Investigating the Underlying Event with Heavy Quarks

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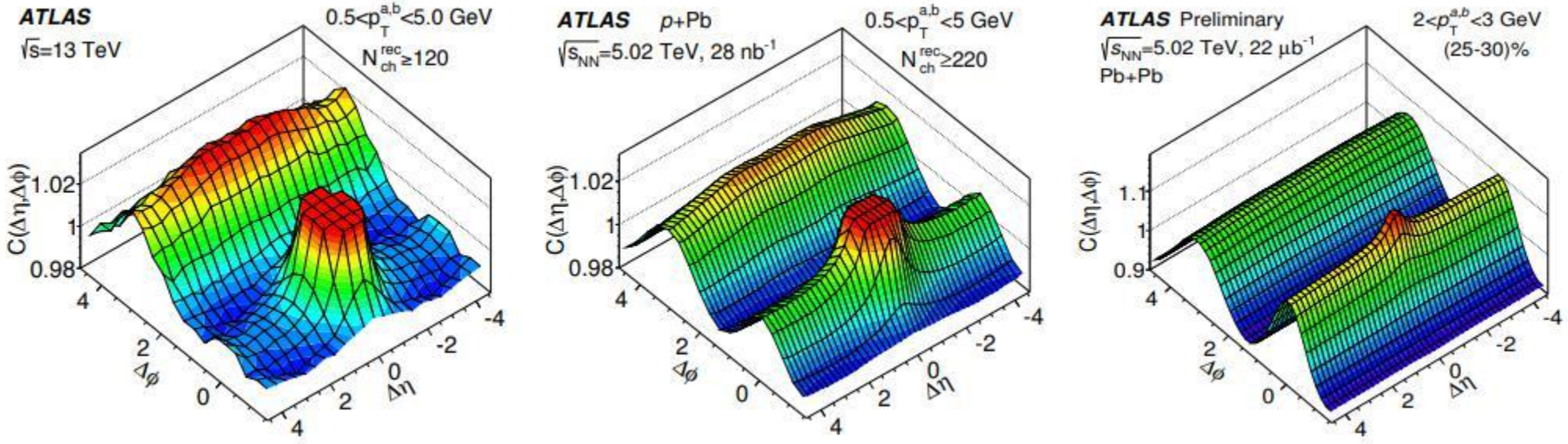
Motivation: collectivity in high-multiplicity pp collisions

Collective phenomena arise in heavy ion collisions at the LHC

This is due to the Quark-Gluon Plasma, which is created in the primary vertex

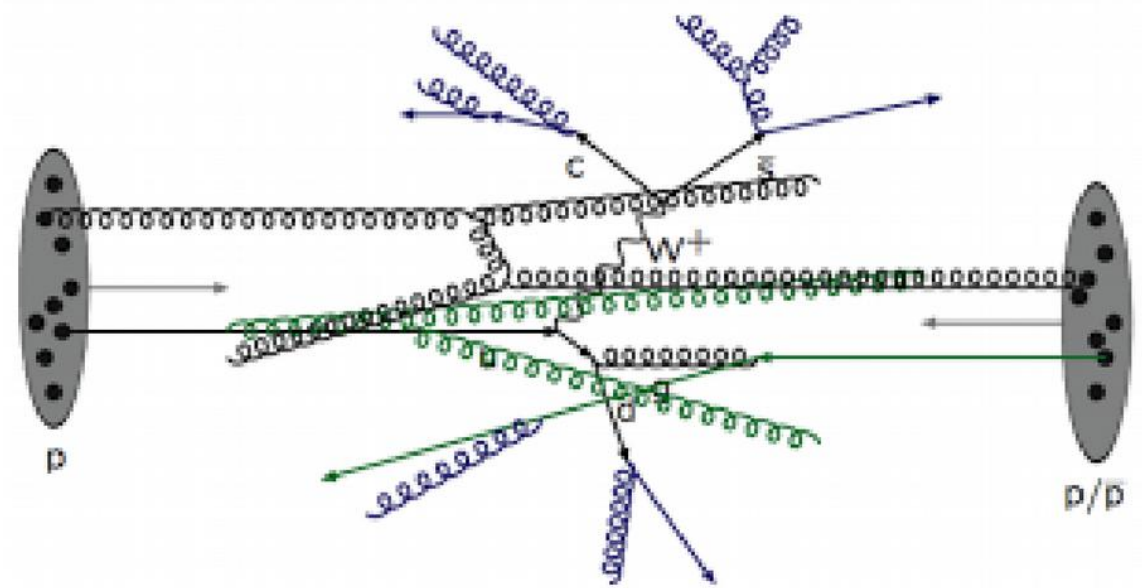


Motivation: collectivity in high-multiplicity pp collisions

The collective-like behaviour is also observed in small systems with high final-state multiplicity

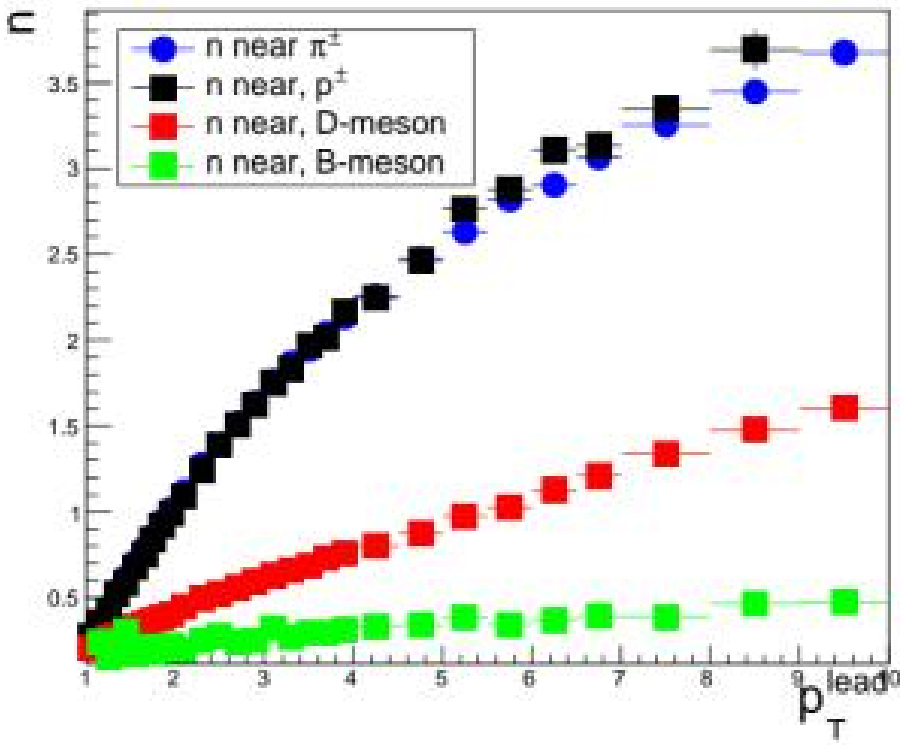
QGP is very unlikely to be created in substantial volume in these collisions. What can be the other explanation?

Vacuum-QCD semihard and soft processes such as MPI may create multi-particle long-range correlations. This will mostly show up in the Underlying event

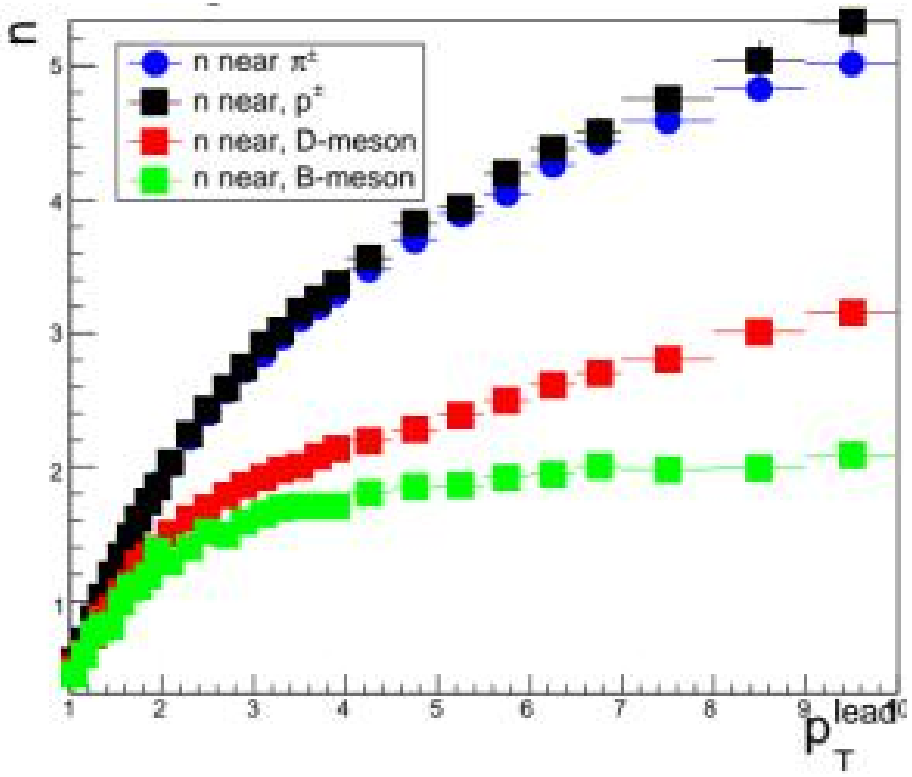


Motivation: collectivity in high-multiplicity pp collisions

MPI off



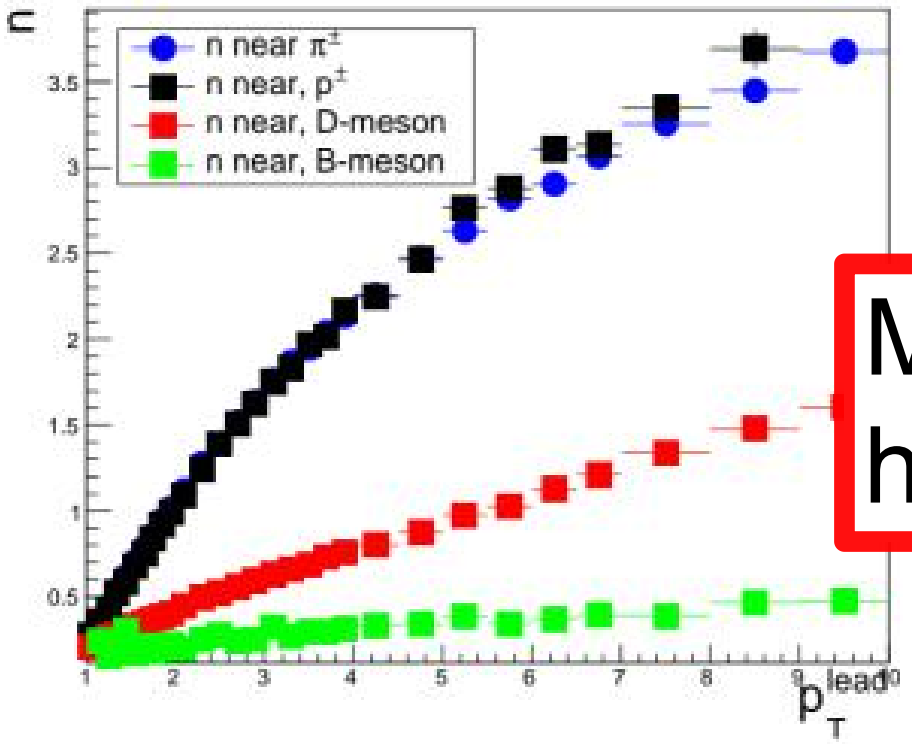
MPI on



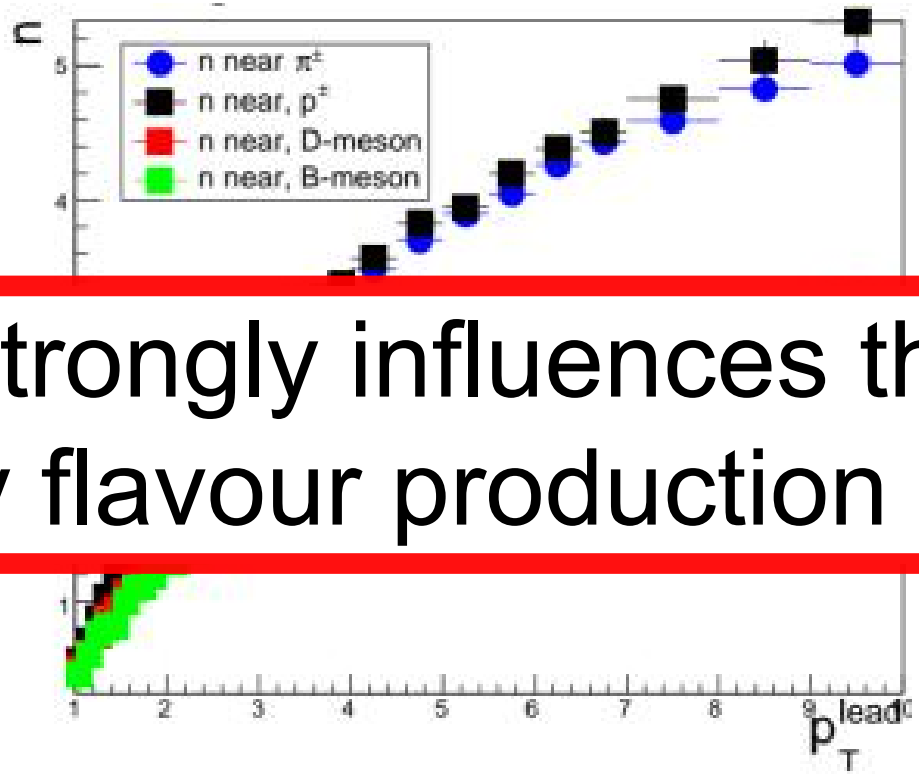
MC simulations by A. Misak [https://indi.to/nSCNc]

Motivation: collectivity in high-multiplicity pp collisions

MPI off



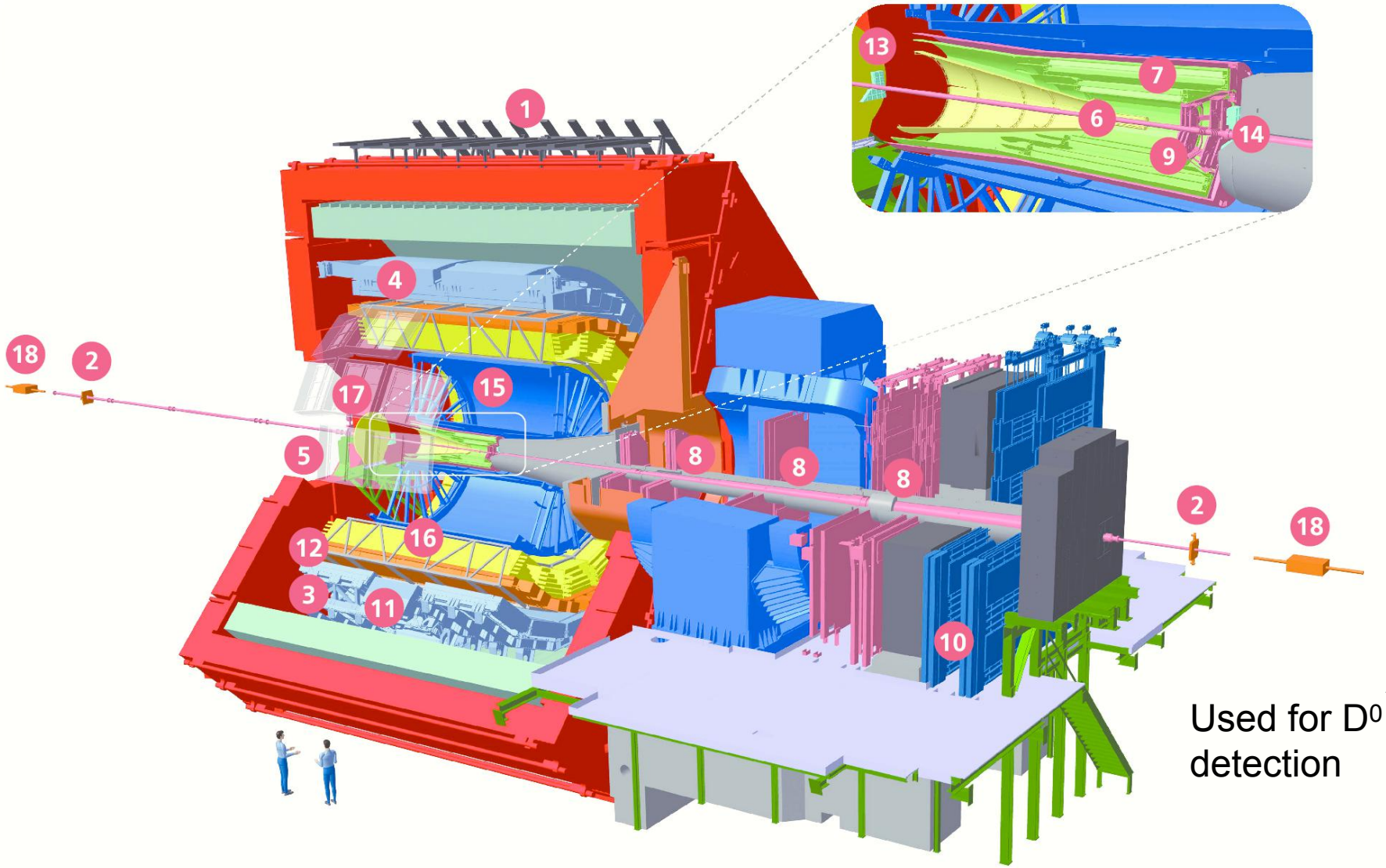
MPI on



MPI strongly influences the heavy flavour production

MC simulations by A. Misak [https://indi.to/nSCNc]

LHC ALICE Experiment

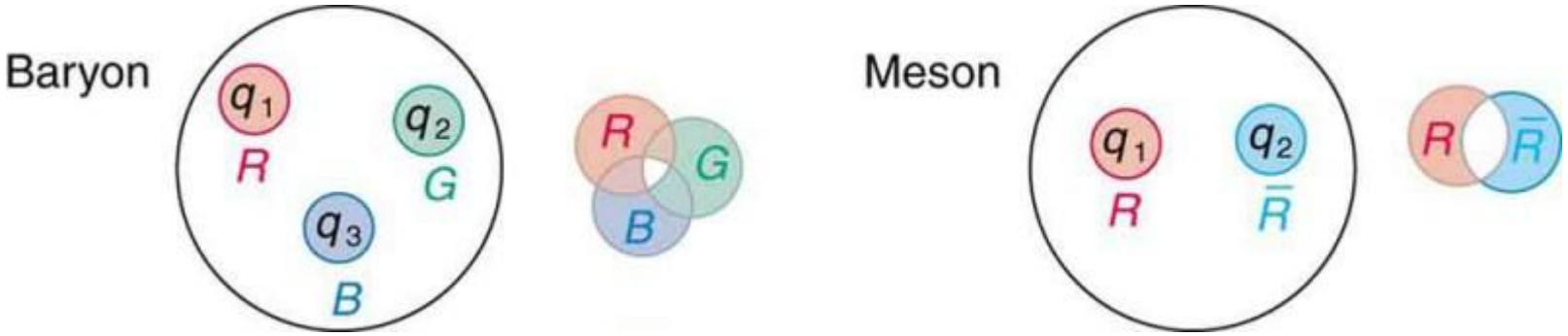


Used for D^0 detection

1. **ACORDE** | ALICE Cosmic Rays Detector
2. **AD** | ALICE Diffractive Detector
3. **DCal** | Di-jet Calorimeter
4. **EMCal** | Electromagnetic Calorimeter
5. **HMPID** | High Momentum Particle Identification Detector
6. **ITS-IB** | Inner Tracking System - Inner Barrel
7. **ITS-OB** | Inner Tracking System - Outer Barrel
8. **MCH** | Muon Tracking Chambers
9. **MFT** | Muon Forward Tracker
10. **MID** | Muon Identifier
11. **PHOS / CPV** | Photon Spectrometer
12. **TOF** | Time Of Flight
13. **T0+A** | Tzero + A
14. **T0+C** | Tzero + C
15. **TPC** | Time Projection Chamber
16. **TRD** | Transition Radiation Detector
17. **V0+** | Vzero + Detector
18. **ZDC** | Zero Degree Calorimeter

Introduction to D mesons

- Hadrons are heavy particles made up of 3 quarks (baryons) or quark-antiquark pair (mesons)



- D mesons are made of charm quark + one of the light u,d or s quarks
- Highly unstable: mean lifetime 4..10*10^{-13} s -> mean path ~ 100 microns
- D mesons don’t reach the detectors!

- Detection is only possible via the daughter particles

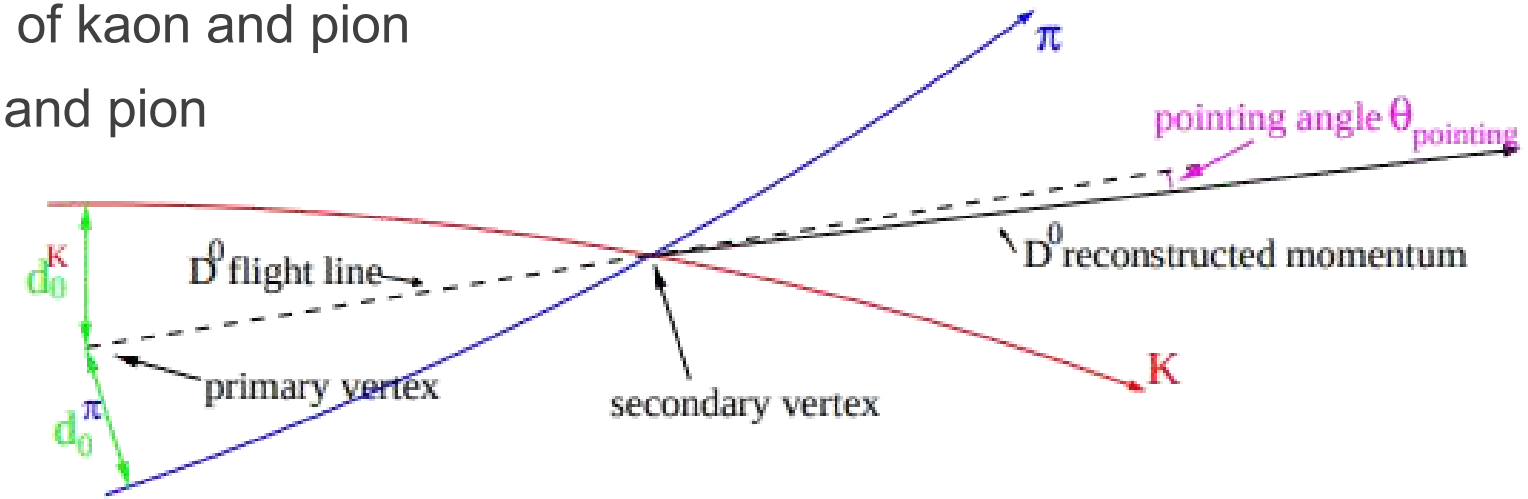
D^0 reconstruction process

$D^0 = c\bar{d}$ $\quad$ $\overline{D^0} = \bar{c}d$

$D^0 \rightarrow \pi^{\pm} + K^{\mp}$ (Branching ratio = 3.89%)

Selection parameters of daughter particles:

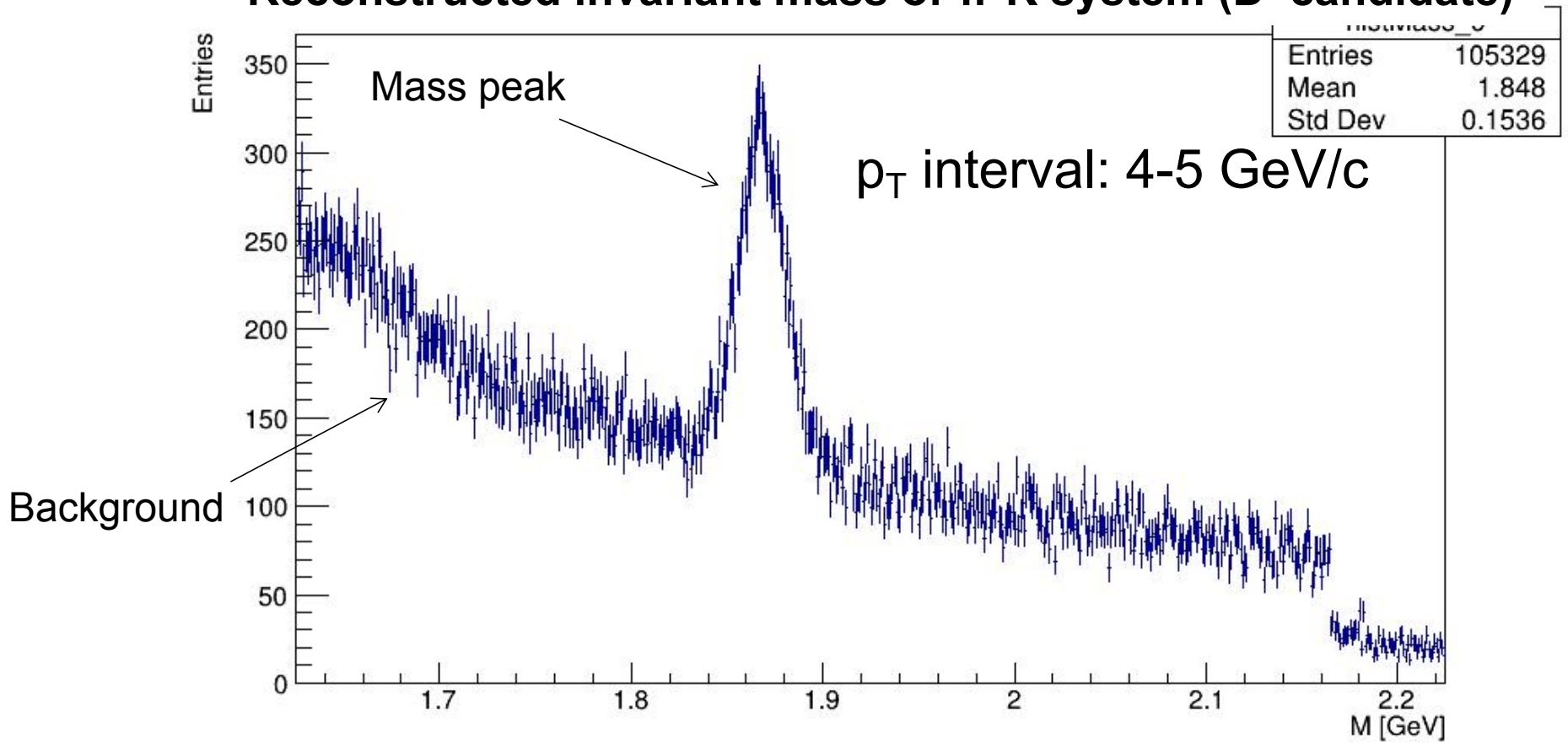
- Mass difference
- Distance of closest approach
- cos θ* (angle between the kaon flight line in the D^0 rest frame and the boost direction)
- Transverse momentum (p_T) of kaon and pion
- Impact parameters of kaon and pion
- cos θ_{point}



D⁰ invariant mass distribution

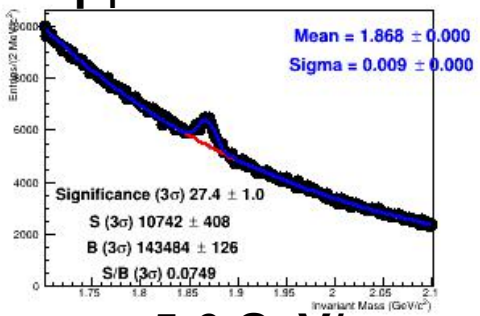
$$m_{inv} = E^2 - \vec{p}^2$$

Reconstructed invariant mass of π-K system (D⁰ candidate)

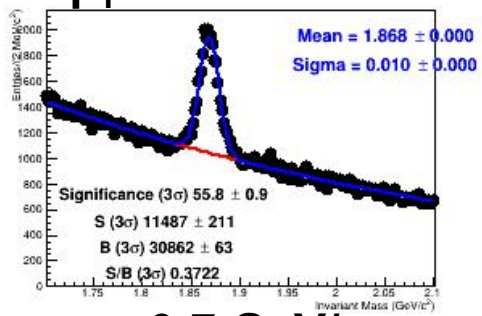


D^0 invariant mass distribution in different p_T regions

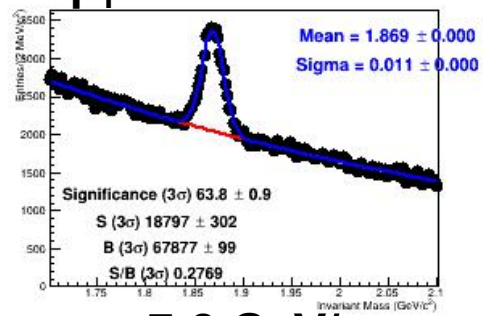
p_T: 1-2 GeV/c



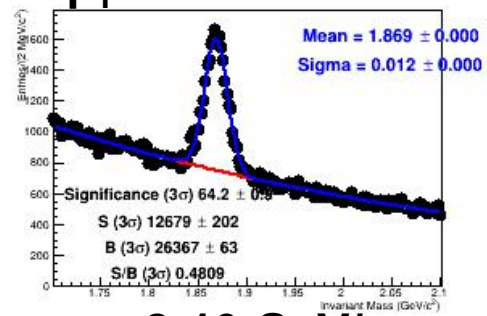
p_T: 2-3 GeV/c



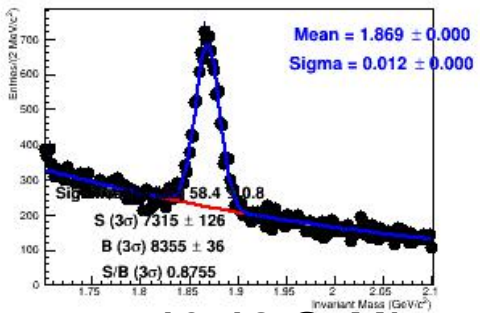
p_T: 3-4 GeV/c



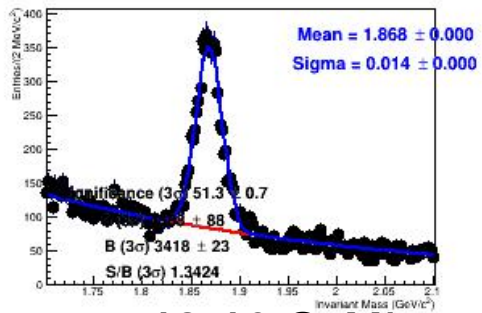
p_T: 4-5 GeV/c



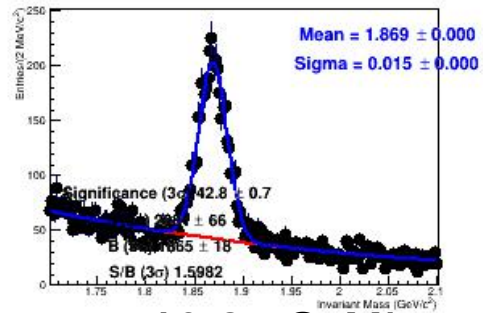
p_T: 5-6 GeV/c



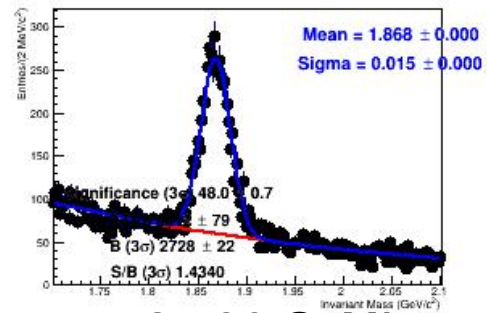
p_T: 6-7 GeV/c



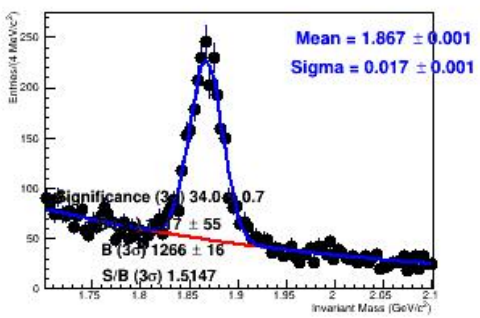
p_T: 7-8 GeV/c



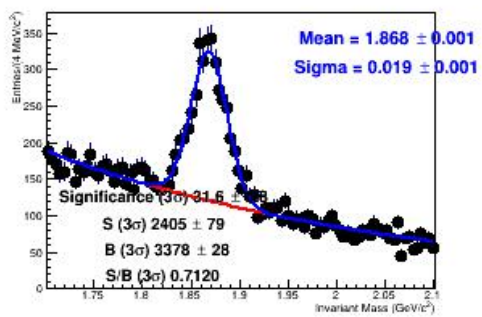
p_T: 8-10 GeV/c



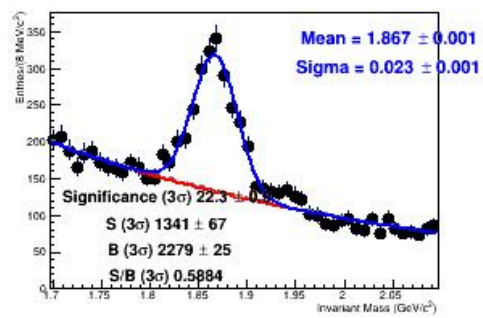
p_T: 10-12 GeV/c



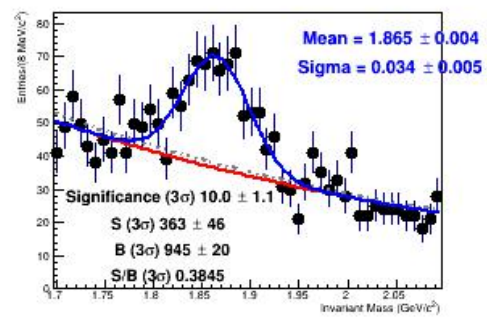
p_T: 12-16 GeV/c



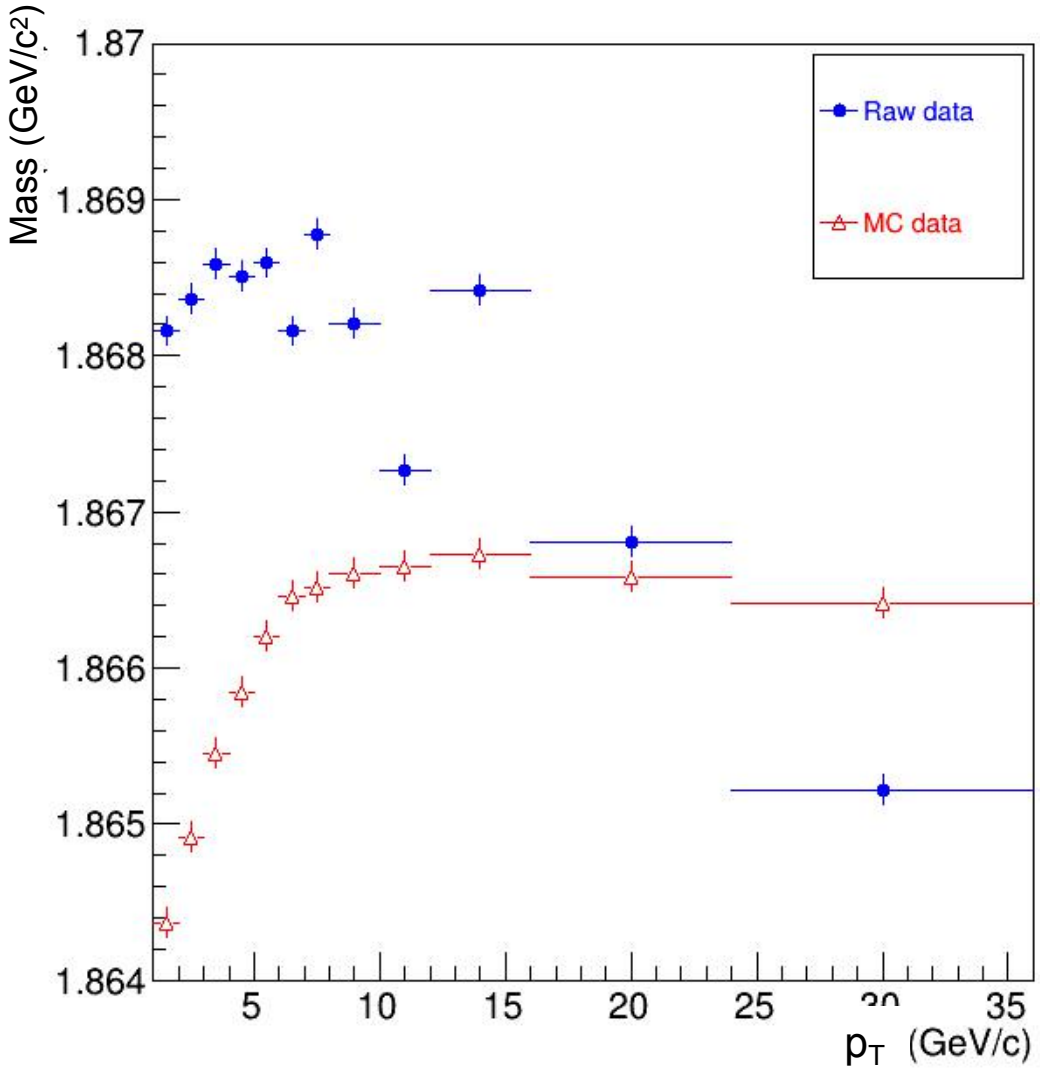
p_T: 16-24 GeV/c

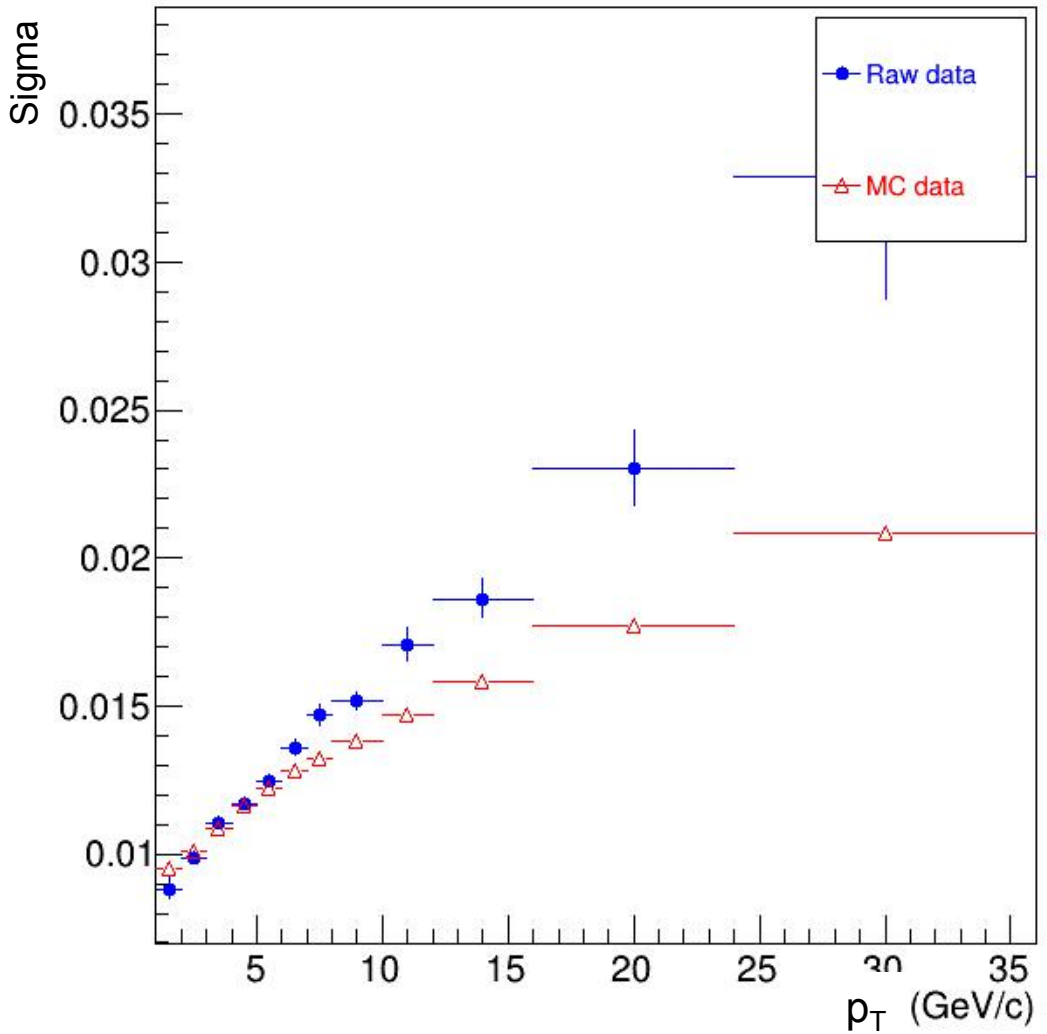


p_T: 24-36 GeV/c



D^0 invariant mass as function of transverse momenta p_T

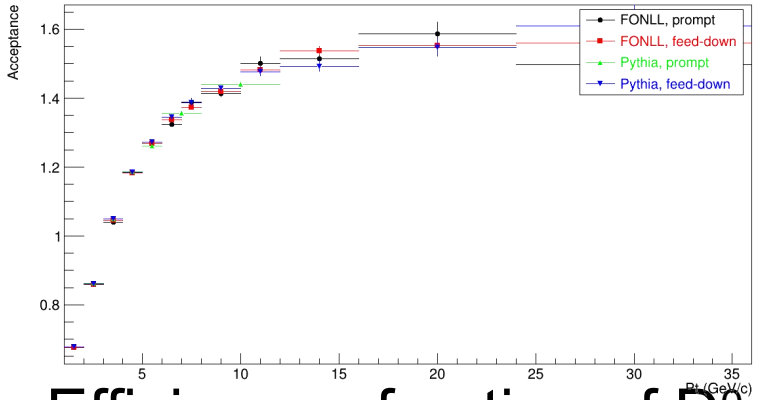




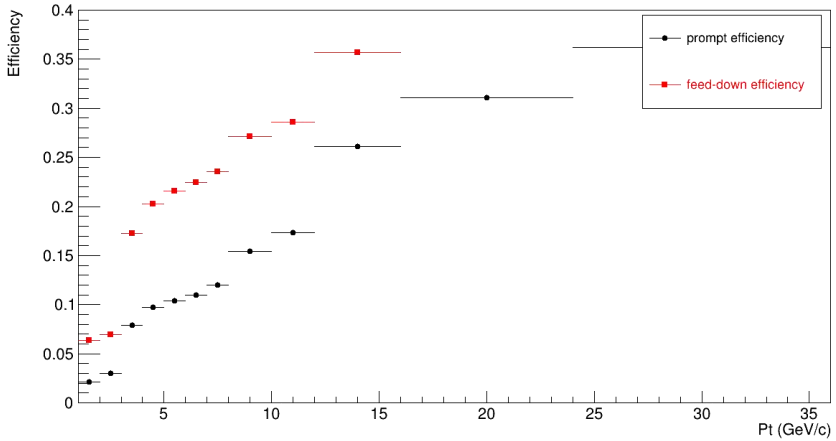
Corrections

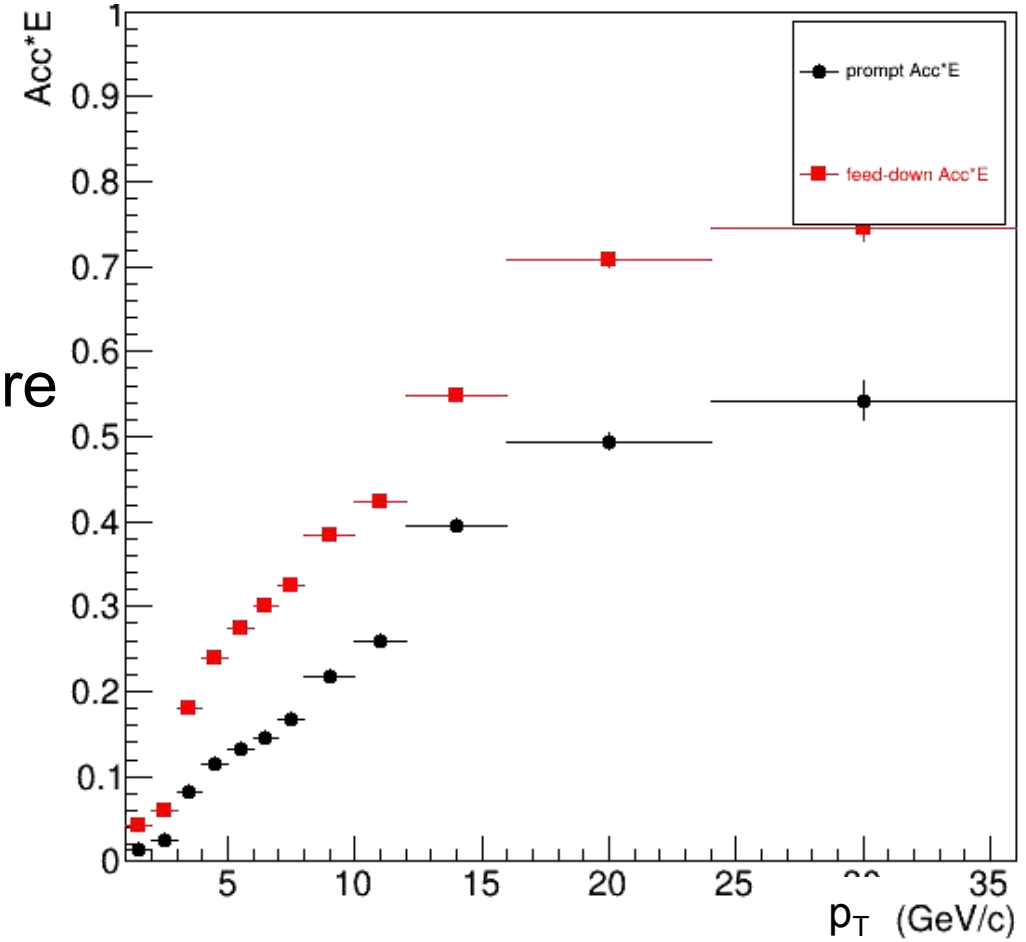
MC based:

- Acceptance - property of detectors (purely geometrical)



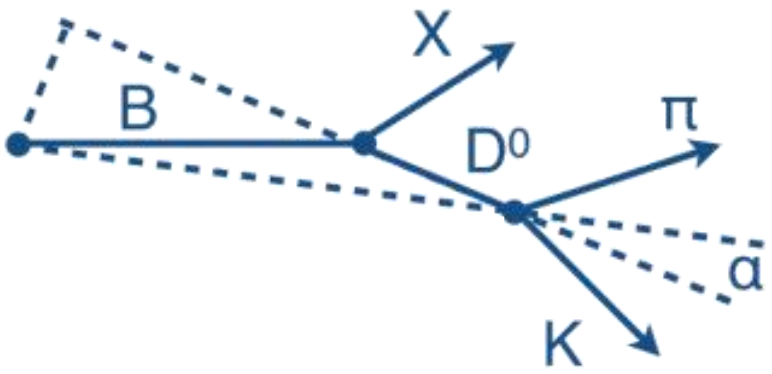
- Efficiency - fraction of D^0 mesons which are successfully reconstructed





D^0 meson cross section

Feed-down contribution - D^0 mesons which come from b quarks



Prompt D mesons - originate from c quarks

$$\left.\frac{d\sigma^{D^0}}{dp_T}\right|_{|y|<0.5} = \frac{1}{\Delta p_T}\frac{1}{BR \cdot L_{int}}\frac{f_{prompt}(p_T)\cdot \frac{1}{2}N^{D_{raw}}(p_T)\big|_{|y|<y_{fid}}}{2y_{fid}(p_T)\,(Acc\times\varepsilon)_{prompt}(p_T)}$$

Prompt D^0 meson spectra

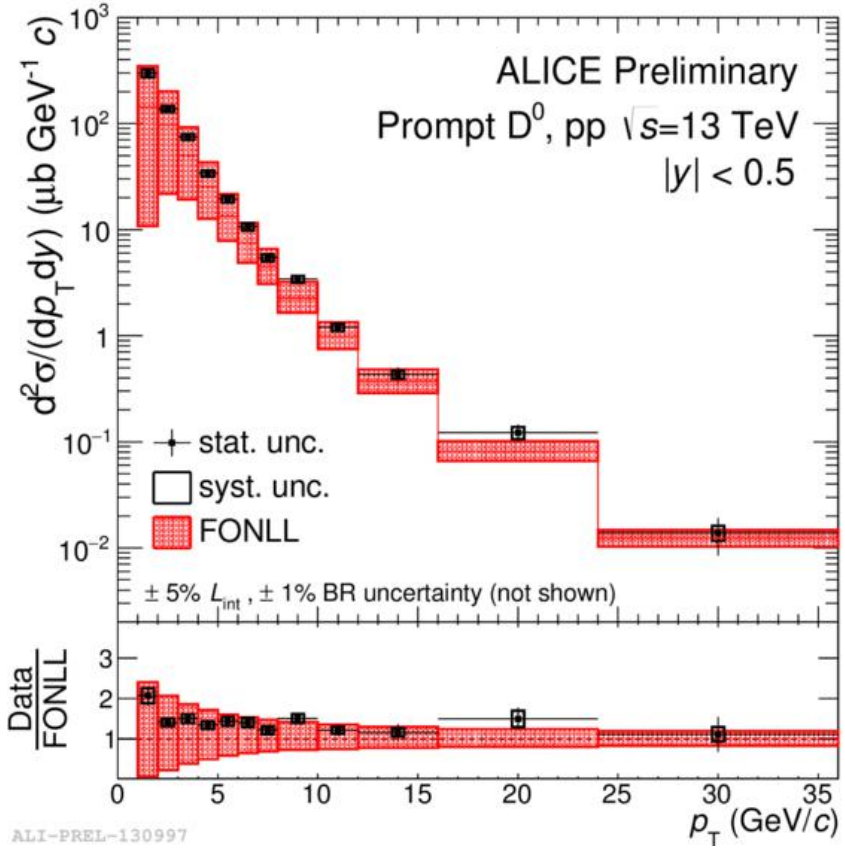


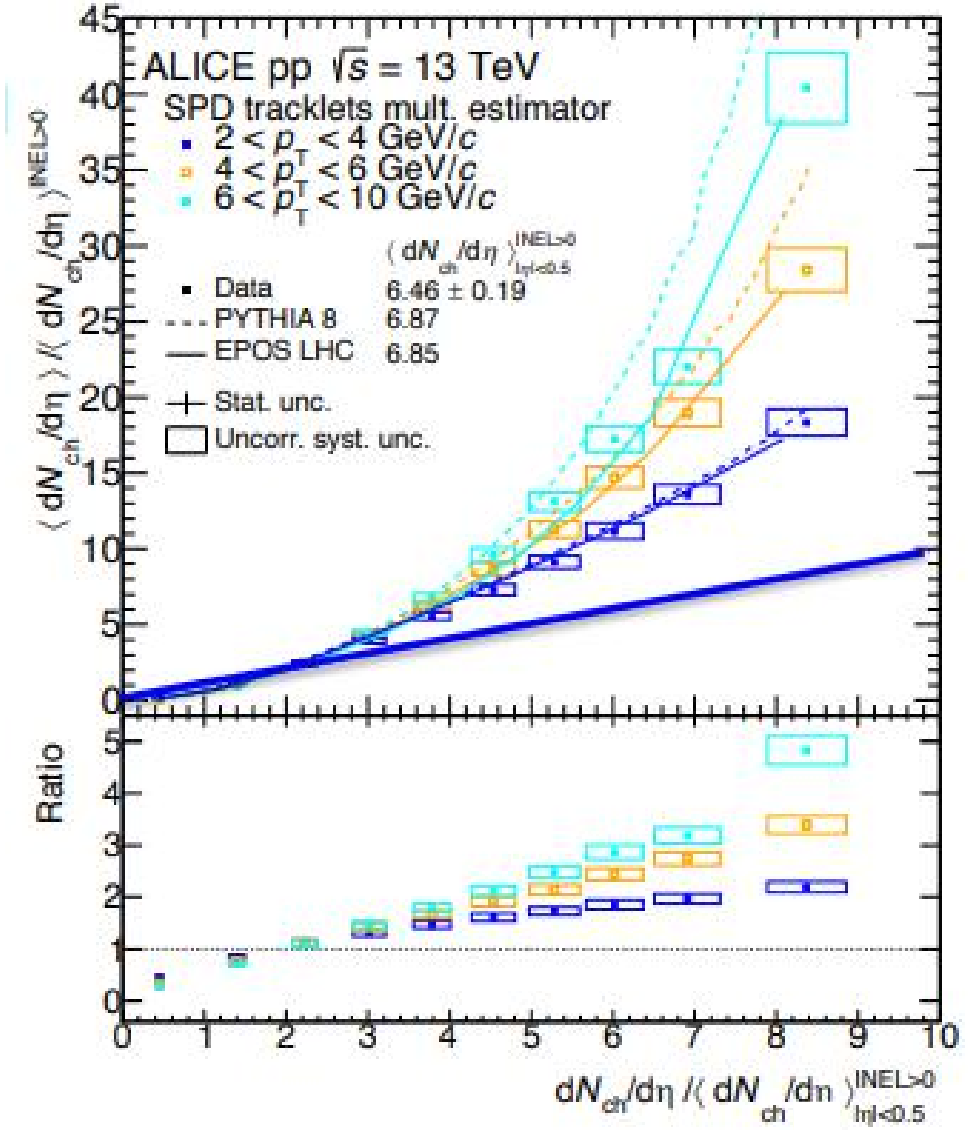
Figure by Susanna Costanza

Forward multiplicity estimator

Heavy flavor particle production increases with multiplicity STRONGER, than linearly

This may be due to the presence of jets, which bias the selection

Is there some other multiplicity estimator, which is independent of the jet production?

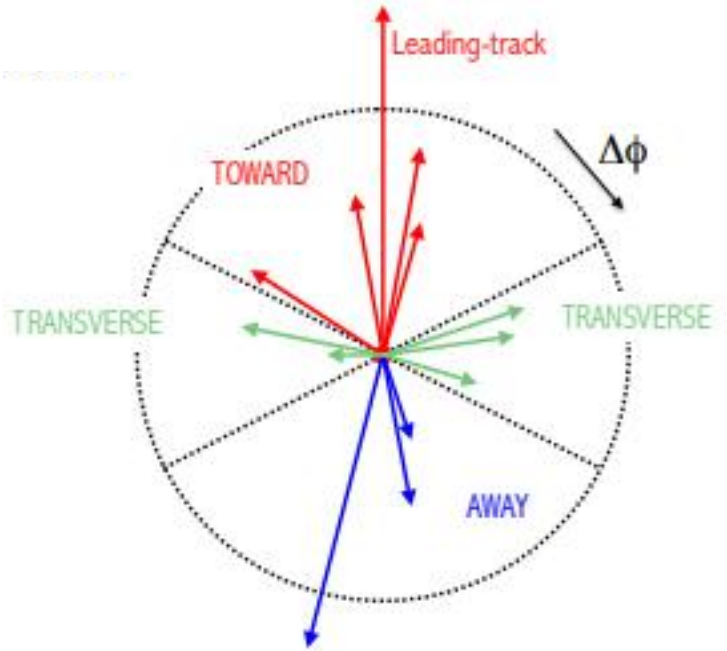


Particle production as function of multiplicity

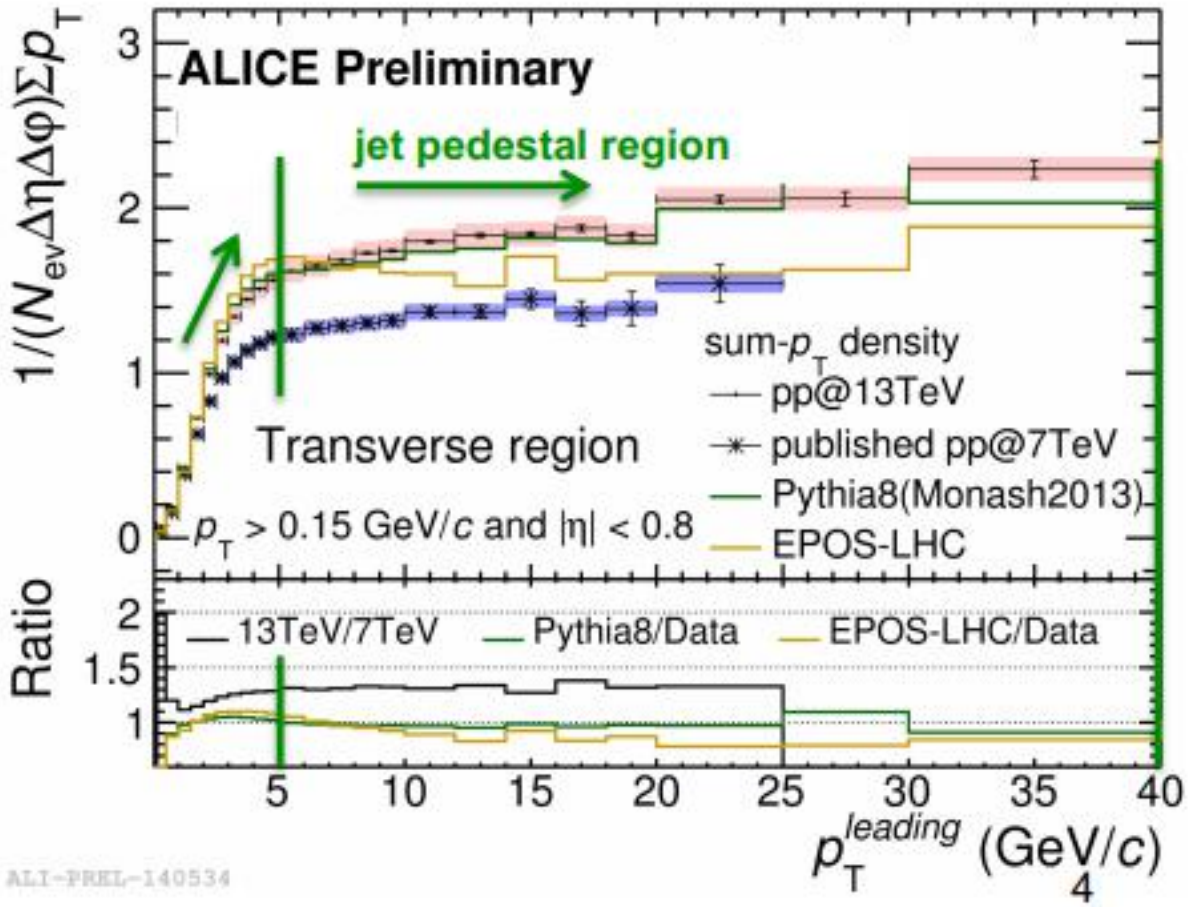
Transverse activity classifier R_T

We look for a variable that

- is not influenced by the initial hard parton scattering
- can discriminate between low and high UE activity



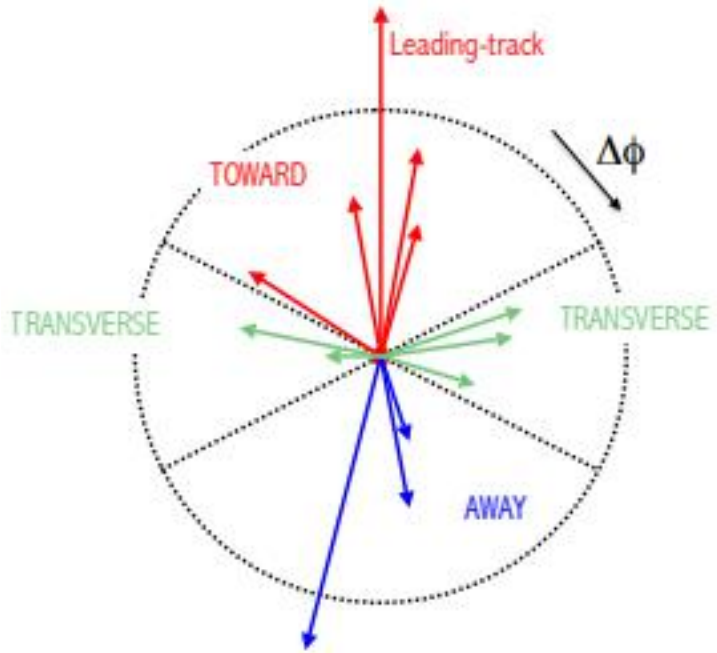
$$R_T = \frac{N_{trans}}{\langle N_{trans} \rangle}$$

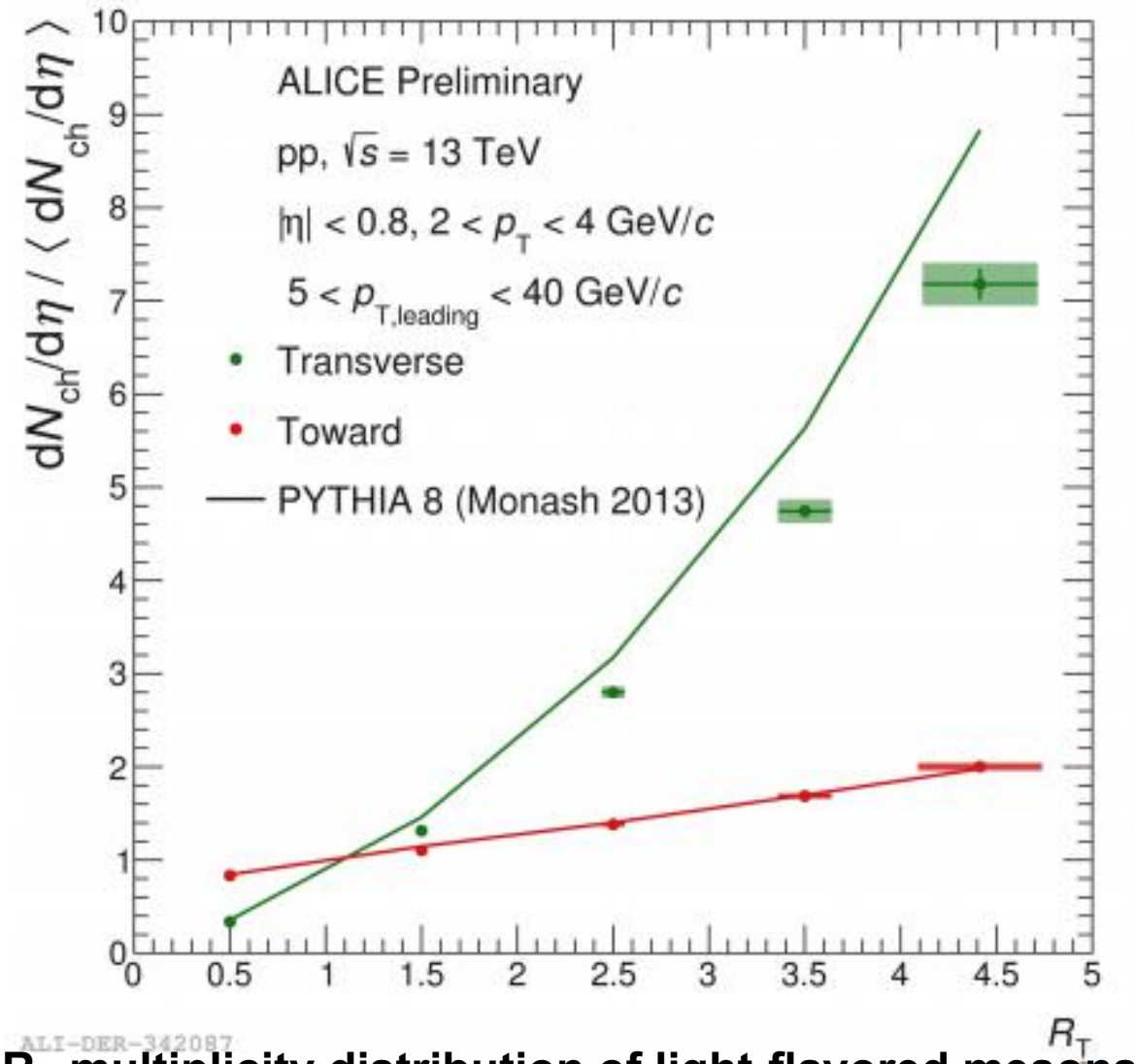


Dependence of sum-p_T density on the transverse momenta of the leading particle

Transverse activity classifier R_T

$$R_T = \frac{N_{trans}}{\langle N_{trans} \rangle}$$

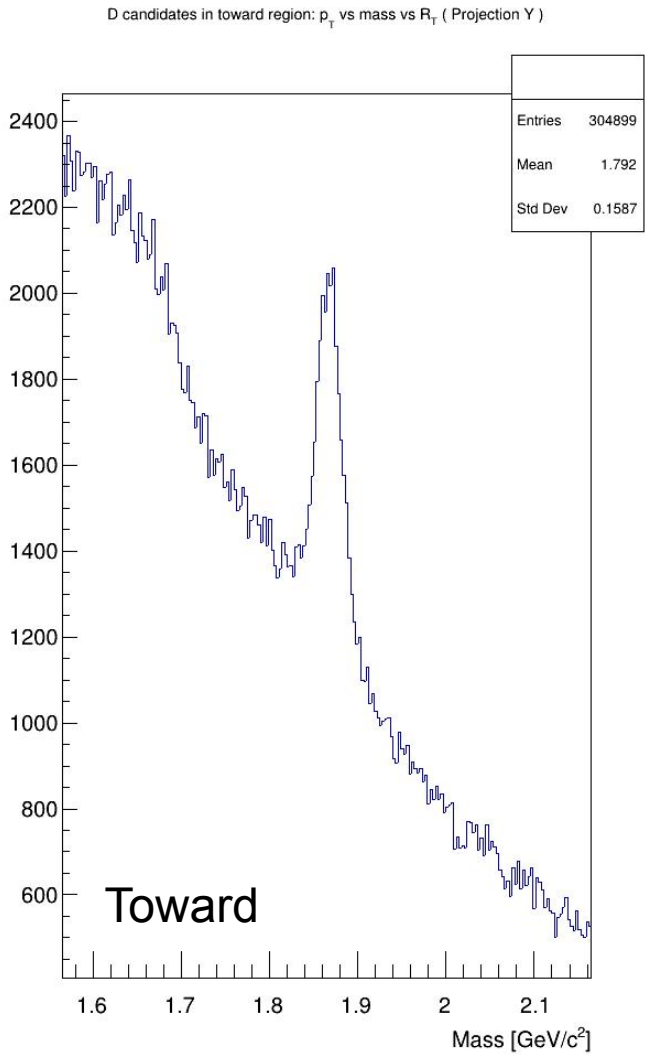


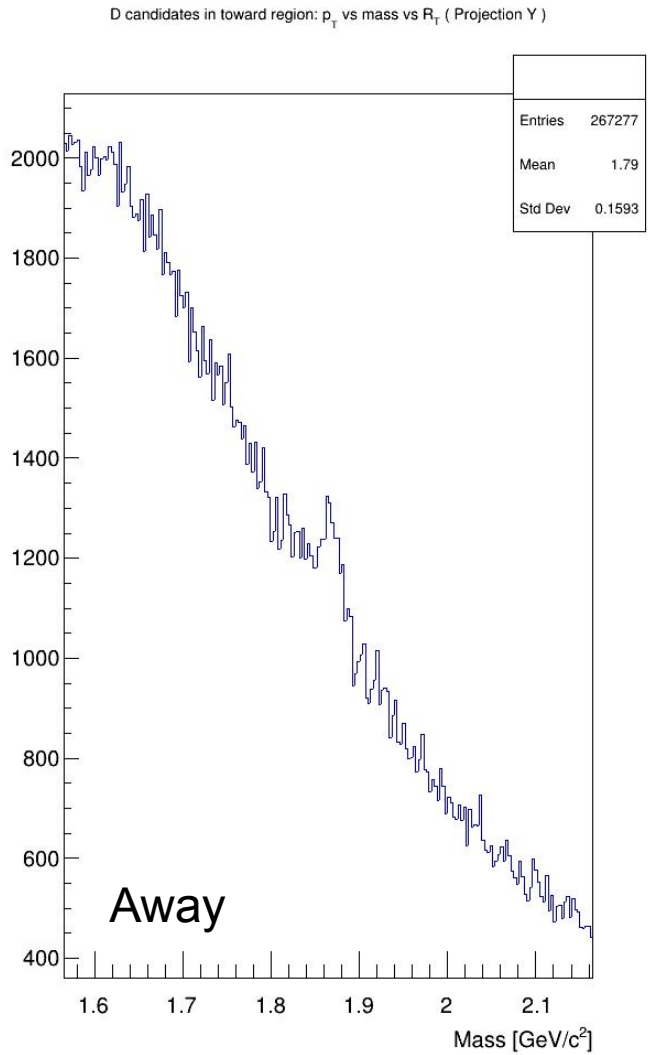


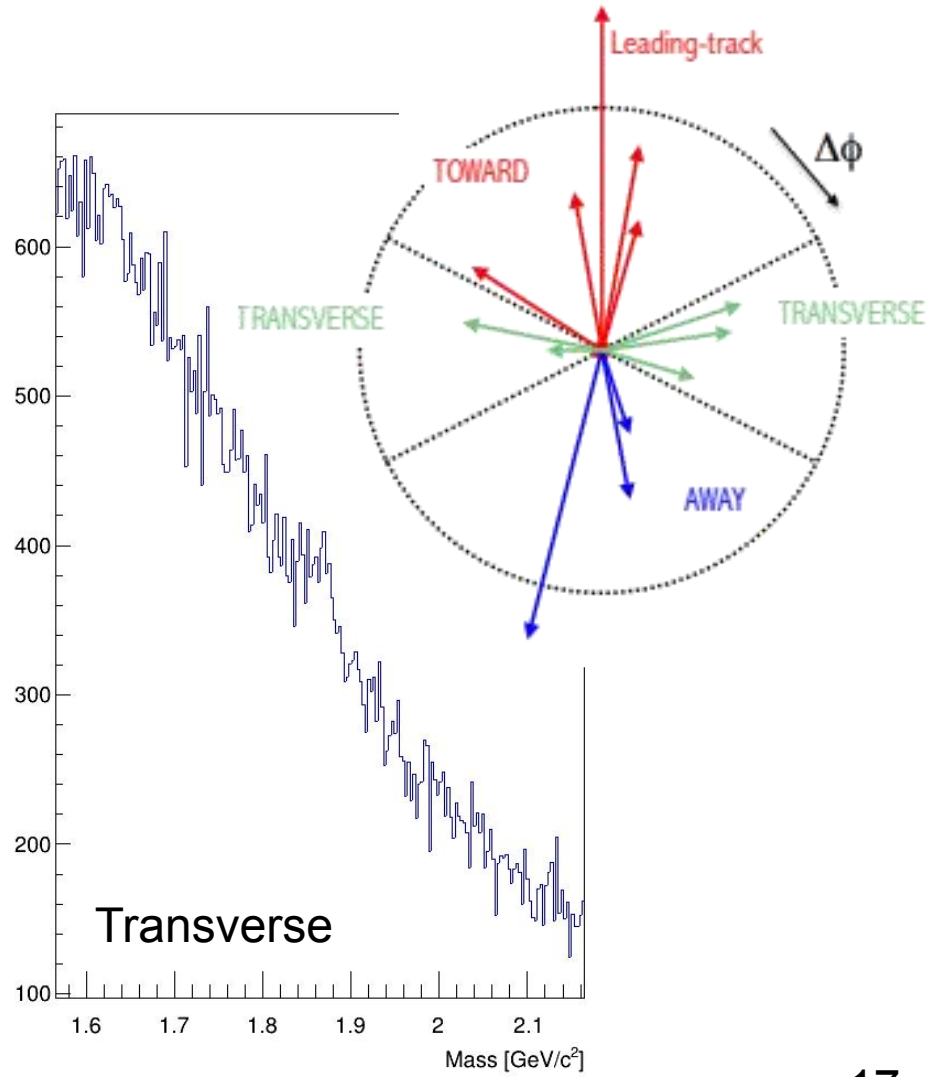
R_T is relatively independent of hard particle production (e.g. D production)

R_T-multiplicity distribution of light-flavored mesons

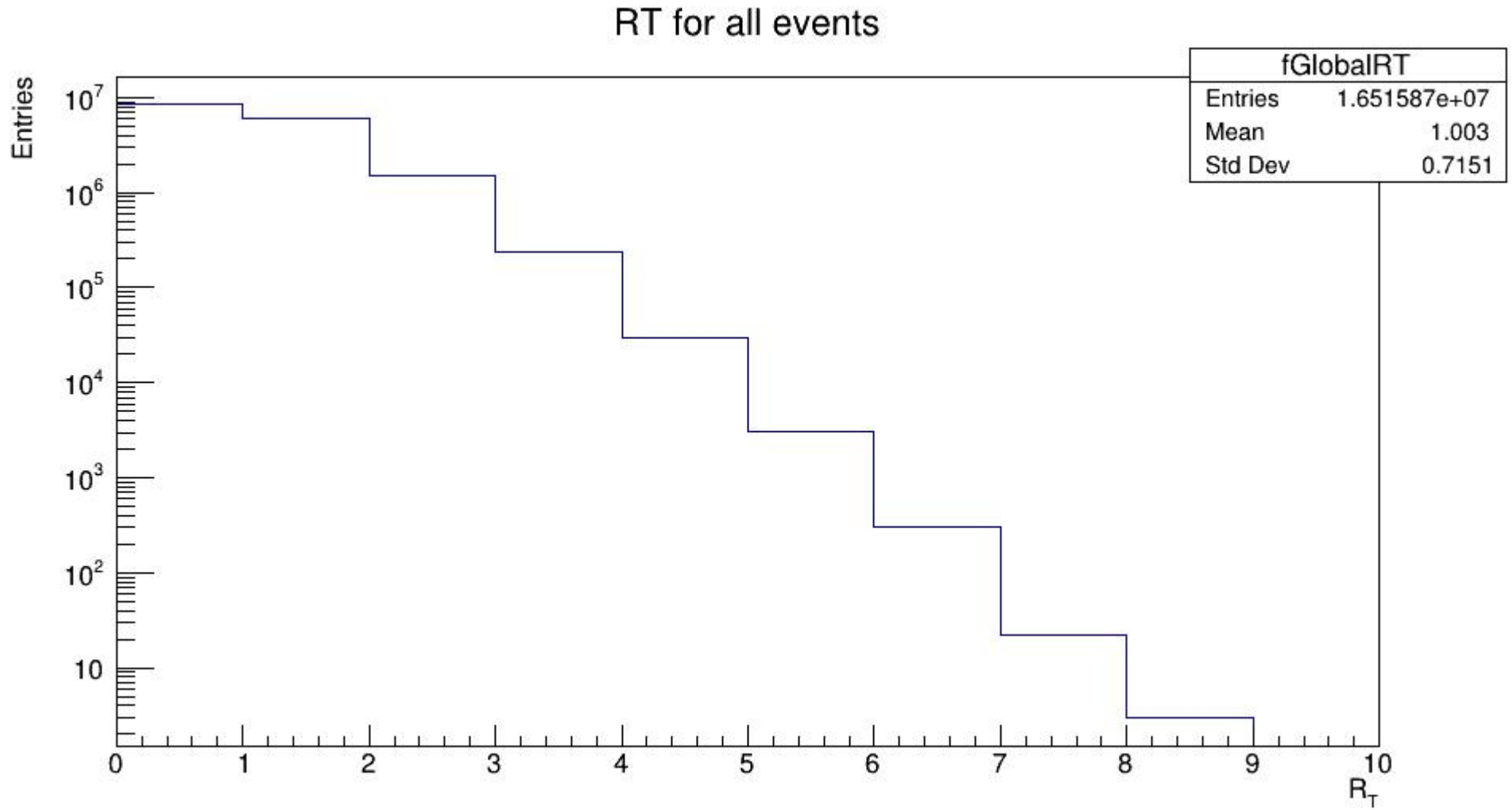
Invariant mass distribution in different regions





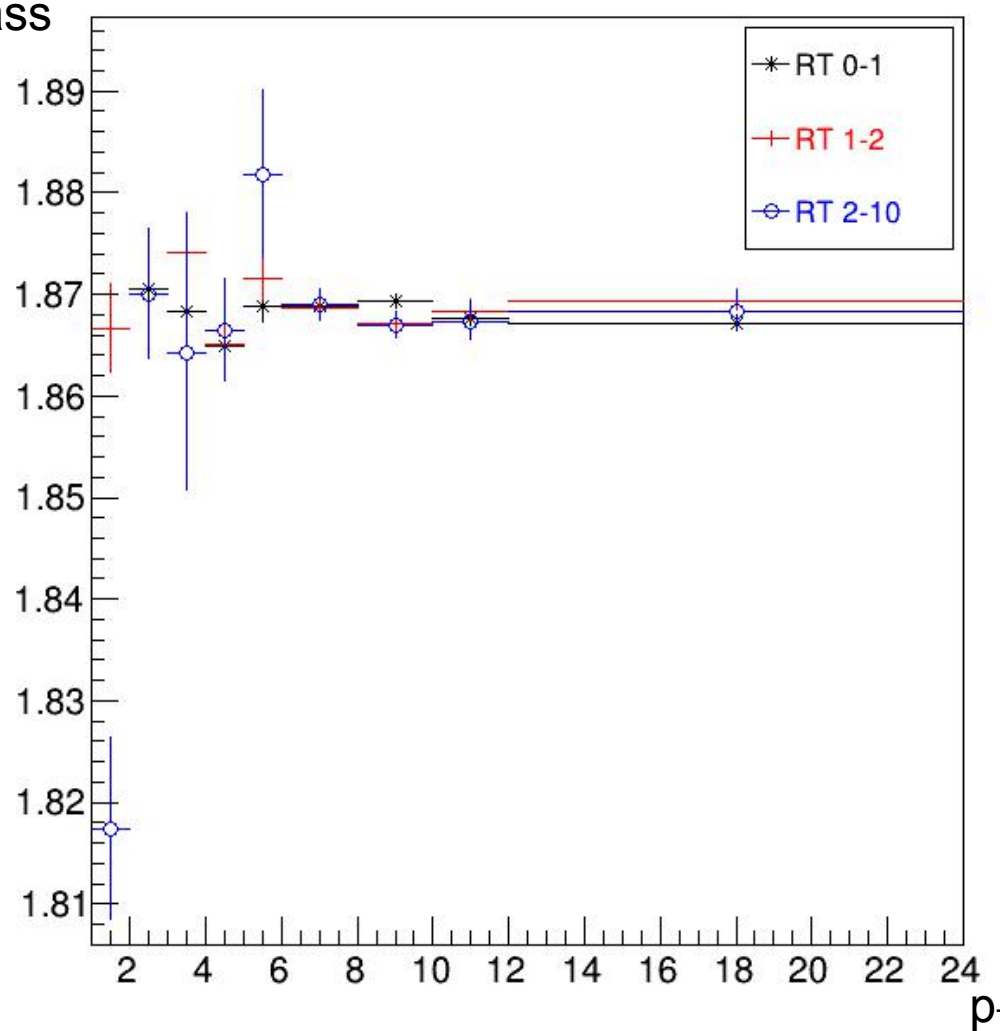


Particles distribution in R_T bins

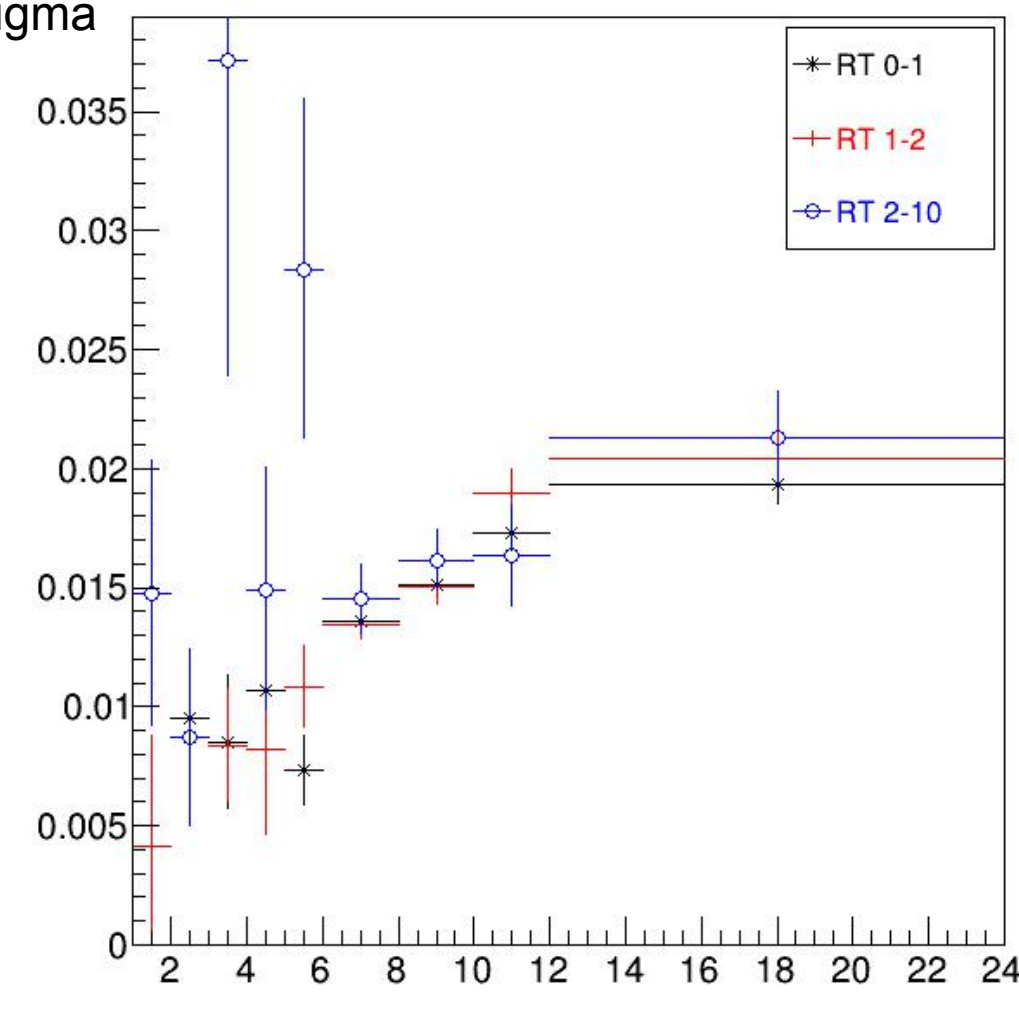


Invariant mass in Toward region

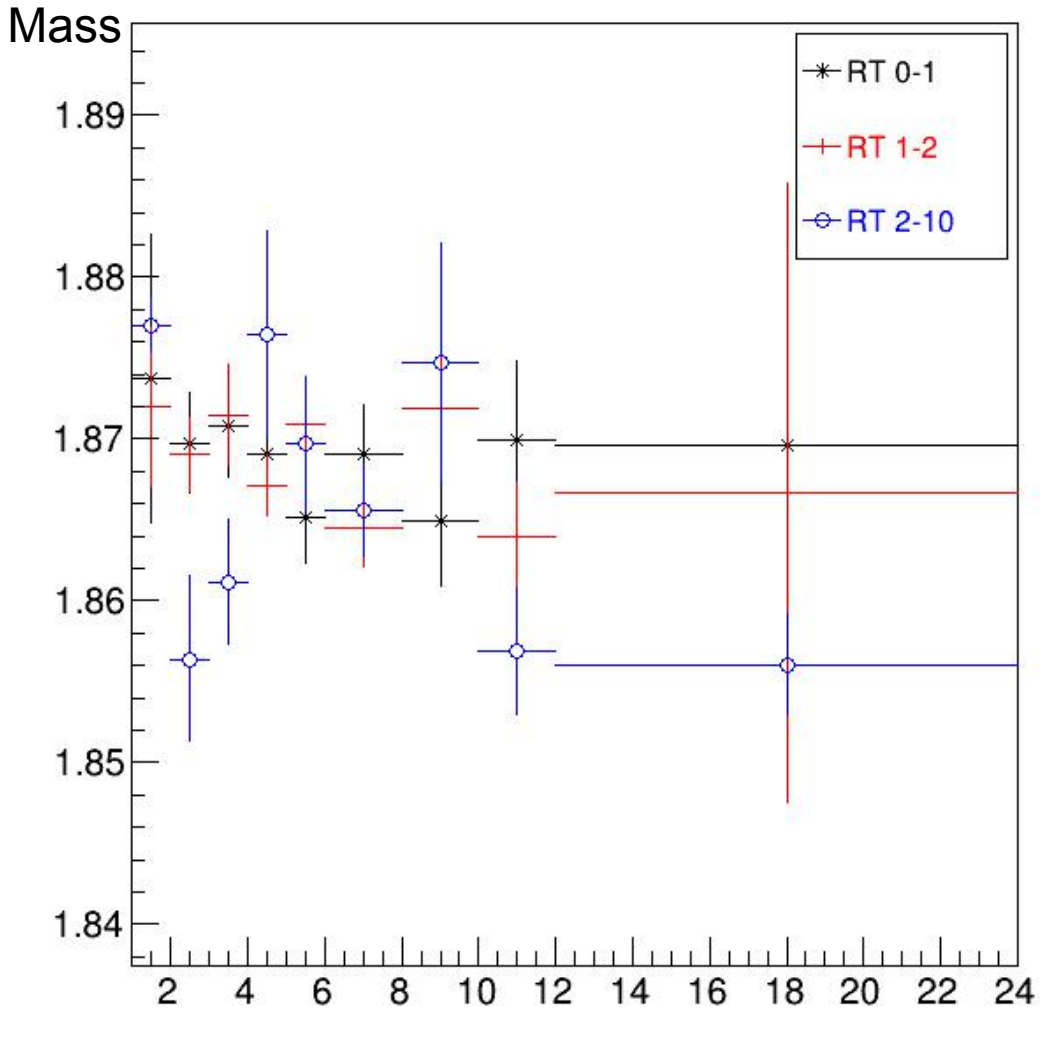
Mass

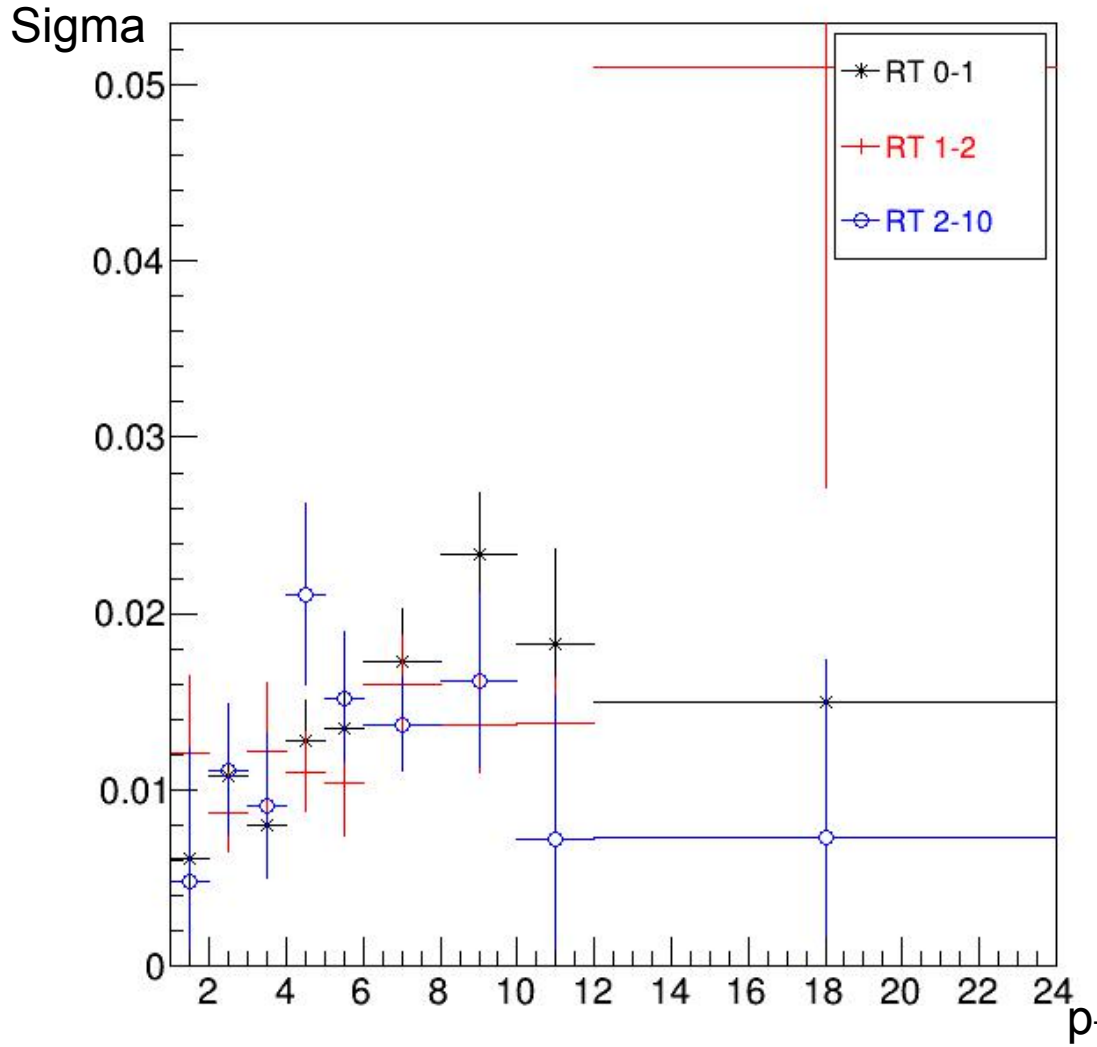


Sigma



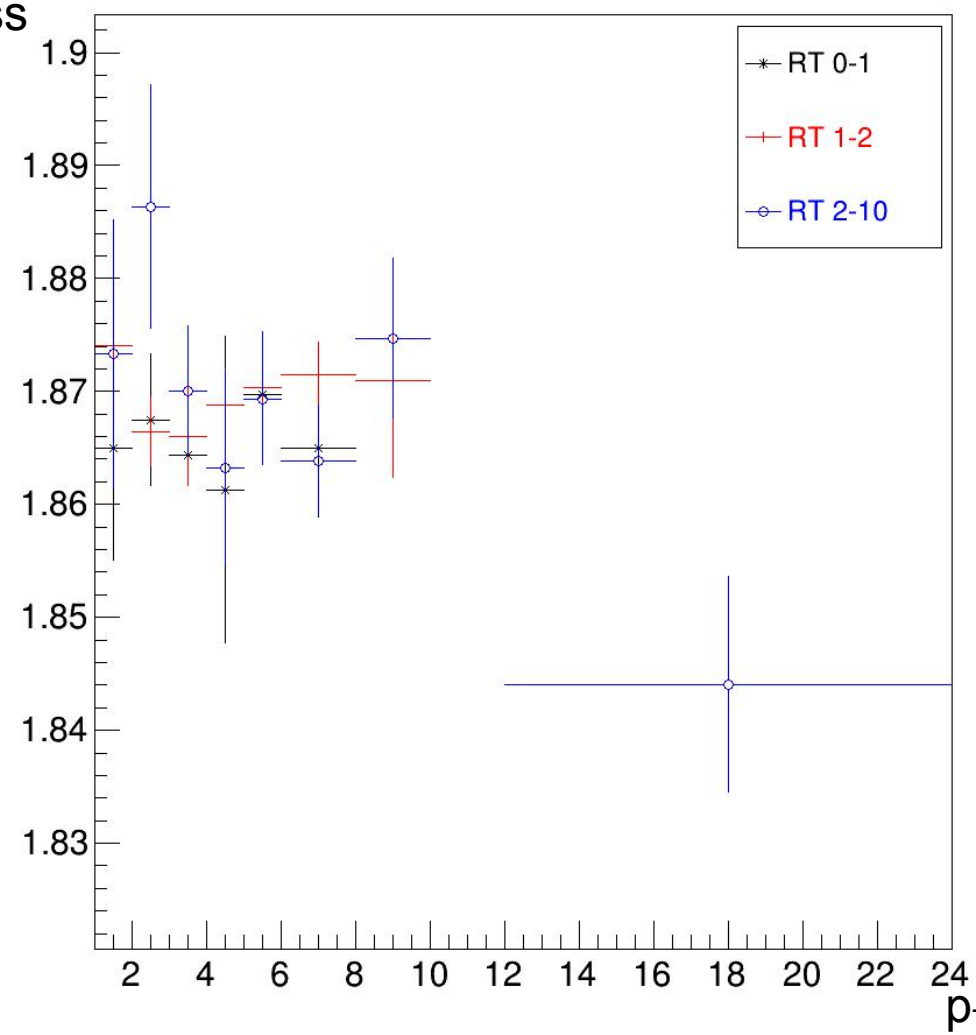
Invariant mass in Away region



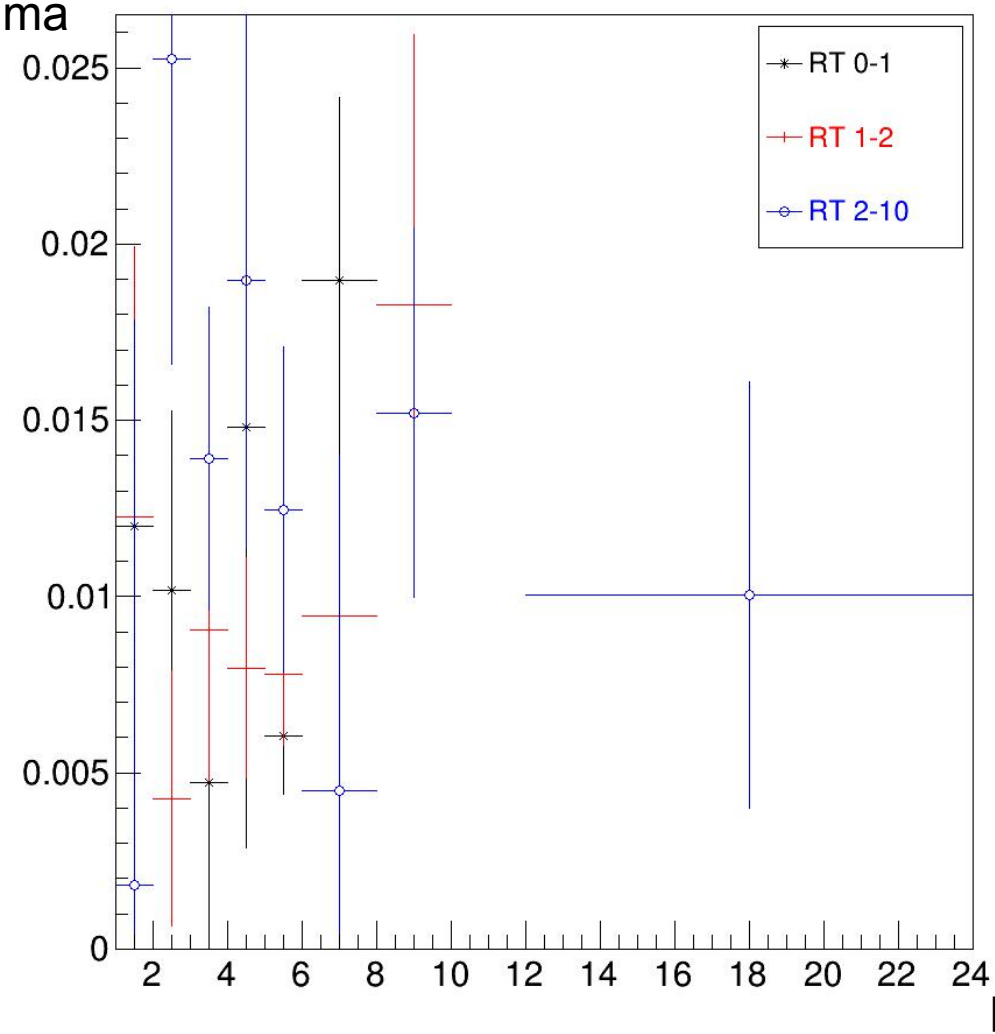


Invariant mass in Transverse region

Mass



Sigma



Conclusion and plans

- Collective behaviour is observed in p-p collisions - one of the possible explanations is MPI

- MPI cannot be measured directly - instead try to use another parameter (R_T), which correlates with MPI

- The initial D^0 analysis is consistent with the simulations

- Goal for the near future: to get the R_T-multiplicity dependence of heavy-flavored D^0 meson
- This may reveal flavor-dependent production and fragmentation mechanisms of mesons