Study of Neutral-Pion Pair Production in Two-Photon Scattering at BESIII

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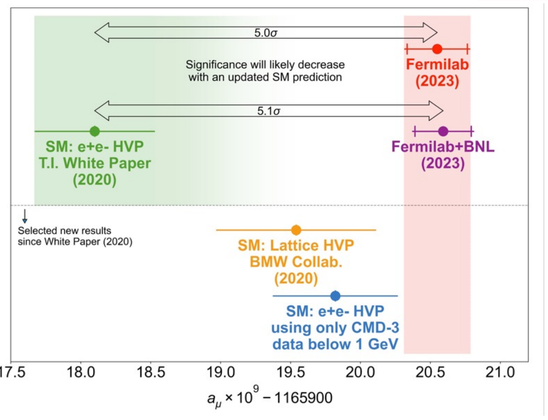
Anomalous Magnetic Moment of the Muon

- Magnetic moment of the muon: $\mu = g_\mu \frac{e}{2m_\mu}\vec{S}$
- Quantum Field Theory: $a_\mu = \frac{g_\mu - 2}{2} \neq 0$ ➡ **Muon anomaly**
- Standard Model (SM) prediction: $\boldsymbol{a_\mu^{SM} = a_\mu^{QED} + a_\mu^{EW} + a_\mu^{QCD}}$



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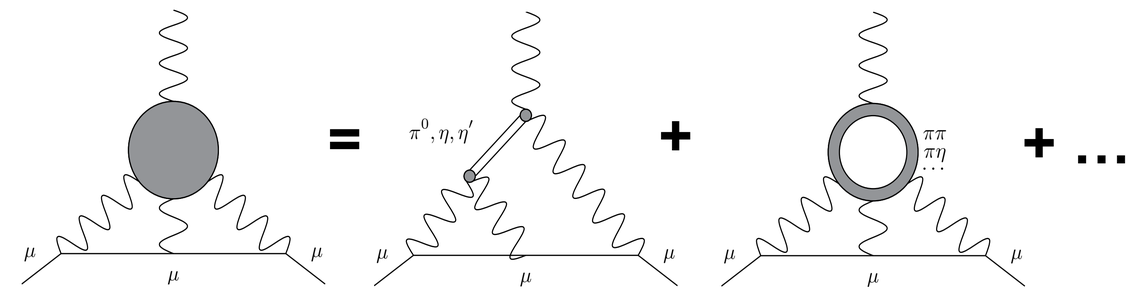
Sizeable Discrepancy!
- ➡ **Hint for New Physics?**
- ➡ **Poor understanding of QCD?**
- ➡ **Discrepancy to Lattice?**

- **Hadronic contributions dominate the uncertainty** uncertainty for a_μ^{SM}
  - Hadronic Vacuum Polarization (HVP)
  - **Hadronic Light-by-Light Scattering (HLbL)**

The Hadronic Light-by-Light Contribution to a_μ

- **Next to leading order** hadronic contribution
- Characterized by the **coupling of four (virtual) photons to a hadronic state**



- Dominated by the exchange of pseudoscalars, pion loops, scalars, tensors …
- **Dispersive calculations** of this process need knowledge of **hadrons coupling to two photons**
- The coupling is typically described by **Transition Form Factors** $F(q_1^2, q_2^2)$

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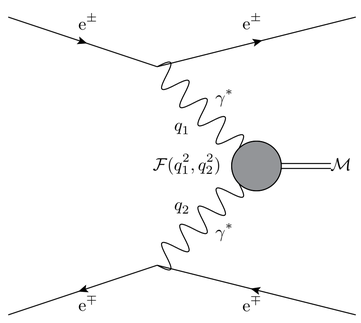
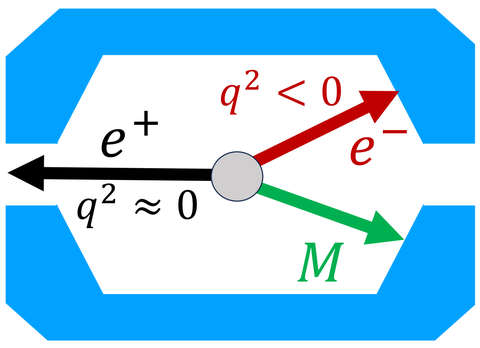
Two-Photon Physics at e^+e^- Colliders

- Transition form factors can be accessed in the two-photon fusion process $\boldsymbol{e^+e^- \to e^+e^-M}$



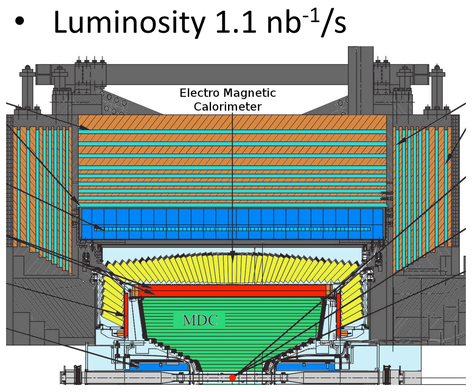
- **Photon Virtuality** q^2 can be connected to the scattered leptons energy and angle $\boldsymbol{q^2 = -4EE' \sin^2\frac{\theta}{2}}$
- **Strong drop of the cross section with increasing -q²**
  - Restricting on of the lepton to small angles allows **one dimensional mapping of the Transition Form Factor**
    ➡ **"Single Tag Analysis"**



Phys.Rev.D 85 (2012) 116001
Phys.Rev.D 93 (2016) 3, 032003
Nucl.Phys.B 34 (1971) 470-476
Nucl.Phys.B 54 (1973) 573-597

The BESIII Experiment

- **Symmetric Electron-Positron Collider** in Beijing/China
  - $\sqrt{s}$ = 2 - 5 GeV
  - Luminosity 1.1 nb^{-1}/s



- Muon Chambers
- Solenoid
- Electromagnetic Calorimeter
- Time-of-Flight System
- Main Drift Chamber

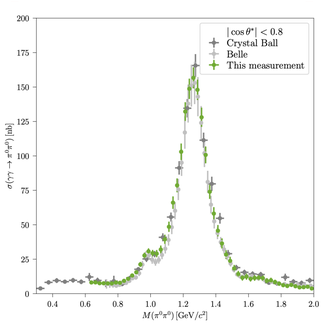
Nucl.Instrum.Meth.A 614 (2010) 345-399

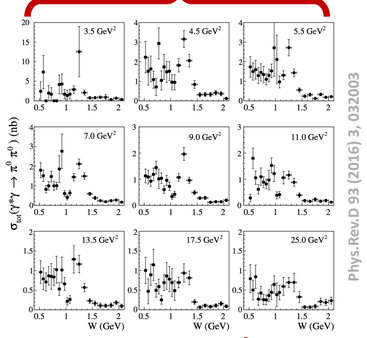
- **World's largest data sets** in the τ and charmonium energy range
- Here: twelve data samples with more than **12 fb^{-1}** integrated luminosity between **3.773 GeV and 4.599 GeV**
- Soon **20 fb^{-1} at 3.773 GeV**

Goal of this Work

Coupled channel partial wave analysis of two-photon reactions at BESIII Meike Küßner, Doctoral Thesis , 28.04.22

Minimum Virtuality | **This Work** | High Virtuality





Photon Virtuality

Phys.Rev.D 93 (2016) 3, 032003

$\gamma\gamma^* \to \pi^0\pi^0$ at BESIII

Comput.Phys.Commun. 234 (2019) 245-255
Phys. Rev. D 101, 054008

Monte Carlo Simulations

- Simulation of signal channel process and two-photon background with **Ekhara3.1**
- **Dispersive input for $\gamma^*\gamma^* \to \pi^0\pi^0$ dynamics by Danilkin, Deineka & Vanderhaeghen**
- Simulation of $\gamma^*\gamma^* \to \eta$ / η' with 3-octet TFF model

Event Selection

- Selection of $e^+e^- \to e^+e^-\pi^0\pi^0$ with one missing final state lepton
- Reconstruction of pion decay into 2 photons
- Kinematic Fit to combine 4 photons to 2 pions and reconstruction of missing lepton

Background Suppression

- Requiring small χ^2 of Kinematic Fit
- Restricting $-q^2$ of missing lepton to small numbers
- Suppression of two-photon background by requiring small transverse momentum of measured particles
- Subtraction of Monte Carlo simulations of remaining two-photon background

Results

- 10000 selected signal events
- **Mass coverage** from threshold to 2 GeV
- **First measurement in the a_μ relevant virtuality range** ($-q^2$ = 0.1 GeV² – 2 GeV²)
- **Full helicity angle coverage**
- **Much more data to come!**