Annual Progress Report presentation

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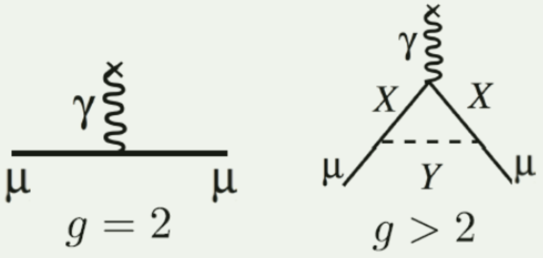
Motivation for MUonE

Experiment

The g-2 experiment at Fermilab aims to measure the anomalous magnetic moment of the muon aμ

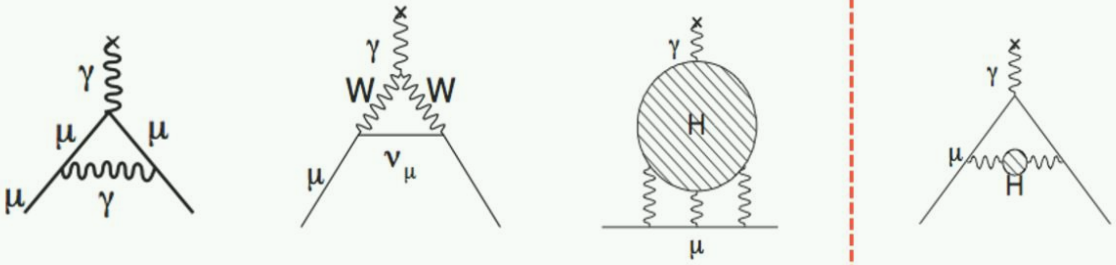
$$a_\mu = \frac{g_\mu - 2}{2}$$



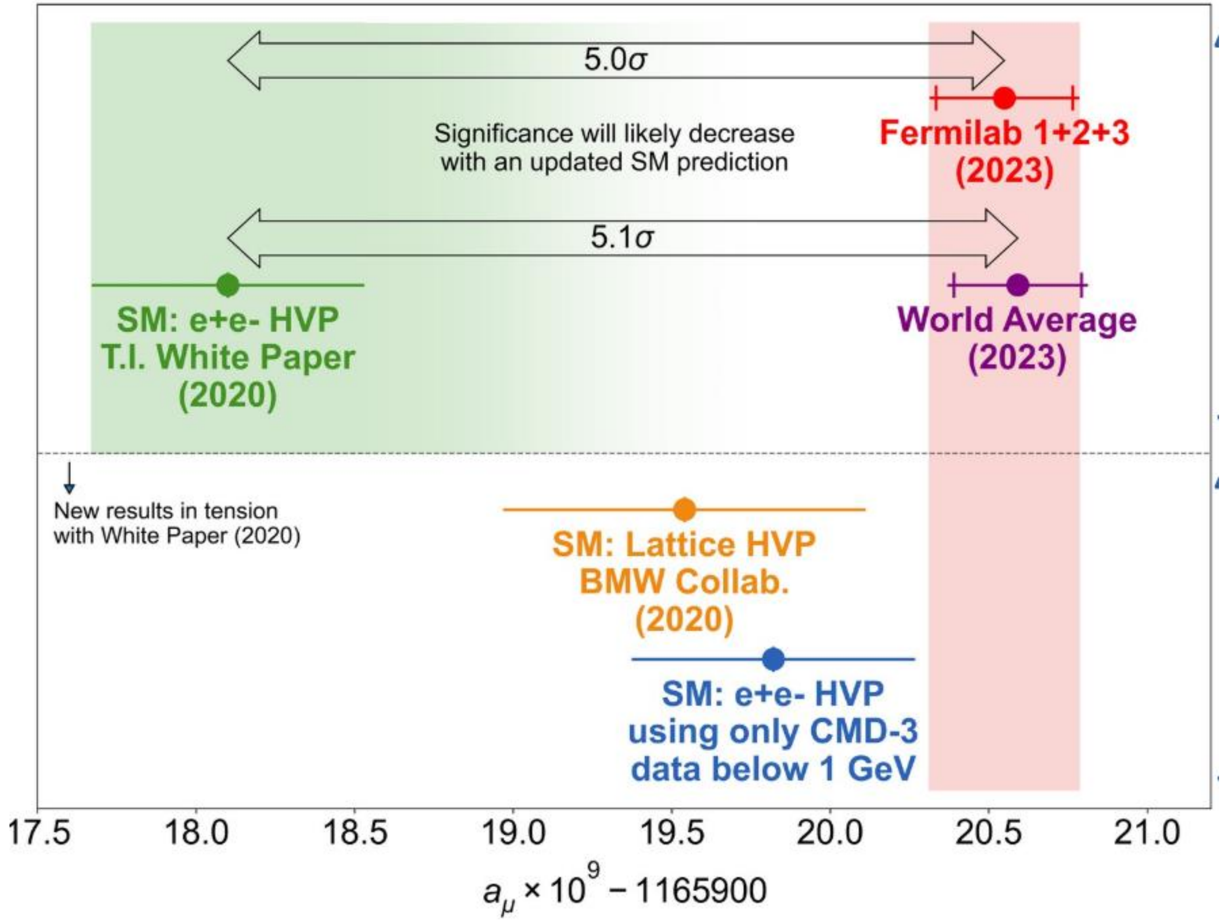
Theory

The different contribution to aμ are:

QED	Electroweak	Hadronic Light-by-Light	Hadronic Vacuum Polarization



QED	Electroweak	Hadronic Light-by-Light	Hadronic Vacuum Polarization
a_μ 99.99%	a_μ 1 ppm	a_μ 1 ppm	a_μ 59 ppm
δa_μ 0.001%	δa_μ 0.2%	δa_μ 16%	δa_μ 84%



A clarification is needed on the theoretical prediction.

The main source of uncertainty comes from the leading order of the hadronic vacuum polarisation contribution

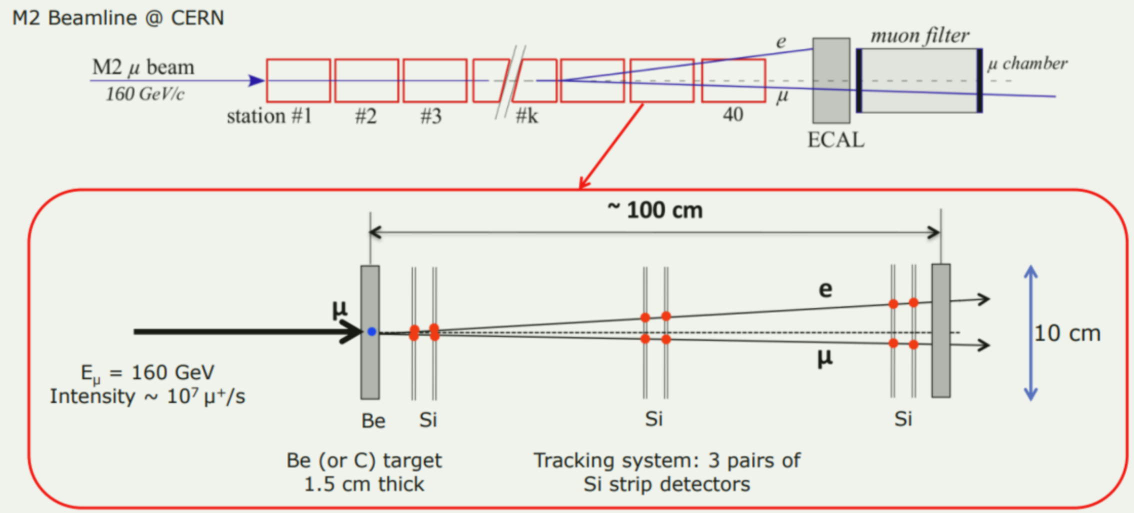
MUonE

MUonE aims to provide an independent measurement of the contribution from hadronic vacuum polarization at leading order to the muon's anomalous magnetic moment using the scattered angles in a muon-electron elastic interaction.

The running of α is parameterized by $\Delta\alpha$ and can be measured by MUonE, which can be expressed in a leptonic and a hadronic part: $\Delta\alpha = \Delta\alpha_{lep} + \Delta\alpha_{had}$

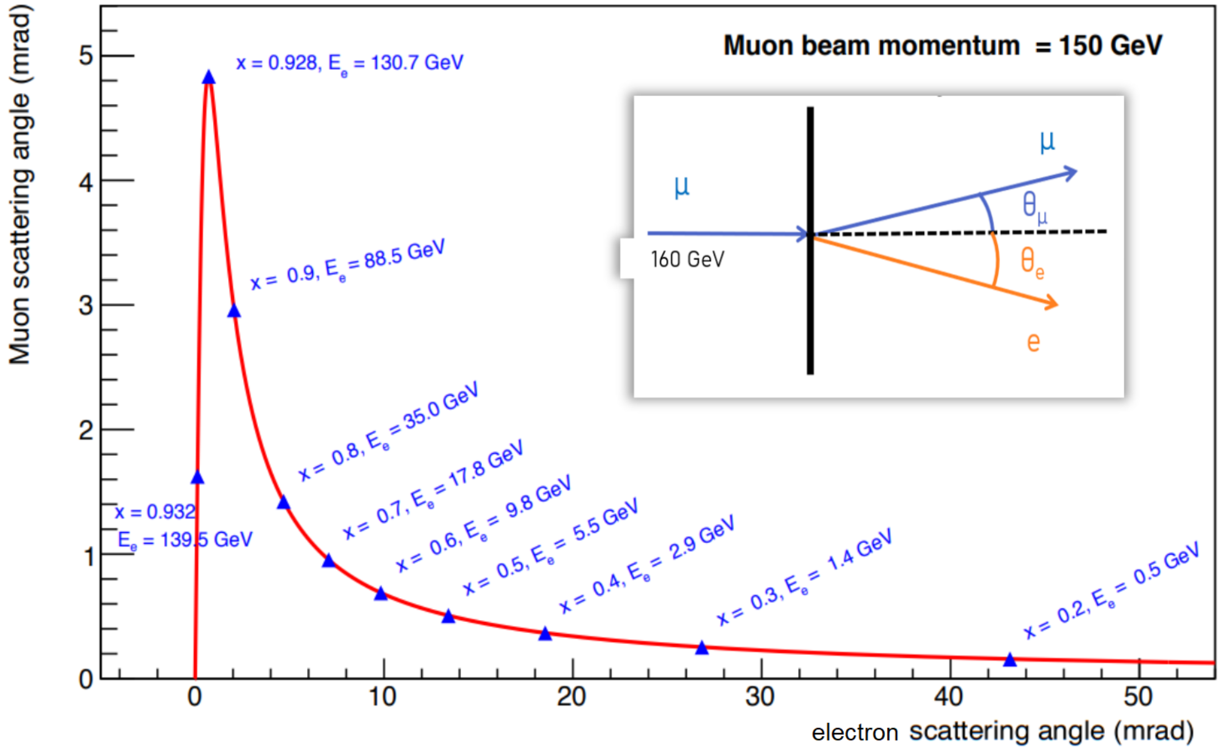
We then extract the hadronic vacuum polarization leading order using :

$$a_\mu^{HLO} = \frac{\alpha}{\pi}\int_0^1 dx(1-x)\Delta\alpha_{had}$$



The final goal of MUonE is to get a_μ^{HLO} with ~0.3% statistical error and comparable systematics.

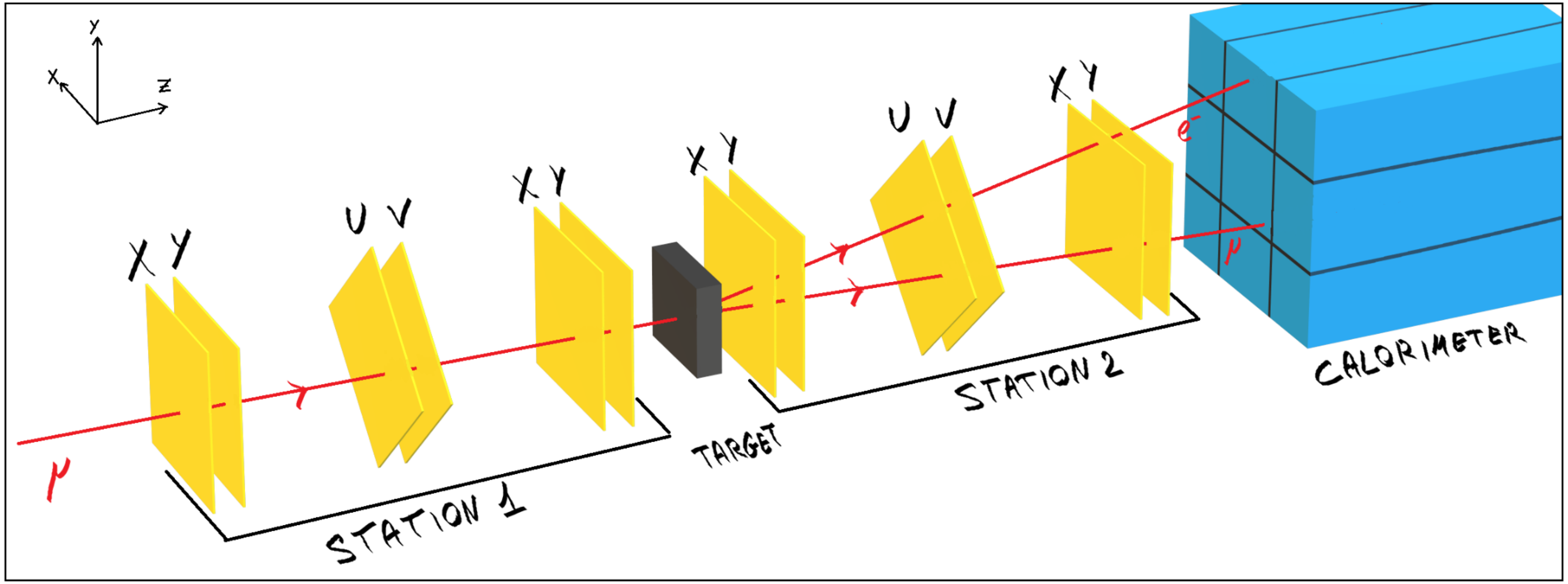
Extract a_μ directly from correlation between outgoing angles for elastic events



MUonE test run 2023

A three-week test run has been conducted in 2023 with:

- A muon beam provided by the M2 beamline at CERN
- 2 tracking station
- A 2 or 3cm target in Beryllium
- An Electromagnetic Calorimeter



We expect to measure $\Delta\alpha_{lep}$ with O(5%)

Studies of the systematics

Definition of R_{lep}

- $\Delta\alpha_{lep}$ is defined by the equation below, from the theoretical calculation of the leptonic vacuum polarization at 1 loop

$$\Delta\alpha_{lep}(t) = k[f(m_e)+f(m_\mu)+f(m_\tau)]$$

$$f(m) = -\frac{5}{9}-\frac{4}{3}\frac{m^2}{t}+\left(\frac{4}{3}\frac{m^4}{t^2}+\frac{m^2}{3t}-\frac{1}{6}\right)\frac{2}{\sqrt{1-\frac{4m^2}{t}}}ln\left|\frac{1-\sqrt{1-\frac{4m^2}{t}}}{1+\sqrt{1-\frac{4m^2}{t}}}\right|$$

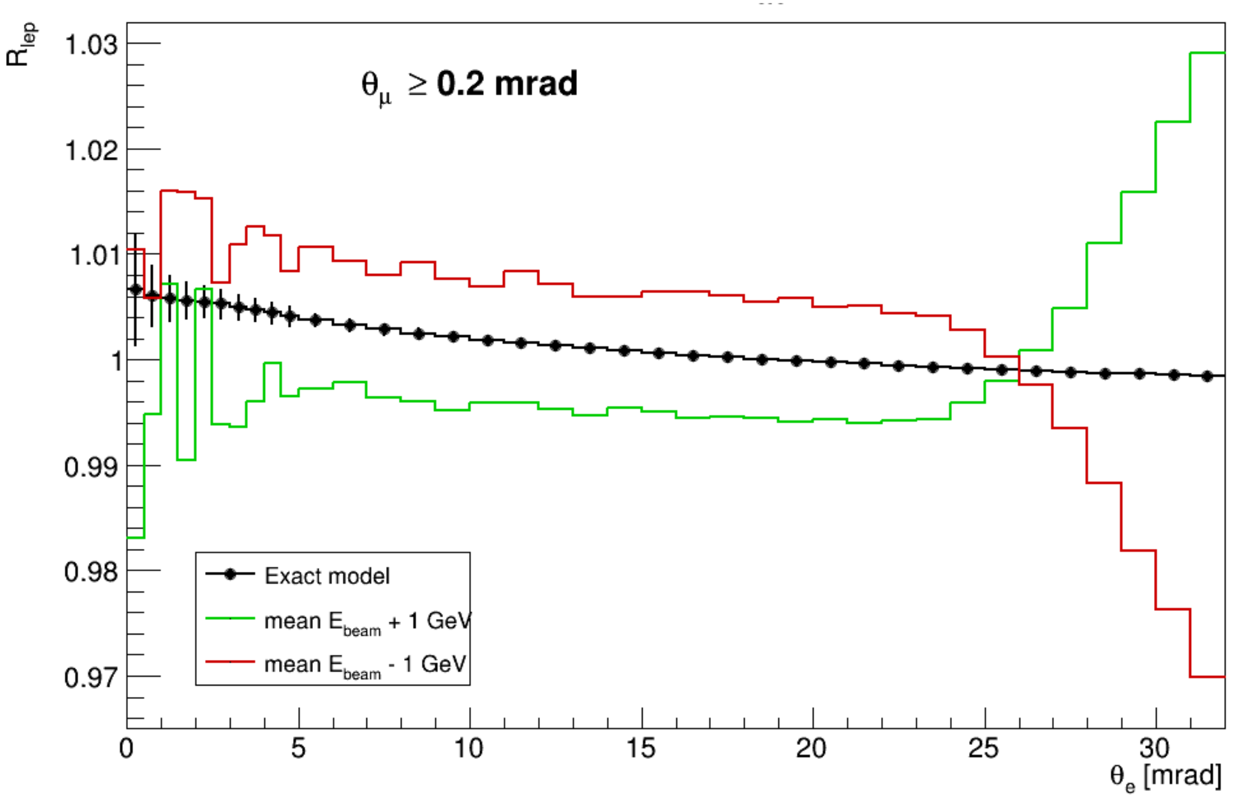
- We use $\Delta\alpha_{lep}$ as input in MESMER, our Monte Carlo event generator, and a fast simulation for the modelisation of the detector effects.

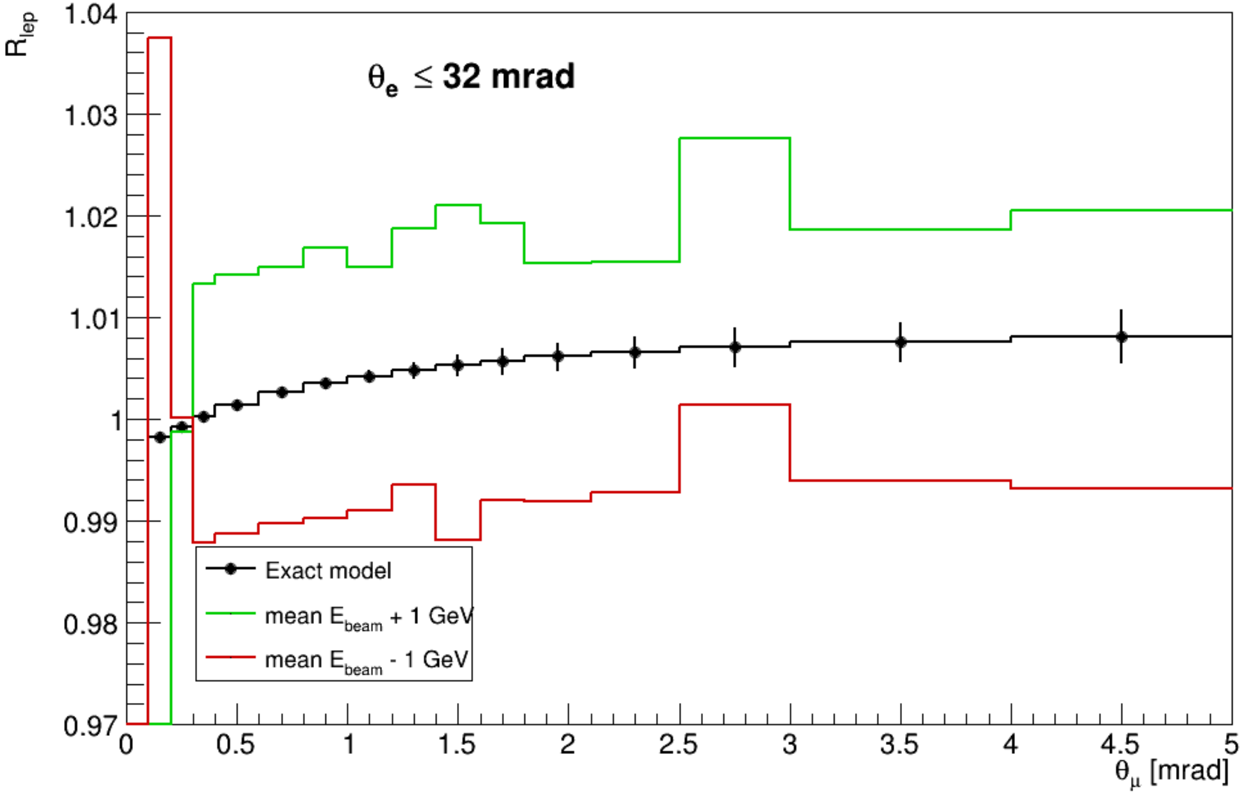
- The ratio R_{lep} is used to visualize easily the effect of an error in the estimation of a systematic, on the extraction of the leptonic running of α

$$R_{lep} = \frac{d\sigma(\Delta\alpha_{lep})}{d\sigma(\Delta\alpha_{lep}=0)} \sim 1+2\Delta\alpha_{lep}$$

Mean Beam Energy shift ± 1GeV

- For the beam energy, a shift (here ±1 GeV) can be easily identified from the data in both $R_{lep}(\theta_e)$ and $R_{lep}(\theta_{muon})$





- *Lumi = 1pb^{-1}*

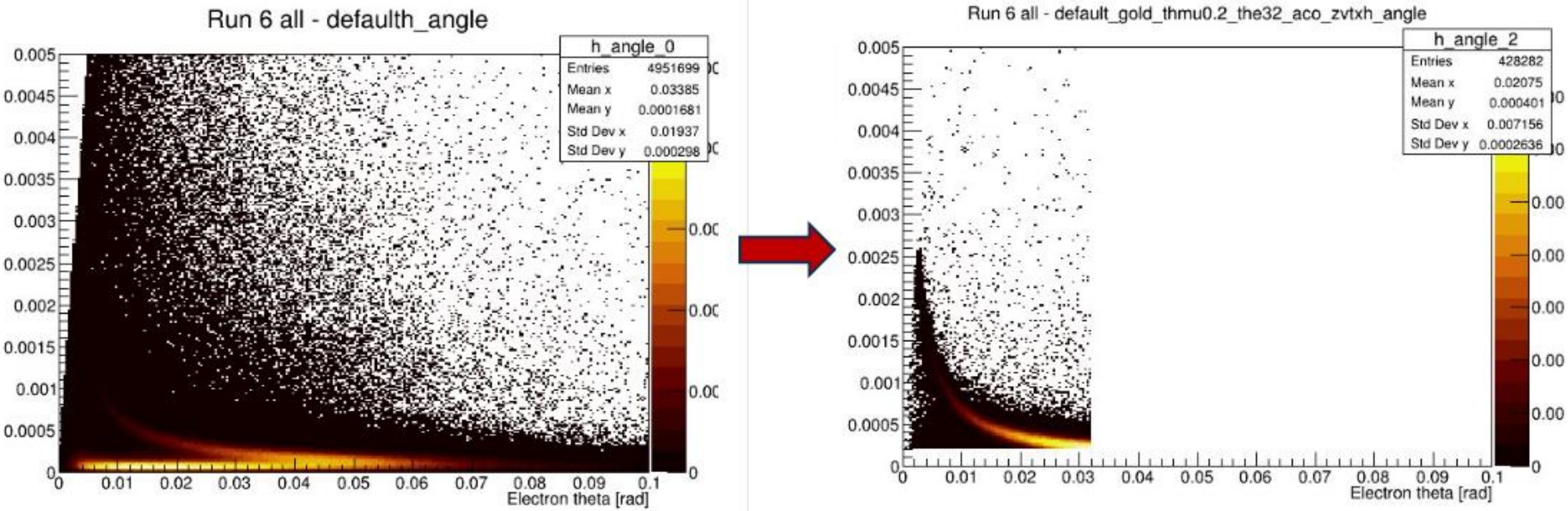
Data – MC comparison

Procedure

We produce histograms from data (test run summer 2023) and Monte Carlo samples, and apply some selection cuts:

- Golden event (1 track in, 2 tracks out)
- Vertex $\chi^2 < 150$
- $\theta_e < 32$ mrad
- $\theta_\mu > 0.2$ mrad
- $|Z_{vertex} - Z_{target}| < 3$ cm
- |Acoplanarity| < 1 rad (the cut is needed because the elastic events are expected to be planar)

Data

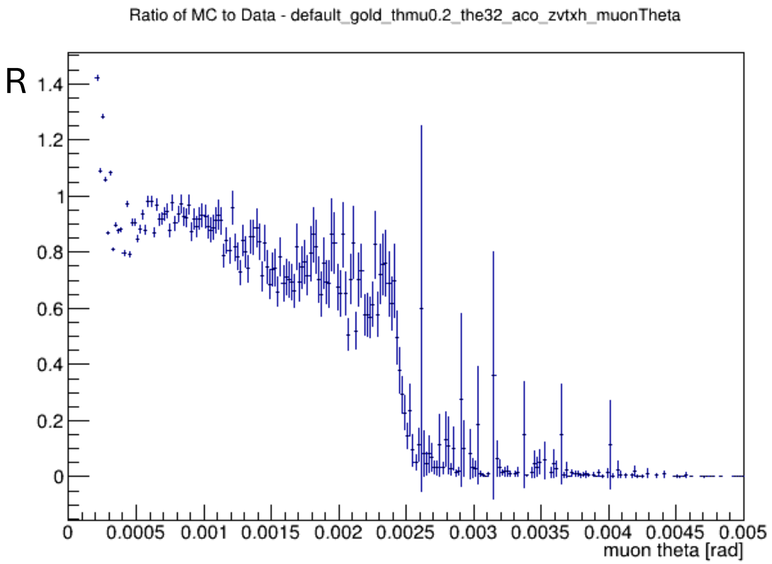


Comparison

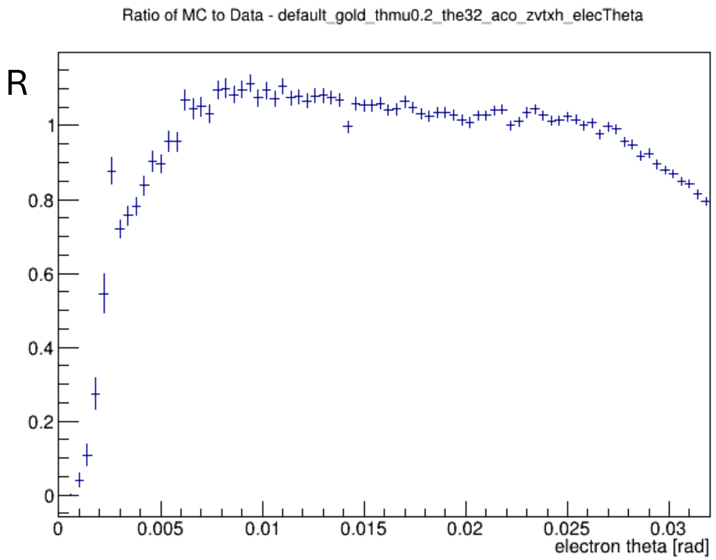
We then compare the ratio R = MC/data for some quantities,

We are doing a **shape** analysis, to do so we use the intergral of the histograms and normalize them

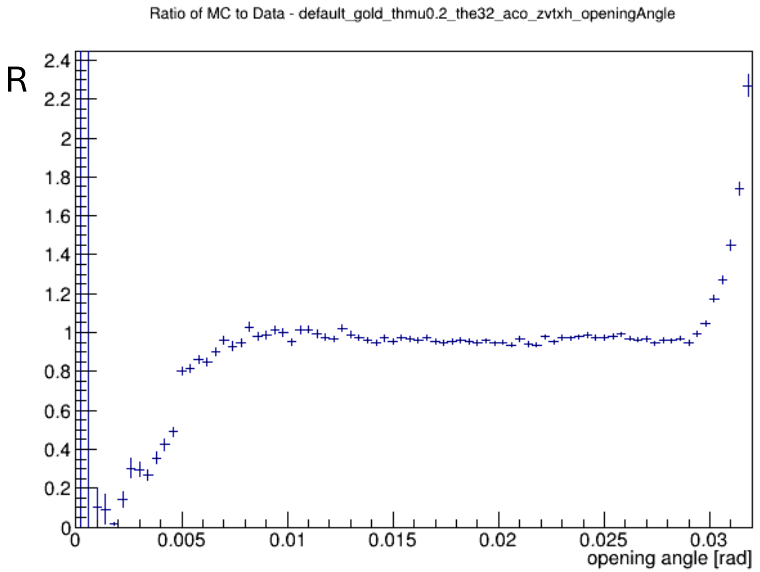
Muon angle



Electron Angle



Opening Angle



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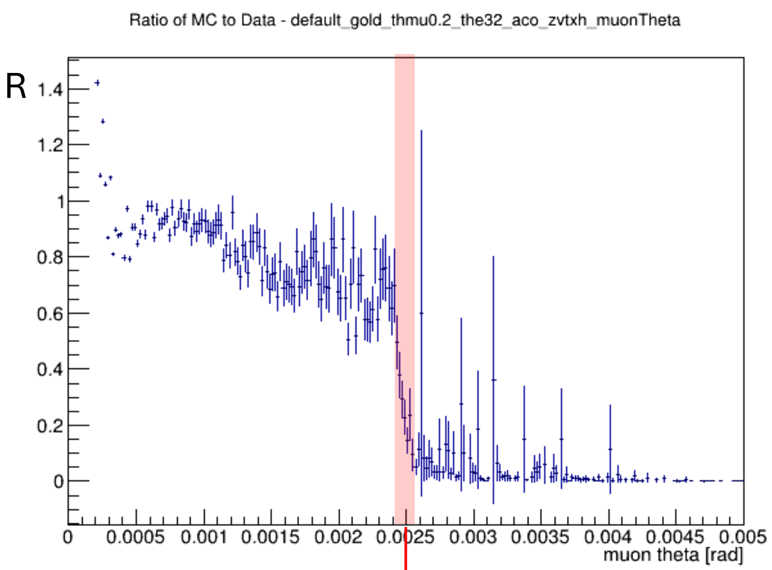
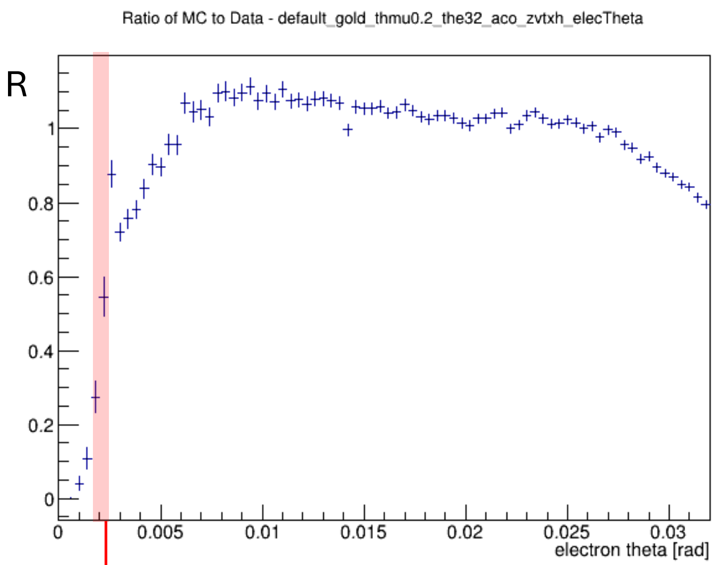
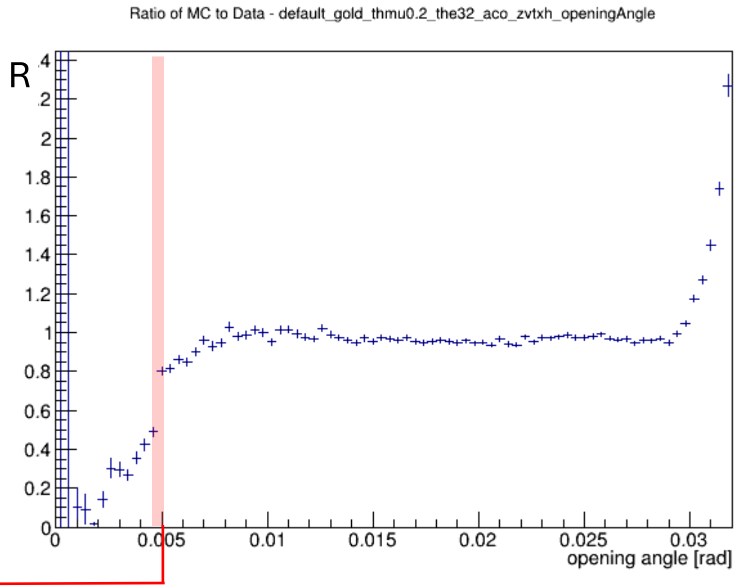


Electron Angle



Opening Angle



Drop around 2.5mrad for both muon and electron angle (5 for opening angle) because we don't have a proper particle identification.

Here we assume the track with the biggest scattered angle is always the electron and the smallest the muon. This is not true for this region

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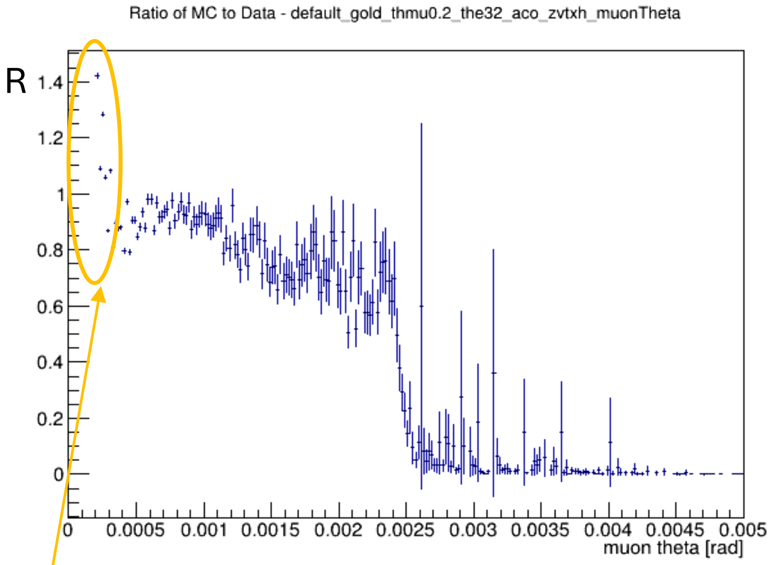
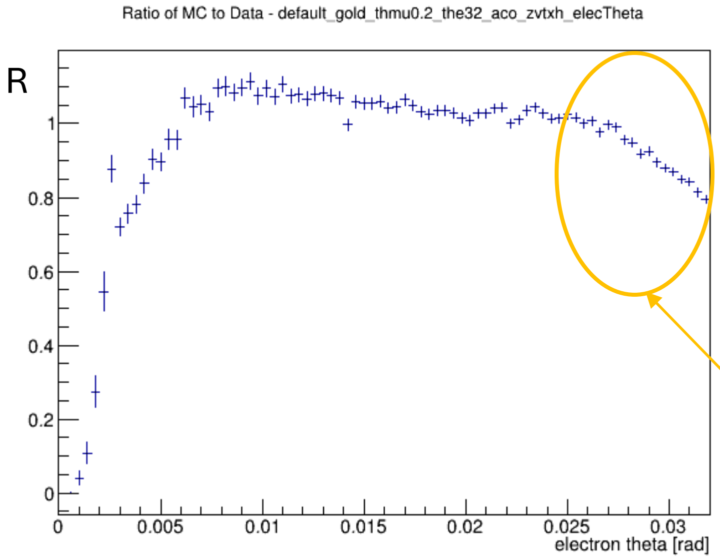
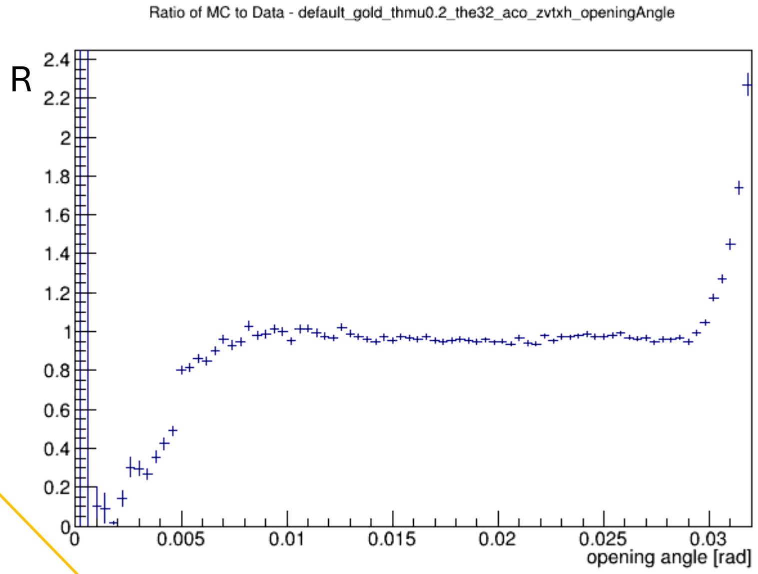
Muon angle

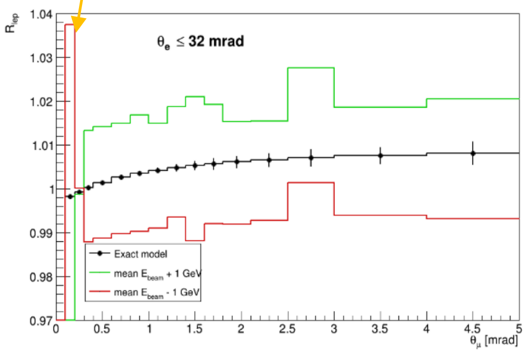


Electron Angle



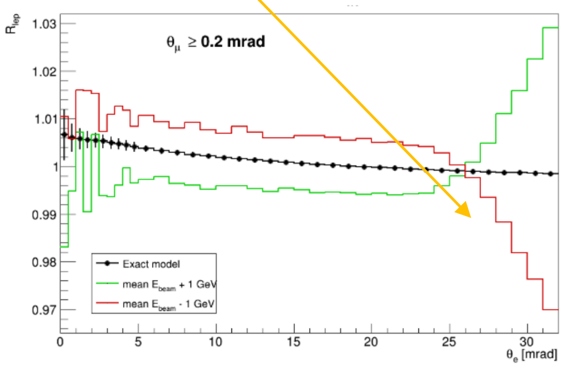
Opening Angle





The large slopes at the very low muon angle and large electron angle are compatible with some systematics effect.

Here we compare with a shift in the Energy beam from fastSim *(care the black slope in fastSim is due to the running of alpha leptonic, not in our data)*



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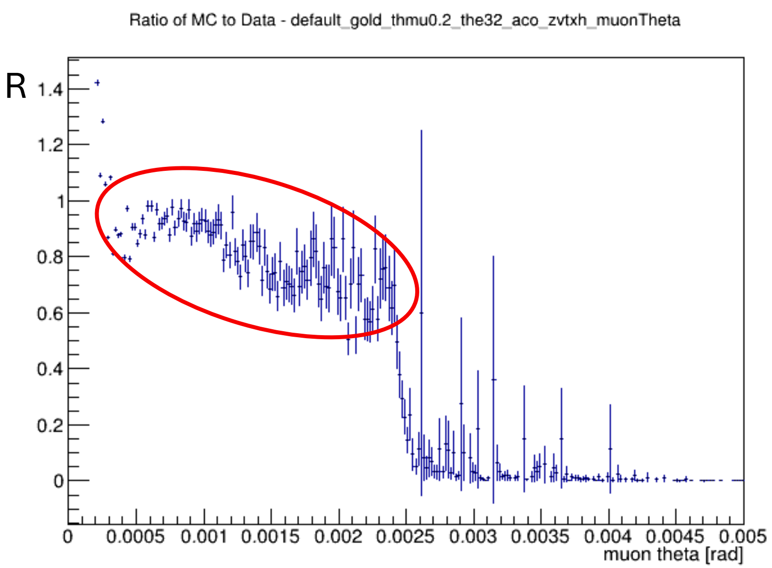
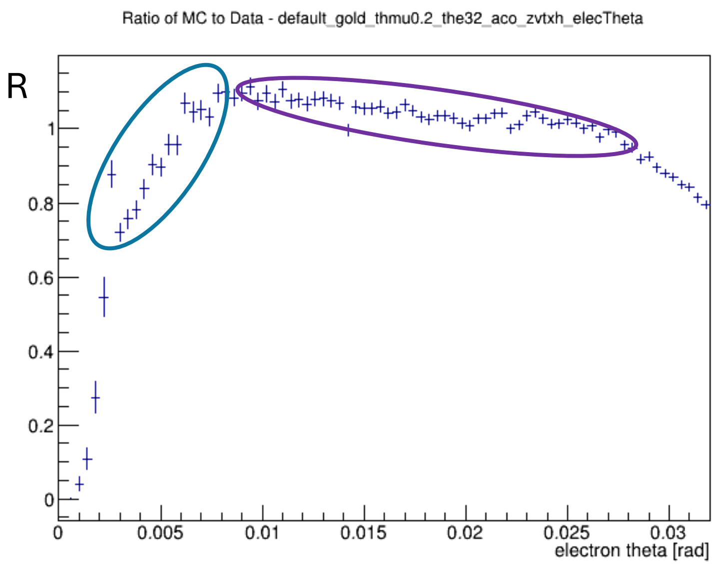
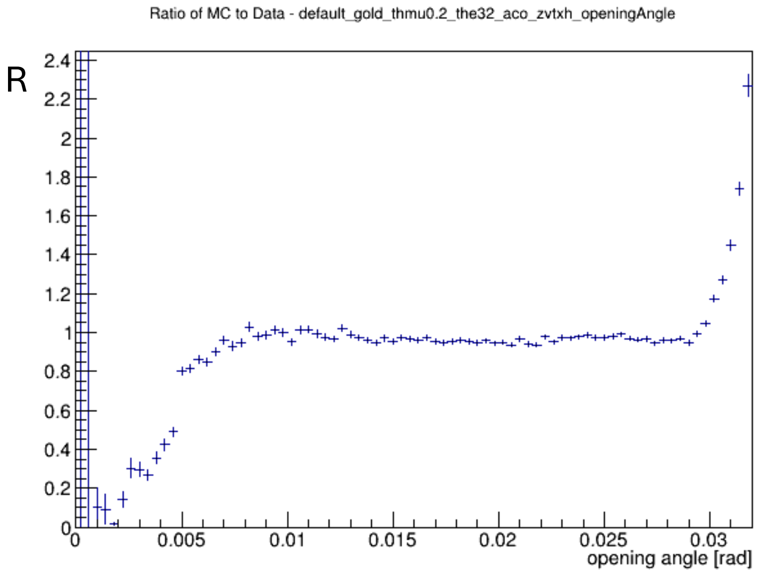
Muon angle



Electron Angle



Opening Angle



But there is some unexplain behavior:

- what is the downward slope for muon angle in ~[0.25 ; 2.5] mrad ?
- what is this large upward slope for electron in ~[2.5 ; 7] mrad ?
- what is the slight downward slope for electron in ~[7 ; 25] mrad ?

Conclusion

- The data-Monte Carlo comparison needs improvement and progress are made:
    - Adding background to Monte Carlo
    - Improving the reconstruction algorithm
    - Analysis on the selection criteria

- I am currently working on the selection criteria