Mott Calibrations

P. Schwendimann

Calibrations based on Mott Positrons for the MEG II Experiment
Monte Carlo Simulation Studies

Patrick Schwendimann
patrick.schwendimann@psi.ch

Paul Scherrer Institut

Muon Group Seminar
20.03.2018

Overview

The Goal

MEG II

Search for the charged lepton flavour violating decay

$$\mu \to e\gamma$$

with a sensitivity to the branching ratio of

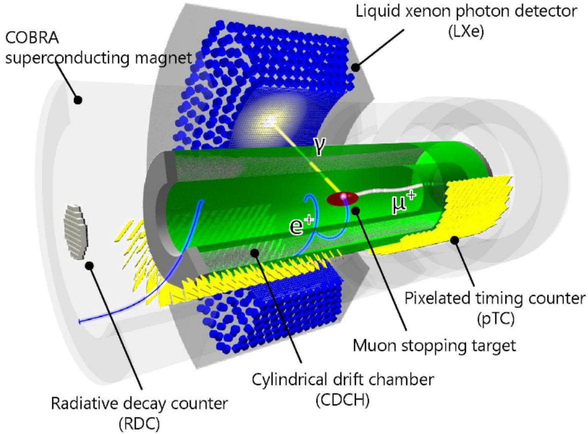
$$BR(\mu \to e\gamma) < 4 \cdot 10^{-14}$$

Improve the current best result by an order of magnitude.
$(BR(\mu \to e\gamma) < 4.2 \cdot 10^{-13}$, MEG)

A. M. Baldini et al. (MEG II Collaboration): *The design of the MEG II experiment*, arXiv:1801.04688v1 [physics.ins-det] (2018)

A. M. Baldini et al. (MEG Collaboration): *Search for the lepton flavour violating decay $\mu^+ \to e^+\gamma$ with the full dataset of the MEG experiment*, Eur. Phys. J. C 76, 434 (2016)

The Setup

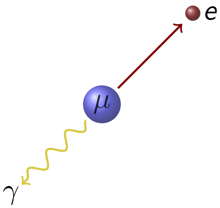


- Readout electronics
- Auxiliary devices
- Calibrations

A. M. Baldini et al. (MEG II Collaboration): *The design of the MEG II experiment*, arXiv:1801.04688v1 [physics.ins-det] (2018)

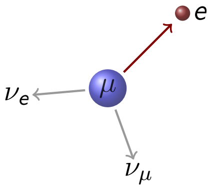
The Signal

The Good



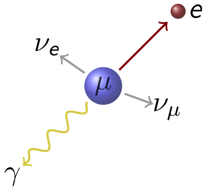
- Back to Back
- 52.8 MeV each

The Bad



- Michel Decay with Neutrinos
- Continuous spectrum

The Ugly



- RMD with Neutrinos
- Background
- Calibrations

The Calibrations

Method	Purpose
CEX	LXe calibration in signal region
RMD	LXe pTC timing intercalibration
Michel Decay	alignment, CDCH energy scale
Mott Scattering	CDCH energy scale, resolution
C-W Accelerator (on ^{7}Li, ^{11}B)	LXe uniformity, purity LXe pTC timing

… and many more methods with different purposes.

The Mott Scattering Process

Theory

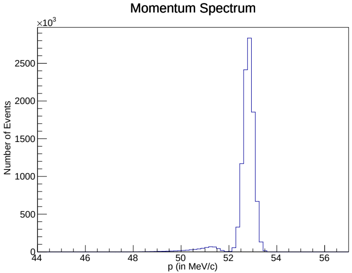
Scattering of a particle with spin (positron) on a Coulomb potential (Nucleus). As the nucleus is much heavier than the positron, the recoil is rather small.

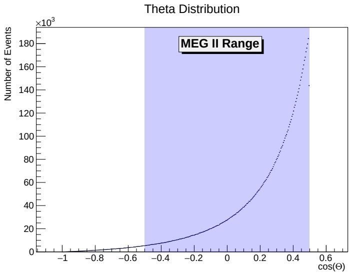
Praxis

Send a positron beam of 52.8 MeV on the usual MEG II target. Some of the positrons get scattered into the spectrometer.

- almost monochromatic energy
- dependent of polar angle Θ, independent of azimuth Φ

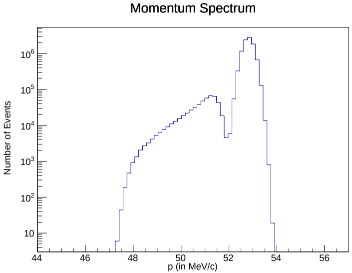
Mott Crosssection I

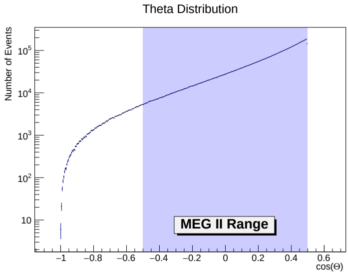




A spread of $\sigma = 0.2\,\mathrm{MeV/c}$ on the incoming momentum of the beam is assumed.

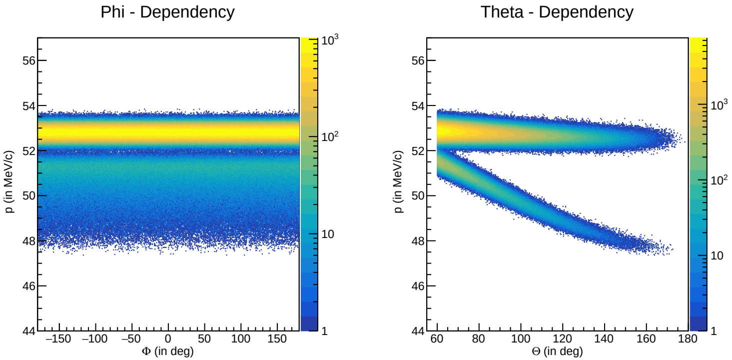
Mott Crosssection II





A spread of $\sigma = 0.2\,\text{MeV/c}$ on the incoming momentum of the beam is assumed.

Angular Dependency of Energy Spectrum



A spread of $\sigma = 0.2\,\mathrm{MeV/c}$ on the incoming momentum of the beam is assumed.

Mott Events in the Drift Chamber

Basic Idea

Use Mott events in the signal region to characterise the behaviour of the drift chamber

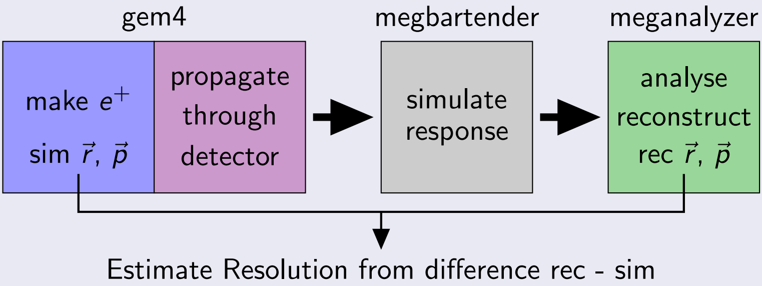
- More or less monochromatic energy
- Θ-dependent, Φ-independent

Use for ...

- Extract positron variable resolutions with drift chamber ✓
- Track Matching *in progress*
- Alignment of the drift chamber *to do*

Extraction of the Resolutions

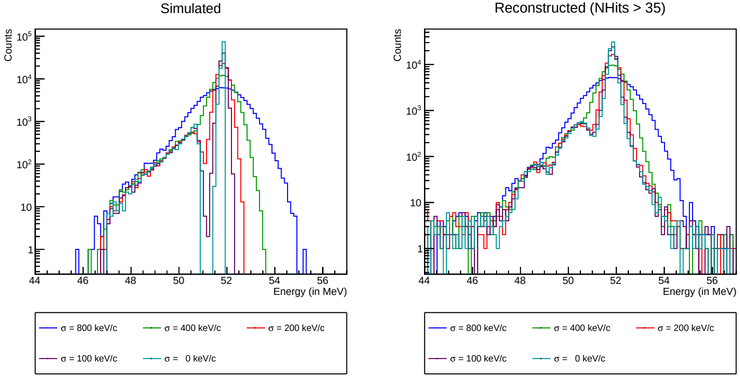
The Simulation



Results: Resolution in Positron Variables for CDCH

	Energy	Polar Angle	Azimuth Angle
Gaussian σ	82.4(7) keV	4.71(4) mrad	4.05(4) mrad

Energy Spectra



beam momentum spread	(MeV/c)	0	0.2	0.4
energy resolution (σ)	(MeV)	0.10	0.23	0.44

Mott Events in the Timing Counter

Basic Idea

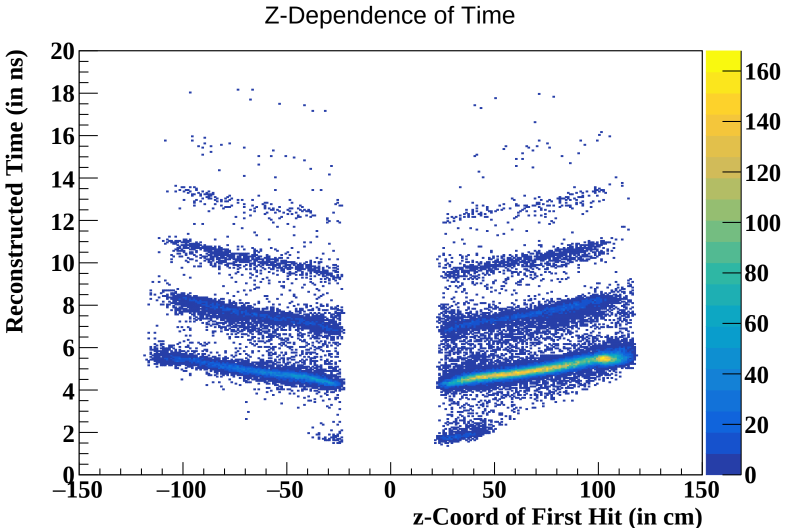
Use Mott events to characterise the response of the timing counter.

- Study behaviour of the timing counter for signal-like positrons.
- Correlated in timing with HIPA RF signal

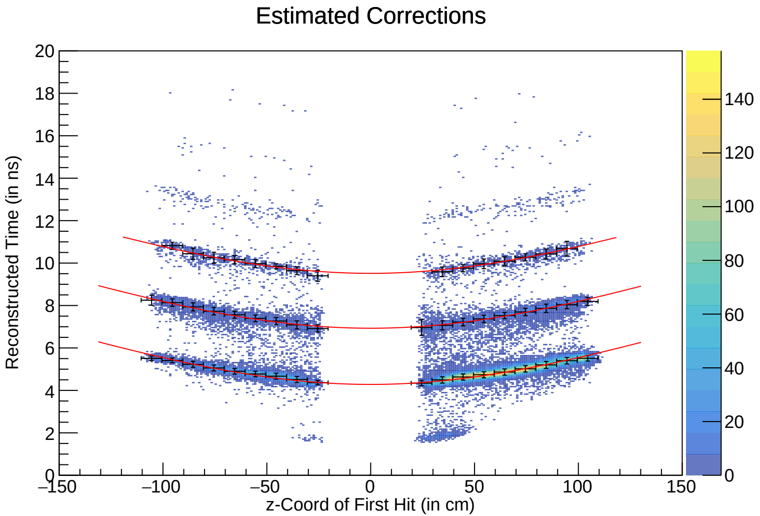
Use for ...

- Extraction of positron time resolution ✓
- Track Matching *in progress*

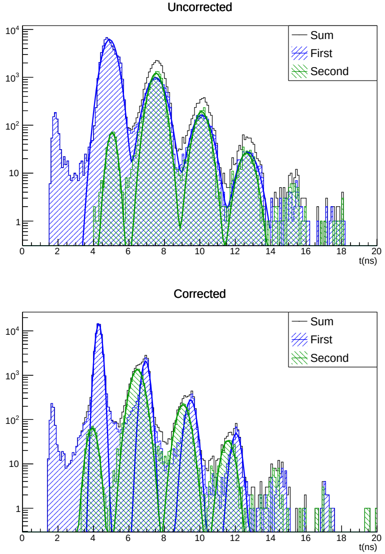
Spatial Dependence of Hit Time



Spatial Correction of Hit Time



Resolution in the Hit Time



Resolutions

Peak	Mean in ns	StdDev in ns
1	4.30	0.15
2	6.94	0.19
3	9.48	0.24
4	12.1	0.23(2)

The Double Turn Method

In real life ...

... one cannot access the simulated values. Thus the methods presented so far are of limited use on the real data.

None the less ...

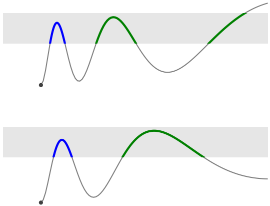
... the resolutions and finally the probability density functions are crucial to the experiment. One needs to obtain them by a measurement to crosscheck the simulation.

The Solution

Consider only tracks with at least two turns in the drift chamber or two clusters in the timing counter. Analyse them individually and calculate the differences.

Different Tracks for the drift chamber

Roughly 6 % of the tracks are suitable



3-4 %

1-2 %

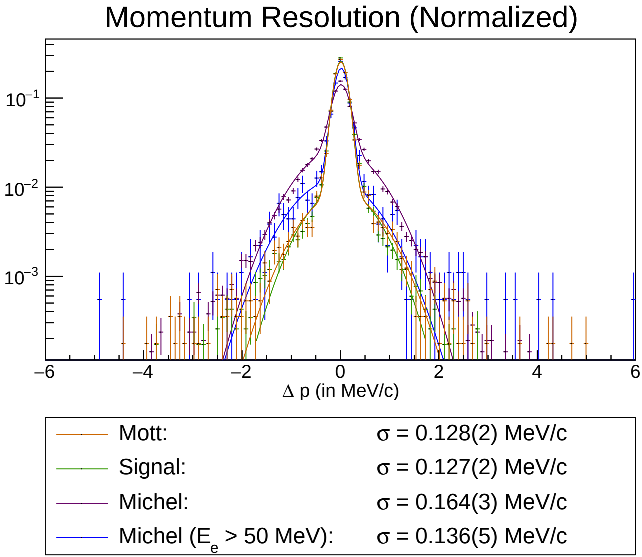
Further possible track classes:

- Tracks with more turns inside CDCH: $< 1\,\%$
- Tracks with mergers outside the CDCH: $< 1\,\%$

Note: Just outside the drift chamber is the timing counter. Hitting the timing counter makes any further parts of the track useless.

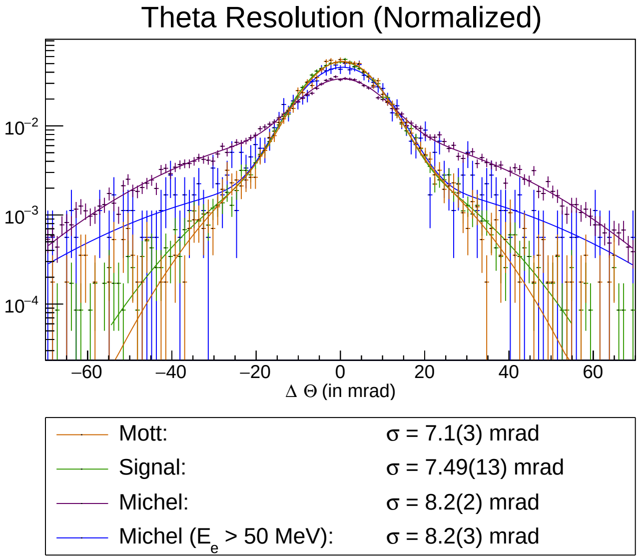
Momentum Resolution

Differences between Mott, Signal and Michel



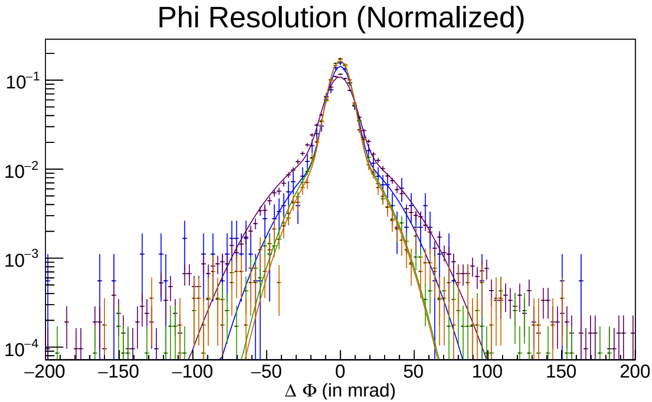
Polar Angle Resolution

Differences between Mott, Signal and Michel



Azimuth Angle Resolution

Differences between Mott, Signal and Michel



Mott:	σ = 6.3(2) mrad
Signal:	σ = 6.27(12) mrad
Michel:	σ = 8.16(15) mrad
Michel (E_e > 50 MeV):	σ = 6.8(3) mrad

Summary

Mott Events

- Provide signal-like positrons in the spectrometer
- Provide the possibility to characterise the detector
- Double turn algorithm allows the extraction of the intrinsic resolutions of the DCH

Obtained Resolutions for Mott Events (Gaussian σ)

Method	Momentum Energy keV	Polar Angle mrad	Azimuth Angle mrad	Time ns
Double Turn	128(2)	7.1(2)	6.3(2)	*coming soon*
$rec - sim$	82.4(7)	4.71(4)	4.05(4)	0.15

Next Steps

Double Turn for Timing Counter

The double turn algorithm can be used on the timing counter as well. Code is currently being implemented. This requires some advanced matching of the tracks between the drift chamber and the timing counter.

Alignment of the Setup

The Mott events exhibit a clear dependence on the polar angle. It is part of a feasibility study if and to what extend this property may be used to estimate a misalignment of the spectrometer.