# **The MUonE Project**

Massimo Passera INFN Padova



"MITP μ-e workshop"
February 19-23 2018
Mainz Institute for Theoretical Physics

# A new approach to $a_{\mu}^{HLO}$

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<sub>μ</sub>HLO is computed via the time-like formula:



$$a_{\mu}^{\text{HLO}} = \frac{1}{4\pi^3} \int_{4m_{\pi}^2}^{\infty} ds \, K(s) \, \sigma_{\text{had}}^0(s)$$
$$K(s) = \int_0^1 dx \, \frac{x^2 \, (1-x)}{x^2 + (1-x) \left(s/m_{\mu}^2\right)}$$

Alternatively, exchanging the x and s integrations in a<sub>μ</sub><sup>HLO</sup>



 $\Delta \alpha_{had}(t)$  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)



#### F. Jegerlehner, arXiv:1511.04473

#### Carloni Calame, MP, Trentadue, Venanzoni, PLB 2015

#### • $\Delta \alpha_{had}(t)$ can be measured via Bhabha scattering:



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

Carloni 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



- $\Delta \alpha_{had}(t)$  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.



**IP** 



μe

 $a_{\mu}^{HLO}$  via muon-electron scattering

- 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 ~13% of the  $a_{\mu}^{HLO}$  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, which has an average of ~ 1.3 × 10<sup>7</sup>  $\mu$ /s, incident on Be layers for a total thickness of 60cm, and 2 years of data taking (using 2 × 10<sup>7</sup> s/yr) one can reach an integrated luminosity of  $\mathcal{L}_{int} \sim 1.5 \times 10^7$  nb<sup>-1</sup>.
- With this integrated luminosity we estimate that we can reach a <u>statistical</u> sensitivity of ~ 0.3% on  $a_{\mu}^{HLO}$ , ie ~ 20 × 10<sup>-11</sup>!
- Systematics? Systematic effects must be known at ≤ 10ppm!
- Theory? To extract Δα<sub>had</sub>(t) from this measurement, the ratio of the SM cross sections in the signal and normalisation regions must be known at ≤ 10ppm!



## Theory workshop in Padova — Sep 2017



# Muon-electron scattering: Theory kickoff workshop

4-5 September 2017

### https://agenda.infn.it/internalPage.py?pageId=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 Physi 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

#### Secretariat

Anna Dalla Vecchia, INFN-Sez. PD +390499677022 anna.da Elena Pavan, INFN-Sez. PD +390499677155 epavan@pd.infi







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• NLO QED corrections known & checked. MC @ NLO ready.



• Missing MI for the planar 2-loop box diagrams computed.



- Progress in the NLO hadronic contributions. NB: No had LbL UM Fael
- Interplay with lattice calculations. M. Marinković
- What is the new physics sensitivity of this experiment?

### Why are we here?

#### Our final TH goal: a running MC for the ratio of the SM cross sections in the signal and normalisation regions at ≤ 10ppm!

Mon 19/2

Wed 21/2

| 14:00 | Lattice results for aµ^HLO   | Marina KRSTIC MARINKOVIC        |          |  |                          |
|-------|--|---------------------------------|----------|--|--------------------------|
|       |  |                                 | 09:00    | Calculations for muon decay at NNLO  | Adrian SIGNER            |
|       | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 14:00 - 14:45                   |          |  |                          |
| Tue   | 20/2   |                                 |          | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 09:00 - 09:45            |
|       |  |                                 |          | Expansion by regions in mu-e scattering  | Alessandro BROGGIO       |
| 09:00 | On the decomposition of 2-loop µe scattering via Adaptive Integrand            | William TORRES BOBADILLA        | 10:00    | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 09:45 - 10:15            |
|       | Decomposition  |                                 | Thu 22/2 |  |                          |
|       | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 09:00 - 09:45                   |          |  |                          |
|       | Automated higher order corrections with GoSam                                  | Nicolas GREINER                 | 11.00    |  |                          |
| 10:00 |  |                                 | 11.00    |  |                          |
|       | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 09:45 - 10:30                   |          | Hadronic corrections at NNLO   | Matteo FAEL              |
|       | Two-loop master integrals for µe-scattering in QED                             | Amedeo PRIMO                    |          |  |                          |
|       |  |                                 |          | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 11:15 - 12:00            |
| 11:00 | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 10:30 - 11:15                   | 12:00    | Hadronic corrections to g-2 via Schwinger's sum rule                           | Ms. Franziska HAGELSTEIN |
|       | Building bases for analytical fits of four-loop master integrals               | Stefano LAPORTA                 |          | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 12:00 - 12:30            |
| 12:00 |  |                                 | 14:00    | Disparsive approach to OCD and its applications                                | Alexander NESTEDENKO     |
|       | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 11:45 - 12:30                   |          |  | Alexander mesterkenne    |
| 14:00 | Monte Carlo generators for flavour factories                                   | Henryk CZYZ                     |          |  |                          |
|       |  |                                 |          | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 14:00 - 14:45            |
|       | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 14:00 - 14:45                   |          | Hadronic effects in muonium hyperfine structure                                | Savely KARSHENBOIM       |
|       | μe at NLO, Calculations and Phenomenology, Towards a MC at NNLO                | Dr. Carlo CARLONI CALAME et al. | 15:00    | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 14:45 - 15:15            |
| 15:00 |  | -                               |          | Tests of QED with the bound electron g-factor                                  | Dr. Robert SZAFRON       |
|       |  |                                 |          | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 15:15 - 15:45            |
|       | 02.430, Mainz Institute for Theoretical Physics, Johannes Gutenberg University | 14:45 - 16:00                   |          |  |                          |

Many interesting dedicated i r tarks:
And now, the EXP challenges...

M. Passera MITP Feb 19 2018