Measurements of K^{*0} production in pp collisions at $\sqrt{s}$ = 13 TeV

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Outline

- Introduction
- Analysis Details
- Results
  - Invariant Mass Distribution
  - Transverse Momentum Spectrum
  - Integrated Yield
  - Mean Transverse Momentum
- Summary

Introduction

- Resonances are short lived particles with a lifetime of the order of 10^{-23} sec.
- They are used to understand the particle production mechanism.
- **Properties of** : K^{*0}

  Mass = 896 MeV/c^2

  Spin = 1

  Quark content :

  $K^{*0}\ (d\bar{s}),\ \overline{K^{*0}}\ (s\bar{d})$

✓ Different resonance particles produced in heavy ion collision.

Resonances	*Width* (Γ) (MeV/c^2)	*Mean lifetime* (τ) (fm/c)	*Dominant Decay modes*
$\rho^0(770)$	150.7	1.30	$\pi\pi/\mu\mu$
$\Delta^{++}(1232)$	117.0	1.67	$p\pi/\pi n$
$K^{*0}(896)$	48.7	4.20	πK
$\Sigma(1385)$	33.0	5.52	$\Lambda\pi$
$\Lambda(1520)$	15.2	12.6	$p\pi$
$\Xi^*(1530)$	9.00	21.6	$\Xi\pi$
$\omega(782)$	8.49	23.2	$\pi\pi\pi/\pi\gamma$
$\varphi(1020)$	4.26	46.5	KK

✓ Study of resonance (lifetime from 1fm/c to 45fm/c) production gives us time evolution of medium properties.

In pp Collisions :

- Used as a reference to understand the results from heavy ion collisions
- Used to test the perturbative QCD calculations.

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Data set

Data Set used

p+p : 13 TeV

Period : LHC15f

Trigger : MinBias (kMB)

Data Type : ESD

No. of Events : ~59.5 M

Run No. : (56 runs)

225000, 225011, 225016, 225026, 225031, 225035, 225037, 225041, 225043, 225050, 225051, 225052, 225106, 225305, 225307, 225309, 225310, 225313, 225314, 225315, 225322, 225576, 225578, 225579, 225580, 225582, 225586, 225587, 225705, 225707, 225708, 225709, 225710, 225716, 225717, 225719, 225753, 225757, 225762, 225763, 225766, 225768, 226062, 226170, 226220, 226225, 226444, 226445, 226452, 226466, 226468, 226472, 226476, 226483, 226495, 226500

MC Data Set used

p+p : 13 TeV

Period : LHC15g3a3

Trigger : MinBias (kMB)

Data Type : ESD

Analysis cuts

Event Selection

-- Event must have a primary vertex located within |z| < 10 cm

Tracks Selection :

Standard ITS TPC track cuts 2011

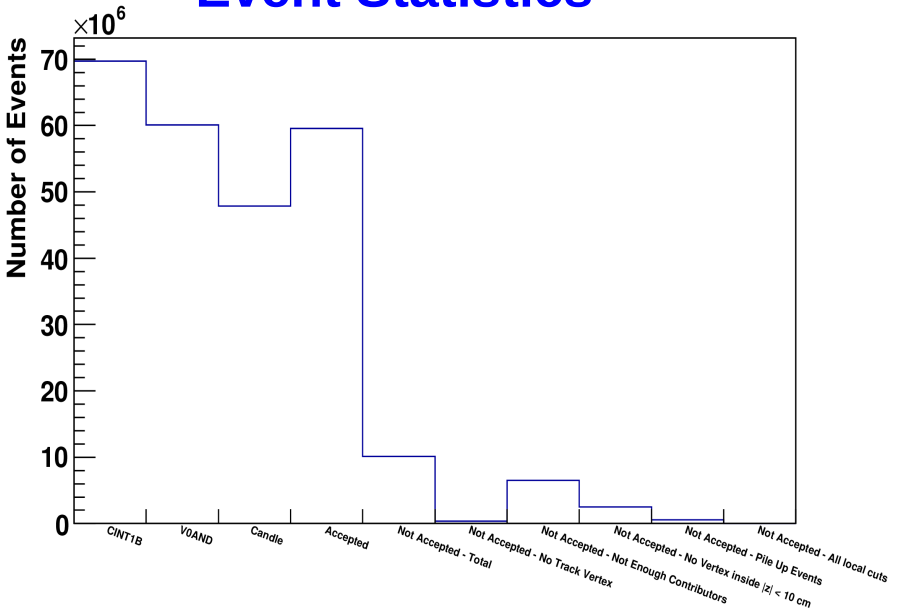
- ✓ $|\eta| < 0.8$
- ✓ $|DCA_Z| < 2.0$ cm
- ✓ $|DCA_{XY}| < 7*(0.0015+(0.005/P_T^{1.1}))$
- ✓ Number of crossed rows in TPC > 70
- ✓ Ratio of crossed rows over findable cluster > 0.8
- ✓ χ^2/TPC cluster < 4.0
- ✓ χ^2/ITS cluster < 36.0
- ✓ p_T > 0.15 GeV/c

- |Pair Rapidity| < 0.5

PID Selection for Pions and Kaons

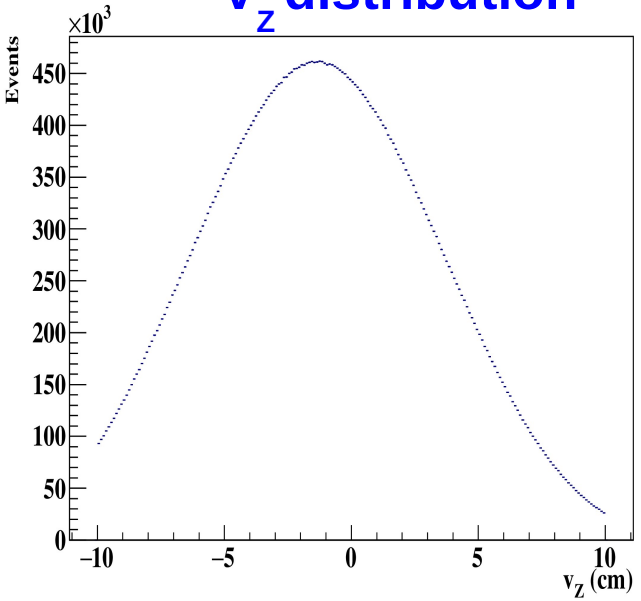
- TPC and TOF as VETO
  - $|n\sigma_{TPC}| < 2.0$
  - $|n\sigma_{TOF}| < 3.0$

Event Statistics

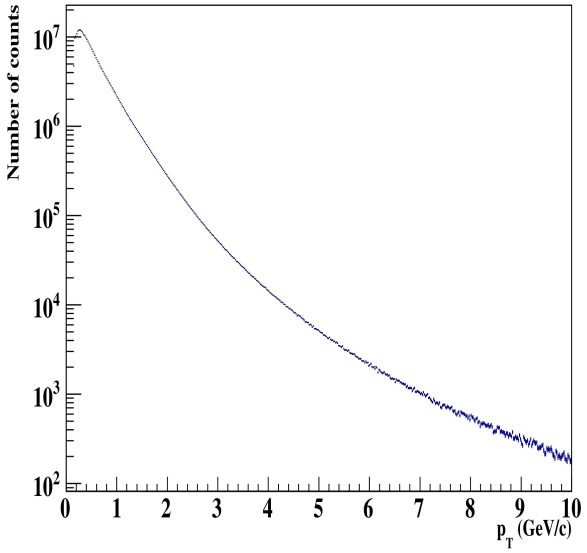


QA

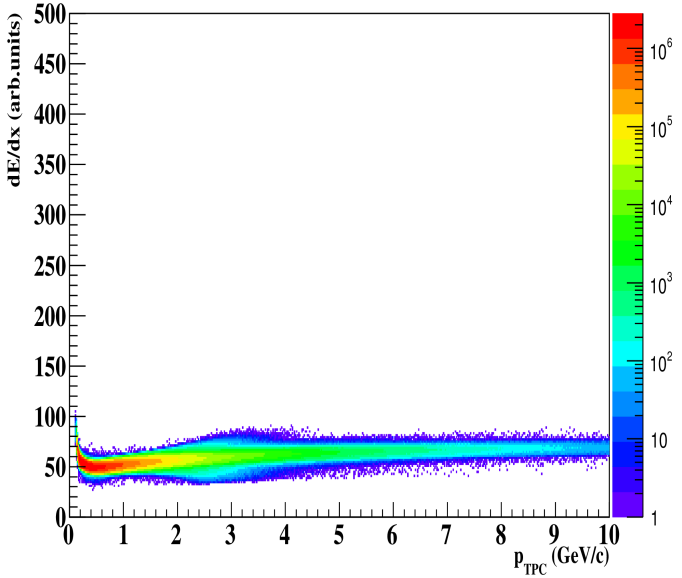
V_z distribution



p_T distribution

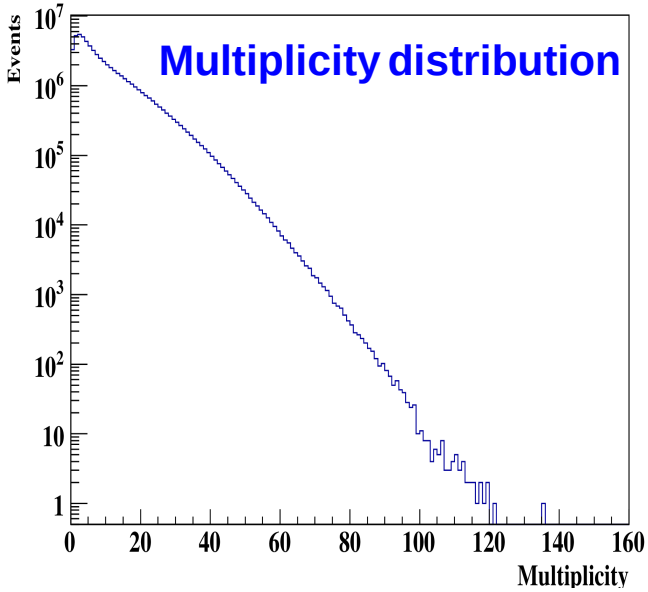


Pion

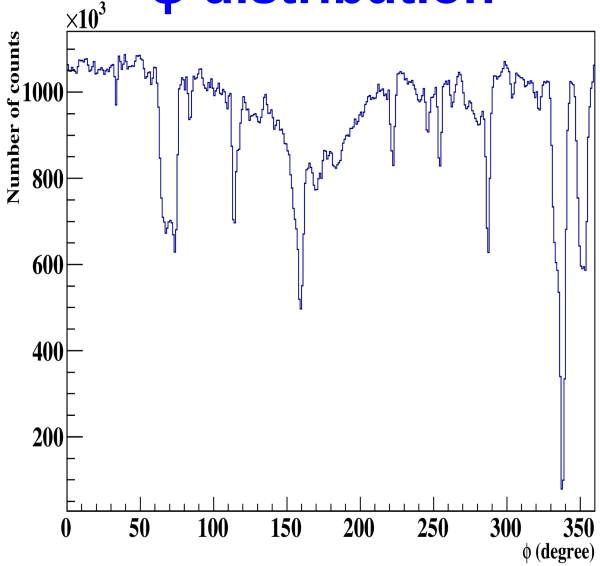


Accepted events vs Multiplicity

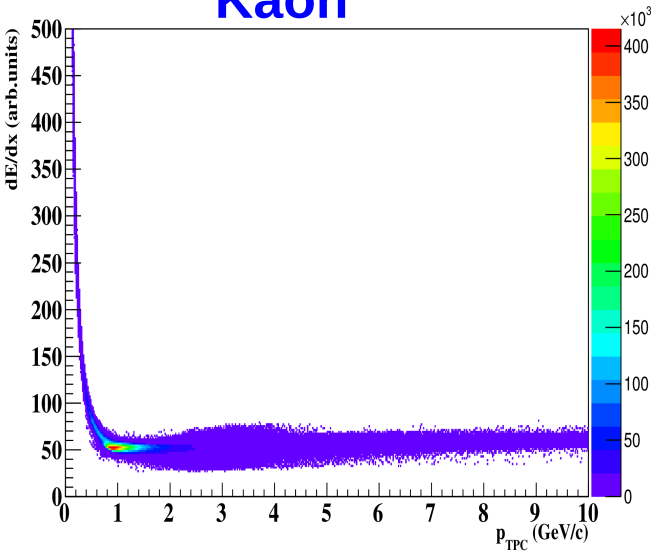
Multiplicity distribution



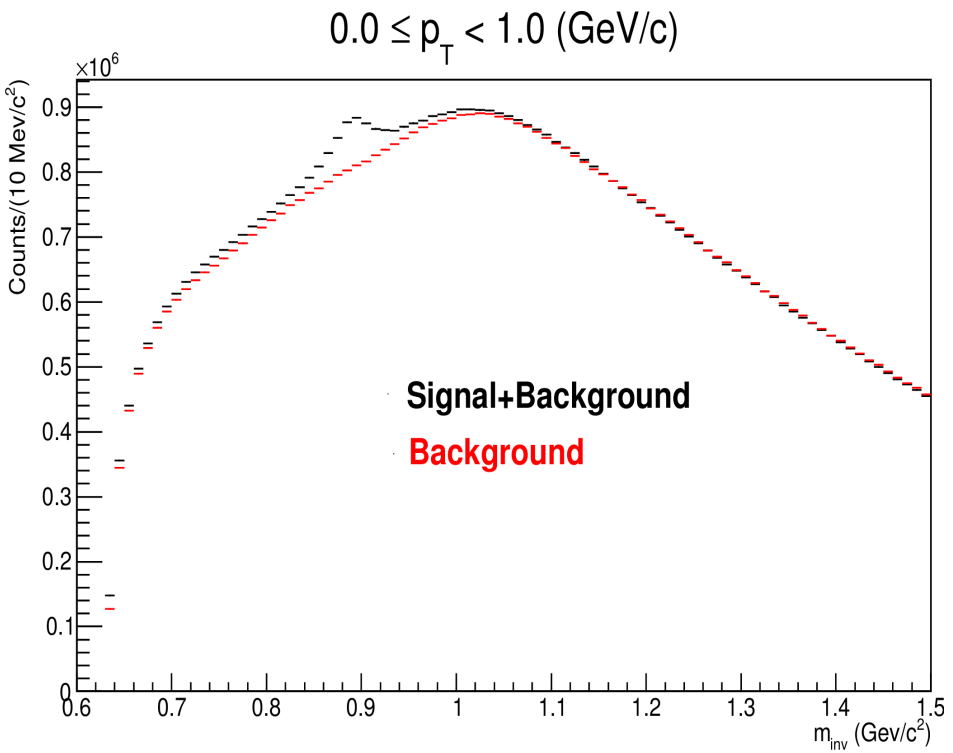
φ distribution

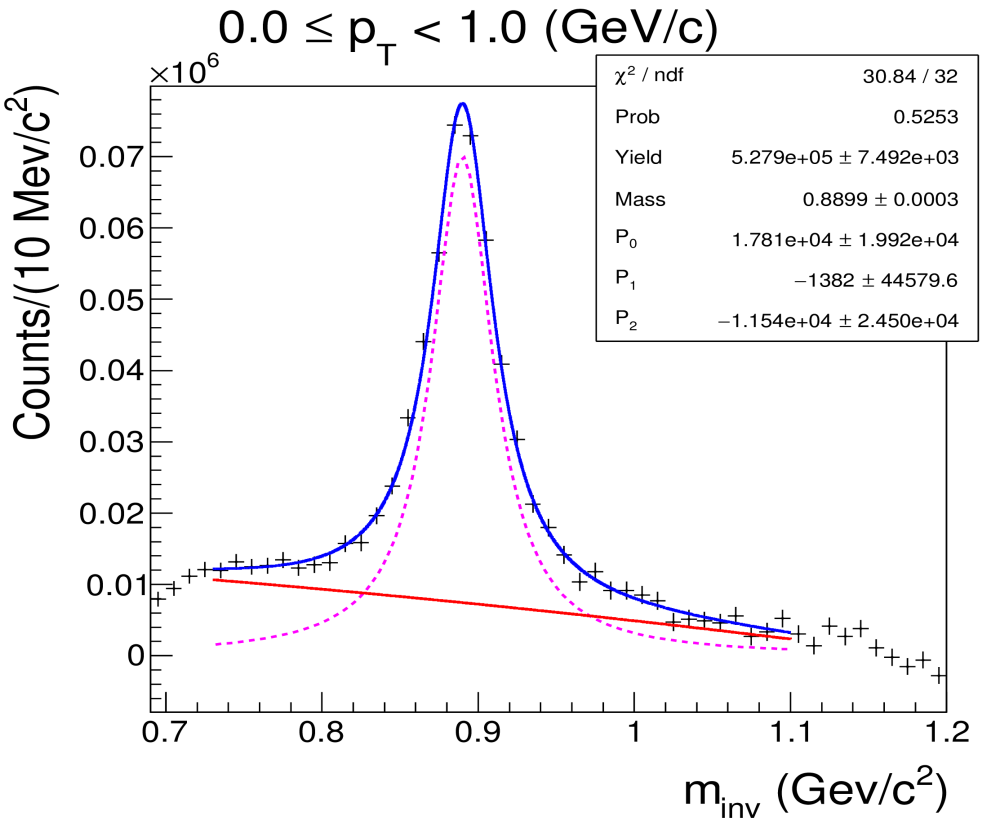


Kaon



Invariant Mass Distribution : LS Method

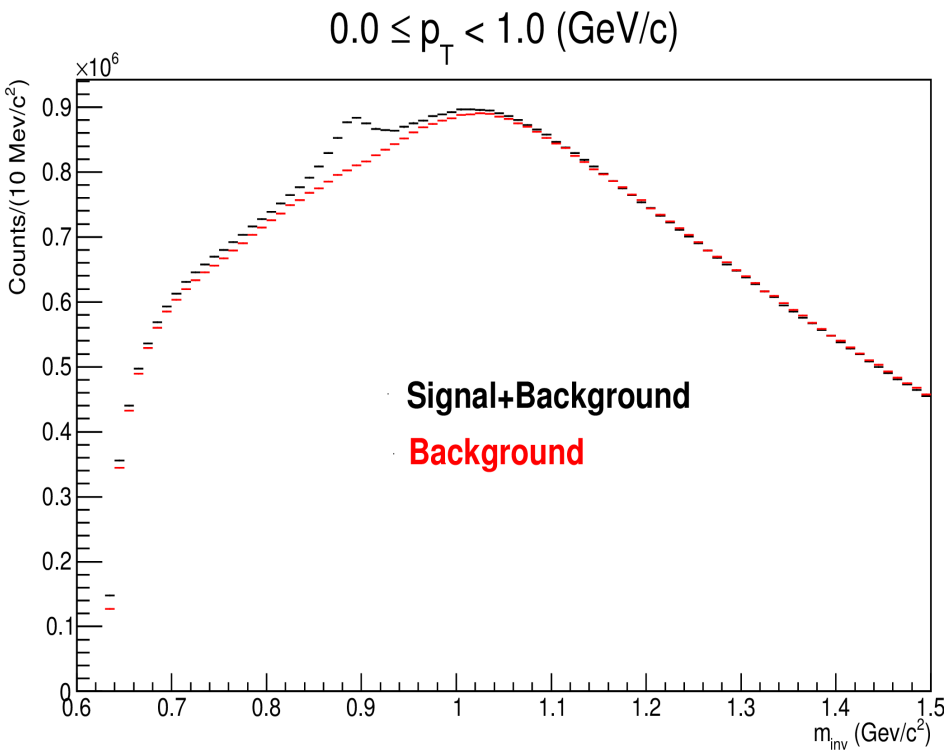


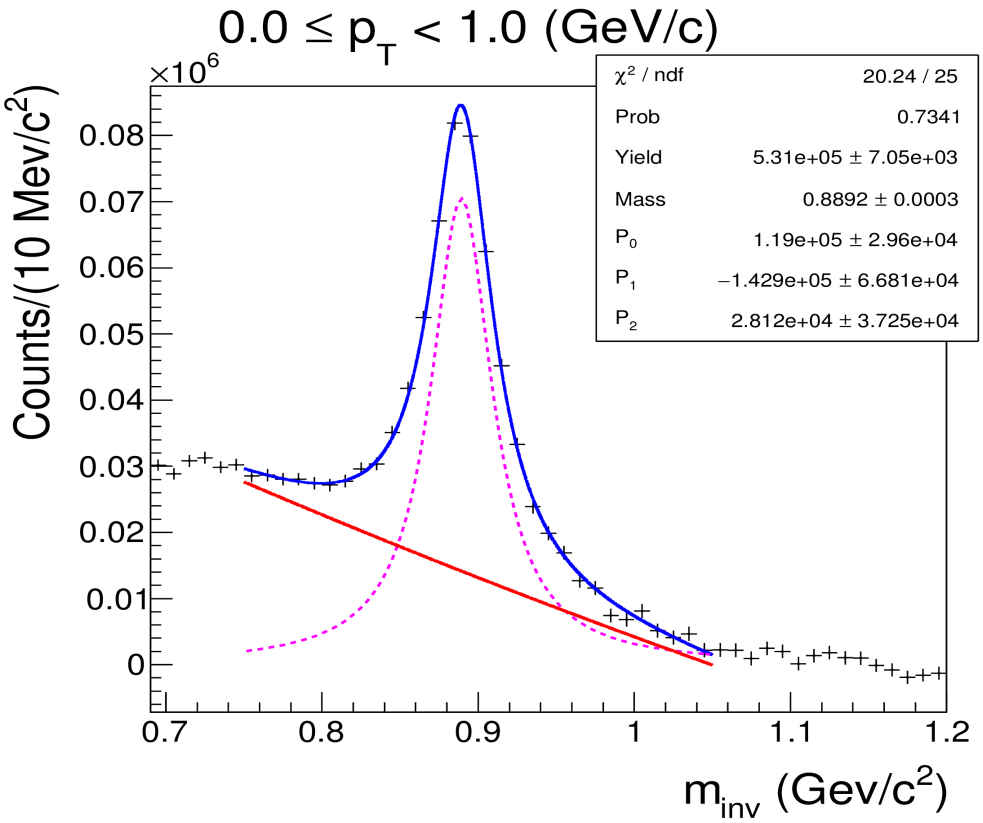


$K^{*0}\left(\overline{K^{*0}}\right) \rightarrow K^{+}\pi^{-}\left(K^{-}\pi^{+}\right)$

- Invariant mass of Unlike sign pair, such as ($K^+ \pi^-$) in an event is used to reconstruct signal for K^{*0}
- Invariant mass of Like sign (+ +, - -) pairs are used to construct the combinatorial background.
- Background Subtraction : Like Sign Normalization : $2\sqrt{(N^{++})\times(N^{--})}$
- Fit Function : Breit-Wigner for Signal + Pol2 for Residual Background
- Fitting Range : 0.73 – 1.1 GeV/c^2

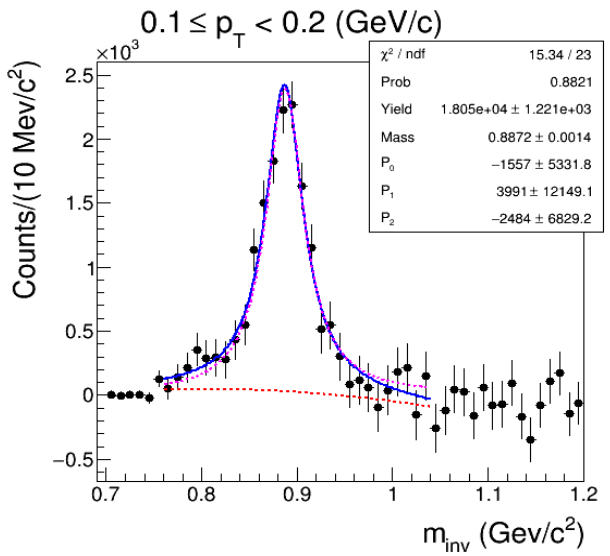
Invariant Mass Distribution : EM Method

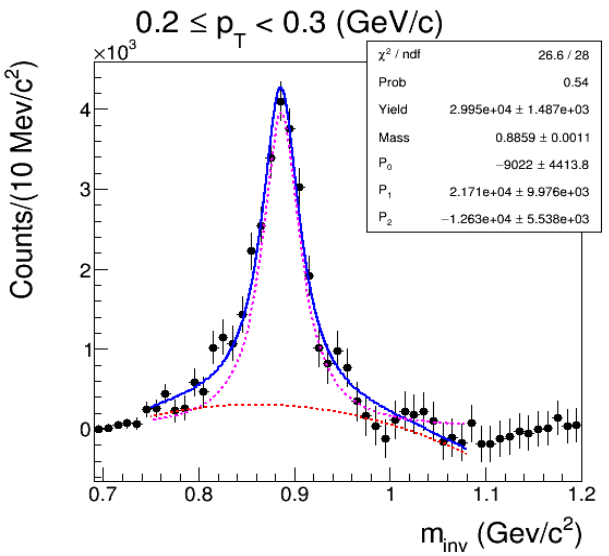


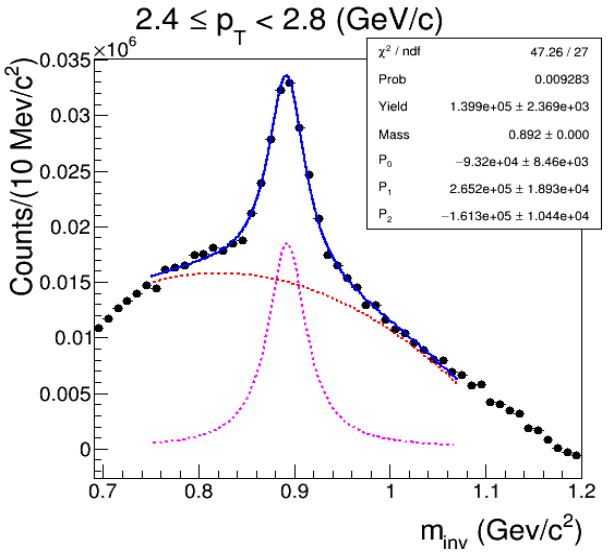


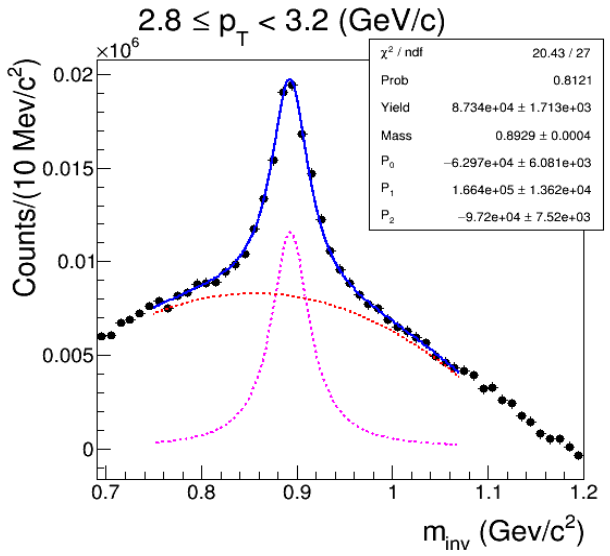
- Background Subtraction: Event Mixing
  - π^{+-} (K^{+-}) from one event mixed with K^{-+} (π^{-+}) from another event. Events of similar multiplicity bin and vertex bin are mixed.
    - ►Number of events mixed : 5
    - ►Multiplicity difference : 5
    - ►z-Vertex difference : 1 cm
- Normalization Range : 1.10 – 1.30 GeV/c^2
- Fit Function : Breit-Wigner for Signal + Pol2 for Residual Background
- Fitting Range : 0.75 – 1.05 GeV/c^2

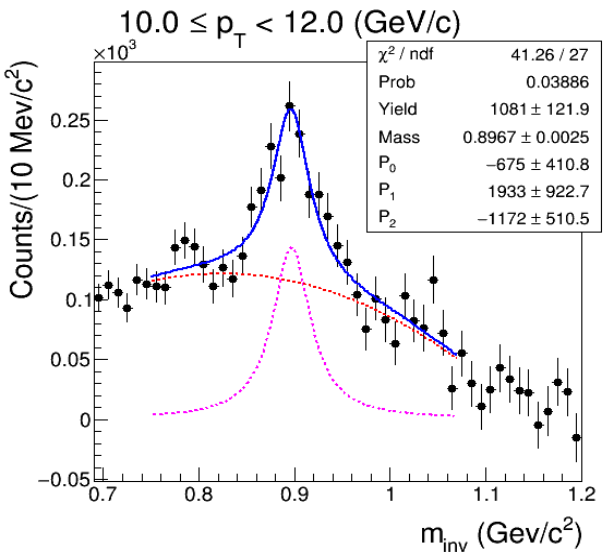
Invariant Mass Distributions

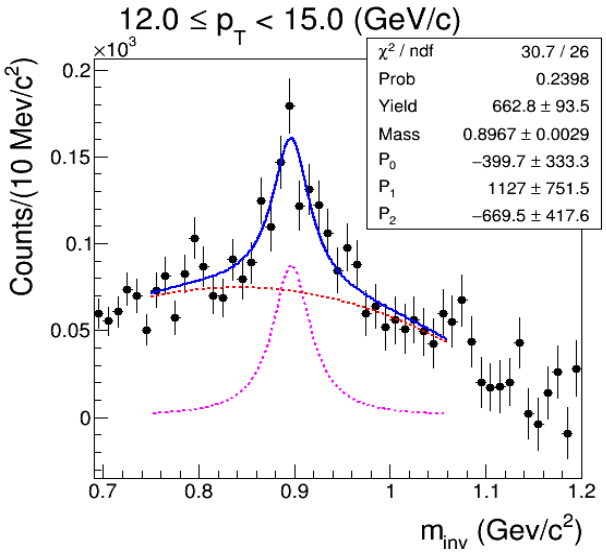






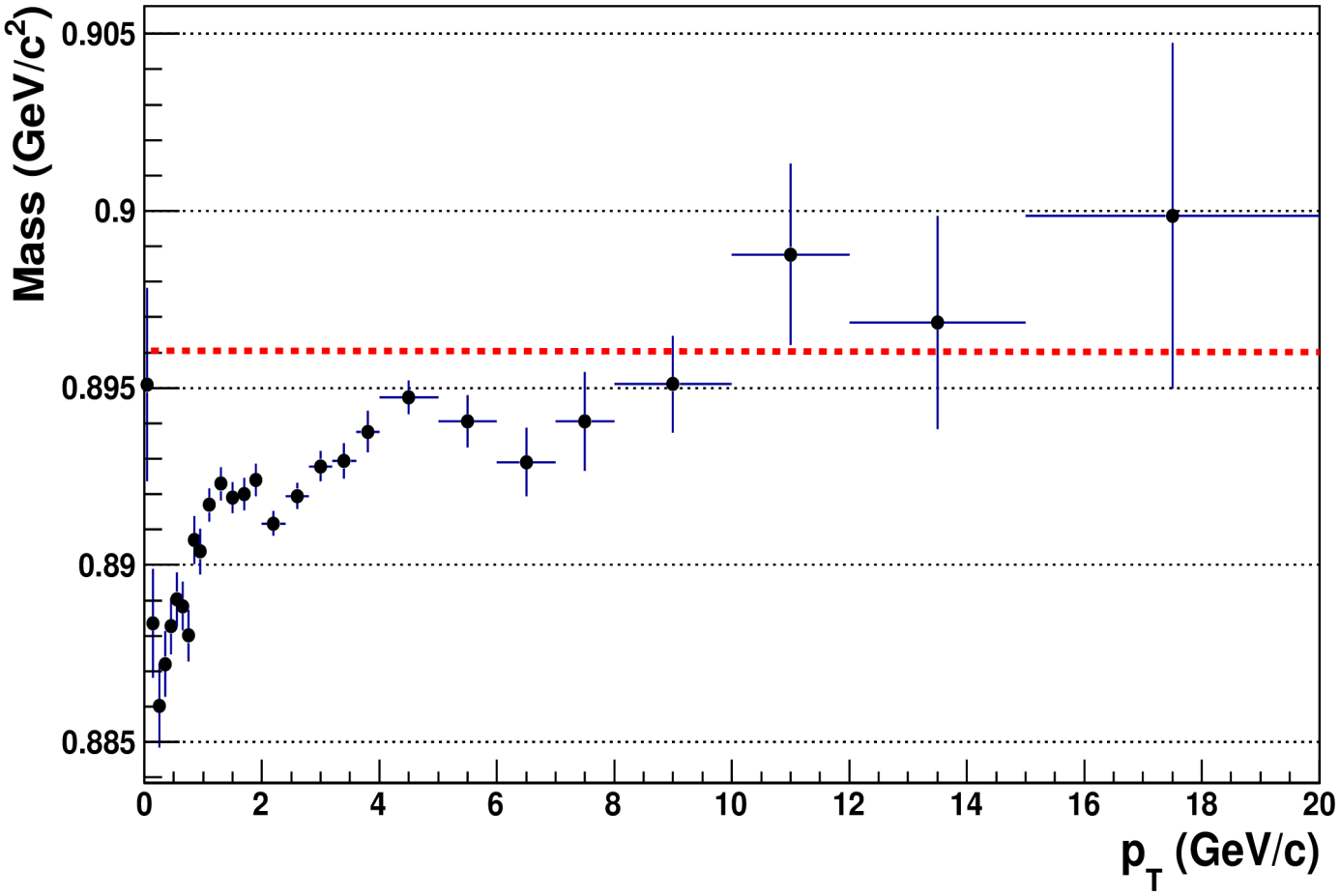






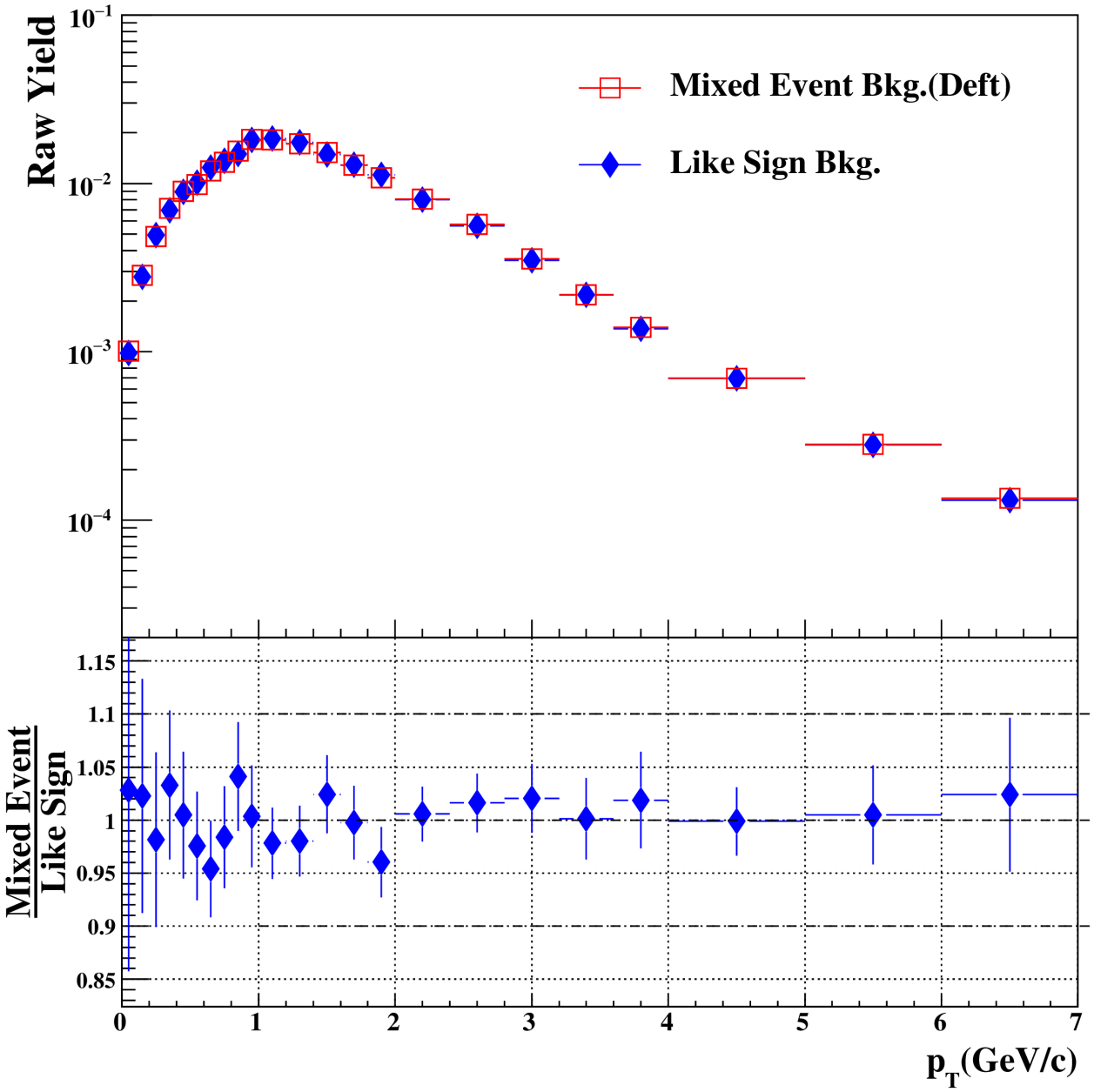
- Background Subtraction: Event Mixing
- Normalization Range : 1.10 – 1.30 GeV/c^2
- Fitting Range : 0.75 – 1.07 GeV/c^2
- Width fixed to PDG value

Mass vs p_T



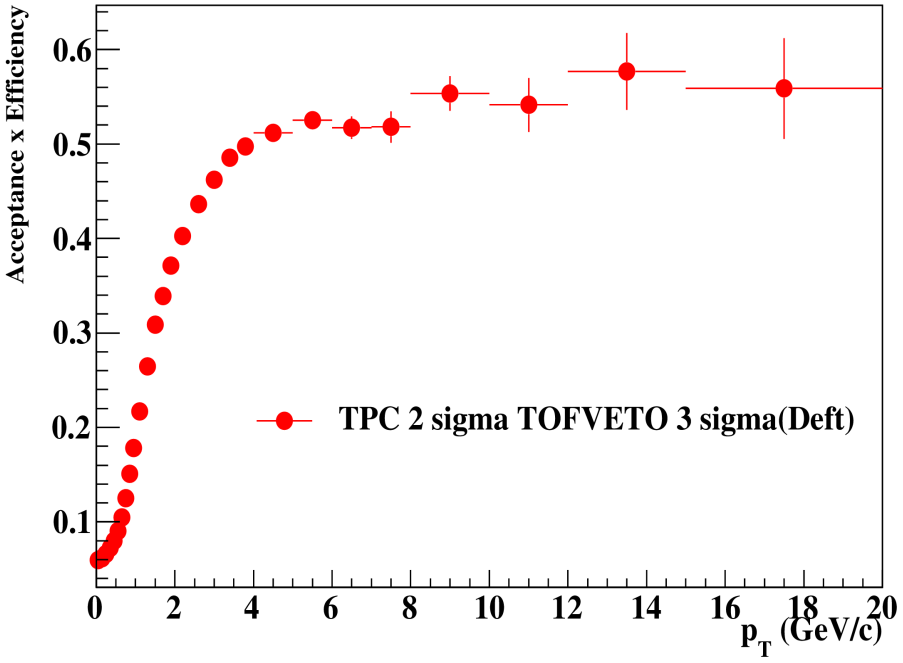
- Red line signifies PDG value

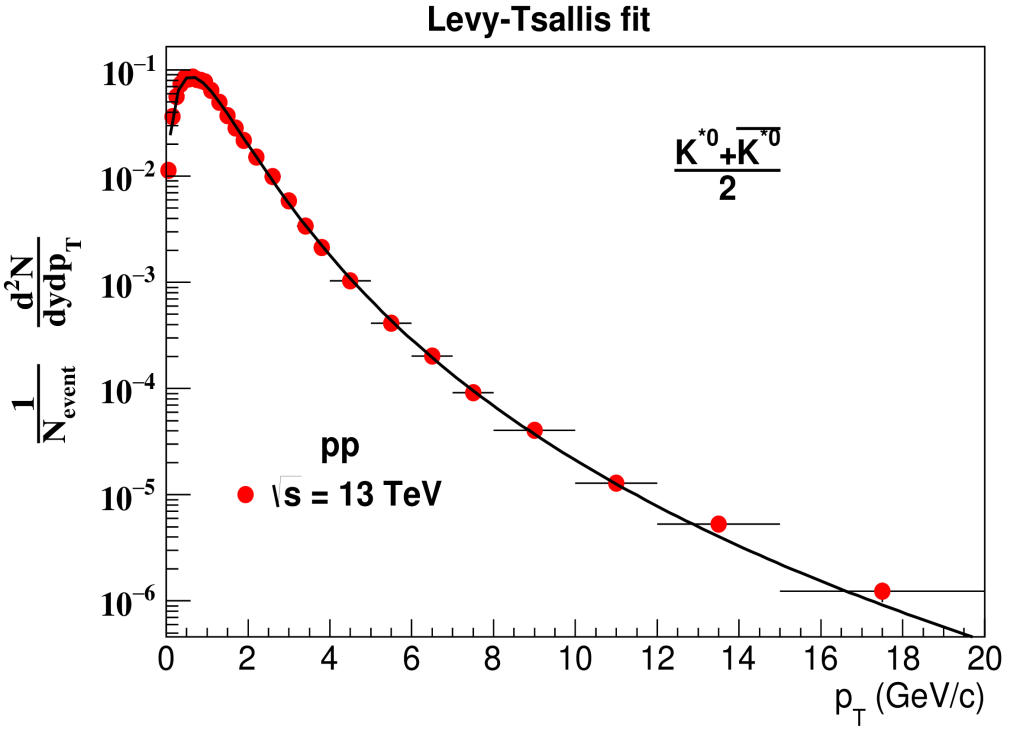
Raw Yield Extraction



- Mixed event and like sign bkg. are consistent within uncertainties

Corrected p_T spectrum





- Efficiency value for p_T 7-8 GeV/c bin is used for higher p_T bins .

$$\frac{d^2N}{dydp_T} = \frac{(dN/dy)(n-1)(n-2)\,p_T}{nT\left(nT+m_0(n-2)\right)}\,x\left(1+\frac{m_T-m_0}{nT}\right)^{-n}$$

$$m_T = \sqrt{m_0^2+p_T^2}$$

- Corrected yield =

$$\frac{Raw\ yield}{BR\,x\left(Acceptance\,x\,Efficiency\right)}$$

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n	7.386 ± 0.091
T	0.321 ± 0.003
dN/dy	0.1233 ± 0.0009

Systematic uncertainties

List of systematics check:

-- Fitrange variation
[0.75-1.07(Deft), 0.8-1.0,0.73-1.12, 0.77-1.09]

-- Normalization variation
[1.1-1.3(Deft), 0.7-0.8, 1.3-1.5 1.1-1.5, 1.2-1.4]

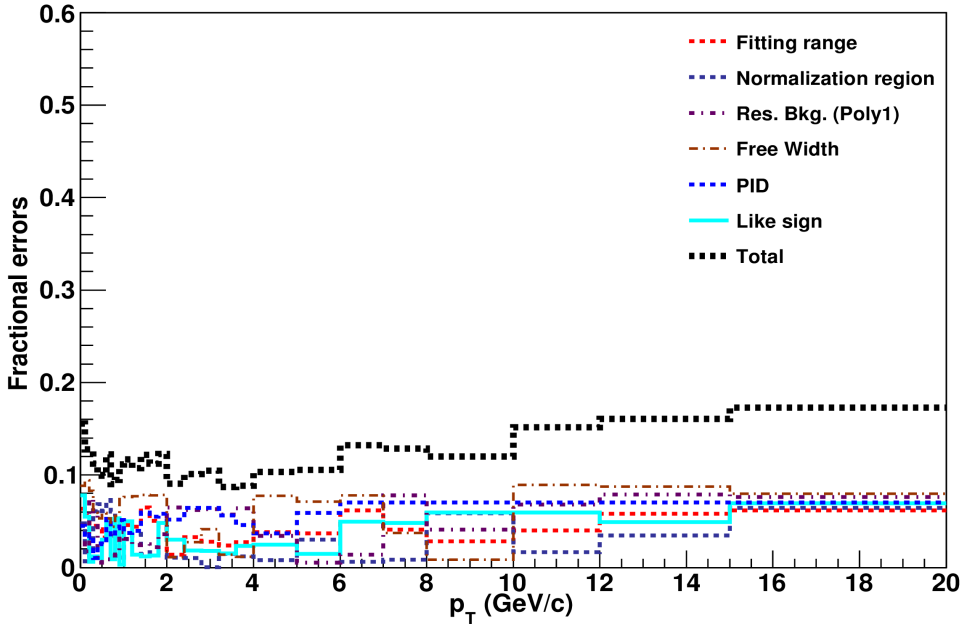
-- Fit Function
Poly2 (Deft), Poly1, Poly3

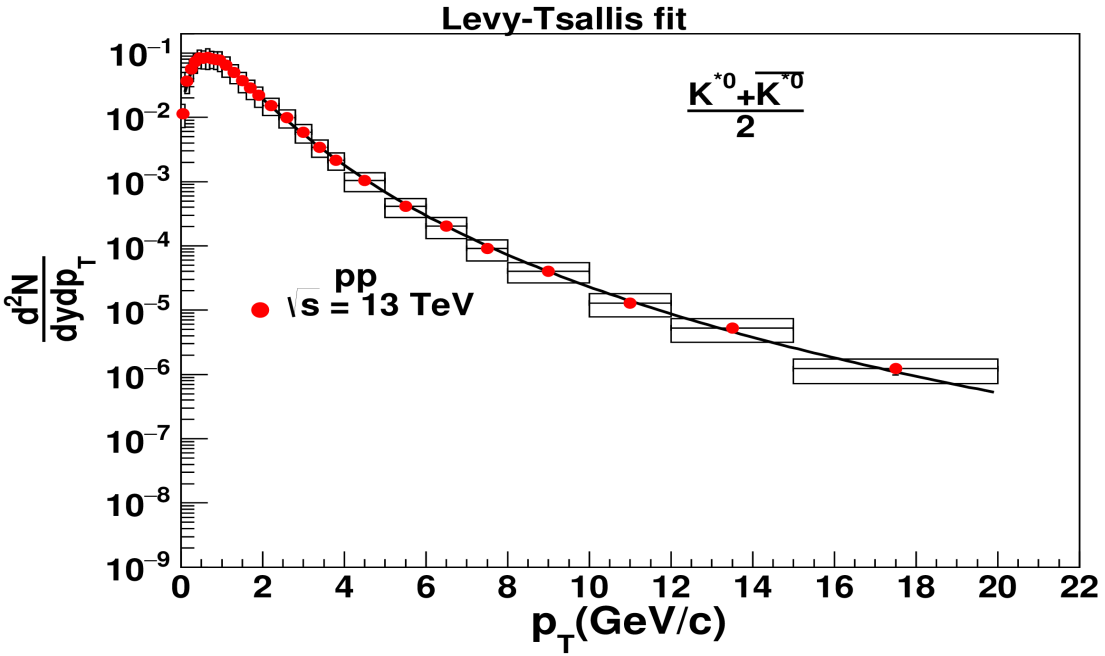
-- Fixed width (Deft) : Free width

-- Mixed event(Deft), Like sign

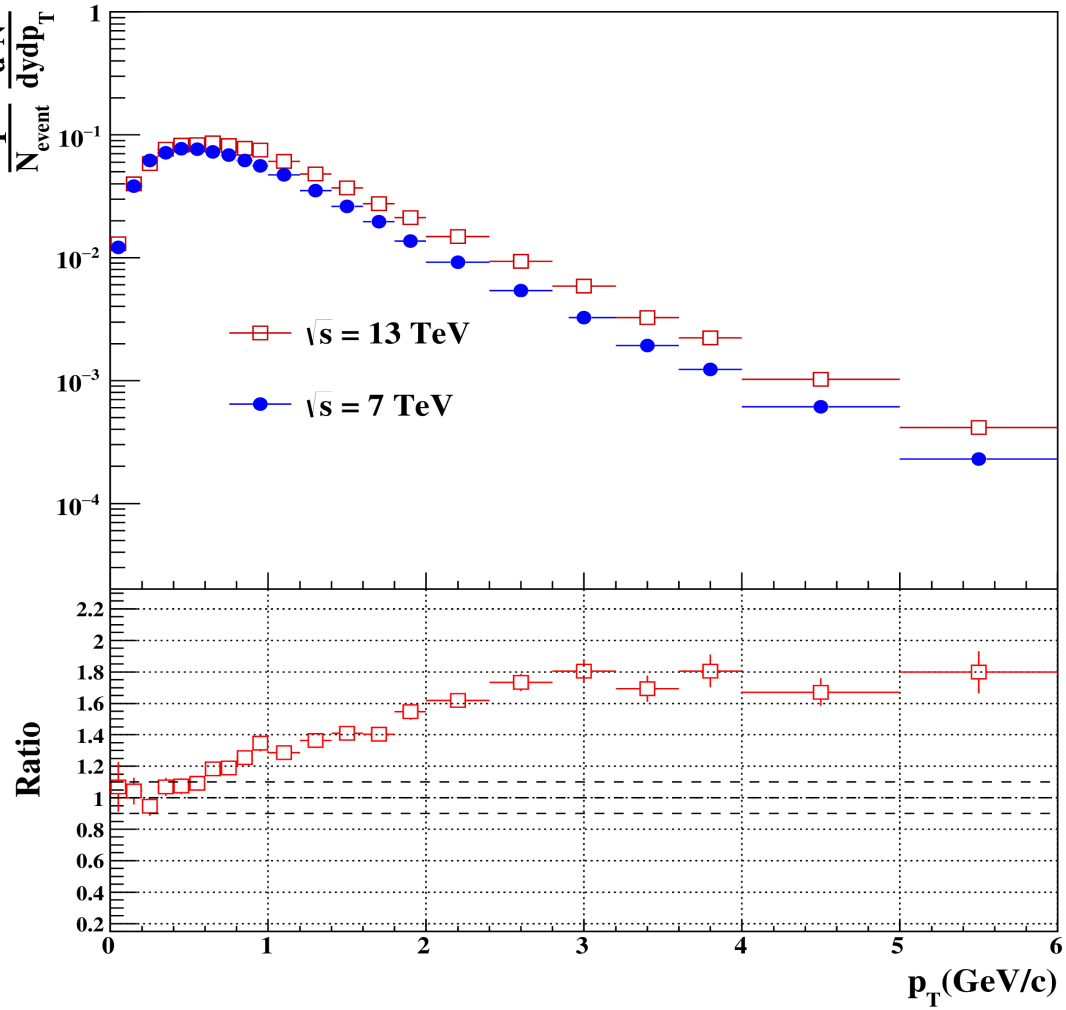
-- PID: TPC2σ TOF3σ veto (Deft), TPC2σ TOF4σ veto, TPC2σ

Total systematics is ~ 8-16%





p_T spectra comparison : 13 TeV Vs 7 TeV



√s (TeV)	dN/dy
13	0.123 ± 0.0009
7	0.097 ± 0.0004 ± 0.01

- Ratio increases with increasing p_T

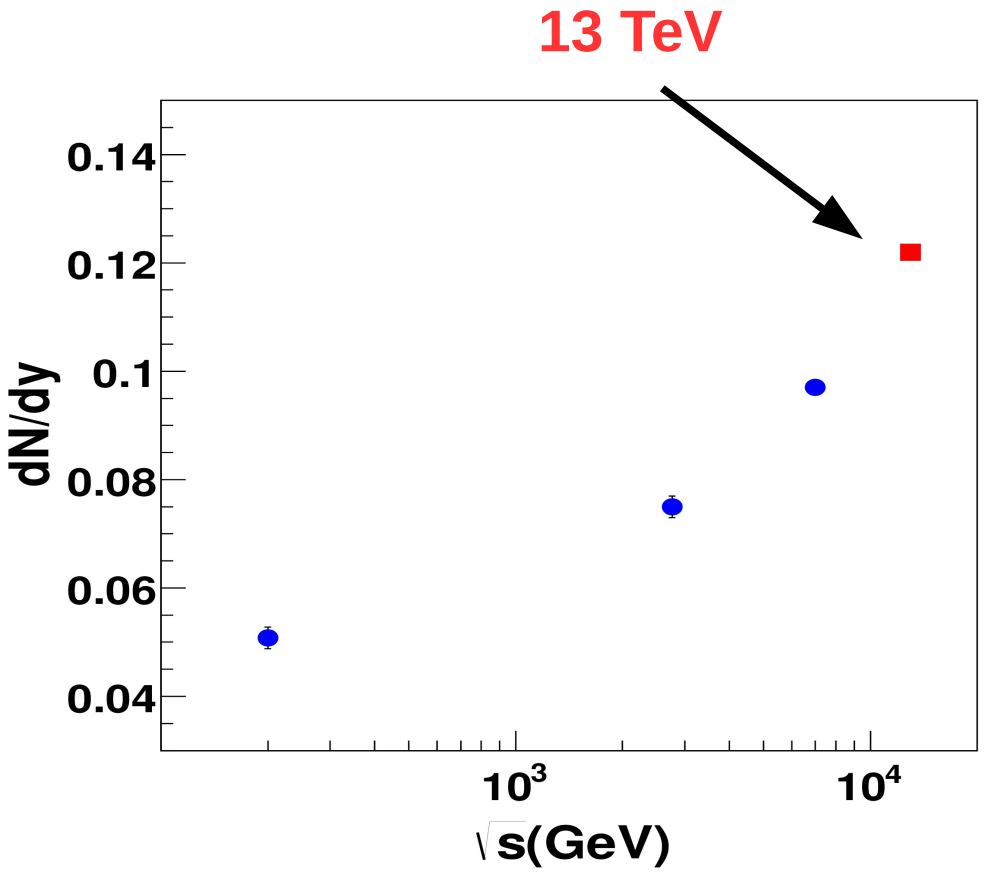
dN/dy

$$Integrated\ \ yield\ \left(\frac{dN}{dy}\right)\ :\ I_{hist} + I_{extrapolated}$$

$$where\ \ I_{hist} = \sum f(p_T, y)\,dp_T,$$

$$I_{extrapolated} = \int f(p_T, y)\,dp_T$$

√s (TeV)	dN/dy
13	0.123 ± 0.0009
7	0.097 ± 0.0004 ± 0.01
2.76	0.075 ± 0.002 ± 0.01
0.2	0.0508 ± 0.002 ± 0.0061



- Extrapolation is not used as data points are from p_T 0 to 20 GeV/c

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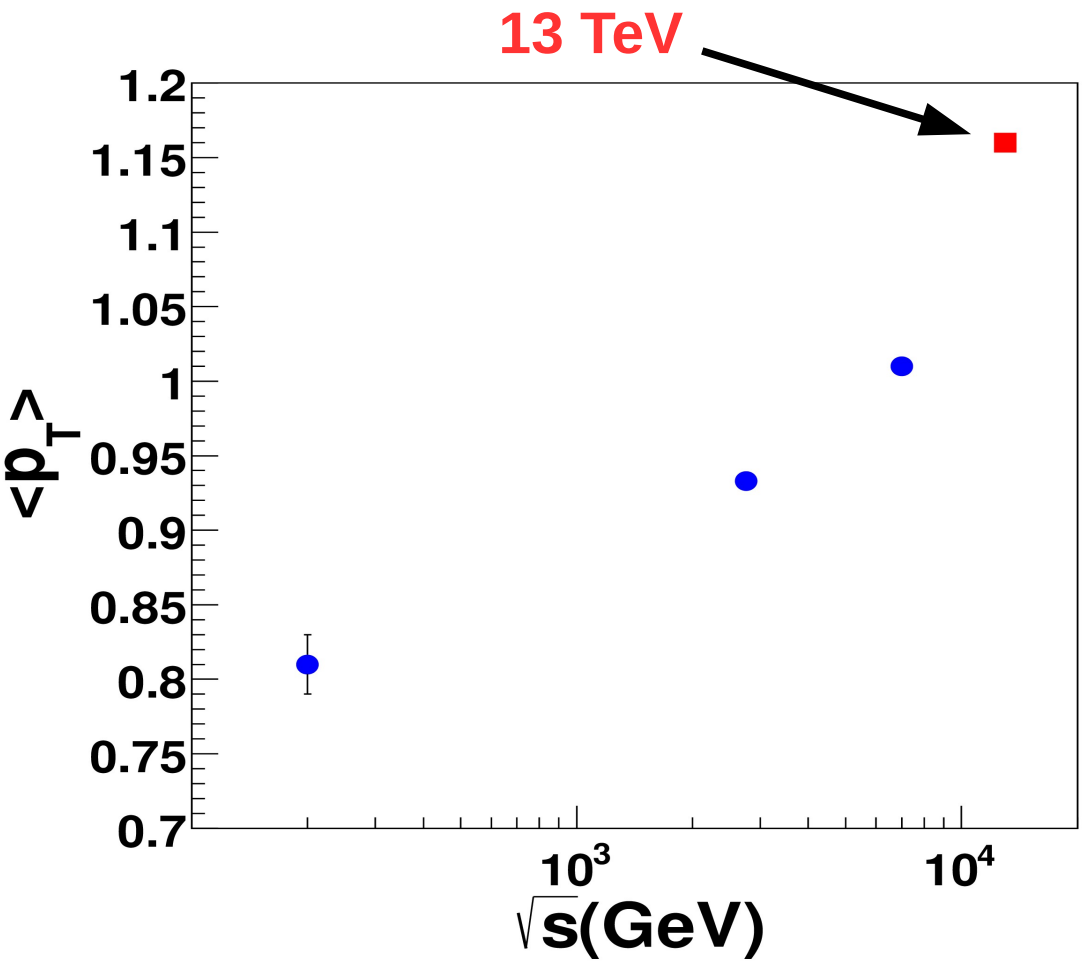
<p_T>

Mean transverse momentum ($\langle p_T \rangle$) : $\left(\sum p_T f(p_T, y)\, dp_T + \int f(p_T, y)\, p_T\, dp_T\right) / \left(I_{hist} + I_{extrapolated}\right)$

- **<p_T> of K^{*0} at √s = 13 TeV is compared with other center of mass energies.**

√s (TeV)	<p_T>
13	1.16 ± 0.004
7	1.01 ± 0.003 ± 0.02
2.76	0.933 ± 0.005 ± 0.035
0.2	0.81 ± 0.02 ± 0.14



Eur. Phys. J. C (2012) 72:218, Phys. Rev. C 71, (2005) 064902, https://aliceinfo.cern.ch/Notes/node/219

Summary

- First measurement of K^{*0} production from p_T = 0 to 20 GeV/c in pp collisions at √s = 13 TeV is presented.
- The p_T spectrum, integrated yield and mean transverse momentum of K^{*0} are measured at √s = 13 TeV.
- The p_T spectrum is well described by the Levy-Tsallis function.
- The measured dN/dy and $\langle p_T \rangle$ of K^{*0} at 13 TeV are increased by 27% and 15% comapre to √s = 7 TeV, respectively.

Outlook

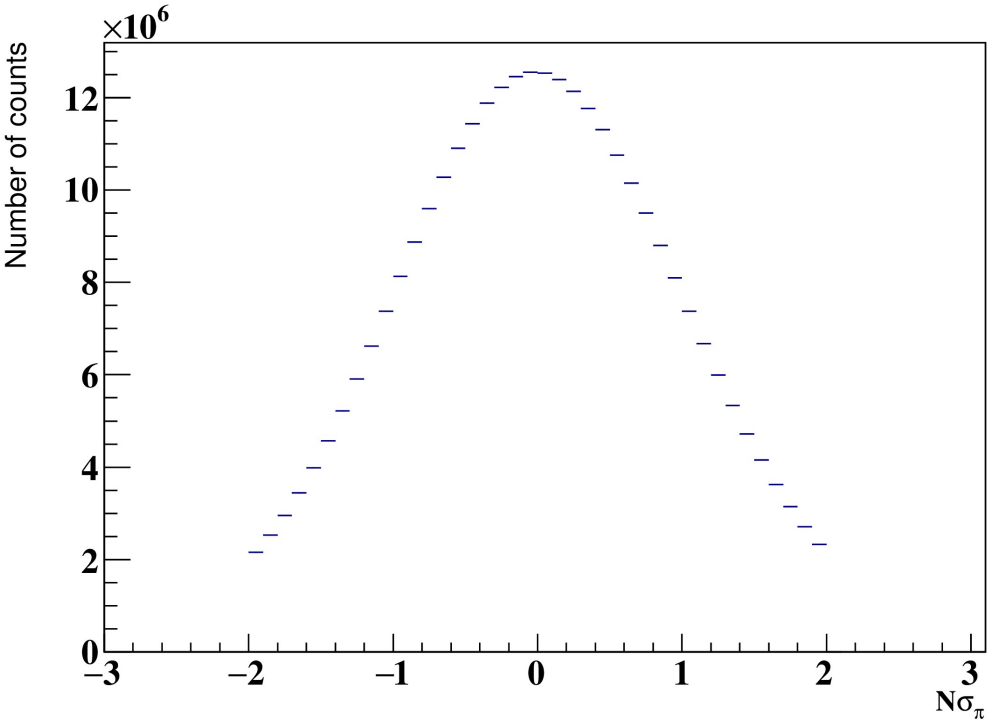
-- Preparation of analysis note is in process
-- Estimation of track cut systematic uncertainties is ongoing.

THANK YOU

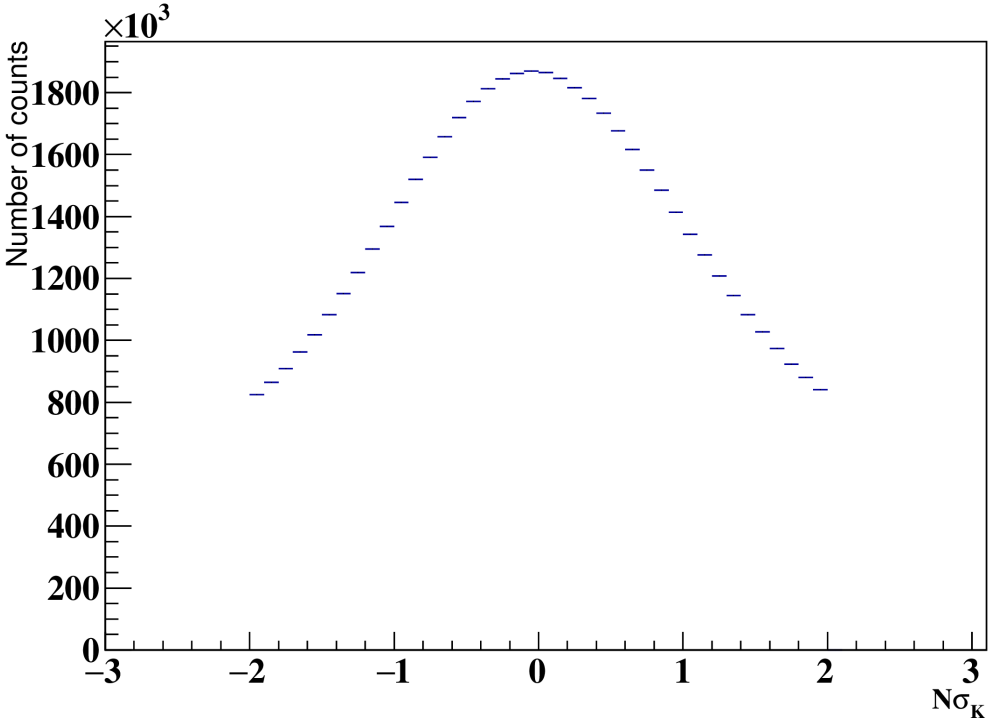
Back Up

PID QA

Nsigma Pion



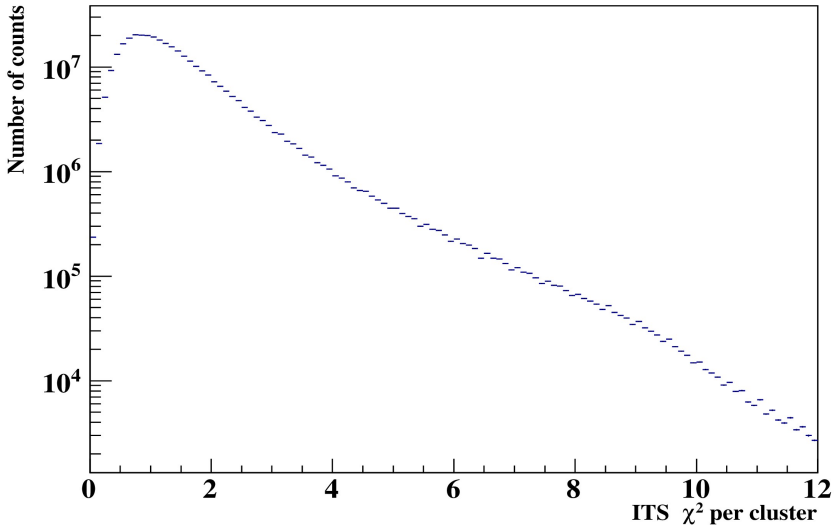
Nsigma Kaon



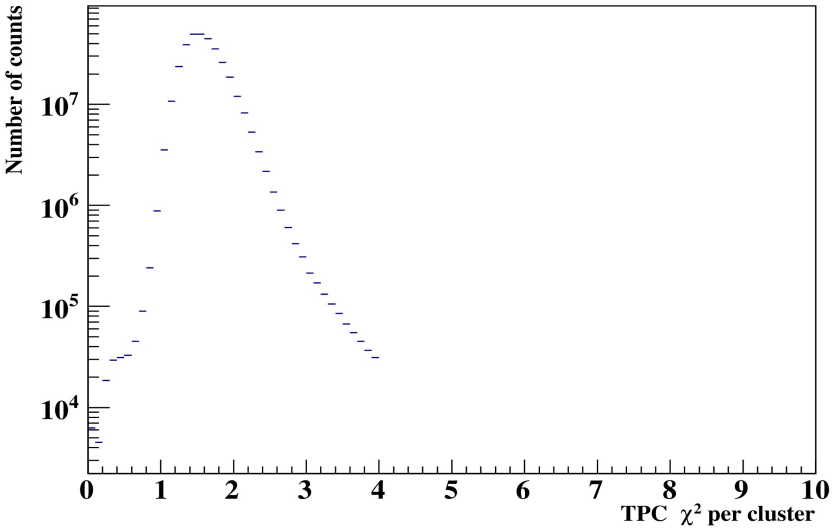
- NSigma distribution for Kaon and Pion are pure Gaussian with mean=0.

Track QA

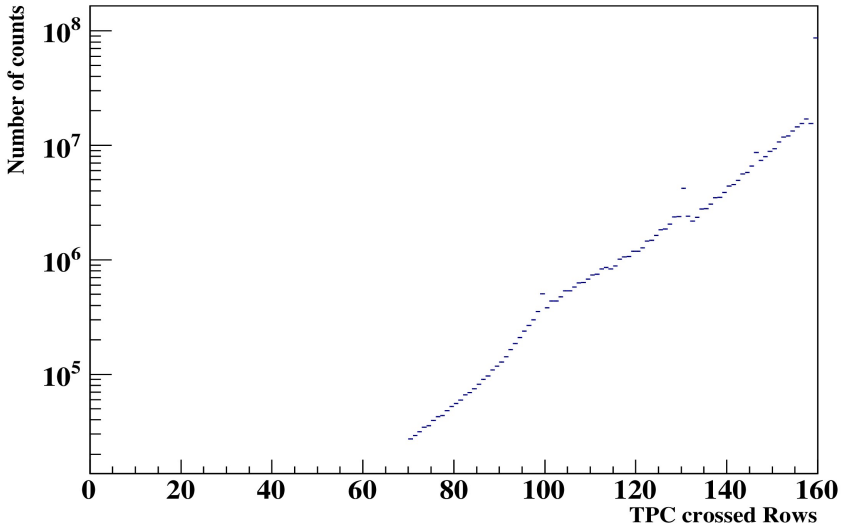
ITS χ^2 per cluster



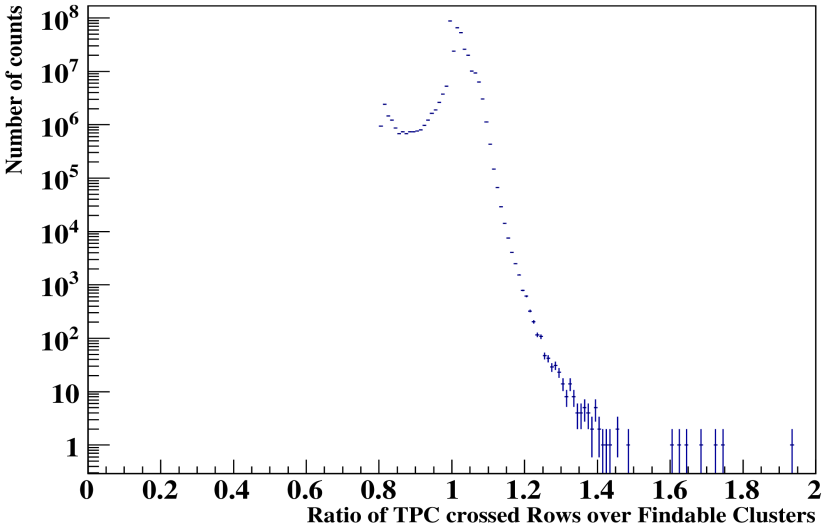
TPC χ^2 per cluster



TPC crossed Rows



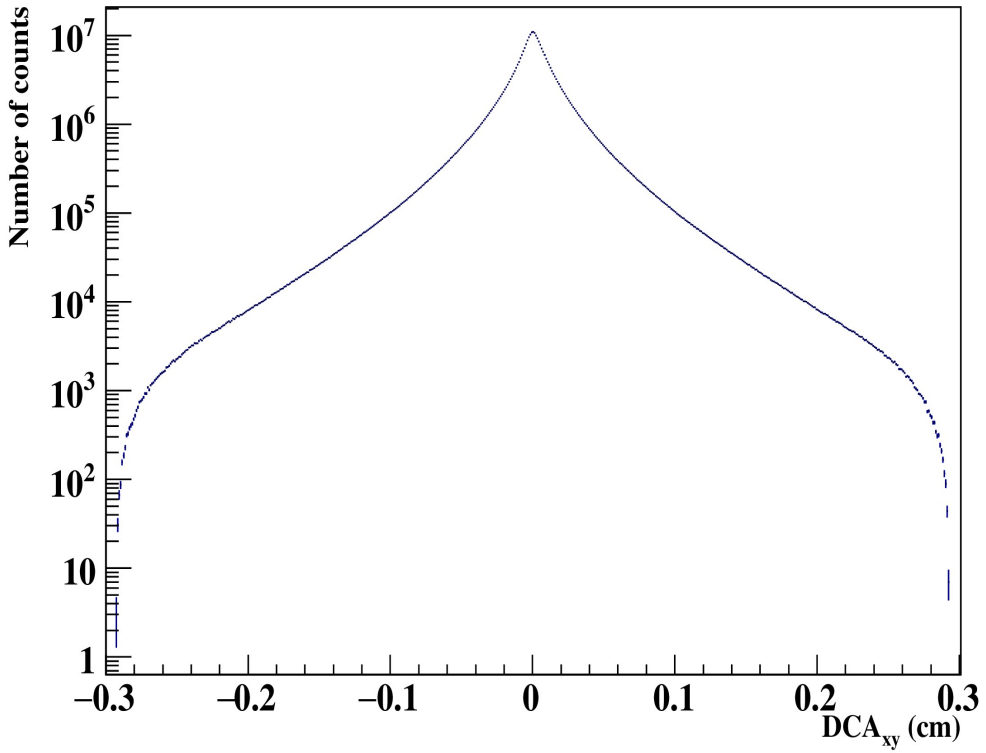
TPC CrossedRows/FindableClusters



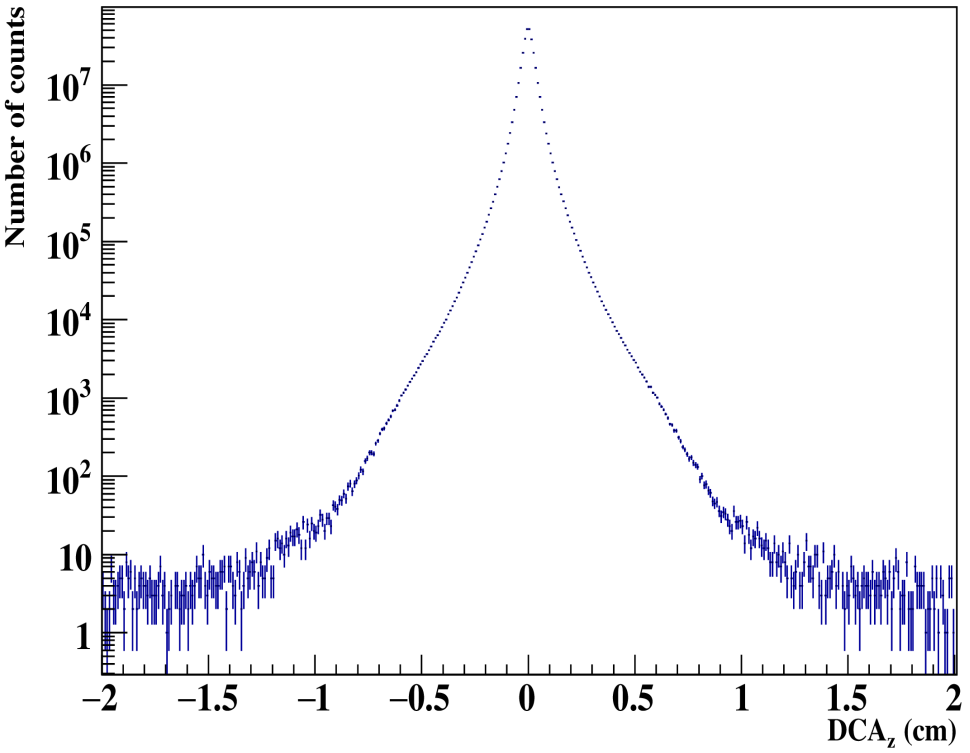
- χ^2 per cluster distributions for TPC and ITS look reasonably good.
- TPC crossed Rows distribution looks good.
- Ratio of TPC crossed rows with findable cluster distribution looks good.

Track QA : DCA

DCA_{xy} distribution

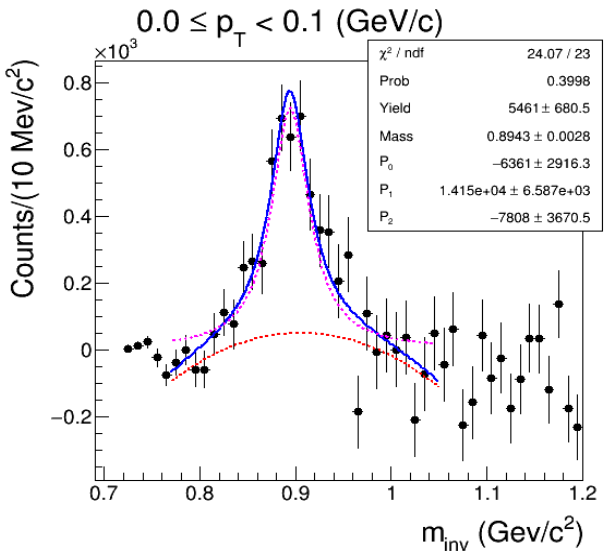


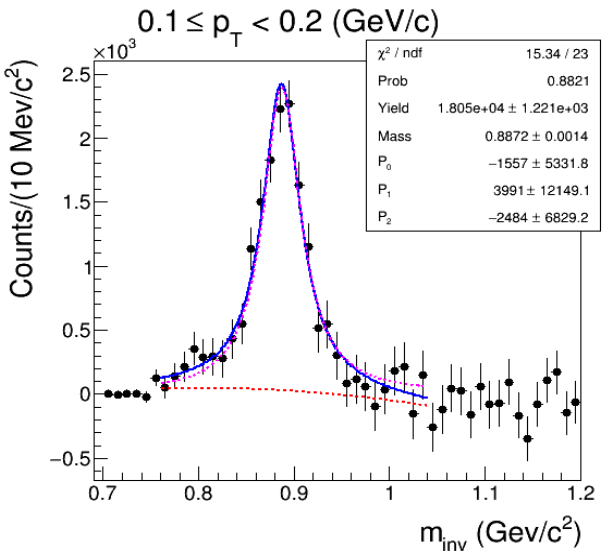
DCA_z distribution

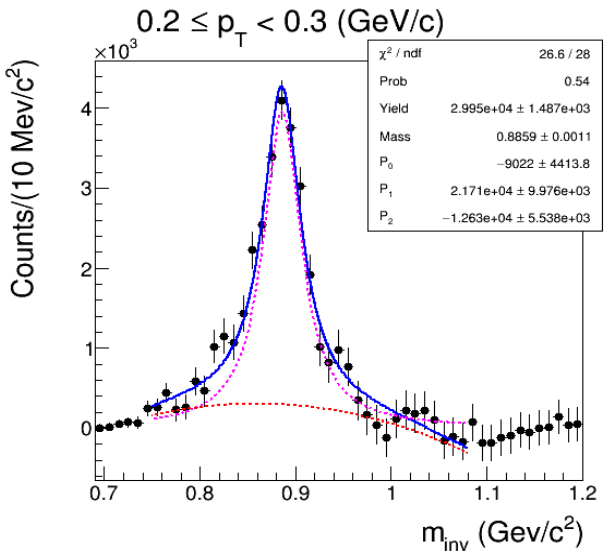


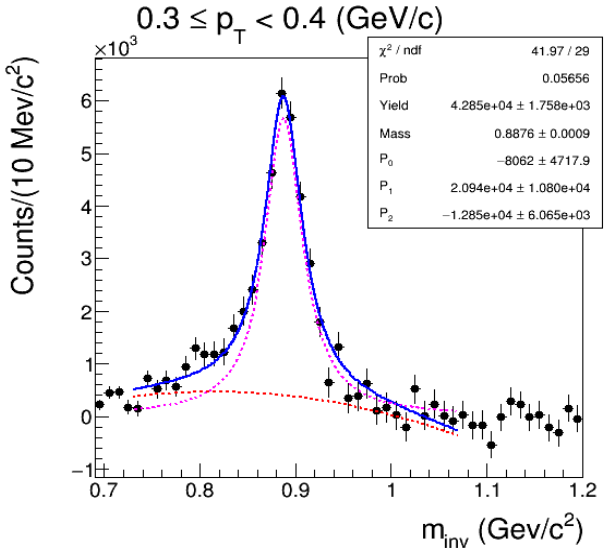
- DCA_{xy} and DCA_z distributions of selected pion candidates look reasonably good.

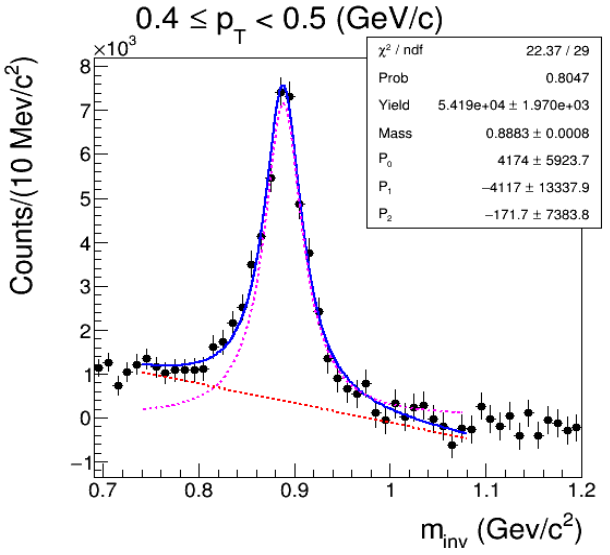
Invariant Mass Distributions - I

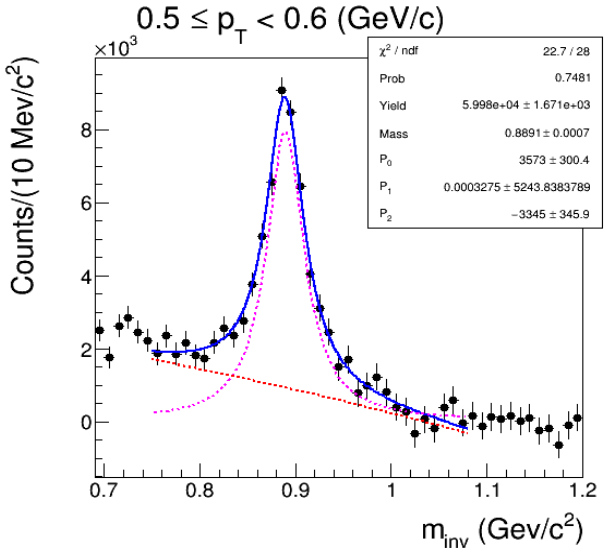






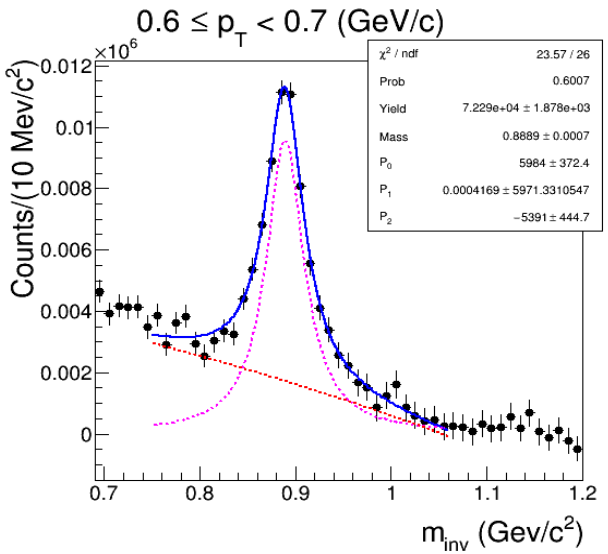


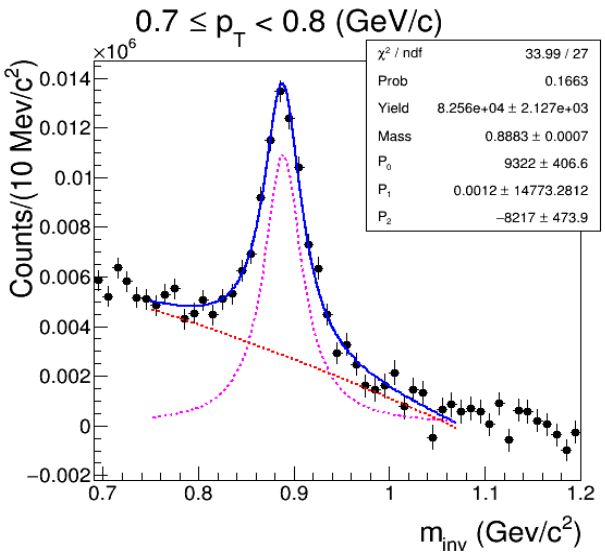


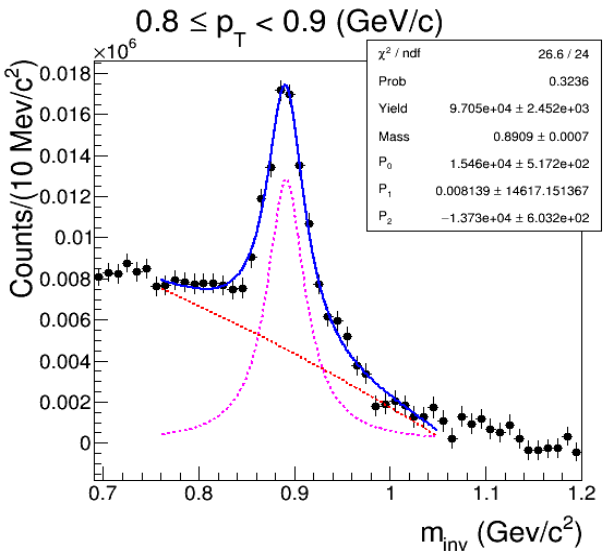


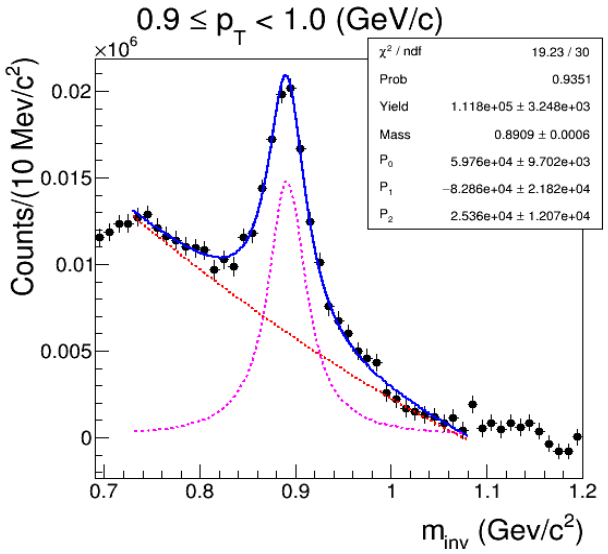
- Background Subtraction: Event Mixing
- Normalization Range : 1.10 – 1.30 GeV/c^2
- Fitting Range : 0.75 – 1.07 GeV/c^2
- Width fixed to PDG value

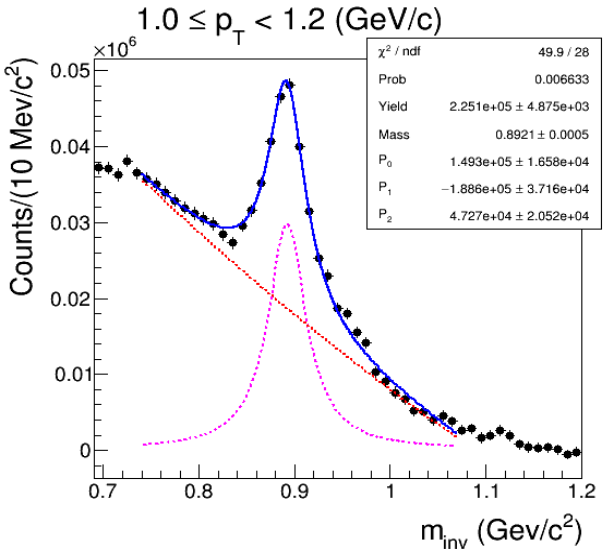
Invariant Mass Distributions - II

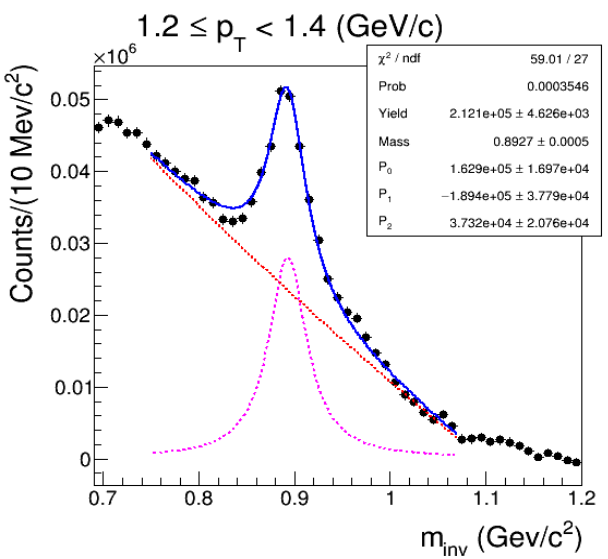






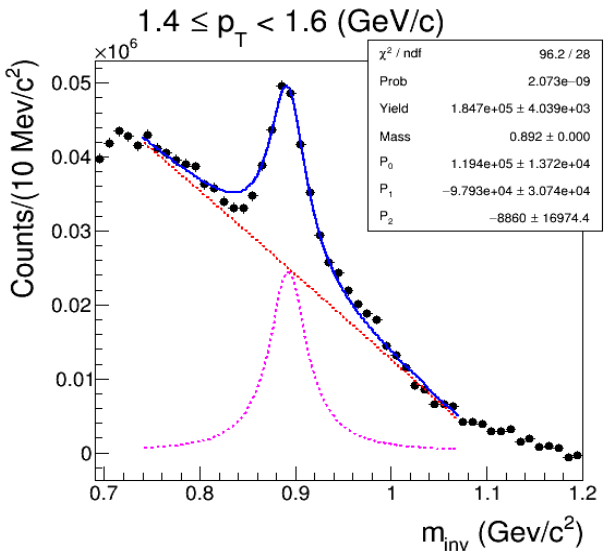


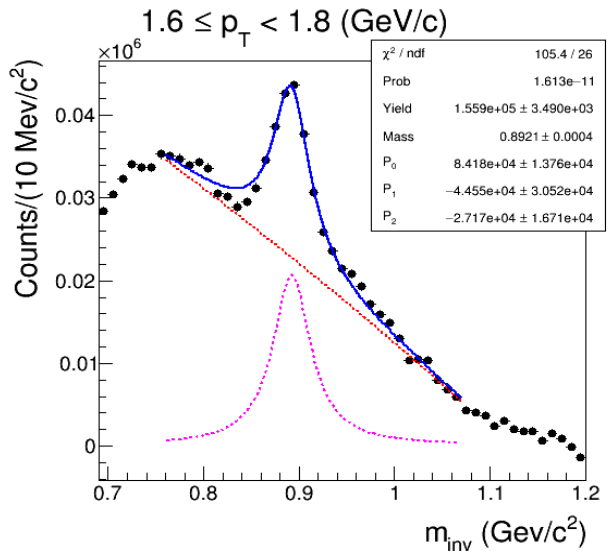


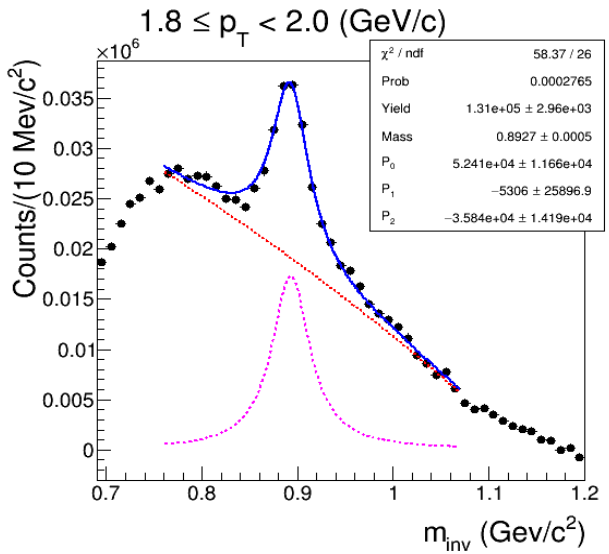


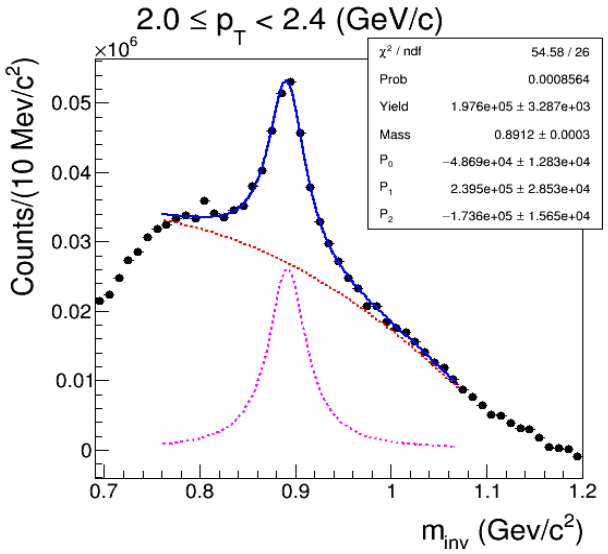
- Background Subtraction: Event Mixing
- Normalization Range : 1.10 – 1.30 GeV/c^2
- Fitting Range : 0.75 – 1.07 GeV/c^2
- Width fixed to PDG value

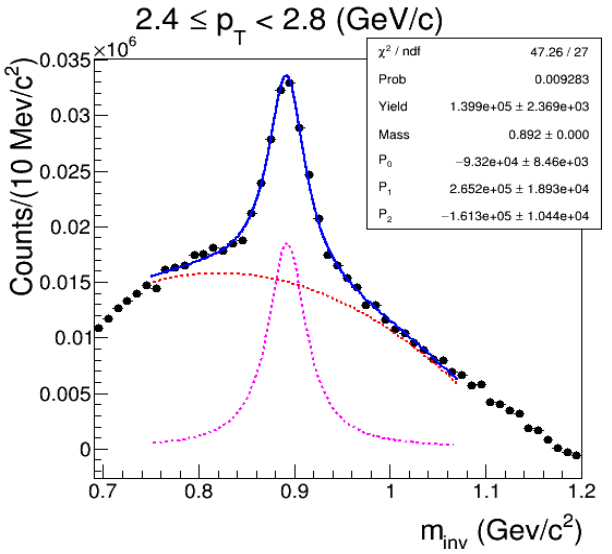
Invariant Mass Distributions - III

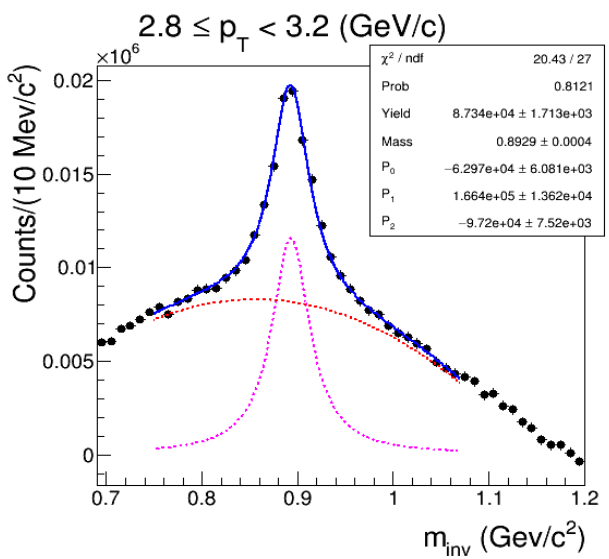






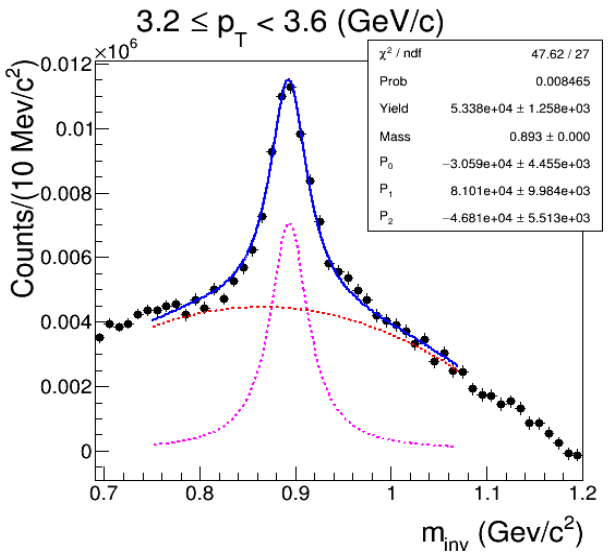


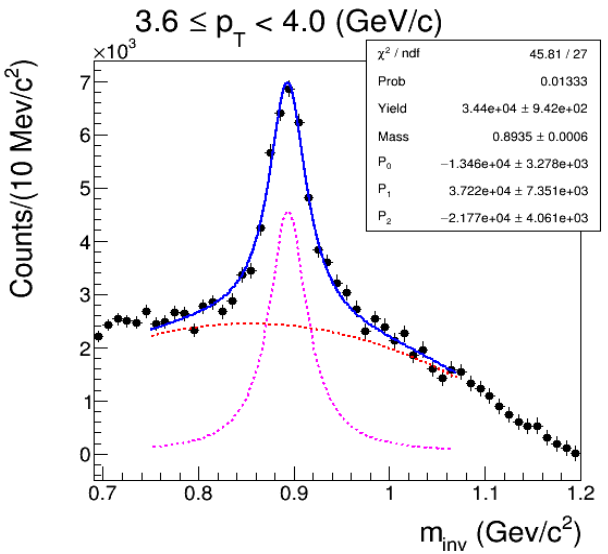


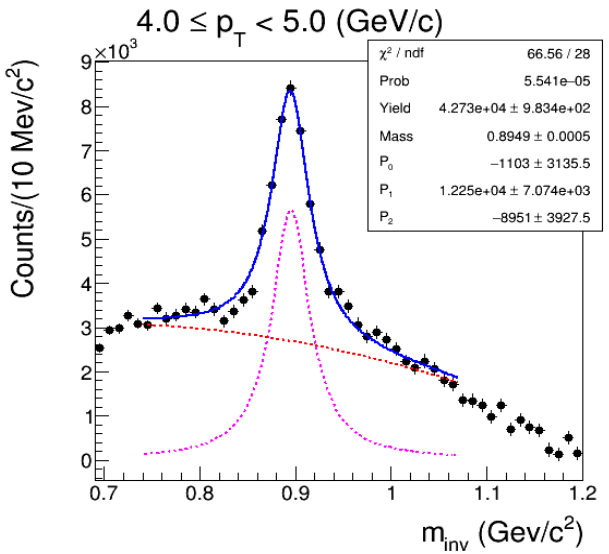


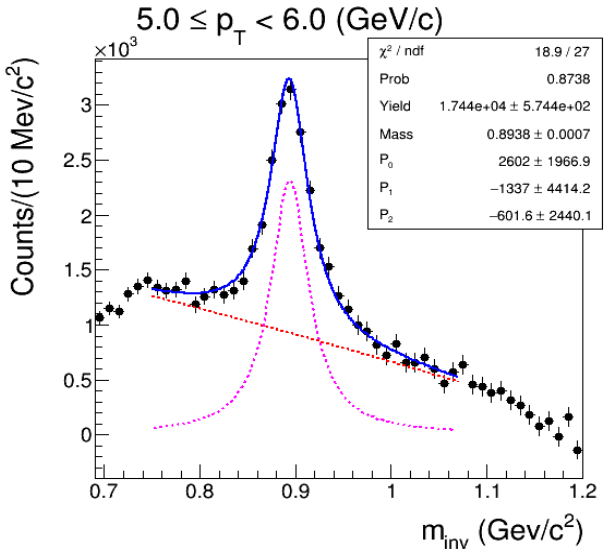
- Background Subtraction: Event Mixing
- Normalization Range : 1.10 – 1.30 GeV/c^2
- Fitting Range : 0.75 – 1.07 GeV/c^2
- Width fixed to PDG value

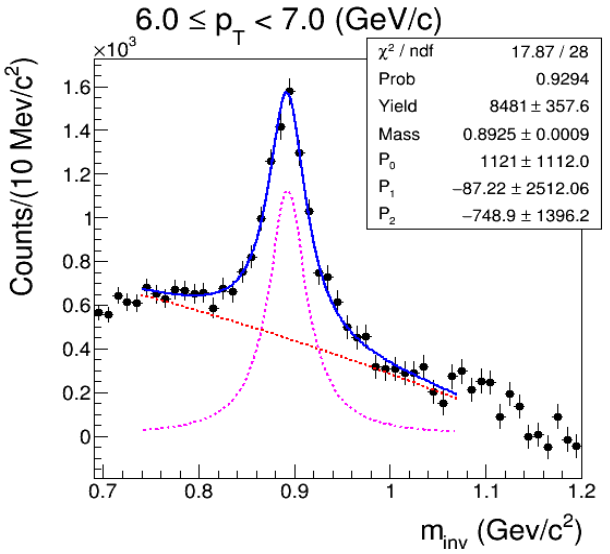
Invariant Mass Distributions - Iv

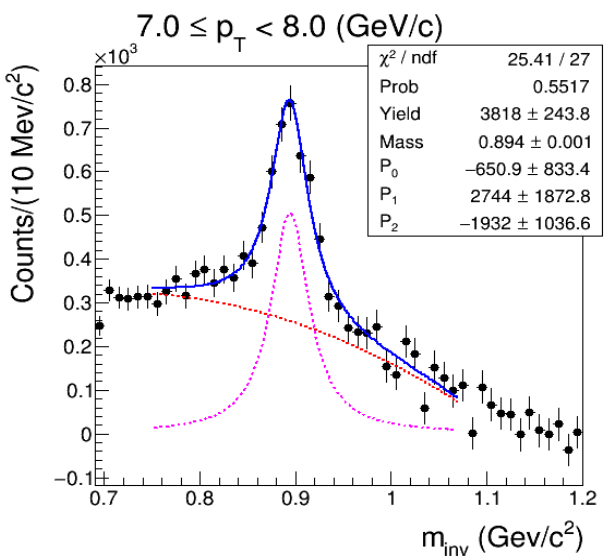






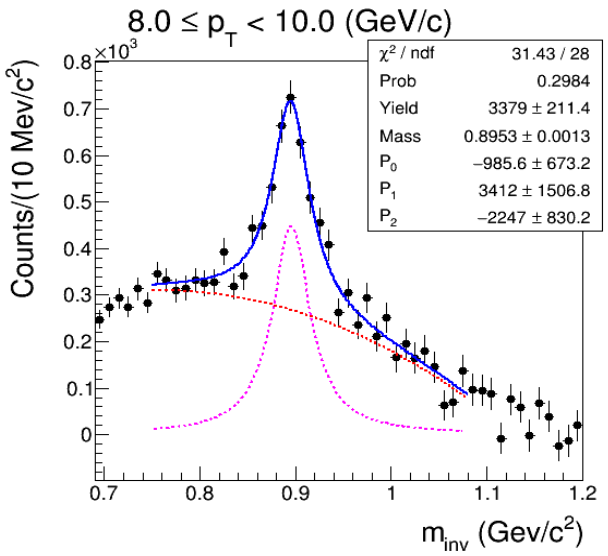


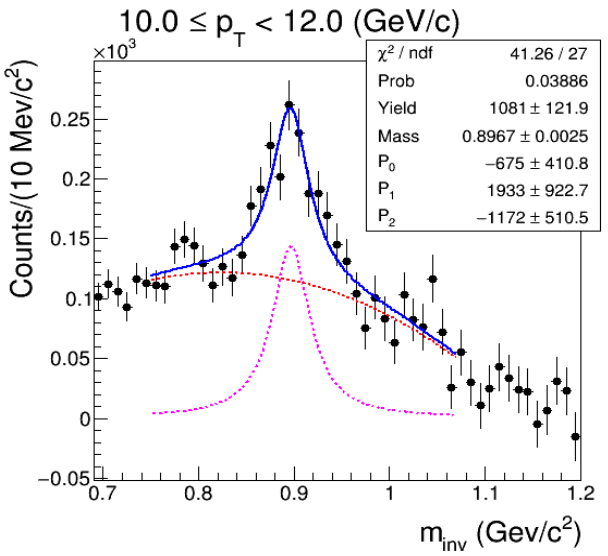


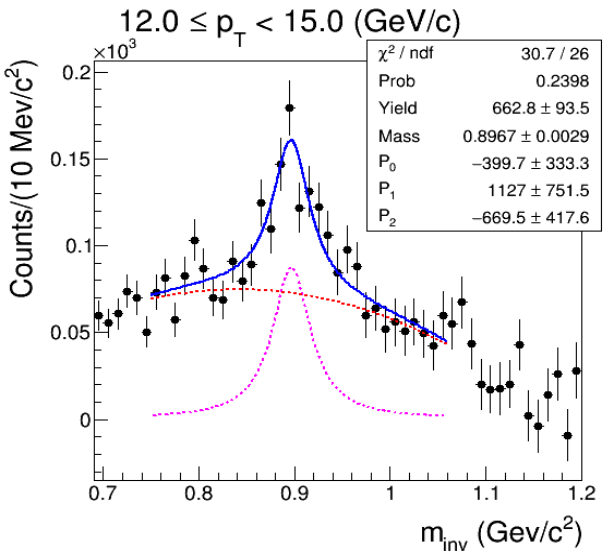


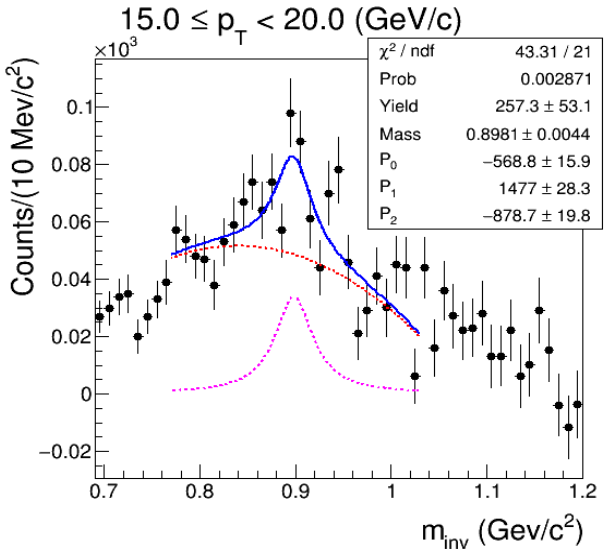
- Background Subtraction: Event Mixing
- Normalization Range : 1.10 – 1.30 GeV/c^2
- Fitting Range : 0.75 – 1.07 GeV/c^2
- Width fixed to PDG value

Invariant Mass Distributions - V





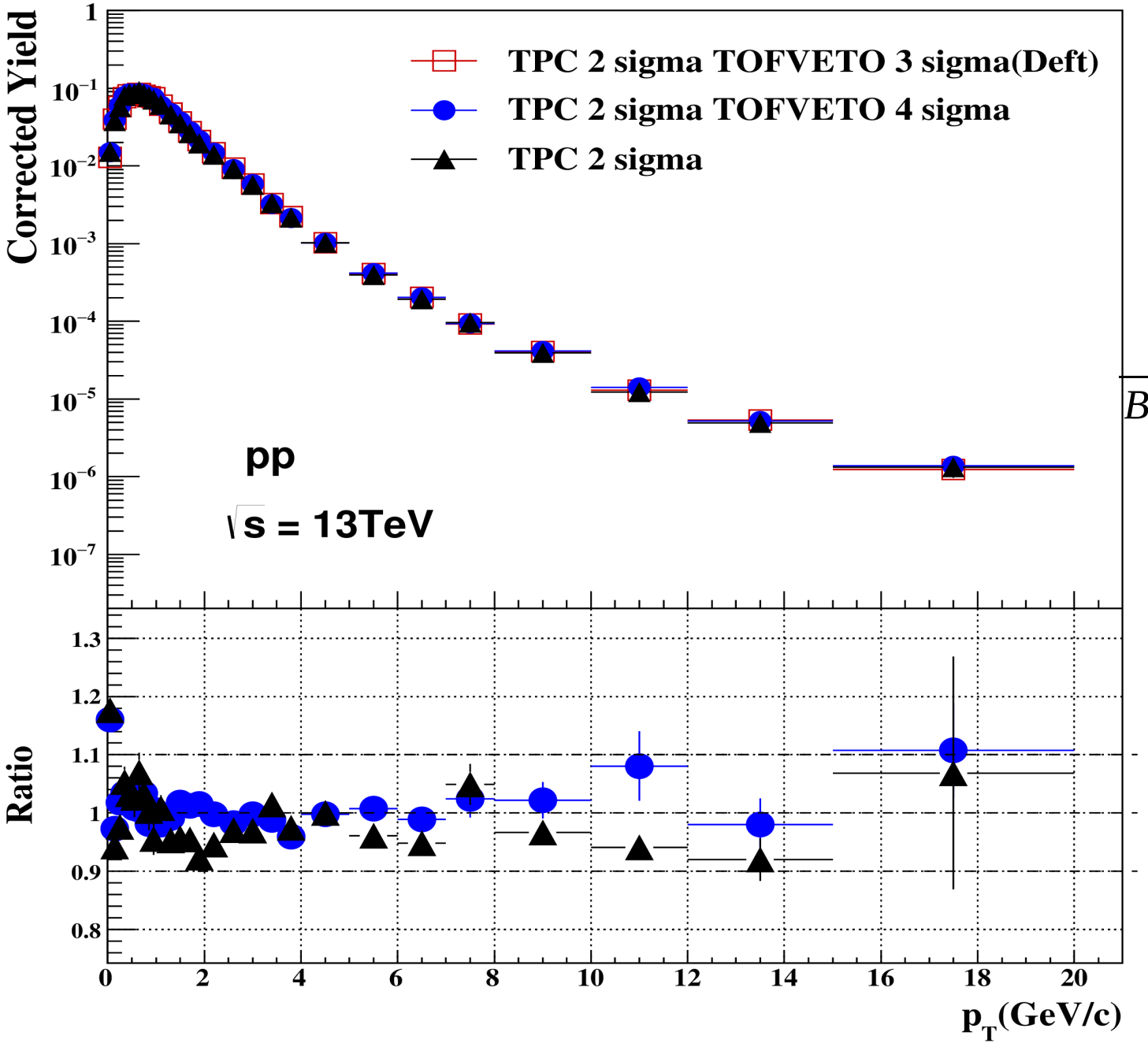




- Invariant mass distributions are shown for different p_T intervals from 0 to 20 GeV/c.
- Each distribution is fitted with Breit-Wigner + pol2 function.

- Background Subtraction: Event Mixing
- Normalization Range : 1.10 – 1.30 GeV/c^2
- Fitting Range : 0.75 – 1.07 GeV/c^2
- Width fixed to PDG value

Corrected Spectra

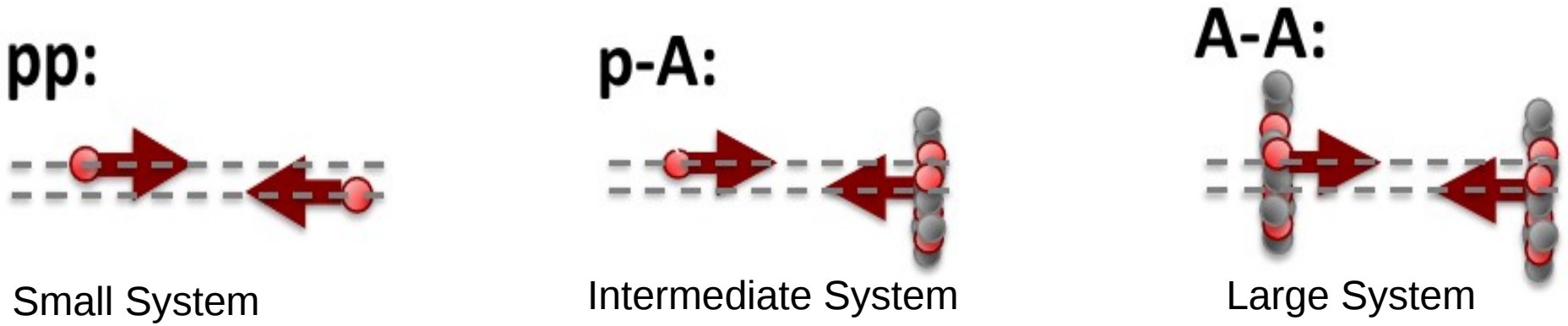


- Corrected yield =

$$\frac{Raw\ yield}{BR\ x\ (Acceptance\ x\ Efficiency)}$$

- Here, BR = 0.66

Introduction



- We don't expect medium formation in pp collisions as compared to p-A and A-A collisions.
- pp collisiosn is used as a base line study for p-A and A-A collisions.
- pp collision can be used for tuning the QCD inspired model.
- Minimun bias spectrum acts as a reference for multiplicity-dependent measurements.