Electromagnetic transition form factor of the η meson with WASA-at-COSY

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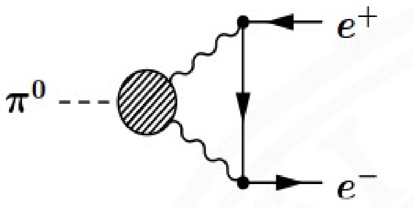
Motivation

Why it is interesting?

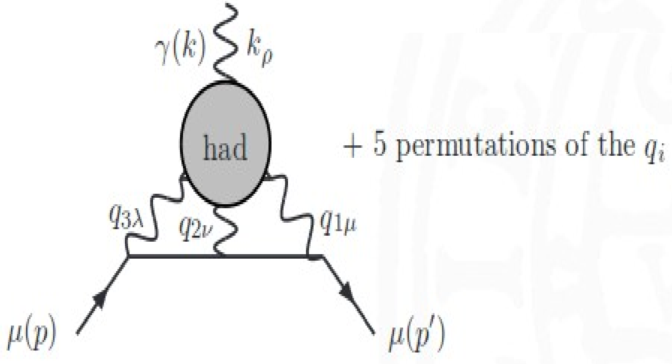
- Intrinsic structure of hadrons
- Vector meson dominance

- Physics beyond standard model

✔ rare pion decay $\pi^0 \rightarrow e^+e^-$



✔ g-2 of muon



Transition Form Factor

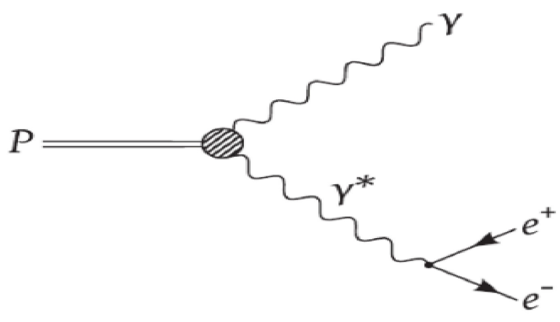
Transition Form Factor F (q^2) of the η meson is observed through the rare electromagnetic decay $\eta \to \gamma e^+ e^-$ (BR → 6.9 × 10^{-3}).

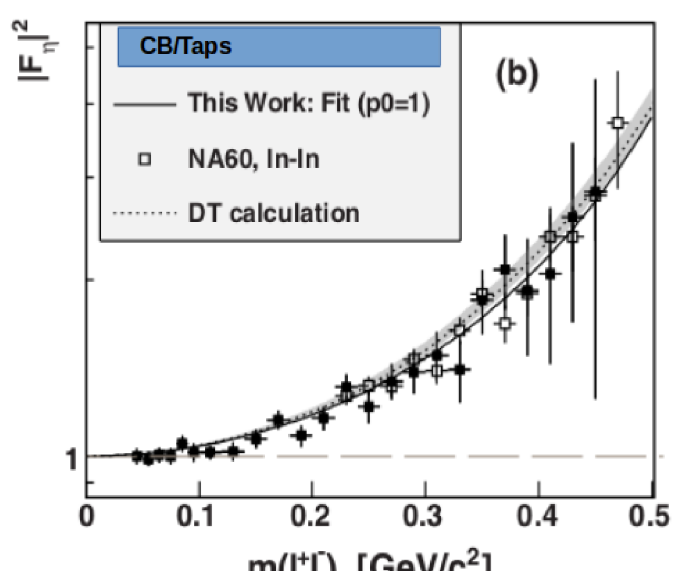
$$\frac{d\Gamma(\eta\to\gamma e^+e^-)}{dq^2\cdot\Gamma(\eta\to\gamma\gamma)} = \frac{2\alpha}{3\pi}\left[1-\frac{4m_e^2}{q^2}\right]^{1/2}\left[1+\frac{2m_e^2}{q^2}\right]\frac{1}{q^2}\left[1-\frac{q^2}{m_\eta^2}\right]^3 |F_\eta(q^2)|^2$$

N.M. Kroll and W. Wada, Phys. Rev. 98 (1955) 1355

$$F(q^2) = \frac{1}{1-\frac{q^2}{\Lambda^2}} \approx 1+\frac{q^2}{\Lambda^2} \qquad \left|\frac{dF(q^2)}{dq^2}\right|_{q^2=0} = \frac{1}{\Lambda^2} = b_\eta$$

Λ is pole mass and b_η is slope of the form factor





PHYSICAL REVIEW C 89, 044608 (2014)

Λ^{-2} = (1.95 ± 0.15$_{stat}$ ± 0.10$_{syst}$) GeV^{-2}

Experimental setup

COSY (Cooler Synchrotron)

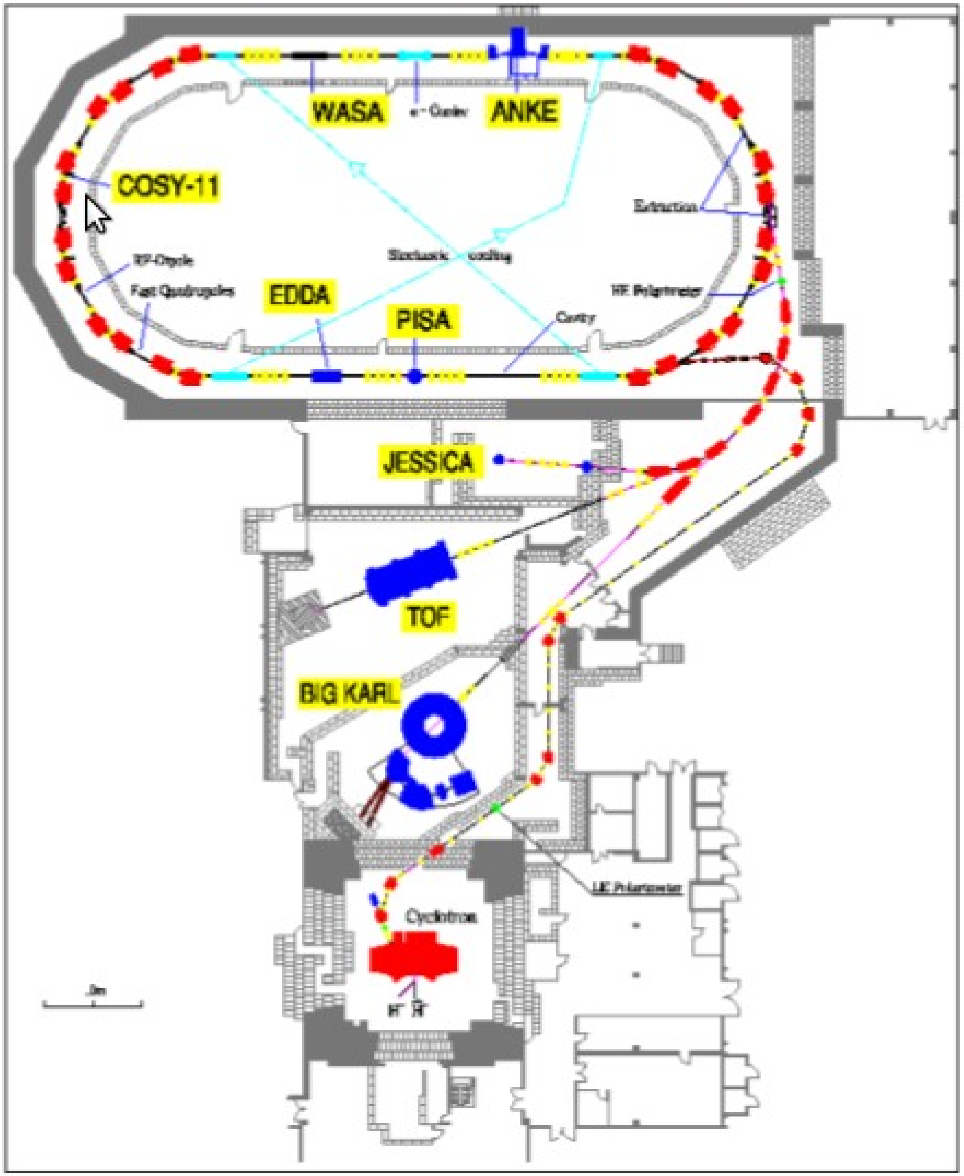
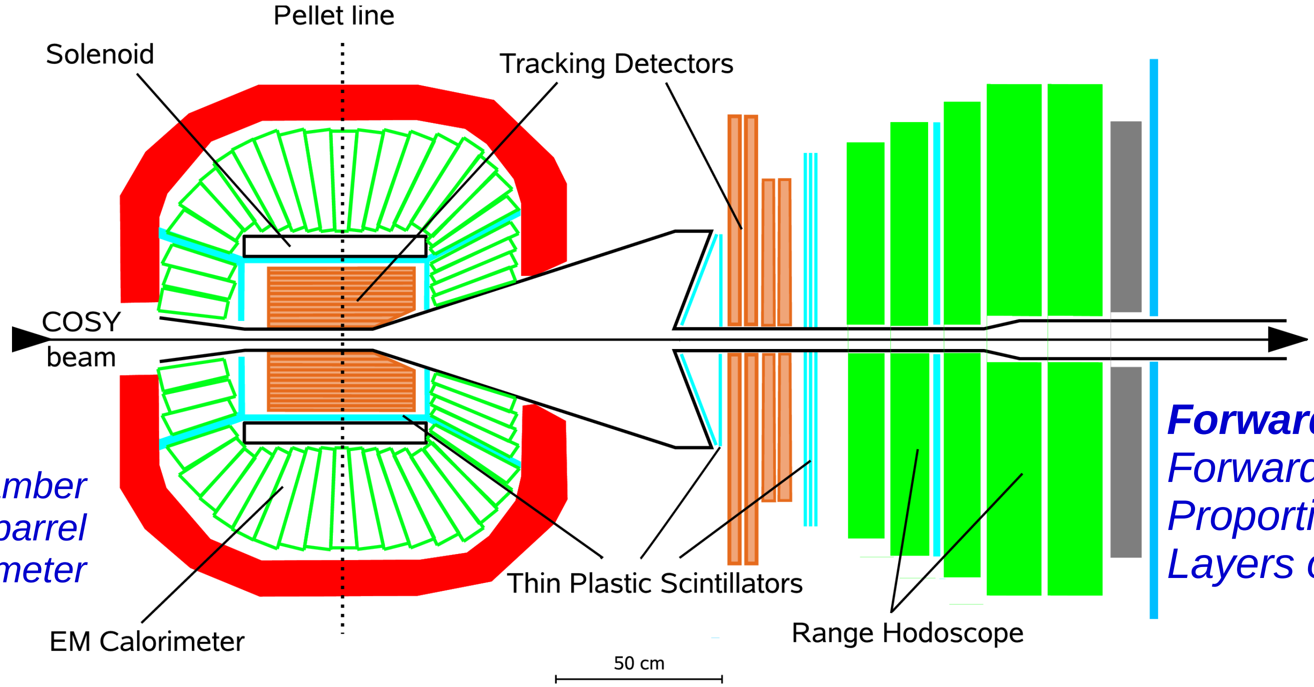


Fig : Schematic view of COSY

- Circumference 184m
- Momentum range 0.3-3.75 GeV

WASA (Wide Angle Shower Apparatus) set up

Reaction: p + p → p + p + η(e⁺ e⁻ γ) at beam energy 1.4 GeV

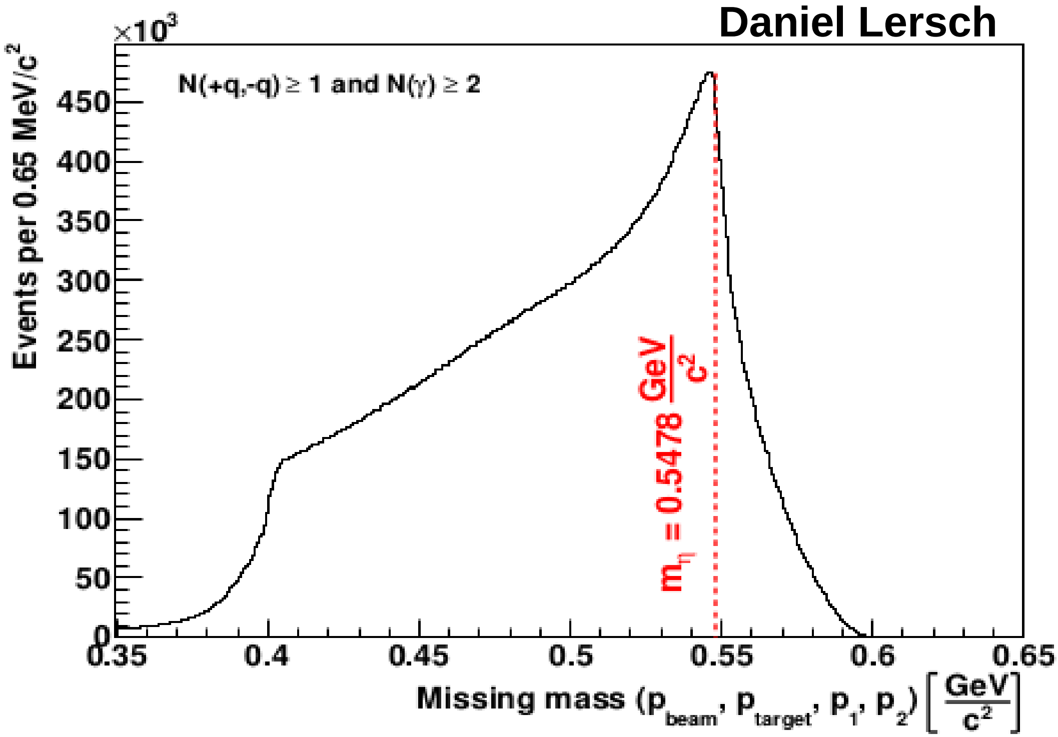


Central part:
Mini drift chamber
Plastic scintillator barrel
Solenoid/EM Calorimeter

Forward part:
Forward window counter
Proportional chamber
Layers of range hodoscope

- ***Fixed target experiment, pellet target, 22.9 % of 4л acceptance***
- ***Recoil protons are detected with the forward detector***
- ***e^+e^- are detected with the mini drift chamber in the magnetic field of solenoid***
- ***Photons are detected in the calorimeter***

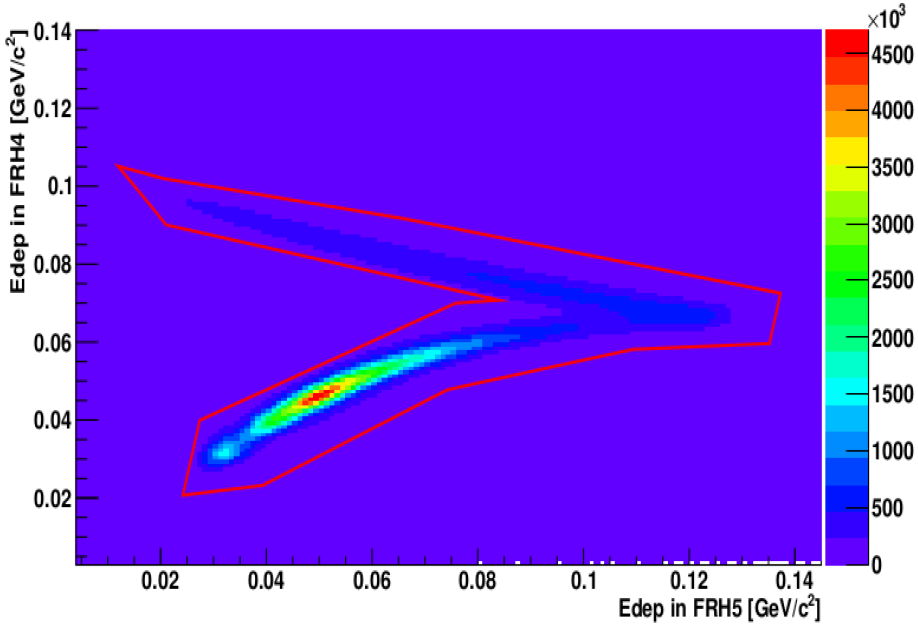
Datasets: *pp→ppη*

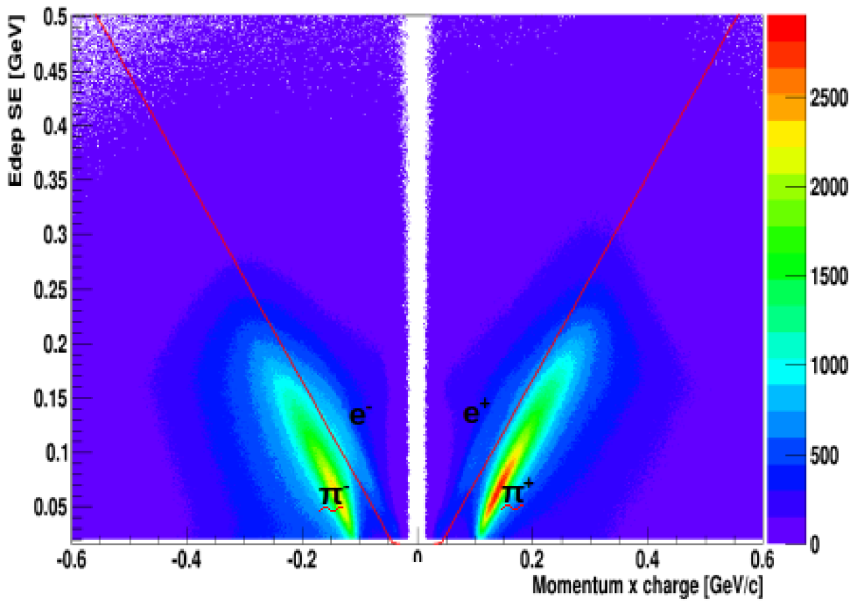


Data taken	2008	2010	2012
Duration of beam time	2 weeks	7 weeks	8 weeks
η detected	~ 1.10^8	~ 4.10^8	~ 5.10^8

Data Analysis: Particle Identification

$$p + p \rightarrow p + p + \eta(e^+ e^- \gamma)$$

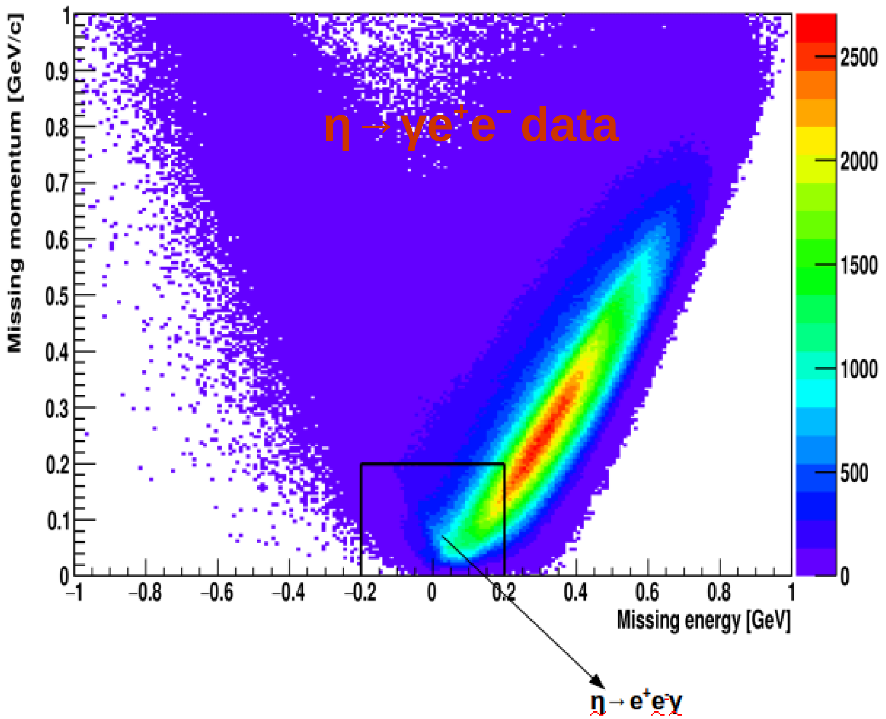


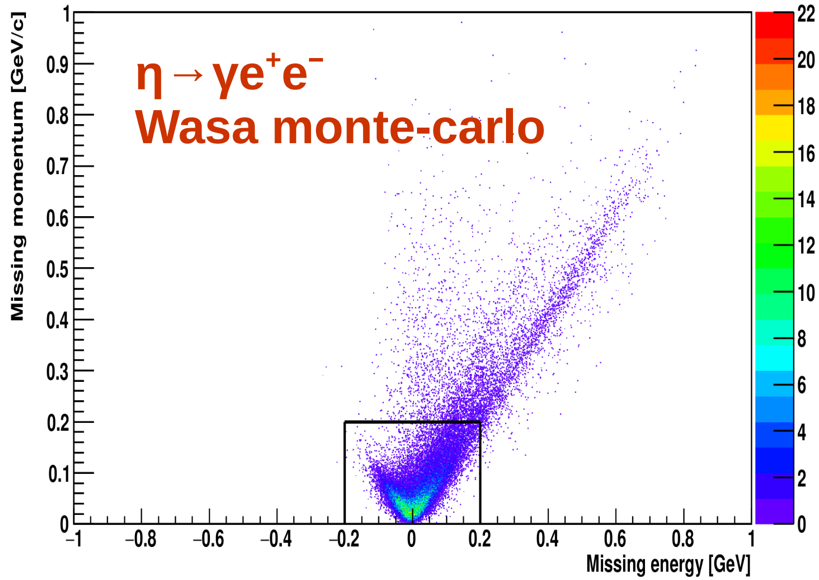


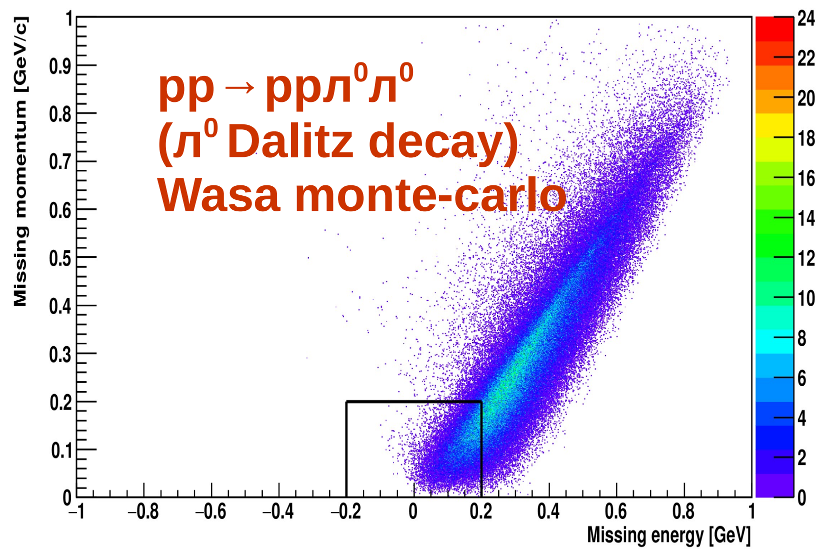
- *Protons are identified in the forward part of the detector*
- *Deposit energy in forward range hodoscope layers*

- *Different types of particles leave distinct bands*
- *Momentum times charge of the particle is plotted against the energy deposited by particle in the calorimeter*

Energy-momentum balance







Missing Energy:

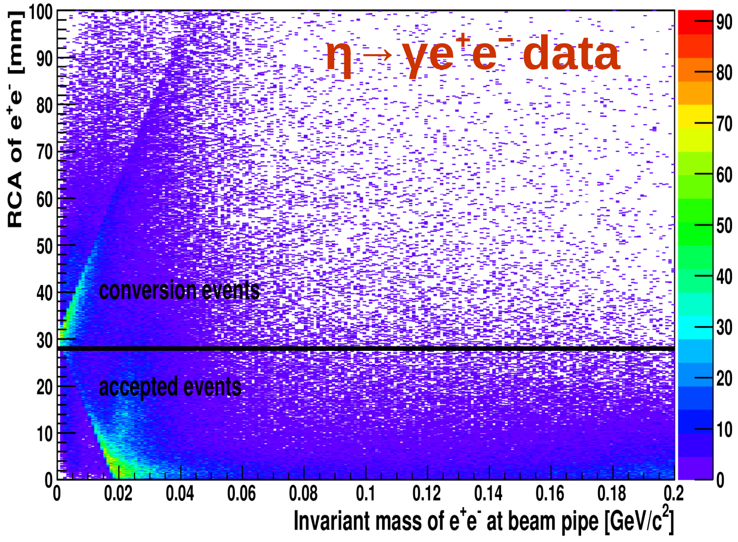
$E_{target} + E_{beam} - (E_{proton1} + E_{proton2} + E_{e+} + E_{e-} + E_{\gamma})$

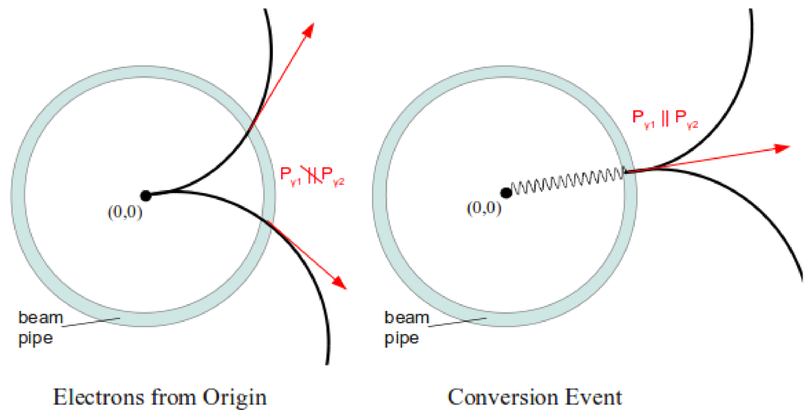
Missing Momentum:

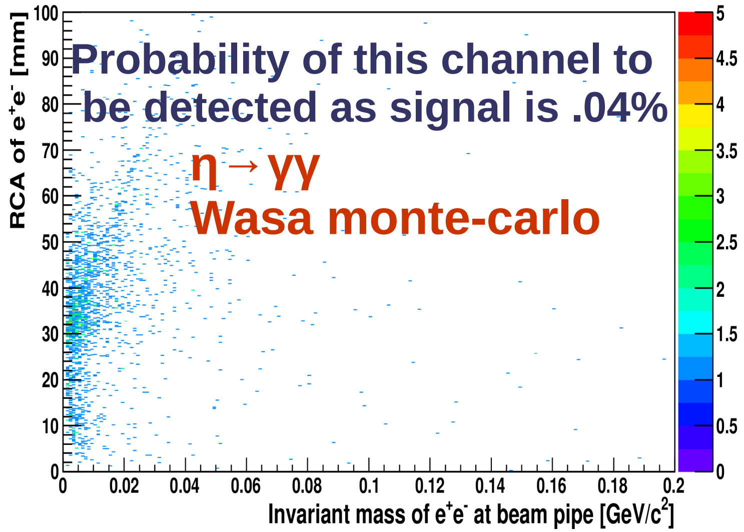
$\mathbf{P_{target} + P_{beam} - (P_{proton1} + P_{proton2} + P_{e+} + P_{e-} + P_{\gamma})}$

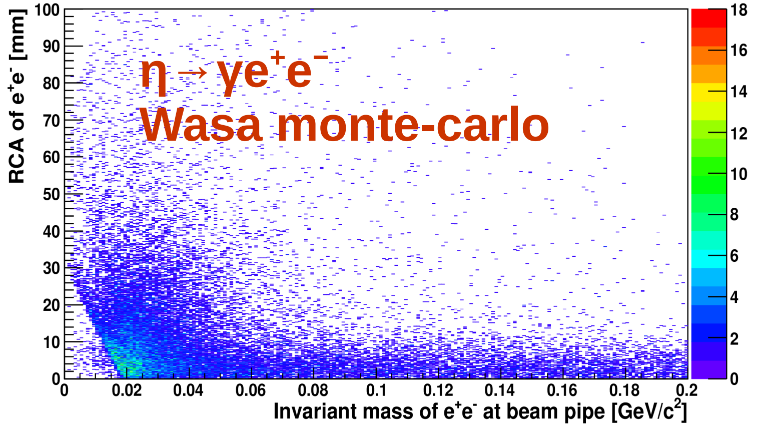
Background suppression:
event candidates will still have pions

Conversion background



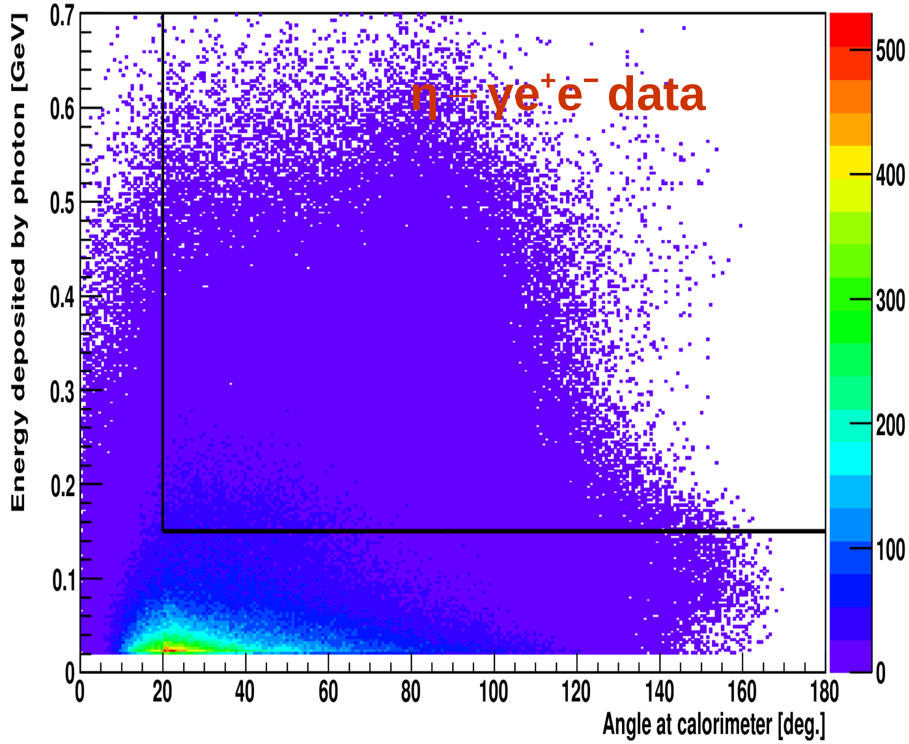


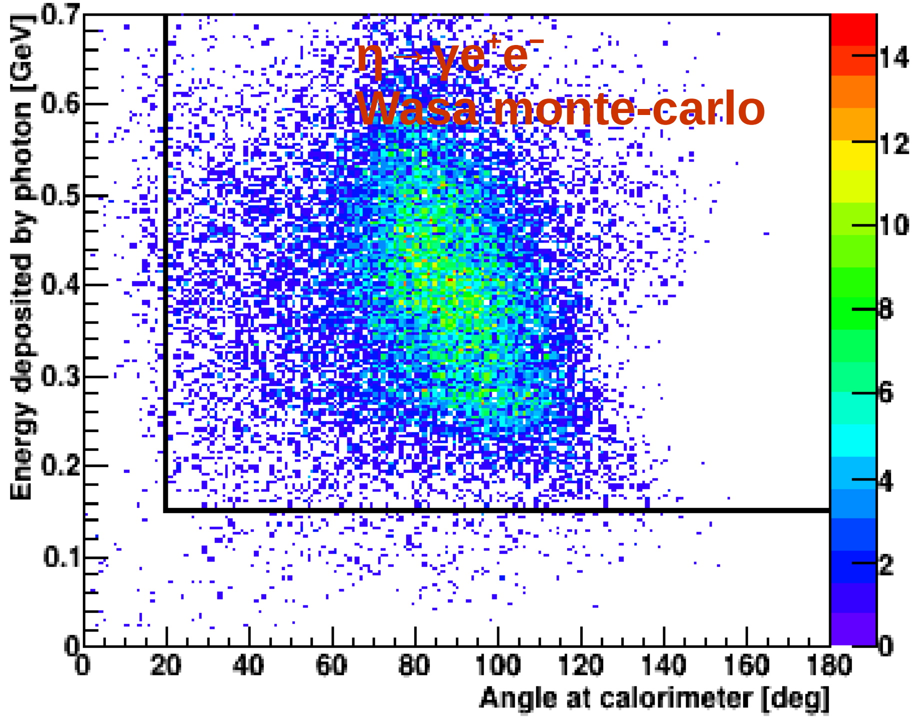




- *Photons interact with beam-pipe material and convert into e^+e^- pairs*
- *$\eta \to \gamma\gamma$ contributes*
- *Invariant mass at beam pipe plotted against the radius of closest approach of e^+e^-*

Split off background

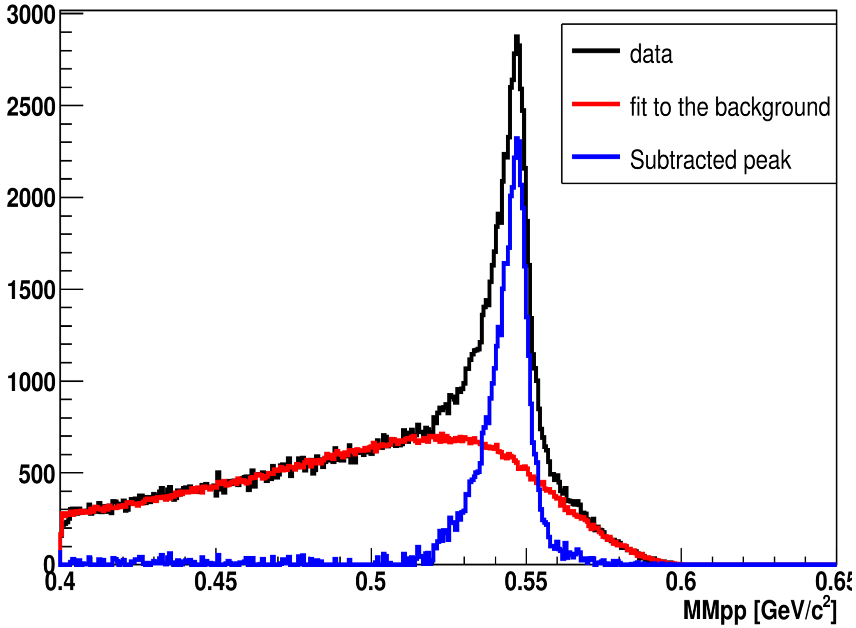


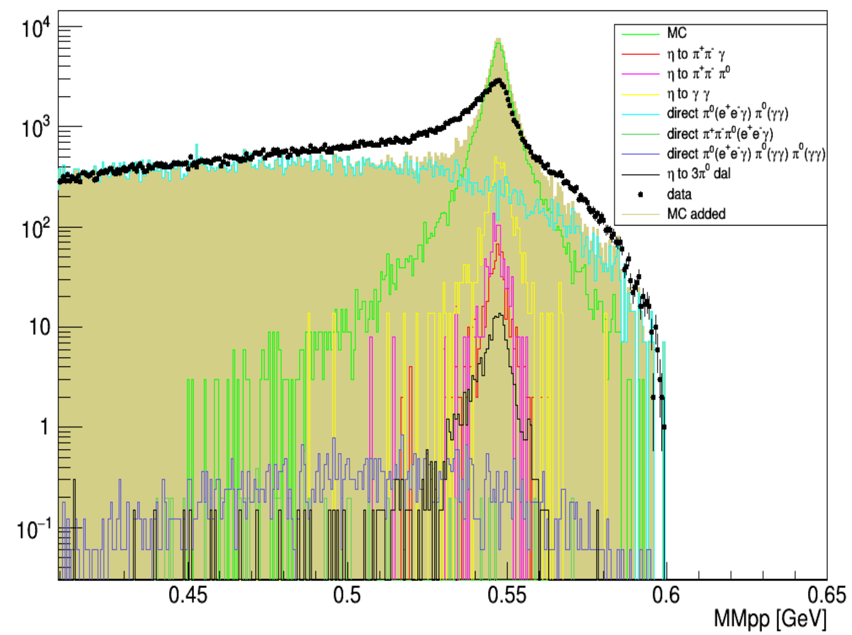


- ***Photons and electrons make electromagnetic shower in the calorimeter***
- ***Split-offs are discontinuous showers***
- ***We look at the energy deposited in the calorimeter v/s the angle between photon candidate and closest charged track***

split offs are located at low energy and small angle

Missing mass of η meson

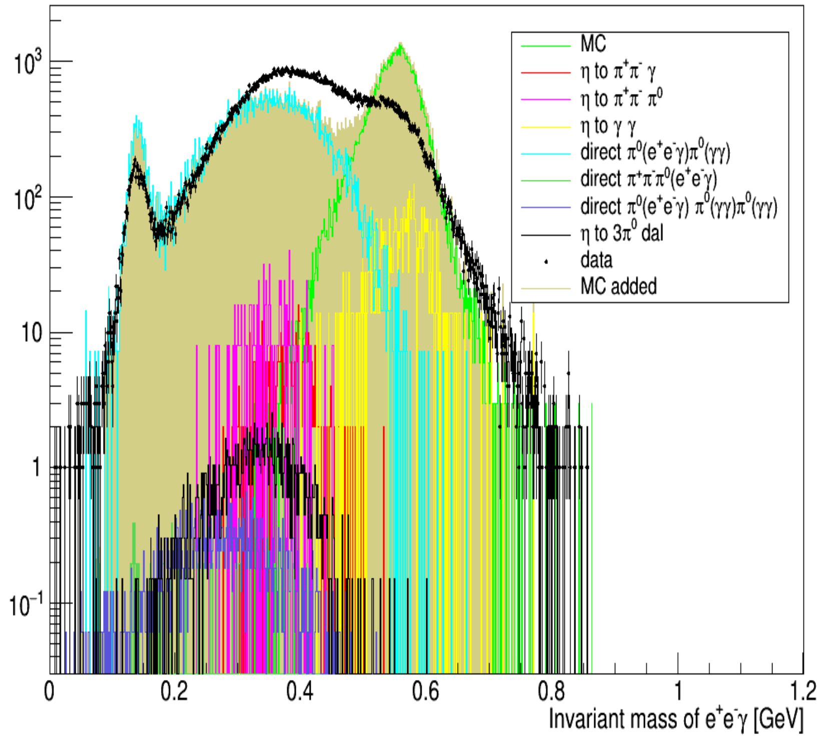




- ***Main background source is pp → pp$\pi^0\pi^0$ (π^0 Dalitz decay)***
- ***Background fit: pol4 × MC (pp → pp$\pi^0\pi^0$ (π^0 Dalitz decay)) excluding the peak region***
- ***produced η : 10^8***
- ***approximately 43k η decays***

Background study: cocktail plots

preliminary and not acceptance corrected



Background channel	Cross-section/ Branching ratio	Probability of being detected as signal (%)
pp→ppл^0(e$^+$e$^-$γ)л^0(γγ)	324 μb	.069
pp→ppл$^+$л$^-$л^0(e$^+$e$^-$γ)	4.6 μb	.00041
pp→ppл^0(e$^+$e$^-$γ) л^0(γγ) л^0(γγ)	1.34 μb	.011
η→л$^+$л$^-$л^0	22.6 %	.0009
η→л$^+$л$^-$γ	4.68 %	.0287
η→γγ	39 %	.0032
η→л^0(γγ)л^0(γγ)л^0(e$^+$e$^-$γ)	32 %	.122

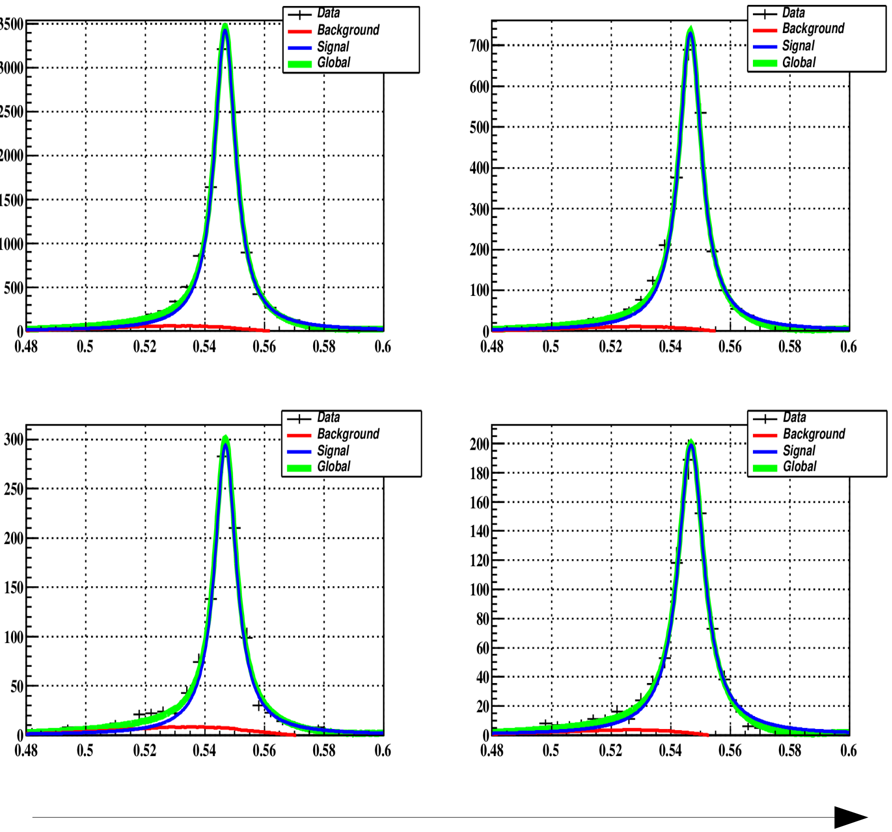
PDG rel. BR. (η→e$^+$e$^-$γ/η→γγ)	**.017 ± .001**
WASA	**.019 ± .0001**

- ***Direct and competing decays***
- ***Phase space simulations (for now)***
- ***Δ-Δ, л$^+$л$^-$ correlations have to be implemented***
- ***Normalization of background channels is done relative to each other and scaled with data***

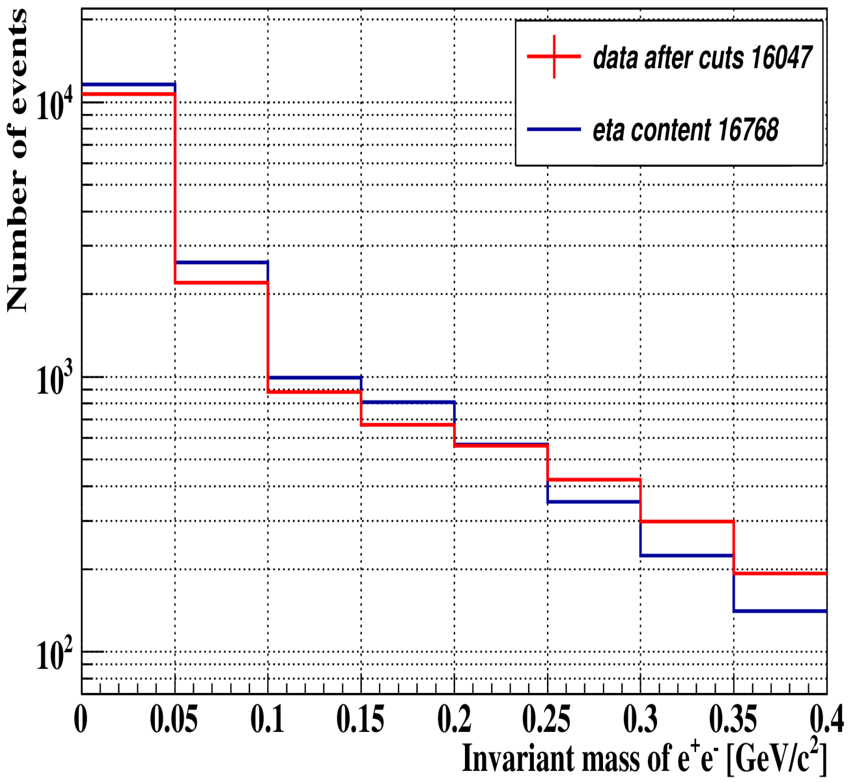
Status of pp2012 data

preliminary and not acceptance corrected

Damian Pszczel



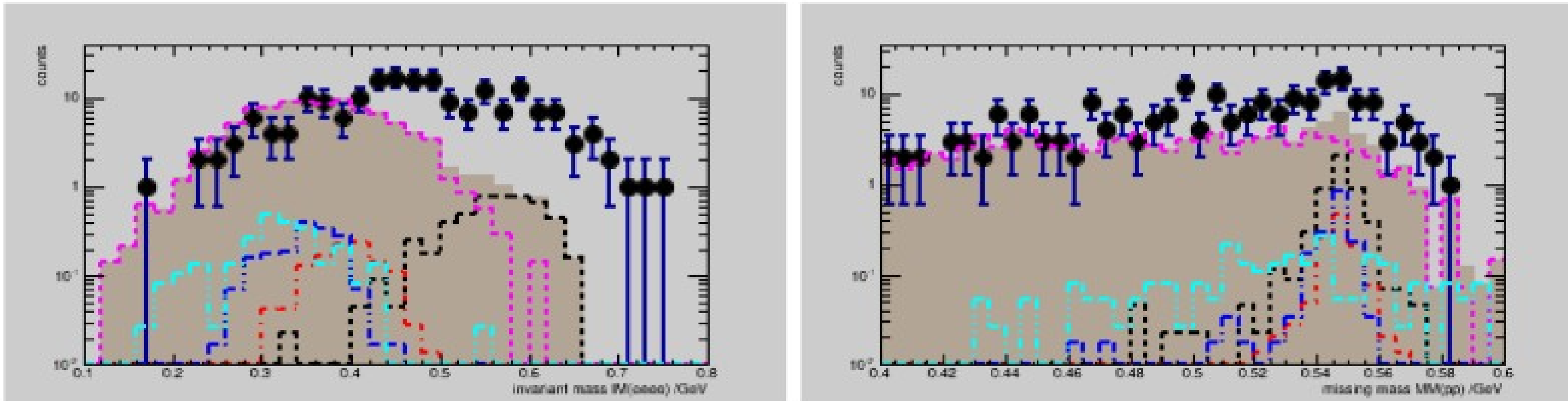
MMpp [GeV]

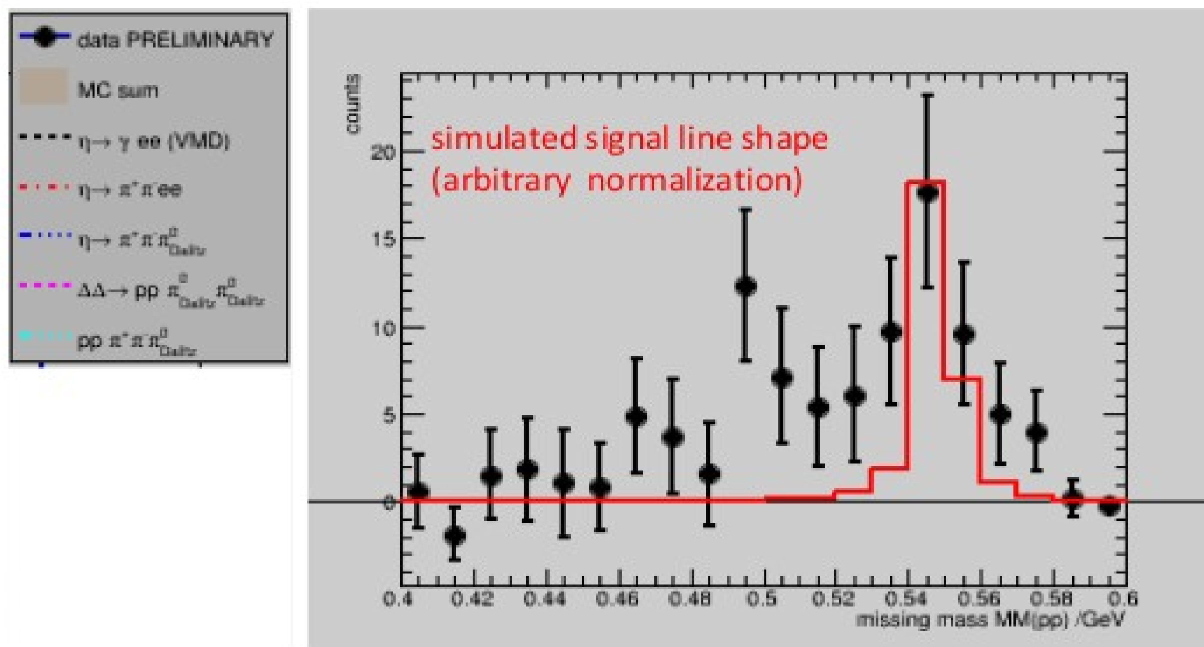


reaching for the double Dalitz decay

Susan Schadmand

ppη 2010 | $\eta \to e^+e^-e^+e^-$ | cut-based analysis: background study





- WASA-at-COSY standard analysis
- preliminary and not acceptance corrected.
- **consistency-check :** yield consistent with our preliminary single Dalitz decay analysis

goal: evaluate branching ratio

latest WASA result: nucl-ex/1509.06588
BR = $(3.2 \pm 0.9_{stat} \pm 0.5_{sys}) \times 10^{-5}$

Summary

$\eta \to \gamma e^+ e^-$

- Main source of background is $pp \to pp$л^{0}л^0(л$^0 \to e^+ e^- \gamma$)
- Detailed study of background channels is ongoing

$\eta \to e^+ e^- e^+ e^-$

- Branching ratio

Outlook

- As a different approach, kinematic fit to suppress background
- Transition form factor of η