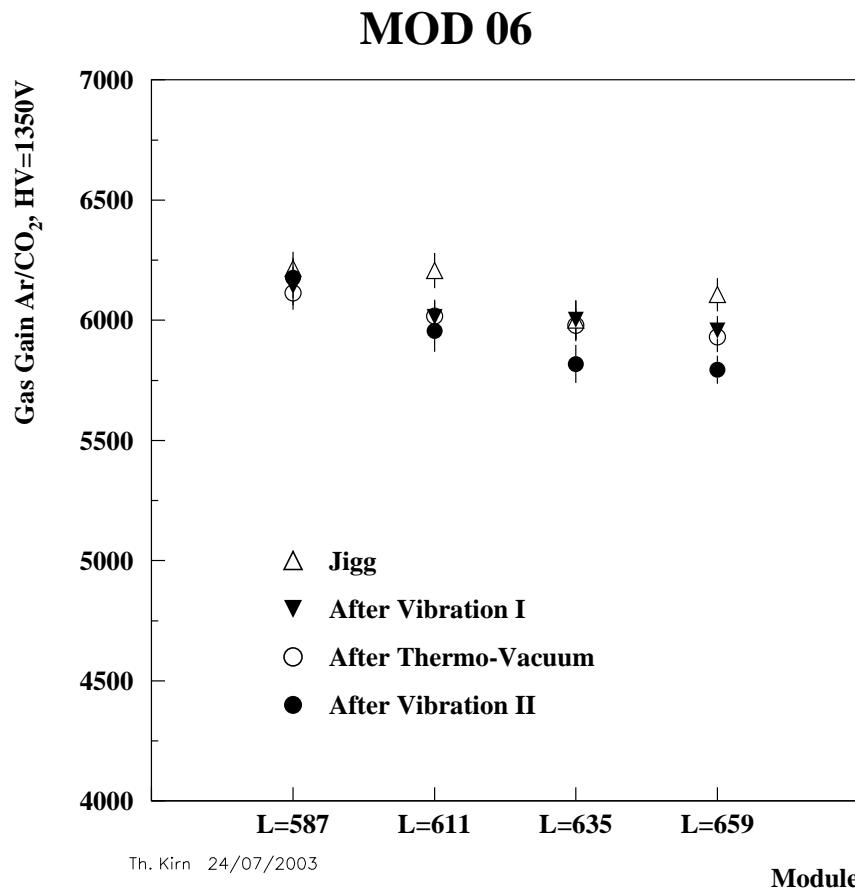


Space Qualification, Eigenfrequencies

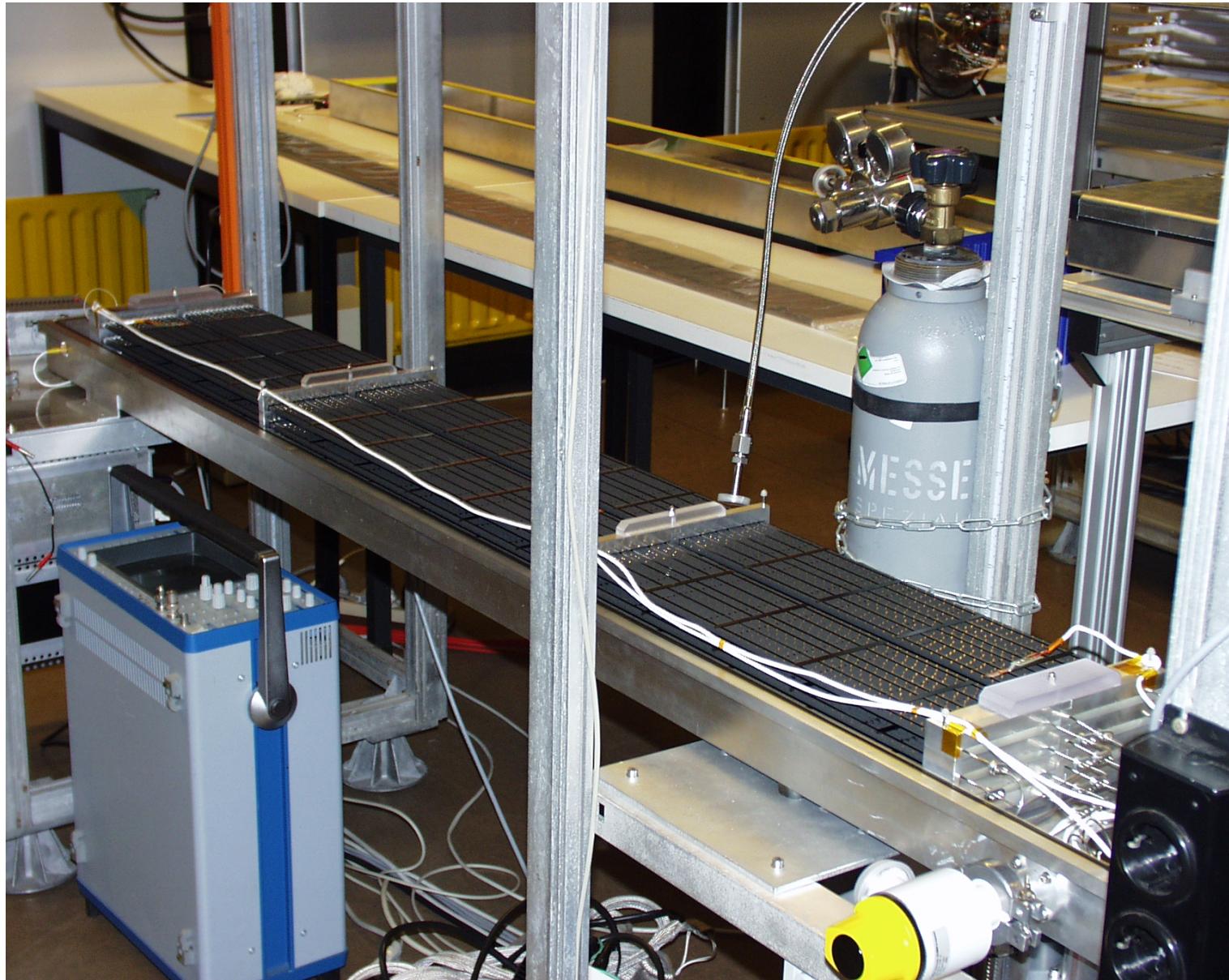
AMS-02 TRD MOD-07

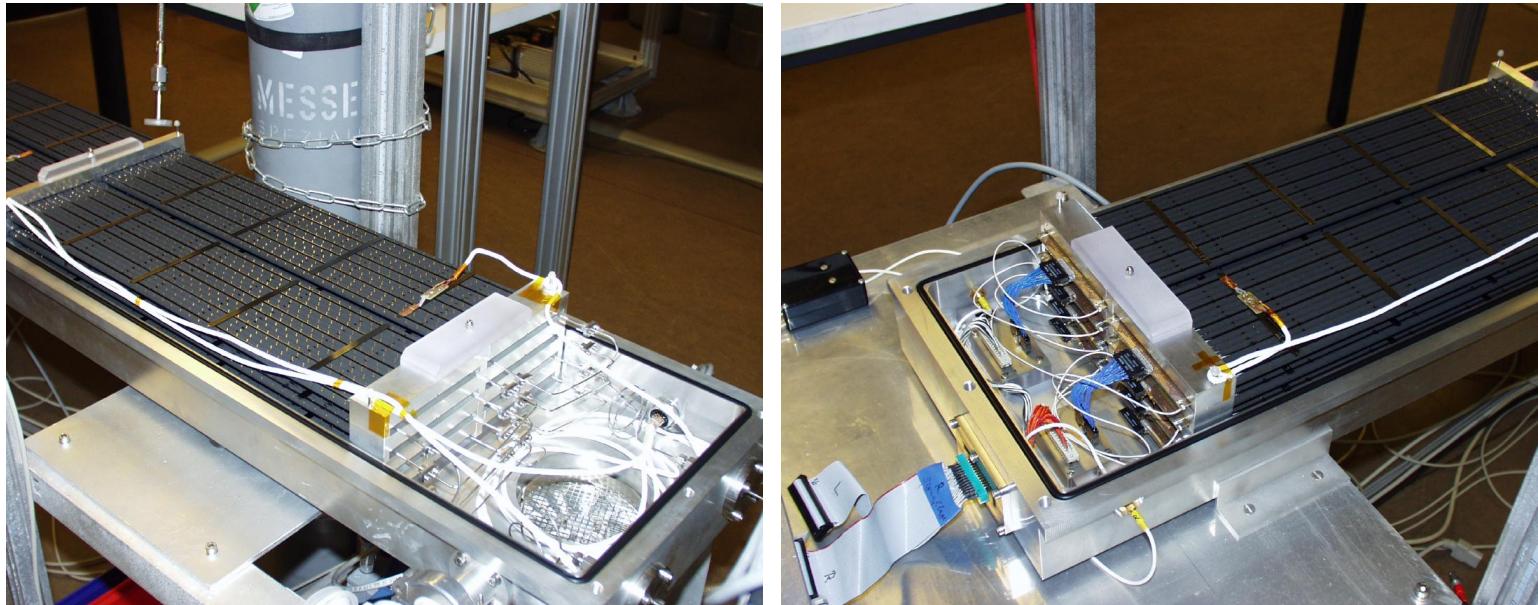


Space Qualification, Gas Gain



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 → 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 → autumn 2004
- AMS02-Assembly end of 2004

