Some Remarks on Ξ^* & Ω^*

Jun 09, 2016 | Albrecht Gillitzer, IKP Forschungszentrum Jülich

LVII PANDA Meeting, GSI Darmstadt, June 2016

Outline

- Summary of Baryons 2016
- Ideas for the Strange Baryon Spectroscopy Program
- MC event generation issues

Baryons 2016

Invitation to give an overview talk on strange baryon spectroscopy

Not a PANDA talk

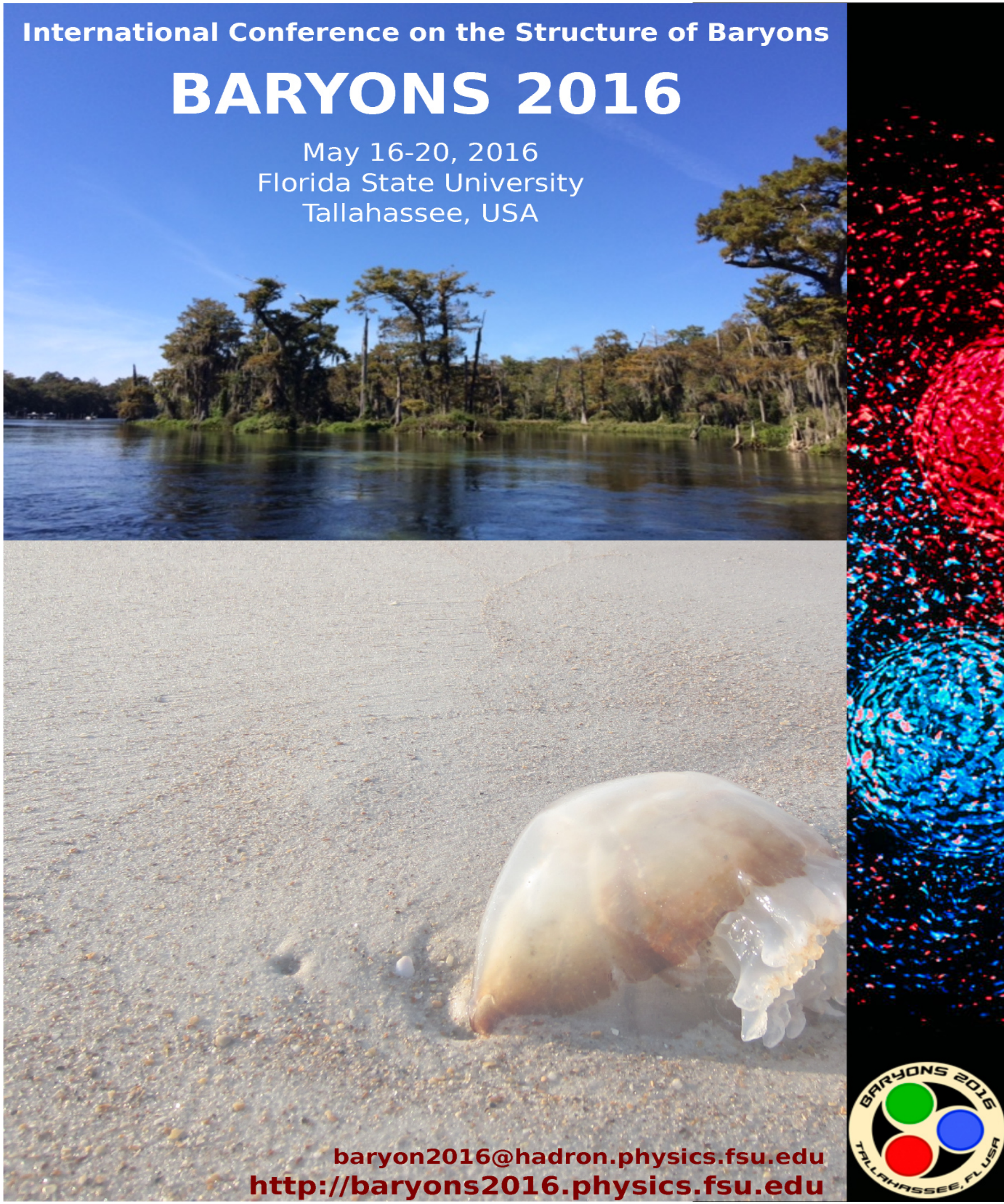
Scientific program:

8 plenary sessions

21 parallel sessions

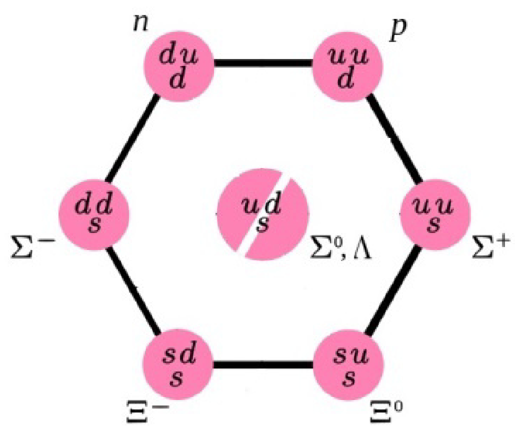
topics: light, heavy and exotic baryons

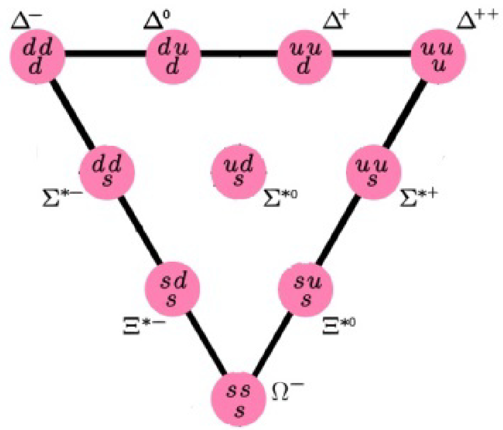
parallel session on „physics of hyperons“



Strange Partners

- Approximate SU(3) flavor symmetry
- N* & Δ states have partners in the strange sector
- focus on Ξ and Ω
  - Ξ: as many states as N* & Δ together
  - Ω: as many states as Δ
- scrutinize our understanding of the baryon excitation pattern





Status of Ξ* Resonances: RPP 2014

Chin. Phys. C 38 (2014) 090001

Ξ(1820):

Teodoro78 favors $J = 3/2$, but cannot make a parity discrimination. Biagi 87c is consistent with $J = 3/2$ and favors negative parity for this J value.

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

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

**** Existence is certain, and properties are at least fairly well explored.

*** Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, *etc.* are not well determined.

** Evidence of existence is only fair.

* Evidence of existence is poor.

SU(6) x O(3) Classification

RPP 2014: Chin. Phys. C 38 (2014) 090001

„Assignments for …
Ξ(1820) and Ξ(2030), are merely educated guesses.“

Ξ(1690), Ξ(1950): ?

T. Melde *et al.*, PRD 77 (2008) 114002

decuplet: no Ξ*, no Ω*

“… nothing of significance on Ξ resonances has been added since our 1988 edition.”

J^P	$(D, L^P_N)\, S$	Octet members				Singlets
$1/2^+$	$(56,0^+_0)$ 1/2	$N(939)$	$\Lambda(1116)$	$\Sigma(1193)$	$\Xi(1318)$	
$1/2^+$	$(56,0^+_2)$ 1/2	$N(1440)$	$\Lambda(1600)$	$\Sigma(1660)$	$\Xi(1690)^\dagger$	
$1/2^-$	$(70,1^-_1)$ 1/2	$N(1535)$	$\Lambda(1670)$	$\Sigma(1620)$	$\Xi(?)$	$\Lambda(1405)$
				$\Sigma(1560)^\dagger$		
$3/2^-$	$(70,1^-_1)$ 1/2	$N(1520)$	$\Lambda(1690)$	$\Sigma(1670)$	$\Xi(1820)$	$\Lambda(1520)$
$1/2^-$	$(70,1^-_1)$ 3/2	$N(1650)$	$\Lambda(1800)$	$\Sigma(1750)$	$\Xi(?)$	
				$\Sigma(1620)^\dagger$		
$3/2^-$	$(70,1^-_1)$ 3/2	$N(1700)$	$\Lambda(?)$	$\Sigma(1940)^\dagger$	$\Xi(?)$	
$5/2^-$	$(70,1^-_1)$ 3/2	$N(1675)$	$\Lambda(1830)$	$\Sigma(1775)$	$\Xi(1950)^\dagger$	
$1/2^+$	$(70,0^+_2)$ 1/2	$N(1710)$	$\Lambda(1810)$	$\Sigma(1880)$	$\Xi(?)$	$\Lambda(1810)^\dagger$
$3/2^+$	$(56,2^+_2)$ 1/2	$N(1720)$	$\Lambda(1890)$	$\Sigma(?)$	$\Xi(?)$	
$5/2^+$	$(56,2^+_2)$ 1/2	$N(1680)$	$\Lambda(1820)$	$\Sigma(1915)$	$\Xi(2030)$	
$7/2^-$	$(70,3^-_3)$ 1/2	$N(2190)$	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	$\Lambda(2100)$
$9/2^-$	$(70,3^-_3)$ 3/2	$N(2250)$	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	
$9/2^+$	$(56,4^+_4)$ 1/2	$N(2220)$	$\Lambda(2350)$	$\Sigma(?)$	$\Xi(?)$	

J^P	$(D, L^P_N)\, S$	Decuplet members			
$3/2^+$	$(56,0^+_0)$ 3/2	$\Delta(1232)$	$\Sigma(1385)$	$\Xi(1530)$	$\Omega(1672)$
$3/2^+$	$(56,0^+_2)$ 3/2	$\Delta(1600)$	$\Sigma(1690)$	$\Xi(?)$	$\Omega(?)$
$1/2^-$	$(70,1^-_1)$ 1/2	$\Delta(1620)$	$\Sigma(1750)$	$\Xi(?)$	$\Omega(?)$
$3/2^-$	$(70,1^-_1)$ 1/2	$\Delta(1700)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$
$5/2^+$	$(56,2^+_2)$ 3/2	$\Delta(1905)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$
$7/2^+$	$(56,2^+_2)$ 3/2	$\Delta(1950)$	$\Sigma(2030)$	$\Xi(?)$	$\Omega(?)$
$11/2^+$	$(56,4^+_4)$ 3/2	$\Delta(2420)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$

Quark Model

Ξ:

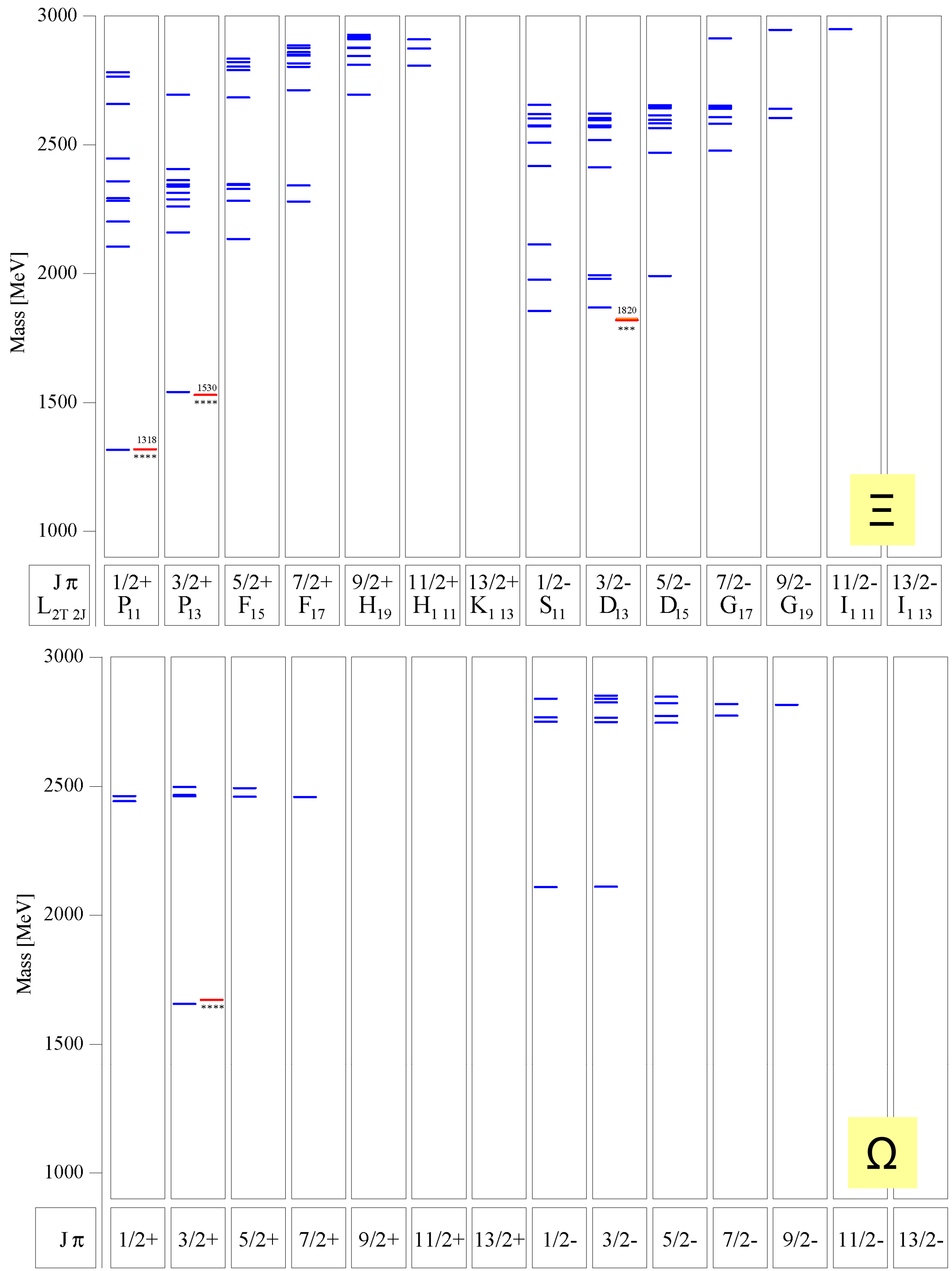
- many states predicted below 3 GeV
- compare $1/2^+$ and $1/2^-$ excitation

Ω:

- several states predicted between 2 GeV and 3 GeV
- compare $3/2^+$ and $3/2^-$ excitation

U. Löring *et al.*, EPJA 10 (2001) 447

s.a.: M. Pervin, W. Roberts, PRC 77 (2008) 025202



Experimental Prospects

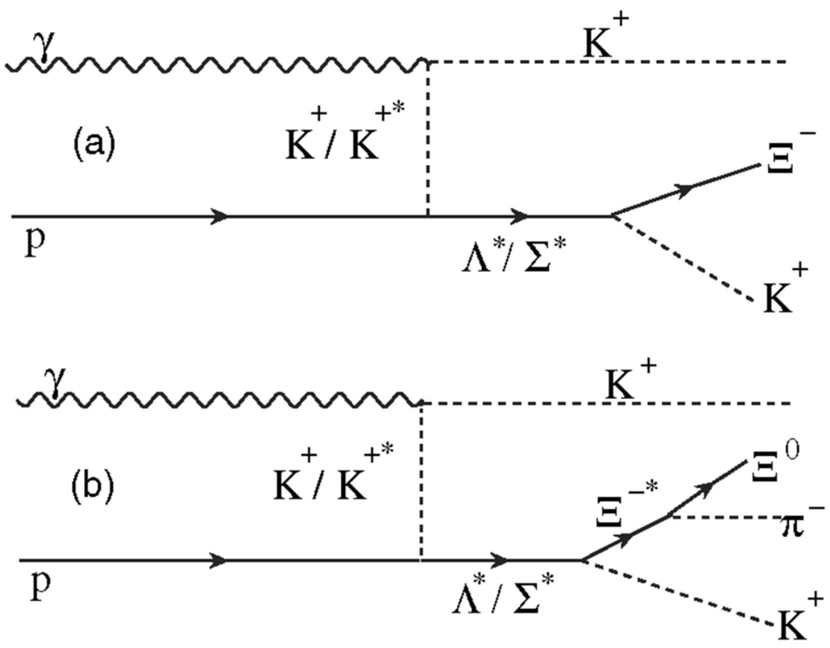
Invitation to give a talk on „Strange Baryons …with reference to the programs at PANDA, GlueX, and LHCb"

$pp \rightarrow \Xi^{*} X$ (prompt or delayed)	LHCb	➢ P. Spradlin, Wednesday
$\gamma p \rightarrow K^{+} K^{+} \Xi^{*}$	GlueX, CLAS12	➢ L. Guo, Tuesday
$\bar{p}p \rightarrow \Xi^{*} \bar{\Xi}$ & c.c.	$\bar{\text{P}}$ANDA	
$e^{+}e^{-} \rightarrow \Xi^{*} X$ (prompt or delayed)	Belle II	➢ J. Yelton, Thursday
	BES III	➢ M. Destefanis, Thursday
$K^{-}p \rightarrow K^{+} \Xi^{*-}$	J-PARC	➢ M. Naruki, Tuesday
$K_{L}p \rightarrow K^{+} \Xi^{*0}$	Hall D K_L beam	➢ S. Taylor, Tuesday

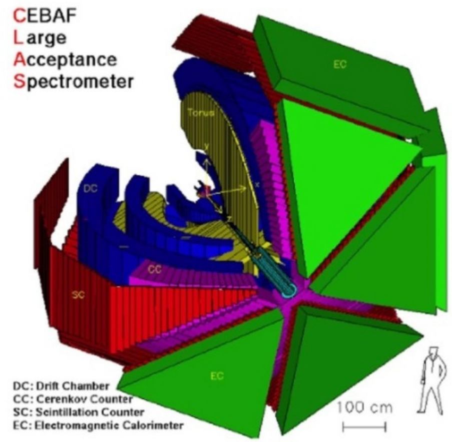
Ξ Production in γp: CLAS

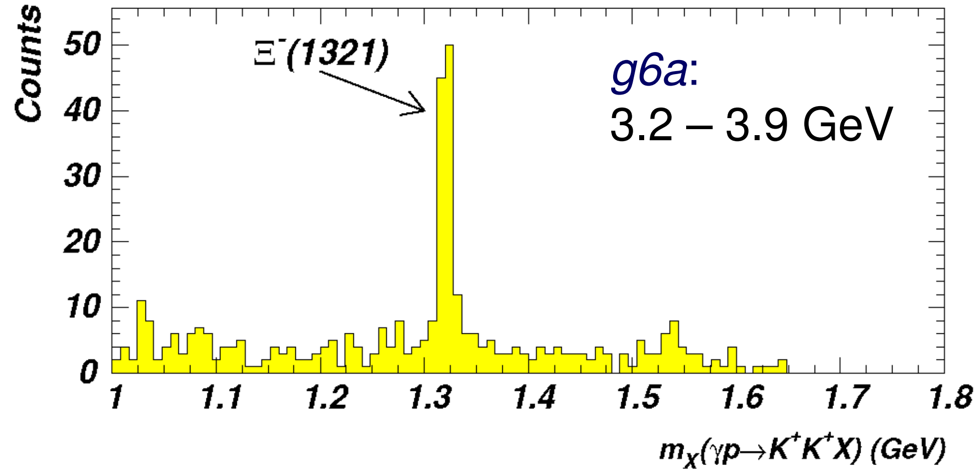
Runs g6a, g6b:

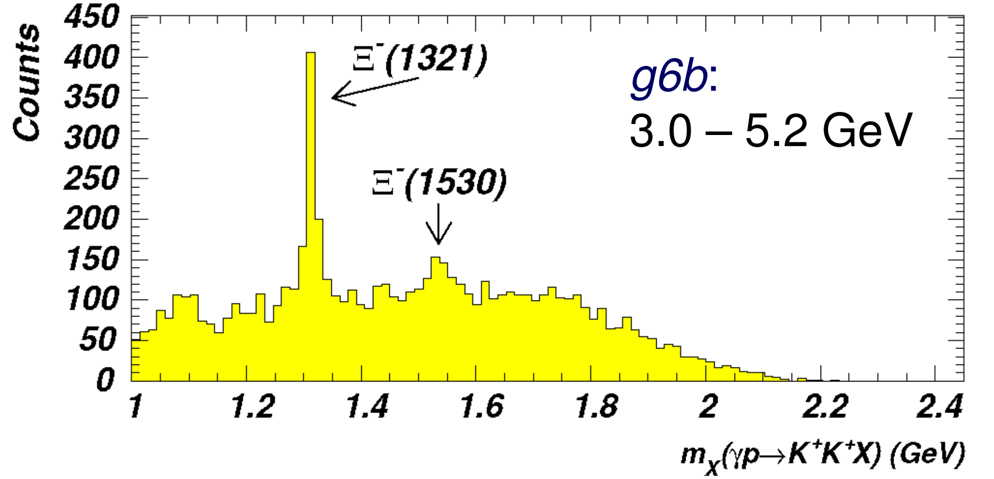
- first exclusive photoproduction of Ξ^-
- reaction $\gamma p \rightarrow K^+K^+\,X$



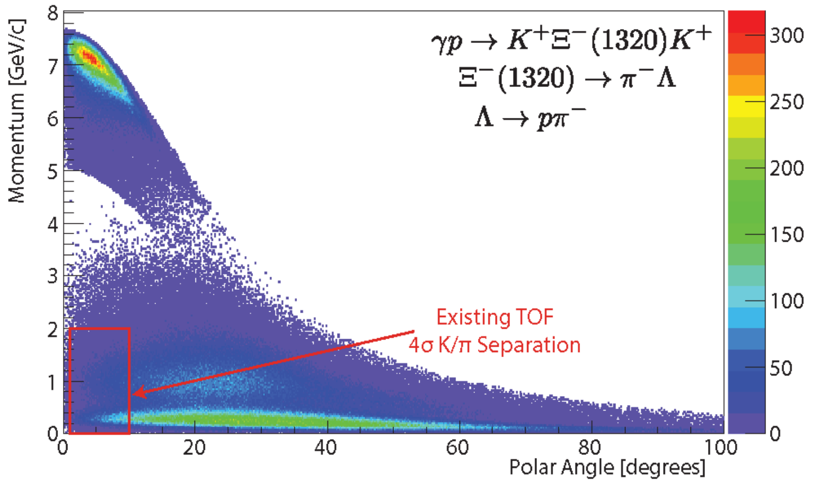
J. Price *et al.*, PRC 71 (2005) 058201

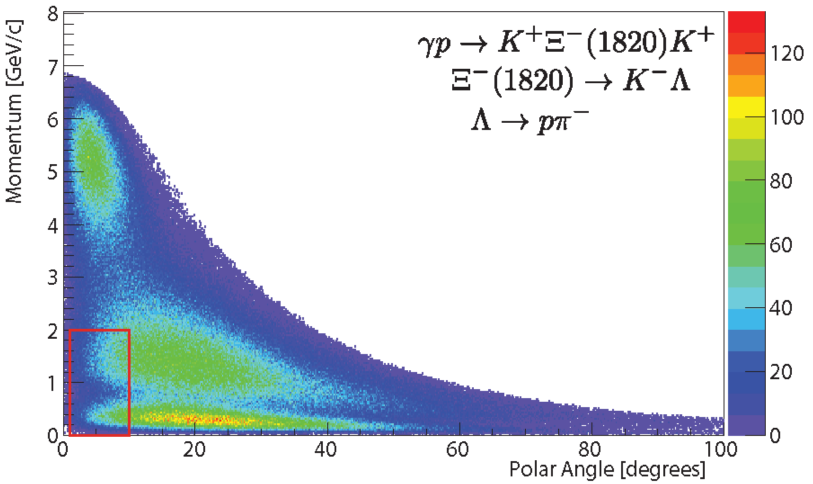




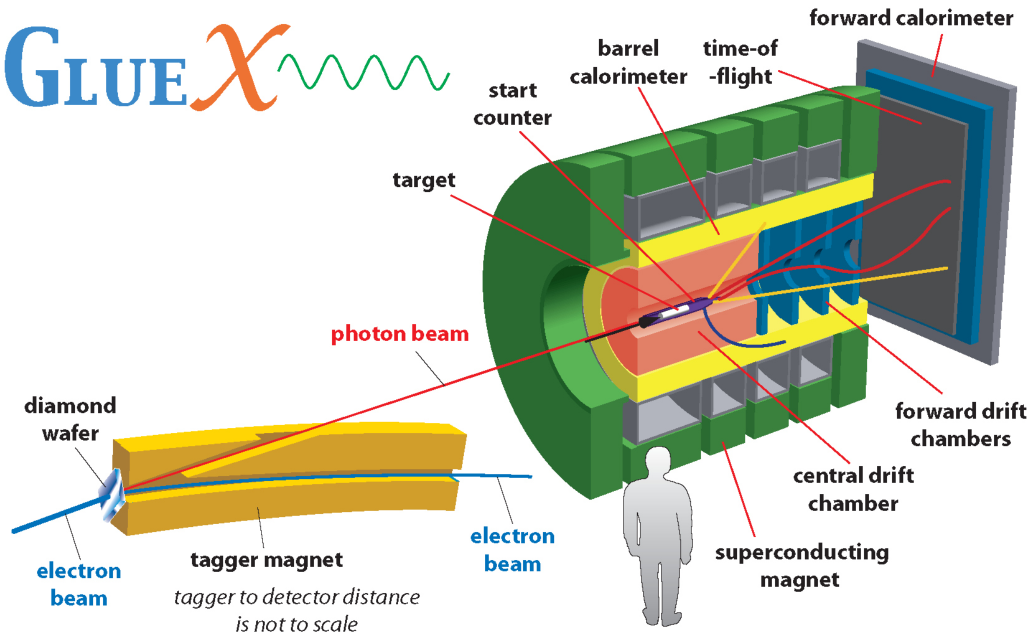


Ξ Production at GlueX





A. AlekSejevs *et al.*, arXiv:1305.1523
GlueX proposal to PAC 40



- GlueX Proposal (JLAB PAC 39, 40 & 42): „Decays to Strange Final States“
- Study excited Ξ states
- parity measurement of the g.s. Ξ^-
- will probably need enhanced kaon identification in forward region
- Components of BaBar DIRC for GlueX

Ξ Spectroscopy with the GlueX Detector

Expected yields of Ξ states using (PAC 40 proposal):

$$N = \epsilon\, \sigma\, n_\gamma\, n_t\, T \quad \text{where}$$

$\sigma_{\Xi(1320)} = 15$ nb and $\sigma_{\Xi(1530)} = 2$ nb at $E_\gamma = 5$ GeV

$\epsilon_{\Xi(1820)} \approx 30\,\%$ (BDT: signal purity 0.9)

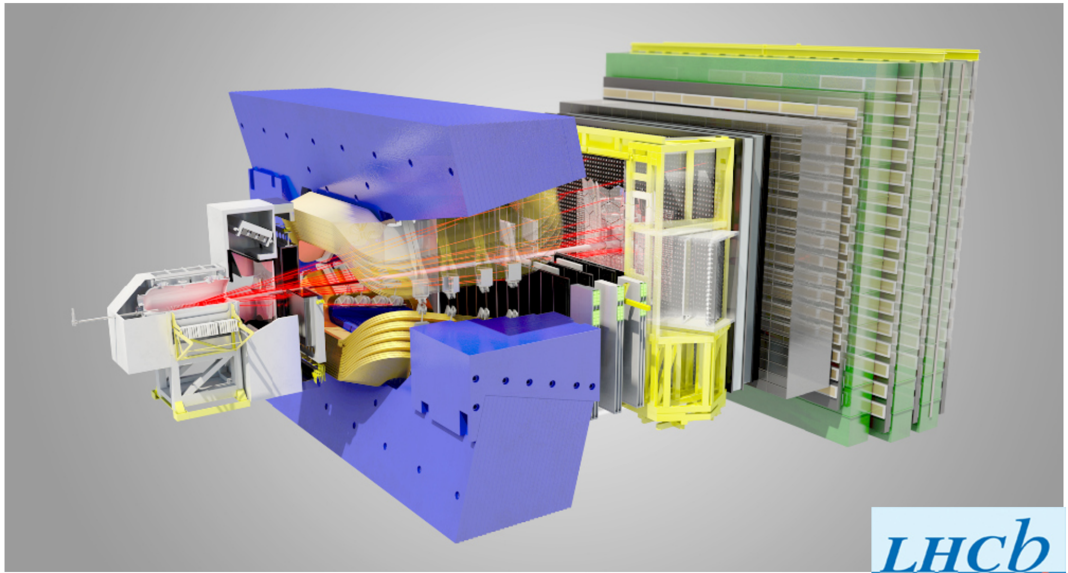
➜ $800,000$ $\Xi^-(1320)$ events
$100,000$ $\Xi^-(1530)$ events
$90,000$ $K^+K^+K^-\Lambda$ events (based on PYTHIA)

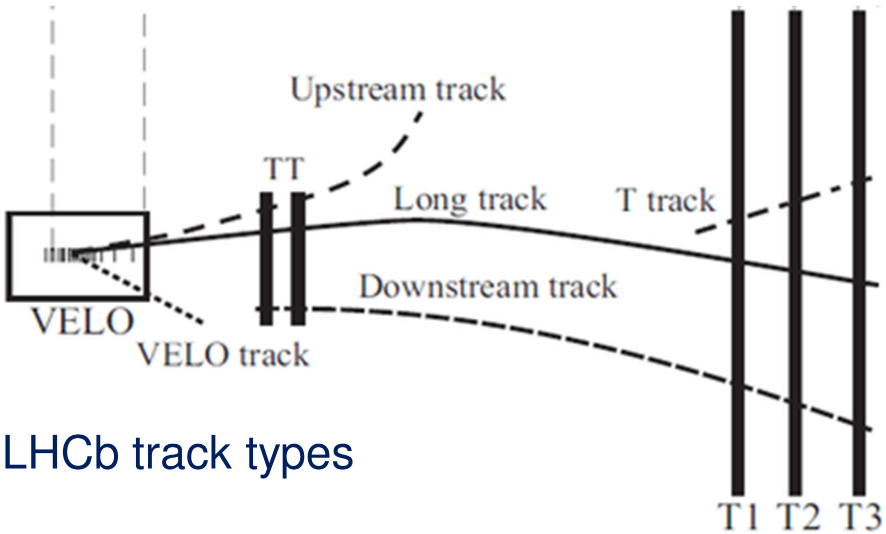
➜ At least x10 more statistics than previous CLAS result.

Talk at EMMI Workshop „Resonances in QCD“, GSI Darmstadt, October 12-14, 2015

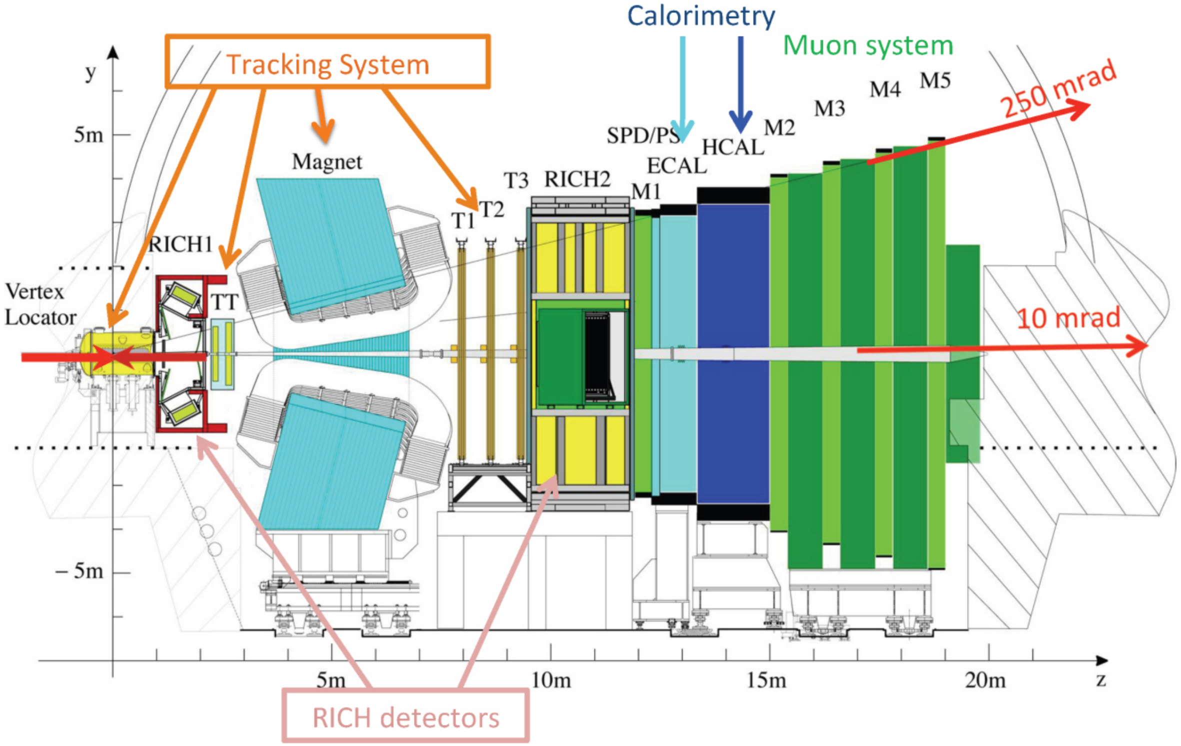
Strange Baryons at LHCb

Run	Year	√s [TeV]	∫Ldt
I	2011	7	1 fb^{-1}
I	2012	8	2 fb^{-1}
II	2015	13	320 pb^{-1}





LHCb track types

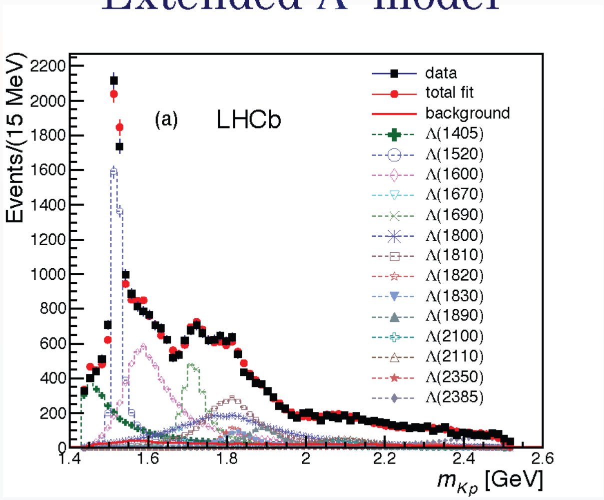


- ➢ Patrick Spradlin, Wednesday
- ➢ Sebastian Neubert, Thursday

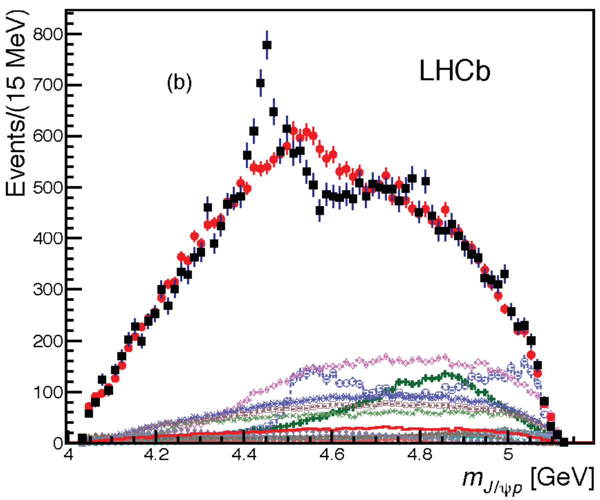
WHY LIGHT SPECTROSCOPY?

[LHCb: PRL 115, 07201 (2015)]

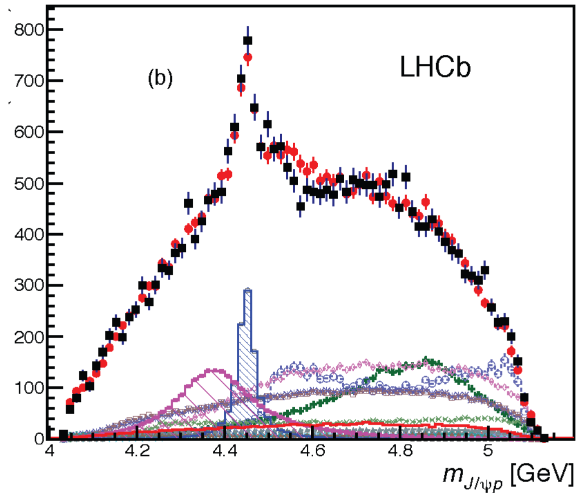
Extended Λ^* model



Extended Λ^* model



Reduced Λ^* model + 2 Pc's



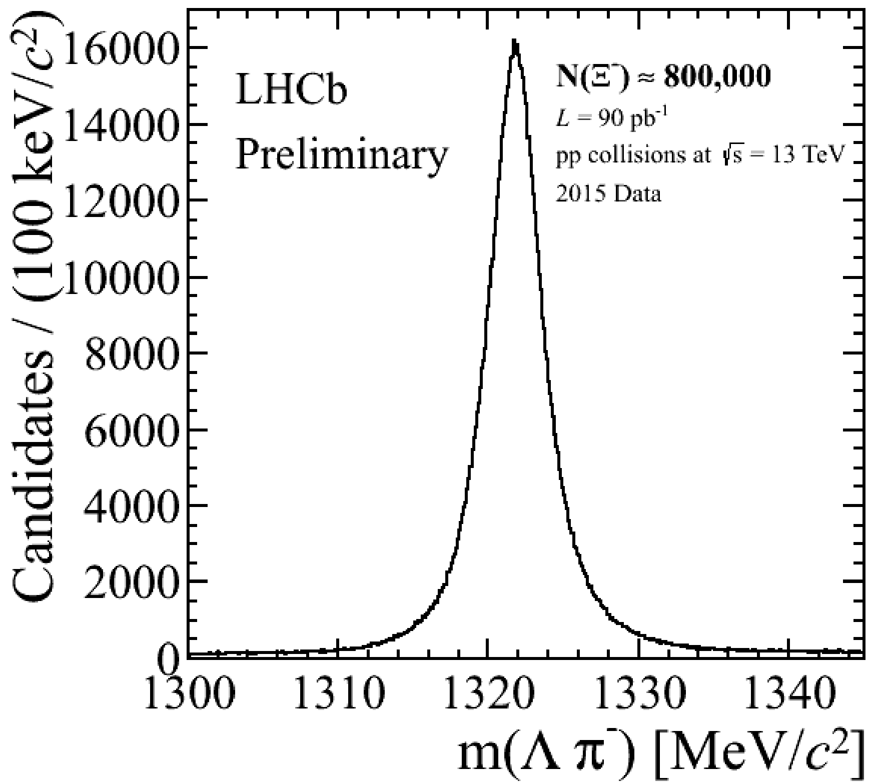
More reliable model for the Λ* sector would implies more precise measurements of P_c properties

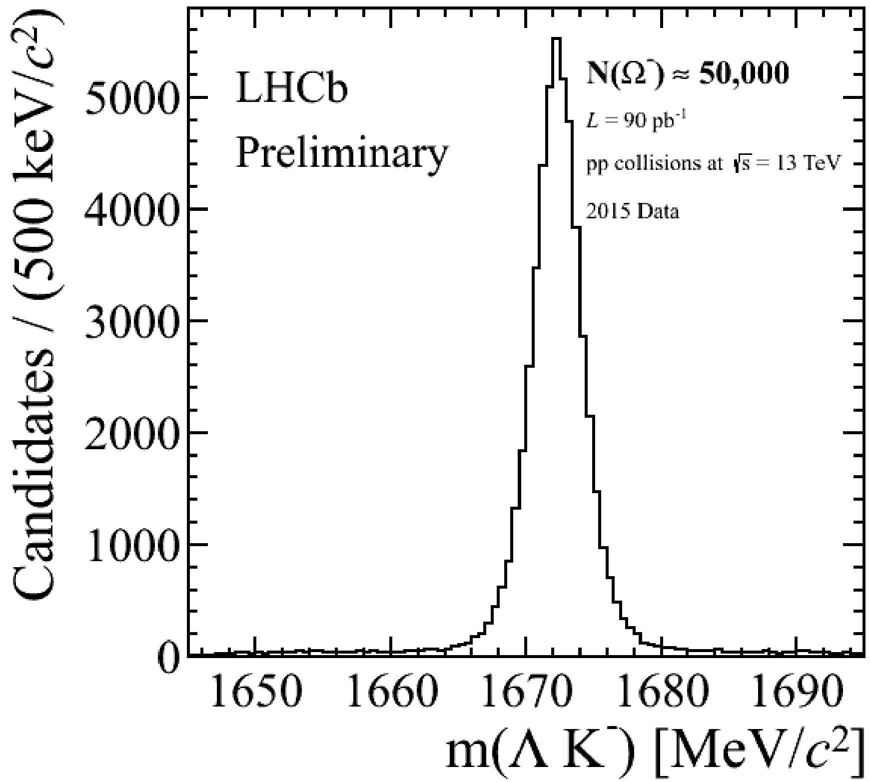
$\Lambda_b \rightarrow K\, P_c \rightarrow K\, J/\psi\, p$

$\Lambda_b \rightarrow J/\psi\, \Lambda^* \rightarrow J/\psi\, K\, p$

Strange Baryons at LHCb

- 2015 Run II data: $\sqrt{s}$ = 13 TeV
- first analysis to study prompt Ξ and Ω production*





* communicated by M. Pappagallo

Early Physics: Expected Rates for Strange Baryons

- initial phase: $L \cong 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ instead of $L \cong 2 \cdot 10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- nevertheless the $\Xi\bar{\Xi}$ production rate will be $R_{\Xi\bar{\Xi}} \cong 10/s \cong 10^6/\mathrm{d}$
- for $\Omega\bar{\Omega}$ production we expect $R_{\Omega\bar{\Omega}} \cong 0.3/s \cong 3 \cdot 10^4/\mathrm{d}$
- for excited states the cross section should be of the same order of magnitude as for the ground state for given $\sqrt{s} - \sqrt{s_{\mathrm{thr}}}$
- the *detected* rate depends on the specific decay mode (branching & reconstruction efficiency)
- e.g. $\bar{p}p \rightarrow \bar{\Xi}^+\Xi^{*-} \rightarrow \bar{\Xi}^+\Xi^-\pi^0 \rightarrow \bar{\Lambda}\pi^+\Lambda\pi^-\pi^0 \rightarrow \bar{p}\pi^+\pi^+p\pi^-\pi^-\pi^0$
  assume $b = 0.5 \cdot 0.64^2 = 0.2$ and $\epsilon = 5\%$ → $R_{det} \cong 10^4/\mathrm{d}$

Ξ^* / Ω^* Studies within the PANDA Physics Program

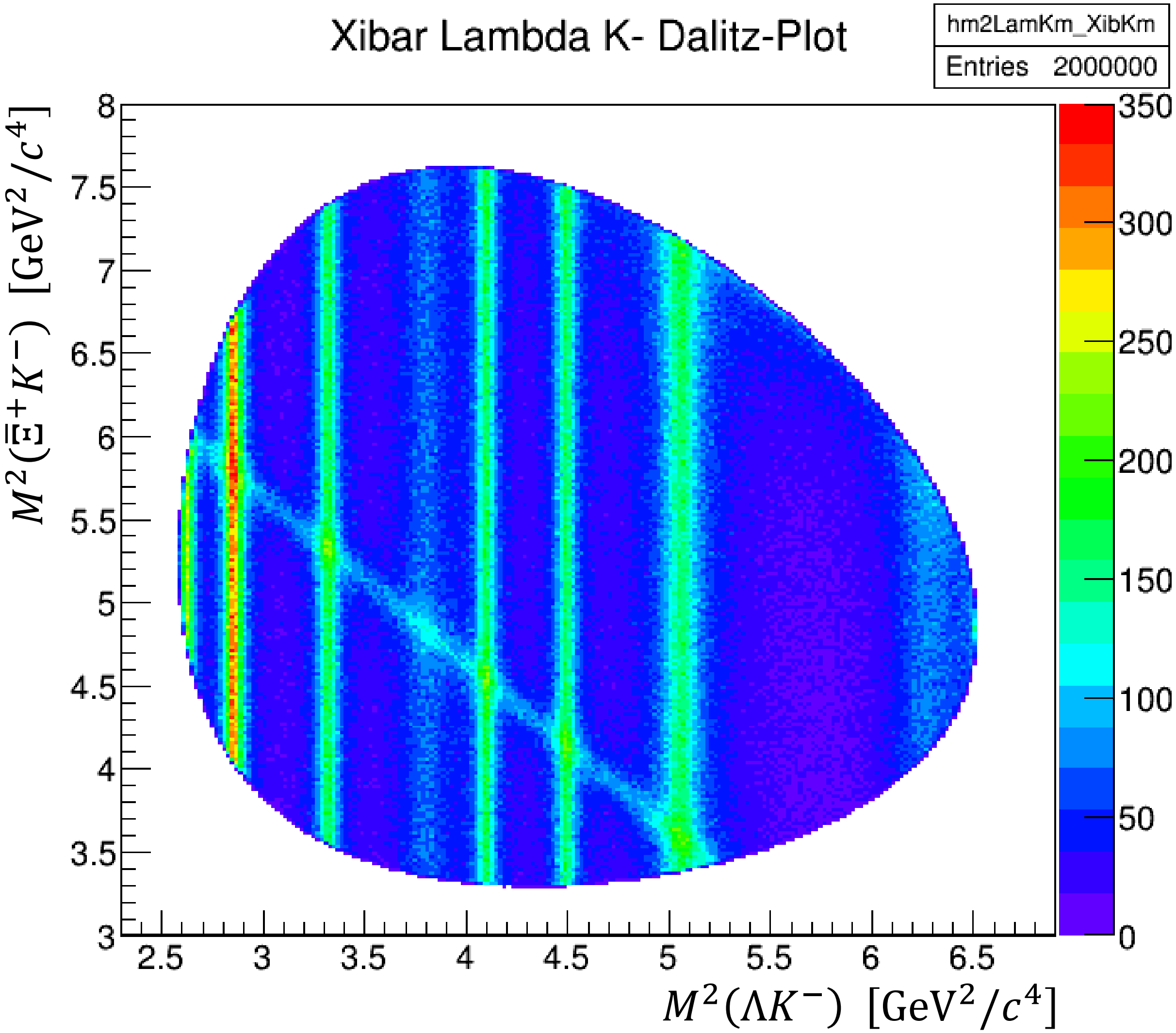
- good case for initial phase with lower L
- Λ & Σ spectroscopy can be done in parallel

- long runs to measure the X(3872) width in energy scan planned:
- parallel trigger for Ξ^* and Ω^*
- $p \approx 7.0$ GeV/c
- $M_{max}(\Xi^*) \approx 2.55$ GeV   ($M_{max}(\Omega^*) \approx 2.20$ GeV)

- later: long runs for threshold scan of $D_s^{\pm} D_s(2317)^{\mp}$
- $p \approx 8.8$ GeV/c
- $M_{max}(\Omega^*) \approx 2.61$ GeV

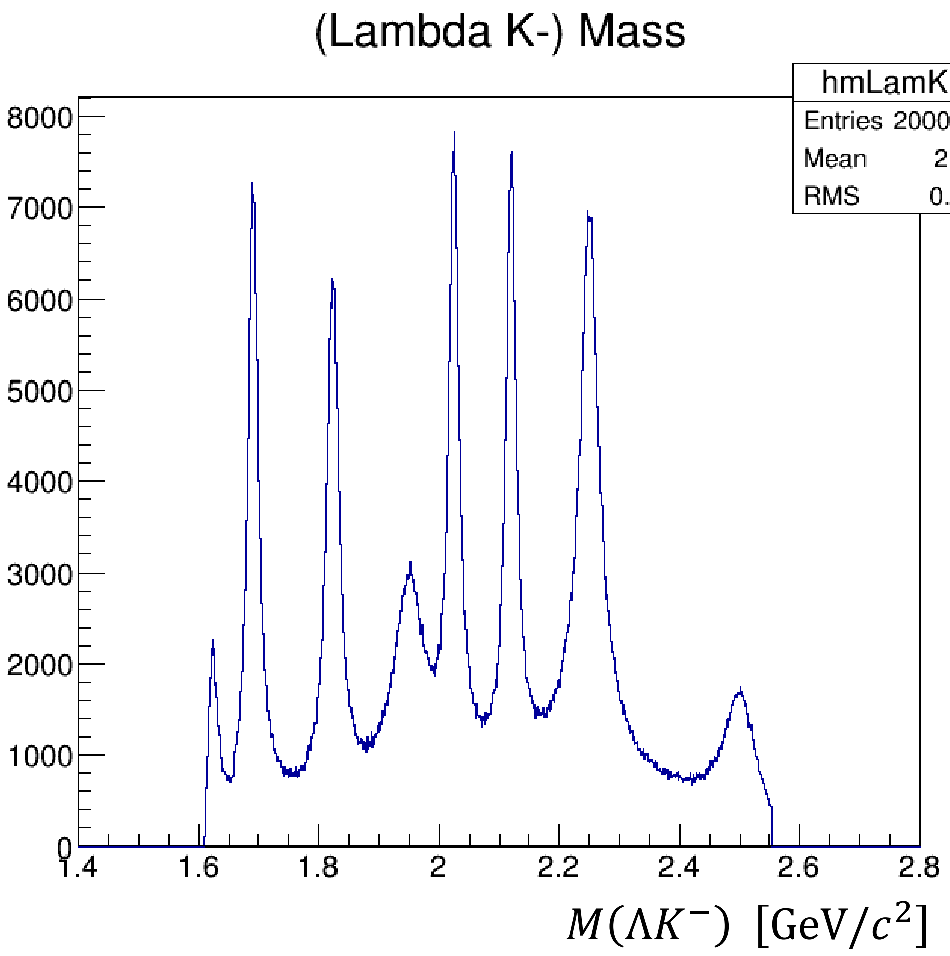
Ξ^* Production at p = 7.0 GeV/c

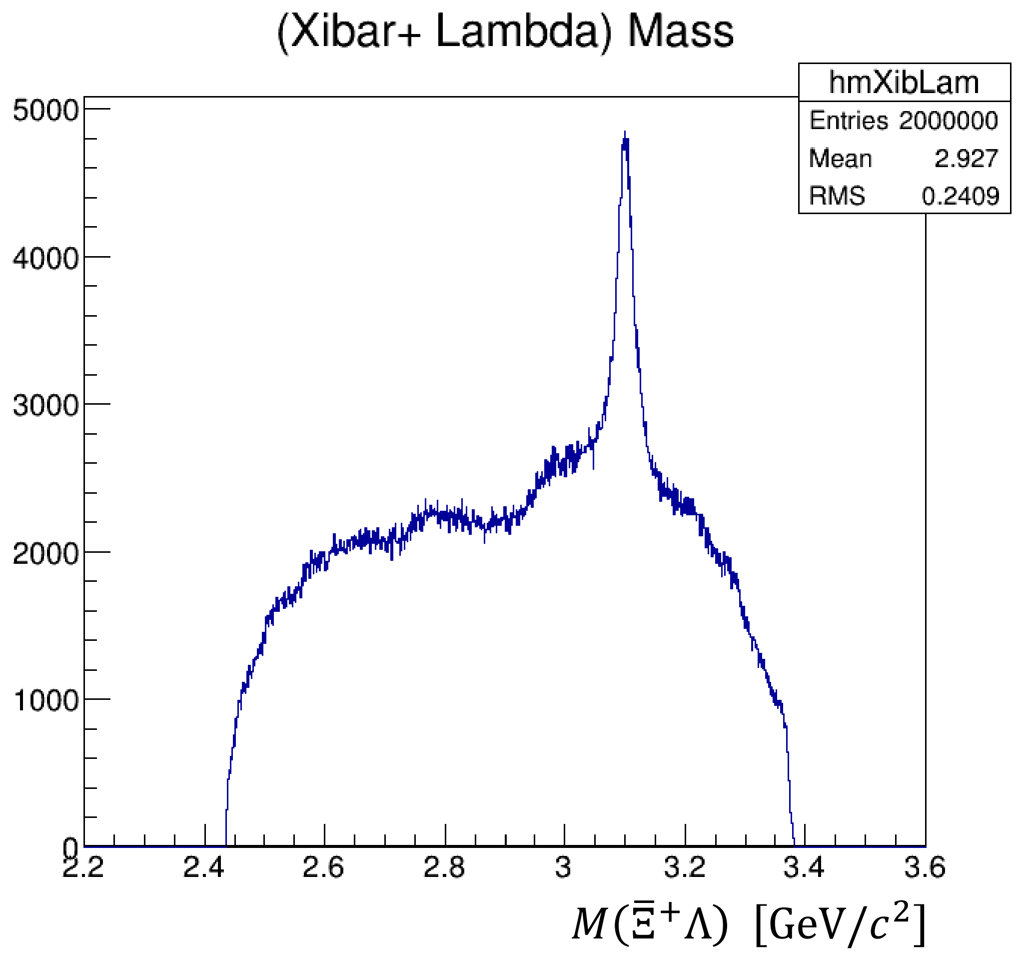
- EvtGen
- $\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{*-} \rightarrow \bar{\Xi}^{+}\Lambda K^{-}$
- included all Ξ^* states in PDG above $\Lambda\bar{K}$ threshold
- typical width ~20 MeV
- decay: PHSP
- added $\bar{\Xi}^{+}\Lambda K^{-}$ cont.
- added $K(3100)$ seen in $\bar{p}\Lambda$, $\bar{p}\Lambda\,n\pi$ & c.c.



Ξ^* Production at p = 7.0 GeV/c

- projections on ΛK^- and $\bar{\Xi}^+\Lambda$ mass

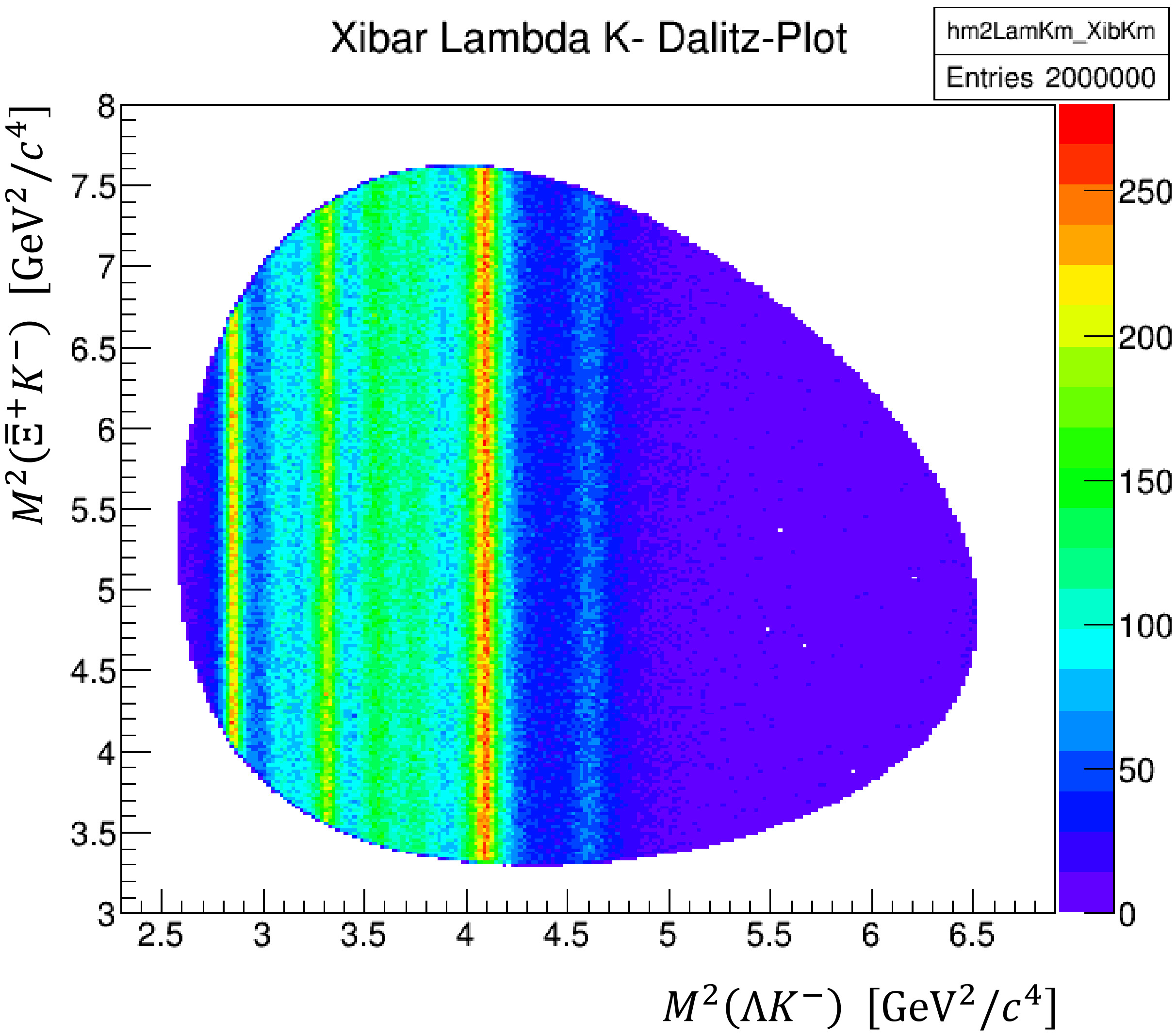




Ξ^* Production at p = 7.0 GeV/c

- same as before but Ξ^* states taken from
  M. Pervin, W. Roberts, PRC 77 (2008) 025202:

J^P	Ξ		Ω	
	Experiment	Model	Experiment	Model
$1/2^+$	1.317 ± 0.001	1.325	–	2.175
	–	1.891	–	2.191
	–	2.014	–	–
$3/2^+$	1.532 ± 0.001	1.520	1.672	1.656
	–	1.934	–	2.170
	–	2.020	–	2.182
$5/2^+$	1.950 ± 0.015	1.936	–	2.178
	–	2.025	–	2.210
$7/2^+$	2.025 ± 0.005	2.035	–	2.183
		2.148	–	–
$1/2^-$	1.690 ± 0.010	1.725	–	1.923
	–	1.811	–	–
$3/2^-$	–	1.759	–	1.953
	1.823 ± 0.005	1.826	–	–
$5/2^-$	–	1.883	–	–



13 states above $\Lambda\bar{K}$ threshold

J^P	Ξ Experiment	Ξ Model	Ω Experiment	Ω Model
$1/2^+$	1.317 ± 0.001	1.325	–	2.175
	–	1.891	–	2.191
	–	2.014	–	–
$3/2^+$	1.532 ± 0.001	1.520	1.672	1.656
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		2.148	–	–
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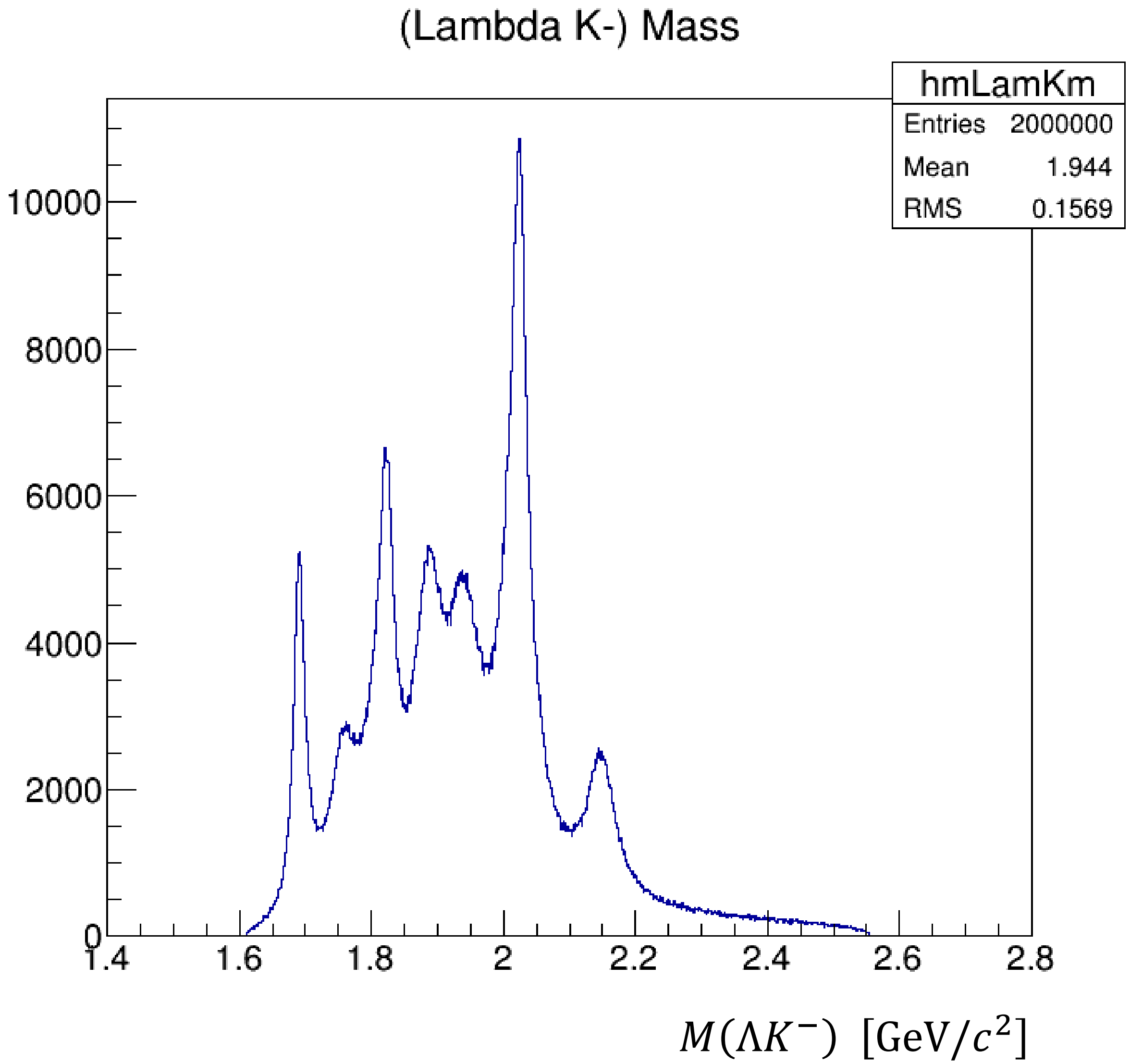
	–	1.811	–	–
$3/2^-$	–	1.759	–	1.953
	1.823 ± 0.005	1.826	–	–
$5/2^-$	–	1.883	–	–

M. Pervin, W. Roberts,
PRC 77 (2008) 025202

Ξ^* Production at p = 7.0 GeV/c

- Ξ^* states taken from
  M. Pervin, W. Roberts, PRC 77 (2008) 025202
- width taken from PDG or assumed to be 50 MeV
- projection on ΛK^- mass
- partial overlap: 13 states result in 7 bumps



Ω^* Production at p = 7.0 GeV/c

- $\bar{p}p \rightarrow \overline{\Omega}^+\Omega^{*-} \rightarrow \overline{\Omega}^+\Xi^-K_S$
- Ω^* states taken from
  M. Pervin, W. Roberts, PRC 77 (2008) 025202:

J^P	Ξ		Ω	
	Experiment	Model	Experiment	Model
$1/2^+$	1.317 ± 0.001	1.325	–	2.175
	–	1.891	–	2.191
	–	2.014	–	–
$3/2^+$	1.532 ± 0.001	1.520	1.672	1.656
	–	1.934	–	2.170
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$5/2^+$	1.950 ± 0.015	1.936	–	2.178
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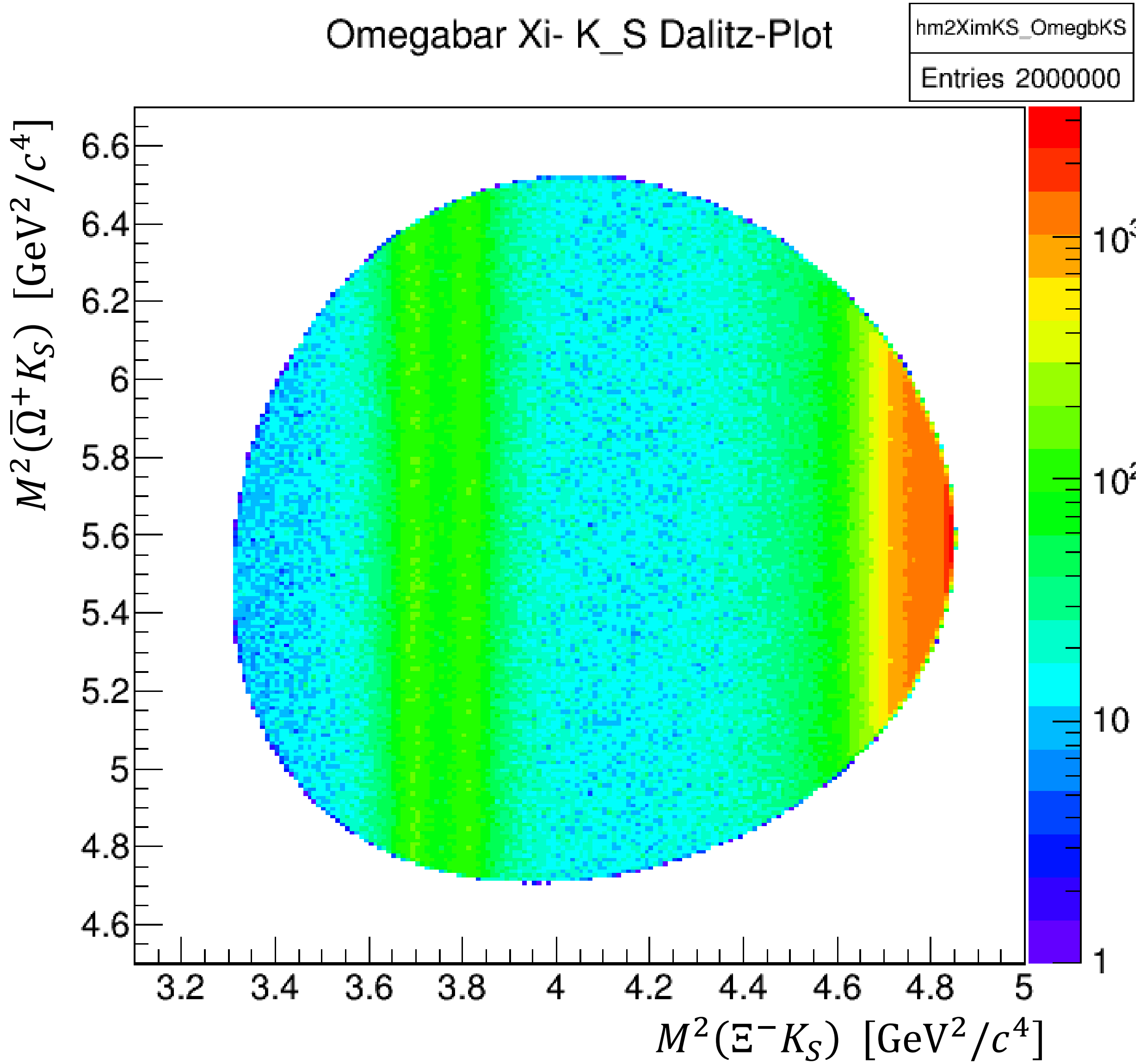
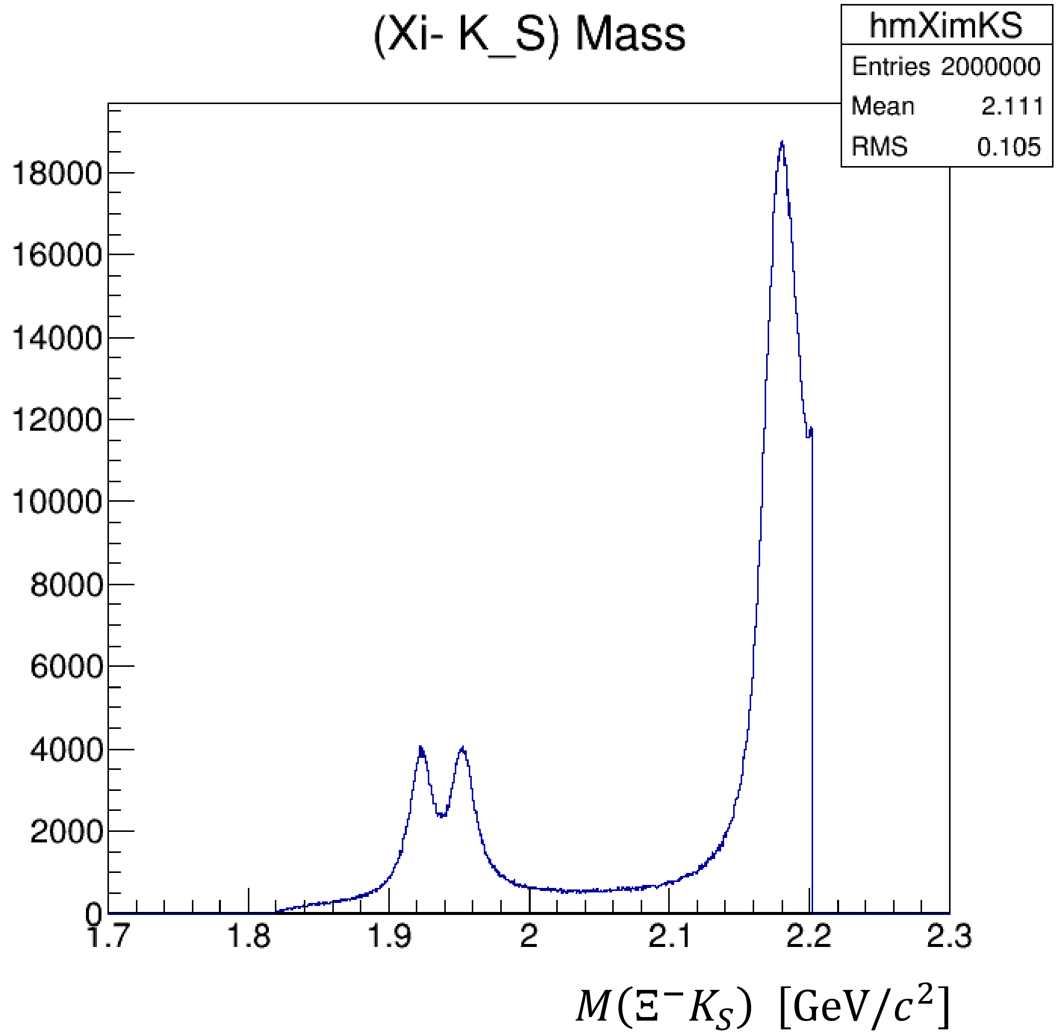
$7/2^+$	2.025 ± 0.005	2.035	–	2.183
		2.148	–	–
$1/2^-$	1.690 ± 0.010	1.725	–	1.923
	–	1.811	–	–
$3/2^-$	–	1.759	–	1.953
	1.823 ± 0.005	1.826	–	–
$5/2^-$	–	1.883	–	–



Ω^* Production at p = 7.0 GeV/c

- Ω^* states taken from M. Pervin, W. Roberts, PRC 77 (2008) 025202
- 20 MeV width assumed
- projection on $\Xi^- K_S$ mass
- large overlap: 9 states result in only 3 bumps



Issues in MC Event Generation

- Problem in EvtGen: in reaction $\bar{p}p \rightarrow \bar{X}X^*$ a flat mass distribution is generated instead of Breit-Wigner if $\bar{X}X^*$ mass is larger than mass of pbarpSystem in file evt.pdl. (solved)
- Would like to generate realistic angular distributions for Ξ^* and Ω^* decay particles depending on J^P value
- No appropriate decay model implemented in EvtGen
- **Question:**
  - include this in EvtGen?
  - use independent PWA code?