Update on K^0_S, Λ and Λ (1520) production in p-Pb collisions at 8.16 TeV

ALICE-India Collaboration Meeting

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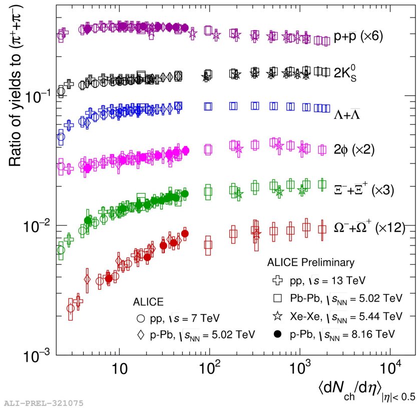
University of Jammu

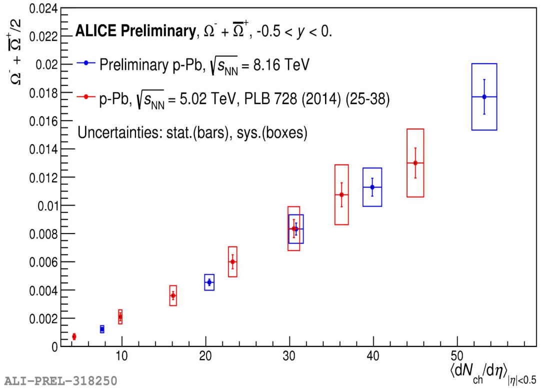
Analysis note: https://alice-notes.web.cern.ch/node/1191
Analysis note: https://alice-notes.web.cern.ch/node/1110

Outline of the talk

- Motivation Plots
- Dataset used and Primary Selections
- Signal Extraction
- Results
  - p_T spectra
  - dN/dy and $\langle p_T \rangle$ vs Multiplicity
  - Ratio To Pions vs Multiplicity
  - Λ / K^0_s
  - R_{pPb}
  - $\Lambda(1520) / \Lambda$

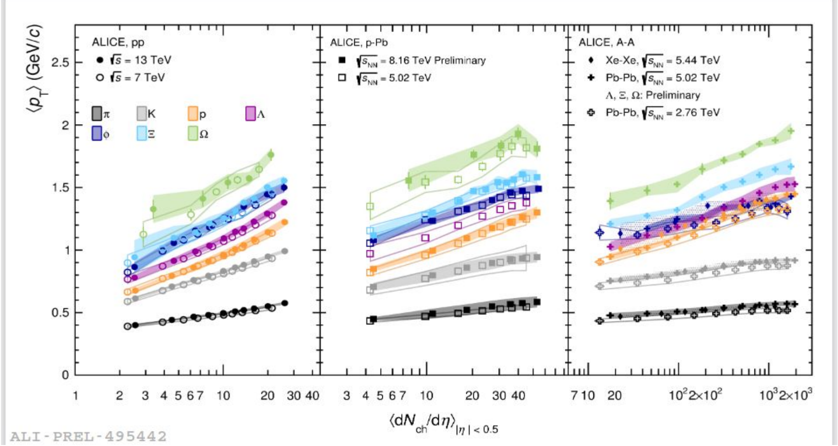
Motivation Plots





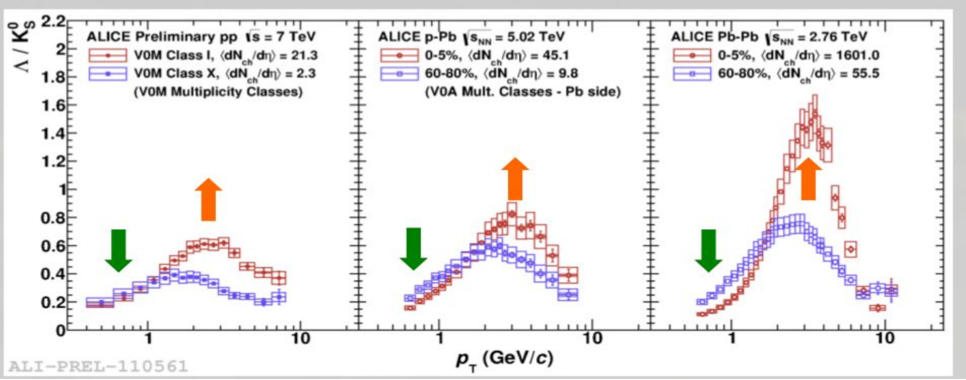
Strange to non-strange ratios in the four systems

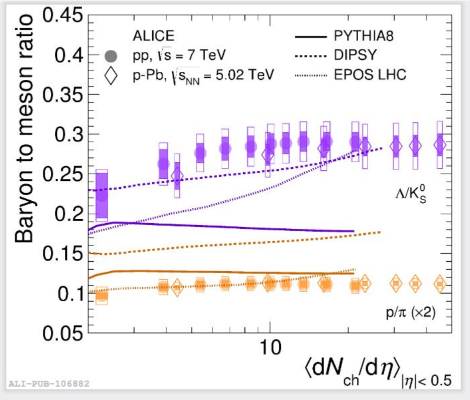
- Enhancement of strange to non-strange hadron production from low multiplicity pp to central Pb-Pb collisions
- Smooth evolution between pp, p-Pb and Pb-Pb collisions
- Strange to non-strange ratios are saturated in central Pb-Pb collisions for all particles

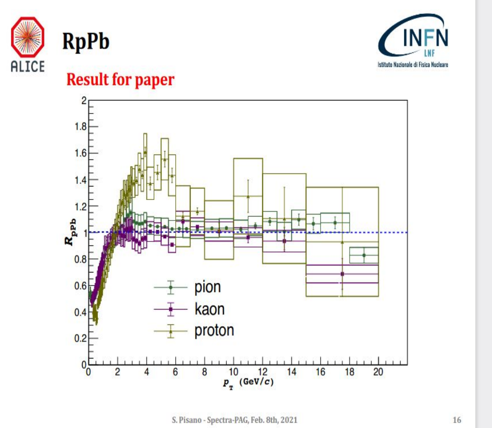


- Yields of (multi-)strange particles measured in different systems as a function of multiplicity lie on the same trend
- Both dN/dy and $\langle p_T \rangle$ increase as a function of multiplicity.

Motivation Plots



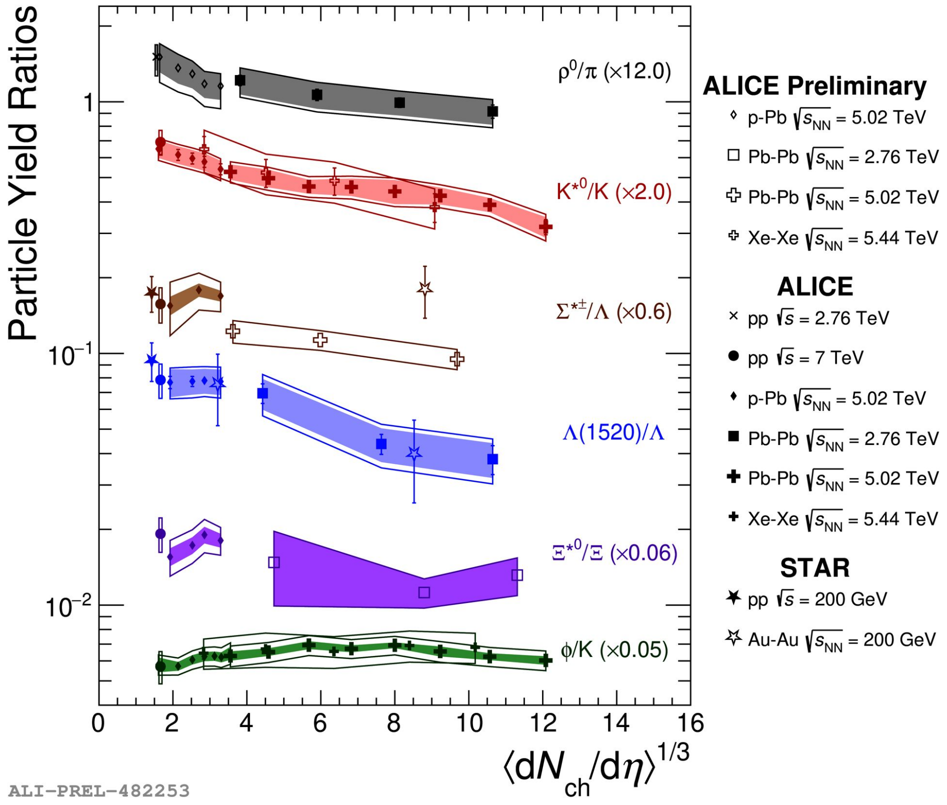




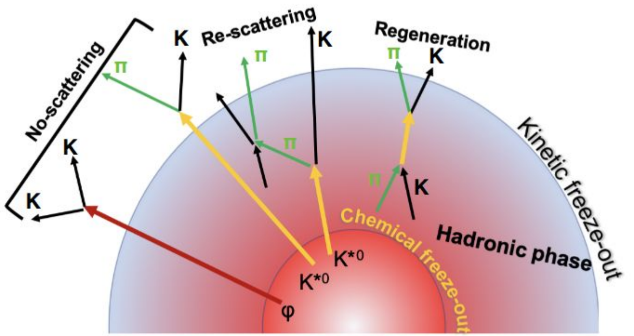
- Across the three systems Λ/K^0_S evolves with multiplicity in qualitatively similar way:
  - Depletion at low p_T, enhancement at intermediate p_T

  ---->Hint of collective behaviour in small systems
- Baryon over Meson ratio as a function of p_T shows peak at intermediate (Baryon enhancement)
  - interplay of radial flow and parton recombination at intermediate p_T
- Baryon over Meson ratio shows no significant change as a function of multiplicity
  - Strangeness enhancement is not driven by mass nor it is a baryon/meson effect
- Mass ordering of R_{pPb} at intermediate p_T which is qualitatively similar to that in Pb–Pb collisions (Mass ordering or Baryon meson splitting?)

Motivation Plot



- Suppression or enhancement in yields depend upon
  - →Lifetime of resonance particle
  - →Interaction cross section of decay daughters
  - →Lifetime of hadronic phase
- Their lifetimes are exploited for the estimation of lifetime of the hadronic phase



Dataset **(for strange particles in ground states)**

- Analysing Minimum Bias LHC16r CENT low interaction rate runs (comparable with 5TeV rates):
- 265594, 265596, 265607, 266318, 266317, 266316 (40% full triggered statistics)

	No. Events
No. Events Processed	15.9 x 10^6
No. Events After Trigger Selection	12.5 x 10^6
No. Events After Event Selections	11.4 x 10^6

Trigger: AliEvent::kINT7
DAQ Rejection: IsIncompleteDAQ()
Pileup Rejection: IsPileupFromSPDInMultBins()
Vertex quality: $|Z_{SPD}$- $Z_{Track}|$ < 0.5 cm, Resolution < 0.25 cm
Z-vertex selection: $|Z_{Vtx}|$ < 10 cm
Multiplicity Selection: AliMultSelection::GetMultiplicityPercentile("V0A")

- MC: Using merge of same 6 low interaction runs in GP EPOS-LHC and GP DPMJET
  - LHC17f3a_cent_fix - GP EPOS-LHC: https://alice.its.cern.ch/jira/browse/ALIROOT-7100
  - LHC17f3b_cent - GP DPMJET: https://alice.its.cern.ch/jira/browse/ALIROOT-7100
- MC: ~ 2.2 x 10^6 events after event selections

Data samples and cuts for resonances

System@energy	p-Pb@8.16 TeV	pp@8 TeV
Dataset	LHC16r_CENT_wSDD, LHC16r_FAST	LHC12a, LHC12b, LHC12c, LHC12d, LHC12f, LHC12h, LHC12i
Data type	Pass1, ESD	Pass2, ESD
Trigger	kINT7	kINT7
Events	28, 7 M	13.5, 5.4, 4, 14.3, 4.4, 16, 2.4 M
Anchored MC production	LHC17l7a2_cent, LHC17l7a2_fast	LHC15h2a, LHC15h2b, LHC15h2c, LHC15h2d, LHC15h2f, LHC15h2h, LHC15h2i

- Event selection:
  - Trigger: kINT7
  - Pileup rejection
  - $|v_Z| < 10$ cm
- Analysis cuts
  - StandardITSTPCTrackCuts2011
  - $|\eta| < 0.8$
  - $0 < y_{pair} < 0.5$ for p-Pb
    $-0.5 < y_{pair} < 0.5$ for pp
  - $p_T > 0.15$ GeV/c
  - PID

    Track not present in TOF, (Nσ) TPC =2

    Proton:0 <p(GeV/c)< 1.1

    and Kaon: 0 <p(GeV/c)< 0.6

    Track present in TOF, (Nσ) TOF =3 with (Nσ) TPC =5 as veto

Signal Extraction

For K^0_s

p_T range -> 0.2 to 10 (GeV /c)

Multiplicity = {0, 1, 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 100}%

(Multiplicities based on V0A estimator)

For $\Lambda(\bar{\Lambda})$

p_T range -> = 0.6 to 10 (GeV /c)

Multiplicity = {0, 1, 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 100}%

(Multiplicities based on V0A estimator)

Decay Channel used:

$K^0_s \rightarrow \pi^+ \pi^-$ (B.R 69.2%) $\Lambda \rightarrow p\pi^-$ (B.R 63.9%)

Method for signal extraction:

The invariant mass distributions are fitted with a gaussian peak and second order polynomial for background

Signal region defined as **[M − 4σ, M + 4σ]**, where

- M = Mean of fitted Gaussian (mass of V0)

- σ = standard deviation of fitted Gaussian

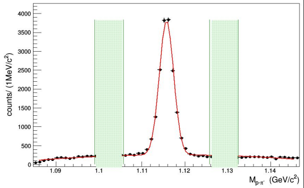
- Background region defined as **[M − 10σ, M − 6σ]** and

[M +6σ, M + 10σ];

- signal counts determined by subtracting the sum of the background counts in the sidebands from the total counts in the signal region

(Bin Counting Method)

Lambda



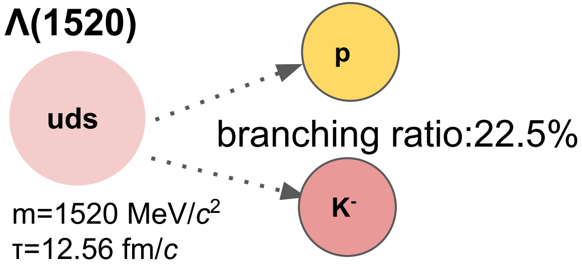
Analysis details: resonance reconstruction

1. Invariant mass method: Resonances reconstructed by their decay products, adding their 4-momenta

2. Combinatorial background : Removed using mixed event technique (10 events are mixed)

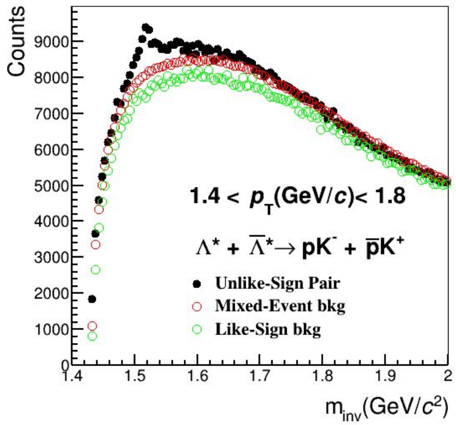
3. Residual background : Correlated pairs or misidentified decay products removed by fitting with polynomial function

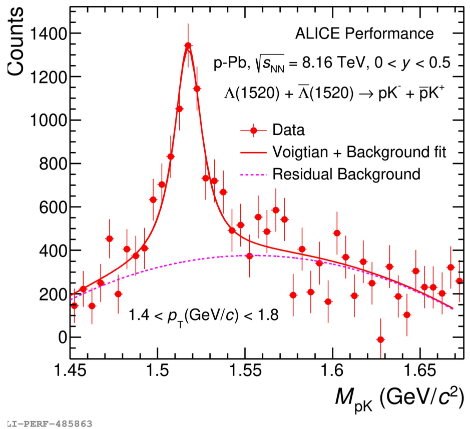
4. Signal : Fit with Voigtian function, yield calculated by integrating the fitting function



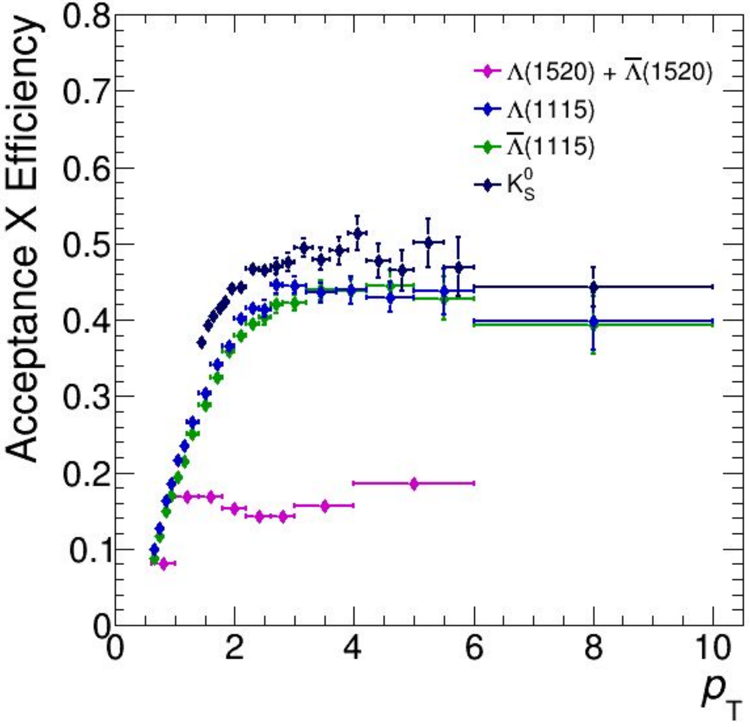
$$\frac{\Gamma/2\pi}{(m-m_0)^2+\Gamma^2/4}\quad\frac{e^{-(m-m_0)/2\sigma^2}}{\sigma/\sqrt{2\pi}}+Am^2+Bm+C$$

Γ is the FWHM of the peak, σ is resolution and m_0 is mass peak position
NR→1.75 – 1.85 GeV/c^2
FR→1.45 – 1.65 GeV/c^2
p_T range pp → (0.5 – 4.5) GeV/c
p_T range p–Pb → (0.6 – 6.0) GeV/c
V0A multiplicity classes for p–Pb in percentile→ 0–20, 20–40, 40–60, 60–100



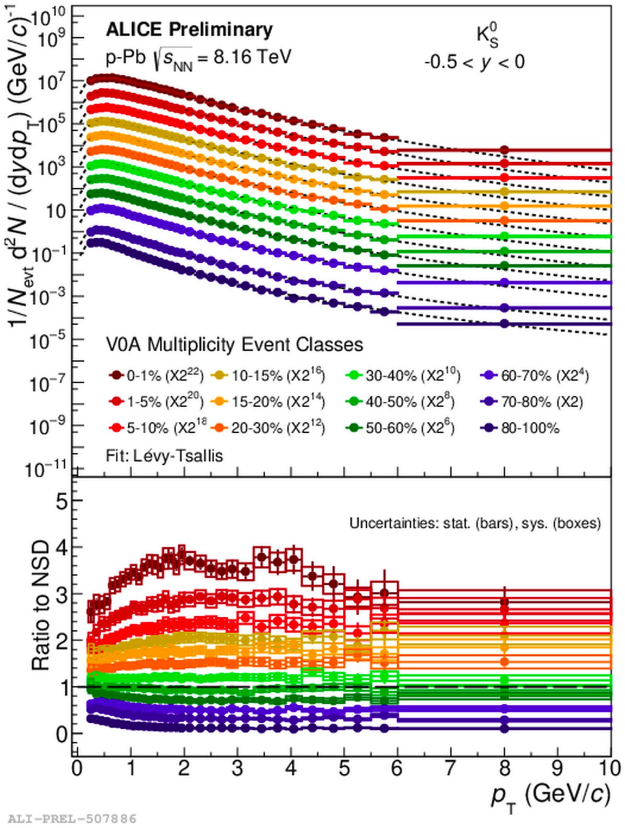


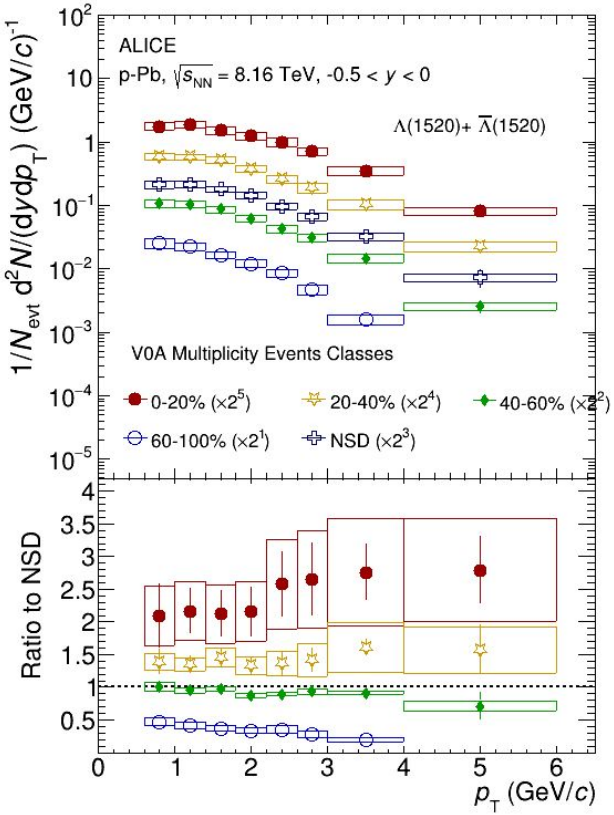
Efficiency Correction



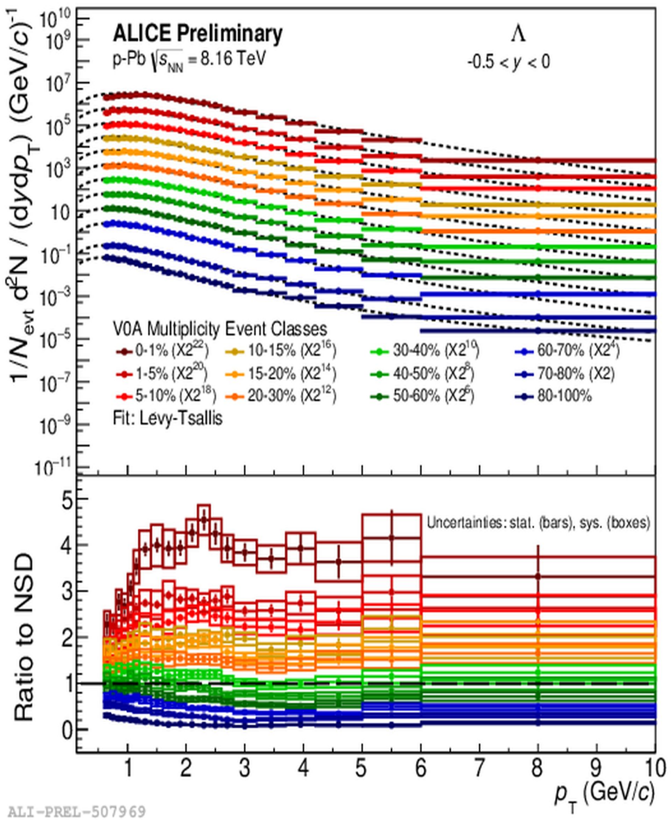
$$\epsilon = \frac{N(V0)_{recontructed+associated}\,(p_T)}{N(V0)_{generated\,primaries}\,(p_T)}$$

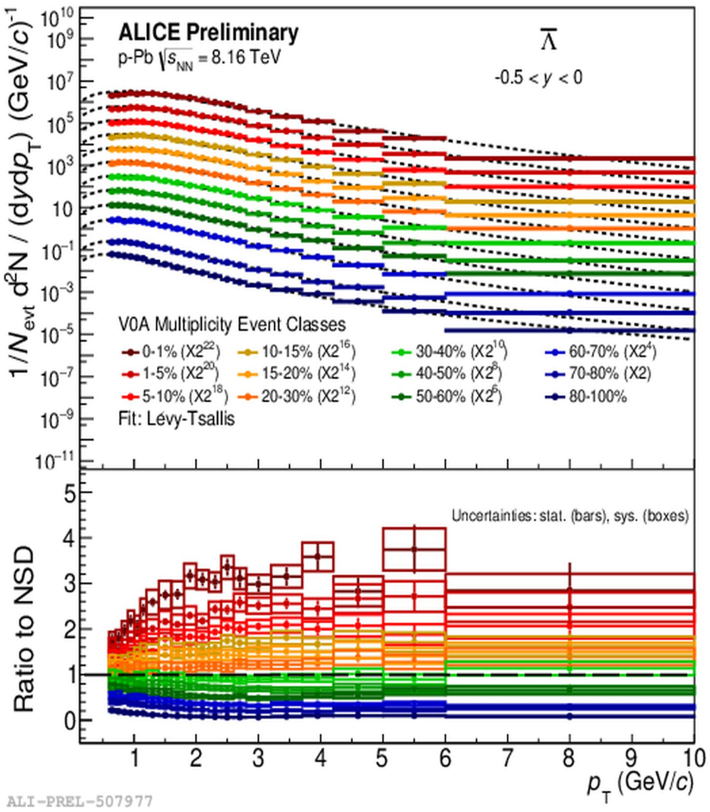
Corrected p_T spectra



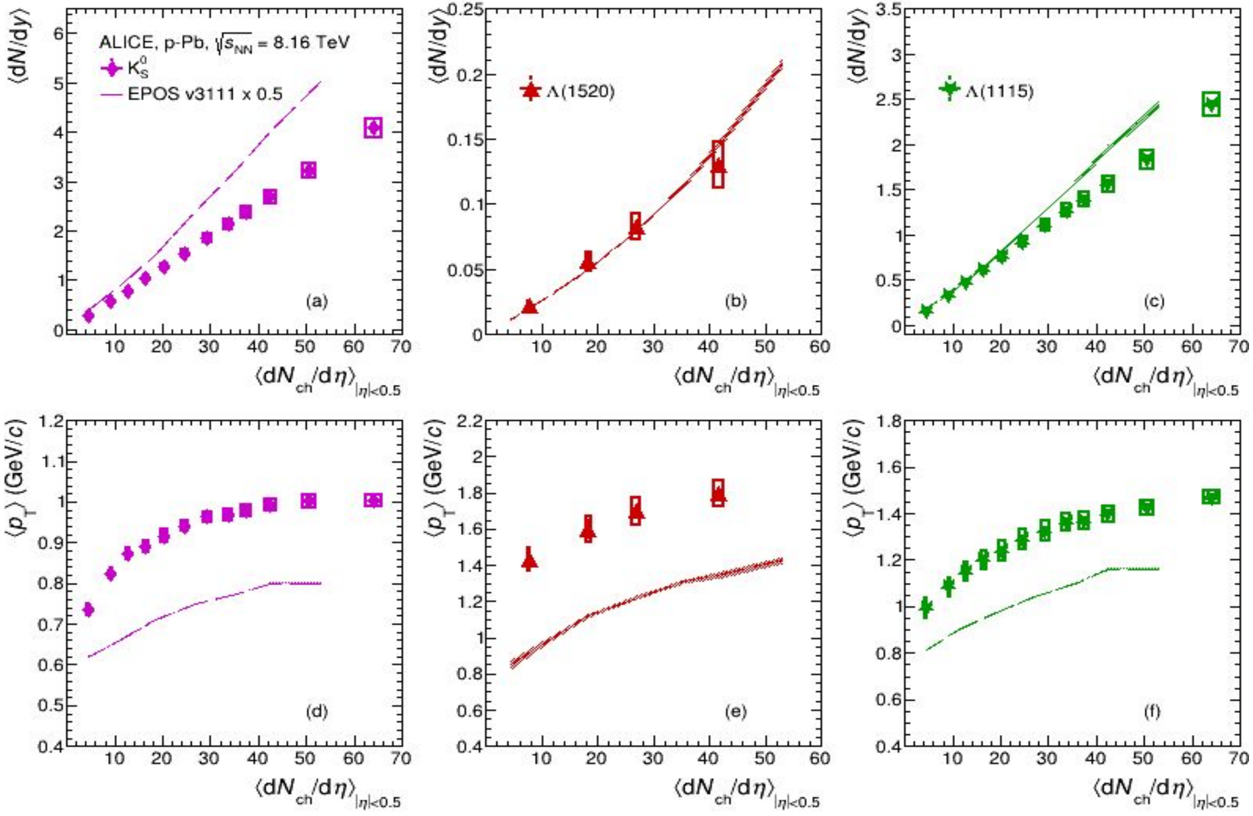


Corrected p_T spectra



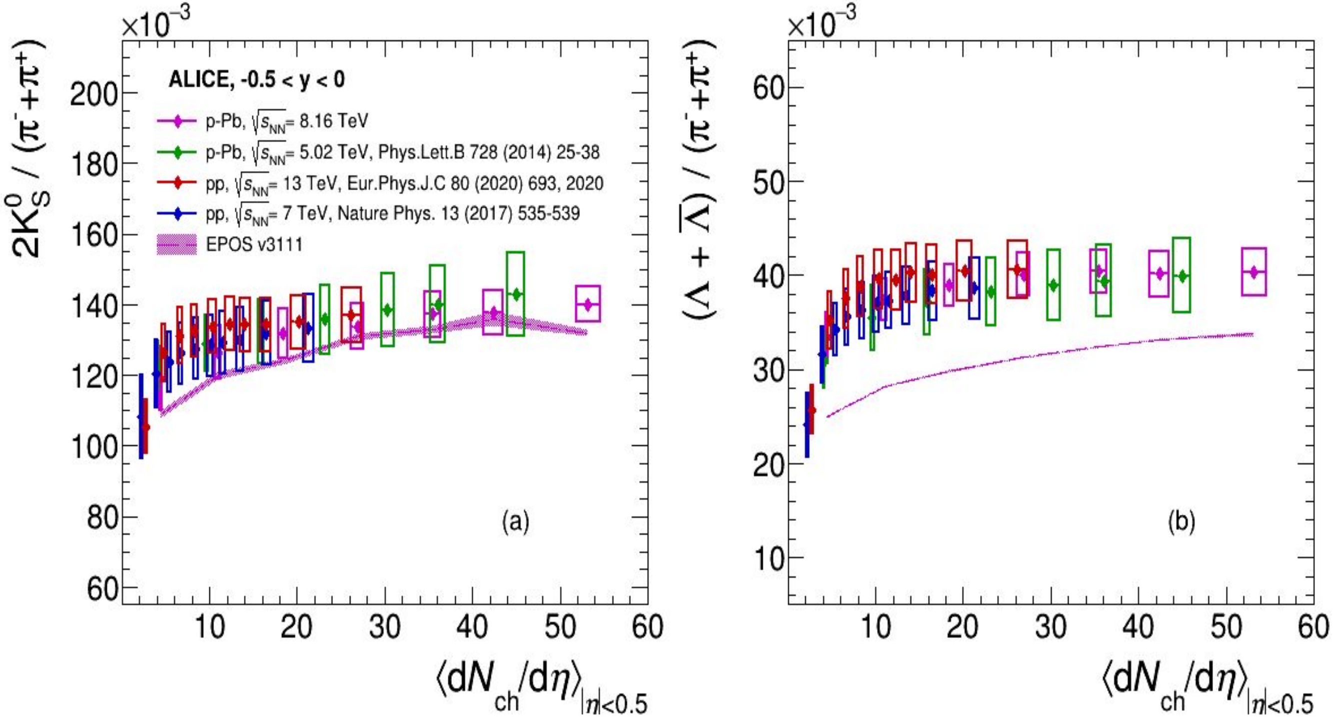


dN/dy and <p_T> vs Multiplicity



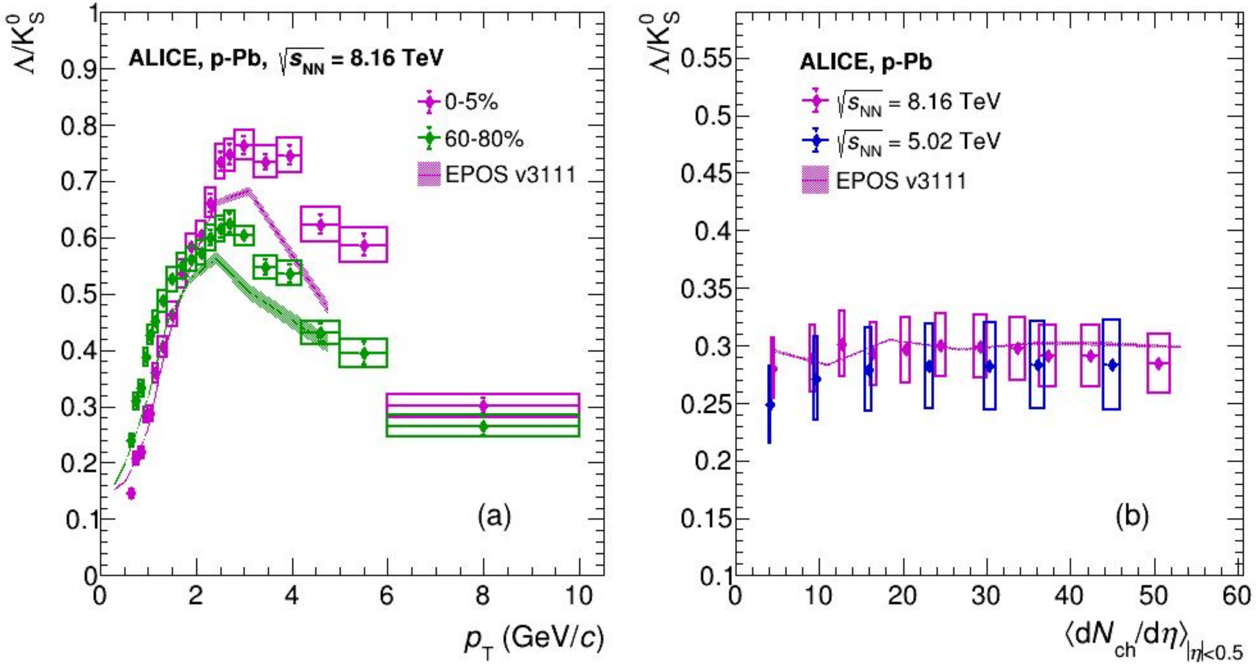
- Both p_T integrated yield and average p_T increase with multiplicity
- EPOS3(hydro+cas) model overestimates the yield, but shows the increasing trend with multiplicity like data.
- Average p_T calculations by model underestimates the data but shows the same increasing trend with multiplicity.

Ratio to Pion vs Multiplicity



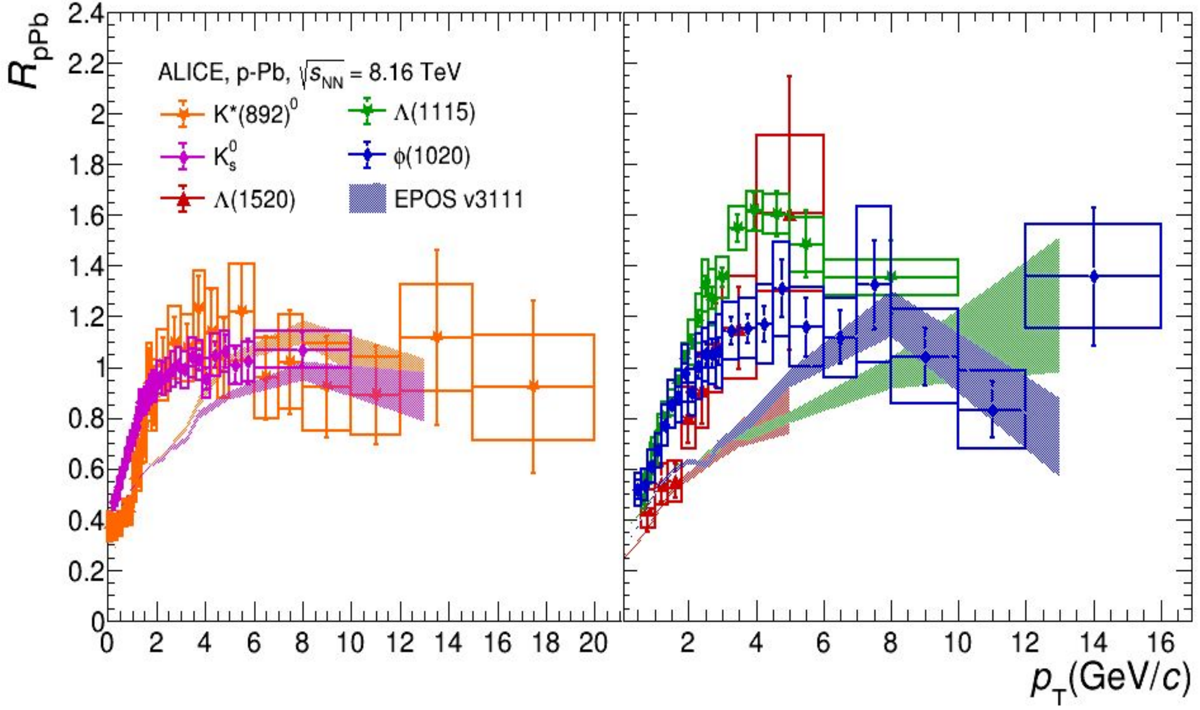
- Ratio increases first with multiplicity then saturates at high charged particle multiplicity
- Also the ratio does not seem to have any energy or system dependence
- Predictions from the model also show the same effects, although it underestimates the lambda/pion ratio

Baryon over meson ratio



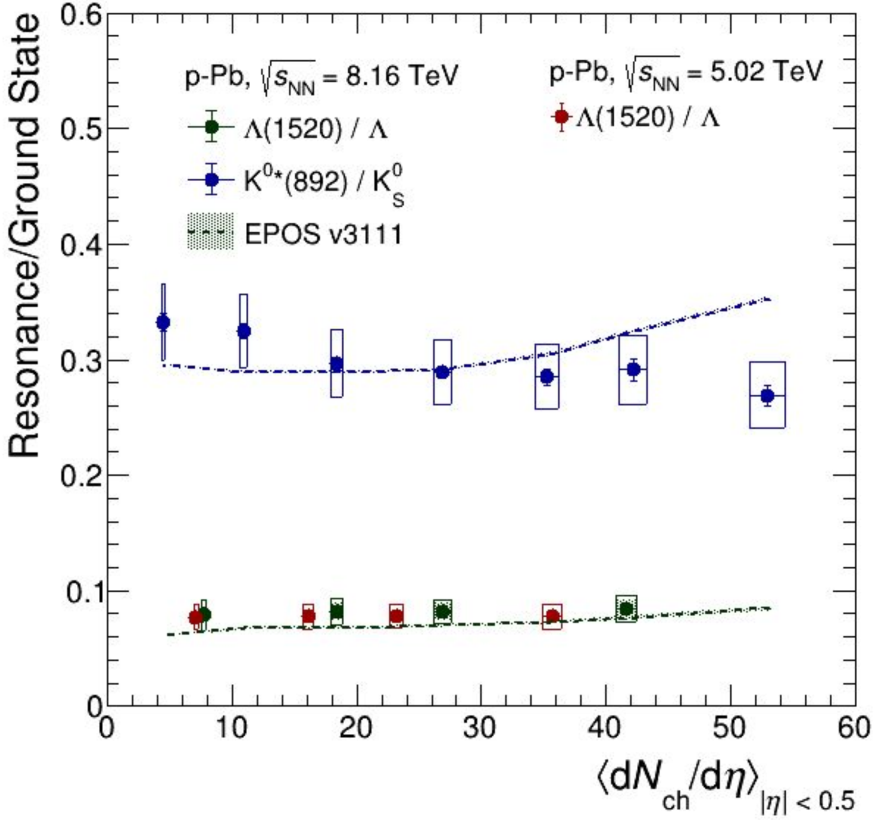
- The baryon to meson ratio with p_T shows a peak in the mid p_T where baryon production is enhanced and the peak is higher in the high multiplicity p-Pb collisions
- This shows the presence of flow like effects which are expected to be more pronounced in the high multiplicity collisions
- Model estimates similar behaviour although it underestimated the data
- The baryon to meson ratio shows no evolution with multiplicity and similar are the predictions from the model as well

Nuclear modification factor (R_{pPb})



- R_{pPb} shows suppression at low p_T. which is more for the resonances.
- In high p_T, R_{pPb} is equal to 1 within systematic uncertainty.
- R_{pPb}: peak at intermediate p_T visible for Λ(1115) and Λ(1520)
- This shows medium effects for the low p_T regime in p-Pb collision systems.
- R_{pPb} prediction from the model underestimated data at low p_T but approaches to unity at the high p_T likewise data.

Particle ratios



- $K^*(892)^0$ shows suppression but Λ(1520) do not
- This provides hint for the formation of hadronic phase and its finite lifetime in p-Pb collision system
- The model predictions are satisfying data for Λ(1520) but it overestimated $K^*(892)^0$ in the high multiplicity

https://doi.org/10.1140/epjc/s10052-020-7687-2
arXiv:2110.10042

Summary

- dN/dy and <p_T> increase with multiplicity
- Ratios to pions increases with multiplicity and then saturates (Strangeness enhancement)
- Ratios depend on multiplicity, irrespective of system size and energy
- Λ / K^0_S: Baryon enhancement at intermediate p_T
- Λ / K^0_S as a function of multiplicity shows no significant evolution
- R_{pPb}: peak at intermediate p_T visible for Λ(1115) and Λ(1520)
- No suppression in the resonance to non-resonance ratio is observed for Λ(1520) in the p-Pb collision system at   8.16 TeV, which provides hint for short lifetime of hadronic phase compared to the lifetime of Λ(1520) baryon in this collision system and energy.
- EPOS3(hydro+cas) either underestimated or overestimated the data but the trend it shows is more or less similar to the data.

THANK YOU

Backup slides

Feed Down for Λ and $\bar{\Lambda}$

The feed-down contribution to the Λ and $\bar{\Lambda}$ spectra coming from both charged (Ξ^-, Ξ^+) and neutral (Ξ^0) is computed by using the following expression:

$$\Lambda^{raw}_{primary}(p_{T_i}) = \Lambda^{raw}_{measured}(p_{T_i}) - \sum_j F_{ij} \int_{p_{T_j}} \frac{dN}{dp_T}(\Xi^-),$$

where dN/dp T (Ξ) is the Levy-Tsallis fit to the measured/extrapolated Ξ spectra and the integral is performed over the bin-j. F_{ij} is the feed-down matrix defined as:

$$F_{ij} = \frac{N_{reco}(\Lambda)^{\text{in bin } i}_{\text{from } \Xi \text{ bin } j}}{N_{gen}(\Xi)_{\Xi \text{ bin } j}}.$$

F_{ij} represents the fraction of reconstructed Λ (or $\bar{\Lambda}$)produced in the p_T bin-i coming from the decay of a Ξ particle (charged or neutral) produced in the $p_T$bin-j

Two methods to fill F_{ij}

MC Ratio: the numerator is filled with Λ ($\bar{\Lambda}$) from decays of both charged and neutral Ξ. In this case the ratio Ξ^- /Ξ^0 as provided by the Monte Carlo generator used to compute the feed-down matrix element F_{ij} is used.

Double Counting: the numerator is filled with Λ (or $\bar{\Lambda}$) from decays of only charged Ξ, and the resulting charged Ξ feed-down is multiplied by a factor two (assume the production of Ξ^0 is the same as for $\Xi^{\pm}$).

Uncorrelated systematics

The following ratio will determine the uncorrelated component of the total systematic uncertainty for each selection cut in multiplicity class m:

$$\mathbf{R = (Y_m^{dev}/Y_m^{def}\ ) / (Y_{MB}^{dev}/Y_{MB}^{def}\ )}$$

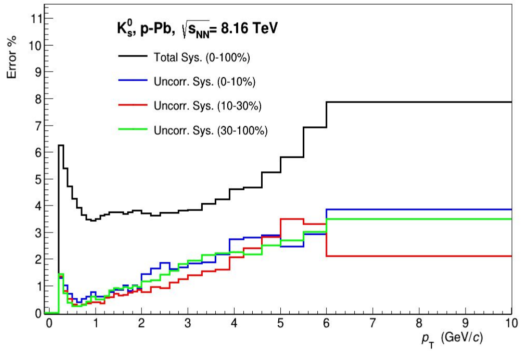
where Y_m^{dev} and Y_m^{dev} are the measured deviated and default yield, respectively (in a given p_T interval). The deviated yield is the one obtained when varying a particular cut.

The compatibility of R with unity means that the systematic uncertainty under study is “correlated” with multiplicity, i.e. it is not dependent on multiplicity.

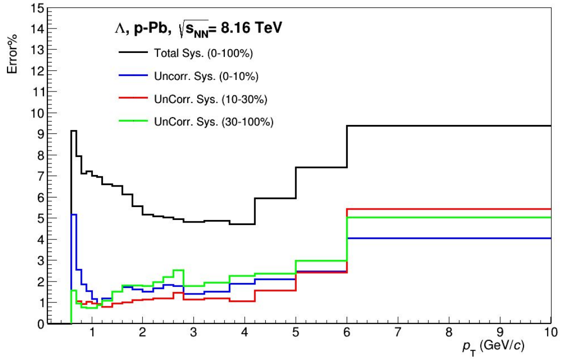
The fraction of uncorrelated systematic is obtained by adding in quadrature all $|R - 1|$ factors (in each p_T bin and multiplicity class) (after performing Barlow Check, reference: https://alice-notes.web.cern.ch/node/978)

Uncorrelated Systematics

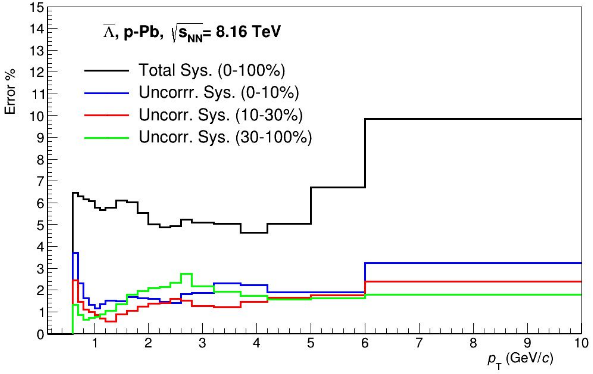
K0Short



Lambda



Anti-Lambda



Cut Study for K^0_s

For K^0_s
p_t bins used are :

(0.2-1) low p_T bin

(1-3) mid p_T bin

(3-10) high p_T bin

For Λ and $\bar{\Lambda}$
p_t bins used are :

(0.2-1) low p_T bin

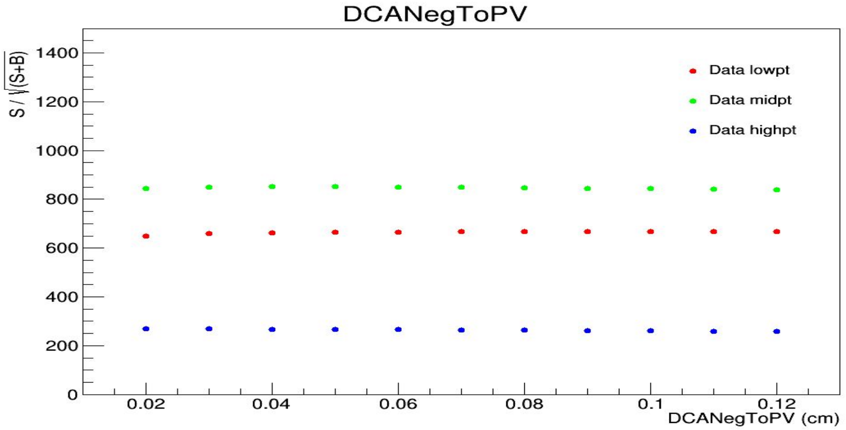
(1-3) mid p_T bin

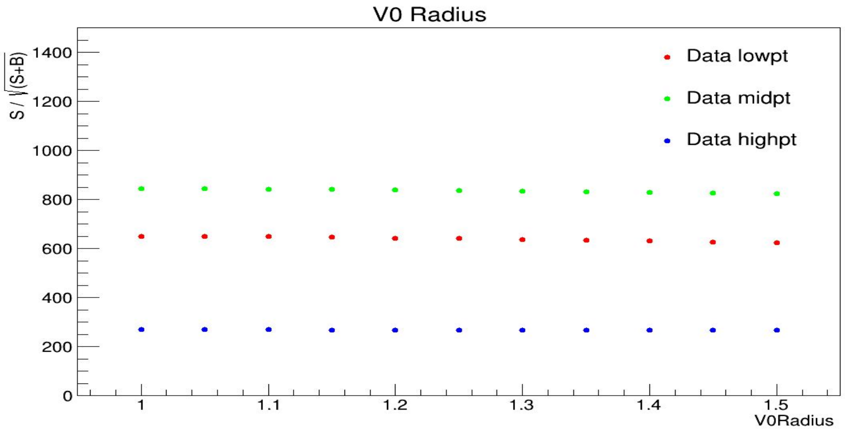
(3-10) high p_T bin

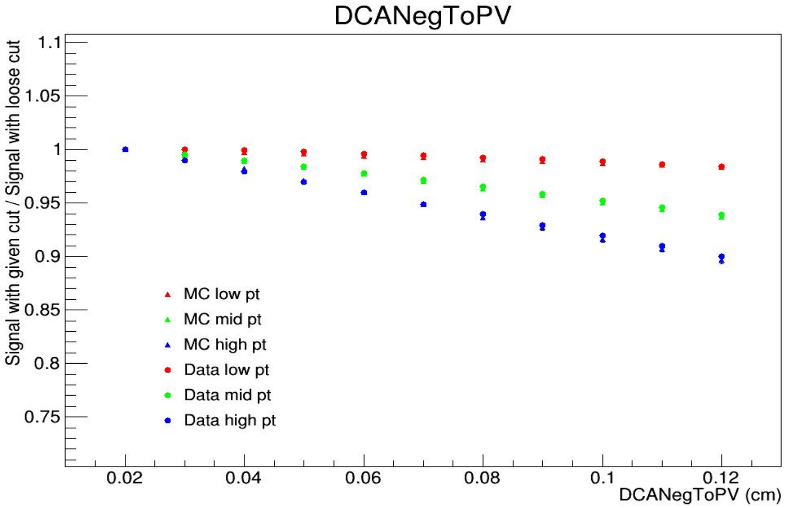
Next slides show:

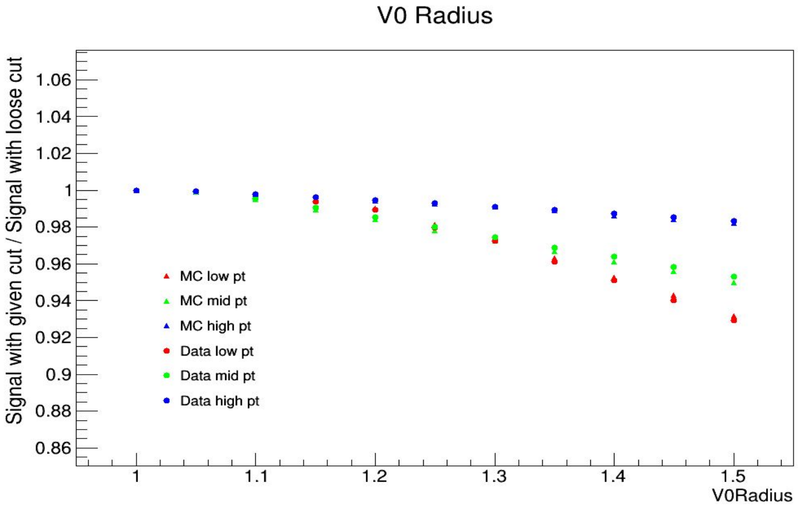
(top) Signal Significance,

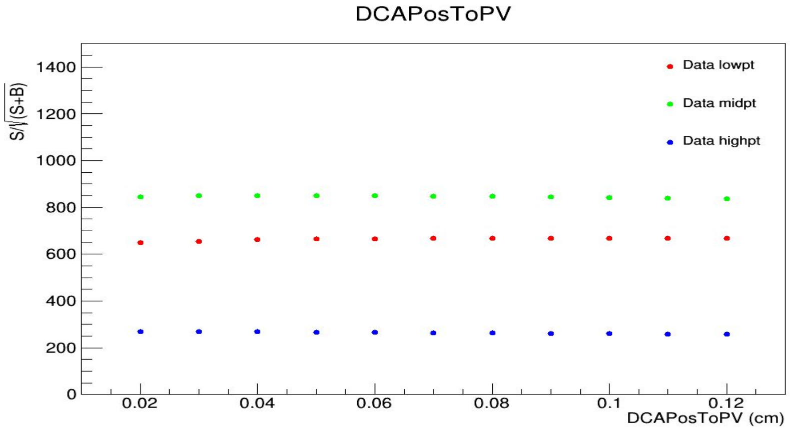
(bottom) Signal losses, with respect to loosest cut considered, in low, mid and high p_T bins of K^0_s

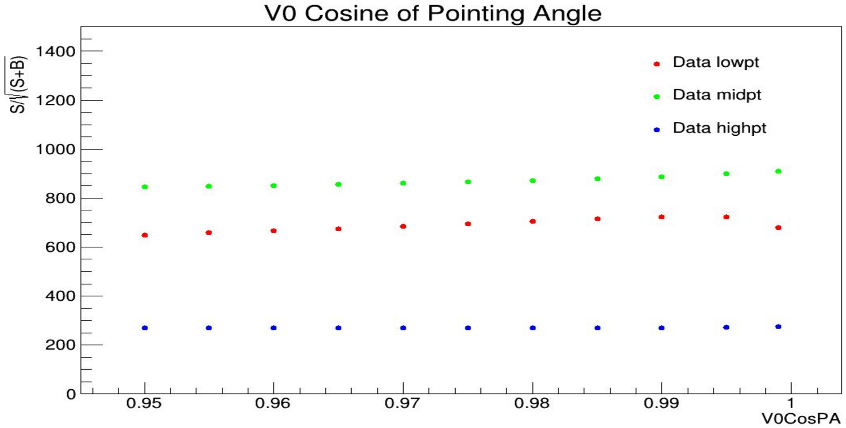

DCANegToPV
S / √(S+B)
Data lowpt
Data midpt
Data highpt
0
200
400
600
800
1000
1200
1400
0.02
0.04
0.06
0.08
0.1
0.12
DCANegToPV (cm)

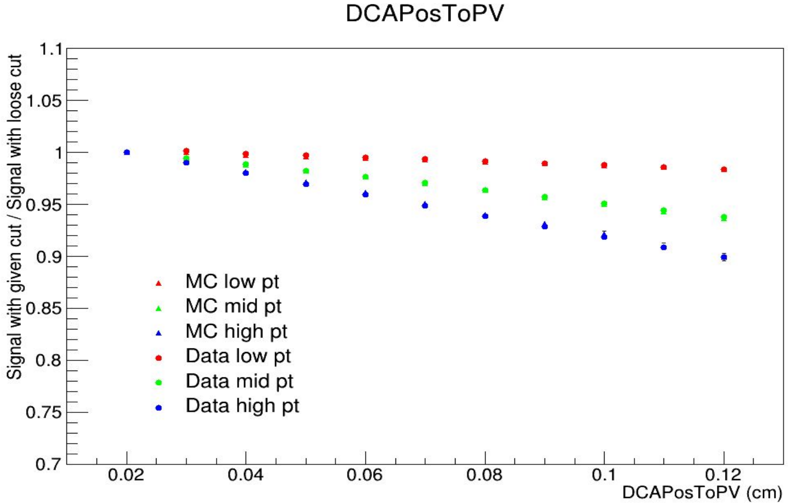

V0 Radius
S / √(S+B)
Data lowpt
Data midpt
Data highpt
0
200
400
600
800
1000
1200
1400
1
1.1
1.2
1.3
1.4
1.5
V0Radius

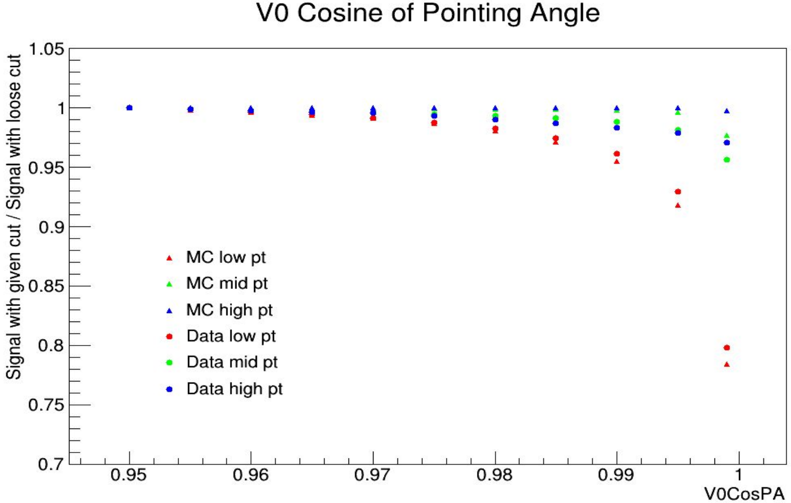

DCANegToPV
Signal with given cut / Signal with loose cut
MC low pt
MC mid pt
MC high pt
Data low pt
Data mid pt
Data high pt
0.75
0.8
0.85
0.9
0.95
1
1.05
1.1
0.02
0.04
0.06
0.08
0.1
0.12
DCANegToPV (cm)

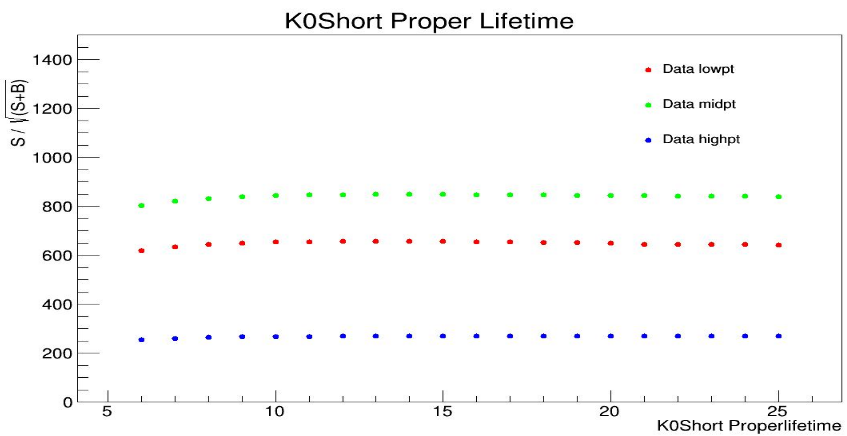

V0 Radius
Signal with given cut / Signal with loose cut
MC low pt
MC mid pt
MC high pt
Data low pt
Data mid pt
Data high pt
0.86
0.88
0.9
0.92
0.94
0.96
0.98
1
1.02
1.04
1.06
1
1.1
1.2
1.3
1.4
1.5
V0Radius

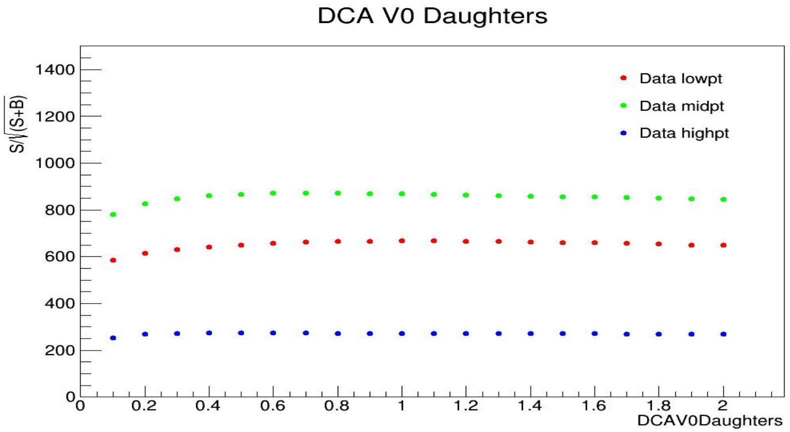

DCAPosToPV
S/√(S+B)
Data lowpt
Data midpt
Data highpt
DCAPosToPV (cm)

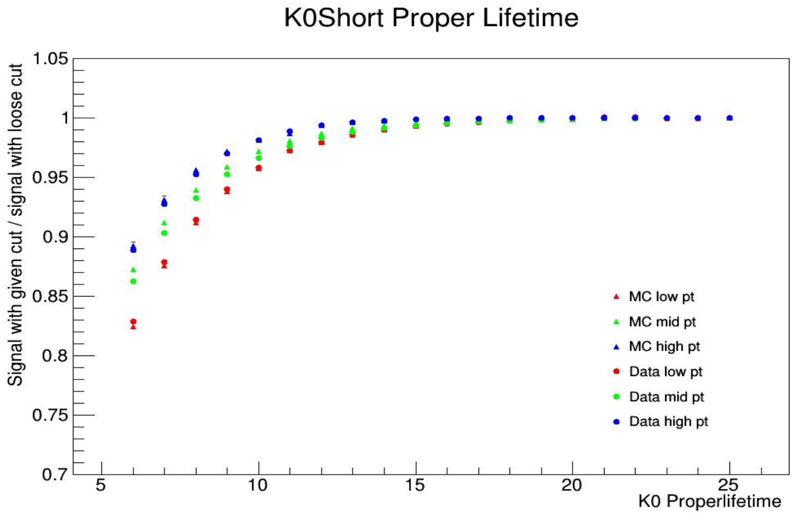

V0 Cosine of Pointing Angle
S/√(S+B)
Data lowpt
Data midpt
Data highpt
V0CosPA

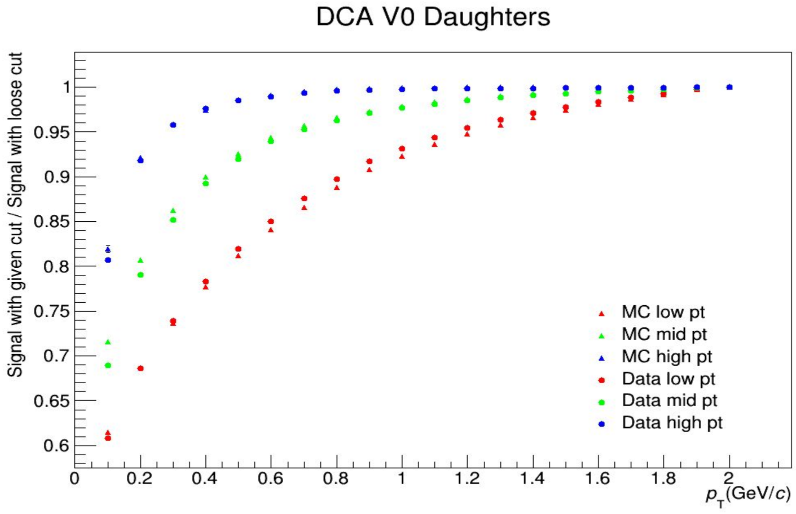

DCAPosToPV
Signal with given cut / Signal with loose cut
MC low pt
MC mid pt
MC high pt
Data low pt
Data mid pt
Data high pt
DCAPosToPV (cm)


V0 Cosine of Pointing Angle
Signal with given cut / Signal with loose cut
MC low pt
MC mid pt
MC high pt
Data low pt
Data mid pt
Data high pt
V0CosPA


K0Short Proper Lifetime
S / √(S+B)
Data lowpt
Data midpt
Data highpt
K0Short Properlifetime


DCA V0 Daughters
S/√(S+B)
Data lowpt
Data midpt
Data highpt
DCAV0Daughters


K0Short Proper Lifetime
Signal with given cut / signal with loose cut
MC low pt
MC mid pt
MC high pt
Data low pt
Data mid pt
Data high pt
K0 Properlifetime


DCA V0 Daughters
Signal with given cut / Signal with loose cut
MC low pt
MC mid pt
MC high pt
Data low pt
Data mid pt
Data high pt
p_T(GeV/c)

Cut Selection

Cuts (all topological and some track quality) chosen based on

- **Default cut** : Tried to take max. value of $\sigma = S/\sqrt{(S+B)}$, whilst keeping fractional signal loss < 10%. Also requiring Monte Carlo agrees with data "signal" to within a couple of percent (2 to 3%).
- **Very Tight** : cut corresponding to 10% signal loss in data
- **Tight** : cut corresponding to 5% signal loss in data
- **Loose** : cut corresponding to 1% signal loss in data
- **Very loose**: apply no cut or loose enough to produce effect of no cut

Systematics

- In the next slides, the relative difference between the corrected spectrum obtained with new chosen cut and the one obtained with the default cut is shown.
- For systematic error associated to the source i for pt bin j

$$\delta_{i,sys} = \sqrt{\frac{1}{N}\sum\left(\frac{y_{def}-y_i}{y_{def}}\right)^2}$$

- All sources are added in quadrature (root sum of squares) in order to obtain the total systematic error
 (after performing Barlow Check)

K^0_S

Cuts	Default			Very Loose	Loose			Tight			Very Tight		
	Low pt	Mid pt	High pt		Low pt	Mid pt	High pt	Low pt	Mid pt	High pt	Low pt	Mid pt	High pt
V0Daughters	1.2	0.7	0.5	2	1.8	1.4	0.6	1.2	0.7	0.3	0.85	0.4	0.15
V0CosPA	0.990	0.999	0.999	0.95	0.97			……………………			0.995	0.999	0.999
V0Radius	1			………..	…………………….			1.4	1.4	2.0	1.6	1.8	3.0
DCAPosToPV	0.1	0.04	0.02	0.02	…………………….			0.2	0.1	0.07	0.4	0.17	0.12
DCANegToPV	0.1	0.04	0.02	0.02	………………………			0.2	0.1	0.07	0.4	0.17	0.12
ProperLifetime	13			25	………………………			10	9	8	8	7	6

K^0_S

Cut	V. Loose	Loose	Default	Tight	Very Tight
No. of TPC Clusters	---	---	70	80	90
No. of crossed rows over findable	---	---	0.8	0.9	---
TPC PID σ	---	4	3	2.5	---
σ for signal extraction	---	5	4	[2, 3, 3]	---
Competing species rejection window	None applied	---	5 Mev/c^2	---	---

Lambda(Anti-Lambda)

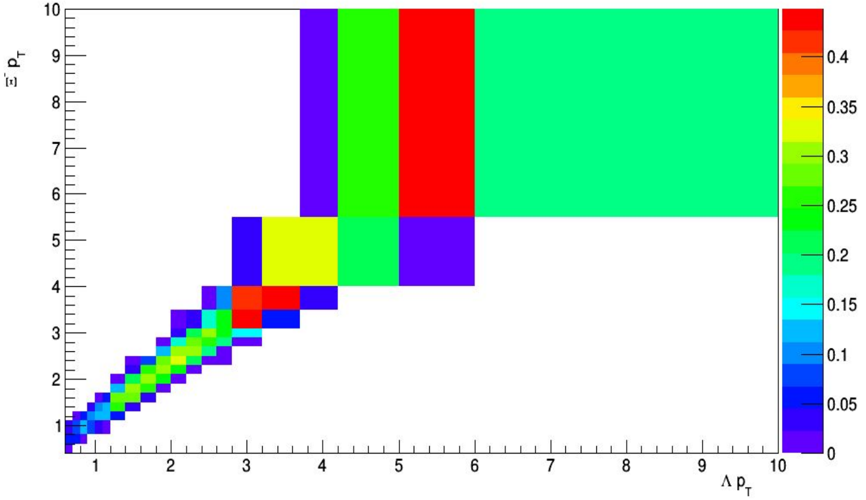
Cuts	Default			Very Loose	Loose			Tight			Very Tight		
	Low pt	Mid pt	High pt		Low pt	Mid pt	High pt	Low pt	Mid pt	High pt	Low pt	Mid pt	High pt
V0Daughters	1.5	1.3	0.9	2	1.8	1.6	1	1.3	0.9	0.4	1	0.6	0.3
V0CosPA	0.985	0.995	0.950	0.95	0.97			....			.....	.....	....
V0Radius	1			....	1.1	1.25	1.7	1.5	1.8	2.0	1.7	3	4.8
DCAPosToPV	0.03(0.04)	0.02 (0.05)	0.02 (0.03)	0.02	....			0.05 (0.16)	0.05 (0.16)	0.04 (0.16)	0.09 (0.26)	0.07 (0.26)	0.05 (0.26)
DCANegToPV	0.04 (0.03)	0.05 (0.02)	0.03 (0.02)	0.02	....			0.16 (0.05)	0.16 (0.05)	0.16 (0.04)	0.26 (0.09)	0.26 (0.07)	0.26 (0.05)
ProperLifetime	40			100	50						......	.....	....

Lambda(Anti-Lambda)

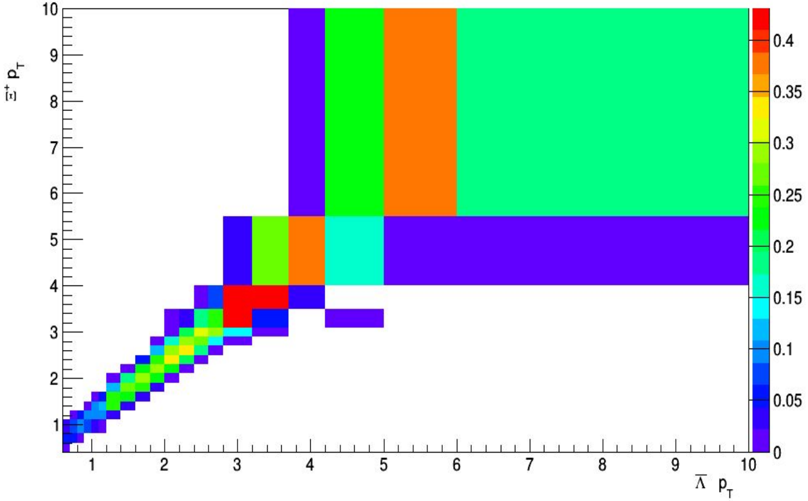
Cut	V. Loose	Loose	Default	Tight	Very Tight
No. of TPC Clusters	---	---	70	85	90
No. of crossed rows over findable	---	---	0.8	0.9	---
TPC PID σ	---	4	3	2.5	---
σ for signal extraction	---	5	4	[2,3,3]	---
Competing species rejection window	None applied	---	10 Mev/c^2	---	---

Feed Down Matrix in Integrated Multiplicity (MC Ratio Method)

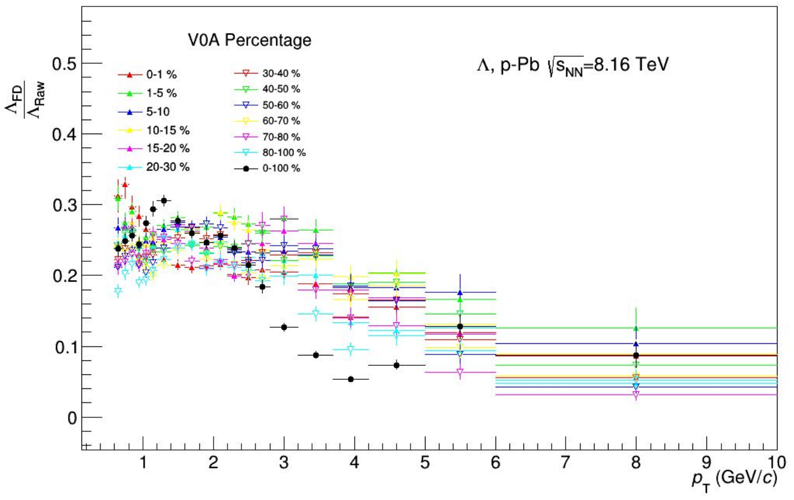
Lambda

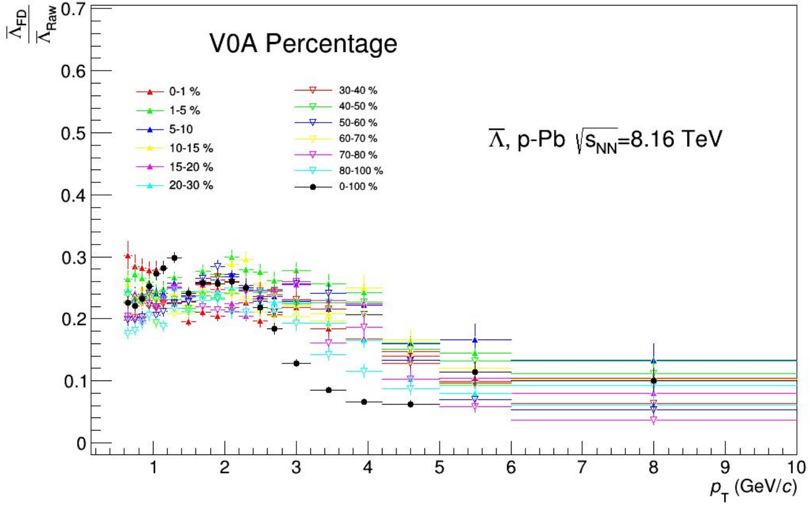


Anti-Lambda



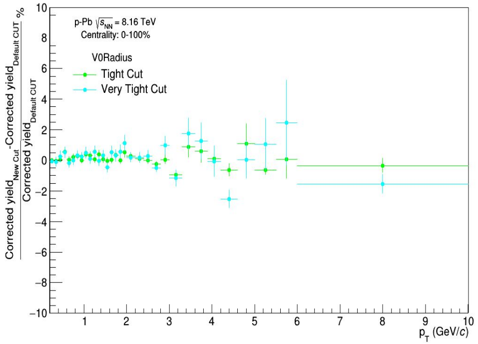
Feed Down Ratio (MC Ratio Method)

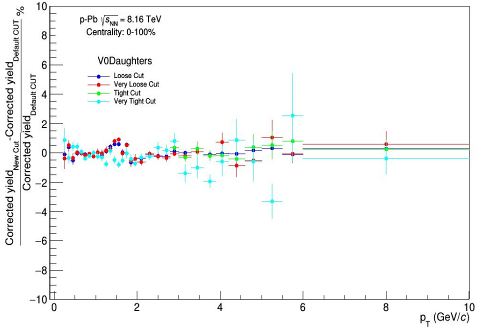


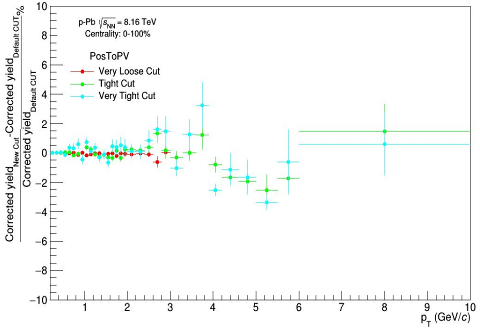


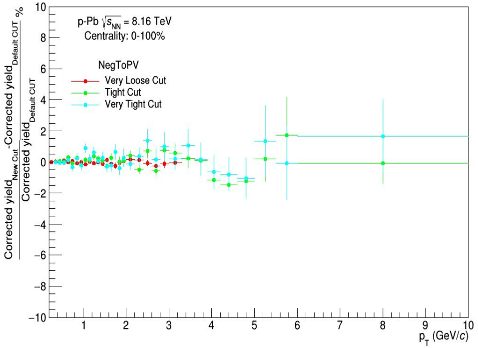
Systematics

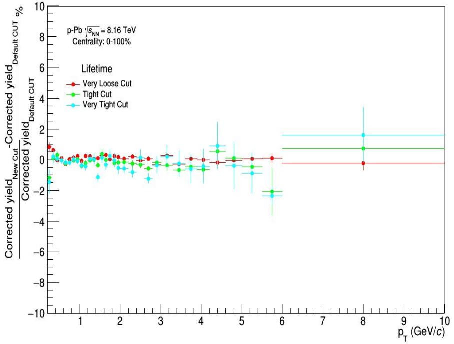
Relative difference between the corrected spectrum obtained with the new chosen cut and the one obtained with the default cut is shown for all the systematic sources considered

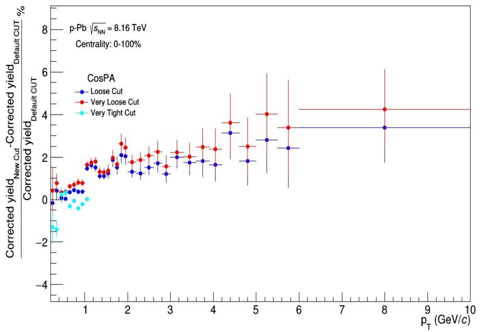




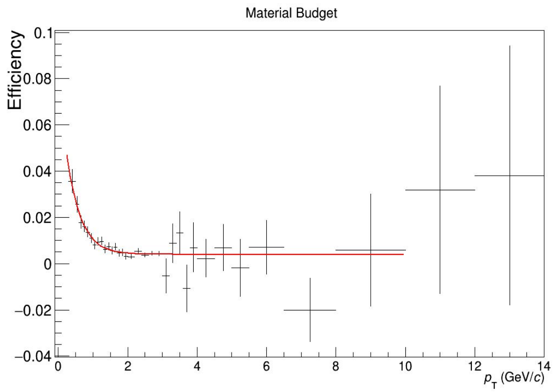


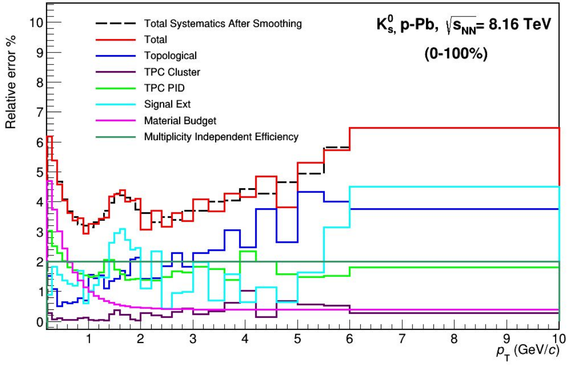






Systematics





For Material Budget thanks to Michal Sefcik.

Fitted with function :
double exponential ([0]*exp(-[1]*x) + [3]*exp(-[4]*x) + [2])

To get a value for the systematic in some p_T bin, simply evaluate the fitting function at the bin center.

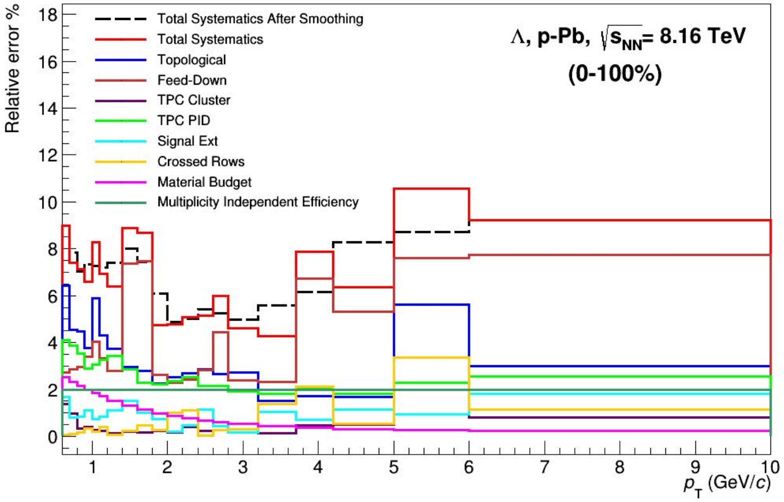
Systematic uncertainty for each p_T bin obtained by quadratically adding the contribution coming from each of the sources considered (after Barlow check) https://alice-notes.web.cern.ch/node/978)

Smoothing process:

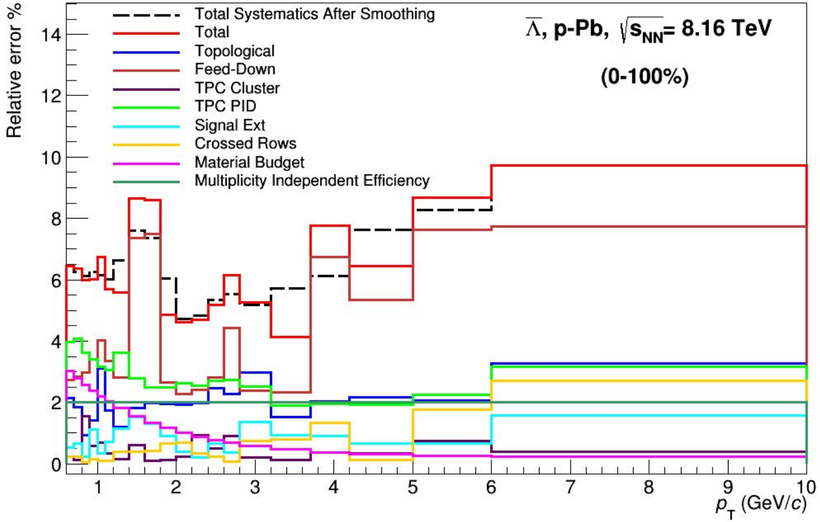
$$\sigma_j^{i+1} = (\sigma_{j-1}^{i-1} + \sigma_j^{i-1} + \sigma_{j+1}^{i-1})/3.0$$

Systematics

Lambda

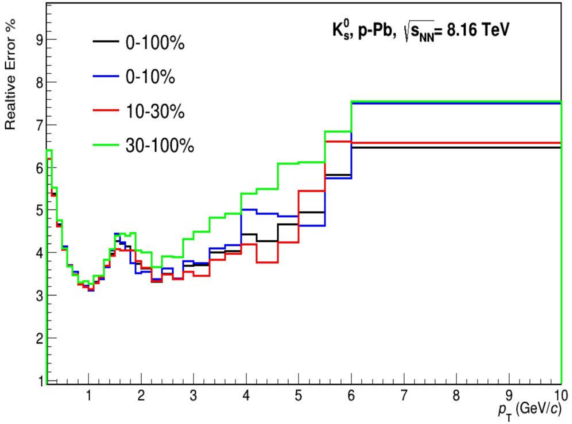


Anti-Lambda

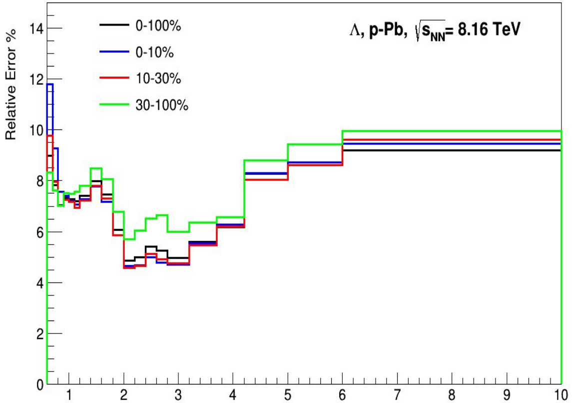


Multiplicity dependent Systematics

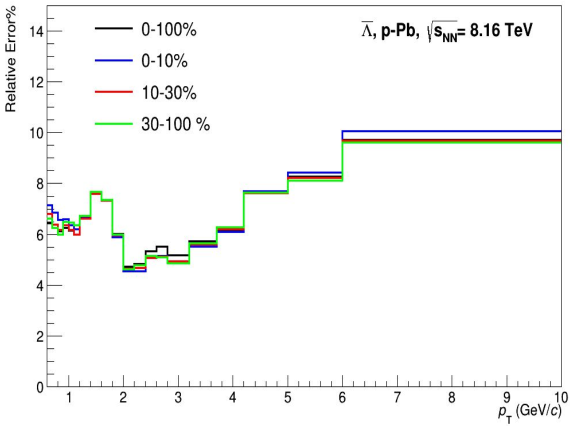
K0Short



Lambda

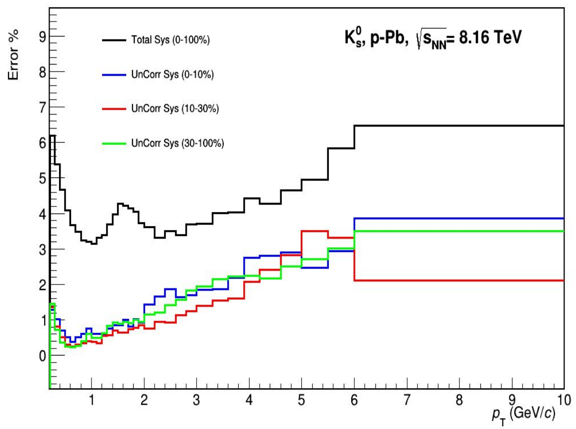


Anti-Lambda

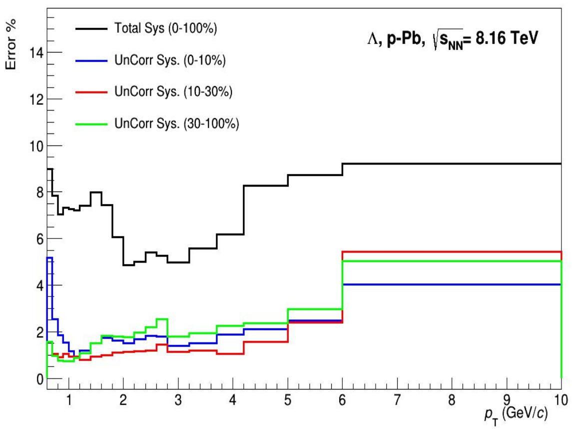


Uncorrelated Systematics

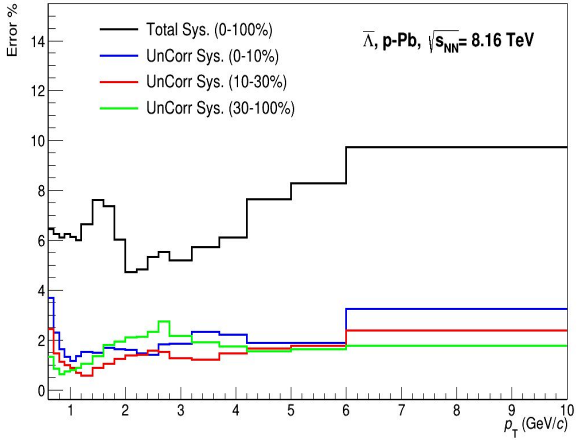
K0Short



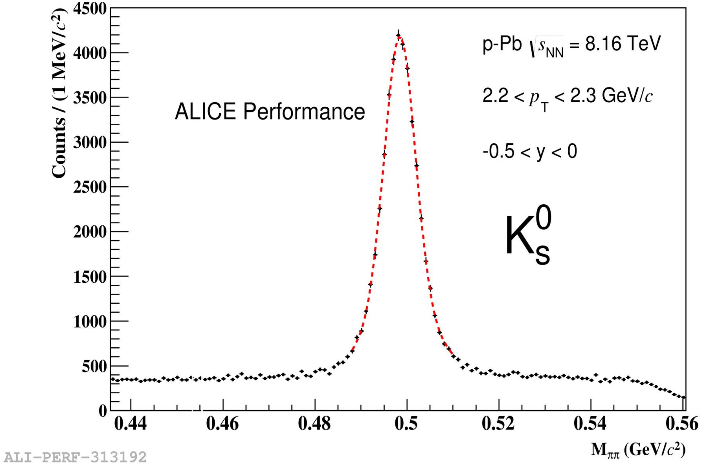
Lambda

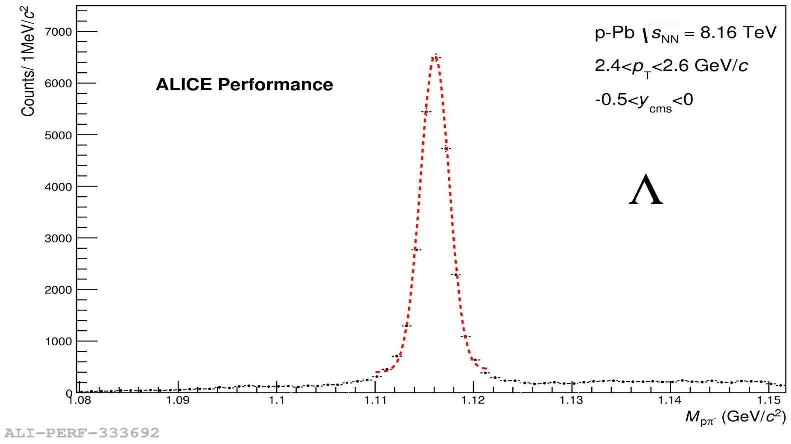


Anti-Lambda

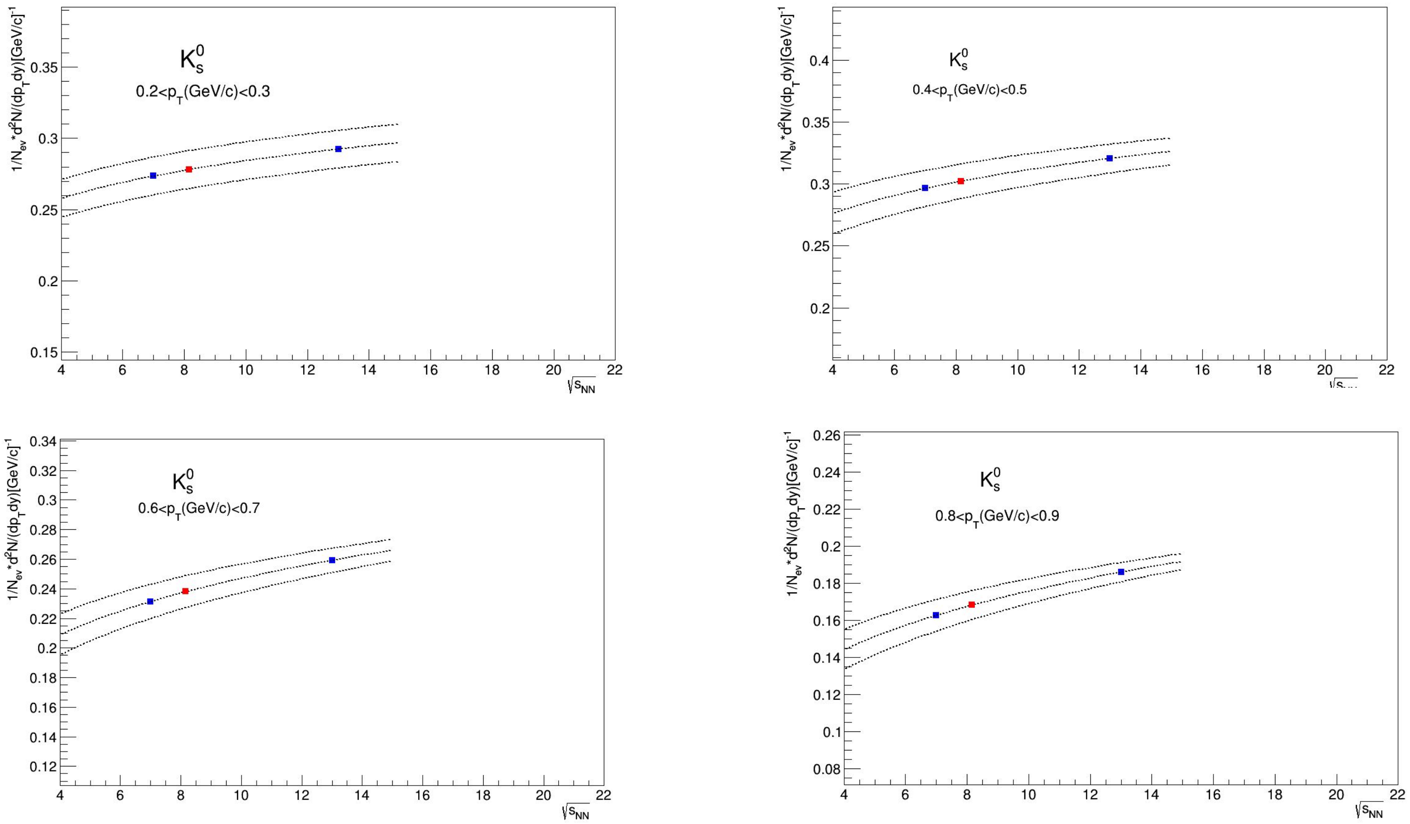


Invariant mass





Extrapolating pp spectra at 8.16 TeV



Steps for Barlow Check :

Then the difference between the yields is denoted as $\Delta = y_{def}$ - y_{sys} and the quadrature difference of their statistical error is $\sigma = \sqrt{\sigma_{def}^2 - \sigma_{sys}^2}$.

Then we define a factor n= Δ/σ;

Now, this n is calculated for each p_T bin and a distribution of n or Δ/σ is plotted. In general, if two measurements are consistent, it is expected that the distribution of n would have a mean near 0, a standard deviation near 1. if n $<$ 1 then the variation passes barlow check and consistent with default measurement with the corresponding statistical error, hence excluded from systematic uncertainties.

We consider following steps to do Barlow check:

step1: For a systematic variation we calculate the factor n for each p_T bin.

step2: Plot the histogram or frequency distribution of n.

step3: If two measurements are statistically consistent then the n distribution should have following criteria:

1) Mean at 0, 2) Rms $<$ 1.0 , 3) In $|n|$ $<$1 there will be $>$ 68% of counts, 4) In $|n|$ $<$2 there will be$>$ 95 %of counts

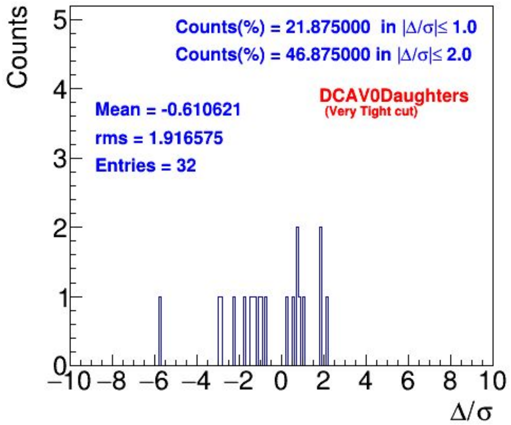
step4: As the entries are less so a modified criteria is proposed for passing the barlow check.

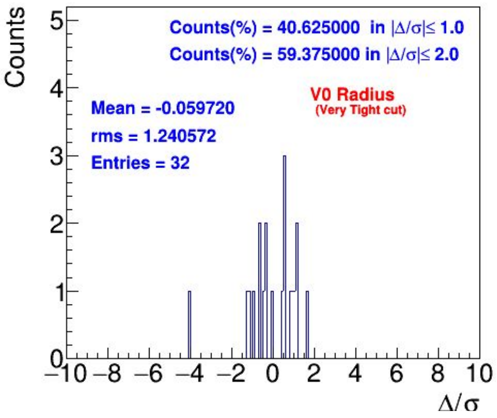
1) $|Mean| < 0.3$, 2) Rms $<$ 1.1 , 3) In $|n|$ $<$1 there will be $>$ 58 to 68% of counts, 4) In $|n|$ $<$2 there will be $>$ 65 to 95% of counts.

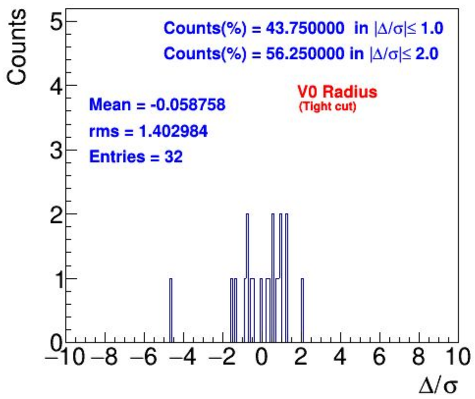
If any 3 of these above mention criteria is passed for a given source then we consider that the source pass barlow check.

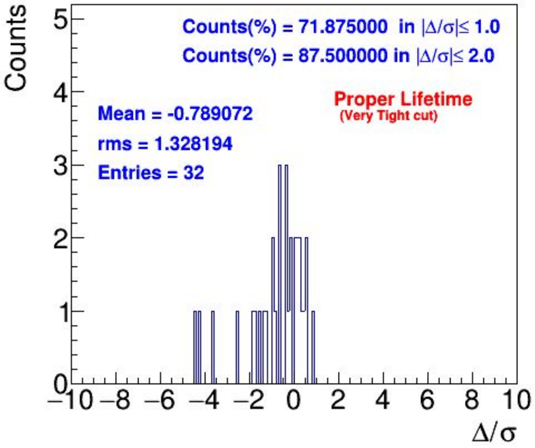
step5: If a source passes the Barlow checks, we exclude it from systematic uncertainties as the variation is governed by statistical uncertainty.

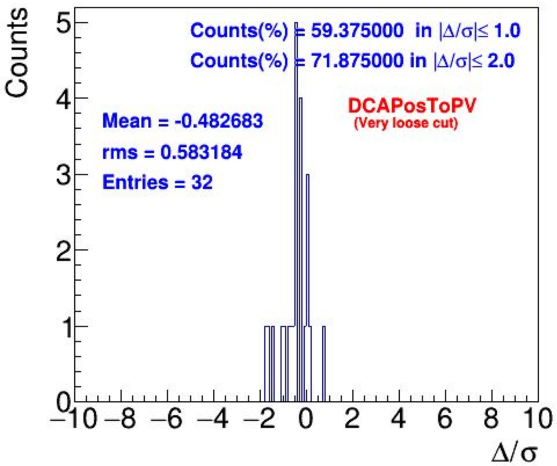
Barlow Check

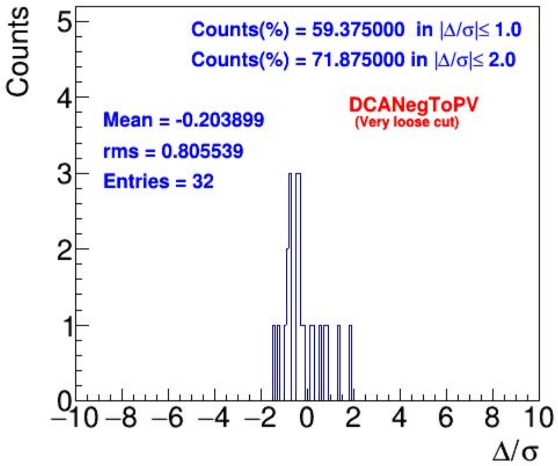












Centrality dependent p-Pb at 8.16 TeV: V0A centrality estimator

Cent (%)	Class	η_{lab}	$dN_{ch}/d\eta$	sys	AN	Paper
0 - 5	NSD	$\|\eta_{lab}\|<0.5$	53.22	± 1.38	link	Eur. Phys. J. C (2019) 79: 307
0 - 1			64.00	± 1.66		
1 - 5			50.50	± 1.31		
5 - 10			42.40	± 1.10		
10 - 15			37.30	± 0.97		
15 - 20			33.64	± 0.87		
20 - 30			29.30	± 0.76		
30 - 40			24.49	± 0.66		
40 - 50			20.34	± 0.53		
50 - 60			16.46	± 0.43		
10 - 20			35.49	± 0.92		
20 - 40			26.89	± 0.70		
40 - 60			18.39	± 0.48		
60 - 80			10.97	± 0.29		
60 - 70			12.77	± 0.34		
70 - 80			9.21	± 0.24		
80 - 100			4.47	± 0.14		
5 - 15			39.86	± 1.04		
15 - 30			30.77	± 0.80		
30 - 60			20.42	± 0.53		
60 - 100			7.63	± 0.24		

Reference :
https://twiki.cern.ch/twiki/bin/view/ALICE/ReferenceMult

Multiplicity dependent pp at 13 TeV: V0M multiplicity estimator

Data set : LHC16k_pass2, MC : LHC18f1, Trigger Efficiency : INT7>0 | INEL>0 / INEL>0

Mult (%)	Class	η	$dN_{ch}/d\eta$	sys	η	$dN_{ch}/d\eta$	sys	Trigger efficiency	AN	Paper
0 - 0.01	INEL>0	$\|\eta\|<0.5$	35.37	+0.92 -0.86	$\|\eta\|<1$	35.90	+0.93 - 0.88	1.0	link	in preparation
0.01 - 0.1			30.89	+0.57 -0.51		31.44	+0.58 -0.52	1		
0.1 - 0.5			26.96	+0.37 -0.30		27.43	+0.37 -0.30	1		
0.5 - 1			24.23	+0.36 -0.30		24.69	+0.37 -0.31	1		
1 - 5			20.02	+0.27 -0.22		20.39	+0.28 -0.22	1		
5 - 10			16.17	+0.22 -0.18		16.48	+0.23 -0.18	0.999		
10 - 15			13.77	+0.19 -0.16		14.04	+0.20 -0.16	0.998		
15 - 20			12.04	+0.17 -0.14		12.27	+0.17 -0.14	0.997		
20 - 30			10.02	+0.14 -0.11		10.22	+0.14 -0.11	0.995		
30 - 40			7.95	+0.11 -0.09		8.11	+0.11 -0.09	0.988		
40 - 50			6.32	+0.09 -0.07		6.45	+0.09 -0.07	0.975		
50 - 70			4.50	+0.07 -0.05		4.59	+0.07 -0.05	0.942		
70 - 100			2.55	+0.04 -0.03		2.60	+0.04 -0.03	0.795		
0 - 1			26.02	+0.35 -0.29		26.49	+0.36 -0.29	1		
0 - 5			21.20	+0.28 -0.23		21.59	+0.29 -0.23	1		
0 - 100			6.94	+0.10 -0.08		7.08	+0.10 -0.08	0.921		

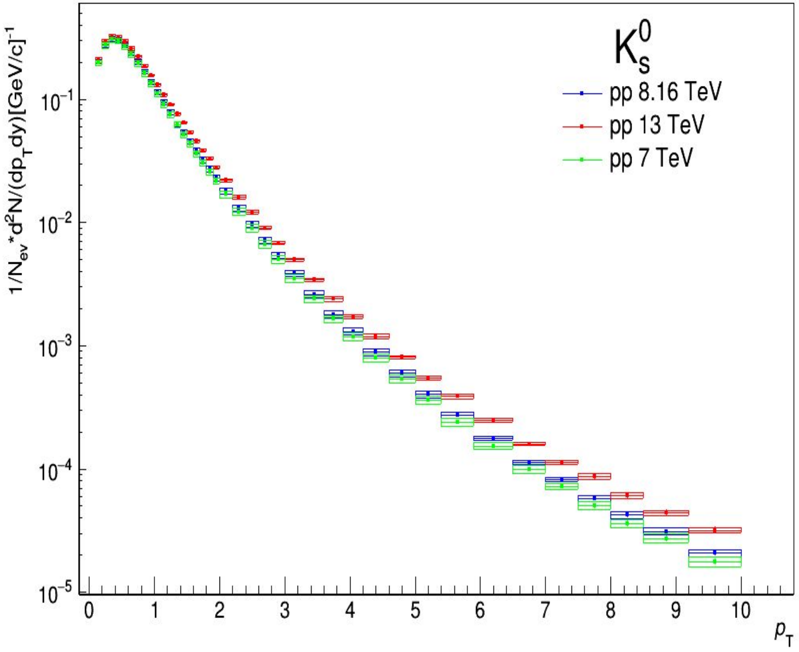
Trigger Efficiency

Mult Bin	Trigger Efficiency
0-1	0.998
1-5	0.994
5-10	0.994
10-15	0.994
15-20	0.9944
20-30	0.994

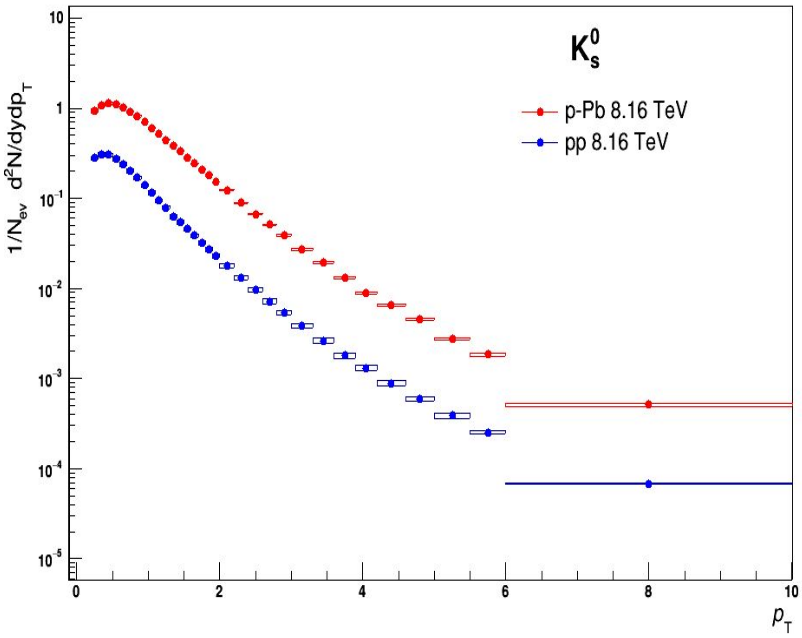
Mult Bin	Trigger Efficiency
30-40	0.995
40-50	0.9949
50-60	0.9947
60-70	0.9945
70-80	0.9929
80-100	0.9166

RpPb

Interpolated spectra

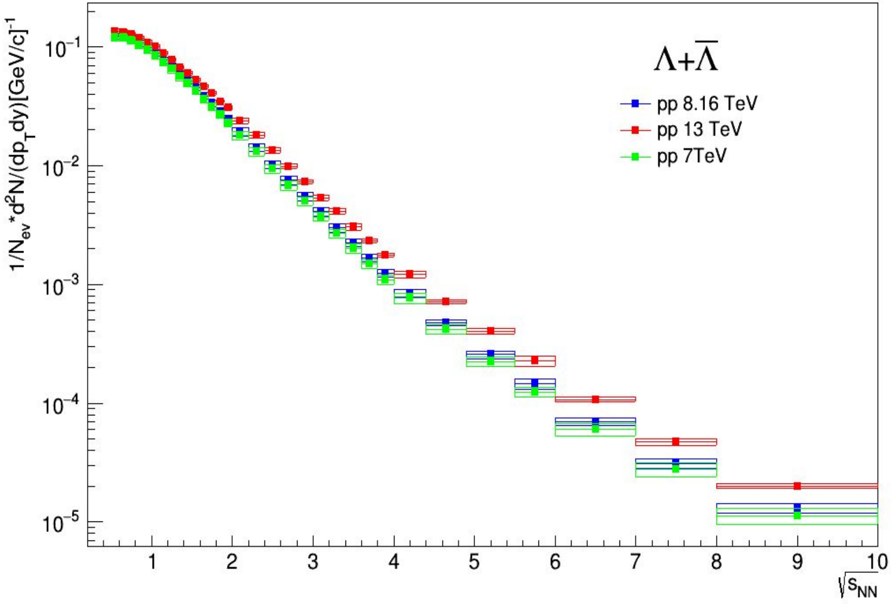


Interpolated spectra (after rebinning)

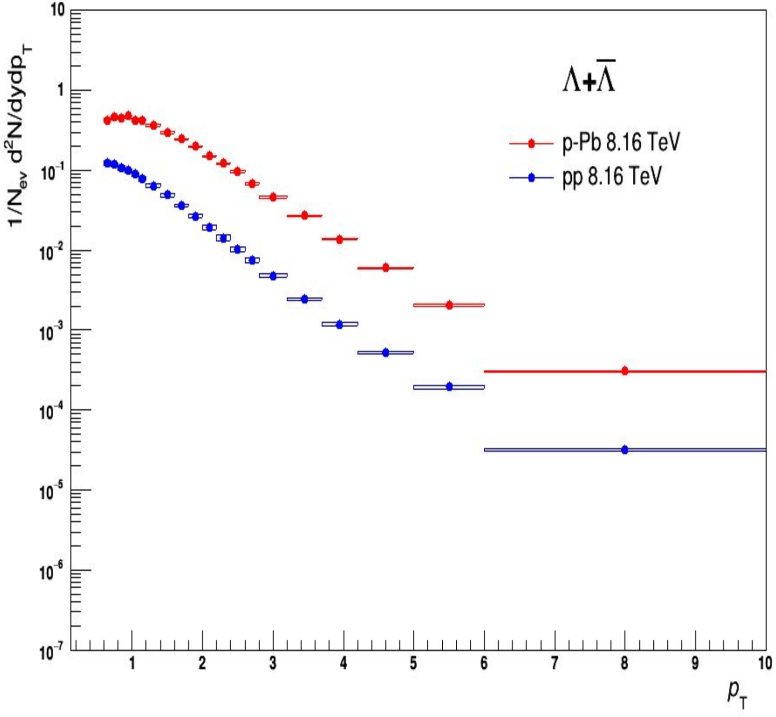


RpPb

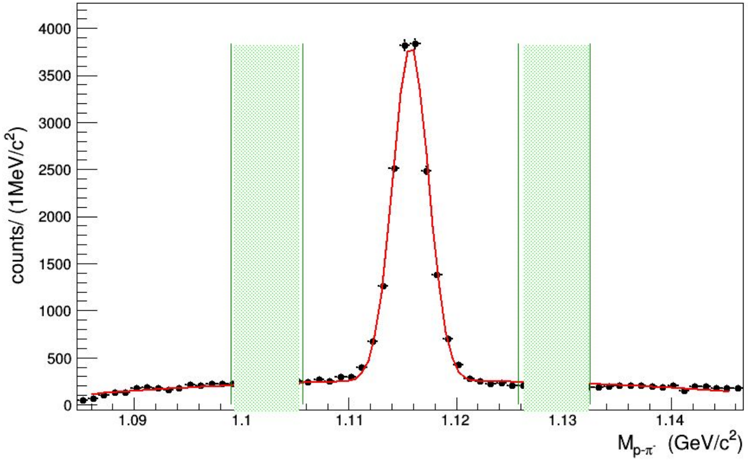
Interpolated spectra

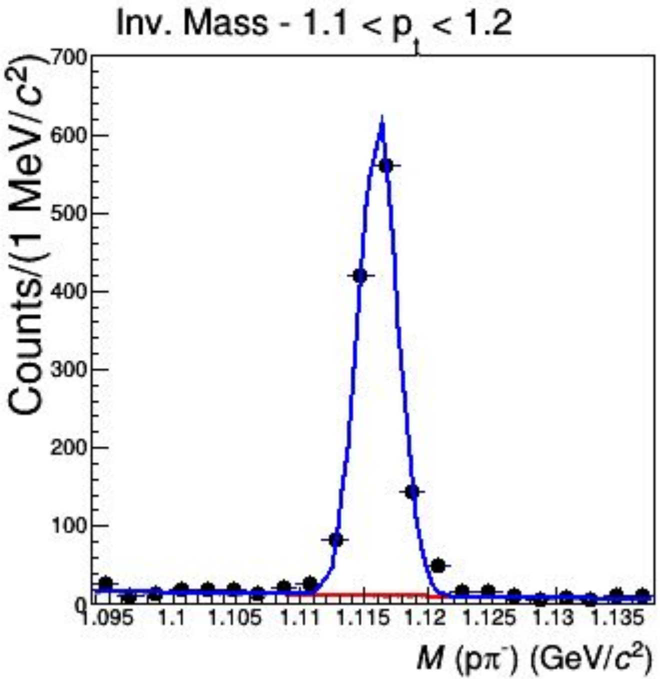


Interpolated spectra (after rebinning)



Signal extraction using two different methods



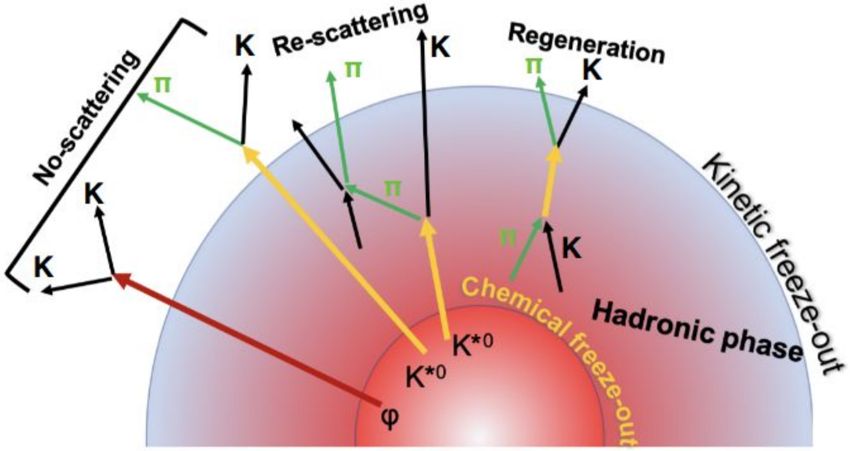


Motivation

Resonances are short lived particles (few fm/*c*) which decay by strong interaction

Hadronic phase: time span between chemical and kinetic freeze-out

Resonance	Lifetime (fm/*c*)	Decay channel	Branching ratio (%)
$\rho(770)^0$	1.3	$\pi^+\pi^-$	100
$K^*(892)^\pm$	3.6	$\pi^\pm K_s^0$	33
$K^*(892)^0$	4.16	$\pi^- K^+$	66
$\Lambda(1520)$	12.56	pK^-	22.5
$\phi(1020)$	46.2	K^-K^+	49.2



- **Modification of yields (re-scattering vs re-generation)**
- **Hint for finite lifetime of hadronic phase**
- **Hydrochemistry of particle production**
- **Study of in medium energy loss**

Event QA

p-Pb@ 8.16 TeV

Event information:

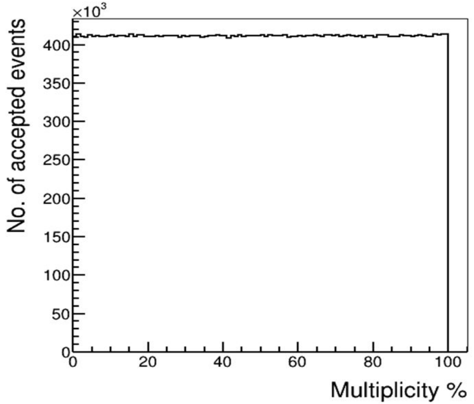
$|v_Z|$< 10cm

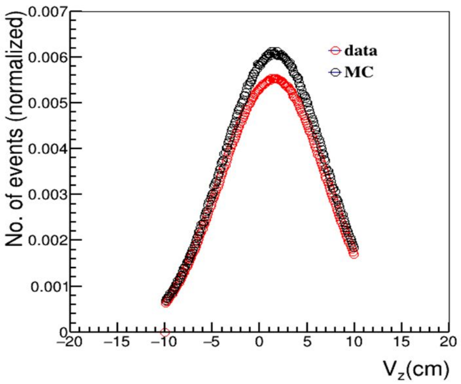
Number of events ~ 35M

Track information:

p_T > 0.15 *GeV/c*

$|\eta|$ < 0.8





pp@ 8 TeV

Event information:

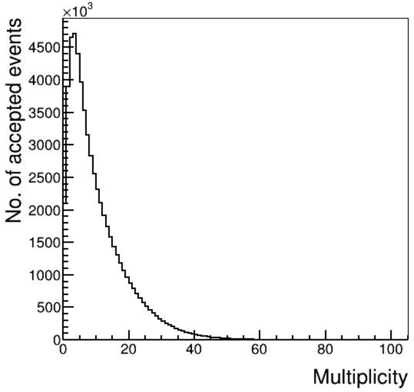
$|v_Z|$< 10cm

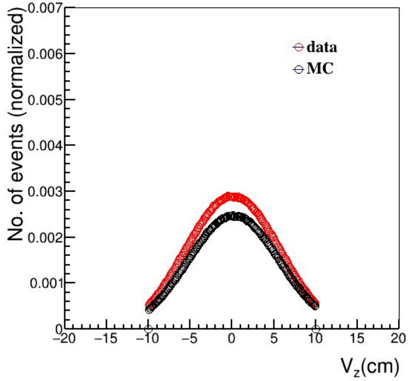
Number of events ~ 60M

Track information:

p_T > 0.15 *GeV/c*

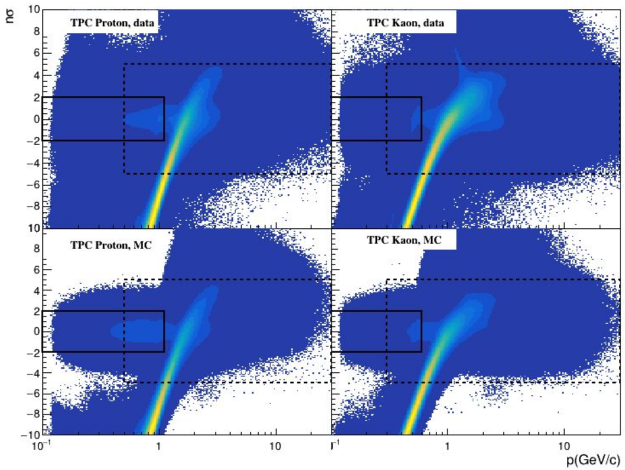
$|\eta|$ < 0.8



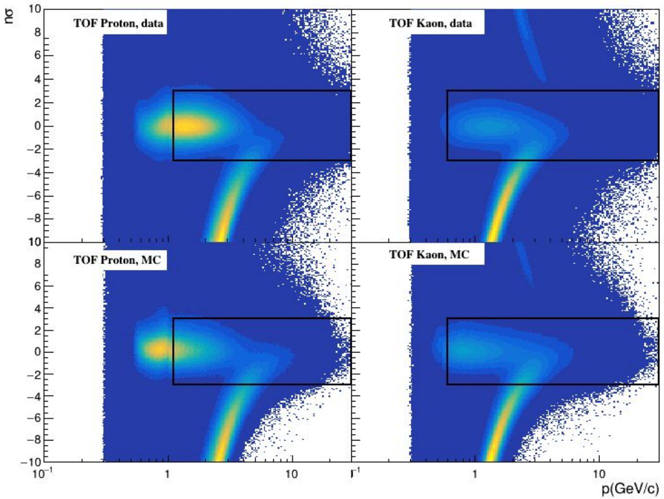


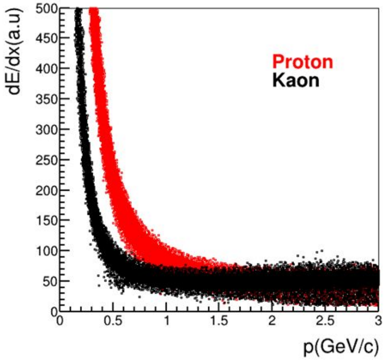
PID QA

TPC



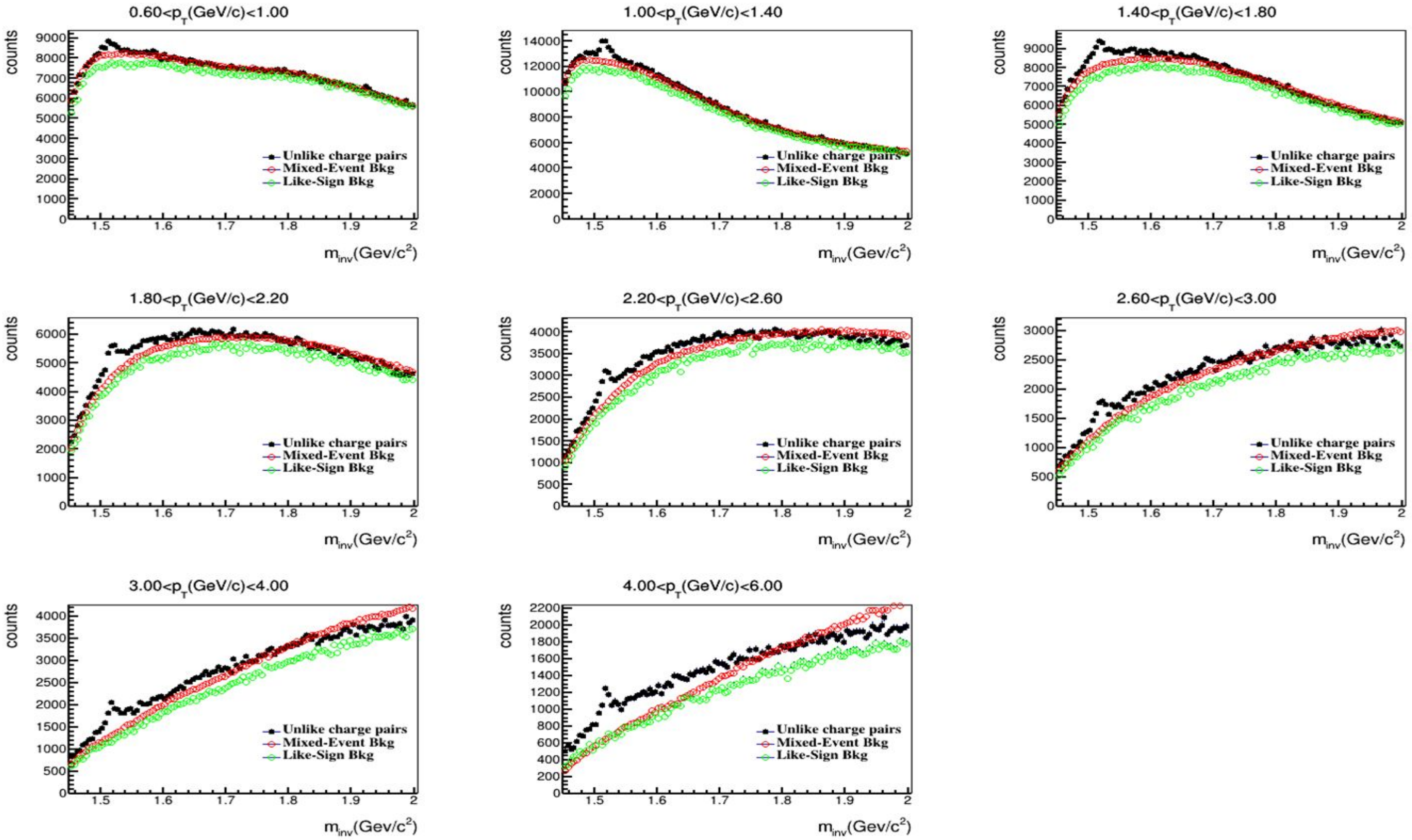
TOF



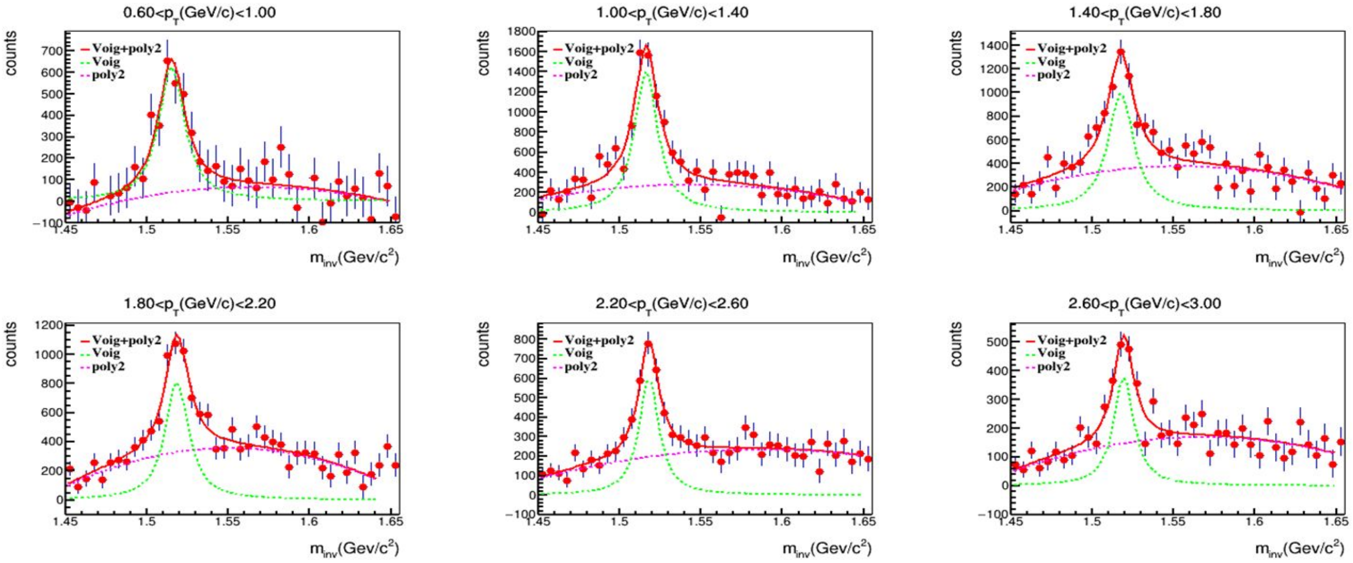


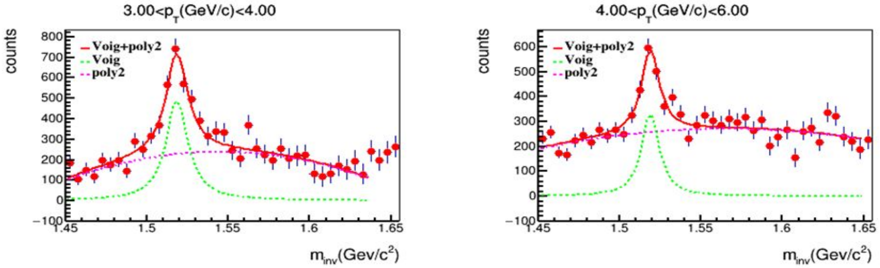
- Upper panels are for Data and lower panels are for MC
- Left panels are for proton and right panels are for Kaon
- Solid back lines show the area from which PID selection is done while dotted black lines show the area where TPC veto is used

Invariant mass spectra for minimum bias p-Pb collisions before bkg subtraction



Invariant mass spectra for minimum bias p-Pb collisions after bkg subtraction

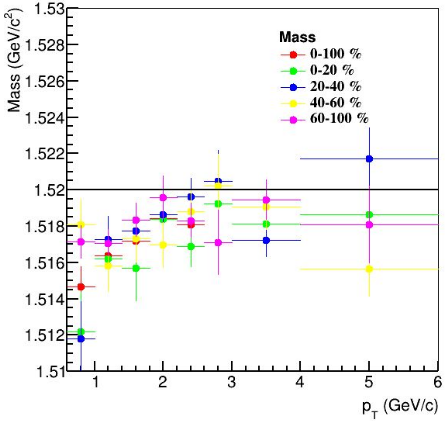


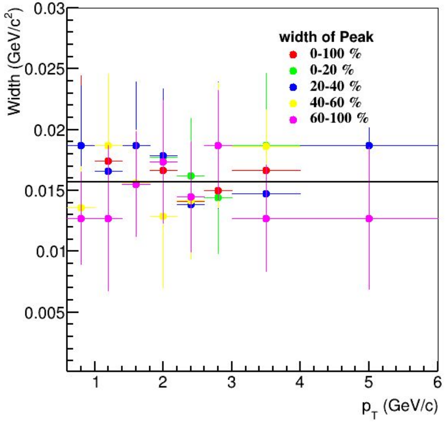


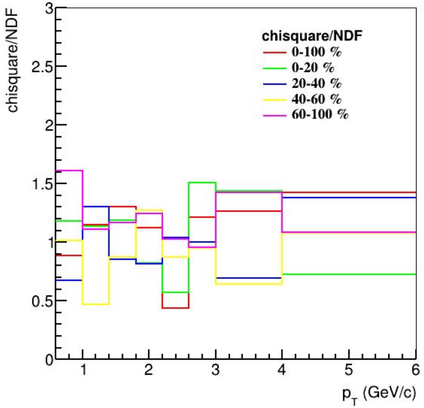
Fitting function: Voigtian for signal & Poly2 for Residual BG
Fitting Range:1.45-1.65 GeV/c^2

Parameters from the fit

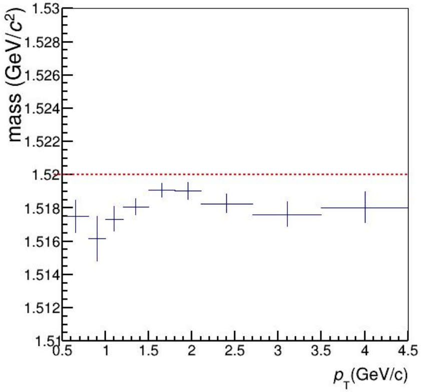
p-Pb@ 8.16 TeV

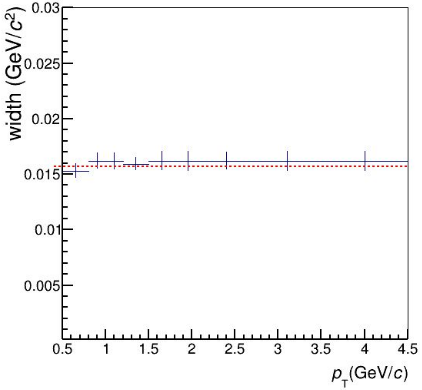


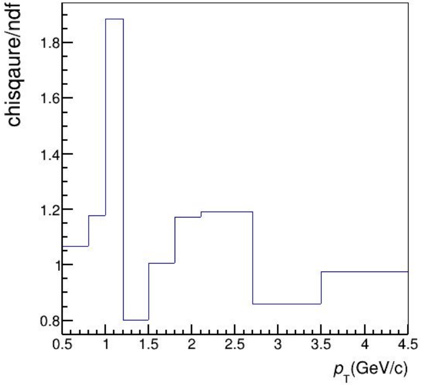




pp@ 8 TeV



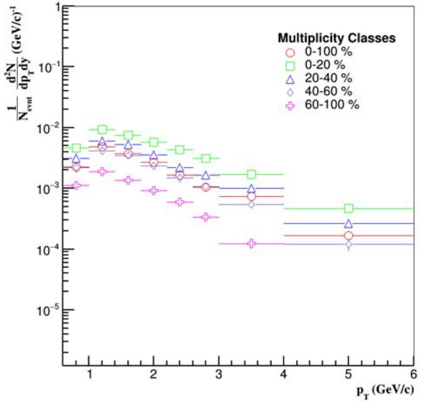


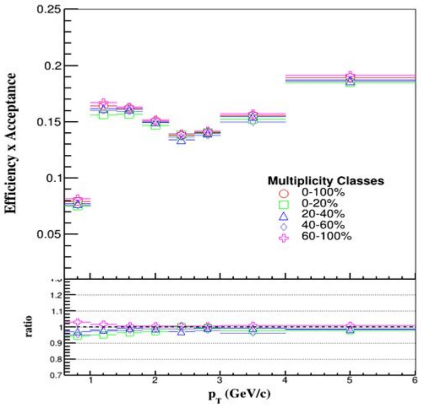


Raw p_T spectra and detector reconstruction efficiency

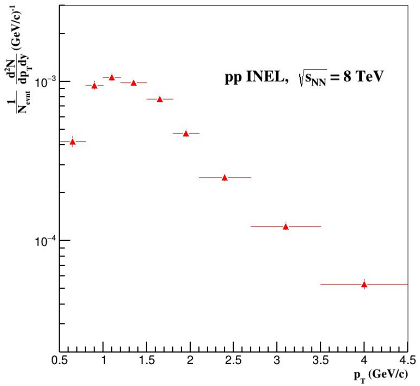
ALICE

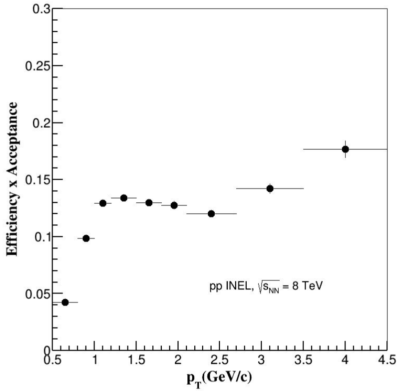
p-Pb@ 8.16 TeV





pp@ 8 TeV





- Raw yield is calculated using bin counting of histogram in the invariant mass region (1.48,1.55) GeV/c^2 . For the tail part contributions, fitting function is used.
- Efficiency is calculated by taking the weighted average of efficiencies calculated from different MC productions

$$\epsilon_{rec} = \frac{k}{n}$$

  k is number of reconstructed Λ(1520)

  n is number of generated Λ(1520)
- Error in reconstruction efficiency is calculated using Bayesian approach

$$\sigma_{\epsilon} = \sqrt{\frac{k+1}{n+2}\left(\frac{k+2}{n+3} - \frac{k+1}{n+2}\right)}$$

Systematic uncertainties

→ $\sigma_{sys} = \frac{|y_{def} - y_{sys}|}{y_{def}}$

- y_{def} *is the yield due to default set of parameters*
- y_{sys} *is the yield due to systematic variation*

→ For more than one variations of a systematic source, RMS is taken as systematic uncertainty

→ Quadrature sum of systematic uncertainties from all the sources is taken as the final systematic uncertainty

$$Final\ sys\ uncer = \sqrt{\sigma_{SE}^2 + \sigma_{PID}^2 + \sigma_{QTR}^2 + \sigma_{MB}^2 + \sigma_{Tr}^2}$$

→For local fluctuations in the systematic uncertainty, smoothening is done

- For *ith* p_T bin $\frac{\sigma_{i-1} + \sigma_i + \sigma_{i+1}}{3}$
- First and last p_T bin are excluded from smoothening procedure

- Signal extraction:
  - ✓ Fitting regions (3 variations)
  - ✓ BG Normalization regions (2 variations)
  - ✓ Yield extraction method (functional integral)
  - ✓ Residual BG (poly2 is default poly3 and poly4 as variations)
  - ✓ Width fixed (default width set as free)
  - ✓ Fit function (default is Voigtian and BW as variation)
  - ✓ Detector mass resolution (1 variation)
  - ✓ No. of mixed events (2 variation)
  - ✓ Mass range for bincounting (2σ is default 1σ is variation)
- PID cuts (3 variations)
- Quality track selection cuts (6 variations of Std 2011 cut)
- Material budget from p-Pb analysis at 5.02 TeV
- Tracking from p-Pb analysis

RMS is taken for systematic sources with more than 1 variation

- Final systematic uncertainty is the quadrature sum of uncertainties from all different sources.