



$\eta \rightarrow 3\pi^0$ decays with WASA-at-COSY

$\eta \rightarrow 3\pi^0$ Workshop
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Outline

- Physics with $\eta \rightarrow 3\pi^0$ decay
- Recent measurements of the $\eta \rightarrow 3\pi^0$ decay with WASA-at-COSY
- Data overview
- Summary and Outlook

$\eta \rightarrow 3\pi^0$ Dalitz plot

- The mechanism of the decay is described by expansion of the amplitude for the case of the three identical particles in final state (Dalitz plot):
- Slope of the linearized $\eta \rightarrow 3\pi^0$ Dalitz plot is proportional to the decay amplitude

$$|A(x, y)|^2 \sim 1 + 2\alpha(x^2 + y^2)$$

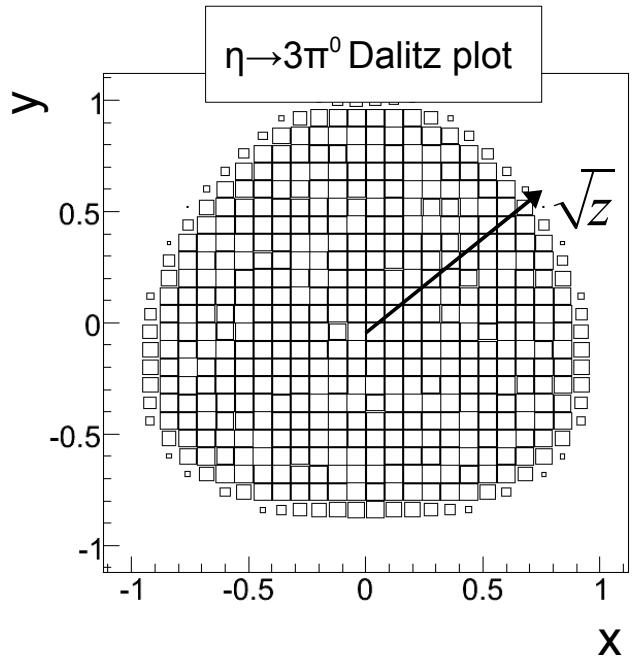
where

$$x = \frac{1}{\sqrt{3}}(T_{\pi_1} - T_{\pi_2})/\bar{T}, \quad y = (\bar{T} - T_{\pi_3})/\bar{T}$$

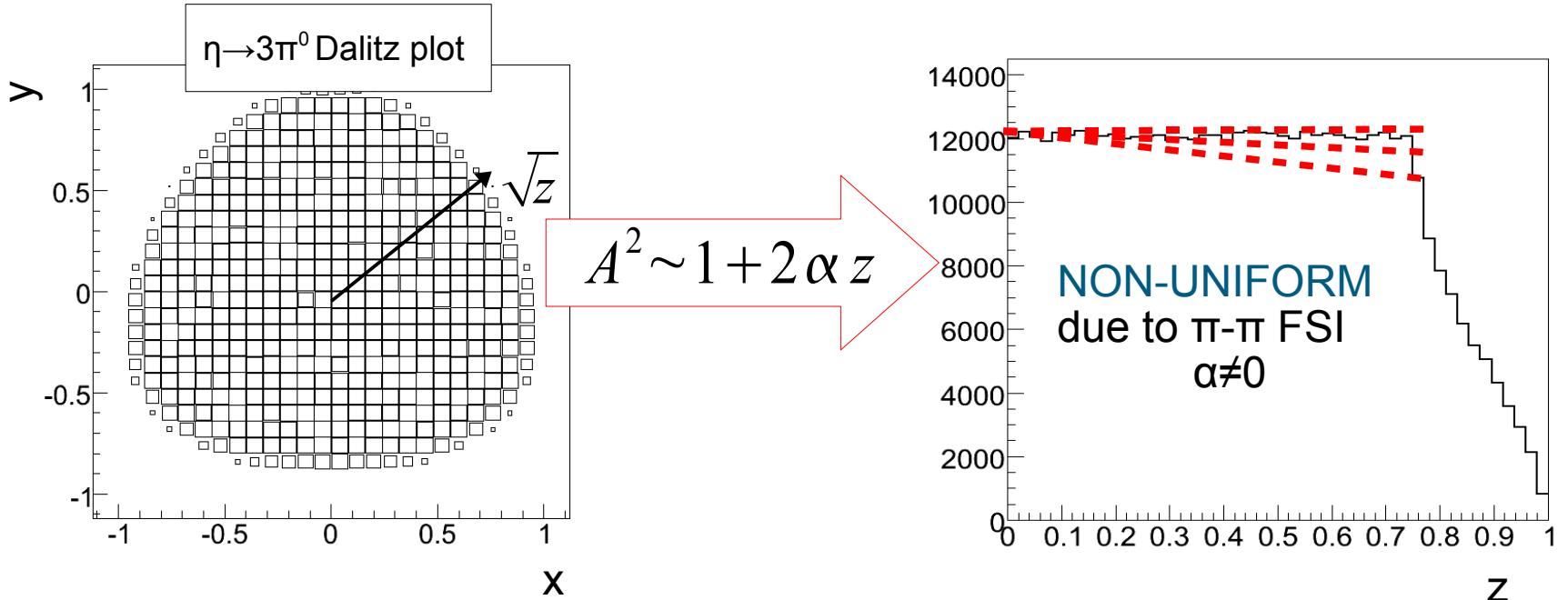
- Linear transformation:

$$\Rightarrow |A(x, y)|^2 \sim 1 + 2\alpha z$$

$$z = x^2 + y^2$$



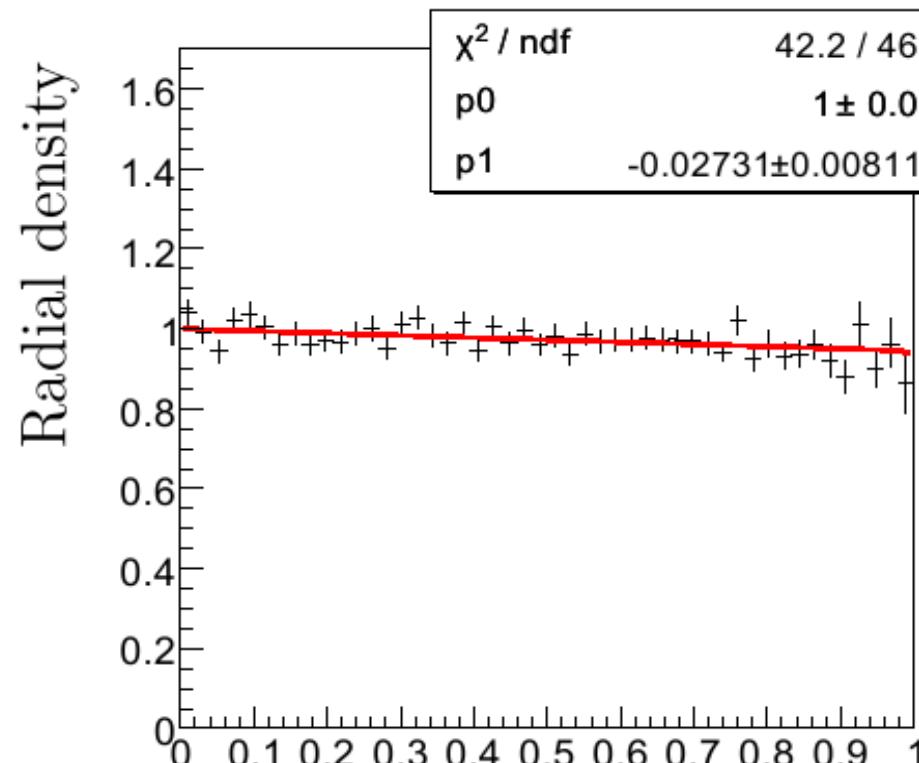
$\eta \rightarrow 3\pi^0$ Dalitz plot



- Current Algebra calculations predict uniform Dalitz plot
- Advanced ChPT calculations, including e.g. π - π scattering at higher non-leading orders shows deviation from uniformity

Results from WASA-at-COSY

WASA-at-COSY
 $-0.027 \pm 0.008(\text{stat}) \pm 0.005(\text{syst})$



$$z = 6 \sum_{i=1}^3 \frac{(E_{\pi_i} - m_\eta/3)^2}{(m_\eta - m_{\pi^\circ})^2}$$

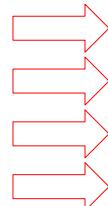
Published in PLB

Experimental and theoretical status

Slope parameter

$\alpha \pm stat \pm syst$

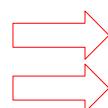
-0.022 ± 0.023
 $-0.052 \pm 0.017 \pm 0.010$
 $-0.031 \pm 0.004 \pm 0.004$
 $-0.014 \pm 0.004 \pm 0.005$
 $-0.027 \pm 0.004 \begin{array}{l} +0.004 \\ -0.006 \end{array}$
 $-0.026 \pm 0.010 \pm 0.010$
 $-0.027 \pm 0.008 \pm 0.005$
 $-0.032 \pm 0.002 \pm 0.002$



Comment

GAMS-2000
 Crystal Barrel
 Crystal Ball
 KLOE, preliminary
 KLOE, reanalysis
 WASA/CELSIUS
WASA-at-COSY
 Crystal Ball

0
 $+0.015$
 $-(0.007 \div 0.014)$
 -0.031 ± 0.003
 $+0.016 \pm 0.030$



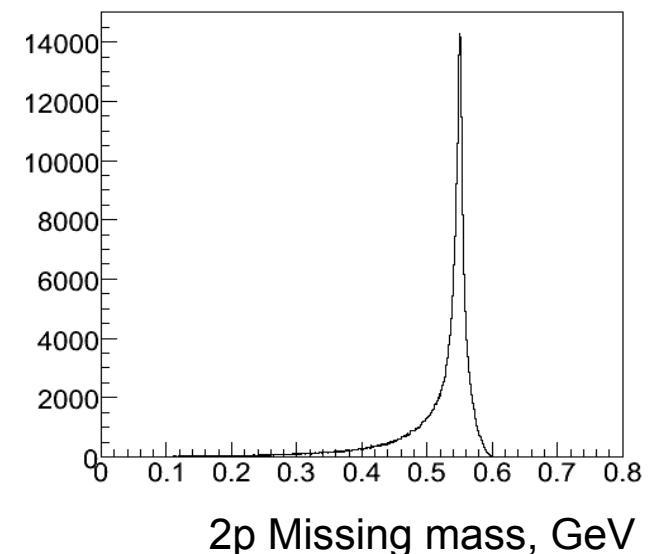
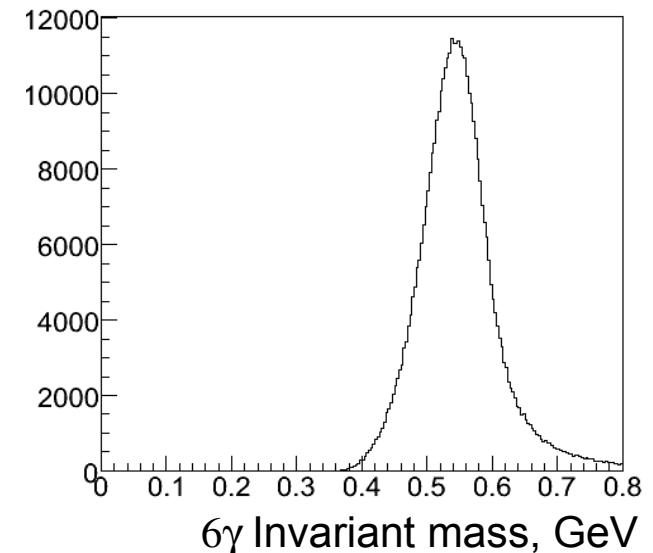
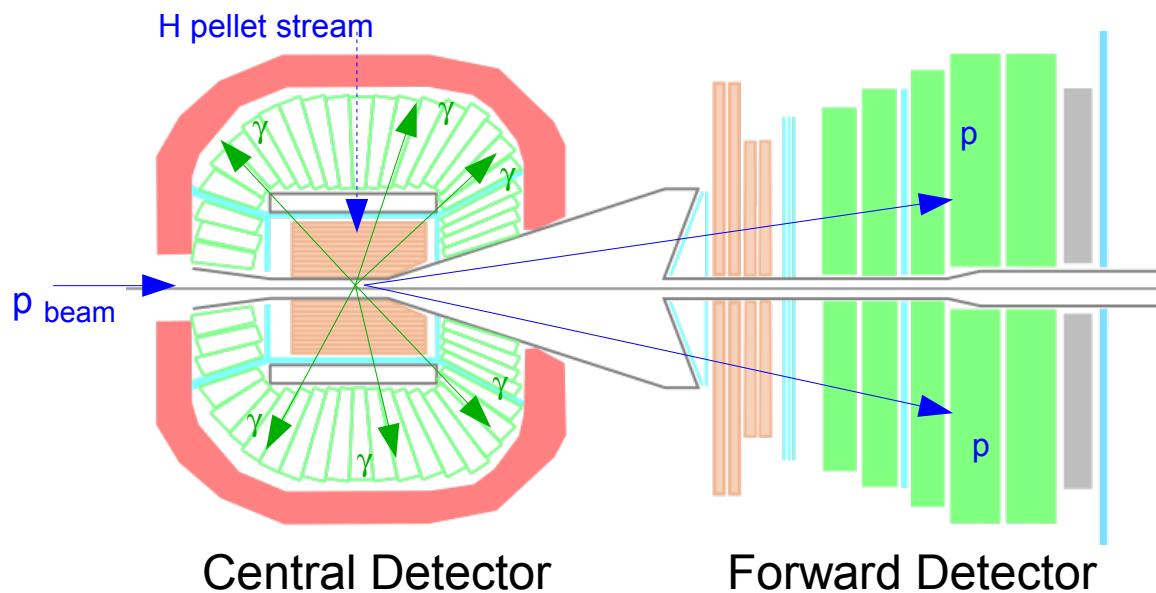
Current Algebra
 ChPT NLO 1-loop
 ChPT+dispersive
 UChPT fit
 ChPT NNLO

Recent measurements

- $\text{pp} \rightarrow \text{pp}\eta$ at $T_{\text{beam}} = 1.4 \text{ GeV}$
 - 4 day in April 2007
 - 2 weeks in October 2008
- $\text{pd} \rightarrow \text{He}^3\eta$ at $T_{\text{beam}} = 1.0 \text{ GeV}$
 - 4 weeks in November 2008

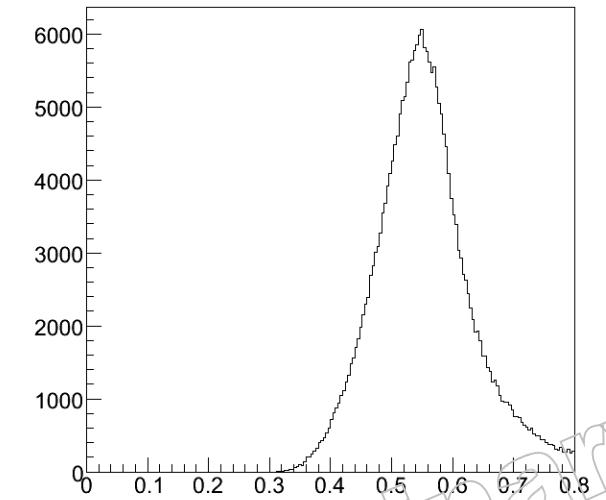
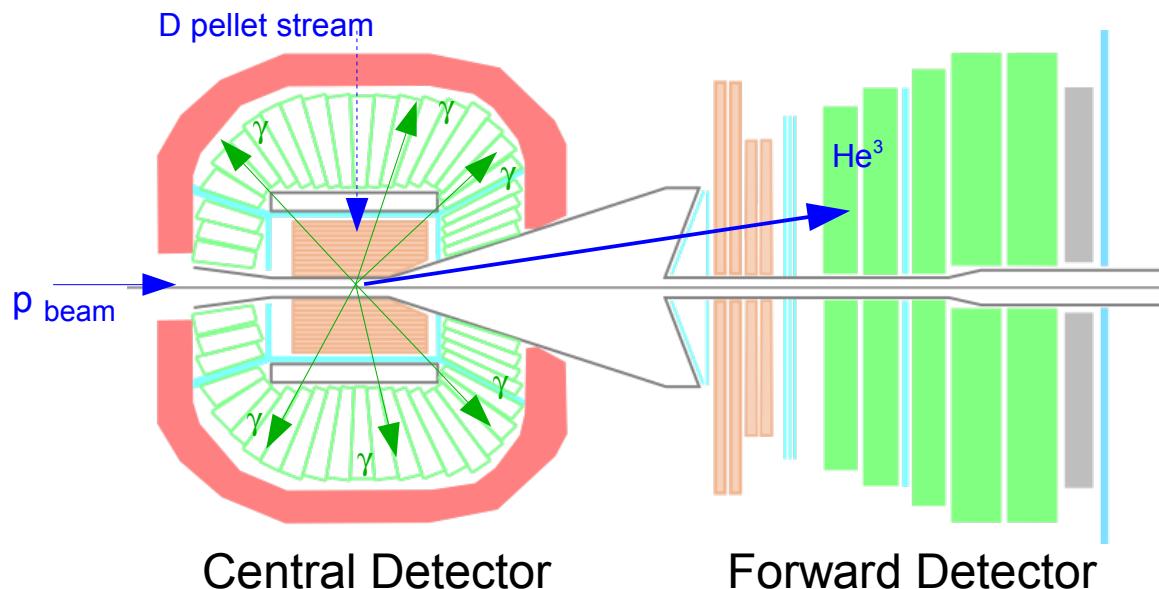
6 γ final state in pp \rightarrow ppn

- pp \rightarrow pp η at T_{beam}=1.4 GeV
 - 4 day in April 2007 (published data)
 - 2 weeks in October 2008 (**20% overview**)

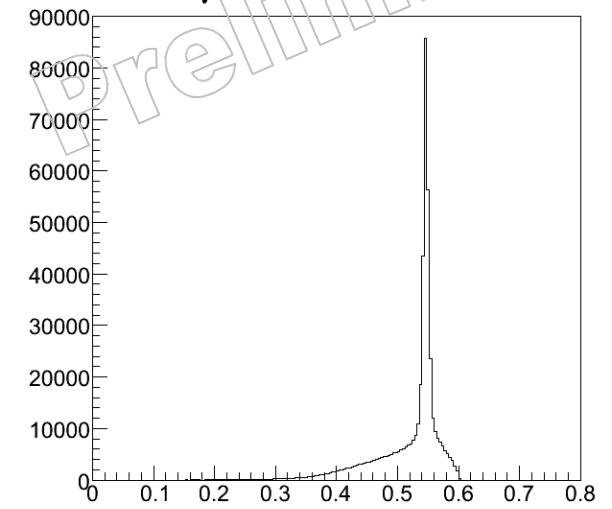


6 γ final state in $pd \rightarrow He^3\eta$

- $pp \rightarrow pp\eta$ at $T_{beam} = 1.4$ GeV
 - 4 day in April 2007 (published data)
 - 2 weeks in October 2008 (20% overview)
- $pd \rightarrow He^3\eta$ at $T_{beam} = 1.0$ GeV
 - 4 weeks in November 2008 (**40% overview**)



6 γ Invariant mass, GeV



He^3 Missing mass, GeV

Event selection and reconstruction

- Combinations

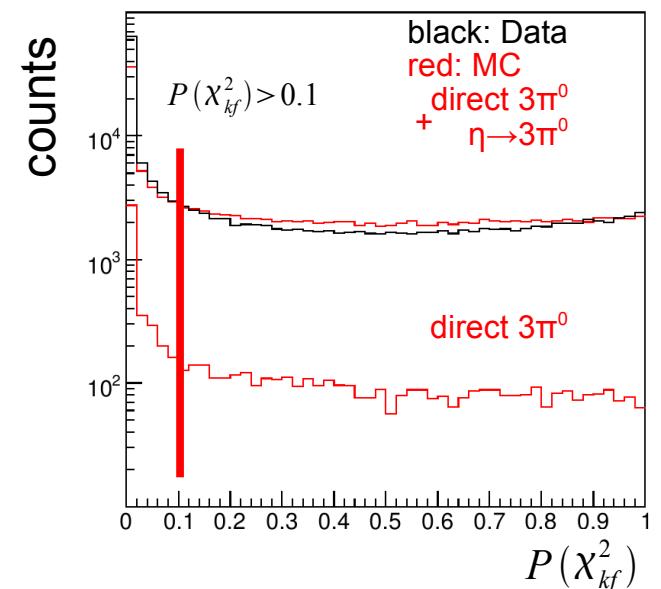
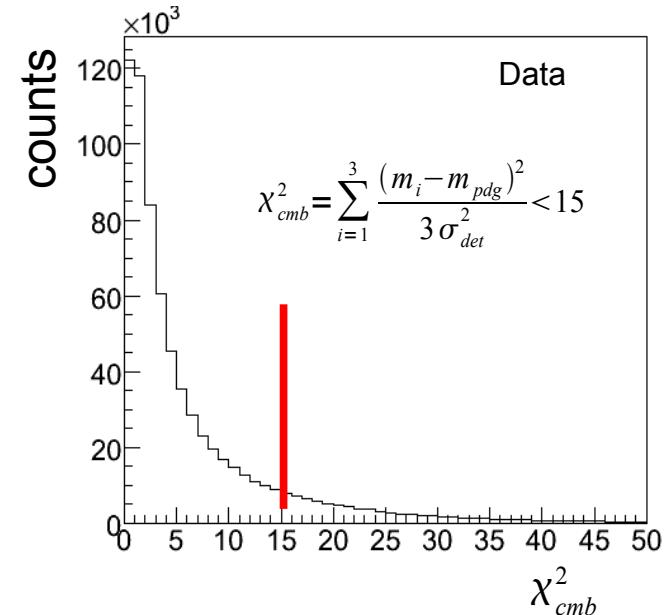
- combine six photons to 3 pairs such that the $M_{\gamma\gamma}$ of each pair is closest to the pion's mass

- Kinematic fit

- LS fit with constraints: masses of intermediate particles are used to constrain the decay system
- Options for pd data analysis

- Background

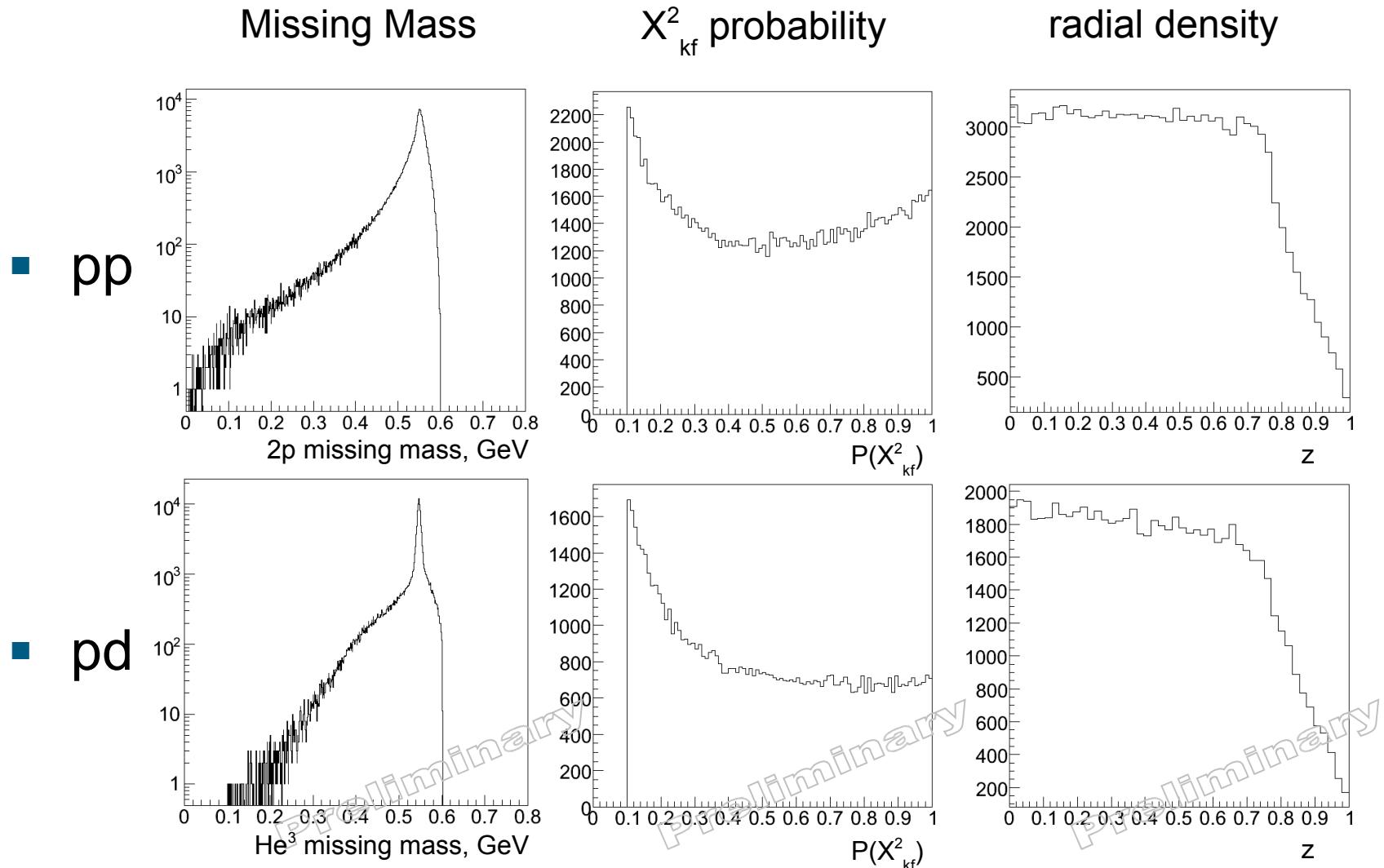
- pp: contribution from direct $3\pi^0$ production is below 4% in final data sample
- pd: clean data, almost bg free



Systematic uncertainties

- Combinatorial impurity
 - probability of the best combination
- Direct $3\pi^0$ production
 - remaining background
- Rest gas
 - gas stemming from pellet evaporation
 - pellets bouncing in the beam pipe
- Kinematic fit confidence level
- Alternative errors for Kinematic Fit

Data compared: 6γ state in pp vs pd



5γ state in pd data

- October pd data
 - ${}^1_{\text{He}} {}^5_g$ case: 1 photon lost in forward detector
3 times more events than ${}^1_{\text{He}} {}^6_g$ case
- Suggestion
 - 1st iteration – E-P conservation
=> obtain 6th photon parameters
 - 2nd – 15 4C fits (NB: 3 unmeasured pars.)
=> accept best combination

Data outlook

- $pp \rightarrow pp\eta$
 - April 2007 4 days => 120k events (100%)
 - October 2008 2 weeks => 70k events (~20%) => 350k
- $pd \rightarrow He^3\eta$
 - November 2008 4 weeks => 70k 6 γ events (~40%) => 160k*
■ => 3 times for 5 γ => ~500k
- In all
 - pp 470k Events
 - pd 660k Events

* probably factor 2 more after new preselection

Summary and Outlook

- WASA-at-COSY is an “ η -factory”
 - pp – larger cross section, but unavoidable background
 - pd – background free, low cross section
- Upcoming 8 weeks of high quality pd data: $n \cdot 10^6$ events in final Dalitz plot?
- Extensive MC is needed
 - Combinatorial purity in $pd \rightarrow He^3 5g$ final states
 - resolutions