Electromagnetic Transition Form Factors of Light Mesons

QNP 2018
Tsukuba

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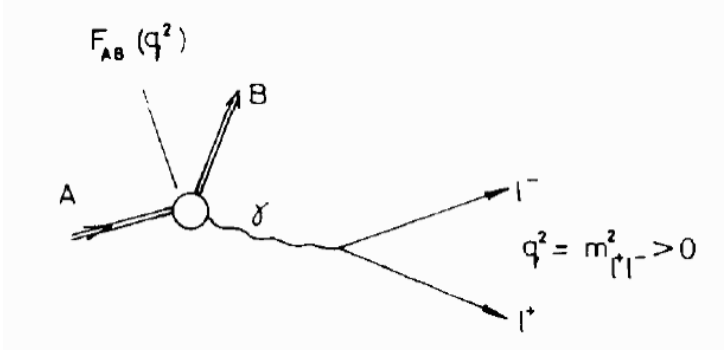
conversion decays

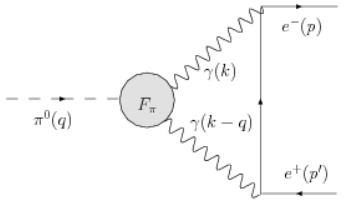
Reactions of hadrons with virtual photons

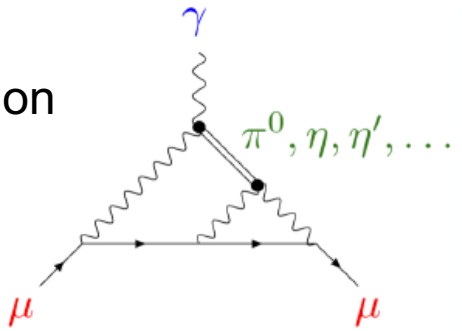
- intrinsic structure of hadrons
  - transition form factors
  - validity of vector meson dominance



- 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

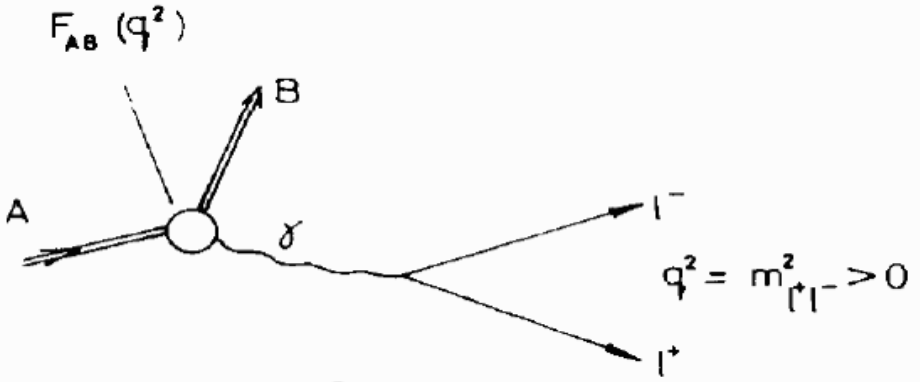
g-2 measurements: Fermilab and J-PARC





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

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

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

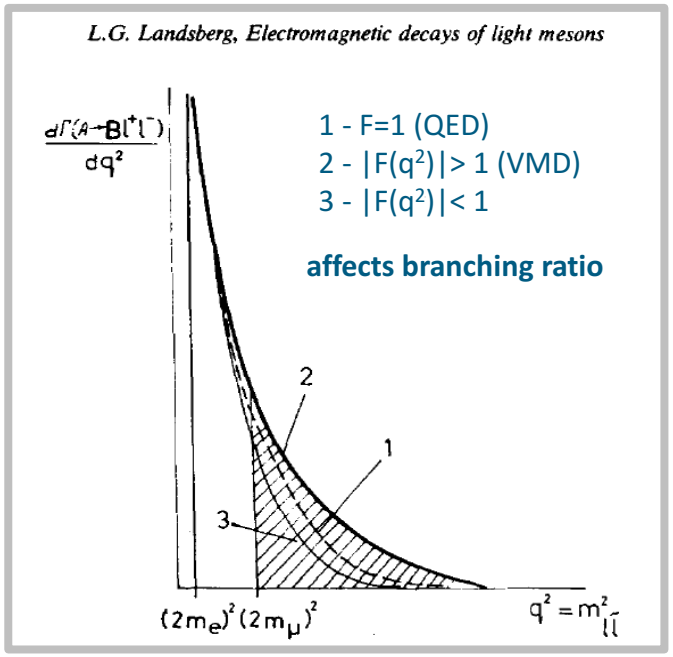
'standard' VMD, b~1.69/GeV^2

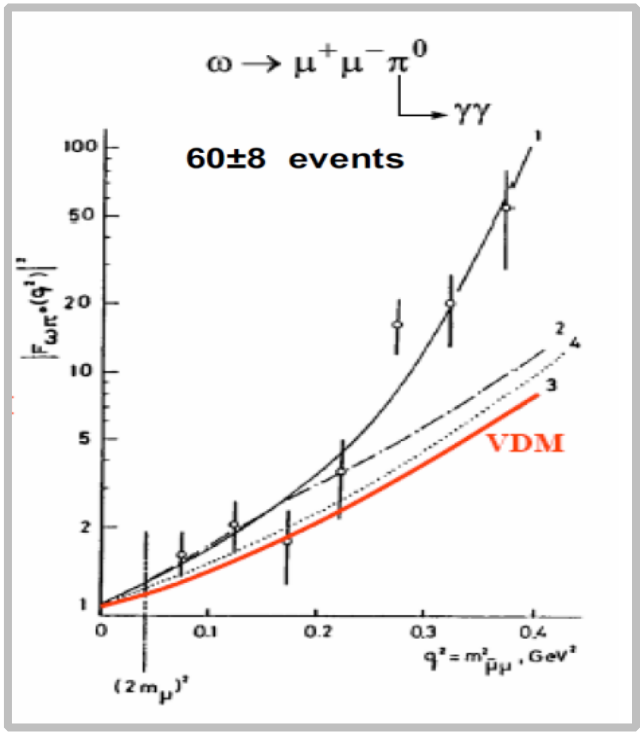
slope parameter

size (transition region)

conversion decays

Transition Form Factors

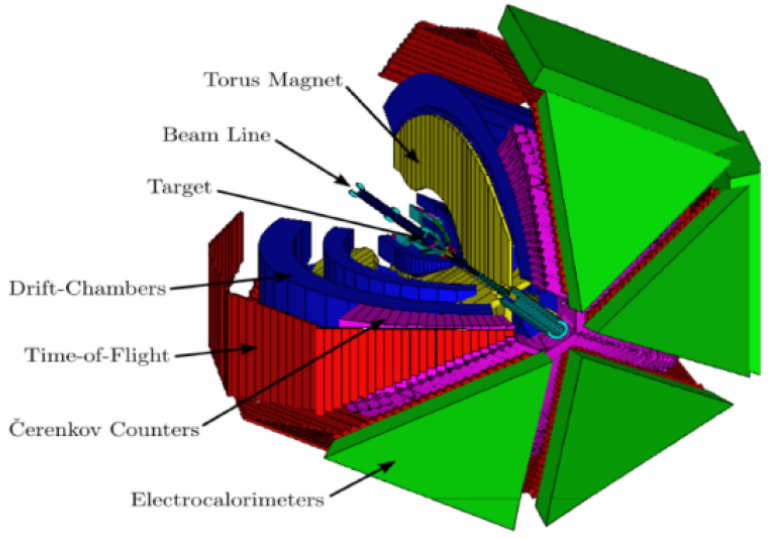


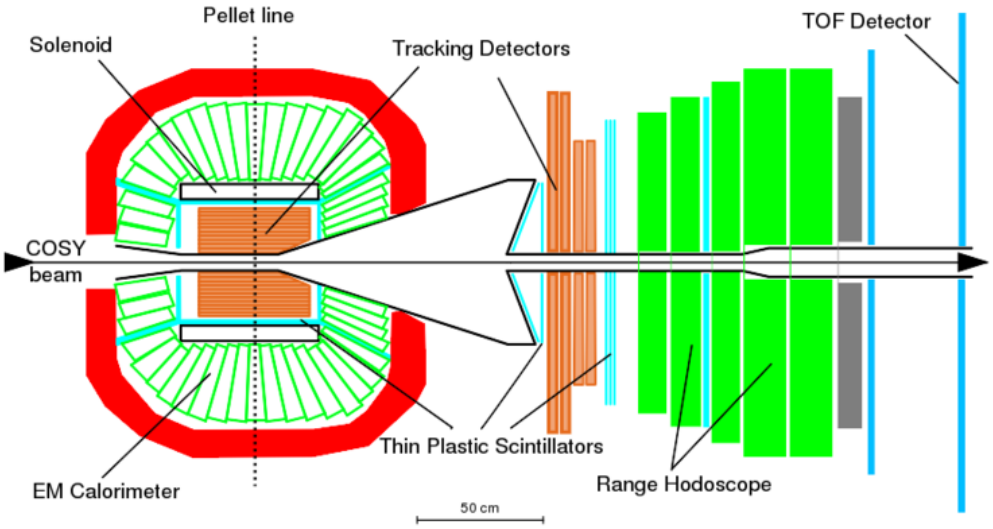


form factor: divide experimental q^2 distribution by QED

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

a tale of two experiments





CLAS Jefferson Lab	experimental issue	WASA COSY-Jülich
$\gamma + p$ (g12 experiment)	• cross section • multipion background	$p + p$
LH_2 target	external γ conversion	pellet target + beam pipe
Cerenkov Counters	dilepton identification	
EM calorimeter	photon detection	CsI EM Colrimeter

experimental challenge p+p reactions

method:
reconstruct meson mass peak, use full final state information

2 types of background:

1. multi-pion background
   meson production cross sections

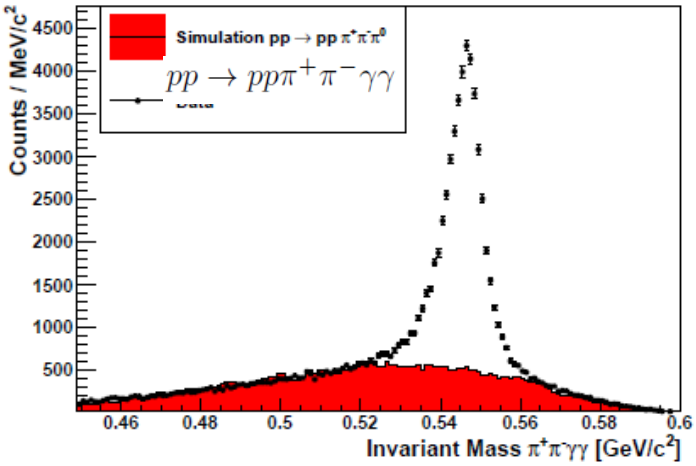
→ smooth background under meson mass peak
example:

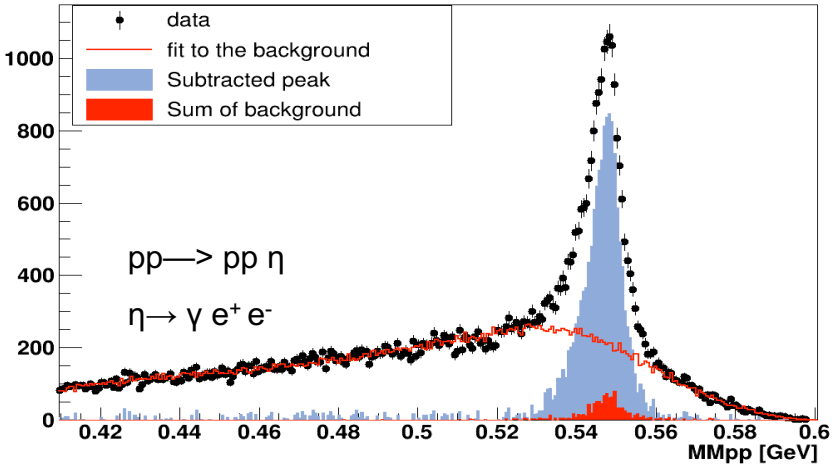
- signal $\eta \to \pi^+\pi^-\pi^0$ decay
- background direct $\pi^+\pi^-\pi^0$ production

2.) competing meson decays
relative branching ratios

→ peaked background at the meson mass peak
subtract via simulations
example:

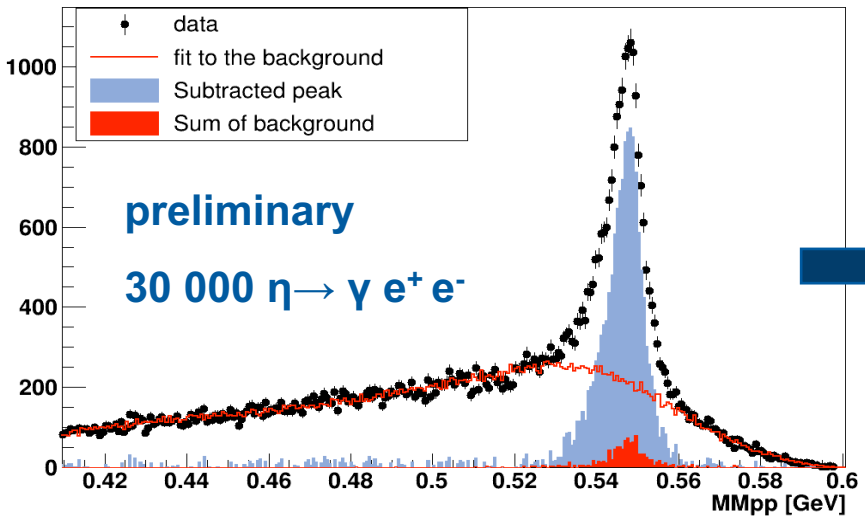
- signal $\eta \to e^+e^-\gamma$ decay
- background (eg) from $\eta \to \gamma\gamma$ decay

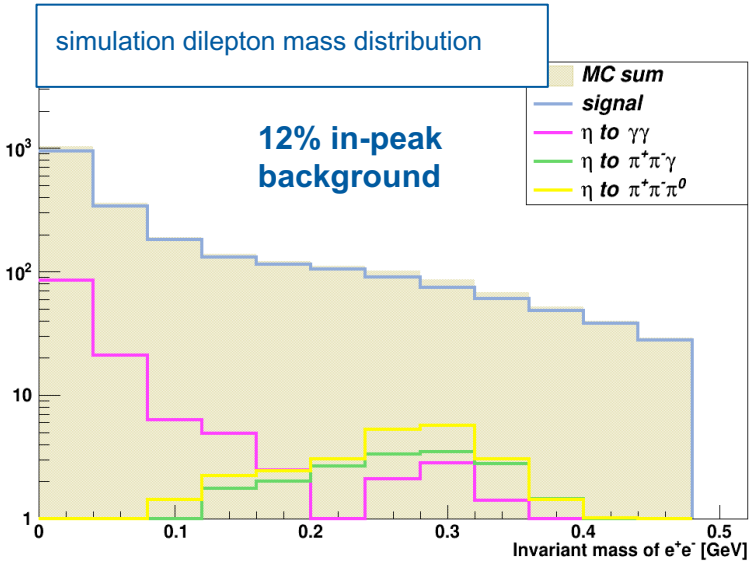




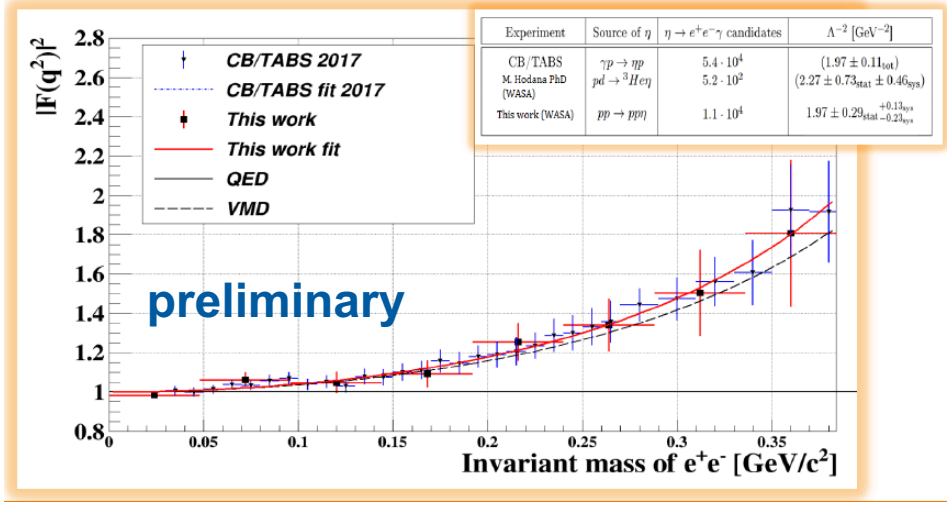
conversion decay η→ γ e+ e-

pp—> pp η (2010 data set) Ankita Goswami (IIT Indore)





pp—> pp η (2012 data set) Damian Pszczel (Warsaw)



Experiment	Source of η	η → e+e-γ candidates	Λ⁻² [GeV⁻²]
CB/TABS	γp → ηp	5.4 · 10⁴	(1.97 ± 0.11tot)
M. Hodana PhD (WASA)	pd → ³Heη	5.2 · 10²	(2.27 ± 0.73stat ± 0.46sys)
This work (WASA)	pp → ppη	1.1 · 10⁴	1.97 ± 0.29stat +0.13sys −0.23sys

'benchmark decay'

analysis: new base class for pp eta analyses

- full particle multiplicities
- improved particle id (neural networks)
- kinematic fit

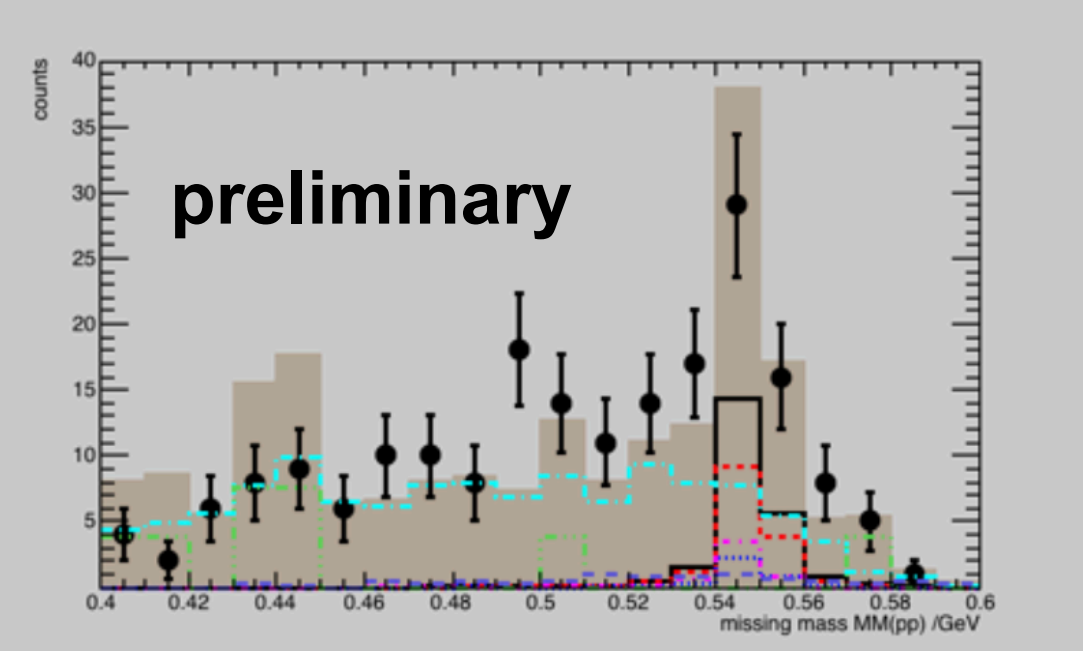
→ can improve the efficiency and signal/background

- in parallel, look at **η→ eeee**

further: *study in γ p—> p η(') and ω with CLAS/JLab*

status analysis η→eeee

$pp \rightarrow pp\eta$



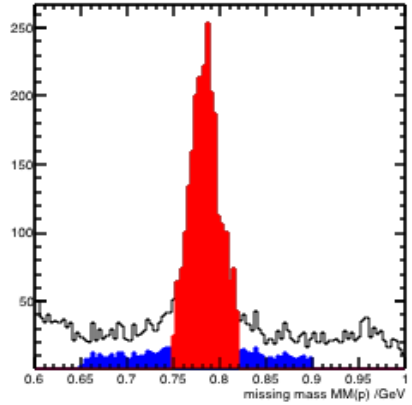
further new analysis:

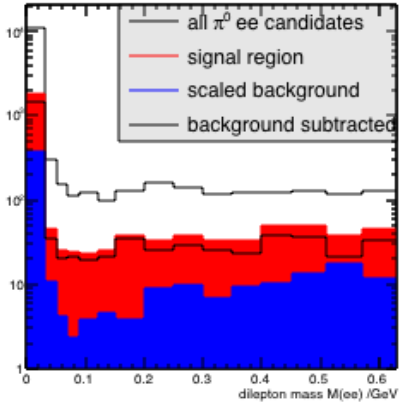
improve statistics
study combinatorics
look at pp pi0 data?

preliminary look at ω-π⁰ transition form factor

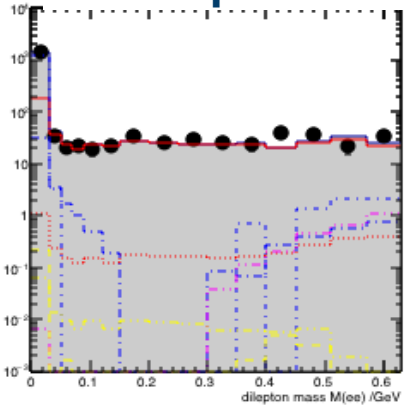
$$\gamma p \rightarrow p\omega$$

smooth background subtraction

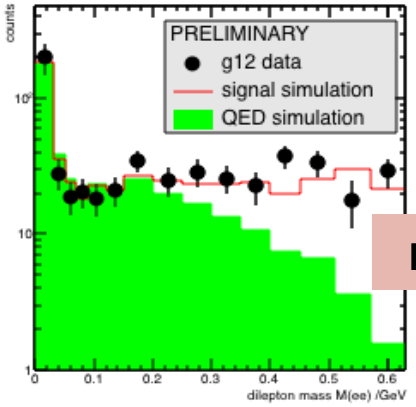




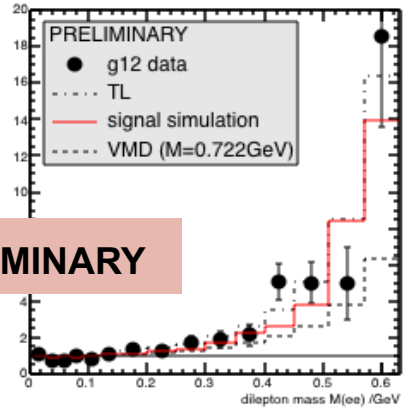
in-peak background



in-peak and smooth background subtracted



data / QED simulation



PRELIMINARY

simulations for in-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)

summary

light meson transition form factors

results coming up from the experiments
CLAS g12 and WASA at COSY:

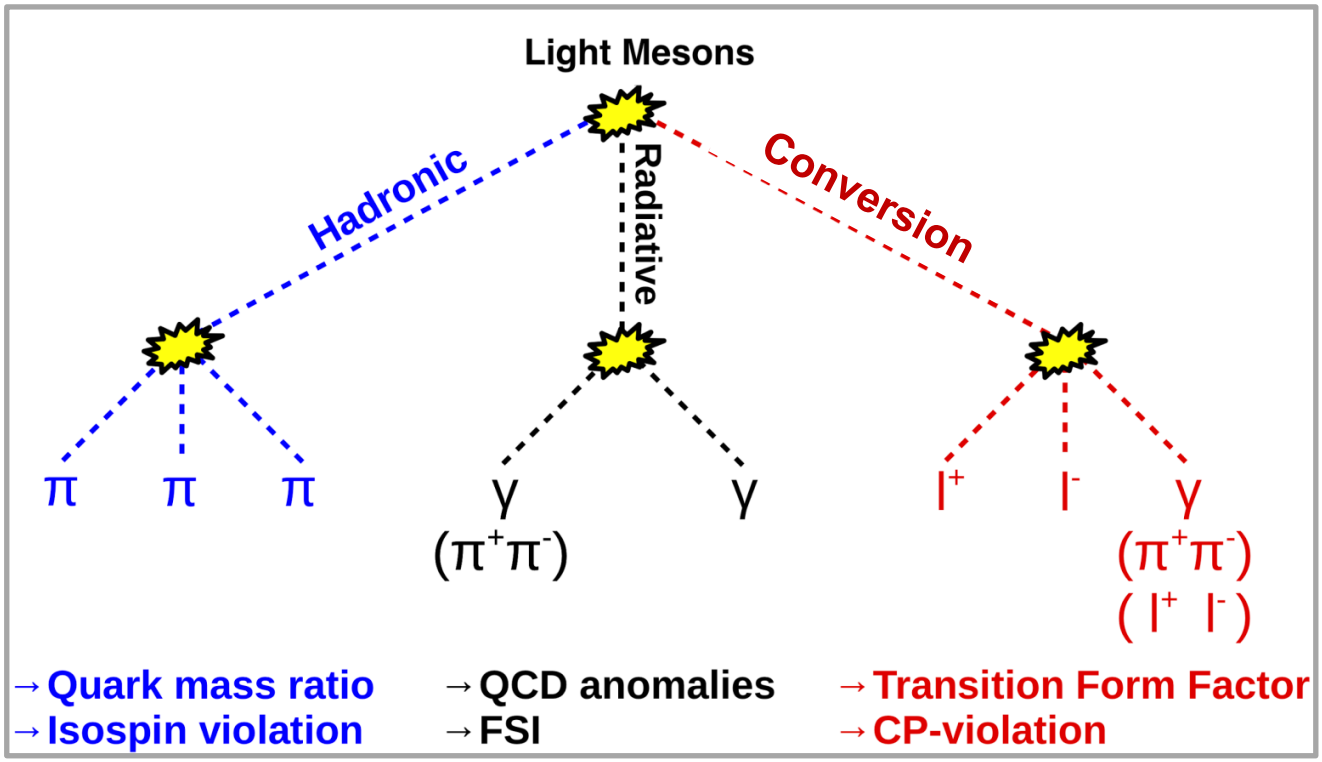
$\eta \rightarrow \gamma\, e^+ e^-$ benchmark channel
$\eta \rightarrow e^+ e^- e^+ e^-$ double VMD ?

ω-π^0 transition form factor solve the puzzle?

next generation measurements from CLAS12

xtras

light meson decays



WASA-at-COSY: π, η

the orginal proposal for bringing WASA to COSY :

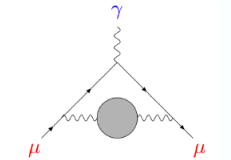
Proposal for the wide angle shower apparatus (WASA) at COSY-Julich: WASA at COSY
WASA-at-COSY Collaboration, e-Print: **nucl-ex/0411038**

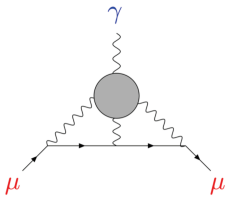
CLAS: π, η, ω, η'

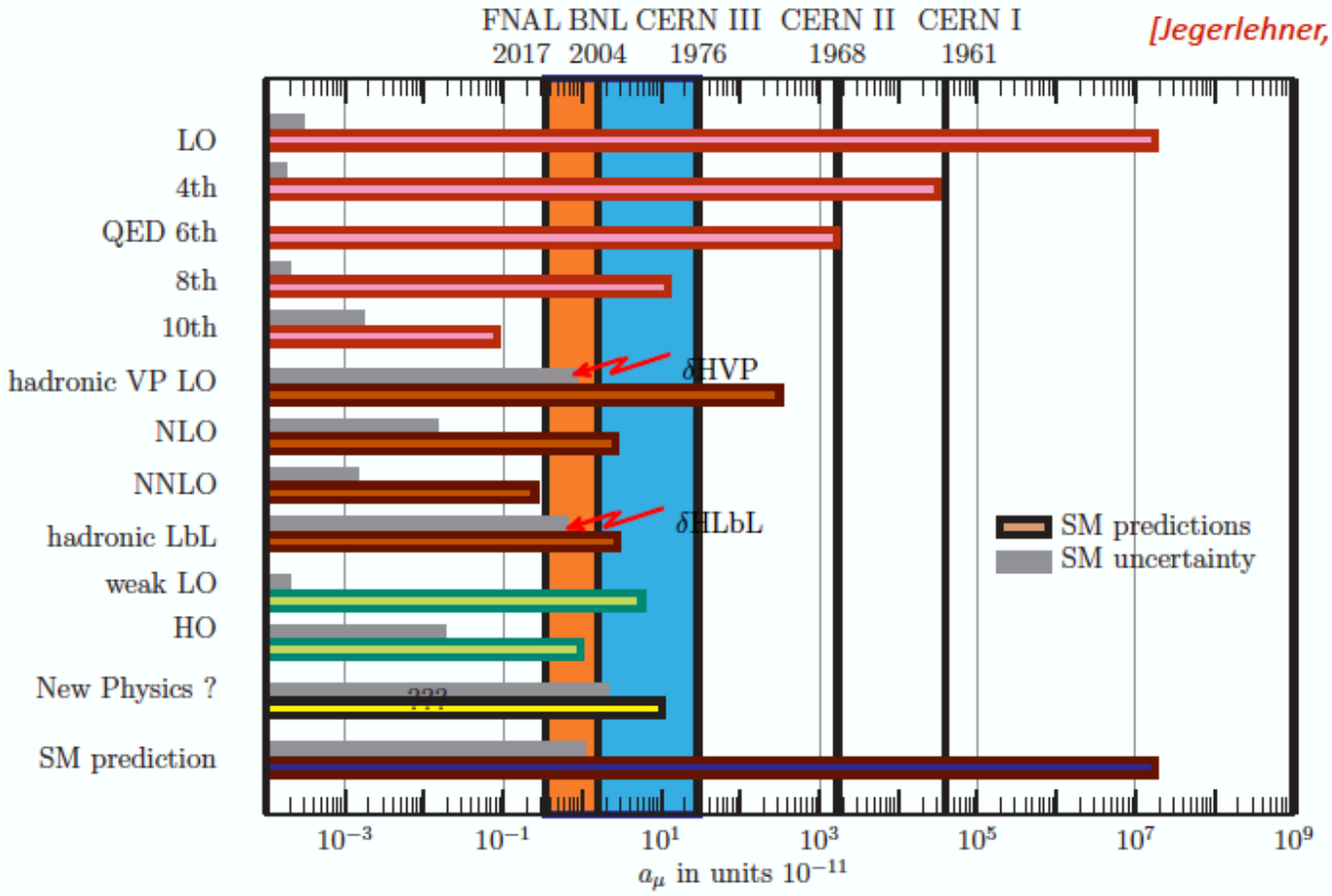
the orginal proposal:
CAA Photoproduction and Decay of Light Mesons in CLAS
https://wiki.jlab.org/lmd/

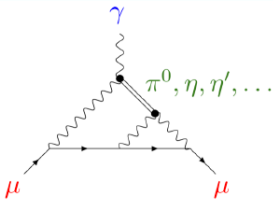
theory confronts experiment

Role of hadronic decays for g-2

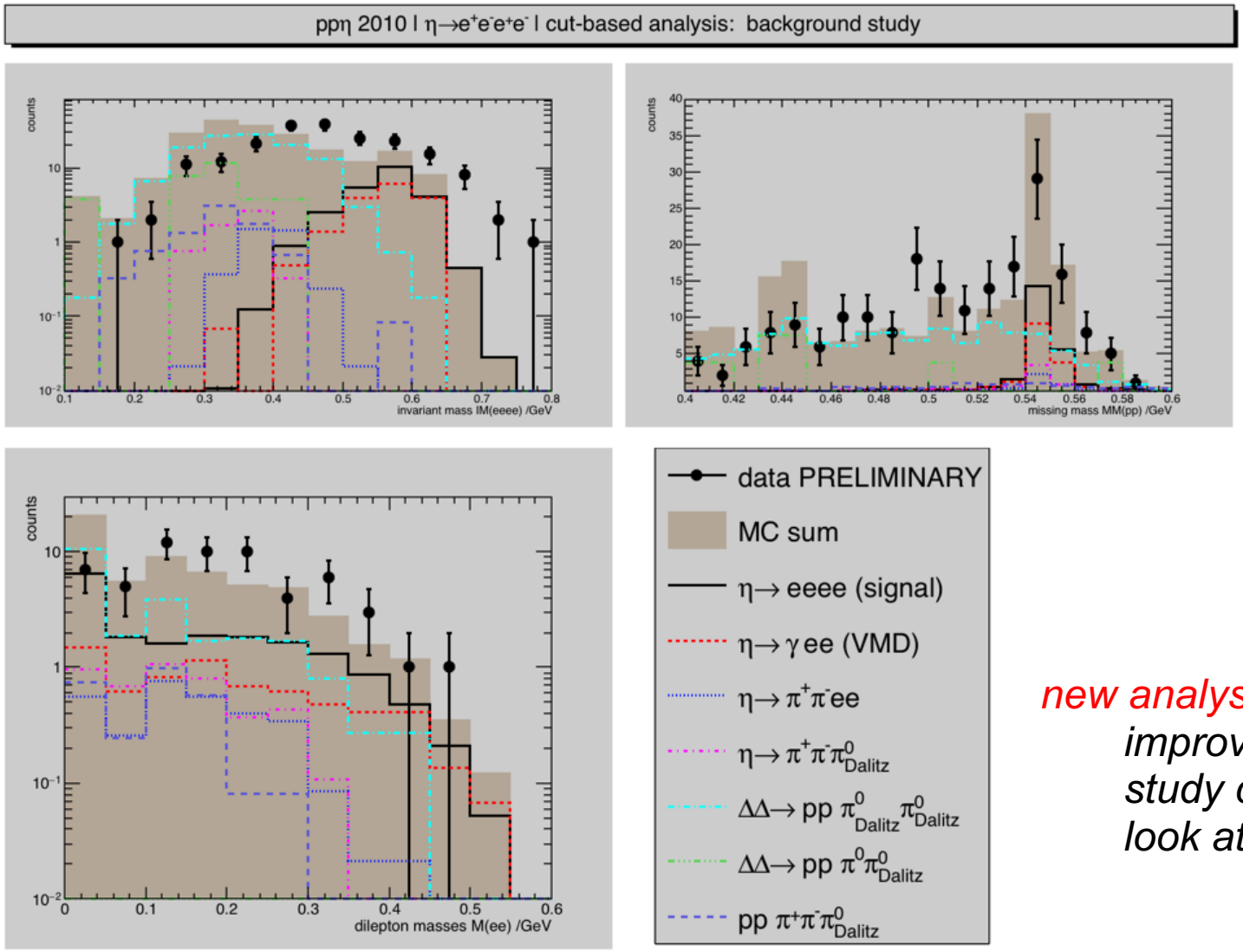








status analysis η→eeee



new analysis:

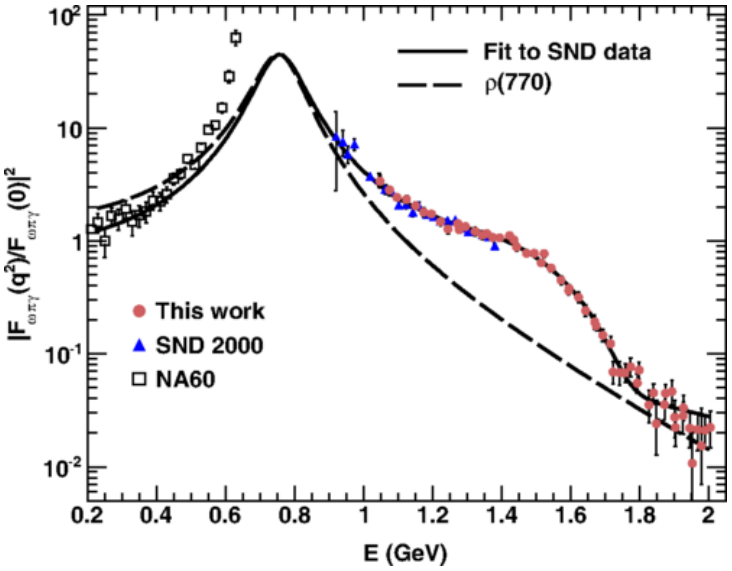
improve statistics

study combinatorics

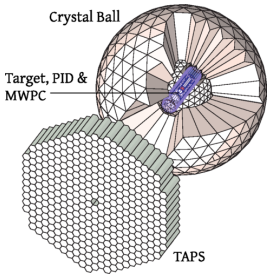
look at pp pi0 data?

status of the ω-π transition form factor

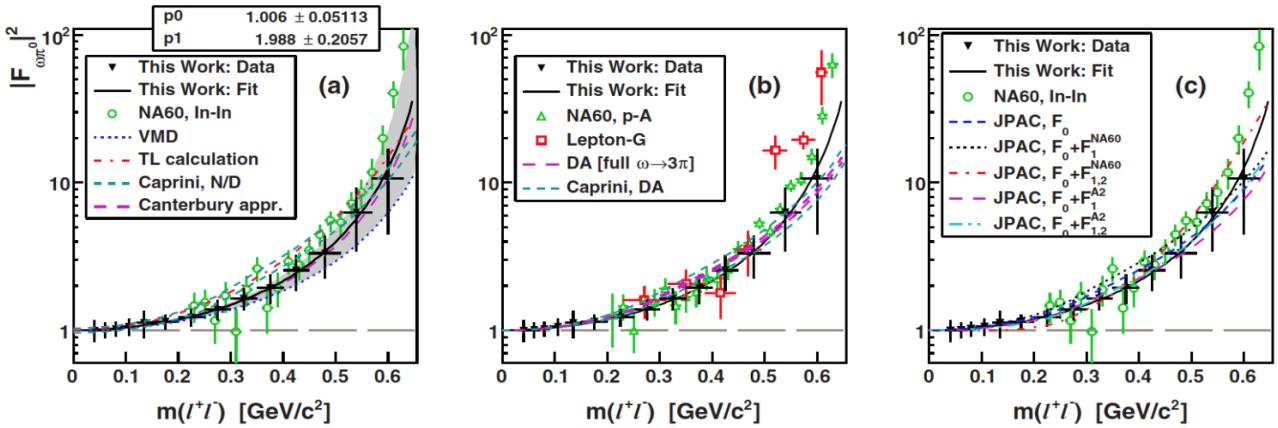
M. N. Achasov *et al.*, Phys. Rev. D 94, (2016) 112001



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



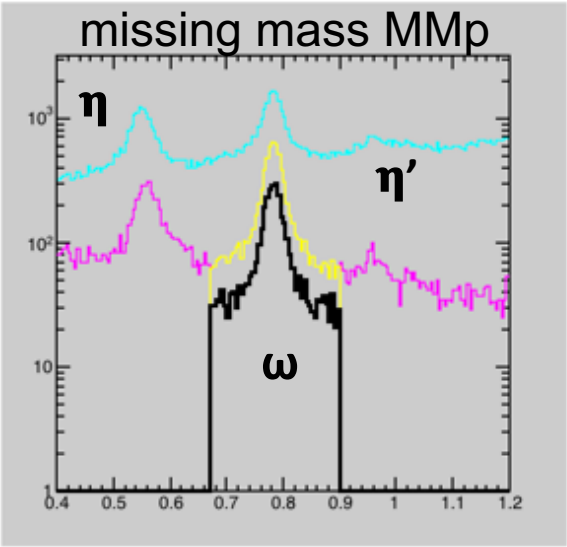
$\Lambda^{-2}=(1.99\pm0.21_{tot})$ GeV^{-2}
1100 overall statistics

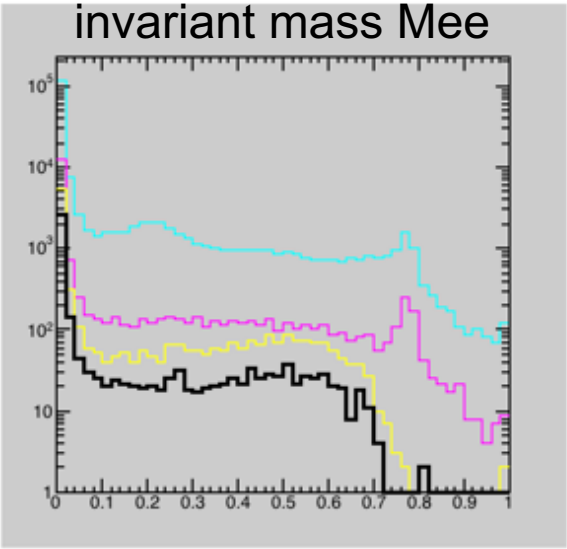


conclusion:

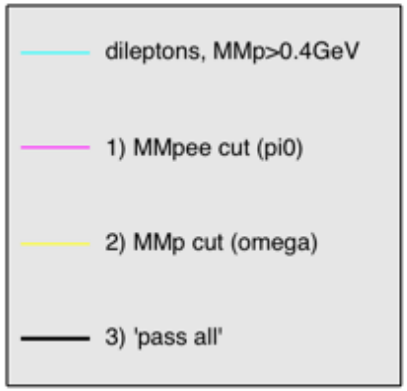
- A2 results are in better agreement with theoretical calculations, compared to earlier experiments
- statistical accuracy of the present data points at large m (ee) masses does not allow a final conclusion

analysis strategy cut-based analysis

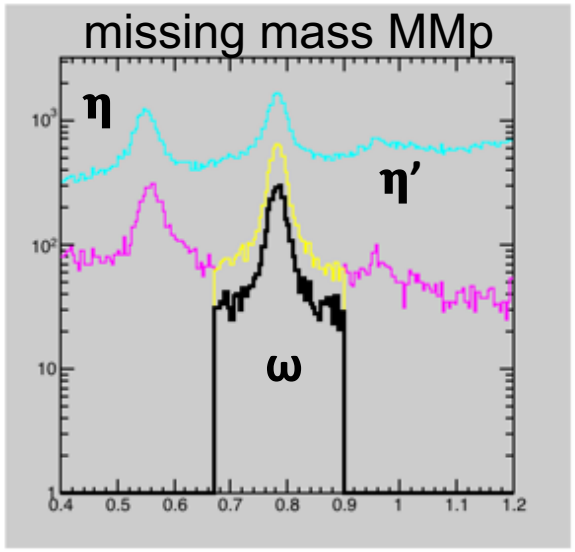


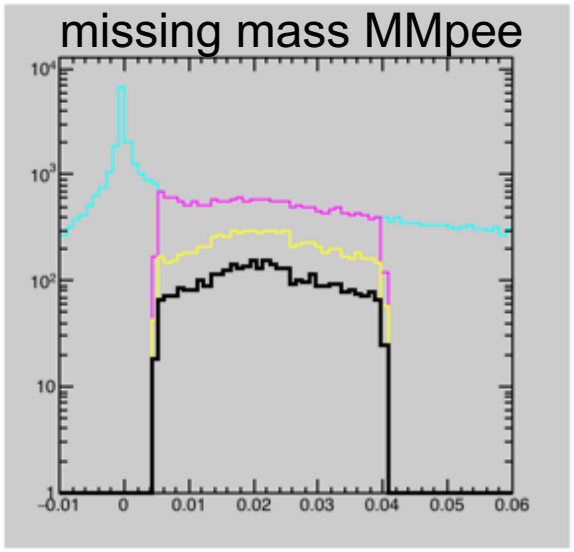


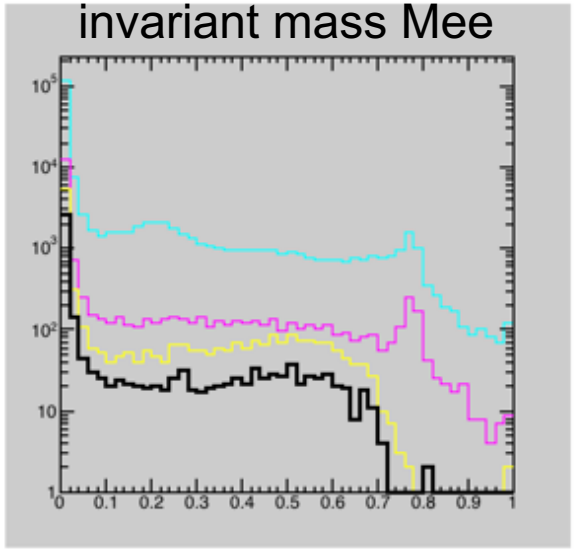
- smooth background
  ← subtract via MMp spectrum
- in-peak background (competing decays)
  ← simulations
- photon conversion from $\pi \rightarrow \gamma\gamma$ (small ee masses)
  ← simulations

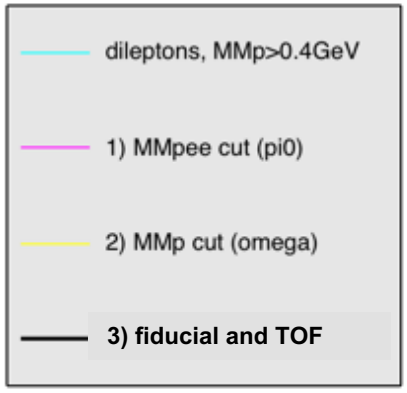


analysis strategy cut-based analysis









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