# Measurement of Transition Form Factor of $\eta$ meson with WASA detector at COSY 

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## Introduction

- How quarks and gluons are confined inside the nucleon ?
- The study of phenomenological characteristics of hadrons should lead to better understanding of QCD .
$\longrightarrow$ Transition Form Factor
- Transition Form Factor $F\left(q^{2}\right)$ is defined as :

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

where, $\left|\mathrm{d} \Gamma / \mathrm{dq}^{2}\right|$ is experimentally measured and $\left|\mathrm{d} \Gamma / \mathrm{dq}^{2}\right|_{\text {poinlike }}$ is the theoretically calculated transition probability for a point like meson.

- One can use the Dalitz decay of $\eta \rightarrow \gamma^{*} \gamma \rightarrow 1^{+} 1^{-} \gamma$.

$$
q^{2}=m_{l^{+} l^{-}}^{2}
$$

## Transition Form Factor

- Vector Meson Dominance Model (VMD) describes the $q^{2}$ dependency of the transition form factor. (L. G. Landsberg, Phys. Rep. 128, 301(1985))

$$
F^{V D M}\left(q^{2}\right)=\sum_{V} \frac{g^{\prime{ }_{P V \gamma}}}{2 g_{V \gamma}} \frac{M_{V}^{2}}{M_{V}^{2}-q^{2}}
$$



- The transition form factor of a scalar meson is parameterized using the pole approximation

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

- Additionally one can determine the slope of the transition form factor

$$
b_{\eta}=\left.\frac{d F_{\eta}}{d q^{2}}\right|_{q^{2}=0}=\frac{1}{\Lambda^{2}}
$$

## Transition Form Factor

Earlier results by investigating the Dalitz decays : $\eta \rightarrow e^{+} e^{-\gamma}$ and $\eta \rightarrow \mu^{+} \mu \gamma$

| Experiments | $b_{\eta} / \mathrm{GeV}^{-2}$ |
| :---: | :---: |
| Lepton-G $^{1}$ | $1.9 \pm 0.04$ |
| NA60 |  |
| SND $^{3}$ | $1.95 \pm 0.17 \pm 0.05$ |
| HADES $^{4}$ | $1.6 \pm 2.0$ |


$V D M$ predicts $b_{\eta}=1.8 \mathrm{GeV}^{-2}$

Hence the measurements also test VMD

1 R. Djeliadin, et al., Phys. Lett. B 94 (1980) 548.
2. R. Arnaldi et. al , Phys. Lett .B 677(2009), 260-266).
3. M.N. Achsov et. al. , Phys. Lett. B 504 (2001) 275 -281
4. B. Spruck, GSI Scientific Report, 2008


- WASA (Wide Angle Shower Apparatus) at COSY ( Juelich , Germany )is a $4 \pi$ detector
- Data analyzed with reaction :
$\mathrm{pp} \rightarrow \mathrm{pp} \mathrm{\eta}\left(\mathrm{e}^{+} \mathrm{e}^{-} \gamma\right)$, at beam kinetic energy 1.4 GeV .


## Analysis

, Event Selection for Dalitz decay ( $\mathrm{pp} \rightarrow \mathrm{pp} \mathrm{\eta} \rightarrow \mathrm{pp} \mathrm{e}^{+} \mathrm{e}^{-\gamma}$ ).

- Two charged tracks in FD
- Two charged tracks in CD having opposite charge
- One neutral track in CD with $\mathrm{E}_{\text {dep }}>180 \mathrm{MeV}$
- Invariant Mass is obtained by summing the reconstructed masses of the decay products of $\eta$ meson ( $\mathrm{e}^{+}, \mathrm{e}^{-}, \gamma$ ).
. Missing Mass is obtained as following:

$$
M M_{p p}^{2}=\left(E_{\text {beam }}-E_{p_{1}}-E_{p_{2}}\right)^{2}-\left(\vec{p}_{\text {beam }}-\vec{p}_{p_{1}}-\vec{p}_{p_{2}}\right)^{2}
$$

where, $E_{p}$ and $\vec{p}$ are energy and momentum of scattered proton.

## Simulations studies

$10^{7}$ events generated using Pluto event generator.

| Channel | Cross section |
| :---: | :---: |
| $\eta \rightarrow \mathrm{e}^{+} \mathrm{e}^{-} \gamma$ | $6.8 \times 10^{-5}$ |
| $\eta \rightarrow \pi^{+} \pi^{-} \gamma$ | $4.68 \times 10^{-4}$ |
| $\eta \rightarrow \pi^{+} \pi^{-} \pi^{0}$ | $2.2 \times 10^{-3}$ |
| $\eta \rightarrow \gamma \gamma$ | $3.9 \times 10^{-3}$ |
| $p p \rightarrow p p \pi^{+} \pi^{-} \pi^{0}$ | 0.02 |
| $p p \rightarrow p p \pi^{+} \pi^{-}$ | 1 |
| cross section of signal and background. |  |

$\mathrm{S} / \mathrm{B}=0.0005$


Invariant Mass $\left(\mathrm{GeV} / \mathrm{c}^{2}\right)$

Analysis


Data from the production run April 07


Total $10^{7} \eta$ produced



## Kinematic studies

Conditions are used to suppress the background coming from direct pion production


Scattering angle of $\eta$ in the lab system.

| $\square$ | $\eta \rightarrow \mathbf{e}^{+} \mathbf{e}^{-} \gamma$ |
| :--- | :--- |
| $\square$ | $\mathbf{p p} \rightarrow \mathbf{p p} \pi^{+} \pi^{-} \pi^{0}$ |
| $\square$ | $\mathbf{p p} \rightarrow \mathbf{p p} \pi^{+} \pi^{-}$ |



Phi angle diff. between photon and lepton pair in the lab system.


Kinematic studies


Conditions are used to suppress the pion background coming from $\eta$ decays


Opening angle between photon and lepton pair in the lab system



Opening angle between photon and electron in the lab system
with these conditions
$\eta \rightarrow \gamma \gamma$ cannot be eliminated

Edep / P ratio

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

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


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

Preliminary Results


After conditions

Selection Criteria

| Criteria | Range |
| :---: | :---: |
| $M M_{\eta}$ | 1.80 to 2.0 GeV |
| $E d e p / P$ | 0.7 to 1.3 |
| $\theta_{\gamma^{*}}$ | 1.4 to 2.2 rad |
| $\Delta \Phi_{\gamma^{*}}$ | $135^{\circ}$ to $220^{\circ}$ |
| $\phi_{V}$ | $>1.2 \mathrm{rad}$ |
| $\theta_{\gamma e}$ | $75^{0}$ to $140^{0}$ |
| $\theta \eta$ | $<30^{\circ}$ |



## Preliminary Results


$270 \pm 18$ Dalitz's events with in $3 \sigma$


## Summary and outlook

$\Rightarrow$ Large amount of pion background has been removed successfully.
$\Rightarrow 270 \pm 18, \eta$ - Dalitz events have been reconstructed .

- For further cleaning the data, use of kinematic fitting is being investigated.
- To increase the statistics we are analyzing new pp data taken in Oct-2008.

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

Angular orientation of the plane $\boldsymbol{v}$ (vector product of $\boldsymbol{p}_{e_{+}}$and $\boldsymbol{p}_{e_{-}}$) define as follows:

$$
\Phi_{V}=\cos ^{-1}\left(\frac{\vec{w} \cdot \vec{u}_{a}}{|\vec{w}| \vec{u}_{a} \mid}\right)
$$

where, $\vec{u}=\frac{\vec{p}_{e^{+}}+\vec{p}_{e^{-}}}{\vec{p}_{e^{+}}+\vec{p}_{e^{-}} \mid}$is the apparent decay plane of the conversion pair.

$$
\vec{v}=\vec{p}_{e^{+}} \times \vec{p}_{e^{-}} \quad, \quad \vec{w}=\vec{u} \times \vec{v} \quad \text { and } \quad \overrightarrow{\boldsymbol{u}}_{a}=\frac{\overrightarrow{\boldsymbol{u}} \times \hat{z}}{|\overrightarrow{\boldsymbol{u}} \times \hat{z}|}
$$

