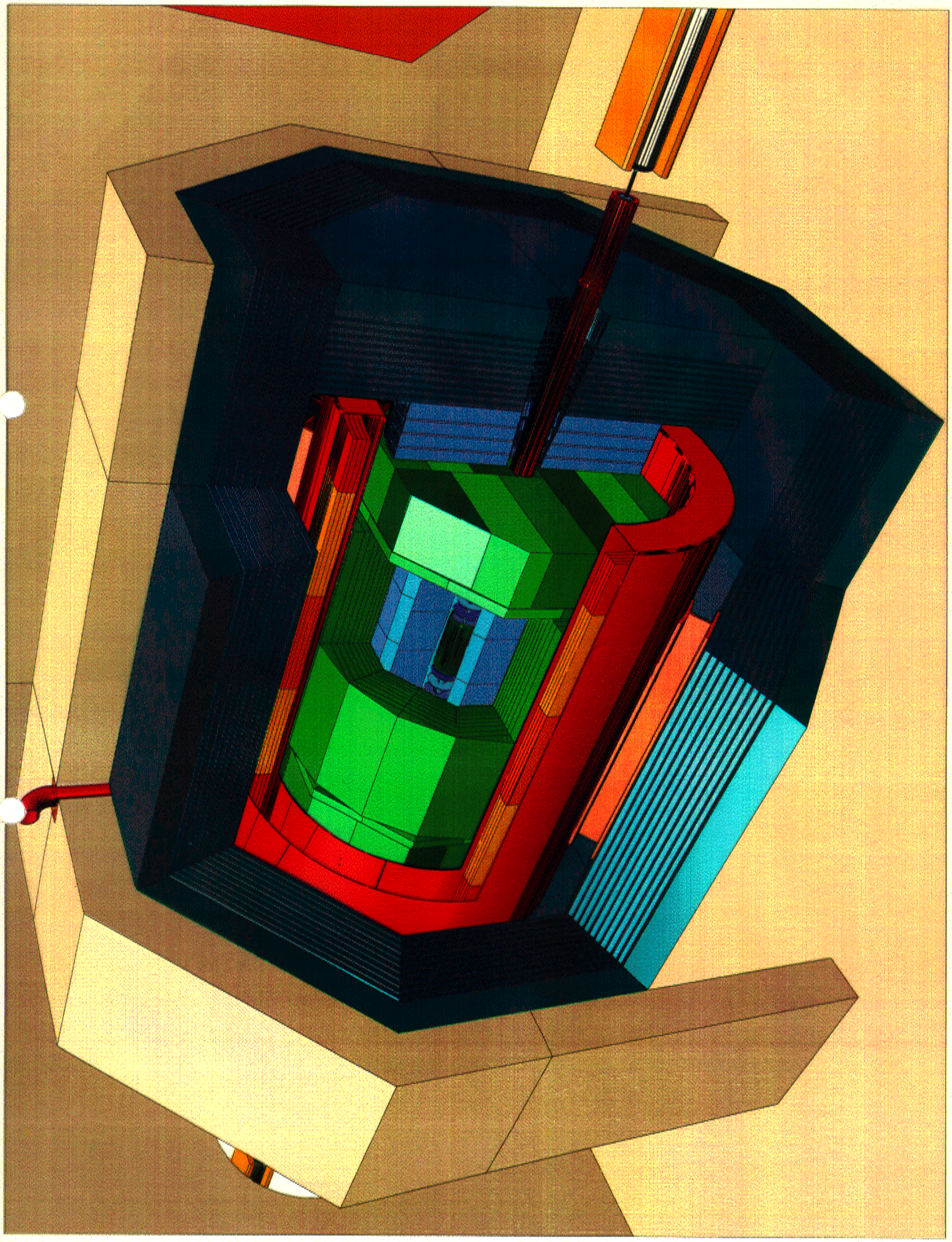
The hadronic
Tile Calorimeter
for the TESLA detector

Design and performance studies in frame of:

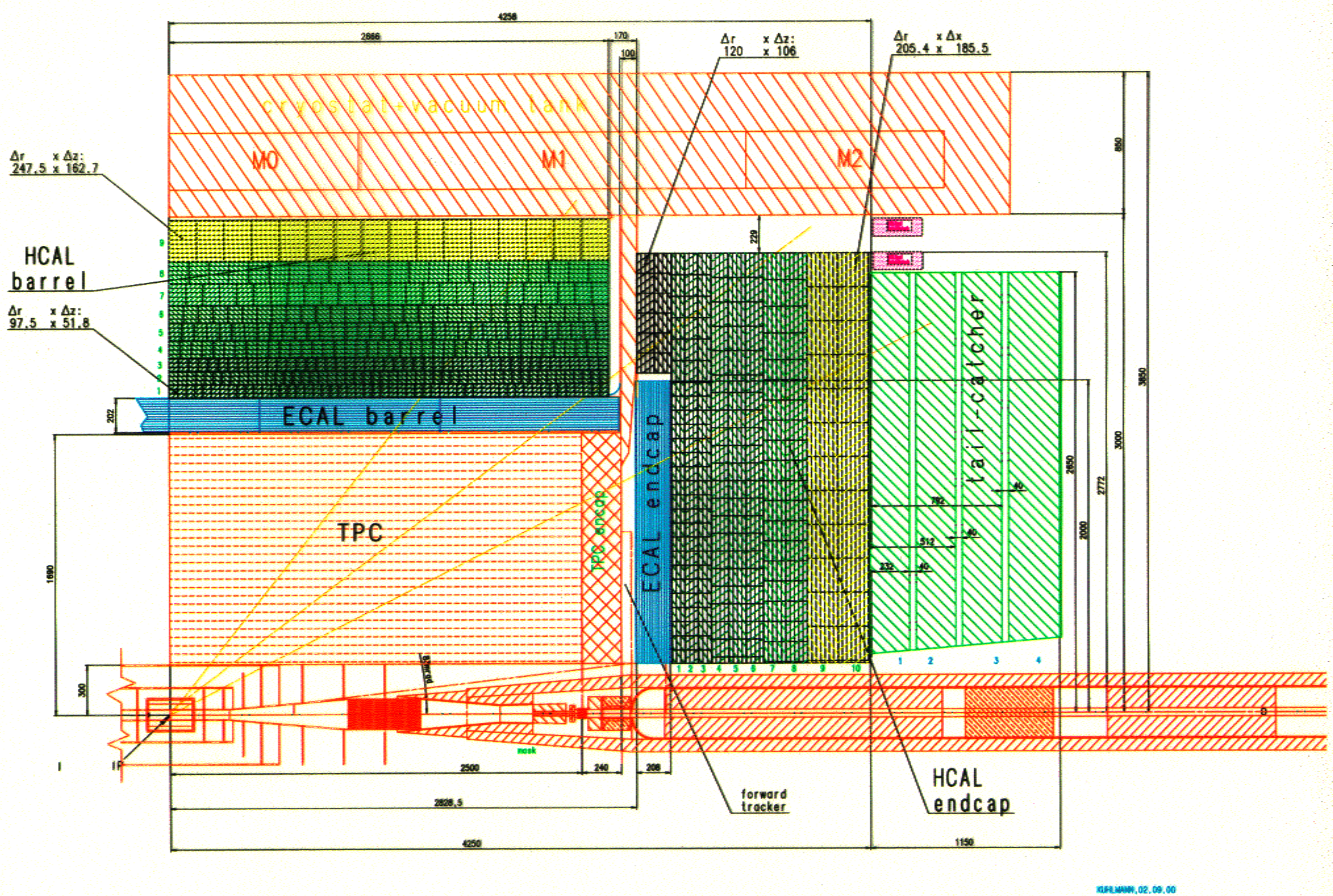
ECFA DESY
Linear Collider Workshop

Actual status of

- design of HCAL
  - scientific view
  - engeneering view
- the readout system
  - scintillator-WLS-fibre RO
  - photodetectors
  - electronic RO
- performance
- calibration
- installation
- R&D and future tests



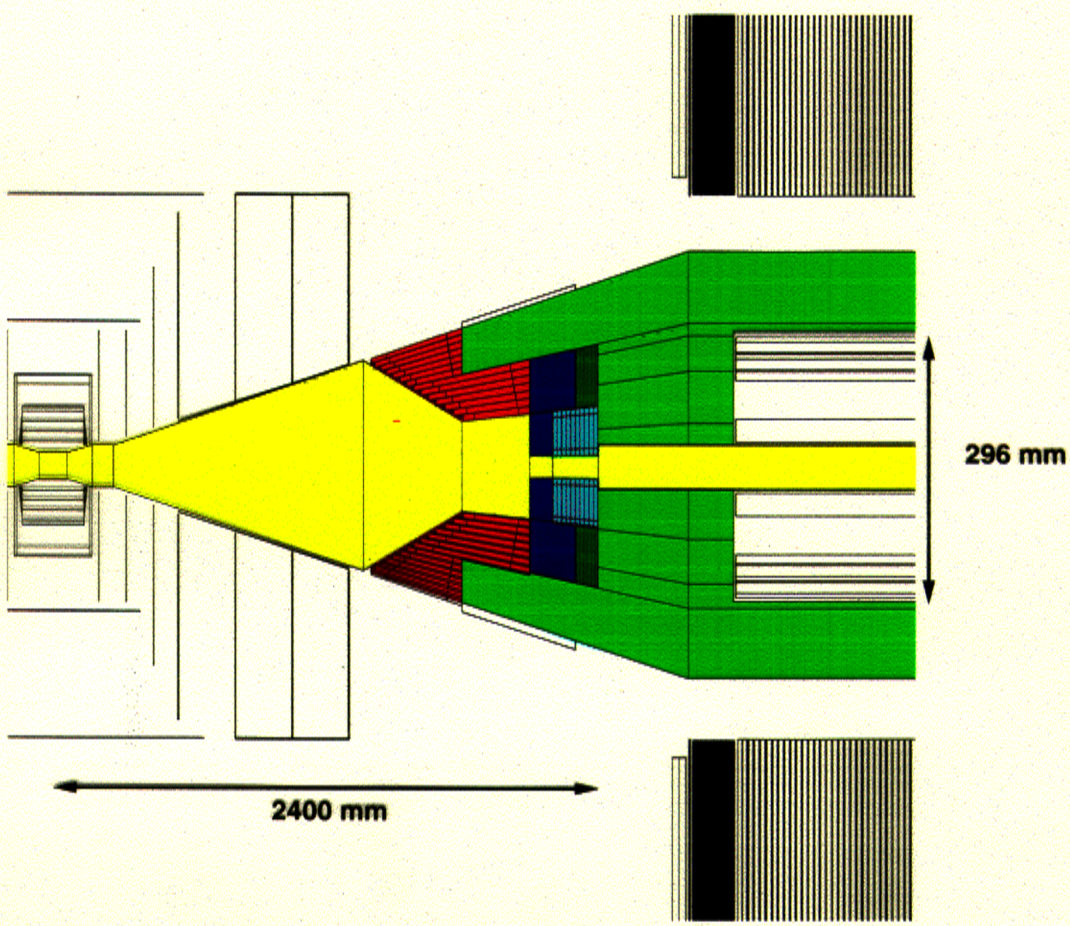
longitudinal cut through the TESLA inner detector



The Mask Region

Design of the mask region

- Tungsten shield for backscattered pairs and secondaries
- Neutron shield (graphite absorbers)
- Shield for synchrotron radiation



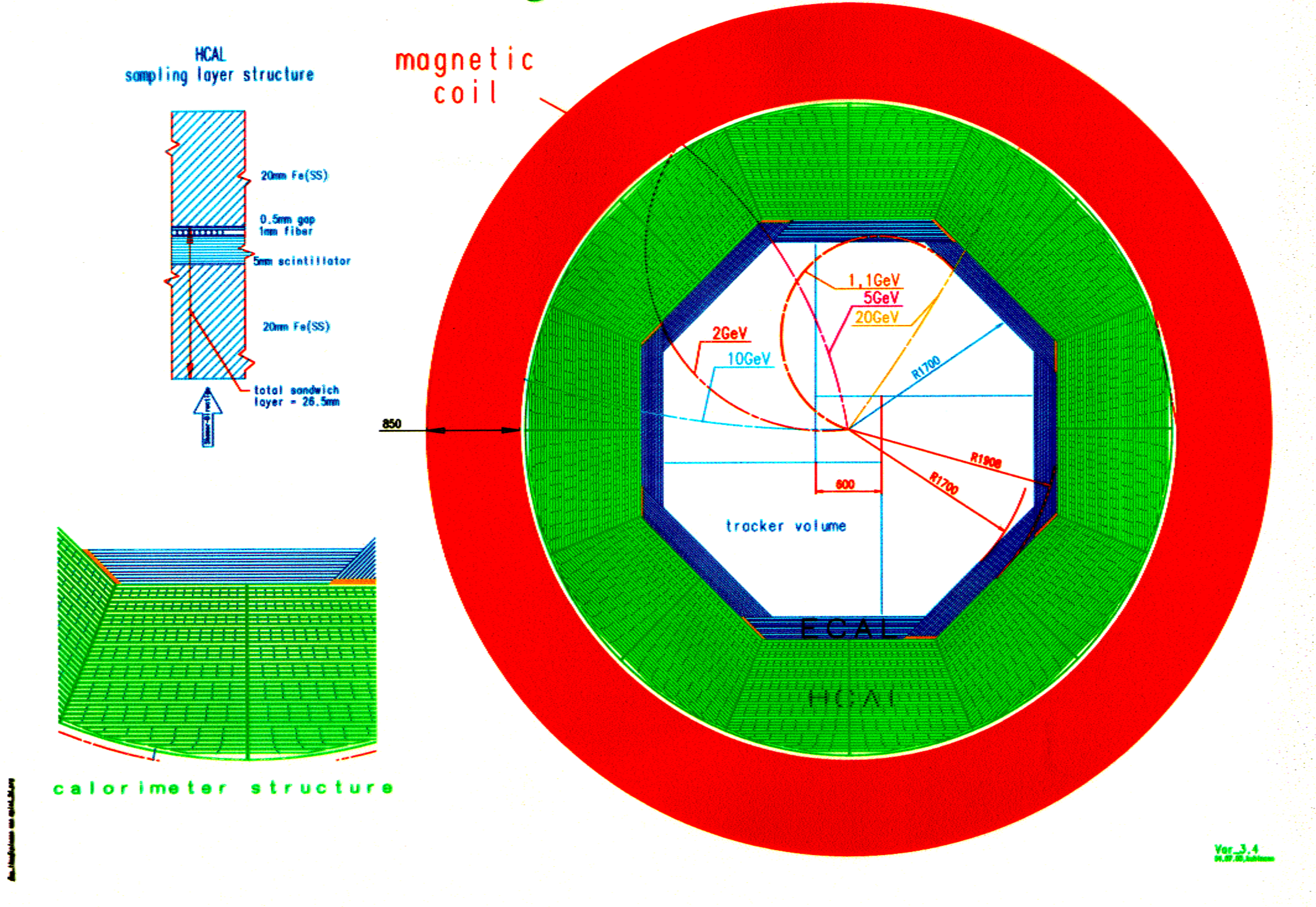
- Instrumentation for small angles
  - Low Angle Tagger (LAT)
  - Luminosity CALorimeter (LCAL)

The measurement of particles and jets

- TPC (measures charged tracks)
  - r= 150 cm, 5 x 10^7 pixels, 3-dim. reconstr.,
  - $dp/p^2 = 0.6 \times 10^{-4} (GeV/c)^{-1}$,
  - dE/dx for e,μ,π,p-separation
- calorimeter barrel (2 halfs)
  - electromagnetic, ECAL,(γ's)
    - 24 ~~30~~ Xo, ≈ 1 λ
    - Si pads / W absorber
  - hadronic, HCAL,(neutral hadrons)
    - 4-7 λ
    - scintillating tiles/Fe absorber
- calorimeter endcap (2 caps)
  - electromagnetic structure as barrel
  - hadronic structure as barrel, but 10 λ deep
  - Fe instrumented yoke with 4 RO gaps adds 4 λ
- coil

  4 Tesla, 80 cm thick, 1.8 λ of dead material
- muon system
  - leakage measurement
  - more than 10 λ deep
- mask calorimeter around beamline

lateral cut through the TESLA inner detector



more on the HCAL

The sampling structure

•Fe/scintillator sandwiches, 2/0.5 cm,

•0.1 cm gap for clear RO fibres (d = 0.8...1.0 mm)

•0.05 mm gap for reflector foil and tolerances

more about the scintillator and tiles

•scintilltor: area : 5860 m^2, weight 30 to

•high multiplicity events, separation of neutrals:

•>> very high granularity even in HCAL

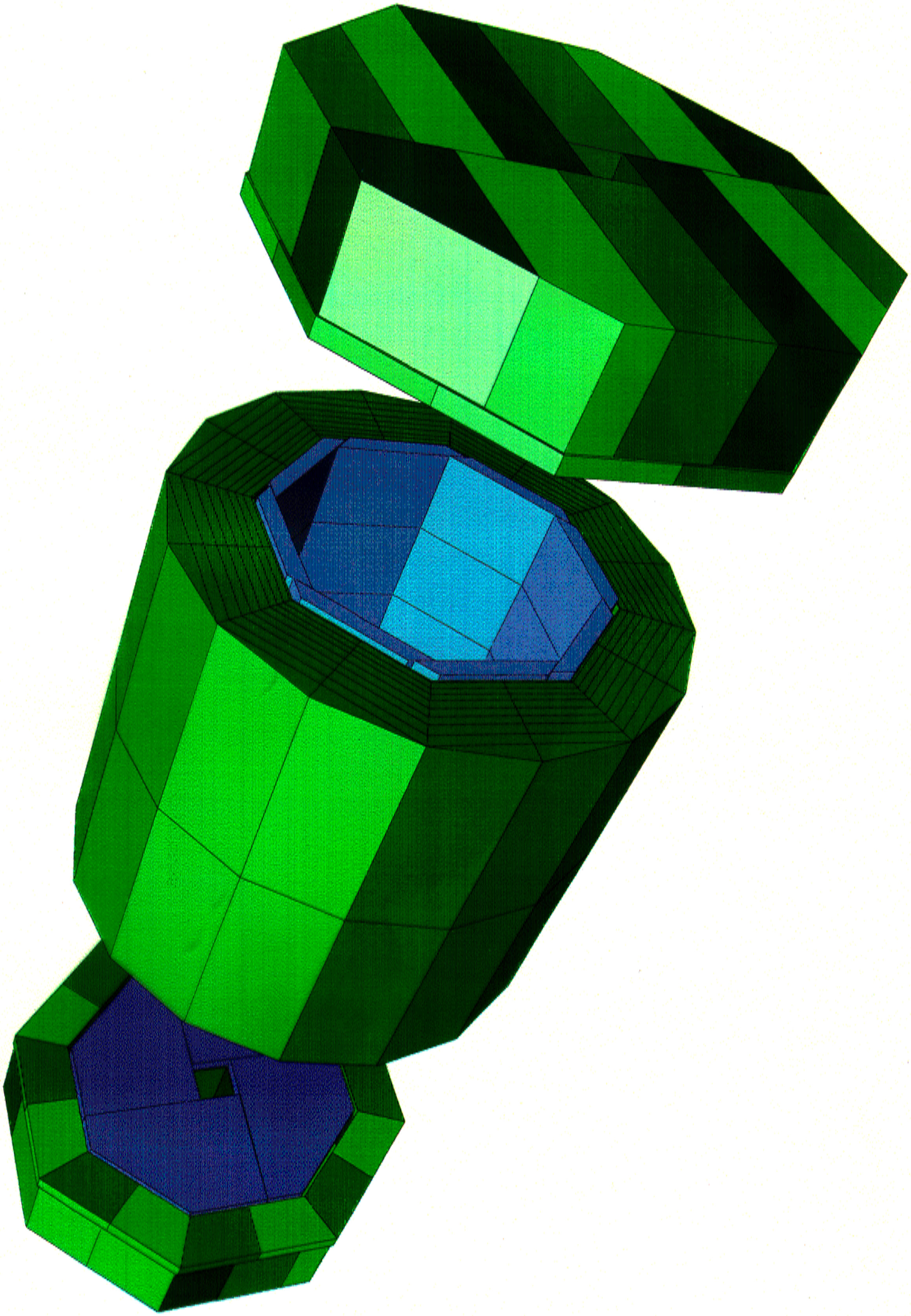
•scintillator tile sizes: 5 x 5 up to 25 x 25 cm^2

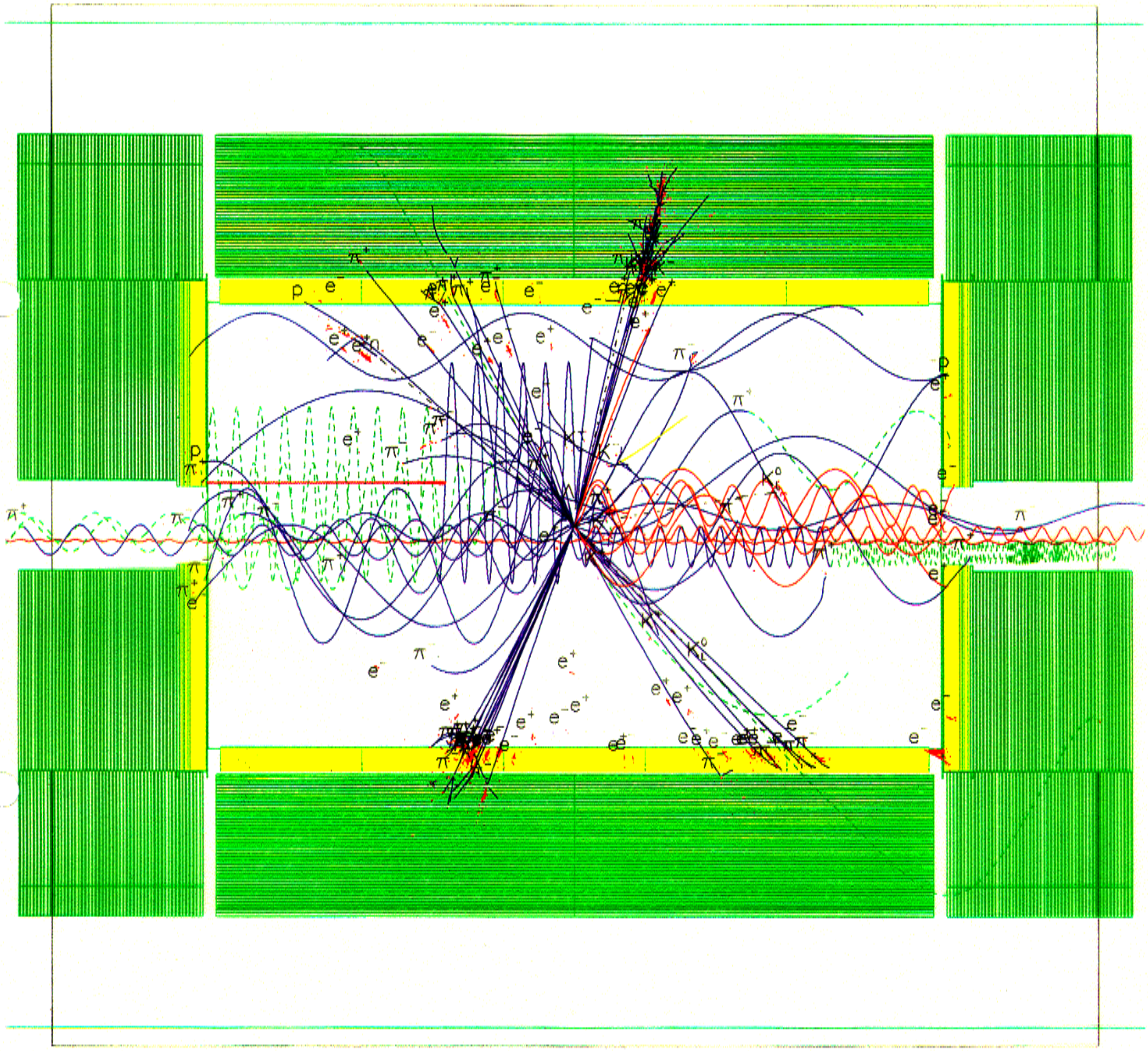
•0.73 x 10^6 scintillator tiles

The way of the light to the readout

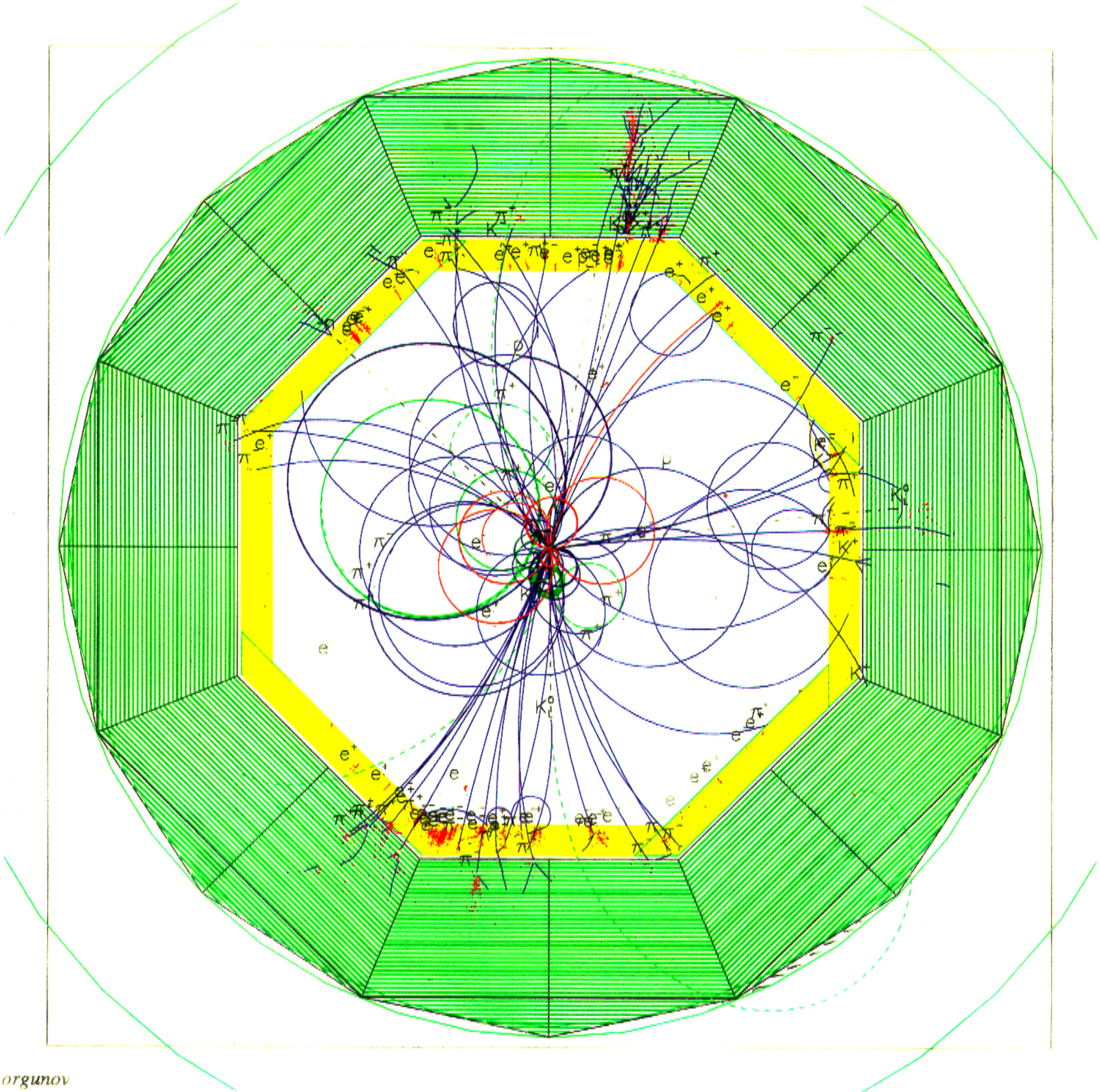
- wave lenght shifter fibres (d≈1 mm)
- coupling to tiles in engraved loops
- coupling to long clear RO fibres (d≈ 0.8...1 mm)
- mixing of adjacent tile fibres to cells in
- green fibre mixers in front of photodetectors
- total HCAL: 202000 ADC-RO channels:

  128500 in barrel + 73500 in endcap





orgunov



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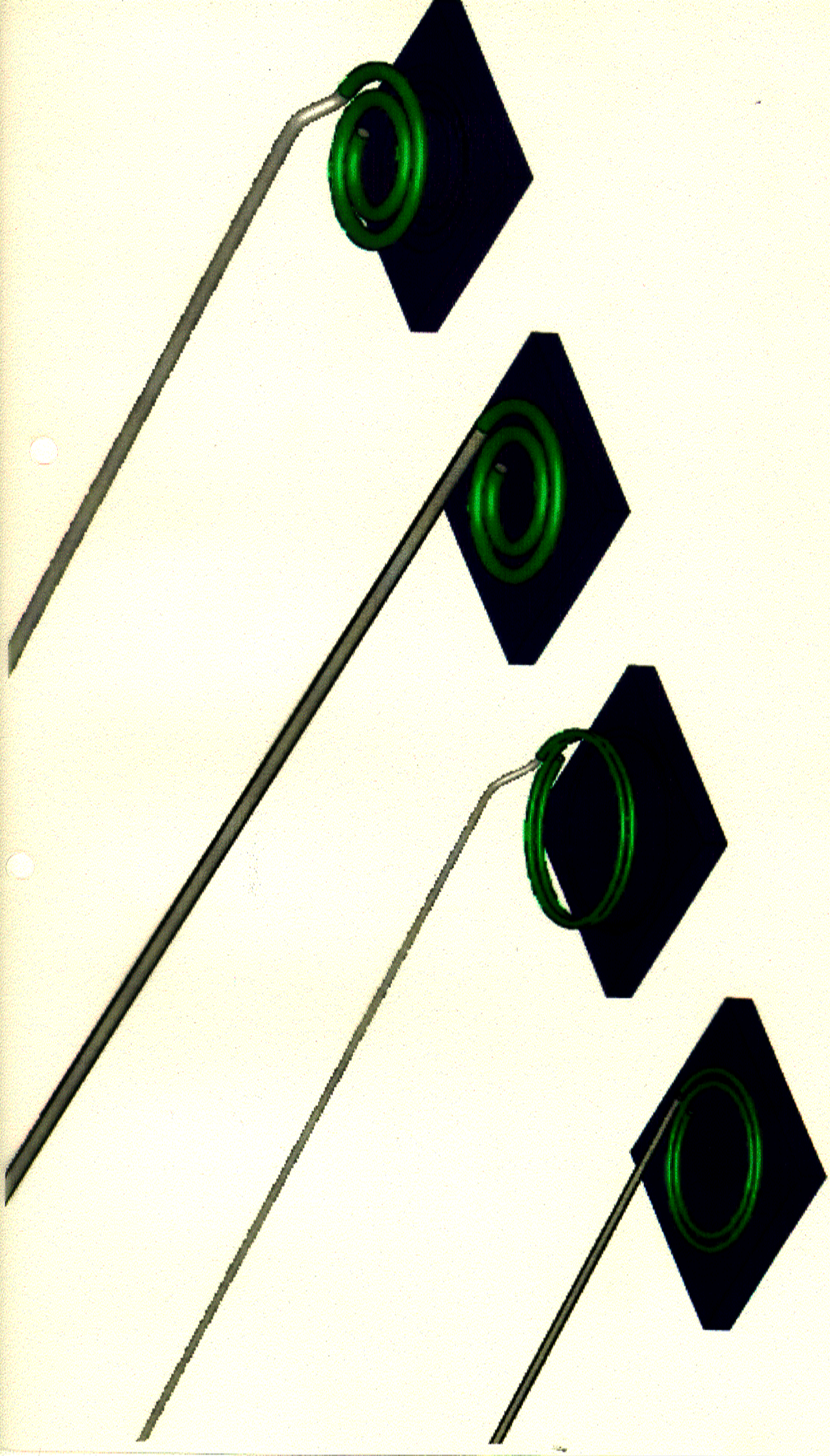
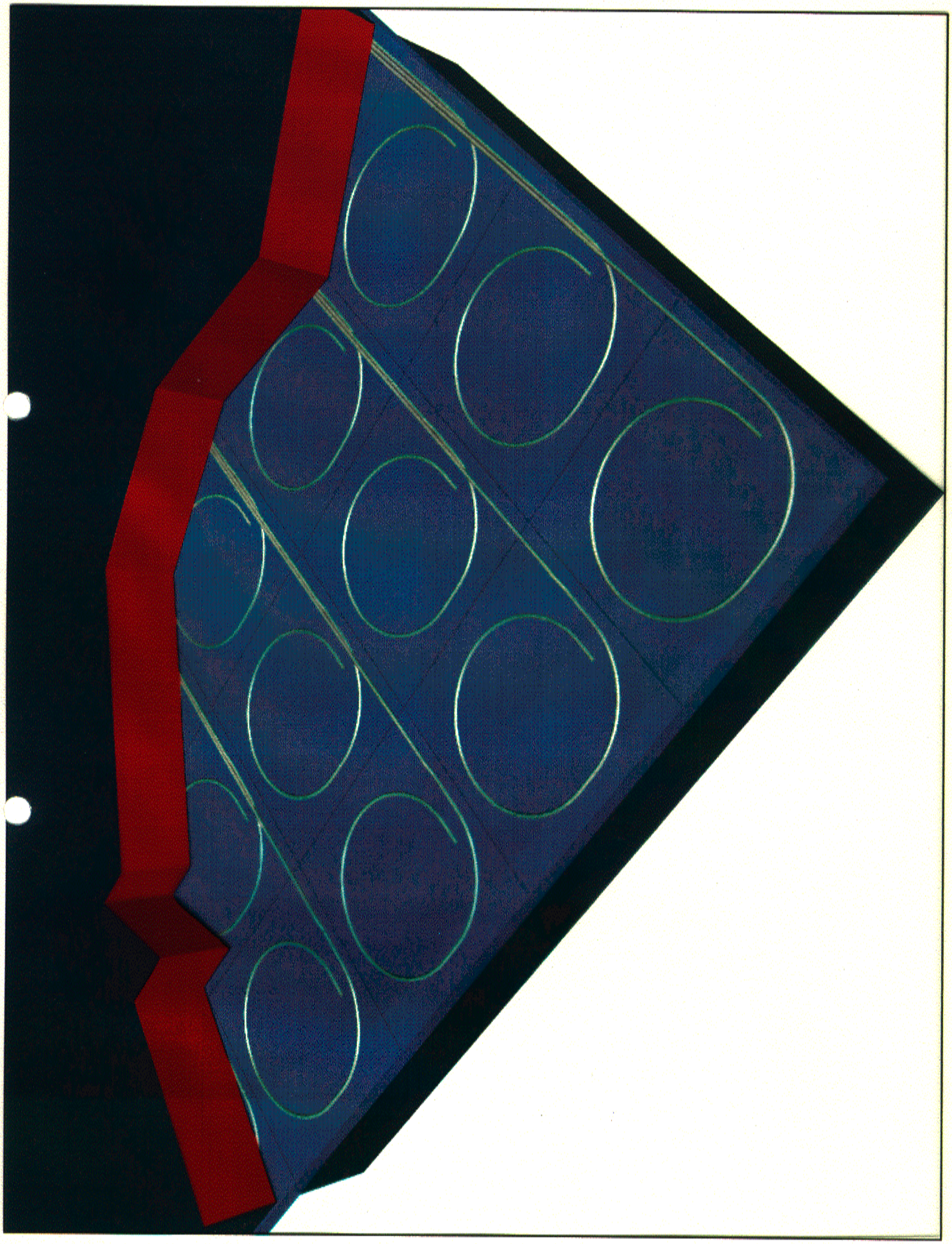
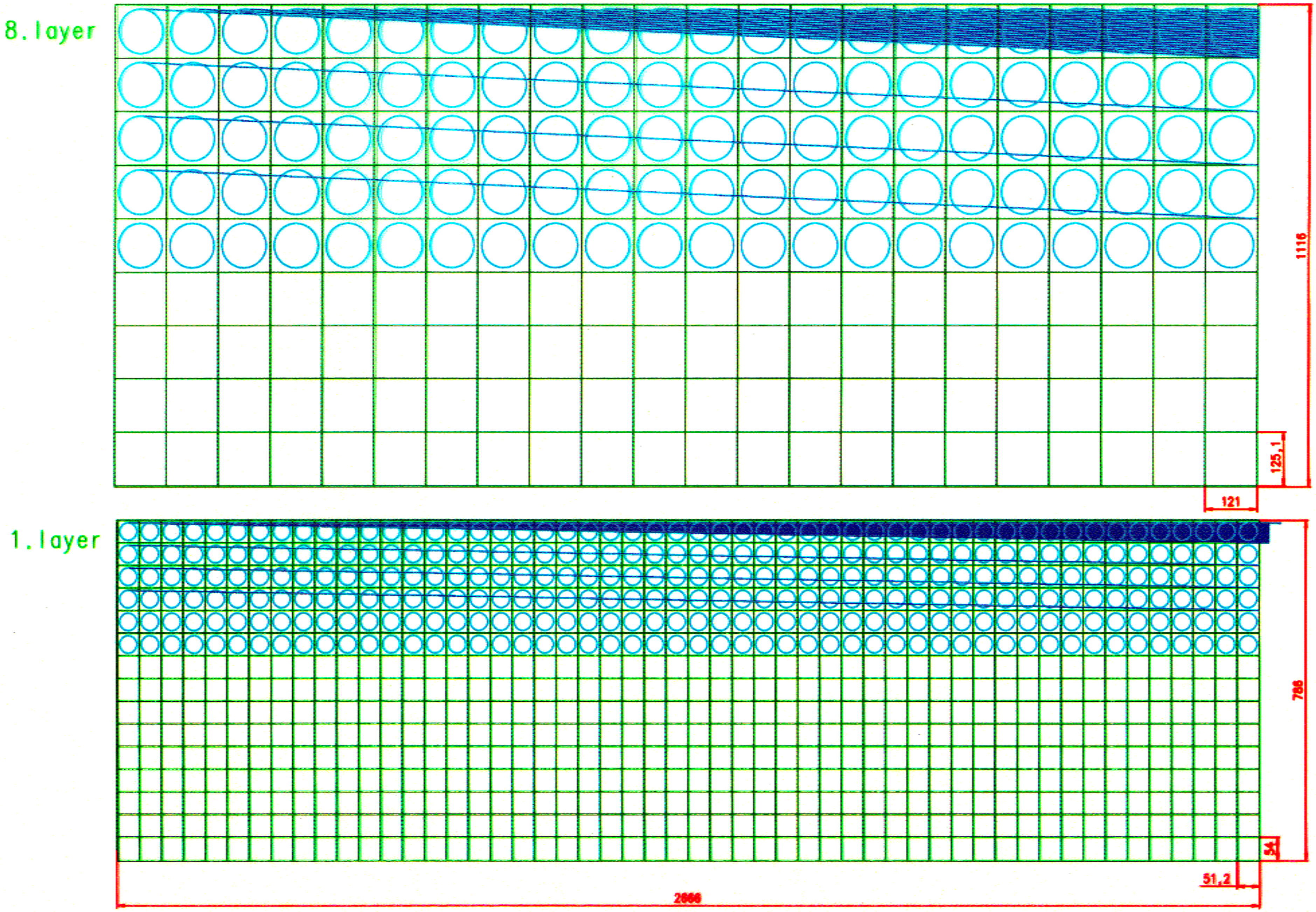
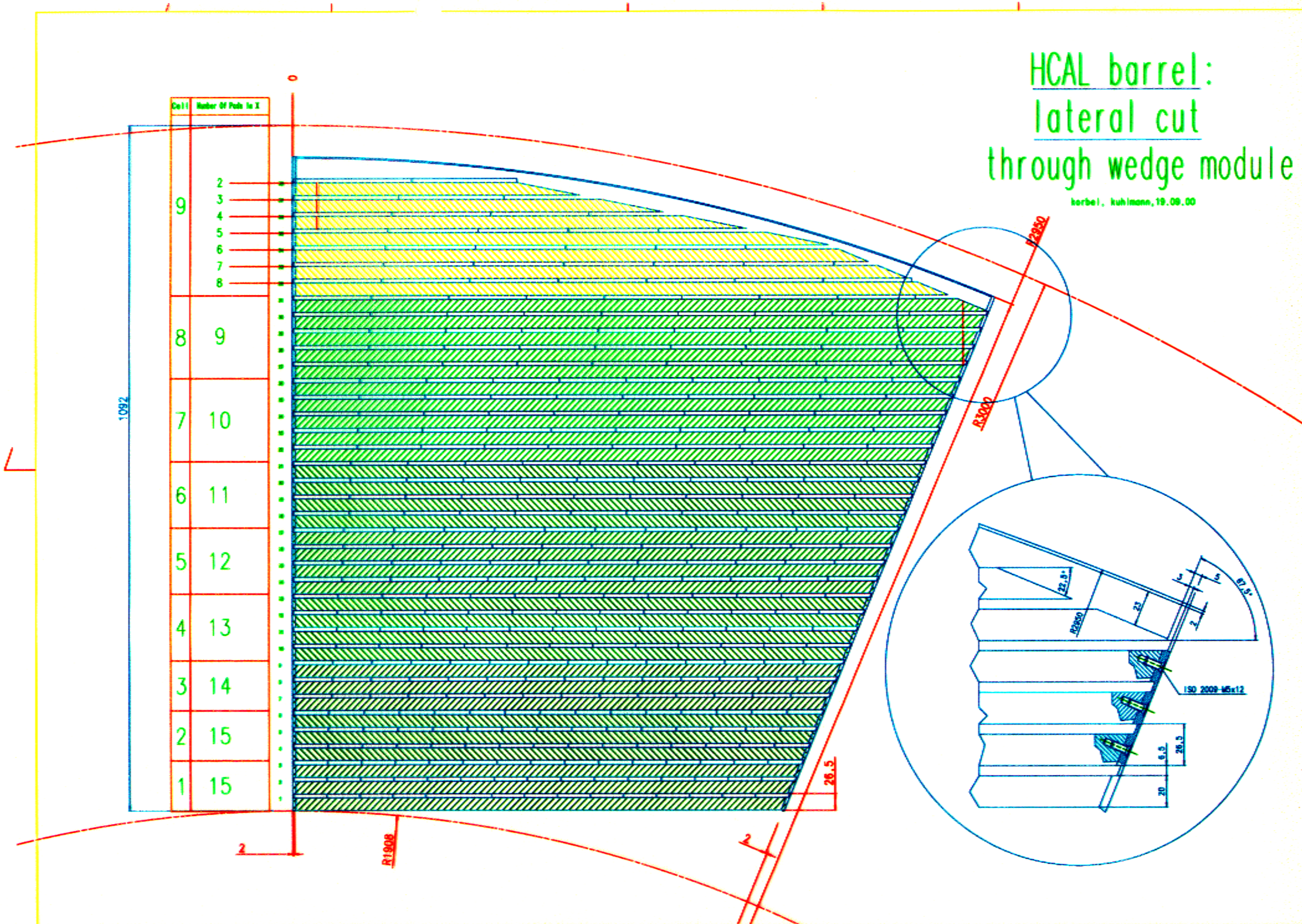


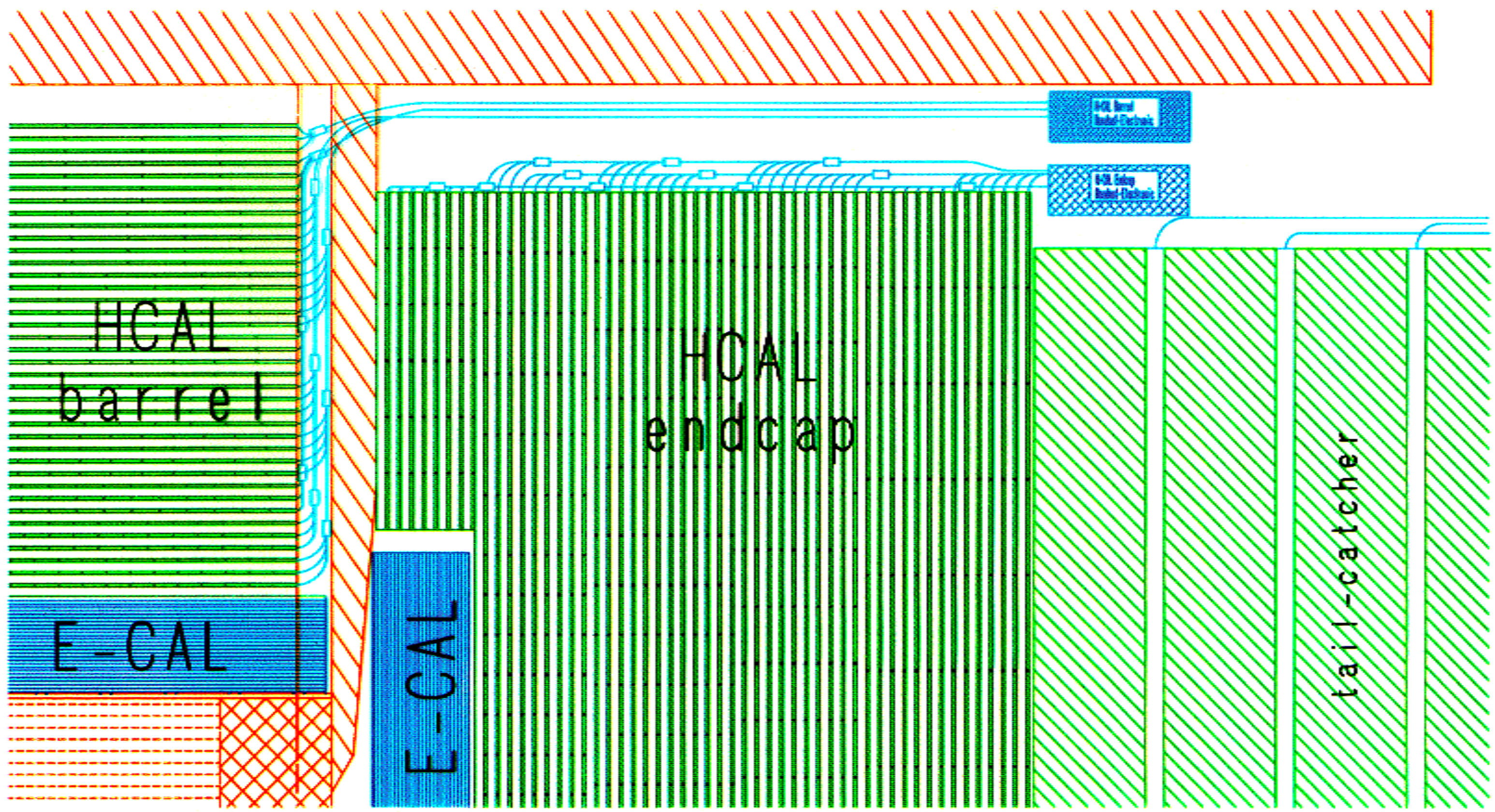


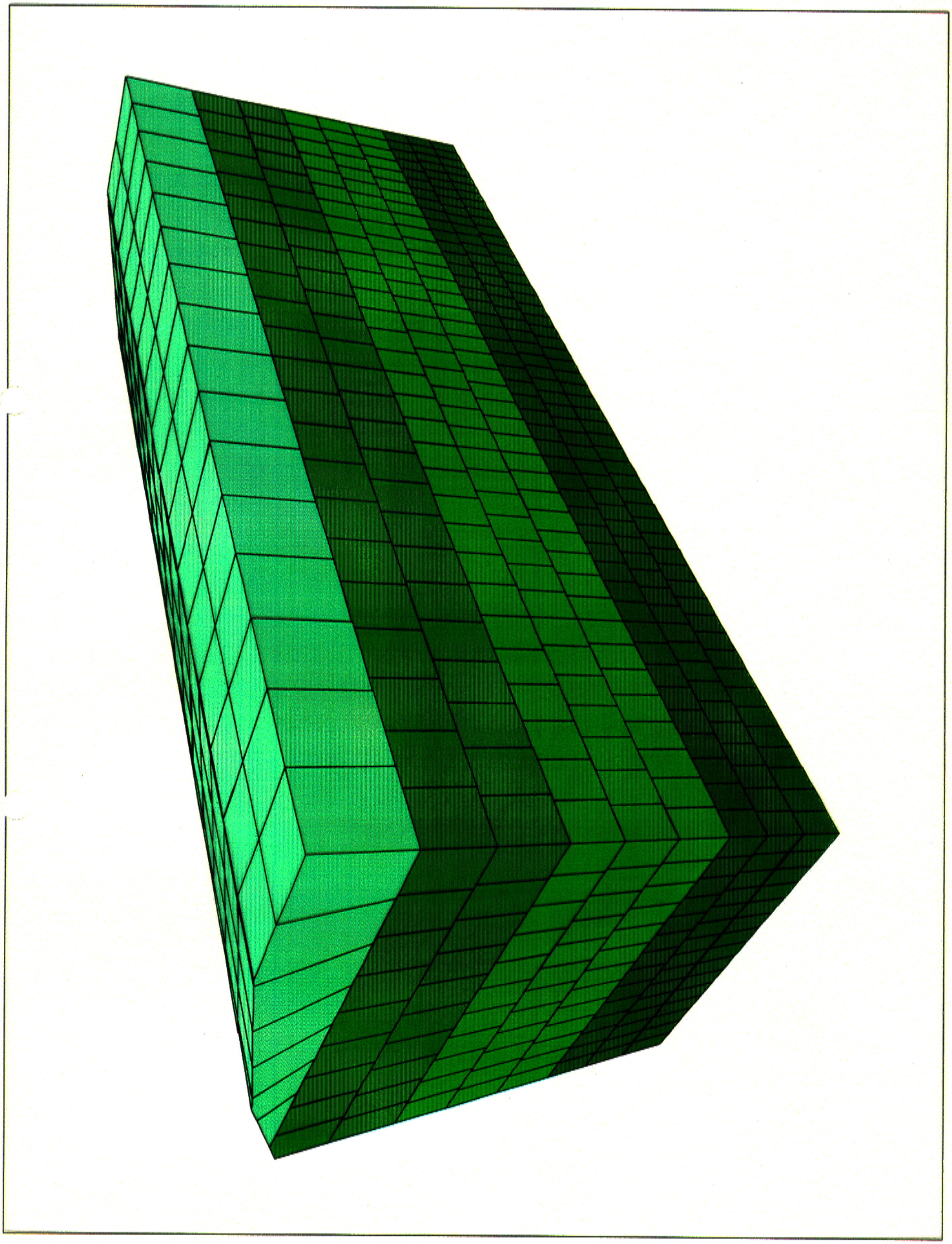
barrel calorimeter tile plate structures

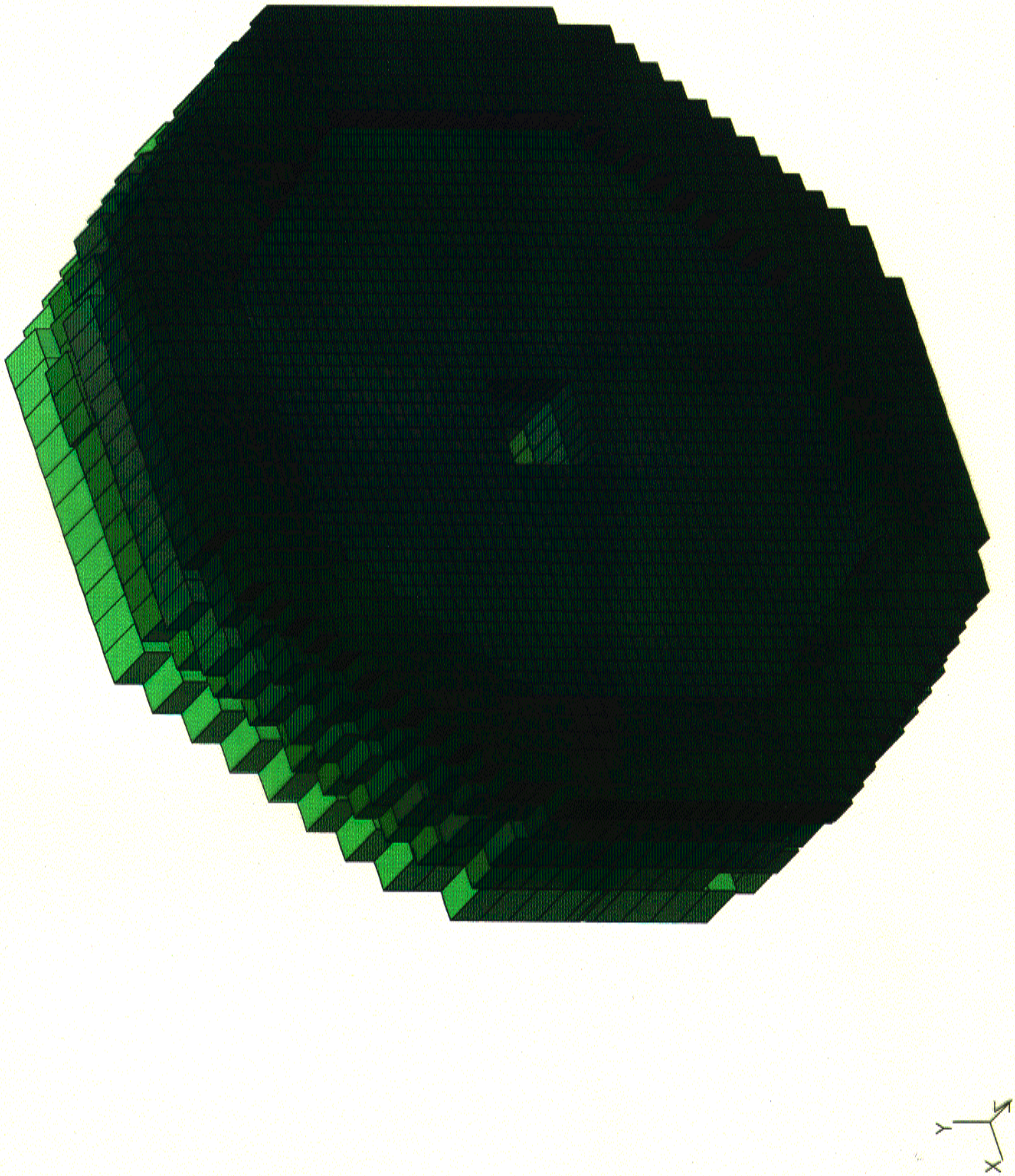



HCAL barrel:
lateral cut
through wedge module
korbel, kuhlmann, 19.09.00
Cell
Number Of Pads In X
9
2
3
4
5
6
7
8
8
9
7
10
6
11
5
12
4
13
3
14
2
15
1
15
1092
0
2
R1908
R2950
R3000
26.5
2
22.5°
R2950
23
67.5°
3
5
2
ISO 2009-M5x12
26.5
6.5
20

HCAL, readout






Y
X

Estimation of signal amplitude for MIP's:

Consider: and optimize!

- •light attenuation in scintillator (≈ 100 cm)
- •light multiple reflection efficiency in scintillator
- •light transition to WLS fibre
- •WLS absorption depth for blue light,(≈ 0.03 cm)
- •WLS light conversion efficiency (blue >> green),(≈ 1)
- •WLS fibre green light trapping efficiency,(≈ few %)
- •light loss in WLS fibre bending curvature
- •WLS fibre attenuation length (> 3.5m)
- •WLS to clear fibre transition losses, (≈ 10%)
- •clear fibre attenuation length (> 10 m, needed 4-6 m)
- •light loss in clear fibre bending
- •light attenuation in fibre mixer
- •photodetector conversion efficiency.

Estimation of signal amplitude, my first approximation:

light reduction from scintillator to electr. signal

	reduction factor:		
tile tickness = 5 mm:		10000	photons
Scint. to WLS transition	0.25	2500	
trapping of green light	0.065	163	
attenuat. along WLS fibre	0.9	146	
transition to clear fibre	0.9	132	
attenuat. along clear fibre 6 m, 10 m att. length	0.55	72	
fiber mixer	0.9	65	
Photoeffic.			
PM (green sensitive!)	0.07	5	p.e.
APD	0.8	52	p.e.
minimum 3 tile layers:			
Signal:			
PM	0.08	14	p.e.
APD	0.8	156	p.e.
APD noise signal from DC		104	e
2nA DC, 10 ns shaping	excess noise	+/-25	e
	gain:		
APD	40	6255	e
PM	10^6	2x10^7	e

APD needs preamp and shaper

R&D at Desy: MIPs from 5x5cm Scint. are seen with PM APD!

Conclusion:

Need of photodetectores with high photon conversion efficiency at $\lambda \approx$ 500 nm.

Electronic chain:

photodetectors

magnetic field, green light!

- APD
- MPD
- HPD
- VPD, VPT
- ?

preamplifier

low capacity (20-30 pF) APD's

- noise < 1 MIP
- capacitive adaption
- shaping for good time measurement
- linearity
- time measurement
- additional shaper

FADC(40-100 MHz)

- 12 bit range, 3 thresholds
- Δt = +/- 2 nsec

see LC-Notes on all 3 topics

Untriggered contineous readout

TESLA calorimeter studies

calorimeter simulation studies with GEANT:

- containment
- energy resolution
- missing energy sensitivity
- MIP signal -noise separation
- in detail:
  - shower development and cluster sizes
  - lateral tile size and cell layer thickness
  - cell arrangement in depth
  - neutral hadron (K_L^0, n) identification

energy and position resolution:

- particles
- jets

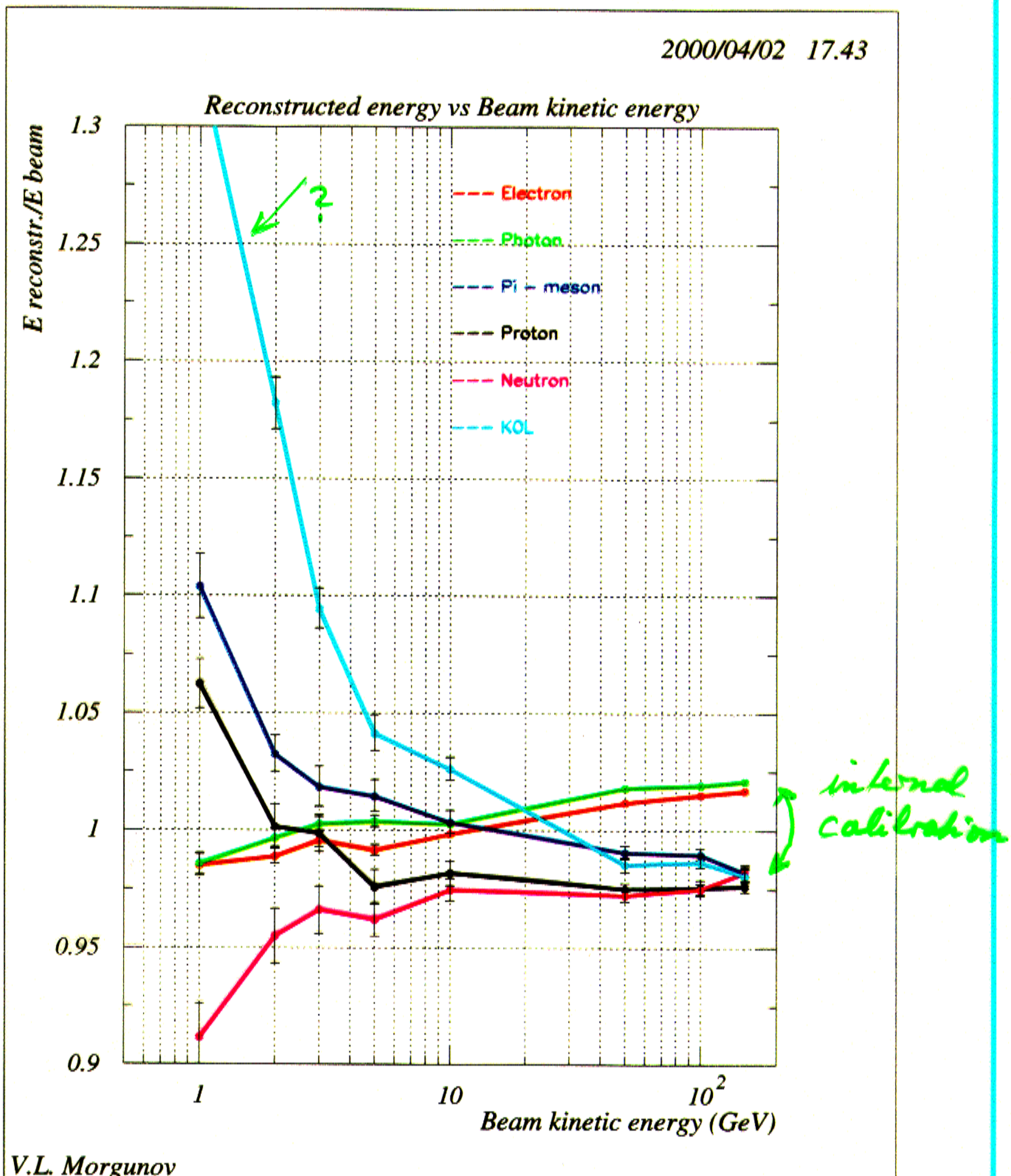
so far:

final realistic tile and cell sizes ?

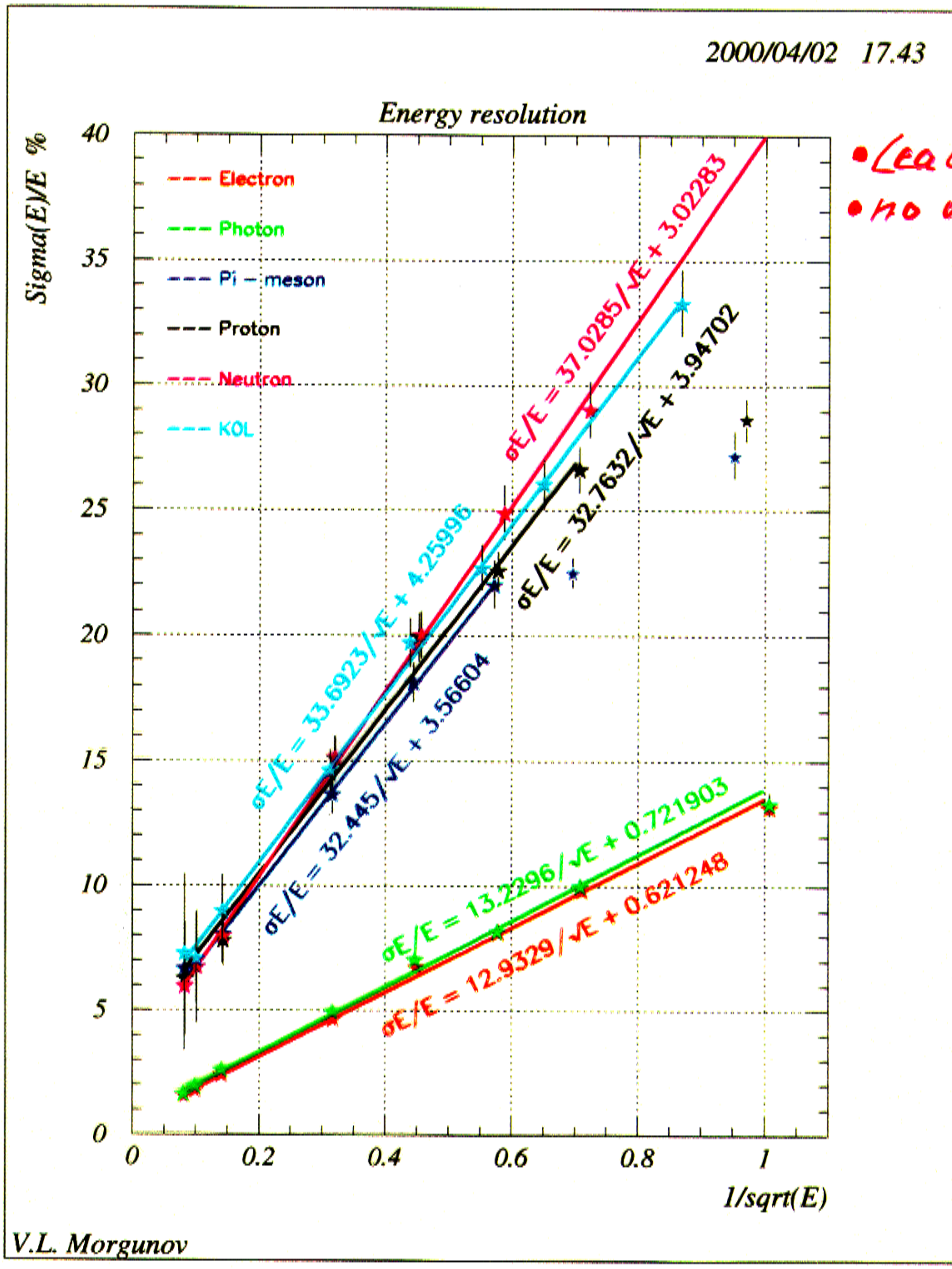
>> 5 x 5 cm^2 ...... 25 x 25cm^2 tiles ?

>> cells of 3,3,3,4,4,4,5,5 and 8 tiles in depth?

Particle reconstructed energy

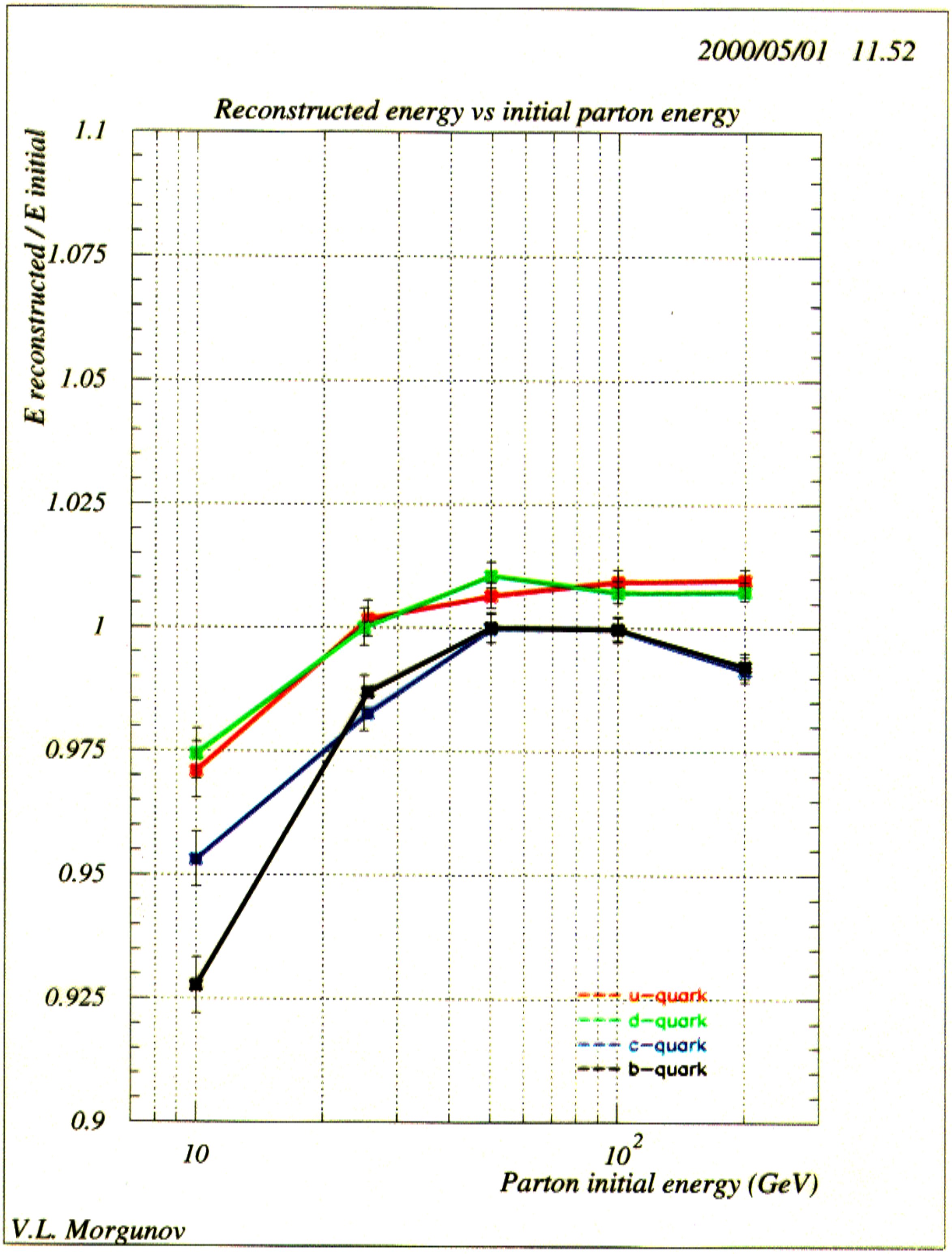


Particle energy resolution

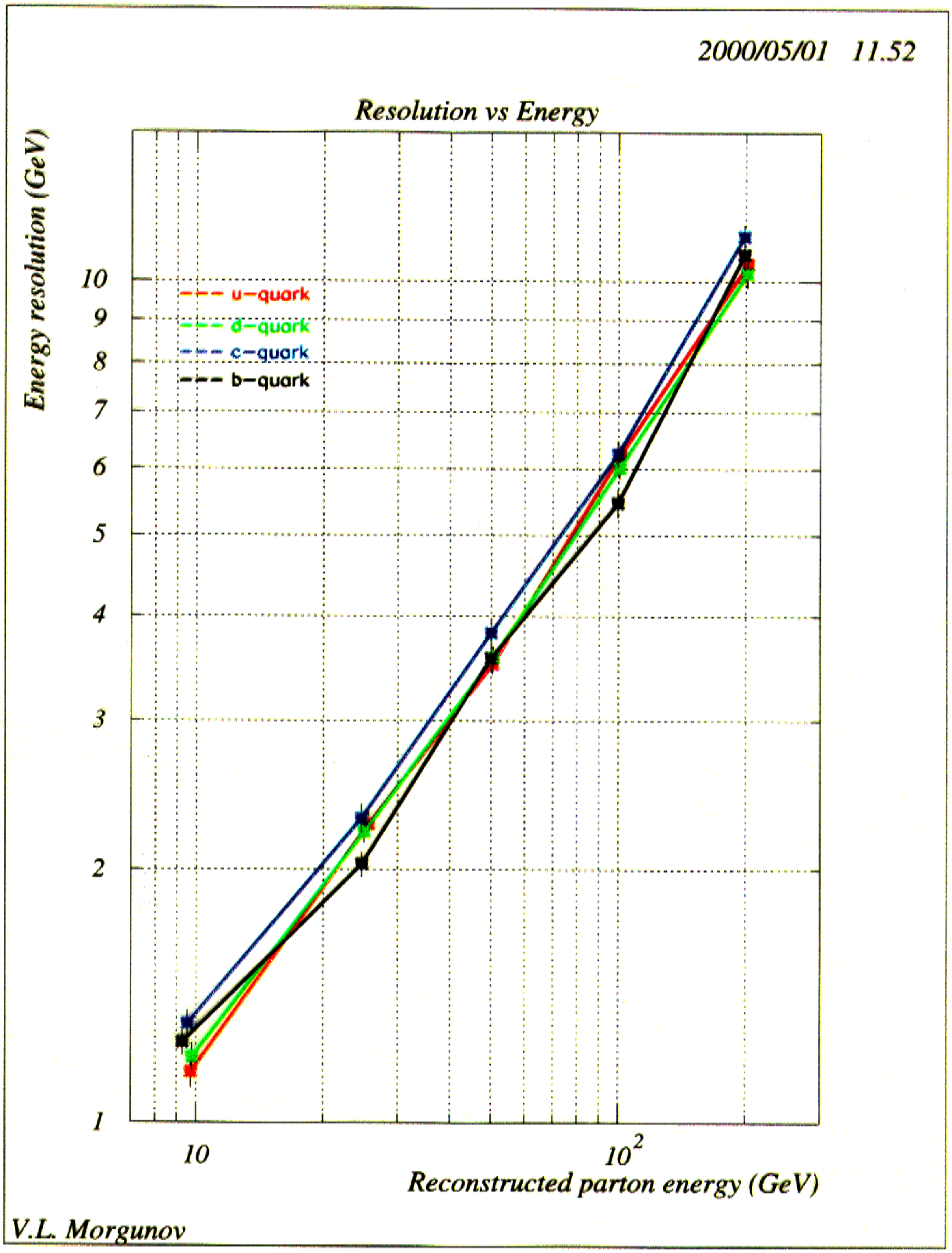


• Leacage
• no weighting

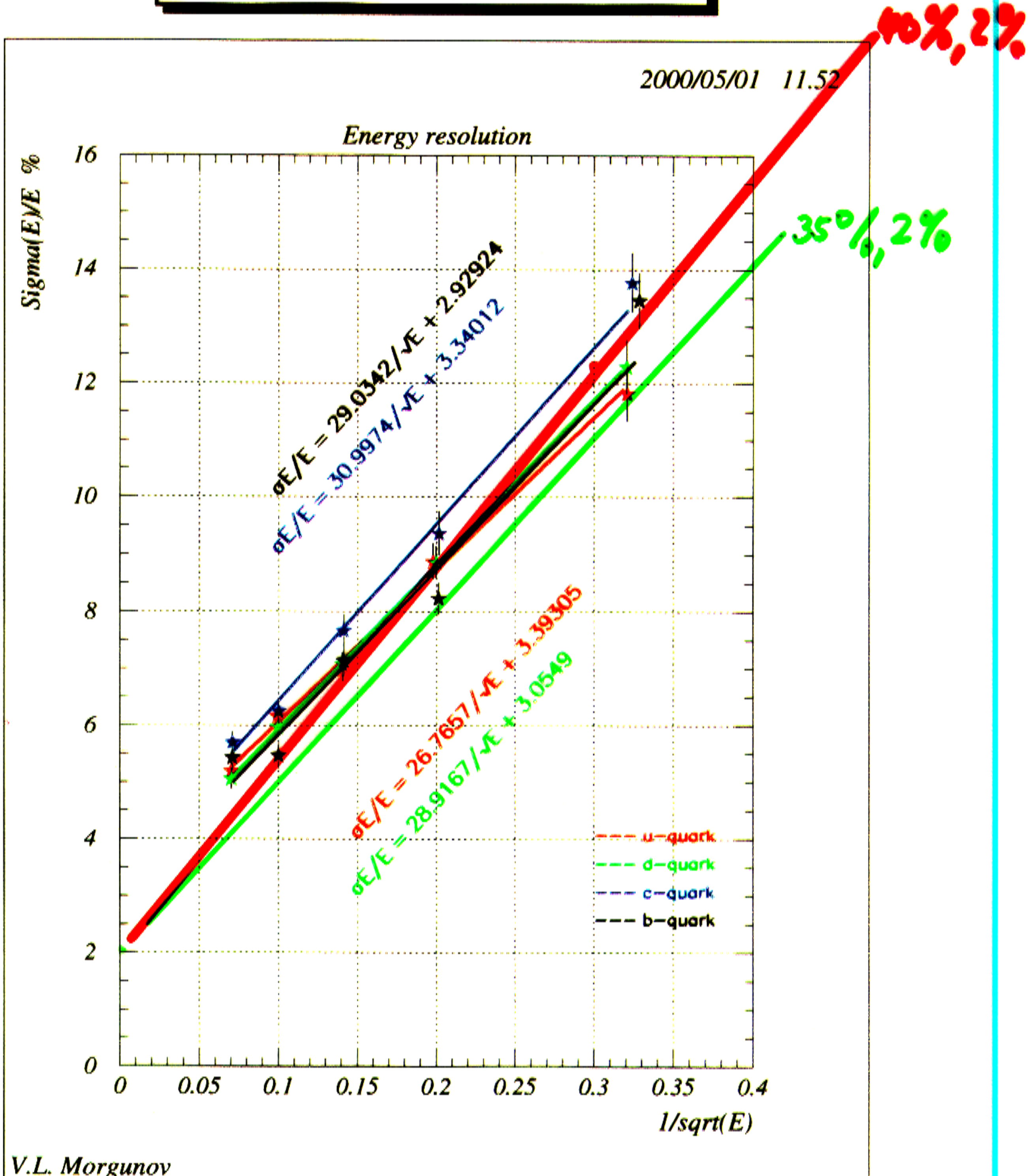
Jet reconstructed energy



Jet energy resolution



Jet energy resolution



Calibration of HCAL:

- prototype calibration runs in test beams (0 T)
- cosmic μ's (0 and 4 T), useful rate < 1 μ/sec/m²
  - energy cut by detector material → (≈1 GeV)
  - strongly bent by field
- halo μ's from TESLA, rate is several 10/sec/endcap
- real events from TESLA:
  - •500, 800 GeV running
  - •Giga-Z^0

Event rates (E(GeV), Lumi)

	bypass							
energy:	91	91	300	500	1000	GeV		
luminos.:	4.5	7	2	3.5	4.5			
	10^33	10^31	10^34	10^34	10^34	$cm^{-2}s^{-1}$		
time	20	200	200	200	200	days	for calibration:	
ee	1943	1943	400	120	40	pb	Xsect.	
	15	2.3	132	73.2	36	events		
						(10^6)		
qq	40000	40000	7.0	2.5	0.7	pb	Xsect.	
	310	48.2	2.5	1.6	0.7	events	hadrons	pt of jets
						(10^6)	tracker-calo	
WW			10.2	5.0	1.5	pb	Xsect.	
			3.5	3.0	1.3	events	11% e,v	
						(10^6)	68% hadr.	pt jet, W mass
Z+γ			6.0	2.0	0.4	pb	Xsect.	
			2.1	1.2	0.3	events	3.4% e,e	
						(10^6)		
ZZ			1.0	0.3	0.1	pb	Xsect.	
			0.3	0.2	0.1	events	3.4% e,e	
						(10^6)	70% hadr.	pt jet, Z mass
γ + γ			7.0	3.0	0.6	pb	Xsect.	
			2.5	1.8	0.5	events		
						(10^6)		

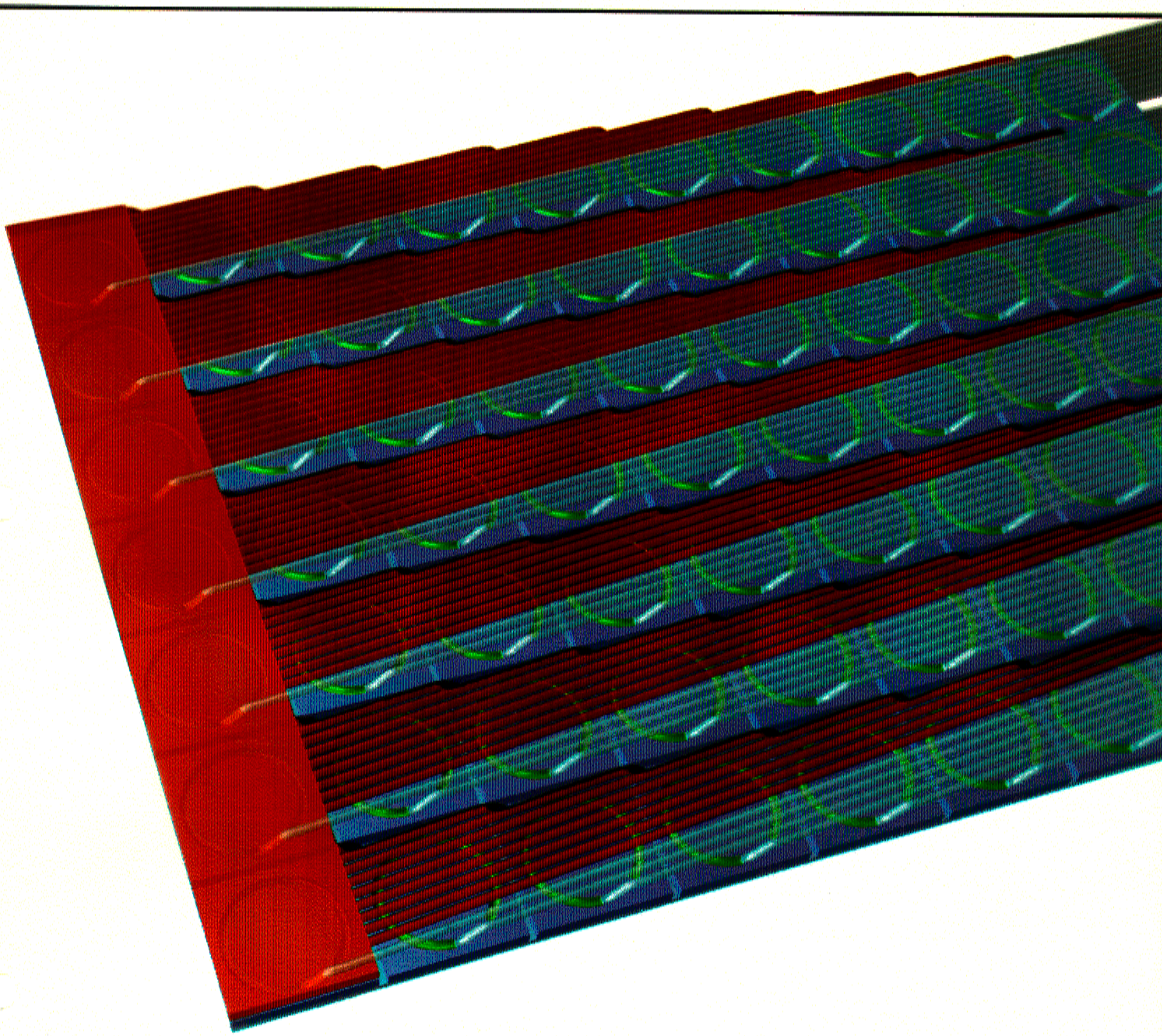
Calibration of HCAL:

use of:

- single charged track, comparison with tracker
- π^0, η reconstruction with 2 γ's
- $e^+ e^-$, $\mu^+ \mu^-$ final states
- jet pt balance
- $e^+ e^- \gg \gamma Z^0$, pt balance
- Z^0 special running (Giga-Z)

calibration accuracy:

- relative cross calibration with μ's, $\approx$ 1 %/cell
- absolute calibration with μ's, 4 T,
  cosmic and halo μ's,
  no vertex pointing,
  needs long data collection time,
  >> data taking also in gaps between BC's,
  also trackers to be read out!
- particles from vertex interactions:
  - e.g.. H1,
    constant term of hadronic LAr calorimeter:
    $\Delta E/E \approx 4\%$ (1. year)
    $\Delta E/E \approx 2\%$ (after 5 years)
    further improvement expected >> $\approx 1.5\%$??
  - TESLA: soon results from detailed simulation expected



Installation of calorimeters:

1/2 Barrel:

individual 16 HCAL modules

modules have 2 support bars >>

modules are equipped and tested with cosmic μ's

assembly outside the coil vessel in circular scaffolding

with special installation machine, gap distortions small >>

strong fastening between adjacent module pairs

adjustment of assemby to loaded cryostat dimensions >>

fixing of barrel by 2 steel belts

test of all channels with full electronic and cosmic μ's

roll in on few 'tank weels' >>

Barrel:

insertion of both 1/2 HCAL barrels

insertion of ECAL modules,

5 modules along 2 3 parallel rails

Endcaps:

quadrants are tested in horizontal position with cosmic μ's

final assembly outside the coil vessel on floor rail

2 quadrants assembled on place in half wheels, left/right

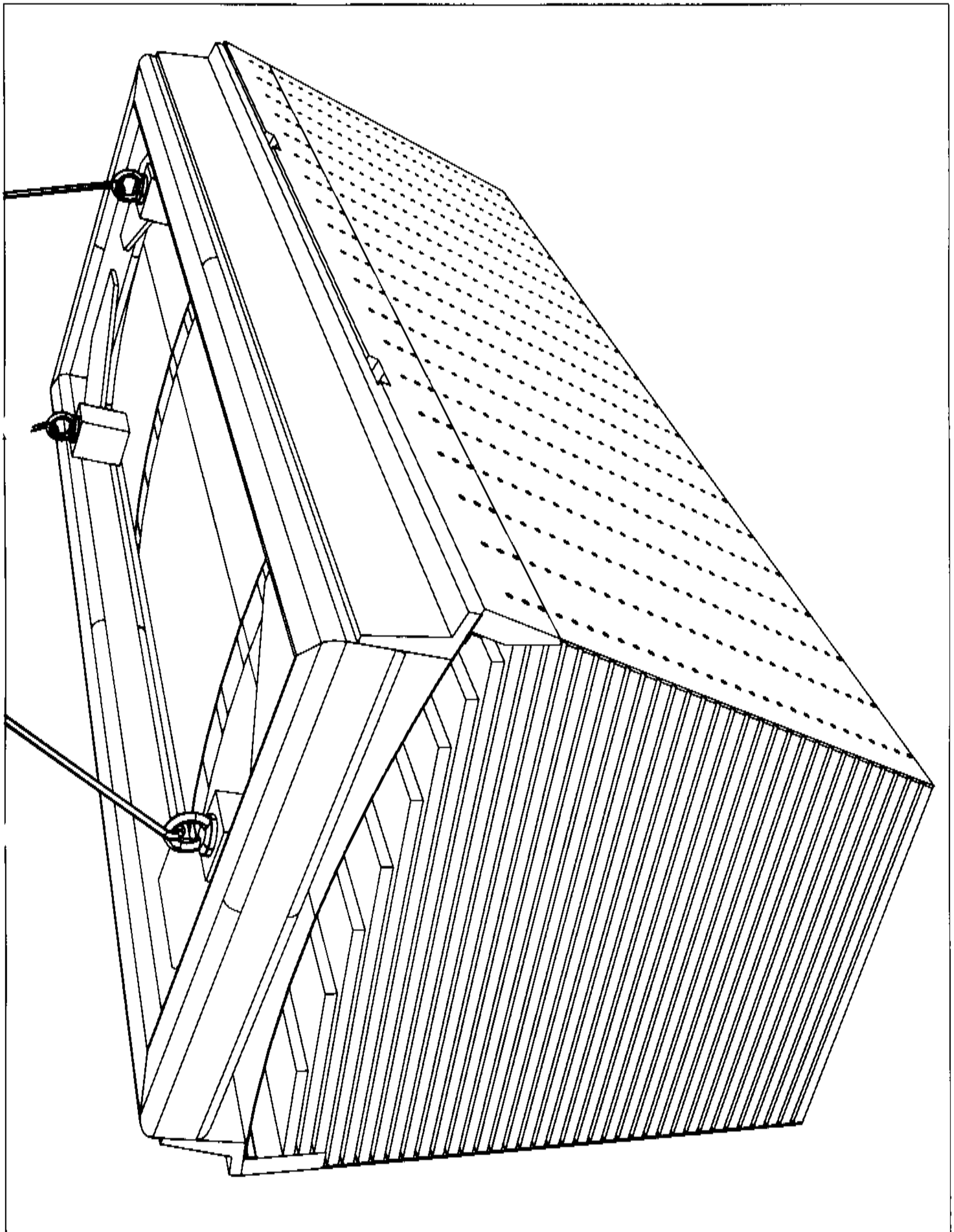
roll in on few 'tank weels' along beamline

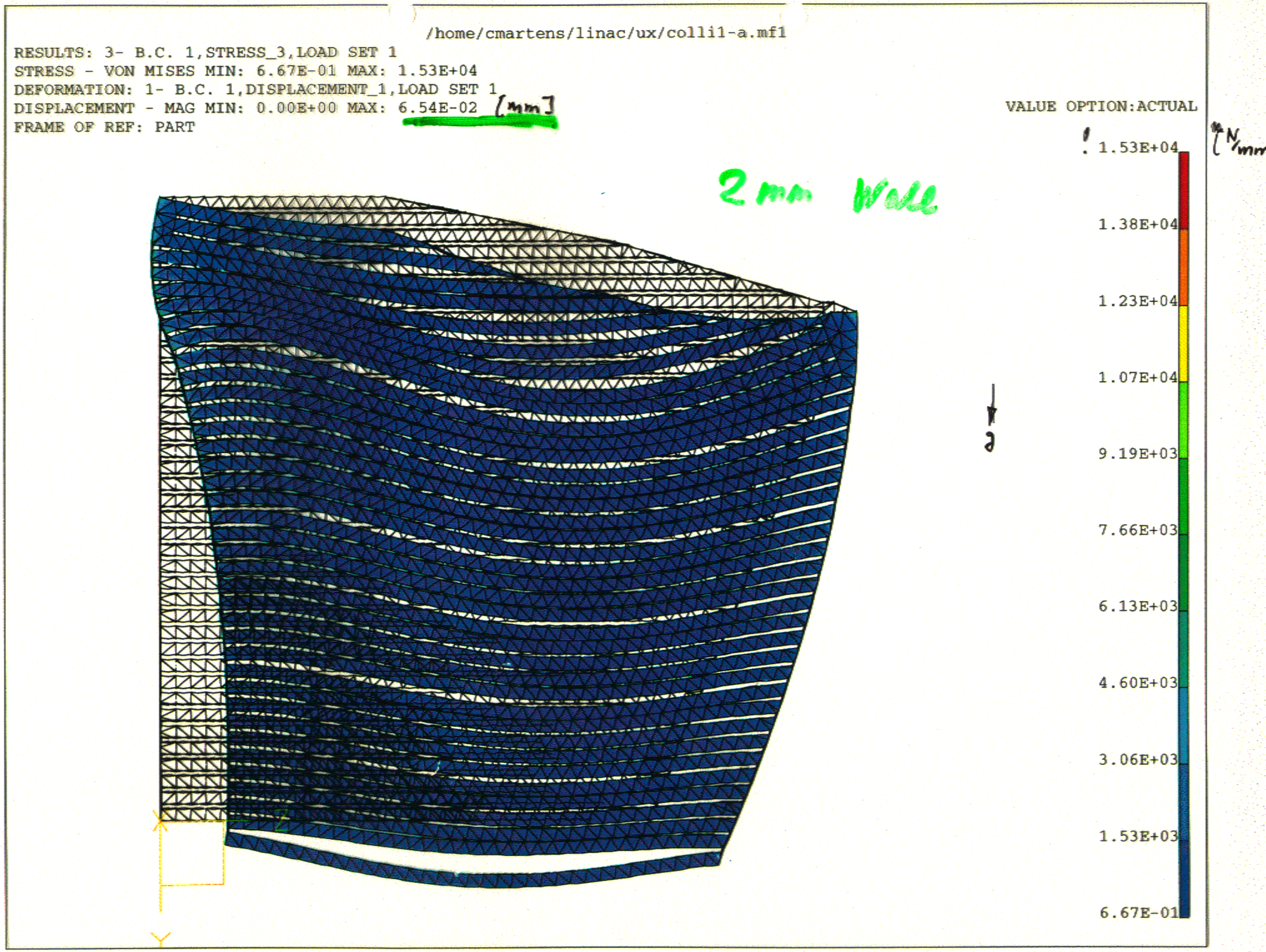
closing of half wheels around beamline >>

insertion of some leakage detectors in the gap to the mask?

Some technical HCAL/ECAL Dat

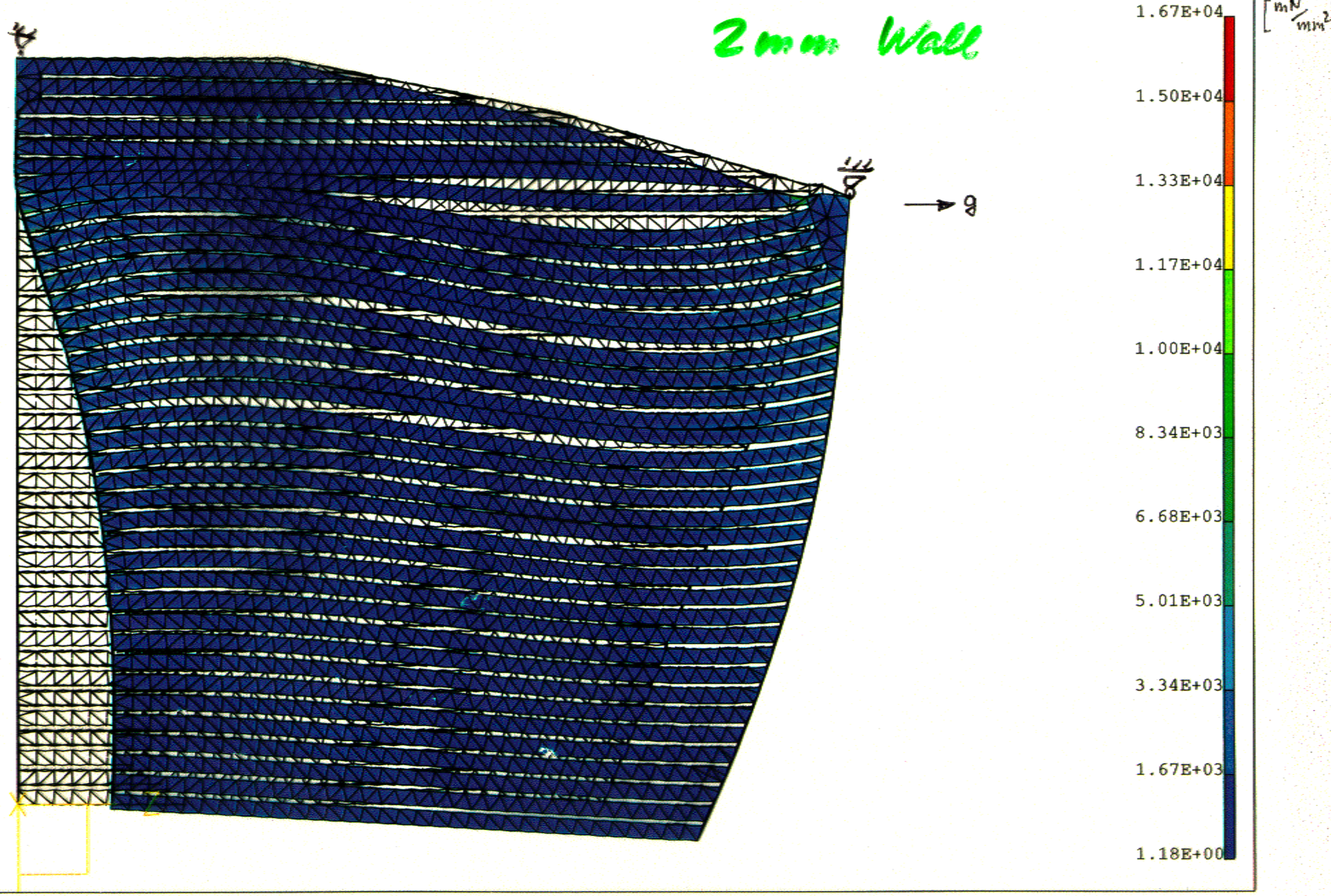
- 2 x 16 barrel modules
- weights:
  - 15.8 to / barrel module, x 16 = 250 to,
  - 4 quadrants build 1 endcap module with 210 to
  - total HCAL weight is 920 to
  - barrel HCAL carries ECAL
  - ECAL weight: 206 to W and 4.4 to Si
- instrumented Fe yokes follow hadr. endcaps
- mask calorimeter around the beamline installed first
- "simple insert calorimeter", for leakage measurement between mask and endcap ECAL and HCAL possible installed as last calorimeter part
- access to all operating HCAL electronics,
  without any moving of HCAL
  when only instrumented iron shell is opened

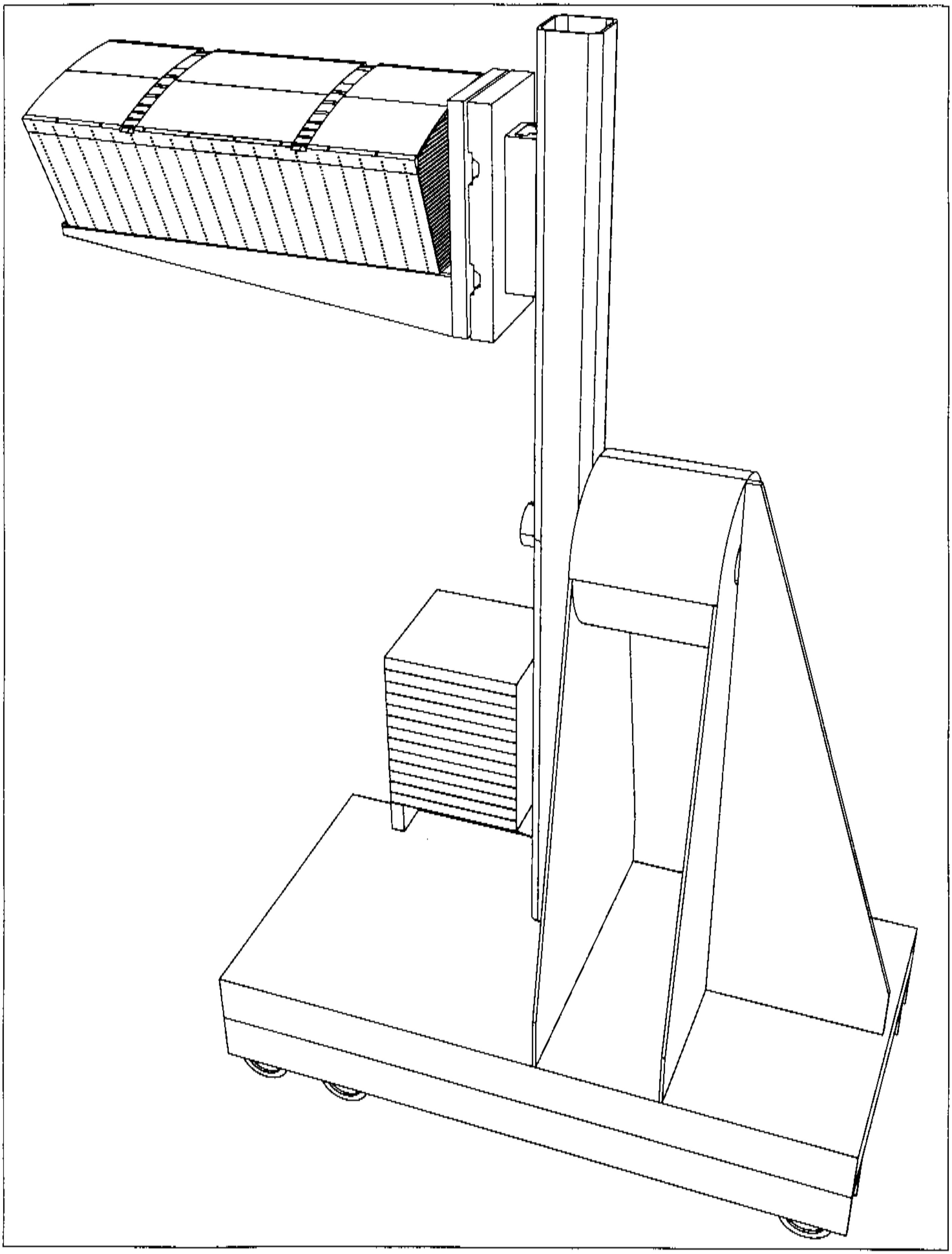


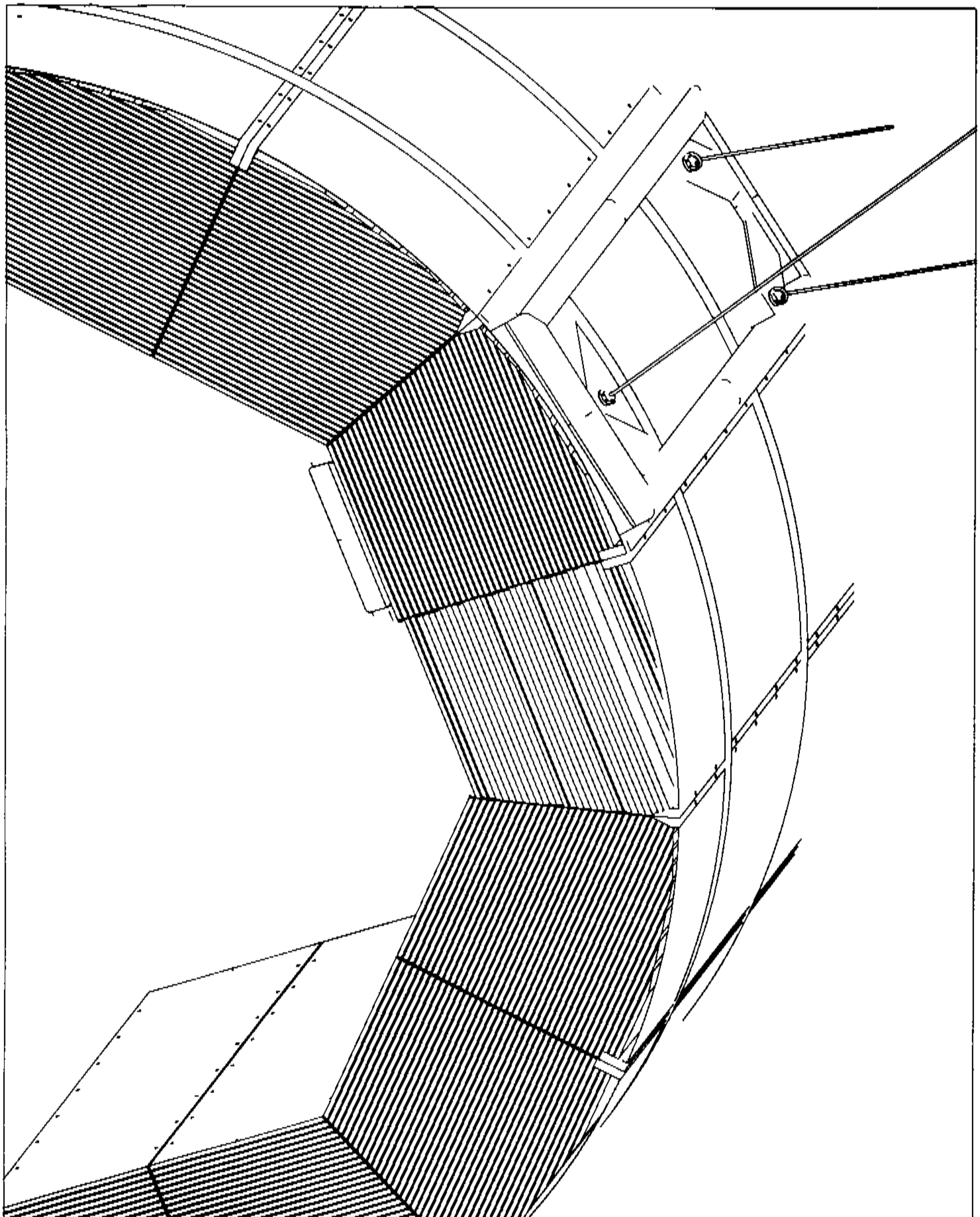

/home/cmartens/linac/ux/colli1-a.mf1
RESULTS: 3- B.C. 1,STRESS_3,LOAD SET 1
STRESS - VON MISES MIN: 6.67E-01 MAX: 1.53E+04
DEFORMATION: 1- B.C. 1,DISPLACEMENT_1,LOAD SET 1
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 6.54E-02 [mm]
FRAME OF REF: PART
VALUE OPTION:ACTUAL
[N/mm²]
1.53E+04
1.38E+04
1.23E+04
1.07E+04
9.19E+03
7.66E+03
6.13E+03
4.60E+03
3.06E+03
1.53E+03
6.67E-01
2 mm Wall
X
Y

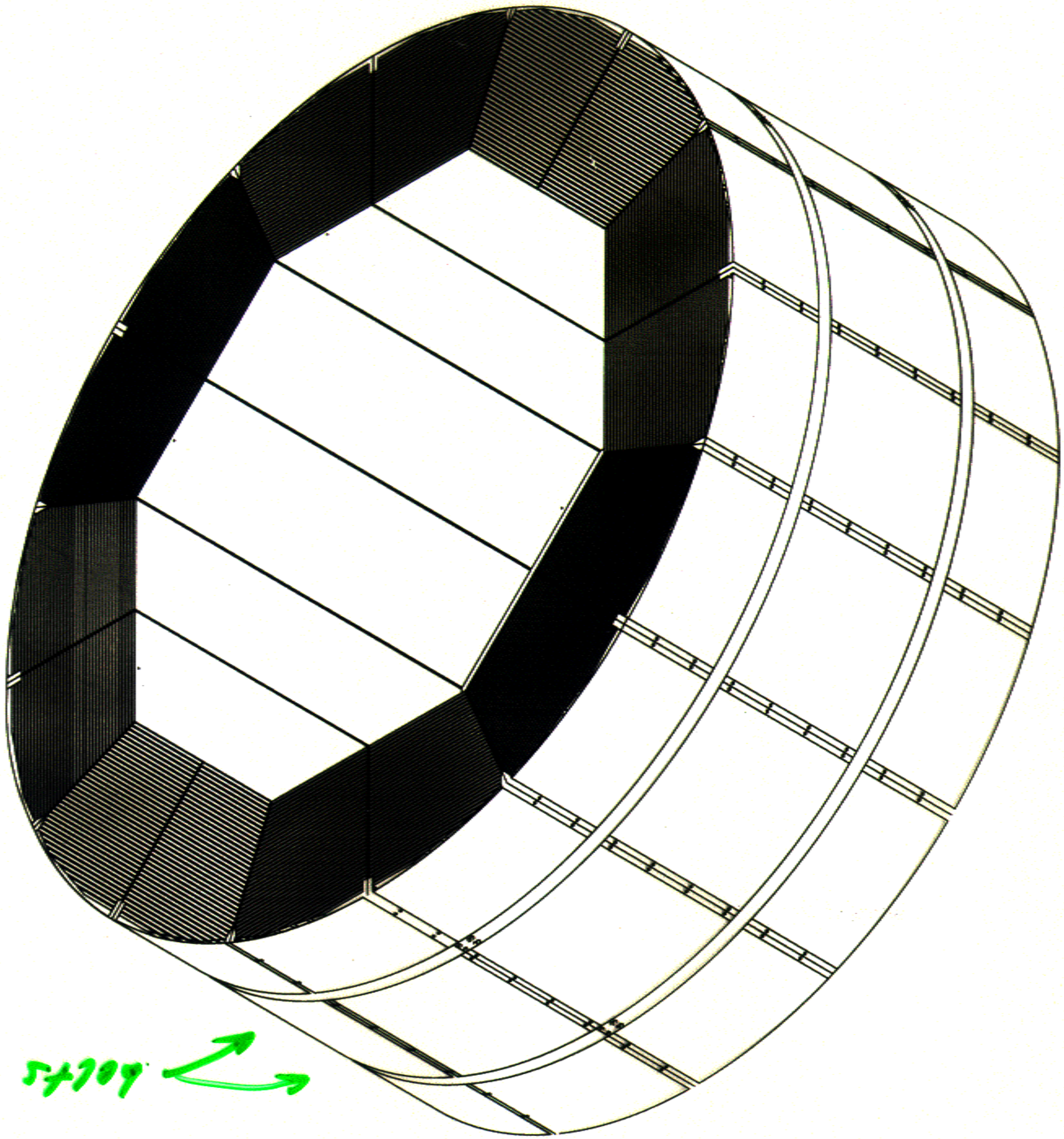
/home/cmartens/linac/ux/colli1-b.mf.

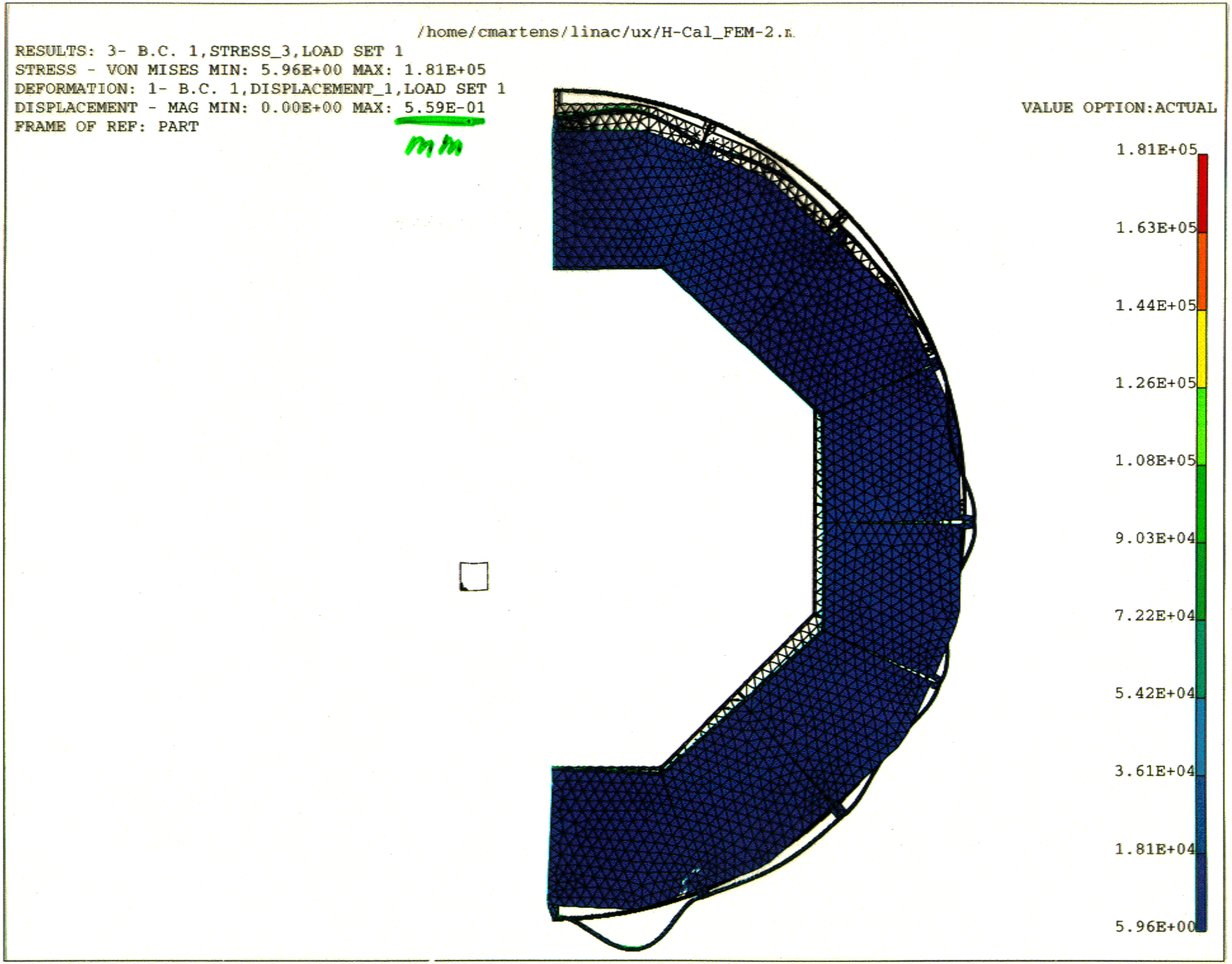
RESULTS: 3- B.C. 1,STRESS_3,LOAD SET 1
STRESS - VON MISES MIN: 1.18E+00 MAX: 1.67E+04
DEFORMATION: 1- B.C. 1,DISPLACEMENT_1,LOAD SET 1
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 2.21E-01 [mm]
FRAME OF REF: PART



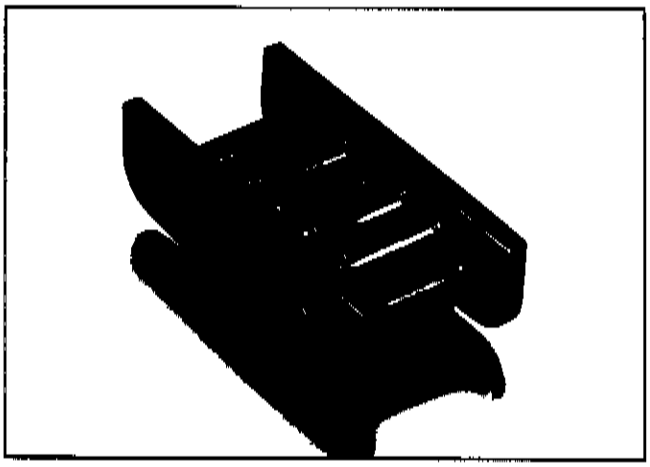





54709


/home/cmartens/linac/ux/H-Cal_FEM-2.r
RESULTS: 3- B.C. 1,STRESS_3,LOAD SET 1
STRESS - VON MISES MIN: 5.96E+00 MAX: 1.81E+05
DEFORMATION: 1- B.C. 1,DISPLACEMENT_1,LOAD SET 1
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 5.59E-01
FRAME OF REF: PART
mm
VALUE OPTION:ACTUAL
1.81E+05
1.63E+05
1.44E+05
1.26E+05
1.08E+05
9.03E+04
7.22E+04
5.42E+04
3.61E+04
1.81E+04
5.96E+00

Wälzwagen Express – Die Soliden



Anwendungsbereich:

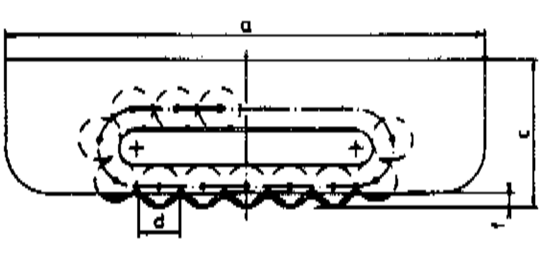
- für kurze Transportwege
- möglichst auf geeigneten Fahrbahnen wie (Kran-) Schienen oder Stahlträgern
- Transportieren mittelschwerer Lasten z.B. in Öfen, von technischen Einrichtungen, für Betonverschalungen, in der Lagertechnik
- als schwere Rollenbahn geeignet
- bei geringsten Einbauabmessungen einsetzbar

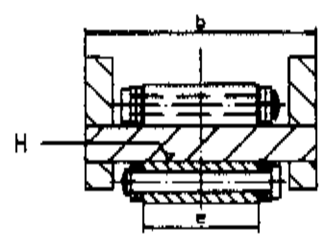
Gebrauchshinweise:

- bei längeren Stillstandzeiten (diskontinuierlichen Transporten) Modelle mit gehärtetem Mittelsteg wählen
- im Falle möglicher Überbelastung höherwertiges Rollenmaterial 50CrV4 verwenden
- Maximale Verschiebegeschwindigkeit: ≤ 5 m/min
- Höhe auf Wunsch weiter reduzierbar
- Der Rollwiderstand beträgt bei den Modellen I-IIIv je nach Fahrbahn 7–5 %, bei den größeren Modellen 5–3 % der Gesamtlast
- im Gerüstbau möglicher Einsatz von losen Rollenketten (in der Regel Länge nach Wunsch lieferbar)

Hauptmerkmale der Baureihe ... C :

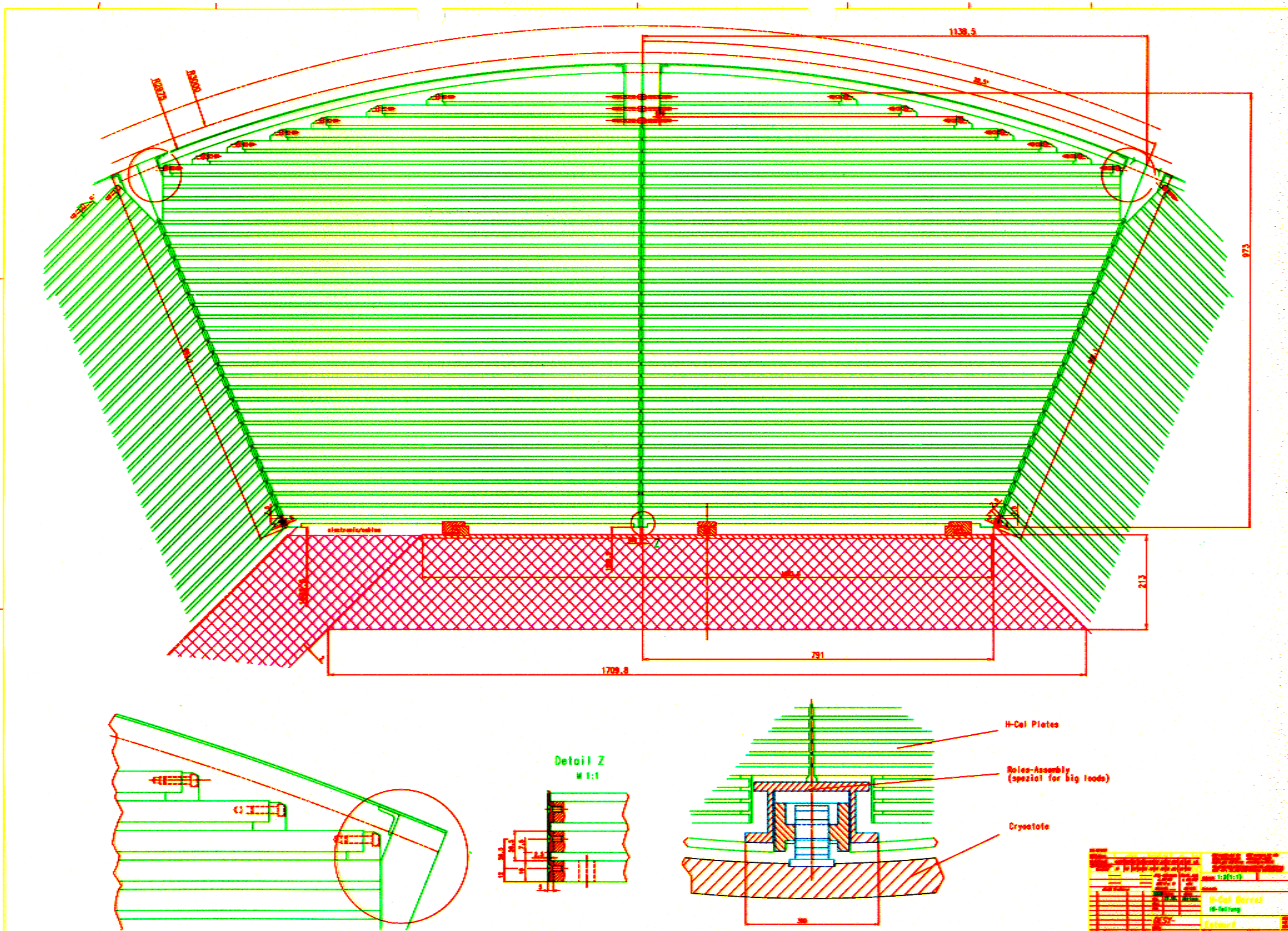
- stabile, solide Grundkonstruktion
- **niedrigste Bauhöhe mit toleriertem Höhenmaß.** Baureihen ... B + ... C höhengleich
- kann gegebenenfalls an die Last geschweißt werden
- lieferbar mit gehärtetem Mittelsteg (= Modelle C-H) oder zusätzlich mit höherwertigem Rollenmaterial 50CrV4 (= Modelle C-H- 50 CrV4)





Baureihe C, C-H (H: Mittelsteg gehärtet und geschliffen), **C-H-50CrV4** (Rollenmaterial 50CrV4)

Mod.	a	b	c	∅d	e	f						trag Rollen	Rollen-anzahl	Tragkraft max kN	Gewicht kg
I	210	100	63	18	51	6						5	15	100	5,0
II	220	113	73	24	60	10						4	13	150	7,0
III	270	130	90	30	68	10						4	13	300	12,5
IV	380	168	126	42	76	19						4	13	600	32,0
V	530	182	146	50	86	19						6	17	800	61,0



1138.5
973
213
791
1709.8
R3000
R2975
electronic/cables
Detail Z
M 1:1
H-Cal Plates
Rolex-Assembly
(spezial for big loads)
Cryostate
H-Cal Barrel

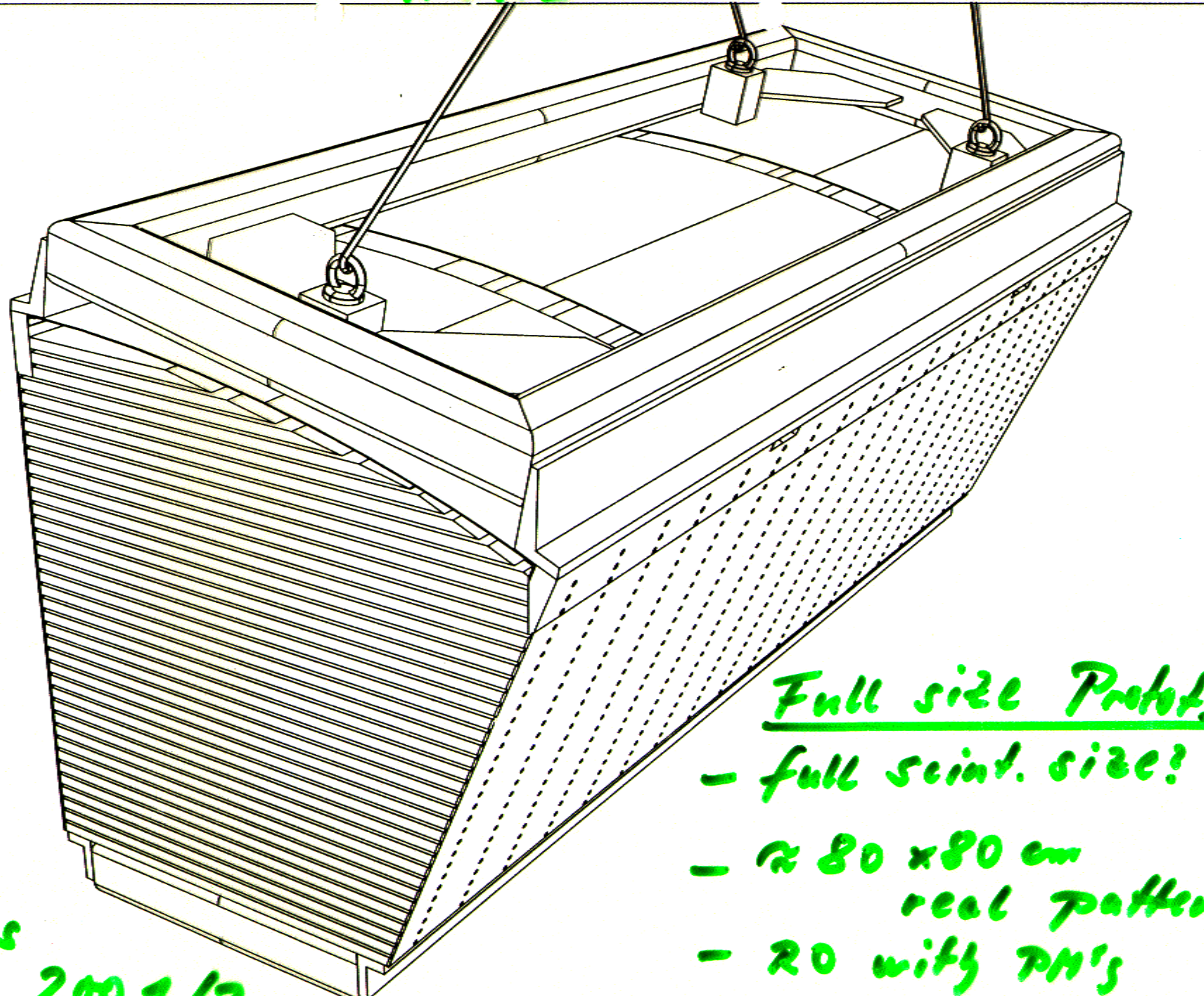
R&D program for HCAL:

- find optimal
    - scintillator
    - wave length shifter fibre
    - reflector foil (mirror or diffractive reflection)
    - optical glue
    - clear fibre with long attenuation length
- optimize scintillator WLS light transition
    - shape of WLS fibre
    - contact of WLS fibre
    - reflectors (mirror /diffractive?)
- light transmission as function of bending radius
    - WLS fibre
    - clear fibre
- single or multiple cladding ofWLS and RO fibres
- noise minimizing: light tightness required for fibres
- tile mould casting or cutting on large boards? ⟵
- optimize fibre mixer in front of photodetector
- find appropriate:
    - photodetectors
    - preamps (to develop ?)
    - shaper (to develop ?)
    - FADC
- optimal degree of multiplexing?
- study stability of system (temp, HV, LV)
- establish good gain monitoring (LED, laser?)
- minimize noise >> observation of MIP's
- ensure radiation hardness of all components
- calibration studies with MIP's

R&D:
DESY
LPI Moskow
Tashkent
started

Barrel module prototype test >>>

HCAL



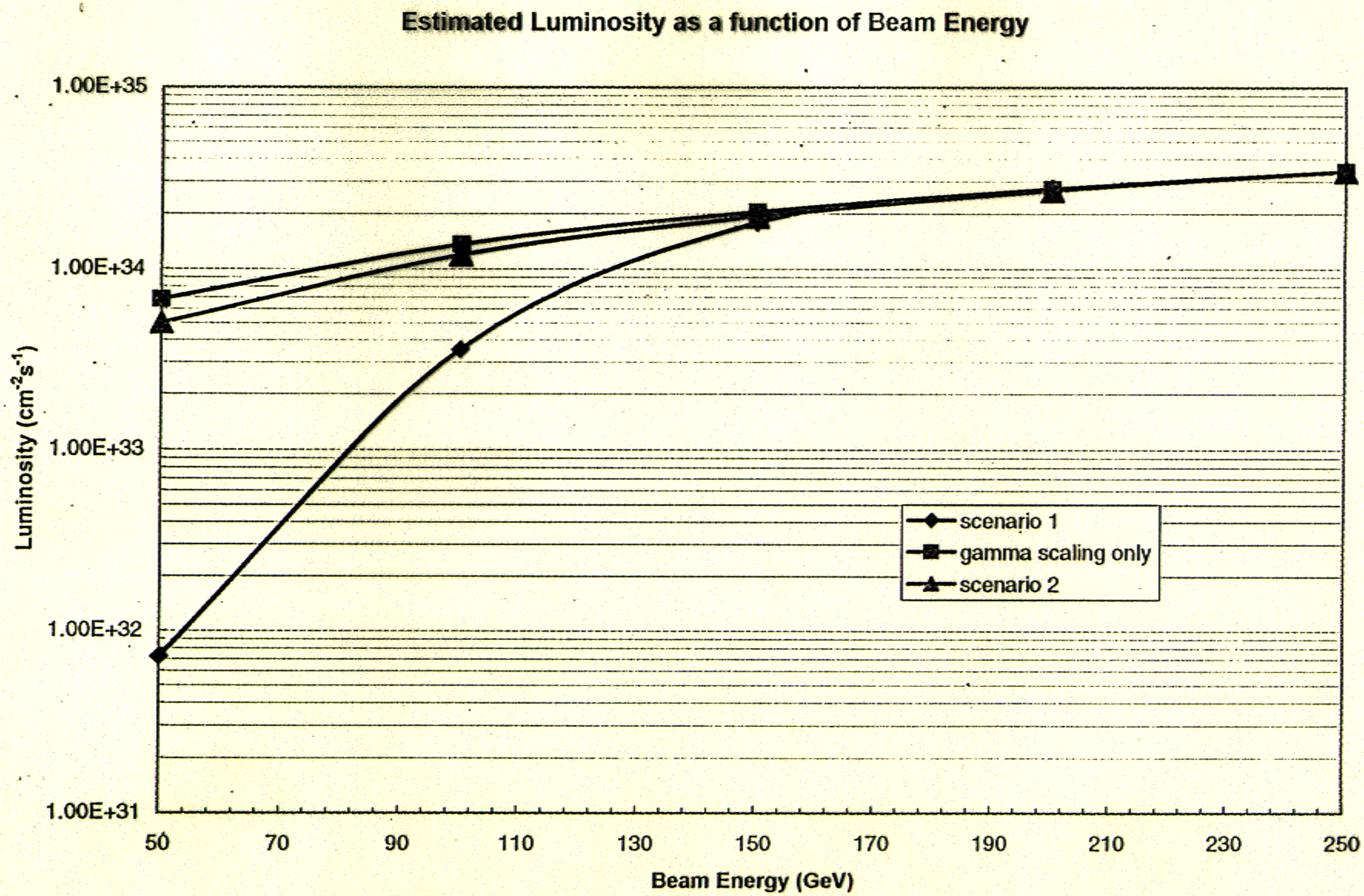
Full size Protot.

- full scint. size?
- ≈ 80 × 80 cm real pattern
- 20 with PM's

Tests in 2001/2

DESY / ITEP (CERN)

High - $\mathcal{L}$ at $E_{bm.} \lesssim 150$ GeV with 2nd e^{+}- source / bypass line



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