Event reconstruction in MUonE experiment at SPS

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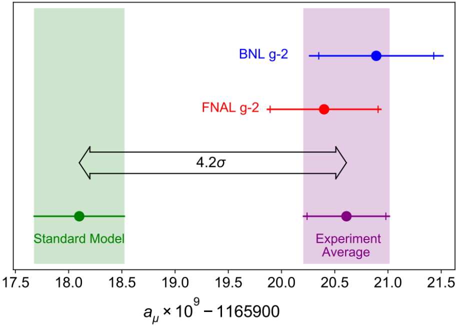
Outlook:

Muon g-2 experiments

The discrepancy between theoretical prediction and measurements of anomalous magnetic moment of a muon can be referred as:

$$a_\mu = a_\mu^{QED} + a_\mu^{EW} + a_\mu^{QCD} + a_\mu^{NP}.$$



At this moment research provides a 4.2σ level discrepancy. This is still not enough to claim a discovery.

$$\Delta a_\mu = a_\mu^{exp} - a_\mu^{SM} = (251 \pm 59) \times 10^{-11}$$

Problem - hadronic leading-order contribution to theoretical value of a_μ.

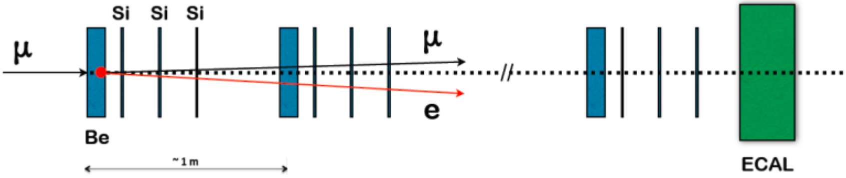
How to get $a_\mu^{HVP,\,LO}$ value?

- Lattice calculations.
- Dispersion relation - employs experimental data from e^+e^- annihilation to hadrons.
- MUonE uses a novel method - calculating a_μ^{HLO} using measured hadronic contribution to running fine-structure constant value. This can be done in the $\mu - e$ elastic scattering process.

$$a_\mu^{HVP,\,LO} = \left(\frac{\alpha_0}{\pi}\right)^2 \int_0^{0.932} dx(1-x)\Delta\alpha_{had}[t(x)].$$

MUonE experiment

MUonE needs to control very well both systematic and statistical errors.

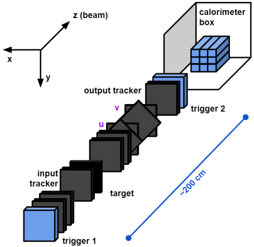


- 160 GeV incoming muon beam.
- Targets made of a Low-Z material.
- Tracking layers made of Si tracking planes.
- Integrated luminosity L_{int} $1.5 \times 10^7 nb^{-1}$.
- Systematic effect known at 10 ppm.
- Hit resolution 10 μm.

- Precise measurement of the outcoming electrons and muons angles.
- Precise measurement of the incoming muon direction.

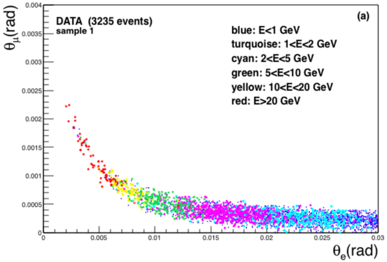
MUonE timescale

- Test run 2018



Goals:

- Specify the outlines for the final MUonE experimental setup.
- A good quality, clean sample of elastic scattering events were obtained.



JINST 16 (2021) P06005

- Pilot runs in 2021/2022

  The detector setup is mostly like it will be in the final run.

- Final run 2023-2026

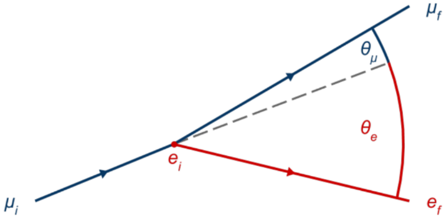
Reconstruction in MUonE

IFJ PAN MUonE group main responsibilities:

- software environment based on FairRoot implementation and maintenance, detector simulation and event reconstruction,
- involvement in physics analyses,
- Dominant role in the simulation, software alignment, event reconstruction and final data analysis of testbeam data 2018. Results published: JINST 16 (2021) P06005.

FairMUonE software package successfully used for testbeam 2018 and is expected to be the software environment for the final experiment.

The topology of $\mu - e$ elastic scattering is relatively simple.



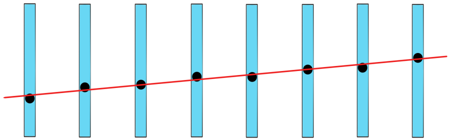
Track reconstruction process must be performed as precisely as possible.

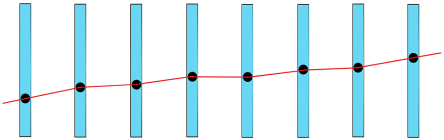
- The original track reconstruction method was the linear fit.
- Finally - Kalman filter based track reconstruction algorithm.

Why do we need Kalman filter?

Kalman filter is an useful data-fusion algorithm.

- Combines the knowledge from prediction and measurement,
- has a status of an optimal estimator for linear systems with Gaussian error statistics,
- enables to achieve better estimation than prediction and measurement provide separately
- takes into account additional effects that linear fit does not, i.e. multiple scattering.



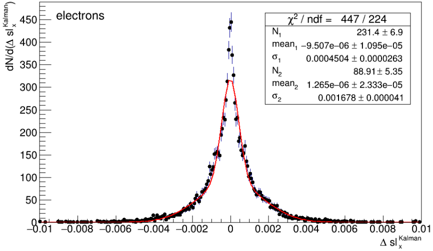


In contrast to the linear fit, the output of Kalman filter algorithm do not have to be a straight line.

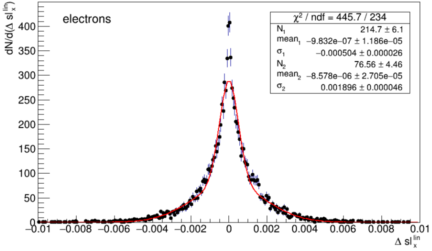
Comparing the resolutions

The performance of linear fit and Kalman filter based algorithm were compared.

Distribution of a difference between x-slopes for MC true and reconstructed electrons. The distribution is fitted with double Gaussian. The σ value from fit results means the resolution.

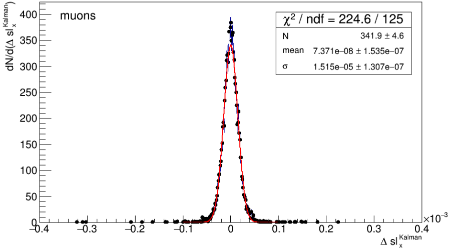


Kalman filter based algorithm.

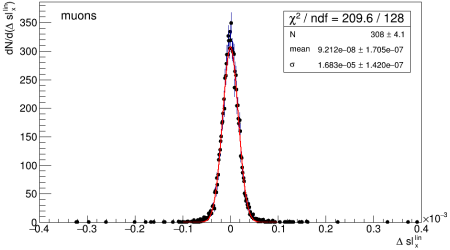


Linear fit.

Comparing the resolutions



Kalman filter based algorithm.



Linear fit.

For both electrons and muons, resolutions for Kalman filter based algorithm are about 10% better than for linear fit.

	Kalman filter		Linear fit	
muons	1.515(013)		1.683(017)	
electrons	σ_1	σ_2	σ_1	σ_2
	4.504(263)	1.678(041)	5.040(260)	1.896(046)

Summary

The mystery of anomalous magnetic moment of a muon may be solved soon.

Precise measurements together with better than before determination of hadronic leading order contribution from MUonE experiment are expected to reach the 7σ level.

Improving the hadronic leading order contribution is crucial!

The results from MUonE testbeam 2018 appeared to be very successful and promising.
Pilot runs in 2021/2022 towards final data taking in 2023-2026.