Dalitz plot analysis of $\omega \to \pi^+\pi^-\pi^0$ decay

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Outline

Introduction

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

Experimental setup

Analysis

- Cut based analysis
- Kinematic fitting

Summary/outlook

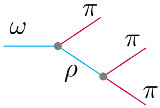
ω meson ($J^P = 1^-$)

Vector Meson Dominance model

$$\text{Hadronic } \gamma = \gamma + (\rho, \omega, \phi)$$

$$(\rho, \omega, \phi) \longleftrightarrow \text{electromagnetic interaction of hadron}$$

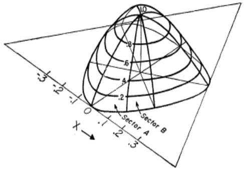
$\omega \to \pi^+\pi^-\pi^0$



- Vector Meson Dominance
- Calculations of contact terms
  [S. Leupold, Eur. Phys. J. A **39**, 205-212 (2009)]
- $\pi\pi$ final state interaction [F. Niecknig, Eur. Phys.J. C **72**, 2014 (2012)]

Dalitz plot

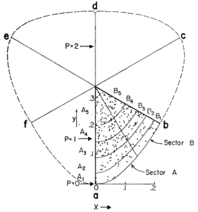
- Illustrates dynamics of three body decay
- Provides tool to study the decay mechanism



Previous experiments:

$\sim$ 4600 $\omega \to 3\pi$ events

[M. L. Stevenson, Phys Rev. **125**, 687 (1962)]



WASA-at-COSY:

Reaction	T_p (GeV)	Expected $\omega \to 3\pi$ events
$p + p \to p + p + \omega$	2.06, 2.54	$\sim 10^4$
$p + d \to {}^3\mathrm{He} + \omega$	1.45, 1.50	7.2×10^4

Experimental setup (WASA-at-COSY)

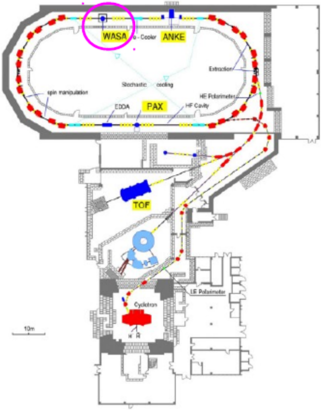
Situated at FZ-Jülich, Germany

COSY

- Cooler synchrotron and storage ring
- Proton and deuteron beam, momentum: 0.3 to 3.7 GeV/c

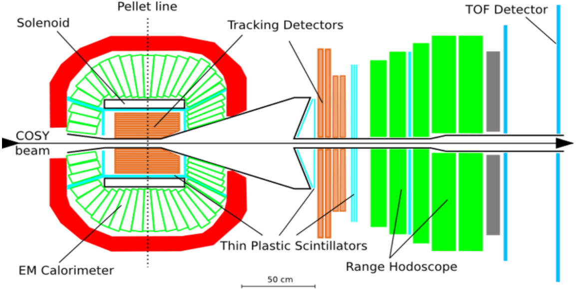
WASA

- Pellet target system
- Luminosity: 10^{31} - 10^{32} cm^{-2} s^{-1}
- 4π detector
- To study production and decays of light mesons, like π, η, ω



COSY accelerator

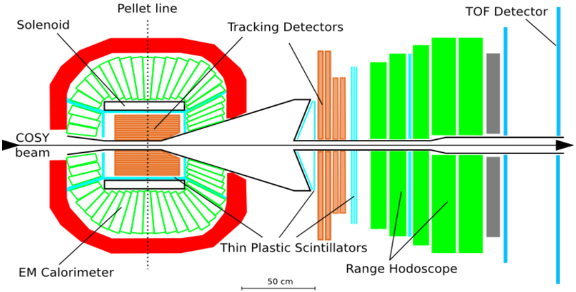
WASA detector



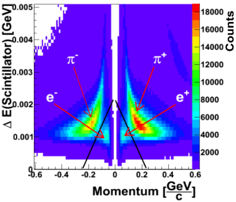
<u>Central detector</u>
decay product of mesons,
like γ, $\pi^{\pm}$ and $e^{\pm}$

<u>Forward detector</u>
scattered particles,
like p, ^{3}He

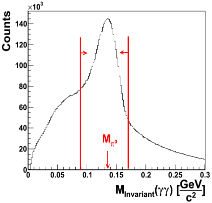
WASA detector



Central detector

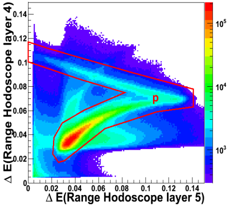


$\pi^{\pm}/e^{\pm}$ *identification*



π^{0} *identification*

Forward detector



p identification

☛ Detects all final state particles

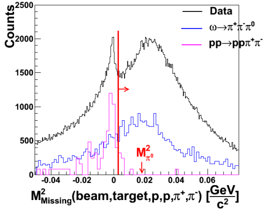
$p_{beam}\ p_{target} \rightarrow p\ p\ \pi^+\pi^-\pi^0$

Basic conditions Particle identification

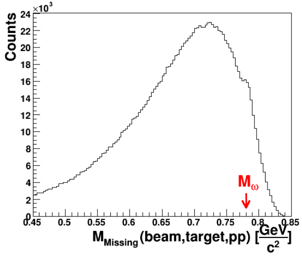
Further condition

$M^2_{Missing}(beam, target, p, p, \pi^+, \pi^-) \quad \longrightarrow$

$p_{beam}\ p_{target} \rightarrow p\ p\ \pi^+\pi^-\ X$



A look at ω signal in data



$p_{beam}\ p_{target} \rightarrow p\ p\ X$

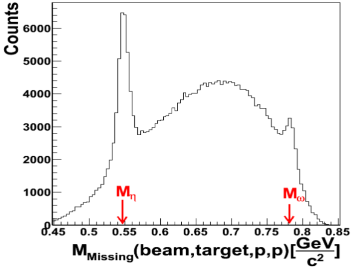
$$M_{Missing}(beam, target, l) = [(E_{beam} + E_{target} - E_l)^2 - (\vec{p}_{beam} + \vec{p}_{target} - \vec{p}_l)^2]^{\frac{1}{2}}$$

Kinematic fitting

Kinematic fitting: a mathematical procedure in which one uses the energy-momentum conservation to improve the measurements of the process (within errors of measurements).

Physical process: $pp \to pp\ \pi^+\pi^-\gamma\gamma$ and $\pi^0 \to \gamma\gamma$

Measurements: (E_{kin}, θ, ϕ) of p, $\pi^\pm$, γ



☛ Clear η and ω signals

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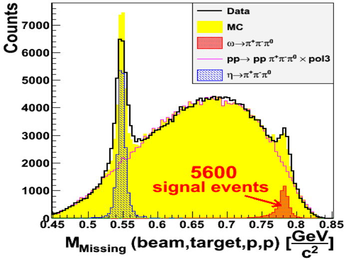


☛ Clear η and ω signals

☛ $N(\omega)/N(\eta)$ consistent in data and simulation

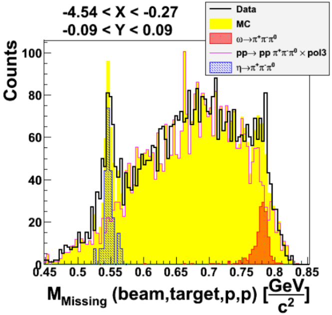
Part of available pilot data

A first look at the Dalitz plot distribution

$$X = \sqrt{3}\,\frac{T_{\pi^+} - T_{\pi^-}}{Q_\omega}, \qquad Y = 3\frac{T_{\pi^0}}{Q_\omega} - 1$$

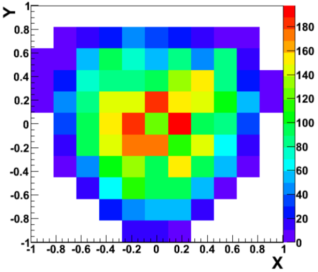
where, T_{π^+}, T_{π^-}, T_{π^0} : kinetic energy of π^+, π^- and π^0
$Q_\omega = T_{\pi^+} + T_{\pi^-} + T_{\pi^0}$

Bin-wise background subtraction



Dalitz plot

Not efficiency corrected



Part of available pilot data

Summary/outlook

- Aim: To perform the Dalitz plot analysis of $\omega \rightarrow \pi^+\pi^-\pi^0$
- WASA-at-COSY: ω produced in *pp* and *pd* reactions
- Obtained the non-efficiency corrected Dalitz plot
(*pp* data @T$_p$=2.06 GeV)

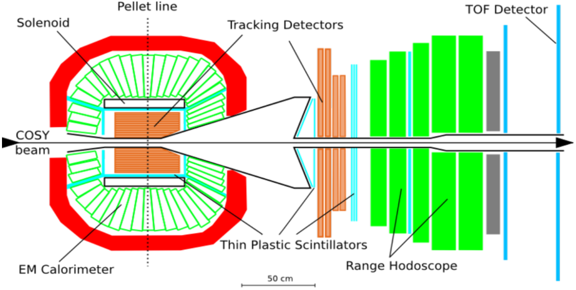
Next,

- Obtain the efficiency corrected Dalitz plot
- Analyze other data set (i.e. *pp* @T$_p$=2.54 GeV)
- Combine all available data sets $\longrightarrow$ Dalitz plot
- Calulate the Dalitz plot parameter

Back up

Experimental setup: (WASA-at-COSY)

WASA detector :

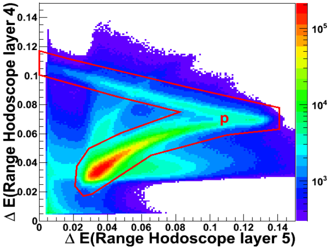


Central detector
decay product of mesons,
like γ, $\pi^{\pm}$ and $e^{\pm}$

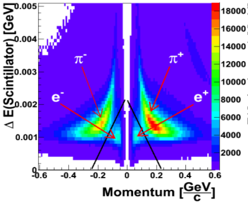
Forward detector scattered particles,
like p, He^3

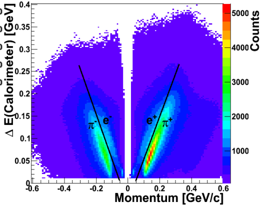
PID

Proton

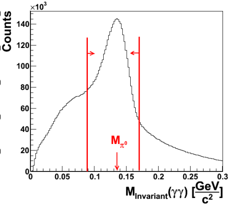


$\pi^{\pm}$





π^0



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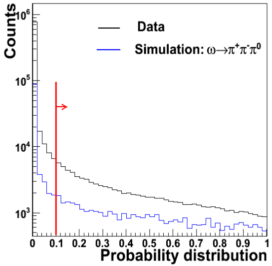
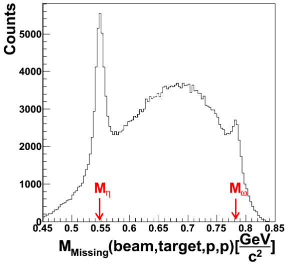
Probability distribution:



With Kinematic fitting:



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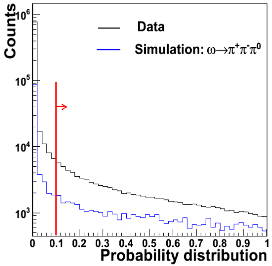

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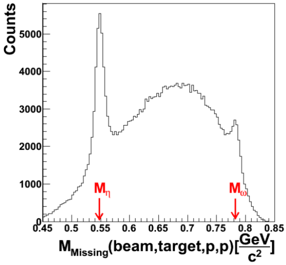

Efficiency (Monte Carlo simulation $\omega \to \pi^+\pi^-\pi^0$) :

No.	Condition	accpt. $\times$ effi. (%)
1	Geometric acceptance	$\sim$ 30.0
2	1 + basic conditions	3.9
3	1 + 2 + after kinematic fitting	0.9

Cross sections (pp)