Preliminary Design Report
PDR

AMS 02

TRD

RWTH Physics AC-I

12.05.00

Transition Radiation Detector (TRD)

1 Introduction

The role of the TRD is to discriminate between $e^-/\overline{p}$ and e^+/p over the range E = 3 - 300 GeV. This is accomplished by detecting the presence of X-ray photons emitted by electrons and positrons when they pass through a radiator. $p, \overline{p}$ and nuclei do not emit such radiation. The radiation is detected in proportional tubes filled with preferentially Xe:CO_2 (80:20) (or Xe:CF_4 (80:20)). Xenon is chosen as it gives a very high efficiency for photon detection. By proportional multiplications the ionization electrons are converted into a measureable signal.

This package describes the flight hardware of the AMS Transition Radiation Detector. An overview of the TRD is given in section 2 (see also fig. 1). The geometrical layout of the TRD is given in section 3. The construction of straw modules - the basic TRD detector elements - is decribed in this section. The mechanical properties of the main components of the TRD are given in section 4. The gas supply system as well as the high voltage system is described in a separate report (U. Becker, J. Burger, P. Fisher MIT). The off-TRD part of the TRD signal electronics (ADC's, power supplies) is explained in the report about the AMS electronics (M. Capell, V. Koutsenko)

2 Overview

2.1 TRD detector functional units

A package of 16 long (2 m) thin (wall 70 μm, $\varnothing$ 6 mm) cylindrical Kapton tubes equipped with a 30 μm diameter goldplated tungsten wire at the center is called a straw module. Filled with Xe:CO_2 at 1bar for low energy photon and charged particle detection the tubes are operated in proportional mode. There are 2 orthogonal sets of strawmodules: 12 layers parallel to the y-axis in between (top, bottom) 2 x 4 layers parallel to the x-axis. The transition radiation ($\approx$ 10 keV photons) is produced by the passage of ultrarelativistic particles ($\gamma > 5000$) through a fleece of fibres ($\varnothing \approx 15$ μm). Layers of strawmodules are covered with this low density fleece (thickness: 6 mm and 17 mm respectively) The electrical signal from the detection of transition radiation photons is amplified (32 channels per chip) in chips mounted on service boards connected to the $\pm$x($\pm$y) ends. Gas (Xe:CO_2) is circulating at low speed through 44 closed loops (see gas supply system report). Straw modules are fixed in position inside two orthogonal set of 2 bulkheads (fig. 2). The detector container forms a truncated pyramide, that is called octagon (fig. 2). The ends of the 2 chamber sets protrude through the octagon for service by the electronics and the gas tubing (fig. 3). The detector container is covered with a CFC plate serving as low energy particle shield at the same time (fig. 4, 5). The octagon sits on the TRD support plate. This plate is mounted together with the ToF support plate on 4 bearing tubes (fig. 6) onto the USS structure. Operational safety aspects (gas pressure, high voltage, out gassing) are described in the safety report.

The total TRD assembly is wrapped in a multilayer thermal insulation (part of which might be used as an emi shield).

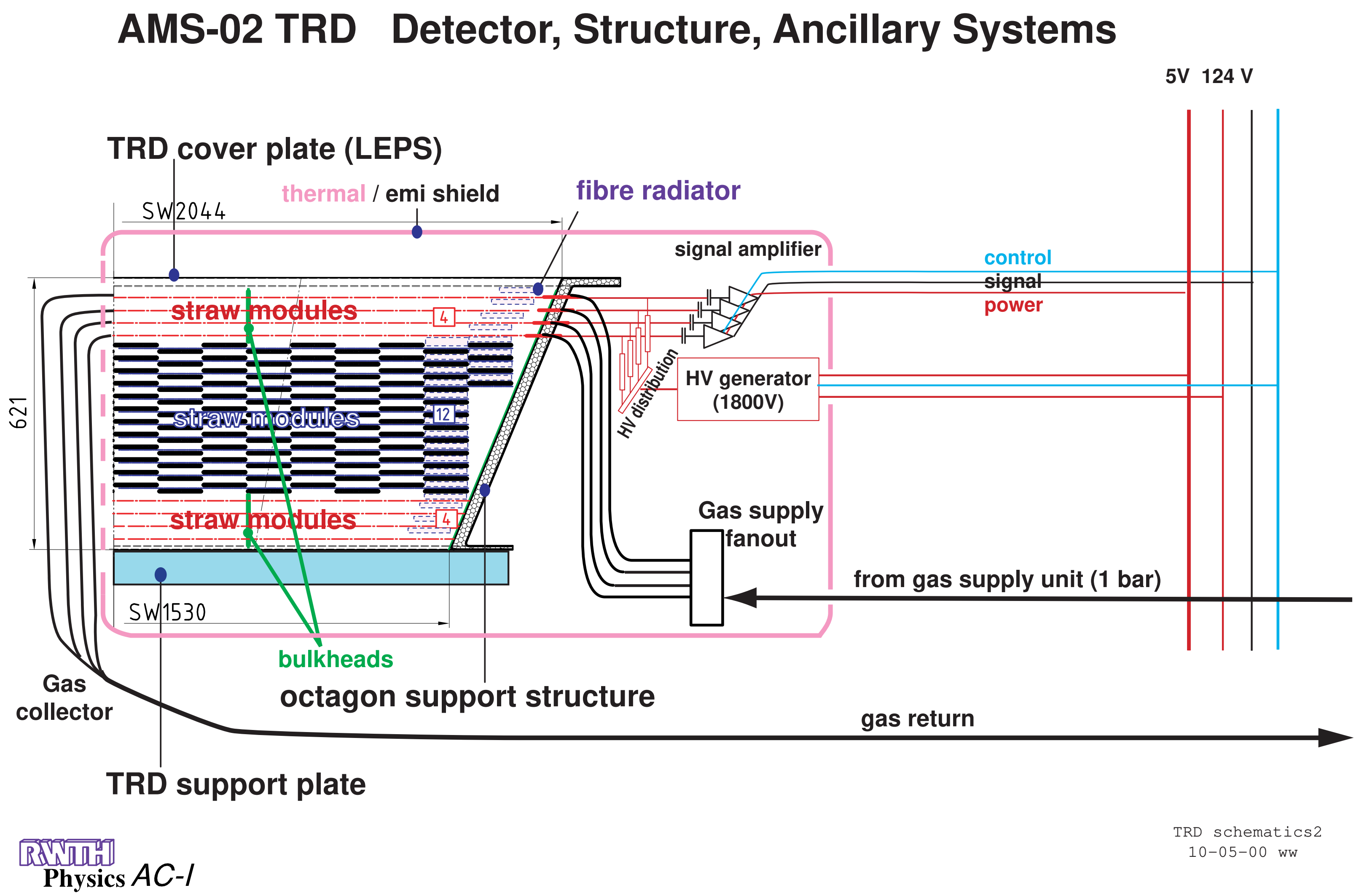

Figure 1: TRD system components

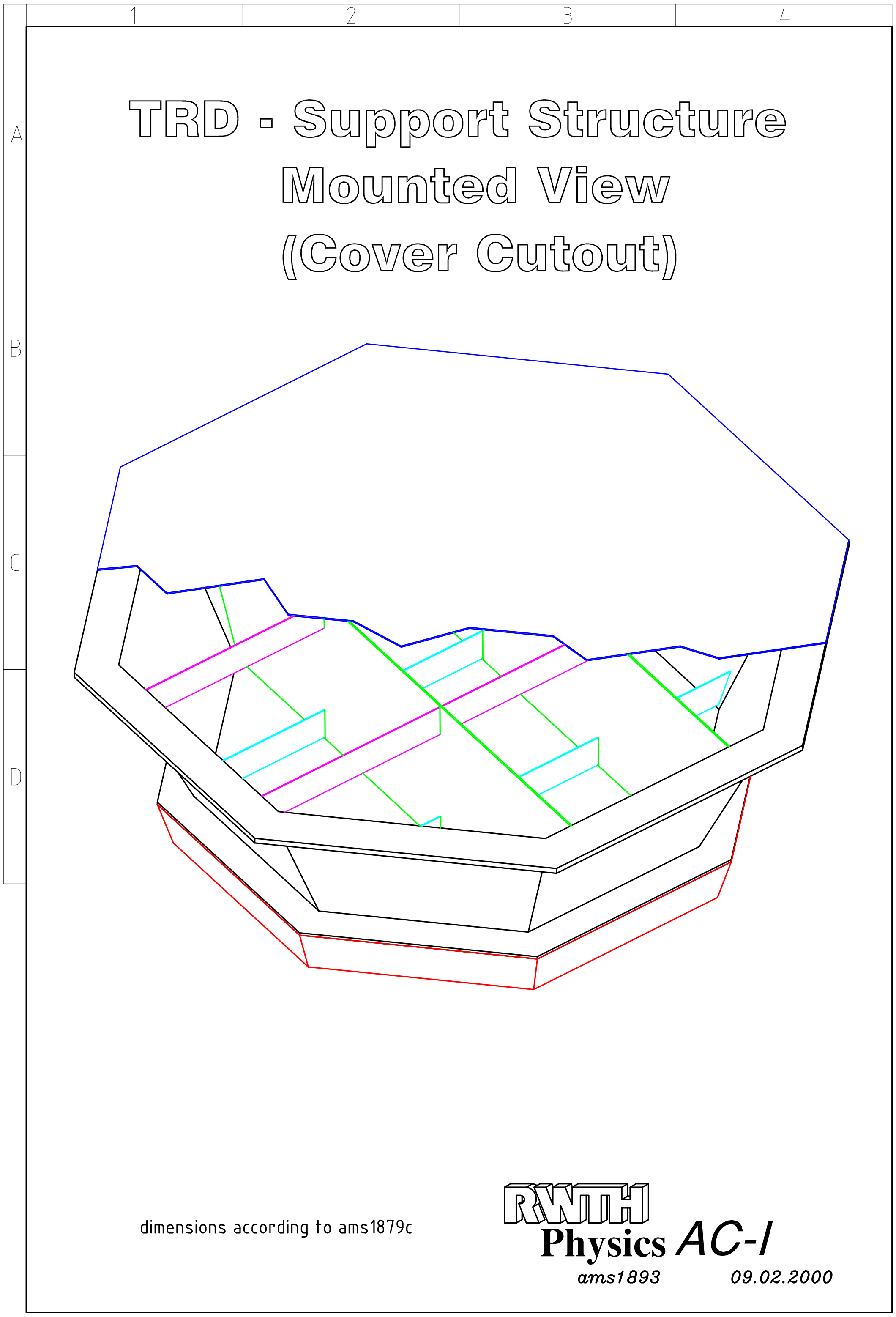

Figure 2: TRD bulkheads inside octagon

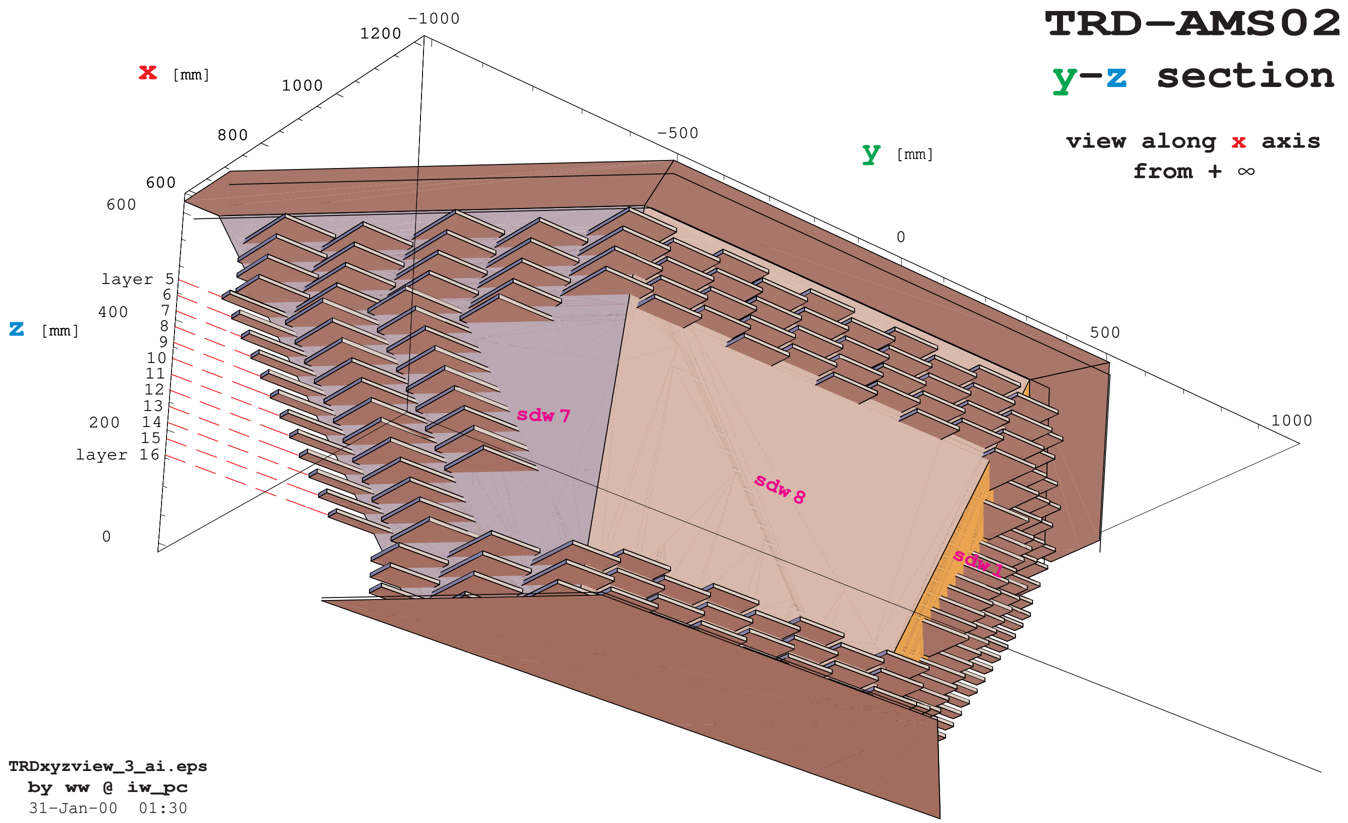

Figure 3: TRD octagon with straw modules, 3D model, view along X-axis

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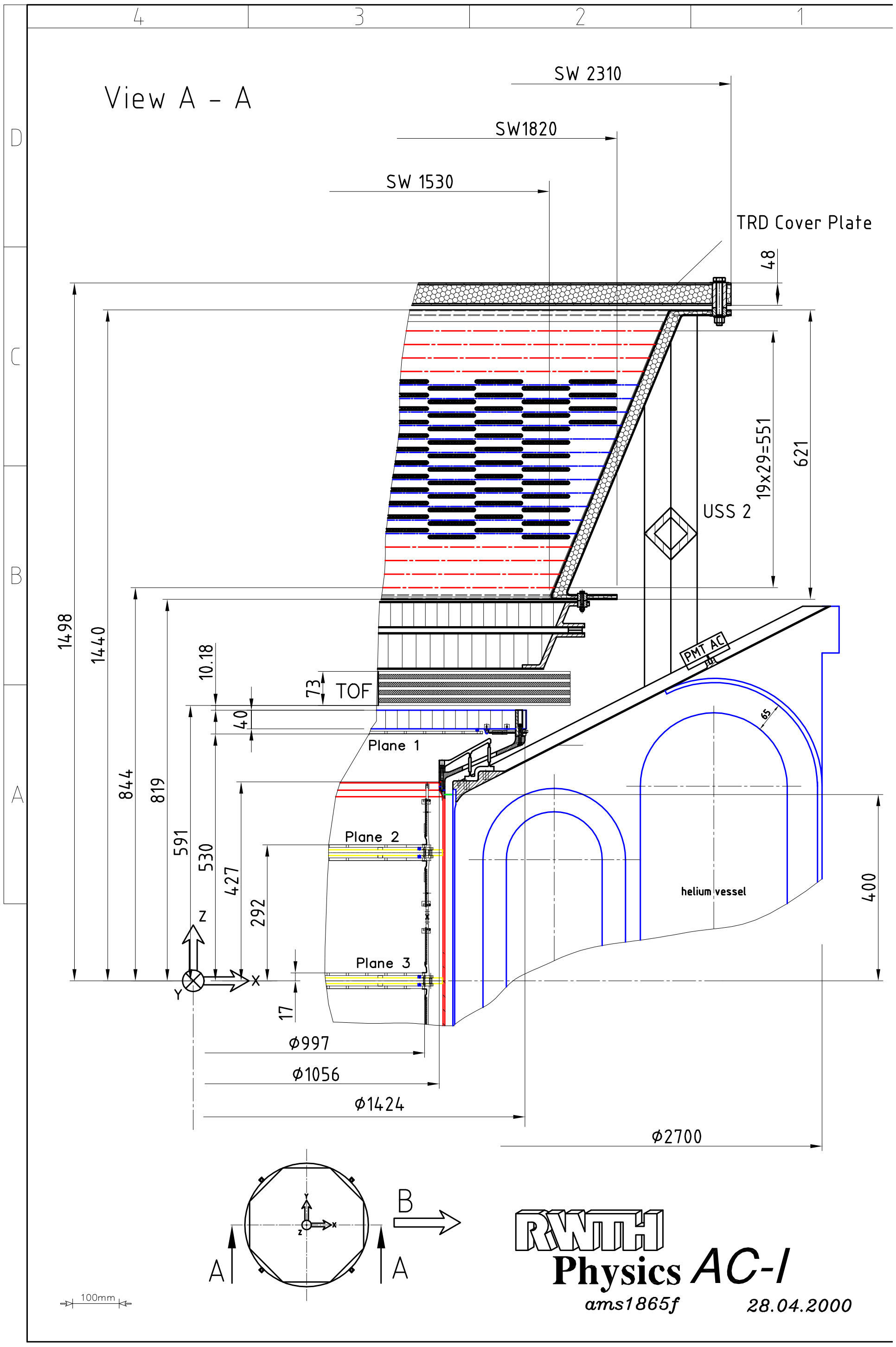


Figure 4: AMS02 TRD/Tracker dimension central (y=0, $\alpha = 0^o$) X-Z cut

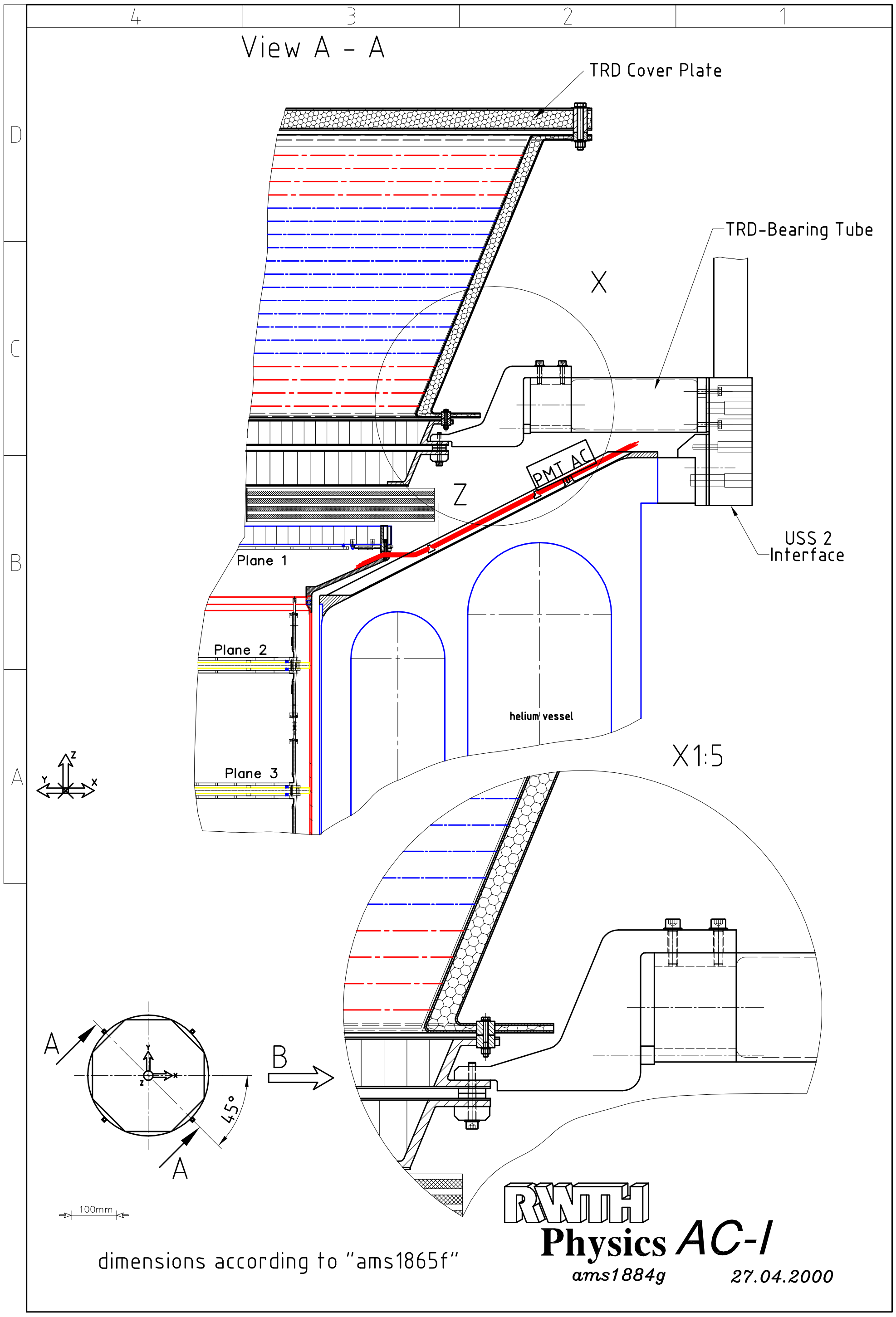


Figure 5: AMS02 TRD support central (y=0, $\alpha = 45^o$) X-Z cut

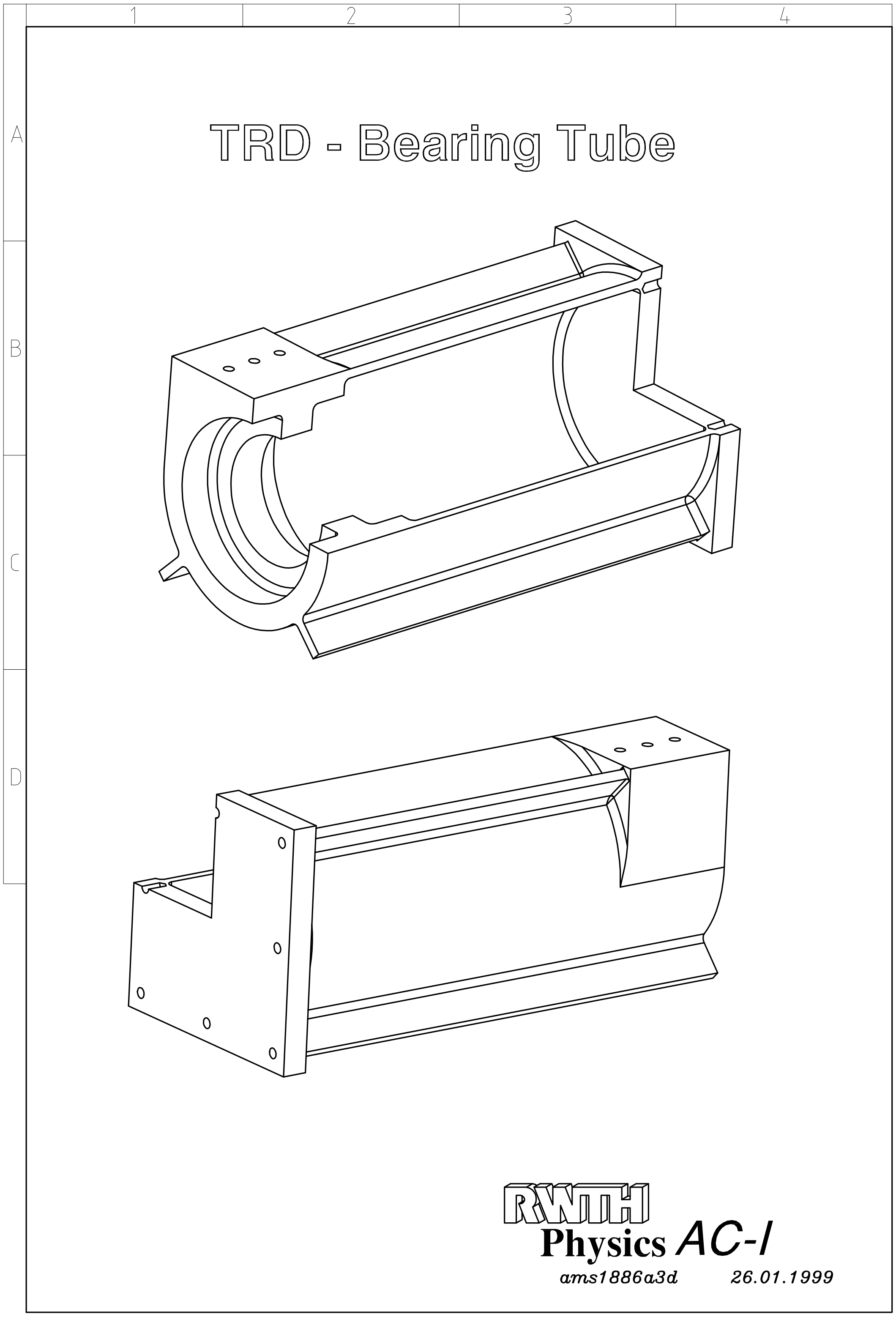


Figure 6: TRD bearing tube

3 Geometry

3.1 Structure

The octagon is built up from CFC honeycomb panels (fig. 7). For some details see section 4.2. The 2 sets of bulkheads transmit the straw chamber load to the octagon structure. The maximum free span of a chamber modele is $\approx$ 2 ft.

3.2 Straw chambers

Straw chambers (60) are in production right now (May 2000) for beam tests later this summer (figs. 8, 11, 13). The prototype strawmodule has 3 stiffeners (fig. 20). The flight strawmodule (fig. 23) has 6 (fig. 24) stiffeners, providing high transversal stiffness ($f_0 > 100$ Hz). The individual straws are fabricated from a multilayer foil. The foil cross section is shown in figure 9.

Polycarbonate endpieces do accomodate 1) the wire fixations (CuTe), 2) the gas supply and outlet channels and provide support for 3a) signal and 3b) high voltage contact points. For detail on strawmodule production the figures 11 to 22 may be consulted. The materials used for construction are listed in figure 10.

Neighbouring columns of straw chamber modules are offset in z by half a layer thickness (fig. 23) for better bulkhead stiffeness.

3.3 Readout- and HV-grouping

Blocks of 8 (6) straw chamber modules form a readout-group (fig. 25, fig. 26). The HV channels are grouped accordingly (figs. 27, fig. 28).

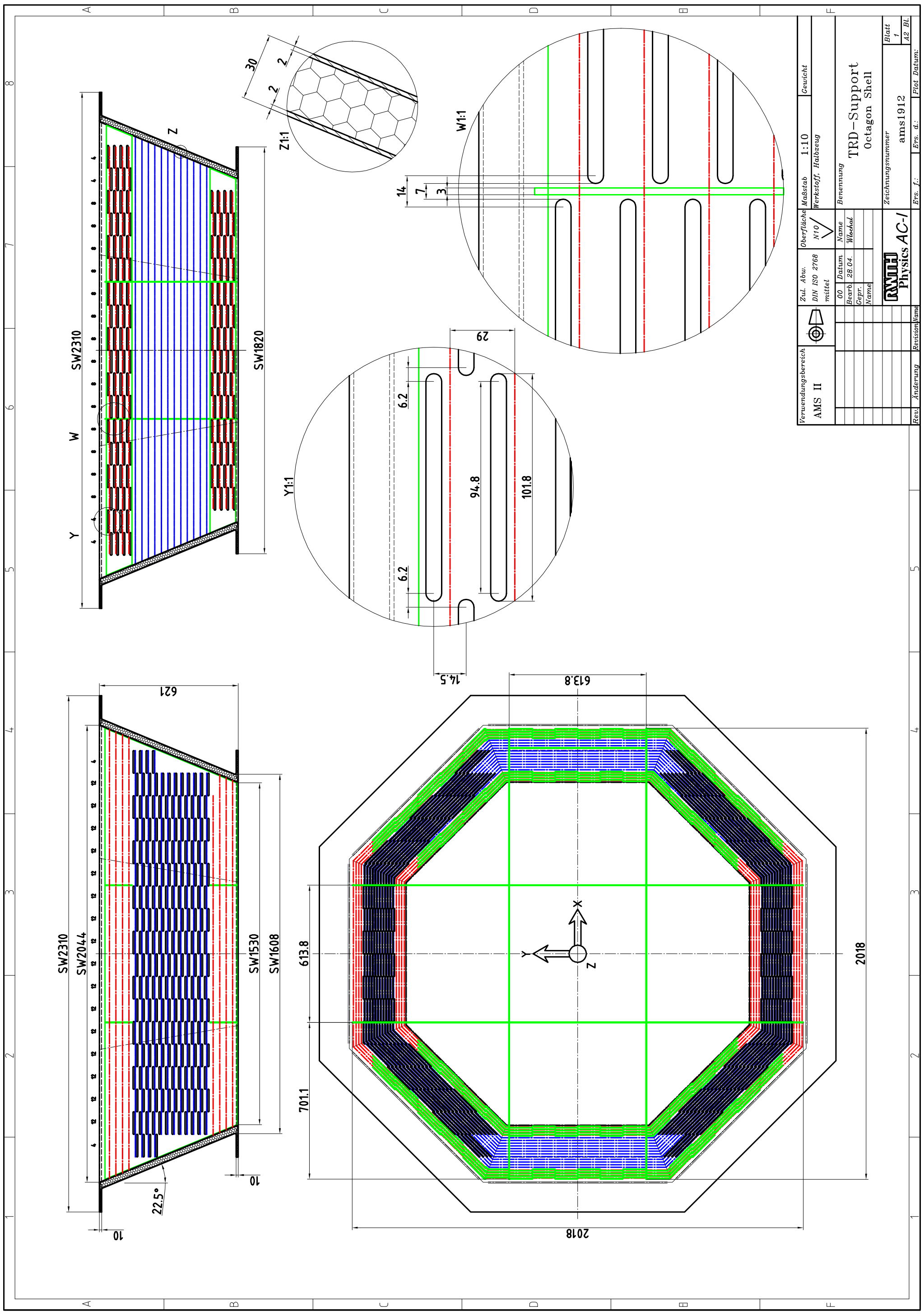


Figure 7: TRD principal views X-Y, X-Z, Y-Z, inserts show bulkhead cut outs

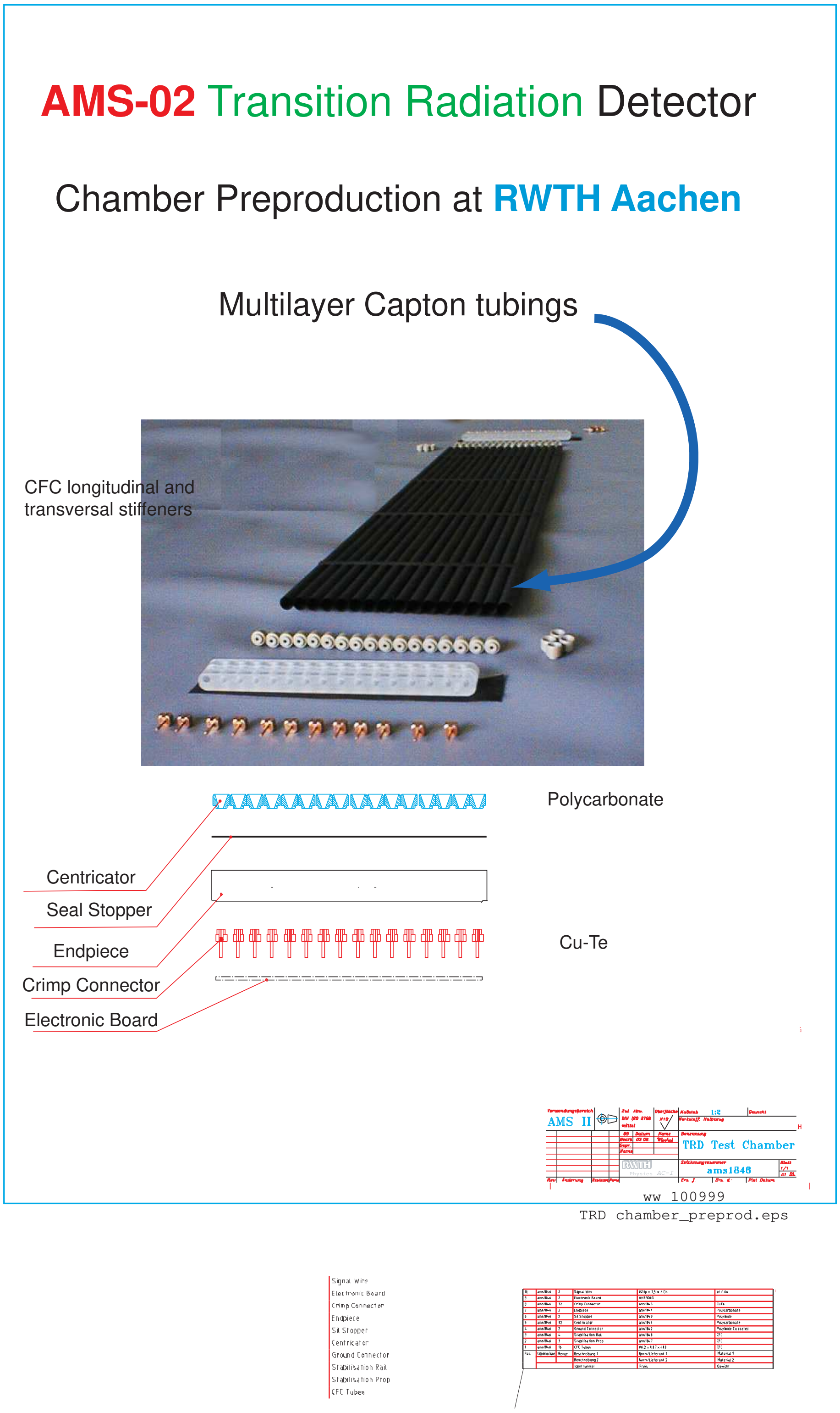


Figure 8: Straw module production

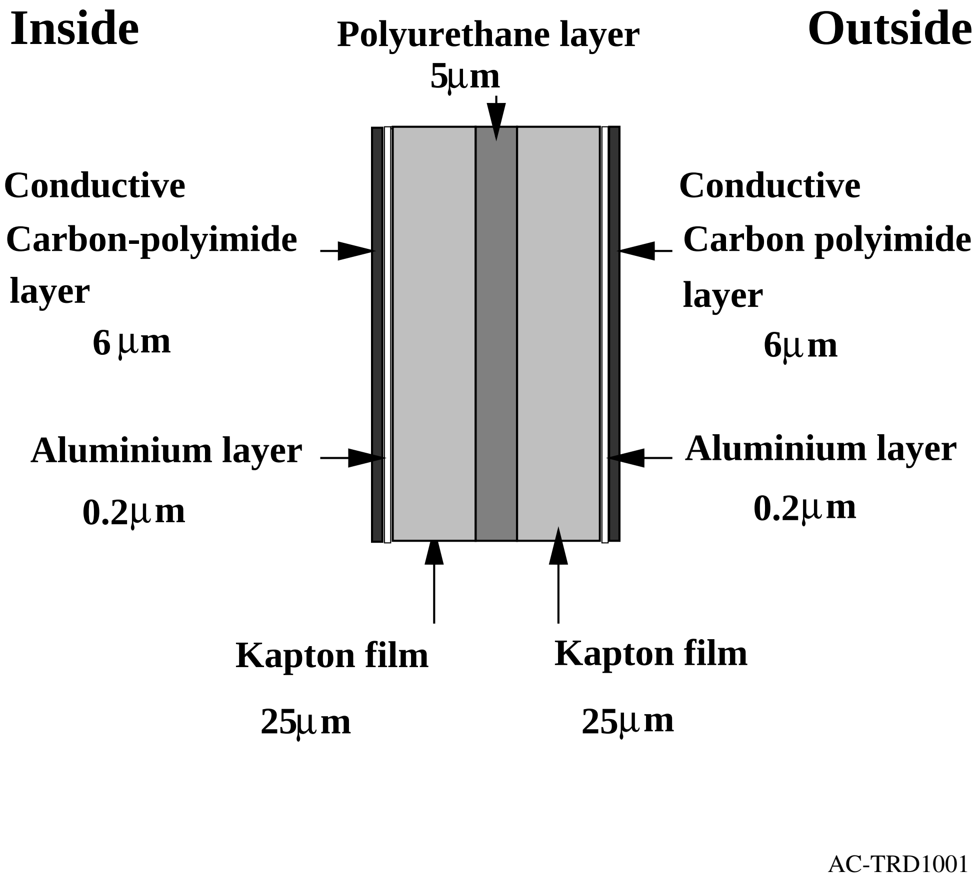


Figure 9: Composition of straw wall

- Inner diameter: 6.02 mm
- Wall thickness: 72 μm
- Length: 1.5 to 2.2 m

10	ams1846	2	Signal Wire	Φ20μ x 7,5 m / Ch.	W / Au
9	ams1846	2	Electronic Board	HVBRD03	
8	ams1846	32	Crimp Connector	ams1845	CuTe
7	ams1846	2	Endpiece	ams1841	Polycarbonate
6	ams1846	2	Sil Stopper	ams1843	Polyimide
5	ams1846	32	Centricator	ams1844	PEEK
4	ams1846	2	Ground Connector	ams1842	Polyimide Cu coated
3	ams1846	4	Stabilisation Rail	ams1848	CFC
2	ams1846	3	Stabilisation Prop	ams1847	CFC
1	ams1846	16	CFC Tubes	Φ6.2 x 0.07 x 400	Polyimide
Pos.	Stücklisten-Name	Menge	Beschreibung 1	Norm/Lieferant 1	Material 1
			Beschreibung 2	Norm/Lieferant 2	Material 2
			Identnummer	Preis	Gewicht

Verwendungsbereich AMS II	Zul. Abw. DIN ISO 2768 mittel	Oberfläche N10	Maßstab 1:2	Gewicht
			Werkstoff, Halbzeug	
99	Datum	Name	Benennung	
Bearb.	02.08.	Wlochal	TRD Test Chamber	
Gepr.				
Name				
RWTH Physics AC-I			Zeichnungsnummer ams1846	Blatt 1/1 A1 Bl.
Rev. Änderung	Revision	Name	Ers. f.: Ers. d.:	Plot Datum:

Figure 10: Straw module material list

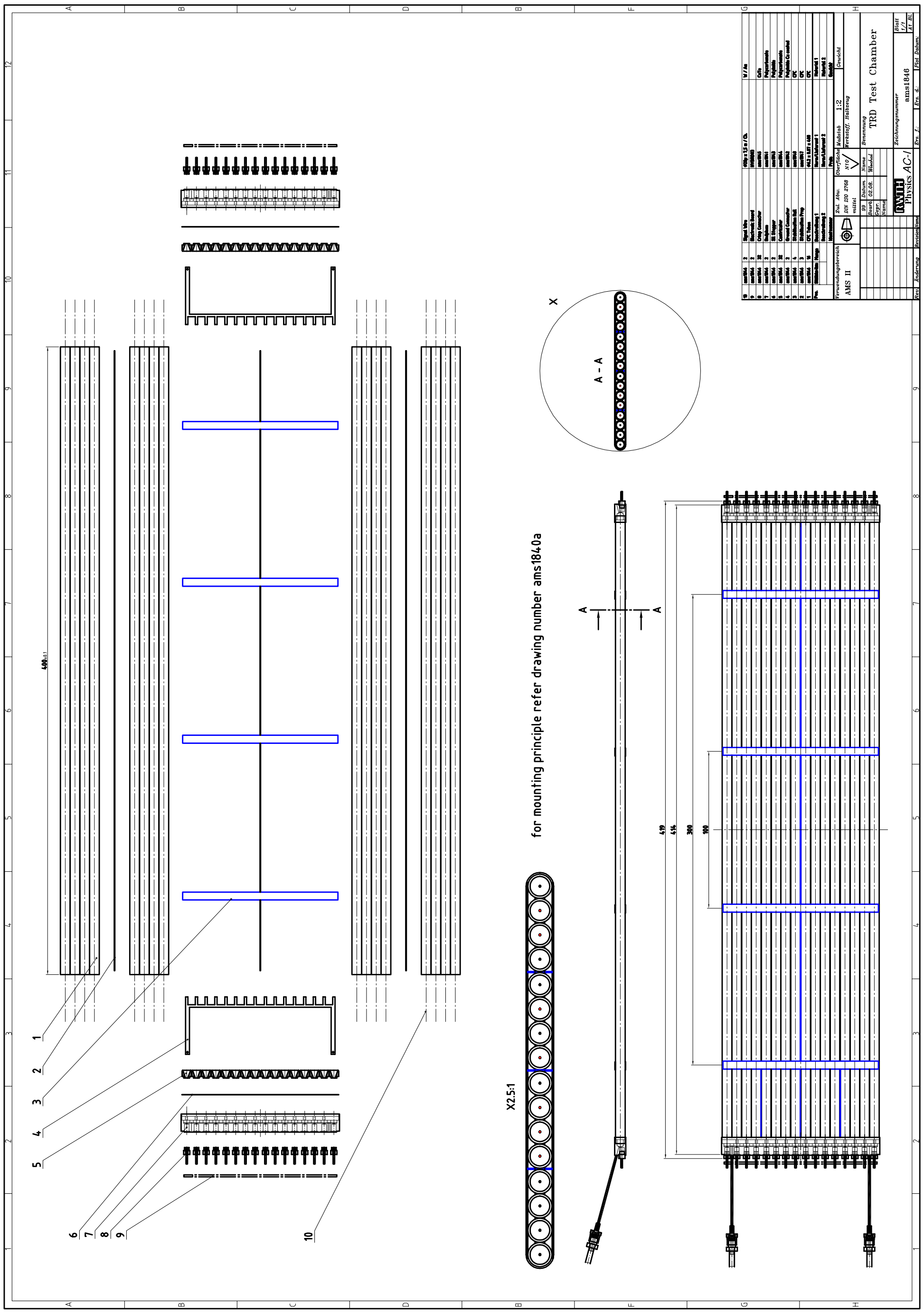


Figure 11: straw module assembly (CERN 2000 test)

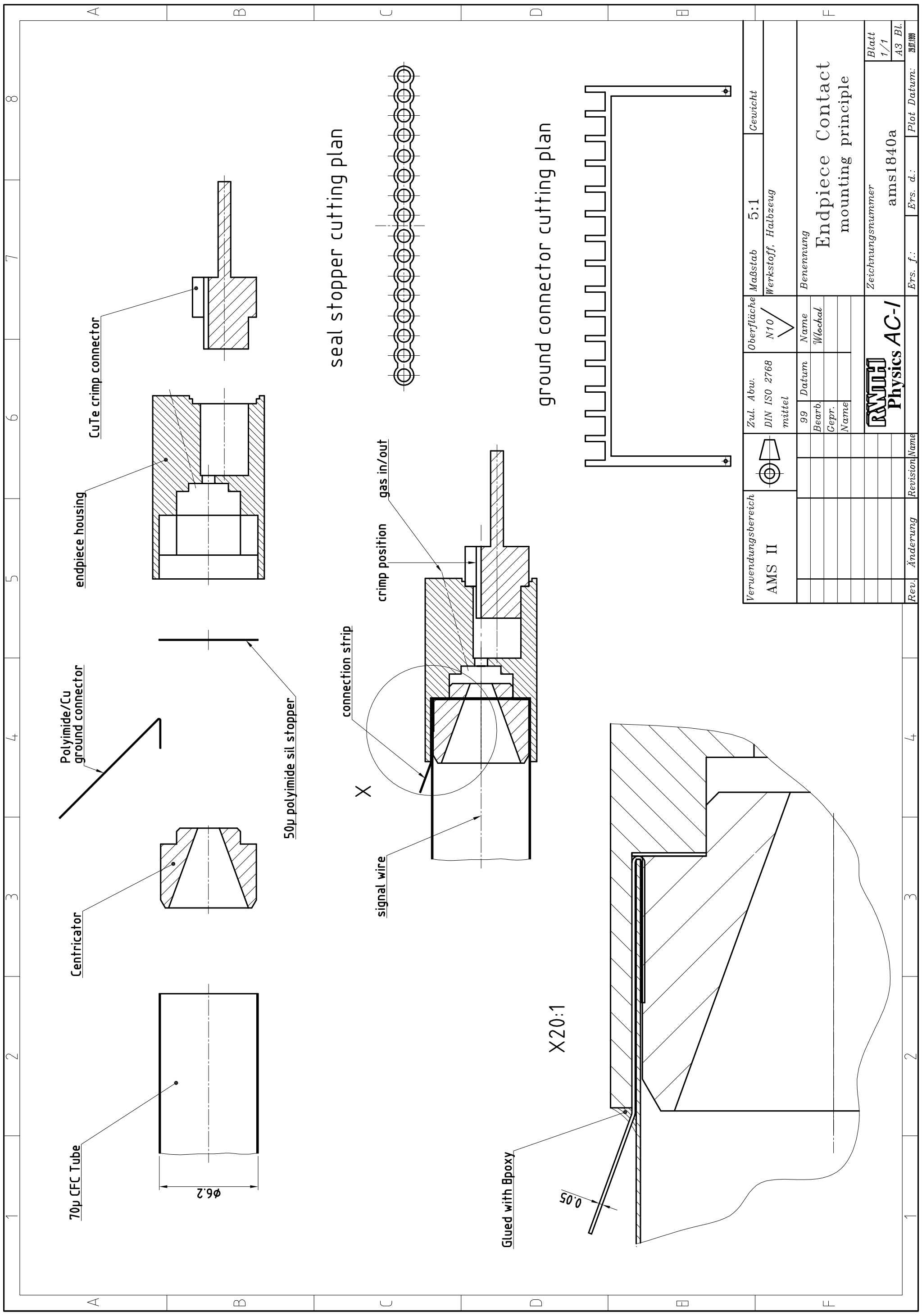


Figure 12: Endpiece contact mounting principle

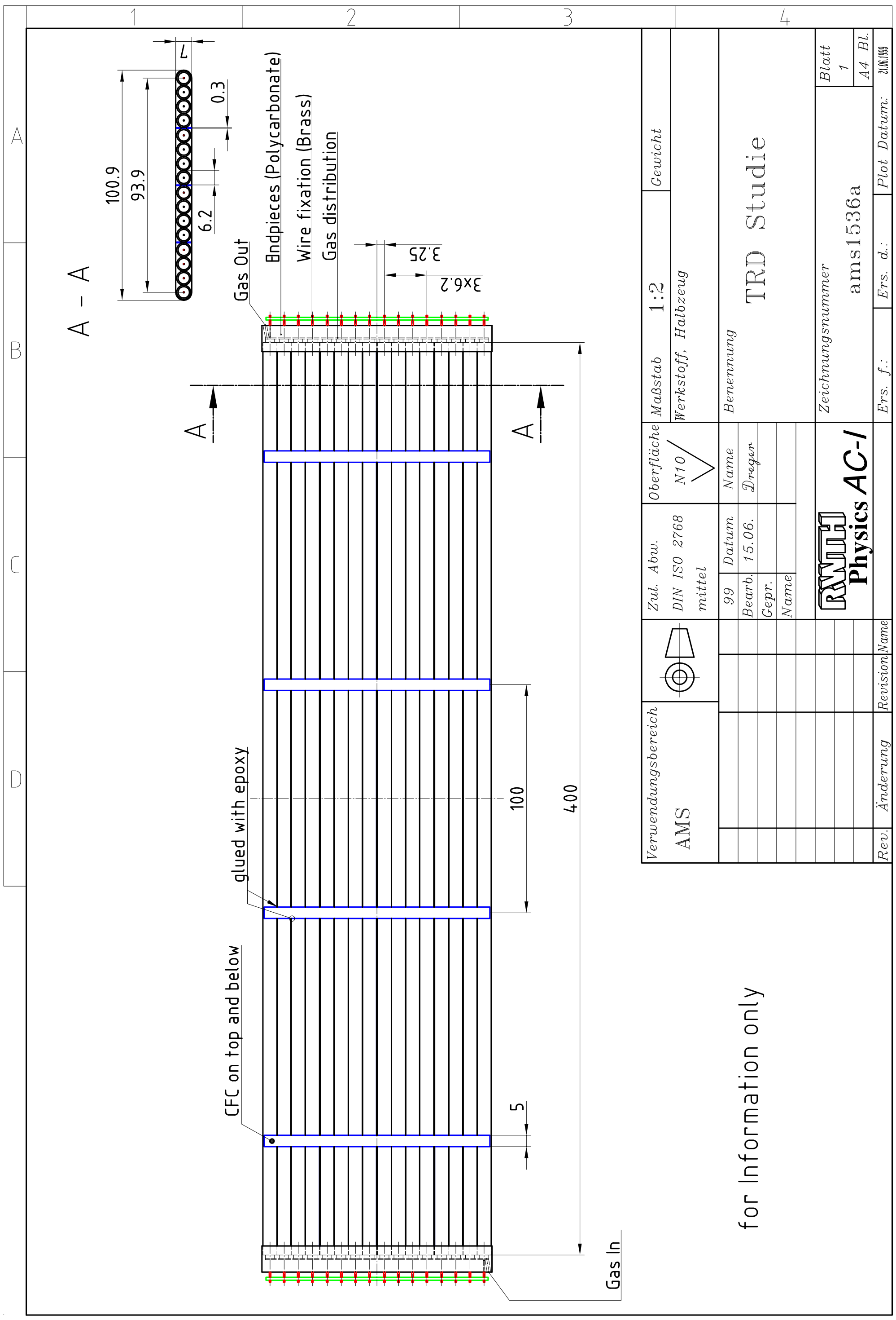


Figure 13: Prototype straw module

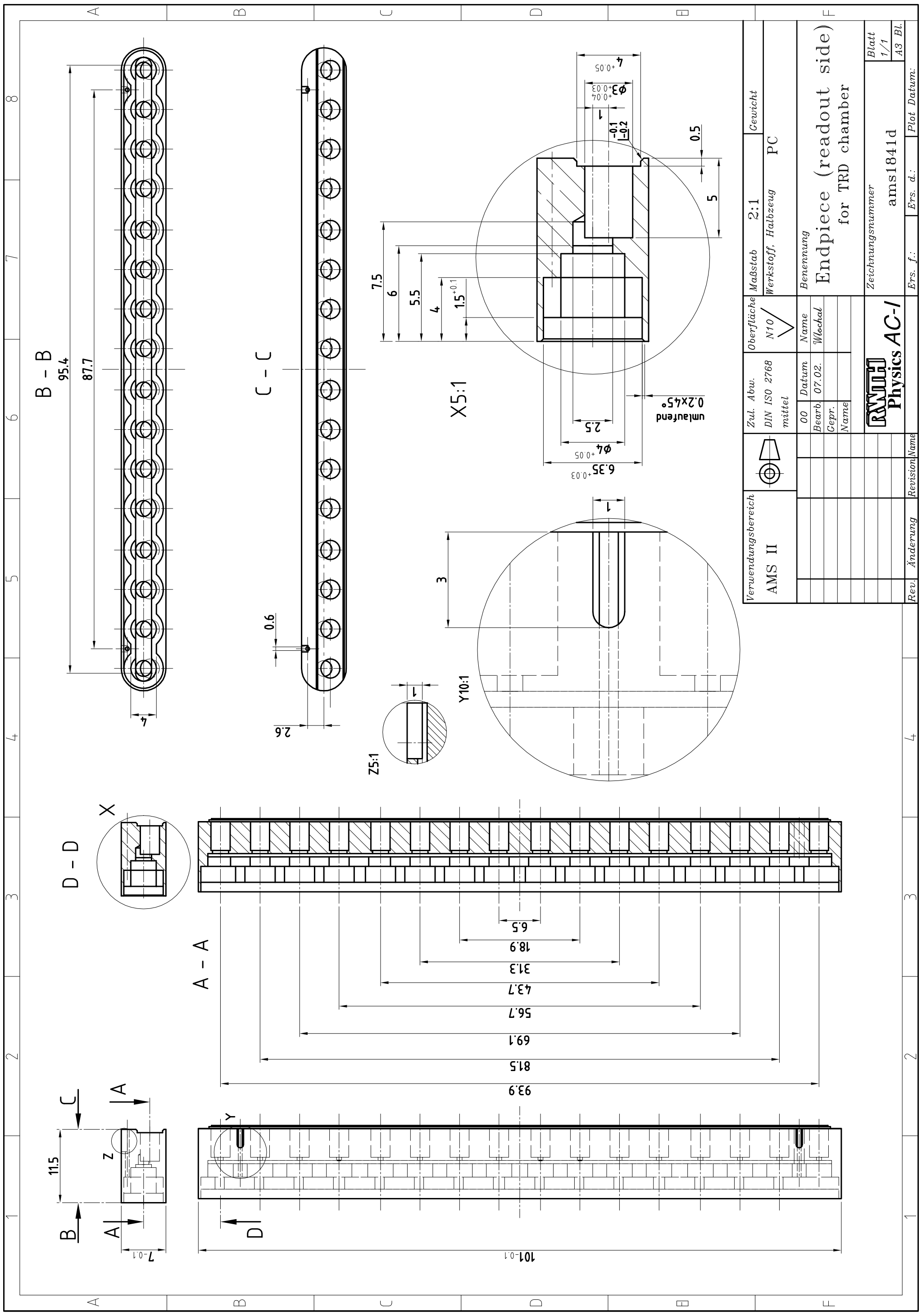


Figure 14: Endpiece on readout side

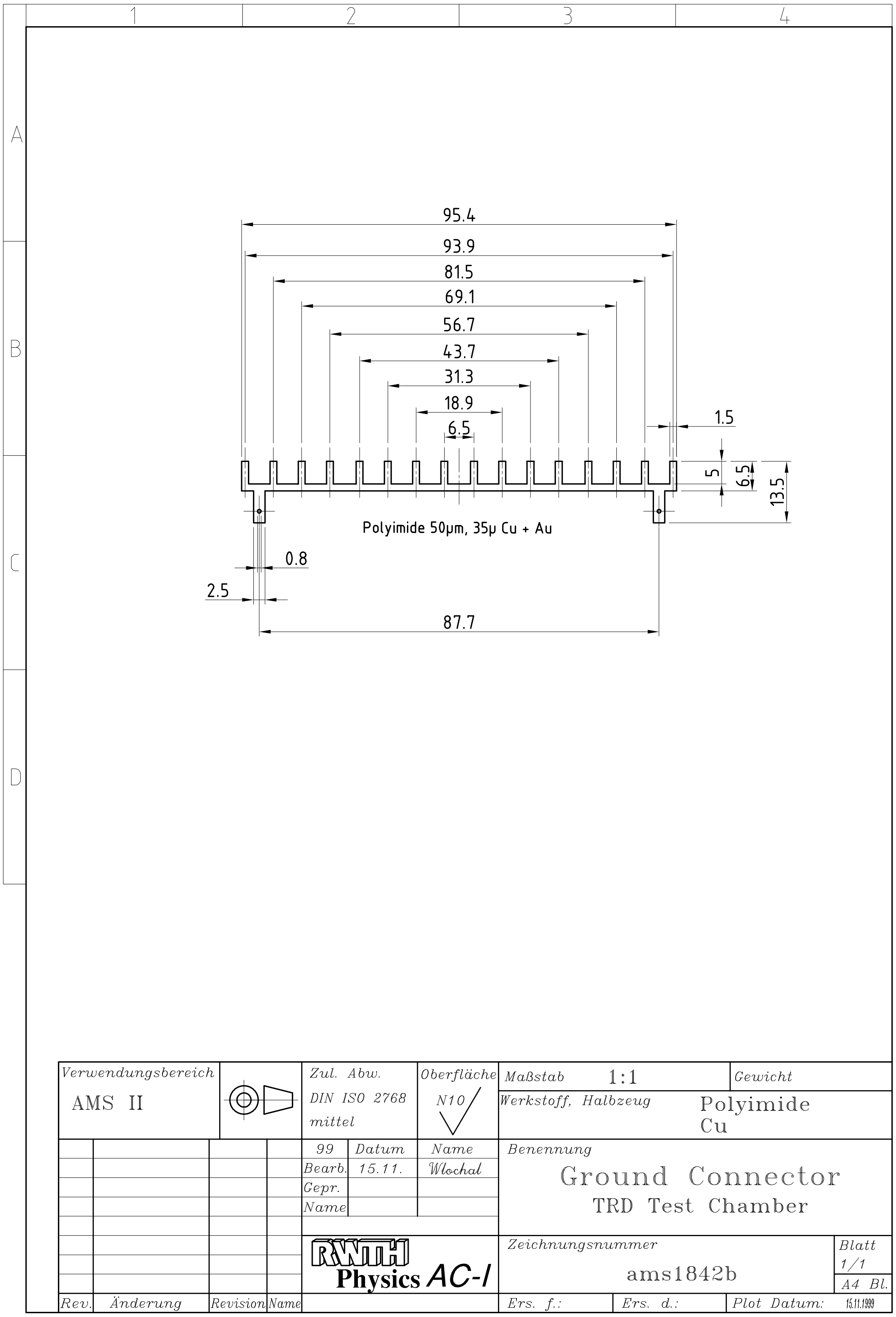


Figure 15: Ground connector TRD test chamber

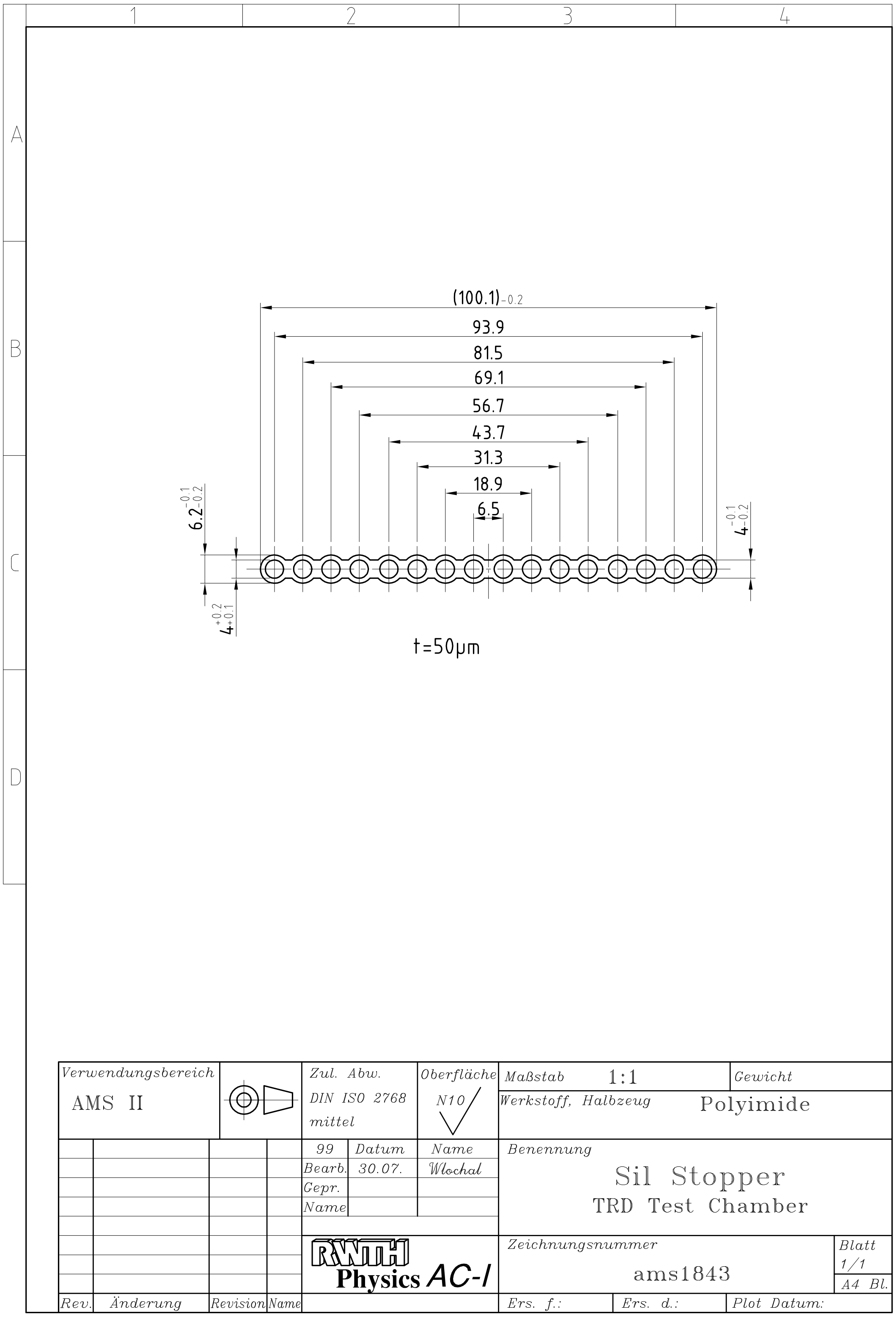


Figure 16: Glue stopping seal for TRD test chamber

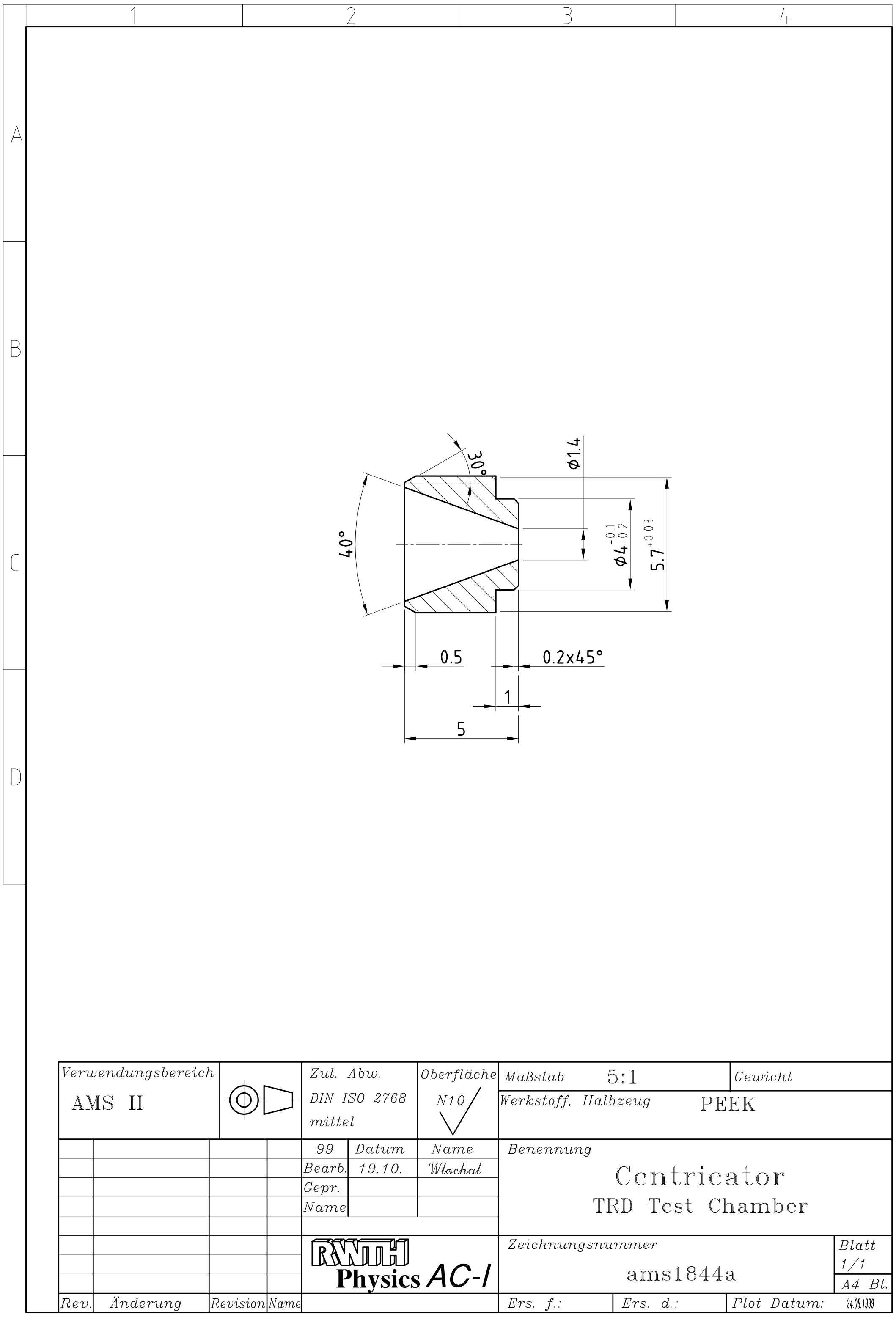


Figure 17: Centricator TRD test chamber

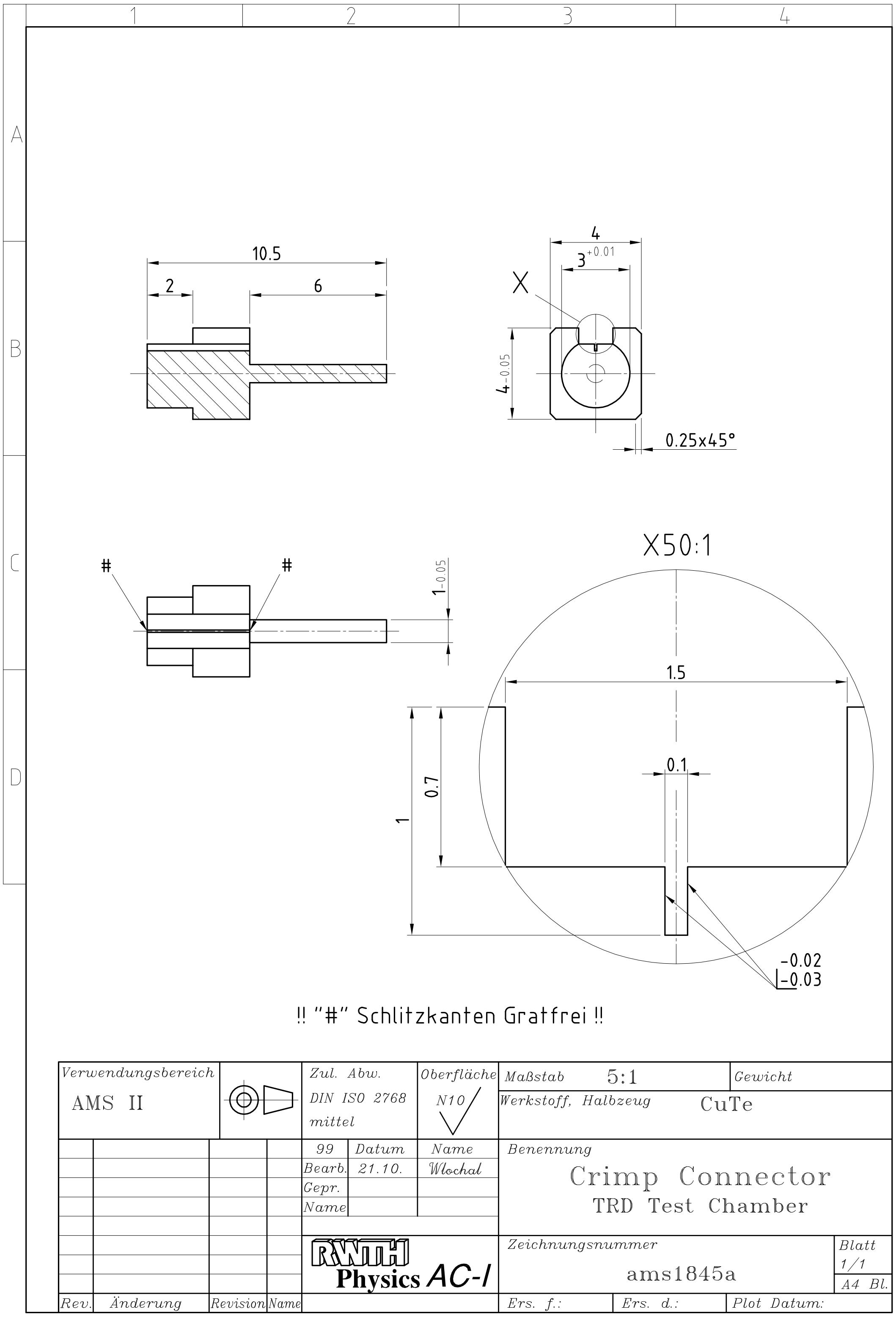


Figure 18: Crimp connector TRD test chamber

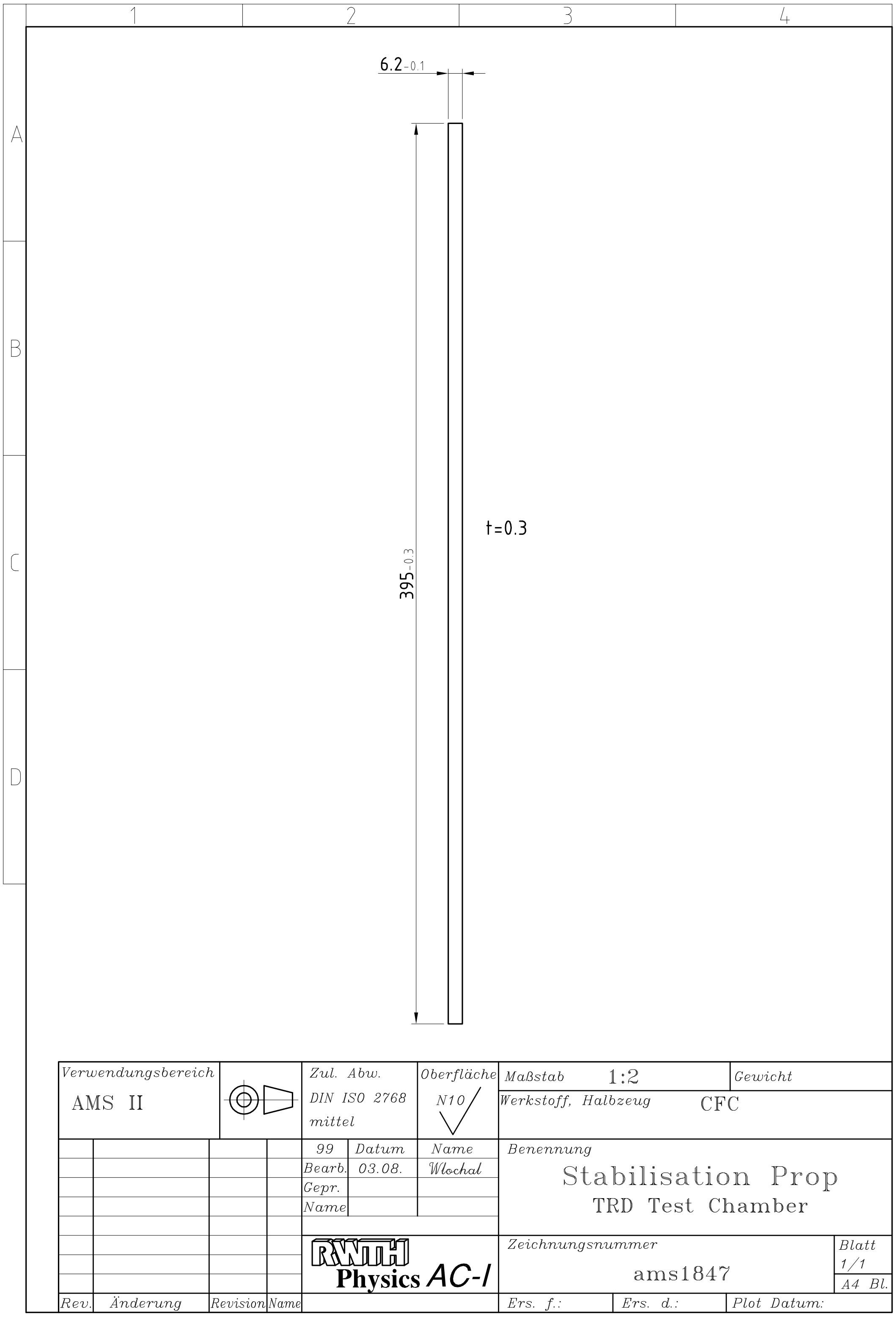


Figure 19: Stabilisation Prop (longitudinal stiffener) TRD test chamber

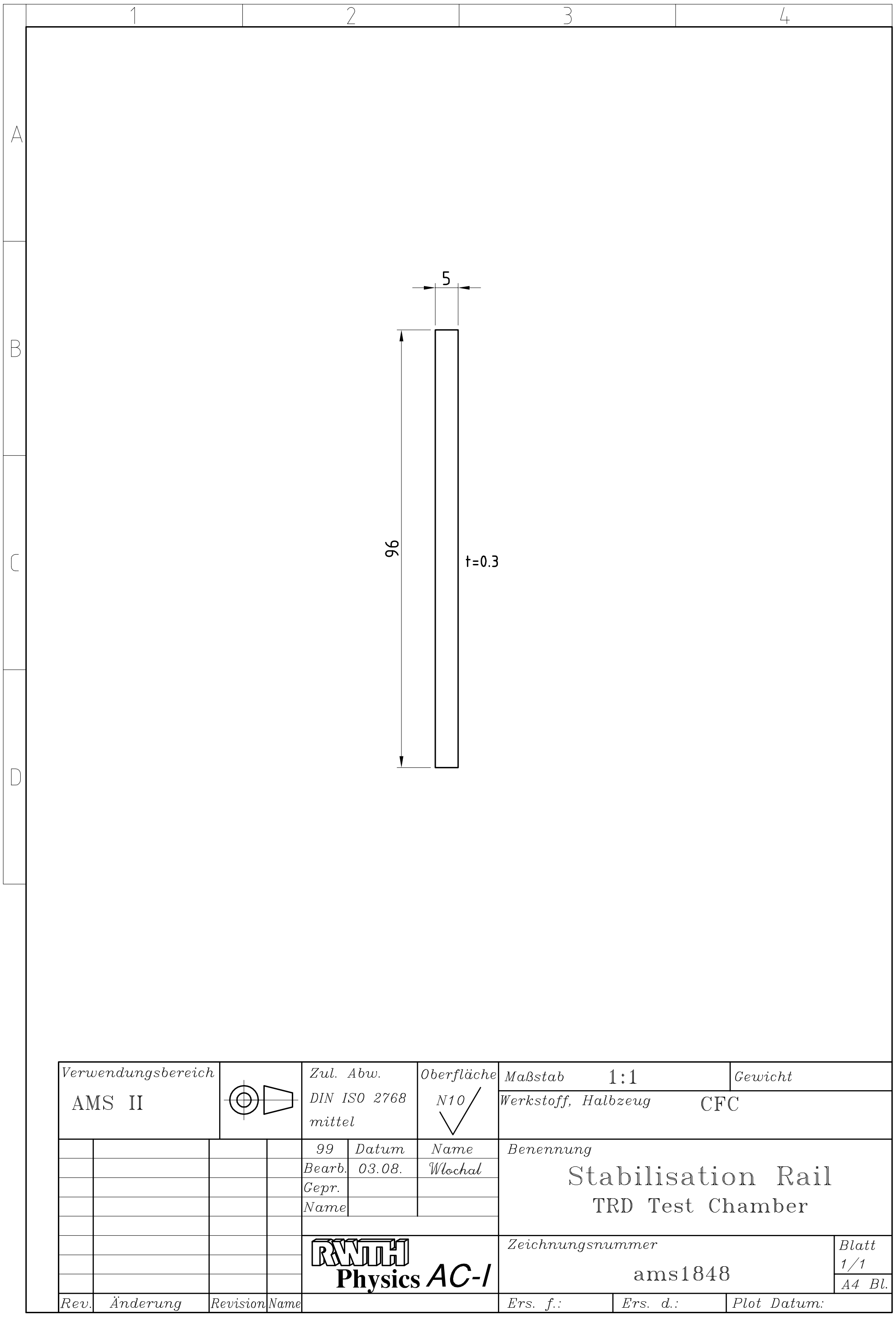


Figure 20: Transversal stabilisation strip TRD test chamber

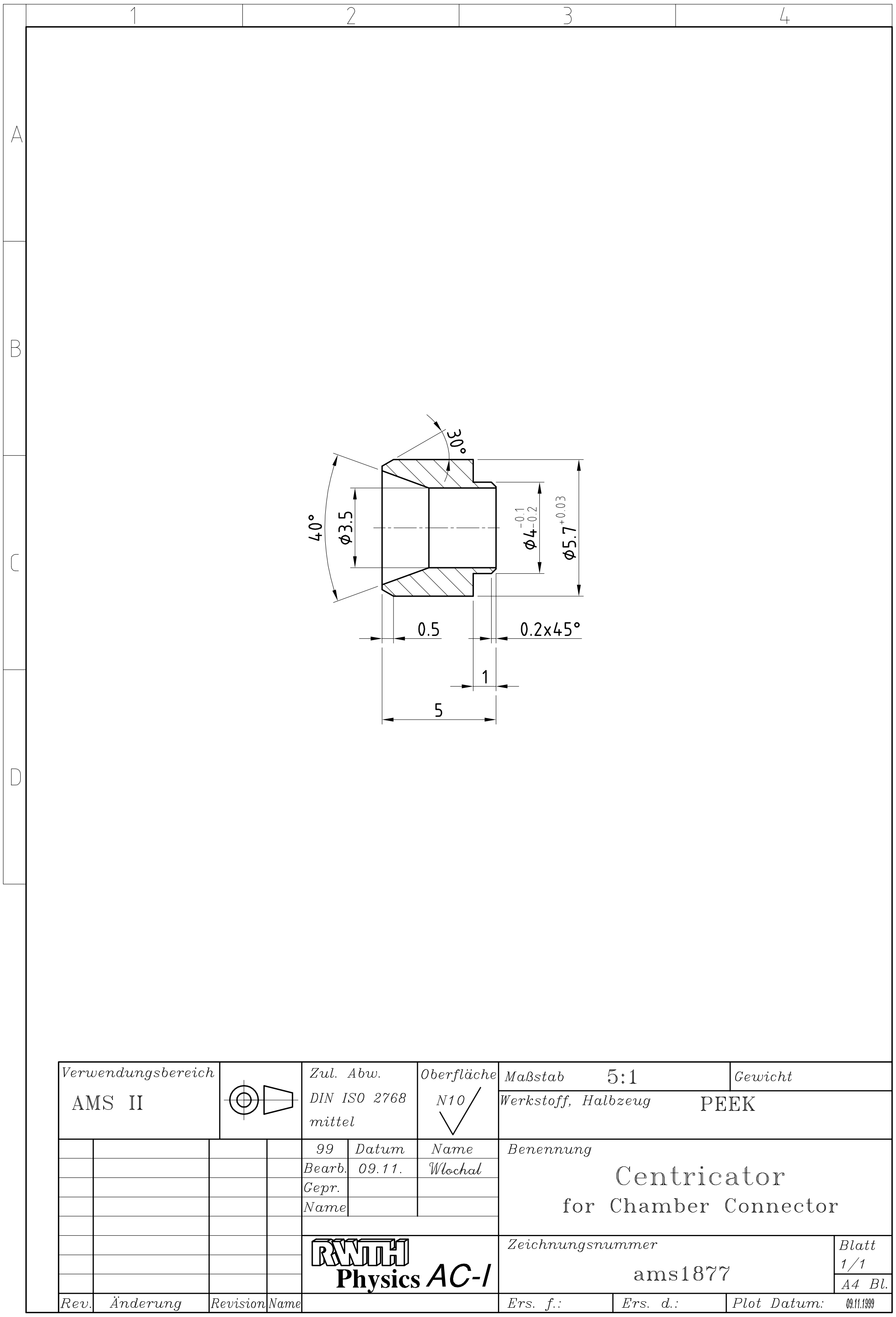


Figure 21: Centricator for chamber connector

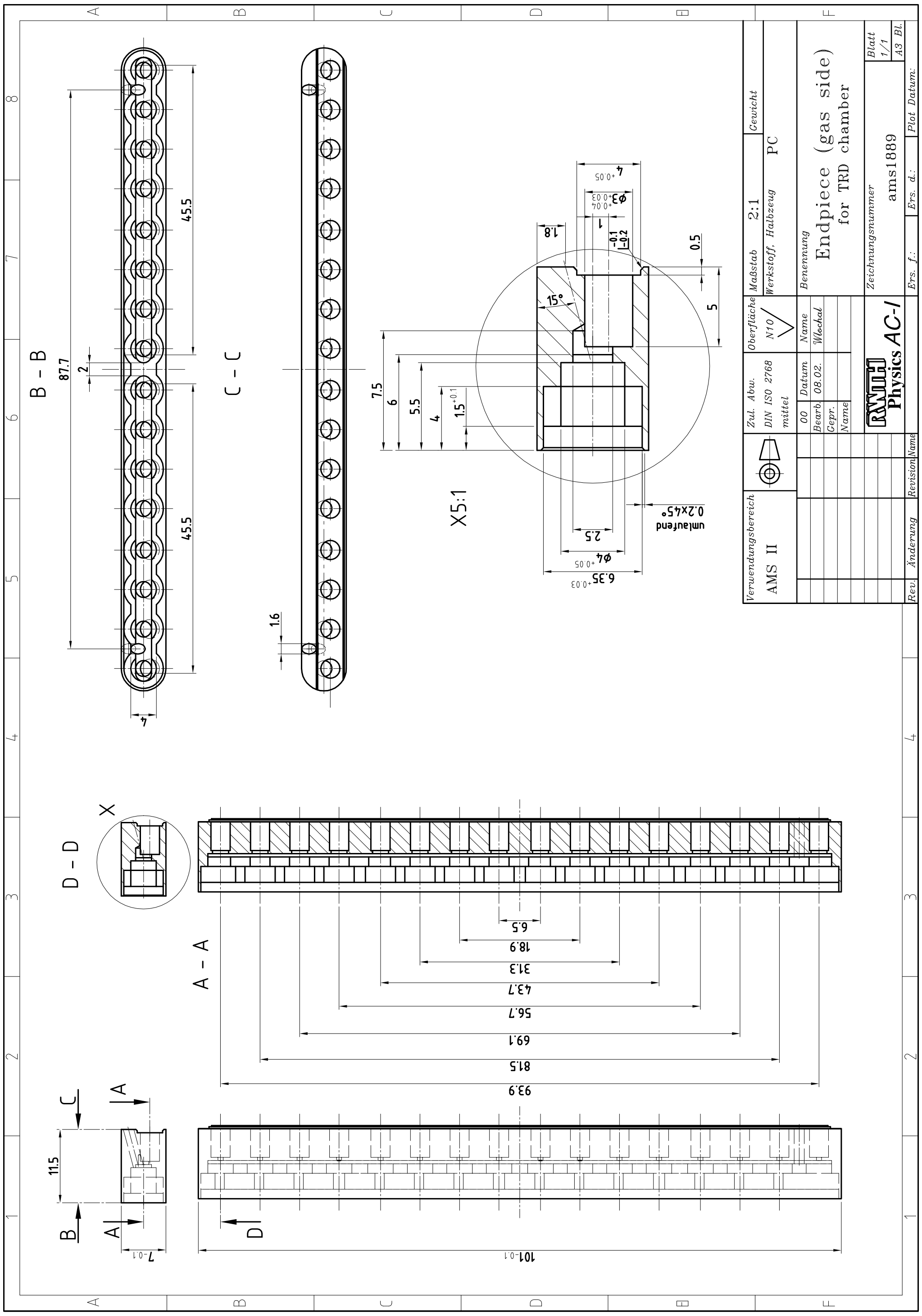


Figure 22: Endpiece (at gas side) for TRD chamber

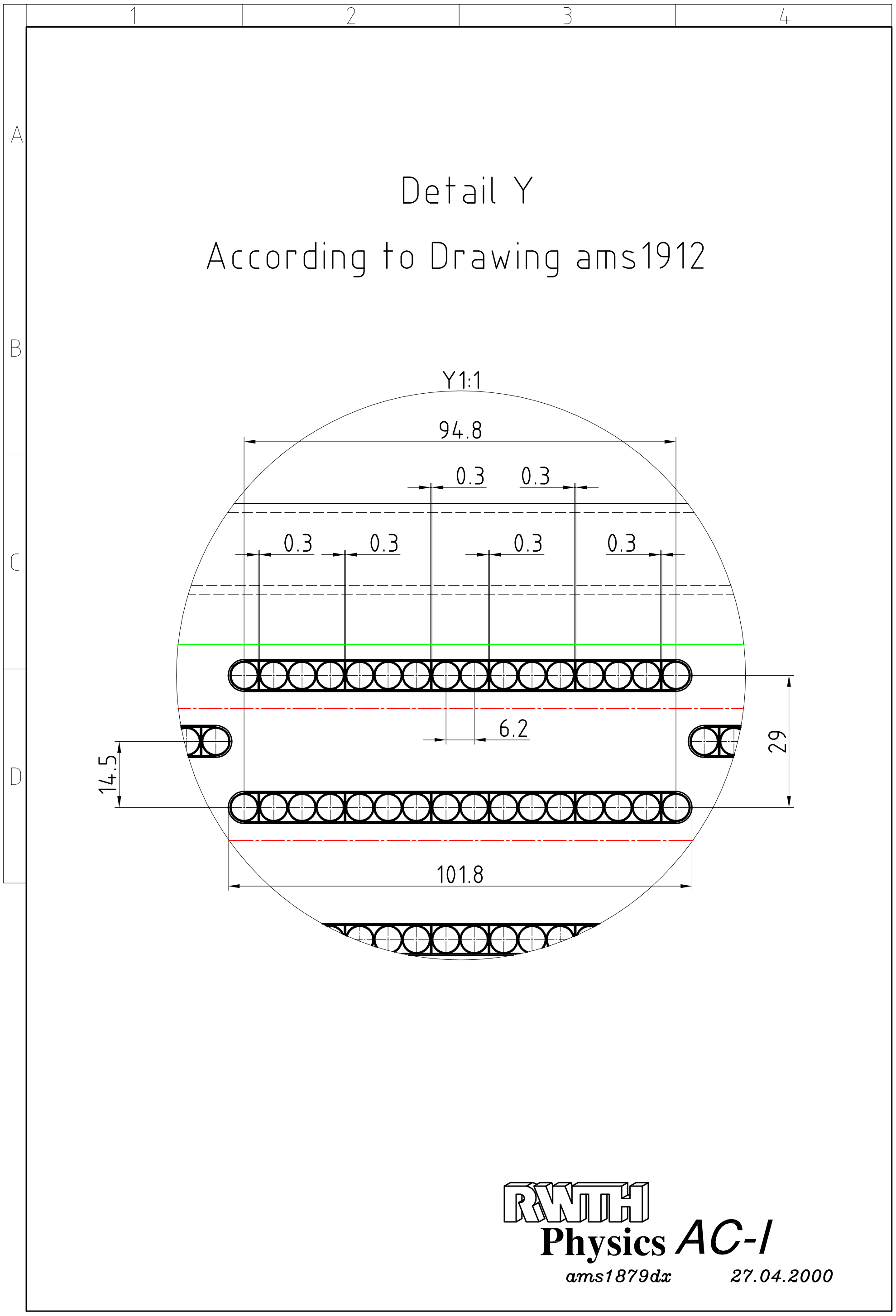


Figure 23: Straw module cross section with longitudinal stiffeners

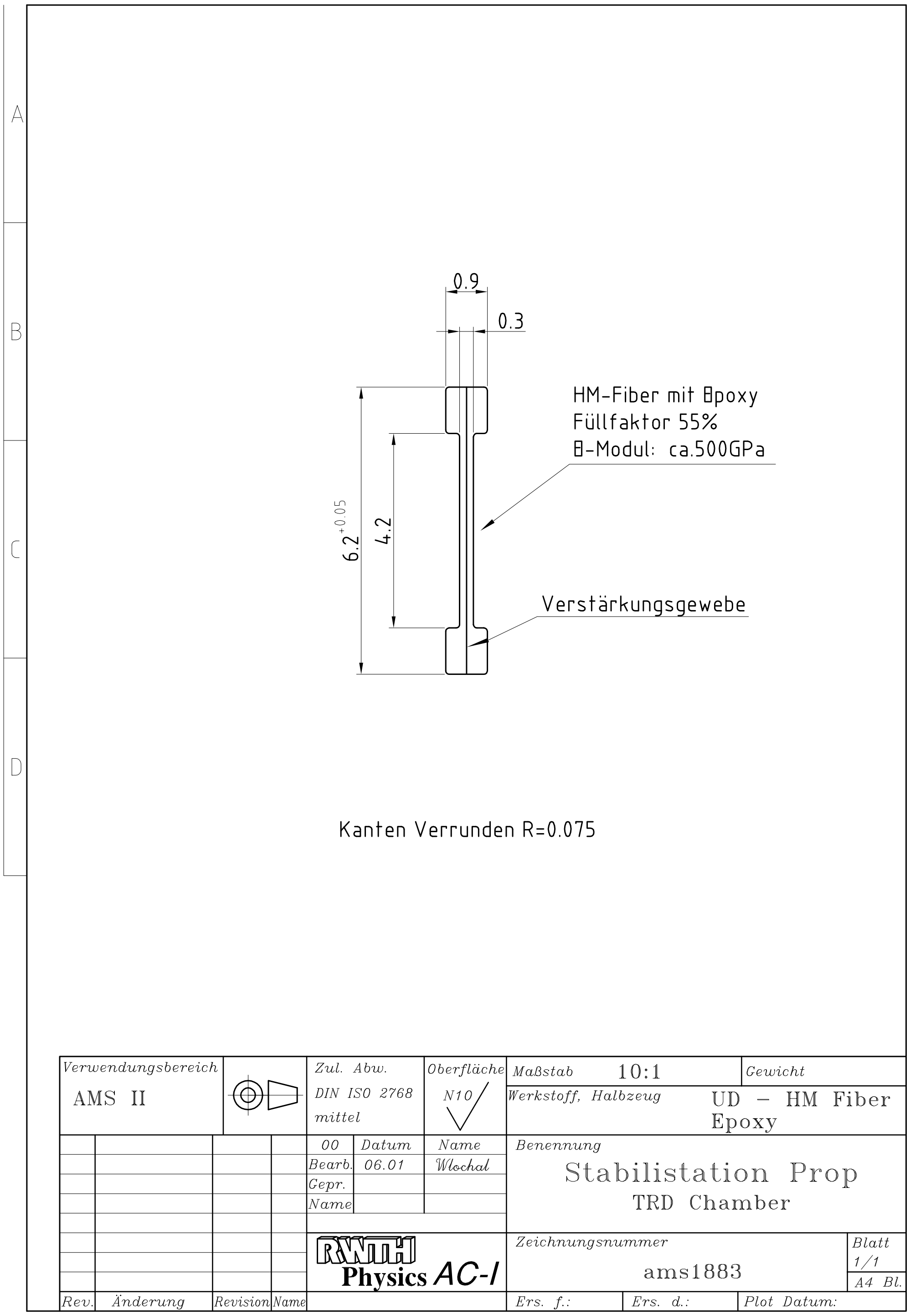


Figure 24: Longitudinal stiffener with reinforced head

Figure 25: Readout groups, Y-Z TRD cross section

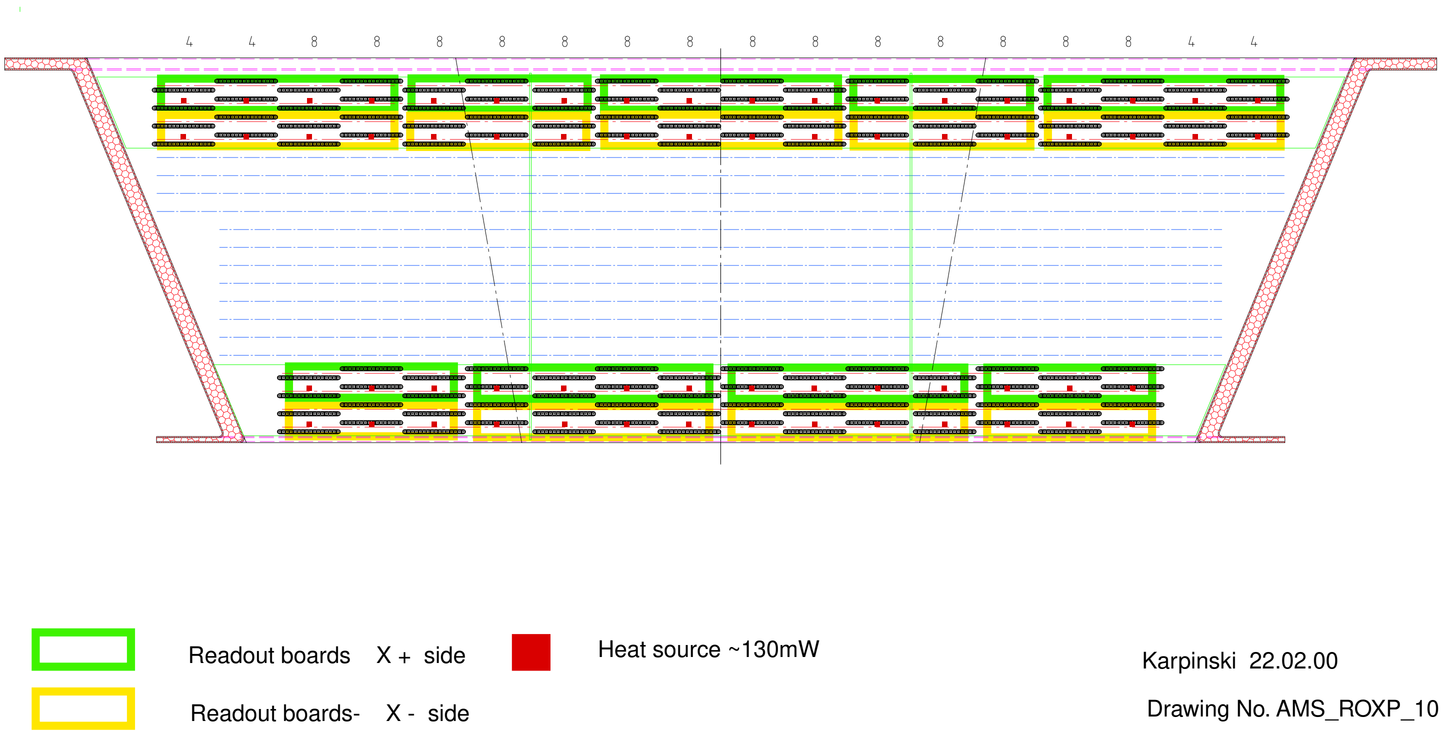
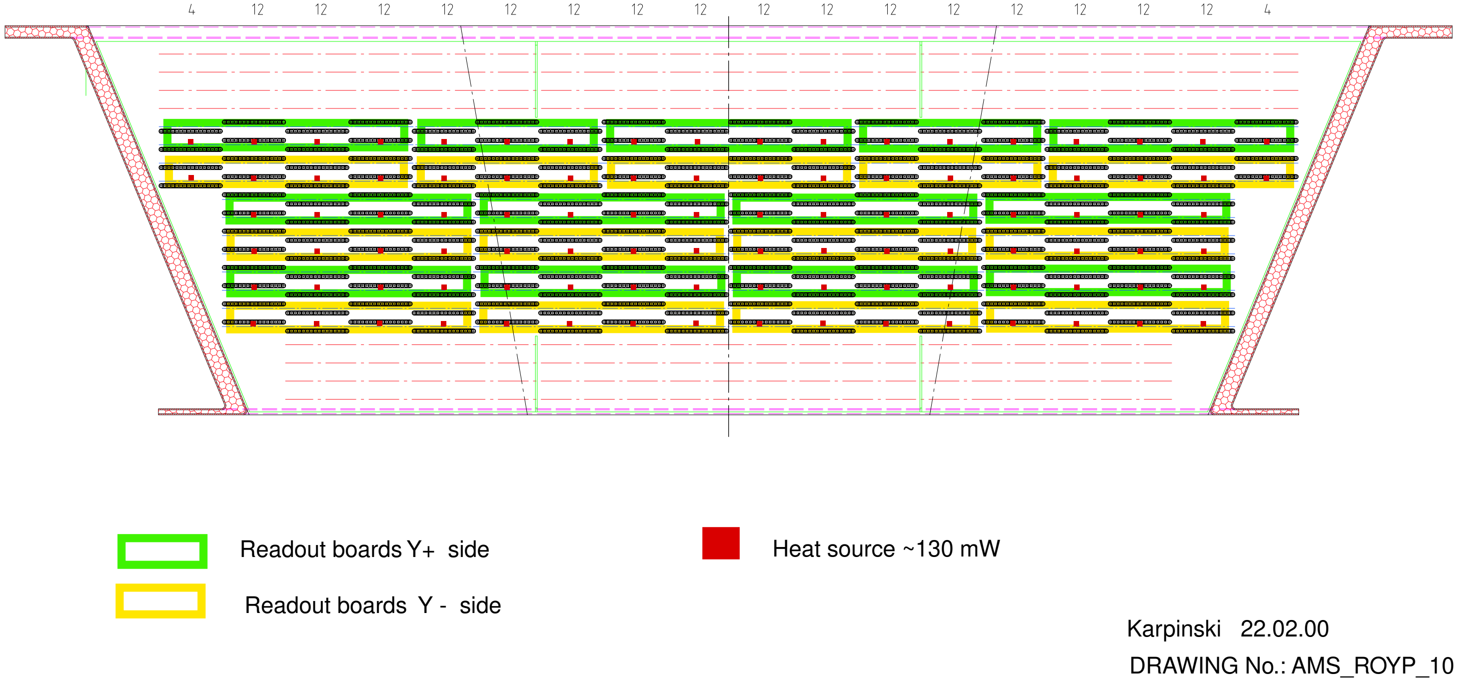


Figure 26: Readout groups, X-Z TRD cross section



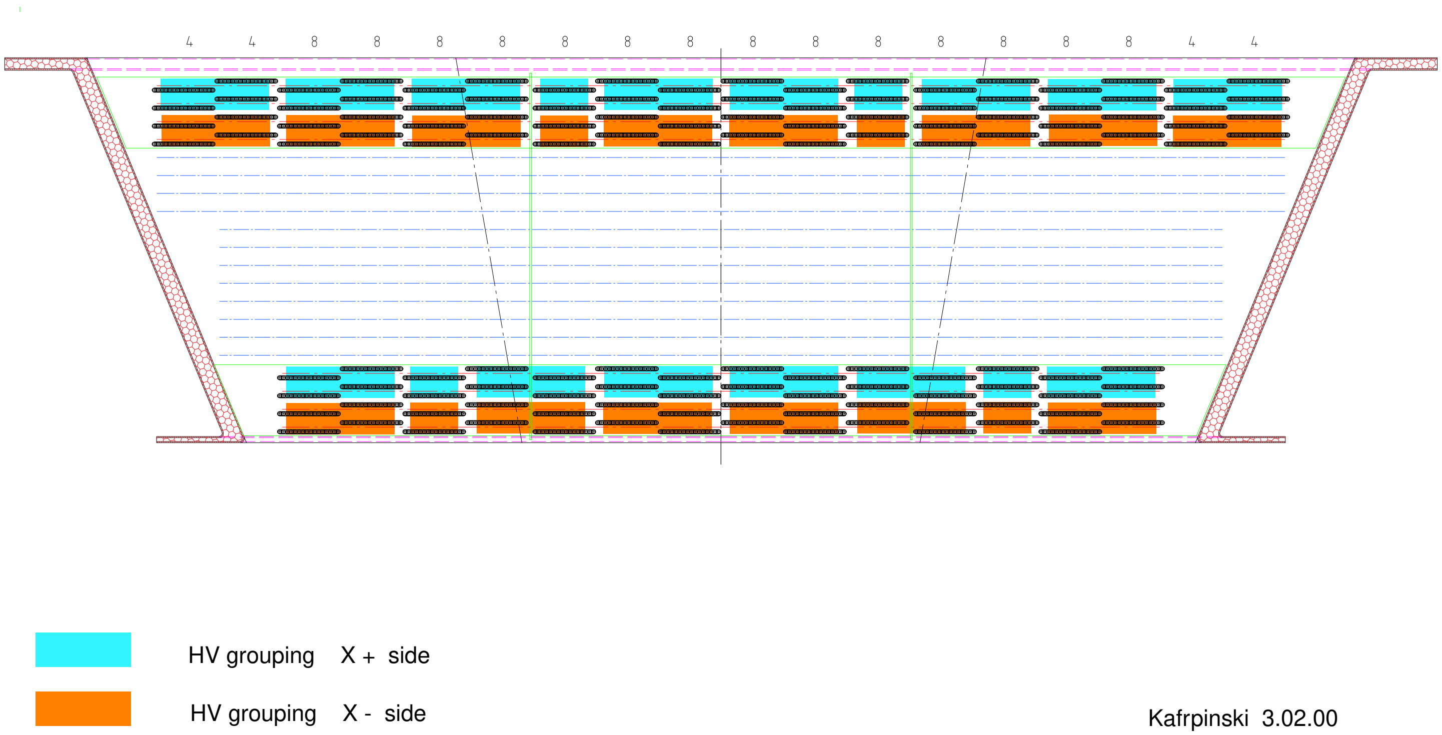


Figure 27: HV groups, X-Z TRD cross section

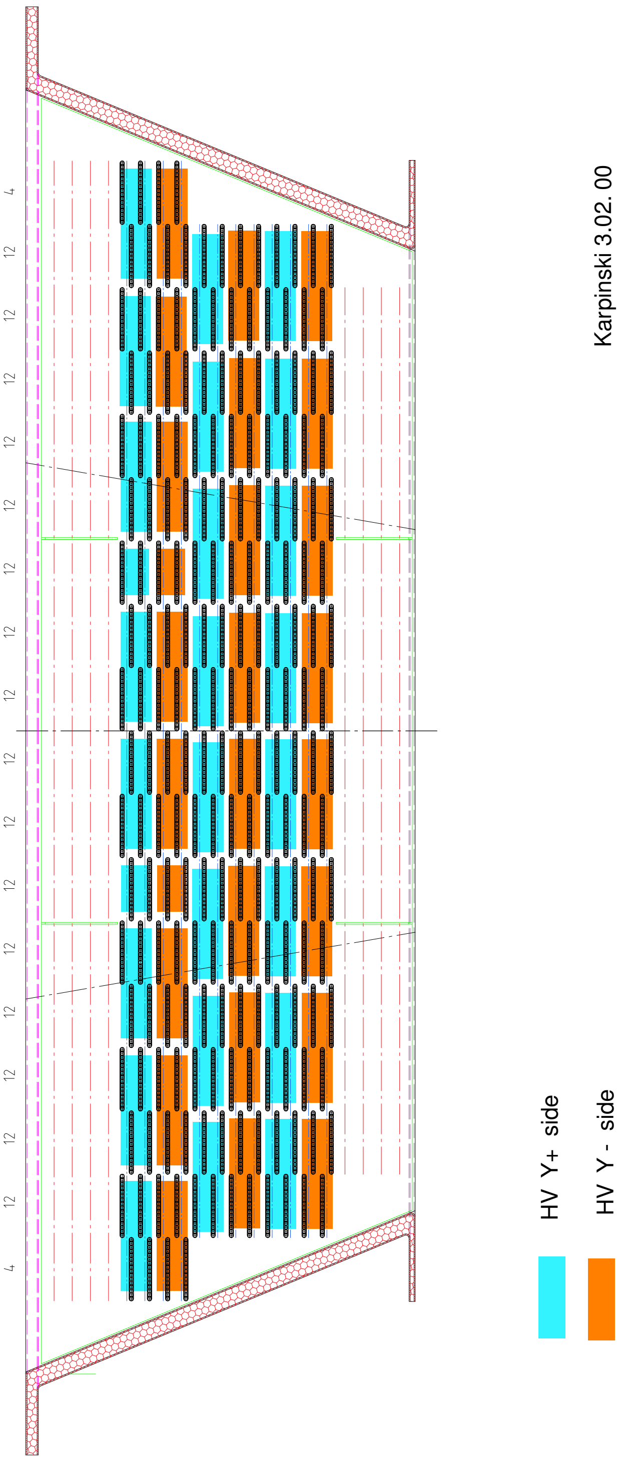


Figure 28: HV groups, Y-Z TRD cross section

4 Subsytems mechanical properties

AMS02
TRD
Weight

		(kg)
1.	Straw Detector	125
2.	TRD/TOF Support Plates	47*
3.	Upper Ring	8
4.	Octagon Panels	33
5.	Reinforcement Walls	12
6.	Connecting Pieces	10
7.	Support Feet to USS	50*
8.	Electronics (incl. HV)	80
9.	Shielding	23
10.	Upper Plate incl. LEPS	61
11.	Gas System and Storage (incl. Support and Meteor-Shielding	96
	TRD Total	545

*Includes Support of TOF System

Table 1: AMS02 TRD Weight of principal components

4.1 Material List

Octagon Support Structure	
TOF/TRD Support Double Plate	Carbon Fiber M40-J, Core Al, Araldite LY556
Octagon Panels	Carbon Fiber M40-J, Core Al, Araldite LY556
Bulkheads	Carbon Fiber M40-J, Araldite LY556
TRD/LEPS Cover Plate	Carbon Fiber M40-J, Core Al, Araldite LY556
Insert	Al EN AW-7075, T7351, Peek
TOF/TRD Bearing Tubes	Al 7050
TRD Straw Modules	
Straw	Polyimide, Graphite, Polyurethane
Stabilisation Rail	Carbon Fiber Composite, Epoxy
Stabilisation Prop	Carbon Fiber Composite, Epoxy
Glue	Epoxy 2020, HW 106
Ground Connector	Polyimide Copper Coated
Centricator	Peek
Seal Stopper	Polyimide
End Piece	Polycarbonate
Crimp Connector	CuTe (1,5%Te)
Signal Wire	Tungsten Gold Plated
Gas Connector	Peek Tubes, SST No. 1.4305, AlMgCuPb
TRD Radiator	
Fiber	85% polypropylene, 15% polyethylene TML: (0.04±0.02)%, CVCM: (-0.01±0.03)% (E 595)

Table 2: **AMS02 TRD Material List**

Table 3: Material list TRD-frontend electronics

Parts List for TRD-Frontend Electronics

No.	Item	Quantity	Material
1.	HV Board	328	FR4, Polyimid, Parylene C, Polyphenylene Sulfide, Copper, Silver, Nickel, Tin, Brass, Gold, Ceramics
2.	HV Board - Readout Board cable connector	328	Tefzel, Polyphenylene Sulfide, Epoxy Copper, Silver, Nickel, Tin, Brass, Gold
3.	HV Board - HV Supply cable connector	328	Teflon, Kynar, Solithane Copper, Silver, Nickel, Tin, Brass, Gold
4.	VA Hybrid	164	FR4, Parylene C, Polyphenylene Sulfide, Epoxy Copper, Silver, Nickel, Tin, Brass, Aluminium, Gold
5.	Readout Board	24	FR4, Parylene C, Valox Polyester, Epoxy Copper, Silver, Nickel, Tin, Brass, Aluminium, Gold Si, Ceramics,
6.	Signal Cable	44	Tefzel, Valox Polyester, Epoxy Copper, Silver, Nickel, Brass, Aluminium, Gold
7.	HV Power Supply	88	FR4, Parylene C, Valox Polyester, Epoxy Copper, Silver, Nickel, Tin, Brass, Aluminium, Gold Si, Ceramics,
8.	HV Control cable	88	Tefzel, Valox Polyester, Epoxy Copper, Silver, Nickel, Brass, Aluminium, Gold

4.2 Platesystem

Support Plate System

The idea of the support plate system instead of one single plate is to be able to assemble TRD-System and TOF-System independently.

FE-Model

The model, see figures 29 and 30, is generated by different element types. Shell elements are used for the CFC-Faces and border C- and S-Profiles (fig. 31), while volume elements represent the core material and the aluminium spacers. The model does not enclose the octagon side-walls. So stiffening effects caused by the side-walls are not yet included. The shells representing the M40J-Faces of the plates imply 2 mm wall-thickness as well as a $[0°, -45°, +45°, 90°]_{symm.}$ layup. The upper face of the TRD plate (fig. 31) is additionally loaded inside the imaginary wall-thickness of the octagon walls by a mass of 352 kg (table 5). The lower face of the TOF plate (fig. 31) is additionally loaded inside the cell width of 1410 mm by a mass of 80 kg (for the scintillator) and at its border area by 40 kg (representing the TOF electronics). All these additional masses are homogeneously distributed within the given boundaries.
The model is simply supported along a length of 210 mm at 45° to the main directions.

Results

The calculation under 1g z-acceleration results in a vertical displacement of 60 μm, which equals to 64 Hz for the first natural frequency (figs. 32, 33, table 4).

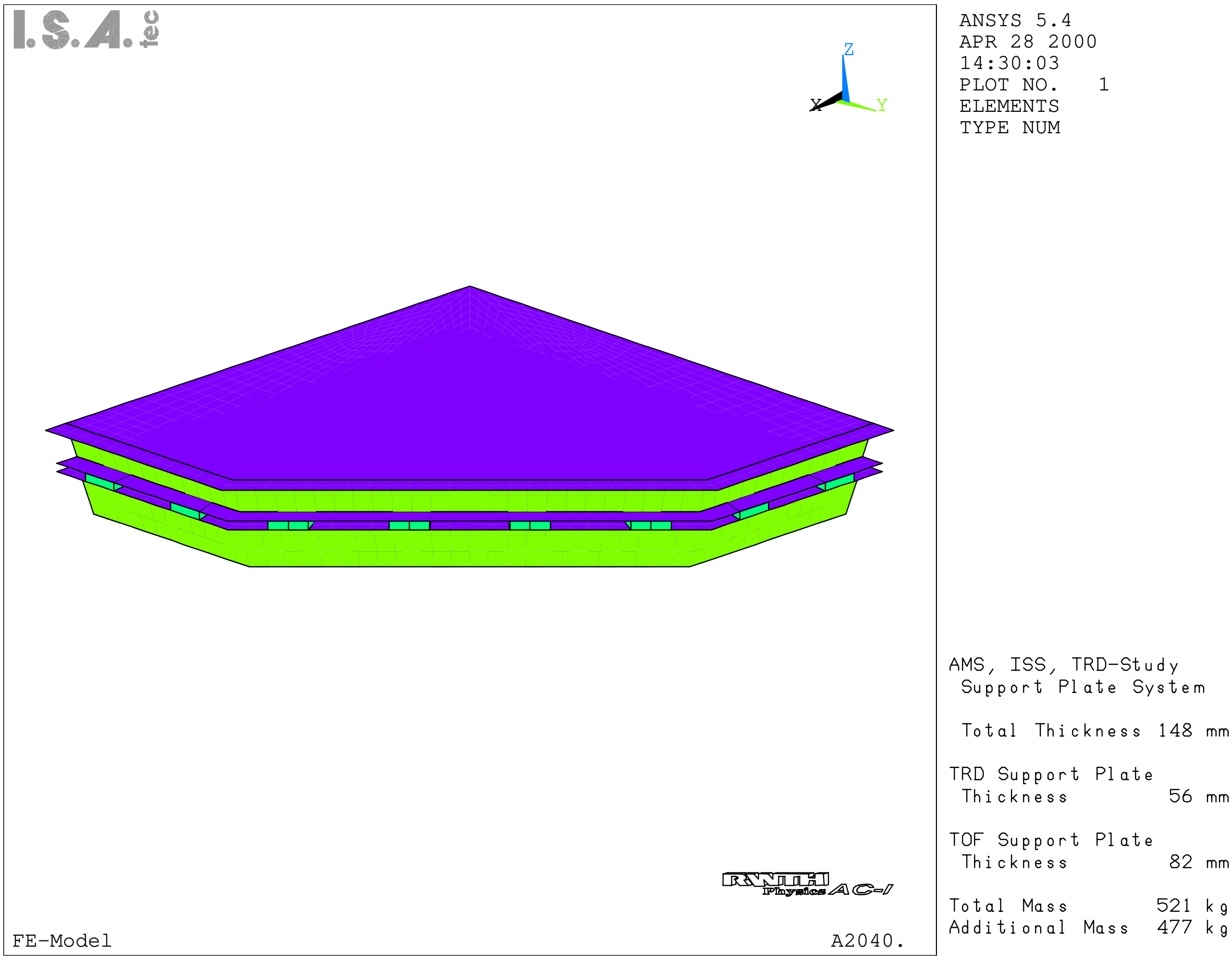


Figure 29: TRD- and TOF-support plates

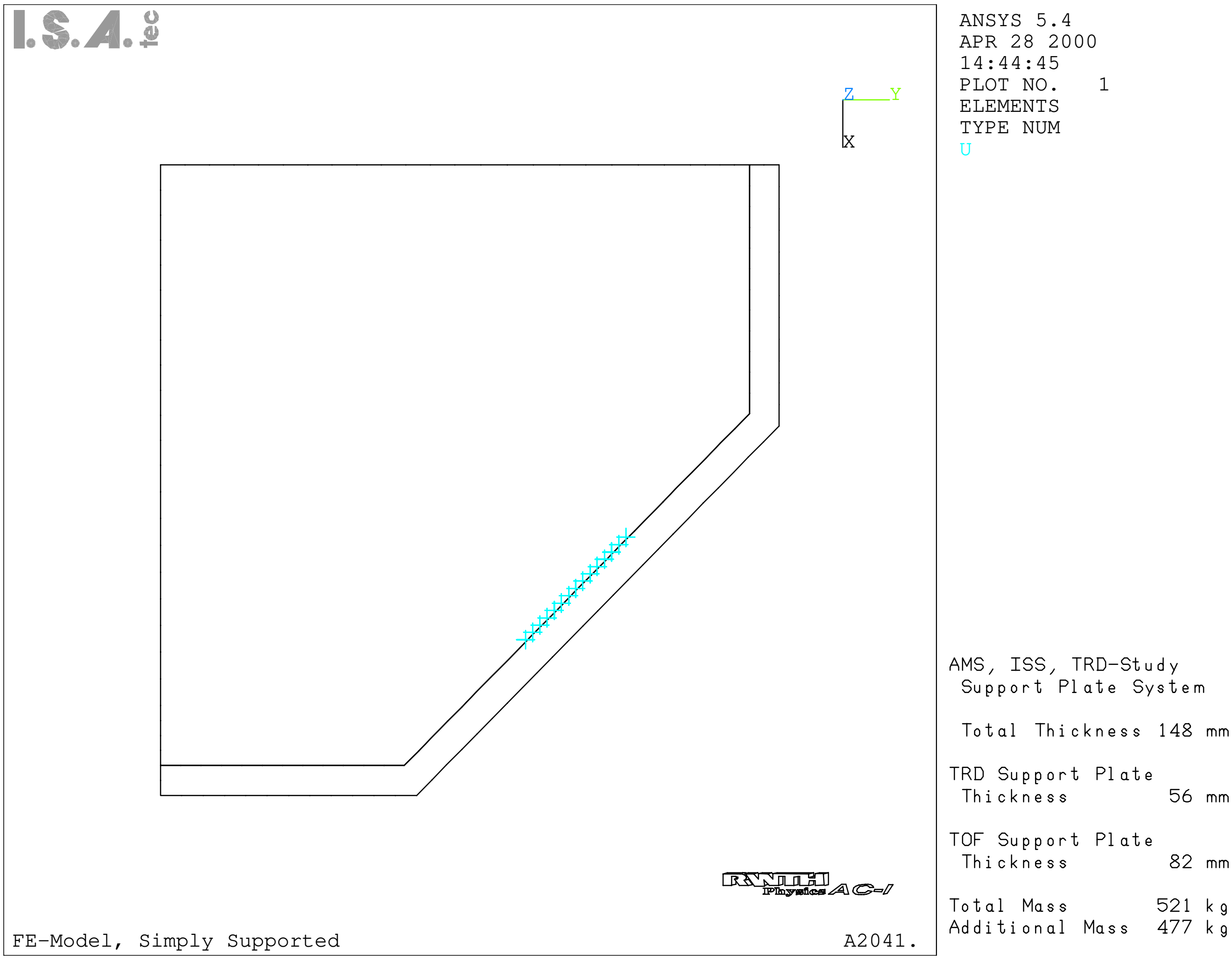


Figure 30: TRD- and TOF-support plates

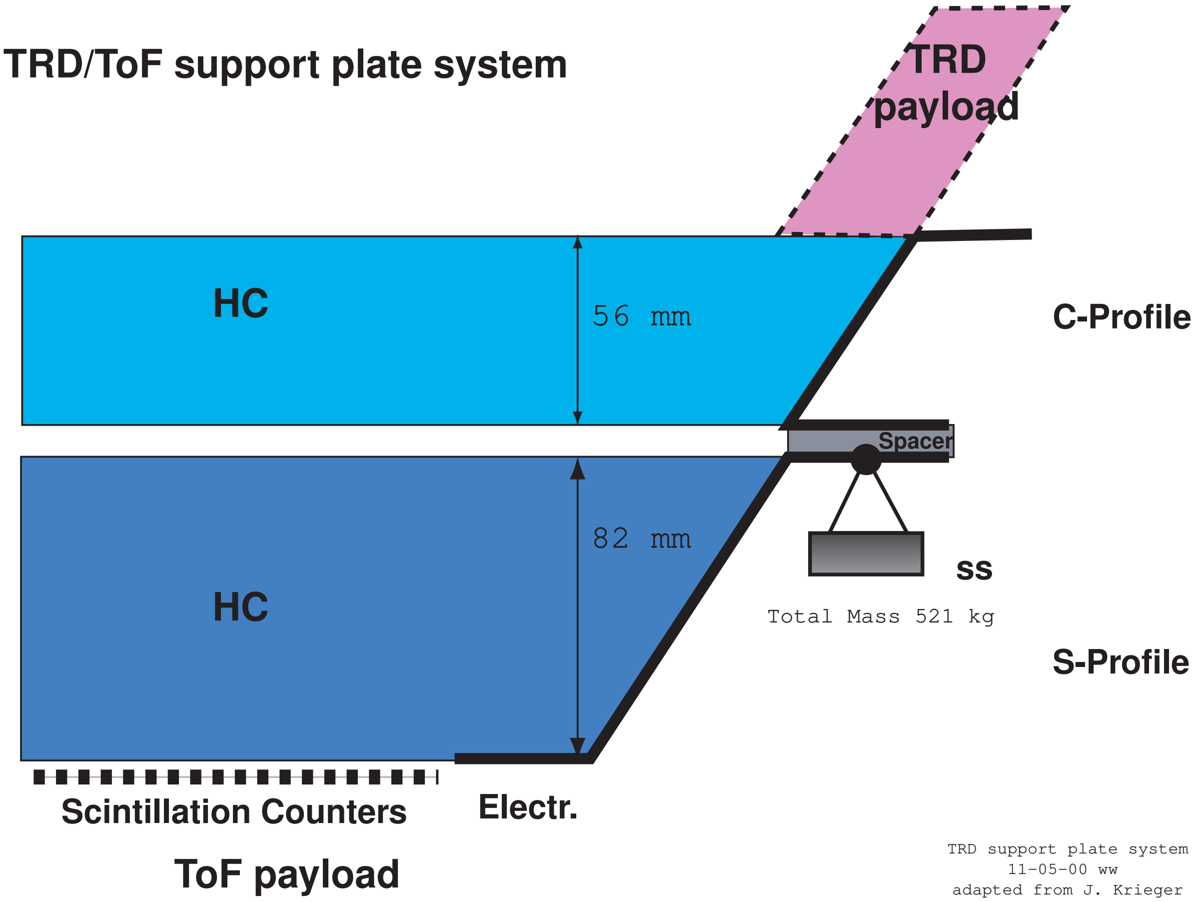


Figure 31: Edge reinforcements for TRD/TOF support plate system

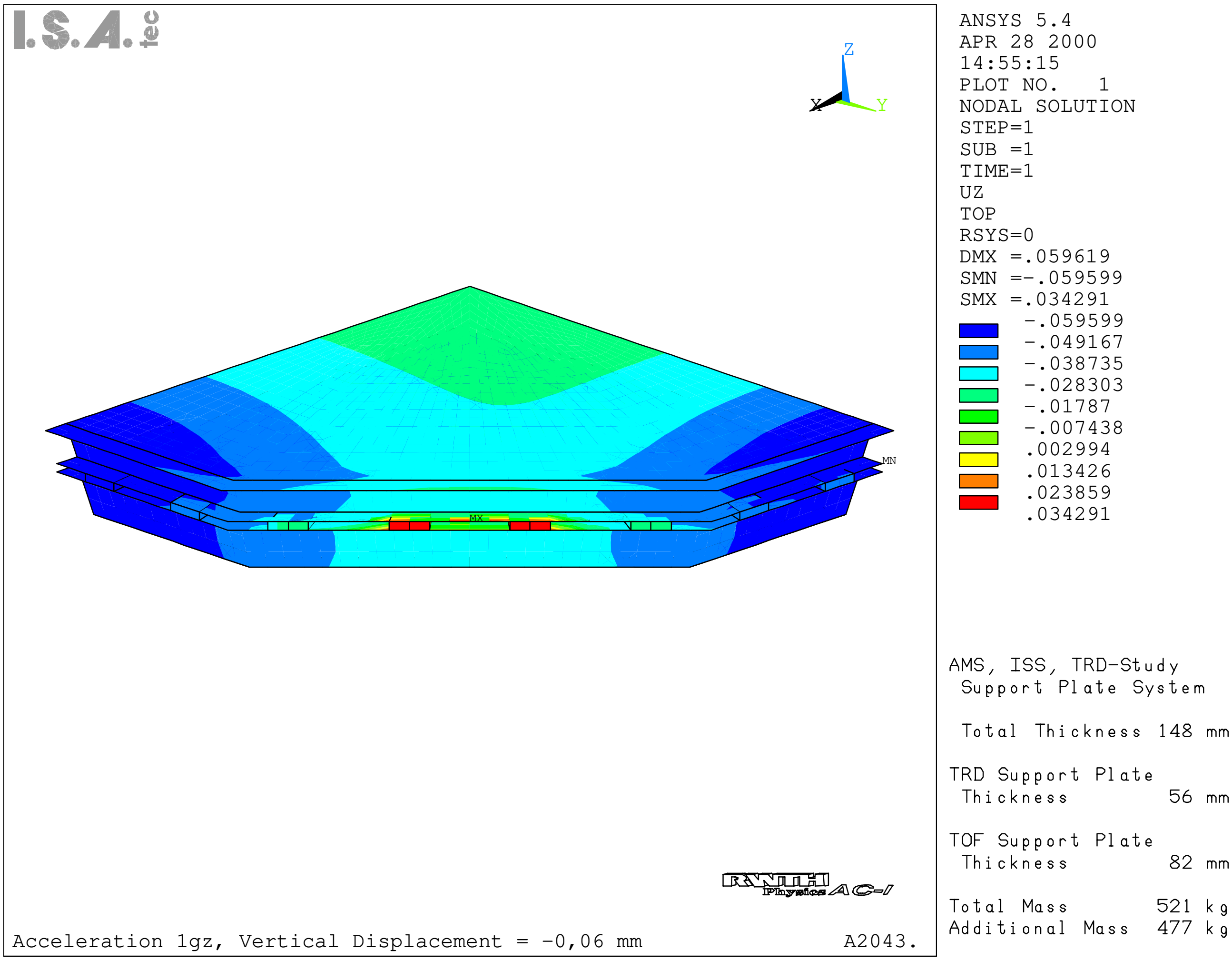


Figure 32: Loaded TRD/TOF support plates

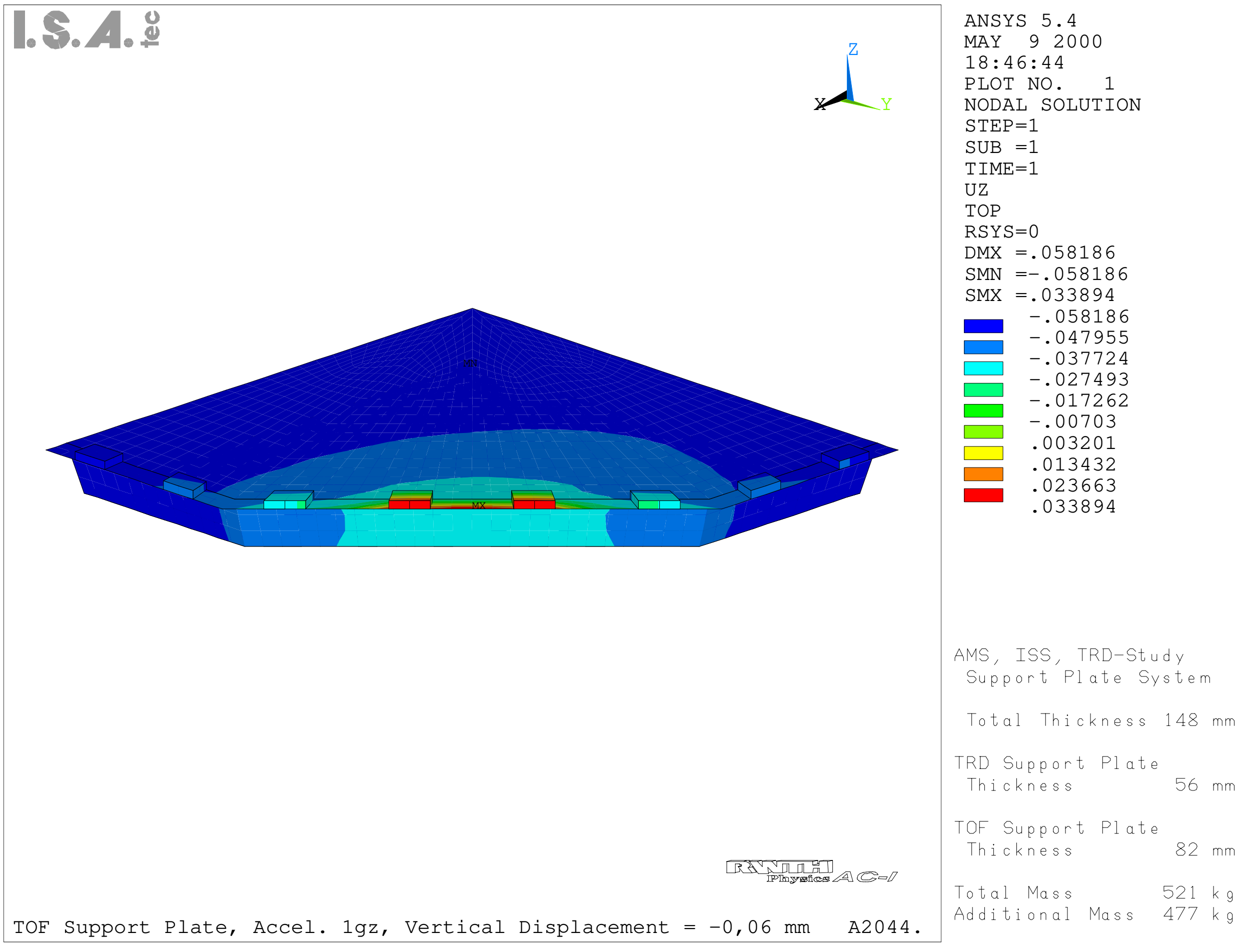


Figure 33: Loaded TOF support plate

AMS, ISS, TRD-Study, Support Plate System, FE-Analysis, Results
Date: 28.4.2000

I.S.A.tec

FE-Model (A2040-2042):	Total Thickness = 148 mm, Total Mass = 519 kg [see Weight Table 2]
TRD Support Plate:	Thickness = 56 mm, Max. Cell Width (CW) = 1680 mm
	Additional Mass[1)] = 352 kg on Upper Face between CW = 1520 mm and CW = 1600 mm
TOF Support Plate:	Thickness = 82 mm, Min. Cell Width = 1490 mm
	Additional Mass[1)] = 80 kg on Lower Face inside CW = 1410 mm
	Additional Mass[1)] = 40 kg on Lower Face between CW = 1410 mm and CW = 1490 mm
CFC-Faces:	M40J, Thickness[2)] = 2 mm, Layup $[0,-45,+45,90]_{symm}$
	E_1 = 205 GPa, $E_2 = E_3$ = 5,6 GPa, ρ = 1,64 g/cm³
Core:	Honeycomb 4.8-32
	E_T = 310 MPa, G_L = 186 MPa, G_W = 90 MPa, ρ = 0,032 g/cm³
C- / S-Profiles:	T300, Thickness = 2mm, Layup Quasi-Isotropic
Spacer:	40 x 40 mm², Thickness = 10 mm, Material Al, E = 70 GPa, ρ = 2,7 g/cm³
Constraints:	Simply Supported (A2041) and Symmetry Conditions
	Stiffening Effects of Octagon Sidewalls not yet Included

1) Additional Masses Homogeneously Distributed
2) CFC Faces of TRD Plates Not yet Optimized

No.	Load	Vertical Displacement u_z [µm]	First Natural Frequency F1 [Hz]	Note
1	Acceleration 1g AMS Z-Direction	-60	64* *Estimation	A2043

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Table 4: FE-Analysis Results for TRD/TOF support plates

AMS02
TRD
Weight

		(kg)
1.	Straw Detector	125
2.	TRD/TOF Support Plates	-
3.	Upper Ring	8
4.	Octagon Panels	33
5.	Reinforcement Walls	12
6.	Connecting Pieces	10
7.	Support Feet to USS	-
8.	Electronics (incl. HV)	80
9.	Shielding	23
10.	Upper Plate incl. LEPS	61
11.	Gas System and Storage (incl. Support and Meteor-Shielding	-
	Payload TRD	352

Table 5: AMS02 TRD payload for support plate and octagon structure

4.3 Bulkheads

There are 2 bulkheads at a distance of 613.8 mm parallel to the AMS x/z-plane to support the straw modules running y-direction (fig. 2). There are two times two bulkhead strips running parallel to the AMS y-z-plane supporting upper four and lower four module planes running x-direction.

FE-Model

The model consists of one complete CFC M40J bulkhead (fig. 34). The shell elements used imply the wall-thickness of 3 mm and the layup $[0°, +14°, -14°]_{symm}$. The chosen layup should provide as many uncutted filaments due to the slot pattern as possible. An additional mass of 125/3 kg is homogeneously distributed on the model, due to one third of the straw detector mass. The model is simply supported at 5 locations at both edges, due to its fixation to the octagon side-walls.

Results

The calculation under 1g z-acceleration (fig. 35) results in a vertical displacement of 28 μm, which equals to 94 Hz for the first natural frequency. The stresses in fibre direction reach from -6 MPa to $+7$ MPa, the stress perpendicular to the fibre direction reach form -2 MPa to $+1$ MPa. The stresses are not averaged and are equal at top and bottom (table 6).

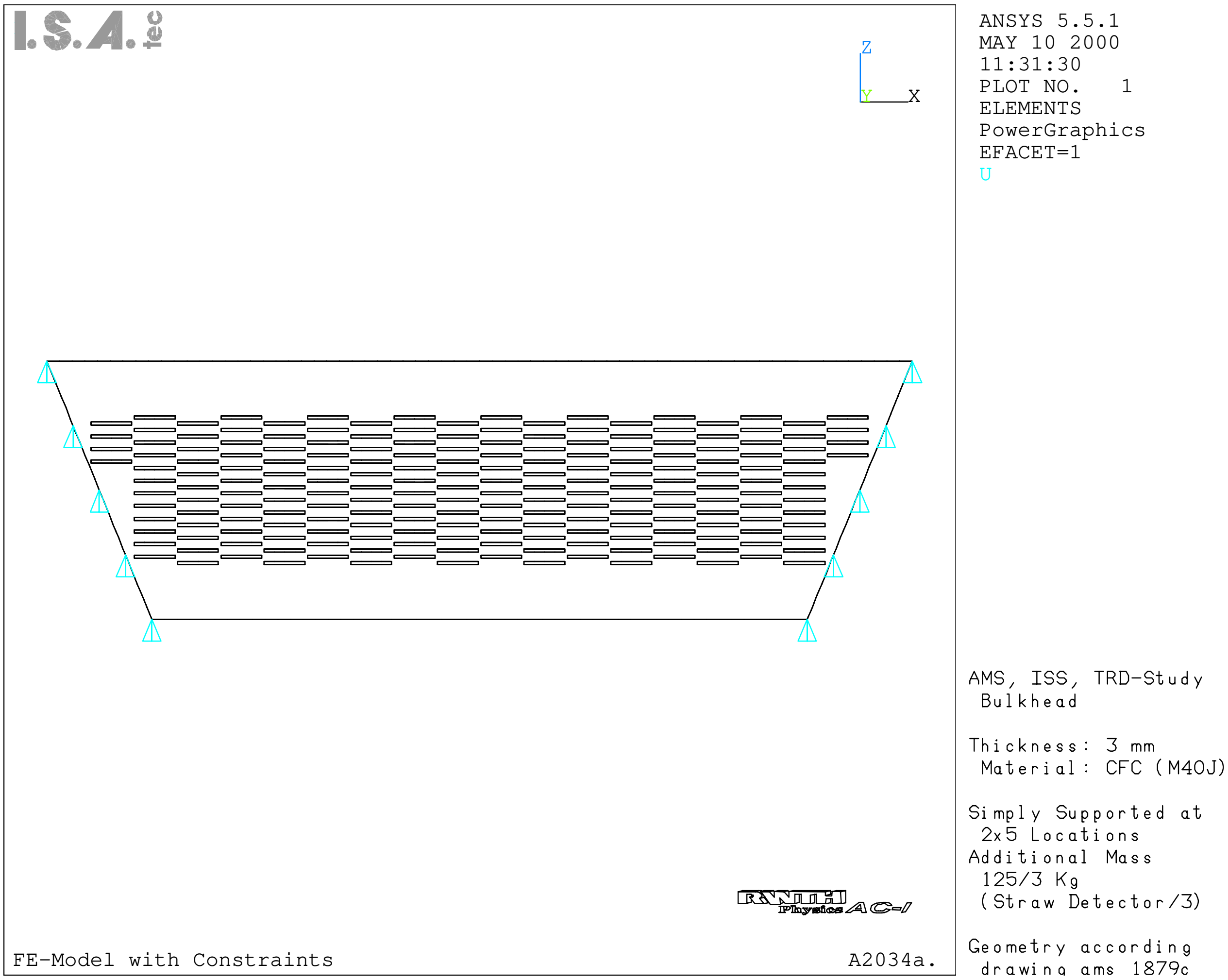

Figure 34: Geometry of bulkhead (in x-z plane)

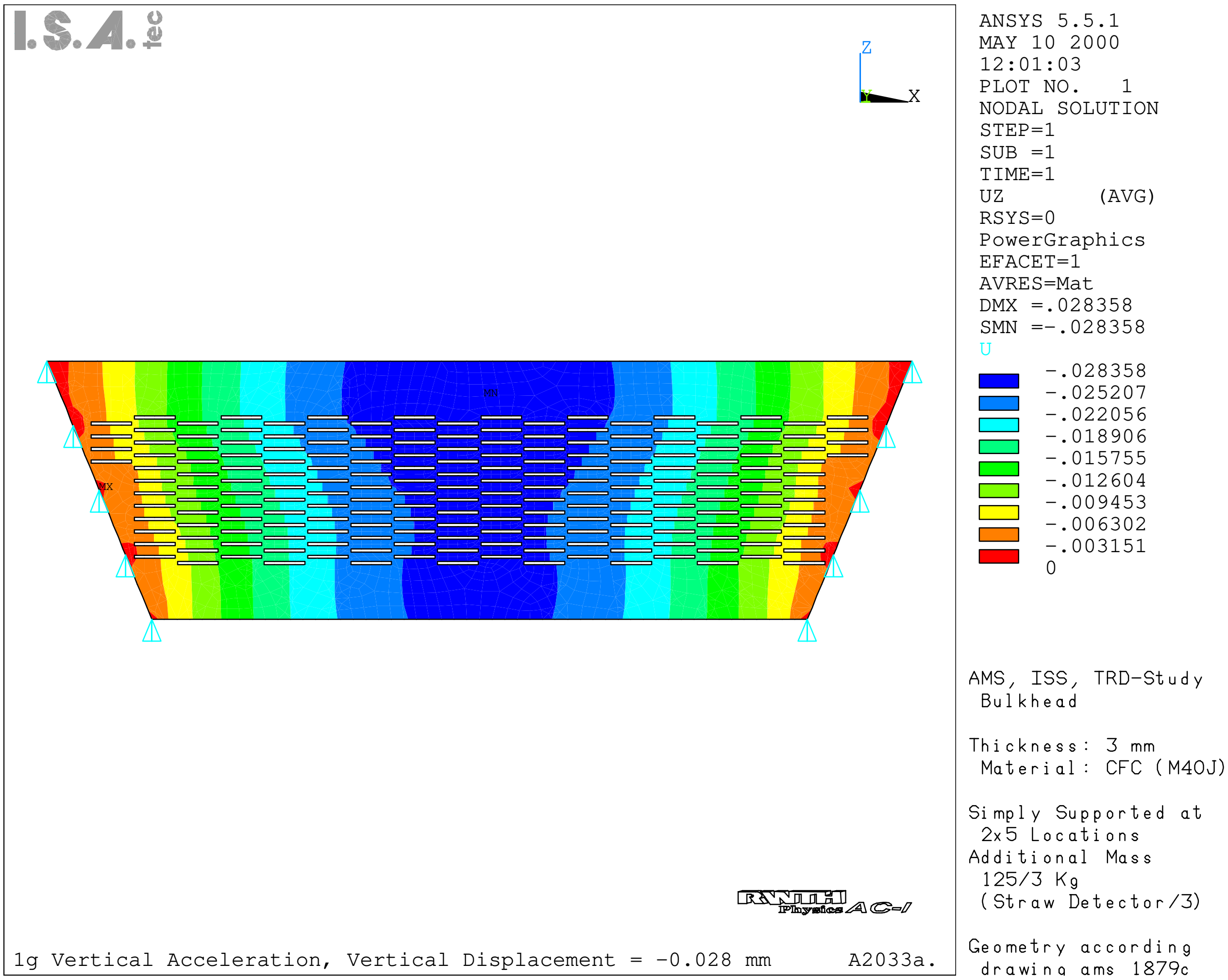

Figure 35: Loaded bulkhead (in x-z plane)

AMS, ISS, TRD-Study, Bulkhead, FE-Analysis, Results, Date: 26.4.2000

FE-Model (A2034a):	Thickness = 3 mm,	Additional Mass = 125/3 kg (Straw Detector / 3)
Geometry:	According Drawing ams 1879c	
Constraints:	Simply Supported at 2 x 5 Locations (A2034a)	
Material:	CFC: M40J, Layup $[0,14,-14]_{symm}$ E_1 = 205 GPa, $E_2 = E_3$ = 5,6 GPa, ρ = 1,64 g/cm³	

No.	Load	Vertical Displacement u_z [µm]	First Natural Frequency F1 [Hz]	Stress: Min./Max. σ_i [MPa]	Note
1	Acceleration 1g AMS Z-Direction	$-28^{1)}$ $^{1)}$ see A2033a	$94^{2)}$ $^{2)}$ Estimation	$\sigma_{\parallel}$: -6 / 7 $^{3)}$ $\sigma_{\perp}$: -2 / 1 $^{3)}$ $^{3)}$ No Average, Equal Results at Top and Bottom	
2	Acceleration 2 x 13g AMS Z-Direction	-728		$\sigma_{\parallel}$: -156 / 182 $^{3)}$ $\sigma_{\perp}$: -52 / 26 $^{3)}$ $^{3)}$ No Average, Equal Results at Top and Bottom	

bulkh.doc

Table 6: FE-Analysis results for bulkhead

4.4 Octagon

The TRD Octagon is supported by a lower plate, which is connected to the USS. It is built up by three types of side-walls, which differ in the slot-pattern. The whole structure is shielded by an upper plate.

FE-Model

The geometry of the FE-model, see 90°- and 180° model plots (figs. 36, 37), is based on the CAD drawing no. 1834, which matches the initial 16 layer configuration (similar to the 20 layer design, fig. 4). With this study the design rules were derived. The model consists of shell elements which implement the real wall thicknesses as well as the real layup of the CFC resp. the honeycomb material (table 7). The side-walls are loaded with additional masses due to the straw detector mass and the equipment mass. A 180° model was chosen to consider a possible parallelogram movement under horizontal acceleration. The model of the lower plate is simply supported along a length of 150 mm at 45° to the main directions.

Results

The calculation under 1g x-acceleration results in a vector sum of displacements of 96 μm (fig. 38). The occurring stresses in fibre direction are less than 16 MPa and perpendicular to the fibre direction are less than 2 MPa (table 8).

TRD/USS Support

A further calculation with an overall model of a rigid TRD octagon connected with elastic bearing tubes to the rigid USS interface revealed a first natural frequency of 65 Hz. Table 9 describes the FE-model and the frequencies and the corresponding modes.

The low radial stiffness of 31500 N/mm in the present design of the USS keeps the forces in the interface to the TRD sufficiently low in case of thermal contraction of the magnet case while going to low temperature operation in orbit. Therefore there is no additional compensating element foreseen at the moment.

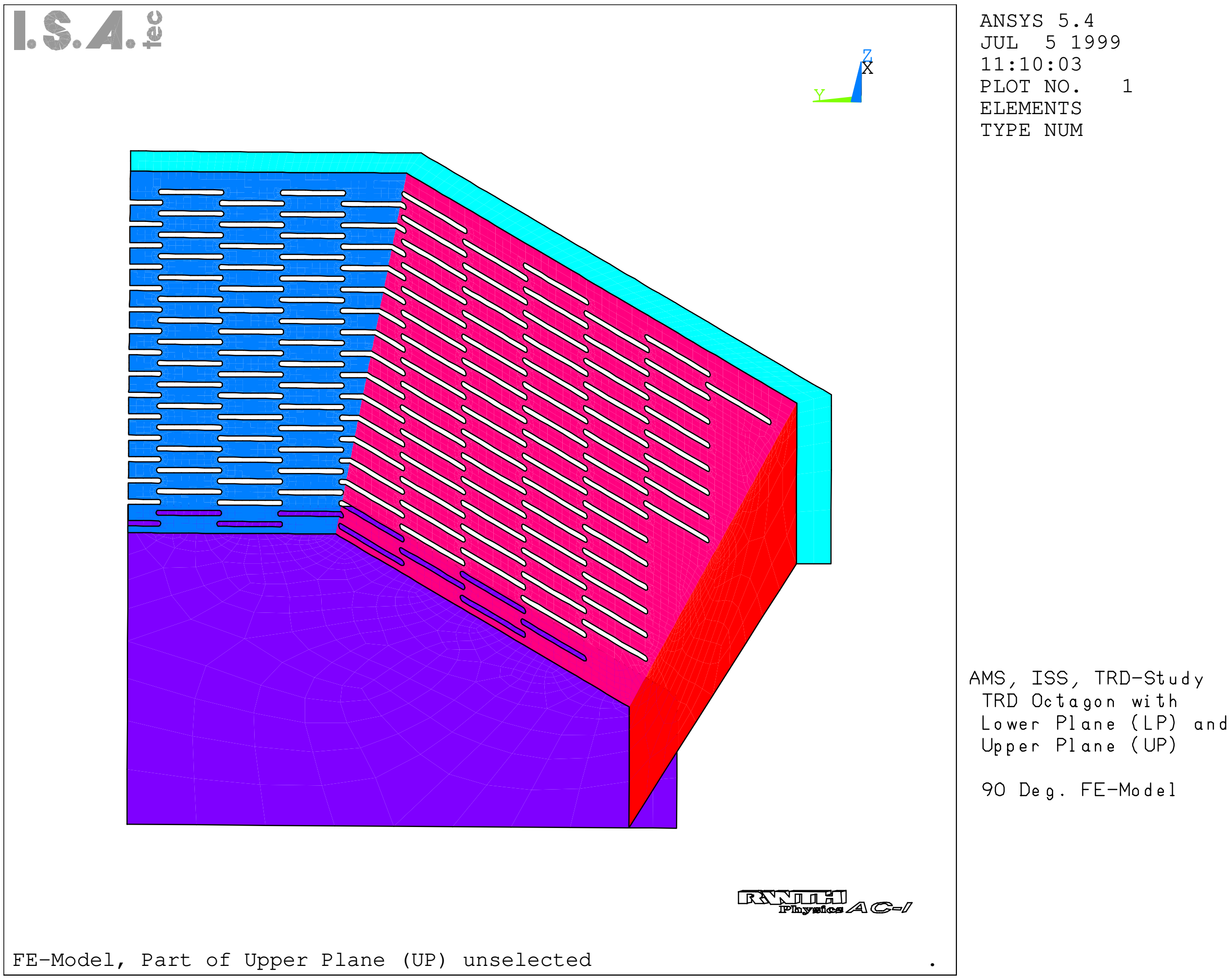

Figure 36: 90°-FE-Model for TRD octagon

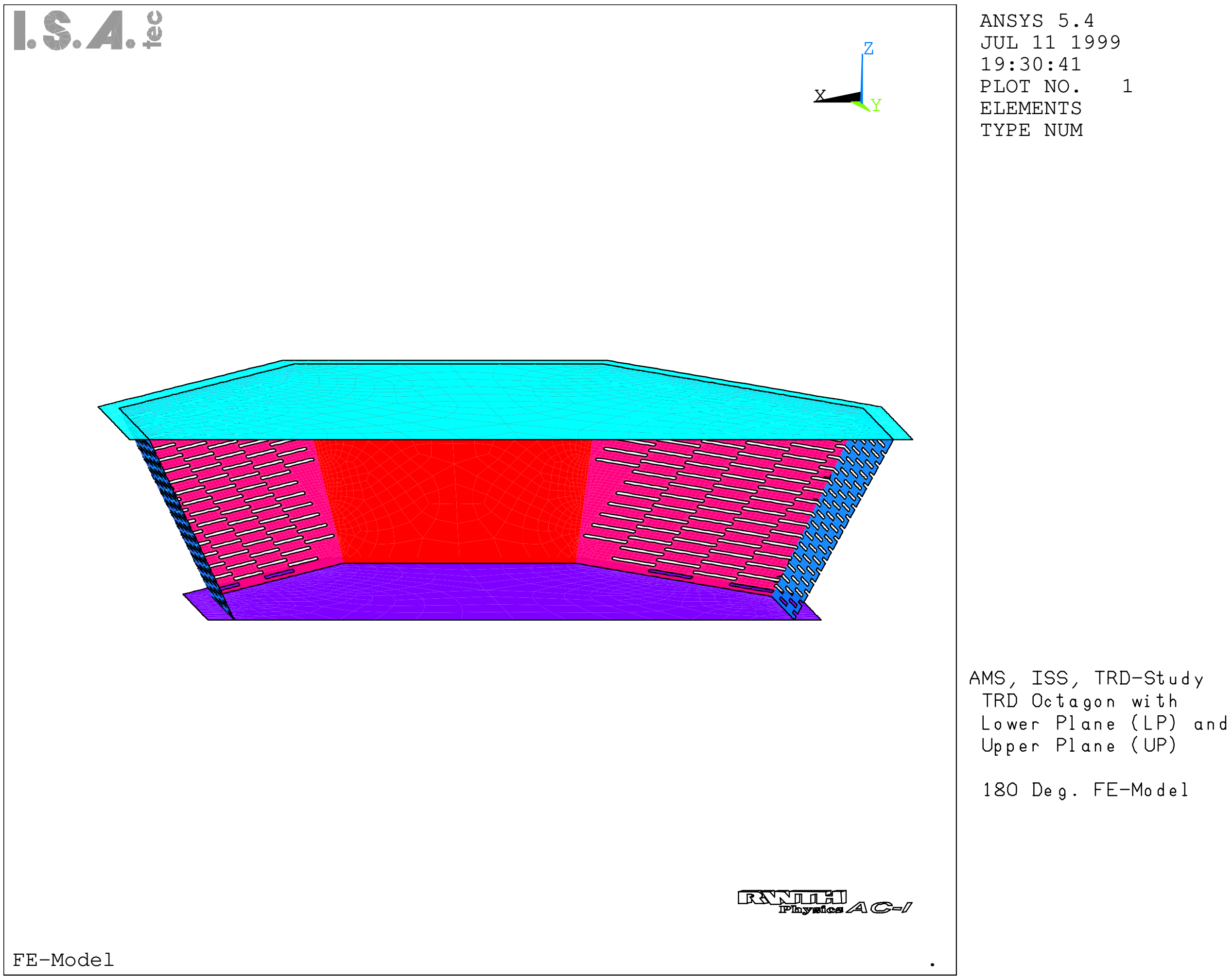

Figure 37: 180°-FE-Model for TRD octagon

AMS, ISS: TRD Study, Octagon

180° FE-Model, Material Data, Date: 5.7.99

I.S.A. tec

Component, Material	Type	Elastic Modulus [N/mm²]	Shear Modulus [N/mm²]	Density [kg/dm³]
Faces, CFC	T300 / EP	$E_{\parallel}$ = 125.000 $E_{\perp}$ = 5.400	2.400	1,6
Core, Honeycomb (LP and UP)	4.8-32	E_T = 310	G_L = 186 G_W = 90	0,032
Core, Foam (Side-Walls)	Airex R82.80	52	22	0,080
Additional Faces (Reinforcement), CFC	-	70.000	26.120	1,6

oct_mat1

Table 7: Material Data for 180°-FE-Model for TRD octagon

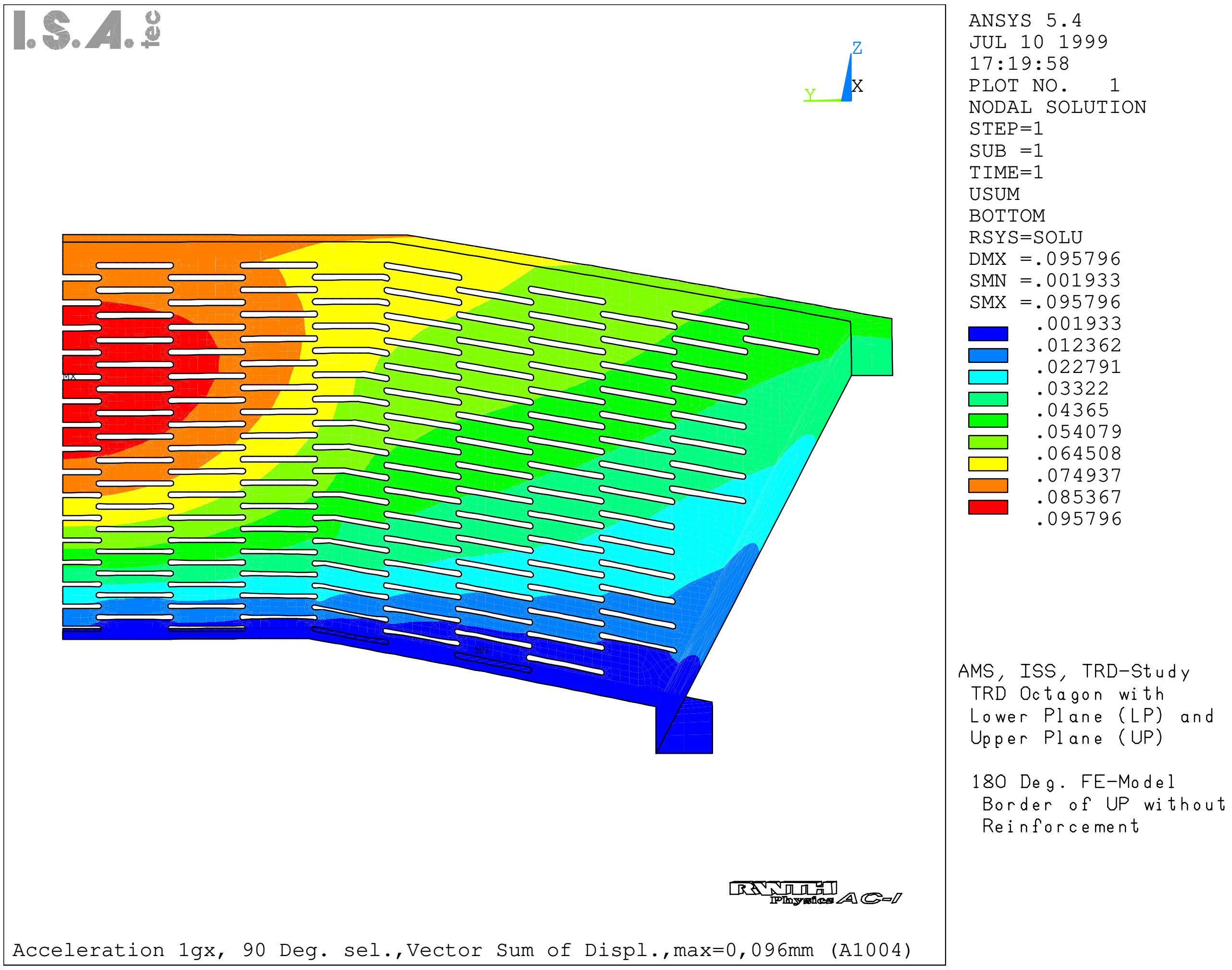

Figure 38: Octagon deformation under 1g x-acceleration

AMS, ISS: TRD Study, Octagon, 180° FE-Model, FEA Results, Date: 24.09.99

I.S.A. tec

Acceleration: 1g in X_{AMS}-Direction

No.	Vector Sum of Displacements u_{SUM} [µm]	Displace-ments u_i [µm]	Side-Wall 1) Stress: Min./Max. σ_i [MPa]	Mass (1/1 Upper Plate) [kg]	Upper Plate Width [mm]	Note
1	96	u_x = 72 u_y = 9 $\lvert u_z \rvert$ = 64	$\lvert\sigma_{\parallel}\rvert$: < 16 $\lvert\sigma_{\perp}\rvert$: < 2	13,7	2168 (=2060+2*(34+20))	Complete UP S(CFC)=2x0,6mm, s(Core)=50mm 34mm = Proj. S-W Thickness 20mm = Flange

oct180_8

Table 8: Octagon stresses under 1g x-acceleration

AMS, ISS: TRD Octagon with Bearing Tubes

FE-Modal Analysis, Date: 3.04.00

Location of FE-Model Origin: Plate Center at Z_{AMS} = 754 mm

Version FE-Model Description	Total Mass [kg]	Bearing Tube Axes, Vertical Location	Centroid, Location above Origin [mm]	USS Stiffnesses	Natural Frequencies [Hz]	Mode	Plots
TRD_Oct_19 inhomogeneous long Bearing Tubes rigid USS see App. A_19	495	Plate, Upper Face	249	rigid	1st : 65 2nd : 87 3rd : 109 4th : 119 5th: 213 6th: 215	Rotation about Z_{AMS} Vertical Translation Rotation about Y_{AMS} Rotation about X_{AMS} Horizontal Translation Horizontal Translation	

TRD_Oct_Res_19

Table 9: Octagon vibration modes in a rigid USS

4.5 TRD cover plate

A preliminary design study of the TRD cover plate results in an acceptable first eigenfreuquency. The required amount of material to obtain this stiffness will also serve as a low energy particle shield (LEPS).

AMS02 TRD-Upper Plate incl. LEPS-Function (Optional)

Cell Width 2310 mm (Drawing ams1865f)
Width of Boundary Condition 2170 mm
Faces T300, Thickness 4 mm Each, Layup 0, -90, 45, -45, 90, 0, -45, 45, Symmetrical
Al-Honeycomb Density 32 kg/m^3
Boundary Condition: Translations x, y, z Pinned

Honeycomb Thickness mm	Total Thickness mm	Max. Deflection mm	First Eigenfrequency Hz
40	48	0,054	84,5

RWTH Physics AC-I

Table 10: TRD cover plate (LEPS) design study

4.6 Vibration tests of straw module prototypes

The 328 straw modules supported by the 2 sets of bulkheads have been demonstrated to behave according to expectations by a vibration test (fig. 40) with a 40 cm long prototype chamber (fig. 39). At this length Eigenfrequencies are around 110 Hz (figs. 42). The chambers are sufficiently resistent against 6.8 g (RMS) random excitation (figs. 43, 44). It is clear that the straw module sandwiched in between the radiators are strongly damped (fig. 45). As the amplification in the straw modules is sensitive to deformations the flight straw modules will have more stiffeners than the prototype ones resulting in higher fundamental frequencies (table 13).

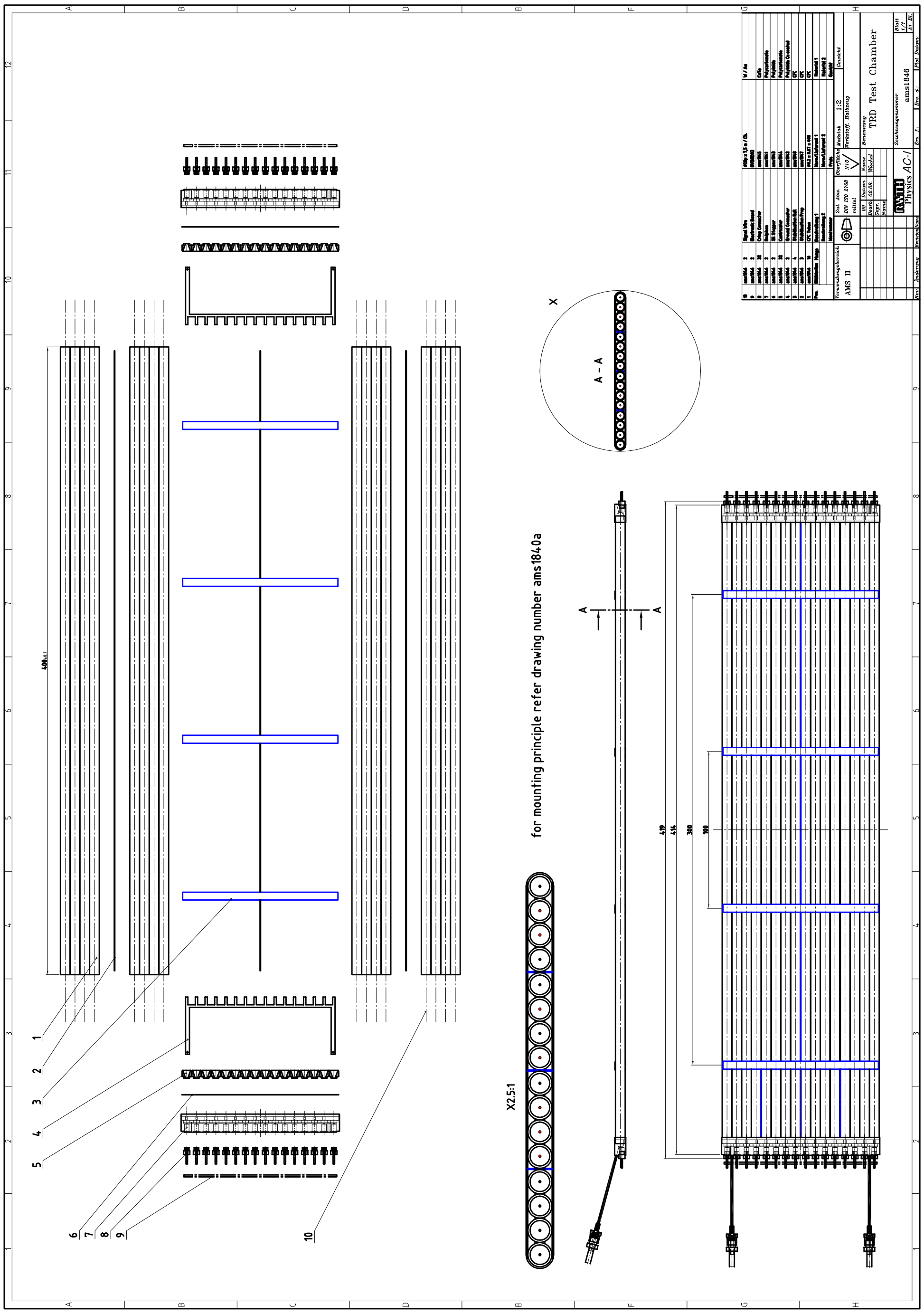

Figure 39: Straw module assembly (CERN 2000 test)

Max-Planck-Institut für extraterrestrische Physik MPE Testlabor
85740 Garching

AMS 02 TRD-Mod 1 / PMT

TESTBERICHT 9957

Testaufbau Z-Achse

Testaufbau -Z-Achse PMT X-Achse

Testaufbau Z-Achse PMT Y-Achse

Garching, den 20.12.99 Stöberl.

Figure 40: Setup for vibration test at MPE Testlabor Garching

Max-Planck-Institut für extraterrestrische Physik MPE Testlabor
85740 Garching

AMS 02 TRD-Mod 1 / PMT

TESTBERICHT 9957

Auftraggeber: RWTH Aachen (Prof. Dr. Lübelsmeyer)

Test Nr	Datum Uhrzeit	Test Achse	Test Art	Frequenz Start (Hz)	End	D Da (mm)	A (g)	PSD (g^2/Hz)	Okt/min g rms	Test Zeit (sec)	Bemerkungen
01	17.12.99 09.20	Z	Sinus Low Level	10	2000		0.2		2		Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf Aufnahme mit D=80µm/V, V=25mm/s (Referenzmessung). Abort bei 745 Hz. Nächster Test mit 0.5g.
02	17.12.99 09.34	Z	Sinus Low Level	10	2000		0.5		2		Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf Aufnahme mit D=80µm/V, V=25mm/s (Referenzmessung). PMT-R5946 WA9214 in Z-Achse.
03	17.12.99 10.23	Z	Sinus Low Level	10	2000		0.5		2		Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf M 1-2 mit D=80µm/V, V=25mm/s. PMT-R5946 WA9214 in Z-Achse.
04	17.12.99 10.47	Z	Sinus Low Level	10	2000		0.5		2		Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf M 1-2 mit D=320µm/V, V=25mm/s. PMT-R5946 WA9214 in Z-Achse.
05	17.12.99 11.10	Z	Random Programm	20 80 500	80 500 2000			+3 dB/Okt 0.04 g^2/Hz -3 dB/Okt	6.79	90 sec	Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf M 1-2 mit D=320µm/V, V=25mm/s. Aufnehmer 2xyz abgebrochen (Daten nicht ausgedruckt). Datenaufzeichnung 150 Mittlungen. PMT-R5946 WA9214 in Z-Achse.
06	17.12.99 11.32	Z	Sinus Low Level	10	2000		0.5		2		Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf M 1-2 mit D=320µm/V, V=25mm/s. Aufnehmer 2xyz neu geklebt. PMT-R5946 WA9214 in Z-Achse.
07	17.12.99 11.46	Z	Sinus Low Level	10	2000		0.5		2		Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf R 1-2 mit D=320µm/V, V=25mm/s. PMT-R5946 WA9214 in Z-Achse.
08	17.12.99 12.24	-Z	Sinus Low Level	10	2000		0.5		2		Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf M 3-4 mit D=320µm/V, V=25mm/s. PMT-R5946 WA9214 in X-Achse.
09	17.12.99 12.38	-Z	Random Programm	20 80 500	80 500 2000			+3 dB/Okt 0.04 g^2/Hz -3 dB/Okt	6.79	90 sec	Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf M 3-4 mit D=320µm/V, V=25mm/s. Datenaufzeichnung 150 Mittlungen. PMT-R5946 WA9214 in X-Achse.
10	17.12.99 12.50	-Z	Sinus Low Level	10	2000		0.5		2		Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf M 3-4 mit D=320µm/V, V=25mm/s. PMT-R5946 WA9214 in X-Achse.

Table 11: Vibration test sequence A

Max-Planck-Institut für extraterrestrische Physik MPE Testlabor
85740 Garching

AMS 02 TRD-Mod 1 / PMT

T E S T B E R I C H T 9 9 5 7

Test Nr	Datum Uhrzeit	Test Achse	Test Art	Frequenz Start (Hz)	End	D Da (mm)	A (g)	PSD (g²/Hz)	Okt/min g rms	Test Zeit (sec)	Bemerkungen
11	17.12.99 13.50	Z	Sinus Low Level	10	2000		0.5		2		Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf M 1-2 mit D=320µm/V, V=25mm/s (mit Dämpfung). PMT-R5946 WA9214 in Y-Achse.
12	17.12.99 14.08	Z	Random Programm	20 80 500	80 500 2000			+3 dB/Okt 0.04 g²/Hz -3 dB/Okt	6.79	90 sec	Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf M 1-2 mit D=320µm/V, V=25mm/s (mit Dämpfung). Datenaufzeichnung 150 Mittl. Meßpunkt 2 abgebrochen (kein Datenausdruck). PMT-R5946 WA9214 in Y-Achse.
13	17.12.99 14.29	Z	Sinus Low Level	10	2000		0.5		2		Regelung an R1z. Mp R2z, R3z; Mp1xyz, 2xyz, 3xyz und Laser 4d, 4v. Laserpunkt auf M 1-2 mit D=320µm/V, V=25mm/s (~~mit~~ Dämpfung). PMT-R5946 WA9214 in Y-Achse.

Garching, den 20.12.99 Stöberl.

Table 12: Vibration test sequence B

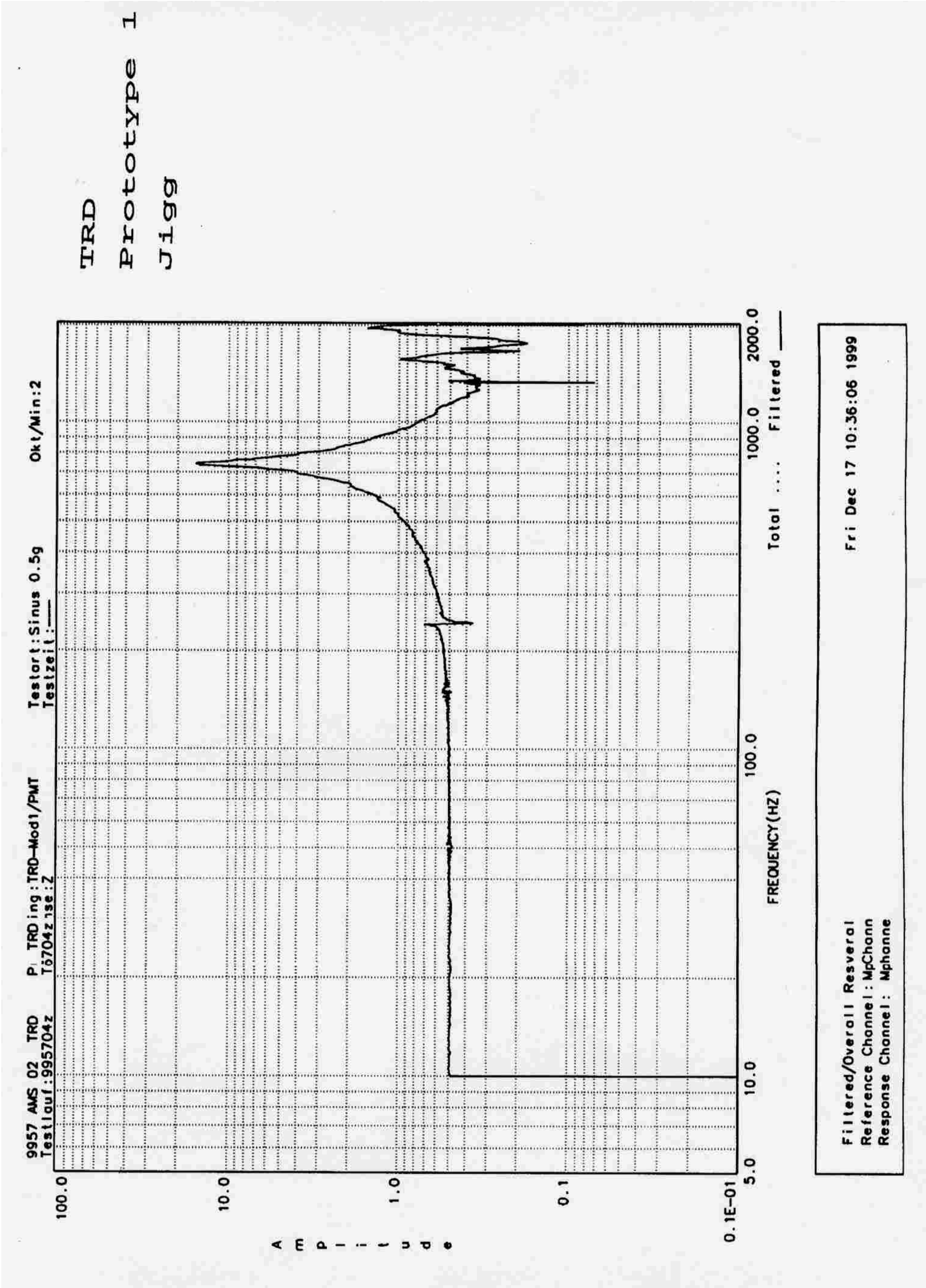

Figure 41: Vibration curve for the straw module jig

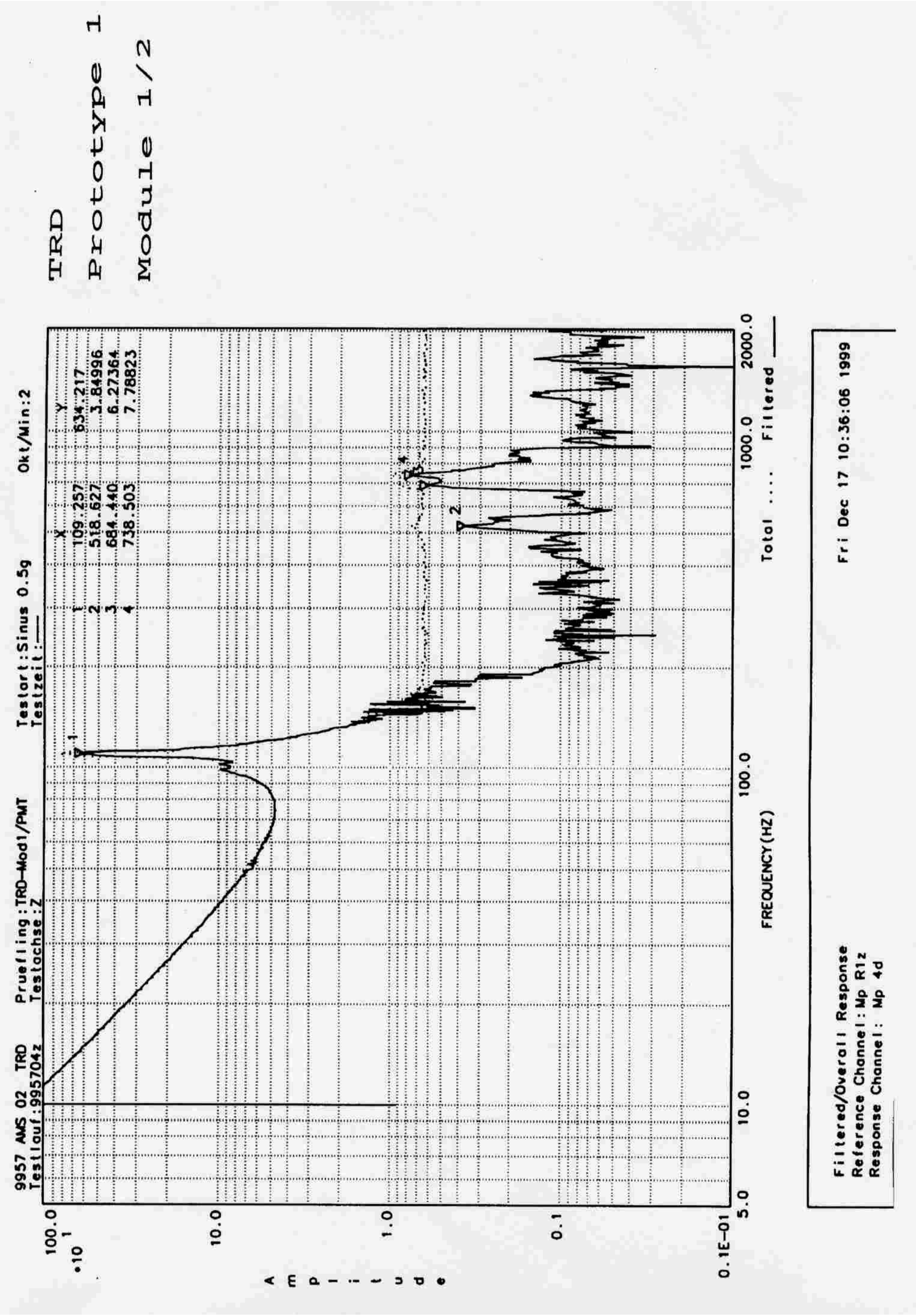

Figure 42: Vibration curve for straw module (without radiator)

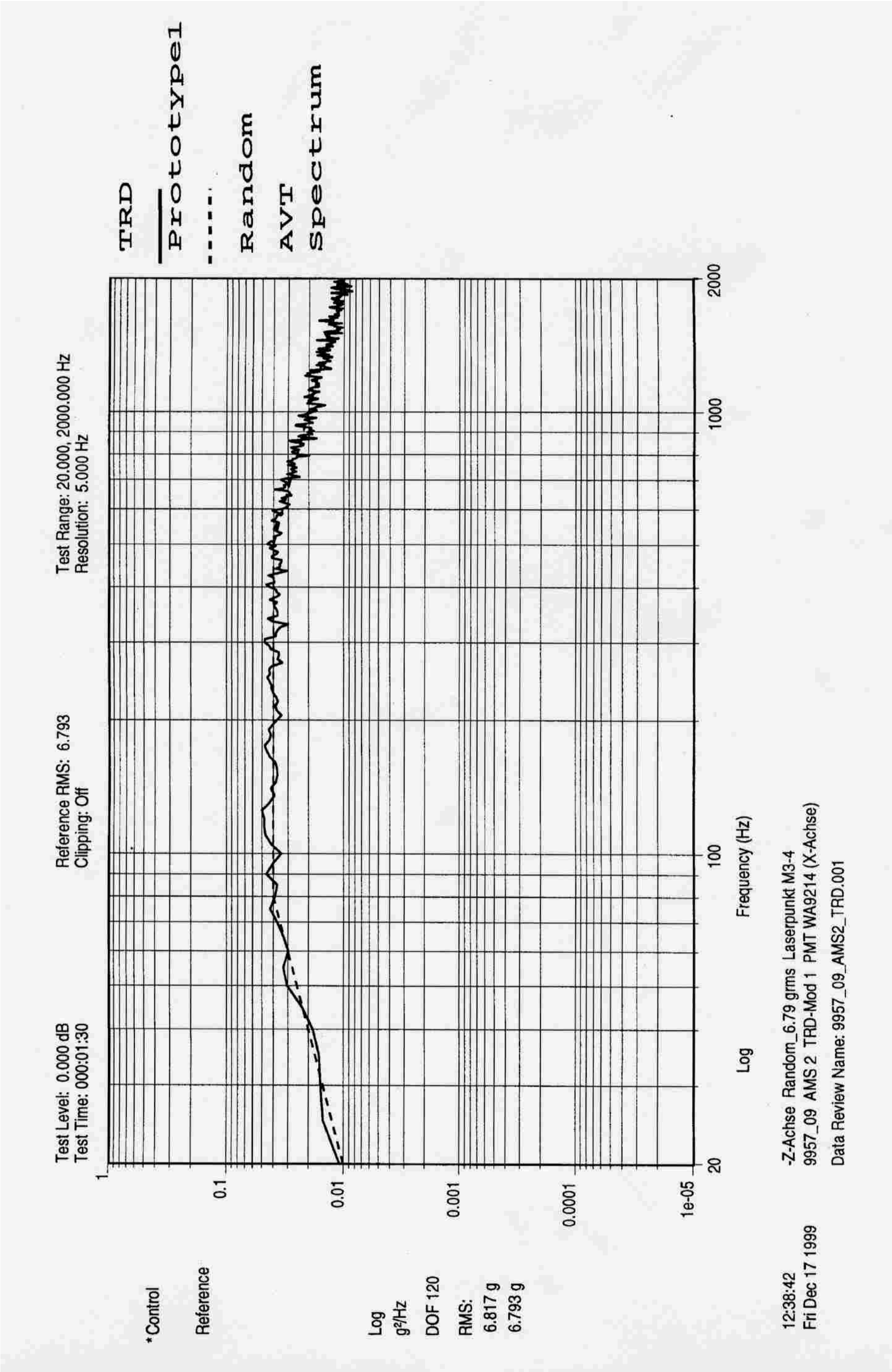

Figure 43: Spectrum of random vibration test

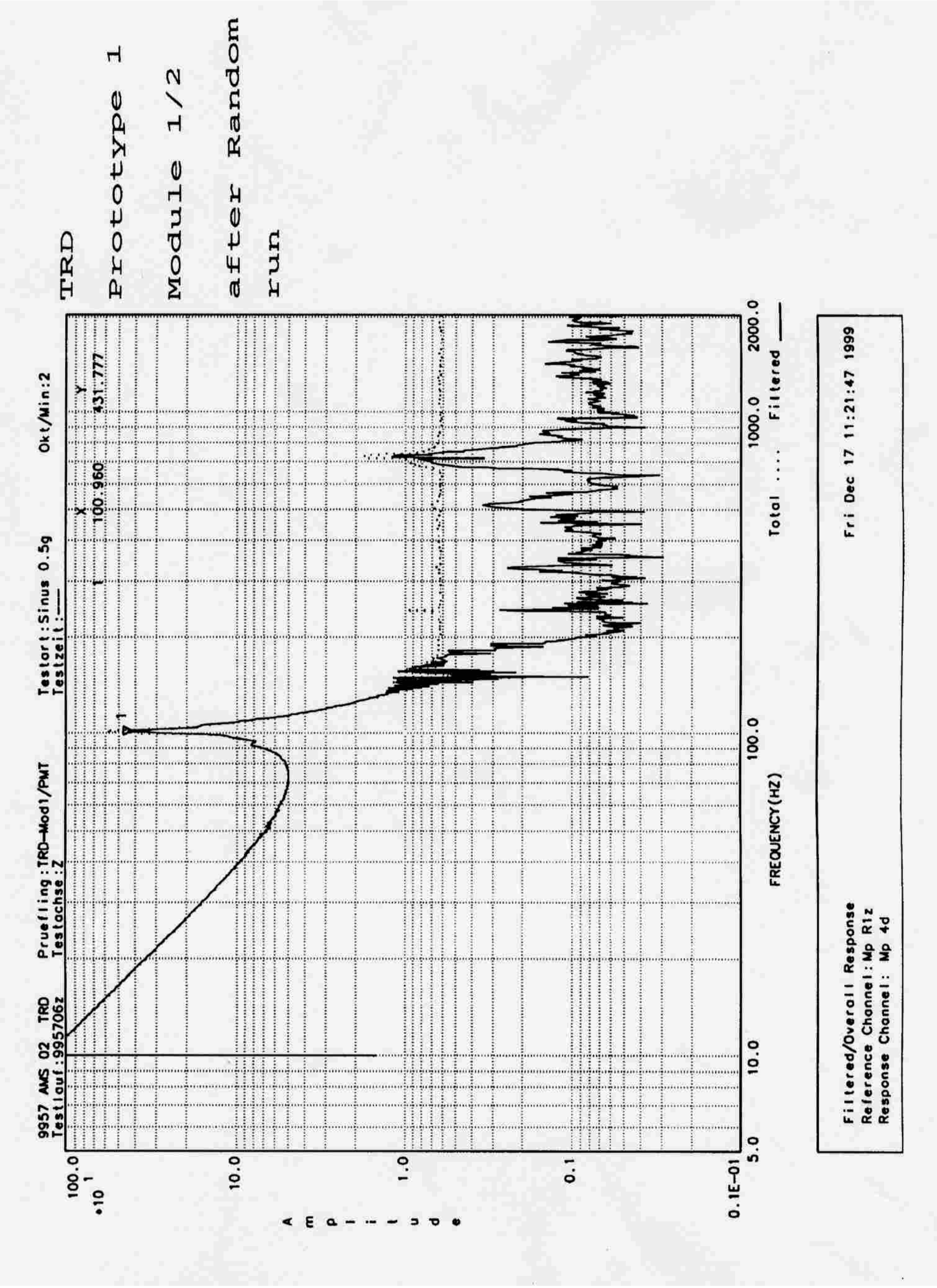

Figure 44: Vibration curve for straw module (without radiator) after random vibration test

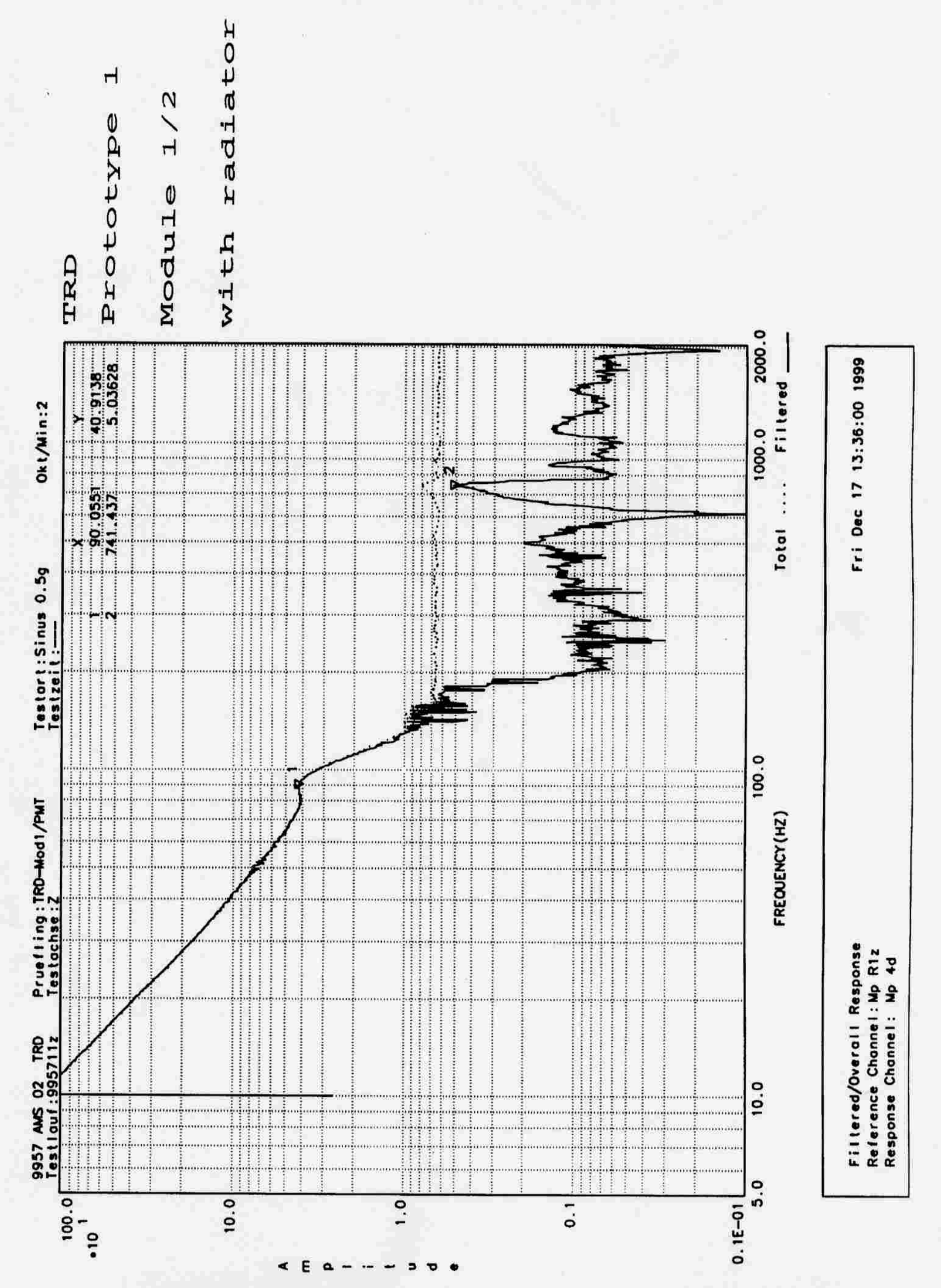

Figure 45: Vibration curve for straw module damped by radiator

Table 13: Comparison of mechanical properties for prototype and flight version of straw modules

AMS02
TRD
16 Straw Module
Mechanical Properties

Material Data:

Straw Modulus	$E_1 =$	2300 MPa
Stiffener Modulus Type 1	$E_2 =$	62000 MPa
Stiffener Modulus Type 2	$E_3 =$	200000 MPa

Module length (mm)	# of stiffener Type 1	# of stiffener Type 2	d_{max} (clamped) (μm)	Frequency (Hz)	Measured Frequency (Hz)
400	3	-	20	111	109
625	-	6	15	128	-