A sensitive search for New Physics: The MEG Experiment

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Outline

- (very) little theoretical motivations
- The MEG experiment concept
- Detector performance
- Calibrations
- Some very preliminary results…

Why a MEG experiment?

Lepton Flavor Violation allows for test possible extensions of SM
- SUSY
- MFV
- SUSY-GUT
- …..

- All LFV processes such as $\mu \rightarrow e\gamma$ are completely clean from SM backgrounds: $BR_{\mu \rightarrow e\gamma} \sim 10^{-48}$, in beyond-SM frameworks $BR_{\mu \rightarrow e\gamma}$ up to 10^{-11}
- Strong interplay between **LFV** and
  - **neutrino physics** (mass pattern and generation mechanism, neutrinoless double beta decay)
  - **anomalous muon magnetic moment**
  - **lepton electric dipole moment**
- Precision test of SM rather than “brute-force” LHC approach
- Energy scale probed up to 2TeV: discovery just around the corner or strong constrain on alternative theories
- But most of all…

WE ARE CURIOUS!!!!!!

MEG basics

- ✓ μ+ decay at rest → event signature is emission of photon and positron with equal energies and opposite momenta, at same time
- ✓ Some definitions:

  R_μ rate of stopped muons

  $\delta E\gamma$,p energy resolution

  δt timing resolution

- ✓ Background sources:
  - Intrinsic *Physic or Prompt* background: μ radiative decay BR / 10 : one "primary particle" → linear dependence on R_μ
  - *Accidental* background: superimposition of positron from one m decay and one or more photons from another μ decay or AIF of an high energy positron: two primary particles → quadratic dependence on R_μ, <u>dominant contribution:</u>

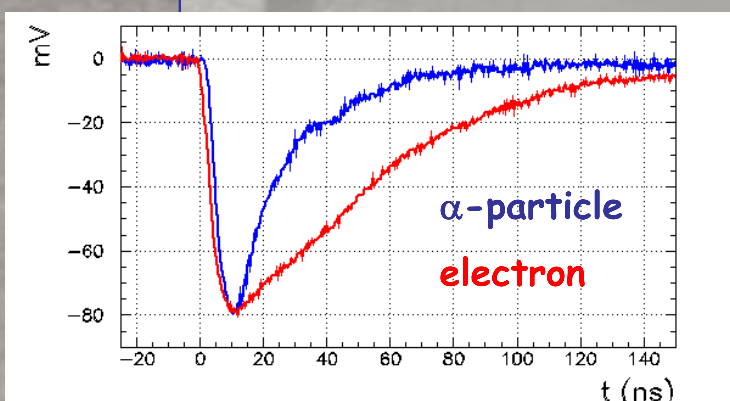
$$R_{acc} = R^2_\mu \; \alpha/2\pi \; 2 \; \delta E\gamma^2 \; \delta Ep \; \delta\theta(e\gamma)^2 \; \delta t(e\gamma)$$

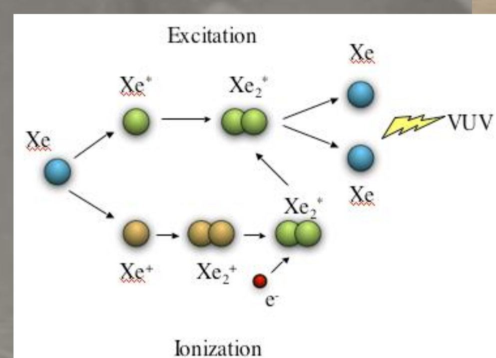
- ✓ Experimental sensitivity and limitations given by:
  - ➢ Muon statistics
  - ➢ Number of accidental events

Photon detector

LXe calorimeter

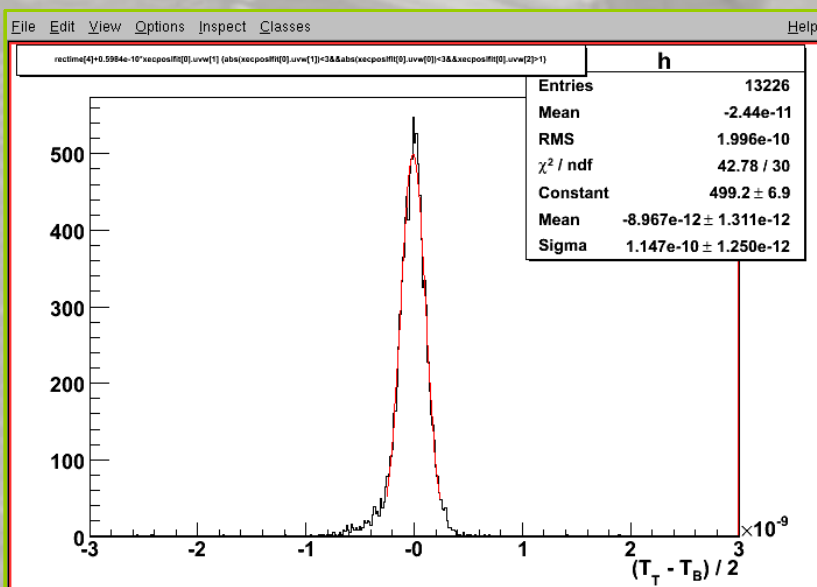
- Good scintillating properties:
  - Fast (allows to obtain the desired timing resolution)
  - High light yield (good energy resolution)
  - High Z (suitable to detect photons)
  - Being liquid we can obtain it “monolithic” with almost every shape
  - Has particle identification capability by means of different emission mechanism

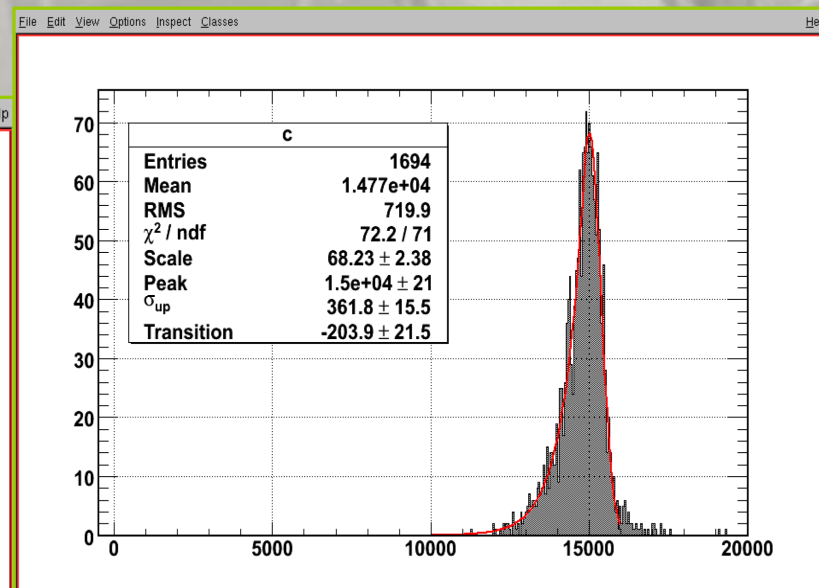




Photon detector

Timing resolution: 115 ps sigma





Energy resolution:2.4% sigma

Positron spectrometer

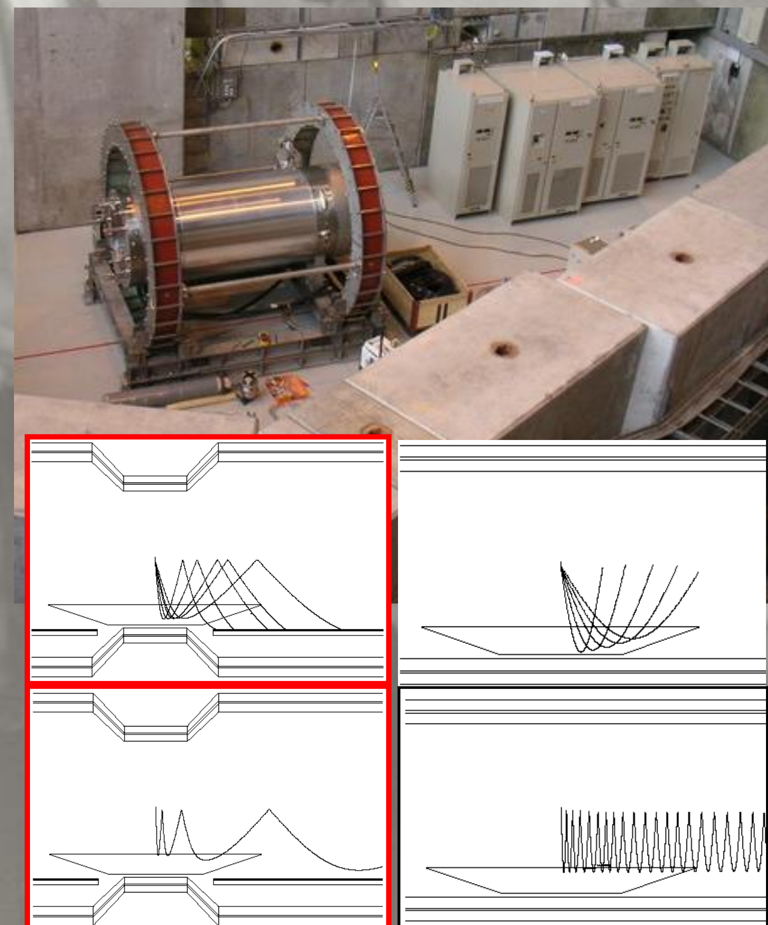
Magnetic field + Tracking detector

COBRA magnet: improvement of solenoidal field to obtain curvature radius depending only on positron energy within large emission angles

Drift_Chambers: especially designed with low mass to minimize multiple scattering, high spatial resolution for measuring positron momentum and trajectory:

σp = 0.9%

Vertex reconstruction 1mm



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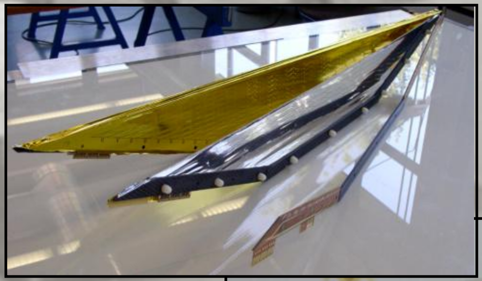
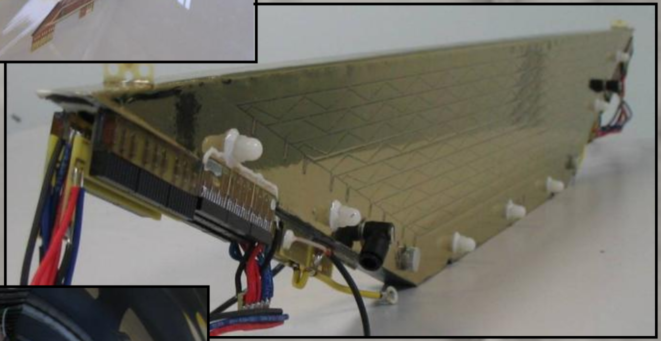
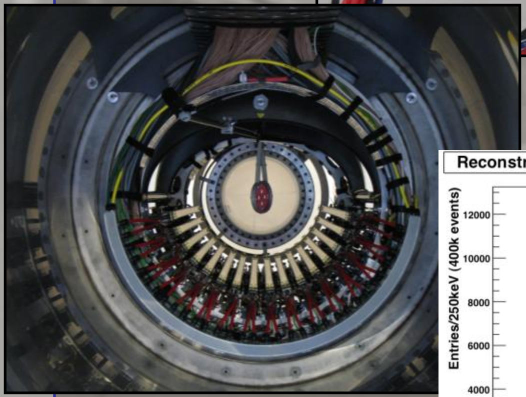
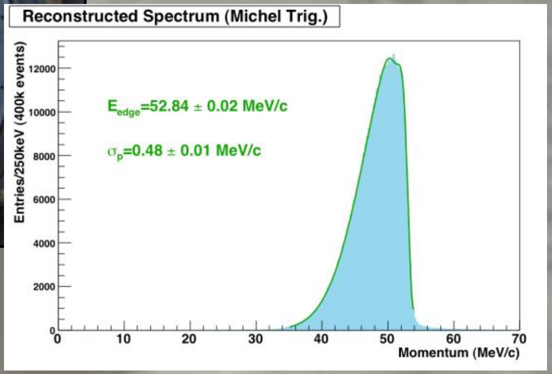








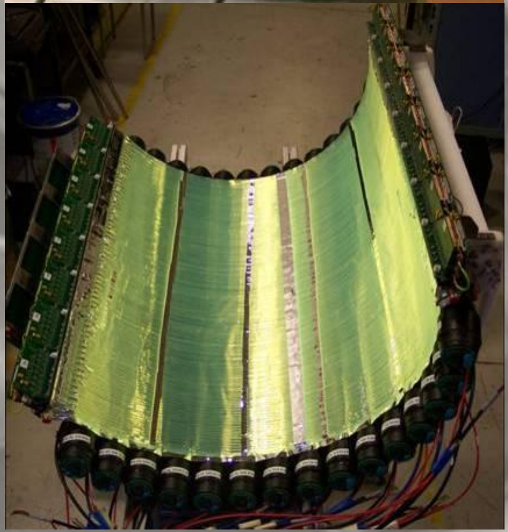
Timing Counter

Is designed to detect positrons emitted by decaying muons, fast signal used for:

- ✓ first level trigger
  - Smart timing resolution (~ns for triggering purposes)
  - Preliminary direction of emission → selecting events → lower trigger rate (data amount);
  - High efficiency (>90%).
- ✓ Allow for precise determination of positron kinematics during event analysis:
  - Impact point for track reconstruction (main contribution to overall time resolution)
  - Very high timing resolution (**<u>100 ps FWHM</u>**) for e+-γ coincidence

Two-fold detector:

- Scintillator bars readout with PMTs for high timing accuracy.
- Highly segmented APD + scintillating fibers for longitudinal coordinate measurement



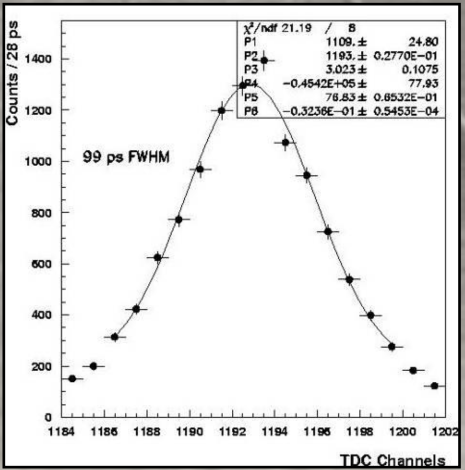
TC performances

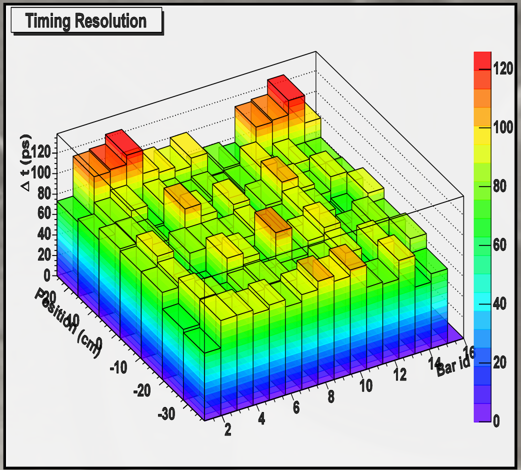
Longitudinal detector

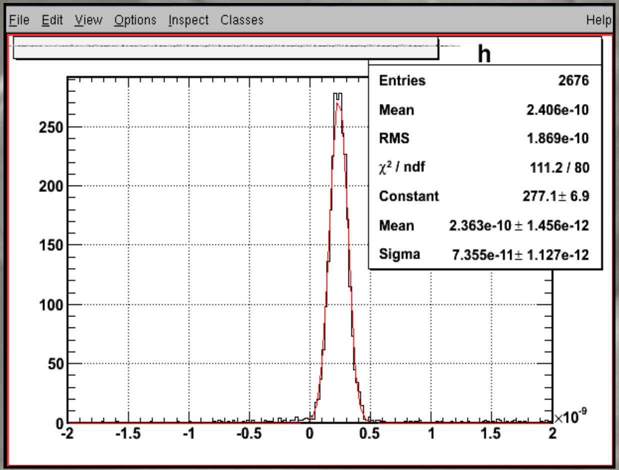
- Comparison with scintillator TOF detectors
- Used fast plastic scintillator and FM PMTs for high B field environment
- Optimization of shape to maximize acceptance, while minimizing energy loss spread improving time resolution
- Custom made discriminators with very low jitter
- Double Threshold method to overcome time-walk

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	**4 x 4 x 90**	**BC404**	**R5924**	**270**	**38**	

device	Time resolution ps	Intrinsic contribution ps
Meg TC DTD	9.0	6.4
Phillips 710	18	12.8





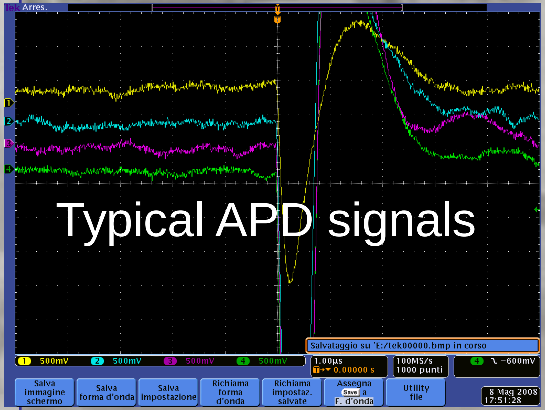


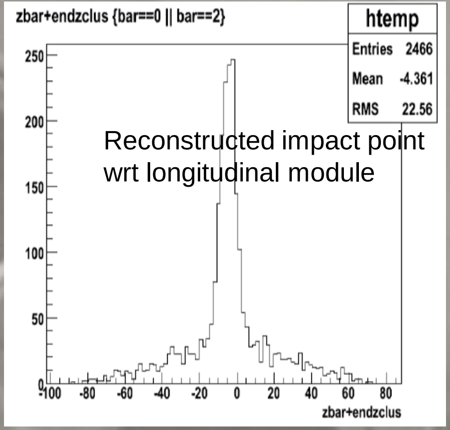
TC performances

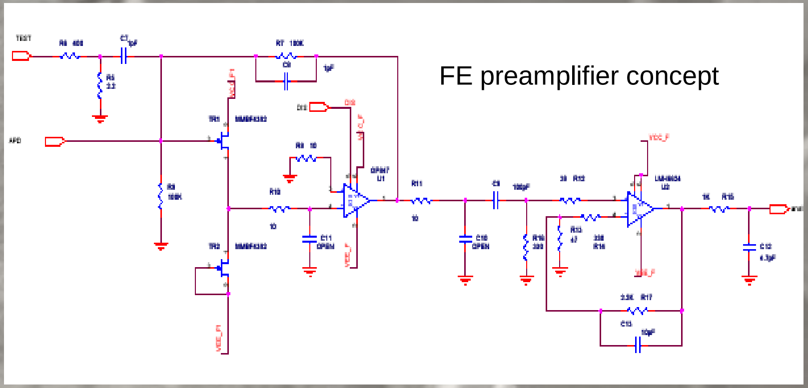
Transverse detector

Newly conceived Scintillating fibers+Avalanche Photodiodes:

- Allows for full customization of the detector shape (very small clearances)
- Suitable to use in high magnetic field
- Low noise electronics for analog signals (ENC = 1500e)
- Digital output with hitmap encoding (saves disk space without information loss)







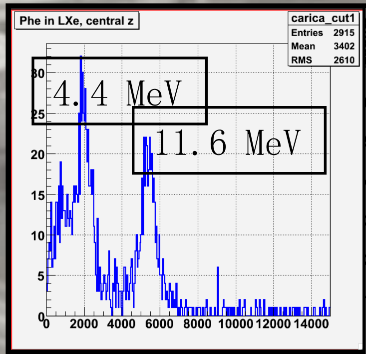
Experiment calibrations

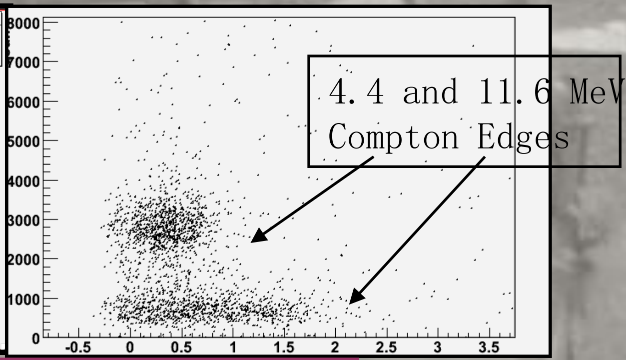
Insure reach and maintaining of expected performance:

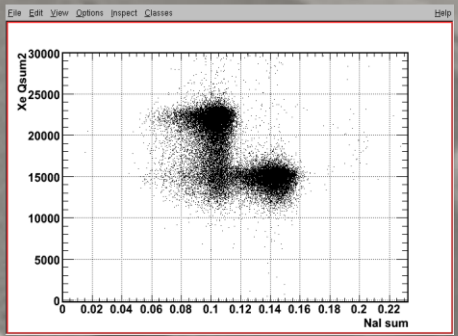
- Online calibrations and monitoring tools, mixed up with the “official” MEG triggers:
  - Radiative Decay events (loose constraint on gamma energy and gamma-positron direction)
  - Michel Decays (DC normalization and tracking)
  - Alpha sources (monitor of calorimeter: LXe purity and PMT working point)
  - Laser system: monitor of TC-LXe timing performance
- “Offline” calibrations, needs to stop official data taking and rearrange the system:
  - Cockcroft-Walton accelerator for production of (p, γ) reactions on light elements (B, Li): calibration lines for LXe, physical timing monitor, pile up rejection
  - Tune up beam for extracting π0: high energy LXe response (55MeV γ)

Experiment calibrations

B lines (two photons simultaneously emitted)



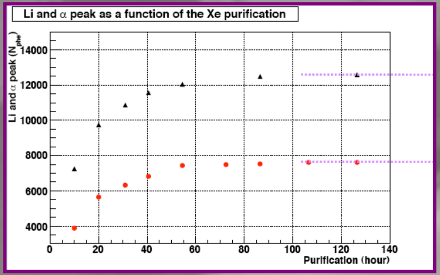




π0 decay

55 Mev and 83 MeV γs

α monitoring of Xe purity



Overall performances

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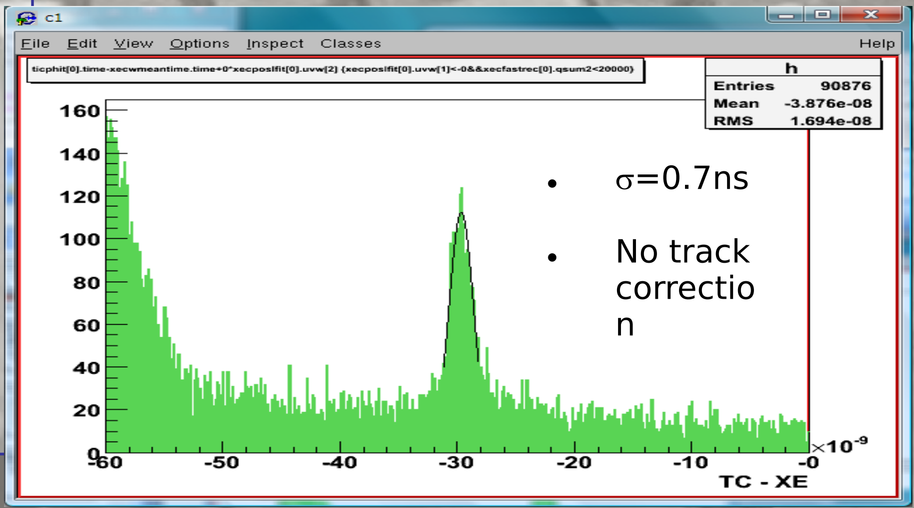

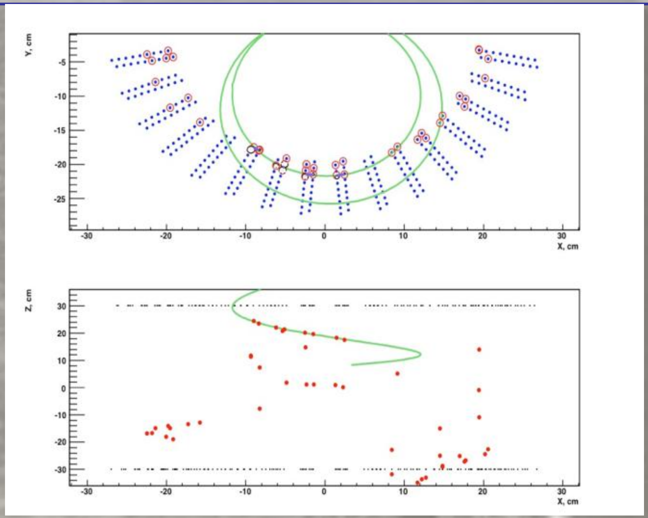

Background and Sensitivity

	"Goal" Measured	"Goal" Simulation	2007 Measured	2008 Prospects
Gamma Energy (%)	4.5-5.0		6.5	5.0
Gamma Timing (nsec)	0.15		0.27*	0.15*
Gamma Position (mm)	4.5-9.0		15.	9.0
Gamma Efficiency (%)	>40		>40	>40
e+ Timing (nsec)	0.1		0.12*	0.12*
e+ Momentum (%)		0.8	2.1	1.1
e+ Angle (mrad)		10.5	[17.]	[17.]**
e+ Efficiency (%)		65	65	65
Muon Decay Point (mm)		2.1	3.	3.**
Muon Rate (10^8/sec)	0.3		0.3***	0.3***
Running Time (week*)	100		8	24
Single Event Sens (10^{-13})	0.5		6.7	2.2
Accidental Rate (10^{-13})	0.1-0.3		6.0*	1.0*
# Accidental Events	0.2-0.5		0.9	0.5
90% CL Limit (10^{-13})	1.7		23.	6.9

* additional contribution of 250psec added for background evaluation

* "1 week" is defined to be 4×10^5 sec ** Very pessimistic

*** Muon rate can be further optimized to obtain the best limit

As an example:

- Preliminary result from ’07 Engineering Run
- Just few days of true MUEGAMMA trigger
- Several improvements already implemented wrt this configiuration
- Others under way
- Obtained:
  - $N_\mu = 1.89 \times 10^{12}$
    - $R_\mu = 3.7 \times 10^{7}$ /sec
    - Total live time = 5.1×10^{4} sec
  - $\Omega/4\Pi = 0.1$
  - $\varepsilon_\gamma = 0.28$
    - ε_γ (detection) = 0.6
    - ε_γ (analysis) = 0.46
  - $\varepsilon_e = 0.18$
    - ε_e (detection) = 0.65
    - ε_e (track rec.) = 0.65
    - ε_e (TC-DC match) = 0.5

Very very preliminary!!