Testing and Planning for the Usage of Lead-Tungstate Calorimeters at Jefferson Lab

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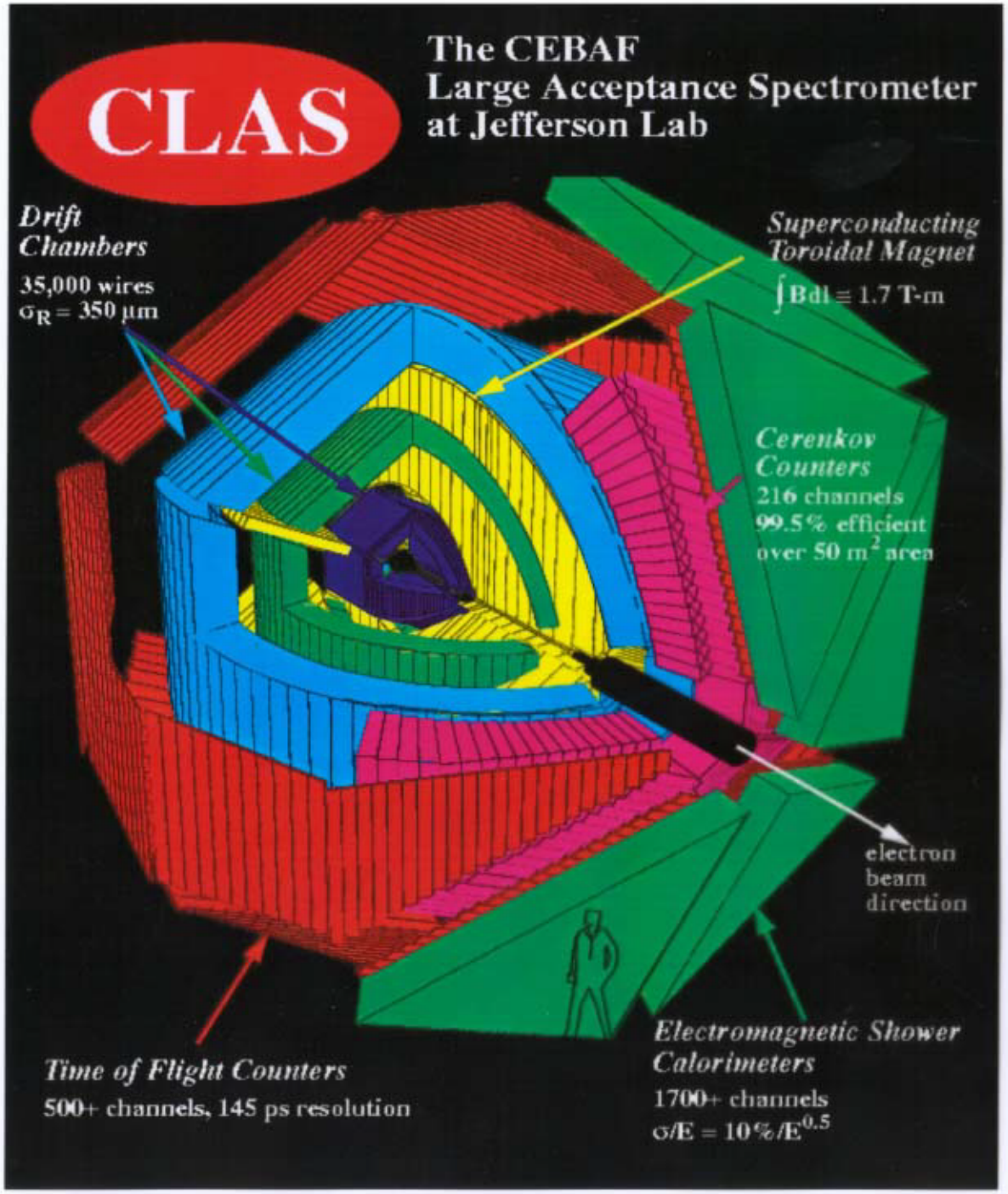
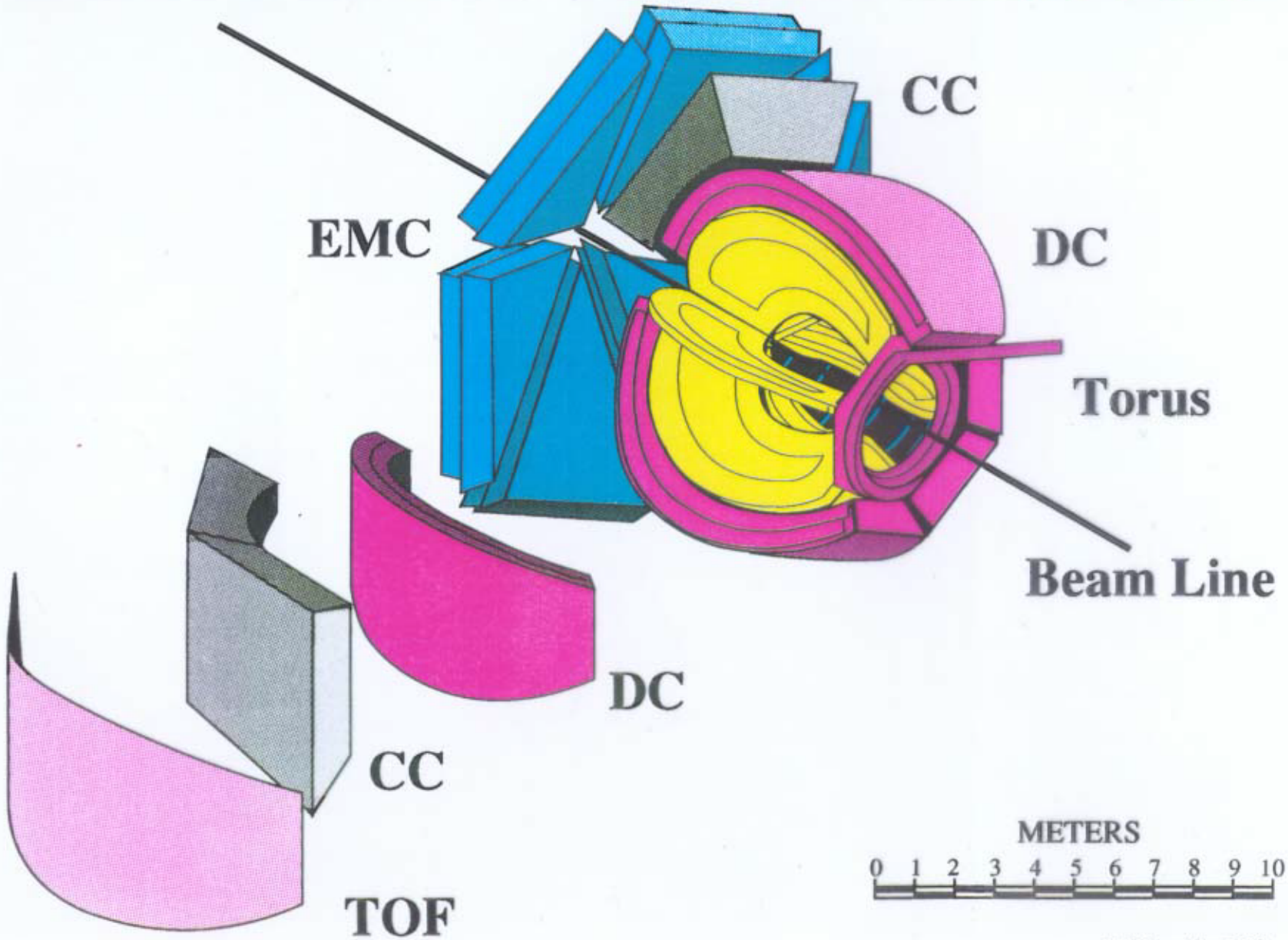
- CLAS (upgrade) (Cebaf Large Acceptance Spectrometer)
- PrimEx (Primakoff Experiment)
- Beam Tests (Tagged photon beam, 1-5 GeV)

CALOR 2000, Annecy, October 13, 2000

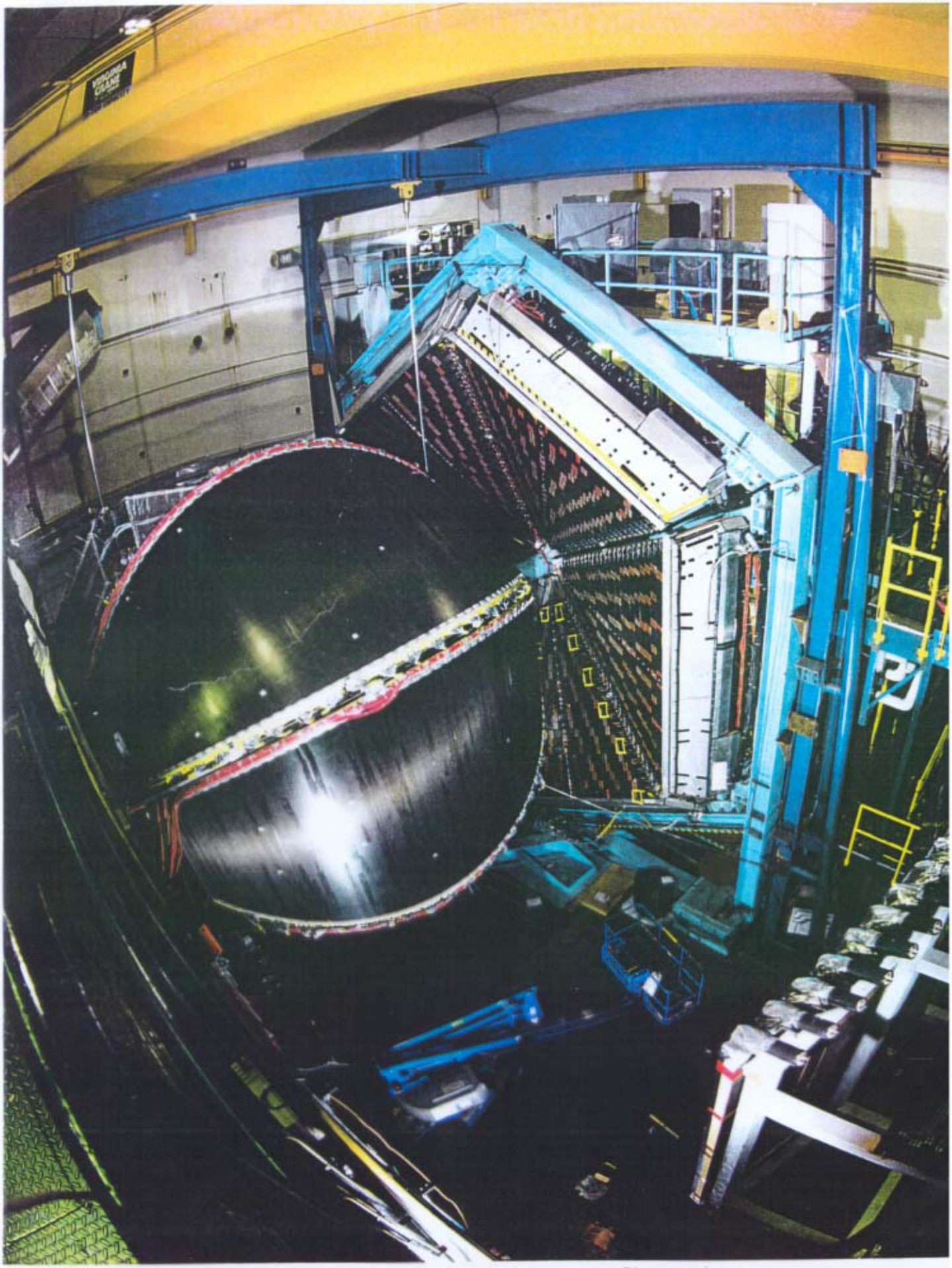

CLAS
The CEBAF
Large Acceptance Spectrometer
at Jefferson Lab
Drift
Chambers
35,000 wires
σ_R = 350 μm
Superconducting
Toroidal Magnet
$\int$ Bdl ≡ 1.7 T-m
Cerenkov
Counters
216 channels
99.5% efficient
over 50 m^2 area
electron
beam
direction
Time of Flight Counters
500+ channels, 145 ps resolution
Electromagnetic Shower
Calorimeters
1700+ channels
$\sigma/E = 10\%/E^{0.5}$

LARGE ACCEPTANCE SPECTROMETER

CEBAF



hallB/lasnectCim 2/3/92



CLAS PHYSICS PROGRAM AT HIGH ENERGY

With an electron beam at 11 GeV CLAS can address one of the most exciting physics problems in the structure of nucleons:

=> The mapping of the Generalized Parton Distributions of the nucleon

The Nucleon GPD Program

=> complete quark correlation functions
=> unpolarized/polarized GPD's
=> flavor-dependent GPD's

> Deep Virtual Meson Production (DVMP)

$ep \to e\pi^+ n$, $ep\pi^o/\eta$ (polarized) $(e\pi^+\Delta^o)$

$ep \to ep\rho^o$, $ep\omega$ (unpolarized)

$\vec{e}p \to e\pi^+ n$ (ϕ dependence !)

$ep \to eK^+\vec{\Lambda}$

> Deep Virtual Compton Scattering (DVCS)

$ep \to ep\gamma$, $\vec{e}p \to ep\gamma$ (ϕ dependence !)

> Kinematics $W > 2GeV$; $Q^2 > 2GeV^2$; $-t < 1\ GeV^2$

CLAS Upgrade – Central detector

- Move target upstream.

- Superconducting solenoid (up to 5 Tesla)
  - ⇨ shielding inner chambers from Moeller electrons.

- Central tracker ⇨ DC or straw tubes.

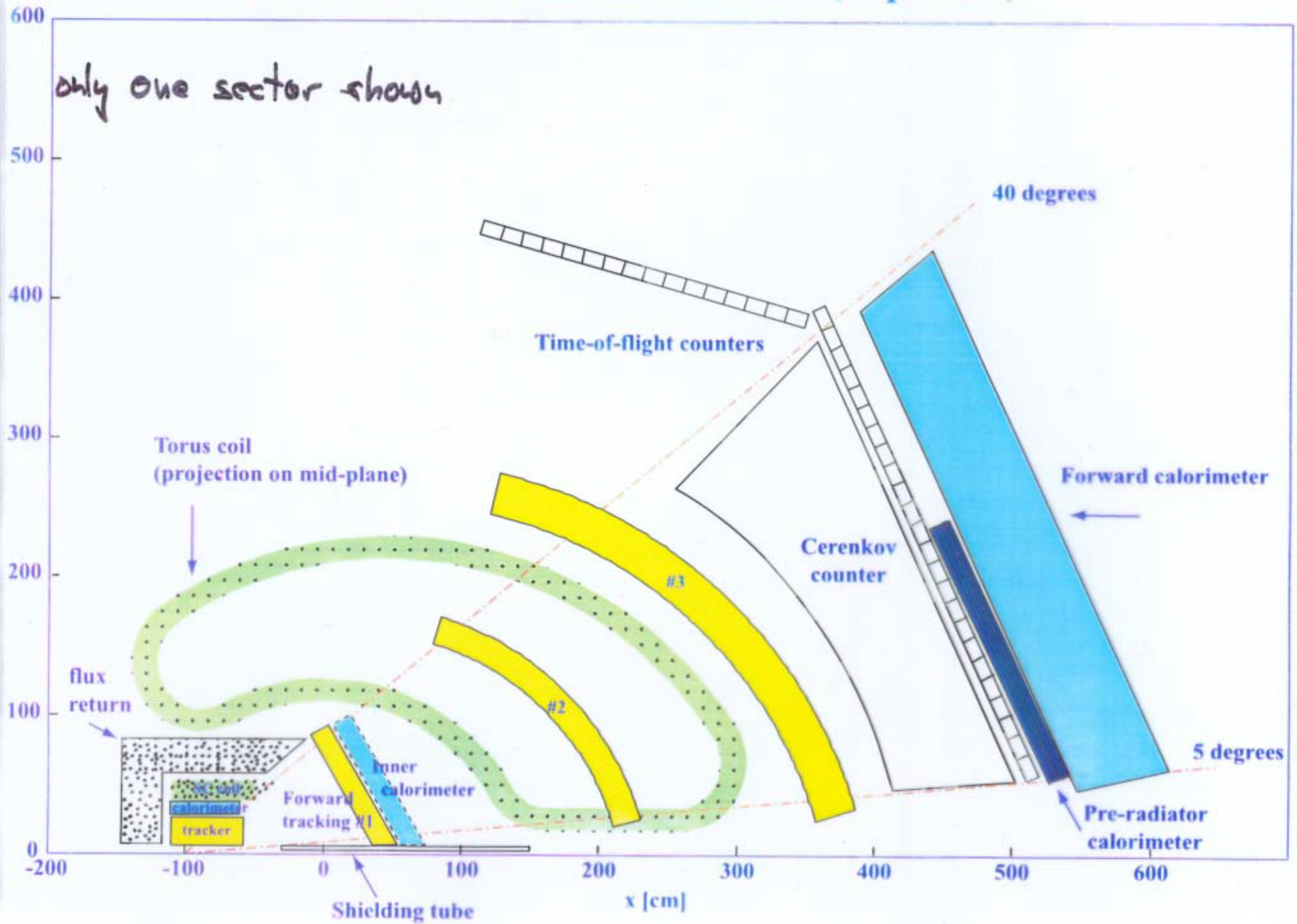
- Very compact EM Calorimeter.

- Improve Forward Calorimeter.

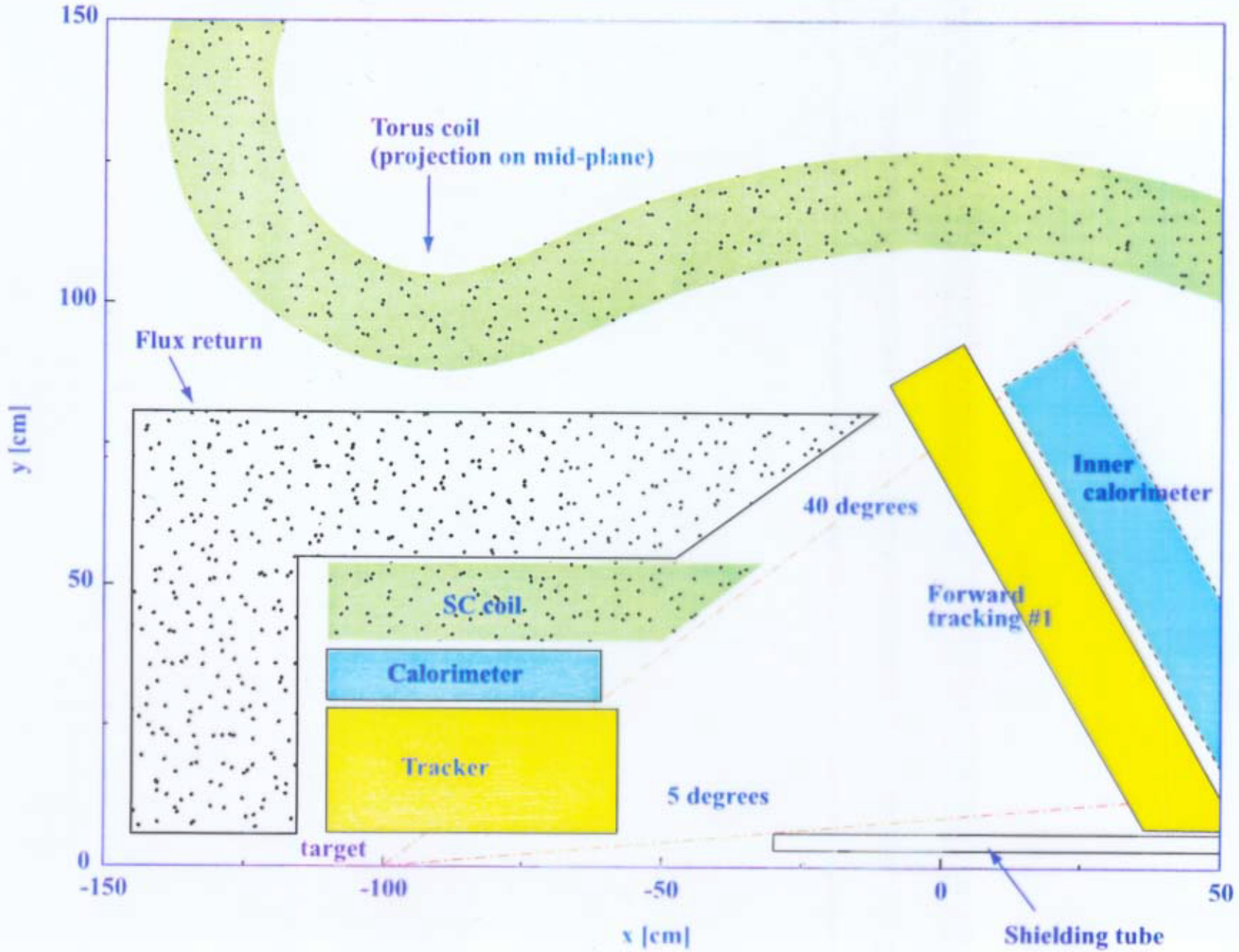
Complete ϕ coverage filling the front return yokes of the torus with a "compact" EM calorimeter.

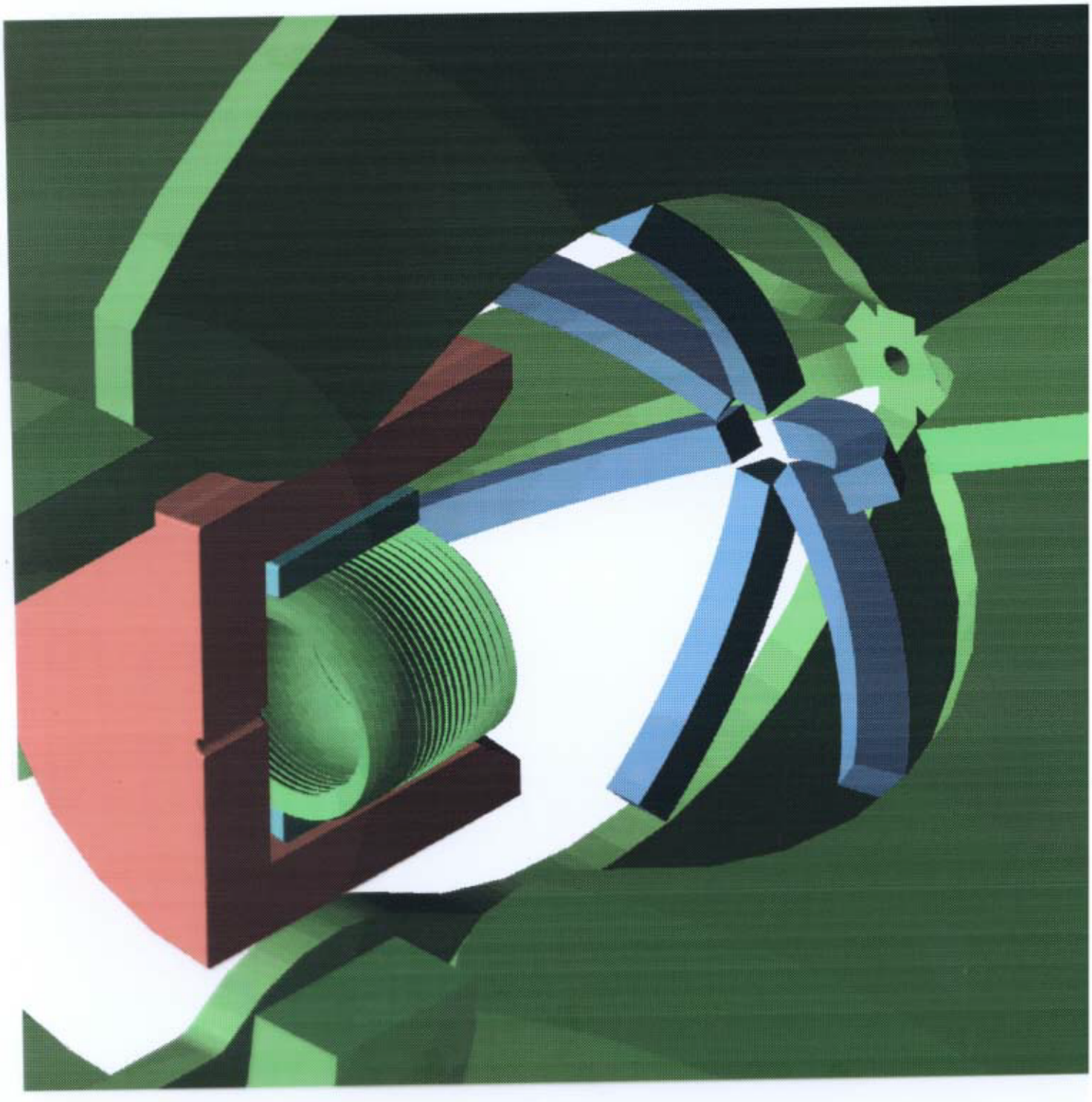
- ⇨ a few kG fringe magnetic field.
- ⇨ About 45 cm gap space
- ⇨ Difficult access
- ⇨ Vertex pointing geometry
- ⇨ Good granularity (~ 1.5 m from target)

CLAS UPGRADE CONCEPT (Top View)

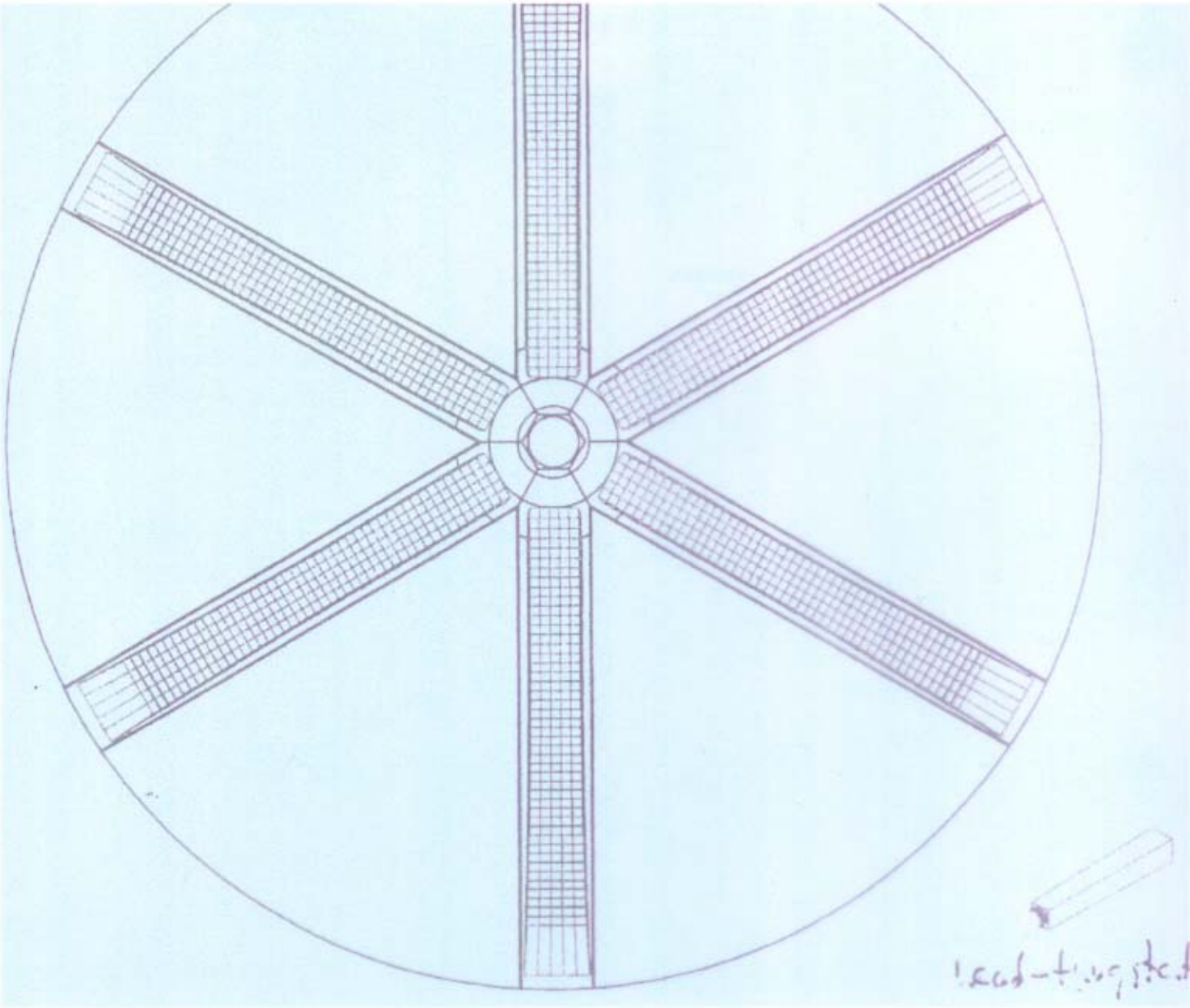


CLAS UPGRADE (Central Detector)





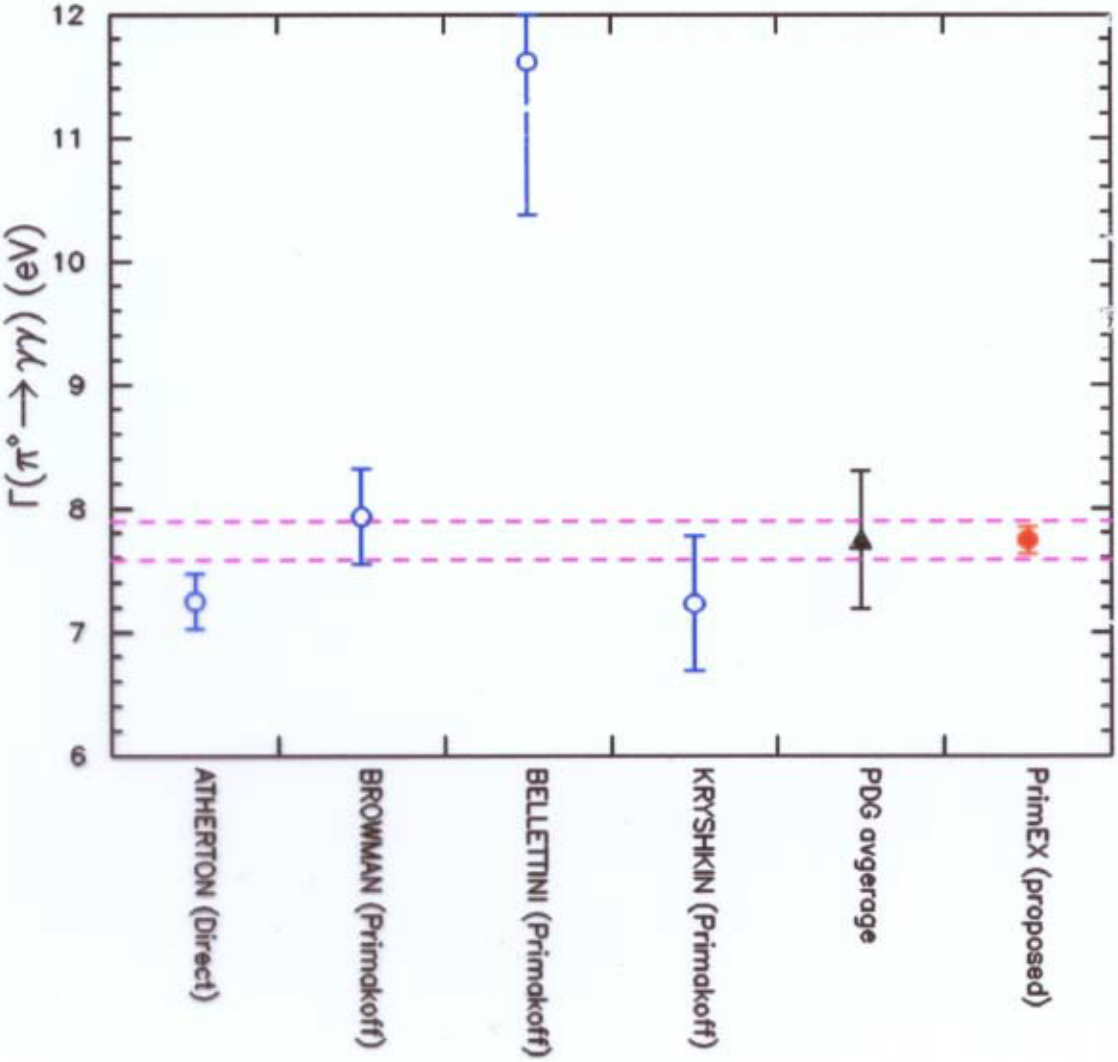
$20 \times 20 \times 180\ mm^3$



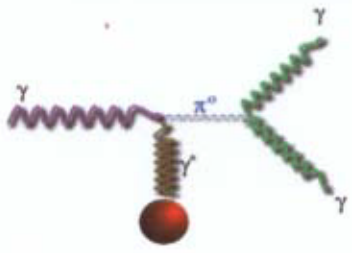
Physics Motivation

The π^o decay width is a fundamental prediction of confinement scale QCD:

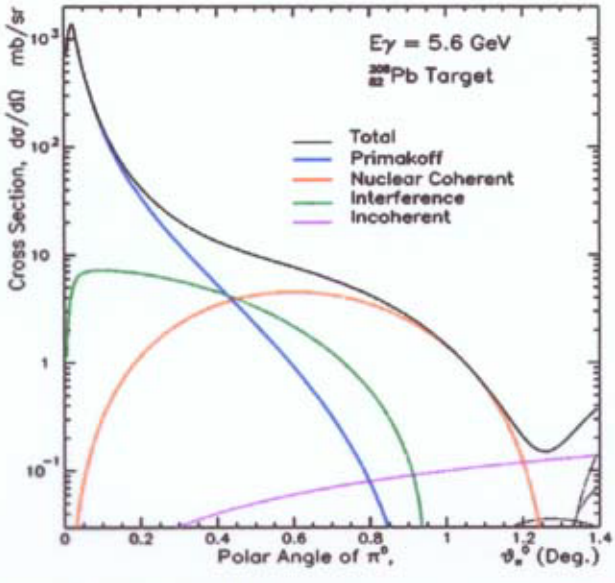
$$\Gamma(\pi^o \to \gamma\gamma) = \frac{\alpha^2 N_c^2 m_\pi^3}{576 \pi^3 f_\pi^2}$$



Primakoff Effect

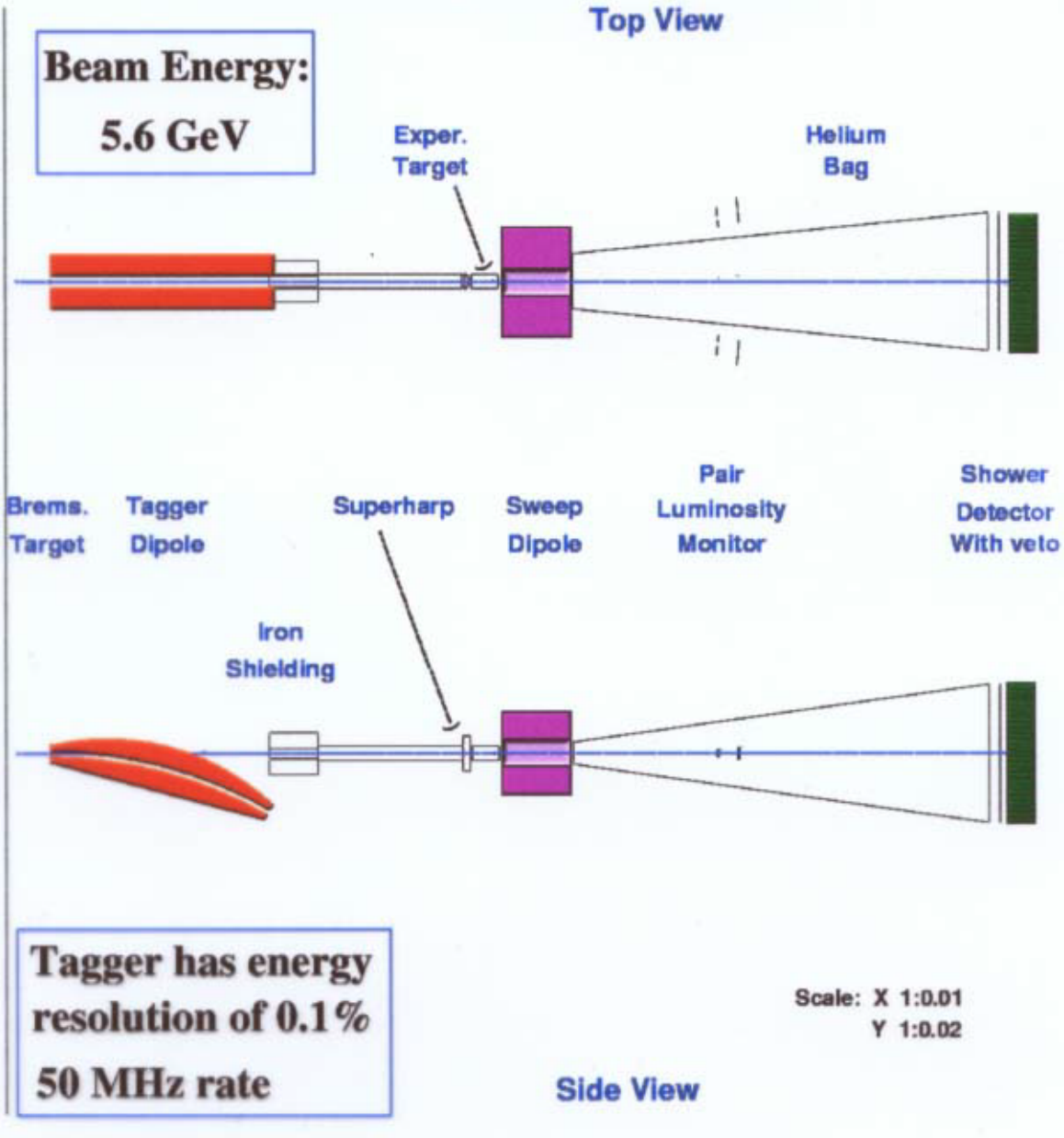


$$\frac{d^3\sigma}{d\Omega^3} = \Gamma(\pi^0 \to \gamma\gamma)\frac{8\alpha Z^2}{m_\pi^3}\frac{\beta_\pi^3 E_\gamma^4}{Q^4}|F_{e.m.}(Q)|^2 \sin^2\vartheta_\pi$$



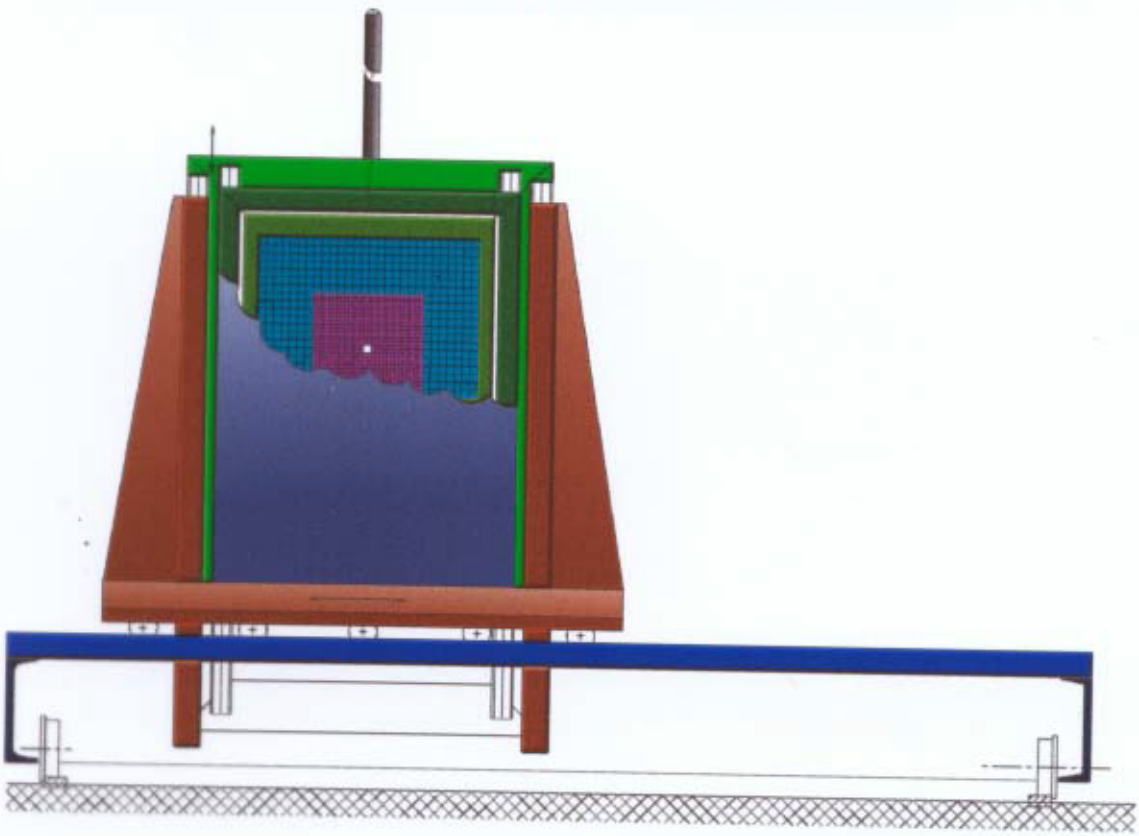
- ϑ –dependence will be used to separate Primakoff cross section from nuclear coherent π^o production and other backgrounds
- Z–dependence will be seen using 3 different nuclear targets: ^{12}C , ^{116}Sn , and ^{208}Pb
- E–dependence will be seen using photon tagger

PrimEx Experimental Layout



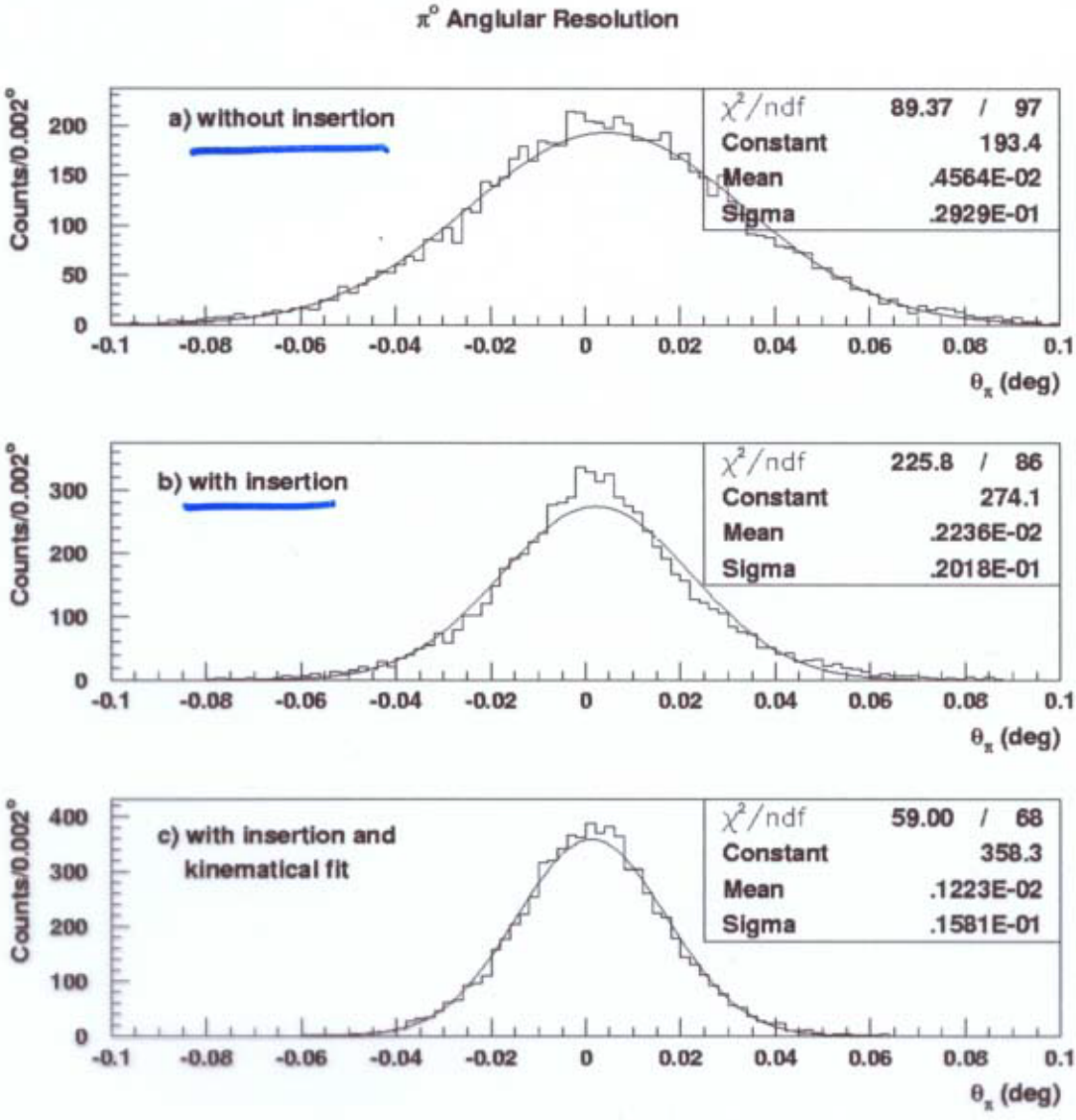
PrimEx

HYCAL– The PrimEx Hybrid Calorimeter



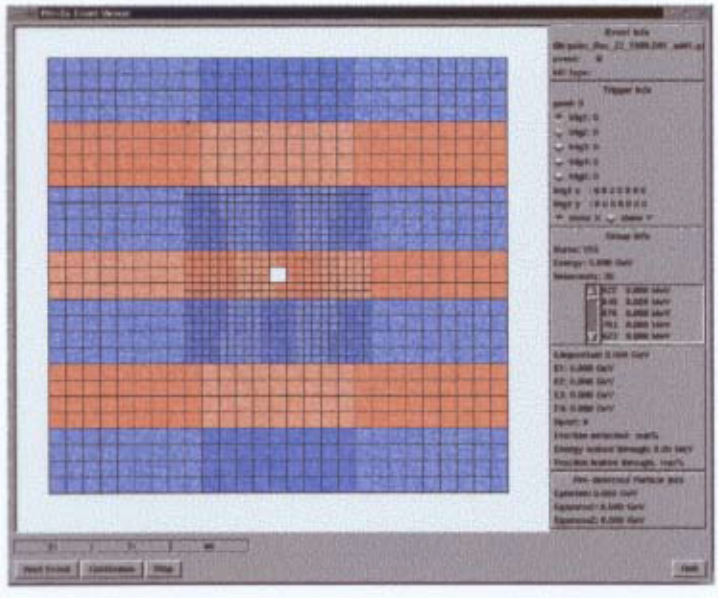
	Lead–glass (outer)	*$PbWO_4$ (inner)*
Mechanism	Cherenkov	Scintillator
Block dimensions (approx.)	4.25x4.25x34 cm^3	2.125x2.125x20 cm^3
Number of blocks	608	480 → 1000
Density	3.85 g/cm^3	8.28 g/cm^3
Moliere Radius	3.6 cm	2.0 cm
Radiation Length	2.7 cm	0.89 cm

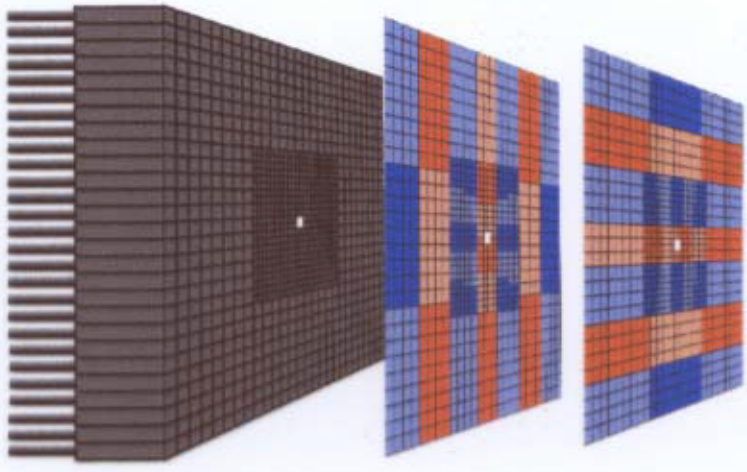
π^o Angular Resolution of the Calorimeter



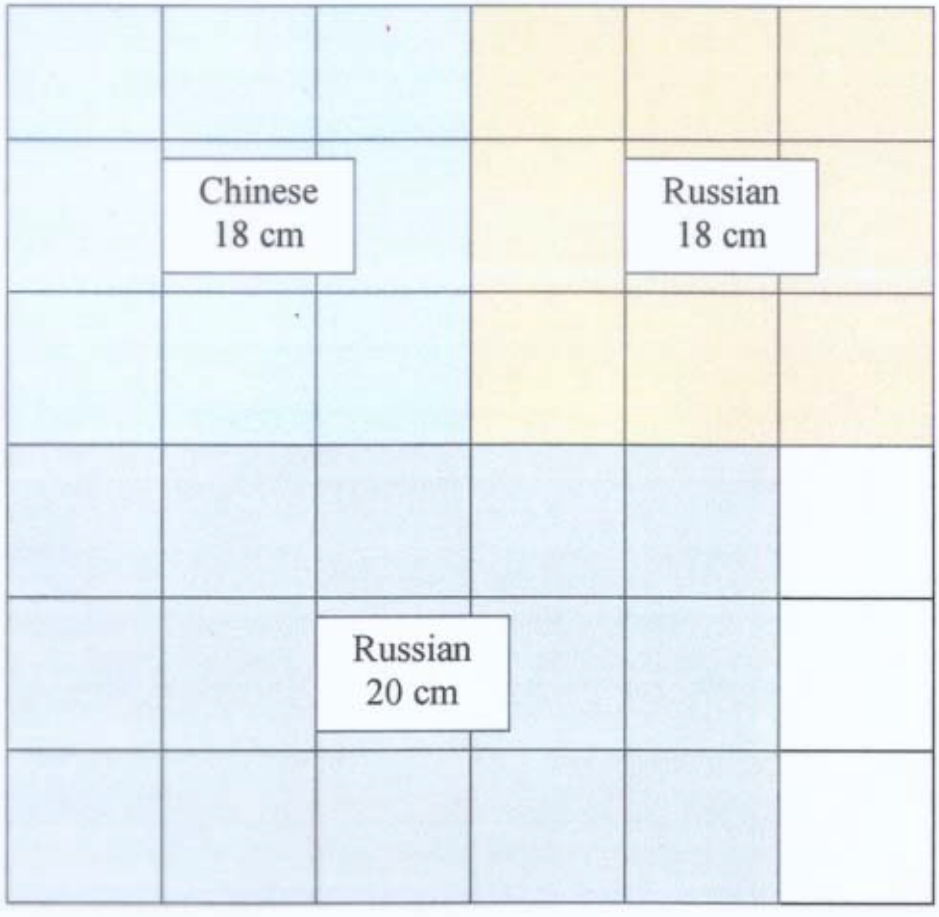
Electronic Trigger

- **2.5° minimum opening angle ⇒ 30 cm separation of photons at calorimeter face**
- **Coincidence rate of ~10 Hz**





Beam Test



* All 20x20 mm^2 face

Shangai

Properties of $PbWO_4$ Crystals (Pre-production)

Crystal number	Longitudinal transmission T(%)		Transversal transmission for T=5% Δ λ *1	Light yield Before irradiation LY(pe/MeV)*2		LY(100ns)/ LY(1000ns) (%)	Light yield after irradiation *3 LY(pe/MeV)		Changes on light yield after irradiation (%)		Geometrical size *4 (20mm+A)x(20mm+B)x(180mm+L)		
	420nm	600nm		100ns	1000ns		100ns	1000ns	100ns	1000ns	A (0.01mm)	B (0.01mm)	L (0.01mm)
H1	60.90	76.35	3.4	9.7	9.9	98	9.5	9.7	-2.1	-2.0	2	2	-22
H2*5	64.49	74.73	1.7	12.1	12.3	98	11.4	11.6	-5.8	-5.7	3.5	4	4
H3	65.76	76.02	2.6	12.4	12.6	98	11.8	12.0	-4.8	-4.8	0	-1	3
H4	62.42	75.96	1.7	10.1	10.3	98	10.0	10.2	-1.0	-1.0	-1	1	4
H5	66.09	75.34	1.4	12.4	12.6	98	11.7	11.9	-5.6	-5.6	3	2	-18
H6	66.20	75.71	1.1	12.0	12.2	98	11.3	11.5	-5.8	-5.7	-2	-1	-18
H7	69.81	79.26	1.7	12.4	12.6	98	11.7	11.9	-5.6	-5.6	-2	1	-19
H9	61.78	77.03	2.0	10.6	10.8	98	10.2	10.4	-3.8	-3.7	0	-1	2
H11	54.13	76.42	3.4	11.1	11.3	98	10.9	11.1	-1.8	-1.8	2	0	4

Comment:

All the parameters in the above table were measured at 20℃

*1 For 5 measurements every 4 cm, the first one at 1 cm from the end with ID engraved.

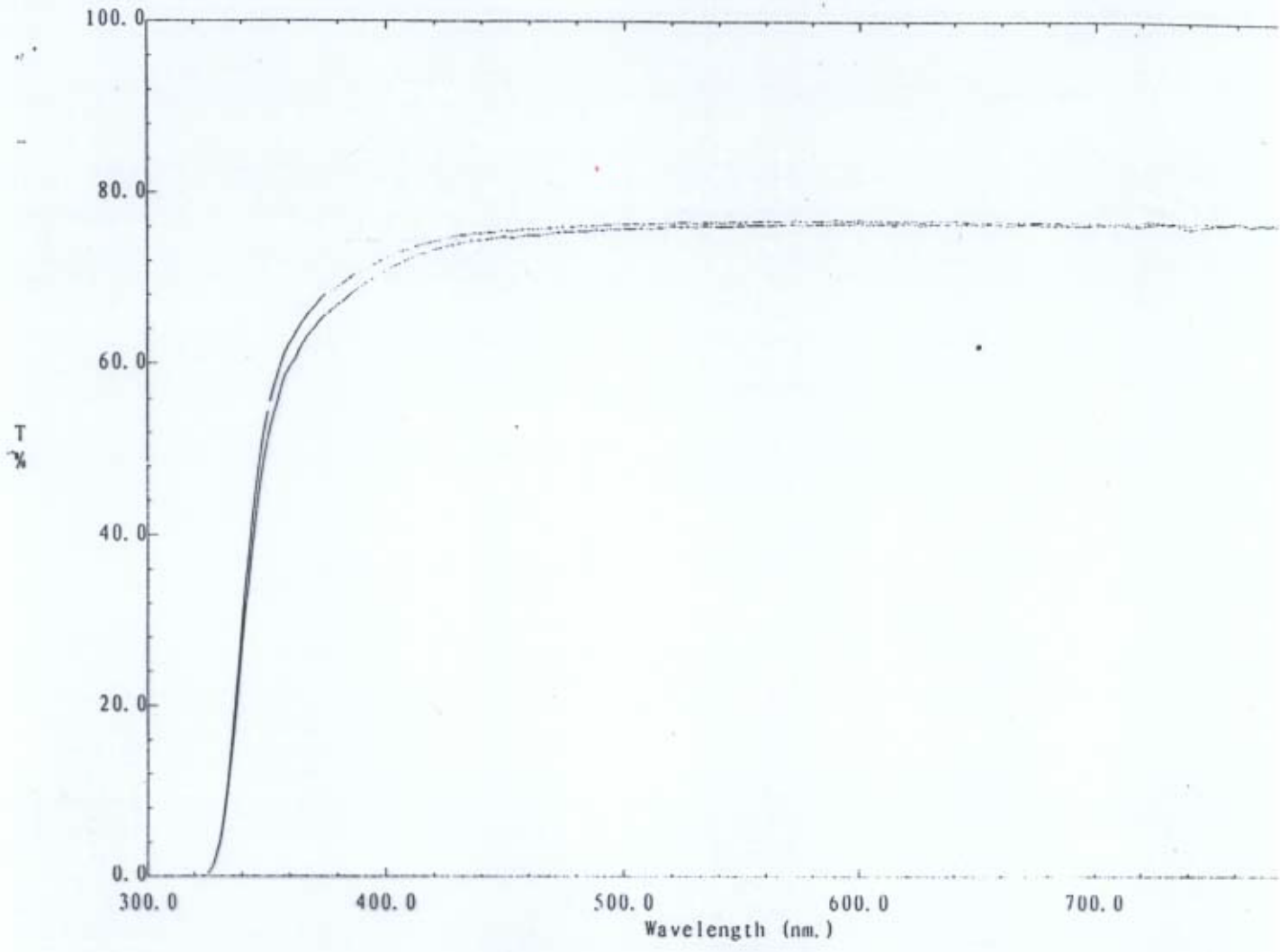
*2 Light yield were measured with a Philips XP2262B photomultitube.

*3 Dose of irradiation: 35rad/h x 70h = 2450rad (lateral)

*4 Both A, B are the minimum value from 5 measurements at different point, the maximum is less than +0.05mm.
L are the minimun value from 5 measurements, the maximum is less than +0.3mm.

*5 Crystal with number "H2" is damaged, to be replaced later.

China Institute of Atomic Energy Sept.,4,1999



Point Pick HE1-4 (13cm)
transversal transmission

No.	Wavelength (nm.)	T%
1	350.00	53.55
2	420.00	74.25
3	520.00	76.45
4	600.00	76.88
5	800.00	76.70

99.8.10 PM

Point Pick HE1-5 (17cm)
transversal transmission

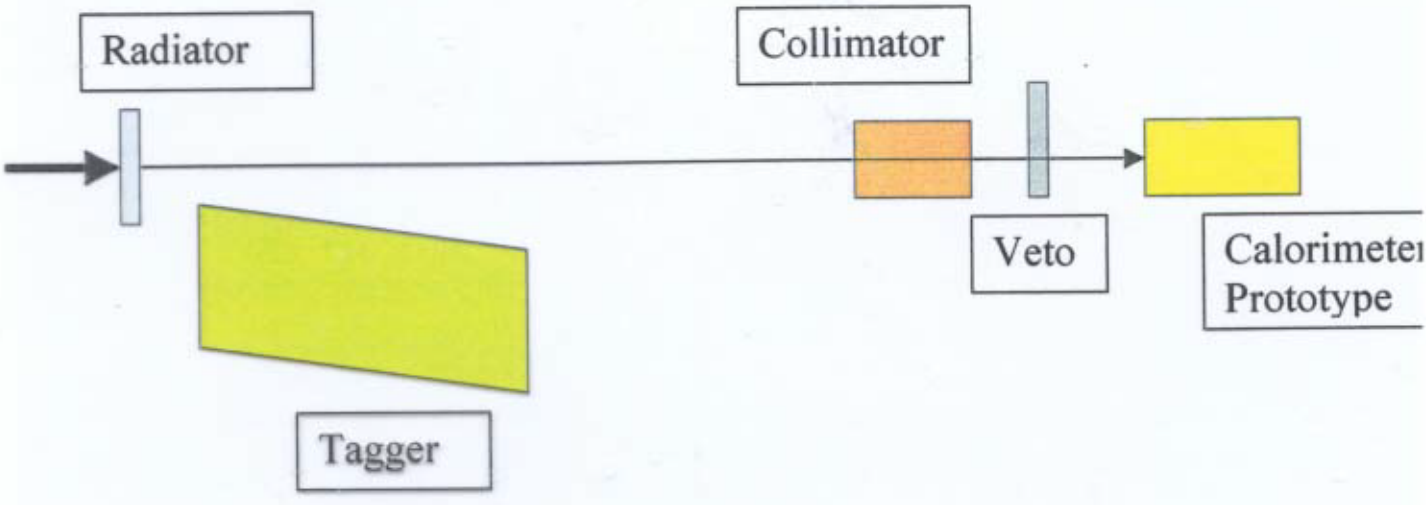
No.	Wavelength (nm.)	T%
1	350.00	50.35
2	420.00	73.30
3	520.00	76.11
4	600.00	76.51
5	800.00	76.89

Purchase Order # PO-10063

Technical characteristics PWO Crystals
20×20×200 mm

N^0	Production number	Light Yield (LY) phe/MeV	LY (100 ns) / LY (1000 ns)	Induced absorption (m^{-1}) measured for reference sample (^{60}Co; 1.22 keV; 10 krad/min; t_{irr}=10 min)
1	388	10.8	96.6	0.18
2	396	12.1	94.8	0.45
3	393	11.1	94.3	0.31
4	395	11.2	94.6	0.22
5	386	11.0	96.6	0.61
6	387	11.0	96.7	0.5
7	394	10.5	95.1	0.48
8	389	10.7	96.8	0.39
9	397	11.0	95.6	0.41

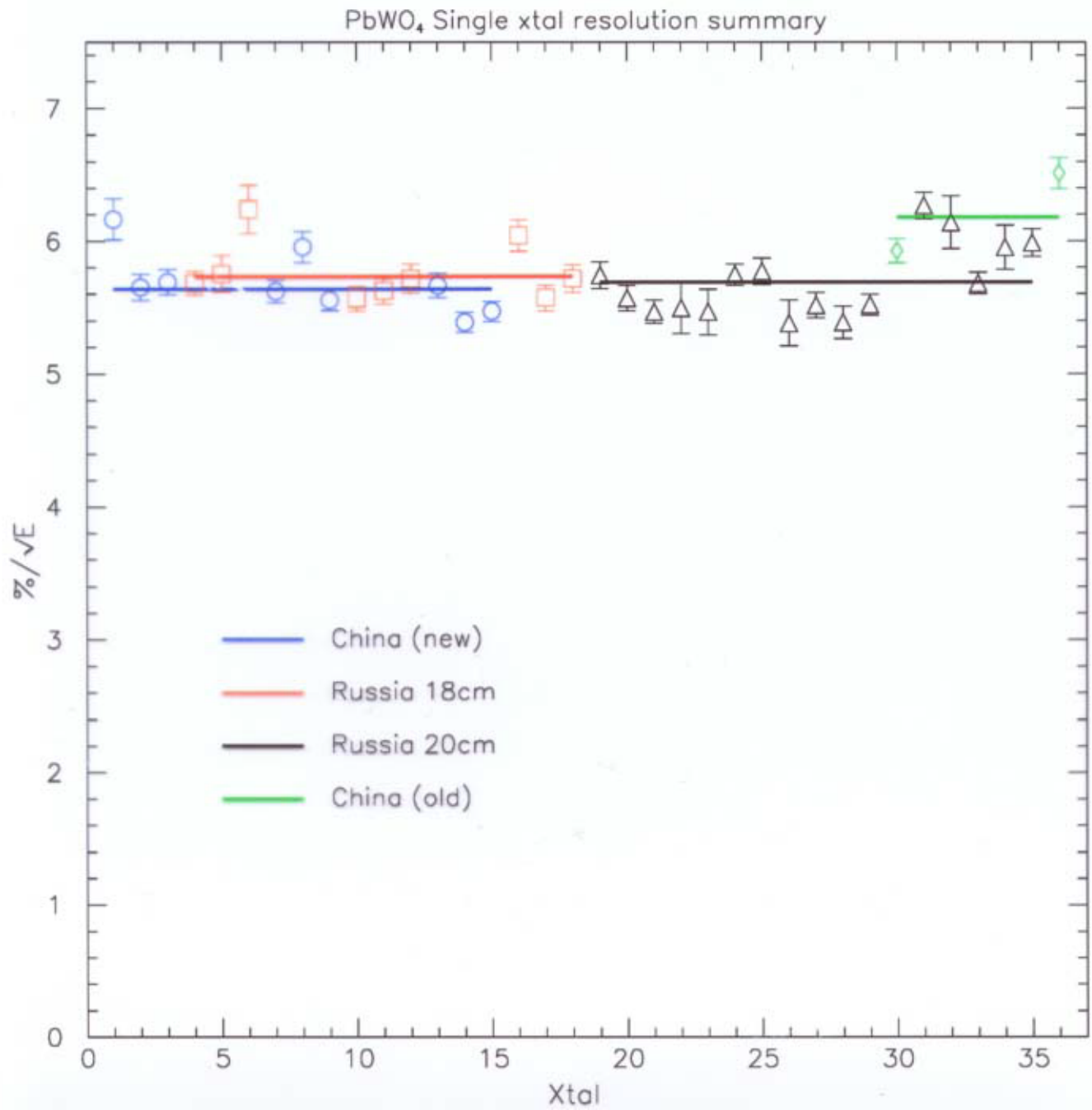
- 5.65 GeV Electron beam
- 95%-25% E_{beam} Photon Energy (0.1% resolution)
- 10^4 γ/s – 1mm collimation



$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}}$$

"a" matrix

6.16±1.06%	5.65±0.66%	5.69±0.62%	5.68±0.59%	5.76±0.95%	6.24±1.23%
5.62±0.56%	5.96±0.79%	5.56±0.52%	5.57±0.63%	5.63±0.65%	5.72±0.77%
5.67±0.63%	5.39±0.50%	5.47±0.51%	6.04±0.77%	5.57±0.63%	5.72±0.68%
5.74±0.68%	5.57±0.65%	5.46±0.58%	5.49±1.29%	5.46±1.17%	5.75±0.53%
5.77±0.67%	5.38±1.16%	5.52±0.64%	5.39±0.82%	5.52±0.51%	5.92±0.61%
6.27±0.66%	6.14±1.32%	5.68±0.52%	5.95±1.13%	5.99±0.71%	6.51±0.77%


PbWO4 Single xtal resolution summary
%/√E
Xtal
China (new)
Russia 18cm
Russia 20cm
China (old)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35