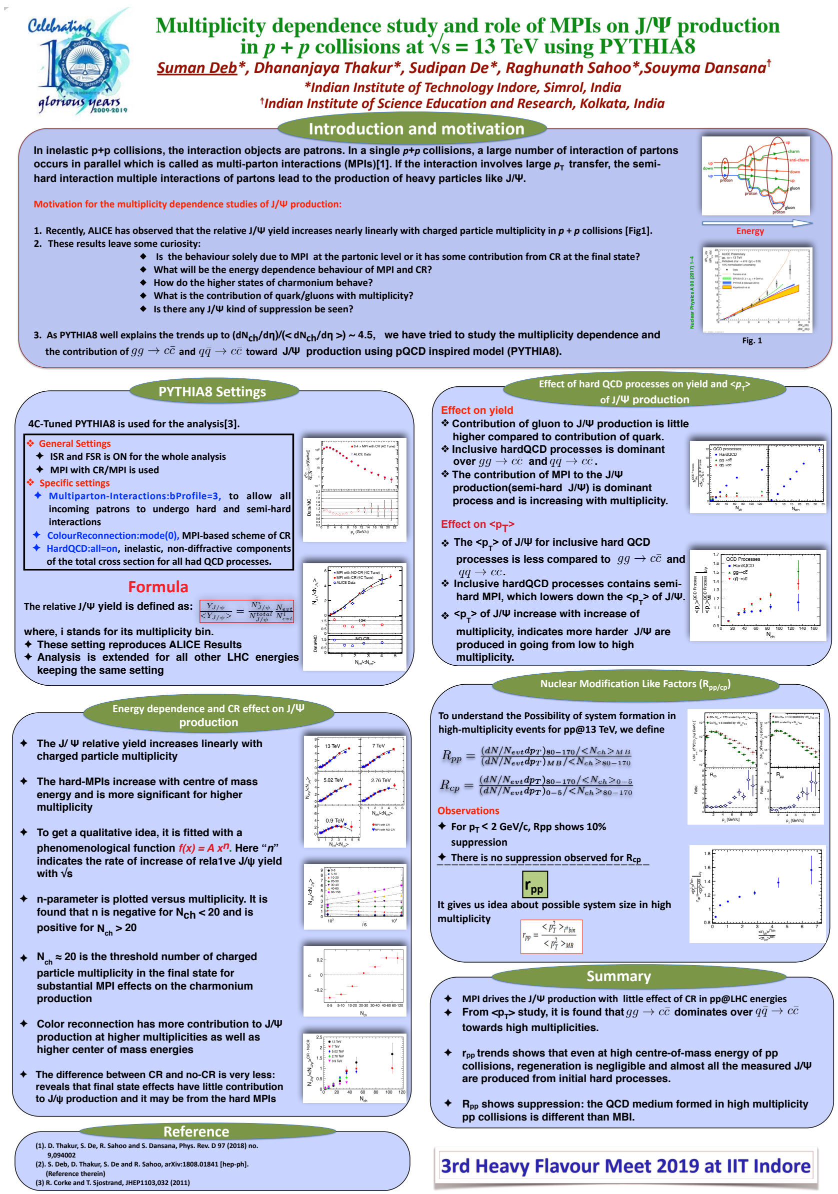
Multiplicity dependence study and role of MPIs on J/Ψ production in *p+p* collisions at √s = 13 TeV using PYTHIA8

Suman Deb

Indian Institute of Technology Indore, India

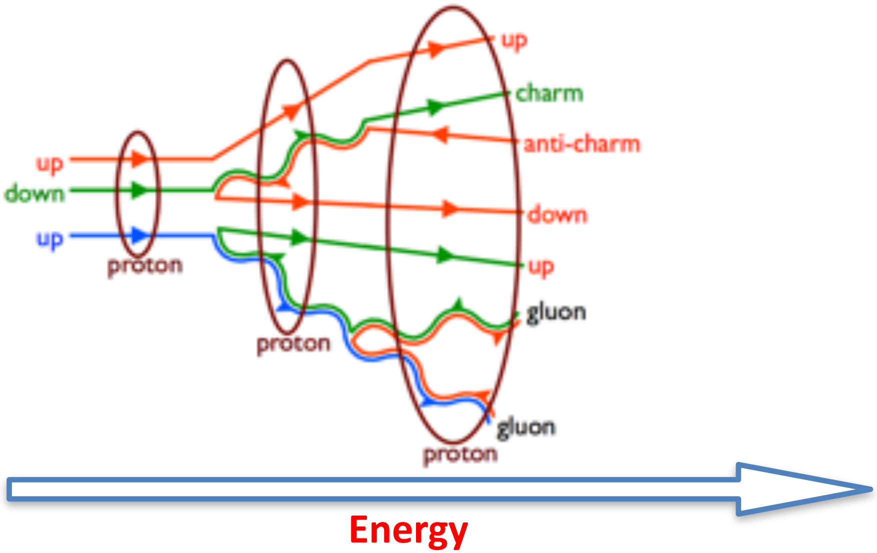


Flash Talk, 3rd Heavy Flavour Meet 2019

(Phys.Rev. D97 (2018) no.9, 094002, arXiv:1808.01841)

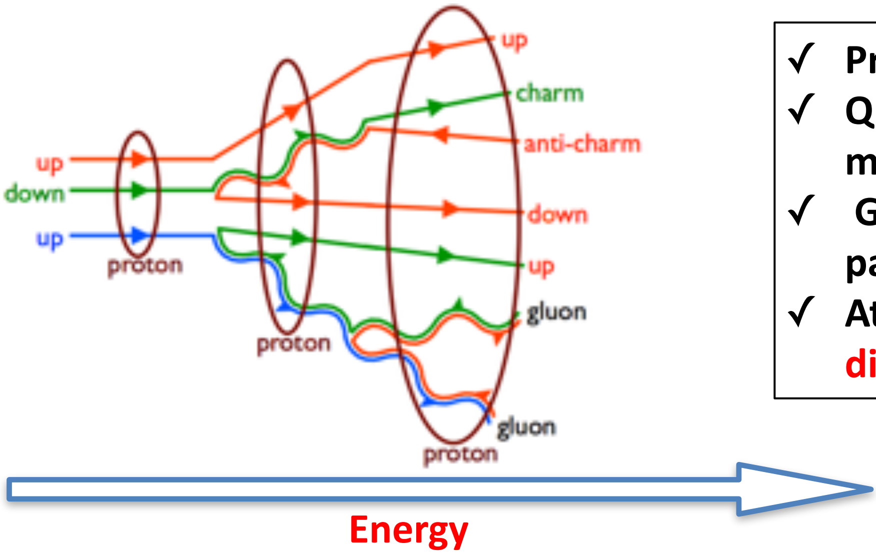
Motivation: The pp Collisions

❖ **At very high LHC energies, protons are no more a point particle.**



Motivation: The pp Collisions

❖ **At very high LHC energies, protons are no more a point particle.**

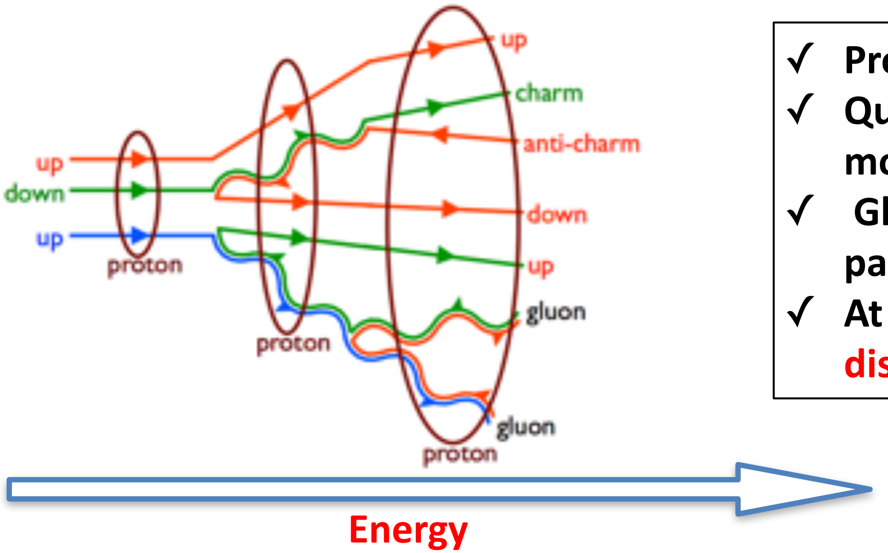


- ✓ **Proton contains partons (quark and gluons)**
- ✓ **Quark radiates gluons and the gluon density is more at very high energy.**
- ✓ **Gluon splits in to quark and anti-quarks or a pairs or gluons.**
- ✓ **At very high energy proton is treated as "Parton distribution"**

T. SjÖstrand, M. van Zijl, Phys. ReV. D36 (1987)

Motivation: The pp Collisions

❖ **At very high LHC energies, protons are no more a point particle.**



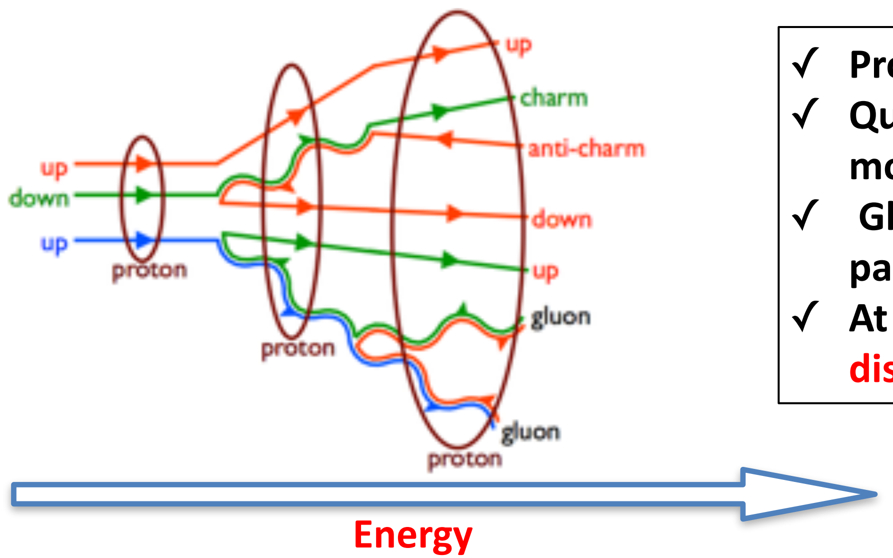
- ✓ **Proton contains partons (quark and gluons)**
- ✓ **Quark radiates gluons and the gluon density is more at very high energy.**
- ✓ **Gluon splits in to quark and anti-quarks or a pairs or gluons.**
- ✓ **At very high energy proton is treated as "Parton distribution"**

T. SjÖstrand, M. van Zijl, Phys. ReV. D36 (1987)

Two interesting questions !!

Motivation: The pp Collisions

❖ **At very high LHC energies, protons are no more a point particle.**



- ✓ **Proton contains partons (quark and gluons)**
- ✓ **Quark radiates gluons and the gluon density is more at very high energy.**
- ✓ **Gluon splits in to quark and anti-quarks or a pairs or gluons.**
- ✓ **At very high energy proton is treated as "Parton distribution"**

T. SjÖstrand, M. van Zijl, Phys. ReV. D36 (1987)

Two interesting questions !!

Associated Event activity

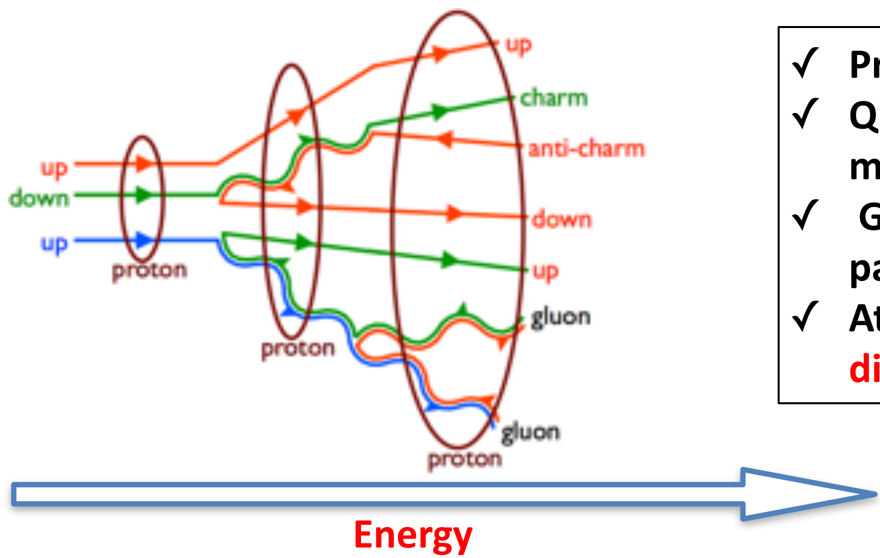
- **Multipartonic interaction (MPI)**
- **Color-reconnection**
- **hadronic activity like**

$q\bar{q} \rightarrow c\bar{c} \quad gg \rightarrow c\bar{c}$

PHYSICAL REVIEW D96,114019 (2017)

Motivation: The pp Collisions

❖ At very high LHC energies, protons are no more a point particle.



- ✓ Proton contains partons (quark and gluons)
- ✓ Quark radiates gluons and the gluon density is more at very high energy.
- ✓ Gluon splits in to quark and anti-quarks or a pairs or gluons.
- ✓ At very high energy proton is treated as "Parton distribution"

T. SjÖstrand, M. van Zijl, Phys. ReV. D36 (1987)

Two interesting questions !!

Associated Event activity

- Multipartonic interaction (MPI)
- Color-reconnection
- hadronic activity like

$q\bar{q} \rightarrow c\bar{c} \quad gg \rightarrow c\bar{c}$

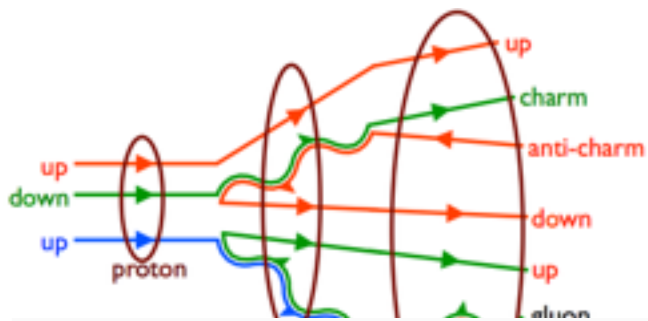
PHYSICAL REVIEW D96,114019 (2017)

QGP signature in high-multiplicity pp events

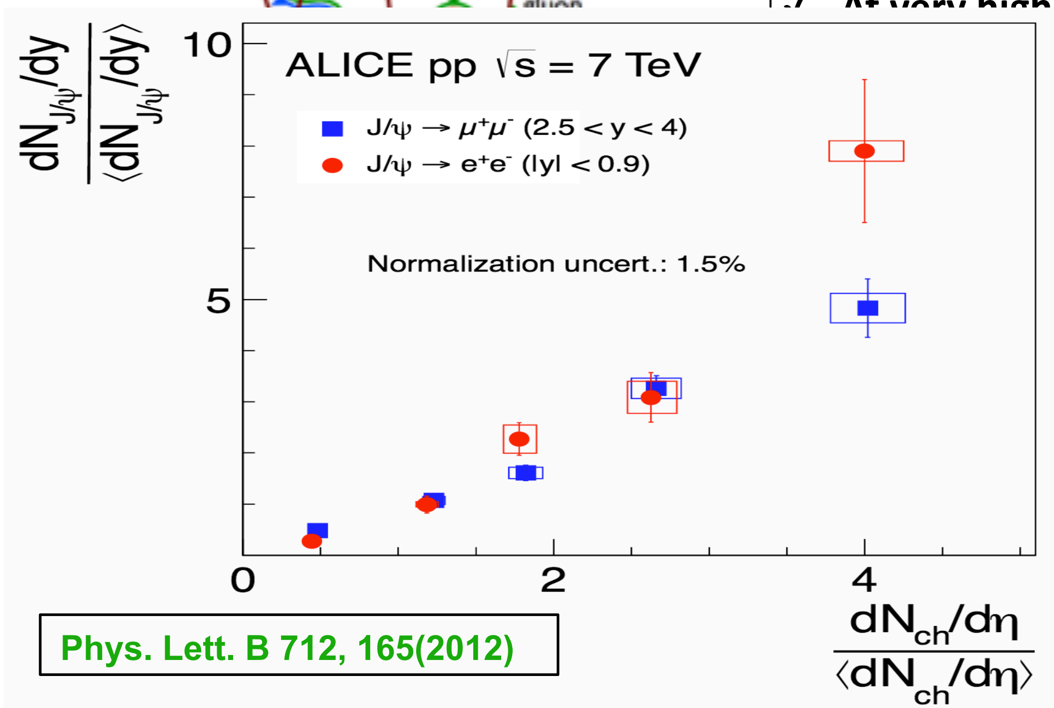
- Strangeness enhancement (Nature Physics 13, 535–539 (2017))
- Indication of collective behavior at $\sqrt{s}$ = 0.9, 2.76 and 7 TeV. (W. Li, et al., CMS Collaboration, J. Phys. G 38 (2011) 124027, V. Khachatryan, et al., CMS Collaboration, JHEP 1009 (2010) 091)
- J/Ψ Suppression?

Motivation: The pp Collisions

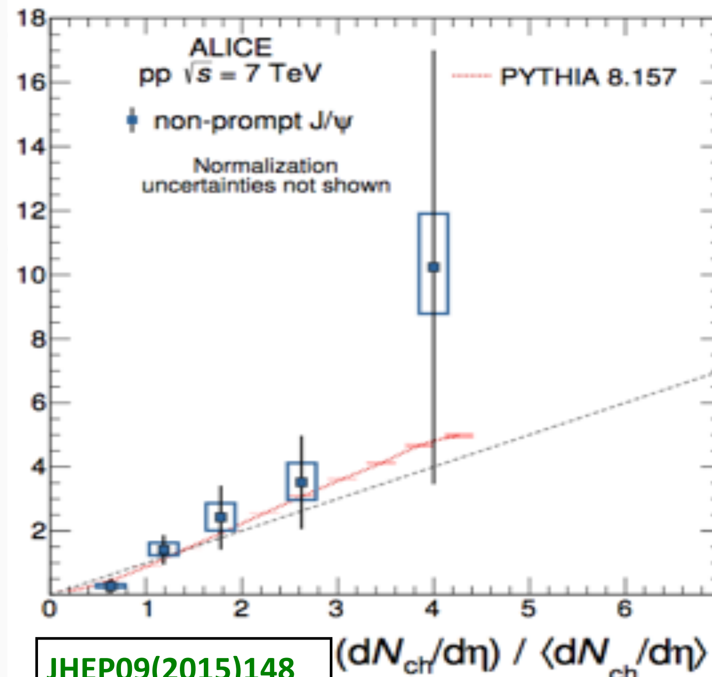
❖ **At very high LHC energies, protons are no more a point particle.**



- ✓ **Proton contains partons (quark and gluons)**
- ✓ **Quark radiates gluons and the gluon density is more at very high energy.**
- ✓ **Gluon splits in to quark and anti-quarks or a pairs or gluons.**
- ✓ **At very high energy proton is treated as “Parton**



Phys. Lett. B 712, 165(2012)



JHEP09(2015)148

❖ **Some of the question can be answered by pQCD inspired model like PYTHIA8, which describes well the multiplicity dependence behaviour of particle production.**

Simulating J/Ψ using PYTHIA8

❖ **Advantages of PYTHIA8 over PYTHIA6 is inclusion of MPI in harder scale**

- **Which can produce "c " and "b" quarks via first 2 -> 2 partonic interaction**
- **Finite probability of production in subsequent hard interactions**

❖ **" 4C Tune" is used, which well explains the charged particle multiplicity in pp@ 7 TeV**

(J. High Energy Phys. 03 (2011)032, Phys. Rev. D 95 , 014016 (2017))

The detailed about the setting is in back up slide

Simulating J/Ψ using PYTHIA8

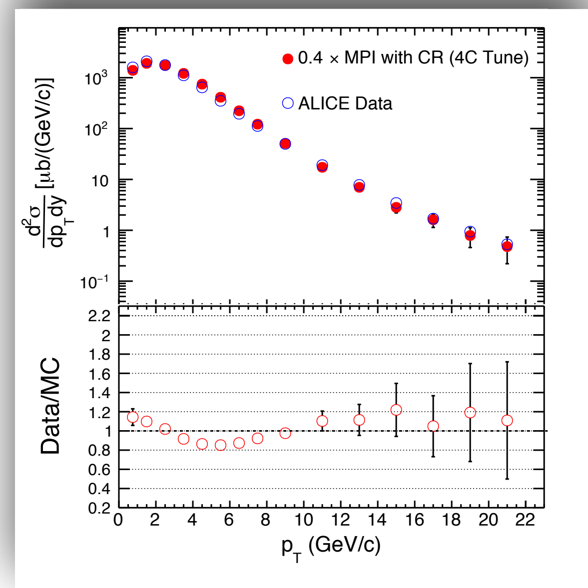
❖ **Advantages of PYTHIA8 over PYTHIA6 is inclusion of MPI in harder scale**

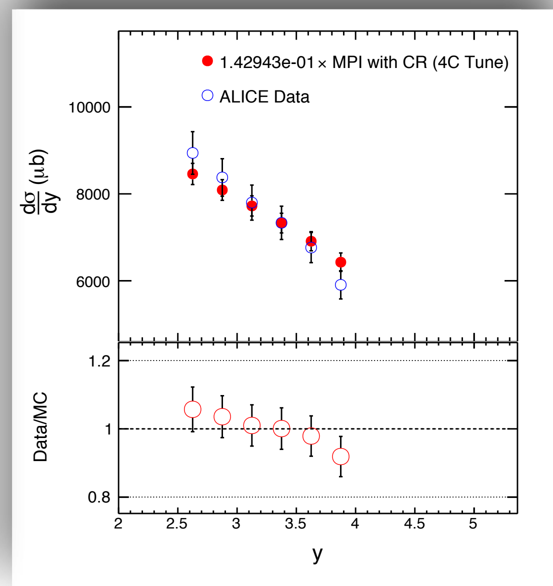
- **Which can produce "c " and "b" quarks via first 2 -> 2 partonic interaction**
- **Finite probability of production in subsequent hard interactions**

❖ **" 4C Tune" is used, which well explains the charged particle multiplicity in pp@ 7 TeV**

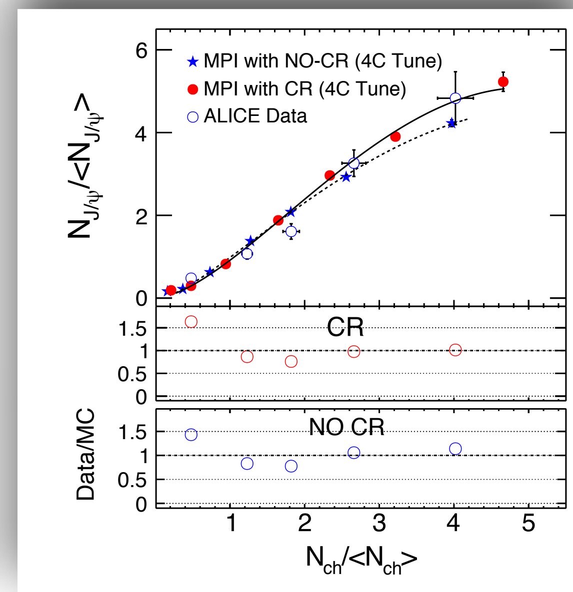
(J. High Energy Phys. 03 (2011)032, Phys. Rev. D 95 , 014016 (2017))

The detailed about the setting is in back up slide





Eur. Phys. J. C77, 392 (2017)



Phys. Lett. B712, 165 (2012)

❖ **PYTHIA8 is well explaining the experimental data!**

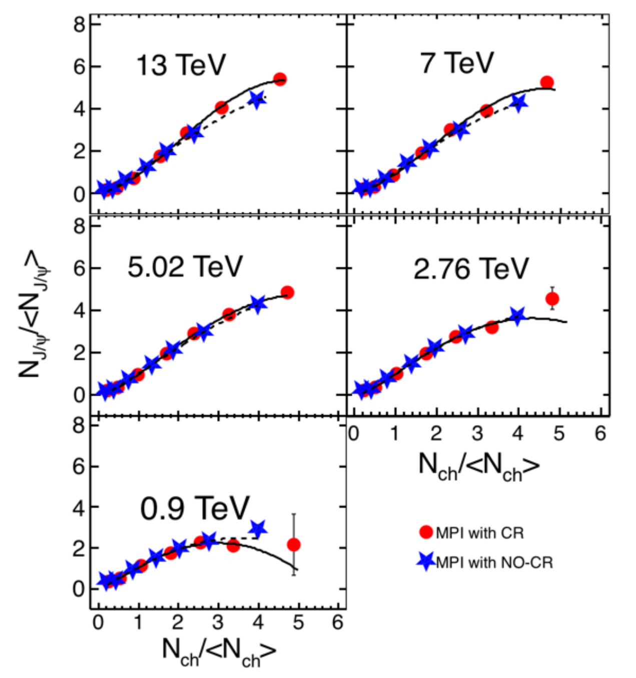
Energy dependence of J/Ψ production

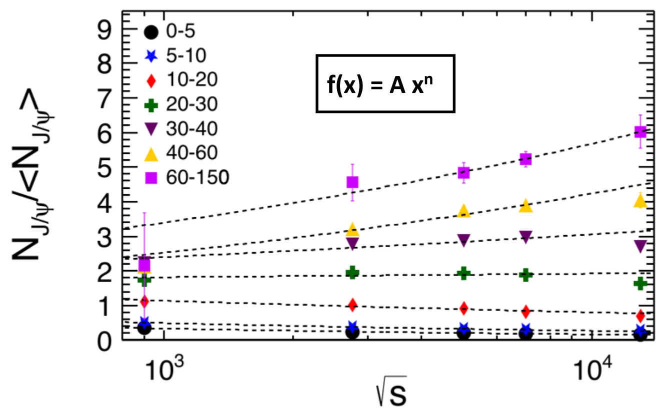
- **The J/Ψ relative yield increases linearly with charged particle multiplicity.**
- **The saturation of relative J/Ψ yield towards higher multiplicity bins needs to be understood.**
- **The hard-MPIs increase with center-of-mass energy**

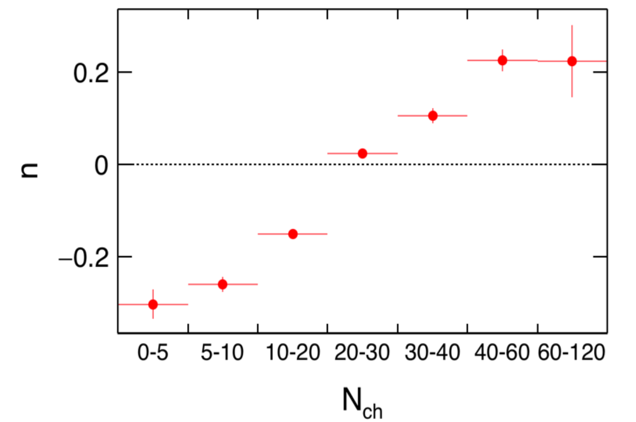
  - **n-parameter vs. N_{ch}**

    ✓**negative for $N_{ch} < 20$**
    ✓**positive for $N_{ch} > 20$**

❖ **The event activity beyond $N_{ch} \approx 20$ is more prominent to the production of charmonia**





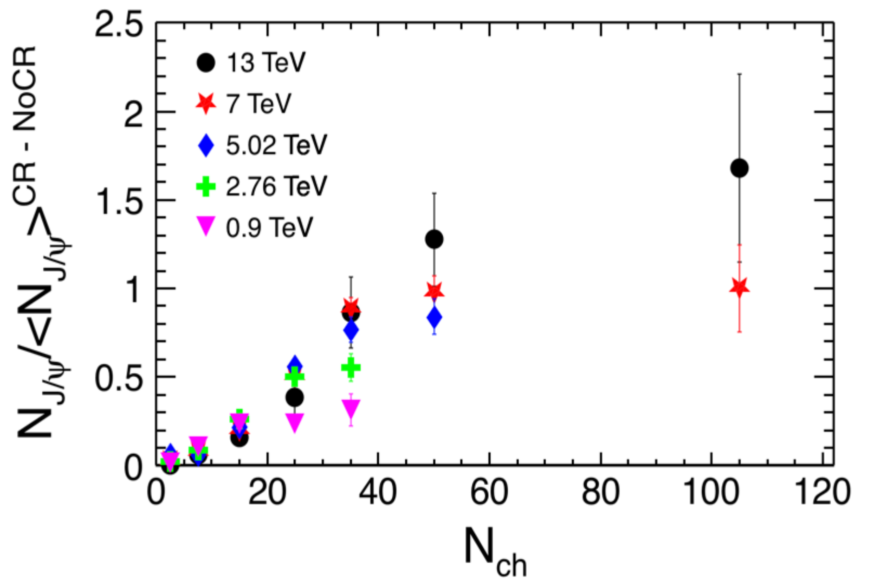


(**Phys.Rev. D97 (2018), 094002**)

✓ **"n" indicates the rate of increase of relative J/Ψ with √s**

Effect of color reconnection on J/Ψ production

- Color reconnection has more contribution to J/Ψ production at higher multiplicities as well as higher center of mass energies.



(Phys.Rev. D97 (2018), 094002)

Expected reasons

✓ High density of color partons

✓ Substantial overlap of color strings in position and momentum space leads to higher probability of color reconnection

✓ Partons from two MPIs connect, hence probability of combination of charm and anti-charm quark increases

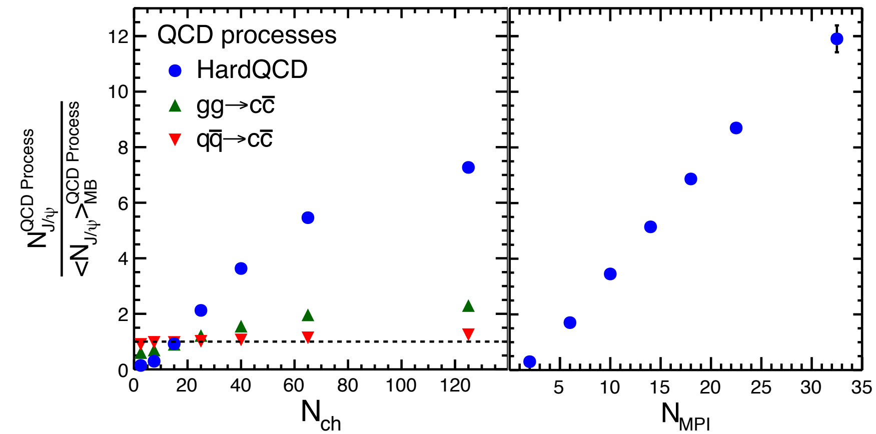
Conclusion of the study

✓ At the final state, CR has less contribution to J/Ψ production. Most of the J/Ψs are coming from the initial event activity.

Multiplicity dependence of quark/gluon contribution to J/Ψ production

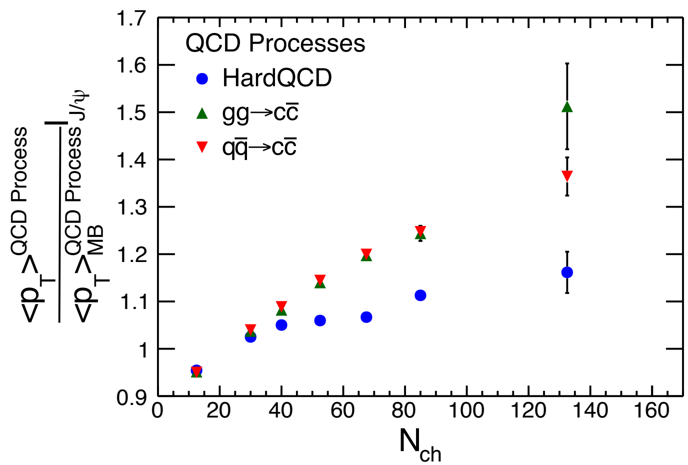
The effect to yield of J/Ψ

- **Contribution of gluon to J/Ψ production is little higher compared to contribution of quark.**
- **Inclusive hardQCD processes is dominant over** $gg \to c\bar{c}$ **and** $q\bar{q} \to c\bar{c}$ **.**
- **The contribution of MPI to the J/Ψ production (semi-hard J/ψ) is dominant process and is increasing with multiplicity.**



Effect to <p$_T$> of J/Ψ

- **The <p$_T$> of J/Ψ for inclusive hard QCD processes is less compared to** $gg \to c\bar{c}$ **and** $q\bar{q} \to c\bar{c}$**.**
- **Inclusive hardQCD processes contains semi-hard MPI is lowering the <p$_T$> of J/Ψ.**
- **With increase of multiplicity, <p$_T$> of J/Ψ is increasing, indicates more harder J/Ψs are produced as we go from low multiplicity to high multiplicity.**



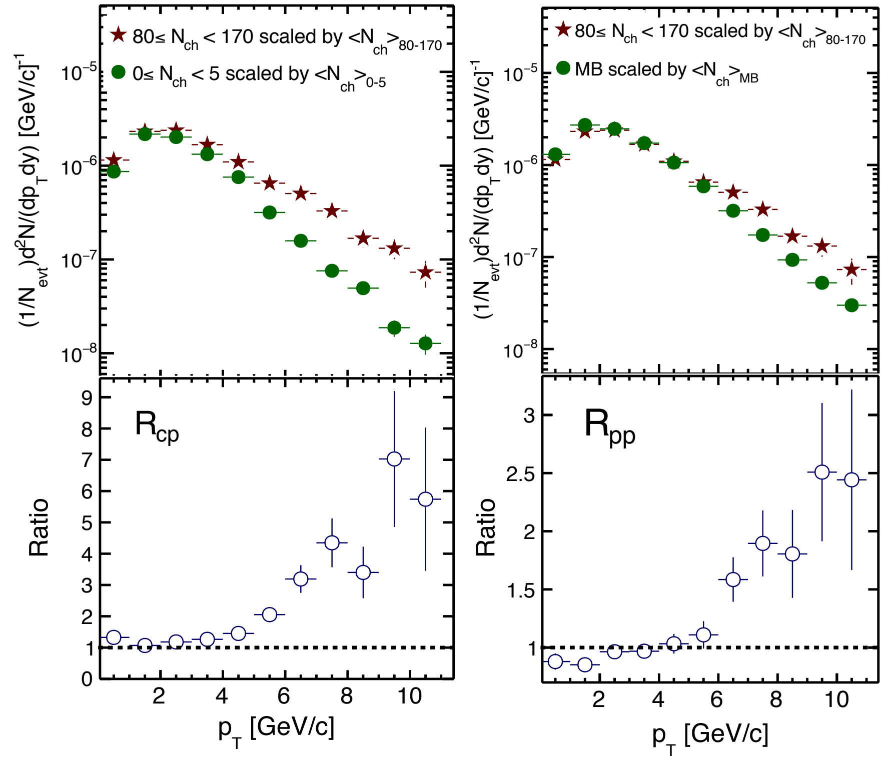
(arXiv:1808.01841)

Medium modification factor (Rpp/Rcp)

- **Medium modification (or biasing to the pp reference) is calculated as:**

$$R_{pp} = \frac{< N_{ch} >_{MB}}{< N_{ch} >_{80-170}} \frac{(dN/N_{evt}dp_T)_{80-170}}{(dN/N_{evt}dp_T)_{MB}},$$

$$R_{cp} = \frac{< N_{ch} >_{0-5}}{< N_{ch} >_{80-170}} \frac{(dN/N_{evt}dp_T)_{80-170}}{(dN/N_{evt}dp_T)_{0-5}},$$



- **For $p_T < 2.0$ GeV R_{pp} show around 10 % medium modification(or biasing), where as there is no medium modification observed from low-multiplicity to high-multiplicity (Rcp).**

- **QCD medium formed at high multiplicity p+p collisions is different than MB.**

(arXiv:1808.01841)

Summary

- ✓ pp@LHC energies, MPI drives the the quarkonia production with little effect of CR at the final state
- ✓ $gg \rightarrow c\bar{c}$ dominates over $q\bar{q} \rightarrow c\bar{c}$ as we go from low multiplicity to high multiplicity
- ✓ R_{pp} hinting that the QCD medium formed in high multiplicity p+p collisions is different than that of MB

Thanks !!

Collaborators

D. Thakur, Dr. R. Sahoo, Dr. S De, S. Dansana

Backup Slide

Summary

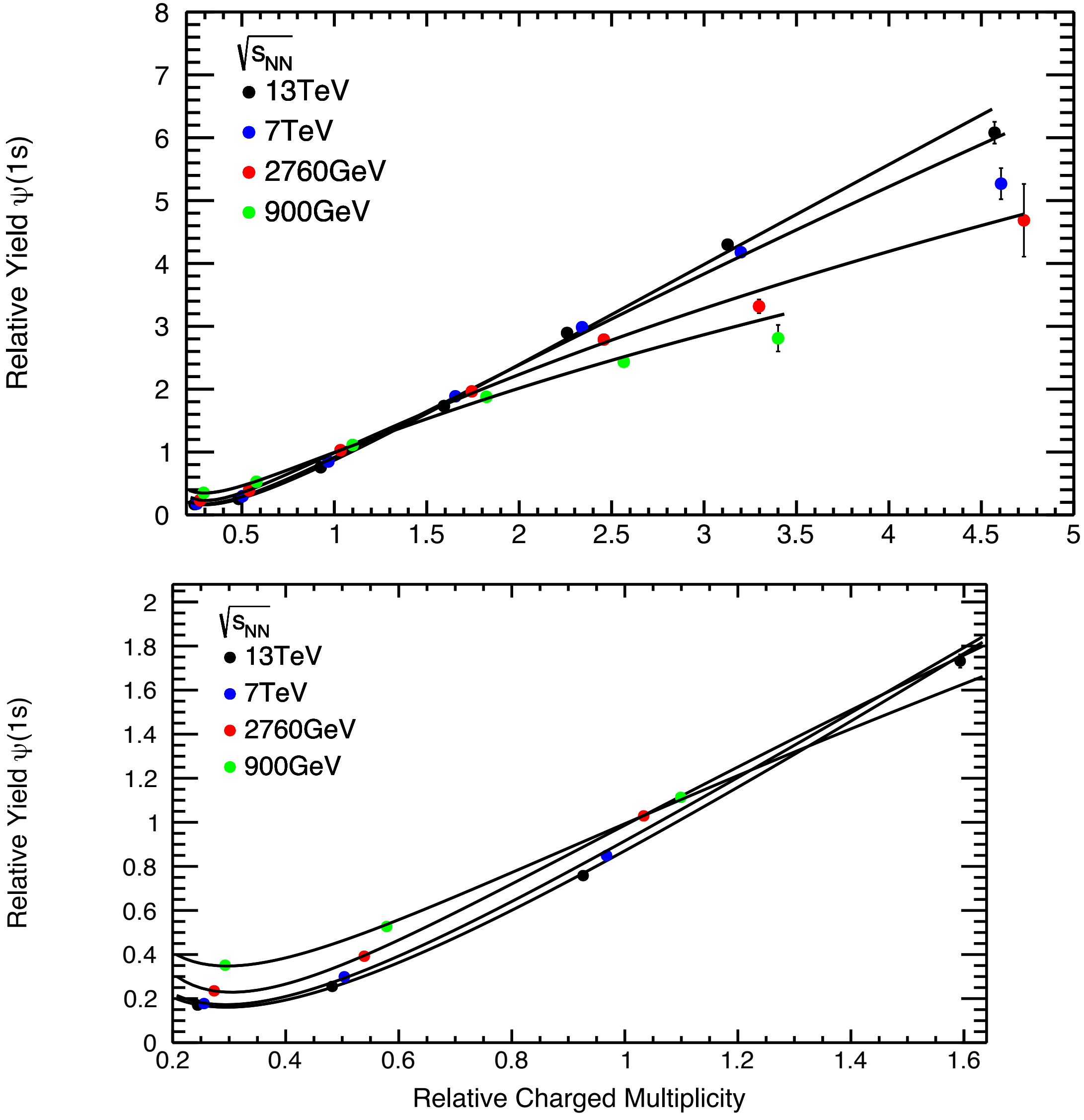
➢ General settings

- ✓ **ISR and FSR are ON for whole analysis**
- ✓ **MPI with CR and MPI with no-CR are used**

➢ Specific Settings

- ✓ **Multiparton-Interactions:bProfile=3, to allow all incoming partons to undergo hard and semi-hard interactions**
- ✓ **ColourReconnection:mode(0), MPI-based scheme of Colour Reconnection**
- ✓ **HardQCD:all=on, inelastic, non-diffractive component of the total cross section for all hard QCD processes**
- ✓ **p_T cut off 0.5 GeV/c is used using PhaseSpace:pTHatMinDiverge, to avoid divergences of QCD processes in the limit $p_T \rightarrow 0$**

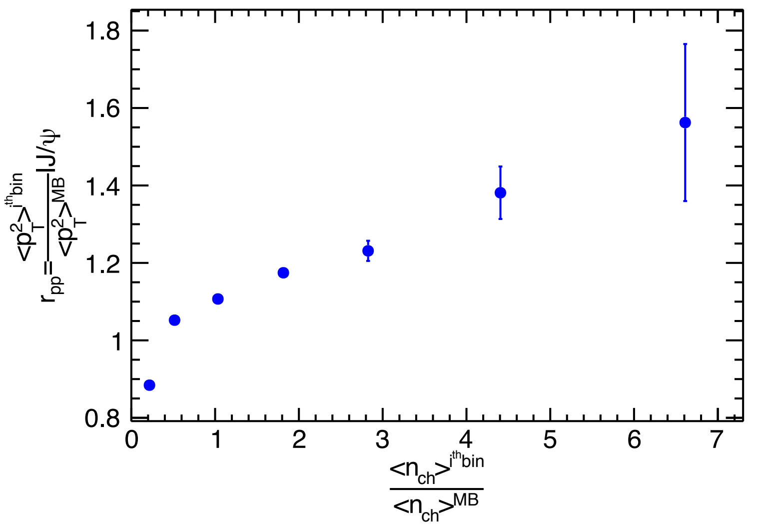
Test



$\sqrt{s_{NN}}$
13TeV
7TeV
2760GeV
900GeV
Relative Yield ψ(1s)
$\sqrt{s_{NN}}$
13TeV
7TeV
2760GeV
900GeV
Relative Yield ψ(1s)
Relative Charged Multiplicity

Medium modification factor (r_{pp})

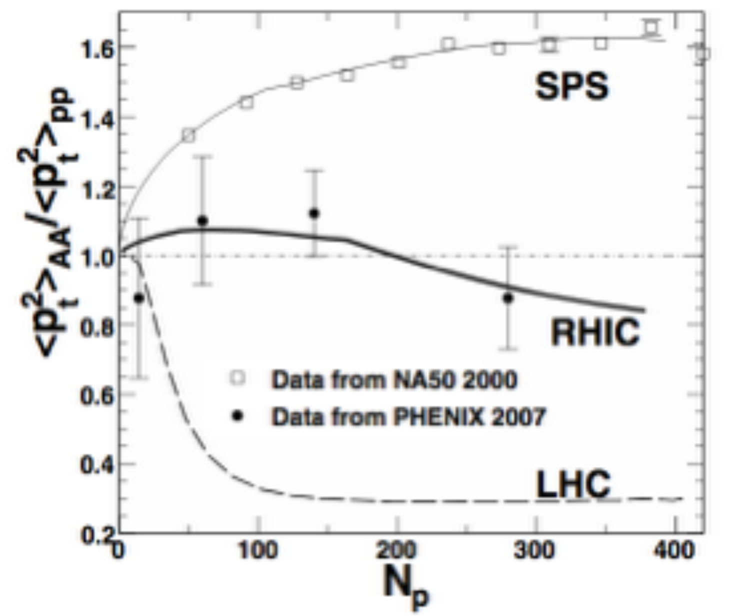
$$r_{pp} = \frac{\langle p_T^2 \rangle_{i^{th} bin}}{\langle p_T^2 \rangle_{MB}}$$



✓ $<p_T^2>_{ith\text{-}bin}$ = mean p_T of i^{th} multiplicity bin

✓ $<p_T^2>_{MB}$ = mean p_T of MB

- $<p_T^2>$ attributes toward the multi scattering of partons in the initial state. Hence, can be treated as random walk in transverse momentum space.
- $<p_T^2>$ is predicated to increase linearly with the mean path length of the traversed parton.
- At SPS almost all the measured J/ψ are produced via initial hard processes and the increase with centrality/ multiplicity.



(Nucl. Phys. A834(2010)249C)

(arXiv:1808.01841)