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Ξ^* Resonances in $\bar{p}p \to \bar{\Xi}^+\Xi^-\pi^0$

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PANDA Collaboration Meeting 1/18, GSI Darmstadt

Status of Ξ^* Resonances

- Little known
- Decay modes:
  - $\Xi^* \to \Xi\pi$
  - $\Xi^* \to \Lambda\bar{K}$
  - $\Xi^* \to \Sigma\bar{K}$
  - $\Xi^* \to \Xi\pi\pi$
  - $\Xi^* \to \Xi^{*\prime}\pi$
  - $\Xi^* \to \Xi\eta$
  - $\Xi^* \to \Xi\eta\pi$
  - $\Xi^* \to \Xi\omega$

Table 1. The status of the Ξ resonances. Only those with an overall status of *** or **** are included in the Baryon Summary Table.

			Status as seen in —				
Particle	J^P	Overall status	$\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$	Other channels
$\Xi(1318)$	$1/2+$?	****					Decays weakly
$\Xi(1530)$	$3/2+$	****	****				
$\Xi(1620)$		*	*				
$\Xi(1690)$		***		***	**		
$\Xi(1820)$	$3/2-$?	***	**	***	**	**	
$\Xi(1950)$		***	**	**		*	
$\Xi(2030)$		***		**	***		
$\Xi(2120)$		*		*			
$\Xi(2250)$		**					3-body decays
$\Xi(2370)$		**					3-body decays
$\Xi(2500)$		*		*	*		3-body decays

Studied Event Samples

- beam momentum p = 4.6 GeV/c
  - data set (1): 4 M events $\bar{p}p \to \bar{\Xi}^{+}\Xi^{-}\pi^{0}$ (PHSP)
  - data set (2): 5 M events $\bar{p}p \to \bar{\Xi}^{+}\Xi^{*-} \to \bar{\Xi}^{+}\Xi^{-}\pi^{0}$ & c.c. with $\Xi(1530)$, $\Xi(1690)$, $\Xi(1820)$ & c.c. & $\bar{\Xi}^{+}\Xi^{-}\pi^{0}$ cont., weight 1/7 each sub-channel
  - data set (3): 22 M events DPM
  - data set (4): 6.6 M events $\bar{p}p \to \bar{p}p\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$ (PHSP)

Simulation & Analysis Parameters

- same procedure for all data sets
- standard detector, Geant4, ‚recoideal', ideal PID
- PandaRoot trunk 30122 & 30127
- no visible difference → both data sets added
- define $\bar{\Xi}^+, \Xi^-$ as stable particles in EvtGen decay file
- use modified decay of $\bar{\Lambda}, \Lambda$ in Geant4 → 98.6% signal events
- both MC & reco info in one ntuple (quasi-complete)

Analysis Procedure

1. require all particles in the signal decay tree in the MC list
2. require all final particle candidates present with ‚hit tag' for charged particles: >3 hits in any central tracking detector
3. reconstruct $\bar{\Lambda}, \Lambda$ vertices (1.: vtx fit, 2.: mass constraint fit)
4. reconstruct π^0
5. reconstruct $\bar{\Xi}^+, \Xi^-$ vertices (1.: vtx fit, 2.: mass constraint fit)
6. reconstruct $\bar{\Xi}^+\Xi^-$ system (vtx fit)
7. reconstruct $\bar{p}p$ system $\equiv$ $\bar{\Xi}^+\Xi^-\pi^0$ system (4C fit)
8. control spectra for each step

MC Signal Efficiencies Data Set (1)

MC losses due to:

- interaction
- missing hits of daughter particles

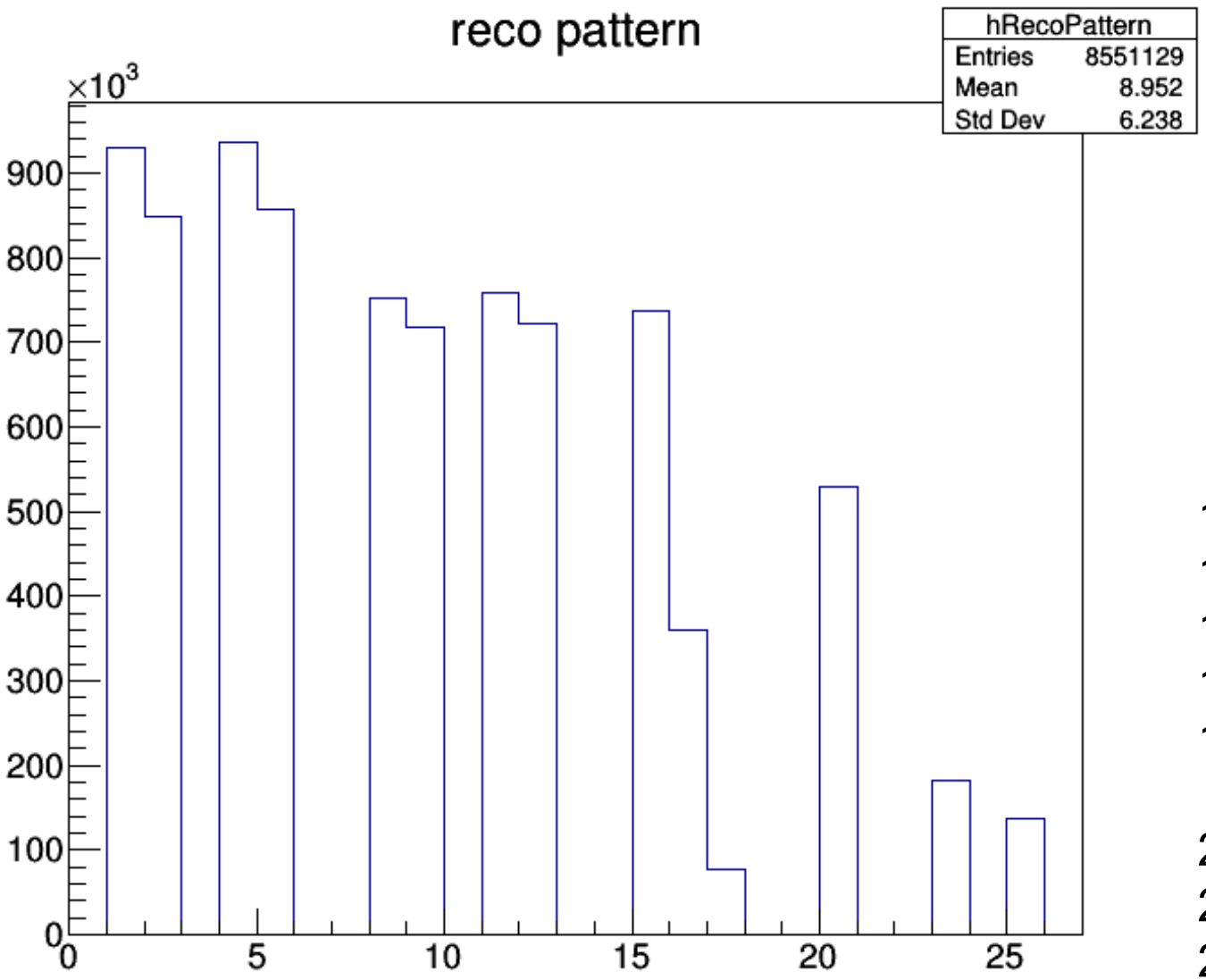
Sample	# Events	n / n_{gen}	n / n_{sig}
generated	4 000 000	1.000	
signal expected	3 943 991	0.986	1.000
MC $\bar{\Xi}^+ \to \bar{\Lambda}\pi^+$	3 908 890	0.977	
MC $\Xi^- \to \Lambda\pi^-$	3 909 768	0.977	
MC $\bar{\Lambda} \to \bar{p}\pi^+$	3 834 971	0.959	
MC $\Lambda \to p\pi^-$	3 838 090	0.960	
MC $\pi^0 \to \gamma\gamma$	3 952 955	0.988	
MC Signal	3 635 933	0.909	0.922
‚reco' tag (R1)	1 014 129		0.257
‚XiXi' tag (R2)	529 137		0.134
‚final' tag (R3)	137 286		0.0348

Resonstruction Efficiency Stable Particles

- n-tuple only filled for fully ‚reconstructable' events
- separate analysis

$\bar{p}$	p	$\pi^+(\bar{\Xi}^+)$	$\pi^+(\bar{\Lambda})$	$\pi^-(\Xi^-)$	$\pi^-(\Lambda)$
0.837	0.867	0.757	0.709	0.753	0.706

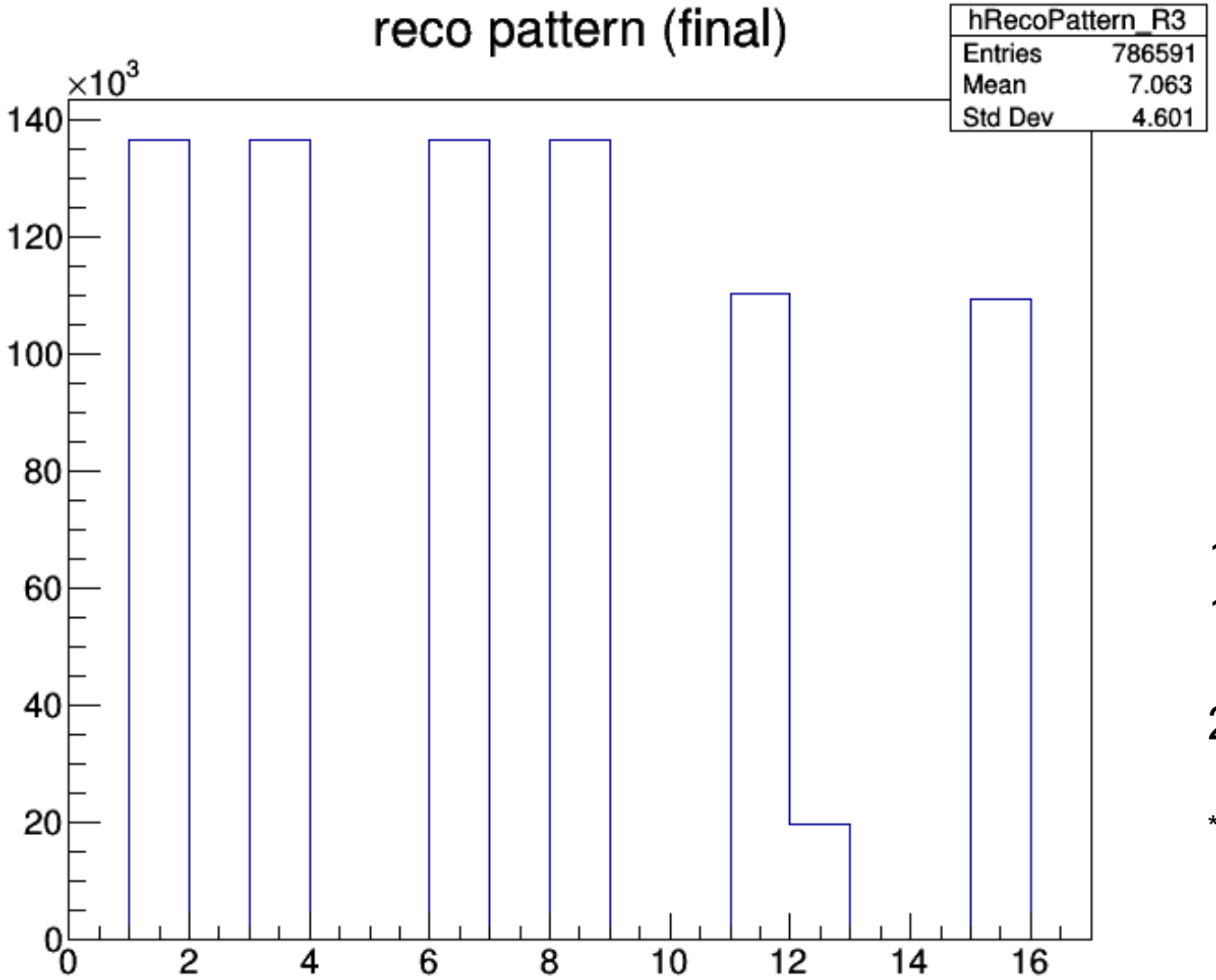
Reconstruction Efficiencies



reference:
reconstructable events

1:	Λ reco	0.916
2:	Λ reco true	0.838
4:	$\bar{\Lambda}$ reco	0.924
5:	$\bar{\Lambda}$ reco true	0.845
8:	Ξ^- reco	0.743
9:	Ξ^- reco true	0.708
11:	$\bar{\Xi}^+$ reco	0.748
12:	$\bar{\Xi}^+$ reco true	0.713
15:	π^0 reco	0.728
16:	π^0 reco true	0.355
17:	π^0 reco conv.	0.076
	π^0 true + conv.	0.431
20:	$\bar{\Xi}^+\Xi^-$ reco	0.522
23:	$\bar{p}p$ cand true	0.180
25:	$\bar{p}p$ reco	0.136

MC Truth Fraction Final $\bar{\Xi}^+\Xi^-\pi^0$ Sample



4C fit & mass cut

reference:
final sample

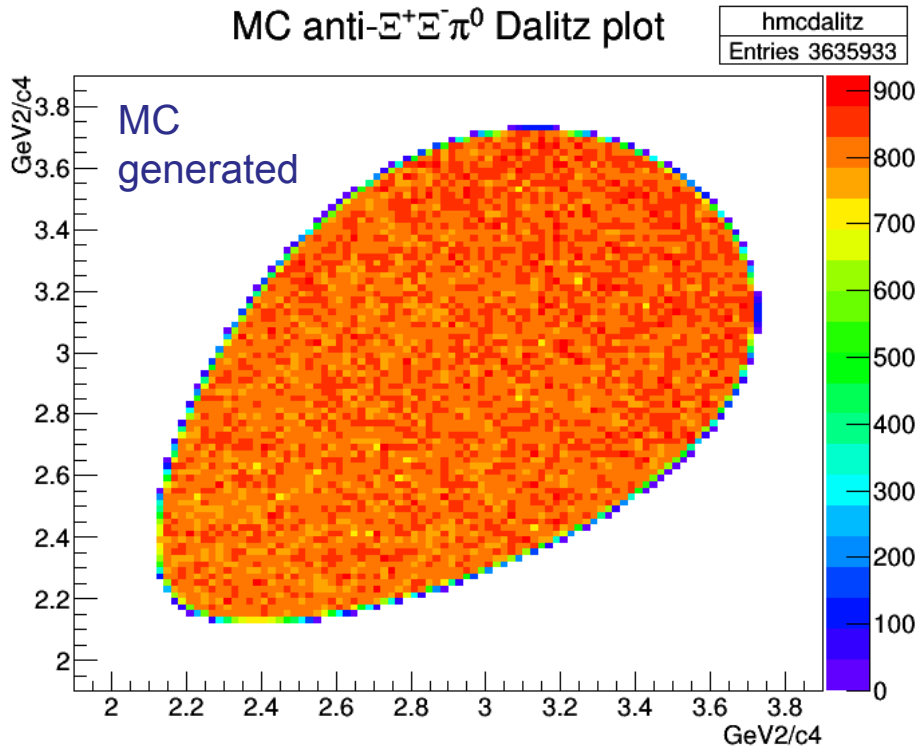
1:	Λ true	0.996
3:	$\bar{\Lambda}$ true	0.996
6:	Ξ^- true	0.996
8:	$\bar{\Xi}^+$ true	0.995
11:	π^0 true	0.805
12:	π^0 conv.	0.144
	π^0 true + conv.	0.949
23:	$\bar{p}p$ true*	0.798

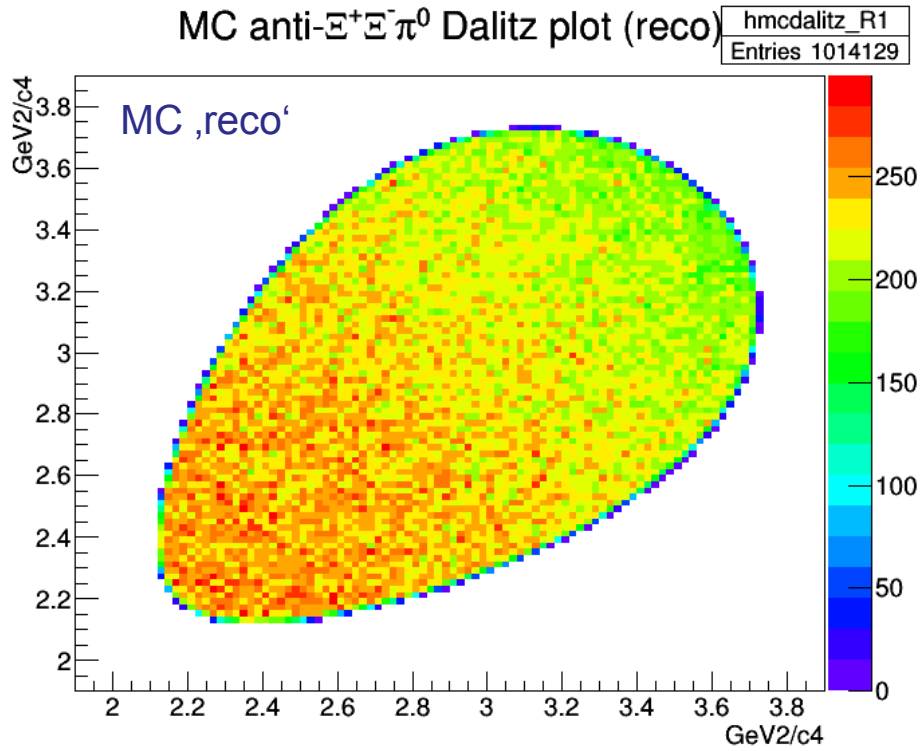
* γ conv. not included

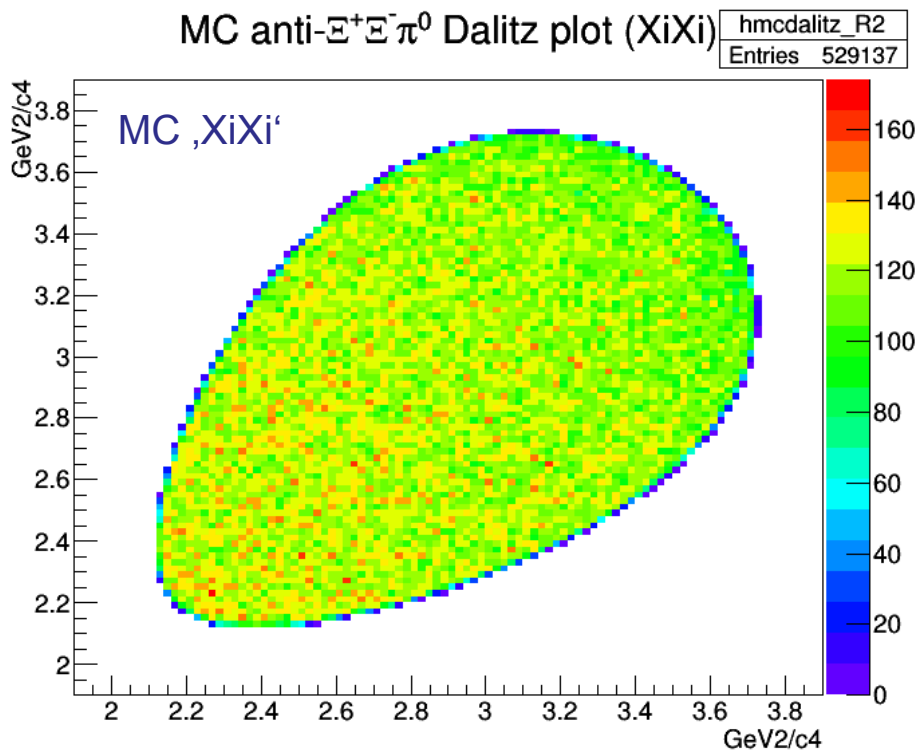
incl. γ conv.: 0.941

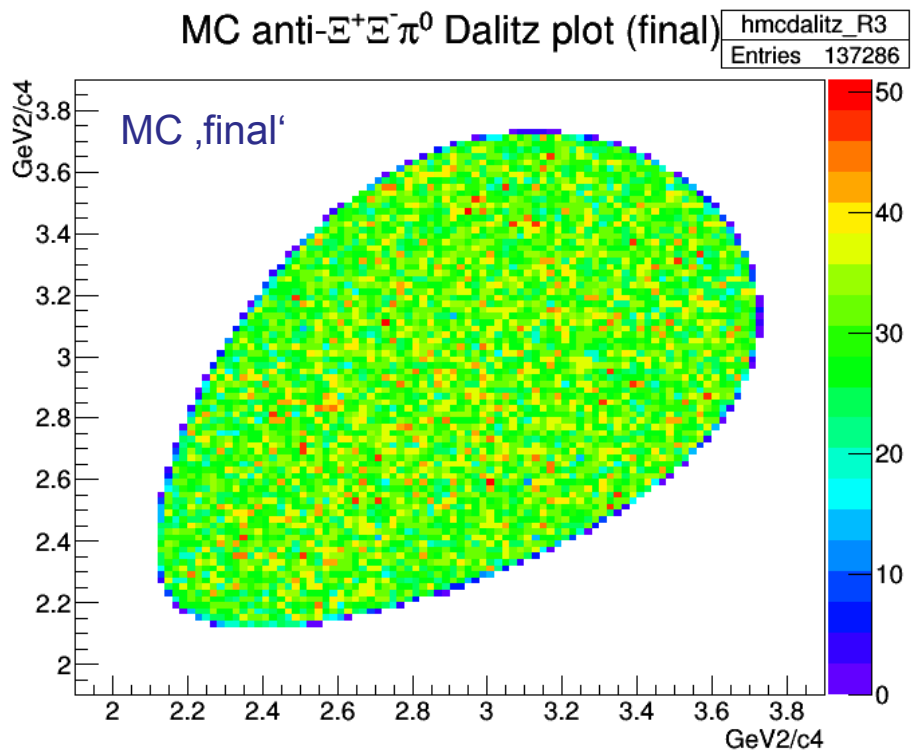
Histograms

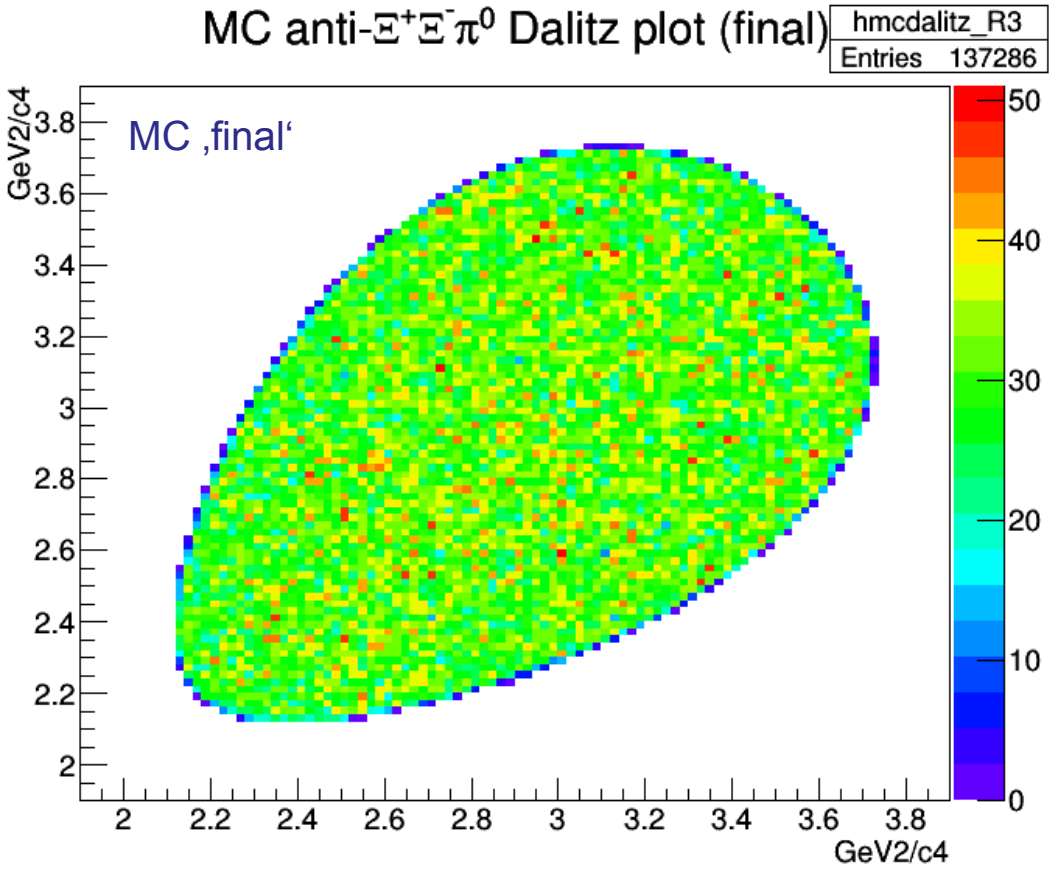
- ~1000 histograms created → here: only few final plots !
- MC spectra:
  - P_x, P_y, P_z, P, P_t, θ, P_t vs P_z, θ vs P for all particles: $\bar{\Xi}^+, \Xi^-, \pi^0, \bar{\Lambda}, \Lambda, \pi^+{}_1, \pi^-{}_1, \gamma_1, \gamma_2, \bar{p}, p, \pi^+{}_2, \pi^-{}_2$
  - decay positions of $\bar{\Xi}^+, \Xi^-, \bar{\Lambda}, \Lambda$
  - $\bar{\Xi}^+\Xi^-\pi^0$ 2-body mass spectra & Dalitz plot
  - 4 analysis levels: ‚generated', ‚reco', ‚XiXi', ‚final'
- reco spectra:
  - $\bar{\Xi}^+, \Xi^-, \bar{\Lambda}, \Lambda$ vertex: position, reco-true, pulls
  - all fits (vtx, m.c.f., 4C; $\bar{\Xi}^+, \Xi^-, \bar{\Lambda}, \Lambda, \pi^0, \bar{\Xi}^+\Xi^-, \bar{\Xi}^+\Xi^-\pi^0$): : χ^2 and prob.
  - mass spectra of composite particles at different stages
  - 4-momenta of all particles before & after 4C fit
- large number of control spectra

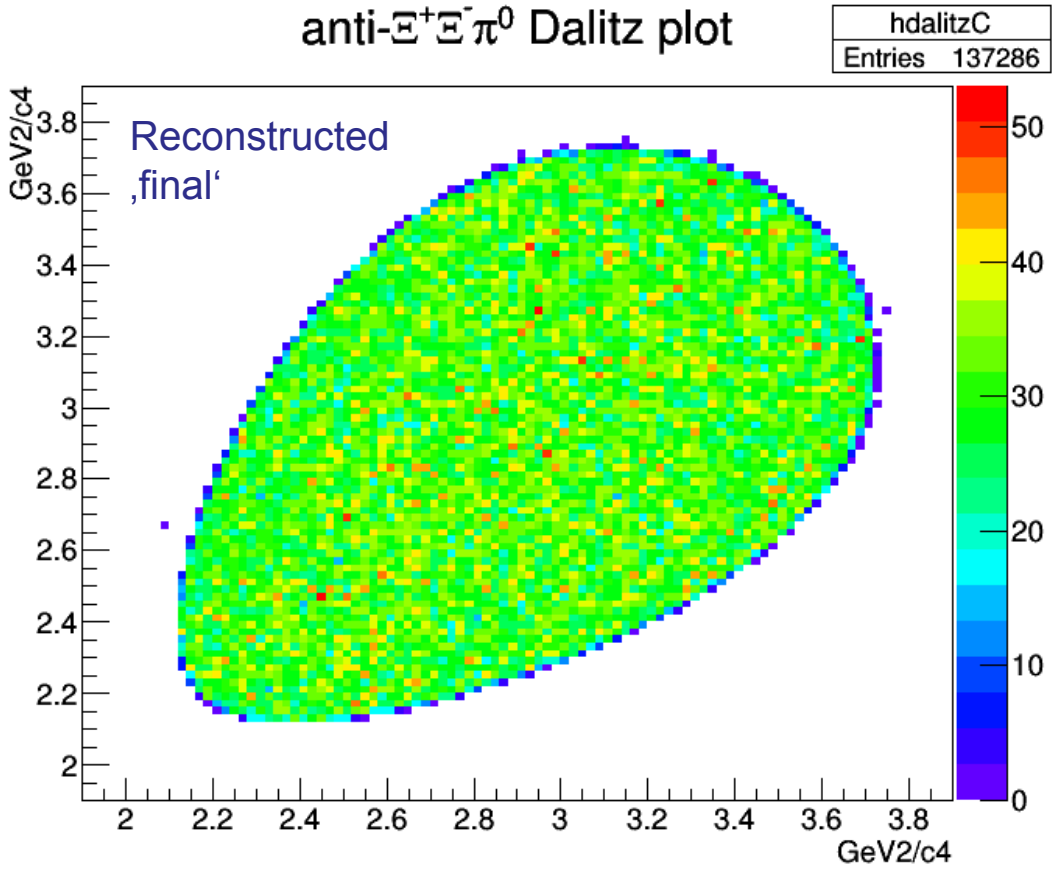

MC anti-Ξ⁺Ξ⁻π⁰ Dalitz plot
hmcdalitz
Entries 3635933
MC
generated
GeV2/c4
GeV2/c4


MC anti-Ξ⁺Ξ⁻π⁰ Dalitz plot (reco)
hmcdalitz_R1
Entries 1014129
MC ‚reco‘
GeV2/c4
GeV2/c4


MC anti-Ξ⁺Ξ⁻π⁰ Dalitz plot (XiXi)
hmcdalitz_R2
Entries 529137
MC ‚XiXi‘
GeV2/c4
GeV2/c4

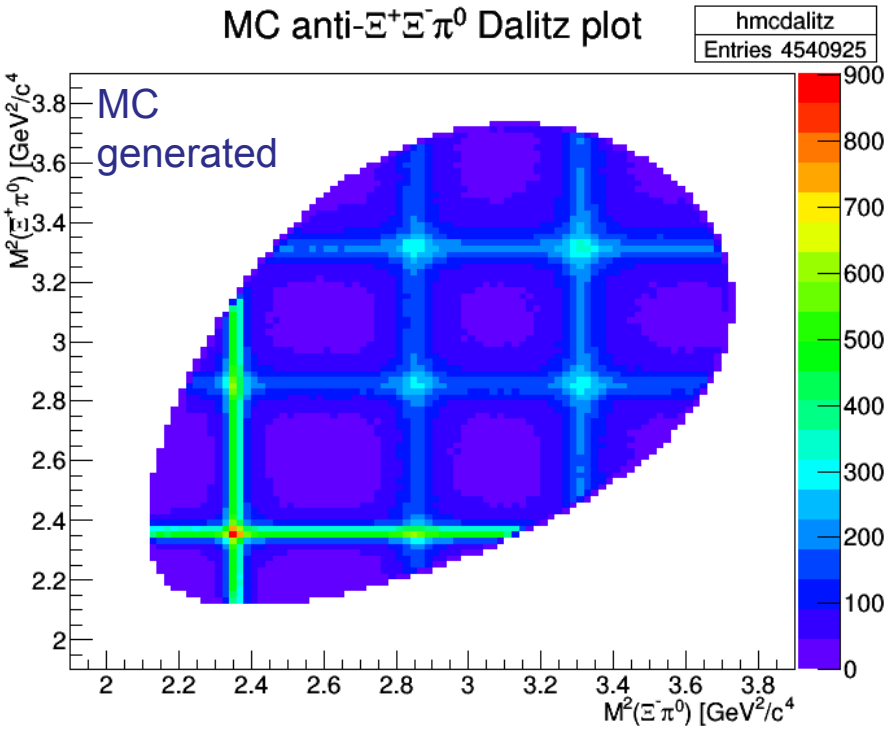

MC anti-Ξ⁺Ξ⁻π⁰ Dalitz plot (final)
hmcdalitz_R3
Entries 137286
MC ‚final‘
GeV2/c4
GeV2/c4

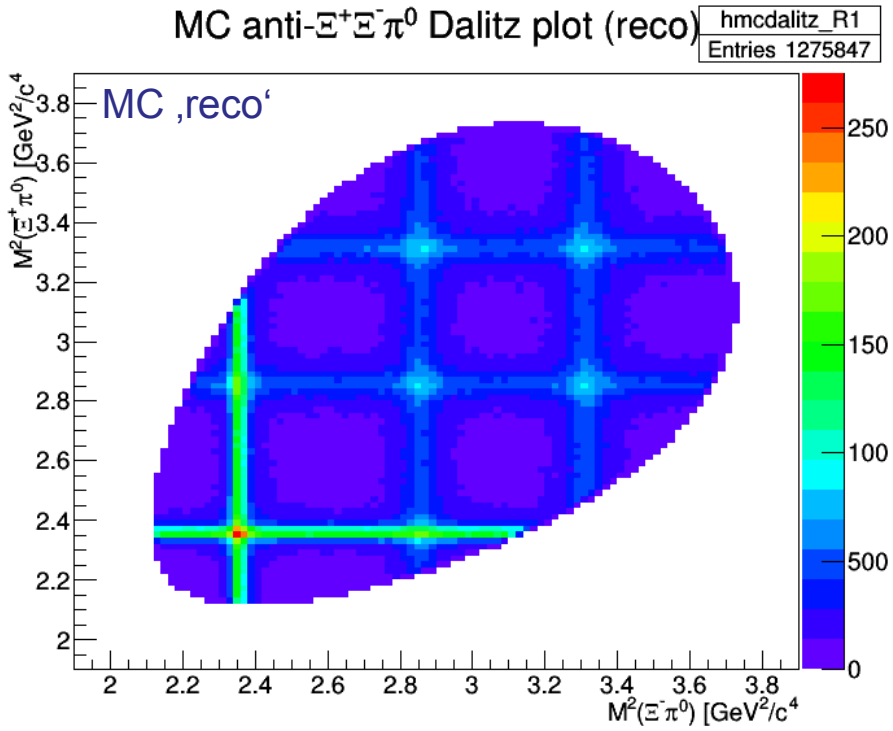

MC anti-Ξ⁺Ξ⁻π⁰ Dalitz plot (final)
hmcdalitz_R3
Entries 137286
MC ‚final‘
GeV2/c4
GeV2/c4

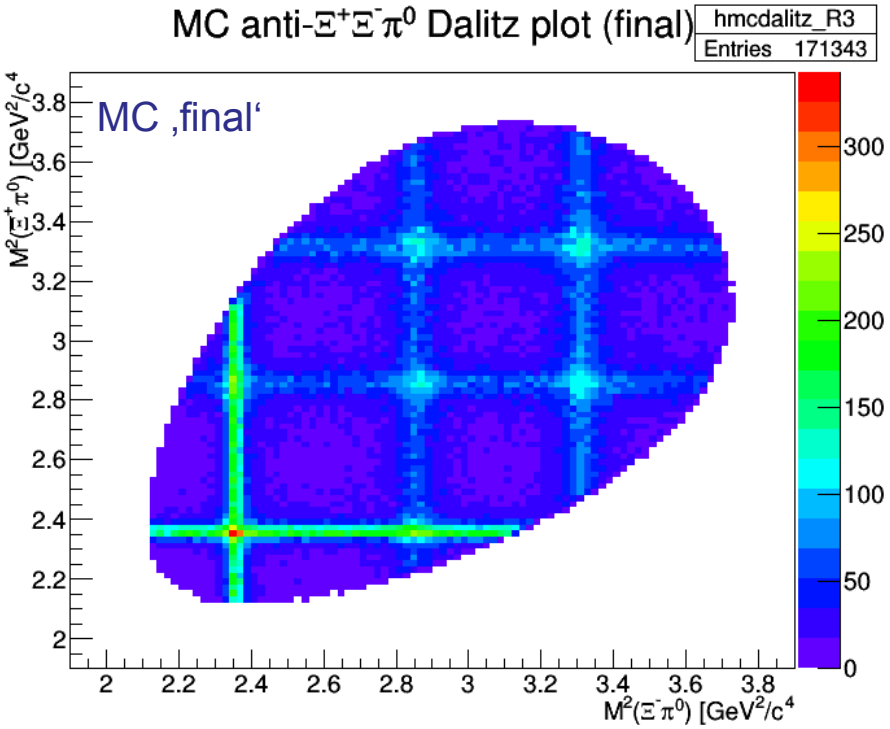

anti-Ξ⁺Ξ⁻π⁰ Dalitz plot
hdalitzC
Entries 137286
Reconstructed
‚final‘
GeV2/c4
GeV2/c4

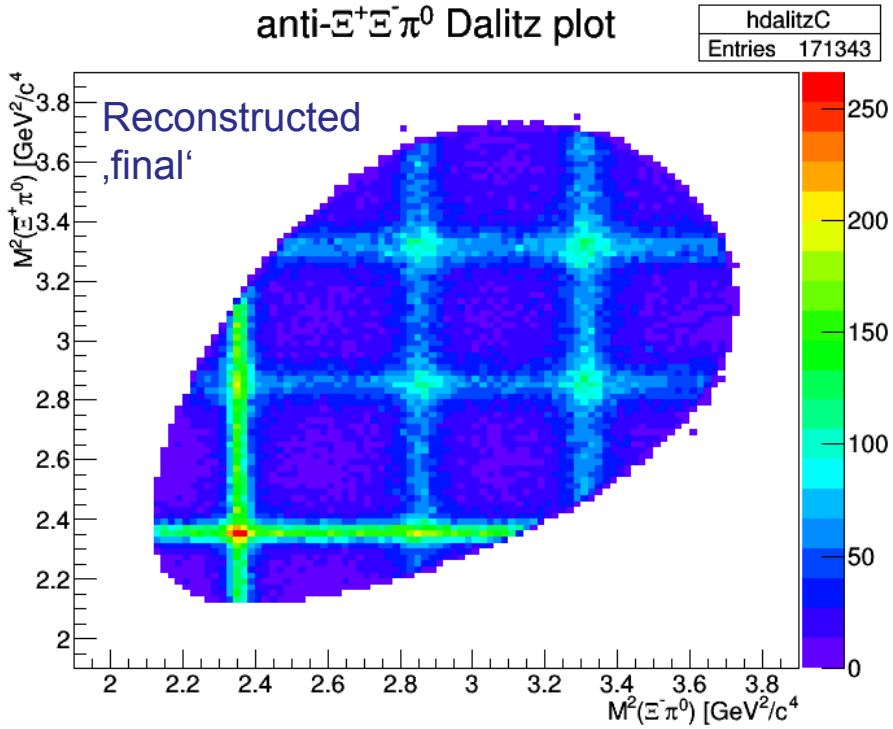
Signal Data Set (2): Include Ξ^* Resonances

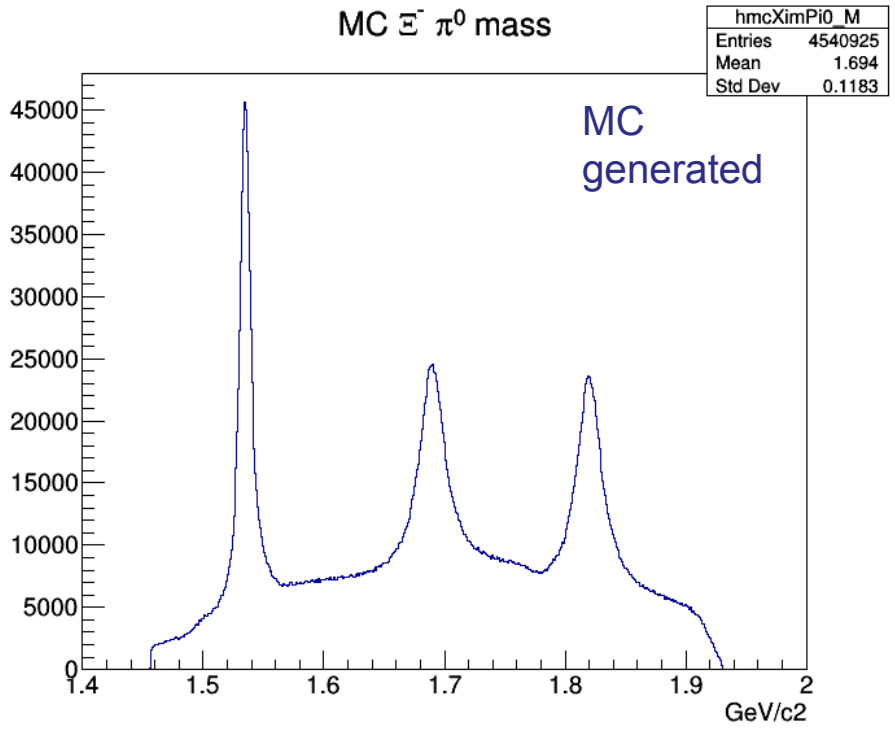
- decay of the $\bar{p}p$ system to (b = 1/7 each):
  - $\bar{\Xi}^+\Xi(1530)^- \rightarrow \bar{\Xi}^+\Xi^-\pi^0$
  - $\bar{\Xi}^+\Xi(1690)^- \rightarrow \bar{\Xi}^+\Xi^-\pi^0$
  - $\bar{\Xi}^+\Xi(1820)^- \rightarrow \bar{\Xi}^+\Xi^-\pi^0$
  - $\bar{\Xi}(1530)^+\Xi^- \rightarrow \bar{\Xi}^+\Xi^-\pi^0$
  - $\bar{\Xi}(1530)^+\Xi^- \rightarrow \bar{\Xi}^+\Xi^-\pi^0$
  - $\bar{\Xi}(1530)^+\Xi^- \rightarrow \bar{\Xi}^+\Xi^-\pi^0$
  - $\bar{\Xi}^+\Xi^-\pi^0$
- 5 M events
- all reco efficiency values are same as for data set (1)

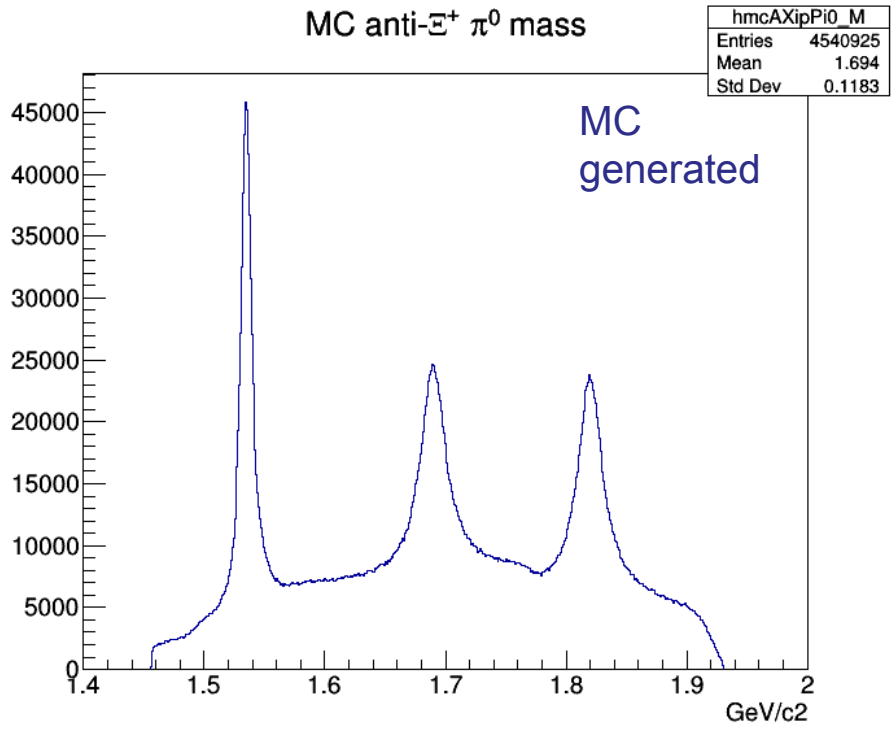

MC anti-Ξ⁺Ξ⁻π⁰ Dalitz plot
hmcdalitz
Entries 4540925
MC
generated
M²(Ξ⁺π⁰) [GeV²/c⁴]
M²(Ξ⁻π⁰) [GeV²/c⁴]

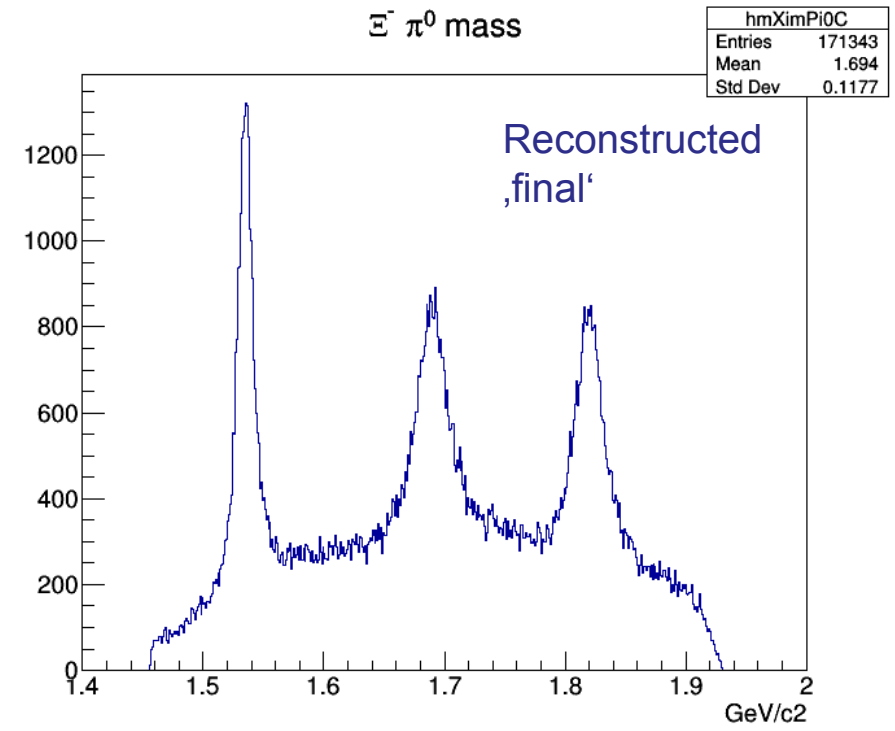

MC anti-Ξ⁺Ξ⁻π⁰ Dalitz plot (reco)
hmcdalitz_R1
Entries 1275847
MC ‚reco‘
M²(Ξ⁺π⁰) [GeV²/c⁴]
M²(Ξ⁻π⁰) [GeV²/c⁴]

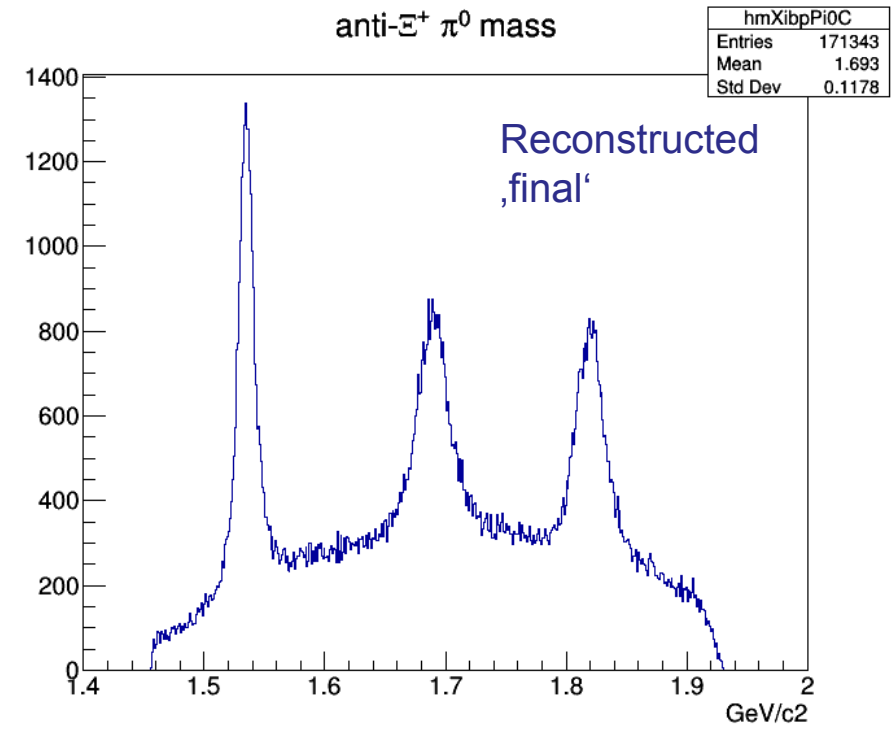

MC anti-Ξ⁺Ξ⁻π⁰ Dalitz plot (final)
hmcdalitz_R3
Entries 171343
MC ‚final‘
M²(Ξ⁺π⁰) [GeV²/c⁴]
M²(Ξ⁻π⁰) [GeV²/c⁴]


anti-Ξ⁺Ξ⁻π⁰ Dalitz plot
hdalitzC
Entries 171343
Reconstructed
‚final‘
M²(Ξ⁺π⁰) [GeV²/c⁴]
M²(Ξ⁻π⁰) [GeV²/c⁴]


MC Ξ⁻ π⁰ mass
hmcXimPi0_M
Entries 4540925
Mean 1.694
Std Dev 0.1183
MC generated
GeV/c2


MC anti-Ξ⁺ π⁰ mass
hmcAXipPi0_M
Entries 4540925
Mean 1.694
Std Dev 0.1183
MC generated
GeV/c2


Ξ⁻ π⁰ mass
hmXimPi0C
Entries 171343
Mean 1.694
Std Dev 0.1177
Reconstructed
‚final‘
GeV/c2


anti-Ξ⁺ π⁰ mass
hmXibpPi0C
Entries 171343
Mean 1.693
Std Dev 0.1178
Reconstructed
‚final‘
GeV/c2

Data Set (3): DPM Background

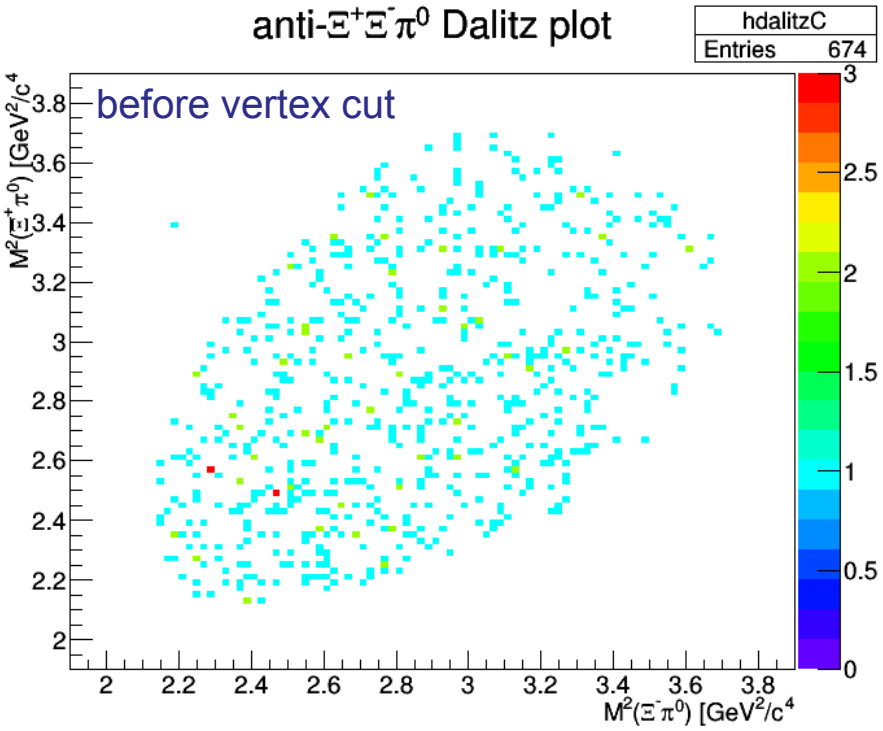
- identical analysis procedure
- 2 events out of 22 million survived all selection criteria
- both events have prompt $\Lambda, \bar{\Lambda}, \Xi^-, \bar{\Xi}^+$ decay vertices within 3 mm
- requiring $3\ \mathrm{mm} < ct_{\Lambda,\bar{\Lambda}} < 1\ \mathrm{m}$ and $d_{\Xi^-\bar{\Xi}} > 2\ \mathrm{mm}$ both events are eliminated

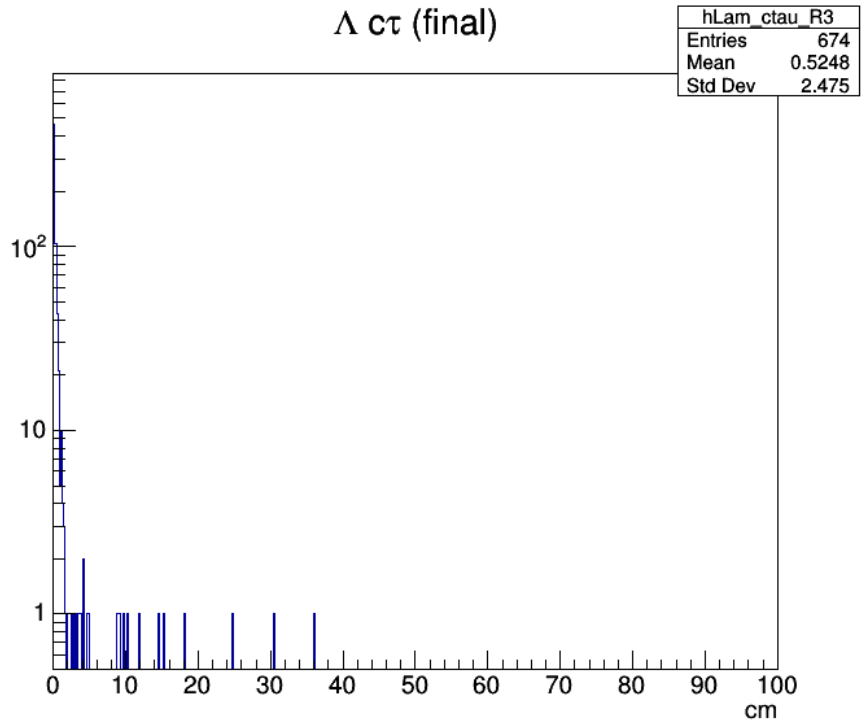
- signal-to-background: $\eta_{S/B} > 4.6$ (90% C.L.)
- significance: $S_{\mathrm{signal}} > 349$ (90% C.L.)

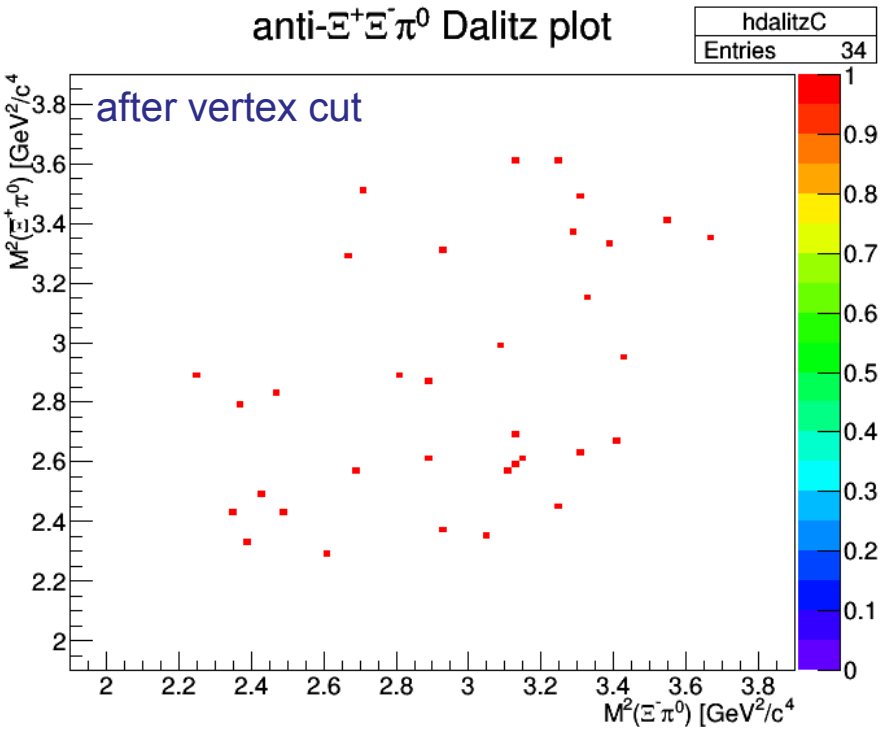
Data Set (4): $\bar{p}p \to \bar{p}p\pi^+\pi^+\pi^-\pi^-\pi^0$

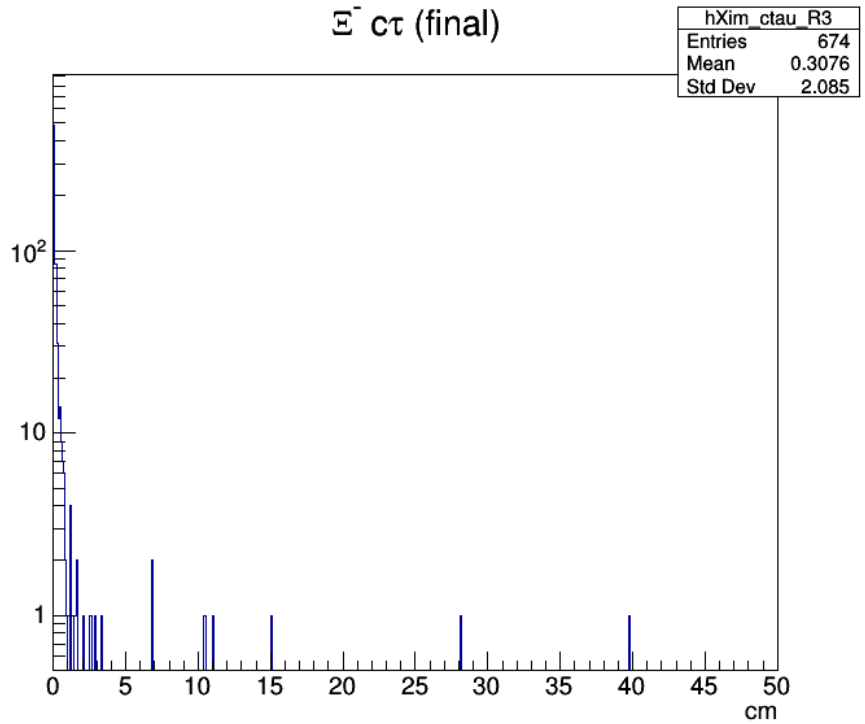
- 6.6 M events, $\sigma \cong 100\ \mu\mathrm{b}$ (extrapolated from data at higher $p_{\bar{p}}$)
- 674 events survived all selection criteria
- most events have $\Lambda, \bar{\Lambda}, \Xi^-, \bar{\Xi}^+$ decay vertices within few mm
- after requiring $3\ \mathrm{mm} < ct_{\Lambda,\bar{\Lambda}} < 1\ \mathrm{m}$ and $d_{\Xi-\bar{\Xi}} > 2\ \mathrm{mm}$, 34 events survive

- signal-to-background: $\eta_{S/B} = 47$
- significance: $S_{\mathrm{signal}} = 381$


anti-Ξ⁺Ξ⁻π⁰ Dalitz plot
hdalitzC
Entries 674
before vertex cut
M²(Ξ⁺π⁰) [GeV²/c⁴]
M²(Ξ⁻π⁰) [GeV²/c⁴]


Λ cτ (final)
hLam_ctau_R3
Entries 674
Mean 0.5248
Std Dev 2.475
cm


anti-Ξ⁺Ξ⁻π⁰ Dalitz plot
hdalitzC
Entries 34
after vertex cut
M²(Ξ⁺π⁰) [GeV²/c⁴]
M²(Ξ⁻π⁰) [GeV²/c⁴]


Ξ⁻ cτ (final)
hXim_ctau_R3
Entries 674
Mean 0.3076
Std Dev 2.085
cm

Detection of Ξ Resonances in the Reaction $\bar{p}p \to \bar{\Xi}^+\Xi^-\pi^0$ with $\bar{\text{P}}$ANDA (I.)

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(Dated: February 7, 2018)

CONTENTS

Summary

- comprehensive analysis of 4.6 GeV/c $\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{-}\pi^{0}$ including background studies
- over-all reconstruction efficiency: ~3.5 %
- π^{0} reconstruction significantly contributes to efficiency losses (~43%) and to ‚fake' combinations in the final data sample (~5%)
- acceptance and reconstruction uniform across $\bar{\Xi}^{+}\Xi^{-}\pi^{0}$ phase space
- 22 M DPM background events → S/B > 4.6
- 6.6 M $\bar{p}p\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$ events → S/B = 47
- release note ready for distribution to the collaboration