19th meeting of the WG Radio Monte CarLow

H. Czyz/G. Venanzoni

Mainz 30 June 2017

Agenda

- Overview
- Registration
  - Modify my registration
- List of registrants
- **Timetable**

Support

Fri 30/06

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09:00	**Introduction**	*VENANZONI, Graziano*	*Mainz*	09:00 - 09:20
	The Coulomb Force Awakens	*BALDINI FERROLI, Rinaldo*	*Mainz*	09:20 - 09:45
	Testing \chi_c properties at BELLE II	*KISZA, Patrycja*	*Mainz*	09:45 - 10:10
10:00	**chi_cJ decays into V \gamma and e+e-**	*KIVEL, Nikolay*	*Mainz*	10:10 - 10:35
	Coffee Break		*Mainz*	10:35 - 11:05
11:00	**Comparison Phokara and Connexc for TL proton FF measurement**	*WANG, Yadi*	*Mainz*	11:05 - 11:30
	Event generator for PANDA pbar p -> e+ e- including NLO radiative corrections	*ZAMBRANA, Manuel*	*Mainz*	11:30 - 11:55
12:00	**Description of J/Psi -> hyperon anti-hyperon decays**	*KUPSC, Andrzej*	*Mainz*	11:55 - 12:20
	Lunch			
13:00				

Agenda

14:00			*Mainz*	12:20 - 14:30
	Updating PHOKHARA event generator	*ZHURIDOV, Dmitry*	*Mainz*	14:30 - 14:55
15:00	**Two photon form factors of the peseudoscalar mesons in Phokhara and Ekhara Monte Carlo generators**	*TRACZ, Szymon*	*Mainz*	14:55 - 15:20
	MCGPJ status	*IGNATOV, Fedor*	*Mainz*	15:20 - 15:45
16:00	**Coffee Break**		*Mainz*	15:45 - 16:15
	Generator for e+e- to hadrons	*EIDELMAN, Simon*	*Mainz*	16:15 - 16:40
	MC generator for radiative corrections to hadrons production with Carlomat 3.1	*JEGERLEHNER, Fred*	*Mainz*	16:40 - 17:05
17:00	**Update on HVP from KNT**	*KESHAVARZI, Alex*	*Mainz*	17:05 - 17:30

G-2 Theory initiative...can we find some synergy?

First Workshop of the Muon g-2 Theory Initiative

3-6 June 2017 *Q Center*
US/Central timezone

Search

66 registered participants, 40 talks, 15 discussion sessions (525 minutes)

Muon g-2 Theory Initiative

Steering Committee:

- Gilberto Colangelo (Bern) gilberto@itp.unibe.ch
- Michel Davier (Orsay) davier@lal.in2p3.fr
- Simon Eidelman (Novosibirsk) eidelman@cern.ch
- Aida El-Khadra (UIUC & Fermilab) axk@illinois.edu
- Christoph Lehner (BNL) clehner@bnl.gov
- Tsutomu Mibe (KEK): mibe@post.kek.jp
  J-PARC E34 experiment
- Andreas Nyffeler (Mainz) nyffeler@uni-mainz.de
- Lee Roberts (Boston): roberts@bu.edu
  Fermilab E989 experiment
- Thomas Teubner (Liverpool) thomas.teubner@liverpool.ac.uk

Muon g-2 Theory Initiative: WGs

- sign-up for the HVP or HLbL WG in the google sheet
  or send email to one of the WG coordinators
- HVP WG coordinators:
  - Michel Davier davier@lal.in2p3.fr
  - Simon Eidelman eidelman@cern.ch
  - Aida El-Khadra axk@illinois.edu
  - Thomas Teubner thomas.teubner@liverpool.ac.uk
- HLbL WG coordinators:
  - Gilberto Colangelo gilberto@itp.unibe.ch
  - Christoph Lehner clehner@bnl.gov
  - Andreas Nyffeler nyffeler@uni-mainz.de

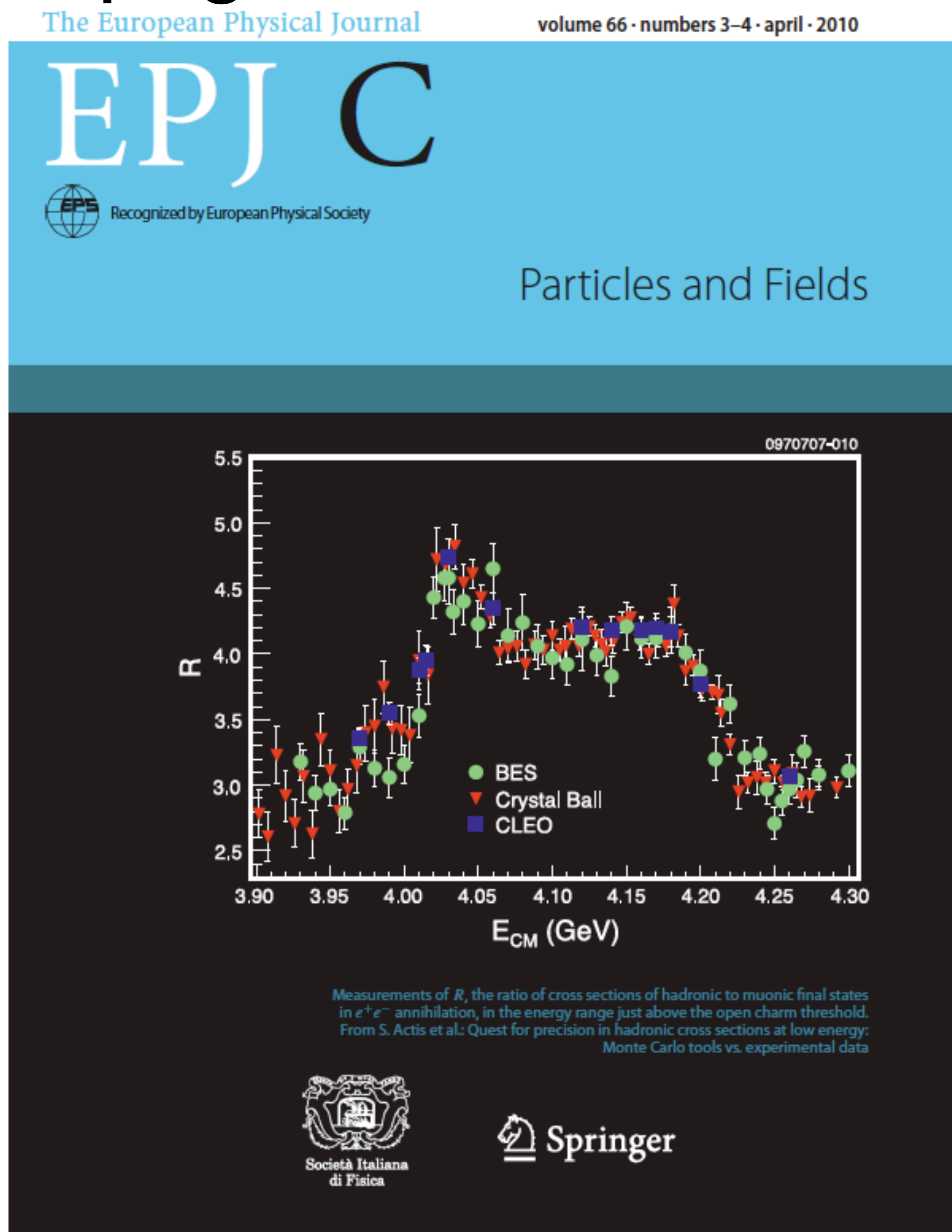
Google sheet available in Aida's presentation: https://indico.mitp.uni-mainz.de/event/86/contribution/64/material/slides/0.pdf

Usual propaganda:

The paper "Quest for precision in hadronic cross sections at low energy: Monte Carlo tools vs. experimental data" has been published on the **Eur. Phys. J. C. Volume 66, Issue 3 (2010), Page 585**

Thanks again to all authors!!!

Remember to quote the paper



Many interesting meetings for our community

- Padova (Italy), Sept 4-5 2017: Muon-electron scattering: Theory kickoff meeting
- Japan, Jan/Feb 2018: HVP Workshop of the g-2: Theory Initiative
- Mainz, Feb 19-22 2018: MITP Topical workshop: “The Evaluation of the Leading Hadronic Contribution to the muon anomalous magnetic moment”, organised by C. M. C. Calame, M. Passera, L. Trentadue, G. Venanzoni
- Mainz Jun 18-22 2018: 2° Workshop of the g-2 Theory Initiative
- Others?

Muon-electron scattering: Theory kickoff workshop

4-5 September 2017

Padova
Europe/Rome timezone

If you are interested please contact massimo.passera@pd.infn.it

Overview
Venue
Timetable
Logistic
Map

Support

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 $\mu e \to \mu e$. 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 and Astronomy Department of Padova 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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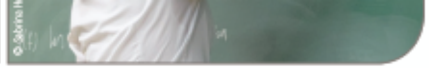
INFN Istituto Nazionale di Fisica Nucleare

Università degli Studi di Padova





mitp Mainz Institute for Theoretical Physics

ACTIVITIES 2018

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
Jens Erler **UNAM**, Mikhail Gorshteyn, Hubert Spiesberger **JGU**
April 23-May 4, 2018

Modern Techniques for CFT and AdS
Bartlomiej Czech **IAS Princeton**, Michal P. Heller **MPI for Gravitational Physics**, Alessandro Vichi **EPFL**
May 28-June 8, 2018

The Dawn of Gravitational Wave Science
Rafael A. Porto **ICTP-SAIFR**, Riccardo Sturani **IIP Natal**, Salvatore Vitale **MIT**, Luis Lehner **Perimeter Inst.**
June 4-15, 2018

The Future of BSM Physics
Giulia Ricciardi **U Naples Federico II**, Gian Giudice **CERN**
Tobias Hurth, Joachim Kopp, Matthias Neubert **JGU**
June 4-15, 2018, Capri, Italy

Probing Baryogenesis via LHC and Gravitational Wave Signatures
Germano Nardini **U. Bern**, Carlos E.M. Wagner **U Chicago / Argonne NatLab.**, Pedro Schwaller **JGU**
June 18-29, 2018

From Amplitudes to Phenomenology
Fabrizio Caola **IPPP Durham**, Bernhard Mistlberger, Giulia Zanderighi **CERN**
August 13-24, 2018

String Theory, Geometry and String Model Building
Philip Candelas, Xenia de la Ossa, Andre Lukas **U Oxford**, Daniel Waldram **Imperial College London**, Gabriele Honecker, Duco van Straten **JGU**
September 10-21, 2018

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
Paolo Gambino **U Turin**, Andreas Kronfeld **Fermilab**, Marcello Rotondo **INFN-LNF Frascati**, Christof Schwanda **OEWA Vienna**
April 16-20, 2018

Tension in LCDM Paradigm
Cora Dvorkin **U Harvard**, Silvia Galli **IAP Paris**, Fabio Iocco **ICTP-SAIFR**, Federico Marinacci **MIT**
May 14-18, 2018

The Proton Radius Puzzle and Beyond
Gil Paz **Wayne State U**, Richard Hill **Perimeter Inst.**, Randolf Pohl **JGU**
July 23-27, 2018

Scattering Amplitudes and Resonance Properties from Lattice QCD
Maxwell T. Hansen **CERN**, Sasa Prelovsek **U Ljubljana**, Steve Sharpe **U Washington**, Georg von Hippel, Hartmut Wittig **JGU**
August 27-31, 2018

Quantum Fields – From Fundamental Concepts to Phenomenological Questions
Astrid Eichhorn **U Heidelberg**, Roberto Percacci **SISSA Trieste**, Frank Saueressig **U Nijmegen**
September 26-28, 2018

MITP SUMMER SCHOOL 2018

Johannes Henn, Matthias Neubert, Stefan Weinzierl, Felix Yu **JGU**
Juli 2018

For more details: http://www.mitp.uni-mainz.de

Mainz Institute for Theoretical Physics

Cluster of Excellence PRISMA

The aim of the topical workshop is articulated as follows :

1. First of all to assess the state of the art of the determination of the muon anomalous magnetic moment. The workshop is meant to have a particular focus directed towards the hadronic contribution to the anomalous magnetic moment, both analyzing the most recent experimental results for its determination in time-like processes as well as taking into consideration the most recent dedicated lattice calculations;
2. In this context a particular attention and a series of seminars and discussions will be devoted to consider a recently proposed possibility of extracting the muon anomalous magnetic moment by using a different and alternative method exploiting experiments consisting in space-like processes, e.g. as the Bhabha scattering or t-channel in μ-e scattering;
3. For this purpose it is planned to discuss and to explore in detail the state of the art of NLO/NNLO precision radiative corrections to Bhabha/ μ-e scattering in order to master the theoretical tools necessary to develop dedicated Monte Carlo simulation codes;
4. Finally it is planned to survey the experimental challenges facing the extraction of the hadronic contribution to the running of the electromagnetic coupling constant in space-like processes.
5. The foreseeable impact is represented by the possibility of testing the consistency of the Standard Model at the level of quantum corrections with an unprecedented precision as well as the one of ascertain the presence of New Physics virtual effects in a robust (and unambiguous) way.

Day one - World experts will present an overview of the present status of the muon g-2. Topics will include the status of the new E989 experiment at Fermilab and the novel technique of the ultracold muon beam being developed by the E34 collaboration at J-PARC. On the theoretical side, presentations will address the muon g-2 prediction in the Standard Model and some of its extensions. Emphasis will then be placed on the hadronic corrections to the muon g-2 and, in particular, on a new space-like approach to determine its leading contribution.

Day two - World experts will provide the general picture on the state of the art of precision calculations for Bhabha and μ-e scattering; in particular, the existing analytical precision calculations at NNLO accuracy for Bhabha scattering and at NLO accuracy for μ-e will be addressed; the roadmap leading to a NNLO precision calculation for μ-e scattering will be designed.

Day three - World experts will deliver the state of the art of Monte Carlo simulation codes for the processes under consideration; contributions from the teams that developed codes such as BABAYAGA, BHWIDE, MCGPJ, PHOKHARA and similar are expected. The possibility of implementing into a simulation code NNLO precision calculations will be analyzed.

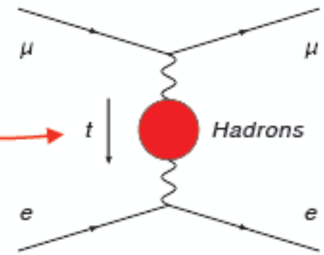
Day four - We will address the experimental challenges posed by measuring the effective electromagnetic coupling in the space-like region at low-momentum transfer with high precision.

We will consider the possibility of performing the measurement by means of the elastic scattering of 150 GeV muons (currently available at CERN North area) on atomic electrons of a low-Z target, as well as by the Bhabha process at flavour factories.

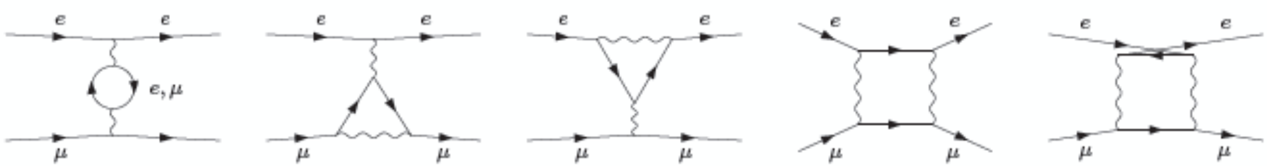
We will discuss the optimization of a detector able to keep the systematic effects at the required level of 10 ppm.

A recent proposal mu-e→mu-e

- To extract $\Delta\alpha_{had}(t)$ from the measured cross section, the SM prediction must be known at NNLO!



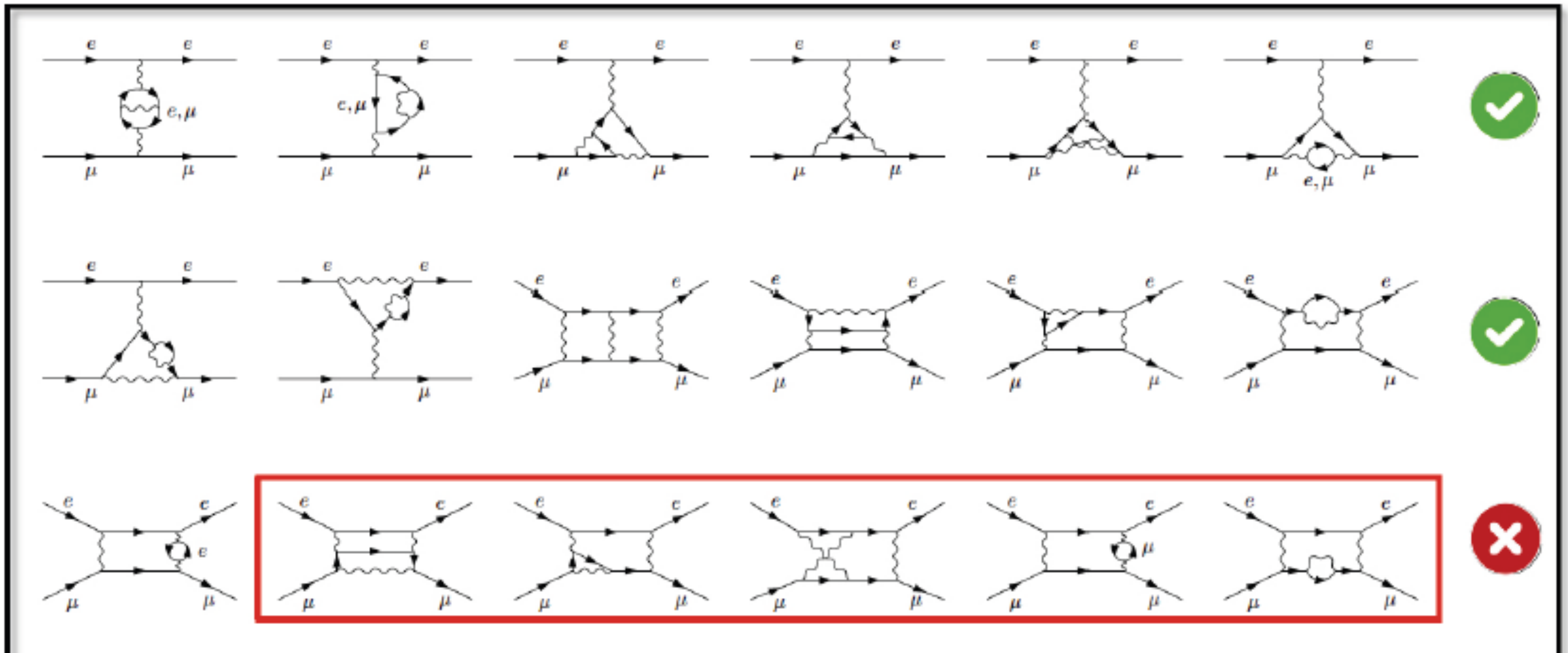
- The NLO corrections are known (we are checking them):



- The NNLO corrections are unknown. It is a large theoretical project.
- Dedicated high-precision MC tools needed.
- Work in progress with A. Broggio, C. Carloni Calame, M. Fael, A. Ferroglia, P. Mastrolia, G. Montagna, O. Nicrosini, L. Pagani, F. Piccinini, A. Primo, M. Rocco, U. Schubert, L. Trentadue.

Muon-electron scattering: SM theory (2)

- State-of-the-art methods required for the calculation of the two-loop diagrams: Differential Equations and Magnus Exponential Series, P. Mastrolia et al., JHEP 1403 (2014) 082.
- Examples of two-loop diagrams:



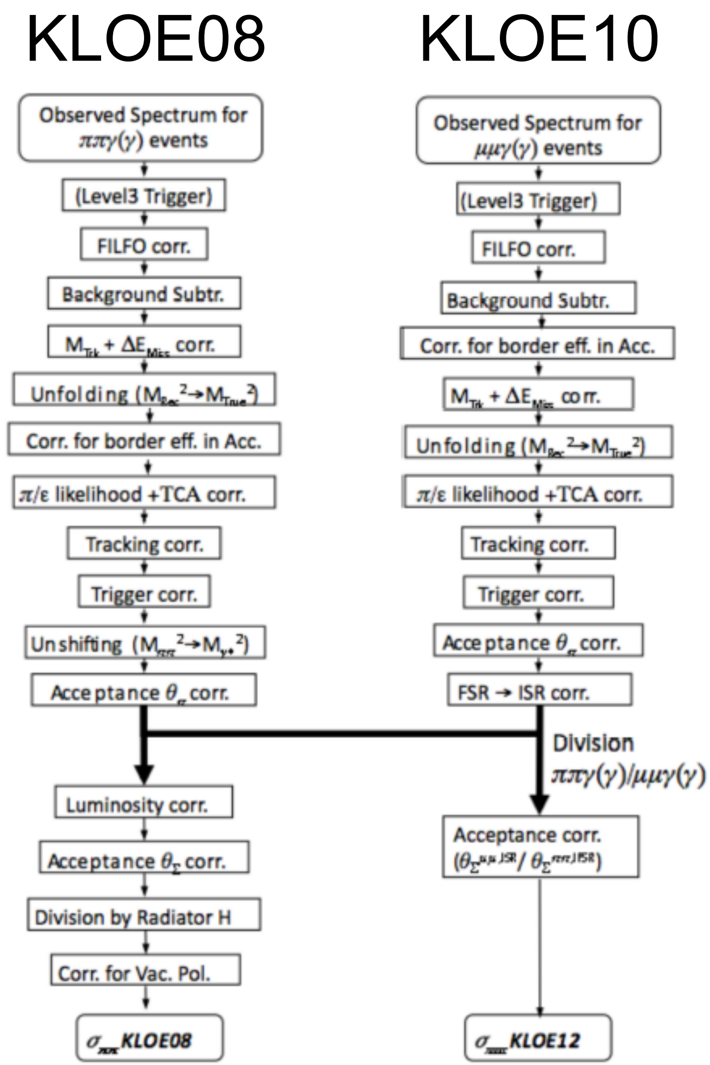
Work in progress with P. Mastrolia, A. Primo, U. Schubert.

Any help would be welcome

A lot of work on HLO & HLbL

- Combination of e+e- data (ISR, SCAN, etc...)
- Comparison of MC generators
- Lattice
- Dipersive approach, new or ibrid methods

Combination of different measurements can be troublesome



Construction of the KLOE covariance matrix

$$\left(\begin{array}{c|c|c} \begin{matrix}\text{KLOE08}\\ 60\times 60\end{matrix} & \begin{matrix}\text{KLOE0810}\\ 60\times 75\end{matrix} & \begin{matrix}\text{KLOE0812}\\ 60\times 60\end{matrix} \\ \hline \begin{matrix}\text{KLOE1008}\\ 75\times 60\end{matrix} & \begin{matrix}\text{KLOE10}\\ 75\times 75\end{matrix} & \begin{matrix}\text{KLOE1012}\\ 75\times 60\end{matrix} \\ \hline \begin{matrix}\text{KLOE1208}\\ 60\times 60\end{matrix} & \begin{matrix}\text{KLOE1210}\\ 60\times 75\end{matrix} & \begin{matrix}\text{KLOE12}\\ 60\times 60\end{matrix} \end{array}\right)$$

More details in Alex’s presentation

A KLOE2 paper (+Alex, Stefan, Thomas) in preparation

Comparison of generators

- ISR NNLO (PHOKHARA) 0.5% → 0.1-0.2%
- EKHARA e+e- → 1-2PS e+e- accuracy? (few%)
- BABAYAGA@NLO (0.1%)
- MCGPJ (0.3%)
- Others?

F. Ignatov: “for precision of ≤0.1% necessary to have exact e+e- →e+e-($\gamma\gamma$) NNLO generator”

See talks of S. Eidelman, F. Ignatov, F. Jegerlehner, Y. Wang, S. Traczs, D. Zhuridov

Lattice: huge improvements in the last years

- HLO at % level (maybe below?)
- HLbL at 20% level [C. Lehner]
- Competitive with dispersive approach?

For more details see the talks at PHIPSI17 or the 1st Workshop of the g-2 Theory Initiative:

https://indico.fnal.gov/conferenceDisplay.py?confId=13795

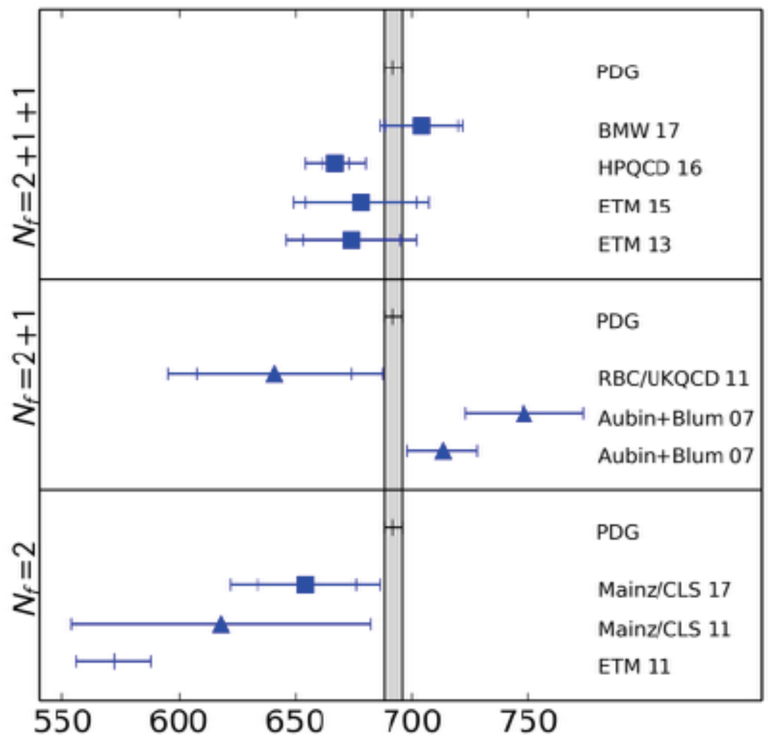
Final result for $N_f = 2$

HLO

- Estimate from TMR including finite-volume correction:

$$a_\mu^{\rm hvp} = (654 \pm 32_{\rm stat} \pm \underbrace{17_{\rm syst} \pm 10_{\rm scale} \pm 7_{\rm FV} {}^{+\,0}_{-10}{}_{\rm disc}}_{3.3\%}) \cdot 10^{-10}$$

4.8%



Current status of the HLbL

C. Lehner

T. Blum, N. Christ, M. Hayakawa, T. Izubuchi, L. Jin, and C.L., PRL118(2017)022005

$$a_\mu^{\rm cHLbL} = \left.\frac{g_\mu - 2}{2}\right|_{\rm cHLbL} = (0.0926 \pm 0.0077)\left(\frac{\alpha}{\pi}\right)^3$$
$$= (11.60 \pm 0.96) \times 10^{-10} \quad (11)$$
$$a_\mu^{\rm dHLbL} = \left.\frac{g_\mu - 2}{2}\right|_{\rm dHLbL} = (-0.0498 \pm 0.0064)\left(\frac{\alpha}{\pi}\right)^3$$
$$= (-6.25 \pm 0.80) \times 10^{-10} \quad (12)$$
$$a_\mu^{\rm HLbL} = \left.\frac{g_\mu - 2}{2}\right|_{\rm HLbL} = (0.0427 \pm 0.0108)\left(\frac{\alpha}{\pi}\right)^3$$
$$= (5.35 \pm 1.35) \times 10^{-10} \quad (13)$$

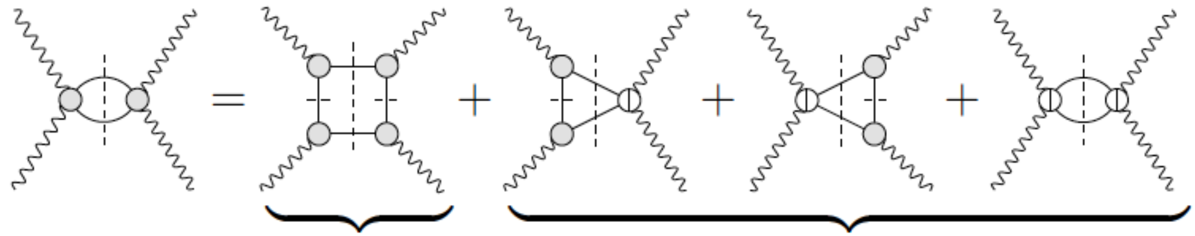
Makes HLbL an unlikely candidate to explain the discrepancy!

Next: finite-volume and lattice-spacing systematics; sub-leading diagrams

Dispersive approach: reduced errors

[G. Colangelo]

Two-pion contributions to HLbL:



$$a_\mu^{\pi-\text{box}} + a_{\mu,J=0}^{\pi\pi,\pi\text{-pole LHC}} = -24(1) \cdot 10^{-11}$$

(also Pauk& Vanderhaegen)

F. Jegerlehner

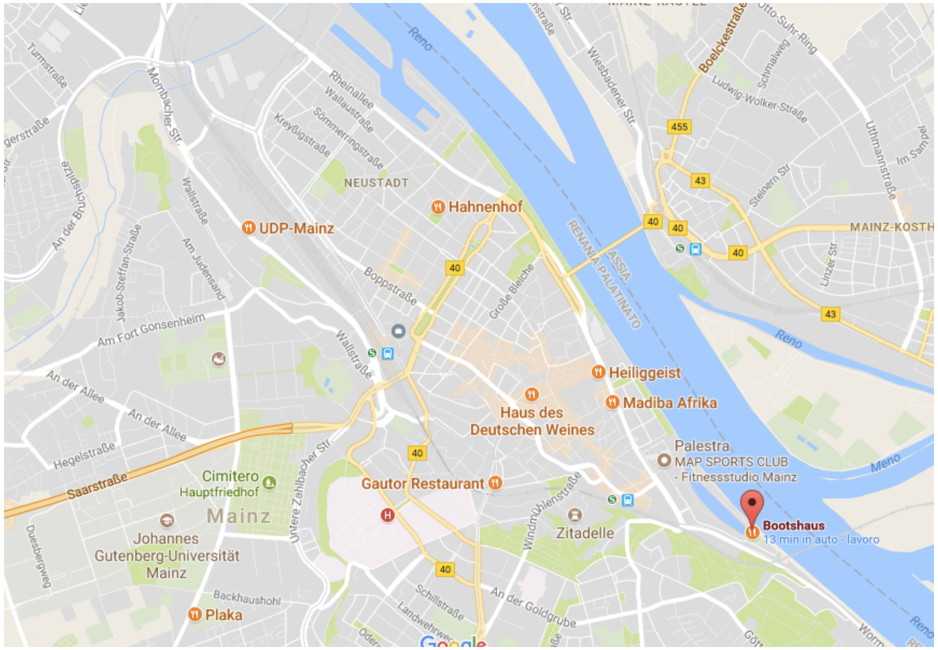
The following tabular collects recent new/updated evaluations:

New contribution	Reference		$\Delta a_\mu \cdot 10^{11}$	
NNLO HVP	Kurz et al. 2014	12.4	±	0.1
NLO HLbL	Colangelo et al. 2014	3	±	2
New axial exchange HLbL	Pauk, Vanderhaeghen [66], FJ14 [1, 67]	7.55	±	2.71
Tensor exchange HLbL	Pauk, Vanderhaeghen 2014	1.1	±	0.1
New π^0 exchange HLbL	$\pi^0\gamma^*\gamma^*$ constraint from LQCD [68]	64.68	±	12.40
...				...
Old axial exchange HLbL	Melnikov, Vainshtein 2004	22	±	5
Old π^0 exchange HLbL	JN [46]	72	±	12
Total change		–5.6	±	12.85 [← 13]

H2020…

Any idea?

- **Dinner this evening:**
  - It will consist of a BBQ menu in a beautiful location along the Rhine river in the evening: http://www.bootshausmainz.de/
  - Cost included in the fee (not drinks)



- **Data and place for next meeting?**

Have a nice meeting!!!!

spare

(C.M. C. Calame)

1. QED NLO corrections. Easy.

2. Resummation of dominant corrections up to all orders, matched with NLO corrections. Non-trivial issue: mass effects in this case are important

3. NNLO corrections: some classes of NNLO re-usable from existing Bhabha calculations, some new due to different mass scales ($\mathbf{m}_\mu$ and $\mathbf{m}_e$). In any case, NNLO must be matched with 1. and 2. [references: Eur. Phys. J. C 66 (2010) 585 and references therein]

4. Development of dedicated MC tools including all the above ingredients

5. Detailed study of all the mentioned corrections, comparison among independent calculations, estimate of further-missing higher-order corrections

6. Theory workshop this year in Padova (5-5 September 2017), and one next year in Mainz (19-24 February 2018). You are all invited!

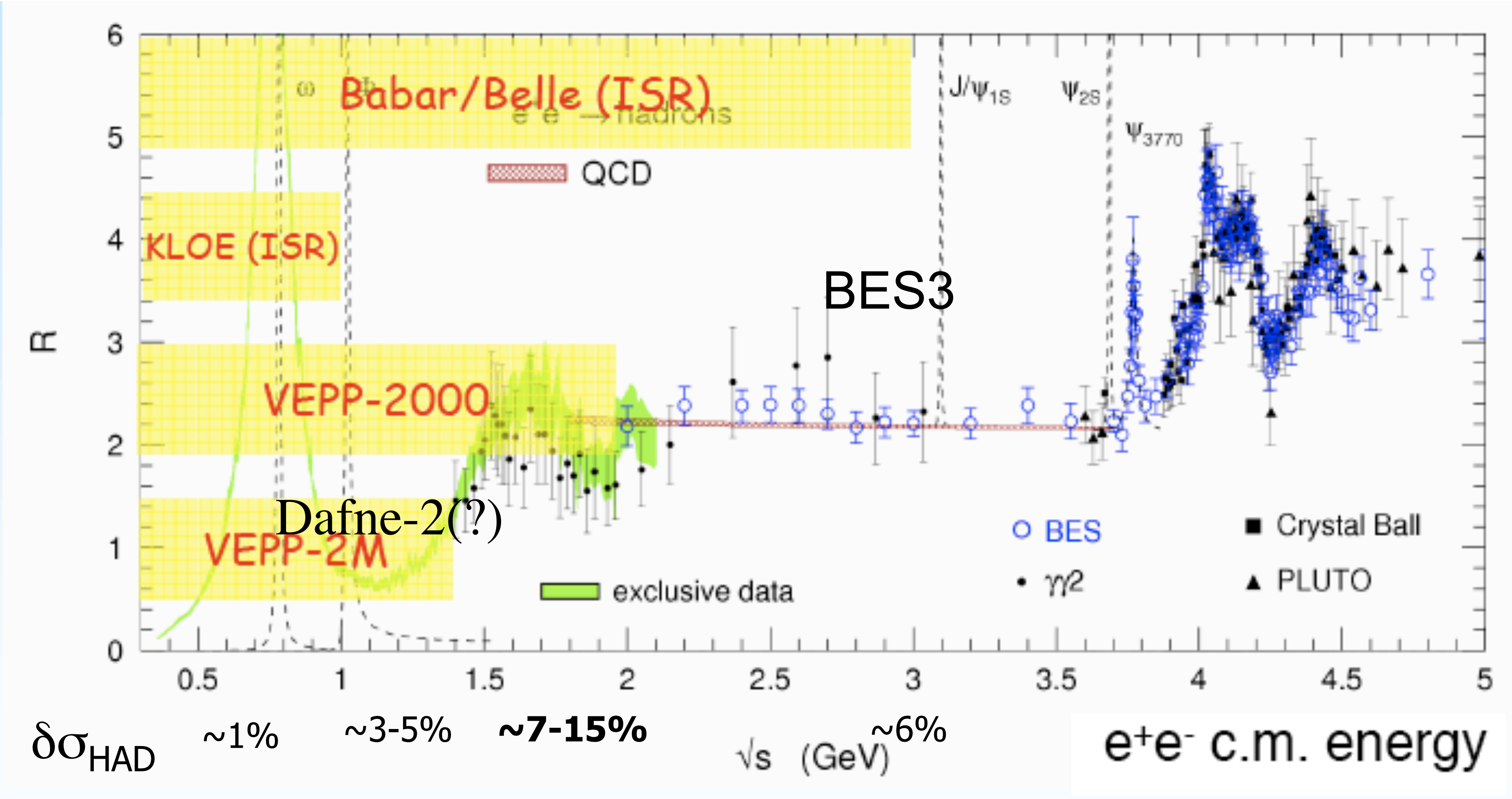
HLbL contribution can be a limiting factor for the calculation of a_μ

- As today δa_μ^{LbL} =[2.5-4]10^{-10}
- δa_μ^{BNL} =$6 10^{-10} \rightarrow 1.5\ 10^{-10}$
- How to improve? $\gamma\gamma$ physics can help?
- $\gamma\gamma$ physics is/will be done at (Super)Bfactory, KLOE-2 and BESIII with dedicated detectors, in a region where data are scarse
- Also e+e- $\rightarrow$ PSγ
- A systematic study which uses data is proposed in **arXiv:1402.7081** (G. Colangelo et al.)

Structure of the WG

- **Luminosity (G. Montagna, F. Nguyen)**
- **R scan (A. Arbuzov, G. Fedotovich)**
- **ISR (H. Czyz, G. Venanzoni)**
- **Tau (Z. Was, D. Epifanov)**
- **Hadronic VP, g-2 and Δa_{em} (T. Teubner, S. Eidelman)**
- **gamma-gamma physics(S. Ivashin, D. Moricciani)**
- **FSR models (S. Gorini, A. Denig)**

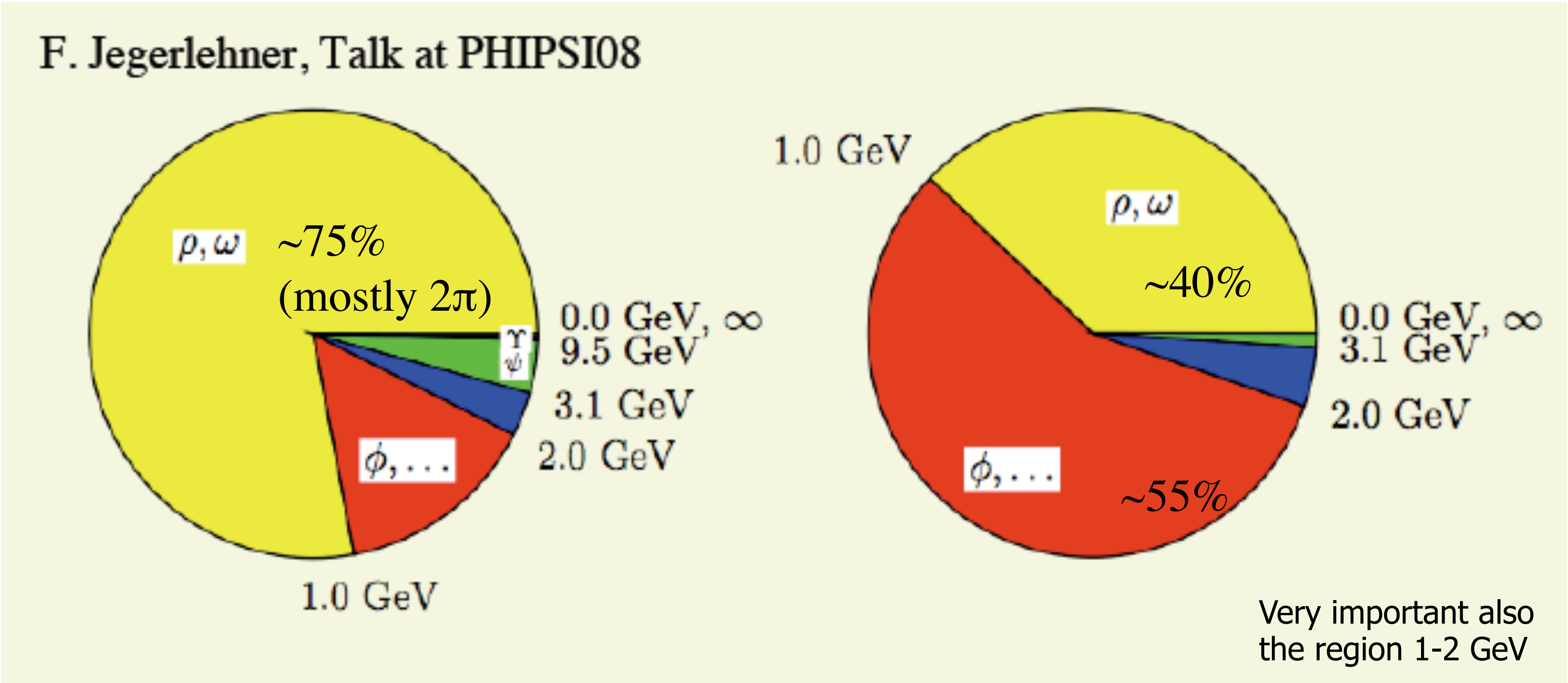
Ultimate goal of σ_{HAD}: 1% up to J/ψ (Ψ(4s)?)



Which is the situation on MC above 1 GeV?

(see S. Eidelman presentation)

Contribution of different energy regions to the dispersion integral and the error to a_μ^{had}



contributions *error²*

Experimental errors on σ^{had} translate into theoretical uncertainty of a_μ^{had}!

→ Needs precision measurements!

A rough estimate for g-2

$a_\mu^{exp} - a_\mu^{theo,SM} = (27.7 \pm 8.4)10^{-10}$ (3.3σ) [Eidelman, TAU08]

$8.4 = \sim 5_{HLO} \oplus \sim 3_{LbL} \oplus 6_{BNL}$

↓ 4 ↓ 3 ↓ 3 ↓ $1.6_{\text{NEW G-2}}$ ↓ $7\text{-}8\sigma$ (if 27.7 will remain the same))

$\delta a_\mu^{HLO} = 5.29 = 3.0(\sqrt{s}<1\text{GeV}) \oplus 3.9(1<\sqrt{s}<2\text{GeV})$ FJ08

$\delta a_\mu^{HLO} \rightarrow 3 = 2.5\ (\sqrt{s}<1\text{GeV}) \oplus 1.5\ (\sqrt{s}<1\text{GeV})$

This means:

$\delta\sigma_{HAD}$ ~ 0.4% $\sqrt{s}<1$GeV (instead of 0.7% as now))

$\delta\sigma_{HAD}$ ~ 2% $1<\sqrt{s}<2$GeV (instead of 6% as now))

Precise measurement of σ_{HAD} at low energies very important also for α_{em} !!!