Ξ^0_c production in pp collision at $\sqrt{s}$ =13TeV

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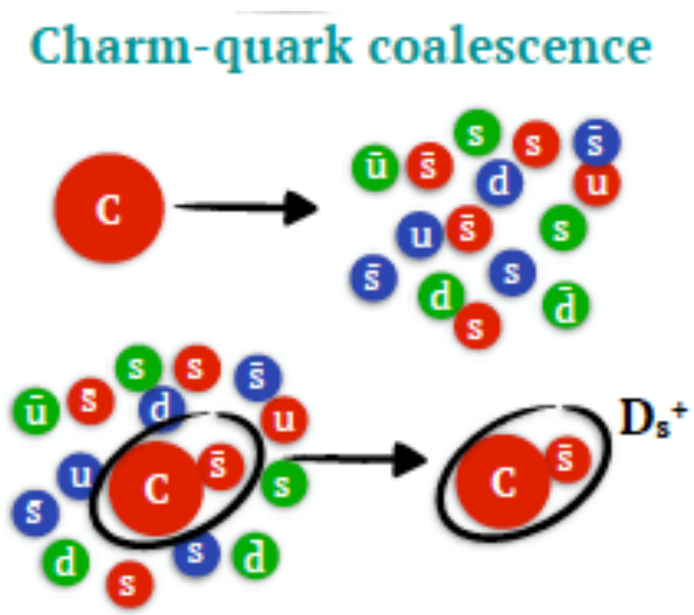
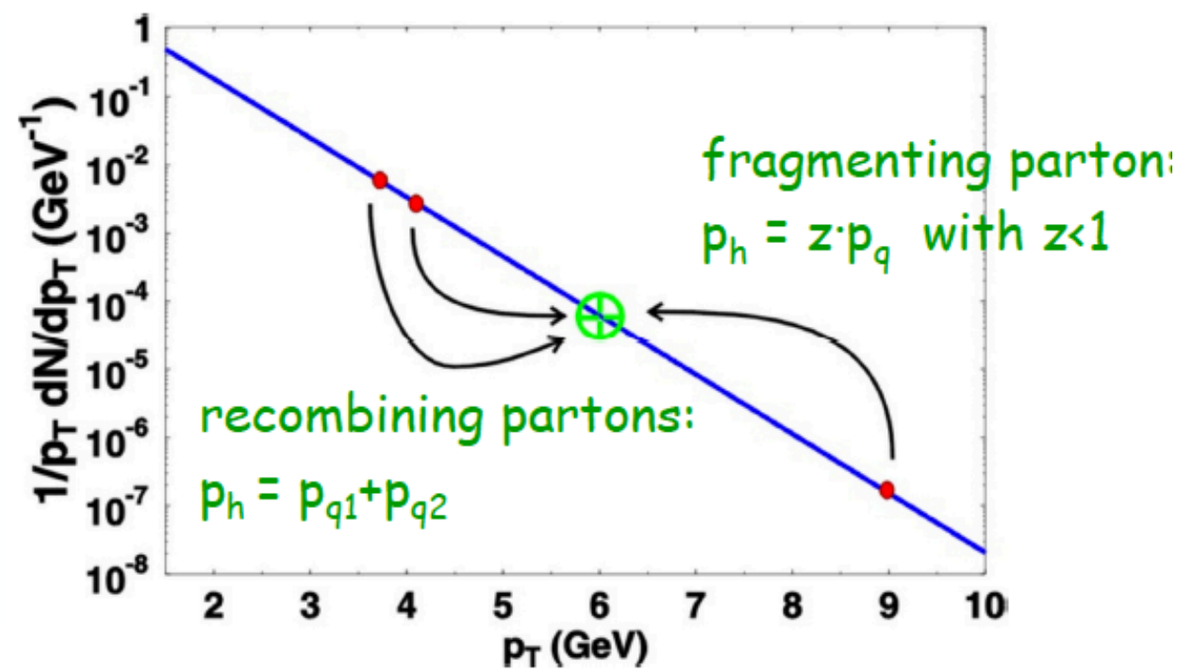
- Motivation

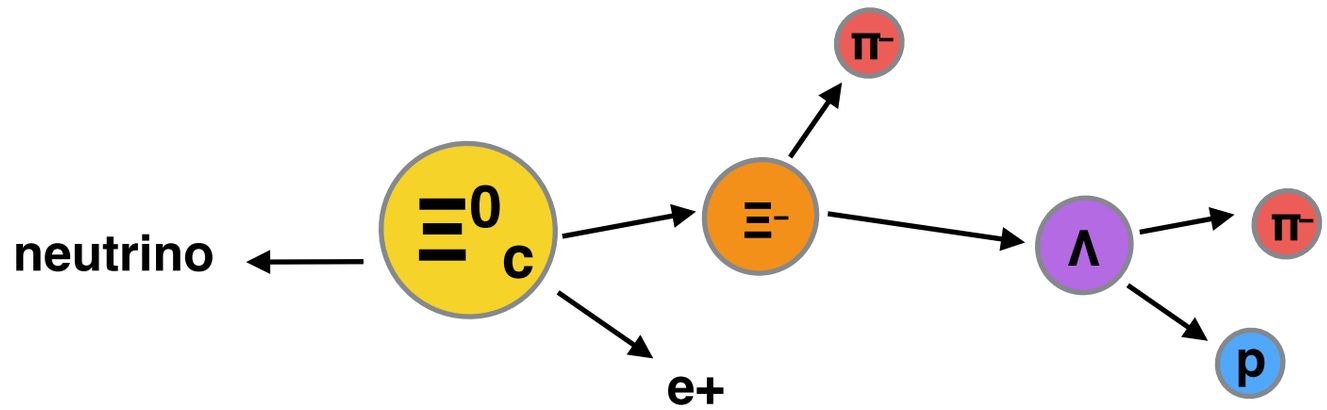
- **QGP probe of Heavy quarks**
  - Charm and beauty quarks are heavier than light quarks (u,d,s) and are produced in initial hard-scattering processes with high Q^2 , transported through the full medium created in the collisions.
  - Production cross sections calculable with perturbative QCD.
  - Traversing the medium while interacting with its constituents.
  - Study charm and beauty hadronization mechanisms using meson and Baryon production D, Λ_c, Ξ_c,…

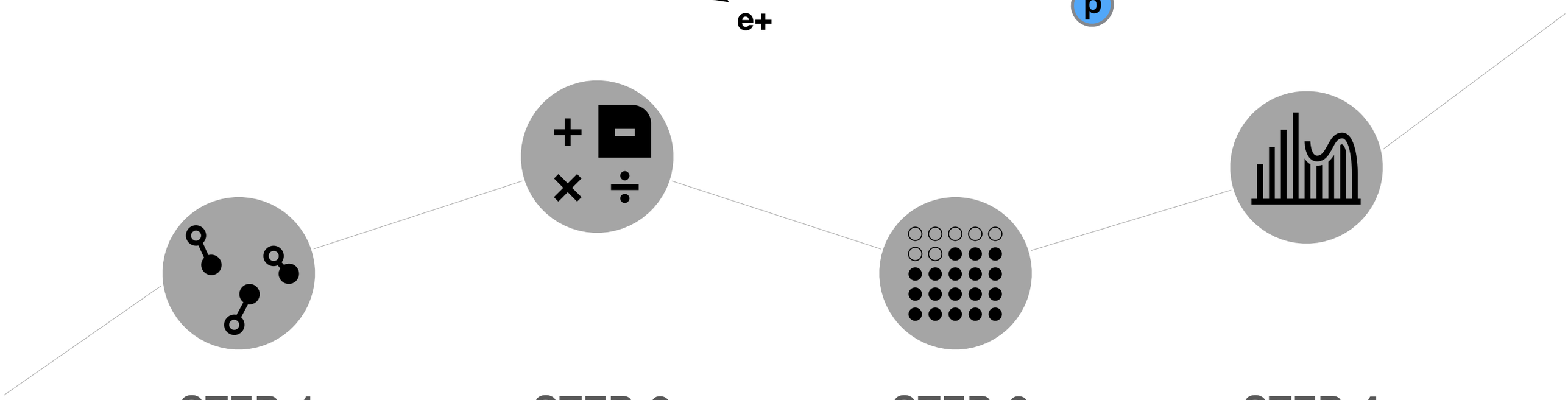




- **pp collisions**
  - Reference for p-Pb and Pb-Pb collisions.
  - Testing ground for perturbative QCD calculations.

Analysis flow





STEP. 1

Select e and Ξ and Make pair of Right Sign and Wrong Sign

STEP. 2

Subtract the Wrong Sign spectra from Right Sign Spectra

STEP. 3

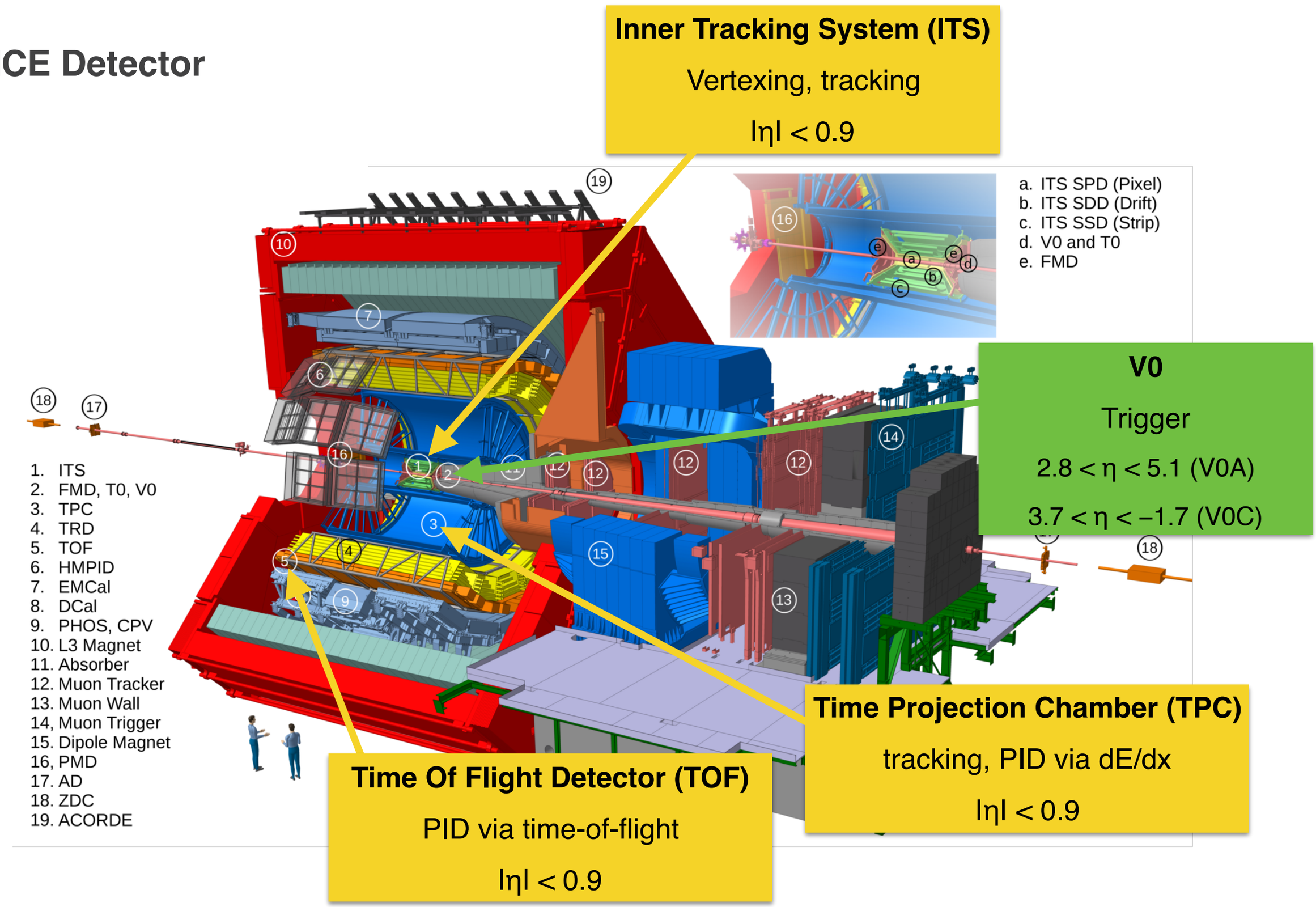
Using Unfolding technique to correct missing neutrino momentum

STEP. 4

Efficiency correction and event normalization

Detector

- ALICE Detector



Dataset

https://twiki.cern.ch/twiki/bin/view/ALICE/AliDPGReconstructedDataTakingPeriodspp13TeV

- Dataset

- Data : LHC16k, pass1 (pp collision, 13 TeV, 189M events, 165 runs)

  258537, 258499, 258477, 258456, 258454, 258452, 258426, 258393, 258391, 258387, 258359, 258336, 258332, 258307, 258306, 258303, 258302, 258301, 258299, 258278, 258274, 258273, 258271, 258270, 258258, 258257, 258256, 258204, 258203, 258202, 258198, 258197, 258178, 258117, 258114, 258113, 258109, 258108, 258107, 258063, 258062, 258060, 258059, 258053, 258049, 258045, 258042, 258041, 258039, 258019, 258017, 258014, 258012, 258008, 258003, 257992, 257989, 257986, 257979, 257963, 257960, 257957, 257939, 257937, 257936, 257892, 257855, 257853, 257851, 257850, 257804, 257803, 257800, 257799, 257798, 257797, 257773, 257765, 257757, 257754, 257737, 257735, 257734, 257733, 257727, 257725, 257724, 257697, 257694, 257692, 257691, 257689, 257688, 257687, 257685, 257684, 257682, 257644, 257642, 257636, 257635, 257632, 257630, 257606, 257605, 257604, 257601, 257595, 257594, 257592, 257590, 257588, 257587, 257566, 257562, 257561, 257560, 257541, 257540, 257539, 257537, 257531, 257530, 257492, 257491, 257490, 257488, 257487, 257474, 257468, 257457, 257433, 257364, 257358, 257330, 257322, 257320, 257318, 257260, 257224, 257209, 257206, 257204, 257144, 257141, 257139, 257138, 257137, 257136, 257100, 257095, 257092, 257086, 257084, 257082, 257080, 257077, 257028, 257026, 257021, 257012, 257011, 256944, 256942, 256941

- Data : LHC16l, pass1 (pp collision, 13 TeV, 55M events, 58 runs)

  259888, 259868, 259867, 259866, 259860, 259842, 259841, 259822, 259789, 259788, 259781, 259756, 259752, 259751, 259750, 259748, 259747, 259477, 259473, 259396, 259395, 259394, 259389, 259388, 259382, 259378, 259342, 259341, 259340, 259339, 259336, 259334, 259307, 259305, 259303, 259302, 259274, 259273, 259272, 259271, 259270, 259269, 259264, 259263, 259261, 259257, 259204, 259164, 259162, 259118, 259117, 259099, 259096, 259091, 259090, 259088, 258964, 258962

Cut list

- Cut list

Event cut

Cut variables	Cuts
Physics Selection	kINT7
Primary vertex	Within 10cm
Pile up	Rejection

eID cut

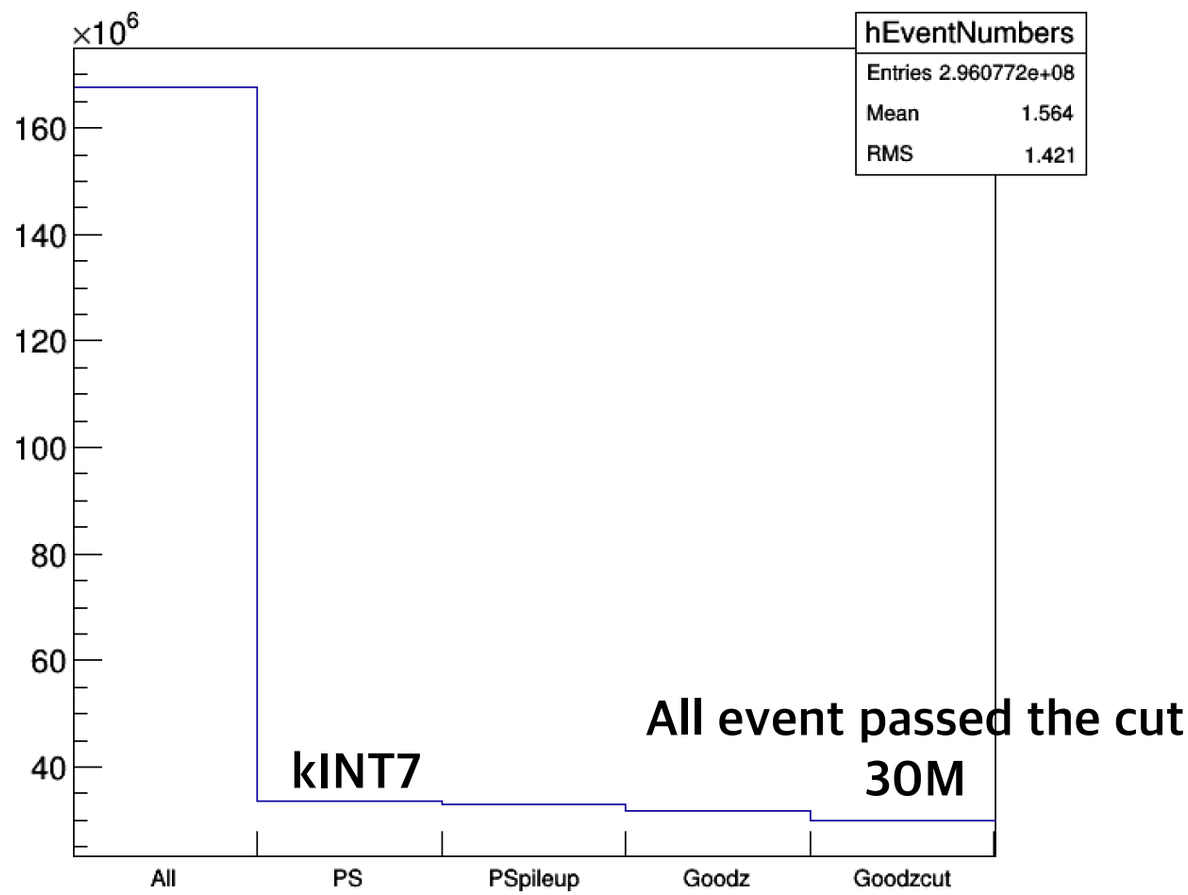
Cut variables	Cuts
AOD Filter Bit	4
Number of TPC clusters	>100
Number of TPC PID clusters	>80
Ratio to findable cluster	>0.6
ITS/TPC refit	TRUE
Number of ITS cluster	>=4
pt	>0.5
$\|\eta\|$	<0.8
SPD hit	Both
$\|$TOF n$\sigma\|$	<3
TPC nσ	−1.5 ~ 3

Ξ cut

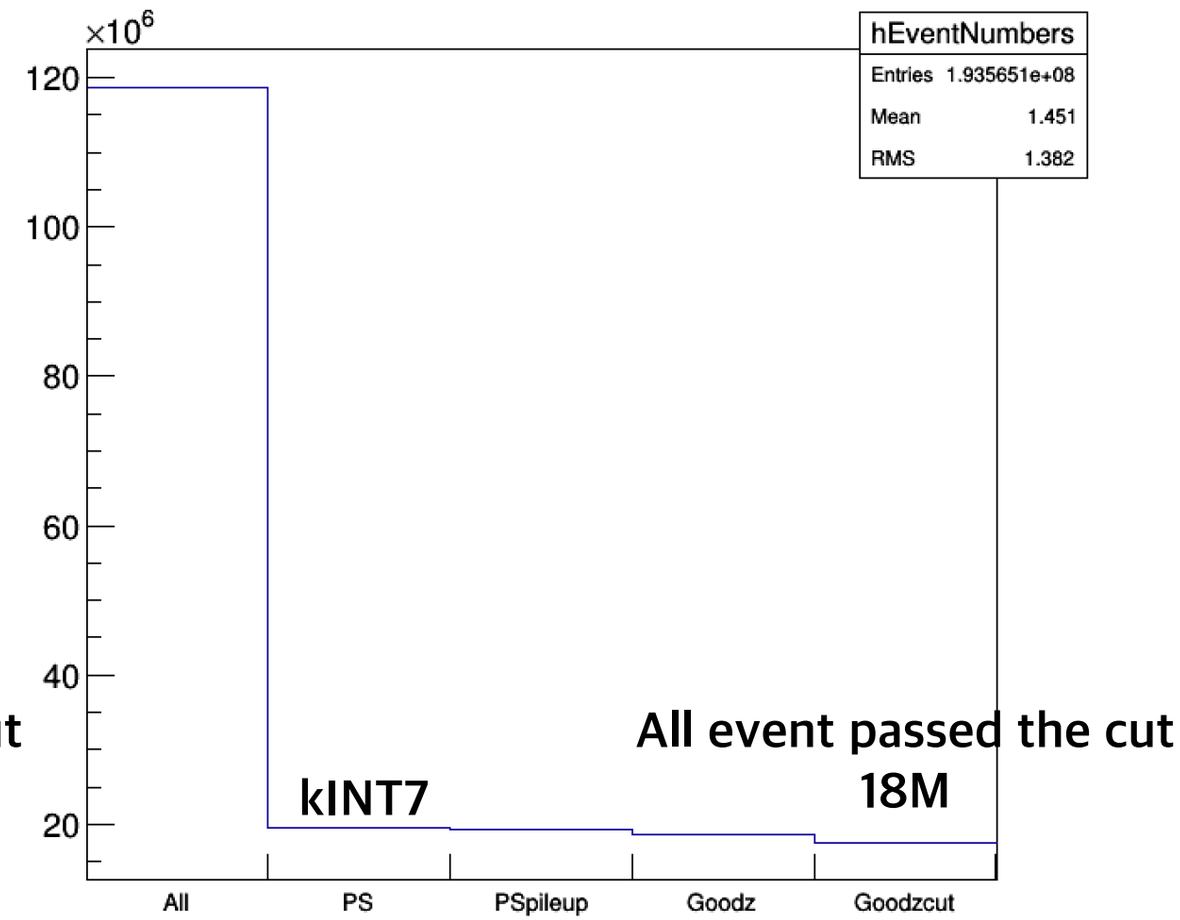
Cut variables	Cuts
Number of TPC cluster	>80
Λ Mass tolerance (MeV/c^2)	7.5
Ξ Mass tolerance (MeV/c^2)	8
DCAof V0 to PV(cm)	>0.03
DCA f V0 daughters PV (cm)	>0.073
V0 cosine pointing angle to Ξ vertex	>0.983
DCA of bachelor track to PV (cm)	>0.0204
V0 decay length (cm)	>2.67
Ξ decay length (cm)	>0.38
TPC nσ (proton)	<4
TPC nσ (pion)	<4

Event cut

- Event cut



LHC16k



LHC16l

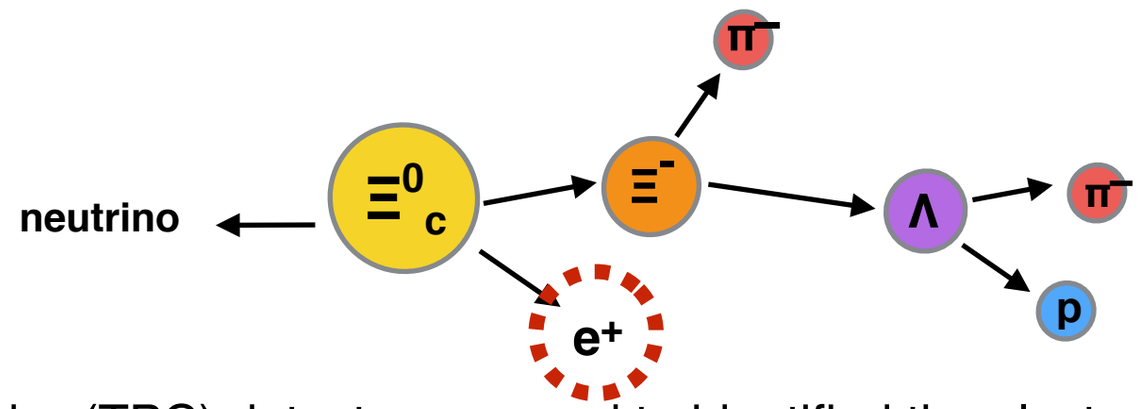
- All : All events in period
- PS : Physics selection + kINT7
- PSpileup : PS+ pile up rejection
- Goodz : PSpileup + Passed the SPD
- Goodzcut : Goodz + SPD primary vertex < 10cm.

- Event cut

Energy	5 TeV	13 TeV
Period	LHC17p : 1063M (kINT7, FAST)	LHC16k : 189M (kINT7, CENT)
	LHC17q : 66M (kINT7, FAST)	LHC16l : 55M (kINT7, CENT)
Total event number	819M (after cuts)	48M (after cuts)

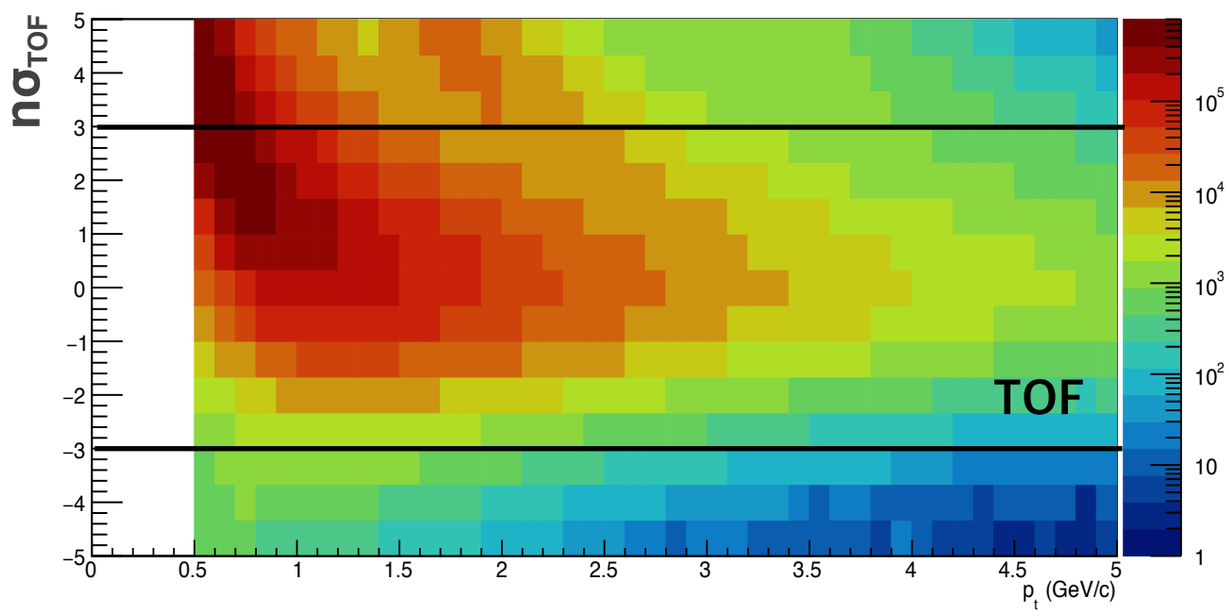
- 5TeV results is used in Andrea's results.
  (https://indico.cern.ch/event/766082/contributions/3222028/attachments/1756106/2847189/20_11_2018_Xic.pdf)
- Compare the event number, at 13TeV, the number of events after the cut is too small.
- The lack of event number occurs the statistics problem.

Analysis status

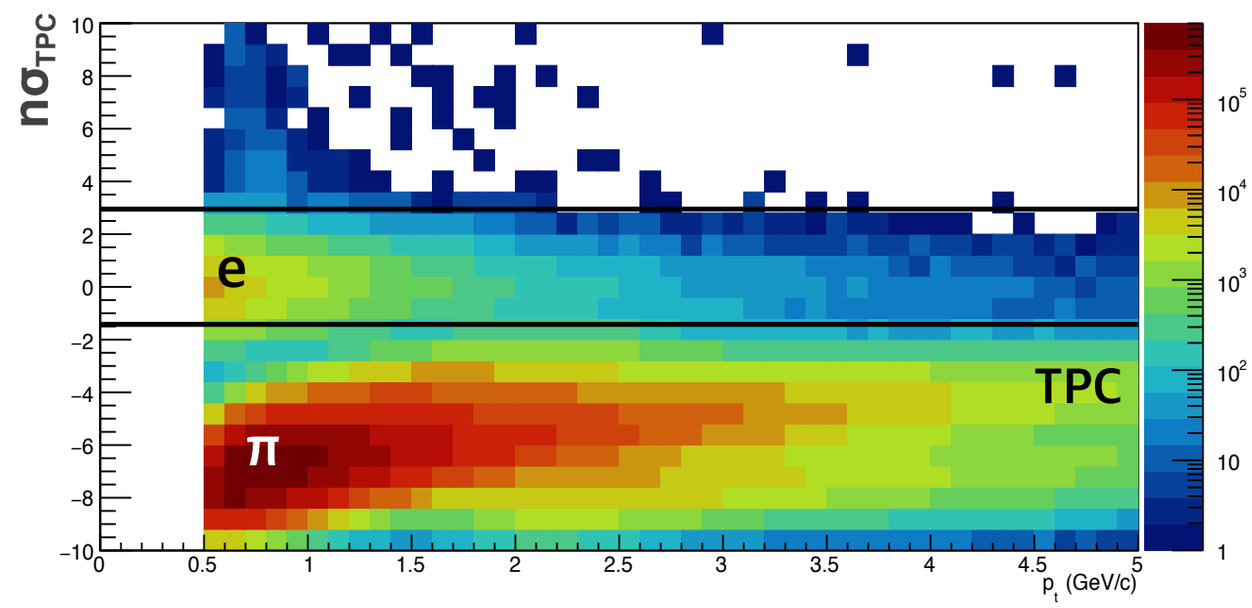


- Select electrons

- Time-Of-Flight(TOF) and Time Projection Chamber(TPC) detector are used to identified the electron.
- The $n\sigma_{TOF}$ and $n\sigma_{TPC}$ distributions of electrons get from real data.
- eID Cuts applied in this analysis



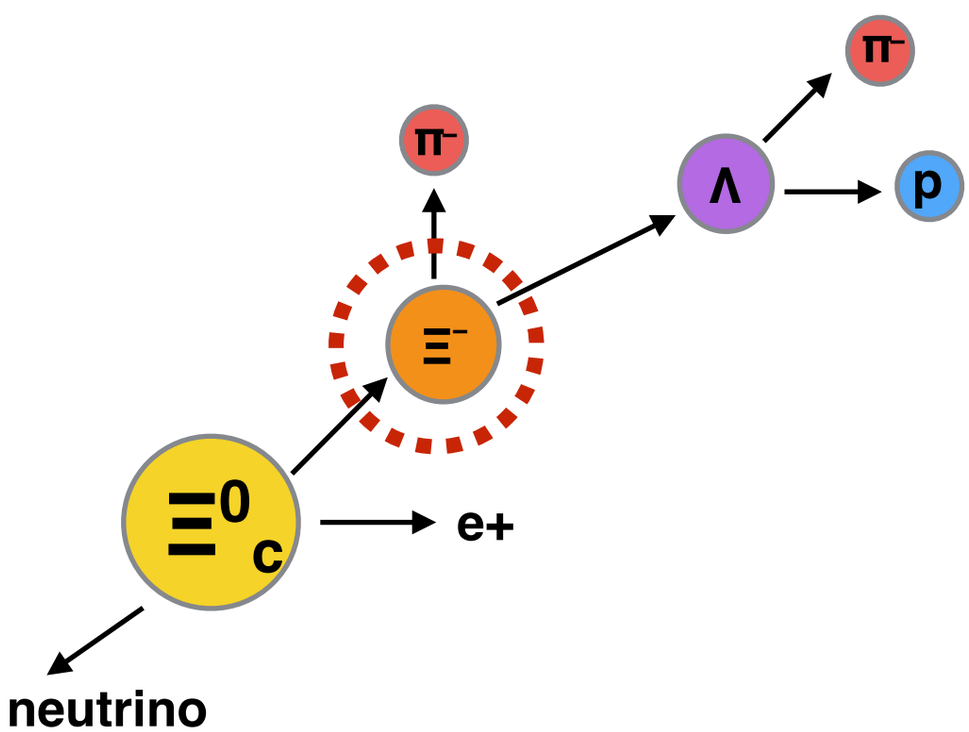
TOF nσ as function of p_T. The black line is the cut values.



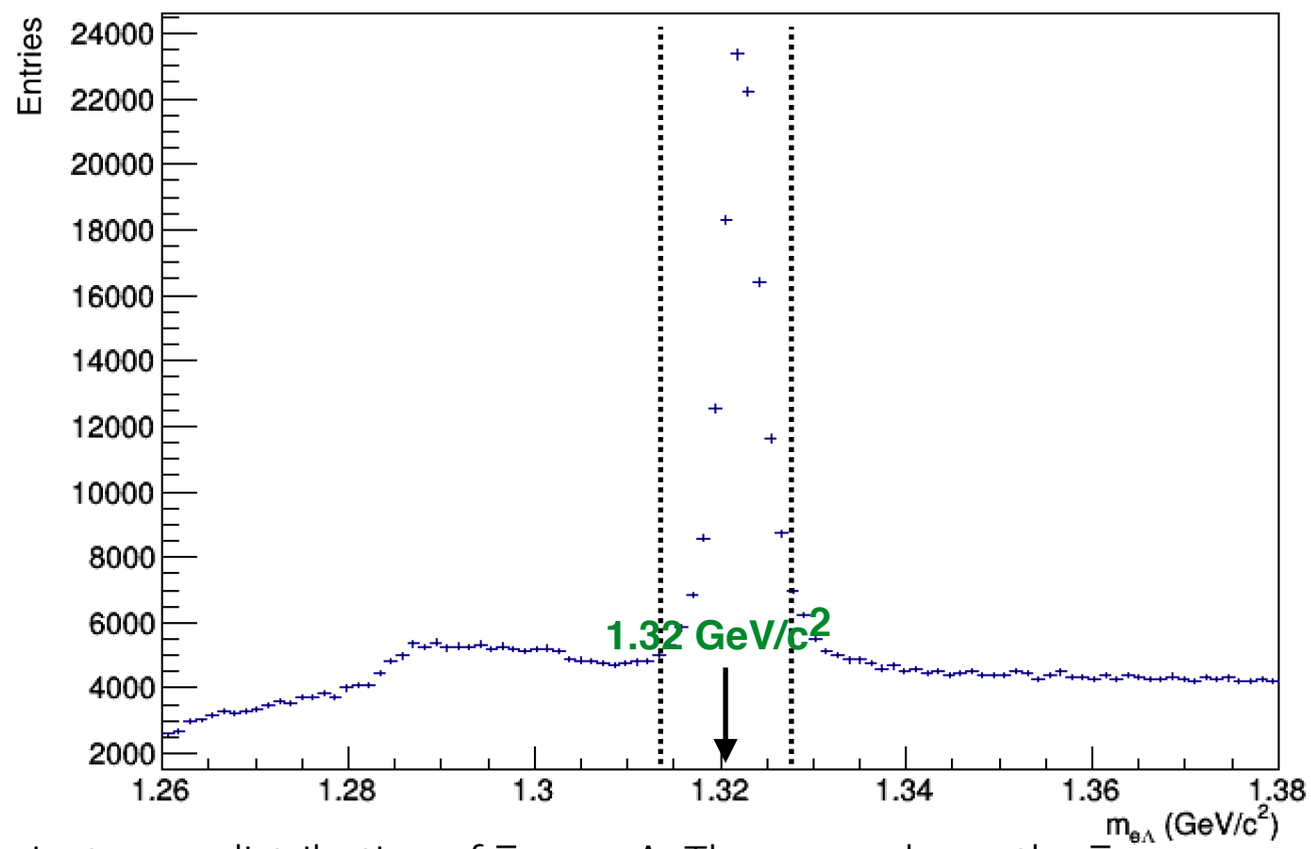
TPC nσ as function of p_T. The black line is the cut values.

- Select the Ξ

- The Ξ^- baryons are reconstructed from the decay chain $\Xi^- \rightarrow \pi^-\Lambda$, followed by $\Lambda \rightarrow p\pi^-$.
- The Ξ^- and Λ candidates were selected based on AliAODcascade, where the pion produced from Ξ^- and Λ can identified using mother particle's lifetimes ($c\tau$ of about 4.91 cm and 7.89 cm)
- Ξ cuts are applied to remove the background.



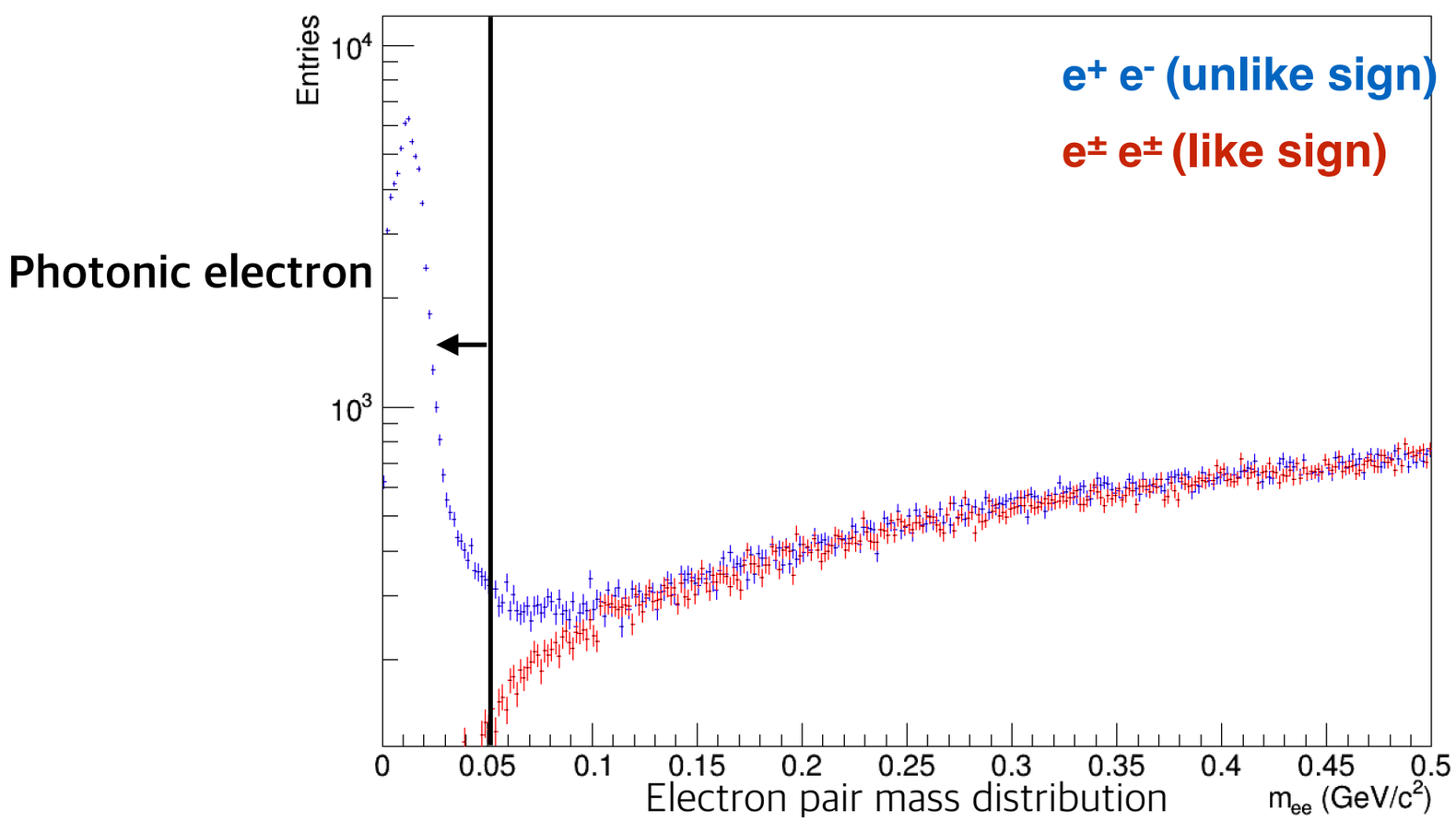
Semi-leptonic decay diagram



Invariant mass distribution of $\Xi^- \rightarrow \pi^-\Lambda$. The arrow shows the Ξ^- average mass.

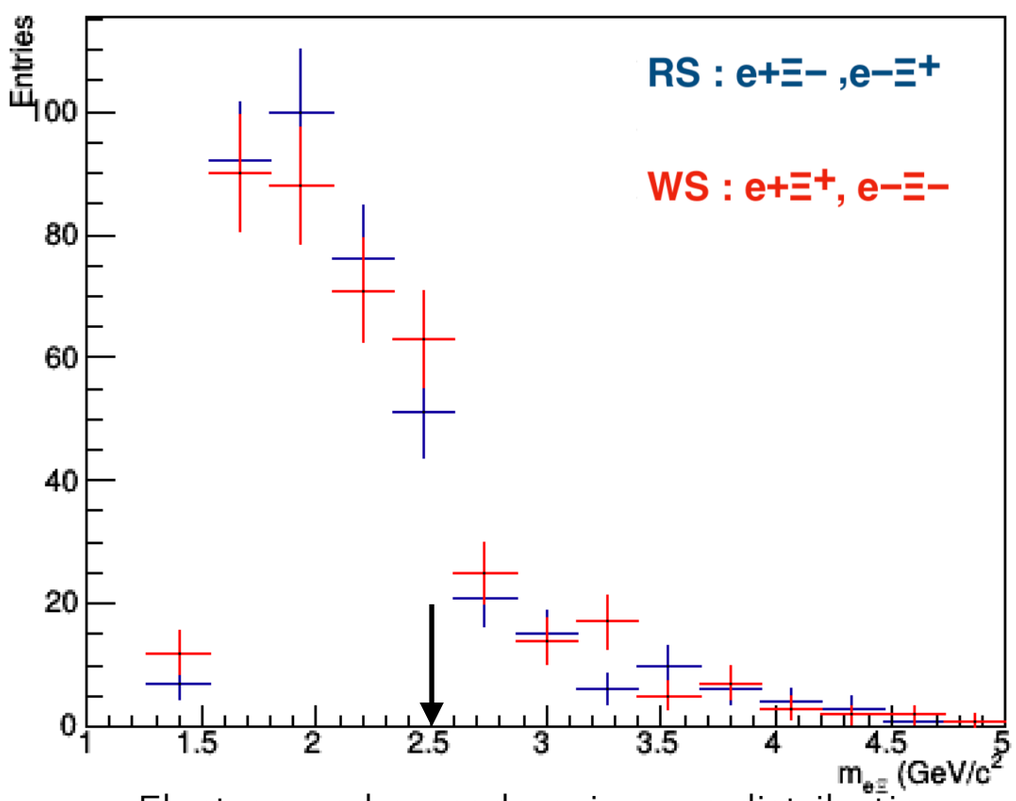
- Remove background electrons

- There are the background electrons that come from gamma conversion and Dalitz decay in the selected electron (photonic electron) after the cuts.
- The background electrons can be identified using a technique based on the invariant mass of e^+e^- pairs.
- The electron tracks are paired with opposite-sign tracks from the same event passing "loose selection criteria" ($|n\sigma_{TPC}| < 5$ without TOF requirement) and are identified as photonic electrons if there is at least one pair with an invariant mass smaller than 50 MeV/c^2.

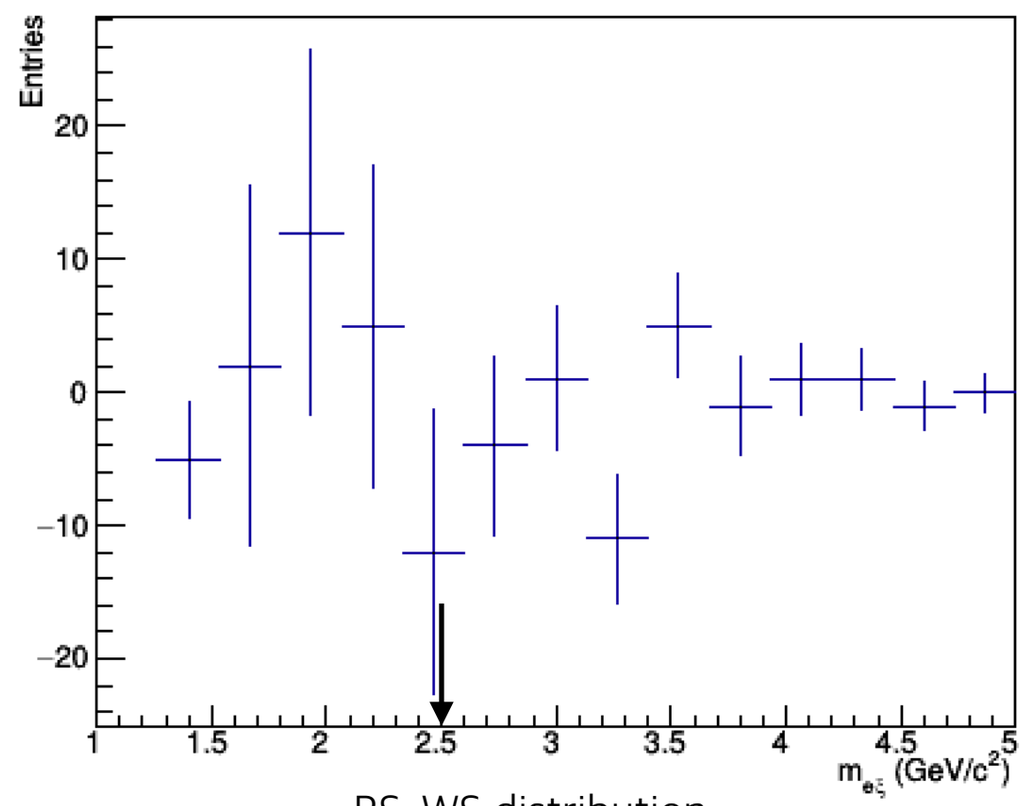


- Make eΞ pair and subtraction

- Make pairs of $e^+\Xi^-$(RS), $e^-\Xi^+$(RS), $e^+\Xi^+$(WS), $e^-\Xi^-$(WS) when they satisfy the following two conditions
  1) The opening angle between e and Ξ is less than 90 degrees
  2) The invariant mass of pair is less than 2.5 GeV/c^2.
- Due to the missing momentum of neutrino, the invariant mass distribution of the $e^+\Xi^-$ and $e^-\Xi^+$ pair does not have a peak at the Ξ^0_c mass.
- The background in the $e^+\Xi^-$ pair distribution is estimated by exploiting the fact that Ξ^0_c baryons decay into RS, but not into WS, while the most of the background sources contribute equally to RS and WS pairs. (RS-WS)



Electron and cascade pair mass distribution



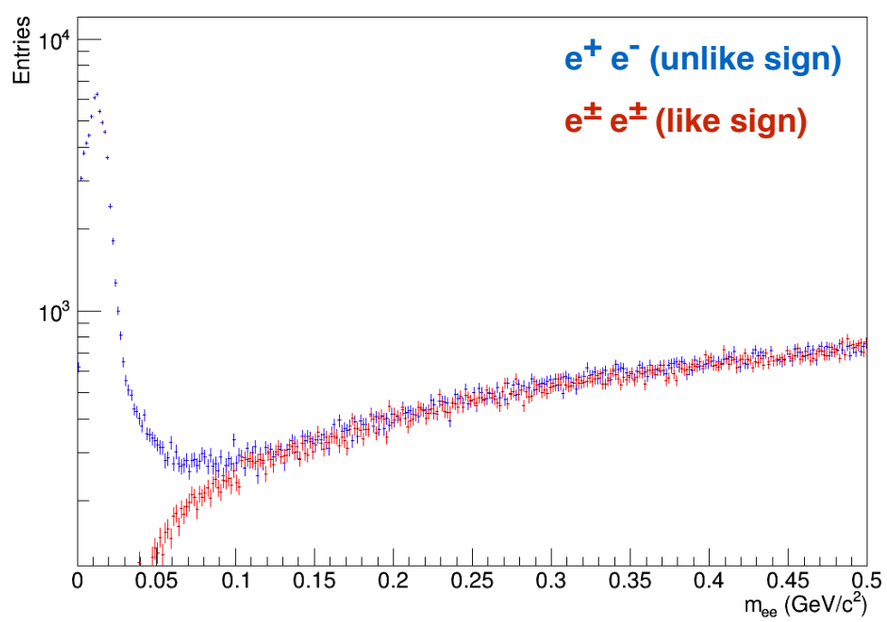
RS-WS distribution

Further step

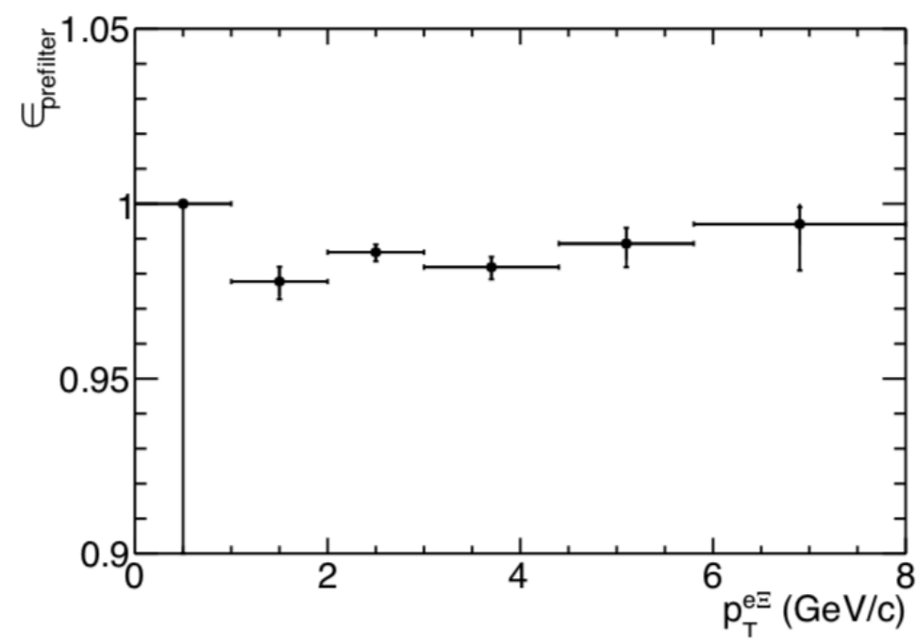
- Correct for the efficiency loss caused by prefilter

- The prefilter can rejects the photonic electrons and also rejects the non-background electrons.
- This efficiency correction is done separately from other efficiency corrections because it is expected to depend on the event multiplicity and topology, which could be different in data and MC.

$$\varepsilon_{prefilter} = \frac{N_{e\Lambda(\Xi)}(\textit{same-sign prefilter on})}{N_{e\Lambda(\Xi)}(\textit{prefilter off})}$$



Electron pair mass distribution



$\varepsilon_{prefilter}$ in $e\Xi$ analysis

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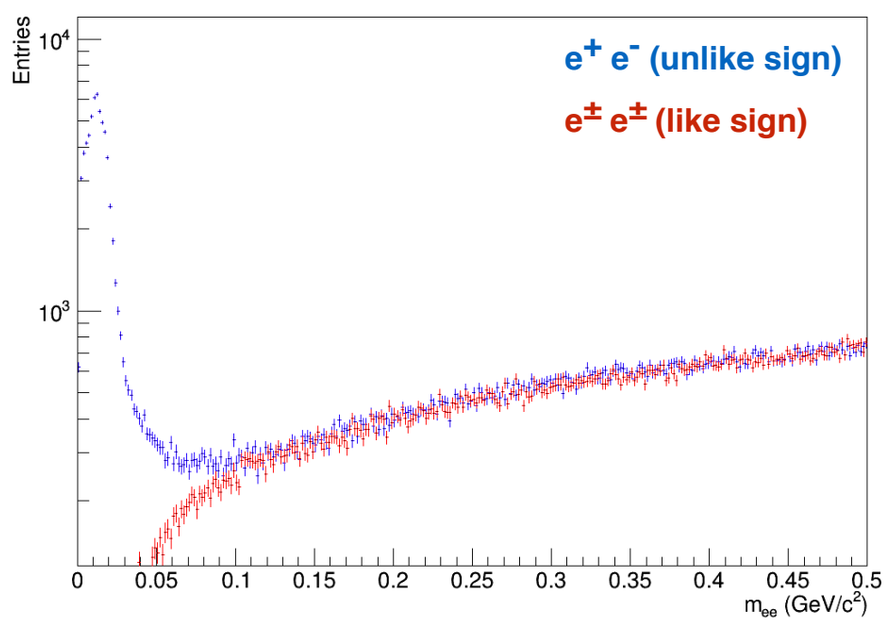
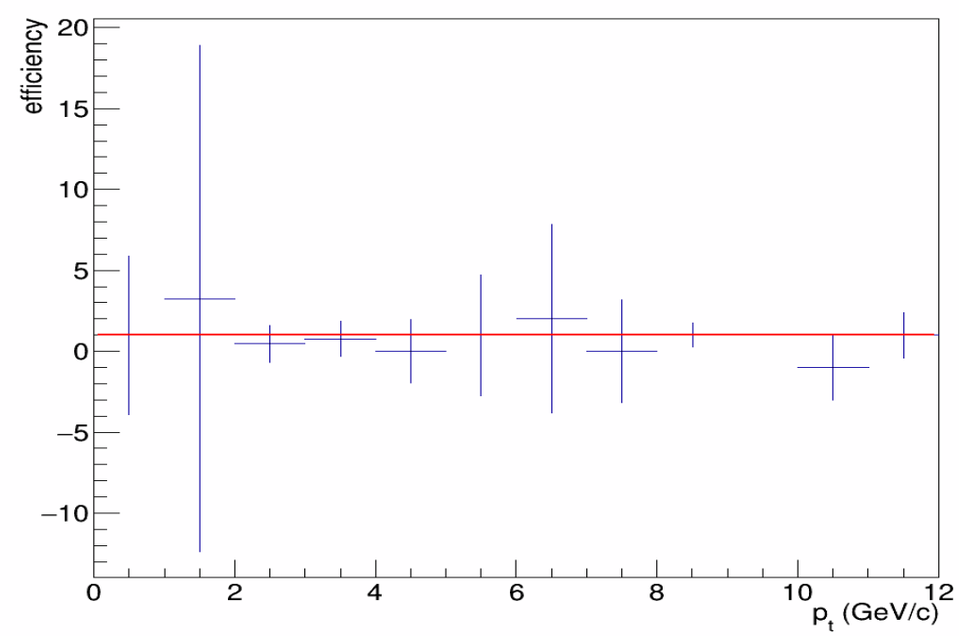


Electron pair mass distribution



$\varepsilon_{prefilter}$ in $e\Xi$ analysis

Further step

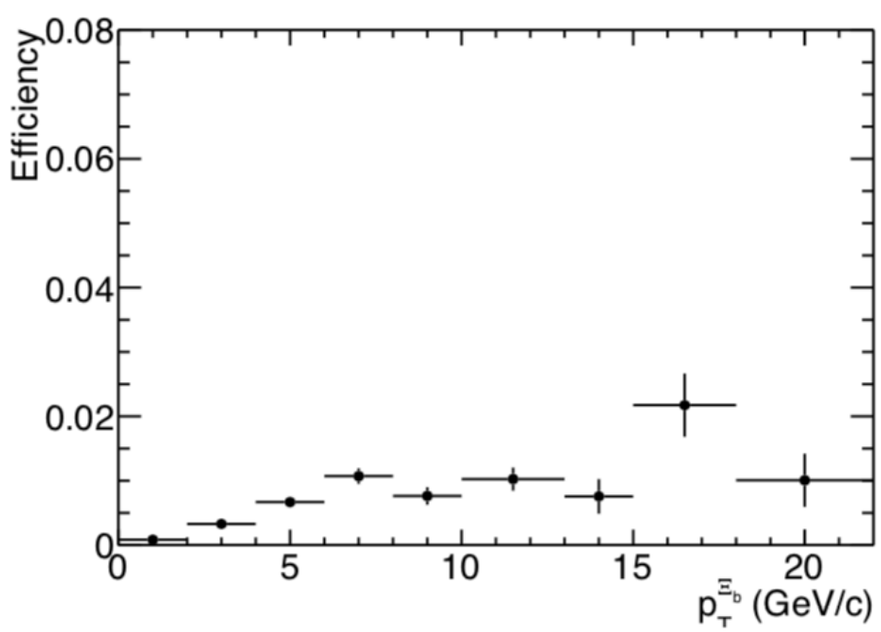
- Correct for the over subtraction caused by bottom baryon contributions

- In the WS spectra, there are contributions from bottom baryons, such as $\Xi_b \rightarrow e^- \Xi^- \nu_e X$.
- The Ξ_b baryons are not measured at LHC energies. Therefore two assumptions are made to estimate the contributions in $e\Xi$ analysis.

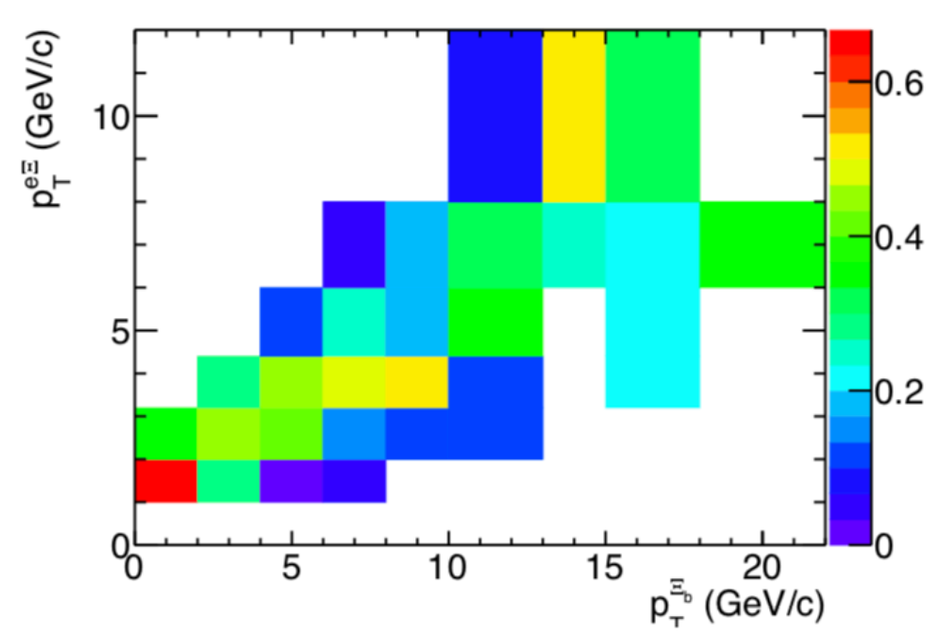
  1) The shape of p_T spectrum is same as Λ^0_b. ($\Lambda^0_b \rightarrow e^- \Lambda^+_c X \rightarrow e^- \Lambda X$)
     This measurement is extrapolated to $p_T = 0$ using the Tsallis function.

$$C \cdot p_T \left[1 + \frac{\sqrt{p_T^2 + m^2} - m}{nT} \right]^{-n}$$

  2) The $B(b \rightarrow \Xi_b) B(\Xi_b \rightarrow e\Xi X) / (B(b \rightarrow \Lambda_b) B(\Lambda_b \rightarrow e\Lambda X))$ ratio is the same in *ee* and *pp* collisions.



The efficiency of Ξ_b as a function of $p_T^{\Xi_b}$

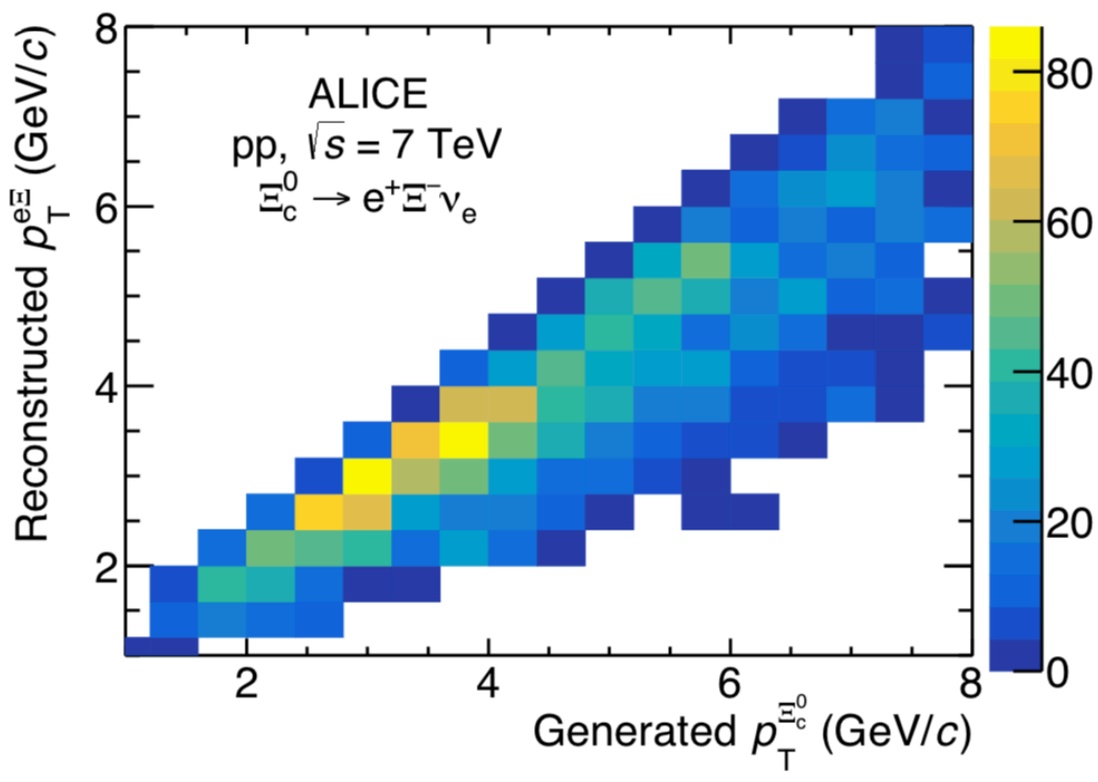


Response matrix of $\Xi_b \rightarrow e\Xi$

Further step

- Using Unfolding technique to correct missing neutrino momentum

- The response matrices are prepared to convert reconstructed $e\Xi$ pair p_T into true Ξ^0_c p_T
- The matrices are calculated in two step
  1) The response matrix is obtained with the p_T distribution generated with PYTHIA 6.
  2) The resulting Ξ^0_c momentum distribution is used to produce the response matrix.
- The unfolding is performed with the RooUnfold implementation of the Bayesian unfolding technique.



Correlation between the generated Ξ^0_c baryon p_T and the reconstructed $e^+\Xi^-$ pair p_T

Summary

- Summary

- Ξ^0_c production is being studied via semi-leptonic decay in pp collision at 13 TeV.
- Electrons are identified using Time-Of-Flight(TOF) and Time Projection Chamber(TPC).
- The Ξ^- peak in the $\pi^-\Lambda$ invariant-mass distribution integrated over p_T is found(1321.71 ± 8 MeV/c^2).
- Background electrons are removed to use electron pair mass information.
- Make Right Sign(RS) pair and Wrong Sign(WS) pair and WS was subtract from RS to remove background.

- Outlook

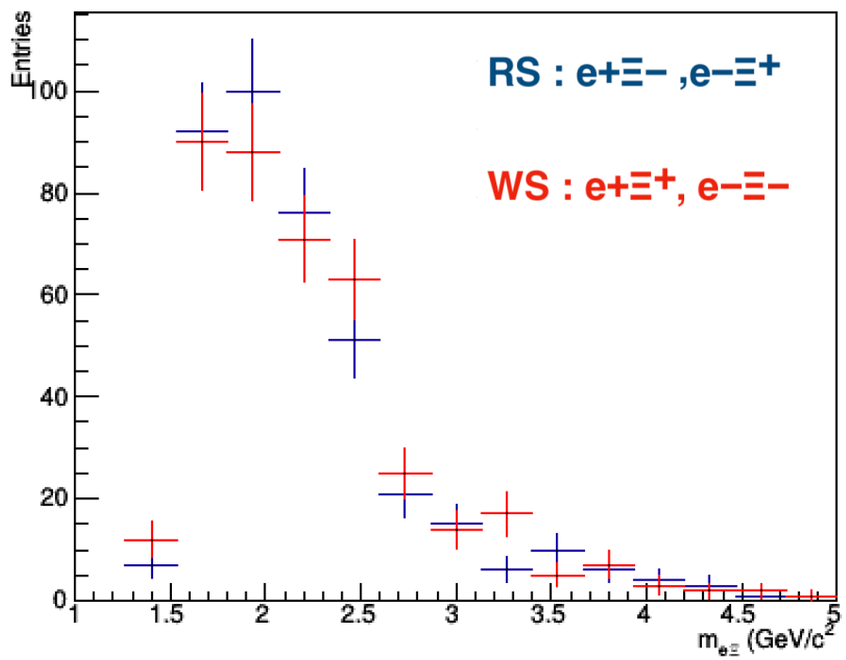
- To increase statistics, we are considering to add another periods of the runs
- The efficiency correction will be done, and the over subtraction effect due to bottom baryon contribution also will be corrected.
- Unfolding procedure will be done considering also the missing neutrino momentum.

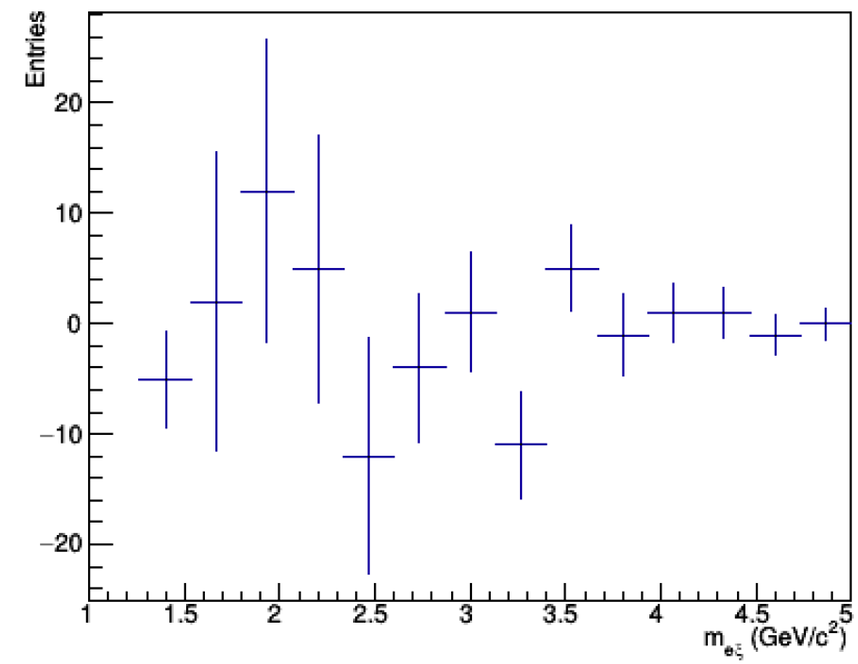
Thank you

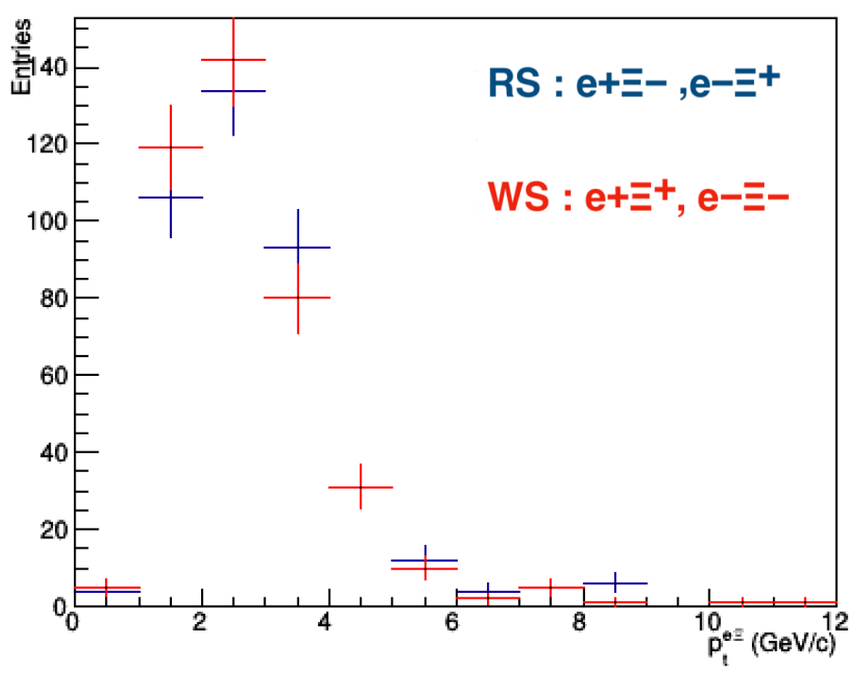
Back up

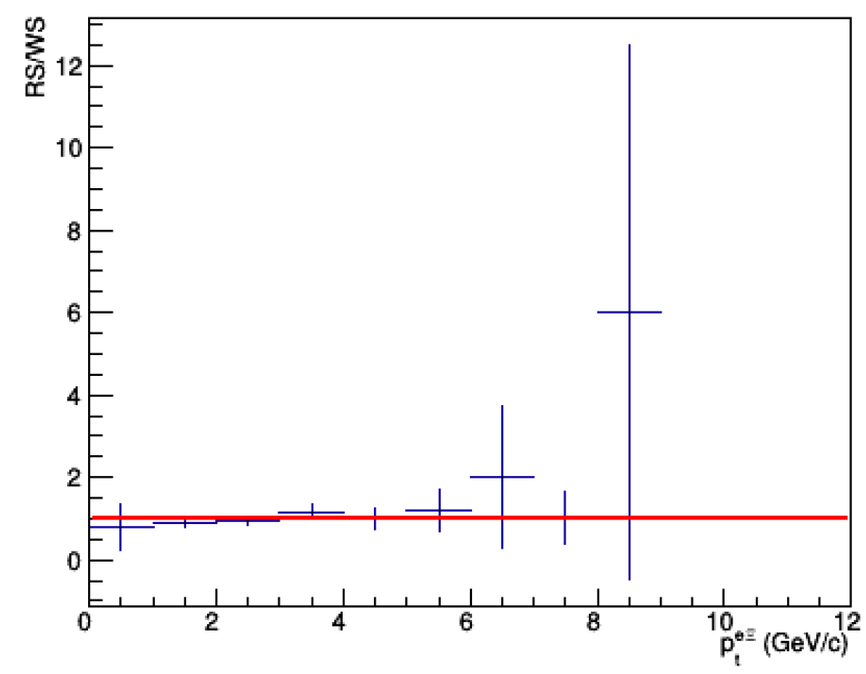
Analysis status

- Make eΞ pair and subtraction



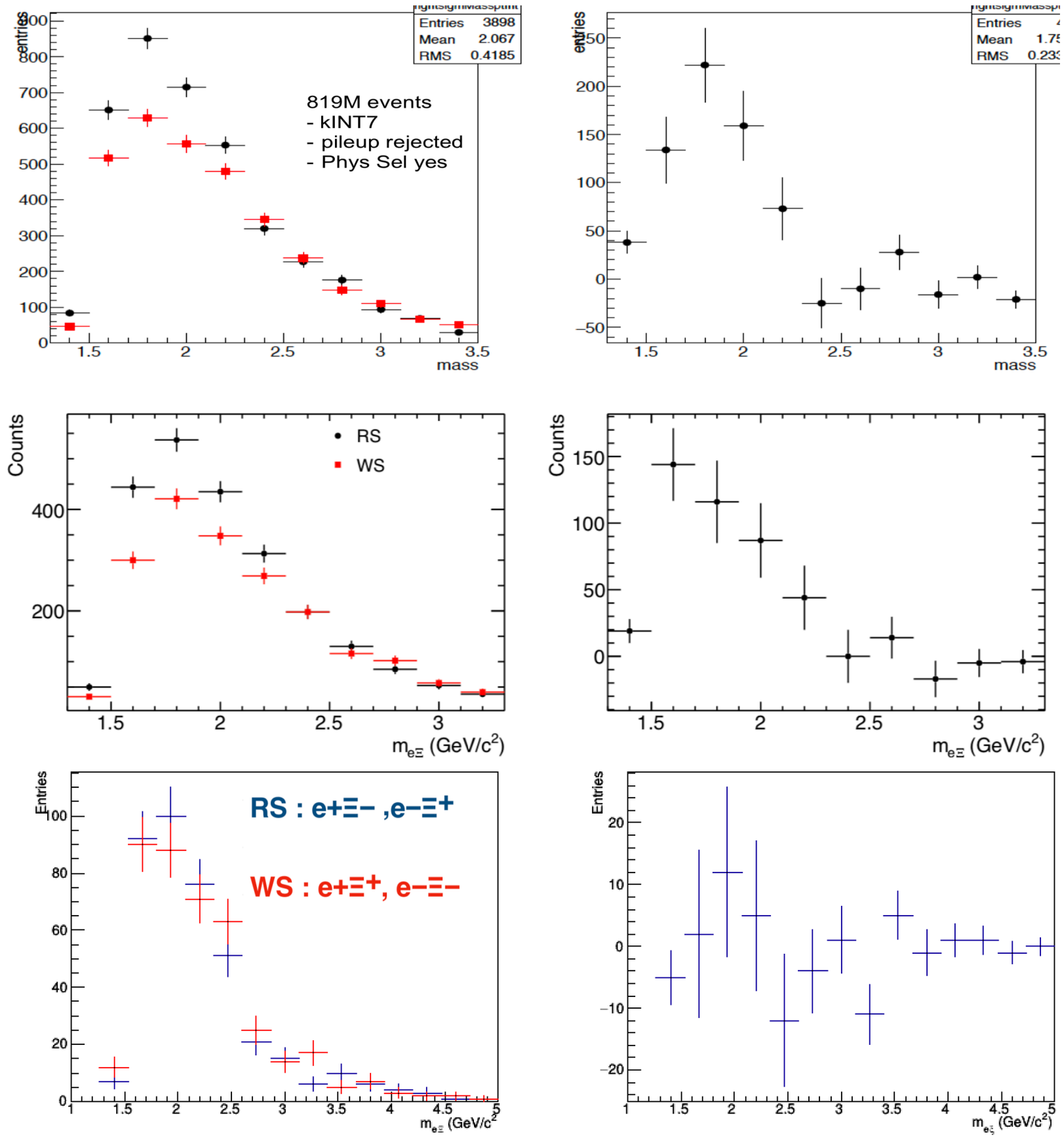






Analysis status

- Make eΞ pair and subtraction



- Cascade_c production in pp collision at 7TeV

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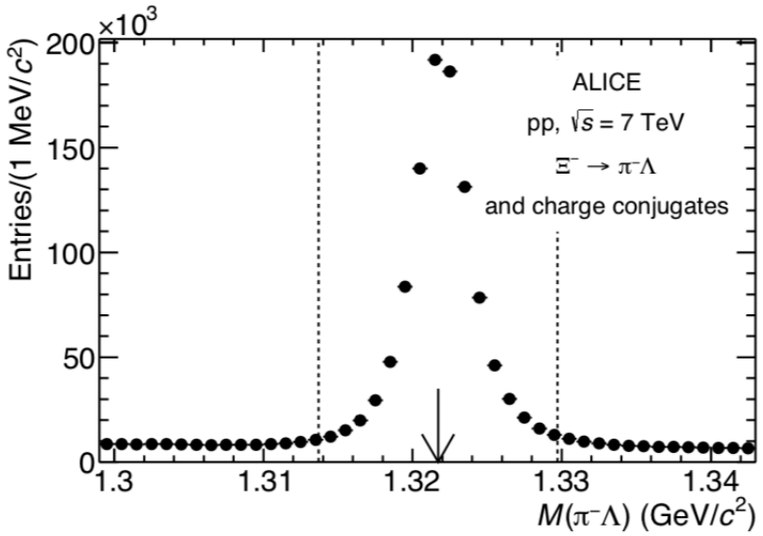
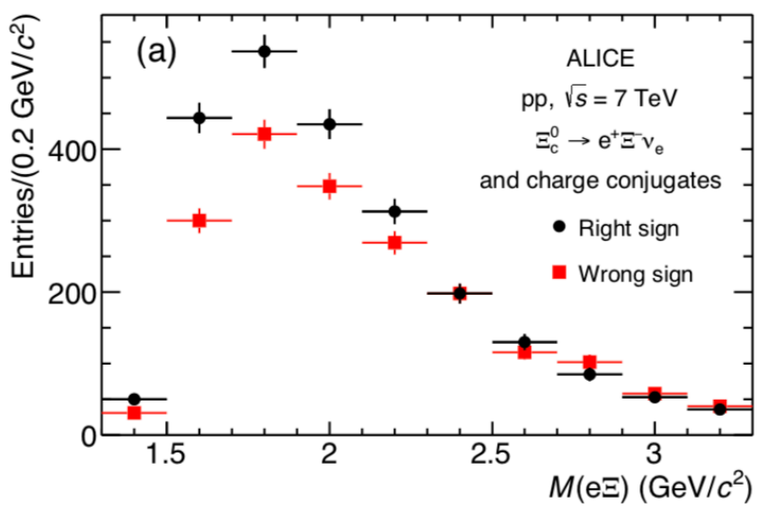
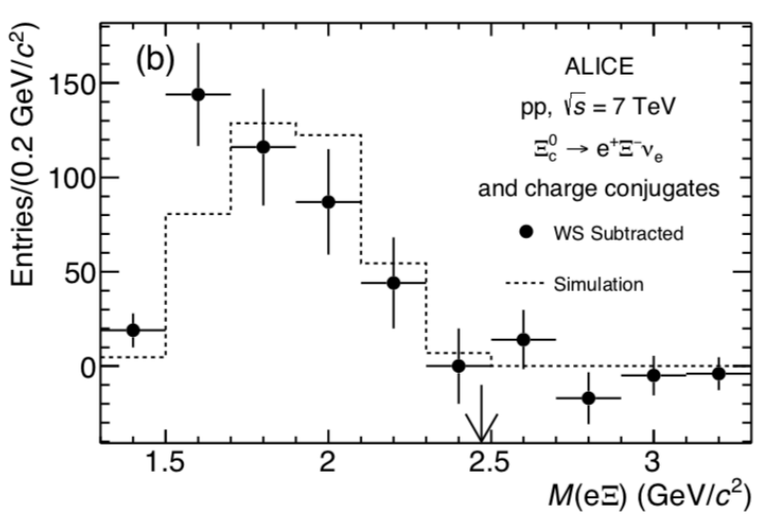


Invariant-mass distribution of $\Xi^- \rightarrow \pi^-\Lambda$ (and charge conjugate) candidates integrated over p_T.

The arrow indicates the world average Ξ^- mass and the dashed lines indicate the selected interval for the Ξ^- candidates.

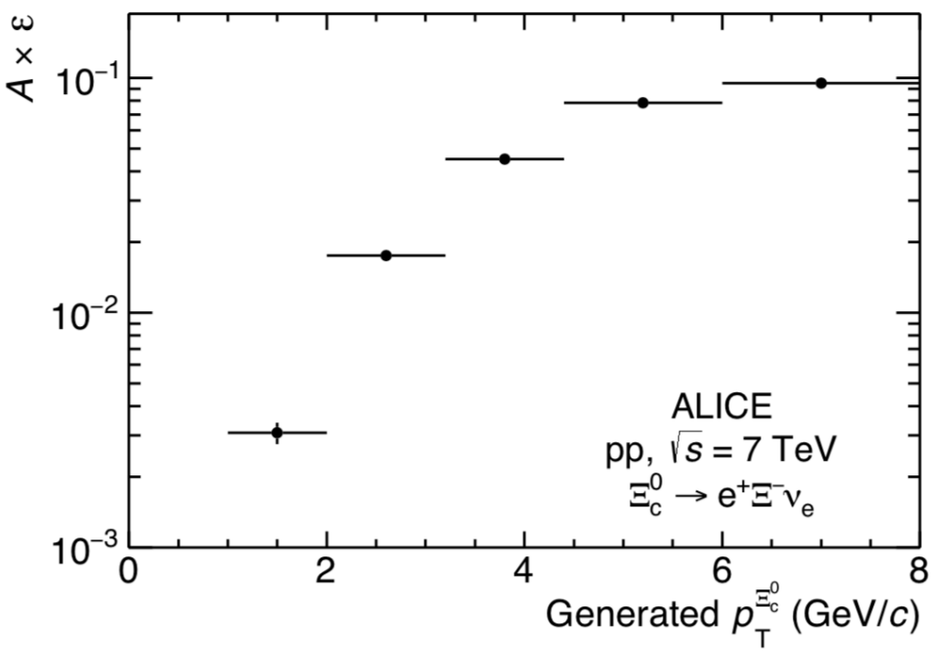


Invariant-mass distributions of right-sign and wrong-sign (and charge conjugate) pairs integrated over the whole p_T interval.

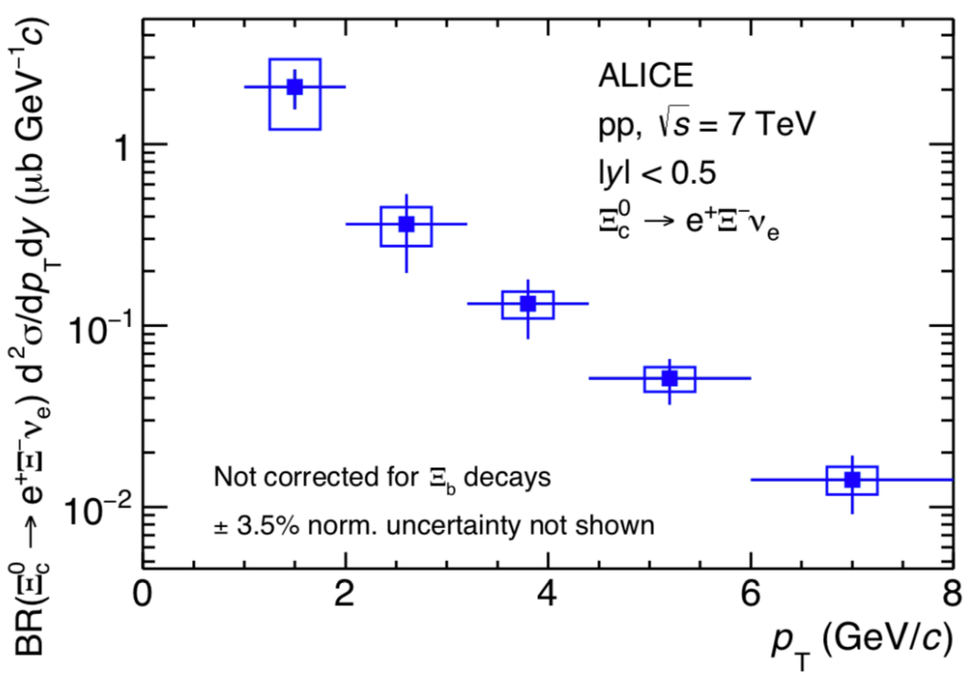


Invariant-mass distribution of Ξ^0_c candidates obtained by subtract- ing the wrong-sign pair yield from the right-sign one compared with the signal distribution from the simulation, which is normalized to the measured RS–WS yield. The arrow indicates the Ξ^0_c mass.

- Cascade_c production in pp collision at 7TeV

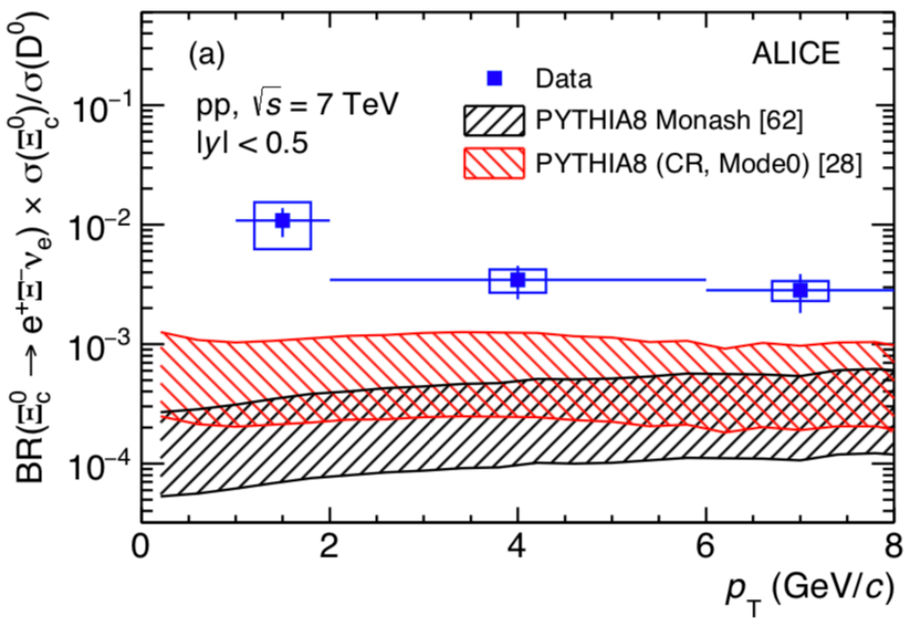


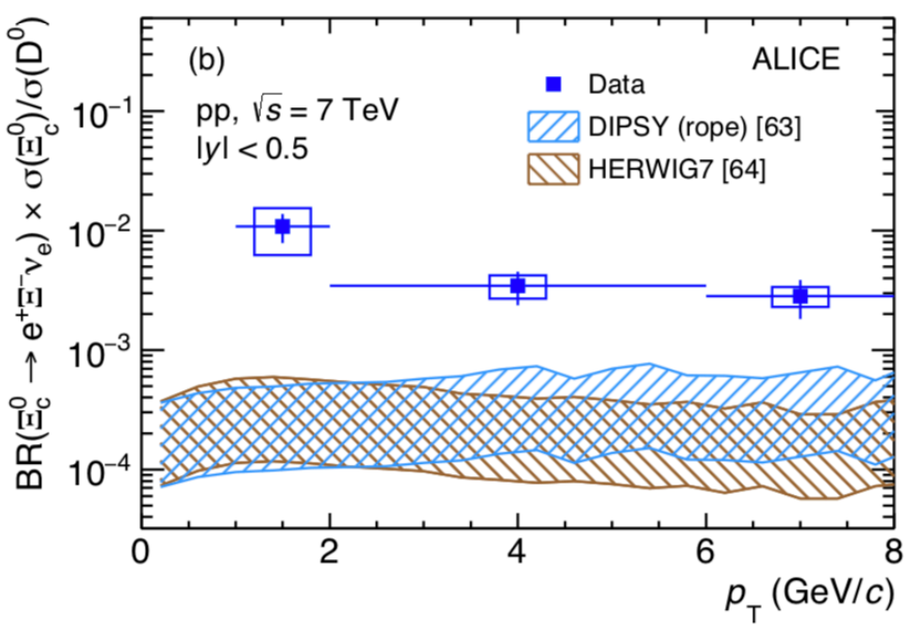
Product of acceptance and efficiency ($A \times \varepsilon$) of Ξ^0_c baryons generated in $|y| < 0.8$ decaying into $e^+\Xi^-\nu_e$ as a function of p_T, determined from simulations PYTHIA 6.



Inclusive Ξ^0_c-baryon p_T-differential production cross section multiplied by the branching ratio into $e^+\Xi^-\nu_e$, as a function of p_T for $|y| < 0.5$, in pp collisions at $\sqrt{s}$ = 7 TeV. The error bars and boxes represent the statistical and systematic uncertainties, respectively. The contribution from Ξ_b decays is not subtracted.

- Cascade_c production in pp collision at 7TeV

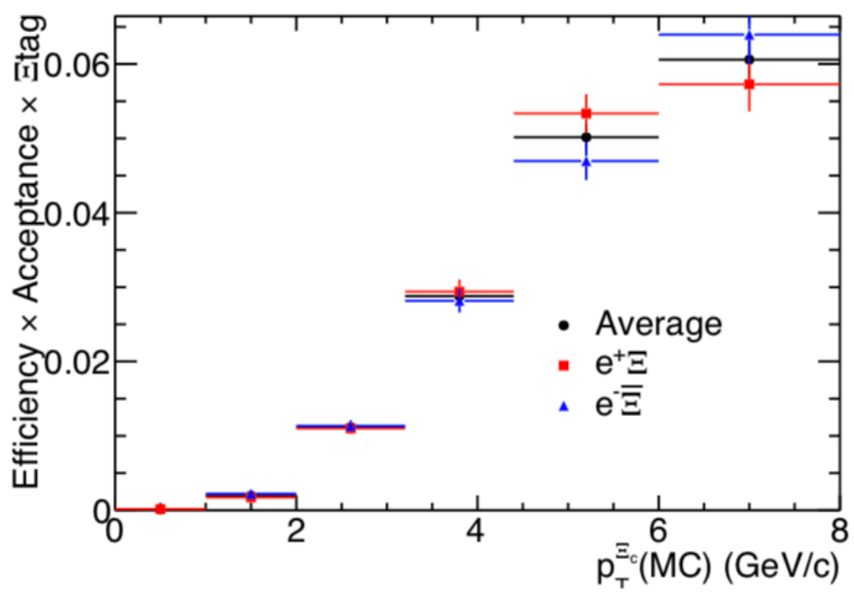




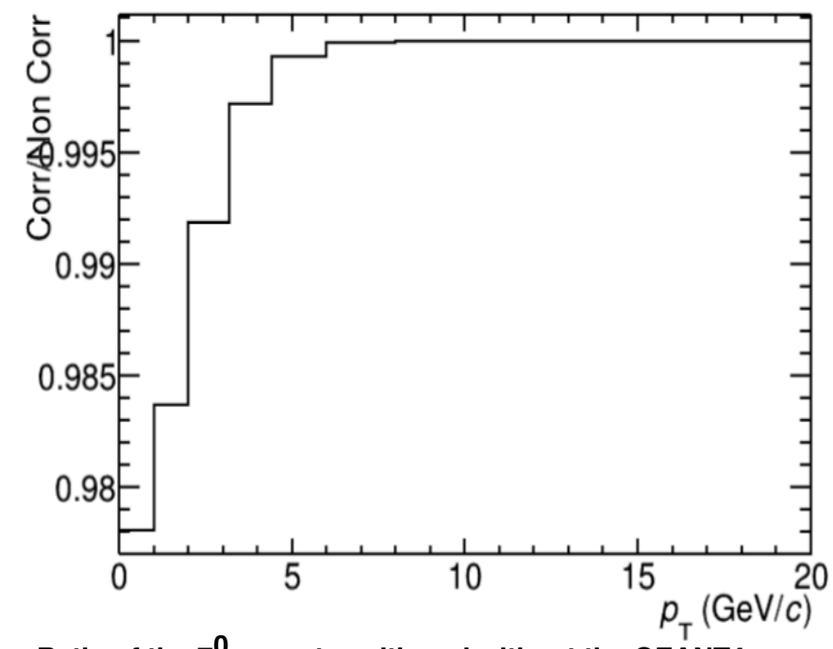
Ratio of the p_T-differential cross sections of Ξ^0_c baryons (multiplied by the branching ratio into $e^+\Xi^-\nu_e$) and D^0 mesons as a function of p_T for $|y| < 0.5$, in pp collisions at $\sqrt{s}$ = 7 TeV. The error bars and boxes represent the statistical and systematic uncertainties, respectively. Predictions from theoretical models, (a) PYTHIA 8 with different tunes (b) DIPSY and HERWIG 7 , are shown as shaded bands representing the range of the currently available theoretical predictions for the branching ratio of the considered Ξ^0_c decay mode.

Efficiency correction and event normalization

$$(Acc \times \varepsilon \times \varepsilon_{\Xi\ tag}) = \frac{N^{\Xi_c^0}_{MC,reco}}{N^{\Xi_c^0}_{MC,gen}}$$



The product of efficiency, acceptance and the Ξ tagging efficiency as a function of p^{Ξ_c}



Ratio of the Ξ^0_c spectra with and without the GEANT4 correction

- $N_{gen}^{\Xi^0_c}$: The number of Ξ^0 baryons within Δy decaying into $e\Xi\nu$ counted at the generation level in the MC simulations.
- $N_{reco}^{\Xi^0_c}$: The number of Ξ^0 baryons decaying into $e\Xi\nu$ counted at the reconstruction level in the MC simulations.
- The elastic cross section of anti-proton in GEANT3 is known to be inaccurate, therefore, further correction based on GEANT4 is applied.