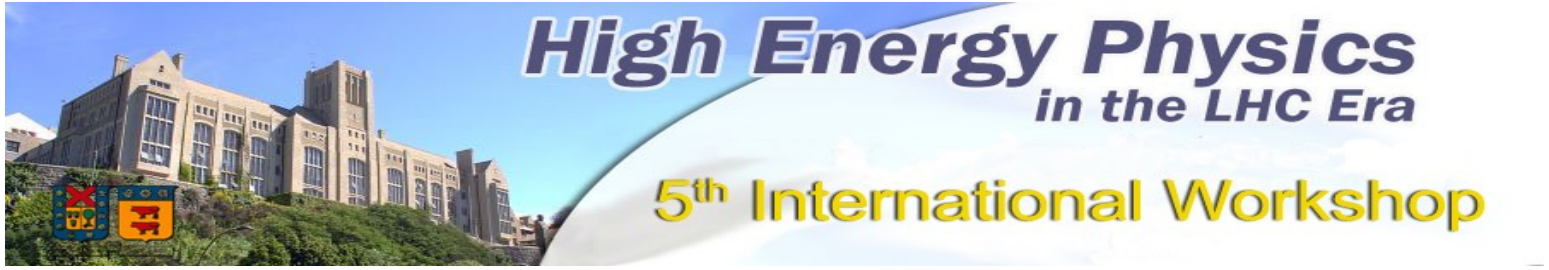


Does the color reconnection produces a collective phenomena?

Eleazar Cuautle
Instituto de Ciencias Nucleares,
Universidad Nacional Autónoma de México

Talk based on:
Phys. Rev. Lett. 111, 042001 (2013)
A. Ortiz, P. Christiansen, E. Cuautle, I. Maldonado and G. Paic

December 18th, 2013

Contents

- *Introduction:*
  - ➔*Words about collective phenomena*
  - ➔*Flow in heavy ions*
- *Possible causes of flow in pp collisions!*
  - ➔*Multiple Parton Interaction(MPI)*
  - ➔*Color Reconnection (CR)*
- *MPI and CR effects*
  - ➔*Pt Spectrum*
  - ➔*B/M, baryon vs Multiplicity and MPI*
  - ➔*Average Pt*
- *Final remarks*

Collective motion in the nature

Birds migrate in flock. Geese in V- formation may conserve 12-20 % of the energy they would need to fly alone; **J. Exp. Biol. 189 (1) 251-261, (1994)**

What the Fish Saw: How Swimming Fish Maintain Orderly Schools.

Synchronized swimming that could impress even the toughest Olympic judge

Phase transition from order to disorder in the system!!

PRL 98 095703 (2007)

Words about collective phenomena

- *In heavy ion collisions is well accepted such phenomena, as indicate the latest results of the LHC. However, those data are not yet completely exploited.*
- *Hydrodynamic theory are used to explain data, however this could no be applied to partonic level, such as pp interactions.*

The pp collisions could give rise to collective phenomena, when in the hadronization of the final state are introduce models that reassign colors among partons, the so call CR (Phys. Rev. D36, 2019 (1987)).

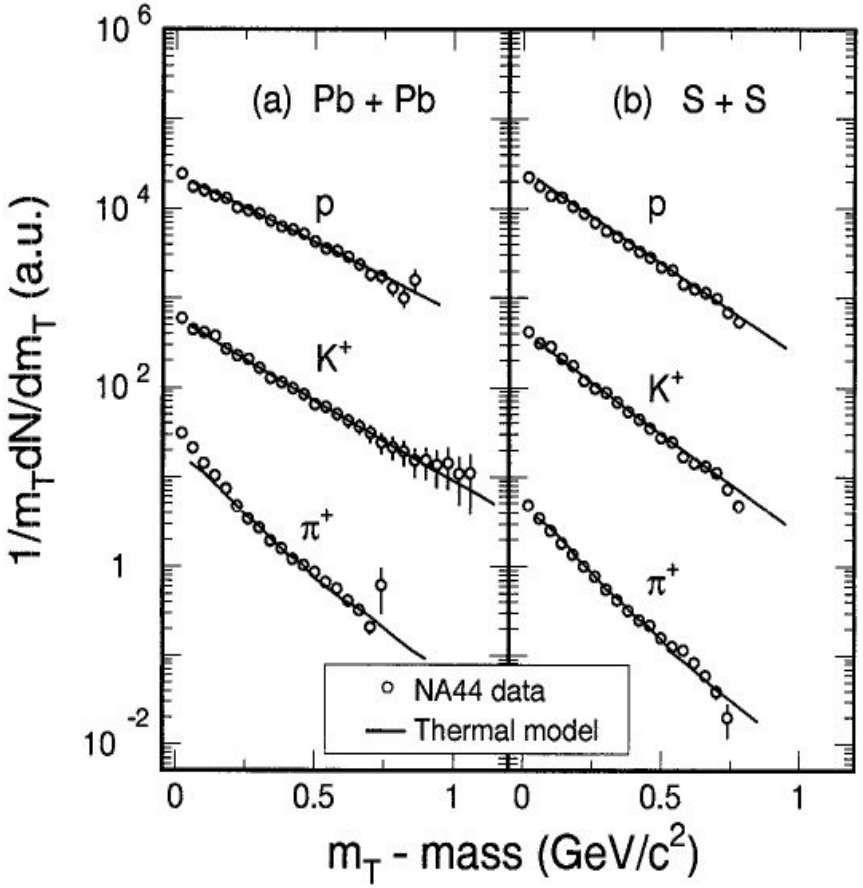
- *The CR and the MPI, seems to introduce flow-like effects observed in results of simulated pp collisions with PYTHIA 8.1:*
  - *Pt spectrum by species,*
  - *Baryon to meson ratio versus multiplicity, MPI, etc.*
  - *< pt> versus multiplicity.*

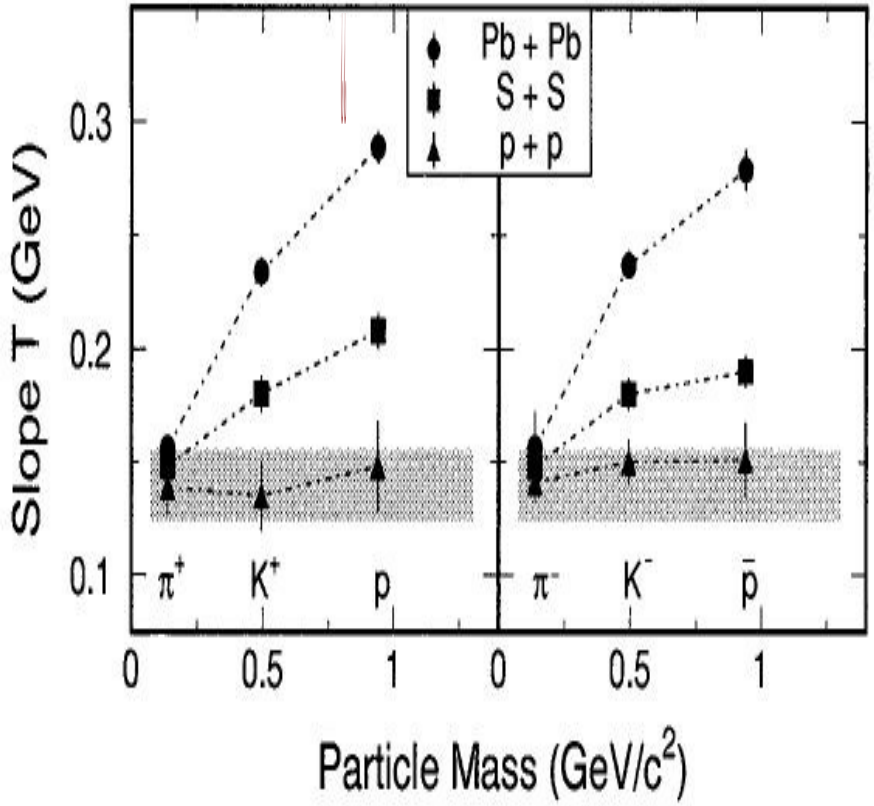
  .... (Phys. Rev. Lett. 111 042001, (2013))

Collective Expansion in High Energy Heavy Ion Collisions

$$\frac{1}{m_t}\frac{dN}{dm_t} = A\exp\left(\frac{-m_t}{T}\right)$$

Abstract: ...The mass dependence of the slope parameters provides evidence of collective transverse flow from expansion of the system in heavy-ion induced central collisions



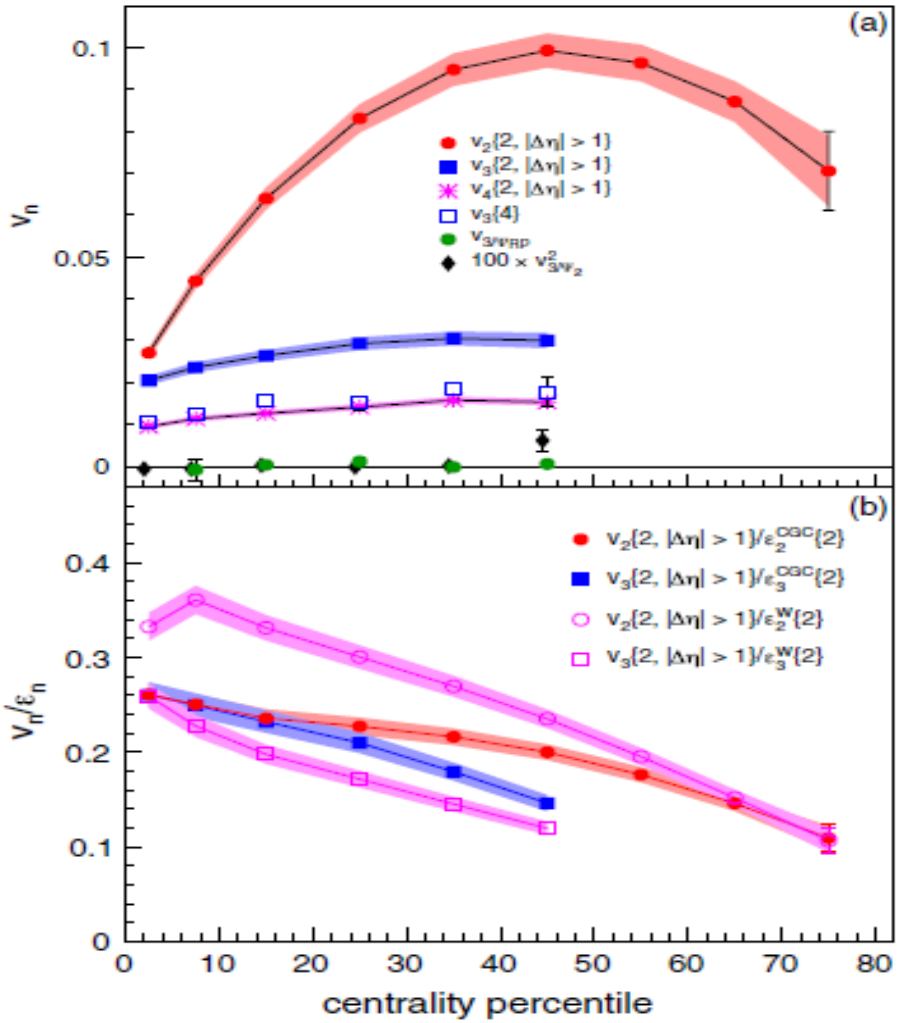


NA44: Phys. Rev.Lett. 78,2080 (1997)

Figure 3: Transverse mass distributions for pions, kaons, and protons (open circles) compared with results of a thermal model calculation (lines). Resonance decays are included in the pion spectra and resonance effects on kaon and proton spectra are neglected.

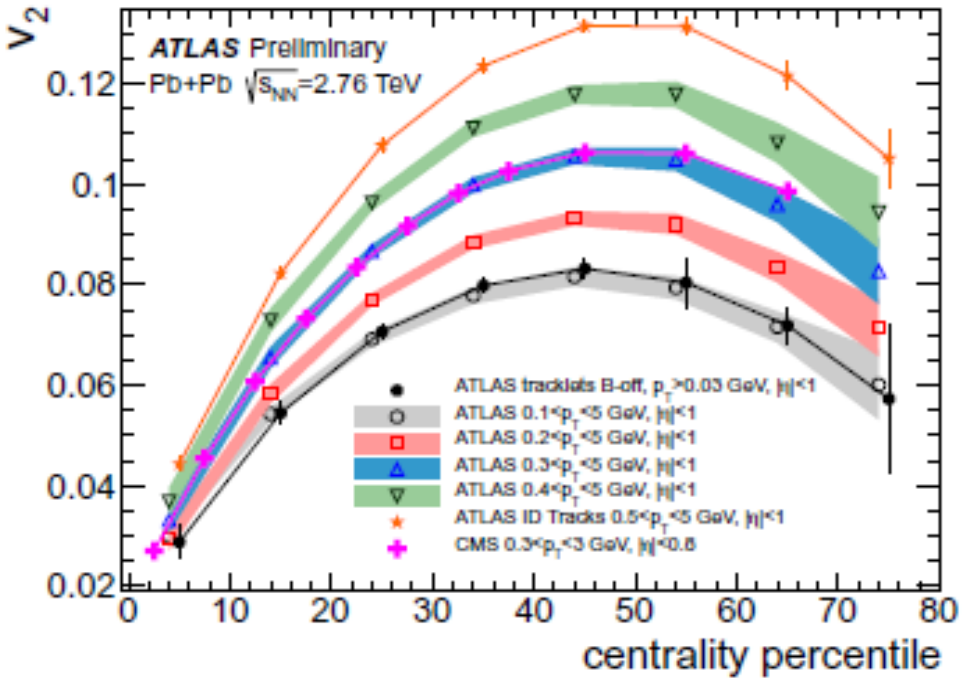
Figure 2: Slope parameter T as a function of particle mass. The p+p results are taken from Refs. [16,17]. The shaded band shows the range where the slopes converge at zero mass.

Flow at LHC, PbPb a 2.76 TeV



Integrated flow over pt range $0.2 < p_t < 5GeV/c$ as function of the centrality.
The lower case correspond to flow divide by the eccentricity.

ALICE: Phys. Rev. Lett. 107, 032301 (2011)

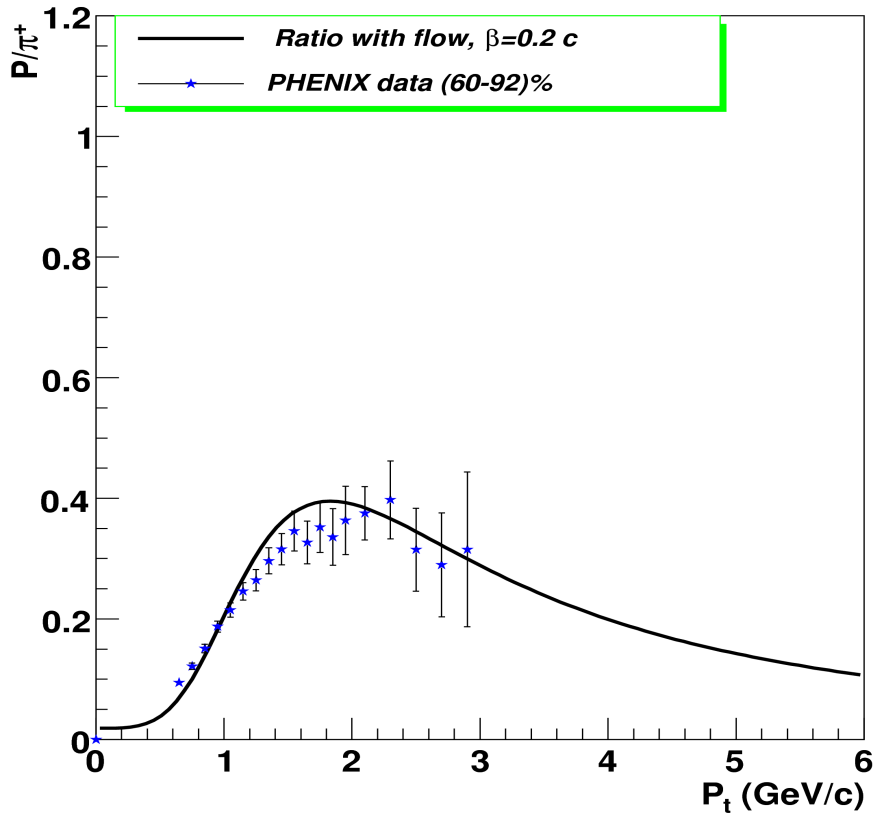


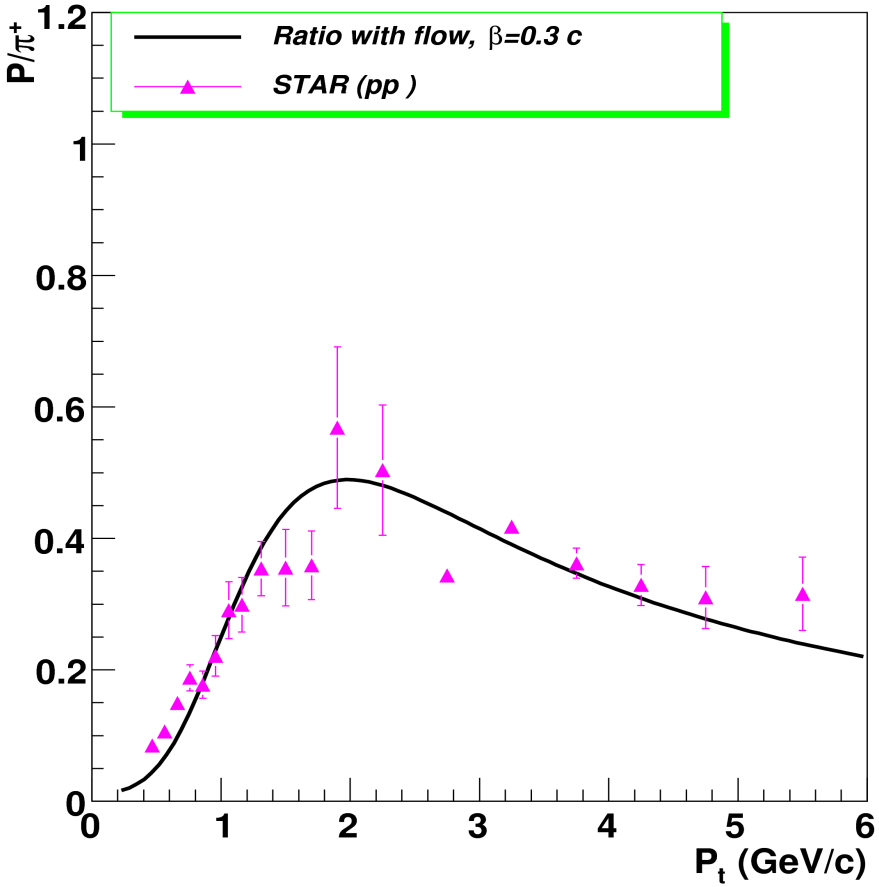
The elliptic flow depends on the centrality and the p_t range.

ATLAS: NPA 904-905 (2013)106c-113c

Flow in pp collisions:
Multiple Parton Interaction,
Color reconnection

Radial flow in pp collision





Pythia + radial flow: radial flow introduced in Pythia allow a qualitative description of the p / π ratio. Indicating that radial flow is necessary to explain the ratio p / π

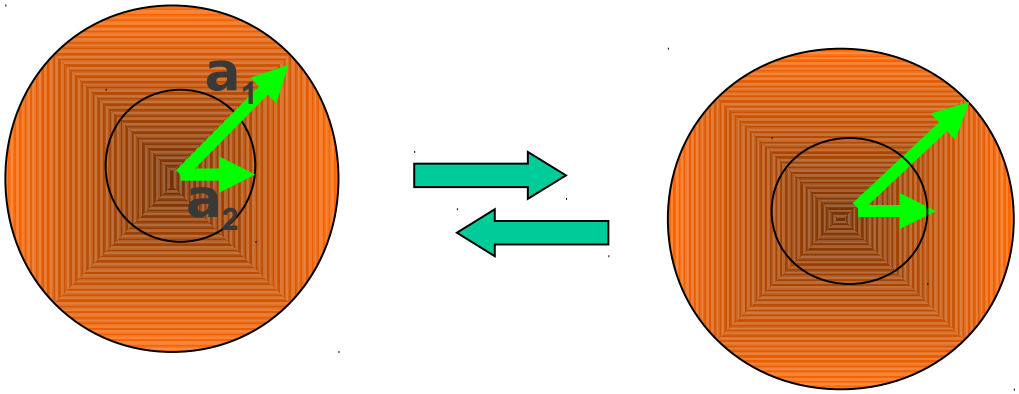
J. Phys. G35, 075103 (2008)

Source of MPI and impact parameter

Hadronic matter distribution: Double Gaussian

$$\rho \propto (1-\beta)\frac{1}{a_1^3}\exp\left(\frac{-r^2}{a_1^2}\right)+\beta\frac{1}{a_2^3}\exp\left(\frac{-r^2}{a_2^2}\right)$$

β *is the fraction of the matter inside the sphera* a_2 *The ratio* a_2/a_1 *regulate the size ...*



PARP(83) =0.5 = β
PARP(84)= 0.2= a_2/a_1

SG: Single Gaussian
DG: Double Gaussian
Overlap: Overlap function wit p=1.5
JHEP 1105 (2011) 009

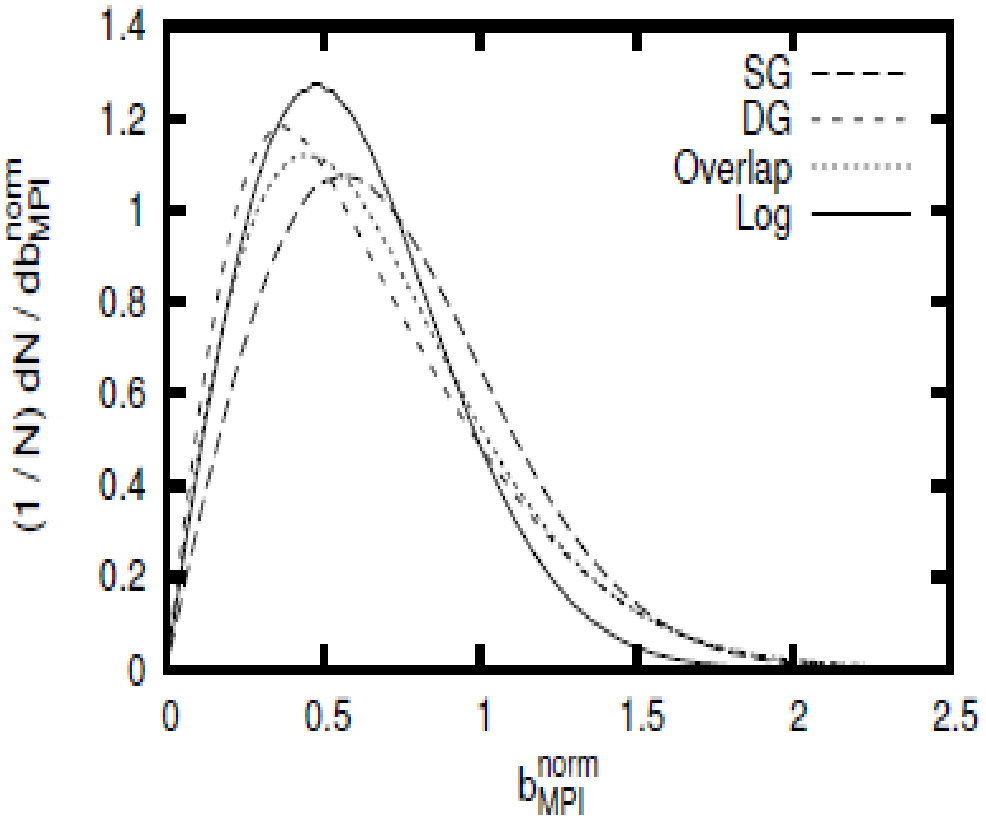
Impact parameter (b)

If $\bar{n}(b)$ gives the average number of interactions when two hadrons pass each other with an impact parameter b, the probability that there is at least one interaction is given by.

$$P(b) = 1 - \exp(-\bar{n}(b))$$

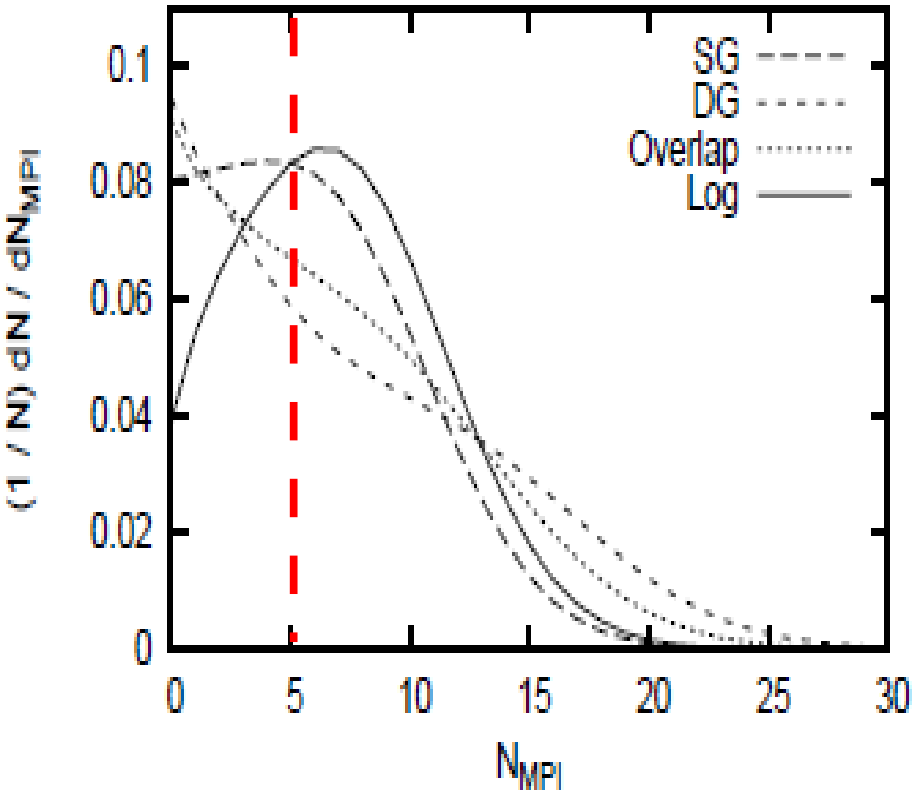
$$b_{avg} = \frac{1}{\sigma_{ND}} \int b\, P(b)\, d^2 b$$

$$b_{MPI}^{norm} = \frac{b}{b_{avg}}$$



SG: Single Gaussian
DG: Double Gaussian
Overlap: Overlap function wit p=1.5
Log: Logarithmically x-dependence Gaussian, a=0.15
JHEP 1105 (2011) 009

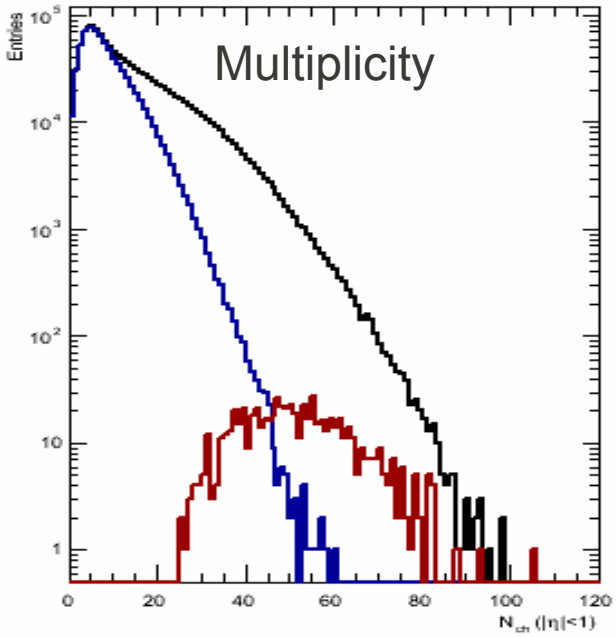
Multiple Parton Interaction (MPI)

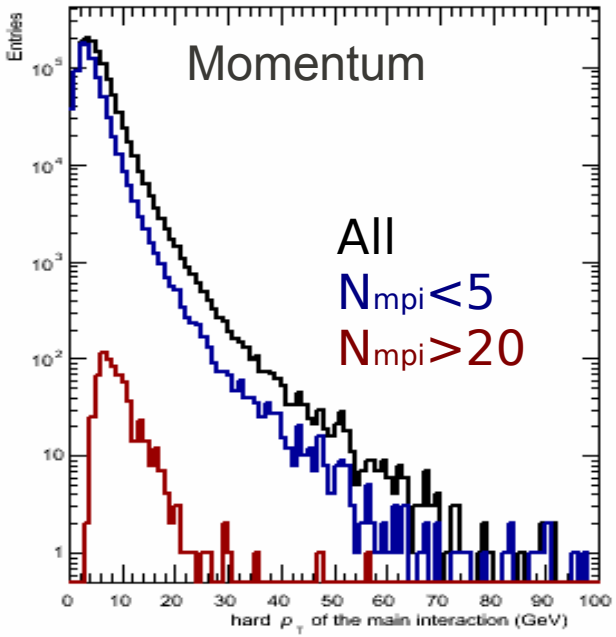


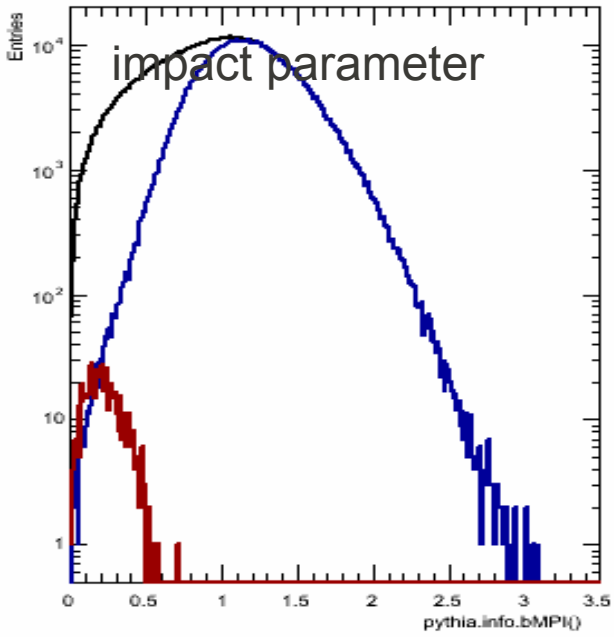
$$\langle n \rangle = \frac{\int \bar{n}(b)\, d^2 b}{\int (1 - \exp(-\bar{n}(b)))\, d^2 b} = \frac{\sigma_{hard}}{\sigma_{ND}}$$

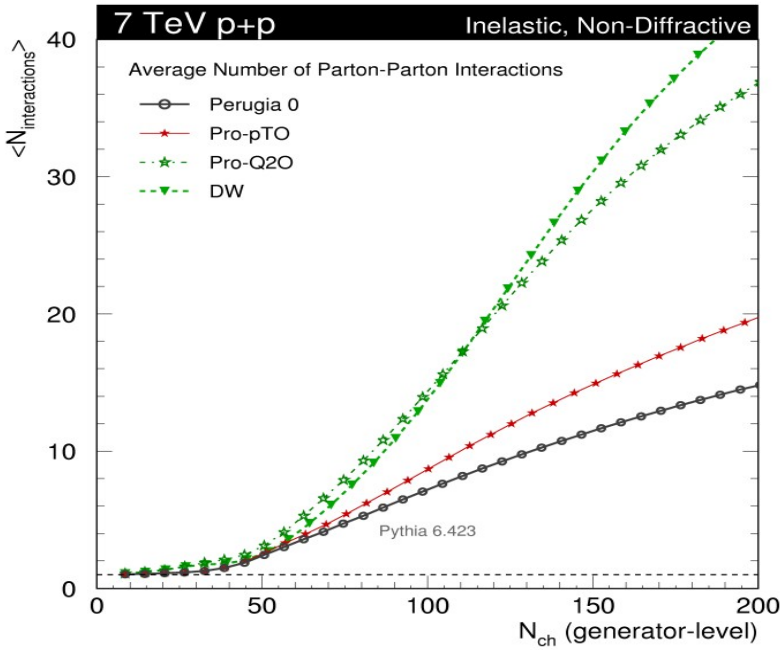
SG: Single Gaussian
DG: Double Gaussian
Overlap: Overlap function wit p=1.5
Log: Logarithmically x-dependence Gaussian, a=0.15
JHEP 1105 (2011) 009

MPI, Multiplicity, momentum and impact parameter







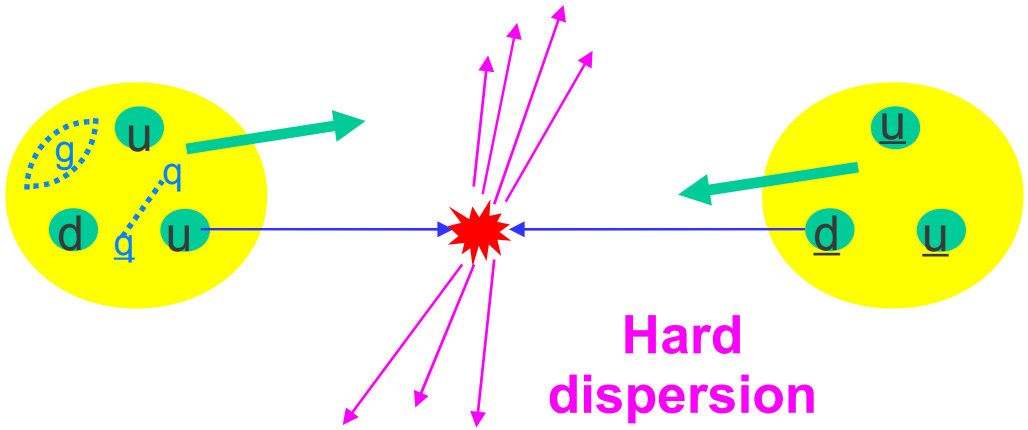


Multiplicity, momentum and impact parameter are function of the MPI.

The <MPI> depends hadronic matter distribution of the protons interacting:

http://home.fnal.gov/~skands/leshouches-plots/lhc07m-19-1.png

Color Reconnetion



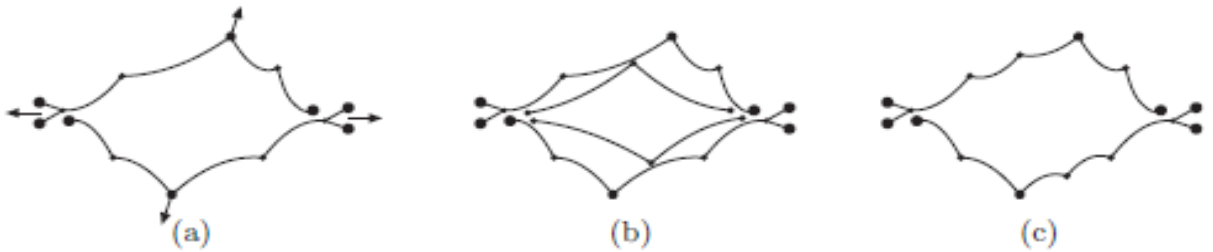
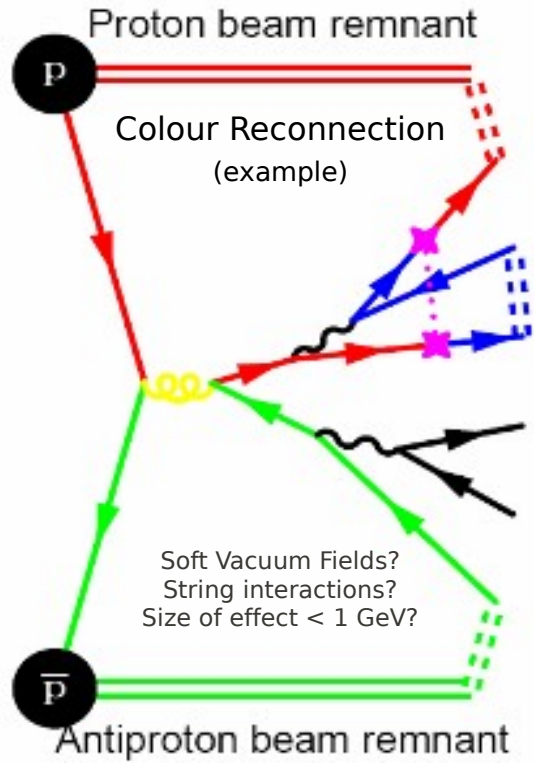


Fig. 2. (a) In a hard gluon-gluon subcollision the outgoing gluons will be colour-connected to the projectile and target remnants. Initial state radiation may give extra gluon kinks, which are ordered in rapidity. (b) A second hard scattering would naively be expected to give two new strings connected to the remnants. (c) In the fits to data the gluons are colour reconnected, so that the total string length becomes as short as possible.

Acta Physica Polonica B40,1981 (2009)

Color Reconnetion



Toy model (non-perturbative) color reconnection, applicable to any final state.

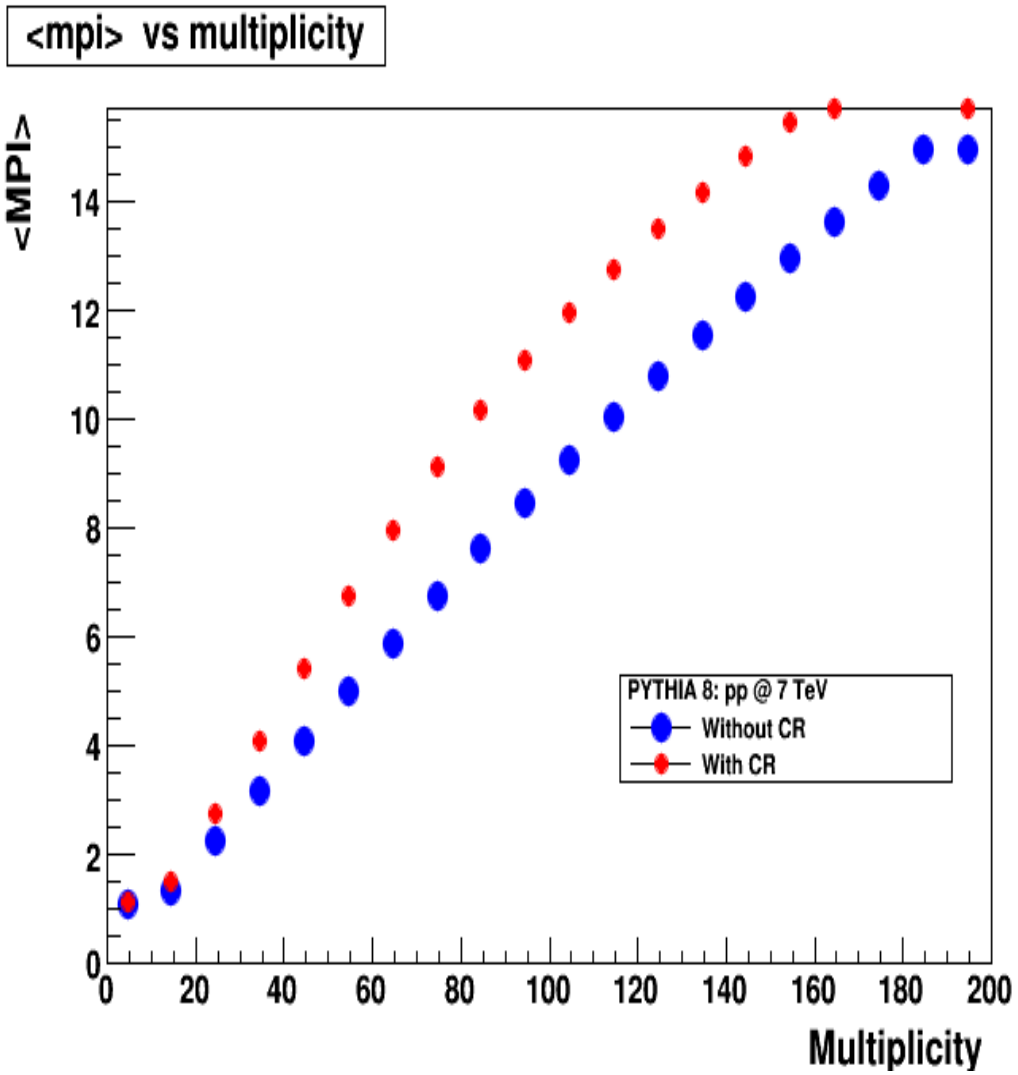
At hadronization time, each string piece has a probabiity to interact with other strings:

$$P_{rec} = 1 - (1 - \chi)^N$$

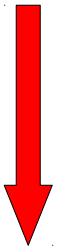
χ is the strength parameter (free parameter)
N = Number of multiple interactions in an event

Consequences of:
Color Reconnection
Multiple Parton Interaction

MPI and Color Reconnection

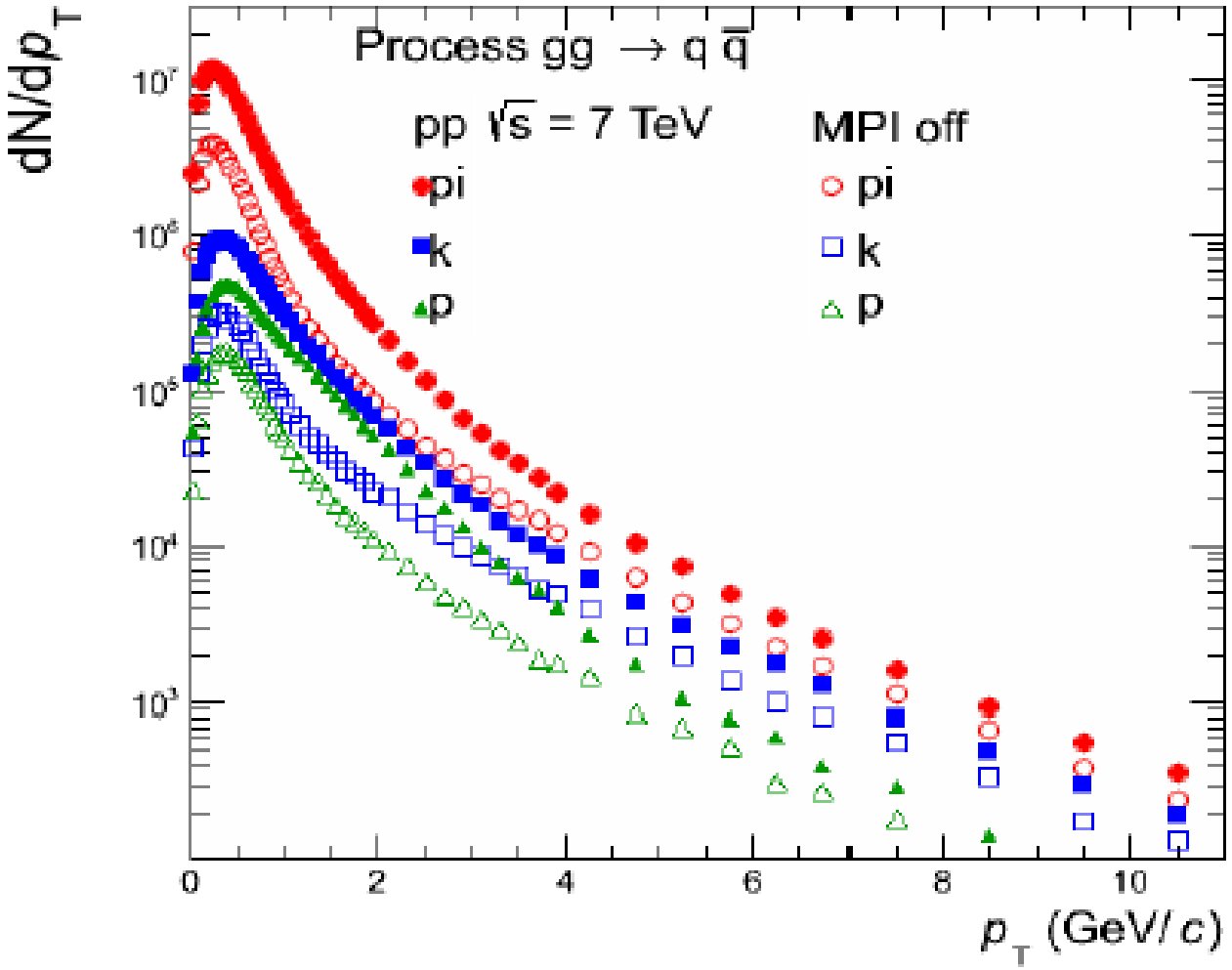


- *<MPI> rise up with multiplicity.*
- *CR introduce a not negligible effects in <MPI>, mainly at high multiplicity*



- *We need to study the high multiplicity events in details.*

Pt spectrum with / without MPI



MPI produce a harder pt respect to distributions without MPI. The effect is larger at low pt.

Effects of CR and MPI on p/π ratio

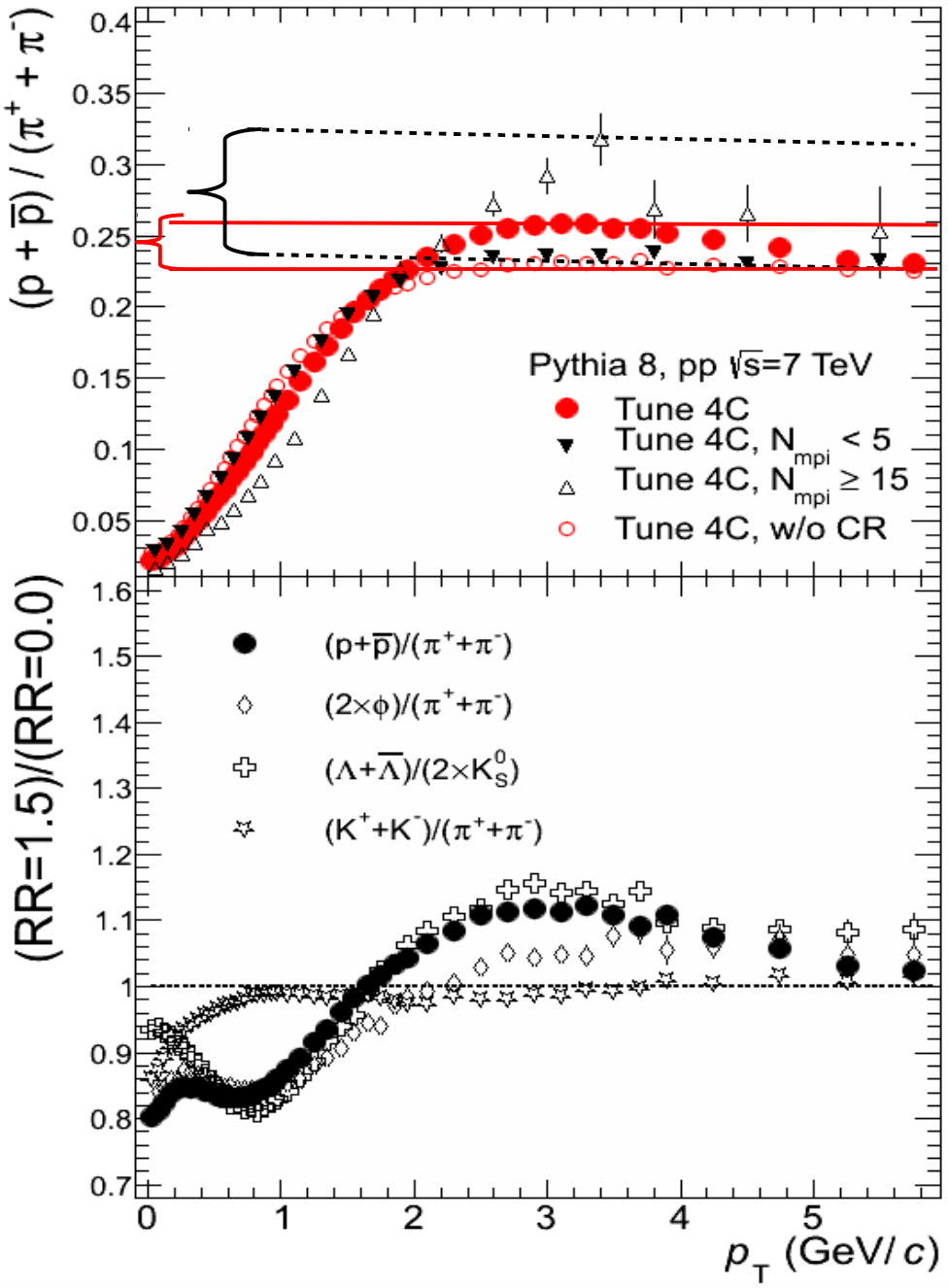
✔*It is observed that an increase of the MPI increase the ratio* p/π.

✔*Also is observed that CR produce an enhancement of the ratio around the maximum.*

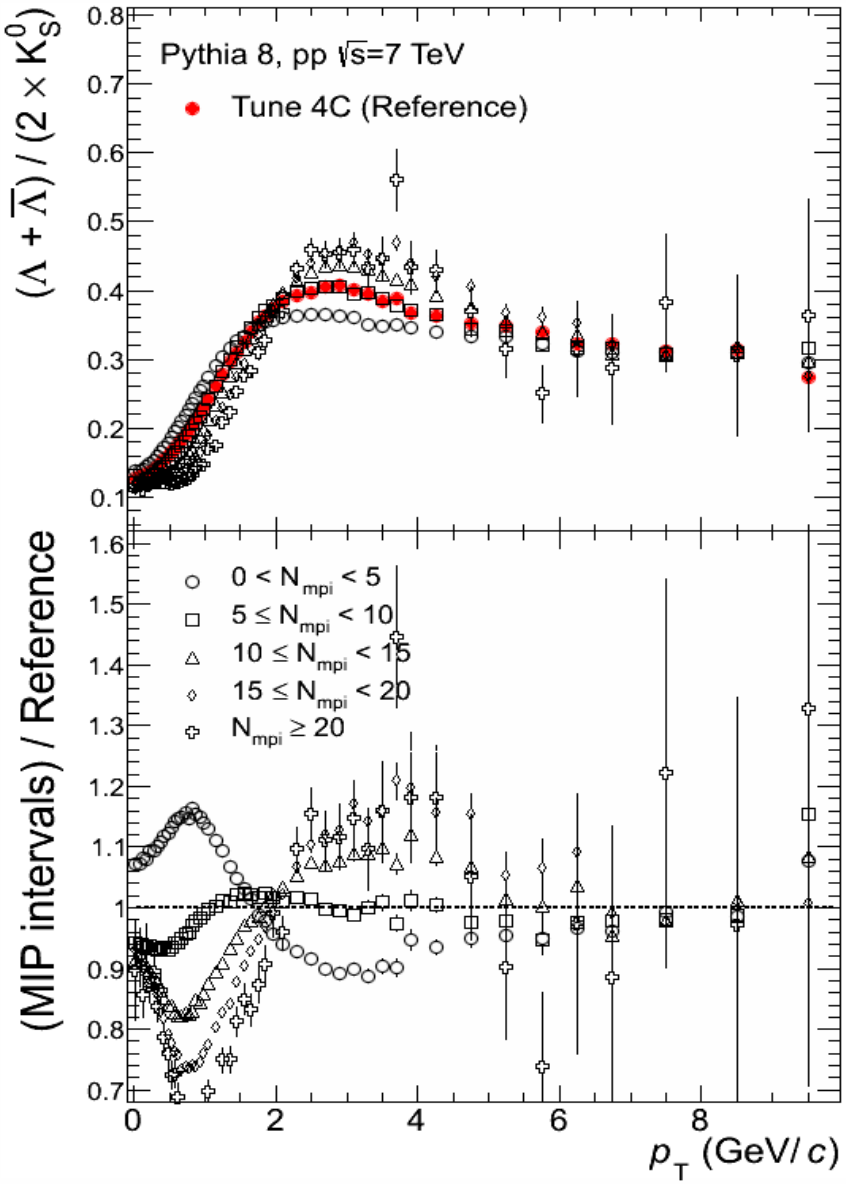
✔ϕ/π *and* p/π *are larger than* K/π *ratio, indicating a mass effect.*

✔*The Color Reconnection effects are clearly manifested in double ratio, around 3 GeV.*

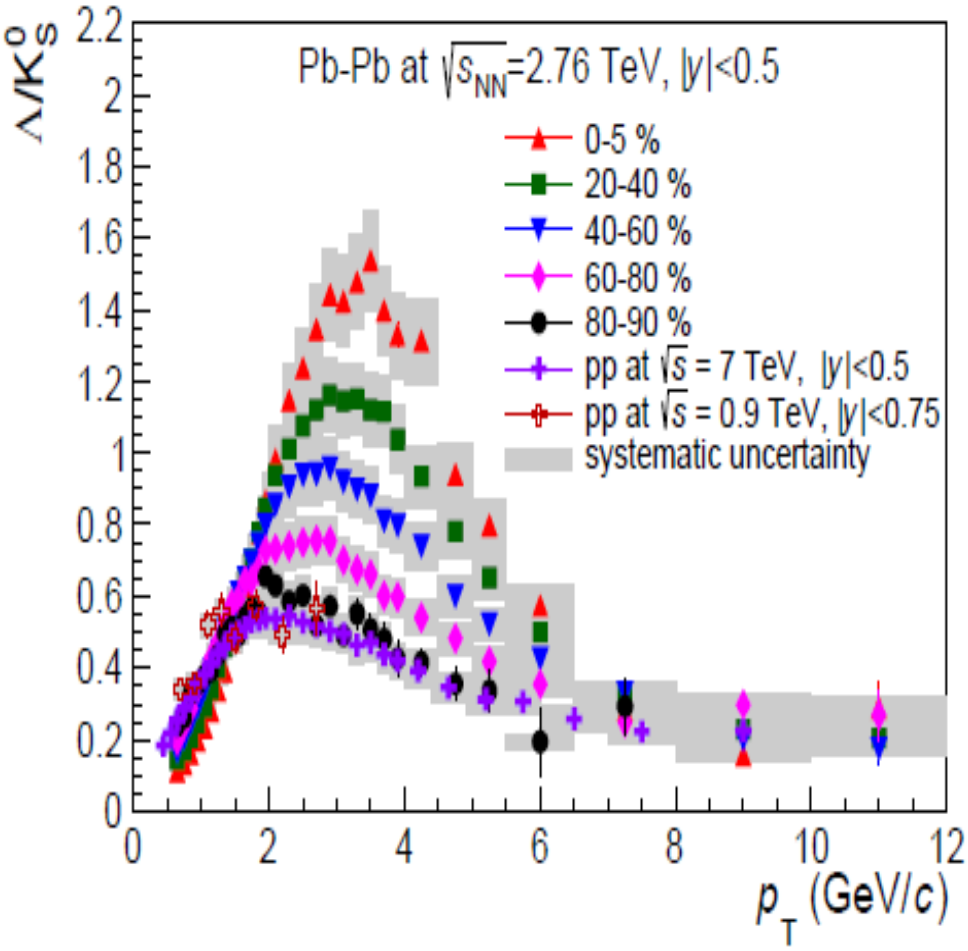
Phys. Rev. Lett. 111, 042001 (2013)



Effects of CR and MPI in Λ/K^0 ratio



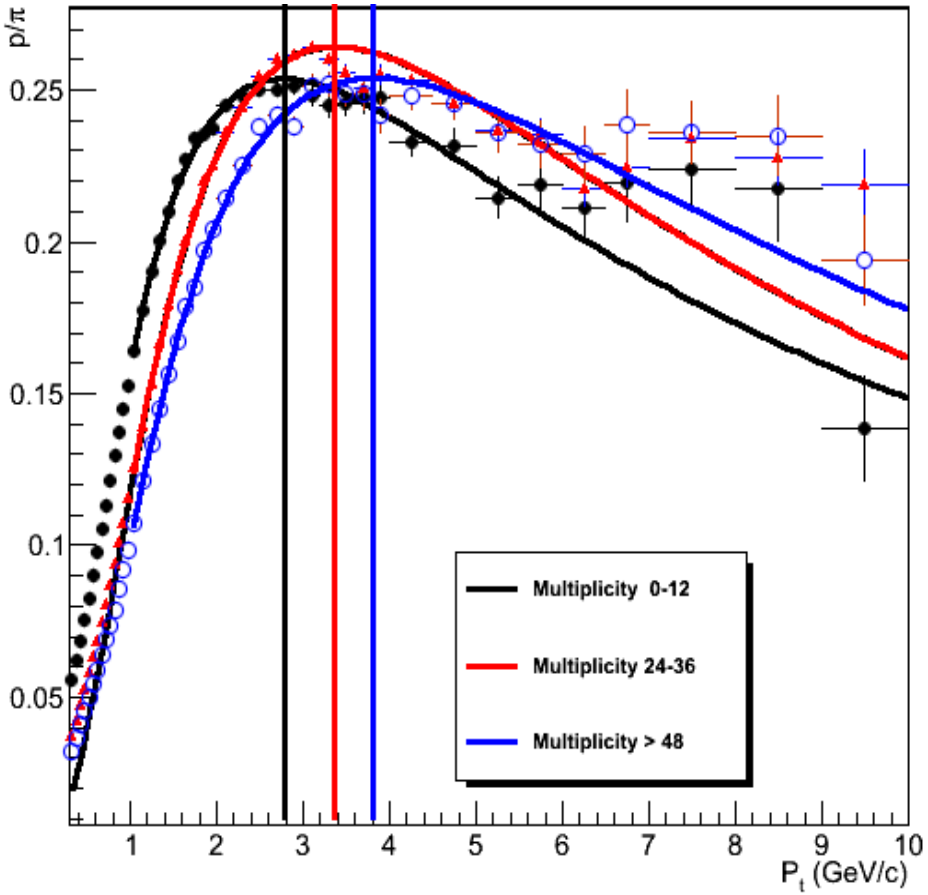
Phys. Rev. Lett. 111, 042001 (2013)



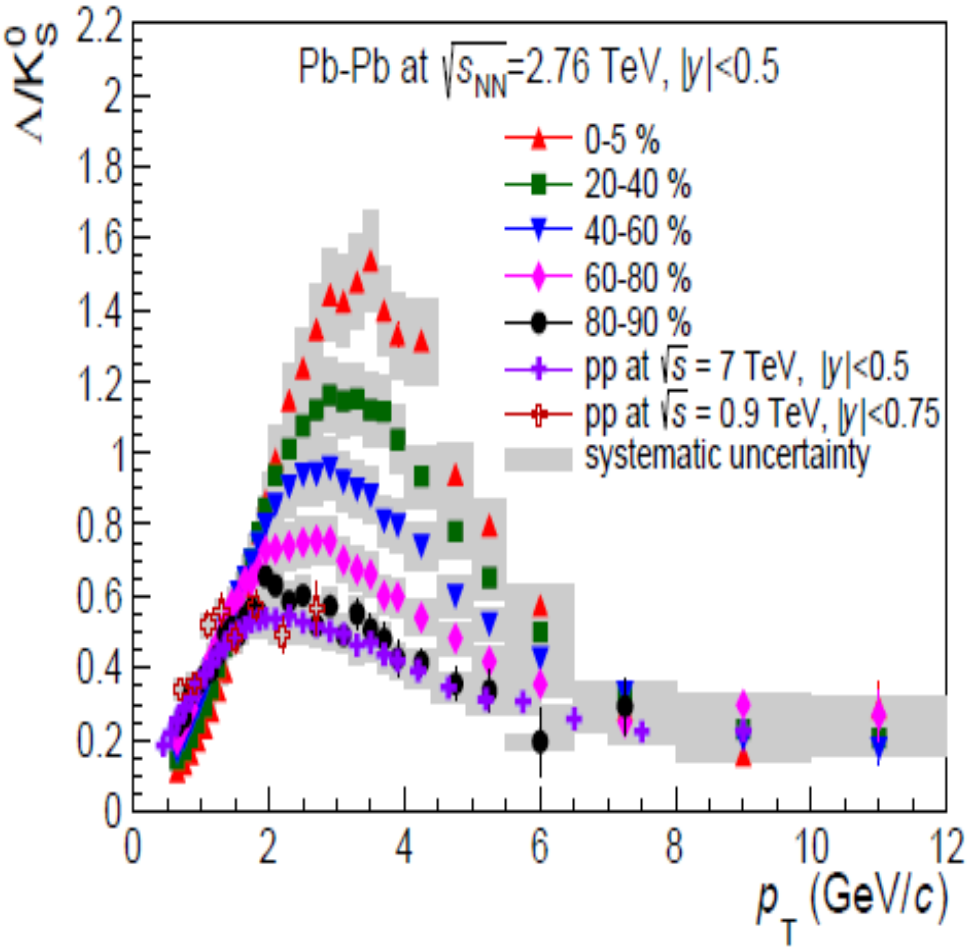
ALICE: Phys.Rev.Lett. 111 (2013) 222301

Shift in the maximum of p/π ratio

The ratio p/π as function of the multiplicity show shift in its maximum at higher pt when the multiplicity increase.



The ratio Λ/K as function of centrality bins show a shift in its maximum at higher p_t when the centrality increase.



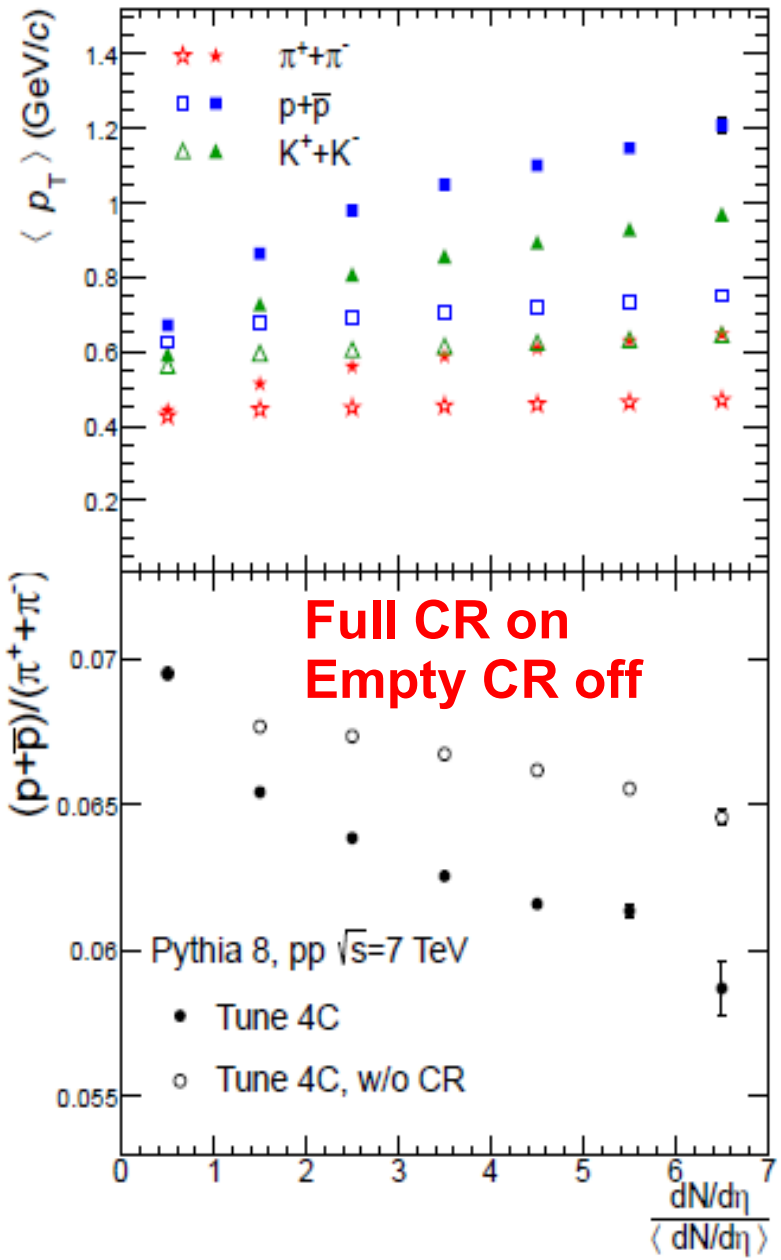
ALICE: Phys.Rev.Lett. 111 (2013) 222301

Effects of CR in $\langle p_t \rangle$

Transverse momentum increase as the multiplicity does. This is an observation at Tevatron, RHIC, ALICE, CMS.

The increase in $\langle p_t \rangle$ with CR respect to no CR, is well known phenomena in heavy ion collisions, and it is associated to MPI leading to a collective phenomena.

The p / π ratio with / without CR is affected by flow-like effects.

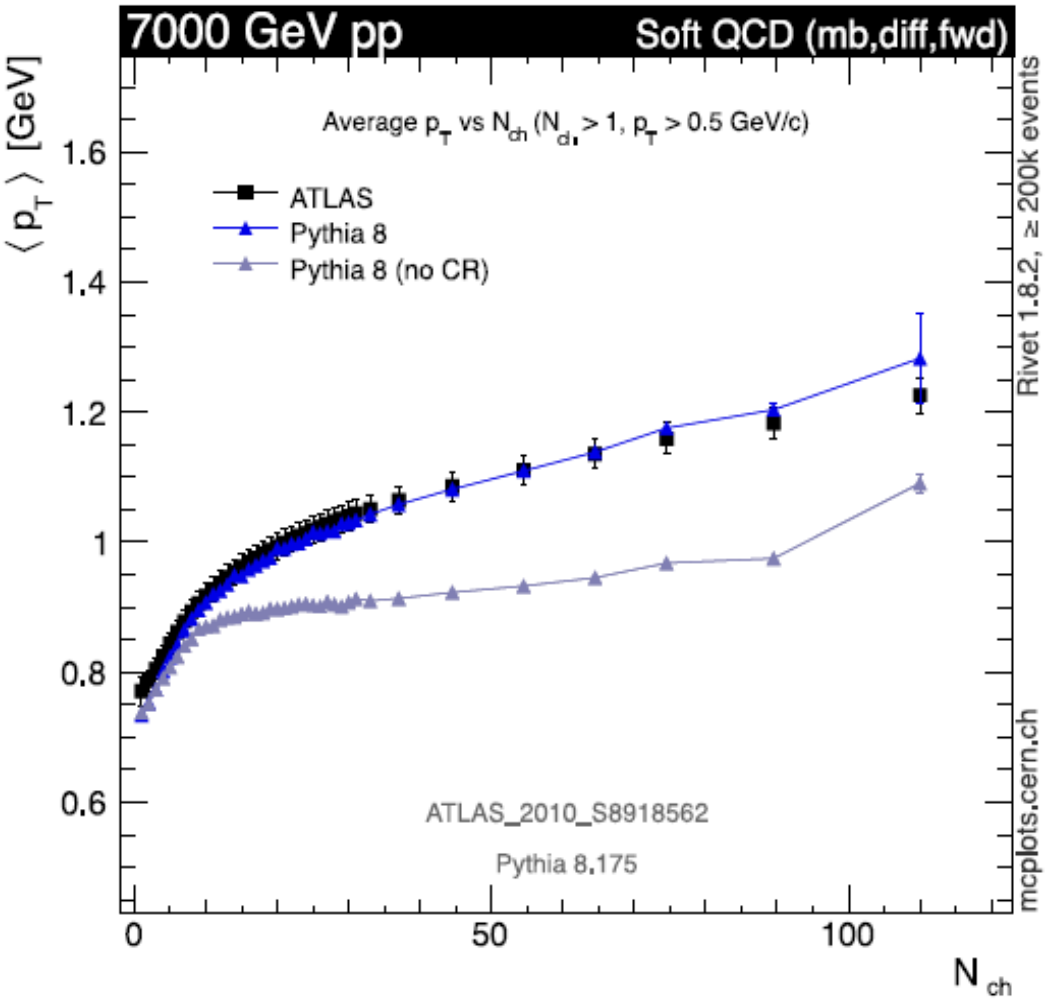


Effects of CR in $\langle p_t \rangle$

The increase in $\langle p_t \rangle$ with CR respect to no CR, is well known phenomena in heavy ion collisions, and it is associated to MPI leading to a collective phenomena.

CR switched on/off is need to explain ATLAS $\langle p_t \rangle$

.



ArXiv:1310.8073v1 [hep-ph]

Remarks

✔*Using Pythia 8 with / without CR we compute observables that reflect collective phenomena, up to certain p_t values. CR produce an enhancement of MPI implying an increase of the multiplicity, as well as the probability to enhancement the number of partons.*

✔*The increase of the number of partons is reflected as and enhancement of the number of hadrons, this is observed in heavy ion collisions. The excess of hadrons are eliminated in reconnection color process.*

✔ *Reconnection process induce flow-like effects:*

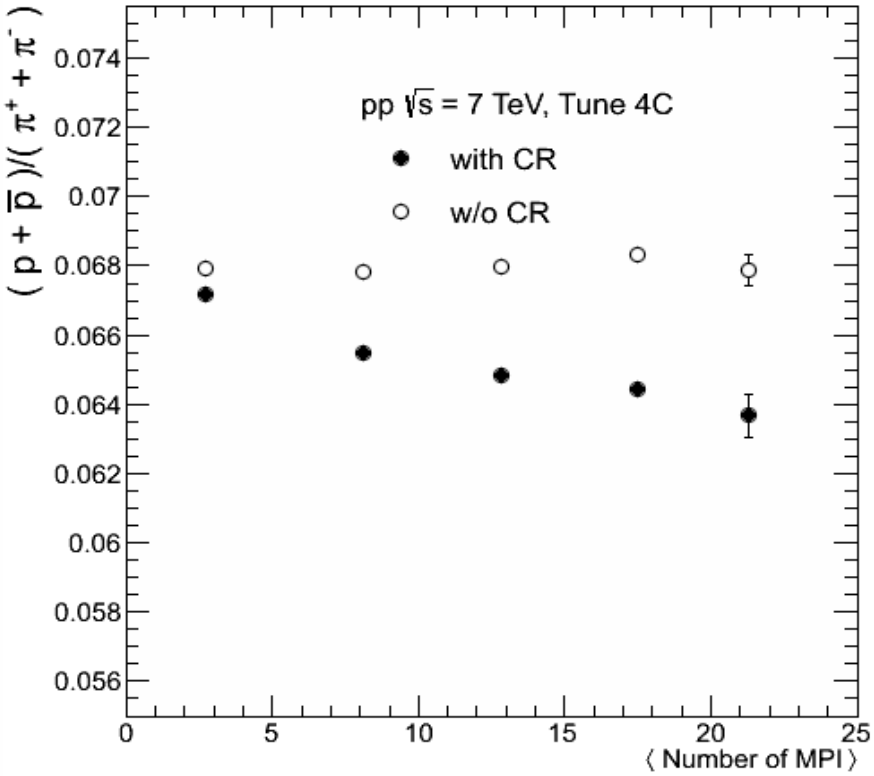
- ➢ *Effects on MPI*
- ➢ *Enhancement of ratio B/M and shift to high p_t of the maximum;*
- ➢ *Mass effects are observed on the ratio meson to meson*
- ➢ *Increase of $\langle p_t \rangle$ as function of the multiplicity, need to describe LHC data.*

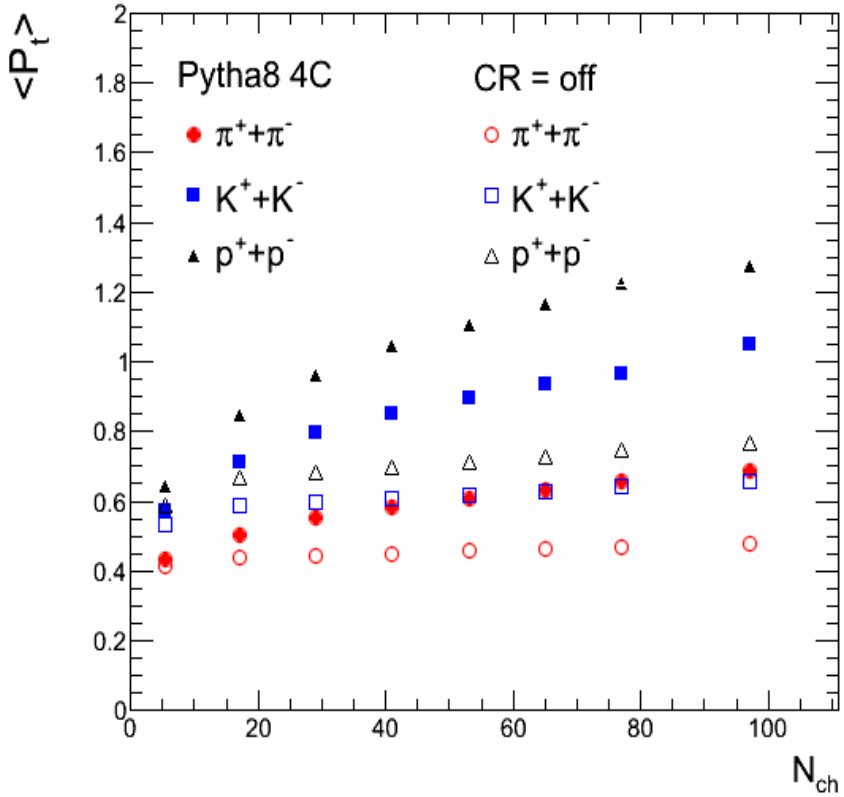
✔*Other possible studies under progress: ridge, etc.*

✔*Study of the pp events should be understand in MB and at high multiplicity*

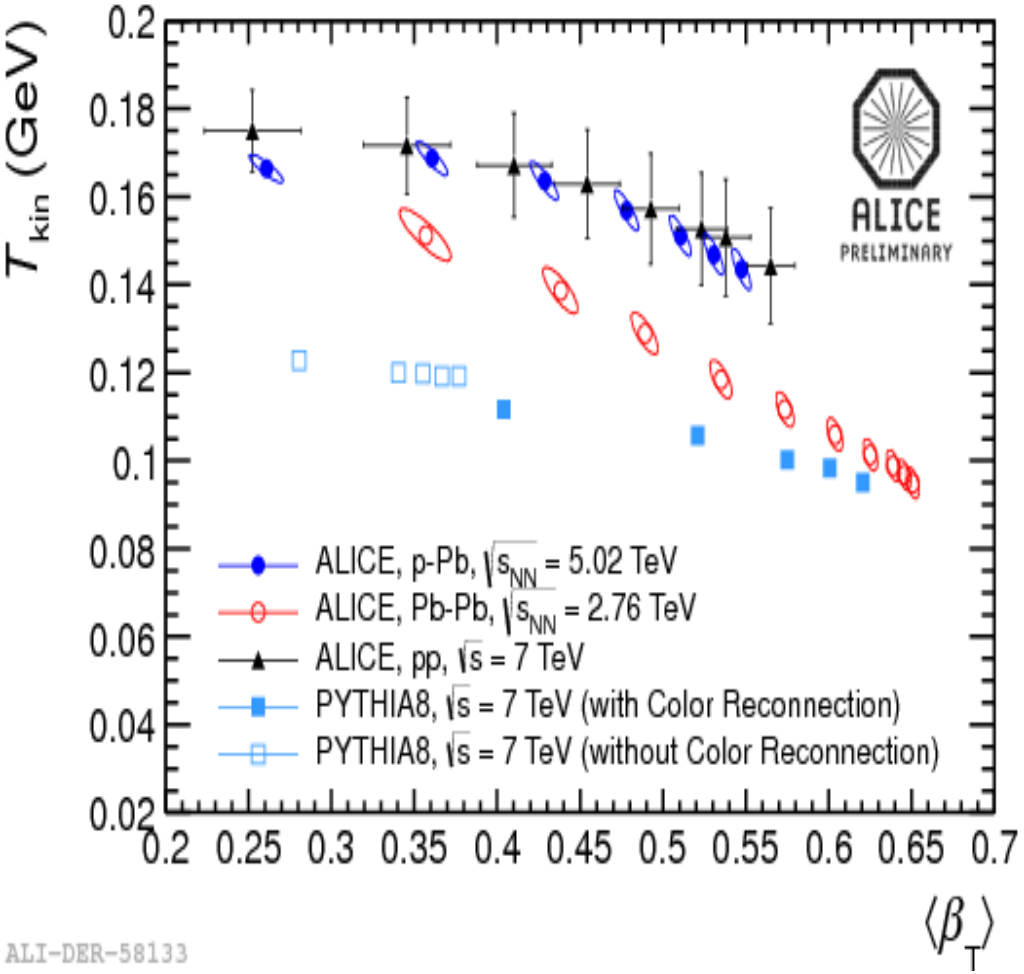
Effects of the color reconnection

p/pi ratio as function of MPI



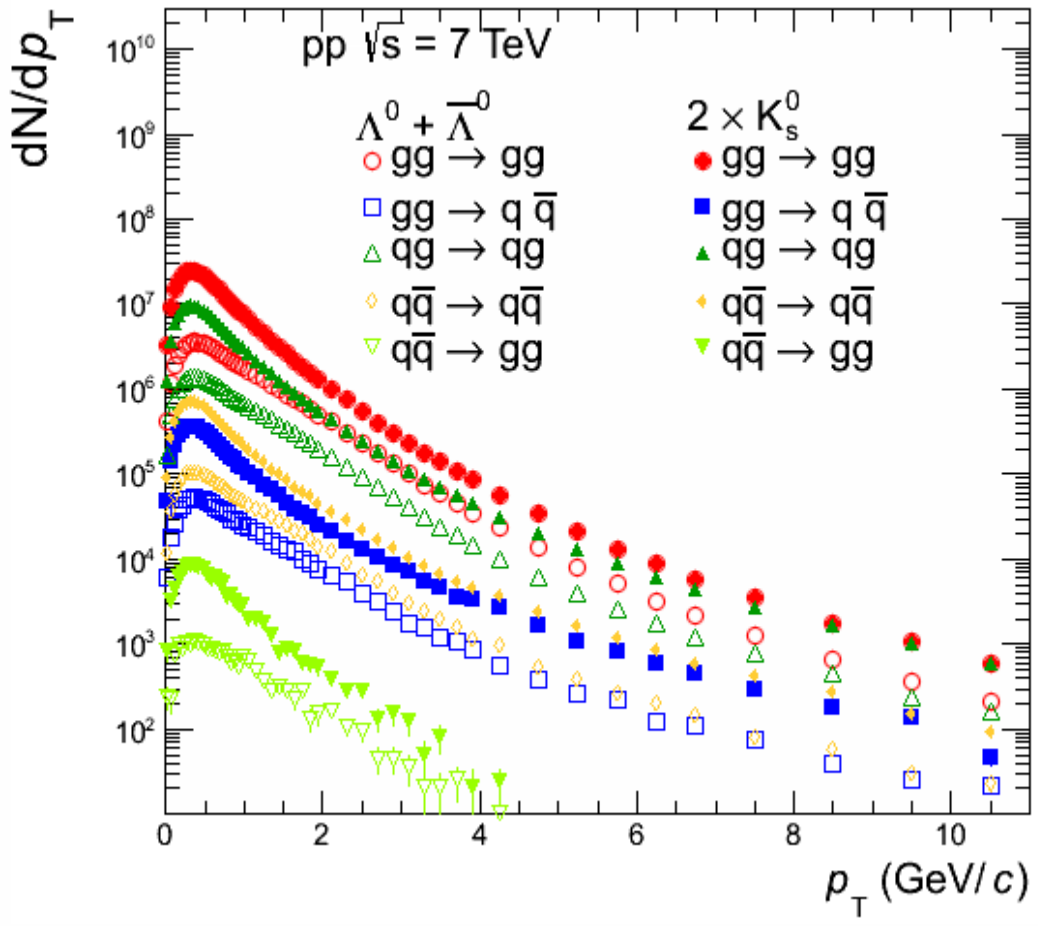


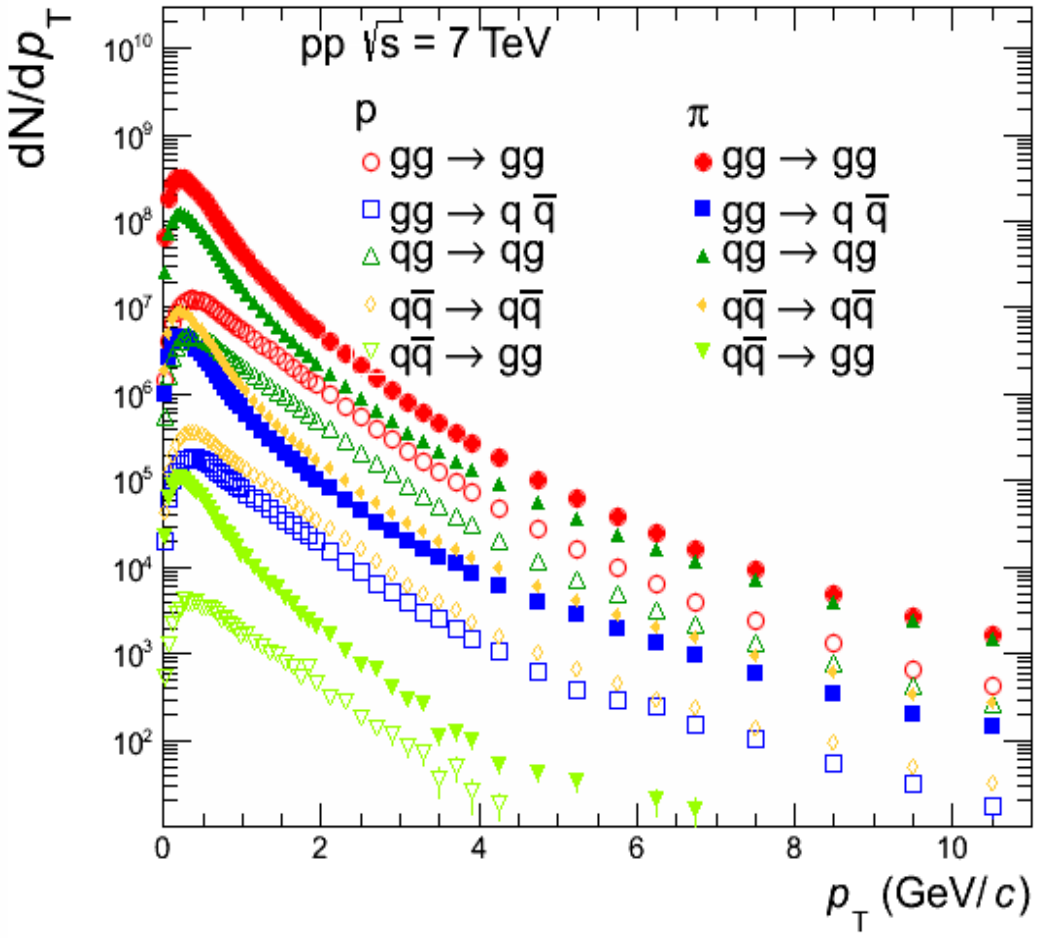
Blast Wave Fit in pp collisions!



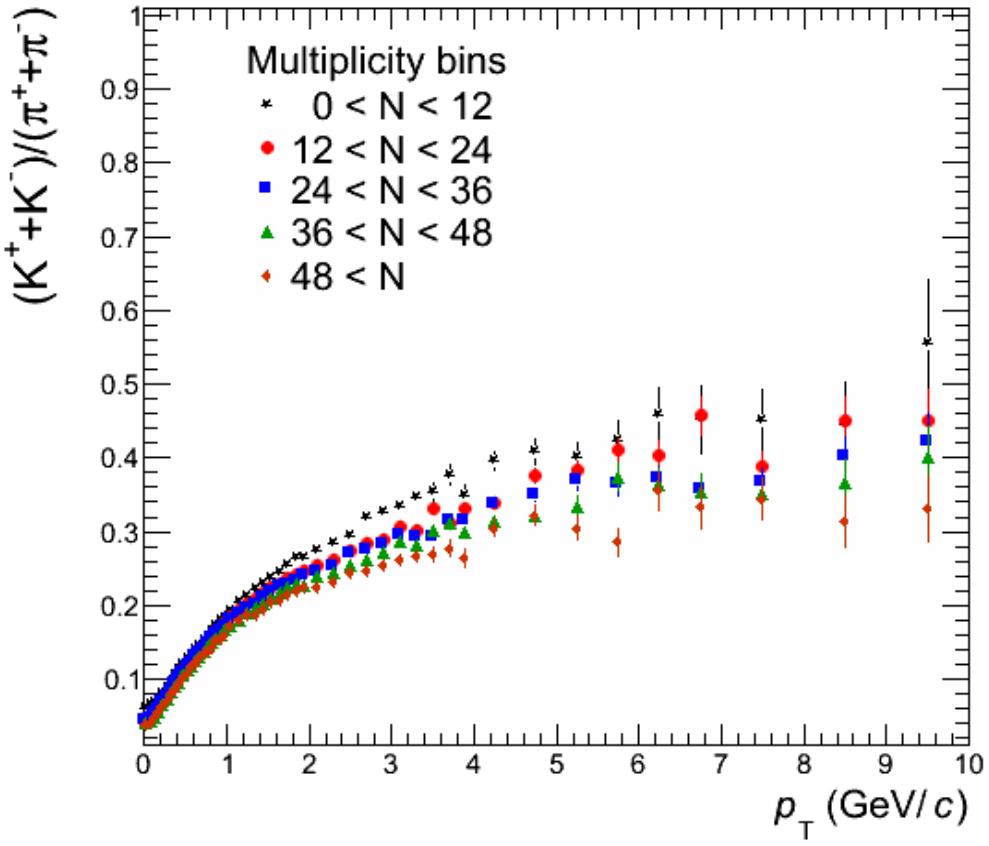
BWF allow to determine the kinetic freeze out and transverse expansion velocity, which appear in heavy ion collisions.

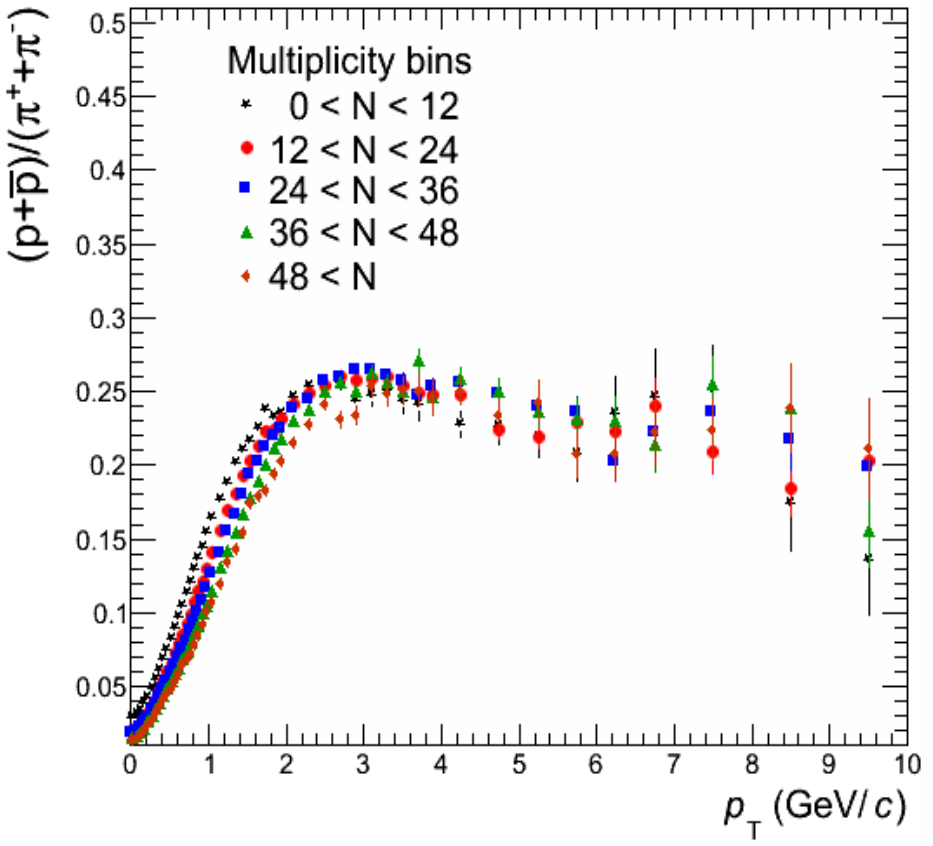
The BWF observed in pp collisions has the trend of the heavy ions, indicating possible collective effects

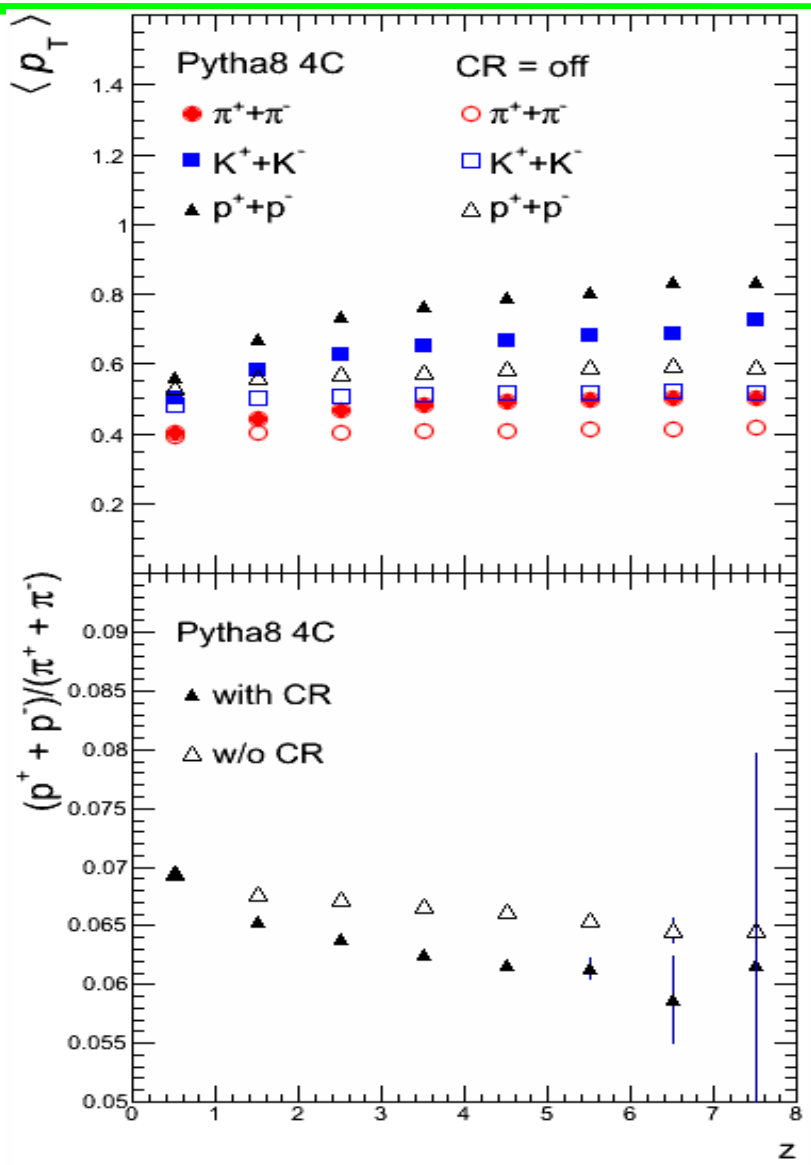

pp √s = 7 TeV
$\Lambda^0 + \overline{\Lambda}^0$
$2 \times K^0_s$
gg → gg
gg → q q̄
qg → qg
qq̄ → qq̄
qq̄ → gg
dN/dp_T
p_T (GeV/c)

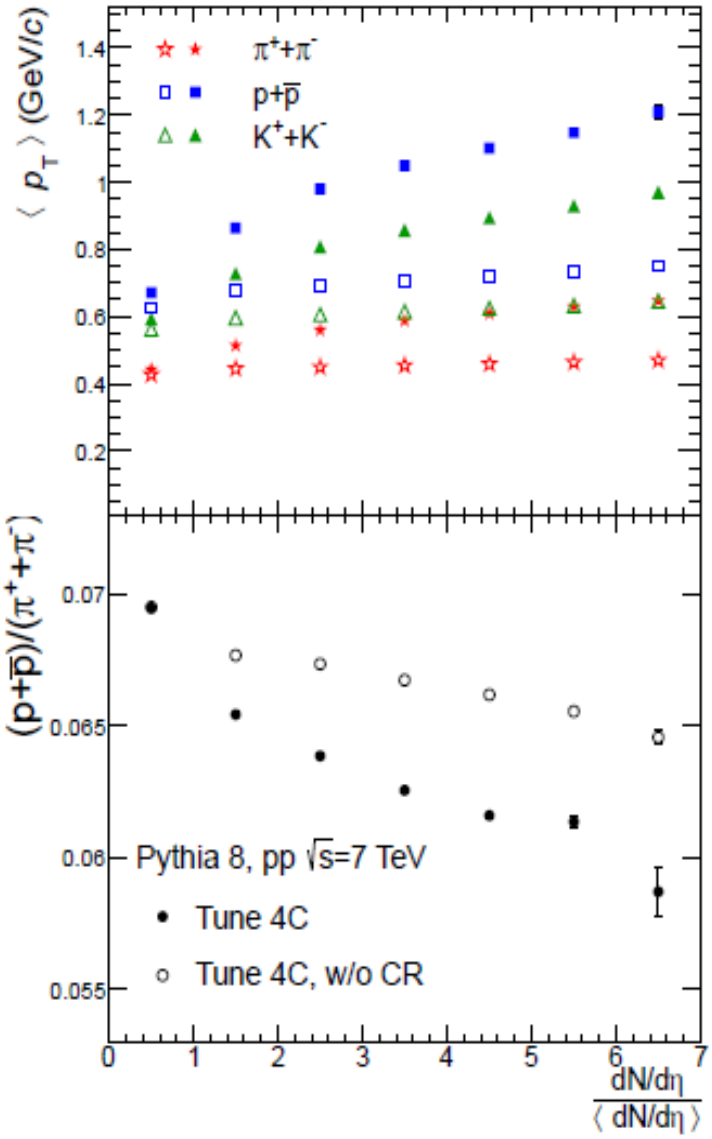

pp √s = 7 TeV
p
π
gg → gg
gg → q q̄
qg → qg
qq̄ → qq̄
qq̄ → gg
dN/dp_T
p_T (GeV/c)

The multiplicity is a variable that allow characterize properties of the system.






Pytha8 4C
CR = off
π⁺+π⁻
K⁺+K⁻
p⁺+p⁻
⟨ p_T ⟩
Pytha8 4C
with CR
w/o CR
(p⁺ + p⁻)/(π⁺ + π⁻)
z


π⁺+π⁻
p+p̄
K⁺+K⁻
⟨ p_T ⟩ (GeV/c)
(p+p̄)/(π⁺+π⁻)
Pythia 8, pp √s=7 TeV
Tune 4C
Tune 4C, w/o CR
dN/dη
⟨ dN/dη ⟩