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$\eta \rightarrow \pi^+ \pi^- \pi^0$

decay with  
WASA-at-COSY

Patrik Adlarson



# $\eta \rightarrow \pi^+ \pi^- \pi^0$ decay with WASA-at-COSY

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STORI'11



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## Introduction

Contemporary studies

WASA@COSY

Experimental analysis

Result

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# Low energy QCD

For low energies perturbative QCD breaks down.

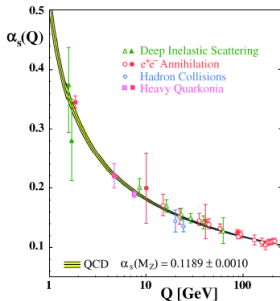


Figure obtained from *arXiv:hep-ex/0606035v2*.

## One low energy systematic approach of QCD:

Effective field theory  $\Rightarrow$  Chiral Perturbation Theory

- Using Goldstone bosons ( $\pi, K, \eta$ ) as degrees of freedom
- Perturbative expansions in powers of momenta.
- Keeping relevant symmetries.



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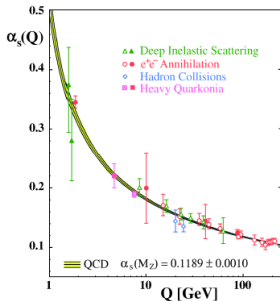


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# Introduction

In ChPT  $\eta$ -decays to  $\pi\pi\pi$  are driven by isospin violating terms in the Lagrangian proportional to  $m_d - m_u$  difference.

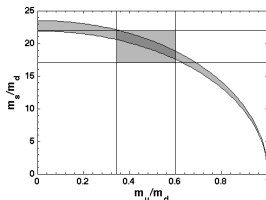


Figure. *The  $\eta \rightarrow 3\pi$  give constraint on quark mass ratios.*

The decay rate can be expanded around  $X = Y = 0$  in Dalitz plot:

$$\frac{d\Gamma}{dXdY} \propto |A(X, Y)|^2 \propto 1 + aY + bY^2 + dX^2 + fY^3 + \dots \quad (1)$$

$$X = \sqrt{3} \frac{T_+ - T_-}{Q_\eta}, \quad Y = \frac{3T_0}{Q_\eta} - 1 \quad (2)$$

$$Q_\eta = T_+ + T_- + T_0 \quad (3)$$



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## Recent work : theory

A lot of theoretical interest in  $\eta \rightarrow \pi^+ \pi^- \pi^0$ , with recent and ongoing work

- $\chi$ PT to NNLO- [Bijnens, Ghorbani JHEP11:030,2007]
- EM corr.- [Ditsche, Kubis, Meißner, et al. arXiv:0910.0210v1 [hep-ph]]
- Bern-Lund-Valencia dispersive [Colangelo, Lanz, Passemar arXiv:0910.0765v1 [hep-ph]]
- Modified NREFT [Schneider, Kubis, Ditsche, JHEP 1102:028,2011]
- Prague-Lund-Marseille Dispersive - [Kampf, Knecht, Novotny, Zdrahal, arXiv:1103.0982v1 [hep-ph]]
- resummed  $\chi$ PT - [Descotes-Genon, Kolesar, Novotny to appear]



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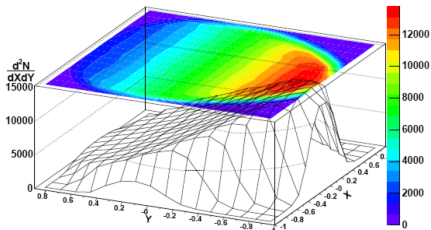
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## Recent work : experiment

- Best experimental result comes from measurement by KLOE with 1.34 million events. [Ambrosini, et al. JHEP 0805:006,2008]
- $b$  and  $f$  parameters are difficult to reproduce in theoretical approaches.
- Important with independent results with similar statistics.



Goal of WASA-at-COSY to provide two high-statistics measurements of the Dalitz Plot.  $\Rightarrow$   $pp$  and  $pd$  data



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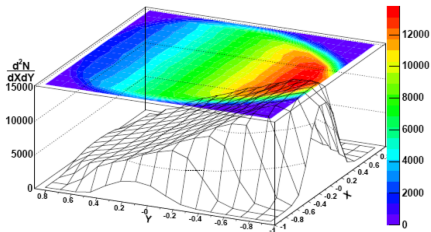
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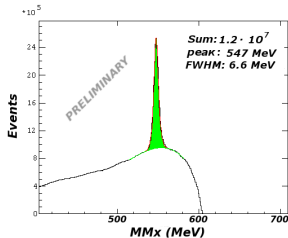
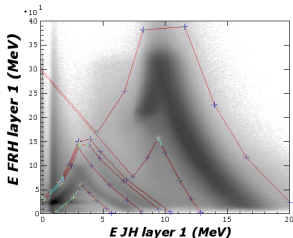
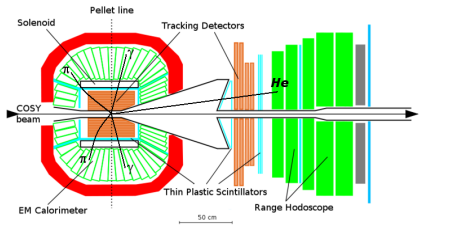
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$pd \rightarrow {}^3\text{He} \eta$  at 1.0 GeV

WASA-at-COSY detector setup



Approx.  $12 \cdot 10^6$   $\eta$  on disk from fall 08 run (1/3 of total data).





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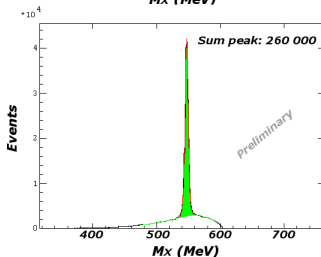
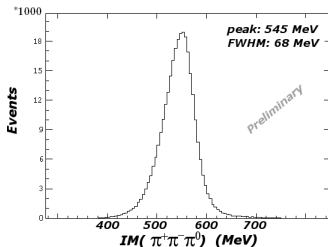
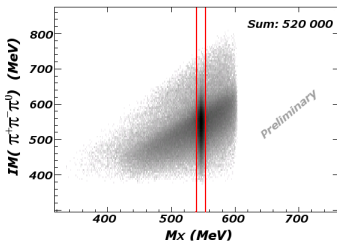
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# MM( $^3\text{He}$ ) vs IM( $\pi^+\pi^-\pi^0$ ) after cuts

To clean up data sample, cuts are made on time-distributions, vertex-position. To reduce prompt pion background and  $\eta \rightarrow \pi^+\pi^-\gamma$ , four cuts are made.





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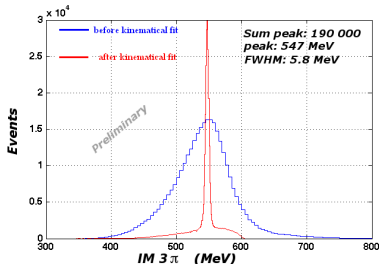
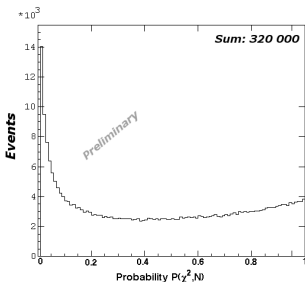
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# Kinematical Fit EXP

Describing errors of all particles and using four-momentum as constraint, requiring PDF > 0.01 for the hypothesis



Approximately 200 000 events in Dalitz Plot.



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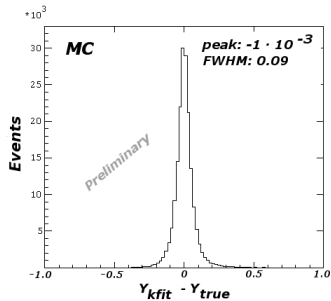
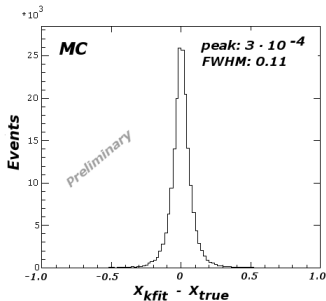
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# Resolution X and Y

MC: 0.1 FWHM in Dalitz Plot variables.  
0.2 bin width provides reasonable statistics.





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## Selecting $\eta$ from bin content

Perform a polynomial fit over background region to get the  $\eta$  content in Dalitz plot.

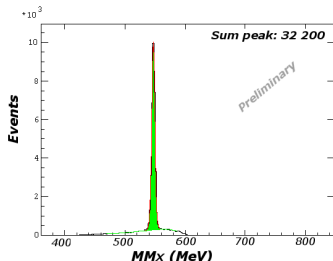
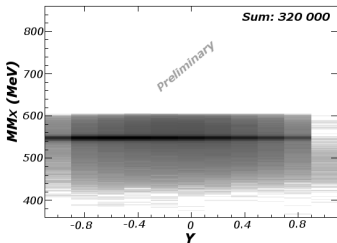


Figure. Left: Scatterplot  $Y$  vs  $MM_x$ . Right: The  $\eta \rightarrow 3\pi$  events in  $-0.7 \leq Y \leq -0.5$ .



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# Dalitz Plot acceptance

To get the Dalitz plot parameters the experimentally measured number of  $\eta$  events are divided by the acceptance in each bin.

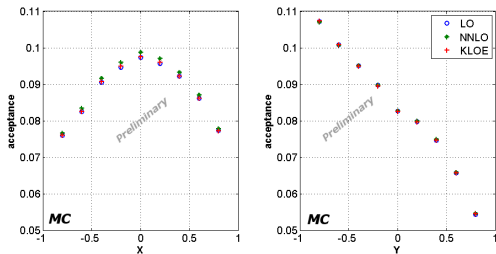


Figure. Acceptance of projected X- and Y-distributions for three different sets of Dalitz plot parameters.



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# Dalitz Plot projections, acceptance corrected

PRELIMINARY acceptance corrected Dalitz plot distribution of  $\eta \rightarrow \pi^+ \pi^- \pi^0$  from WASA-at-COSY.

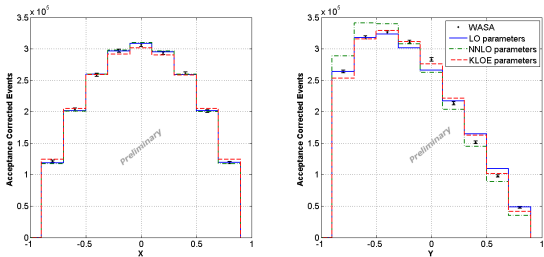


Figure. Acc. corr. data points with statistical errors, projected on X and Y.



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# Conclusion and Outlook

## Conclusion:

- First preliminary acceptance corrected results of Dalitz plot projection.
- Reasonable agreement with KLOE result.

## Outlook:

- Study sources of systematical effects.
- Dalitz Plot parameters.
- More data available.