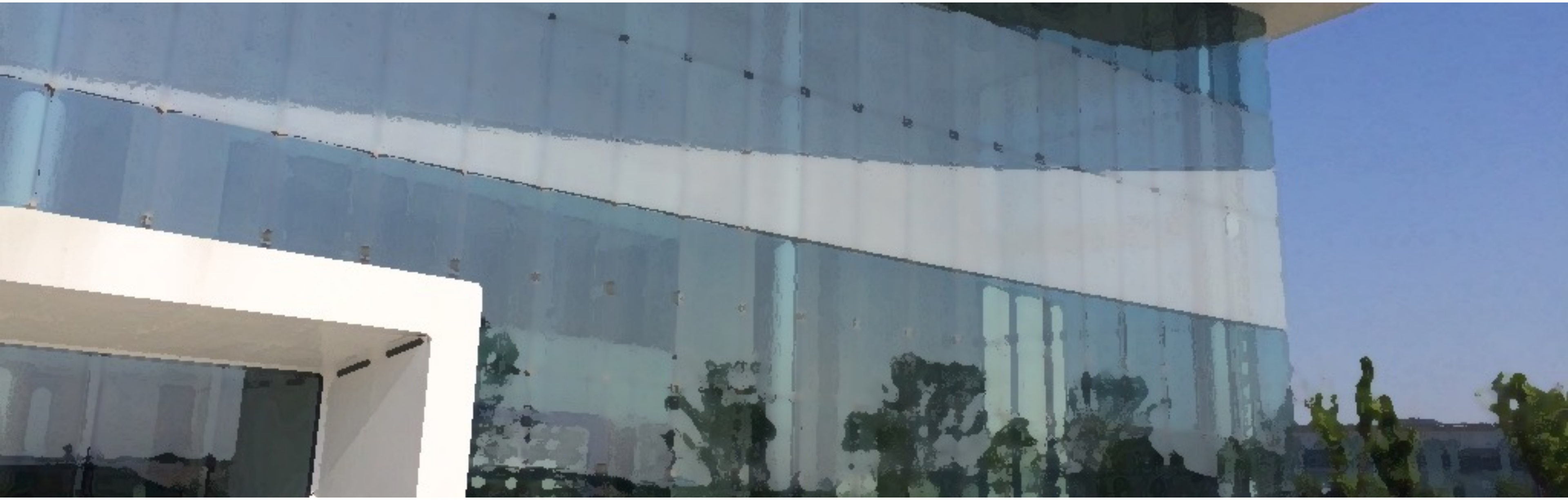


Meson Transition Form Factors- experimental results

Patrik Adlarson
Johannes Gutenberg Universität, Mainz, A2 collaboration

Hadron-China Friday Aug 7, 2015

Outline

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Introduction

Space Like TFF

Time Like TFF

Outline

Introduction

TFF and connection to $(g-2)_\mu$

Space Like TFF

Time Like TFF

Outline

Introduction

TFF and connection to $(g-2)_\mu$

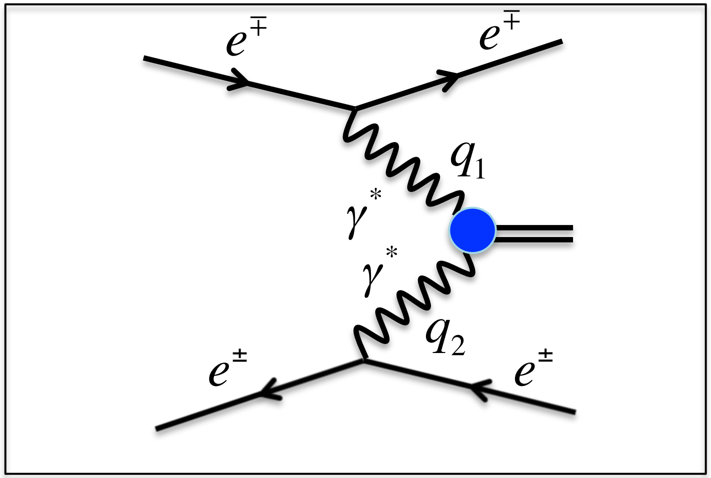
CELLO, CLEO, CMD-2, GLUEX, NA48, NA60, SINDRUM, SND

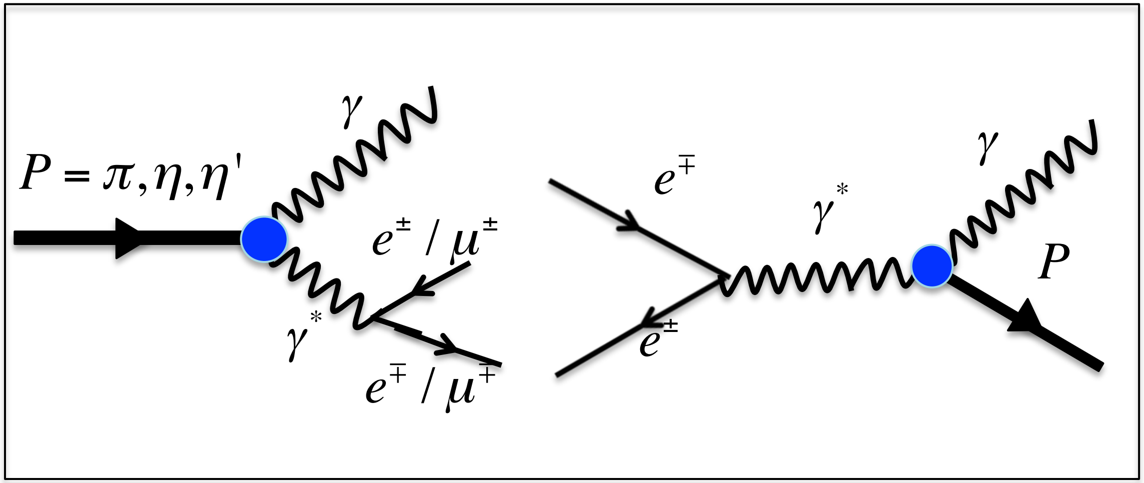
Space Like TFF

Time Like TFF

Space & Time-like Form Factors

The Form Factor $F(q^2)$ expresses influence of hadronic internal structure on scattering cross-section
Meson TFF accessed in kinematical regions of (transfered squared four-momentum) q^2 through study of space- and time like processes





Space-like $q^2 < 0$

Photon-photon fusion
Accessed at e^+e^- colliders

Time-like $q^2 > 0$

Single or double Dalitz decay, $4m_l^2 < q^2 < m_P^2$
Annihilation process, $q^2 > m_P^2$

VMD

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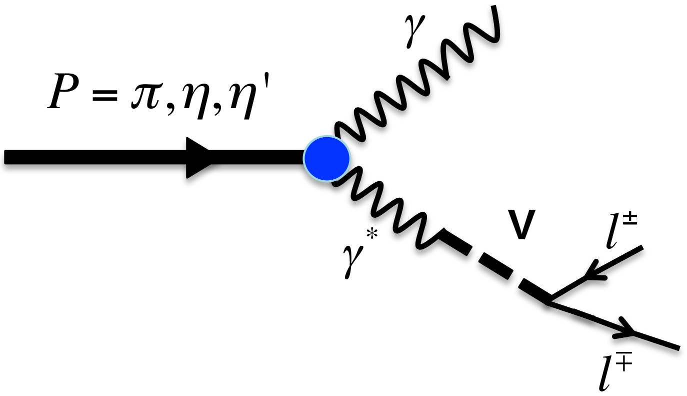
In Vector Meson Dominance (VMD), virtual photon couples to intermediate vector meson state: ρ, ω, ϕ, … $J^{P}=1^{-}$



Effect of VMD seen in annihilation process when q^2 approaches the resonant region of the vector meson

[L. G. Landsberg, Phys. Rept. 128, 301 (1985)]

$(g\text{-}2)_\mu$ Exp vs SM

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The anomalous magnetic moment of muon known to very high precision

$$a_\mu^{exp} = 11\,659\,208.9 \pm 6.3 \cdot 10^{-10}$$ BNL, PRD 73, 072(2006)

$$a_\mu^{SM} = 11\,659\,180.2 \pm 4.9 \cdot 10^{-10}$$ Eur Phys J C71, 1515(2011)

$$\Delta a_\mu^{exp-SM} = 28.7 \pm 8.0 \cdot 10^{-10}$$

3.6σ discrepancy…Beyond Standard Model Physics?

$(g\text{-}2)_\mu$ SM contribution

$$a_\mu^{QED} = (11\,658\,471.809 \pm 0.015) \cdot 10^{-10}$$

$$a_\mu^{W,Z} = (15.4 \pm 0.2) \cdot 10^{-10}$$

$$a_\mu^{hadr} = (692.3 \pm 4.2) \cdot 10^{-10} + (10.5 \pm 2.6) \cdot 10^{-10} + \ldots$$

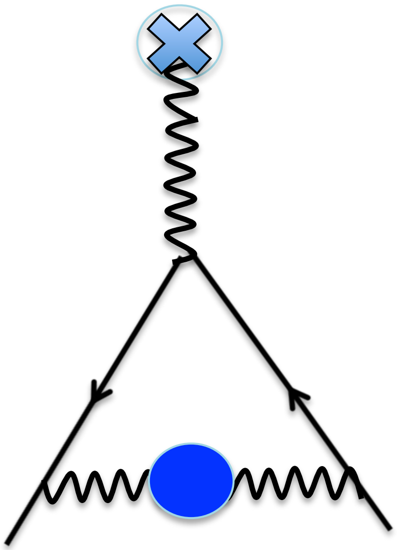
Future experimental measurements at BNL and J-PARC expected to reduce uncertainty to $\delta a_\mu \sim 1.6 \times 10^{-10}$

The uncertainty of the SM calculation dominated by hadronic contributions and soon greatest limiting factor

$(g\text{-}2)_\mu$ HVP contribution

$$a_\mu^{hadr} = (692.3 \pm 4.2)\cdot 10^{-10} + (10.5 \pm 2.6)\cdot 10^{-10} + \ldots$$

Hadronic Vacuum Polarisation contribution to a_μ related to hadronic cross section in e^+e^- collisions via dispersion relations



$$a_\mu^{HVP} \cong \frac{1}{4\pi^3} \int_{4m_\pi^2}^{\infty} K(s)\sigma(e^+e^- \to hadr)\,ds$$

2π contribution below 1 GeV dominating contribution

$(g\text{-}2)_\mu$ Recent HVP contribution

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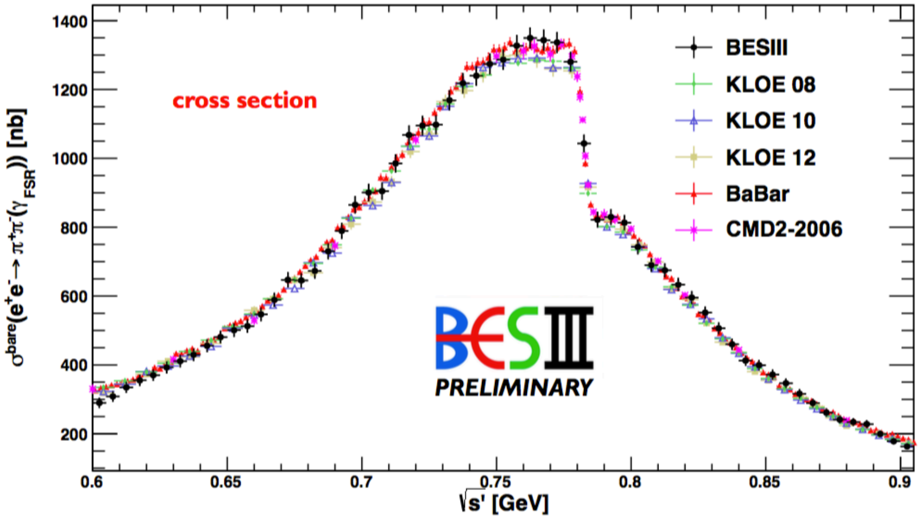
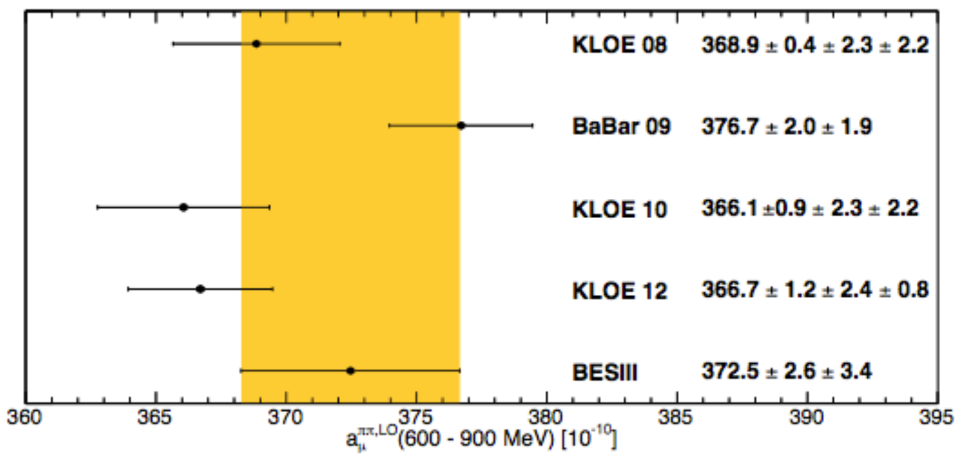
Precision data from Novosibirsk, BaBar, Belle, KLOE, BESIII





BESIII estimate of $a_\mu^{\pi\pi,LO}$ arXiv 1507.08188, Initial State Radiation (ISR) data

See Symmetry Breaking Hidden Local Symmetry Model (BHLS) for *one recent* theoretical evaluation 4.5σ (BESIII data points not included) arXiv:1507.02943

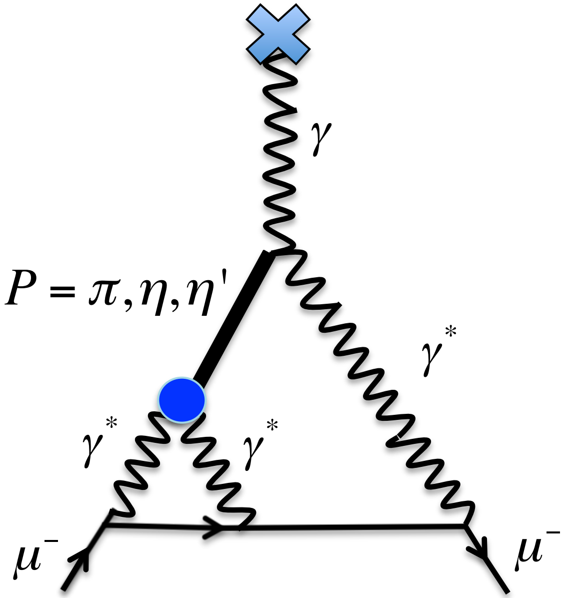
$(g-2)_\mu$ HLbL contribution

$$a_\mu^{hadr} = (692.3 \pm 4.2)\cdot 10^{-10} + (10.5 \pm 2.6)\cdot 10^{-10}$$

J. Prades, E. de Rafael, A. Vainshtein, arXiv:0901.0306

$$(11.6 \pm 3.9)\cdot 10^{-10}$$

F. Jegerlehner and A. Nyffeler, Phys. Rept. 477, 1 (2009)



Interaction of virtual mesons with $\gamma^{(*)}$

No direct relation to measureable quantities- model dependence

Off-shell P form factors not accessible experimentally…but any aspiring model should be able to correctly describe also the on-shell scenario

TFF used as experimental input

HLbL Data Driven Approaches

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Based on dispersion relations

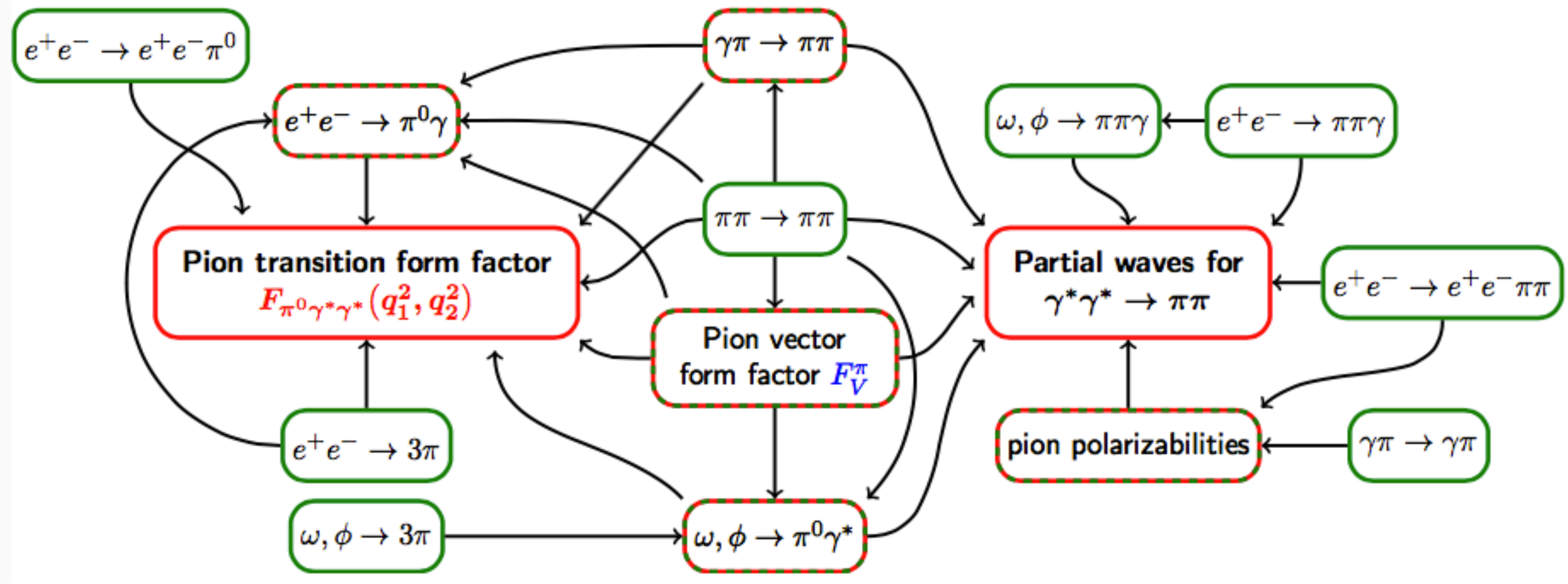
Provide direct link between HLbL contribution and experimental data

More reliable theoretical uncertainties

Approach based on analytic structure on HLbL tensor:
G. Colangelo, M. Hoferichter, M. Procura, and P. Stoffer
arXiv: 1402.7081v2 , 1408.2517v2, 1410.491v2 [hep-ph]

Approach based on analytic properties of the EM vertex function of muon:
V. Pauk and M. Vanderhaeghen
arXiv: 1403.7503 , 1409.0819 [hep-ph]

HLbL Data Driven Approaches



Final contributions to a_μ

Input

Both measurement and calculation

Approach based on analytic structure on HLbL tensor:

G. Colangelo, M. Hoferichter, M. Procura, and P. Stoffer

arXiv: 1402.7081v2 , 1408.2517v2, 1410.491v2 [hep-ph]

Transition Form Factors

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Largest individual HLbL contribution is π^0 pole, single and double virtual FF

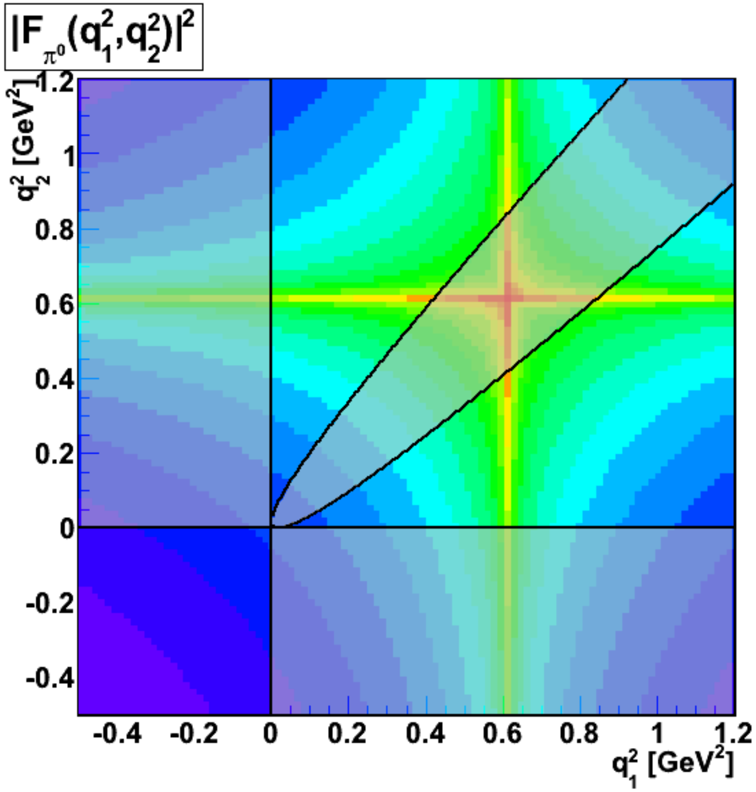

Figure by A. Kupsc, Uppsala University

TFF F_π^2 naïve VMD model where photons *only* couple to vector mesons, ρ, …

Space- and Time- like processes used to access different kinematical regions

Kinematically forbidden regions shaded

π^0 Transition Form Factors

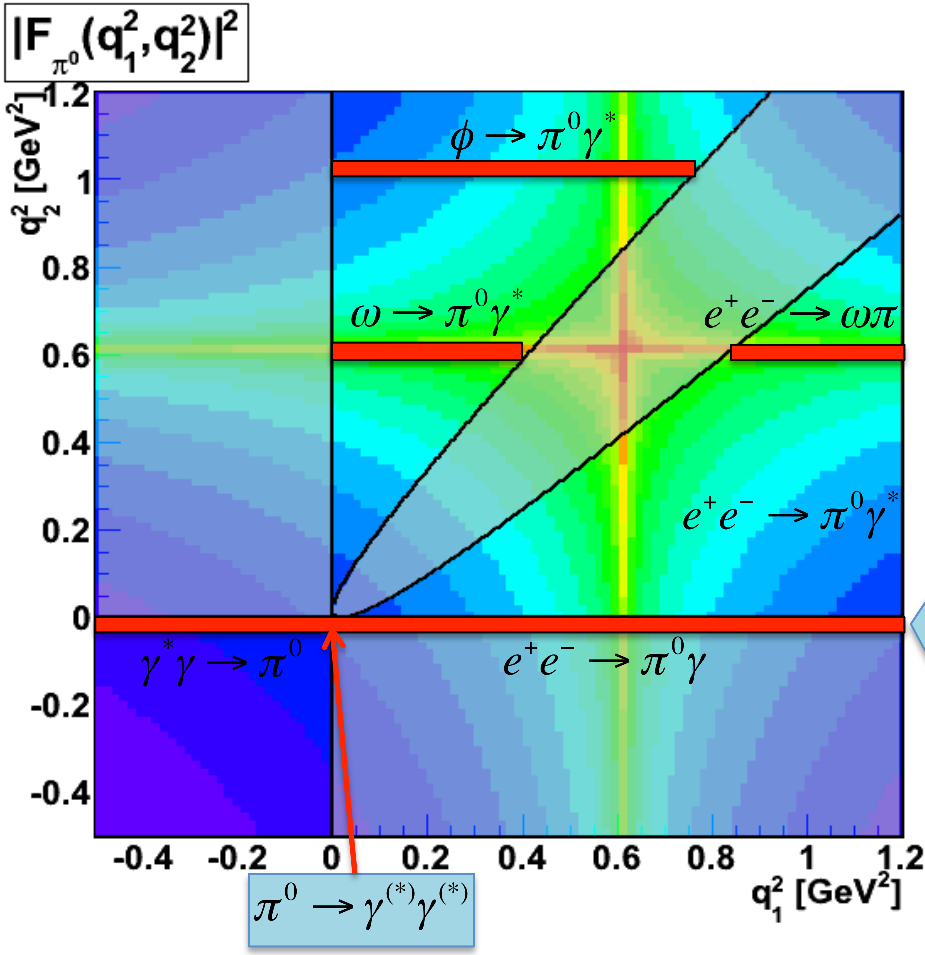

Figure by A. Kupsc, Uppsala University

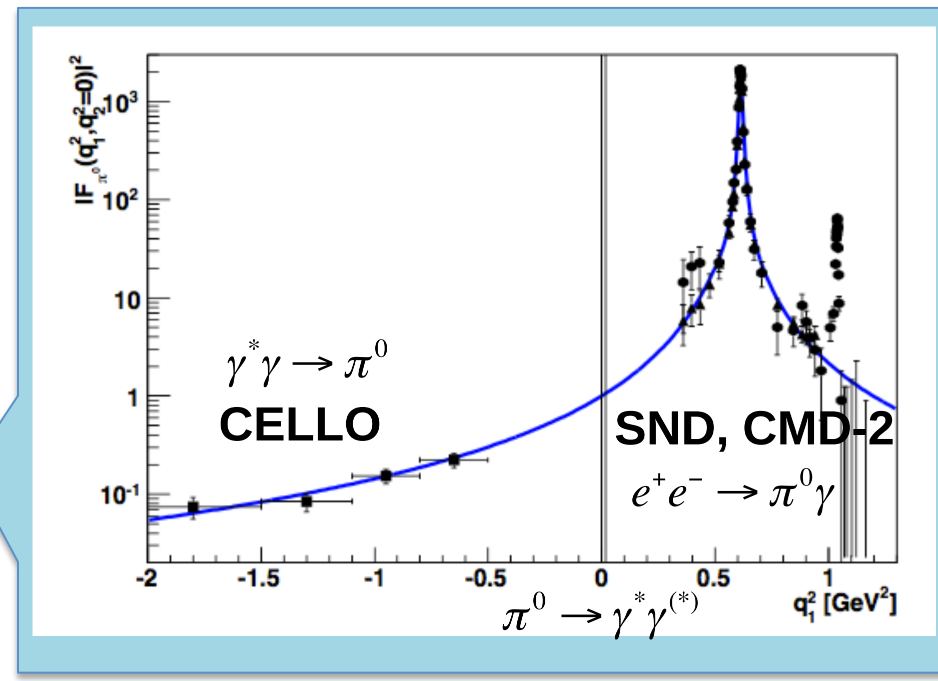

Figure from arXiv:1207.6556

CMD-2 [Phys. Lett. B 605, 26 (2005)]
SND [Phys. Lett. B 504, 275 (2001)]
CELLO [Z. Phys. C 49, 401 (1991)]

π^0 Dalitz Decay

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Observable: slope parameter a_π
FF = $(1 - a_\pi x)^{-1} \sim 1 + a_\pi x$ for small a_π

Theory

VMD	+0.031
ChPT 2 –loop	+0.029(5)

Kampf, Knecht, Novotný, EPJ C46 (2006) 191

Experiment

SINDRUM-I Coll. $+0.025(14)_{stat}(26)_{syst}$ 54k
Drees *et al* Phys.Rev.D 45 (1992) 1439

"...we think that a precise measurement of a_π which would not rely on any kind of extrapolation remains an interesting issue."

Extrapolation from space-like region

CELLO	+0.0326(26)stat(26)syst

Behrend *et al* (CELLO) Z. Phys.C 49 (1991) 401

CLEO	+0.0303(8)stat(9)syst(12)

Gronberg *et al* (CLEO) Phys.Rev.D 57 (1998) 33

π^0 Dalitz Decay

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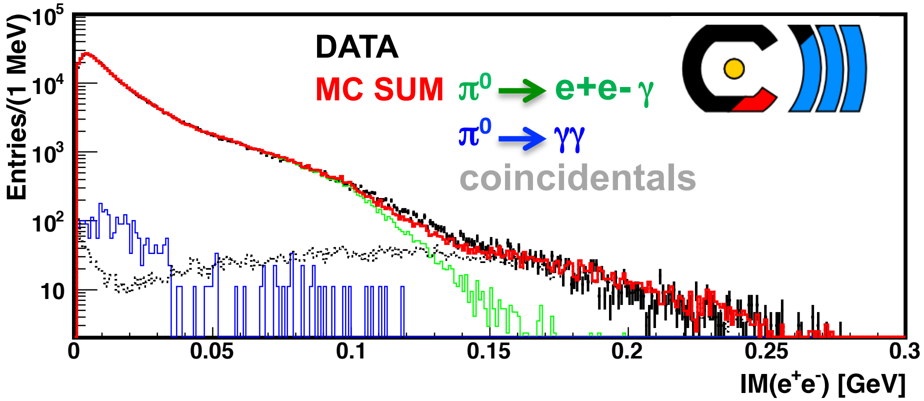
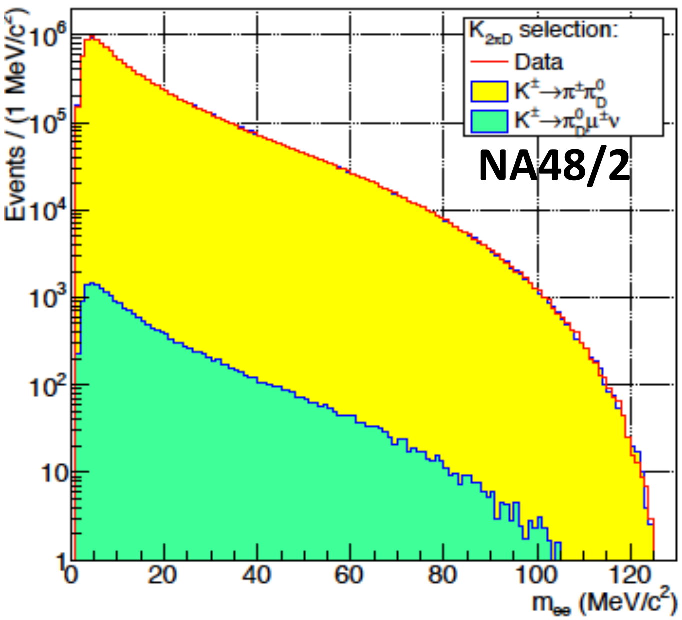
Phys. Lett. B 726, 187 (2013)



Phys.Lett. B746, 178 (2015)



In search of a dark photon in $\pi^0 \to \gamma U \to e^+e^- \gamma$

Data sample can be used to determine π^0 TFF

~5.0 x 10^5 events in final event sample.
To be analysed ~8.0 x 10^6 π^0 Dalitz

Based on 1.7 x 10^7 π^0 Dalitz decays
TFF measurement in progress

V-P Transition Form Factors

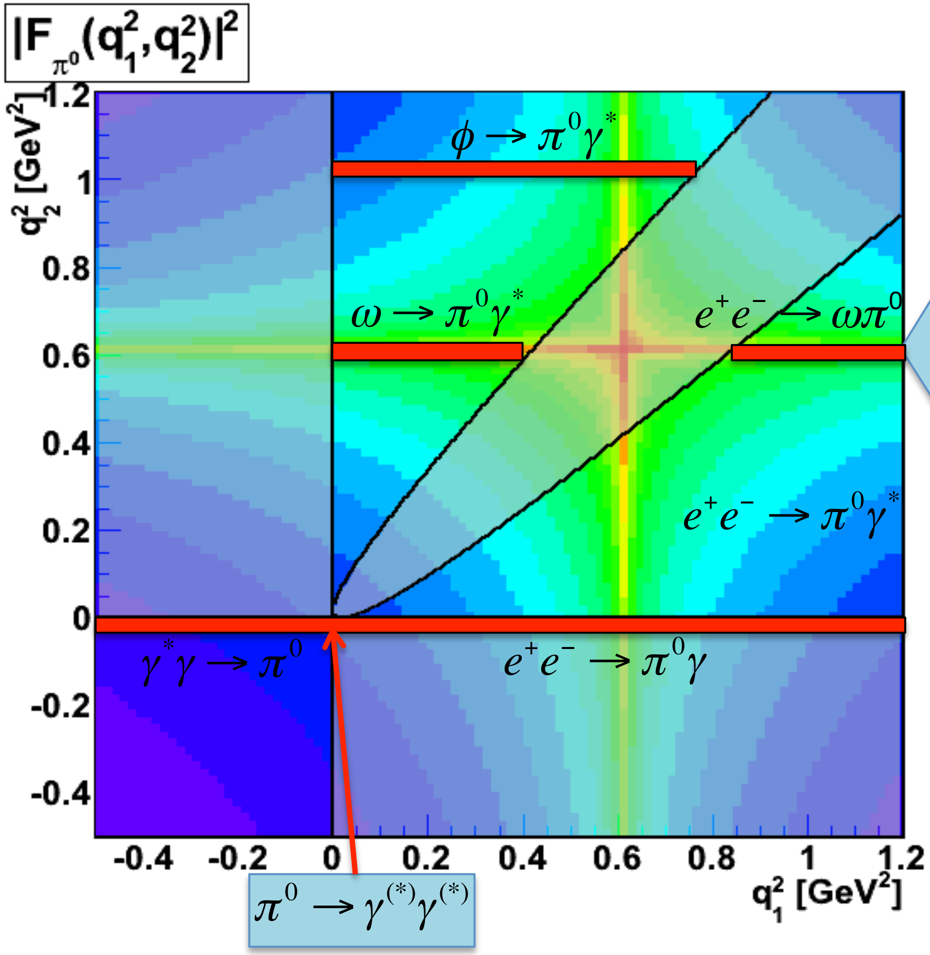


Figure by A. Kupsc, Uppsala University

Since Vector mesons act as intermediate states for TFF of Pseudoscalar mesons, also information obtained by studying TFF of Vector mesons to Pseudoscalar mesons are of interest.

NA60	[Phys. Lett. B 677, 260 (2009)]
SND	[Phys. Lett. B 486, 29 (2000)]
CMD-2	[Phys. Lett. B 562, 173 (2003)]
KLOE	[Phys. Lett. B 669, 223 (2008)]

π^0 Transition Form Factors

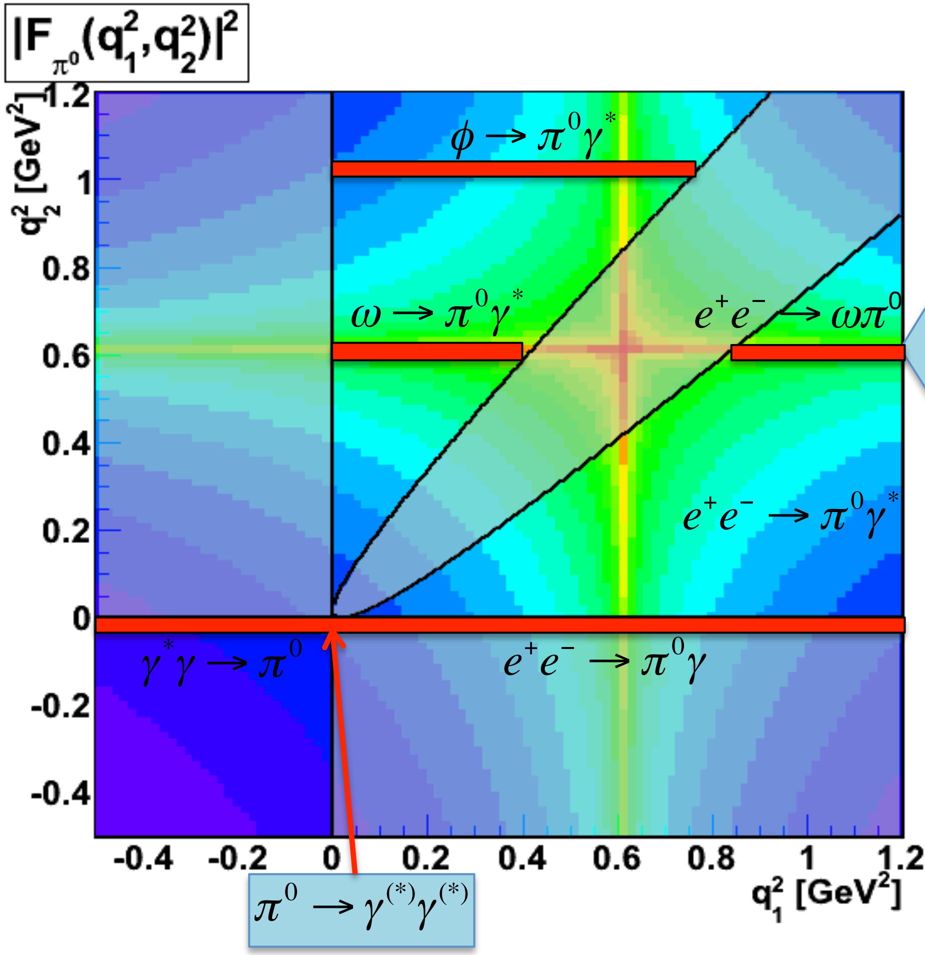


Figure by A. Kupsc, Uppsala University

VMD description fails to reproduce data

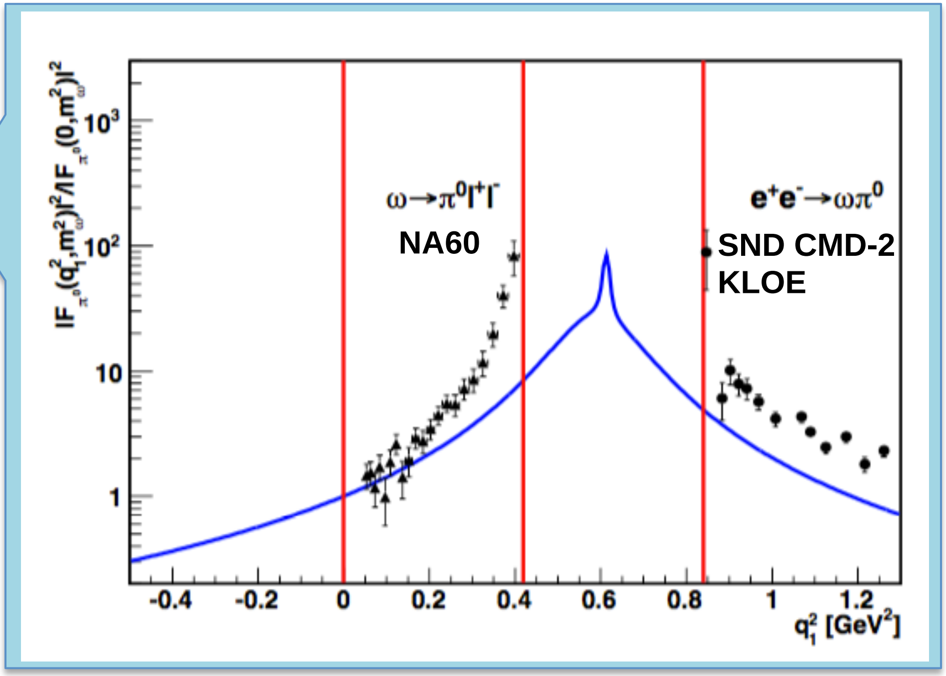


Figure from arXiv:1207.6556

NA60	**[Phys. Lett. B 677, 260 (2009)]**
SND	**[Phys. Lett. B 486, 29 (2000)]**
CMD-2	**[Phys. Lett. B 562, 173 (2003)]**
KLOE	**[Phys. Lett. B 669, 223 (2008)]**

$e^+e^- \rightarrow \omega\pi^0$- SND

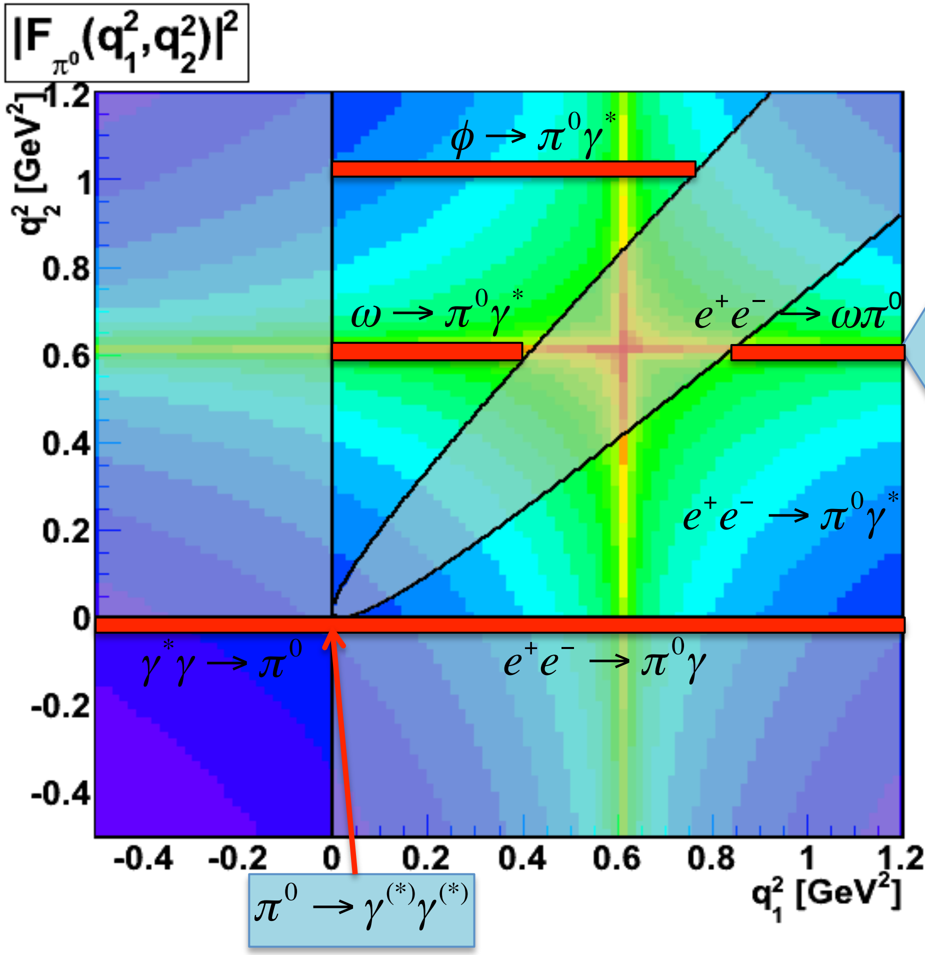
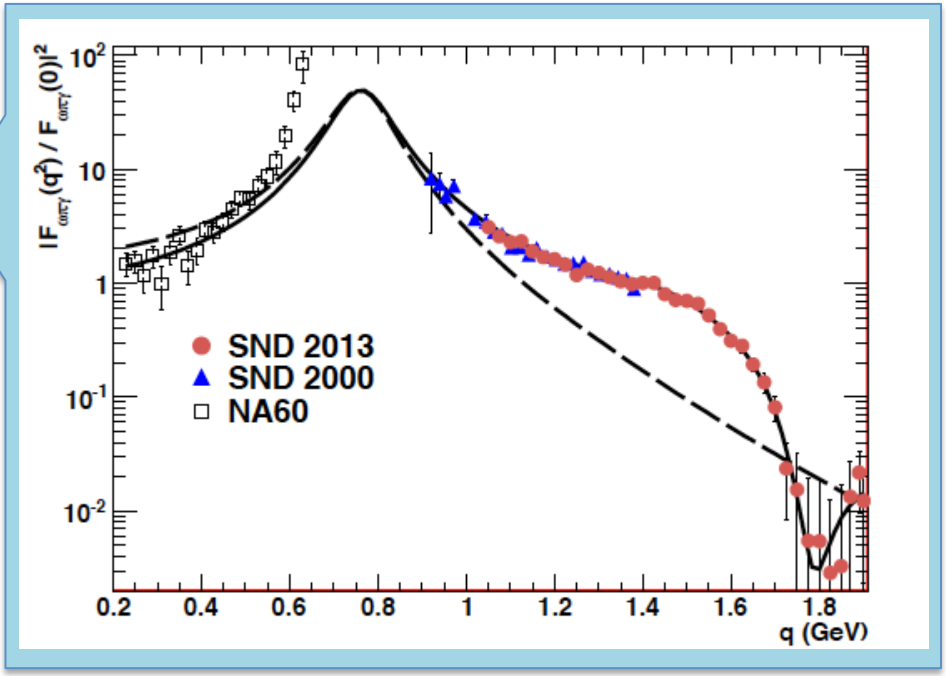


Figure by A. Kupsc, Uppsala University

Recent measurement 1.05 – 2 GeV

SND [Phys. Rev. D 88, 054013, (2013)]



Fit to data found by using VMD fit with ρ(770), ρ(1450), ρ(1700)

However, NA60 data does not fit with this description

NA60 and effective field theory

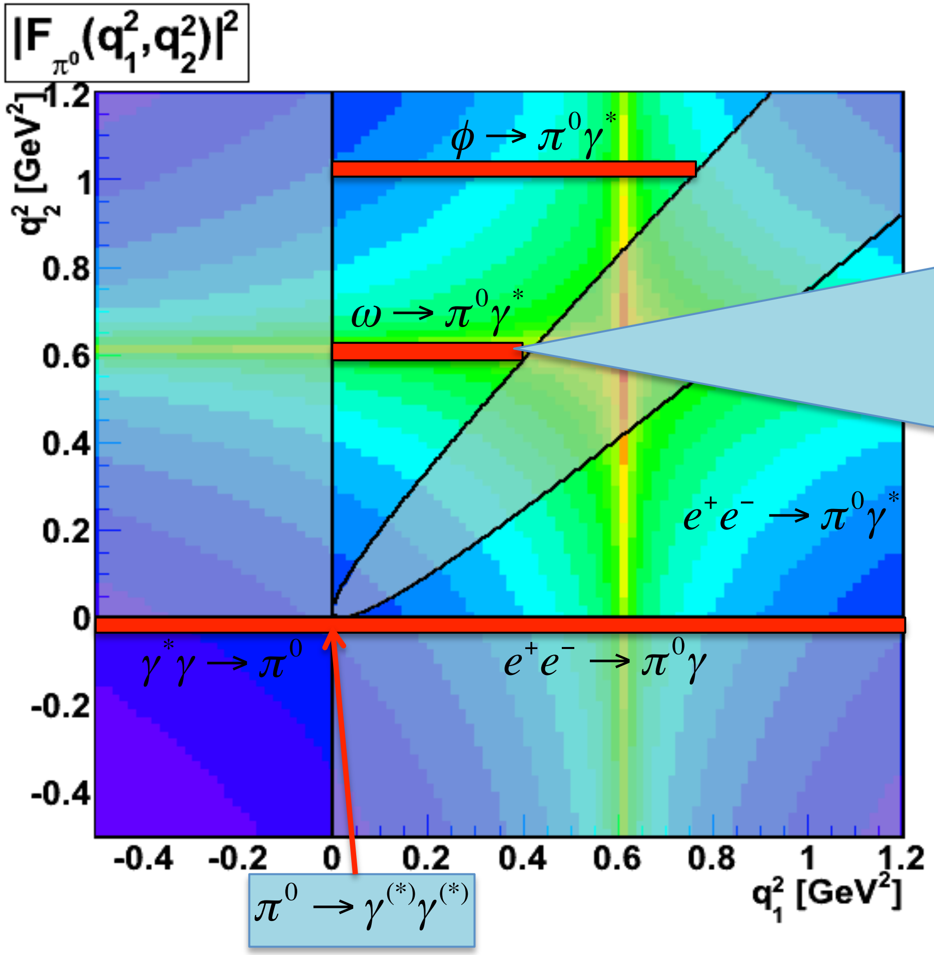
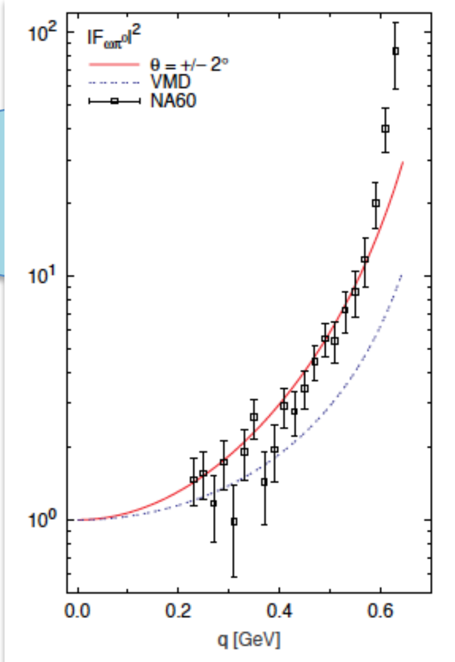


Figure by A. Kupsc, Uppsala University



…but NA60 dimuon data finds better agreement in another effective field theory approach which includes both P nonet and light V nonet

[Terschlüsen, Leupold, Lutz, EPJ. A48 (2012) 190]

$\omega\pi^0$ dilepton and CLAS

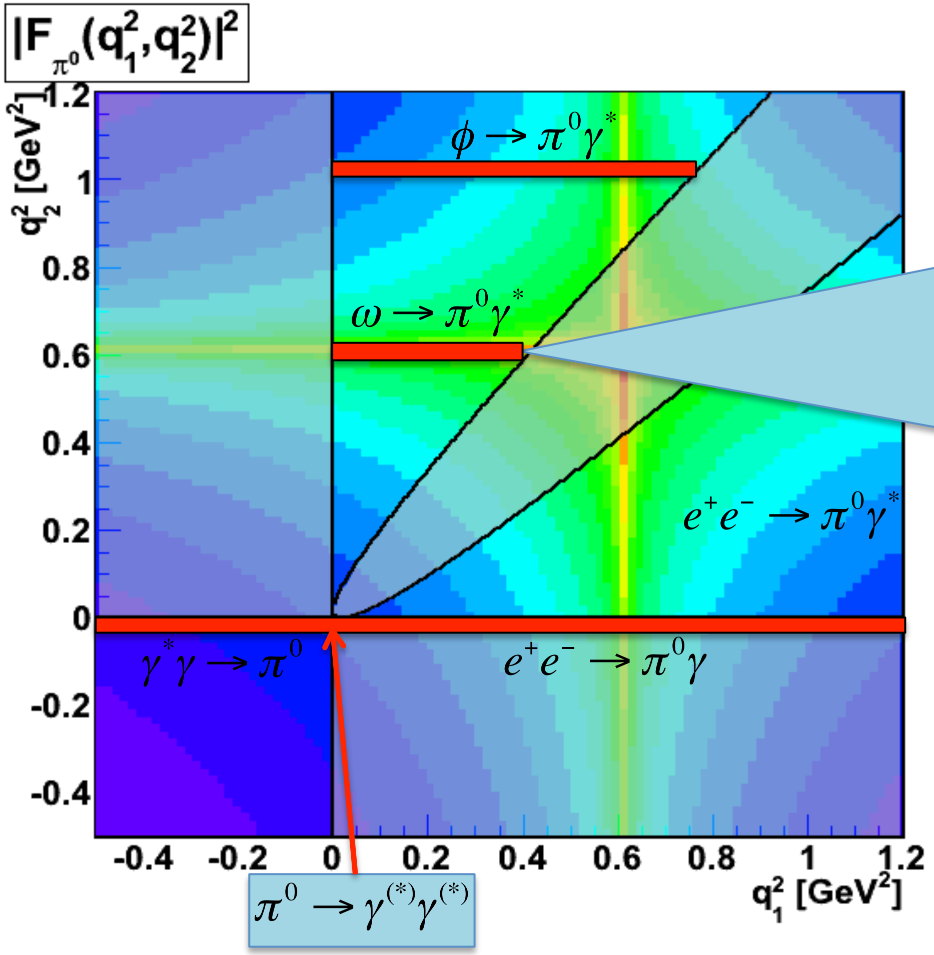


Figure by A. Kupsc, Uppsala University

Preliminary results from CLAS

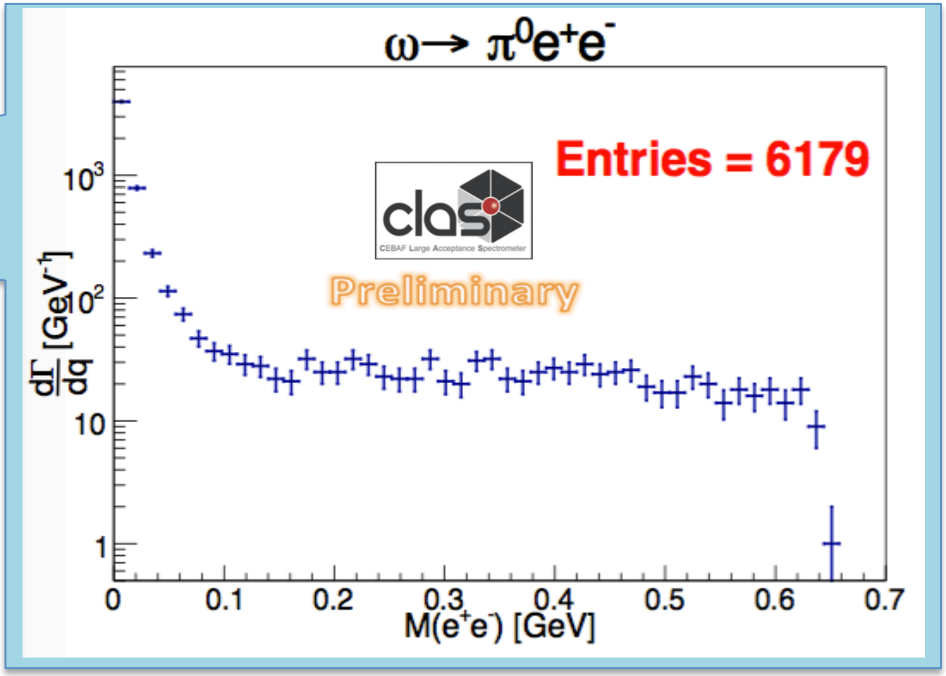


Figure by M.C. Kunkel, from MesonNet meeting '14

Future results from A2

π^0 Transition Form Factors

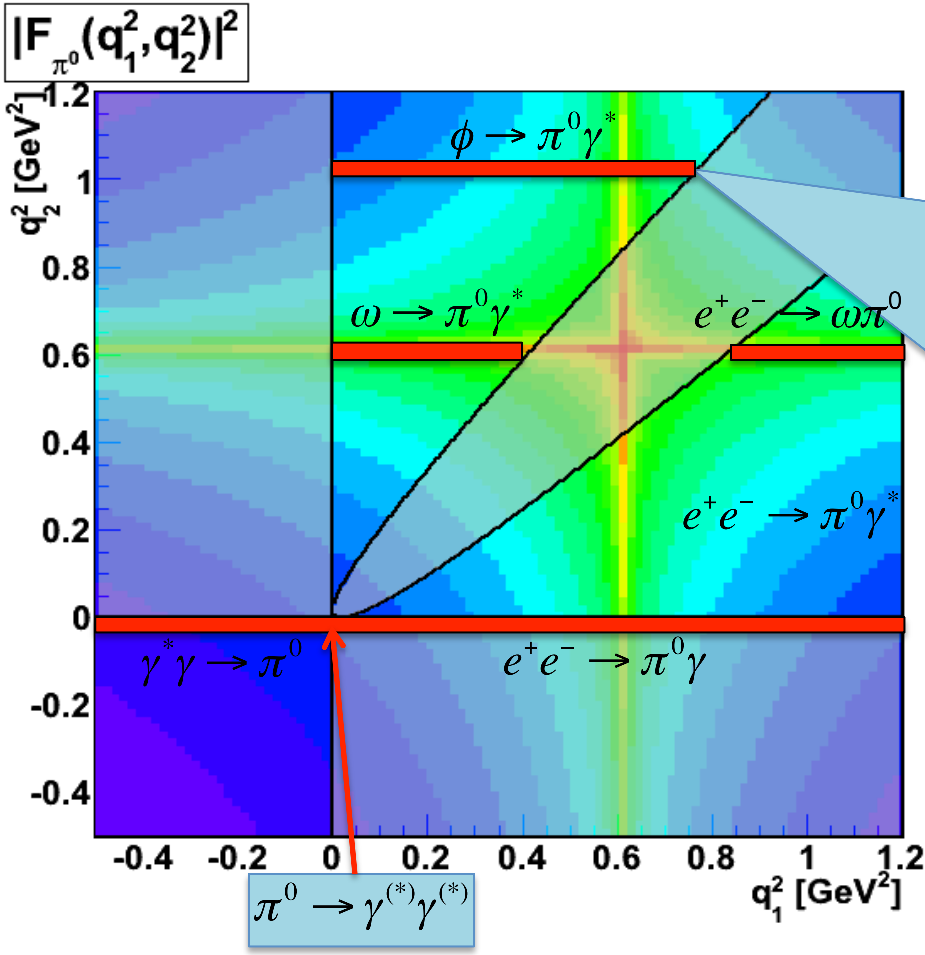
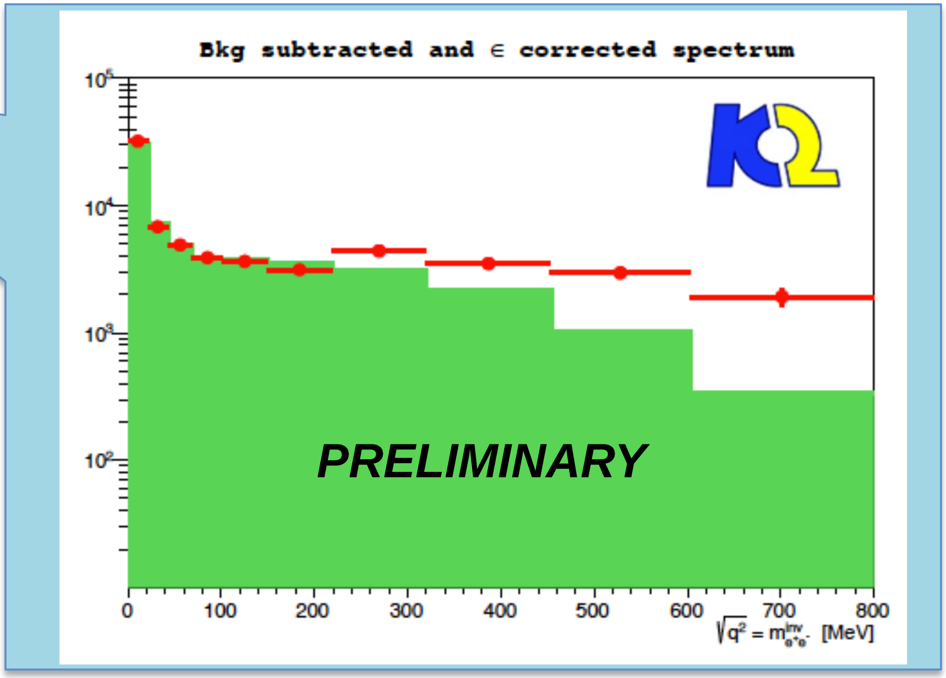


Figure by A. Kupsc, Uppsala University



KLOE arXiv:1501.05434 [hep-ex]

First measurement of $\phi\pi^0\gamma^*$ TFF under way
9000 signal events based on 1.7 fb^{-1}
MC (green) based on constant TFF

π^0 SL TFF Single Tag

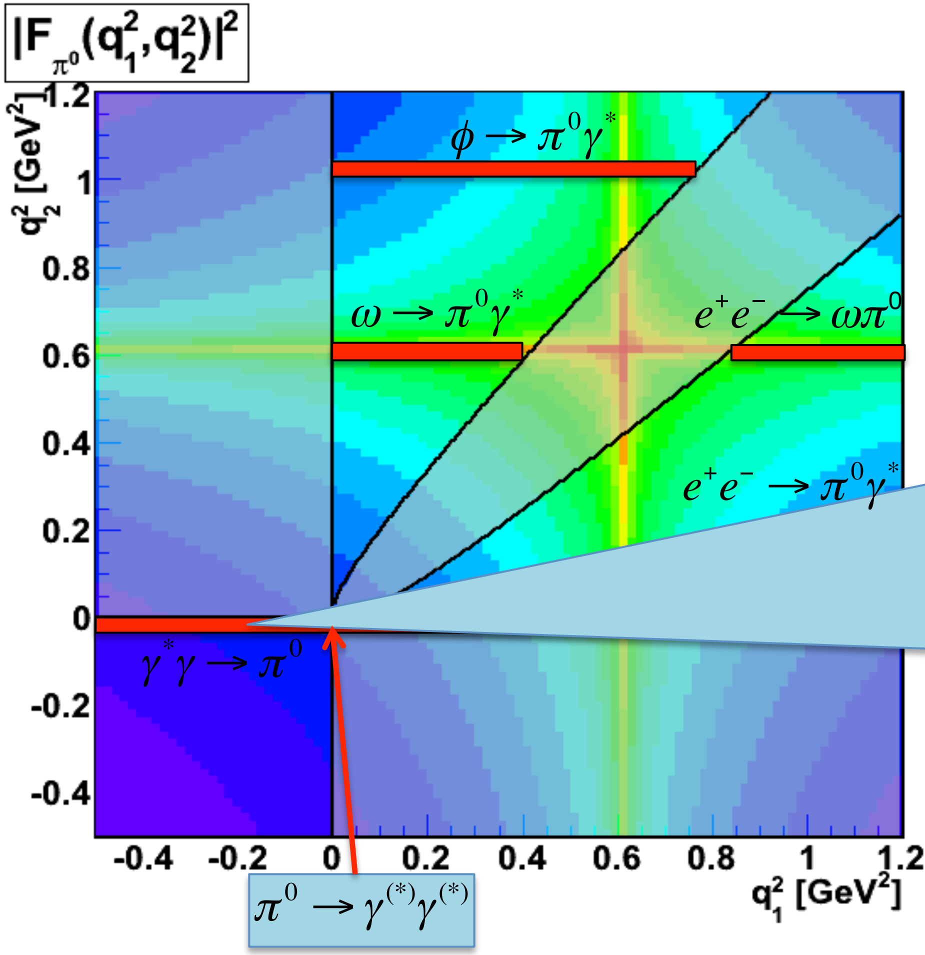
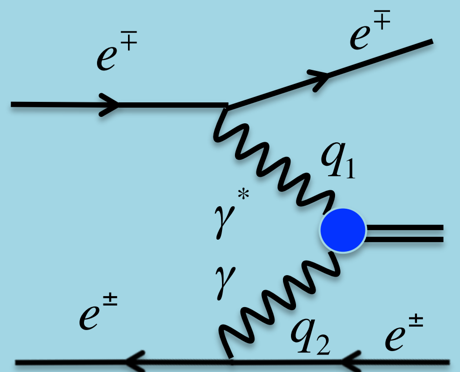
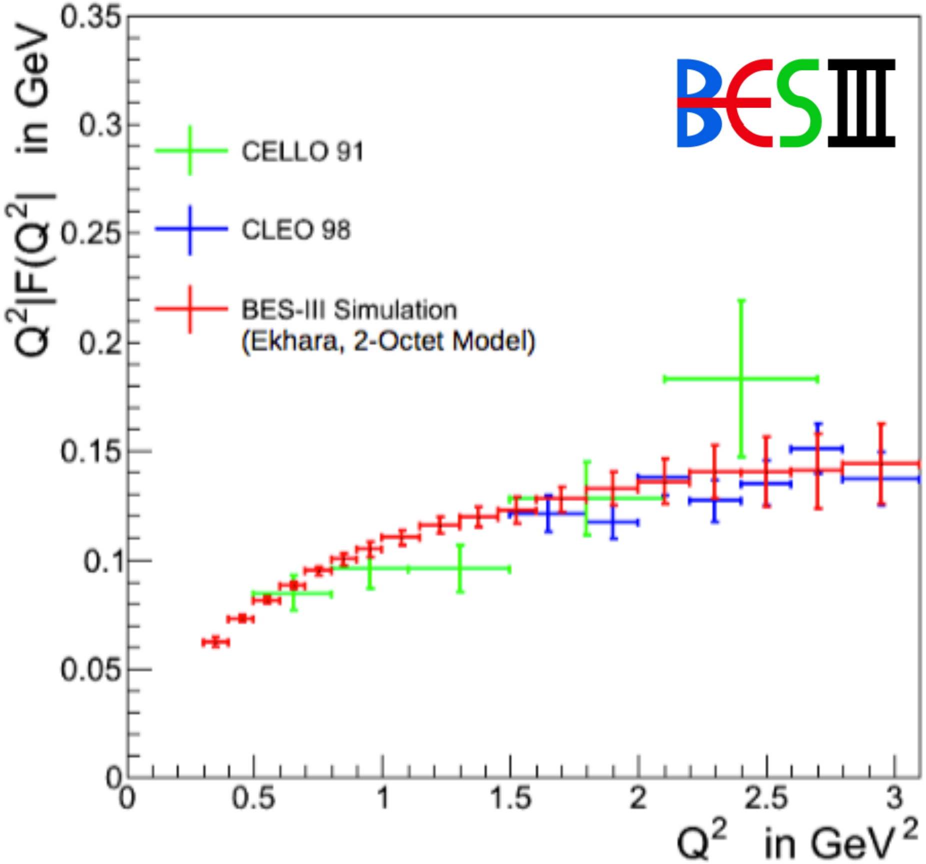


Figure by A. Kupsc, Uppsala University



Single tag measurement:
Reconstruct one lepton + produced system
Require scattering angle to be small
One photon quasi-real $F(q_1^2, q_2^2) \Rightarrow F(q_1^2, 0)$

π^0 SL TFF Single Tag BESIII



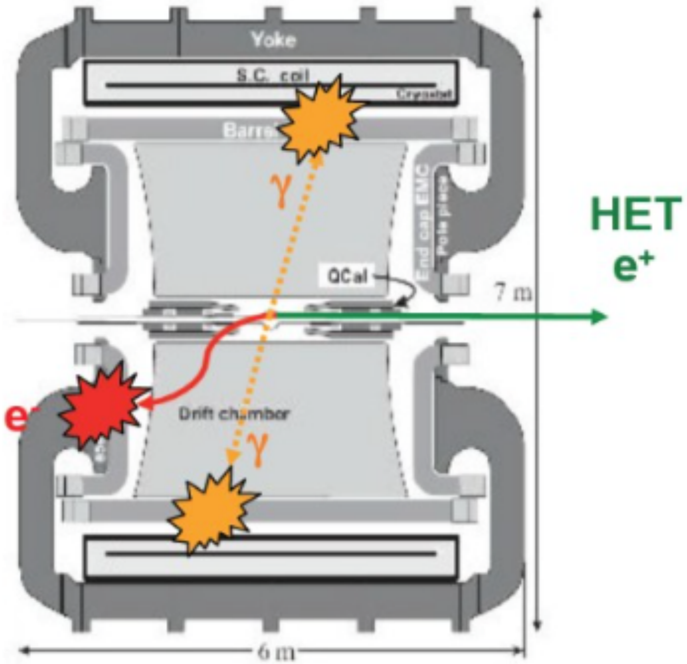
Analysis based on 2.9 pb^{-1} $\Psi(3770)$ data (simulation shown in figure)

Possible to extract TFF in region Q^2 ($Q = -q$) 0.3 – 3.1 GeV^2

Projected statistical uncertainty shown

Systematical studies on data currently being performed

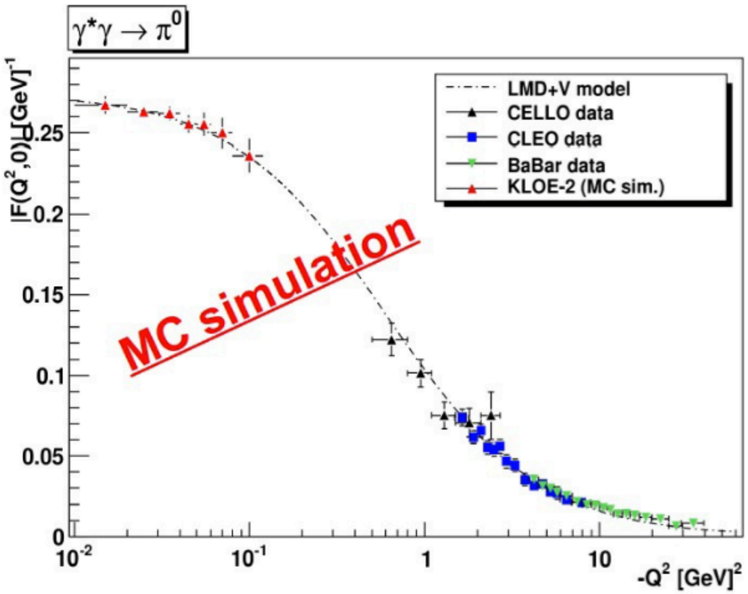
π^0 SL TFF Single Tag KLOE-2



HET
Scintillator hodoscope
11m from the Interaction Point
$420 < E_e < 495$ (MeV)

Makes it possible to extract TFF in region Q^2 ($Q = -q$) < 0.1 GeV^2

With $5fb^{-1}$ integrated luminosity
Stat. unc 6% per data point



η Transition Form Factors

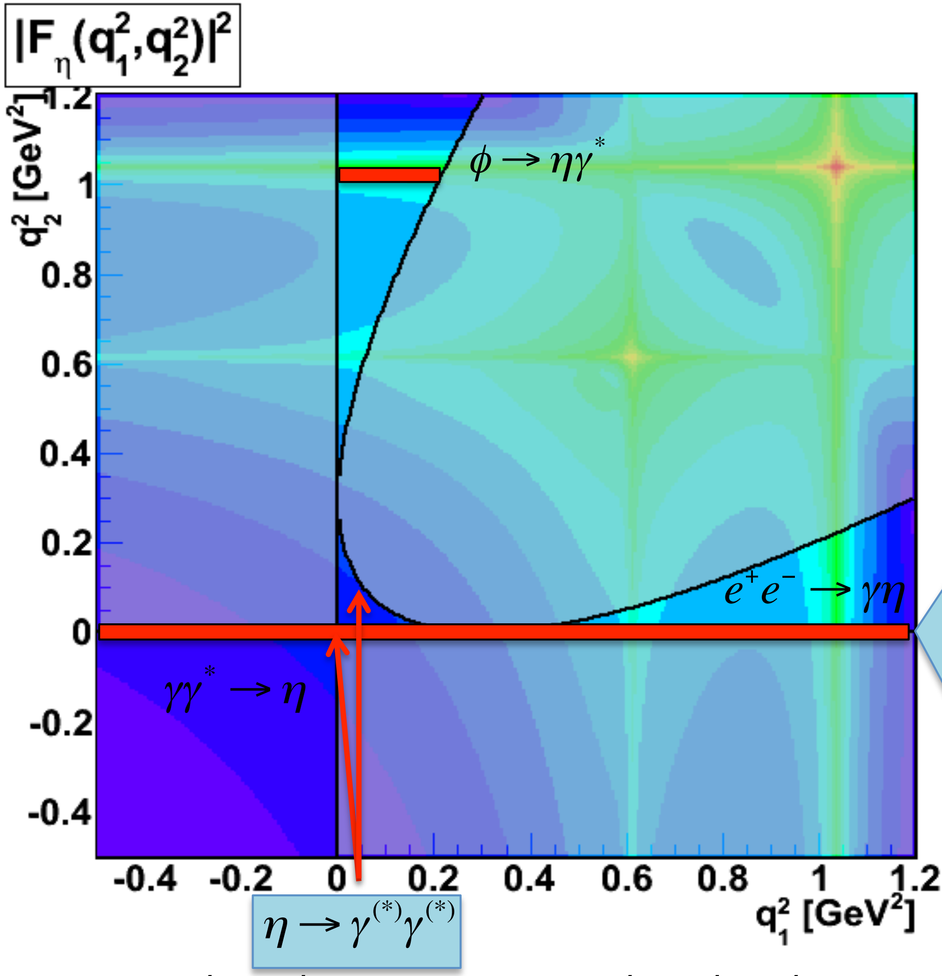


Figure by A. Kupsc, Uppsala University

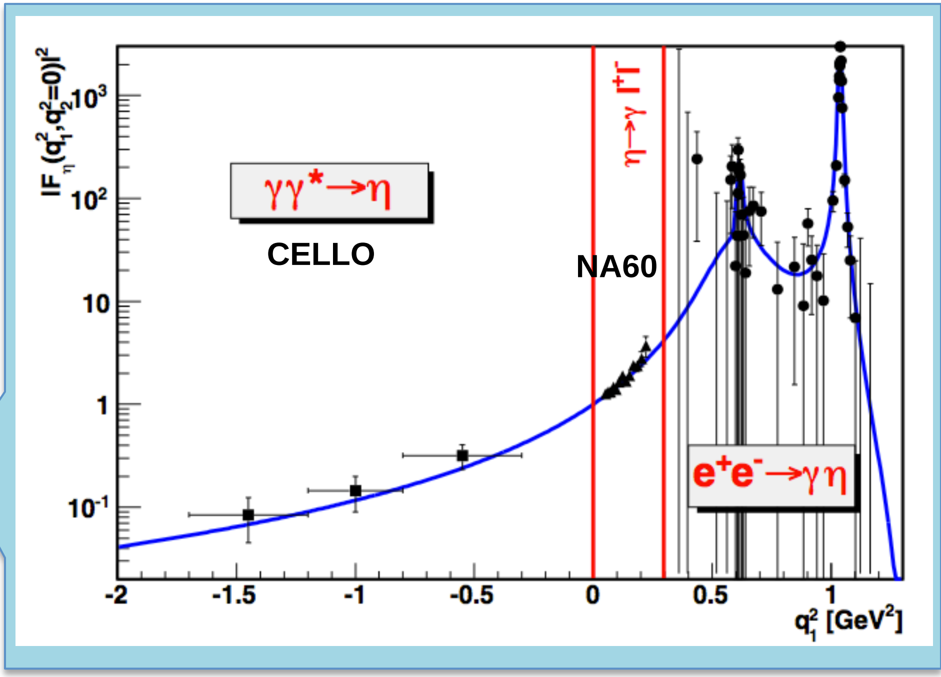


Figure from arXiv:1207.6556

CELLO	[Z. Phys. C 49, 401 (1991)]
NA60	[Phys. Lett. B 677, 260 (2009)]
CMD-2	[Phys. Lett. B 605, 26 (2005)]
SND	[Phys. Lett. B 504, 275 (2001)]

η double Dalitz decay

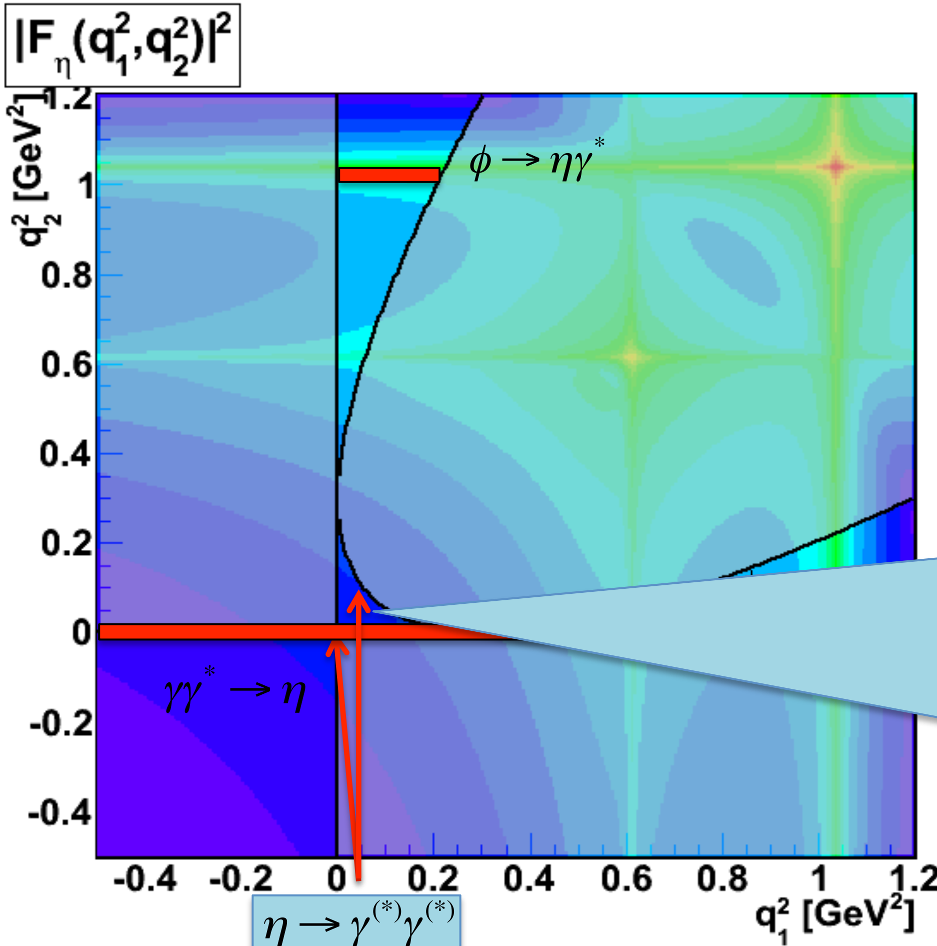
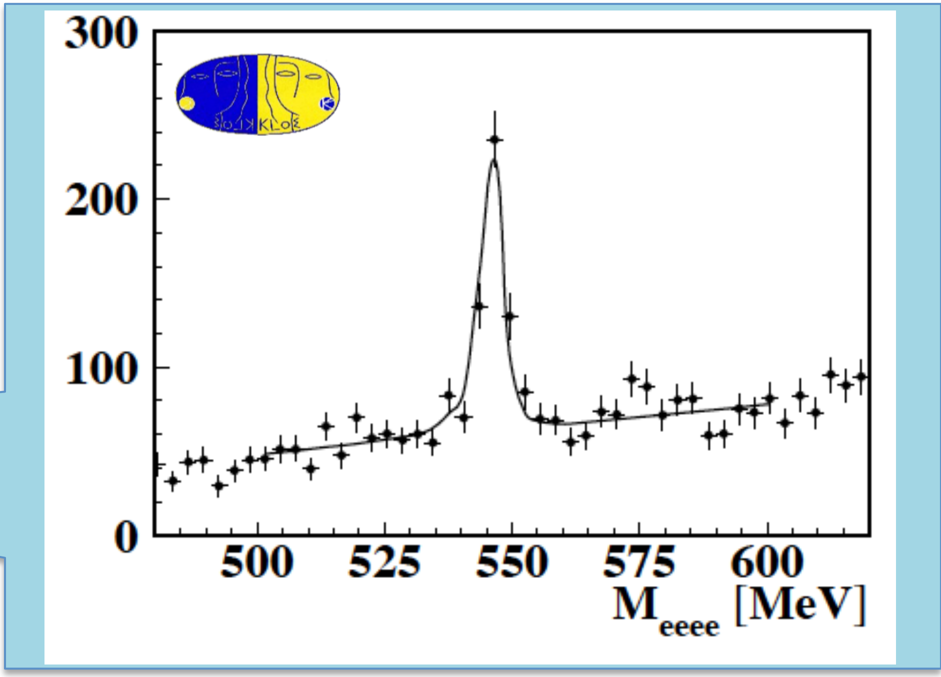


Figure by A. Kupsc, Uppsala University

First observation η double Dalitz decay

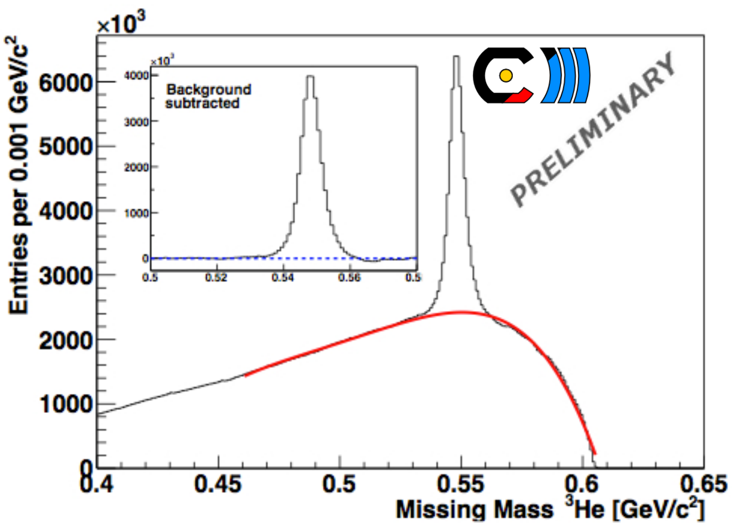
KLOE [Phys Lett B 702 (2011), 324]



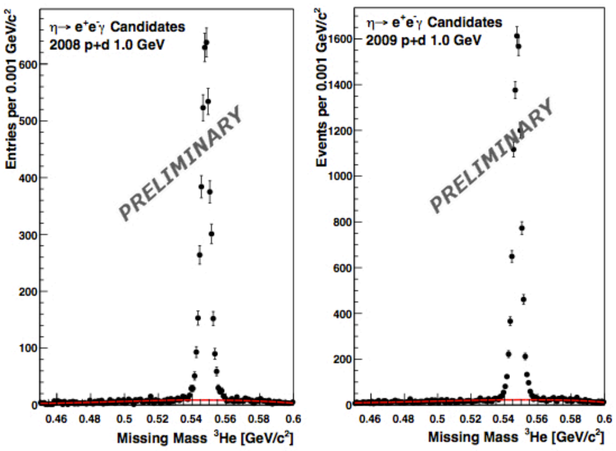
362 ± 29 events, 1.7 fb^{-1}

BR($\eta \to e^+e^-e^+e^-$) = (2.4±0.2±0.1) x 10^{-5}

Theor. calculations (2.41 – 2.67) x 10^{-5}



3.0 x 10^7 η MM(^{3}He)

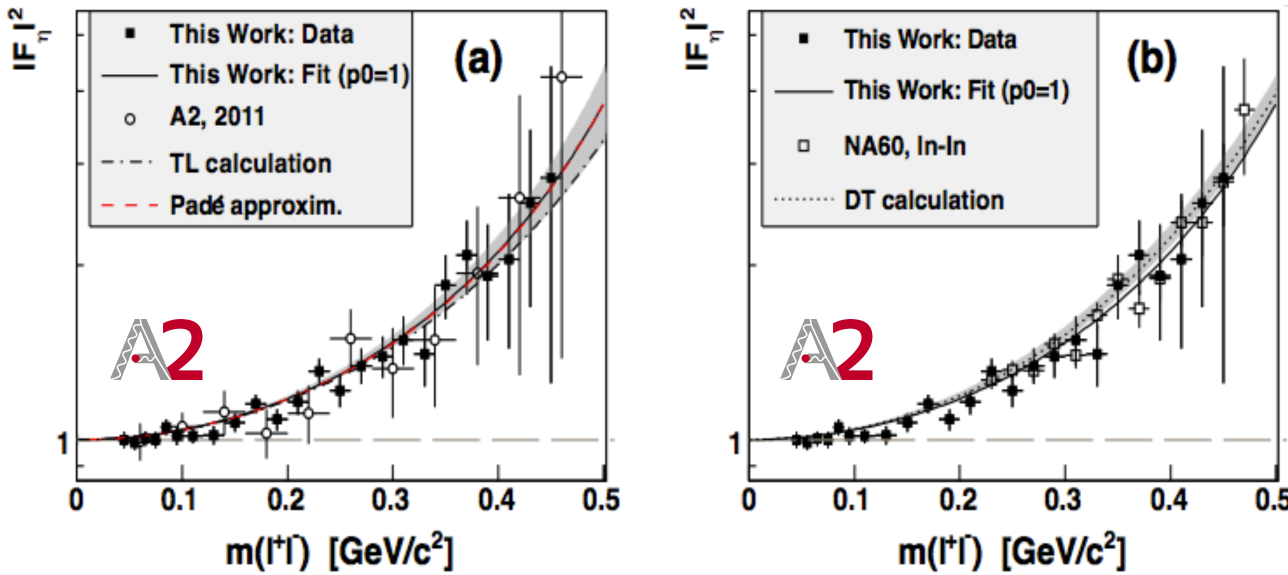


1.4 x 10^4 $\eta \rightarrow e^+e^-\gamma$

Several anomalous η decay channels analysed with same analysis scheme
Norm. to $\eta \rightarrow \pi^+\pi^-\pi^0$

PRELIMINARY RESULTS

Channel	Branching Ratio
$\eta \rightarrow \pi^+\pi^-\gamma$	$(4.68 \pm 0.07_{stat/fit} \pm 0.19_{sys}) \times 10^{-2}$
$\eta \rightarrow e^+e^-\gamma$	$(6.75 \pm 0.06_{stat/fit} \pm 0.29_{sys}) \times 10^{-3}$
$\eta \rightarrow \pi^+\pi^-e^+e^-$	$(2.7 \pm 0.2_{stat} \pm 0.1_{sys}) \times 10^{-4}$
$\eta \rightarrow e^+e^-e^+e^-$	$(3.2 \pm 0.9_{stat} \pm 0.4_{sys}) \times 10^{-5}$



Λ^{-2} reflects FF slope at $m_{ll} = 0$

A2 Λ^{-2} = 1.95 $(15)_{stat}$ $(10)_{syst}$ GeV^{-2} ($l = e$) [Phys. Rev. C 89, 044608 (2014)]
$|F_\eta|^2$ = 0.982(11) compatible with 1 within 2σ

NA60 Λ^{-2} = $1.95(.59)_{stat}$ $(.42)_{syst}$ GeV^{-2} ($l = \mu$) [Nucl. Phys. A 855, 189(2011)]

TL : Terschlüsen, Diploma thesis, University Gießen, 2010.
Padé : Escribano, Masjuan, Sanchez-Puertas, Phys. Rev. D 89 (2014) 034014.
DT : Hahnhart, Kupść, Meißner, Stollenwerk, Wirzba, Eur. Phys. J. C73 (2013) 2668.

A2 result agrees best with Padé, but all within statistical uncertainty

$\phi\eta\gamma^*$ Transition Form Factor

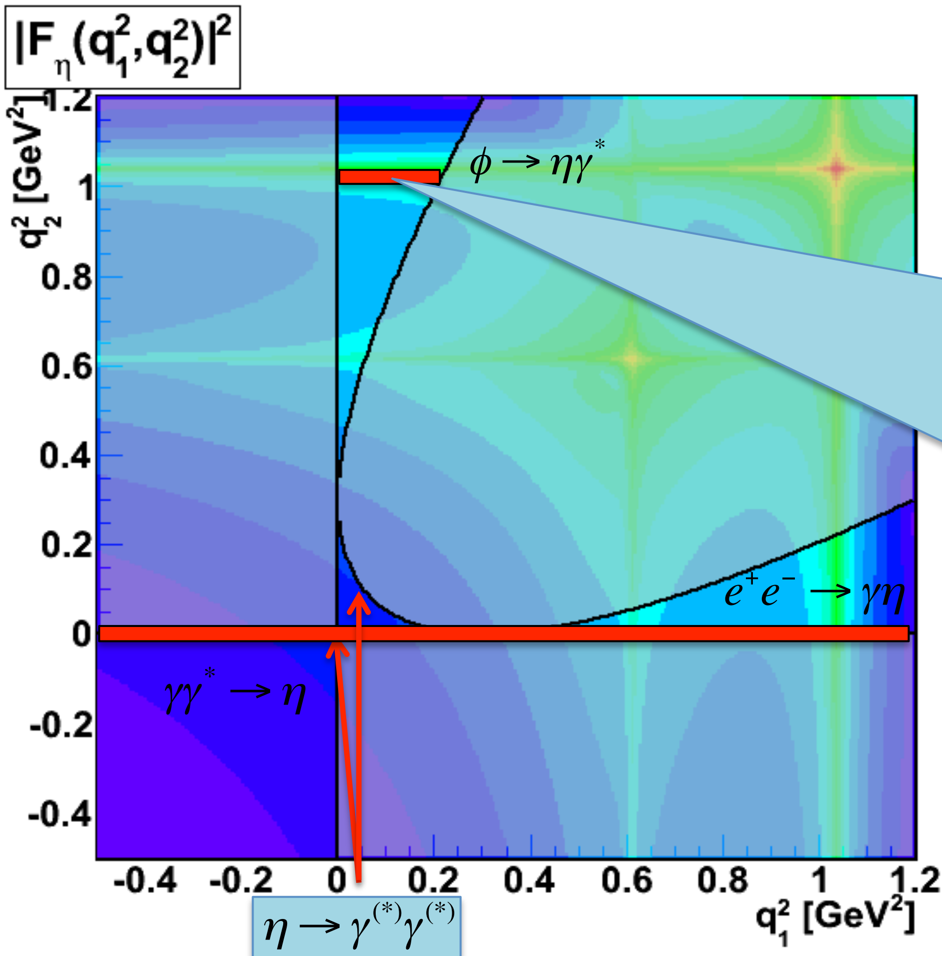
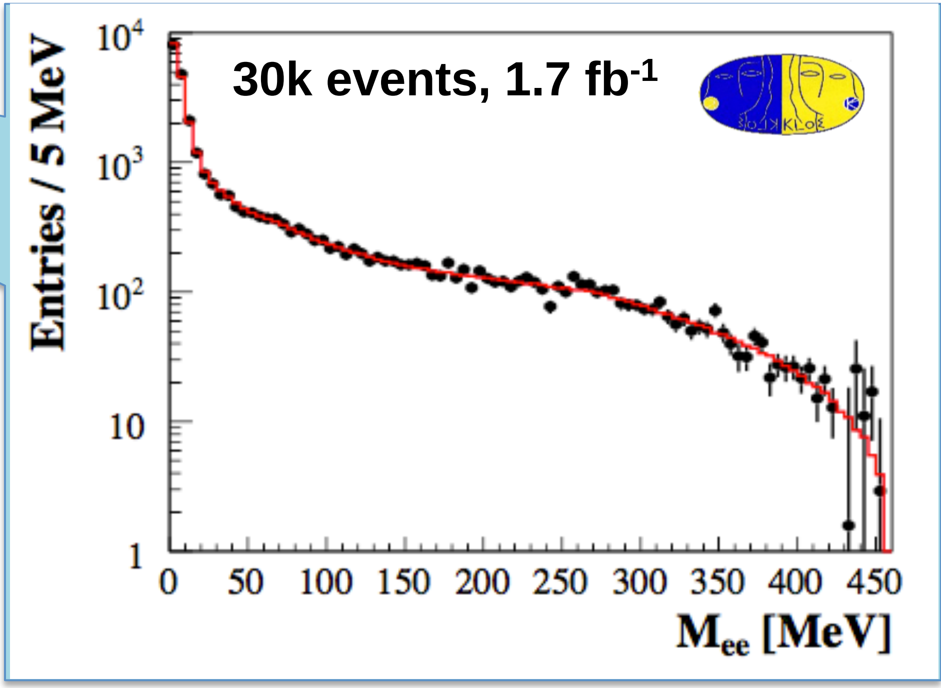


Figure by A. Kupsc, Uppsala University

KLOE [Phys Lett B 742 (2015), 1]



BR($\phi \to \eta e^+ e^-$) = (1.075 ± 0.007 ± 0.038) x 10^{-4}

Previous experiments (BR only)

SND (1.19 ± 0.19 ± 0.07) x 10^{-4}

CMD-2 (1.14 ± 0.10 ± 0.06) x 10^{-4}

$\phi\eta\gamma^*$ Transition Form Factor

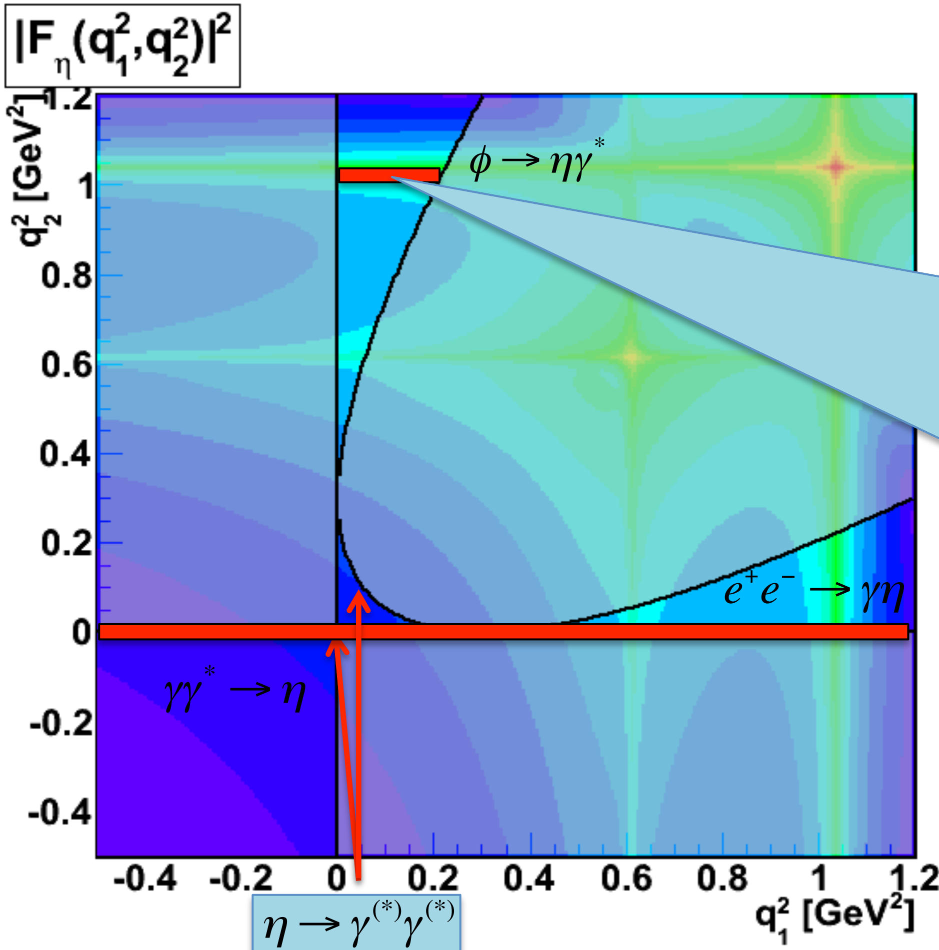
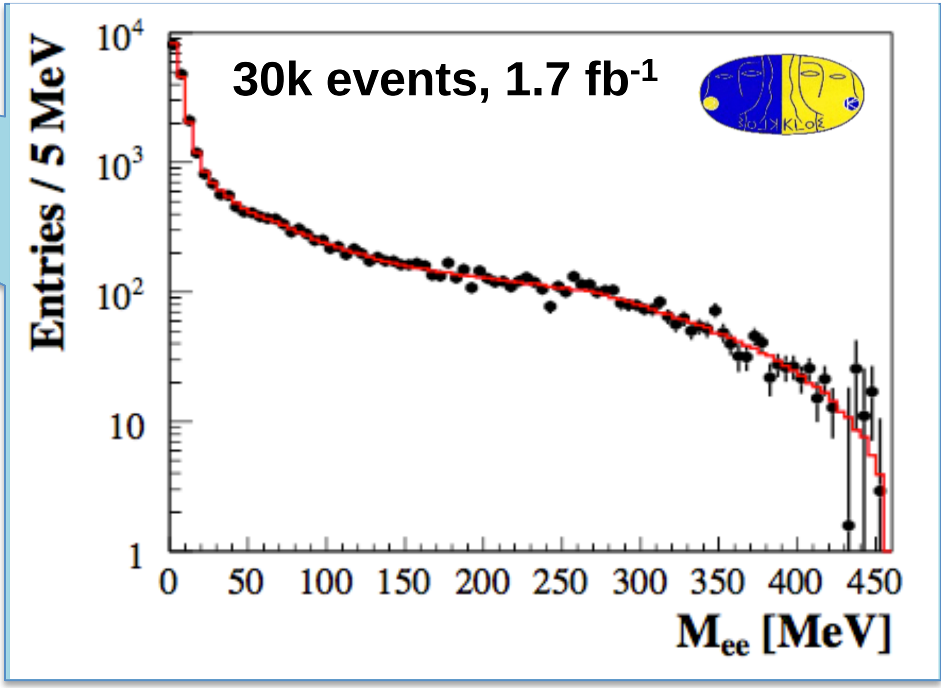


Figure by A. Kupsc, Uppsala University

KLOE [Phys Lett B 742 (2015), 1]



BR($\phi \to \eta e^+e^-$) = (1.075 ± 0.007 ± 0.038) x 10^{-4}

Theory:

VMD = 1.1 x 10^{-4} [Phys Rev C 61, 035206 (2000)]

EFT = (1.09 ± 0.06)x10^{-4} [Phys.Lett. B691 (2010) 191]

$\phi\eta\gamma^*$ Transition Form Factor

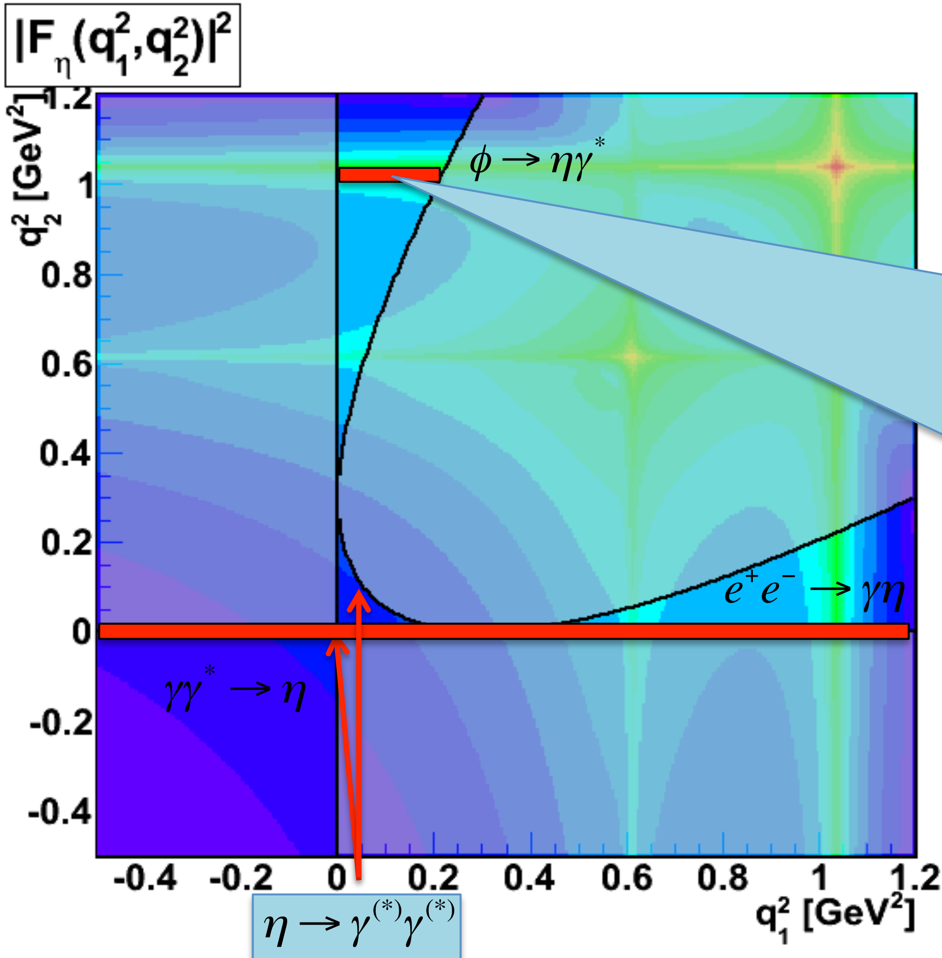
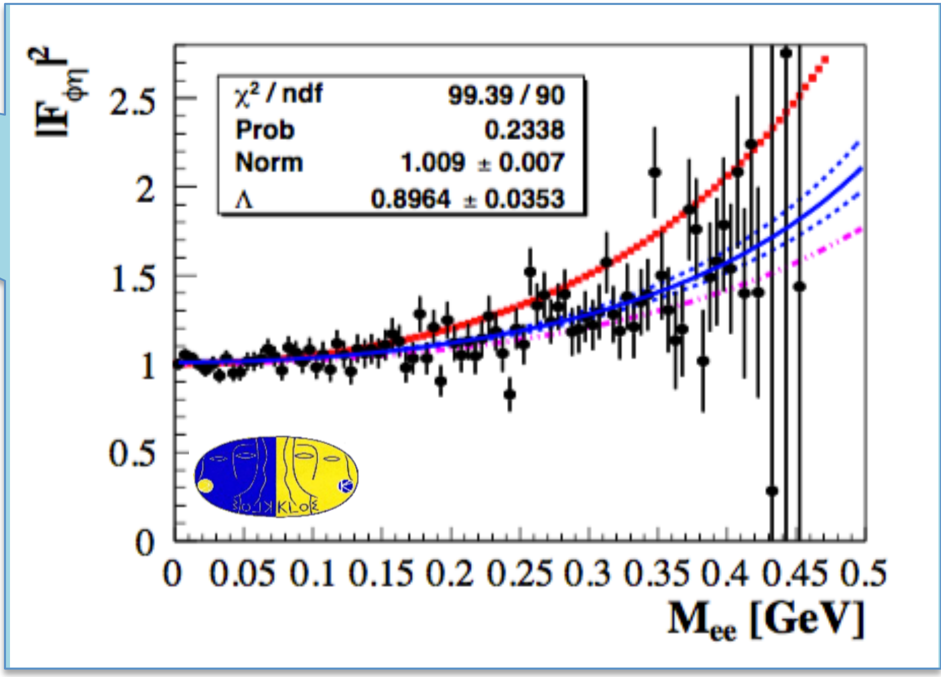


Figure by A. Kupsc, Uppsala University

KLOE [Phys Lett B 742 (2015), 1]

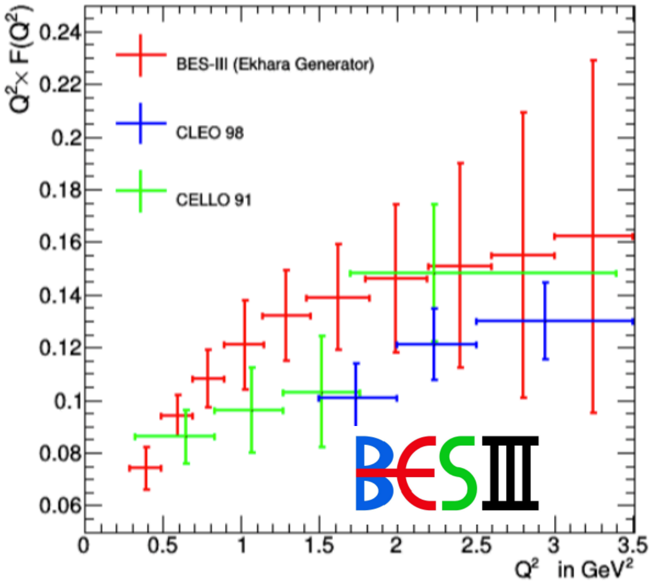


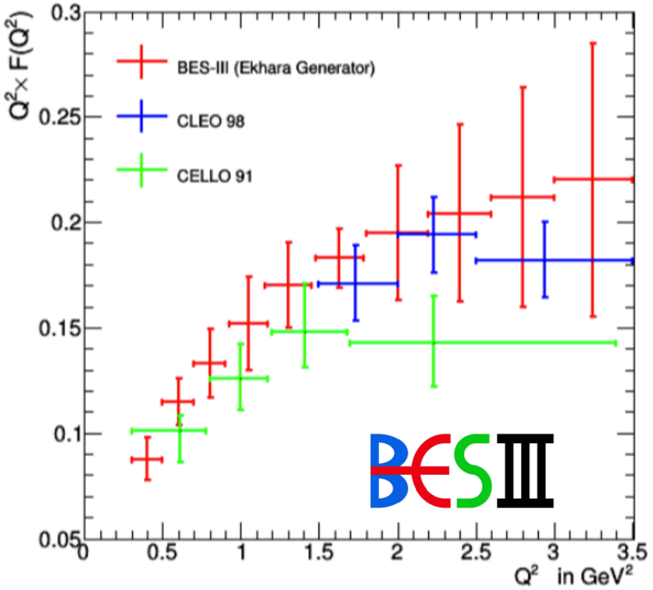
Λ^{-2} = b = (1.17 ± 0.10+0.07) GeV^{-2}

Λ^{-2} = b = 1 VMD [Phys Rev C 61, 035206 (2000)]

EFT = [Phys.Lett. B691 (2010) 191]

η/η' SL TFF Single Tag BESIII

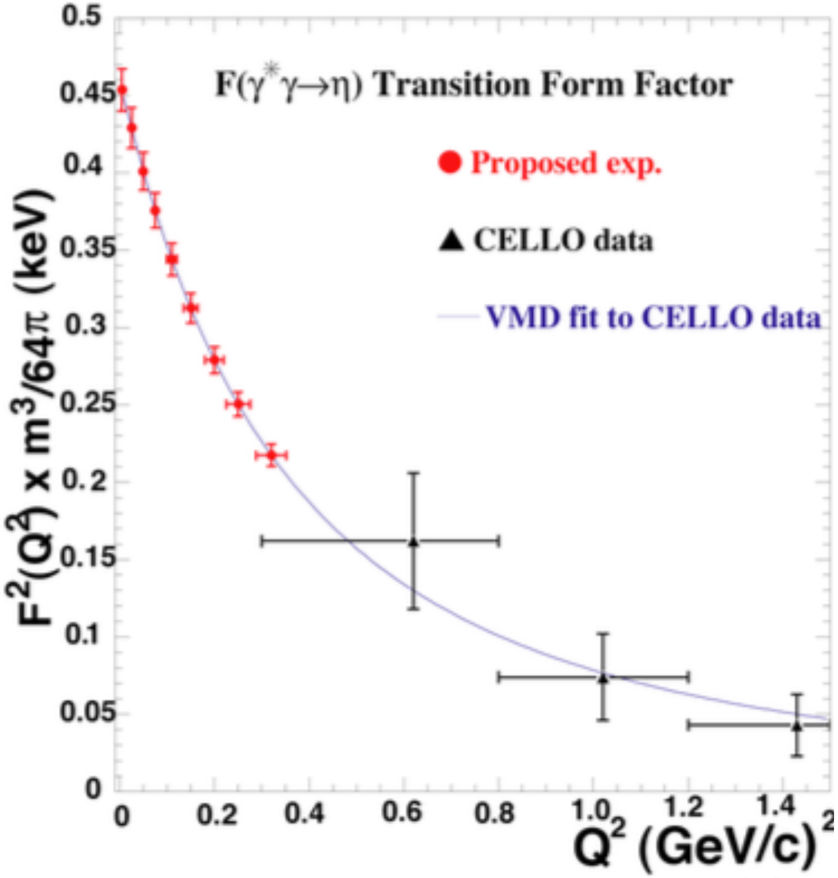




At the level of accuracy needed for $(g\text{-}2)_\mu$ contributions from η and η' cannot be neglected.

Analysis based on 2.9 pb^{-1} $\Psi(3770)$ data (simulation shown in figure)

η SL TFF GLUEX



GLUEX projected FF data points complementary to BESIII

Talk Liping Gan Wednesday 10.00

η' Dalitz decay

First observation of η' Dalitz decay
Based on 1.3 x 10^9 J/ψ events

BR(η' → e+e- γ) = (4.69 ± 0.20 ± 0.23) x 10^{-4}

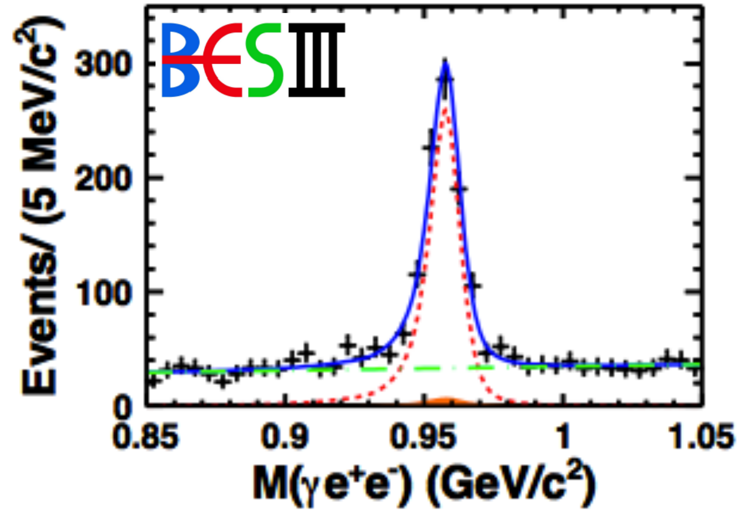
Pole is inside kinematical boundary
Form Factor parametrisation

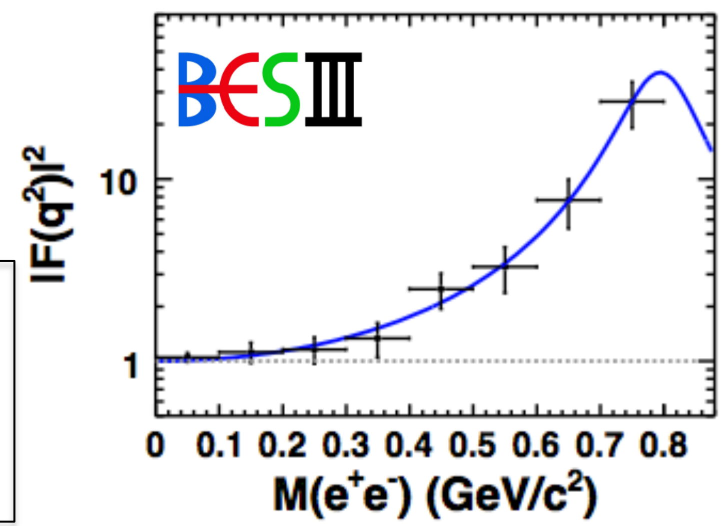
$$|F(q^2)|^2 = \frac{\Lambda^2(\Lambda^2+\gamma^2)}{(\Lambda^2-\gamma^2)^2+\Lambda^2\gamma^2}$$

Λ, γ: mass and width of Breit-Wigner effective contributing V meson

Λ^{-2} = b = 1.58 ± 0.34	GeV^{-2}	BESIII
Λ^{-2} = b = 1.45	GeV^{-2}	VMD
Λ^{-2} = b = 1.60	GeV^{-2}	ChPT
Λ^{-2} = b = $1.53^{+0.08}_{-0.15}$	GeV^{-2}	Disp

Phys. Rev. D 92, 012001 (2015)





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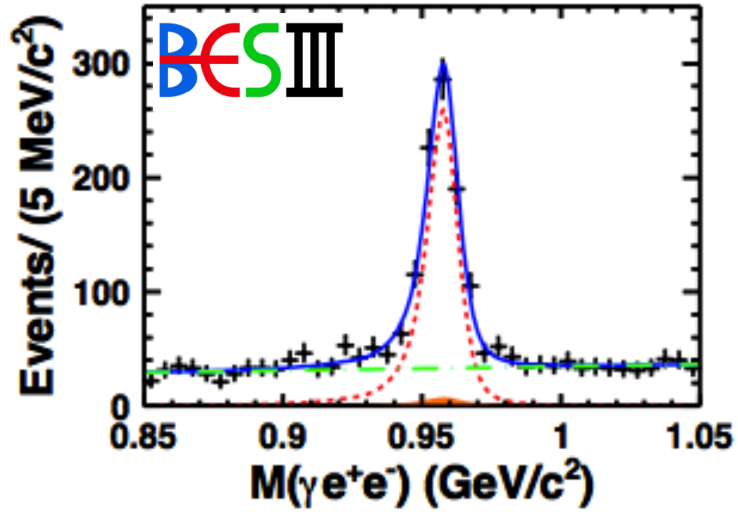
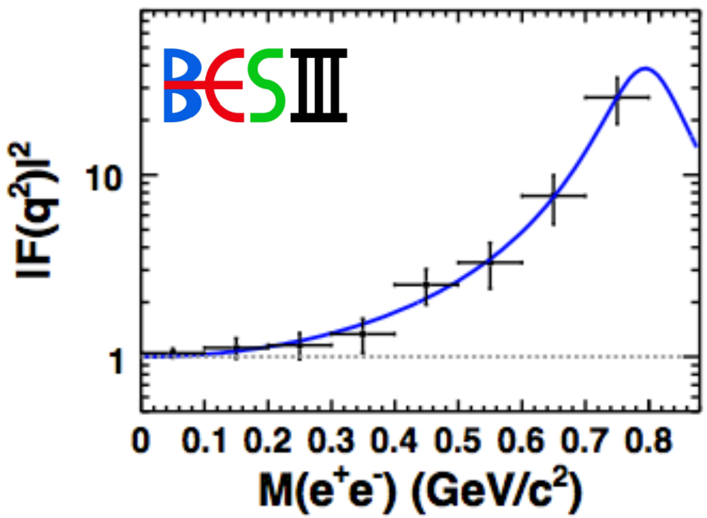
Future experimental results from A2 and CLAS

Phys. Rev. D 92, 012001 (2015)





$\eta' \rightarrow \omega e^+e^-$ first observation

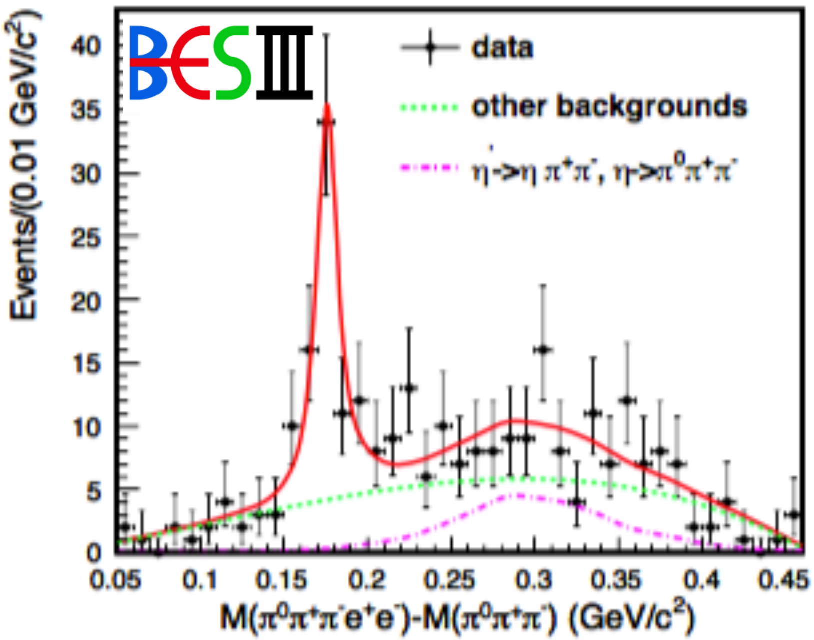
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

First observation of $\eta' \rightarrow \omega e^+e^-$
Based on 1.3×10^9 J/ψ events

BR($\eta' \rightarrow \omega$ e+e-) = $(1.97 \pm 0.34 \pm 0.17) \times 10^{-4}$

Theory:
2.0×10^{-4}
[Faessler, Fuchs, Krivoruchenko, Phys. Rev. C 61, 035206 (2000)]
$1.69 \pm 0.56 \times 10^{-4}$
[Terschlüsen, Leupold, Lutz, EPJ. A48 (2012) 190]

arXiv:1507.06734



CLAS additional measurement?

$J/\psi \rightarrow Pe^+e^-$ Theory input

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

EM Dalitz decays of light unflavored mesons studied by many experiments

What about experimental input for charmonium states interacting with EM field?

Theoretical prediction assuming simple pole approximation

[Fu, Li, Qin, Yang, Mod. Phys. Lett. A 27 1250223 (2012)]

$$\left|F_{\psi P}(q^2)\right| = \frac{1}{1 - q^2/\Lambda^2}$$

$\Lambda = m_{\psi'} = 3.686$ **GeV**

Decay mode	e^+e^-	$\mu^+\mu^-$
$\psi \to \pi^0 l^+ l^-$	$(3.89^{+0.37}_{-0.33}) \times 10^{-7}$	$(1.01^{+0.10}_{-0.09}) \times 10^{-7}$
$\psi \to \eta l^+ l^-$	$(1.21 \pm 0.04) \times 10^{-5}$	$(0.30 \pm 0.01) \times 10^{-5}$
$\psi \to \eta' l^+ l^-$	$(5.66 \pm 0.16) \times 10^{-5}$	$(1.31 \pm 0.04) \times 10^{-5}$

$J/\psi \rightarrow Pe^+e^-$ Theory input

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

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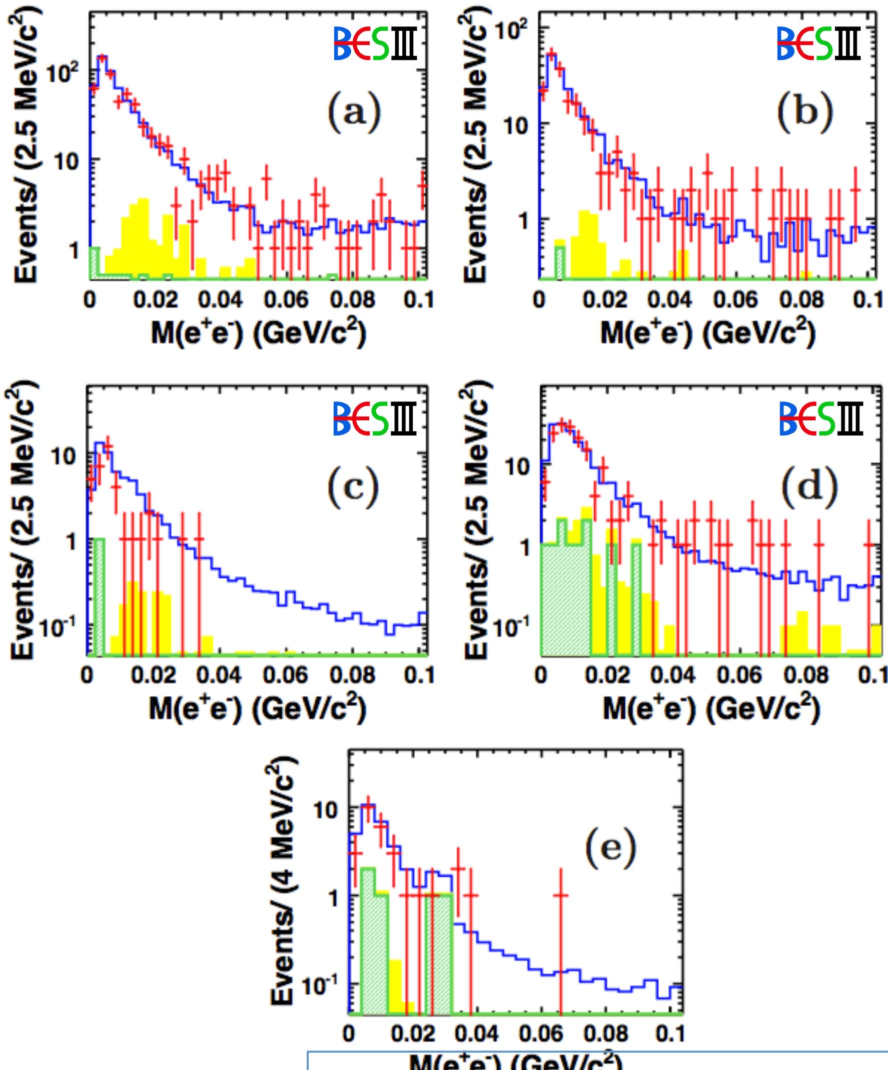
$J/\psi \rightarrow Pe^+e^-$ first observation



[Phys. Rev. D 89, 092008 (2014)]

	Modes	N_S	N_B	ϵ
a)	$J/\psi \to \eta' e^+e^- (\eta' \to \gamma\pi^+\pi^-)$	983.3 ± 33.0	27.4 ± 1.0	24.8%
b)	$J/\psi \to \eta' e^+e^- (\eta' \to \pi^+\pi^-\eta)$	373.0 ± 19.9	8.5 ± 0.3	17.6%
c)	$J/\psi \to \eta e^+e^- (\eta \to \pi^+\pi^-\pi^0)$	84.2 ± 9.6	5.3 ± 0.3	14.9%
d)	$J/\psi \to \eta e^+e^- (\eta \to \gamma\gamma)$	235.5 ± 16.4	8.7 ± 0.3	22.7%
e)	$J/\psi \to \pi^0 e^+e^- (\pi^0 \to \gamma\gamma)$	39.4 ± 6.9	1.1 ± 0.1	23.4%

Red	**– data points**
Blue	**– total MC fits**
Yellow	**– peaking bgd**
Green	**– non peaking bgd**

$J/\psi \rightarrow Pe^+e^-$ first observation

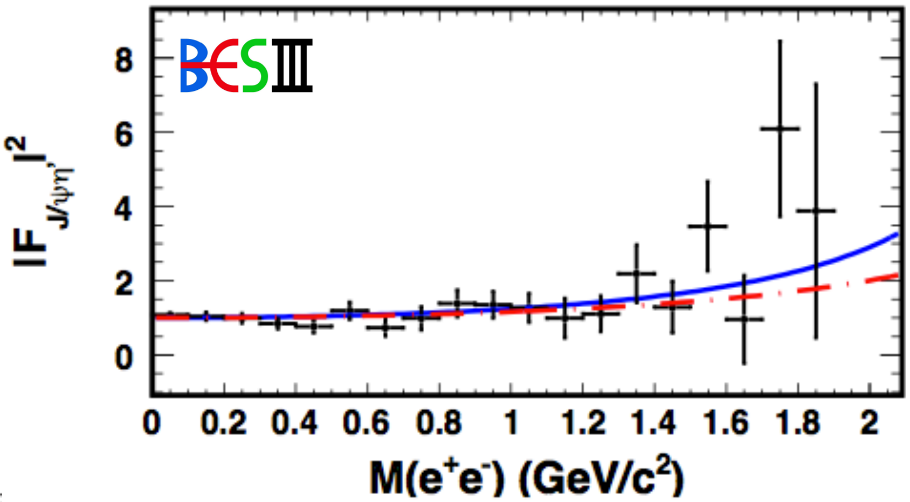
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Λ_{MC} = 3.686 GeV/c^2 Λ_{fit} = 3.1 (1.0) GeV/c^2

Agreement theory and exp for P = η, η'
2.5 σ cf. theory and exp for P = π^0

Result based on 1/5 of full statistics

Phys. Rev. D 89, 092008 (2014)



Mode	Branching fraction	Combined Result	Theoretical prediction
$J/\psi \to \eta' e^+e^- (\eta' \to \gamma\pi^+\pi^-)$	$(6.01 \pm 0.20 \pm 0.34) \times 10^{-5}$		
$J/\psi \to \eta' e^+e^- (\eta' \to \pi^+\pi^-\eta)$	$(5.51 \pm 0.29 \pm 0.32) \times 10^{-5}$	$(5.81 \pm 0.16 \pm 0.31) \times 10^{-5}$	$(5.66 \pm 0.16) \times 10^{-5}$
$J/\psi \to \eta e^+e^- (\eta \to \pi^+\pi^-\pi^0)$	$(1.12 \pm 0.13 \pm 0.06) \times 10^{-5}$		
$J/\psi \to \eta e^+e^- (\eta \to \gamma\gamma)$	$(1.17 \pm 0.08 \pm 0.06) \times 10^{-5}$	$(1.16 \pm 0.07 \pm 0.06) \times 10^{-5}$	$(1.21 \pm 0.04) \times 10^{-5}$
$J/\psi \to \pi^0 e^+e^- (\pi^0 \to \gamma\gamma)$	$(7.56 \pm 1.32 \pm 0.50) \times 10^{-7}$	$(7.56 \pm 1.32 \pm 0.50) \times 10^{-7}$	$(3.89^{+0.37}_{-0.33}) \times 10^{-7}$

Summary TFF

TFF important as theoretical input to $(g\text{-}2)_\mu$

Data driven approaches next steps to reduce HLbL contribution

VMD good approximation to explain experimental data (except $\omega \rightarrow \pi^0 e^+ e^-$?)

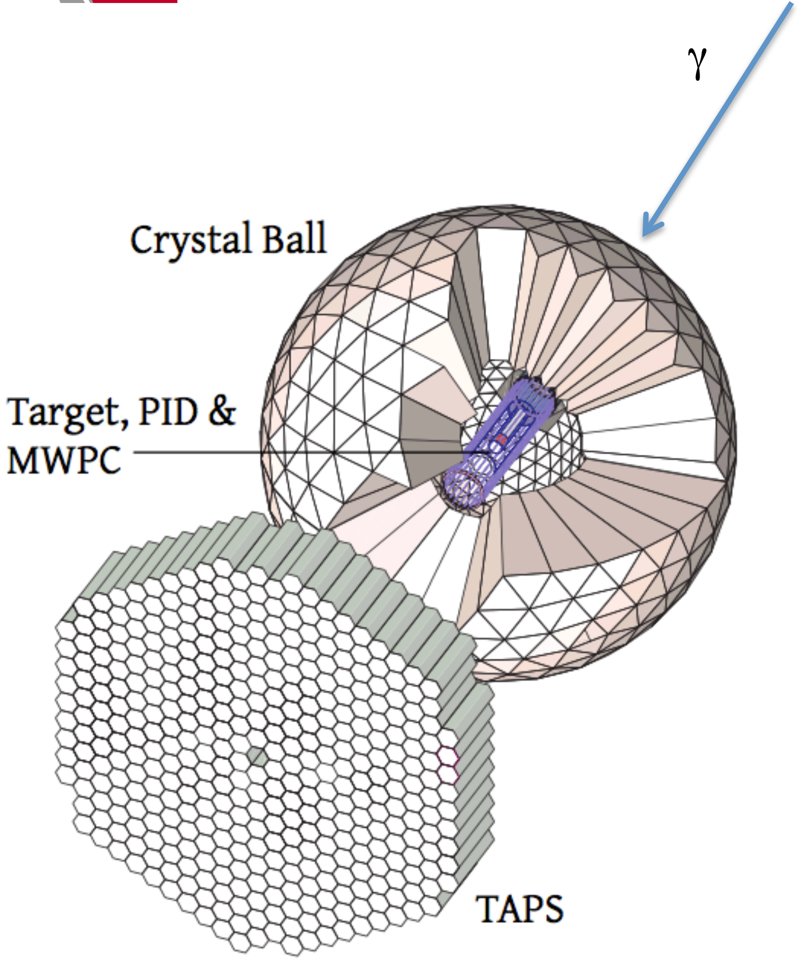
Active field and many experiments can participate in this quest

Chinese perspective: BESIII plays important role in constraining the uncertainties to $(g\text{-}2)_\mu$

CELLO, CLEO, CMD-2, GLUEX, NA48, NA60, SINDRUM, SND

Thank you

CB-TAPS setup

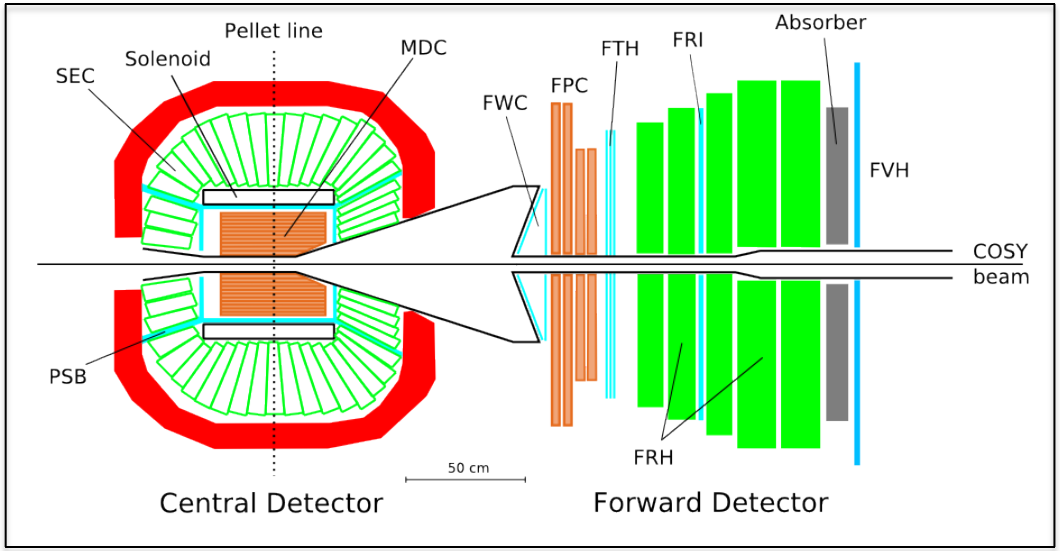


CB - NaI(Tl) crystals
TAPS - BaF_2
PID - discr. charged/neutrals

$$\frac{\Delta E}{E_{\text{dep}}} = \frac{2\%}{(E[\text{GeV}])^{0.36}} \qquad \text{(CB)}$$

$$\frac{\Delta E}{E_{\text{dep}}} = 1.8\% + \frac{0.8\%}{(E[\text{GeV}])^{0.5}} \qquad \text{(TAPS)}$$

WASA at COSY



$pp \rightarrow pp\,\pi^0$ 550 MeV (2010)

$pd \rightarrow {}^3He\,\eta$ 1 GeV (2008-2009)

Central Detector:

- Superconducting Solenoid
- Plastic Barrel
- Wire Chamber
- Calorimeter

Forward Detector:

- Plastic Scintillators
- Tracker

BESIII detector

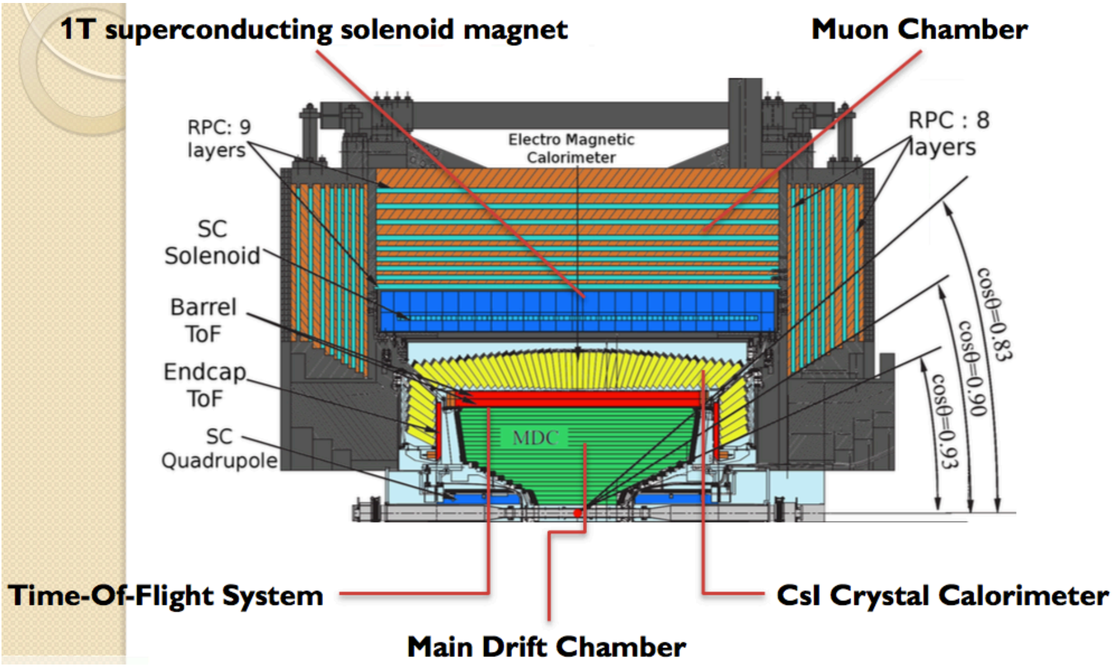
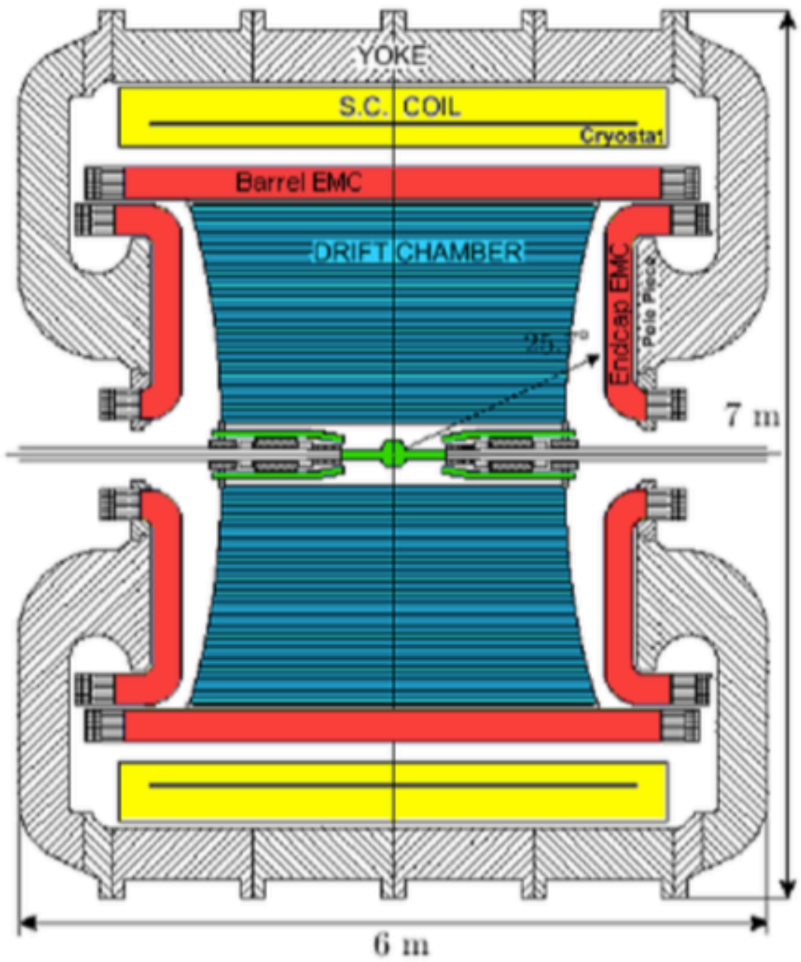


Figure: Matthias Ulrich, Gießen

BESIII four main components

MDC	
Resolution @1 GeV/c	**0.5%**
$\sigma_{dE/dx}$	**6%**
EMC	
E Resolution Barrel	**2.5%**
E Resolution End Cap	**5%**
TOF	
Barrel	**80 ps**
End caps	**110 ps**
Muon chambers	
Position resolution	**~ 2 cm**

KLOE detector



Motivation TFF

TFF enters in γγ physics can improve measurement of radiative widths

Cross section for X production in γγ interactions with photon 4-mom q_n

$$\sigma(e^+e^- \to e^+e^-X) = \int \sigma_{\gamma\gamma\to X}(q_1,q_2)\Phi(q_1,q_2)\frac{d\vec{q}_1}{E_1}\frac{d\vec{q}_2}{E_2}$$

The formation cross section for a narrow spin 0 resonance is

$$\sigma_{\gamma\gamma\to X} = \frac{8\pi^2}{m_X}\Gamma_{X\to\gamma\gamma}\delta((q_1+q_2)^2 - m_X^2)\left|F(q_1^2,q_2^2)\right|^2$$

Both radiative width and transition form factor plays role in formation