Transverse spherocity dependent study of Lambda(1520) production in pp collisions

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ALICE INDIA Collaboration

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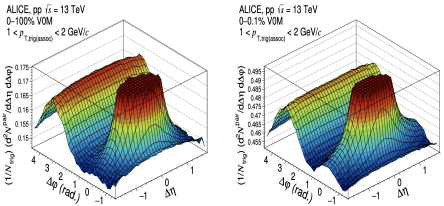
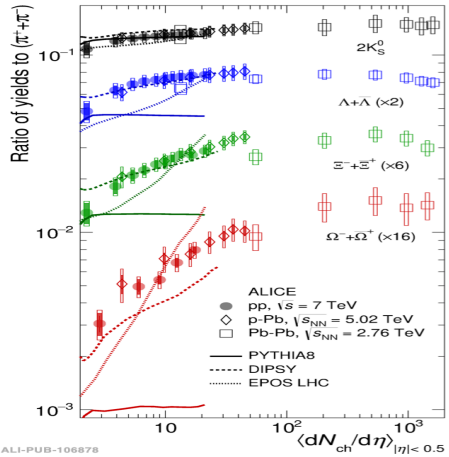
Outline

* Motivation and Introduction
* Introduction
* Track and Event Selection
* Acceptance $\times$ Efficiency
* Correction factor
* Invarient Mass(CL1)
* systematics uncertainities (CL1)13TeV)
* Spectra 13TeV and 5.02TeV
* Spectra 13TeV(CL1)
* SUMMARY & OUTLOOK

Is there any hadronic phase formed in high multiplicity pp collisions?

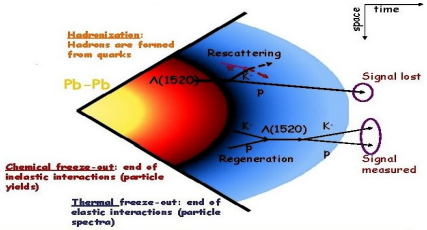


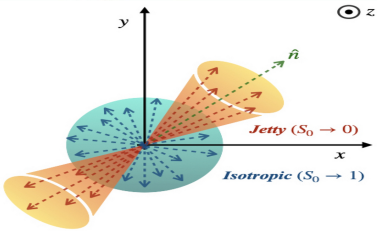
Ridge structure in high multiplicity pp collisions but not in minimum bias pp collisions



QGP like signature

- Study of hadronic resonance production tell about re-scattering and regeneration effects during the evolution of hadronic phase.
- Λ(1520)/Λ ratio suppressed In central Pb-Pb collisions w.r.t pp and peripheral Pb-Pb collisions
- Due to QGP like effects observed at high multiplicty as discussed in previous slides
  - Multiplicity dependent analysis could help to understand the hadronic phase(if any) in small collision systems.
  - To further gain insight into production mechanism at high multiplicty, transverse spherocity dependent study might be useful.





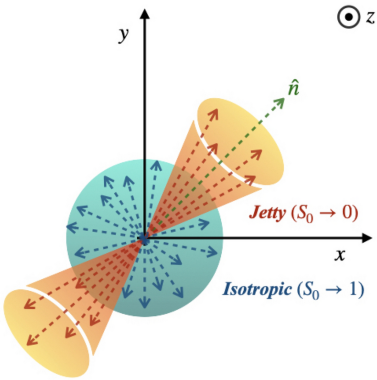
Introduction

Event shapes are characterised using transverse sphericity S_0.

$$S_0^{p_T=1.0} = \frac{\pi^2}{4} \min_{\vec{n}=(n_x,n_y,0)} \left(\frac{\sum_i \left| \vec{P_{T_i}} \times \hat{n} \right|}{N_{tracks}} \right)^2$$

Where,

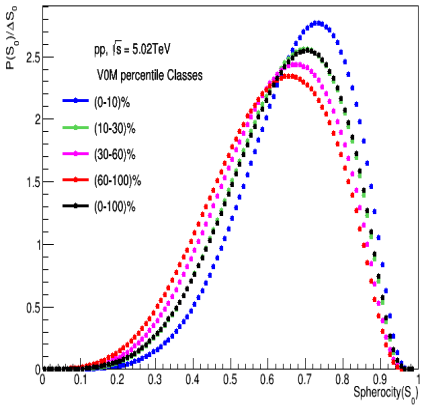
$$S_0 = \begin{cases} 0, & \text{"pencil-like" limit (hard events)} \\ 1, & \text{"isotropic" limit (soft events)} \end{cases}$$

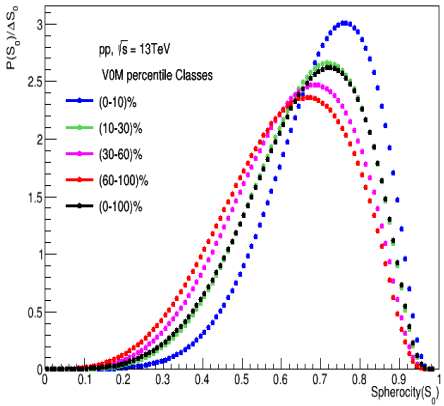


Source: Prasad, S., Mallick, N., Behera, D. et al. Sci Rep 12, 3917 (2022). https://doi.org/10.1038/s41598-022-07547-z

and $\hat{n}$ is a two dimensional unit vector in the transverse plane,chosen in a way so that S_0 is minimised.

Spherocity Distribution (Multiplicity dependence)





Dominance of isotropic events in high multiplicity pp collisions. Dominance of jetty events in low multiplicity pp collisions.

Data Set

Period	AOD	$\sqrt{s}$
LHC17p/LHC17q	pass1_CENT_wSoDD	
	pass1_fast	5.02TeV
LHC15n	pass4	5.02TeV
LHC18	b,e,f,g,h,l,k,l,m,n,p(pass2)	
LHC17	e,i,j,k,l,m,o,r,h,c,f(pass1)	13TeV
LHC16	d,e,g,h,i,j,o,p (pass1), k,l(pass2)	

Table: Data production table

*pass1 used(No MC production in pass2)

Period AOD	Anchored to
LHC18c8b_CENT_woSDD	LHC17p/q,cent,no SDD(pass1)
LHC18c8b_fast	LHC17p/q,fast(pass1)
LHC18c8a	LHc15n(pass4)
LHC18c6d	LHC18 datasets(pass1)
LHC18c6b4	LHC16k,l datasets(pass2)
LHC18c6b	LHC16d,e,g,h,i,o,p datasets(pass1)
LHC18c6a	LHC17 datasets(pass1)
LHC18j4	G.P MC for event loss and signal loss correction

Table: MC Production(Injected)

Event and Track Selection

Resonance

$Lambda(1520) \rightarrow pK^-$	Width 15.7 Mev/c^2
Branching Ratio 22.5	Mean life time $12.6fm/c$

- V0M task→UseMultiplicity("AliMultSelection_V0M")
- CL1 task→UseMultiplicity("AliMultSelection_RefMult08")

- TriggerMask: AliEvent::kINT7
- Pileup rejection
- $|V_Z| < 10cm$
- $|\eta| < 0.8$
- $|y| < 0.5$
- StandardITSTPCTrackCuts2011
- kHighMultV0 trigger (pp High-multiplicity)

PID Selection

Track present in TOF,
$(N\sigma)$ TOF =3 with $(N\sigma)$ TPC =5 as veto

Track not present in TOF,
$(N\sigma)$ TPC =3
Proton:0 <(GeV/c)< 1.1 &
Kaon:0 $< p(GeV/c) < 0.6$

Analysis details::

Signal Extraction: Invariant mass technique.

Combinatorial background subtraction:

Number of mixed events = 10 ,

Raw yield extraction:- Raw yield estimated via Bin counting method.

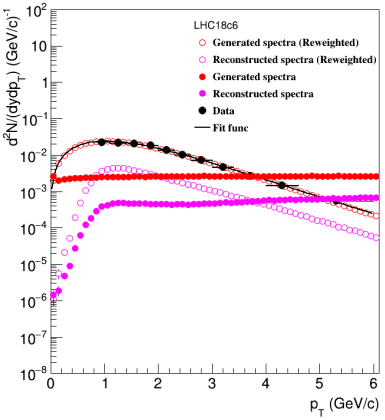
- Multiplicity 0-10%

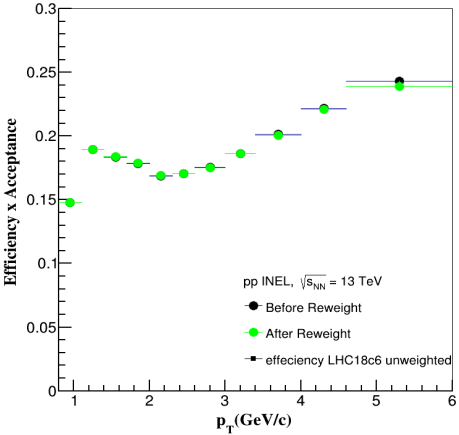
$\sqrt{s}$	**Multiplicity**	**Jetty 0-10%(lower)**	**Isotropic 0-10%(upper)**
5.02 TeV	0-10% (V0M)	0-0.485	0.849-1.00
13 TeV	0-10%(V0M)	0-0.528	0.865-1.00
13 TeV	0-10%(CL1)	0-0.559	0.872-1.00

  - p_T bins(GeV/c) for 13TeV(V0M CL1): (0.8-1.3),(1.3-1.7),(1.7-2.1),(2.1-2.4),(2.4-2.7),(2.7-3.0),(3.0-3.4),(3.4-4.0),(4.0-4.5),(4.5-6.0)
  - p_T bins(GeV/c) for 5.02TeV(V0M): (1.0-1.4),(1.4-1.7),(1.7-2.0),(2.0-2.3),(2.3-2.6),(2.6-3.0),(3.0-4.0),(4.0-4.5)
- High-Multiplicity Binning: 0-0.01%, 0.01-0.05%, 0.05-0.1%
  - p_T bins(GeV/c) for 13TeV: (0.4-0.6), (0.6-0.8) , (0.8-1.0), (1.0-1.2), (1.2-1.4), (1.4-1.6), (1.6-1.8), (1.8-2.0), (2.0-2.5), (2.5-3.0), (3.0-3.5), (3.5-4.0), (4.0,6.0)

- Normalisation range : 1.60 -1.70 GeV/c^2
  except For Isotropic and for first two pt interval norm range 1.45-1.47
- Voigtian(Peak) + Pol2(Residual Back ground)
- Fitting range:1.45-1.65 GeV/c 2
  except For Isotropic and for first two pt interval fit range 1.48-1.65
- Width:- In each pT bin,for every configuration, fitted BW to generated mass spectra with free width. Extract the width from the fit. Using this width as a fixed parameter, we fit the signal.

Acceptance × Efficiency(13TeV)





As the generated spectrum has a different shape than the measured resonance spectrum, it is necessary to weight the generated and reconstructed spectra.

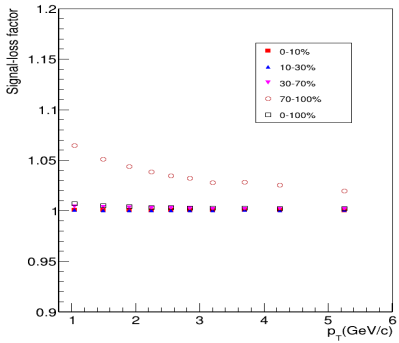
Correction factor(13TeV)

$$\frac{d^2N}{dp_T dy} = \frac{1}{BR \times N_{ev}} \frac{Y_{raw}}{dp_T dy} \frac{f_{SL}}{\epsilon_{rec}} \times f_{vtx} \times f_{trig}$$

- Trigger efficiency factor:
  $$f_{trig/INT7} = \frac{N^{evt}_{INt7|TrueINEL>0}}{N^{evt}_{TrueINEL>0}}$$
- Vertex factor: $f_{vtx} = \frac{N^{evt}_{vtx|TrueINEL>0}}{N^{evt}_{INt7|TrueINEL>0}}$

$Multiplicity(V0M)$	$f_{trigger}$	f_{vtx}
0-10%	0.9995	0.9999
10-30%	0.9996	0.9995
30-50%	0.9985	0.9977
50-70%	0.9896	0.9923
70-100%	0.8827	0.9810
0-100%	0.9427	0.9897

$f_{SL} = \frac{Y_{INEL10}}{Y_{selected}}$ m_T scaling is used to estimate the f_{SL} for $\Lambda(1520)$ using other abundant particles. (Proton,Lambda,Xi,Omega).



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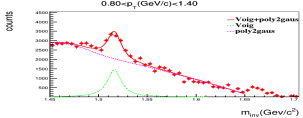
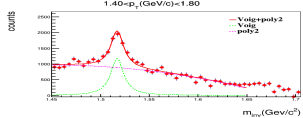
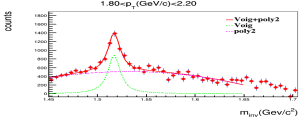
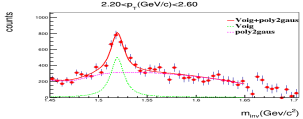
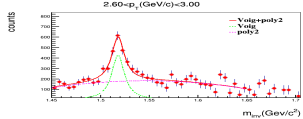
Inv mass 13TeV-0-10%-Jetty (CL1)

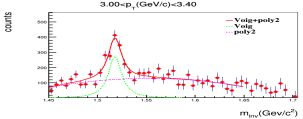


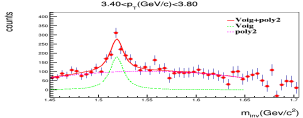


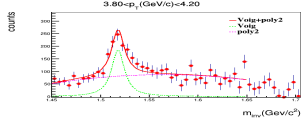


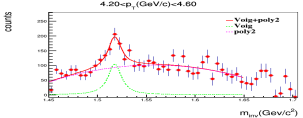


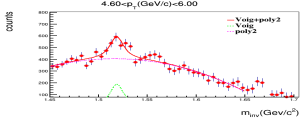




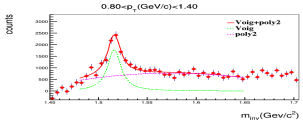


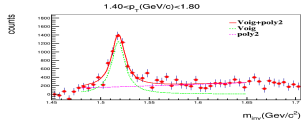


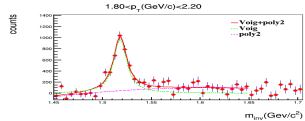


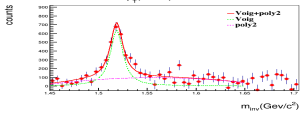


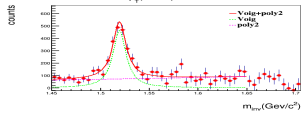
Inv mass 13TeV-0-10%-Isotrophic (CL1)

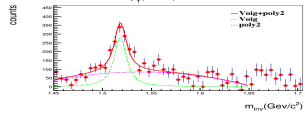


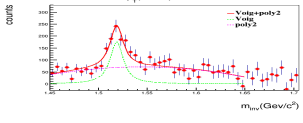


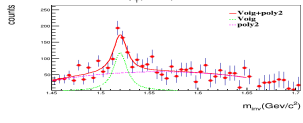


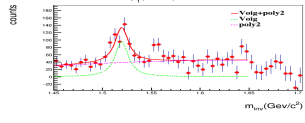


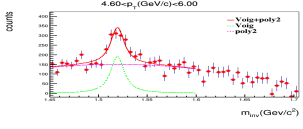




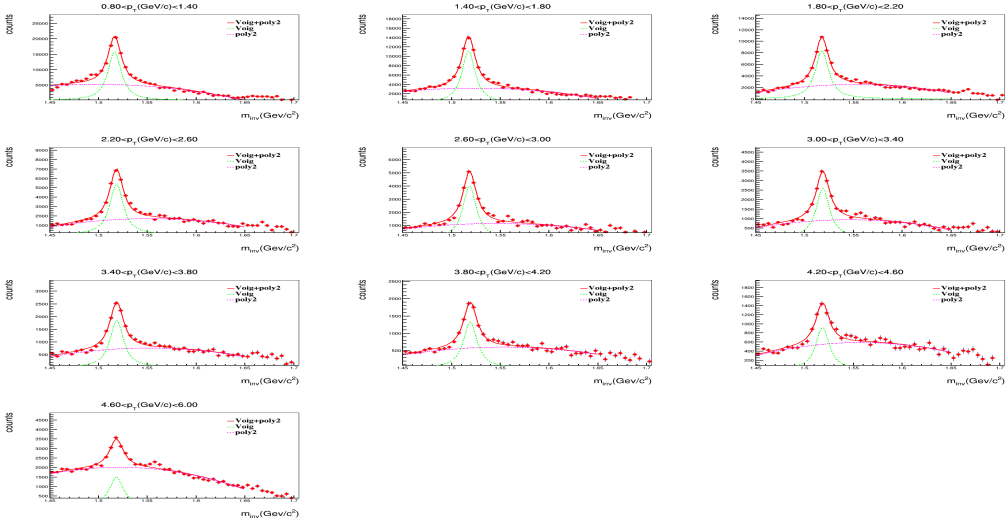




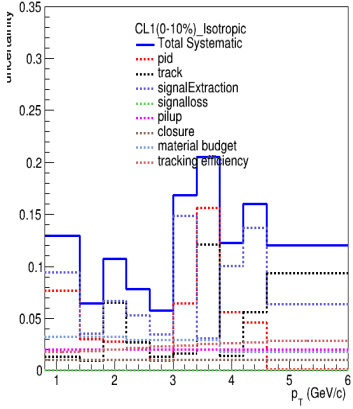


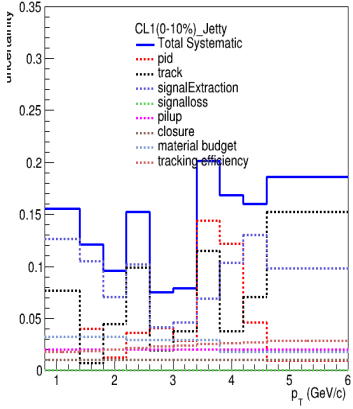


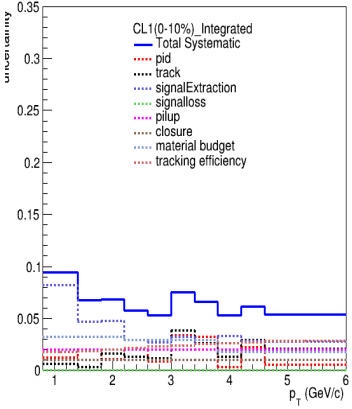
Inv mass 13TeV-0-10%-Integrated (CL1)



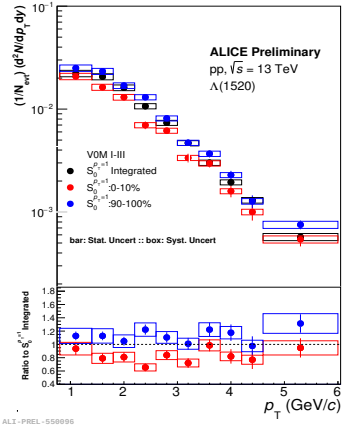
systematics uncertainities (CL1)13TeV

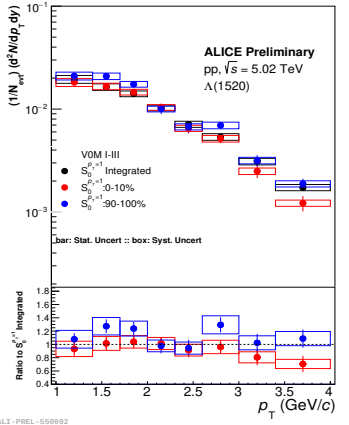




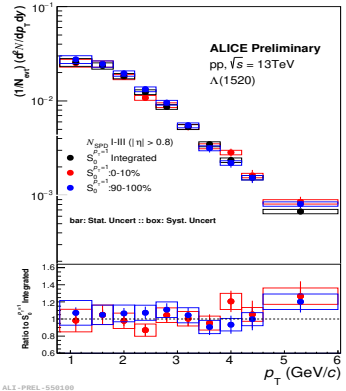


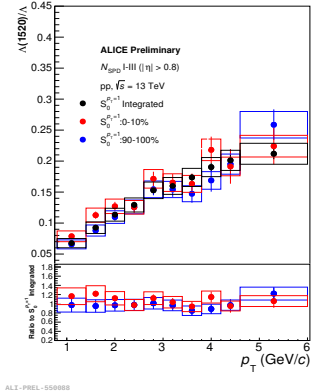
spectra13TeV (0-10%)





spectra13TeV CL1(0-10%)





No significance difference on the event shape

SUMMARY & OUTLOOK

SUMMARY

- Raw yield is estimated by using bin counting and Integral method.
- Spectra is corrected with efficiency, BR, number of event.
- Spectra corrected with re-weighted efficiency, f_{vtx} and f_{trig} factors(0-100% multiplicity class).
- The results for $\Lambda(1520)$ as a function of spherocity and multiplicity is presentes in pp collisions at 5.02 TeV(V0M) and 13 TeV(V0M & CL1) .
- Ratio of $\Lambda(1520)$ to Lambda as a function of spherocity is presented for CL1 estimator.

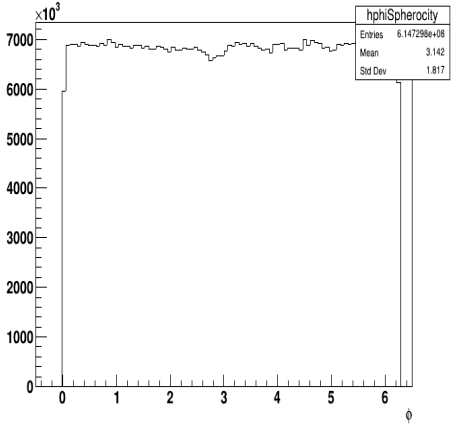
OUTLOOK

- working om Model comparison (stand alone).
- As $\Lambda(1520)$ not included in General purpose Monte Carlo generator.

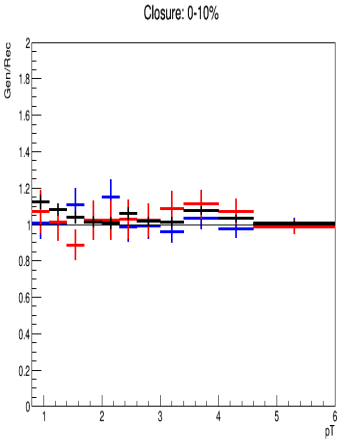
Thank You

Uniform azimuthal acceptance & closure tests

Uniform azimuthal acceptance is needed for spherocity calculation:



- Multiplicity, pT, Spherocity bin selection: did you correct for detector effects? How are you going to compare with theory?
  - closure test are done to evaluate expermental bias.



comparsion of spherocity integrated spectra with min. bias

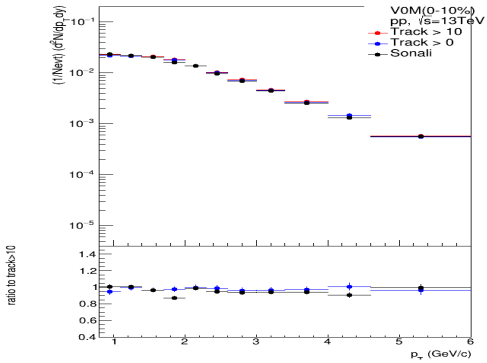
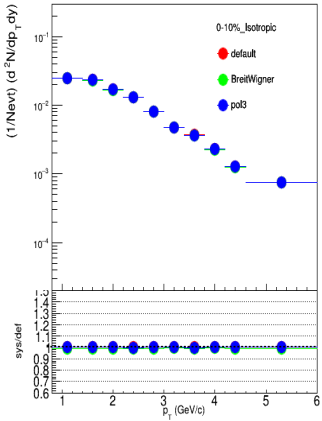


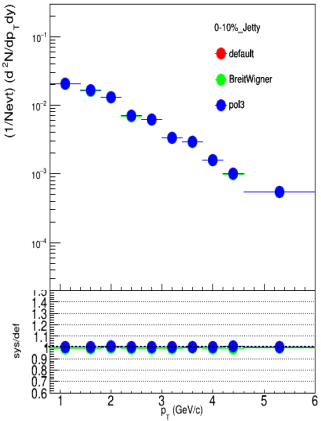
Figure: 0-10%

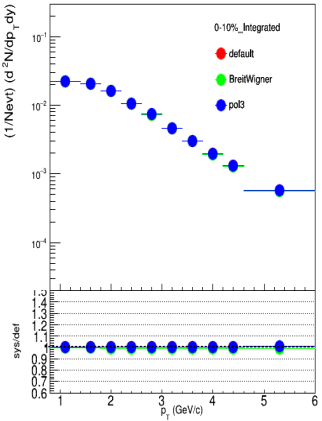
spectra comparsion with BW fit fn and background pol3)

For the systematic uncertainties on the signal extraction you should also consider different fit functions for the background

Default:- Voign+pol2

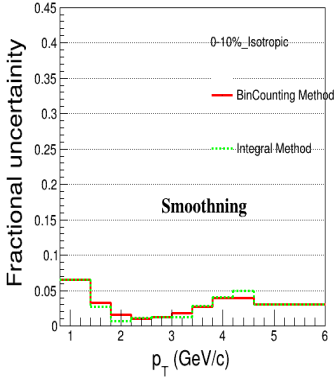


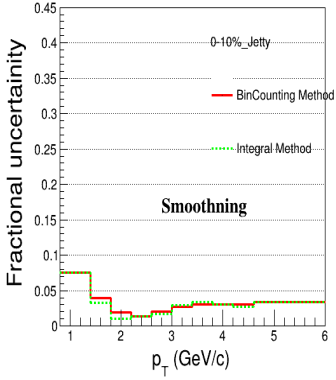


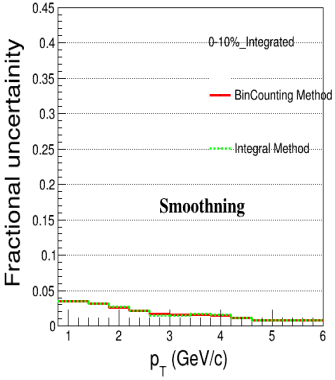


Viaration in Bincounting and fitfunction method

Cross-check the difference between bin counting and integral, which is mostly related to how good is the signal description, which is not extremely important. The most important thing is that you properly describe your background.







Source of systematics uncertainities

Grouped

- Signal Extraction
  - Normalisation Range:-1.60-1.70(Default), 1.60-1.65, 1.60-1.80
  - Fit Range:- 1.45-1.65(Default), 1.46,1.65, 1.45,1.64
  - Fit function: Voigtian function+pol2 (default), Breit-Wigner, Voigtian function+pol3
  - Yield Extraction:- Bin counting(default), Integral Method
- PID
  - $n\sigma_{TPC} = 3.5$, $n\sigma_{TOF} = 3.5$
  - $n\sigma_{TPC} = 2.5$, $n\sigma_{TOF} = 2.5$
- Track cuts
  - #TPC Crossedrow >70(Default) ,60,100
  - $\chi^2/Cluster_{TPC} < 4$(default), 2.3, 3.5
  - $\chi^2/Cluster_{ITS} < 36$(default), 49
  - DCAToVertexZ < 2.0cm(default) 0.2, 1.0

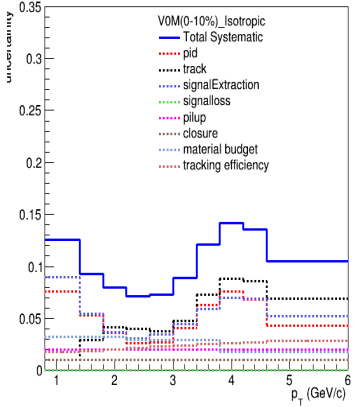
Ungrouped

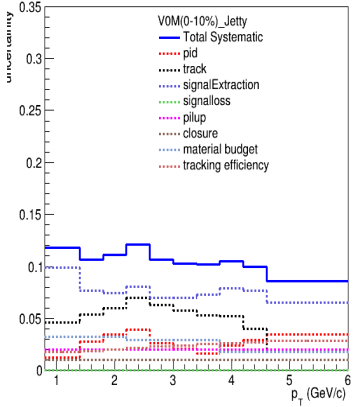
- Material Budget: The systematic uncertainty due to uncertainties in the ALICE material budget is calculated as quadratic sum of daughter particles(kaon and proton) material budget taken form the analysis of Multiplicity dependent of π, K and p production in pp collisions at $\sqrt{s_{NN}} = 13\,TeV$ https://arxiv.org/pdf/2003.02394.pdf
- Signal Loss:- From Proton(default) , Lambda, Xi
- Tracking Efficiency : Global tracking efficiency is taken from https://twiki.cern.ch/twiki/bin/view/ALICE/AliDPGtoolsTrackSystematicUncertaintyBookkeping

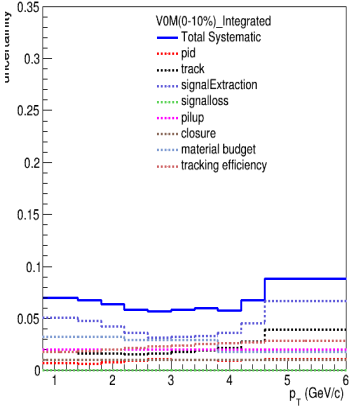
Procedure

- Uncertainties are grouped
- Barlow check
- The RMS values of each subgroups are taken as systematic uncertain ties.
- A smootheing procedure is applied.
- The systematics uncertainities from different sources added in quadrature to obtain the total systematic uncertainty.

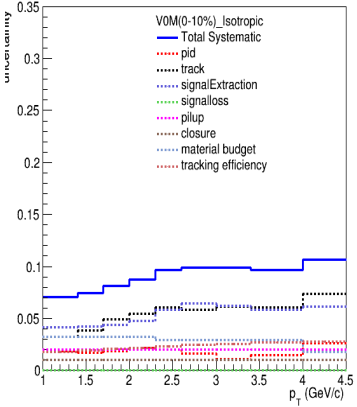
systematics uncertainities(after smoothing) 13TeV(V0M)

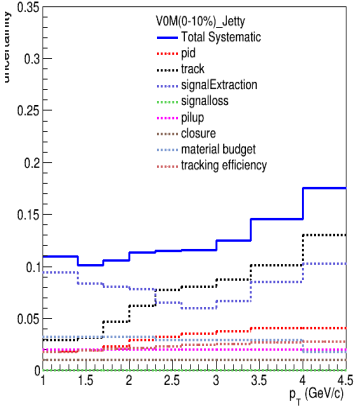


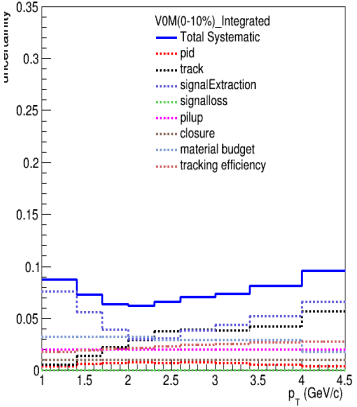




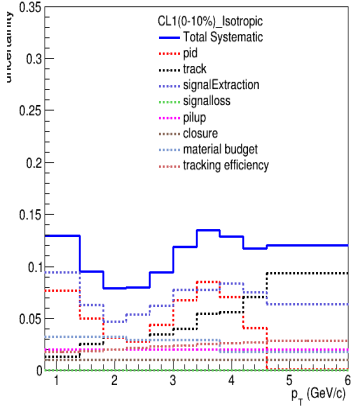
systematics uncertainities(after smoothing) 5.02TeV(V0M)

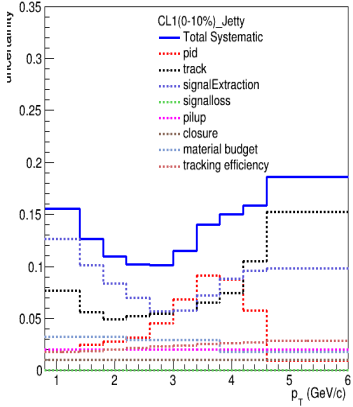


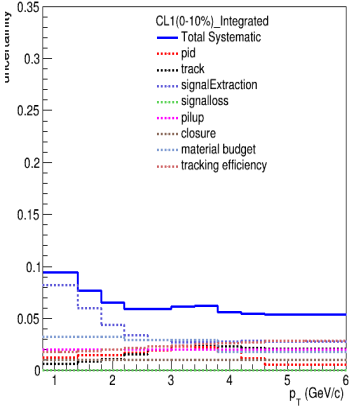




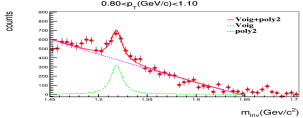
systematics uncertainities(after smoothing) 13TeV(CL1)

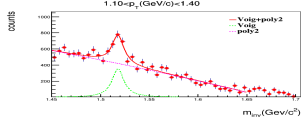


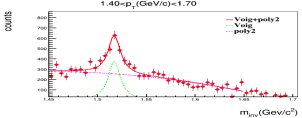


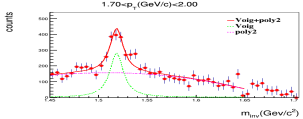


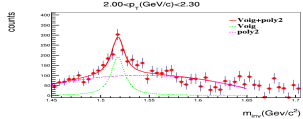
Inv mass 5.02 TeV-0-10%-Jetty

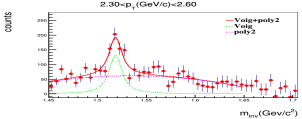


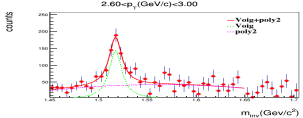


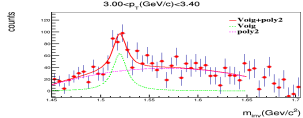


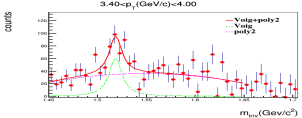


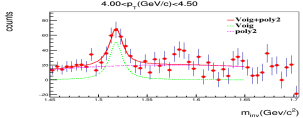




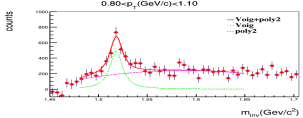


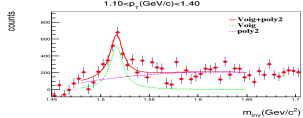


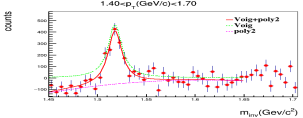


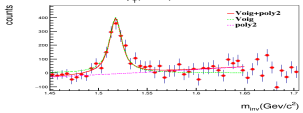


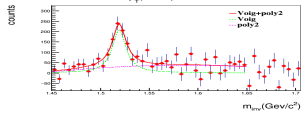
Inv mass 5.02 TeV-0-10%-Isotrophic

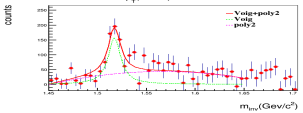


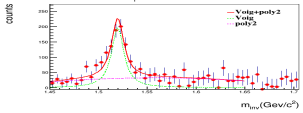


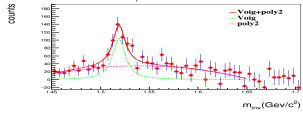


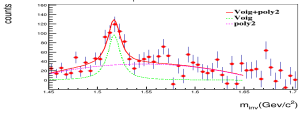


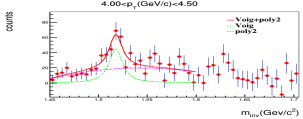




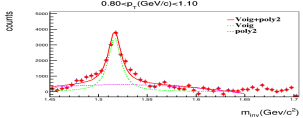


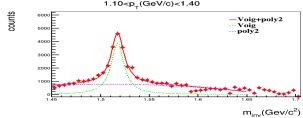


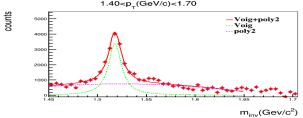


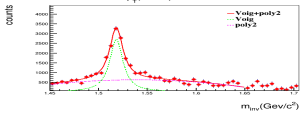


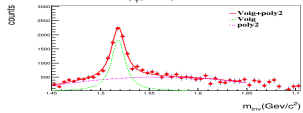
Inv mass 5.02 TeV-0-10%-Integrated

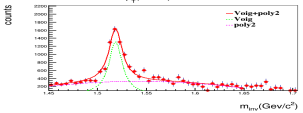


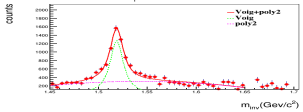


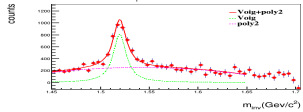


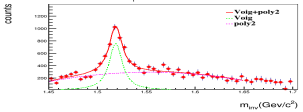


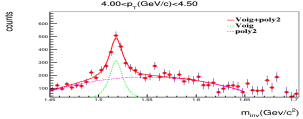




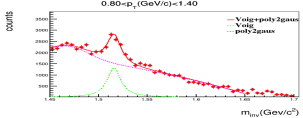


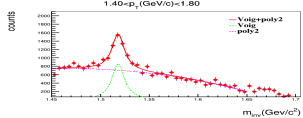


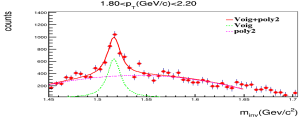


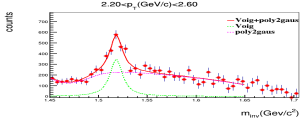


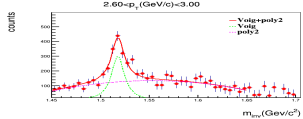
Inv mass 13TeV-0-10%-Jetty

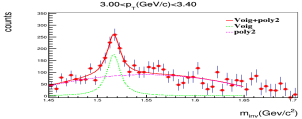


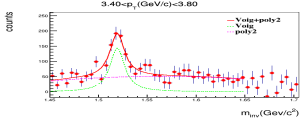


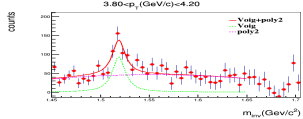


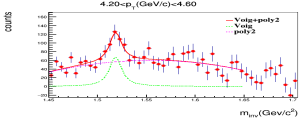


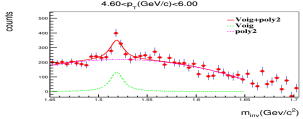




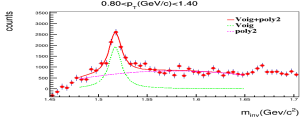


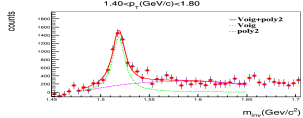


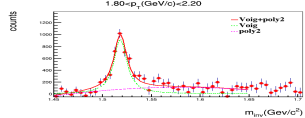


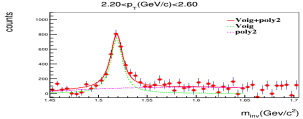


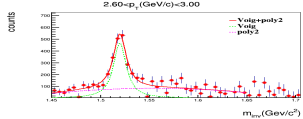
Inv mass 13TeV-0-10%-Isotrophic

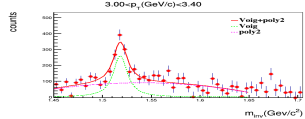


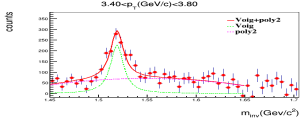


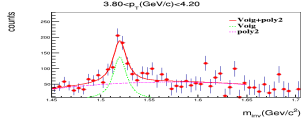


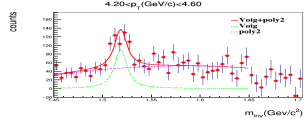


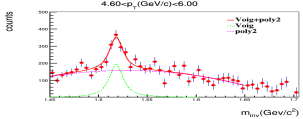




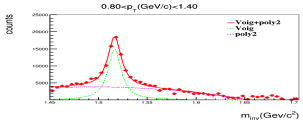


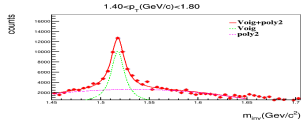


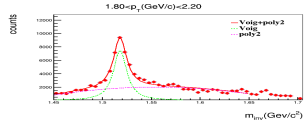


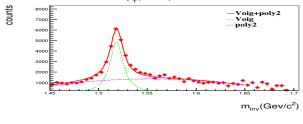


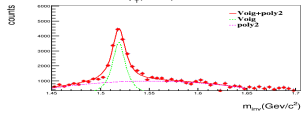
Inv mass 13TeV-0-10%-Integrated

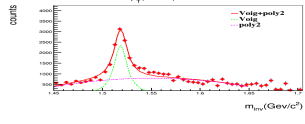


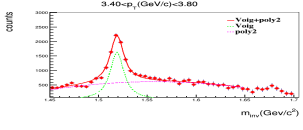


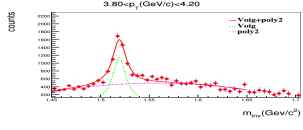


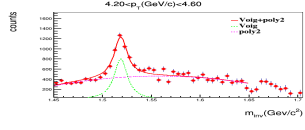


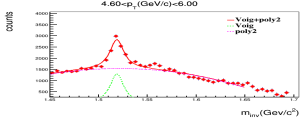




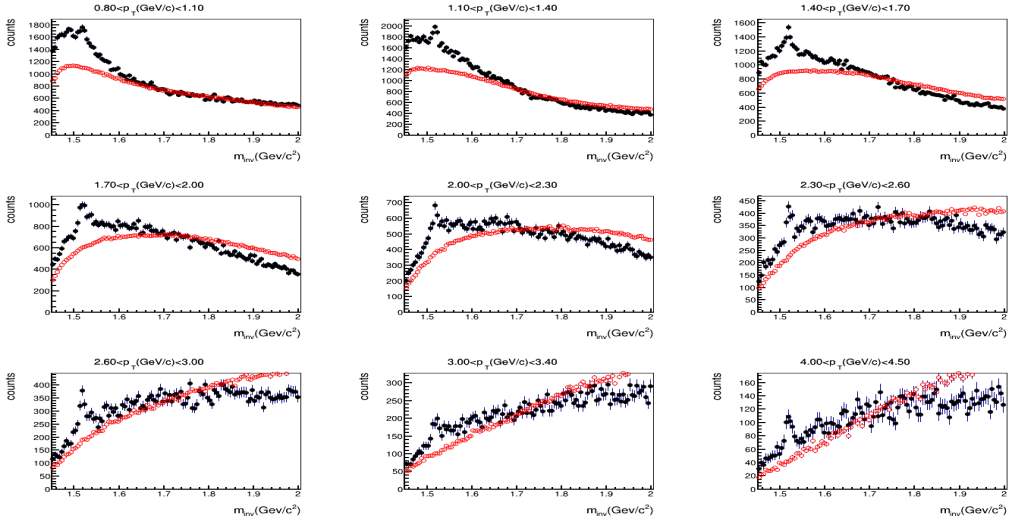




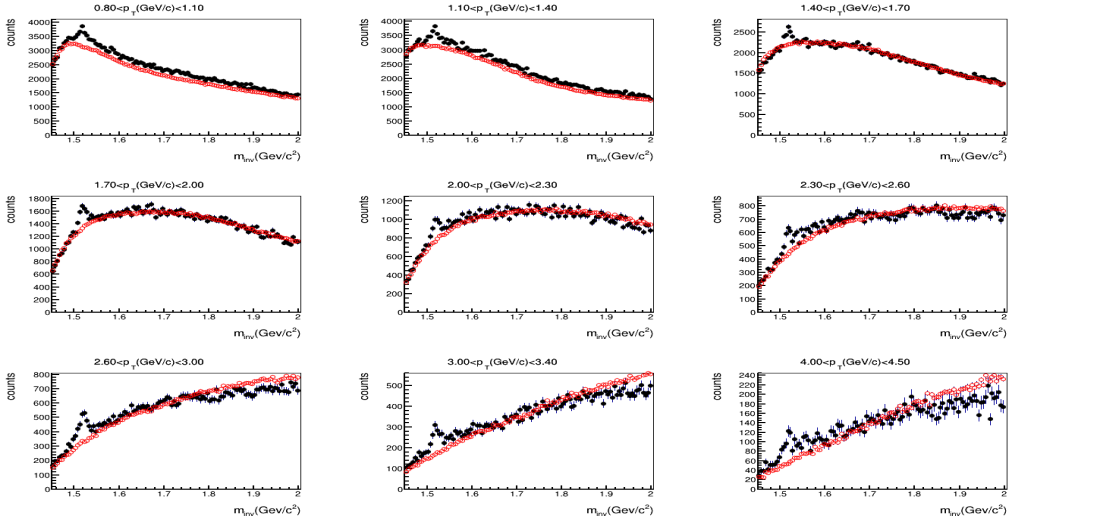




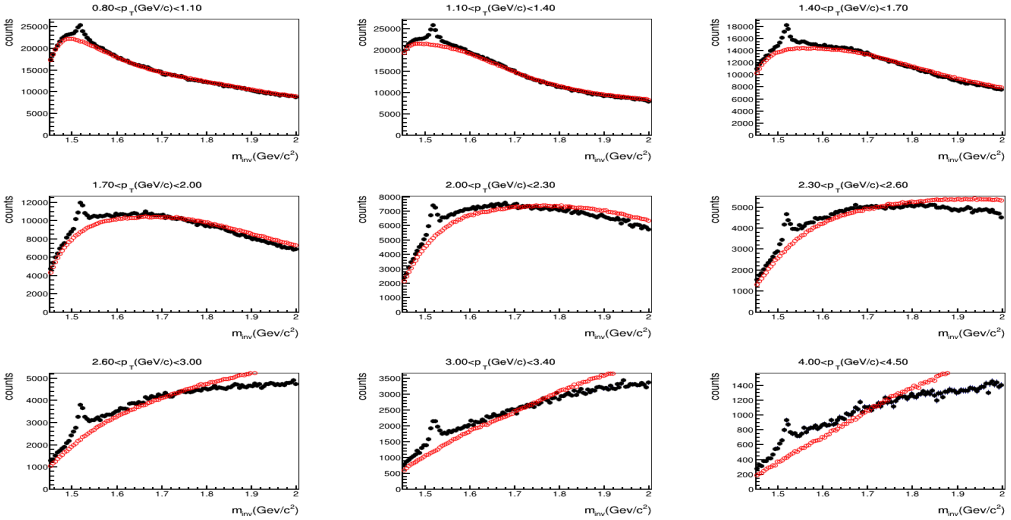
Inv mass 5.02 TeV-0-10%-Jetty



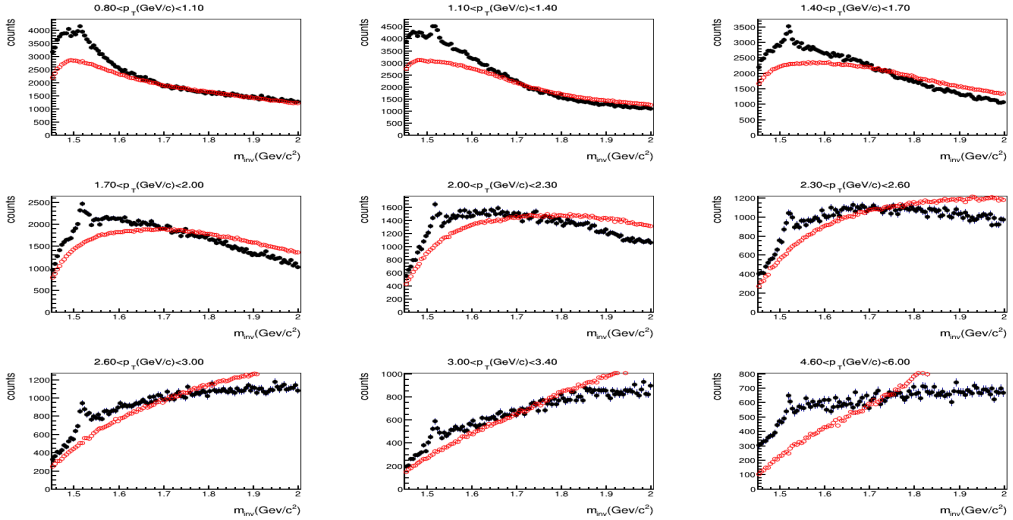
Inv mass 5.02 TeV-0-10%-Isotrophic



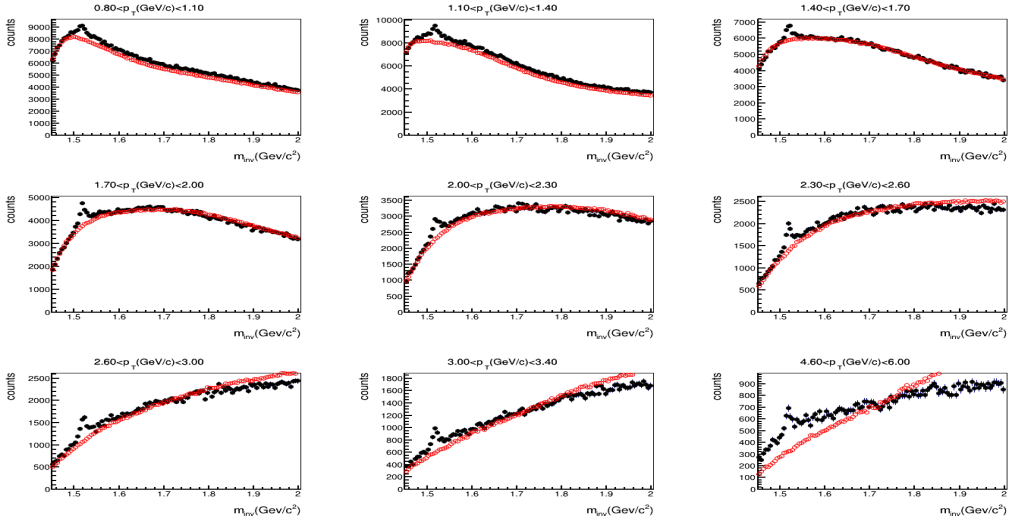
Inv mass 5.02 TeV-0-10%-Integrated



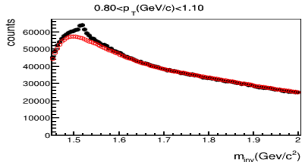
Inv mass 13TeV-0-10%-Jetty

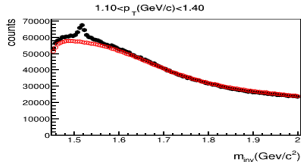


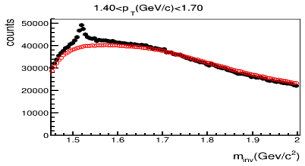
Inv mass 13TeV-0-10%-Isotrophic

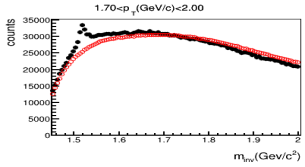


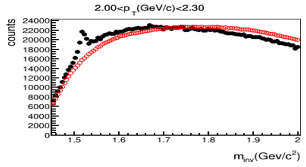
Inv mass 13TeV-0-10%-Integrated

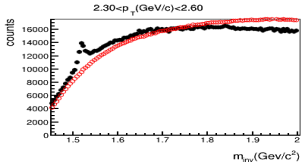


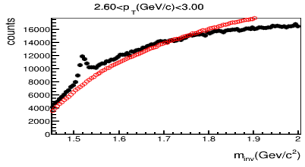


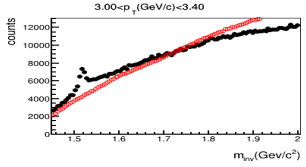


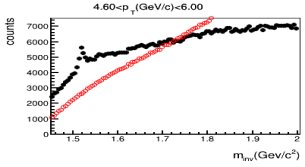




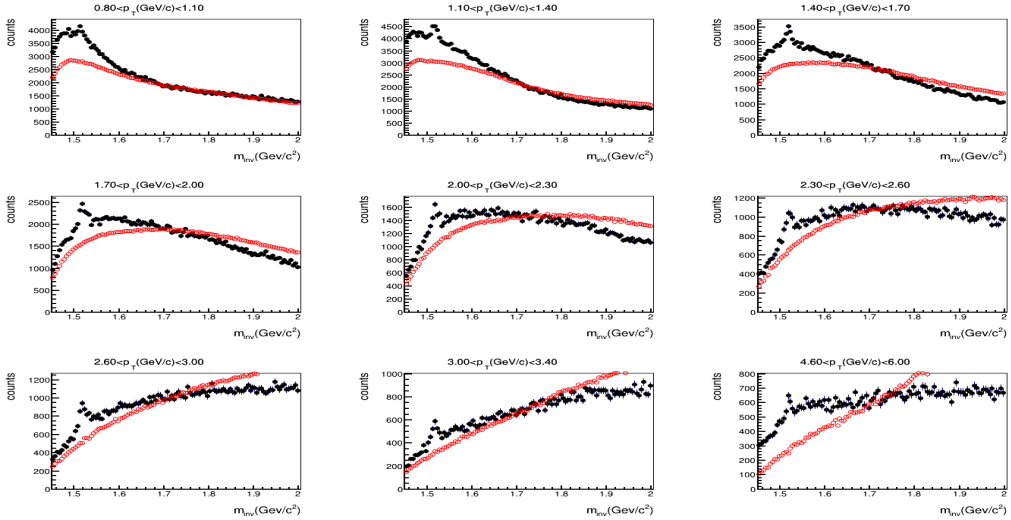




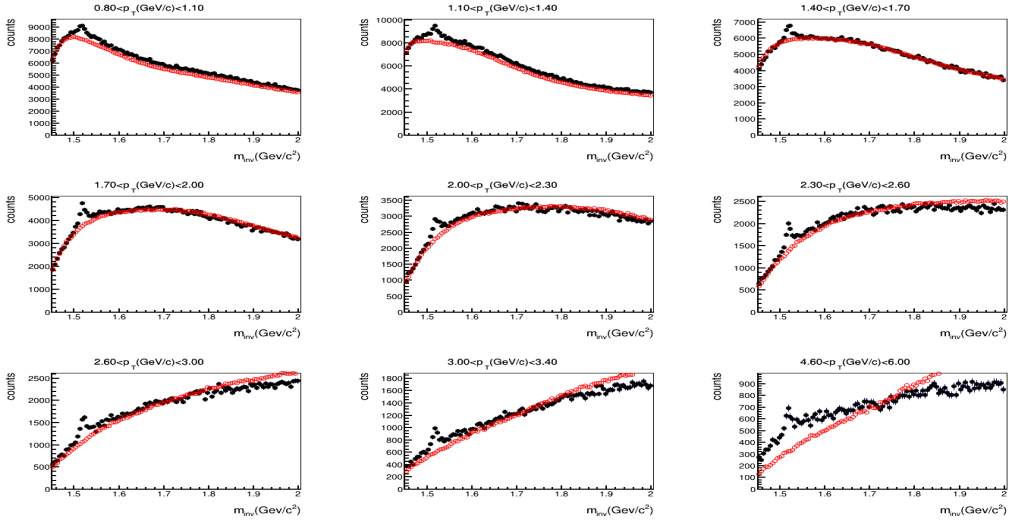




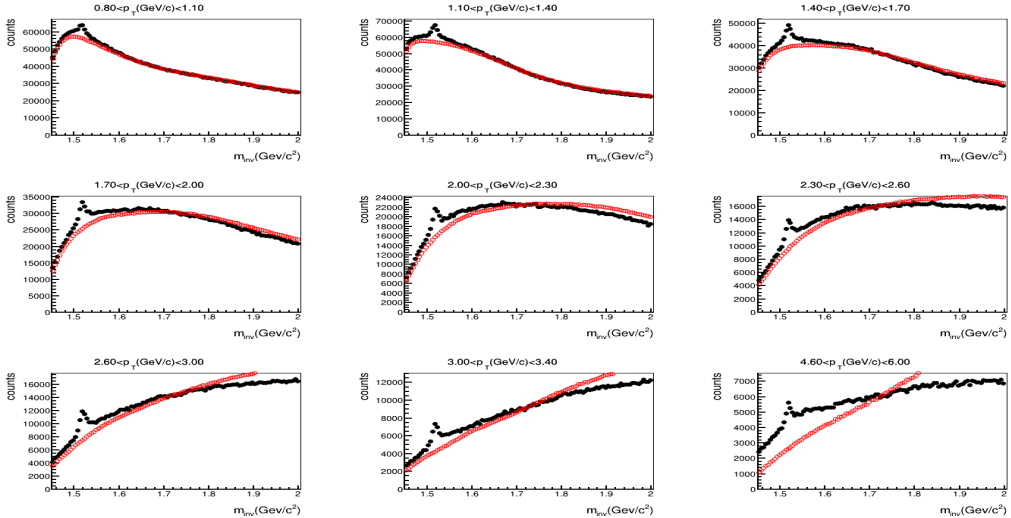
Inv mass 13TeV-0-10%-Jetty (CL1)



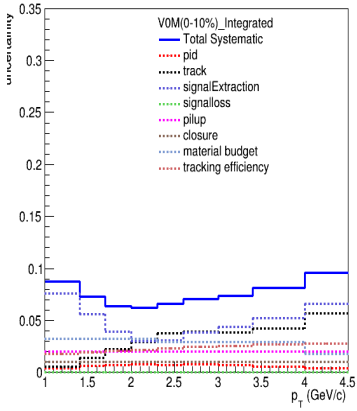
Inv mass 13TeV-0-10%-Isotrophic (CL1)



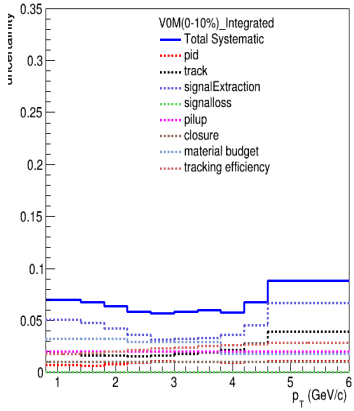
Inv mass 13TeV-0-10%-Integrated (CL1)



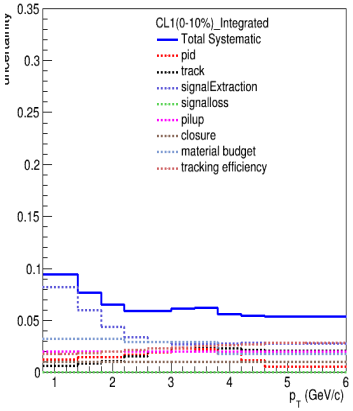
systematics uncertainities(after smoothing)



5.02TeV(V0M)

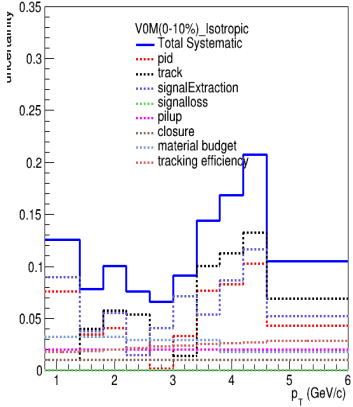


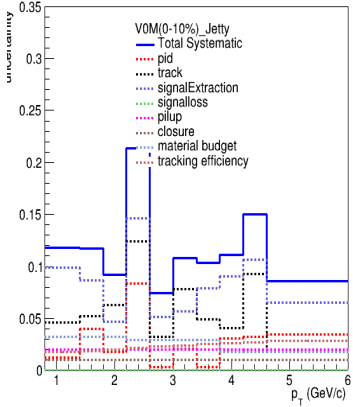
13TeV(V0M)

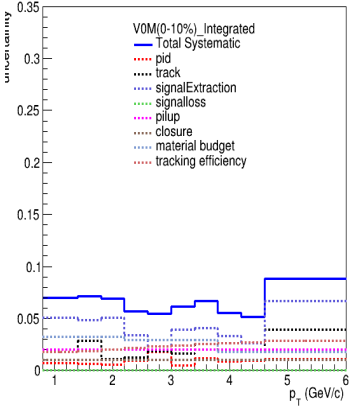


13TeV(CL1)

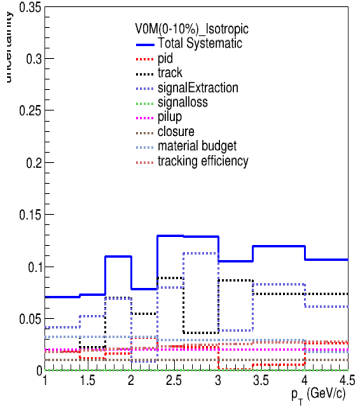
systematics uncertainities 13TeV(V0M)

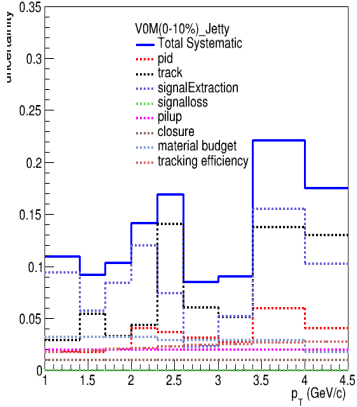


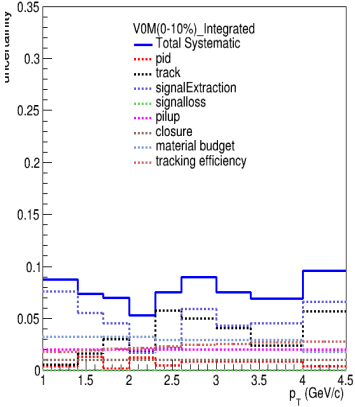




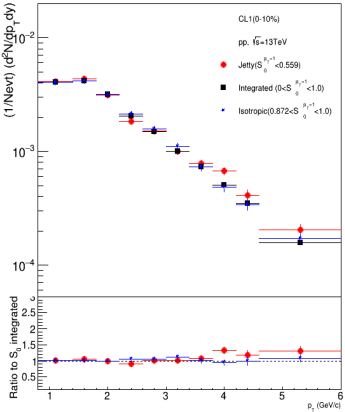
systematics uncertainities 5.02TeV(V0M)





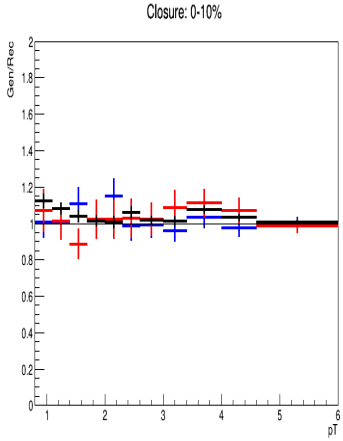


Raw spectra 13TeV(0-10%) CL1

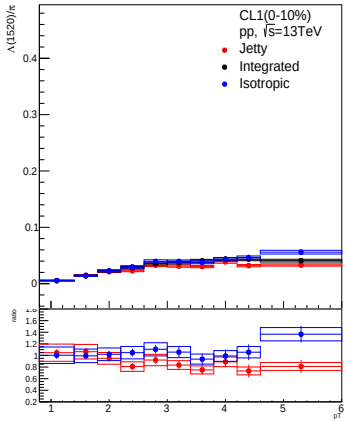


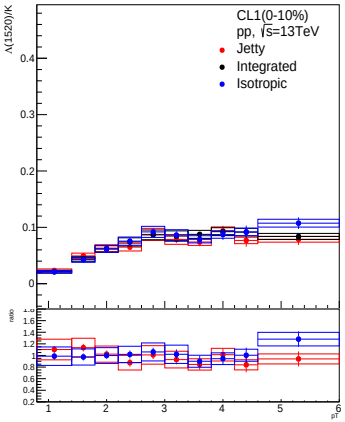
- Multiplicity, pT, Spherocity bin selection: did you correct for detector effects? How are you going to compare with theory?

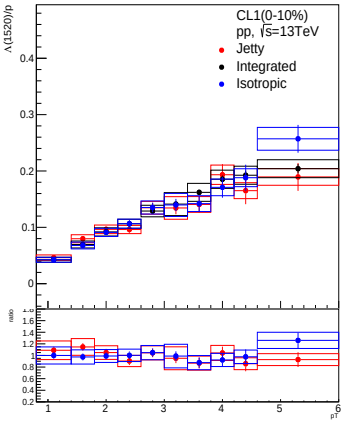
closure test are done to evaluate expermental bias.



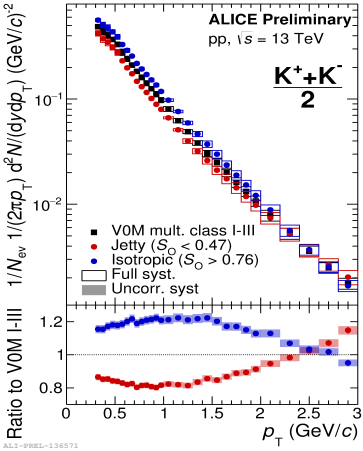
Ratio to Pion, kaon and Proton

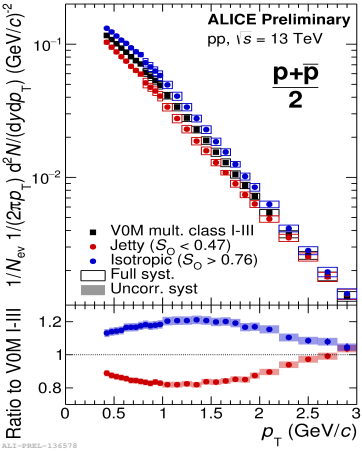


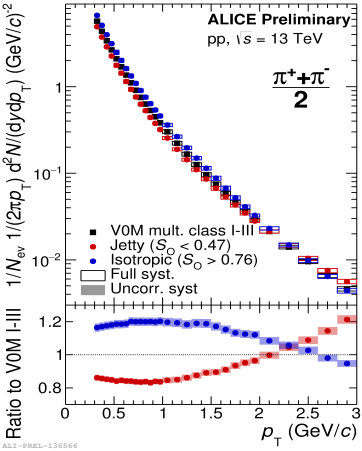




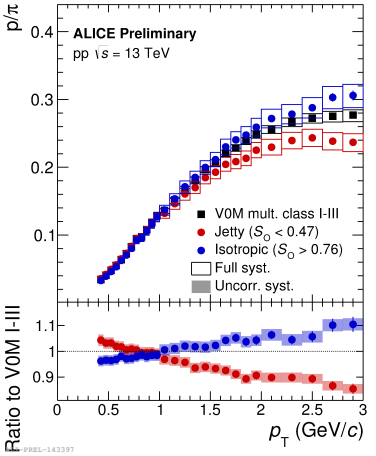
No significance difference on the event shape

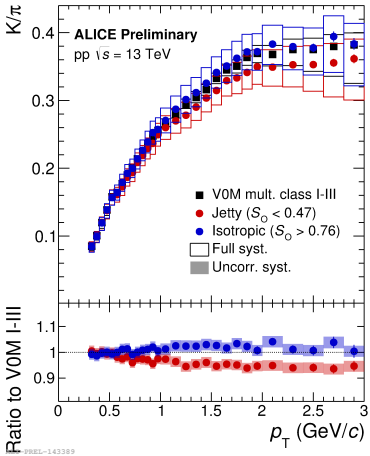

ALICE Preliminary
pp, √s = 13 TeV
K⁺+K⁻
2
V0M mult. class I-III
Jetty (S_O < 0.47)
Isotropic (S_O > 0.76)
Full syst.
Uncorr. syst
1/N_ev 1/(2πp_T) d²N/(dydp_T) (GeV/c)^-2
Ratio to V0M I-III
p_T (GeV/c)
ALI-PREL-136571

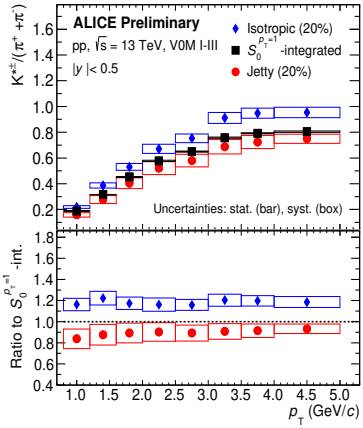

ALICE Preliminary
pp, √s = 13 TeV
p+p̄
2
V0M mult. class I-III
Jetty (S_O < 0.47)
Isotropic (S_O > 0.76)
Full syst.
Uncorr. syst
1/N_ev 1/(2πp_T) d²N/(dydp_T) (GeV/c)^-2
Ratio to V0M I-III
p_T (GeV/c)
ALI-PREL-136578


ALICE Preliminary
pp, √s = 13 TeV
π⁺+π⁻
2
V0M mult. class I-III
Jetty (S_O < 0.47)
Isotropic (S_O > 0.76)
Full syst.
Uncorr. syst
1/N_ev 1/(2πp_T) d²N/(dydp_T) (GeV/c)^-2
Ratio to V0M I-III
p_T (GeV/c)
ALI-PREL-136566

Particle ratio







Particle ratio