DIRAC setup

Installation and upgrade of the DIRAC setup for lifetime measurement of $\pi^+\pi^-$ and $\pi^\pm K^\mp$ atoms

A.Kuptsov

DIRAC Collaboration

75 Physicists from 19 Institutes

DIRAC collaboration

75 Physicists from 19 Institutes

CERN
Geneva

Czech Technical University
Prague

Institute of Physics ASCR
Prague

Nuclear Physics Institute ASCR
Czech Republic

INFN-Laboratori Nazionali di Frascati
Frascati

Trieste University and INFN-Trieste
Trieste

University of Messina
Messina

KEK
Tsukuba

Kyoto Sangyou University
Kyoto

Tokyo Metropolitan University
Tokyo

IFIN-HH
Bucharest

JINR
Dubna

SINP of Moscow State University
Moscow

IHEP
Protvino

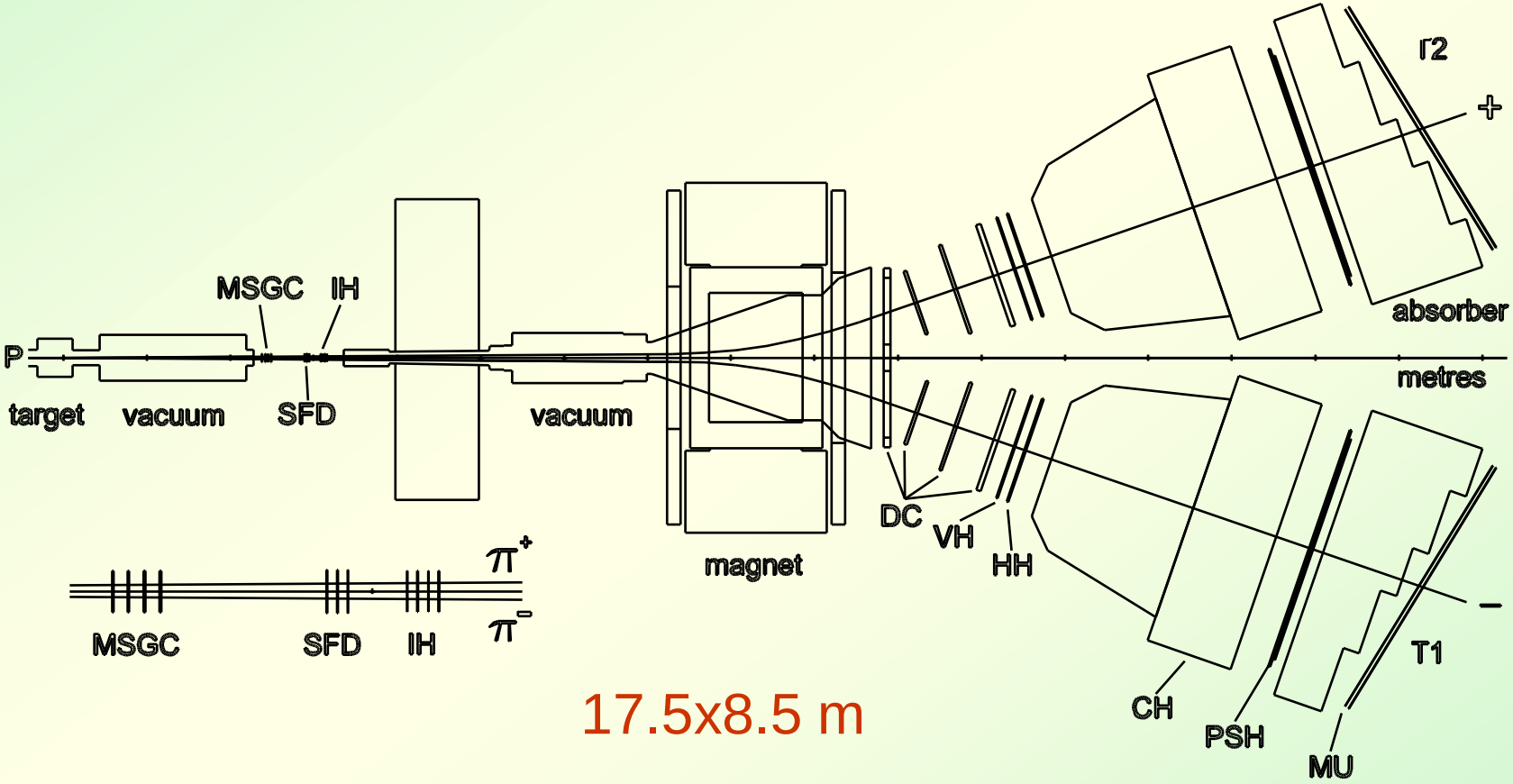
Santiago de Compostela University
Santiago de Compostela

Basel University
Basel

Bern University
Bern

Zurich University
Zurich

DIRAC-I setup (1998)

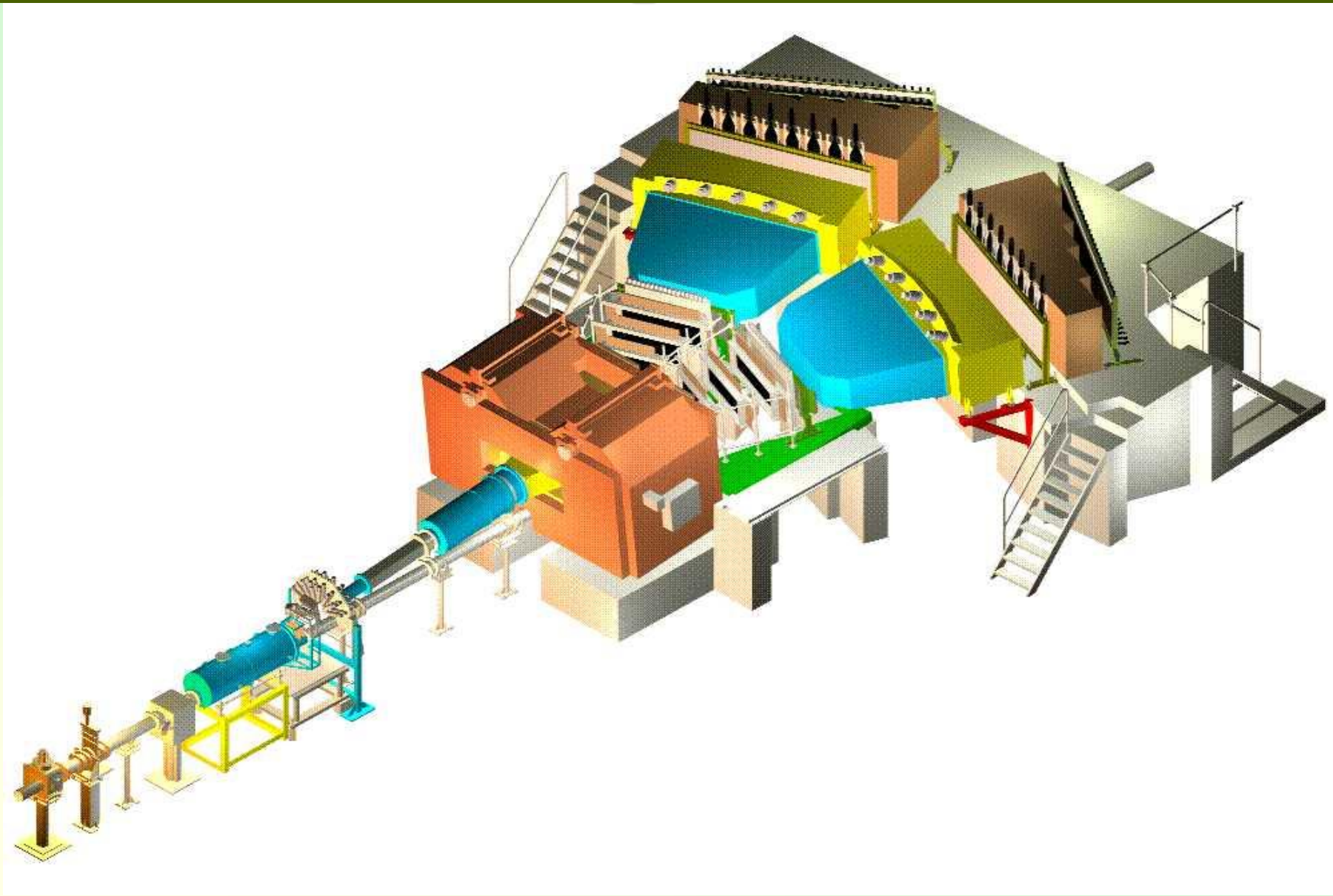


17.5x8.5 m

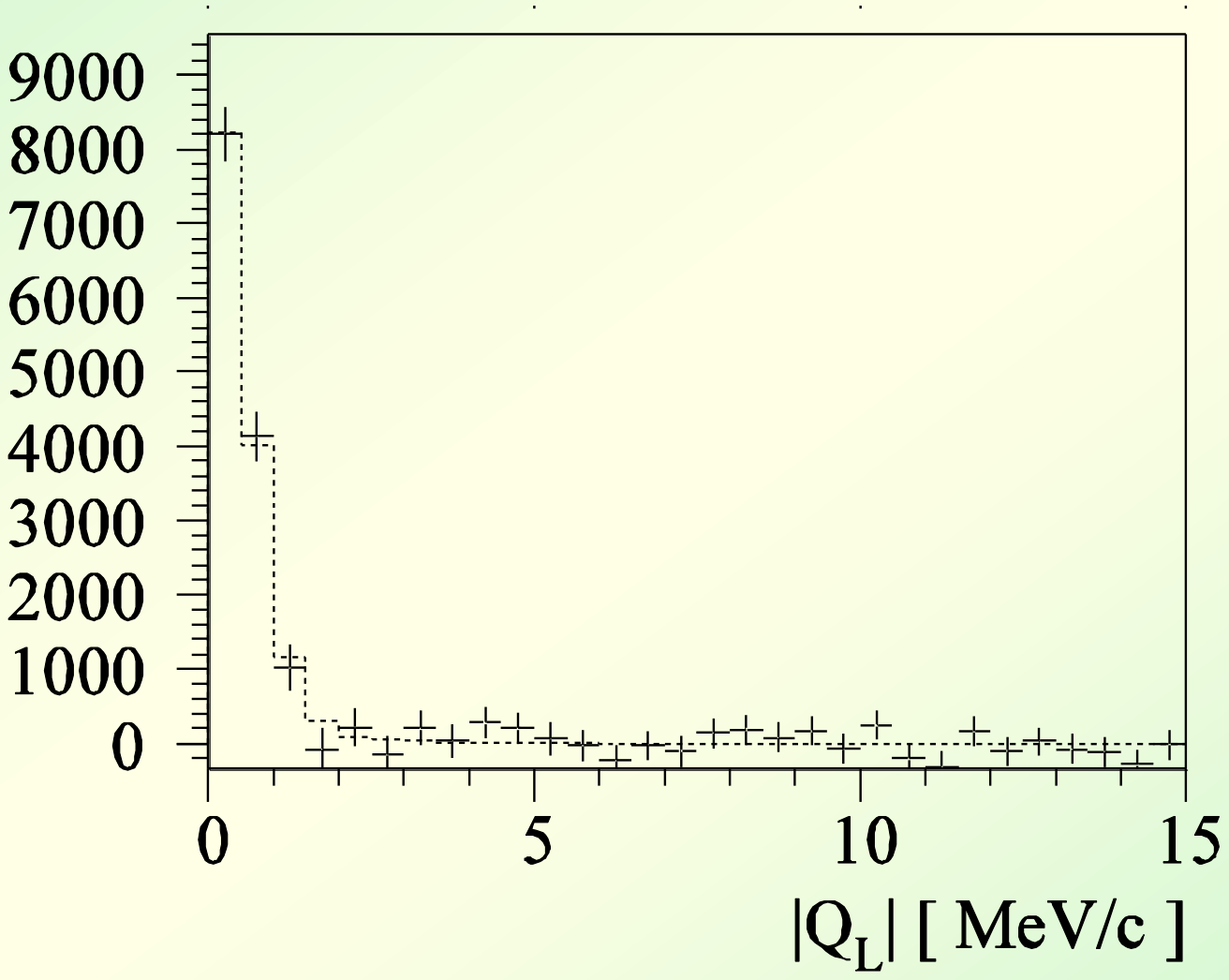
Momentum resolution = 3x10**(-3)

Relative momentum resolution = 0.5 MeV/c

DIRAC-I setup (1998)



Results 2001-2003, $\pi^+\pi^-$ signal



Results 2001-2003

2008 **DIRAC** (SPSC 22/04/08)

major part 2001-03 data (13300 observed pi+pi- atoms)

$$\tau = \left(2.82\,^{+0.25}_{-0.23}\big|_{stat} \pm 0.19\big|_{syst}\right)\text{fs} = \left(\ldots\,^{+0.31}_{-0.30}\big|_{tot}\right)\text{fs}$$

$$\Rightarrow |a_0 - a_2| = 0.268 \pm 4.4\%\big|_{stat} \pm 3.7\%\big|_{syst} = \ldots \pm 5.5\%\big|_{tot}$$

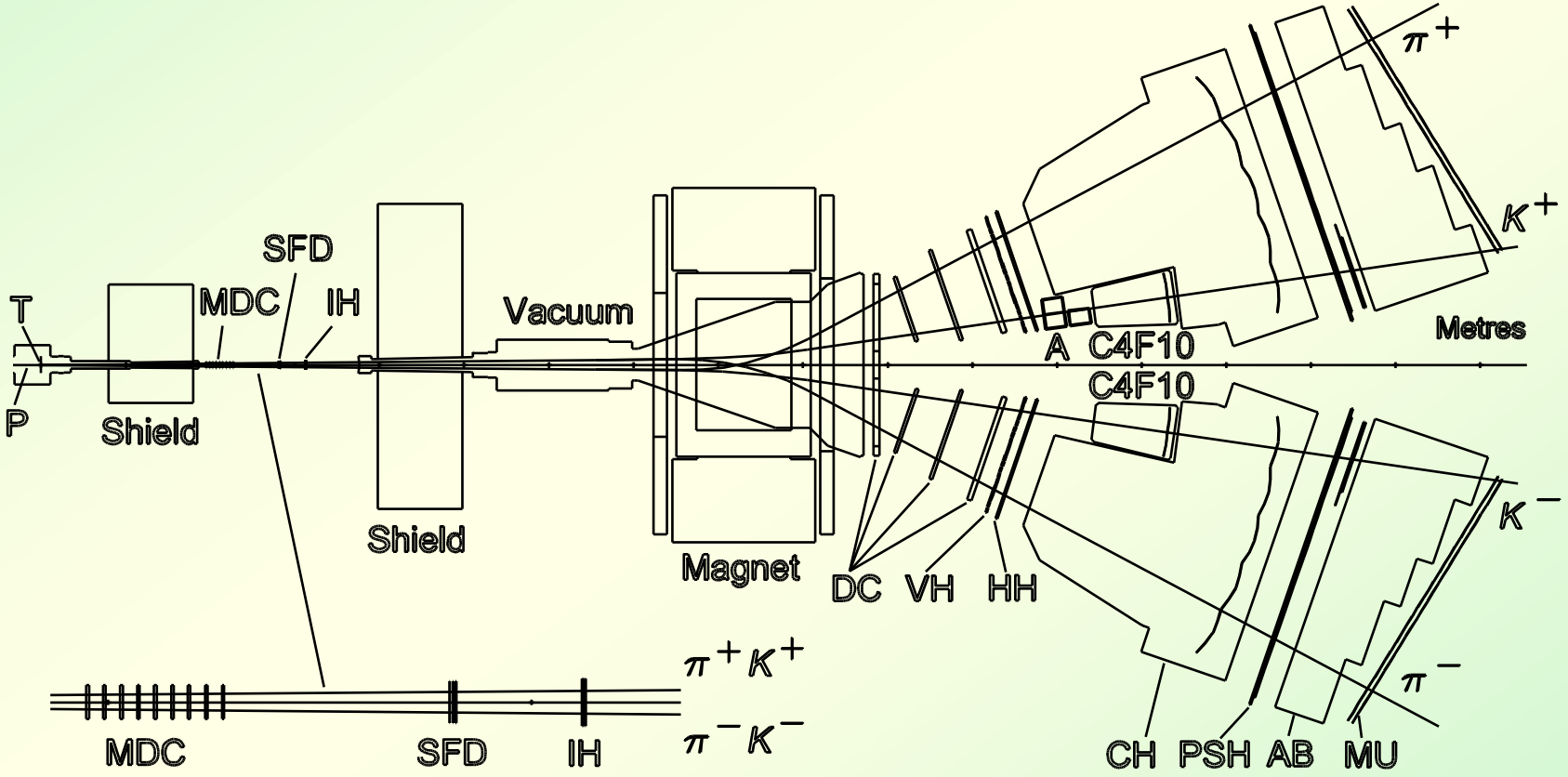
With MSGC : number of events is 17000,
statistical error in $|a_0\text{-}a_2|$ is 3%, and full error is <5%.

Theory predicts π+π- scattering lengths with accuracy ~ 1.5 % :

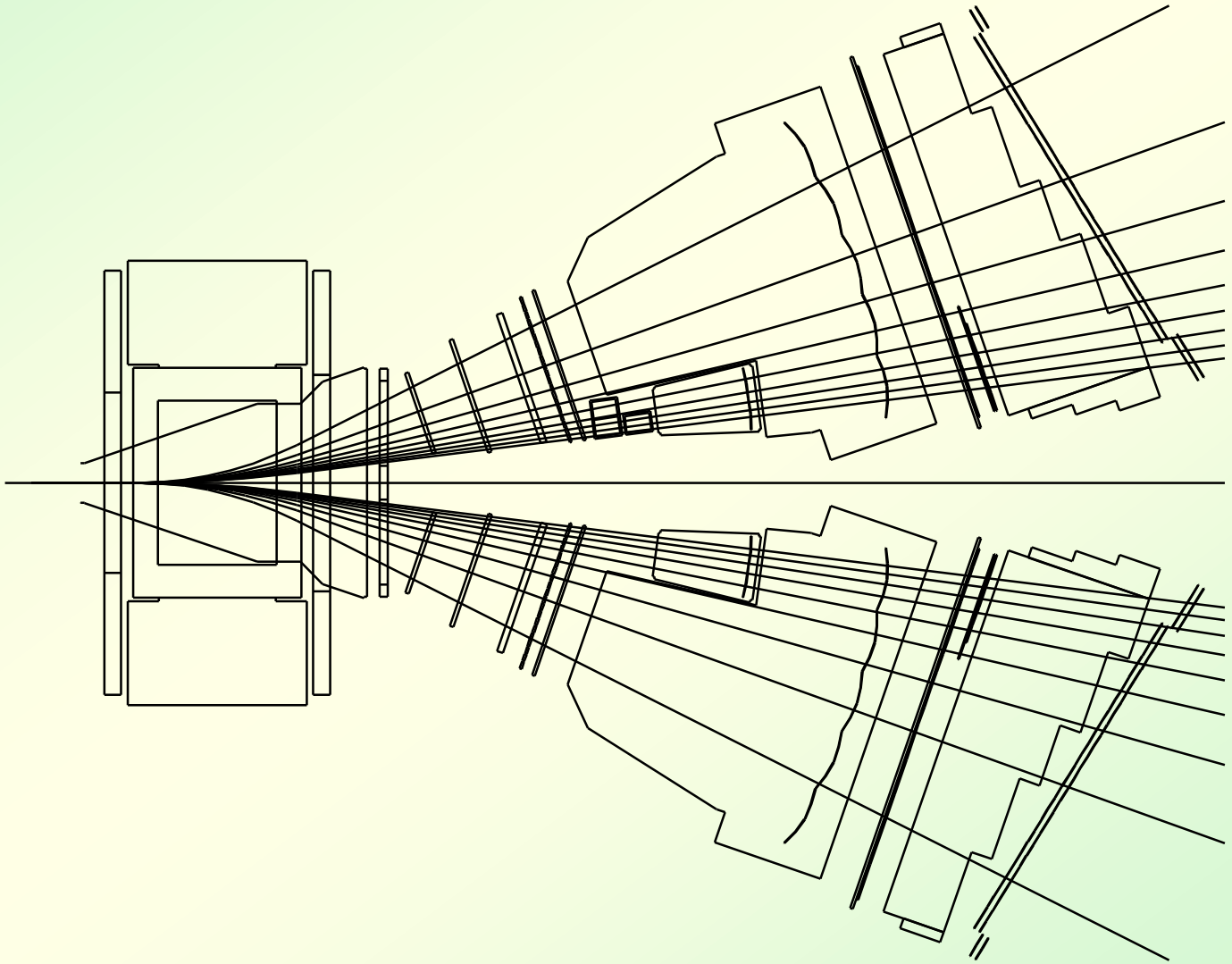
$$|a_0 - a_2|_{ChPT} = 0.265 \pm 0.004 \quad [m_\pi^{-1}]$$

$$\tau = (2.9 \pm 0.1) \times 10^{-15} s$$

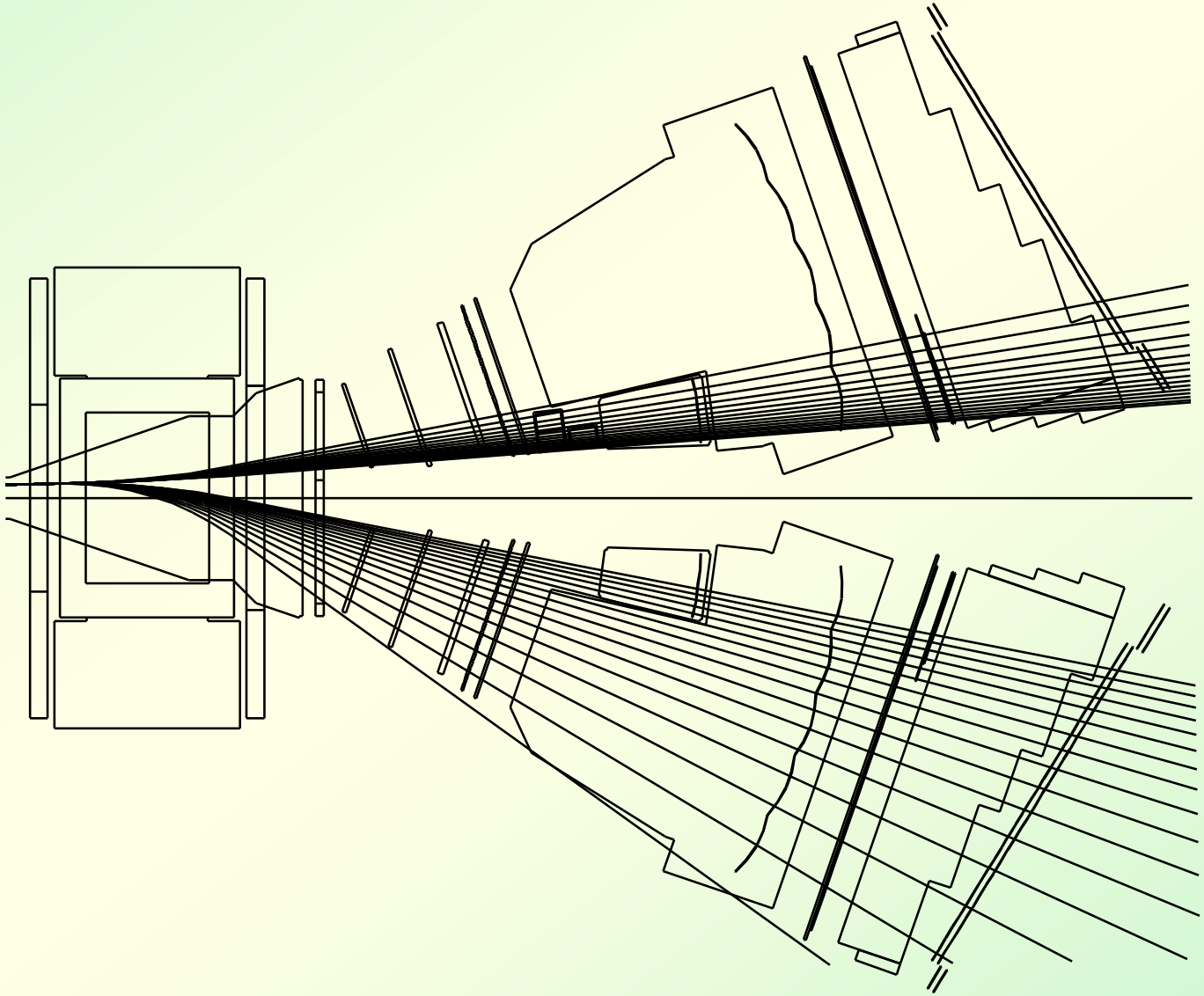
DIRAC-II setup (2006)



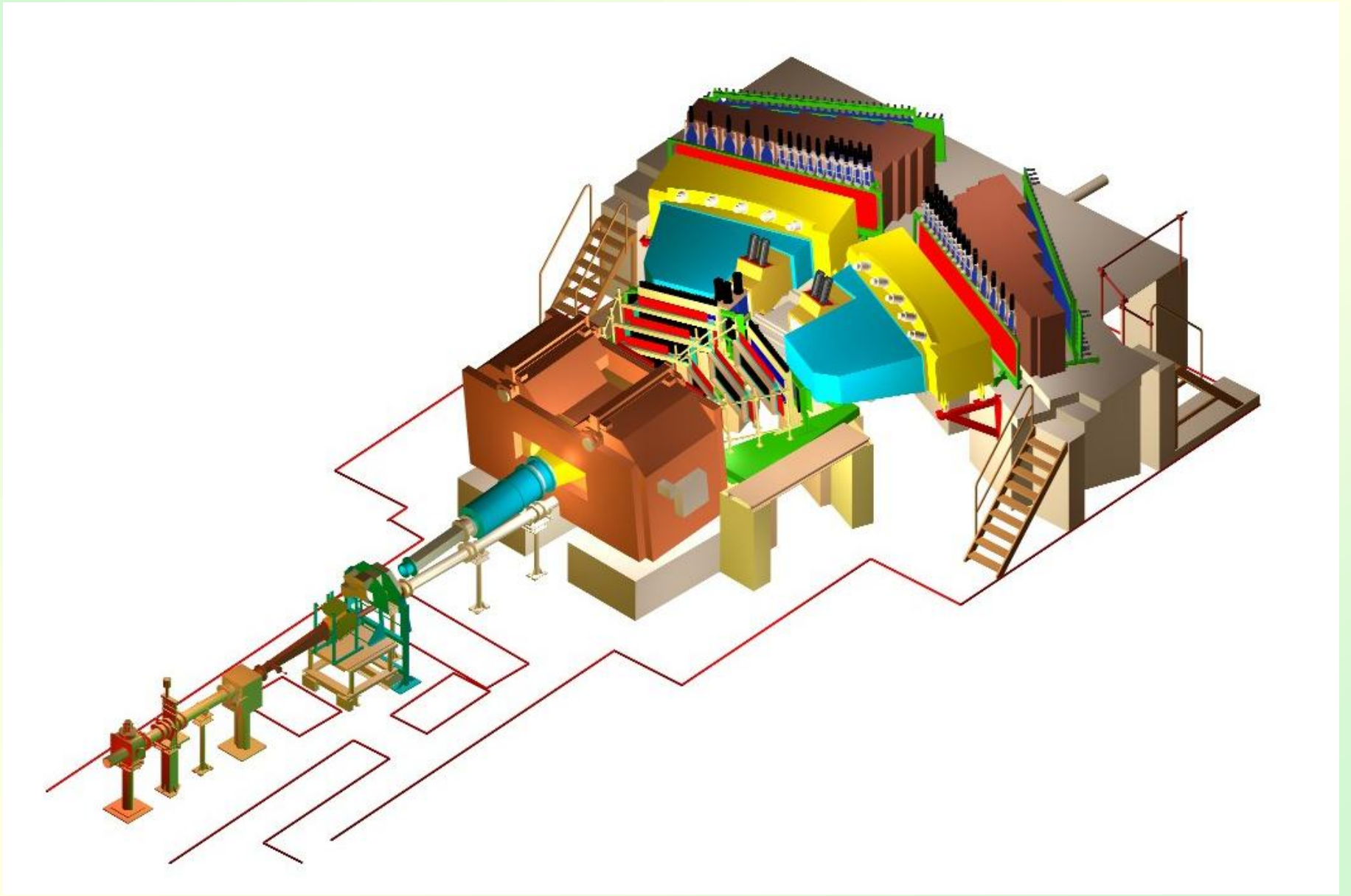
pi-pi tracing through the magnet



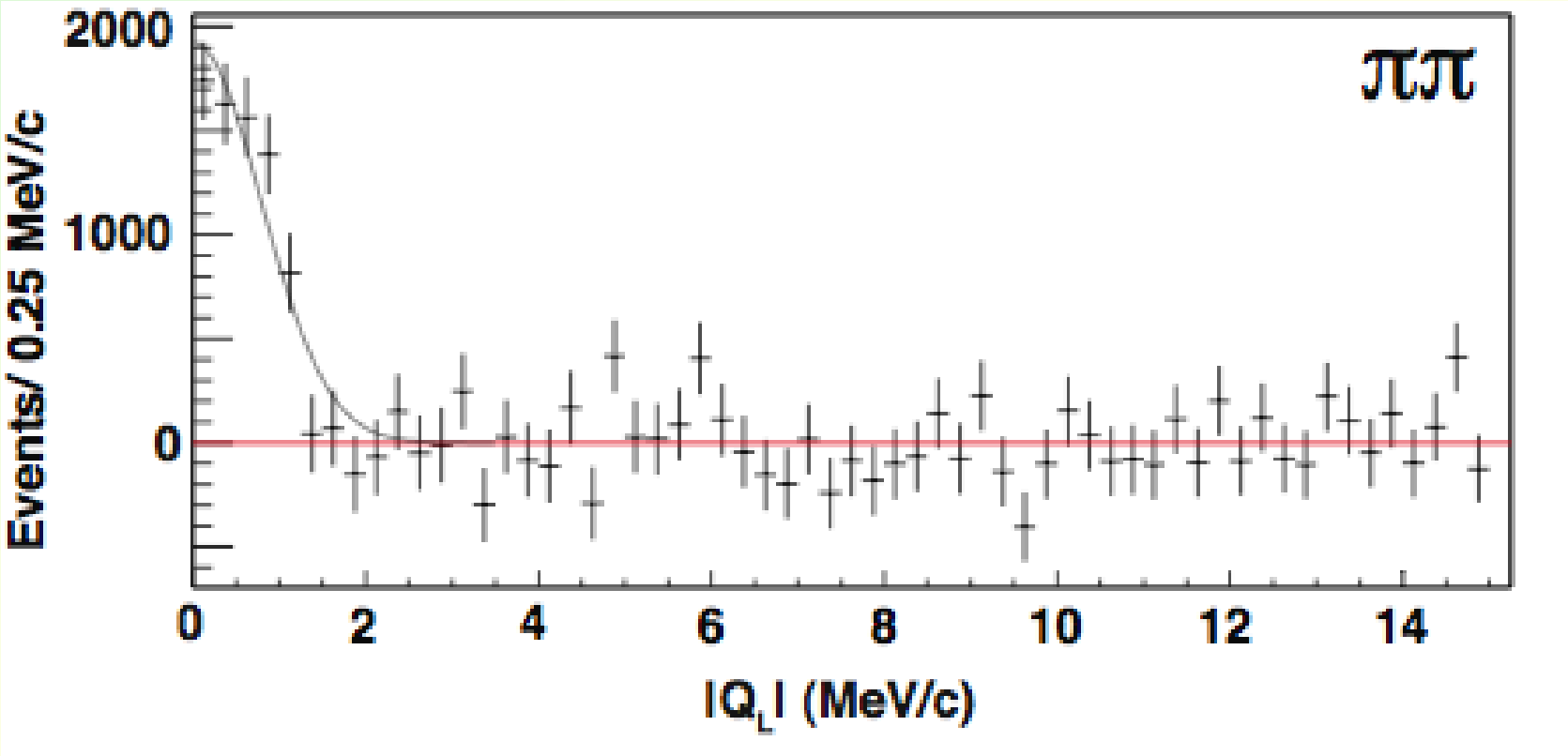
K-pi tracing through the magnet



DIRAC-II setup (2006)

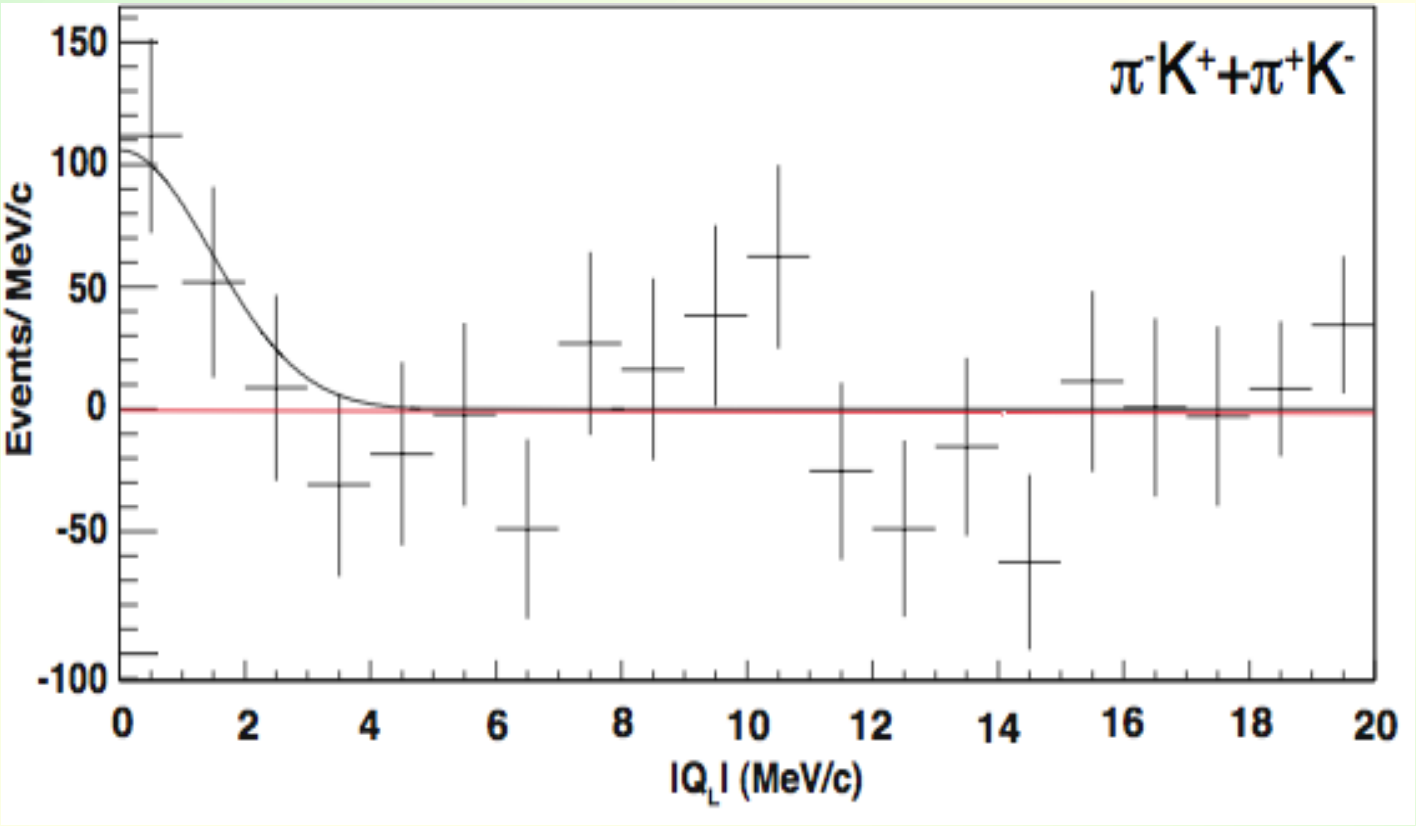


π+π− signal (2007)



Observation of $\pi^+\pi^-$ atoms with the Platinum target

π^-K^+ and π^+K^- signal (2007)



In total: 173±54 πK-atomic pairs are observed with a significance of 3.2σ.

$$\tau > 0.8 * 10^{-15} s \text{ at } 90\% CL$$

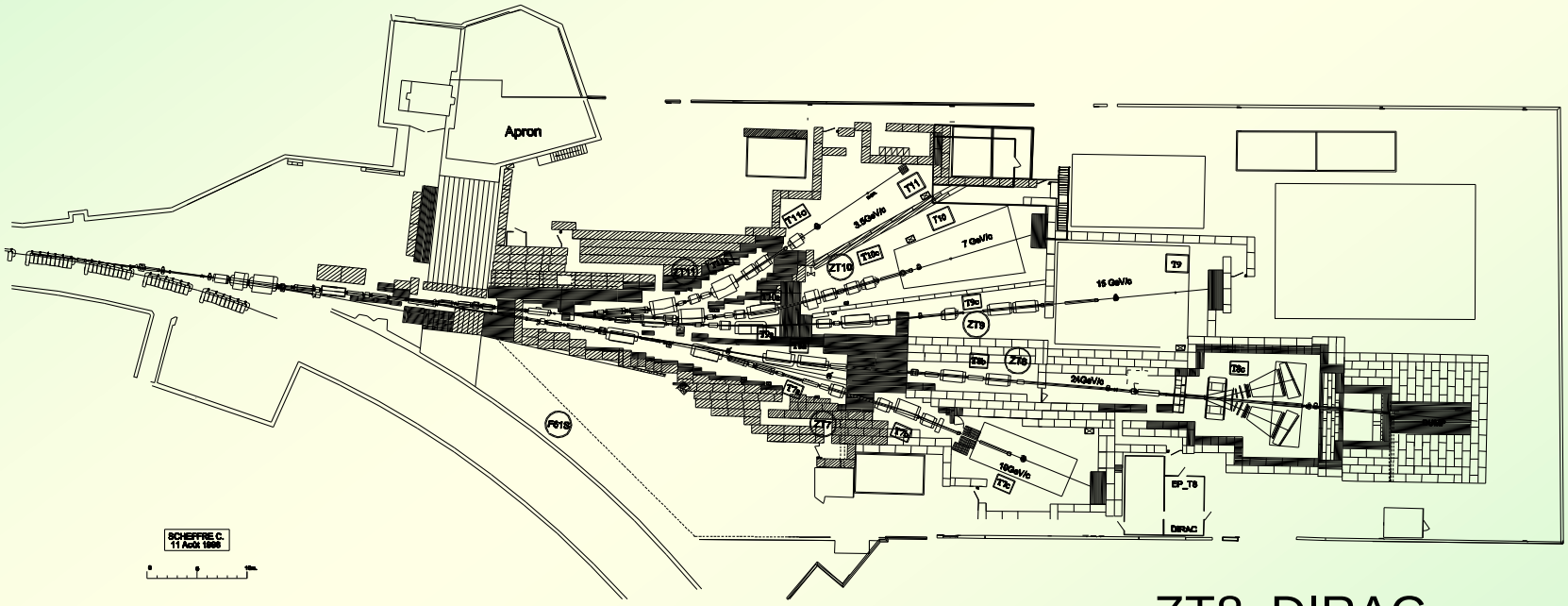
B. Adeva et al.,"Evidence for πK-atoms with DIRAC", Physics Letters B 674 (2009) 11

Y. Allkofer, PhD Thesis, Universität Zürich, 2008.

DIRAC history

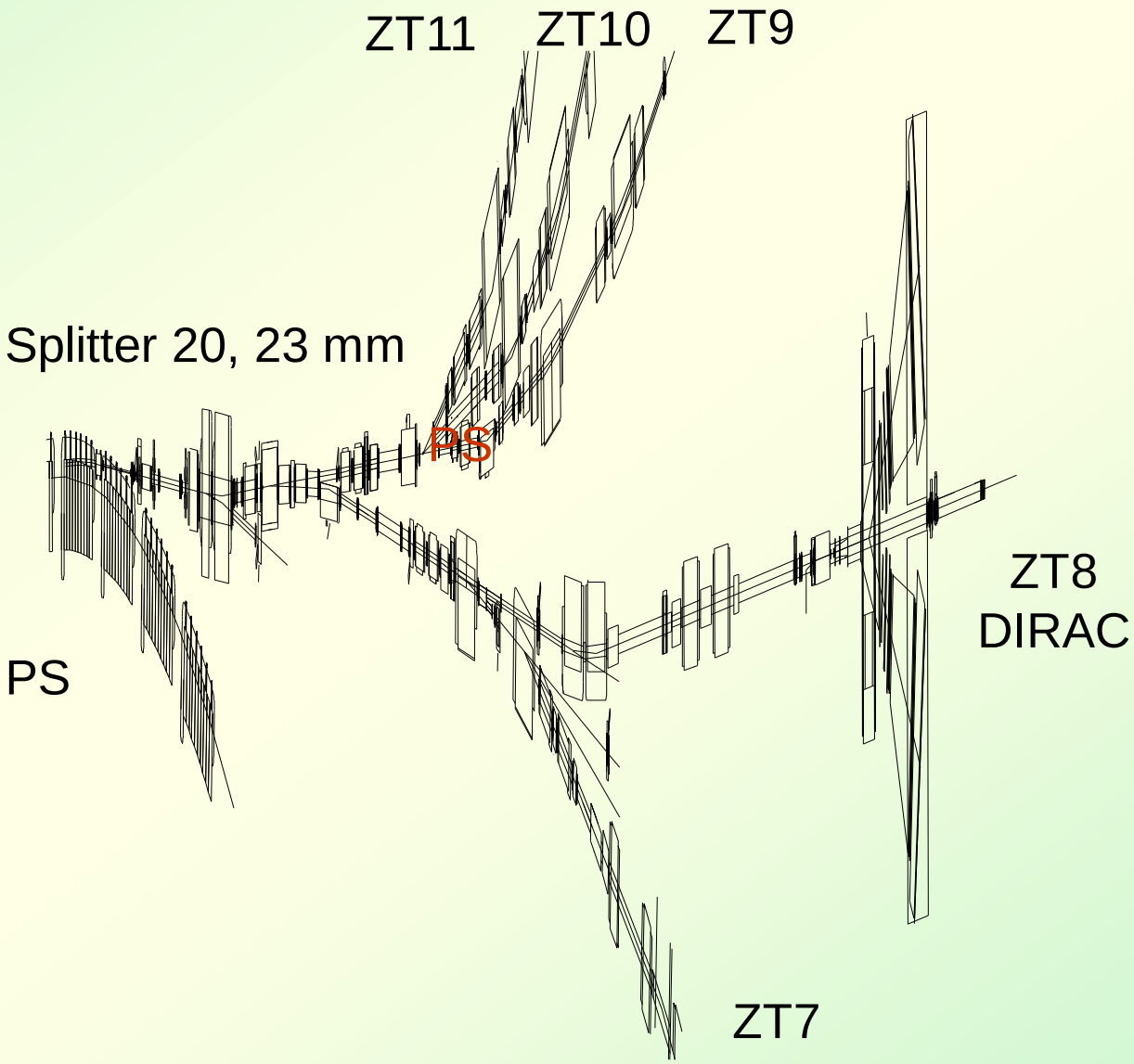
92: Letter of Intent was prepared
93: Letter of Intent was approved by SPSLC
94: Proposal was prepared in Dubna
95: Proposal was approved by JINR Advisory Committee
96: Proposal was approved by SPSLC and RB
96: Memorandum of understanding
96: L. Nemenov – spokesman
96: Secondary particle channel at 5.7 deg. (instead of 3.5 deg.)
96: A. Kuptsov – technical coordinator
97: Proton beam line and radiation shield were designed
98: Magnet installation and field measurement
98: Setup and radiation shield installation
98: First accelerator run
01-03: Main statistics on pi+pi- atoms was collected
04: Addendum to Proposal was prepared for pi K atoms detection
04: Addendum was approved by SPSLC
05: Detectors were designed and manufactured
06: New detectors were installed
07-08: Accelerator run, pi+pi-, piK

PS East Hall

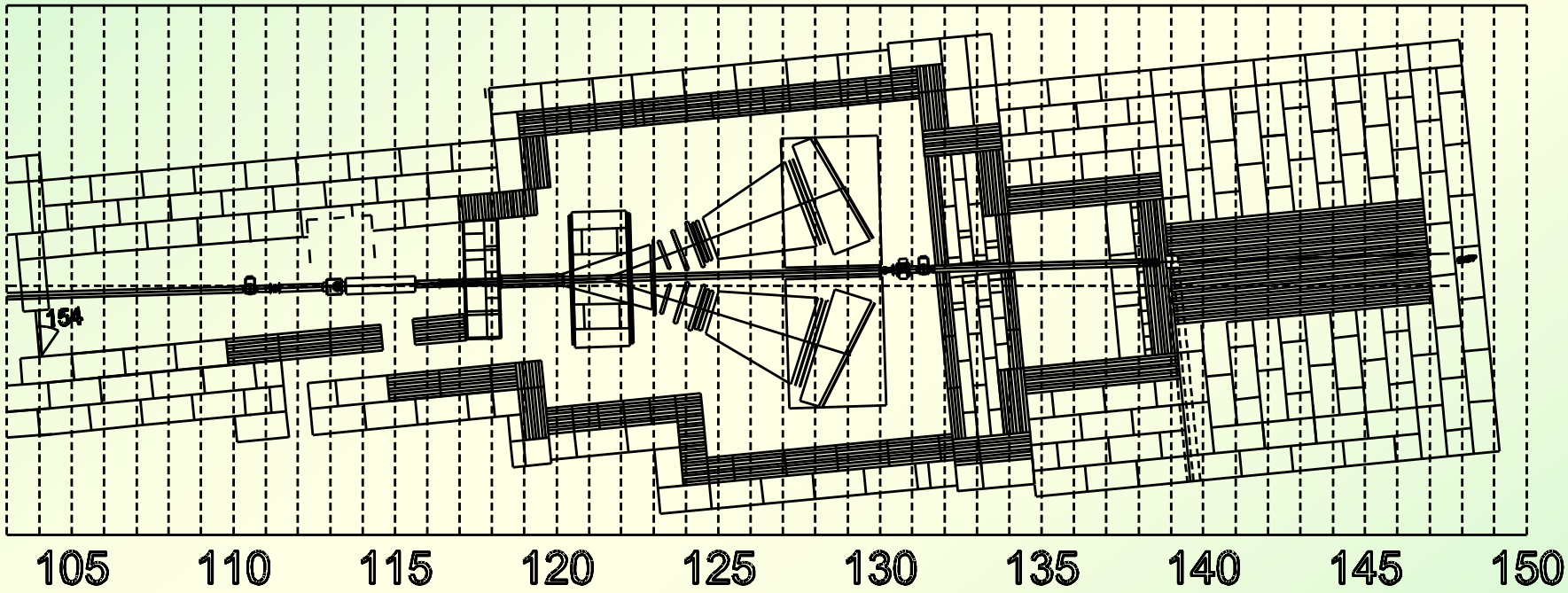


ZT8, DIRAC

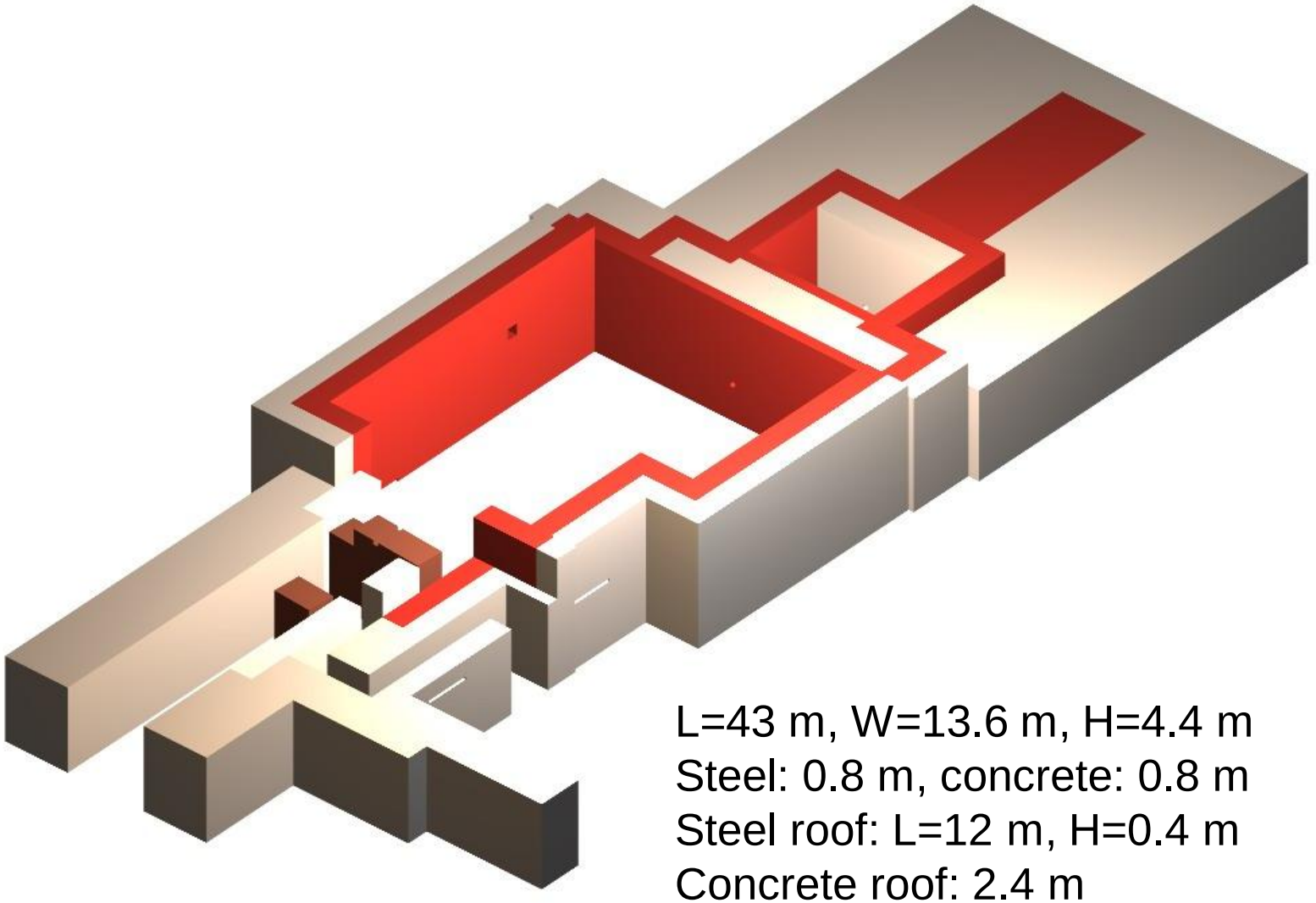
Beam lines in the PS East Hall



DIRAC area, distances in metres

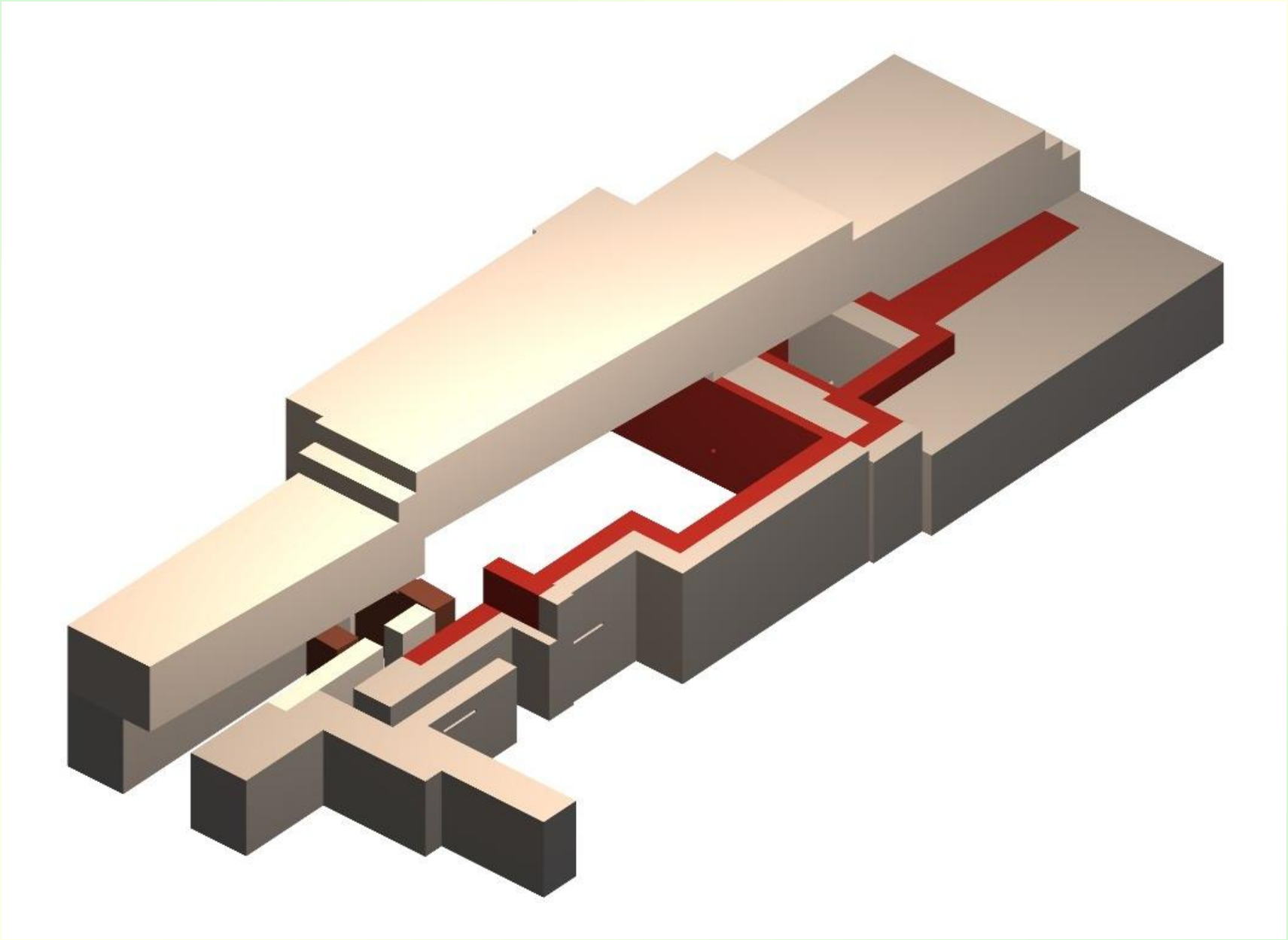


Radiation shield (1998)

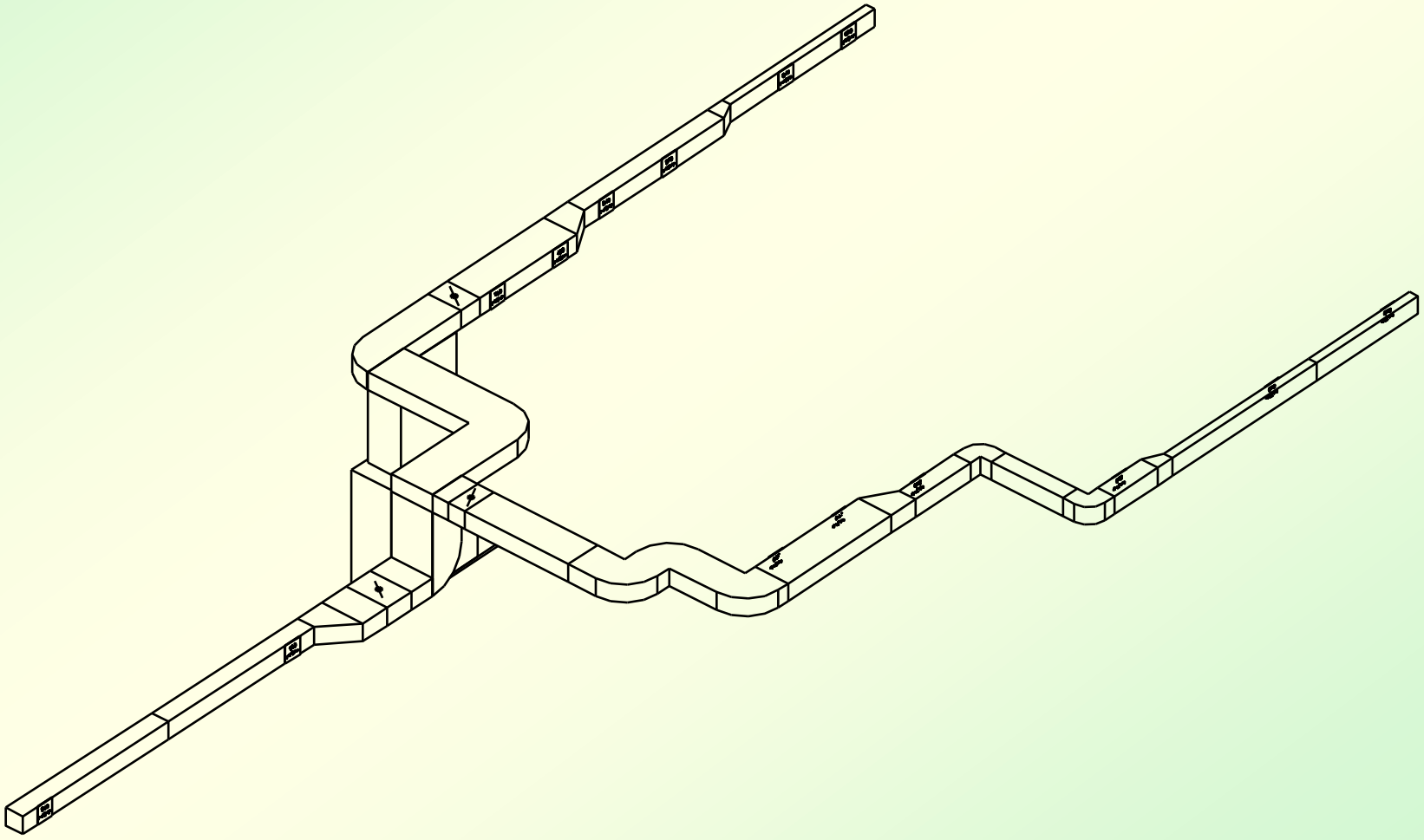


L=43 m, W=13.6 m, H=4.4 m
Steel: 0.8 m, concrete: 0.8 m
Steel roof: L=12 m, H=0.4 m
Concrete roof: 2.4 m
Beam dump: 8.0x3.2x3.2 m3

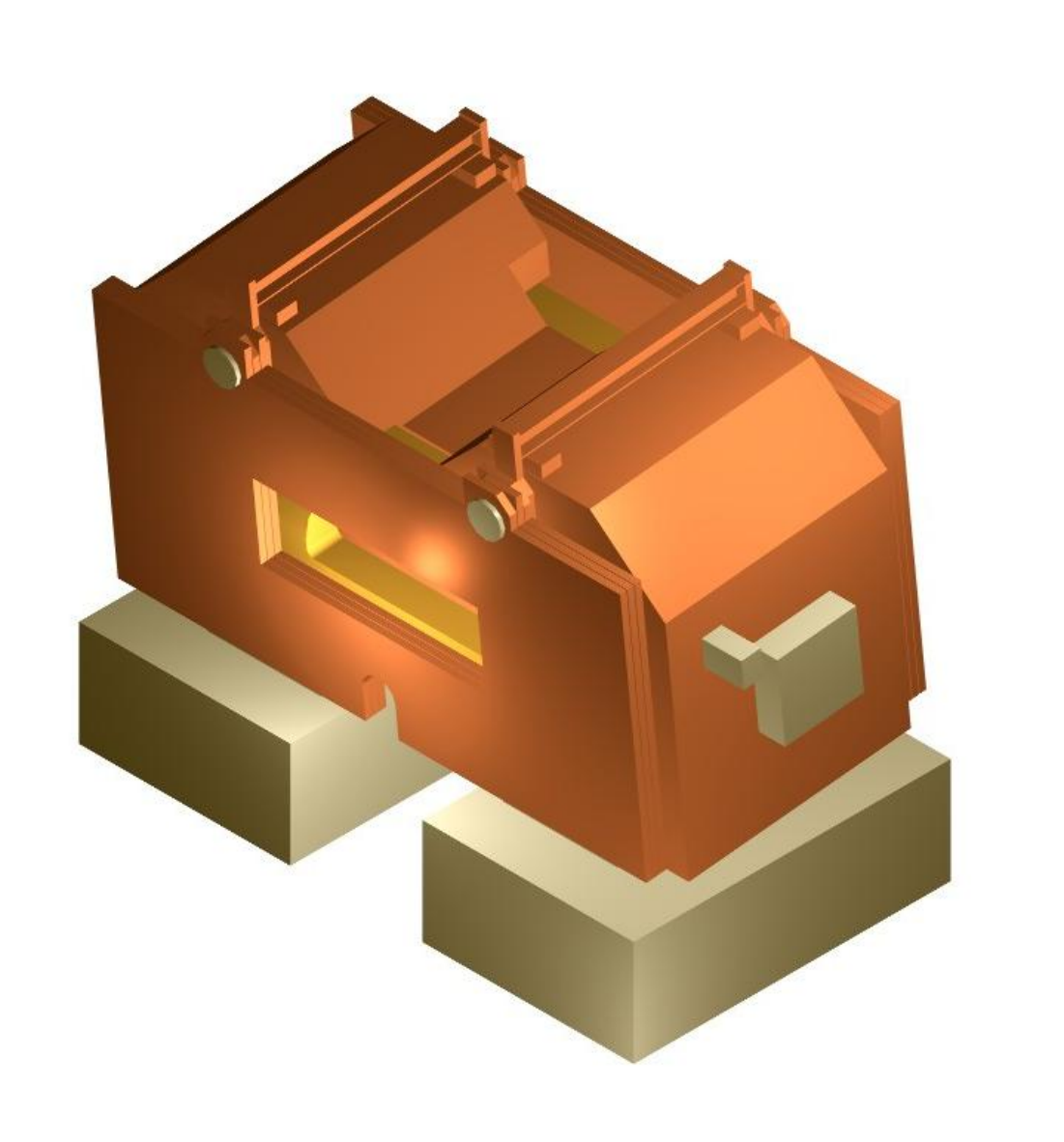
Radiation shield (1998)



Cooling system (1998)

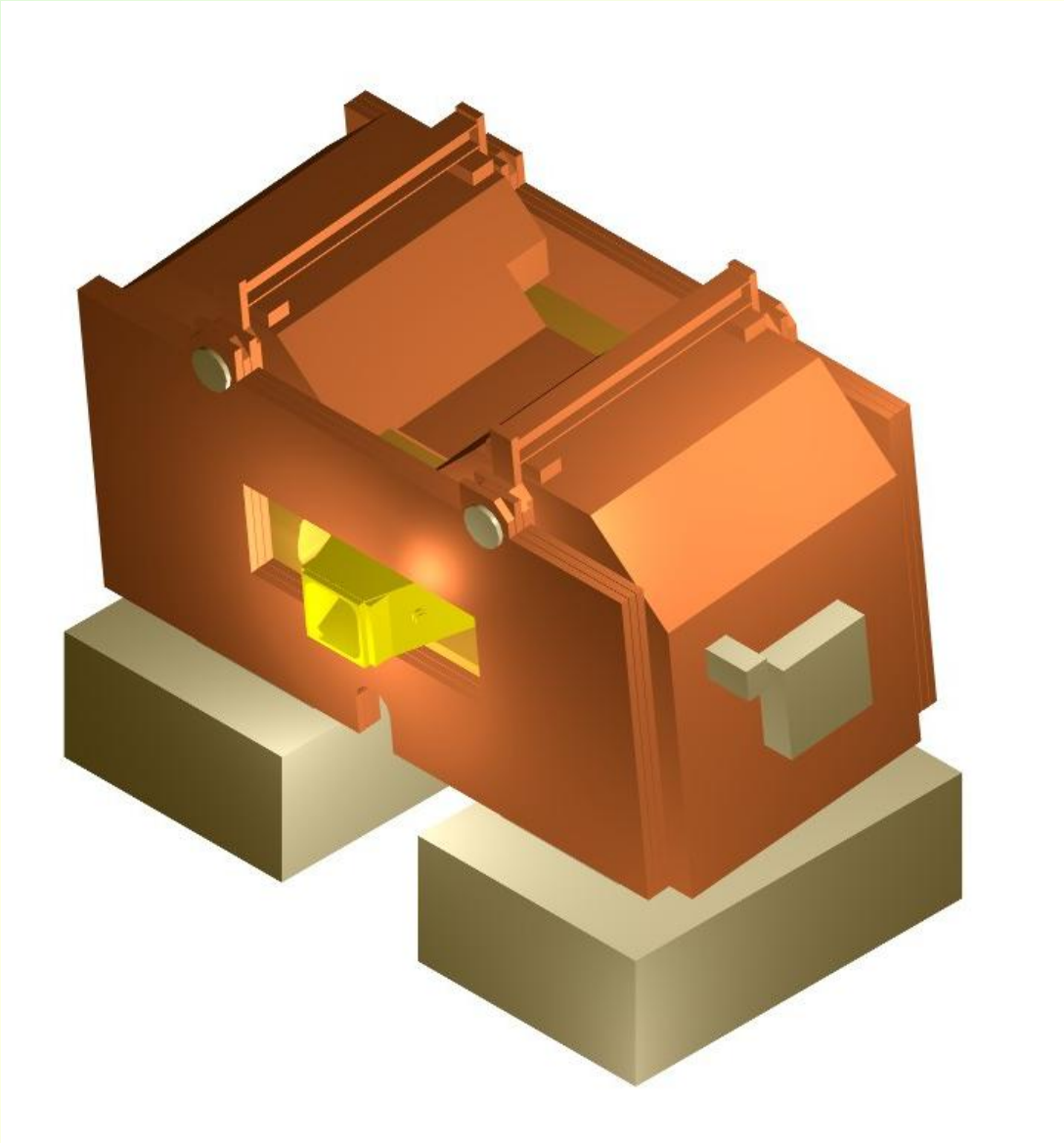


Magnet (1998)

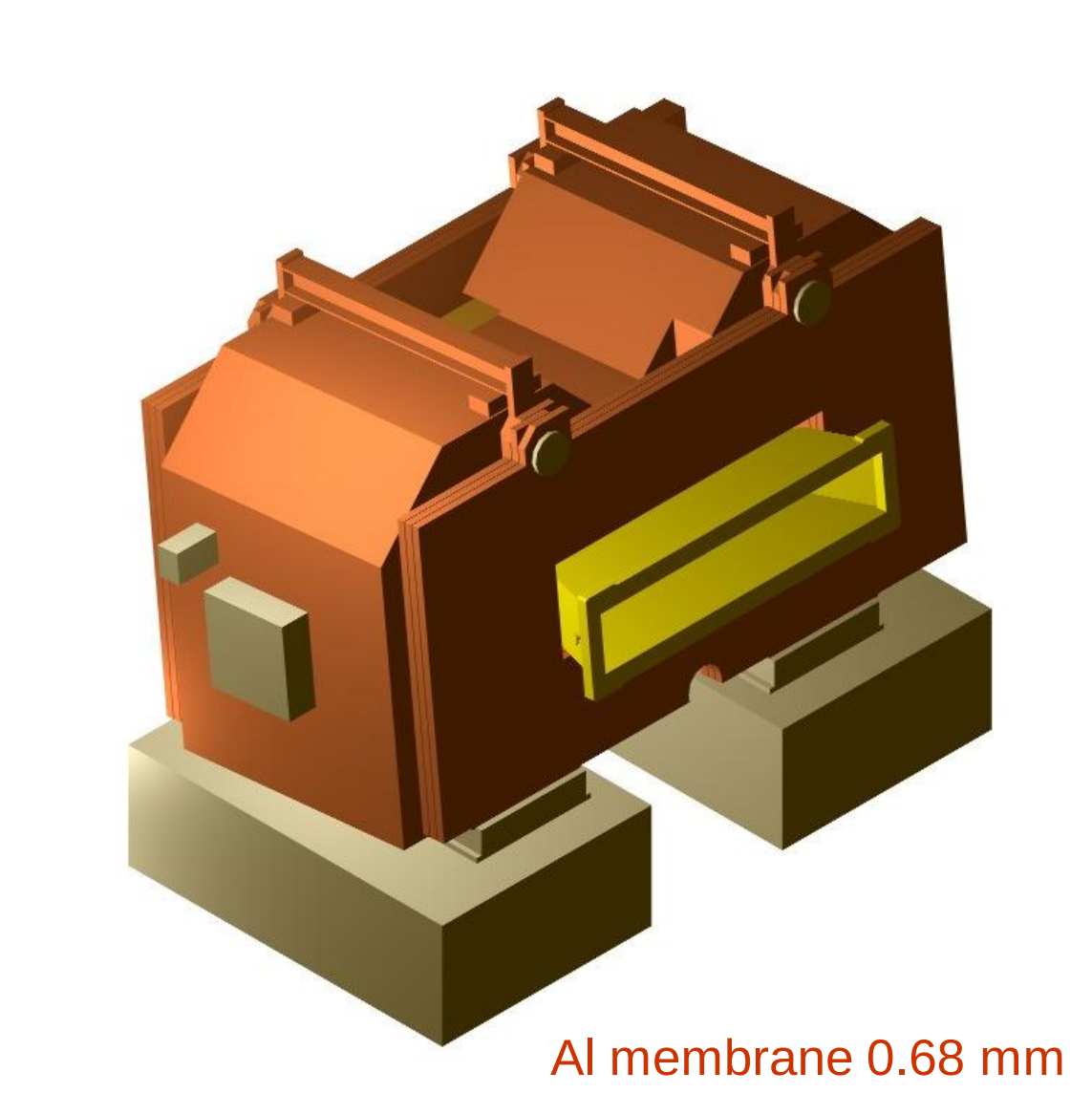


MNP21/3
B = 1.65 T
BL= 2.2 Tm
Current 2500 A
Power 1.43 MW
Weight 120 ton
Dim. 4.2x2.5x2.0 m
Gap 1.5x0.5x1.1 m
Screens
400x200x15 cm
Coils 2x165 turns
Coils 18x18 mm
Water 23 kg/cm2
Water 540 l/min

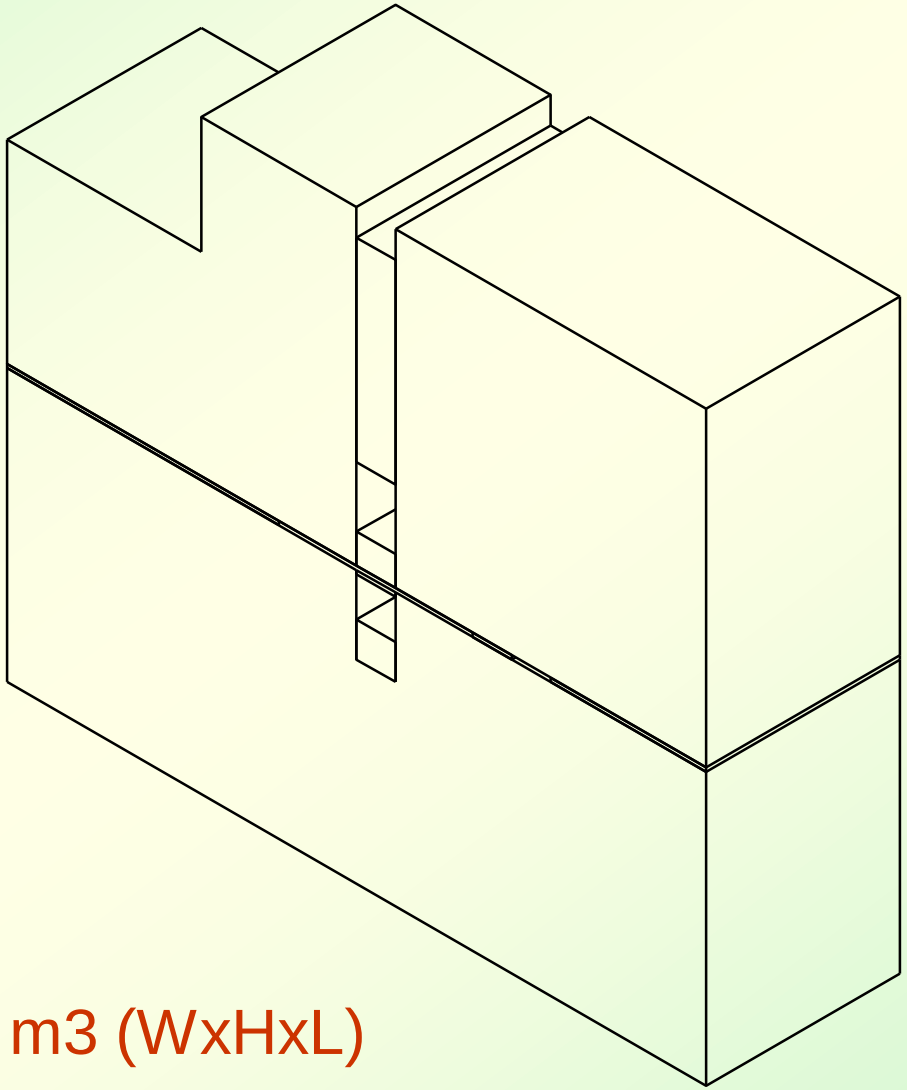
Magnet and flat chamber (1998)



Magnet and flat chamber (1998)

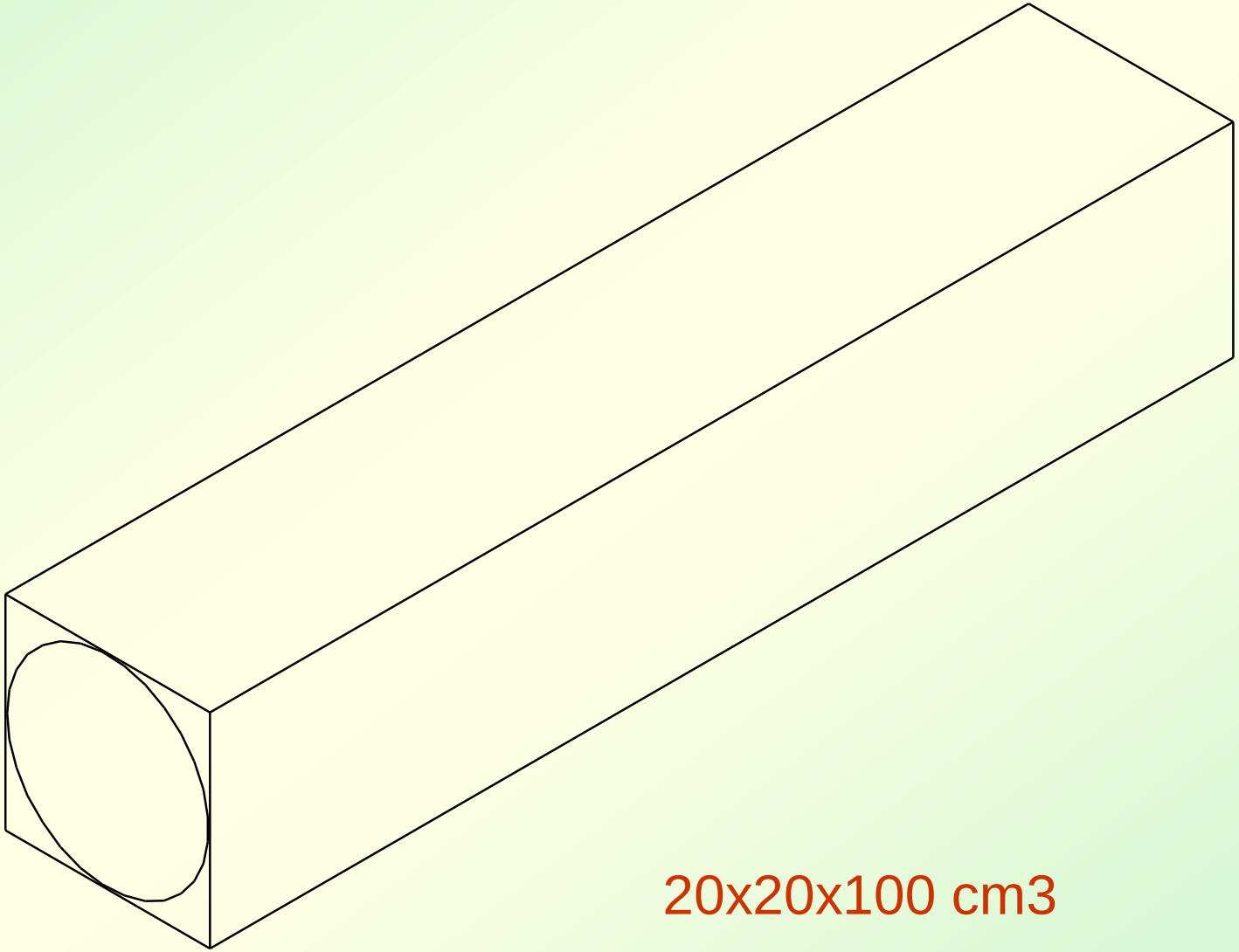


Shield (1998)



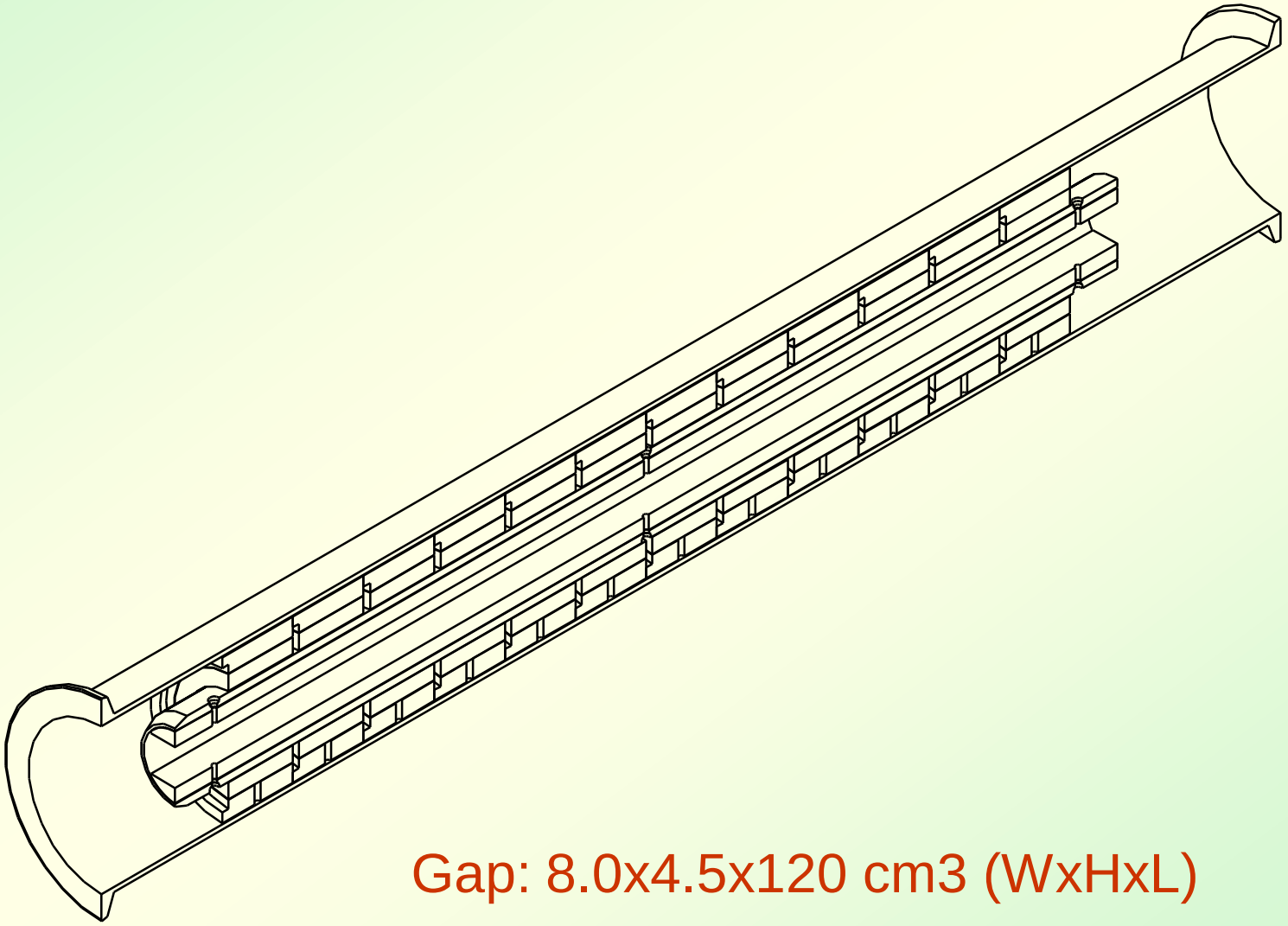
3.6x3.0x1.0 m3 (WxHxL)

Collimator (1998)



20x20x100 cm3

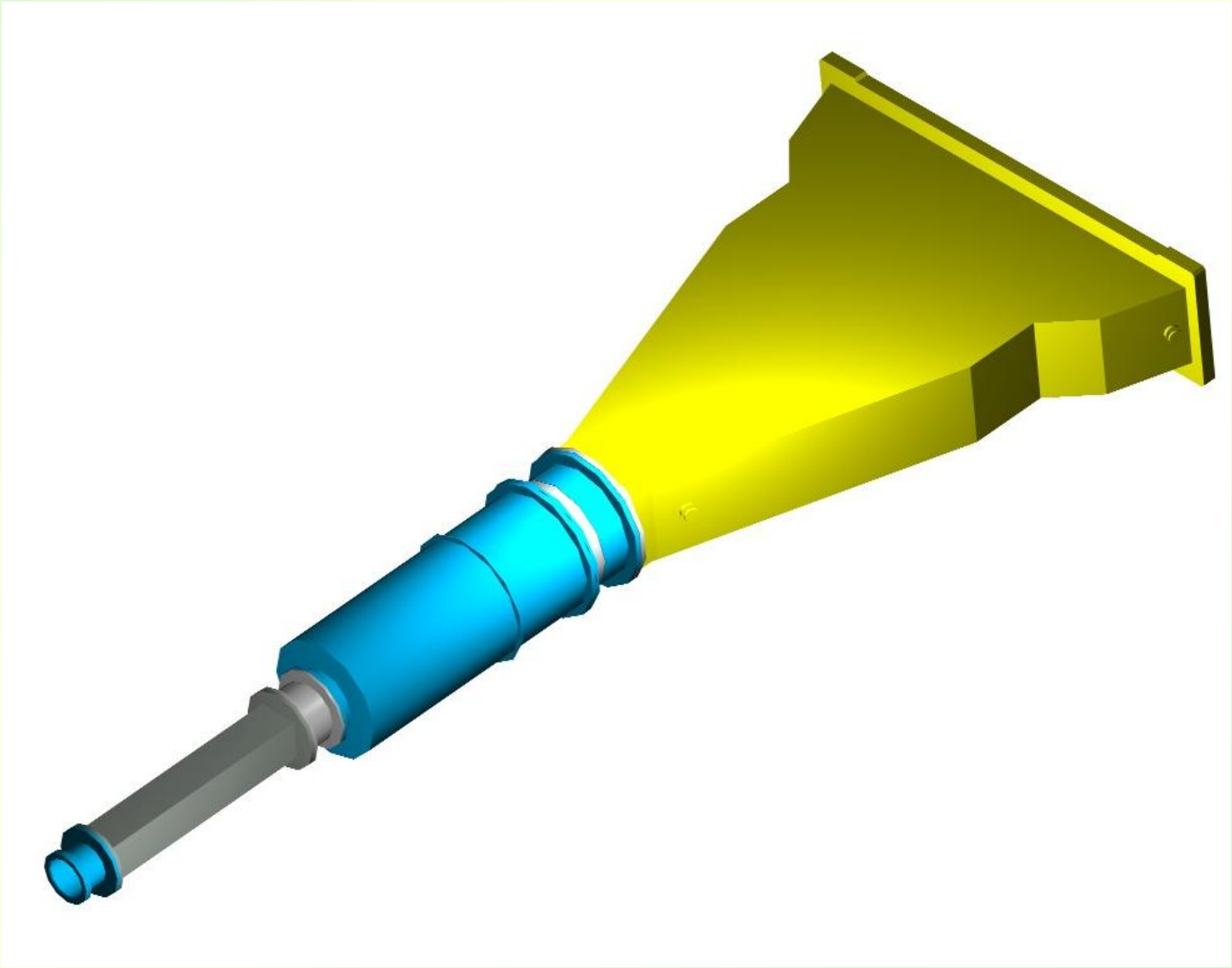
Collimator (2000)



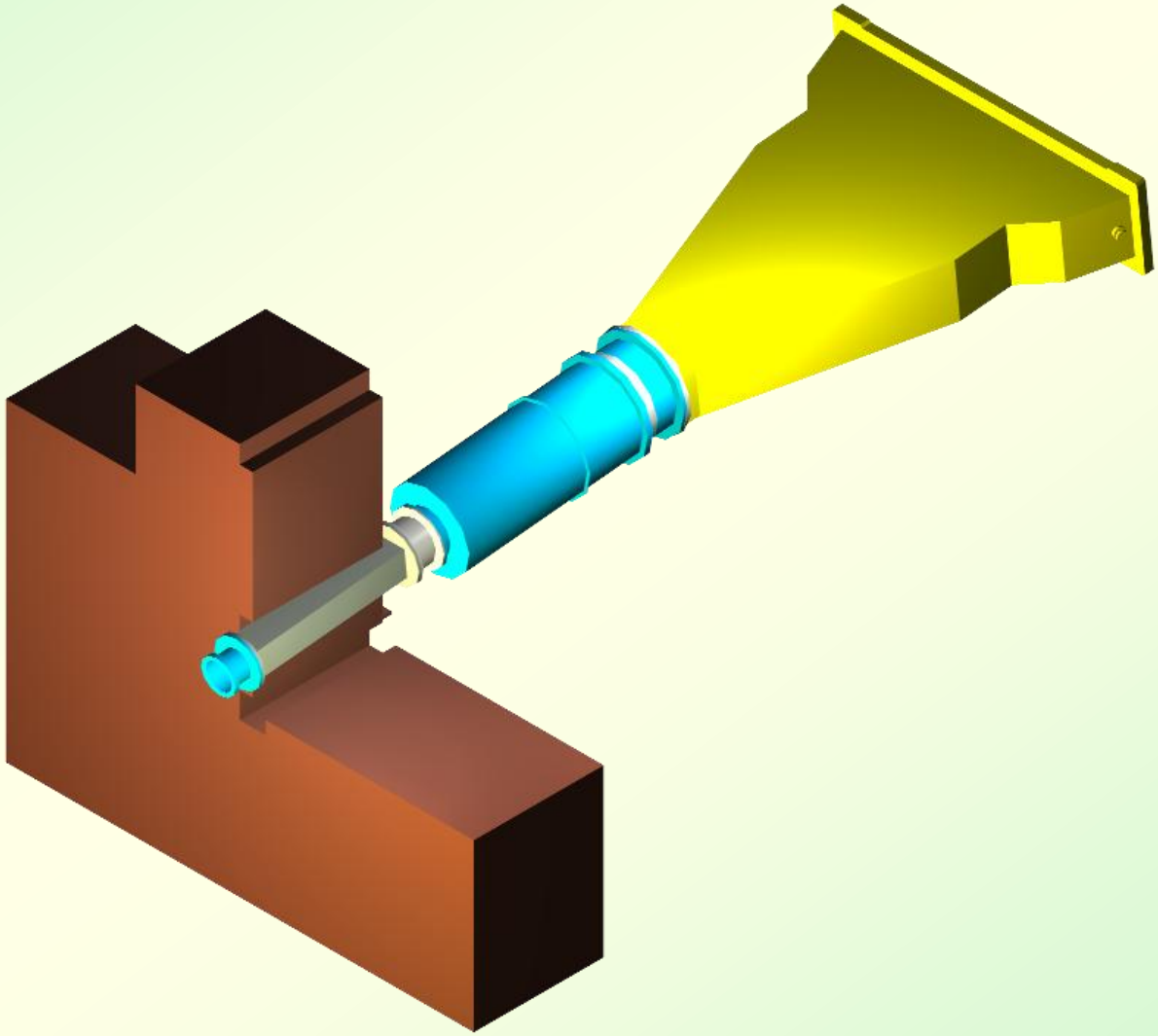
Gap: 8.0x4.5x120 cm3 (WxHxL)

Secondary particle channel (1998)

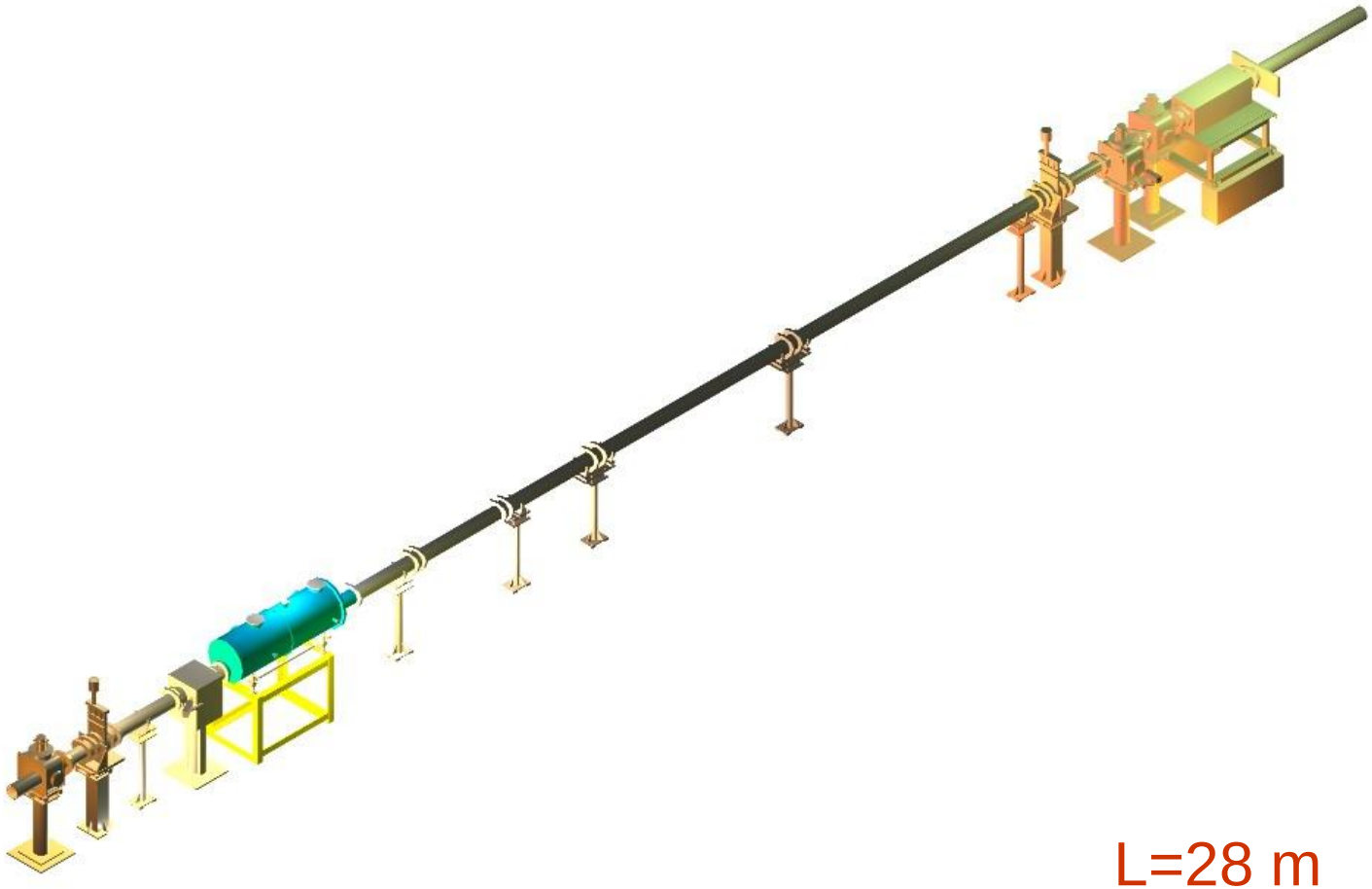
Collimator:
L=1.2 m
Entr.
136x136 mm
Exit:
178x178 mm
+-1 degree
Tube diam.
600 mm
Flat chamber:
L=2.74 m
Entr. 38x38 cm
Exit: 215x38 cm
Walls 25 mm
Weight: 2 ton
Channel:
L=6 m



Secondary particle channel and shield

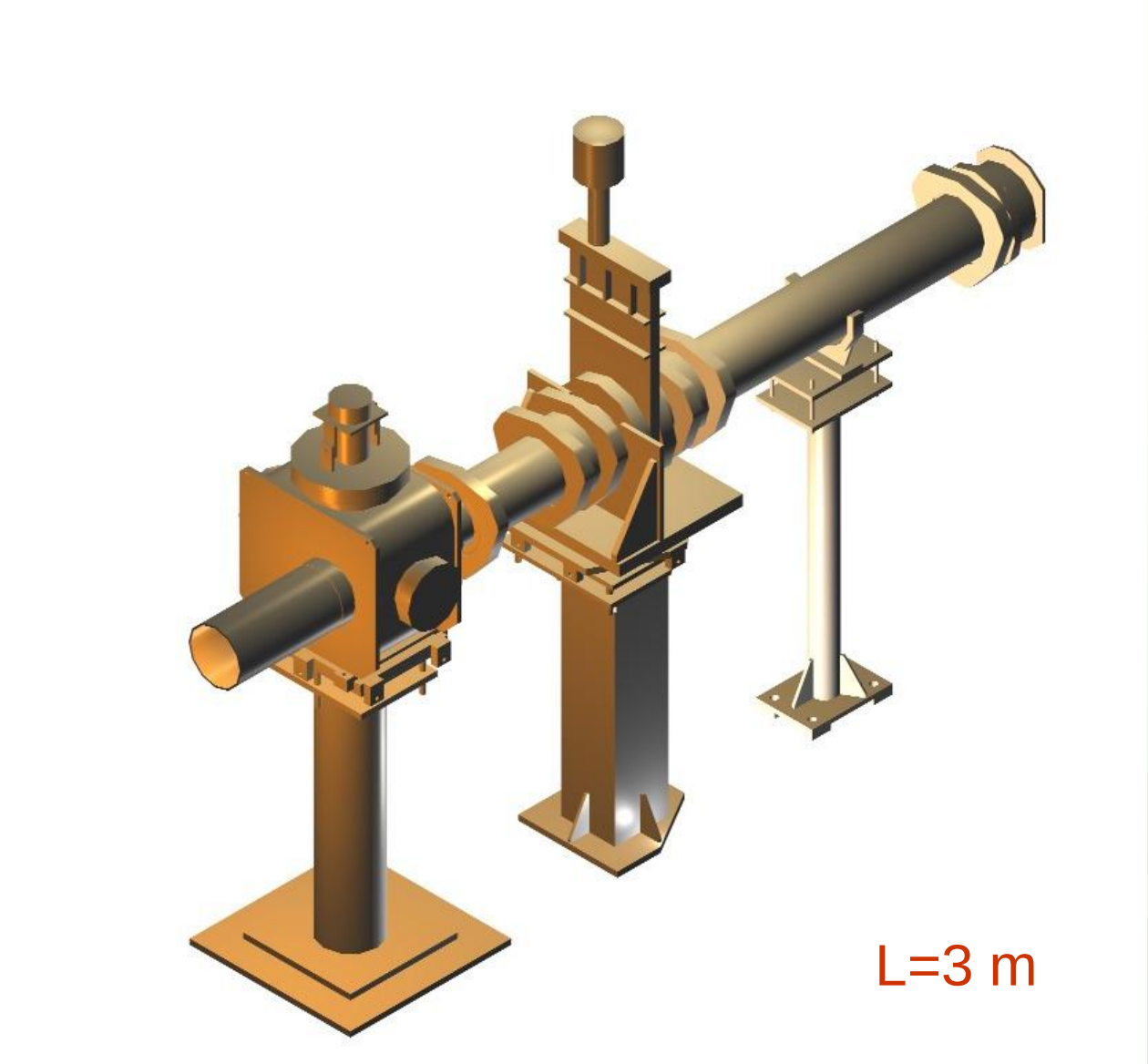


Proton beam line (1998)

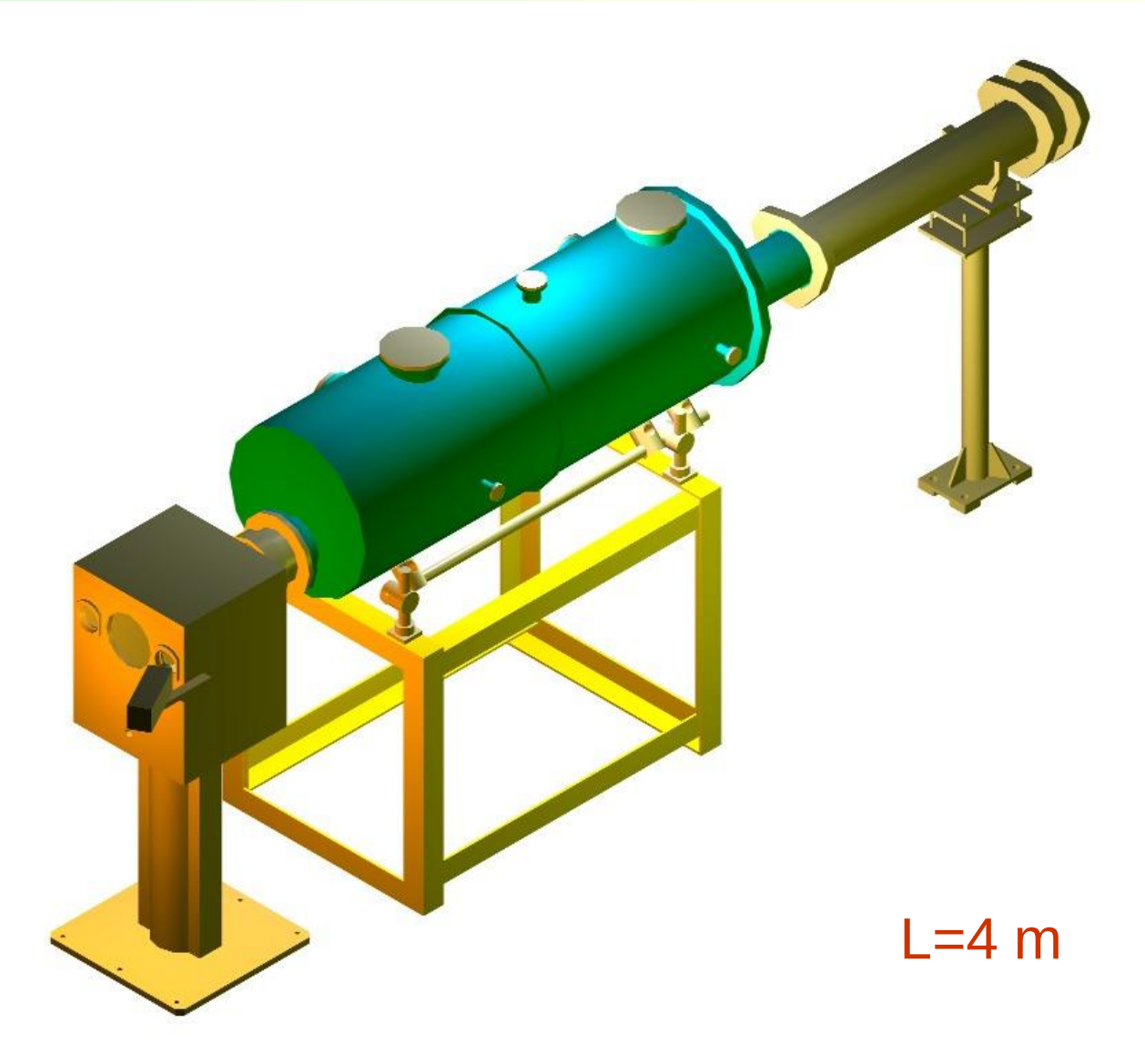


L=28 m

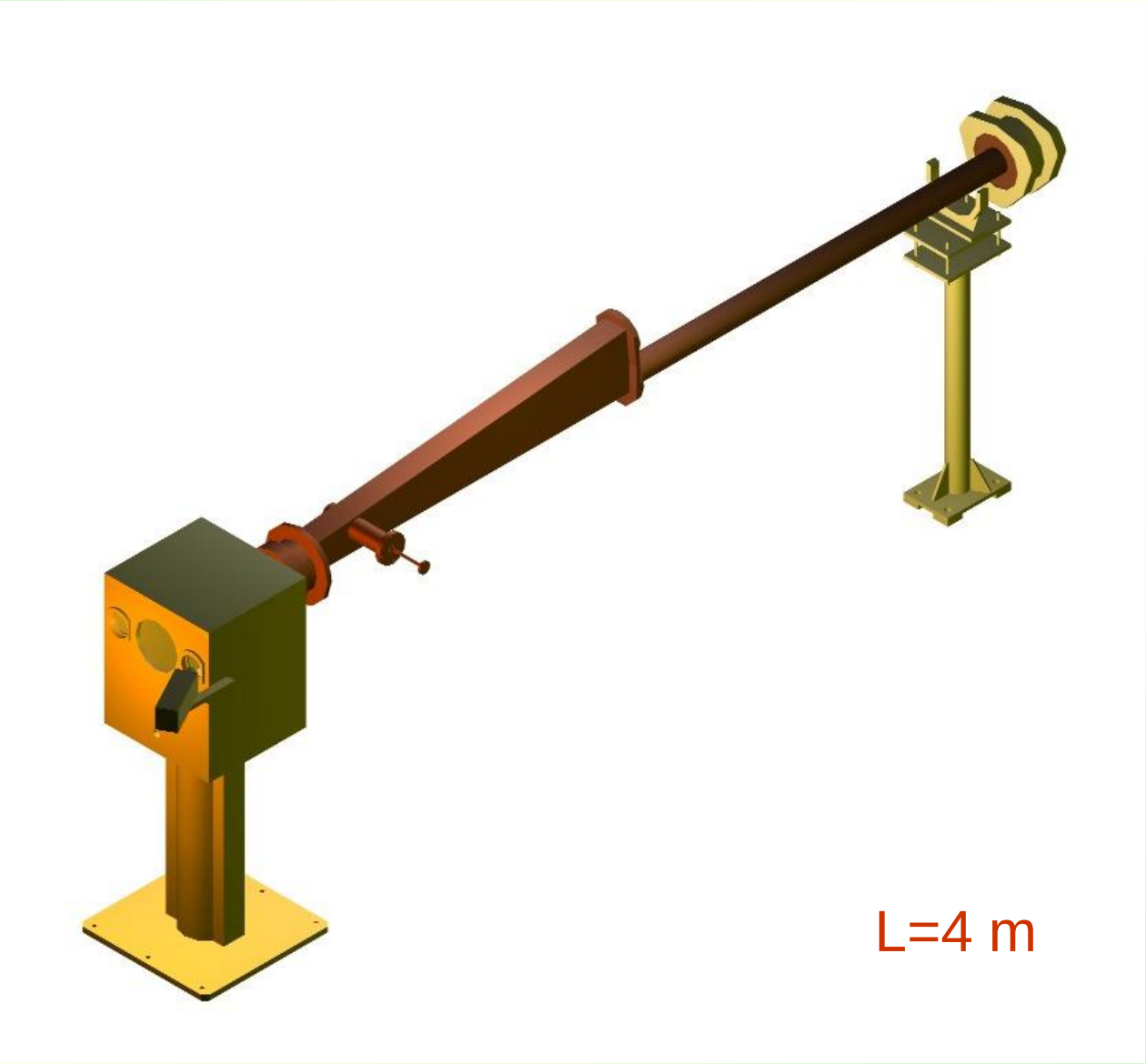
Proton beam line 1 (1998)



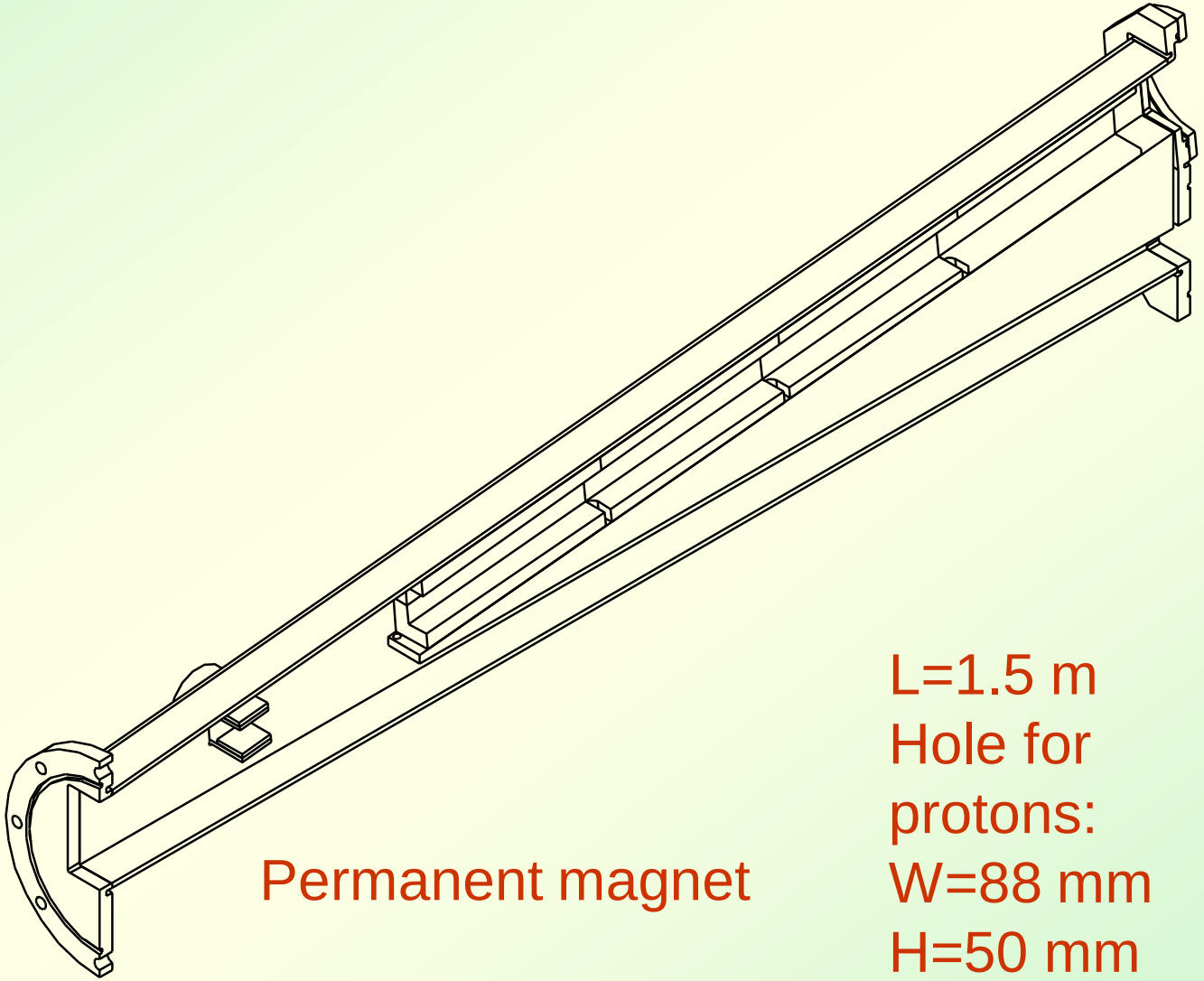
Proton beam line 2 (1998)



Proton beam line 2 (2006)



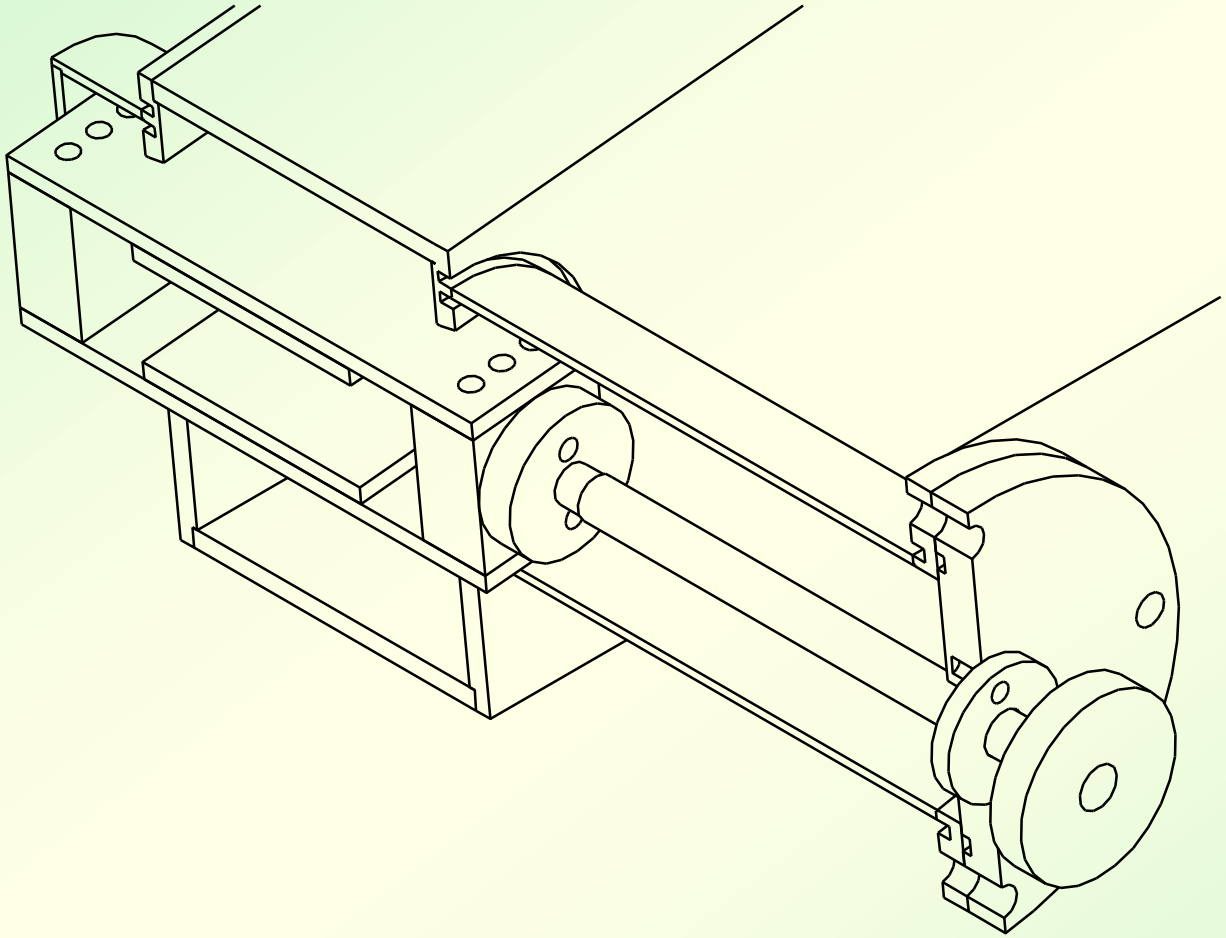
Collimators (2006)



Permanent magnet

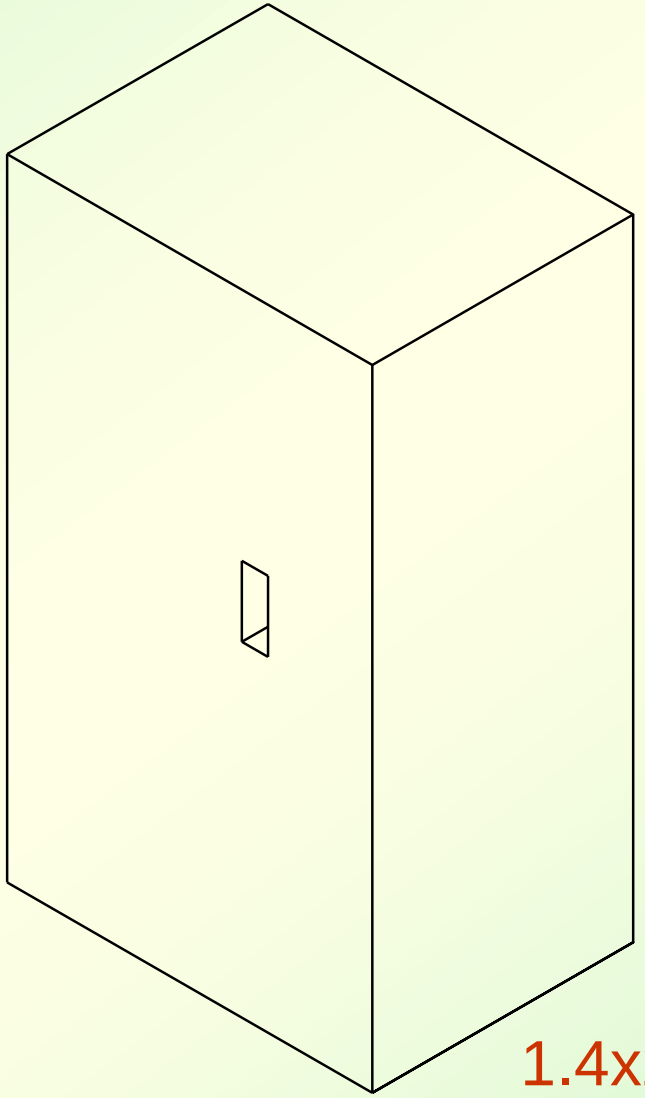
L=1.5 m
Hole for protons:
W=88 mm
H=50 mm

Permanent magnet (not installed)



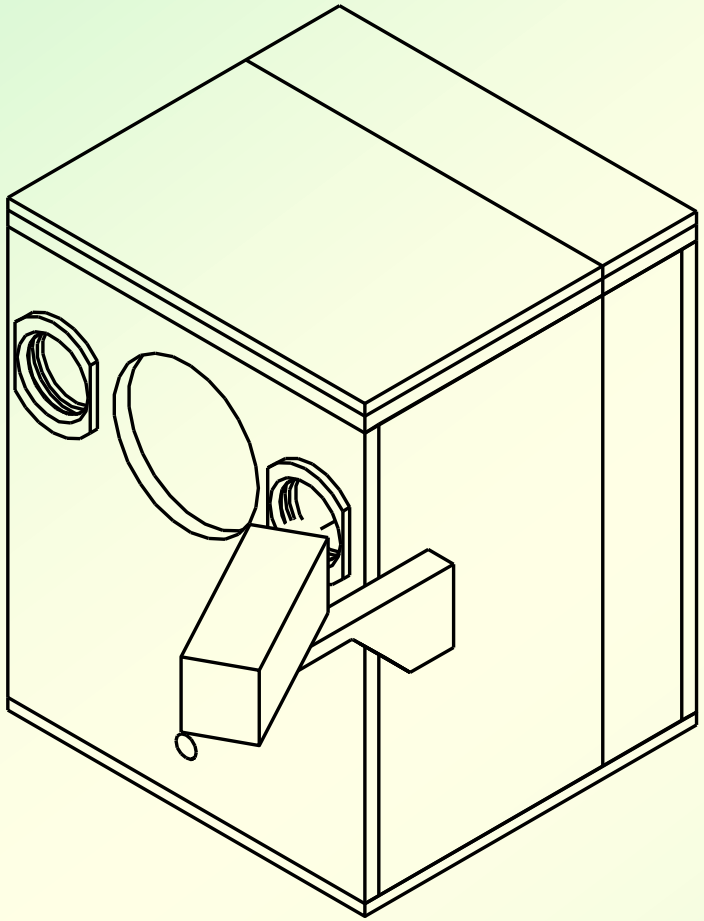
For SFD
150x40x50 mm (WxLxH)
Soft iron yoke
Weight 1 kg
Poles Nd-Fe-B
Pole size
70x40x5 mm (WxLxH)
Gap 30 mm
B=0.27 T
BL=0.01 Tm
Precision <0.5%
3 GeV/c - 1 mrad
SFD +-2.35 mm
550 mm from target
Beam sect. 20x20 mm
Clearance for p 30 mm
Rectractable

Shield (2006)

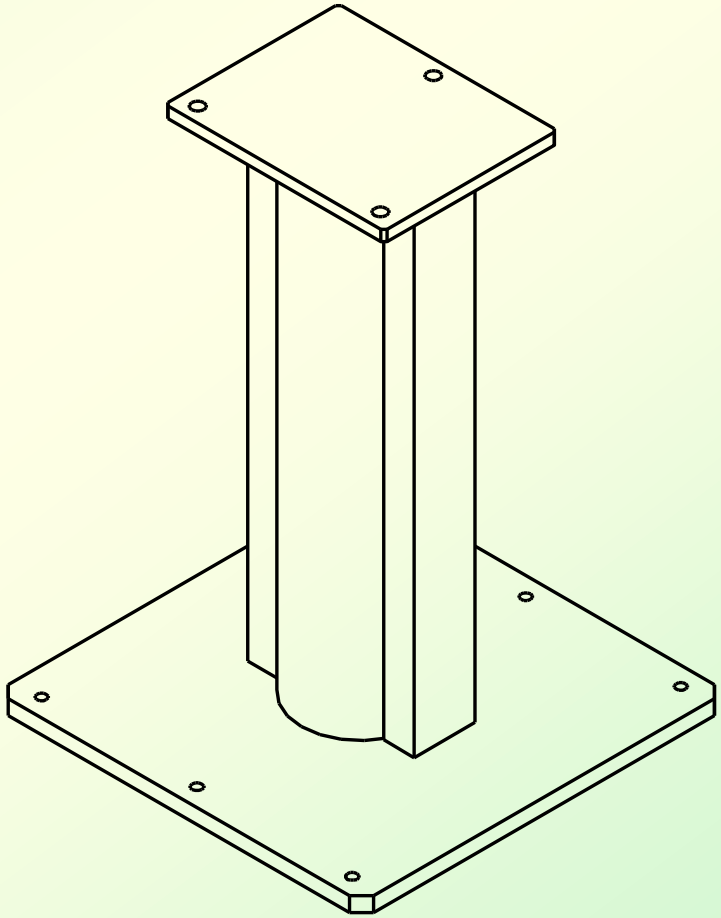


1.4x2.4x1.0 m3 (WxHxL)

Target station and support (1998)

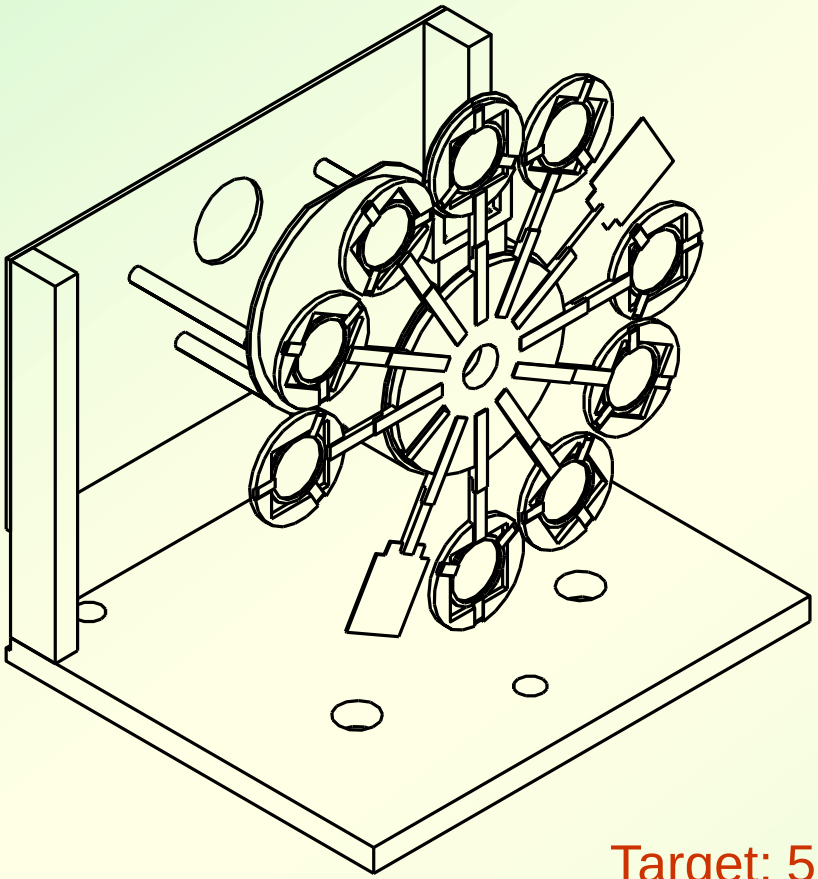


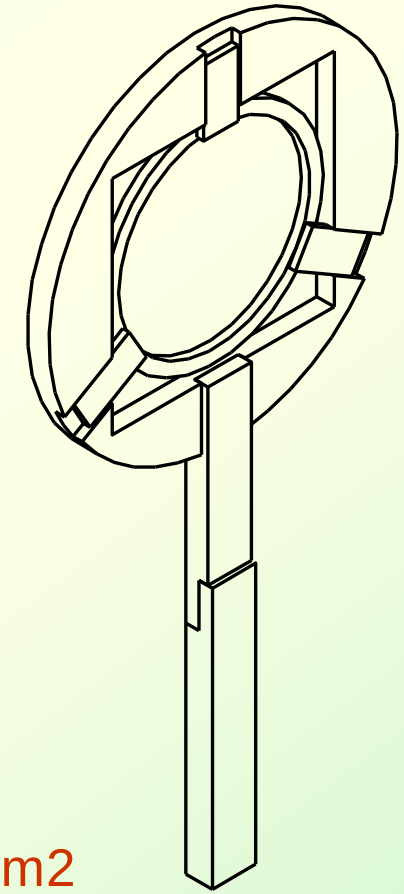
50x61x46 cm3 (WxHxL)



H=184 cm

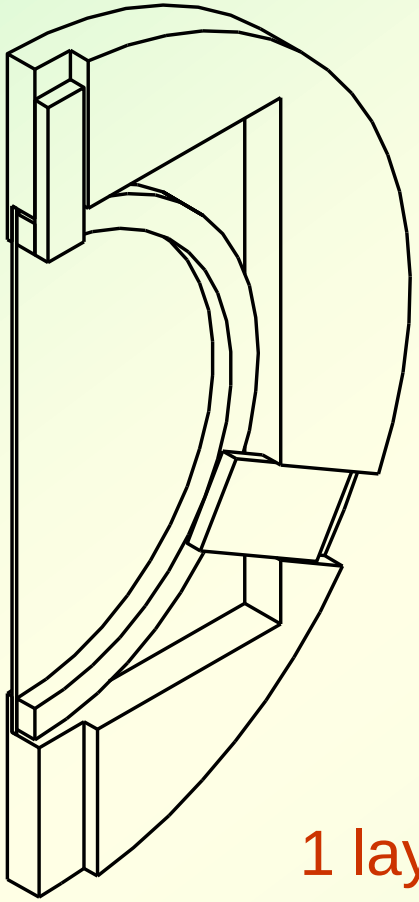
Targets (1998)



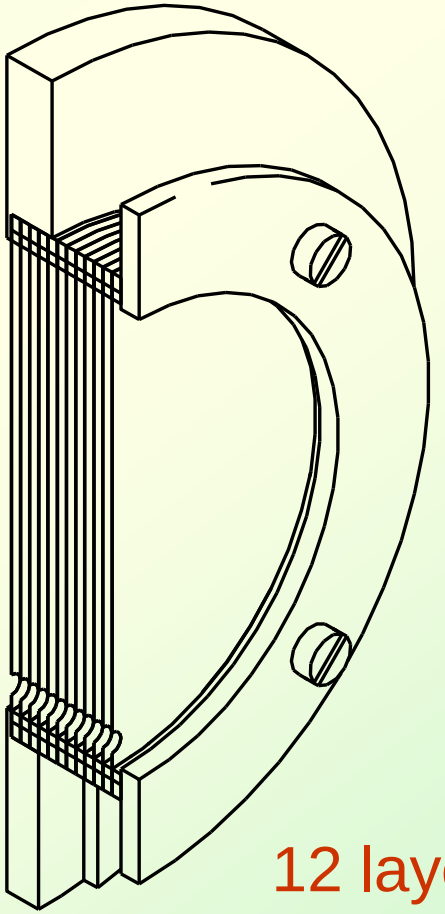


Target: 50x50 mm2

Single (1998) and multilayer (2002) targets

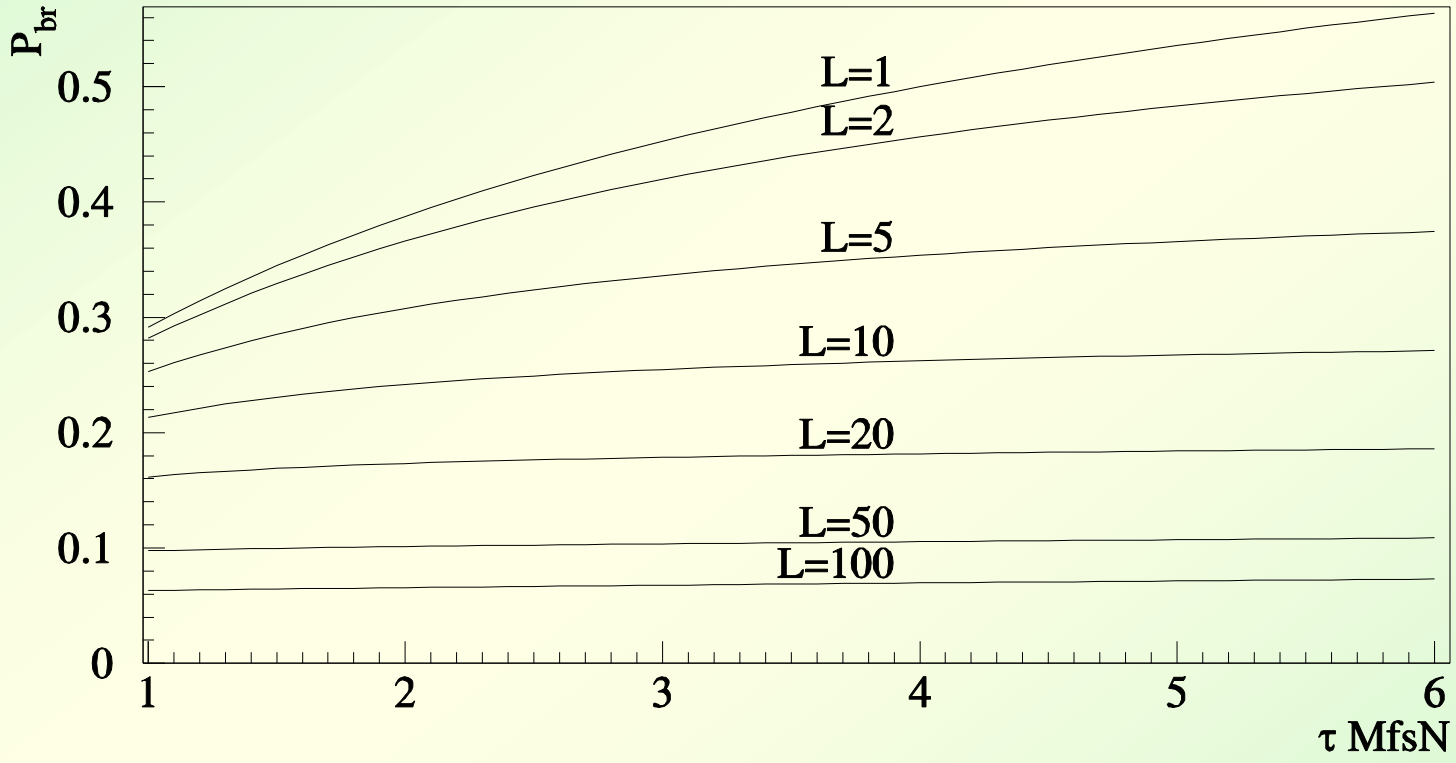


1 layer



12 layers

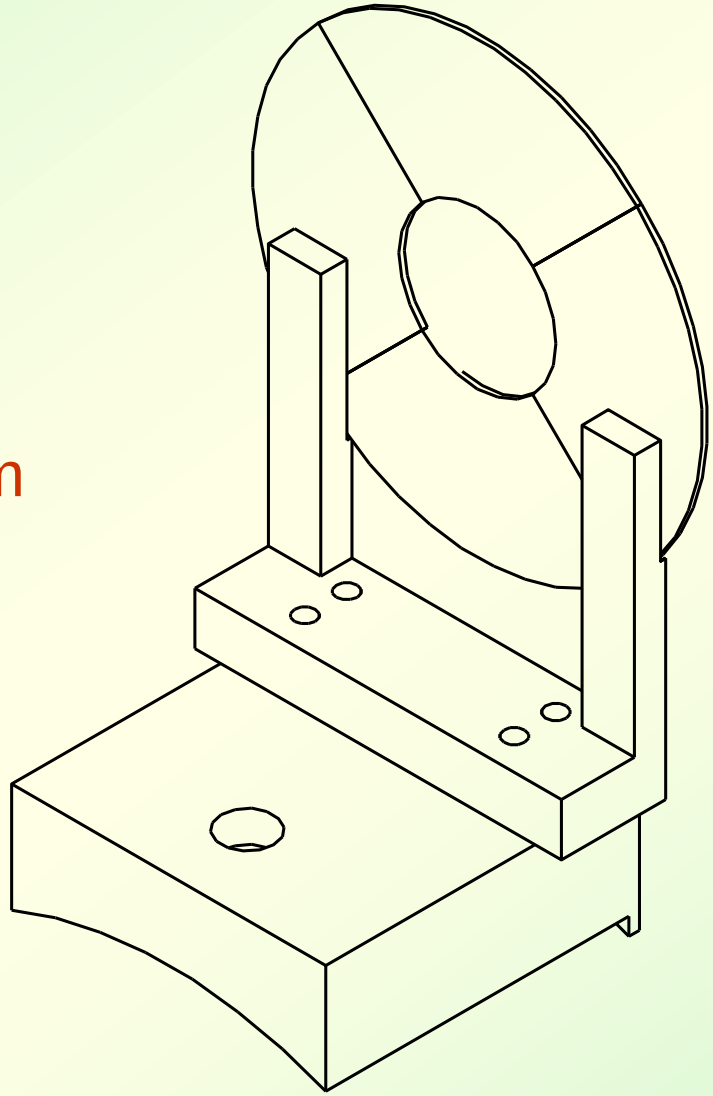
Pbr for single and multilayer targets



Probability of A2pi breakup in Ni targets consisting of layers with 1 mm gaps and total thickness of 100 mkm as a function of lifetime.

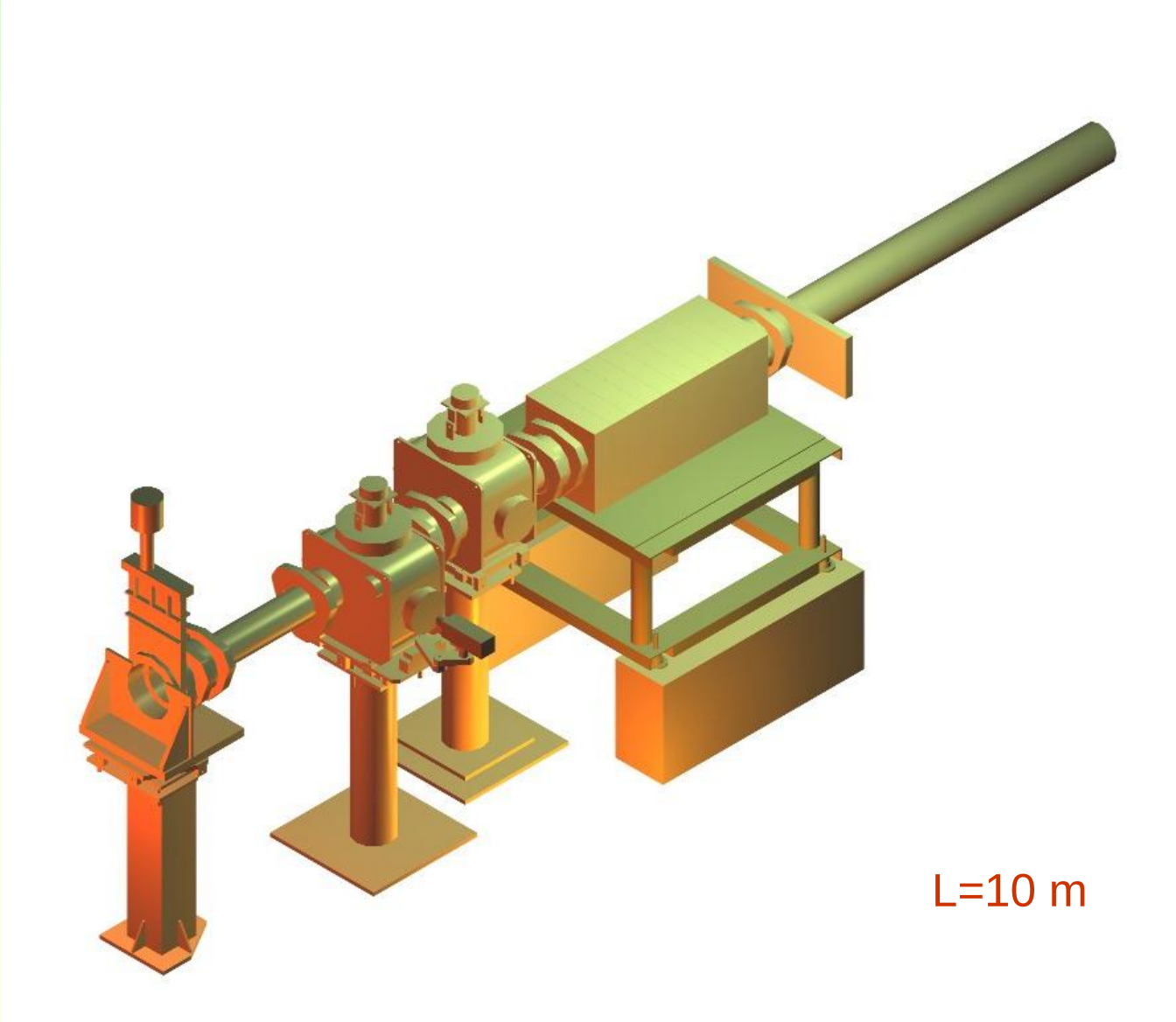
Beam position detector (1998)

Diameters:
30 and 86 mm

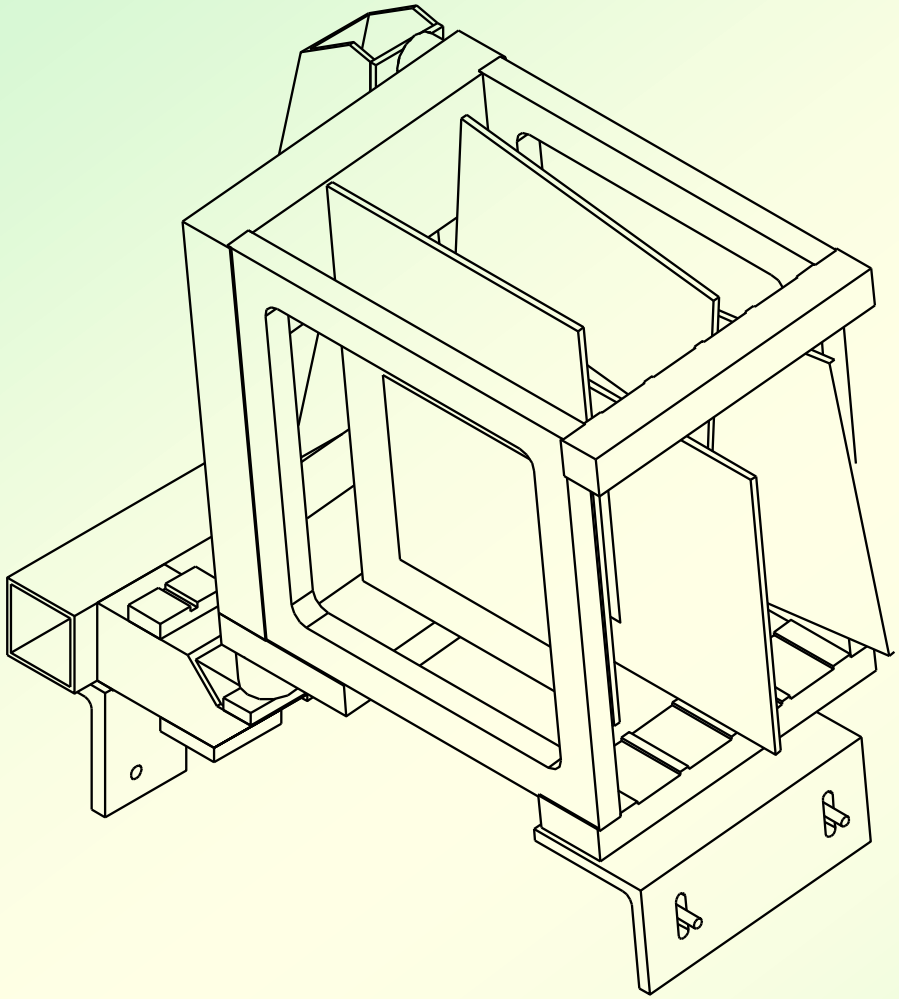


Proton beam line 3 (1998)

Proton beam line 4 (1998)

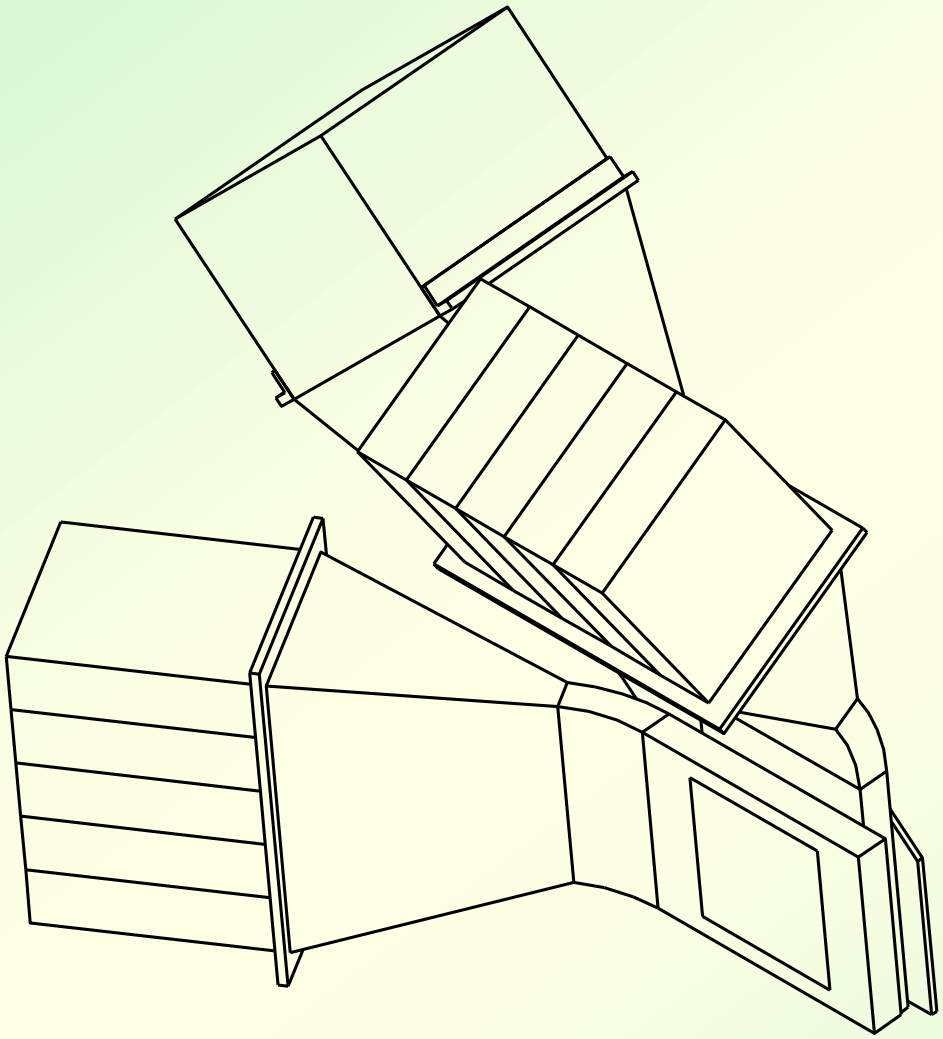


Micro strip gas chambers (1998)



Proportional gas detector
Gas Electron Amplifier (GEM) +
Micro Strip Gas Chambers (MSGC)
Active area 10.24x10.24 cm2
Single-hit resolution 54 mkm
4 planes

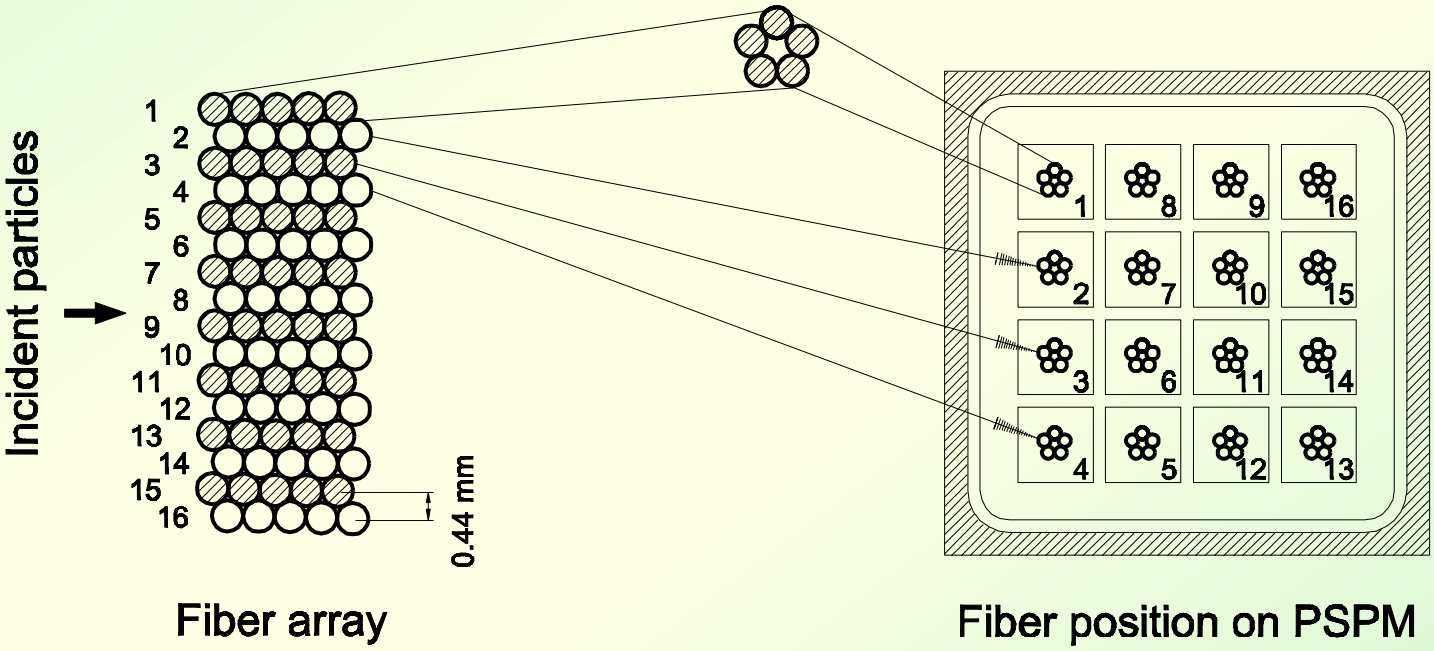
Scintillation fiber detector (1998, 2002)



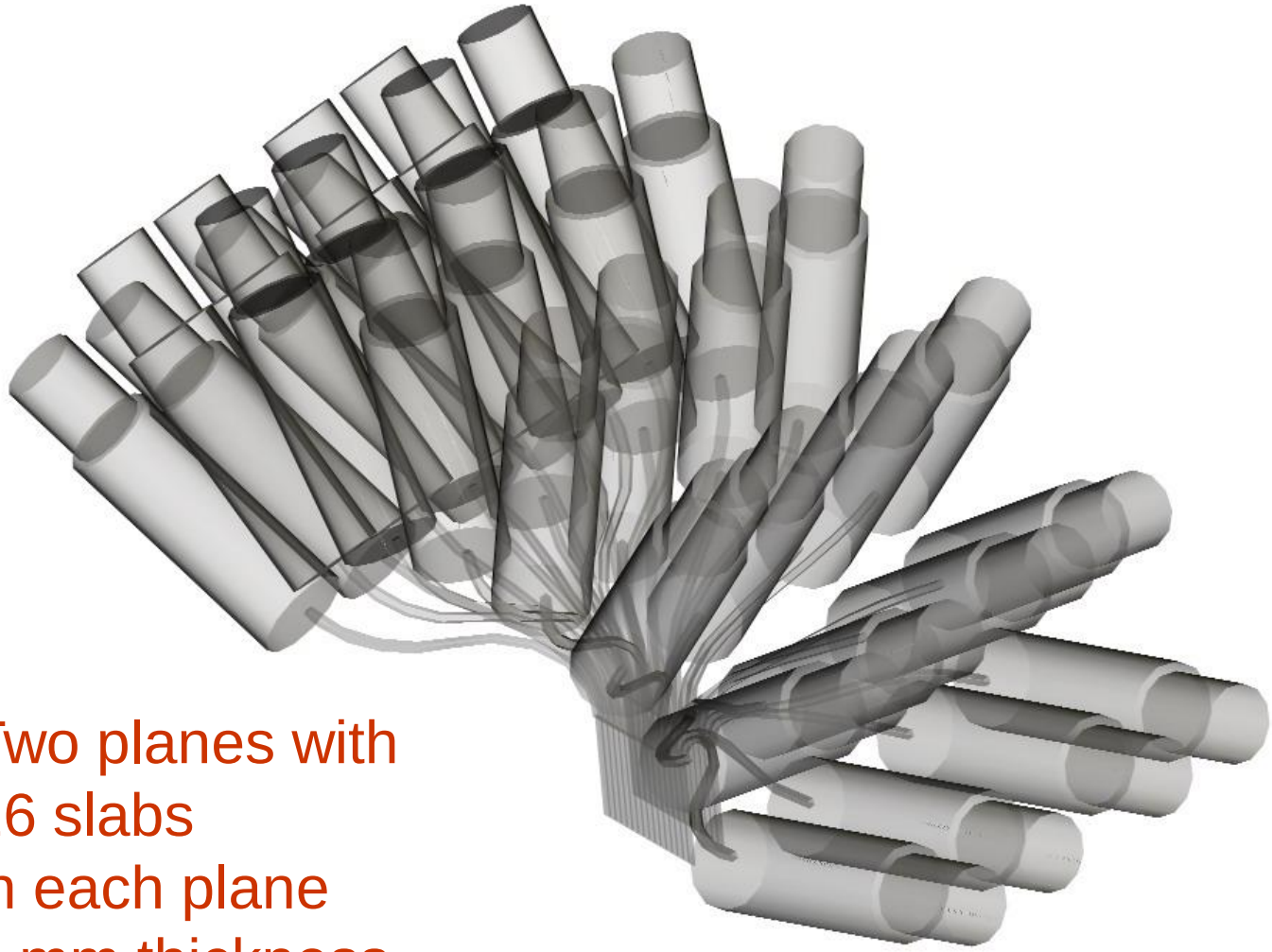
X (Y) plane (1998):
105x105 mm
Fibres KURARAY SCSF38
Fibre diameter 0.50 mm
Fibres in column 5
Columns pitch 0.44 mm
Number of channels 240
15 16-ch Hamamatsu H6568
Rise time 0.7 ns
Light output 6-10 phe
Spatial resolution 127 mkm
Time resolution 0.65 ns

U plane (2002):
Fibres: SCSF78M
Fibre diameter 0.57 mm
Fibres in column 3
Number of channels 320
Number of PSPM 20

Scintillation fiber detector (1998)



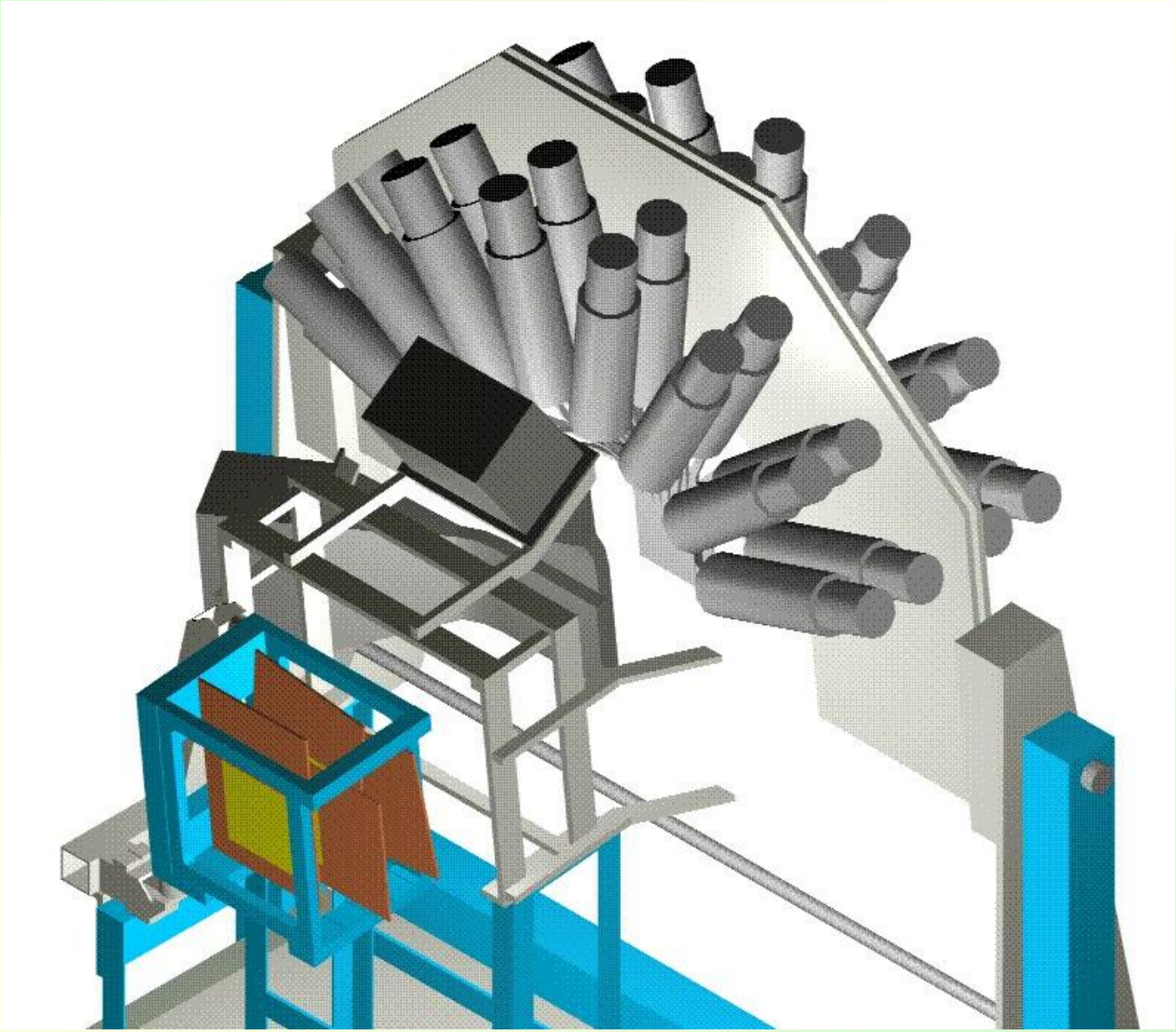
Scintillation ionization detector (1998)



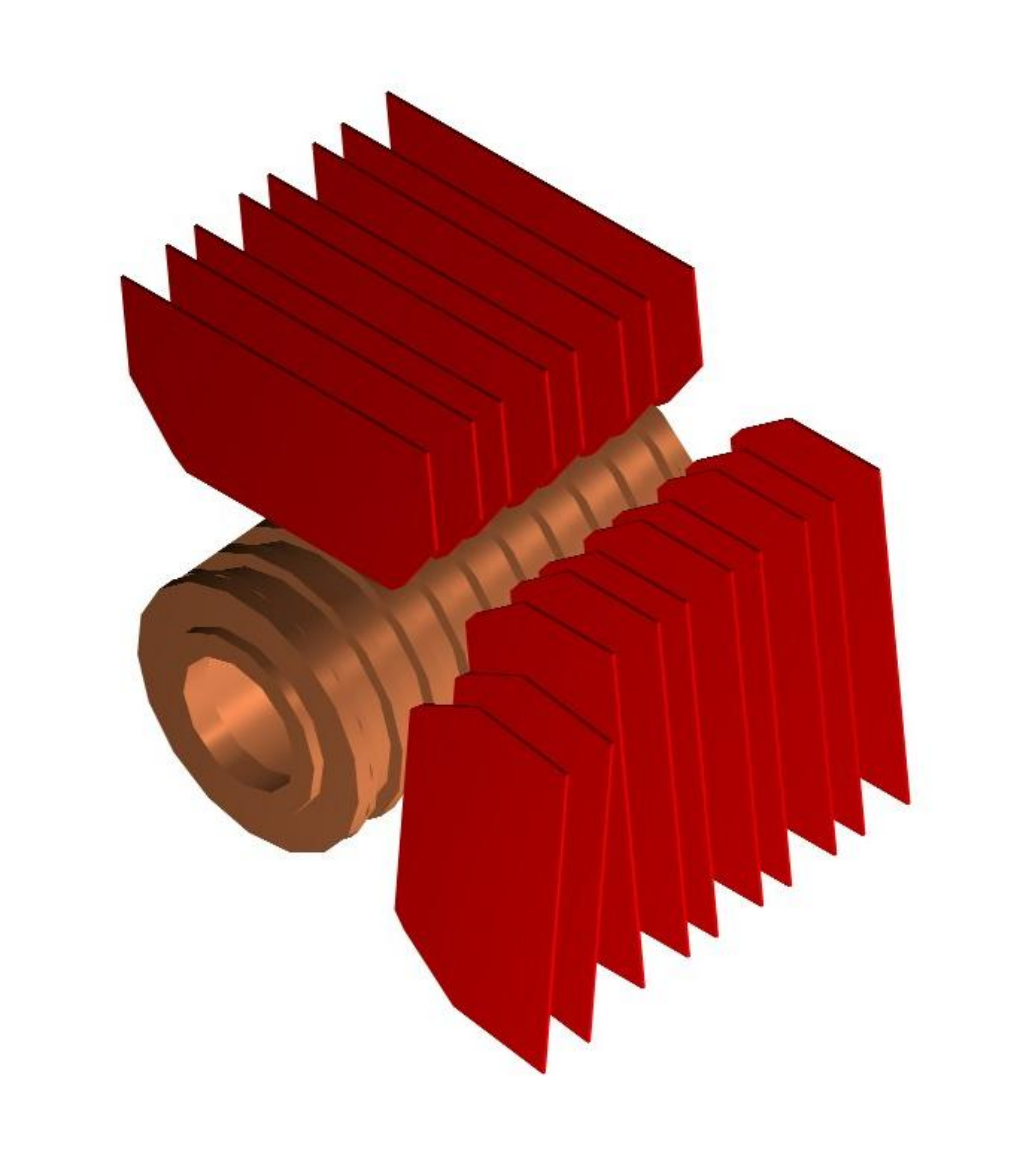
Two planes with
16 slabs
in each plane
2 mm thickness

Upstream detectors MSGC, SFD, IH (1998)

Upstream detectors MSGC, SFD, IH (1998)

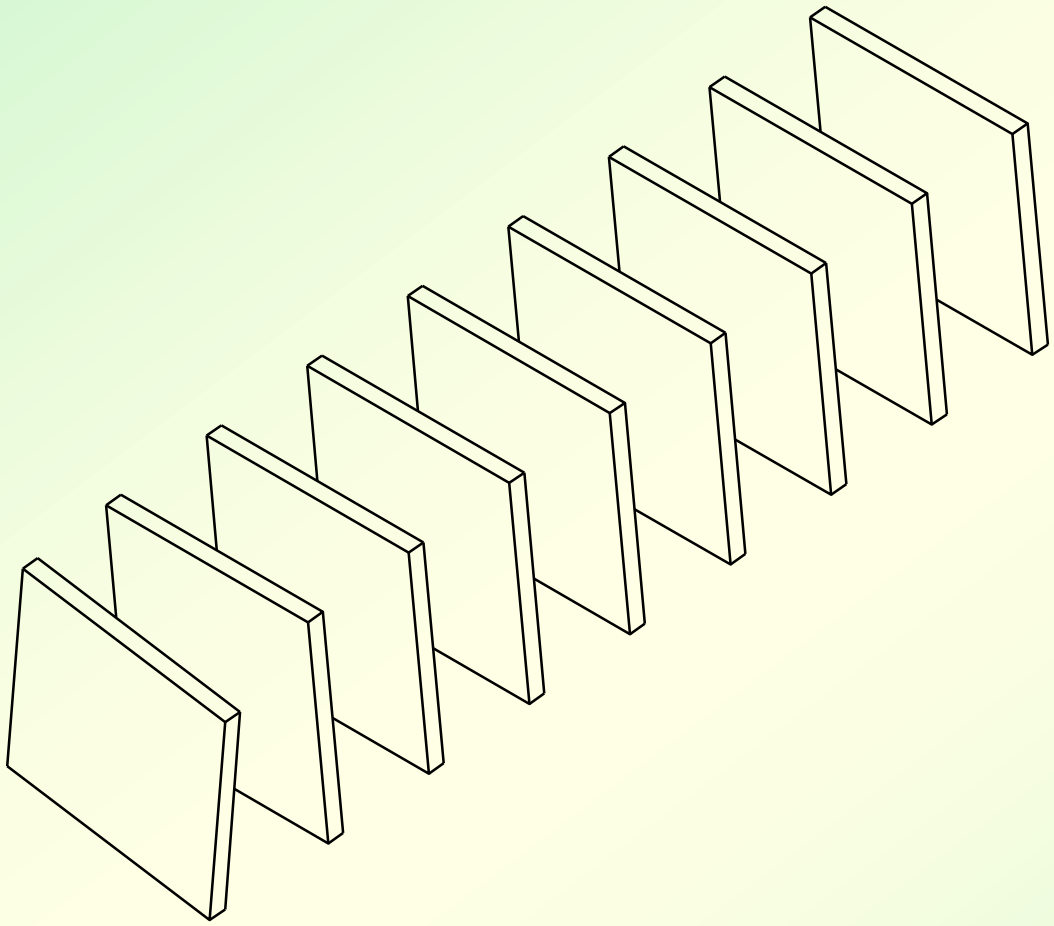


Micro drift chambers (2006)



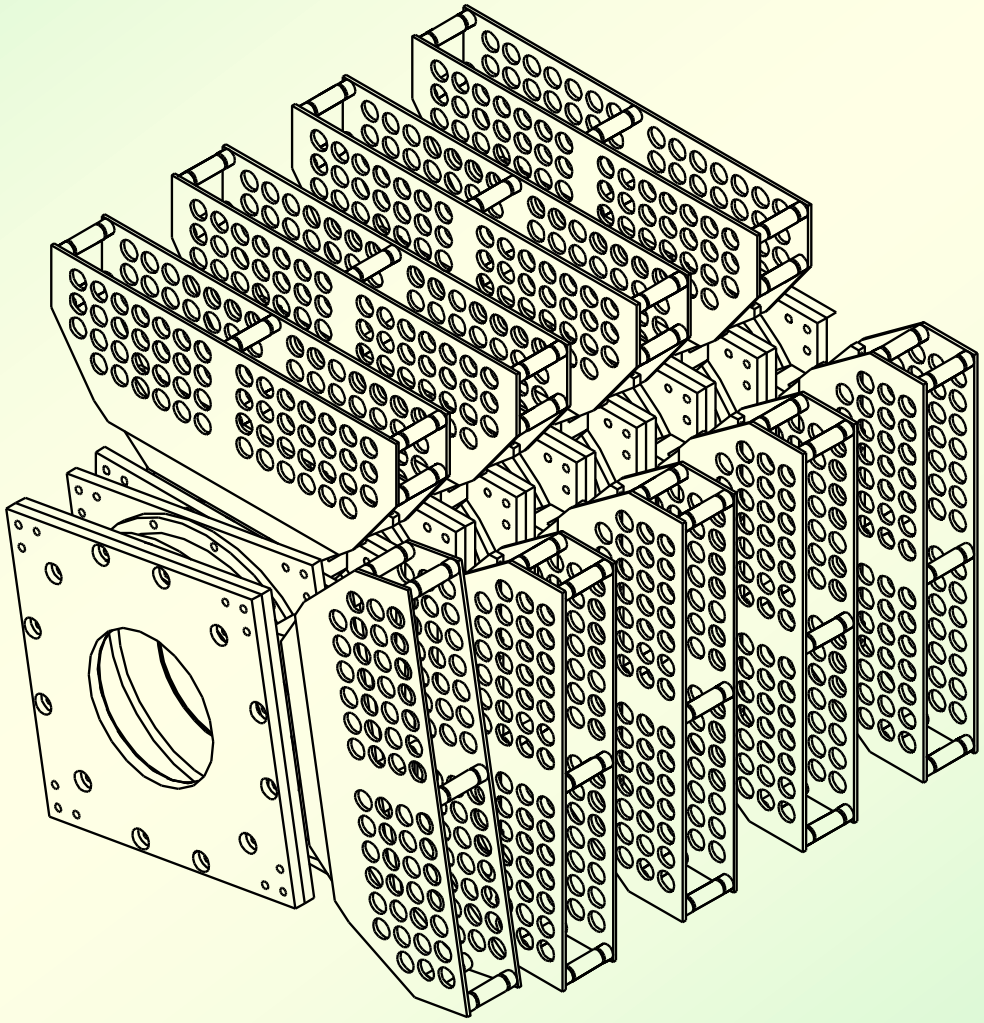
18 planes: X, Y, U
Area: 80x80 mm
Gas mixture: Ar(0.33)+ iC4H10(0.66)+H2O(0.01)
Anode pitch 2.5 mm
32 wires in a plane
Sell size: 2.5x2 mm
Drift time: 26 ns
Time resolution: <1 ns
Space. resol. <80 mkm
2 track resol. <200 mkm
Readout time: <3 mks

Micro drift chambers (2006)

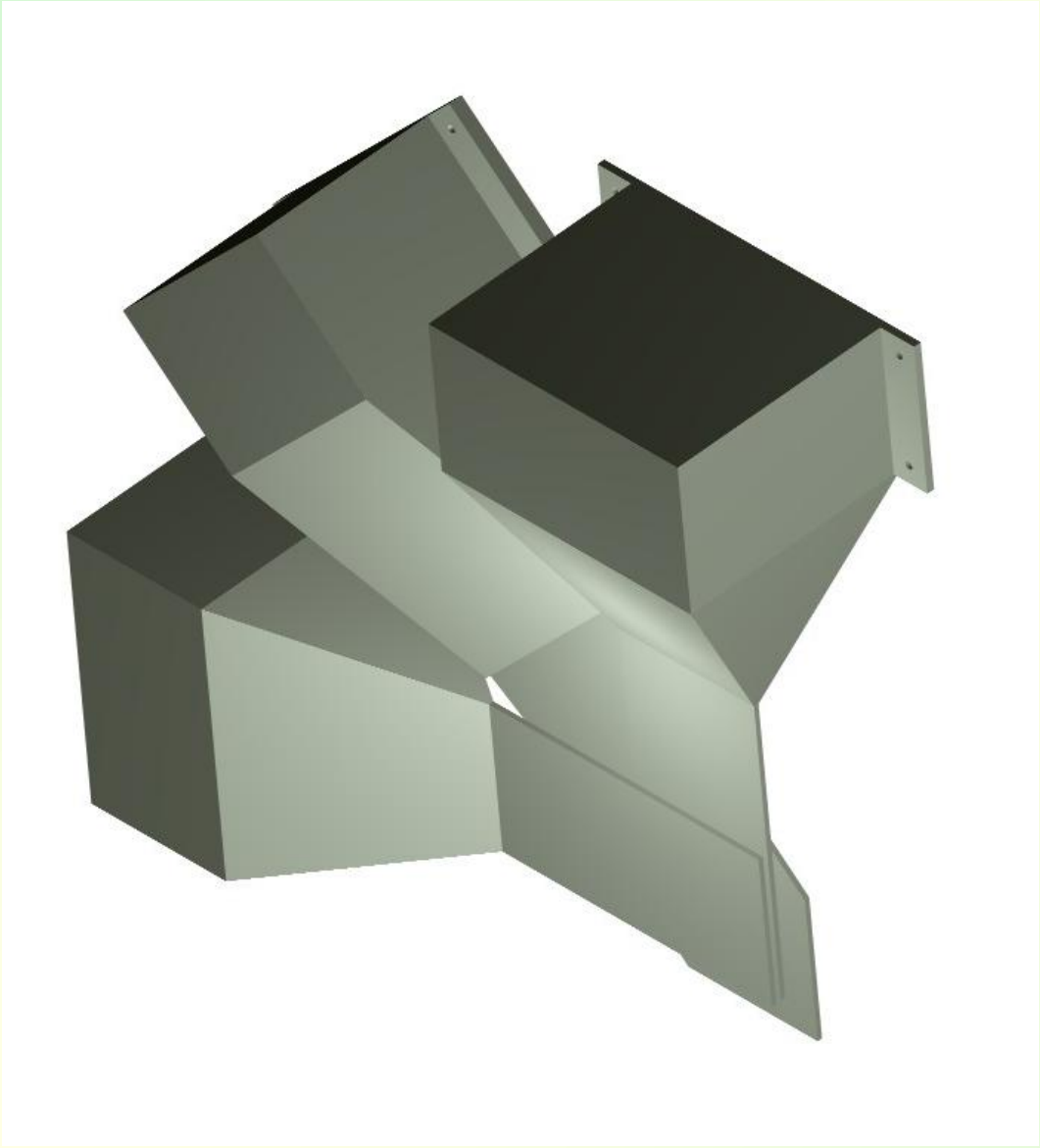


Base 325 mm
Each of 9 modules consists of two planes (XX, YY, UU)
U planes: 10 degrees
Two planes in a module are displaced by half of pitch
for two close track resolution

Micro drift chambers (proposal)

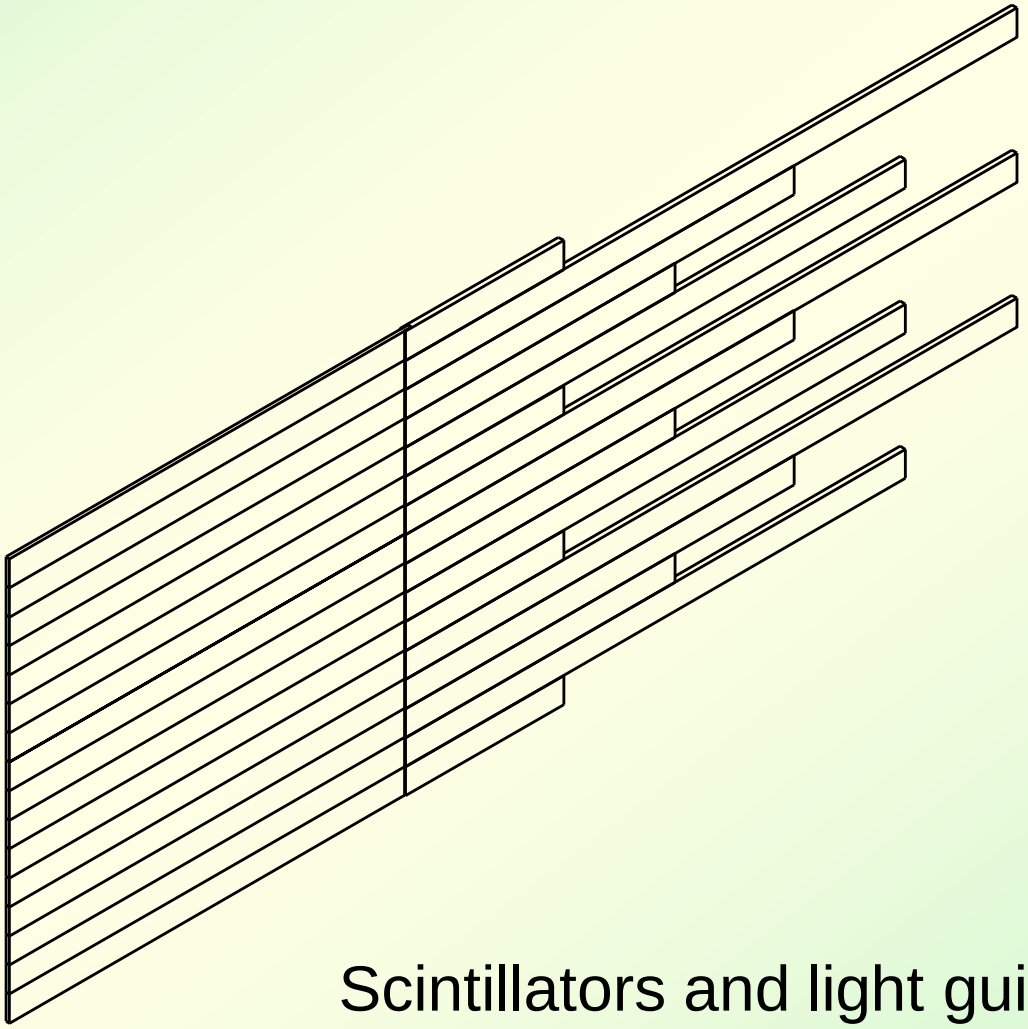


Scintillation fiber detector (2002, 2006)



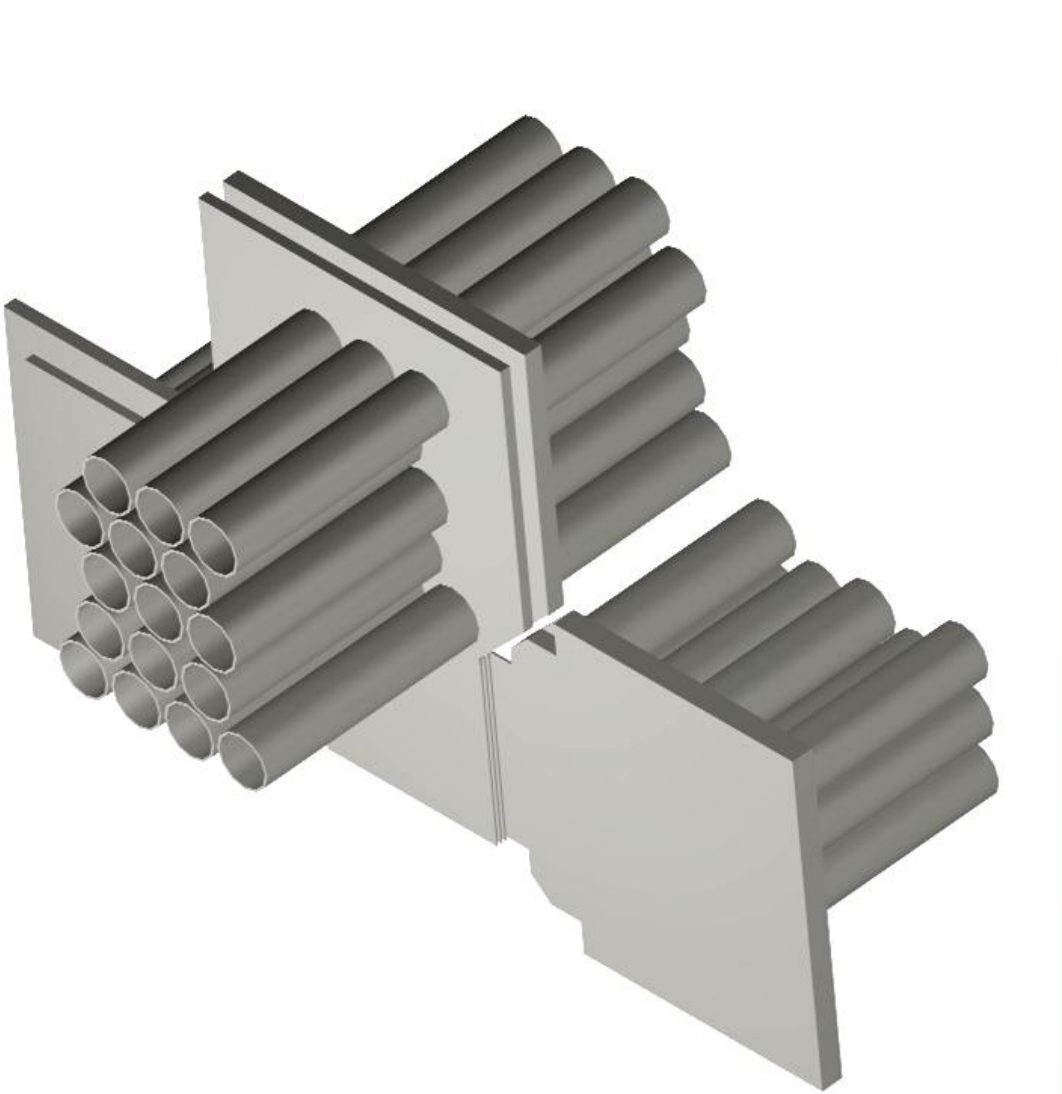
Plane X (Y) (2006)
Area 98.5×107 mm
Thickn. (one plane) 3.1 mm
480 columns
8 fibres in a column
Fibre diameter 0.5 mm
Column pitch 0.205 mm
30 16 ch H6568 per plane
Light output 11 p.e.
Time resolution 0.46 ns
Space resol. $\sigma \approx 60$ μm
New electronics
ADC-TDC for 960 channels
Plane U (2002)

Scintillation ionization detector (2001)



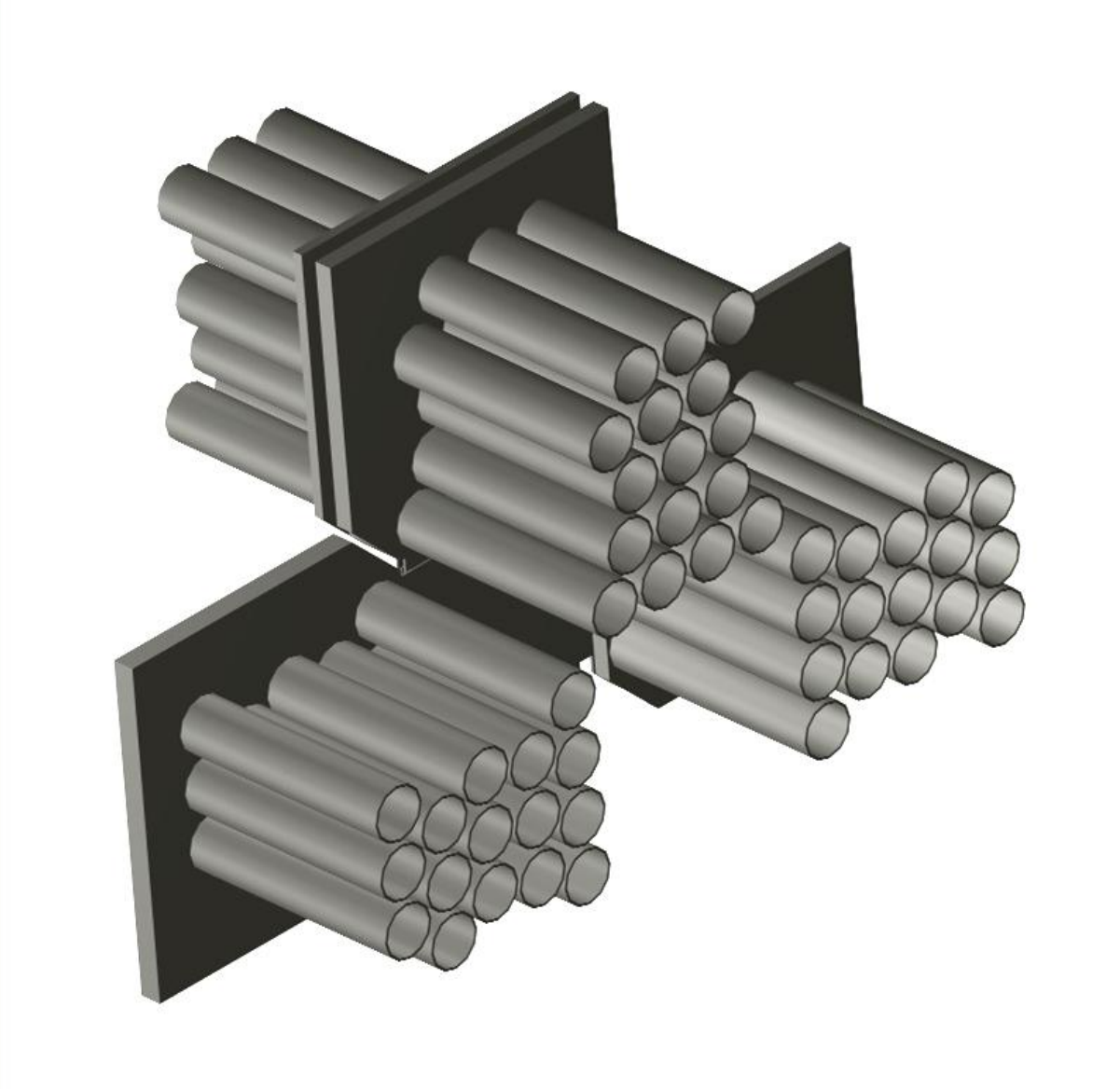
Scintillators and light guides

Scintillation ionization detector (2001)

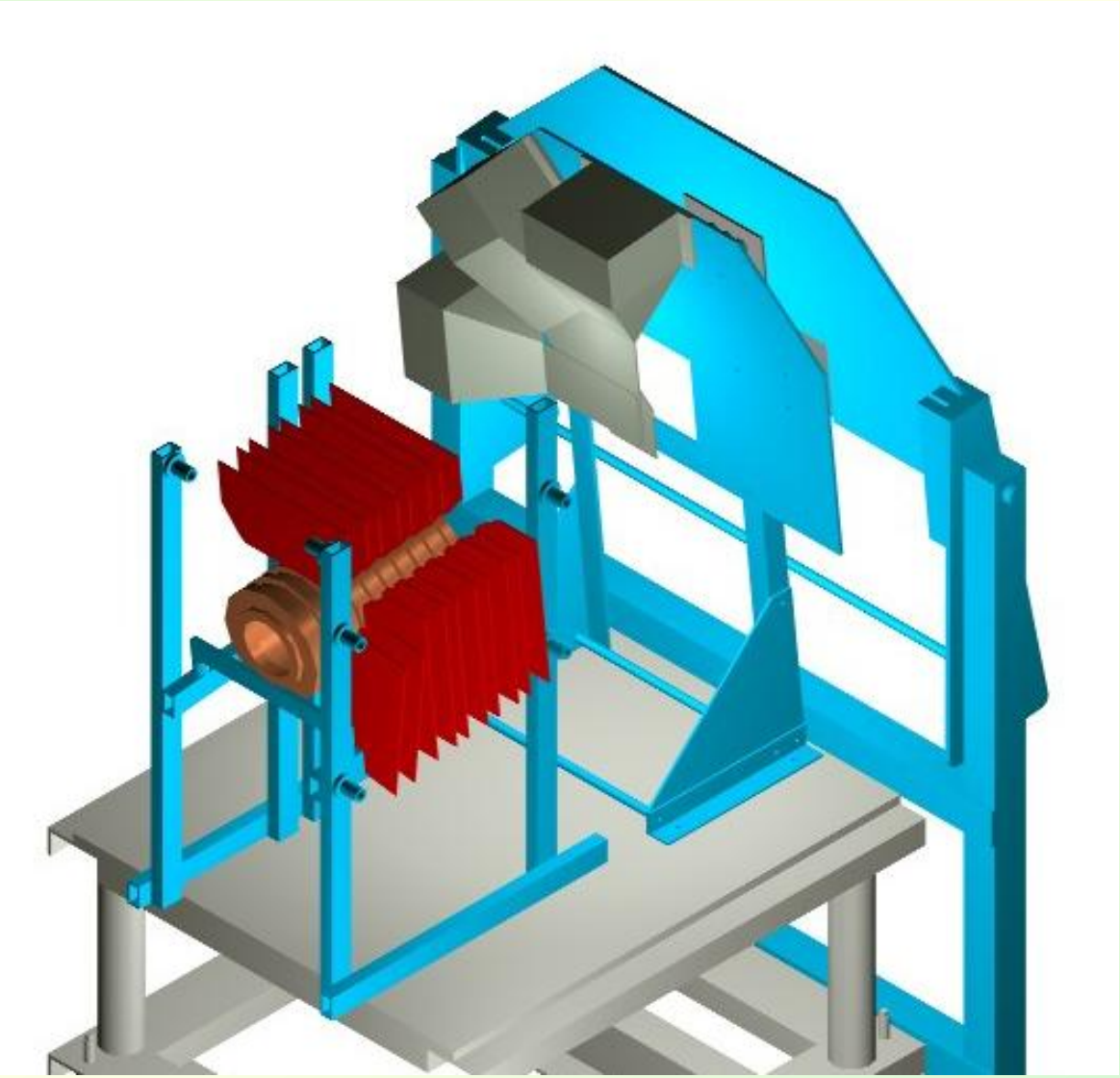


4 planes 11x11 cm
X-A, Y-A, X-B, Y-B
Slabs 11x7x1 mm
Scintillator BC-408
Light guides 2x7 mm
Millipore film
30 mkm Al mylar
Gap 70 mkm
FEU-85, 16 units
Contact
with wide side of LG
Light increase by 50%.
Time resol. <1 ns
At 90 % of doubles,
singles <15%.

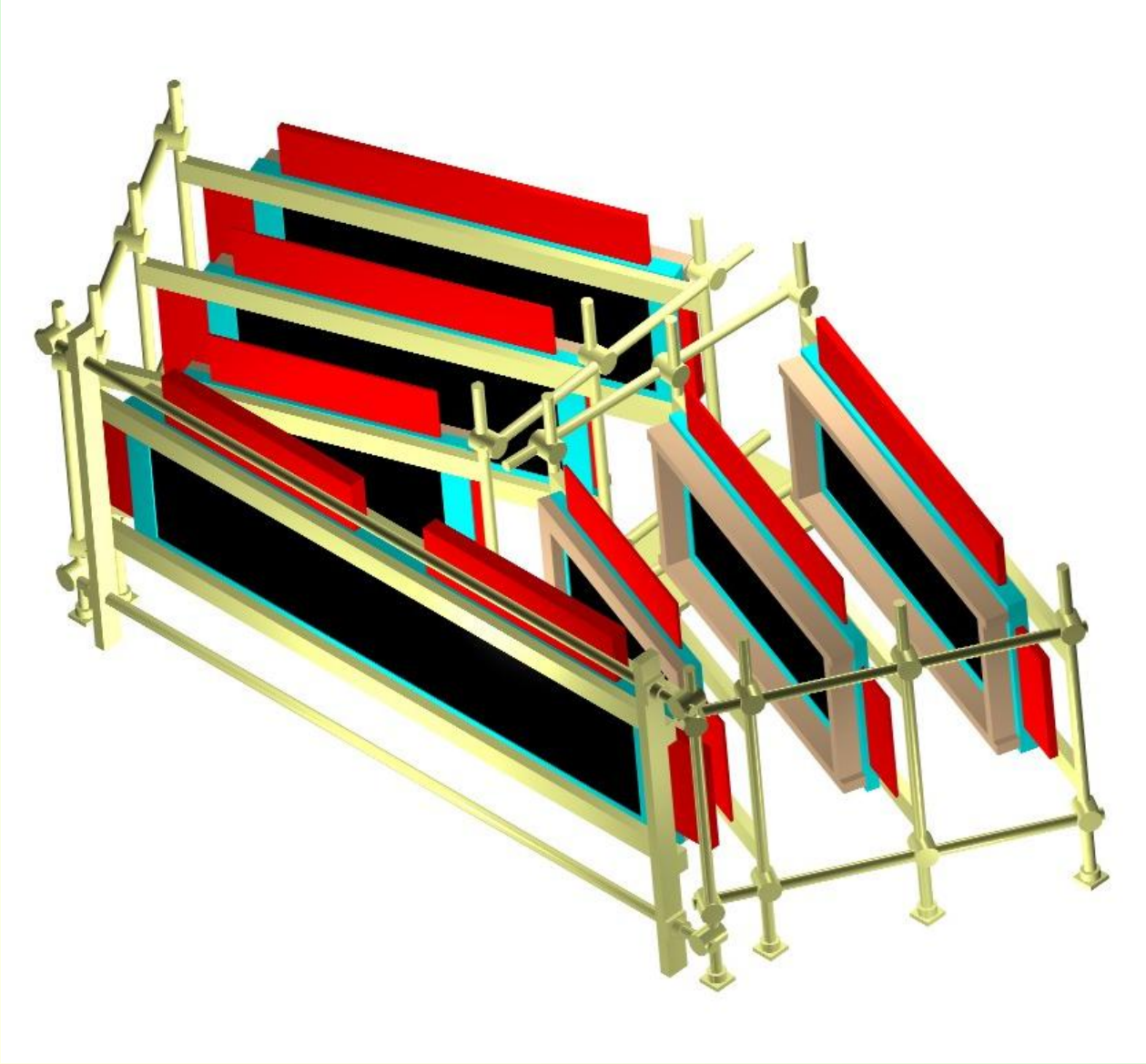
Scintillation ionization detector (2001)



Upstream detectors MDC, SFD, IH (2006)

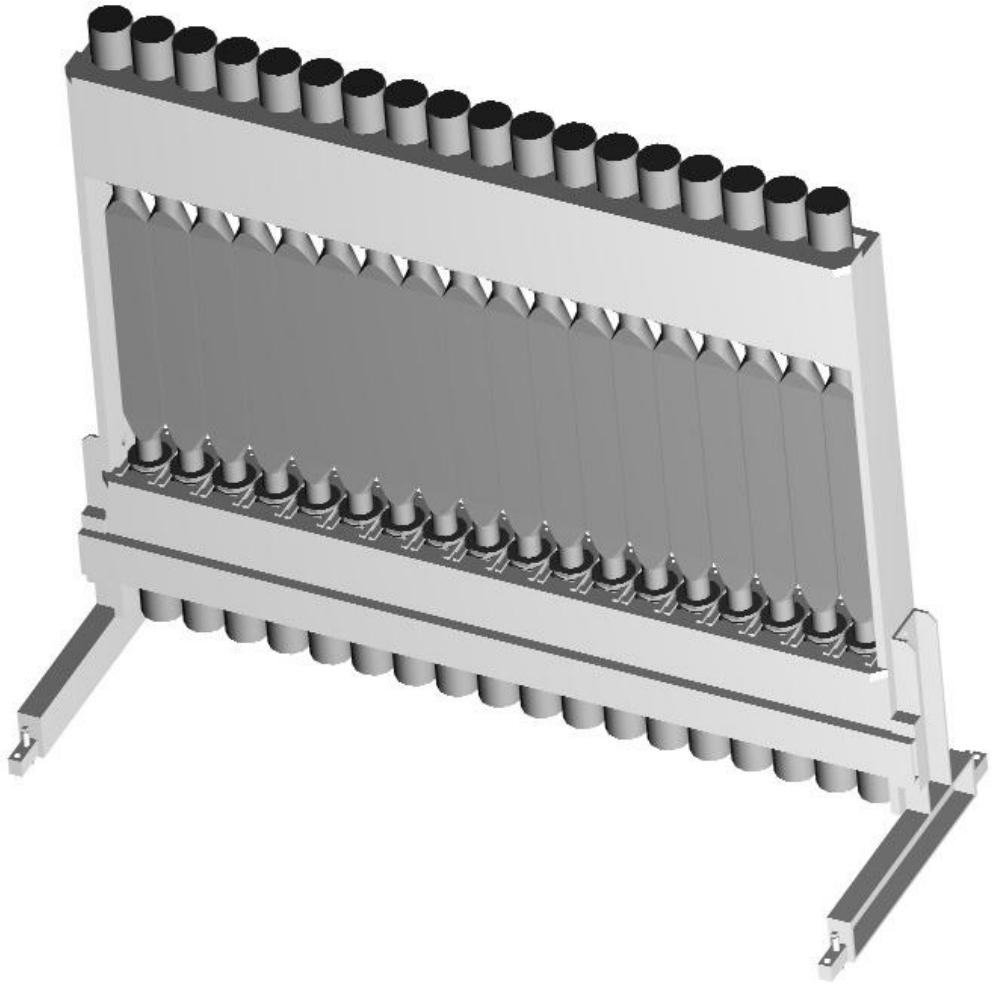


Drift chambers (1998)



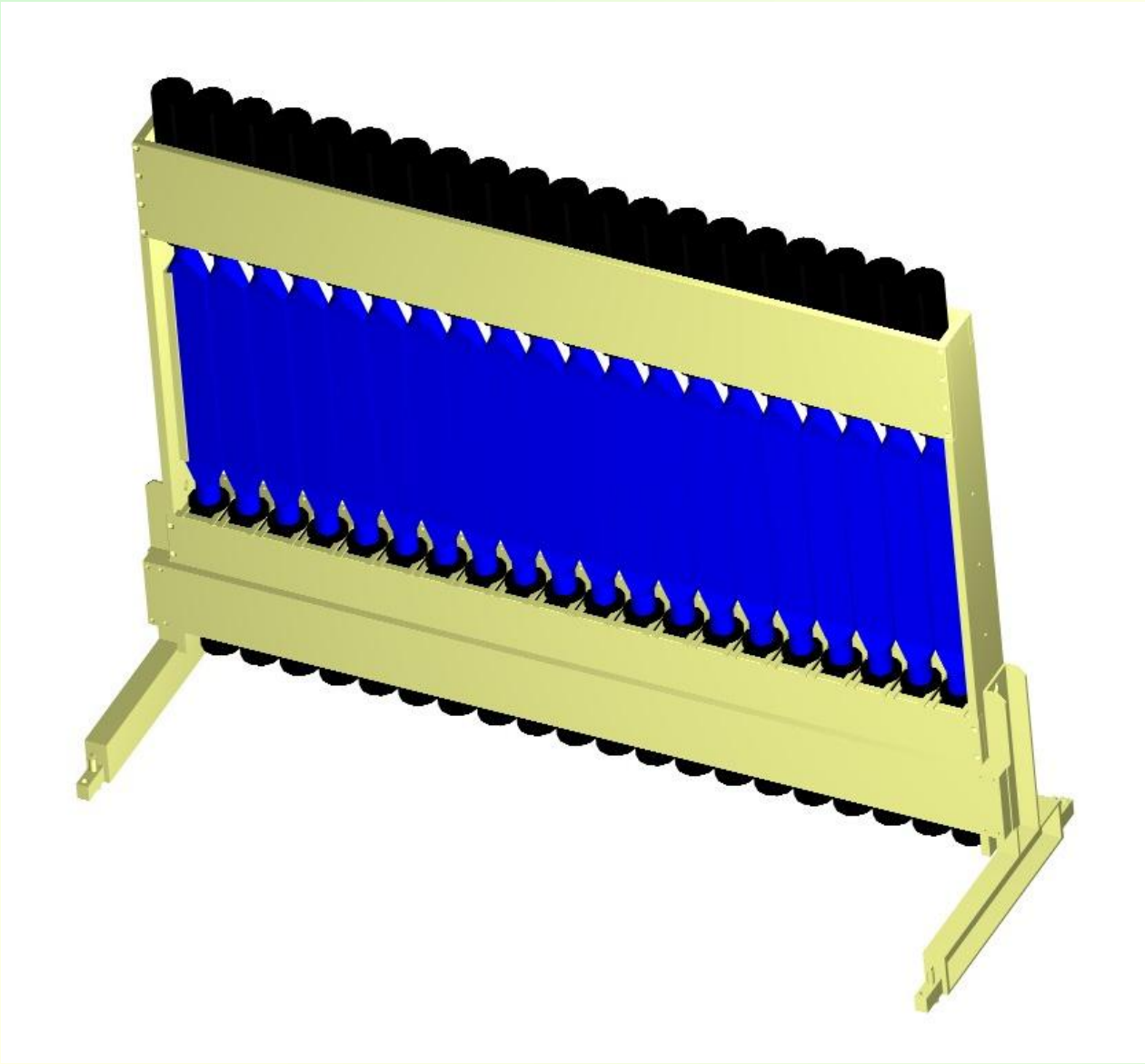
DC1: 2x80x40 cm
X,Y,W,X,Y,W. 800 ch
DC2: X,Y, 80x40 cm
DC3: X,Y, 112x40 cm
DC4: X,Y,X,Y,
128x40 cm
Both arms: 1216 ch
Anode pitch: 10 mm
Cell: 10x10 mm
Cathode: 20 mkm
carbon-coated mylar
Anode wires: 50 mkm
copper-beryllium alloy
Drift velocity: 50 mkm
Amplitude: 1 mA
Pulse width: 20 ns
Resolution 90 mkm

Vertical hodoscope (1998)



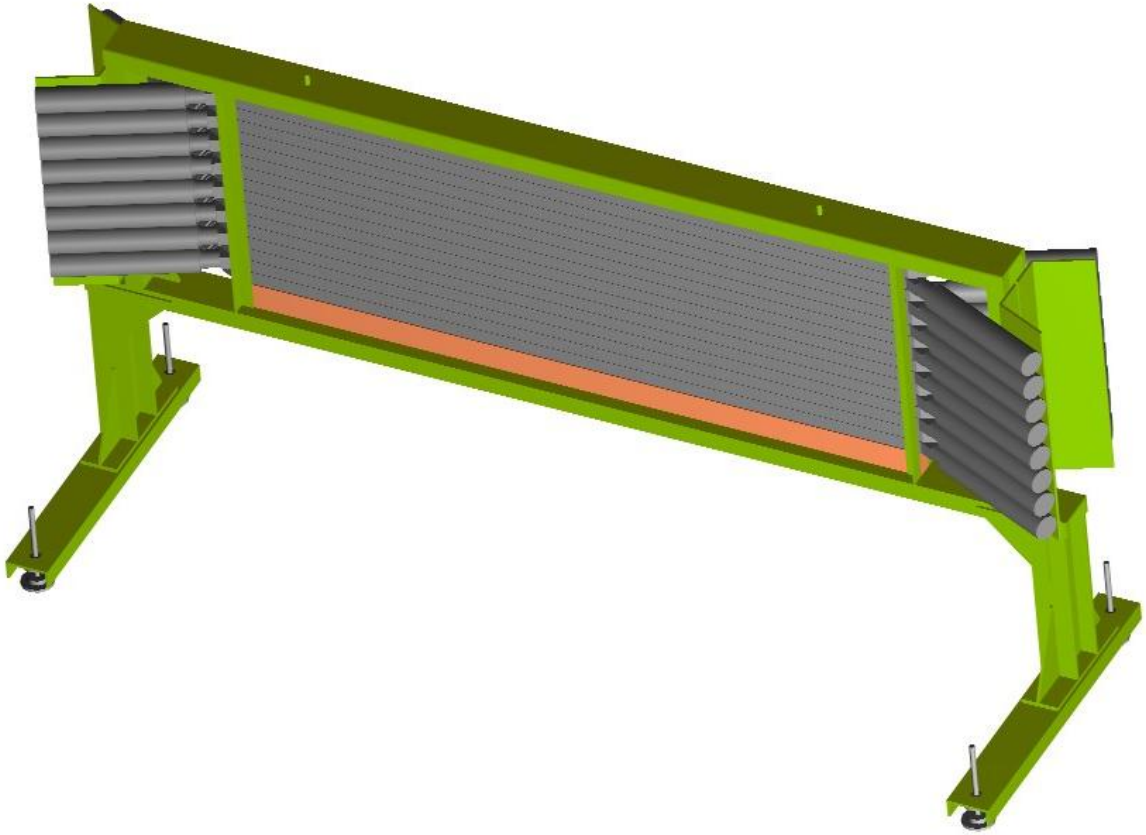
Area: 130x40 cm
18 slabs: 40x7x2.2 cm
BICRON BC420
Two Hamamatsu
R1828-01
Least count: 62 ps
Time resolution 174 ps (2)
Time resolution 127 ps (1)

Vertical hodoscope (2006)



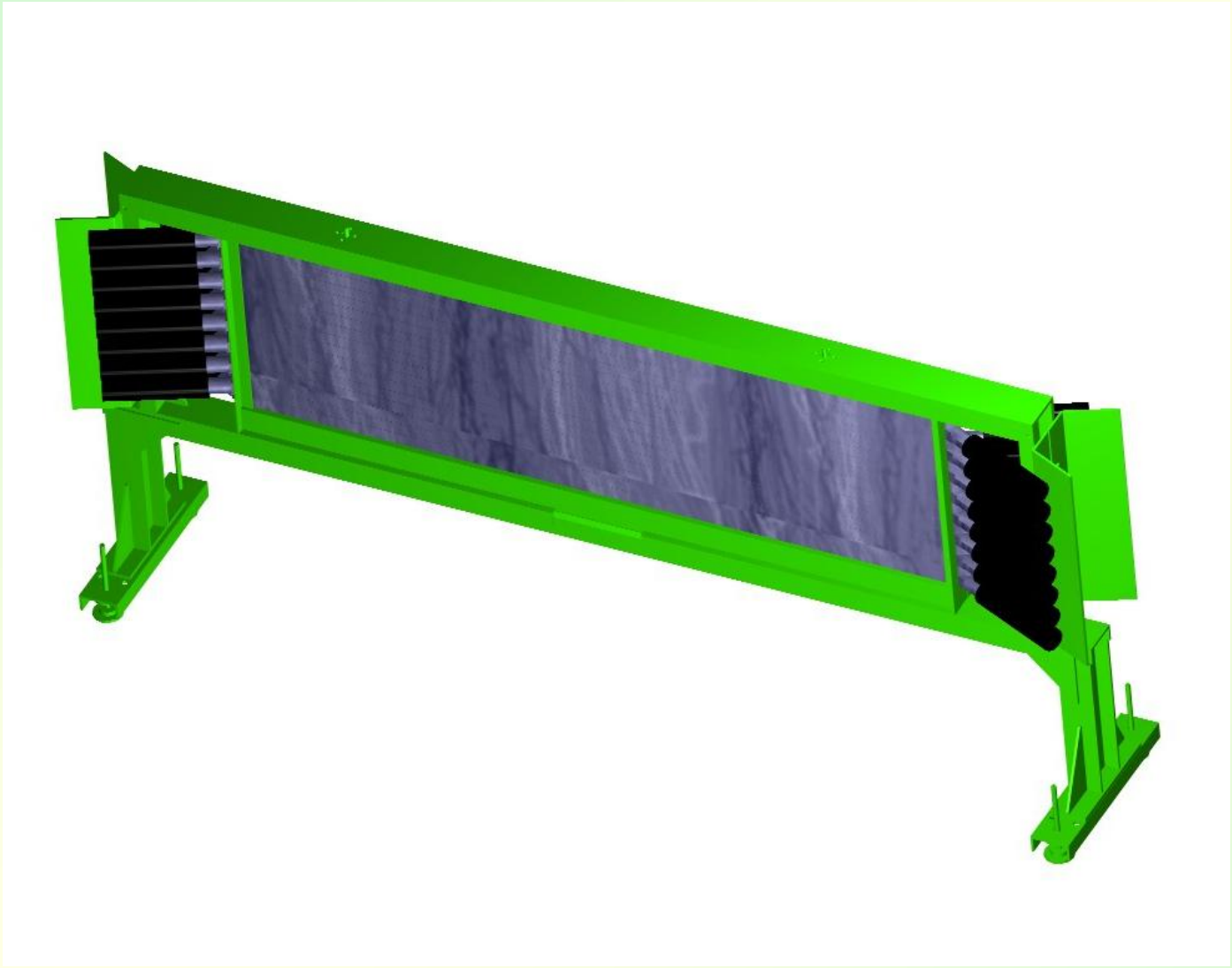
Area 144x40 cm
20 slabs 40x7x2.2 cm
BICRON BC420
Two Hamamatsu
R1828-01
Time resol. 153 ps (2)
Time resol. 108 ps (1)

Horizontal hodoscope (1998)



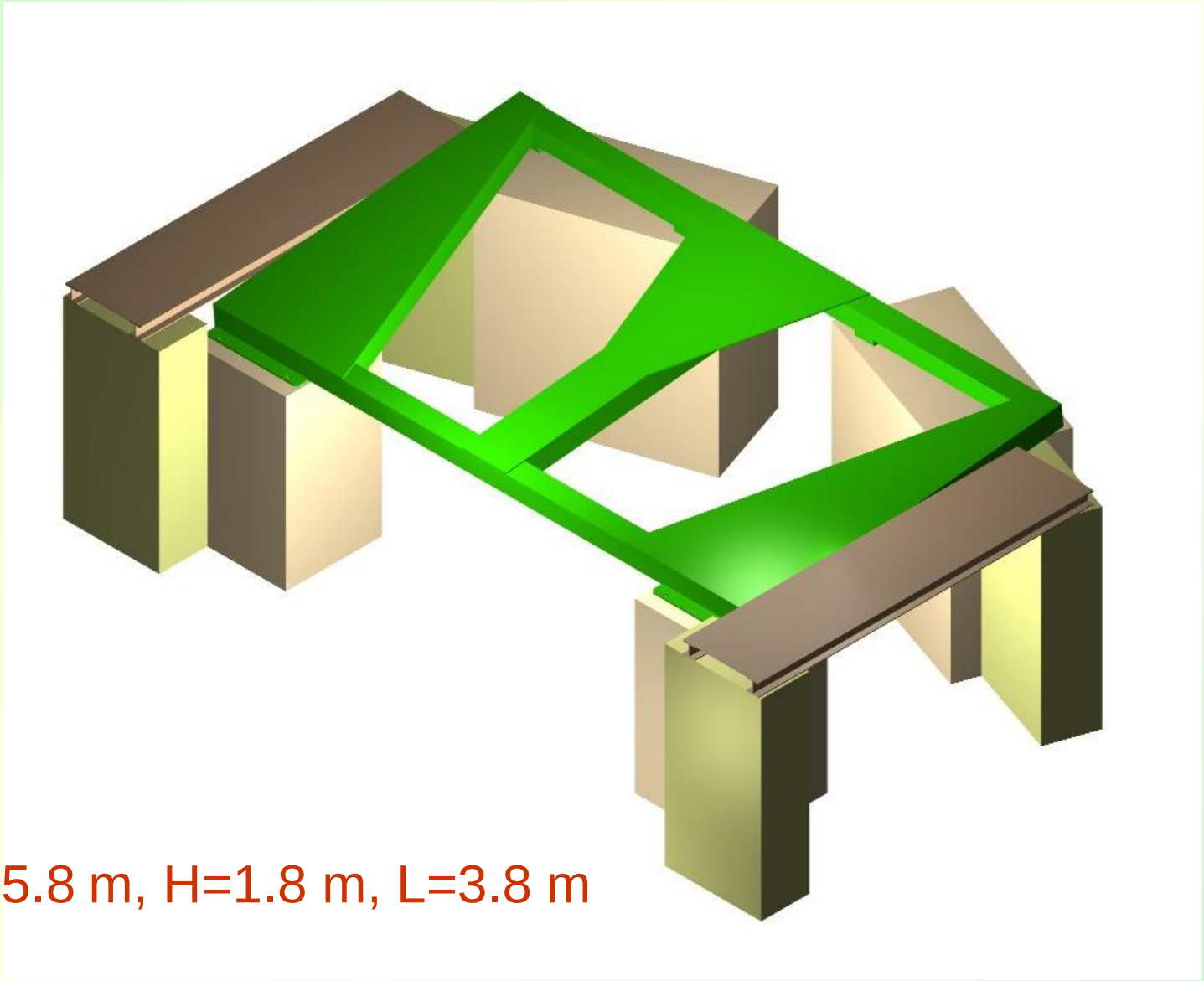
Area: 130x40 cm
16 slabs
130x2.5x2.5 cm
Philips XP2008
Time resolution
320 ps
Coplanarity criterion

Horizontal hodoscope (2006)



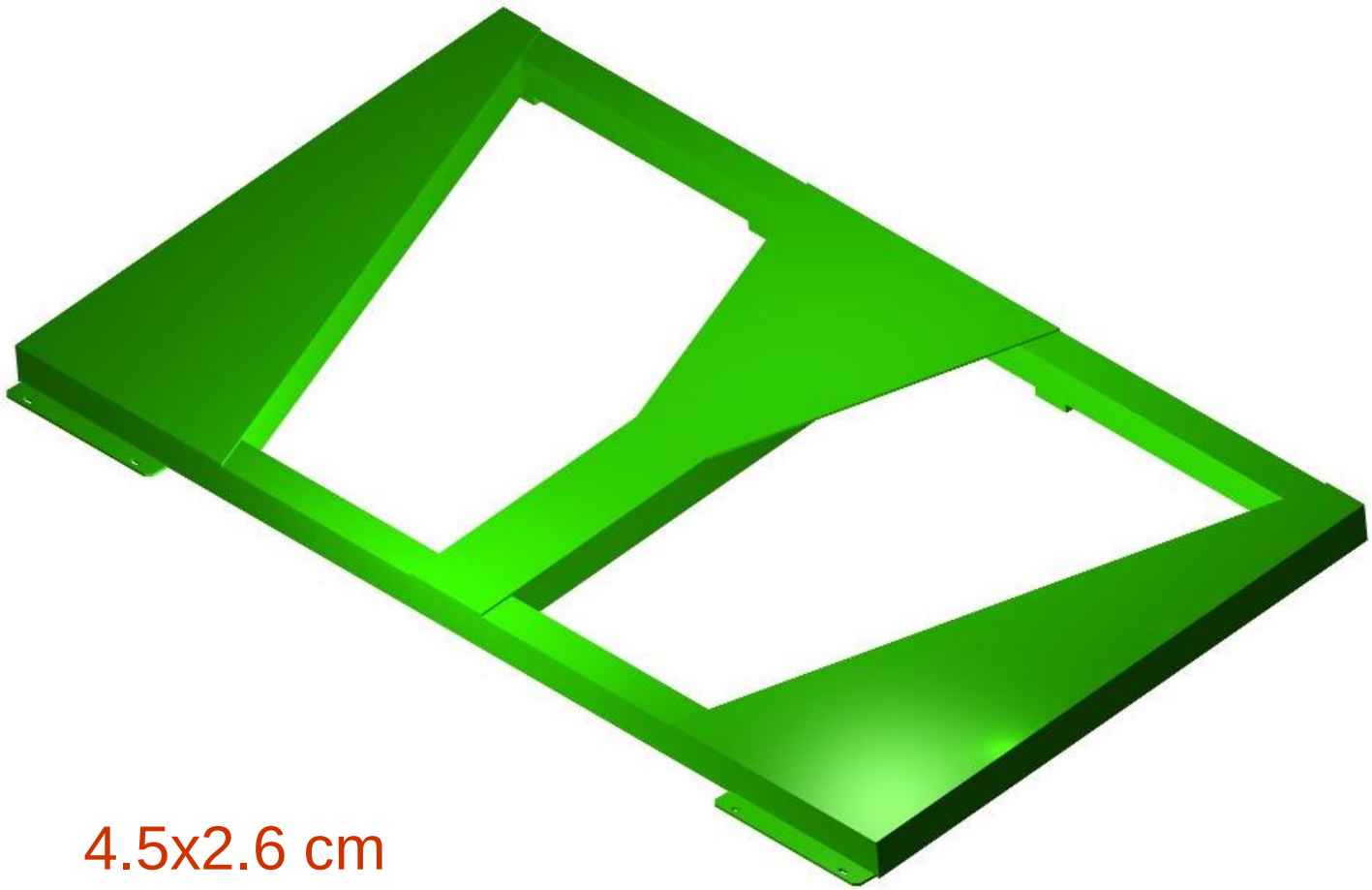
Area 150x40 cm
16 slabs
150x2.5x2.5 cm
Philips XP2008
Time resolution
330 ps (2)
Time resolution
233 ps (1)

Support for DC, VH, HH (1998)



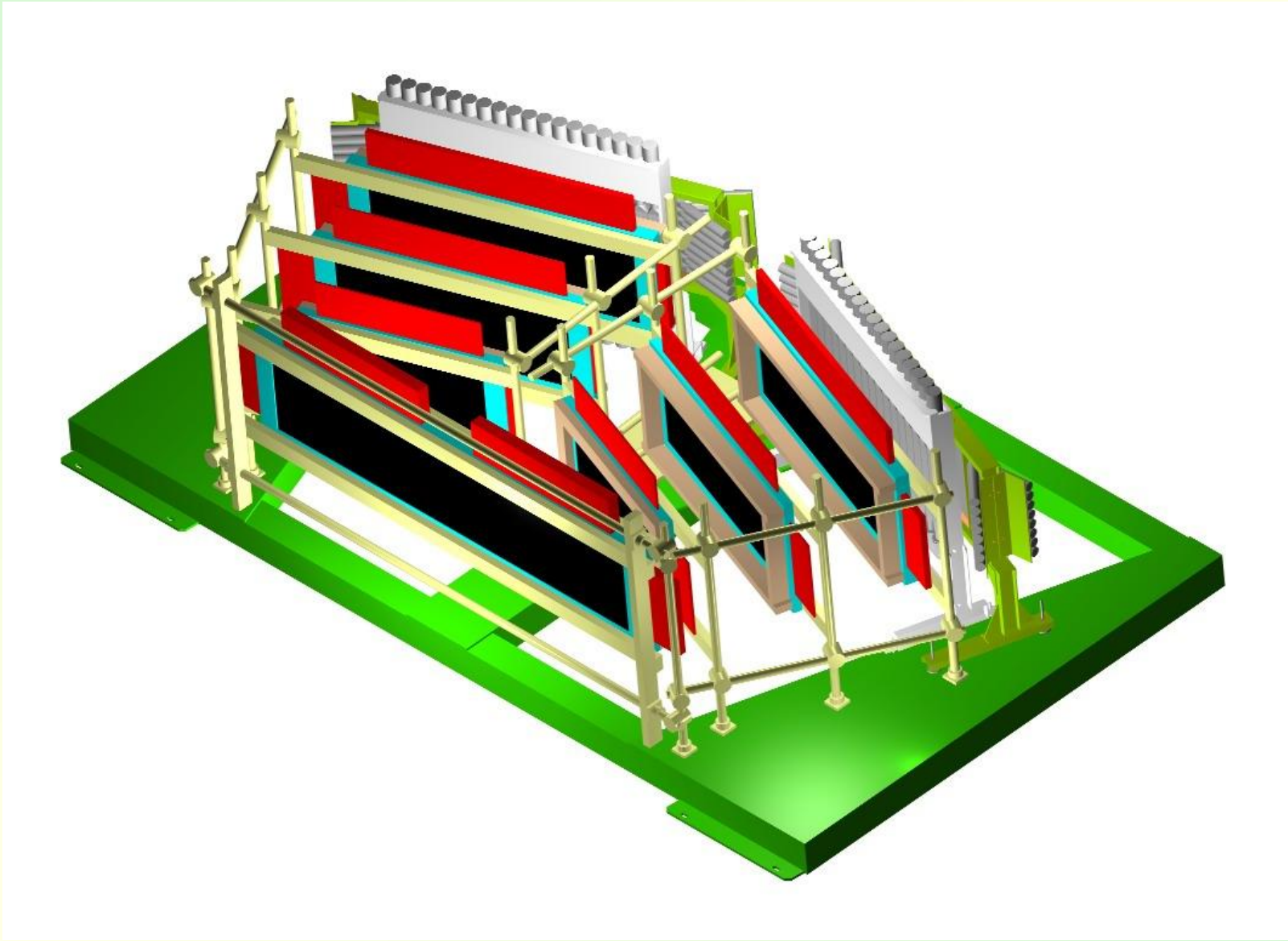
W=5.8 m, H=1.8 m, L=3.8 m

Support for DC, VH, HH (1998)

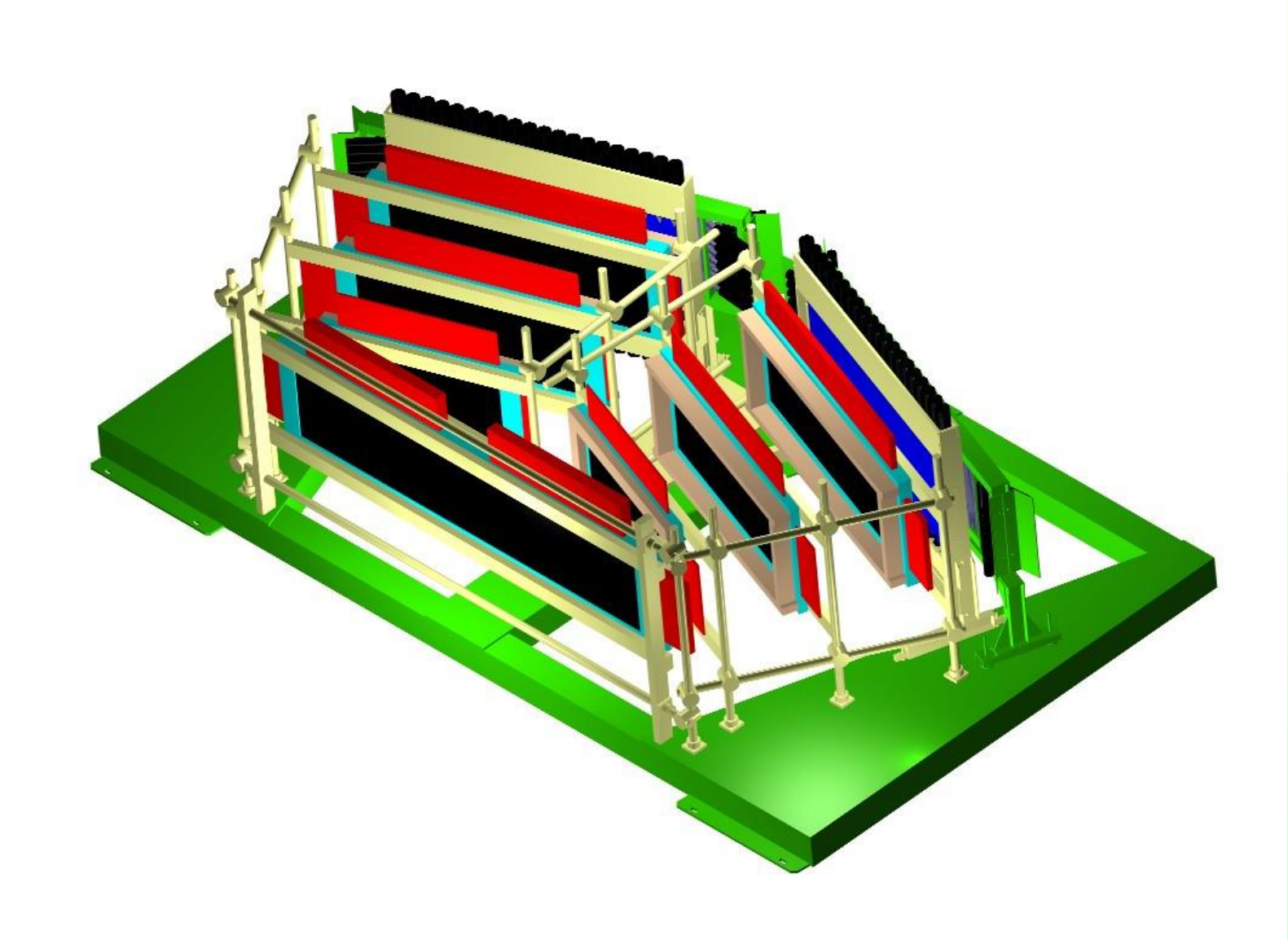


4.5x2.6 cm

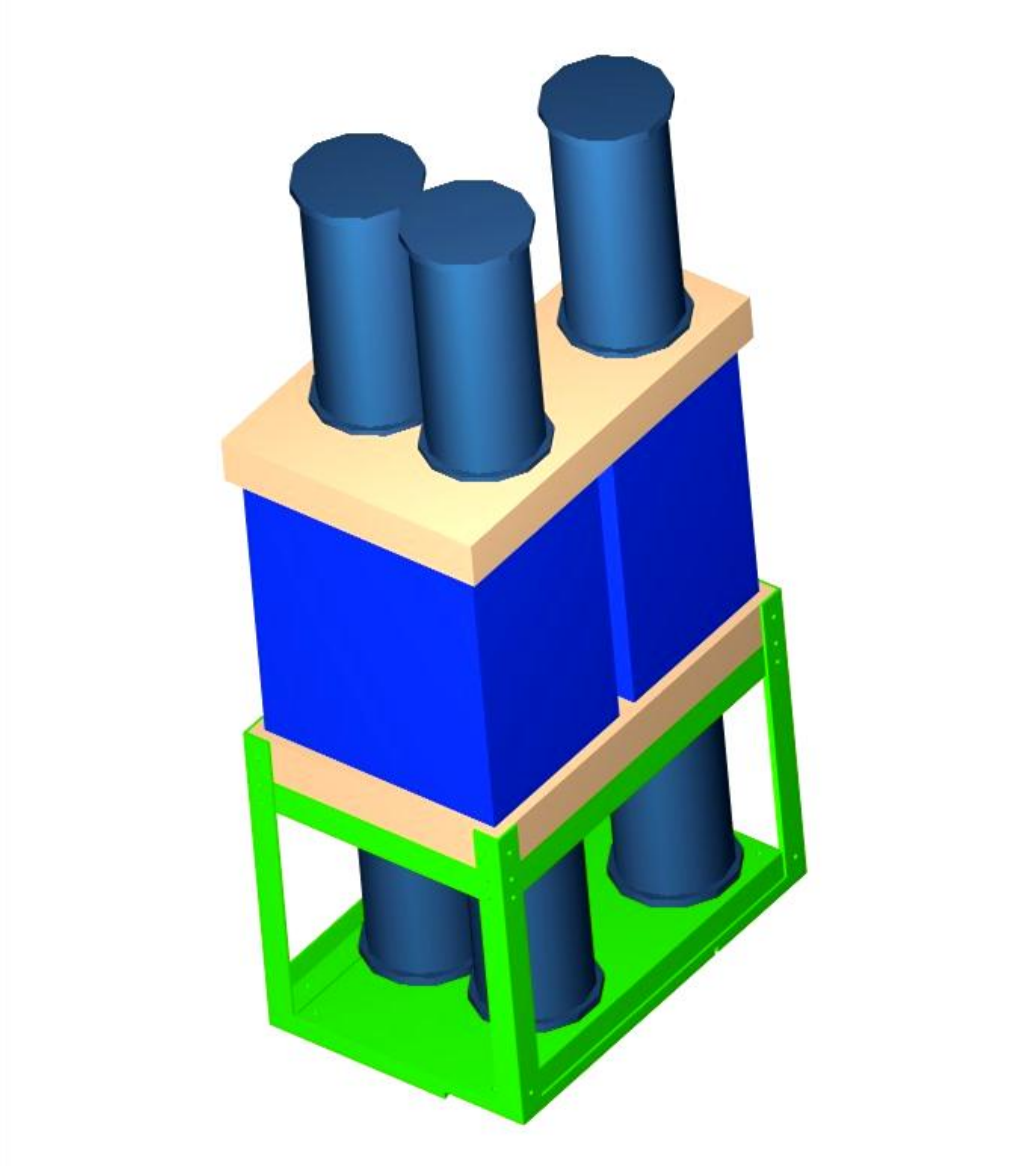
Downstream detectors DC, VH, HH (1998)



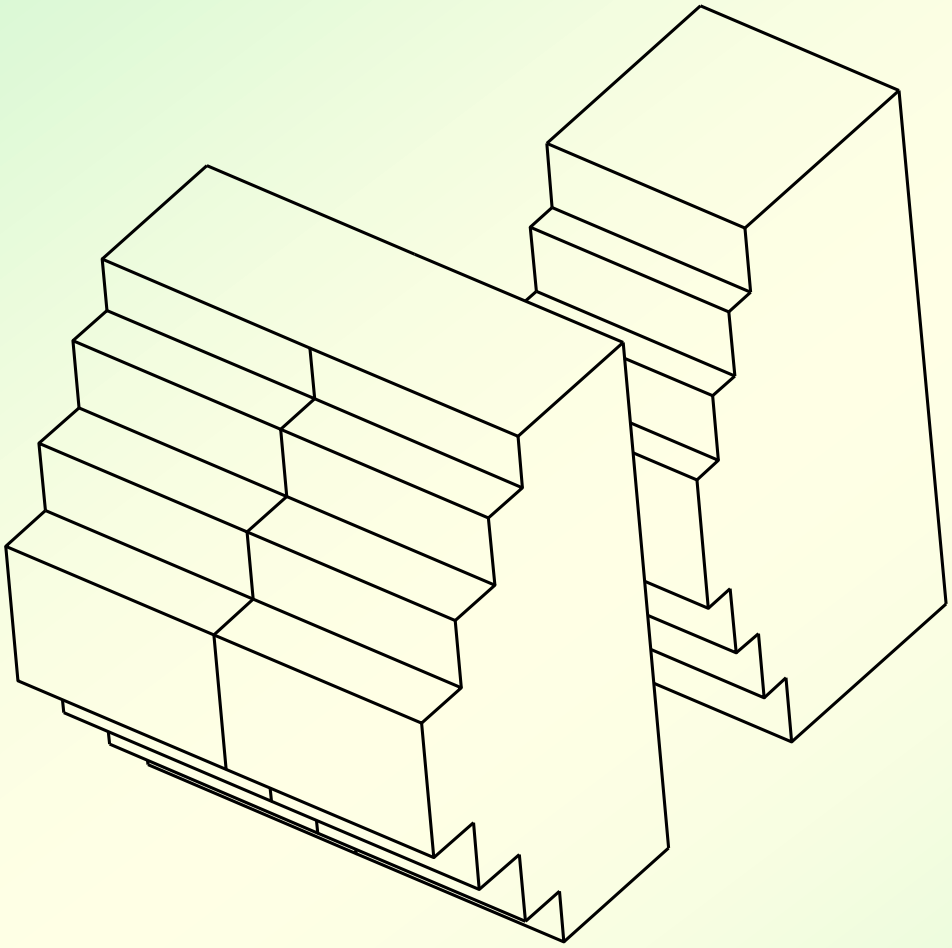
Downstream detectors DC, VH, HH (2006)



Aerogel Cherenkov detector (2006)

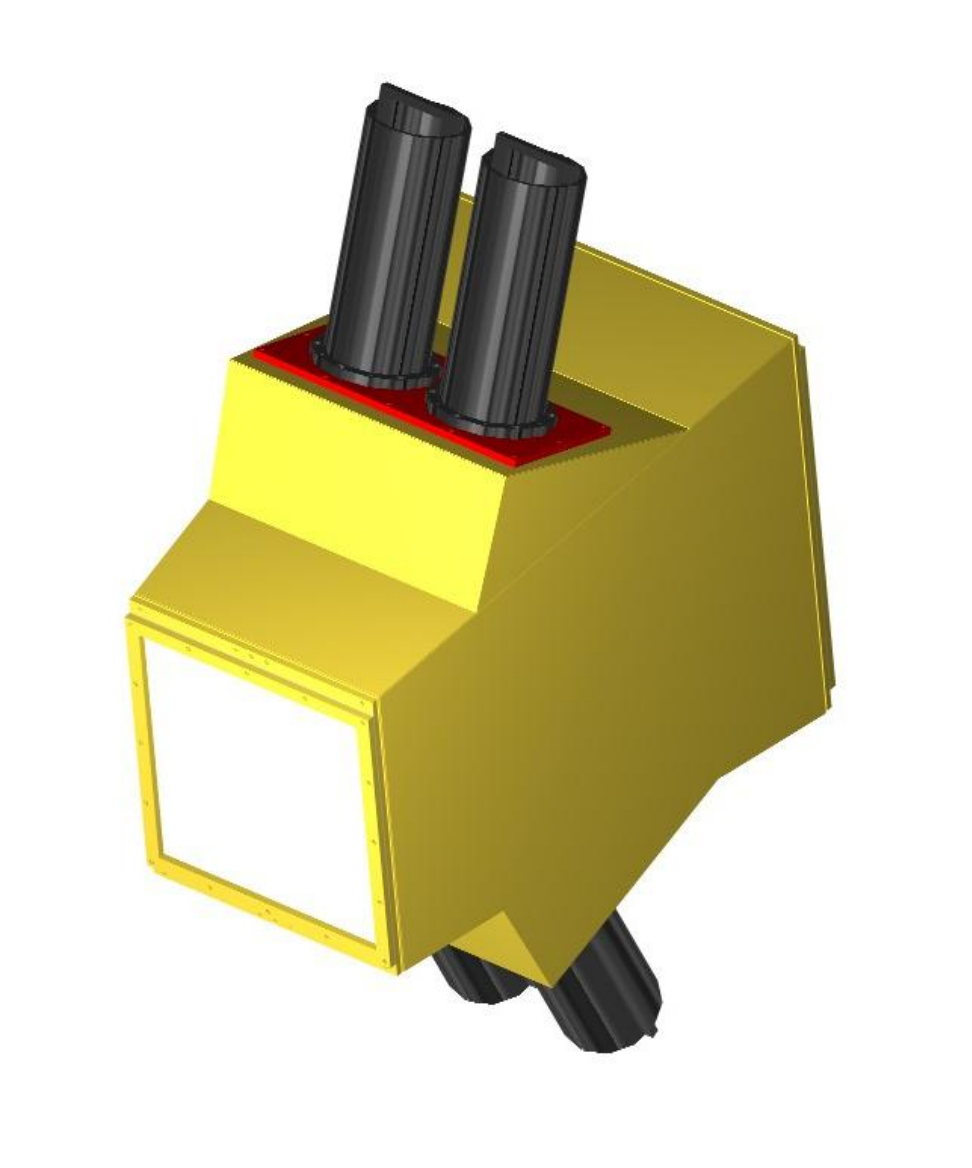


Aerogel (2006)



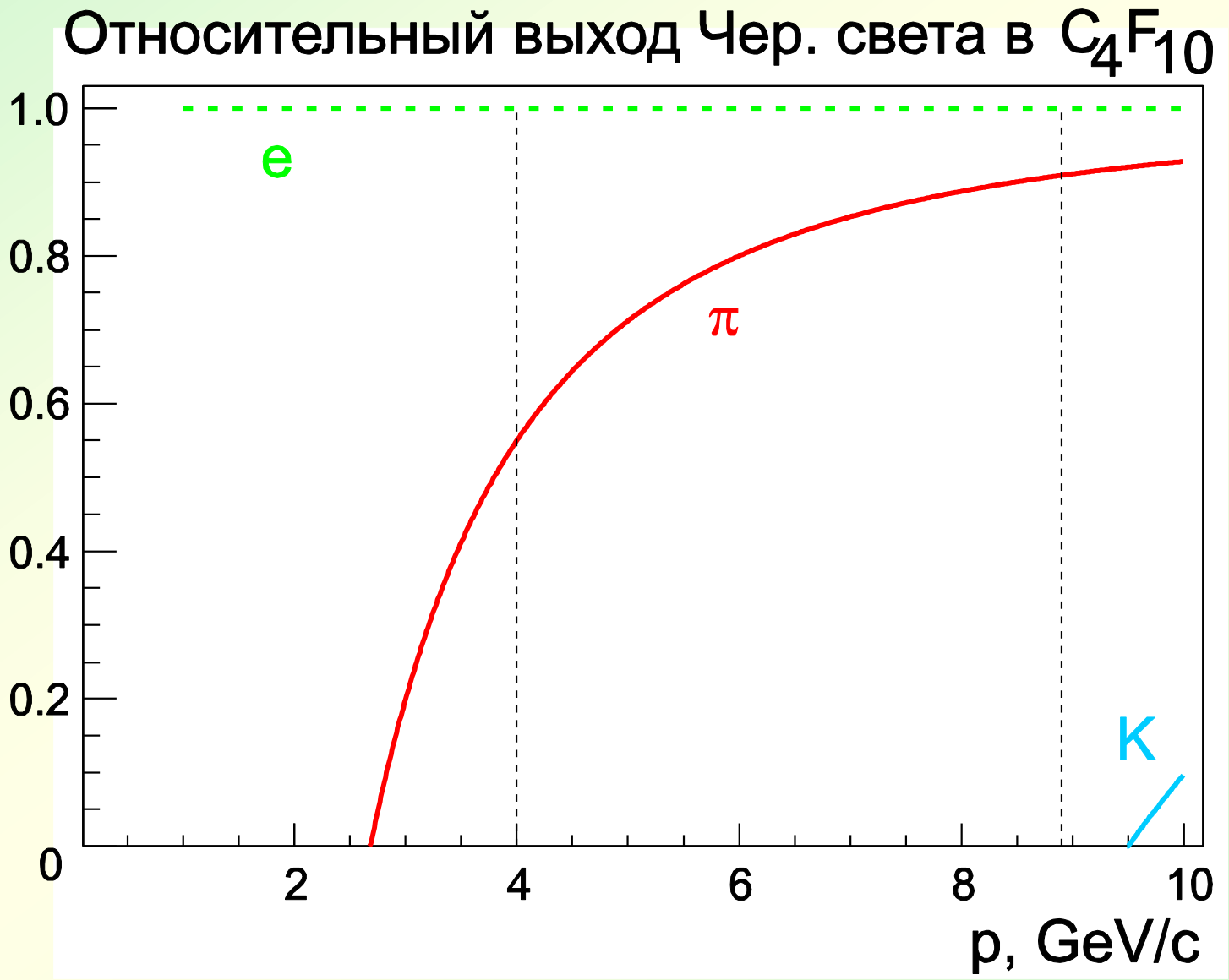
Three modules
Novosibirsk
n=1.015: for 4-5.5 GeV/c
33x42 cm, L=11-23 cm
Japan
n=1.008: for 5.5-8 GeV/c
16x42 cm, L=16-23 cm
Pyramidal shape
Wavelength shifter
p-terphenyl on
tetratex reflector foils
50% increase in light
PMTs Photonis XP4570/B
5-inch. UV-glass
Nphe: 6.9 and 3.9 for
heavy and light modules
Efficiency for K+: 85-95%

C4F10 Cherenkov detector (2006)

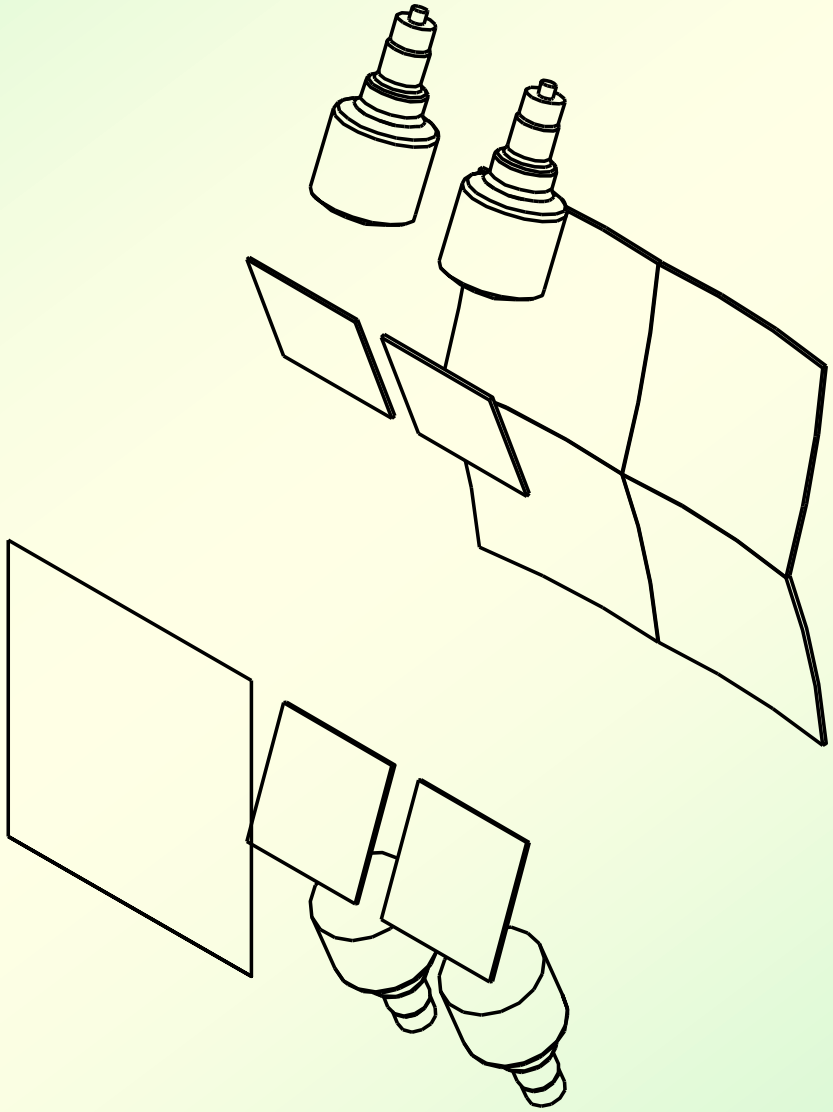


C4F10, perfluorocarbon
Transparency up to 190 nm
n=1.00135
Max. Cherenkov angle 3.03 deg
For pion detection 4-8 GeV/c
Threshold for pions 2.7 GeV/c
Window 42x44 cm
Radiator thickness 85 cm
Volume 0.4 m3 per detector
4 spherical mirrors 293x286 mm
R=1194 mm
4 flat mirrors 185x185 mm
4 PMs: HAMAMATSU 6528
5 inch with UV-glass
Nphe=30 for electrons
Quality factor $N0$= 125 cm-1
Efficiency for pions with
p >4 Gev/c >99.5%

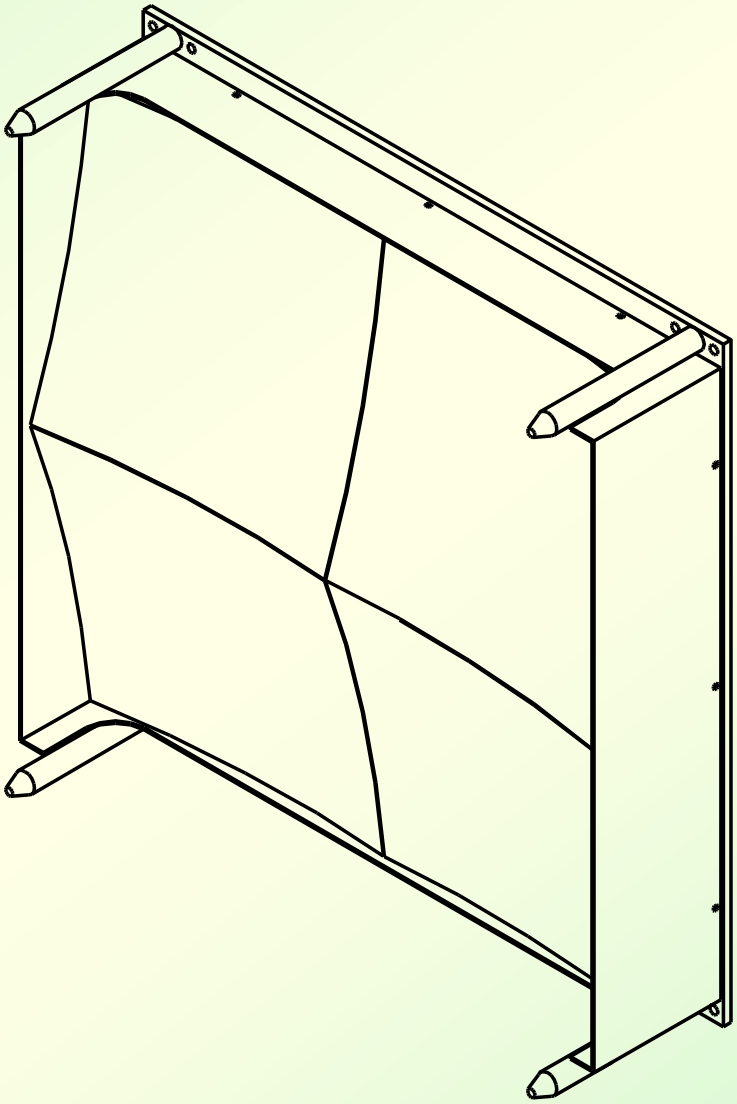
C4F10, light vs pion momentum



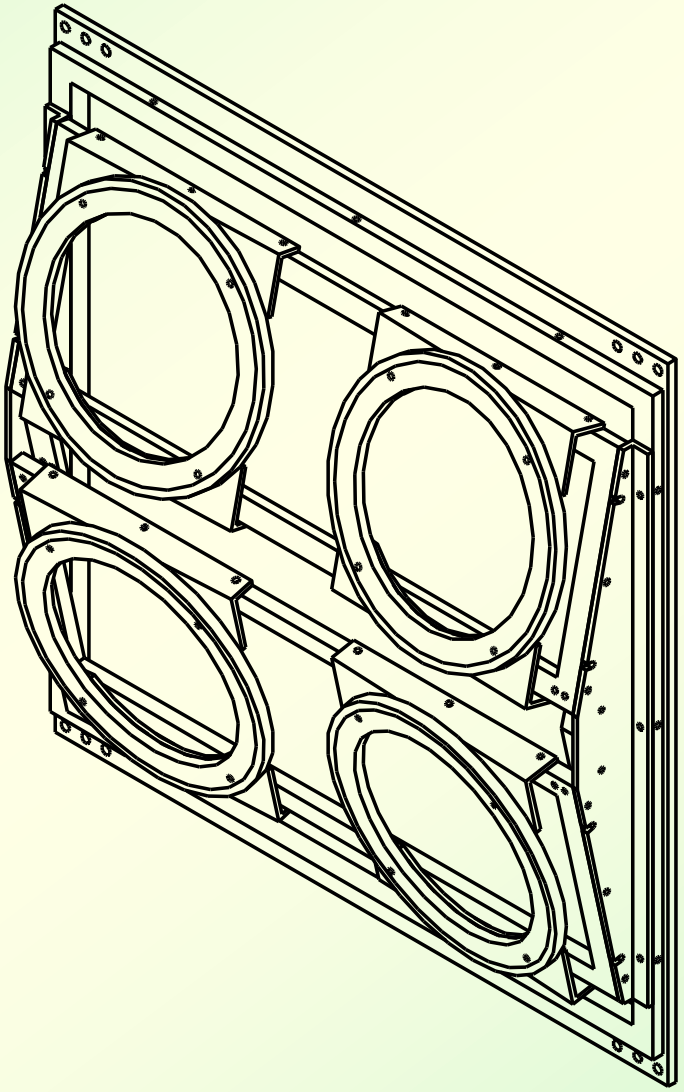
C4F10, spherical, flat mirrors, PMs



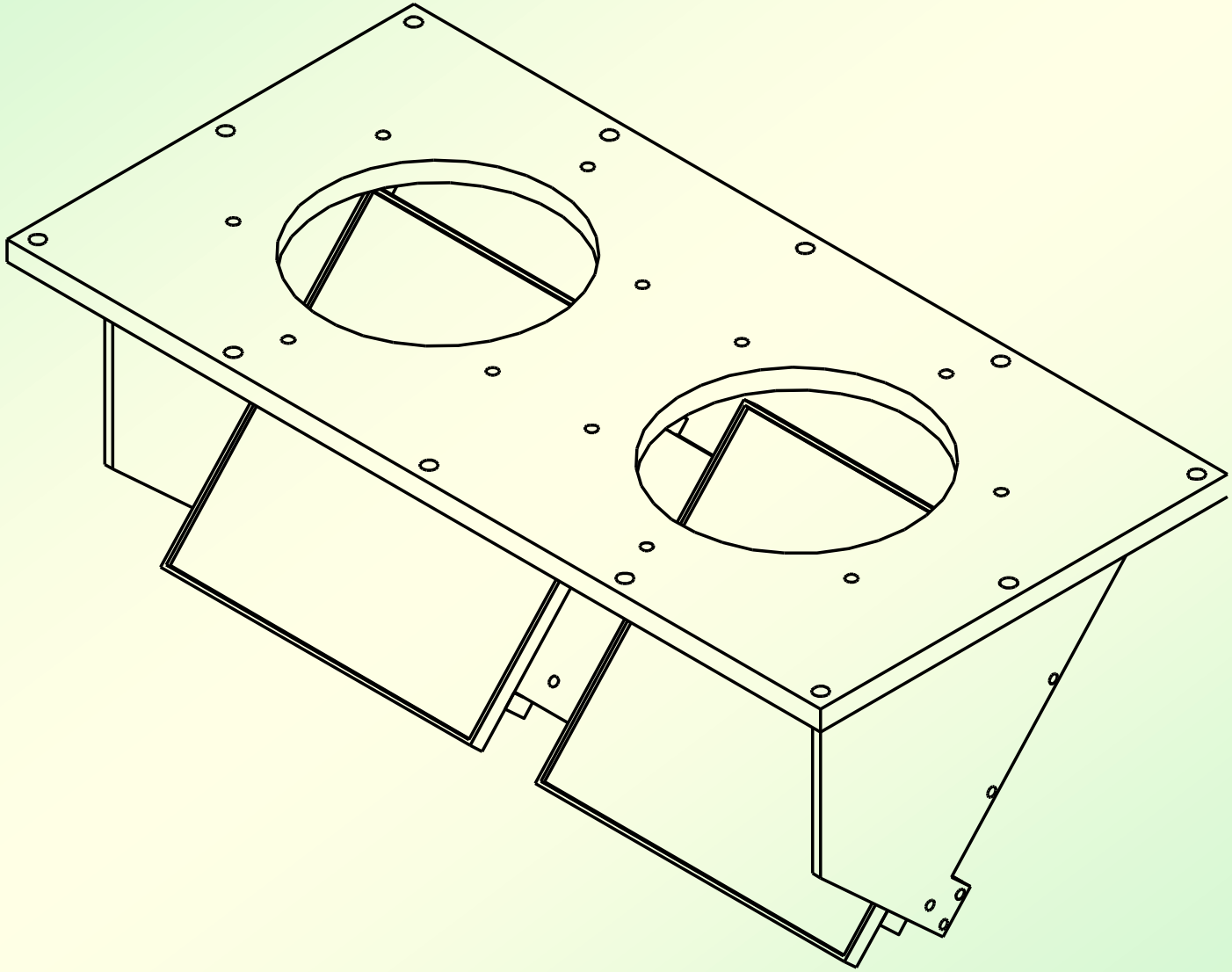
C4F10, spherical mirrors and support



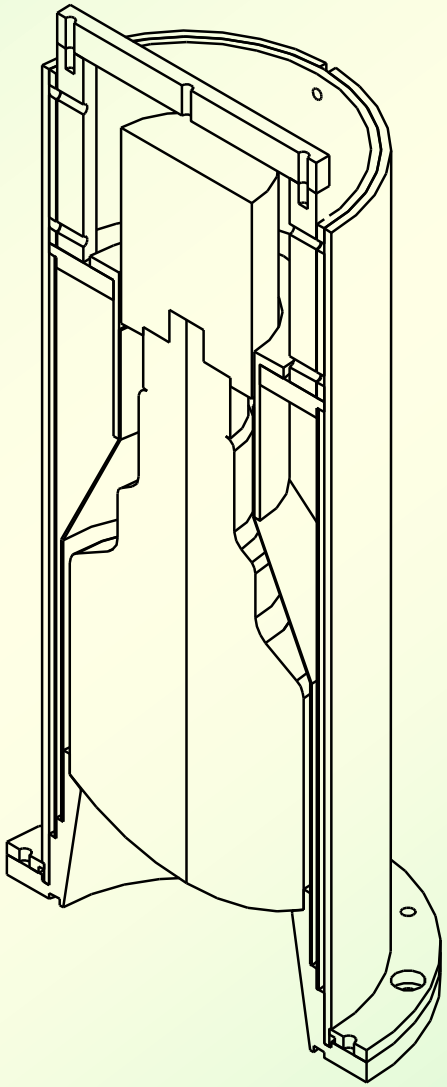
C4F10, support for spherical mirrors



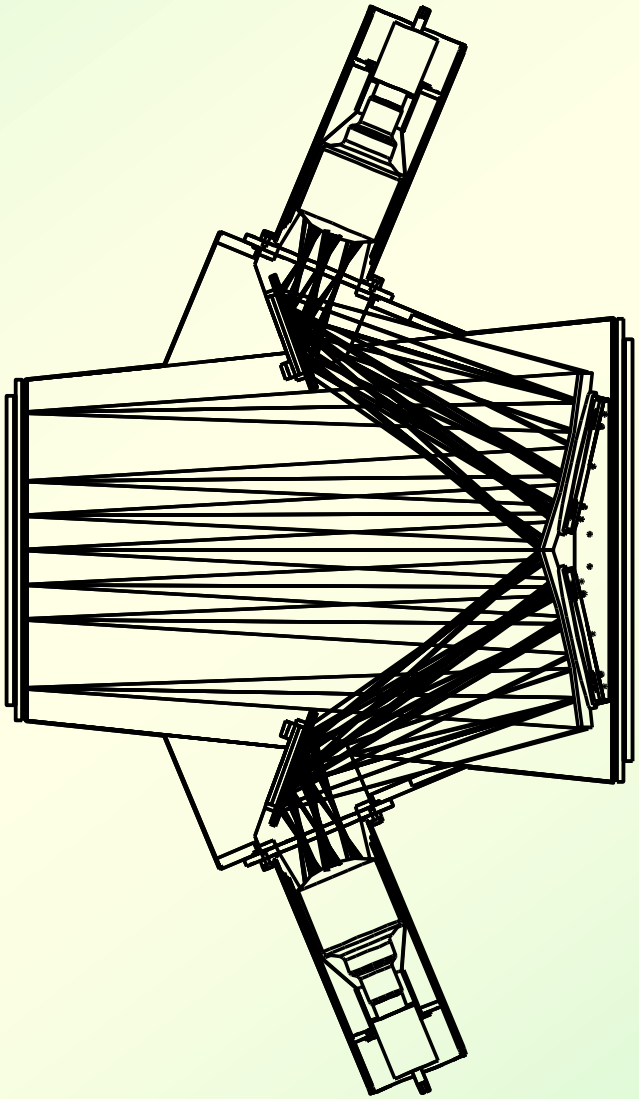
C4F10, flat mirrors and support



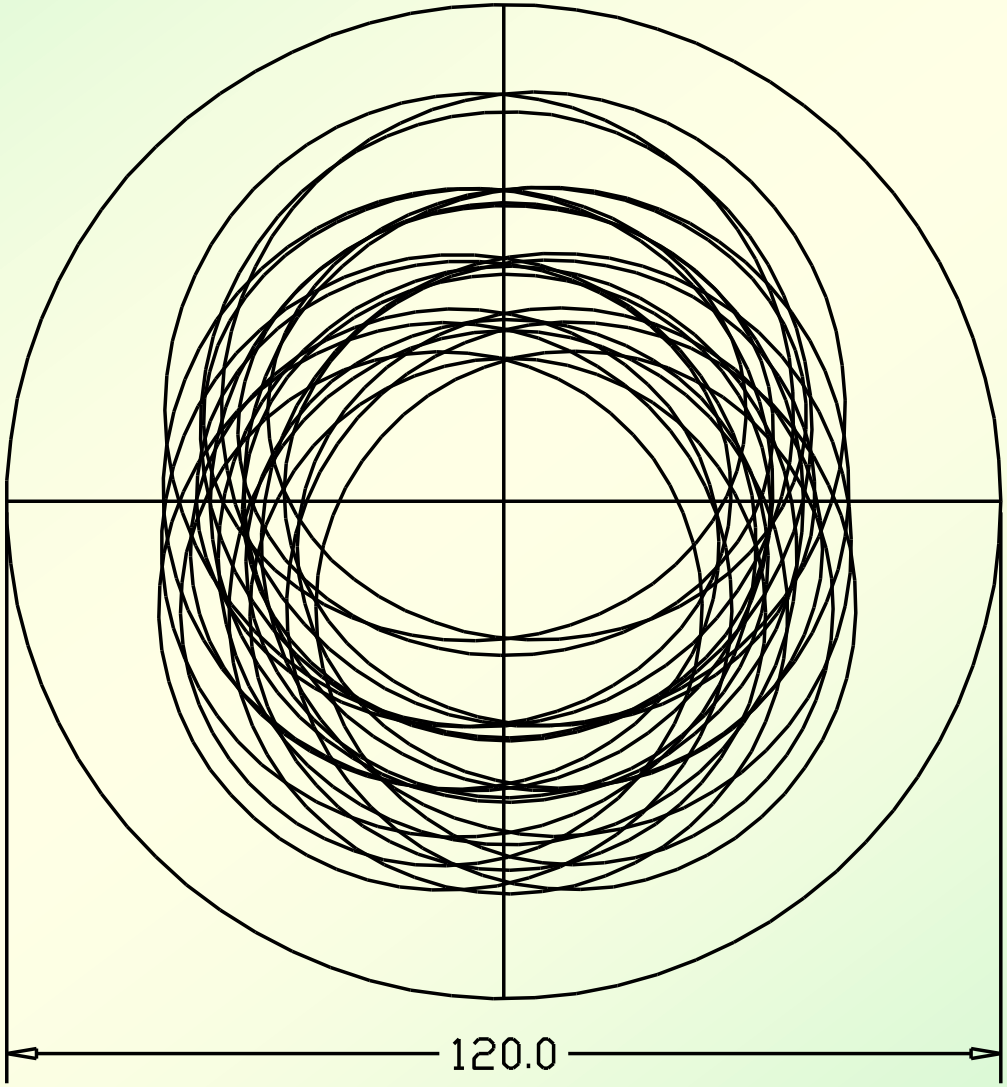
C4F10, PM and housing



C4F10, Cherenkov light

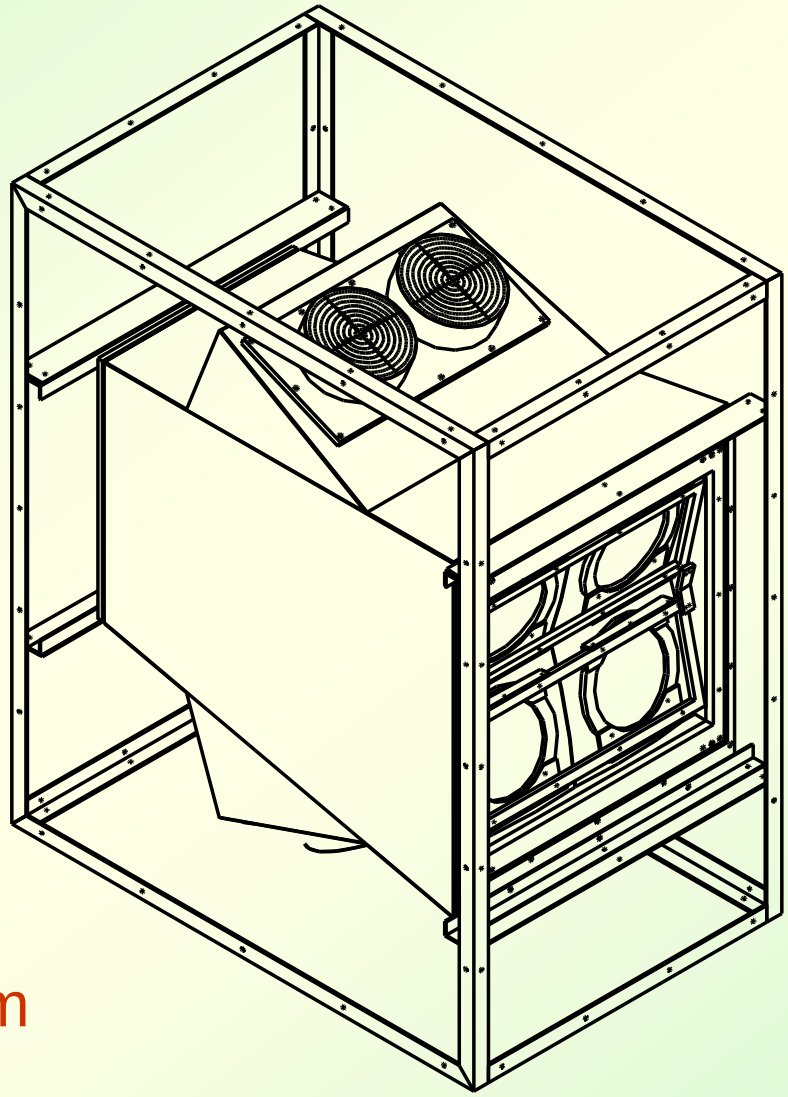


C4F10, Cherenkov rings



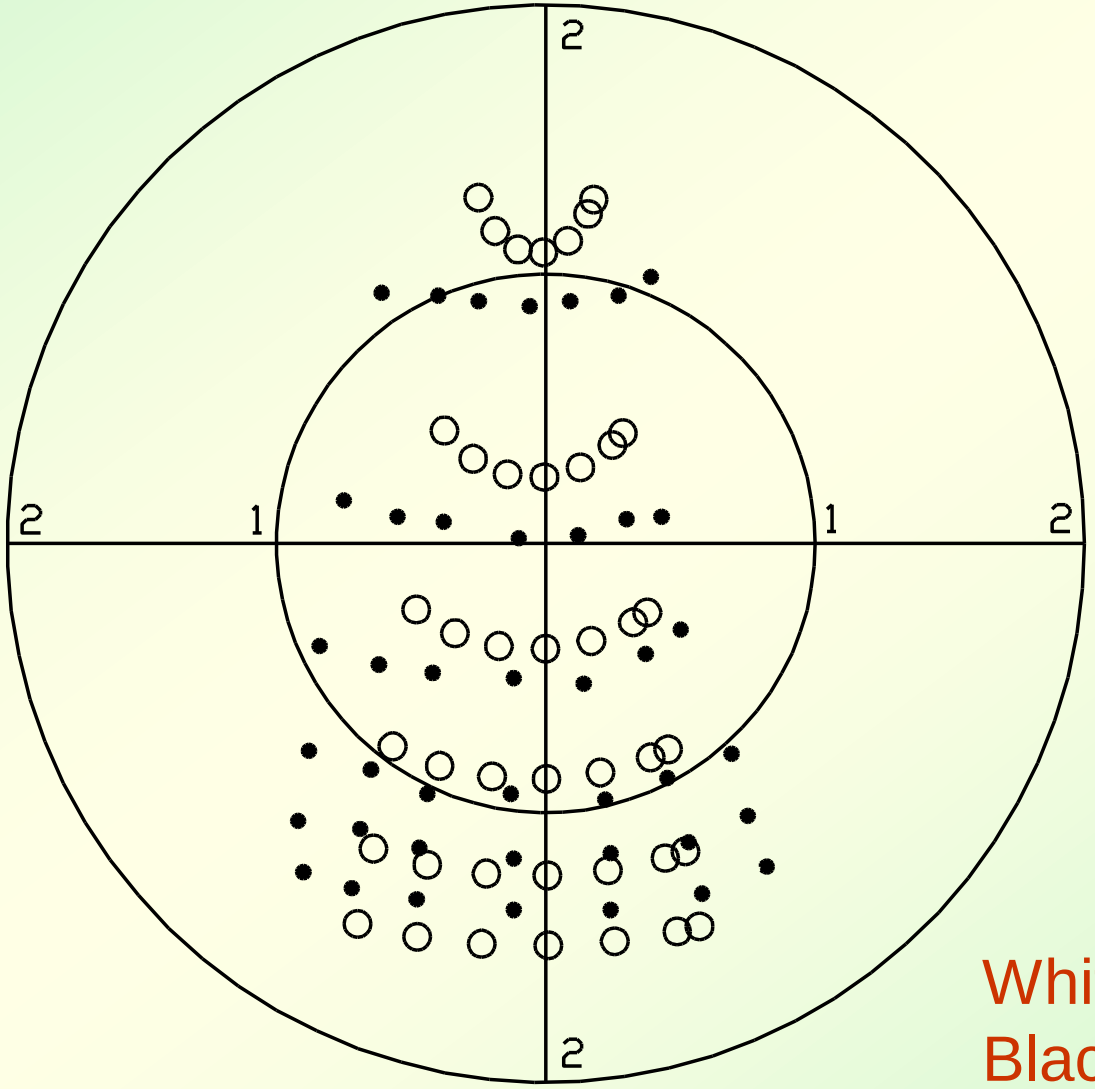
C4f10, Cherenkov ring

C4F10, laser test



Base 4.4 m

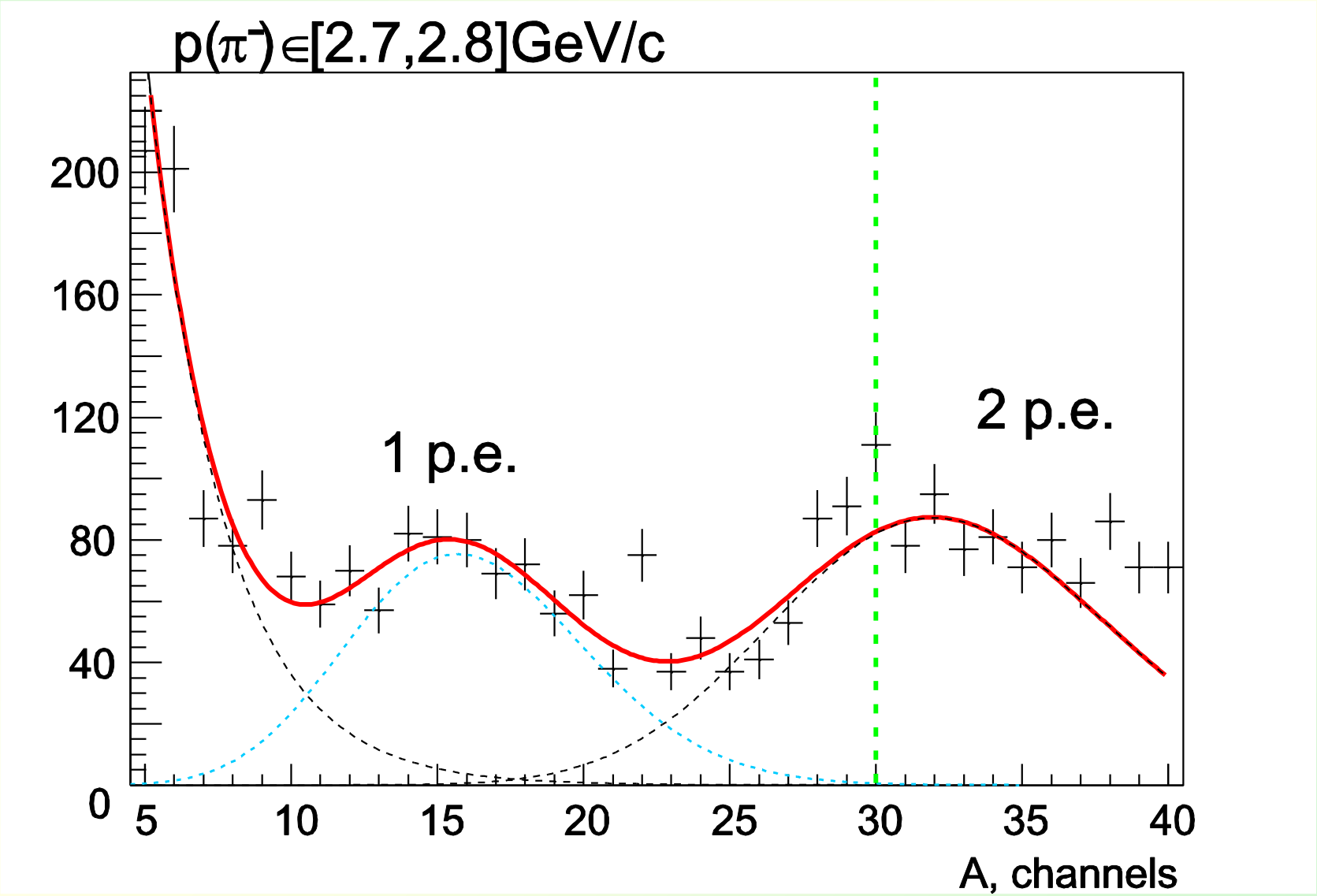
C4F10, laser test



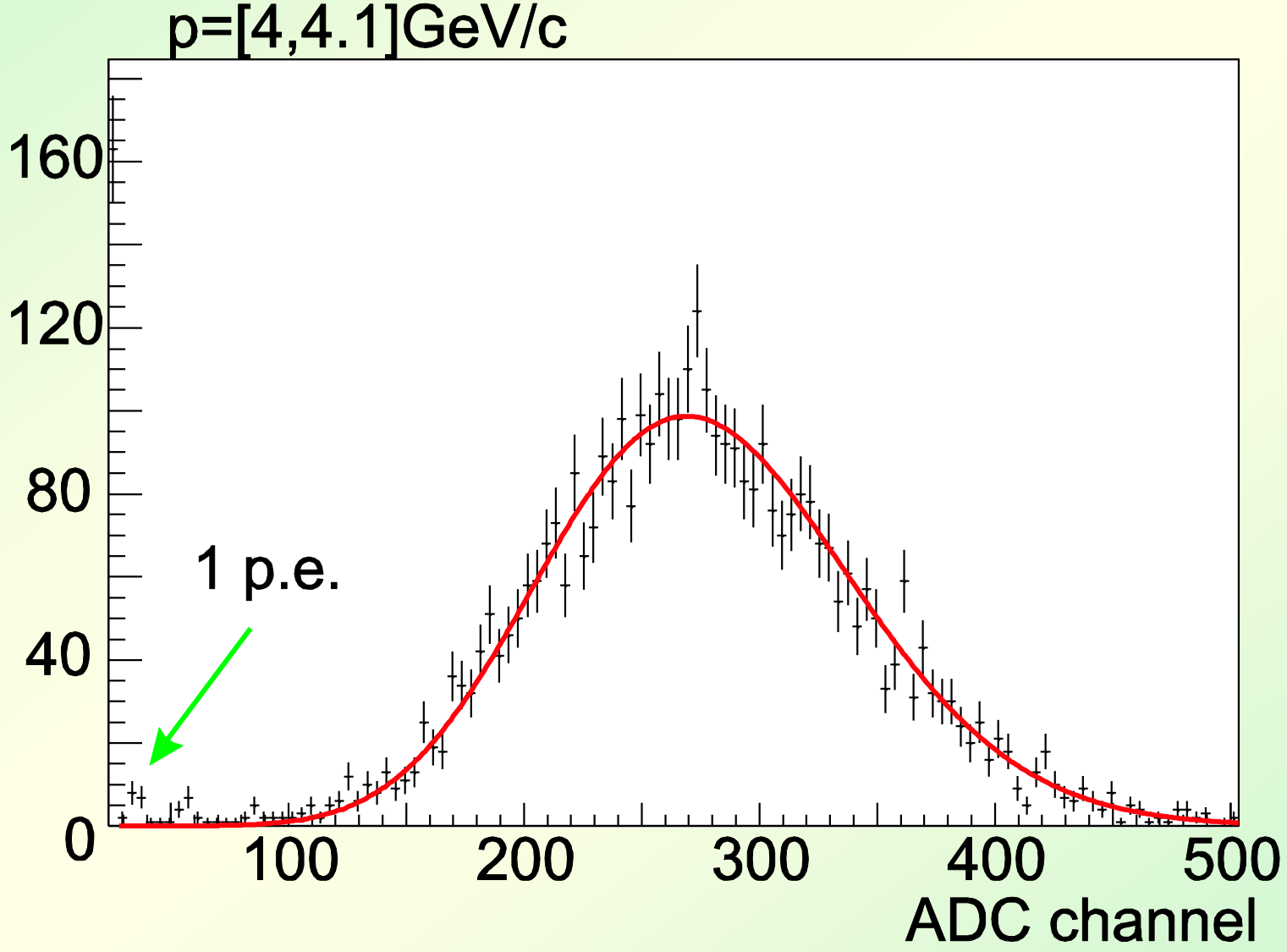
cm

White: calculation,
Black: measurement

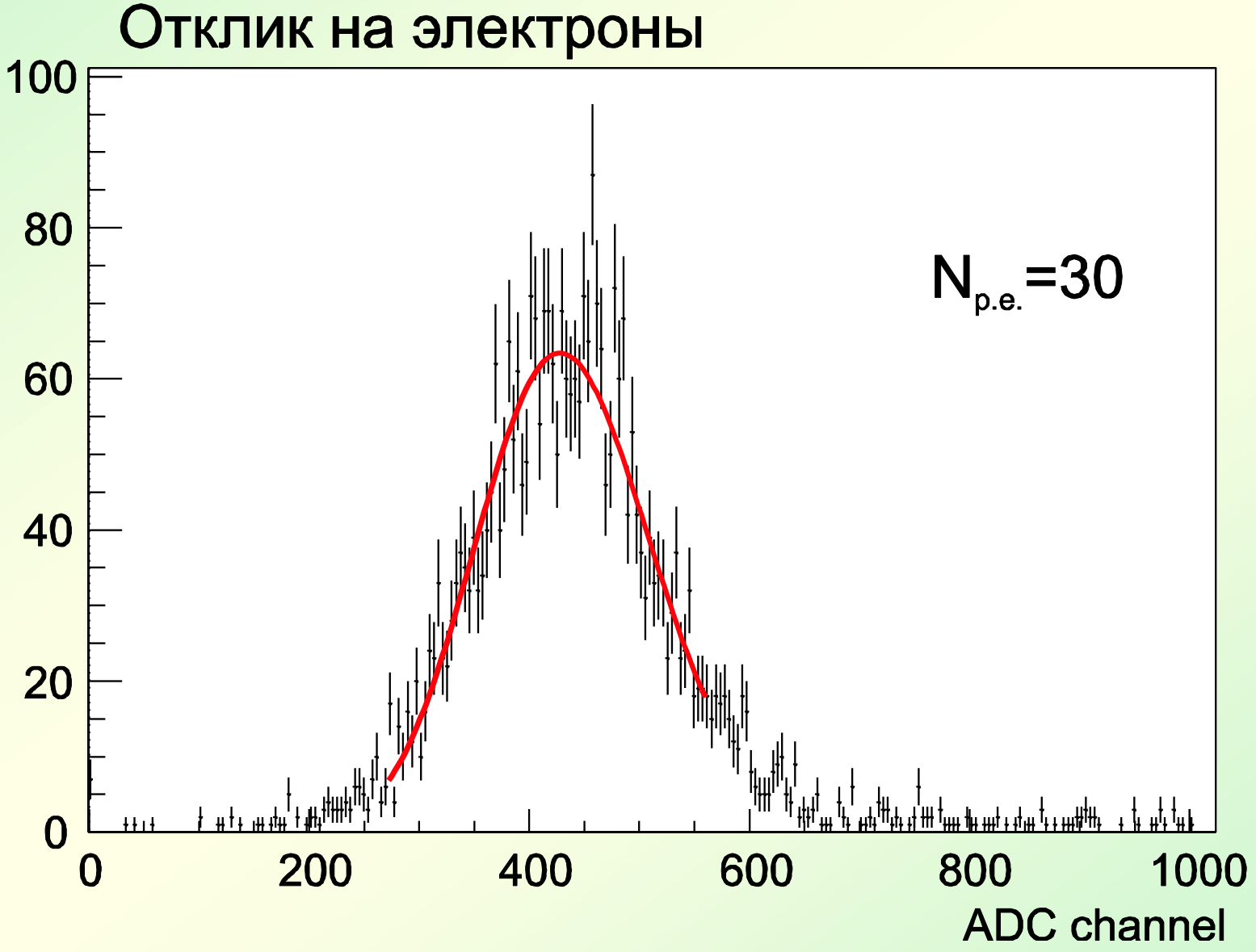
C4F10, single and double photoelectrons



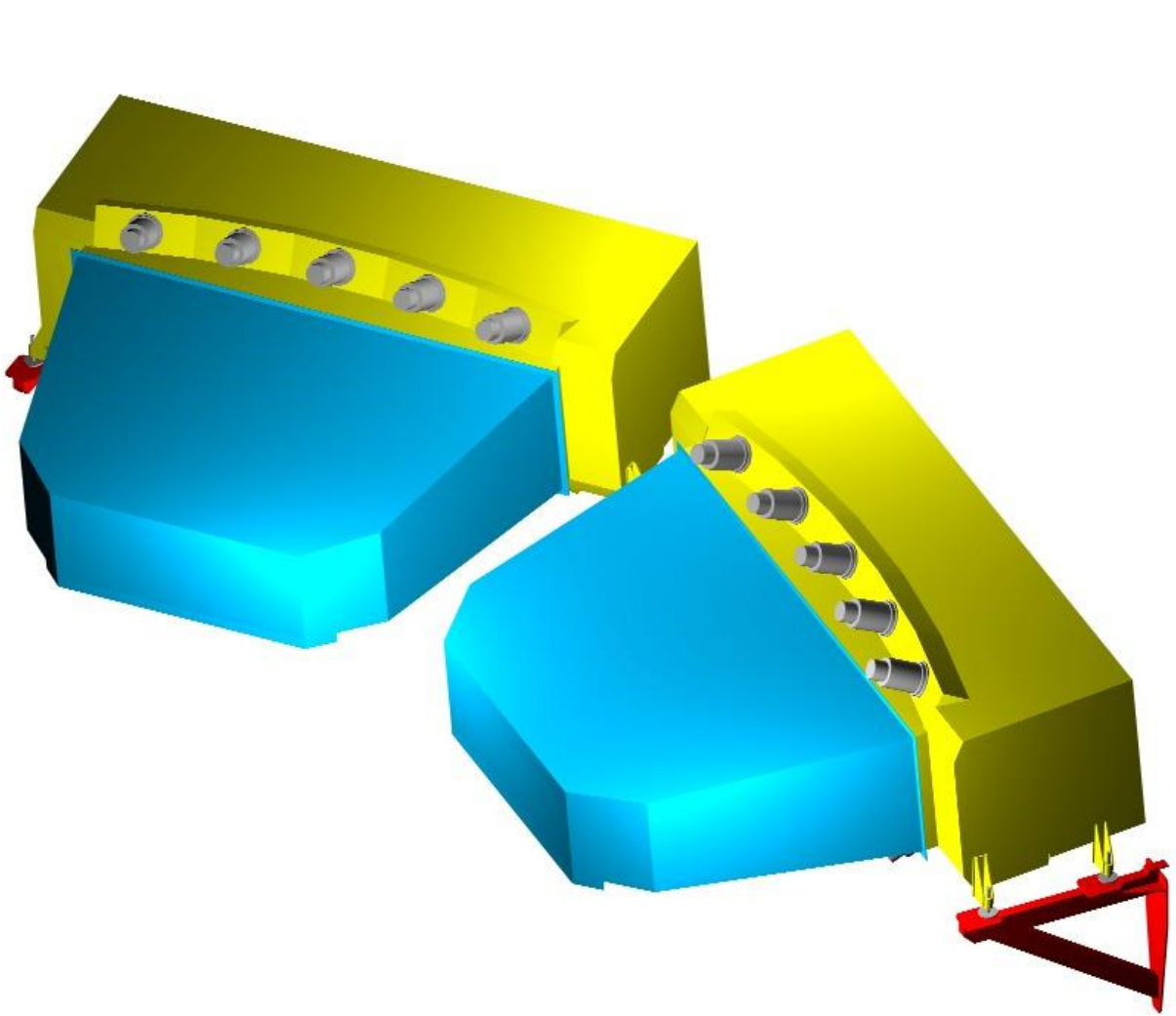
C4F10, pions



C4F10, electrons

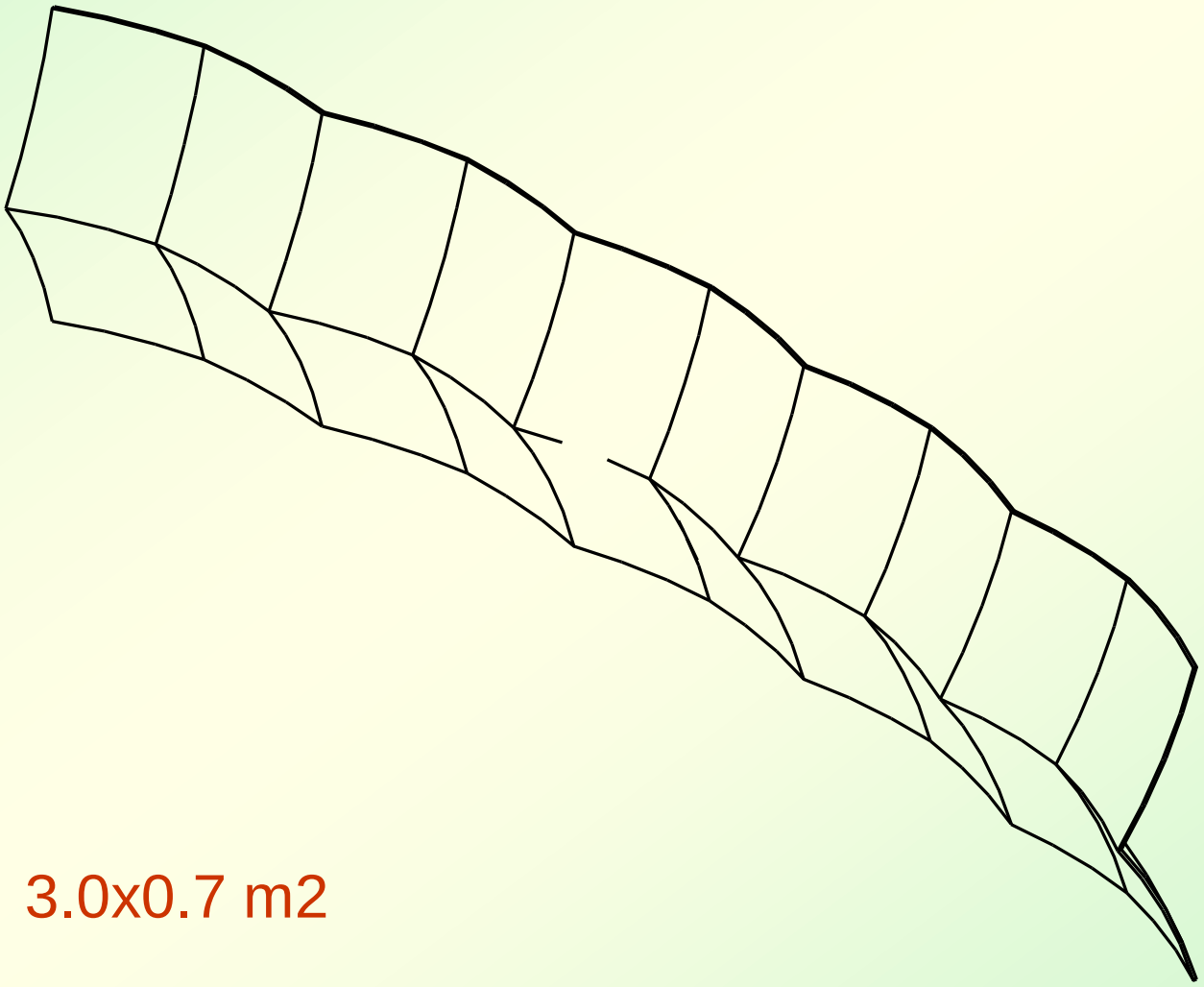


Nitrogen Cherenkov detectors (1998)



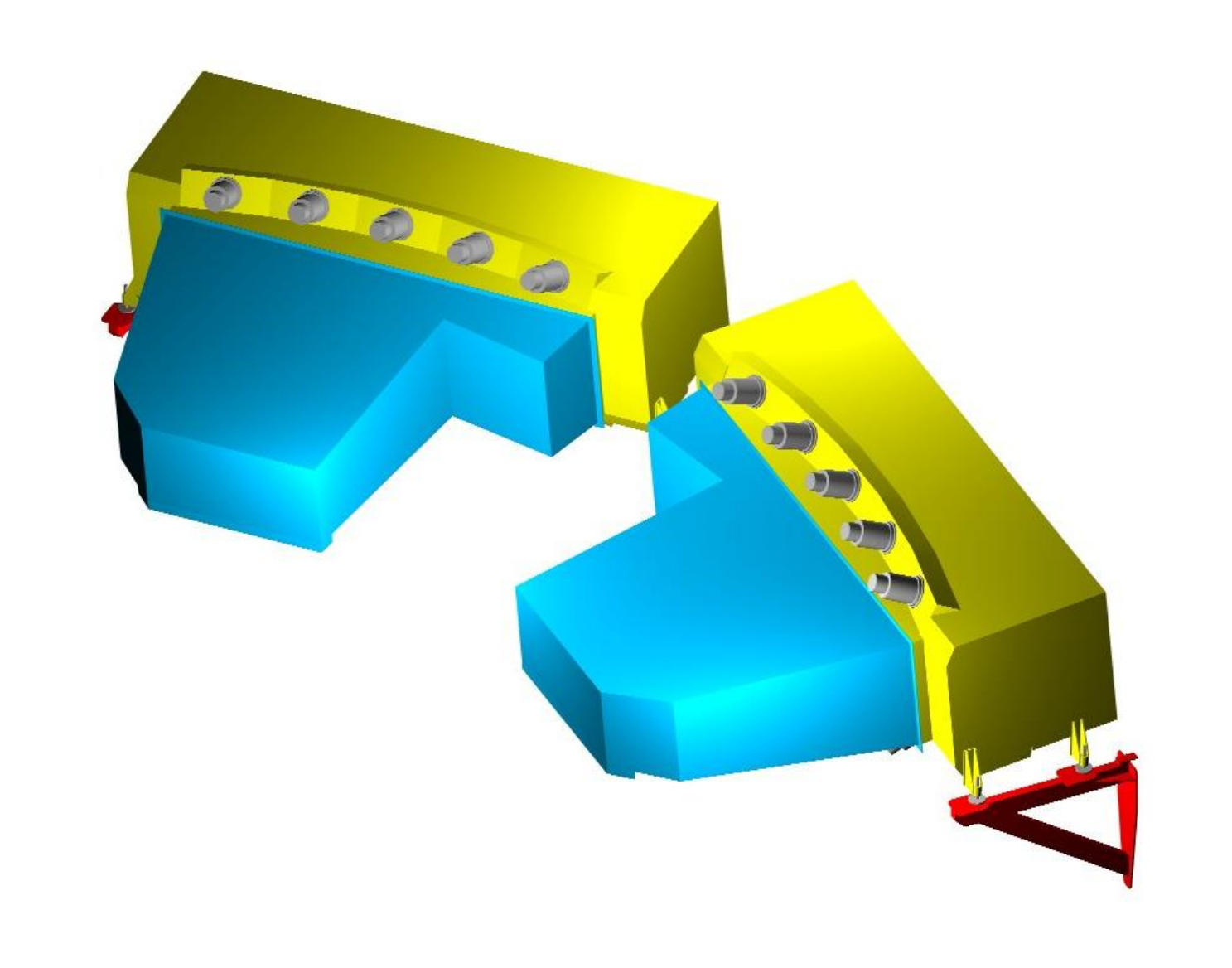
Nitrogen n=1.00029
theta=1.39 deg
Windows
143x56 cm, 336x96 cm
L=310 cm
Radiator length 285 cm
20 spherical mirrors
30x35 cm, 6 mm thick
R=1194 mm
10 PMs
Hamamatsu R1587
130 mm UV-glass
Nphe=16
Efficiency >99.8 %
Pions <1.5 %.

Mirrors of Nitrogen Cherenkov detector

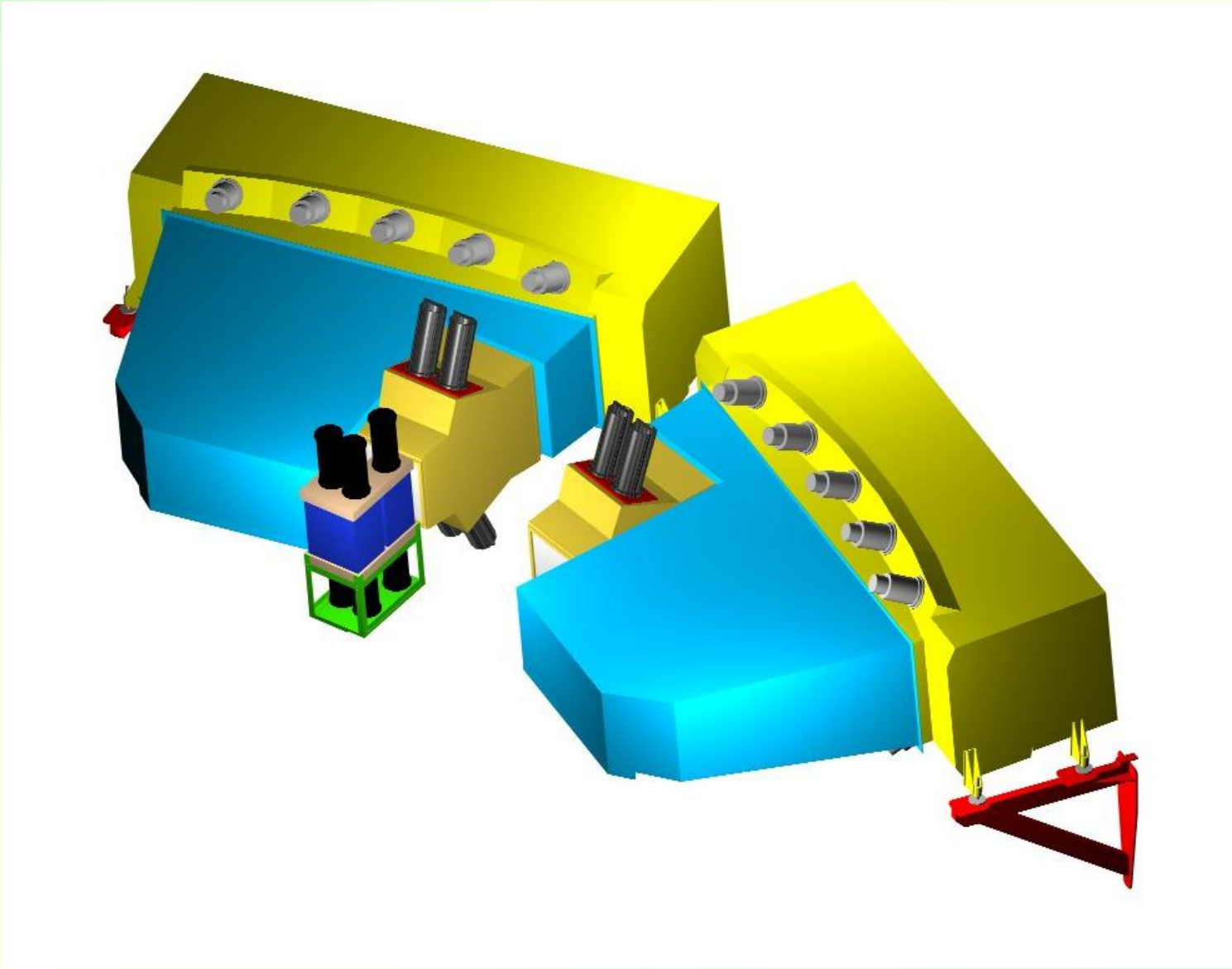


3.0x0.7 m2

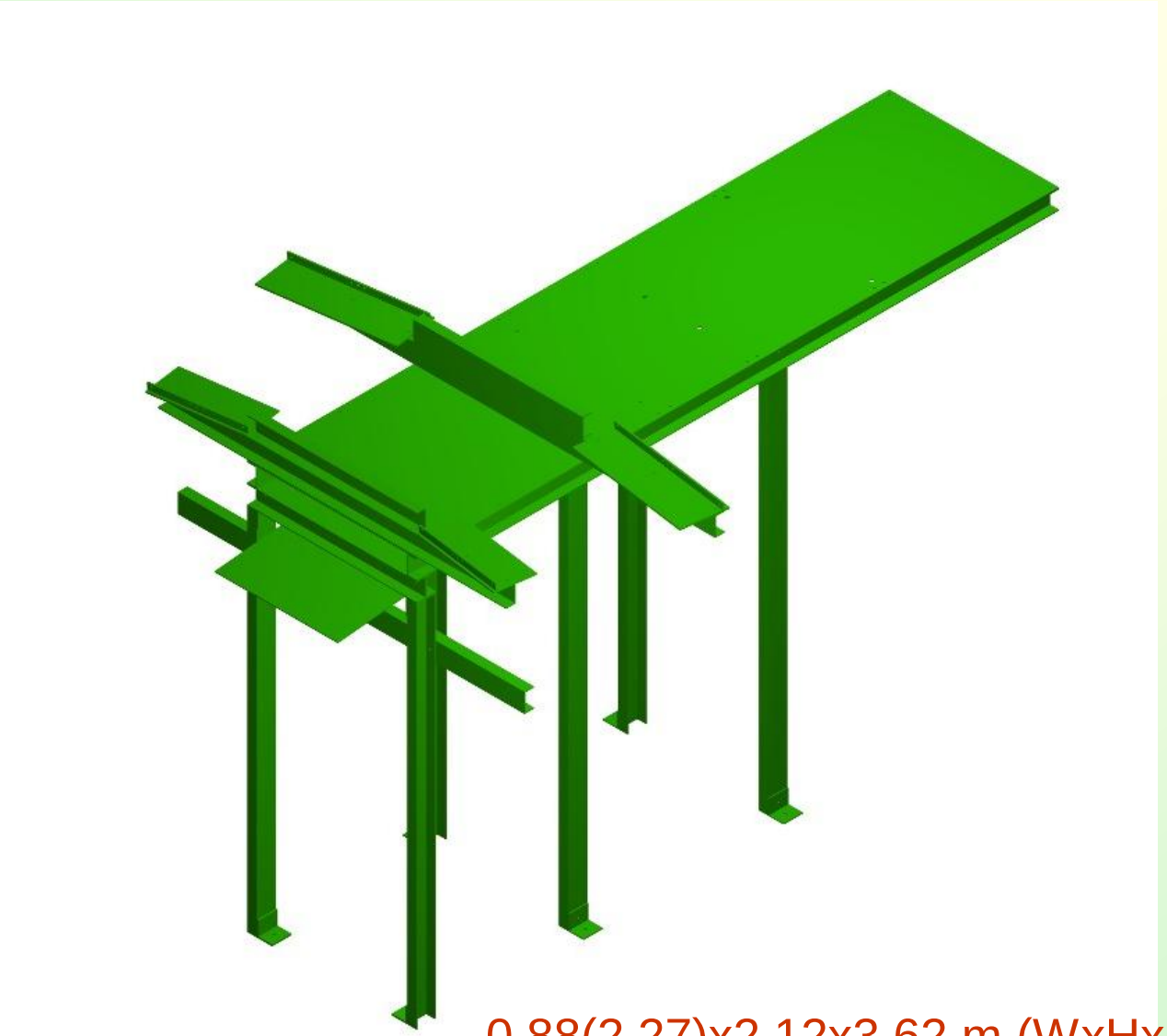
Nitrogen Cherenkov detectors (2006)



All Cherenkov detectors (2006)

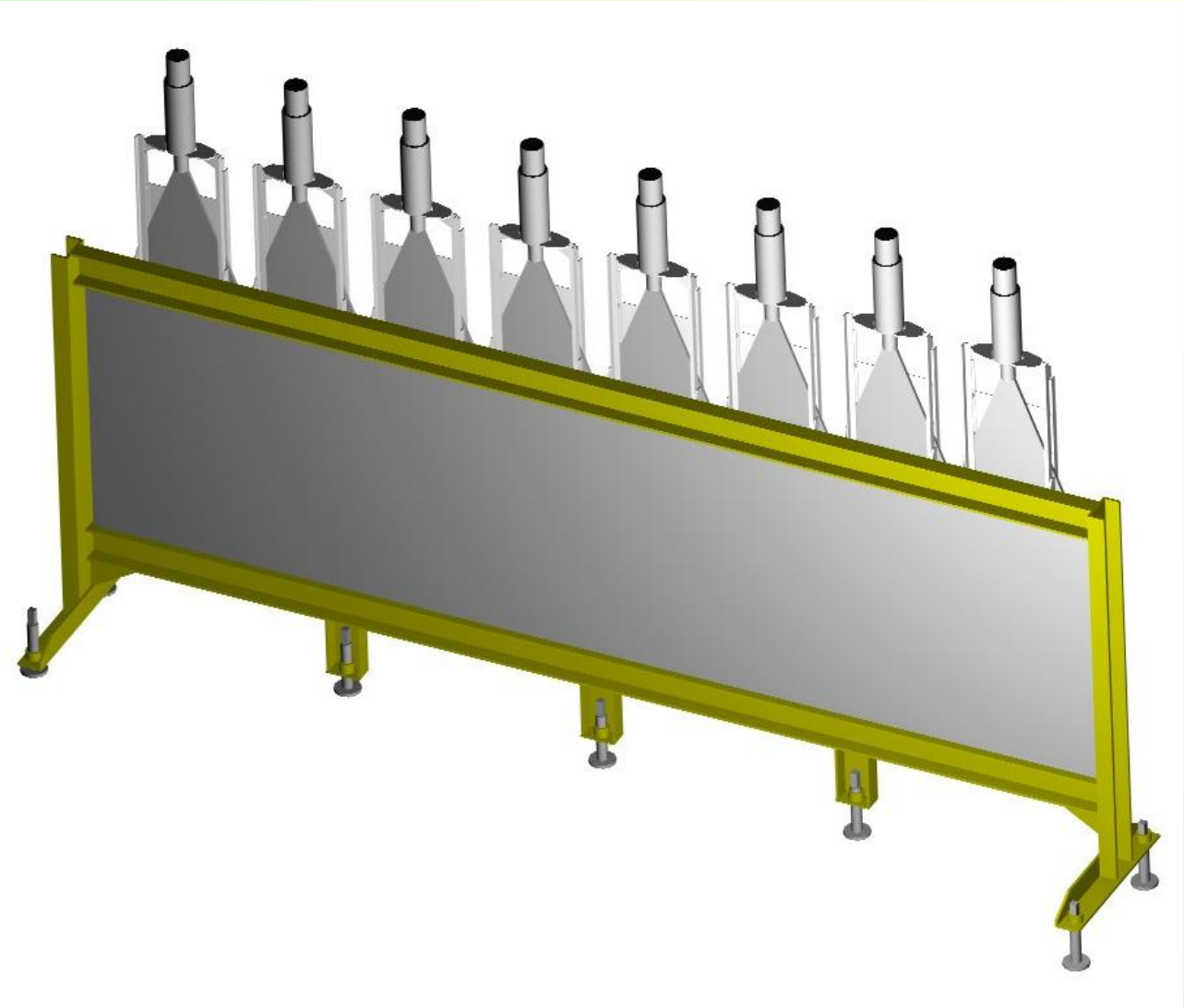


Bridge-support for C4F10 detectors



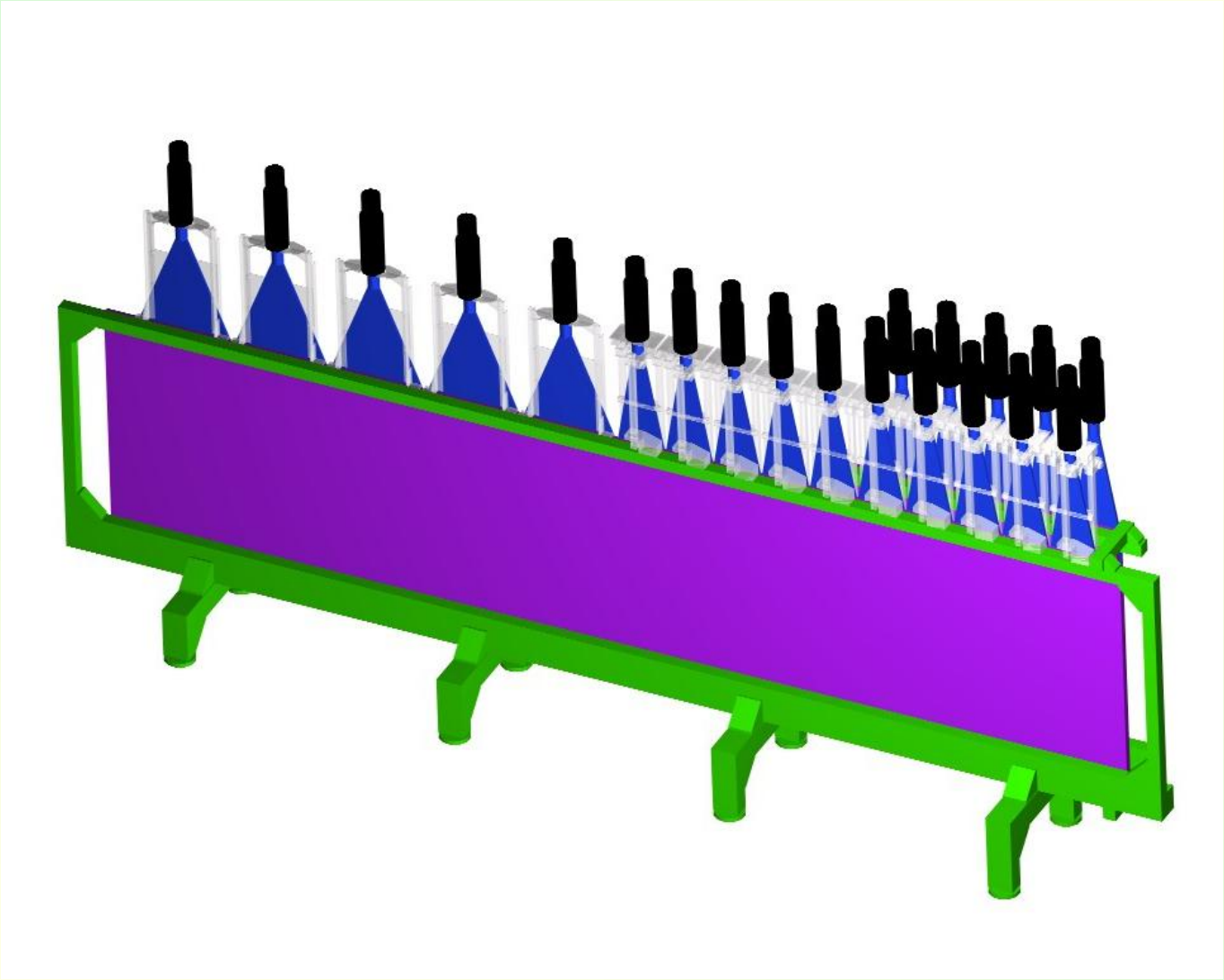
0.88(2.27)x2.12x3.62 m (WxHxL)

Preshower detector (1998)



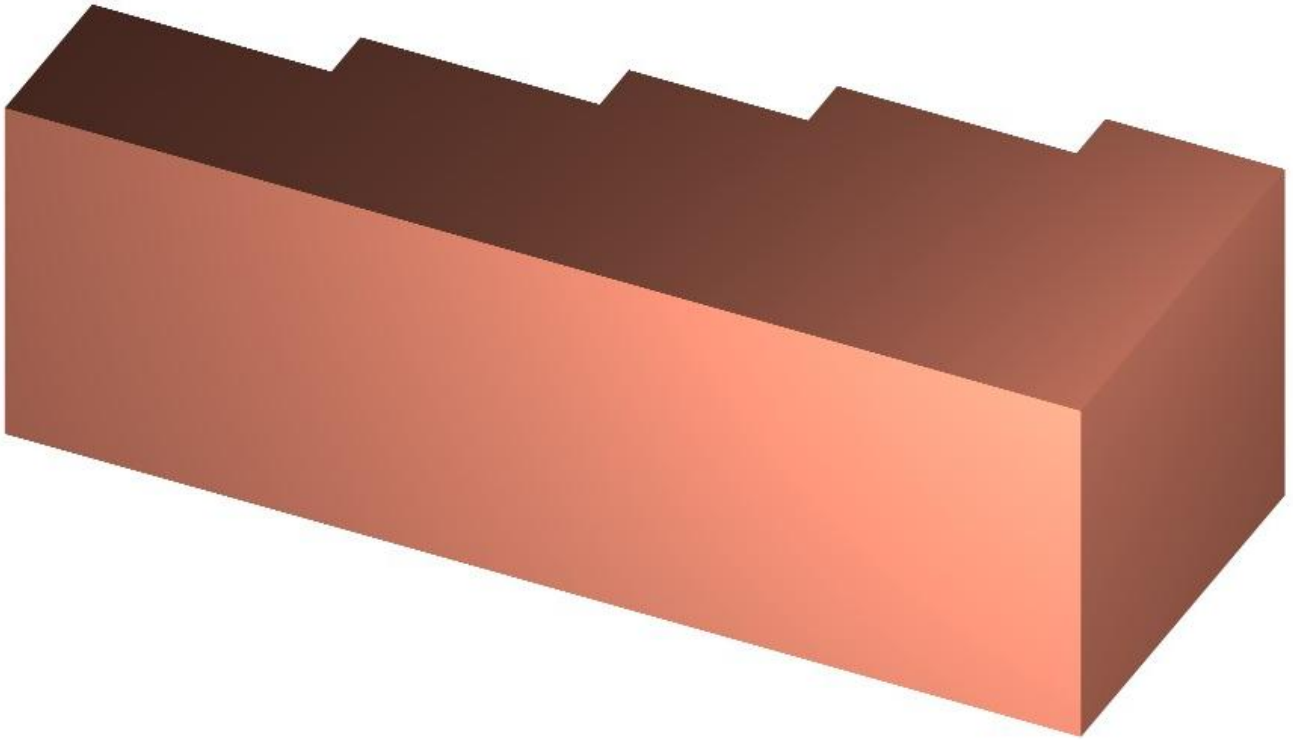
Area
280x75 cm
8 counters
Slabs: 35x75x1 cm
BICRON BC-408
PMs EMI 9954-B
Pb 25 mm, 10 mm
Eff. for pions 99.5%
Loss. of pions <5%.

Preshower detector (2006)



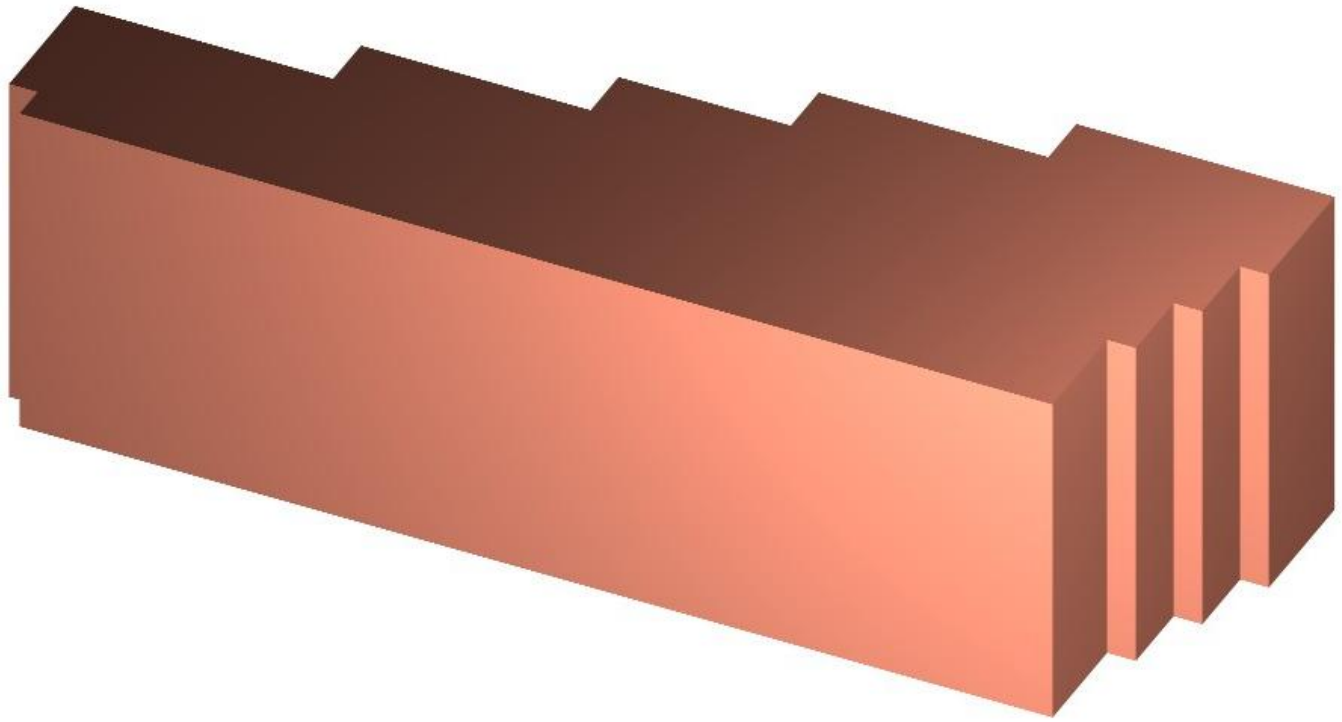
Area:
350x75 cm
First layer:
Area 1:
175x75 cm
5 counters
35x75x1 cm
Area 2:
175x75 cm
10 counters
17.5x75x1 cm
Second layer:
Area:
87.5x75 cm
5 counters
17.5x75x1 cm

Absorber (1998)



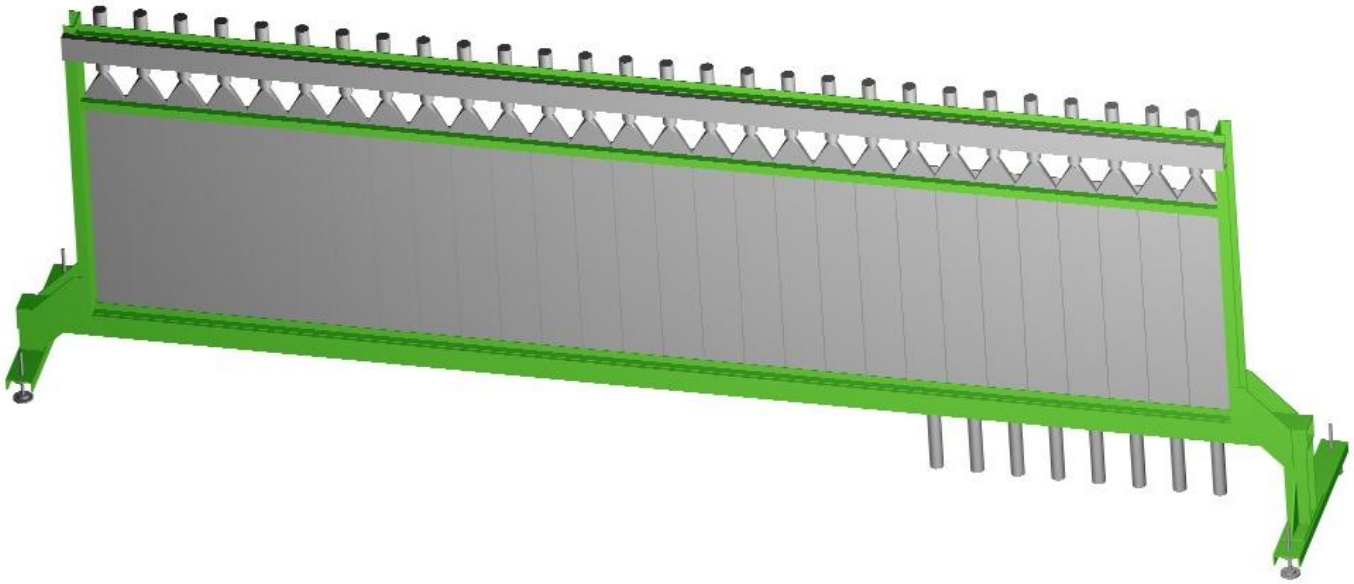
3.6x1.2x1.4(0.6) m3 (WxHxL), 30.8 ton

Absorber (2006)



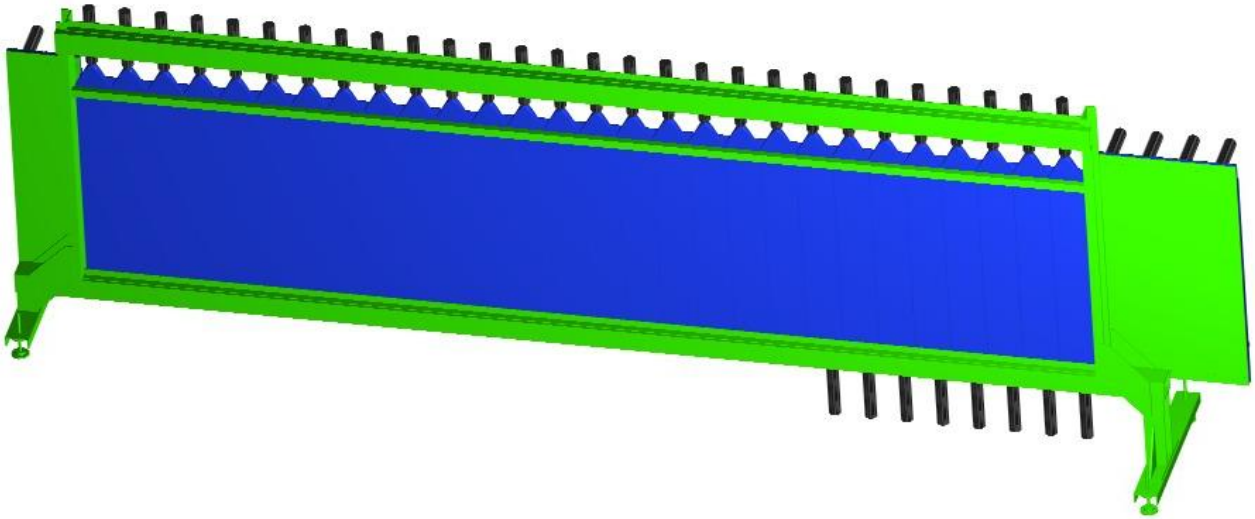
3.6x1.2x1.4(0.6) m3 (WxHxL) with additions, 33.3 ton

Muon scintillation detector (1998)



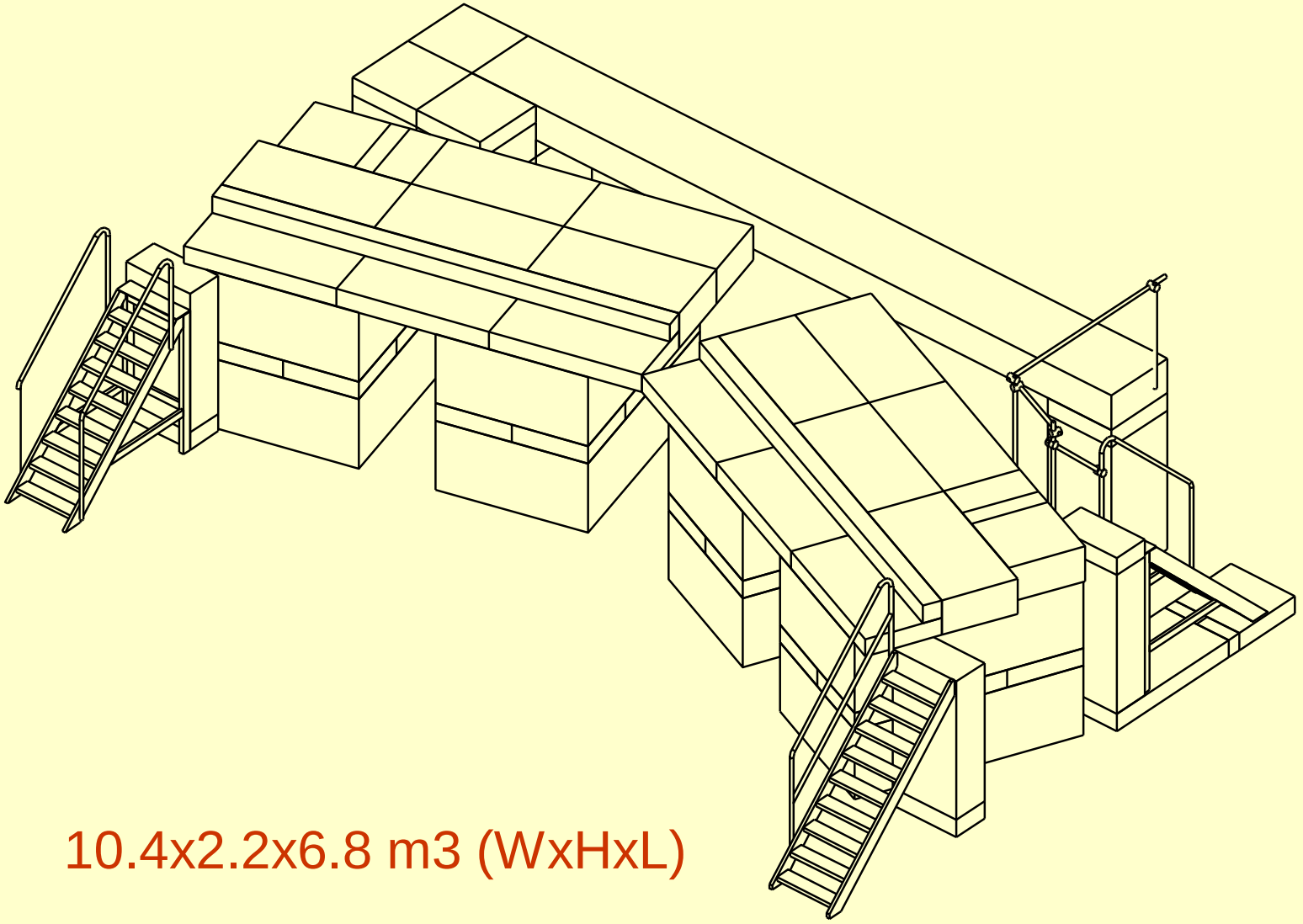
340x75 cm
Slab 12x75 cm
Scint. 5 mm
2 layers
28x2 counters
PMs FEU-85
Resol. 1.3 ns
Muons: 10%

Muon scintillation detector (2007)



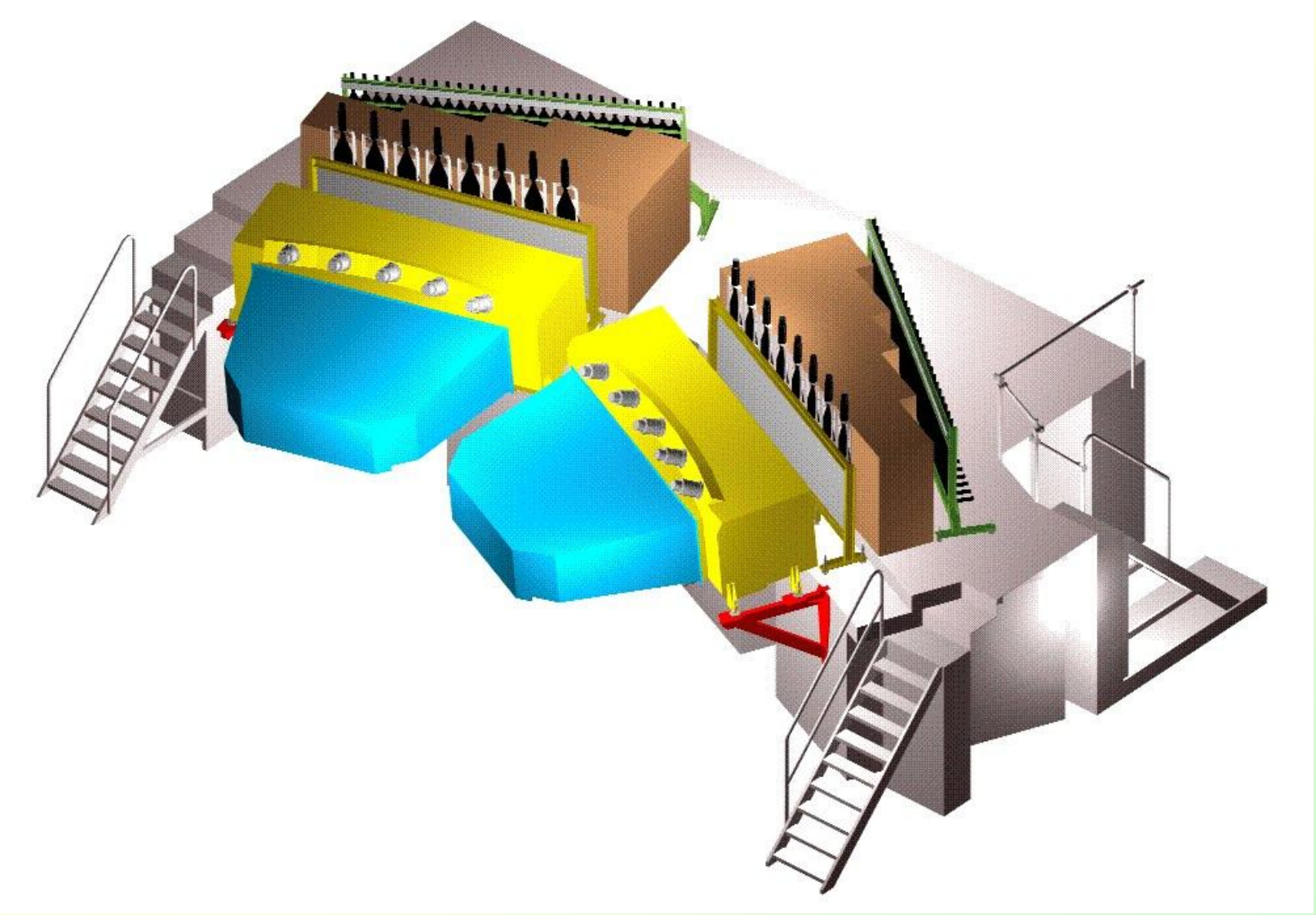
410x75 cm
New counters:
Int. 8 in two layers
Ext. 4 in two layers
New slabs:
12x88 cm
10 mm thick

Support for CH, PSH, AB, MU (1998)



10.4x2.2x6.8 m3 (WxHxL)

Downstream detectors CH, PSH, MU (1998)



Downstream detectors (2006)