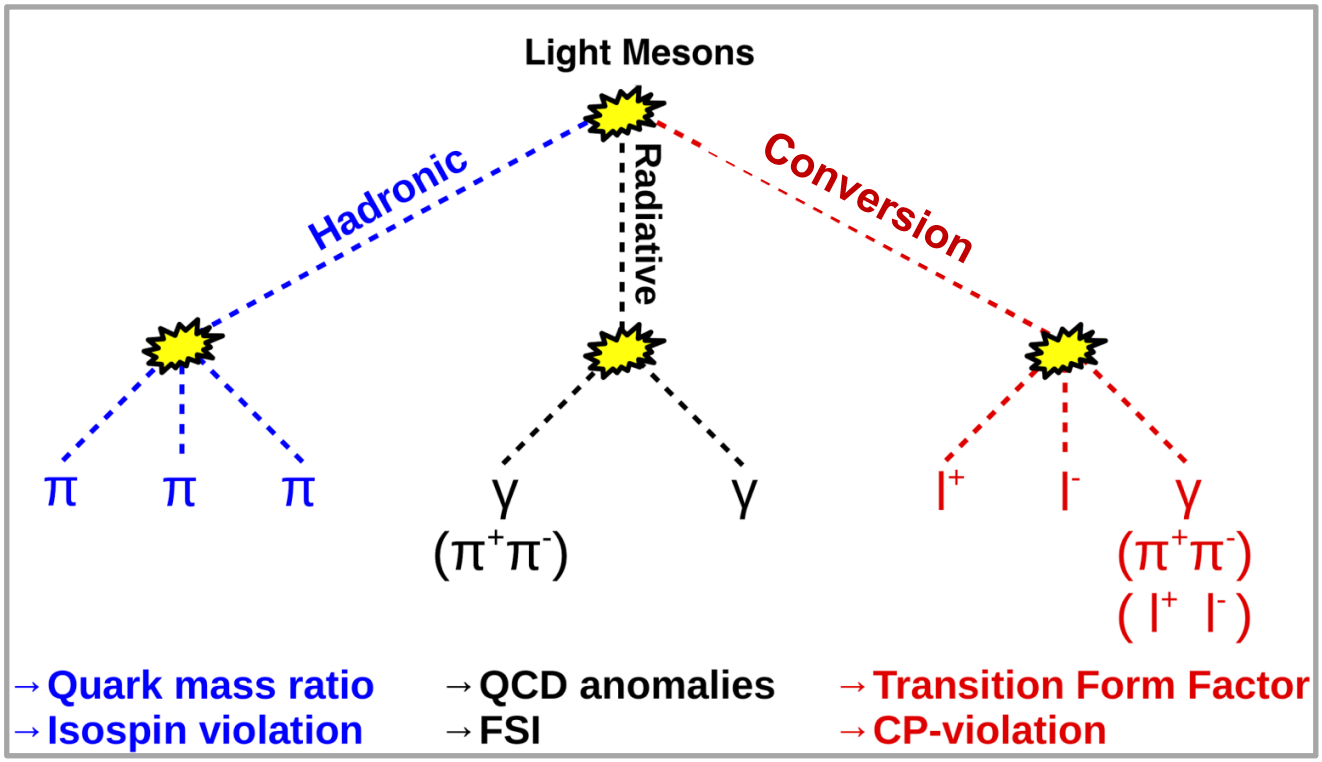
ω→πee analysis of CLAS g12 data

HSWG at CLAS collaboration meeting
July 2018

Susan Schadmand, IKP

light meson decays



WASA-at-COSY: π, η

the orginal proposal for bringing WASA to COSY :

Proposal for the wide angle shower apparatus (WASA) at COSY-Julich: WASA at COSY
WASA-at-COSY Collaboration, e-Print: **nucl-ex/0411038**

CLAS: π, η, ω, η'

the orginal proposal:
CAA Photoproduction and Decay of Light Mesons in CLAS
https://wiki.jlab.org/lmd/

CLAS approved analysis CAA-LMD

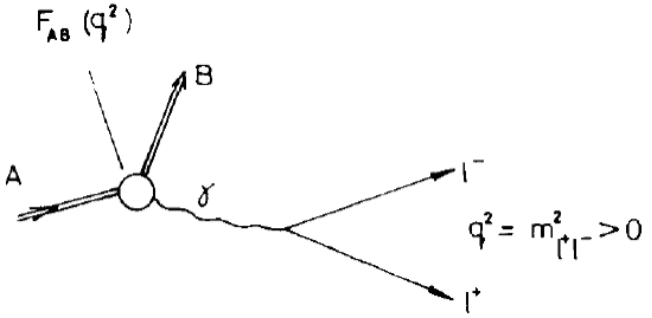
hadronic decays: Dalitz plot analysis			
$\eta \rightarrow \pi^0 \pi^+\pi^-$	g12	Daniel Lersch	• analysis report in progress
$\omega \rightarrow \pi^0 \pi^+\pi^-$	g12	Chris Zeoli	• PhD 2016 FSU
$\eta' \rightarrow \eta \pi^+\pi^-$	g12,(g11)	Sudeep Ghosh	• analysis report submitted • PhD thesis submitted
f.s. $\eta \pi^+\pi^-$	g12	Cathrina Sowa	• PhD 2016 Bochum
radiative decays: box anomaly, branching ratio			
$\eta' \rightarrow \pi^+\pi^-\gamma$	g11	Georgie Mbianda Njencheu	• analysis report submitted • PhD 2017 ODU
$\eta \rightarrow \pi^+\pi^-\gamma$	g11	Torri Roark	
$\rho \rightarrow \pi^+\pi^-\gamma$	g11	Tyler Viducic	
conversion decays: electromagnetic transition form factor			
$\pi \rightarrow \gamma e^+e^-$	g12	Michael Kunkel	• paper submitted (π^0 cross section) • PhD 2014 ODU
$\omega \rightarrow \pi^0 e^+e^-$	g12	Susan Schadmand	
$\eta' \rightarrow \gamma e^+e^-$	g12	(Michaela Schever, Master 2015)	• Jülich proposal for CLAS12 (M.Kunkel and D.Lersch),

Stefan Leupold
Uppsala University

conversion decays

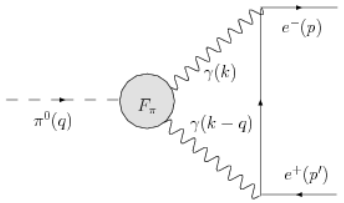
Reactions of hadrons with virtual photons

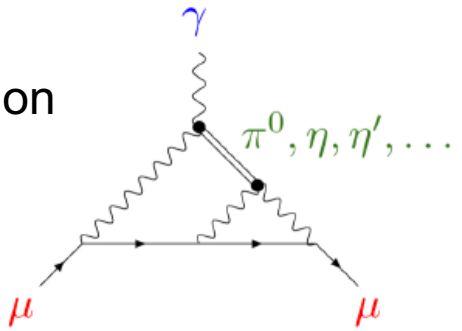
- intrinsic structure of hadrons
  - transition form factors
  - validity of vector meson dominance



- background for physics beyond the standard model
  - rare decays
    - eg $\pi \to ee$
  - g-2 anomalous magnetic moment of the muon
    - light-by-light scattering

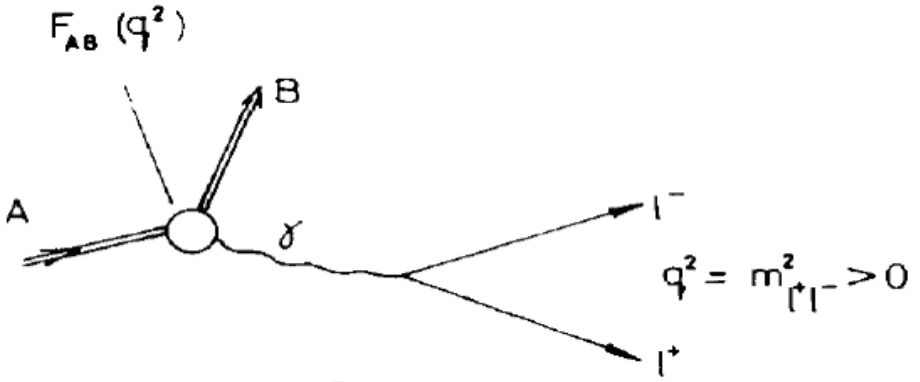
g-2 measurements: Fermilab and J-PARC





conversion decays

Transition Form Factors



$$\frac{d\Gamma(A \to B\, l^+ l^-)}{dq^2 \cdot \Gamma(A \to B\gamma)} = \left|F_{A\to B}(q^2)\right|^2 \cdot |\mathrm{QED}|$$

$F_{AB}(q^2) = [1 - q^2/\Lambda^2]^{-1}$ (single) pole approximation

$$F_{AB}(q^2) \simeq 1 + q^2[\mathrm{d}F_{AB}/\mathrm{d}q^2]|_{q^2\simeq 0} = 1 + q^2 b_{AB} = 1 + \tfrac{1}{6}q^2\langle r^2_{AB}\rangle$$

$\Lambda \simeq m_\rho$ $(\Lambda^{-2} = b_{AB})$

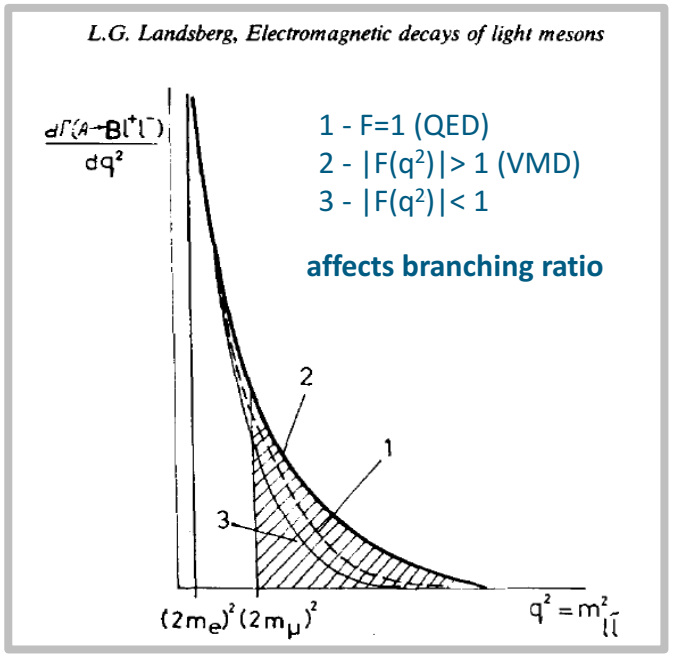
'standard' VMD, b~1.69/GeV^2

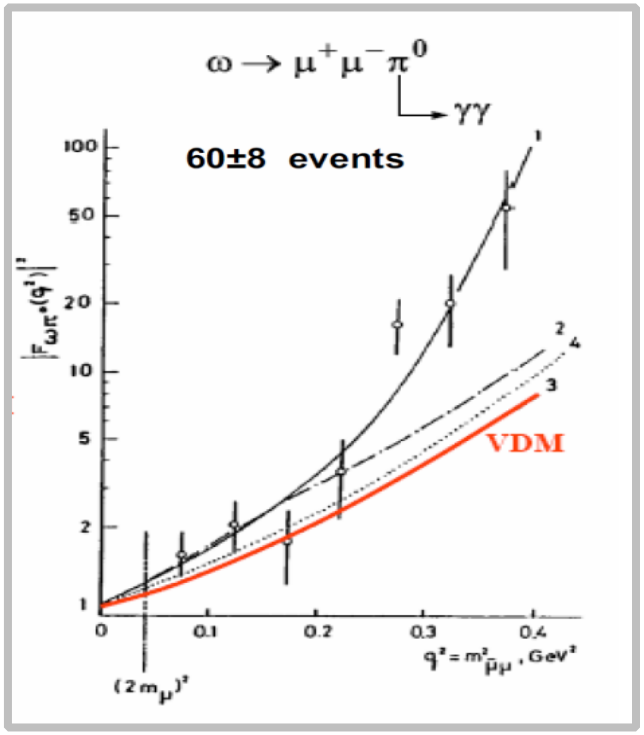
slope parameter

size (transition region)

conversion decays

Transition Form Factors



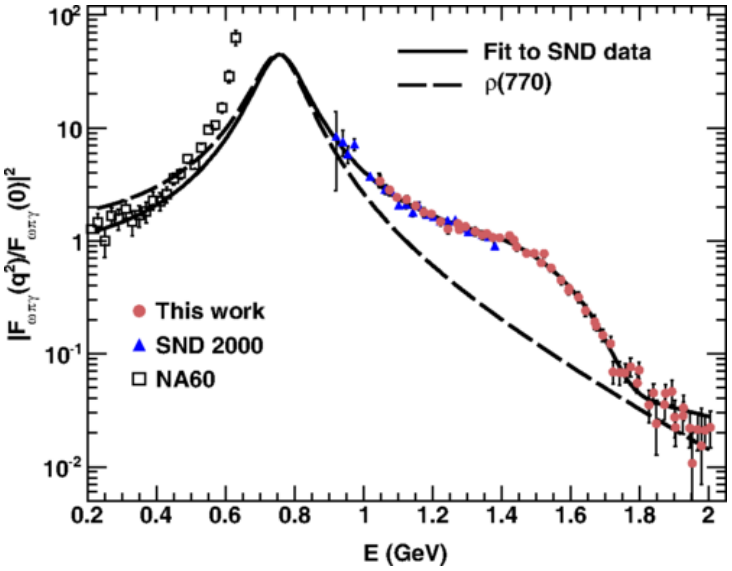


form factor: divide experimental q^2 distribution by QED

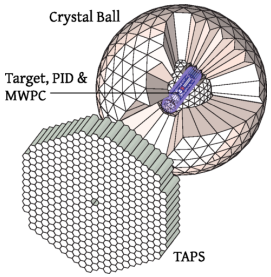
$$\Lambda \simeq m_\rho \ (\Lambda^{-2} = b_{AB})$$ 'standard' VMD, b~1.69/GeV^2

status of the ω-π transition form factor

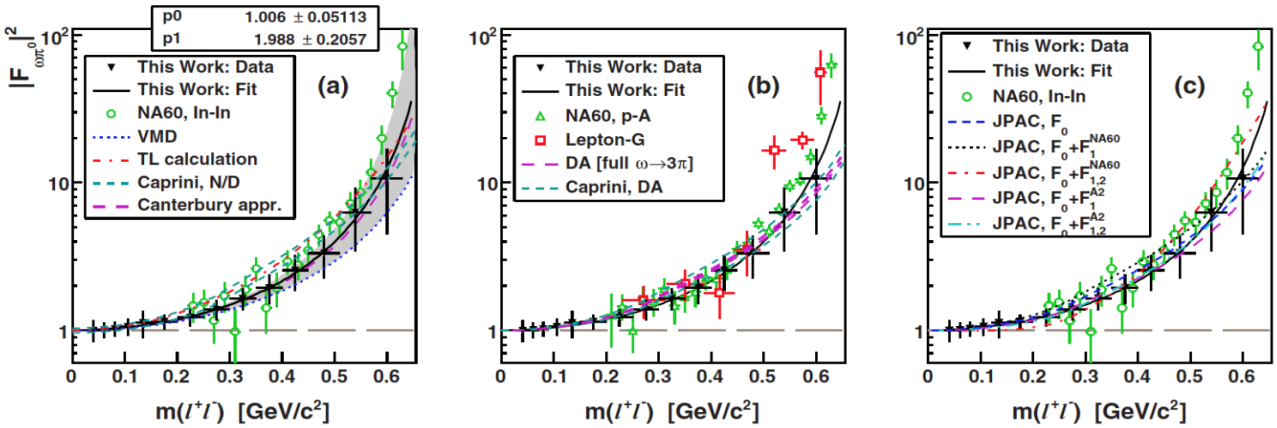
M. N. Achasov *et al.*, Phys. Rev. D 94, (2016) 112001



S. Prakhov (A2 Collaboration at MAMI)
Phys. Rev. C 95, 035208



$\Lambda^{-2}=(1.99\pm0.21_{tot})$ GeV^{-2}
1100 overall statistics



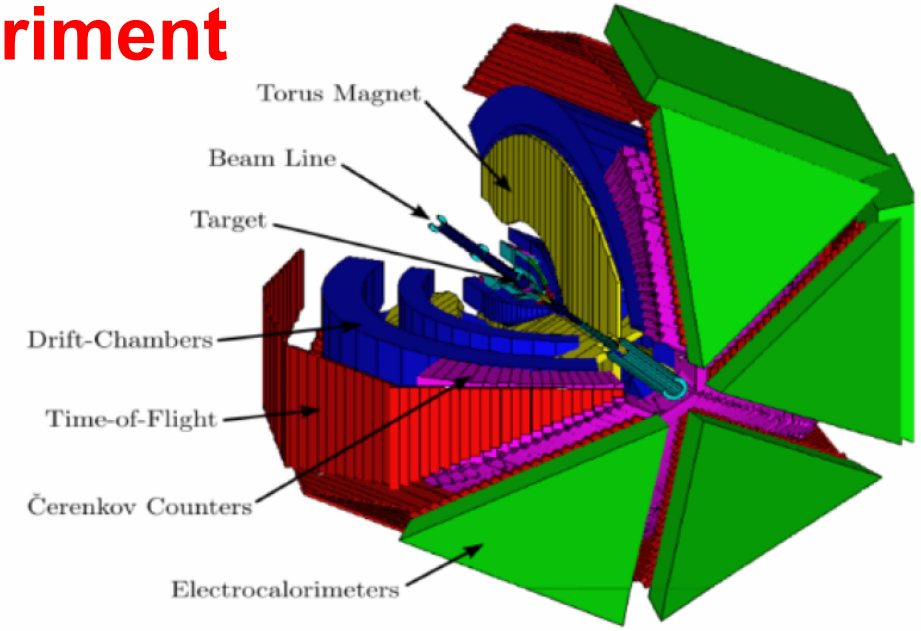
conclusion:

- A2 results are in better agreement with theoretical calculations, compared to earlier experiments
- statistical accuracy of the present data points at large m (ee) masses does not allow a final conclusion

CLAS6 experiment

g12 experiment

$\gamma + p \rightarrow p\,X$



fixed target experiment with energy-tagged Bremsstrahlung photon beam from 6GeV CEBAF	
LH_2 target	main source for *external γ conversion*
magnetic field	charged particle tracking momenta and *charge state*
Cerenkov Counters	excellent *electron-positron identification*
EM calorimeter	particle identification (limited acceptance photon detection)

ω→πee cut-based g12 analysis

corrections and cuts*:

- skim:
  =1proton and =1positive and =1negative topology
- available root tree:
  =1electron and =1positron (IsLepG7)

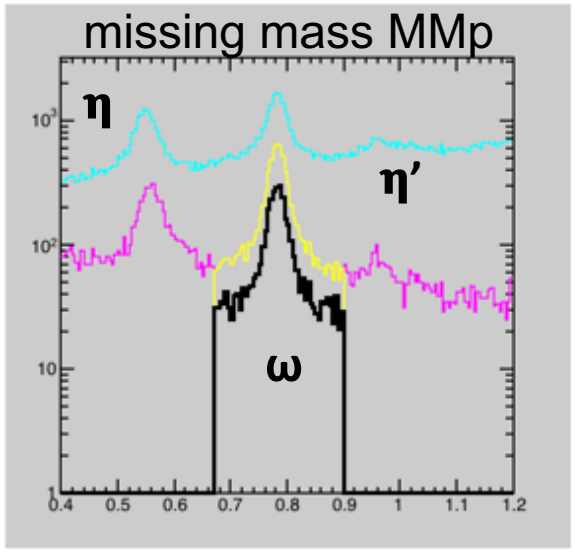
- data only:
  - loop over in-time photons
  - beam corrections
  - momentum corrections

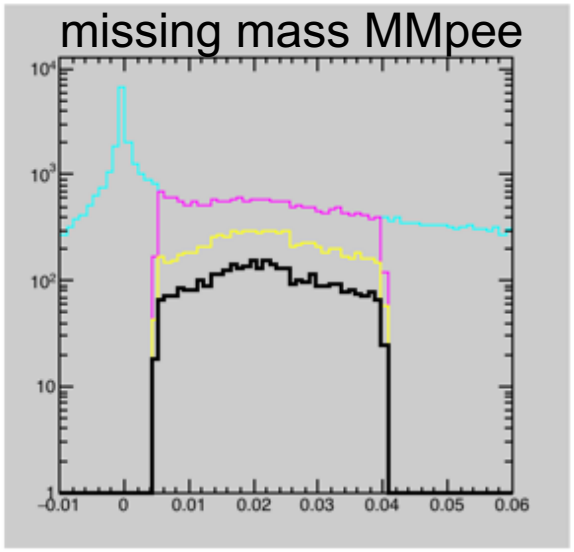
- event cuts:
  - sqrt(Vx*Vx+Vy*Vy)<2.
  - abs(Ep_Beta -1.)<0.05 && abs(Em_Beta -1.)<0.05

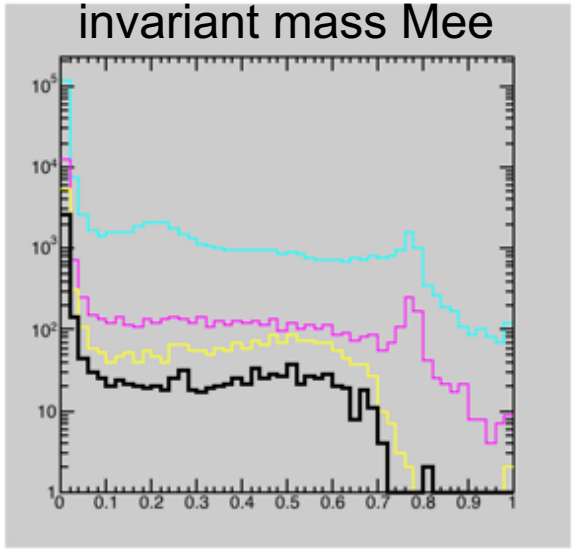
- fiducial and TOF cuts
  - (Em_tofpass && Ep_tofpass && P_tofpass && Ep_EC_pass && Em_EC_pass && Ep_geofid && Em_geofid && P_geofid)

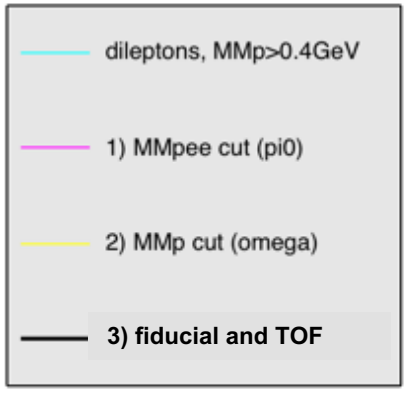
* based on dilepton analysis by M.C.Kunkel

analysis strategy cut-based analysis









e^+e^- detection
and missing particle

missing pion:
- missing mass is pion
- missing energy finite

ω→πee

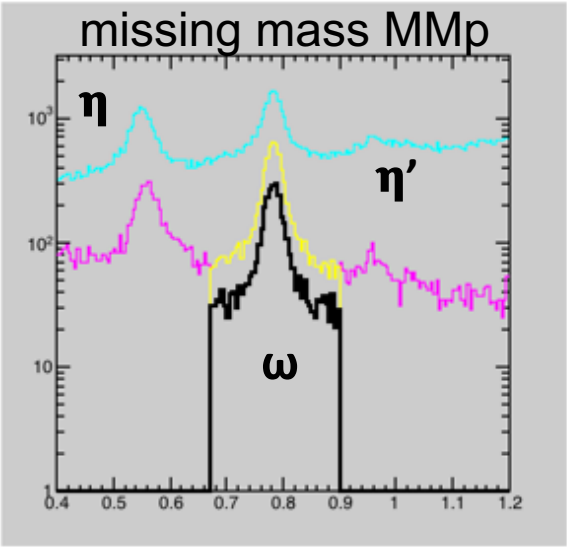
missing photon:
- missing mass zero
- missing energy finite

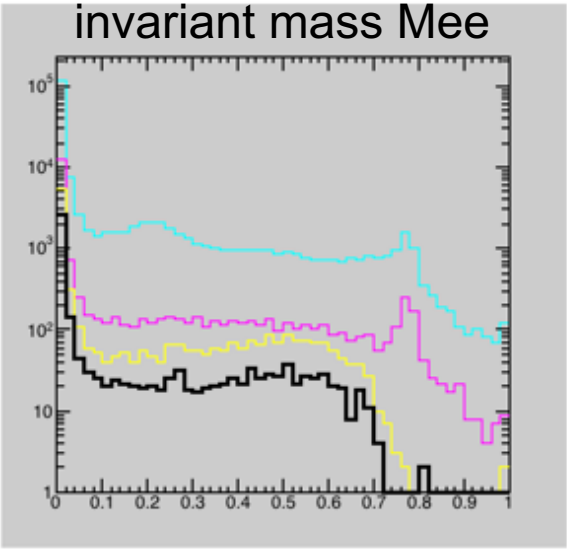
η(´)→γee

missing nothing:
- missing mass zero
  missing energy zero

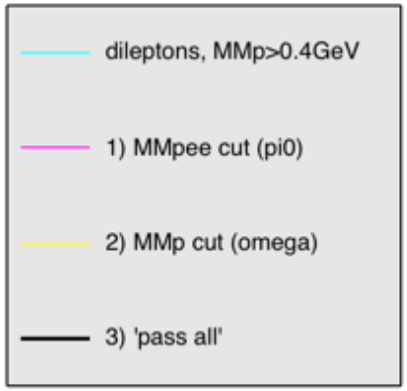
ρ/ω→ee

analysis strategy cut-based analysis



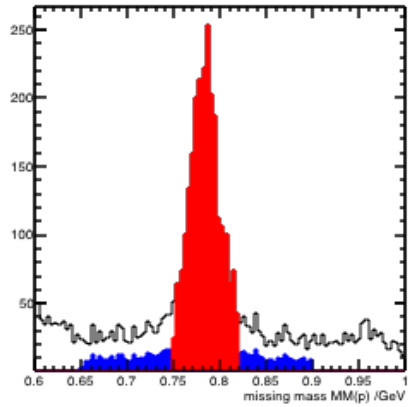


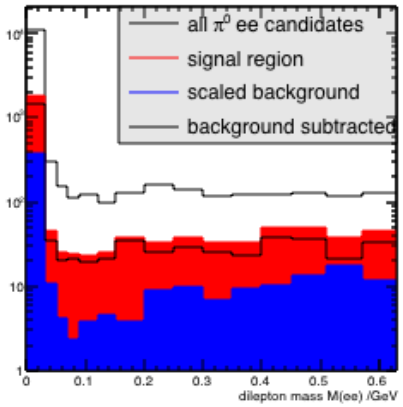
- smooth background
  ← subtract via MMp spectrum
- in-peak background (competing decays)
  ← simulations
- photon conversion from $\pi \rightarrow \gamma\gamma$ (small ee masses)
  ← simulations



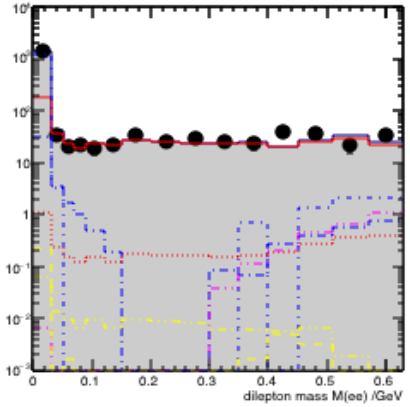
previous look at ω-π^0 transition form factor

smooth background subtraction

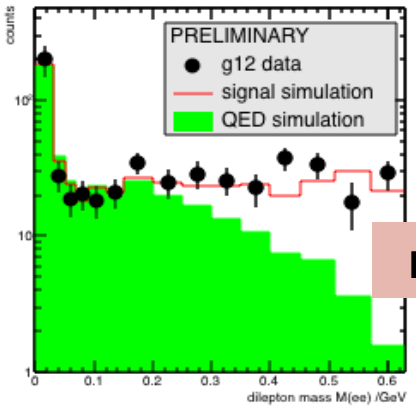




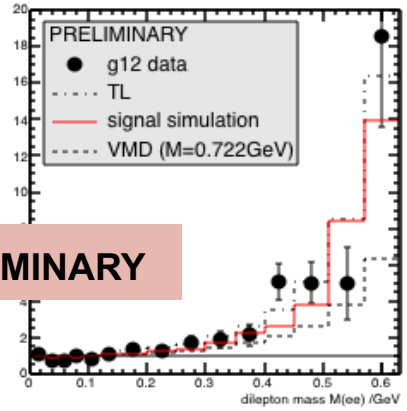
in-peak background



in-peak and smooth background subtracted



data / QED simulation



PRELIMINARY

simulations for n-peak background reveal:

- **external conversion** at small masses
- **combinatorics** at large masses
- influence of rho/omega dilepton decay

- effect of (strict) cut-based analysis
- **new analysis**
  - **statistics**
  - **combinatorics**

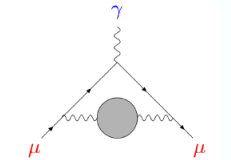
preliminary analysis:
so far, consistent with A2 result (and 'extended' VMD)

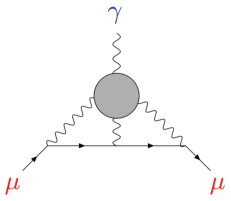
C. Terschlüsen and S. Leupold, Phys. Lett. B 691, 191 (2010)

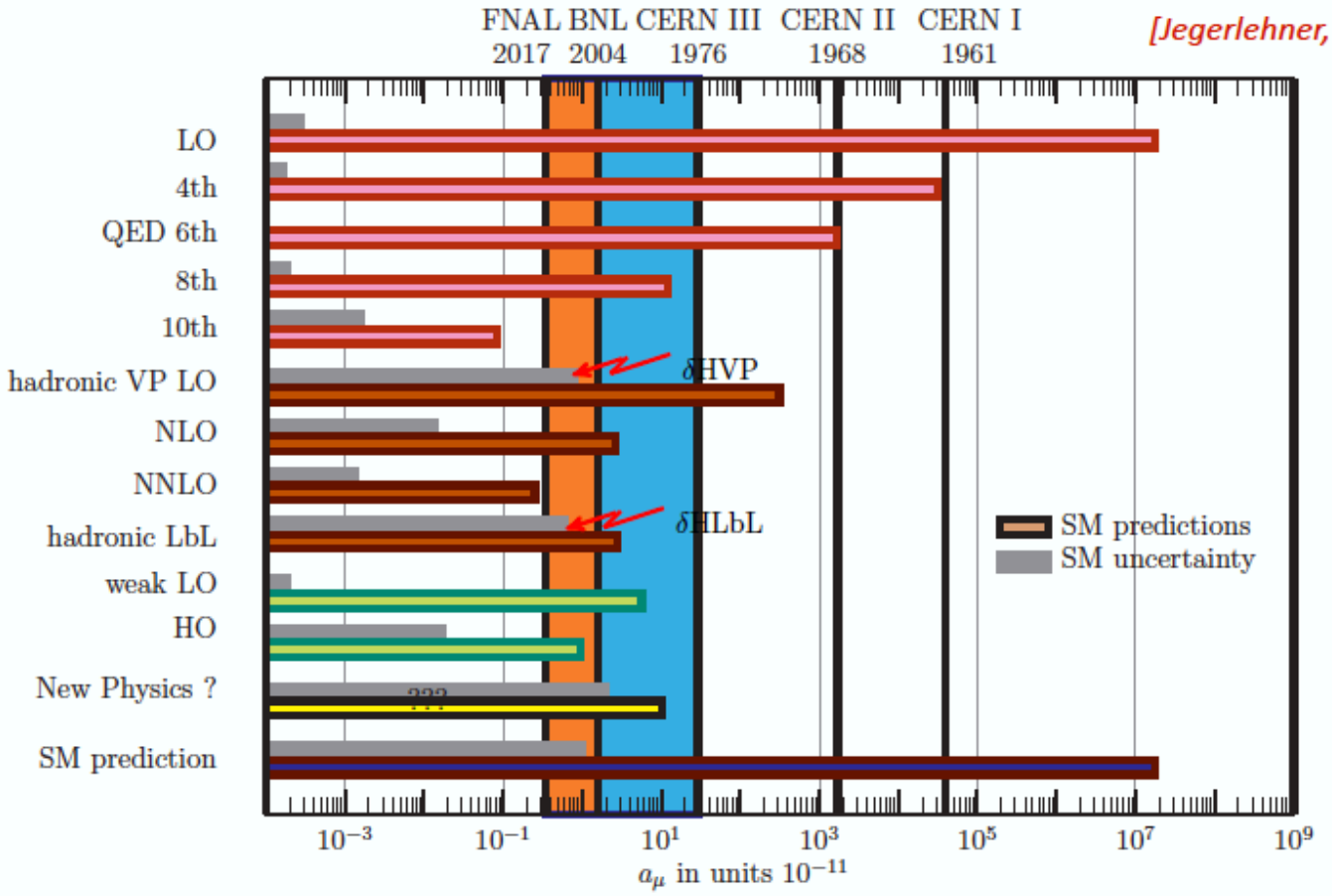
xtras

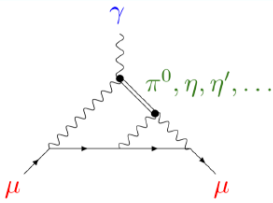
theory confronts experiment

Role of hadronic decays for g-2









simulation ω decays

PLUTO event generator
incl. Bremsstrahlung beam profile and ω angular distribution
event cut:
=2 g7leptons, event vertex, TOF, pass all acceptance cuts, pi0 missing mass

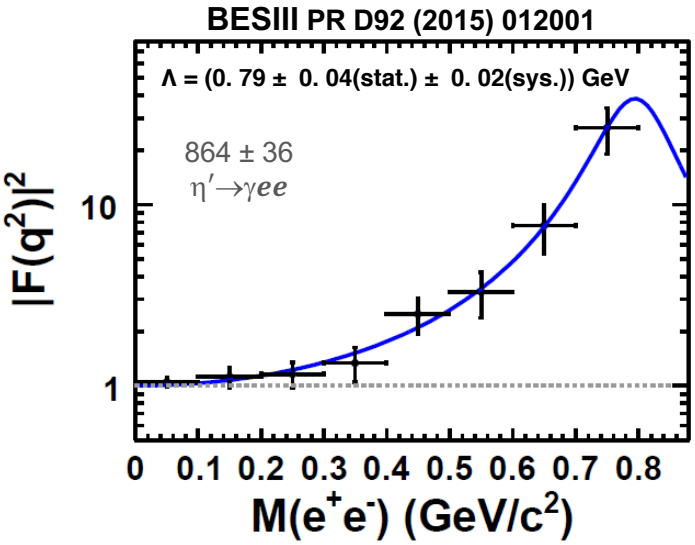
decay chain	thrown events	BR of chain	events after event cut	after normalization	
$\omega \rightarrow \pi\, ee \rightarrow 2\gamma\, ee$	2.19995e+06	7.60937e-04	4597	494.7	signal (need QED, too)
$\omega \rightarrow \pi_D\, ee \rightarrow \gamma\, 2(ee)$	1.93004e+07	9.0398e-06	26861	3.8	
$\omega \rightarrow \pi\, \gamma \rightarrow 3\gamma$	2.14984e+07	8.18254e-02	1148	1339.7	need more stats
$\omega \rightarrow \pi_D\, \gamma \rightarrow 2\gamma\, ee$	1.9999e+07	9.72072e-04	2548	38.0	
$\omega \rightarrow ee$	1.99998e+07	7.28e-05	3858	2.9	need ρ/ω line shape
$\omega \rightarrow \eta\, \gamma \rightarrow 3\gamma$	2.00004e+07	1.81286e-04	148	0.4	
$\omega \rightarrow \eta_D\, \gamma \rightarrow 2\gamma\, ee$	2.00004e+07	3.174e-06	3209	0.2	

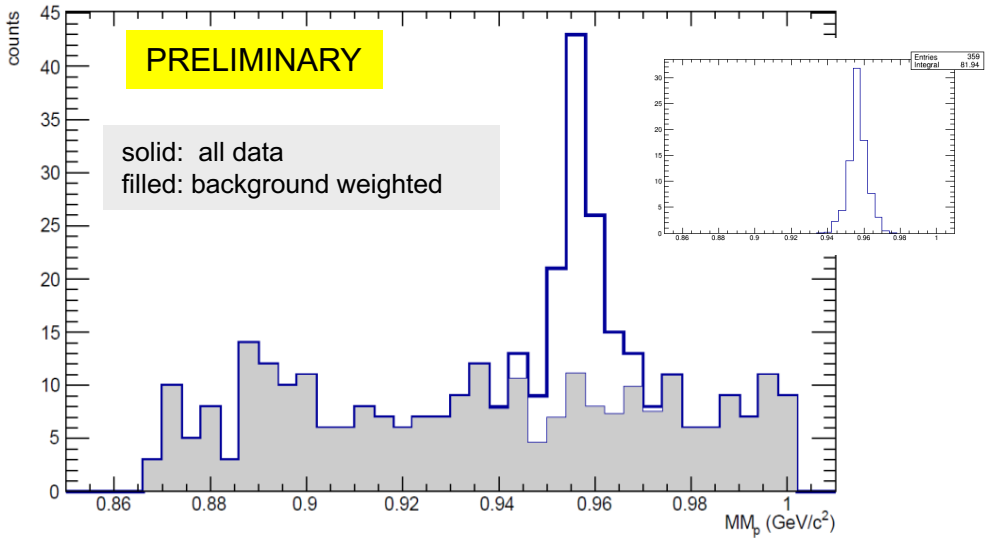
$\eta' \to \gamma ee$: cut-based analysis

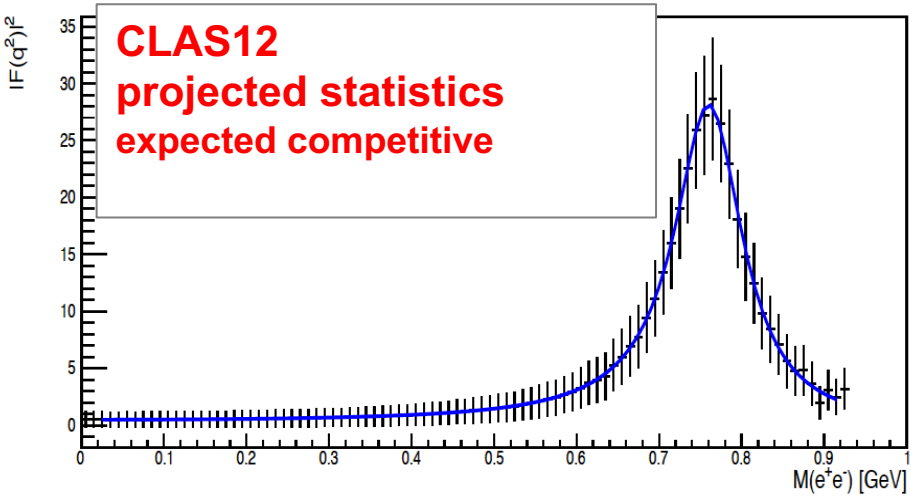
- CLAS g12 experiment
- data analysis: g12 procedures
- q-factor signal extraction:
  evaluate smooth background event-by-event

➢ 359 event candidates
➢ **82 events (signal weight)**

CLAS6 not competitive with BESIII

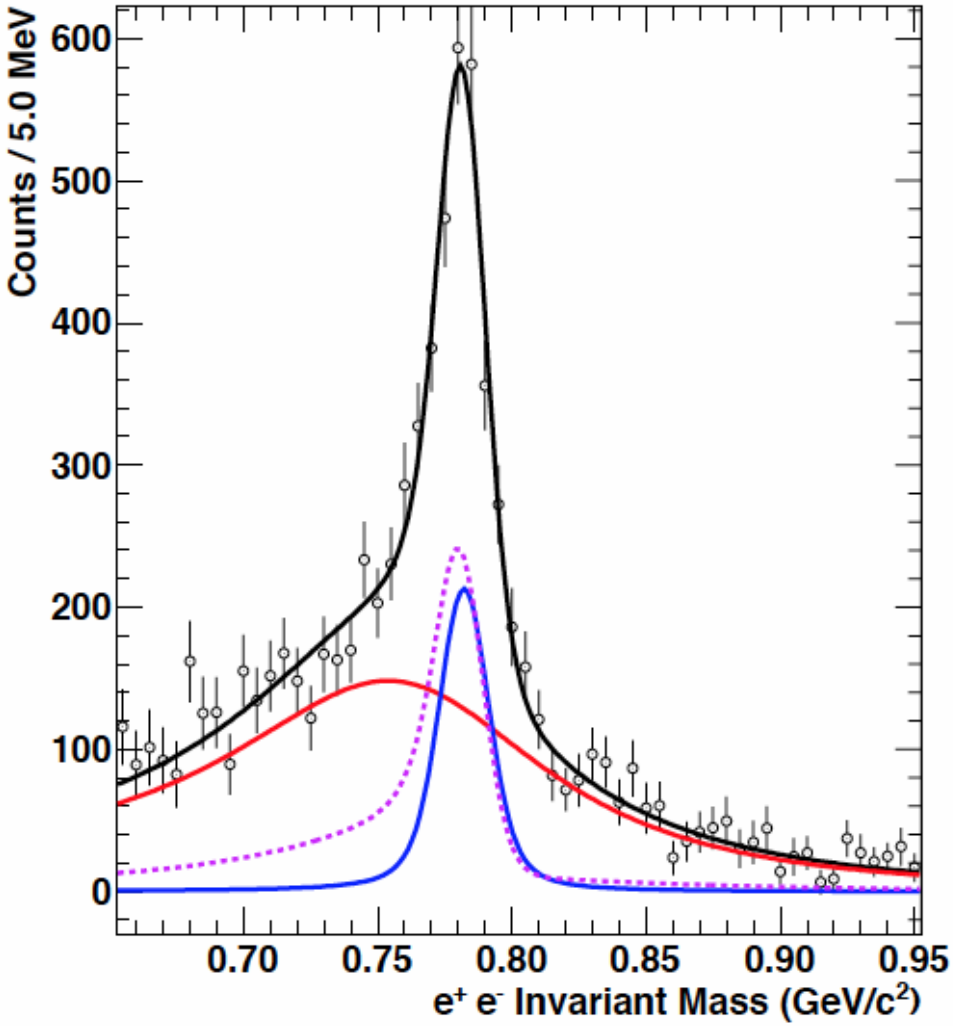






JÜLICH Forschungszentrum

ρ -ω interference



PoS Hadron2013 (2013) 176
JLAB-PHY-13-1839

based on same data
CLAS g12 experiment

targeted channel
γ + p → p + ee (in the ρ regime**)**

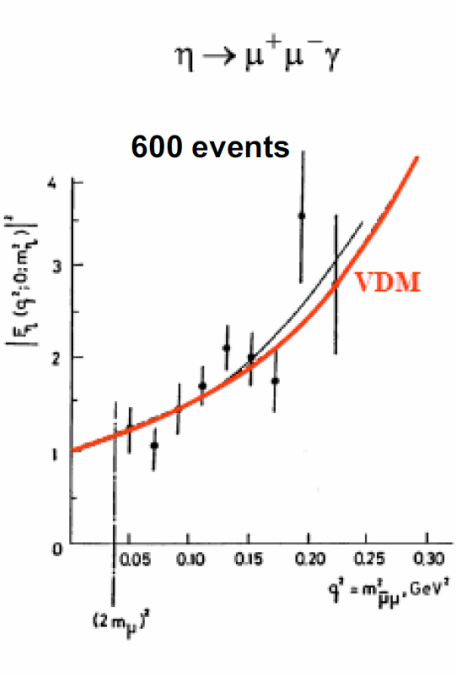
event selection via
- PID dilepton
- missing mass MM(ee)=M(p)

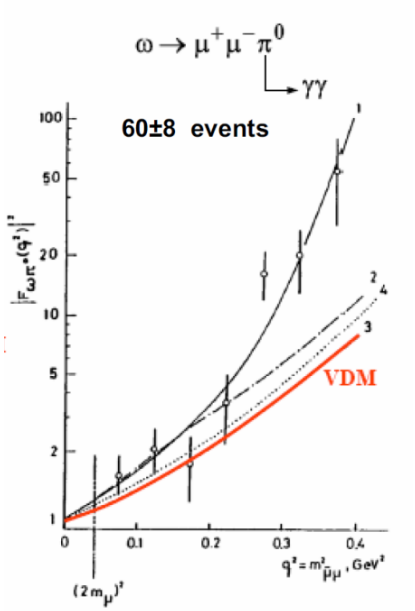
interference
causes low-mass tail

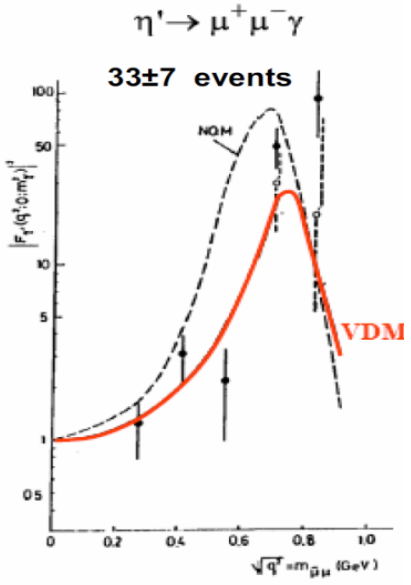
(old) world data set: conversion decays

L.G. Landsberg, Electromagnetic decays of light mesons

IHEP in 1978—1980 on the “Lepton-G” spectrometer







for ω meson, additional mechanisms apart from standard VMD ?

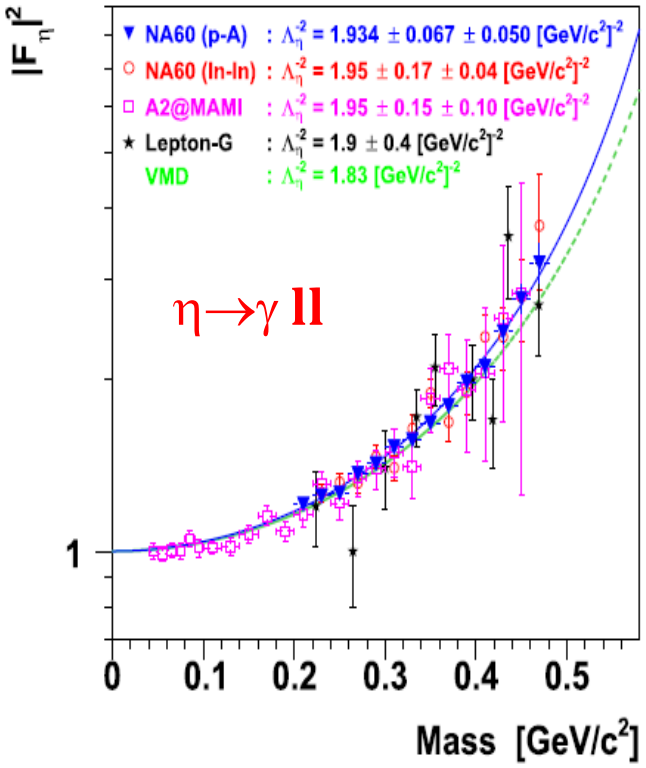
(black curves are fits to the data)

- confirmed by NA60 AA reactions, S. Damjanovic, PLB 677 (2009) 260
- confirmed by NA60 pA reactions, A.Uras, J.Phys. Conf.Ser.270(2011) 012038

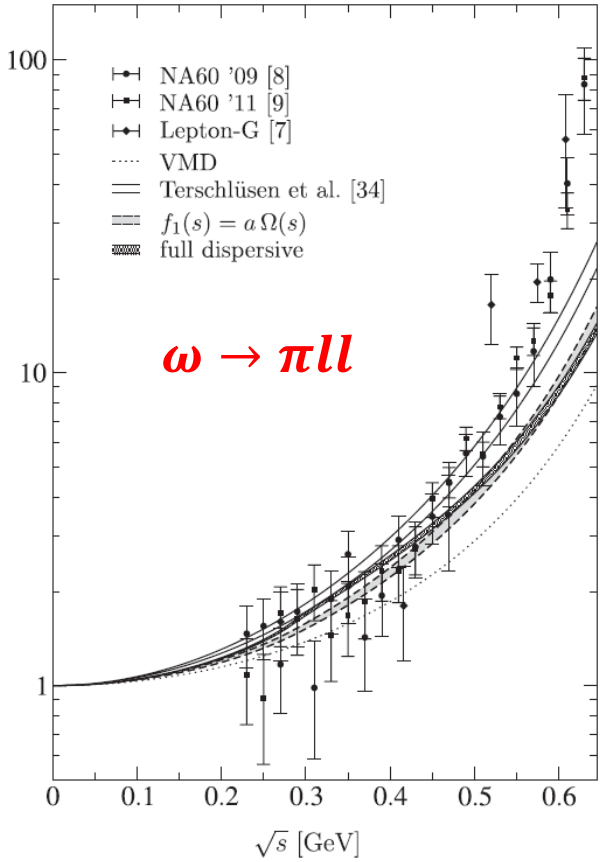
different experimental approach: elementary reactions, using di-electrons

new data sets: conversion decays

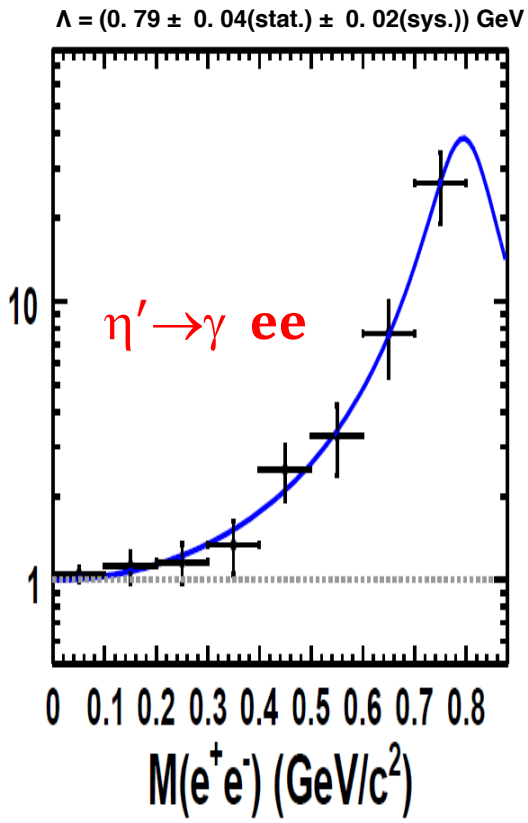
A2 **Phys.Rev. C89 (2014) 044608**
NA60 **Phys.Lett. B757 (2016) 437**



Schneider, Kubis, Niecknig
PRD 86 (2012) 054013



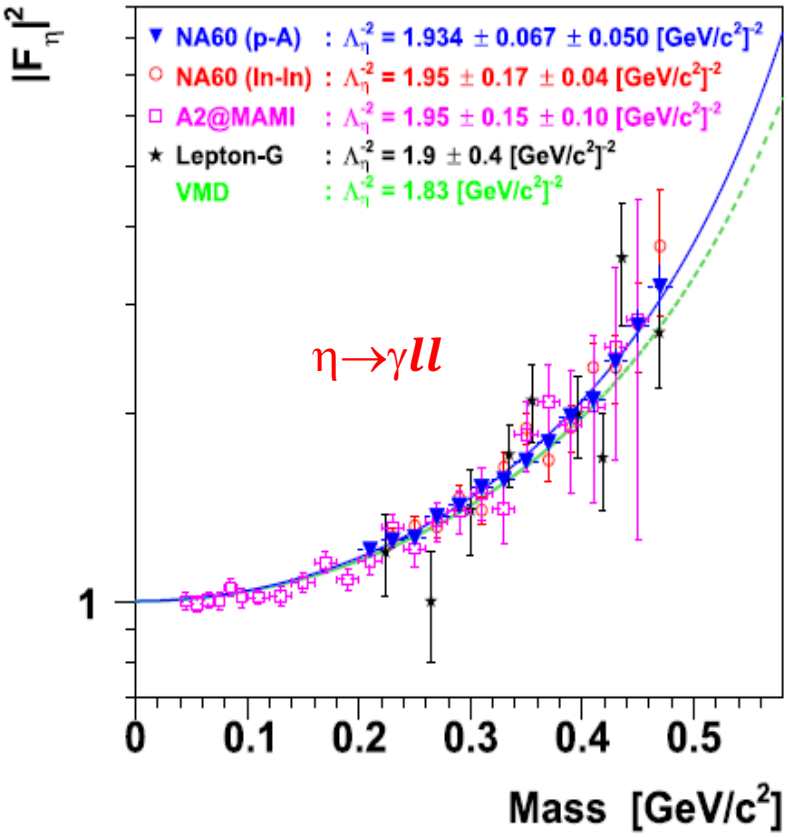
BESIII **PR D92 (2015) 012001**

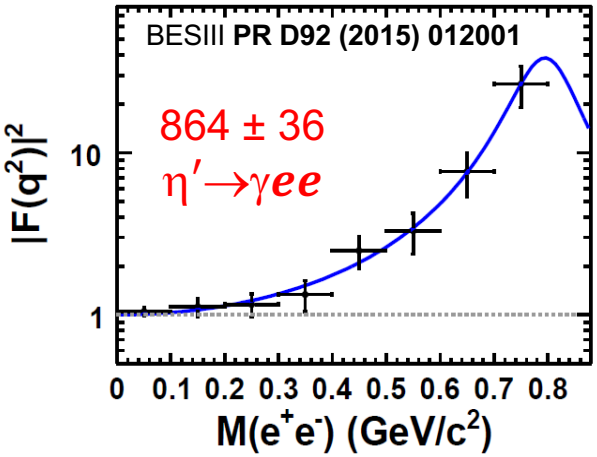


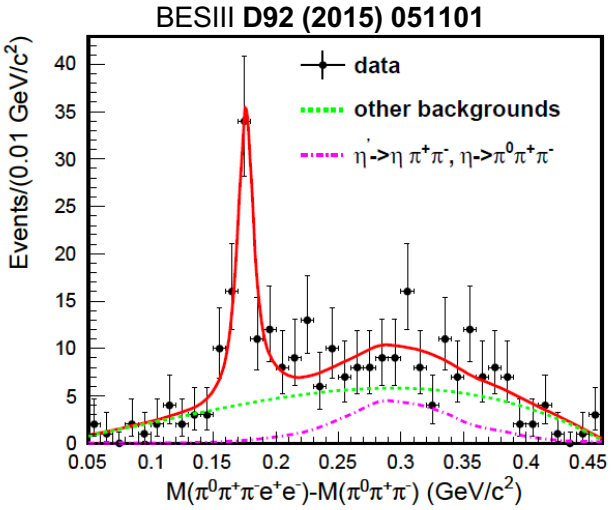
η and η′ improve data base and look for double conversion decays
ω meson, whats happening at the high mass end?

NEW DATA SETS: η AND η‘

A2 **Phys.Rev. C89 (2014) 044608**
NA60 **Phys.Lett. B757 (2016) 437**



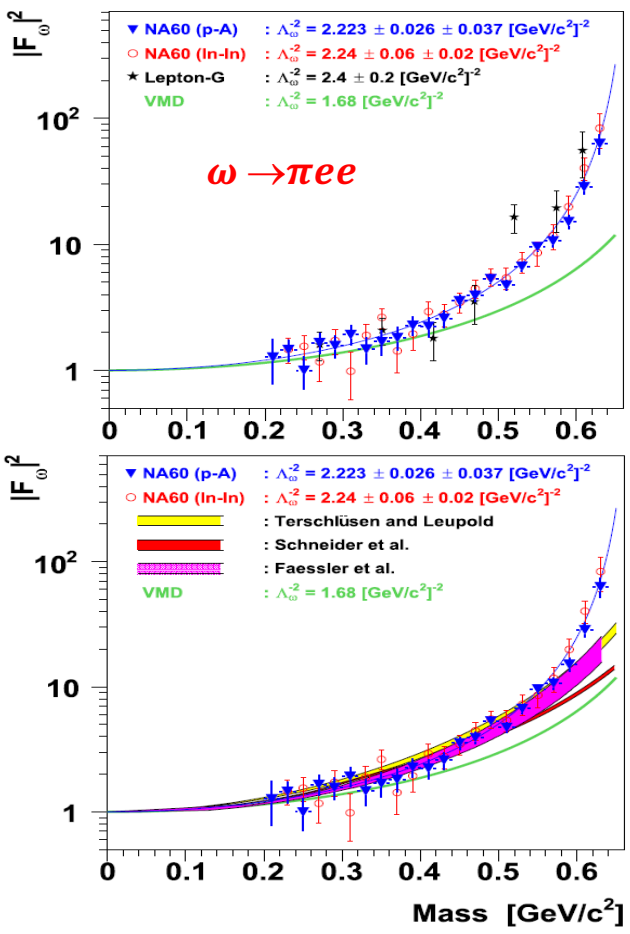




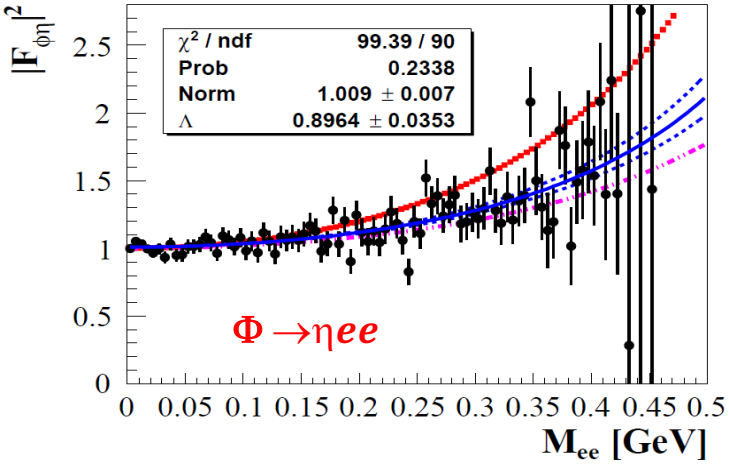
BR($\eta' \to \omega ee$) $(1.97 \pm 0.34(\text{stat}) \pm 0.17(\text{syst})) \times 10^{-4}$

NEW DATA SETS: ω AND Φ

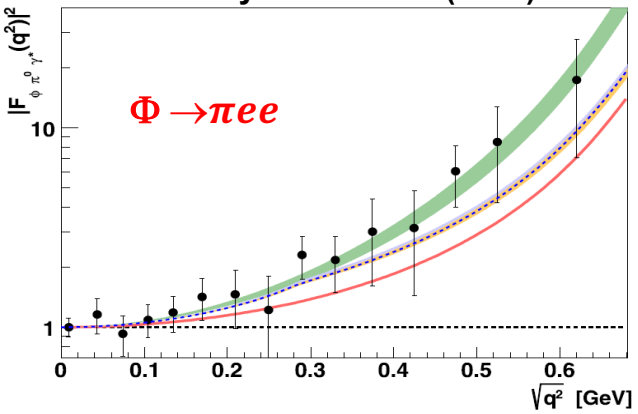
NA60 **Phys.Lett. B757 (2016) 437**



KLOE2 **PLB742 (2015) 1**



KLOE-2 **Phys.Lett. B757 (2016) 362**



puzzle not solved yet