Modelization of multiple scattering effects for the MUonE experiment

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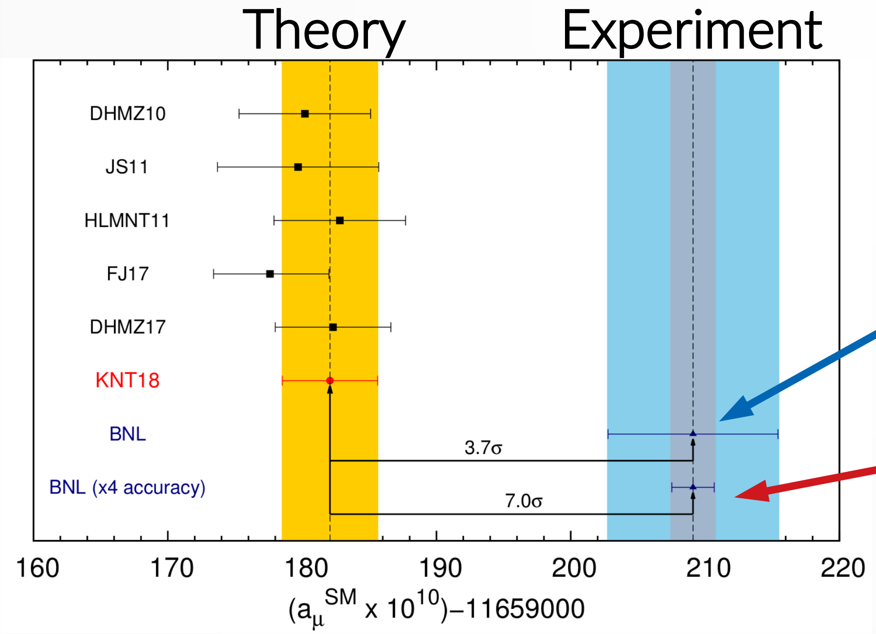
Outline

- The MUonE experiment:
    - Motivation: the hadronic contribution to the muon g-2.
    - Experimental apparatus.

- Multiple Scattering effects:
    - Results of Test Beam 2017.
    - Modelization of Multiple Scattering.
    - Required accuracy.

- Conclusions.

Motivation: the muon g-2 and the hadronic contribution



Latest measurement of a_μ (BNL)
Accuracy: 540 ppb.
3.7σ discrepancy with SM.

New experiment at Fermilab.
Aimed accuracy: 140 ppb.

The SM prediction is limited by the hadronic contribution a_μ^{HLO}.

$$a_\mu^{HLO} = (693.1 \pm 4.0) \times 10^{-10}$$

$$\delta a_\mu^{HLO} \sim 0.6\%$$

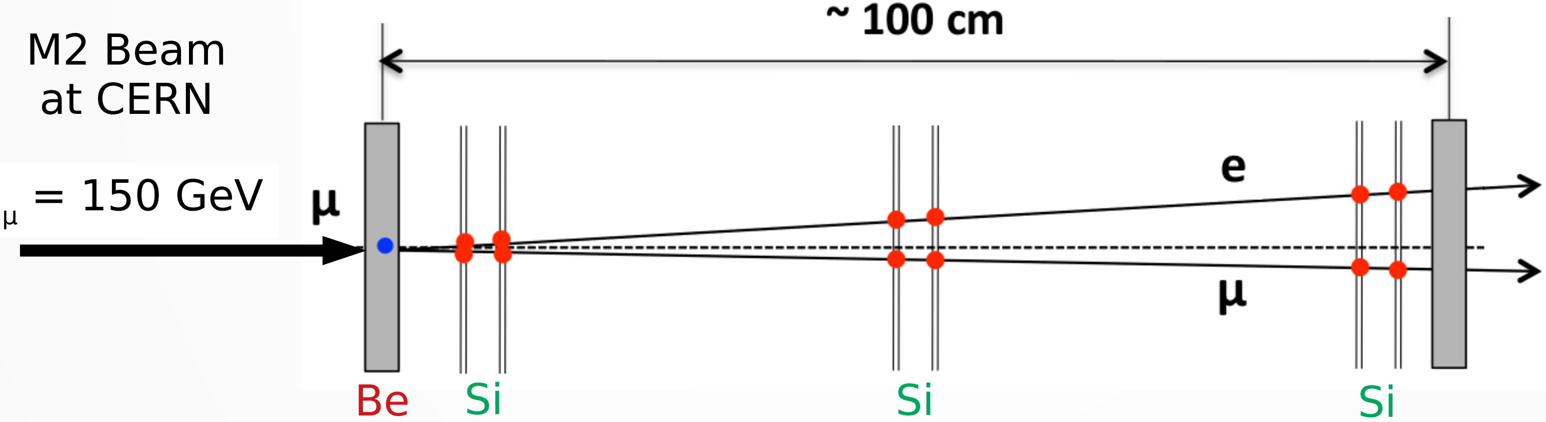
The MuonE collaboration aims at measuring a_μ^{HLO} proposing a novel approach: measure $\Delta\alpha_{had}$ in the space-like region, via μ-e elastic scattering.

[see talk by U. Marconi]

The MUonE experiment

M2 Beam
at CERN

E_μ = 150 GeV



Measure the scattering angles.

Beryllium target
15 mm thickness

Tracking system: 3 pairs of silicon strip detectors

40 stations
+
3 years of data taking:

Statistical accuracy on a_μ^{HLO}: 0.3%

Main challenge:
reach a comparable
systematic accuracy.

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Systematic uncertainty of
10 ppm in the low θ_e region.

Multiple scattering represents one of the main systematic effects.

Test Beam 2017

Multiple scattering effects of electrons with 12 and 20 GeV on Carbon targets (8 and 20 mm).

Main goals:

- Compare data with a GEANT4 simulation of the apparatus.
- Determine a parameterization able to describe also the non Gaussian tails.

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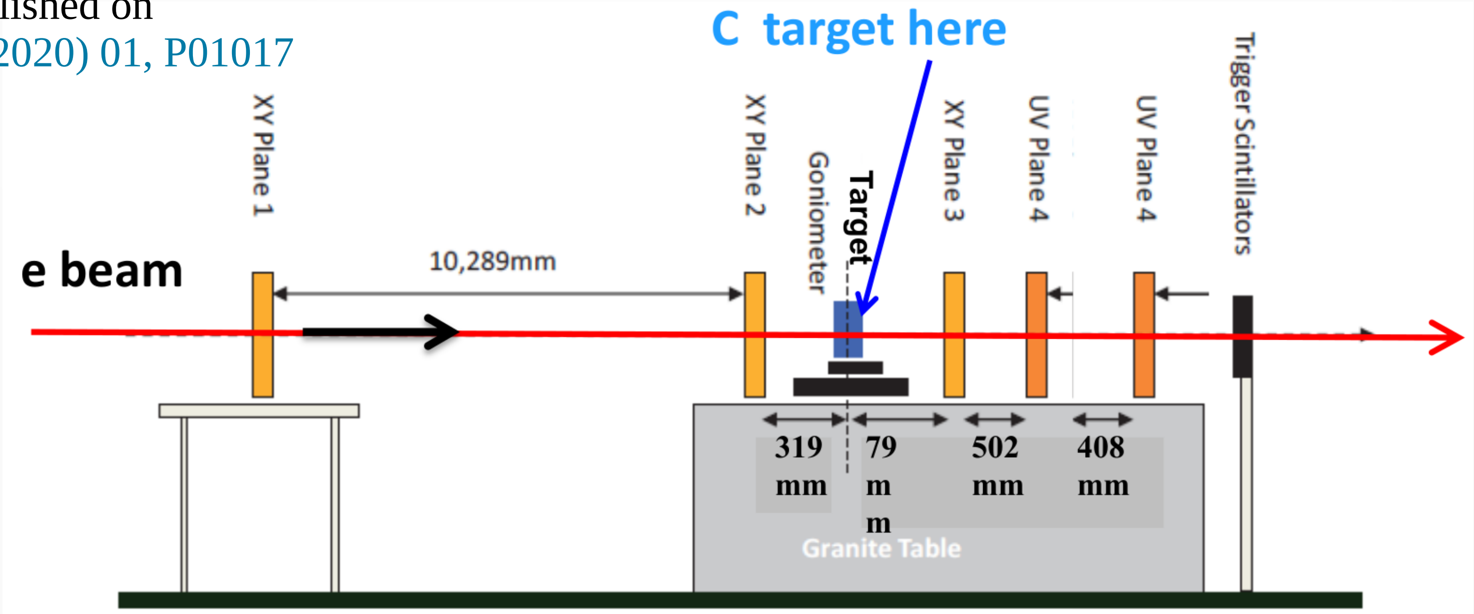
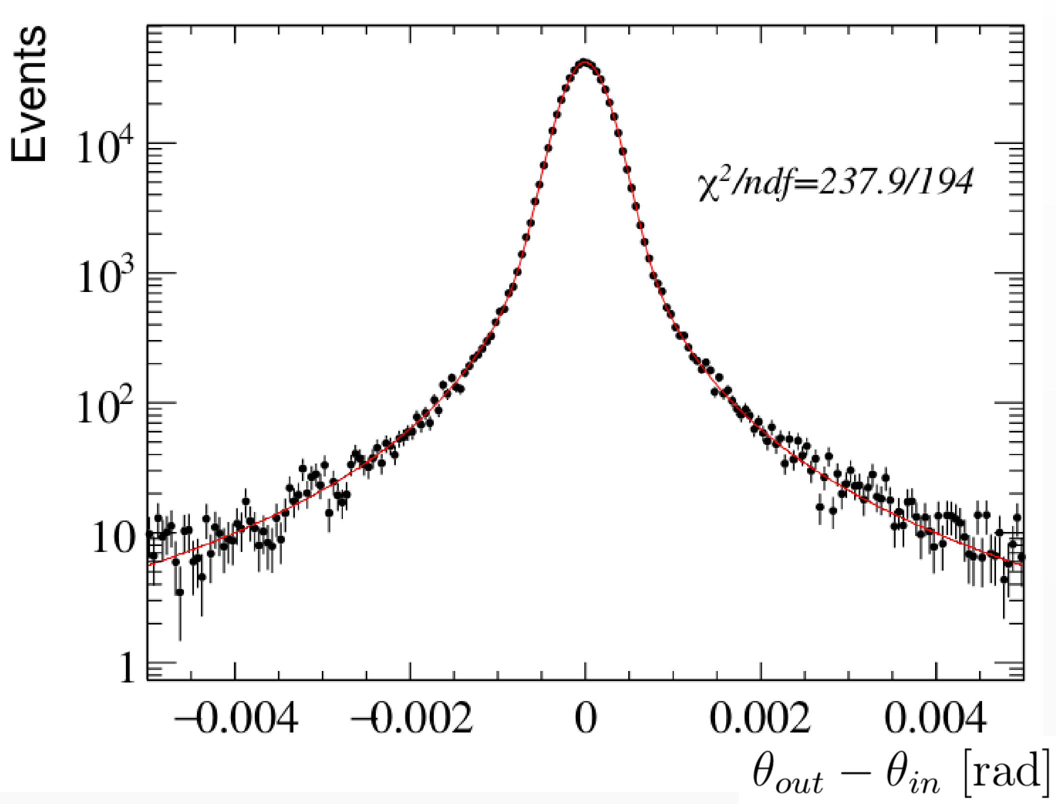


Results from TB2017

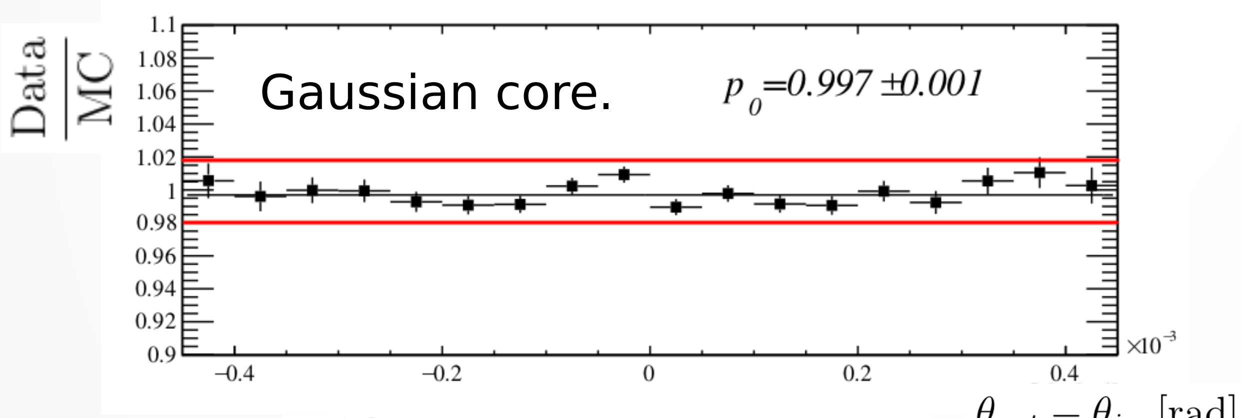
$$f_e(\delta\theta_e^x) = N\left[(1-a)\frac{1}{\sqrt{2\pi}\sigma_G}e^{-\frac{(\delta\theta_e^x-\mu)^2}{2\sigma_G^2}} + a\frac{\Gamma(\frac{\nu+1}{2})}{\sqrt{\nu\pi}\sigma_T\Gamma(\frac{\nu}{2})}\left(1+\frac{(\delta\theta_e^x-\mu)^2}{\nu\sigma_T^2}\right)^{-\frac{\nu+1}{2}}\right]$$



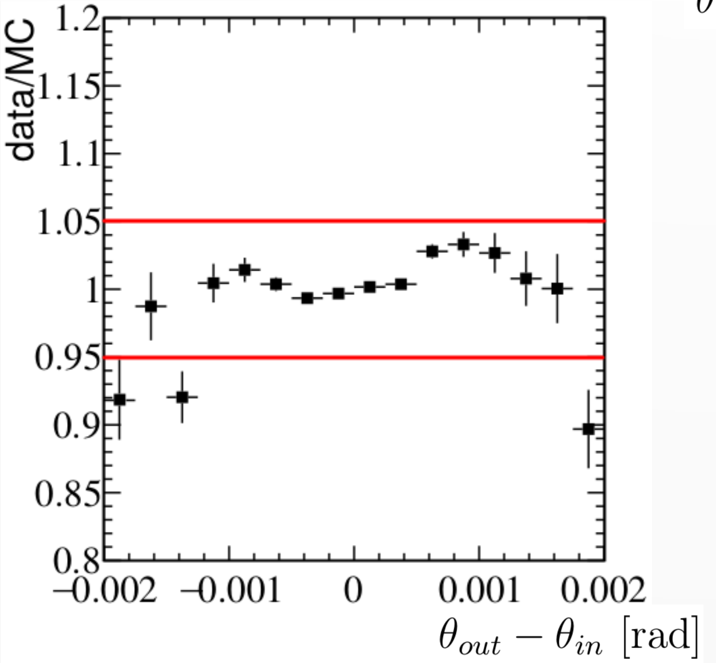
$$\vec{p} = [N,\ a,\ \mu,\ \sigma_G,\ \nu,\ \sigma_T]$$

Gaus + Student parameterization fits well the multiple scattering distribution. It allows to model also the non Gaussian tails.

Results from TB2017



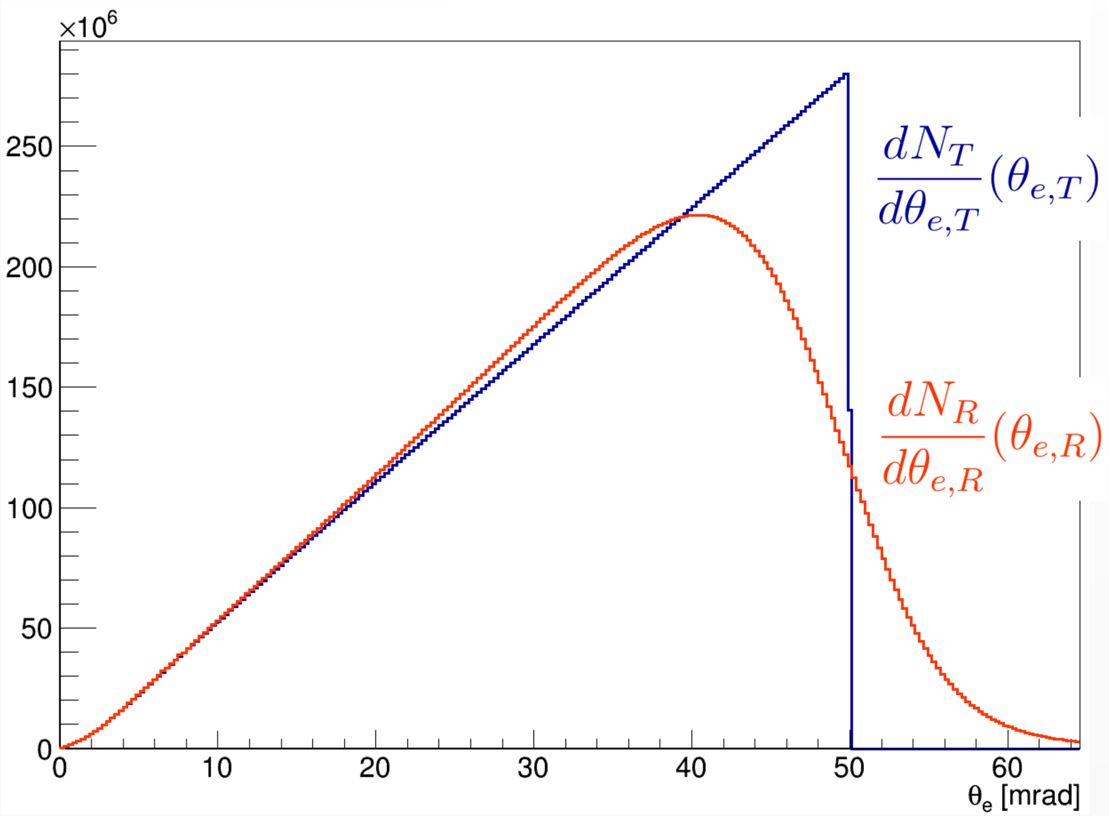
Results show also a ~1% agreement between data and MC for the Gaussian core.



Agreement between data and MC is up to 10% in the tails, but with large statistical fluctuations.

Modelization of MS effects on the distribution of θ_e

$$\frac{dN_R}{d\theta_{e,R}}(\theta_{e,R}) = \int \frac{dN_T}{d\theta_{e,T}}(\theta_{e,T})\, g(\theta_{e,R},\ \theta_{e,T})\, d\theta_{e,T}$$

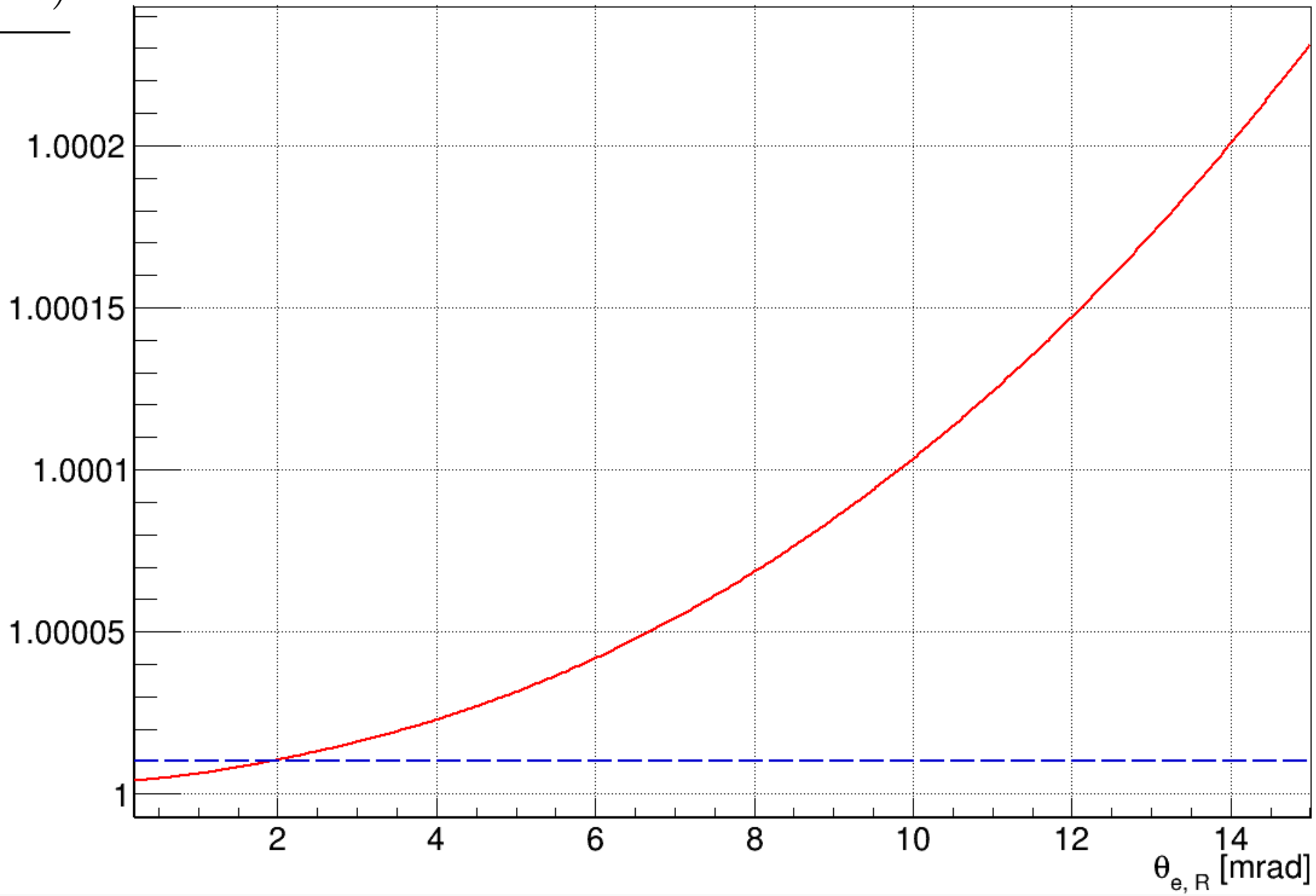


Multiple scattering effects modeled as Gaus + Student

Geant4 simulation of the apparatus exploited to parameterize multiple scattering effects as a function of θ_e.

Effect of a 1% systematic error on the Gaussian core

$$\frac{\frac{dN}{d\theta_{e,R}}(\theta_{e,R} \mid \sigma_G + 1\%)}{\frac{dN}{d\theta_{e,R}}(\theta_{e,R})}$$



1% systematic error on σ_G has an effect of 10ppm at low angles (θ_{eR} < 2 mrad).

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Meets the requirements of MUonE

Conclusions

- Control of multiple scattering effects plays an important role in the MUonE experiment.

- Test Beam 2017: multiple scattering of 12 and 20 GeV electrons on C target. An agreement of ~1% is found between data and MC for the Gaussian core. A Gaus+Student parameterization fits well the multiple scattering distribution.

- A precision of 1% on the Gaussian core of the multiple scattering distribution is sufficient to keep this systematic effect within the requirement of 10 ppm.