First Look at Resonance Production in pp and Pb-Pb Collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

A.K. Dash, R.S. Guleria, C. Jena, B. Mohanty and H. Neog

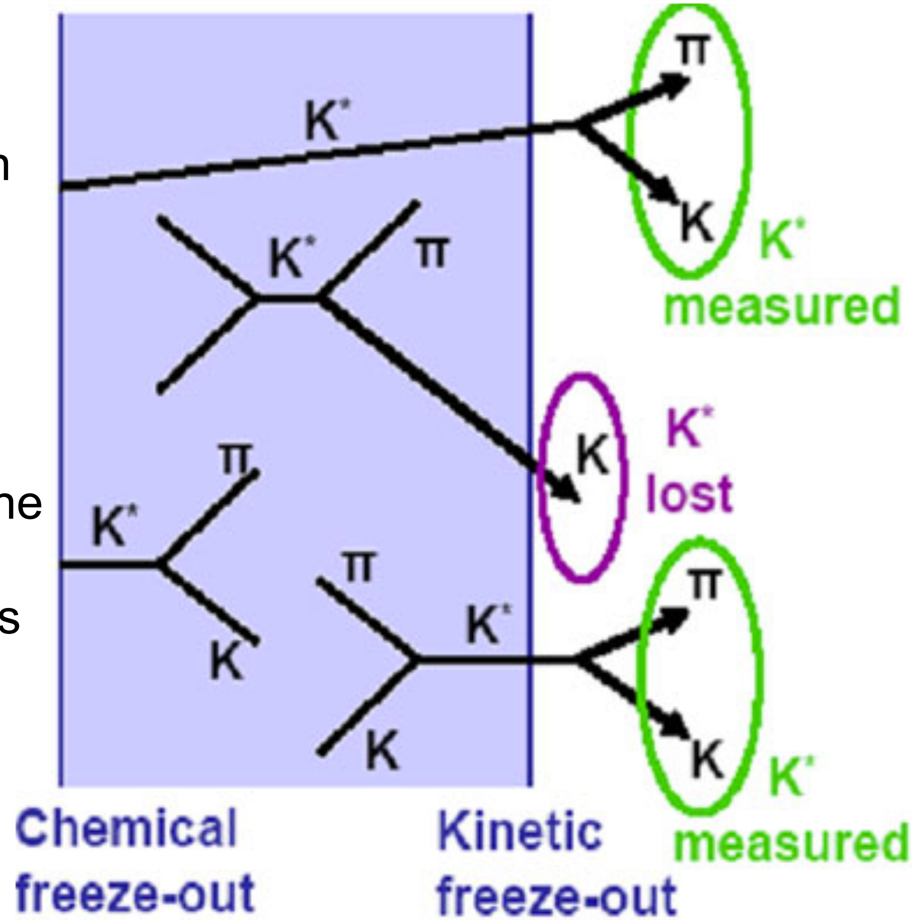
School of Physical Sciences,
National Institute of Science Education and Research, India

Outline

- Introduction
- Resonance Production in pp Collisions at $\sqrt{s_{NN}}$ = *5.02 TeV*
  - ✓ Data set and analysis cuts
  - ✓ QA plots
  - ✓ Results:
    - -- Signal extraction, p_T spectra, dN/dy and $\langle p_T \rangle$
- Resonance Production in Pb-Pb Collisions at $\sqrt{s_{NN}}$ = *5.02 TeV*
  - ✓ Data set and analysis cuts
  - ✓ QA plots
  - ✓ Results:
    - -- Signal extraction
- Summary

Why Resonance?

- ✓ Due to short life time **(~ few fm/c)** of resonances, they can be used to study the evolution of the system formed in heavy-ion collisions
- ✓ **Chiral Symmetry Restoration**
  Expect mass shift and width broadening
- ✓ **Particle Production Mechanisms**:
  Hydrodynamics: particle masses determine shapes of p_T spectra
  Recombination: baryon/meson differences in shapes of p_T spectra
- ✓ **In-medium Energy Loss:**
  Study of nuclear modification factor
- ✓ **Properties of Hadronic Phase:**
  Rescattering vs. Regeneration:
  Study of yield, particle ratios, compare resonances with different lifetimes



K^{*0}(892)->Kπ, BR = 66.6%, Lifetime ~4 fm/c
φ(1020)->K^+K^-, BR = 48.9%, Lifetime ~46 fm/c

What We Know?

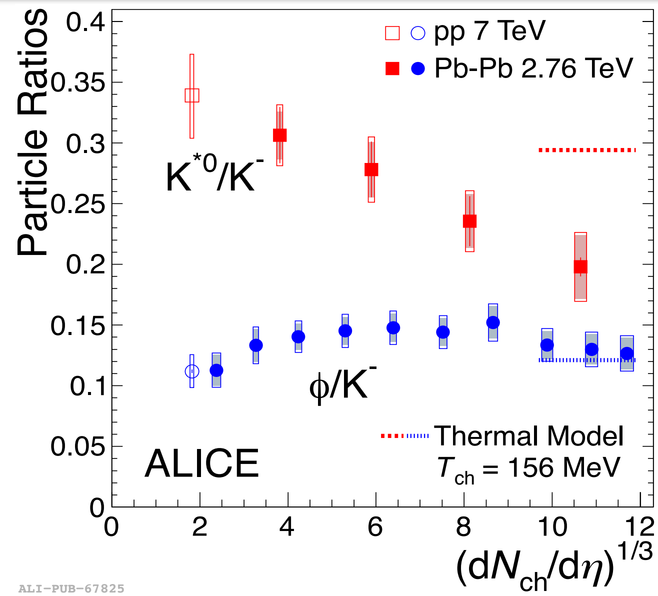
➢ **Rescattering vs. Regeneration:**

✓ K^{*0}/K^{-} ratio is suppressed in the most central Pb-Pb collisions

✓ ϕ/K^{-} ratio does not exhibit a strong centrality dependence

✓ Indicates rescattering of the K^{*0} decay products in the hadronic medium

Phys. Rev. C 91, 024609 (2015)

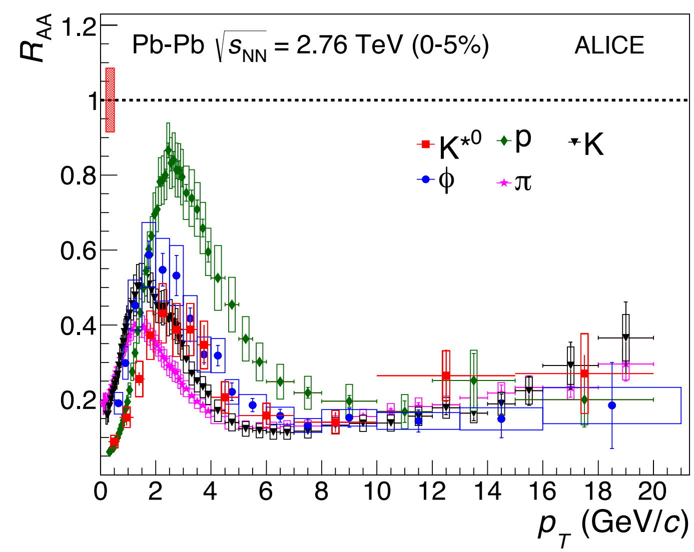


➢ **In-Medium Energy Loss:**

✓ More suppression of K^{*0} than other hadrons at low p_T (consistent with **rescattering**)

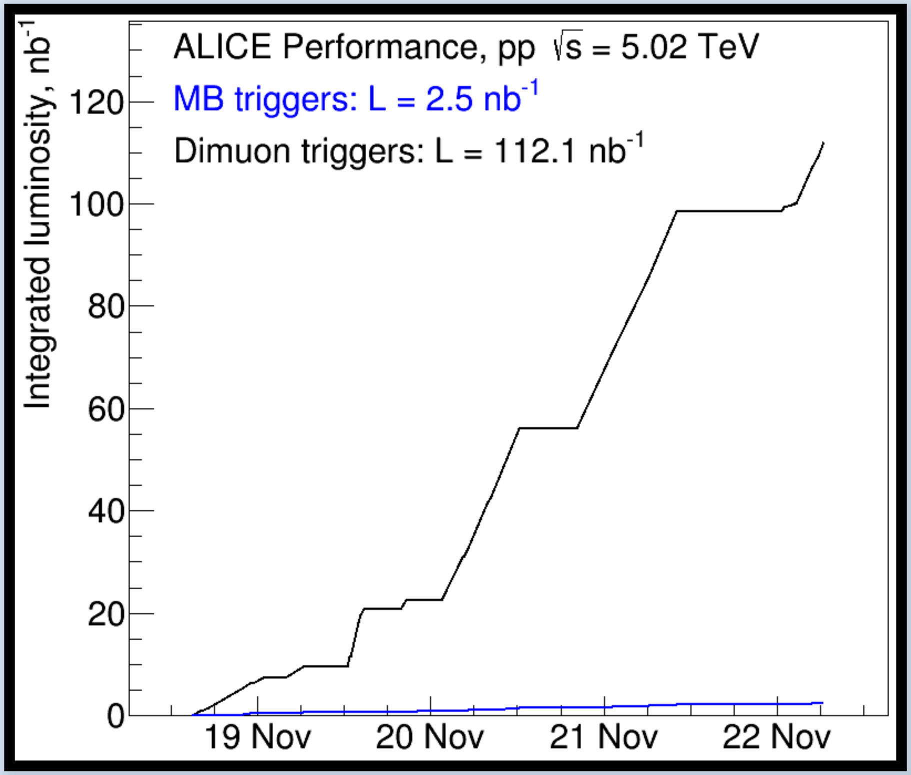
✓ p and ϕ exhibit different trend at intermediate p_T (**recombination?**)

✓ Similar suppression of all hadrons at high p_T (**no flavour dependence**)



Interesting to look at new (run-II) data for pp and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

Resonance Production in pp Collisions at $\sqrt{s_{NN}}$ = 5.02 TeV



Data Set & Analysis Cuts

❑ Data: pp @ 5.02 TeV

Period: LHC15n (ESD, pass1)
Trigger: INT7
Run No.: 244340, 244343, 244351, 244355, 244359, 244364, 244377
244369 244374 244375 (No TOF)
Number of events: **~24.1 M** (|Vz| < 10 cm)

❑ MC: pp @ 5.02 TeV

Period: LHC15l1b (ESD)
Trigger: INT7
Run No.: 244340 244351
Number of events: **~2.0 M**

❑ Single Track Cuts: StandardITSTPCTrackCuts2011()

- $p_T > 0.15$ GeV/c
- $|\eta| < 0.8$
- $|(DCA)_z| < 2.0$ cm
- $|(DCA)_{XY}| < (0.0105+0.0350/p_T^{1.1})$
- TPC and ITS refits
- Minimum number of clusters in SPD = 1
- Number of cross rows in TPC > 70
- CrossedRowsOverFindableClusters > 0.8
- TPC χ^2 per cluster < 4
- ITS χ^2 per cluster < 36
- Reject kink daughters

✓|Pair Rapidity| < 0.5

❑ PID:

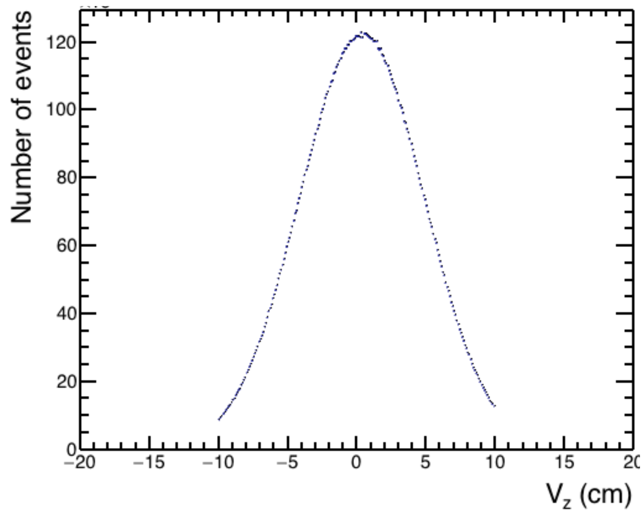
For ϕ: $|n\sigma_K| < 3.0$ in TPC
For K^{*0}: $|n\sigma_{\pi, K}| < 2.0$ in TPC
$|n\sigma_{\pi, K}| < 3.0$ in TOF as Veto

❑ Event Mixing:

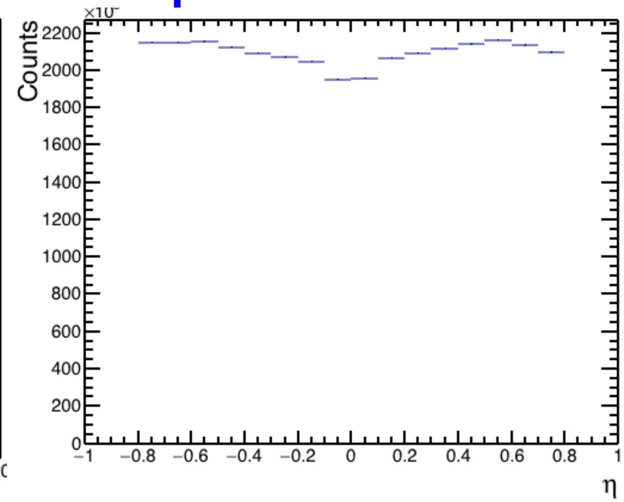
Number of events mixed: 5
Vertex-Z bins: 20 ($-10 < V_z < 10$ cm)
Multiplicity bin: 5

QA plots

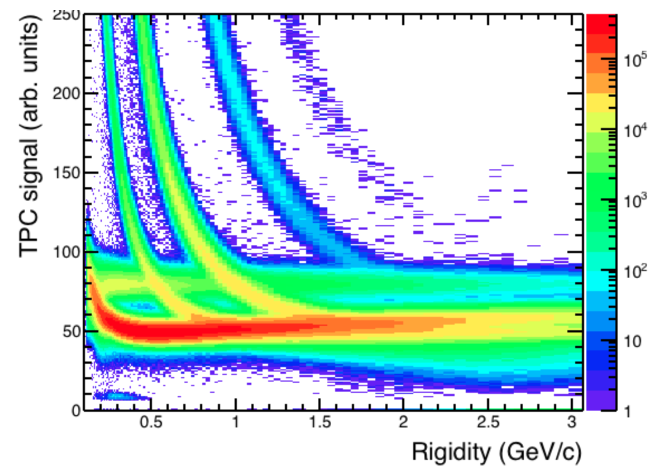
Vertex Z distribution



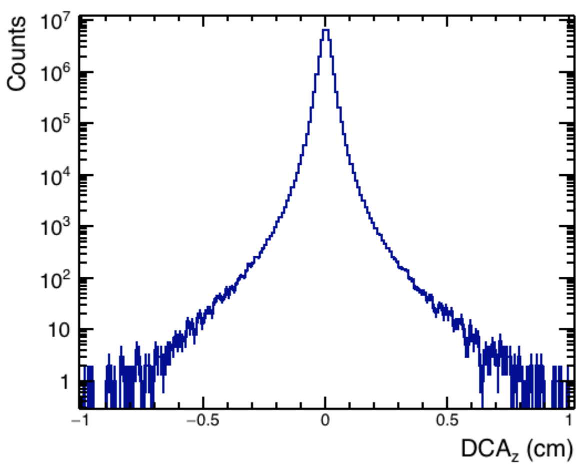
η distribution



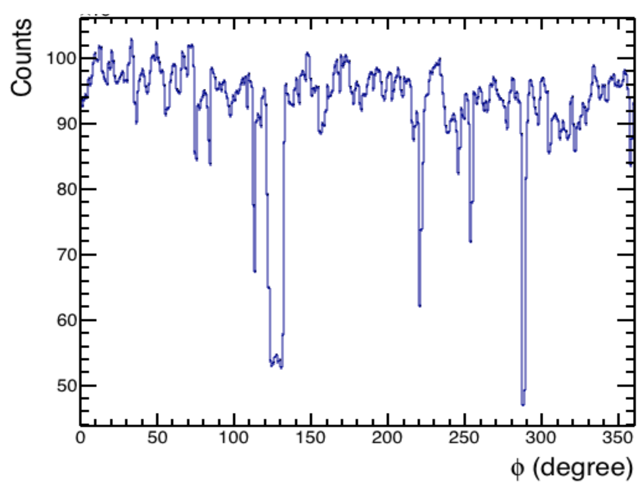
dE/dx vs. Rigidity



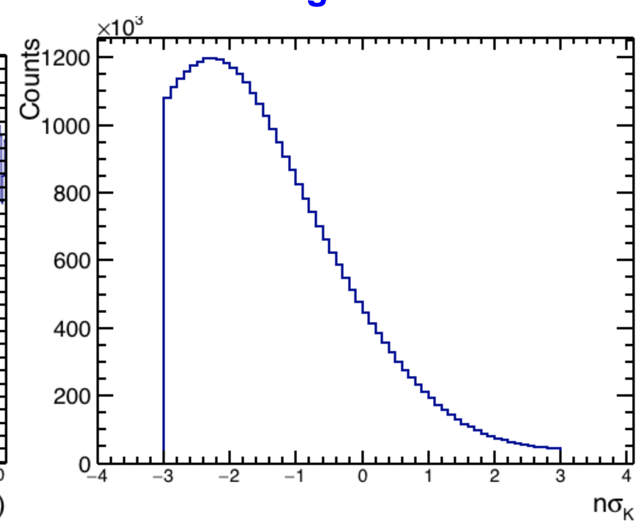
DCA_z distribution



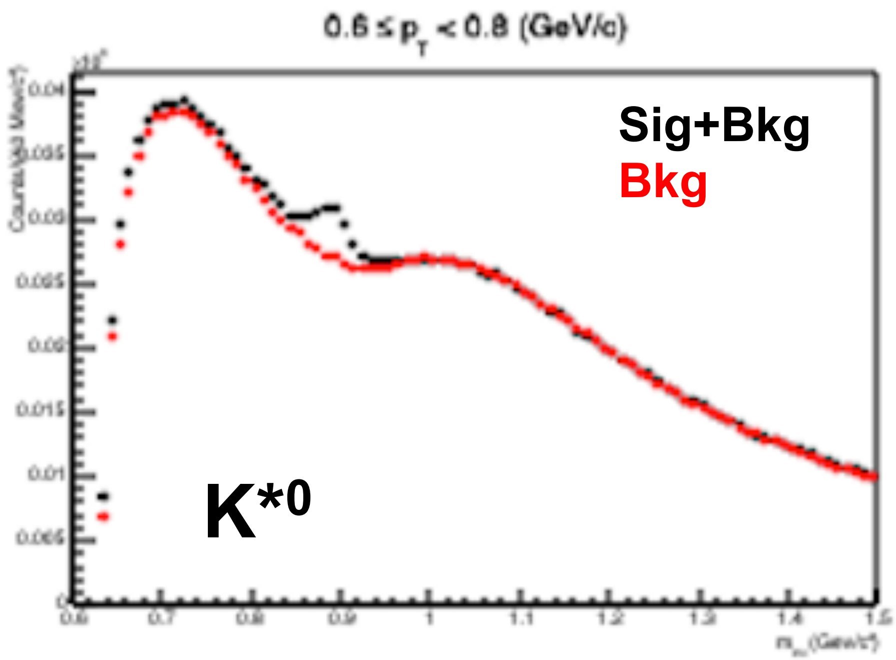
φ distribution

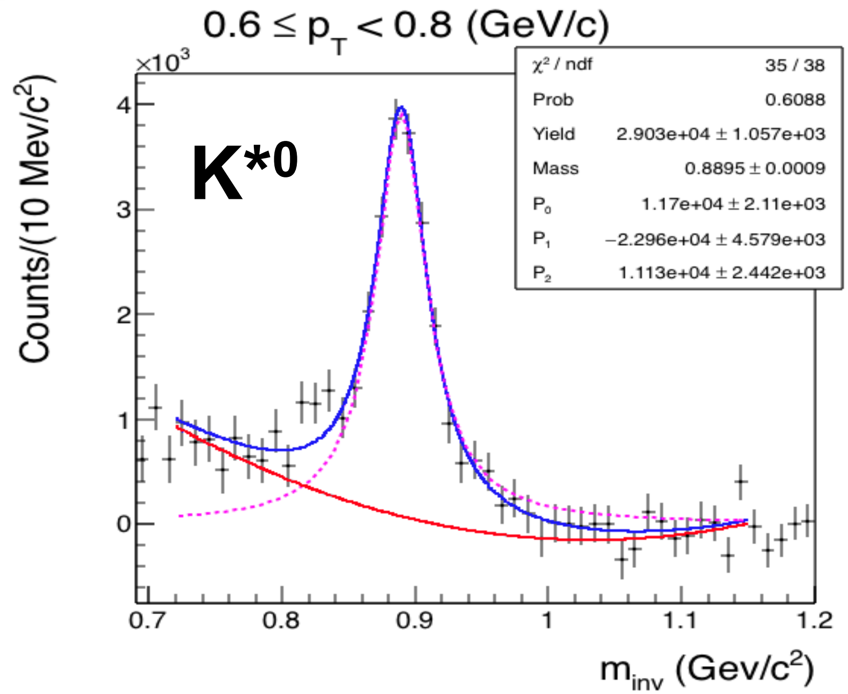


nSigmaKaon



K^{*0} Reconstruction





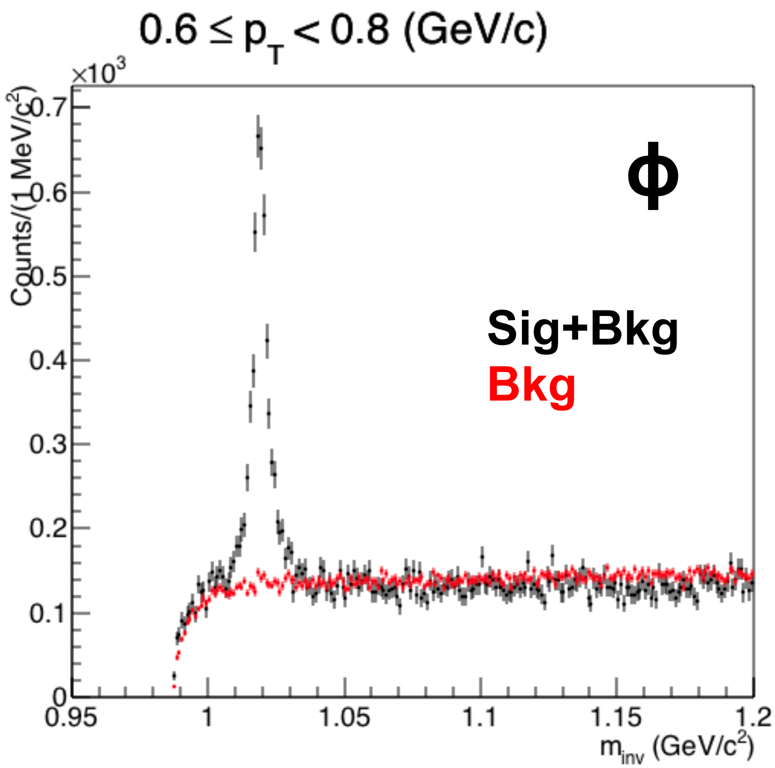
Background Subtraction: Event Mixing
Normalization Range: 1.1 – 1.2 GeV/c^2

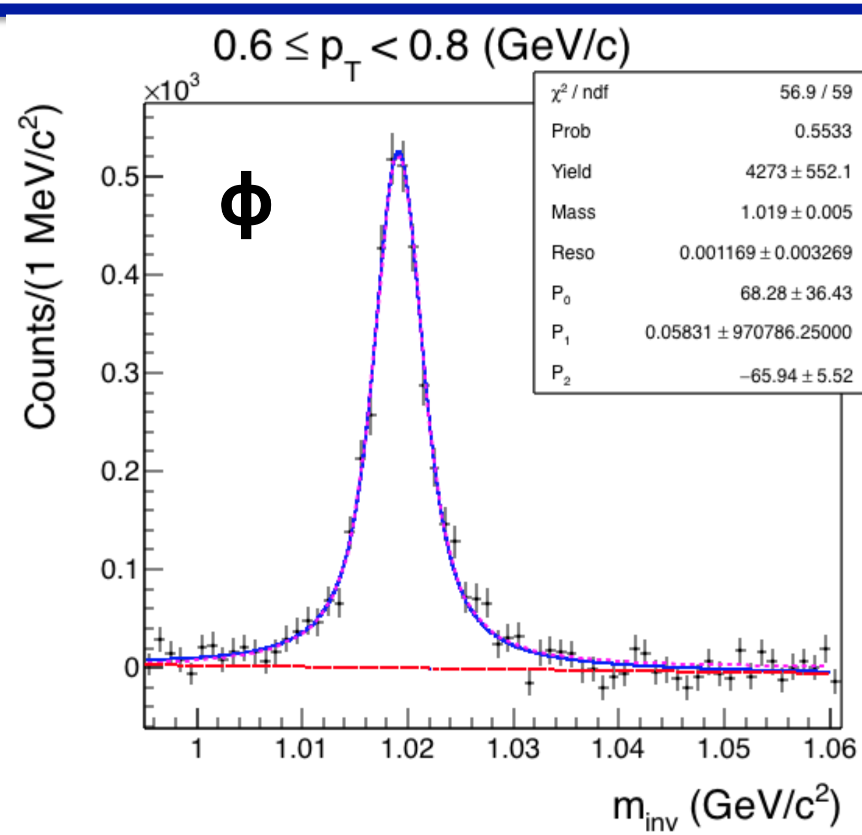
Fit function :

$$\frac{1}{2\pi}\times\frac{Y\Gamma}{\left(M_{inv}-m_0\right)^2+\left(\Gamma/2\right)^2}+p_0M_{inv}^2+p_1M_{inv}+p_2$$

Fit Function: Breit-Wigner for Signal + Pol2 for Residual Background
Fitting Range: 0.72 – 1.15 GeV/c^2
Width fixed to the PDG value

ϕ Reconstruction



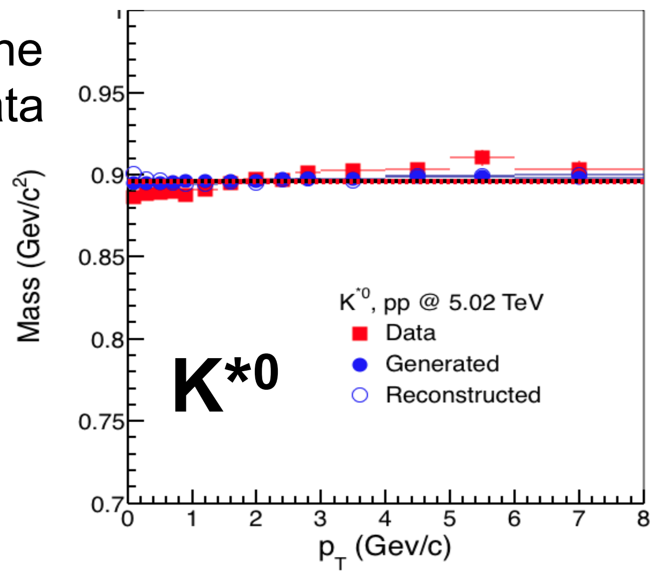


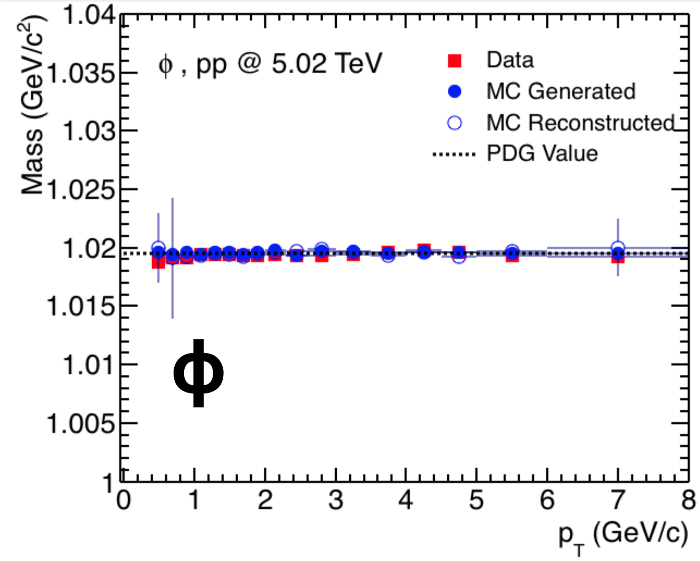
Background Subtraction: Event Mixing
Normalization Range: 1.04 – 1.06 GeV/c^2

Fit Function: Voigtian for Signal + Pol2 for Residual Background
Fitting Range: 0.995 – 1.06 GeV/c^2
Width fixed to the PDG value

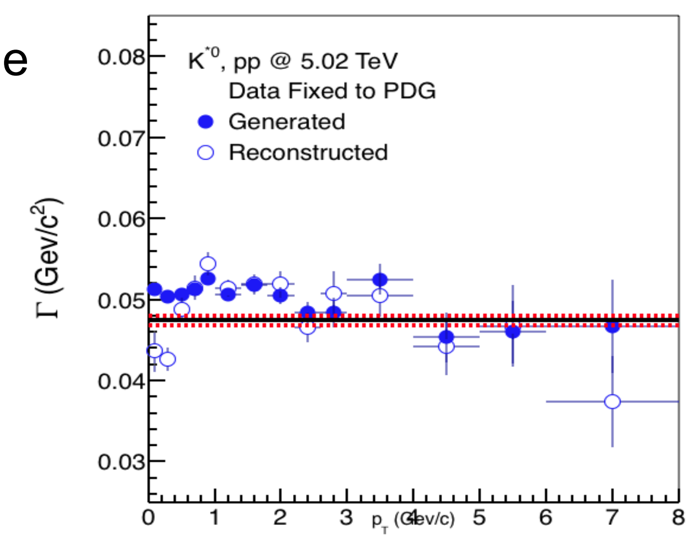
Mass and Width

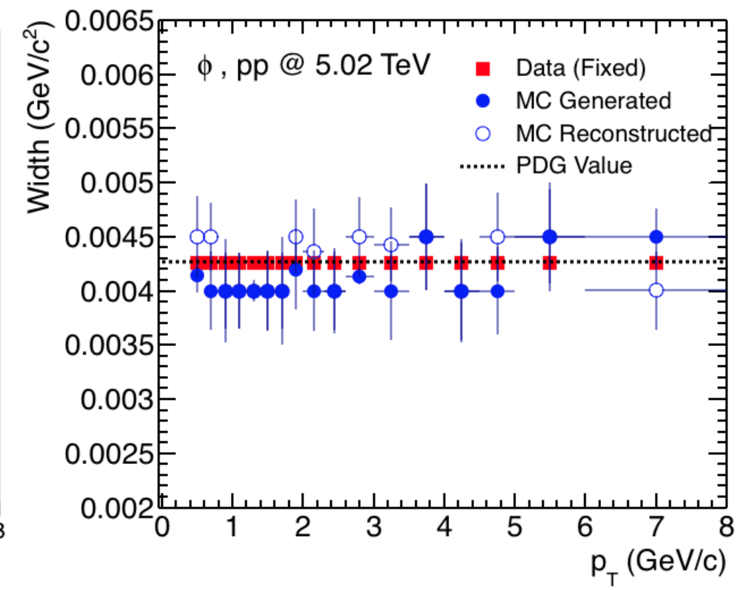
✓ Mass agrees with the PDG value both for data and MC.





✓ Width is fixed to the PDG value in data.

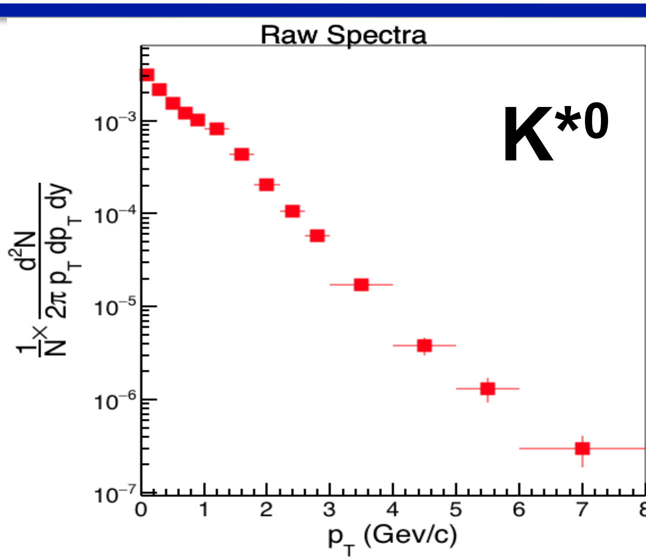


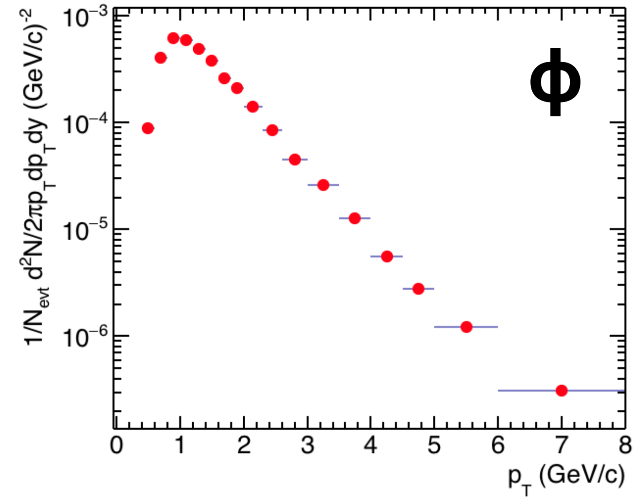


Uncorrected Spectra and Efficiency

Raw Yield:

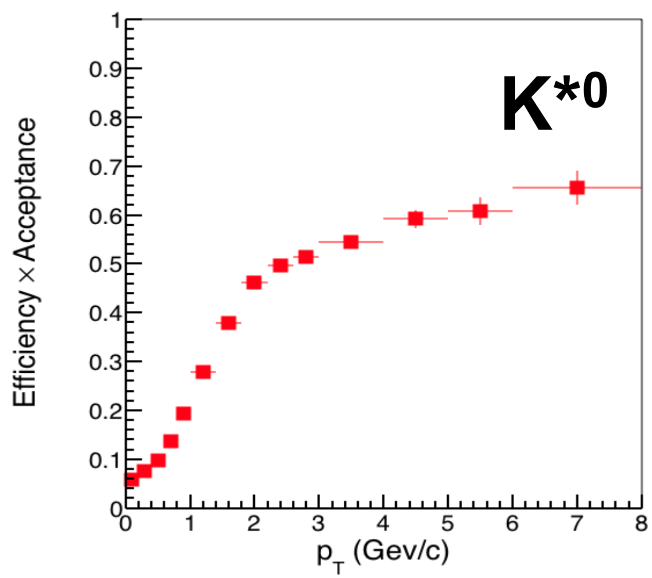
$$\frac{1}{2\pi p_T}\frac{d^2N}{dp_T dy}$$

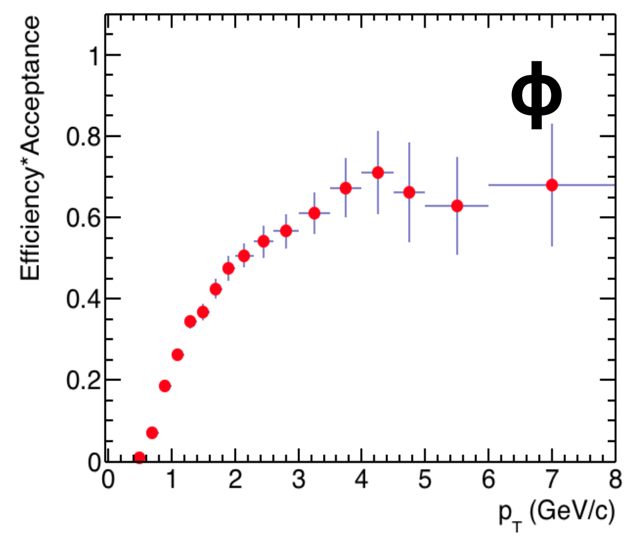




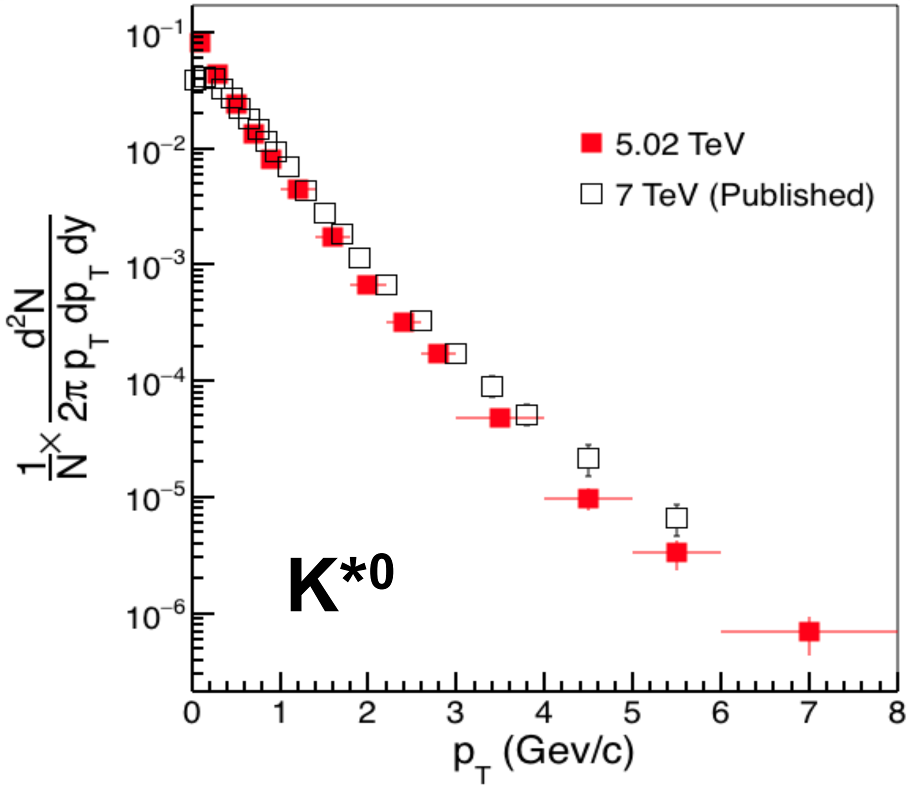
Efficiency x Acceptance

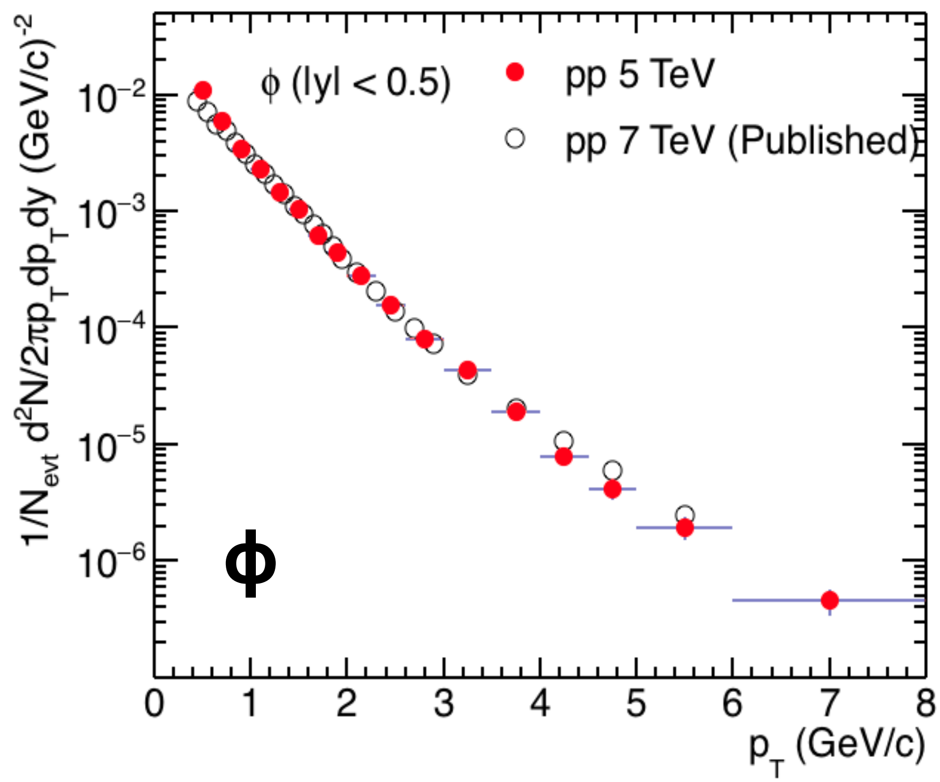
$$= \frac{N_{reconstructed}}{N_{generated}}$$





Corrected Spectra

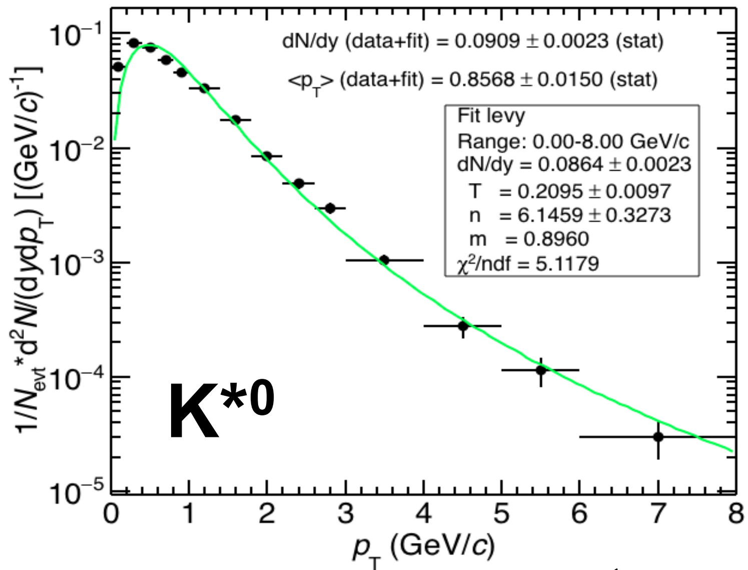


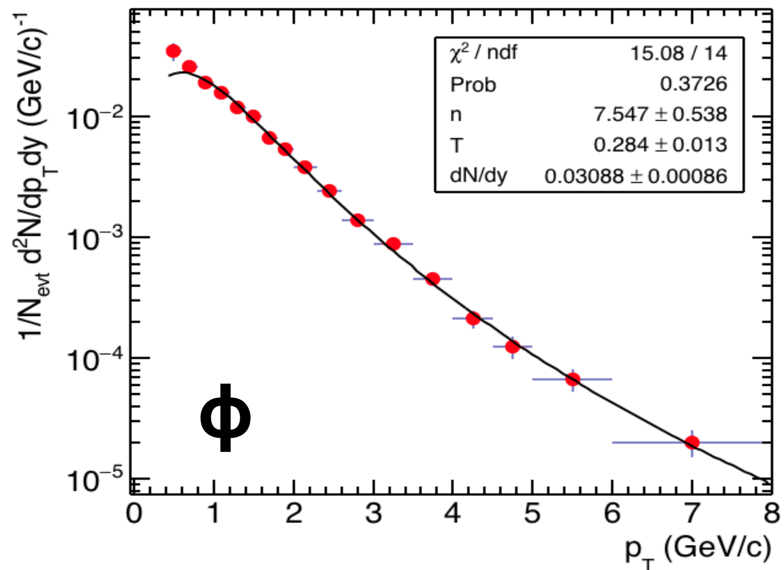


➢ Spectra comparison between 5.02 TeV and 7 TeV look reasonably good.

N.B. Normalized events in pp 5.02 is not corrected for trigger efficiency.
In pp 7 TeV, the trigger selection efficiency for inelastic collisions was 85.2%

dN/dy and $\langle p_T \rangle$





✓ *only statistical errors are shown.*

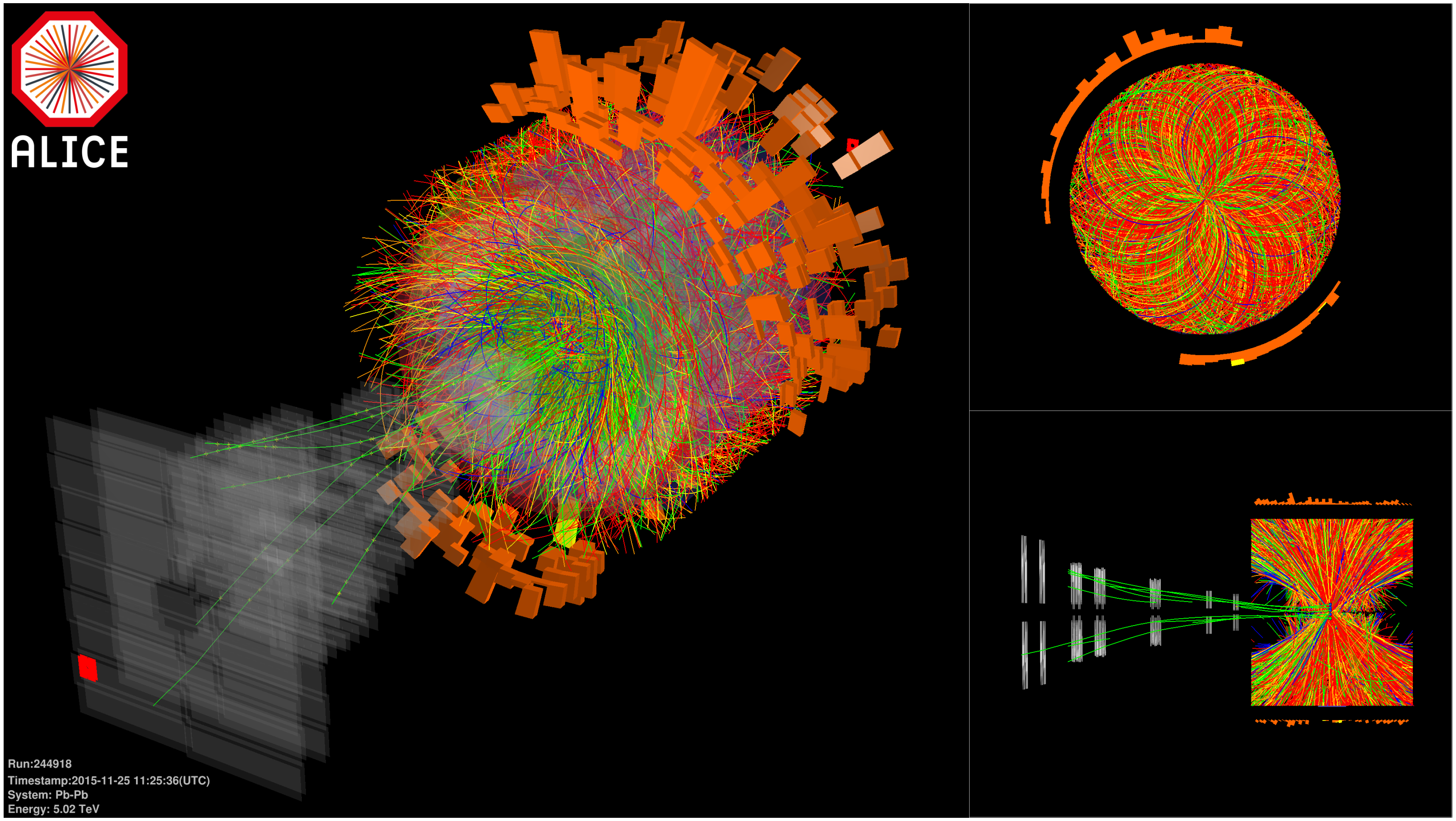
Levy-Tsallis Function:

$$\frac{d^2N}{dp_T dy} = \frac{dN/dy(n-1)(n-2)}{nT(nT+m_0(n-2))} \times p_T \left(1 + \frac{\sqrt{p_T^2 + m_0^2} - m_0}{nT}\right)^{-n}$$

K^{*0}	dN/dy	$\langle p_T \rangle$
5.02 TeV	0.0909 ± 0.0023	0.8568 ± 0.0150
7 TeV	0.097 ± 0.0004	1.01 ± 0.003

ϕ	dN/dy	$\langle p_T \rangle$
5.02 TeV	0.0337 ± 0.0013	1.037 ± 0.0219
7 TeV	0.032 ± 0.0004	1.07 ± 0.005

Resonance Production in Pb-Pb Collisions at $\sqrt{s_{NN}}$ = 5.02 TeV



Data Set & Analysis Cuts

❑ Data: Pb-Pb @ 5.02 TeV

Period: LHC15o (ESD, pass1)
Trigger: INT7
Run No.: **244918** (Golden Run)
Number of events: **~145 k** (|Vz| < 10 cm)

❑ Single Track Cuts: StandardITSTPCTrackCuts2011()

- $p_T > 0.15$ GeV/c
- $|\eta| < 0.8$
- $|(DCA)_z| < 2.0$ cm
- $|(DCA)_{XY}| < (0.0105+0.0350/p_T^{1.1})$
- TPC and ITS refits
- Minimum number of clusters in SPD = 1
- Number of cross rows in TPC > 70
- CrossedRowsOverFindableClusters > 0.8
- TPC χ^2 per cluster < 4
- ITS χ^2 per cluster < 36
- Reject kink daughters

✓|Pair Rapidity| < 0.5

❑ PID:

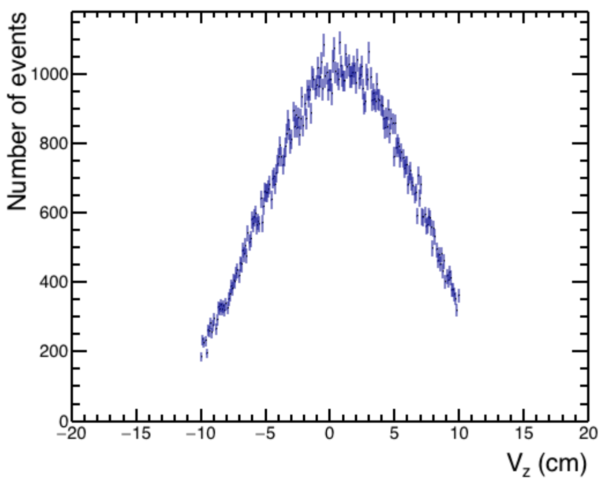
For ϕ: $|n\sigma_K| < 3.0$ in TPC
For K^{*0}: $|n\sigma_{\pi,K}| < 2.0$ in TPC
$|n\sigma_{\pi,K}| < 3.0$ in TOF as Veto

❑ Event Mixing:

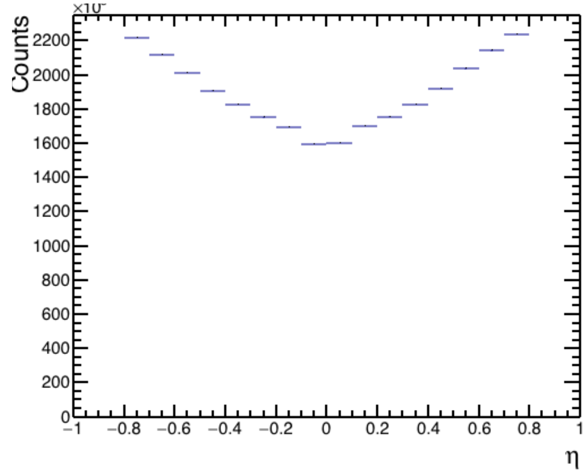
Number of events mixed: 5
Vertex-Z bins: 20 ($-10 < V_z < 10$ cm)
Multiplicity bin: 5

QA plots

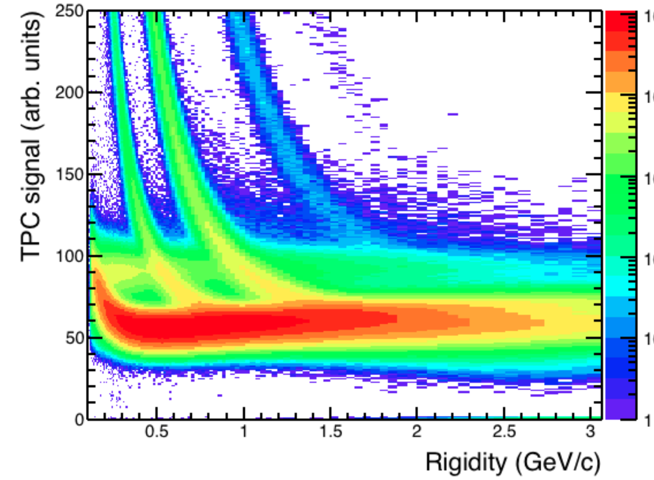
Vertex Z distribution



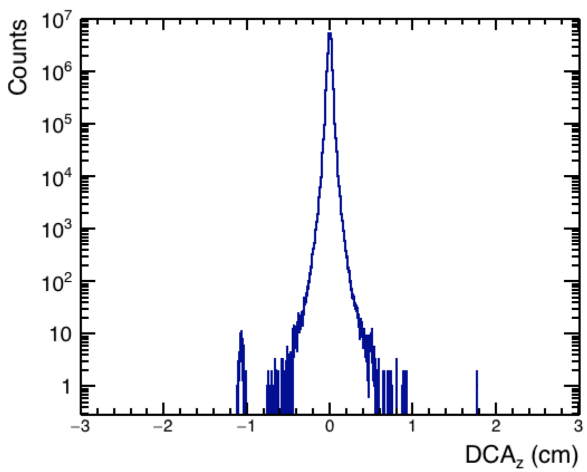
η distribution



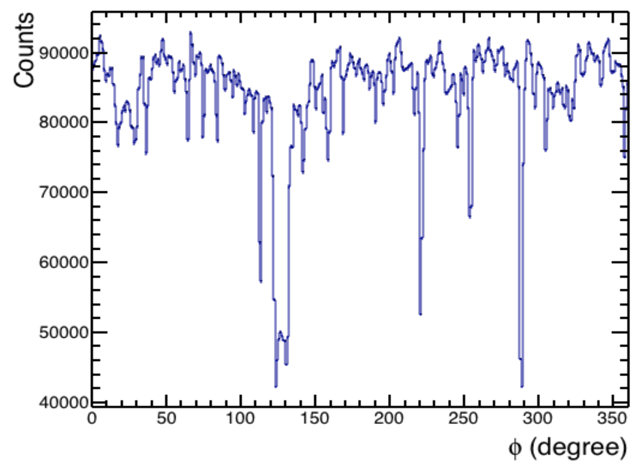
dE/dx vs. Rigidity



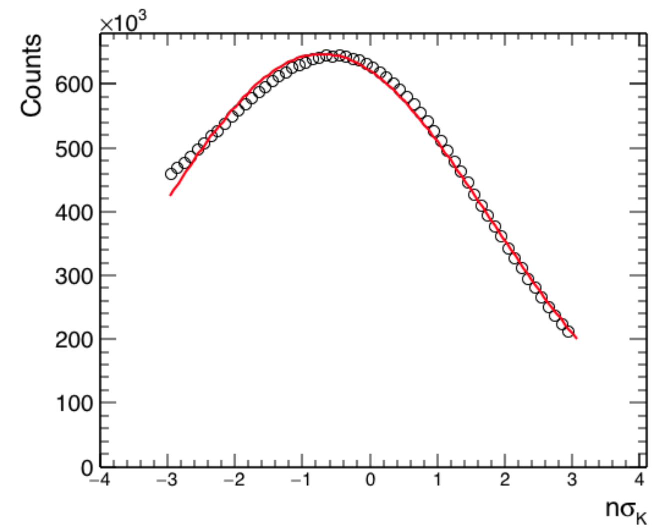
DCA_z distribution



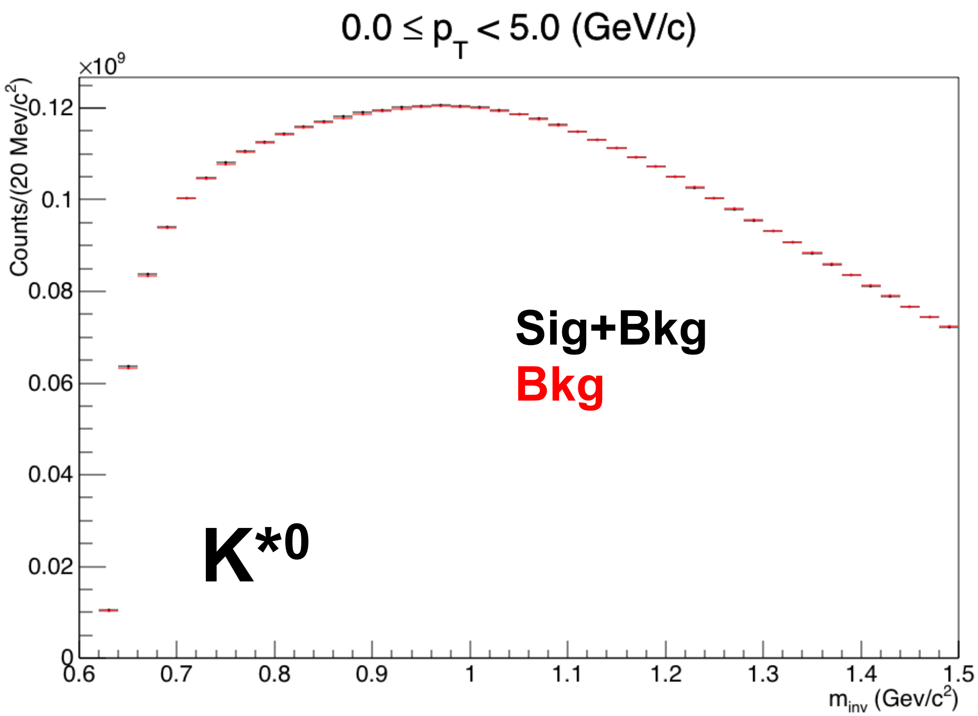
φ distribution

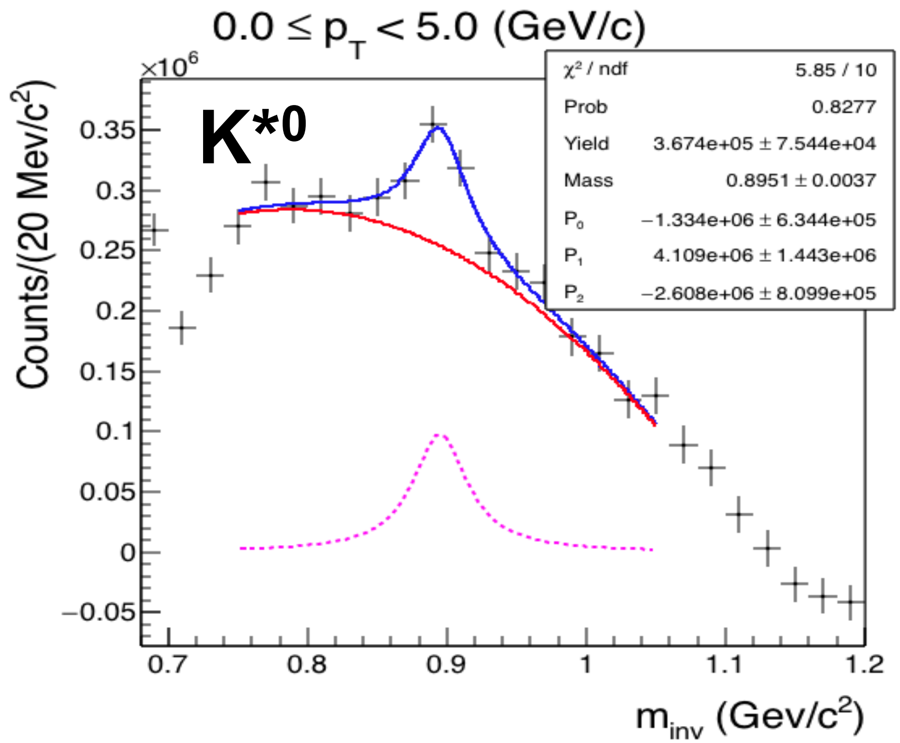


nSigmaKaon



K^{*0} Reconstruction: LS method



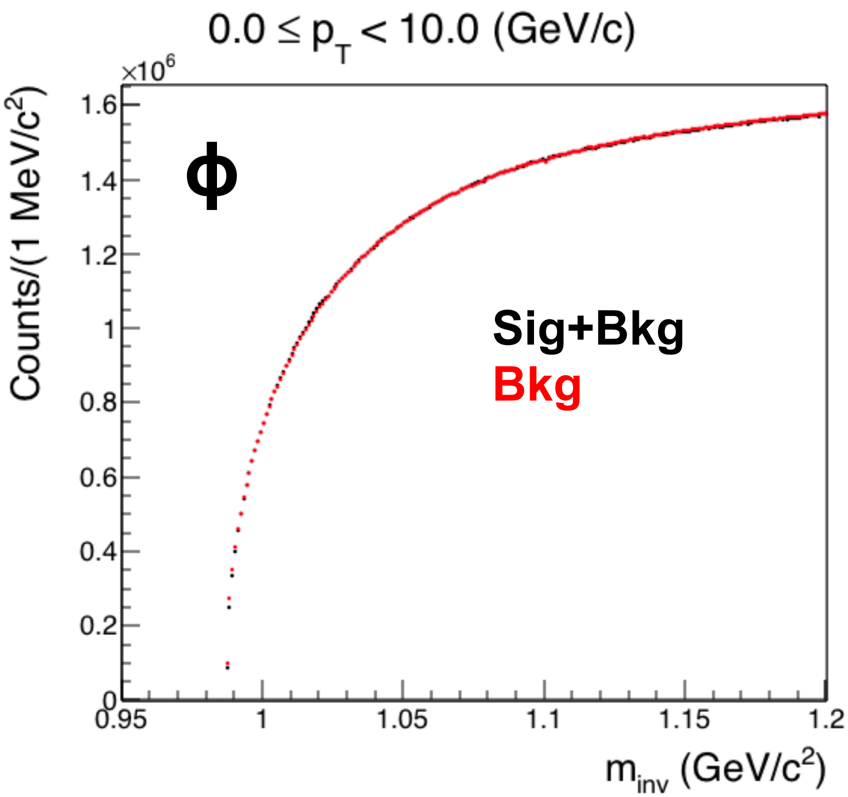


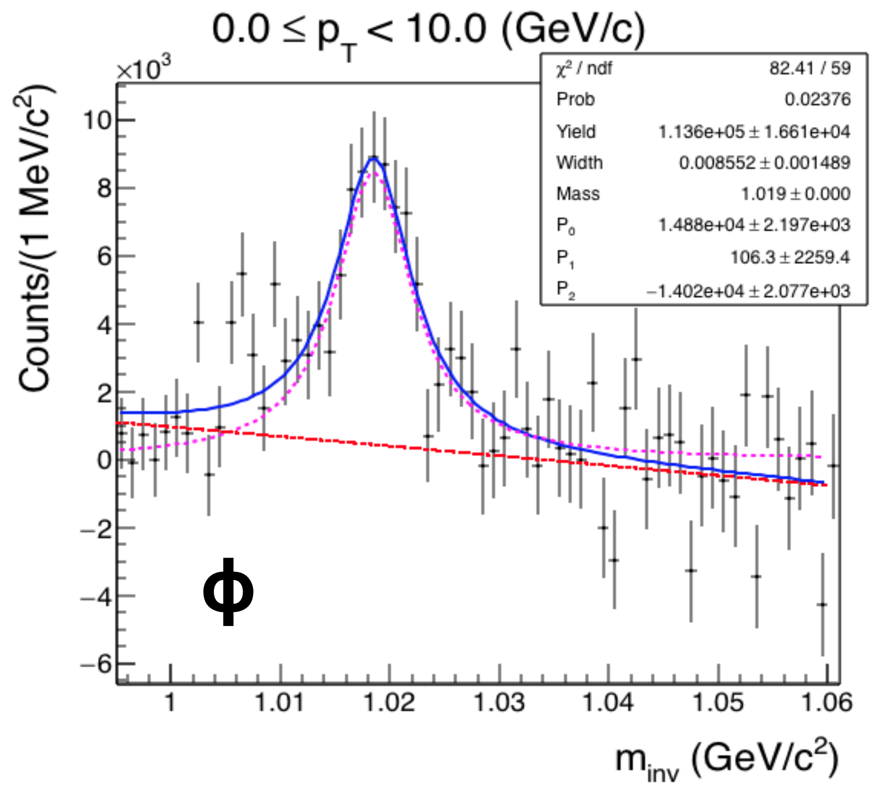
Background Subtraction: Like Sign
Normalization : $2\sqrt{(N^{++})\times(N^{--})}$

Mass = 0.8951 ± 0.0037 GeV/c^2
Width = 47.4 ± 0.6 MeV/c^2 (Fixed)

Fit Function: Breit-Wigner for Signal + Pol2 for Residual Background
Fitting Range: 0.76 – 1.15 GeV/c^2

ϕ Reconstruction: LS method



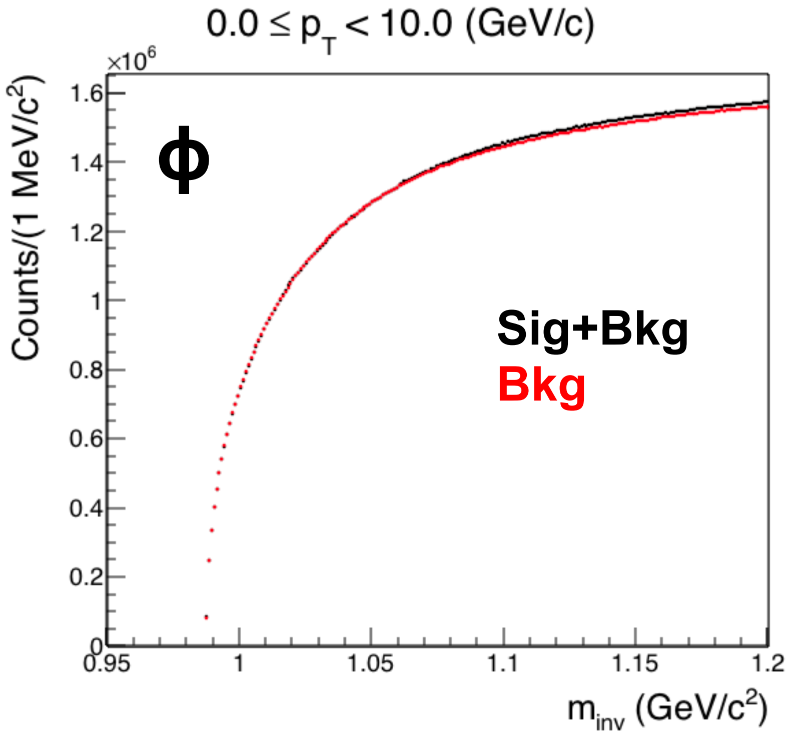


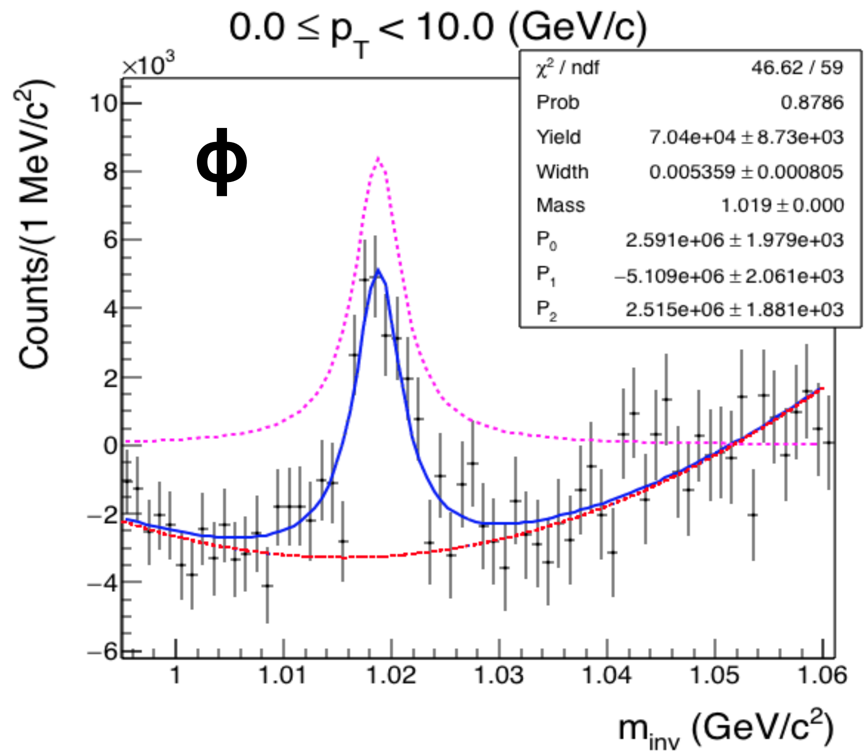
Background Subtraction: Like Sign
Normalization : $2\sqrt{(N^{++})\times(N^{--})}$

Mass = 1.019 ± 0.000 GeV/c^2
Width = 8.55 ± 1.5 MeV/c^2
Significance = 17.2

Fit Function: Breit-Wigner for Signal + Pol2 for Residual Background
Fitting Range: 0.995 – 1.06 GeV/c^2

ϕ Reconstruction: EM method





Background Subtraction: Event Mixing
Normalization Range: 1.04 – 1.06 GeV/c^2

Mass = 1.019 ± 0.000 GeV/c^2
Width = 5.34 ± 0.08 MeV/c^2
Significance = 10.6

Fit Function: Breit-Wigner for Signal + Pol2 for Residual Background
Fitting Range: 0.995 – 1.06 GeV/c^2

Summary

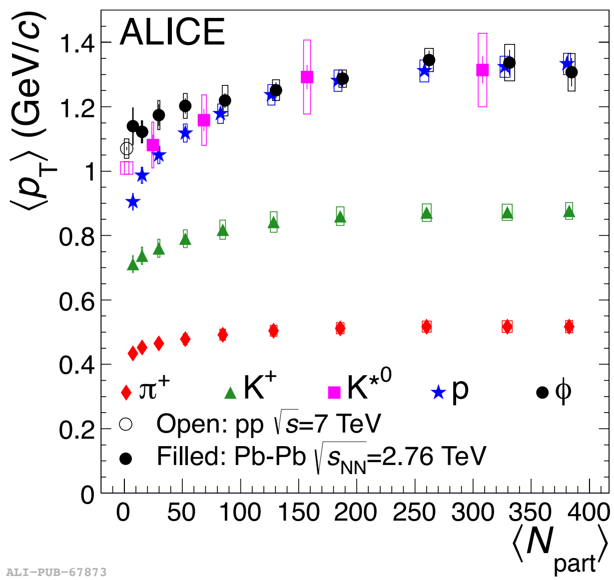
- First look at K^{*0} and ϕ production in pp and Pb-Pb collisions at $\sqrt{s_{NN}}$= 5.02 TeV.
- Corrected spectra have been obtained for K^{*0} and ϕ in pp collisions.
- Initial results look very promising.
- Signals have been extracted in integrated p_T bin in Pb-Pb collisions.
- PID calibration needs improvement in both these datasets.

Outlook:

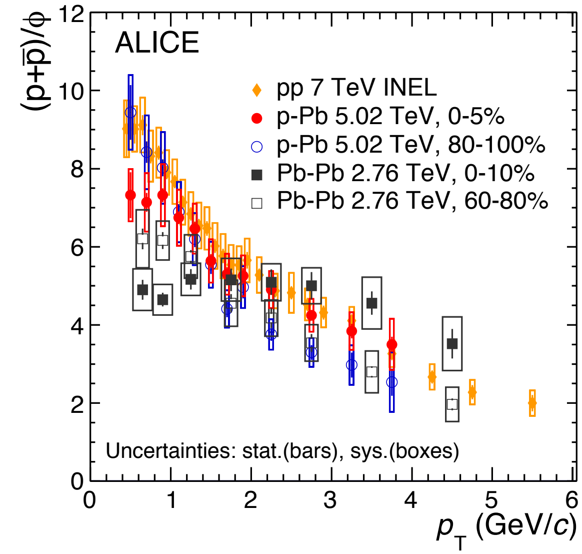
- Systematic checks are ongoing for K^{*0} and ϕ in pp collisions.
- Need higher statistics to extract the signal in differential p_T and centrality bins in Pb-Pb collisions.
- Checking the low intensity runs (12 runs are available) for Pb-Pb collisions.

Back-up

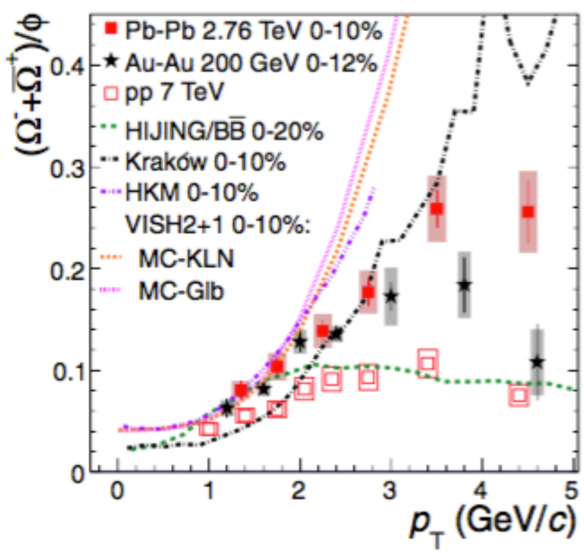
What We Know?



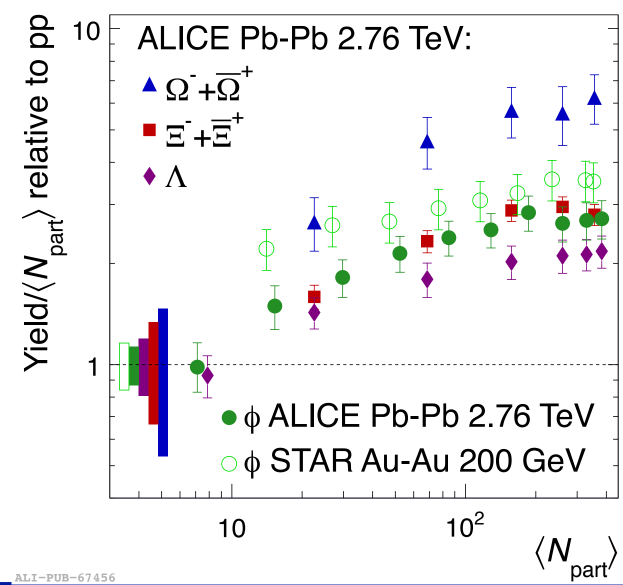
ALICE
⟨p_T⟩ (GeV/c)
π^+ K^+ K^{*0} p φ
Open: pp $\sqrt{s}$=7 TeV
Filled: Pb-Pb $\sqrt{s_{NN}}$=2.76 TeV
⟨N_{part}⟩
ALI-PUB-67873



ALICE
$(p+\bar{p})/\phi$
pp 7 TeV INEL
p-Pb 5.02 TeV, 0-5%
p-Pb 5.02 TeV, 80-100%
Pb-Pb 2.76 TeV, 0-10%
Pb-Pb 2.76 TeV, 60-80%
Uncertainties: stat.(bars), sys.(boxes)
p_T (GeV/c)

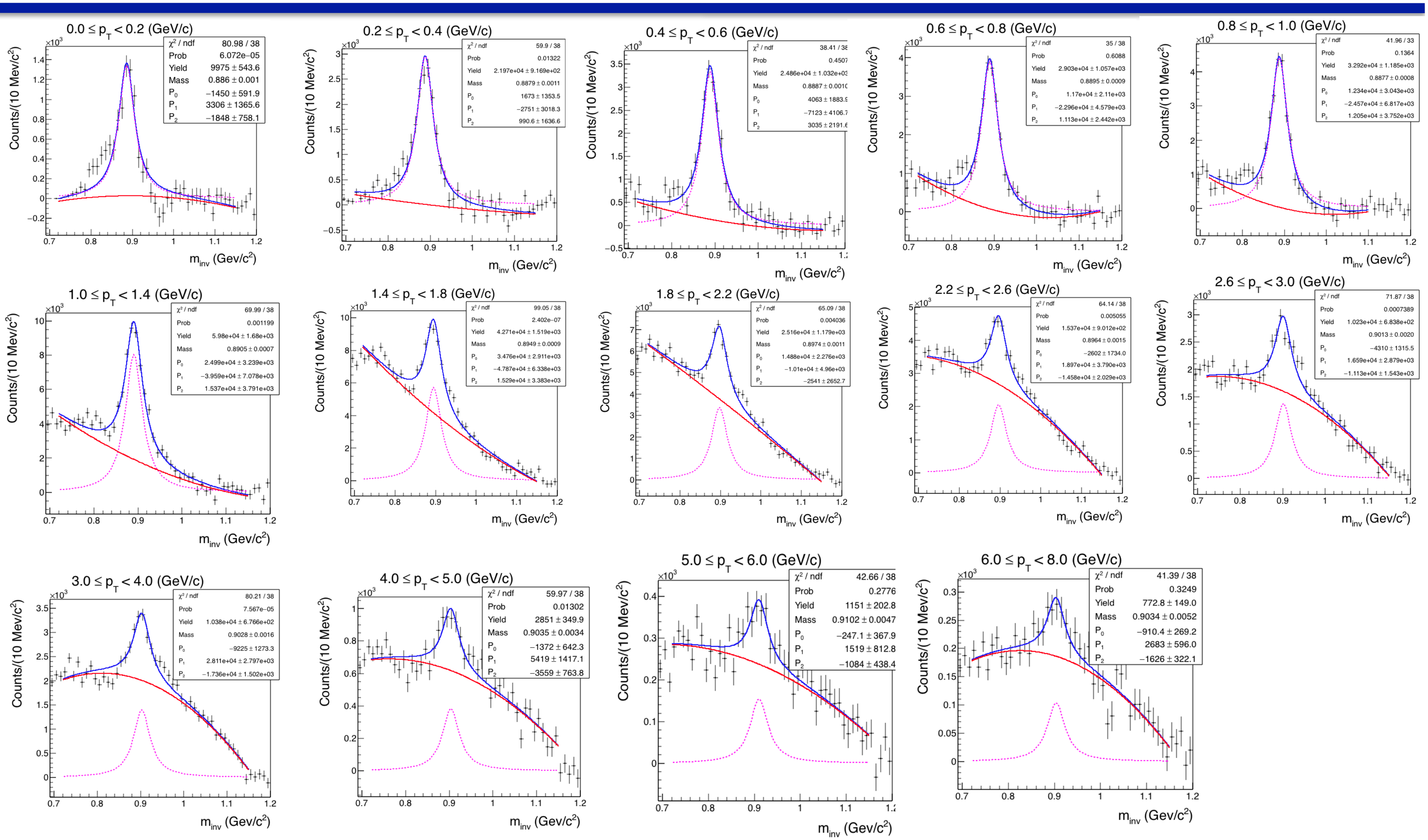


$(\Omega^- + \bar{\Omega}^+)/\phi$
Pb-Pb 2.76 TeV 0-10%
Au-Au 200 GeV 0-12%
pp 7 TeV
HIJING/B$\bar{B}$ 0-20%
Kraków 0-10%
HKM 0-10%
VISH2+1 0-10%:
MC-KLN
MC-Glb
p_T (GeV/c)



ALICE Pb-Pb 2.76 TeV:
$\Omega^- + \bar{\Omega}^+$
$\Xi^- + \bar{\Xi}^+$
Λ
φ ALICE Pb-Pb 2.76 TeV
φ STAR Au-Au 200 GeV
Yield/⟨N_{part}⟩ relative to pp
⟨N_{part}⟩
ALI-PUB-67456

Invariant Mass Distributions for K^{*0}



Invariant Mass Distributions for ϕ