A Detector for a PSI Experiment

T. Mori
ICEPP, University of Tokyo

ICHEP, Amsterdam, July 2002

The Detector for the New $\mu^+ \to e^+\gamma$ Experiment

MEG

T. Mori
representing the MEG Collaboration

ICHEP, Amsterdam, July 2002

Physics

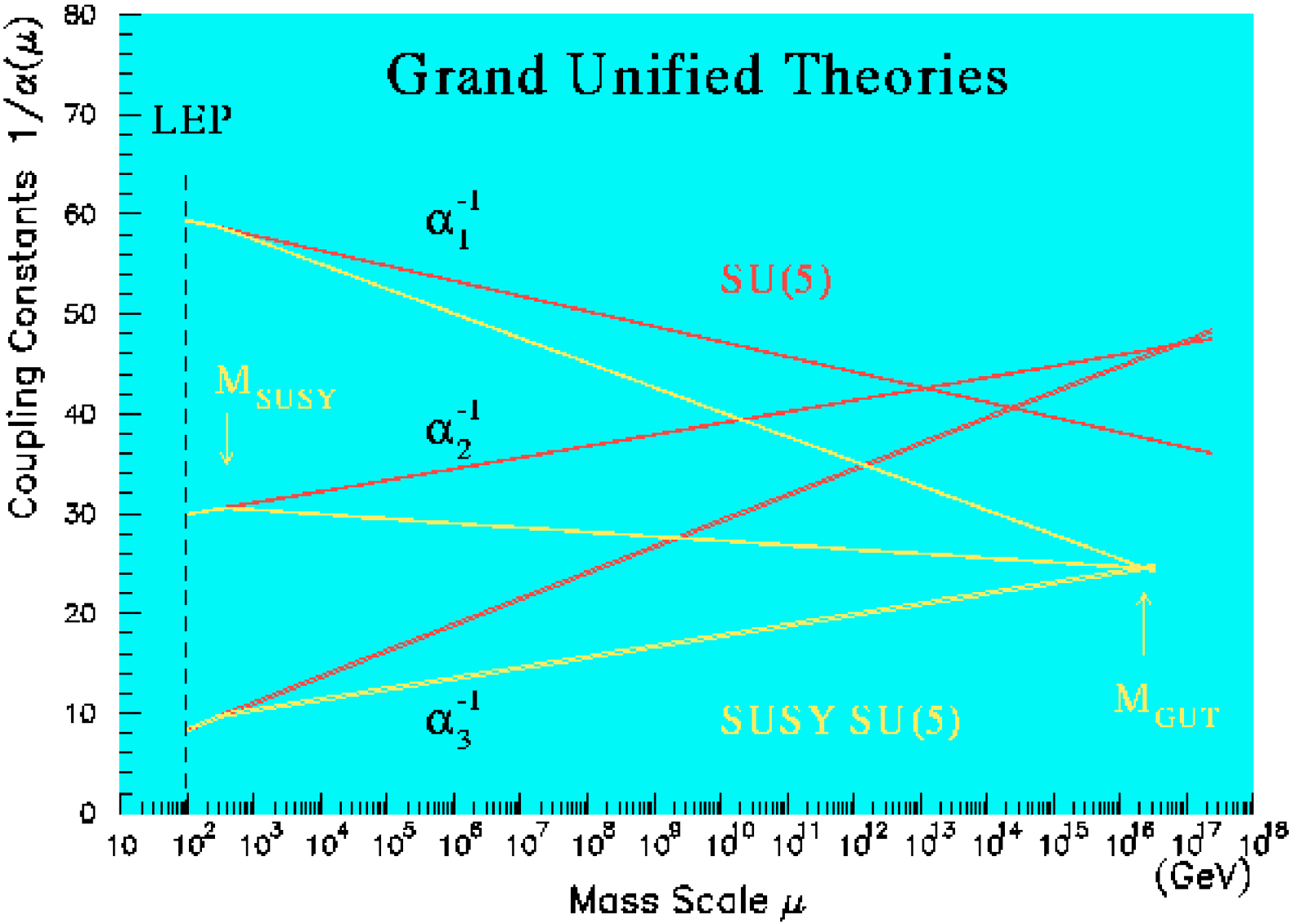
Discover or place the most stringent limit on the lepton-flavor-violating process $\mu^- \to e^-$ to probe the new physics

- **Supersymmetric Grand Unification**
- **Neutrino Oscillations**

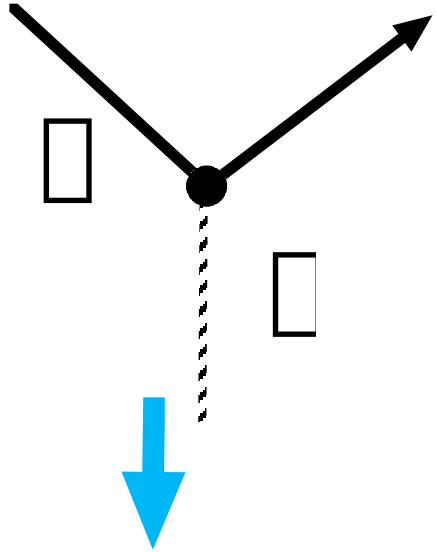
They could add up to give a higher BR.

cf. present limit $= 1.2 \times 10^{-11}$

SUSY GUT predicts $\not{L}/\not{B}$ $e\not{L}$ $10^{-11} \sim 10^{-14}$



Muon g-2



large B.R. for

$\mu \to e\gamma$

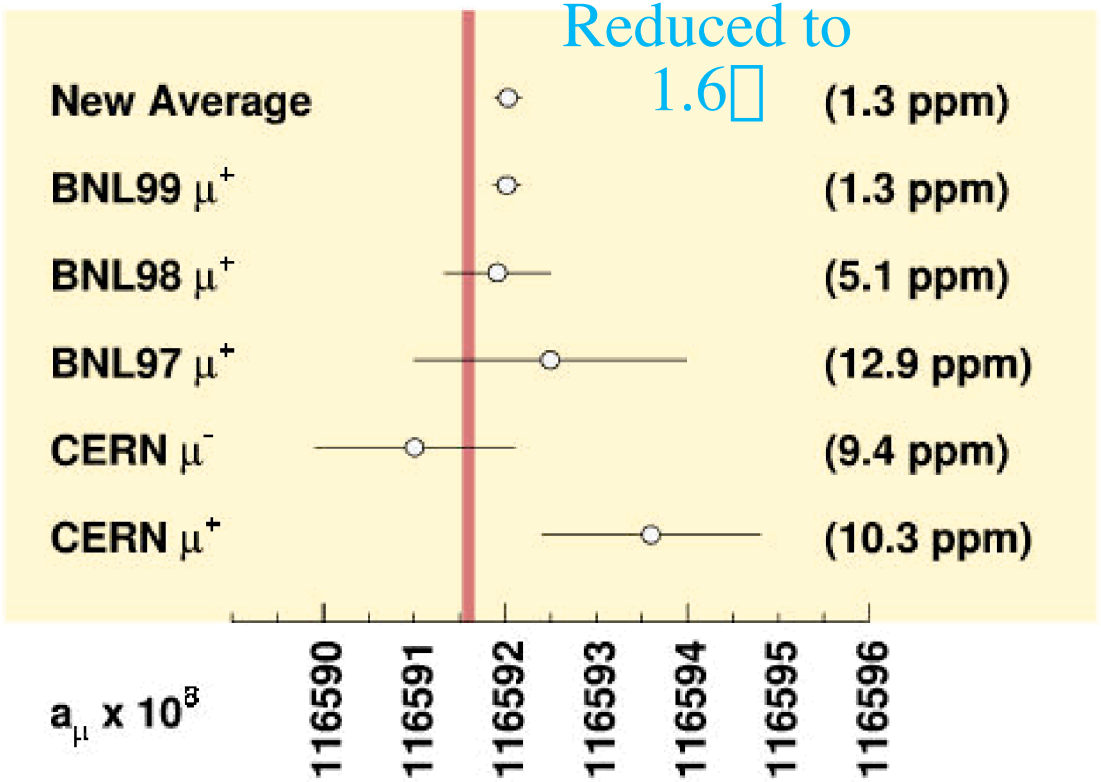
$\sim 10^{-12}$

$$a_\mu(\text{'99}) = 11\,659\,202\,(14)(6) \times 10^{-10}\ (1.3\ \text{ppm})$$

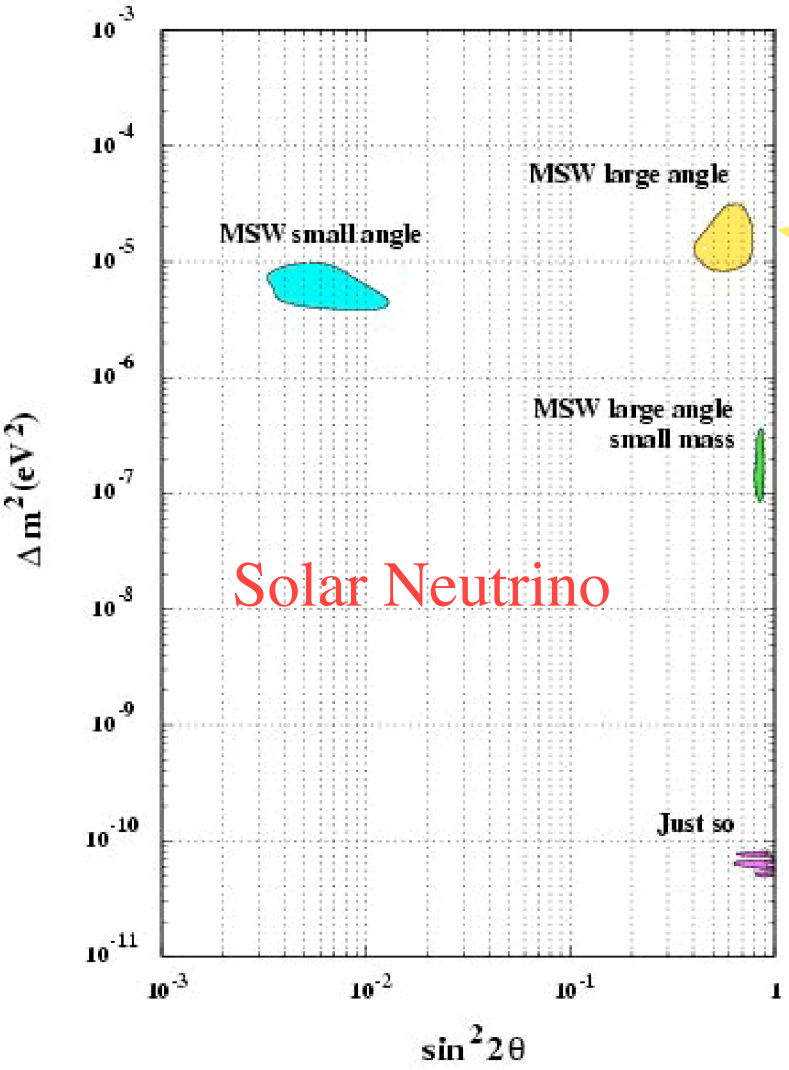
$$a_\mu(\text{SM}) = 11\,659\,160\,(7) \times 10^{-10}\ (0.6\ \text{ppm})$$

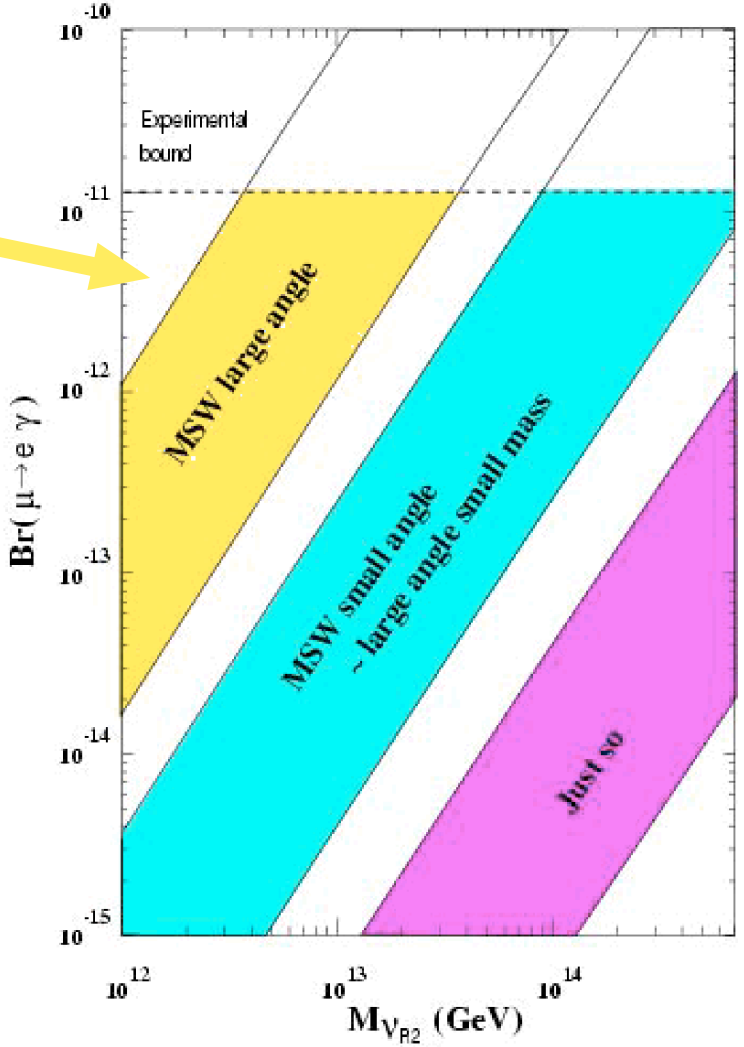
$$a_\mu(\text{'99}) - a_\mu(\text{SM}) = 42\,(17) \times 10^{-10}$$

Reduced to 1.6σ



Neutrino Oscillation → $\mu_L \to e_L$

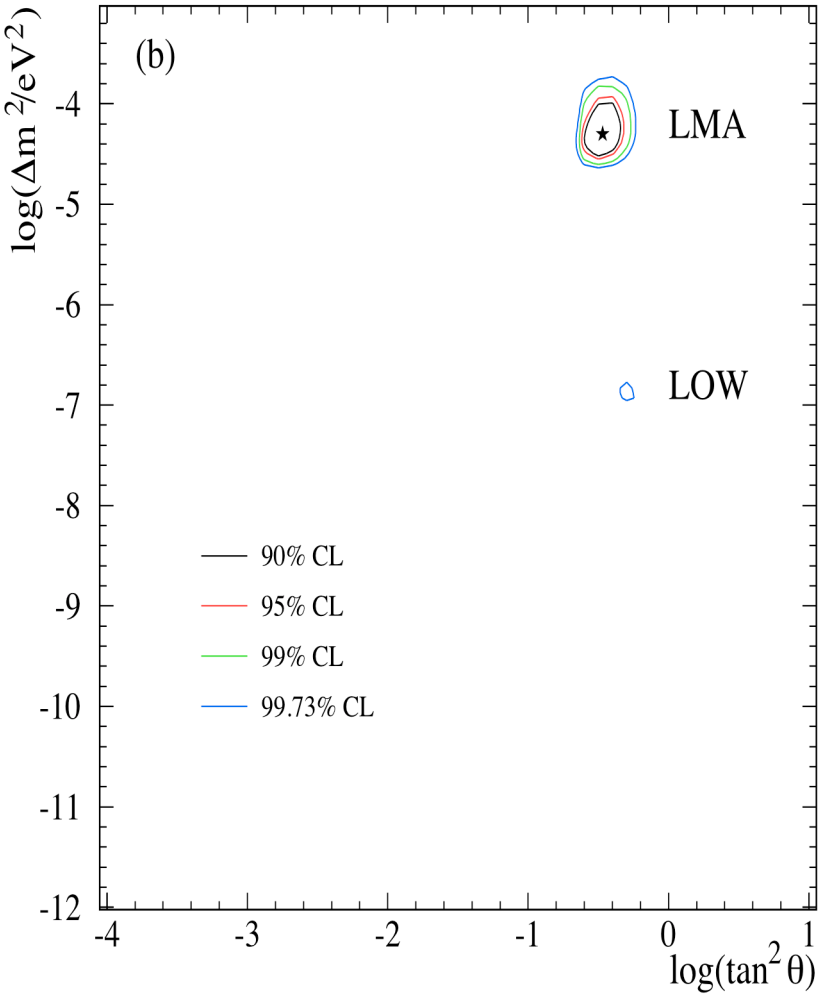




Hisano, Nomura 1998

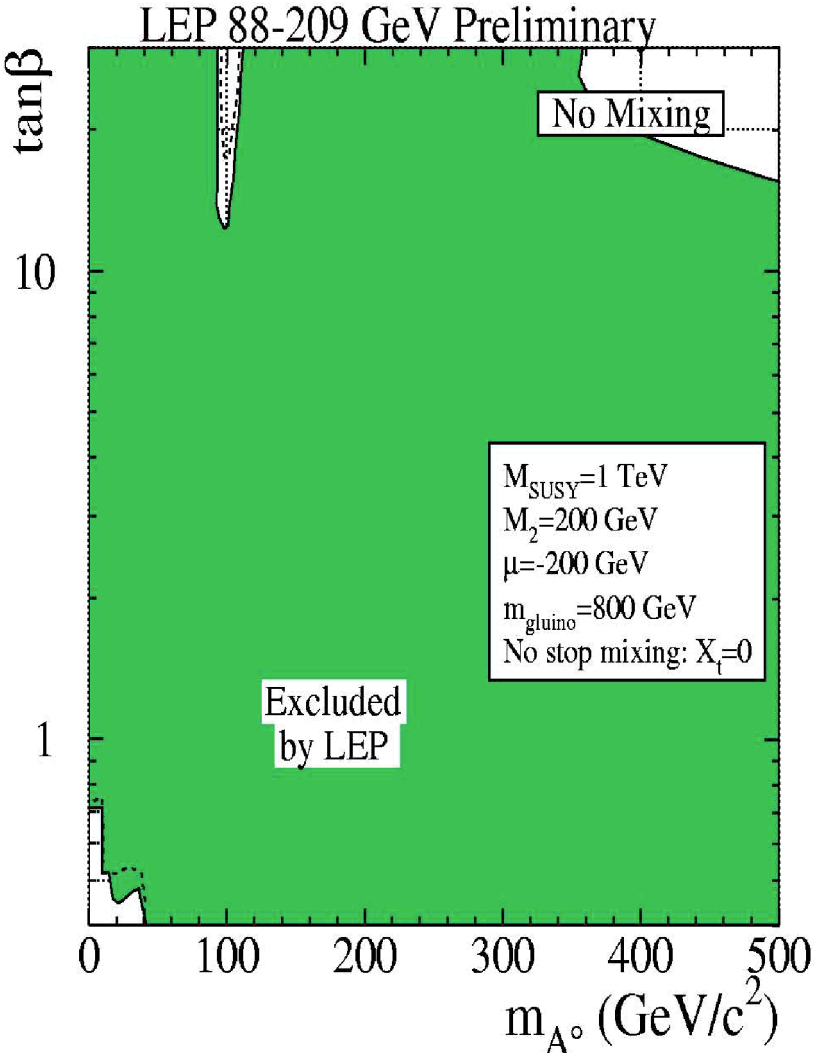
SuperK + SNO etc.

→ Large Mixing Solution



No SUSY Discovered at LEP

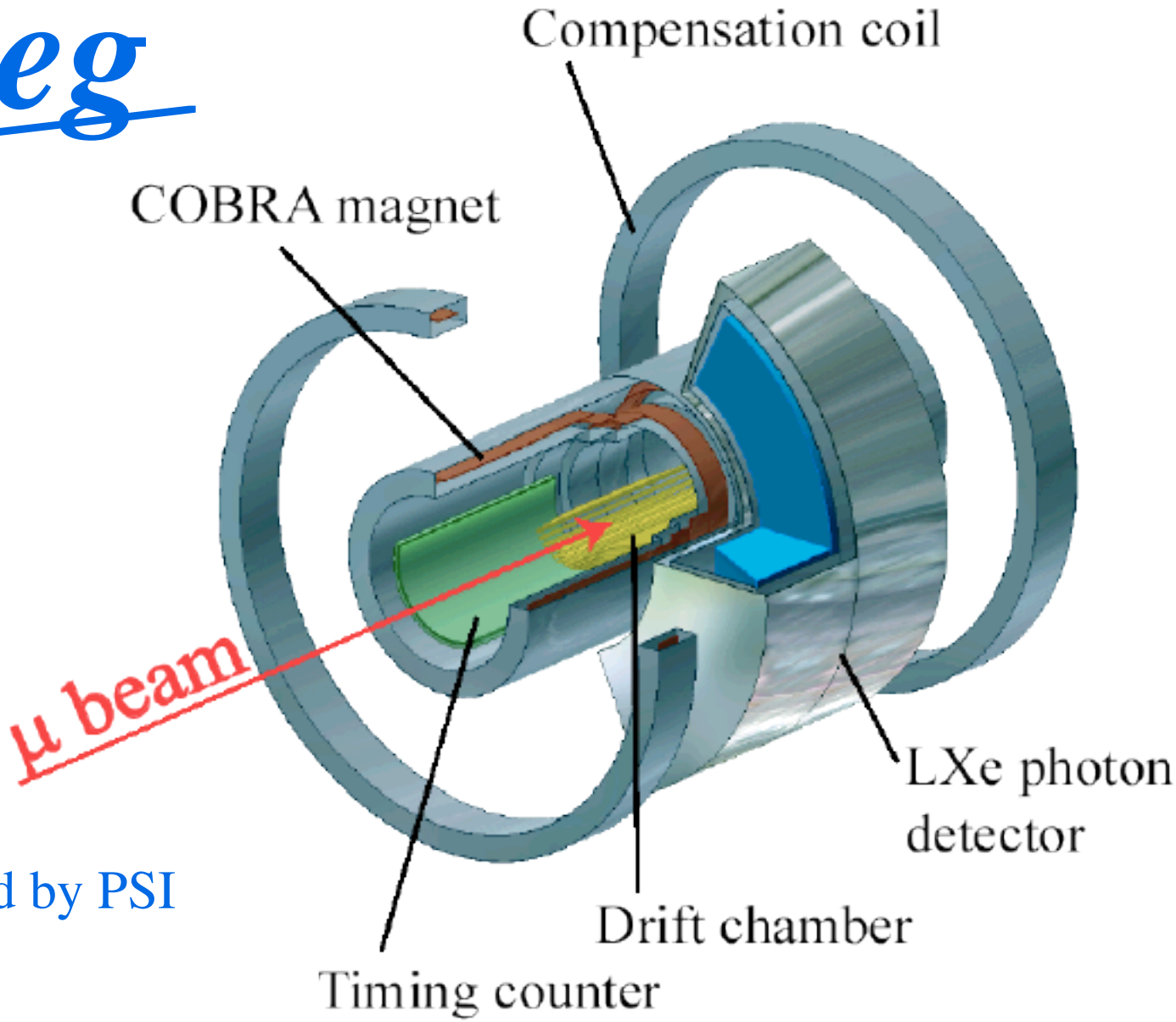
→ Small tan□ Excluded



Physics:

The expectation for the experiment
is now
much higher than ever !

Meg



Proposal
Approved by PSI
in 1999

The *MEG* Collaboration

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Japan - Switzerland - Italy - Russia

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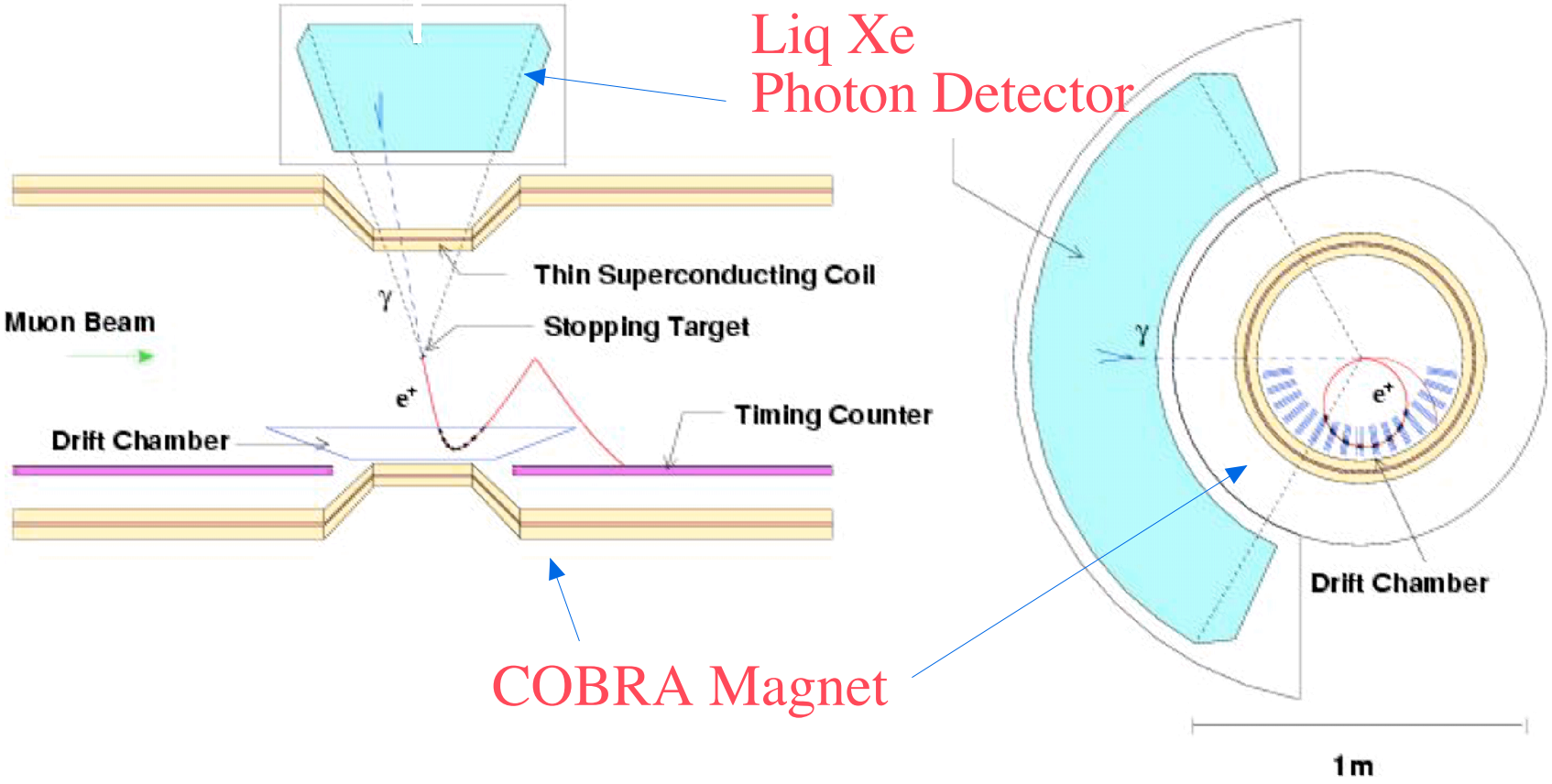
High Rate Experiment

If aiming at Br = 10^{-14} :

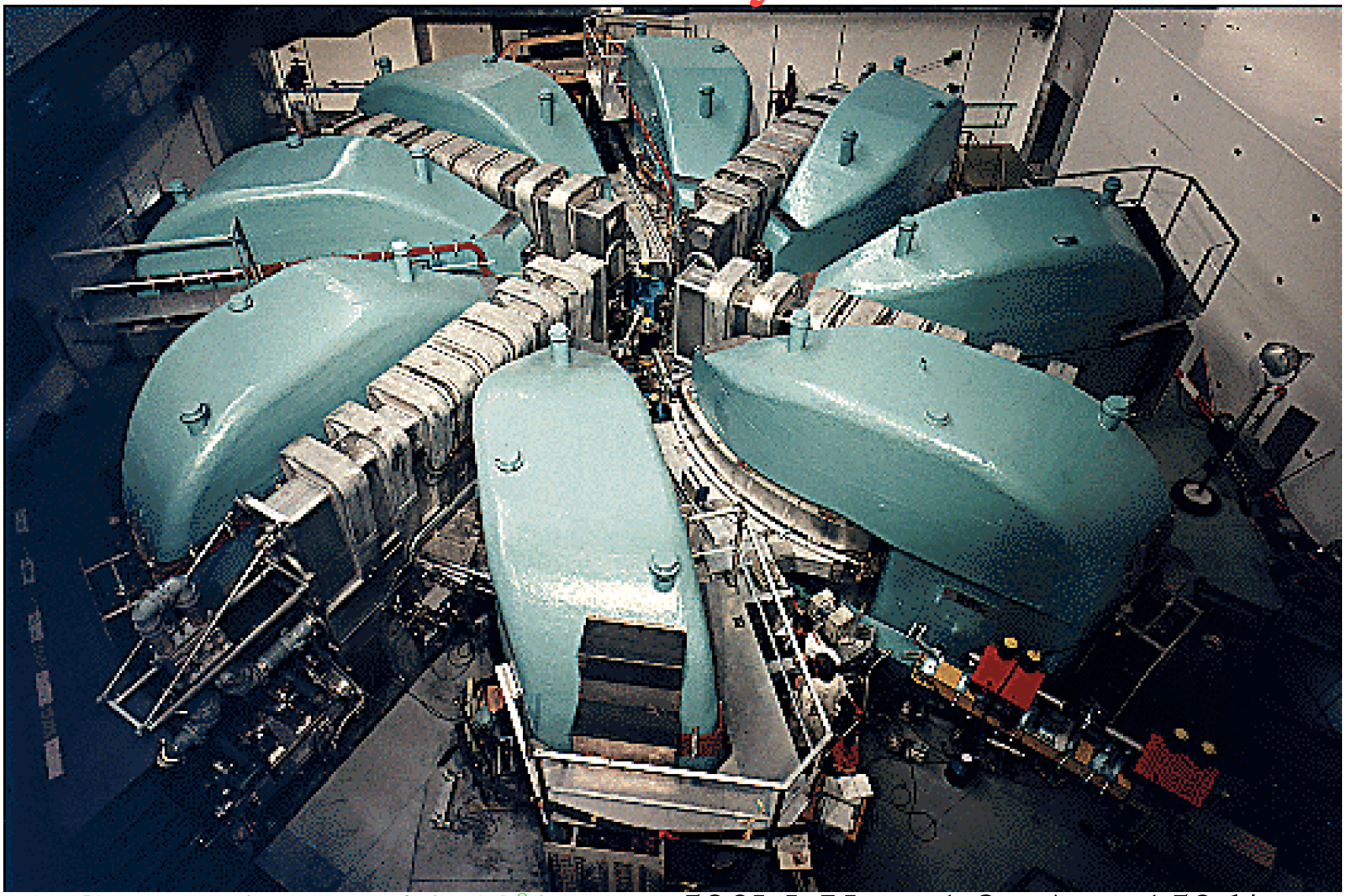
$\geq 10^{14}\,\mu^+ / \square\square / 1\square 2 years \square 10^8\,\mu^+ / \sec$

dominant background = accidental

→ PSI DC beam



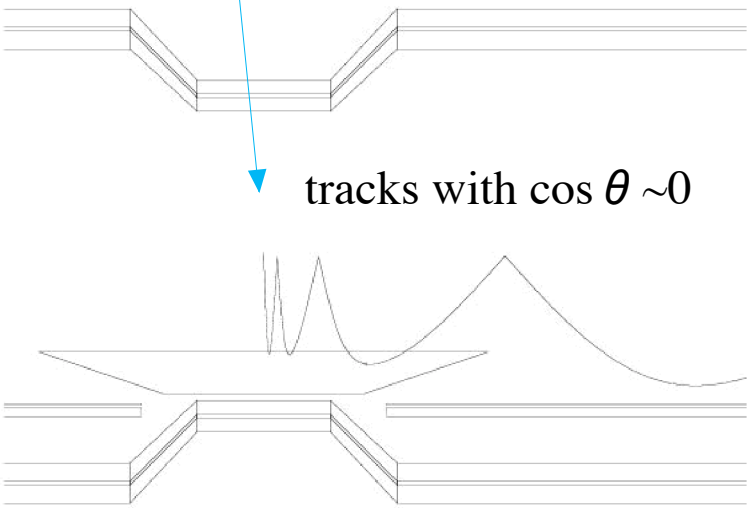
PSI Proton Cyclotron



DC muon beam with 10^8/sec 590MeV, > 1.8mA, >150d/yr

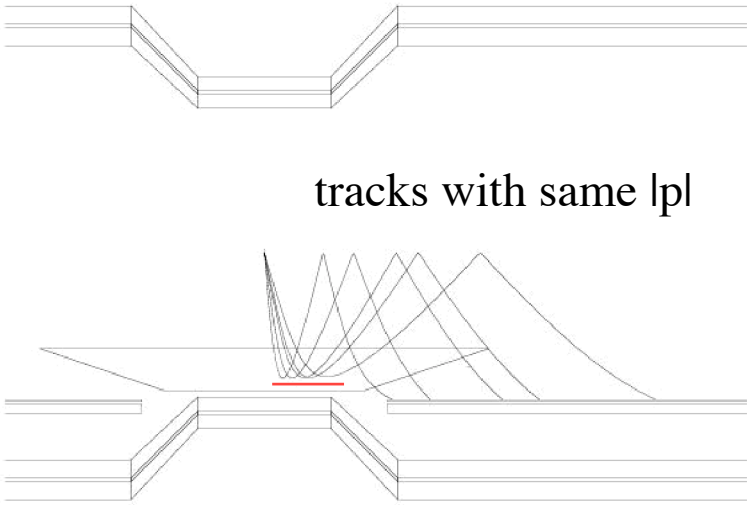
COnstant Bending RAdius Magnet (COBRA)

stronger field in the center



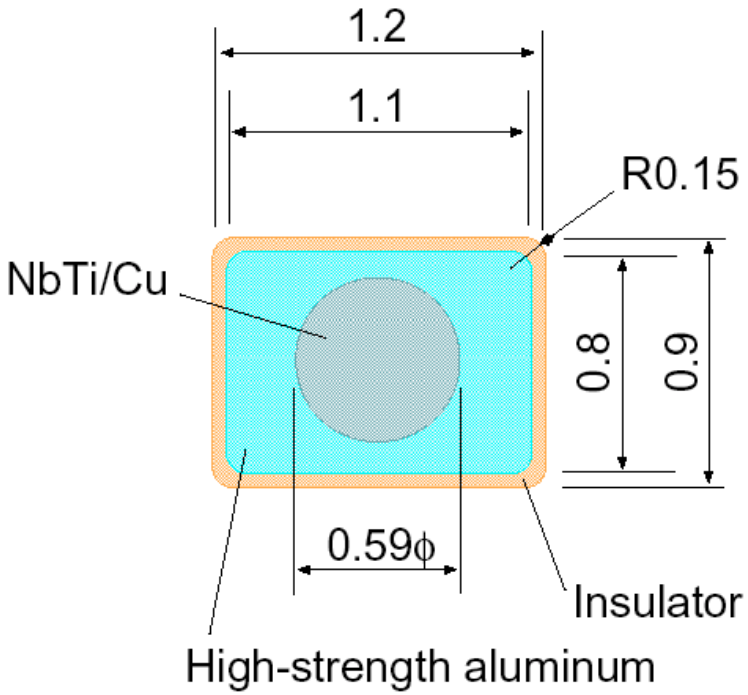
tracks with cos θ ~0

tracks quickly swept away



tracks with same |p|

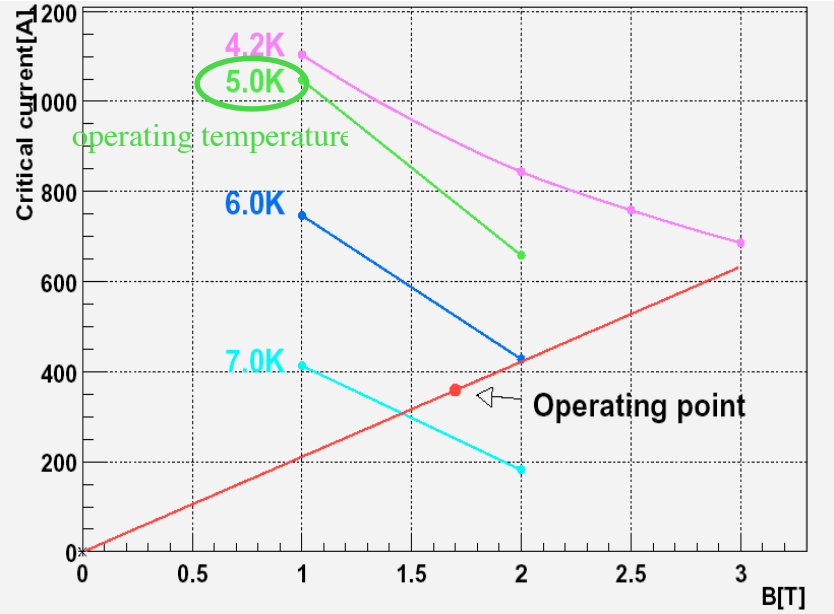
bending radius depends only on |p|

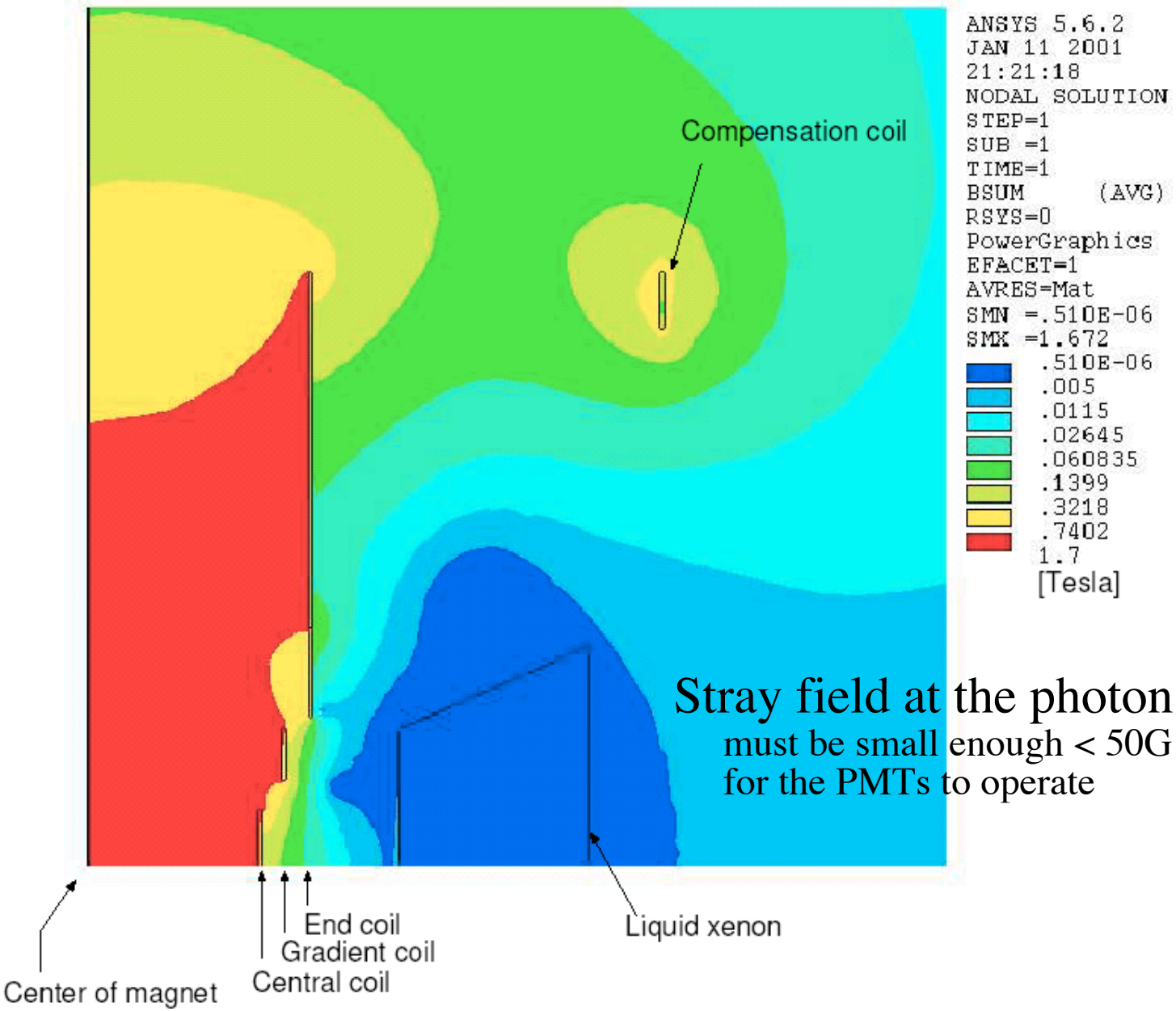


Development of *Very Thin* Superconducting Cables

Gamma rays traverse the magnet

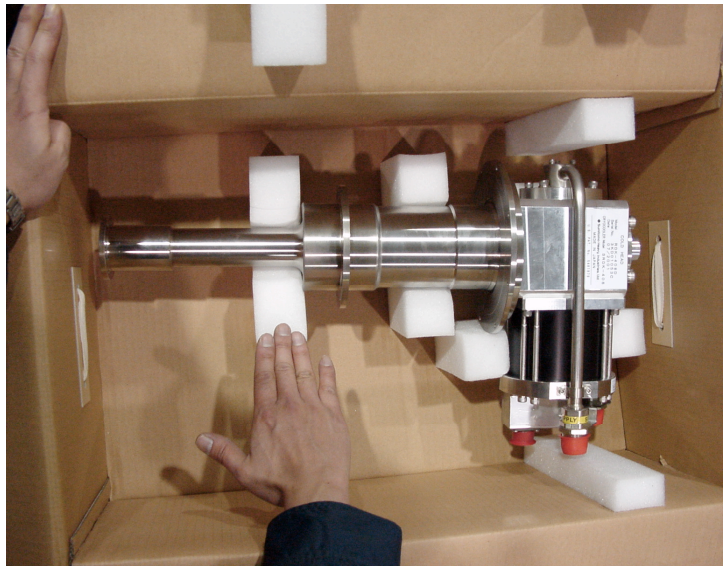
~ 20 % radiation length
(~ 3.8 g/cm^2)

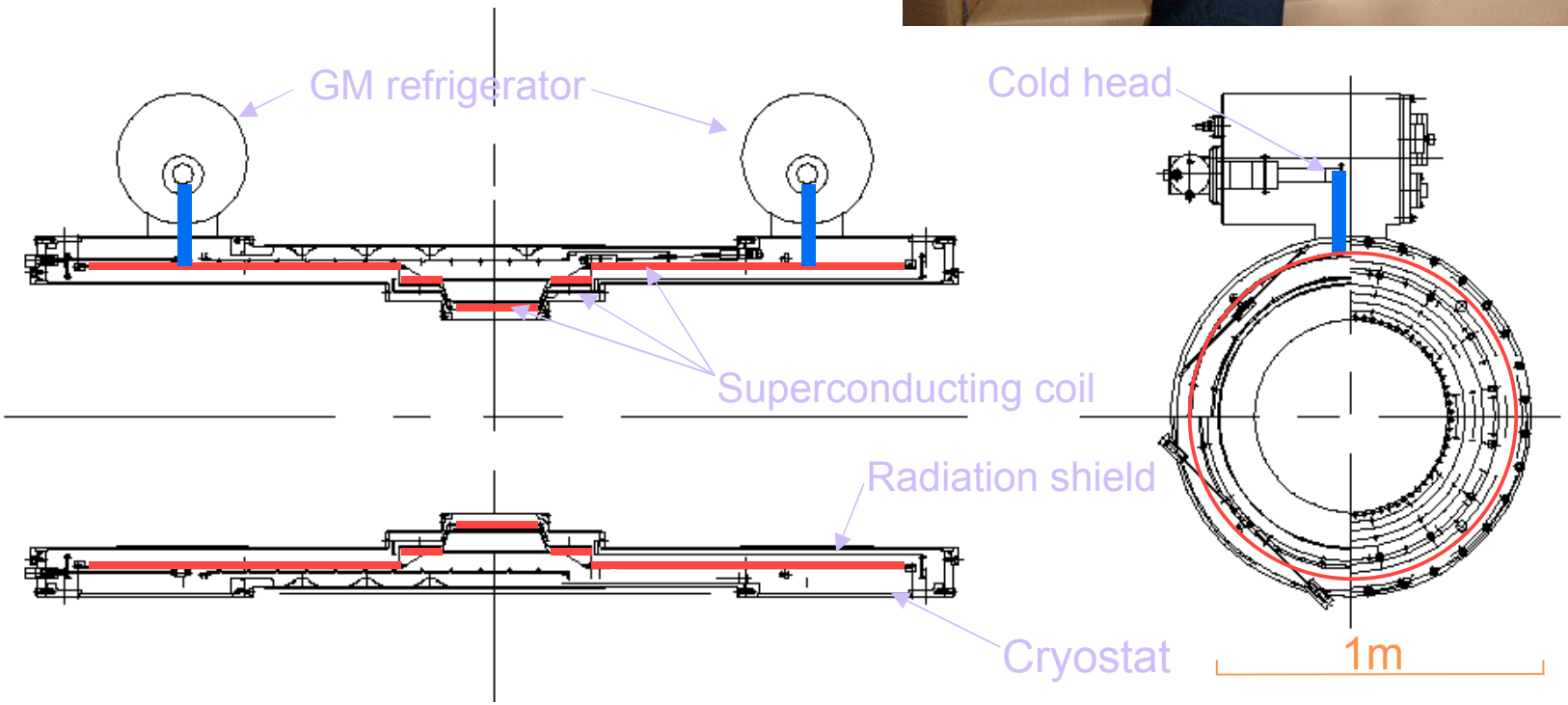



Compensation coil
ANSYS 5.6.2
JAN 11 2001
21:21:18
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
BSUM (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
SMN =.510E-06
SMX =1.672
.510E-06
.005
.0115
.02645
.060835
.1399
.3218
.7402
1.7
[Tesla]
Stray field at the photon detector
must be small enough < 50G
for the PMTs to operate
Liquid xenon
End coil
Gradient coil
Central coil
Center of magnet

He-free Operation with Refrigerator

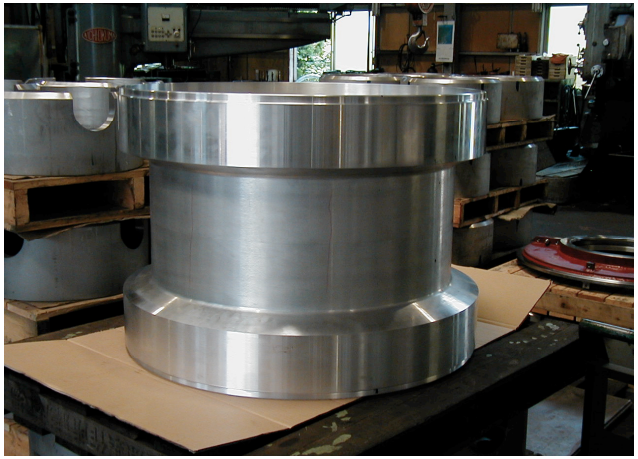
simpler and easier

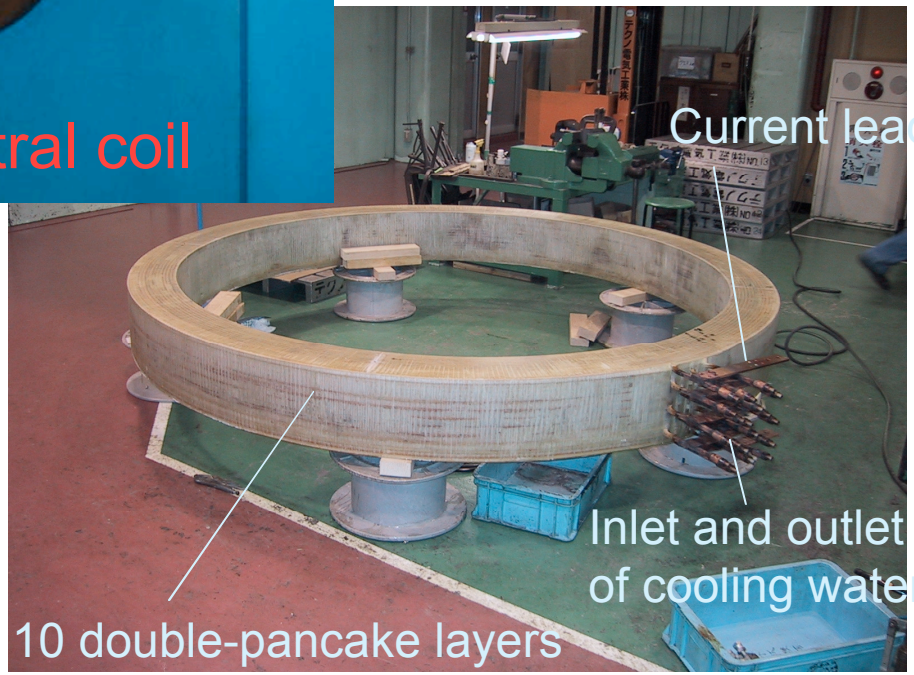


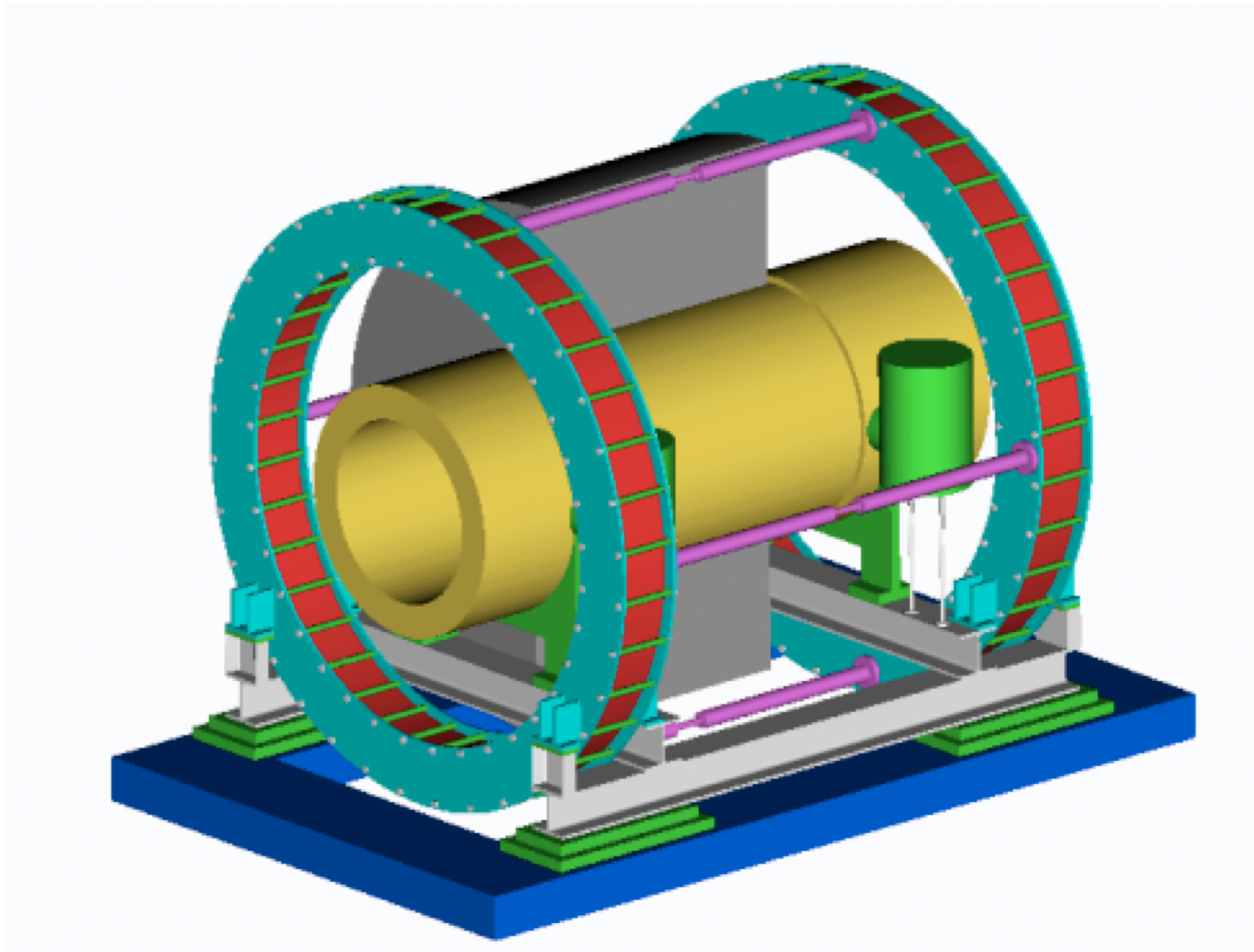


Production/Tests/ Assembly in Progress

will be ready next spring







Liq. Xenon Photon Detector

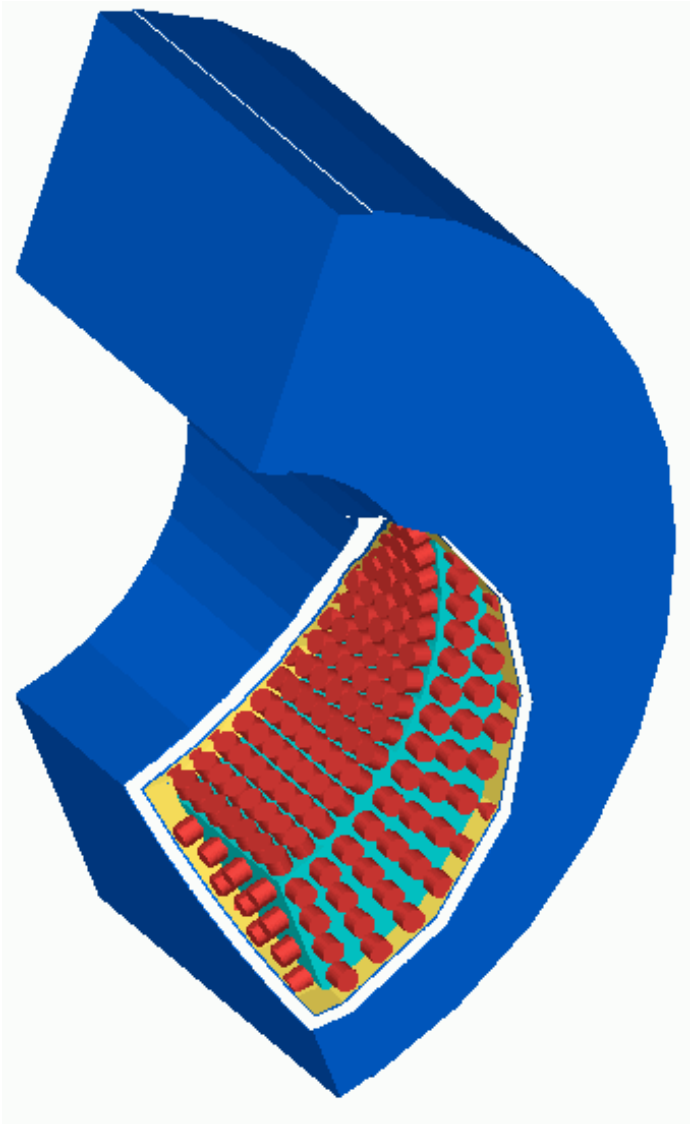
Measure Scintillation

~800 liters xenon
~800 phototubes

High Light Yield

~70% of NaI

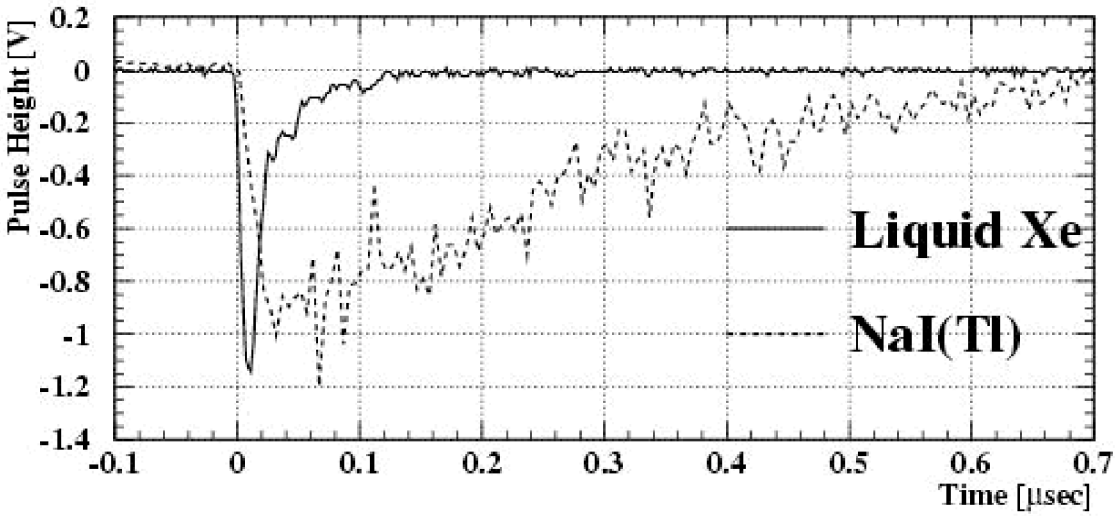
Fast Signal



Properties of Liquid Xenon

density	3.00g/cm^3
boiling and melting points	165 K, 161 K
energy per scintillation photon	24 eV
radiation length	2.77 cm
photon attenuation length	5.4 cm at 52.8 MeV
decay time	4.2, 22, 45 nsec
scintillation light wave length	175nm
Rayleigh scattering length	~30 cm
scintillation absorption length	> 100 cm (?)

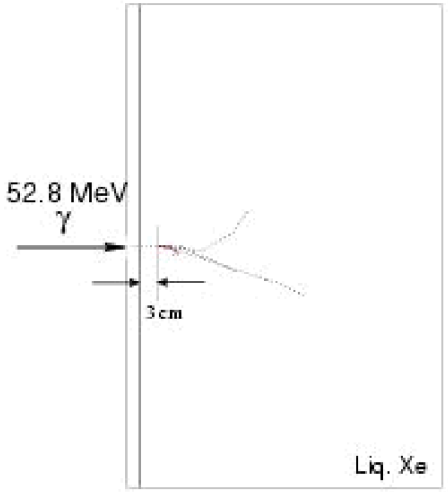
High Light Yield

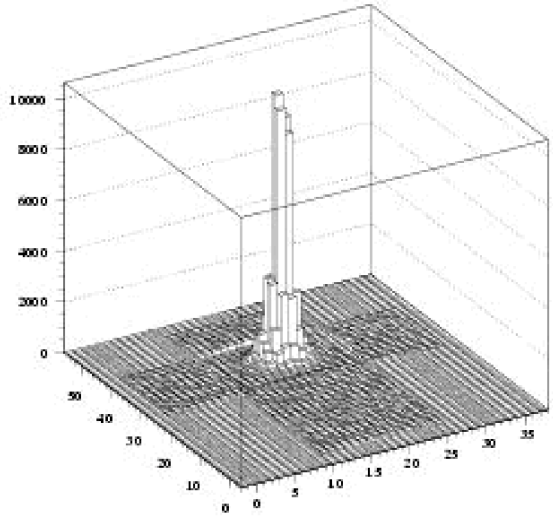


Fast Signals

Measure Photon Conversion Points

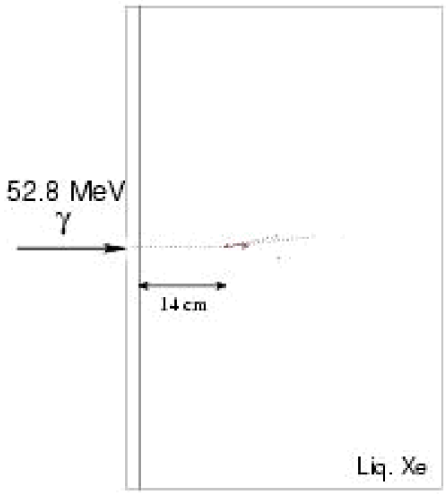
a few mm in xy
< 1 cm in z

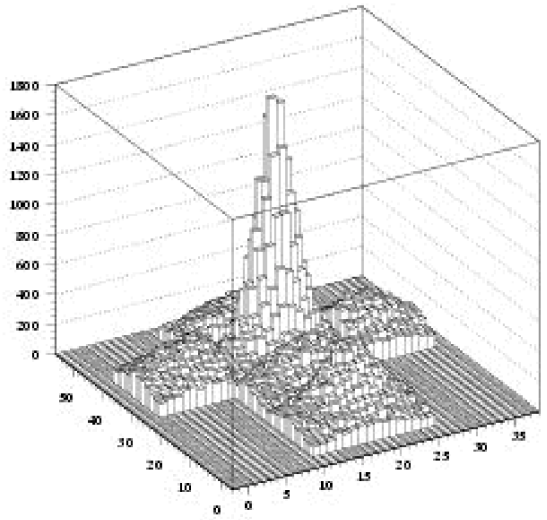


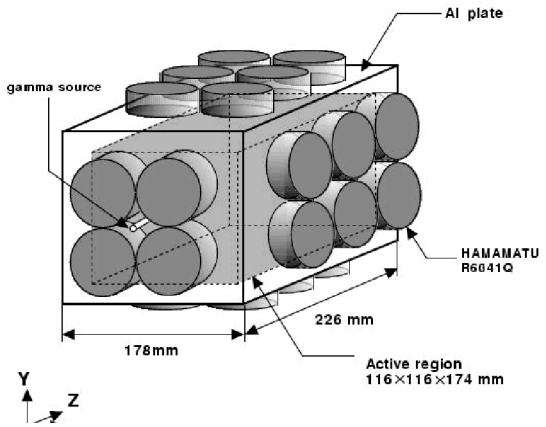


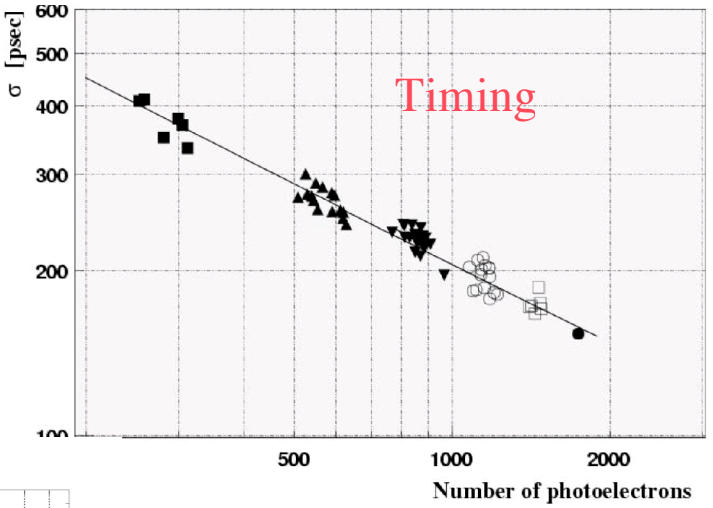
(a)

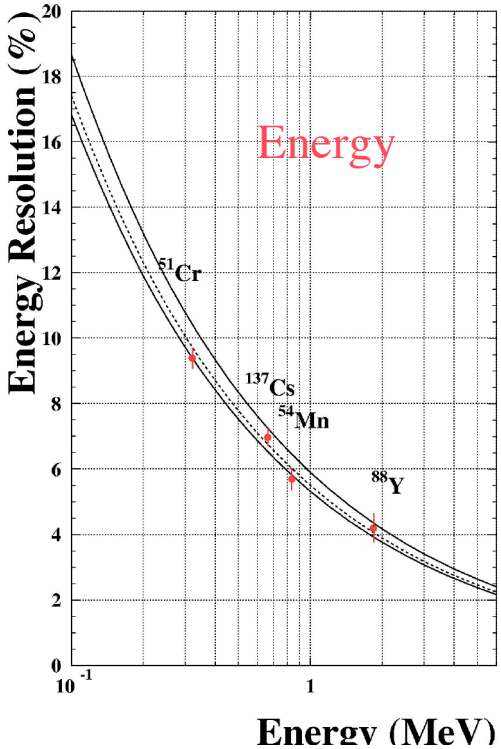
PMT outputs distribution

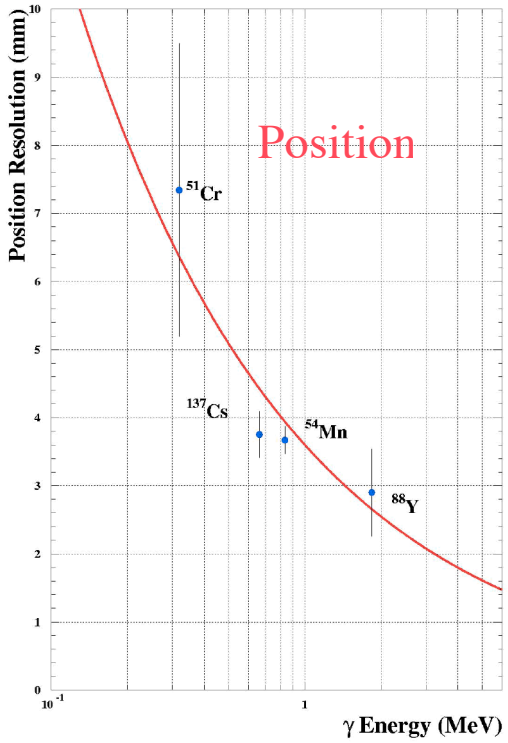










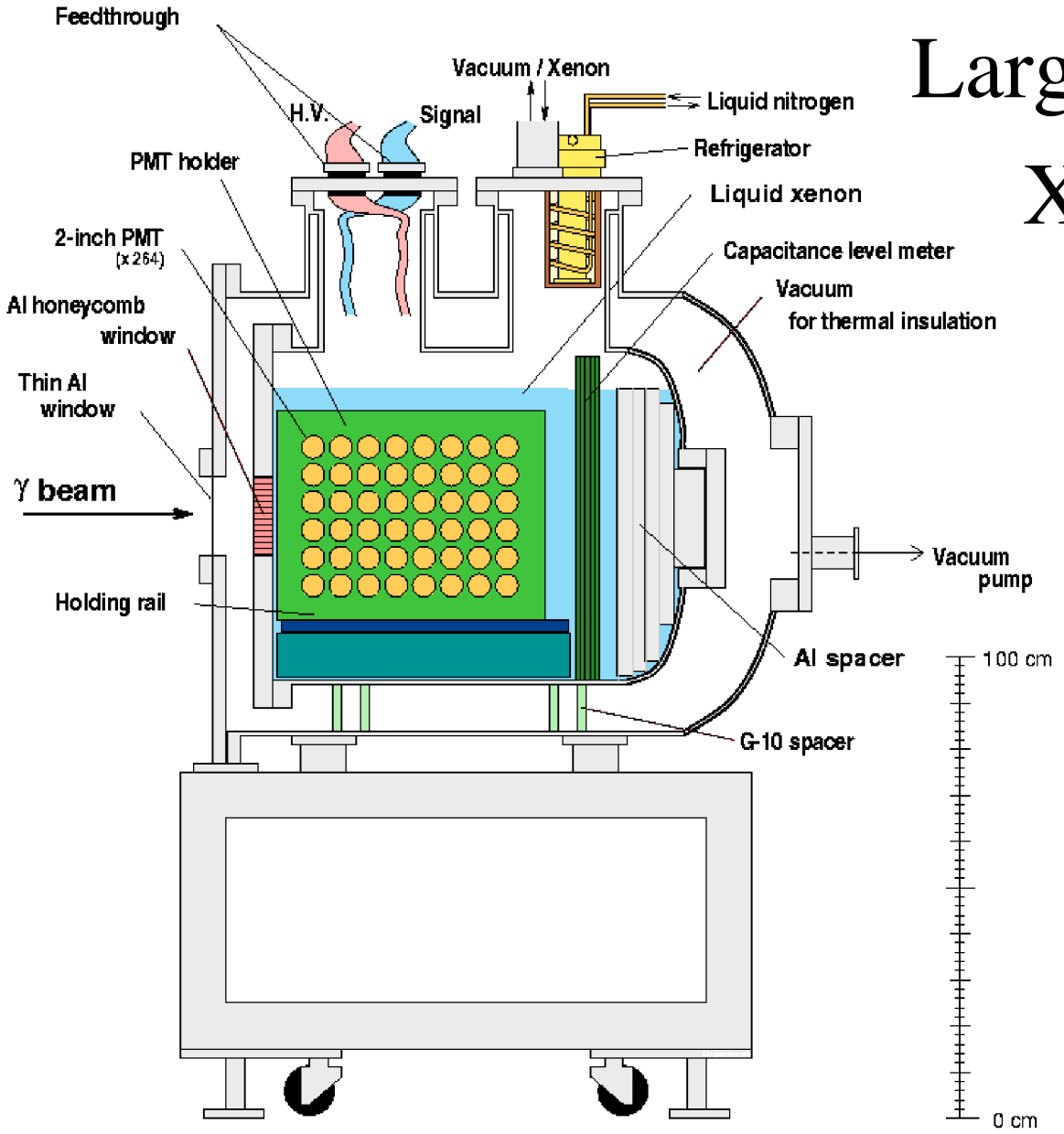


Tests of Small Prototype

measure 0.3-1.8MeV gamma ray sources

necessary resolutions ~ achievable

Large Prototype Xe Detector

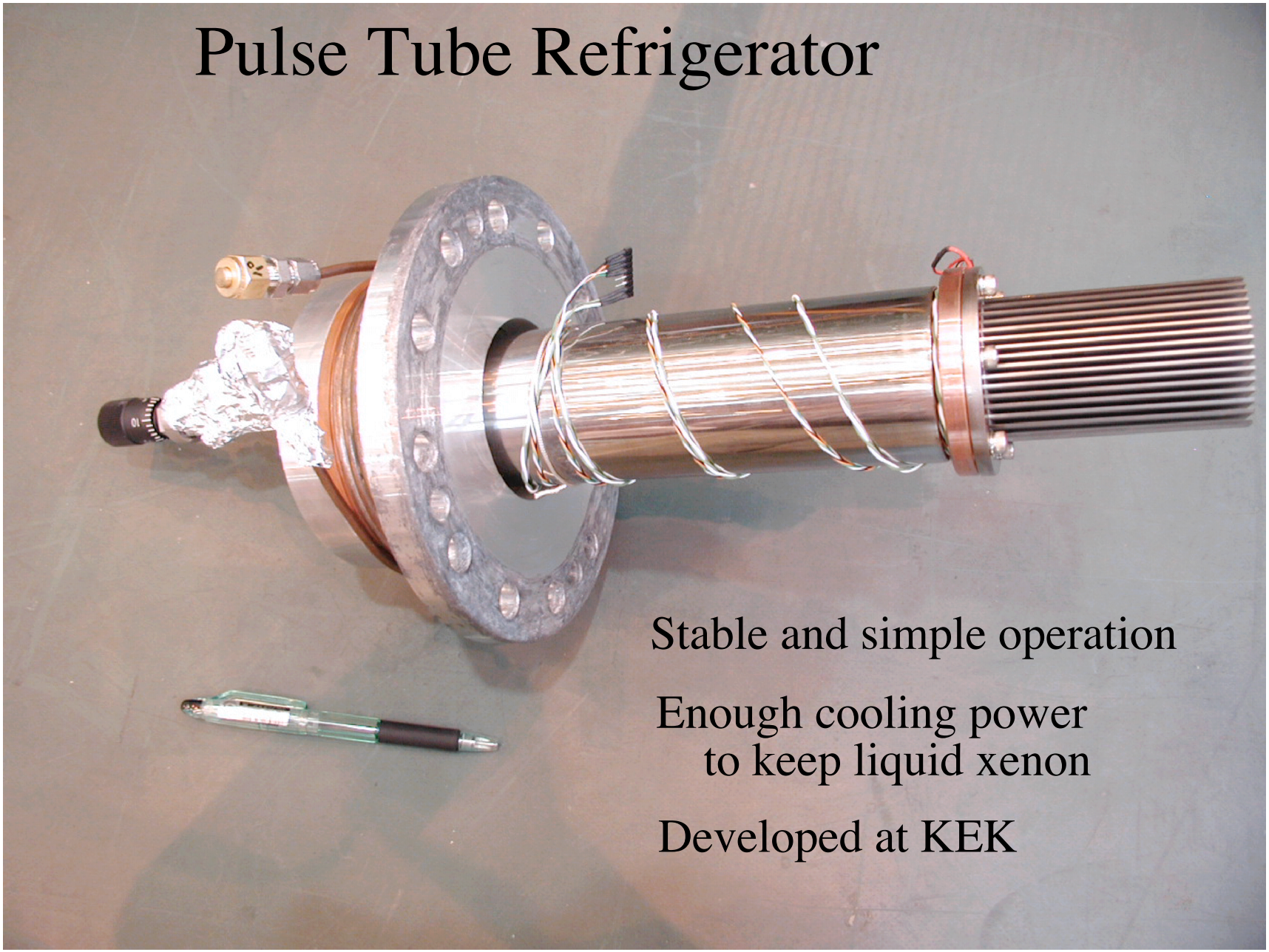


~100 liters Xe

Test detector components (PMT, refrigerator, etc)

Verify performance by cosmic ray & 40MeV photons

Pulse Tube Refrigerator



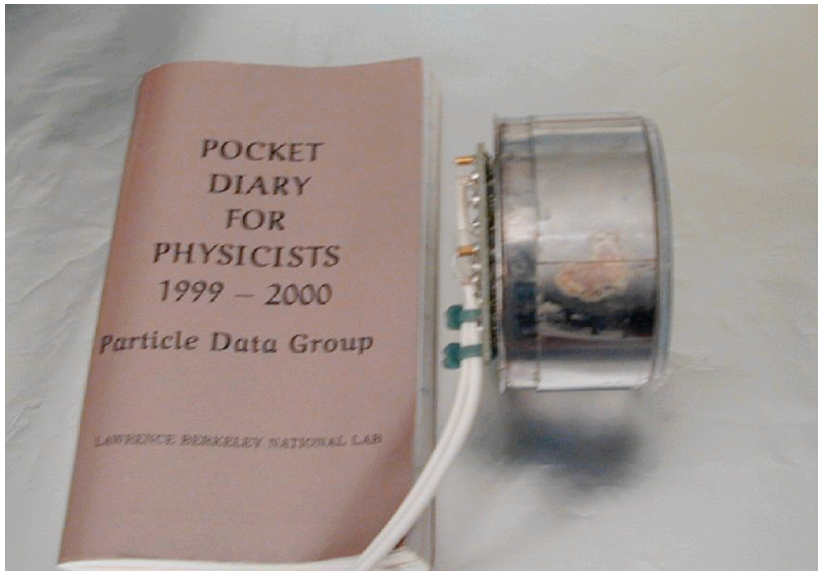
Stable and simple operation

Enough cooling power
to keep liquid xenon

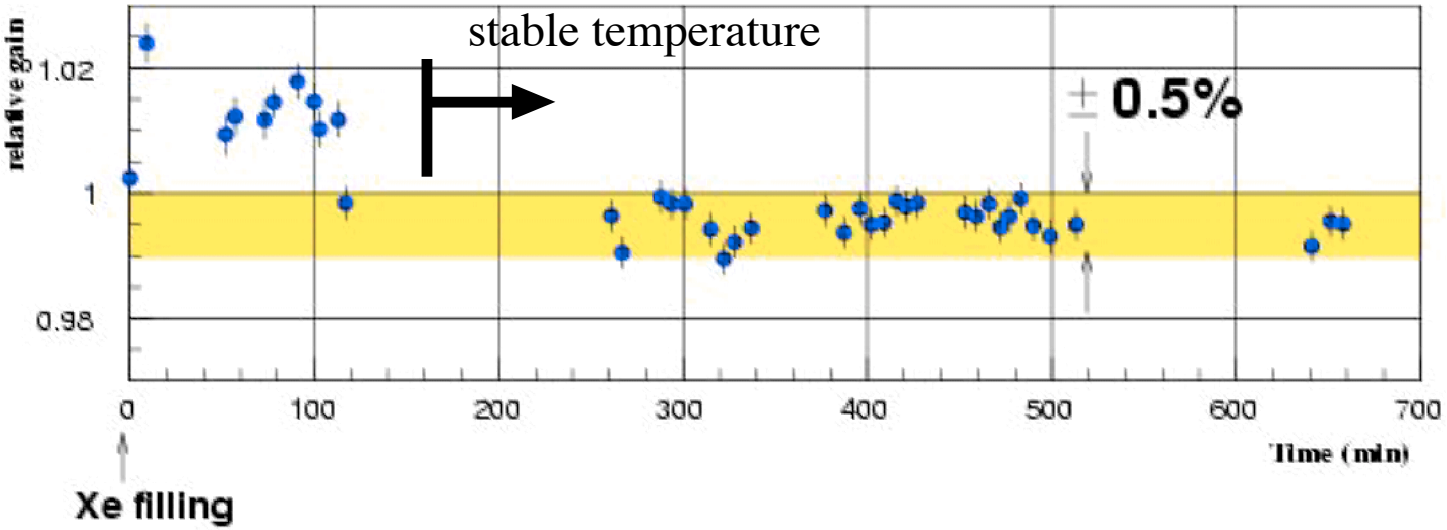
Developed at KEK

R6041Q (Hamamatsu)

Developed thin phototubes
that operate stably
inside liquid xenon

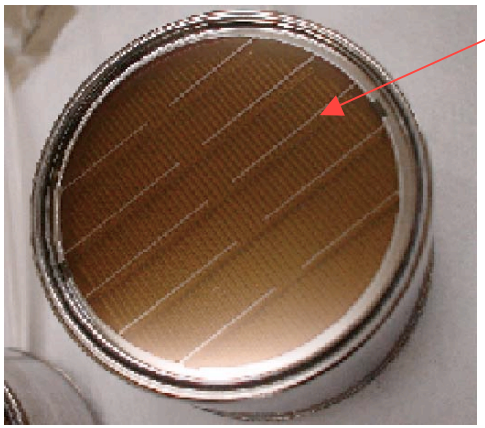


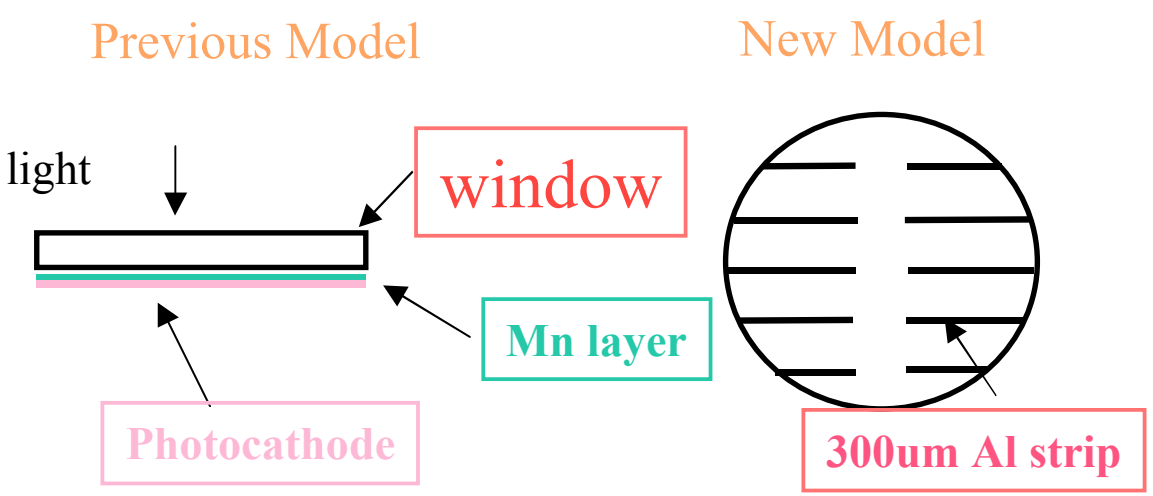
Quartz window for UV light
Operational at -100°C

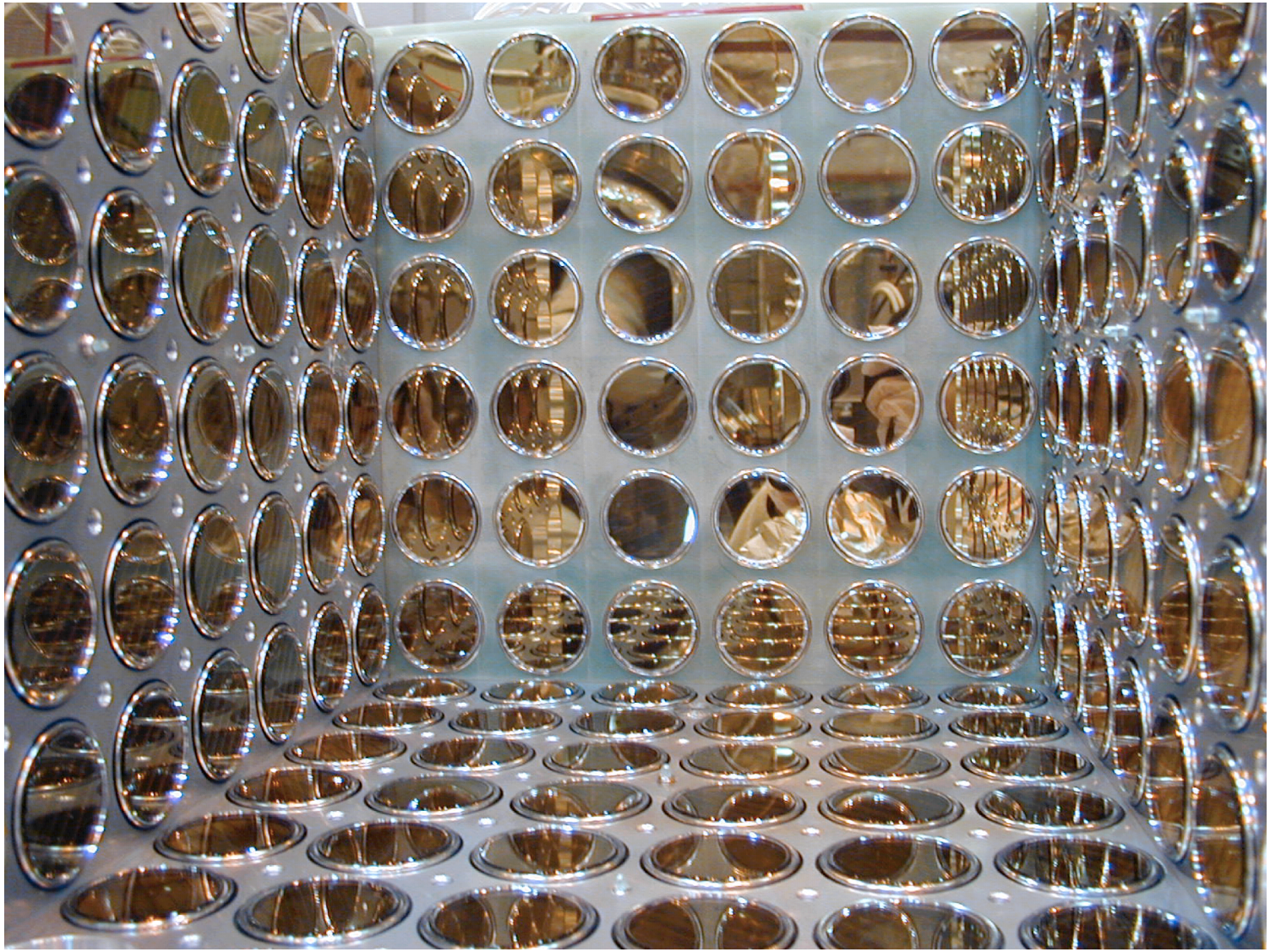


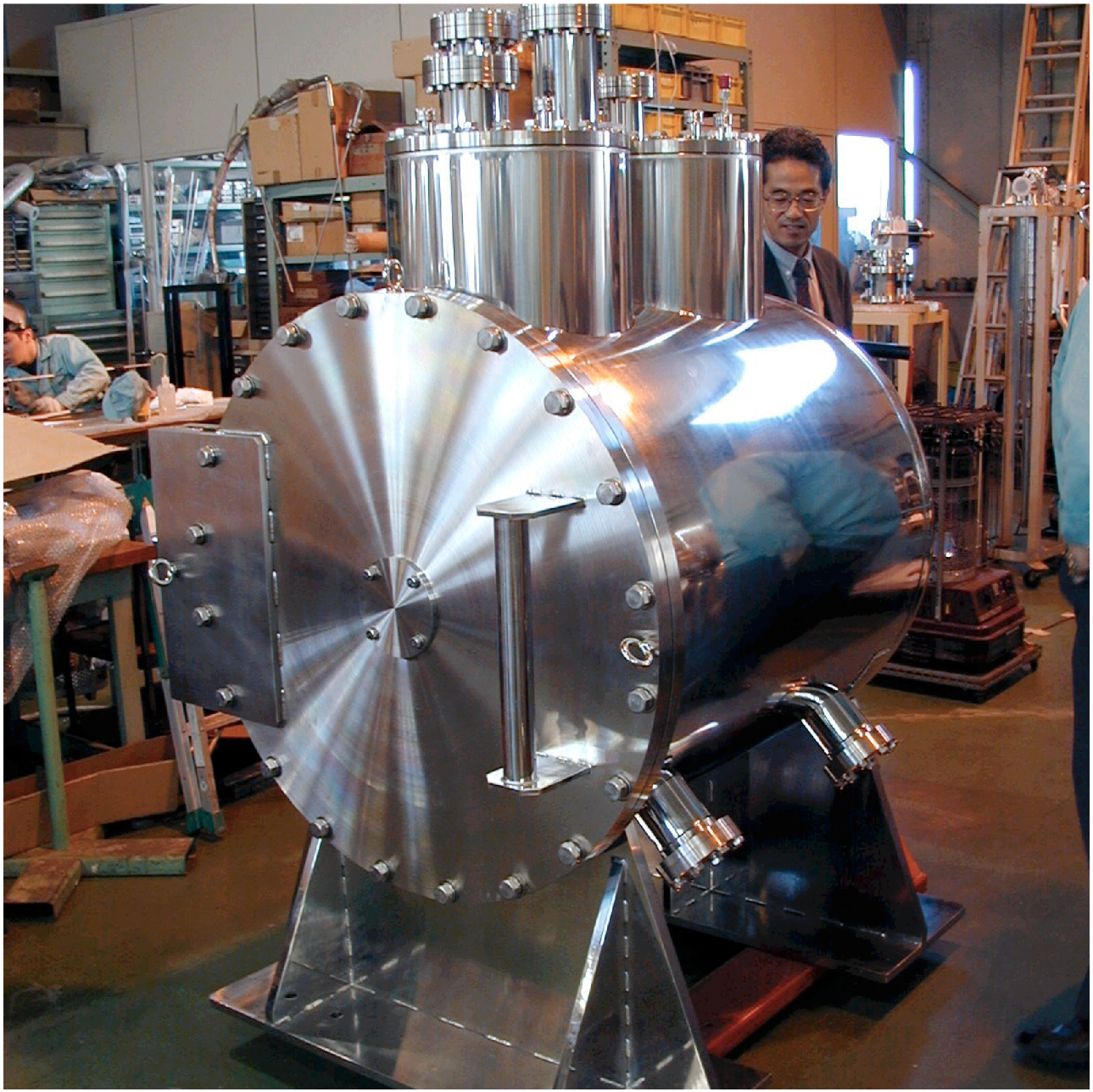
New PMT Development

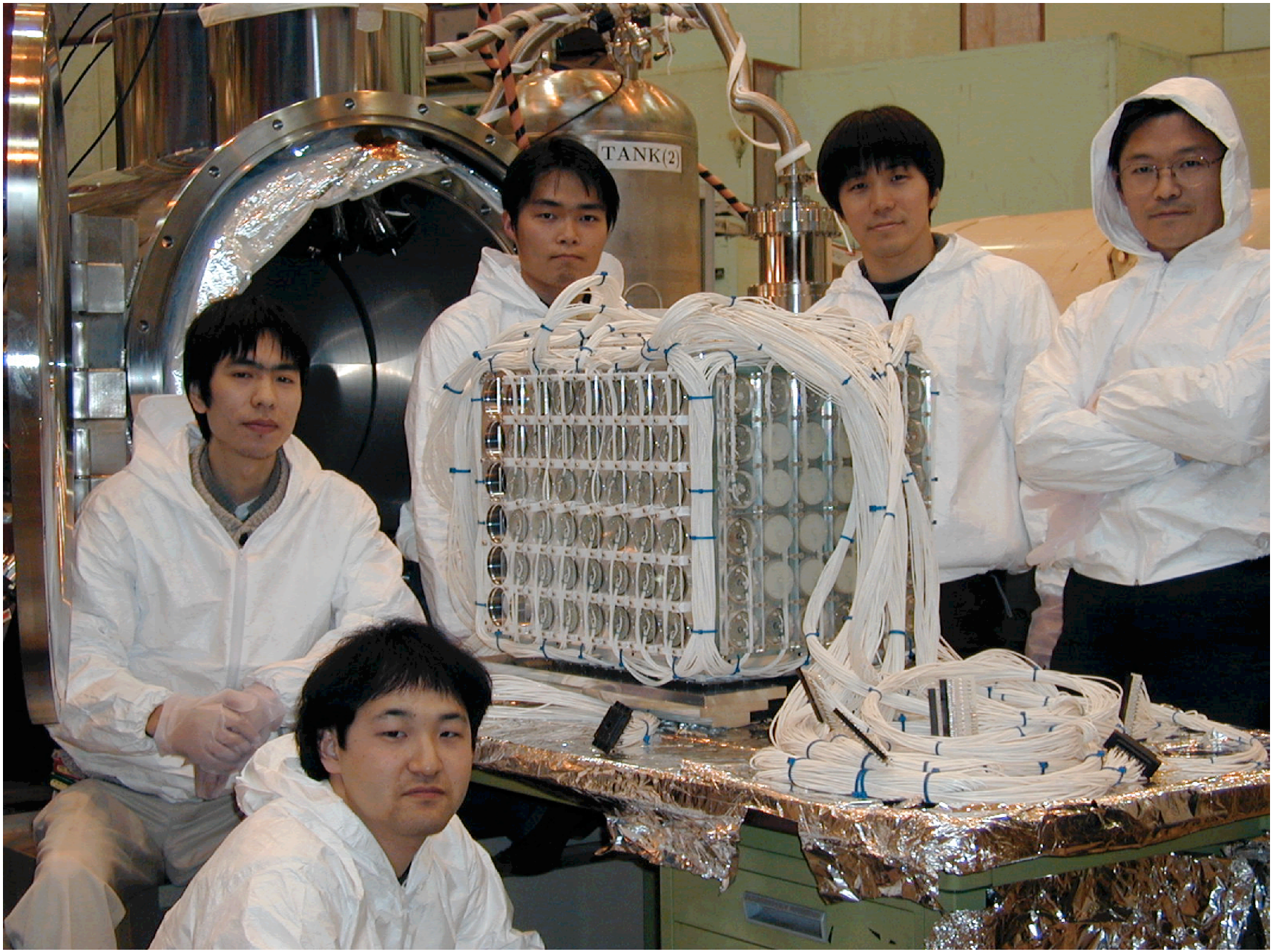
higher and more uniform
quantum efficiency



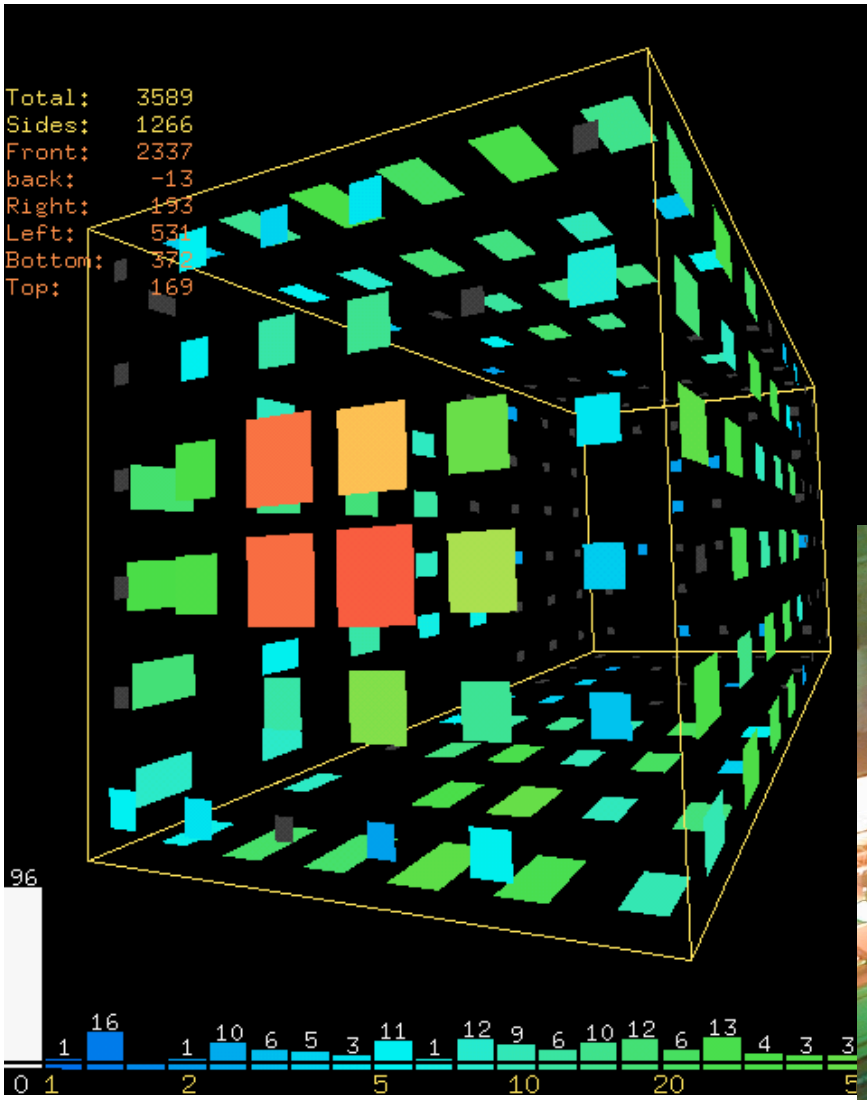


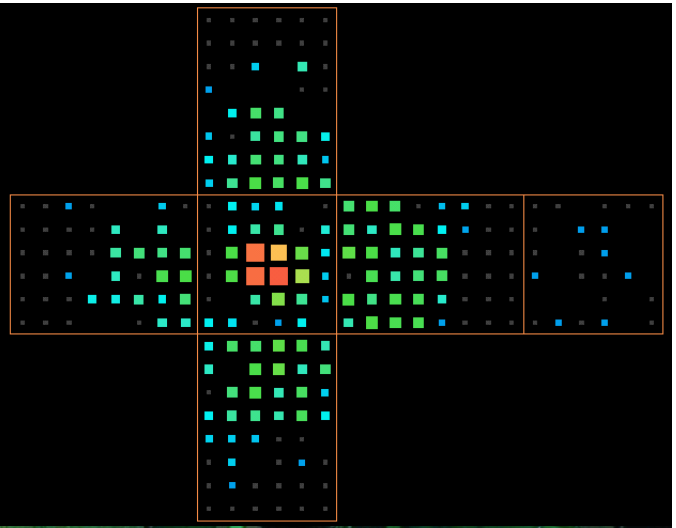


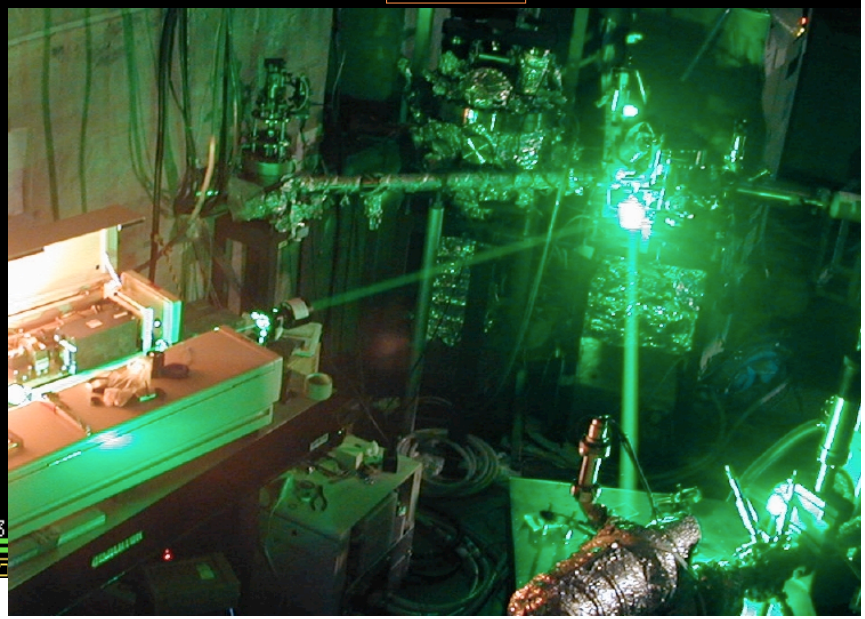


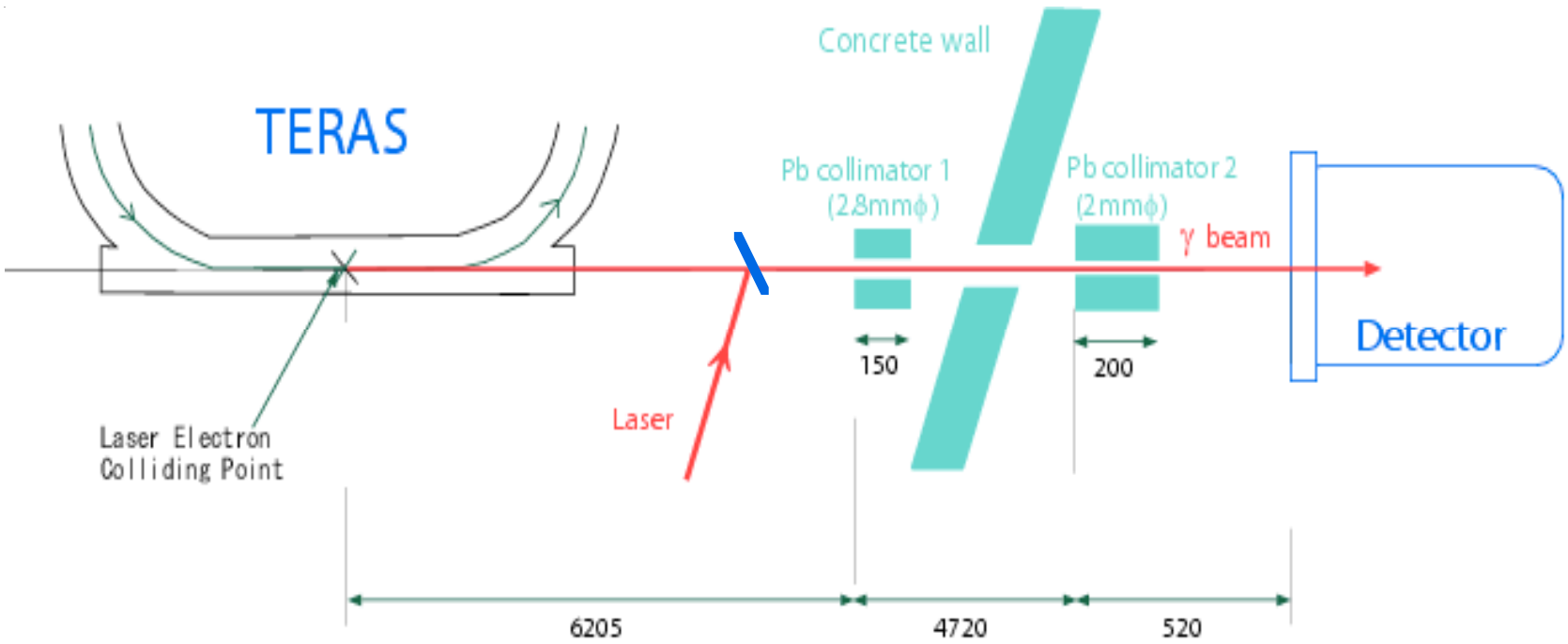

TANK(2)

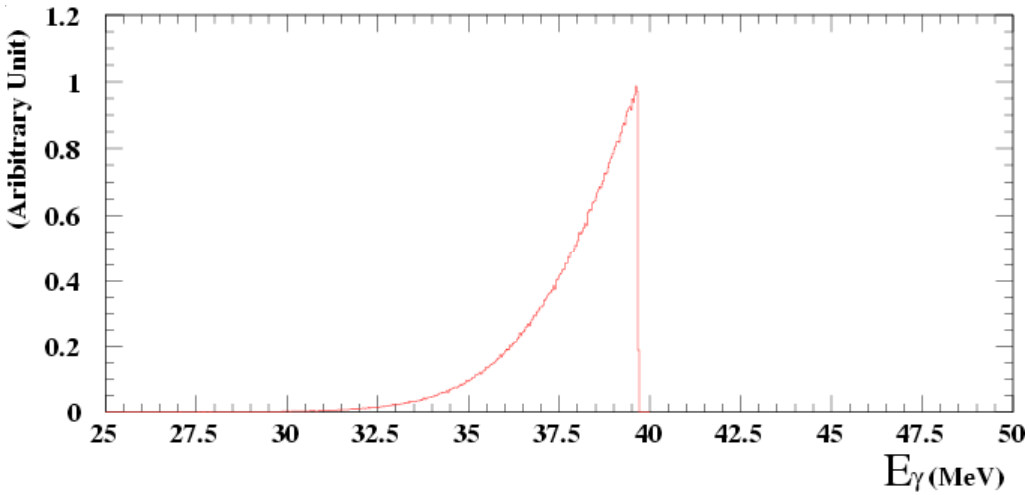
Laser Compton Gamma Ray Beam Test









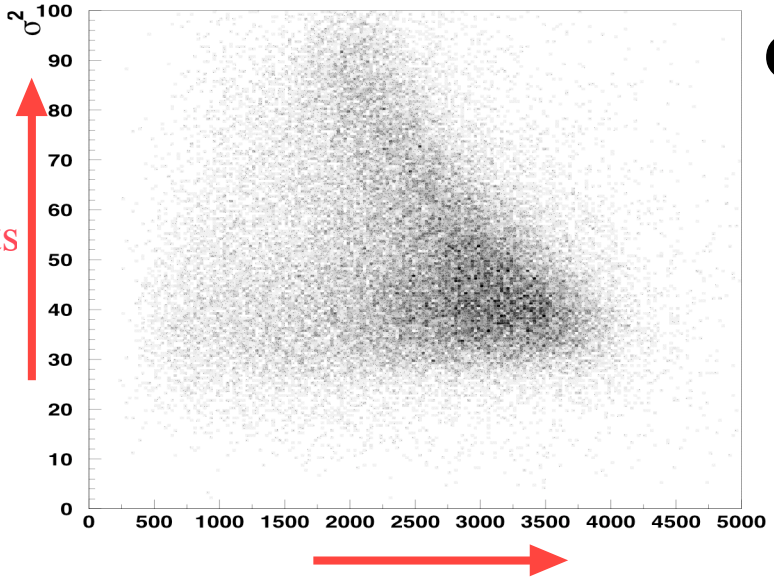


Laser compton Gamma rays

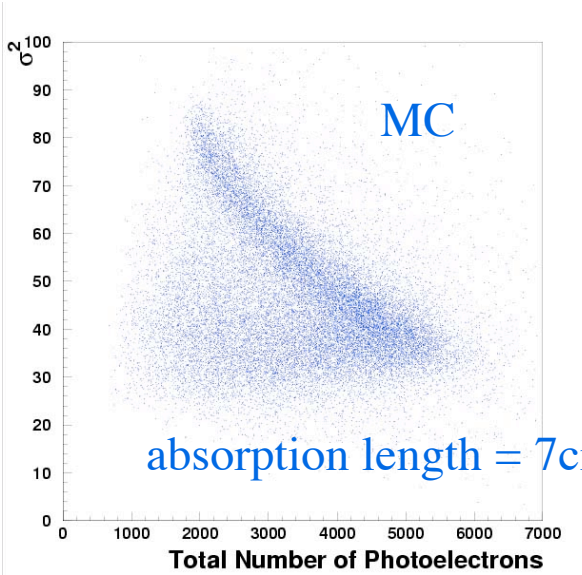
at AIST, Tsukuba, Japan

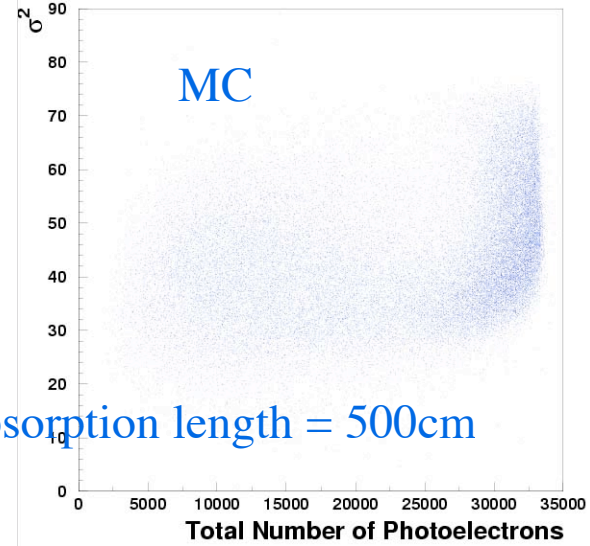
Gamma Ray Energy
up to 40MeV @500-1000Hz

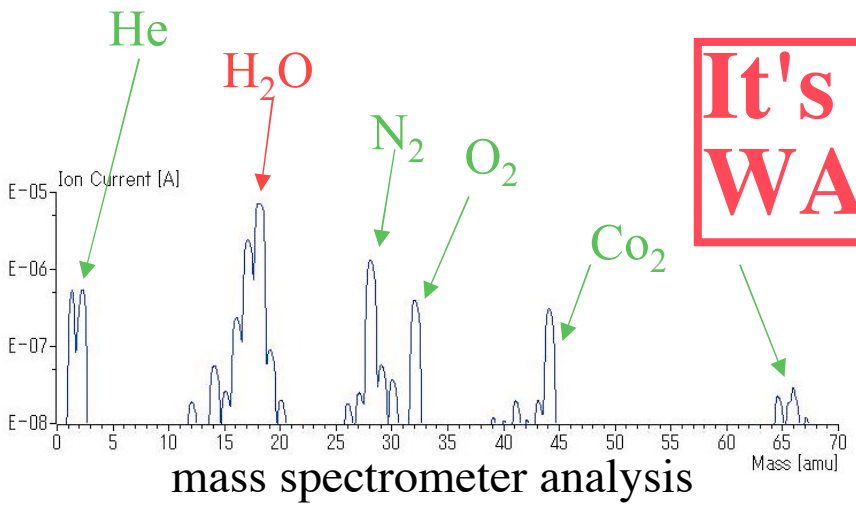
DATA



Observed significant light absorption inside the detector

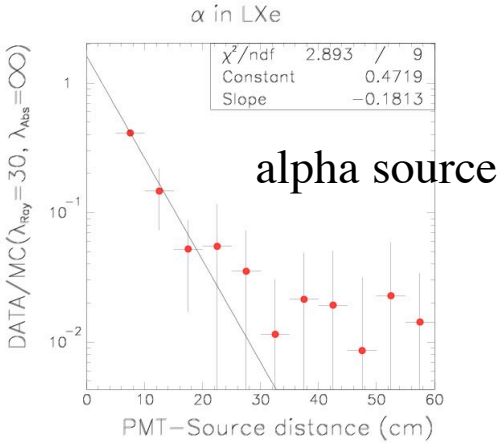




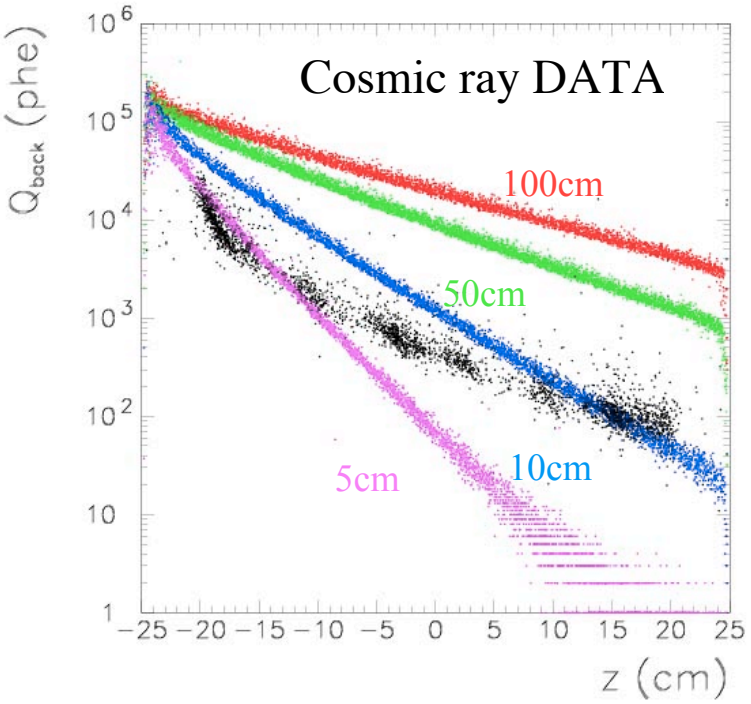


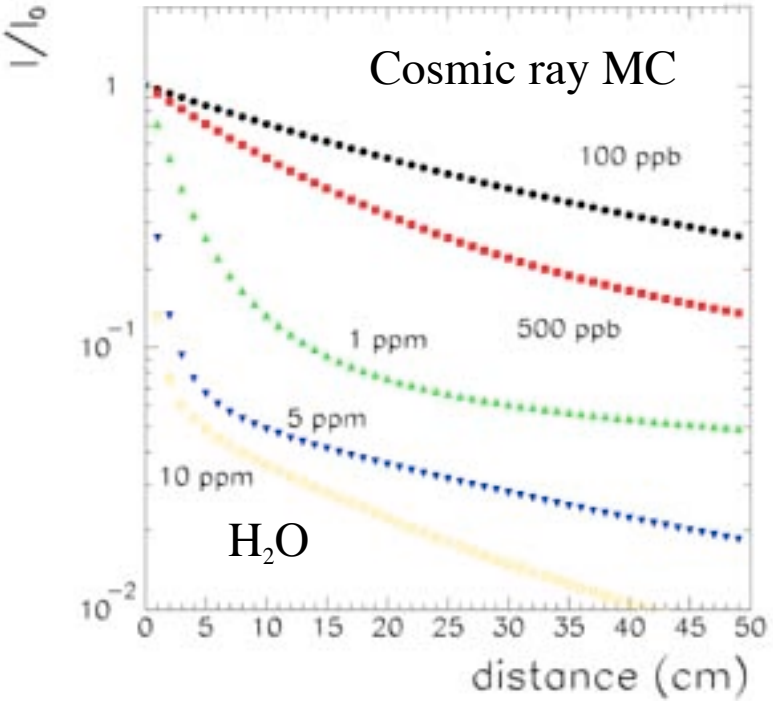
mass spectrometer analysis

It's WATER!



alpha source



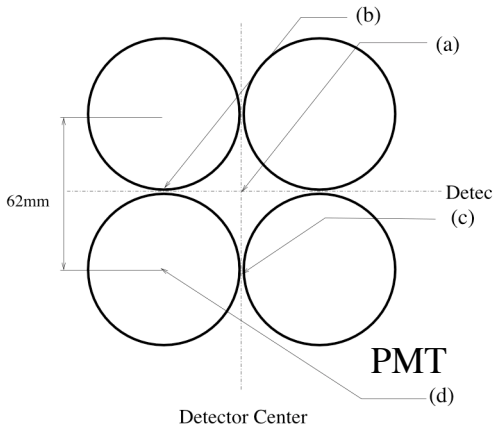


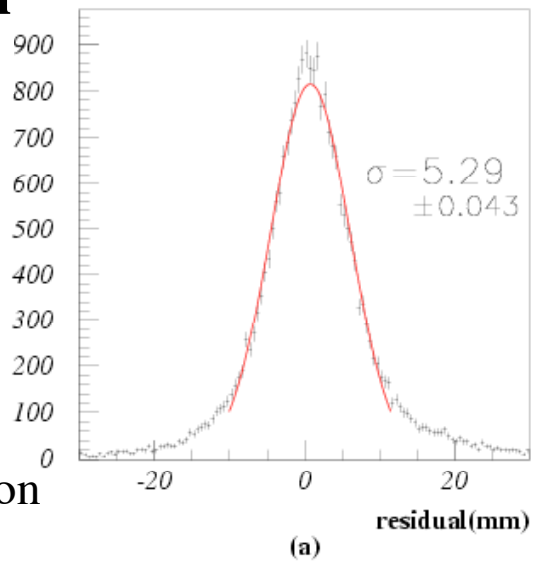
Position Resolution for gamma rays

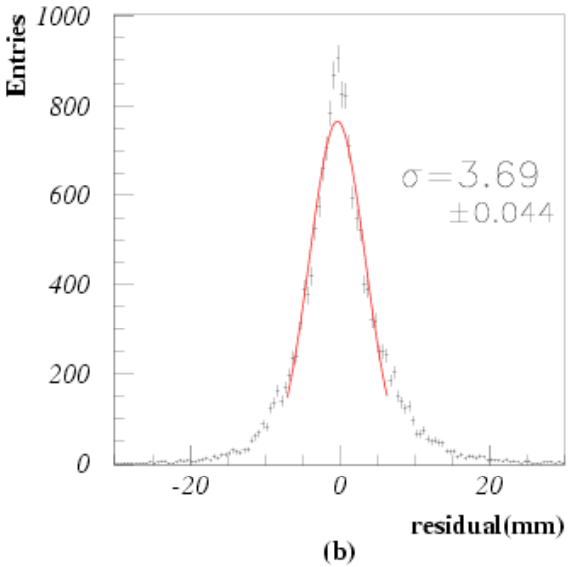
σ = 3 - 5 mm

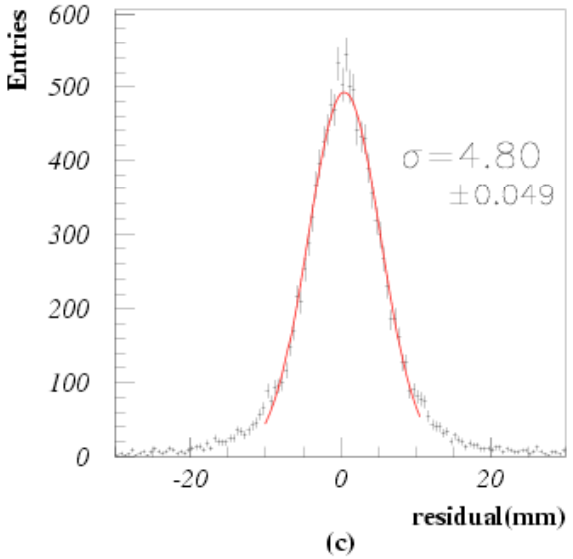
as expected by MC

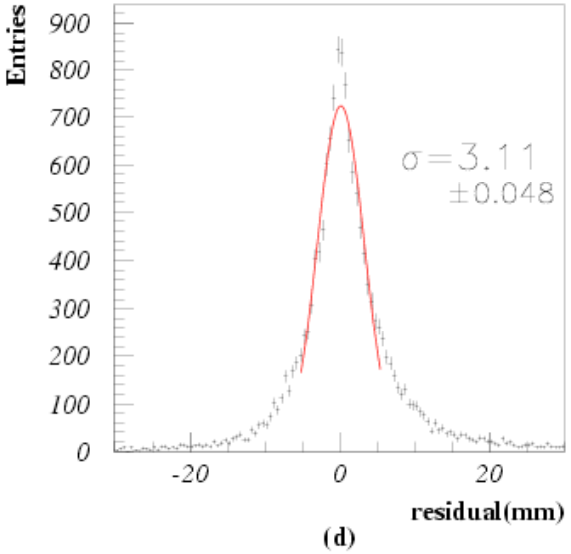
not as sensitive to absorption as energy measurement





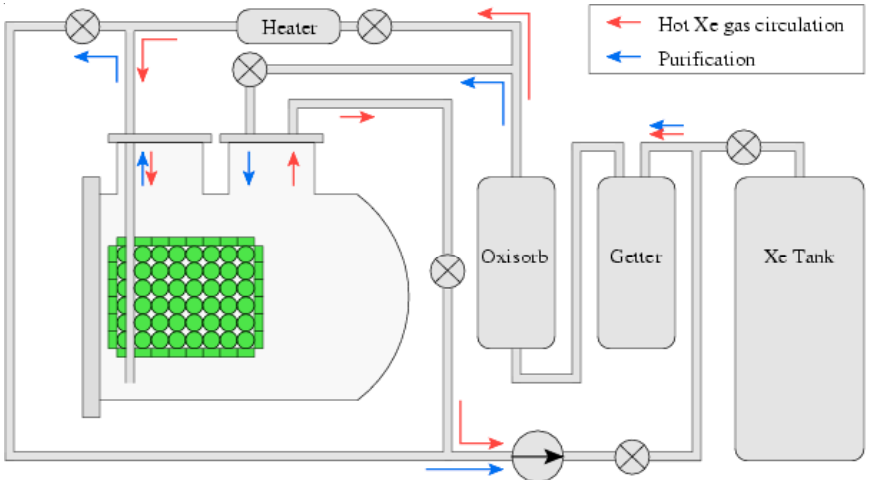


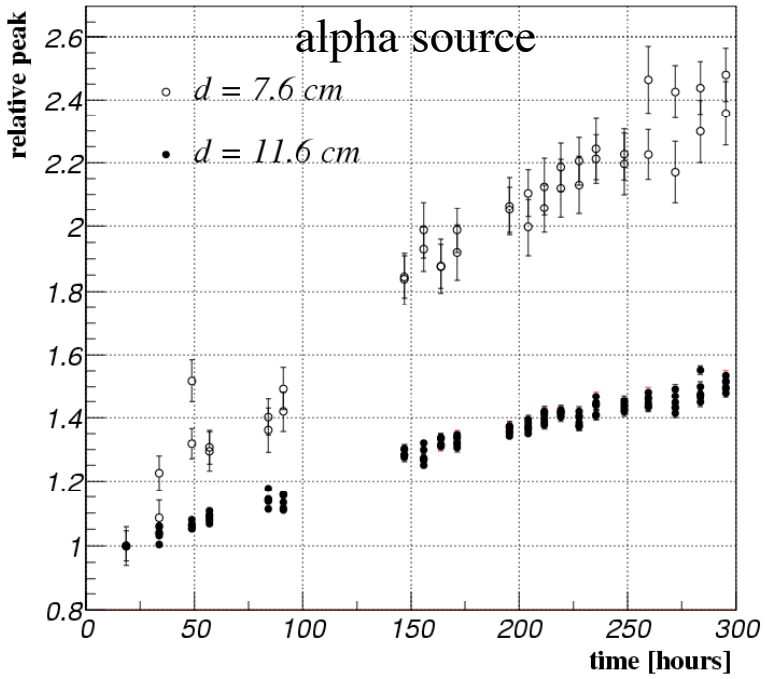


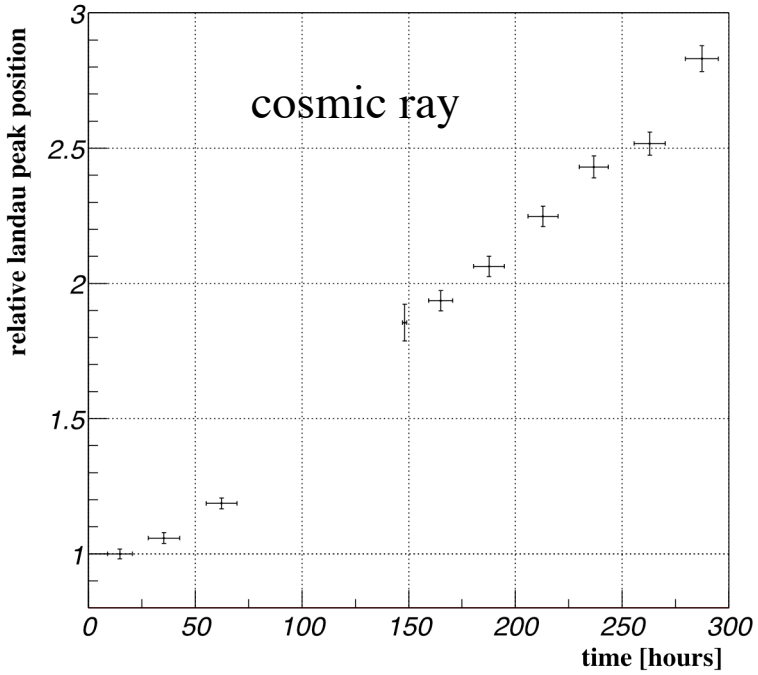


Purification

by xenon circulation



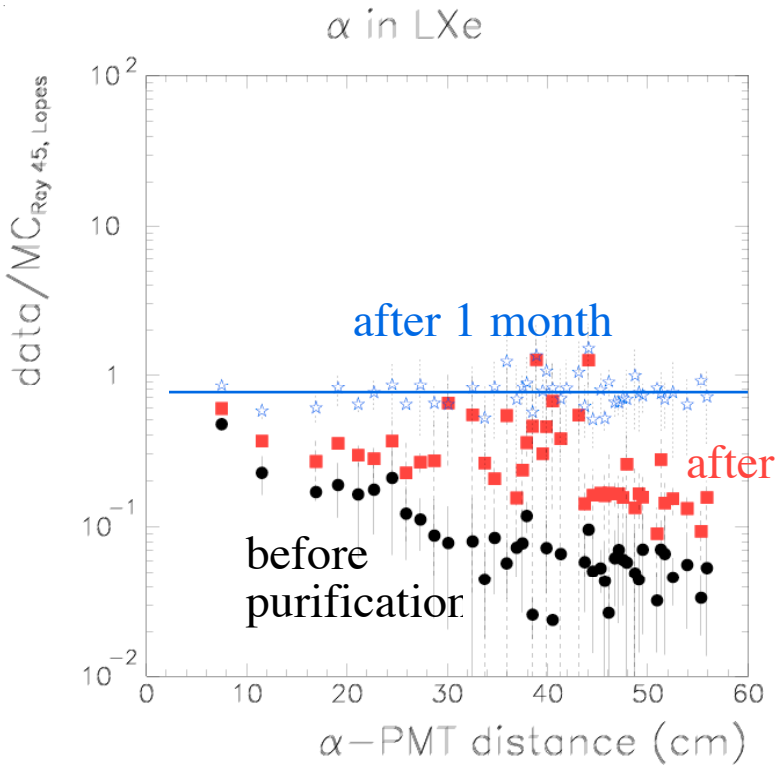


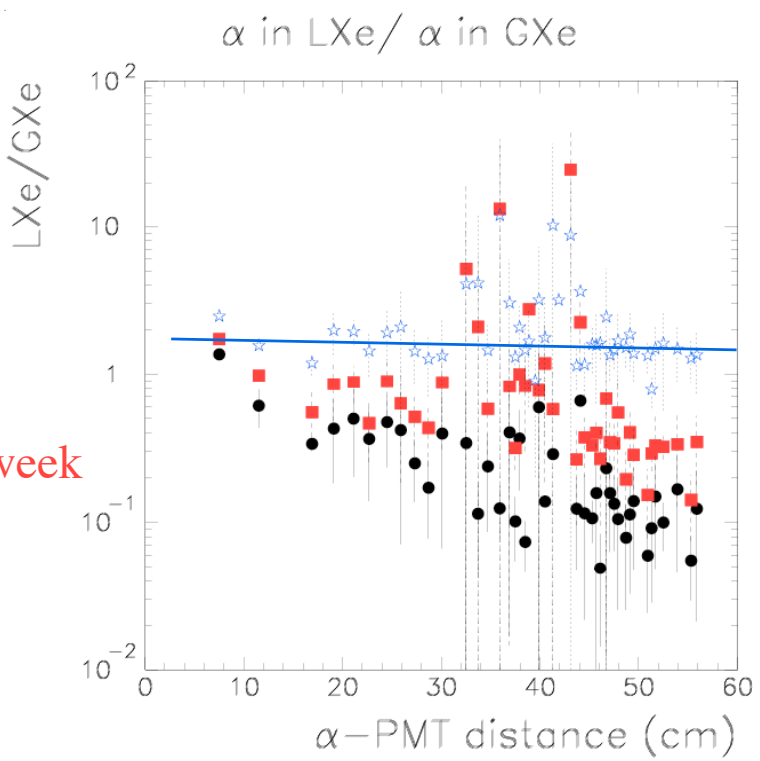


Absorption Length ~ 100 cm
is achieved by one month purification

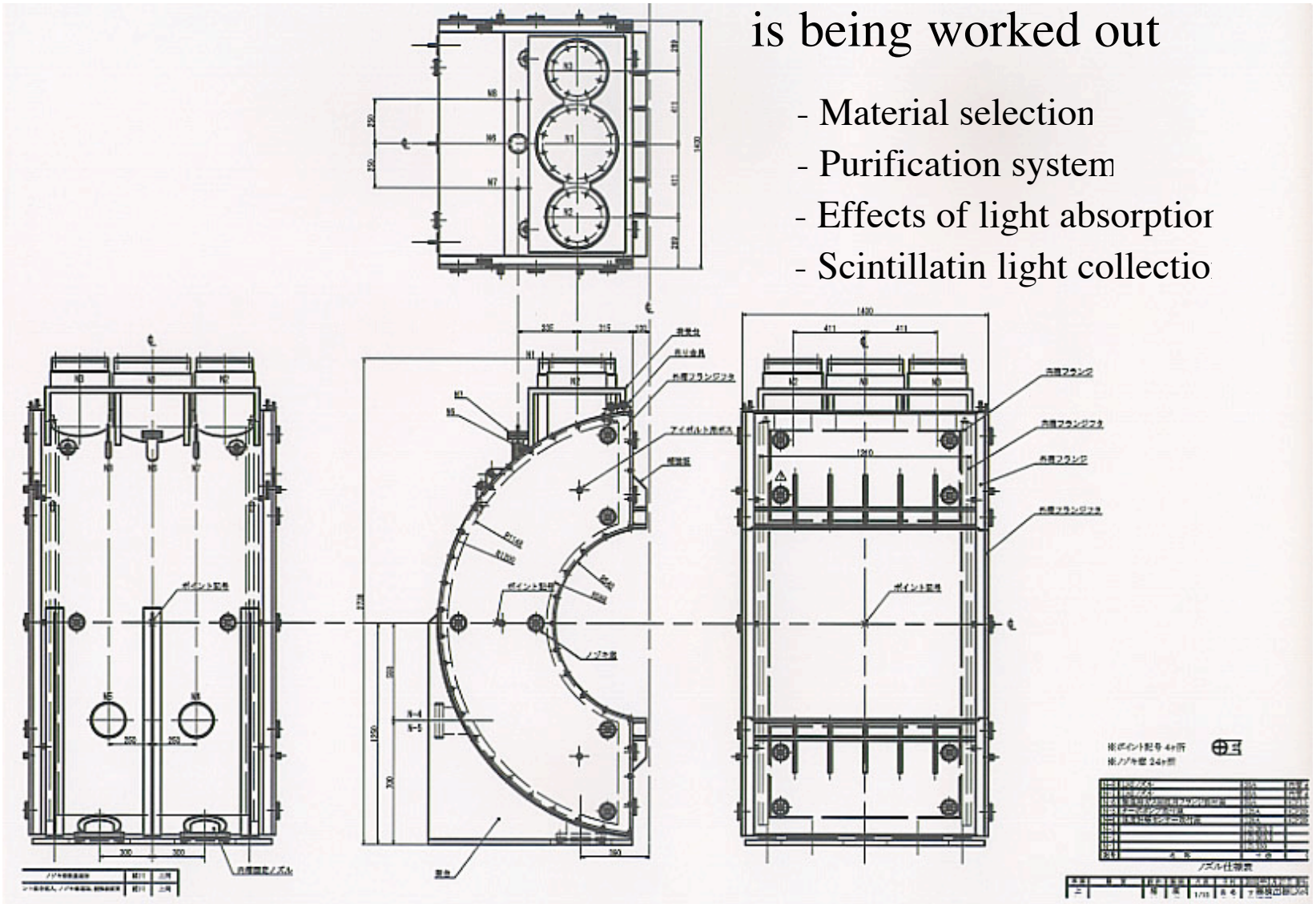
energy resolution ~ 2% FWHM expected (MC)

next gamma beam test this fall





Optimization of Detector Configulation



is being worked out

- Material selection
- Purification system
- Effects of light absorptior
- Scintillatin light collectio

Conclusion

Good Prospects:

- solar neutrino - large mixing
- muon (g-2) might be SUSY

Necessary performance to reach ~10^{-13}
or better now within reach

Our final goal:
the first discovery before LHC !