# P09    The muon anomalous magnetic moment and the search for new physics in the LHC era

**Started:** Jan. 1st 2015

**Participants:**

Cyril HUGONIE (LUPM)

*Marc KNECHT* (CPT)

Jean-Loïc KNEUR (LCC)

Kohtaroh MIURA (post-doc, since April 2015)

Laurent LELLOUCH (CPT)

Rehan MALAK (PhD)

Gilbert MOULTAKA (LCC)

Stephan NARISON (LUPM)
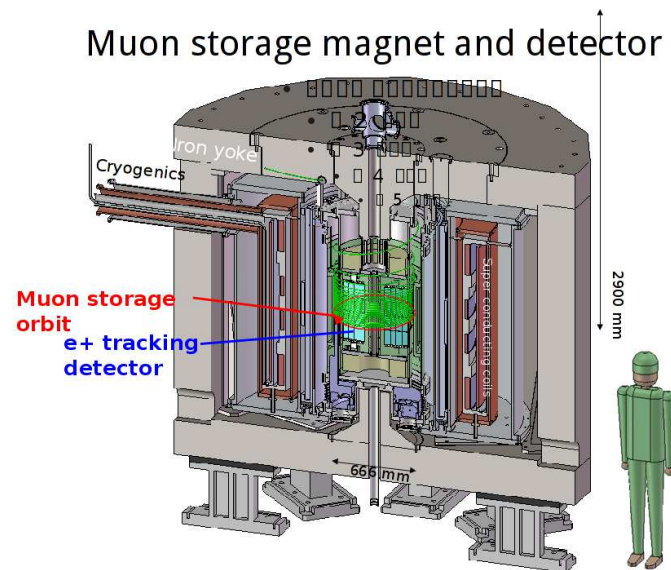
Eduardo de RAFAEL (CPT)

Strong experimental context



FNAL E989

2016: Commissioning, first
data
2018: Data run



Muon storage magnet and detector

Cryogenics

Iron yoke

Muon storage
orbit

e+ tracking
detector

Super conducting coils

2900 mm

666 mm

JPARC E34

Persistent discrepancy $\sim 3 - 3.5\,\sigma$ between theory and experiment

# Aims and scope

Address theoretical challenges surrounding the study of the anomalous magnetic moment of the muon

- reduce the hadronic uncertainties

develop new approaches (lattice QCD, RGOPT, moment analysis,...)

- determine the impact of the forthcoming precision measurements on models of new physics

higher order calculations and/or RG resummations, updating numerical codes (SuSpect, NMSSMTools)

# Direct lattice QCD calculation of LO HVP

L. Lellouch, R. Malak, K. Miura et al (BMW collaboration)

- Initial goal: determine $a_\mu^{\mathrm{HVP,LO}}$ with $\sim 3\%$ total accuracy (later $\sim 1\%$)

  $\rightarrow$ already interesting as $\dfrac{a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{SM}}}{a_\mu^{\mathrm{HVP,LO}}} \simeq 4\%$

- Ultimate goal: compete with phenomenology with accuracy $\lesssim 0.5\%$

First calculation directly at physical quark masses, in large volumes, at 4 (going on 5) lattice spacings, for full control over all sources of error
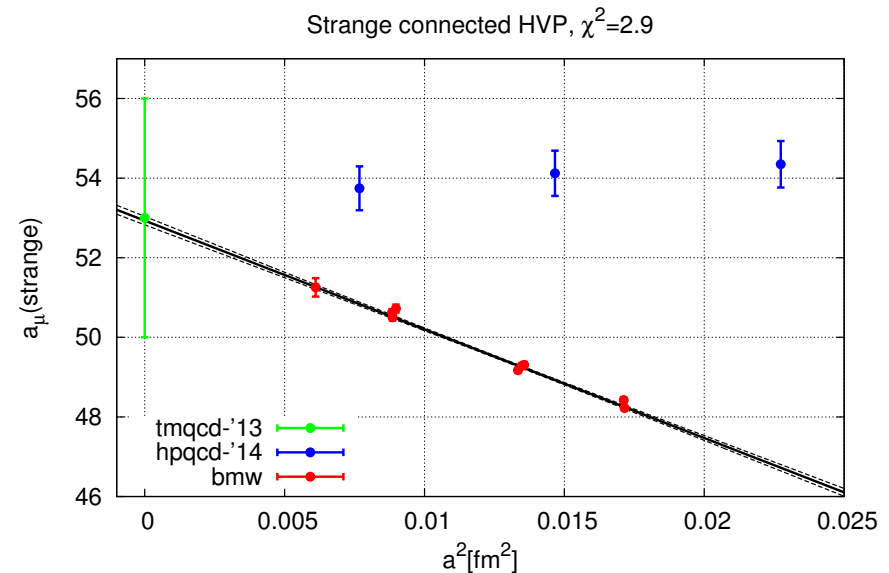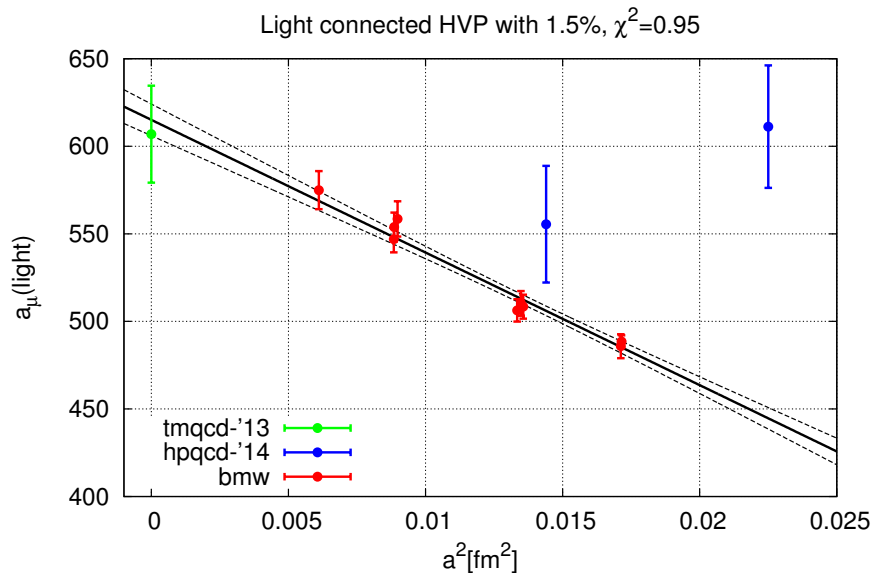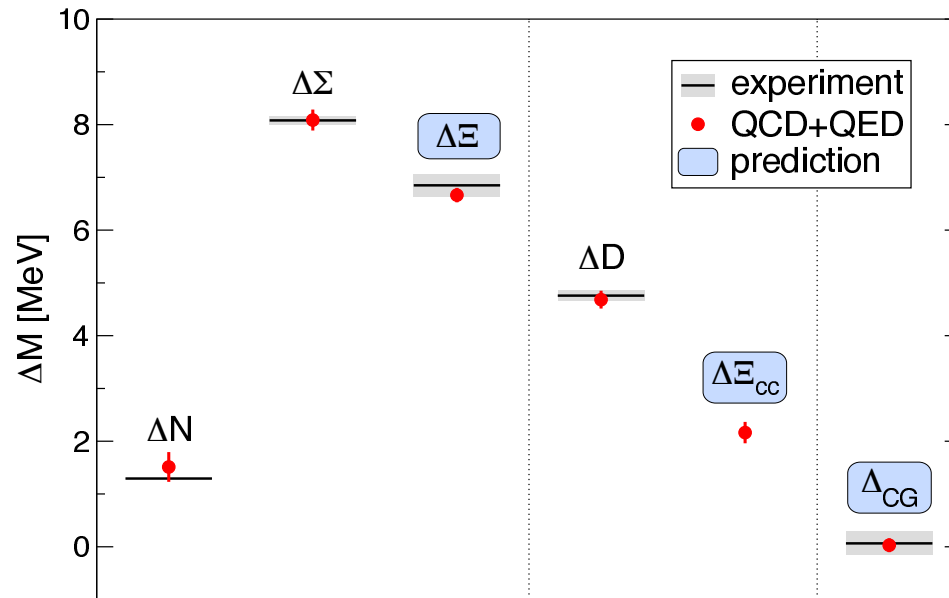


$\Rightarrow$ clearly on the right track

# Beyond LO HVP and toward HLbL on the lattice

M. Knecht, J.-L. Kneur, L. Lellouch, K. Miura, S. Narison, E. de Rafael, B. Reichert, et al

Most promising route $\rightarrow$ include EM directly in lattice QCD calculations



First step
**Ab initio calculation of the neutron-proton mass difference**
*S. Dürr et al, Science 347 (2015) 1452*
*BMW collaboration*
(cf. PP highlights by L. Lellouch)

Goal: beyond taking apart the physics behind this important mass difference, develop the tools for inclusion of EM effects and validate the approach

With K. Miura: using this new technology to develop and explore entirely new approaches to calculation of HVP and HLbL

# Expansion of HVP in moment approximants

$$a_\mu^{\text{HVP}} = \frac{\alpha}{\pi} \left\{ \frac{1}{3}\mathcal{M}(0) + \frac{25}{12}\mathcal{M}(-1) + \tilde{\mathcal{M}}(-1) + \frac{97}{10}\mathcal{M}(-2) + 6\tilde{\mathcal{M}}(-2) + \frac{208}{5}\mathcal{M}(-3) + 28\tilde{\mathcal{M}}(-3) + \ldots \right\}$$

$$\mathcal{M}(-n) = \int_{4M_\pi^2}^\infty \frac{dt}{t} \left(\frac{m_\mu^2}{t}\right)^{1+n} \frac{1}{\pi} \operatorname{Im}\Pi(t) \quad n = 0, 1, 2, \ldots$$

$$\tilde{\mathcal{M}}(-n) = \int_{4M_\pi^2}^\infty \frac{dt}{t} \left(\frac{m_\mu^2}{t}\right)^{1+n} \ln\frac{m_\mu^2}{t} \frac{1}{\pi} \operatorname{Im}\Pi(t) \quad n = 1, 2, 3, \ldots$$

- Tested with a toy-model $\longrightarrow$ 4th approximation already within 0.4 % of toy model's result for $a_\mu^{HVP}$

- Moments can be determined in lattice QCD

- Tests of lattice QCD as compared to evaluation of moments with data

## Project for 2016

Series of Workshops started in 2010 at
LPNHE (Jussieu)
Two other editions in 2012 and 2014
$\sim 25 - 30$ participants
https://indico.in2p3.fr/events/6637
https://indico.in2p3.fr/events/10304



2nd Workshop on Muon g-2 and EDM in the LHC Era

2012 May 25  LPNHE Paris
1222RC08

This Workshop is aiming at getting all theoreticians, experimentalists and engineers, involved or interested in the preparation of the g-2/EDM at JPARC experiment. Presentations of the current status and the ongoing activities will inform the french nuclear and particle physics community members on the activities of the already existing and growing g-2/EDM french collaboration.
The impact of muon g-2 and EDM measurements will be reviewed in the context of the narrowing of the space for New Physics by the LHC experimental results.

Chaired by

W. da Silva,
F. Kapusta,
T. Mibe,
N. Saito

Local Organization

W. da Silva
J. David
J.F. Genat
F. Kapusta
M. Knecht
L. Marquet

http://indico.in2p3.fr/conferenceDisplay.py?confId=6637



3rd Workshop on Muon g-2, EDM and Flavour Violation in the LHC Era

9-12 december 2014 LPNHE Paris

Have the next meeting in
Marseille in 2016