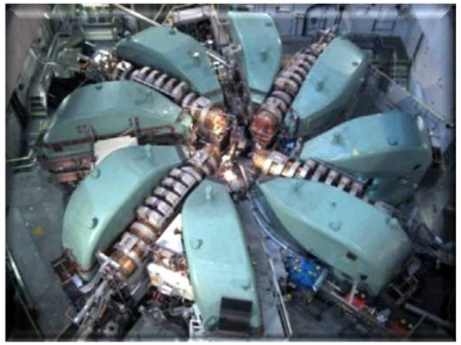
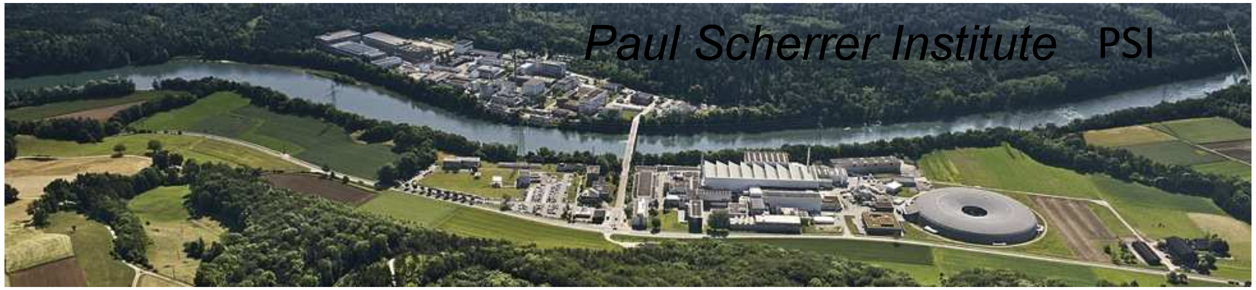
The MEG experiment.

Dmitry Grigoriev
Budker Institute of Nuclear Physics
Novosibirsk State University
Novosibirsk, Russia
On behalf of MEG collaboration

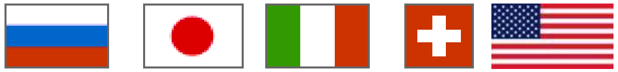
NuFact-2015
Rio de Janeiro, Brazil, 10/08/2015

MEG HOME





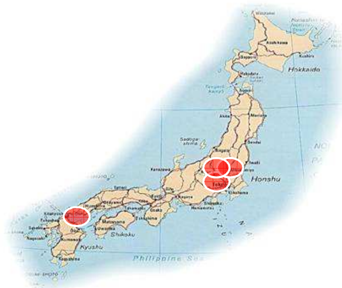
Switzerland
PSI, ETH-Z



MEG Collaboration
some 65 Physicists
5 Countries, 14 Institutes

Russia
BINP, Novosibirsk,
JINR, Dubna

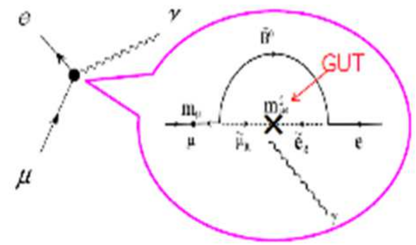
Japan
Univ.Tokyo, KEK
Waseda Univ.,
Kyushu Univ.



Italy
INFN + Univ. :
Pisa, Genova,
Pavia, Roma I
& Lecce

USA
University of
California Irvine
UCI

Why $\mu^+ \rightarrow e^+\gamma$



- cLFV Forbidden in SM (background: $Br(\mu^+ \rightarrow e^+\gamma) < 10^{-54}$) Discovery will be an unambiguous evidence of new physics.
- So far, no cLFV signal has been observed.
- Many new physics beyond SM (e.g. SUSY, Extra dimensions etc.) predict observable Br (10^{-14} — 10^{-11})
- Complementary search of new physics:
  - LHC Run 2
  - New experiments to search for other muon channels ($\mu \rightarrow e$ convertion, $\mu \rightarrow eee$)

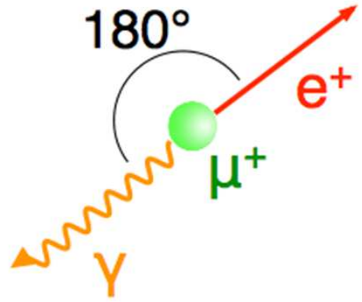
Signal and backgrounds

Signal μ+ decay at rest

52.8 MeV (half of M_μ) (E_γ,E_e)

Back-to-back ($\theta_{e\gamma}$,$\varphi_{e\gamma}$)

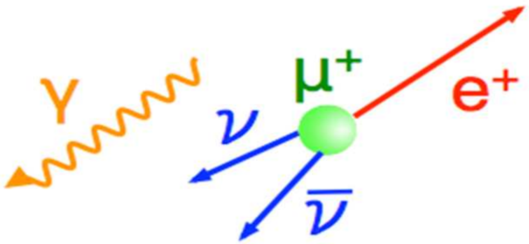
Timing coincidence ($T_{e\gamma}$)



Accidental background (dominant)

Michel decay e^+ + random γ

Random timing, angle, E < 52.8MeV

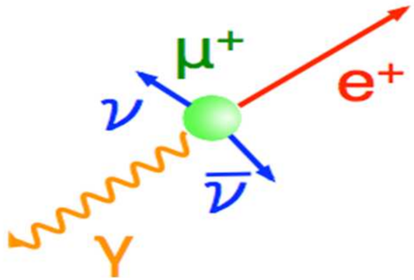


Radiative muon decay

$\mu^+ \rightarrow e^+\nu\nu\gamma$

Timing coincident, not back-to back,

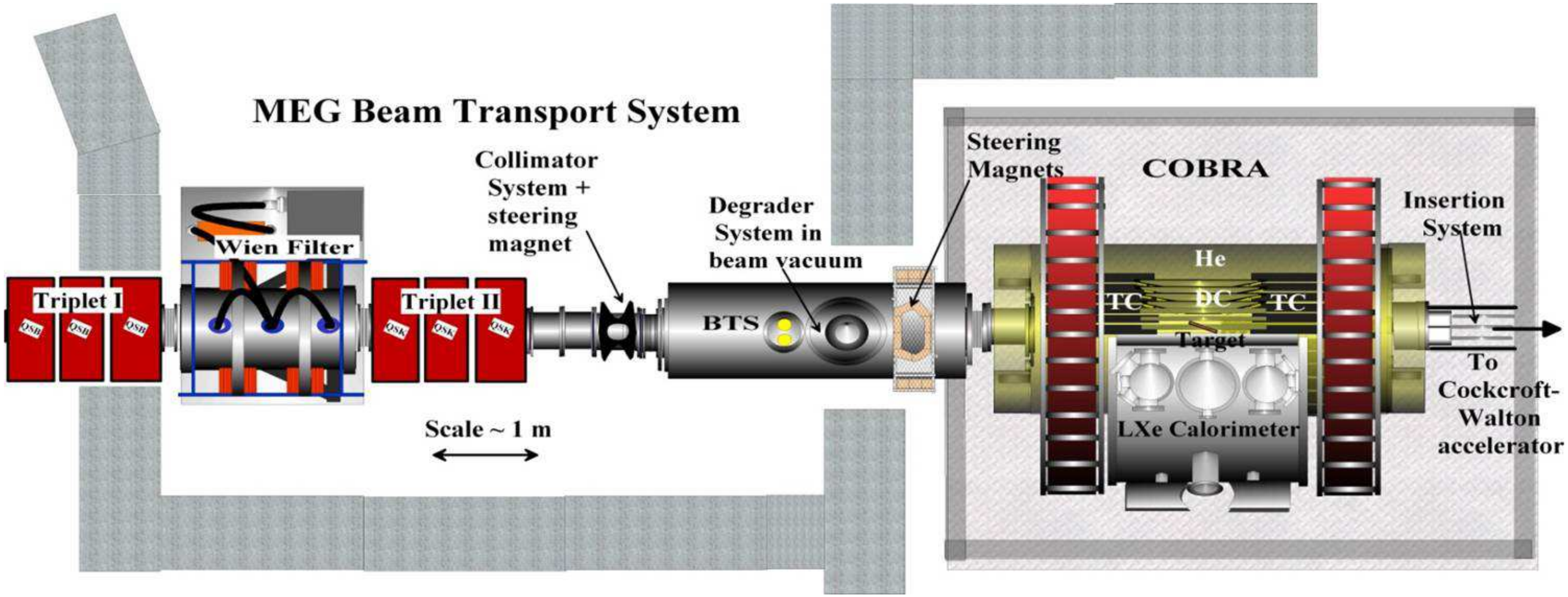
E <52.8MeV



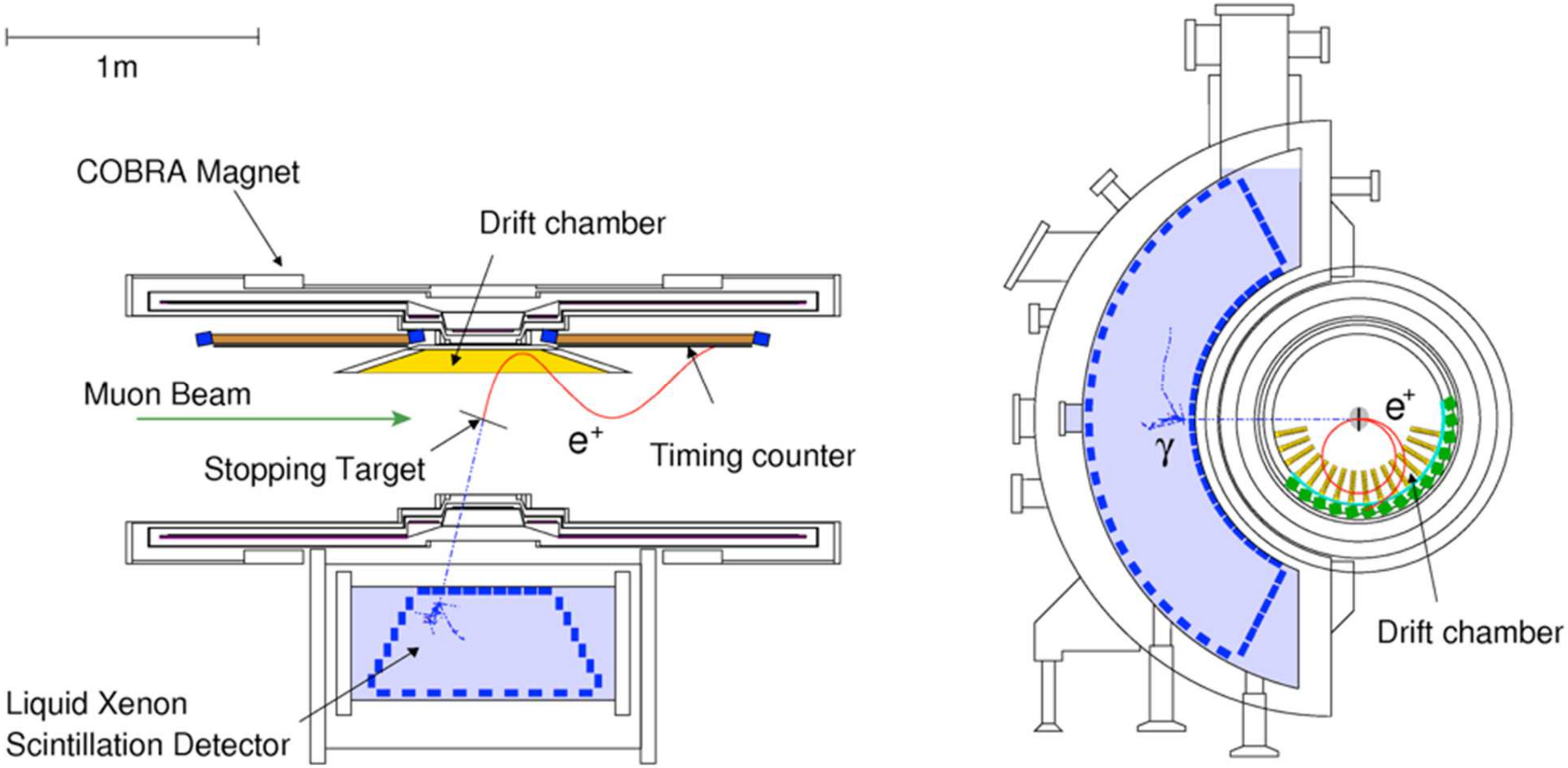
Key points of the experiment

- high quality & rate stopped μ-beam ⇨ surface muon beam, $(\overline{E} \times \overline{B})$ Wien filter, SC-solenoid-focusing+degrador.
- e^+ magnetic spectrometer with excellent tracking & timing capabilities ⇨ COBRA magnet, DCs & TCs.
- photon detector with excellent spatial, timing & energy resolutions ⇨ 900 litre LXe detector (largest in world).
- Stable and well monitored & calibrated detector ⇨ Arsenal of calibration & monitoring tools.

Layout of the experiment



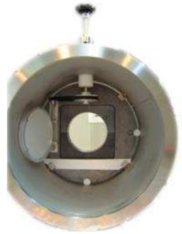
Layout of the detector



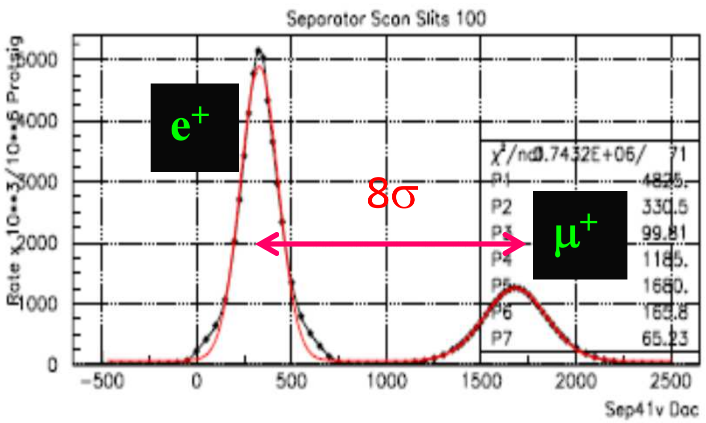
The important part – gradient field COBRA magnet:
tracks radius is independent on incident angle at 52.8 MeV/c

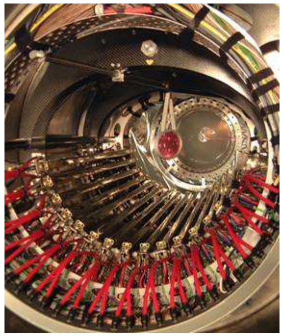
Beam line

- High-intensity DC surface muon beam - πE5+MEG
  ⇨ capable of>10^8 μ^+/s at 28 MeV/c(optimal rate $3x10^7$/s)
- "pure" muon beam - Wien filter(ExB)+Collimator system
- ⇨ μ-e separation at collimator >7.5σ (12 cm)
- Small beam-spot + high transmission -BTS
  ⇨ focus enhancement, beam σ~10 mm at target
  ⇨ second focus at centre BTS – degrader 300 μm
- Thin stopping target + minimal scattering – end-caps
  ⇨18mg/cm^2 CH_2 target at 70^o+He COBRA environment
  + remote Target & End-cap insertion system

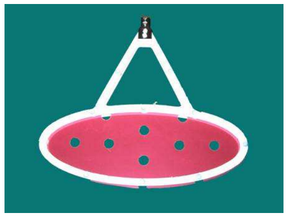


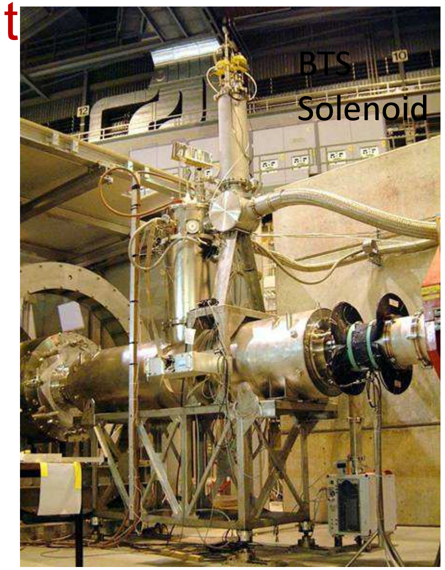
collimator





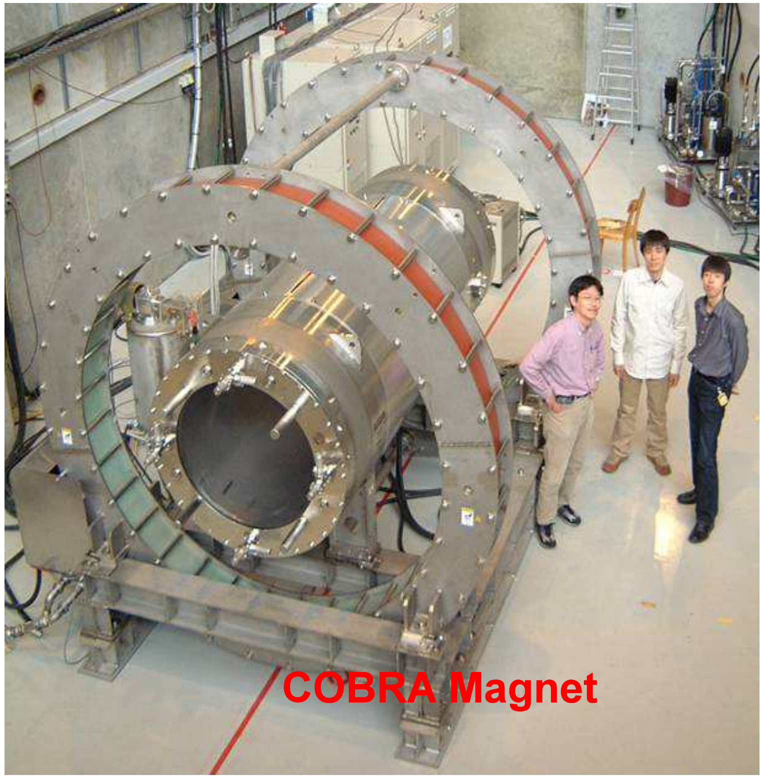
Target



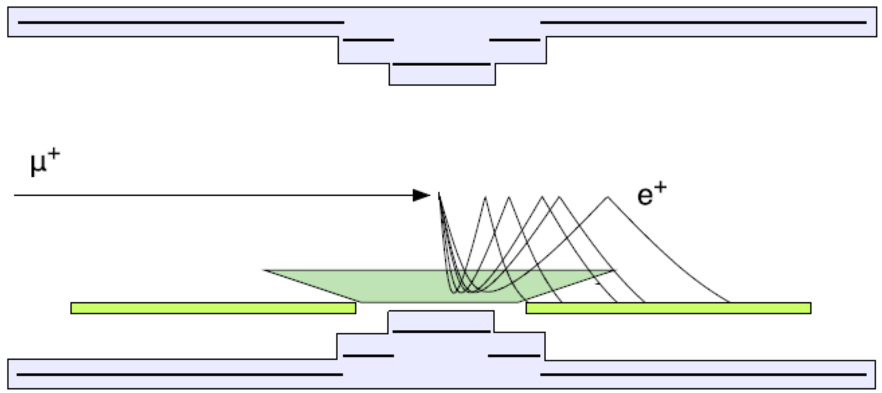


Positron spectrometer

- **SC COBRA Magnet**
- Gradient Bfield (1.27-0.5) T
  CОnstant Bending RAdius
- 0.2 X_0 fiducial thickness
  γ-transparency 95%
- NC Compensations coils
  reduce Bfield at Calorimeter
  < 5mT at PMT positions

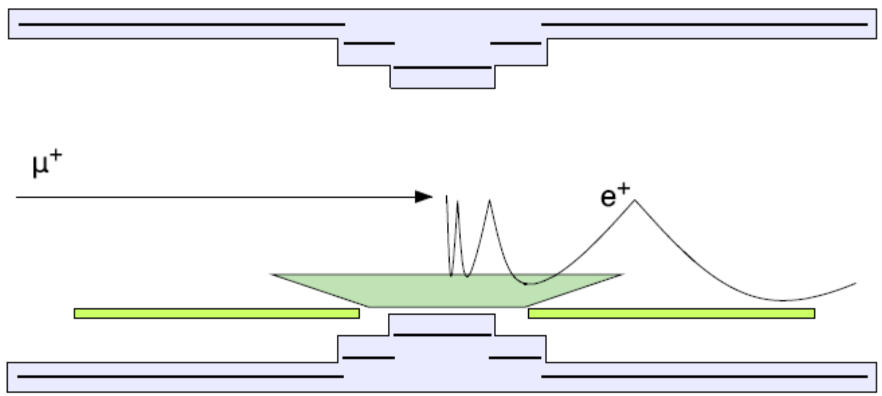


Positron spectrometer



(a)

(a) "MEG" positrons

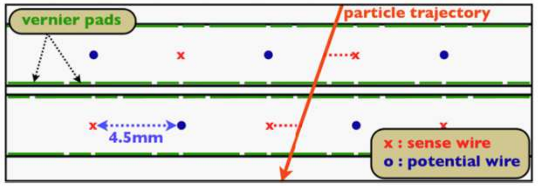


(b)

(b) Lower momentum positrons: Don't trigger DAQ

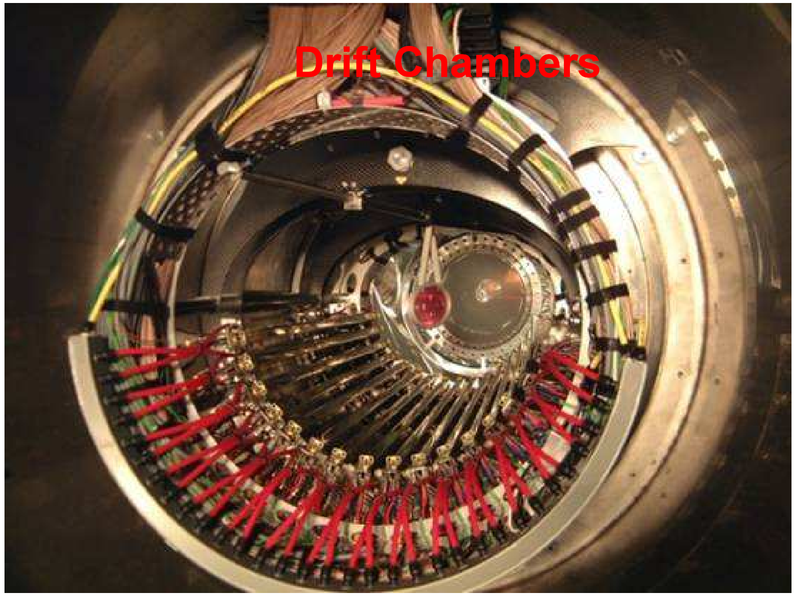
Positron spectrometer

- **Drift Chambers**
- 16 radial, staggered double-layered DCs



- each 9 cells with "Vernier" cathodes (5 cm pitch)

- 50:50 He/C_2H_6
- Ultra-thin $2 \cdot 10^{-3} X_0$ along e^+ path



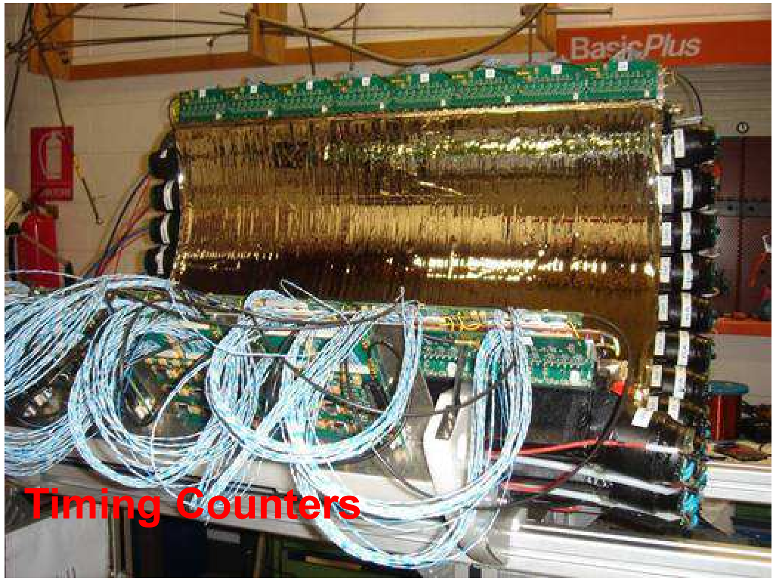
Momentum resolution $<\sigma p/p)$ 6‰

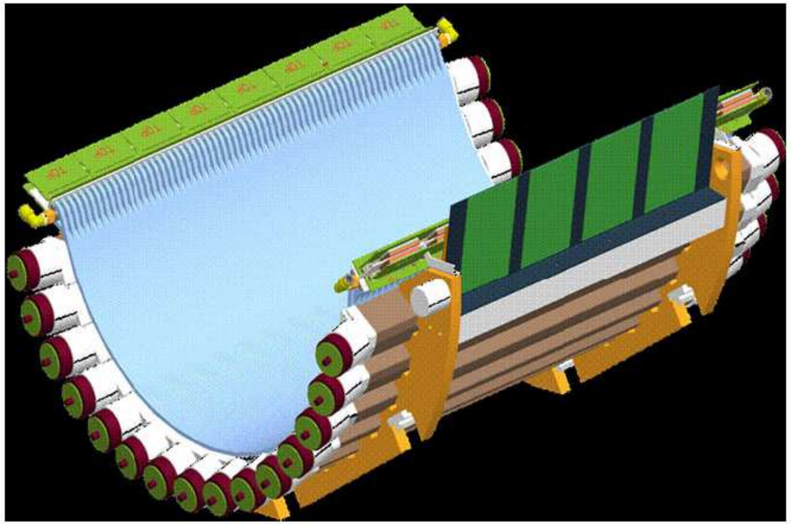
Angular resolution (e^+) ϕ ~7 mr

θ~ 10 mr

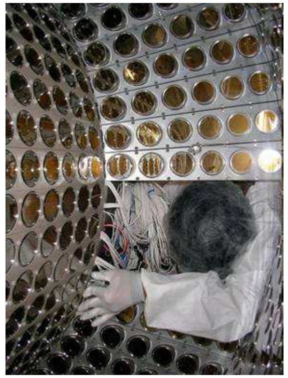
Positron spectrometer

- **Timing Counter Arrays**
- 2 arrays of each –
  15 axial scintillator bars
  BC404 + 2” fine mesh PMT
  e^+ impact point + timing
  intrinsic $\sigma_t \approx$ 70ps over 90 cm
- 256 orthogonal radial
  scintillating fibres
  BCF-20 + APDs
  triggering (angular matching)





Calorimeter



- Largest LXe calorimeter in the world 900 litres $\Delta\Omega/4\pi = 10\%$
- Fast response (4, 22 ns) - minimize “pileup”
- Large light-yield ~80% NaI
- high density, short X_0
- Homogeneous medium uniform response,
- no segmentation needed
- Sensitive to impurities at sub –ppm level (mainly H_2O, O_2, N_2)
- Scintillation light used for shower reconstruction λ= 175 nm (

- 846 PMTs wall-mounted inside LXe-volume
  signals digitized @ 1.6 GHz
- Light material between PMTs
- Thin honeycomb window
- 14 X_0 of LXe

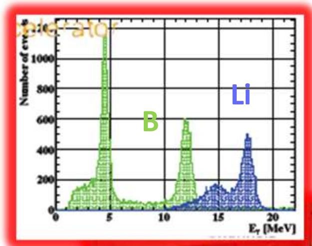
Energy resolution $<\sigma E/E>$ < 2% at 52.8 MeV
Timing resolution = 67 ps
Position resolution (X,Y) 5 mm, (depth) 6 mm
γ-efficiency 59% (ε_{Detect} x ε_{Anal})

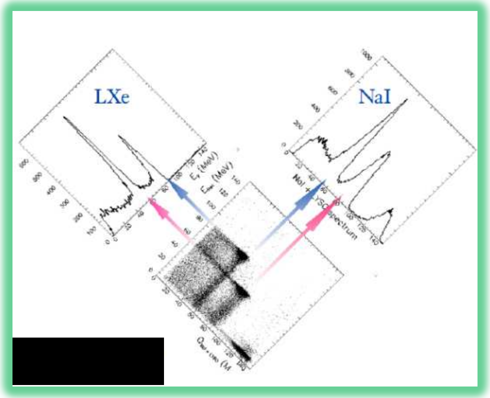
Calibration and Monitoring

<u>PMT</u>: Gain, QE,
<u>LXe</u>: Light-yield , Attenuation-length
<u>Calorimeter</u>: Energy-scale
DC: Momentum scale
<u>Calo.+TC+DC</u>: Relative detector timing, Alignment

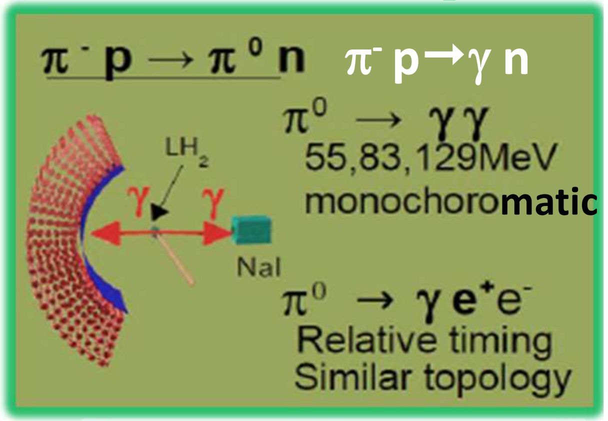
e.g. αs, LED, CEX ($\pi^- p \rightarrow \pi^0 n$ or γn, "Dalitz-decay"), RMD, protons from C-W accelerator on $Li_2B_4O_7$, n-generator+ Ni, cosmics, Mott e^+ beam

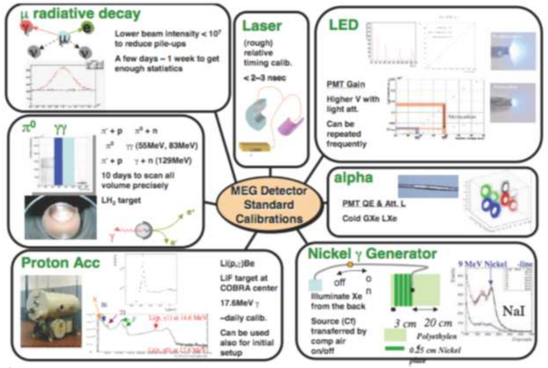
Crockcroft-Walton





Pion CEX on LH_2

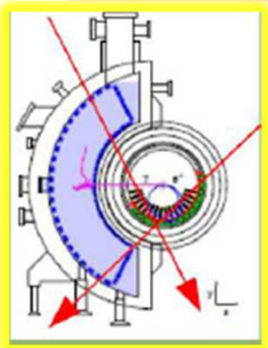




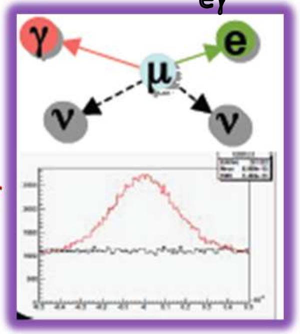
Radiative Muon Decay

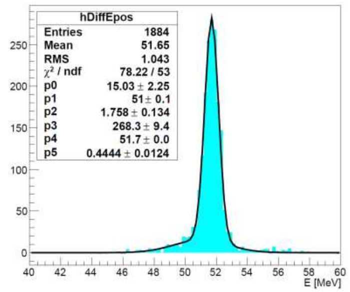
RMD $\rightarrow t_{e\gamma}$

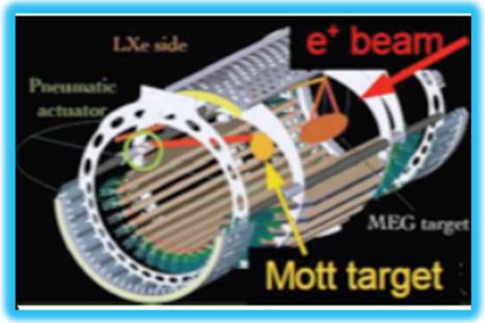
Mott mono.
e+ scattering



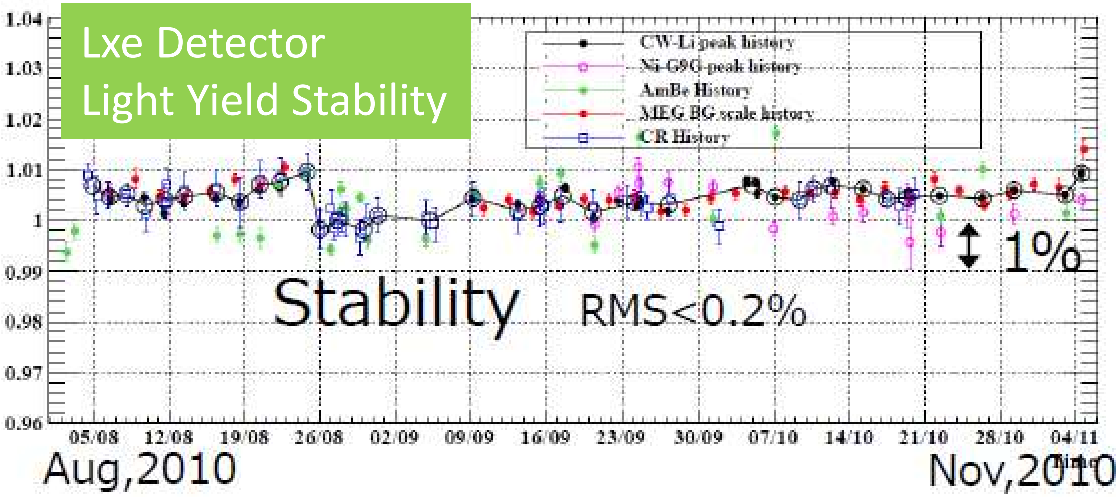
Cosmic rel.
alignment LXe
+ spectrometer

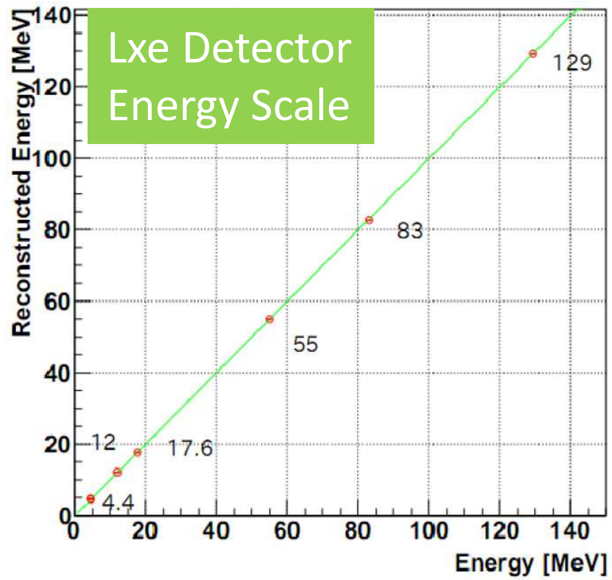


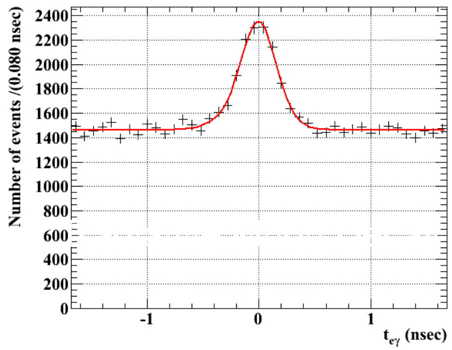




Detector Stability







<u>Detector Stability permanently monitored</u>

- Light Yield stable to < 1% rms < 2‰
- Photon energy-scale cross-checked using BG-spectrum from LXe side-bands
- Timing stability checked using radiative muon decay events (RMD) taken simultaneously during run (multi-trigger) $T_{e\gamma}$ stable ~ 15 ps over whole run

Analysis Principle

Blind likelihood Analysis:

Data Sample defined by 5 Observables:

E_e^+, E_γ, $\theta_{e\gamma}$, $\phi_{e\gamma}$, $T_{e\gamma}$

Analysis-box for Likelihood fit
Defined in 5D-space as:

Analysis Box vs 5 Observables

(~10σ wide windows cf. res.)

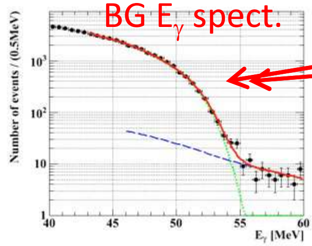
$48 \le E_\gamma \le 58$ MeV

$50 \le E_e \le 56$ MeV

$|T_{e\gamma}| \le 0.7$ ns

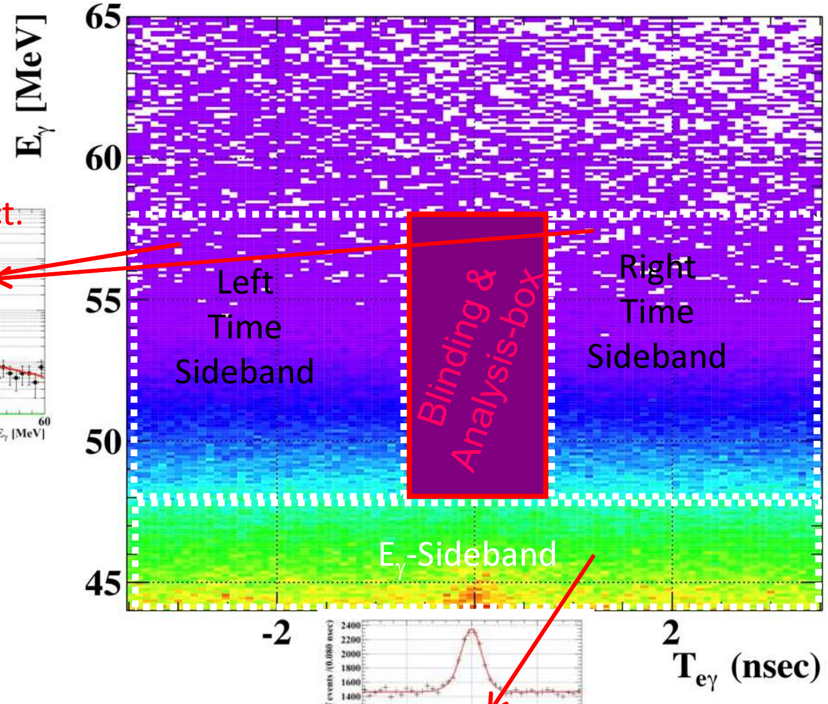
$|\phi_{e\gamma}|$, $|\theta_{e\gamma}| \le 50$ mrad

(angles between e⁺ & flipped γ vec.)



Analysis box
"Blinded" in the
E_γ vs $T_{e\gamma}$ plane
during calibration
and
optimization of
physics analysis

Analysis Region shown in 2D
(No Selection)



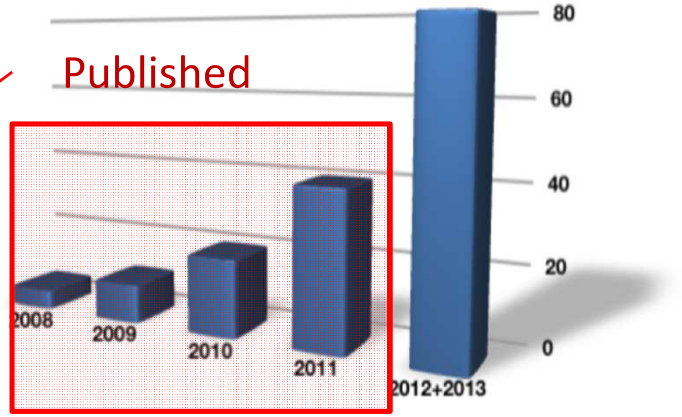
!!! Time and E_γ sidebands Important Ingredient to Analysis also angular sidebands introduced

⇨ Since our background is dominated by "accidentals" the side bands can be used to estimate the background in the signal region, check of experimental sensitivity & measure the timing resolution using RMD in the E_γ-sideband

Results

Phy. Rev. Lett. 110, 201801 (2013)

Data taking finished at 31.08.2013
Statistics is doubled compare to published



year	Nstop μ, $x10^{13}$	Sensitivity, $x10^{-13}$	Br, Upper limit (CL 90%), $x10^{-13}$
2009+2010	17.5	13	13
2011	18.5	11	6,7
2009+2010+2011	36.0	7.7	**5.7** (20 times better
All data (expected)	~80	~5	than MEGA)

Final result of analysis is expected by the end of 2015 with the improved analysis. The data are reprocessed now.

Improvement of the analysis

- Event reconstruction algorithm.
- Calibration procedures.
- Background rejection techniques.
  - recover positron tracks which cross the target twice (missing turn analysis)
  - Identify background γ-rays generated when a positron annihilates with an electron on some detector material (annihilation-in-flight (AIF) analysis)
  - refine the alignment procedure of the target and drift chamber system.

Conclusion

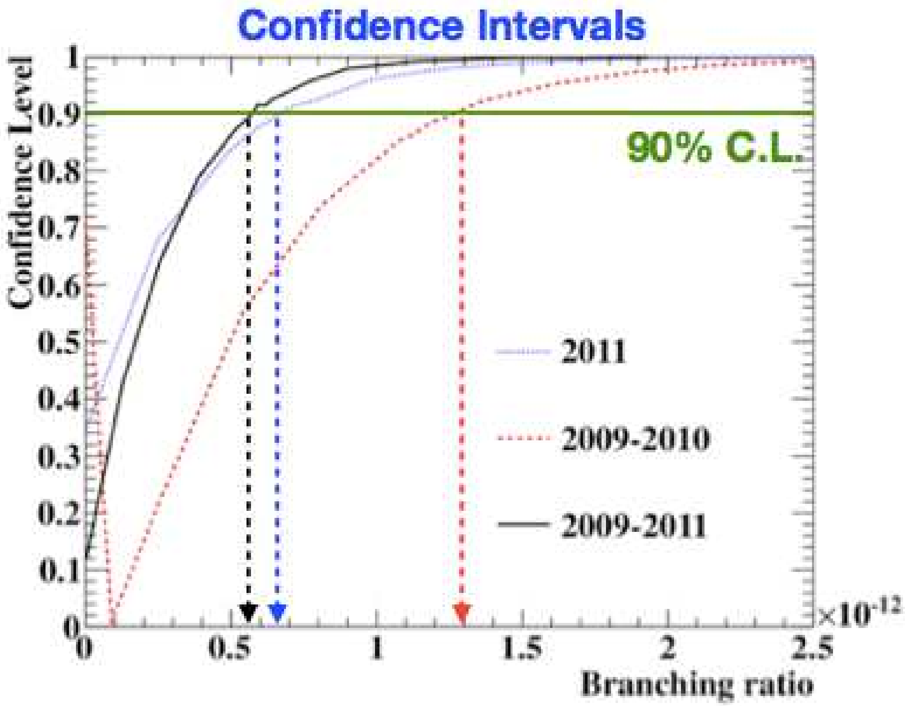
- MEG experiment successfully finished data taking 31.08.2013.
- The statistics is double compare to published result. The data analysis will be finished at 2015.
- Expected improvement of sensitivity from 7.7×10^{-13} to $\sim5\times10^{-13}$.
- MEG-2 with an order of magnitude better sensitivity is coming (see Angela Papa’s talk).

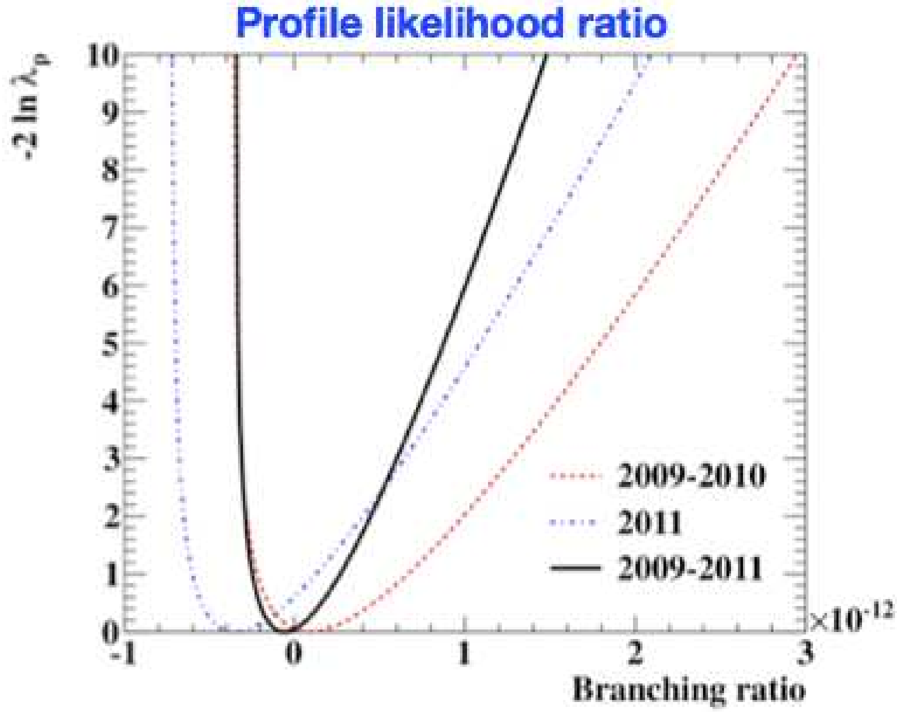
Thanks for your attention!

Backup

Confidence Interval

- Confidence interval calculated with Feldman-Cousins method + profile likelihood ratio ordering





Consistent with null-signal hypotesis