PHENIICS FEST 2022

Charmonium production in p-Pb collisions with ALICE at LHC

Theraa TORK

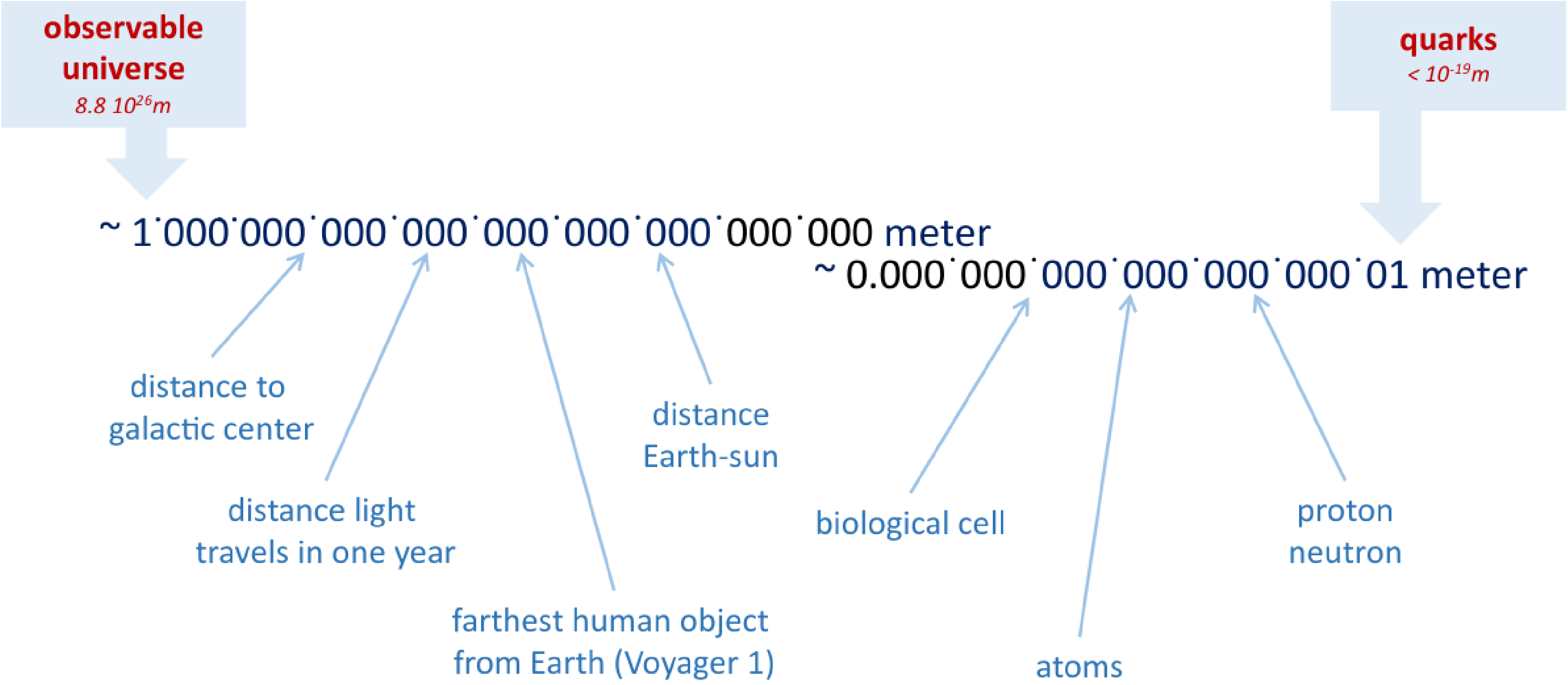
PHENIICS Fest, 19-20 May 2022

IJCLab Irène Joliot-Curie

université PARIS-SACLAY

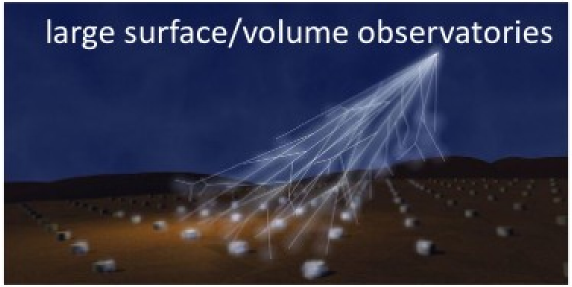
ALICE

Our curiosity drives us to the extremes

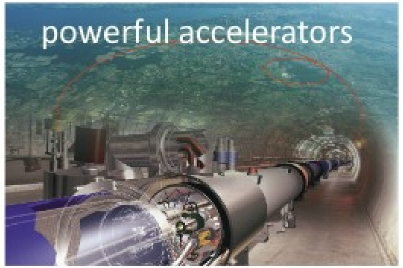


observable universe

8.8 10^{26}m



visible with our own eyes



quarks

< 10^{-19}m

~ 1˙000˙000˙000˙000˙000˙000˙000˙000˙000 meter

~ 0.000˙000˙000˙000˙000˙000˙01 meter

distance to galactic center

distance light travels in one year

farthest human object from Earth (Voyager 1)

distance Earth-sun

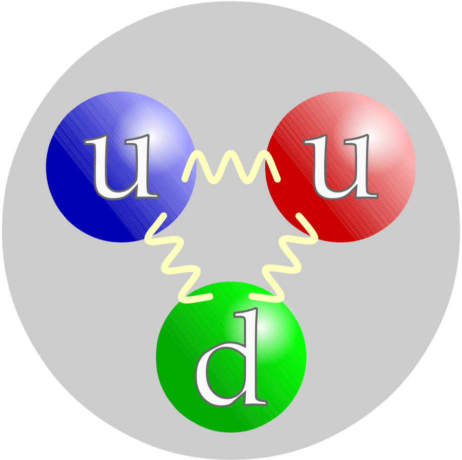
biological cell

atoms

proton neutron

Theraa TORK

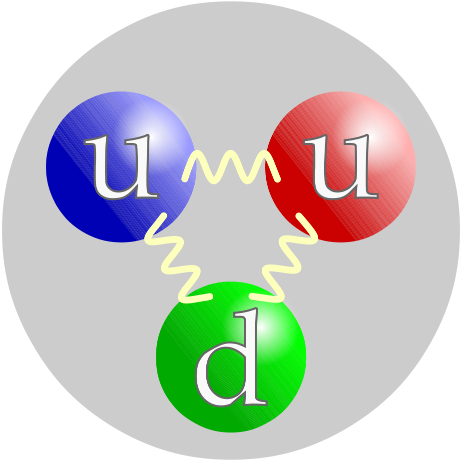
The proton



A hadron made up of three valence quarks **uud.**

Flavor	Mass(GeV/c²)
u up	.005
d down	.01

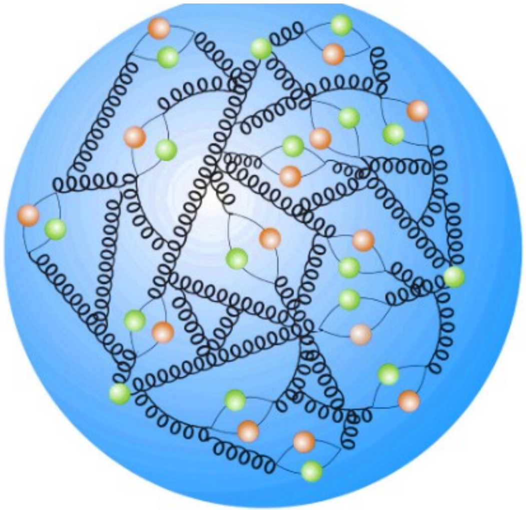
The proton



Flavor	Mass(GeV/c²)
u up	.005
d down	.01

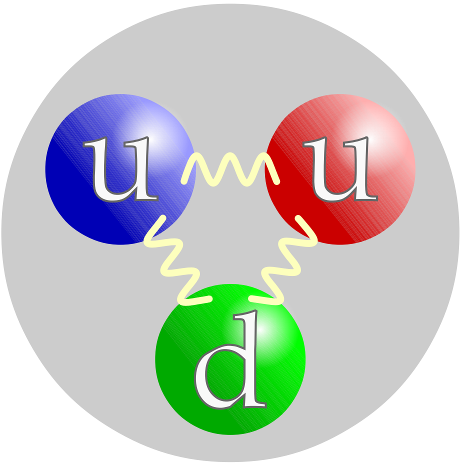
A hadron made up of three valence quarks **uud.**

but it is not this simple

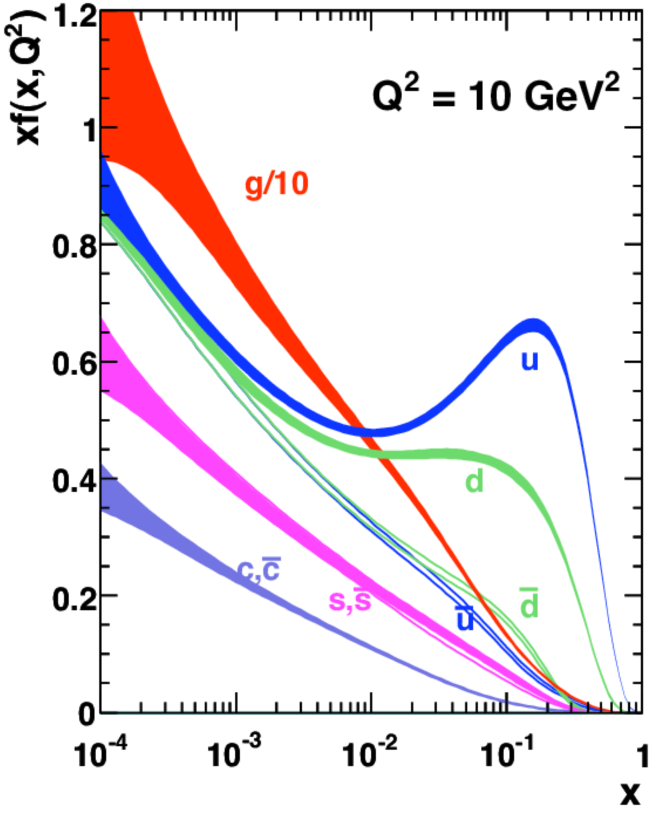


How to describe this ?

Parton distribution functions (PDFs)



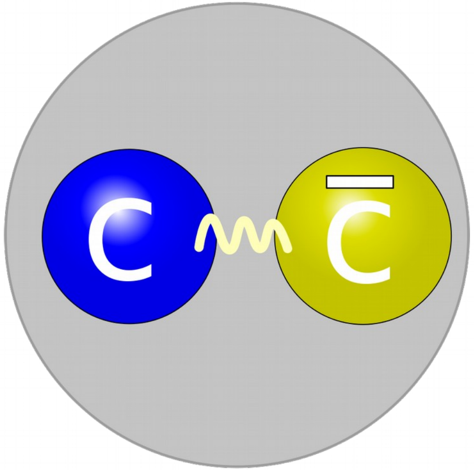
PDFs: probability to find a parton with a given momentum x.

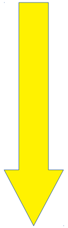


Charmonia

The charm of linking perturbative and non-perturbative QCD

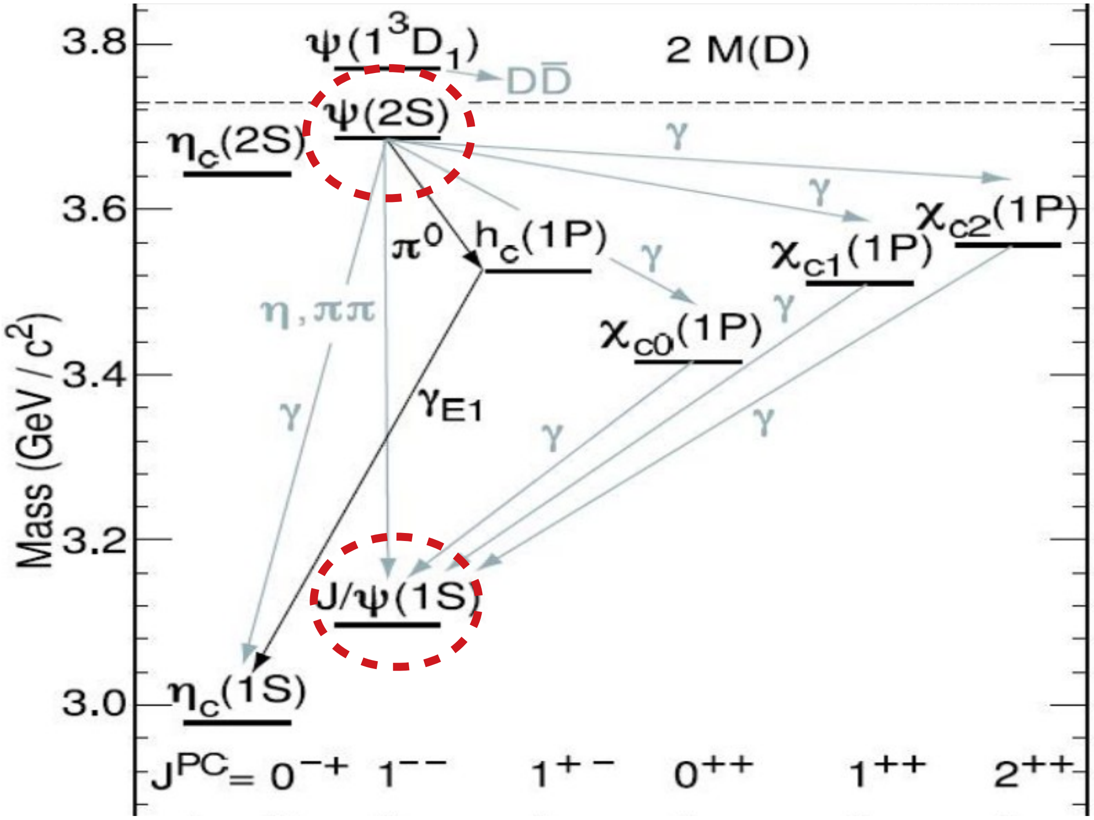
- c-quarks are created during the hard QCD process.
  Due to their heavy mass ~ 1.5 GeV.
- The bound state is formed during soft QCD process.
  Binding energy is few MeV.





Provide an excellent tool to test perturbative and non perturbative QCD processes.

Charmonia

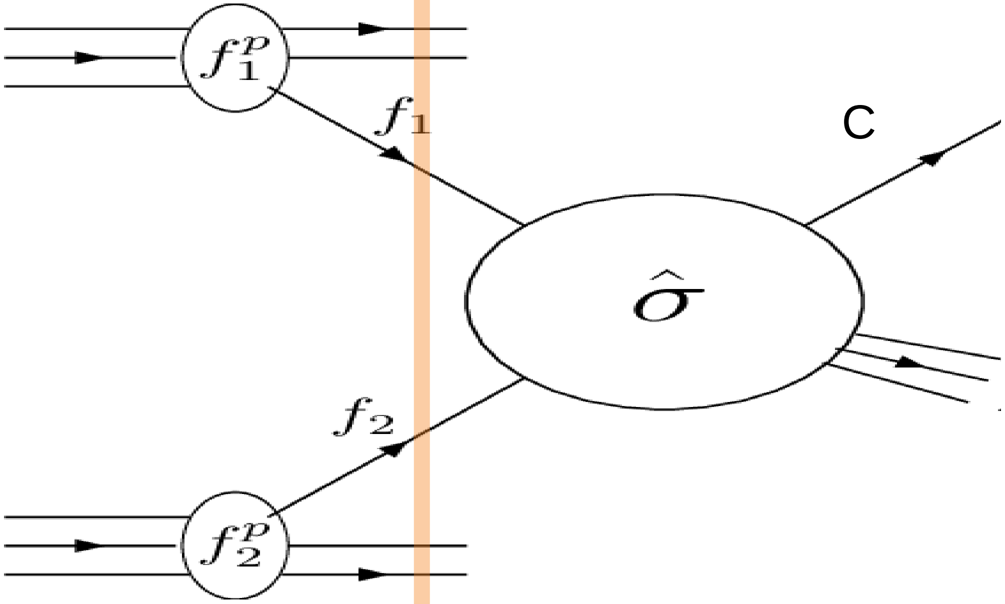


ψ(1³D₁)
2 M(D)
DD̄
ψ(2S)
η_c(2S)
γ
γ
π⁰
h_c(1P)
χ_c2(1P)
χ_c1(1P)
γ
γ
η, ππ
χ_c0(1P)
γ
γ
γ_E1
γ
γ
J/ψ(1S)
η_c(1S)
Mass (GeV / c²)
3.8
3.6
3.4
3.2
3.0
J^PC = 0⁻⁺ 1⁻⁻ 1⁺⁻ 0⁺⁺ 1⁺⁺ 2⁺⁺

Factorization theorem

Confinement
Non perturbative QCD

Freedom
perturbative QCD

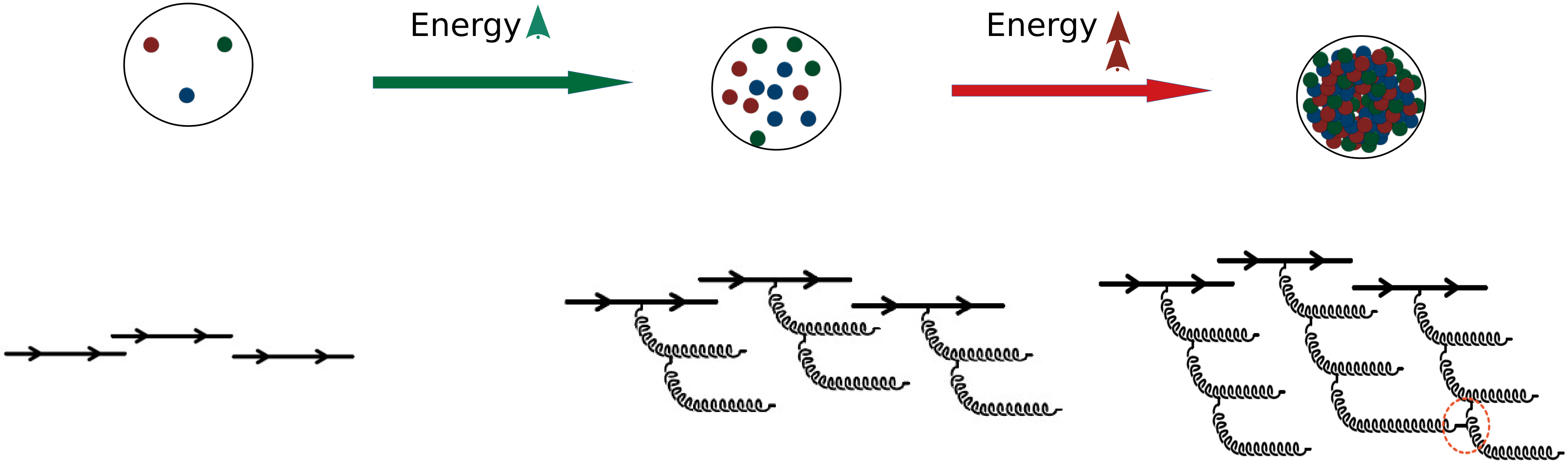


Parton distribution functions

Calculable via pQCD

Hadrons at high energy

PDFs and saturation concept



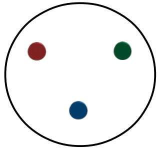
Only valence quarks

New partons are emitted

Partons overlap

What will happen when collide them?

Single parton interactions

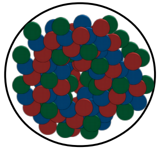


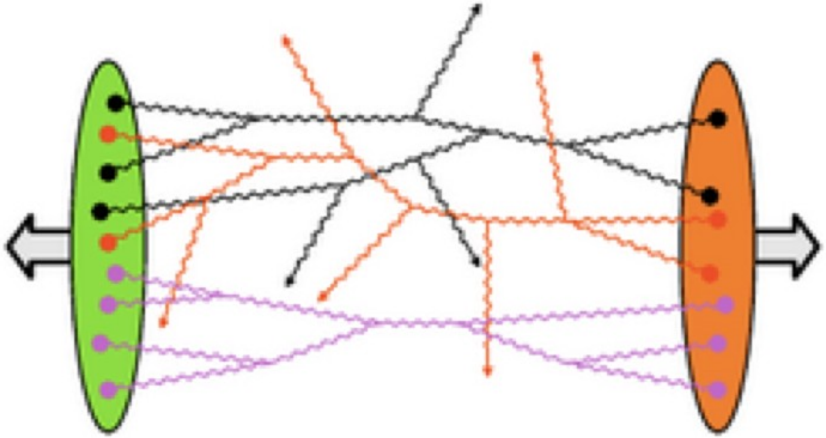
Single parton-parton interaction.

A naive picture of hadron-hadron collision.

What will happen when collide them?

Multiparton interactions





When there is a large density of partons.

Several parton-parton interactions in a single hadron-hadron collision.

Where to look for MPIs ?

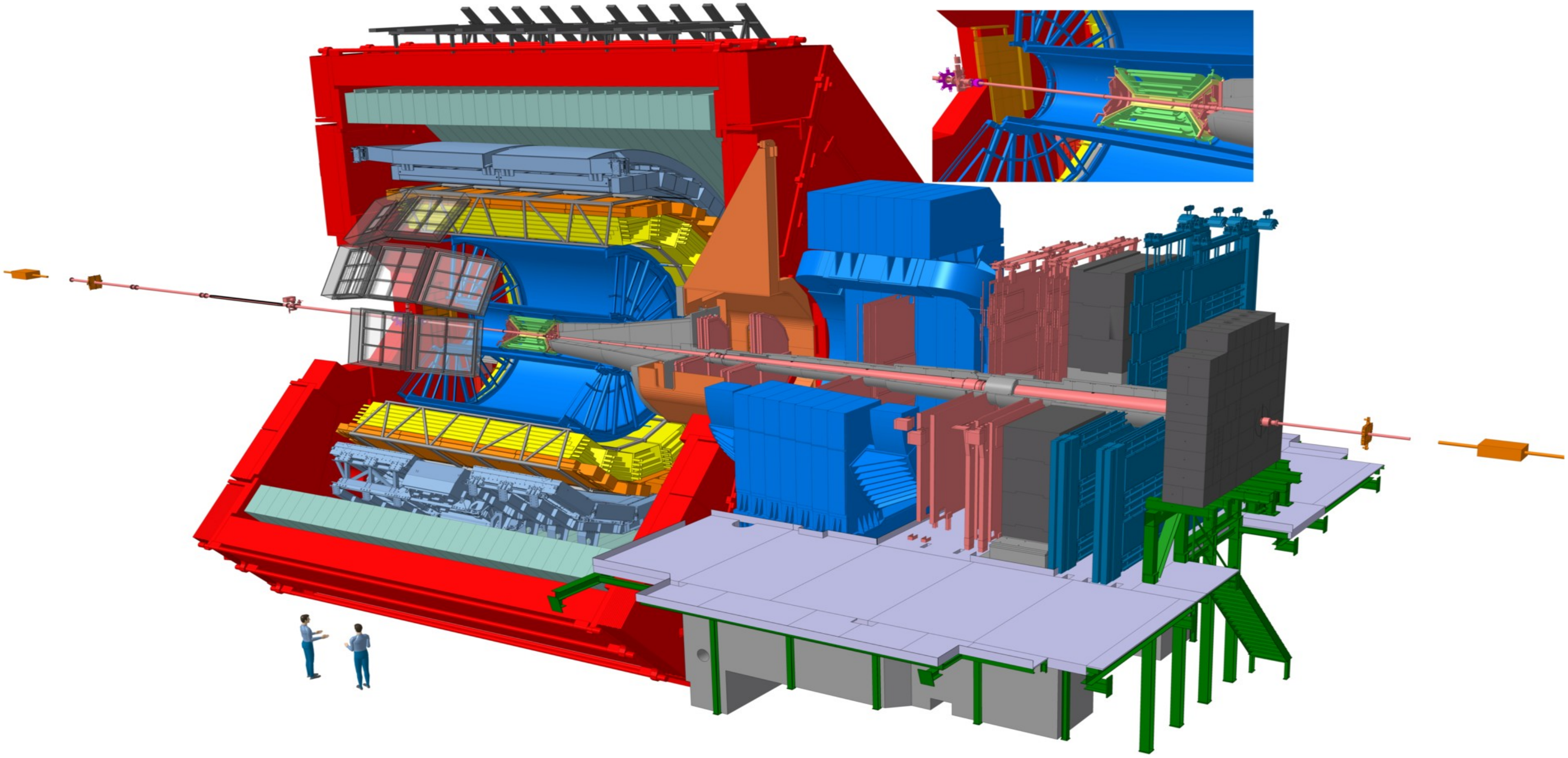
- Double Chrmonia production:
  - Direct probe to MPIs.
  - Provide information about the single Charmonia production.

    Needs large statistics to measure differential cross sections.
- Charmonia production vs charged-particle multiplicity:
  - Indirect probe to MPIs.
  - Information about the correlation between soft and hard QCD process.

In this presentation we are going to discuss the charmonium production as a function of multiplicity exploiting ALICE run 2 data for p-Pb collisions.

ALICE detector

LHC heavy-ion dedicated experiment



ALICE detector

$J/\psi,\ \psi(2S) \rightarrow \mu^- \mu^+$

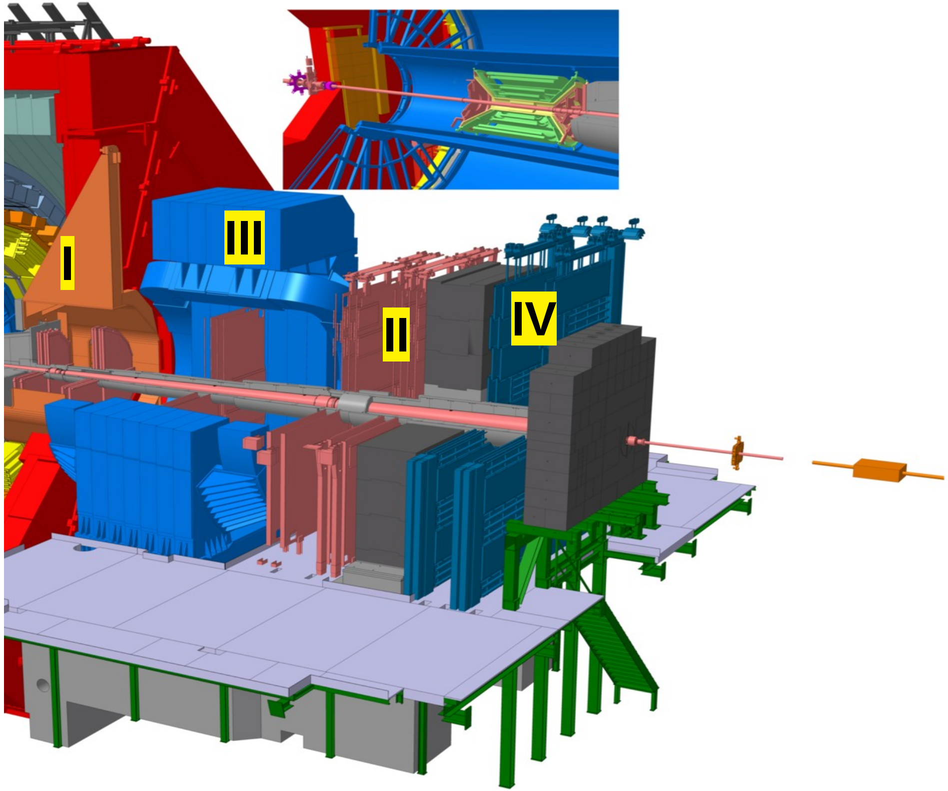
$2.5 < y_{lab} < 4.0$

I. Front absorber.

II. Muon tracking chambers.

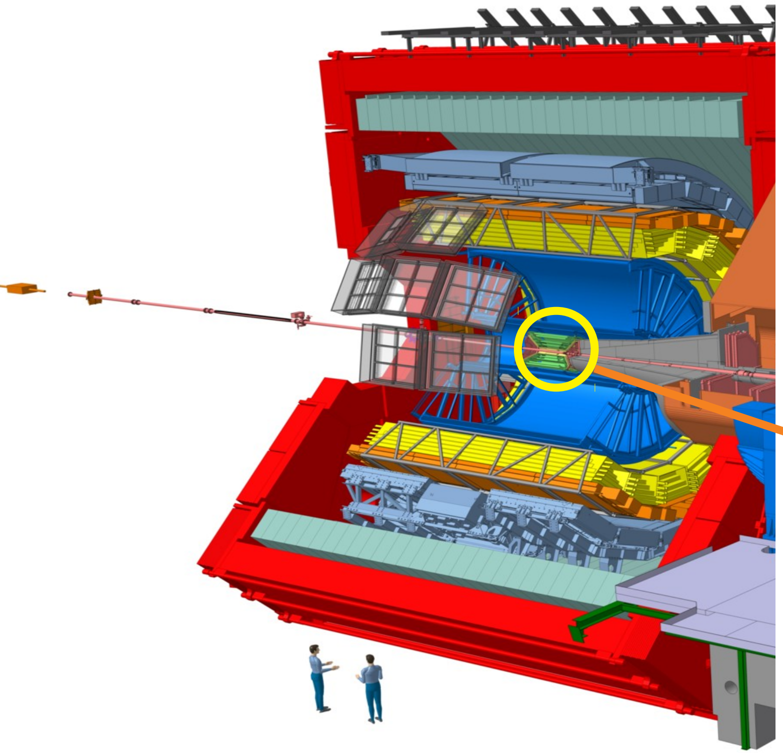
III. Dipole magnet 3T.m.

IV. Muon trigger chambers.



ALICE detector

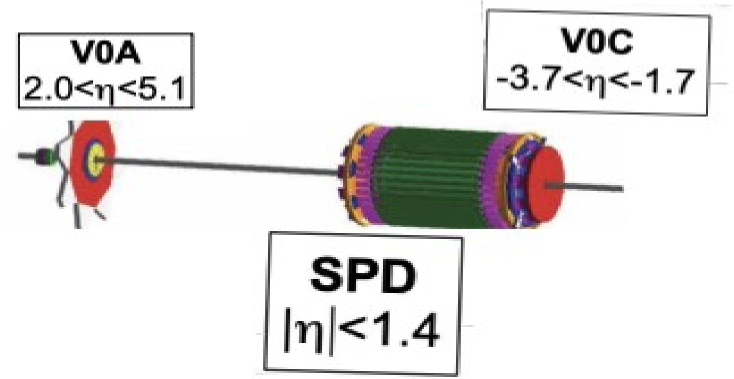
Central barrel



Measure the charged-particle multiplicity

V0 detectors

Silicon pixel detector (SPD)



Particle production vs multiplicity

$$\frac{\mathrm{d}N_Q/\mathrm{d}y}{< \mathrm{d}N_Q/\mathrm{d}y >}$$

yields of charmonia normalised to the their average yields

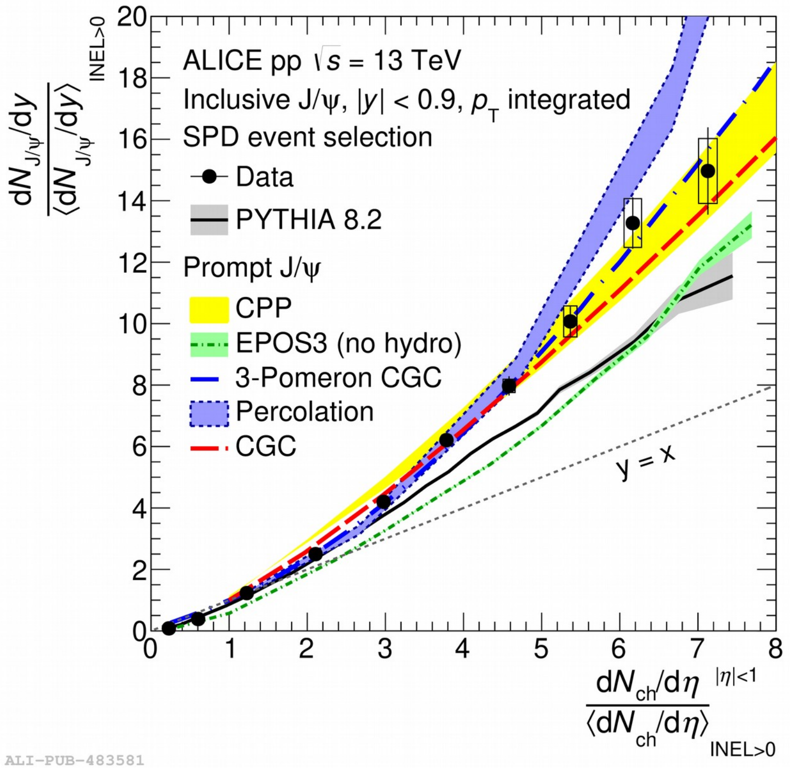
$$\frac{\mathrm{d}N_{ch}/\mathrm{d}\eta}{< \mathrm{d}N_{ch}/\mathrm{d}\eta >}$$

Number of charged-particle in each rapidity normalised to the average number of charged particles

Multiplicity dependence of J/ψ

pp collisions

PLB 810 (2020) 135758

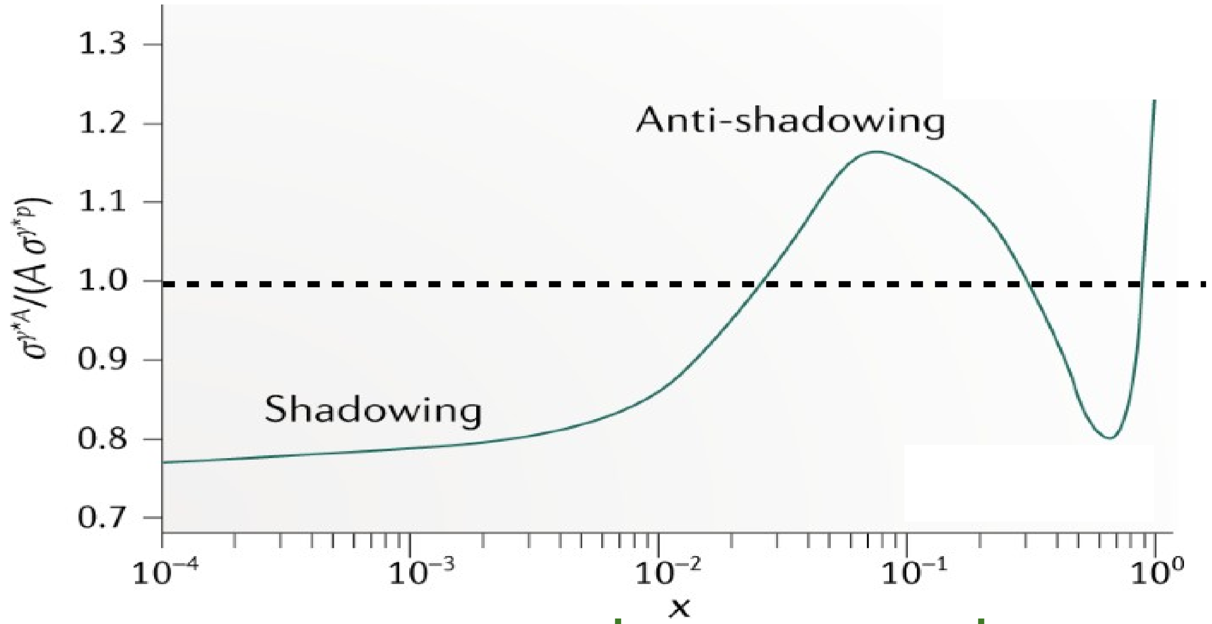


- Self normalized J/ψ yields vs multiplicity at midrapidity.
- Faster than linear increase of J/ψ yields vs multiplicity .
- The trend is described by several theoretical models which include the initial state effects and MPI in their calculations.

How dœs the nuclear environment affect charmonium production ?

Nuclear parton distribution functions

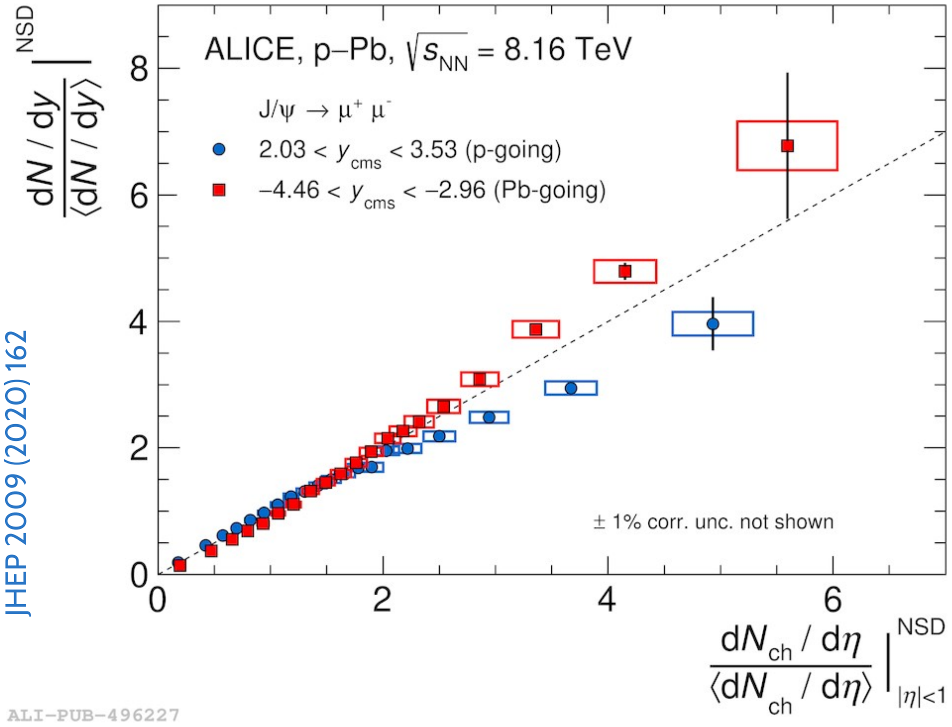
What is the effect of nuclear environment on the particle production



Suppression

Enhancement

Multiplicity dependence of J/ψ in p-Pb



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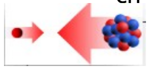
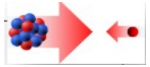
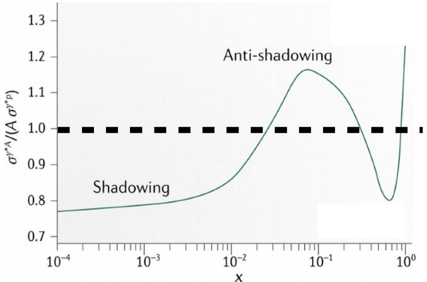
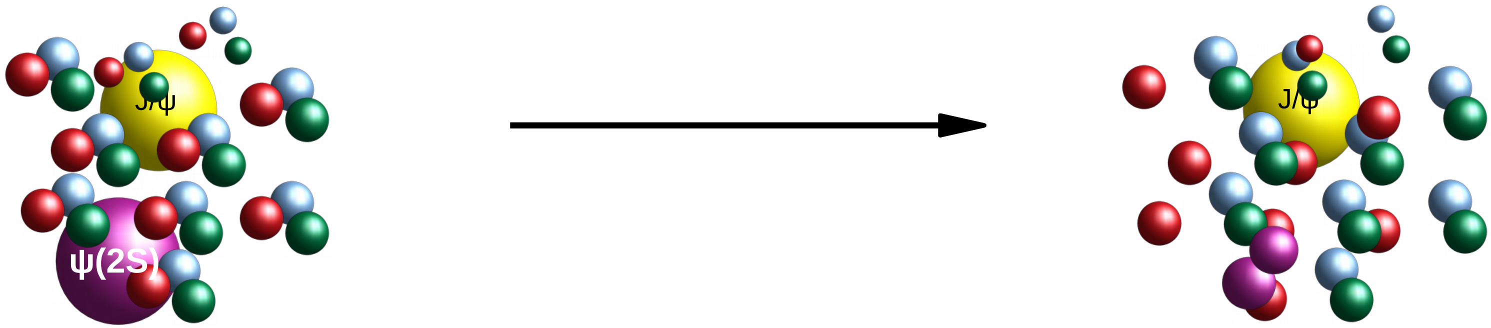
- J/ψ yields increase with $dN_{ch} / d\eta$ in
  - **Forward rapidity:**  **p-going**
  - **Backward rapidity:**  **Pb-going**
- Faster (slower) than linear increase observed at backward (forward) rapidity.
- The different behavior likely due to different Bjorken-*x* regions probed.



Final state effects

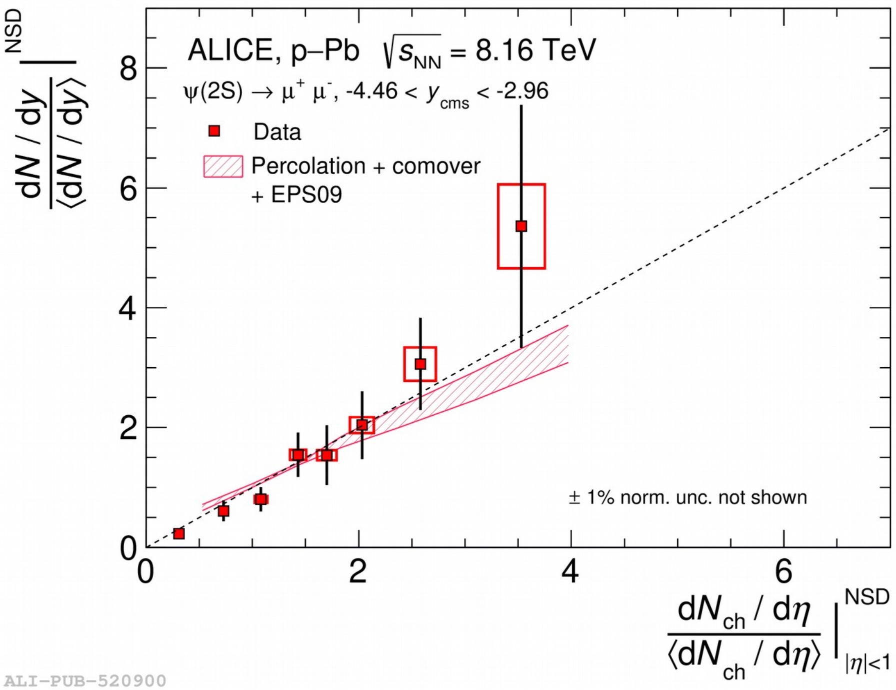
Comovers model

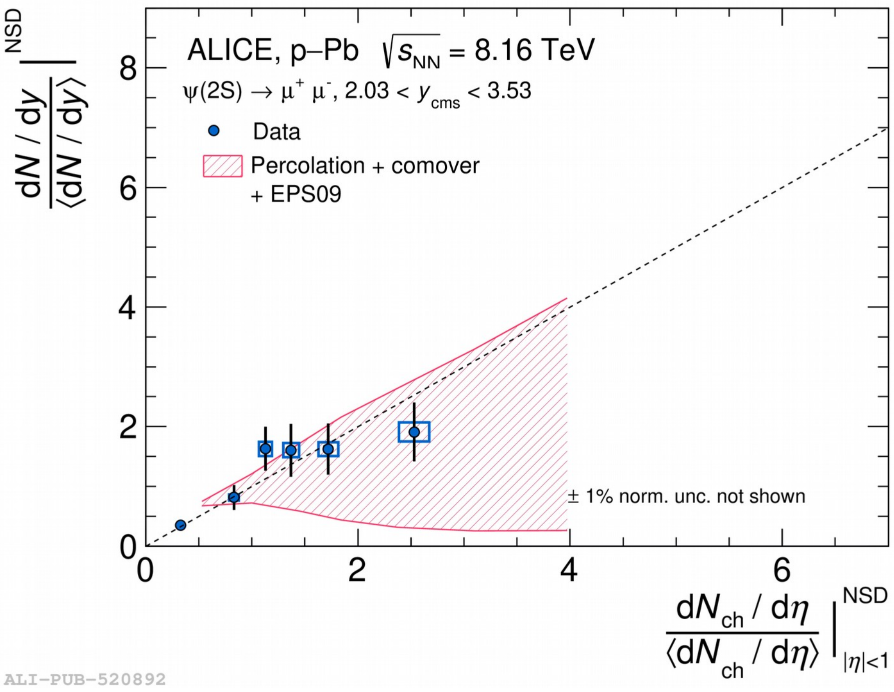
Do we expect different effects for different particles?



The effect of the interaction of the final state particles with the comoving-particles

ψ(2S) production vs multiplicity

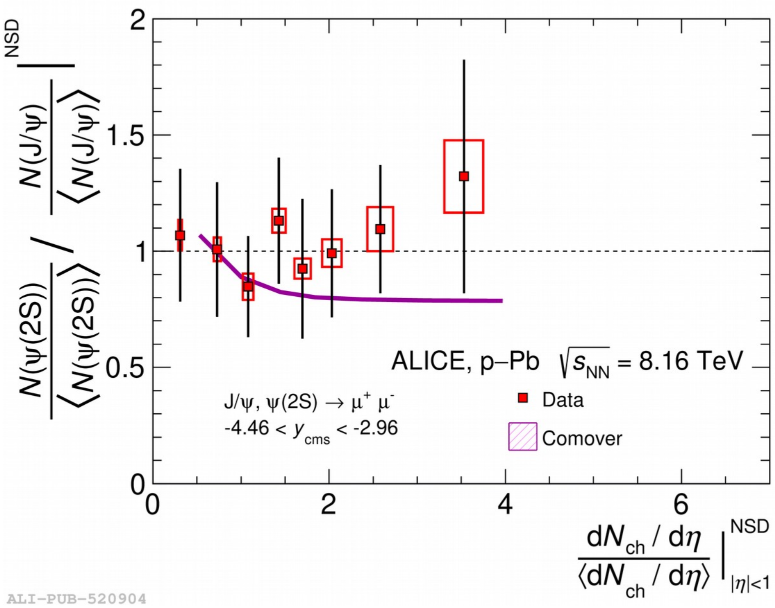


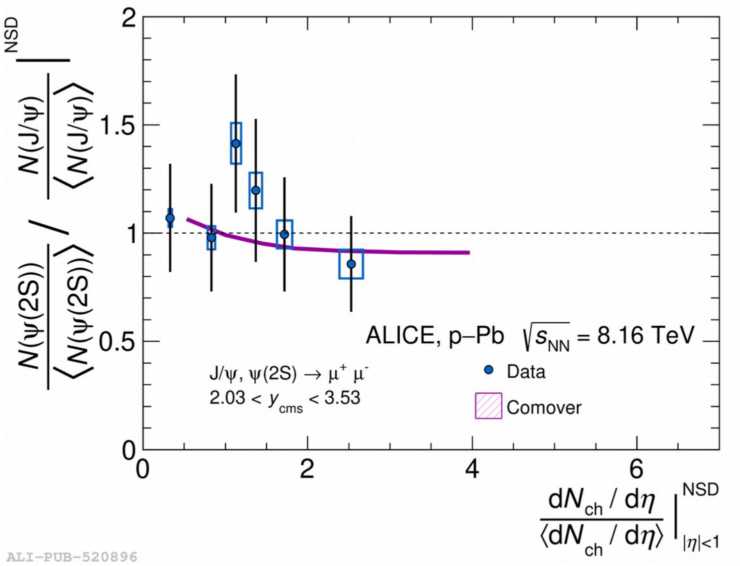


- The ψ(2S) yield increases with increasing $dN_{ch}/d\eta$ in p-Pb collisions.
- The model includes nPDFs and the final state effect in its calculation.

Multiplicity dependence of ψ(2S)-over-J/ψ

arXiv:2204.10253





- Similar behavior of J/ψ and ψ(2S) vs multiplicity in p-Pb.
- Similar trend of the ψ(2S)-to-J/ψ ratio vs multiplicity in both rapidity regions.
- The comovers calculation describes the data within statistical and systematic uncertainties.

Conclusion

- **ALICE measured the J/ψ and ψ(2S) production vs multiplicity**
  - On arXiv: arXiv:2204.10253
- **ψ(2S) vs charged-particle multiplicity:**
  - Models with intial state effects and MPIs reproduce the trend of the data.
  - Similar behavior of J/ψ and ψ(2S) as a function of multiplicity.

- Outlook
  - **LHC run 3 with high statistics will allow to**
    - Much more precise measurements.

Thank you