MEG Calibrations

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MEG Review meeting February 2010

Outlook

- Introduction
- Cockcroft-Walton accelerator
- Am-Be source
- CEX reaction
- LED
- Alpha-sources

- Neutron generator
- Positrons

Introduction

- Calibrations during 2009
  - methods and upgrades
- Use of the shutdown to further improve the calibration methods
- Opportunity for reaching a performance plateau

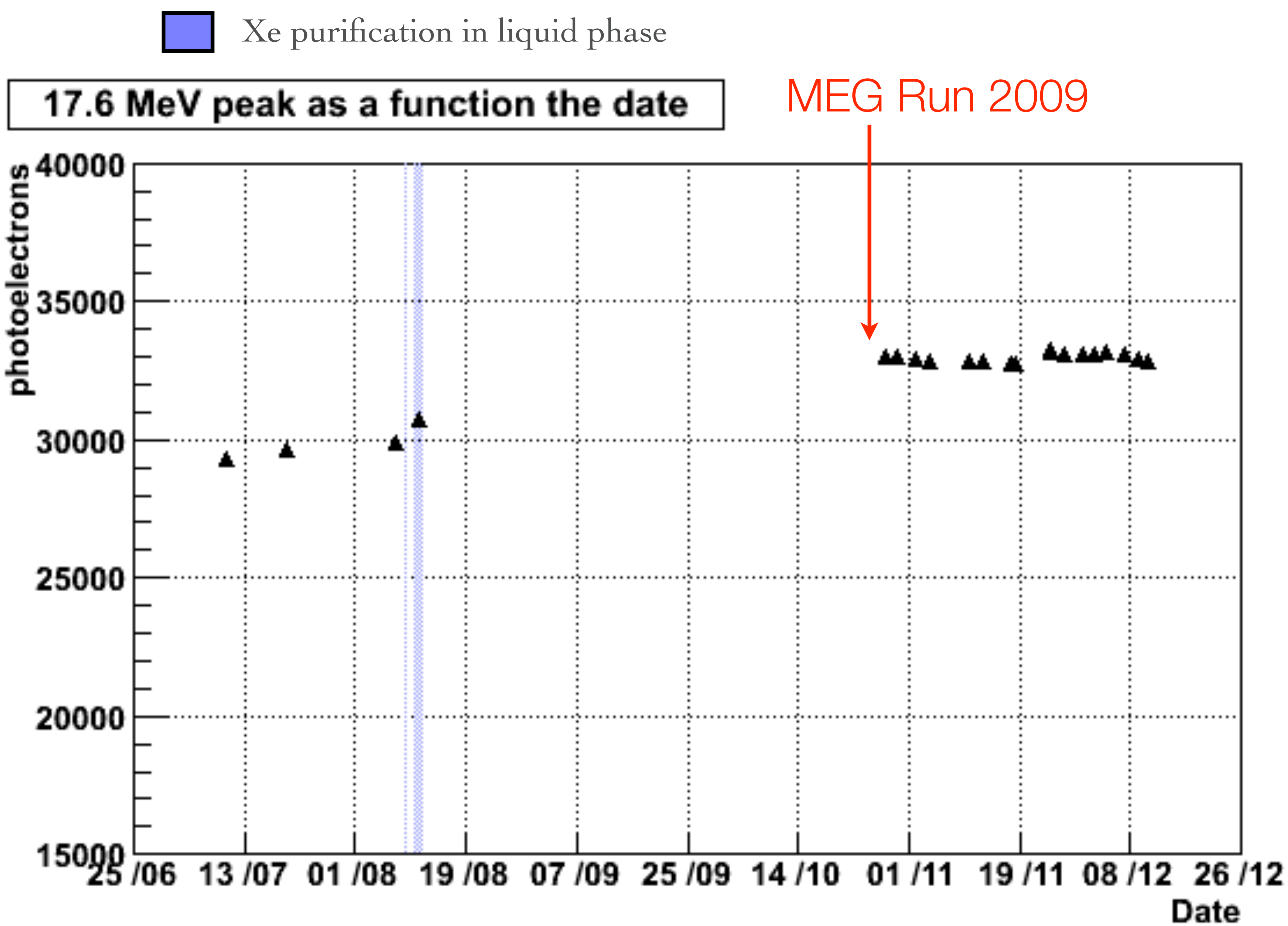
LXe calorimeter and TC

Cockcroft-Walton accelerator

- Gamma line at different energies (17.6 MeV, 12 MeV, 4.4 MeV)
  - LXe light-yield monitoring
  - LXe calorimeter energy resolution
  - LXe calorimeter uniformity
- Time coincident gammas
  - LXe calorimeter-TC timing

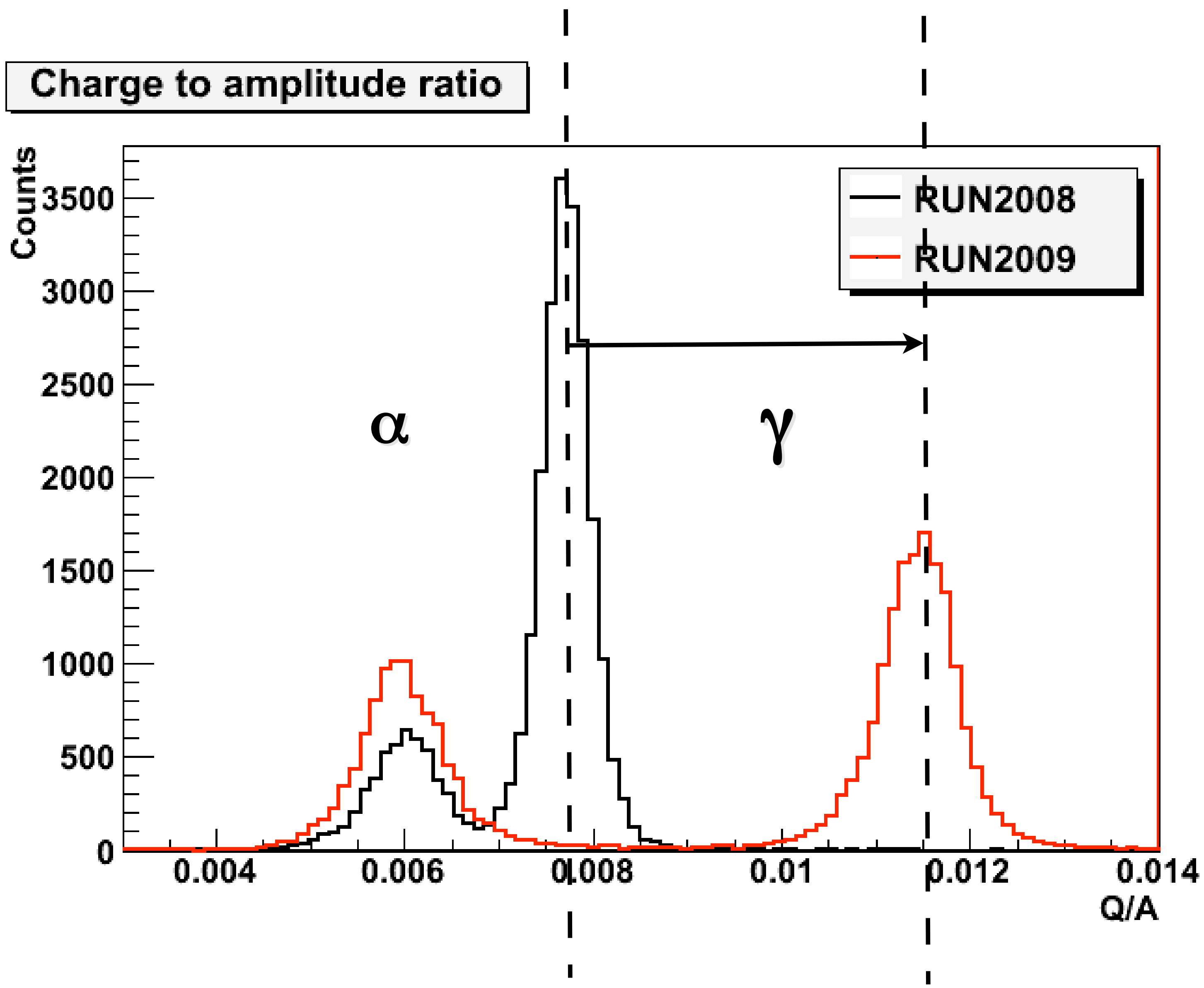
LXe LY monitoring 2009

- LY stable at the 1% level during data taking 2009



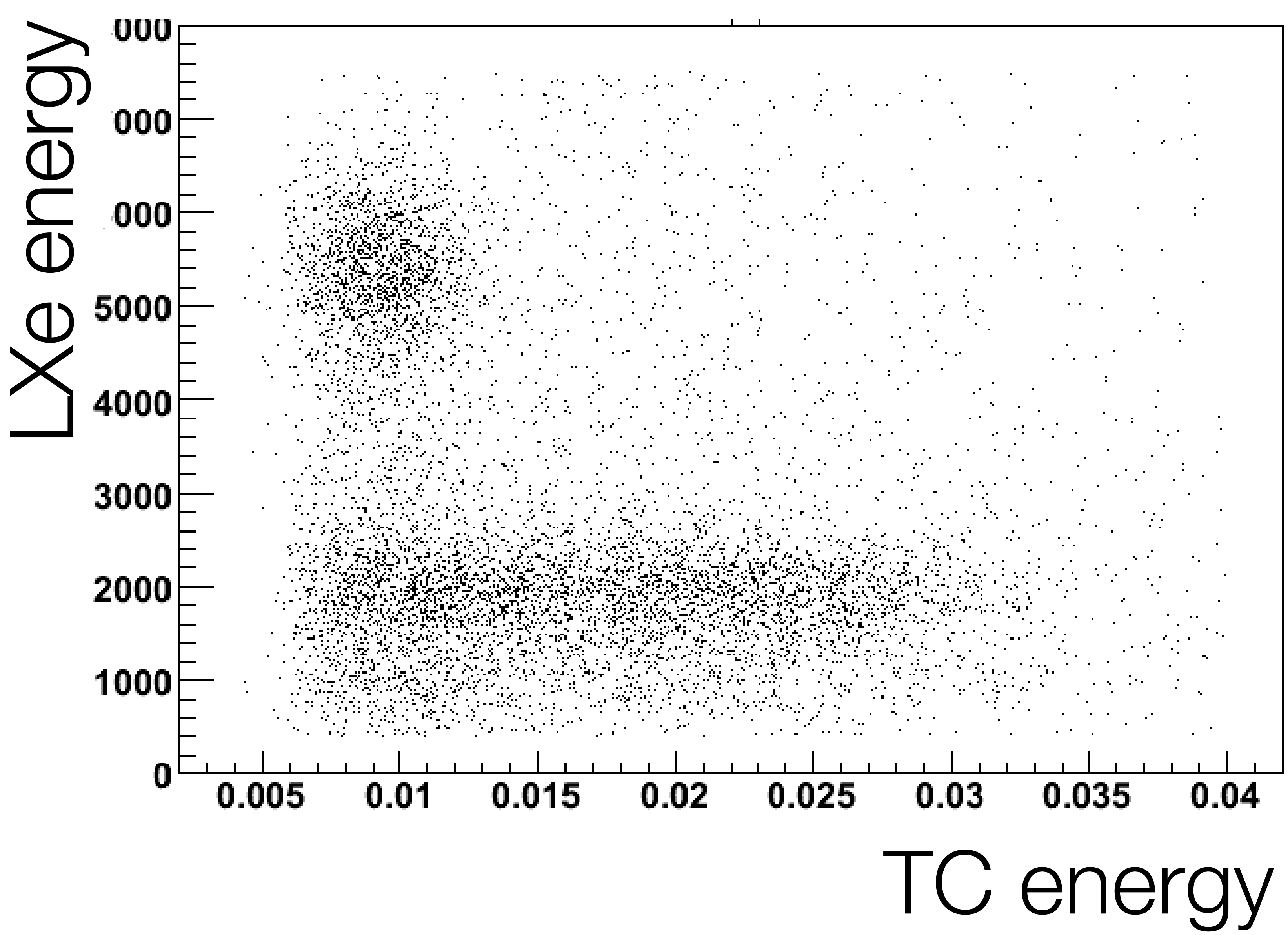
Alpha and gamma separation

- Charge to Amplitude ratio (Q/A)
  - Q/A of gamma increased by purification
  - Clear alpha and gamma separation based on pulse-shape



LXe-TC timing

- Boron data: coincident gammas

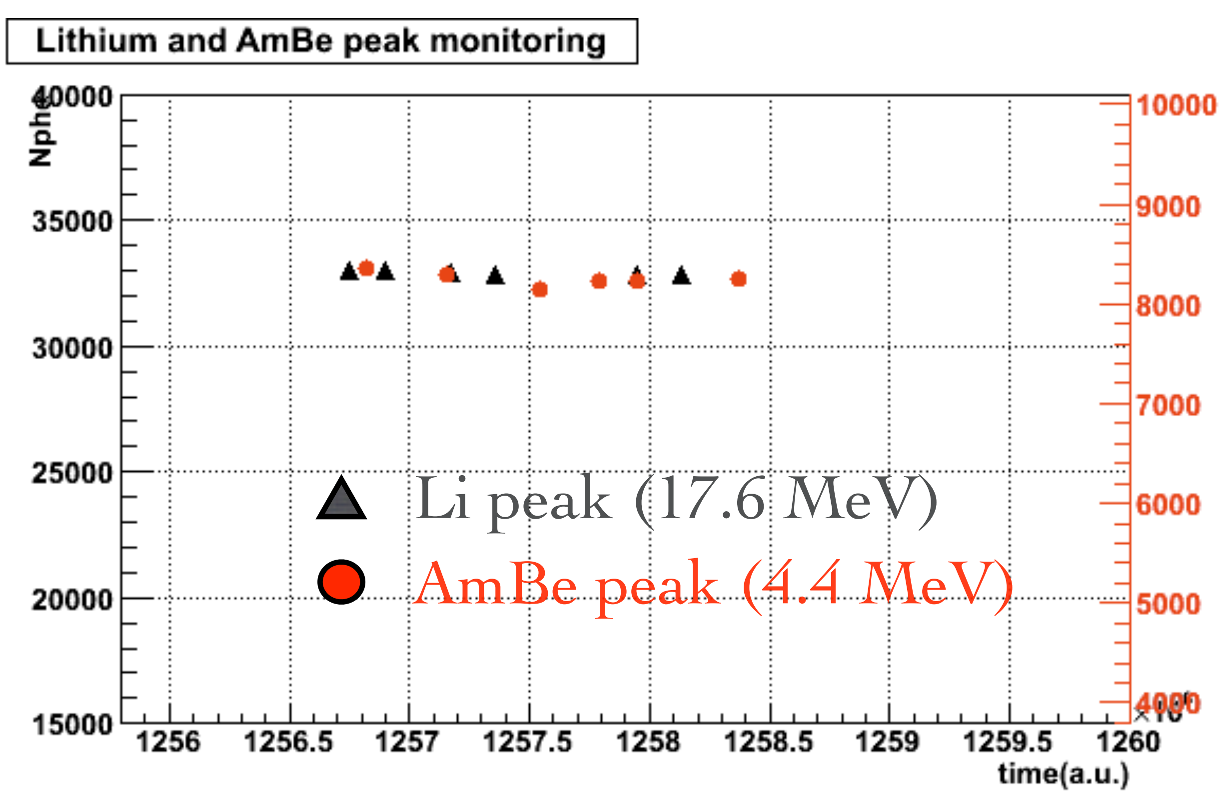


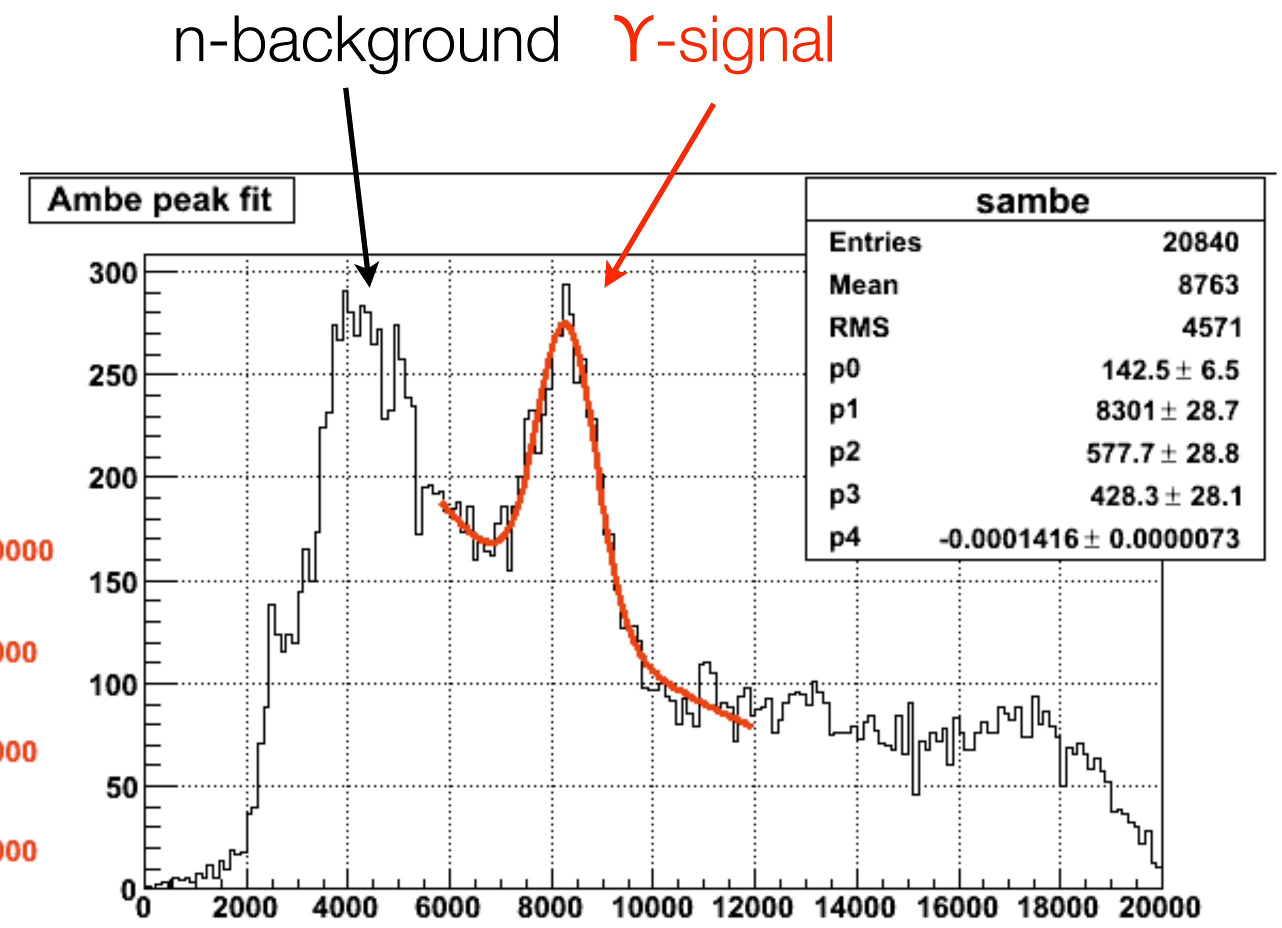
2010 improvements: CW beam-line set-up

- New Turbo pumping station (primary + turbo pumps)
- New vacuum pressure gauge
- New UPS system (PC for the CW)

Am-Be source (4.4 MeV from C^* de-excitation)

- Backup method during C-W maintenance, dismounted CW beam-line, etc.
- Neutron Activity ~20 KBq (PSI source)
- Calibration time: 20 min
- No background subtraction



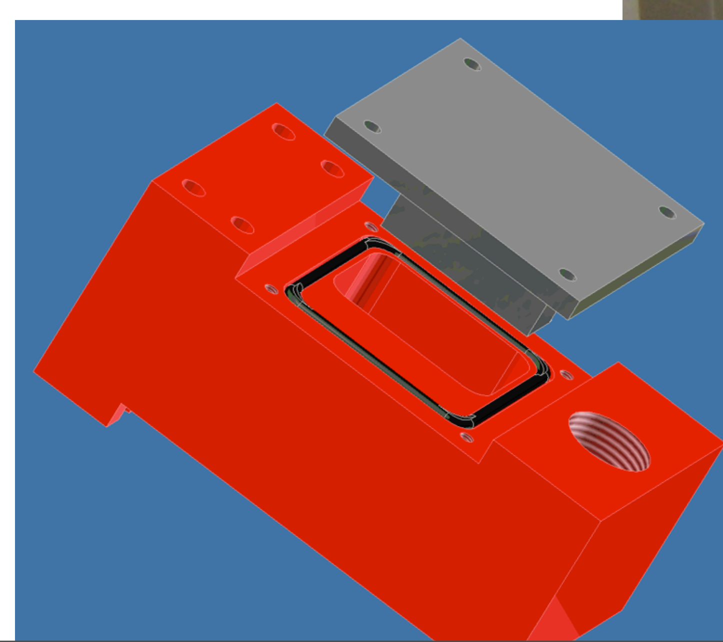


2010 improvements: MEG Am-Be source

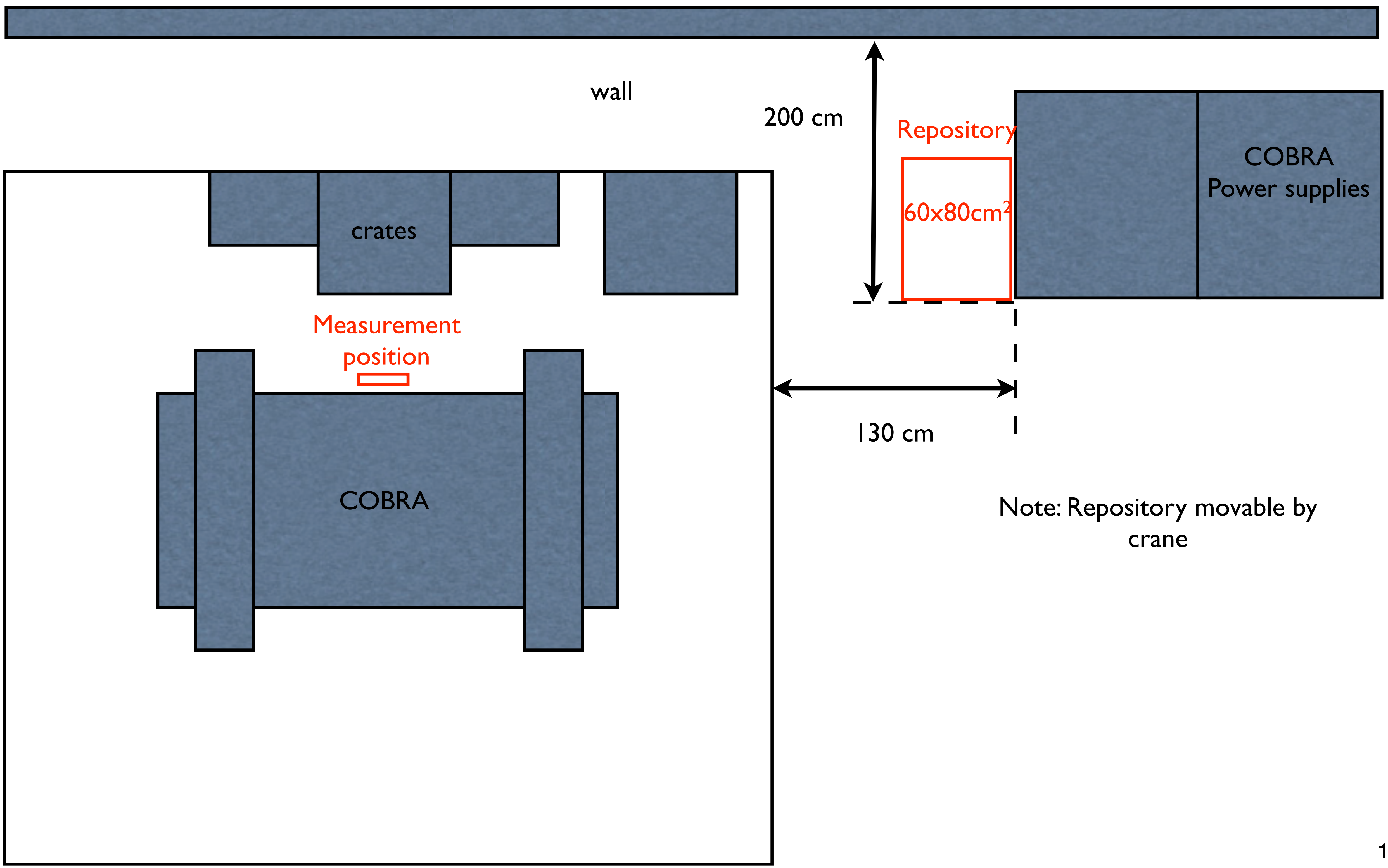
- New source: Neutron activity ~50 KBq (2.5 x PSI one)
- Calibration time: 10 min
- Remote control to reduce neutron exposure and loss of time
  - Compressed air circuit
  - Safe source repository
  - Position sensors
  - Labview interface

Compressed air circuit

- Repository: polietylene (50x50x50 cm^3) surrounded by lead (5 cm thickness)
- Position sensors: microswitches mounted on “ad-hoc” stoppers
- System already tested
- Determination of the source magnetic properties
- Labview control ready
- To be completed:
  - microswitches and electrical valves



Am-Be set-up



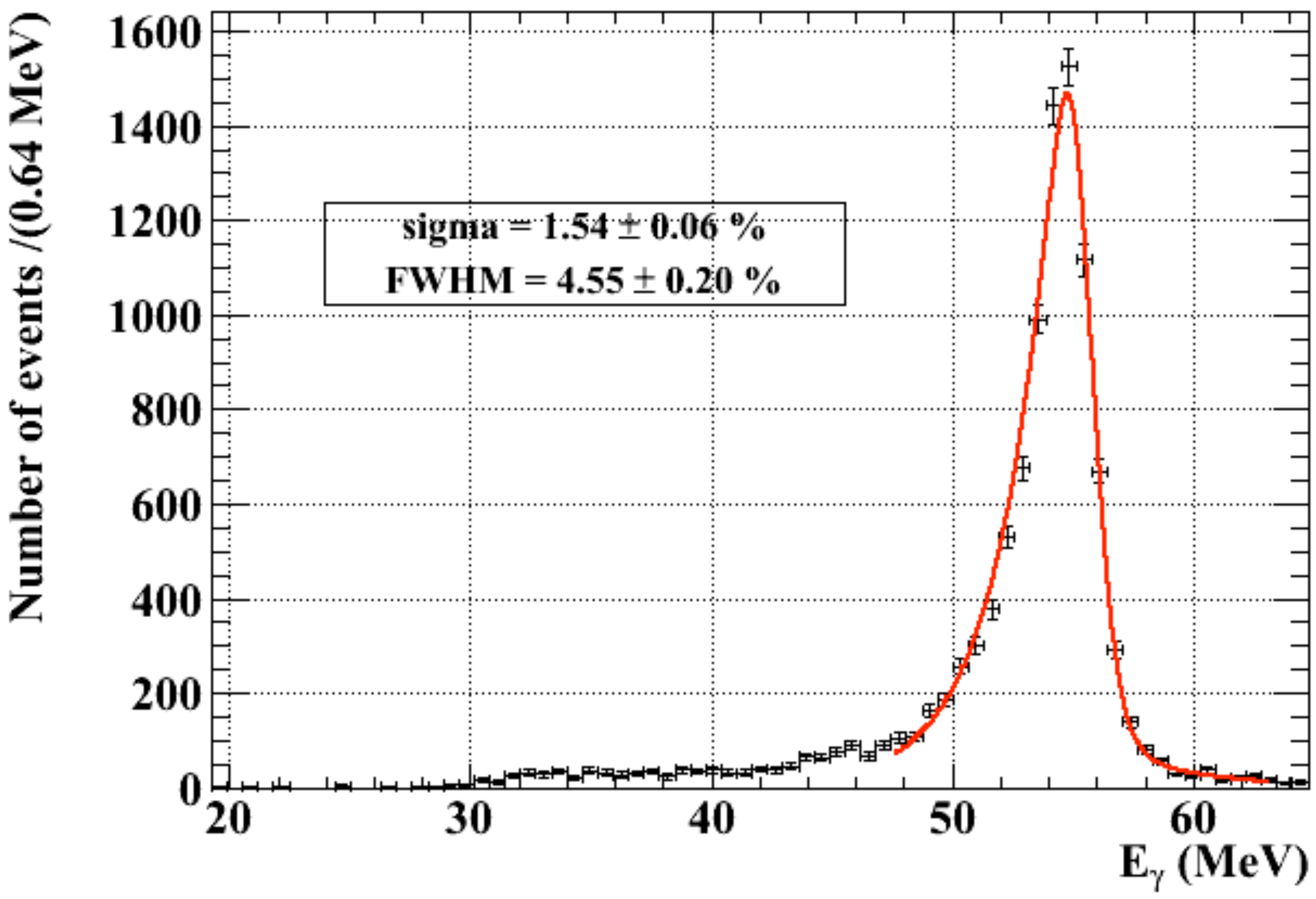
wall
200 cm
Repository
60x80cm²
COBRA
Power supplies
crates
Measurement
position
130 cm
COBRA
Note: Repository movable by
crane

CEX runs $\pi^-(p,n)\pi^0$

- Concident gammas at 54.9 MeV and 82.9 MeV ($\pi^0 \rightarrow \gamma\gamma$)
  - LXe calorimeter energy, timing and position resolution at an energy close to the MEG signal
  - LXe calorimeter energy linearity
  - LXe calorimeter uniformity
  - LXe calorimeter efficiency
- Dalitz events for timing ($\pi^0 \rightarrow \gamma e^+ e^-$)

LXe energy resolution

- σ/E @ 52.8 MeV ~ 1.95 %

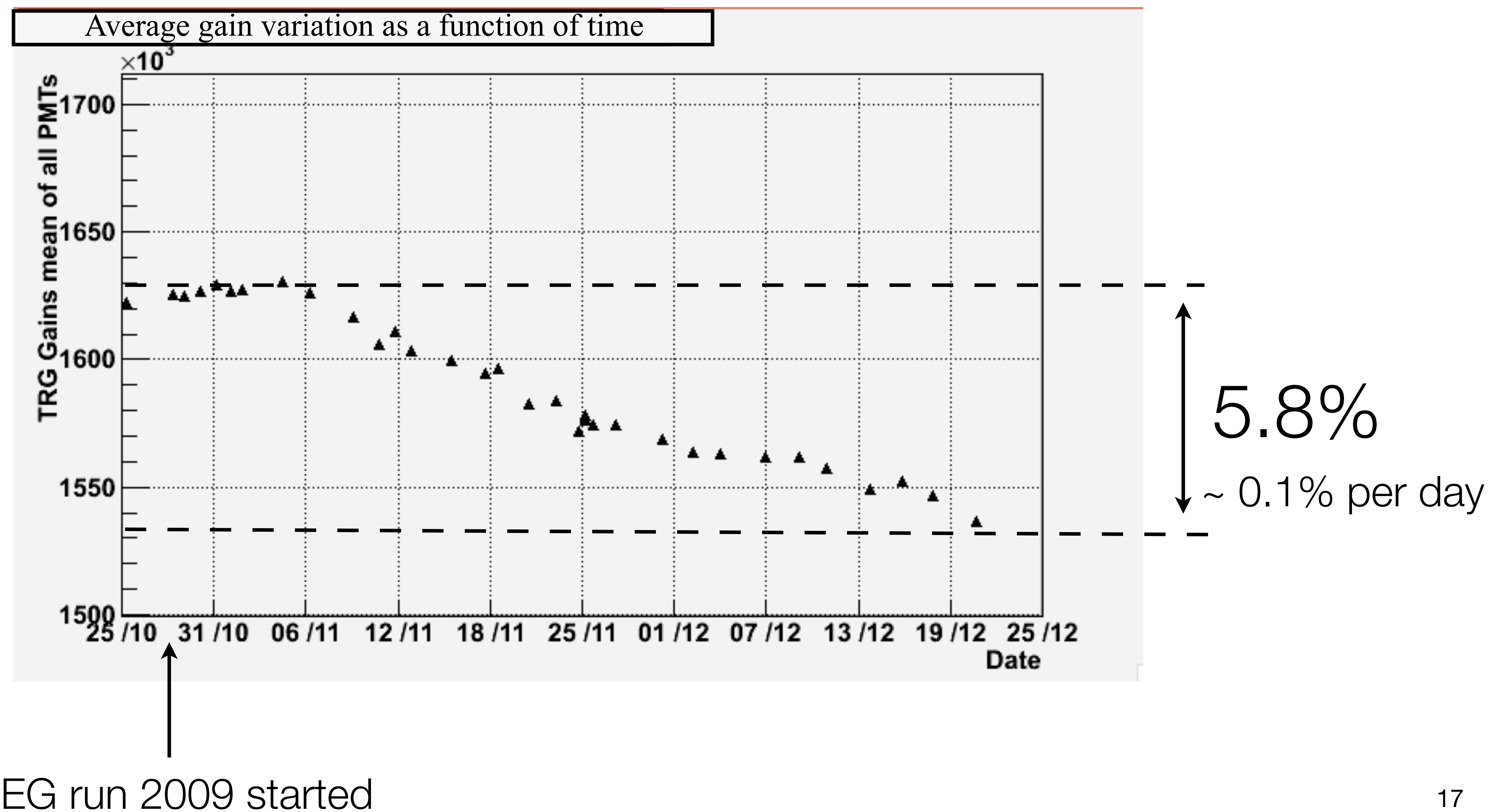


LED runs

- Gain determination and gain time-variation
- Relative PMT gain variation with/without beam (muons/pions)

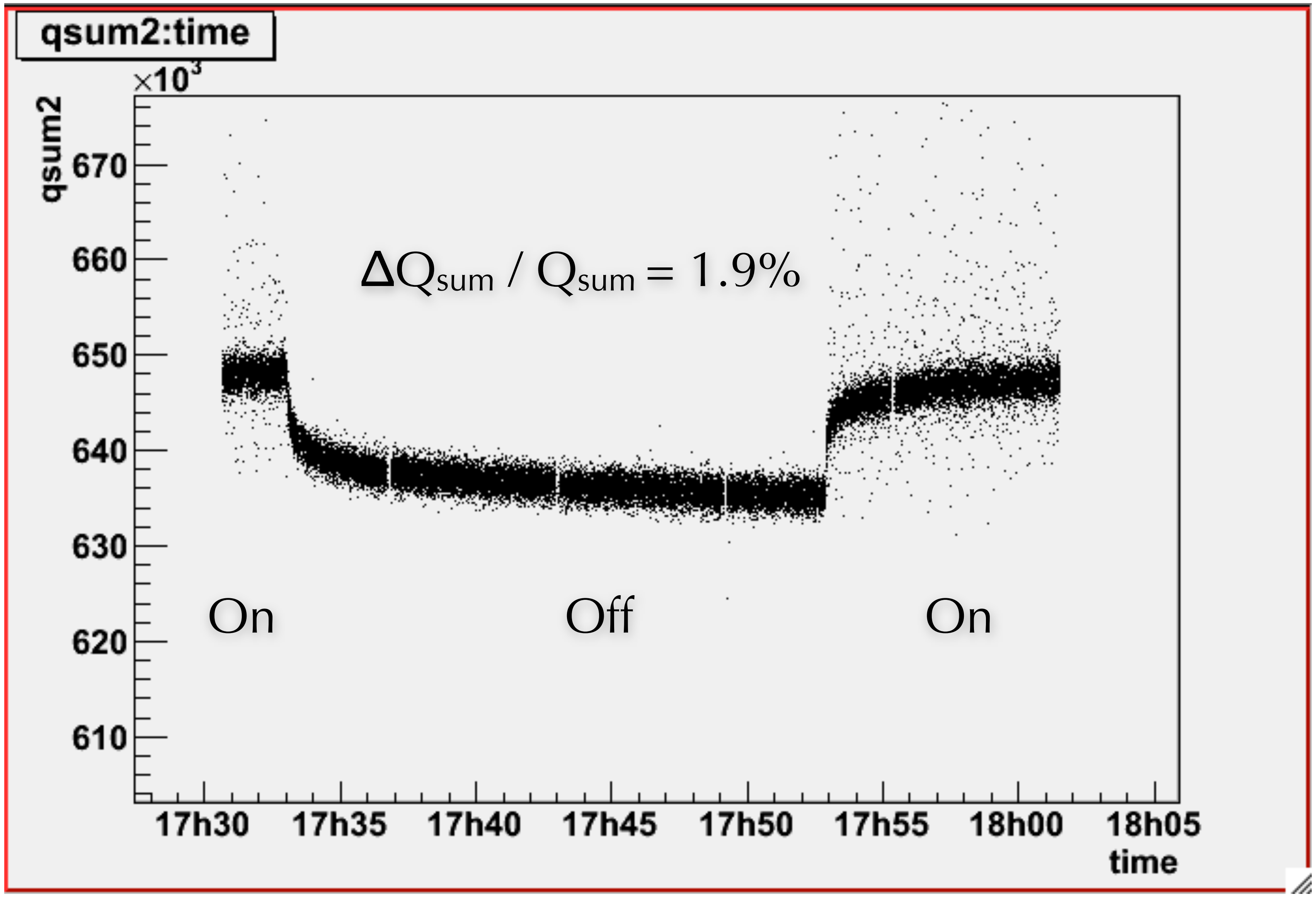
PMT gain monitoring

- Beam Off (alpha-CW-AmBe calibrations)
- Similar behavior with Beam On (MEG runs)



Relative PMT gain variation with/without beam

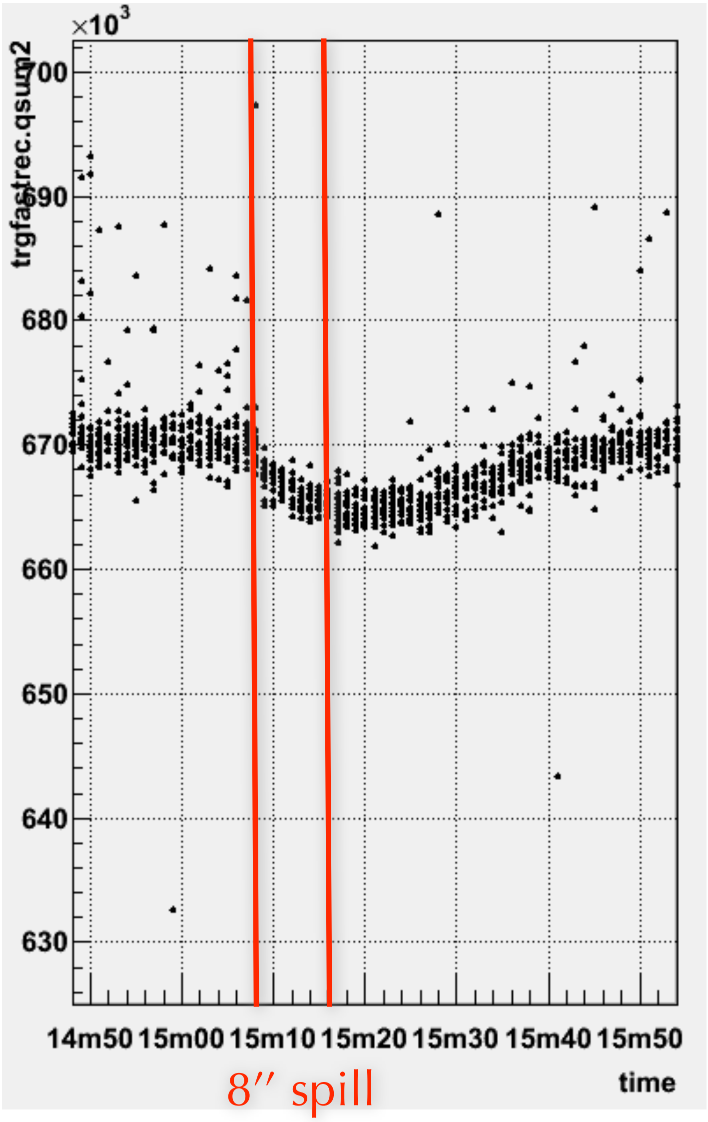
- Same behavior is observed for π^0 runs (3%) and for MEG runs (1.9%)



Cyclotron 2010 plans for Ultra Cold Neutron spill

- Proton current for MEG disappears for 8 seconds every 900 seconds
  - abrupt transition for LXe calorimeter PMTs

Can the effect be corrected by the injection of pulsed-light into the calorimeter?

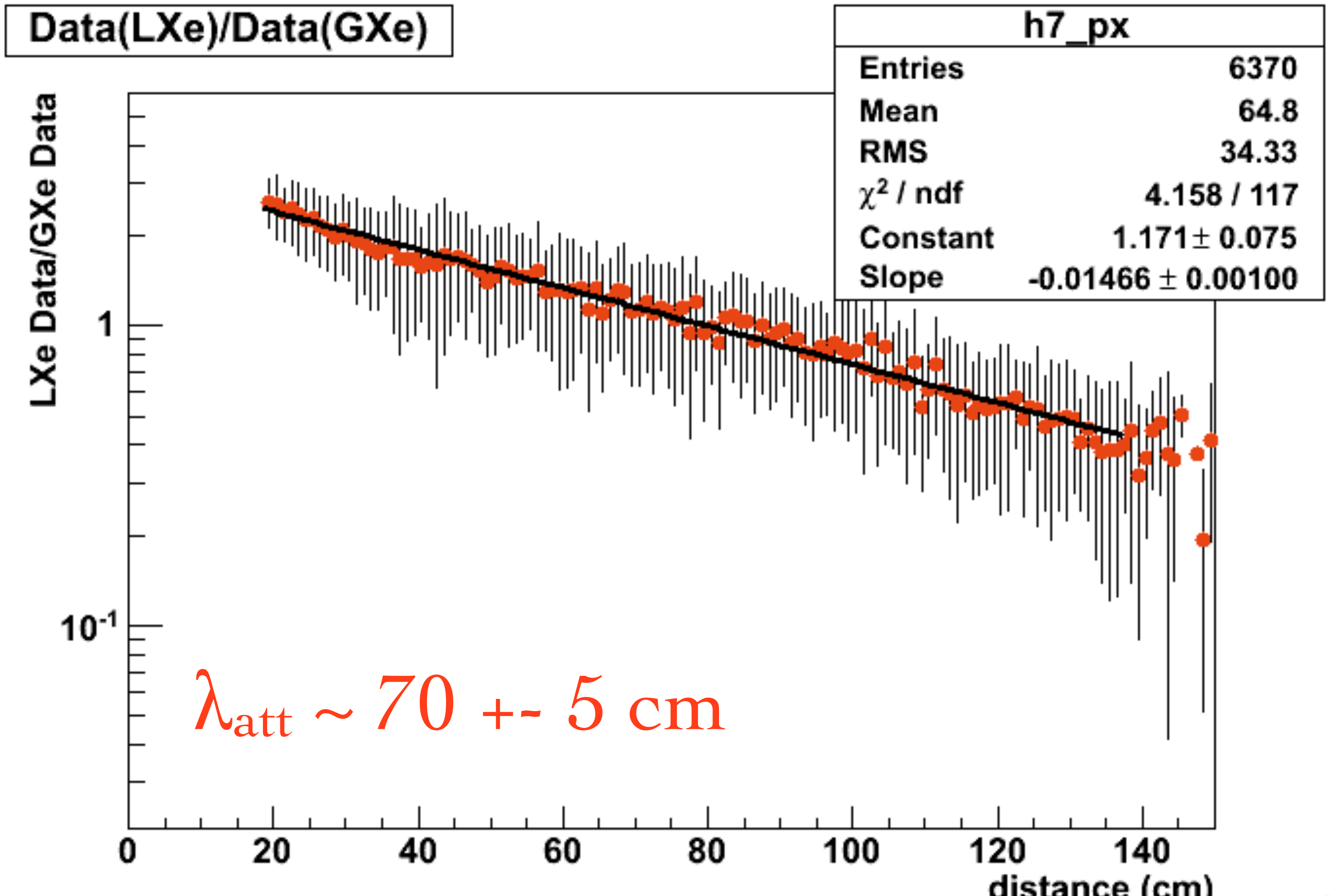


Alpha-runs

- Alpha events: known position and energy
- LXe optical properties
  - λ_{att} , λ_{abs}
- QE determination
- LXe light monitoring

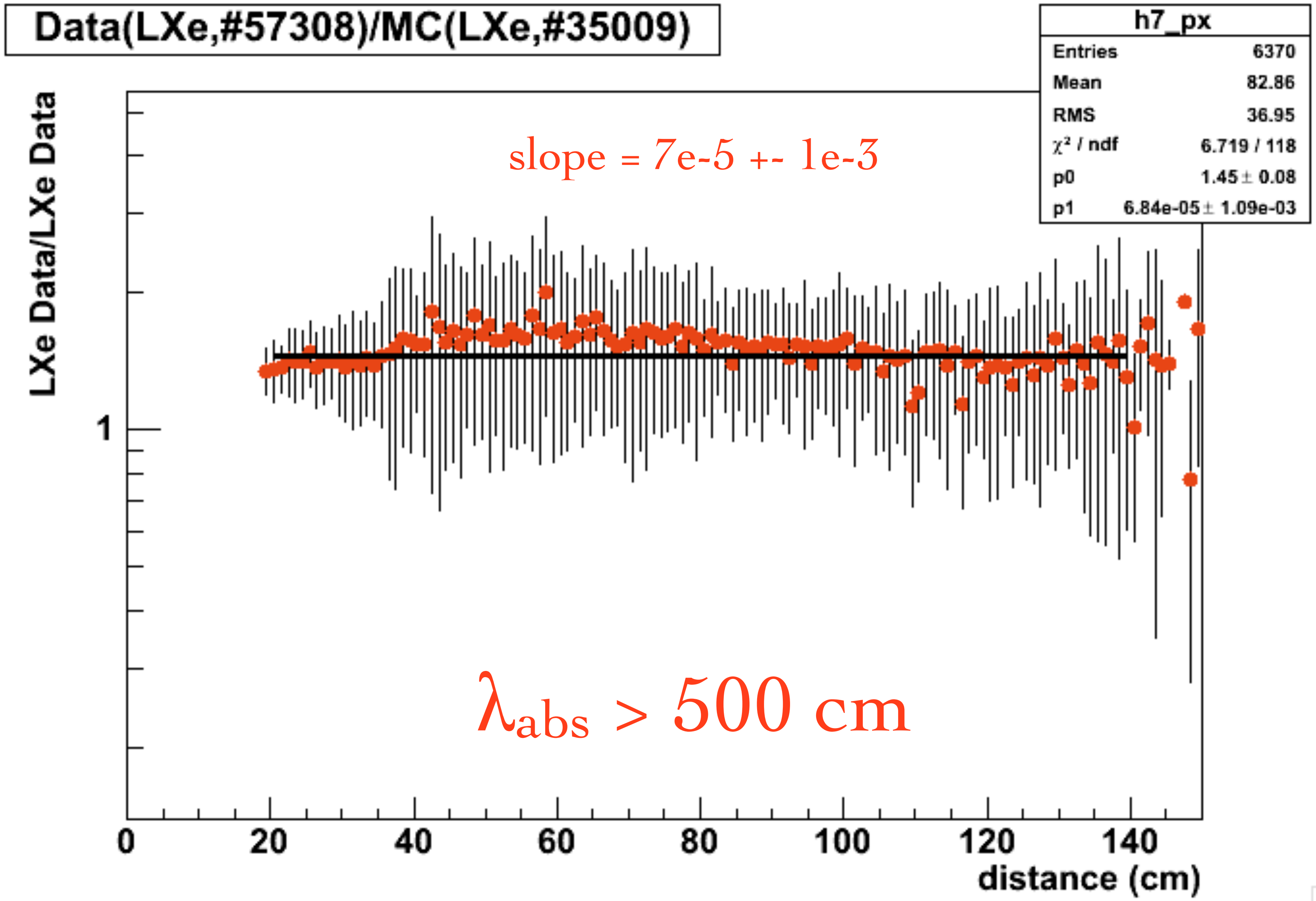
λ_{att} measurement

- Data sample
  - LXe data, id = 57308, 2009
  - GXe data, id = 42397, end of 2008



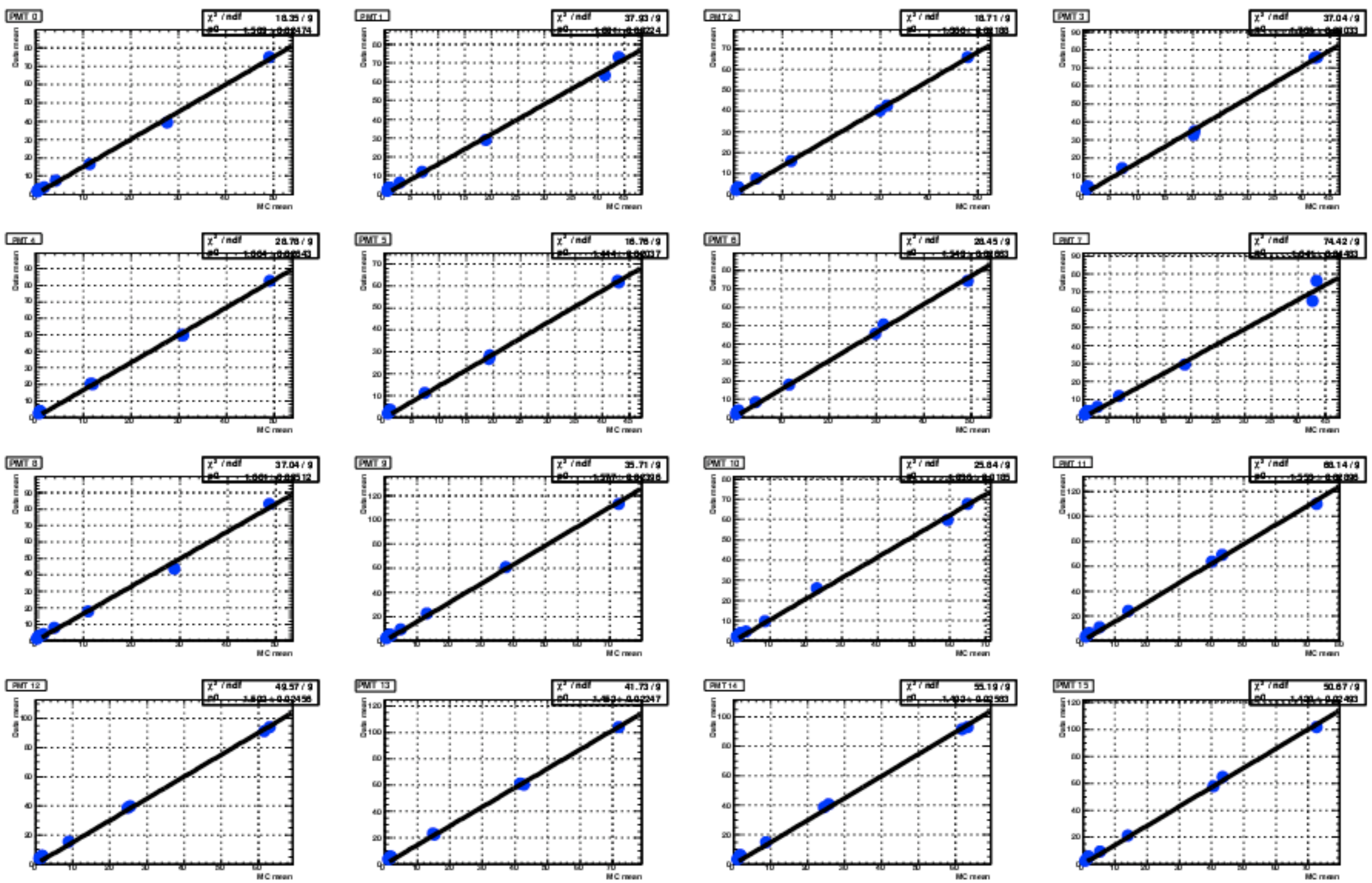
λ_{abs} limit

- MC inputs:
  - λ_{Ray} = 70 cm, λ_{Abs} = 500 cm, NO ref. on walls



QE determination

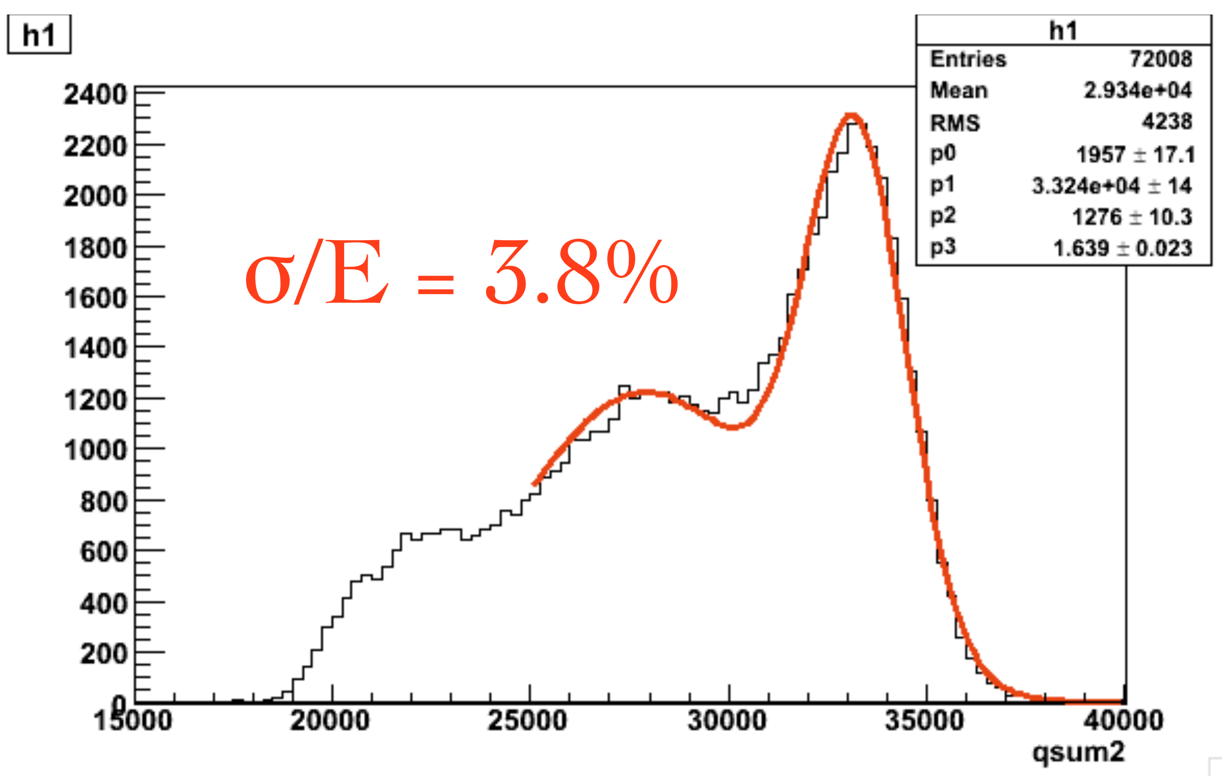
- Measurement of QE in liquid xenon for TRG and DRS data



QE benefit...

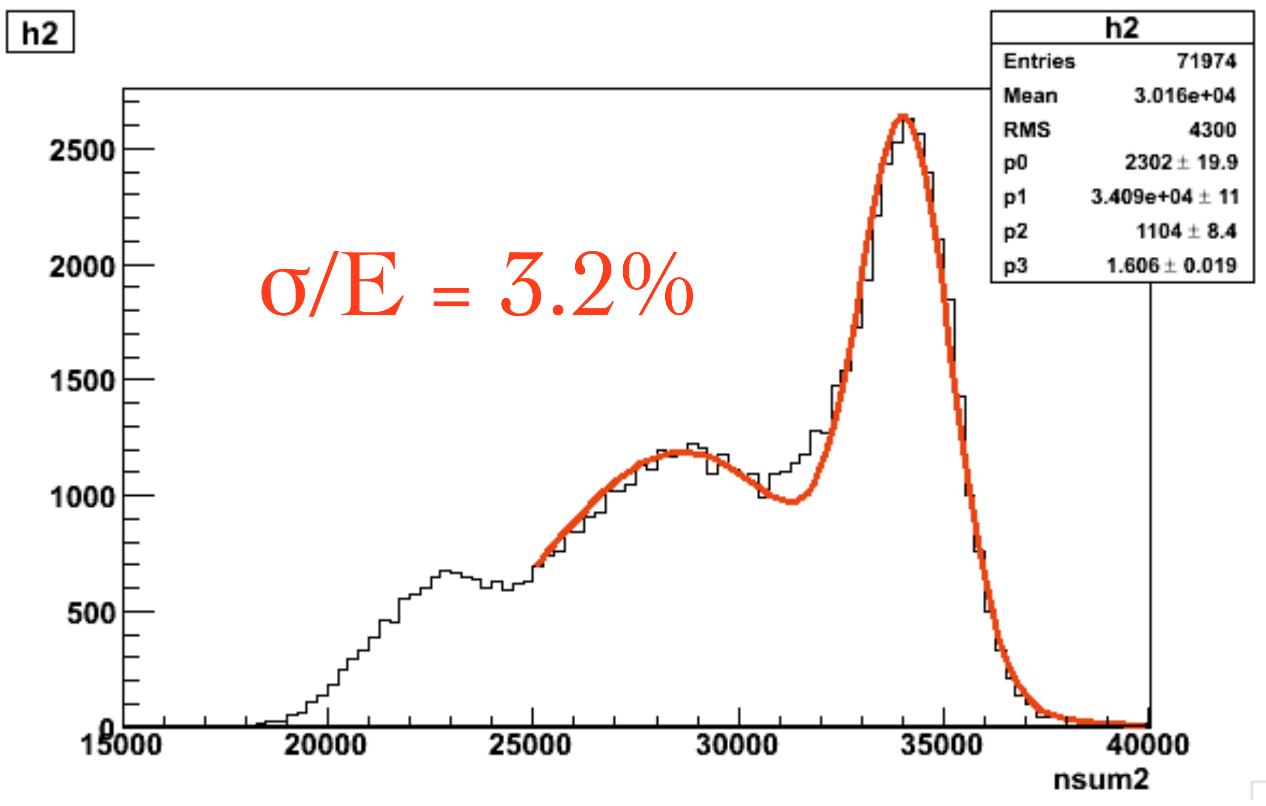
- Sample: Lithium runs (E_γ = 17.6 MeV)

Before QE



Extrapolation to 52.8 MeV σ/E = 2.2%

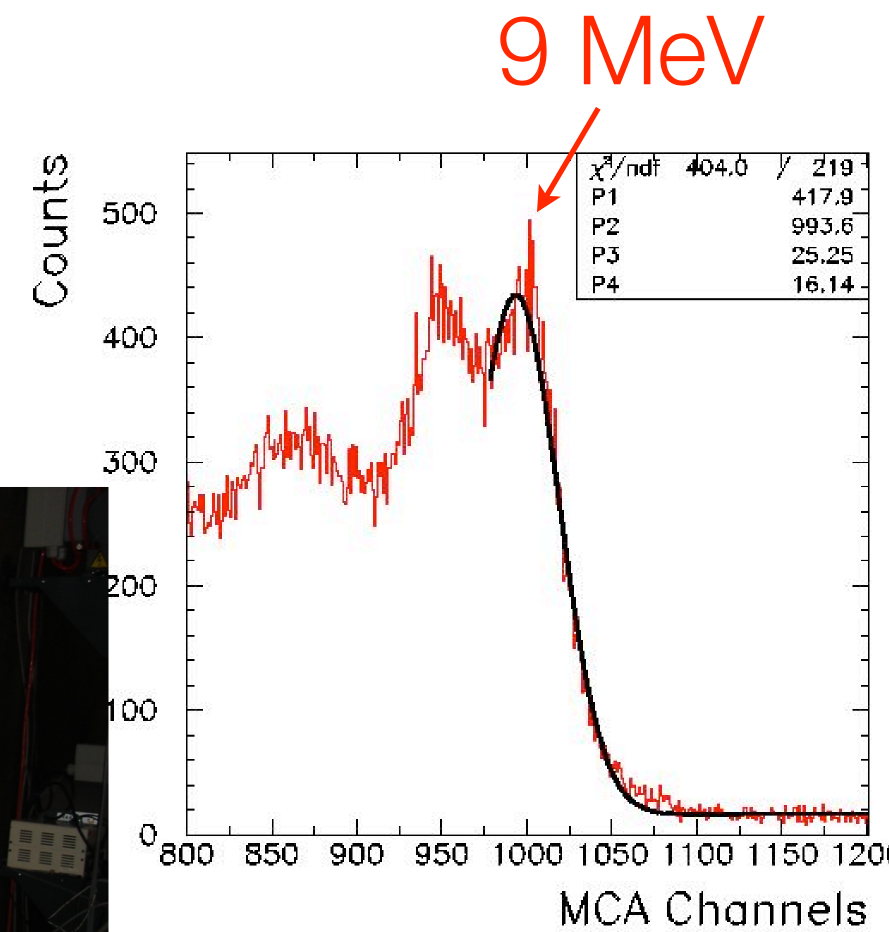
After QE



Extrapolation to 52.8 MeV σ/E = 1.8%

2010 improvements: Neutron generator

- 9 MeV gamma line from thermalized neutron capture on Ni
- Monitoring of the LXe calorimeter during normal data taking (muon-beam)



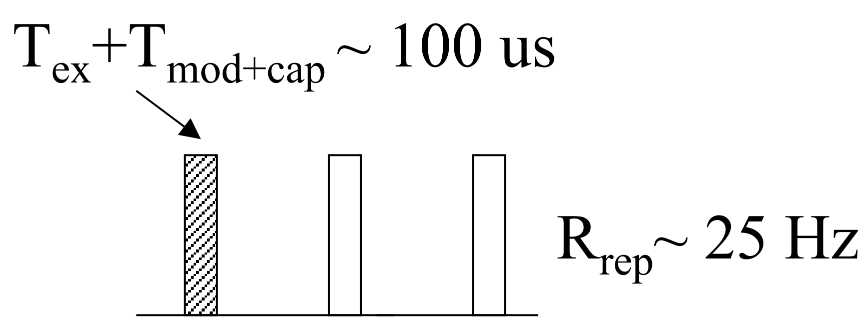
Summary of the neutron generator working conditions for MEG

neutron generator type	DD reaction
neutron emission energy	2.5 MeV
neutrons/pulse	$< 4\ 10^4$
pulses/second	< 25
pulse duration	10 us
neutrons/second	$< 10^6$

Expected delivery time: march 15^{th}

Calibration performances

- Beam off: no important background
    - alpha (rejection online by pulse shape)
- Beam on: background sources
    - alpha (rejection online by pulse shape)
    - electromagnetic background from the muon beam



SOURCE	ev/pulse	ev/sec
Neutron Generator	8	175
Alpha	0.5	$5\ 10^3$
Gamma from muon beam	4	$4\ 10^4$

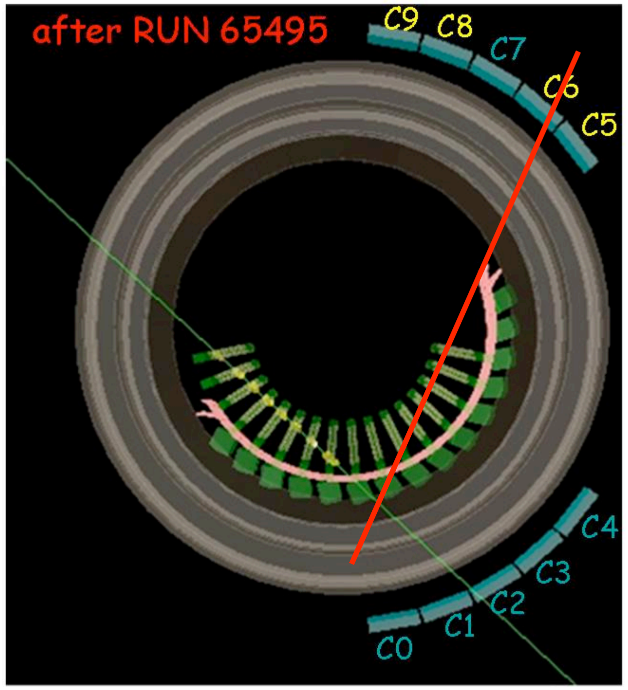
(*) New studies underway to optimize the moderator + Nickel system

Spectrometer

2010 improvements: methods for DC study

- Michel positrons are the natural candidates to study the spectrometer resolutions
  - continuous energy spectrum

CR set-up



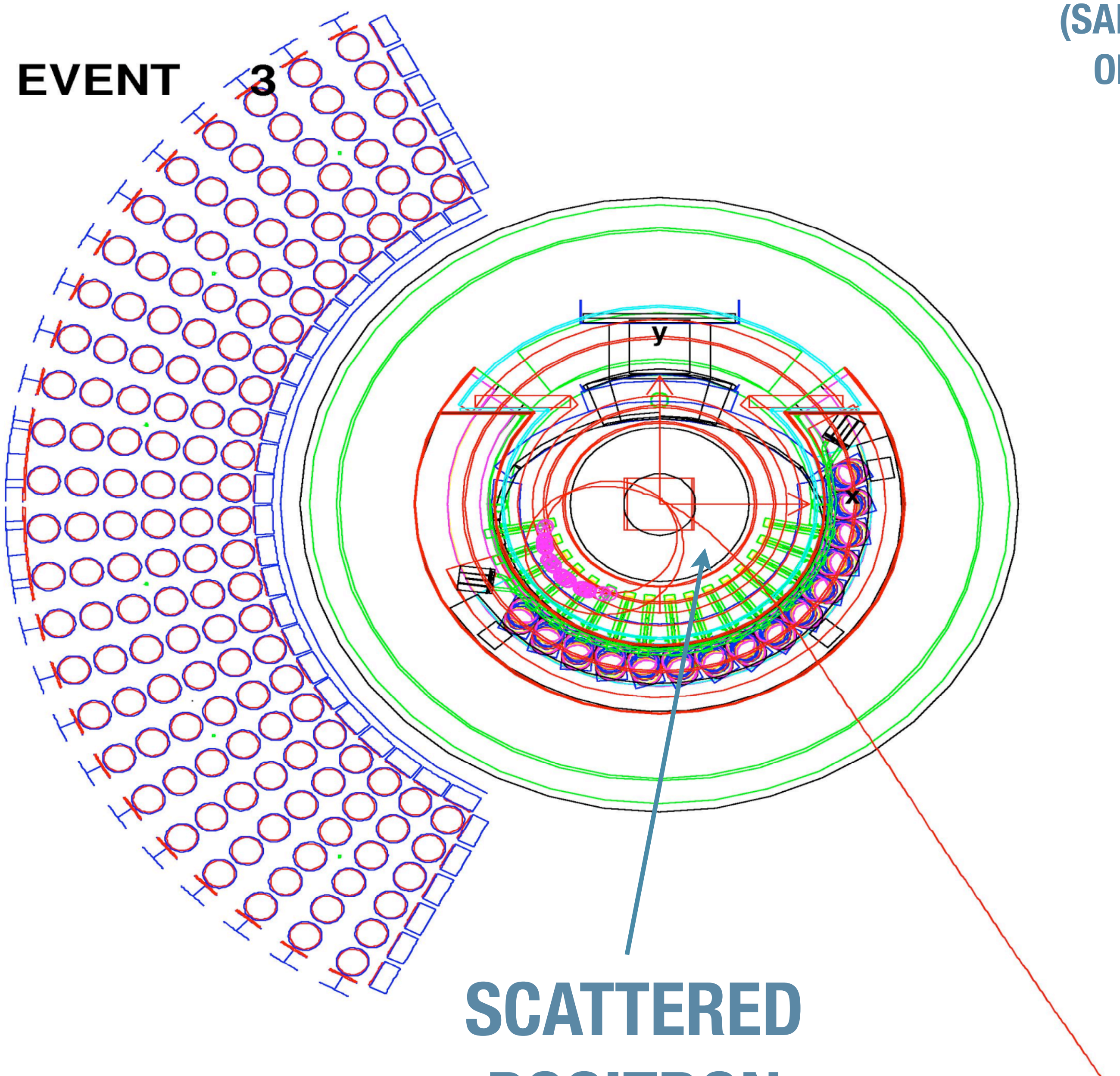
- Dedicated alternative methods:
  - Cosmic rays (done, as discussed in the DC's talk)
    - no beam, no magnetic field (Cobra)
    - straight tracks
    - once in a while, since it needs an "ad-hoc" set-up
  - Positron beam and Mott scattering on carbon target
    - possible between MEG runs
    - curved trajectories
  - A careful study of the positron beam is nedeed

Positrons

- A spectrometer calibration based on an intense positron beam
  - monoenergetic
  - energy-tunable (even over 50 MeV)
- Physics process
  - Coherent elastic scattering (Mott scattering) on light nuclei
- Measurement of:
  - momentum resolution
  - angular resolution (double turn)
  - DC efficiency as a function of momentum
  - DC efficiency as a function of angle

  with trajectories similar to the ones of the signal
- Number of events (MEG fiducial angular acceptance $\vartheta = 70^0$-110^0)
  @ 2 10^7 e^+/s, CH_2 target thickness 2.5 mm = ~200 ev/s

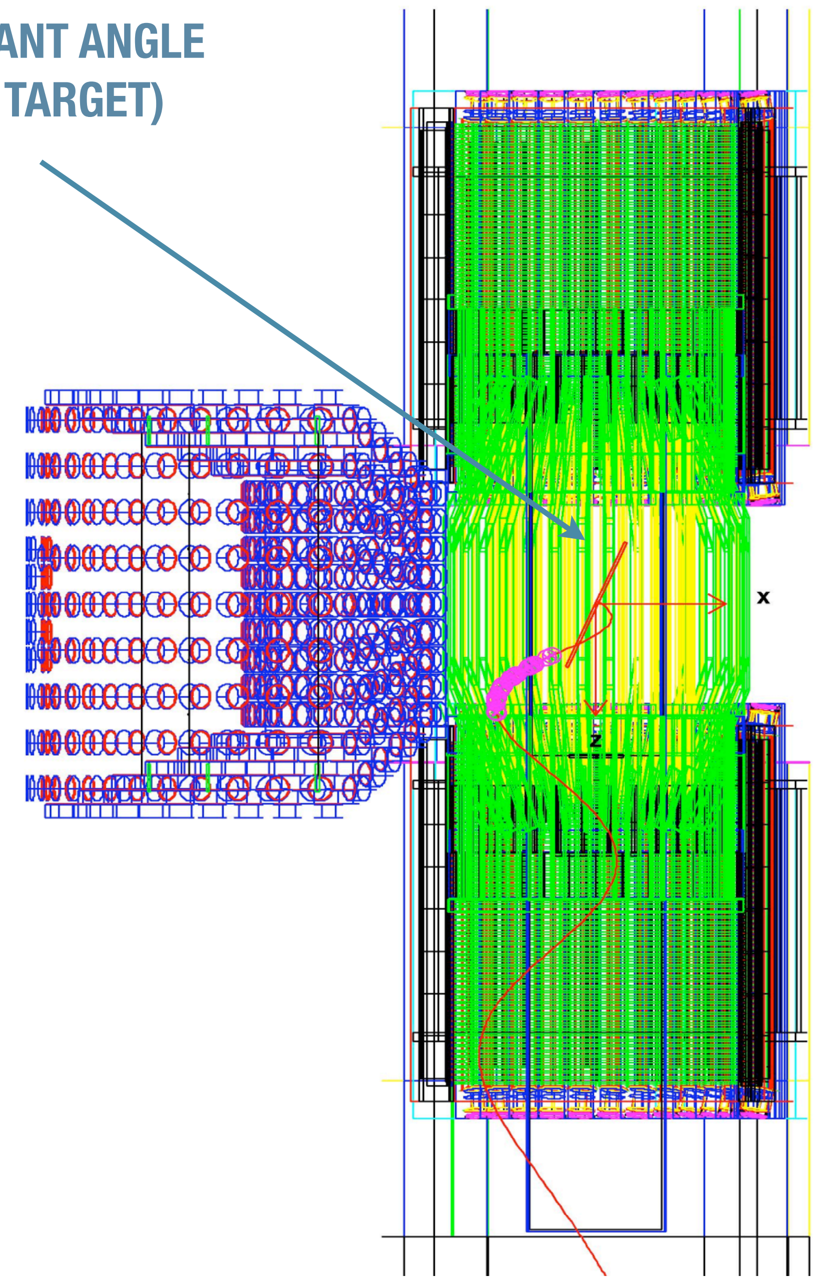
Example of one event



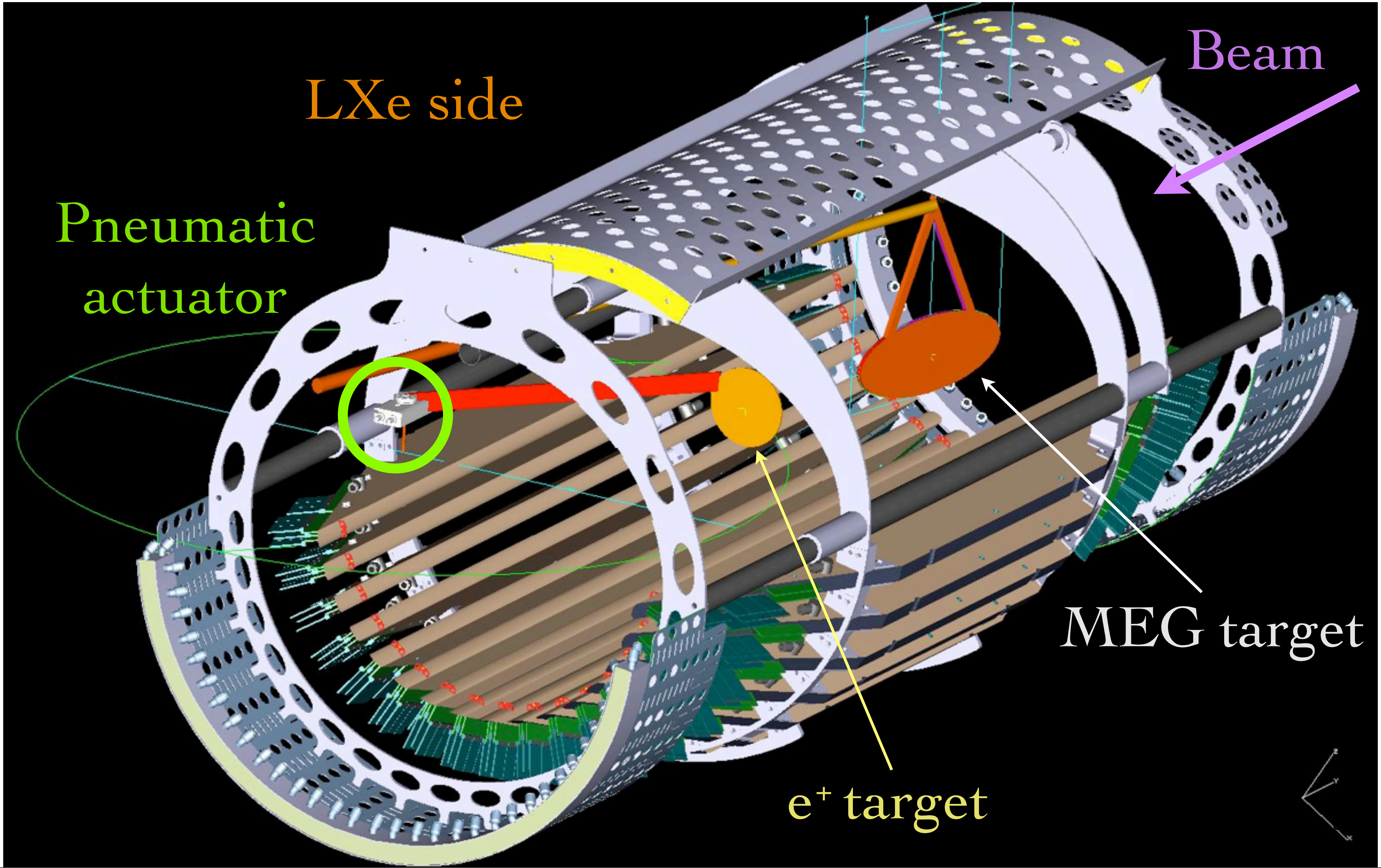
SCATTERED POSITRON TRACK

MOTT TARGET

(SAME SLANT ANGLE OF MEG TARGET)

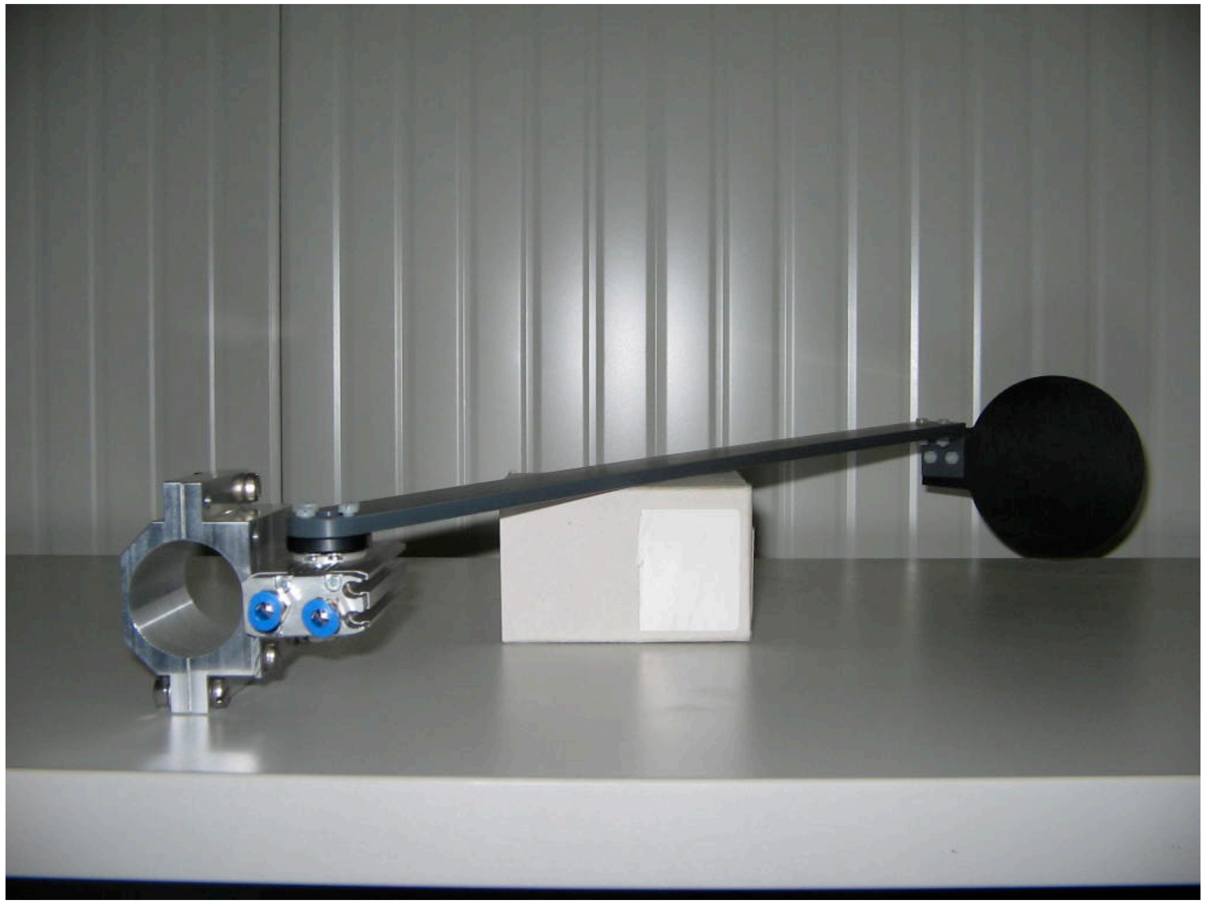


Layout



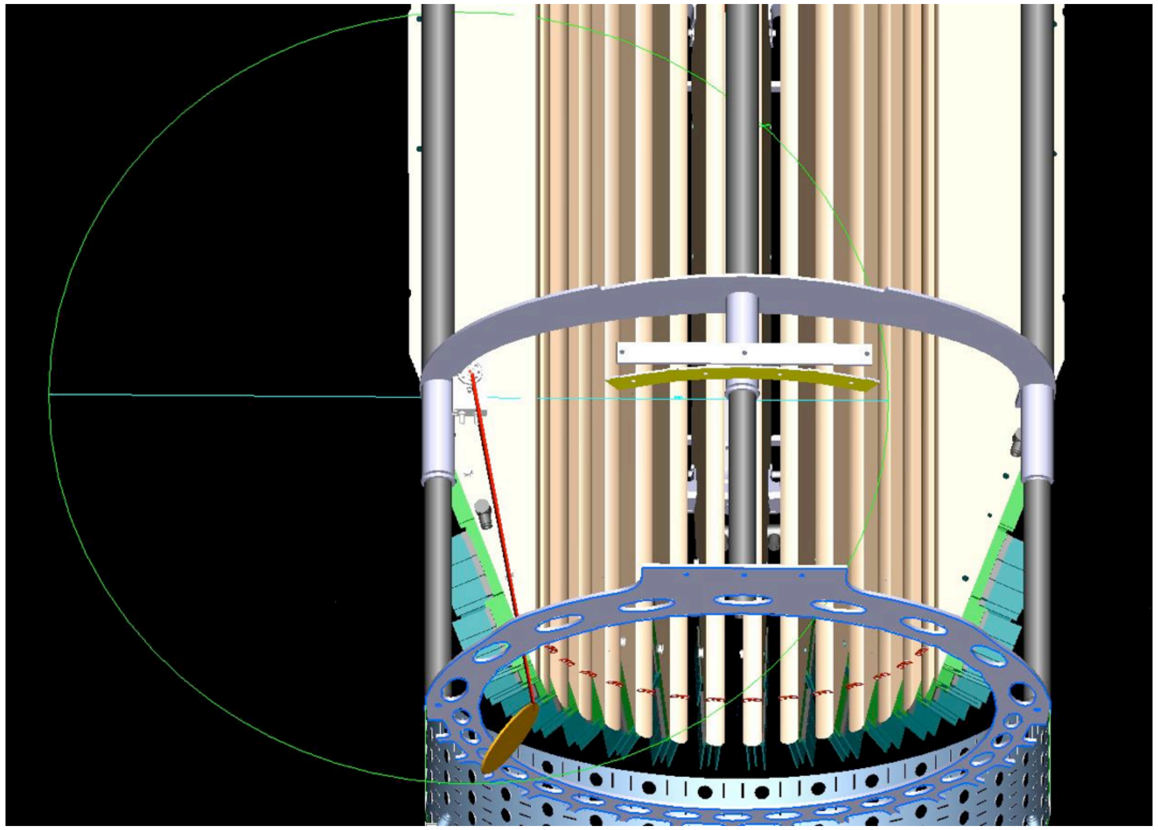
Hardware status

- CH_2 target is ready; thickness 2.5 mm
- Pneumatic actuator: all small steel parts replaced (home-made: shaft, or ordered: ceramic bearings)
- To be completed
  - compressed helium circuit and labview program (all parts already available (tubes, valves, connectors)



MC status

- Added event type #70 (Mott scattering)
- User's option (gem.cards)
  - spot, momentum bite and divergence of incident positron beam;
  - angular and momentum distribution of outgoing positrons;
  - radiative corrections;
  - target type (C, CH_2);
  - possible slant angle of target;
  - tracking of outgoing positrons in target and spectrometer;
- Added target support and actuator



Conclusion

- All calibration methods worked rather well
- Improvements foreseen for 2010 run

Back-up

Relevant expressions for electron-nucleus elastic scattering

$$\frac{d\sigma}{dQ^2} = \frac{4\pi\alpha^2 Z^2}{Q^4}(1 - \frac{Q^2}{4p_0^2})|\, F(Q^2)\,|^2 \qquad Q^2 = 4pp_0 \sin^2\theta/2$$

Mott cross-section

$$p = \frac{p_0}{1 + \frac{p_0}{M}(1 - \cos\theta)}$$

$$F(Q^2) \approx 1 - \frac{Q^2\langle R^2\rangle}{6} + \cdots$$

approx. form factor

$$dQ^2 = {p_0}^2\,\frac{d\Omega}{\pi}$$

$< R^2 >^{1/2} = 0.94\ A^{1/3}$ fermi

$$\hbar c = 0.1973\ \text{GeV fermi} \quad (\hbar c)^2 = 0.3894\ \text{GeV mbarn}$$

$F(Q^2)$ **nuclear form factor** p_0 **positron initial momentum**

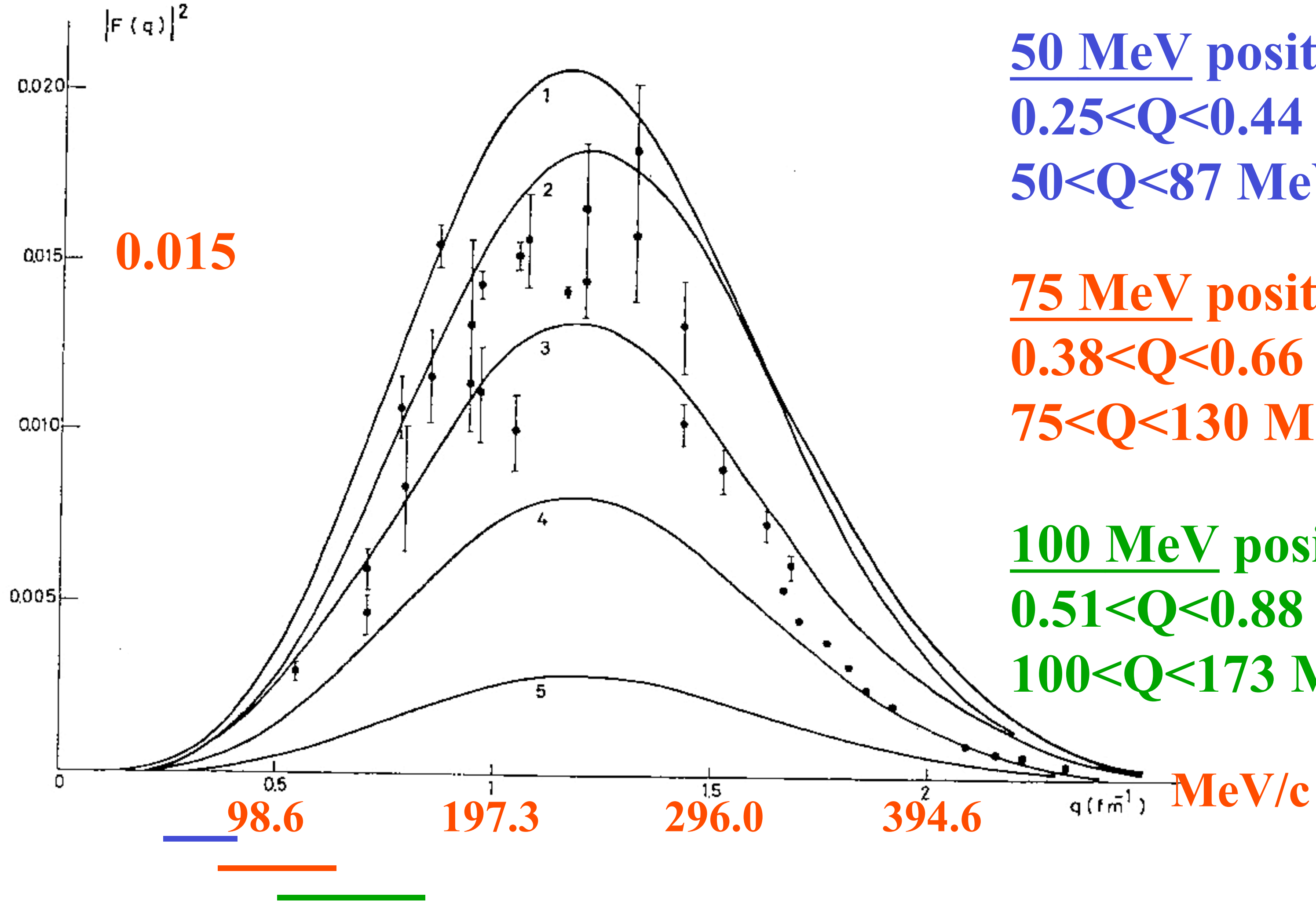
$\langle R\rangle^{1/2}$ **nuclear root-mean-square radius**

M **nucleon or nuclear mass**

INELASTIC FORM FACTOR FOR ^{12}C 4.4 MeV line

INELASTIC FORM FACTOR FOR ^{12}C 4.44 MeV line
experimental data and theoretical evaluation

$$| F_{in}(Q^2) |^2 = [1/Z^2(2J_i+1)] \, | \sum_{M_i} \sum_{M_f} \langle J_f M_f \mid \sum exp(i\vec{Q}\cdot\vec{r}) \mid J_i M_i \rangle |^2$$



50 MeV positrons 60°-120 °
$0.25<Q<0.44$ fm $^{-1}$
$50<Q<87$ MeV/c

75 MeV positrons 60°-120 °
$0.38<Q<0.66$ fm $^{-1}$
$75<Q<130$ MeV/c

100 MeV positrons 60°-120 °
$0.51<Q<0.88$ fm $^{-1}$
$100<Q<173$ MeV/c