New experiment to search for $\mu \rightarrow e\gamma$ at PSI

status and prospects

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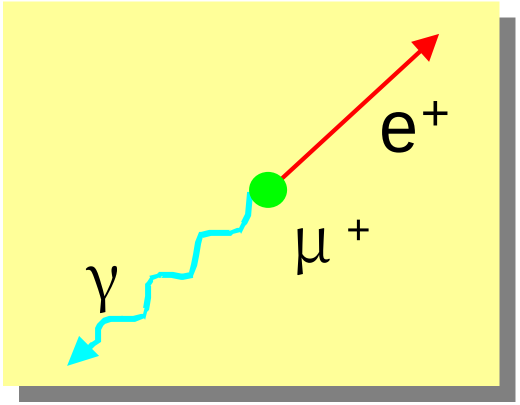
For the MEG collaboration

NOON01

Kashiwa, Dec. 8, 2001

Physics Motivation

$\mu \rightarrow e\, \gamma$ decay

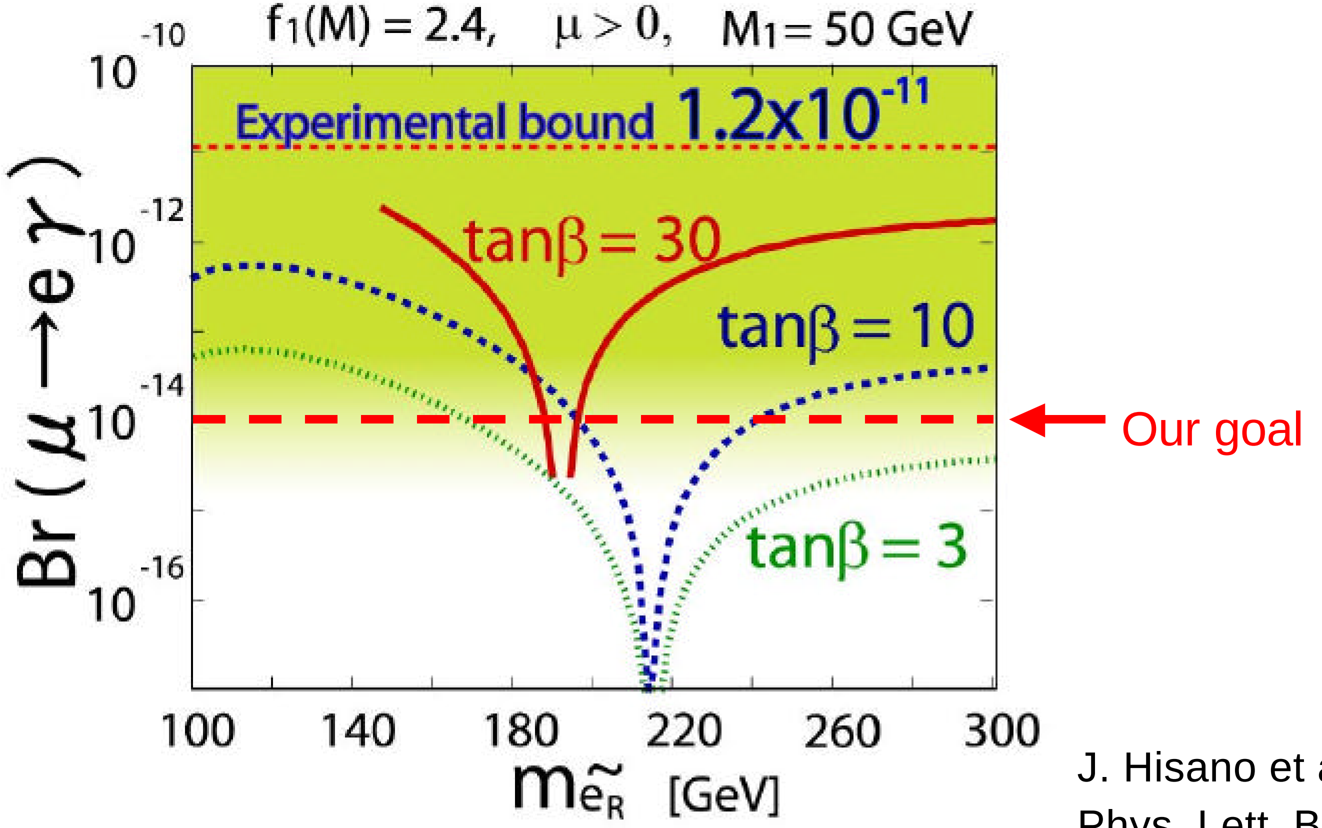


- Event signature
  - Back to back,
  - Time coincident
  - $E_e = E\gamma = 52.8$MeV
- Lepton-family-number nonconserving process
- Forbidden in the standard model
- Sensitive to physics beyond the standard model

  SUSY-GUT, SUSY+ ν_R, ...
- Present experimental bound

  $Br(\mu^+ \rightarrow e^+ \gamma) < 1.2 \times 10^{-11}$ (MEGA experiment, 1999)
- New experiment with a sensitivity of BR~10^{-14} planned at PSI

Physics Motivation, cont'd



J. Hisano et al.,
Phys. Lett. B391 (1997) 341

SU(5) SUSY-GUT predicts BR $(\mu \to e\gamma) = 10^{-15} - 10^{-13}$

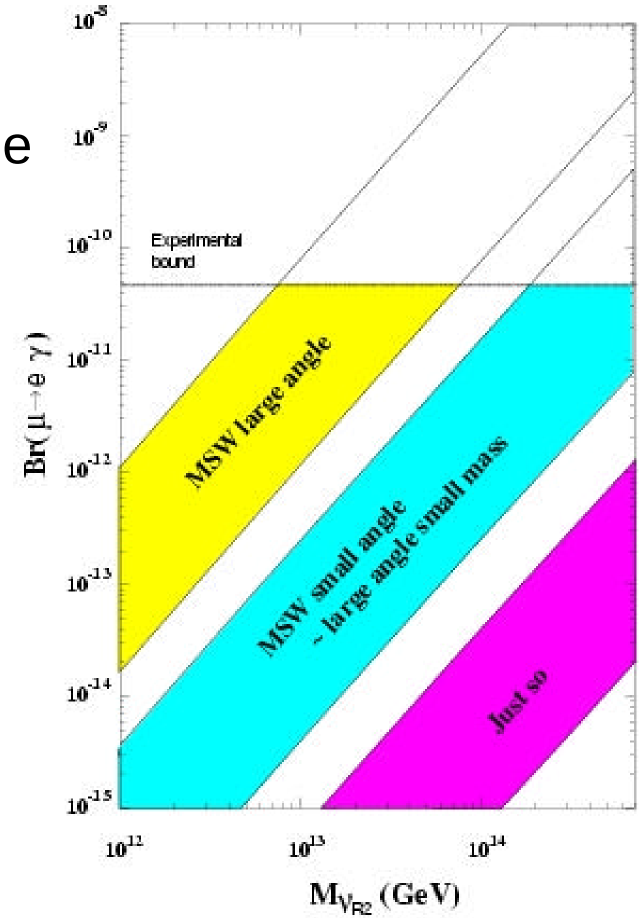
(SO(10) SUSY-GUT: even larger value $10^{-13} - 10^{-11}$)

Physics Motivation, cont'd

Good news from …

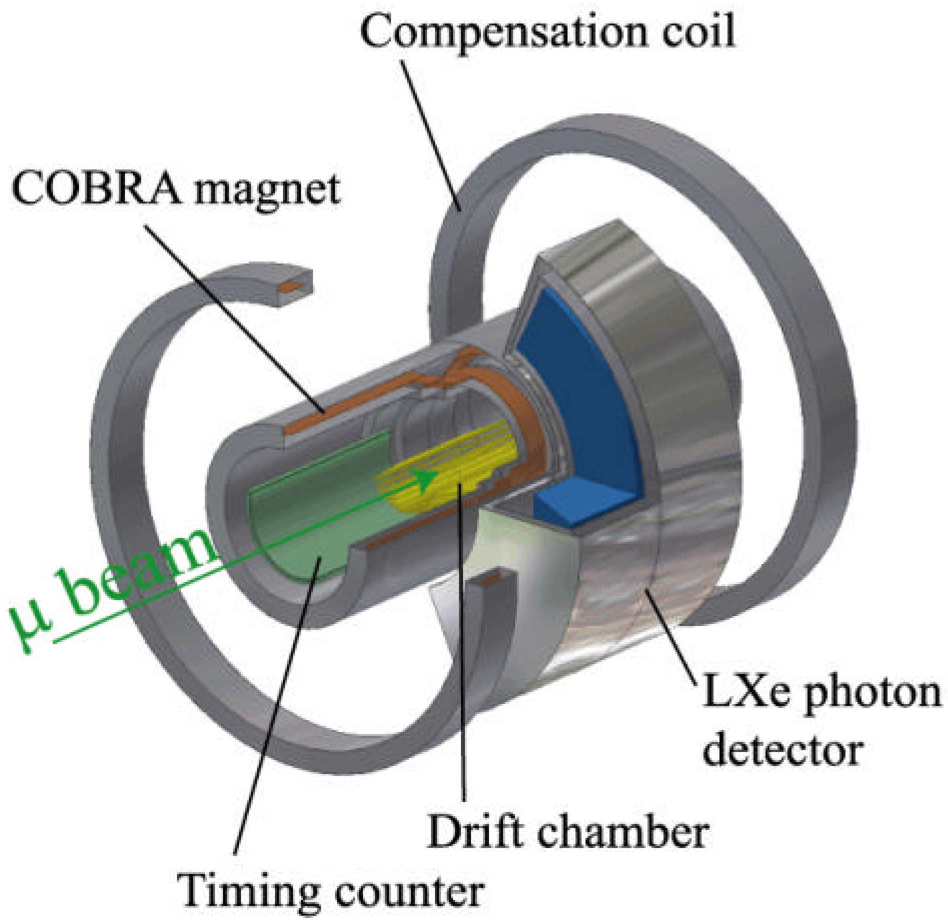
- Solar neutrino results from Super-Kamiokande
  "MSW large angle mixing" is favored
  ⇨ enhance $\mu \rightarrow e\gamma$ rate

- Muon *g-2* experiment at BNL
  2.6σ deviation from the SM prediction
  ⇨ enhance $\mu \rightarrow e\gamma$ rate



Signature of $\mu \rightarrow e \gamma$ could be discovered somewhere above BR ~ 10^{-14}

New $\mu \rightarrow e \gamma$ experiment at PSI



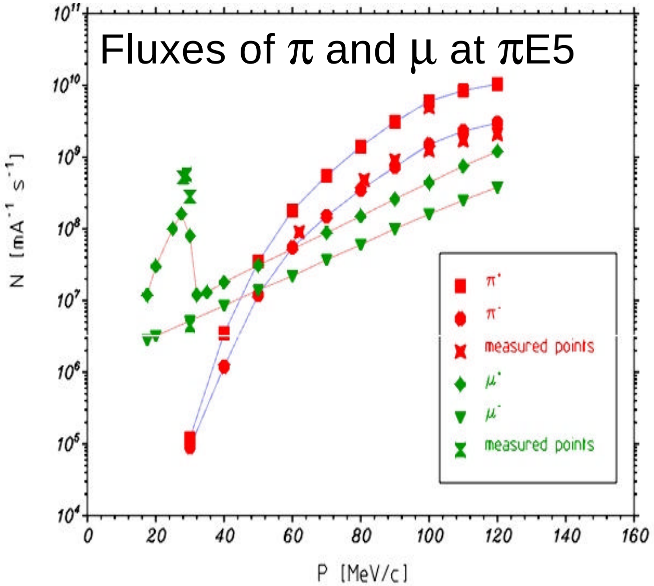
- Sensitivity down to BR~10^{-14}
- Most intense DC muon beam at PSI
- Liquid xenon photon detector
- Positron spectrometer with gradient magnetic field
- Thin superconducting magnet
- Positron tracker and timing counter
- Engineering/physics run will start in the summer of 2003

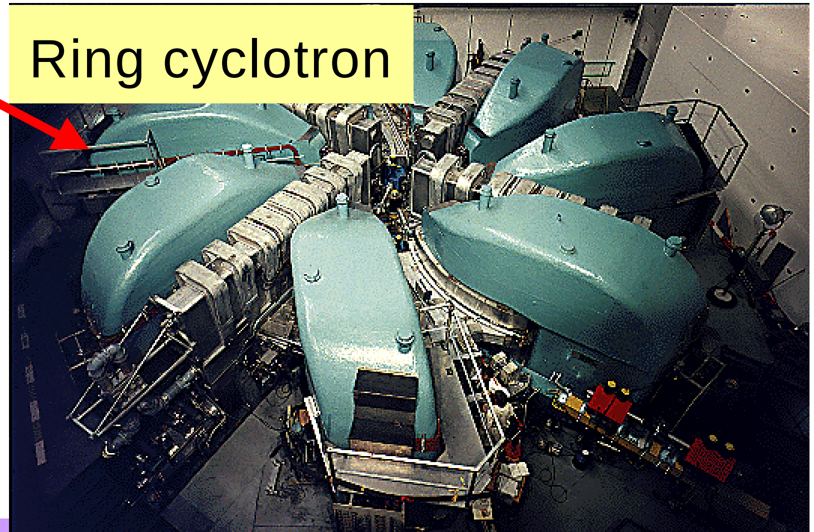
MEG collaboration

Proposal approved in May 1999 at PSI

Institute	Country	Main Resp.	Head	Scientists	Students
ICEPP, Univ. of Tokyo	Japan	LXe Calorimeter	T. Mori	12	3
Waseda University	Japan	Cryogenics	T. Doke	5	3
INFN, Pisa	Italy	e^+ counter, trigger, M.C.	C. Bemporad	4	3
IPNS, KEK, Tsukuba	Japan	Supercoducting Solenoid	A. Maki	5	-
PSI	Switzerland	Drift Chamber, Beamline, DAQ	S. Ritt	4	-
BINP, Novosibirsk	Russia	LXe Tests and Purification	B. Khazin	4	-
Nagoya University	Japan	Cryogenics	K. Masuda	1	-

Where to search for $\mu \rightarrow e \gamma$?





- Ring Cyclotron:
  Operating current ~ 1.8 mA (Max >2.0mA)
- DC muon beam rate above 10^8 μ/s
  at πE5 beam line

Sensitivity and Backgrounds

- Single event sensitivity

  N_μ=1x10^8/sec, T =2.2x10^{7}sec, $\Omega/4\pi$=0.09, ε_γ=0.7,ε_e=0.95

  ➡ $BR(\mu^+ \rightarrow e^+ \gamma) \sim 0.94 \times 10^{-14}$

- Major backgrounds

  - Accidental Coincidence

    Michel decay($\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$)

    + random γ

    $B_{accidental} \sim 5 \times 10^{-15}$

  - Radiative muon decays

    $\mu^+ \rightarrow e^+ \nu_e \nu_\mu \gamma$

    $B_{prompt} \sim 10^{-17}$

Expected detector performance

ΔE_e	0.7% (FWHM)
ΔE_γ	1.4 – 2.0 % (FWHM)
$\Delta \theta_{e\gamma}$	12 – 14 mrad(FWHM)
$\Delta t_{e\gamma}$	0.15 nsec (FWHM)

Gamma detection

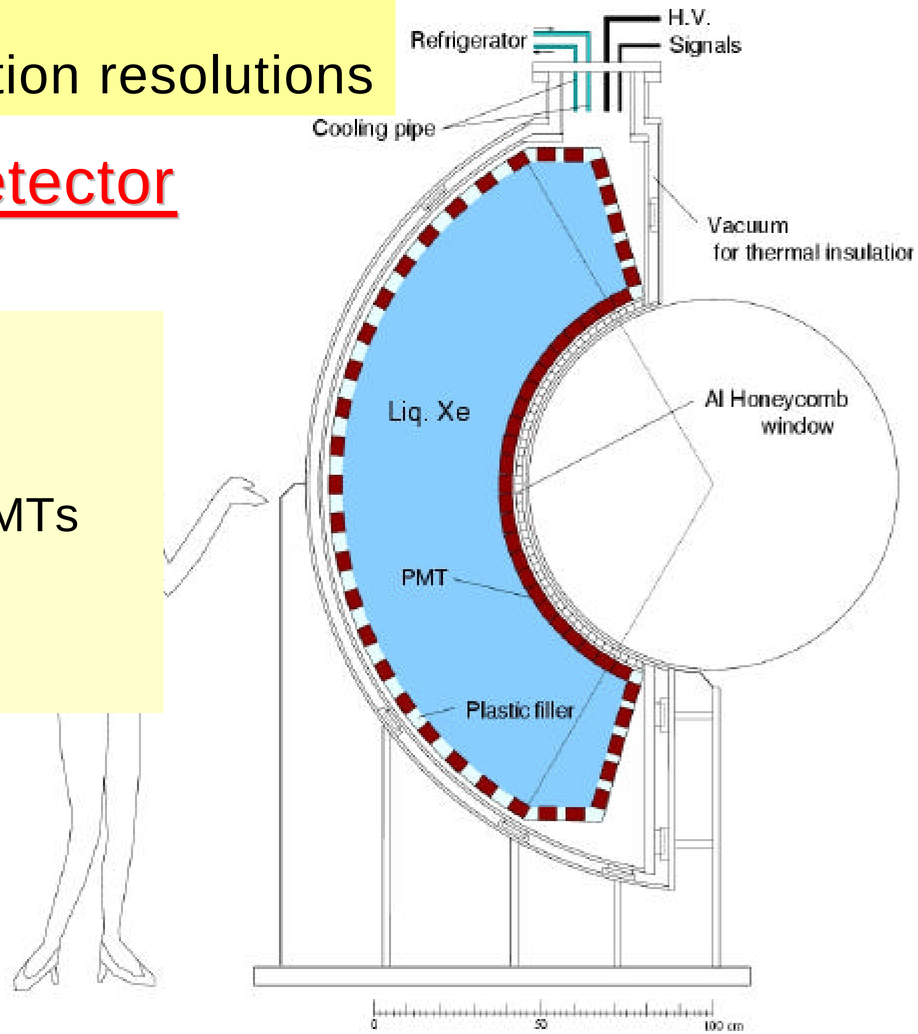
Detector requirements:

Excellent energy-, timing-, and position resolutions

⇨ Liquid xenon scintillation detector

Detector design

- Active volume of LXe: 600 liter
- Scintillation light is collected by ~800 PMTs immersed in LXe
- Effective coverage: ~ 35%

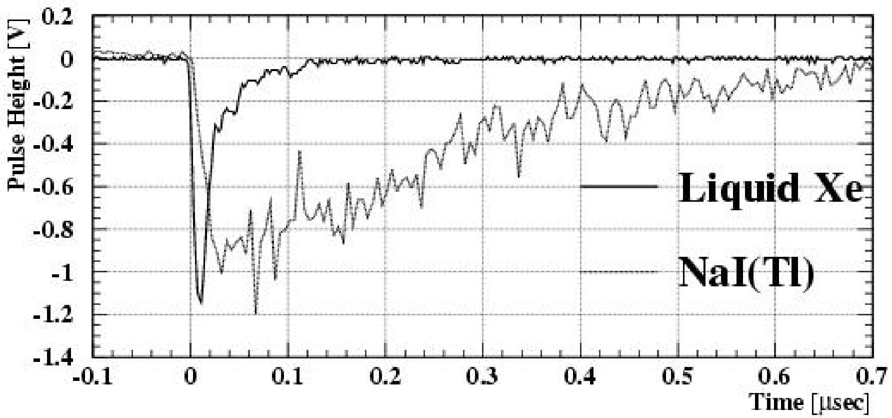


Liquid Xenon Scintillator

- High light yield (75% of NaI(Tl))
- Fast signals

  →avoid accidental pileups
- Spatially uniform response

  No need for segmentation



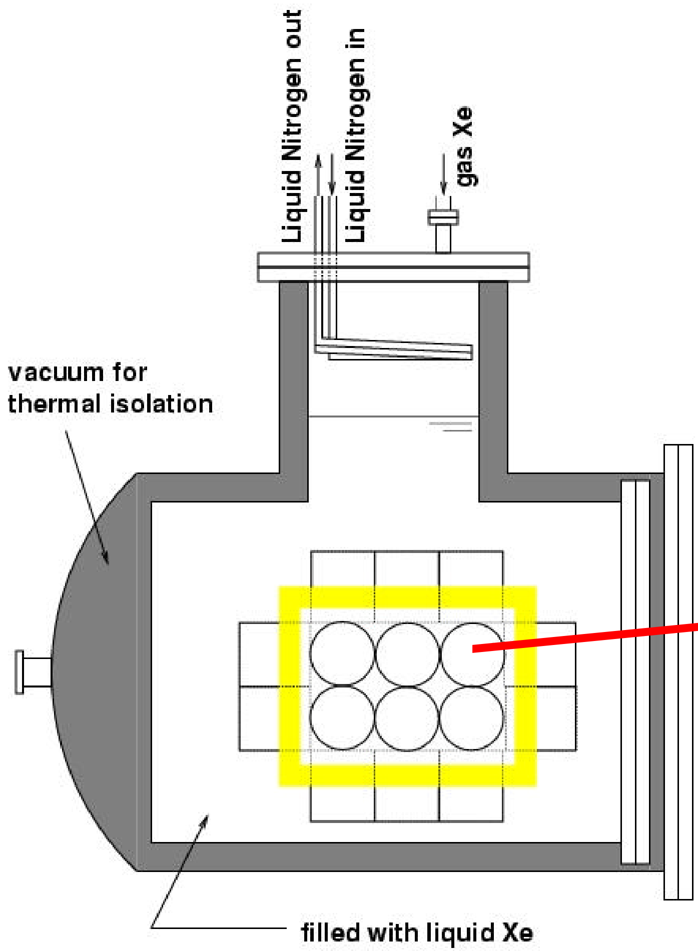
LXe properties

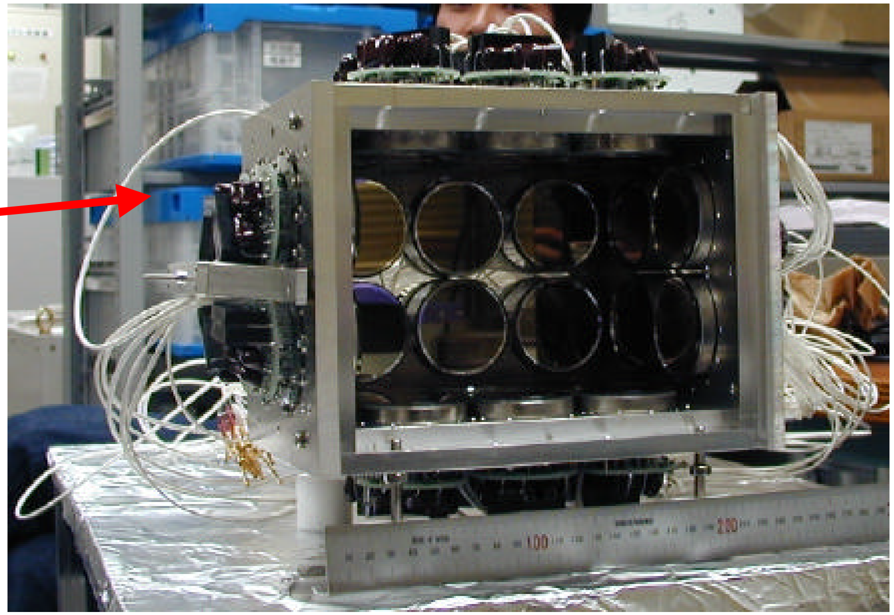
Mass number	131.29
Density	3.0 g/cm^3
Boiling and melting points	165 K, 161 K
Energy per scintillation photon	24 eV
Radiation length	2.77 cm
Decay time	4.2 nsec (fast) 22 nsec (slow) 45 nsec (recombi.)
Scintillation light wave length	175 nm
Refractive index	1.57 – 1.75?

Small Prototype

- 32 x PMTs
- Active Xe volume

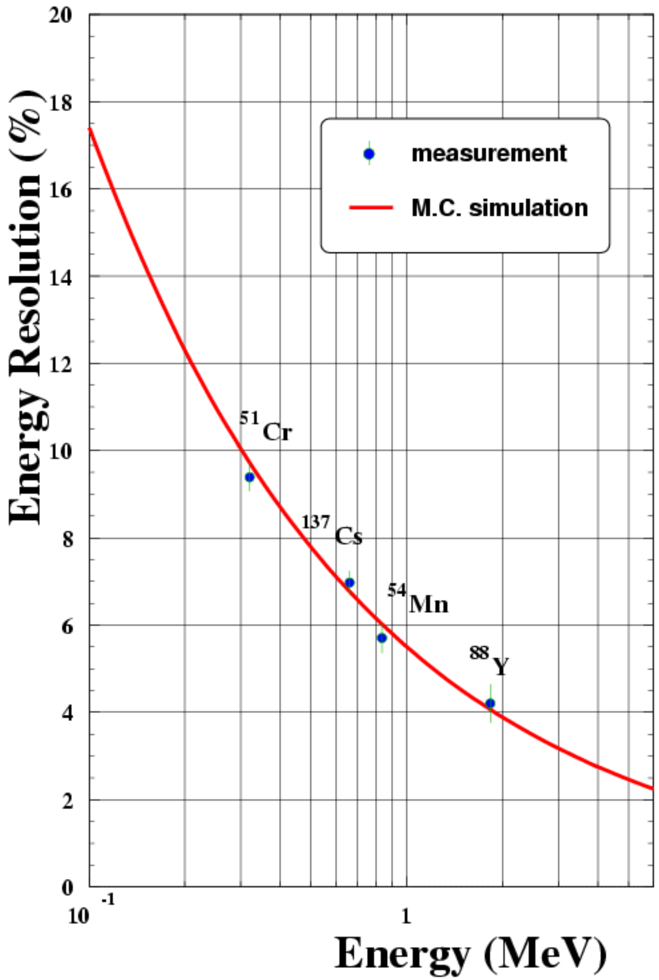
  116 x 116 x 174 mm^3 (2.3liter)
- Energy-, Position-, and Timing resolution for gamma up to 2MeV





Small Prototype results

Energy



Simple extrapolations from the results implied

σ_{energy} ~ 1%,

$\sigma_{position}$ ~ a few mm,

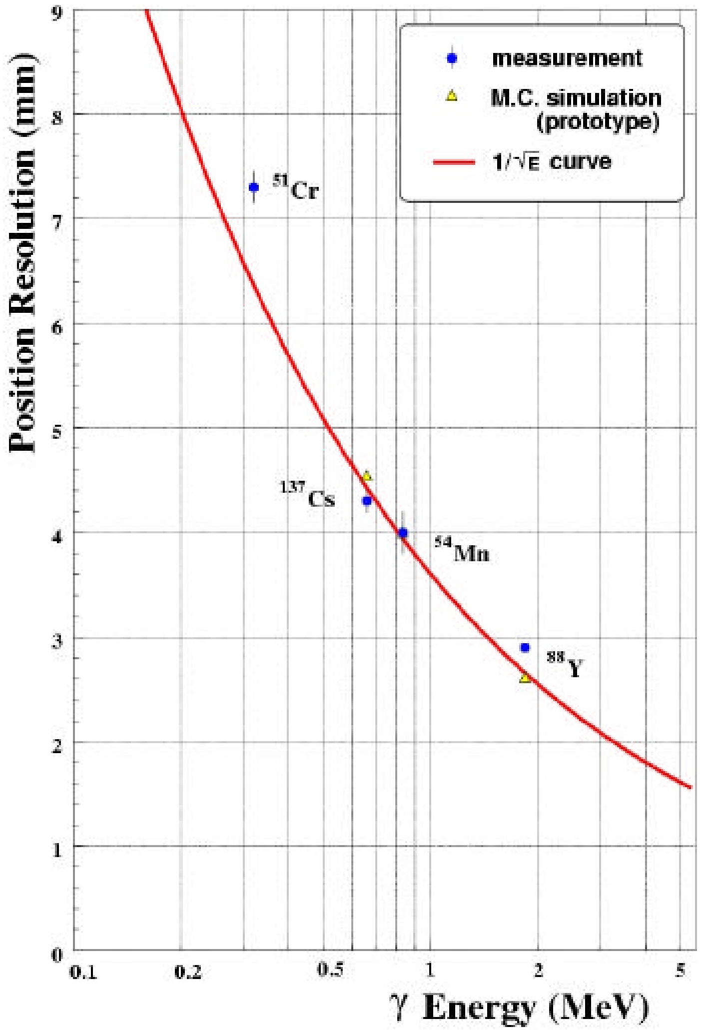
σ_{time} ~ 50psec

for 52.8MeV gamma from $\mu \rightarrow e\ \gamma$

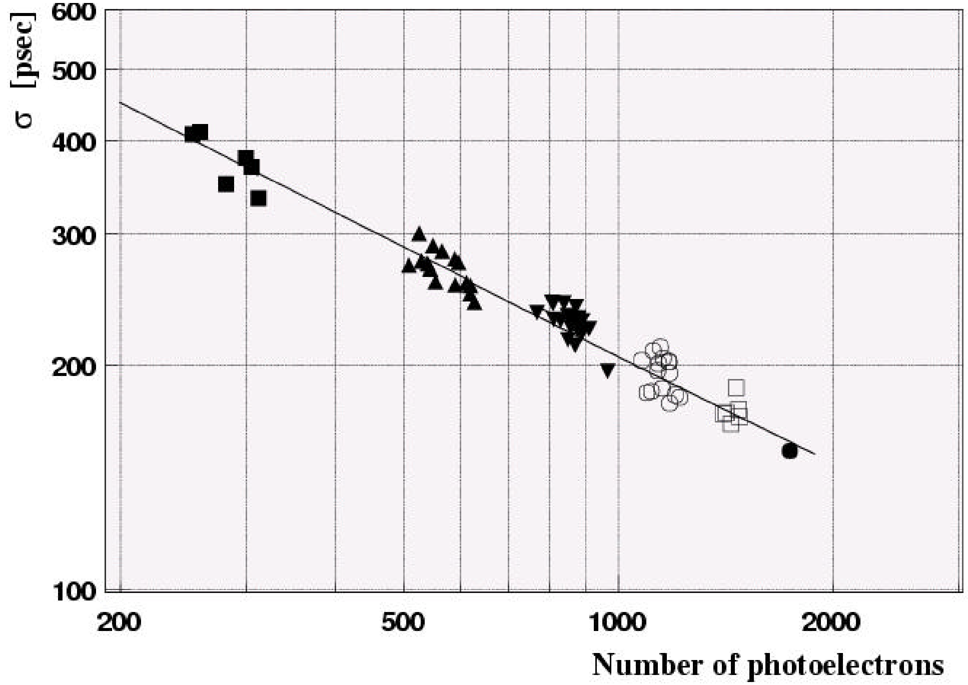
But, has to be verified with larger detector for higher energy(~50MeV) gamma rays

Small Prototype results, cont'd

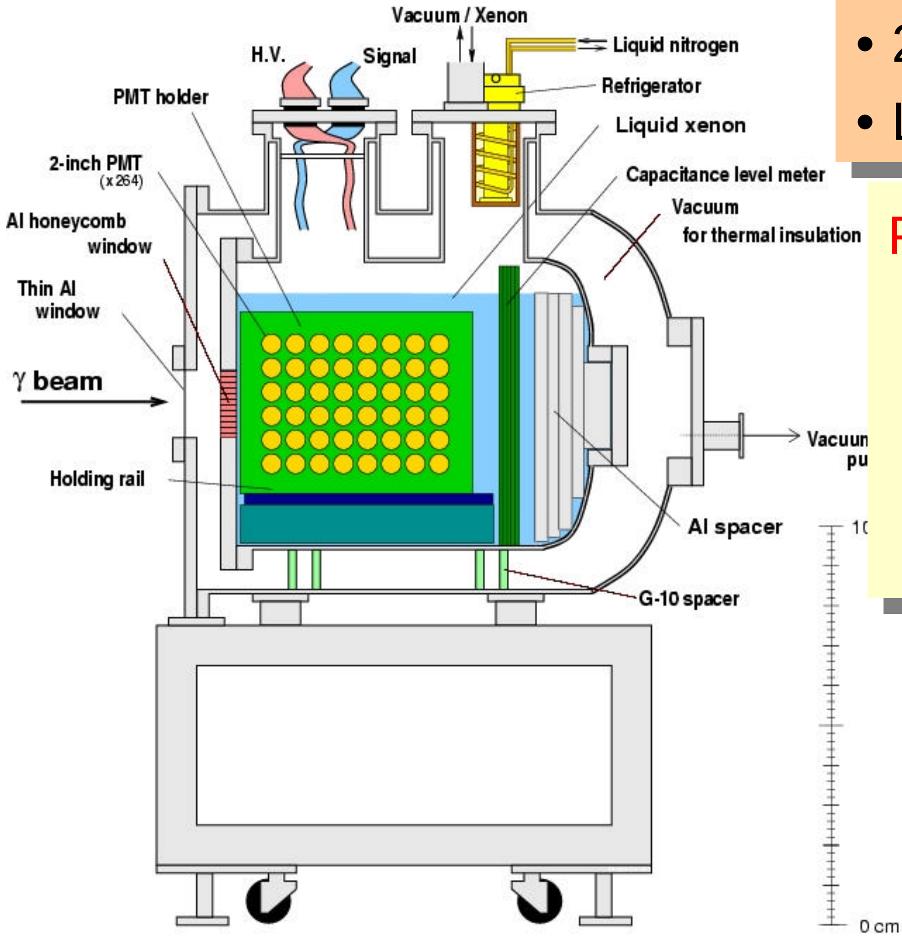
Position



Time

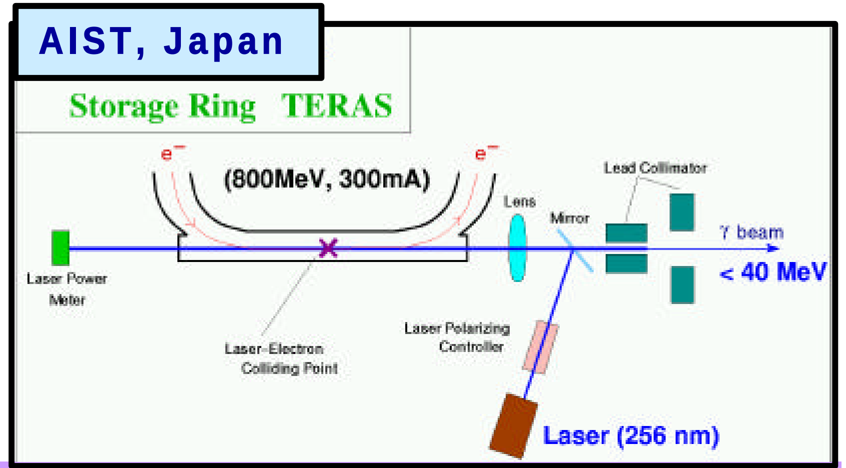


Large Prototype



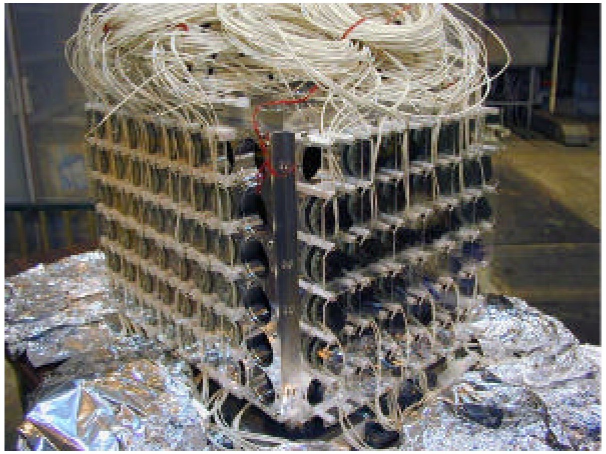
- 228 PMTs, 69liter LXe
- Large enough to test with ~50MeV γ

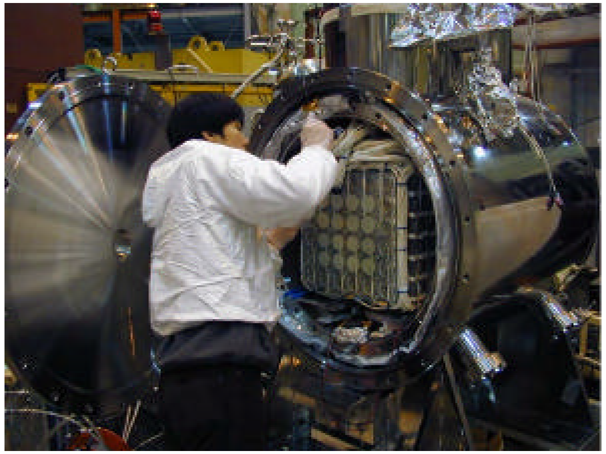
Purposes
- Performance test with high energy γ (Energy-, position-, time resolutions)
- Check of cryogenics and other detector components
- Absorption length measurements



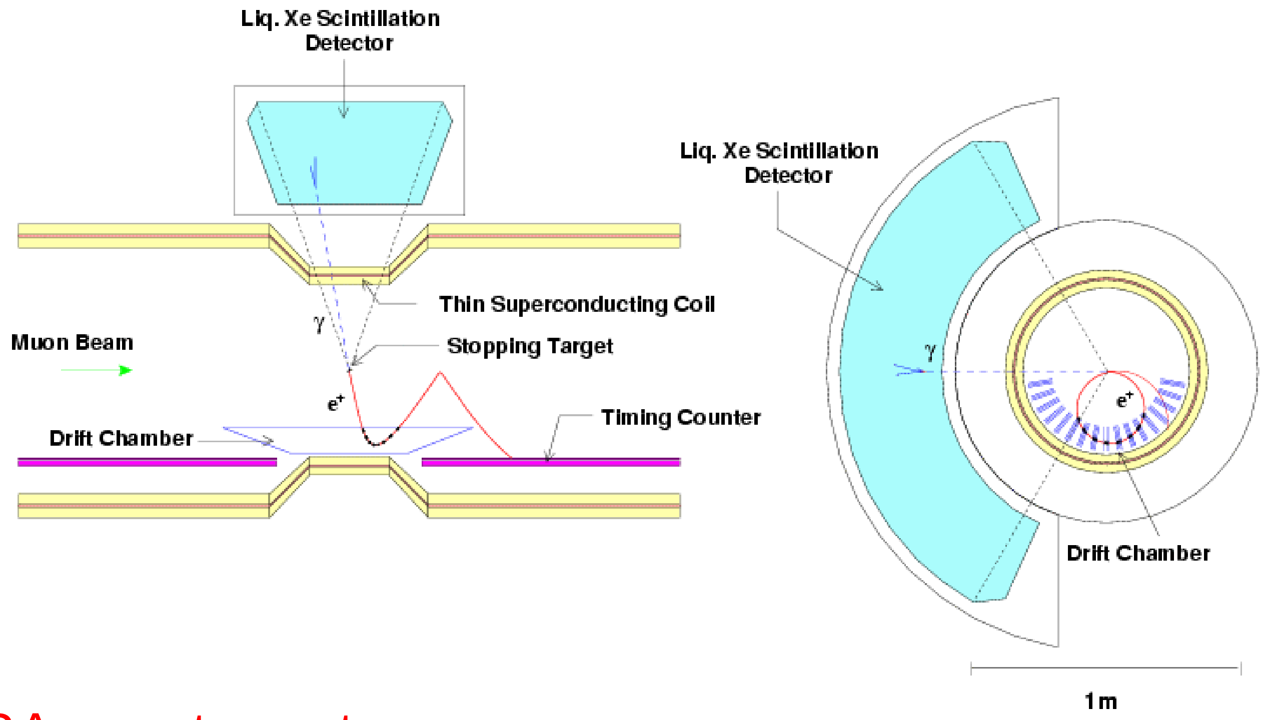
Large Prototype Current Status

- Construction finished
- Performance of the cryogenics very good!
- First test with 40MeV γ beam in June 2001 at AIST, Tsukuba, Japan
    - 40MeV γ observed, analysis in progress
    - Various detector components worked well (refrigerator, feedthrough, PMT holder, etc.)
- Second beam test is scheduled at the beginning of 2002
- Test with cosmic rays in progress





Positron Detection



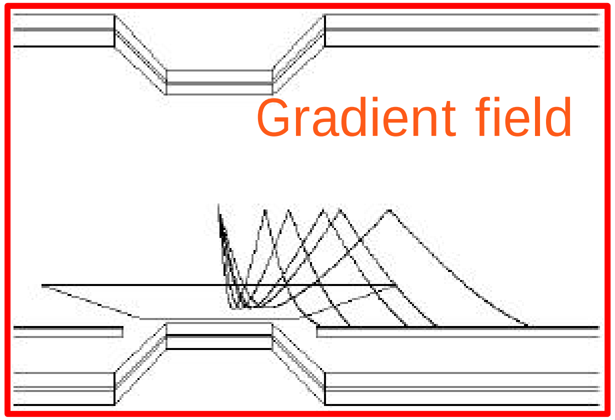
COBRA spectrometer

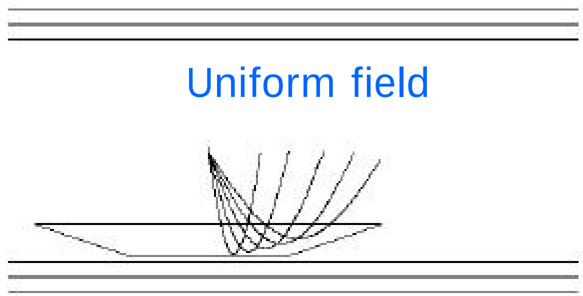
- Thin superconducting magnet with gradient magnetic field
- Drift chamber for positron tracking
- Scintillation counters for timing measurement

COBRA spectrometer

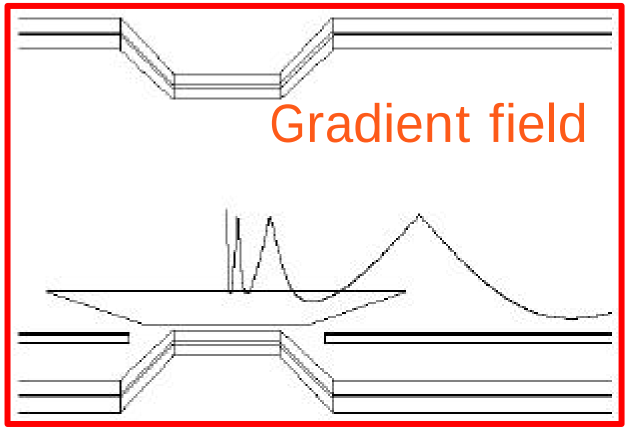
COnstant Bending RAdius (COBRA) spectrometer

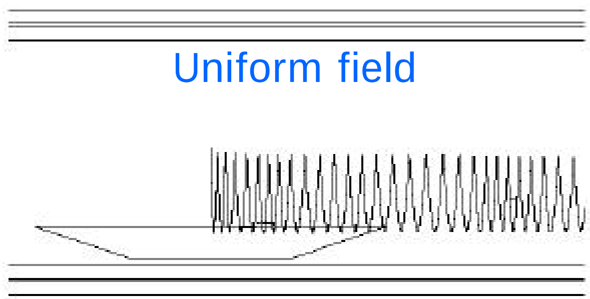
- Constant bending radius independent of emission angles



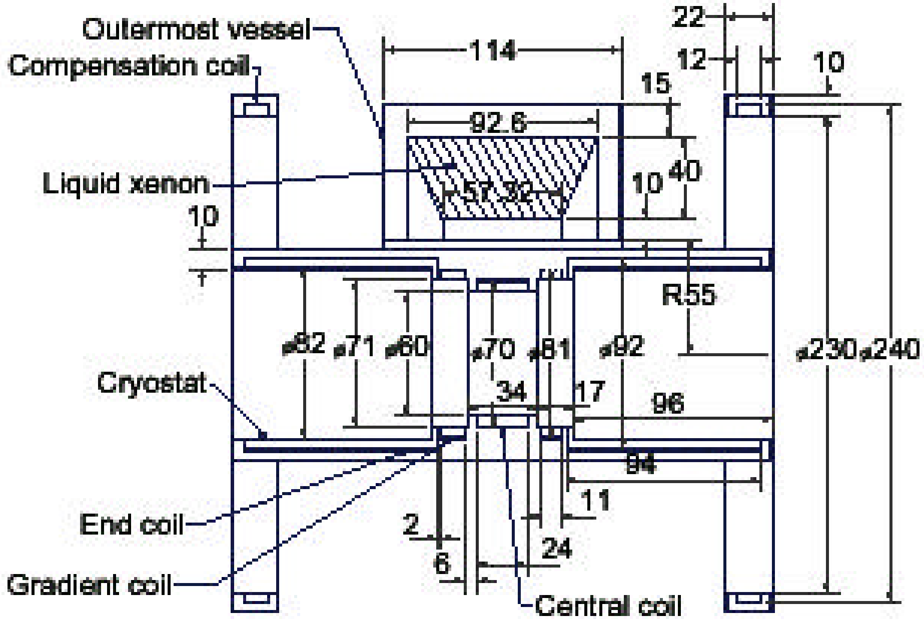


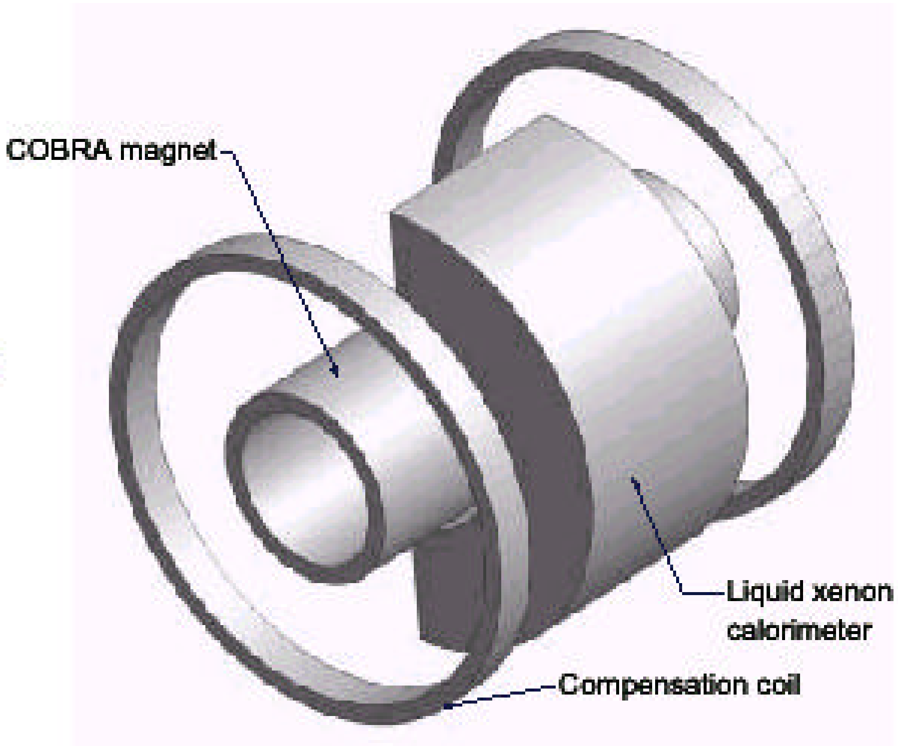
- Low energy positrons quickly swept out





Magnet





- B_c = 1.26T, $B_{z=1.25m}$=0.49T, operating current = 359A
- Five coils with three different diameter to realize gradient field
- Compensation coils to suppress the residual field around the LXe detector
- High-strength aluminum stabilized superconductor →thin superconducting coil

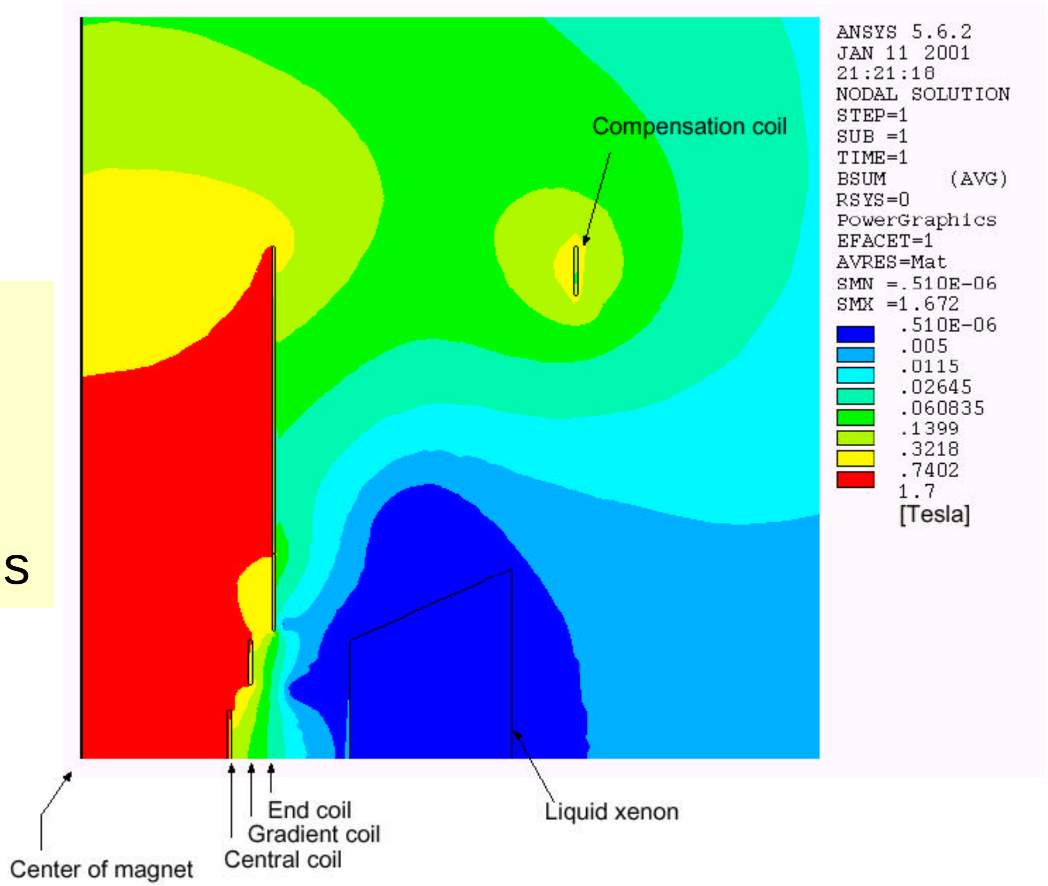
Magnet Residual field around LXe detector

Tolerance to magnetic field of PMT

$B_{//} < 50$ Gauss

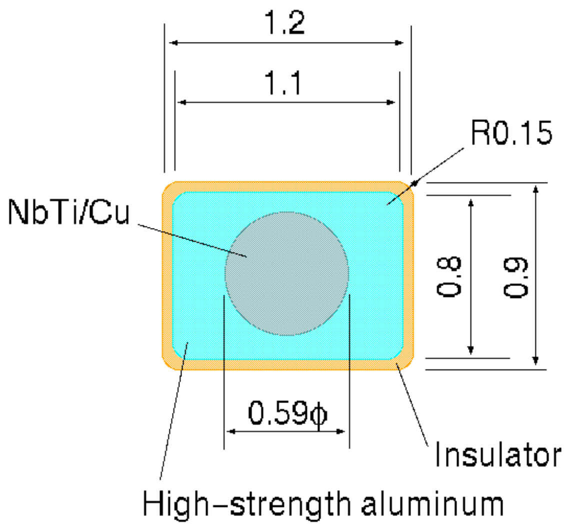
$B_{\perp} < 150$ Gauss

- Field cancellation with compensation coil
- Residual field below 50Gauss



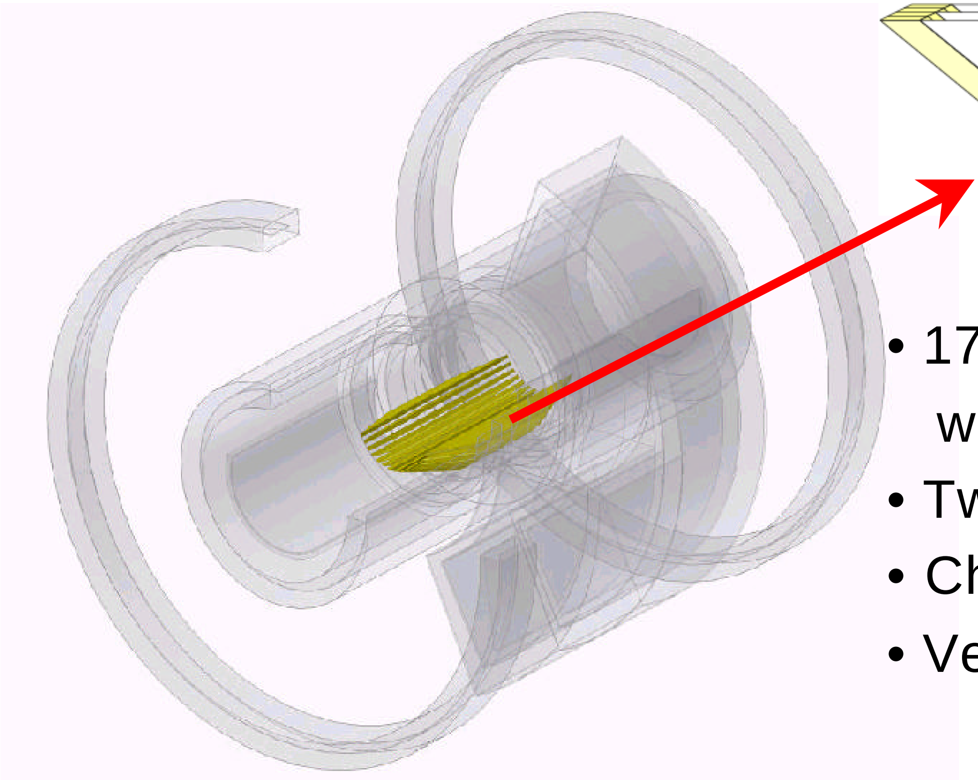
Magnet current status

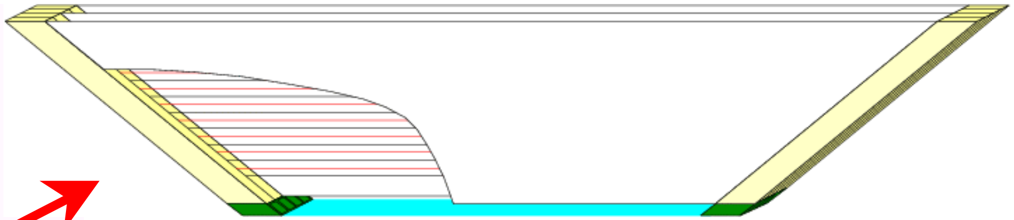
- Magnet design finalized
- High-strength aluminum stabilized superconductor
  All the cable fabricated and delivered.
- Coil winding is starting
- Construction of the cryostat and assembly will be finished by the end of 2002



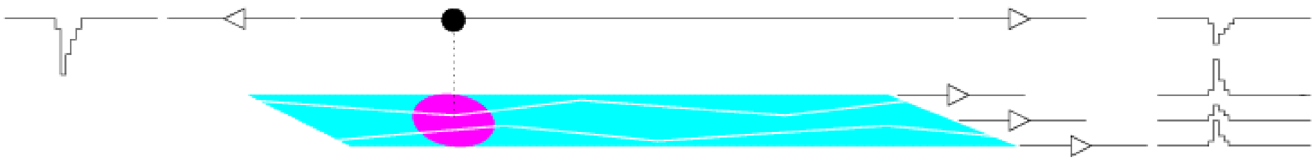
Superconductor

Positron Tracker

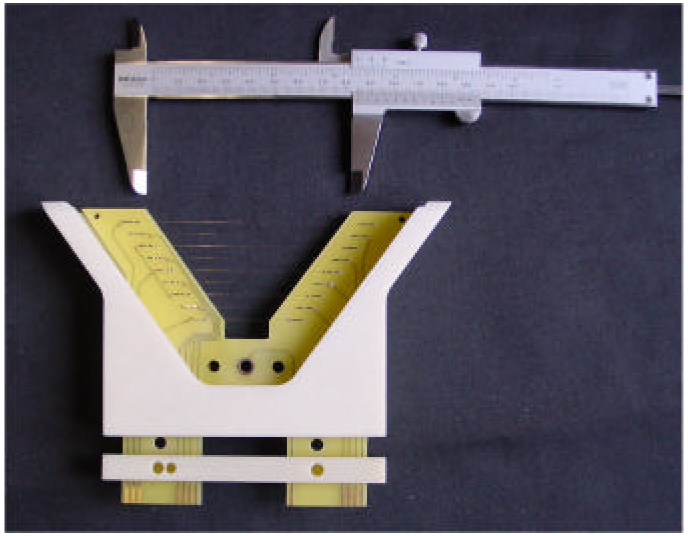


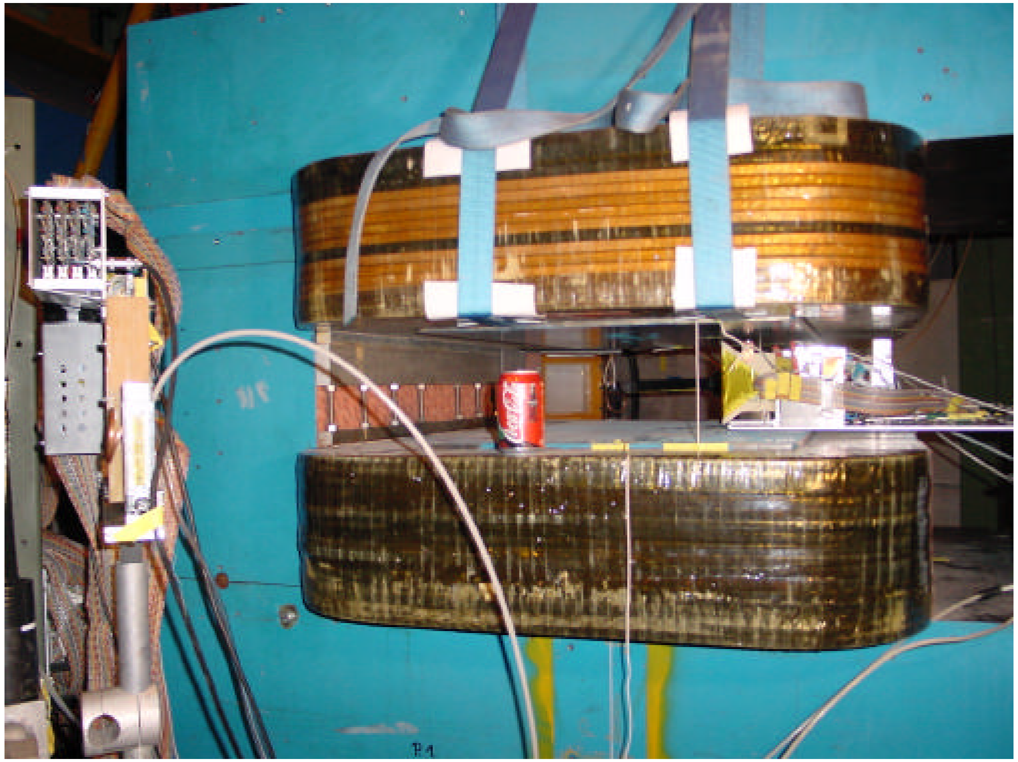


- 17 chamber sectors aligned radially with 10 ° intervals
- Two staggered arrays of drift cells
- Chamber gas: He-C_2H_6 mixture
- Vernier pattern to determine z-position



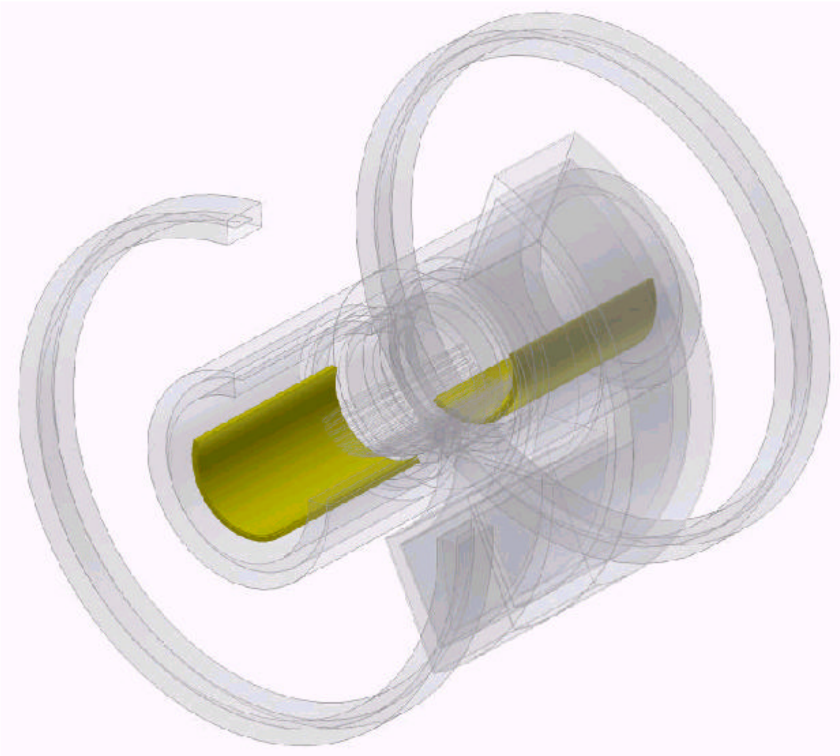
Positron Tracker, cont'd

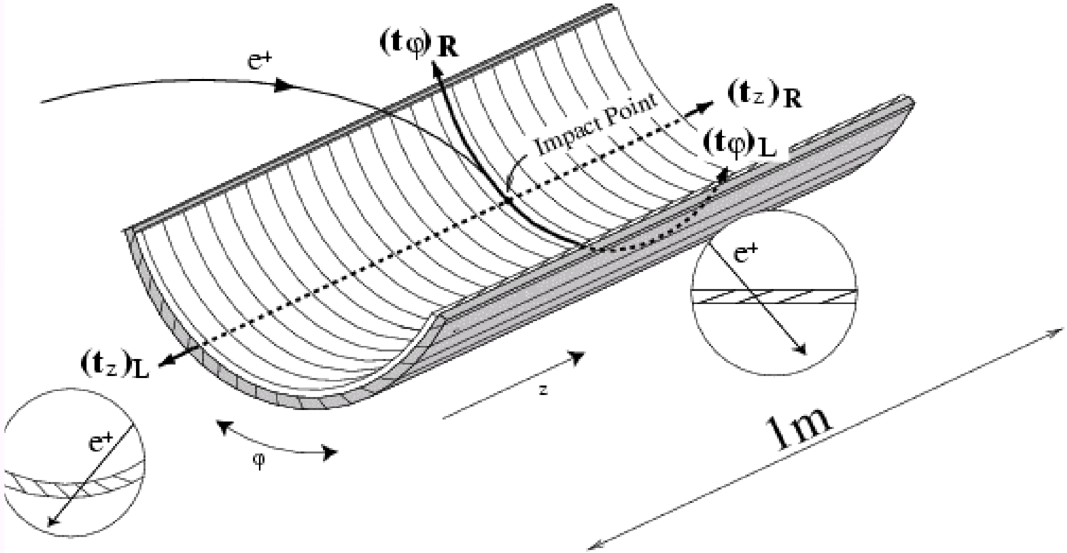




- Prototype with same cell geometry as the final detector.
- Test in the magnetic field up to 1T.

Positron Timing Counter





- Two layers of scintillator bars placed at right angles with each other

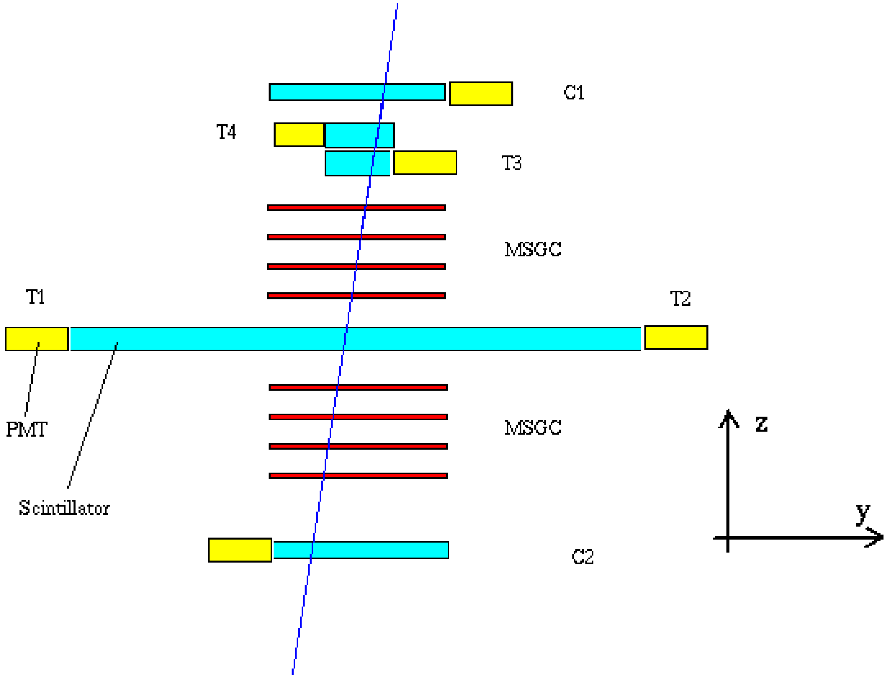
  Outer: timing measurement

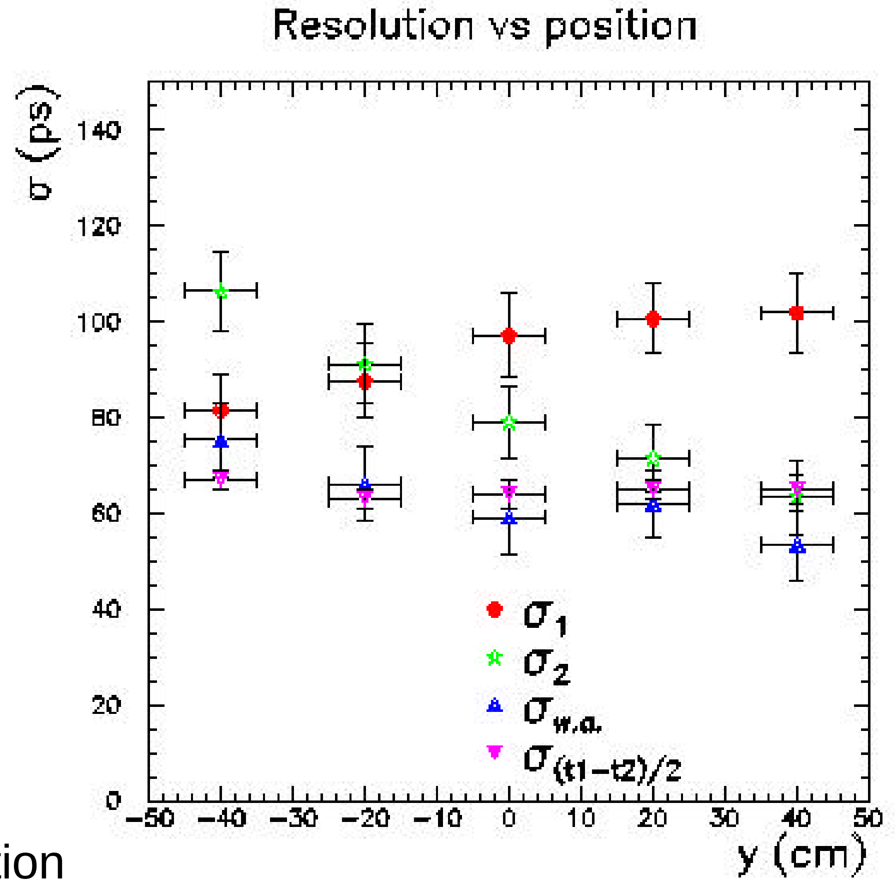
  Inner: additional trigger information

- Goal σ_{time}~ 50psec

Positron Timing Counter, cont'd

CORTES: Timing counter test facility with cosmic rays at INFN-Pisa





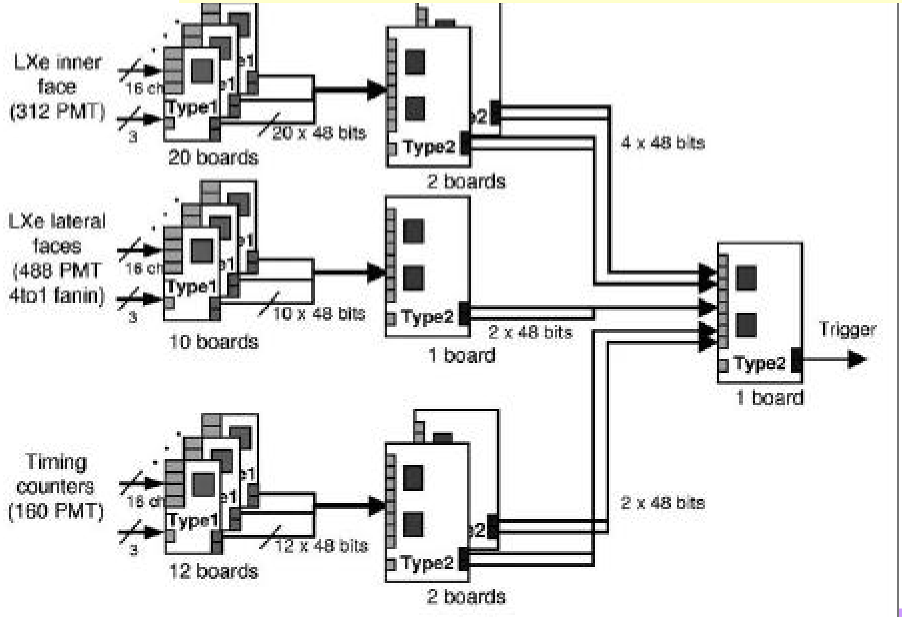
- Scintillator bar (5cm x t1cm x 100cm long)
- Telescope of 8 x MSGC
- Measured resolutions

  σ_{time}~60psec independent of incident position
- σ_{time} improves as ~1/ $\sqrt{}$ Npe

Trigger Electronics

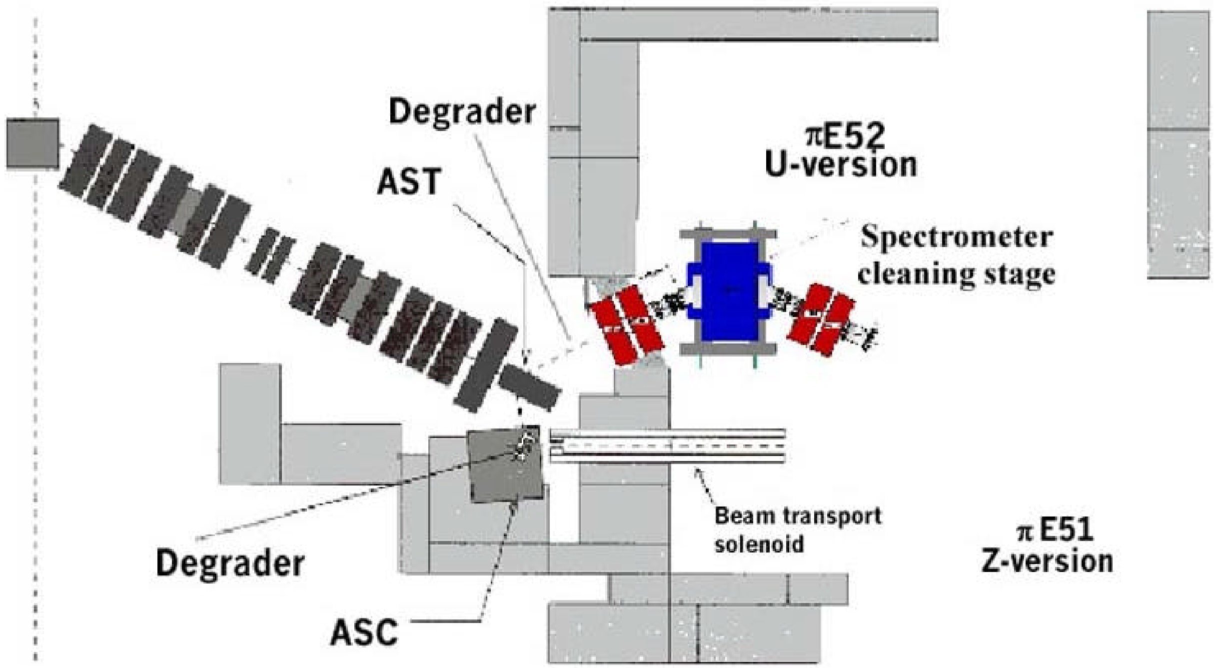
❖ Beam rate	10^8 s^{-1}
❖ Fast LXe energy sum > 45MeV	2×10^3 s^{-1}
❖ γ interaction point	
❖ e^+ hit point in timing counter	
❖ time correlation $\gamma - e^+$	200 s^{-1}
❖ angular correlation $\gamma - e^+$	20 s^{-1}

Possible trigger system structure



Beam Transport System

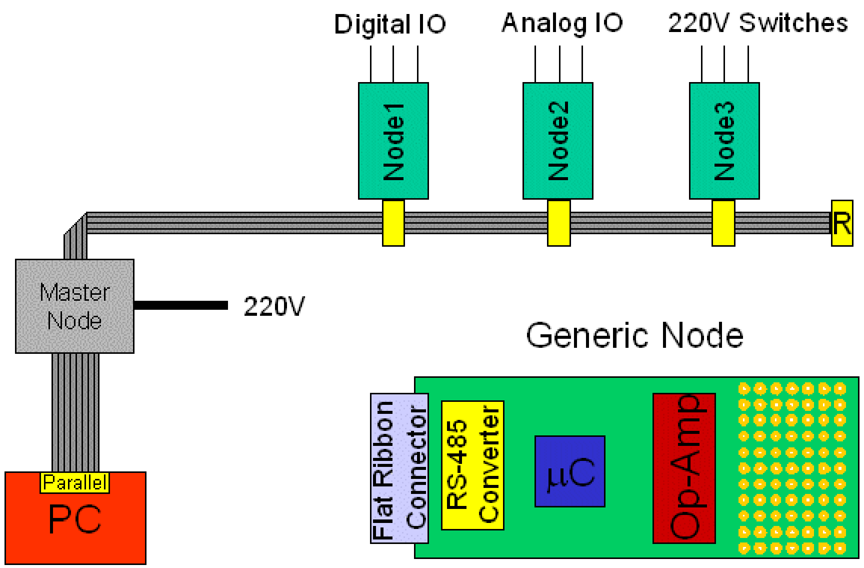
- Two separate branches of the πE5 beam line, "U"-branch and "Z"-branch
- Comparative study between two branches on going.
  Muon instensity, μ/e ratio,…

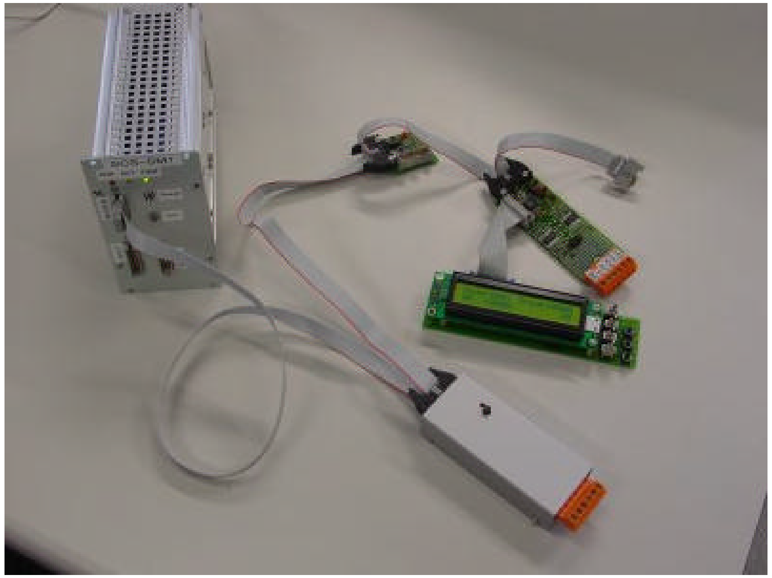


The layout of πE5

Slow Control System

- New field bus system under development for reliable control of cryogenics of LXe detector, superconducting magnet, high voltage supply
- Low cost (typ. 20 US$ per node)
- Several prototypes have been built and tested at PSI
- See ***http://midas.psi.ch/mscb***





Summary

- New experiment to search for $\mu \rightarrow e \gamma$ down to $BR \sim 10^{-14}$ at PSI is in preparation.

- Signature of new physics such as SUSY-GUT could be discovered somewhere above $BR \sim 10^{-14}$.

- Preparations of all the detector components are going well.

- Next big milestone is the second gamma beam test with the large prototype of the xenon detector at AIST in the beginning of 2002.

For more info, see ***http://meg.icepp.s.u-tokyo.ac.jp***