

# Il Progetto MUonE

Massimo Passera  
INFN Padova

on behalf of



IFAE 2018 - XVII edizione  
4-6 Aprile 2018

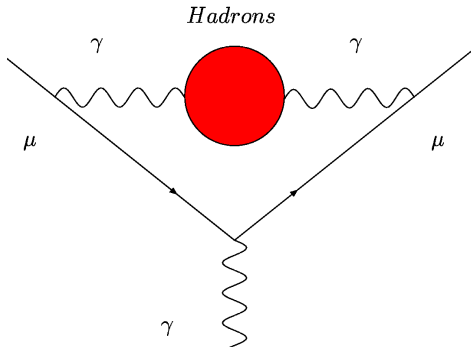
INFN e Università degli Studi di Milano-Bicocca

# **A new approach to the leading hadronic contribution to the muon $g-2$**

**C. Carloni Calame, MP, L. Trentadue, G. Venanzoni  
PLB 2015 - arXiv:1504.02228**

# New space-like proposal for HLO

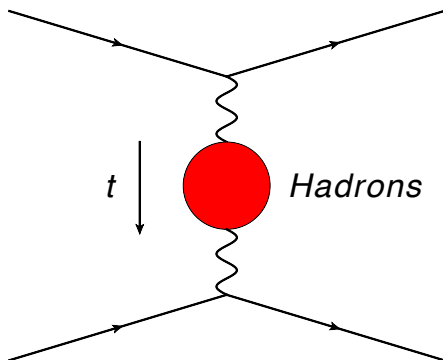
- At present, the leading hadronic contribution  $a_\mu^{\text{HLO}}$  is computed via the **time-like** formula:



$$a_\mu^{\text{HLO}} = \frac{1}{4\pi^3} \int_{4m_\pi^2}^{\infty} ds K(s) \sigma_{\text{had}}^0(s)$$

$$K(s) = \int_0^1 dx \frac{x^2 (1-x)}{x^2 + (1-x) (s/m_\mu^2)}$$

- Alternatively, exchanging the  $x$  and  $s$  integrations in  $a_\mu^{\text{HLO}}$



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

$$t(x) = \frac{x^2 m_\mu^2}{x-1} < 0$$

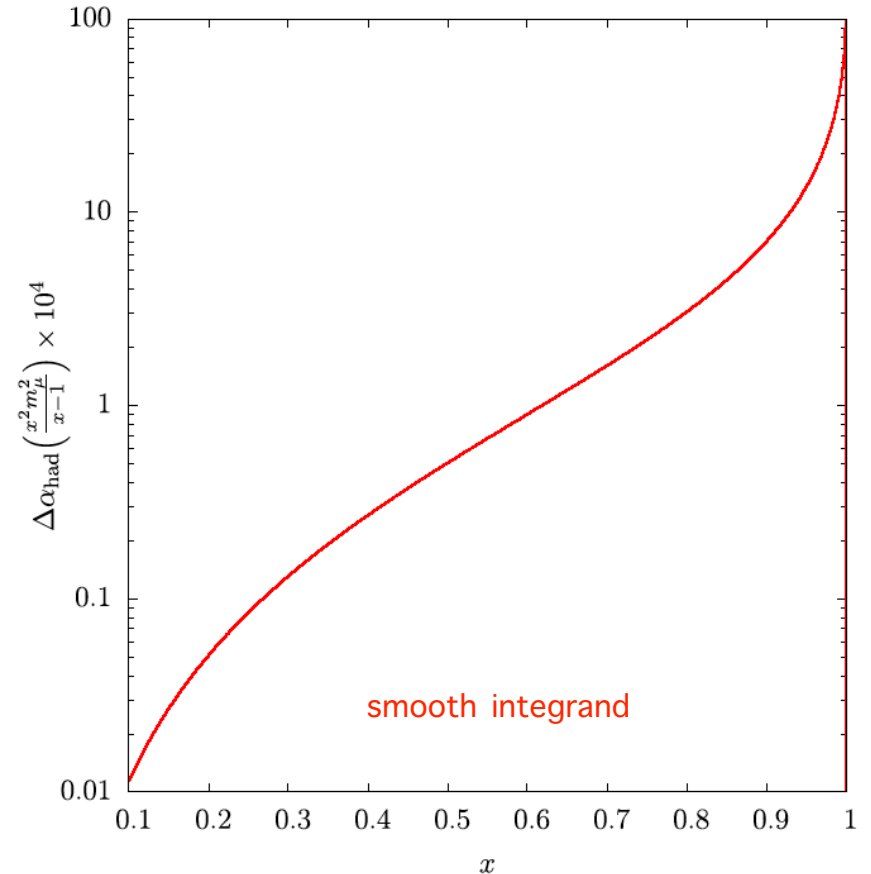
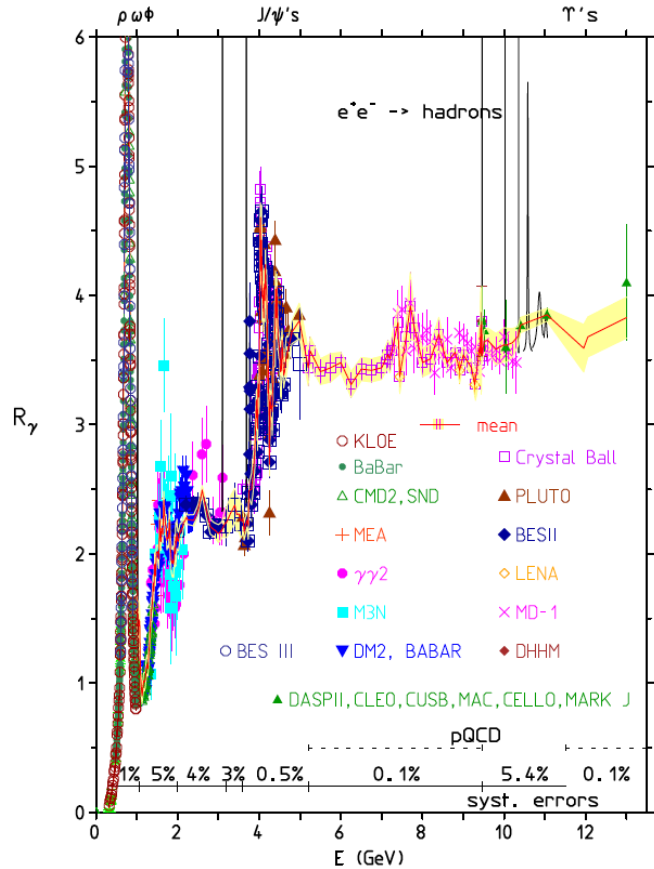
$\Delta\alpha_{\text{had}}(\mathbf{t})$  is the hadronic contribution to the running of  $\alpha$  in the **space-like** region. It can be extracted from scattering data!

# New space-like proposal for HLO (2)

Time-like



Space-like

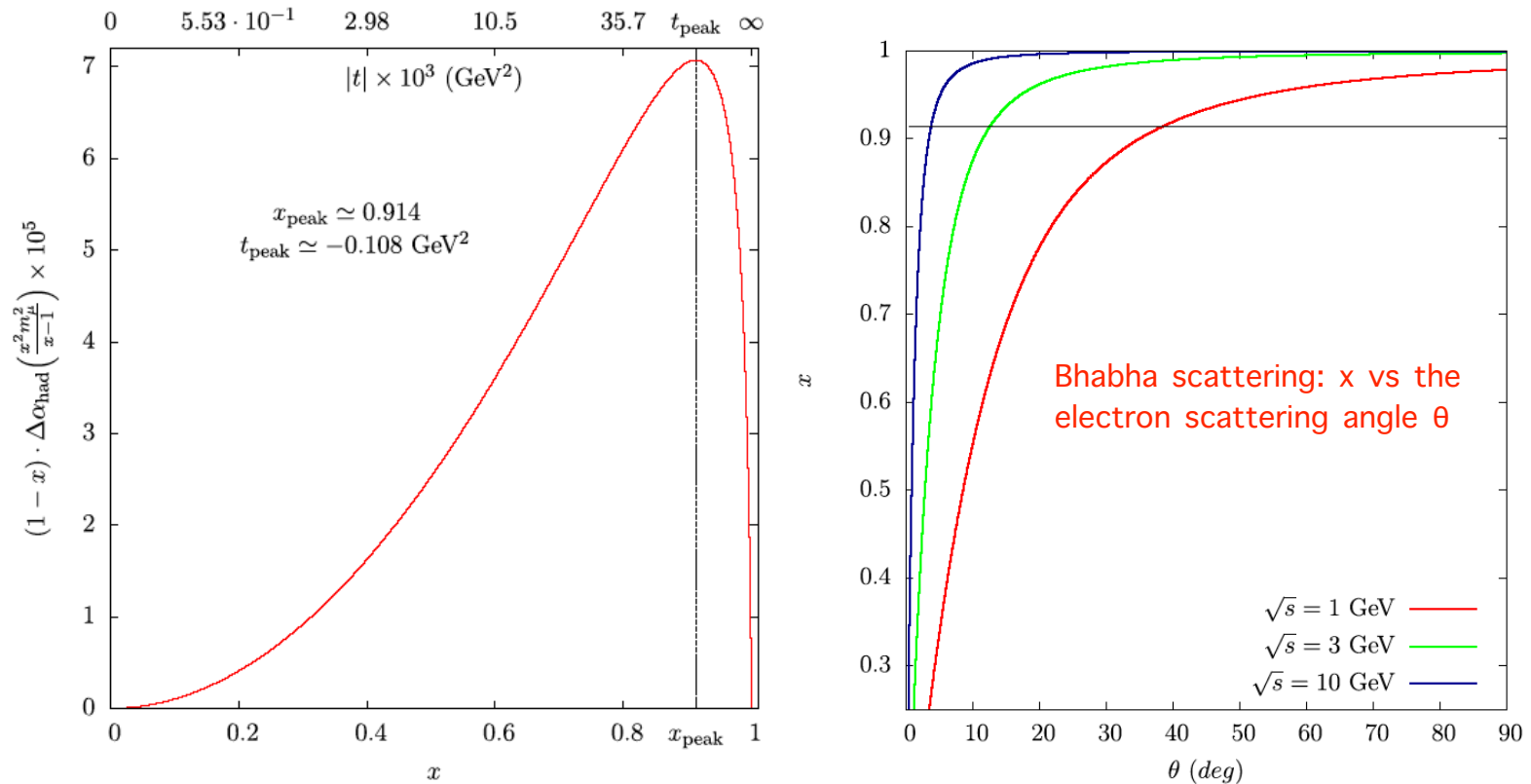


F. Jegerlehner, arXiv:1511.04473

Carloni Calame, MP, Trentadue, Venanzoni, PLB 2015

# New space-like proposal for HLO: which experiment?

- $\Delta\alpha_{\text{had}}(\mathbf{t})$  can be measured via Bhabha scattering:

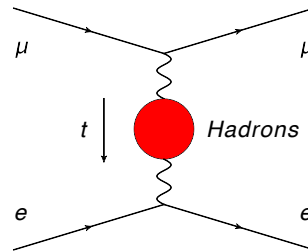


- The peak occurs at  $x_{\text{peak}} = 0.914$ ,  $t_{\text{peak}} = -0.108 \text{ GeV}^2 \simeq -(330 \text{ MeV})^2$

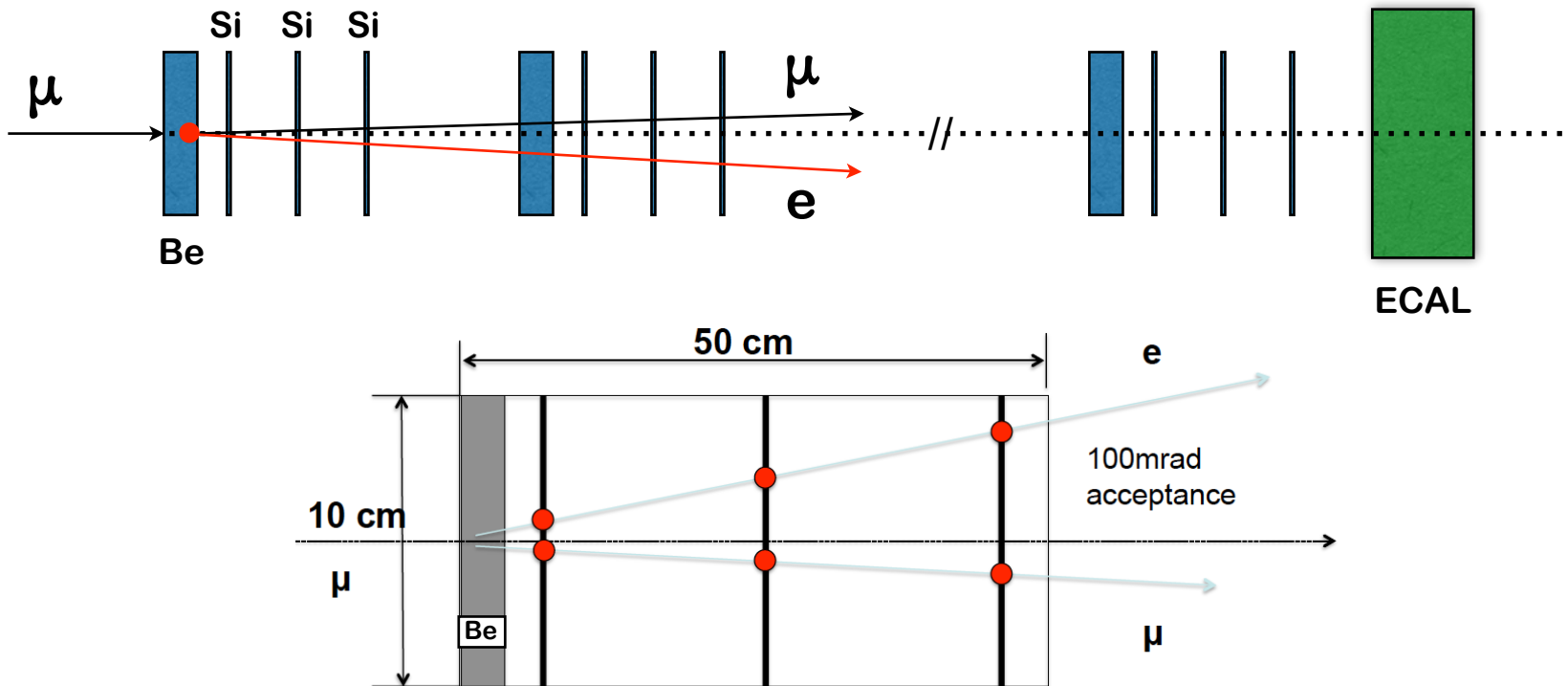
Carlioni Calame, MP, Trentadue, Venanzoni, PLB 2015

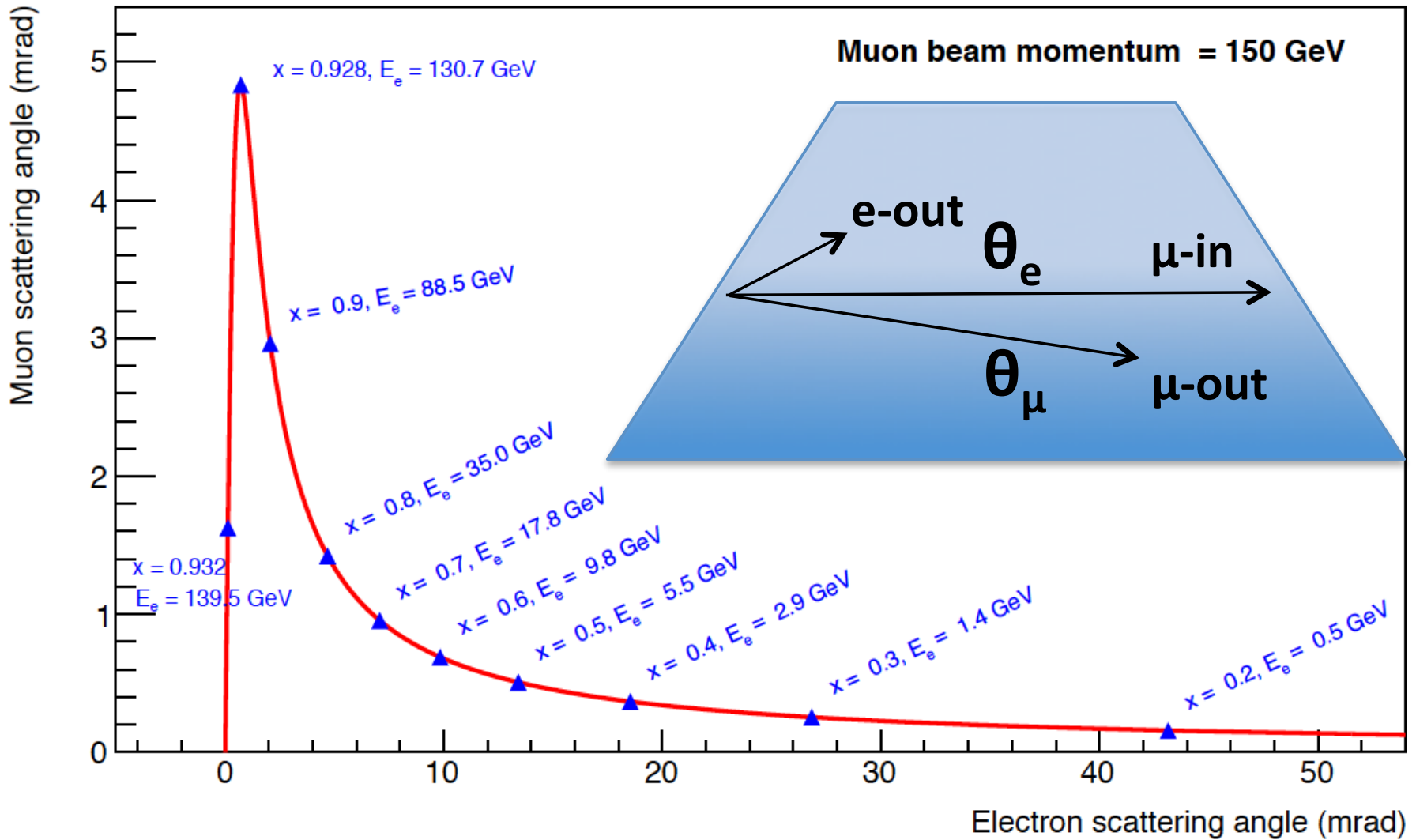
# Muon-electron scattering

Abbiendi, Carloni Calame, Marconi, Matteuzzi, Montagna,  
Nicrosini, MP, Piccinini, Tenchini, Trentadue, Venanzoni  
EPJC 2017 - arXiv:1609.08987



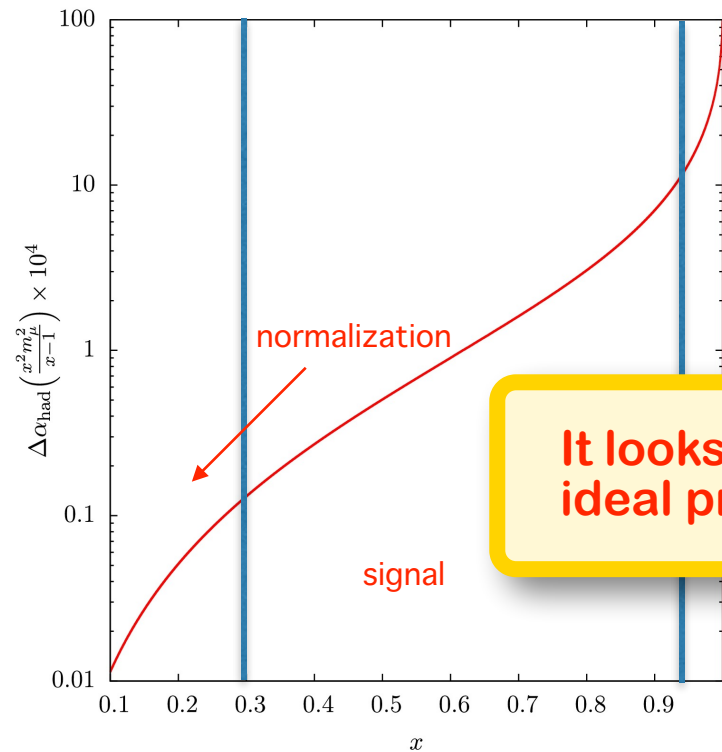
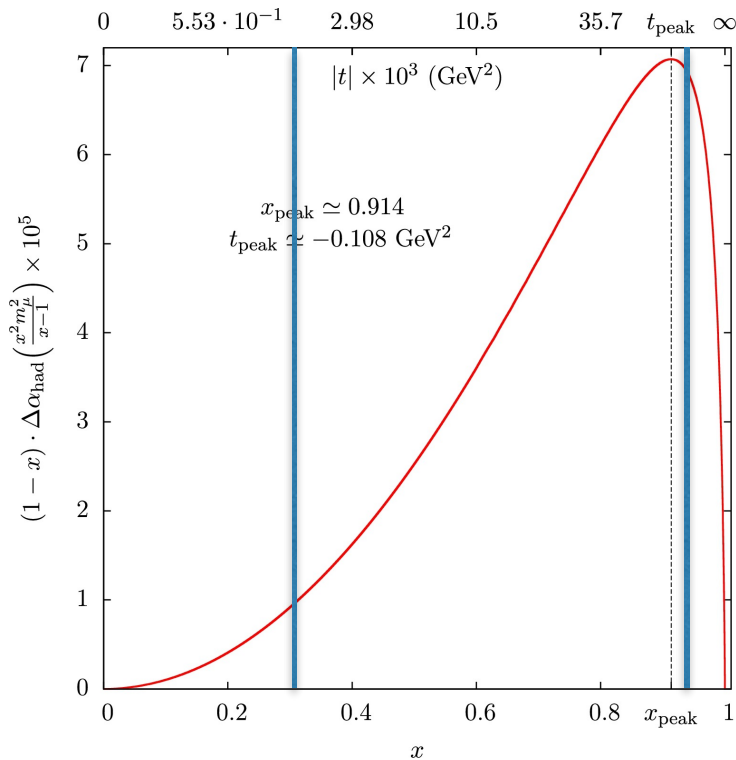
- $\Delta\alpha_{\text{had}}(t)$  can also be measured via the **elastic scattering**  $\mu e \rightarrow \mu e$ .
- We propose to scatter a 150 GeV muon beam, available at CERN's North Area, on a fixed electron target (Beryllium). Modular apparatus: each module has one layer of Beryllium (target) followed by several thin Silicon strip detectors.



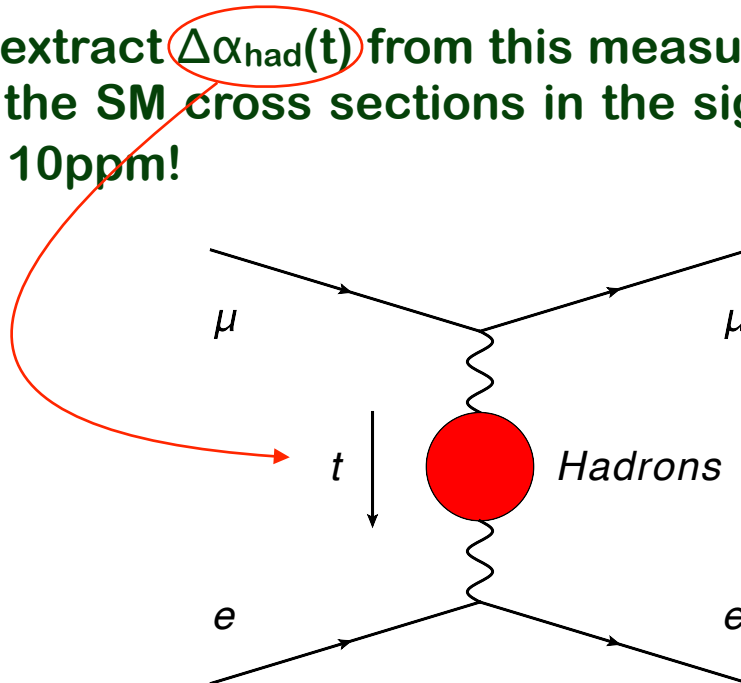




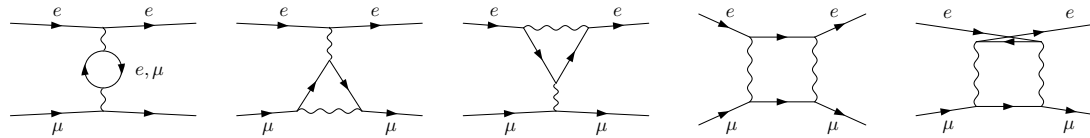
- For a 150 GeV muon beam, the scan region extends up to  $x=0.932$ , ie beyond the peak! (the peak is at  $x=0.914$ )
- The integrand in the remaining region  $x \in [0.932, 1]$  accounts for  $\sim 13\%$  of the  $a_\mu^{\text{HLO}}$  integral. It cannot be reached by our experiment but it can be determined using time-like data & pQCD, and/or lattice QCD results.



- **Statistics:** With CERN's 150 GeV muon beam M2 ( $1.3 \times 10^7 \mu/\text{s}$ ), incident on several Be layers (total thickness 60cm), 2 years of data taking ( $2 \times 10^7 \text{ s/yr}$ )  $\rightarrow$  integrated luminosity  $\mathcal{L}_{\text{int}} \sim 1.5 \times 10^7 \text{ nb}^{-1}$ .
- With this  $\mathcal{L}_{\text{int}}$  we estimate that we can reach a statistical sensitivity of  $\sim 0.3\%$  on  $a_\mu^{\text{HLO}}$ , ie  $\sim 20 \times 10^{-11}$ .
- **Systematics:** Systematic effects must be known at  $\leq 10\text{ppm}$ .
- **Theory:** To extract  $\Delta\alpha_{\text{had}}(t)$  from this measurement, we must know the ratio of the SM cross sections in the signal and normalisation regions at  $\leq 10\text{ppm}$ !

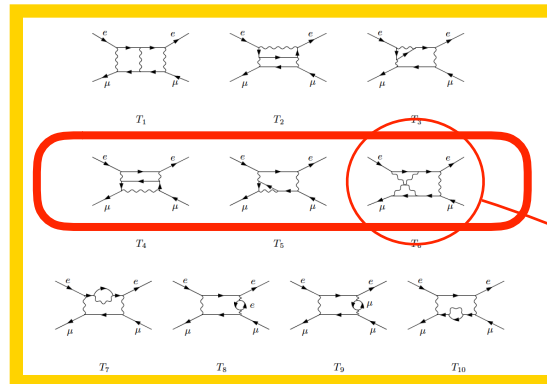


- **NLO QED corrections known & checked. MC @ NLO ready and tailored to the fixed target kinematics.**



Pavia Group

- **NNLO: Missing MI for the planar 2-loop box diagrams computed.**



Mastrolia, MP, Primo & Schubert, arXiv:1709.07435.

Non-planar: not yet!

- **NNLO amplitudes: virtual 2-loop, real-virtual, double real, automation, subtractions...**

Mastrolia, Ossola, MP, Primo, Schubert, Torres,...

- **NNLO hadronic contributions**

Fael, MP

- **Fixed-order NNLO + Resummation**

Broggio, Signer, Ulrich

- **Towards a MC at NNLO**

Pavia group, Czyz

- **Interplay with lattice calculations**

Marinković

- **Explore the new physics sensitivity of this experiment!**

Paradisi, MP,...



## Muon-electron scattering: Theory kickoff workshop

4-5 September 2017

<https://agenda.infn.it/internalPage.py?pagelId=0&confId=13774>

The aim of the workshop is to explore the opportunities offered by a recent proposal for a new experiment at CERN to measure the scattering of high-energy muons on atomic electrons of a low-Z target through the process  $\mu e \rightarrow \mu e$ . The focus will be on the theoretical predictions necessary for this scattering process, its possible sensitivity to new physics signals, and the development of new high-precision Monte Carlo tools. This kickoff workshop is intended to stimulate new ideas for this project.

It is organized and hosted by INFN Padova and the Physics University.

### Organizing Committee

Carlo Carloni Calame - INFN Pavia  
Pierpaolo Mastrolia - U. Padova  
Guido Montagna - U. Pavia  
Oreste Nicrosini - INFN Pavia  
Paride Paradisi - U. Padova  
Massimo Passera - INFN Padova (Chair)  
Fulvio Piccinini - INFN Pavia  
Luca Trentadue - U. Parma

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## Mainz Institute for Theoretical Physics

### SCIENTIFIC PROGRAMS

**Probing Physics Beyond SM with Precision**  
Ansgar Denner U Würzburg, Stefan Dittmaier U Freiburg, Tilman Plehn U Heidelberg  
**February 26-March 9, 2018**

**Bridging the Standard Model to New Physics with the Parity Violation Program at MESA**

### TOPICAL WORKSHOPS

**The Evaluation of the Leading Hadronic Contribution to the muon anomalous magnetic moment**  
Massimo Passera INFN Padua, Luca Trentadue U Parma, Carlo Carloni Calame INFN Pavia Graziano Venanzoni INFN Frascati  
**February 19-23, 2018**

**Challenges in Semileptonic B Decays**

**Next theory workshop in Zurich Feb 2019**

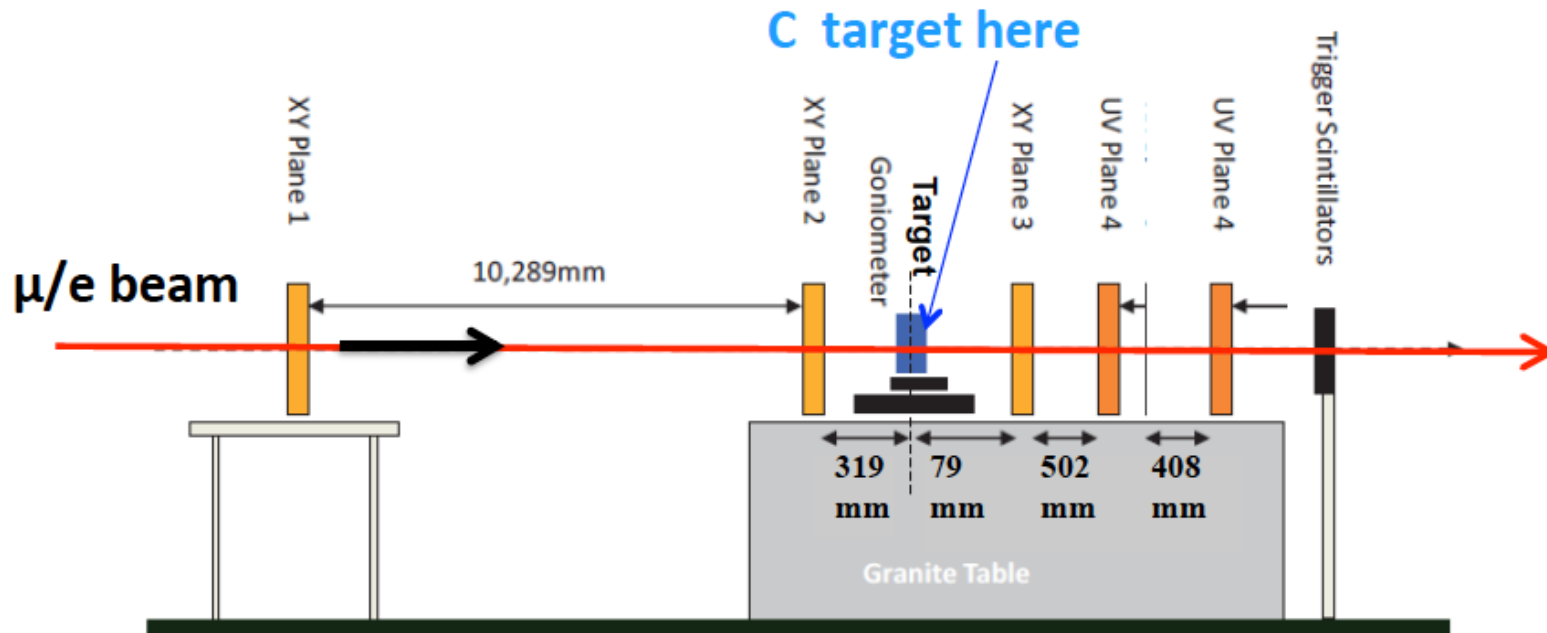
2018

Il. Pas

14/2018

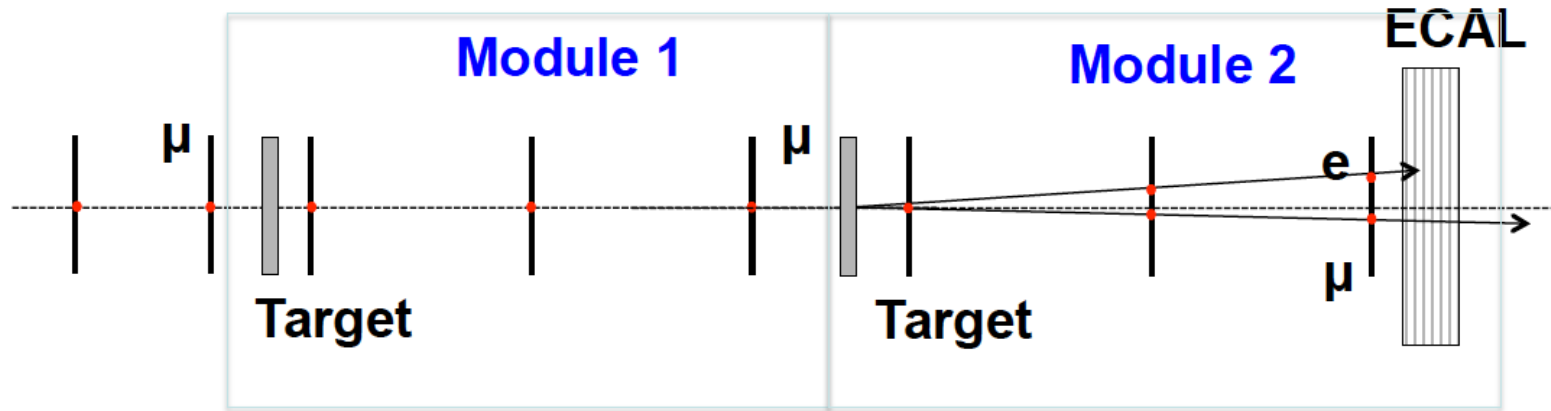
## Check GEANT MSC prediction and populate the 2D ( $\theta_e, \theta_\mu$ ) scattering plane

- 27 Sep-3 October 2017 at CERN "H8 Beam Line"
- Adapted UA9 Apparatus
- Beam energy: e- of 12/20 GeV;  $\mu$  of 160 GeV
- $10^7$  events with C targets of different thickness (2,4,8,-20mm)



Preliminary analysis: Vedi poster di Antonio Principe




- Run on the M2 line, behind COMPASS, of a full-scale prototype with 2 modules (start-up in April):



- Study of the detector performance: signal/background.
- This proposal is part of the Physics Beyond Colliders activities @ Cern.
- Planned request to INFN's Commissione I to fund next year's activities.
- Lol planned for 2019. Detector construction 2020-21. Start Run in 2022.

Vedi poster di Antonio Principe

# Conclusions

-  New proposal for an experiment at CERN to measure the leading hadronic contribution to the muon  $g-2$  via  $\mu$ -e elastic scattering.
-   $\mu$ -e exp: first  $\mu$ -e testbeam completed at CERN in October. Preliminary data analysis completed. New test run planned on CERN's M2 line starting in April with a full-scale prototype with 2 modules. Planned request to INFN's Commissione I to fund next year's activities.
-   $\mu$ -e th: NLO MC generator ready. Lots of theoretical work needed! NNLO QED & NLO hadronic corrections unknown. First results obtained for the NNLO planar box diagrams contributing to  $\mu$ -e scattering in QED. Dedicated high-precision MC tools needed.

**JOIN US!**



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**The End**

