JÜLICH
FORSCHUNGSZENTRUM

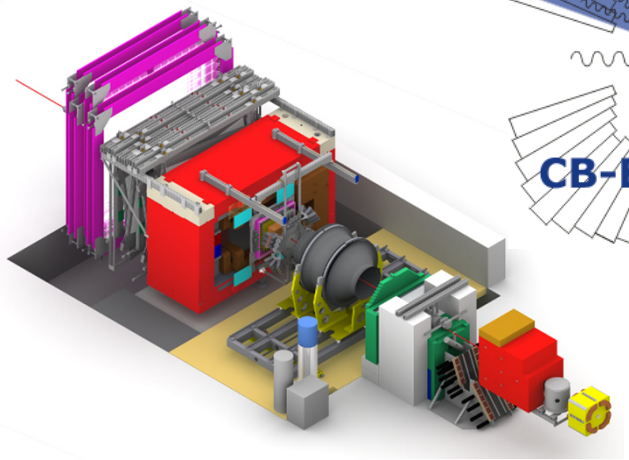
Hyperons in Baryon Spectroscopy

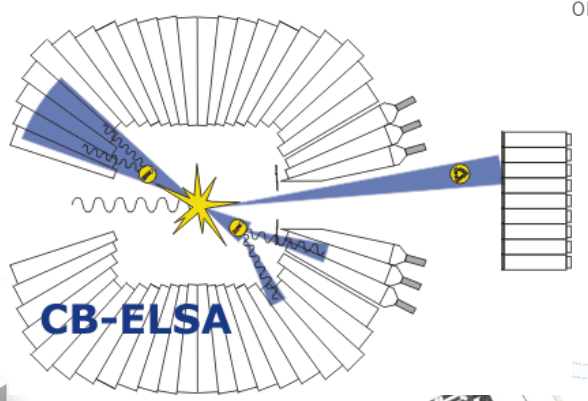
Dec 9, 2014 | Albrecht Gillitzer, IKP Forschungszentrum Jülich

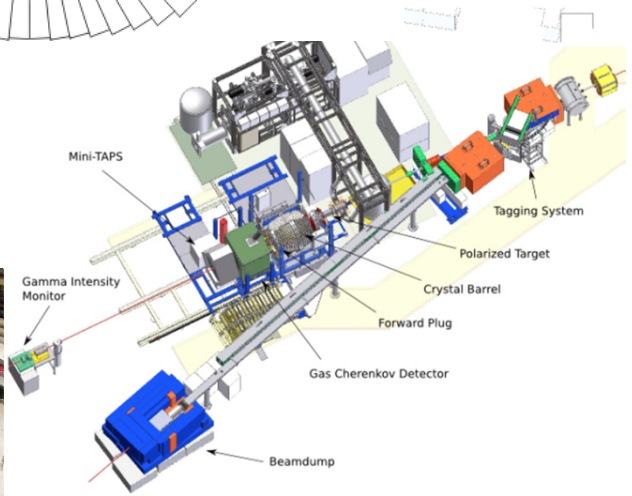
LI $\overline{\text{P}}$ANDA Meeting, FZ Jülich, December 2014

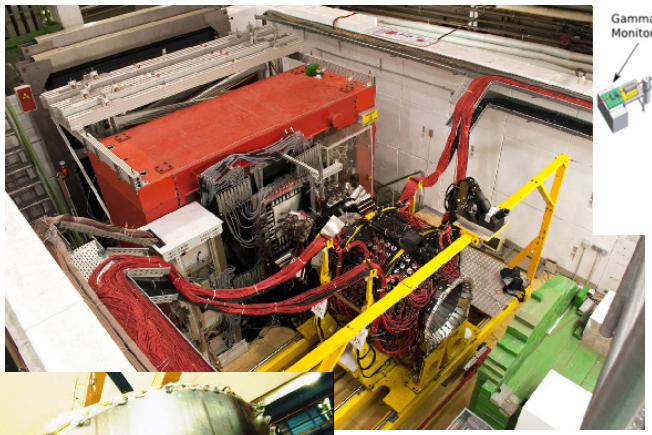
Why to be Interested in Baryons?

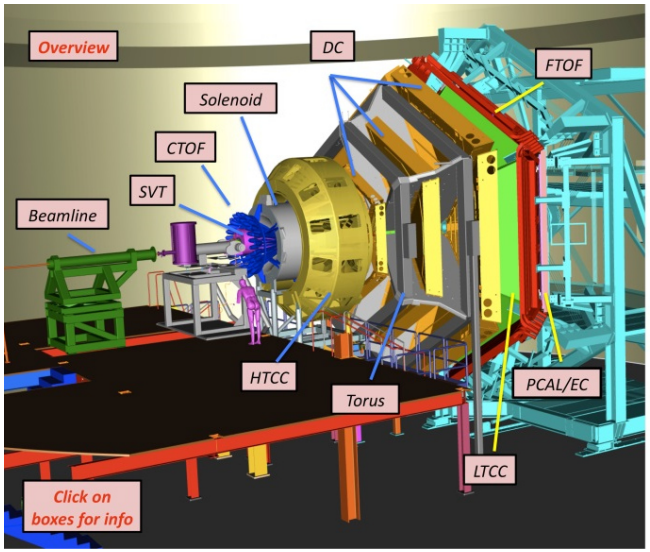
- No understanding of strong interaction without understanding the excitation pattern of baryons!
- Strong worldwide activity in „Baryon Spectroscopy“ with in photo-induced reactions

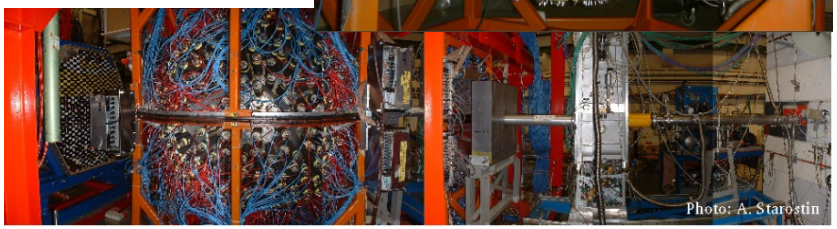






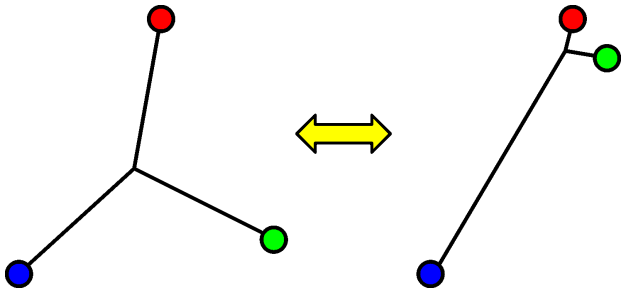


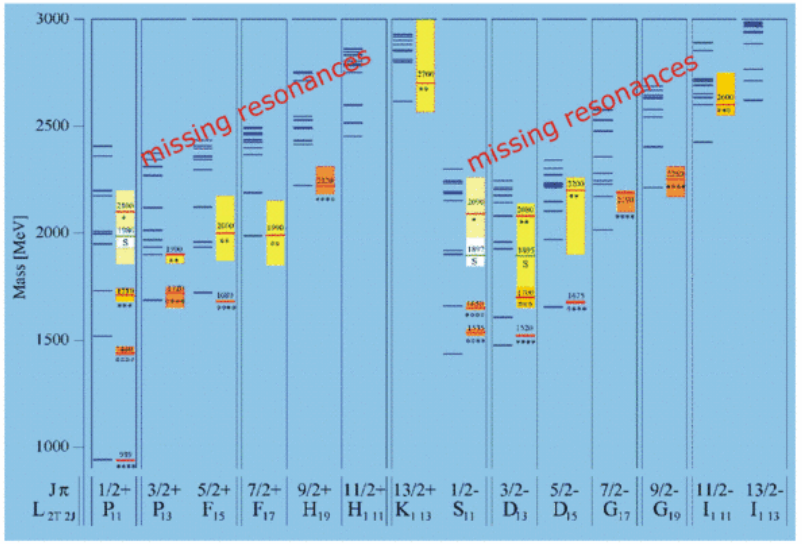


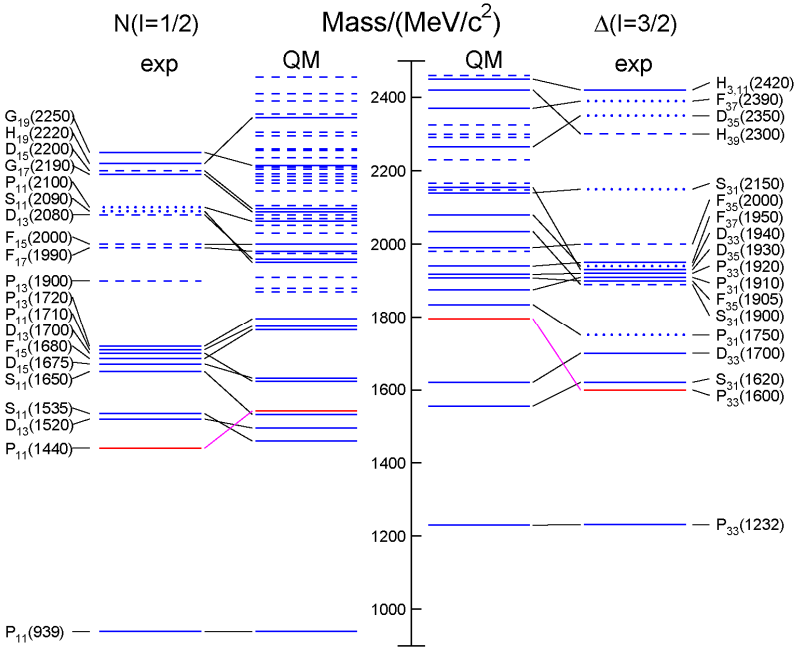


Open Questions

- Missing resonances
- Wrong masses, wrong sequence
- Relevant degrees of freedom?
  - 3-quark or quark-diquark structure?
  - single particle excitation modes
  - meson-baryon dynamics

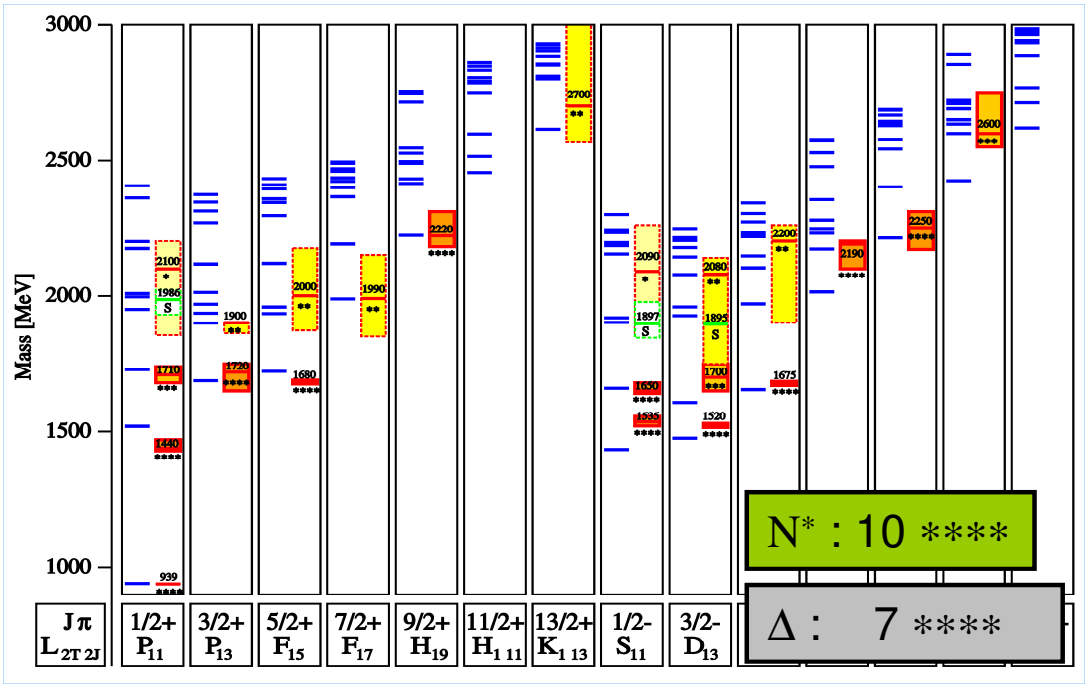


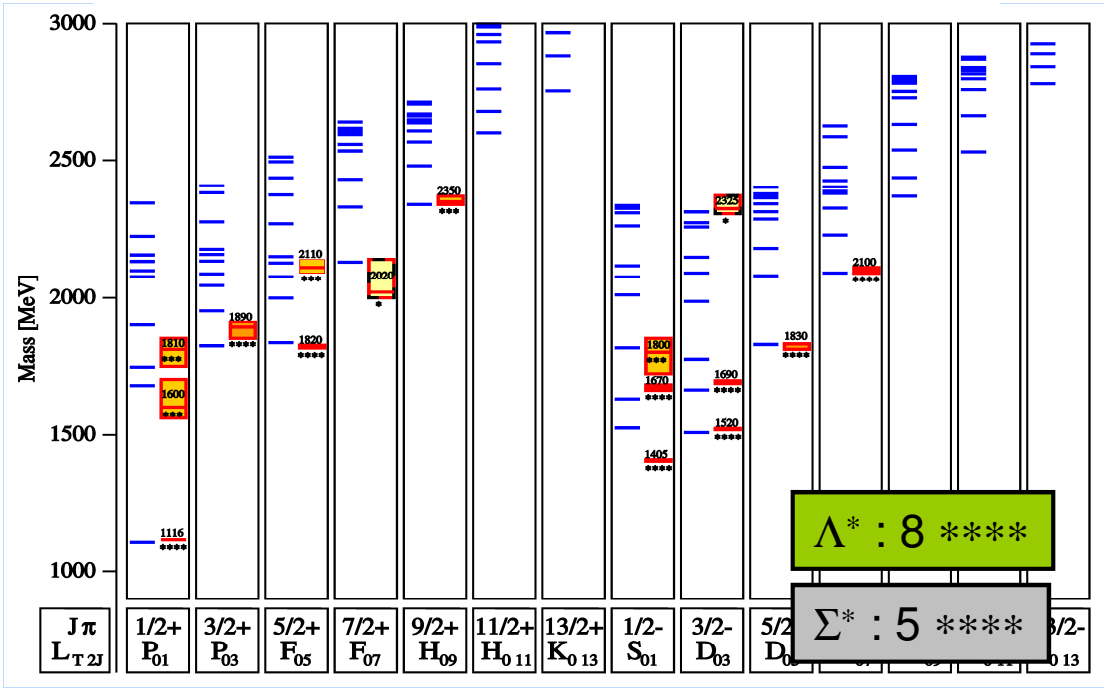


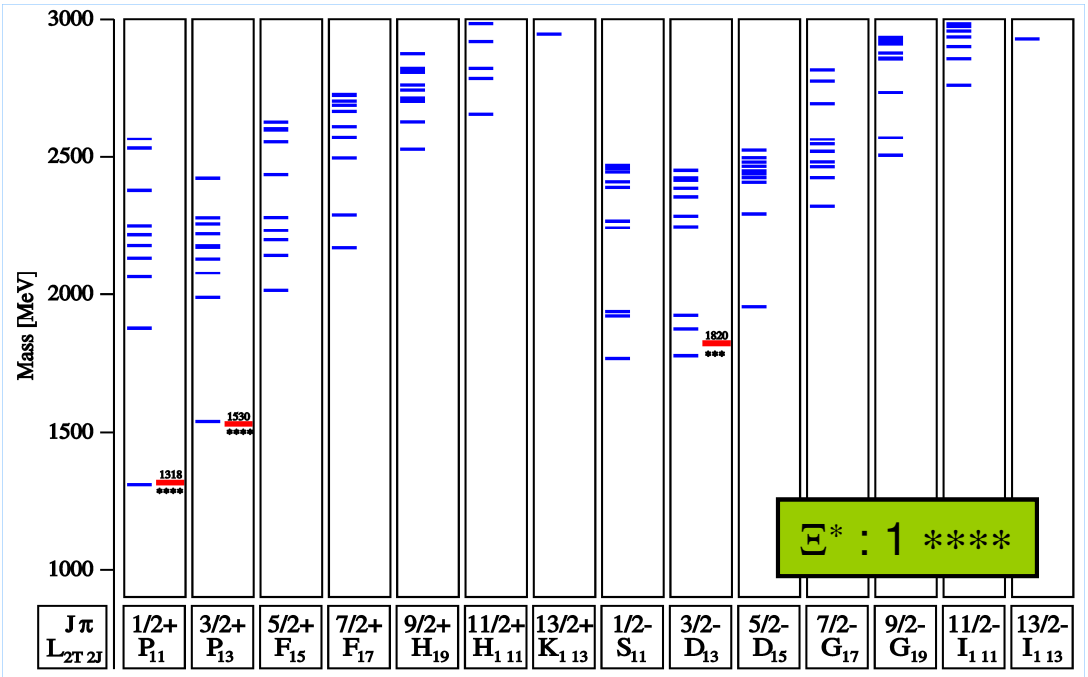


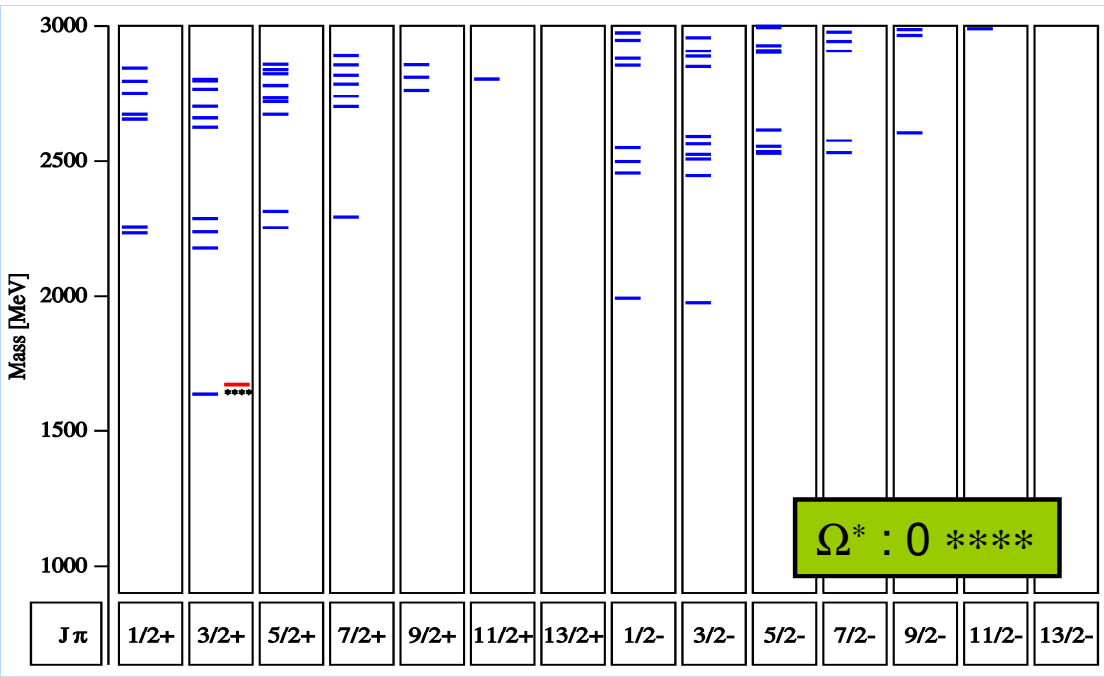
Excited Hyperon States?

U. Löring, B.Ch. Metsch, H.R. Petry,
Eur. Phys. J A 10 (2001) 309, 395,447









SU(6) x O(3) Classification

PDG:

- octet Ξ states: no partner states of most known N* states
- Ξ(1820) and Ξ(2030) "educated guess"
- decuplet Ξ and Ω states: no Δ* partner state
- note on Ξ resonances:

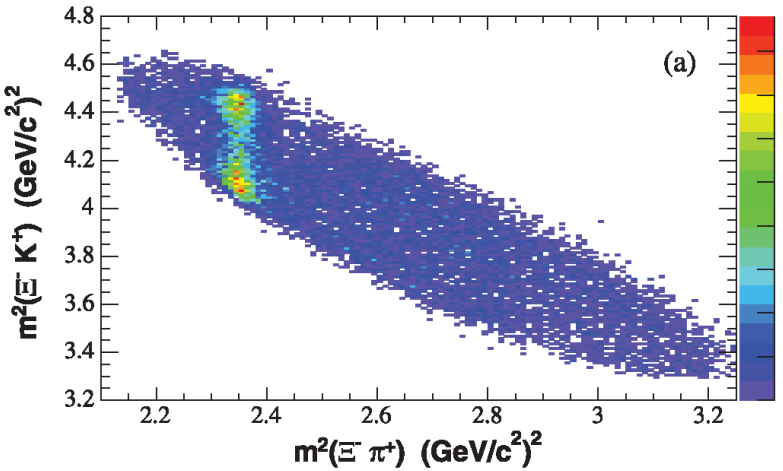
  "… nothing of significance on Ξ resonances has been added since our 1988 edition."

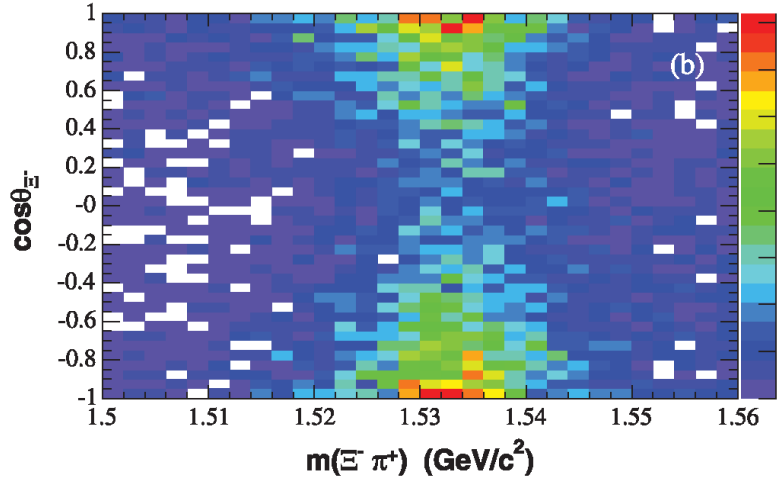
J^P	(D, L^P_N)	S	Octet members			Singlets
$1/2^+$	$(56,0^+_0)$	1/2	$N(939)$	$\Lambda(1116)$	$\Sigma(1193)$	$\Xi(1318)$	
$1/2^+$	$(56,0^+_2)$	1/2	$N(1440)$	$\Lambda(1600)$	$\Sigma(1660)$	$\Xi(?)$	
$1/2^-$	$(70,1^-_1)$	1/2	$N(1535)$	$\Lambda(1670)$	$\Sigma(1620)$	$\Xi(?)$	$\Lambda(1405)$
$3/2^-$	$(70,1^-_1)$	1/2	$N(1520)$	$\Lambda(1690)$	$\Sigma(1670)$	$\Xi(1820)$	$\Lambda(1520)$
$1/2^-$	$(70,1^-_1)$	3/2	$N(1650)$	$\Lambda(1800)$	$\Sigma(1750)$	$\Xi(?)$	
$3/2^-$	$(70,1^-_1)$	3/2	$N(1700)$	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	
$5/2^-$	$(70,1^-_1)$	3/2	$N(1675)$	$\Lambda(1830)$	$\Sigma(1775)$	$\Xi(?)$	
$1/2^+$	$(70,0^+_2)$	1/2	$N(1710)$	$\Lambda(1810)$	$\Sigma(1880)$	$\Xi(?)$	$\Lambda(?)$
$3/2^+$	$(56,2^+_2)$	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	$N(2220)$	$\Lambda(2350)$	$\Sigma(?)$	$\Xi(?)$	

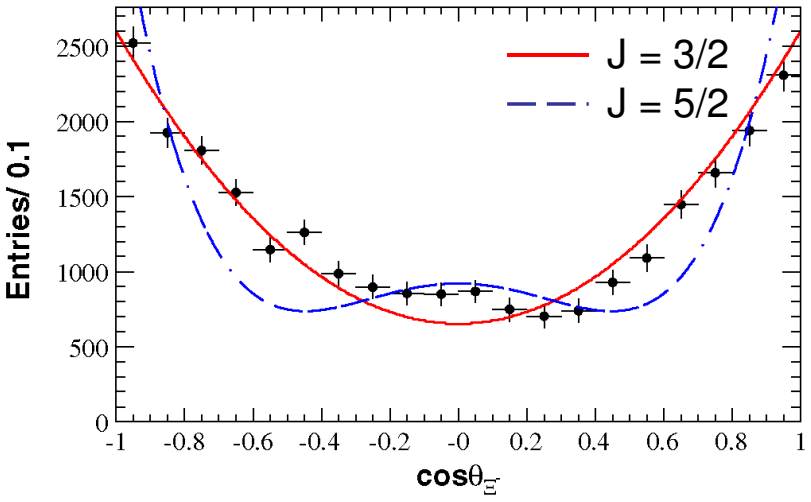
			Decuplet members			
$3/2^+$	$(56,0^+_0)$	3/2	$\Delta(1232)$	$\Sigma(1385)$	$\Xi(1530)$	$\Omega(1672)$
$3/2^+$	$(56,0^+_2)$	3/2	$\Delta(1600)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$
$1/2^-$	$(70,1^-_1)$	1/2	$\Delta(1620)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$
$3/2^-$	$(70,1^-_1)$	1/2	$\Delta(1700)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$
$5/2^+$	$(56,2^+_2)$	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	$\Delta(2420)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$

Data on Ξ States: Ξ(1530)

- The only reasonably well studied Ξ resonance:
- Ξ(1530) - decuplet g.s.
  $J^P = 3/2^+$
- Γ = 9…10 MeV *Compare to Δ!!*
- decay: ~100% Ξπ
- BaBar measured the
  $\Xi(1530)^0$ spin J = 3/2 in
  $\Lambda_c^+ \rightarrow \Xi^- \pi^+ K^+$







BaBar 2008

B. Aubert *et al.*,
PRD 78 (2008) 034008

Why to Study Excited Baryons with $\bar{P}$ANDA?

- Large cross sections for $\bar{p}\,p \rightarrow \bar{B}\,B^*$
  - $\sigma(\bar{p}p \rightarrow \bar{\Xi}\Xi) \approx \mu b$
  - $\sigma(\bar{p}p \rightarrow \bar{\Omega}\Omega) \approx 0.03 \ldots 0.1 \mu b$ (prediction)
- No extra mesons to balance strangeness or charm
- Symmetry in baryon and antibaryon observables
- Capabilities of the PANDA detector
- ***$\bar{P}$ANDA is unique in baryon spectroscopy beyond nucleon and Δ !!***

Physics Subtopics:

Study excited states of

- double-strange hyperons (Ξ^*)
- triple-strange hyperons (Ω^*)
- charmed hyperons (Λ_c^*, Σ_c^*)
- hidden-charm nucleons ($N_{c\bar{c}}$)

- non-strange baryons (N^*)
- single-strange hyperons (Λ^*, Σ^*)

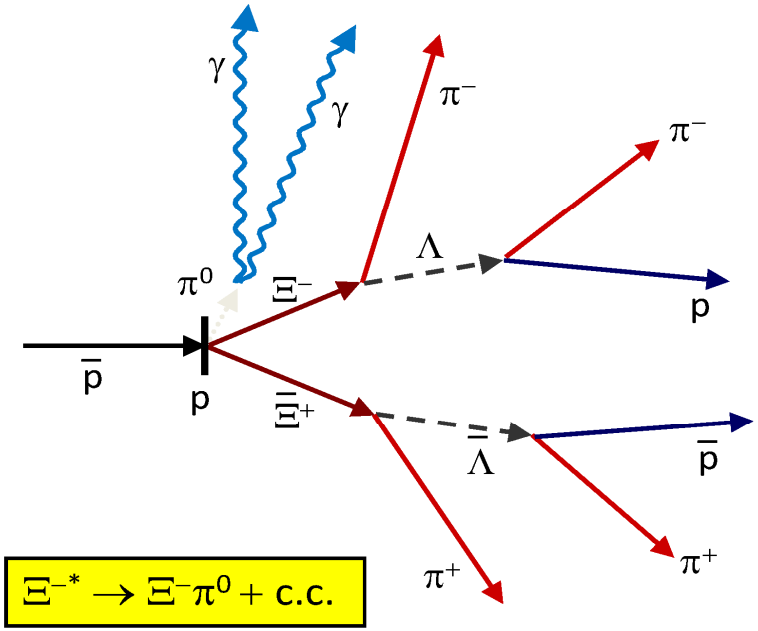
} Comes as by-product
Identify specific issues

$\bar{P}$ANDA Physics Book: $\Xi^* \rightarrow \Xi\pi$

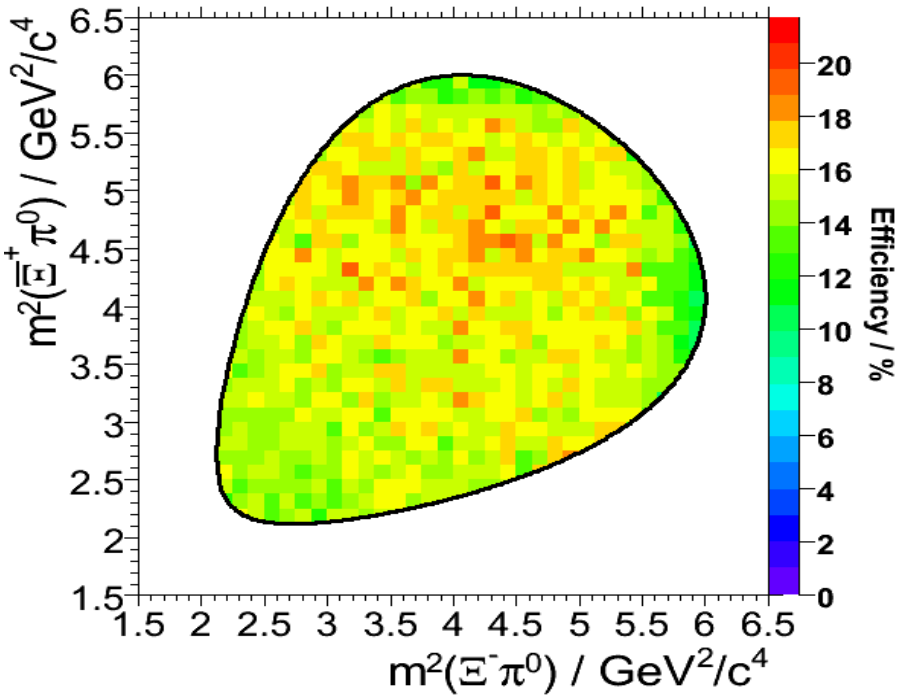
- characteristic event topology
- $\sigma \sim \mu b$: $\sim 10^7$ Ξ /d produced
- final states to be studied:
  $\Xi^* \rightarrow \Xi\,\pi$, $\Xi\,\eta$, $\Lambda\,\bar{K}$, $\Sigma\,\bar{K}$,
  $\Xi(1530)\,\pi$, $\Xi\,\pi\,\pi$, …
- benchmark channel:
  6.57 GeV/c $\bar{p}\,p \rightarrow \Xi^-\,\bar{\Xi}^+\,\pi^0$
- no empty regions or discontinuities in Dalitz plot
- $\Xi^-\pi^0$ mass resolution < 4 MeV;
  rec. eff. ~15%, S/B >19*

*DPM generated background

To be repeated with Pandaroot !

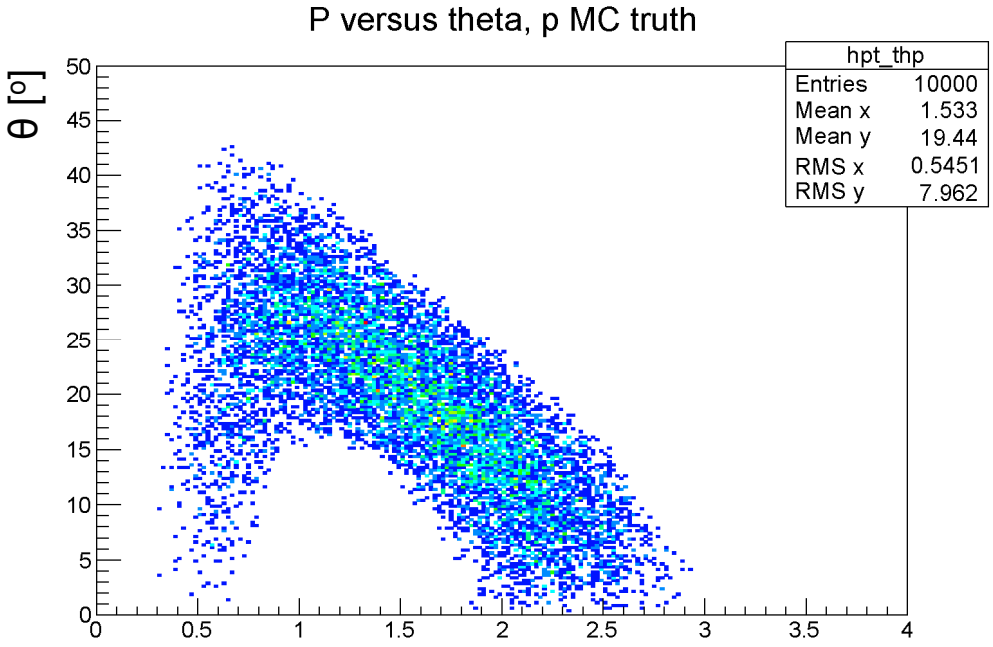


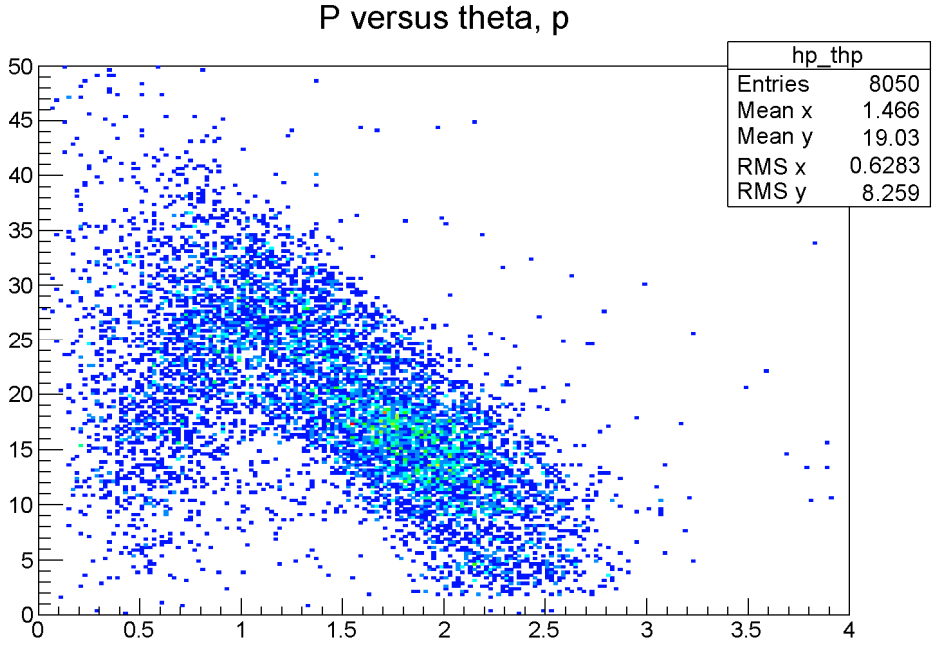
$\bar{\Xi}^{-*} \rightarrow \bar{\Xi}^-\pi^0$ + c.c.

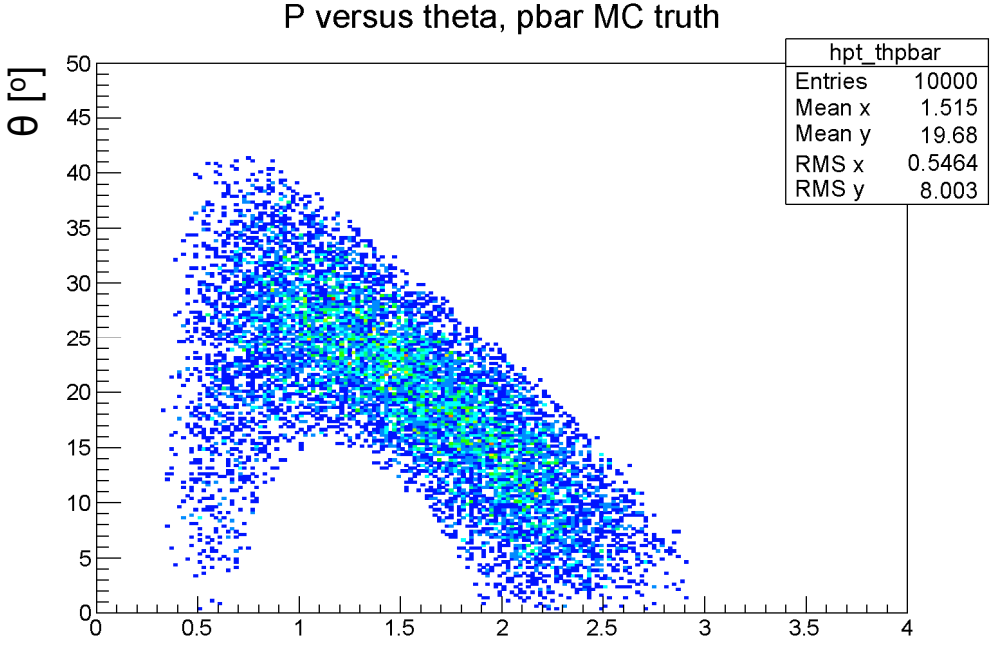


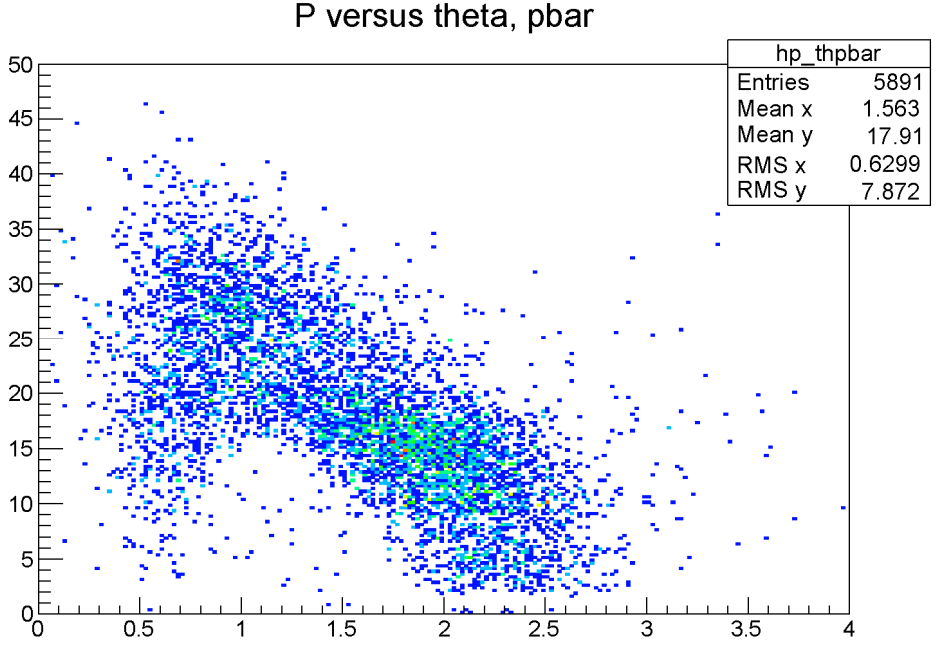
Simulation of $\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{-}$

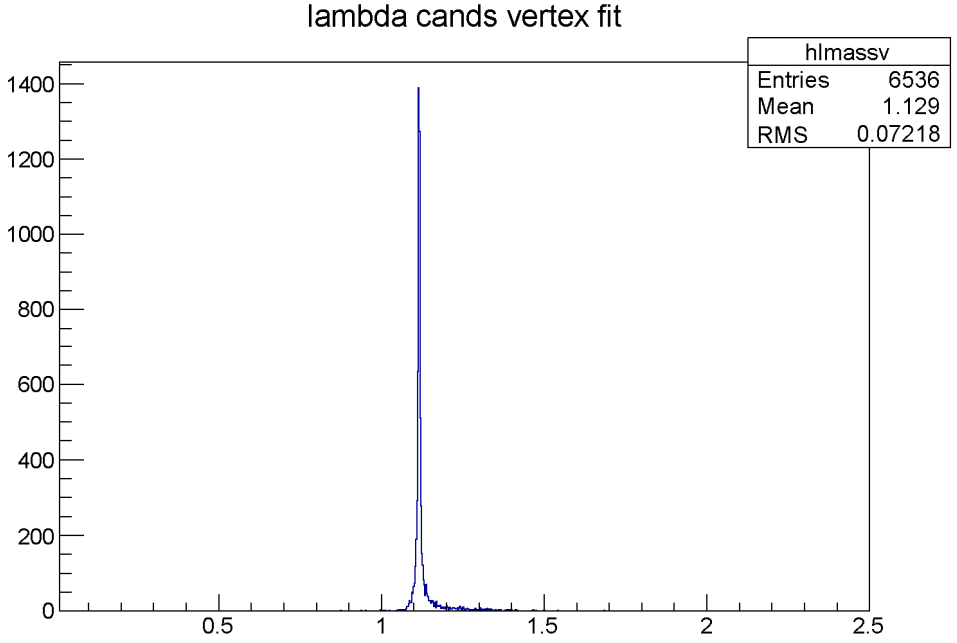
- p = 4 GeV/c
- Pandaroot versions: scrut14 (2×10^5 events), oct14 (10^6 events)
- Analysis in progress
- Problems:
  - ideal reco for displaced vertices
  - no vertex fitter yet for $\Xi \rightarrow \Lambda\pi$
  - reduced efficiency for $\bar{p}$ as compared to p
  - Multiple tracks for same MC index
  - Λ mass spectrum after vertex fit

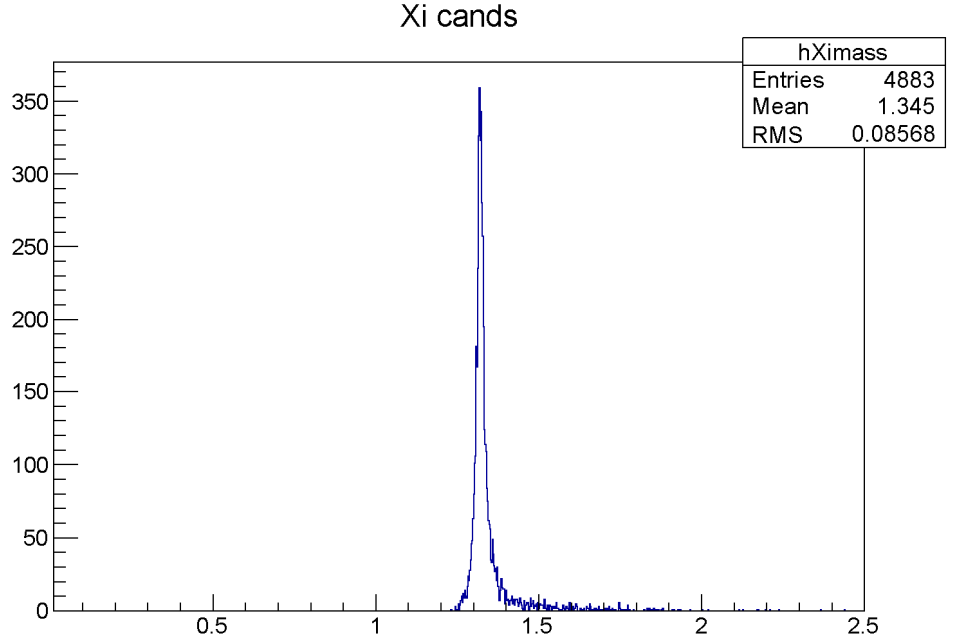

P versus theta, p MC truth
θ [°]
hpt_thp
Entries 10000
Mean x 1.533
Mean y 19.44
RMS x 0.5451
RMS y 7.962

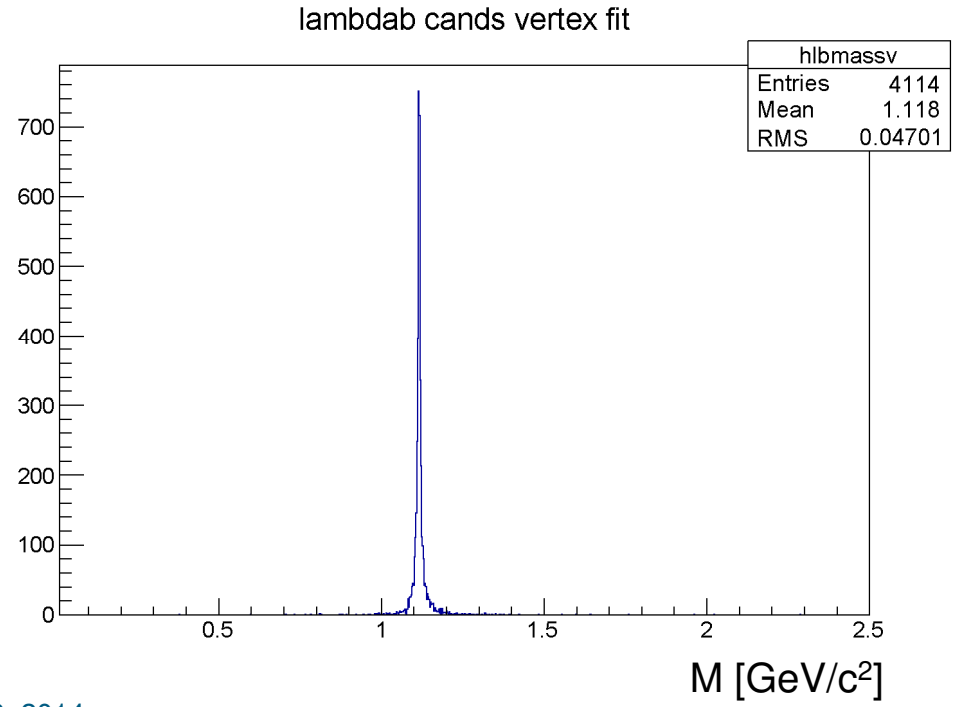

P versus theta, p
hp_thp
Entries 8050
Mean x 1.466
Mean y 19.03
RMS x 0.6283
RMS y 8.259

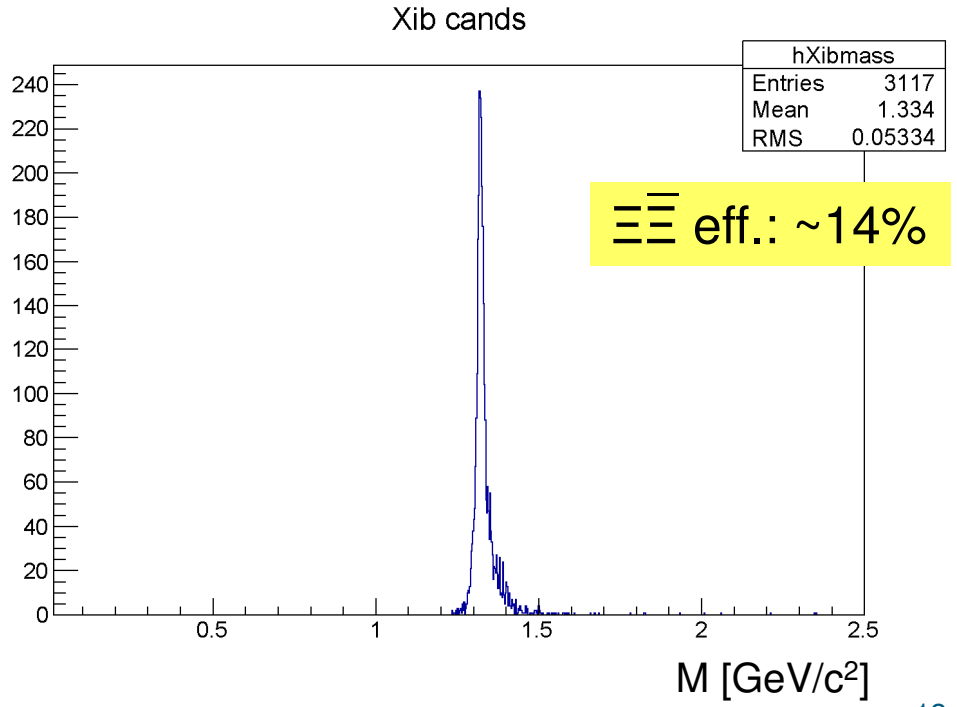

P versus theta, pbar MC truth
θ [°]
hpt_thpbar
Entries 10000
Mean x 1.515
Mean y 19.68
RMS x 0.5464
RMS y 8.003
p [GeV/c]


P versus theta, pbar
hp_thpbar
Entries 5891
Mean x 1.563
Mean y 17.91
RMS x 0.6299
RMS y 7.872
p [GeV/c]



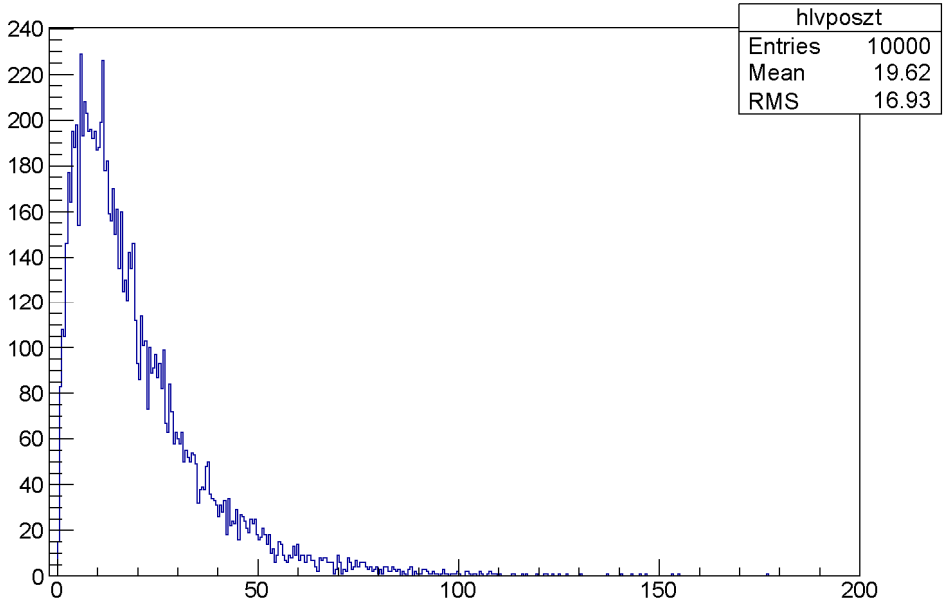




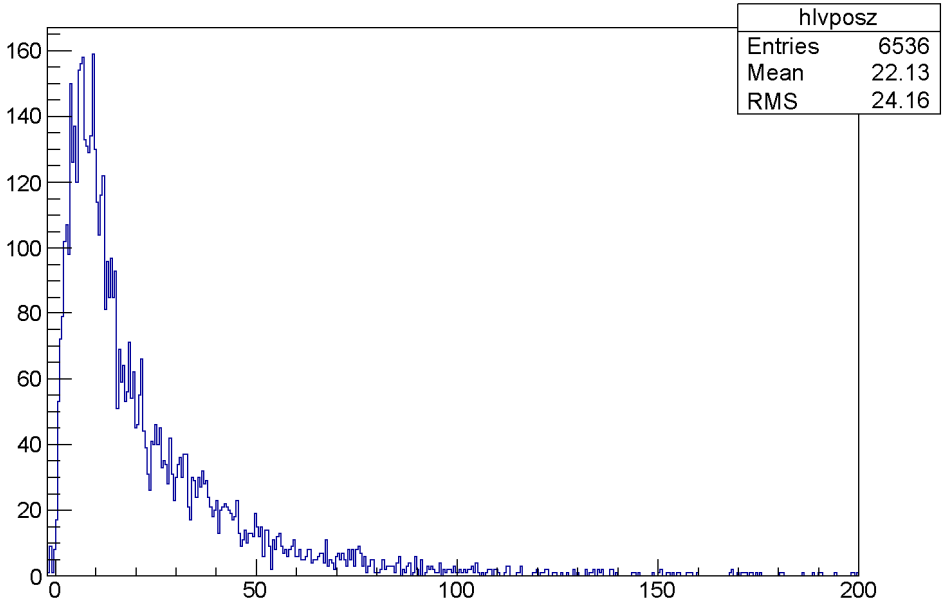


$\Xi\bar{\Xi}$ eff.: ~14%

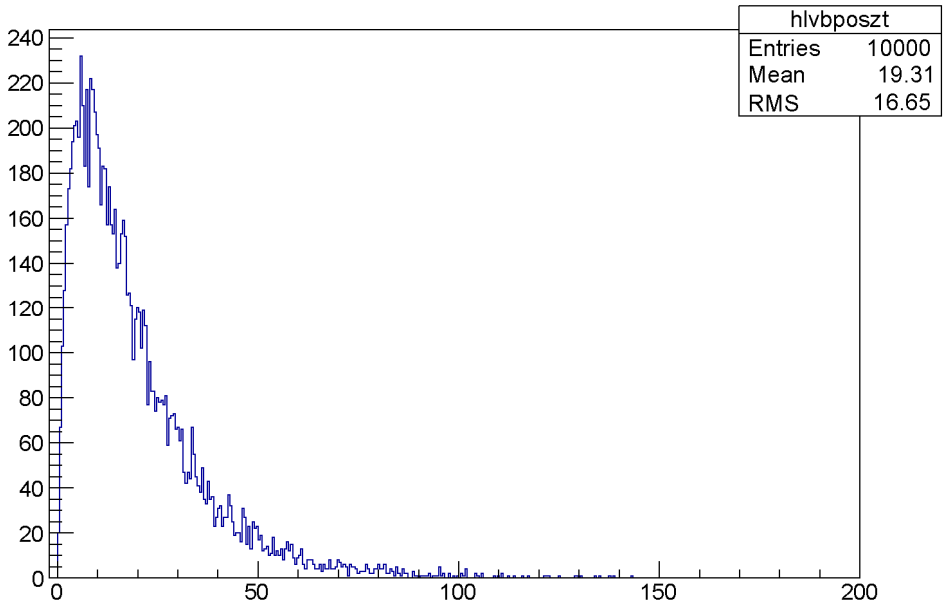
lambda true vertex z pos



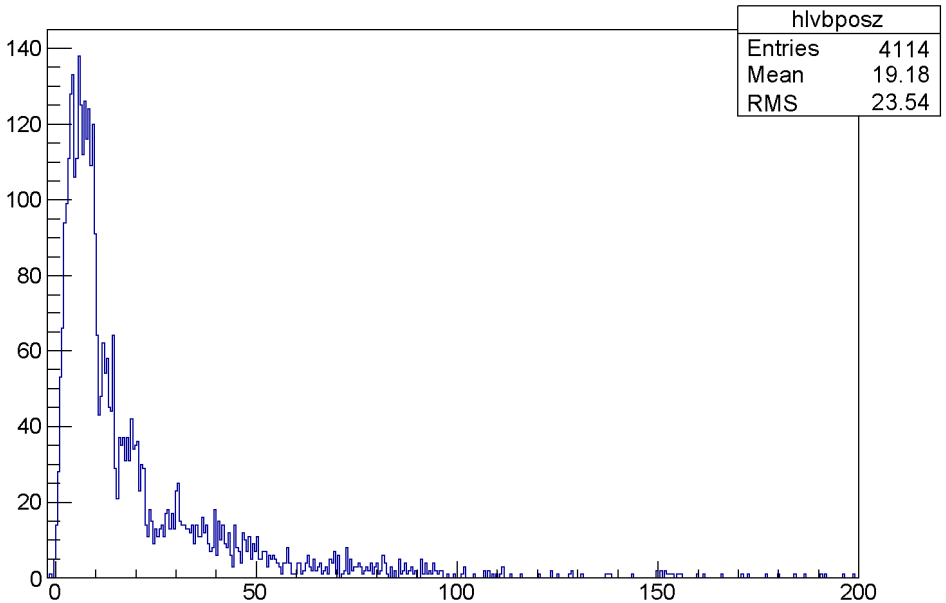
lambda vertex z pos



lambdabar true vertex z pos



lambdabar vertex z pos



- Physics Group: **Baryon Spectroscopy**
- Physics Group Convener(s):
  Albrecht Gillitzer
- Interested groups:
  U Basel, U Bonn, JU Cracow, U Giessen, KVI Groningen,
  JCHP / FZ Jülich, IHEP Protvino
- TAG contact persons:
  Ch. Fischer, M. Lutz, S. Ryan