Exclusive production of η and ω in pp at 4.5 GeV with HADES

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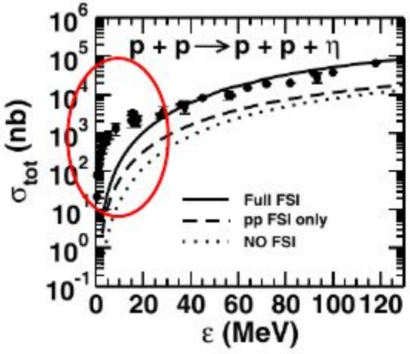
Motivation

- Measure cross-section and angular differential cross-section for exclusive η/ω production:
  - Expand cross-section database for given energy scale
  - Input for Heavy-ion transport models (GIBUU, SMASH)
  - Test models prepared by IFJ PAS theory group
- Studies of Dalitz plots:
  - $pp \to pp\eta$ - measure resonance contribution, FSI
  - $\eta \to \pi^+\pi^-\pi^0$ - decay dynamics, FSI,
  - $\omega \to \pi^+\pi^-\pi^0$- decay dynamics, FSI,
- For ω production:
  - Partial wave analysis, resonance contributions
  - Extract spin-density matrix, study polarization

Previous measurements

R. Shyam, PRC 75, 055201 (2007)



Eta study:

- WASA@COSY (1.4 GeV)
- DISTO Collaboration (2.115, 2.5, 2.85 GeV)
- HADES Collaboration (2.2, 3.5 GeV)

Omega study:

- DISTO Collaboration (2.82 GeV)
- HADES Collaboration (3.5 GeV)

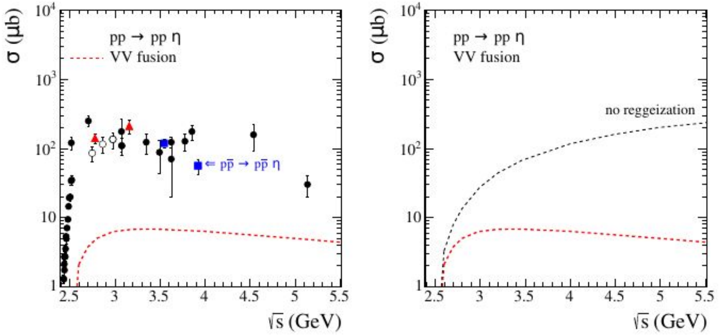
This measurement: 4.5 GeV

Close to threshold:

❑ FSI needed to take into account
❑ very important role played by baryonic resonances, mostly N(1535)

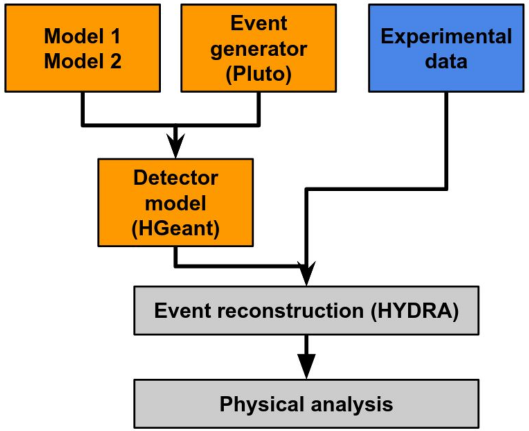
Higher energies (>20 GeV):

❑ pomeron-pomeron exchange
❑ reggeon exchange
❑ diffraction processes



Data samples

- **Proton-proton collision at 3.46 GeV center of mass energy**
- **Two theoretical models, phase space reference and real data**



Eta: Models 1 and 2 include:

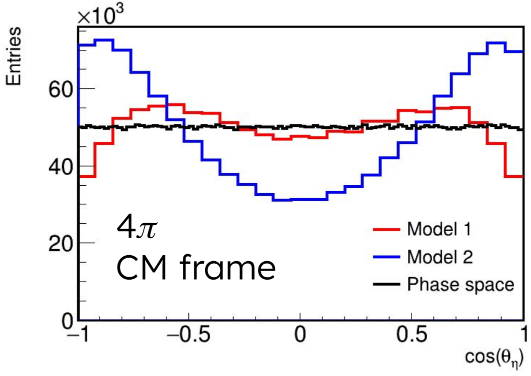
- Production via nucleon resonance N(1535) (by the π^0 and σ meson exchange)
- VV-fusion mechanism (by the $\varrho^0\varrho^0$ and $\omega\omega$ mesons exchange)
- Difference between models: coupling ϱ^0-proton-N(1535)
- Prepared by IFJ PAN theory group (A. Szczurek, P. Lebiedowicz)

Eta, Omega: Pluto MC generator

- Phase space

Data

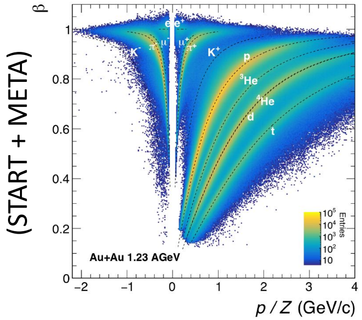
- February 2022 Beamtime
- Gen 3
- Luminosity used: 208 nb^{-1} (total luminosity of the beamtime: 5900 nb^{-1})



HADES Detector

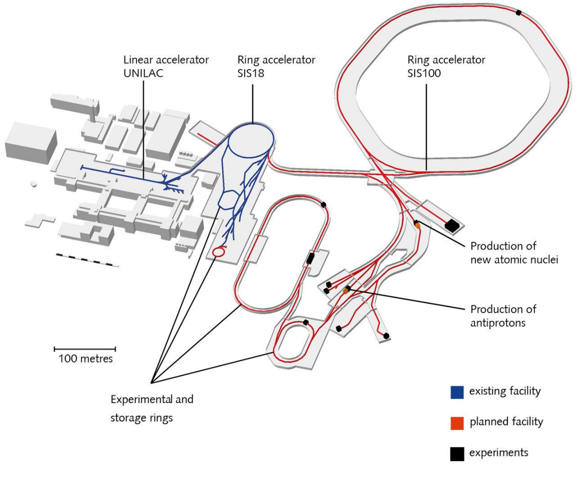
(High Acceptance DiElectron Spectrometer)

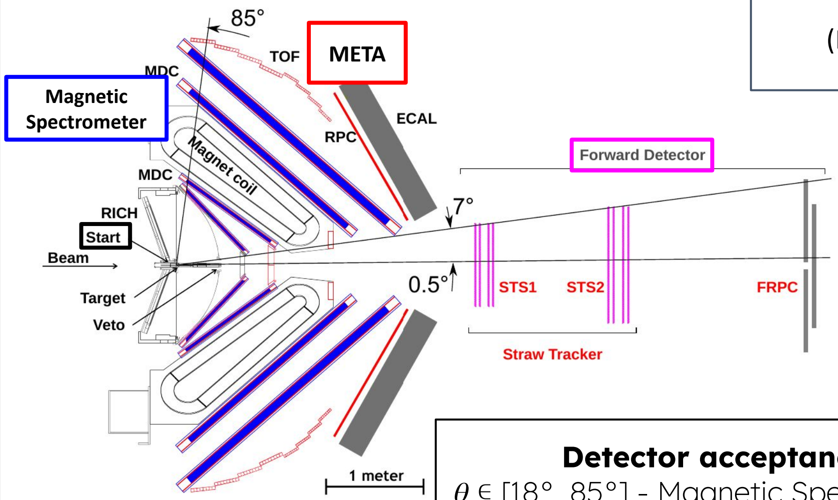
MS: PID by time-of-flight



(Magnetic Spectrometer)

GSI/FAIR in Darmstadt, Germany





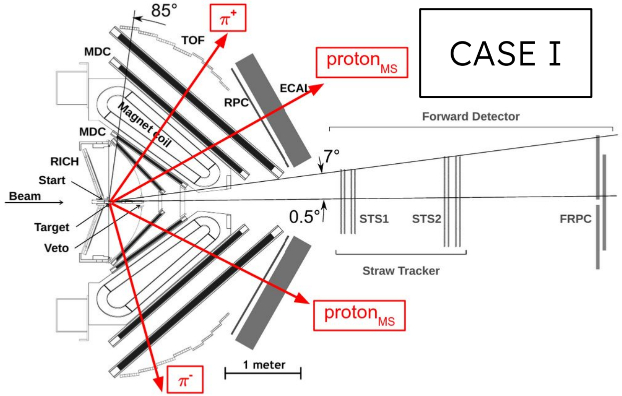
Detector acceptance

$\theta \in [18°, 85°]$ - Magnetic Spectrometer

$\theta \in [0.5°, 7°]$ - Forward Detector

Analysis setup

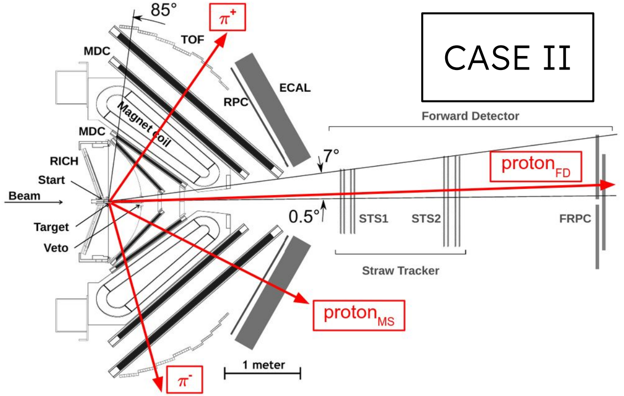
- 4-particle hypothesis: 2 protons, π^+, π^-
- Two cases:
  - Both protons from HADES
  - One proton from HADES, one from Forward Tracker
- Momentum vs beta PID cuts
- Using Forward Detector
- Using Kinematic Fit



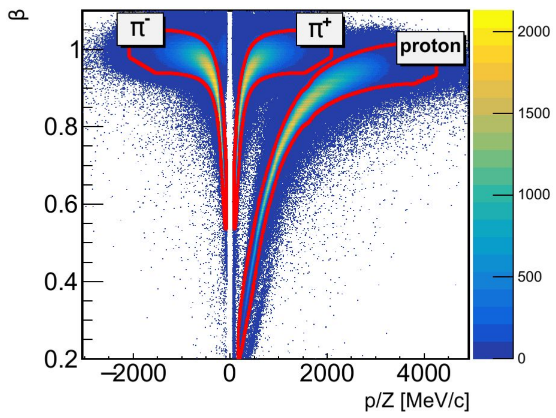
$$pp \rightarrow pp\eta \rightarrow pp\pi^+\pi^-\pi^0$$

$$pp \rightarrow pp\omega \rightarrow pp\pi^+\pi^-\pi^0$$

π^0 obtained from kinematic fit (missing particle constraint)



PID in HADES



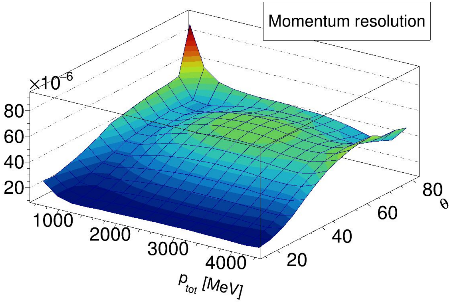
PID in FD

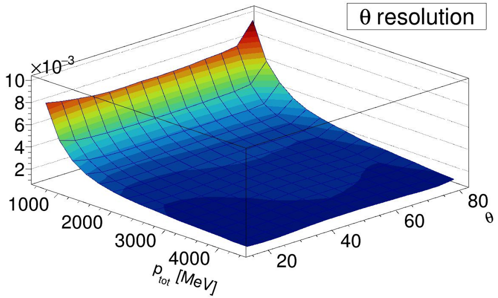
No PID for particles in Forward Tracker - we assume that every particle in the FD is a proton.

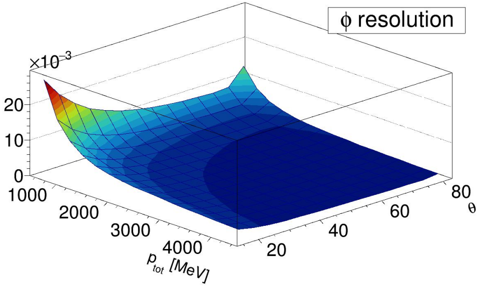
Input and performance of kinematic fit

Detector resolution parametrization

- Based on white simulations of protons, $\pi^+\pi^-$
- Error parametrization as a function of theta and momentum



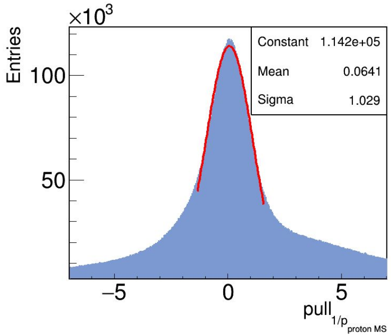


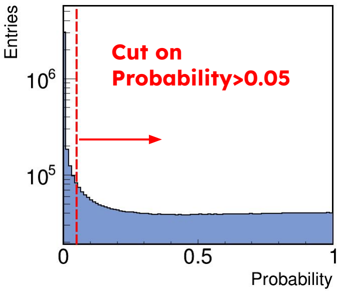


Control plots of Kinematic fit

Proper distributions:

- Pull distributions - gaussian like with $\mu = 0$, $\sigma = 1$
- Probability distributions - flat at whole range [0, 1] except peak at 0 originating from background events





Missing Mass(pp) distributions

Similar mesons mass resolutions in data as in simulations

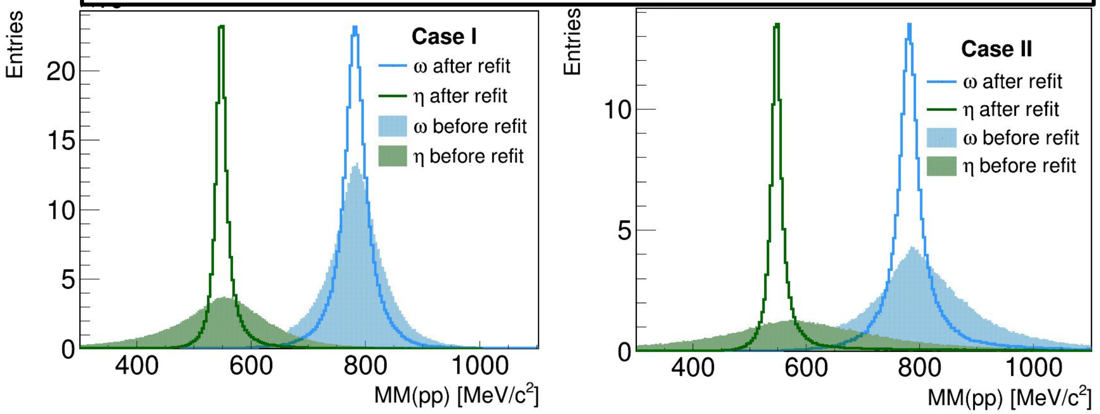
PDG masses: η(547.7), ω(782,7)

		Mean mass $[\mathrm{MeV/c^2}]$	σ $[\mathrm{MeV/c^2}]$	Signal/BKG ratio
η	Case I	547.0	9.6	1.08
	Case II	546.8	9.1	0.35
ω	Case I	782.3	18.9	0.55
	Case II	779.0	16.7	0.21

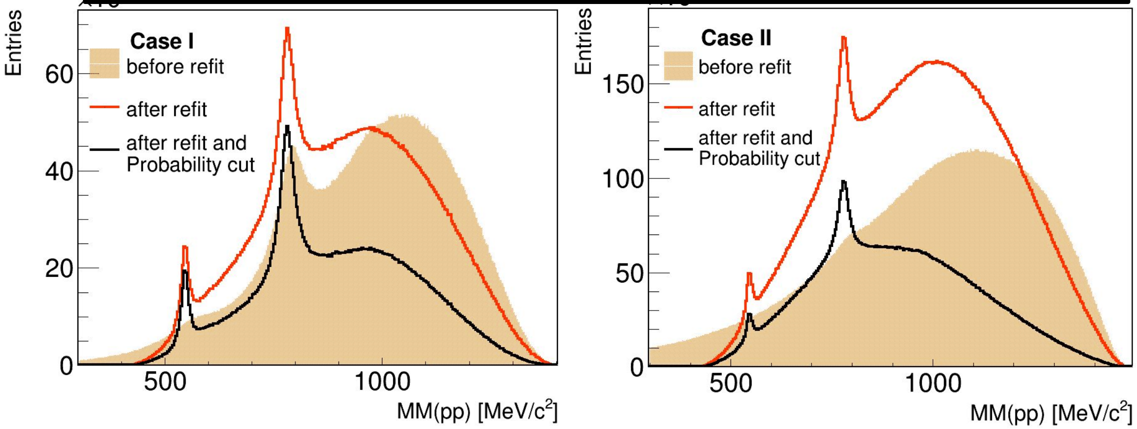
Main BKG channels

Process	Cross-section $[\mu b]$
$pp \rightarrow pp\pi^+\pi^-$	2840
$pp \rightarrow pp\pi^+\pi^-\pi^0$	1840
$pp \rightarrow pp\pi^+\pi^-\pi^0\pi^0$	300
$pp \rightarrow pp\pi^+\pi^+\pi^-\pi^-$	227

Simulated data



Real data



Background subtraction

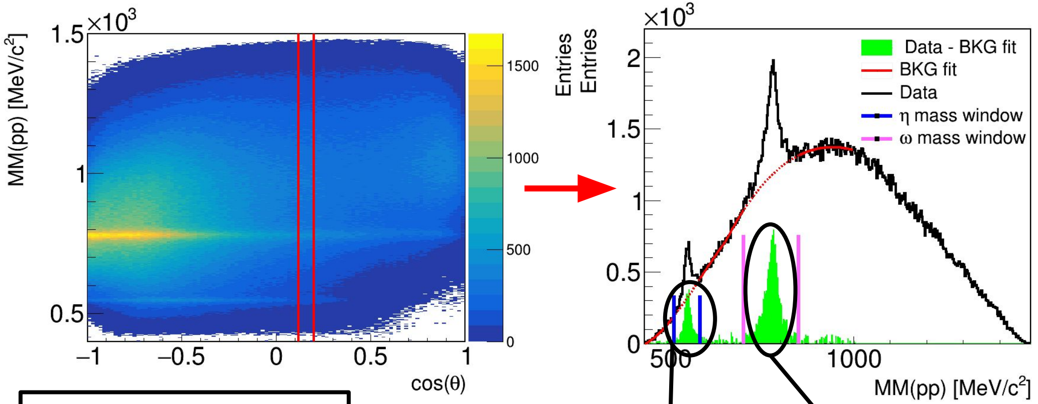
- 4-th order polynomial fitted as background
- Reconstruction of signal observables by subtracting background in consecutive bins

First look at the cross-section

Number of reconstructed mesons obtained from day 63 (lumi: 208 nb^{-1})

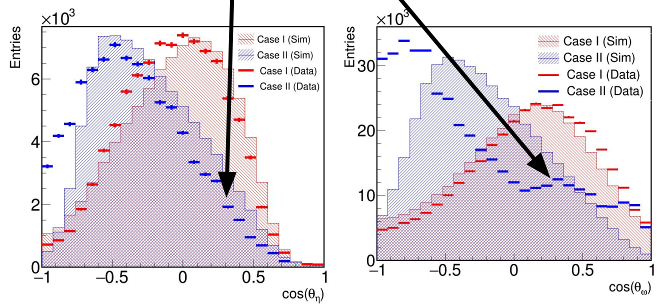
Expected cross-section	
	$pp \rightarrow pp\eta$ (~100 μb)
	$pp \rightarrow pp\omega$ (80-150 μb)

		Reconstructed mesons	Expected number of mesons for the full beamtime	Cross-section [μb]
η	Case I	$34 \cdot 10^3$	$1.0 \cdot 10^6$	37
	Case II	$42 \cdot 10^3$	$1.2 \cdot 10^6$	59
ω	Case I	$134 \cdot 10^3$	$3.8 \cdot 10^6$	44
	Case II	$210 \cdot 10^3$	$6.0 \cdot 10^6$	104



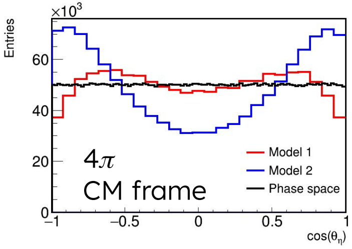
Cross-section smaller by factor 2-3 than expected - multivariable reconstruction efficiency studies needed

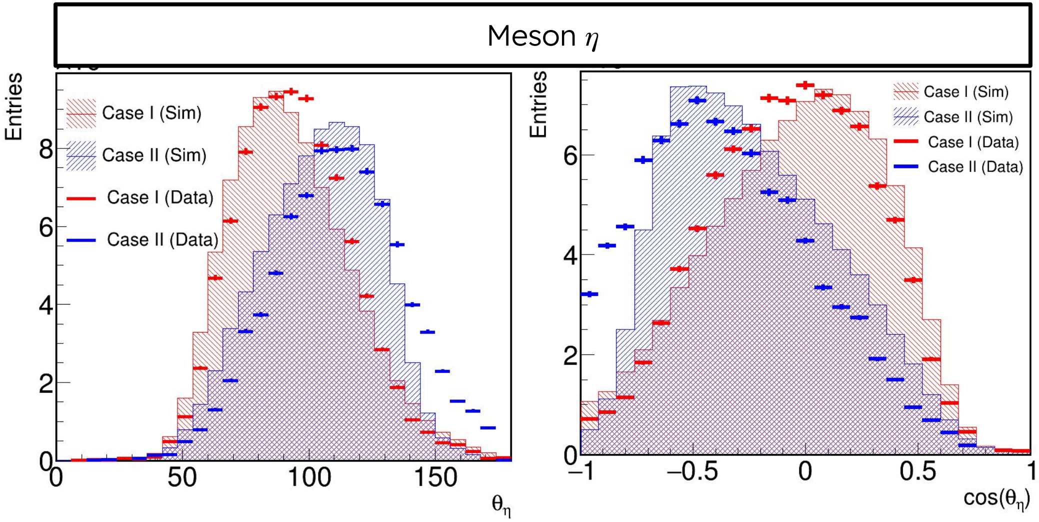
Comparable statistics of ω with glueX experiment

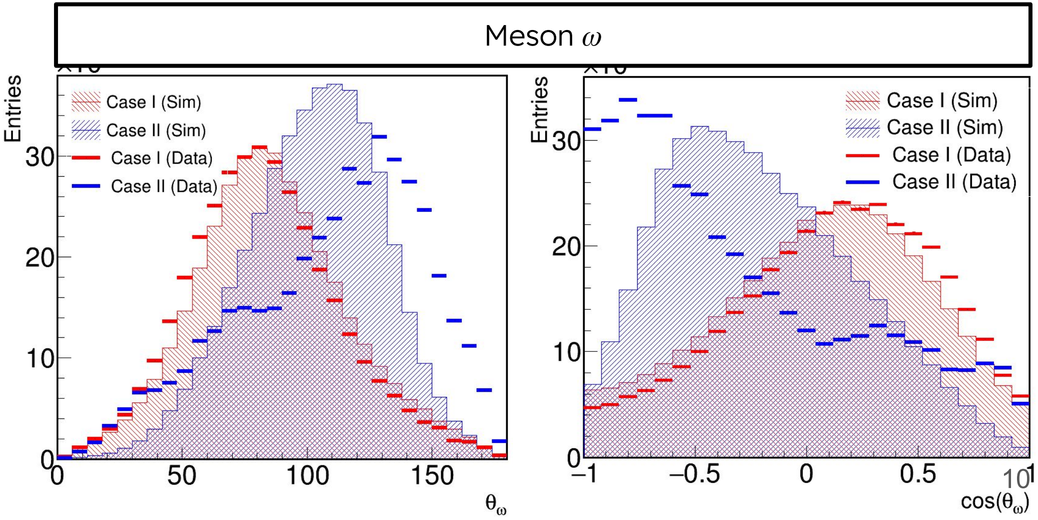


Angular distributions of η/ω

- Extracted shapes of distributions seem to roughly agree with phase space simulation in Case I → similar detector acceptance influence
- In Case II big differences between data and phase space simulations → possible not rejected background, further studies of purity needed







Dalitz plots $\eta/\omega \rightarrow \pi^{+}\pi^{-}\pi^{0}$

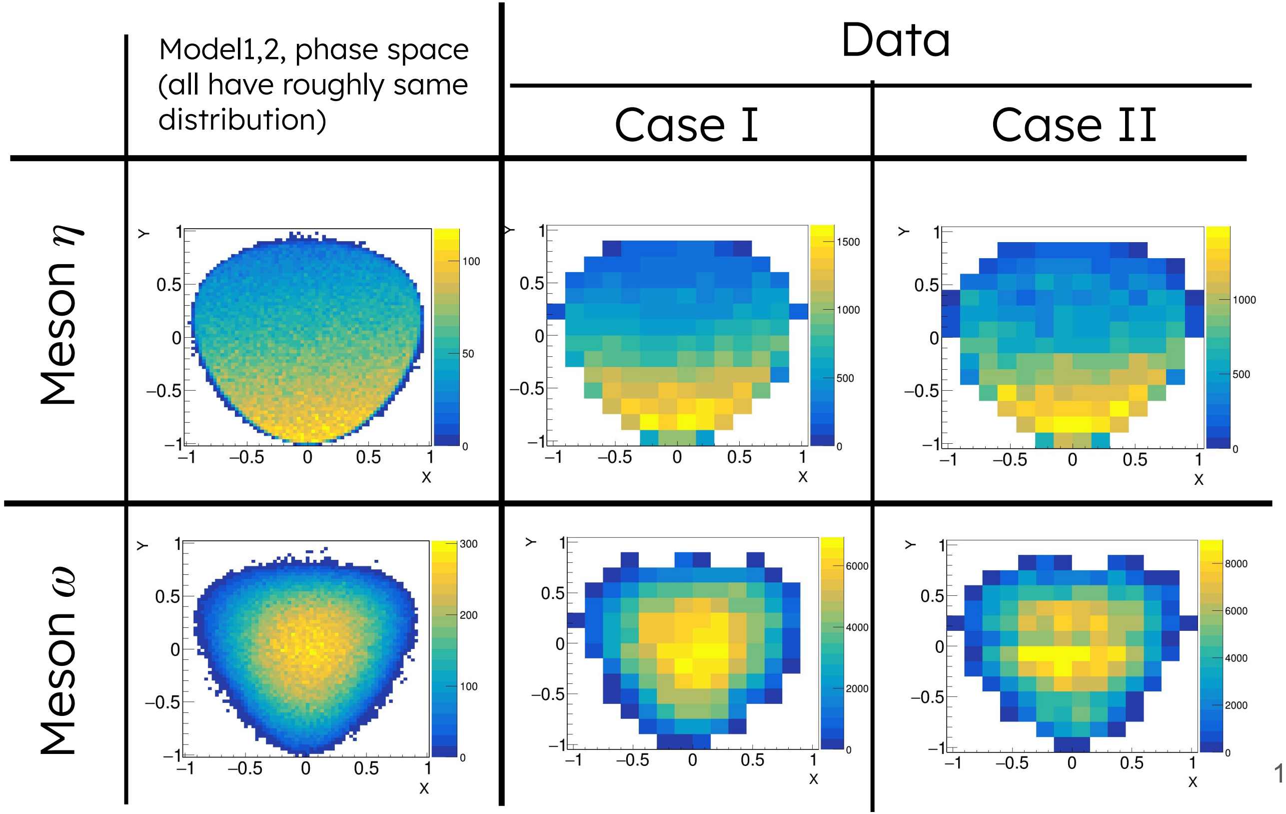
Preliminary study
in HADES Acc

- In 4π - uniform distributions
- In HADES acceptance - visible maxima → **Detector acceptance influence**

$$X = \sqrt{3}\frac{(T_{\pi^+} - T_{\pi^-})}{Q},$$

$$Y = 3\frac{T_{\pi^0}}{Q} - 1,$$

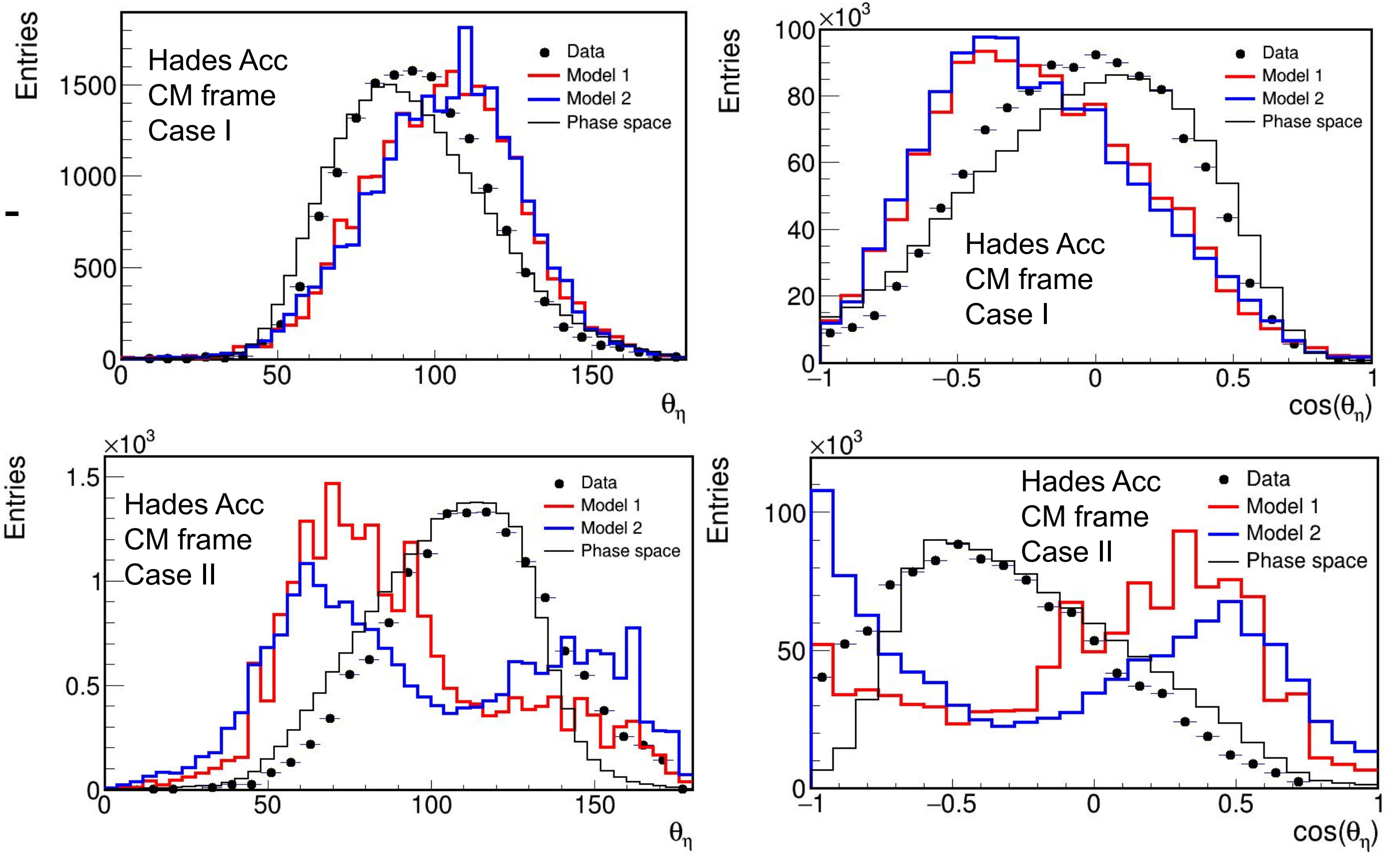
$$Q = T_{\pi^+} + T_{\pi^-} + T_{\pi^0},$$



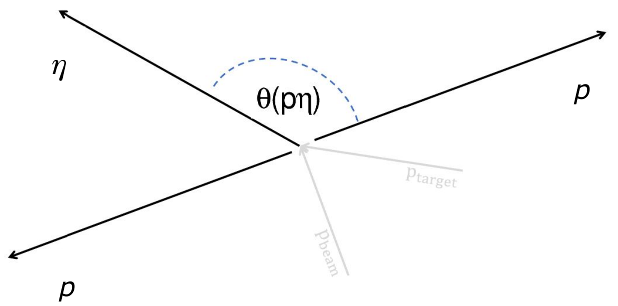
Study of Eta - Angular distributions of η in center-of-mass frame

Simulations normalized to data - only shape comparison

- Data favoure phase-space distribution

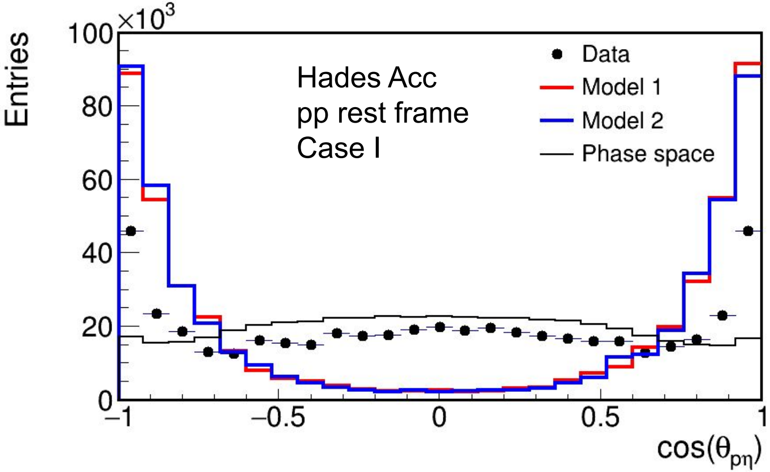


Study of Eta - Helicity frame (pp rest frame)



- Resonance contribution seen in data

- Underestimated non-resonant production in models?



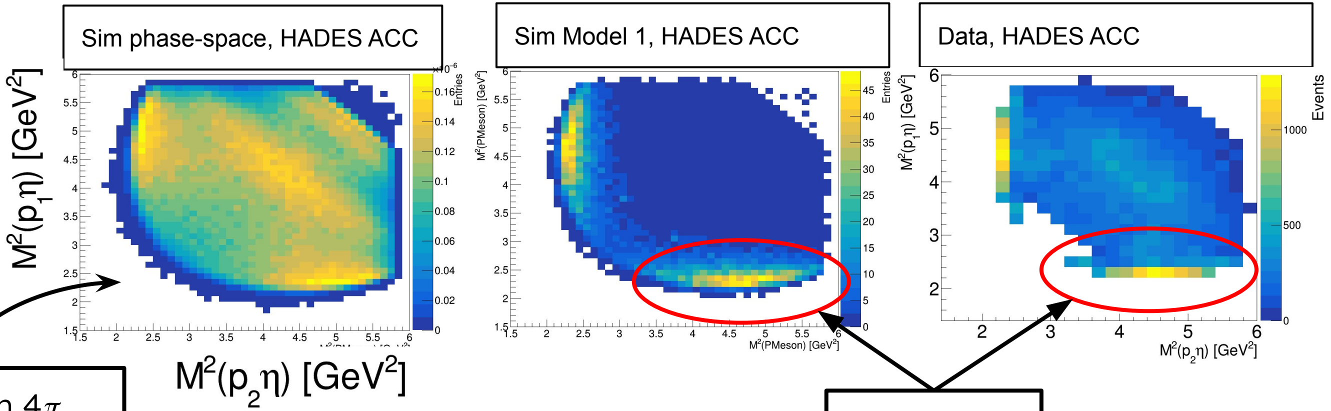
Summary

- Mean mass of mesons from fit consistent with PDG
- Similar influence of detector acceptance on both data and simulation - evidence of signal in data
- Eta models - greater than expected contribution from non-resonant production?

Outlook

- Check purity of kinematic fit
- Perform multivariable reconstruction efficiency studies

Backup - Dalitz $pp \rightarrow pp\eta$



Uniform in In 4π, pattern - detector acceptance

Baryonic resonances