MEG実験2010 現状と展望

日本物理学会2010年秋季大会
@九州工業大学戸畑キャンパス
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東京大学 素粒子物理国際研究センター
内山　雄祐

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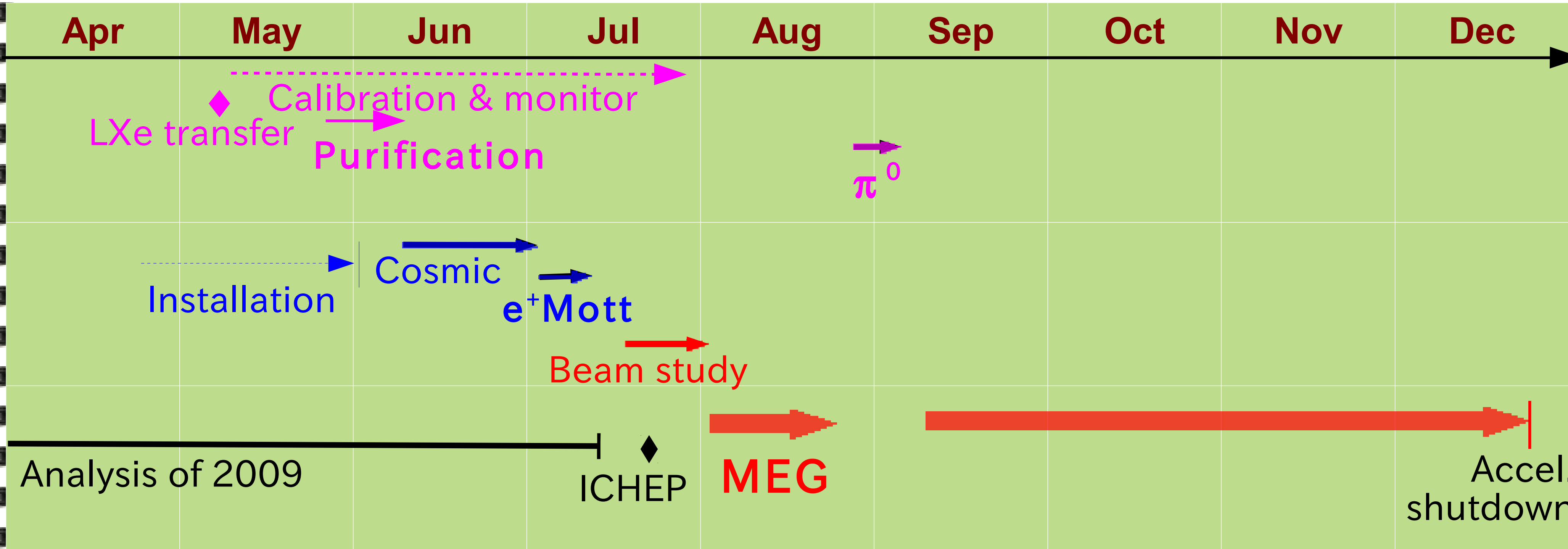
- **2010 status**
  - Run schedule
  - Detector condition
- **Update, modification**
  - DRS timing tune
  - Mott scat data
  - Neutron generator
- **Performance**
- **Sensitivity 2010**
- **Further prospects**

2010スケジュール

RUN2010 : MEG3年目の物理ラン

Already started



- Re-install spectrometer after repair & maintenance work (~1 month delay)
- Positron beam test
- Beam optimization
- MEG RUN 2010- I
- Pi0 calibration run
- MEG RUN 2010-II

Total
117 days for physics data taking

x2.7

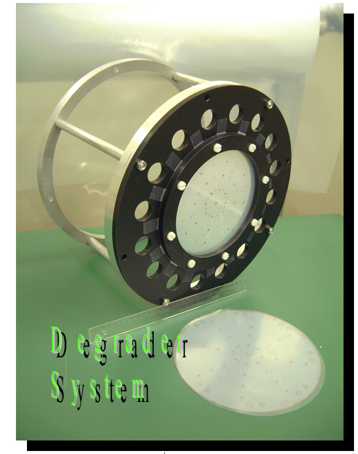
cf. 43 days in 2009

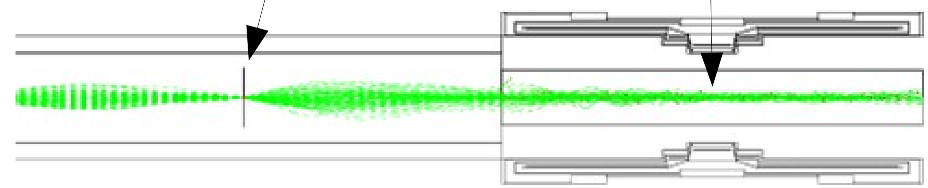
New things, modifications

- Beam optimization
- Replaced 5 Drift Chamber modules with new ones
- Z-measuring Timing Counter integration
- Electronics (waveform digitizer) timing tuning
- New calibration method (feasibility test, mounting)
  - Positron mott scattering
  - Neutron generator for 9 MeV gamma

Beam optimization

- Beam intensity
- Stopping distribution
- Degrader, momentum slit
- Event distribution (asymmetry)
- Optimize S/N





- Originally planed before 2009 run
  - 1^{st} half of 2009 data shows strong asymmetry (200μm degrader)
    - Less stopping efficiency (~65% of that with 300μm degrader)
    - Higher BG
  - Changed degrader setting during run2009
    - $T_{live}^{200} : T_{live}^{300} = 37 : 63$
    - $N_{stop}^{200} : N_{stop}^{300} = 29 : 71$
- This study shows the setting of 2^{nd} half of 2009 was optimal
  - Tuned beam center for this setting
  - Rate was adjusted to $3.6\times10^7 \mu$/sec at center $\rightarrow$ **R_{stop} = 2.9 x $10^7 \mu$/sec**

This year
More efficient and less BG beam condition for all period

Detector condition

- Drift chamber
  - Replaced 5 modules with new ones
  - 30 layers (out of 32) working at nominal voltage
  - (still) large noise on cathode readout
- Liquid xenon
  - Slightly higher light yield (full (updating best record))
  - A few PMTs becoming dead
    - Continuous decreas of PMT gain
    - Total 7 dead channels
- Timing counter
  - Phi-bars working fine (for this 3 years)
    - Optimization of thresholds for better timing resolution are ongoing
  - Z-fibers just integrated into our DAQ
    - Conditioning, noise study, readout tuning under way
    - Integrating into trigger is under study

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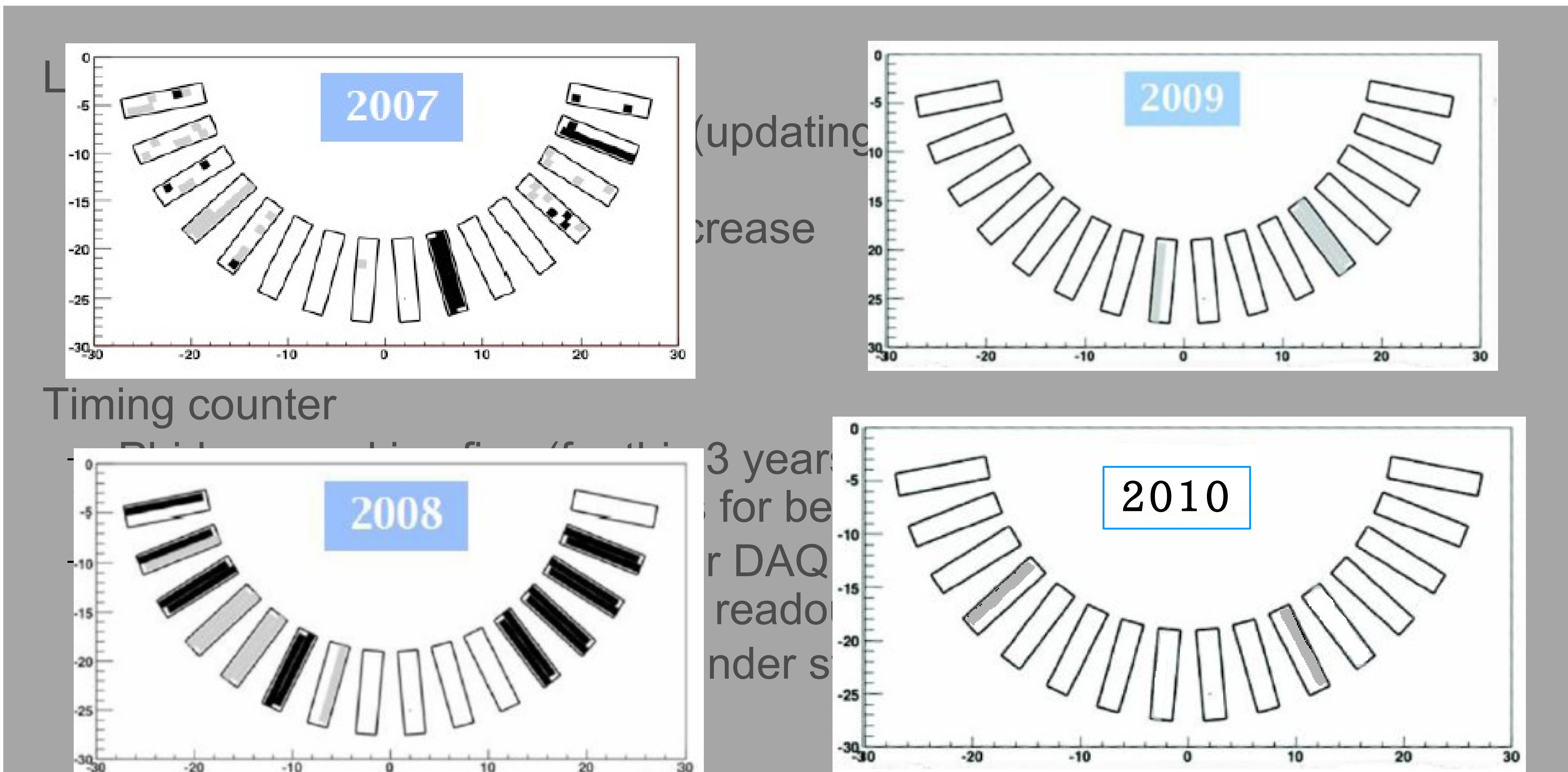

13pSM-1：He/C_2H_6を用いたドリフトチェンバーの高頻度照射下でのエイジング　西口創

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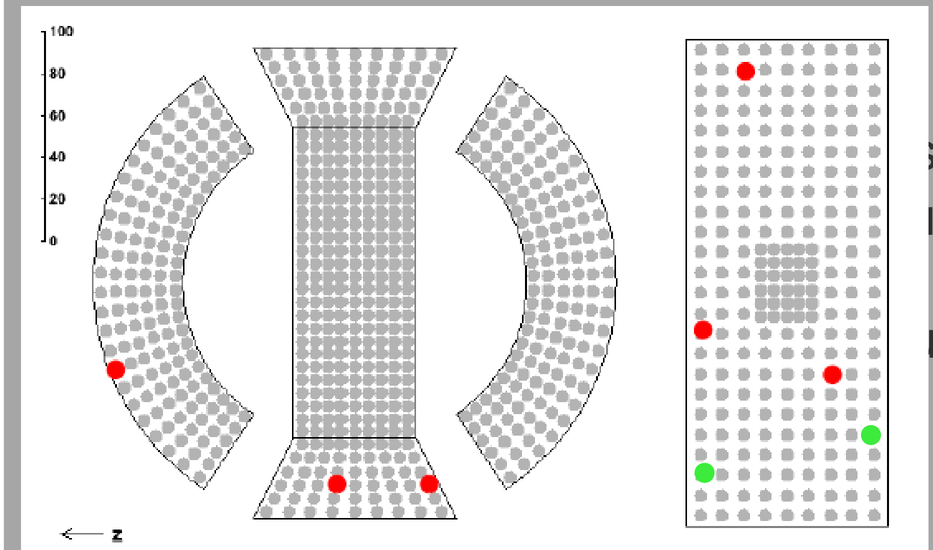

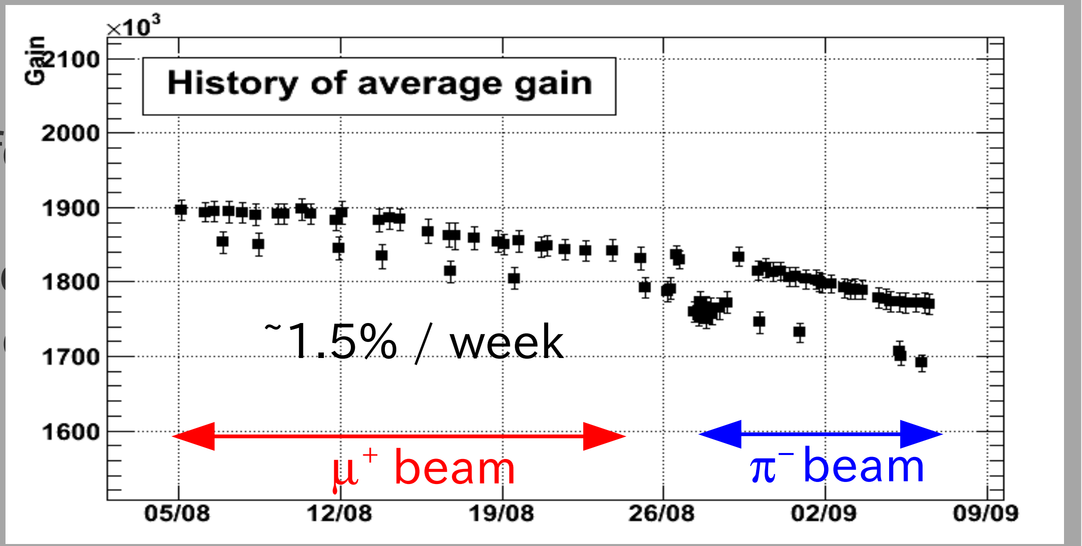

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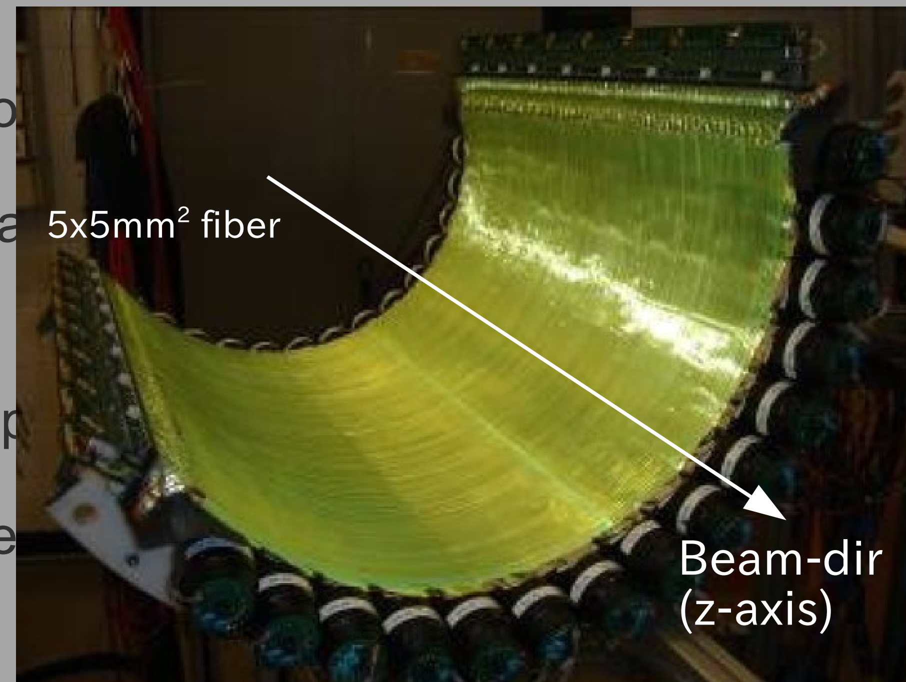
Two-layer (orthogonal)
- Z-fiber
- Phi-bar

Online resolution
- ~5cm → ~2.5cm



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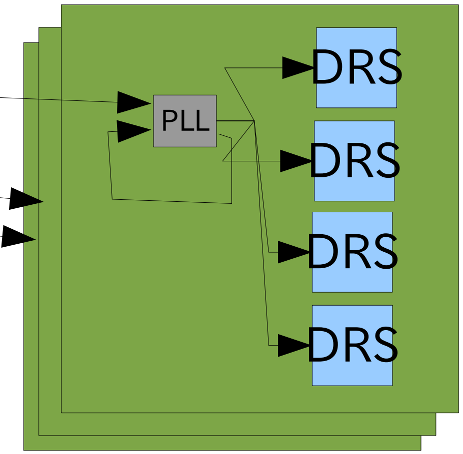
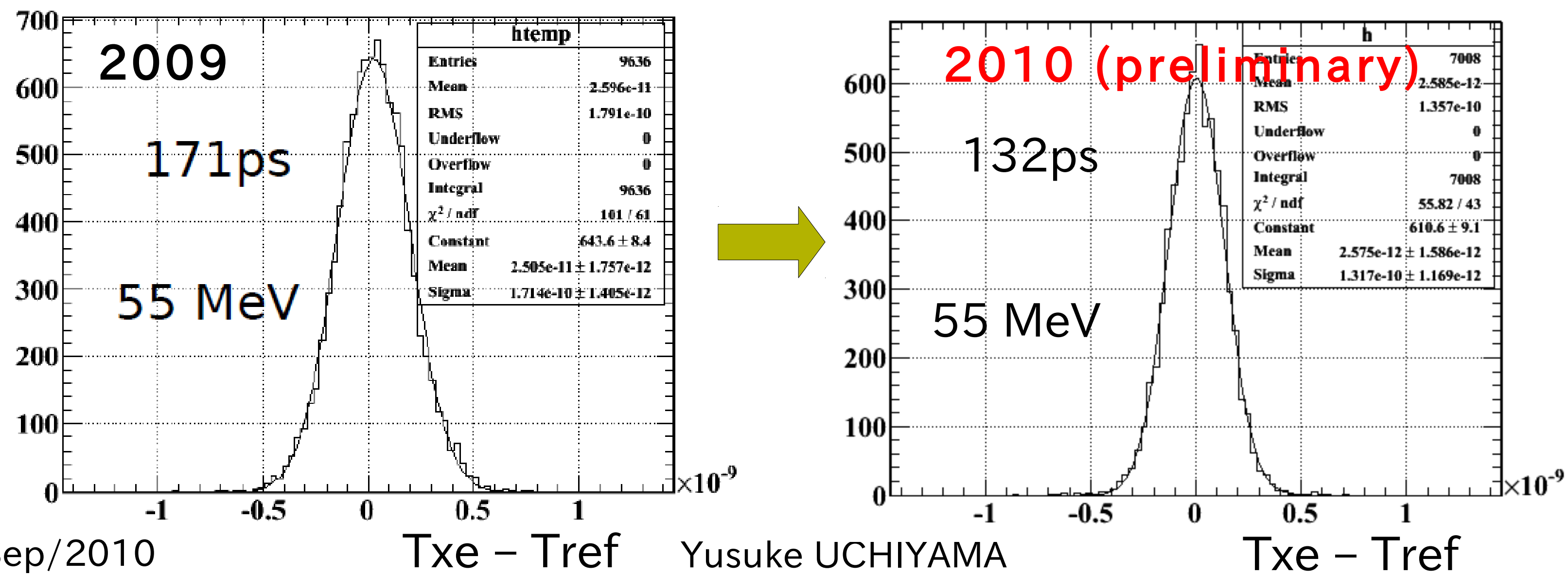
Electronics Timing Accuracy

- In 2009, we introduced new version of waveform digitizer (DRS4)
  - Low noise, better linearity
  - Sampling frequency is regulated by PLL
  - However, found to have worse timing accuracy
  - 2009 timing resolution was largely worsened by the electronics
- Modification during shutdown period
  - Reduce digital noise on acquisition board
  - Optimize PLL regulation circuit to minimize jitter



Time difference of two gamma from π^0 decay

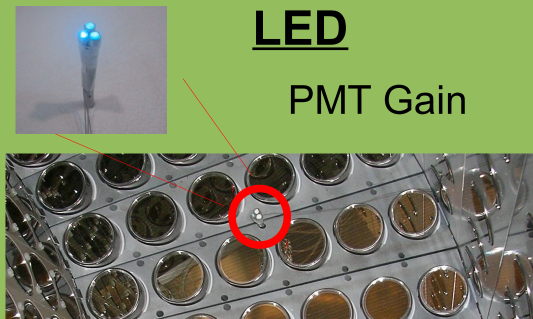


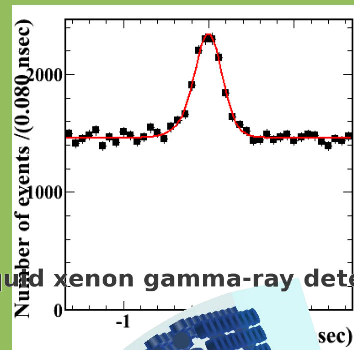
MEG calibrations

Established

LED

PMT Gain



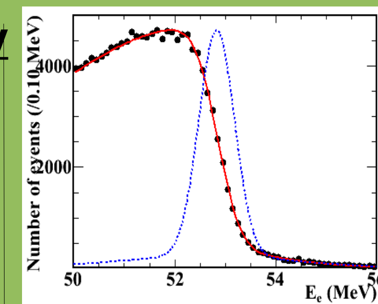


Radiative Decay

$\mu \to e\nu\nu\gamma$

Relative timing

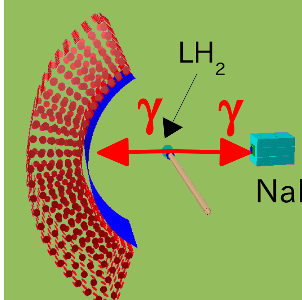
Similar topology



Michel Decay

$\mu \to e\nu\nu$

$\pi^- p \to \pi^0 n$



$\pi^0 \to \gamma\gamma$

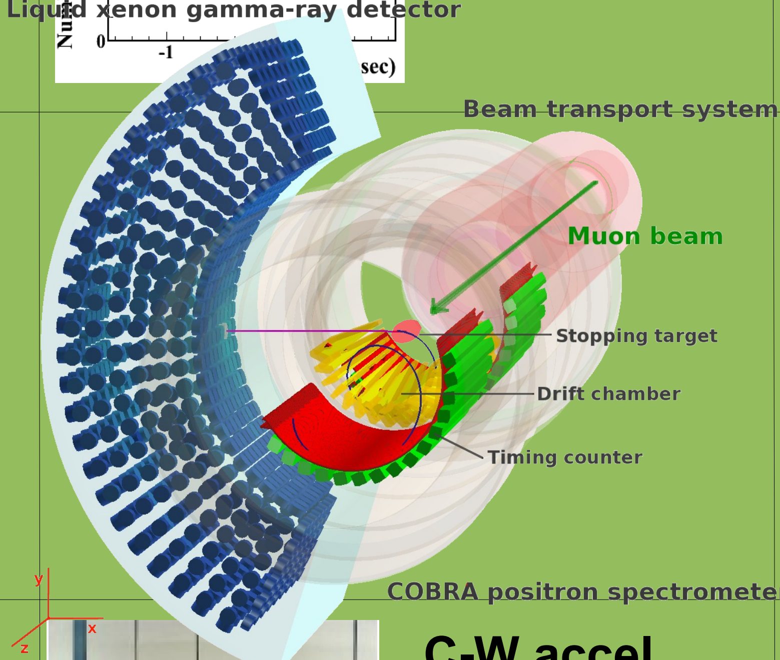
55,83,129MeV

monochoro

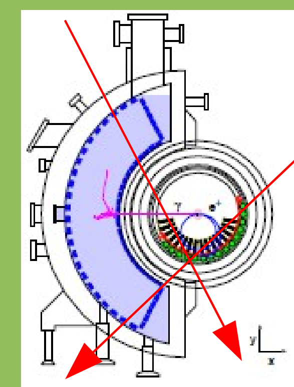
$\pi^0 \to \gamma e^+ e^-$

Relative timing

Similar topology



CosmicRay

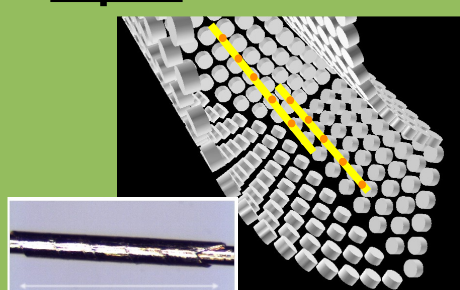


DC alignment

TC uniformity

LXe monitor

Alpha



PMT QE

Am source on wire

C-W accel.

Li(p,γ)Be

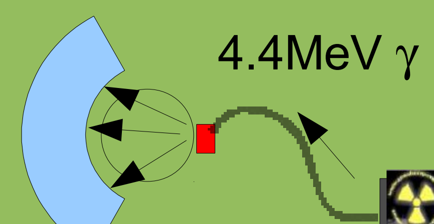
– 18MeV γ

B(p,γ)C

– 4,11MeV 2γ

AmBe

4.4MeV γ source



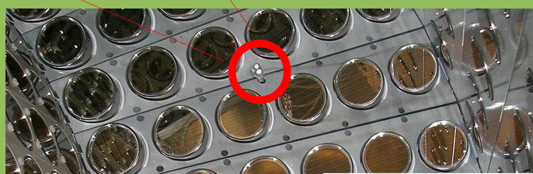
Complementary for completeness

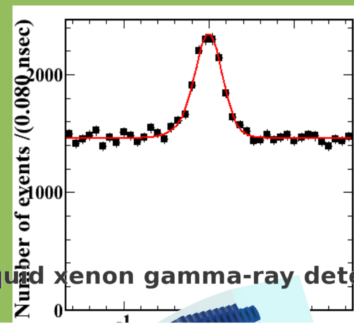
Duplicative for cross check

MEG calibrations

LED

PMT Gain



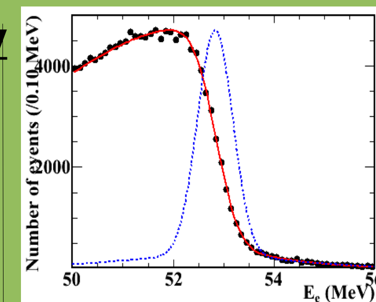


Radiative Decay

$\mu \rightarrow e\nu\nu\gamma$

Relative timing

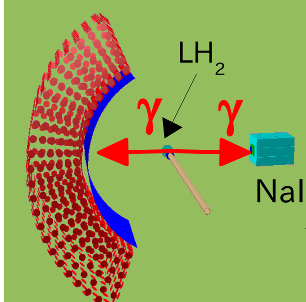
Similar topology



Michel Decay

$\mu \rightarrow e\nu\nu$

$\pi^- p \rightarrow \pi^0 n$



π^0
5
n
π^0
R
Si

- **What's missing ?**
  - **Monochromatic positrons**
  - **Gamma source used in beam ON**
  - **Angle calibration**

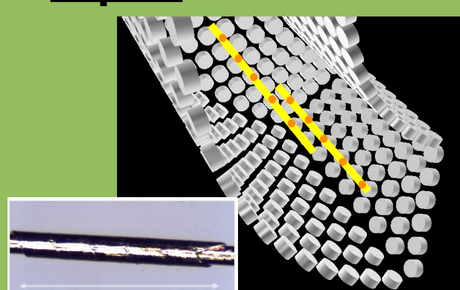
CosmicRay

DC alignment

TC uniformity

LXe monitor

Alpha



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Am source on wire

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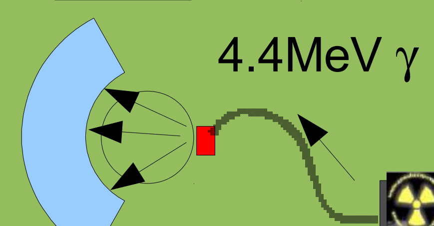
Li(p,γ)Be
- 18MeV **γ**

B(p,γ)C
- 4,11MeV 2**γ**

AmBe

4.4MeV γ source

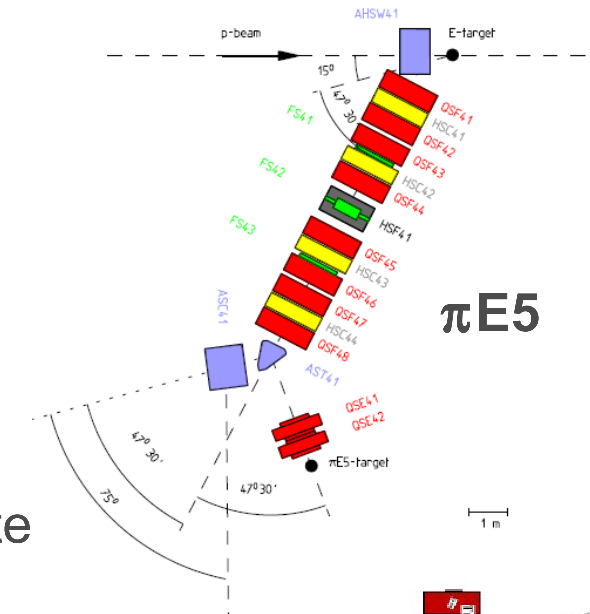


Complementary for completeness
Duplicative for cross check

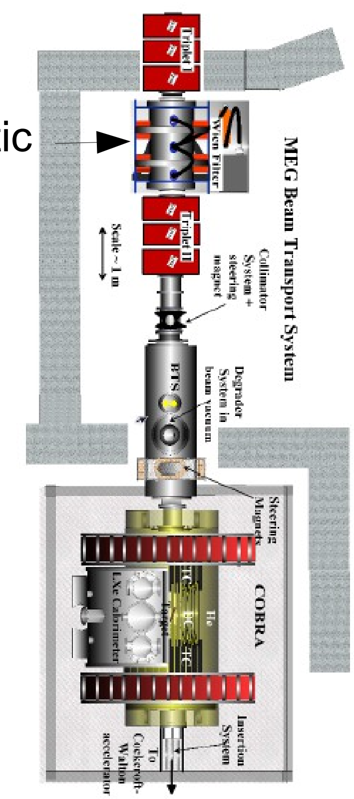
New calibration method 1

- Spectrometer calibration with **e^+ Mott scattering**
  - Coherent elastic scatter of e+ on light nuclei
    - **Precisely known cross-section**
  - **e^+ beam**
    - High intensity @ PiE5 beamline
      - For MEG, e^+ are separated and rejected
    - **Monochromatic, and momentum tunable**
      - Select momentum with low momentum bite (~100keV)
  - **Target** (light nuclei → Carbon is best solution)
    - MEG target (thickness of 205μm)
    - Dedicated target
      - Pure CH2 (thickness of 2mm)
      - Mounted inside COBRA magnet
  - **Calibrate and study**
    - Momentum resolution
    - Efficiency and uniformity
      - Cross section & angular distribution well known

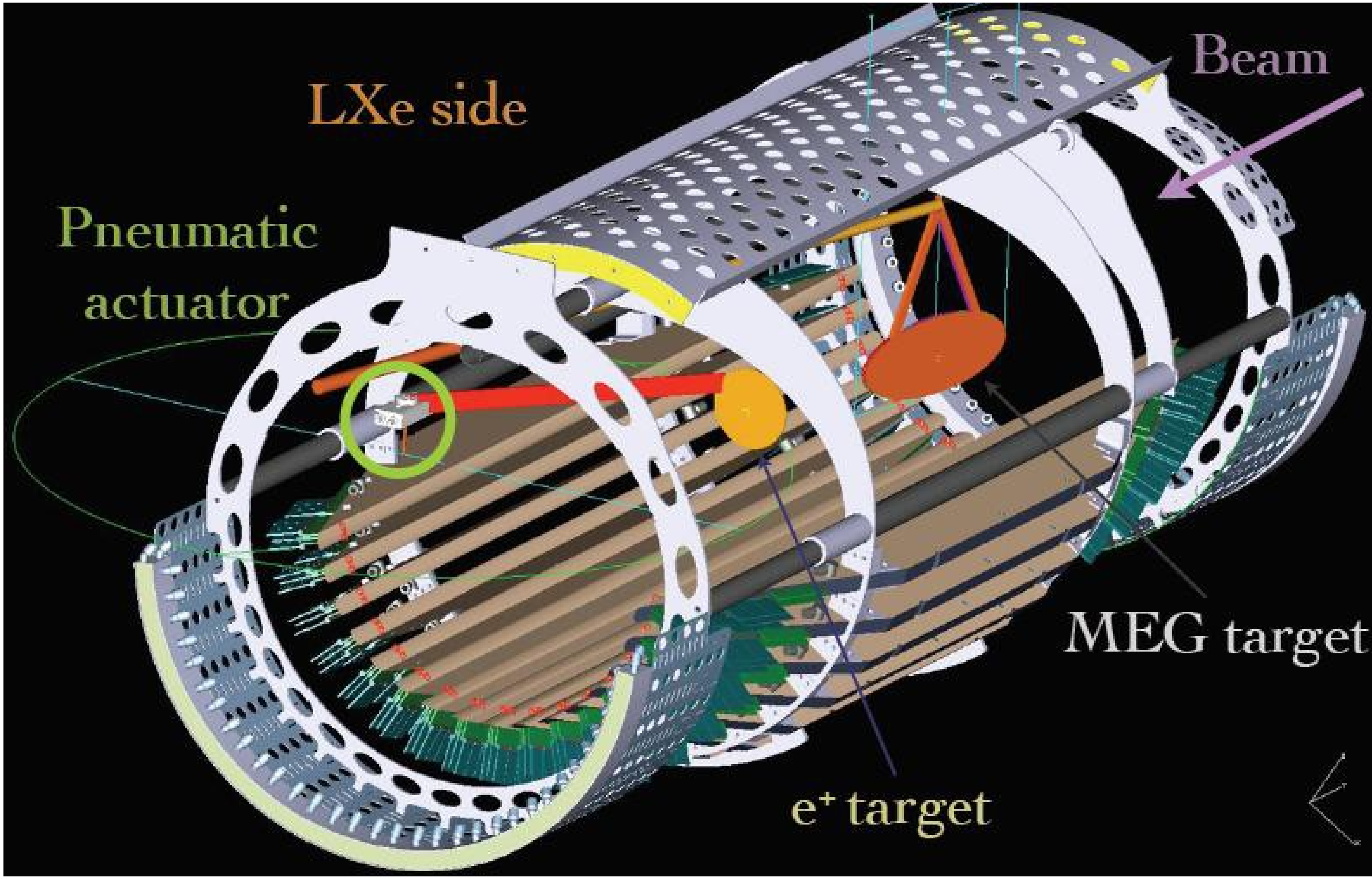
First test in May (feasibility test)
Analysis underway
→ Modification, optimization



electrostatic separator

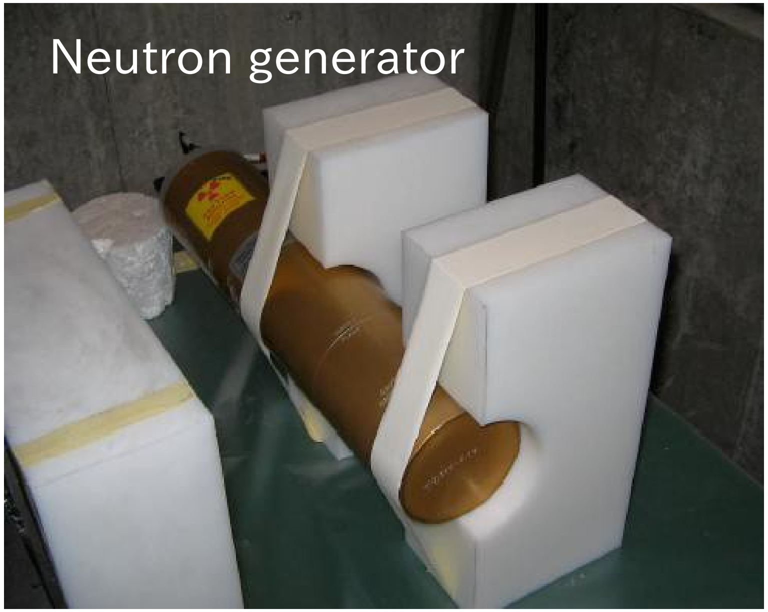


MEG
Mu-E-Gamma Collaboration



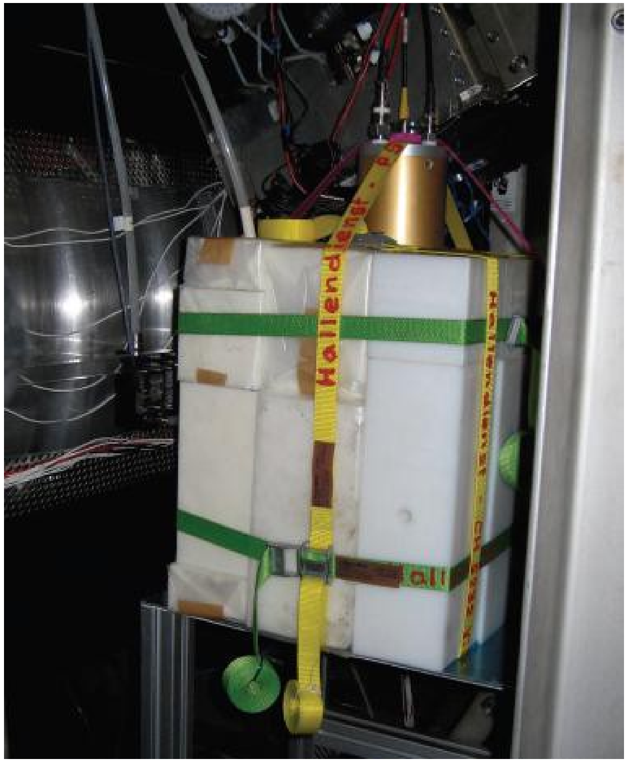
Mounted (May 2010)

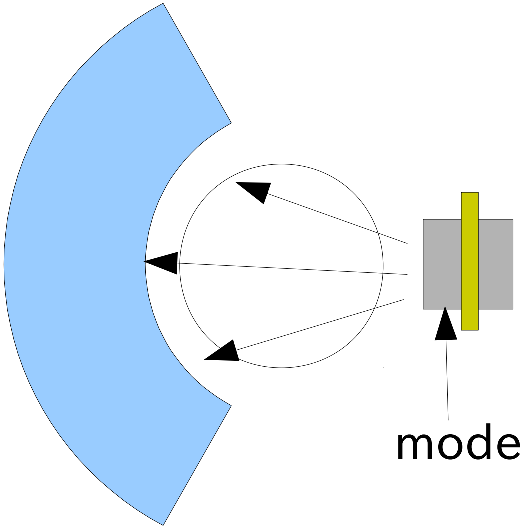
New calibration method 2



- **9 MeV gamma** from n-Ni reaction
  - Thermal neutron capture on Ni
  - Unique possibility of calibrating LXe with gamma under ***beam ON***.
  - **Neutron generator** as n-source
    - D-D reaction
    - Pulsed operation (better S/N under beam condition)
    - Easy to switch ON/OFF
      - Frequent monitoring (any time)

Installed (June 2010)





2010 Expectations

Expected performance

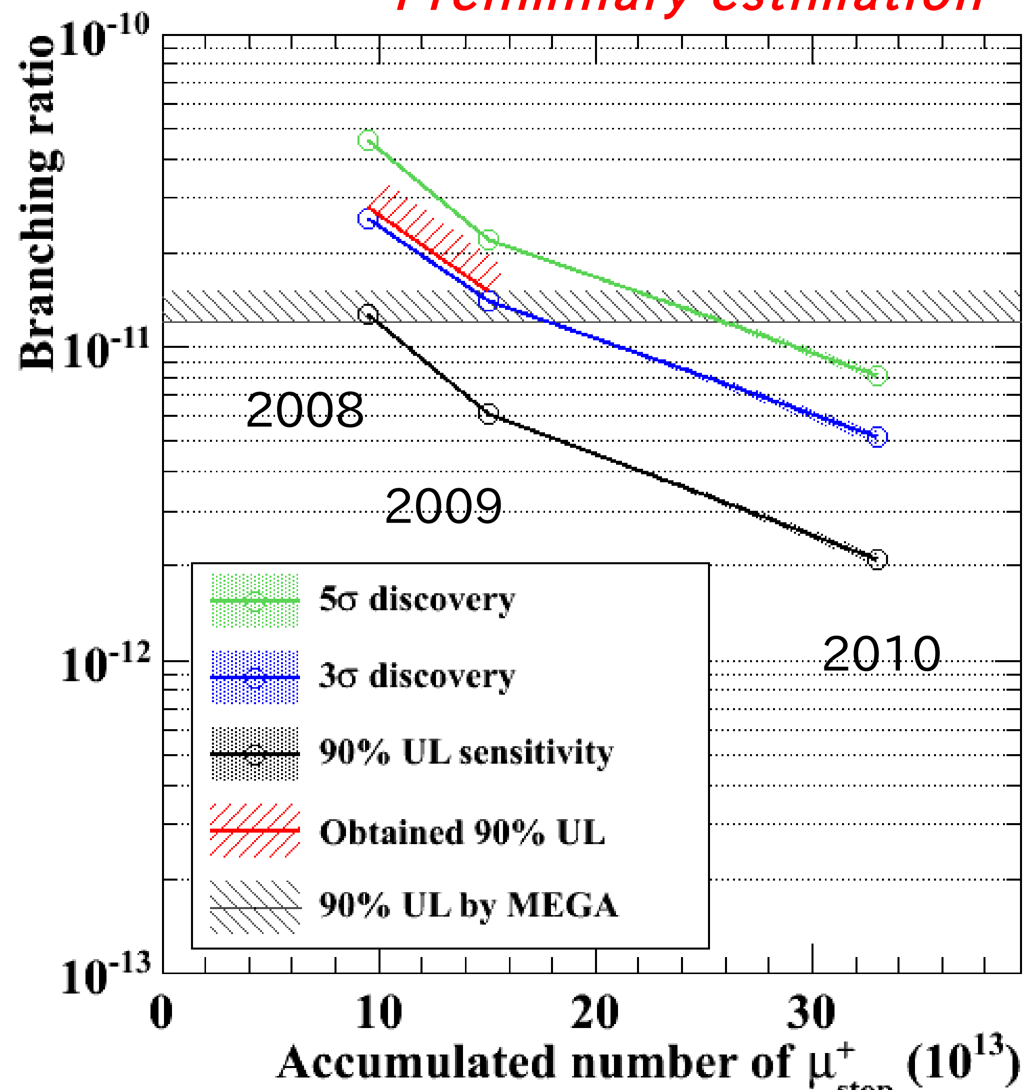
	2008	2009(preliminary)	2010(preliminary estimate)
Gamma energy (%)	2.0 (w>2cm)	←	1.5(w>2cm)
Gamma timing (psec)	80	>67	68
Gamma position (mm)	5(u,v) / 6(w)	←	←
Gamma efficiency (%)	63	58	←
Positron momentum (%)	1.6	0.74(core)	0.7
Positron timing (psec)	<125	<95	←
Positron angle (mrad)	10(ϕ) / 18 (θ)	7.4(ϕ,core) / 11.2(θ)	8(ϕ) / 8(θ)
Positron efficiency (%)	14	40	40
e+-g timing (psec)	148	142(core)	120
Muon decay point (mm)	3.2(R) / 4.5(z)	2.3(R) / 2.8(z)	1.4(R) / 2.5(z)
Trigger efficiency (%)	66	84	84-94
DAQ time/Real time (days)	48 / 78	35 / 43	95 / 117

For detail,
→ 13pSM3 "MEG実験液体キセノン検出器の性能" 白雪
→ 13pSM2 "MEG実験用電子スペクトロメータの性能評価"藤井祐樹

Expected statistics & sensitivity

- 3.1-3.5倍の統計(2009比)
  - 2.7 beam time × 1.15 stopping eff, × trigger eff
- Sensitivity : **(2.0-2.2) x 10^{-12}**
  - cf. S_{2009} = 6.1x10^{-12}
  - Current best UL = 1.2 x 10^{-11} (MEGA 1999)

Preliminary estimation



Summary table

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Trigger efficiency (%)	66	84	84-94
Stopping muon rate (/sec)	3×10^{7}(300μm)	2.8×10^{7}(300μm)	2.9×10^{7}(300μm)
DAQ time/Real time (days)	48 / 78	35 / 43	95 / 117
Sensitivity	1.3×10^{-11}	6.1×10^{-12}	$(2.0\text{-}2.2)\times10^{-12}$
BR upper limit (obtained)	2.8×10^{-11}	1.5×10^{-11}	-

Further prospects, Discussion

- We will run at least until 2012
  - Another two-year full run.
  - No clear schedule for further years
  - We will **clarify the situation (2009 result) by ourselves** with long term stable data taking
- Our goal is a sensitivity of **a few × 10^{-13}**
- To achieve the goal
  - **Gaining statistics is crucial**
  - **Must reduce BG by improving analysis**

Further improvement

- Efficiency and data statistics
  - DAQ and Trigger efficiency by double buffering
    - Current DAQ eff ~ 82%
    - Current TRG eff = 84%
    - → 99x95 %
    - Possibility in our system has been considered since this spring
      - Study underway
      - Possibly implemented from next year
  - e^+ tracking efficiency
    - Even if the full operation of DC, eff is limited to **<50%** due to detector material.
    - Improvement under consideration
      - Use thinner cables, upto 15% improvement
      - Feasibility and design underway, possibly from 2012
    - Drastic improvement requires major upgrade of detector
- Analysis
  - Gamma energy
  - Positron tracking

Strategy for analysis improvement

- Positron tracking
  - Reduce noise, hardware and software
  - Fine tuning of track fitting algorithm

- Gamma energy
  - Understand LXe optical properties
    - MC
      - Reflection with polarization, etc.
    - Improve QE measurement
    - Detail understand of detector
    - Optimize analysis with MC training
  - Fine calibration
    - Stable and better quality data of pi0 run with BGO
    - Uniformity calibration for high energy gamma
  - Develop more sophisticated reconstruct algorithms
  - Possibility of replacing bad PMTs with new ones (2012?)

Summary

- **8月頭から既に物理ランを再開**
  - ３年目、スムーズに。
  - 色々最適化を進めている。

- **新しいキャリブレーション方法を試行**

- **期待される実験感度の見積り**
  - ~3倍の統計を貯められる。(2009比)
  - 期待感度：~2 x 10^{-12}

- **今後の長期ランで2009結果の状況をはっきりさせることができる**
  - 最低3年走る。
  - 目標感度に到達するには、統計を如何に稼ぐかが非常に重要。
  - BGを落とすために解析を鋭意改善

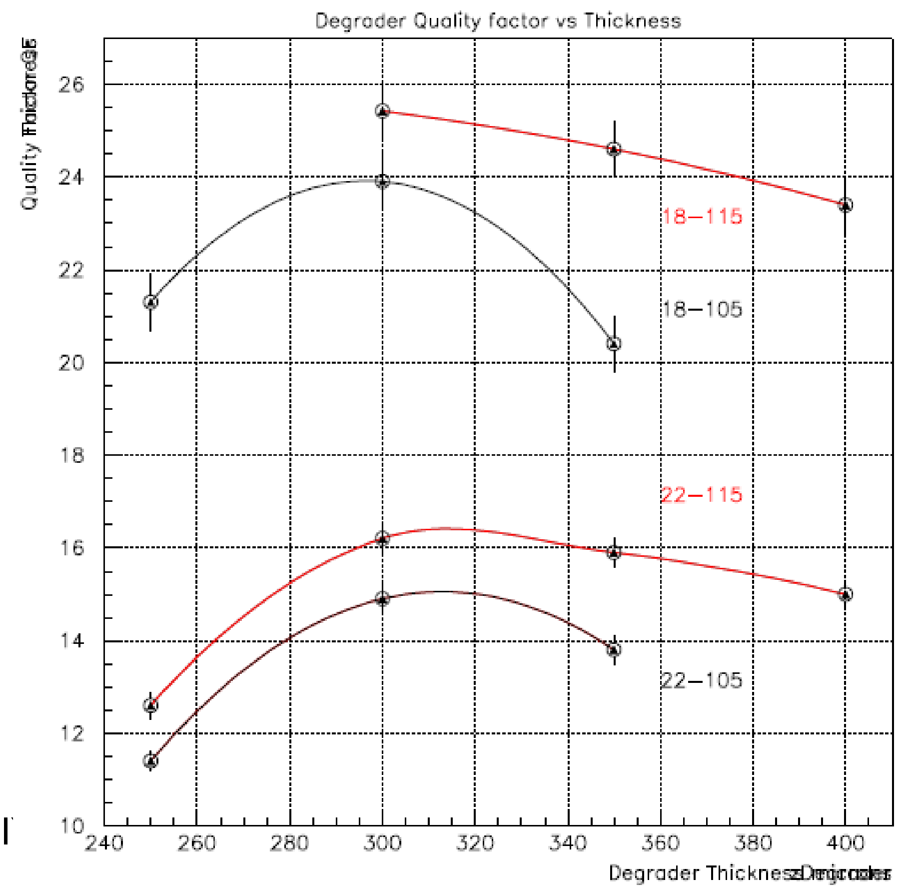
Quality factor for Beam optimization

Trigger#22:
TC trigger

$$QF = \left(\frac{N_{GOOD}}{N_{TC-Clusters}}\right) \bullet \frac{N_{TOT-TRG\#22}}{\langle I_P \rangle \cdot T_{TOT}} \bullet \sqrt{\frac{N_{GOOD}}{N_{TC-Clusters}}}$$

Trigger#18:
DC trigger

$$QF = \left(\frac{N_{GOOD}}{\langle I_P \rangle \cdot T_{TOT}}\right) \bullet \frac{N_{TOT-TRG\#18}}{\left(N_{TRG\#18}\right)_{REC}} \bullet \sqrt{\frac{N_{GOOD}}{\left(N_{TRG\#18}\right)_{REC}}}$$

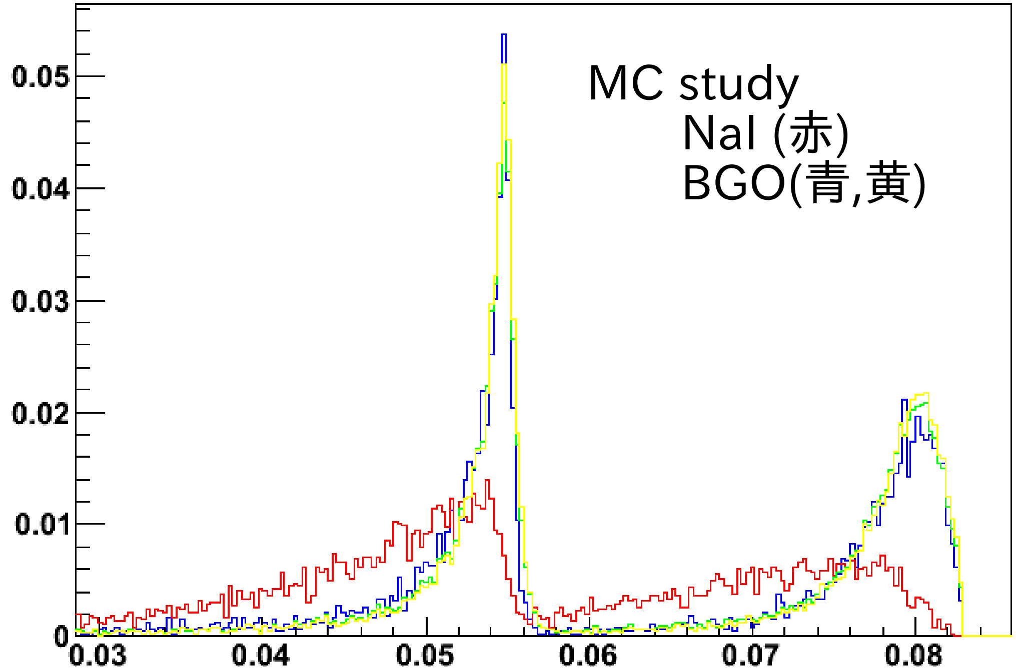


Improve pi0 data with BGO

- Use BGO instead of NaI
  - Higher efficiency, better resolution(位置,エネルギー
  - First test done with 16 crystals on Sep.2010

	LXe	LAr	NaI(Tl)	CsI(Tl)	BGO	LSO(Ce)	$PbWO_4$
Density (g/cm^3)	2.98	1.40	3.67	4.51	7.13	7.40	8.3
Radiation length (cm)	2.77	14	2.59	1.86	1.12	1.14	0.89
Mollier radius (cm)	4.2	7.2	4.13	3.57	2.23	2.07	2.00
Decay time (ns)	45	1620	230	1300	300	40	30/10[1]
Emission peak (nm)	178	127	410	560	480	420	425/420[1]
Relative output	75	90	100	165	21	83	0.083/0.29[1]

[1] slow/fast component



Relative alignment with CR

- Alignment of detectors
  - Optical survey
  - Photogrametric survey
  - Farogauge
  - Michel positron for spectrometer
  -
  - Relative alignment b/w Lxe and spectrometer
    - Took CR w/o magnetic field (May 2010)
    -
  - Reduce uncertainty of relative angle.