The MEG Experiment

A Search for Lepton Flavor Violating Decays of Muons at PSI

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The University of Tokyo

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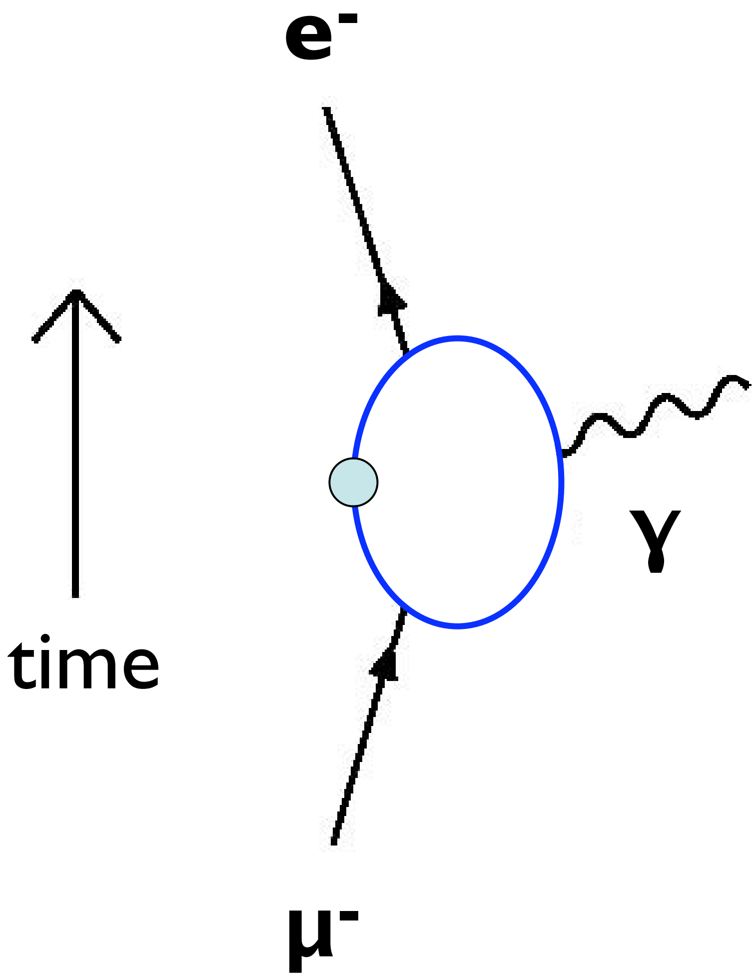
Topics to Cover

- $\mu \rightarrow e\gamma$: Muon decay that violates lepton flavor
  - ✓ Why so interesting?
  - ✓ What limits the experiment?
  - ✓ **The MEG experiment**
    - the beam
    - the positron spectrometer
    - the gamma ray detector
  - ✓ Prospects

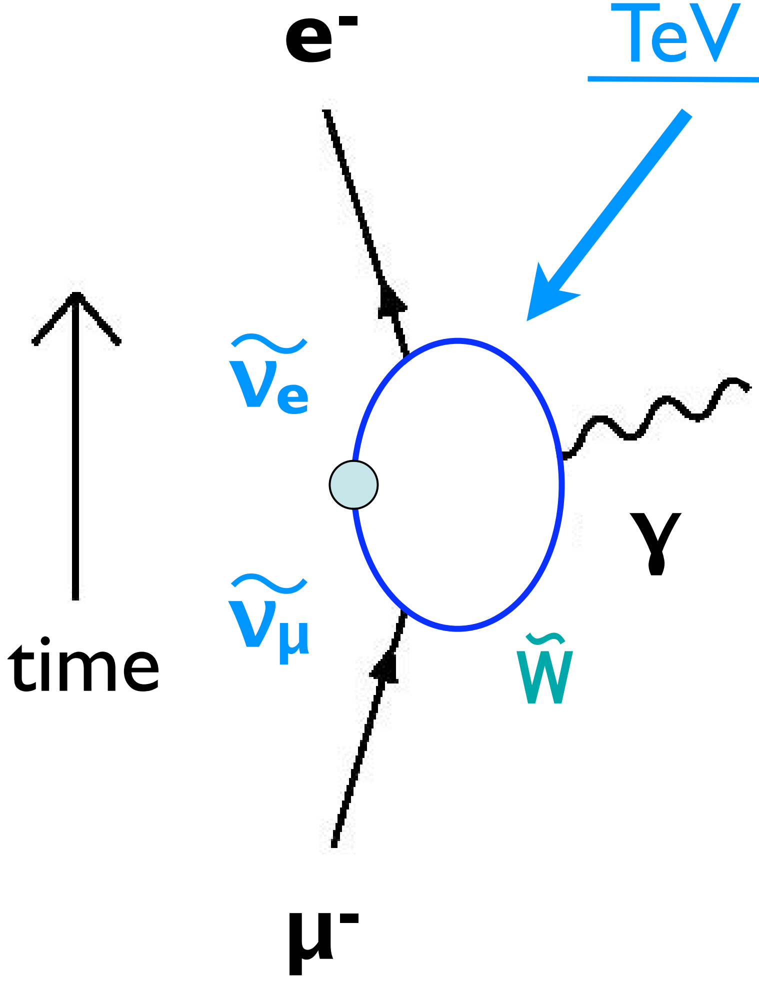
Why $\mu \to e\gamma$ so interesting?

- Neutrino oscillation --> It must happen!
- It is NEW PHYSICS!
  - ✓ Experiments are already sensitive to SUSY GUTs and SUSY seesaw.
- Quark FV is generally contaminated by SM.
  - ✓ Looking for tiny deviations is not easy.

Lepton Flavor Violating Process



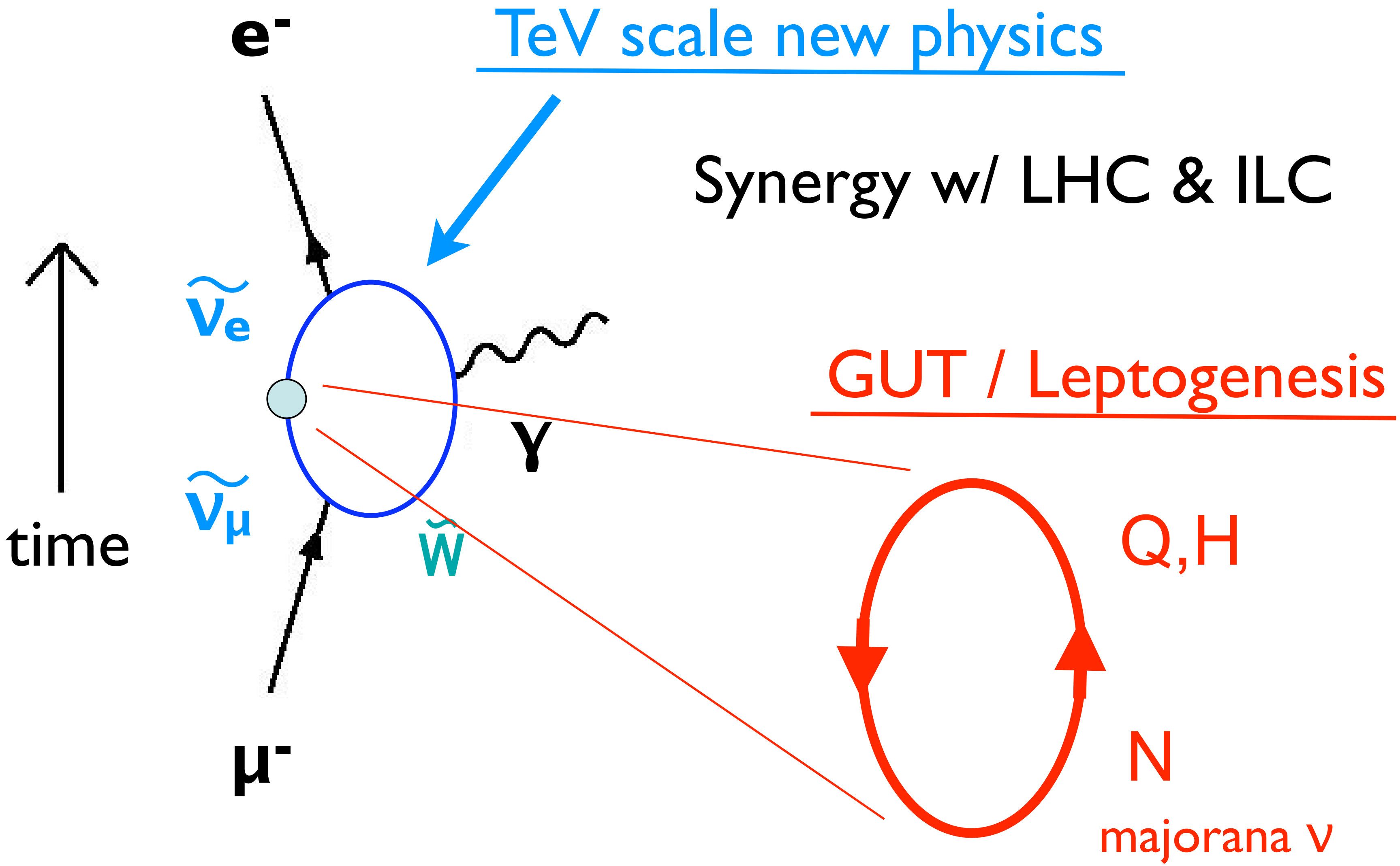
Lepton Flavor Violating Process



TeV scale new physics

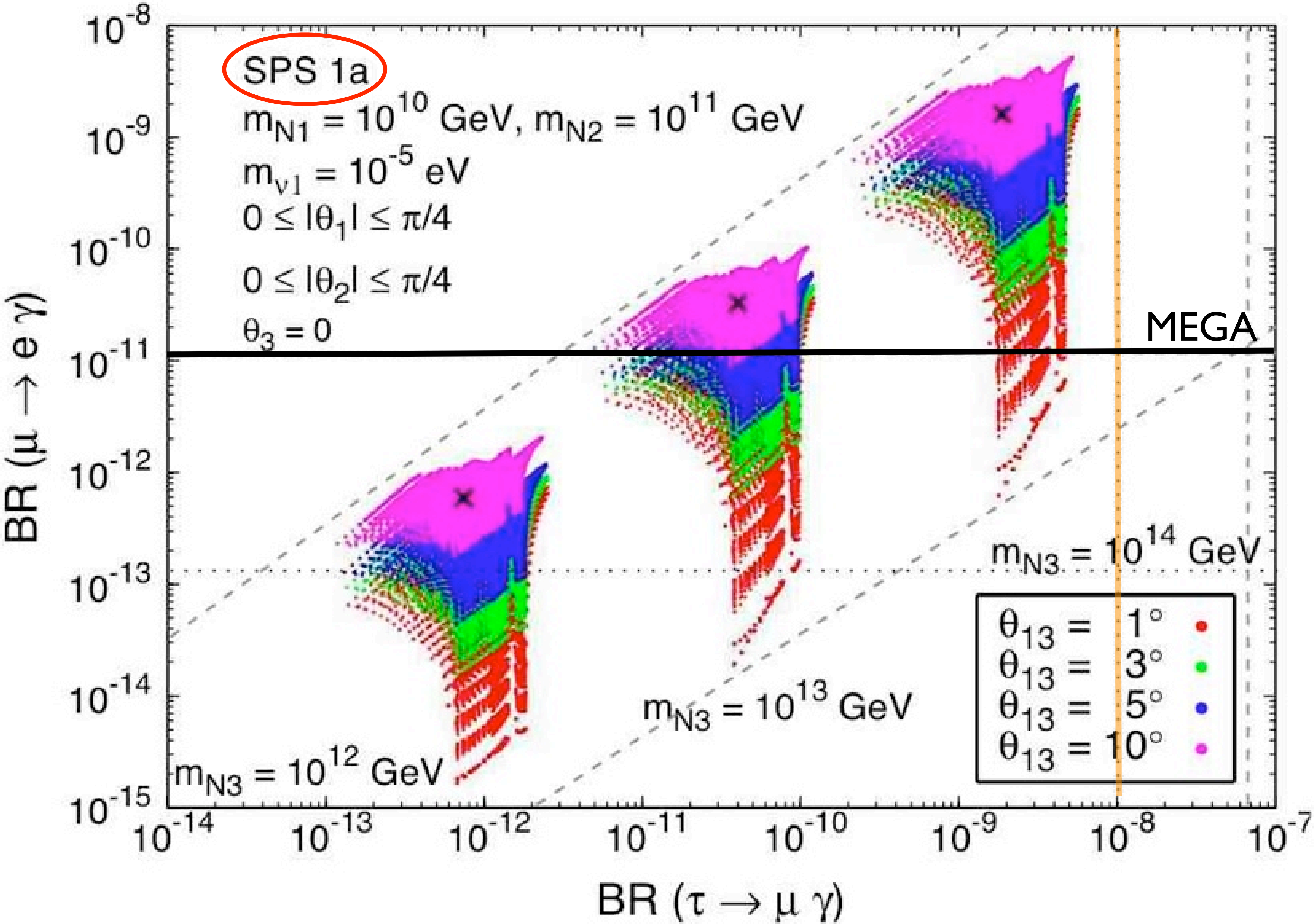
Synergy w/ LHC & ILC

Lepton Flavor Violating Process



Beyond LHC & ILC

Expected Branching Ratios

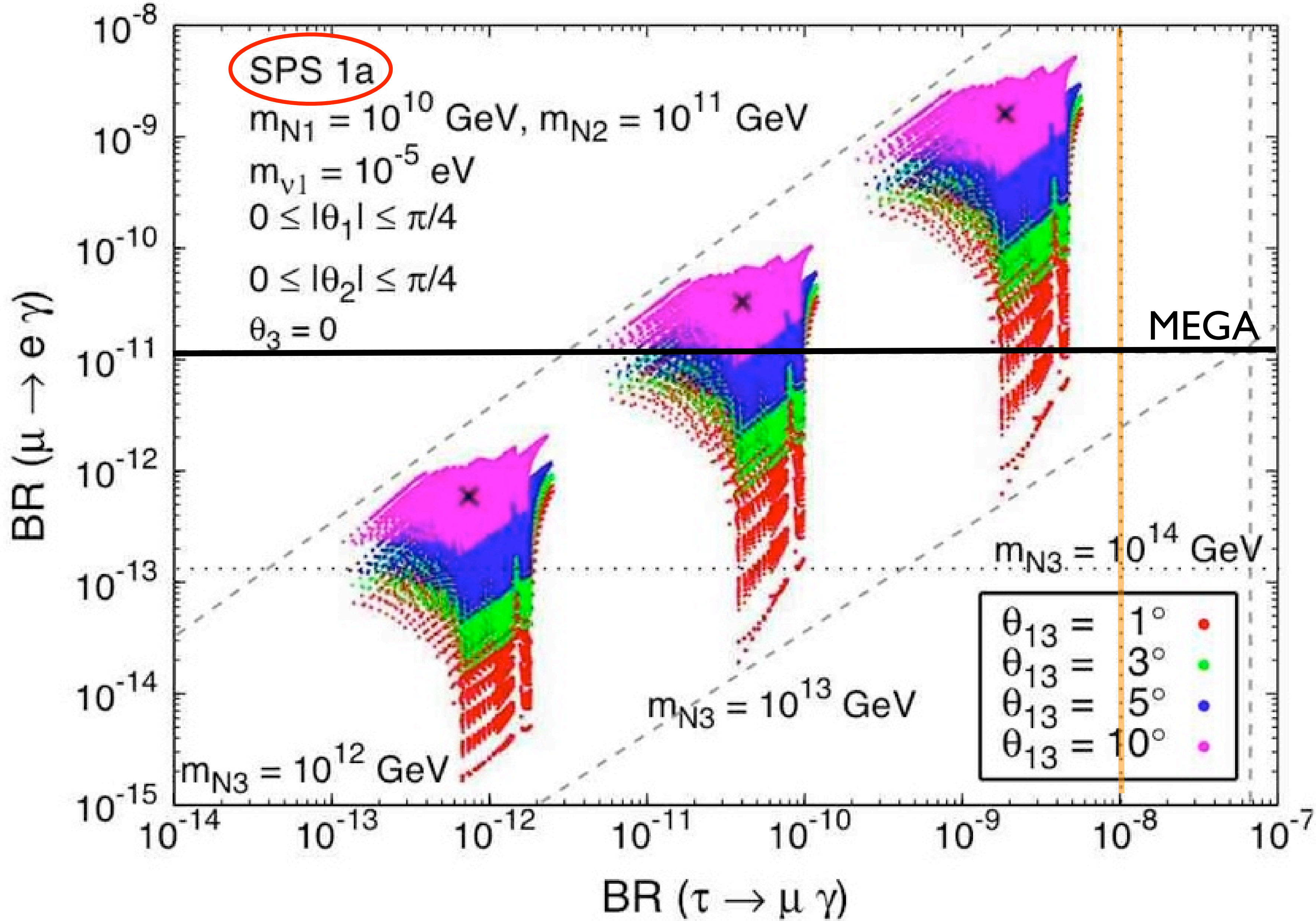


CMSSM (full RGE) + ν_R + seesaw
+ viable BAU + EDM limits

M.J.Herrero @Tau06

PRD73 055003(2006), hep-ph/0607263

Expected Branching Ratios



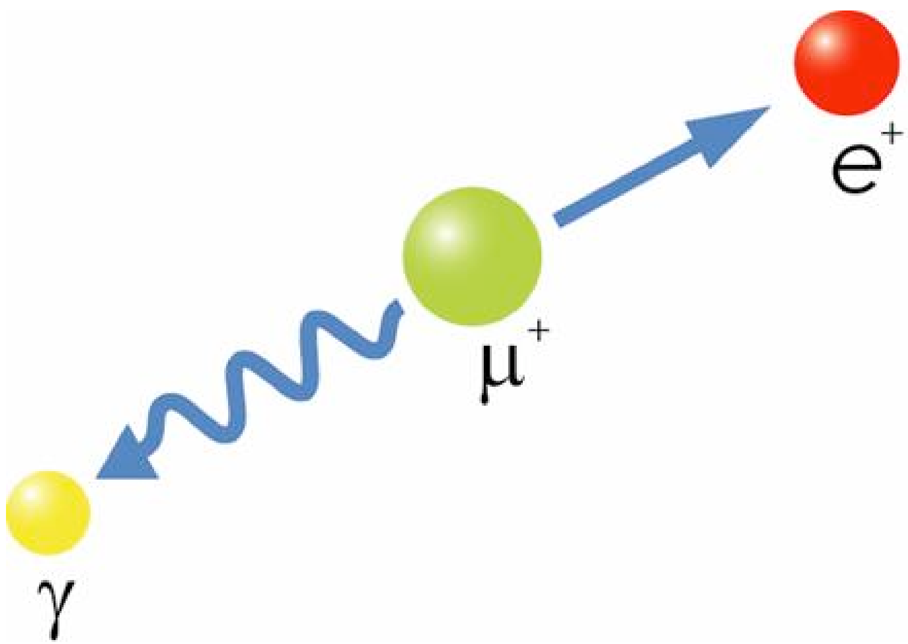
CMSSM (full RGE) + ν_R + seesaw
+ viable BAU + EDM limits

+ GUT!

M.J.Herrero @Tau06

PRD73 055003(2006), hep-ph/0607263

$\mu \rightarrow e\,\gamma$



Clear 2-body kinematics

Use μ^+ to avoid capture inside stopping target

Background dominated by Accidental coincidence

→ lower μ rate is better

→ DC μ beam is best

"surface muon beam": 100% polarized

Good detector system Is essential

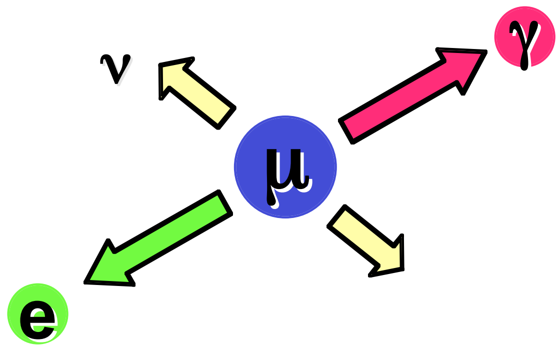
a simple arithmetic to achieve a 10^{-13}-10^{-14} sensitivity

10^{13} muons / a year ~ 10^{7} sec / efficiency ~ 0.1

= ~ 10^{7} muons / sec

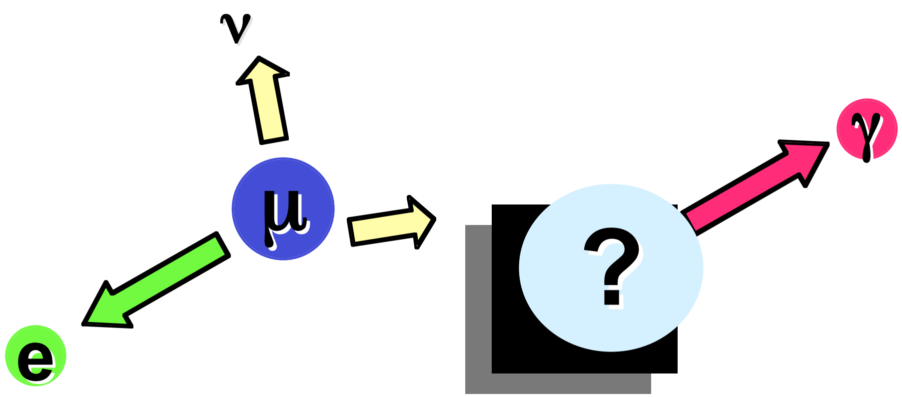
➡ **High rate experiment**

Two Types of Backgrounds



radiative decays

~ manageable



radiative decays
e^+ annihilation in flight

accidental overlaps

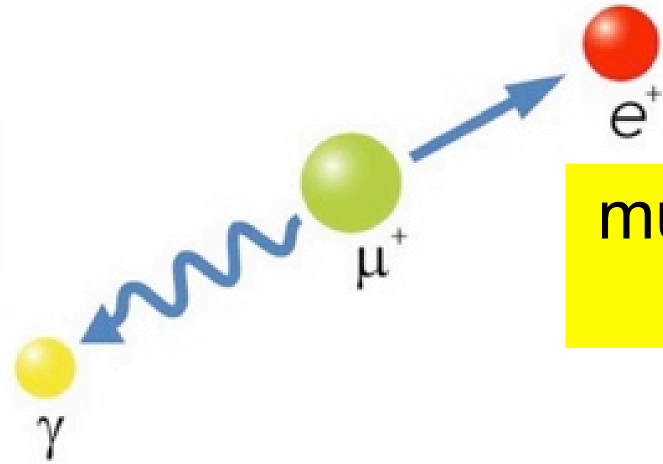
dominant

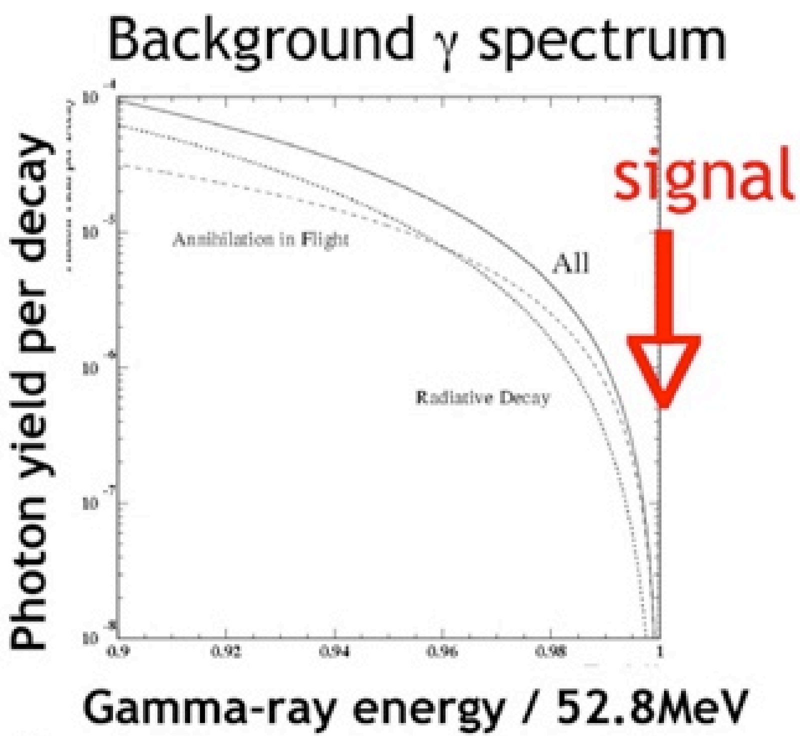
lower μ rate is better
➡ DC beam

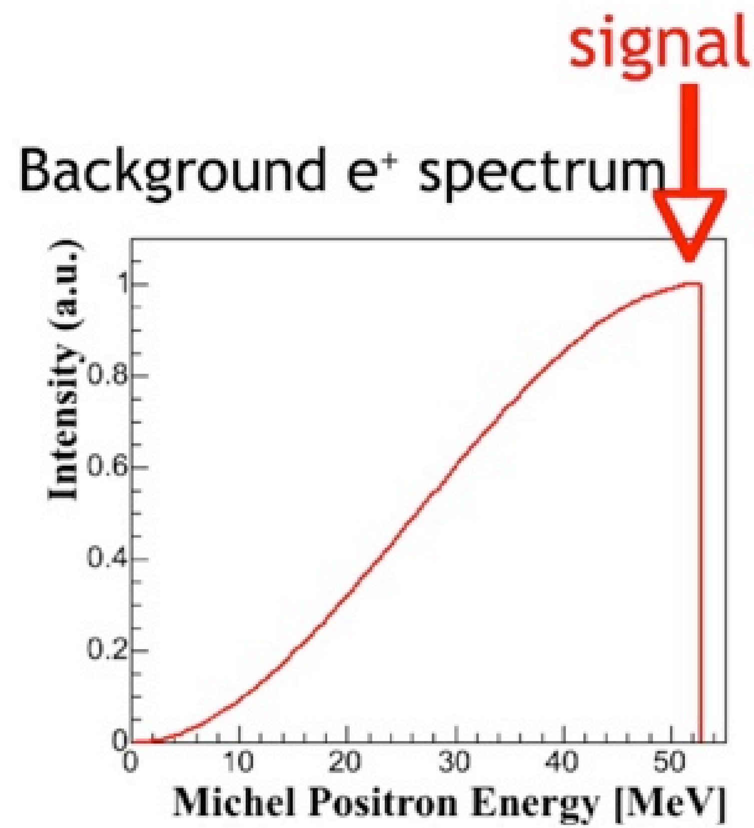
Accidental coincidence of γ and e⁺ is the main background

γ ray measurement Is most important!

must manage to track high rate e+







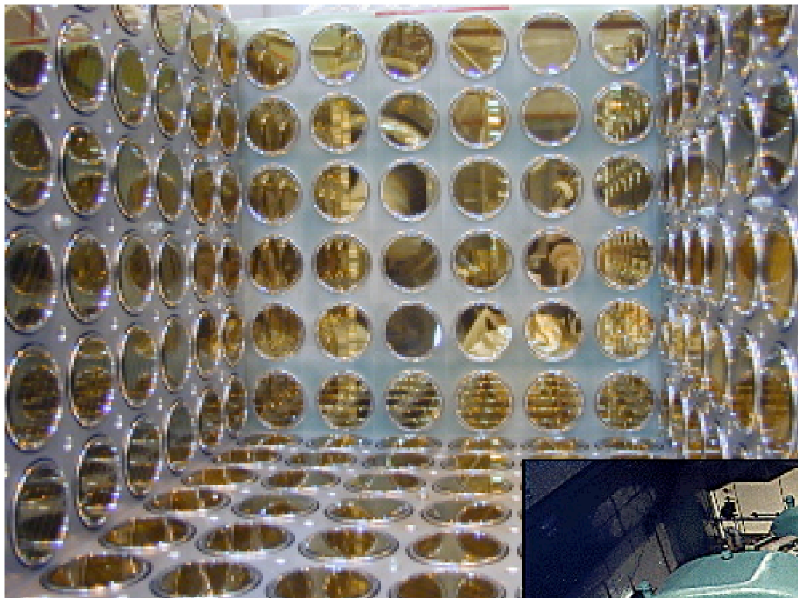
So we need:

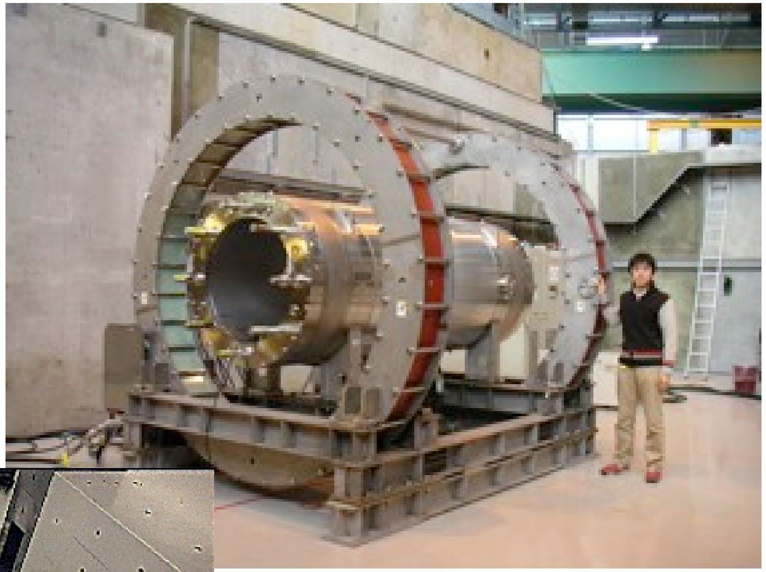
- High rate (~10^7/sec) DC muon beam
- Spectrometer that can manage high rate e^+
- High resolution γ-ray detector

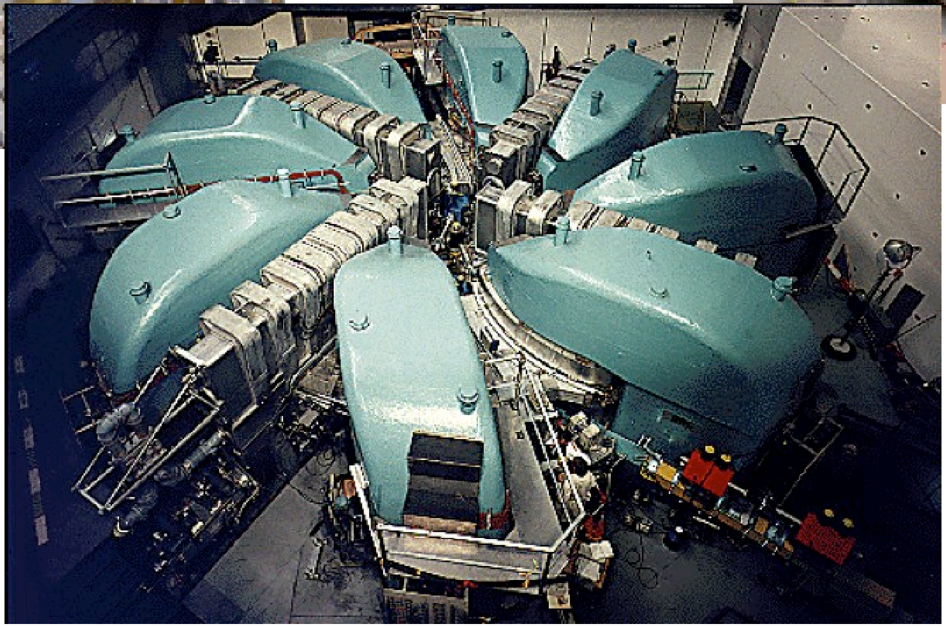
3 Elements that Enabled MEG

COBRA magnet
w/ graded B field

LXe scintillation γ-ray detector







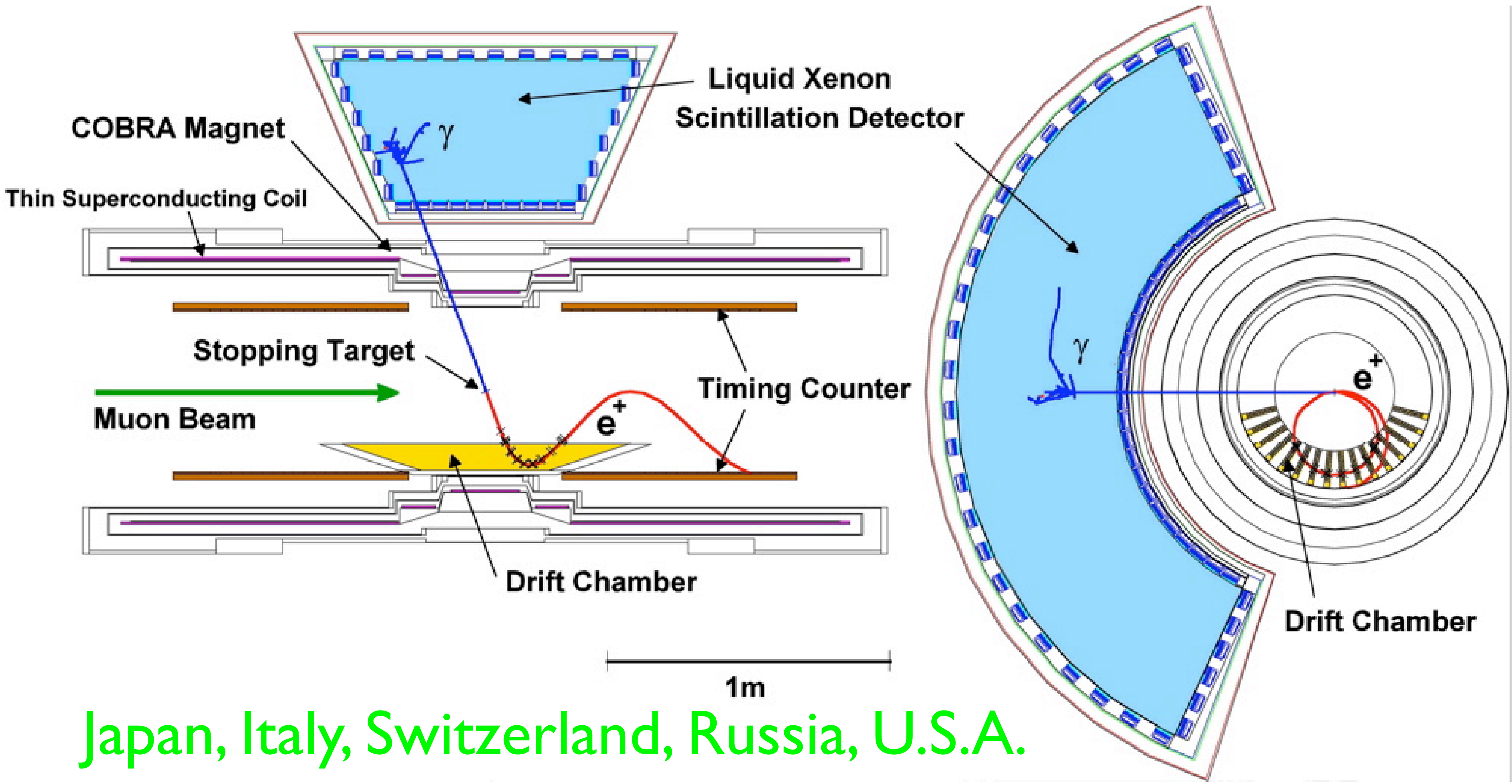
Most intensive DC muon beam (10^8/sec)

The MEG experiment

Approved at Paul Scherrer Institut, Switzerland in 1999

Aiming at a sensitivity of 10^{-13}, a possible future upgrade to 10^{-14}

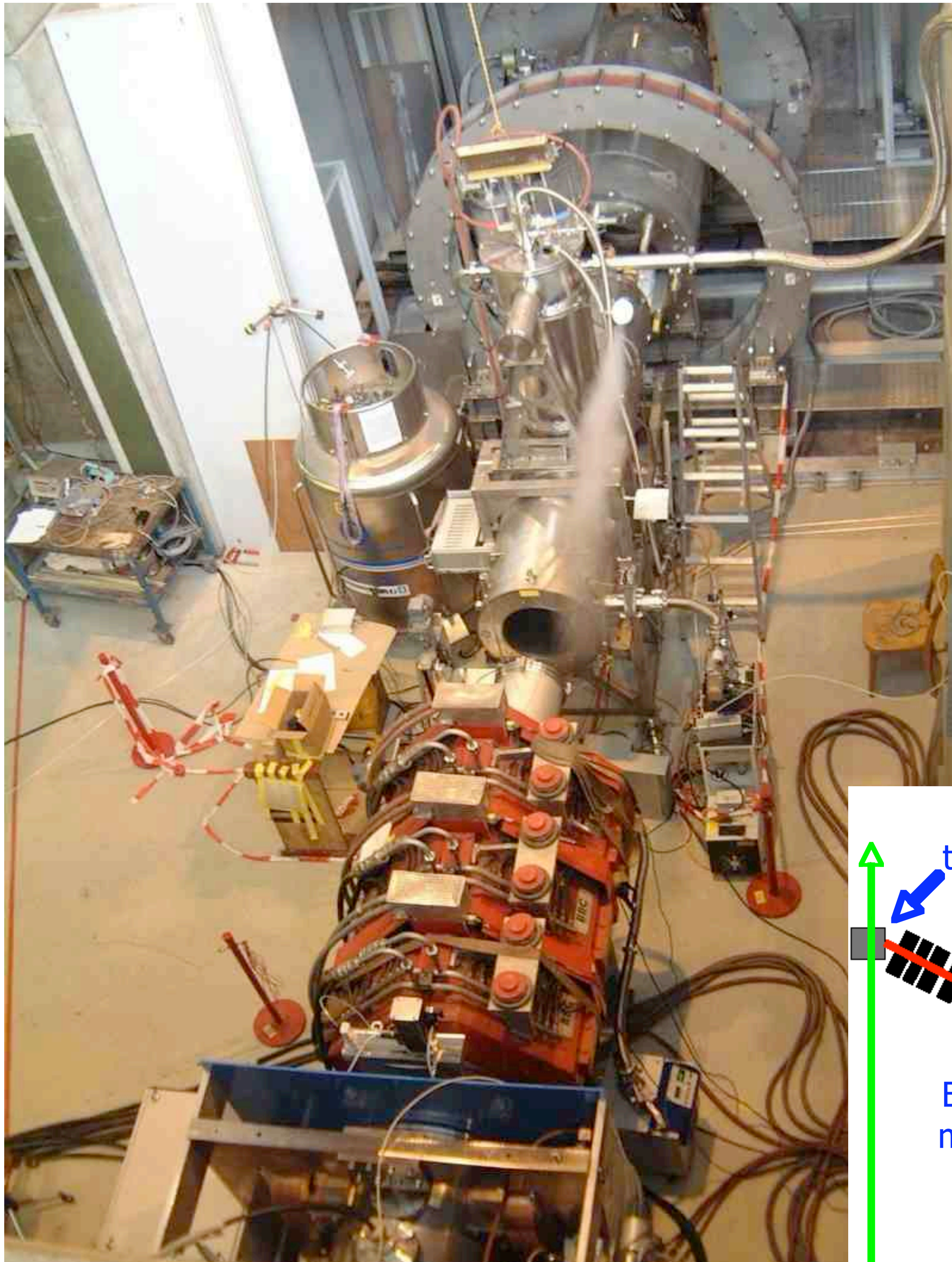
Detectors currently being built and installed



Japan, Italy, Switzerland, Russia, U.S.A.

The Muon Beam

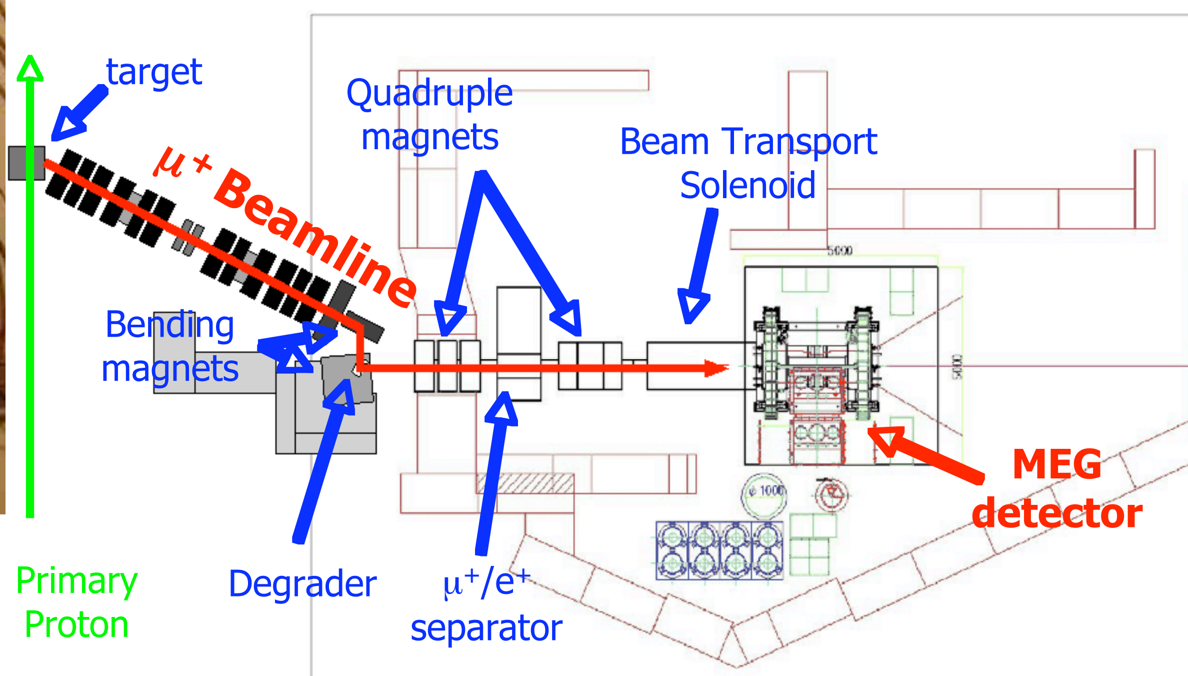
πE5 area @PSI



Muon beam being tuned down to the target position

10^8 muon stops /sec

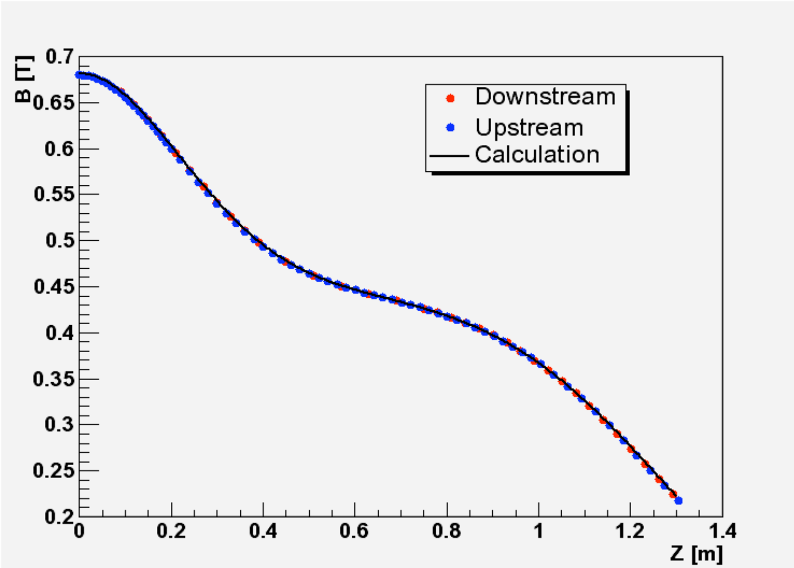
~10mm spot size



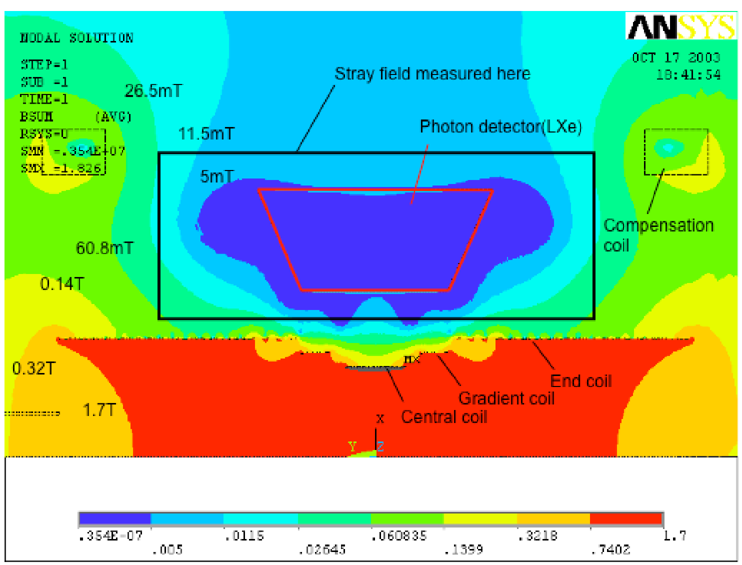
PSI Proton Cyclotron
590MeV, >1.8mA

The Positron Spectrometer

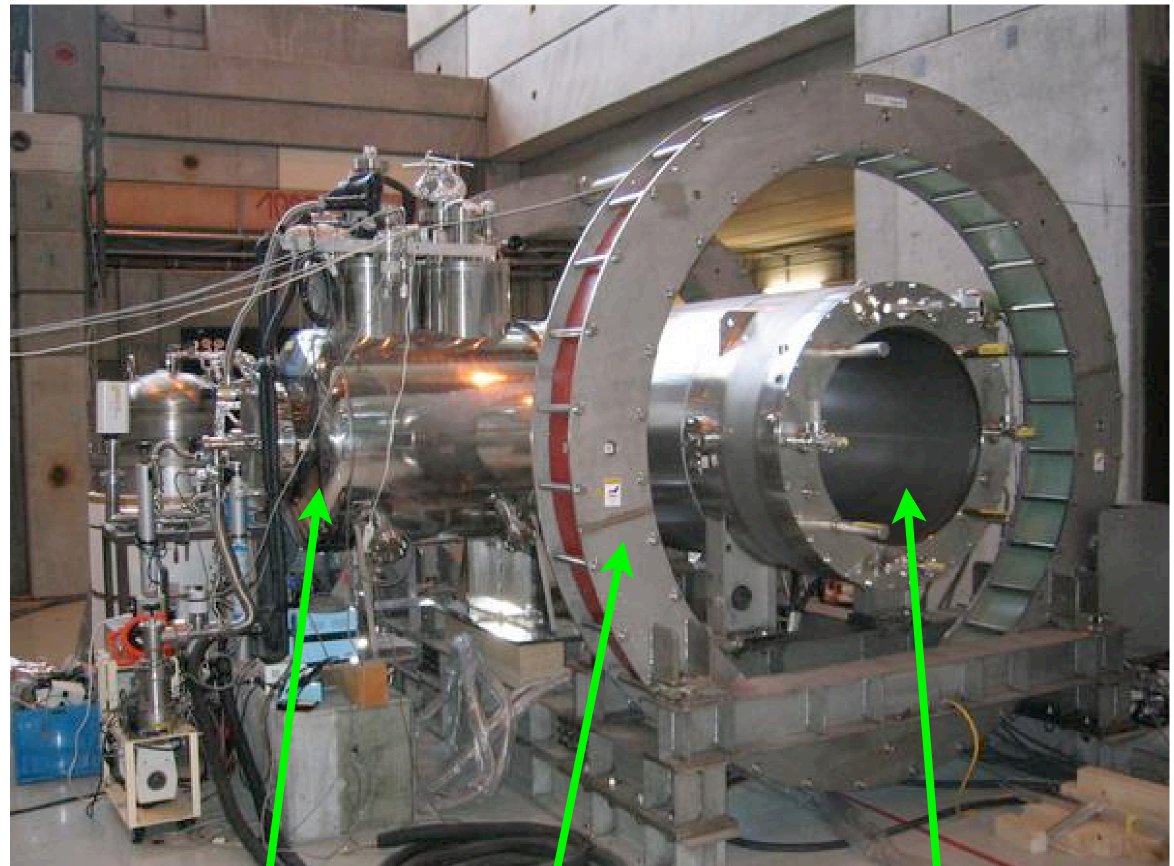
The COBRA Spectrometer



specially graded B field



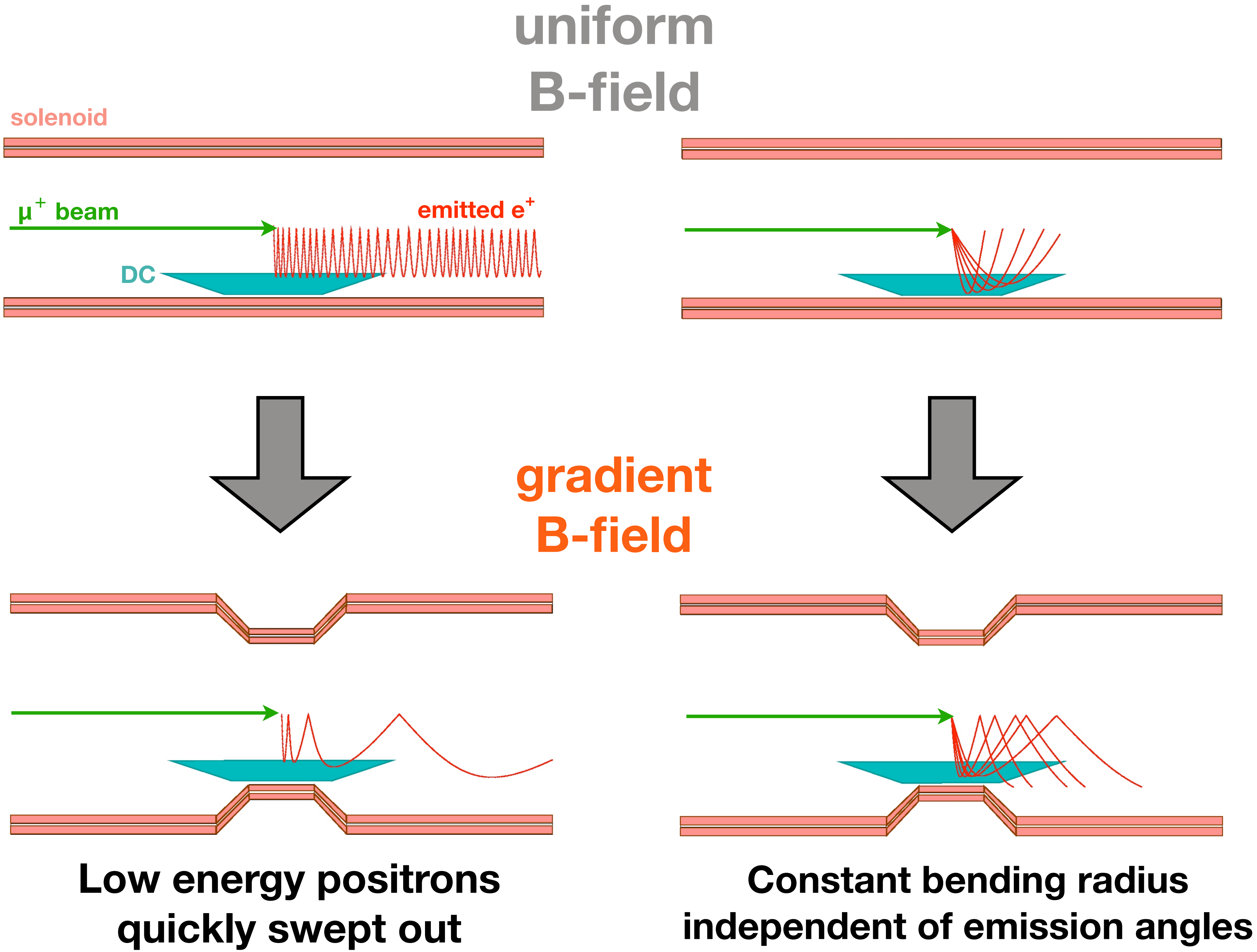
low B field at LXe detector



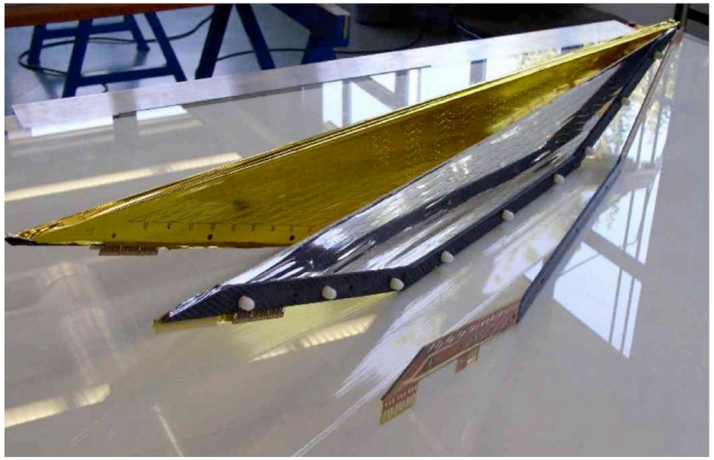
compensation coils

LXe detector prototype

COBRA magnet

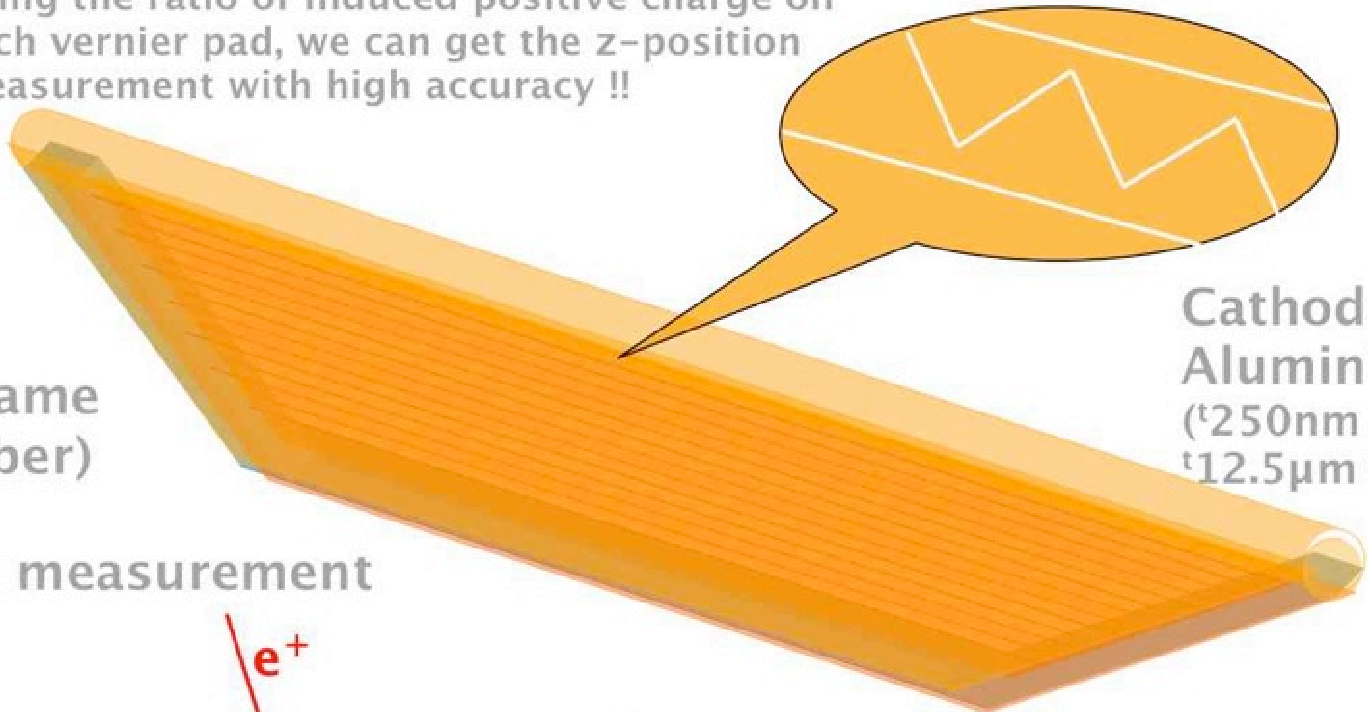

uniform
B-field
solenoid
μ+ beam
emitted e+
DC
gradient
B-field
Low energy positrons
quickly swept out
Constant bending radius
independent of emission angles

Drift Chamber Design



Z-direction measurement

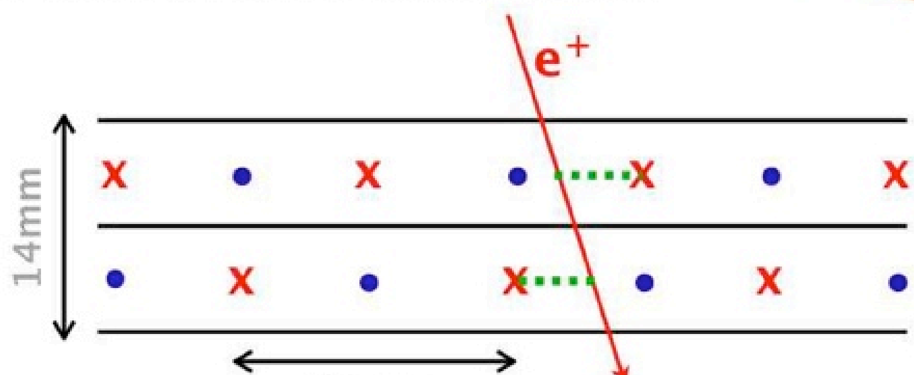
Vernier pattern is printed on cathode plane. Using the ratio of induced positive charge on each vernier pad, we can get the z-position measurement with high accuracy !!



opened-frame (Carbon fiber)

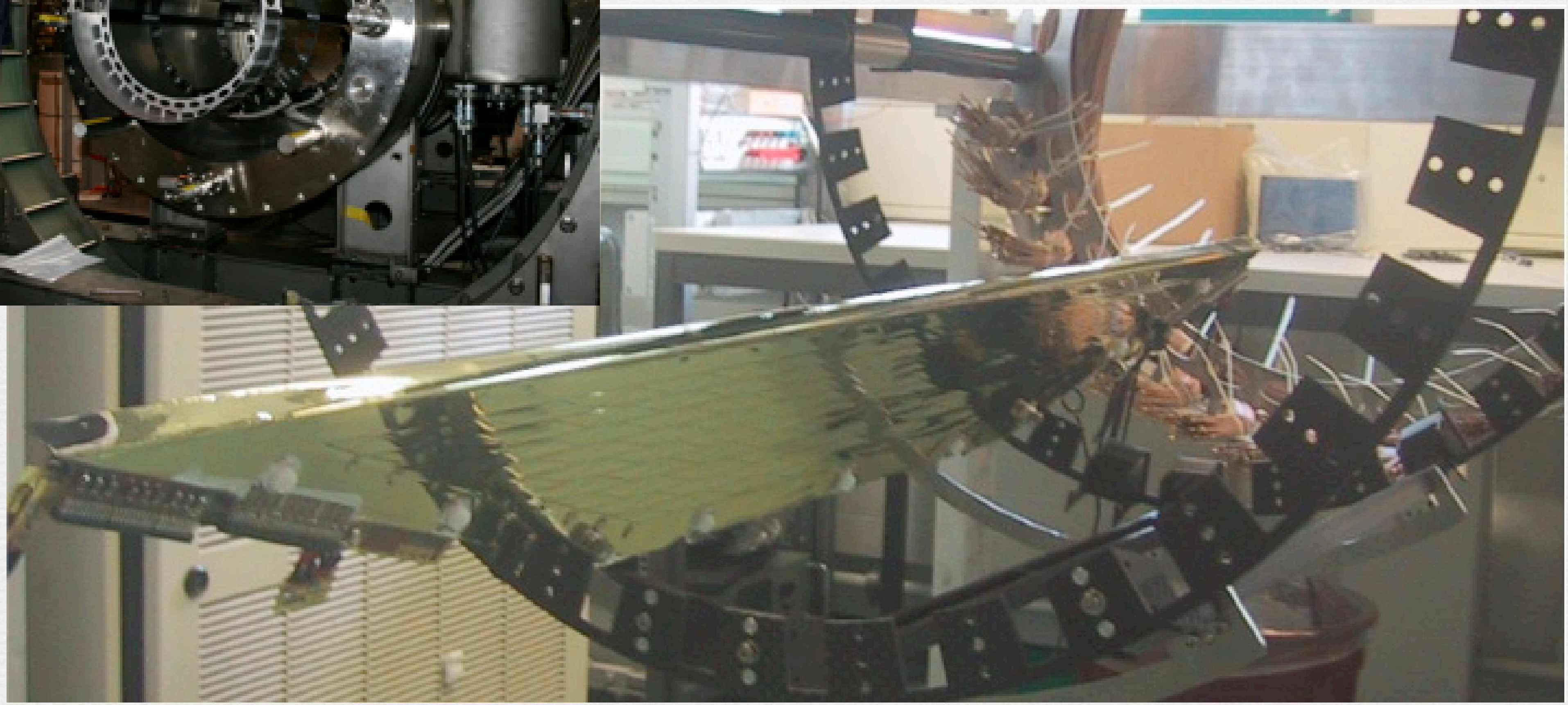
Cathode foil
Aluminized Polyimide
(^{t}250nm Al deposition on ^{t}12.5μm film)

R-direction measurement

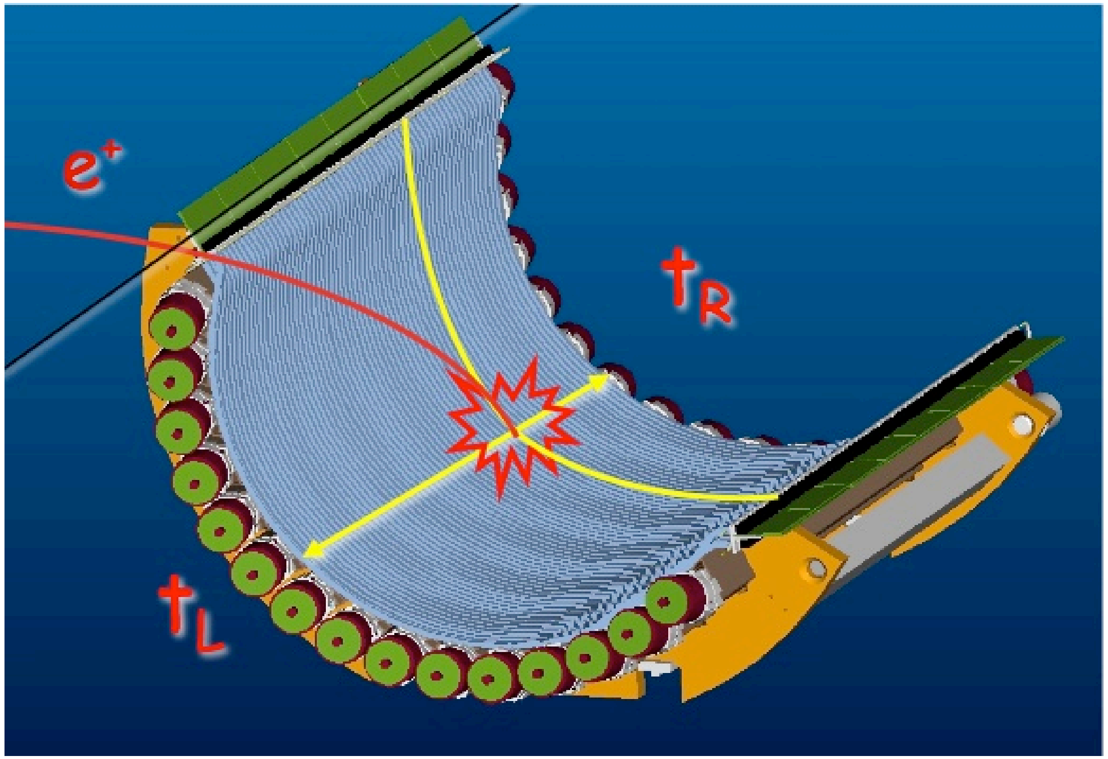


staggered 2-layer wires
sense (Ni/Cr, 25um, 0.5N)
potential (Be/Cu, 50um, 1.1N)

Half the DCs to be installed this week

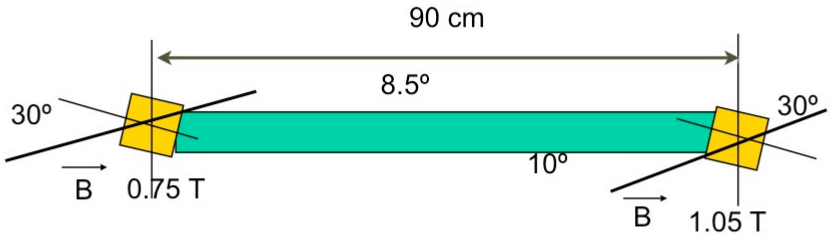


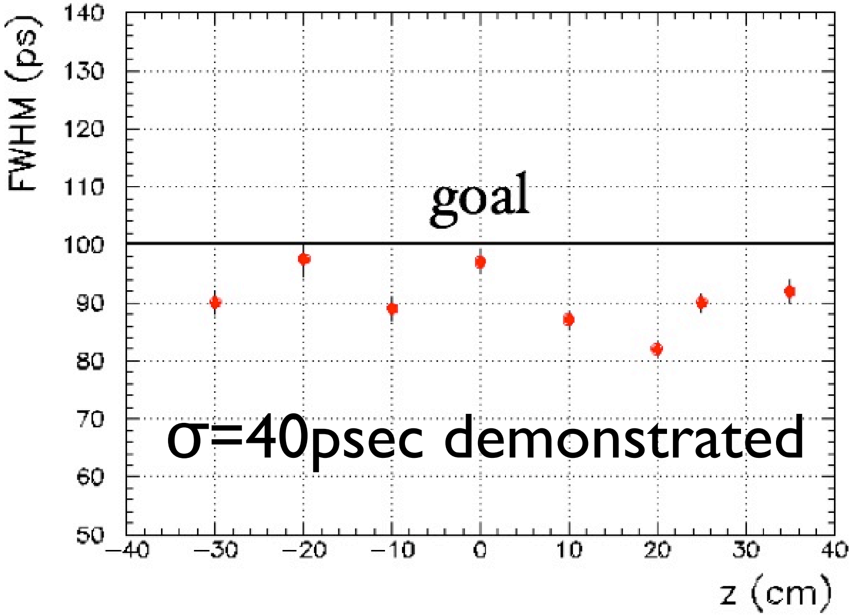
Timing Counters



Two layers of scintillators:

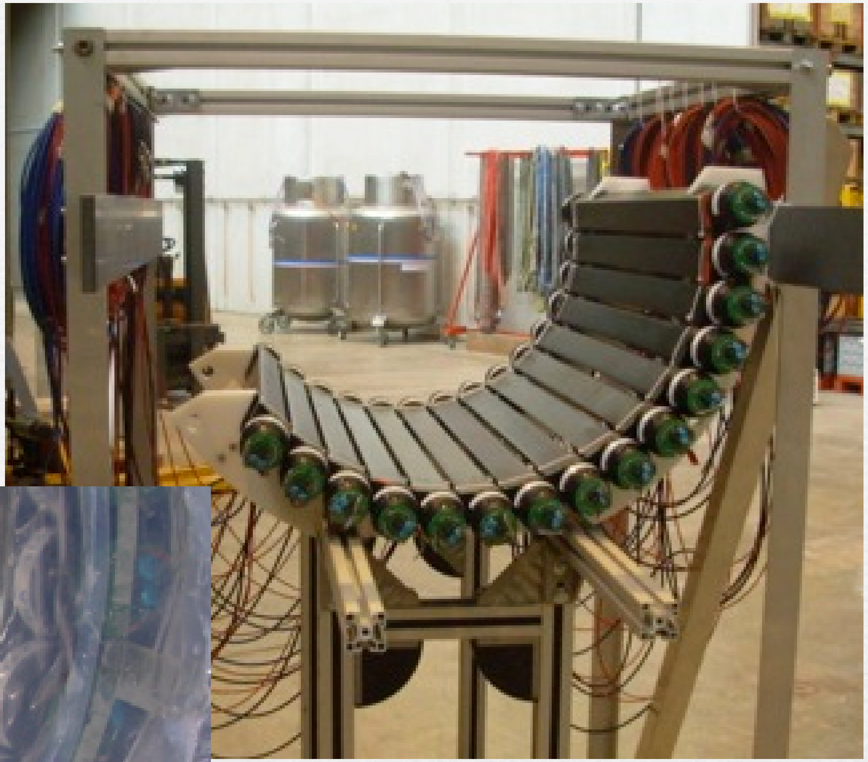
- outer thick bars - timing
- inner thin fibers - redundant Z meas





Expe. application	size(cm)	Scinti.	PMT	L(att) cm	σmeas)	σ(exp)
G.D.Agostini	3x15x100	NE114	XP2020	200	120	60
T.Tanimori	3x20x150	SCSN38	R1332	180	140	110
T.Sugitate	4x3.5x100	SCSN23	R1828	200	50	53
R.T.Gile	5x10x280	BC408	XP2020	270	110	137
TOPAZ	4.2x13x400	BC412	R1828	300	210	240
R.Stroynowski	2x3x300	SCSN38	XP2020	180	180	420
Belle	4x6x255	BC408	R6680	250	90	143
MEG	4x4x90	BC404	R5924	270	38	43

Currently being installed inside the magnet

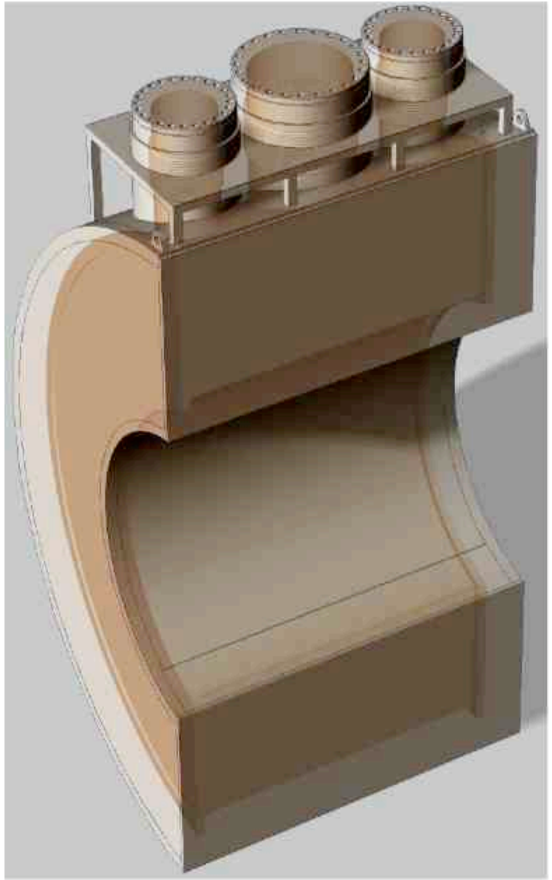


N_2 bag to protect PMTs from He

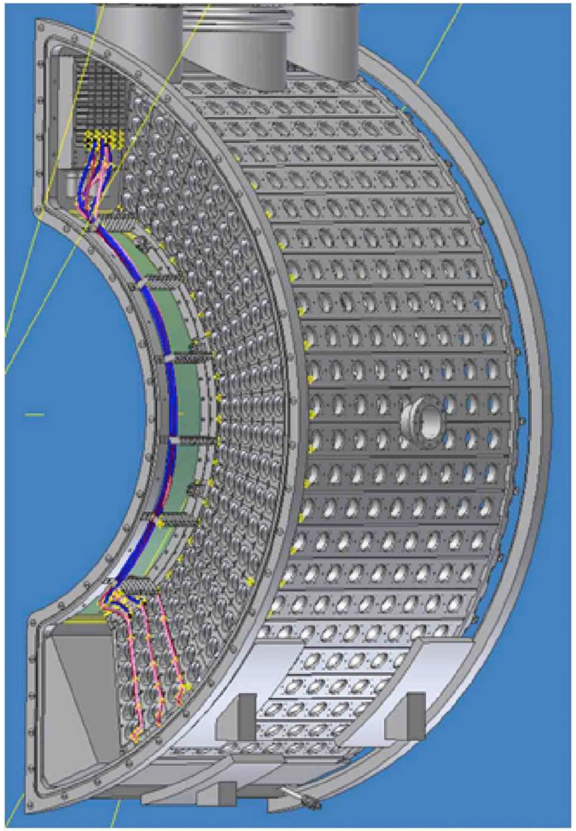
The LXe Gamma-ray Detector

LXe Gamma Ray Detector

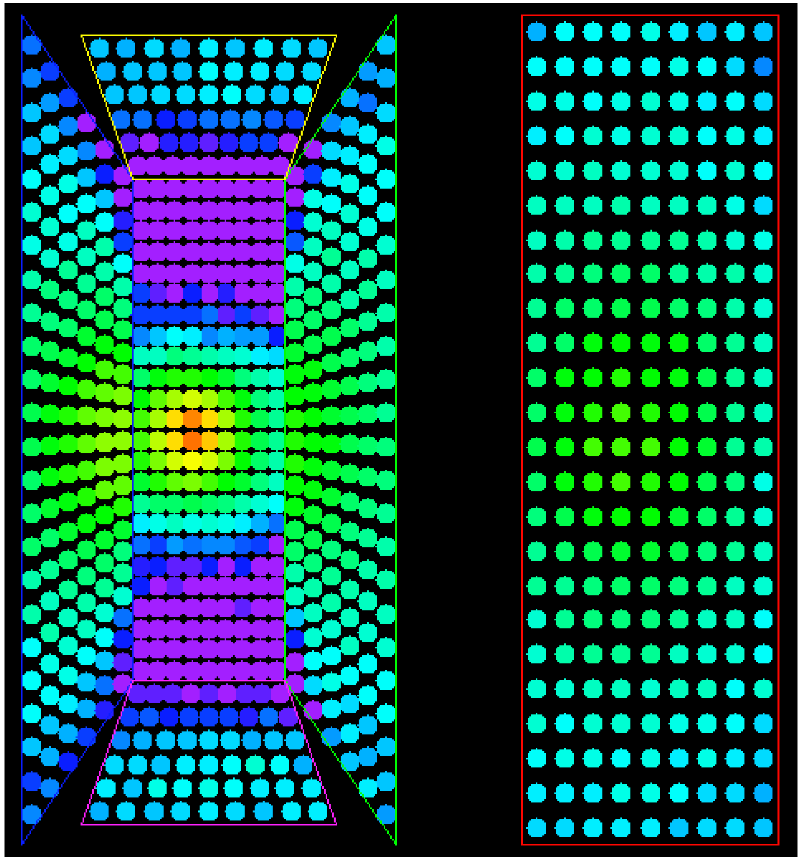
- Scintillation only: High Light Yield, Fast Signal -- Good Resolutions
  - Measures Energy, Time and Position of Gamma Rays
- 3 ton (1000 liters) LXe with ~850 PMTs
- waveform digitizing to reject pile-up
- R&D issues: low temperature (165K), VUV light, H_2O purification



cryostat



PMT holder



a gamma ray simulation

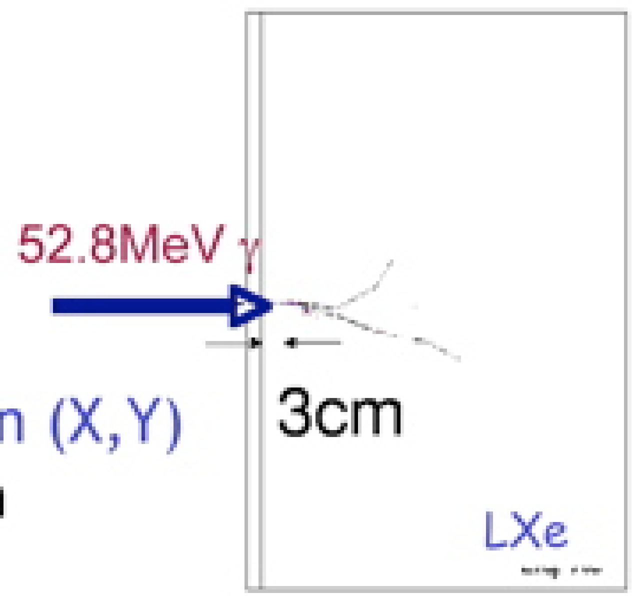
Position measurement

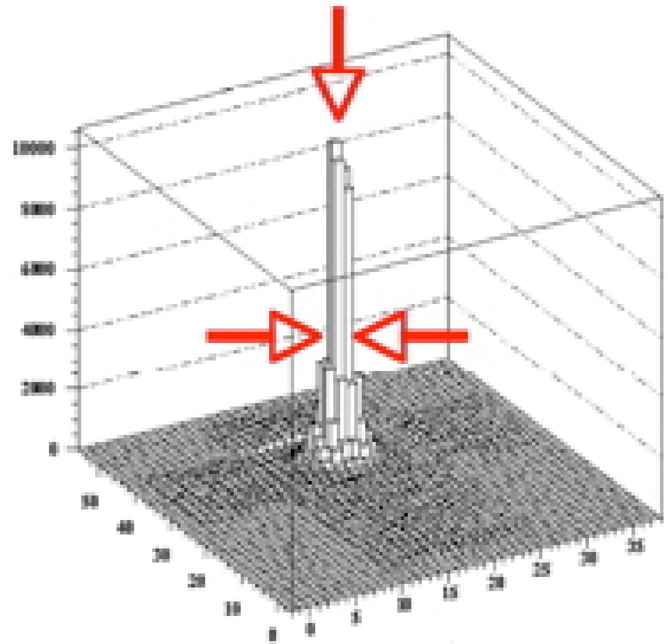
incident position (X,Y)

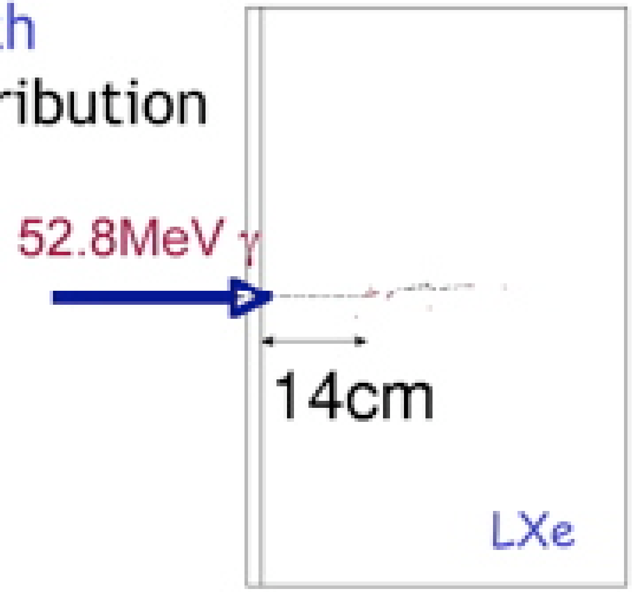
peak position

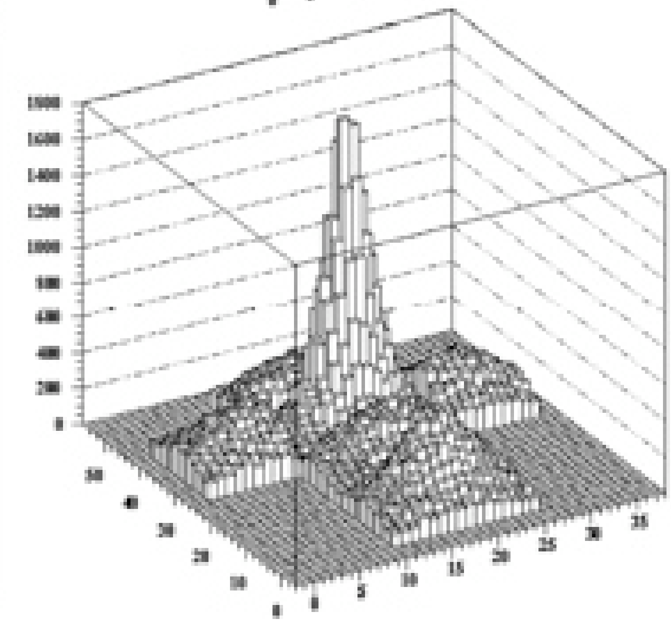
conversion depth

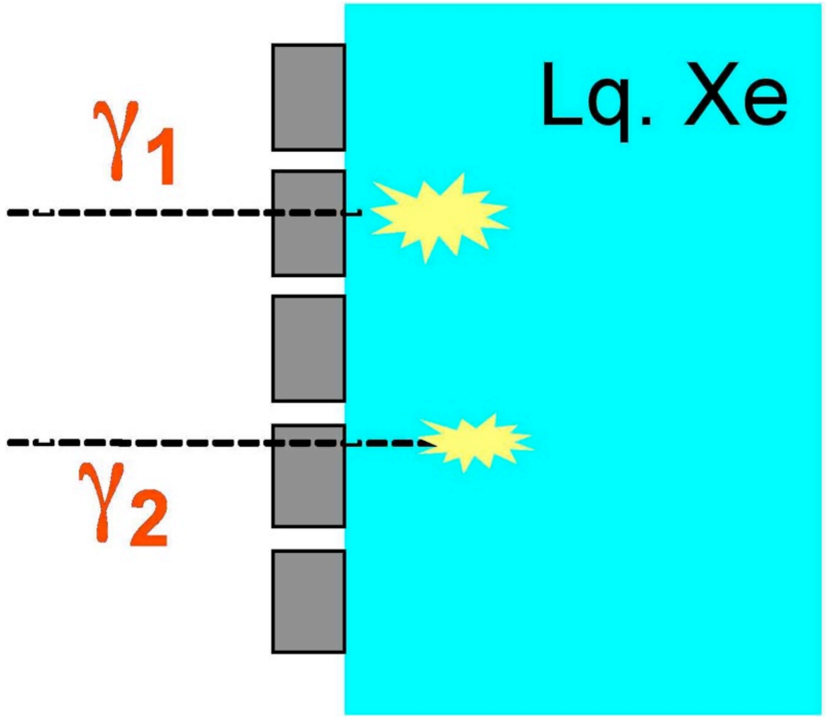
width of distribution





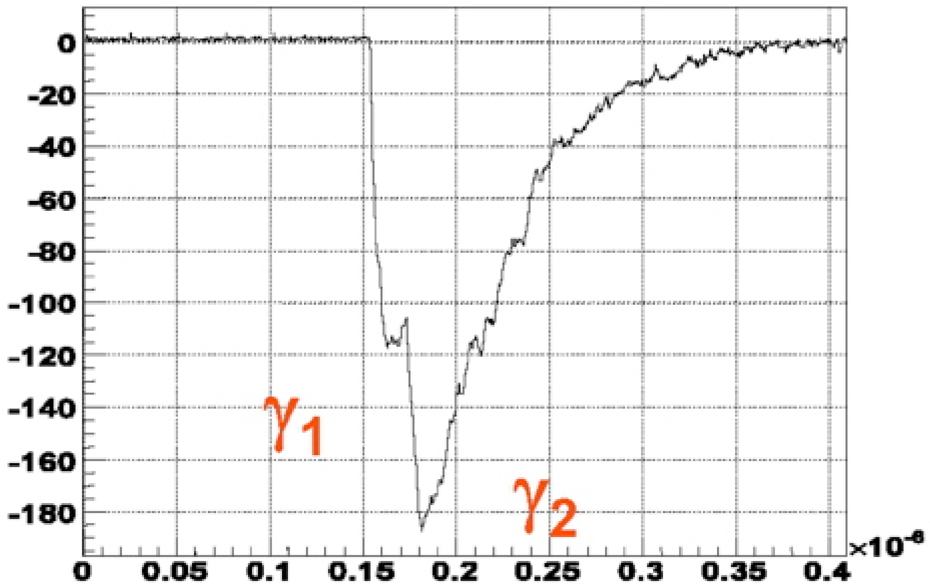






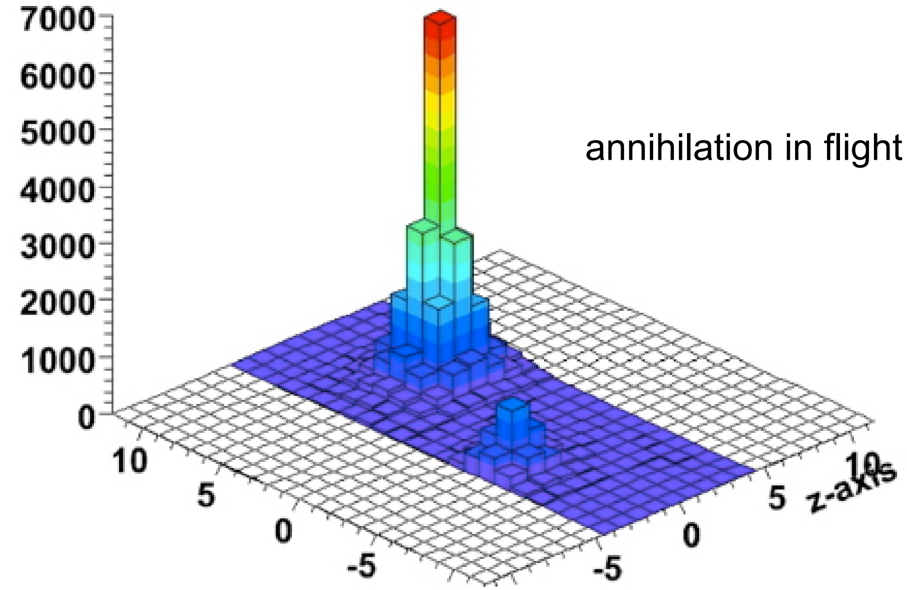
Identification of Gamma ray Pile up

by timing



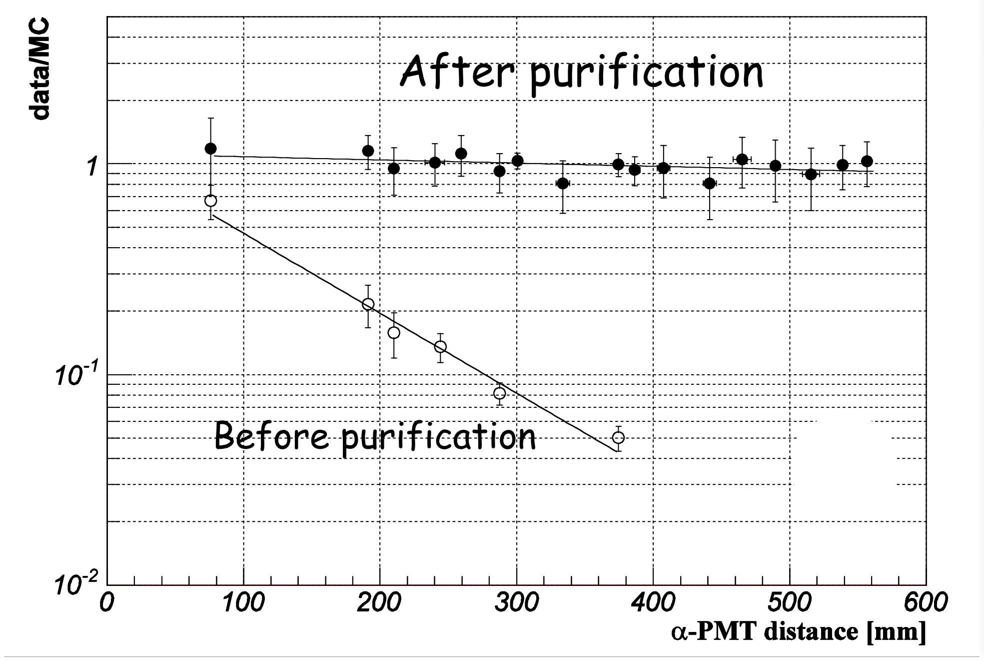
2GHz waveform digitizer

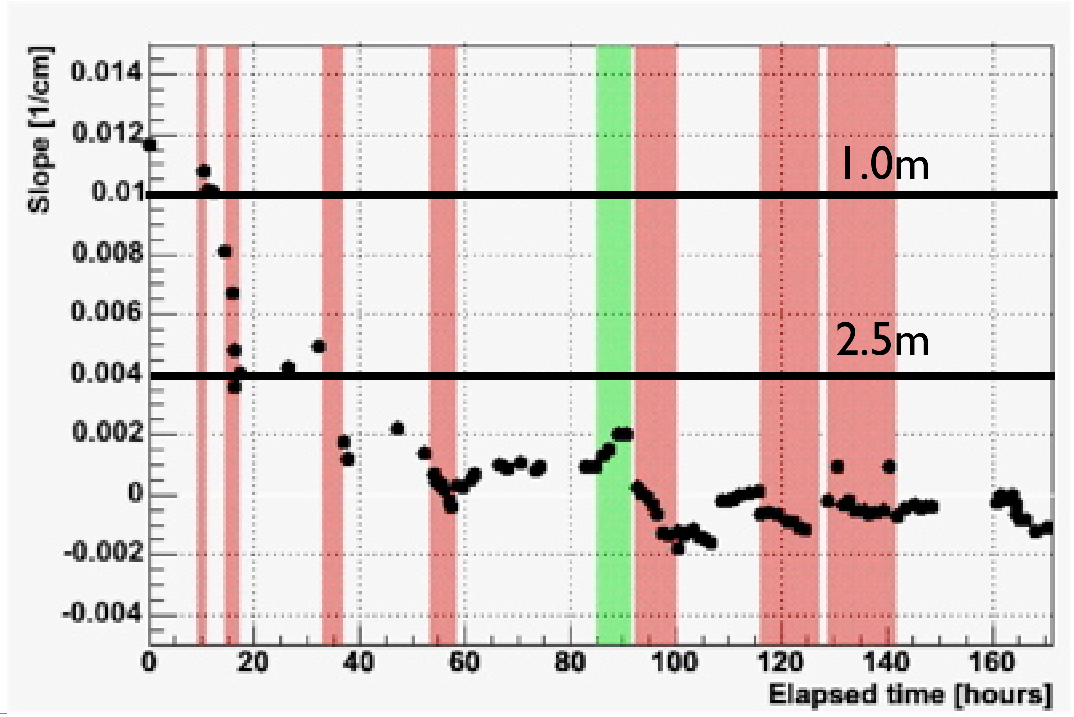
by position



Scintillation Light Attenuation by Water

Gas & liquid phase purification successfully tested:
gas - metal getter (zirconium) ~0.5 l/h
liquid - molecular sieves ~100 l/h

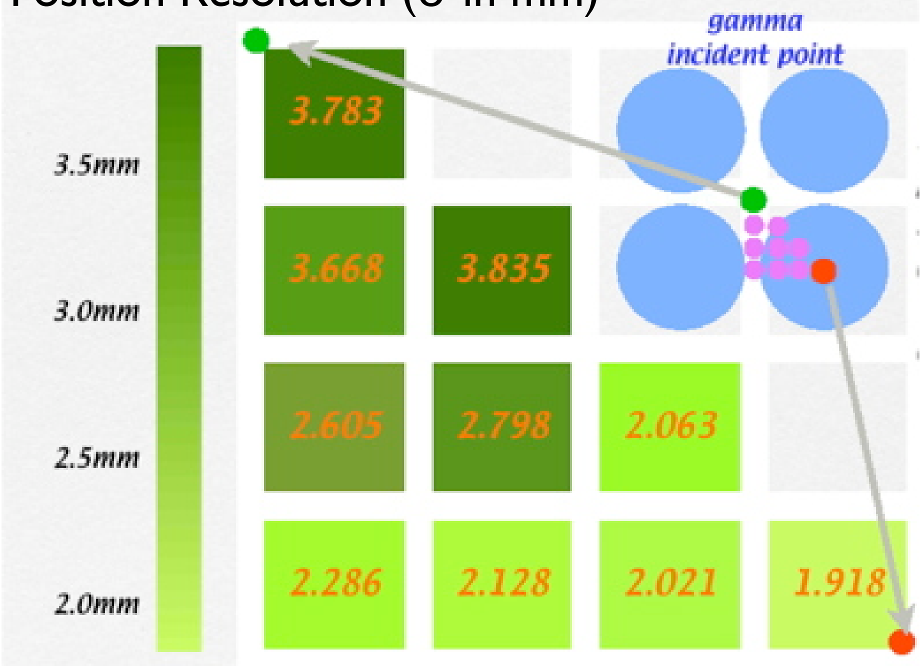


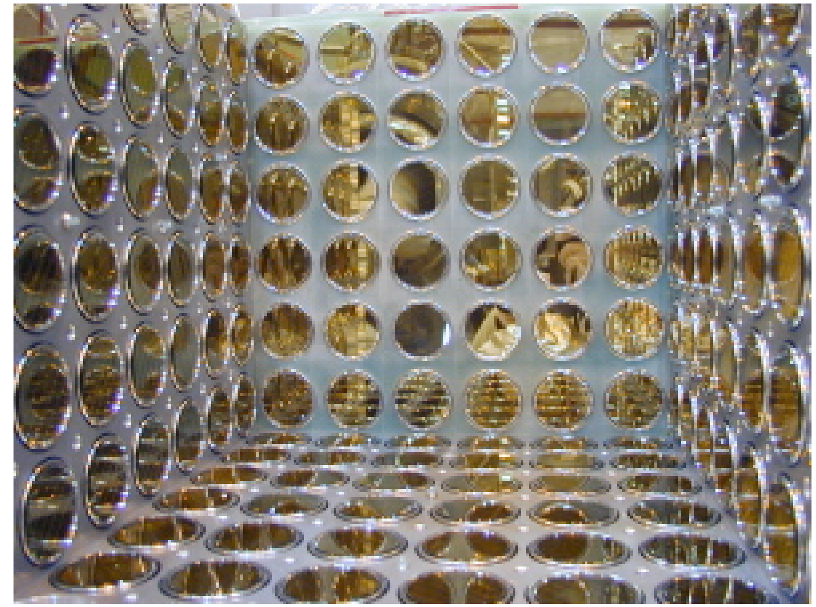


light attenuation > ~3m

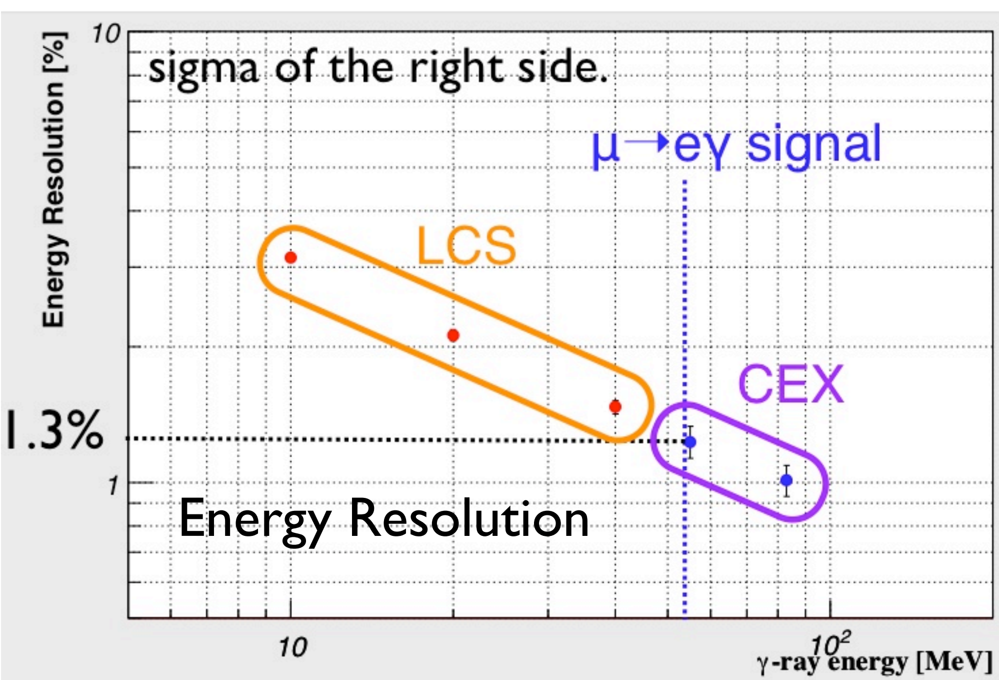
Detector Performance Verified

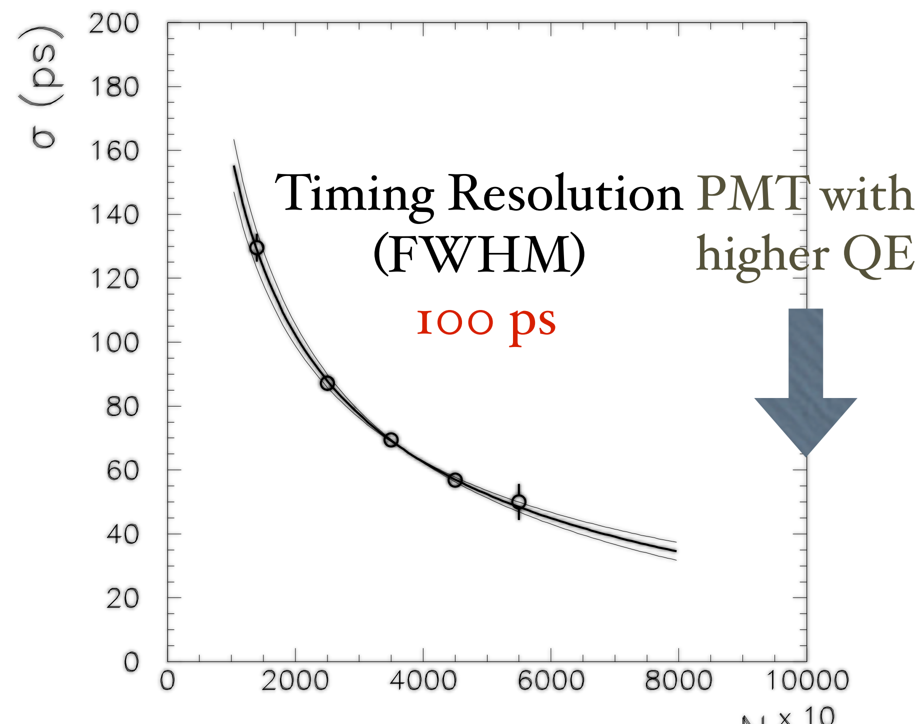
Position Resolution (σ in mm)



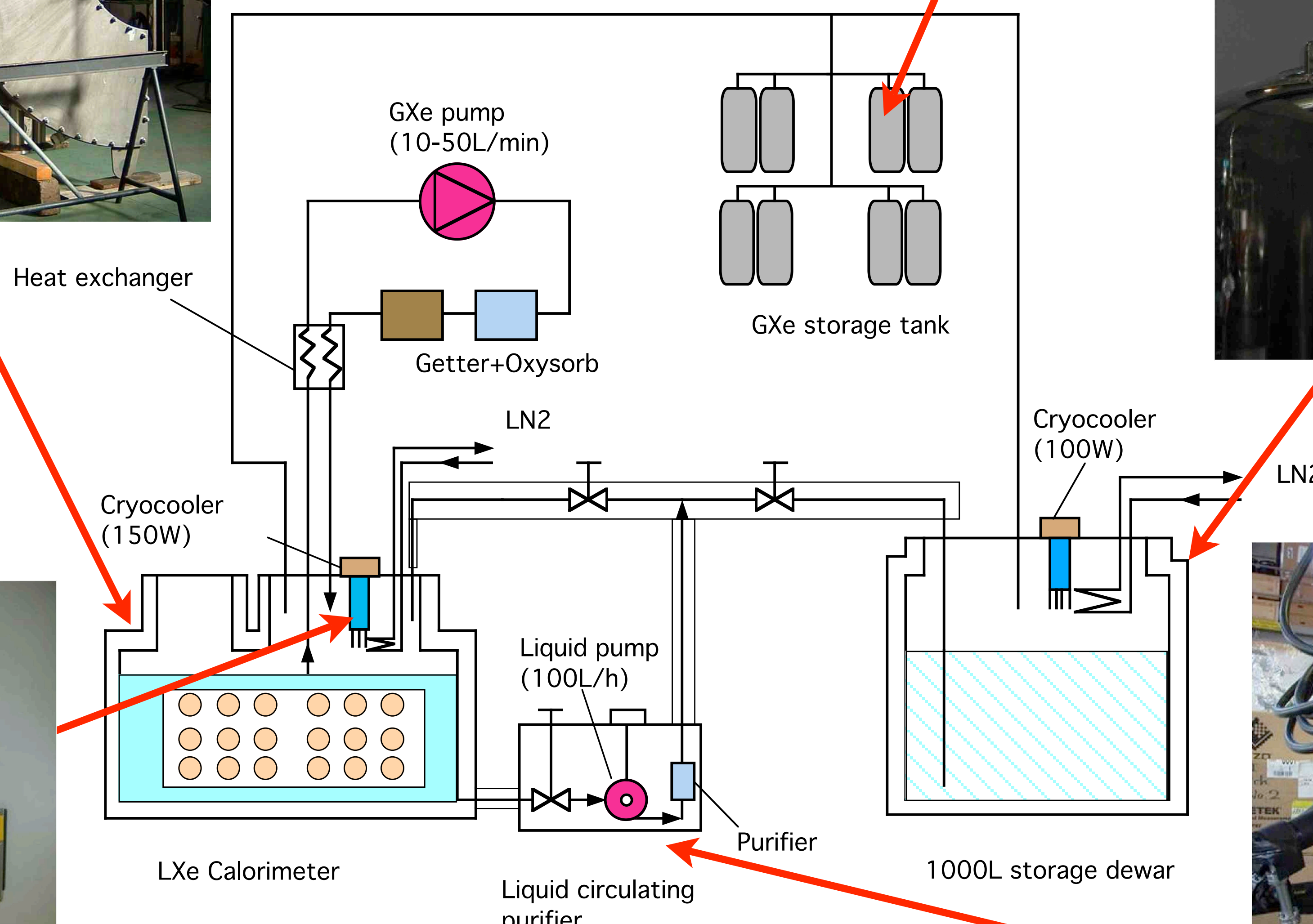


100 liter Prototype Detector

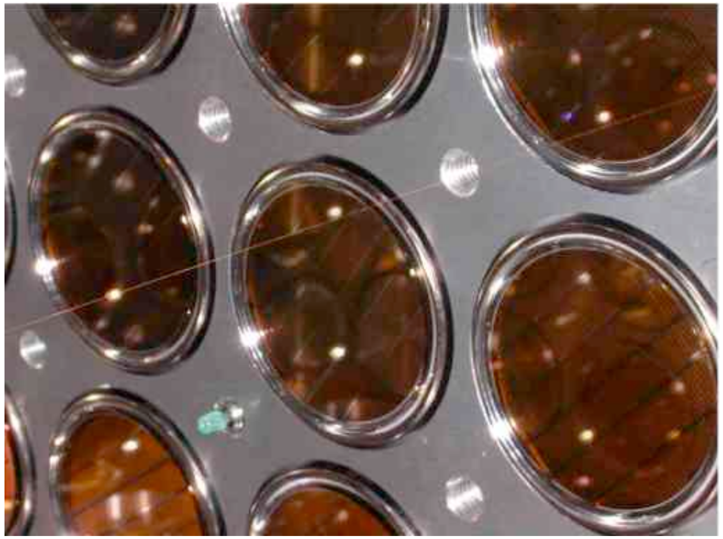




Detector System



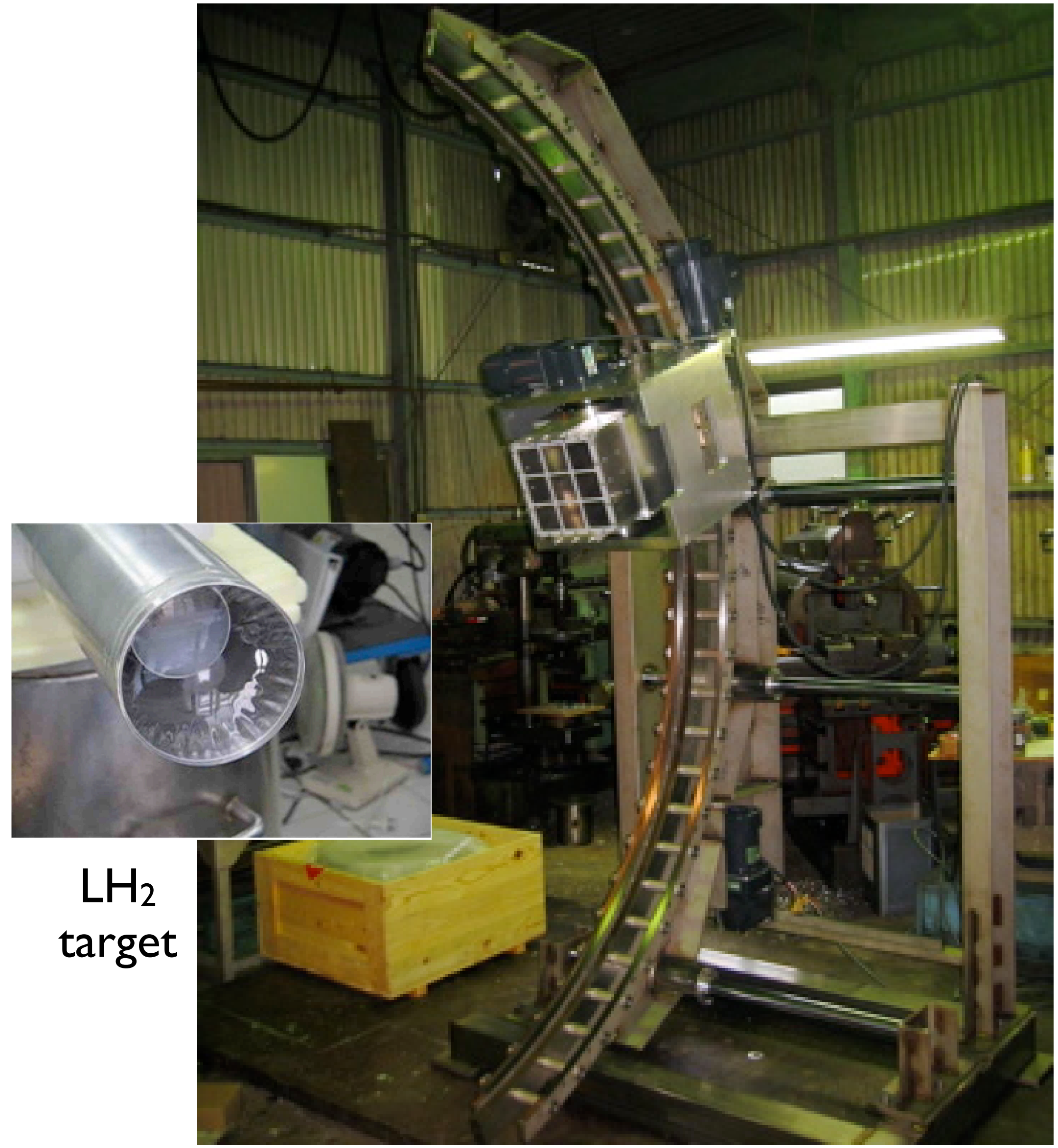
Calibration & Monitoring of LXe Detector



α sources on thin wires

CW proton accelerator for $^{7}Li(p,\gamma)^{8}Be$

monochromatic γ 17.6MeV

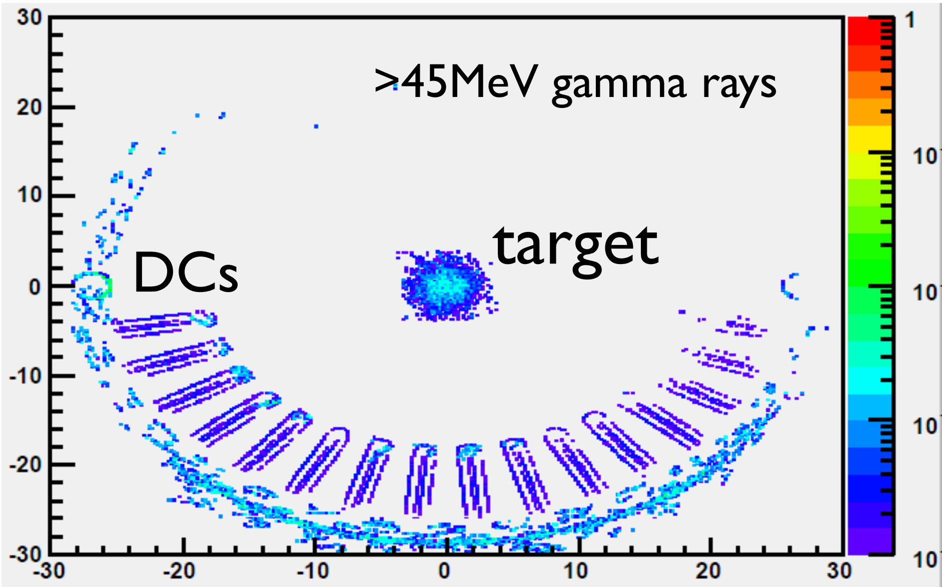


LH_2 target

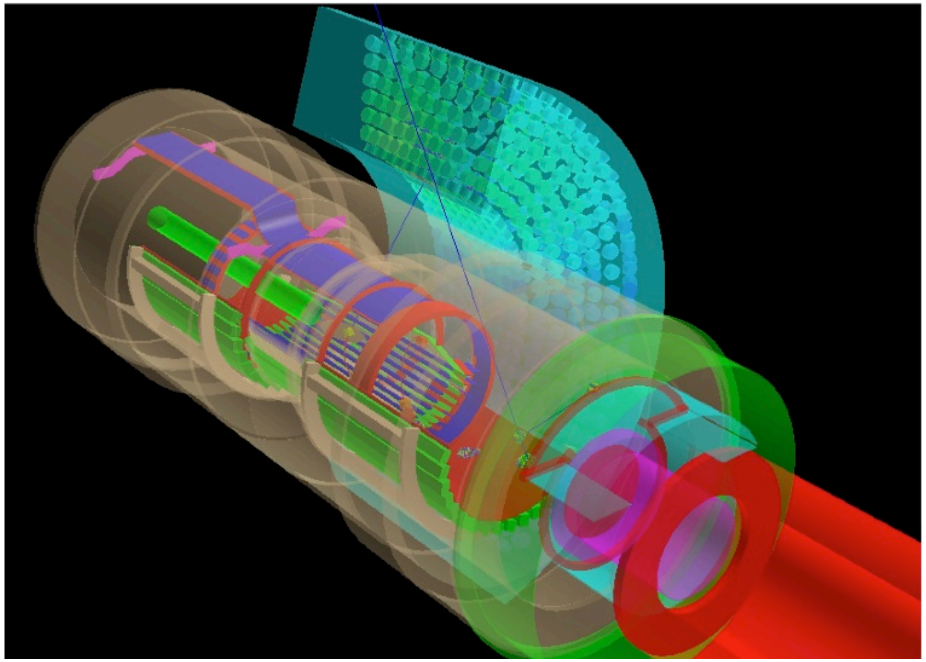
$\pi^{-}p \rightarrow \pi^{0}n$, one γ tagged by NaI

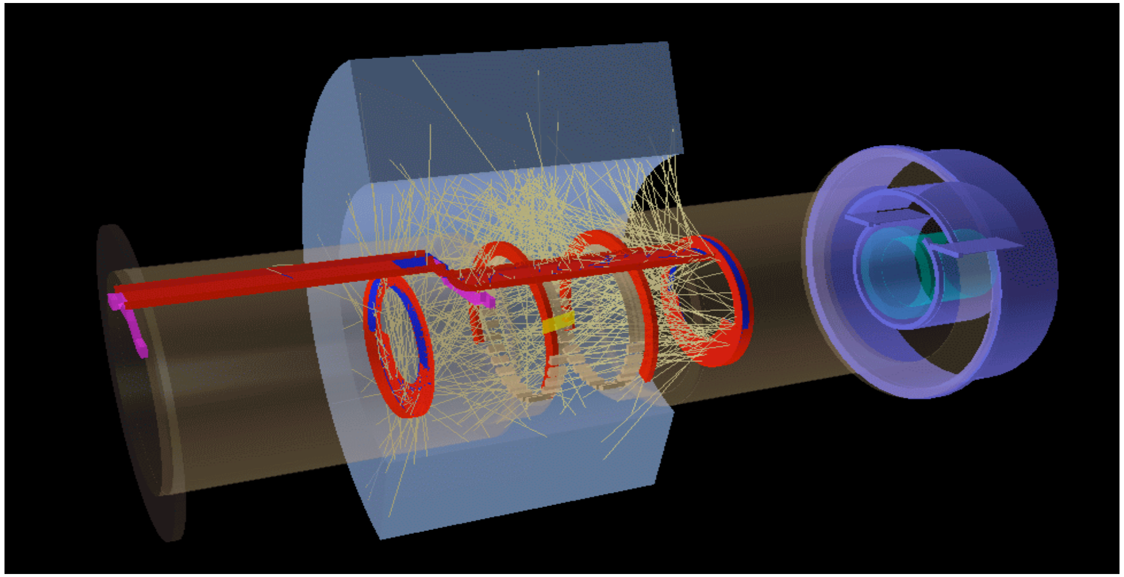
monochromatic γ 55MeV

Detailed background studies are underway



Sources of gamma rays
by e^+ annihilation in flight





low energy gamma rays
from the detector materials
by Michel positrons

MEG Prospects

- Physics run to start next year.
  - Beam line commissioning to be completed this autumn.
  - Engineering run with positron spectrometer toward the end of this year.
  - LXe detector installation & commissioning this winter.
- Could exceed the MEGA limit after a few months running.
- Data taking takes ~2 years with a muon beam of a few x10^7 /sec to reach 10^{-13} sensitivity.
- Our aim is to get a *significant result* before LHC.

a $\mu \rightarrow e\gamma$ event