Symmetry Breaking and Transition Form Factors from Eta and Omega Decays

Ankhi Roy: for the WASA-at-COSY Collaboration

Indian Institute of Technology Indore

Physics Program of WASA-at-COSY collaboration

Meson Decays -

- Symmetries and Symmetry Violation
- Branching Ratio of Rare Decays
- Transition Form Factors (Dalitz Decays)

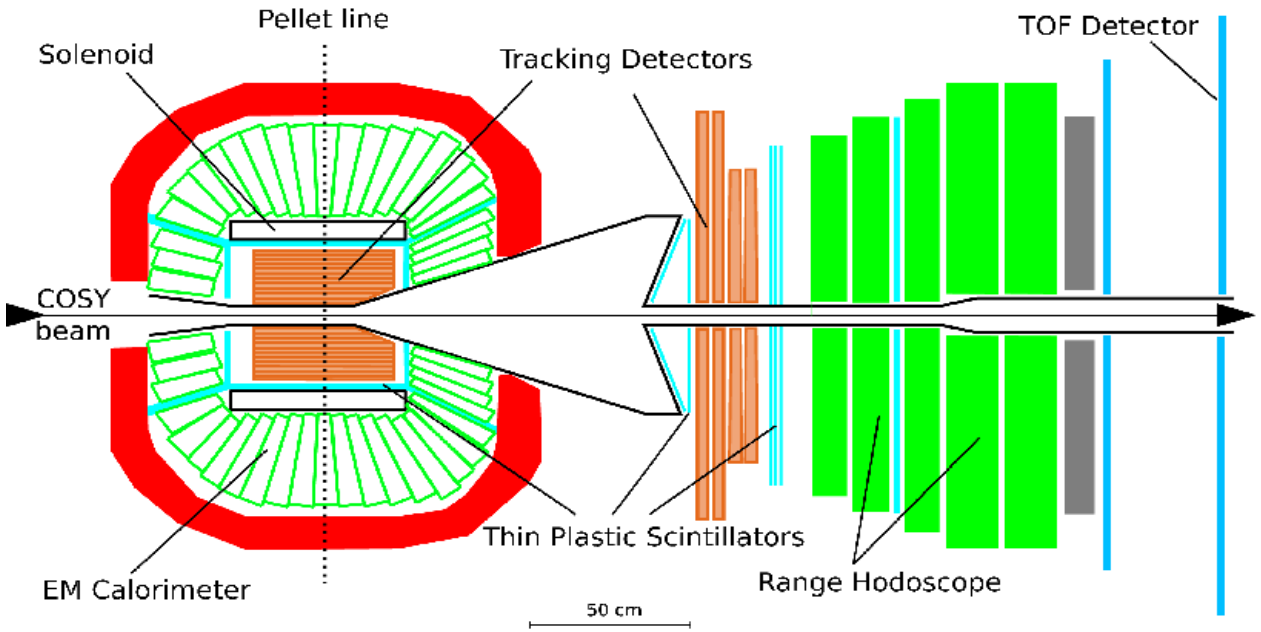
Topics of my talk-

- CP and C violating Decay
- Transition form factor of different mesons

Experimental Setup:

$p(beam) + p(target) \rightarrow ppX(mesons)$

$p + d \rightarrow {}^3 HeX$



- Large solid angle acceptance
- Pellet Target System (High Density and high purity)
- High granularity central and forward tracking detector
- Identification of all final state particles

status of η production

pd $\rightarrow$ ^{3}He η

$T_p = 1.0\ GeV$

$10\eta/s$ $(0.4\mu b)$

4+8 weeks (2008,2009)

$3 \cdot 10^7$ η decays (unbiased)

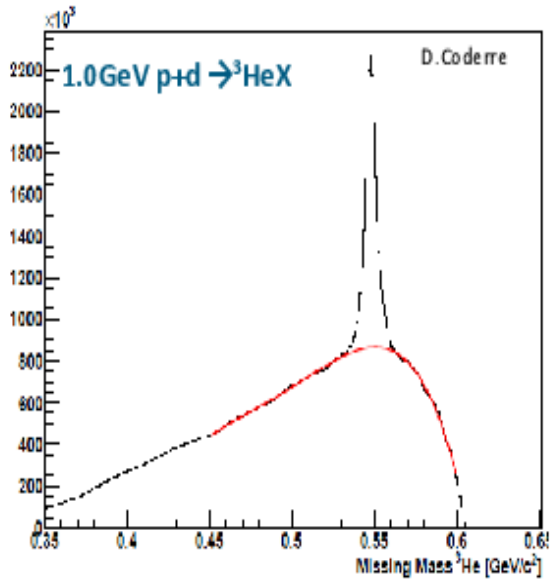
pp $\rightarrow$ pp η

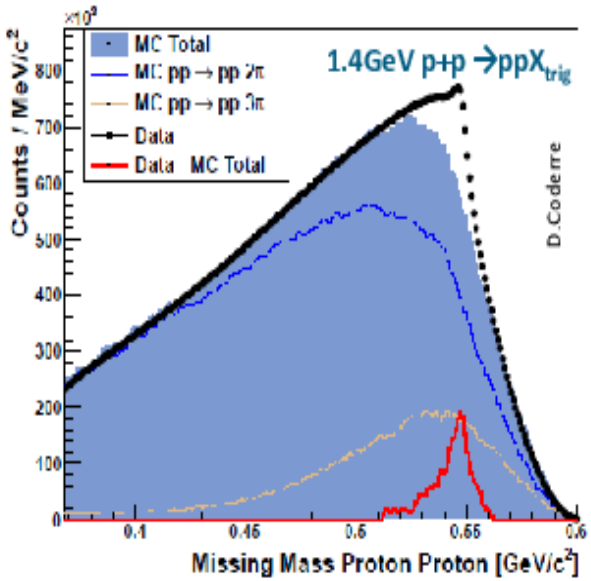
$T_p = 1.4\ GeV$

$100\eta/s$ $(10\mu b)$

4+8+7 weeks
(2007+2008,2010,2012)

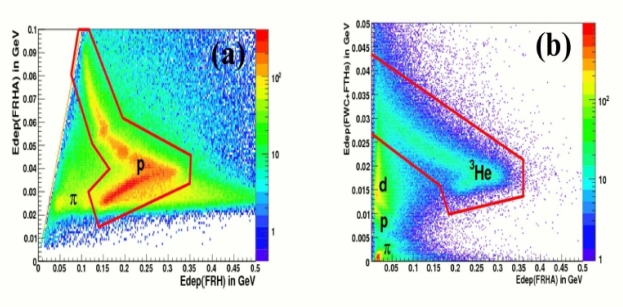
10^9 η decays



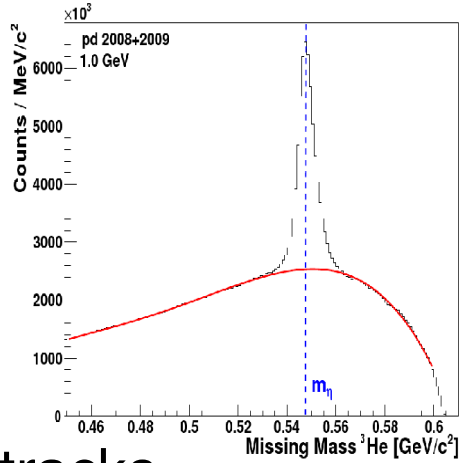


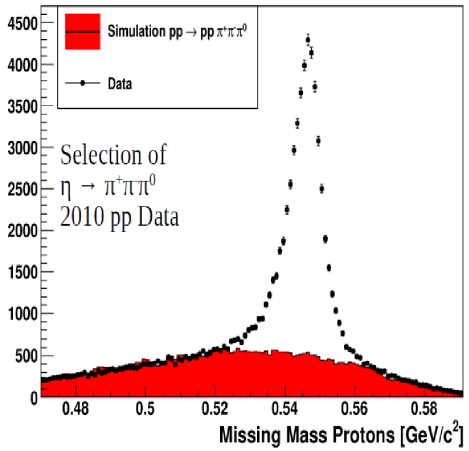
Analysis Method

- Identification of recoil particles

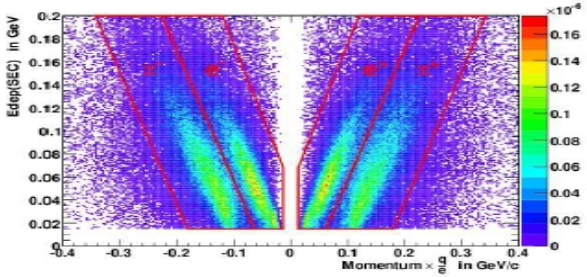


- Missing Mass





- Identification of charged tracks



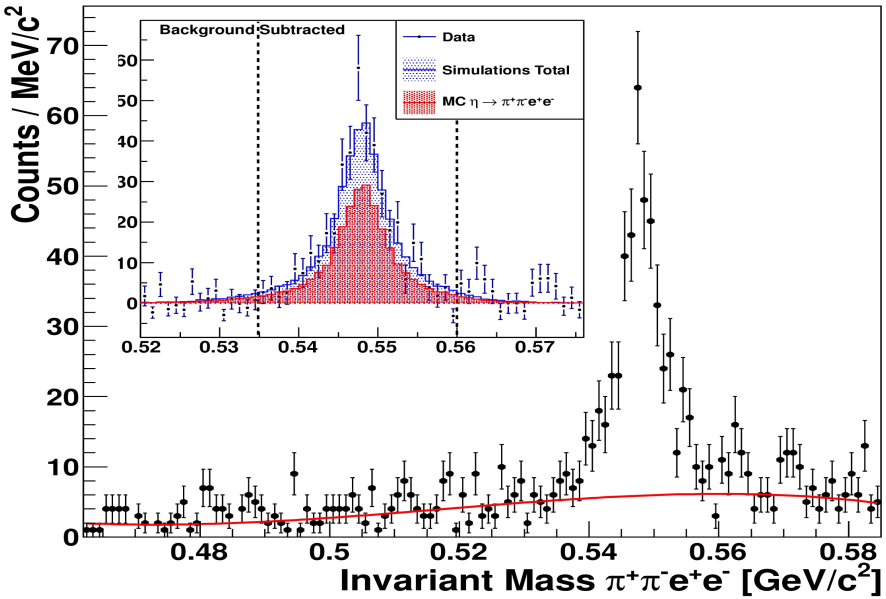
- Invariant Mass
- Kinematic Fitting
- Subtraction of Different background channels

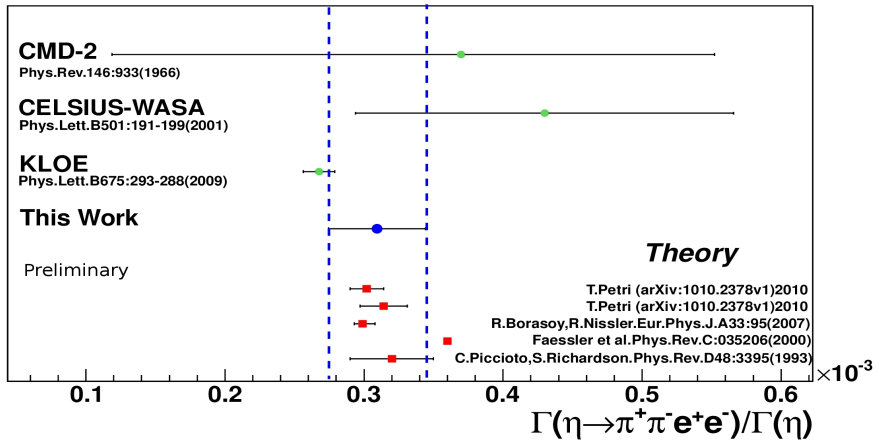
Branching Ratio : $\eta \to \pi^+\pi^- e^+ e^-$

CP violating Decay mode

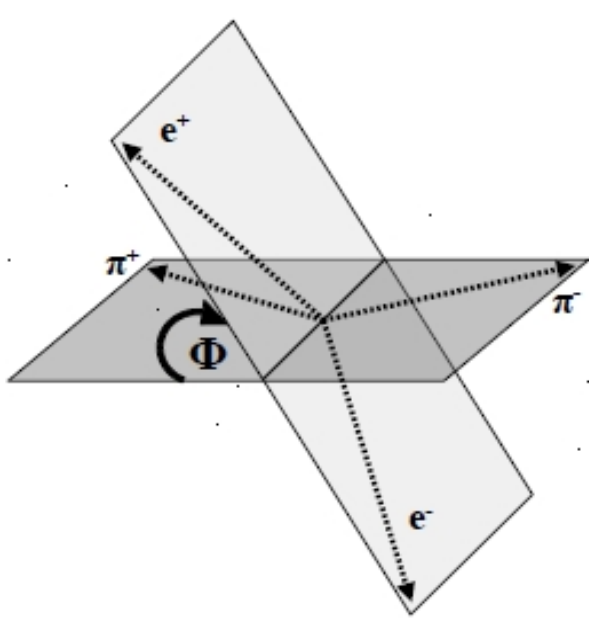
Analysis - Daniel Coderre

- Relative Branching Ratio with identical final states reduce systematic effects $\frac{\Gamma(\eta\to\pi^+\pi^- e^+ e^-)}{\Gamma(\eta\to\pi^+\pi^-(\pi^0\to e^+ e^-\gamma))}$
- Preliminary Result:
  $\mathrm{BR}(\eta \to \pi^+\pi^- e^+ e^-) = (3.10 \pm 0.27_{stat} \pm 0.22_{sys}) \times 10^{-4}$



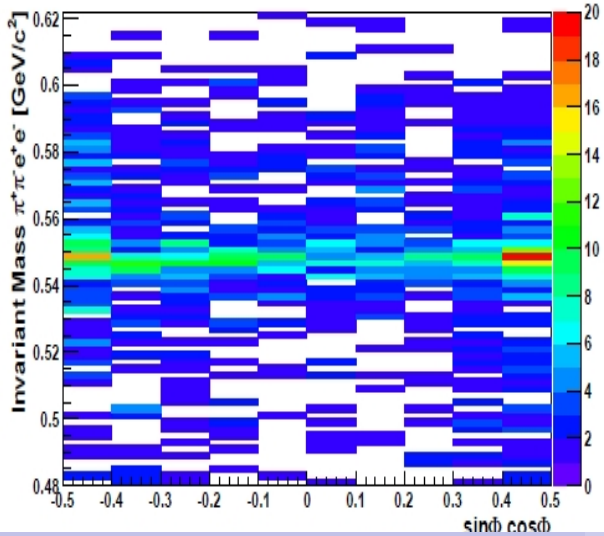


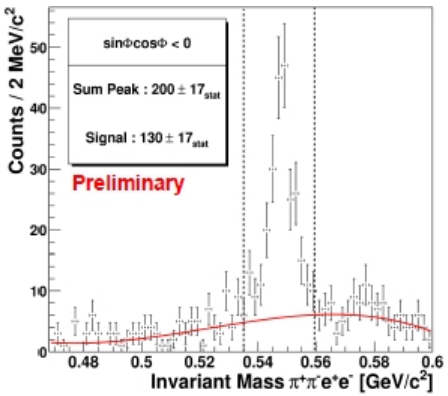
CP-violation in $\eta \to \pi^+\pi^- e^+ e^-$ pd data

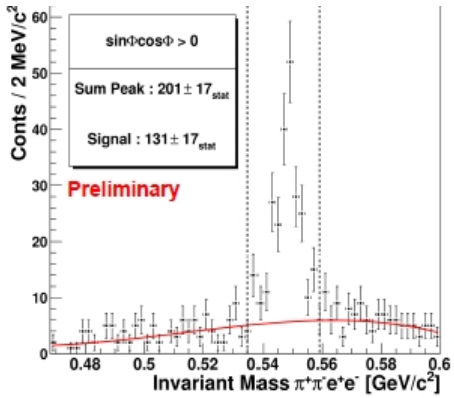


- Asymmetry of the angle betwn the electron and the pion decay plane→CP violation observable
- $A_\phi = \frac{Count(sin\phi cos\phi>0) - Count(sin\phi cos\phi<0)}{Count(sin\phi cos\phi>0) + Count(sin\phi cos\phi<0)}$

$A_\phi = (0.4 \pm 9.0_{stat} \pm 2.8_{sys}) \times 10^{-2}$ (Preliminary) compatiable with zero within errors





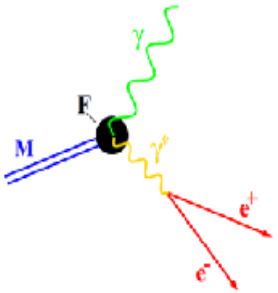


C-violating Decay : $\eta \to \pi^0 e^+ e^-$

- Decay $\eta \to \pi^0 e^+ e^-$ is forbidden since it violates the C-parity conservation $C(\pi^0 + \gamma^*) = (+1).(-1) = -1 \neq C(\eta)$
- Current Upper Limit BR($\eta \to \pi^0 e^+ e^-$) $< 4 \times 10^{-5}$ [PDG-2010]
- Aim : Lowering the existing upper limit by high statistics measurements at WASA-at-COSY to test the C-parity conservation with increased sensitivity and search for Physics beyond the Standard Model
- Status : 1st data set : $10^7 p + d \to^3 He + \eta$ events
  After applying all cuts on the measured data one out of 1.7×10^8 events remains (PhD Thesis A. Winnemoller)
- Currently under evaluation : additional 2×10^7 $p + d \to^3 He + \eta$
- In addition : $10^9 p + p \to p + p + \eta$ events on disk

Transition Form Factor: $M \to \gamma\gamma^* \to \gamma l^+ l^-$

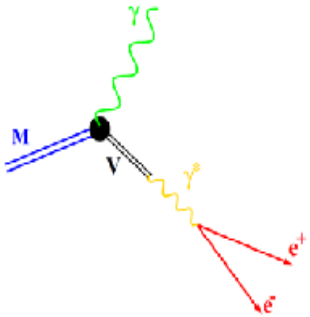
$M \to \gamma e^+ e^-$



Transition Form Factor $F(q^2)$:

$$\frac{d\Gamma_{\gamma e^+e^-}}{dq^2} = \left[\frac{d\Gamma_{\gamma e^+e^-}}{dq^2}\right]_{\text{QED}} |F(q^2)|^2$$

$$= \frac{2\alpha}{3\pi}\frac{\Gamma_{2\gamma}}{q^2}\left(1-\frac{q^2}{m_M}\right)^3 |F(q^2)|^2$$



Form Factor $F(q^2)$:

$$F(q^2) = \frac{1}{1 - q^2/m_V^2}$$

Vector meson ρ :

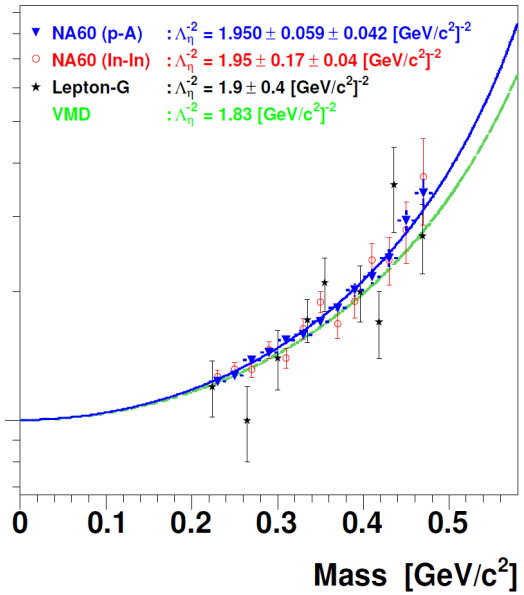
$$m_V = m_\rho = 0.77 \text{ GeV}$$

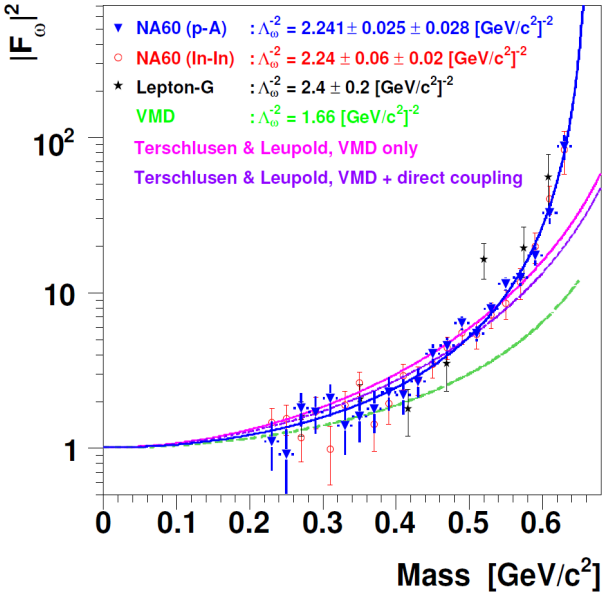
$\Rightarrow$ **Resonance at** $m_{\gamma^*}{=}q{=}m_\rho$

'standard VMD'

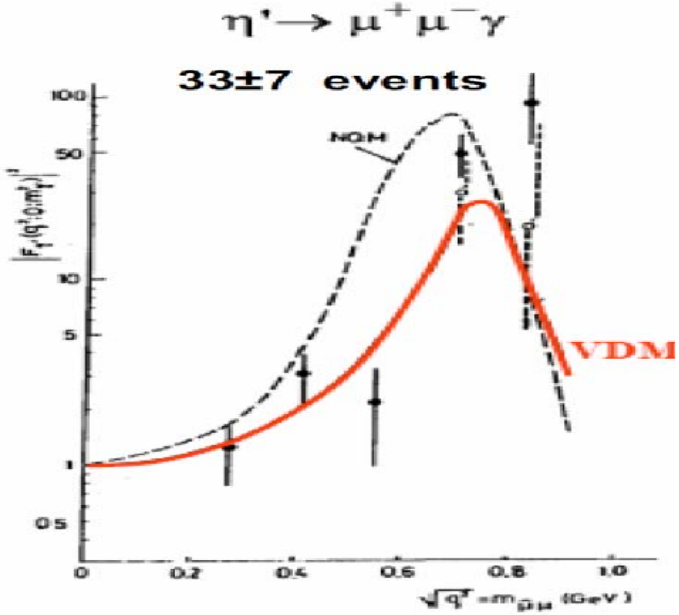
Transition Form Factor :

- $\eta \to \gamma\mu^+\mu^-$ $\omega \to \pi^0\mu^+\mu^-$ $\eta' \to \gamma\mu^+\mu^-$





NA60 pA reactions, A.Uras, J.Phys. Conf. Ser. 270(2011)012038

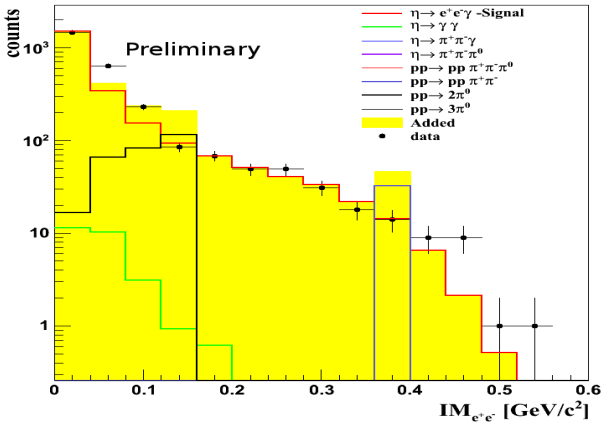


G. Landsberg, Phys. Rep. 128 (1985) 301

- for ω meson clearly additional mechanism apart from standard VMD
- Recent theoretical advance: C. Terschlusen and St. Leupold, Phys. Lett B 691(2010) 191-201 Chiral Lagrangian including light vector mesons and Goldstone Bosons.
- Different experimental approach : elementary reactions, using di-electrons, photon detection

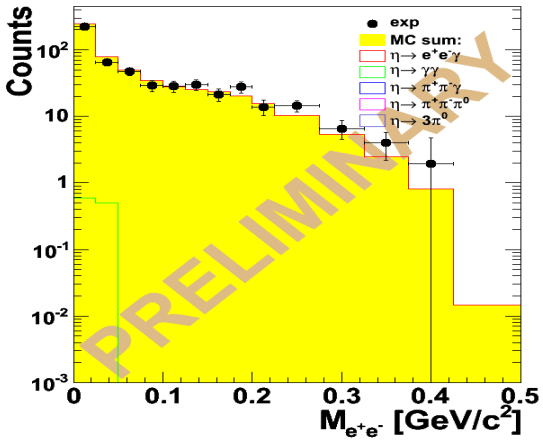
Transition Form Factor of η meson:

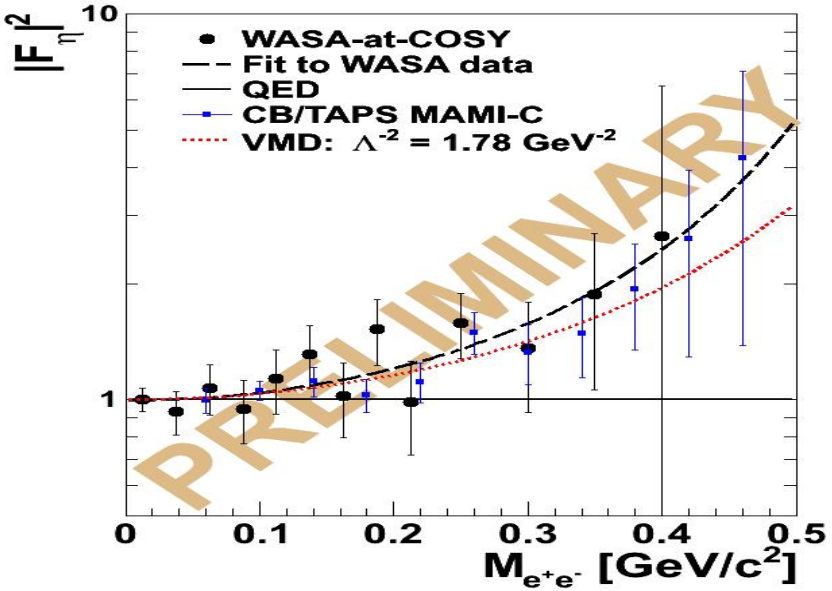
Analysis - H. Bhatt & M. Hodanna



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

$pd \to {}^3He\eta$	$pp \to pp\eta$
525 ± 26 events	2659 ± 51 events
Based on 3×10^7 $^3He\eta$	Based on 10^7 pp





Transition Form Factor of $\omega\pi^0$ meson

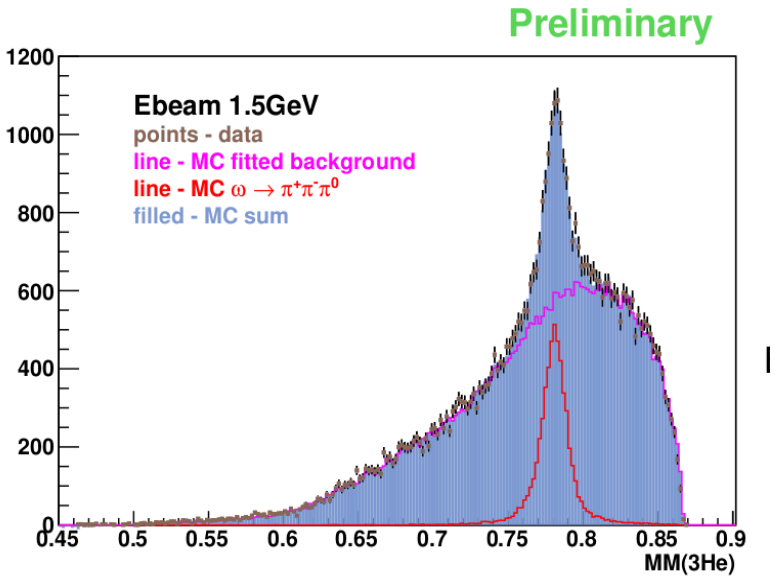
Analysis - F. Khan & A. Goswami

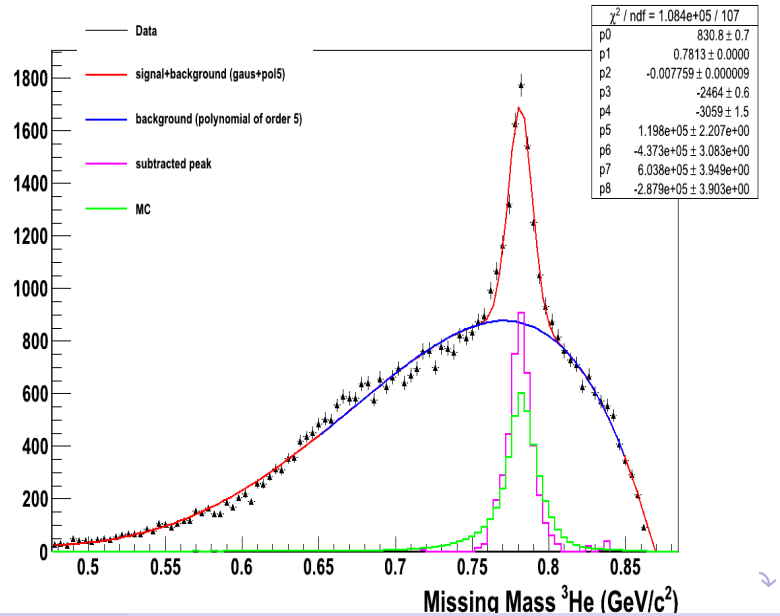
L.Heijkenskjold & S. Sawant

Studies of ω in pd

Missing mass of ^{3}He after $\pi^0\pi^+\pi^-$

Missing mass of ^{3}He after $\pi^0\gamma$ selection (1.5 *GeV*)





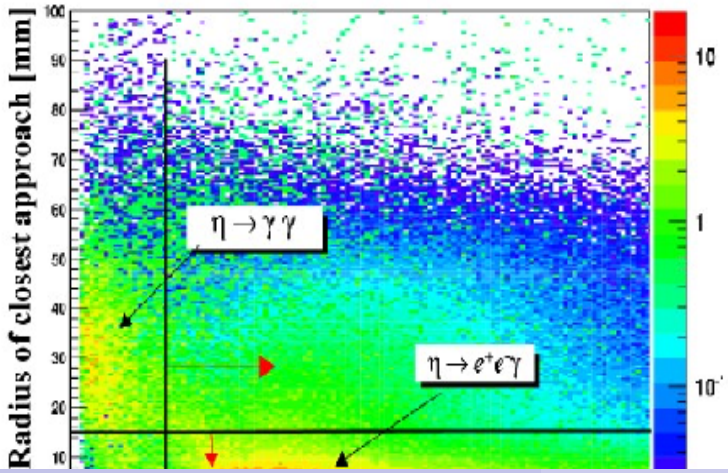
Summary and Outlook :

- Branching Ratio of very rare decay channels like $\eta \rightarrow e^+e^-$ (5×10^8 η meson from pp)
- η , $\omega\pi$ Transition Form Factor

Back up

External Conversion Subtraction Techniques:

Radius of Closest Approach of e^+e^- in MDC as a function of Invariant Mass at beam pipe



Orientation Angle (ϕ^*_V) of plane of pair with respect to magnetic field