D^0-meson yield as a function of event shape variables (Sphero(i)city) in pp collision with ALICE

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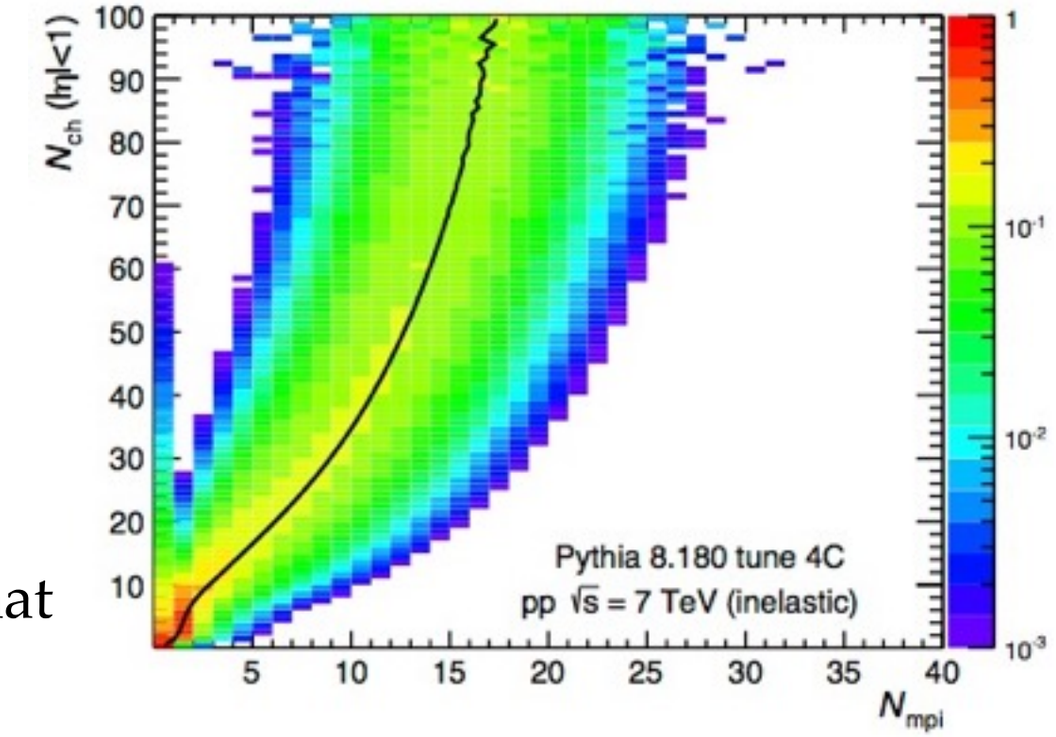
Outline

- Why event shapes?
- Event shape
- Data set and D^0 invariant mass
- Multiplicity study
- Efficiency × Acceptance
- Cross section
- Spherocity Results
- Summary

Why Event Shapes?

- The collective flow-like behaviour in hadron collisions
  - ➡ multi-parton interaction (MPI) and color reconnection

- Figure shows correlation between multiplicity and number of multi-parton interaction (N_{mpi})
  - ➡ width of distribution of MPI - prevents use of multiplicity alone
  - ➡ saturation at high multiplicity



- The use of event shape allows to isolate jetty-like (high p_T jets) and isotropic events

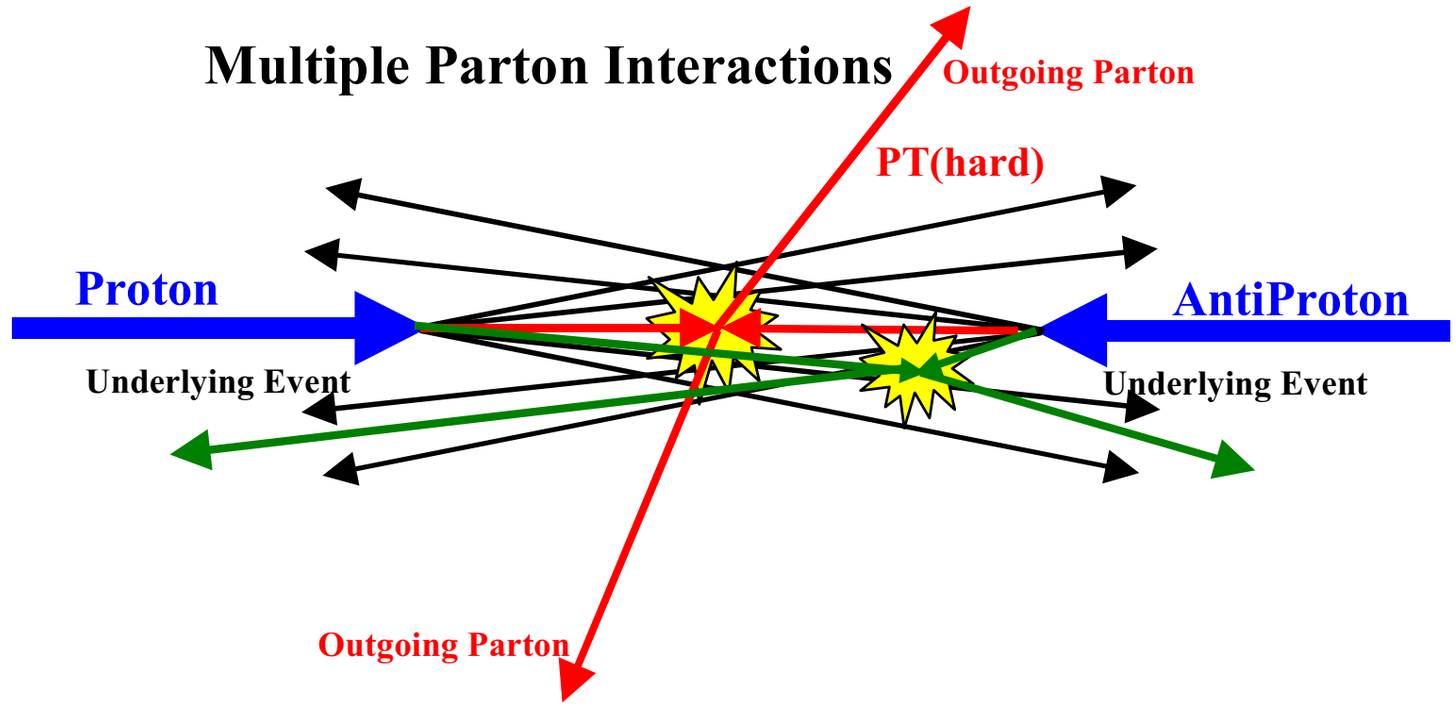
- Average N_{mpi} is higher in isotropic events than that of jetty-like events

- With events shapes, selectivity of events with certain number of MPI can be improved

(arXiv:1503.03129v2)

Event Shapes

- **Jets**
  - Hard Scattered partons
  - Final state radiations
- **Underlying events**
  - Initial state radiations
  - Beam-beam remnants
  - Multiple parton interaction



- Event shapes in Minimum Bias sensitive to underlying events **(arXiv:1205.3963v1)**
- Event Shapes characterise the distribution of the outgoing particle energy from a high energy collision.
- In hadron-hadron collisions, event shape analyses are restricted to the transverse component w.r.t. beam axis to avoid the bias from the boost along beam.

Event Shapes

Sphericity

In terms of the eigenvalues, λ_1 and λ_2 of transverse momentum matrix,

$$S_{xy}^{L} = \frac{1}{\sum_i p_{T_i}} \sum_i p_{T_i} \begin{pmatrix} p_{x_i}^2 & p_{x_i} p_{y_i} \\ p_{y_i} p_{x_i} & p_{y_i}^2 \end{pmatrix}$$

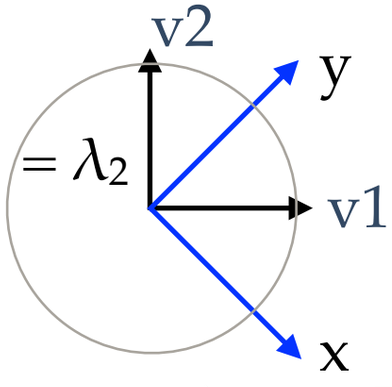
Where, (p_{x_i}, p_{y_i}) are projection of p_{T_i}

Transverse Sphericity,

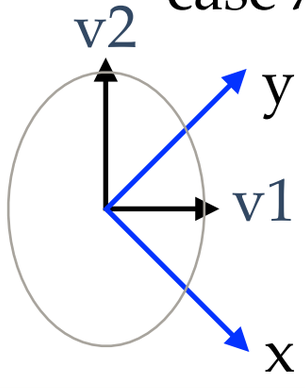
$$S_T = \frac{2\lambda_2}{\lambda_1 + \lambda_2}$$

$where, \lambda_1 \geq \lambda_2$

case $\lambda_1 = \lambda_2$



case $\lambda_1 > \lambda_2$



(arXiv:1205.3963v1)

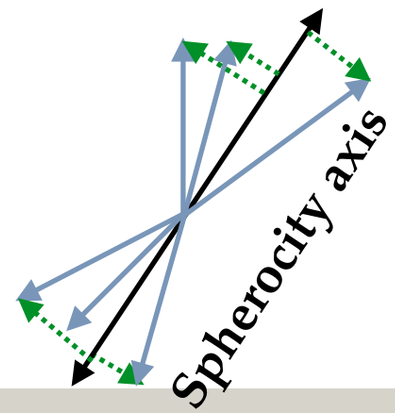
$$S_T, S_0 = \begin{cases} 0 & \text{“pencil-like” limit (hard events)} \\ 1 & \text{“isotropic” limit (soft events)} \end{cases}$$

Spherocity

Mid rapidity charged hadron transverse spherocity,

$$S_0 = \frac{\pi^2}{4} \left(\frac{|\sum_i \vec{p}_{T_i} \times \hat{n}|}{\sum_i p_{T_i}} \right)^2$$

Where, $\hat{n}$ is unit transverse vector which minimises the ratio. **(arXiv:1503.03129v2)**



(arXiv:1001.4082)

$|\eta| < 0.8$;

Transverse momentum, $0.15 < p_T < 10$ GeV/c

events with two particles, NTracklets > 3

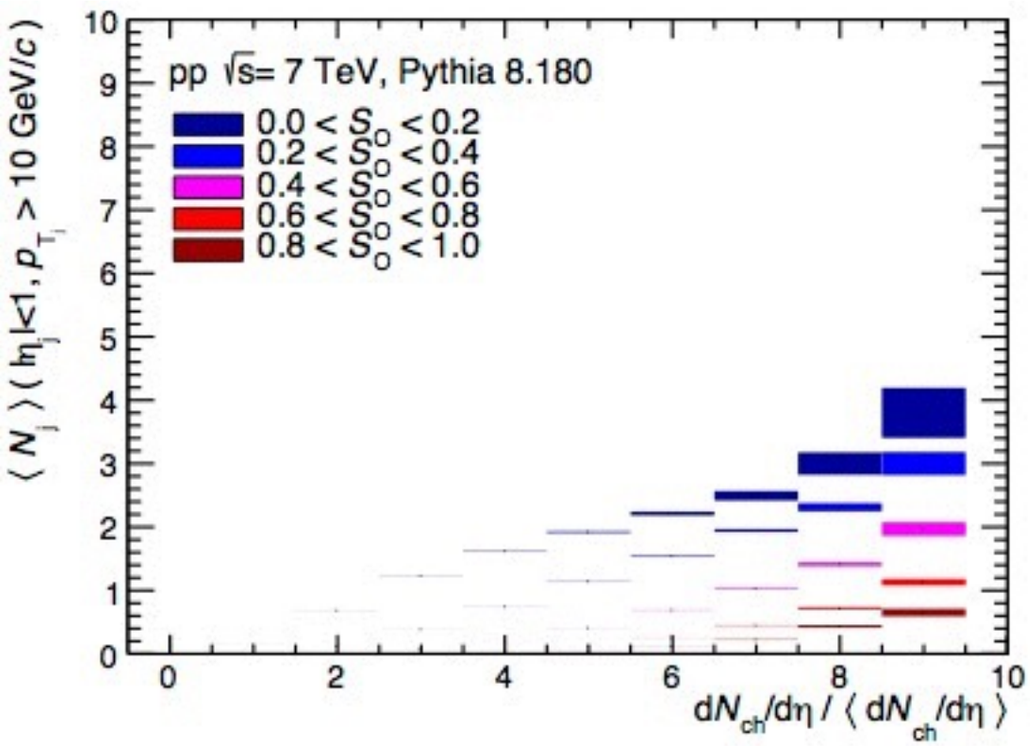
Hybrid track cuts - filter bits 256, 512

(Antonio Ortiz)

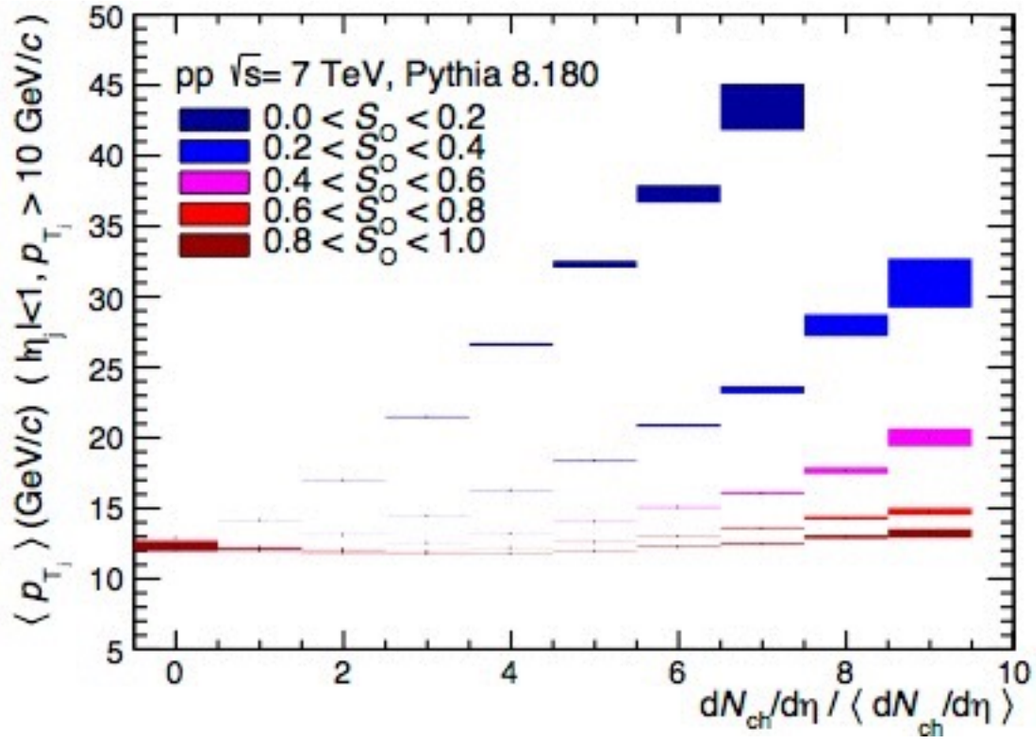
Event Shapes

- For isotropic events ($S_0 > 0.8$), the average no. of jets is below 1 and jet production is largest for jetty-like events ($S_0 < 0.2$) (left figure)
- Small fraction of jet shows flat trend close to 10 GeV for isotropic events (minimum jet p_T was set to 10 GeV/c). For jetty-like events, the average p_T is above 30 GeV/c (right figure)
- Expect to observe the same trend for inclusive charged hadrons instead of jets.

(arXiv:1503.03129v2)



Average no. of jets vs. Event Multiplicity



Average no. of jet p_T vs. Event Multiplicity

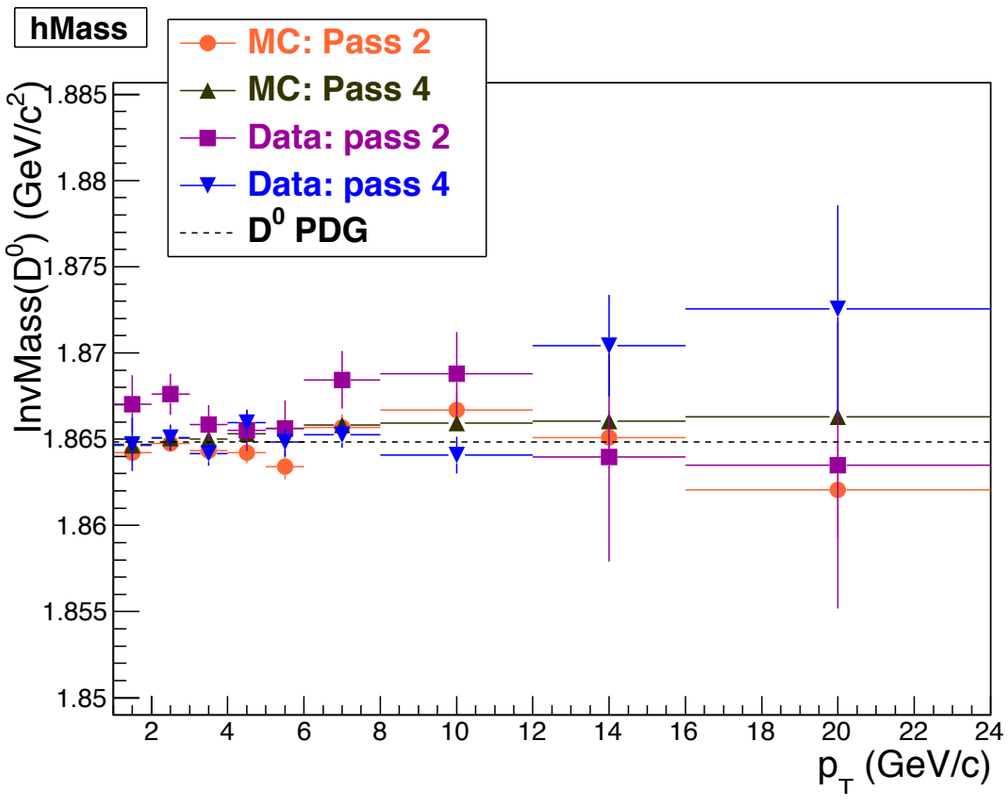
Data Set and Invariant Mass: $D^0 \rightarrow K^-\pi^+$

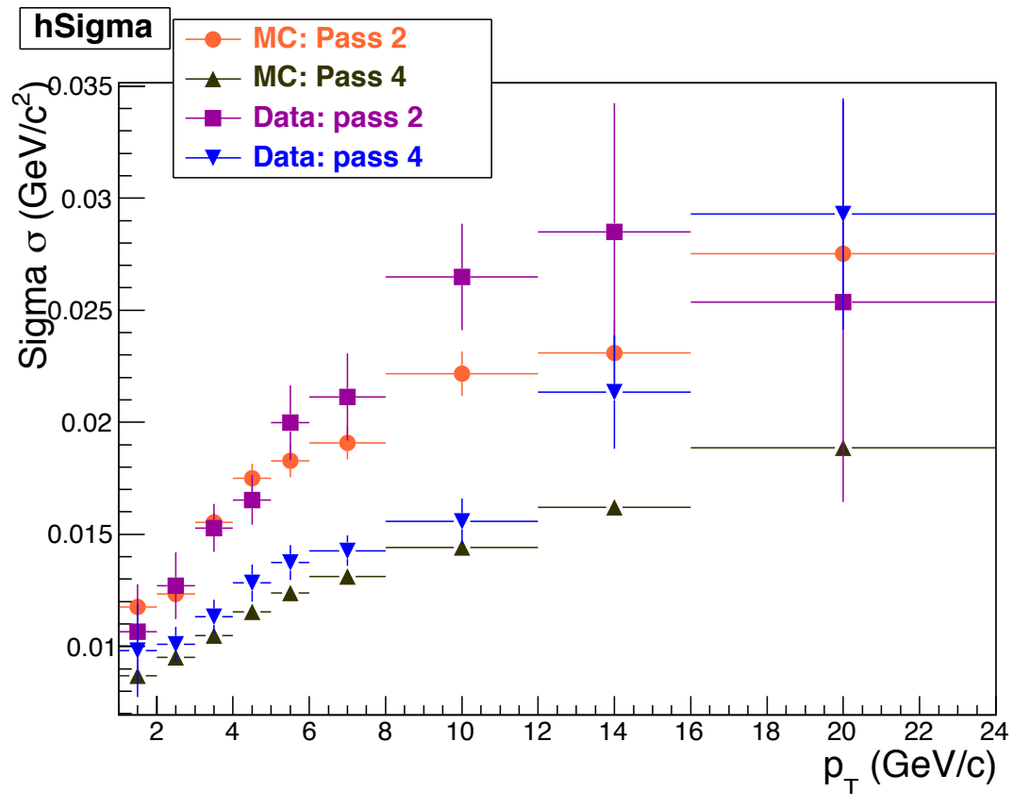
$D^0 \rightarrow K^-\pi^+$ (3.9%)

Checks with Pass 4 data to assure it's use

System	Run/Pass	N_{Events}	Period
pp (data)	2010/pass2	~316M	LHC10b,c,d,e
pp (data)	2010/pass4	~364M	LHC10b,c,d,e
pp (MC)	Anchor pass2	~23M	LHC10f7a
pp(MC)	Anchor pass4	~57M	LHC15a2a

- Inner Tracking System (ITS)
- Time Projection Chamber (TPC)
- Time Of Flight (TOF)



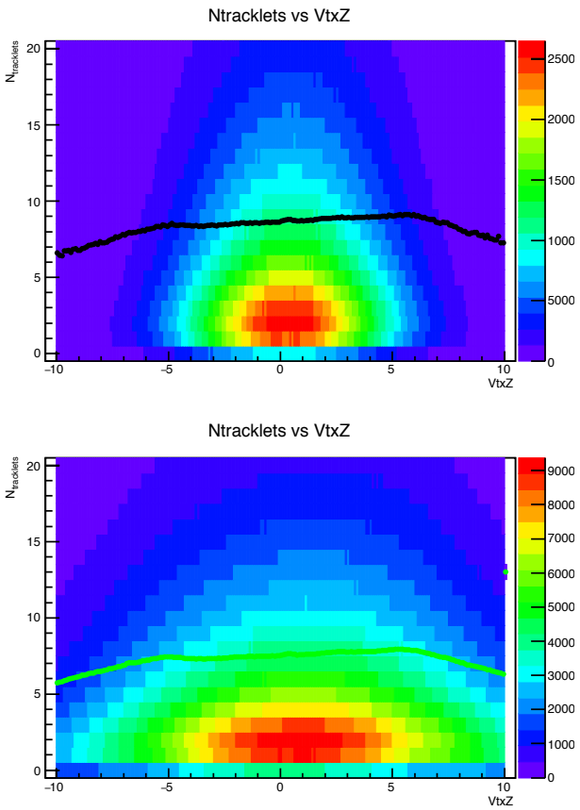


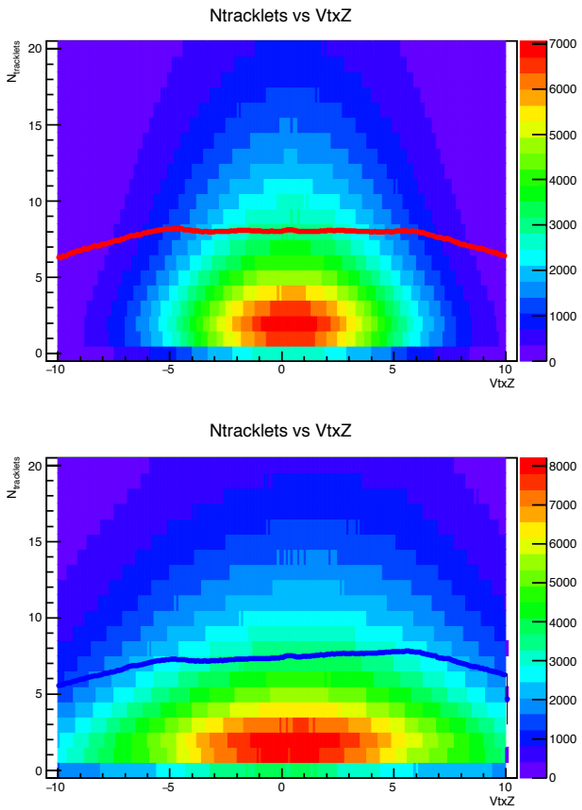
The sigma is narrower in pass 4 ⇒ improved calibration and alignment of the detectors

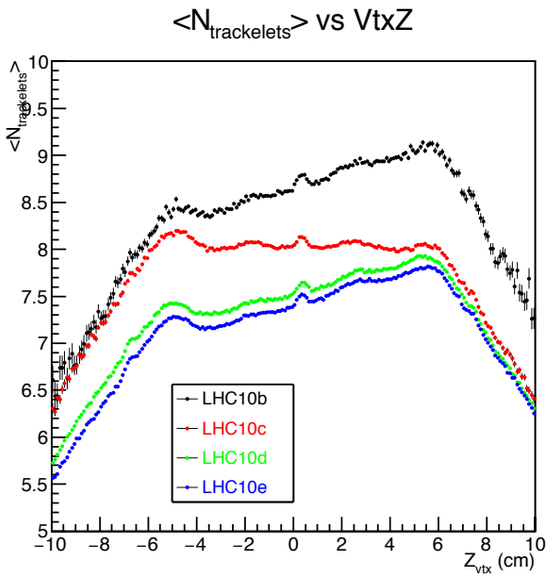
Pass 2 and 4 data, MC are within expected uncertainties

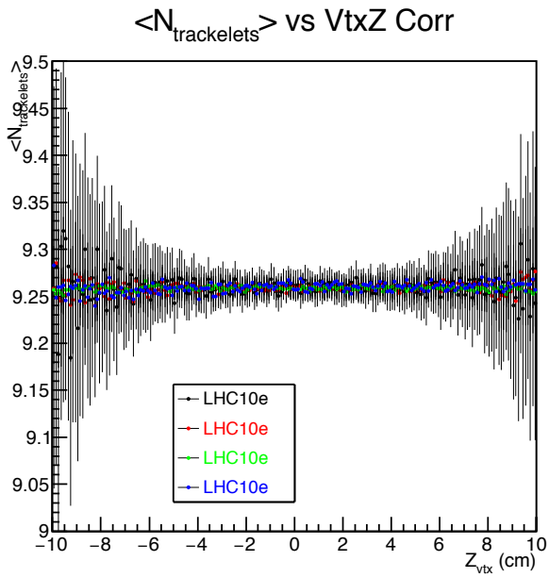
Significance is higher for pass 4 data than pass 2

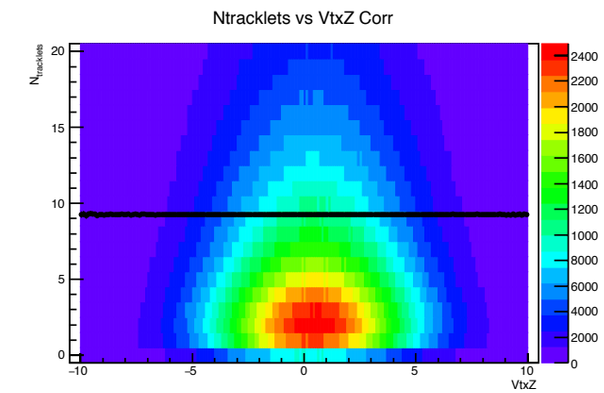
$N_{tracklets}$ vs. Z-vertex (Pass 4 data)

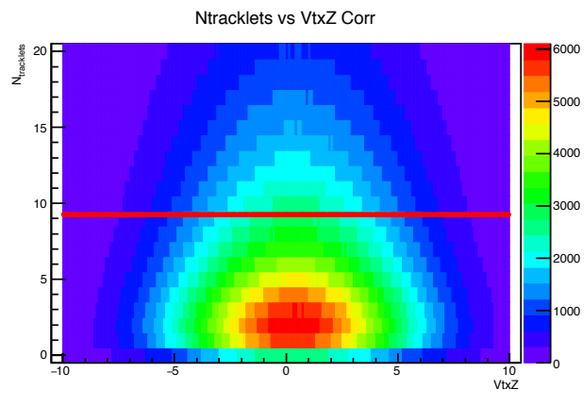










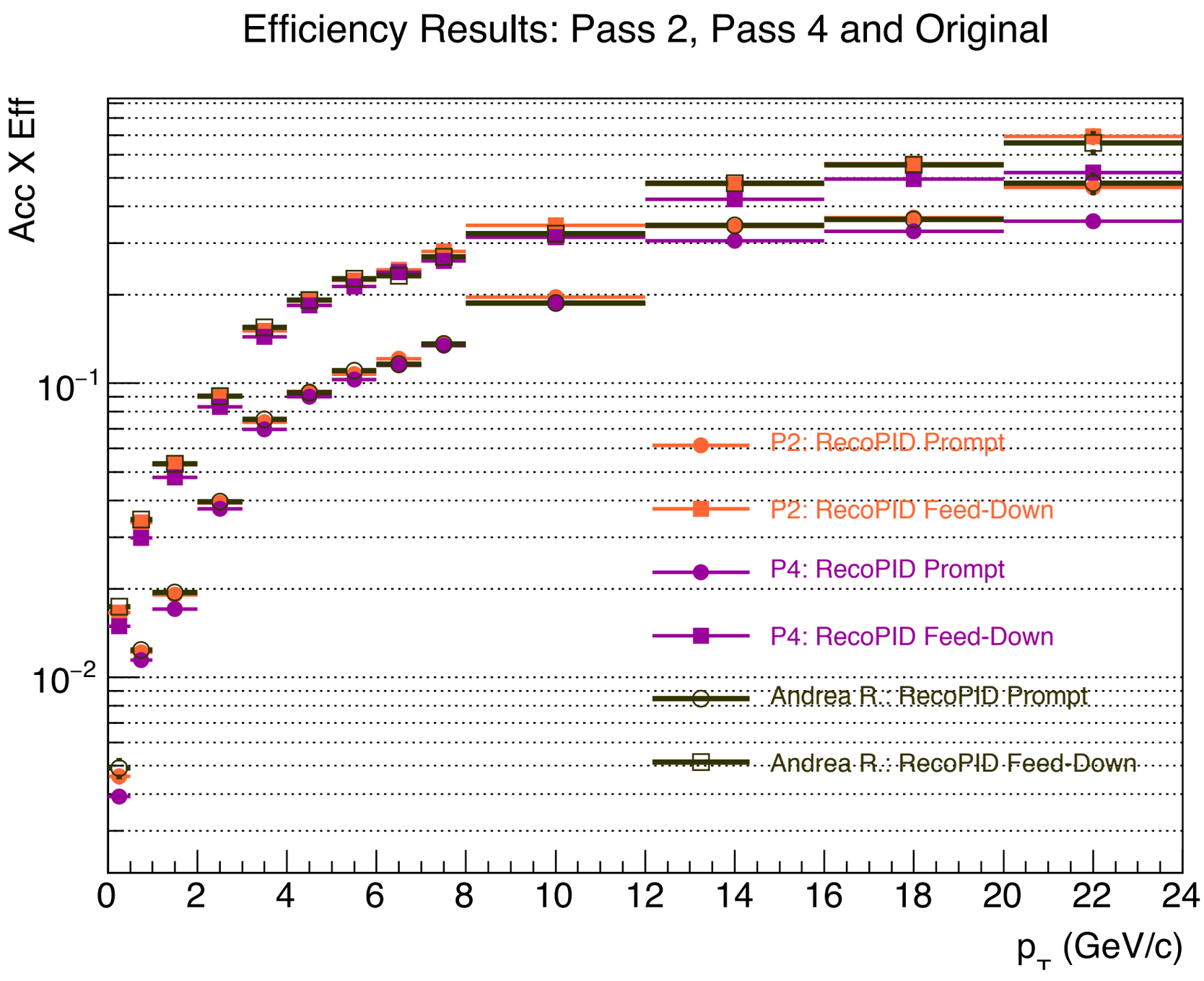


The SPD acceptance drops off with time as well as with the position of the vertex

The number of tracklets N_{raw} is corrected event-by-event to equalise the average number of tracklets among four periods and to correct for the dependence on Z_{vtx}

$$N^{corr} = \frac{< N_{ref} >}{< N_{period}(Z) >} N_{raw}$$

Efficiency × Acceptance(FastMC)

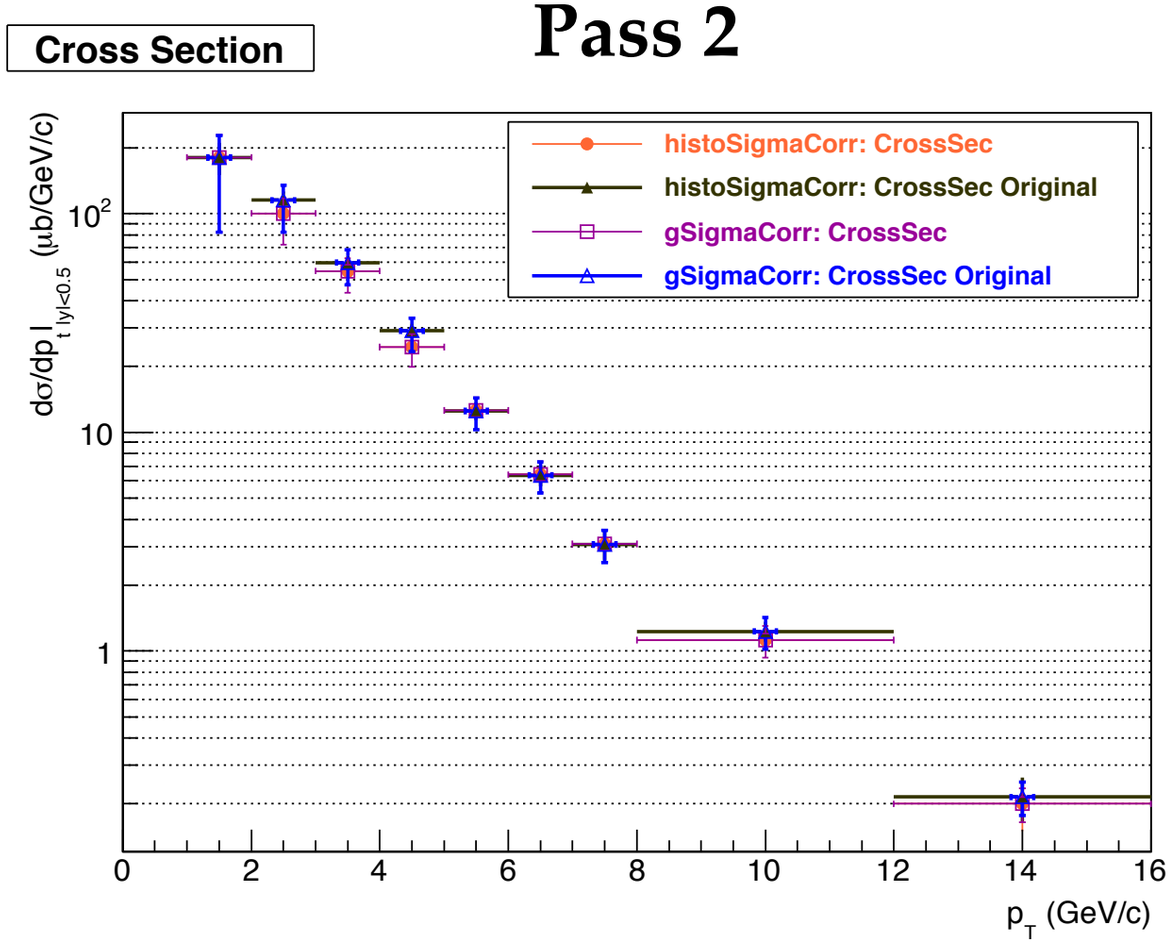


The efficiency of pass 2, pass 4 and published are comparable and they are within 5%

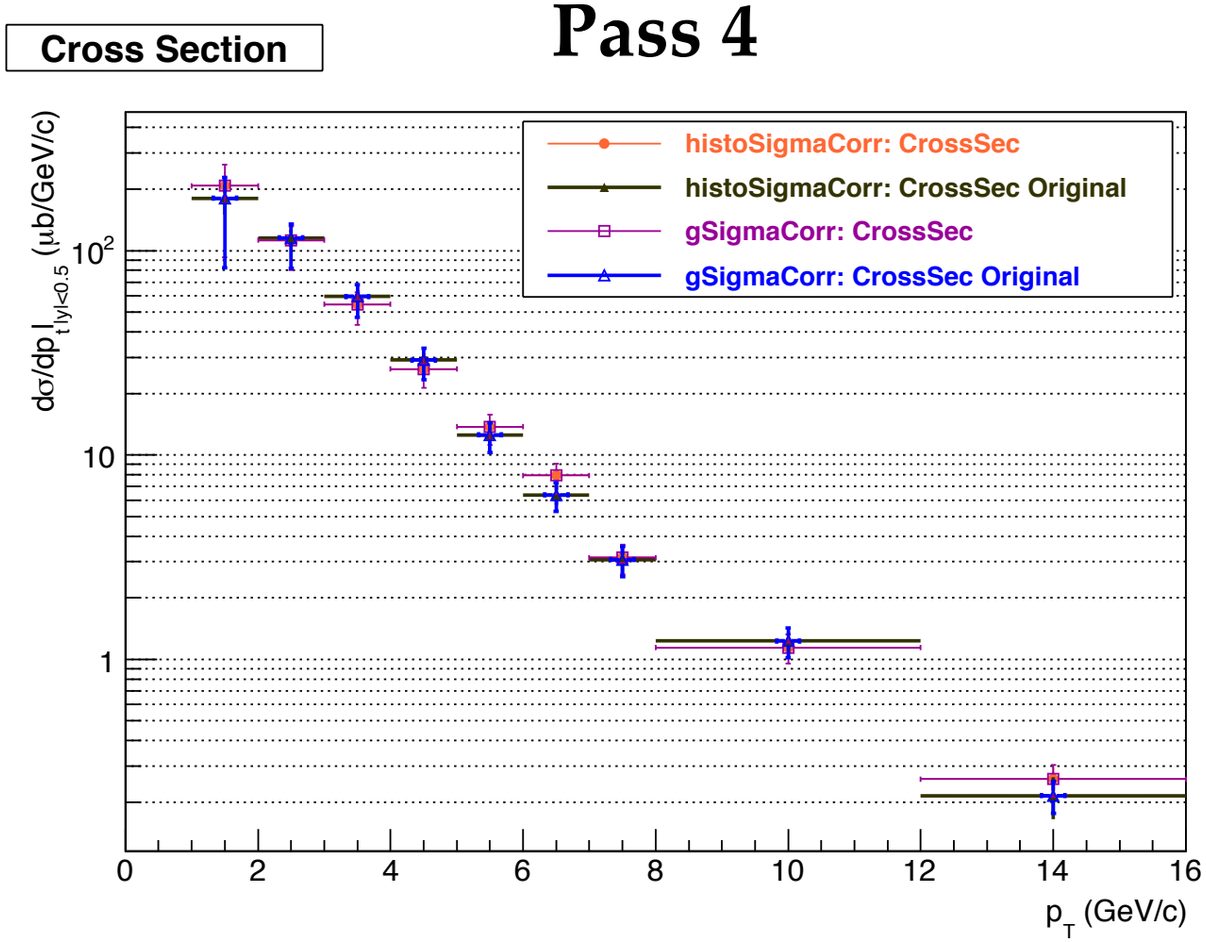
Cross Section

- Cross section for pass 2 data and pass 4 data is computed from efficiencies.
- Raw yield is calculated from invariant mass fitting
- The computed cross section for pass 2 and pass 4 are compared with originally published results

Pass 2

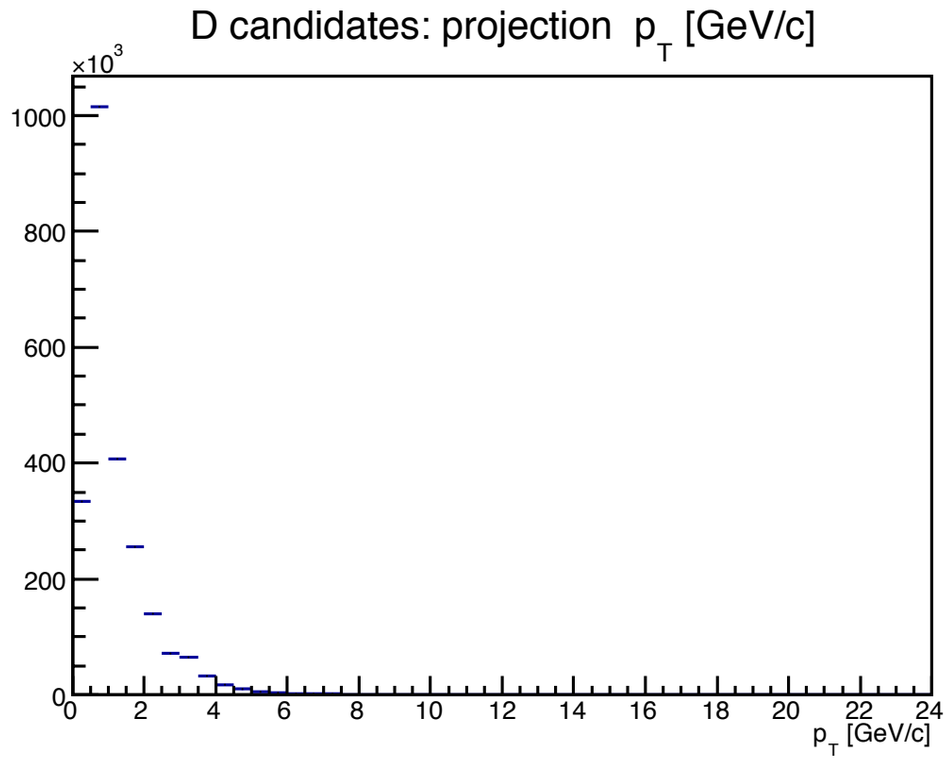


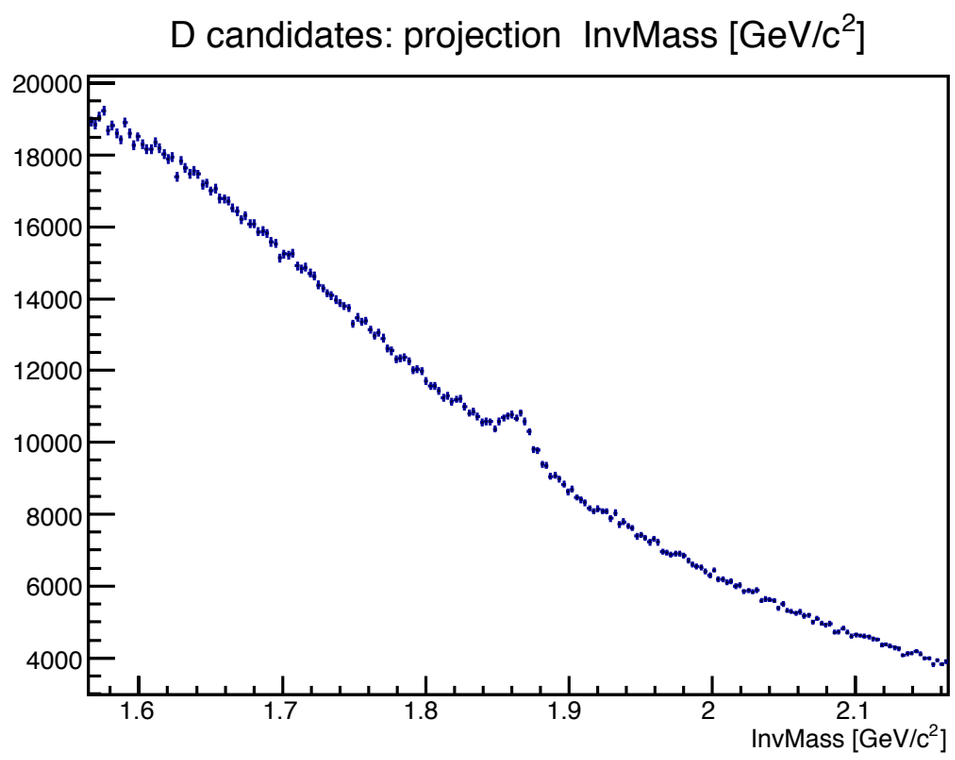
Pass 4

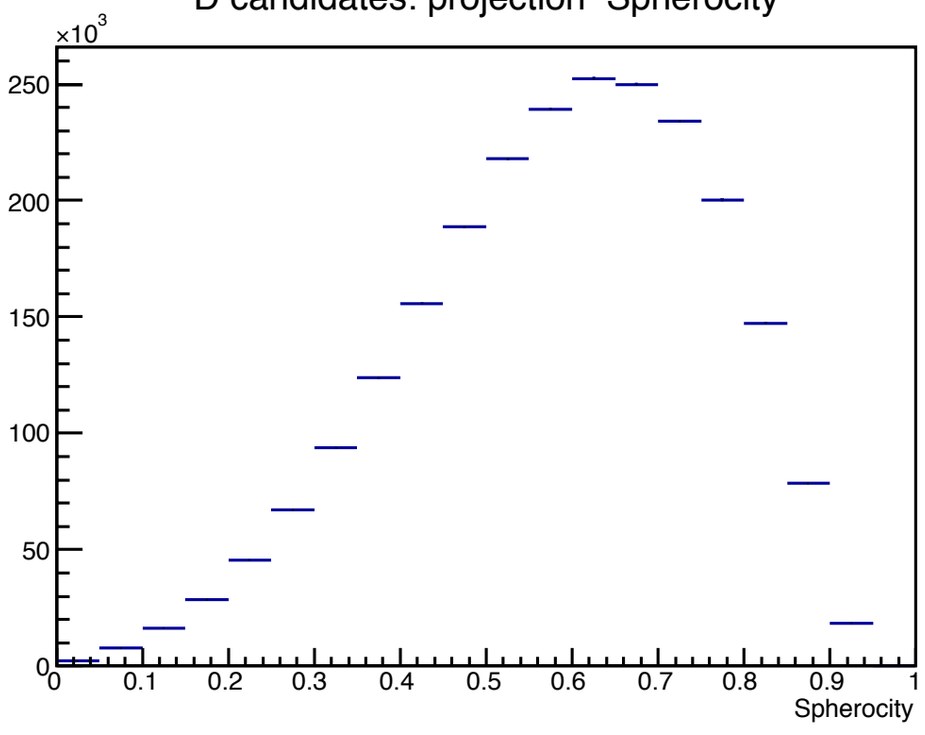


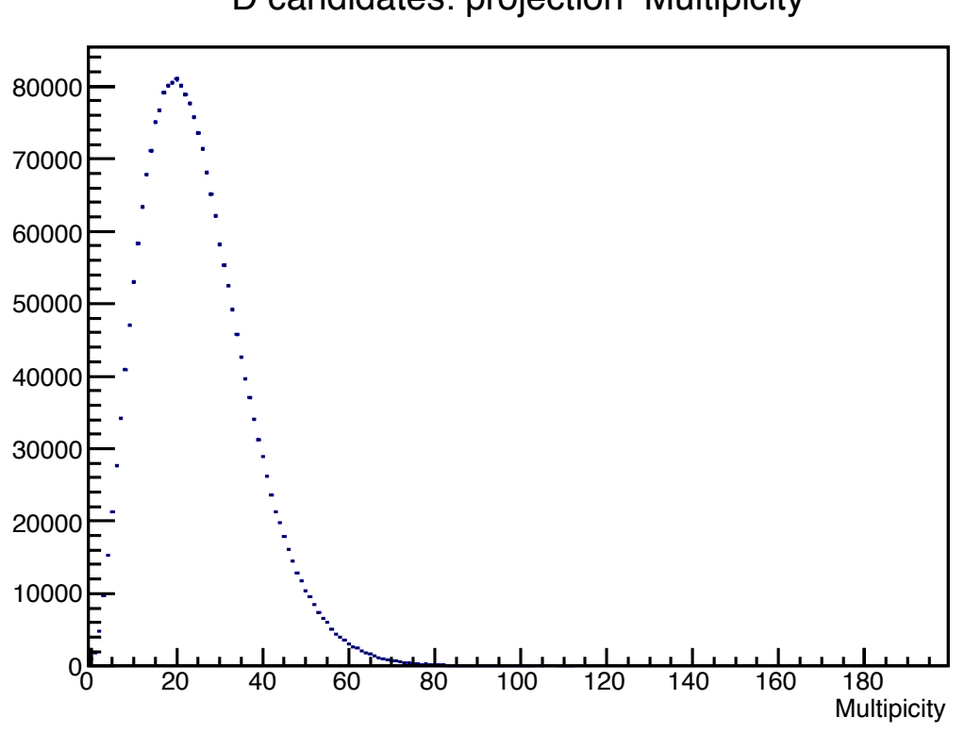
With this we positively concluded our checks for pass 4 data.

Projection: p_T, Mass, Spherocity, Multiplicity

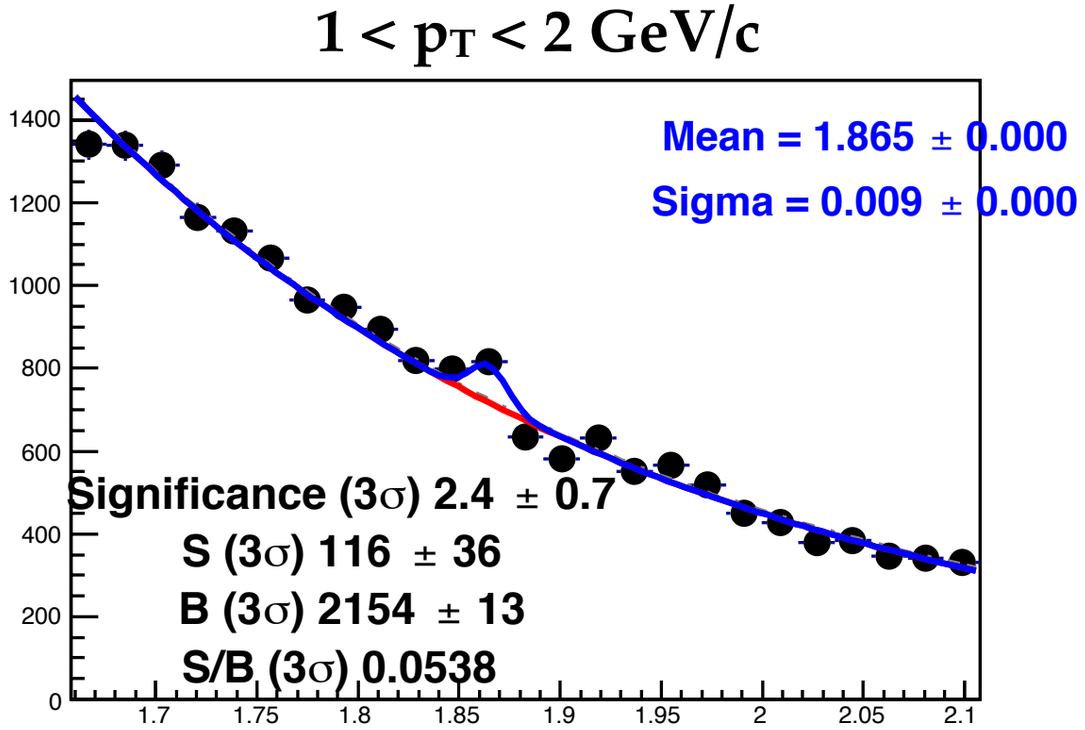


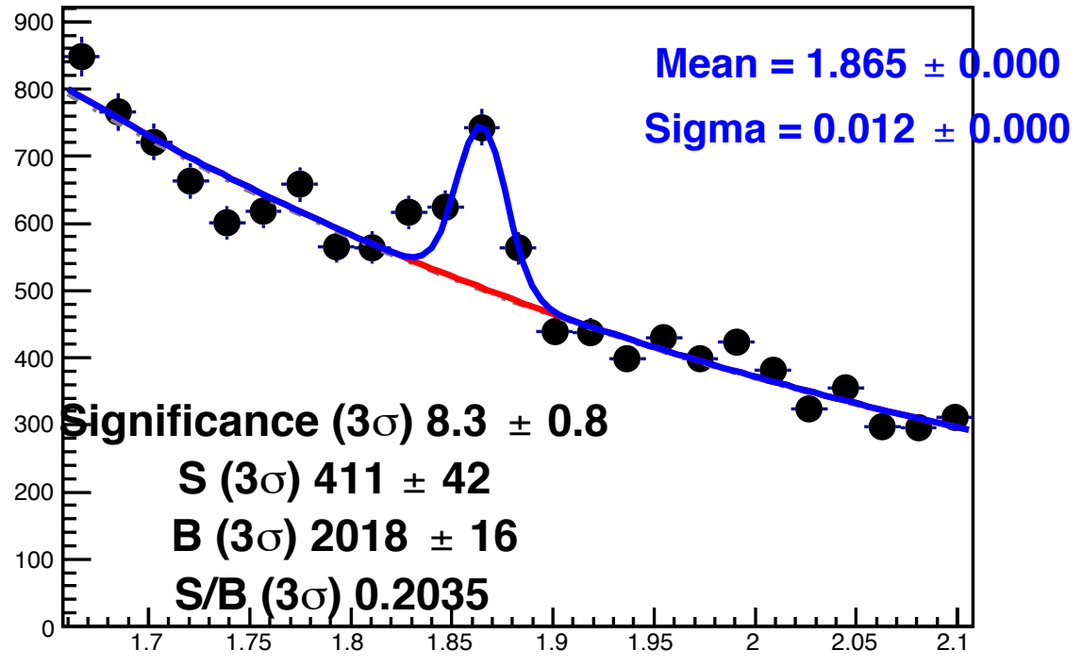


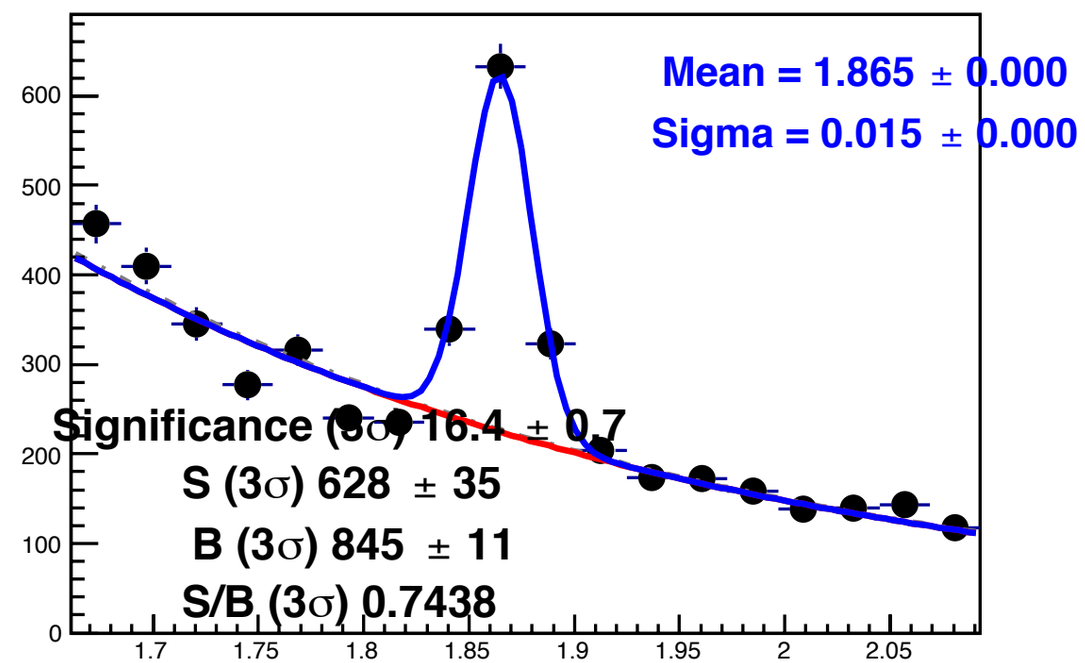


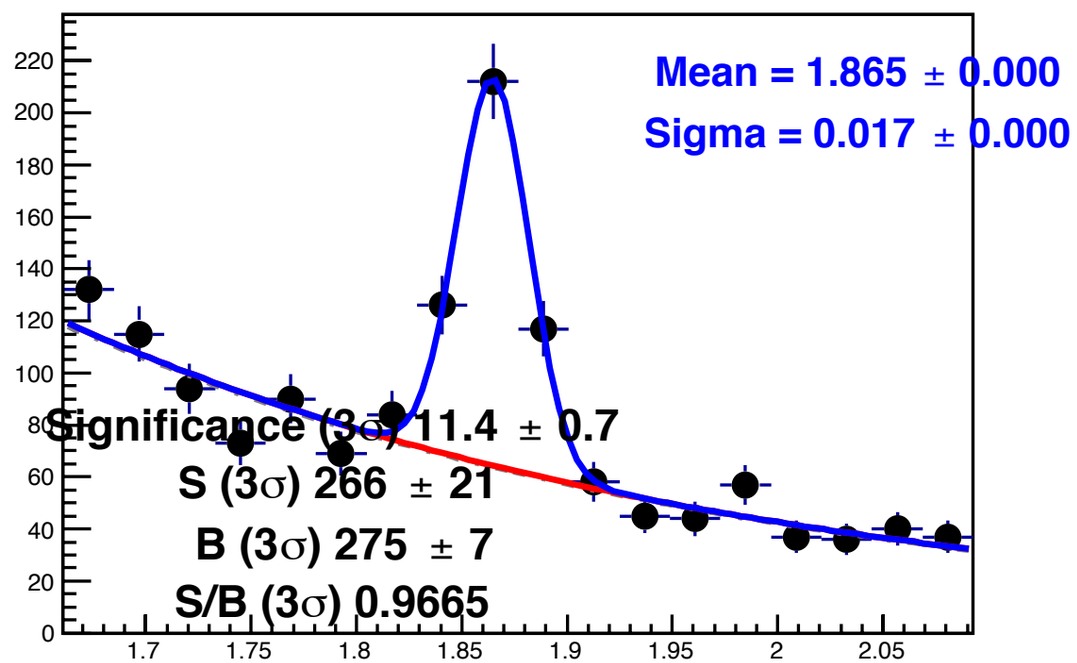


one Mult Bin: Ntrk[1,81]; Sphero[0.0, 0.3]









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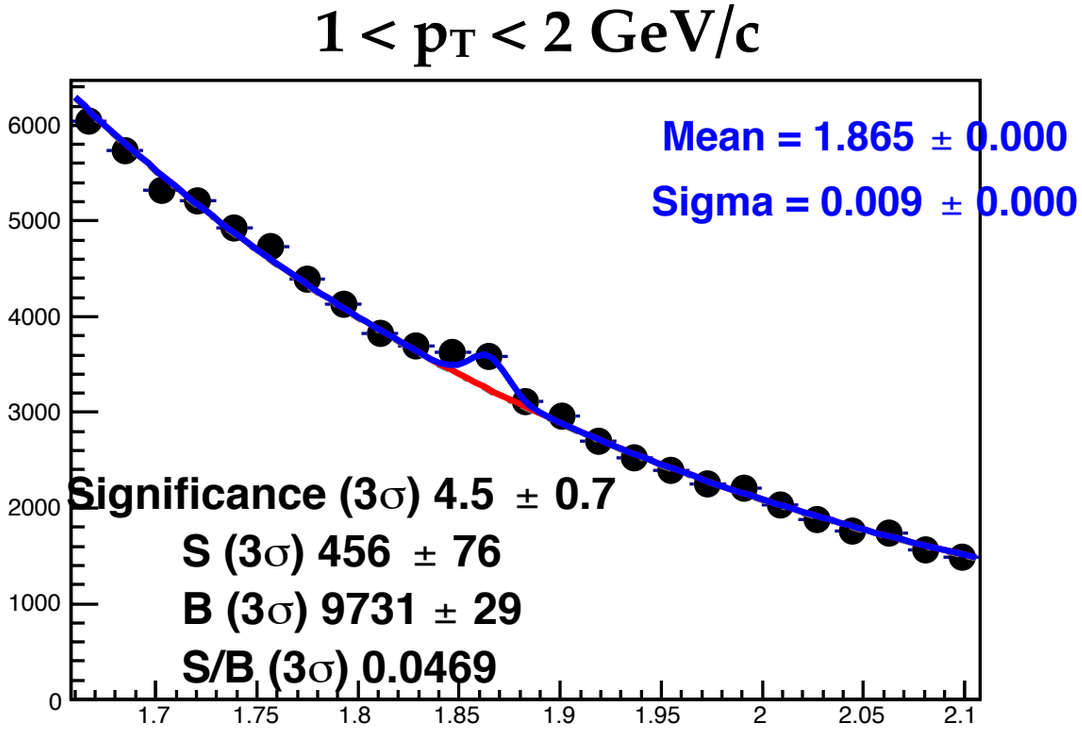

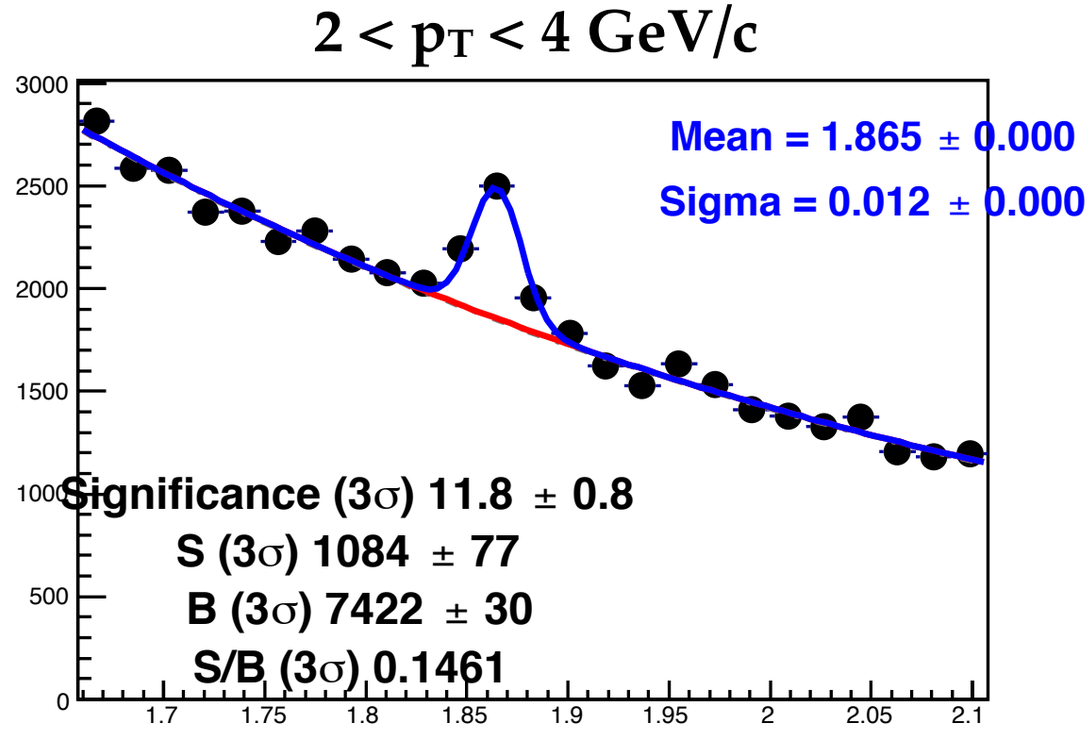

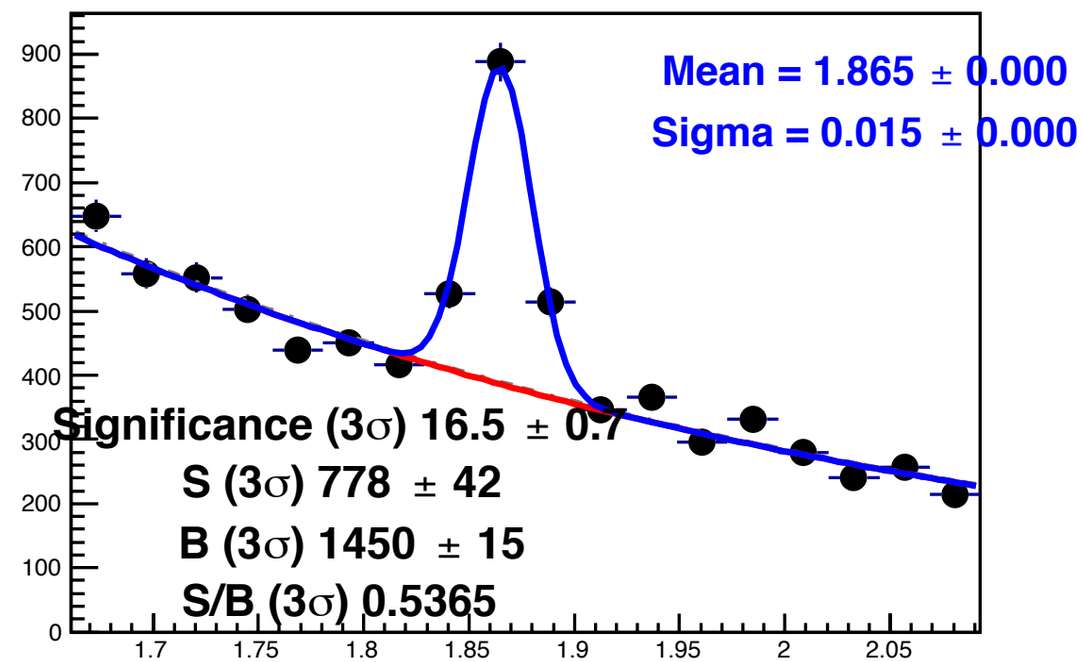

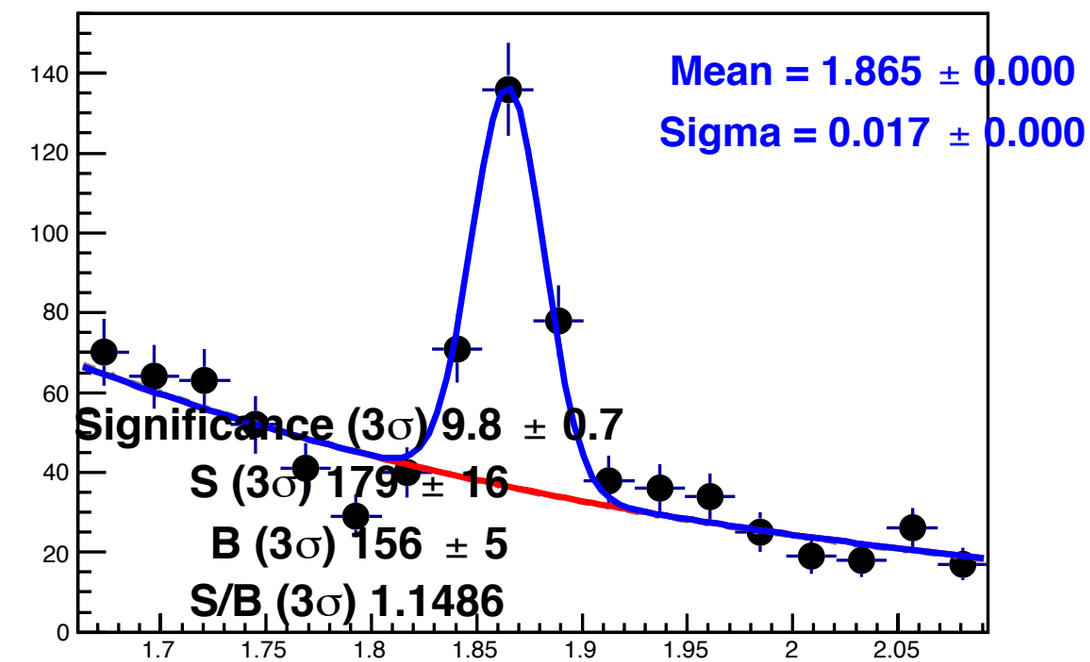

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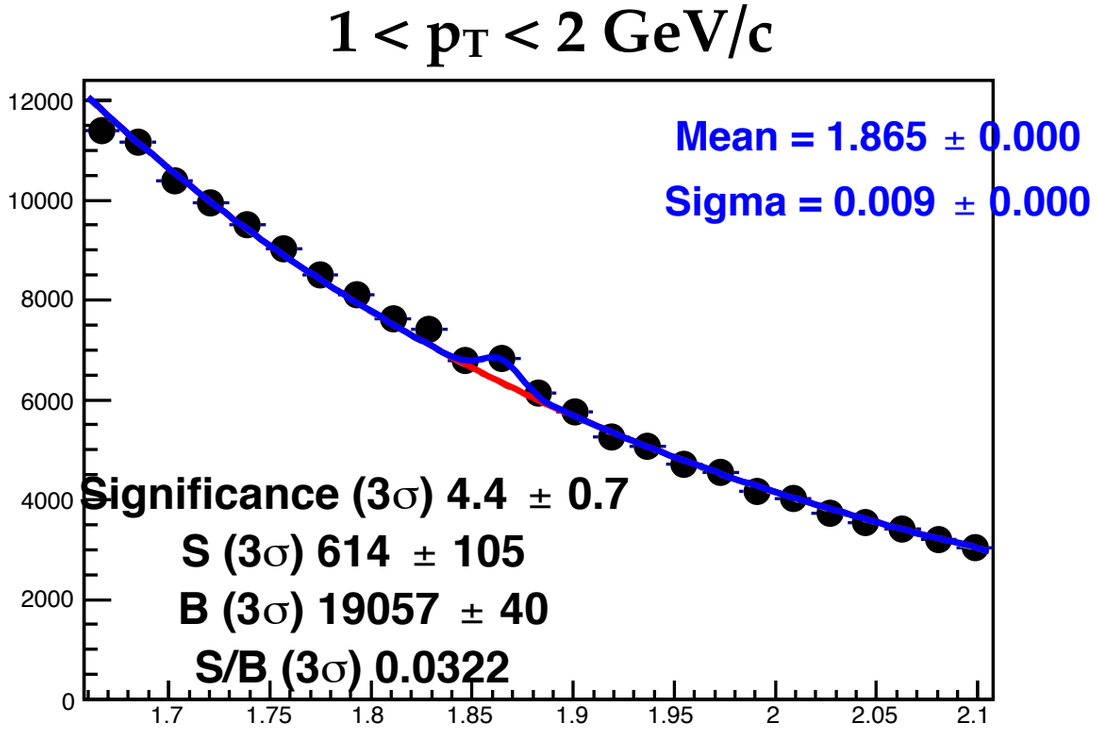

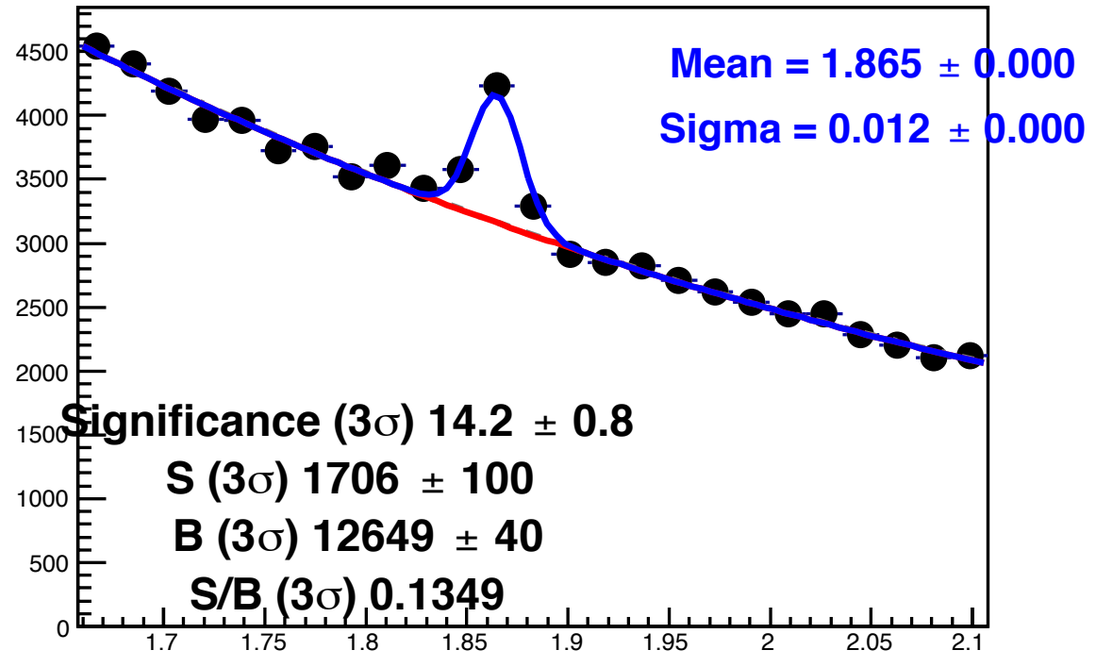

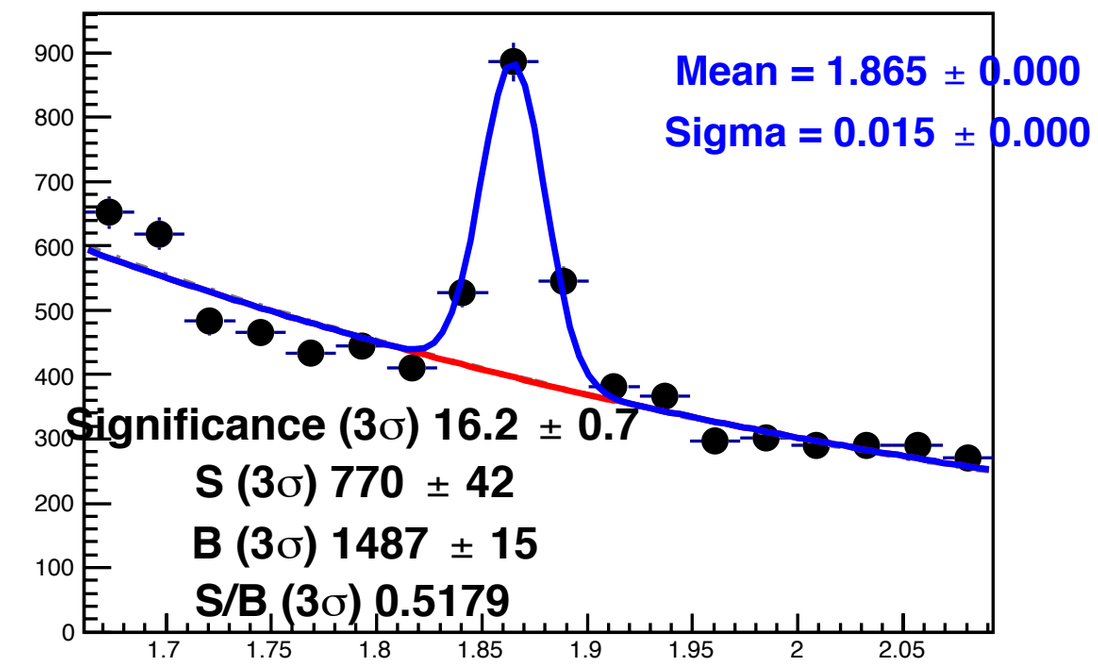

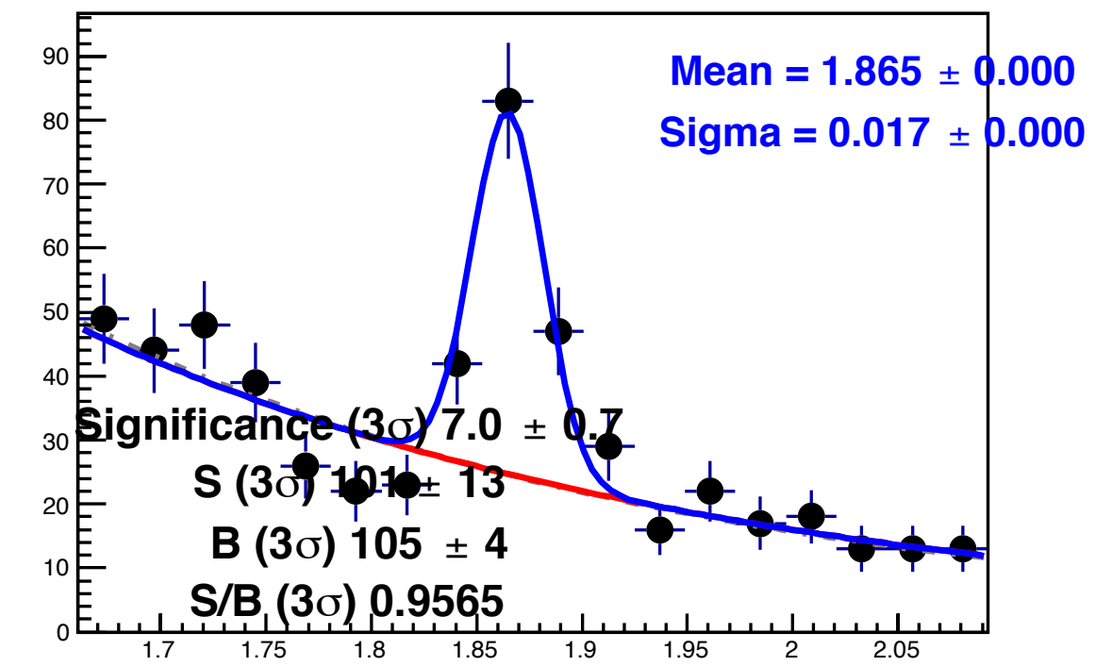

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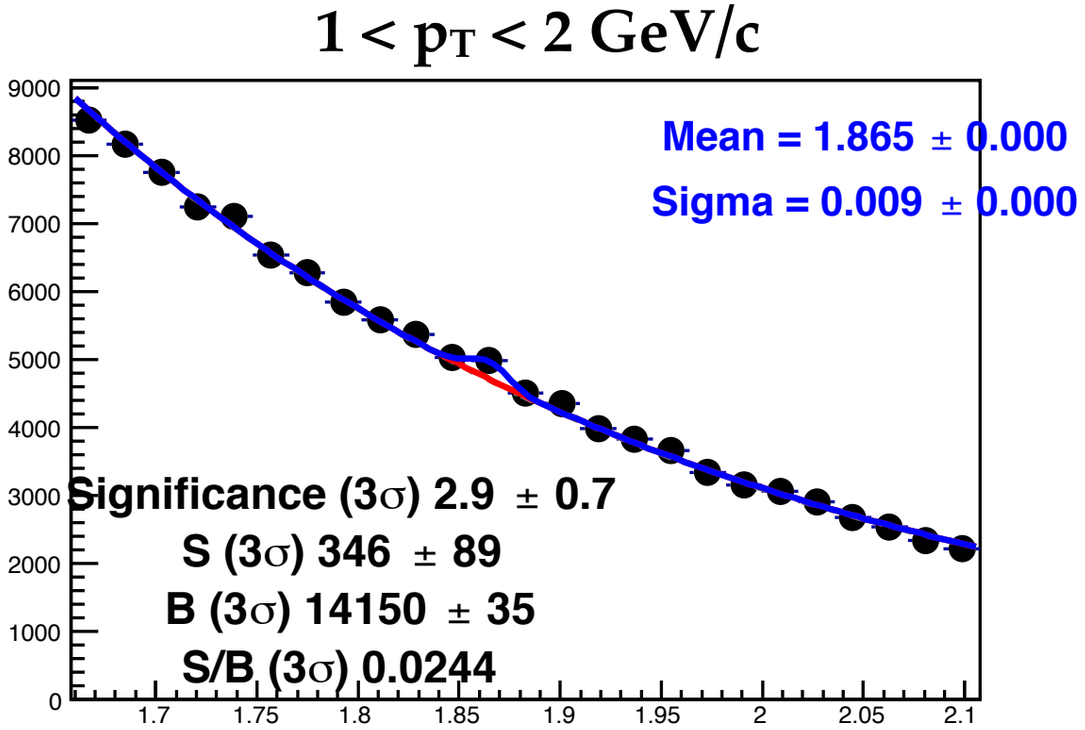
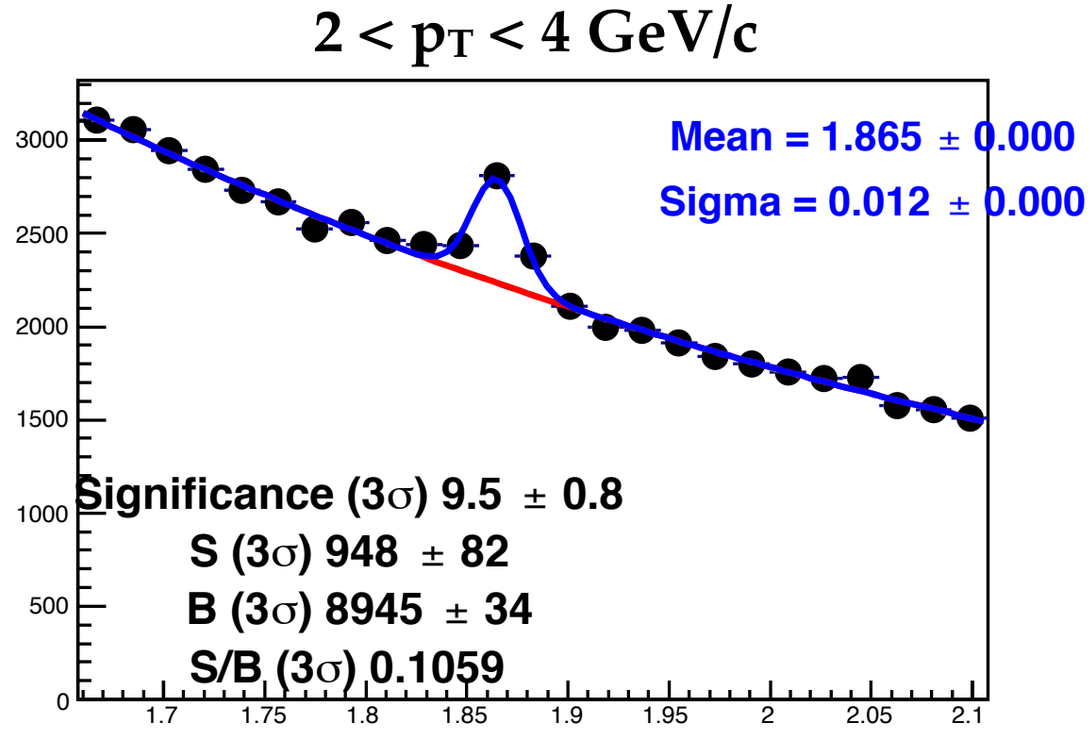
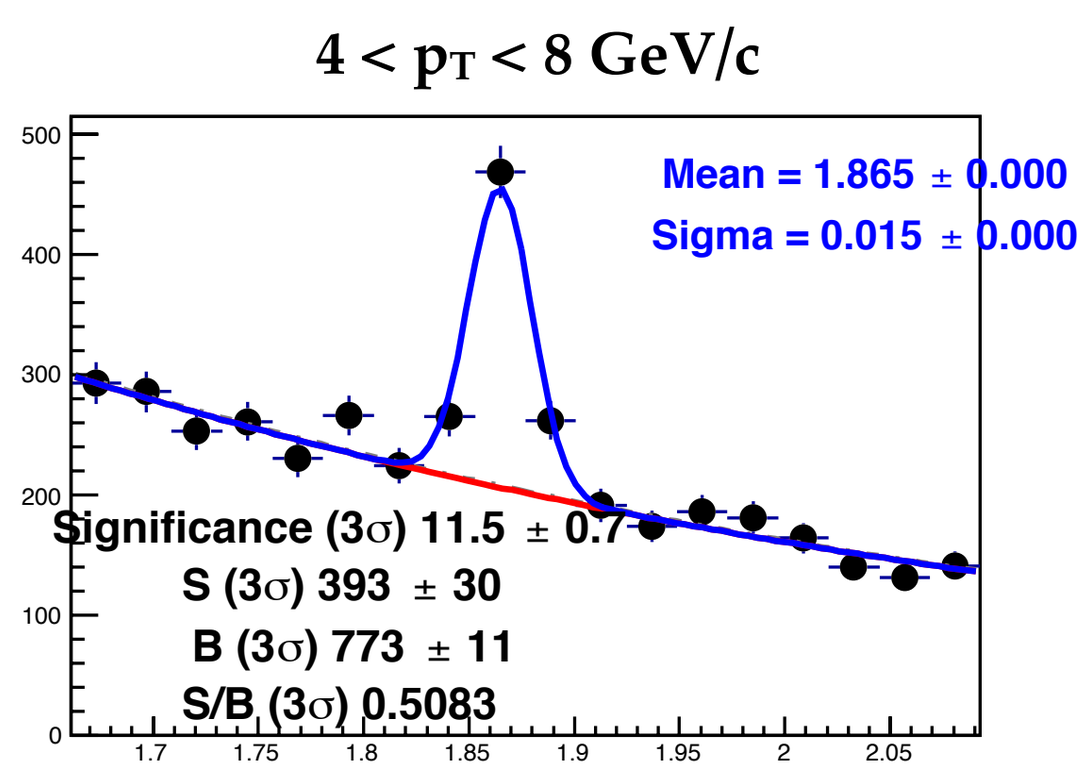
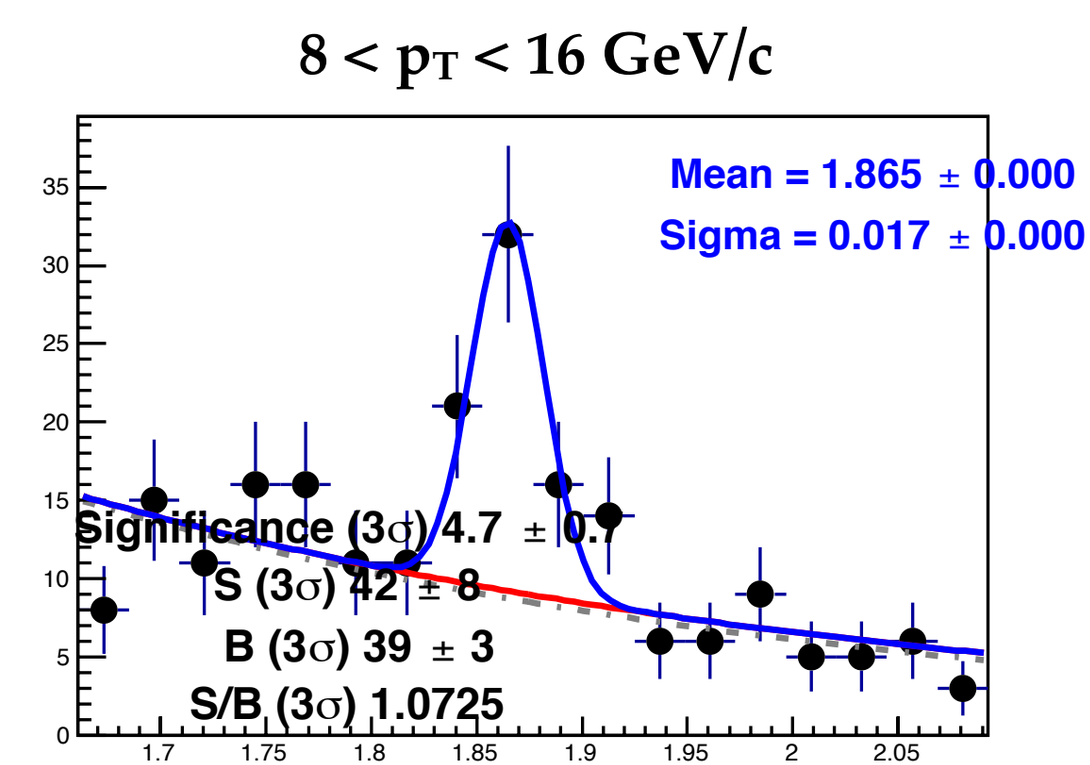


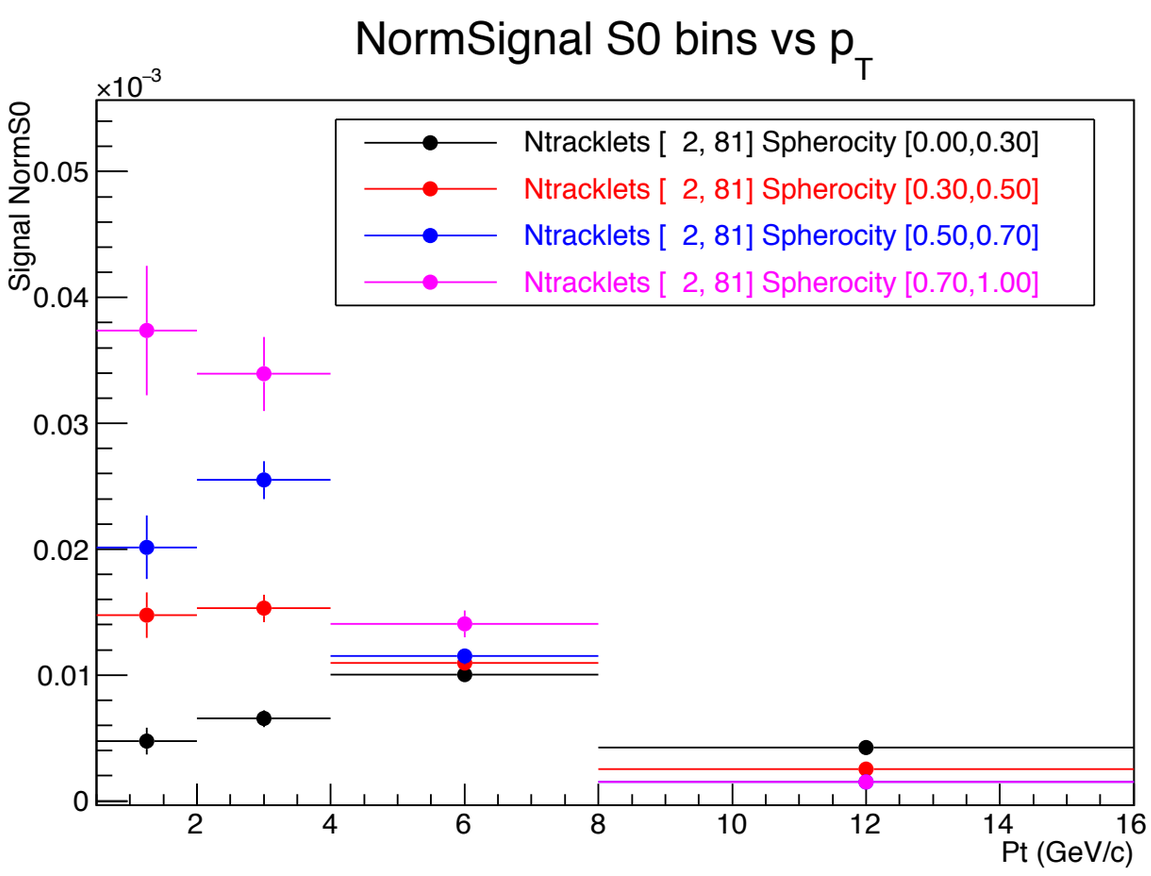




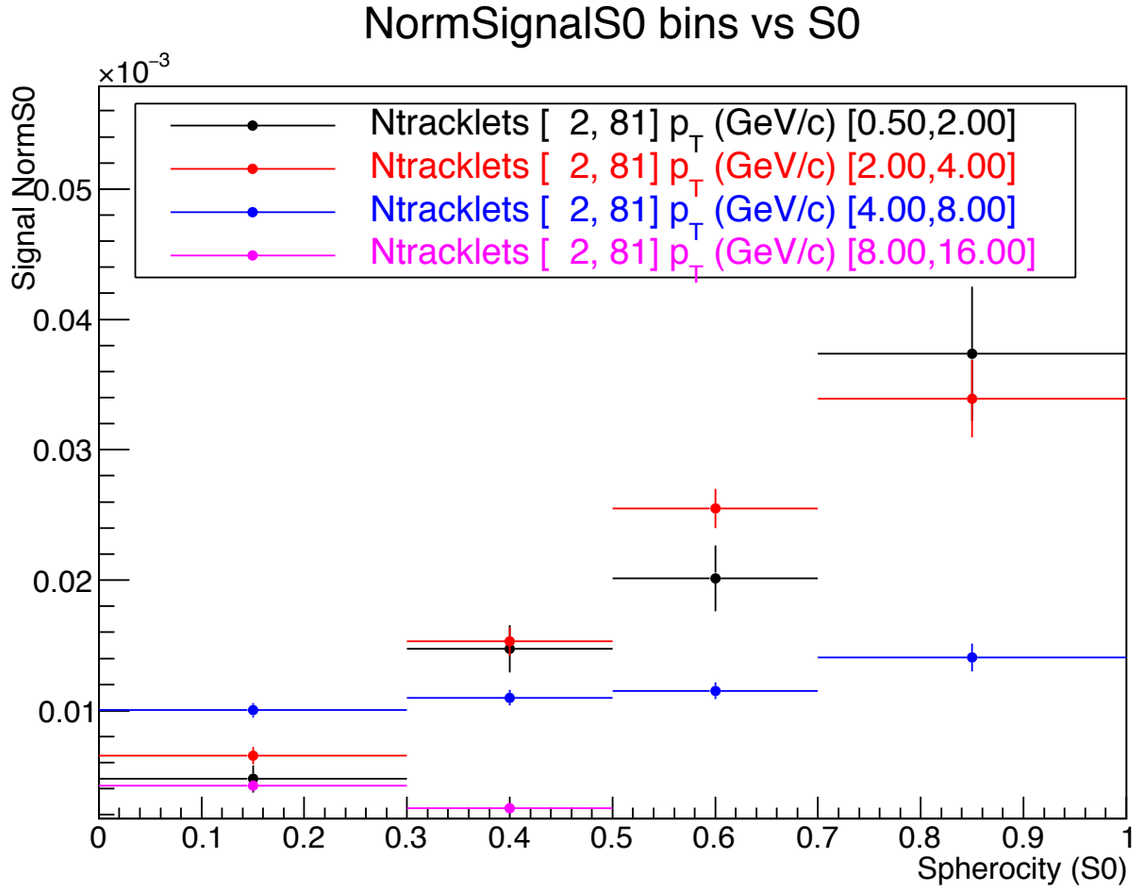


one Mult Bins: Ntrk[1,81]; SignalNorm

Normalised in each Multiplicity and Spherocity bins



SignalNorm vs p_T

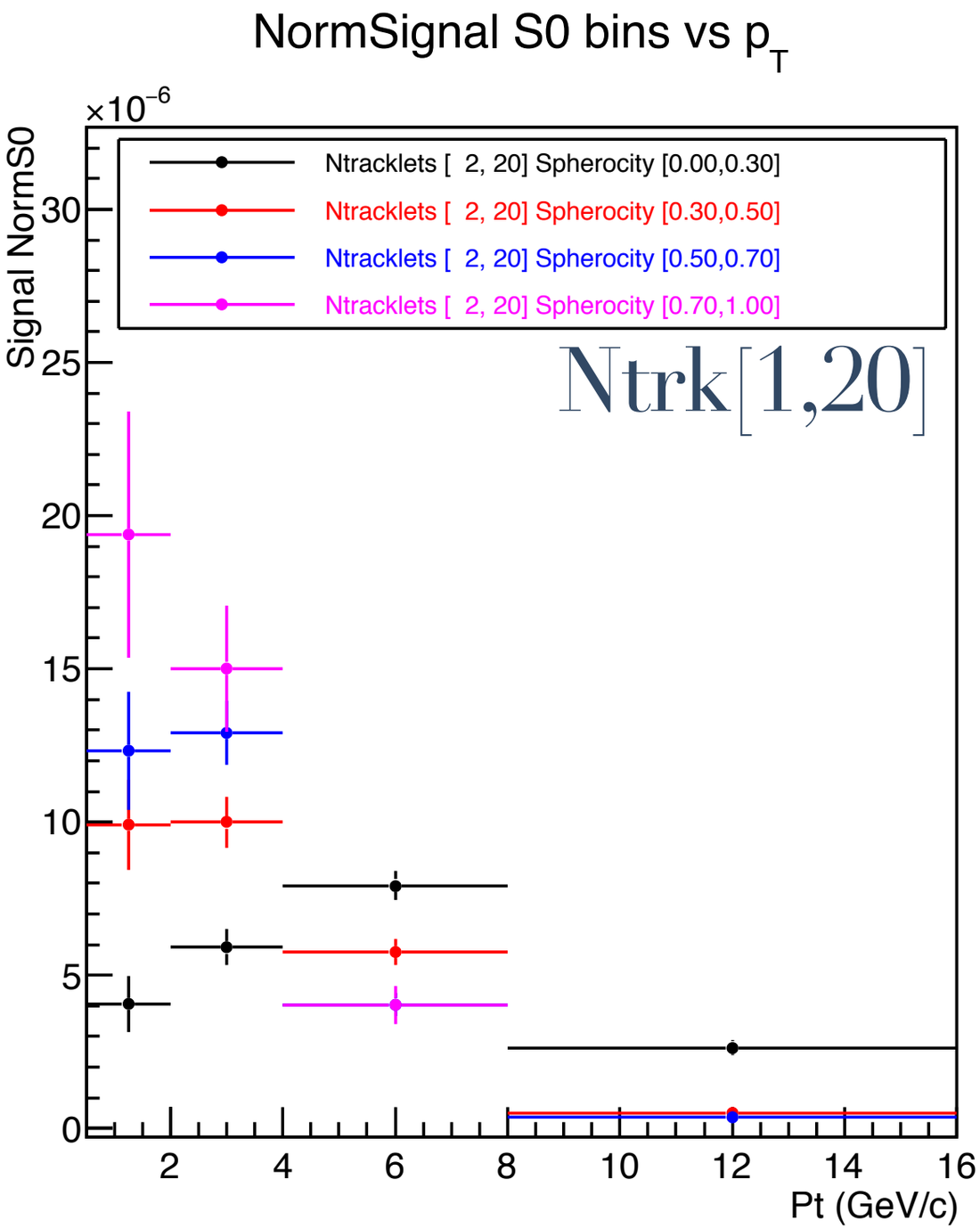


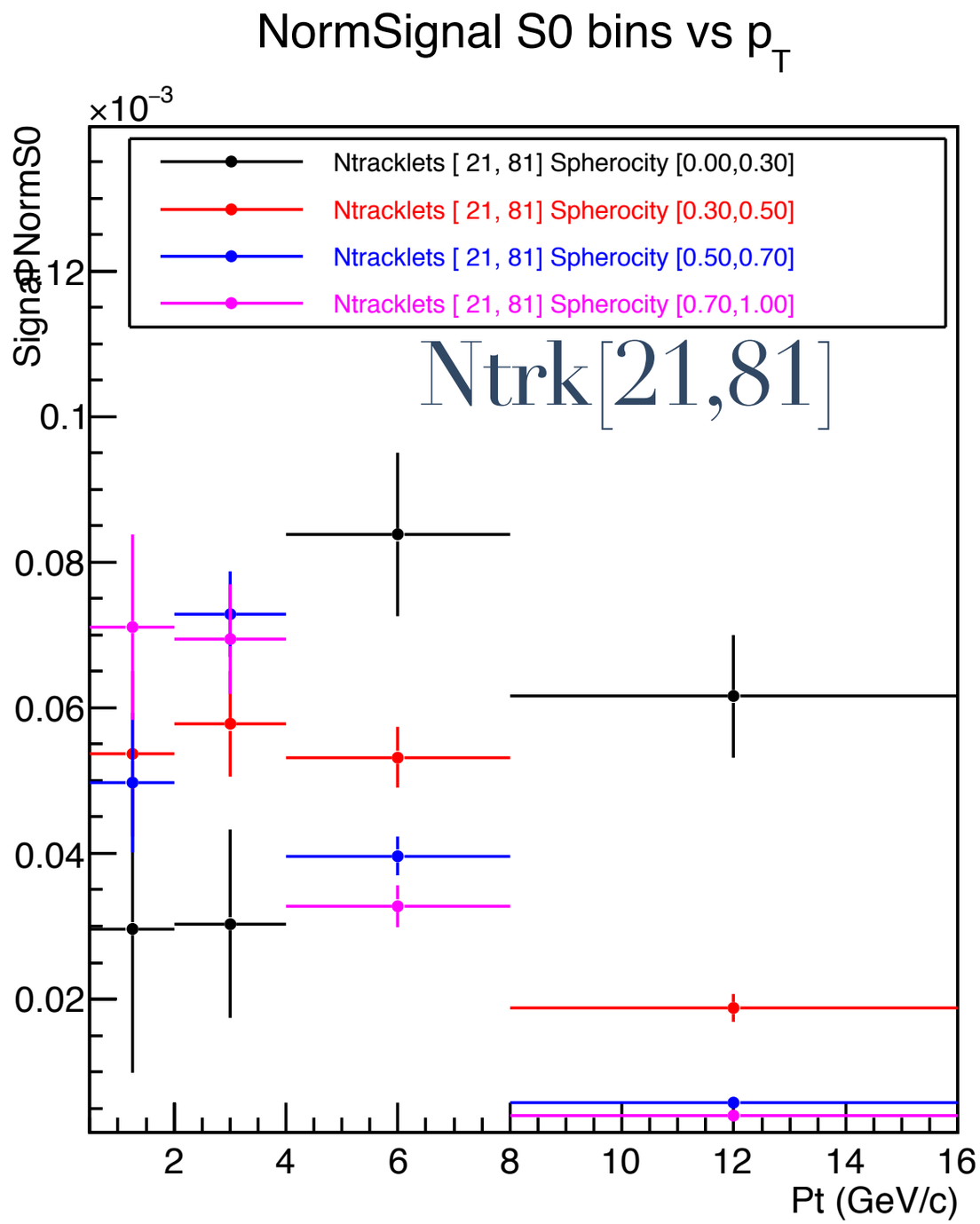
SignalNorm vs S_0

For low pT the signal per event is higher in higher S_0 bins

two Mult Bins: SignalNorm vs. pT

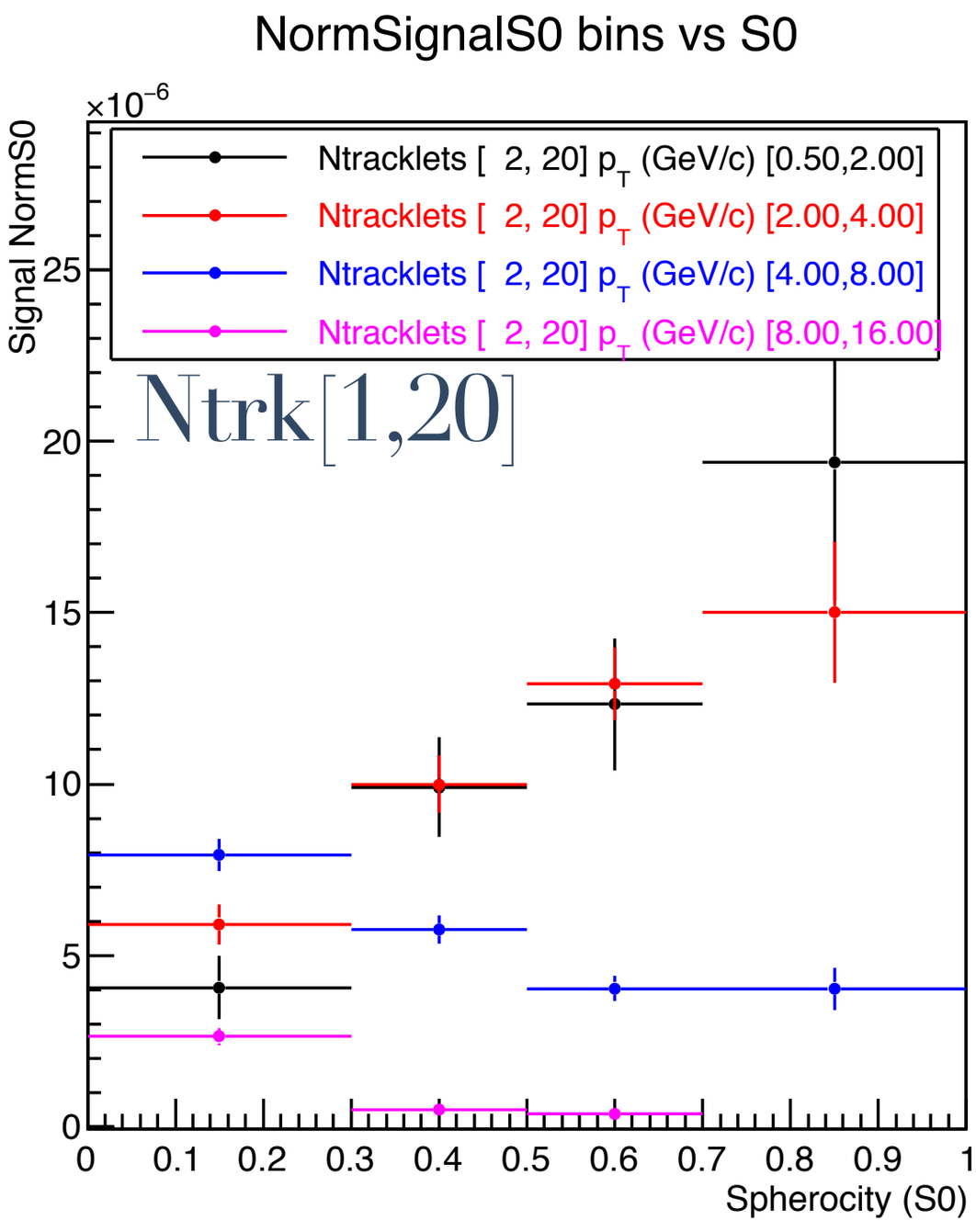
Normalised in each Multiplicity and Spherocity bins

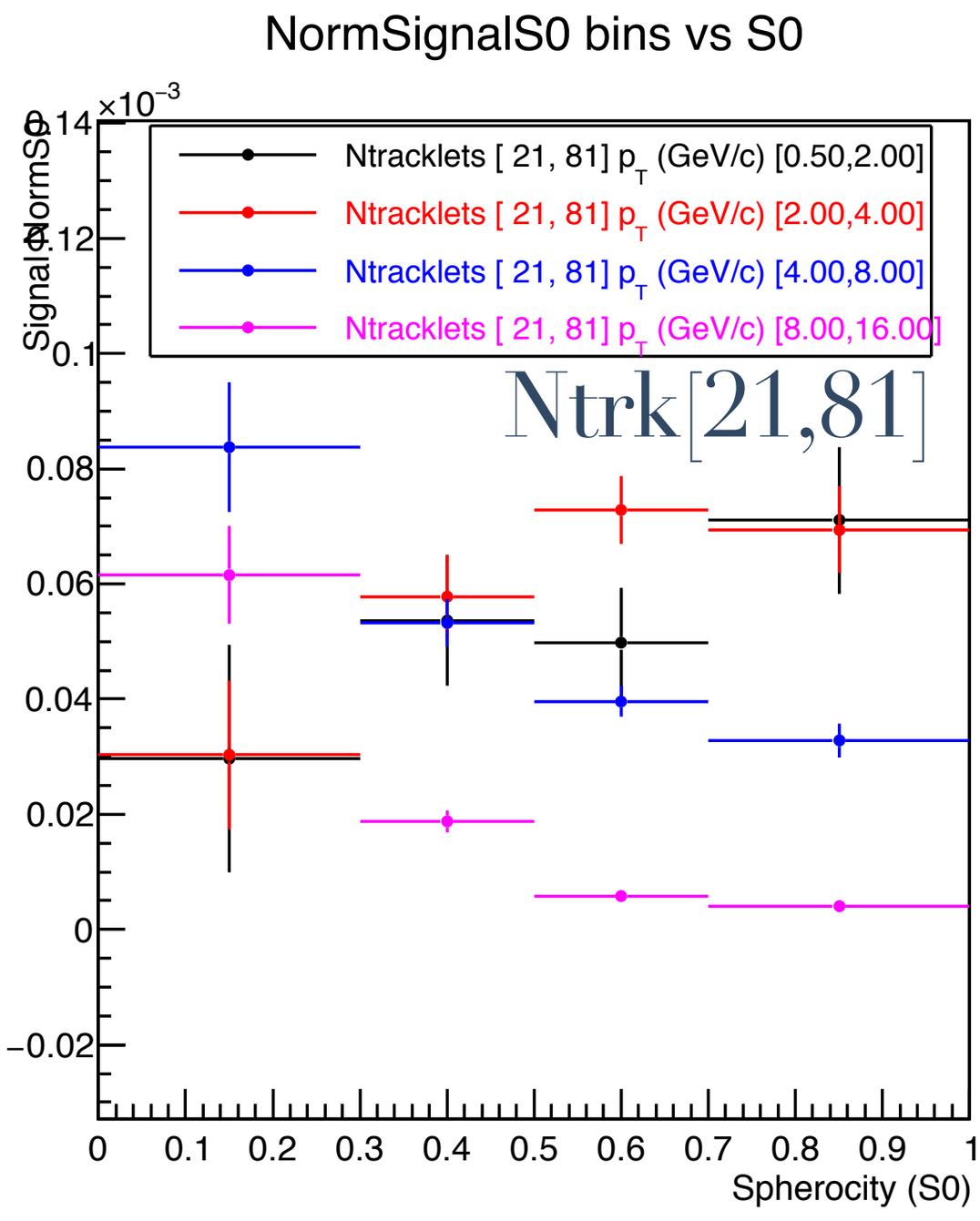




two Mult Bins: SignalNorm vs. S_0

Normalised in each Multiplicity and Spherocity bins





Summary and Plans

- ☑ Invariant mass fitting
- ☑ Multiplicity study
- ☑ Efficiency X Acceptance
- ☑ Cross section calculation
- ☐ Study of Spherocity for event shape analysis
  - ☑ Code for Event Shape is working
  - ☑ Started with spherocity dependence in one and two multiplicity bins
- ☐ Next is efficiency correction with the spherocity …

Thank You…

BACK-UP SLIDES

Event shapes: Hybrid track cuts

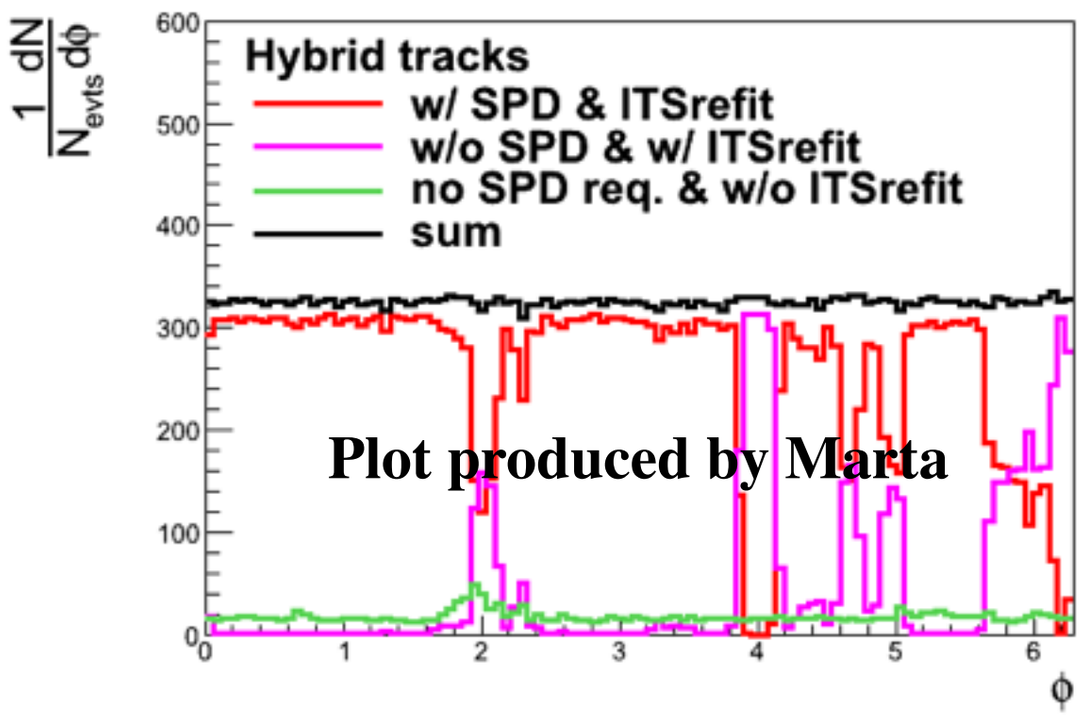
Tested three different sets of cuts.

TPC-only: flat eta and phi distributions, but large contamination from secondaries.

Golden: non uniform phi distribution (this is not optimal for the S_0 calculation).

Hybrid track cuts: developed by Marta Verweij: uniform phi and eta distributions, larger tracking efficiency than for golden track cuts, smaller contribution from secondaries than for TPC-only track cuts. More details can be found here:

https://twiki.cern.ch/twiki/bin/viewauth/ALICE/HybridTracks



A. Ortiz

Good track pT resolution, uniform phi distribution, but track quality is mixed.

Event shapes: Hybrid track cuts

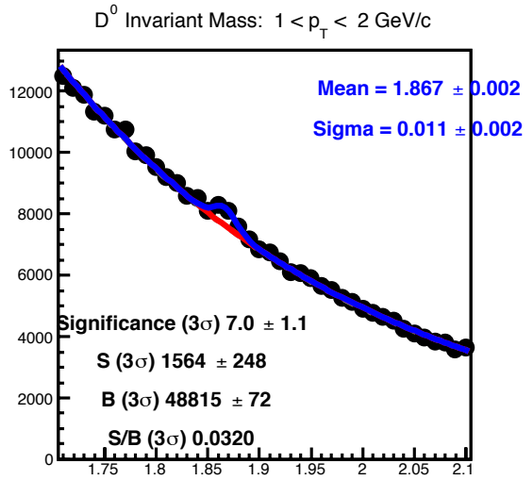
Hybrid: Good global tracks if available, otherwise global constrained tracks.

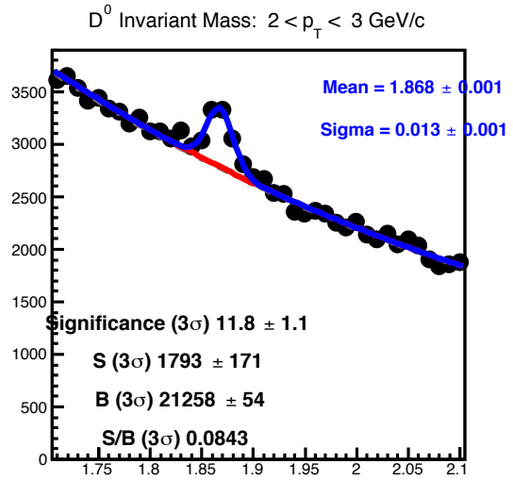
- **Cuts for good global tracks:**
  - pT dependent cut on # of TPC clusters in 1st it.
  - χ^2 p/ TPC cluster in 1st it. < 4
  - No kink daughters
  - Require TPC refit
  - Frac. of shared TPC clusters < 0.4
  - Require ITS refit
  - Chi2 per ITS cluster < 36
  - $DCA_x y < 2.4cm$
  - $DCA_z < 3.2cm$
  - At list one hit on SPD
  - χ^2 between TPC constrained and global < 36

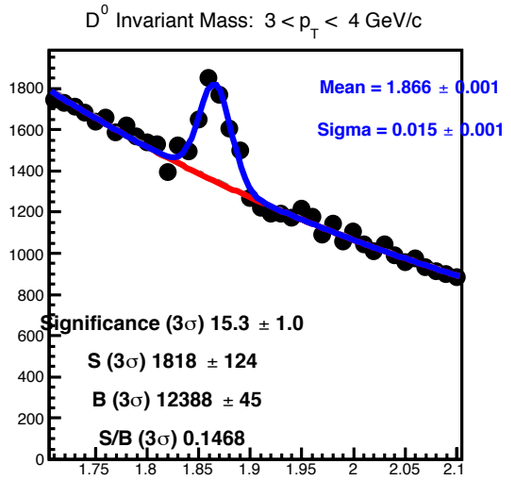
- **Cuts for global constrained tracks:**
  - Same cuts as for the good global tracks shown above except no ITS refit or SPD hits requirement
  - Constrained to primary vertex to improve pT resolution

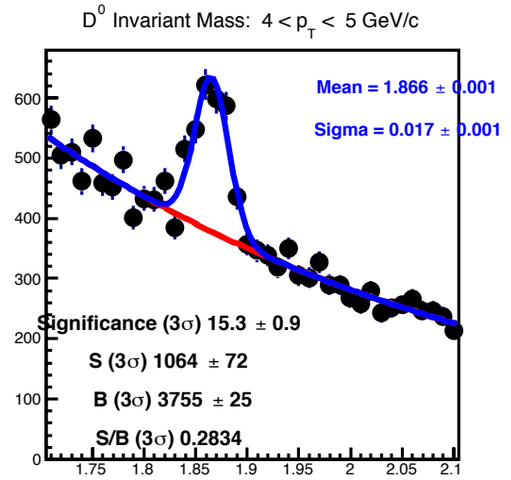
Good track pT resolution, uniform phi distribution, but track quality is mixed.

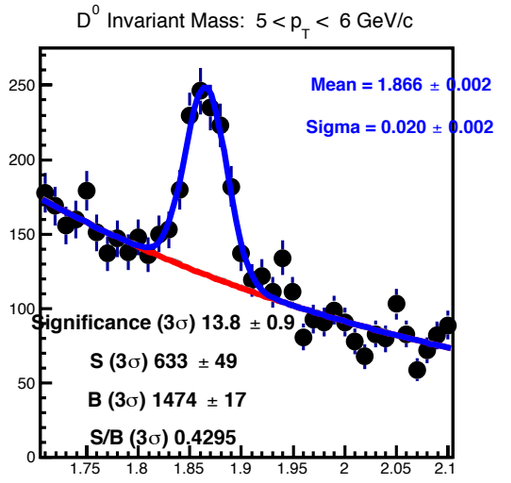
InvMass Fitting: Pass 2

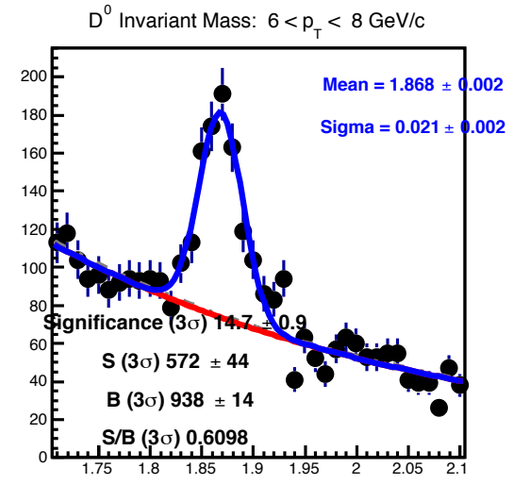


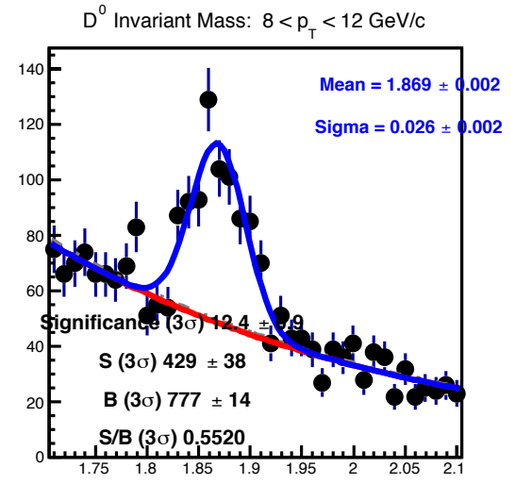


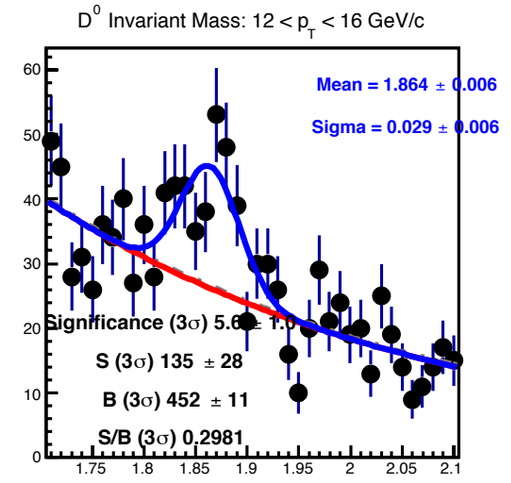


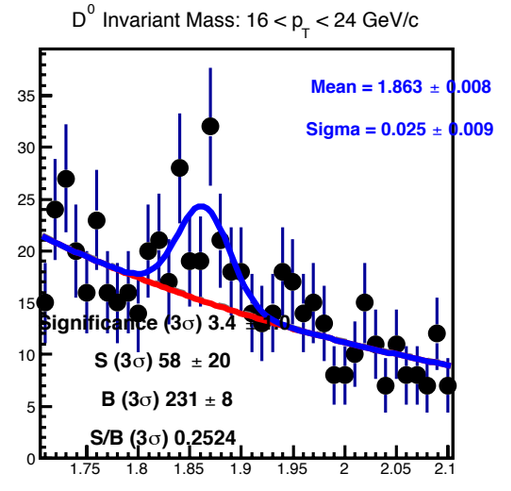




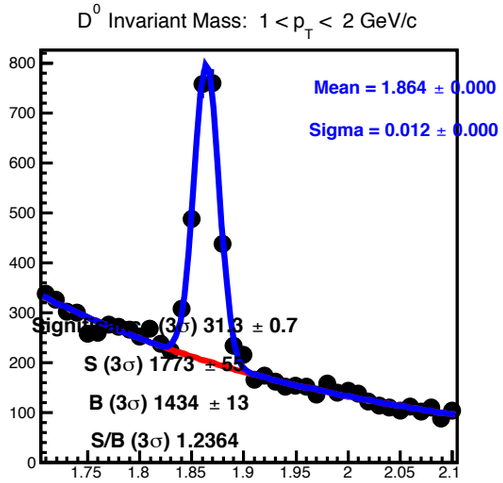


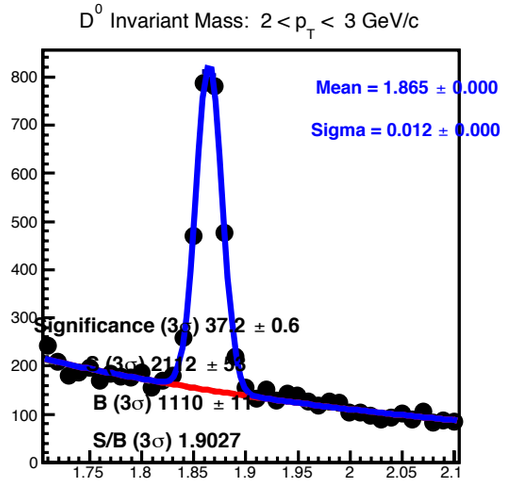


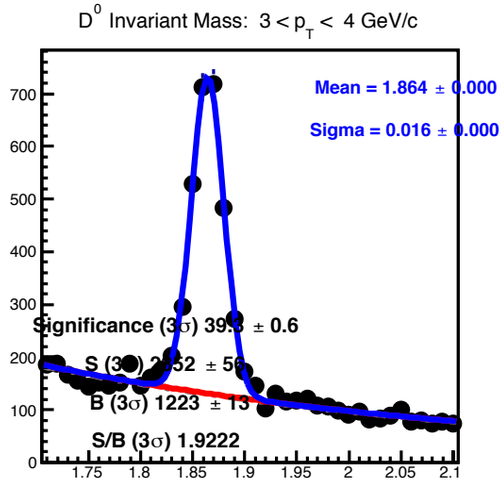


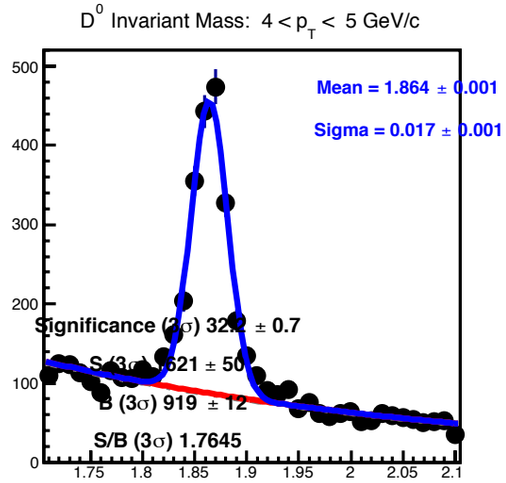


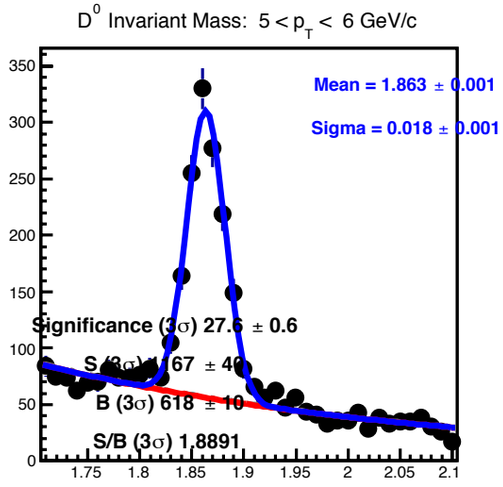
InvMass Fitting: MC Pass 2

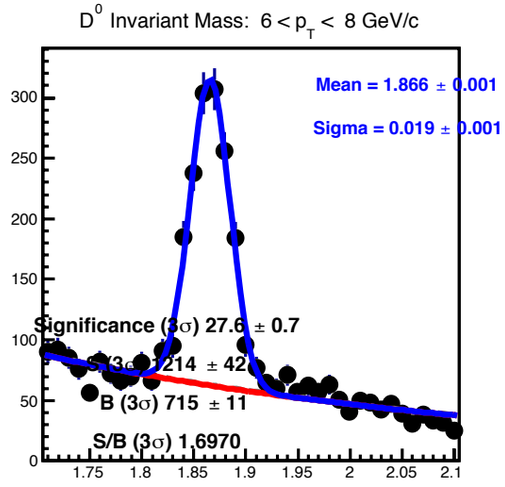


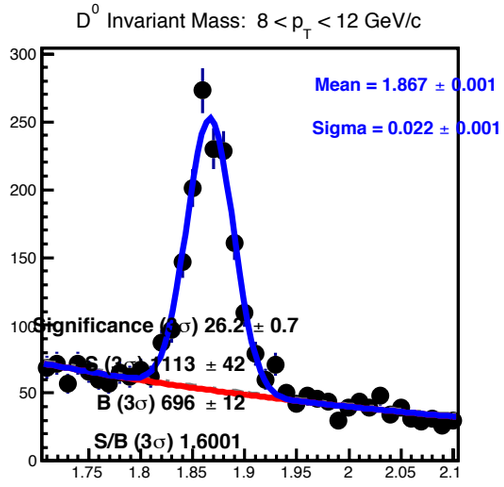


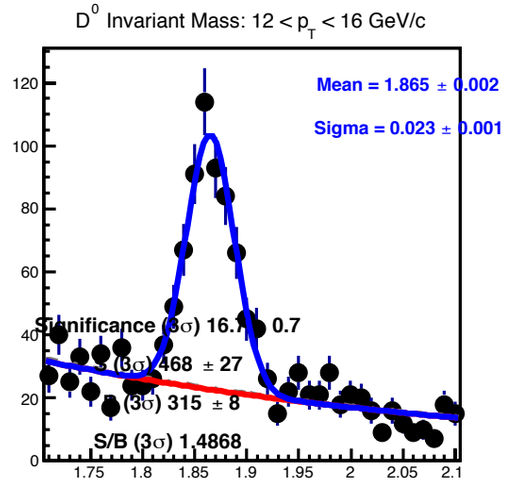


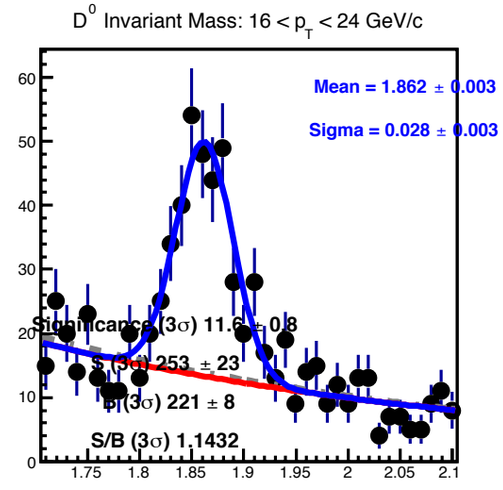




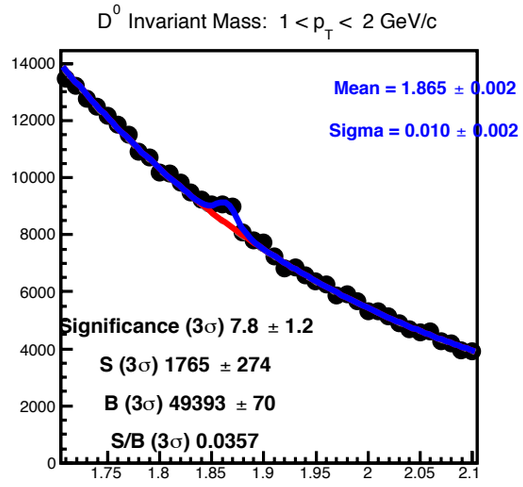


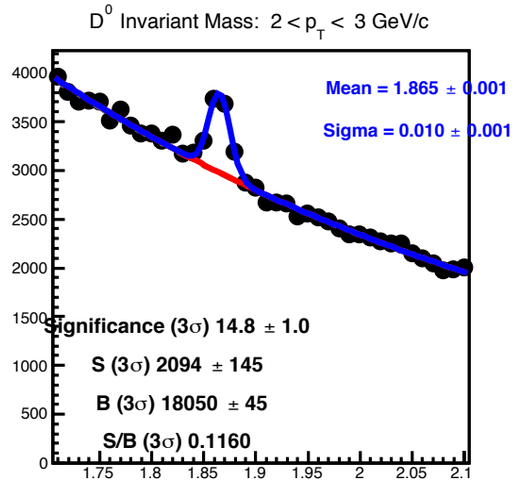


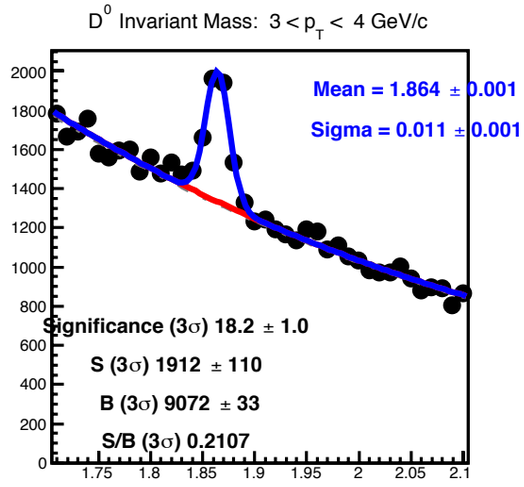


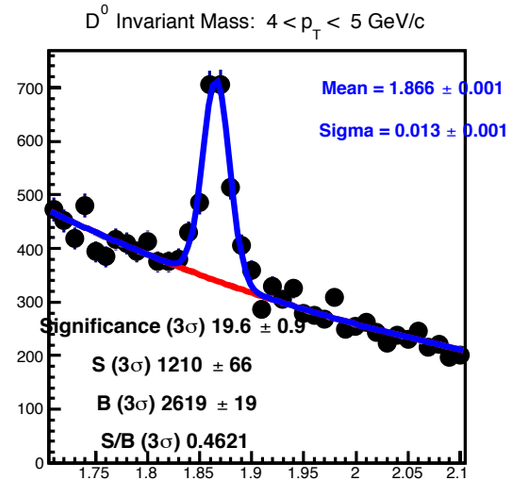


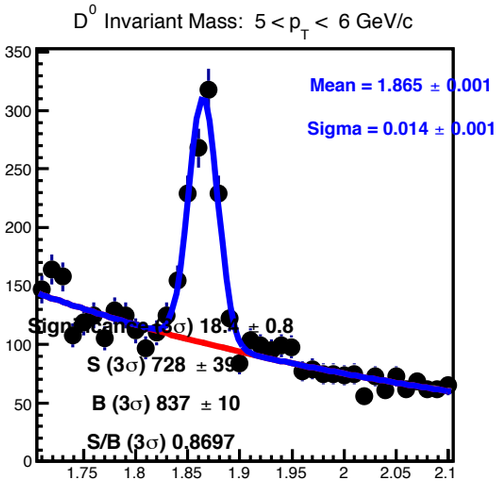
InvMass Fitting: Pass 4

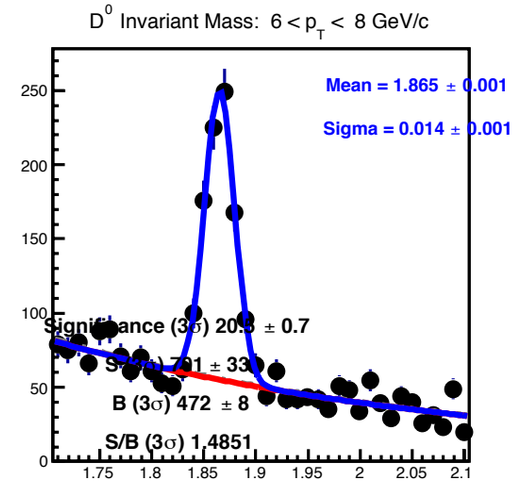


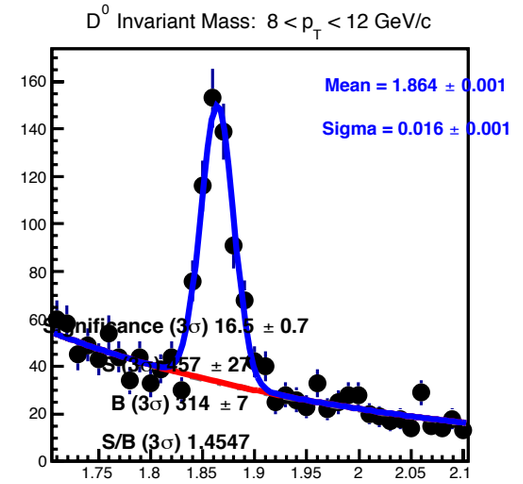


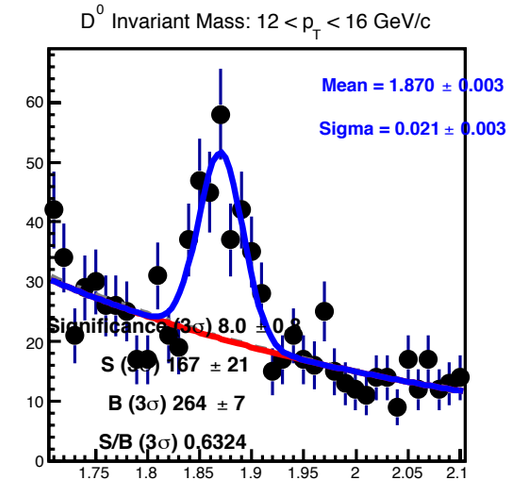


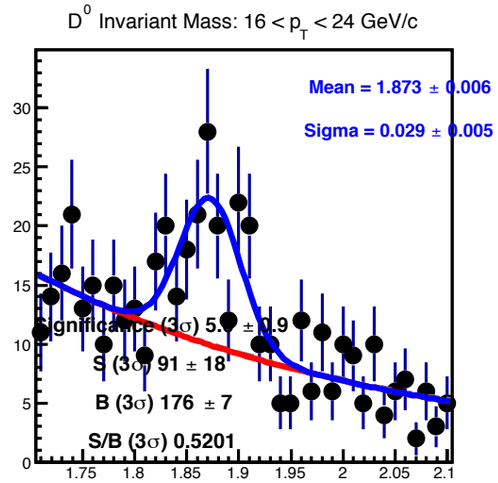




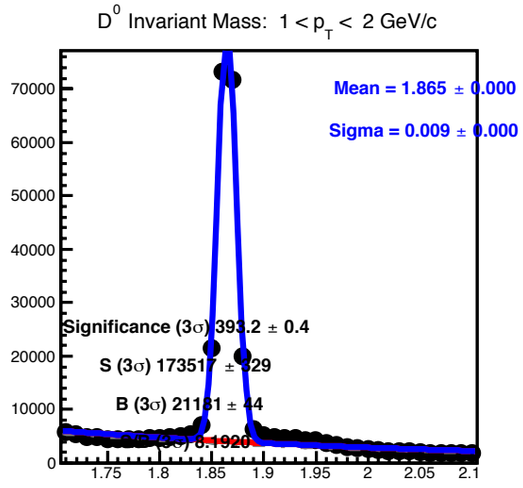


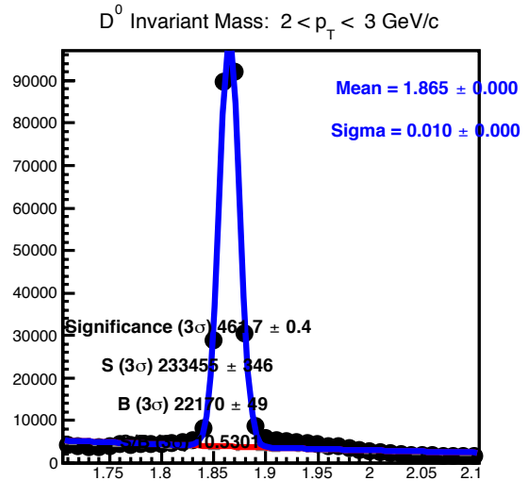


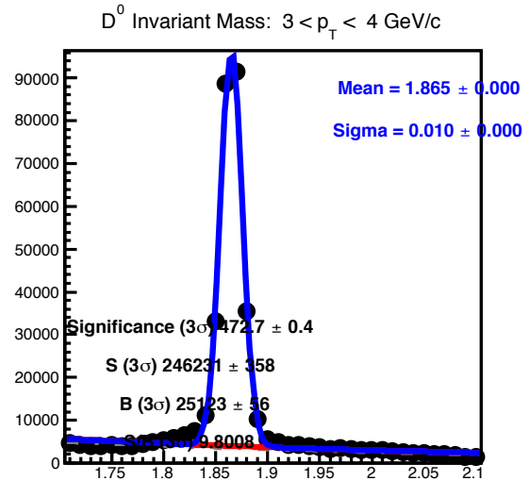


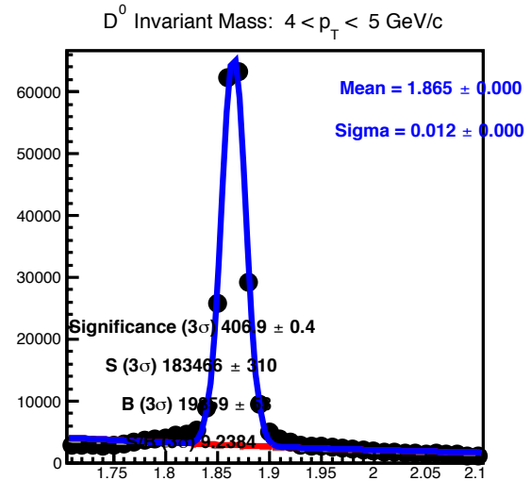


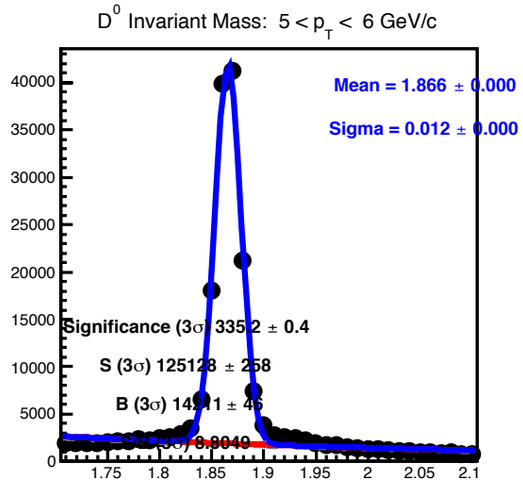
InvMass Fitting: MC Pass 4

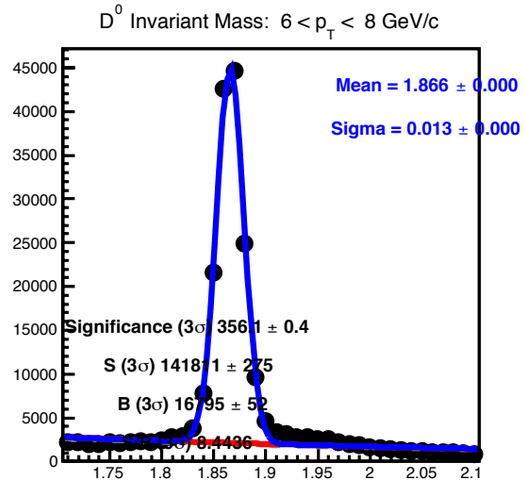


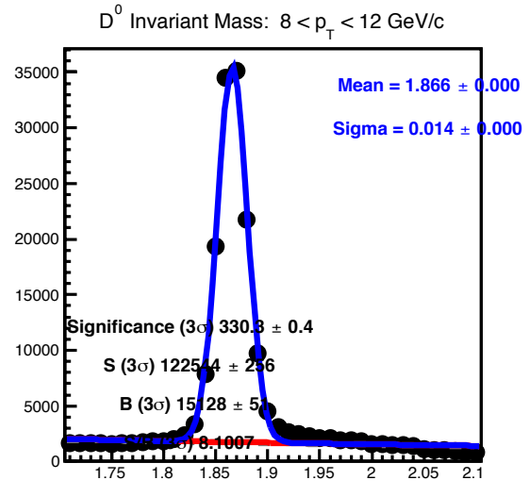


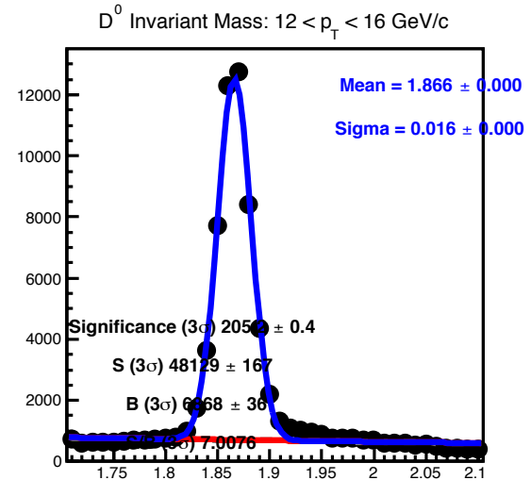


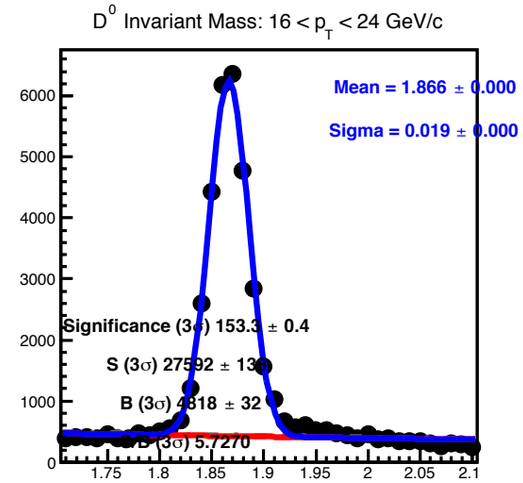






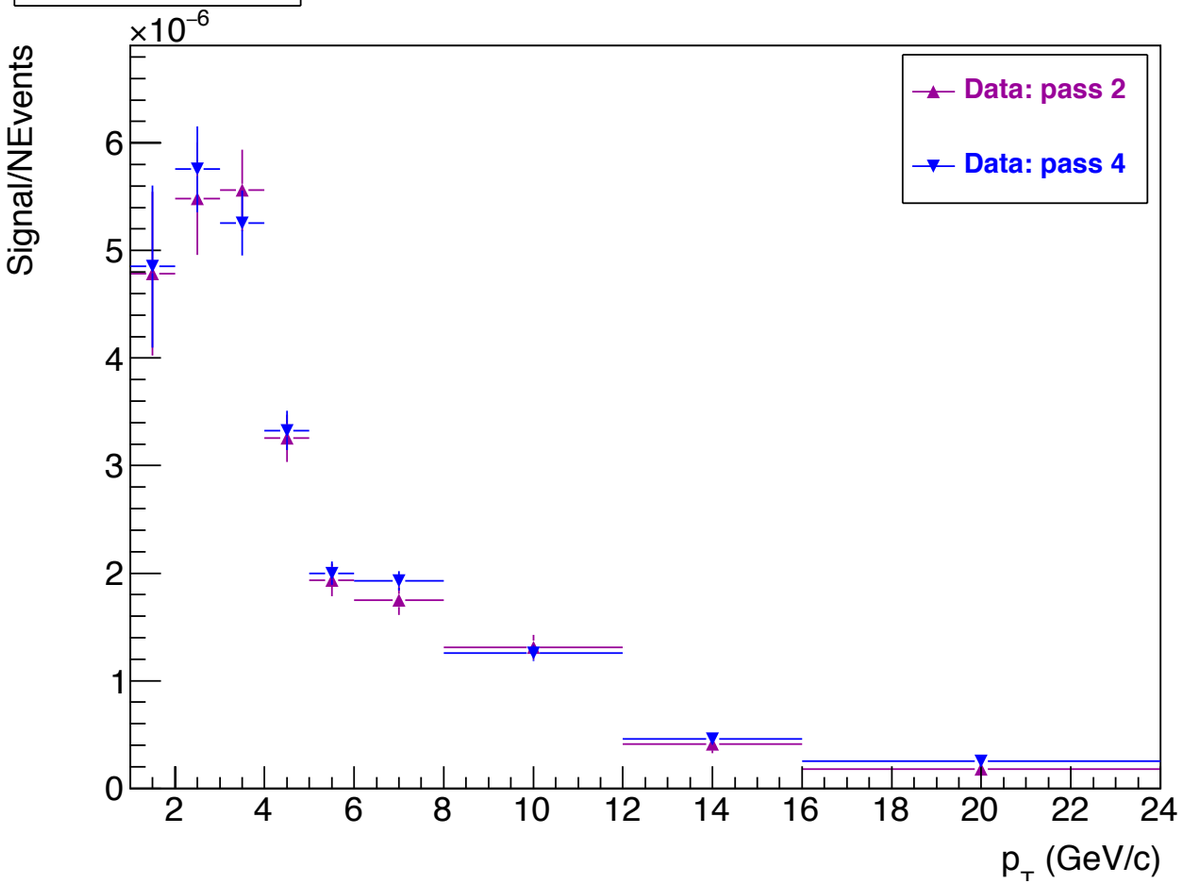




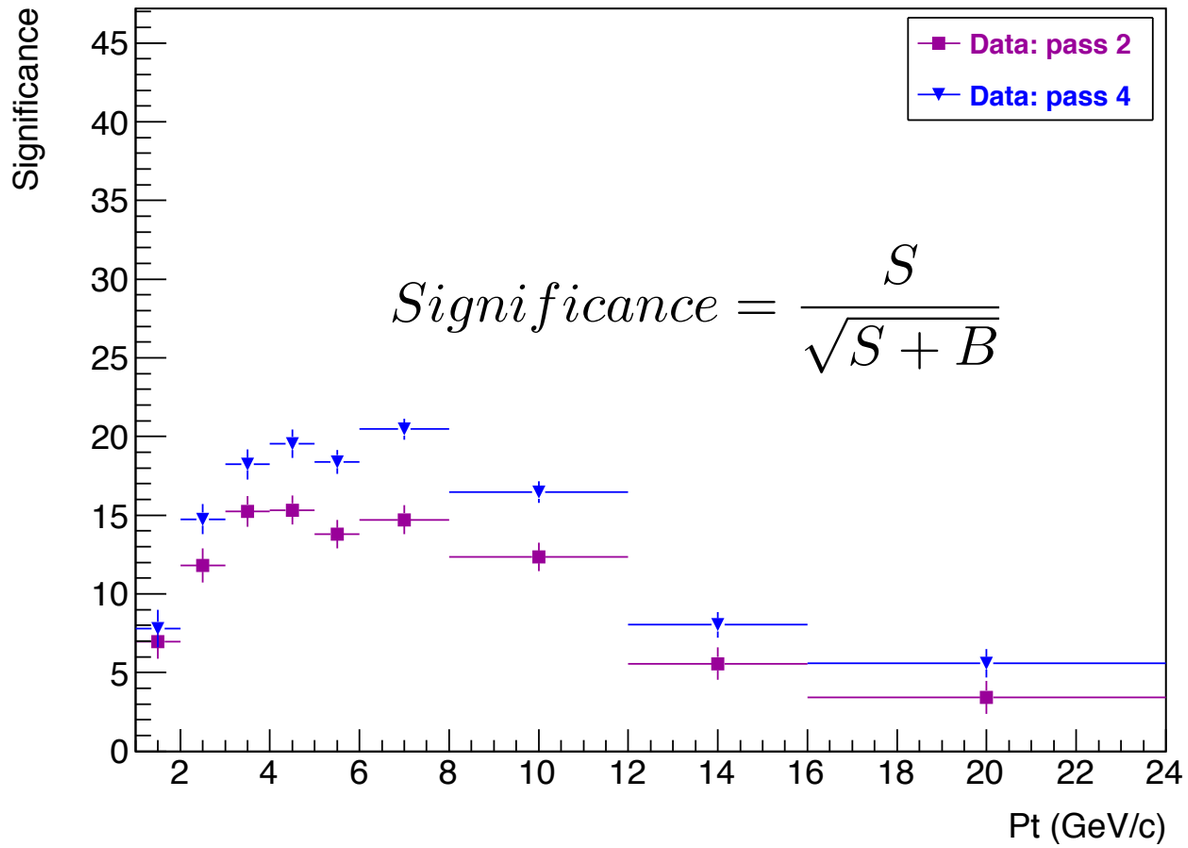


Signal and Significance

hSignalNorm



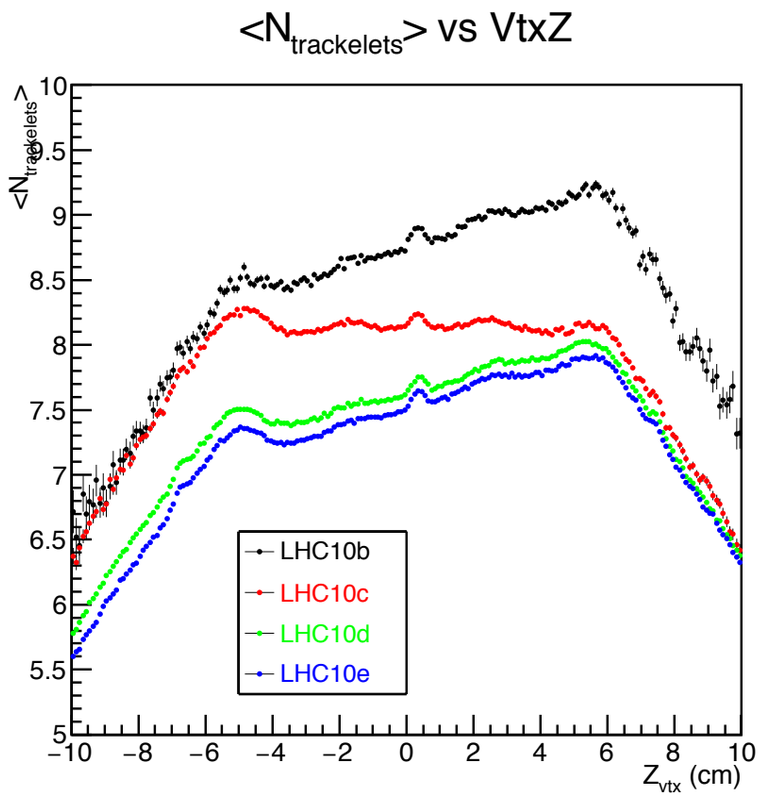
hSignificance

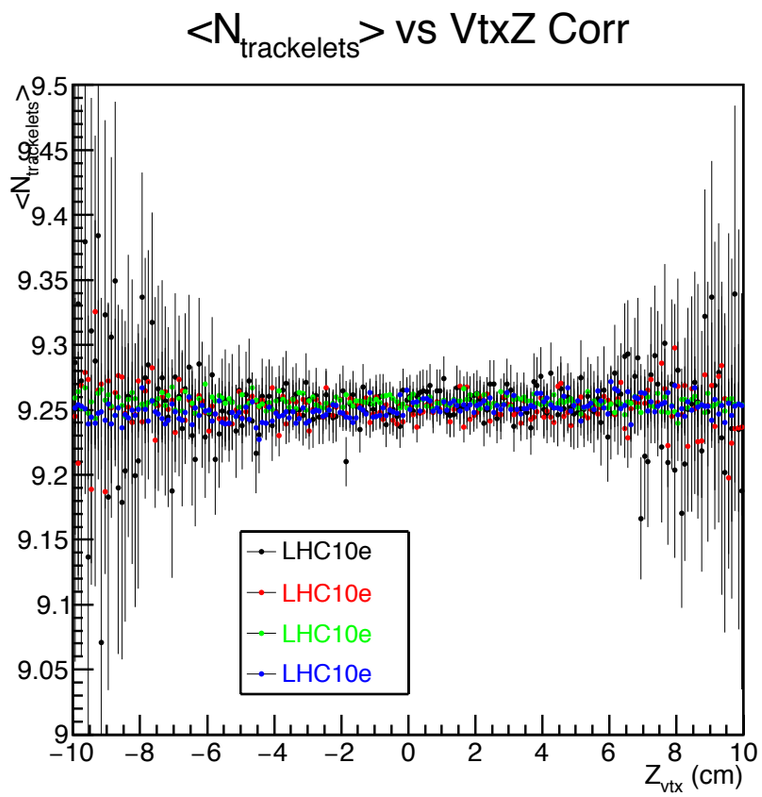


- Pass 2 and 4 data, MC are within expected uncertainties
- Signal and Background in ±3σ (σ from fitting) for pass 2 and pass 4 are compared
- As number of events are different in two, these values are normalised by total number of events in respective data
- Significance is higher for pass 4 data than pass 2

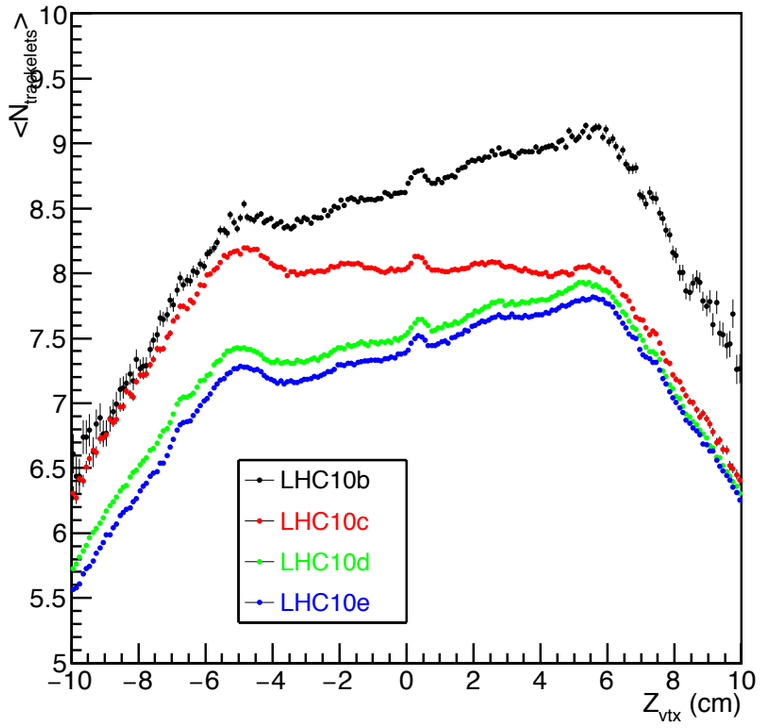
<$N_{tracklets}$> vs. Z-vertex

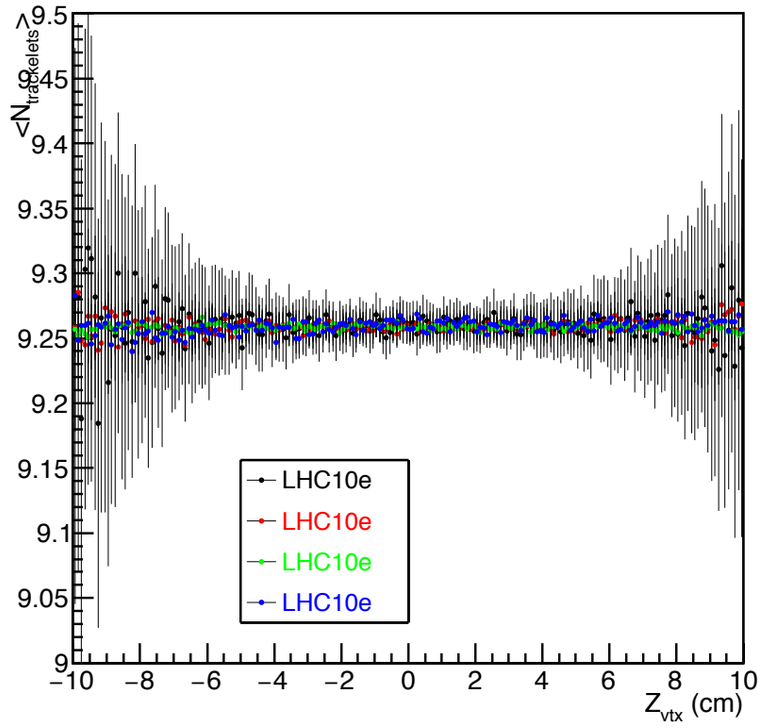
Pass 2 data



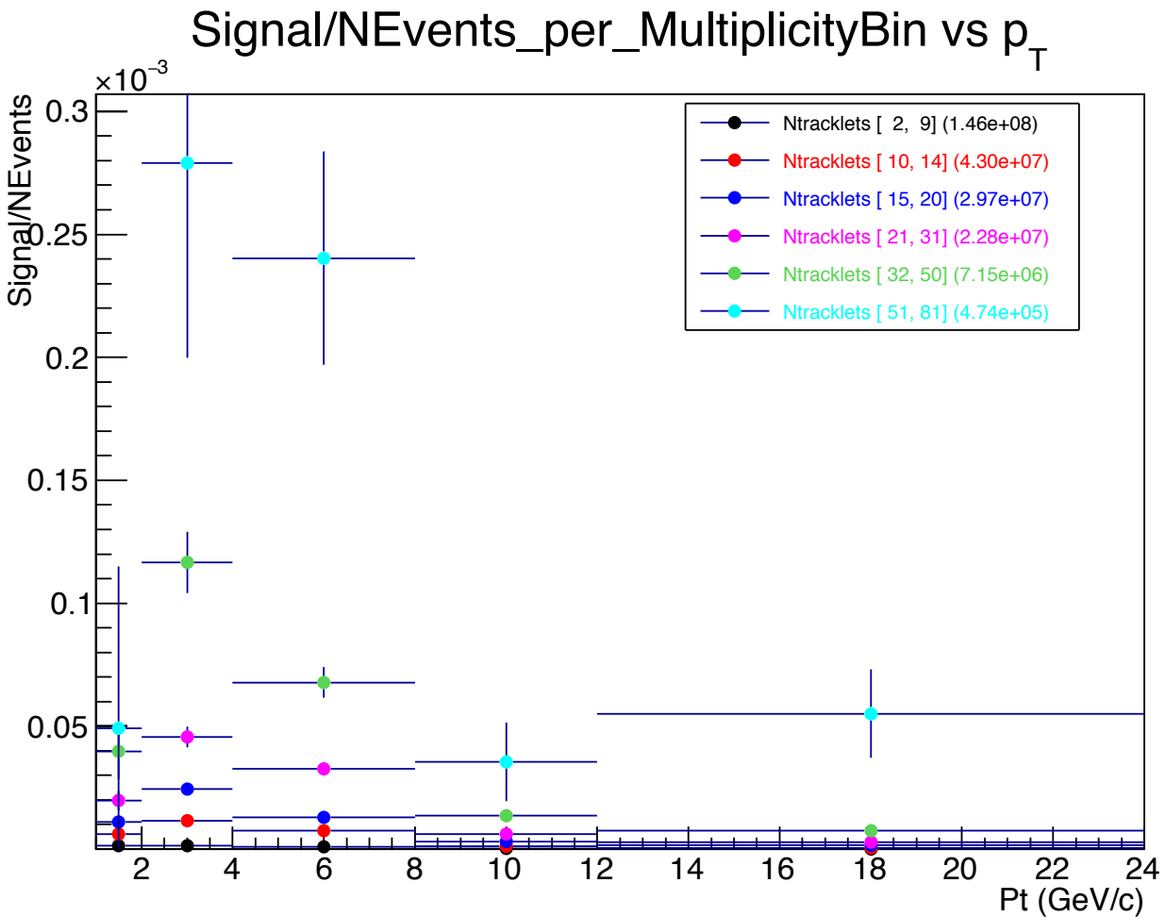


Pass 4 data

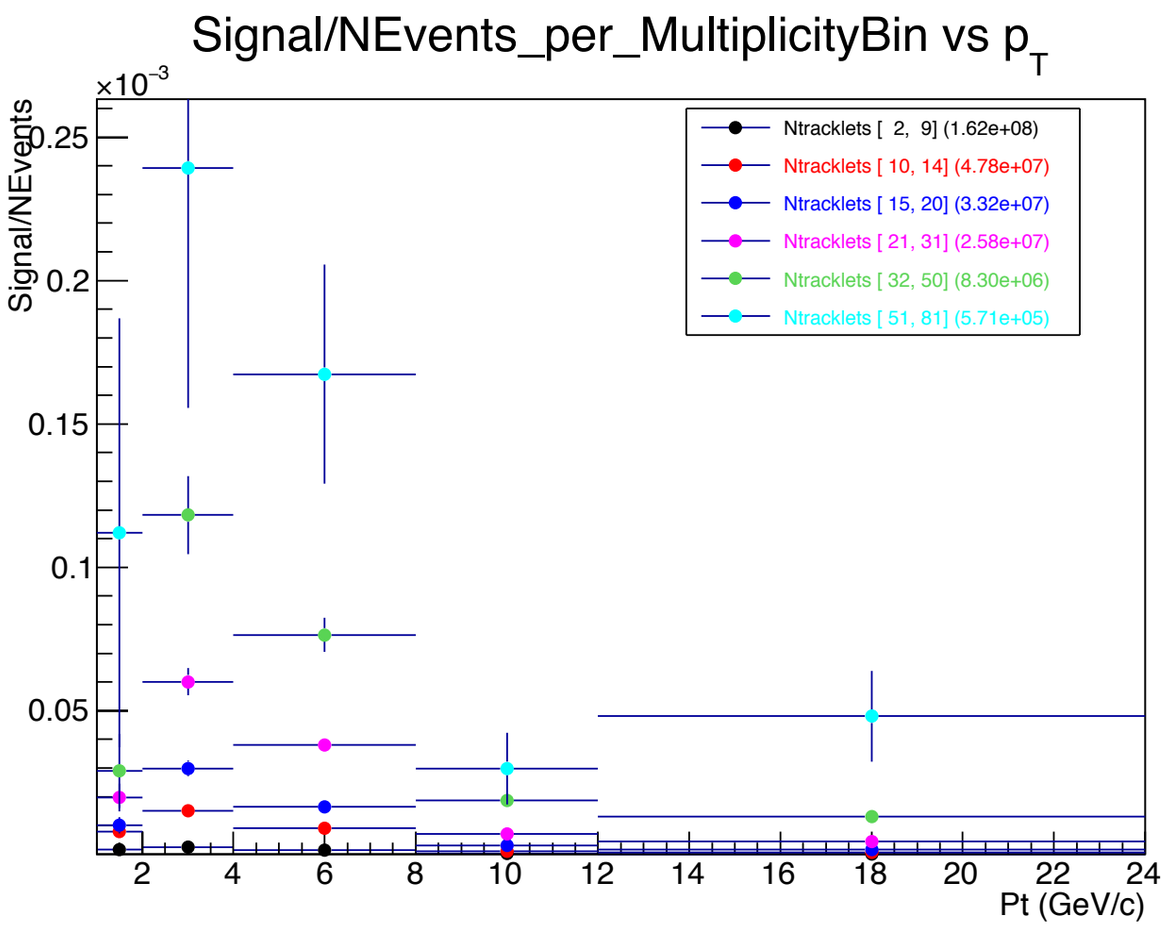




Signal/NEvents in Multiplicity Bins

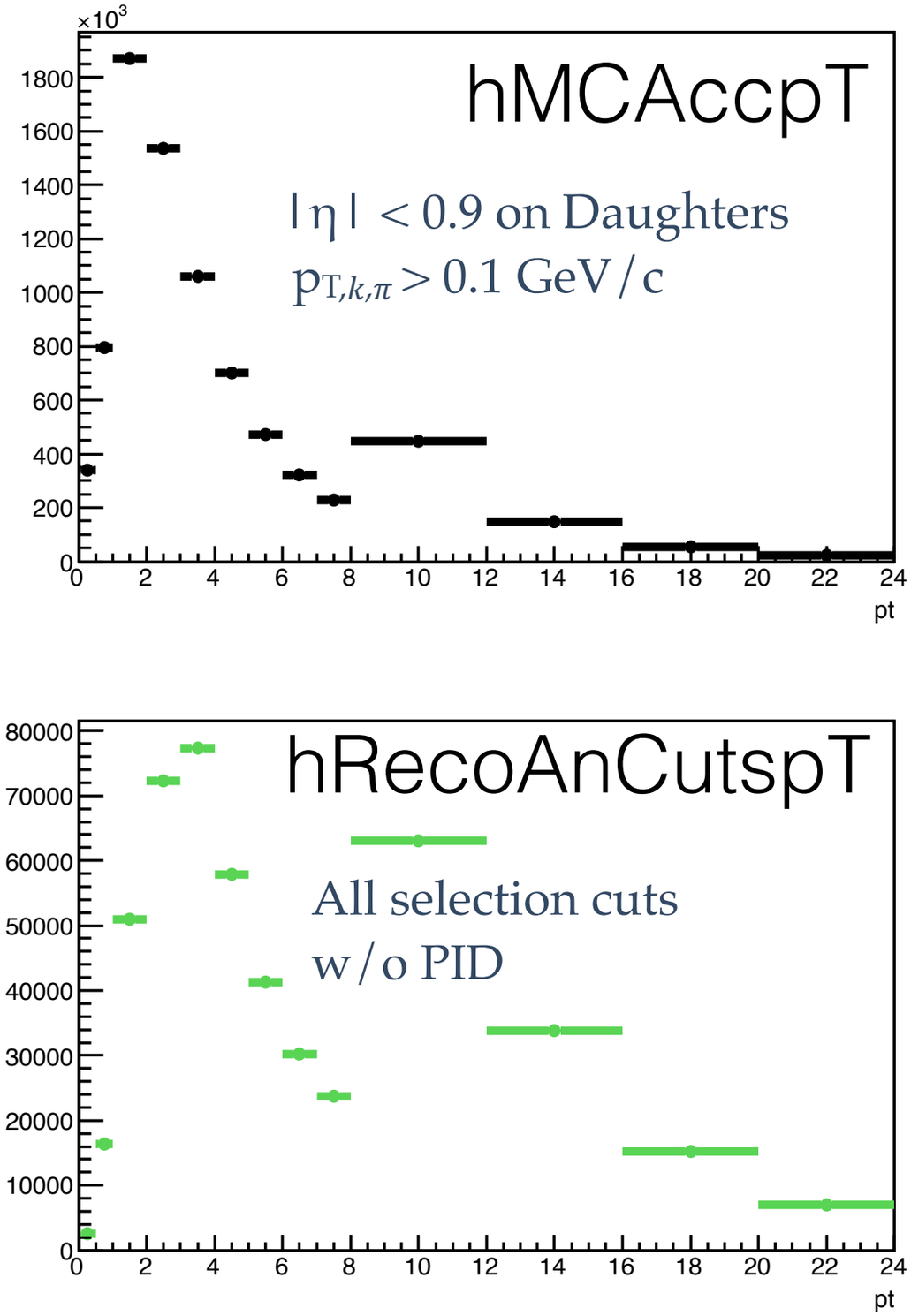


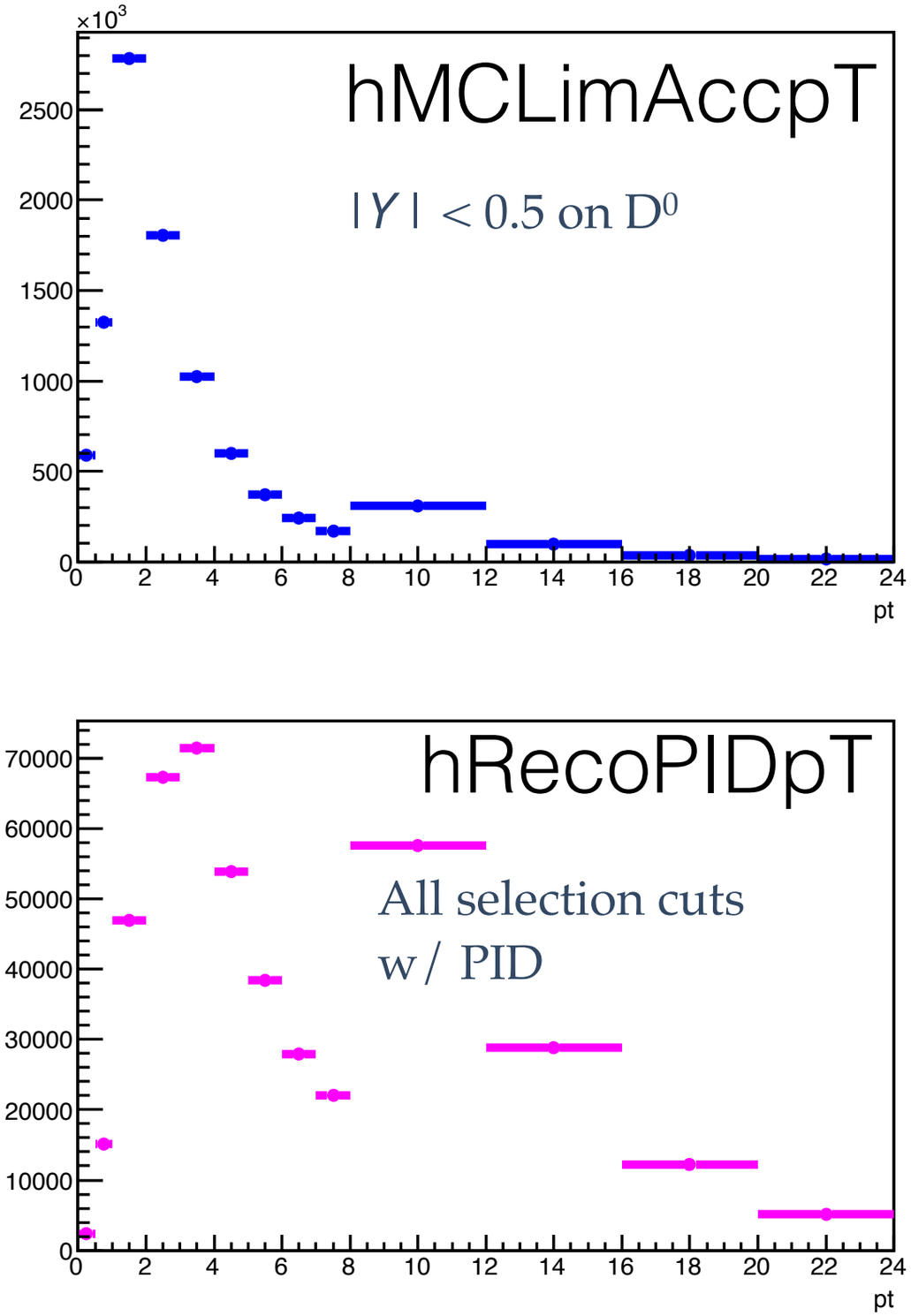
Signal/NEvents using P2 data



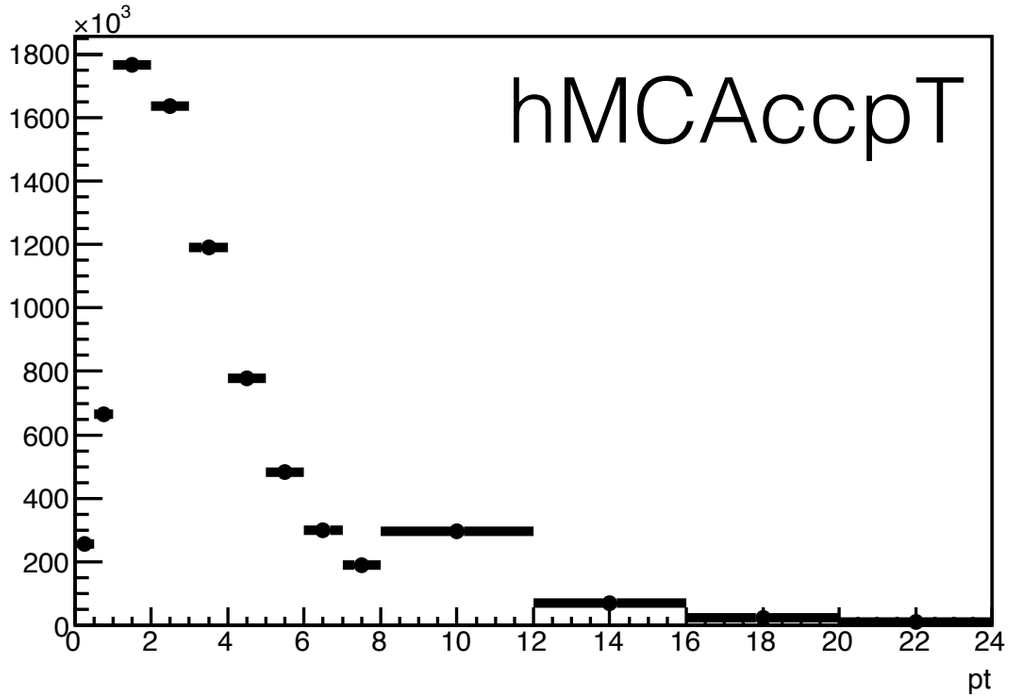
Signal/NEvents using P4 data

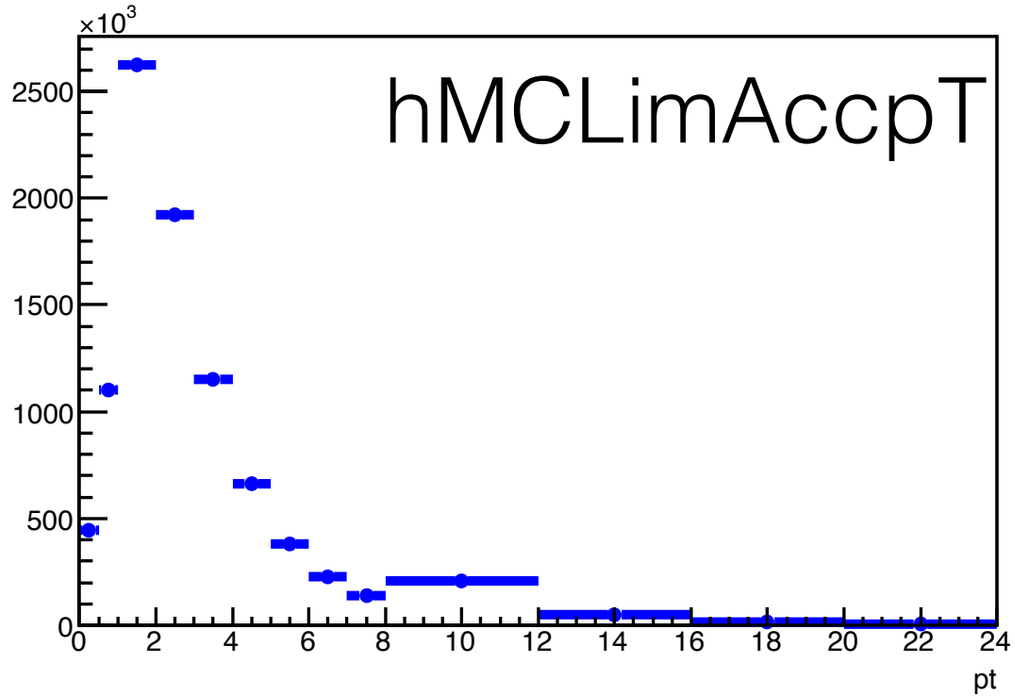
Efficiency kSteps Pass 4, from Prompt

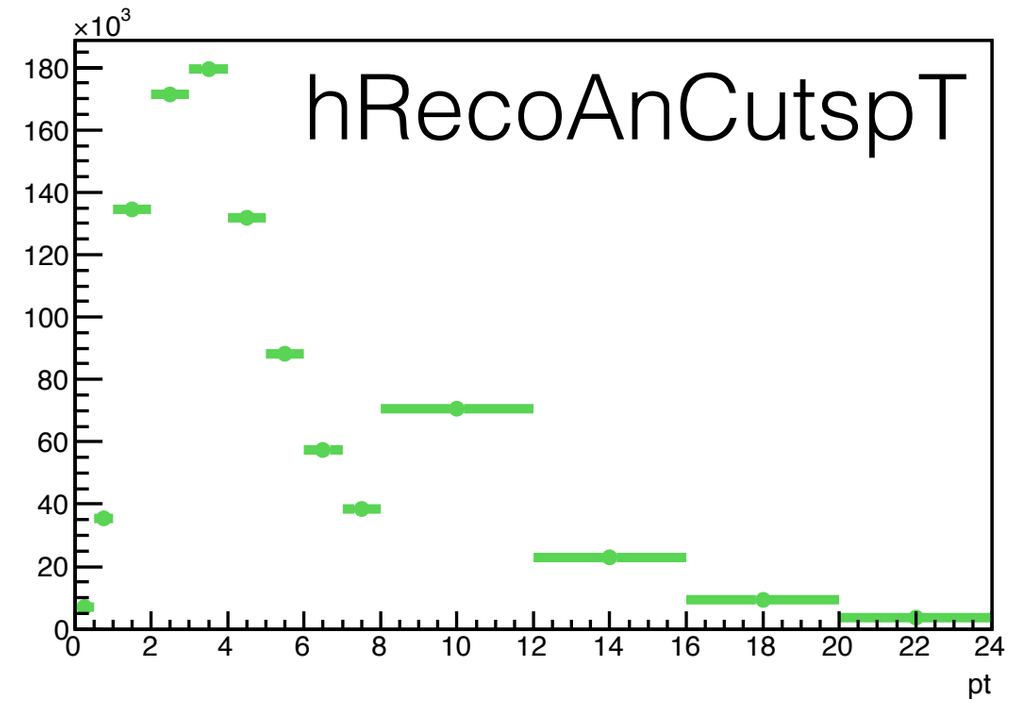


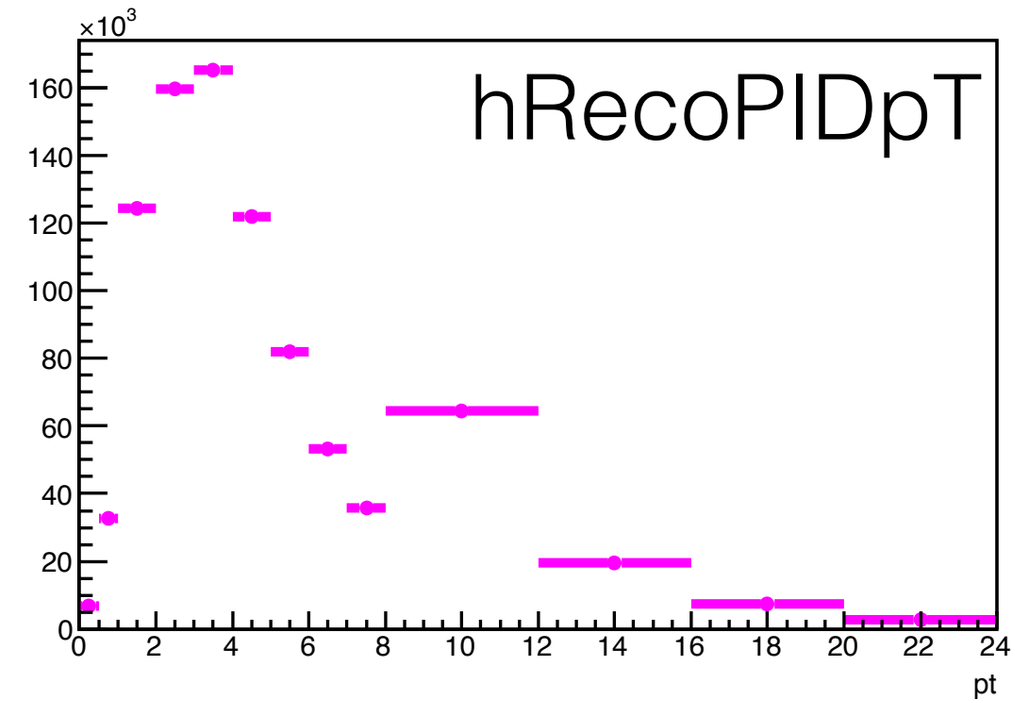


Efficiency kSteps Pass 4, from feeddown

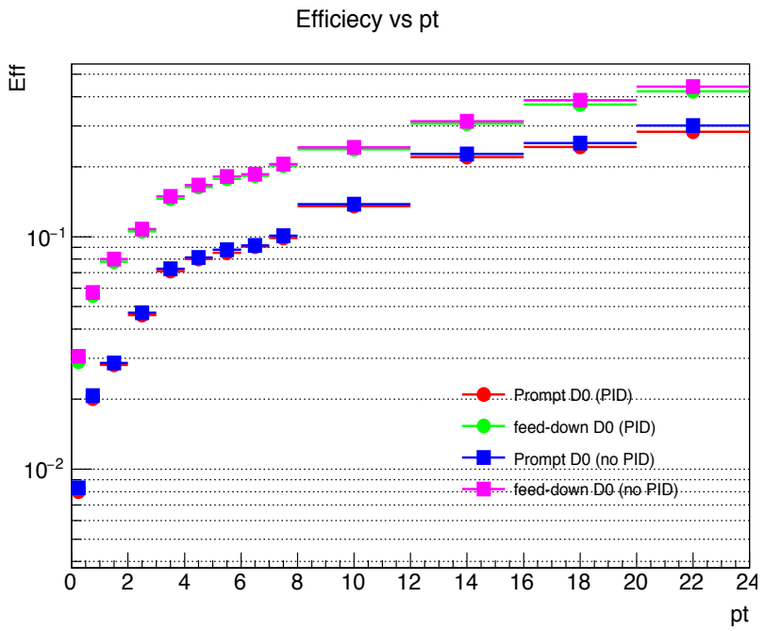


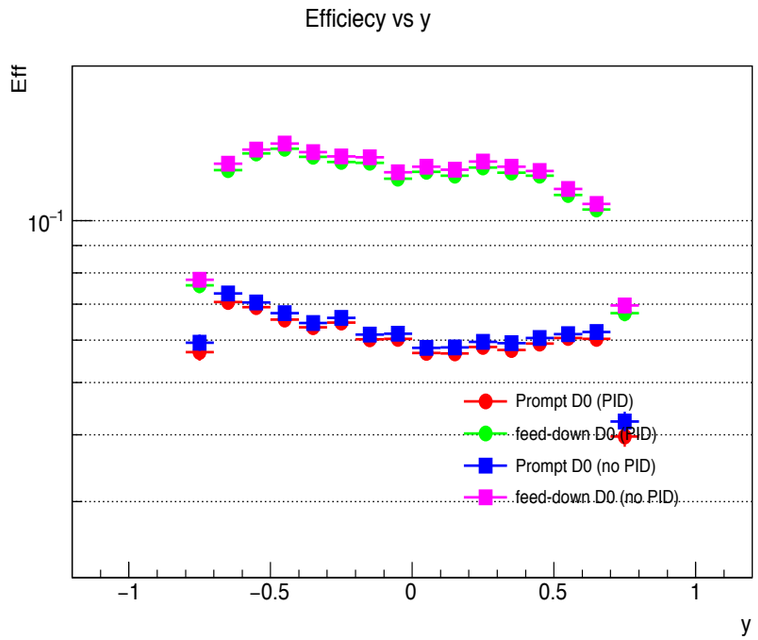


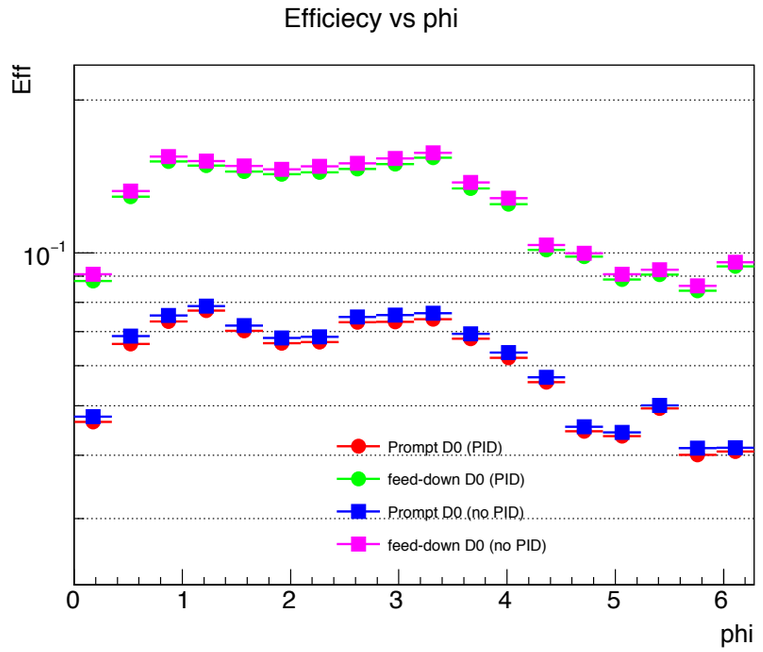


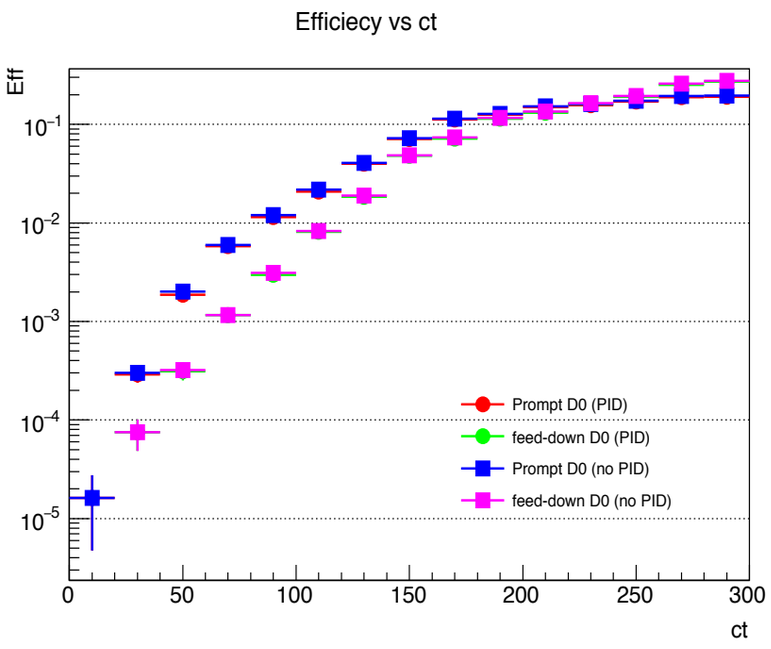


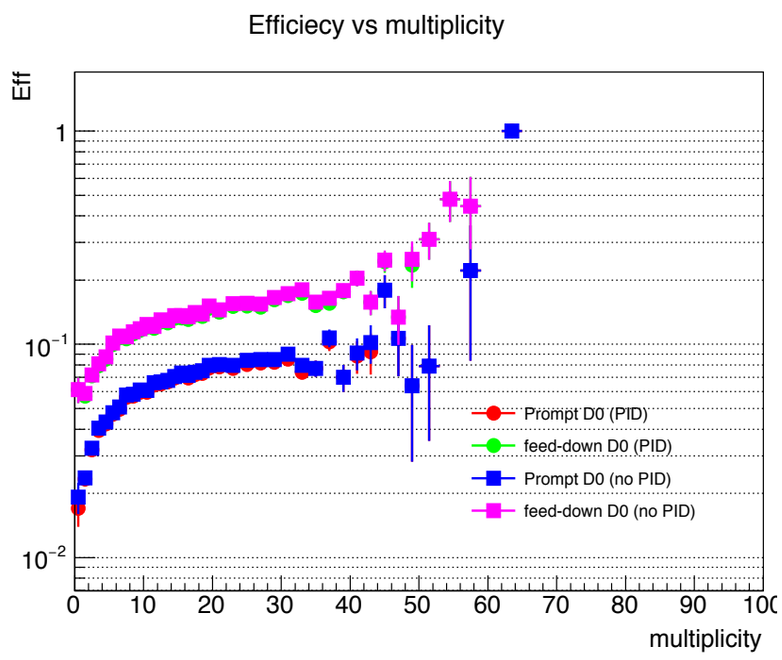
Efficiency vs. Variables: Pass 2

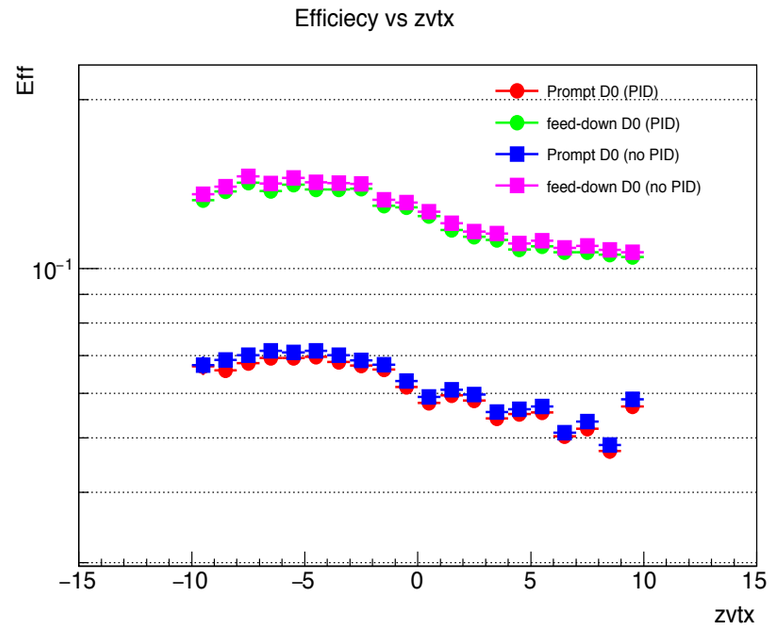




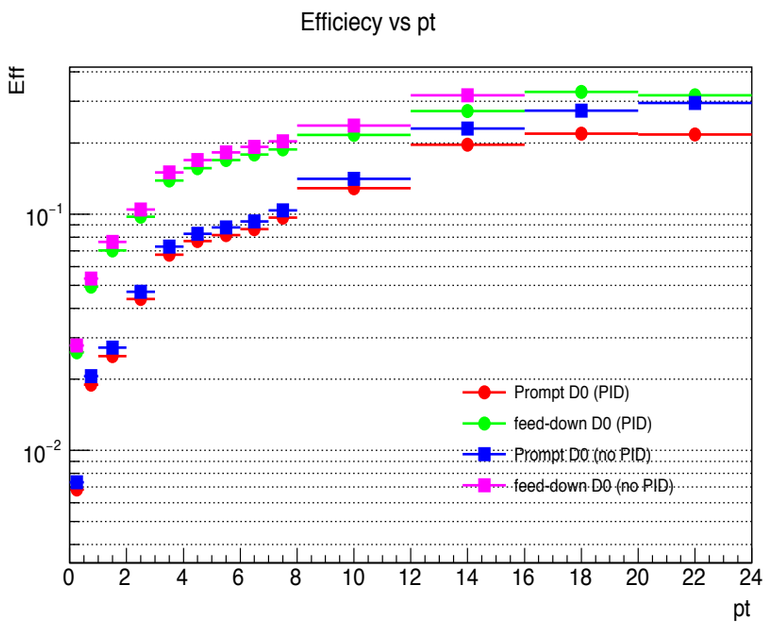


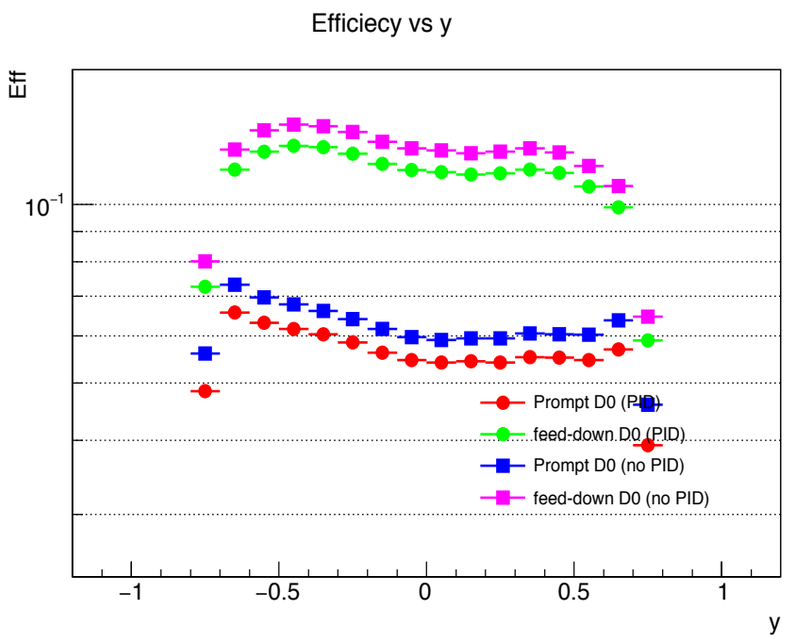


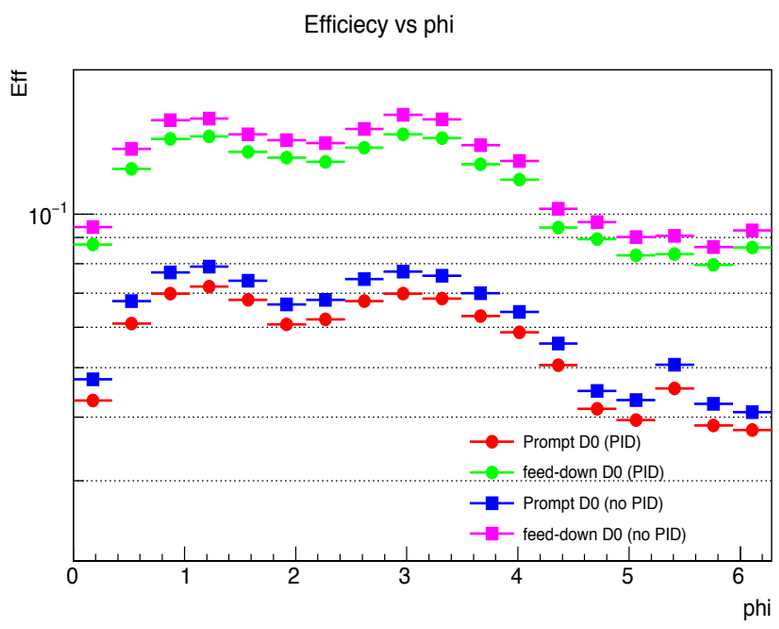


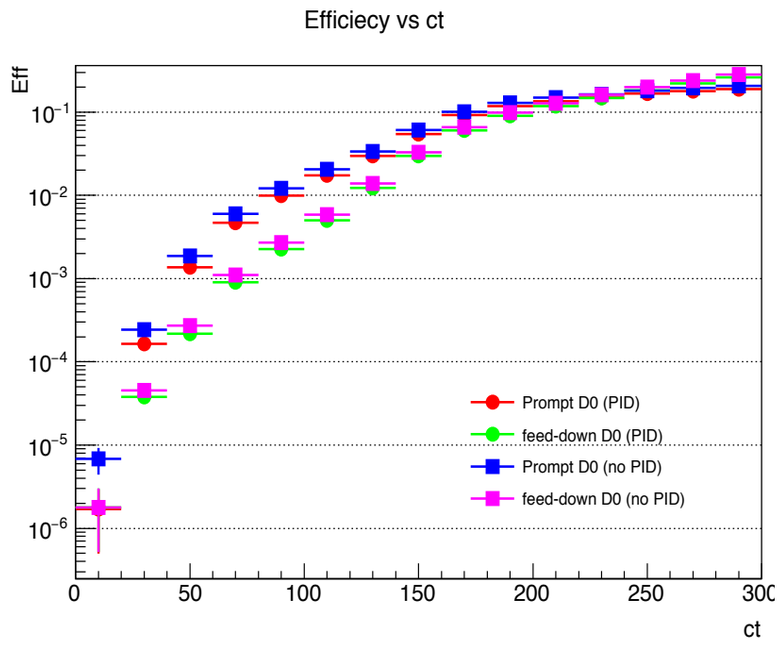


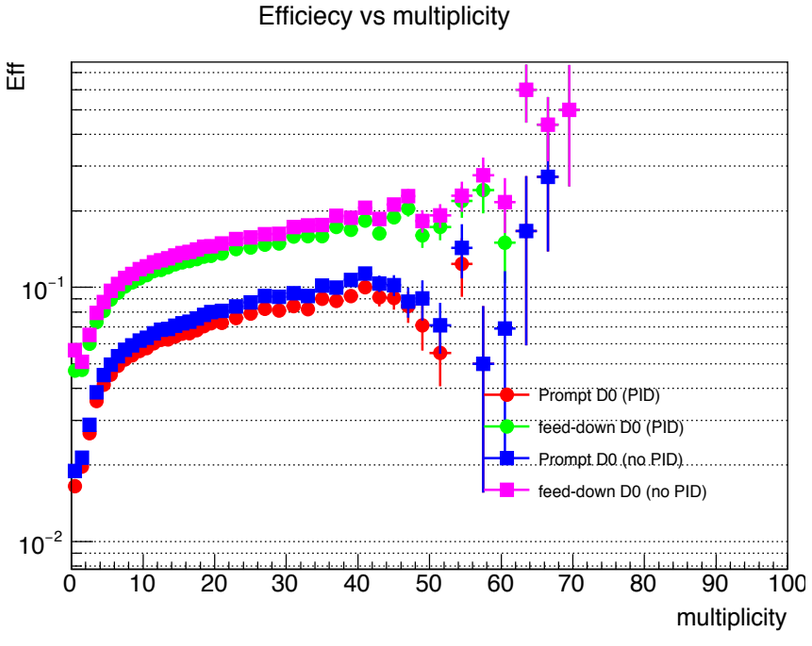
Efficiency vs. Variables: Pass 4

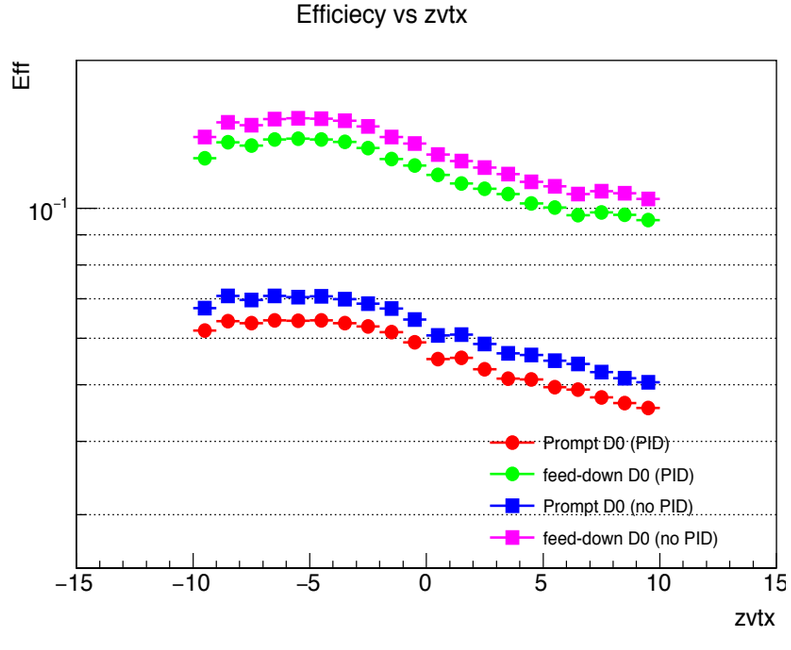




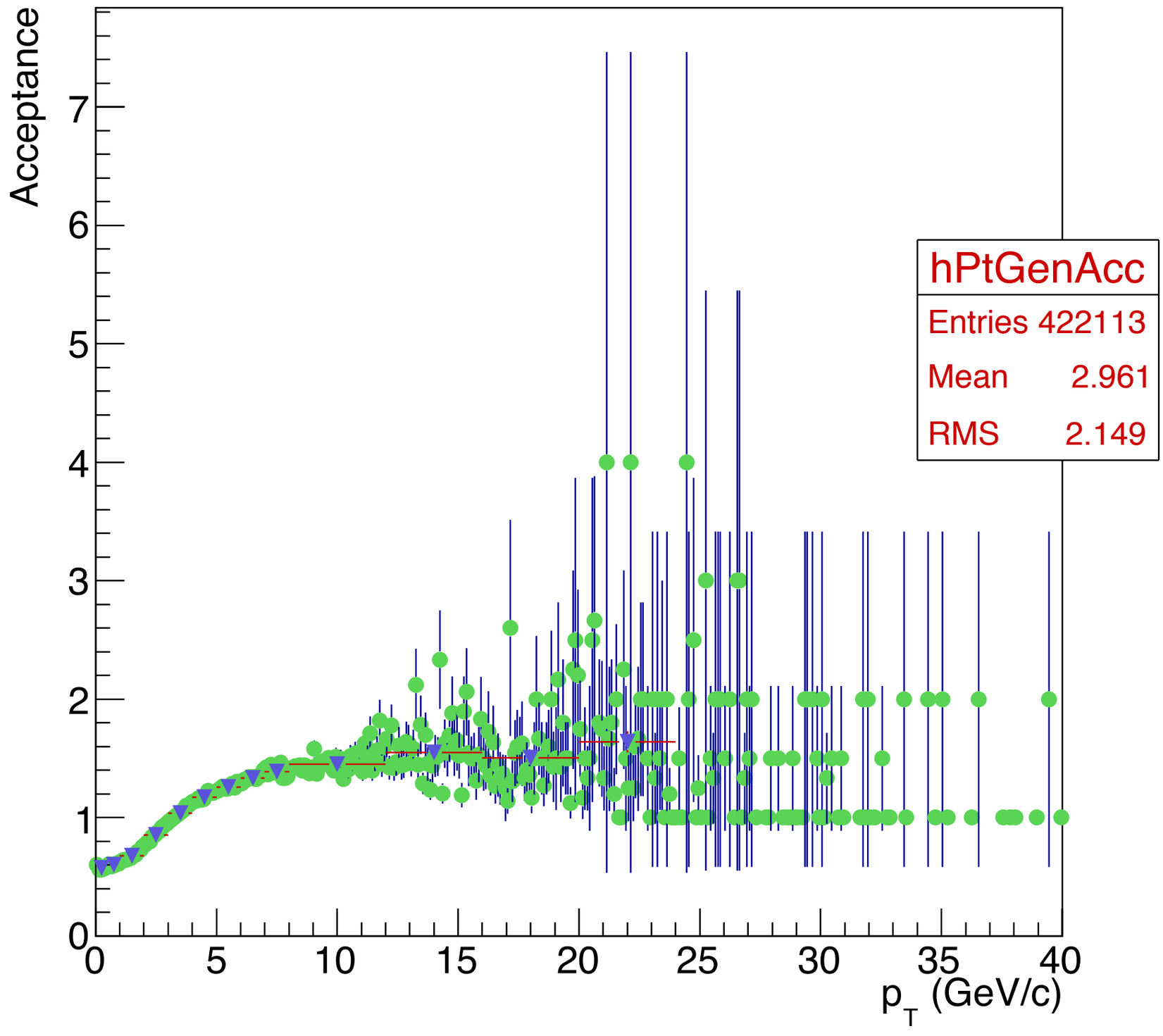






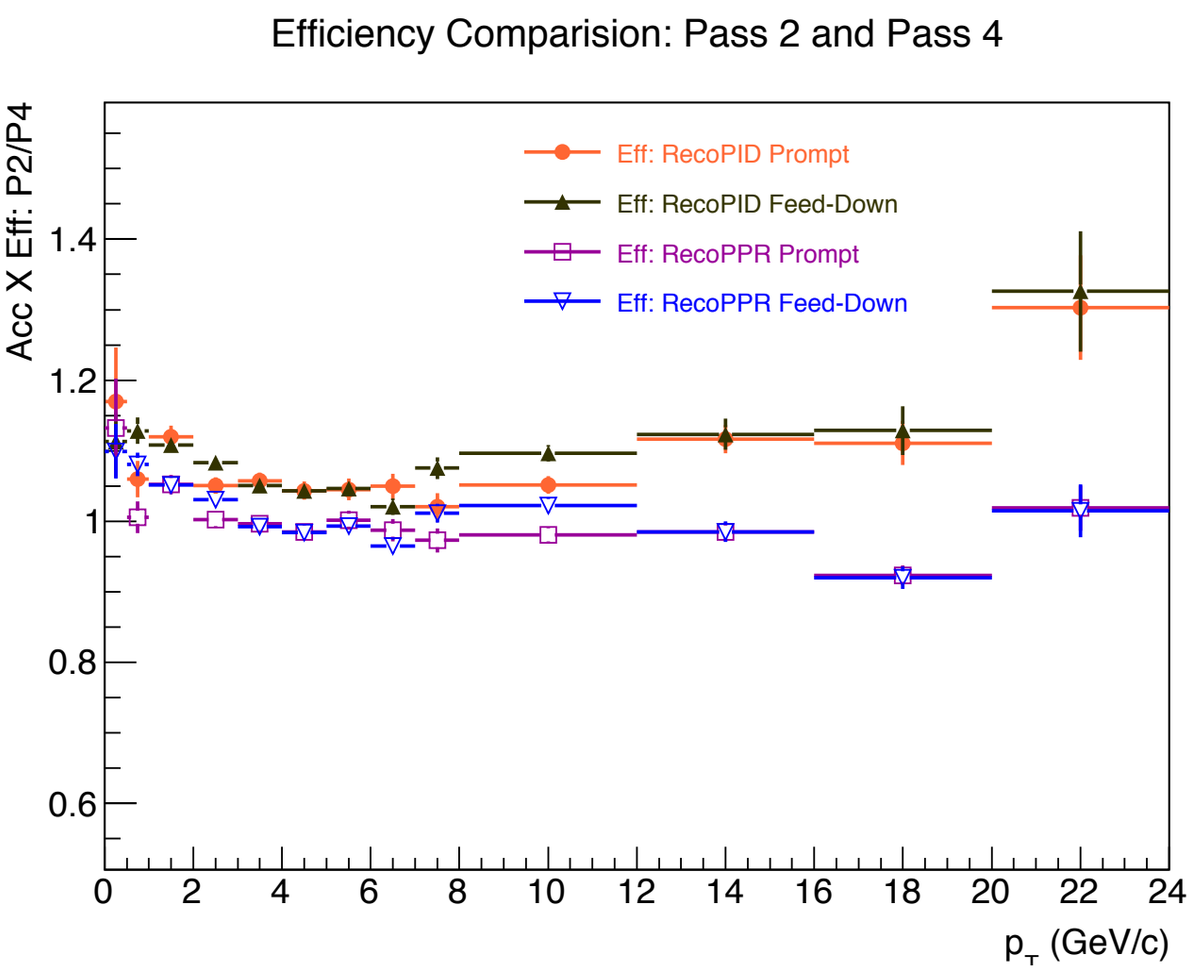


Acceptance (FastMC)

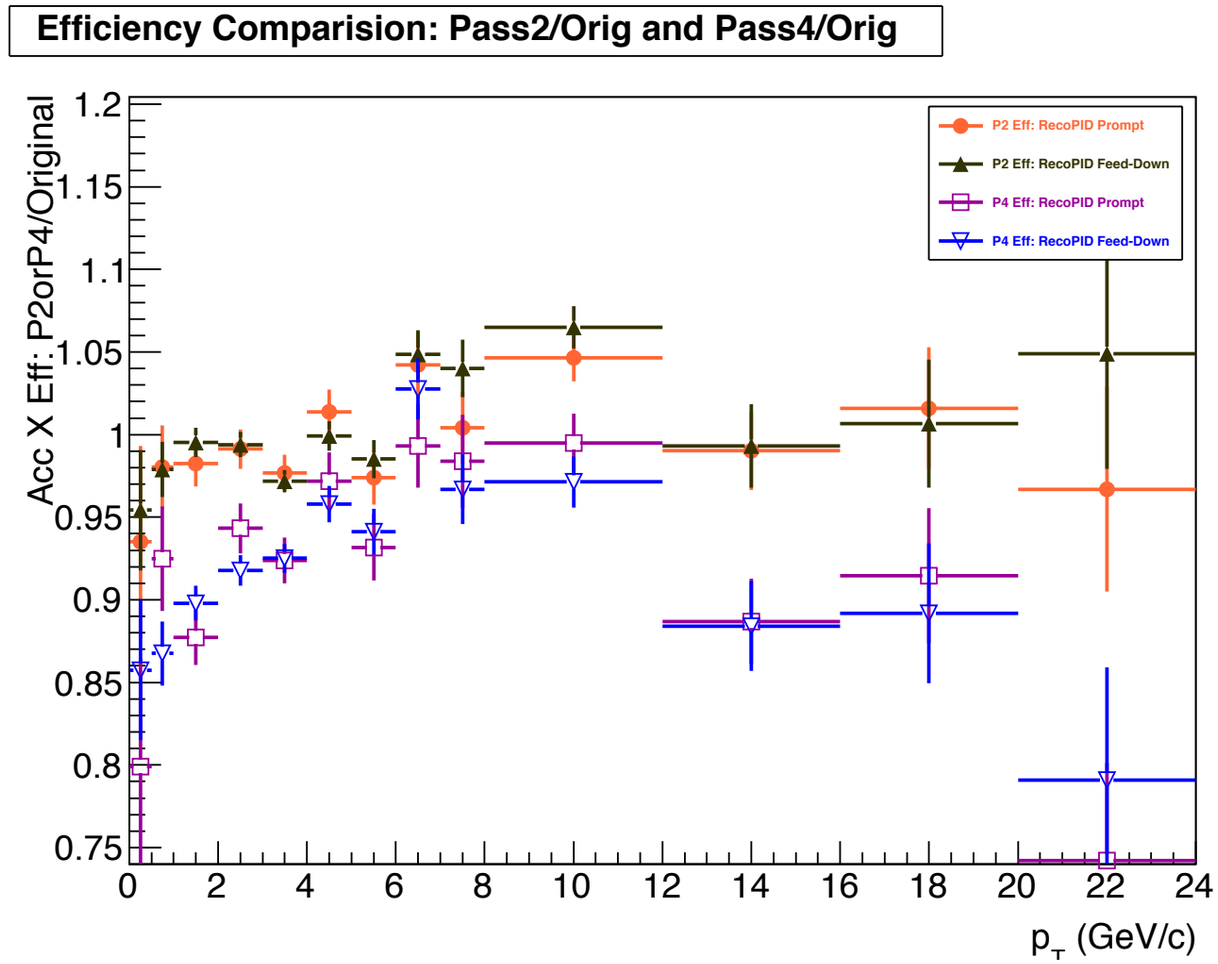


Efficiency × Acceptance

Comparison of Pass2 and Pass4



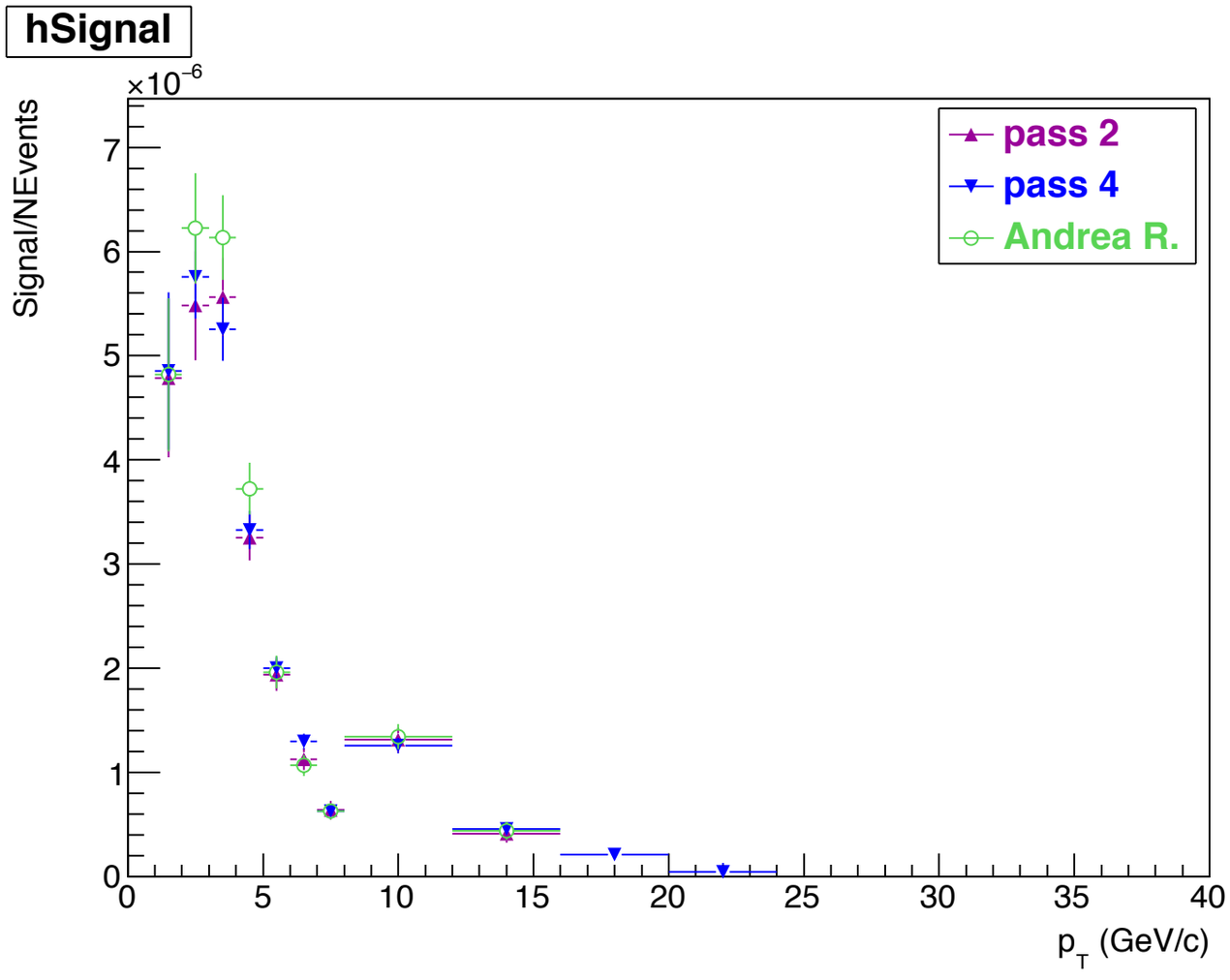
Comparison with original results

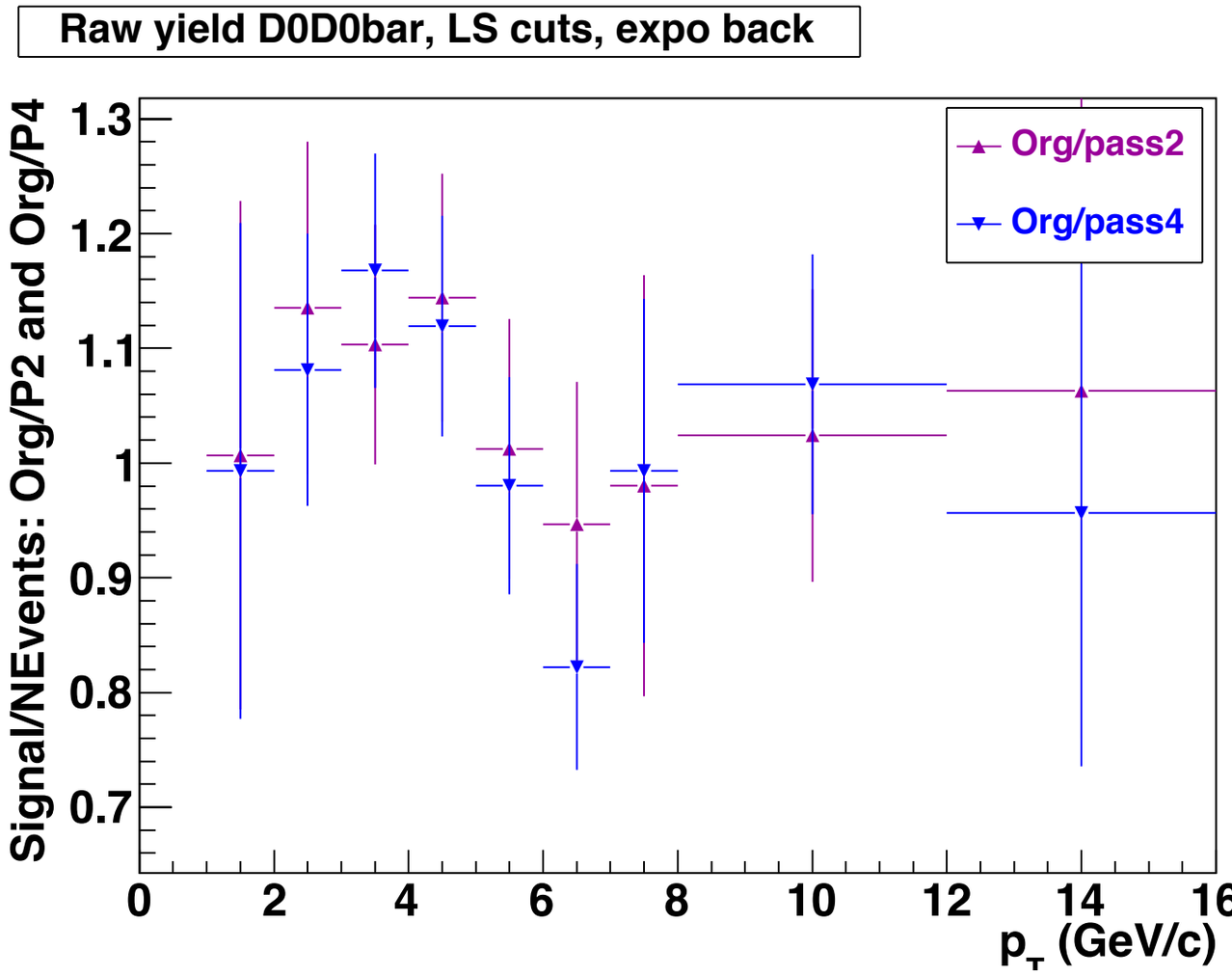


The ratio of efficiency X Acceptance for pass 4 to pass 2 is slightly above 1 for RecoPID

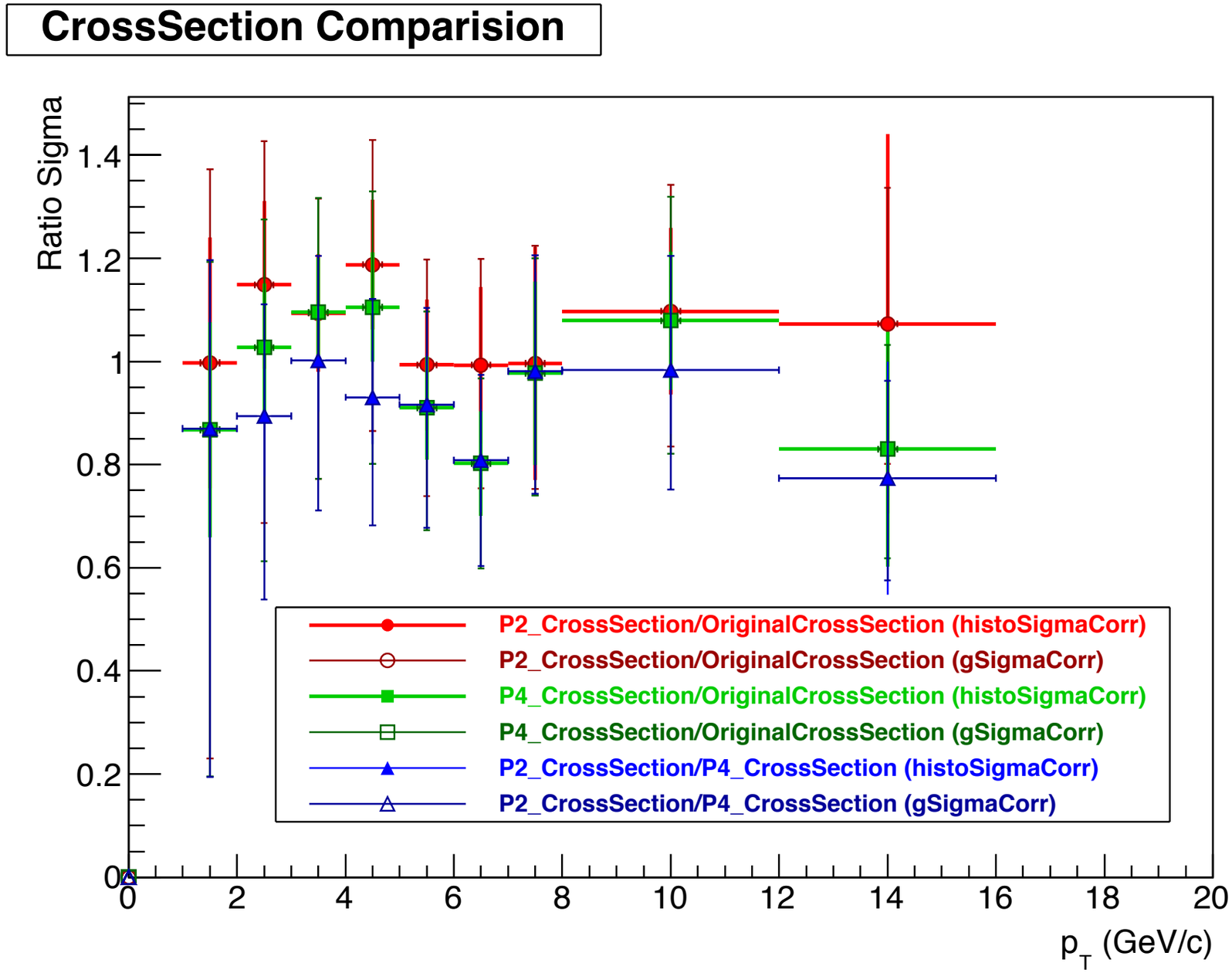
Also, ratio of efficiency of pass 4 to published are comparable and they are within 5%

Signal Pass 2, Pass 4, Original Results





Cross Section Comparison

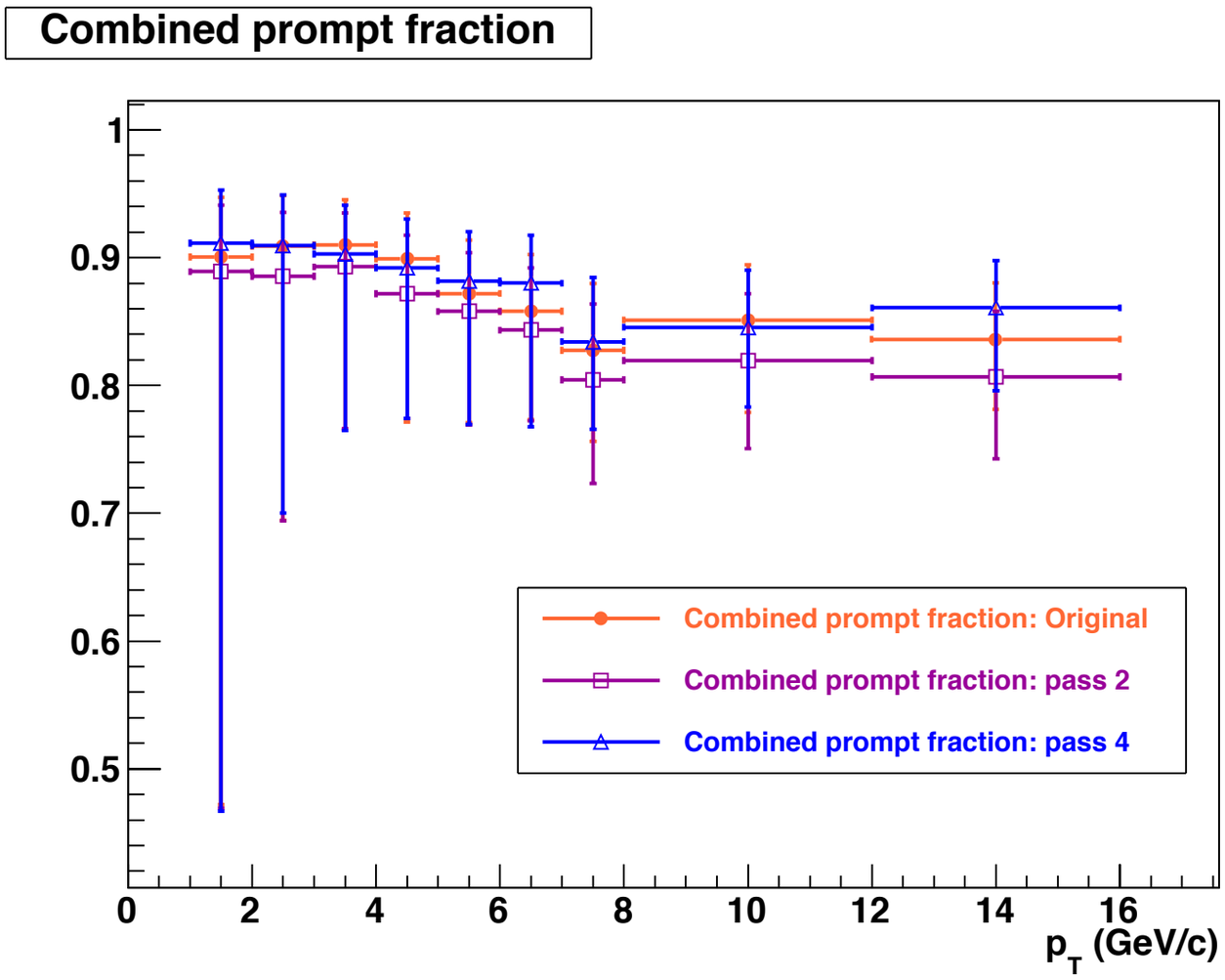


Cross section results for pass 4 and original are matches within some uncertainty which can be explained by differences in pass 2 and pass 4 data

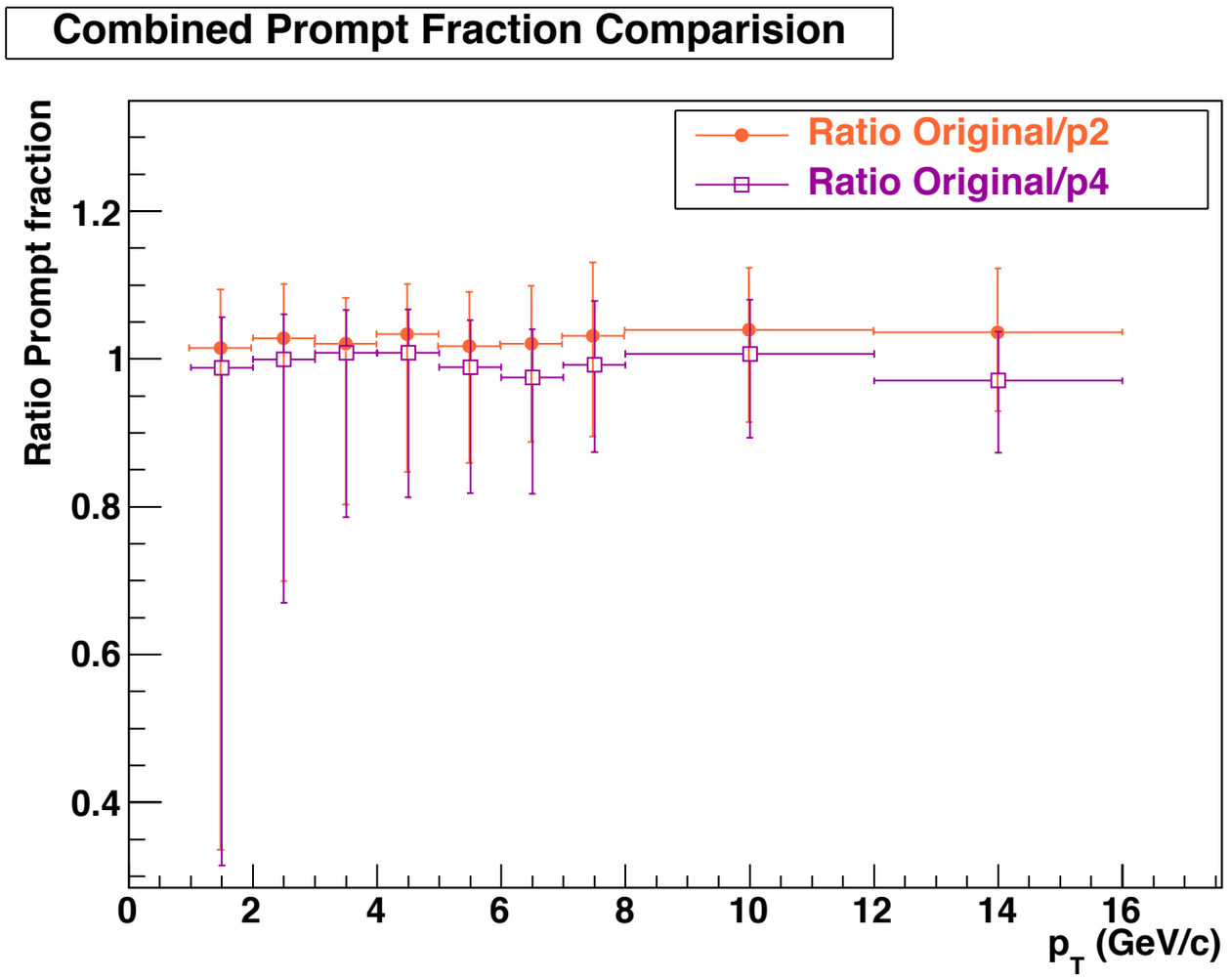
With this we positively concluded our checks for pass 4 data.

Prompt Fraction

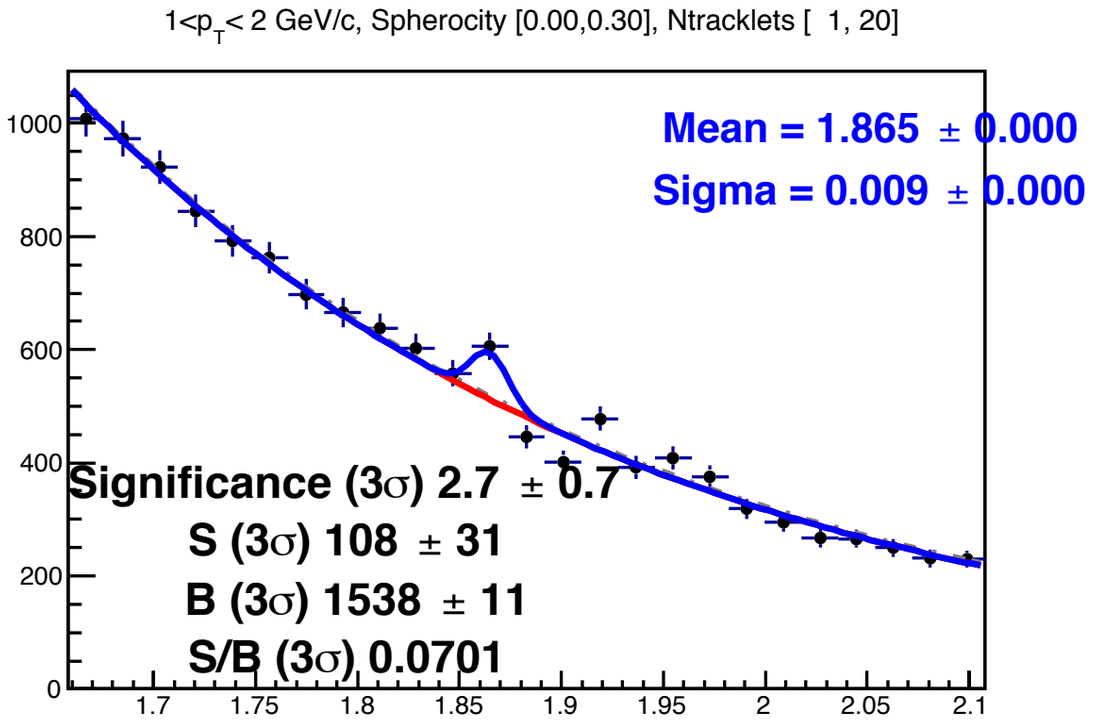
Prompt Fraction

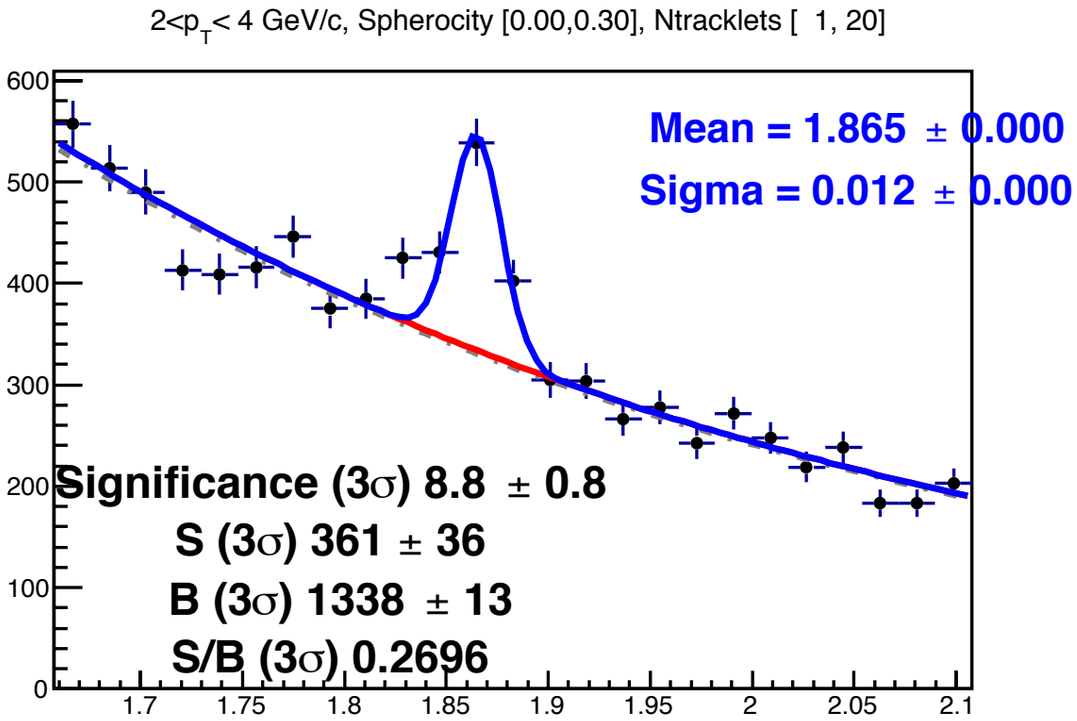


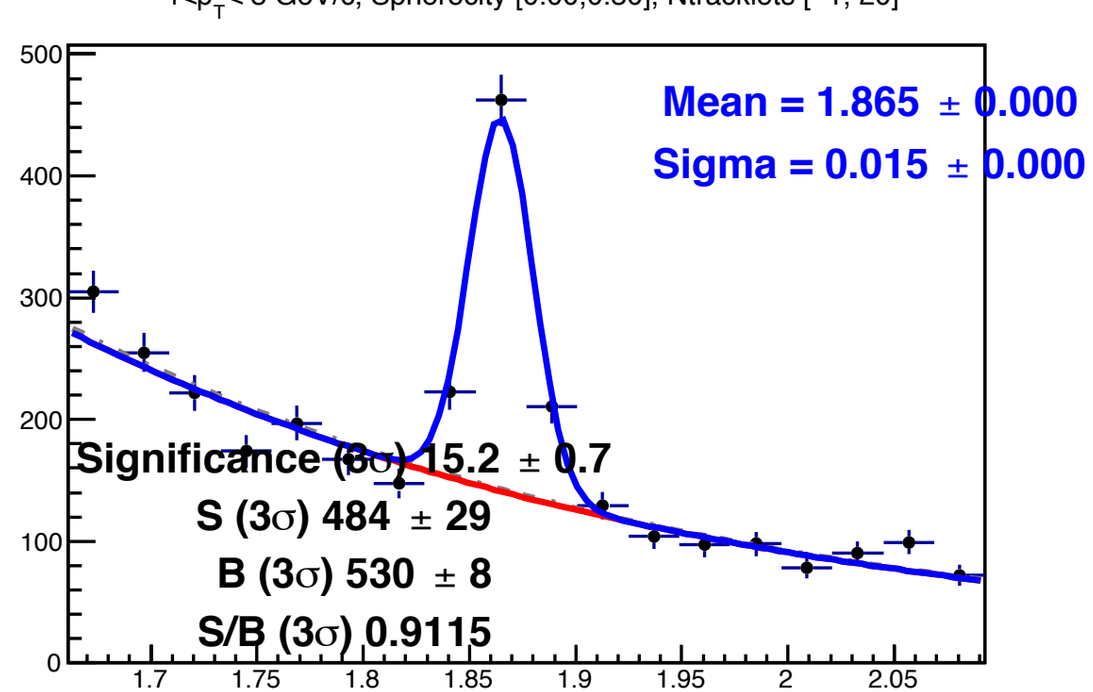
Ratio of Prompt Fraction

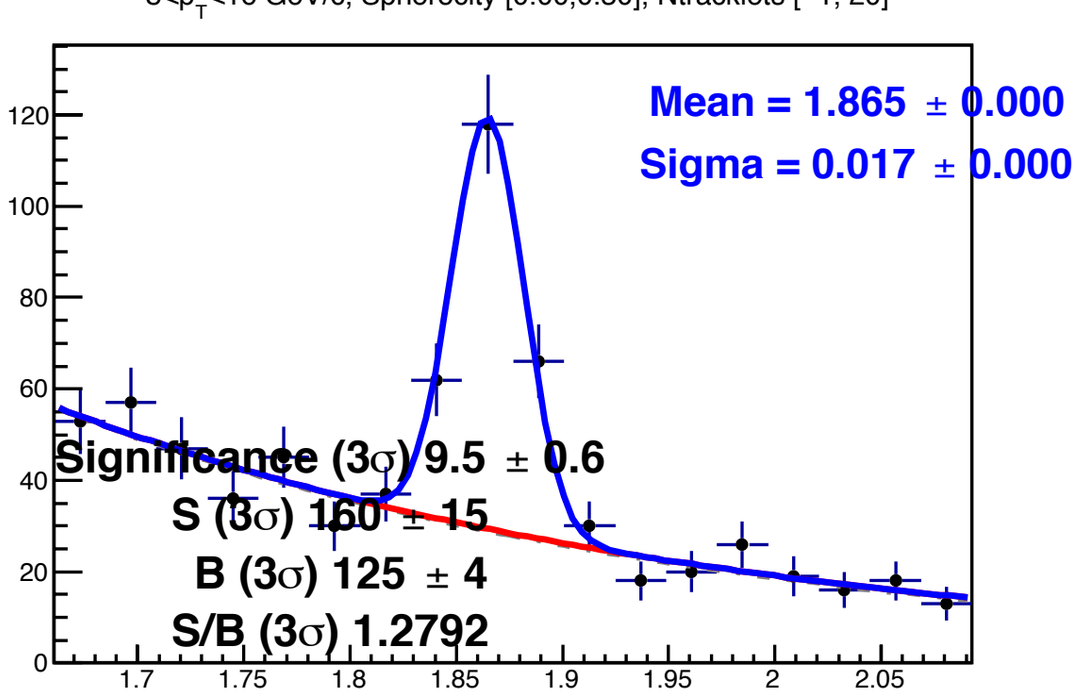


two Mult Bins: Ntrk[1,20]; Sphero[0.0, 0.3]

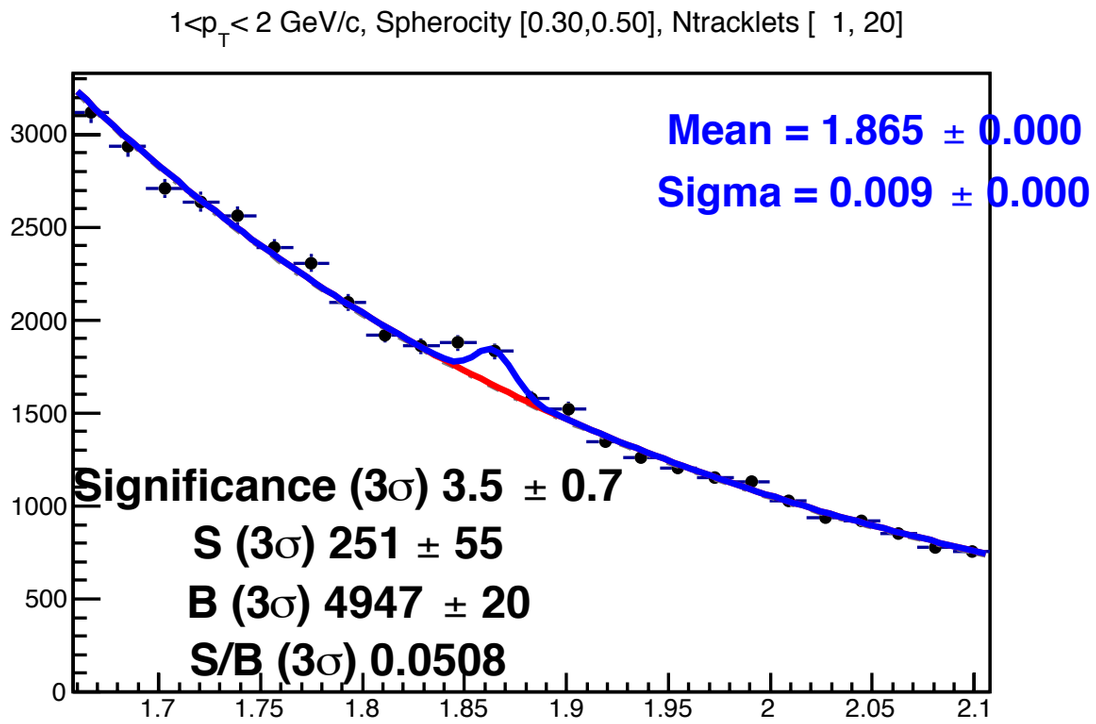


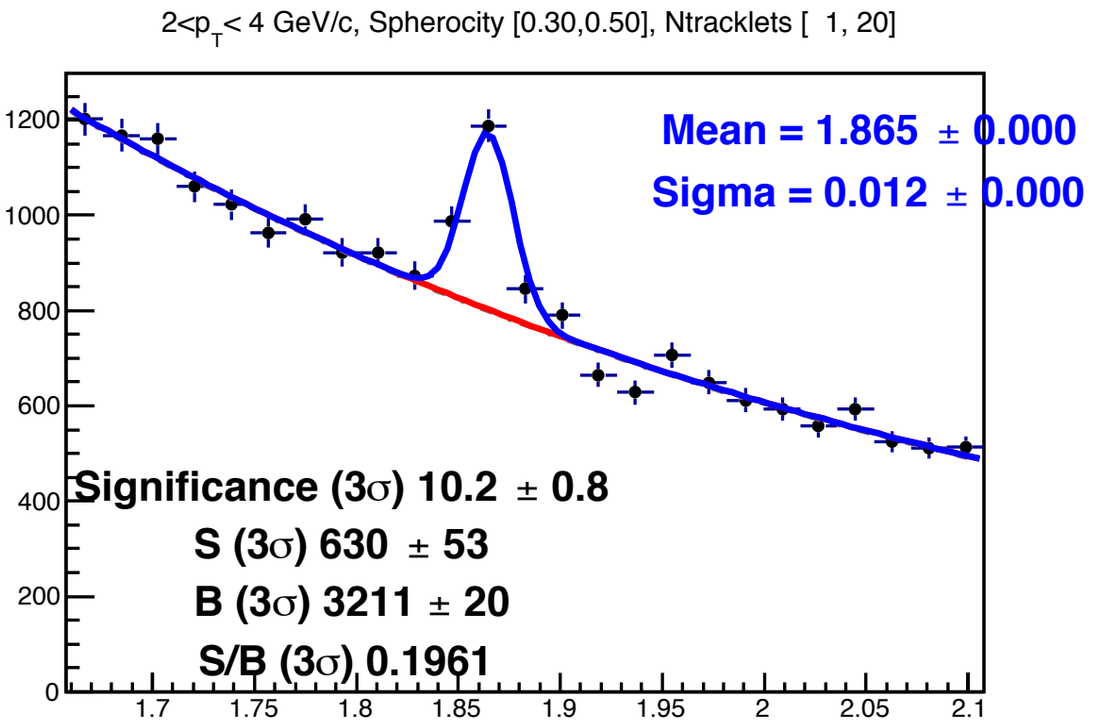


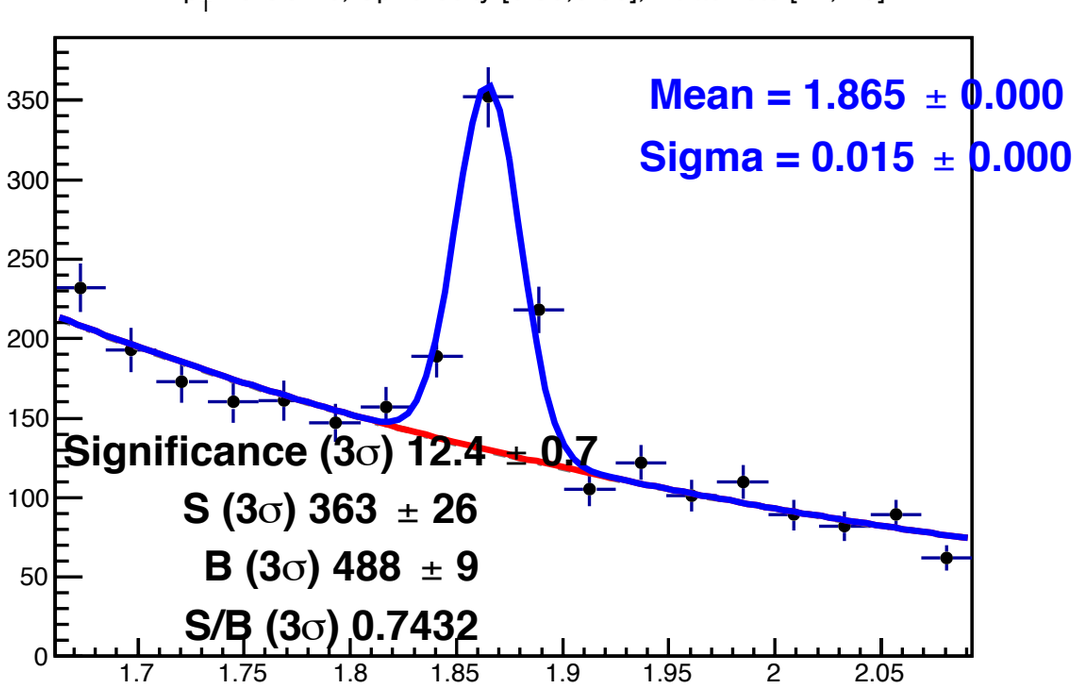


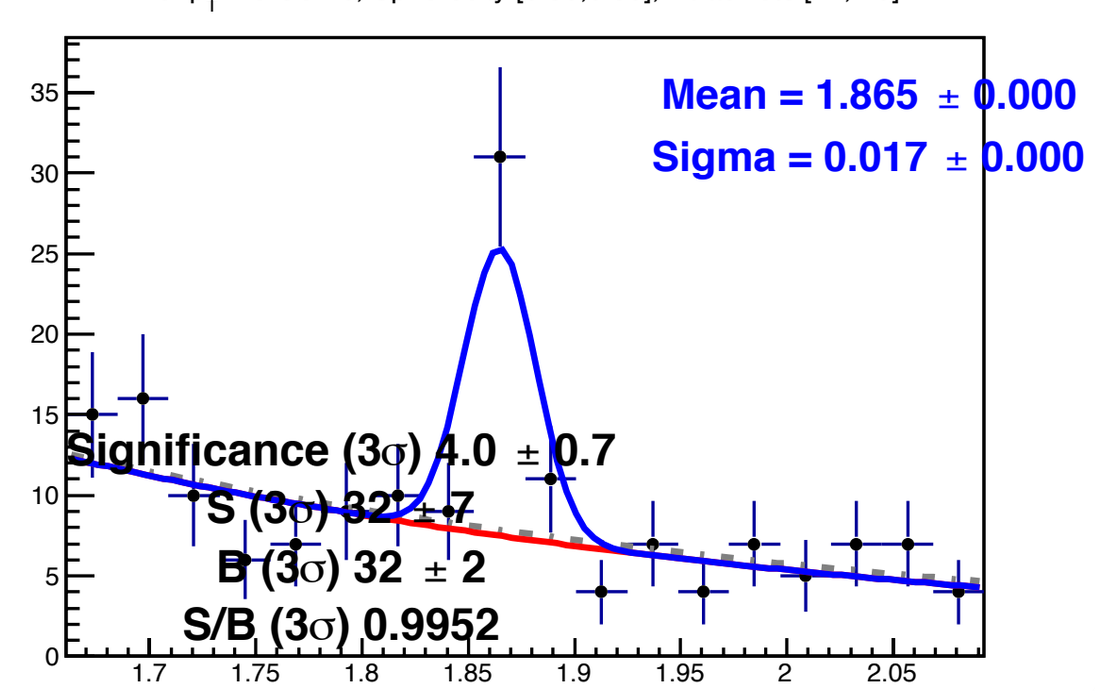


two Mult Bins: Ntrk[1,20]; Sphero[0.3, 0.5]









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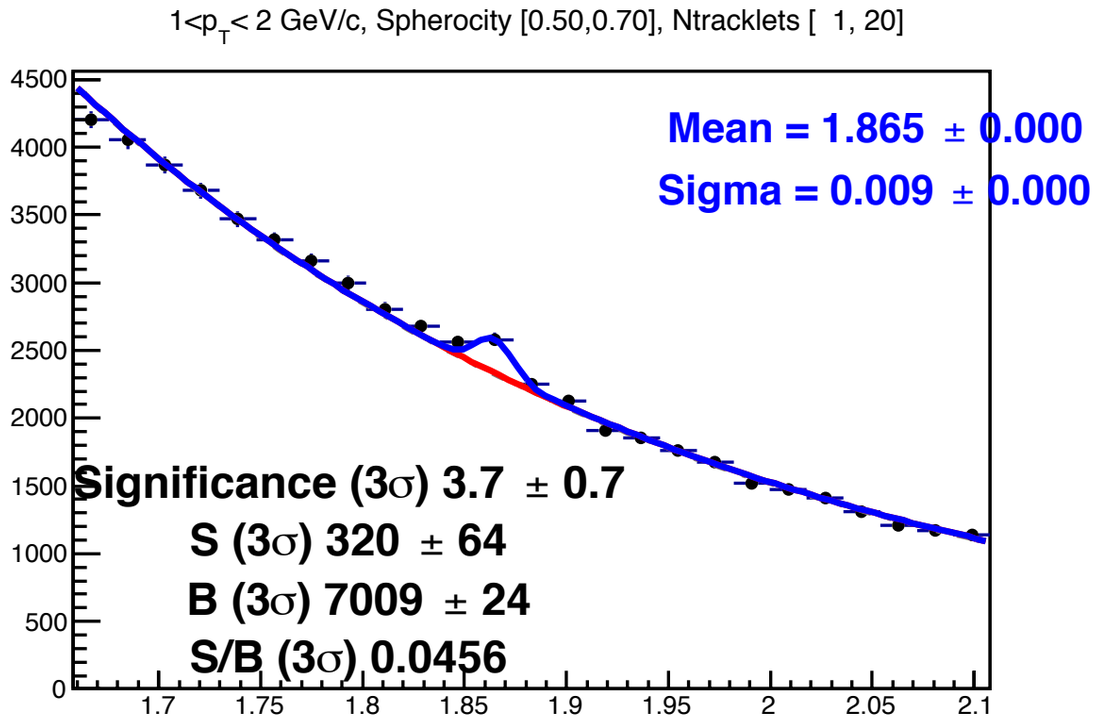

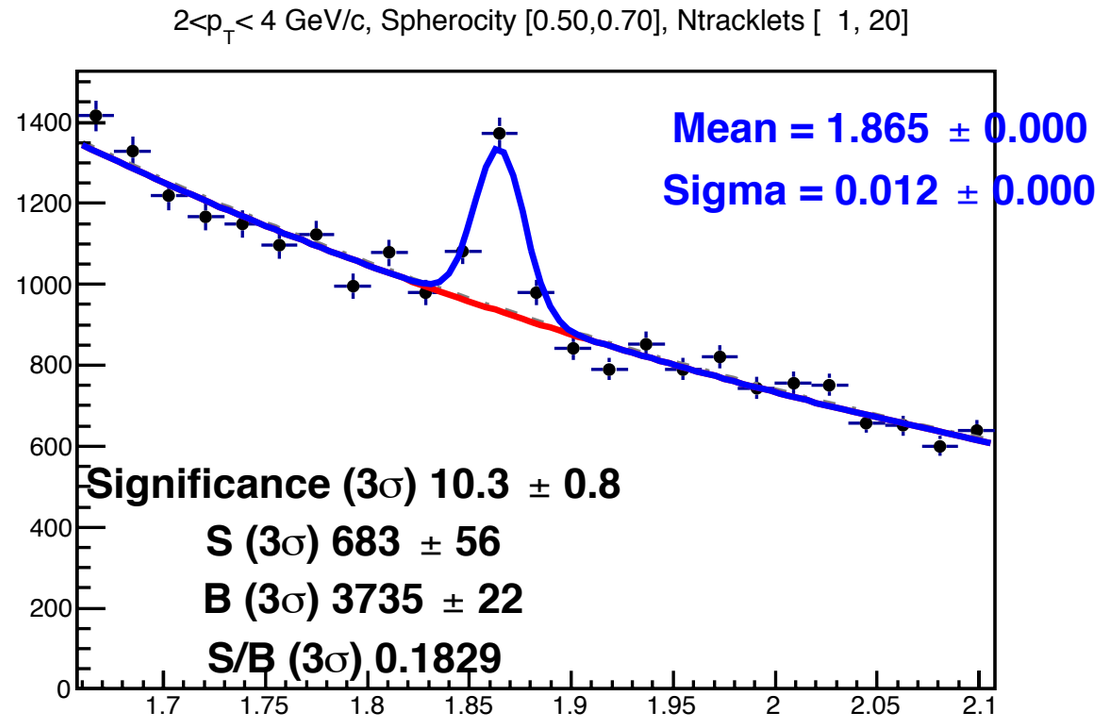

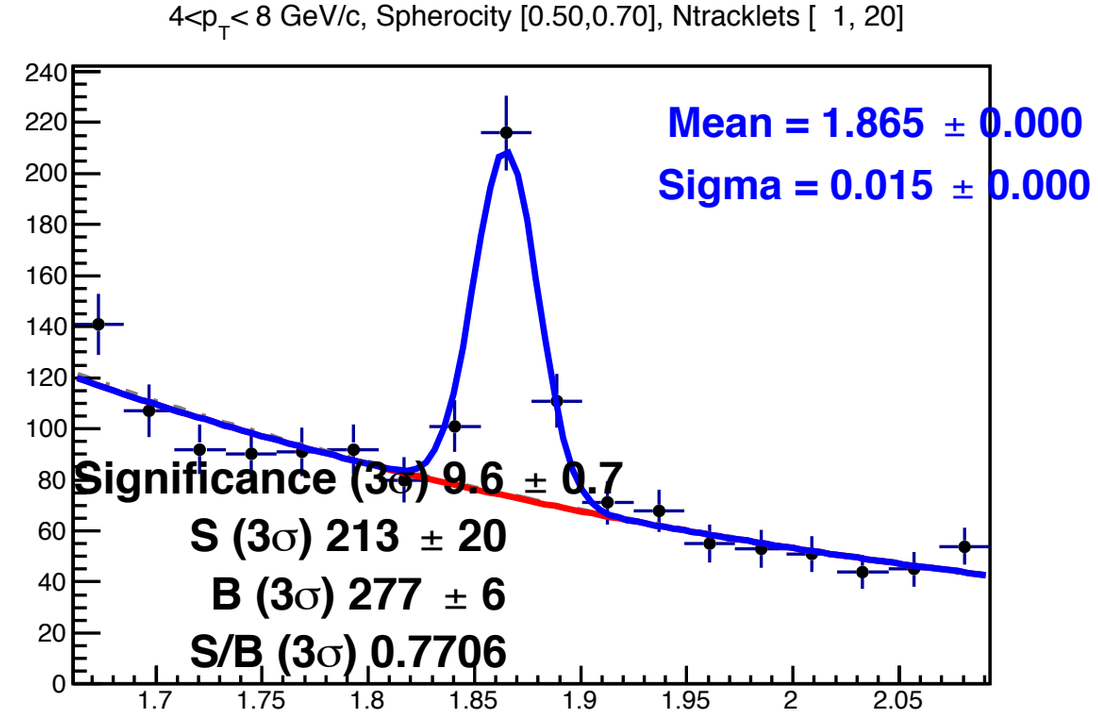

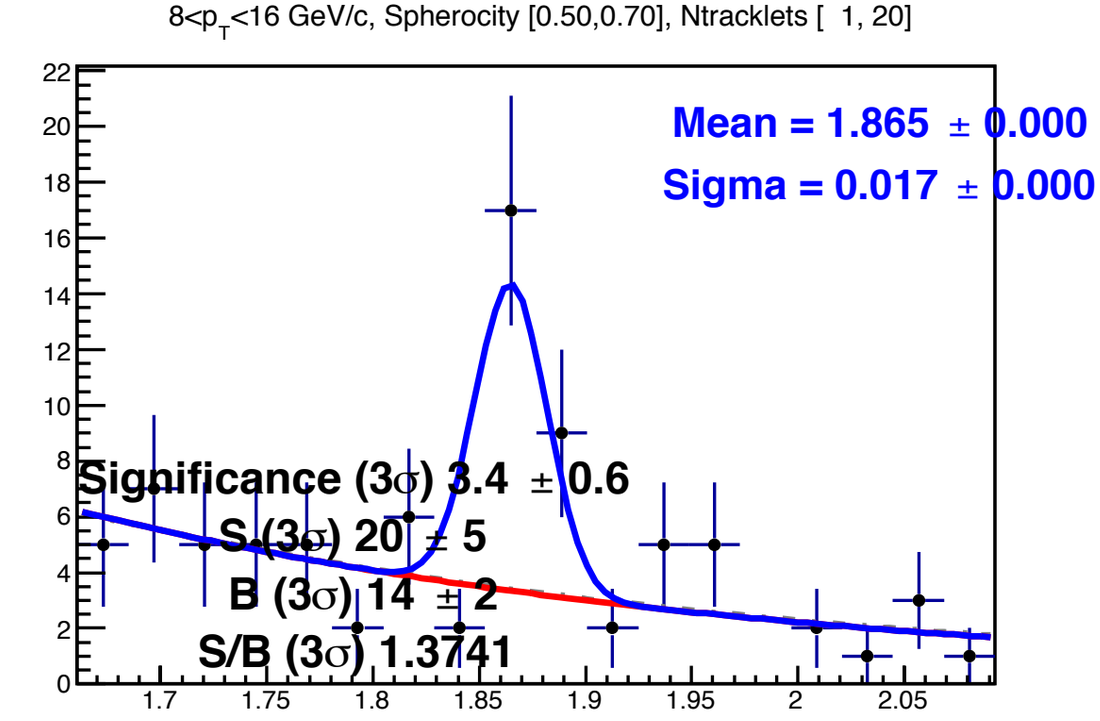

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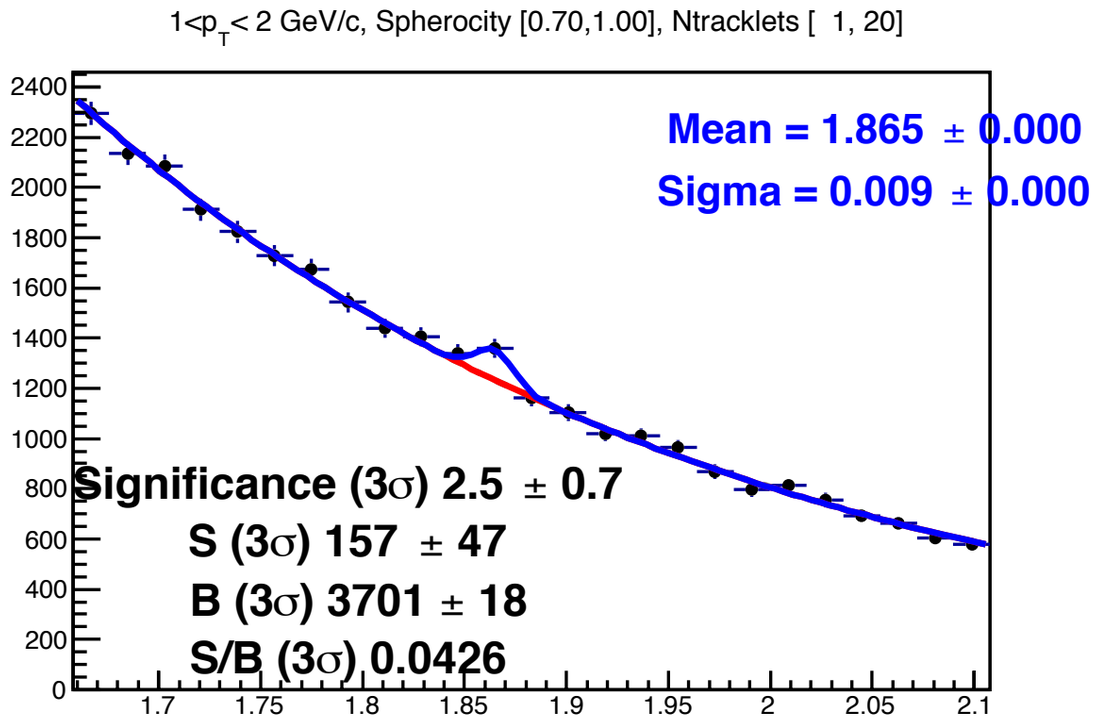

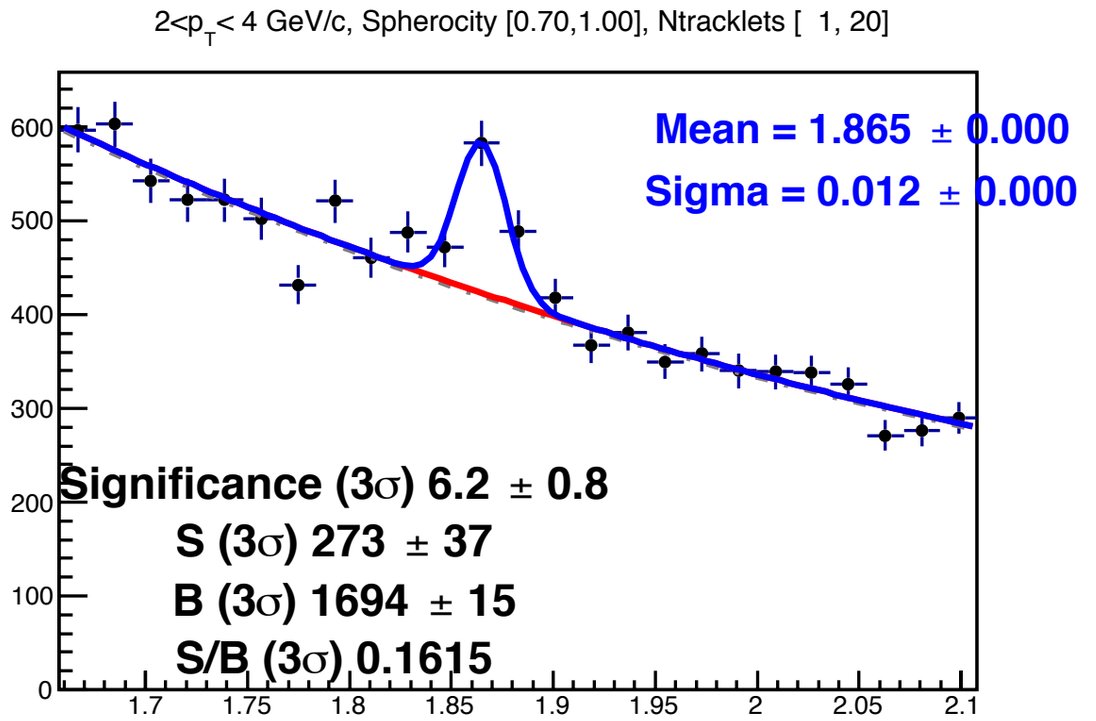

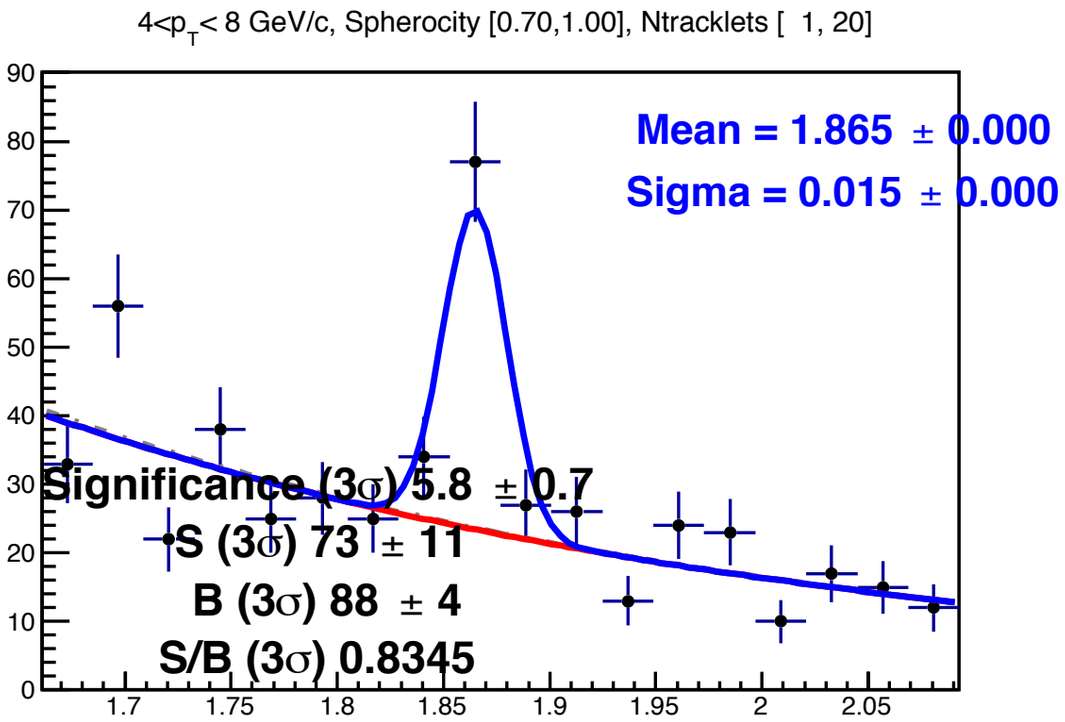

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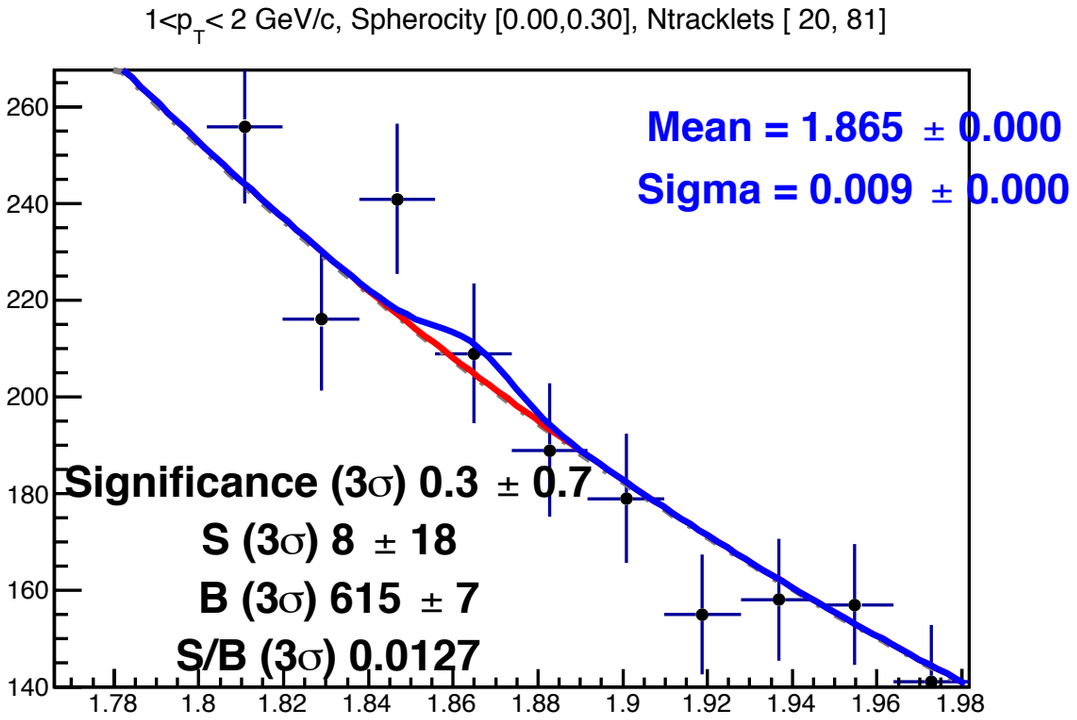

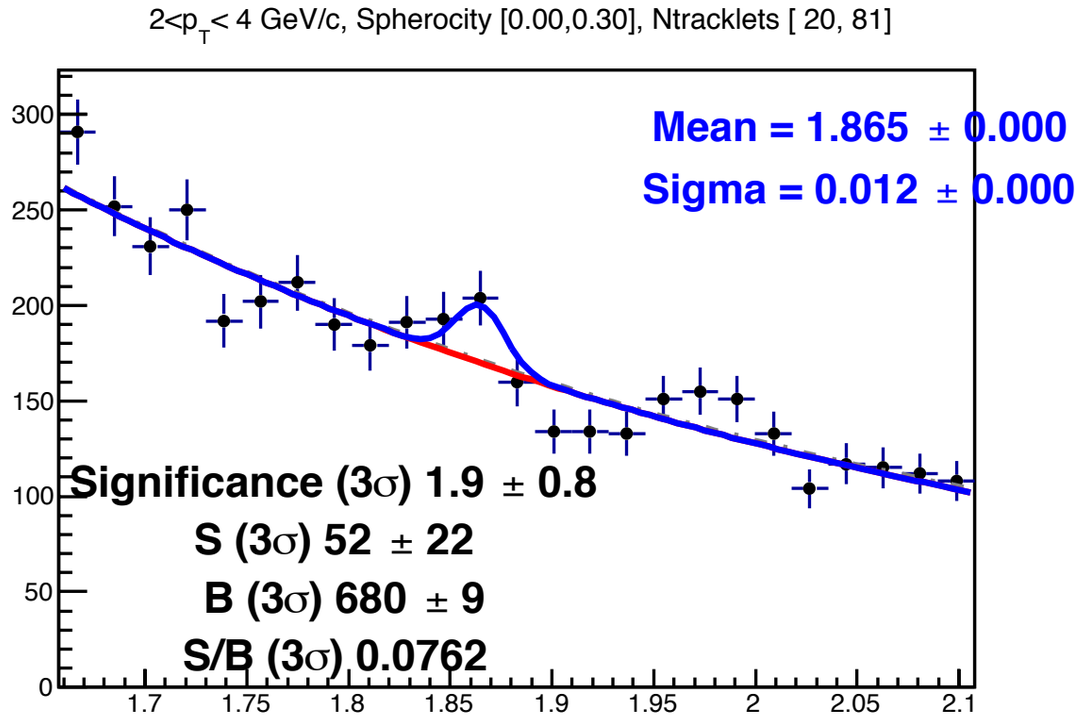

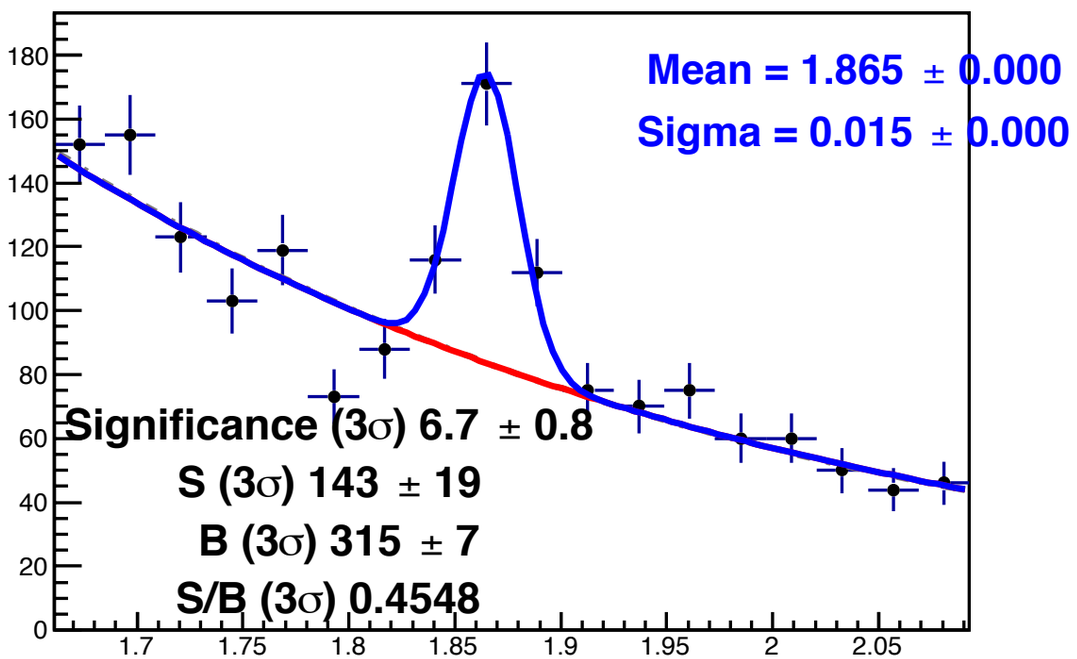

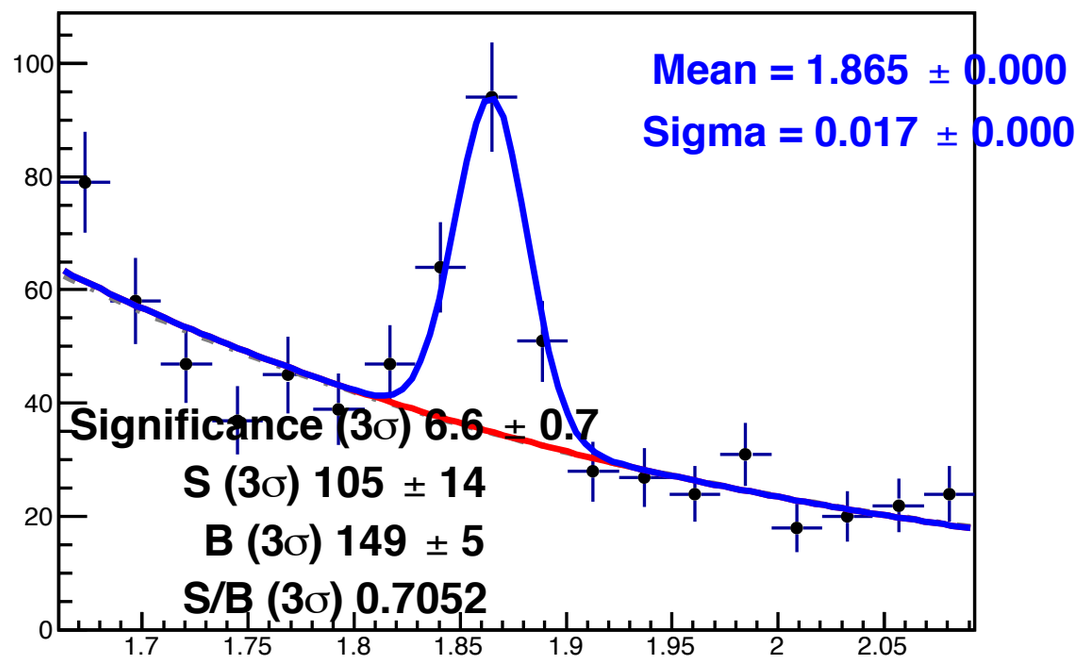

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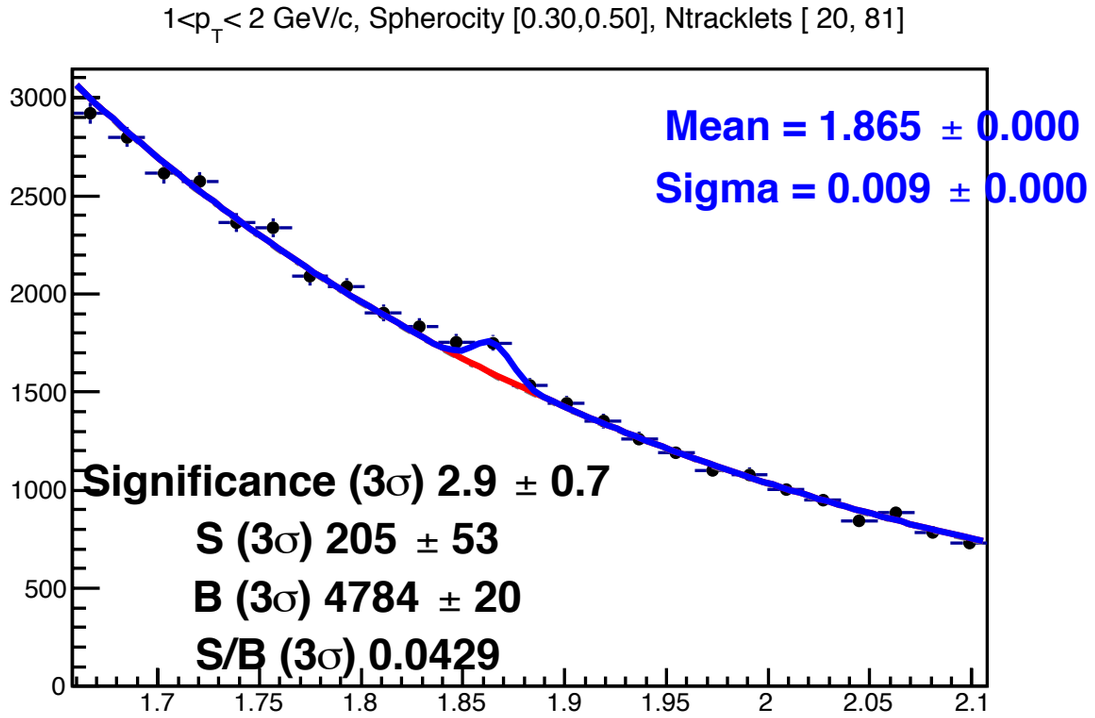

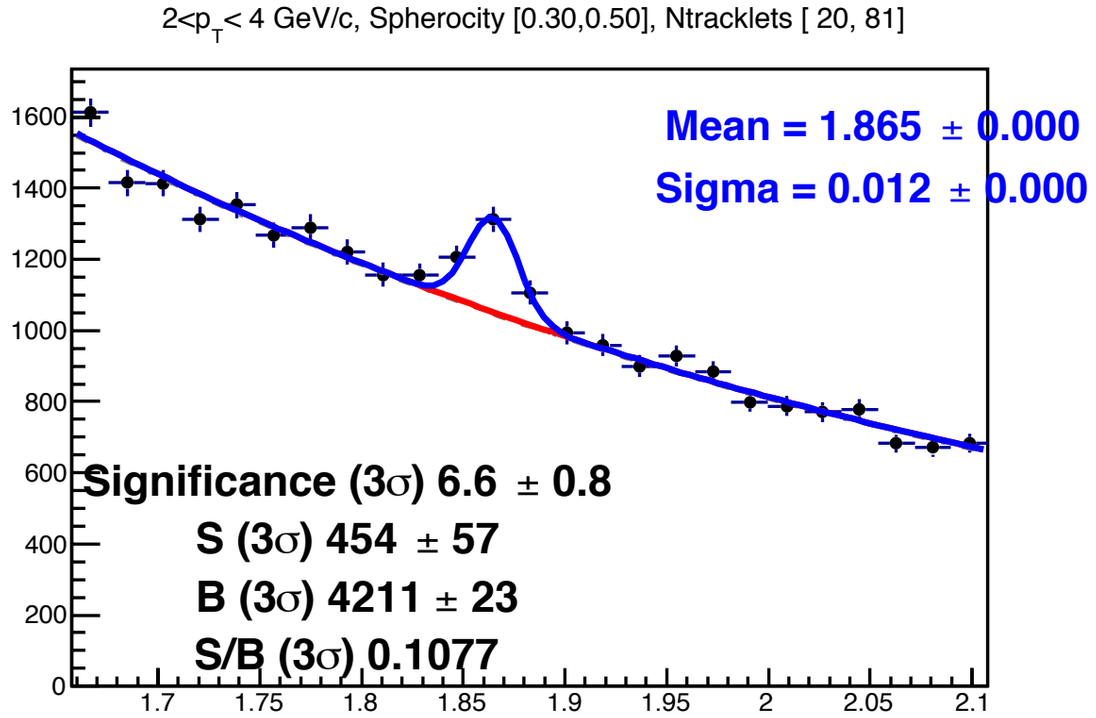

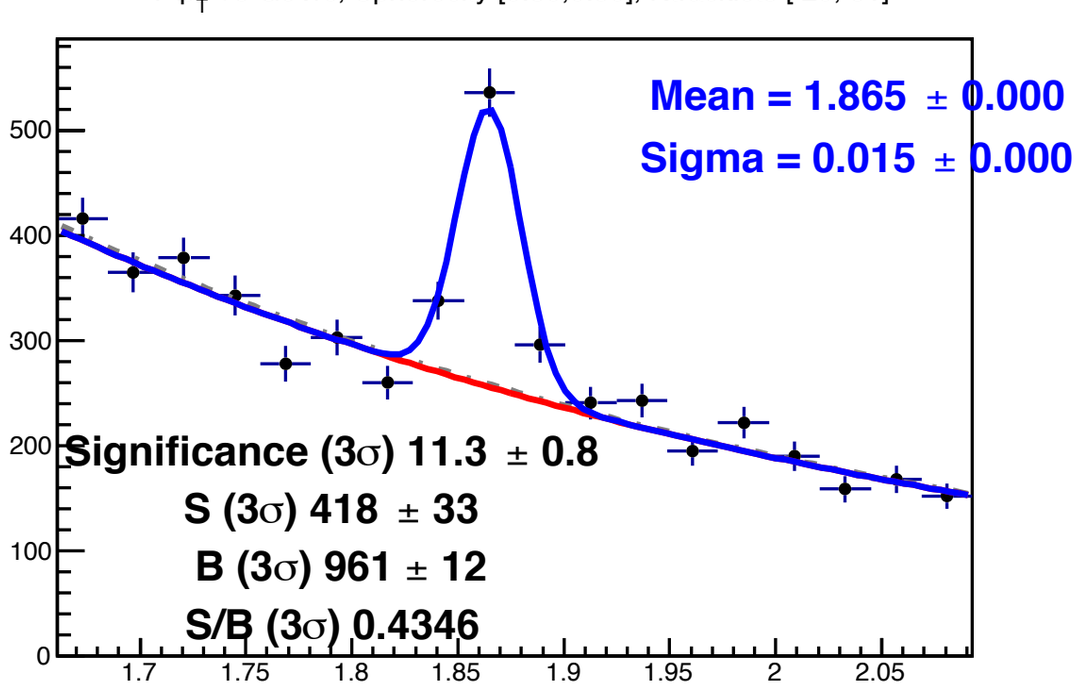

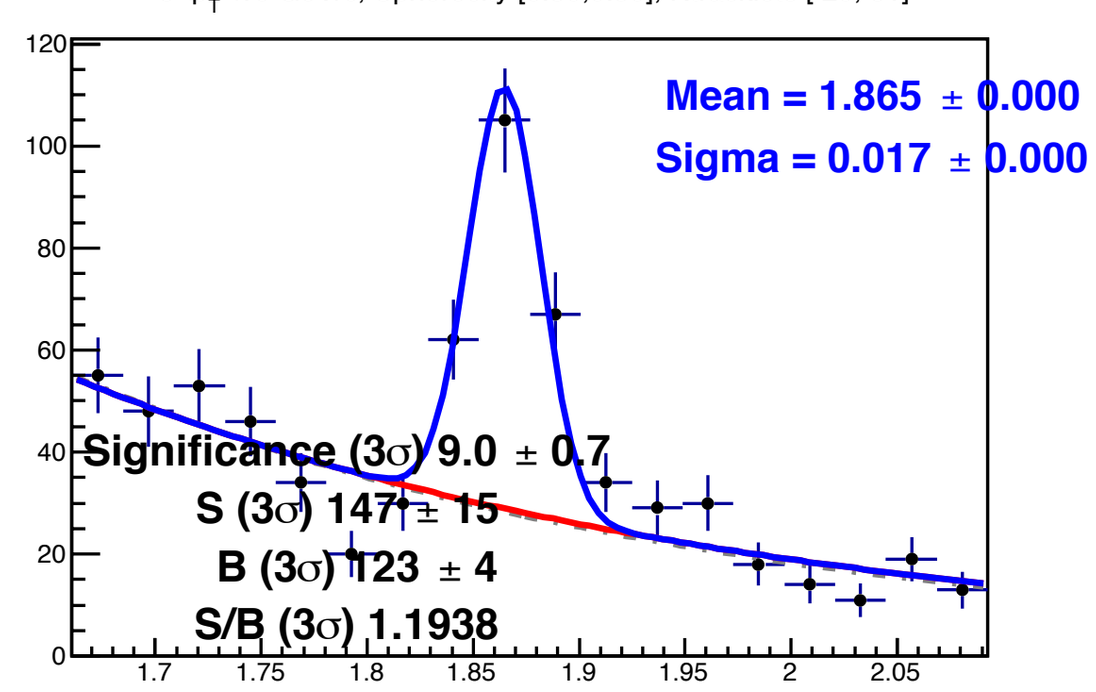

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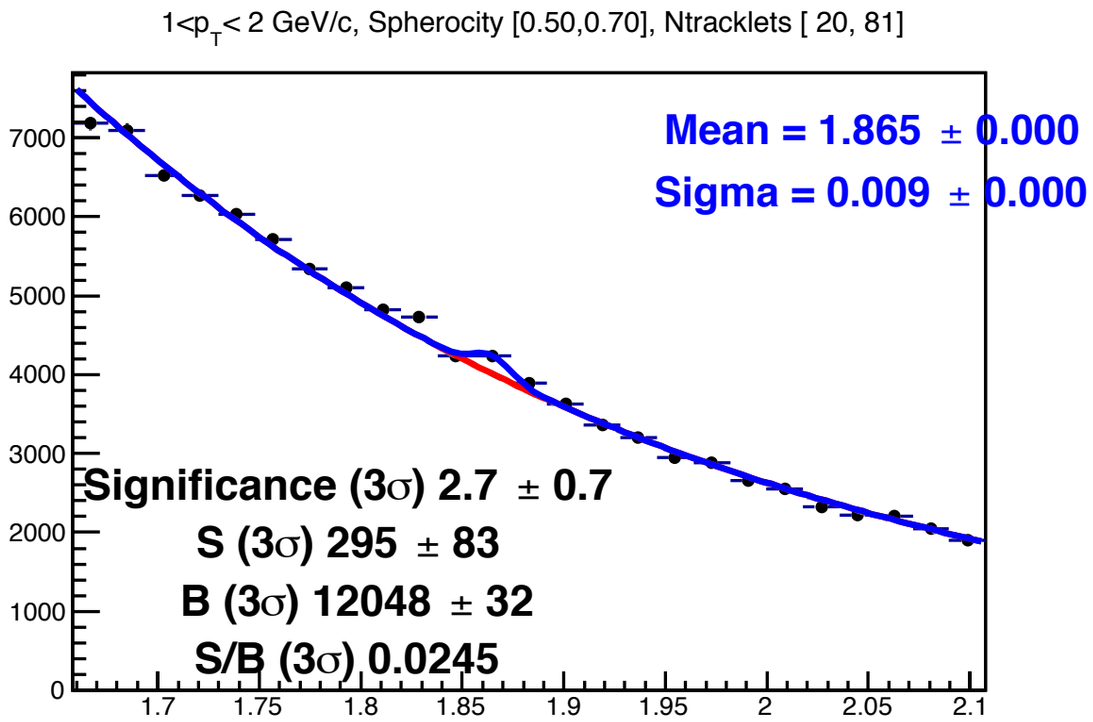

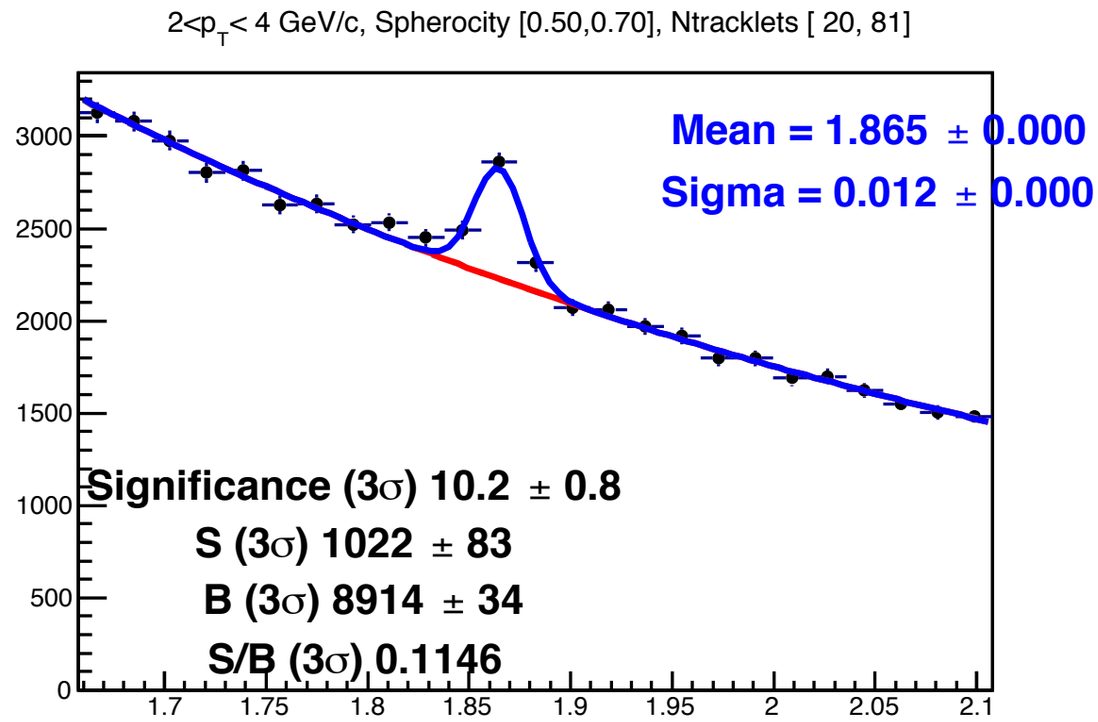

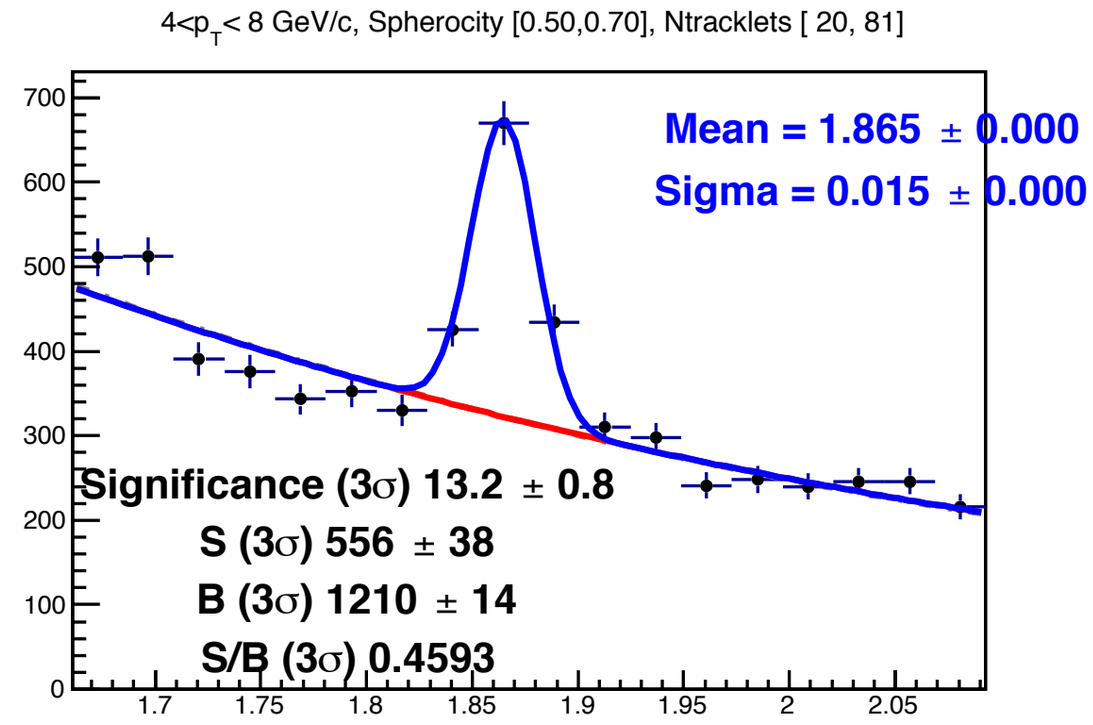

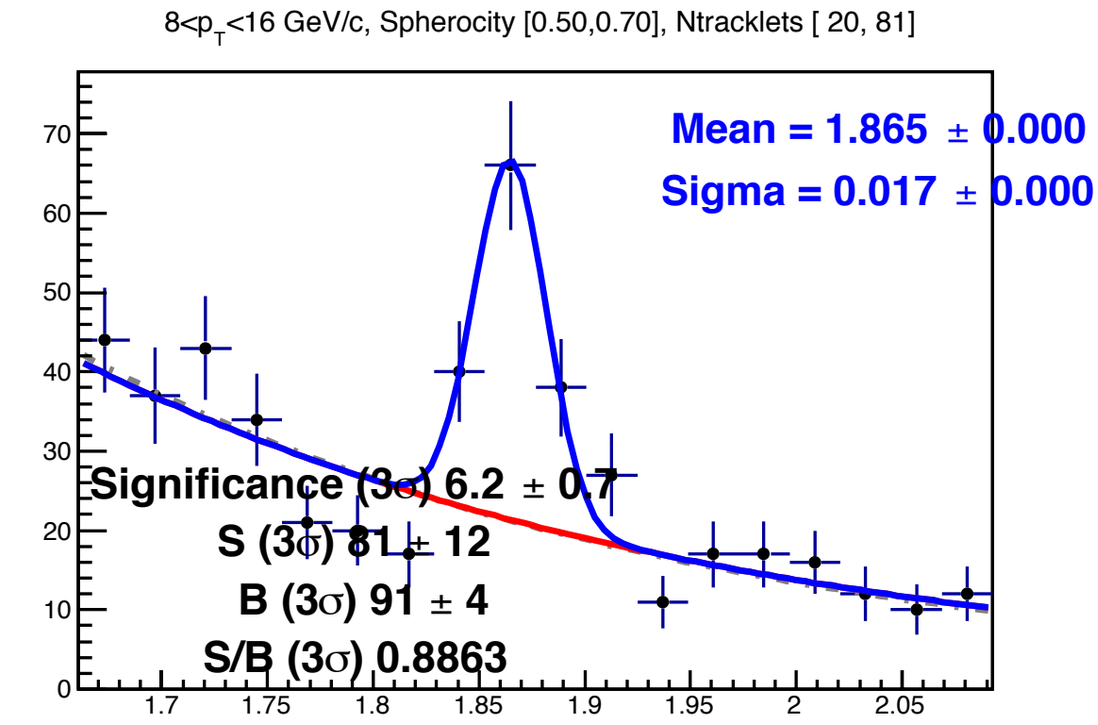

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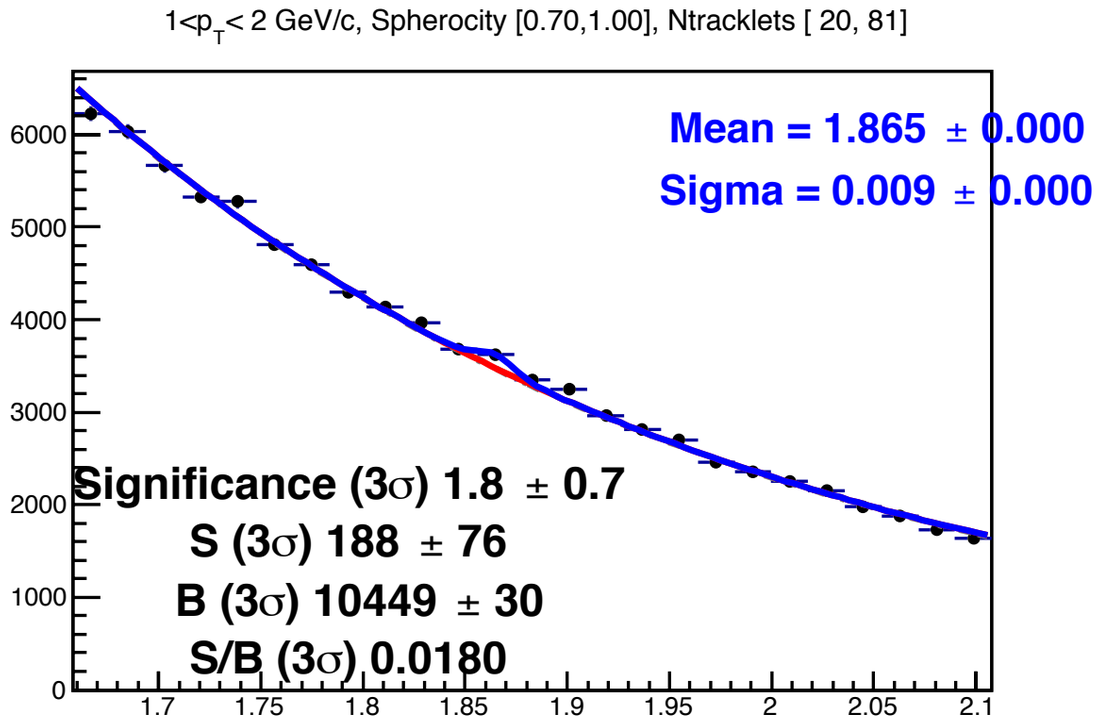

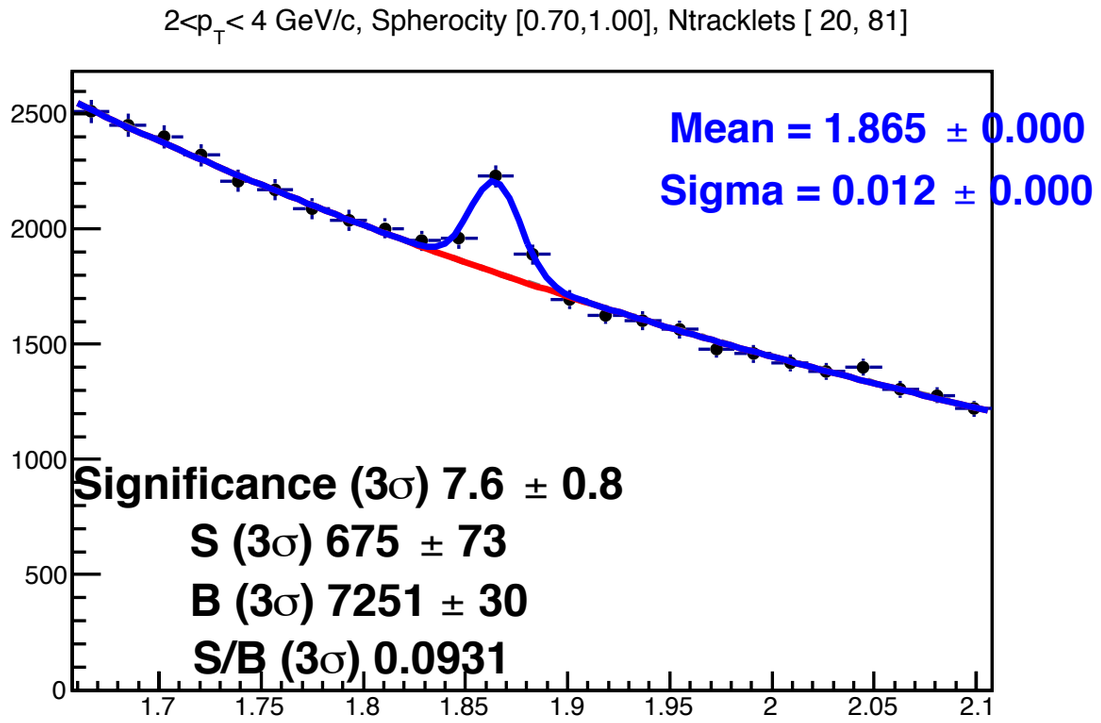

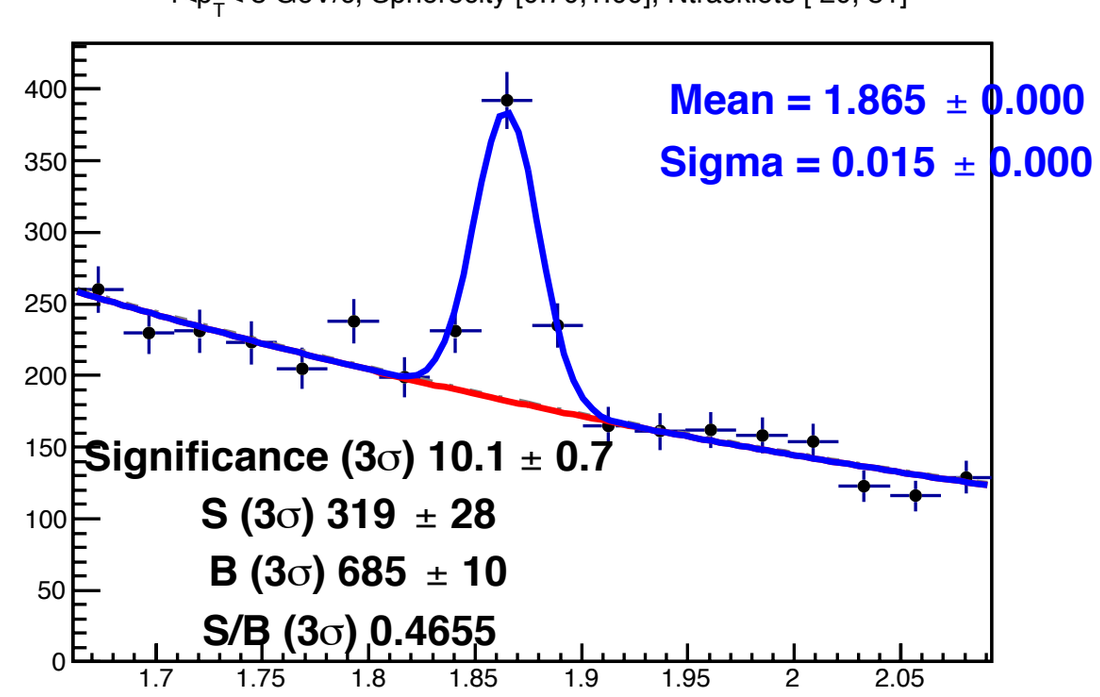

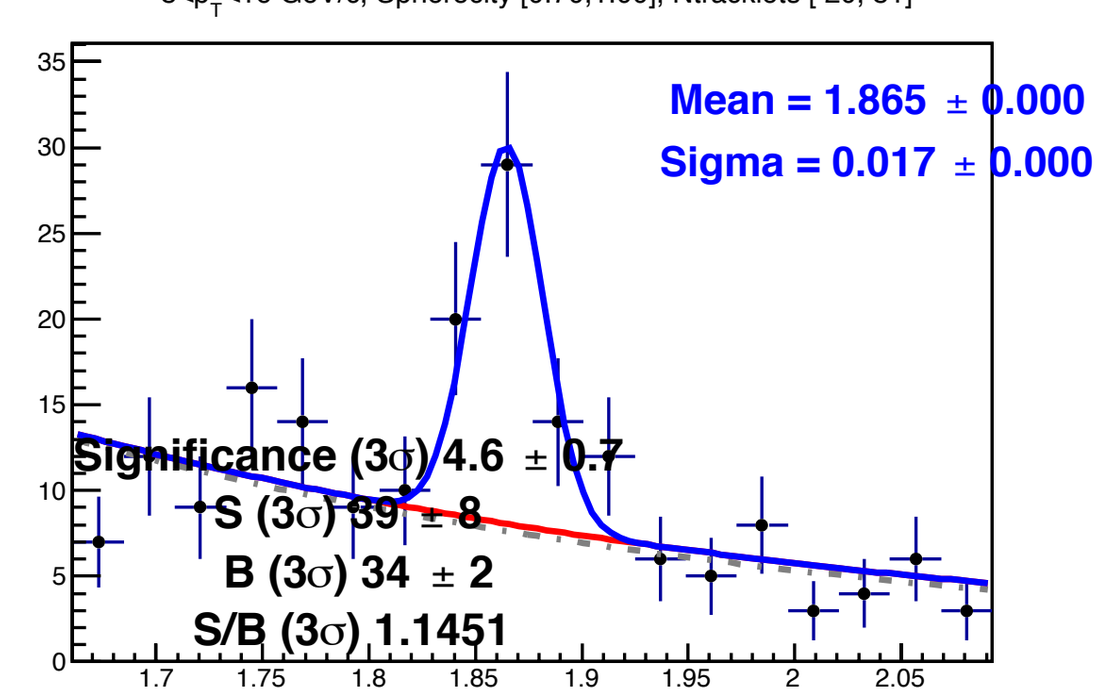

ALICE Detector