Probing the underlying event with identified heavy-flavor triggers

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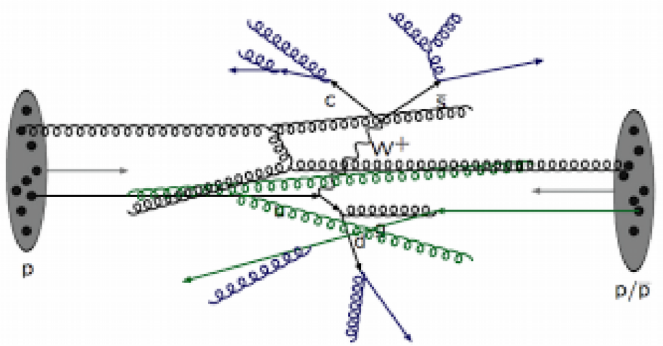
2020. 12. 10.

Motivation

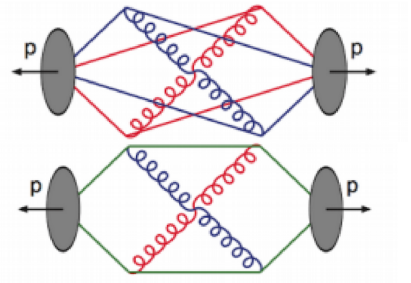
- Existence of QGP in small colliding systems with high final-state multiplicity cannot yet be completely ruled out
- In experiment, the effect of MPI and CR can be investigated by observing the connection of the leading hard process to the underlying event
- we investigate underlying event activity using simulations where with identified heavy and light-flavor triggers
  - UE is the part of the event that does not originate from the leading hard process
  - can help in understanding mass-dependent development as well as color-charge effects in the parton shower and jet fragmentation
- Why we use Heavy Flavor?
  - it mostly arises in initial hard processes
  - it’s persent until the latest stages of the reaction
  - we reconstruct heavy flavor properties from it’s decay products

Definitions and concepts about p-p collision

- Underlying Event (UE):
  - presence of UE from non-hard processes
  - interplay between UE and hard processes
  - significantly influenced by MPI and CR



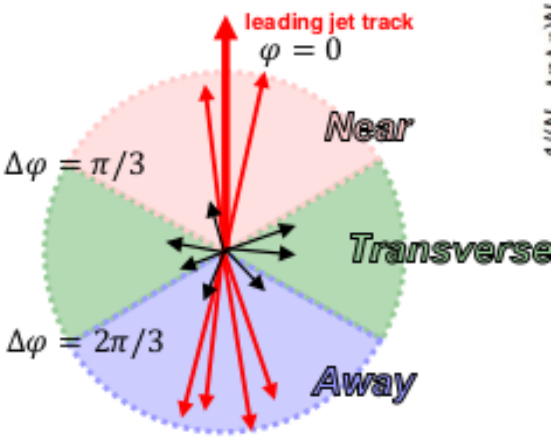
- Multi-Parton Interaction (MPI):
  - more partons interact
  - multistep process
- Color-Reconnection (CR):
  - striving for energy minimum (analogy)
  - CR leads to radial flow
    (*Ortiz-Bencédi-Bello.J.Phys. G44 (2017), 065001*)



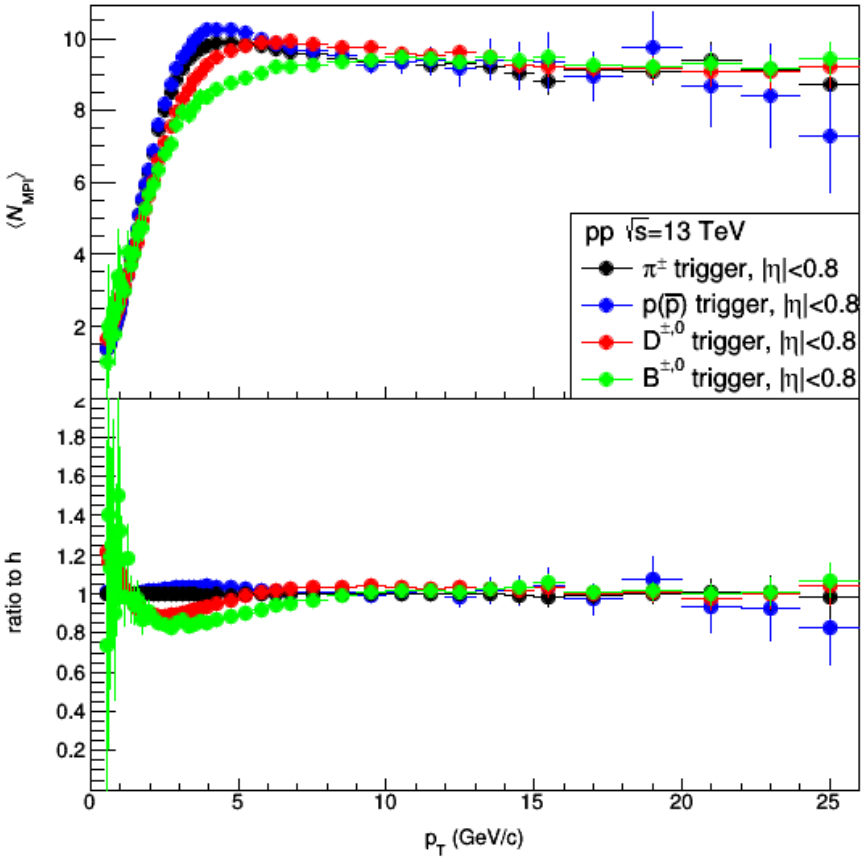
- Initial State Radiation (ISR): particle emitted by one of the incoming partons before the interaction with other partons
- Final State Radiation (FSR): particle emitted by the outgoing parton after the interaction with other partons

Analysis methods and settings

- PYTHIA 8 Settings
  - $\sqrt{s} = 13$ TeV, SoftQCD, MinBias;
  - no decay of $D^+, D^-, D^0, \overline{D}^0, B^+, B^-, B^0, \overline{B}^0$
- Trigger particles $\pi^{\pm}$, p/p, D or B
  - $p_T > 0.5$ GeV/c, $|\eta| < 0.8$
- Associated $pi^{\pm}$, $K^{\pm}$, p/p
  - $p_T > 0.15$ GeV/c, $|\eta| < 0.8$
- Azimuthal regions:
  - **Near-side cone**: $\Delta R < 0.5$
  - Near-side: $|\Delta\varphi| < \pi/3$
  - **Transverse side**: $\pi/3 < |\Delta\varphi| < 2\pi/3$
  - Away-side: $2\pi/3 < |\Delta\varphi|$



The average number of multiple-parton interactions per trigger

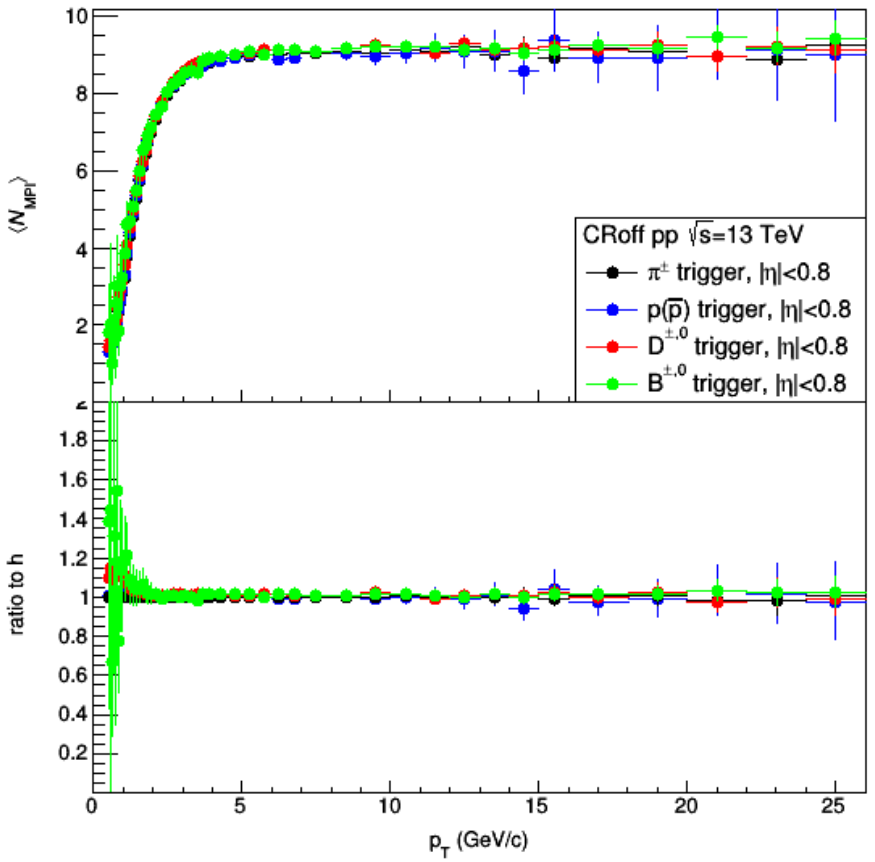


Pion
Proton
D-meson
B-meson

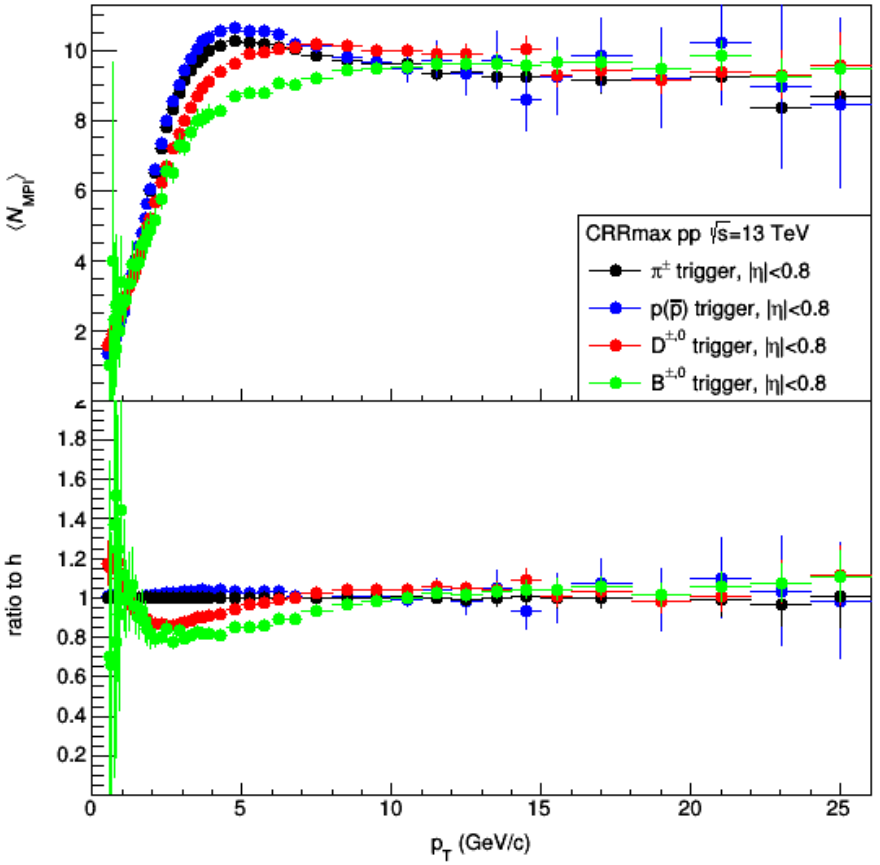
- clear difference seen in N_{MPI} depending on the trigger particle species in the momentum range: $2 < p_T^{leading} < 8$ GeV/c
- The MPI activity corresponds to light-flavor and it is forming a visible bump

Number of MPI in function of pT leading: CR off and CR maximum

CR = off



CR = max

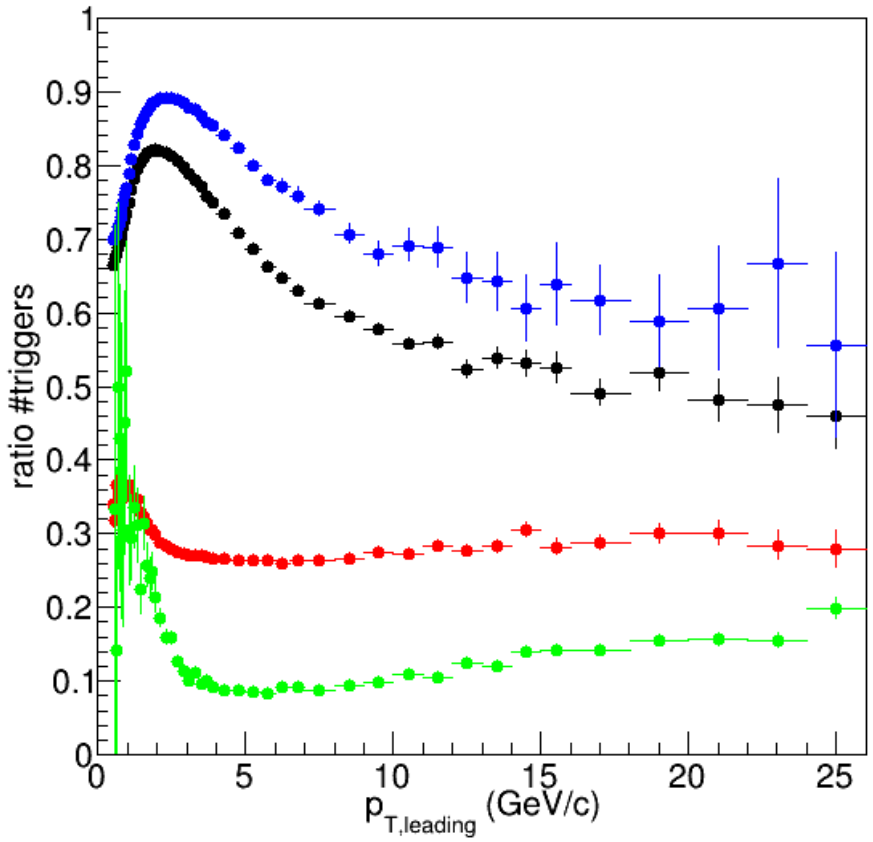


- CR = off: the effect vanishes, bringing all four curves together
- CR = max: the bump is stronger
- Why are we investigeted in Transverse side: the activity in this range is strongly correlated with N_{MPI}

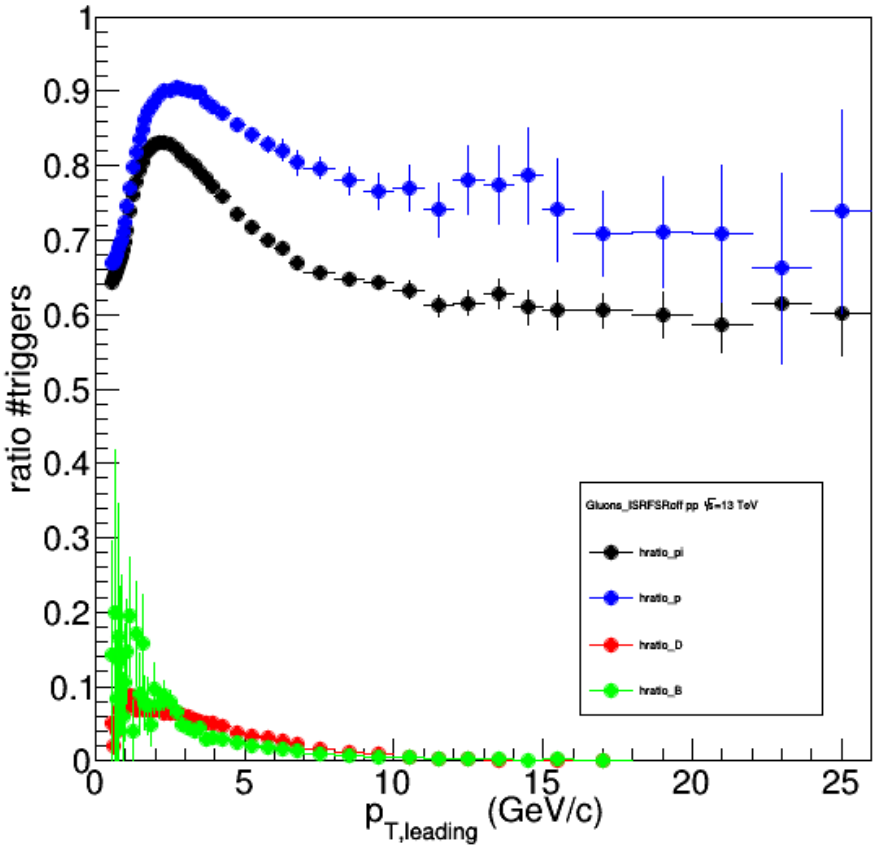
Pion
Proton
D-meson
B-meson

Separated jets - with and without ISR and FSR

with ISR and FSR



without ISR and FSR



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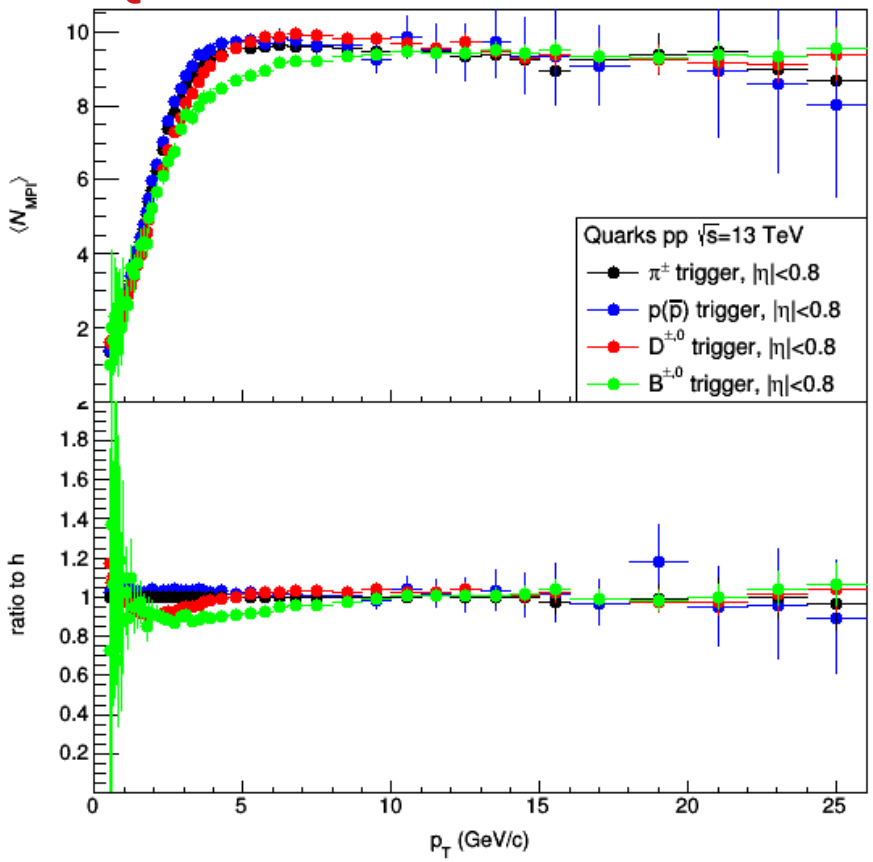
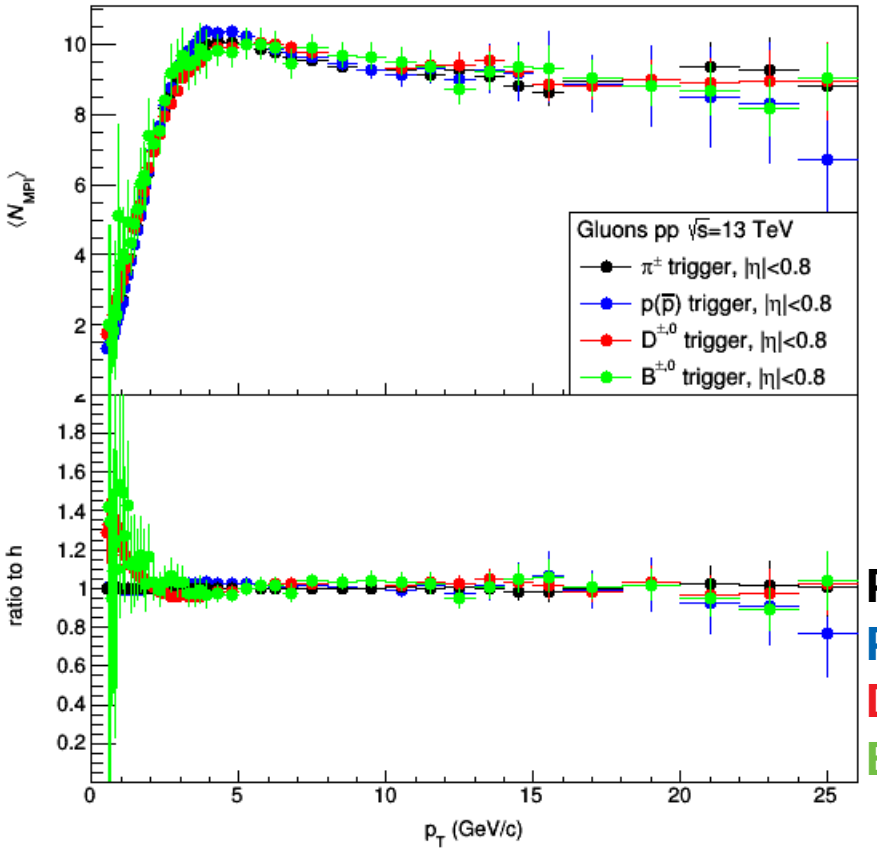
- We seprate contributions from quark and gluon jets
- with: 30% of D-meson triggers and 10–15% of B-meson triggers as gluon-initiated
- without: the fraction of heavy-flavor triggers identified as gluon-initiated is below 5–10% - and low-$p_T^{leading}$ and vanishes toward higher $p_T^{leading}$
- the algorithm can be used for enhancing gluon (quark) initiated triggers in a sample

Separately for quark-initiated and gluon-initiated triggers

Quarks



Gluons



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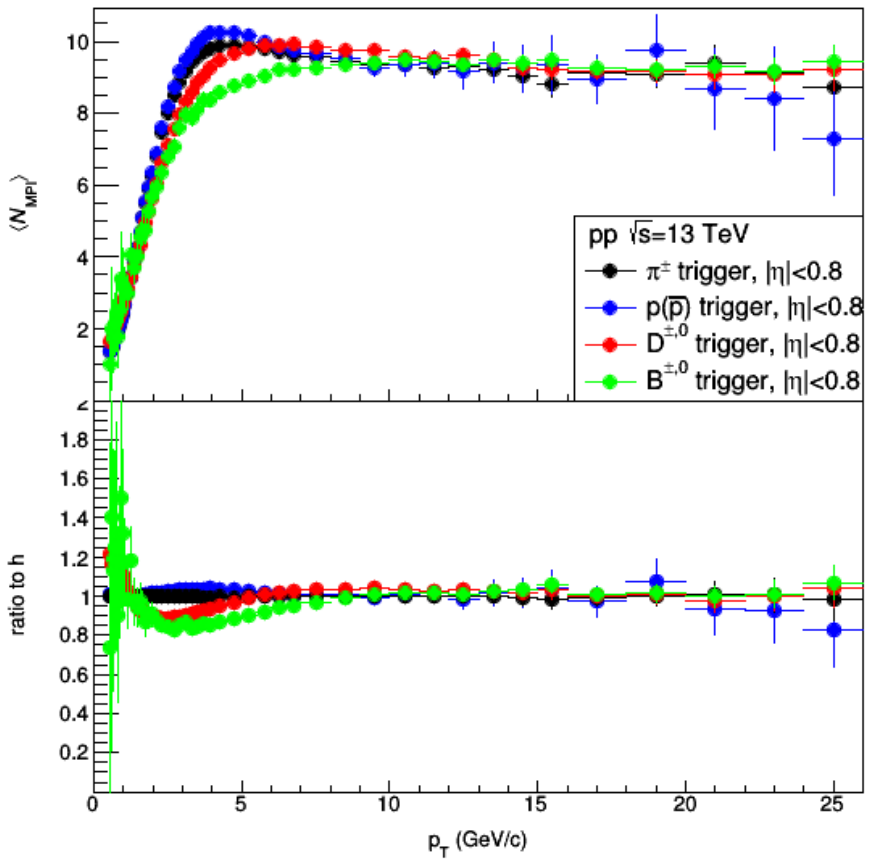
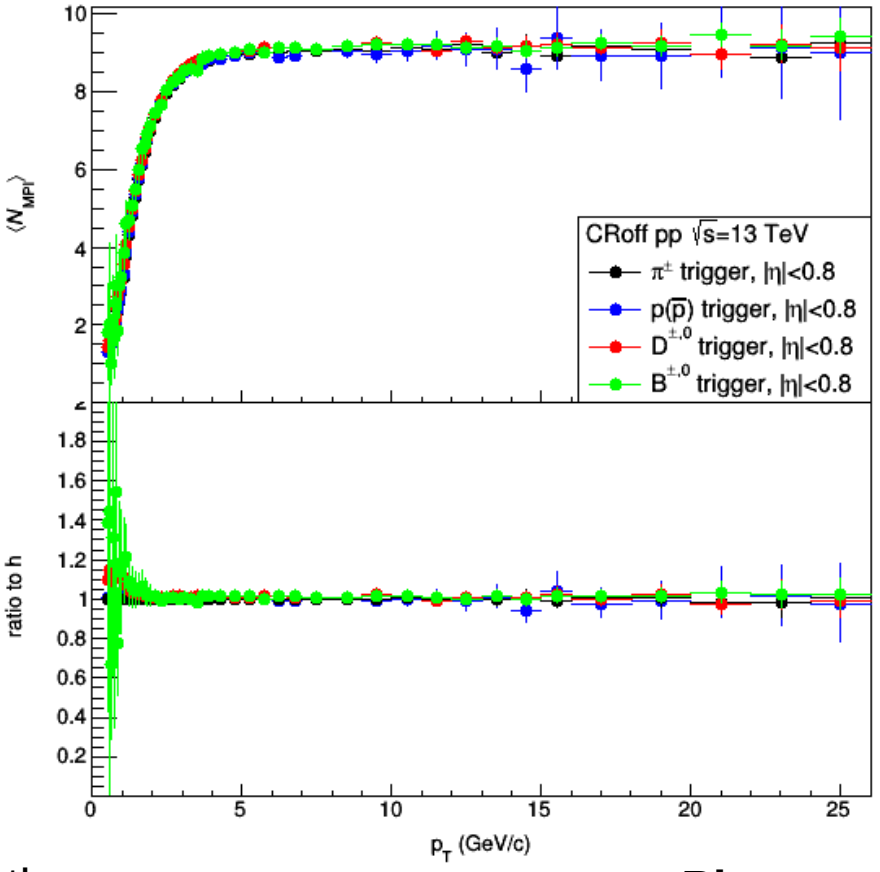
- we investigate the bump structure
- Quarks: there is no bump structure (no significant overshoot above the saturation value) for any of the trigger species
- Gluon: remarkable bump can be seen

MPI CR on vs CR off

CR = on



CR = off



- CR = on: there is differentiation between the curves
- CR = off: the curves coincide
- CR = on level > CR = off level for pions, but the B are same

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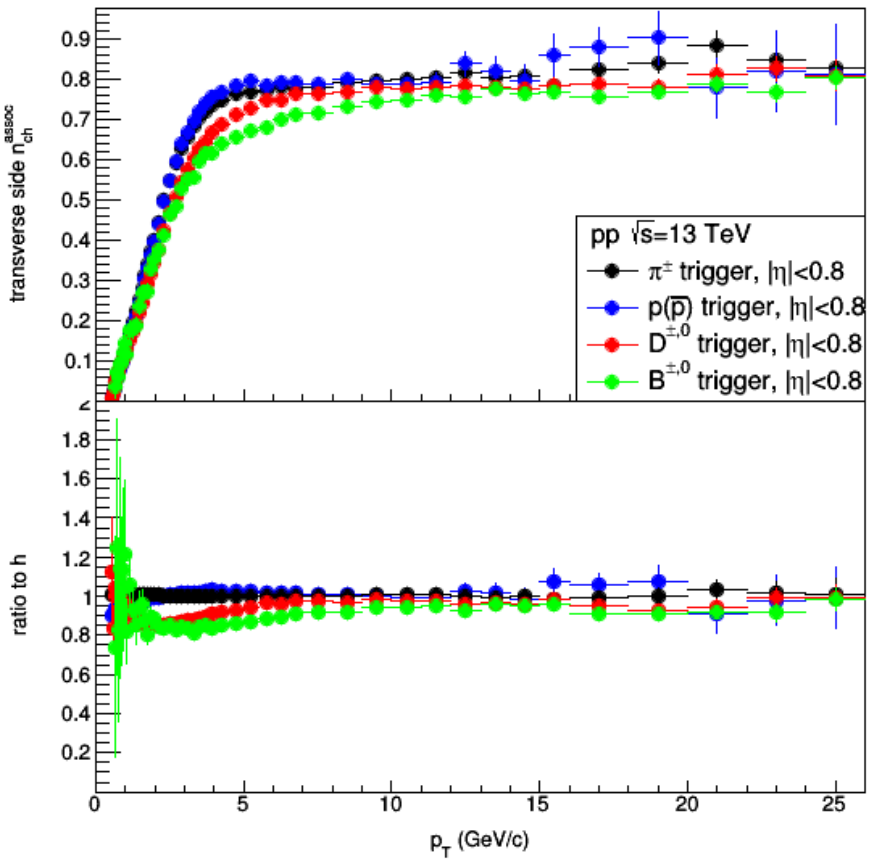
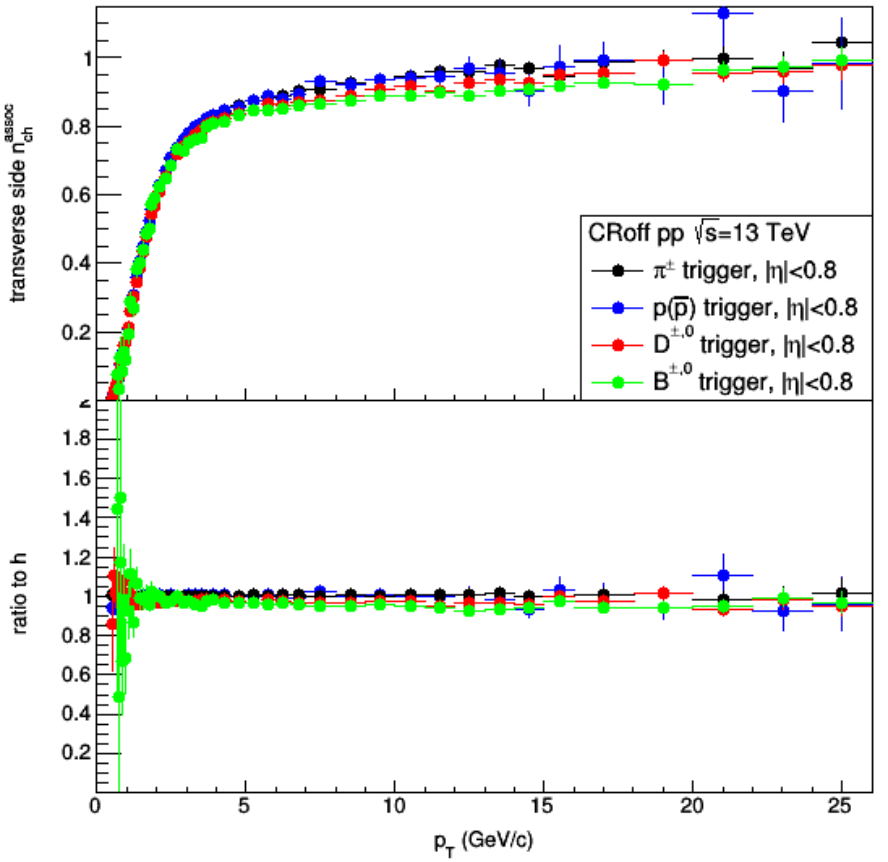
We are looking for the physical quantity that the most closely resembles the MPI

Transverse side: particles yield CR on vs CR off

CR = on



CR = off



- CR = on: there is differentiation between the curves
- CR = off: the curves coincide
- CR = on *Nch* < CR = off *Nch* - that was our expectation, because CR = on event multiplicity less

arXiv:1805.03101

- Can not use for comparison

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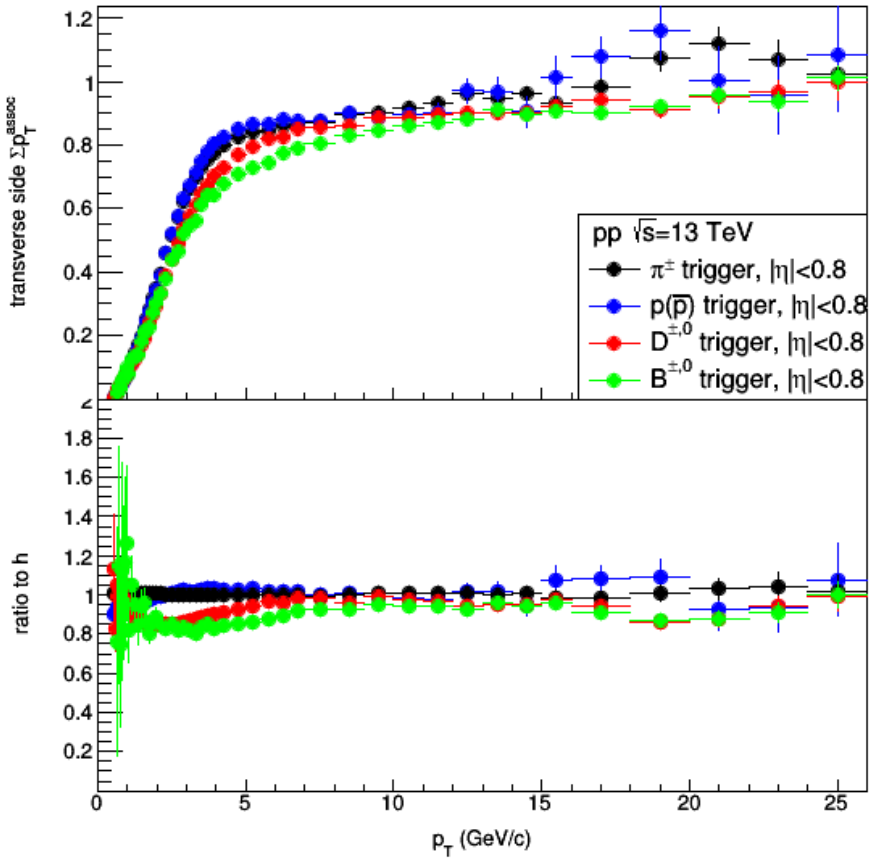
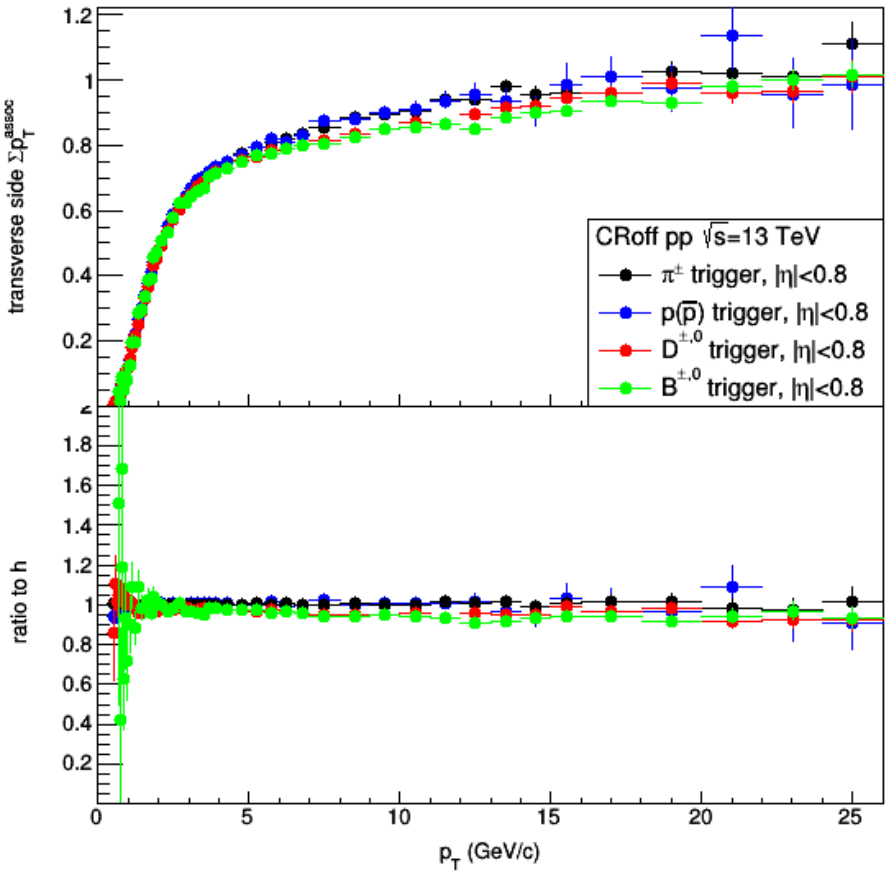
Transverse side: pT sum CR on vs CR off

CR = on



CR = off



- CR = on: there is differentiation between the curves
- CR = off: at low p_T the curves coincide
- CR = on sum p_T > CR = off sum p_T pions, but the B are same
- we check with p_T average and we get same results

We use transverse sum p_T as a proxy for N_{MPI}

Pion
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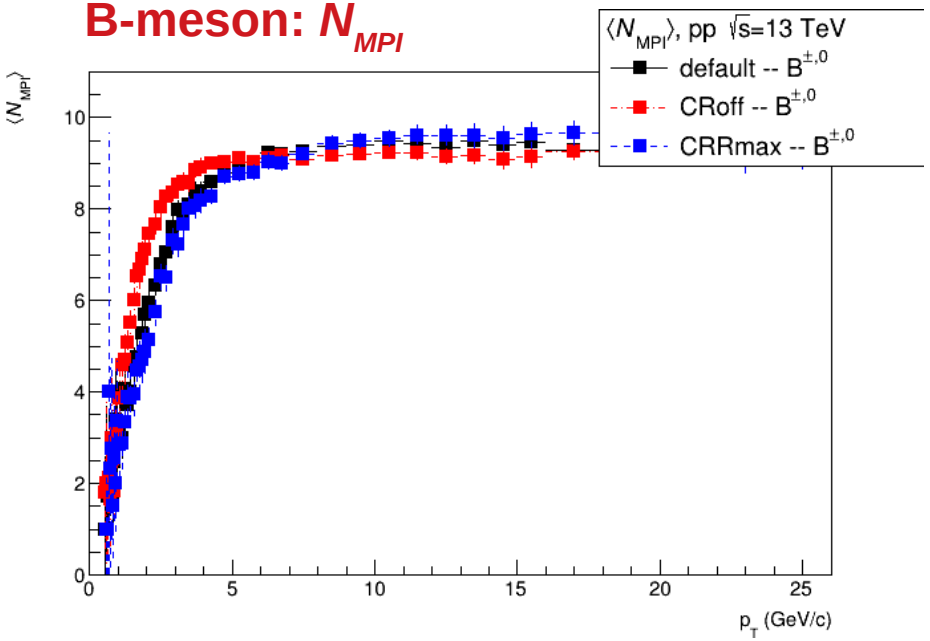
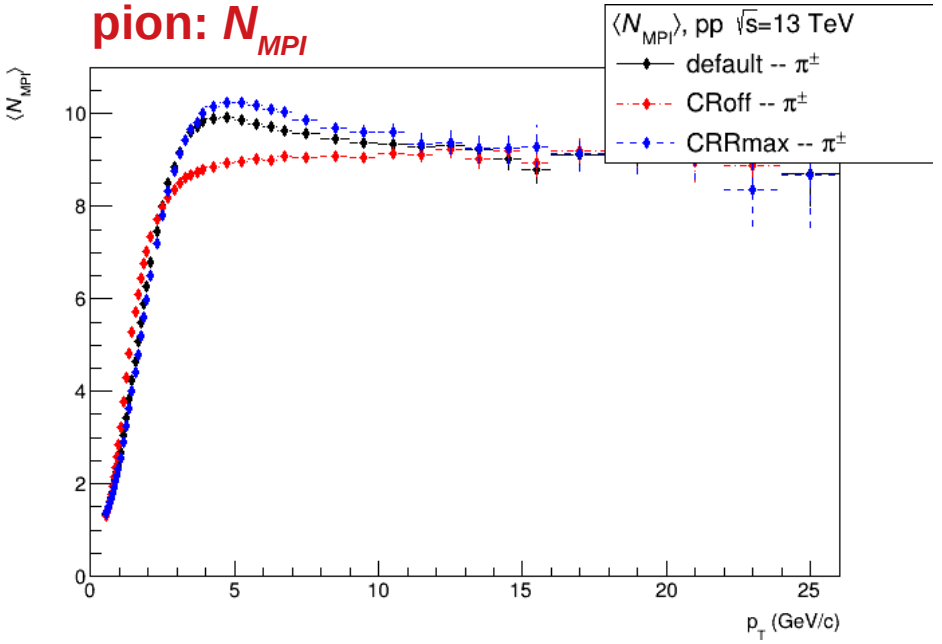
B-meson

B-meson vs pion – Proxy for quark and gluon jets

B-meson: N_{MPI}



pion: N_{MPI}



B-mesons represent quark jets

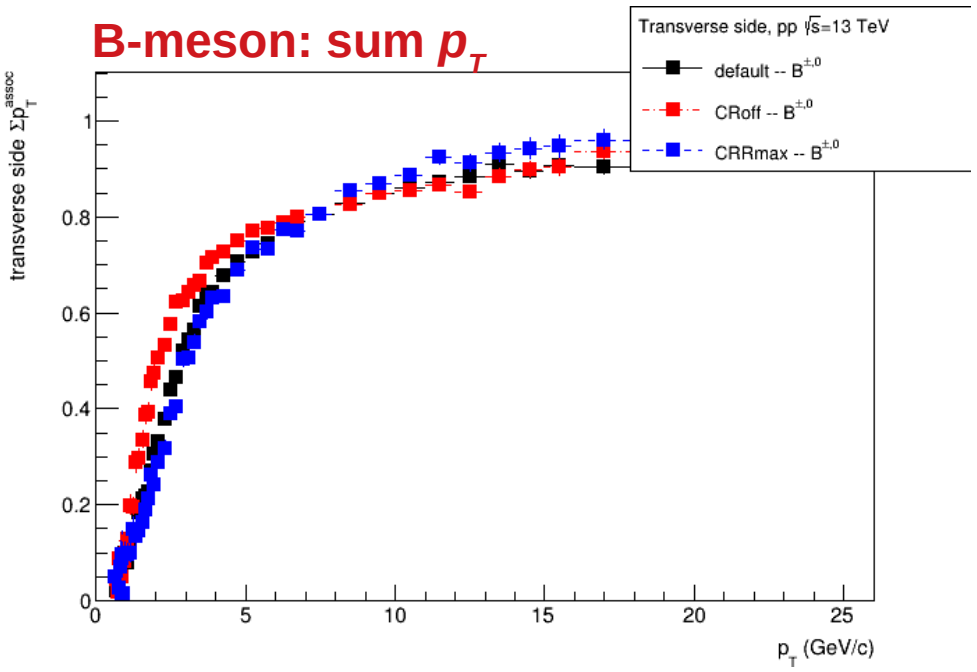
pions represent gluon jets

default
CR = off
CR = max

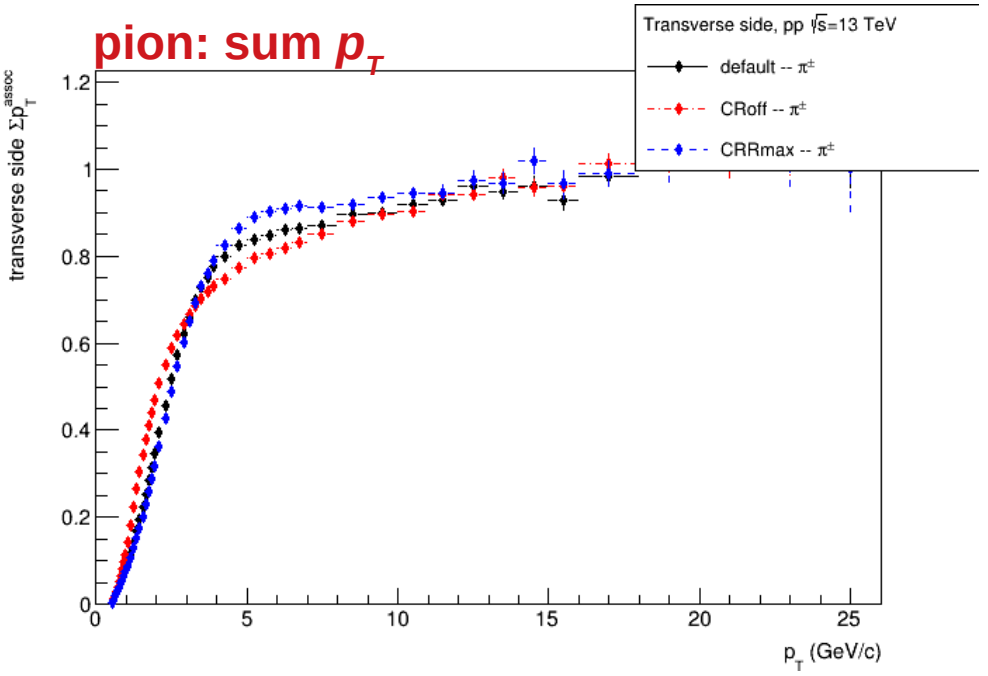
- **Pions: the difference can be seen - CR effect only affects gluon jets**

B-meson vs pion – Proxy for quark and gluon jets

B-meson: sum p_T



pion: sum p_T



B-mesons represent quark jets

pions represent gluon jets

default
CR = off
CR = max

- **Pions: the difference can be seen - CR effect only affects gluon jets**
- **MPI acting on gluons and quarks can be accessed in the experiment by measuring event activity in events triggered with pions and B mesons**

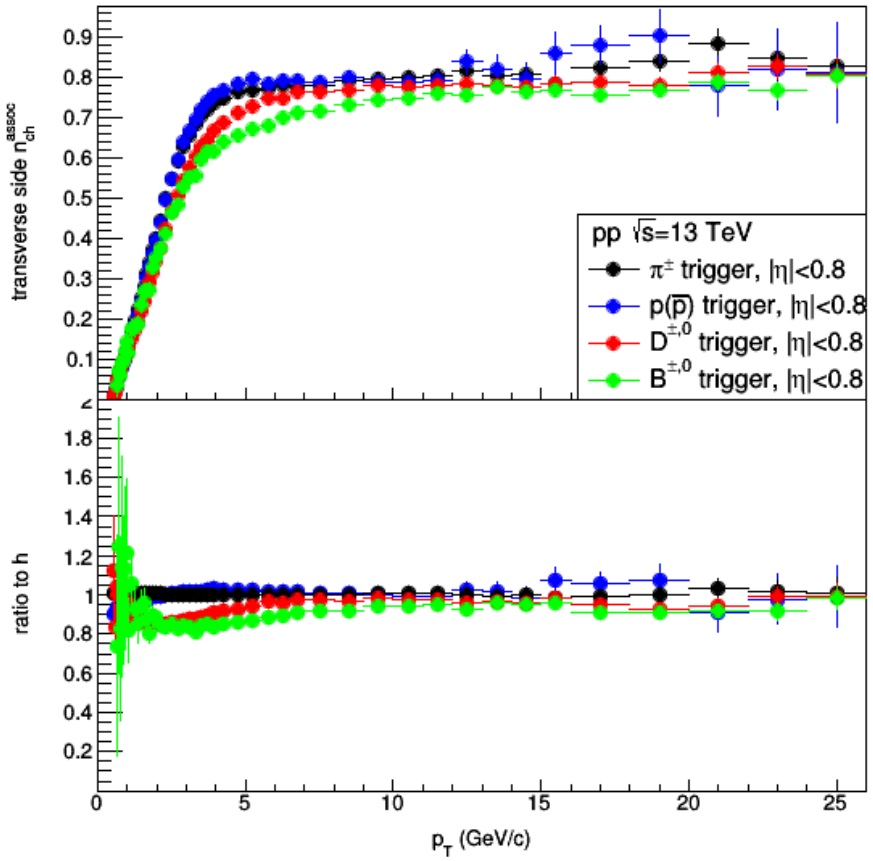
Summary

- We examined the multiple-parton interactions with identified light and heavy-flavor triggers
- We found that the sum transverse momentum represents well the number of MPI
- Color reconnection causes a characteristic enhancement ("bump") in the semi-soft region, that is different depending on the trigger (has also been seen in LF)
  - According to our analysis, the bump is caused by gluons, but the flavor separation comes from the quarks
  - We found that B mesons can be used as a proxy for quarks, and pions are more representative for gluons

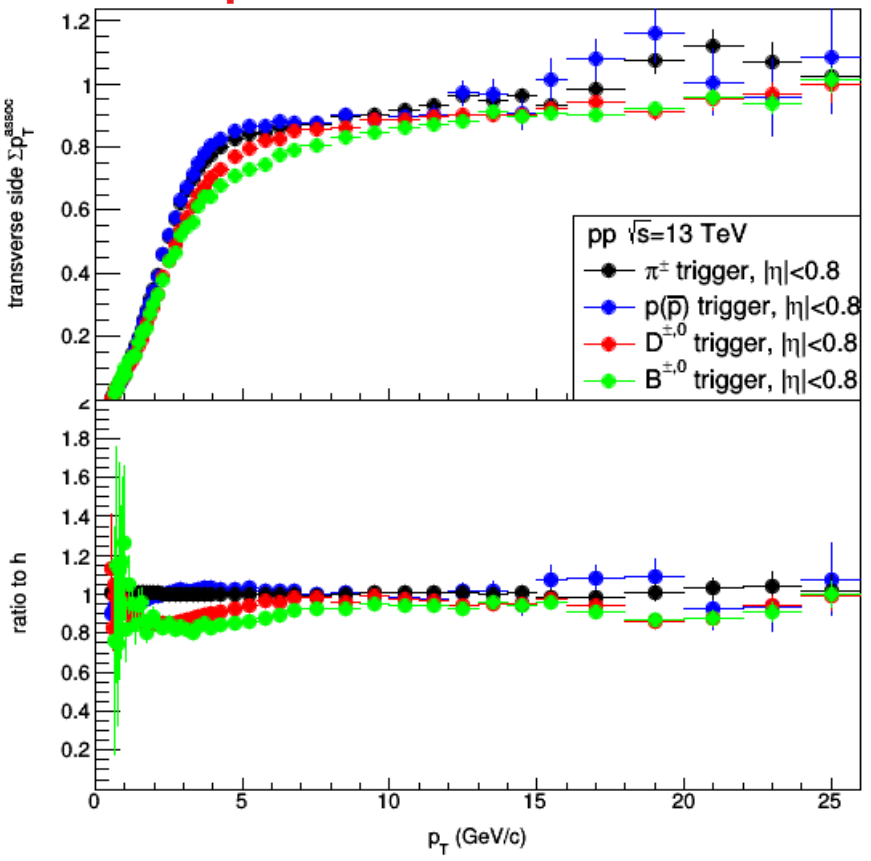
Thank you for your attention

Transverse side: associated charged particle multiplicity vs sum pT

n_ch assoc



sum pT assoc



- Light jets: quark-initiated and gluon-initiated jets,
- Heavy-flavor jets: almost exclusively quark jets (especially at low-pT)
- makes it possible to disentangle effects associated to quark-initiated and gluon-initiated jets
- our algorithm: identifies events based on whether the parton that eventually fragments into the trigger particle is a quark or a gluon

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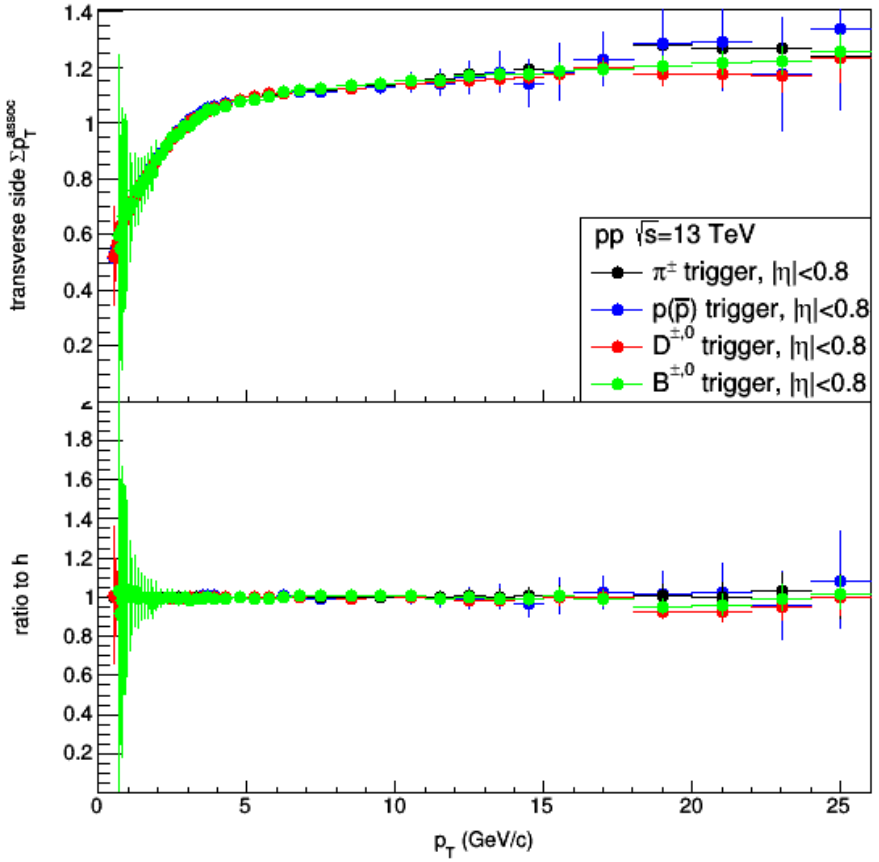
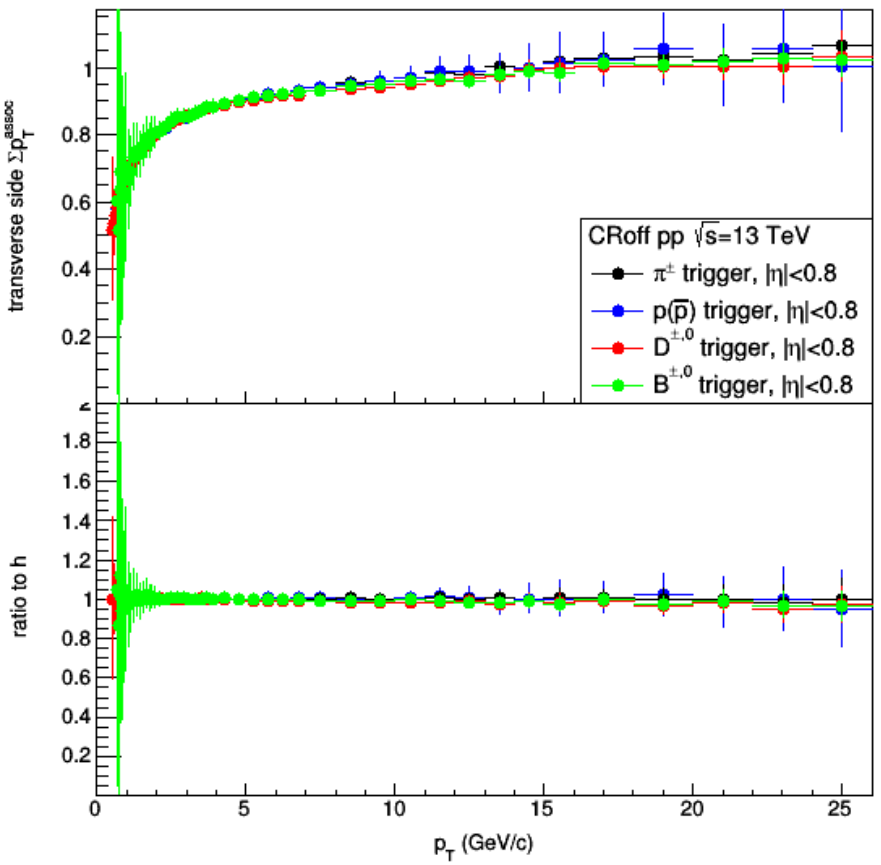
Transverse side: pT Average CR on vs CR off

CR = on



CR = off



Pion
Proton
D-meson
B-meson

- CR = on, CR = off: there is no differentiation between the curves
- CR = on p_T average > CR = off p_T average
- more particles at the transverse side - less than one particle per the average p_T
- independent of the trigger particle