Lepton Flavour Violation

Search for $\mu \rightarrow e \gamma$

at Paul Scherrer Institut

Satoshi Mihara

ICEPP, Univ. of Tokyo

http://meg.icepp.s.u-tokyo.ac.jp,
http://meg.psi.ch,http://meg.pi.infn.it

Contents

- Introduction
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  - detectors
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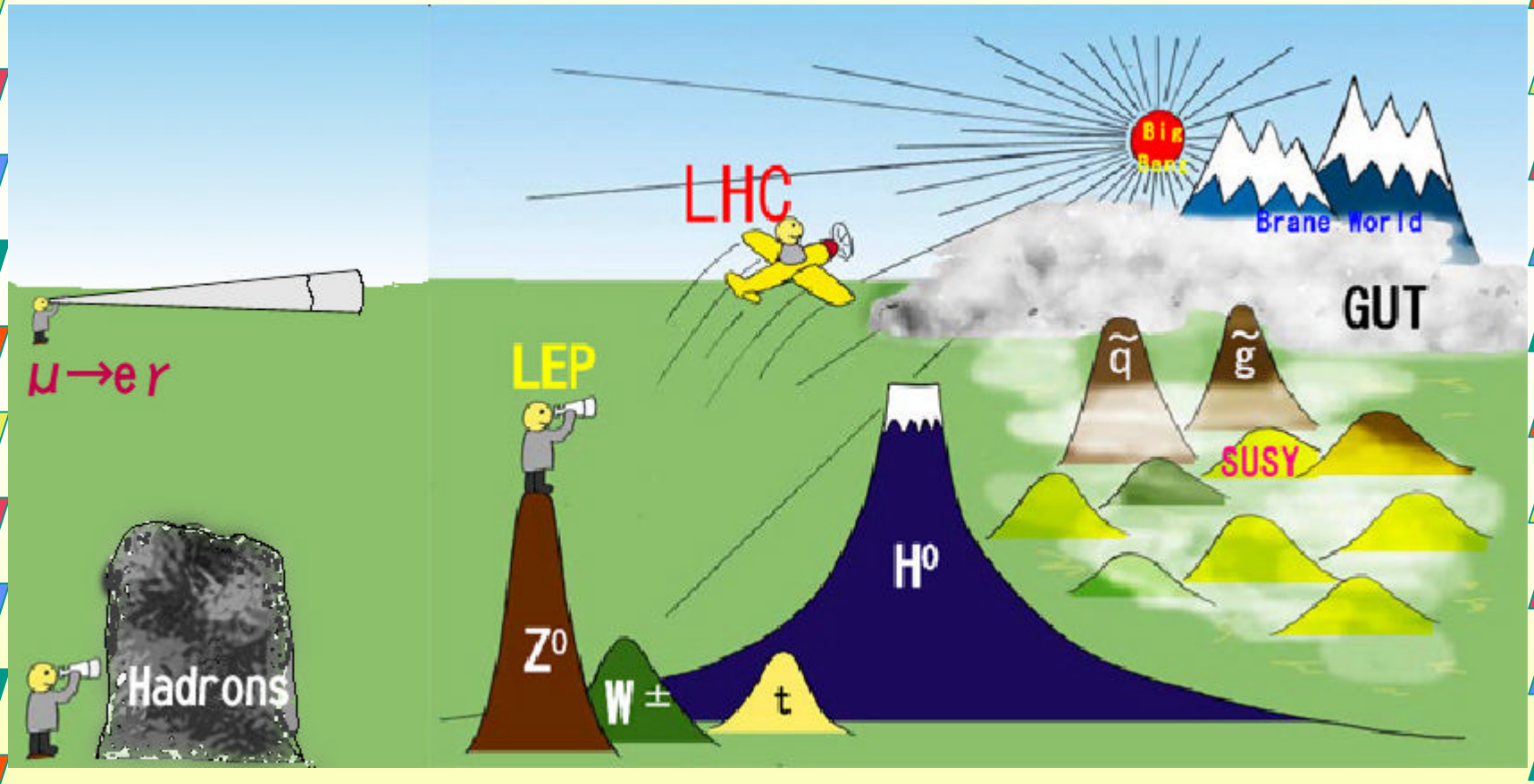
Lepton Flavour Violation

- 素粒子センターのもう一つのメインプロジェクト

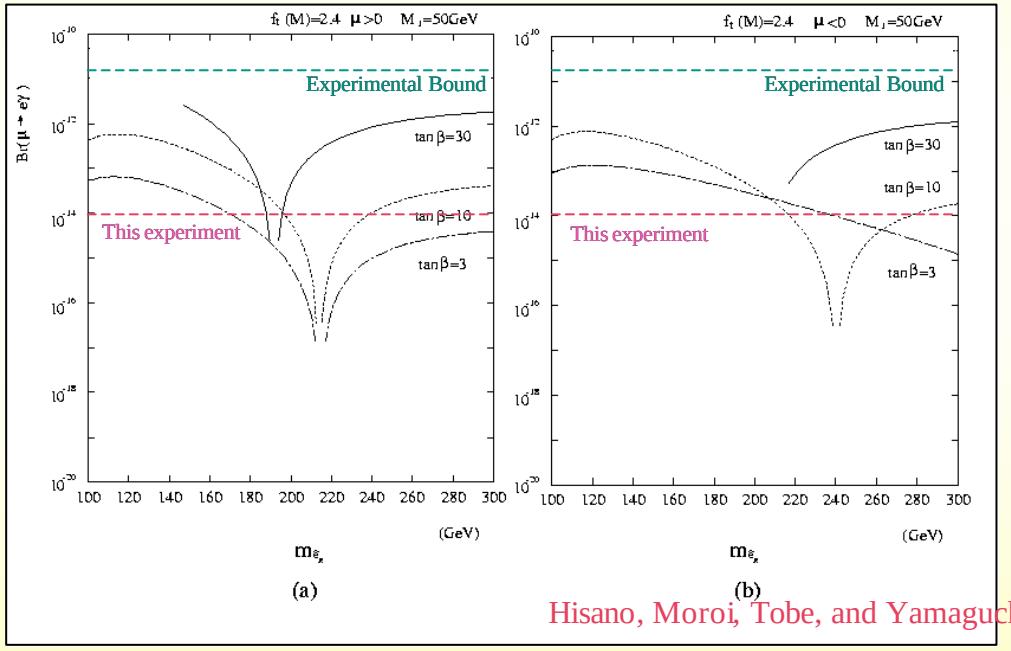


Physics Motivation

Clear Evidence of "beyond the SM" if observed

- **SUSY**

  Finite slepton mixing appears through radiative corrections



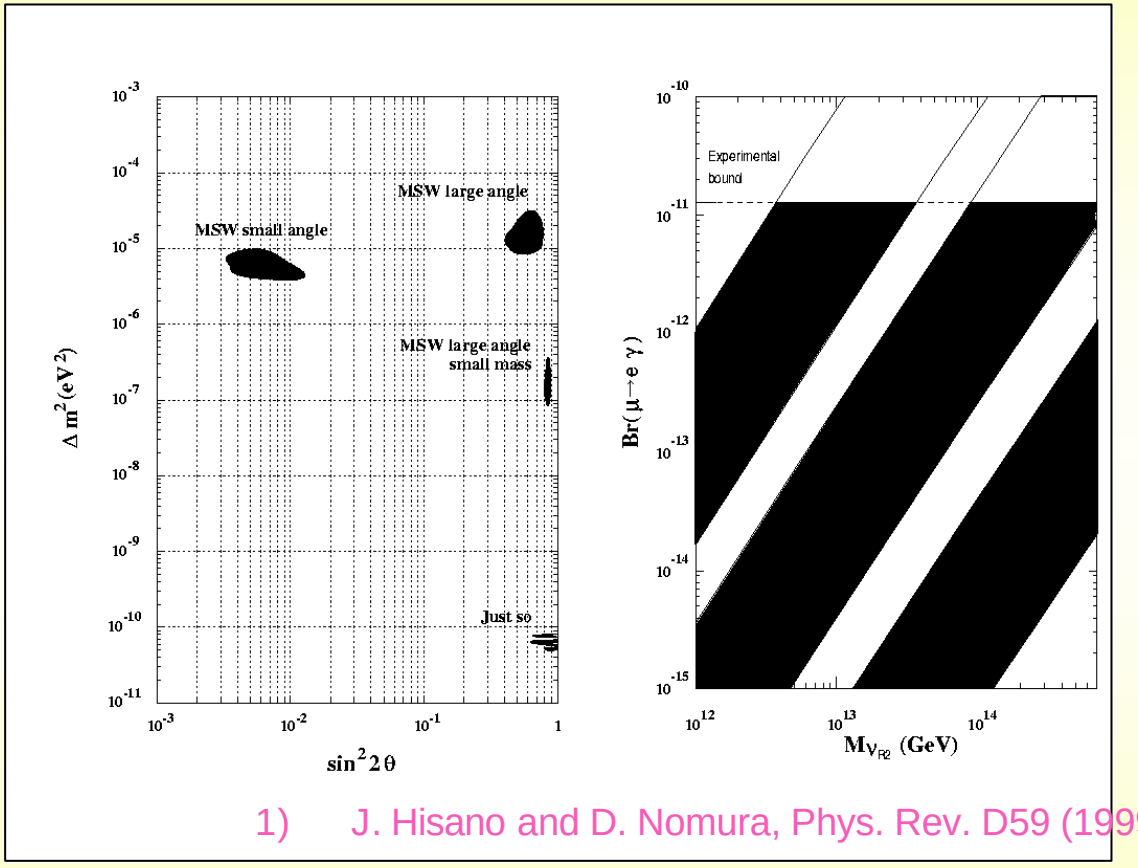
Hisano, Moroi, Tobe, and Yamaguchi PLB391(1997)341

- **SUSY-GUT predicts an even larger value**

  10^{-13}—10^{-11}

Neutrino Oscillation and g-2

- Neutrino Oscillation



1) J. Hisano and D. Nomura, Phys. Rev. D59 (1999) 116005

2) MEGA collaboration, hep-ex/9905013

- Anomalous muon magnetic moment ➡ $Br(\mu \to e\gamma)$ ↗

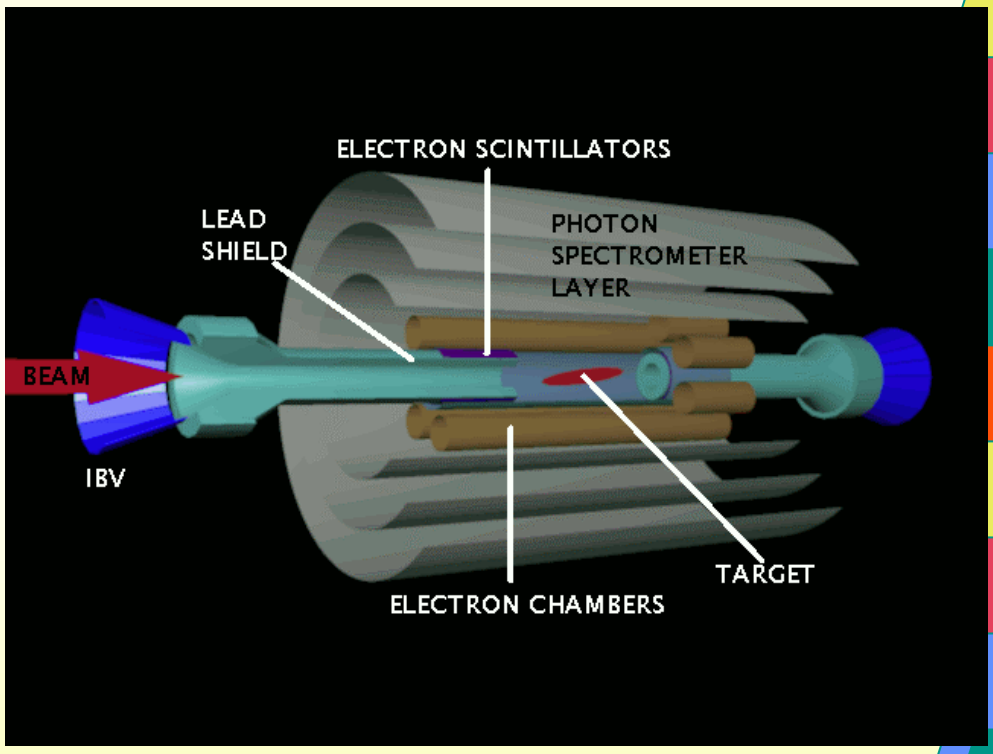
Chronorogy of $\mu \rightarrow e\,\gamma$ Search

- 1937 Discovery of the mesotron in cosmic rays
- 1947 Two meson hypothesis $\pi \rightarrow \mu\ \nu$; $\mu \rightarrow e\ \nu\ \nu$
- 1957 $\mu \rightarrow e\,\gamma$ predicted at 10^{-4} two neutrinos $\nu\, e \neq \nu\ \mu$
- 1967 Lepton number conservation generally accepted
- 1977 $\mu \rightarrow e\gamma$ rumored at 10^{-8} level B.R. limit < 2x10-10 at LAMPF
- 1987 Crystal Box results < 5×10^{-11}
- 1993-5 MEGA data taking
- 1999 MEGA result < 1.2×10^{-11}
- 1999 May $\mu \rightarrow e\gamma$ at PSI Proposal

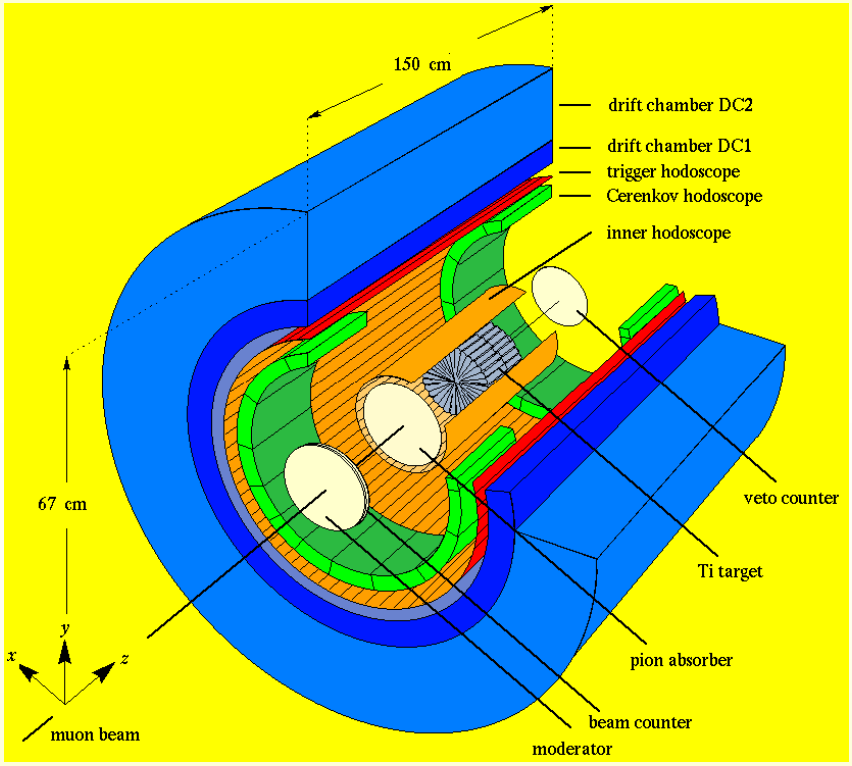
Place	Year	Upper limit	Author
SIN (PSI), Switzerland	1977	$< 1.0 \times 10^{-9}$	A. Van der Schaaf *et al.*
TRIUMF, Canada	1977	$< 3.6 \times 10^{-9}$	P. Depommier *et al.*
LANL, USA	1979	$< 1.7 \times 10^{-10}$	W.W. Kinnison *et al.*
LANL, USA	1986	$< 4.9 \times 10^{-11}$	R.D. Bolton *et al.*
LANL, USA	1999	$< 1.2 \times 10^{-11}$	MEGA Collab., M.L. Brooks *et al.*

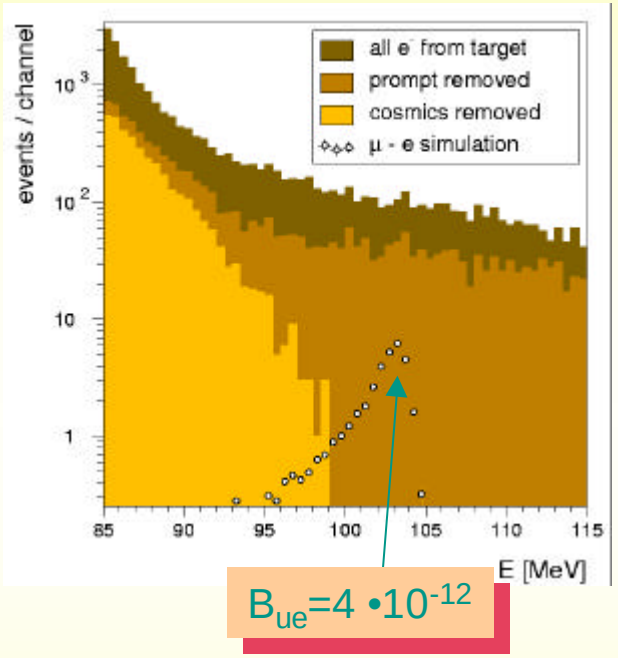
Previous experiments searching for LFV I(MEGA)

- Pulse beam of 2.5×10^{8}/sec with a duty factor of 6%.
- 1.2×10^{14} muons stopped
- Superconducting solenoidal magnet and low material MWPC.
- Photon detector with Pb converters.
- All the signal were treated as degitial data at the detector level.
- Best limit on Br($\mu \rightarrow e\gamma$) of 1.2×10^{-11} .



Previous experiments searching for LFV II (SINDRUM II)



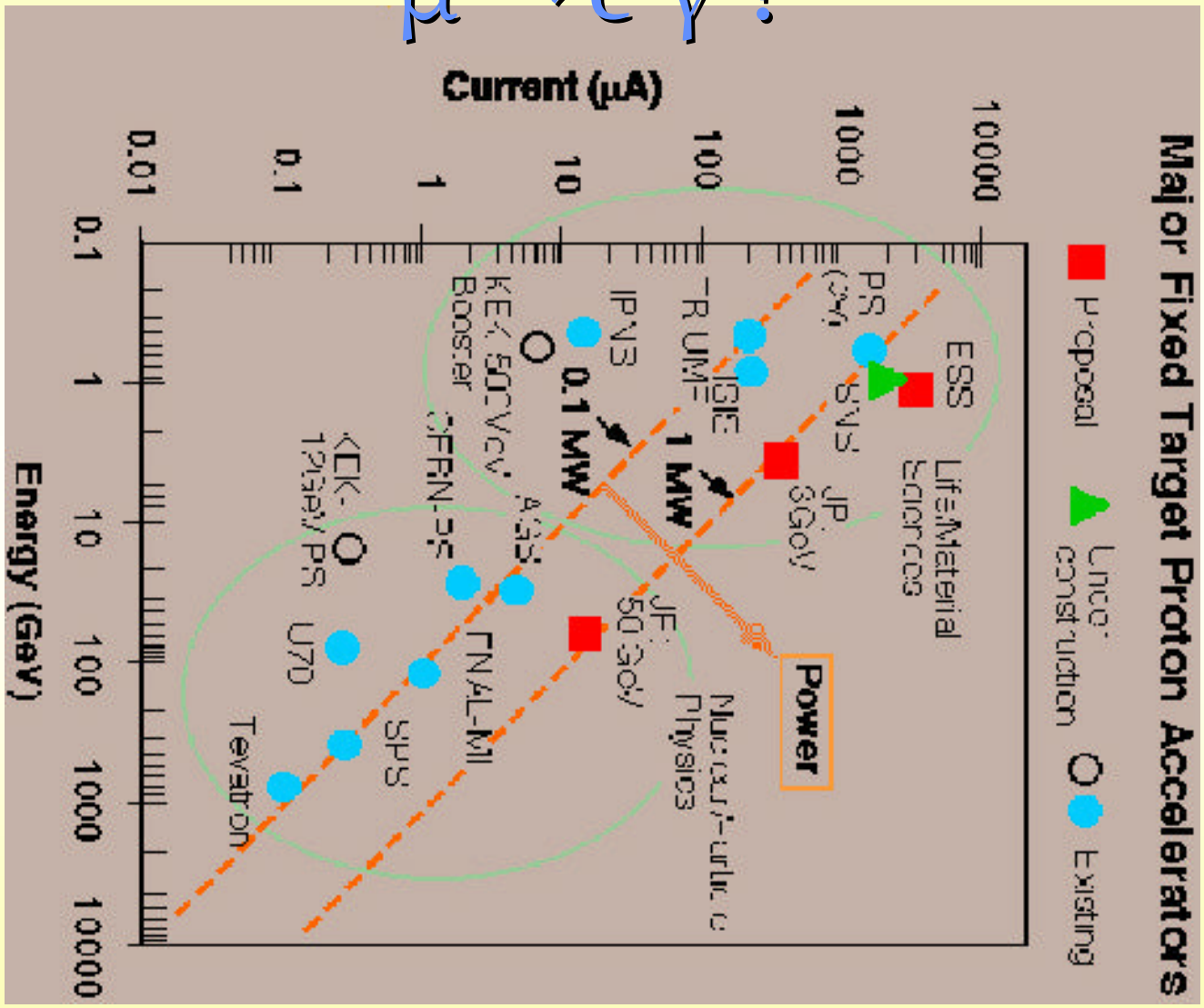


Br(μ N→eN) = 1/(200-400)x Br(μ →e γ)
depends on the target material

What we learned from the MEGA experiment

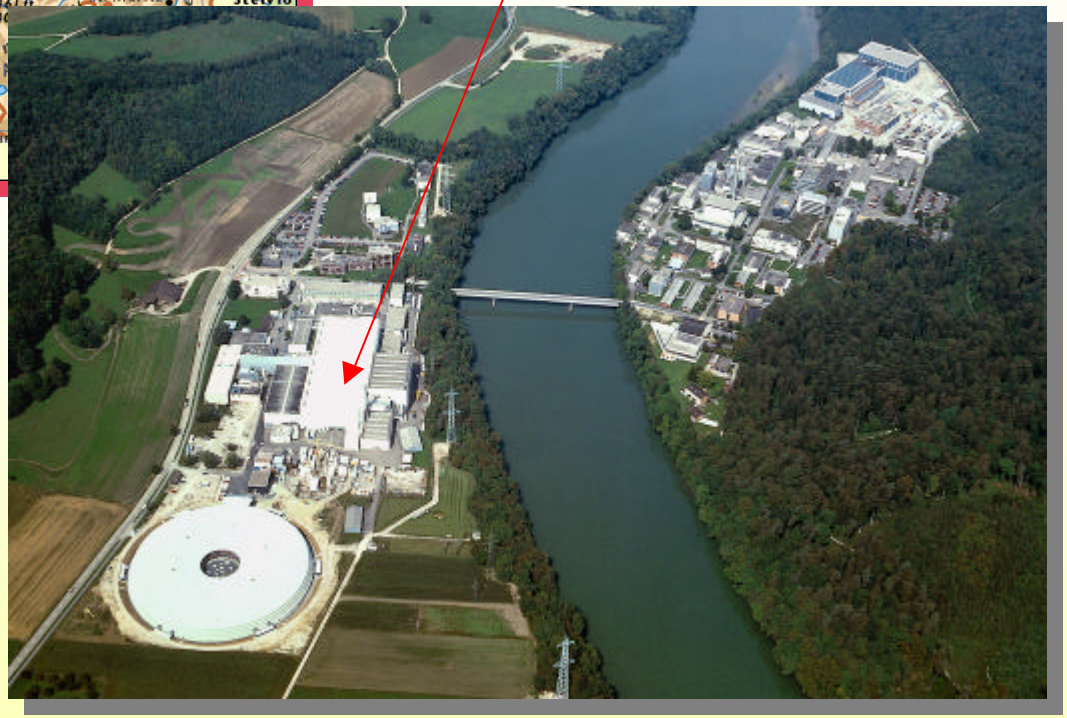
- Use DC beam
- Achieve better γ measurement
  - Energy, Position and Time
- Prepare better tracking environment

Where we should search for $\mu \rightarrow e\gamma$?

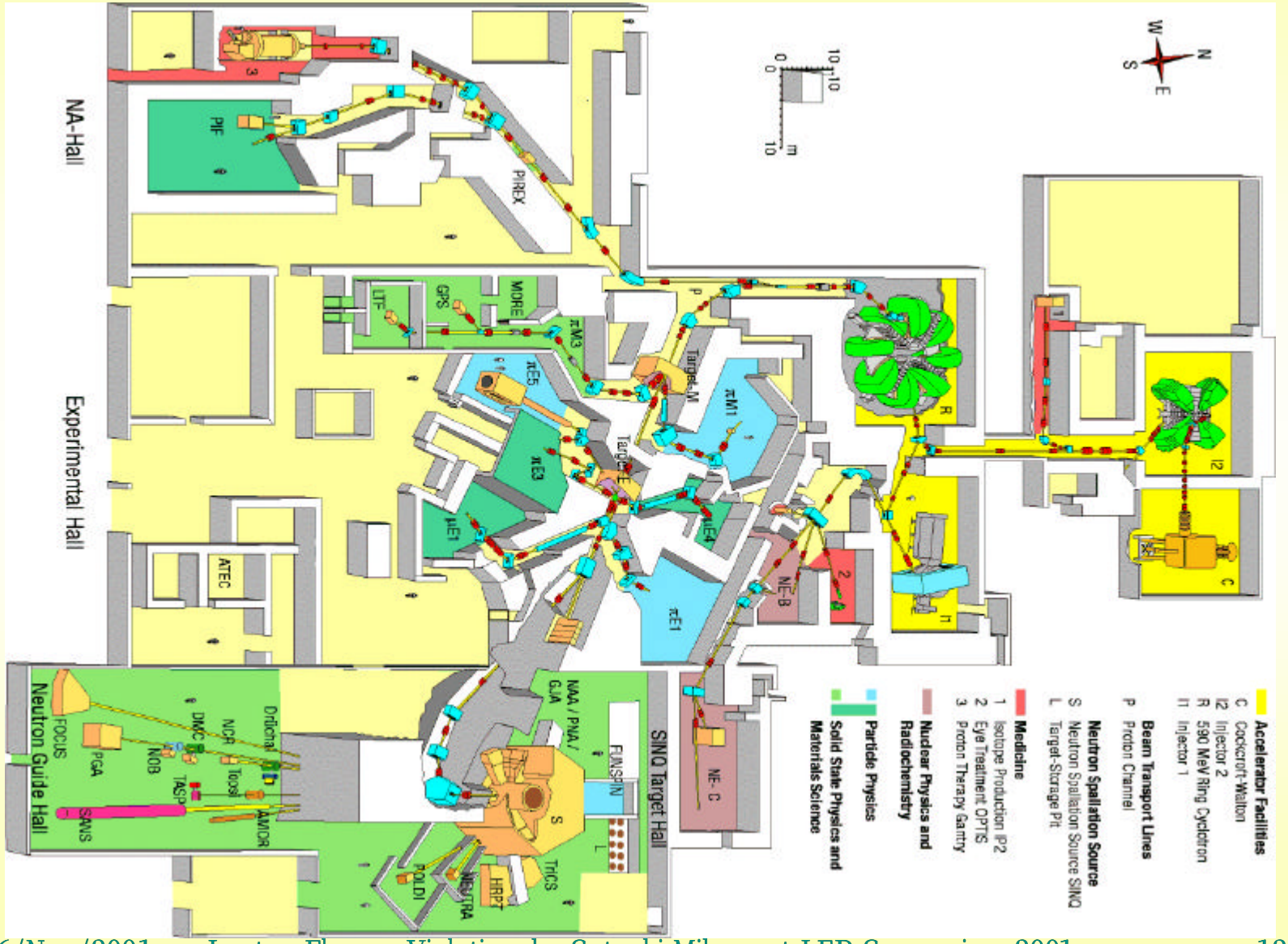


Paul Scherrer Institut

Experimental Hall

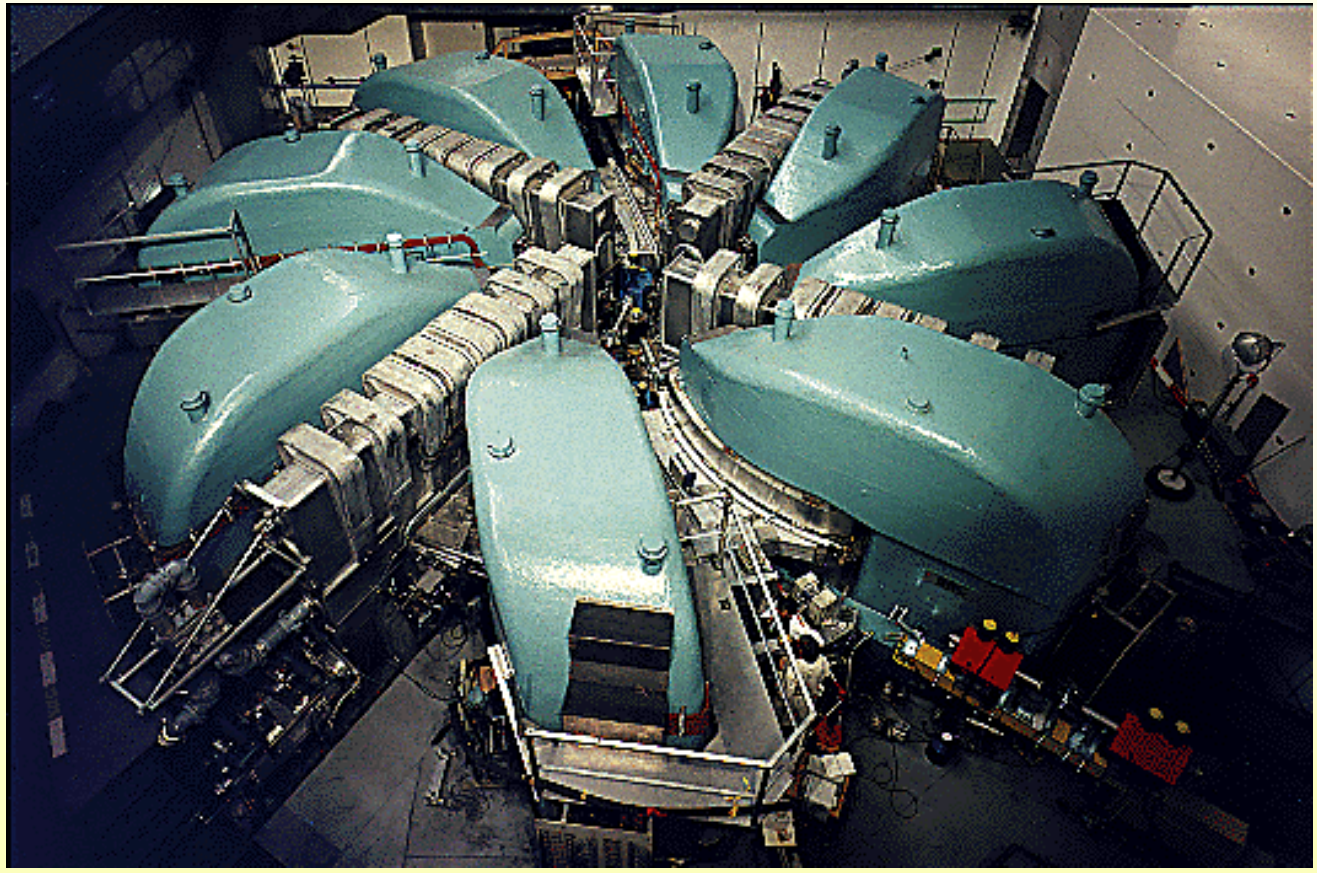


Accelerator facilities at PSI



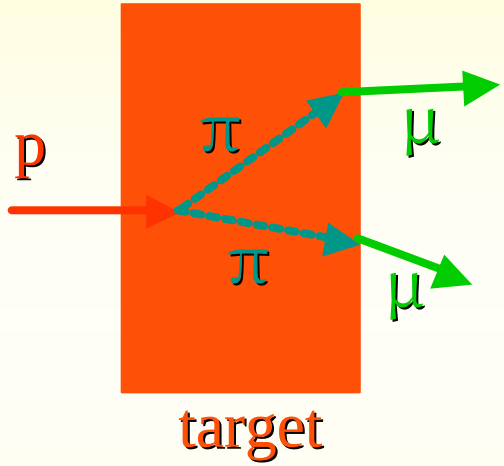
The ring cyclotron

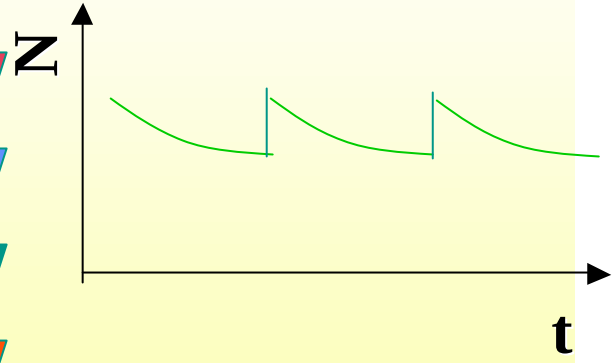
- Nominal operation current -- 1.8mA
- Max > 2.0mA

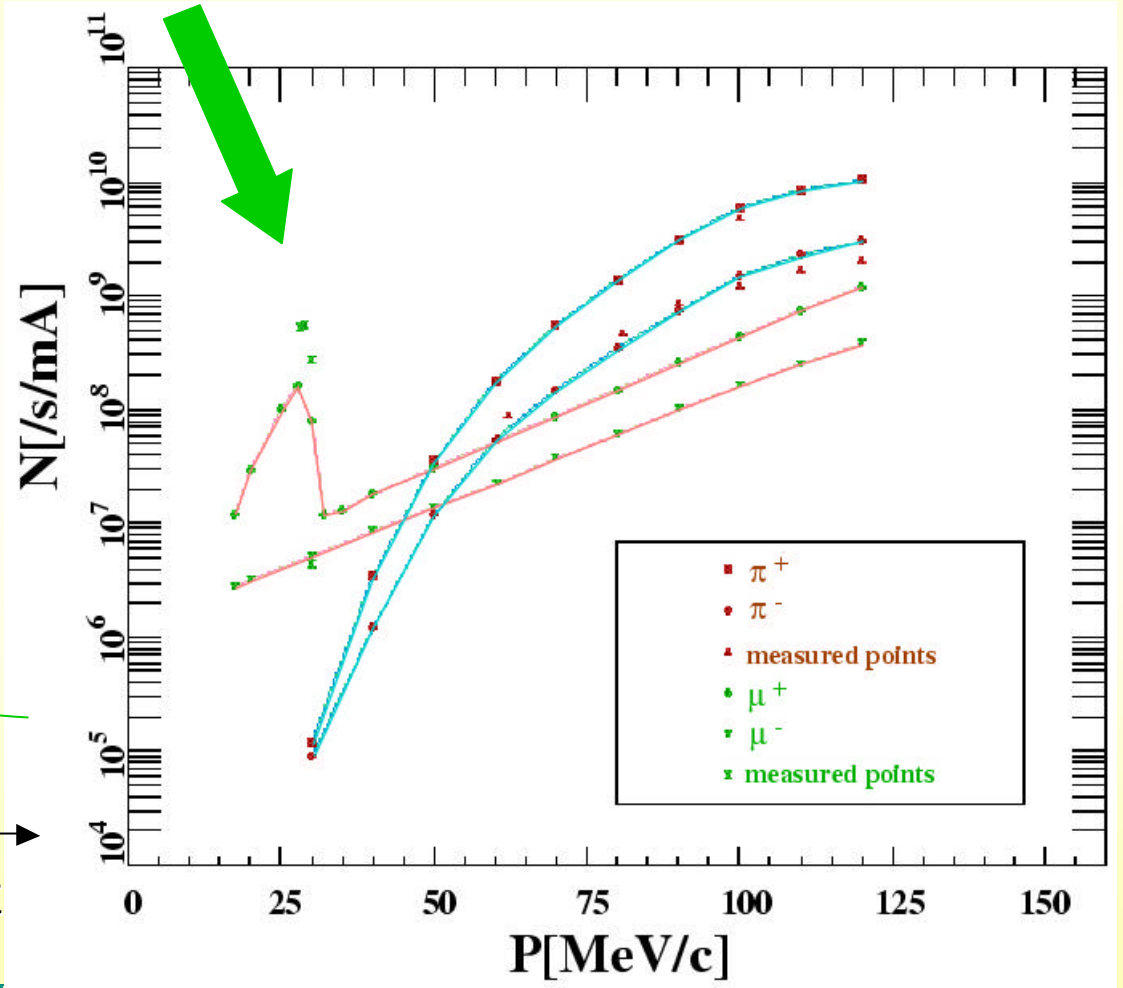


π and μ fluxes at πE5

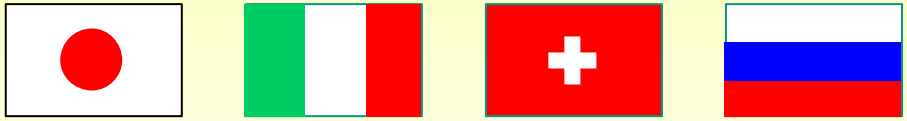
- Surface muon bem







MEG collaboration



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	Supercoductin g 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	-

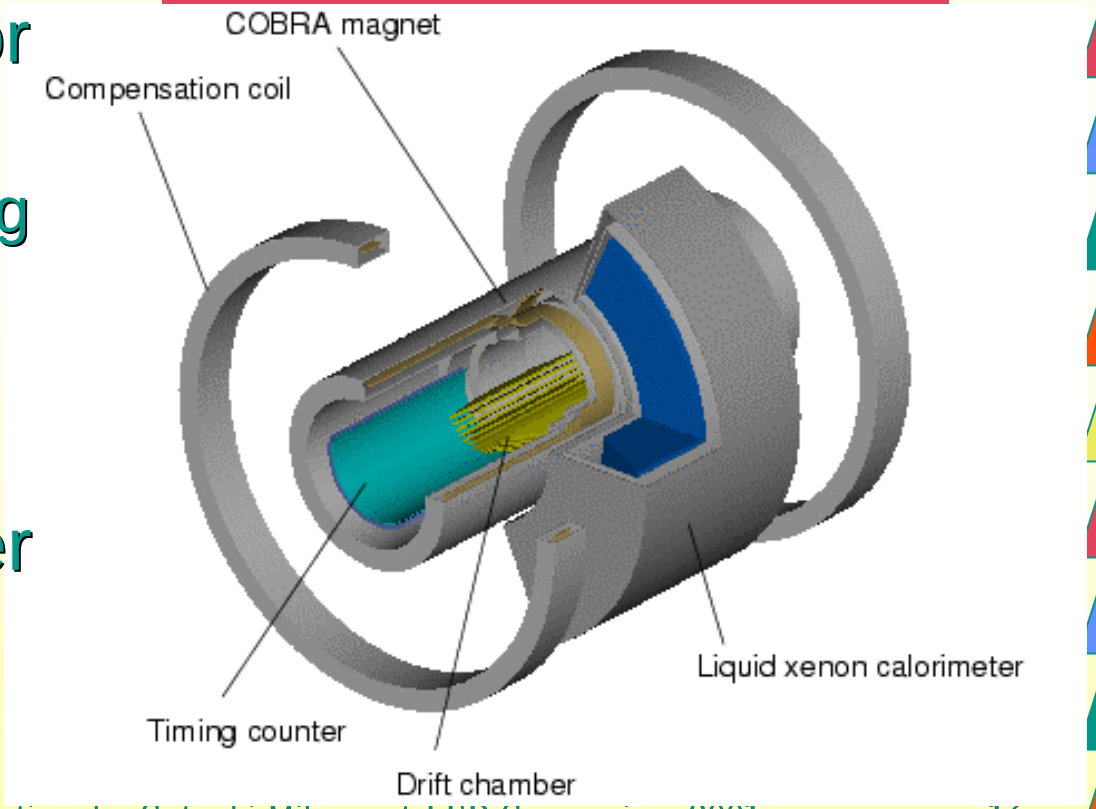
MEG experiment overview

- PSI πE5 μ beam line
- Liquid Xe Photon detector
- COBRA (Constant Bending Radius) spectrometer
- Plan to start DAQ in summer 2003

Kinematics

$\theta_{e\gamma} = 180^\circ$

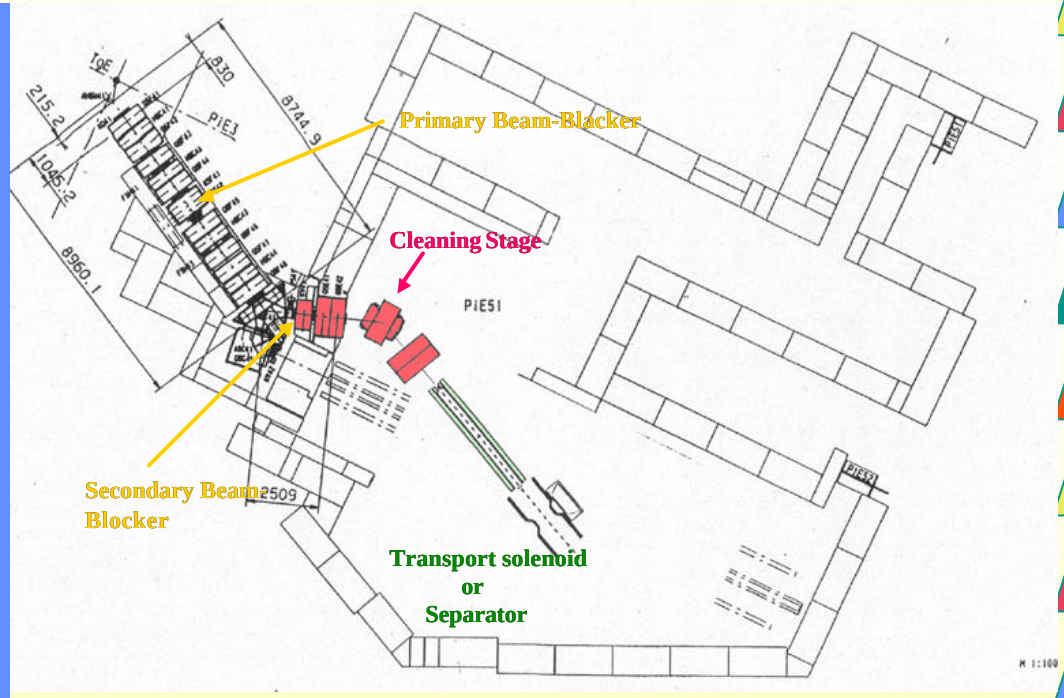
E_e = 52.8 MeV E_g = 52.8 MeV



π E5 beam line

- "Cleaning-Stage" to reduce positron contamination in the beam

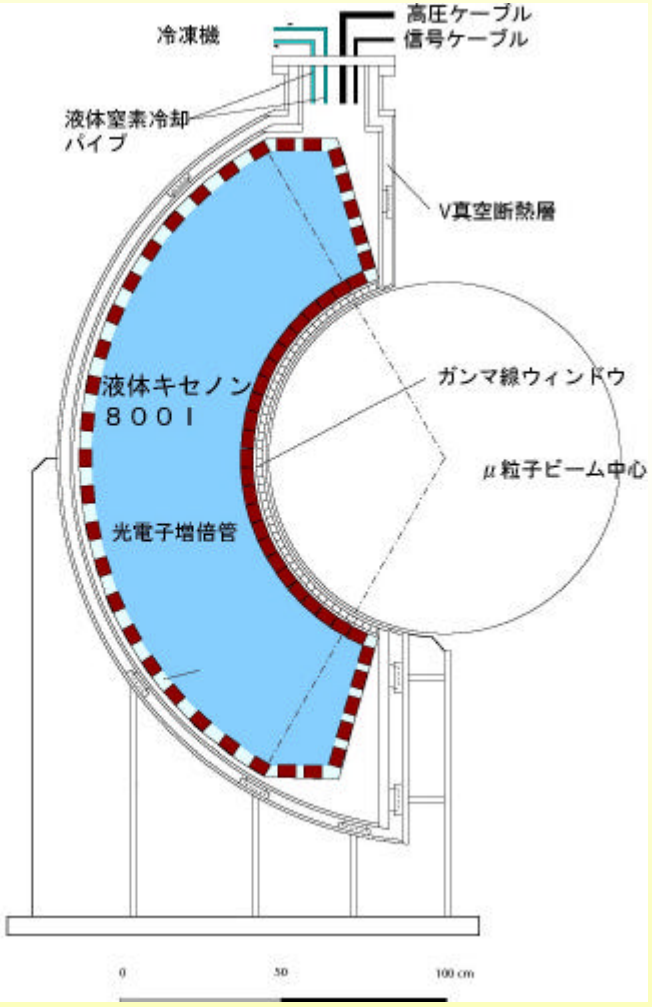
•Beam line study started in summer 2001
  - •Measure Phase space of surface muon beam
    - •-*spot-size*
    - • *divergences*
    - • *stopping-rate*
    - • *momentum*
  - •Measure & optimize positron contamination in the beam
  - •optimal initial beam momentum vs μ^+/e^+-ratio



The photon detector

- Detect scintillation light from Liq. Xe
- Fast response, Good Energy, and Position resolutions
  - Mini-Kamiokande type

NaI: too slow
CsI, BGO: poor resolution at 52.8MeV
Inhomoginity to cover large area



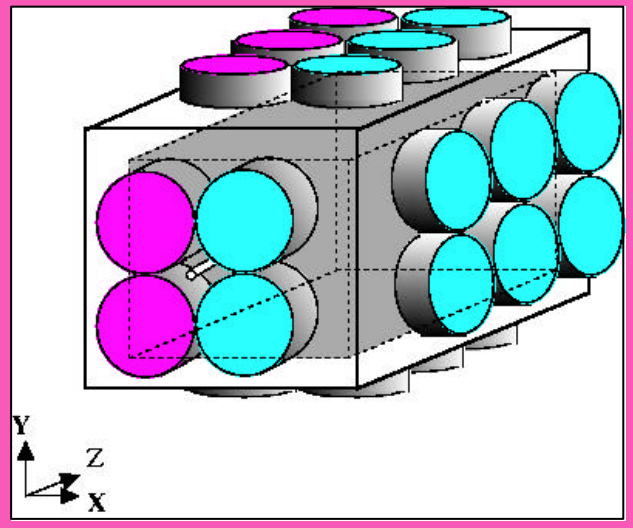
Liquid xenon properties

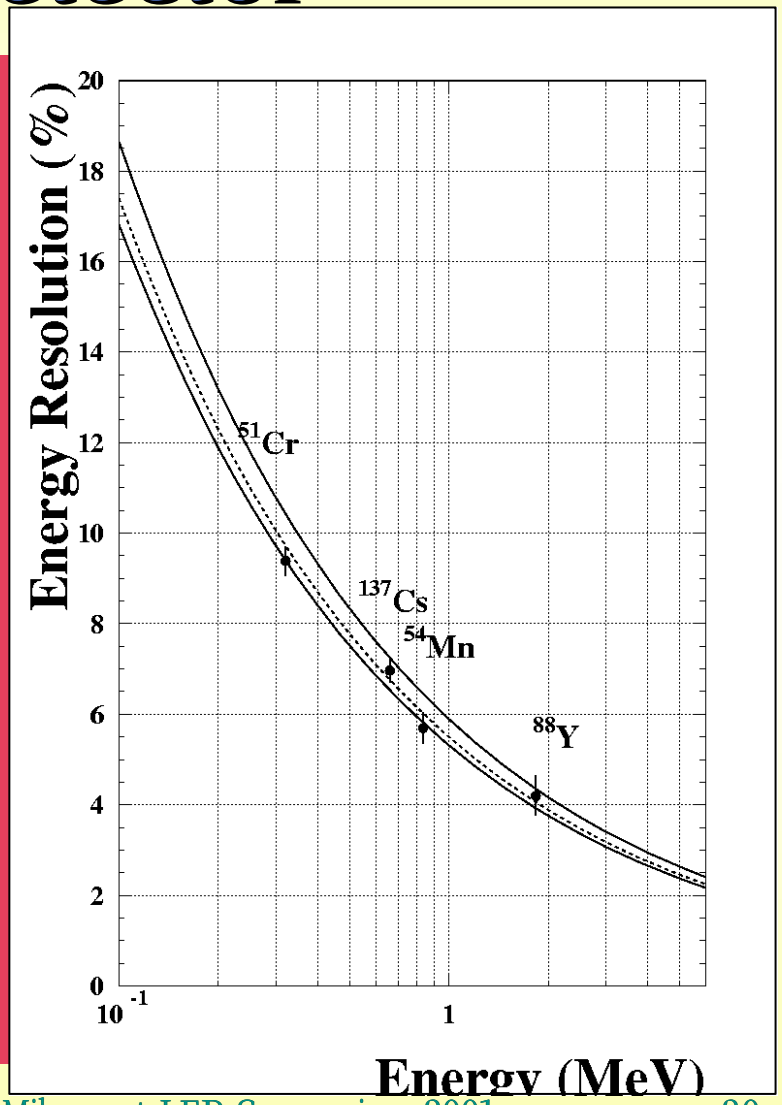
• Atomic Number	54
• Atomic Weight	131.3
• Boiling point	165K
• Liquid density	3.0kg/cm^3
• W_{ph} value (for 1MeV electrons)	24 eV
• Decay time constants	
– τ_f(fast component)	4.2nsec
– τ_s(slow component)	22nsec
– τ_r(recombination)	45nsec
• Peak wavelength of scintillation light	174nm

Small prototype of the liquid xenon detector

"Small"

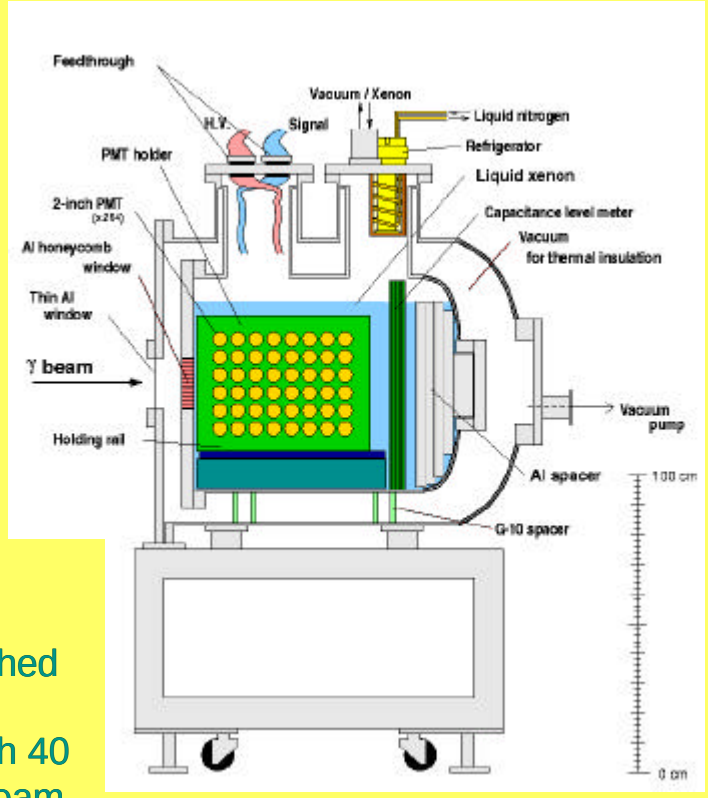
- 32 PMTs, 2.3 l LXe
- Tested with radioactive sources ^{51}Cr, ^{137}Cs, ^{54}Mn, ^{88}Y
- Extrapolated resolutions at 52.8 MeV in agreement with quoted numbers

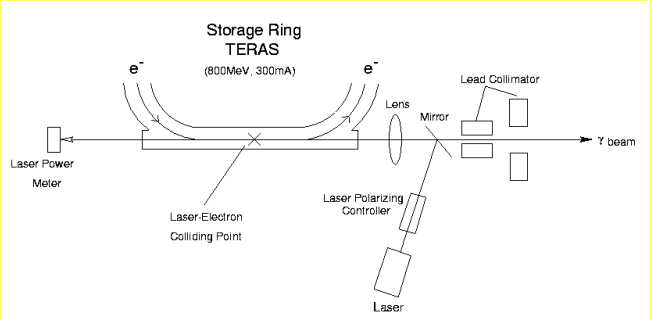




Large Prototype

“Large”

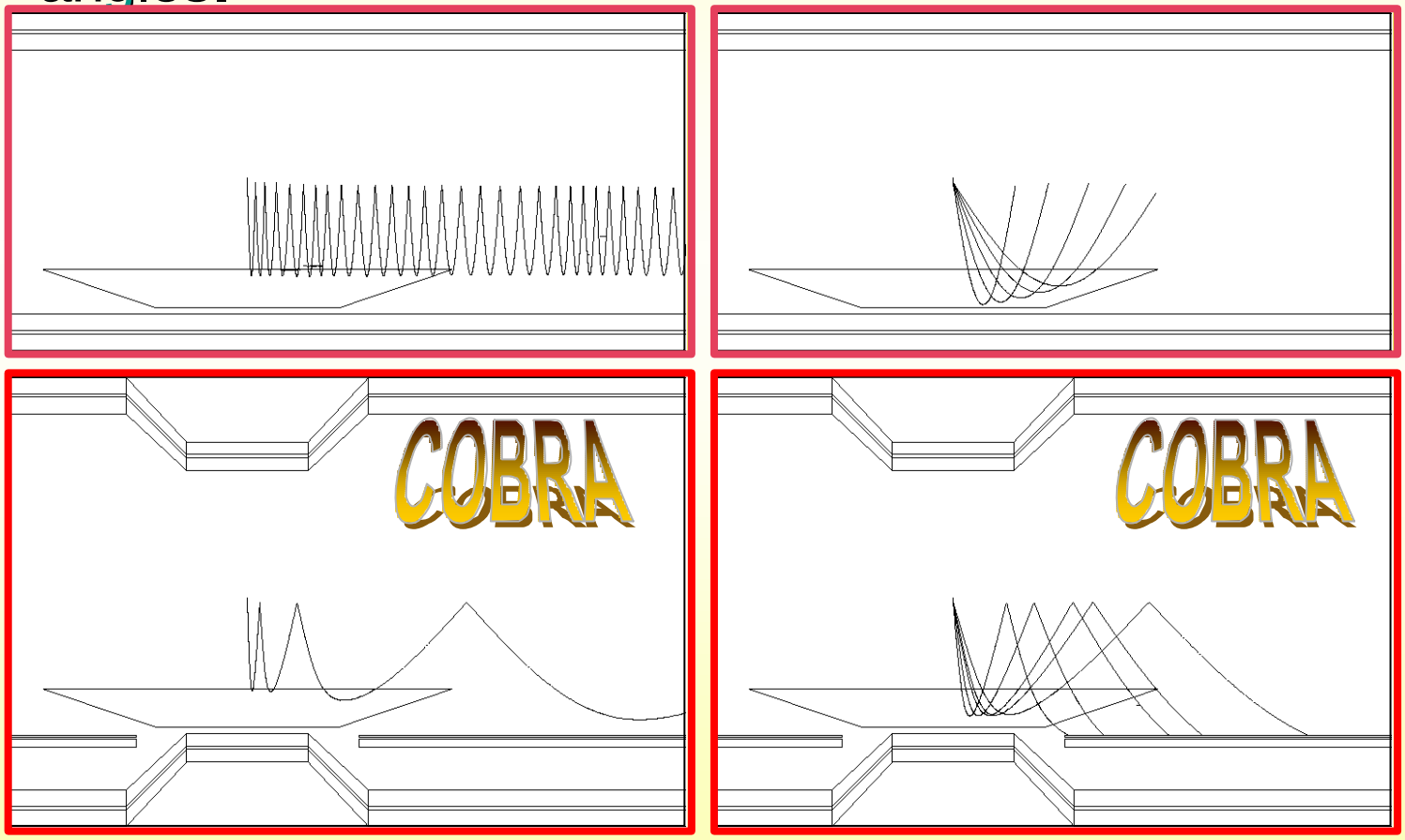




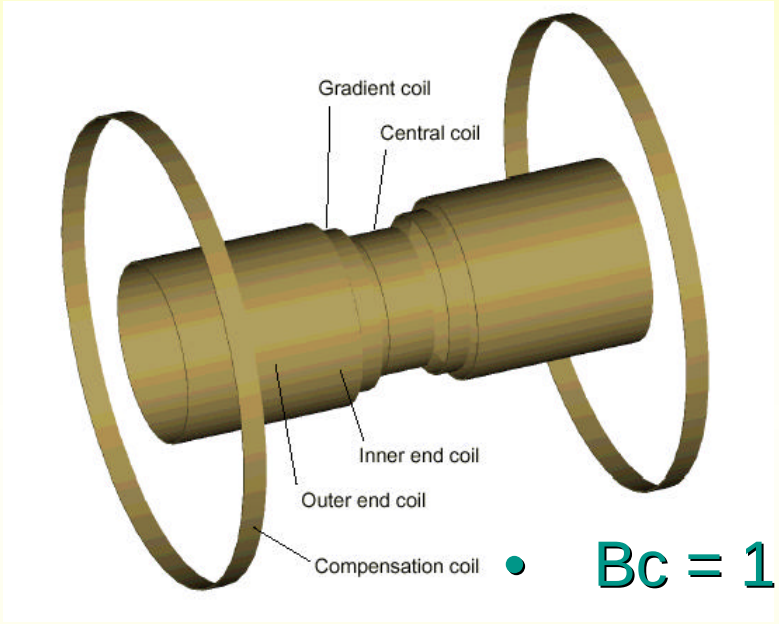
- 264 PMTs, 110 l LXe
- Assembly finished
- Measure resolutions with 40 MeV photon beam at ETL, Tsukuba, Japan

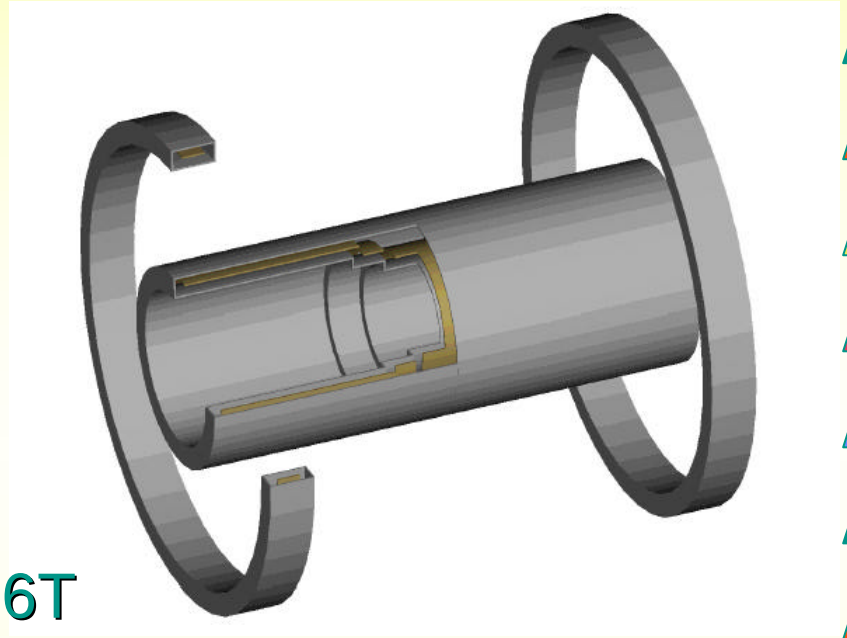
COBRA spectrometer

- Sweep out curling positrons rapidly.
- Constant bending radius independent of the emission angles.



Superconducting solenoid

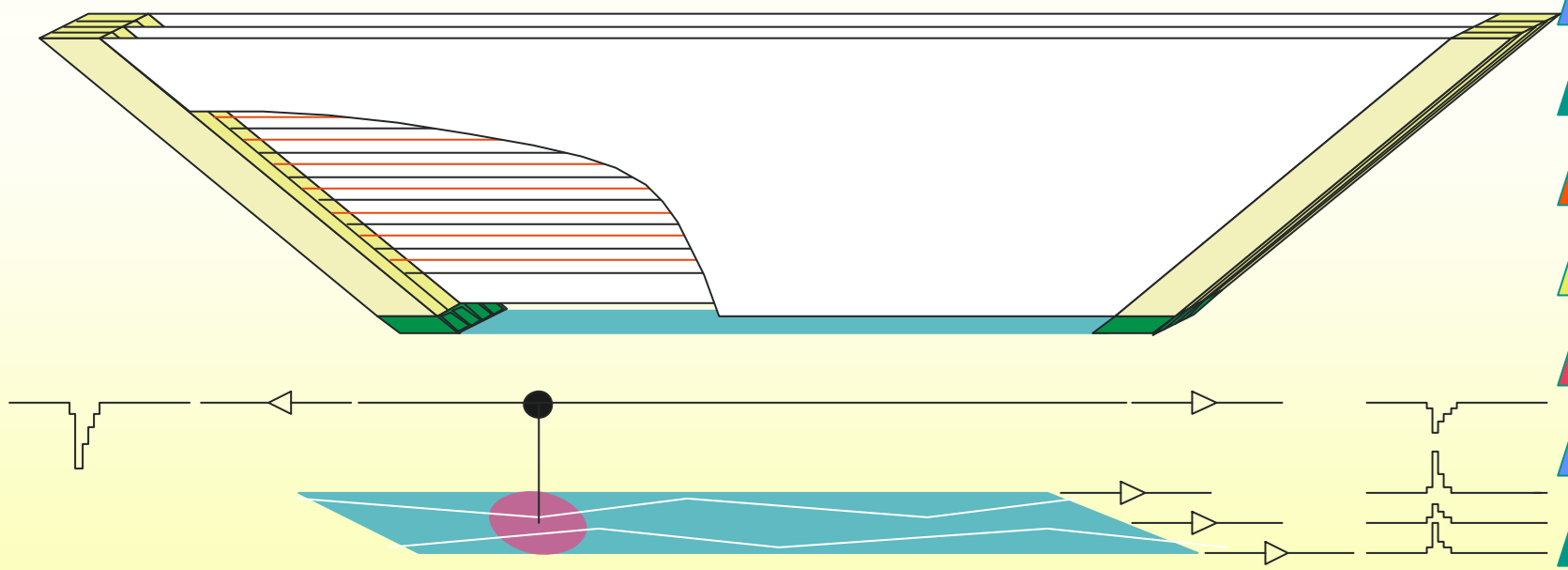




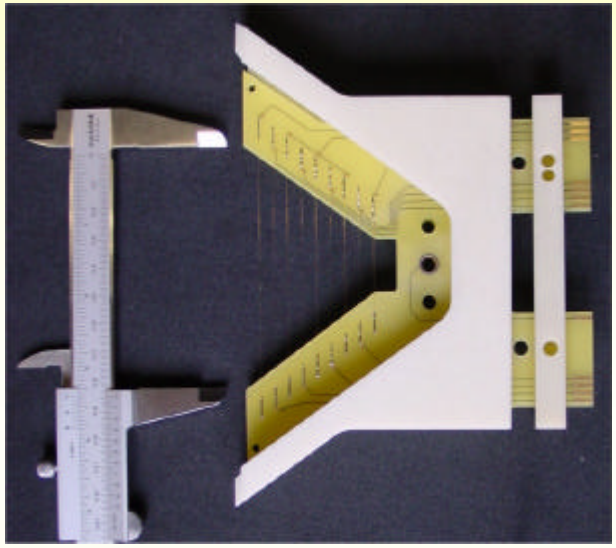
- Bc = 1.26T
- $B_{z=1.25m}$ = 0.49T
- Peak field in the coil 1.72T
- Operating current 359A
- Load line ratio ~ 0.7 @ 5.2K
- Construction has been started

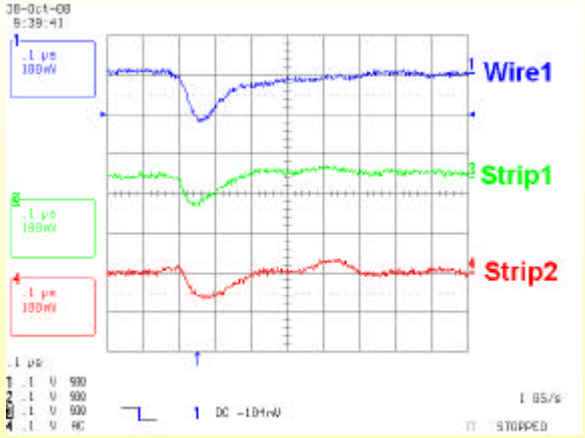
Positron tracker

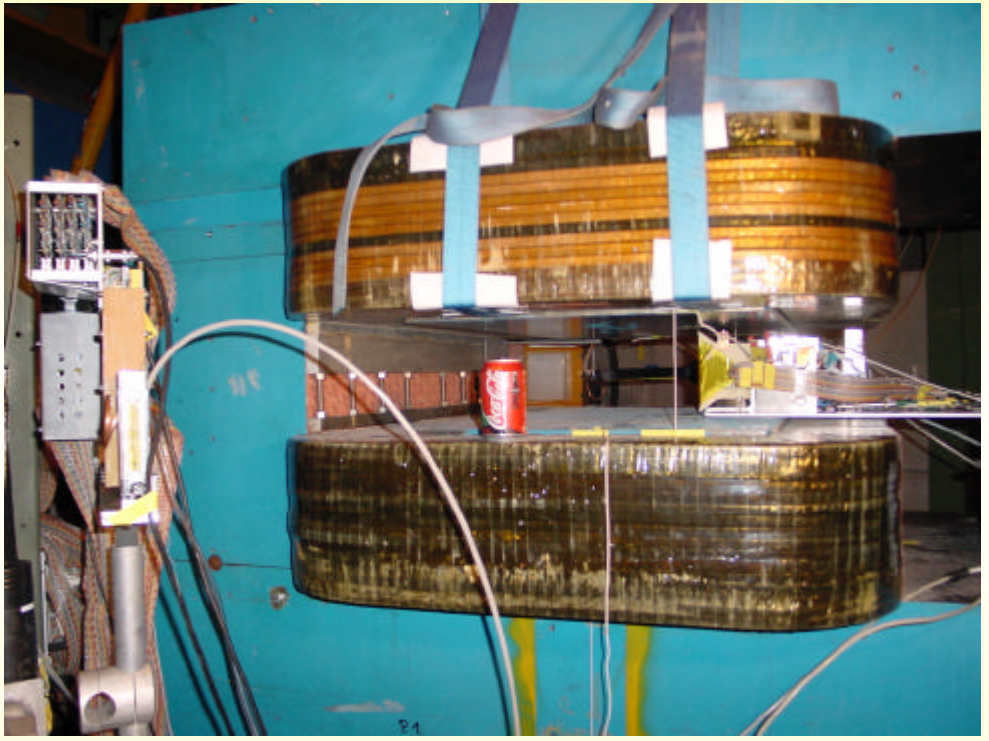
- 16 radial chambers with 20 wires each
- Staggered cells measure both position and time
- He – C_2H_6 gas to reduce multiple scattering
- Vernier pattern to determine z coordinate



Positron tracker mini prototype

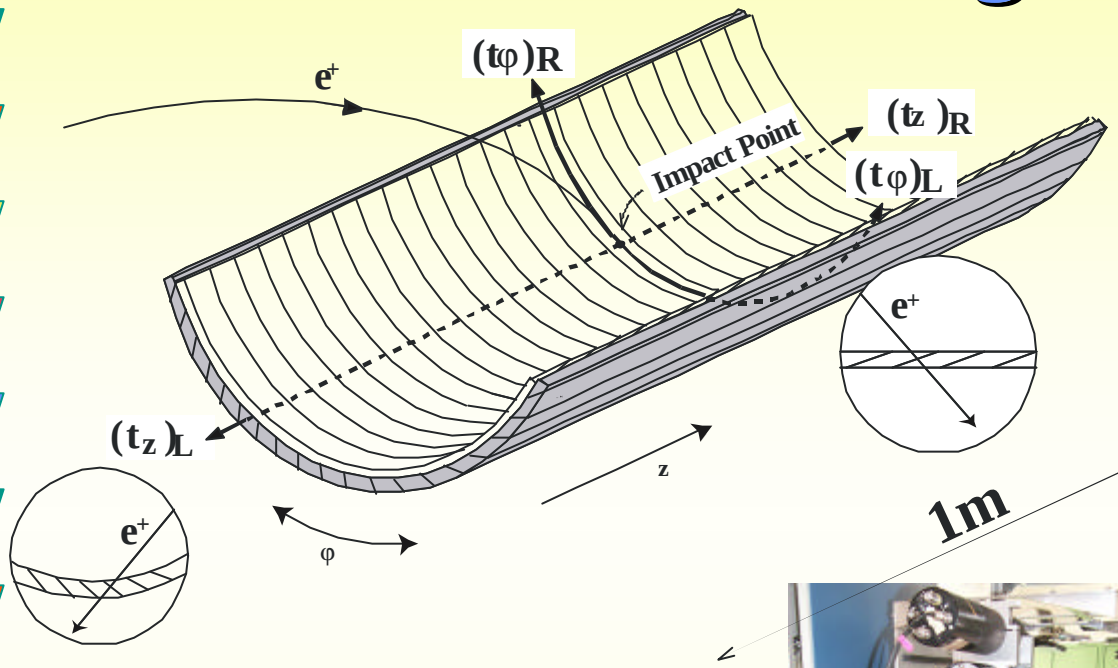


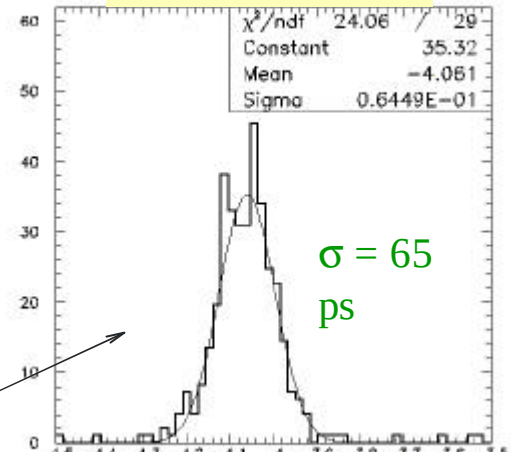


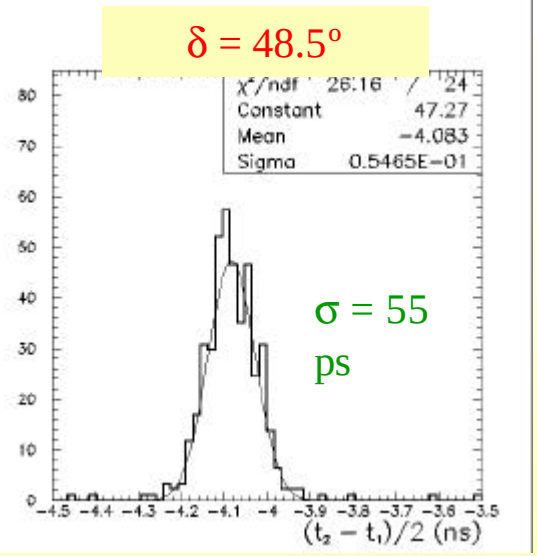


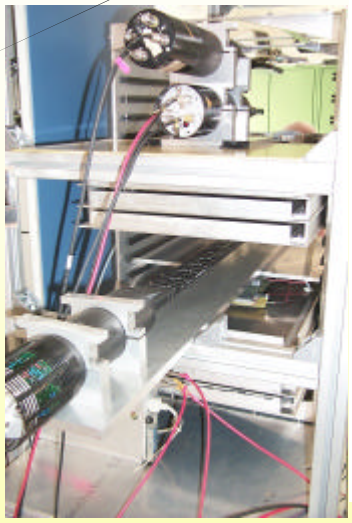
- 0, 0.6, 0.8, 1T field
- 3 tilting angles

Positron timing counter





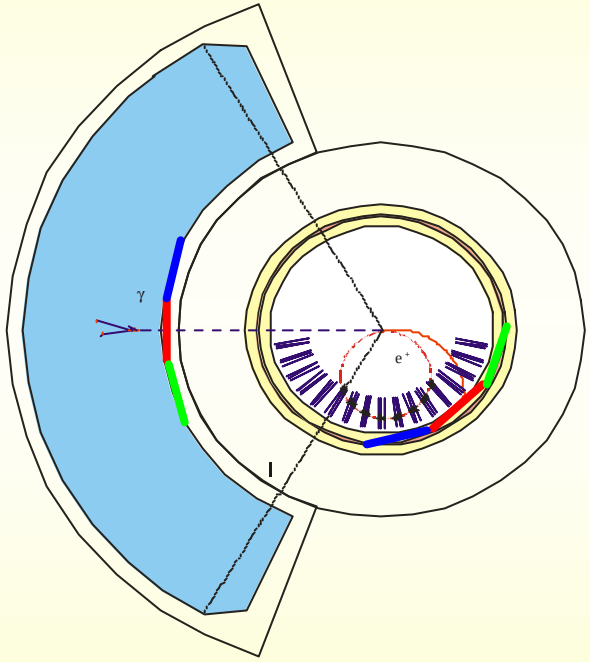




- Aimed resolution ~100ps FWHM
- Beam tests at KEK in July 1999
- Cosmic ray test at CORTES facility

Trigger and DAQ

- Trigger
  - Back to Back positron & gamma and timing coincidence

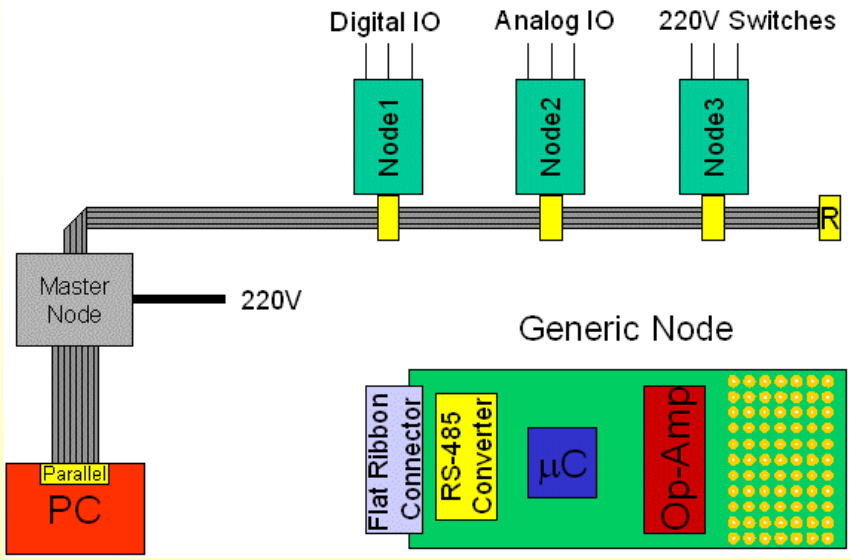


- ❖ Beam rate 10^8 s^{-1}
- ❖ Fast LXe energy sum > 45MeV 2×10^3 s^{-1}
- ❖ γ interaction point
- ❖ e^+ hit point in timing counter
- ❖ time correlation γ – e^+ 200 s^{-1}
- ❖ angular corrlation γ – e^+ 20 s^{-1}

- DAQ
  - All signals are digitized by 2.5GHz wave form digitizers

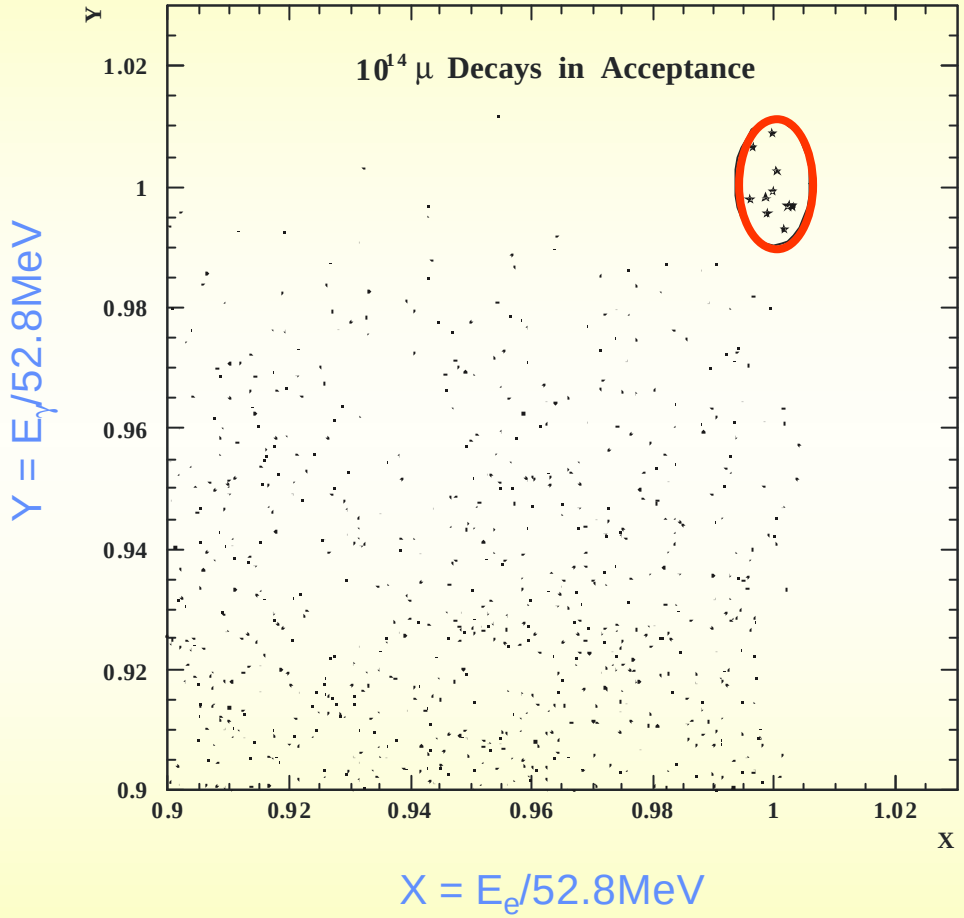
Slow control system

- MSCB (http://midas.psi.ch)
  - The usage of field buses are usually not suitable for small experiments
  - "poor man's" version with less flexibility
  - but optimized for experiment environments and much cheaper (typical 20US$ per node).



Sensitivity

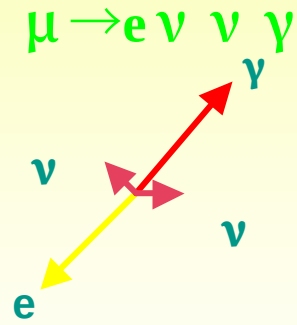
- Sensitivity
  - N_μ=1x10^8/sec, 2.2x10^7 sec running W/4π=0.09,ε_e=0.95, ε_γ=0.7, and ε_{sel}=0.8
  - Single Event sensitivity :0.94x10^{-14}

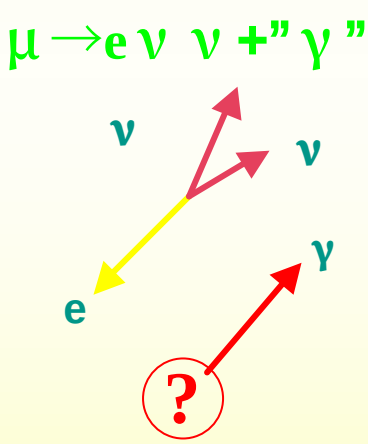


Background

- Main background sources
  - Radiative μ^+ decay
  - Accidental overlap

NOT back to back, NOT in time





Can be reduced

down to 10^{-15} level

Current Status

- Beam line
  - Beam line study has been started this summer
- Photon detector
  - Large Prototype test in progress
  - design work of the xenon vessel is starting
- Superconducting solenoid
  - Coil winding is starting
  - Cryostat construction next year

Current Status cont'd

- Positron tracker
  - R&D using the prototype
  - Mechanical design of the support system in progress
- Positron timing counter
  - Prototype study almost completed
  - Test in magnetic field will start soon
- Electronics
  - be ready in 2002

Summary

- 東京大学を中心とするグループで1999年プロポーザルを提出し、採択
- 国際コラボレーションとして各国で測定器R&Dが進行中
- 日本グループはsimulation、液体キセノンγ線検出器、マグネット建設で中心的役割
- 2003年夏エンジニアリングラン開始予定