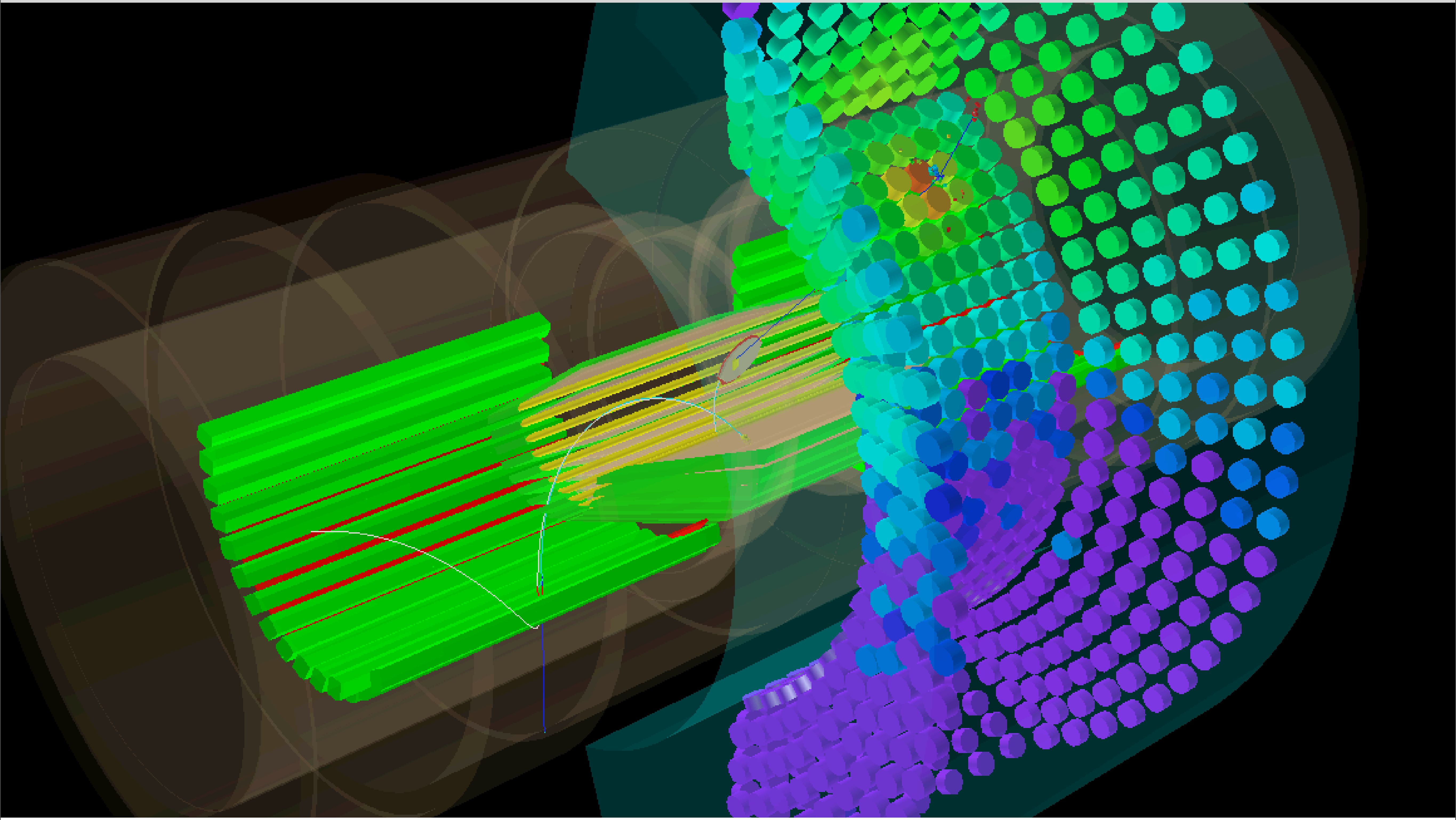


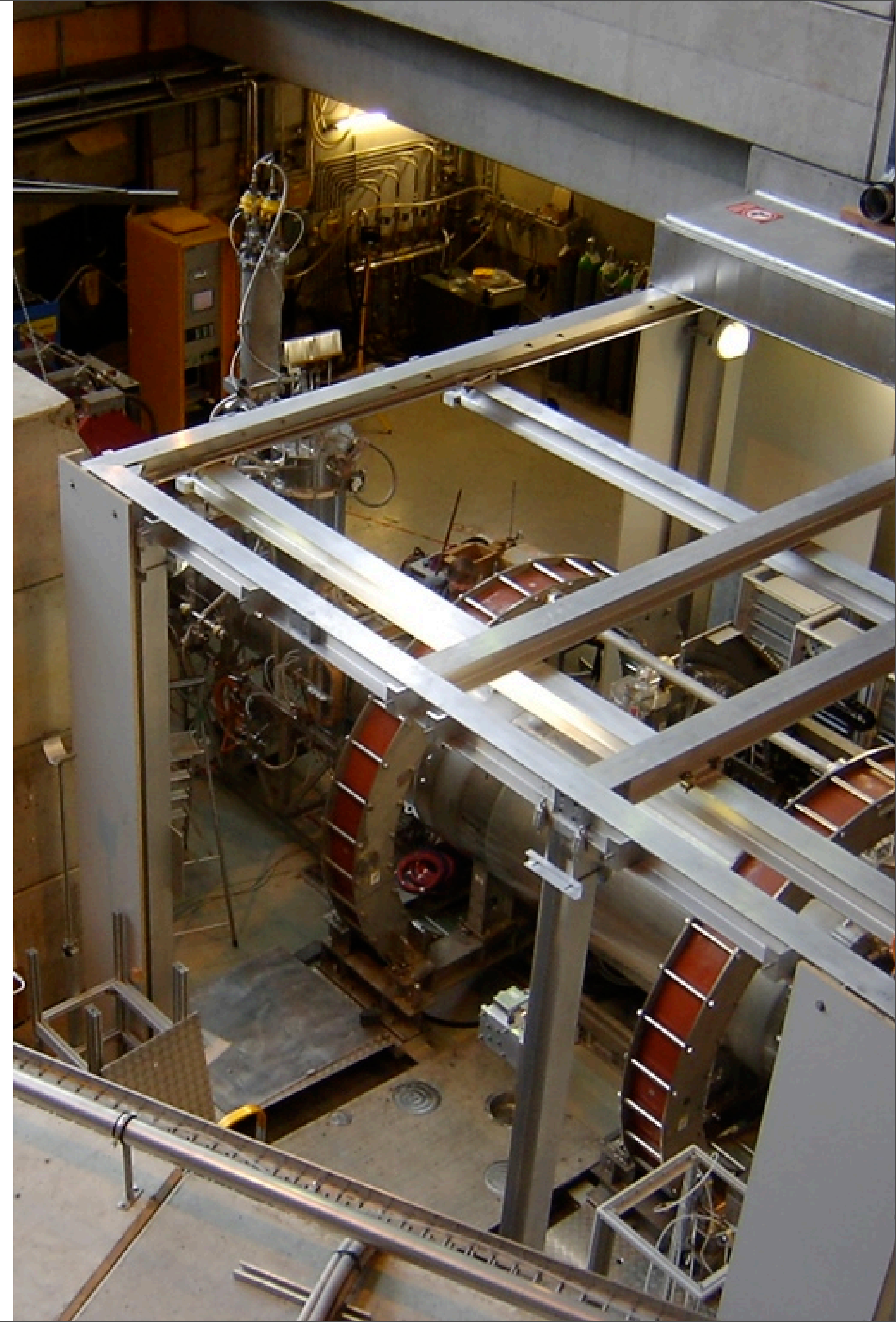
Lepton Flavor Violation in μ→eγ
MEG Experiment

W. Ootani
ICEPP, University of Tokyo

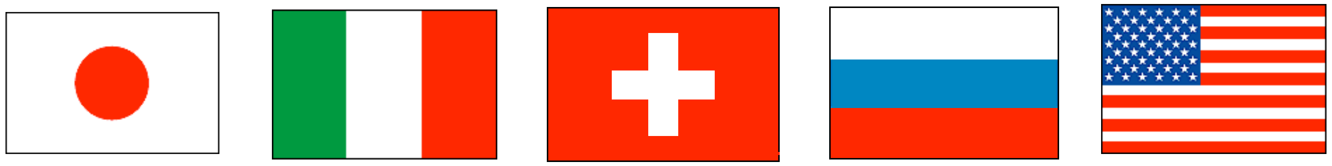
Supersymmetry in 2010's
June 20th-22nd, 2007
Hokkaido University, Sapporo

Contents

- What is MEG?
- MEG Detector
  - Beam and Target
  - LXe Calorimeter
  - COBRA spectrometer
  - Electronics
- Current Status
- MEG Sensitivity
- Summary and Prospect



MEG Collaboration



~60 physicists from 12 institutes in 5 countries

ICEPP, Univ. of Tokyo
X. Bai, Y. Hisamatsu, T. Iwamoto, K. Kaneko, S. Mihara, T. Mori, H. Natori, H. Nishiguchi, Y. Nishimura, W. Ootani, R. Sawada, S. Yamashita, Y. Uchiyama
KEK
T. Haruyama, K. Kasami, A. Maki, Y. Makida, A. Yamamoto
Waseda Univ.
T. Doke, J. Kikuchi, S. Suzuki, K. Terasawa

INFN and University of Pisa
A. Baldini, C. Bemporad, F. Cei, M. Grassi, D. Nicolò, A. Papa, R. Pazzi, F. Sergiampietri, G. Signorelli
INFN and Univ. of Genova
S. Dussoni, F. Gatti, R. Valle
INFN and Univ. of Pavia
G. Boca, P. W. Cattaneo, G. Cecchet, A. De Bari, R. Nardò, M. Rossella
INFN and Univ. of Roma I
A. Barchiesi, D. Zanello
INFN and Univ. of Lecce
M. Panareo

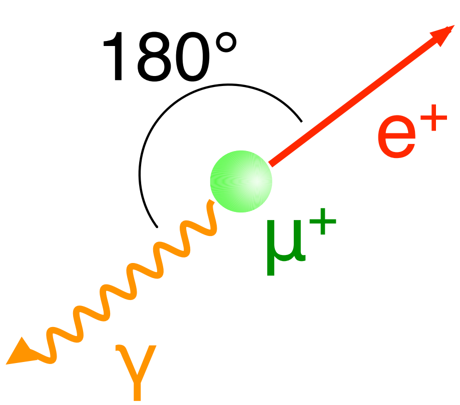
Paul Scherrer Institute
J. Egger, M. Hildebrandt, P.-R. Kettle, S. Ritt, M. Schneebeli

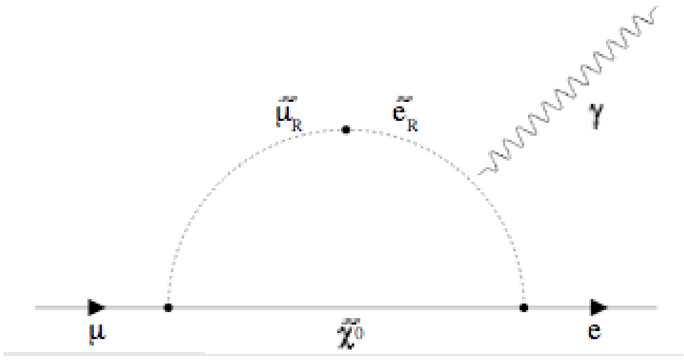
BINP Novosibirsk
L. M. Barkov, A. A. Grebenuk, D. N. Grigoriev, B. I. Khazin, N. M. Ryskulov
JINR Dubna
A. Korenchenko, N. Kravchuk, A. Moiseenko, D. Mzavia

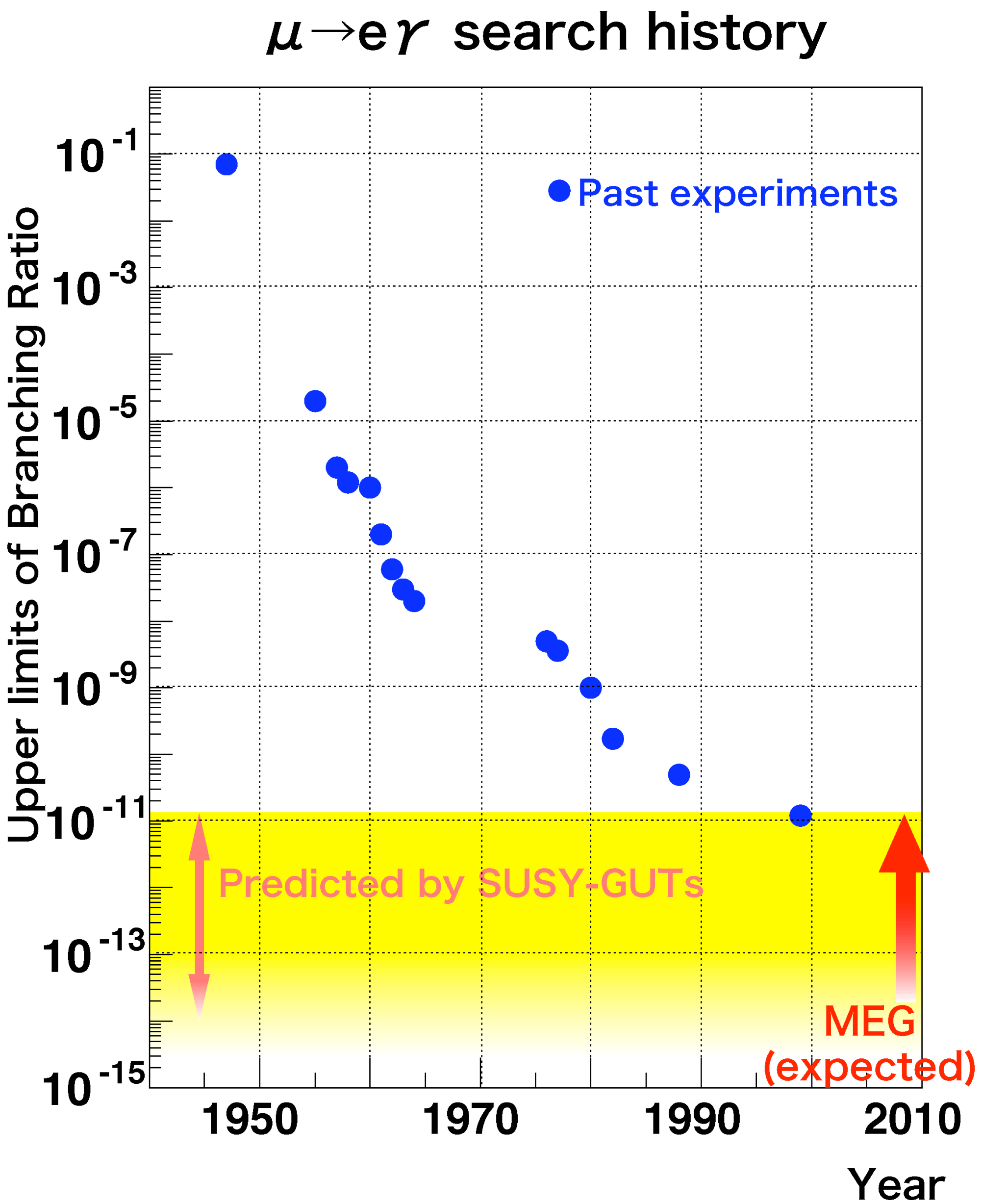
Univ. of California, Irvine
W. Molzon, M. Hebert, P. Huwe, J. Perry, V. Tumakov, F. Xiao, S. Yamada

What Is MEG?

- MEG is an upcoming experiment to seek evidence for lepton flavor violating muon decay, $\mu \rightarrow e\gamma$.
- Expected sensitivity ~ BR~10^{-13} improving the present limit by two orders of magnitude.
- There's a real chance to discover evidence of new physics beyond the SM such as SUSY-GUTs.



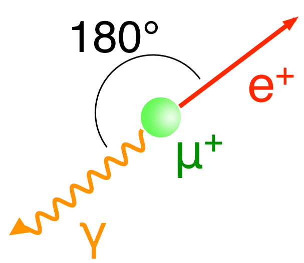




What’s Necessary for μ→eγ Search?

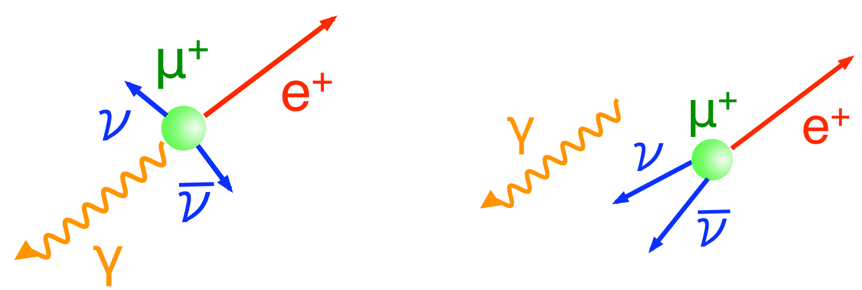
- A lot of muons
  - High intensity μ^+ beam
  - High duty factor to minimize accidental background
- Good detector
  - Precise measurements of energy, timing and angle for positron and gamma
  - Capability to identify pileups

- Signal
  - Back-to-back
  - Mono-energetic
    E_e=52.8MeV E_γ=52.8MeV
  - Coincident in time



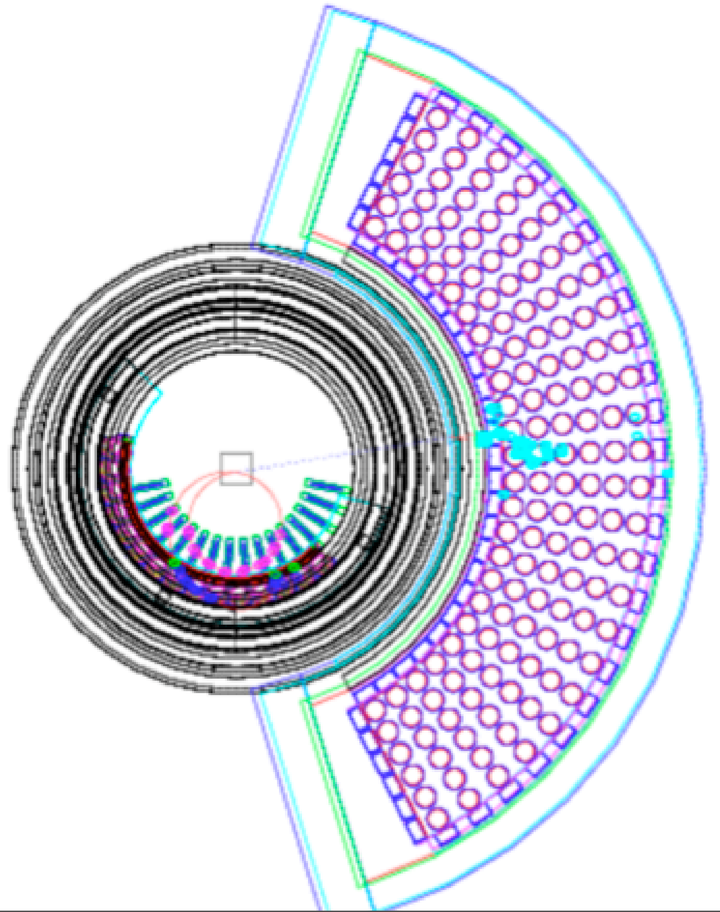
- Background
  - Prompt background: μ→eγνν
  - “Accidental” overlap: μ→eνν + γ

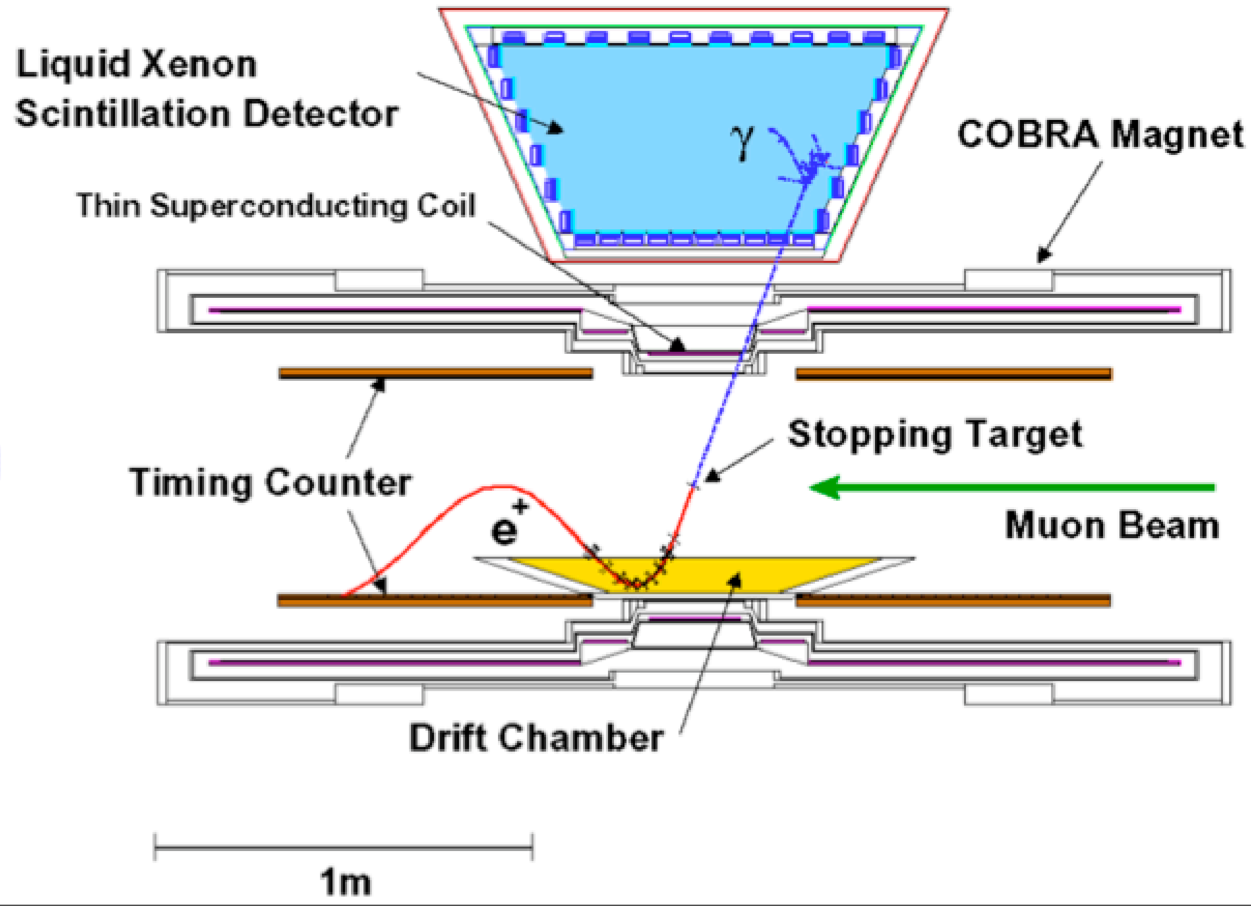
Predominant



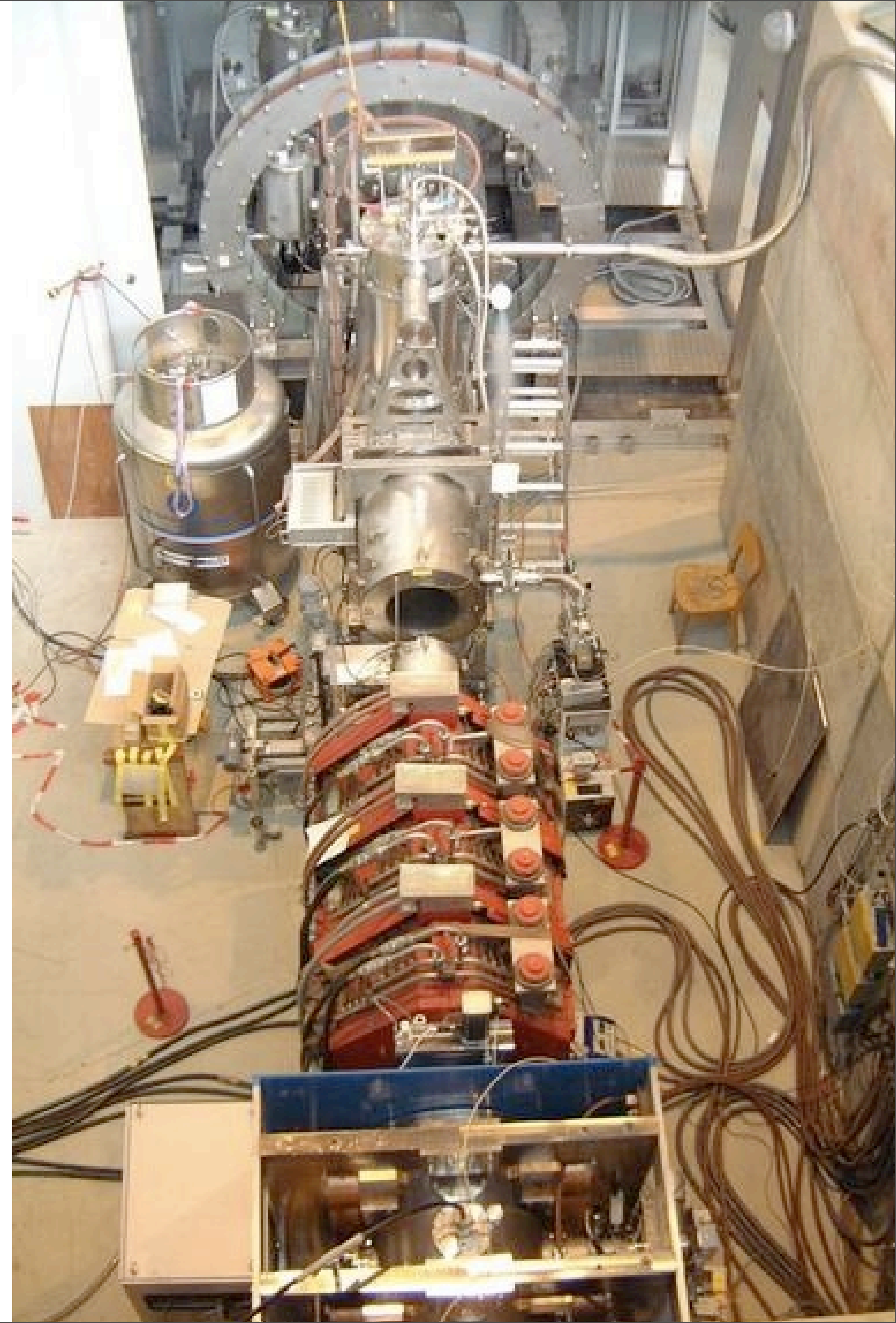
Our Solution

- World's most intense DC muon beam up to 10^8 μ^+/sec at Paul Scherrer Institute
- MEG detector
  - Gamma: LXe scintillation detector
  - Positron: COBRA positron spectrometer with gradient magnetic field.



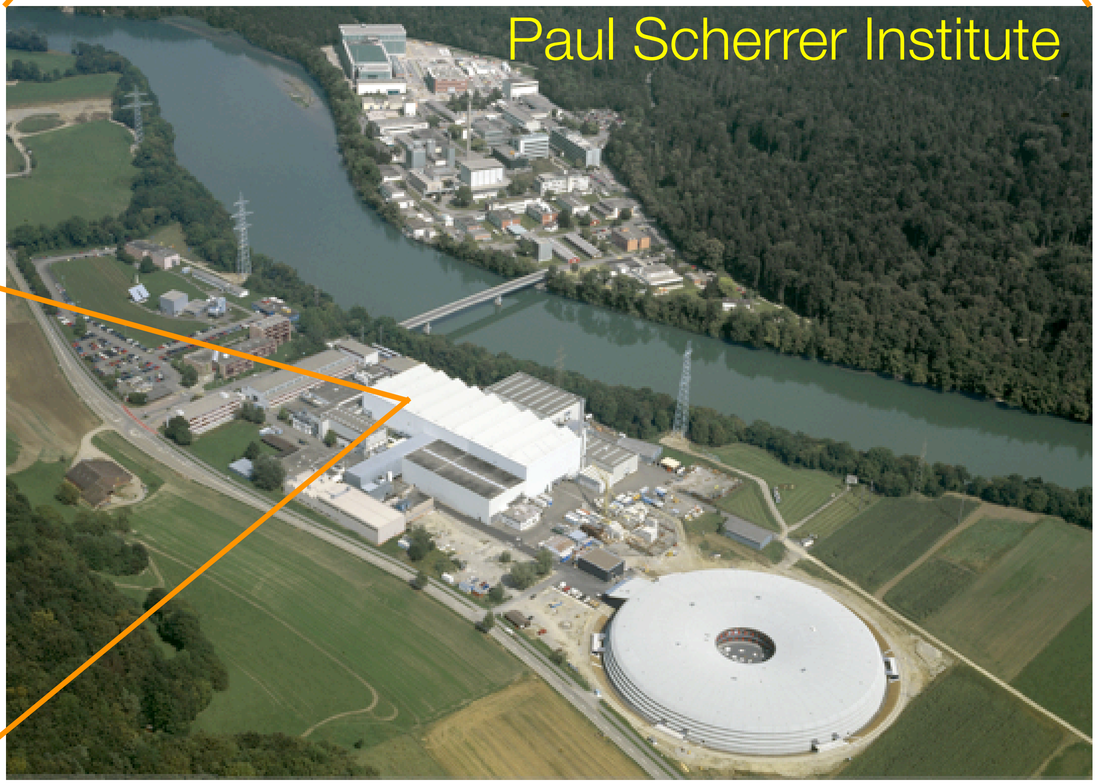


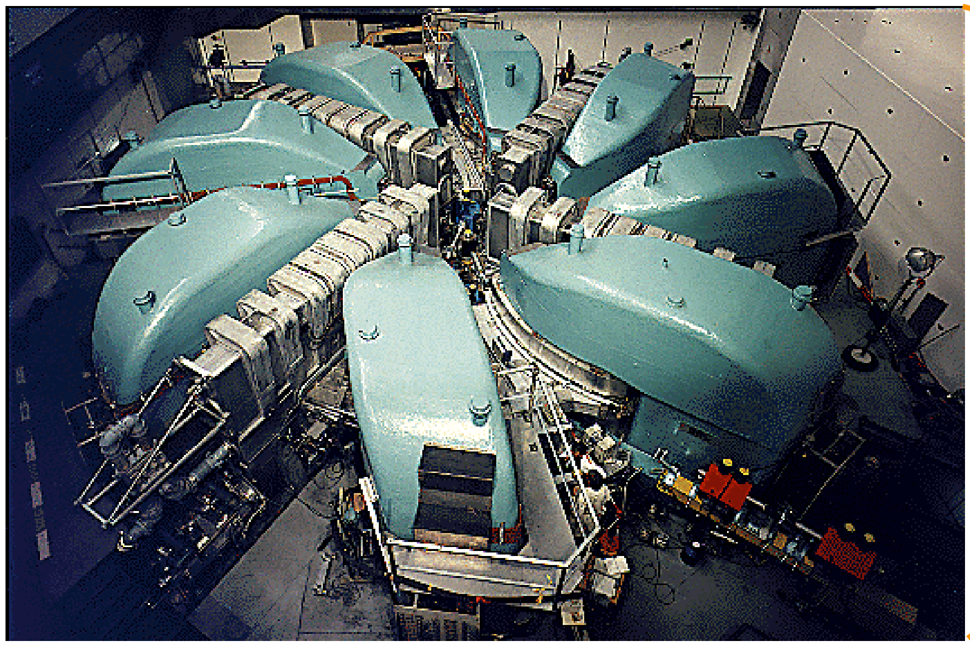
Beam and Target



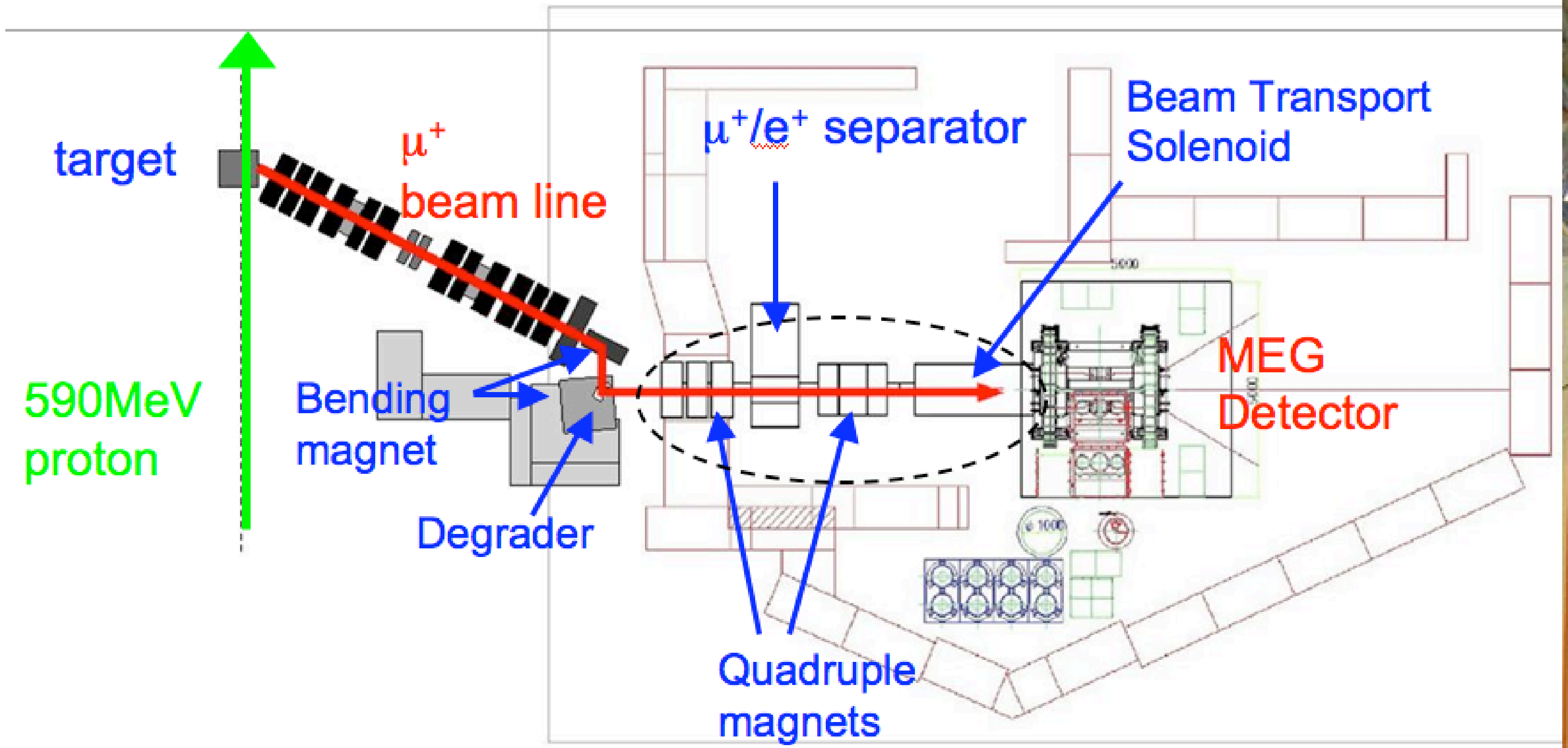
Accelerator

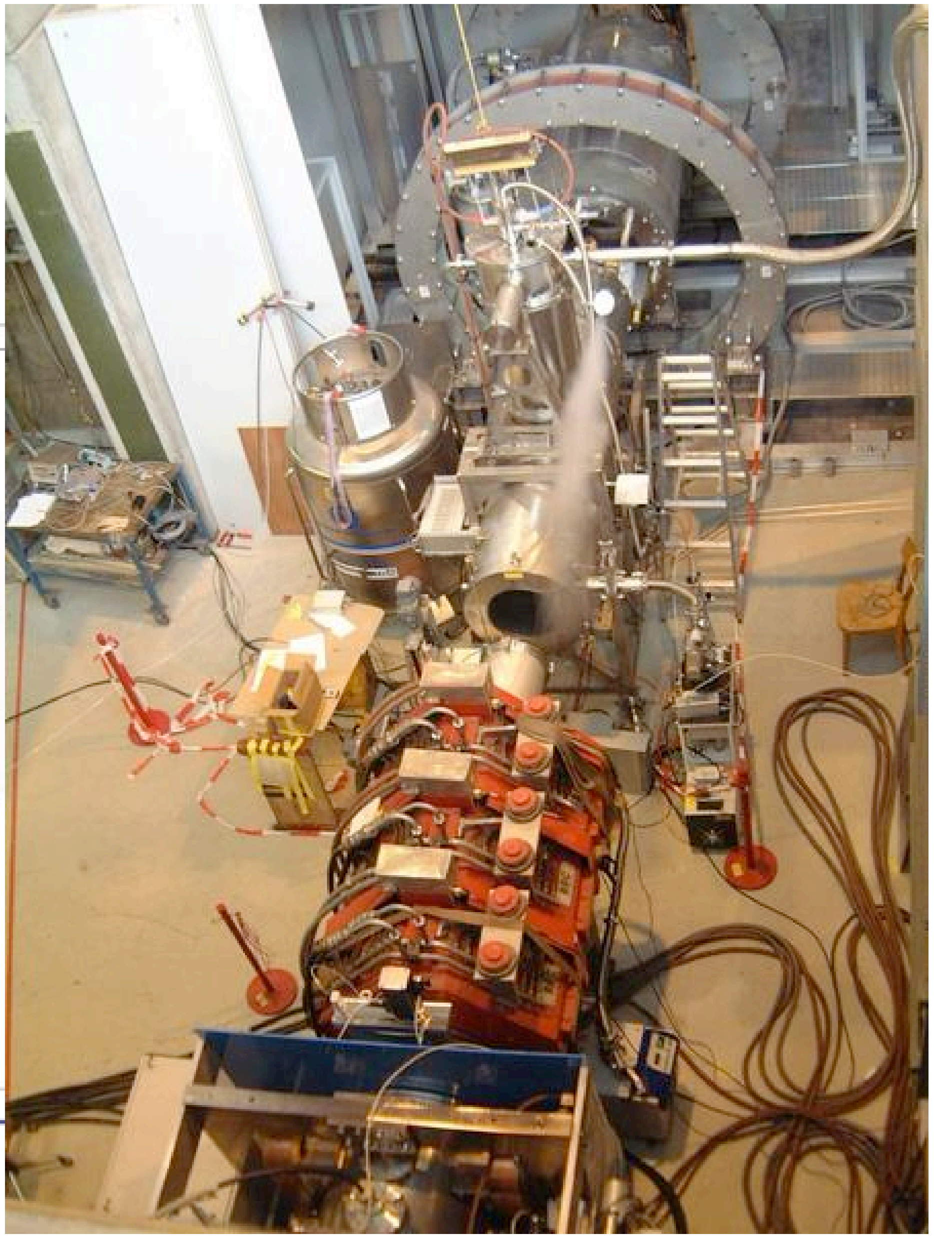
- PSI is the best place for $\mu \to e\gamma$ search.
- 600MeV ring cyclotron
- Beam power over 1MW
- 1.8-2mA proton current
- Continuous muon beam
- MEG at PSI
    - 1998 LOI
    - 1999 Proposal
    - 1999 Approval

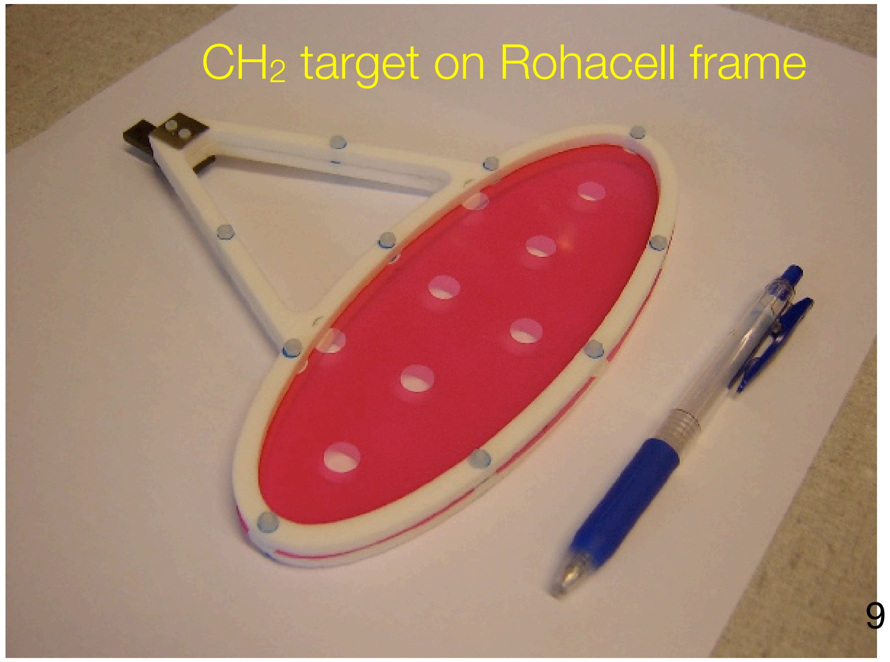




Beam Transport and Target

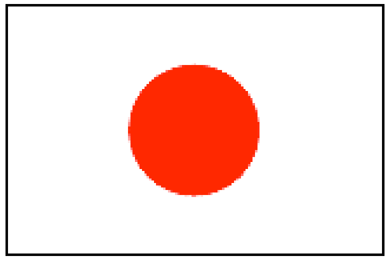


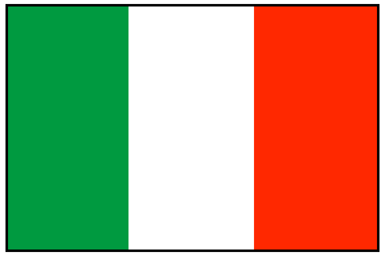


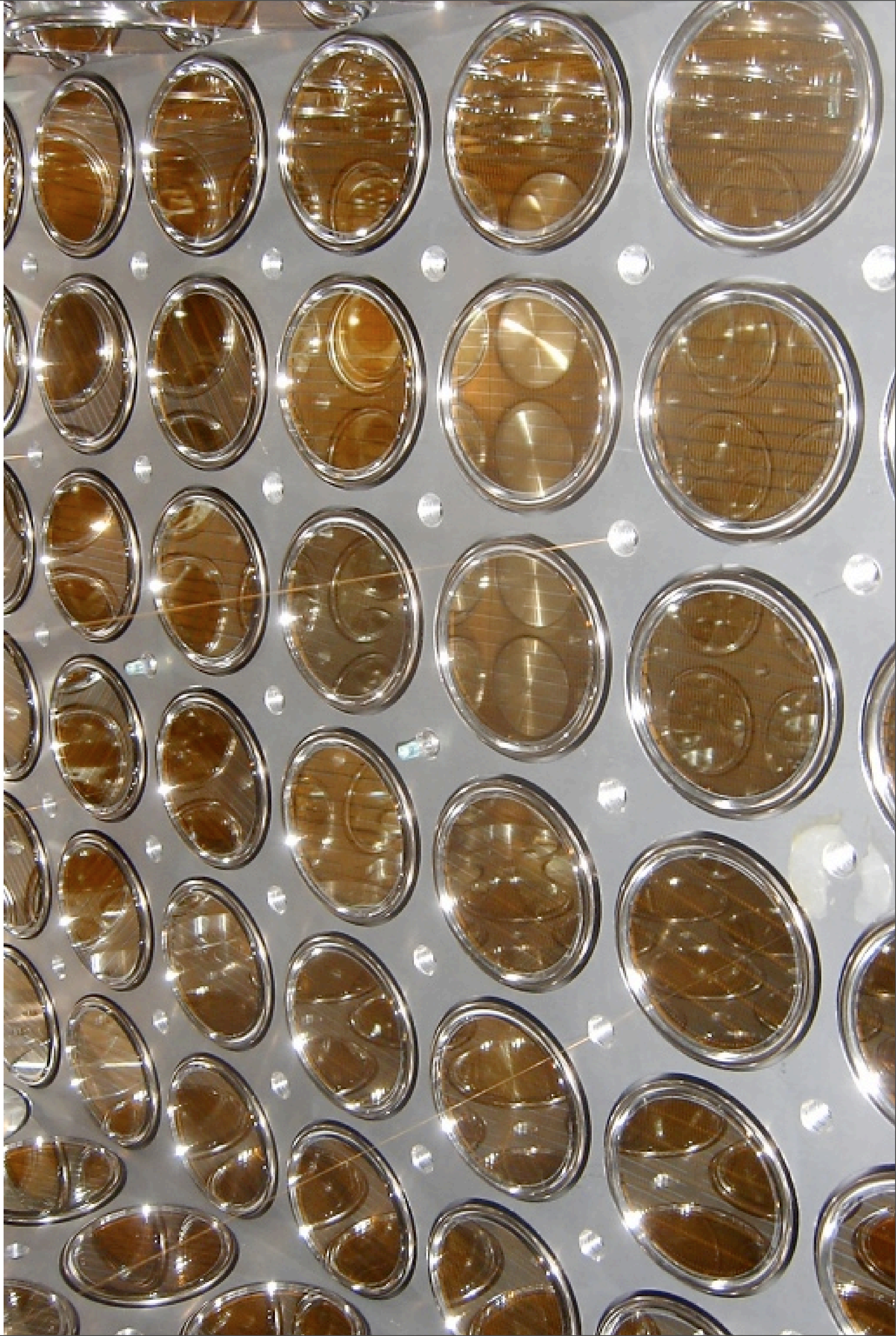


- Beam transport system
  - πE5 beam channel
  - 28MeV/c surface muon beam ~10^8/sec
  - Wien filter for μ^+/e^+ separation
  - Superconducting transport solenoid with degrader
- Target
  - 150μm-thick CH_2 target supported by Rohacell frame
  - slanted angle 22°

Liquid Xenon Detector

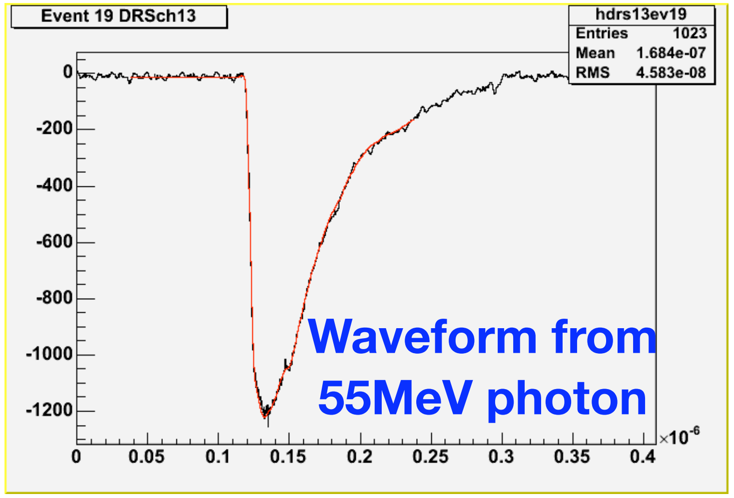


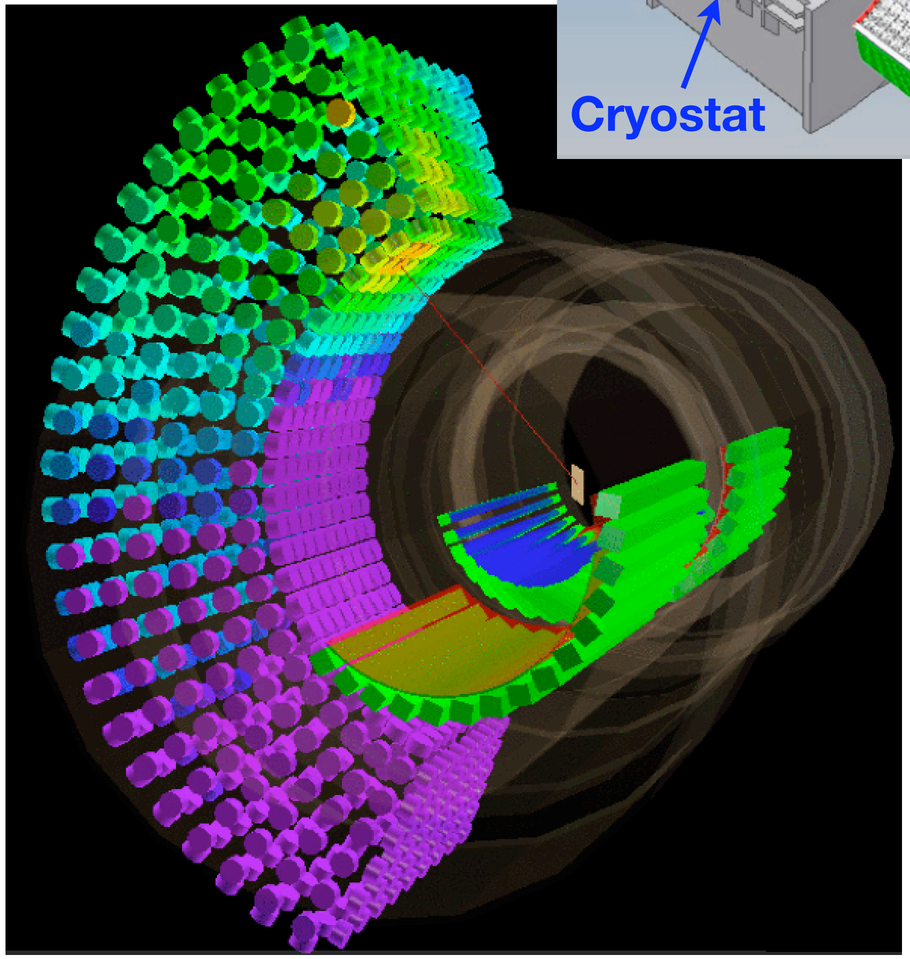


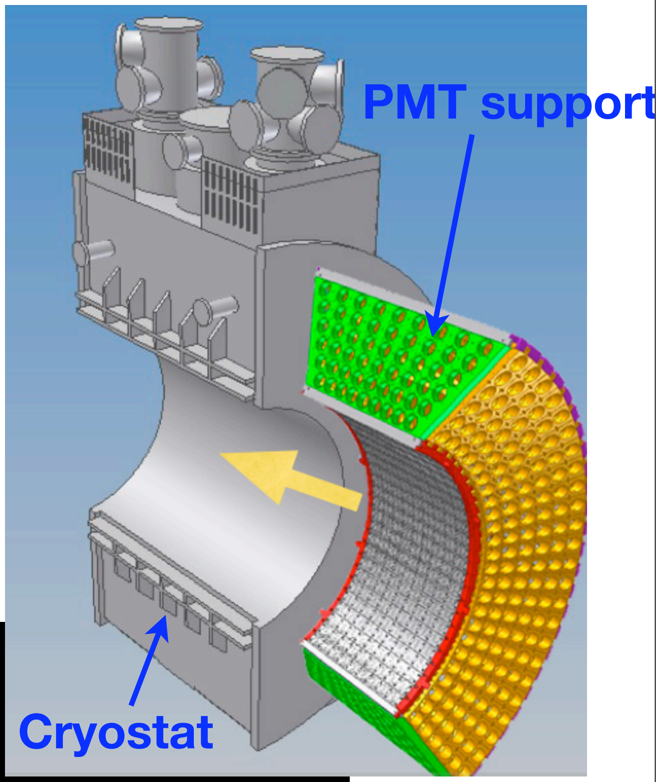


Liquid Xenon Scintillation Detector

- All sides of C-shape 800L LXe are surrounded by 846 photomulipliers (PMTs).
- How to measure high energy gamma-ray?
  - Energy: collect scintillation light as much as possible
  - Position: PMT output distribution
  - Time: average photon arrival time
- All PMTs are read out by waveform digitizer→pileup ID, particle ID

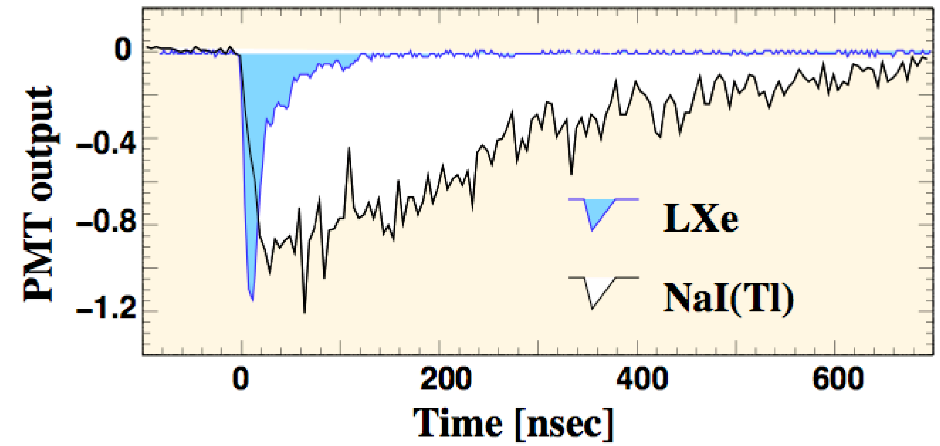


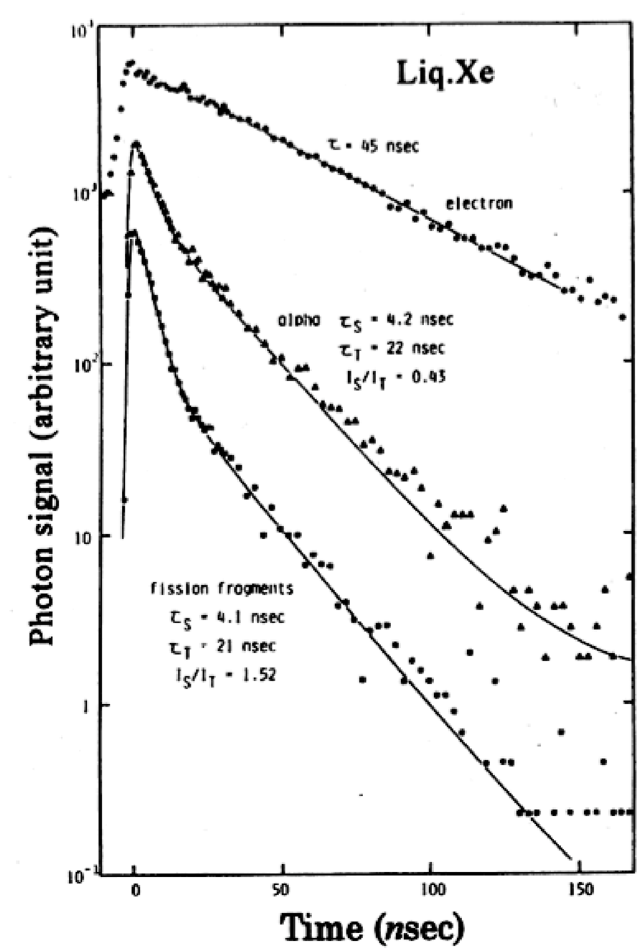




Liquid Xenon Photon Detector, cont’d

- Why LXe?
  - High light yield (75% of NaI(Tl))
  - Short radiation length (X_0=2.77cm)
  - Fast response (τ=4.2ns, 22ns, 45ns)
  - Homogeneous
  - Can be large and non-segmented
  - Purification even after the construction
  - No self-absorption of scintillation light





Excitation

$$
\begin{aligned}
Xe + Xe^* &\rightarrow Xe_2^*, \\
&\rightarrow 2Xe + h\nu
\end{aligned}
$$

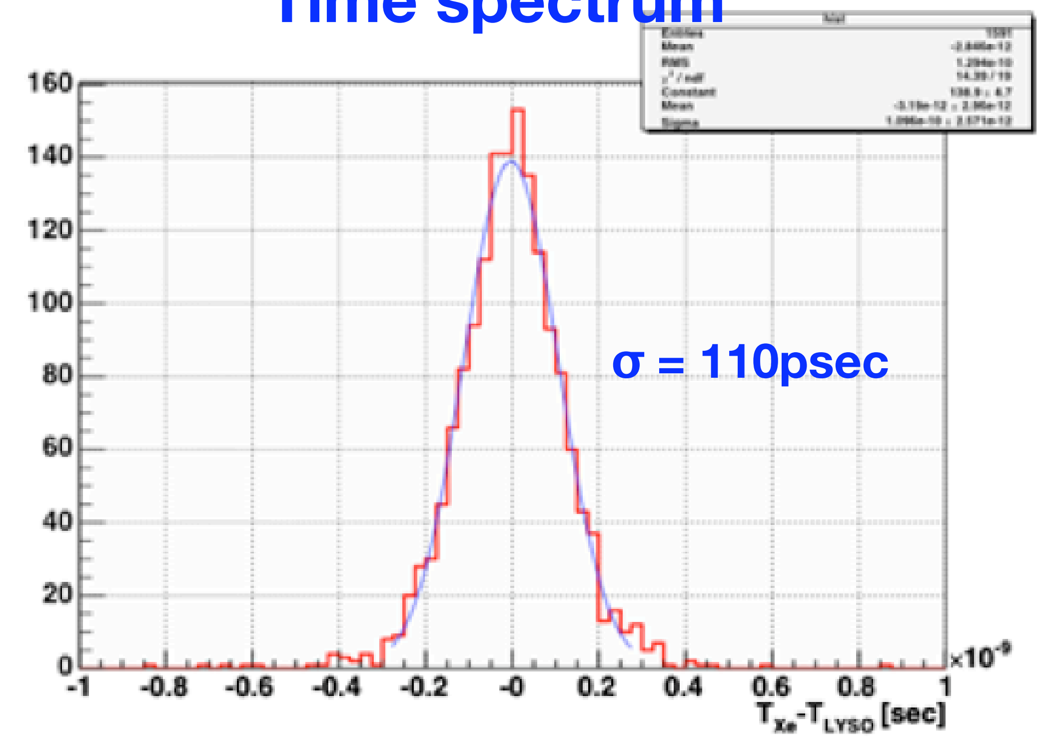
Ionization and recombination

$$
\begin{aligned}
Xe^+ + Xe &\rightarrow Xe_2^+, \\
Xe_2^+ + e &\rightarrow Xe^{**} + Xe, \\
Xe^{**} &\rightarrow Xe^* + \text{heat}, \\
Xe + Xe^* &\rightarrow Xe_2^*, \\
Xe_2^* &\rightarrow 2Xe + h\nu,
\end{aligned}
$$

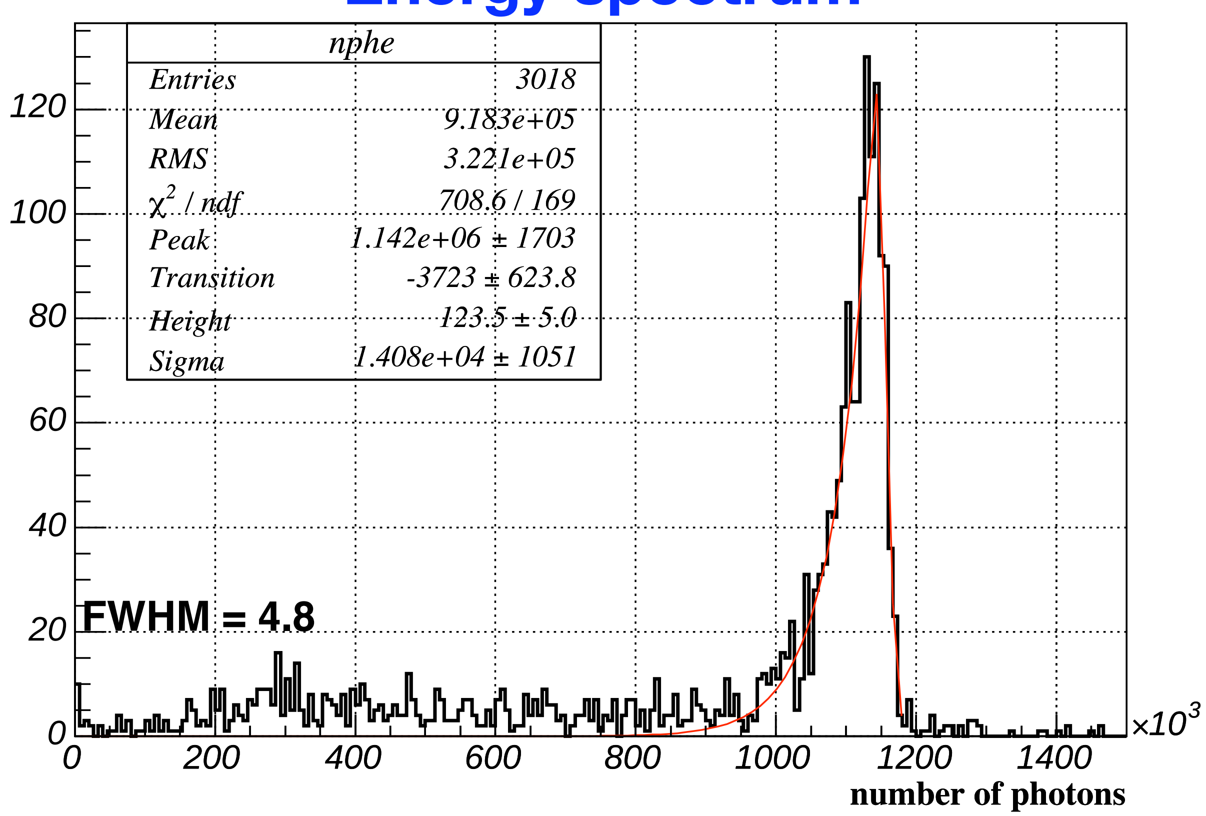
Performance

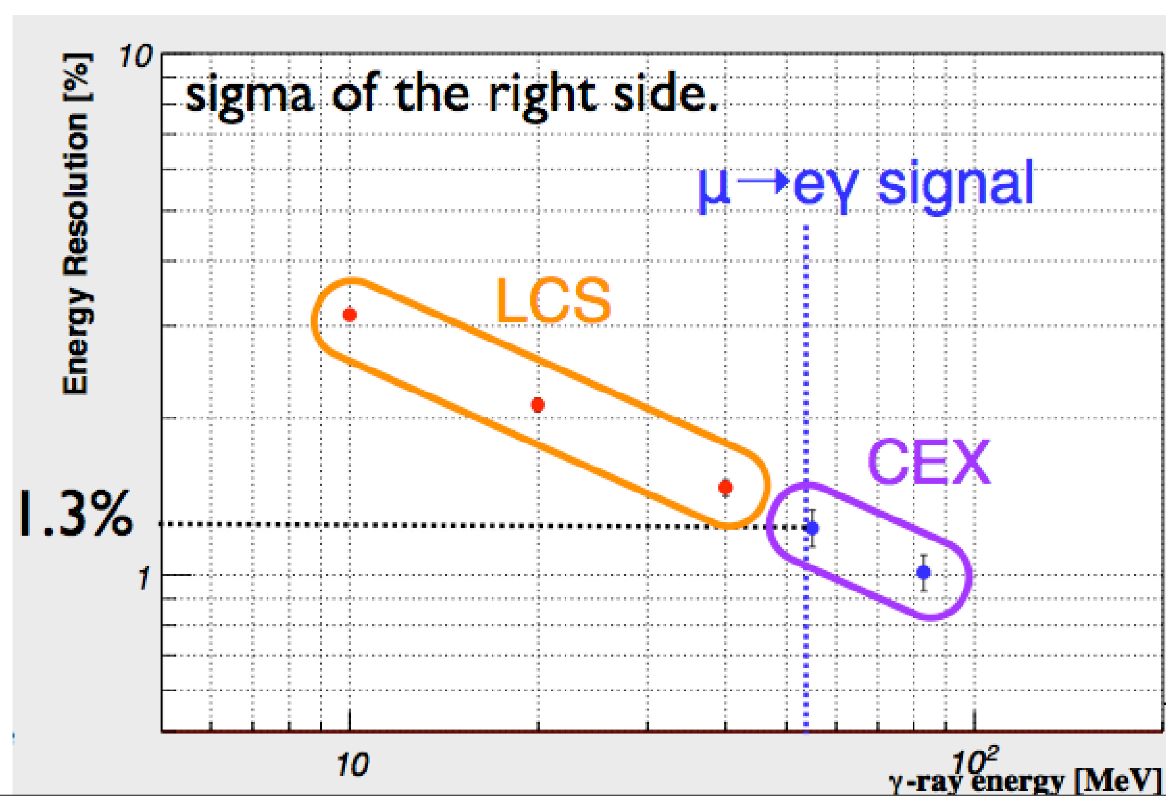
- A prototype (100L LXe + 240 PMTs) was tested out with high energy gamma beam.
- Energy resolution for 55MeV γ
    - 4.8 %(FWHM)
    - 1.23 %(σ on the right side)
- Timing resolution for 55MeV γ: 65 psec (σ)

Time spectrum



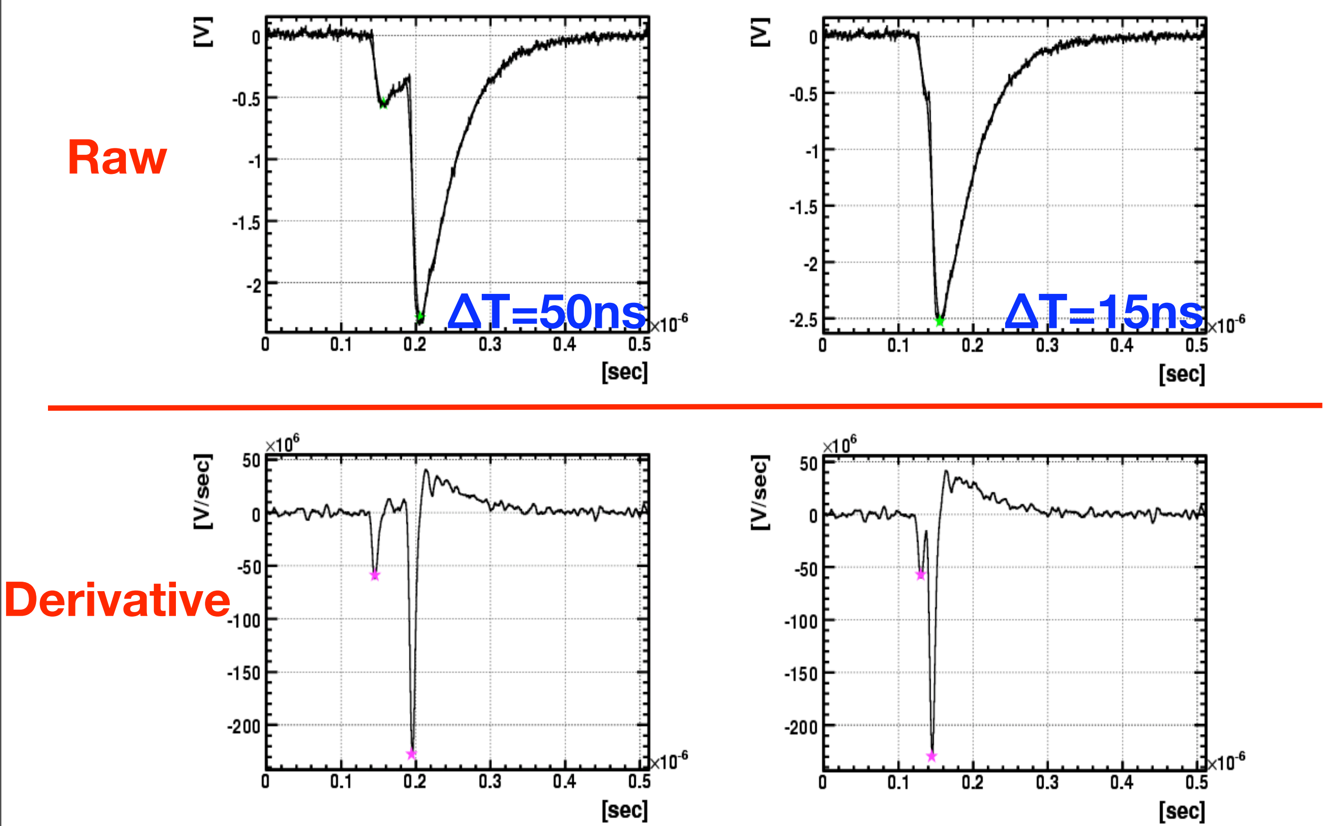
Energy spectrum



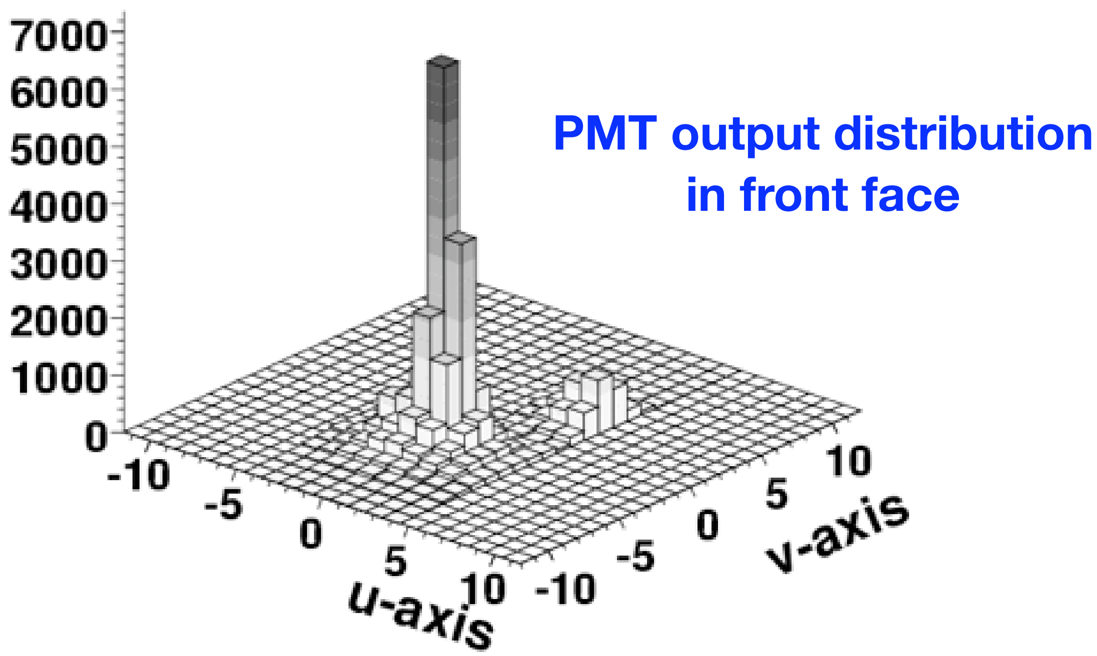


Pileup Identification in LXe Detector

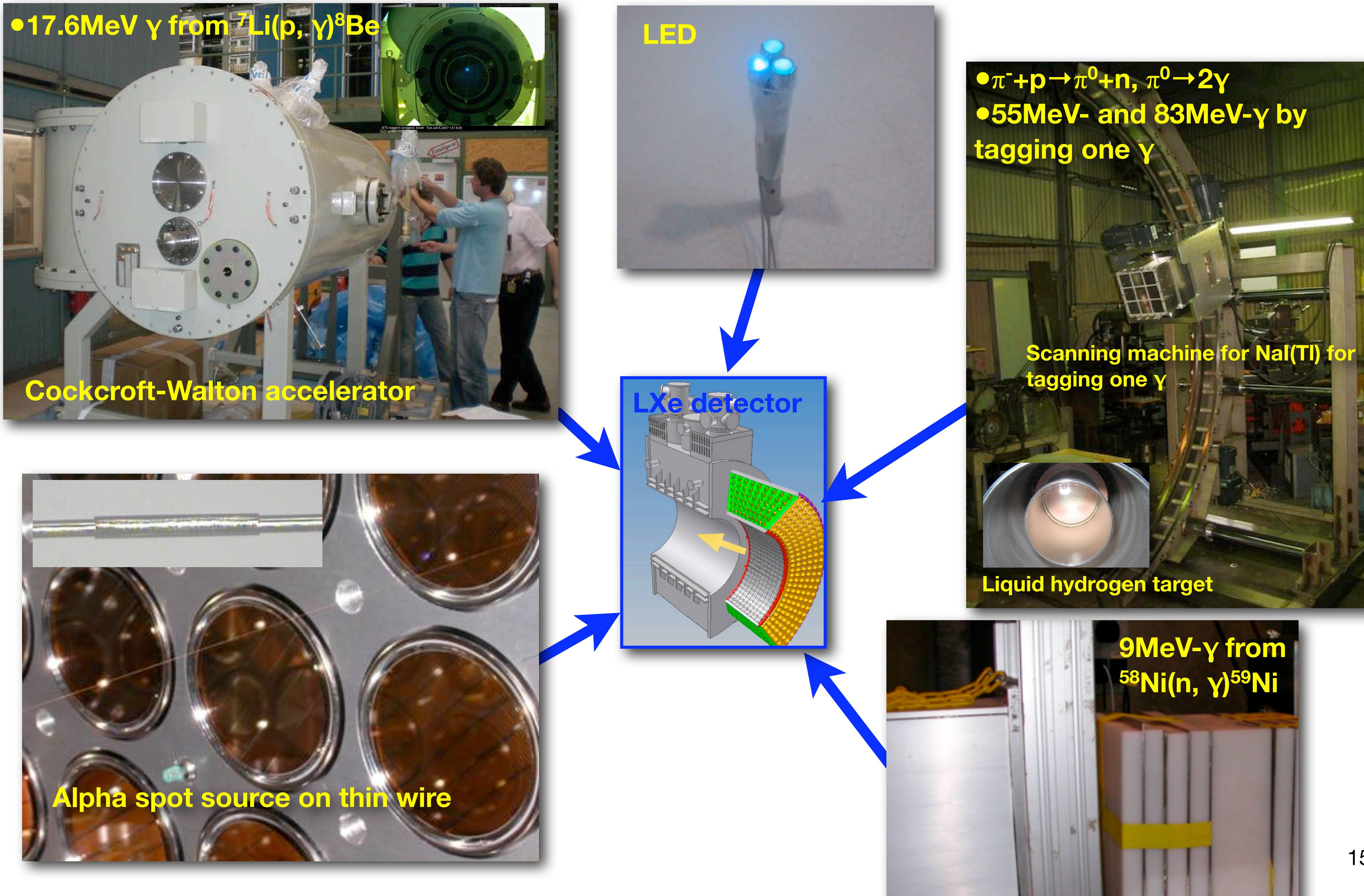
Waveform analysis
(peak finding and pulse shape fitting)



Peak finding in PMT output distribution

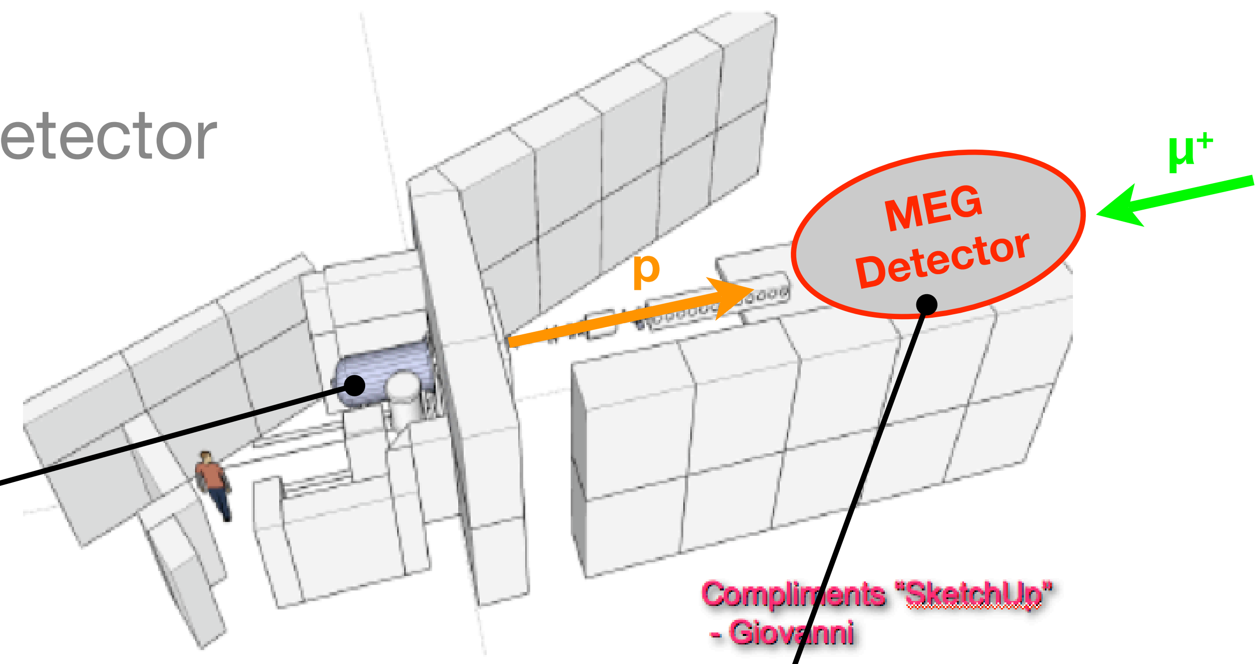


Calibration and Monitoring

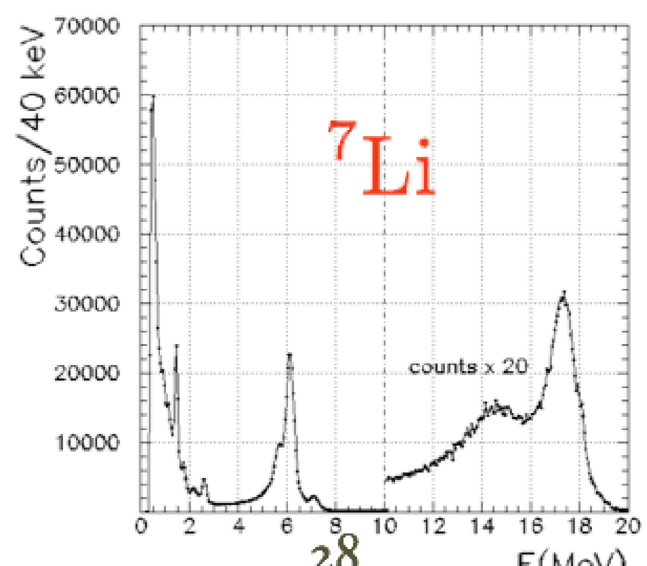


MEG Cockcroft-Walton Accelerator

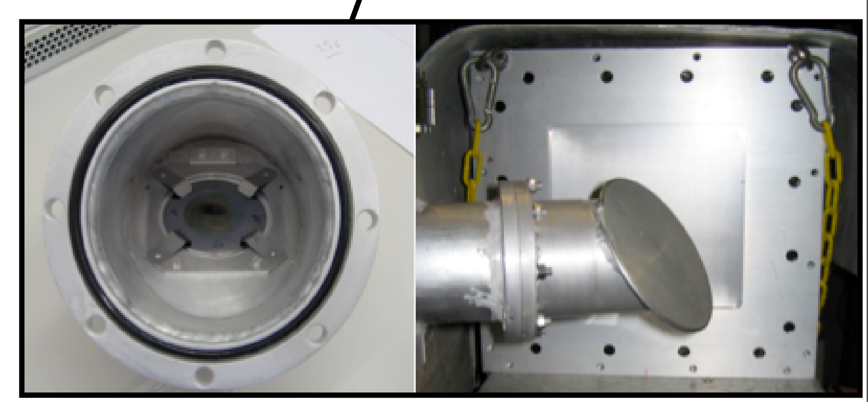
- Cockroft-Walton proton accelerator dedicated for calibration of LXe detector
- Placed at downstream side of the MEG detector
- Monoenergetic γ-ray from $^{7}Li(p, \gamma)^{8}Be$
  - 17.6MeV and 14.6MeV



500keV Cockcroft-Walton accelerator



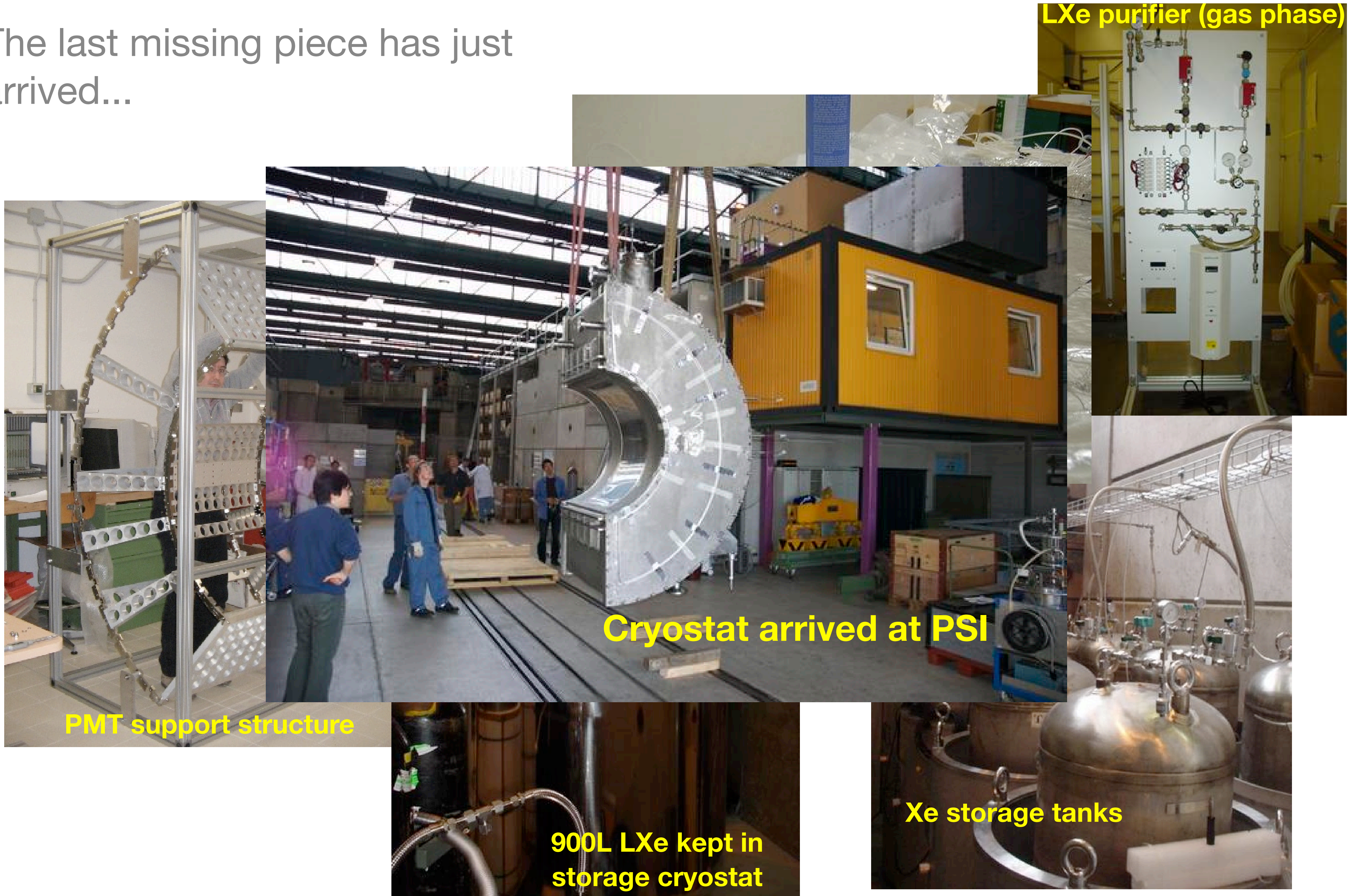
Spectrum taken with NaI(Tl)



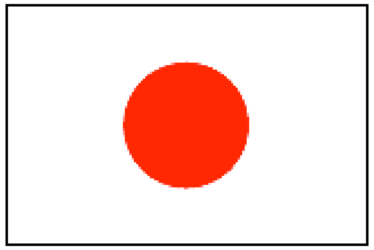
LiF target

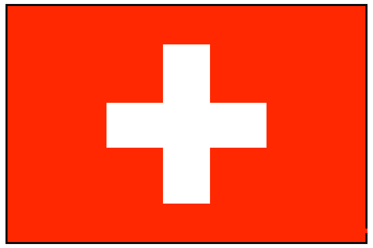
800L Full-Scale Detector

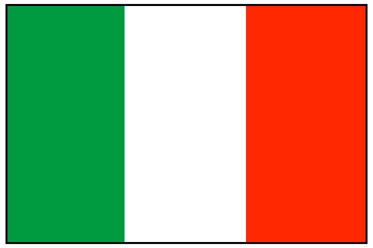
The last missing piece has just arrived...

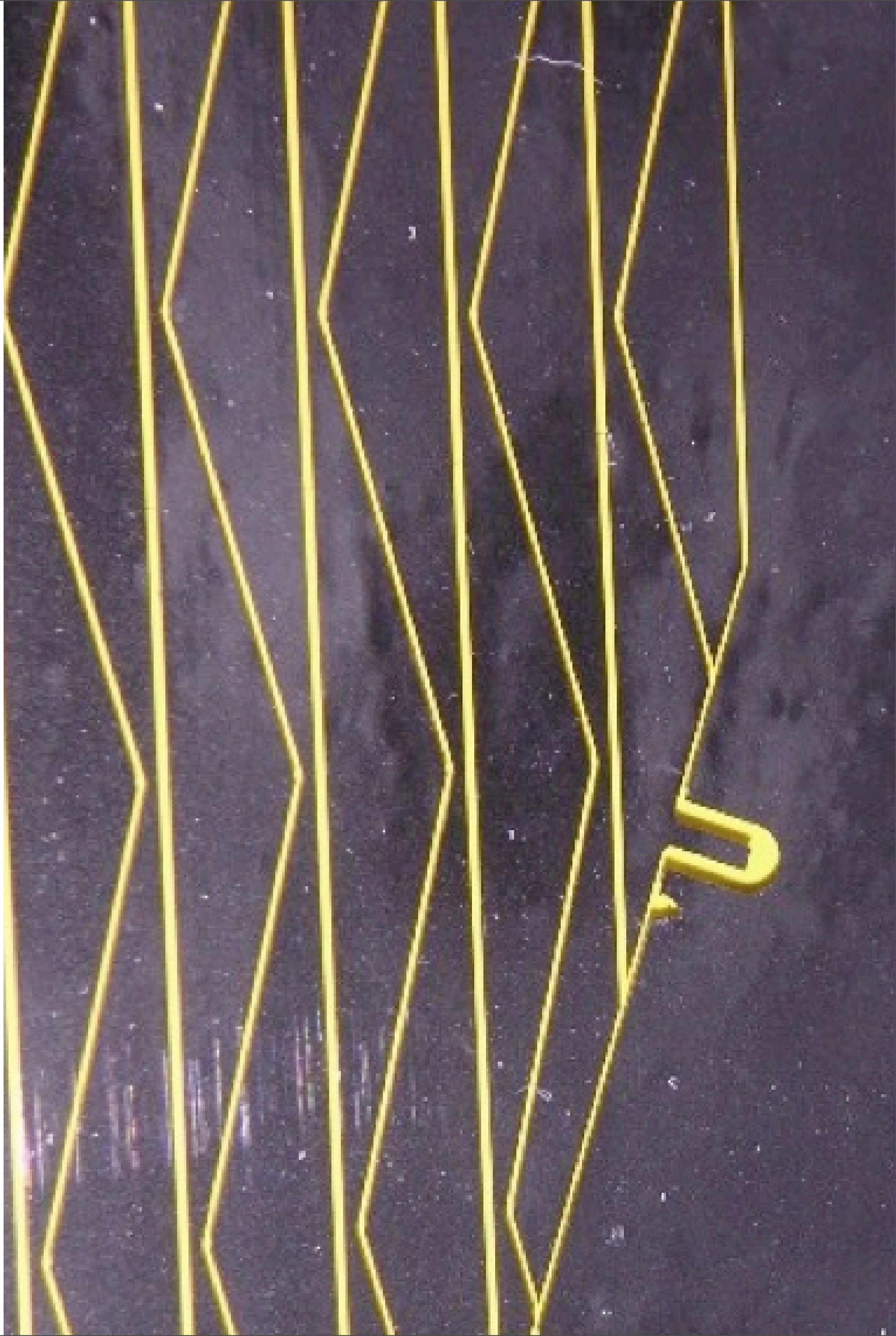


COBRA Spectrometer

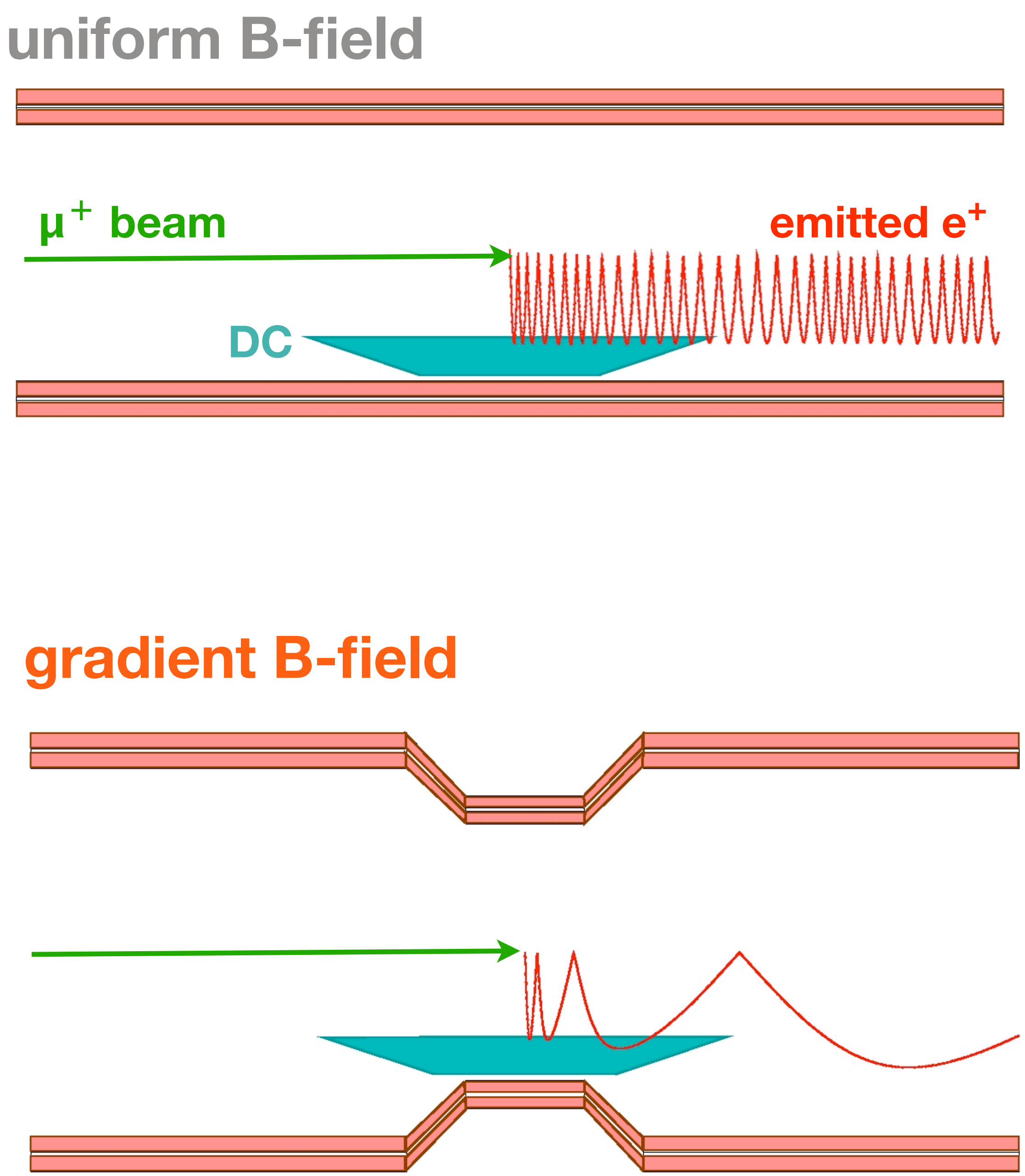




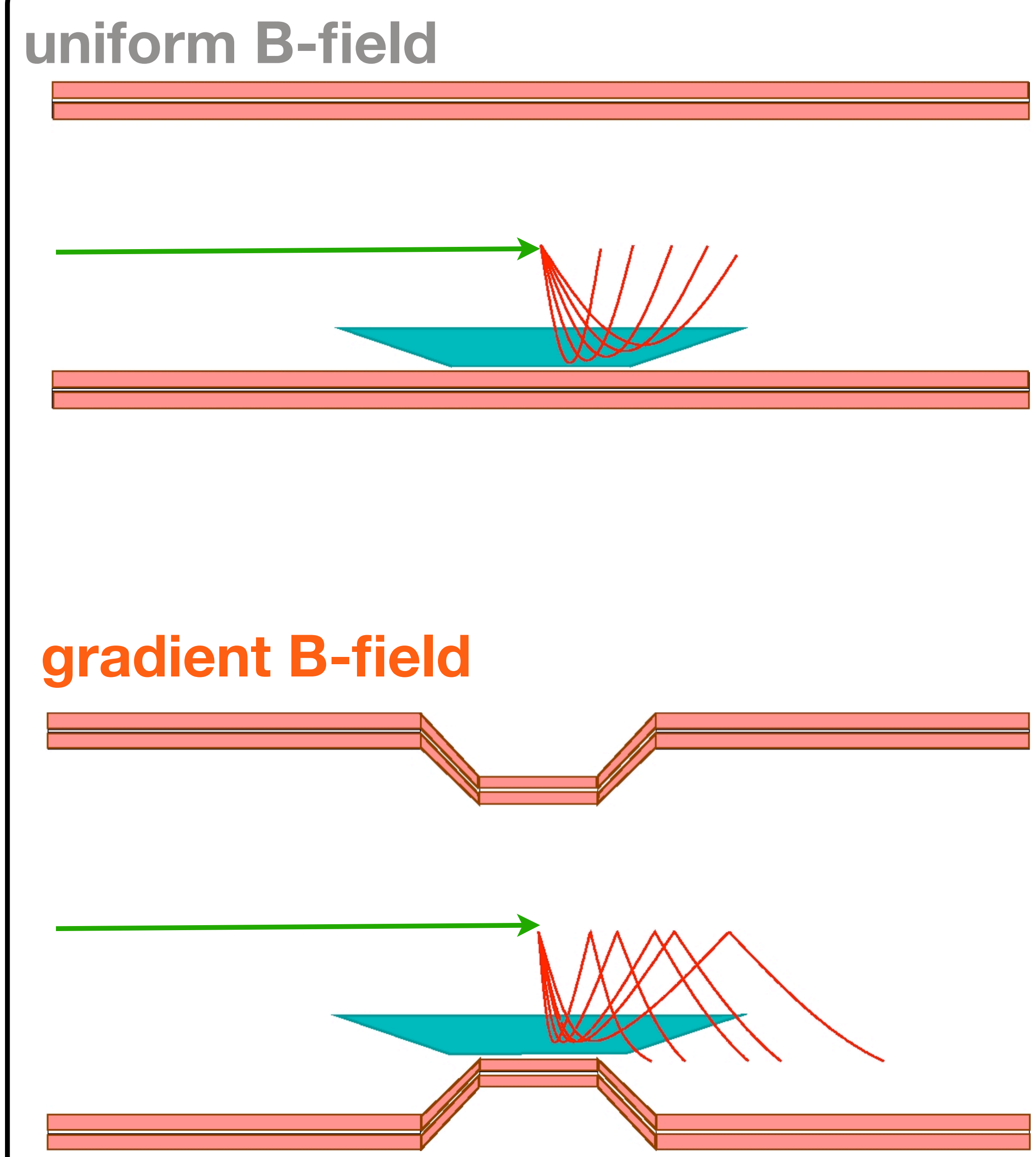




COBRA Spectrometer: Concept



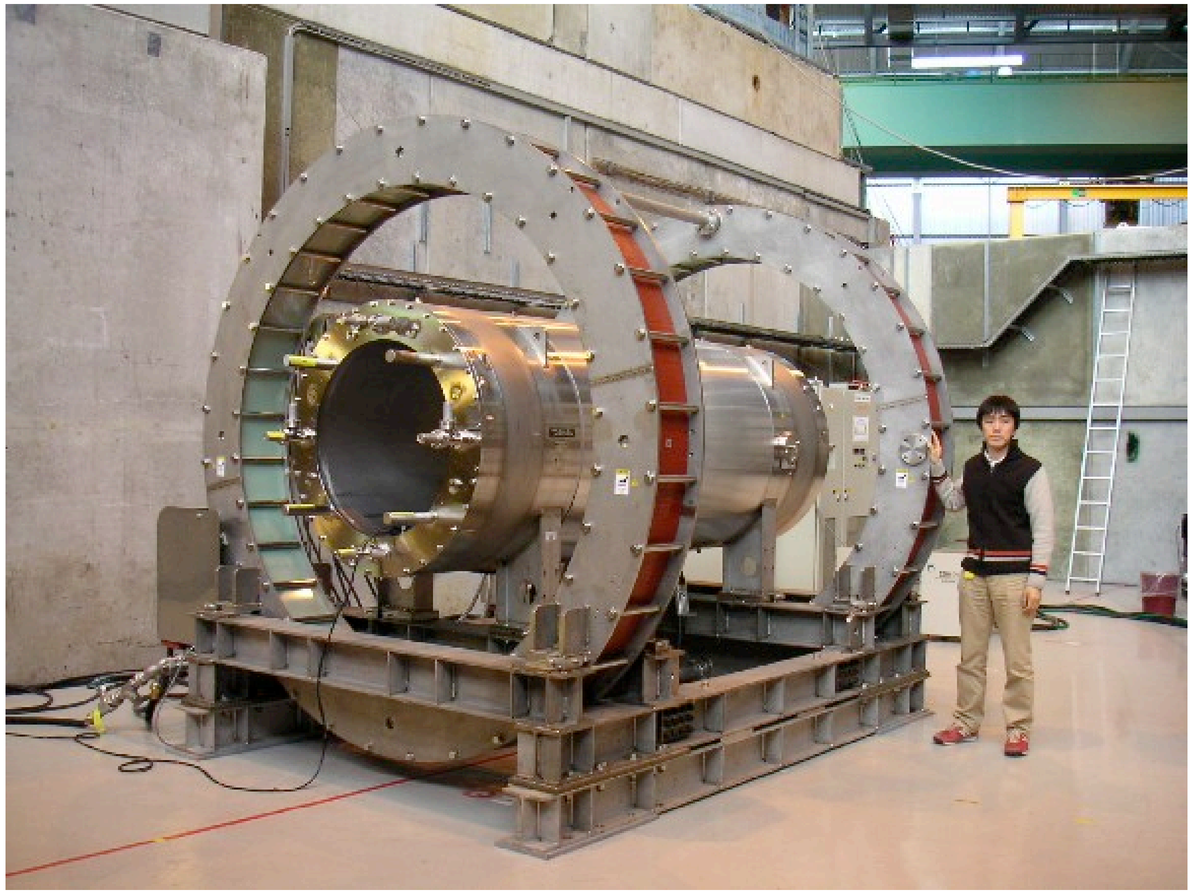
Low energy positrons
quickly swept out

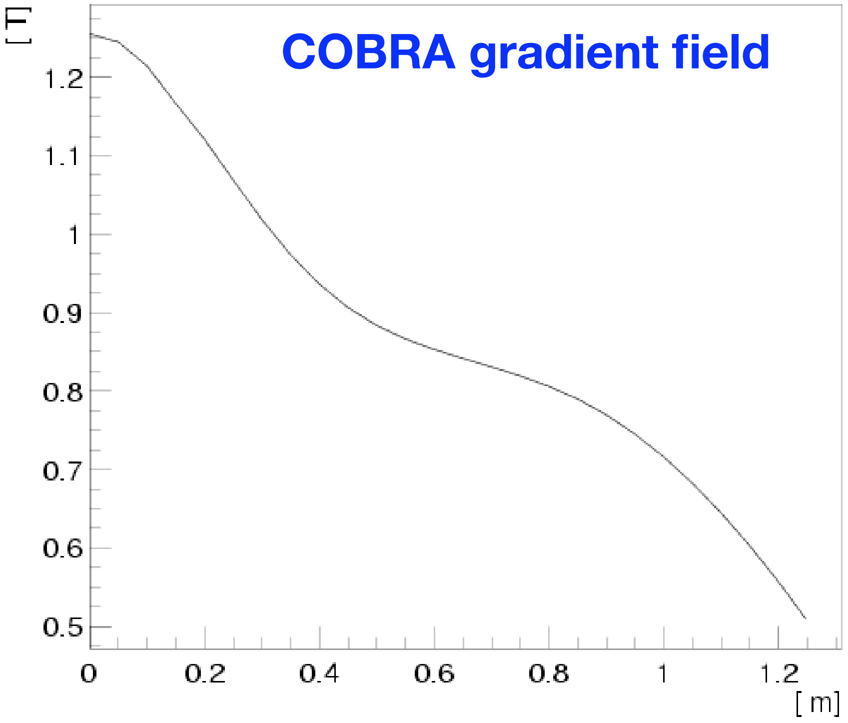


COnstant Bending RAdius
independent of emission angles

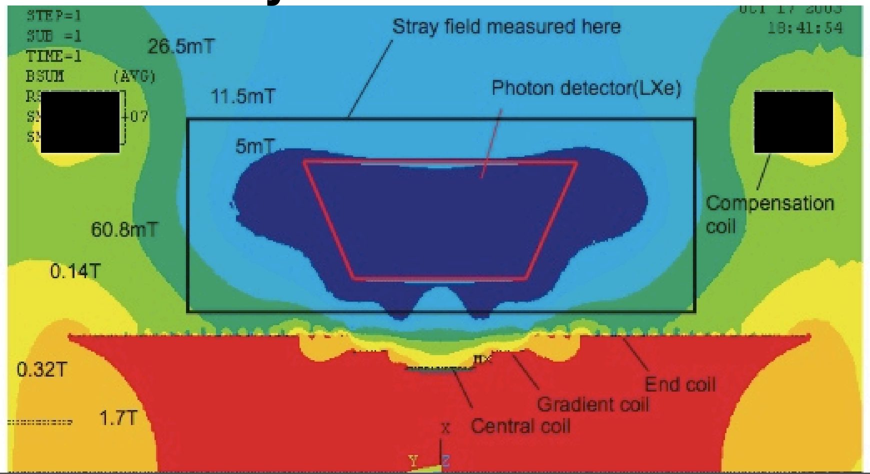
COBRA Magnet

- Thin-wall superconducting magnet designed to form gradient field
- Material thickness within calorimeter acceptance: $0.19X_0$
- Field cancelation by compensation coils for stable operation of the PMTs in the calorimeter



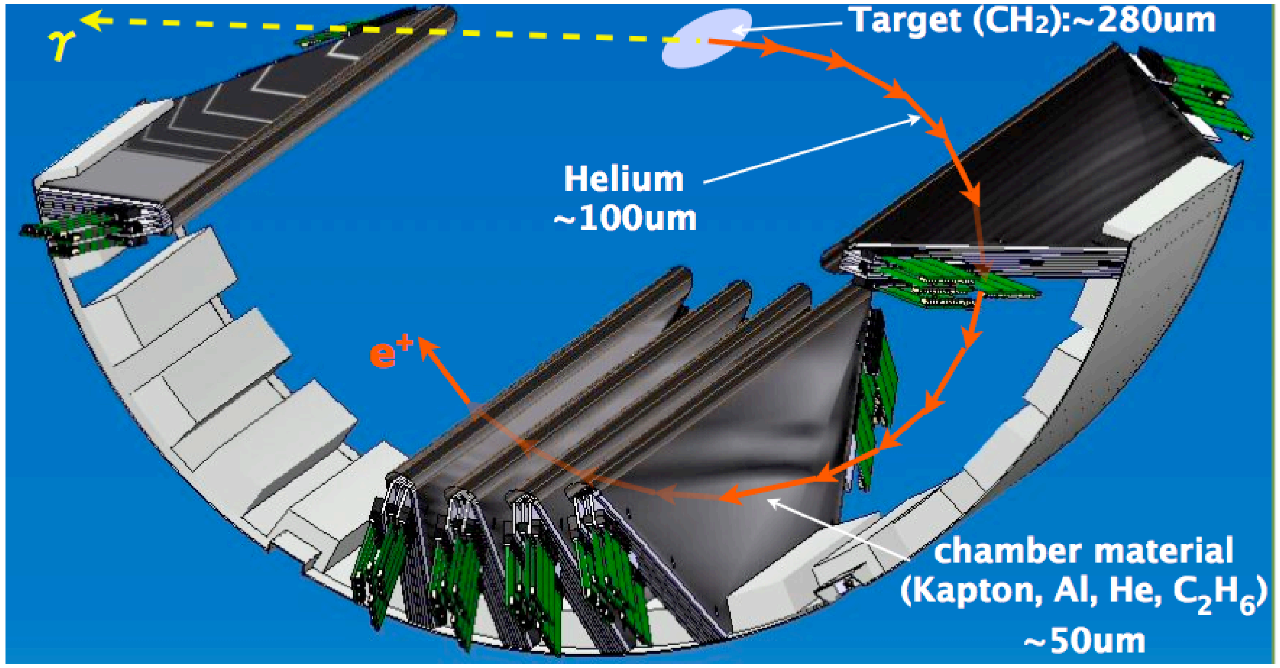


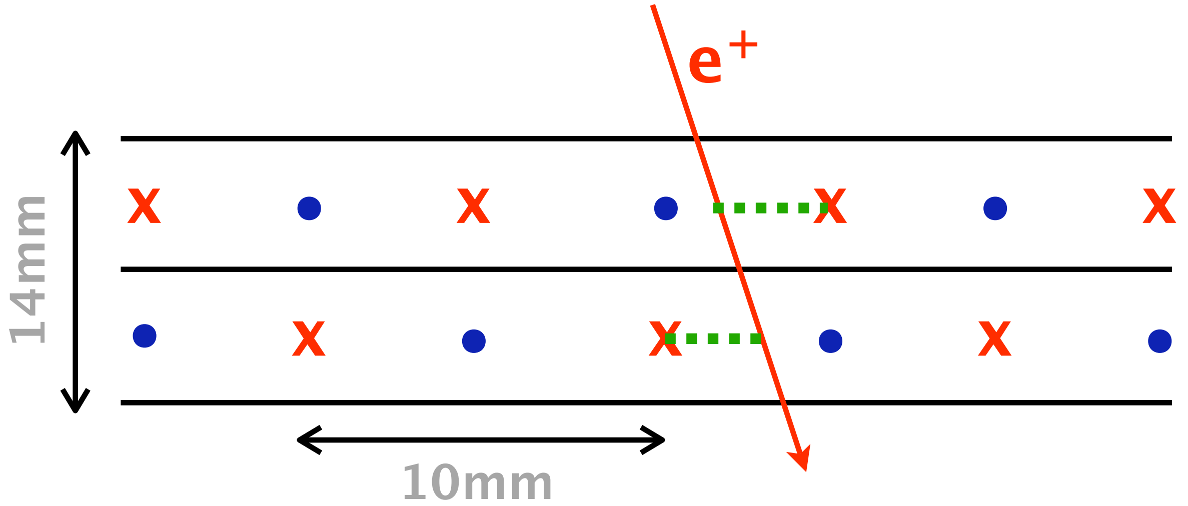
Stray field cancellation

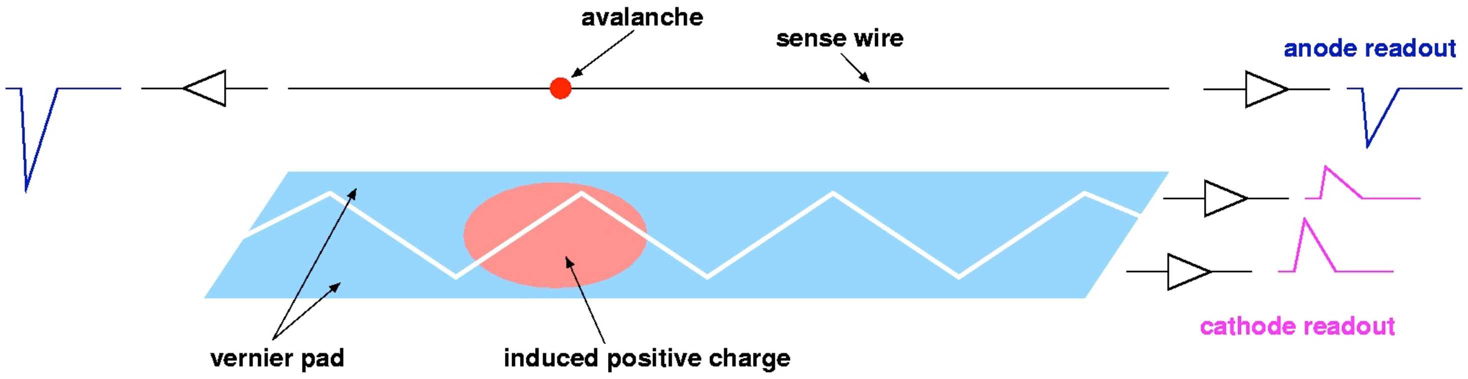


Drift Chamber System

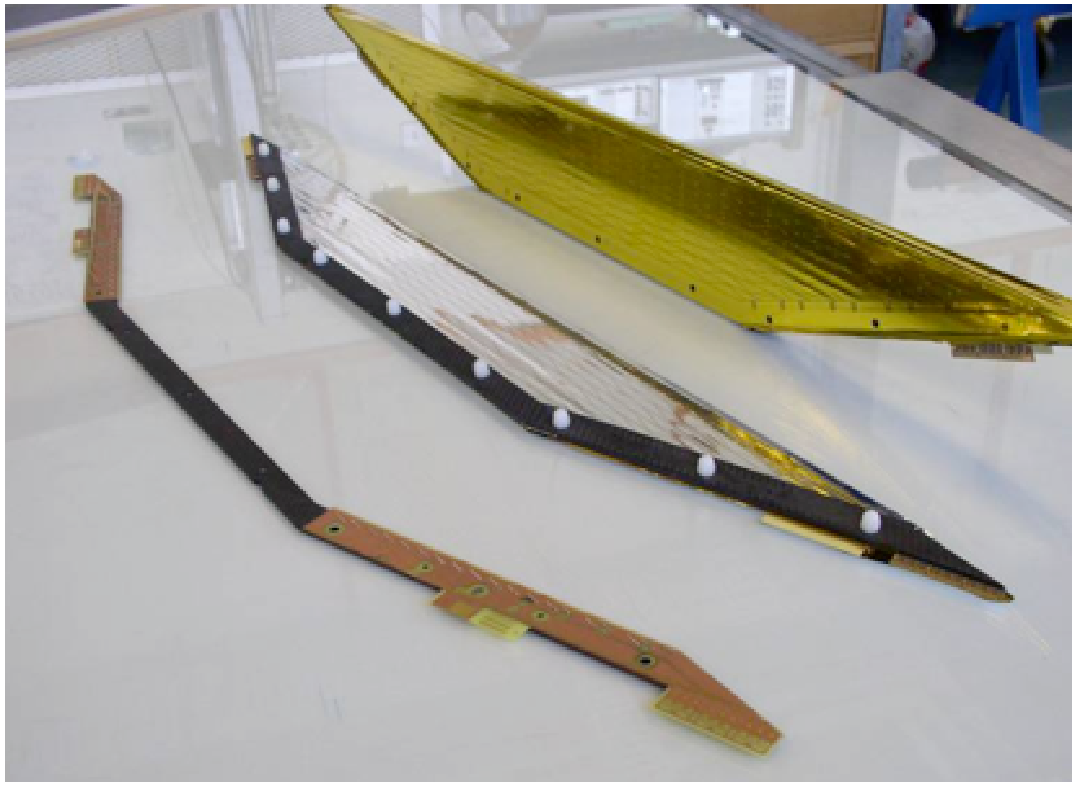
- 16 chambers radially aligned with 10° intervals
- Minimize amount of material to avoid multiple-scattering and annihilation photon BG
- Two staggered layout of drift cells for R measurement (σ_R~100-200μm)
- Charge division on anode wire and Varnier pattern cathode pad to measure Z (σ_Z~300μm)
- Expected momentum resolution: 0.4%

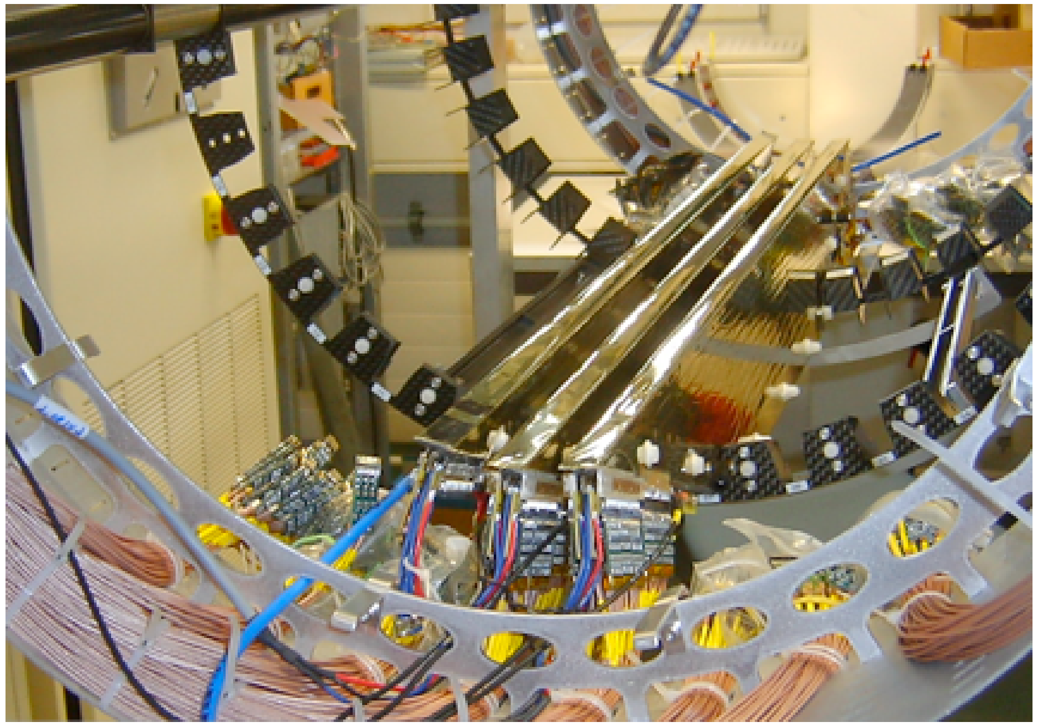


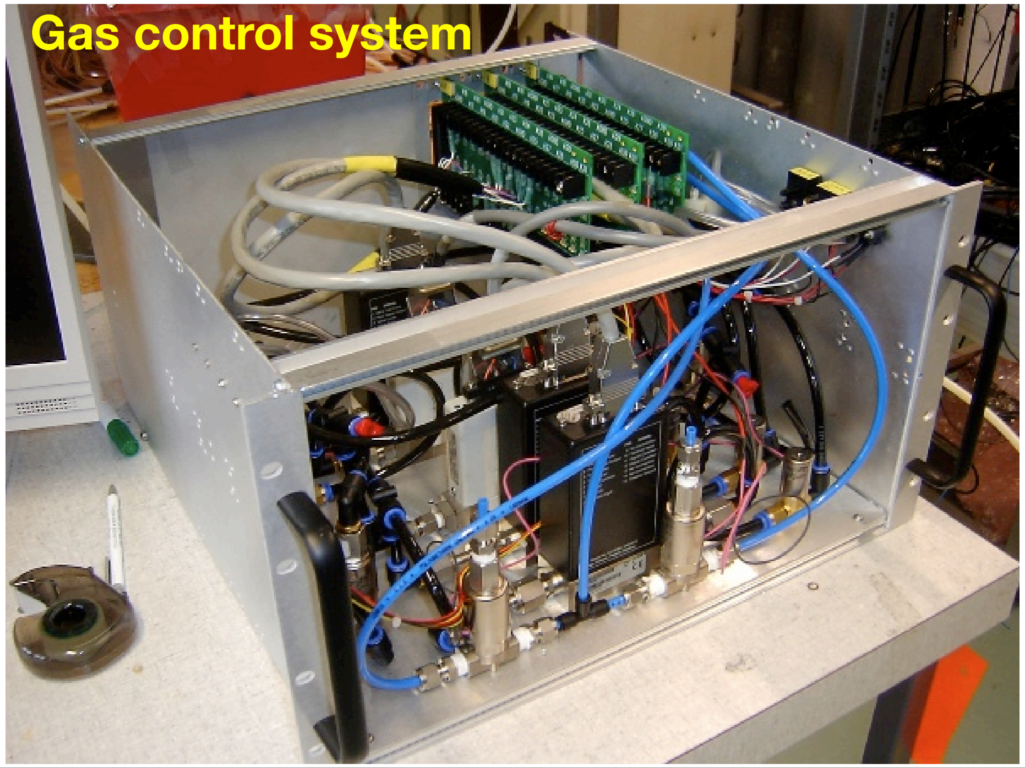




Drift Chamber System, cont'd

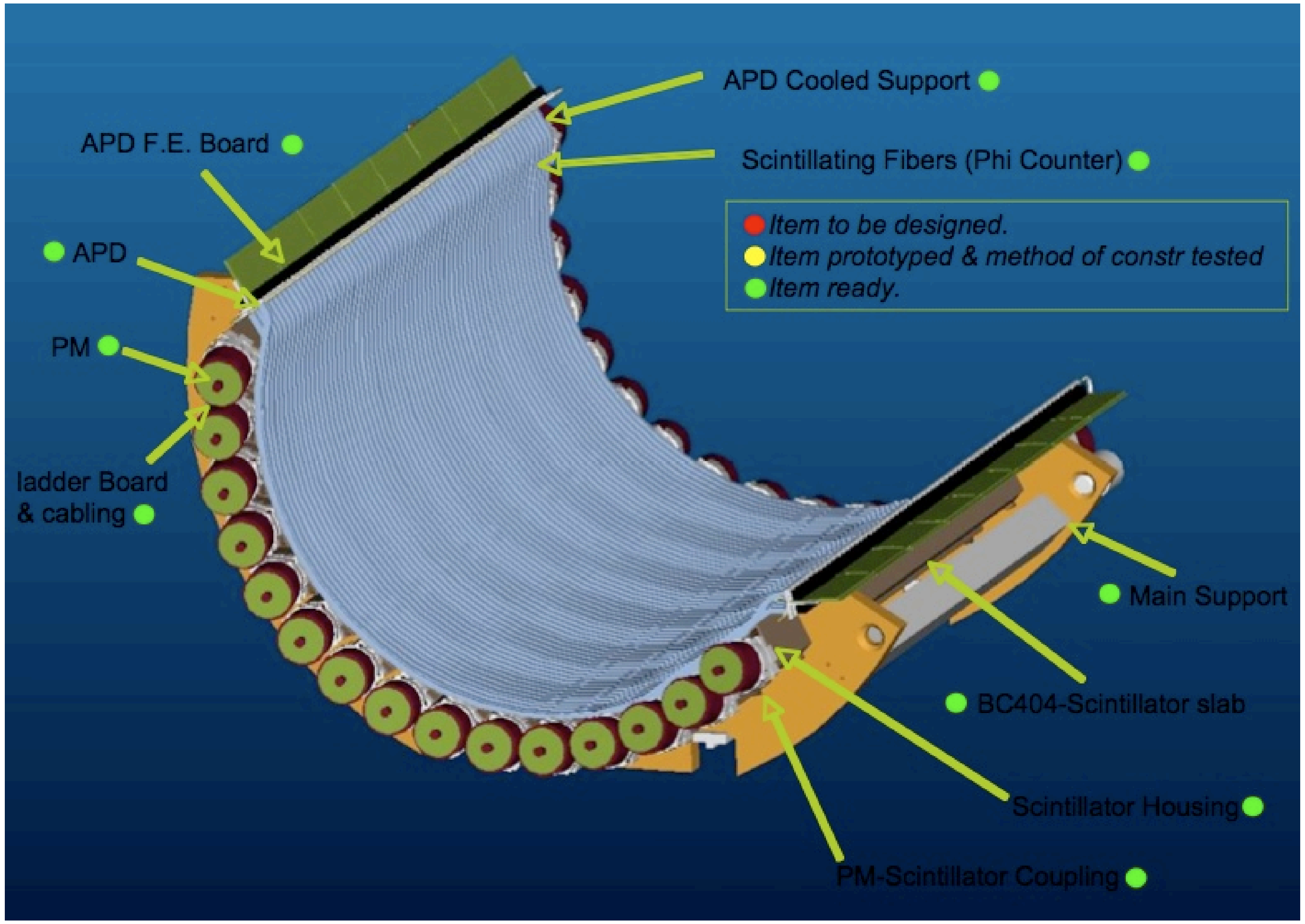






Timing Counter

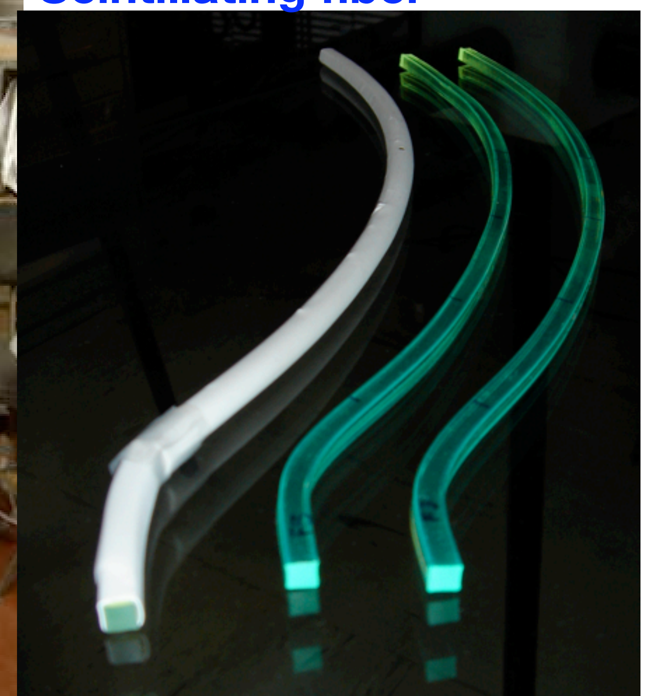
- Fast timing counter for positron
- Phi-counter: scintillator bars read out by fine mesh PMTs at both ends to measure the positron timing.
- Z-counter: Scintillating fiber read out by APD for additional trigger information



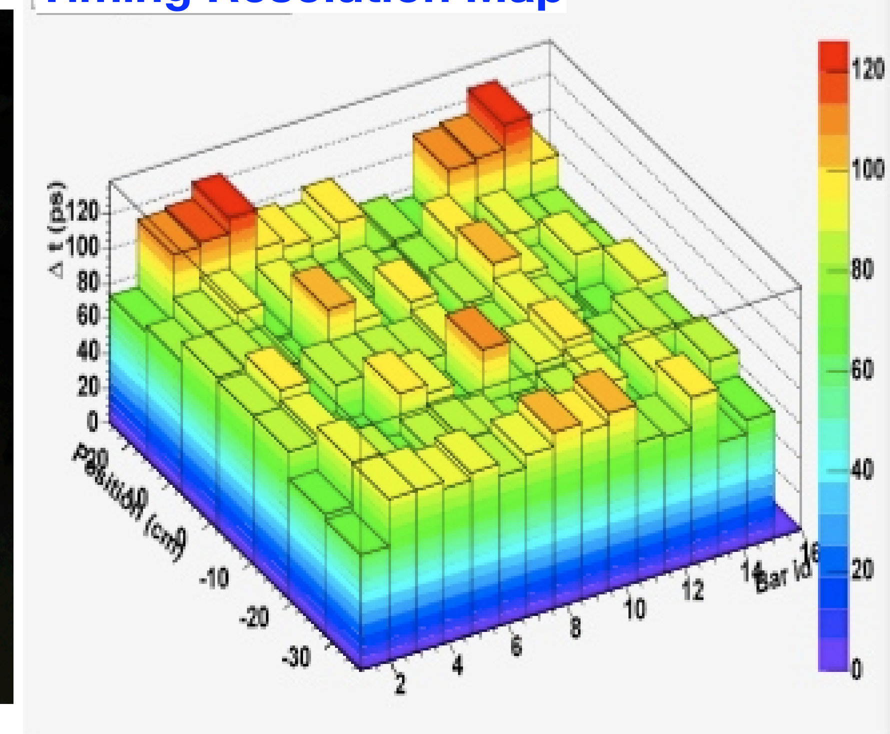
Timing Counter, cont'd

Scintillator bars

Scintillating fiber



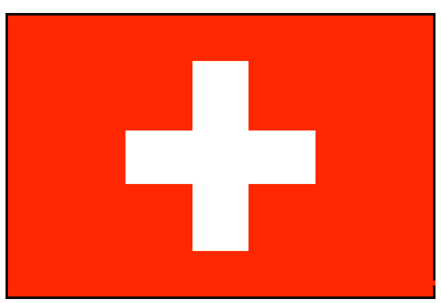
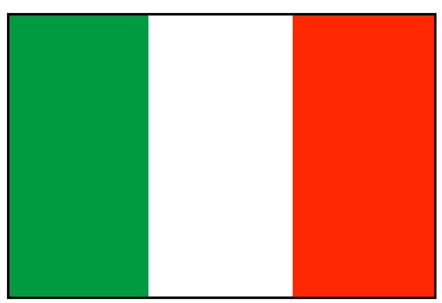
Timing Resolution Map



Comparison of long timing counters (from E. Nappi)

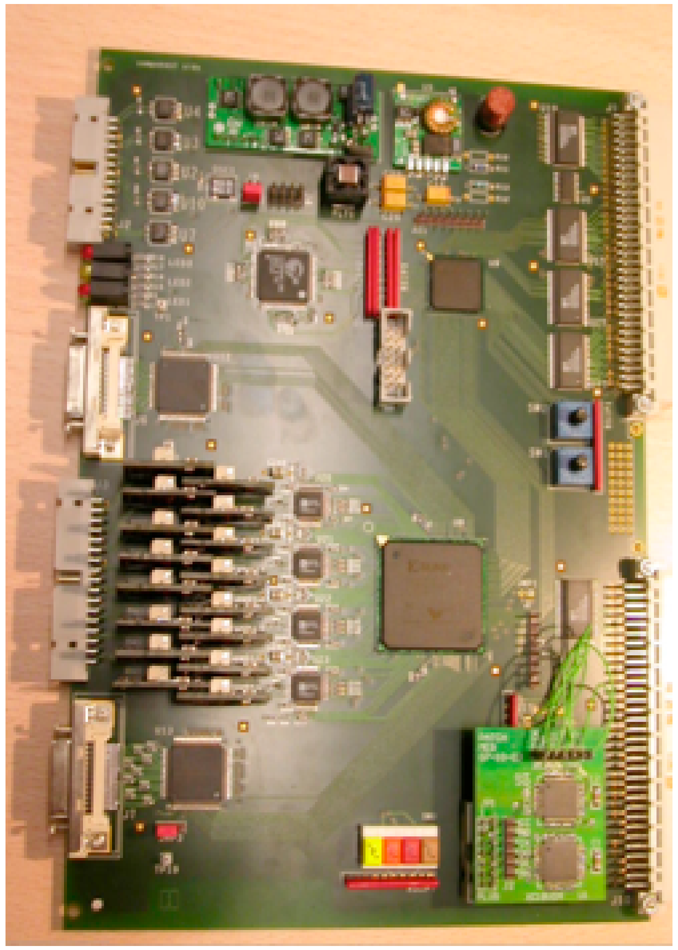
Exp. application (*)	Counter size (cm) (T x W x L)	Scintillator	PMT	λ_{att} (cm)	σ_t(meas)	σ_t(exp)
G.D.Agostini	3x 15 x 100	NE114	XP2020	200	120	60
T. Tanimori	3 x 20 x 150	SCSN38	R1332	180	140	110
T. Sugitate	4 x 3.5 x 100	SCSN23	R1828	200	50	53
R.T. Gile	5 x 10 x 280	BC408	XP2020	270	110	137
TOPAZ	4.2 x 13 x 400	BC412	R1828	300	210	240
R. Stroynowski	2 x 3 x 300	SCSN38	XP2020	180	180	420
Belle	4 x 6 x 255	BC408	R6680	250	90	143
MEG	4x4x90	BC	R5924	270	38	

Electronics

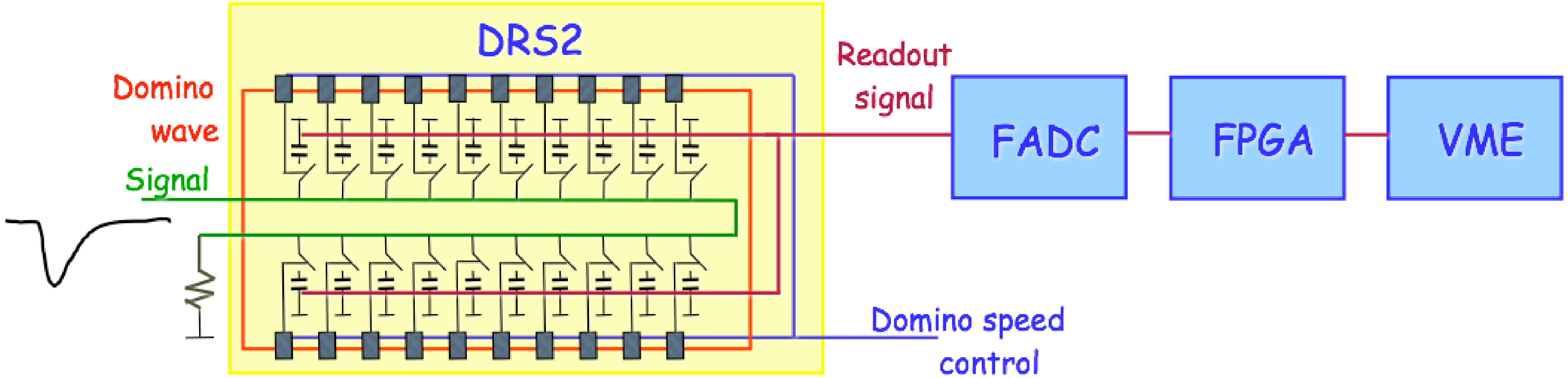
Trigger Electronics

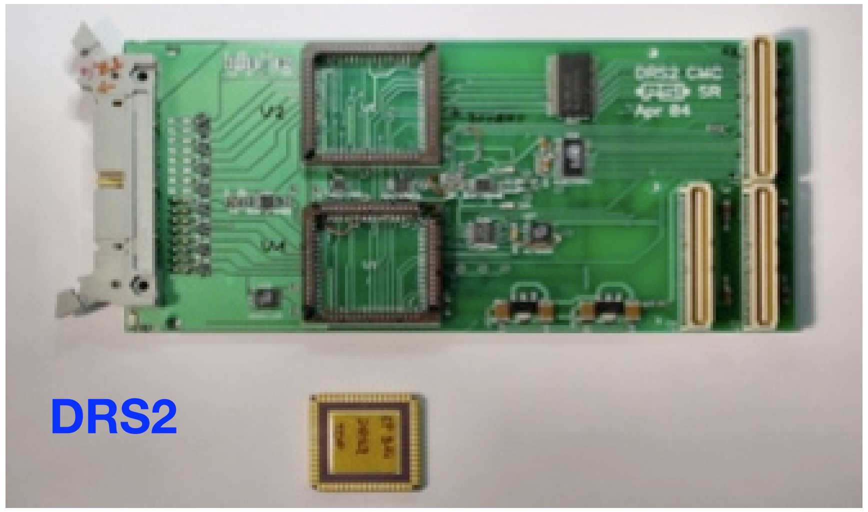
- Digital trigger based on FADC-FPGA architecture on VME boards
- Flexible trigger algorithm
- Trigger rate (for $\mu \rightarrow e\gamma$ trigger with 1×10^8 μ^+ sec^{-1}): 20Hz
  - LXe calorimeter energy cut ∧ e^+-γ time correlation ∧ e+-γ angular correlation bw/e+ and γ

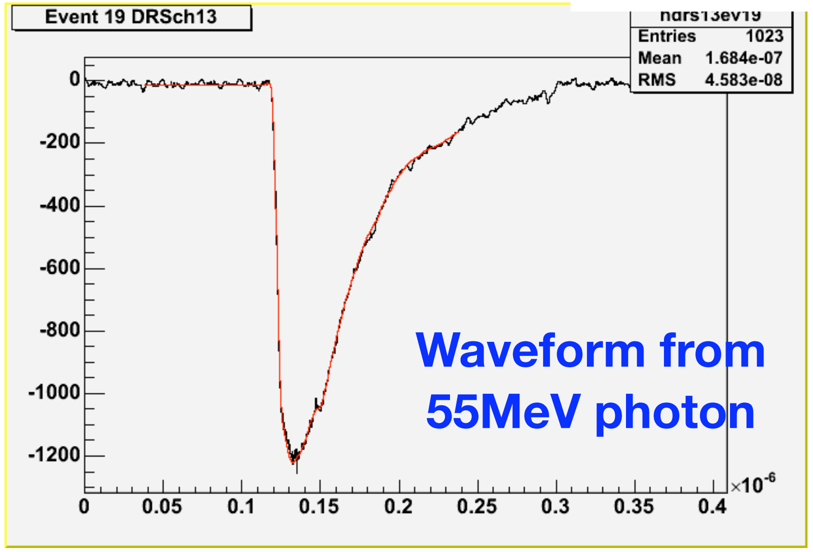


DAQ Electronics

- All detectors will be read by Domino Ring Sampler (DRS).
- Developed at PSI
- Sampling speed: 2GHz for LXe and TC, 0.5GHz for DC
- 1024 sampling cells

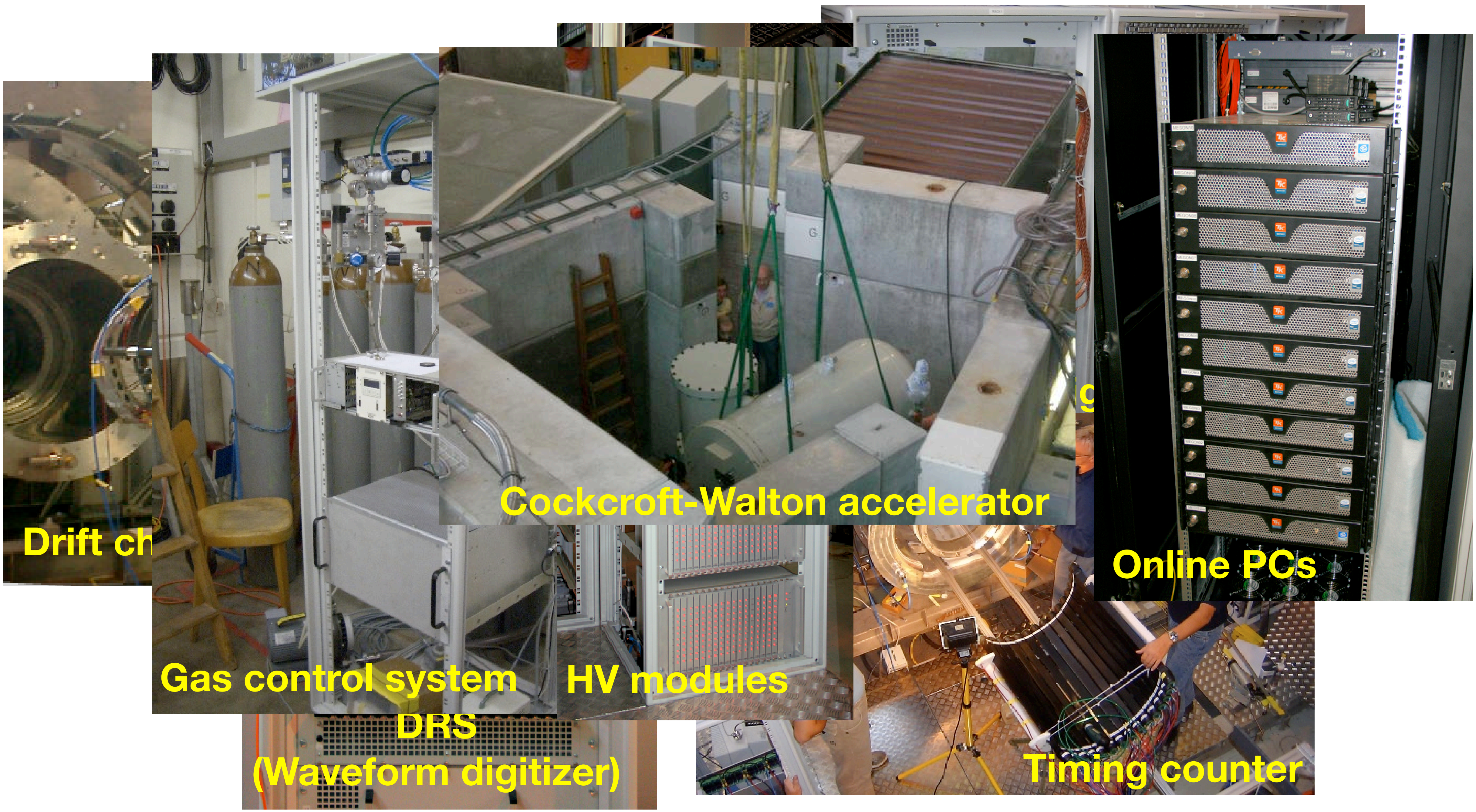






Detector Assembly and Commissioning

- Most of the detector except LXe detector were installed and tested in Dec. 2006.
- Detector assembly is starting again for Run 2007.



Sensitivity and How to Run Experiment

$\Delta E\gamma$	5 %
ΔEe	0.9 %
$\delta t_{e\gamma}$	100 psec
$\delta\theta_{e\gamma}$	23 mrad

- Sensitivity of the MEG experiment
  - Assumptions
    - Measured detector resolutions
    - BG = 0.5 events
    - Running time: T = 4×10^{7} sec (2 years beam time)
    - $R(\mu) = 3\times10^{7}\ \mu\ sec^{-1}$
  - $BR(\mu\rightarrow e\gamma) < 1.5\times10^{-13}$ at 90% CL
- Can we go further?
  - Single event sensitivity
    - $BR(\mu\rightarrow e\gamma) = 1.1\times10^{-14}$ with full beam intensity ($R(\mu) = 1\times10^{8}\ \mu\ sec^{-1}$)
    - This is the best we could reach with the present detector setup and PSI beam.
  - Need detector upgrade to achieve this sensitivity

    ➡ Poster session “MEG: Possible Future Plan”

Summary and Prospect

- The MEG experiment is soon to begin.
- The last missing piece is the cryostat for the LXe full-scale detector, which has just arrived at PSI.
- We are planning to start the full DAQ this fall after setting-up and testing the detector.

We hope the MEG would give a good hint for "supersymmetry in 2010's".

End of Slides