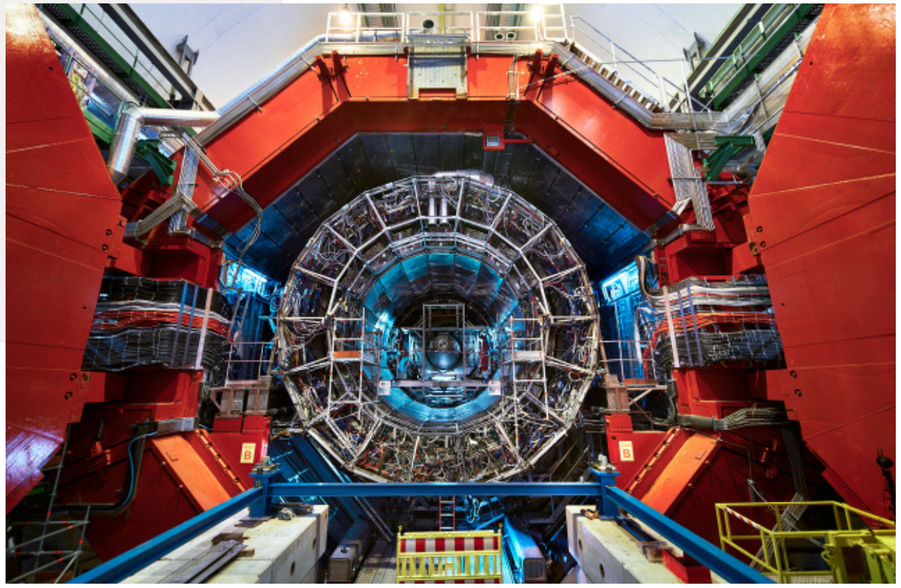
QGP FRANCE

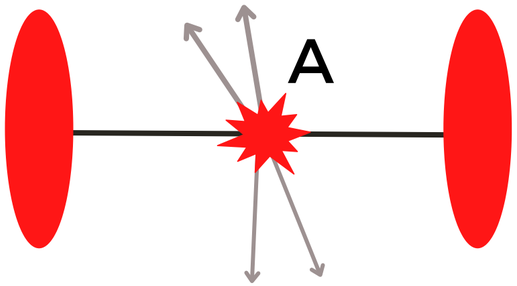
Double Charm Production Studies with ALICE



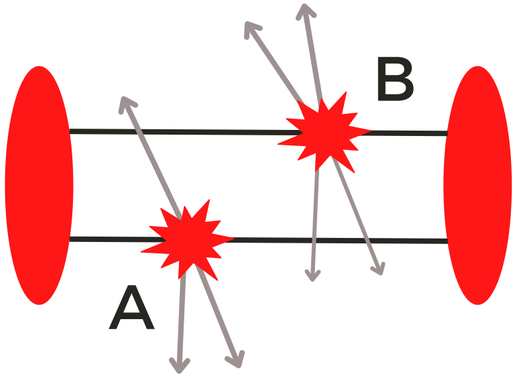
27 June 2023

Andrea Tavira García

MULTIPLE PARTON INTERACTIONS (MPI)



Single Parton Scattering (SPS)

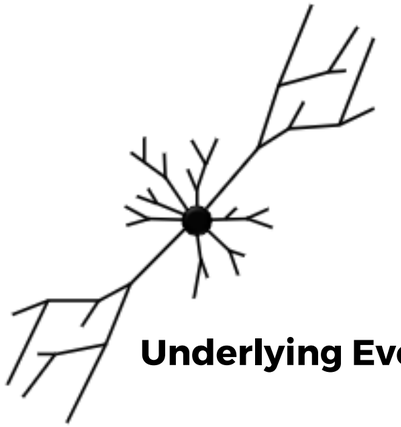


Double Parton Scattering (DPS)

But we can also have more partons involved:
Multiple Parton Interactions (MPIs)

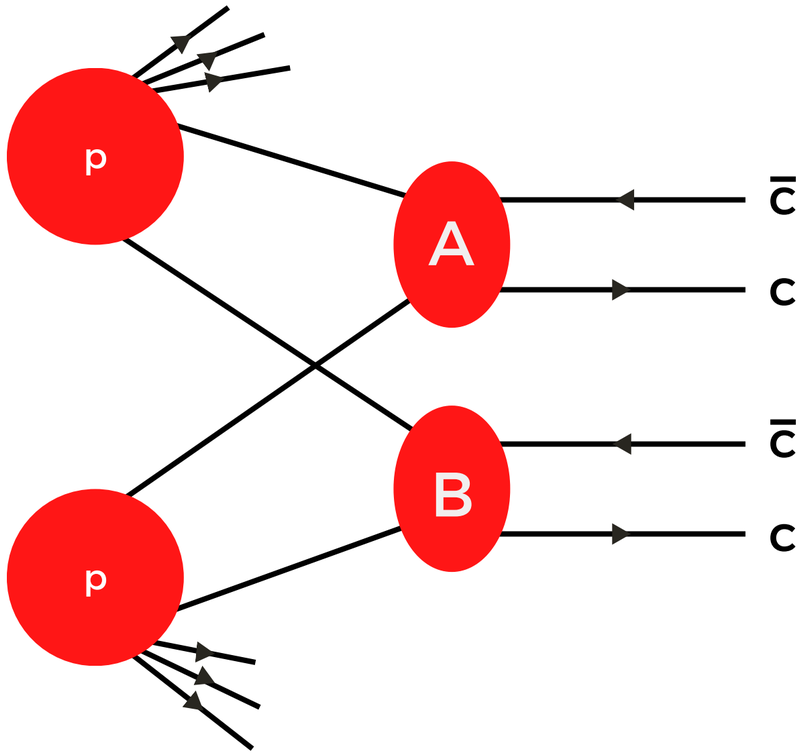
- **MPIs:** events where two or more distinct parton interactions take place simultaneously in a single hadron-hadron collision
- MPIs can help to understand the Underlying Event, and Minimum bias processes
- Very relevant in the soft regime (small x), but harder to model, as pQCD is not enough

Minimum Bias



Underlying Event

DOUBLE PARTON SCATTERING (DPS)



DPS: two distinct hard parton interactions take place simultaneously in a single hadron-hadron collision

At LHC energies, its cross section becomes comparable with that of SPS

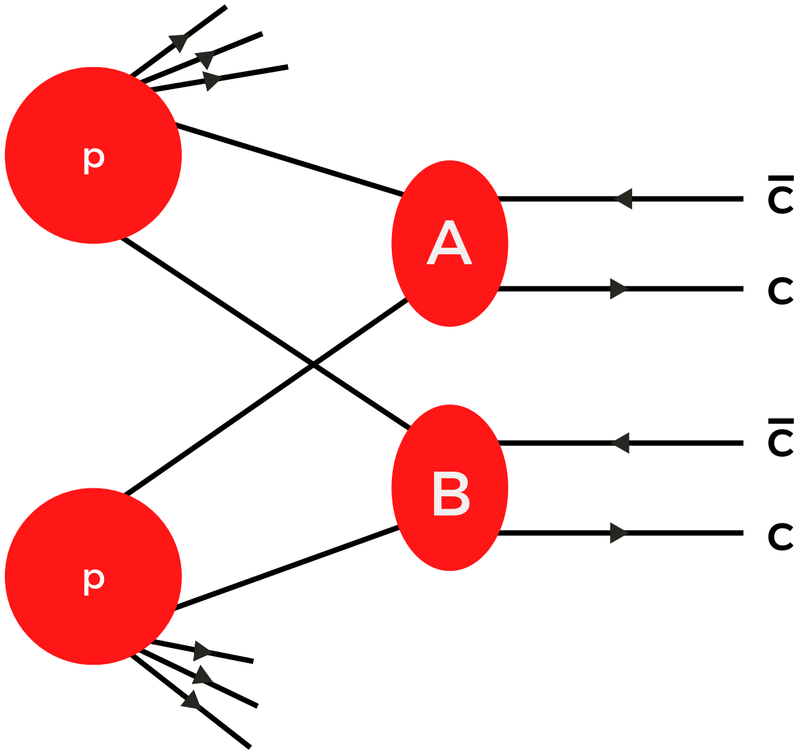
Info on:

- Spatial distribution of partons within the proton
- Parton - parton correlations

$$\sigma_{\mathrm{DPS}}^{AB} = \alpha \frac{\sigma^{A}\sigma^{B}}{\sigma_{\mathrm{eff}}} \quad , \alpha = \begin{cases} \frac{1}{2} & \text{if A = B} \\ 1 & \text{otherwise} \end{cases}$$

σ_{eff} parametrizes the amount of double parton scattering

DOUBLE PARTON SCATTERING (DPS)



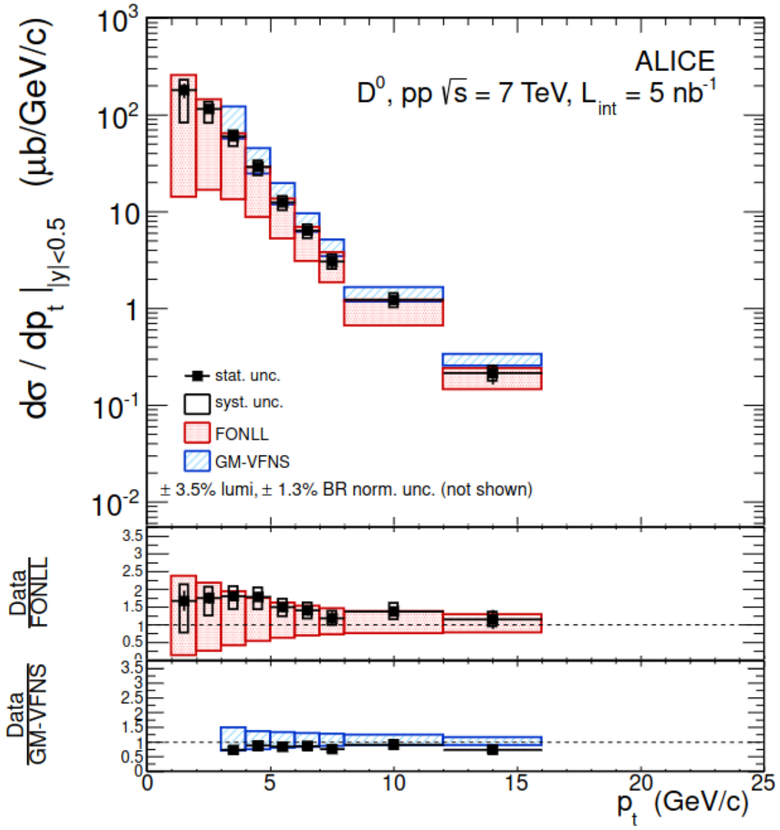
PREVIOUS ANALYSES

- CDF, 10.1103/PhysRevD.56.3811 $p\bar{p} \to \gamma/\pi^0 + 3\,\text{jets} + X$
- D0, arXiv:1402.1550 $p\bar{p} \to \gamma + 3\,\text{jets}$
- CMS, arXiv:1312.5729 $pp \to W + 2\,\text{jets}$
- LHCb, arXiv:1205.0975 Double charm

PROBING DPS

USING HF QUARKS

- HF quarks allow us to reach regions of very low transverse momentum, especially using J/ψ or ϒ mesons
- At low pT, DPS contribution is not suppressed
- Relatively large cross section
- Easier to measure than studies with jets/photons at LHC
- Good choice to compare with results in p-Pb and Pb-Pb collisions



Plot from arXiv:1111.1553

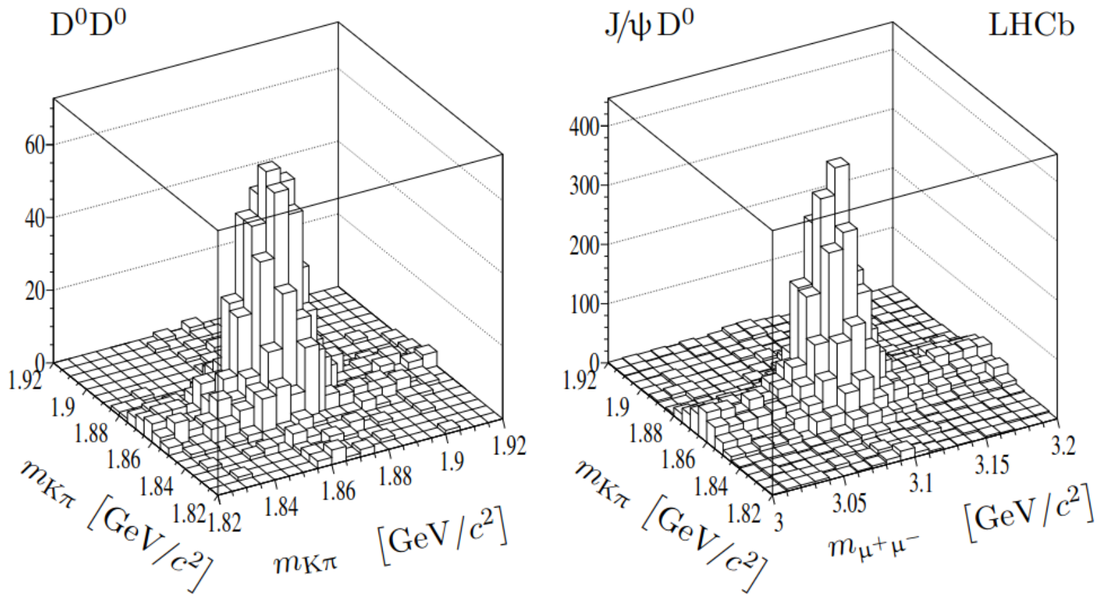
H O W T O

MEASURE DPS USING HF QUARKS

Which A and B do we choose?

Objective: $\sigma_{\mathrm{DPS}}^{AB} = \alpha \dfrac{\sigma^A \sigma^B}{\sigma_{\mathrm{eff}}}$

- **Opposite-Sign pairs (OS):** can be produced by SPS or DPS
  ⟶ We expect correlations between them
- **Like-Sign pairs (LS):** can only be produced by DPS at tree level
  ⟶ We **don't** expect correlations between them
- **J/Ψ - D meson pairs:** can only be produced by DPS
  ⟶ We **don't** expect correlations between them



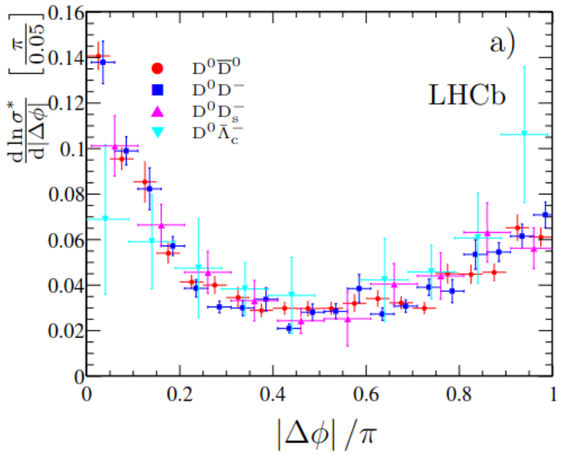
H O W T O

MEASURE DPS USING HF QUARKS

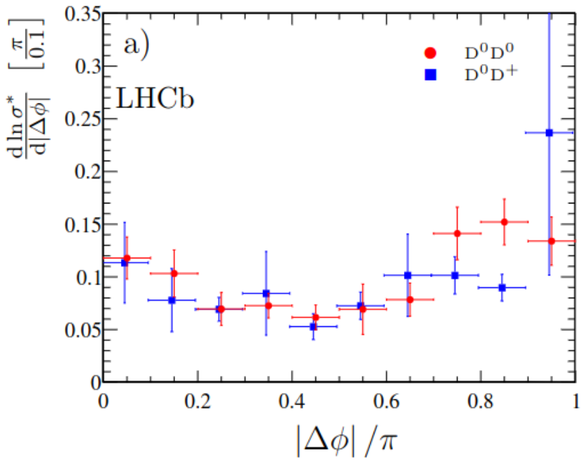
arXiv:1205.0975

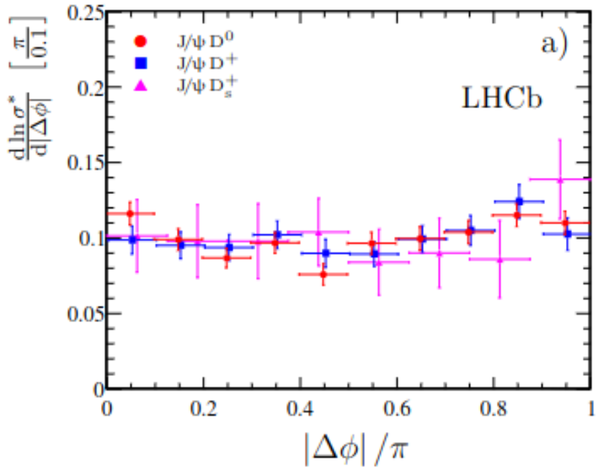
Which variables should we analyse?

Difference in azimuthal angle, $\Delta\phi$



(Almost) no DPS





DPS

- If there is no DPS, we expect to have a peak at 0. Consistent with production via gluon splitting
- With DPS, the peak at 0 disappears, and the distribution flattens out
- The flattening is more significant in the J/Psi D case

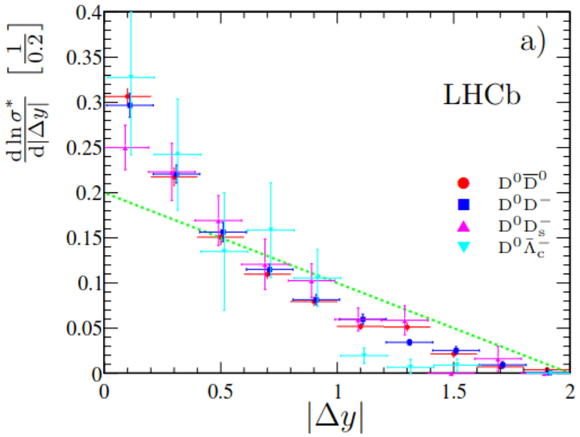
H O W T O

MEASURE DPS USING HF QUARKS

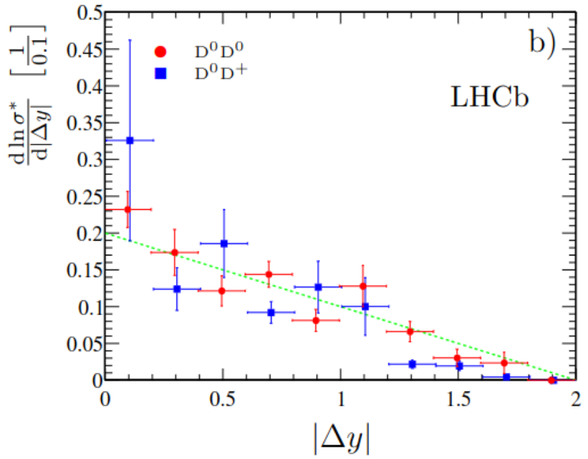
arXiv:1205.0975

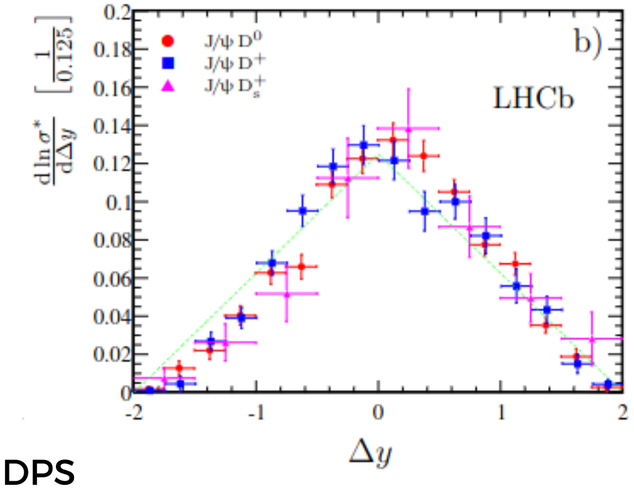
Which variables should we analyse?

Difference in rapidity, Δy



(Almost) no DPS





DPS

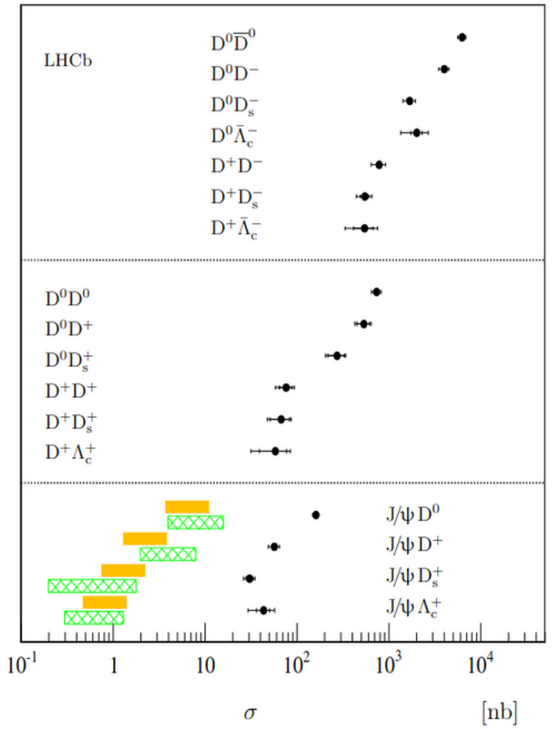
- The case without DPS shows some enhancement at small Δy
- With DPS, triangular shape as if rapidity distribution was flat and there were no correlations

H O W T O

MEASURE DPS USING HF QUARKS

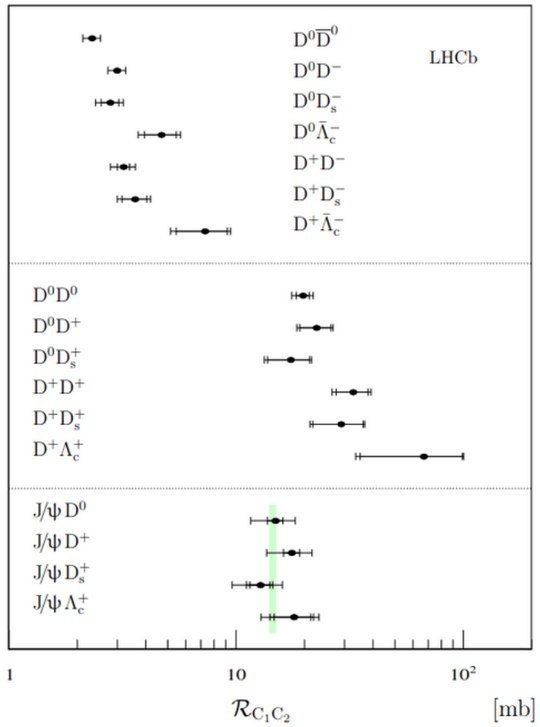
arXiv:1205.0975

Cross section results by LHCb



In yellow and green: theoretical cross sections calculated assuming gluon-gluon fusion (SPS)

⟶ DPS seems to dominate for J/Ψ-D



Results of $\mathcal{R}_{C_1C_2} \equiv \alpha' \frac{\sigma_{C_1} \times \sigma_{C_2}}{\sigma_{C_1C_2}}$

For D-D and J/Ψ-D ratios, $\sigma_{C_1C_2}$ can be interpreted as σ_{eff}

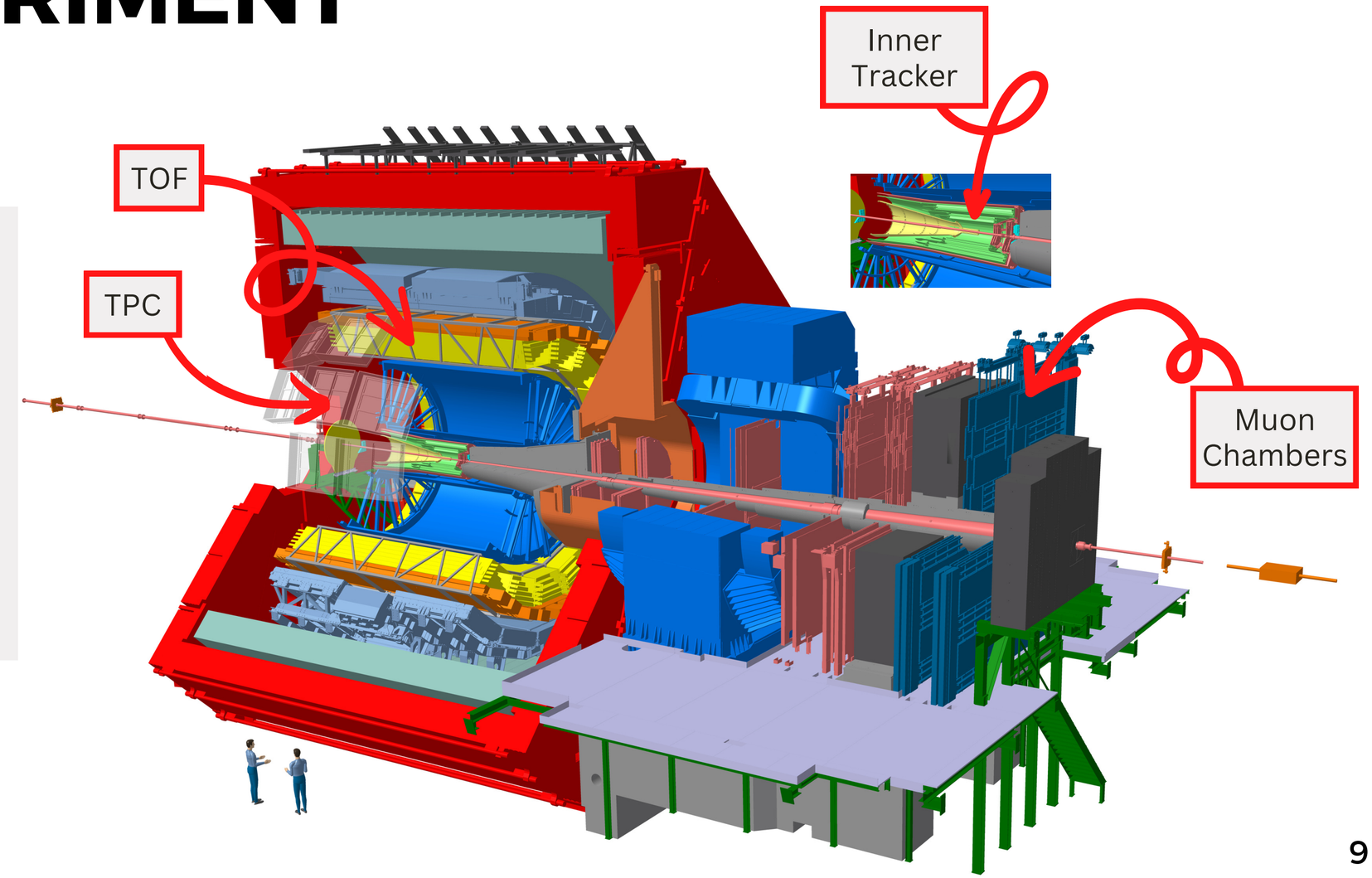
In green: results of the effective cross section calculated at Tevatron

SCHEMATIC VIEW

ALICE EXPERIMENT

- **Central Barrel**, especially ITS, TPC and TOF, used to measure D mesons. Analysis at mid-rapidity.
- **Muon chambers** used to measure J/Ψ's. Analysis at forward rapidity

Very big rapidity gap



WHERE WE ARE RIGHT NOW

Invariant Mass distributions using Run 3 data

We're starting to see a clear D^0 peak in all pT ranges, even in the 0 - 1 GeV region!

Width peaks are still twice as large as those from Run 2

WHERE WE ARE RIGHT NOW

First approximation of D^0 cross section in Run 3: efficiency calculation

WIP

We do not have a MC anchored to a specific dataset yet

Obtained as

$$\epsilon = \frac{N_{\mathrm{MC}}^{\mathrm{reco}}}{N_{\mathrm{MC}}^{\mathrm{Gen}}}\Bigg|_{\mathrm{Prompt}}$$

using Prompt pT vs. y distributions, for y ϵ (-0.8, 0.8)

Reconstructed MC

Increases with pT due to the chosen topological cuts

Generated MC

WHERE WE ARE RIGHT NOW

First approximation of D^0 cross section in Run 3

WIP

Calculated as

$$\frac{\mathrm{d}^2\sigma^{\mathrm{D}}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y} = \frac{1}{c_{\Delta y}\,\Delta p_{\mathrm{T}}}\frac{1}{\mathrm{BR}}\frac{\frac{1}{2}\;f_{\mathrm{prompt}}\cdot N^{\mathrm{D}+\overline{\mathrm{D}},\mathrm{raw}}\Big|_{|y|<y_{\mathrm{fid}}}}{(\mathrm{Acc}\times\varepsilon)_{\mathrm{prompt}}}\frac{1}{L_{\mathrm{int}}},$$

- f prompt was not taken into account yet, but we expect it to have an effect of around 10%
- y fiducial was chosen to be 0.8

WHERE WE ARE RIGHT NOW

Invariant mass distributions for D^0 D^0 bar pair candidates -- Data

Not clear enough to distinguish mass peaks here yet

WHERE WE ARE RIGHT NOW

Invariant mass distributions for D^0 D^0 bar pair candidates -- Data

D

WHERE WE ARE RIGHT NOW

Invariant mass distributions for D^0 D^0 bar pair candidates -- MC

SUMMARY

& NEXT STEPS

- The objective is to measure the DPS cross section using Run 3 pp data with ALICE.
- We can learn about DPS by studying double charm production, particularly J/ΨC and CC, whereas CCbar can be used to compare with a channel dominated by SPS.
- We are starting to see a clear D^0 peak, and we can see small peaks when looking at D^0 pairs.

NEXT STEPS

01 **D^0 cross section**

Continue analysing the D^0 cross section to improve and understand the current results

02 **Study D - D correlations**

Work towards the obtention of a clearer signal and check correlations once it is available

03 **Add J/Ψ - D correlations**

To take advantage of ALICE's bigger rapidity interval

THANKS

FOR LISTENING

tavira-garcia@in2p3.ijclab.fr