Measurement of Transition Form Factor of η meson with WASA detector at COSY

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Outline

- Physics Motivation
- Transition Form Factor
- Experimental Set-up
- Analysis of $\eta \rightarrow e^+e^-\gamma$
  - Simulations
  - Kinematic studies
  - Suppression of $\eta \rightarrow \gamma\gamma$ background
  - Preliminary Results
- Summary and outlook

Physics Motivation

- How quarks and gluons are confined inside the nucleon ?
- The study of phenomenological characteristics of hadrons should lead to better understanding of QCD .

→ **Transition Form Factor**

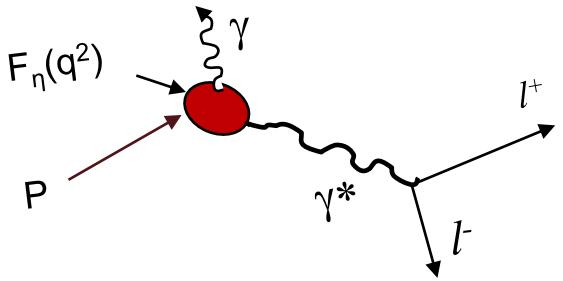
- Transition Form Factor $F(q^2)$ is defined as :

$$\frac{d\Gamma}{dq^2} = \left|\frac{d\Gamma}{dq^2}\right|_{\text{pointlike}} |F(q^2)|^2$$

where, $|d\Gamma/dq^2|$ is experimentally measured and $|d\Gamma/dq^2|_{\text{pointlike}}$ is the theoretically (QED) calculated mass spectrum for a point like meson.

- One can use the Dalitz decay of η meson $(\eta \to \gamma^*\gamma \to l^+ l^- \gamma)$ to determine q^2 which is equal to the invariant mass squared of the lepton pair

Probe : internal structure $\quad q^2 = m^2_{l^+l^-}$



Transition Form Factor

Leptonic pair mass spectrum :

$$\frac{d\Gamma(\eta \to l^+ l^- \gamma)}{dq^2 \cdot \Gamma(\eta \to \gamma\gamma)} = \underbrace{\frac{2\alpha}{3\pi}\sqrt{1-\frac{4m_l^2}{q^2}}\left[1+2\frac{m_l^2}{q^2}\right]\frac{1}{q^2}\left[1-\frac{q^2}{m_\eta^2}\right]^3}_{\text{QED}} \left|F_\eta(q^2)\right|^2$$

★ Parameterized using the pole approximation

$$F = \frac{1}{1-\frac{q^2}{\Lambda^2}} \approx 1 + \frac{q^2}{\Lambda^2}$$

★ ***Vector Meson Dominance Model (VDM)**** describes the q^2 dependency

V = ρ,ω,Φ…

$$F^{VDM}(q^2) = \sum_V \frac{g'_{PV\gamma}}{2g_{V\gamma}} \frac{M_V^2}{M_V^2 - q^2}$$

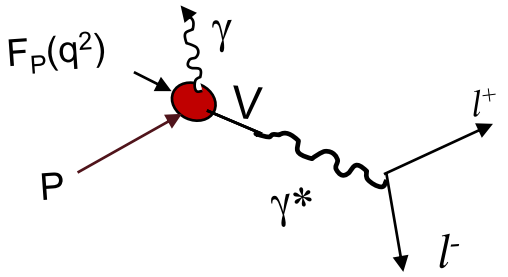


Fig: The diagram for Dalitz decay in the VDM

**L. G . Landsberg, Phys. Rep. 128, 301(1985)*

Transition Form Factor

Earlier experimental results

Experiments	Λ_η GeV	Reference
Lepton-G	0.72 0.09	R. Djeliadin, et al., Phys. Lett B 94 548 (1980)
TPC-2γ	0.70 0.08	H. Aihara et al., Z Phys. C 49, 401 (1990)
CLEO	0.774 0.0011	J. Gronberg et al., Phys. Rev. D 57, 33 (1998)
NA60	0.716 0.031 0.009	R. Arnaldi et al, Phys. Lett.B 677, 260-266 (2009)

VDM predicts $\Lambda_\eta = 0.75$ GeV

Hence the measurements also test the Models

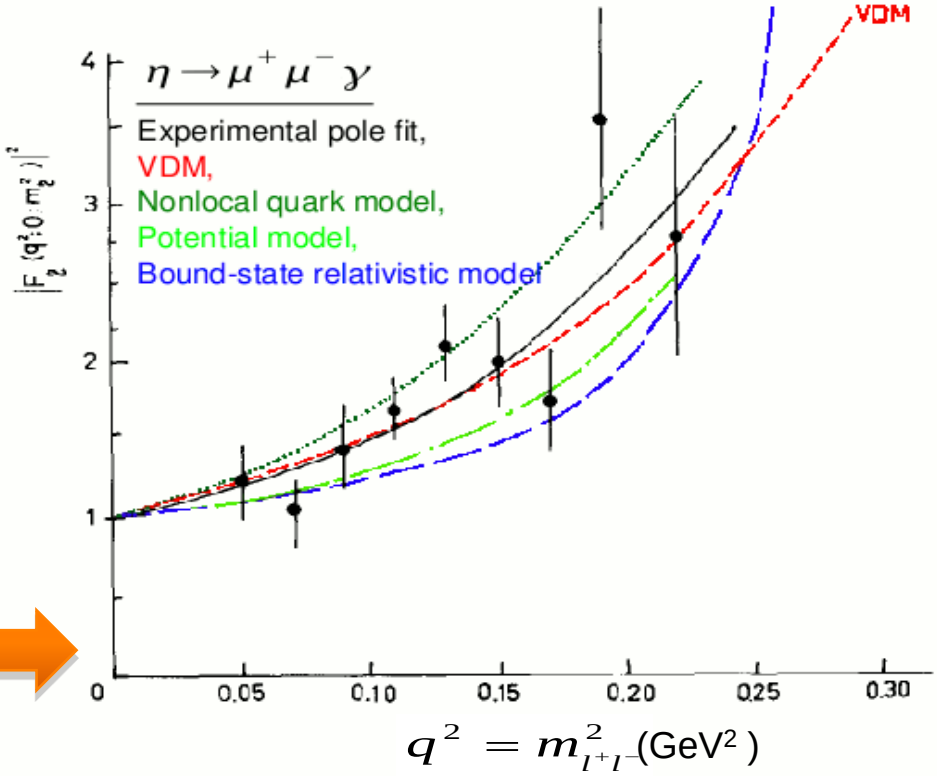


Fig: Comparison of the experimental data with the results of calculations made in a number of theoretical models

Experimental Set up

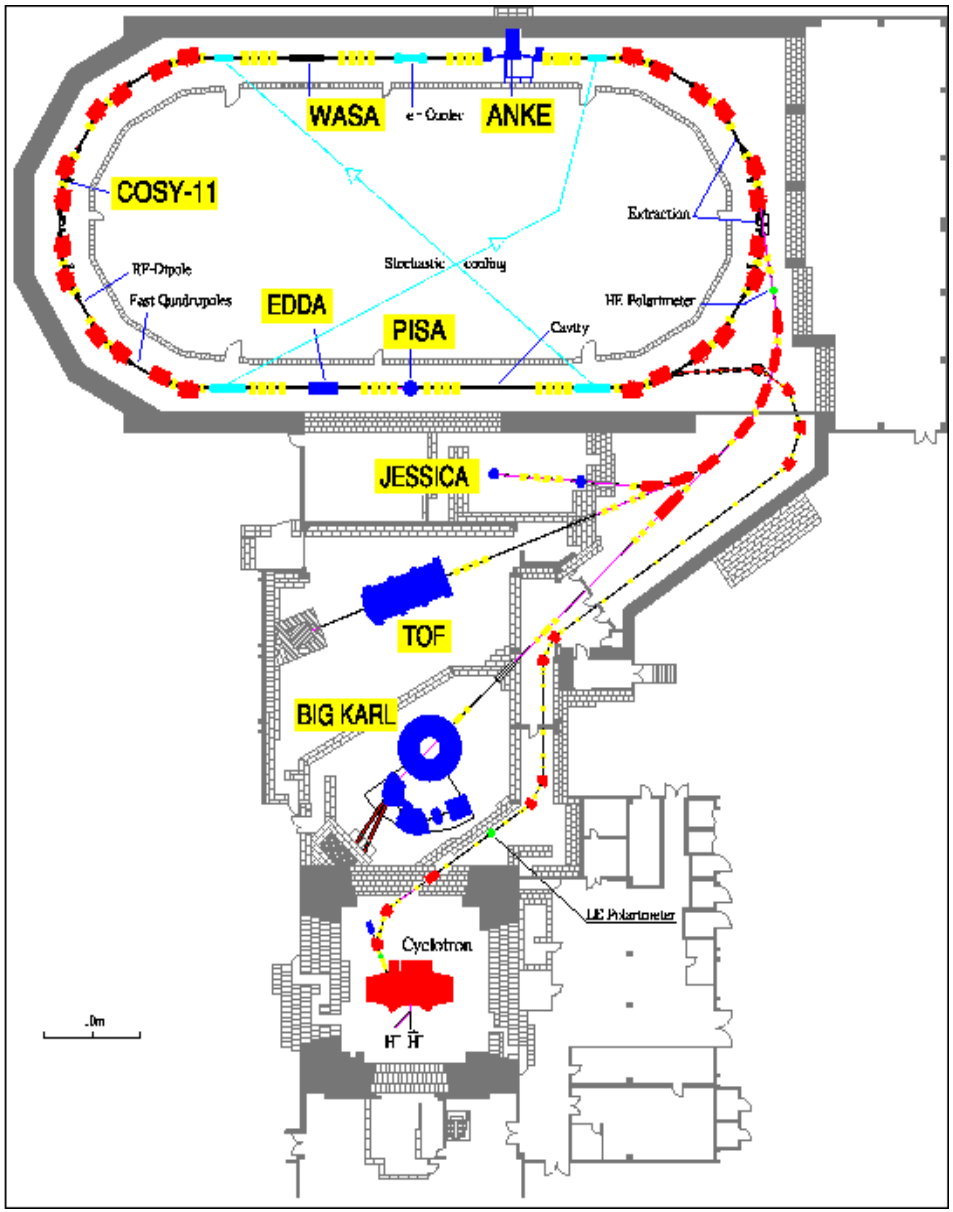


Fig : Schematic view of COSY

- Experiment has been done with WASA-at -COSY.
- WASA (Wide Angle Shower Apparatus) is an internal experiment at COSY (Juelich, Germany)
- Cosy is a Cooler Synchrotron.
- Provides a polarized and unpolarized proton and deuteron beam of momentum range 0.3 – 3.7 GeV.

Experimental Set up….

WASA Detector

Features :

- WASA at COSY is a 4π detector.
- Pellet Target : thickness ~ 35 μm

Reaction $pp \rightarrow pp\eta$ @ E_{beam} 1.4 GeV .

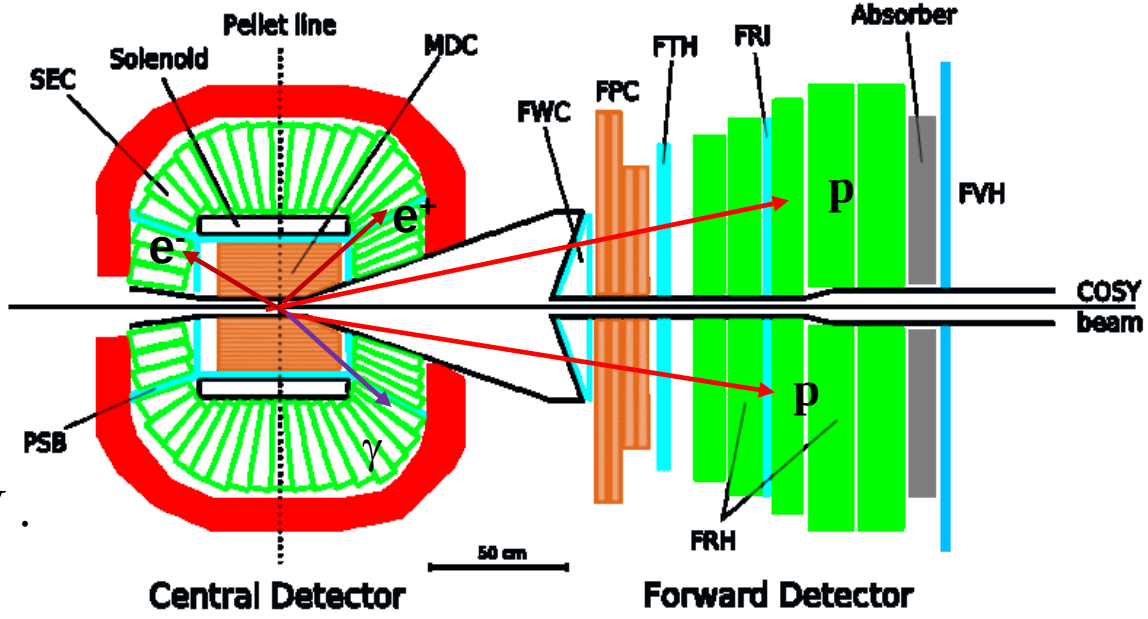
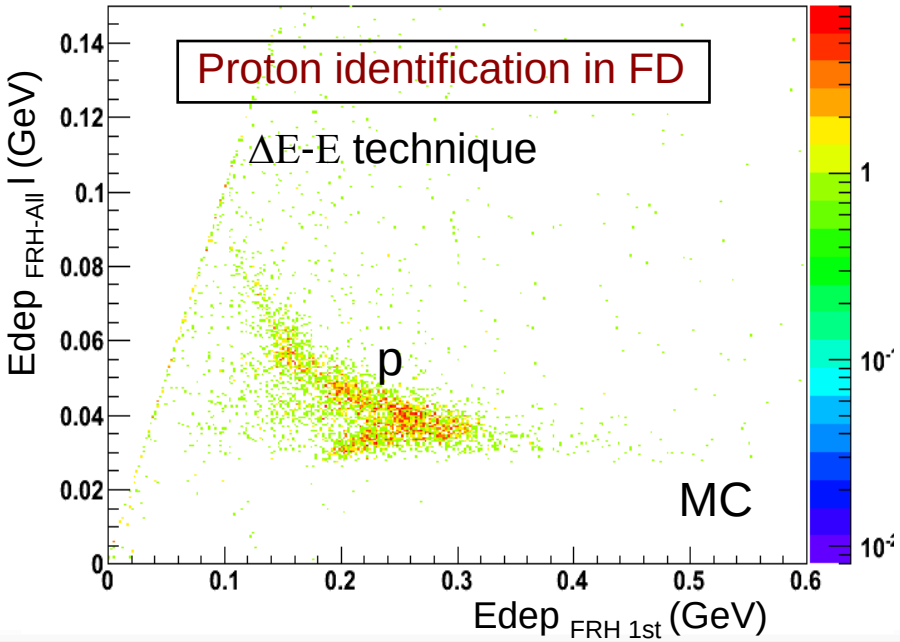
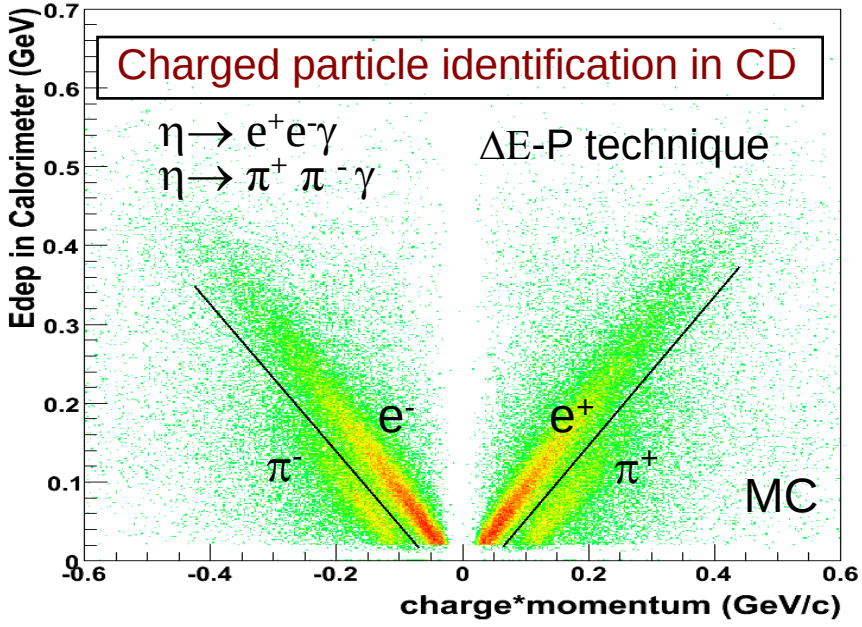


Fig: Schematic view of WASA detector





Analysis of $\eta \rightarrow e^+e^-\gamma$

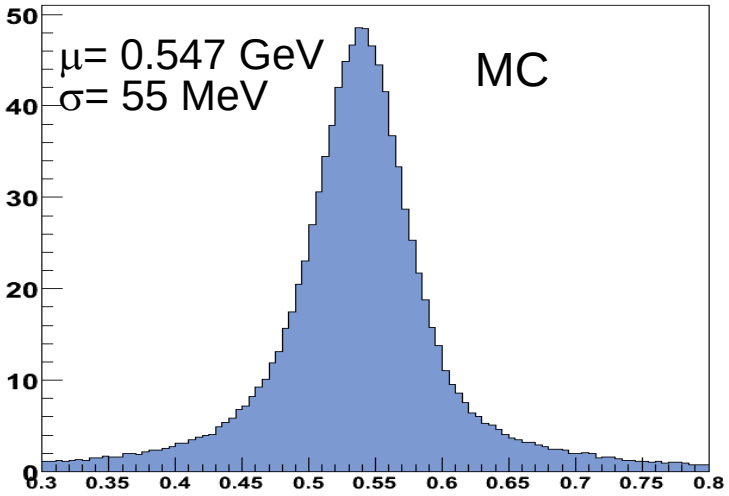
Event Selection for Dalitz decay ($pp \rightarrow pp\eta \rightarrow pp\, e^+ e^- \gamma$) :

- Two charged tracks in Forward Detector ➡ ($3^0 < \theta < 20^0$)
- Two opposite charged tracks in Central Detector .
- One neutral track in Central Detector.

} ($20^0 < \theta < 169^0$)

Invariant Mass in Central Detector

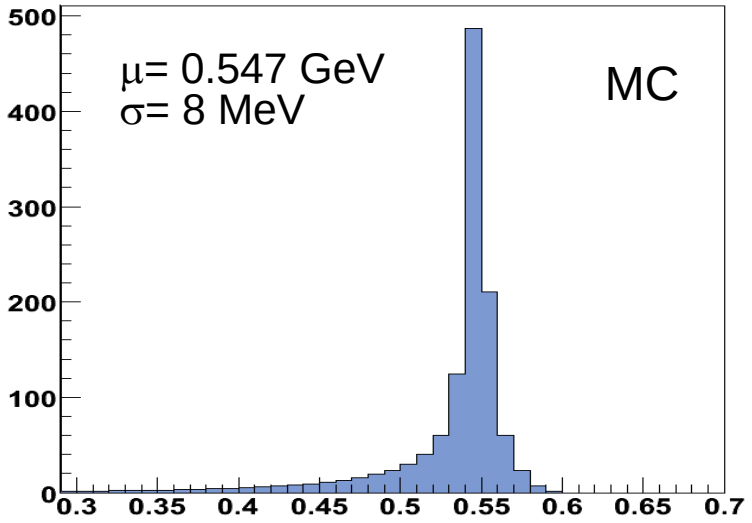
IM = sum of the decay products



Invariant Mass of $e^+e^-\gamma$ (GeV/c^2)

Missing Mass in Forward Detector

$$MM^2_{pp} = (E_{beam} - E_{p_1} - E_{p_2})^2 - (\vec{p}_{beam} - \vec{p}_{p_1} - \vec{p}_{p_2})^2$$



Missing Mass (GeV/c^2)

Simulations

10^7 events generated using **Pluto** event generator.

Channel	Cross Section(mb)/ Branching Ratio
$\eta \rightarrow e^+ e^- \gamma$	7×10^{-3}
$\eta \rightarrow \pi^+\pi^-\gamma$	4.68%
$\eta \rightarrow \pi^+\pi^-\pi^0$	22%
$\eta \rightarrow \gamma\gamma$	0.39%
$pp \rightarrow pp\ \pi^+\pi^-\pi^0$	0.02
$pp \rightarrow pp\ \pi^+\pi^-$	1

Table: cross section of signal and background.

S/B = 0.0005

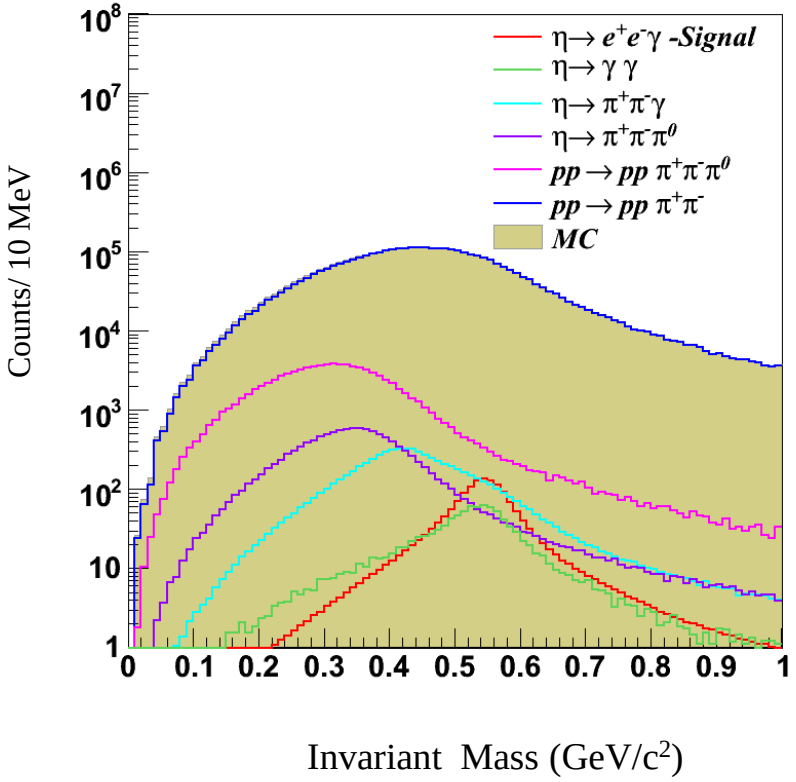
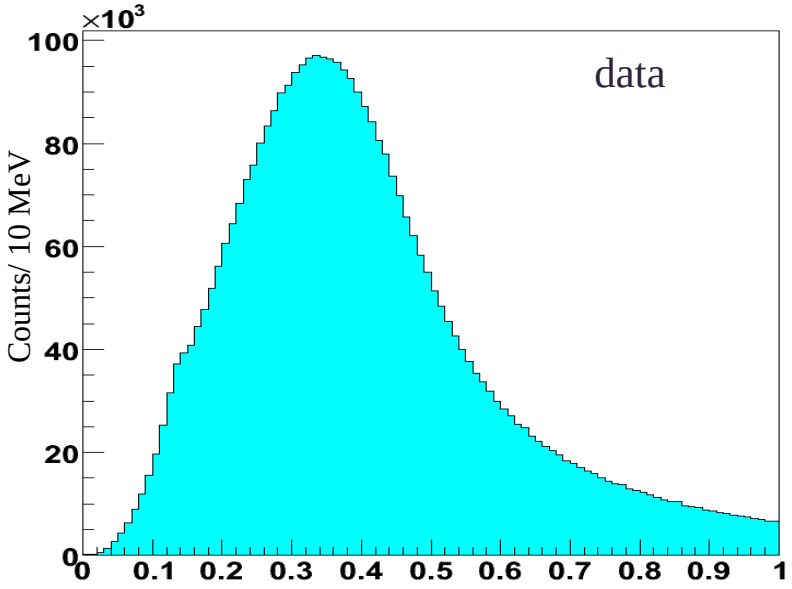


Fig: Cocktail plot of Invariant Mass (2 charged and 1 neutral track in CD)

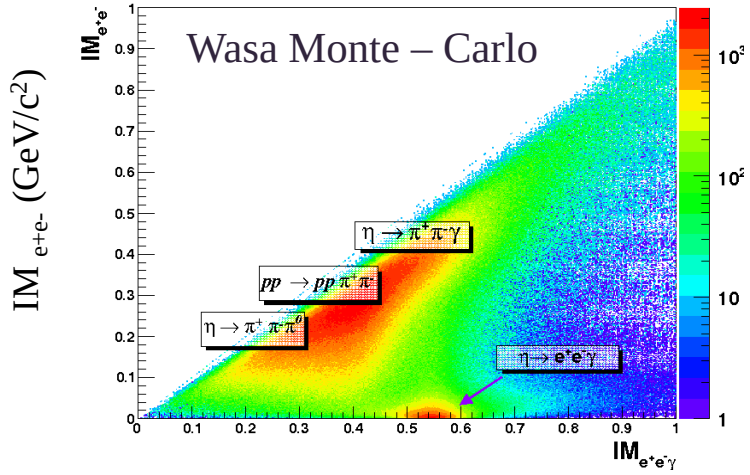
η production cross section @ 1.4 GeV ~10 mb

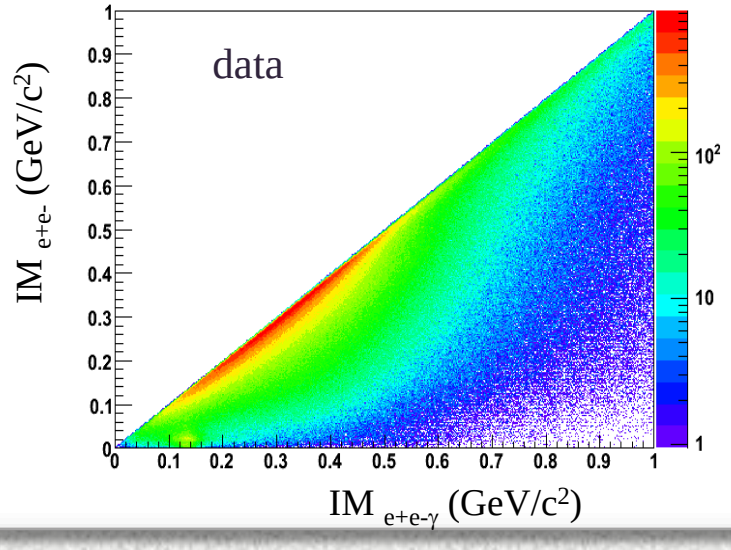
Analysis of $\eta \rightarrow e^+e^-\gamma$

Data taken in April, 2007



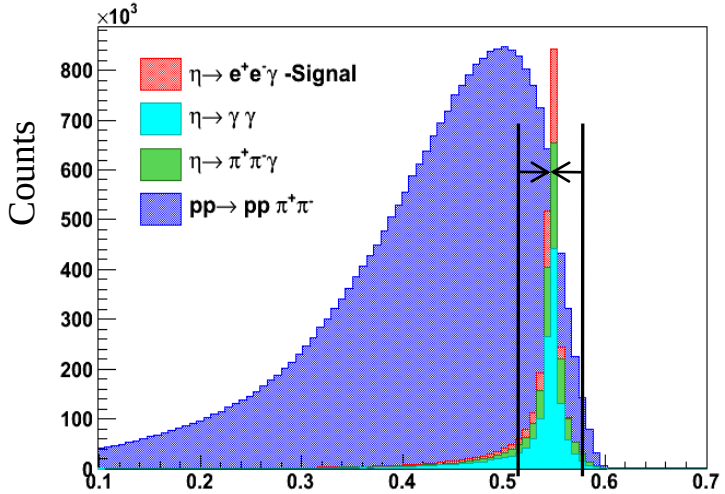
Invariant Mass of $e^+e^-\gamma$ (GeV/c^2)

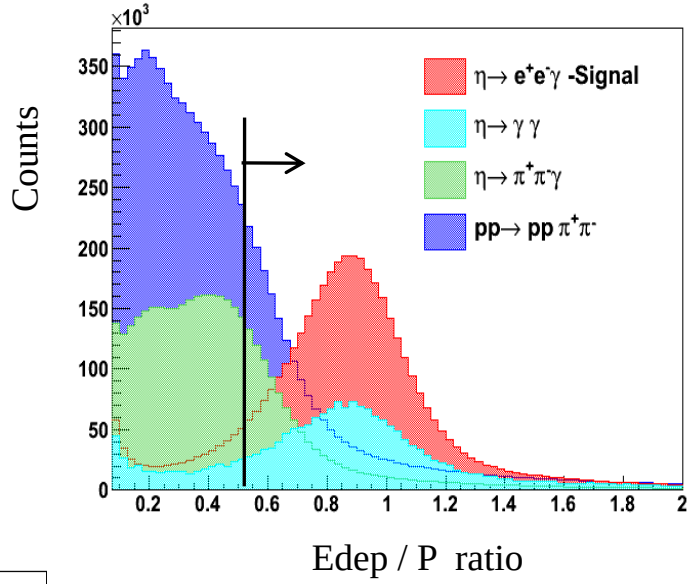


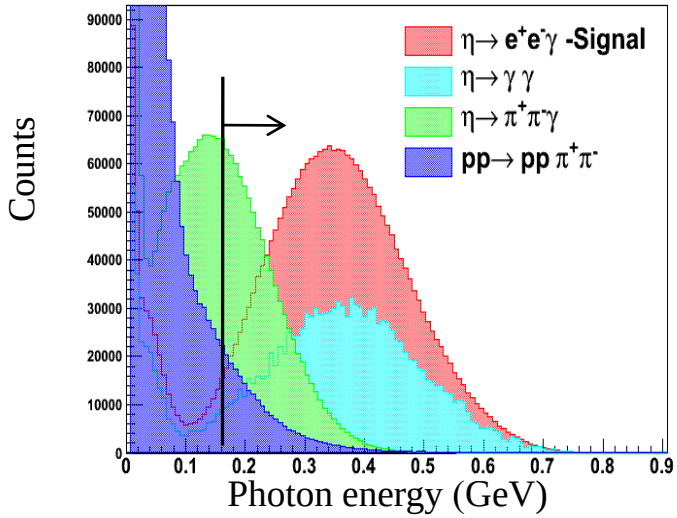


Kinematic studies

Conditions used to suppress the pion background



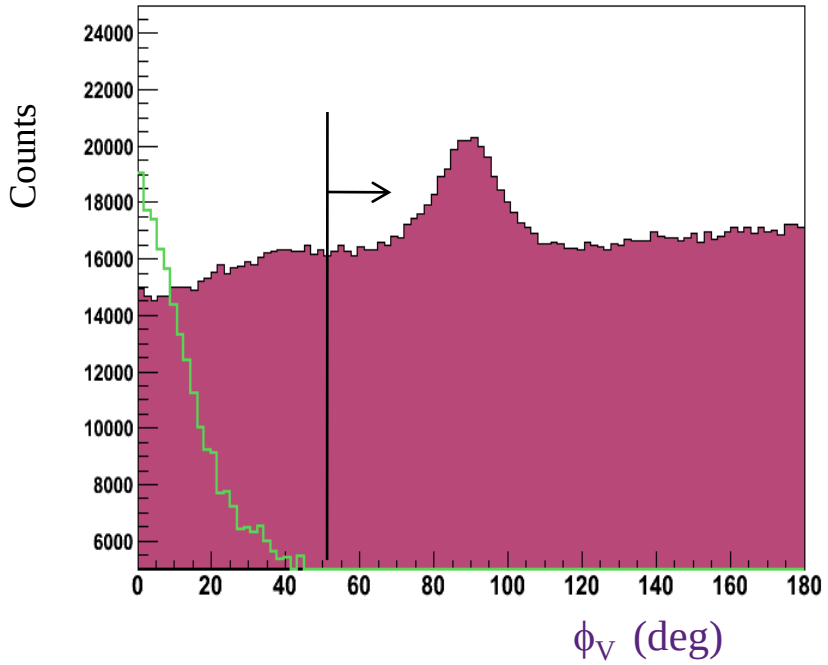


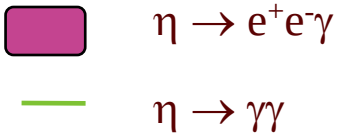


with these conditions
$\eta \rightarrow \gamma\gamma$ cannot be eliminated

Suppression of $\eta \rightarrow \gamma\gamma$

- $\eta \rightarrow \gamma\gamma$ reaction contributes as background due to external conversion of one of the photon at beam pipe.
- An orientation angle (Φ_V)* of plane of e^+ and e^- with respect to magnetic field has been calculated.



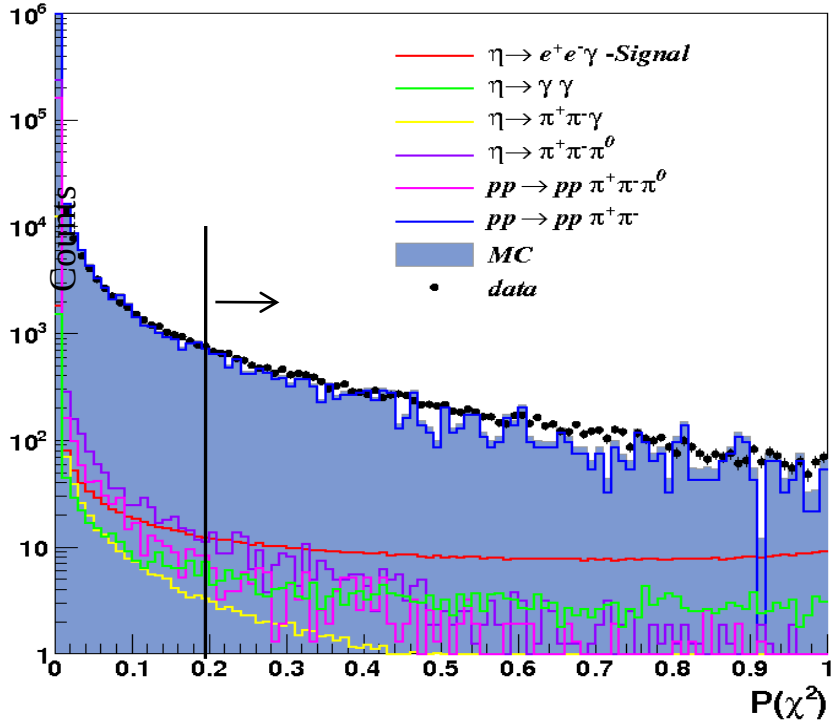


Shows different distribution for signal and $\eta \rightarrow \gamma\gamma$.

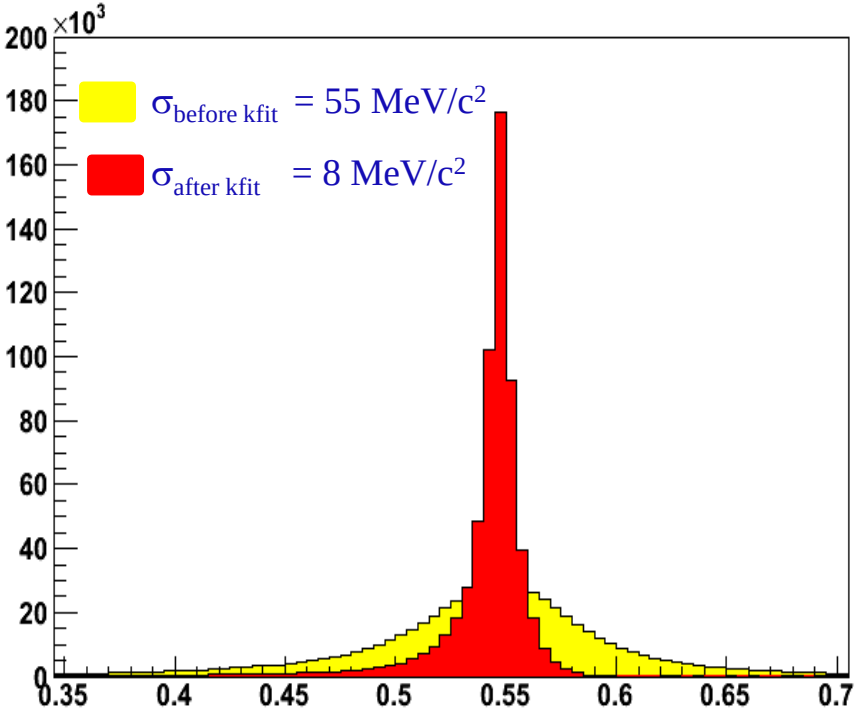
* PhD dissertation by Torsten Dahms (Stony Brook University for PHENIX) , 2008

Kinematic Fitting (kfit)

- *Use to* improve the experimental resolution.
- Constraints : 4 (Energy –momentum balance)
- It helps to suppress the background



Probability Distribution

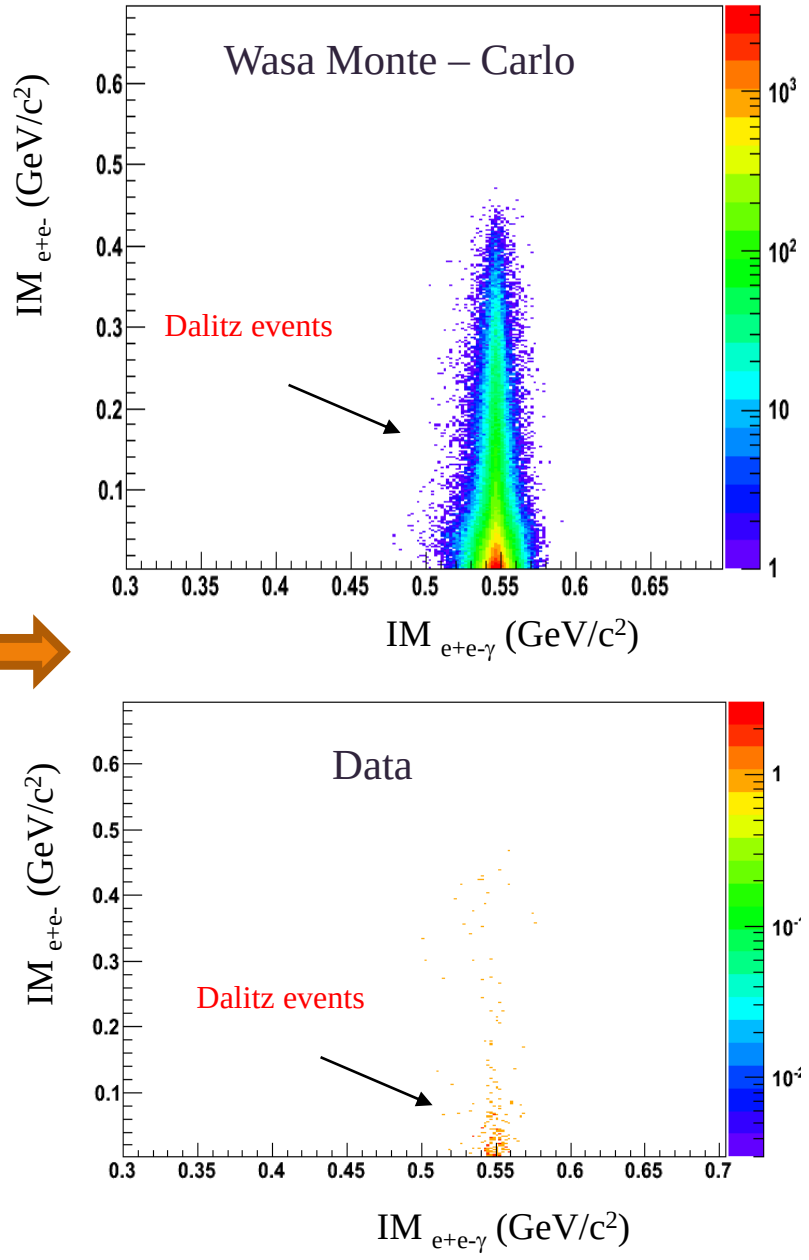


Invariant Mass (GeV/c^2)

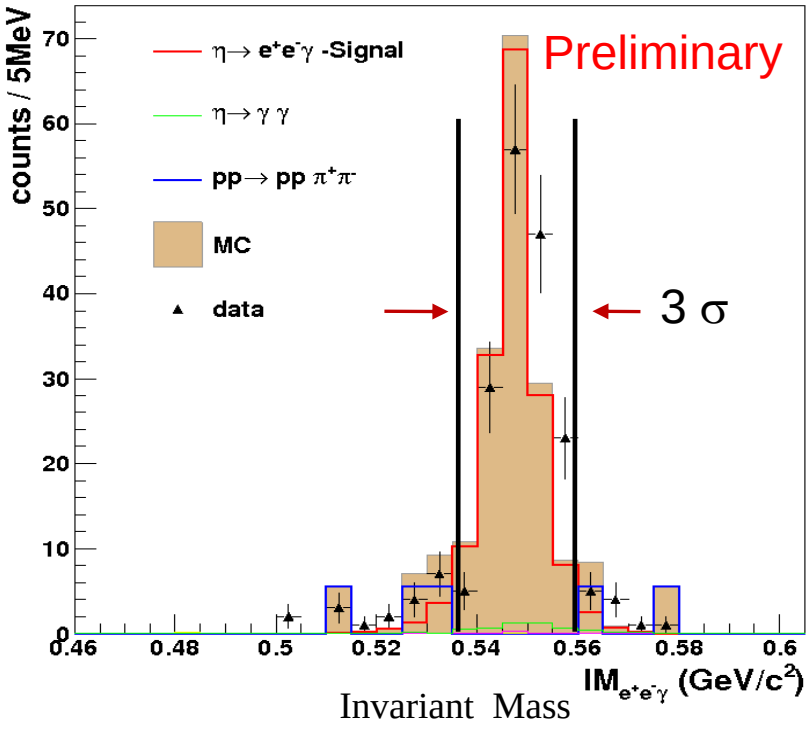
Preliminary Results

Criteria	Range
MM_{pp}	0.530 to 0.570 *GeV*
Edep/P	> 0.55
E_γ	> 180 MeV
ϕ_V	> 1.0 *rad*
$P(\chi^2)$	> 0.2

Table: Selection Criteria



Preliminary Results

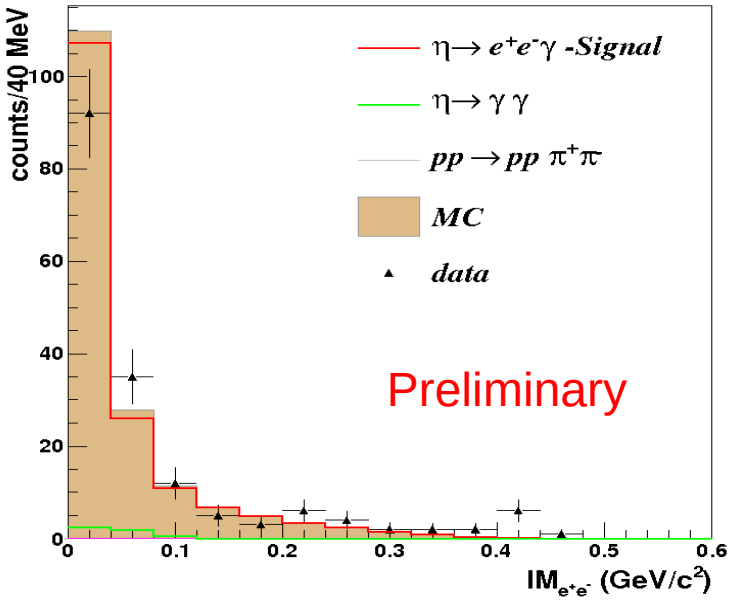


Invariant Mass

In data:

91 % $\eta \to e^+e^-\gamma$
6 % $pp \to pp\ \pi^+\pi^-$
~ 3 % $\eta \to \gamma\gamma$

S/B = 9.54



Invariant Mass of lepton pair

~ 160 13 η Dalitz events reconstructed

Summary and outlook

Summary:

- Large amount of pion background has been removed successfully.

$$S/B = 0.0005 \Longrightarrow S/B = 9.54$$

- ~ 160 13 η- Dalitz events have been reconstructed.

Future Work:

- Measurement of transition form factor needs to be done.
- To increase the statistics we are analyzing new pp data taken in Oct-2008.

Thank You