Hadronic decays of the ω meson measured with WASA-at-COSY

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for the WASA-at-COSY collaboration

Uppsala University

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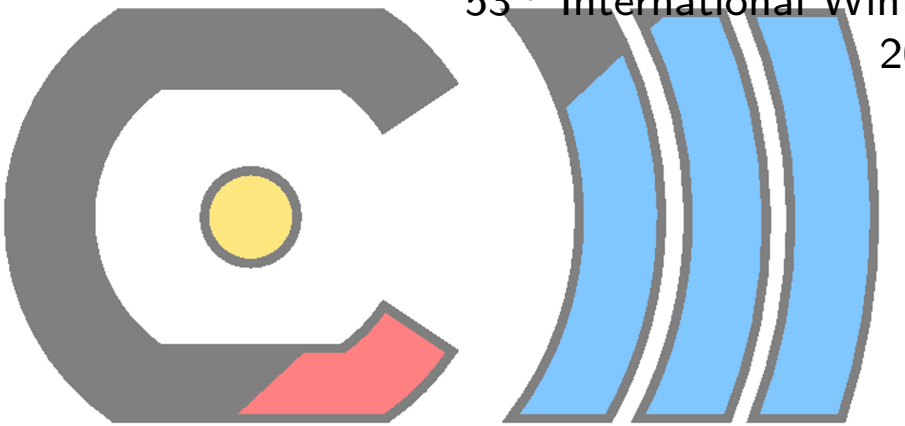
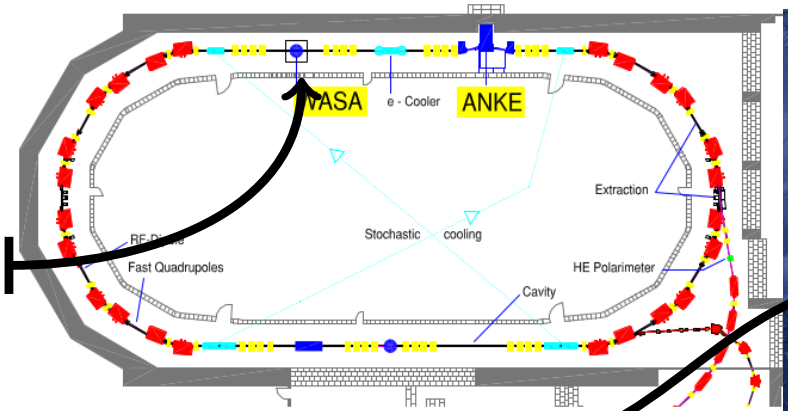


The WASA program

WASA-at-COSY

36 institutes



COSY
Cooler Synchrotron

Study of the decays of the light mesons π^0, η and ω
ideal for investigations of physics in the medium energy range

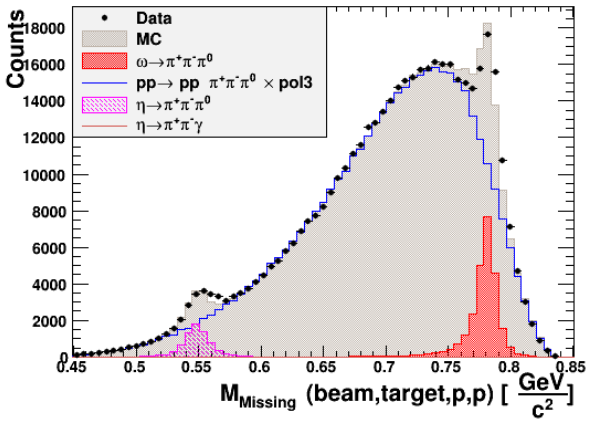
- Precision tests and experimental input to ChPT
- Form factor measurements
- Test symmetries and their breaking
- Search for physics beyond the Standard Model

Studies of ω meson with WASA

Collected data sets

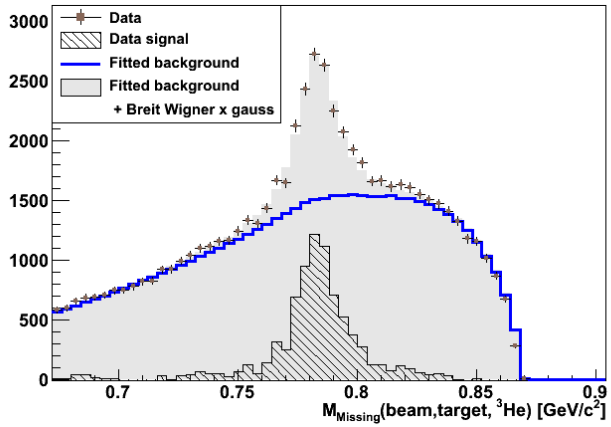
Two complementary near threshold production reactions:

$p + p \to p + p + \omega$



Pilot run, ca 20 000 $\omega \to 3\pi$ events

$p + d \to {}^3\mathrm{He} + \omega$



$\sim$ 2 weeks, ca 24 000 $\omega \to 3\pi$ events

Ongoing studies

Decay	Branching ratio	Interesting physics
$\omega \to \pi^+\pi^-\pi^0$	89.2×10^{-2}	Dalitz plot parameters
$\omega \to \pi^0\gamma$	8.28×10^{-2}	Branching ratio
$\omega \to \pi^+\pi^-$	1.53×10^{-2}	$\rho - \omega$ interference
$\omega \to \pi^0 e^+ e^-$	7.7×10^{-4}	Transition form factor

Studies of ω meson with WASA

Focus for this talk

Status of ongoing studies on

1. $\omega \to \pi^+\pi^-$

$\rho - \omega$ interference in hadronic production

↓

$\pi^+\pi^-$ mass distribution

2. $\omega \to \pi^+\pi^-\pi^0$

Decay dynamics

↓

Dalitz plot

where ω is produced as $p + d \to {}^3\mathrm{He} + \omega$.

Why study $\omega \to \pi^+\pi^-$

$\omega \to \pi^+\pi^-$ G - parity forbidden

$\rho - \omega$ mixing $\longrightarrow$ Interference at m_ω in $\pi^+\pi^-$ mass distribution

Interference also depending on ρ/ω production amplitudes

- relative magnitude
- relative phase

[1] Akhmetshin et al., Phys. Lett., **B** (2002) 161

[2] Behrend et al., Phys. Rev. Lett., **27** (1971) 61

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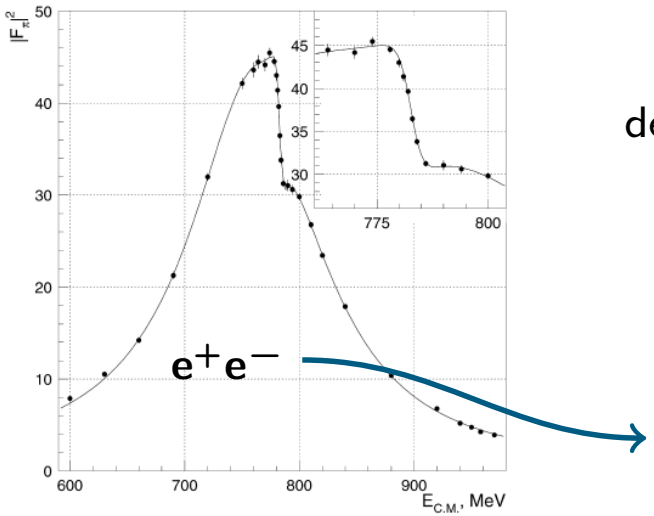
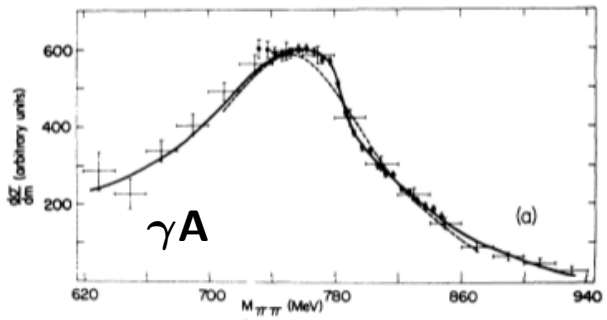
$\rho - \omega$ interference in e^+e^- [1] and photo production [2]



destructive interference



$$F_\pi(s) = \left(BW^{GS}_{\rho(770)}(s) \cdot \left(1 + \delta \frac{s}{M_\omega^2} BW_\omega(s) \right) + \beta \cdot BW^{GS}_{\rho(1450)}(s) \right) (1+\beta)^{-1}$$

$|\delta| \sim 1.5 \times 10^{-3}$ $\quad arg(\delta) \sim 10^\circ$

[1] Akhmetshin et al., Phys. Lett., **B** (2002) 161

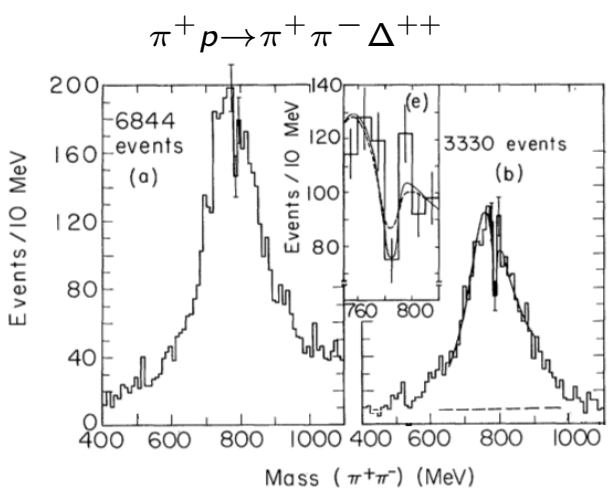
[2] Behrend et al., Phys. Rev. Lett., **27** (1971) 61

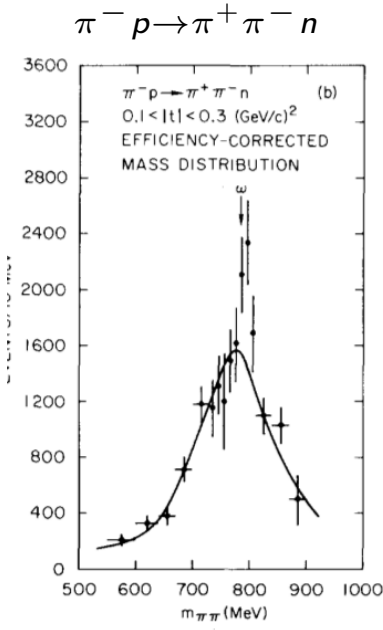
Why study $\omega \to \pi^+\pi^-$

$\rho - \omega$ interference in strong production

Both destructive[3] and constructive[4] observed

⟶ What about $pd \to {}^3\mathrm{He}\pi^+\pi^-$?





[3] Goldhaber et al., Phys.Rev.Lett **23** (1969) 1351

[4] Ratcliff et al., Phys.Lett. **38B** (1972) 345

[5] C. Hanhart, private communication

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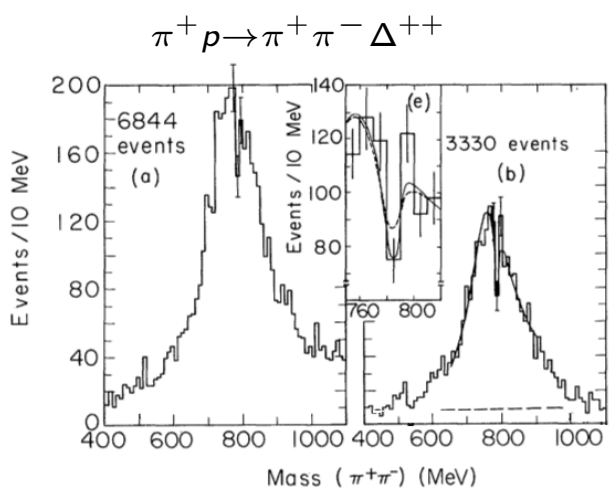
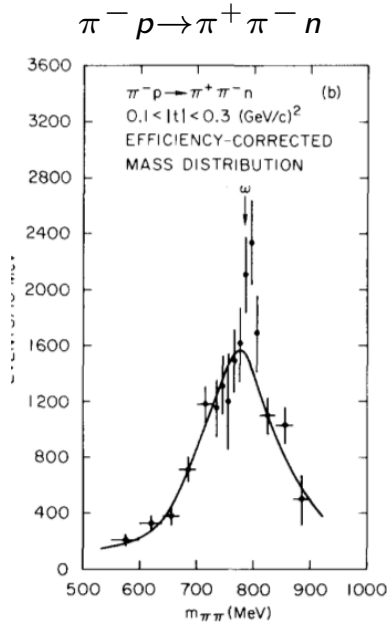
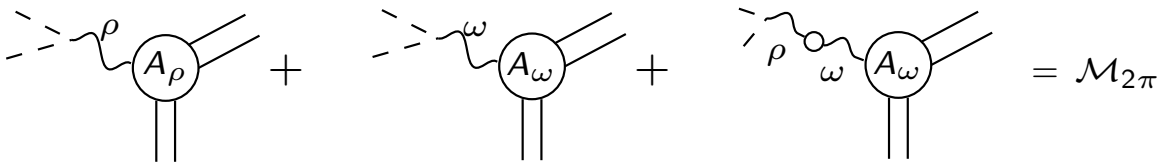
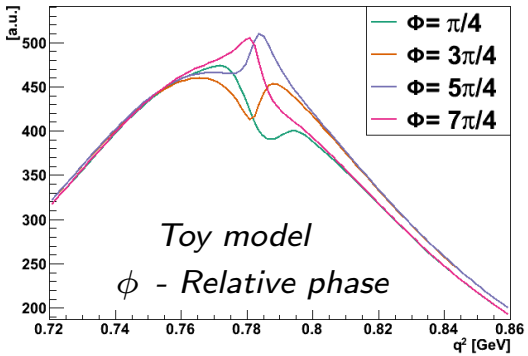




Possible parametrisation[5]



$$\mathcal{M}_{2\pi} = W_2 G_\rho \left\{ A_\rho + g A_\omega + g \Delta m_0^2 G_\omega A_\omega \right\}$$



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Searching for $\omega \rightarrow \pi^+\pi^-$

Signal search

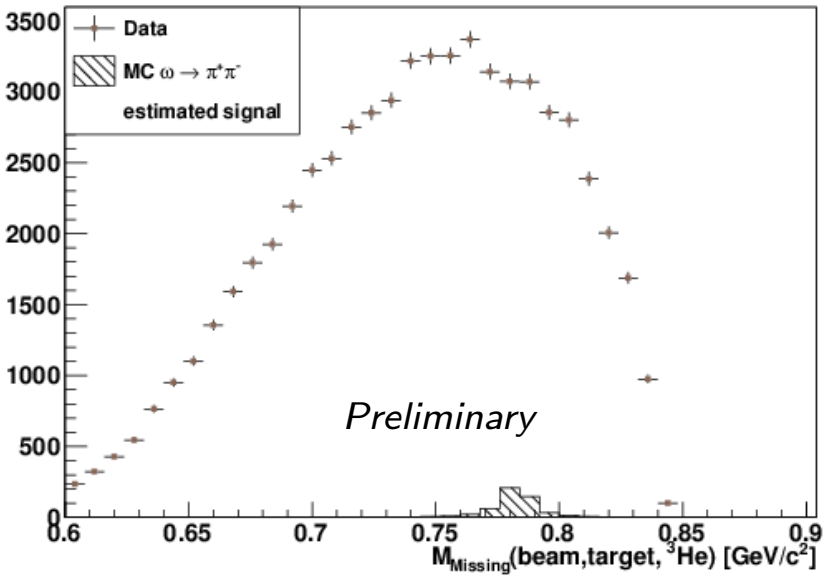
Full reconstruction of ^{3}He, π^+ and π^-.

Strict cut on $IM(\pi^+\pi^-)$ to reduce $\pi^+\pi^-\pi^0$ background.

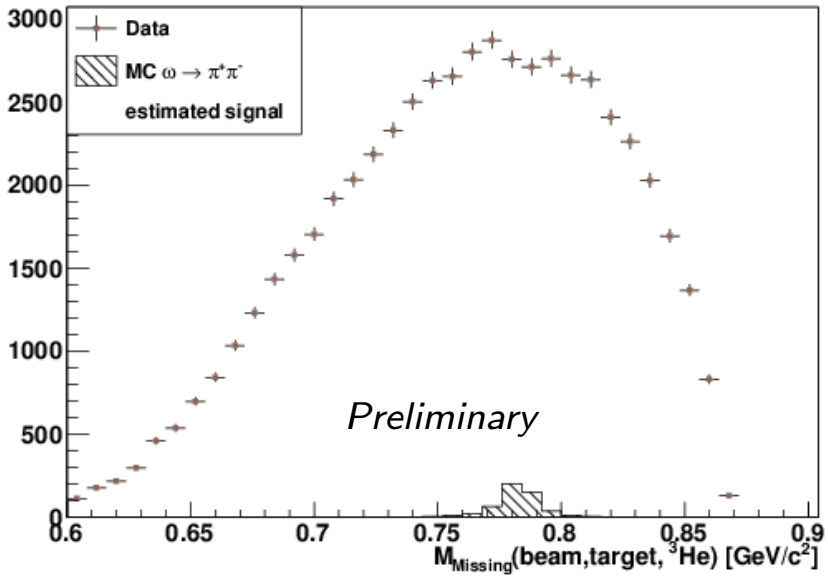
Constrained fit of $P_p + P_d = P_{^3\mathrm{He}} + P_{\pi^+} + P_{\pi^-}$.

Current results on $\pi^+\pi^-$ mass distributions

$T_{beam} = 1.45$ GeV

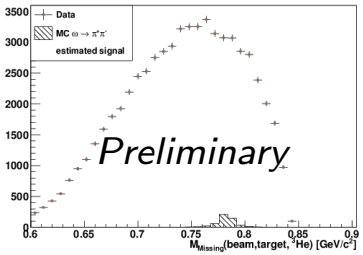


$T_{beam} = 1.5$ GeV



The $\pi^+\pi^-$ mass distribution

$T_{beam} = 1.45$ GeV



Possible to set limits on interference parameters

$$\mathcal{M}_{2\pi} = W_2 G_\rho \left\{ A_\rho + g A_\omega + g \Delta m_0^2 G_\omega A_\omega \right\}$$

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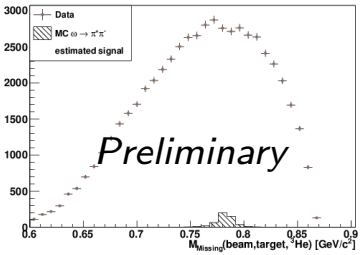


Study the full $\pi^+\pi^-$ mass distribution

$p + d \to {}^3\mathrm{He} + (\pi^+ + \pi^-)$ → I=0 L=0

$p + d \to {}^3\mathrm{He} + (\pi^+ + \pi^-)$ → I=1 L=1 (ρ)

extend study to:

$p + d \to {}^3\mathrm{He} + (\pi^0 + \pi^0)$ → I=0 L=0 only!

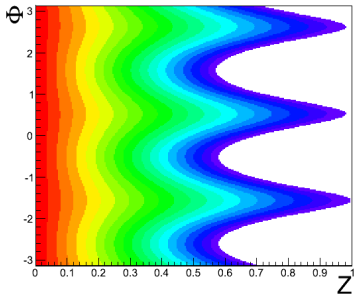
- Shape of $(\pi\pi)_{I=0}$ mass distribution
- Relative $I = 0$ / $I = 1$ contribution in $\pi^+\pi^-$

Why study $\omega \to \pi^+\pi^-\pi^0$

$\omega \to \pi^+\pi^-\pi^0$ decay dynamics

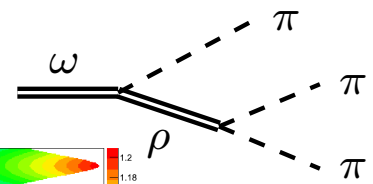
$\frac{d^2|\mathcal{M}|^2}{dZd\Phi}$ $\sim$Dalitz plot distribution, where T_{π^+}, T_{π^-} and T_{π^0} in ω-c.m. $\to$ Z, Φ

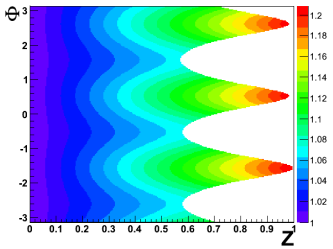
1. ω: I(J^P)=0(1$^-$) $\longrightarrow$ pions in P-wave



Experimentally verified

2. Intermediate ρ



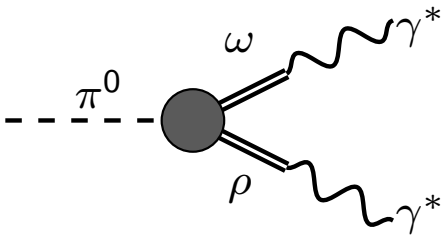


(Normalised by P-wave phase space)

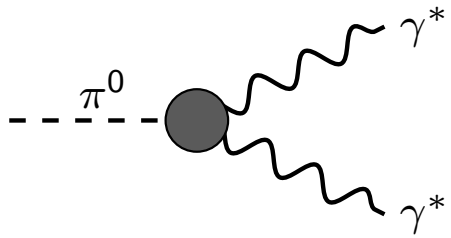
3. Final state interactions
   - $\pi\pi$ rescattering

Why study $\omega \to \pi^+\pi^-\pi^0$

Benchmark for meson transition form factors



a part of



- Probe of hadron structure
- Contribution to HLbL (muon g-2)

Transition form factors calculated by

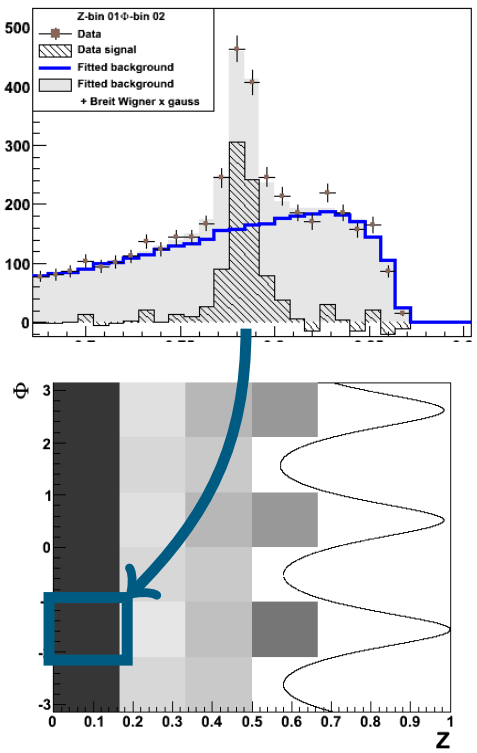
1. Dispersion approach[6]
2. Lagrangian approach[7]

Both have full prediction of $\frac{d^2|\mathcal{M}_{\omega\to 3pi}|^2}{dZd\Phi}$ - to be tested by experimental distribution

[6] S.P. Schneider, B. Kubis, F. Niecknig, Eur.Phys.J.C72:2014,2012

[7] C. Terschlüsen, B. Strandberg, S. Leupold, F. Eichstädt Eur.Phys.J. A49 (2013) 116

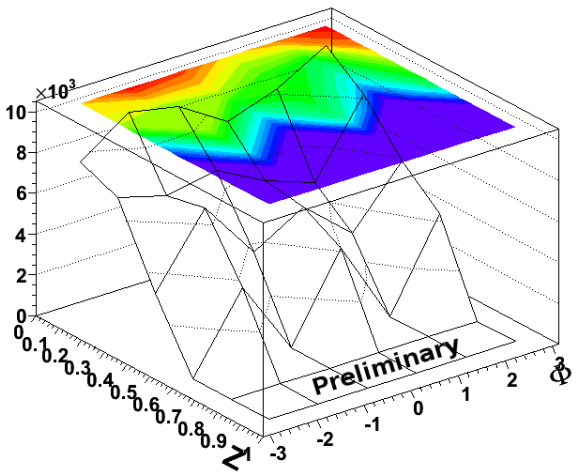
Making the $\omega \to \pi^+\pi^-\pi^0$ Dalitz plots



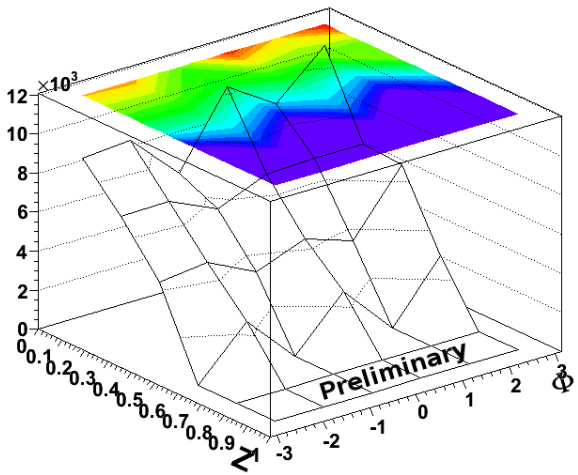
After full analysis:
$\sim$ 24200(600) $\omega \to 3\pi$ events

Bin by bin in Dalitz plot:
estimate background and
ω-peak content

Preliminary acceptance corrected Dalitz plot distributions:



$T_{beam} = 1.45$ GeV



$T_{beam} = 1.5$ GeV

Comparing data and theory

Compare theory - experiment

$$F(Z,\Phi) = \mathcal{P} \cdot \left\{1 + 2\alpha Z + 2\beta Z^{3/2}\sin 3\Phi + 2\gamma Z^2 + \mathcal{O}(Z^{5/2})\right\}$$

$\mathcal{P}$ - p-wave phase space factor *α, β, γ,... - Dalitz plot parameters.*

Minimize

$$\chi^2 = \sum_{bin\ ij} \left[\left(\frac{N_{ij}^a - \mathcal{C}^a \int F(Z,\Phi) dZ d\Phi}{\sigma_{ij}^a} \right)^2 + \left(\frac{N_{ij}^b - \mathcal{C}^b \int F(Z,\Phi) dZ d\Phi}{\sigma_{ij}^b} \right)^2 \right]$$

N_{ij}^a - Content of bin ij in data set a, $\int$ - over bin area

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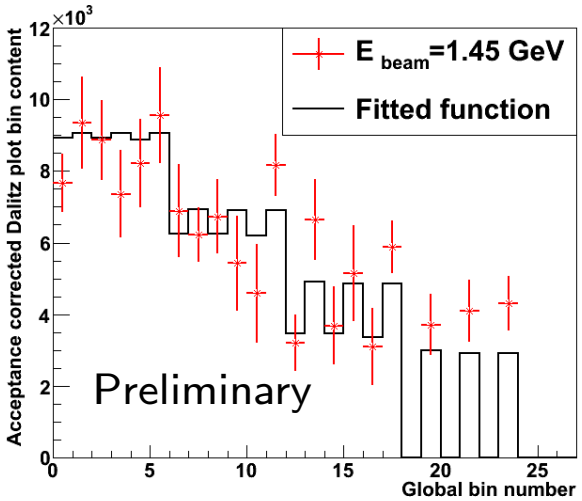
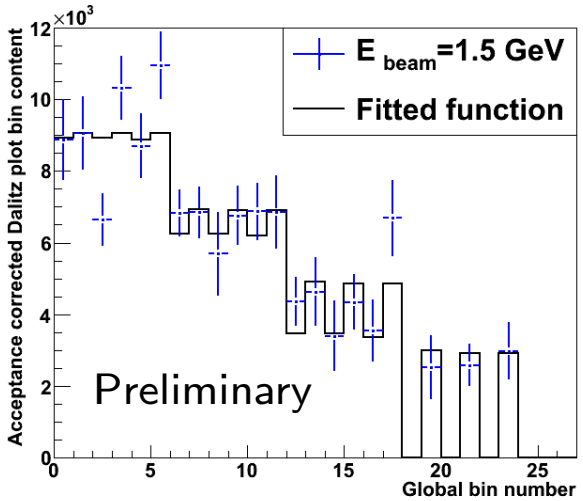
Preliminary data distributions vs P-wave prediction





Summary and Outlook

Studies using $p + d \to {}^3He + \omega$ collected by WASA-at-COSY

$\omega \to \pi^+\pi^-$

- Search for $\rho - \omega$ signal
- Check isospin components in data set
- Possibly set limits on interference parameters

$\omega \to \pi^+\pi^-\pi^0$

- $\sim$ 24200 events in Dalitz plot
- Known systematical corrections to be implemented
- Parametrization procedure ready

Thank you for your attention!