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Charm production in PbPb collisions with LHCb

Samuel Belin

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Introduction

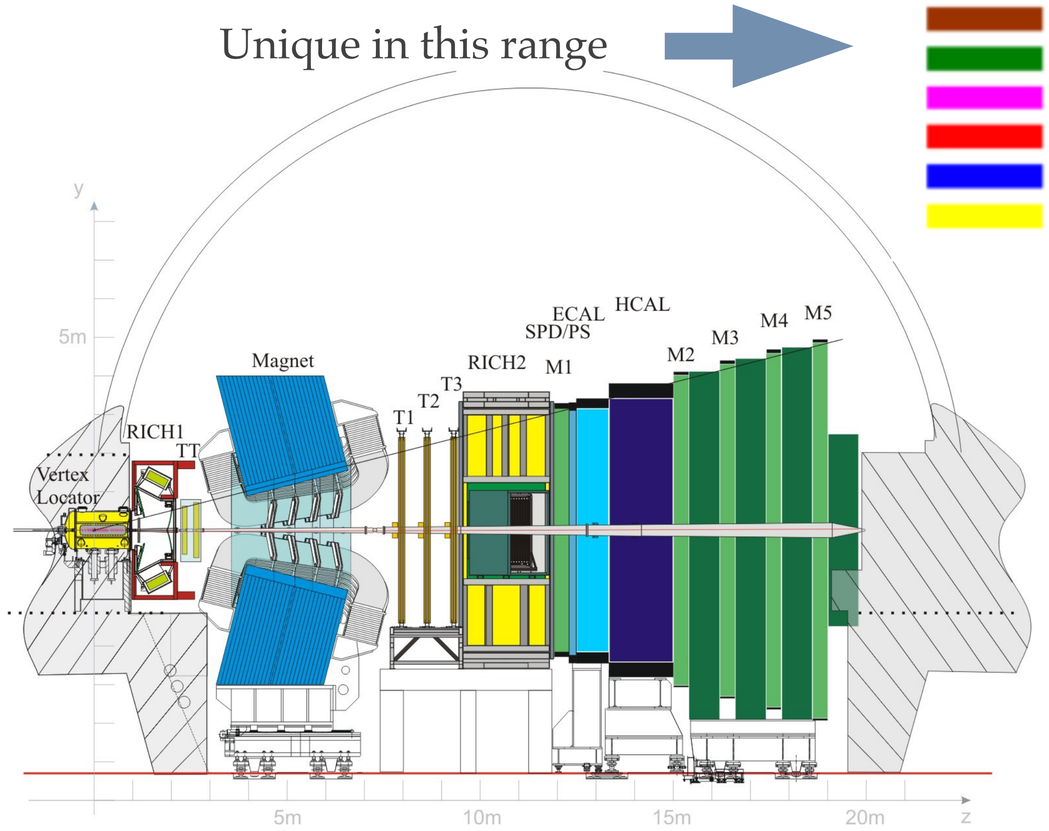
- Recent charm analyses thanks to the 2018 PbPb data sample
- Investigate the forward region complementary to the other LHC experiments.
- Precise identification of μ,π,K,p,e many analyses possible!
- Outline:
  - Λ_c/D^0 in peripheral PbPb collisions
  - J/ψ, ψ(2S) production in PbPb Ultra-Peripheral Collisions (UPC)
  - Photo-production J/ψ in peripheral PbPb collisions

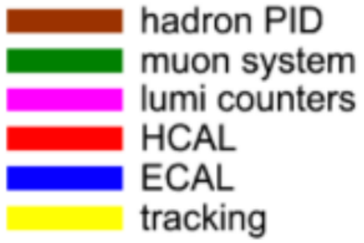
CAVEAT: Measurement limited to 60% centrality (see Benjamin's talk to see how it will improve)

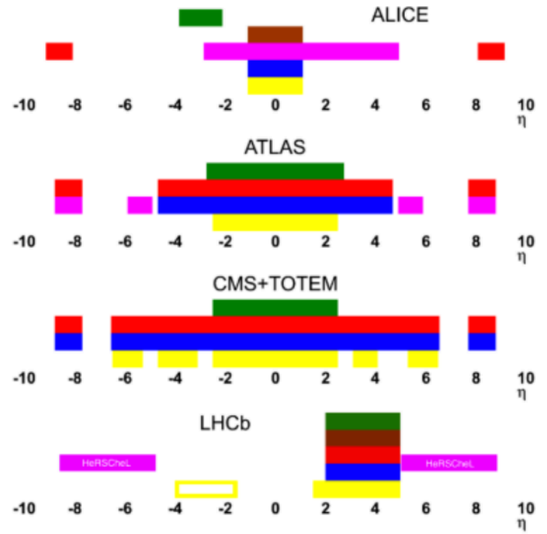
The LHCb detector

Single arm spectrometer fully instrumented in pseudorapidity range $2 < \eta < 5$

Unique in this range







- Excellent tracking down to p_T=0.
- Excellent particle identification.
- Excellent primary vertex determination.

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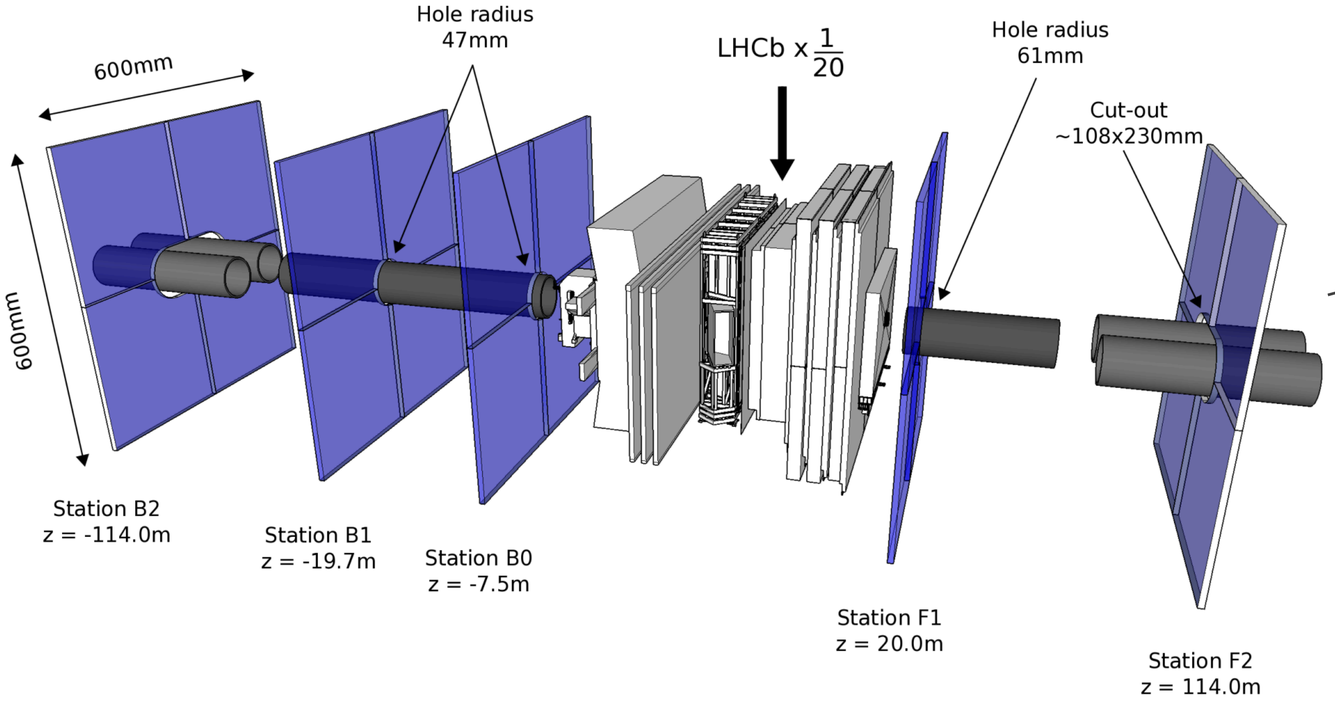
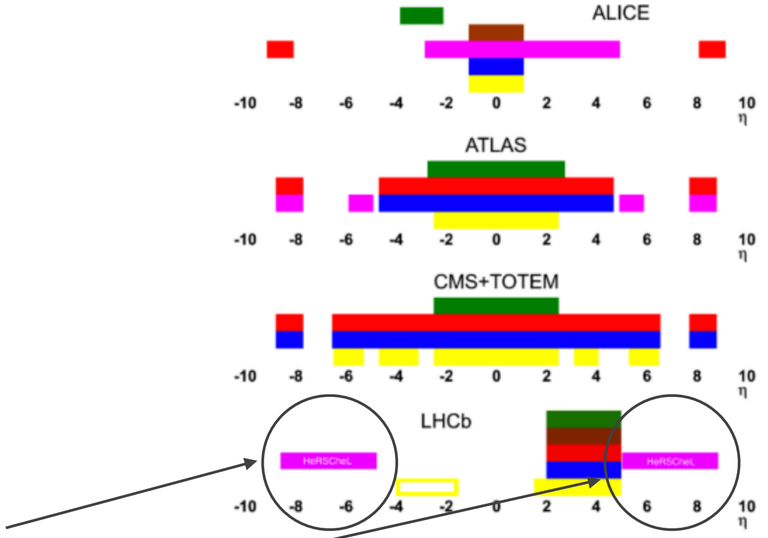
The LHCb detector

Single arm spectrometer fully instrumented in pseudorapidity range $2 < \eta < 5$

2018 JINST 13 P04017 HeRSCheL detector, high-rapidity shower counters





- Excellent tracking down to p_T=0.
- Excellent particle identification.
- Excellent primary vertex determination.

Great detector for UPC!

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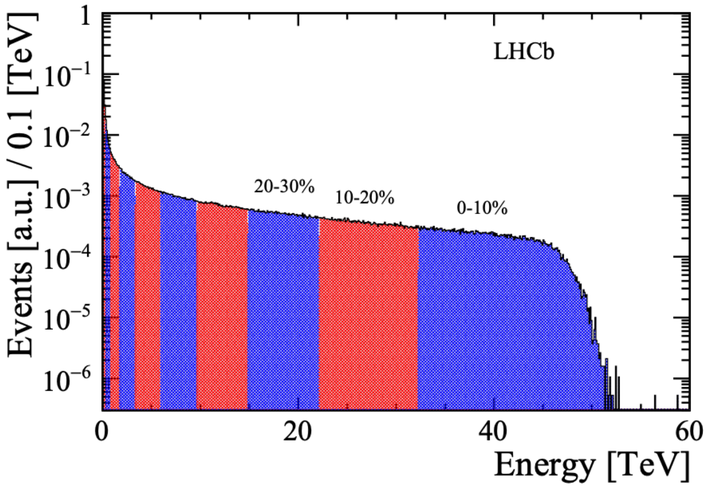
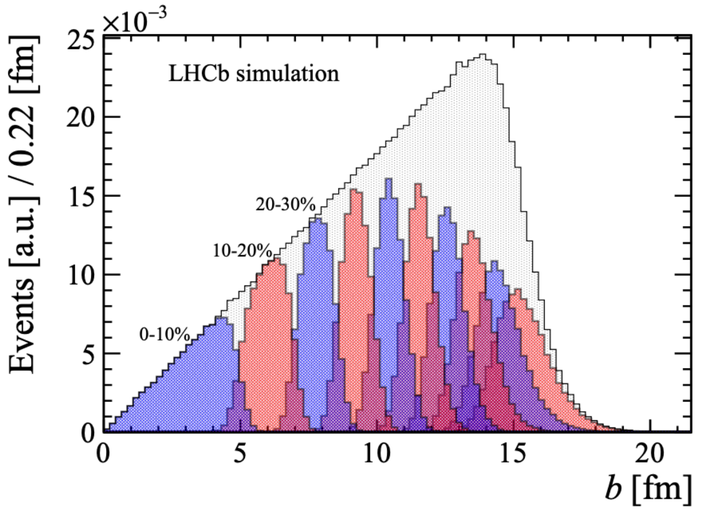
Centrality determination

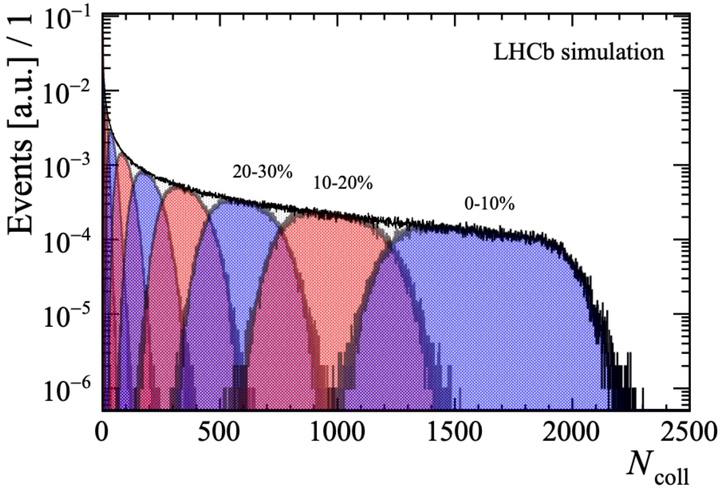
arXiv:2111.01607

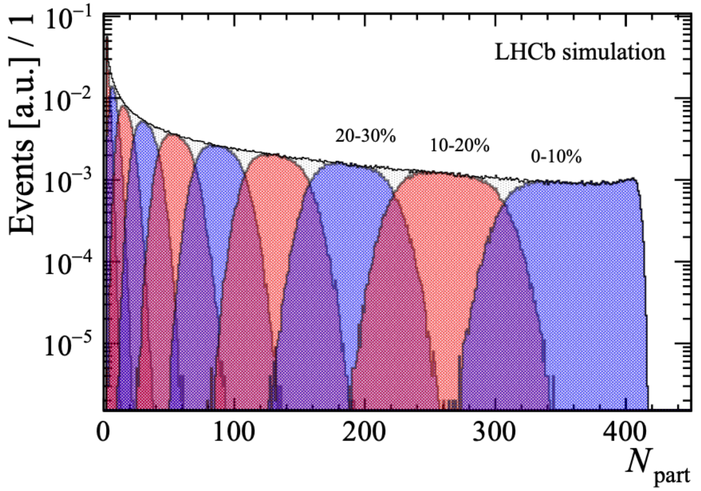
Centrality determination using MCGlauber model

Centrality %	$N_{\text{part}} \pm \sigma$	$N_{\text{coll}} \pm \sigma$	$b \pm \sigma$
$100-90$	2.91 ± 0.54	1.83 ± 0.34	15.41 ± 2.96
$90-80$	7.03 ± 0.78	5.77 ± 0.64	14.56 ± 1.80
$80-70$	15.92 ± 0.64	16.44 ± 0.69	13.59 ± 0.52
$70-60$	31.26 ± 0.67	41.28 ± 0.93	12.61 ± 0.28
$60-50$	54.65 ± 1.13	92.59 ± 2.01	11.59 ± 0.24
$50-40$	87.54 ± 1.01	187.54 ± 2.43	10.47 ± 0.14
$40-30$	131.24 ± 1.15	345.53 ± 3.89	9.23 ± 0.08
$30-20$	188.02 ± 1.49	593.92 ± 6.62	7.80 ± 0.06
$20-10$	261.84 ± 1.83	972.50 ± 10.37	6.02 ± 0.04
$10-0$	357.16 ± 1.70	1570.26 ± 15.56	3.31 ± 0.01



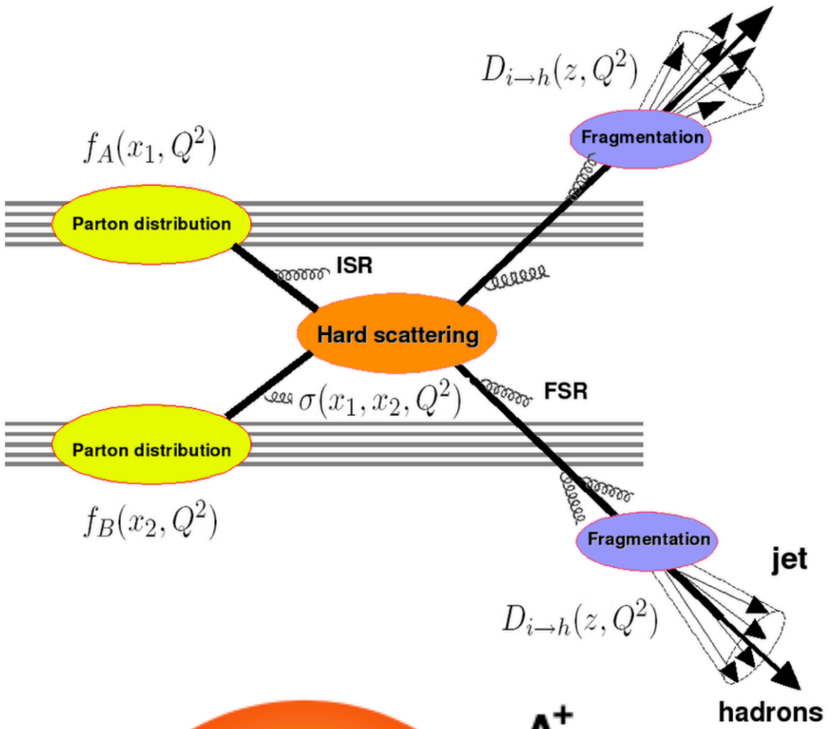


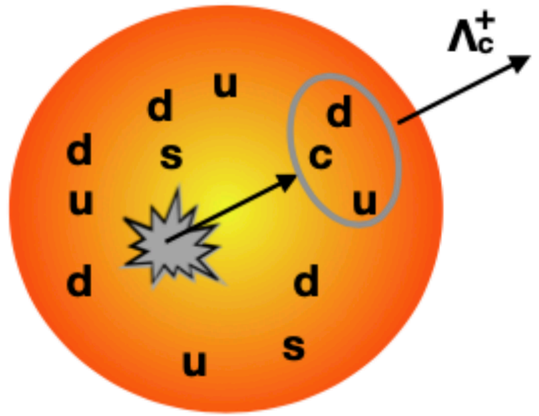




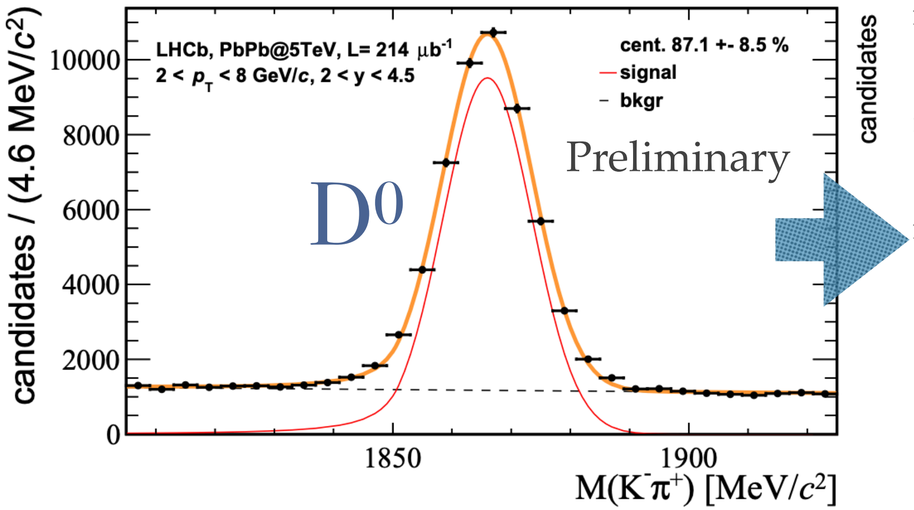
Λ_c/D^0 in PbPb @ 5TeV

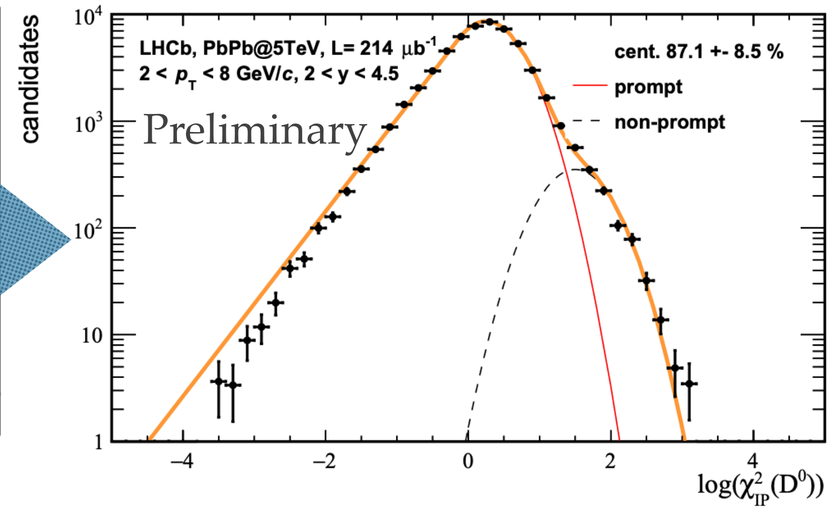
- Large quark mass -> pQCD calculation
- Ratio to test pQCD factorisation
- Probe hadronization mechanisms:
  - Fragmentation functions
  - Coalescense:
    - Occuring in both small and large system?
    - Multiplicity dependent?

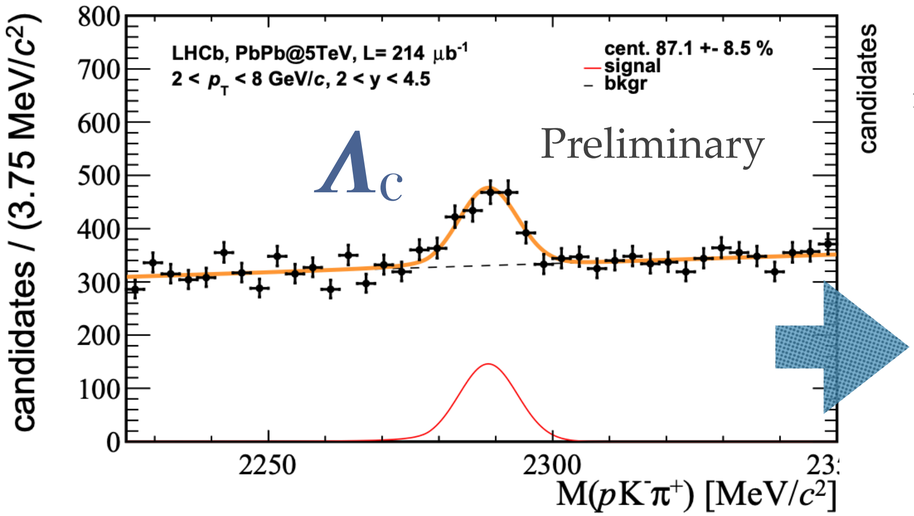


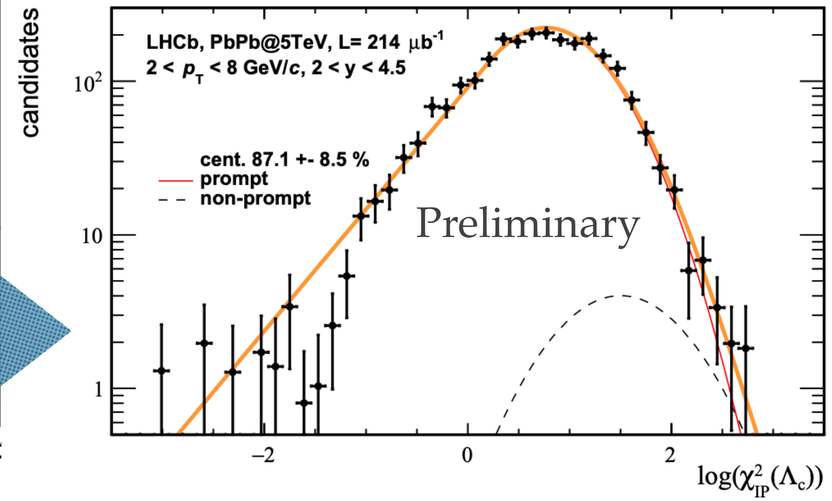


Λ_c/D^0 in PbPb @ 5TeV



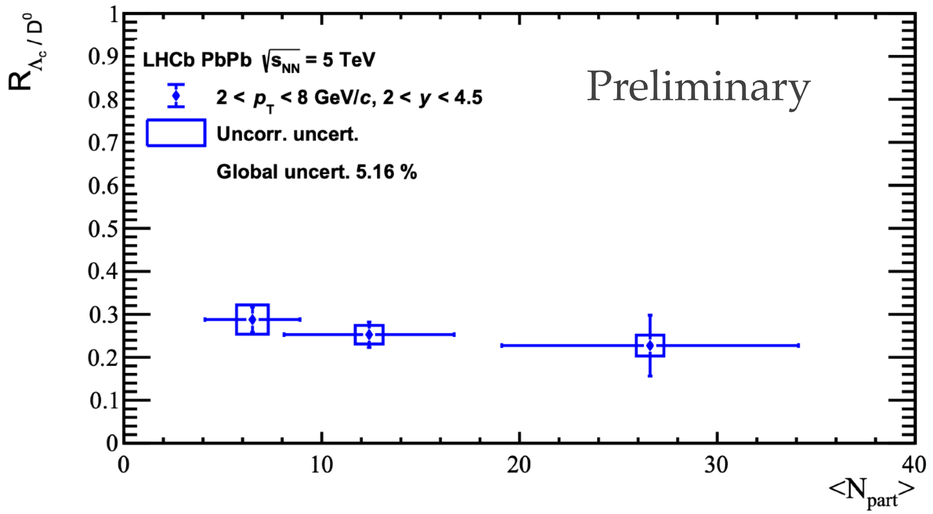


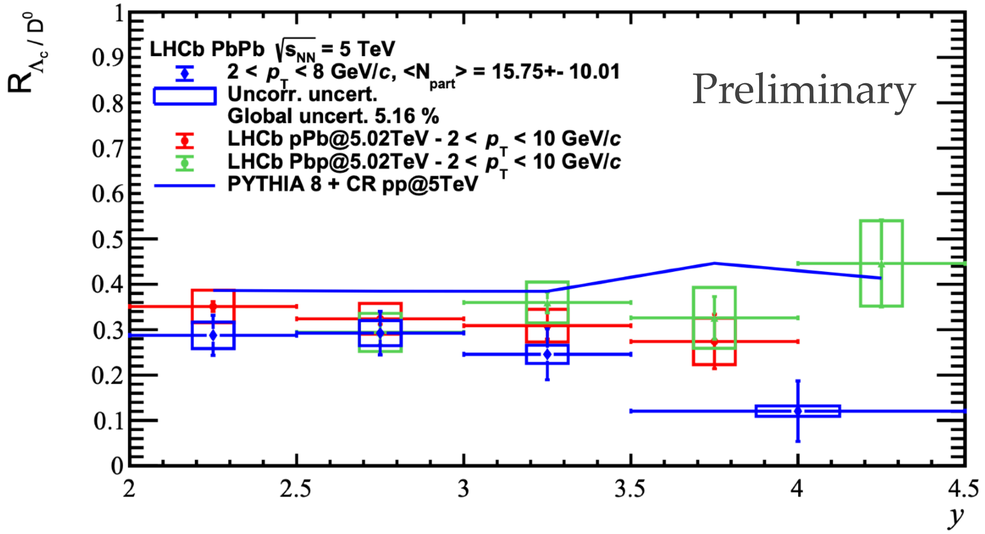


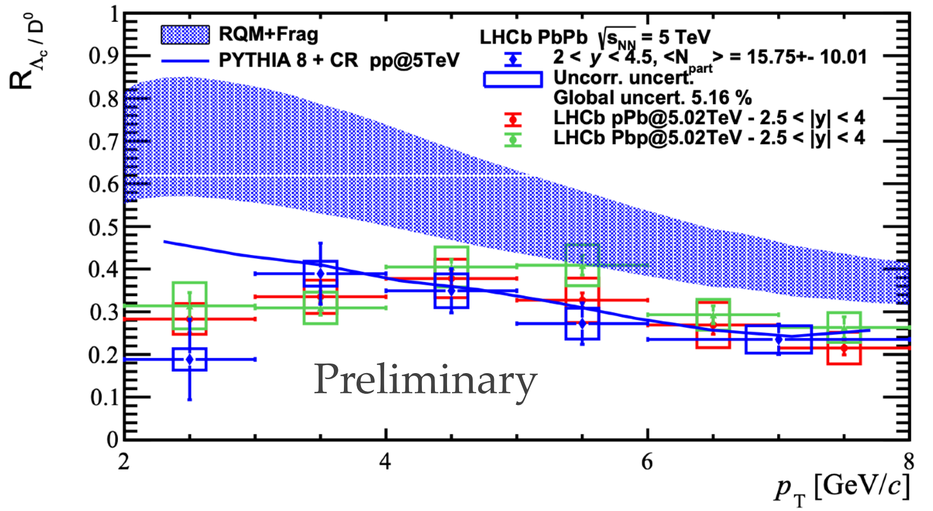


- $D^0 \rightarrow K\pi$
- $\Lambda_c \rightarrow pK\pi$
- Fit to the invariant mass spectrum
- Fit to the $\log(\chi^2_{IP})$ (decay vertex compatibility with the primary vertex)

Λ_c/D^0 in PbPb @ 5TeV

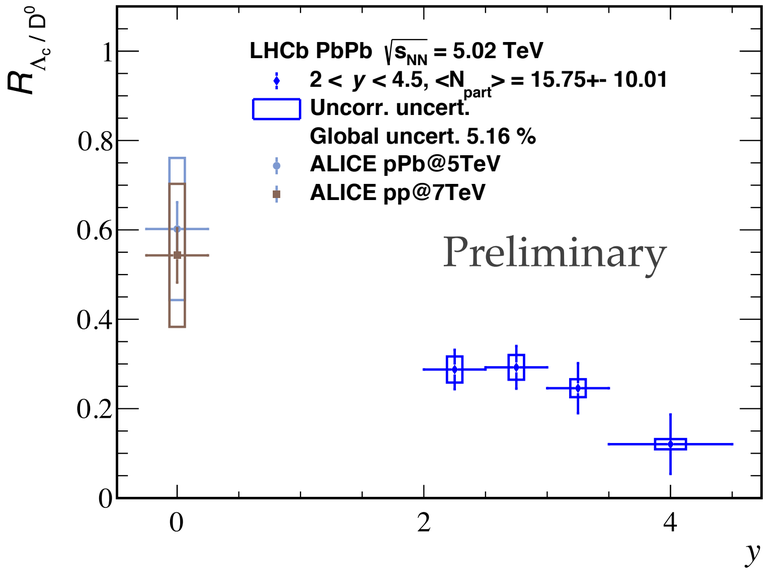


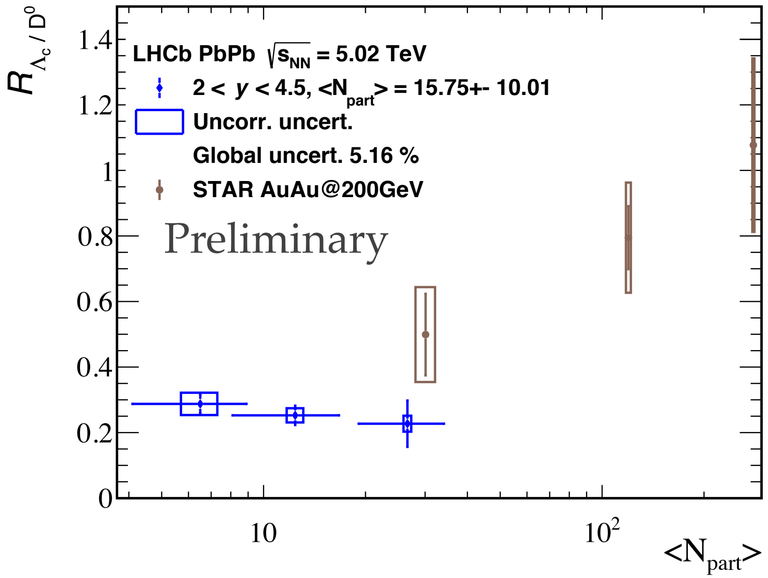




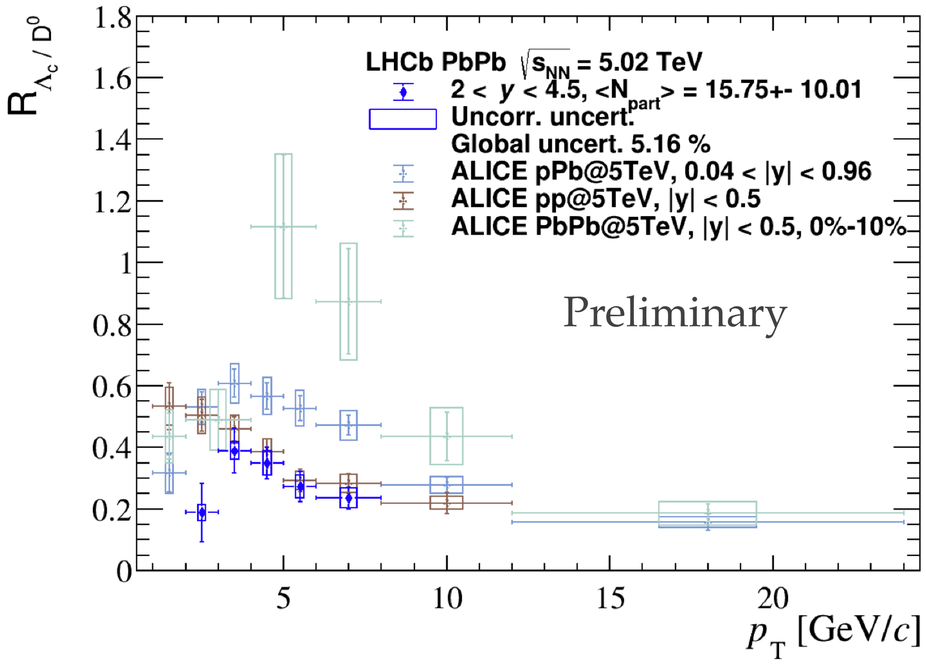
- Flat dependence vs N_{part}
- Results compatible with pPb results at same energy
- Decreasing trend toward high p_T
- Compatible with pythia8 and color reconnection (pp@5TeV)

Λ_c/D^0 in PbPb @ 5TeV

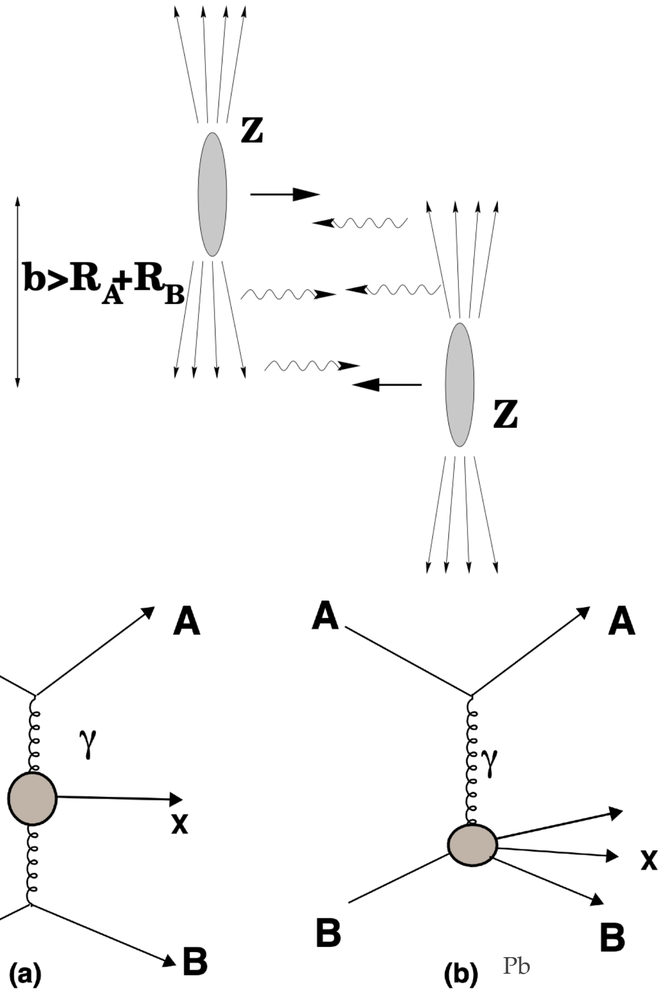




- Confirm tension with ALICE results
- Rapidity dependence?
- New results in central PbPb from ALICE
  - Ratio enhanced with QGP formation ?



J/ψ, ψ(2S) PbPb UPC @5TeV



- Impact parameter $b>R_1+R_2$
- Interaction between two nuclei with no actual hadronic collisions
- No destruction of the nuclei A+A->A+A+X
- Interaction through the quasi real-photon cloud from one or both nuclei.
- Large reaction rate as photon flux $\propto Z^2$
- Production of dileptons, vector mesons…

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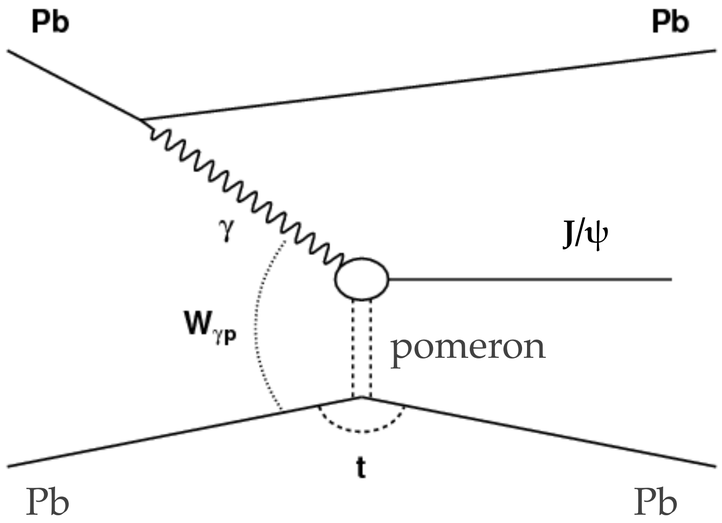
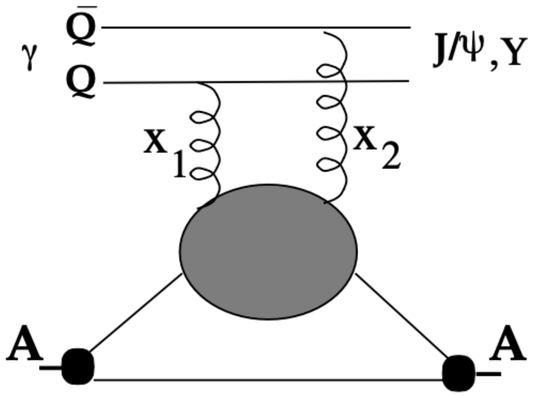
J/ψ, ψ(2S) PbPb UPC @5TeV

Coherent photo-production





- Production of vector mesons through the interaction of a photon and a pomeron
- Amplitude of quarkonium production proportional to the Generalized Parton Distribution functions (GPDs) of the target nucleus $G_A(x_1, x_2, t, Q^2_{eff})$ at large momentum transfer $Q^2_{eff} \propto m_Q^2/4$ and low x-Bjorken $10^{-5} < x < 10^{-2}$

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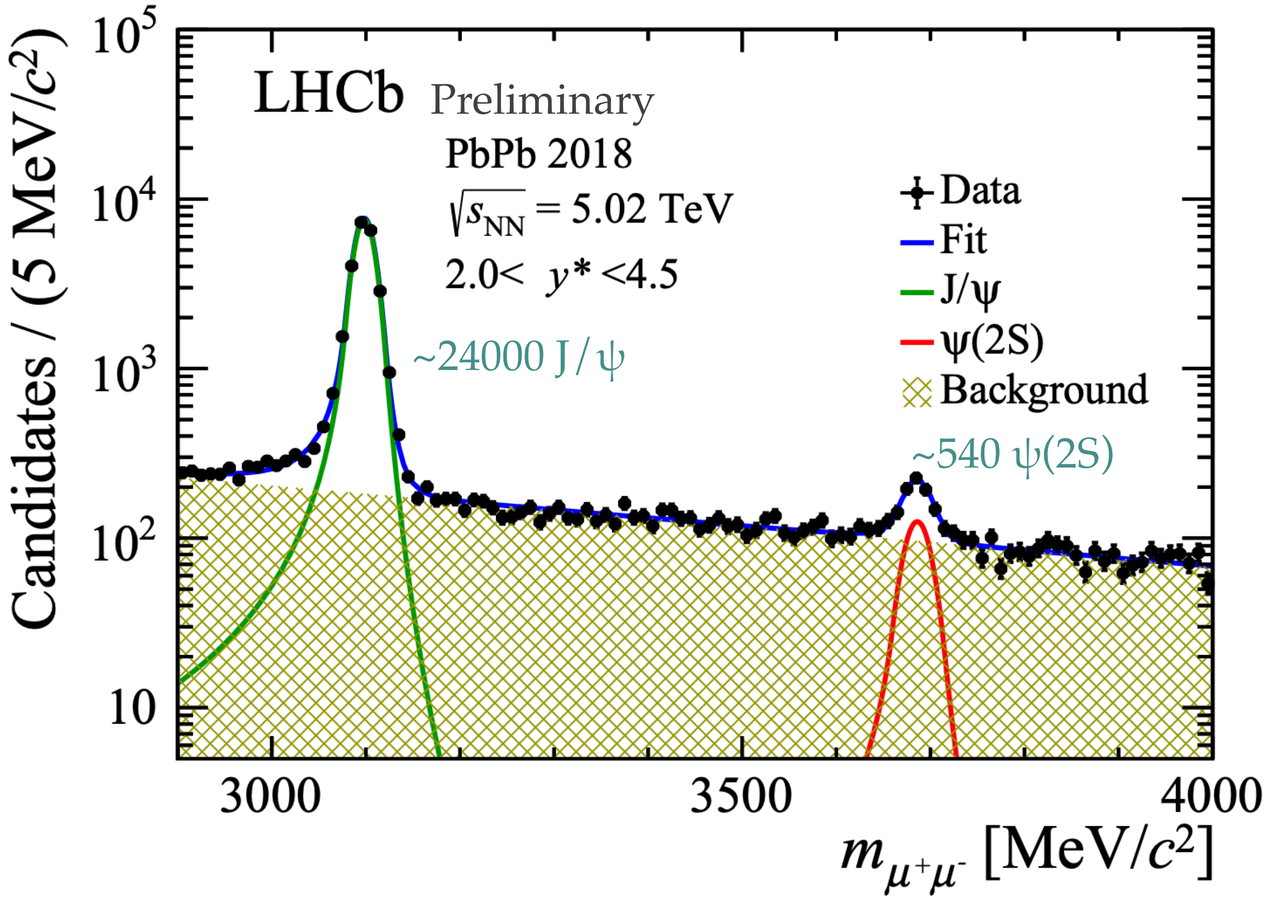
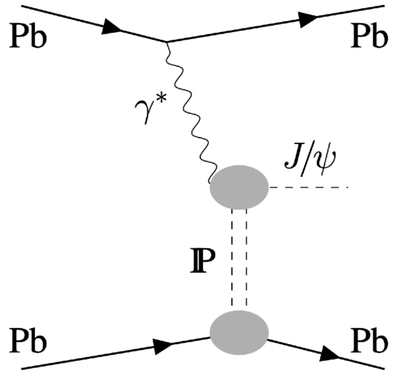
NEW

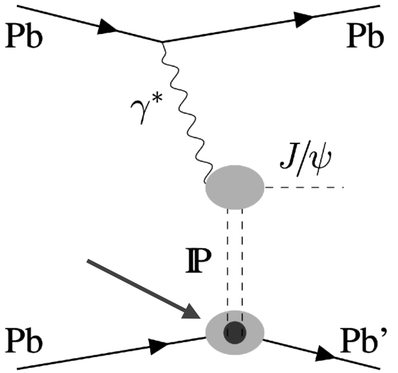
J/ψ, ψ(2S) PbPb UPC @5TeV



- Both signal contain coherent and incoherent produced candidates
- J/ψ from feed-down from ψ(2S)
- Background from $\gamma\gamma \rightarrow \mu\mu$ non -resonnant



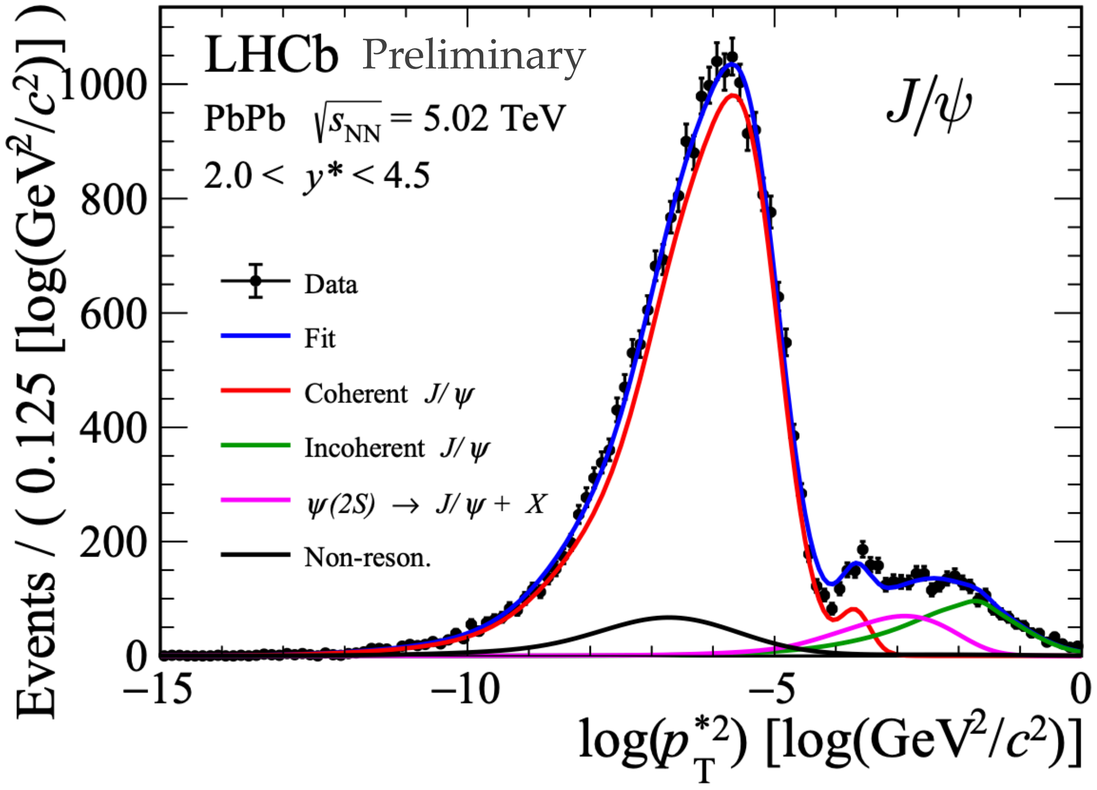
Coherent

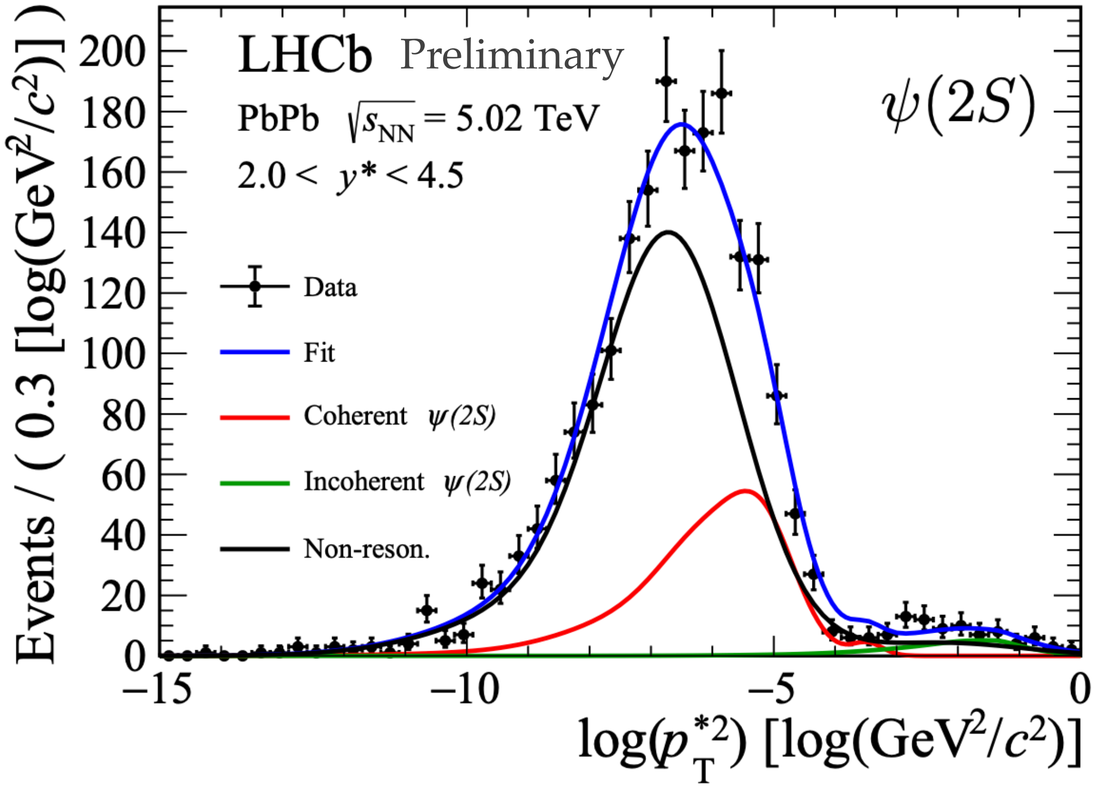


Incoherent

NEW

J/ψ, ψ(2S) PbPb UPC @5TeV





STARLight

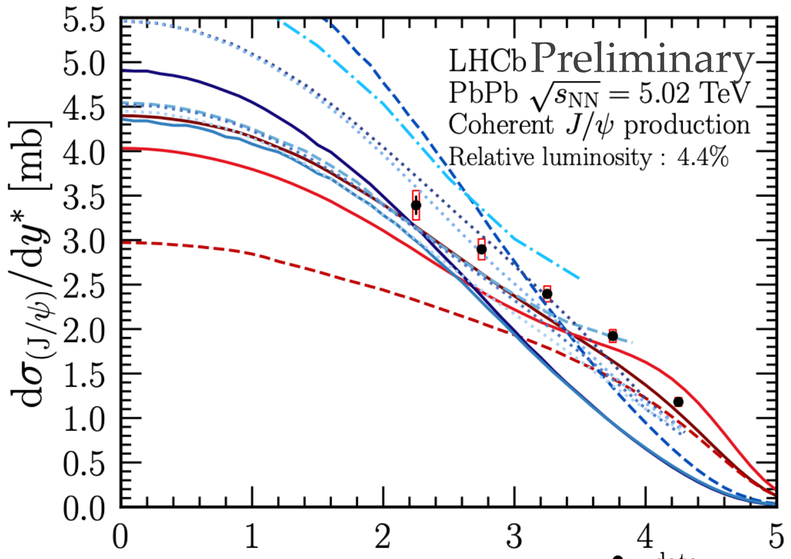
- Template fit based on the STARLight model
- Shape of the background taken from the side band method

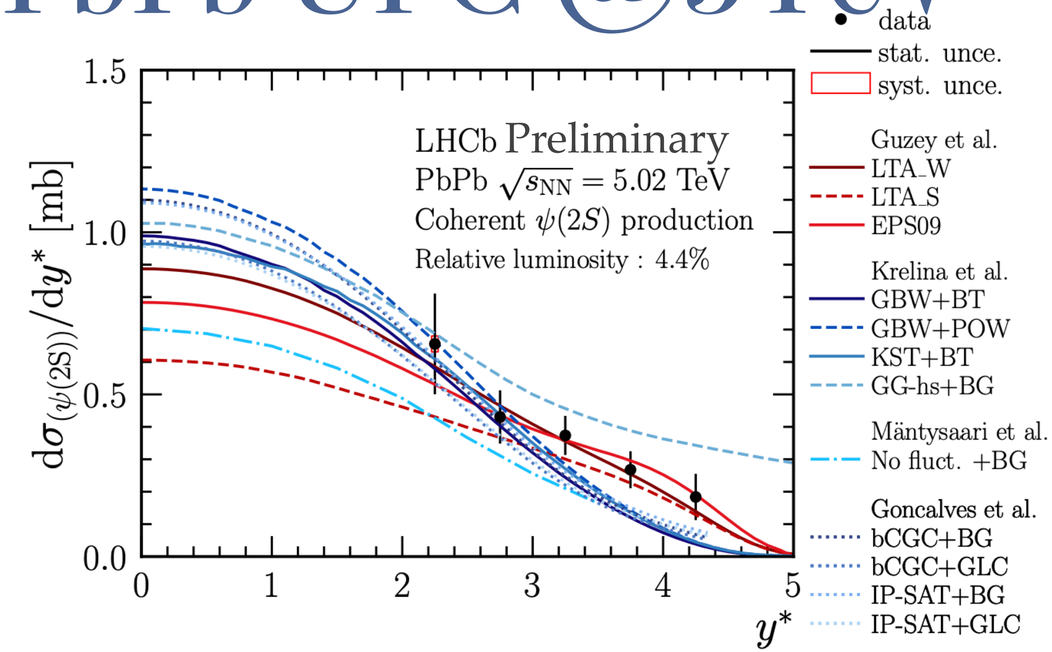
Excellent resolution !

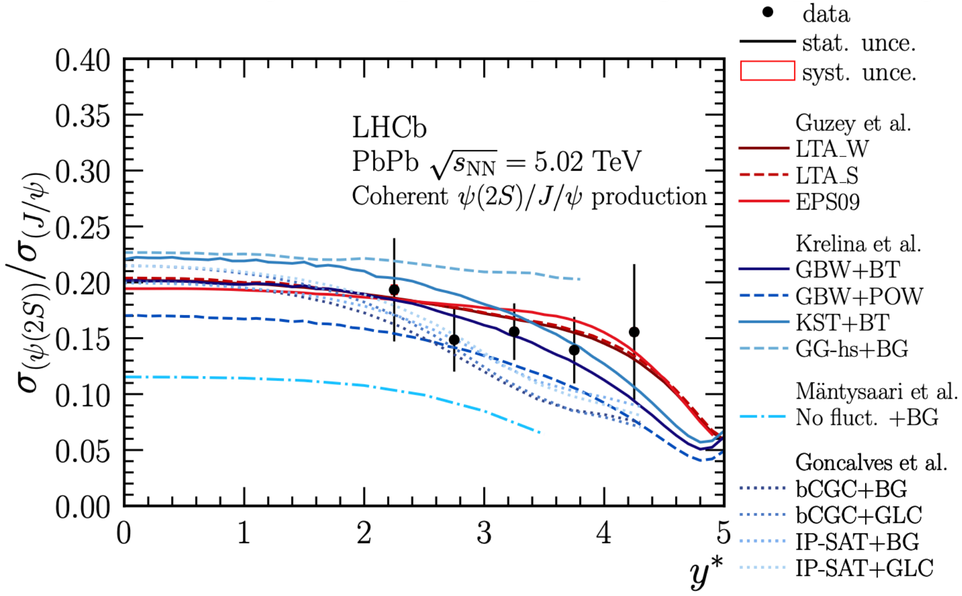
References of models in backup

NEW

J/ψ, ψ(2S) PbPb UPC @5TeV



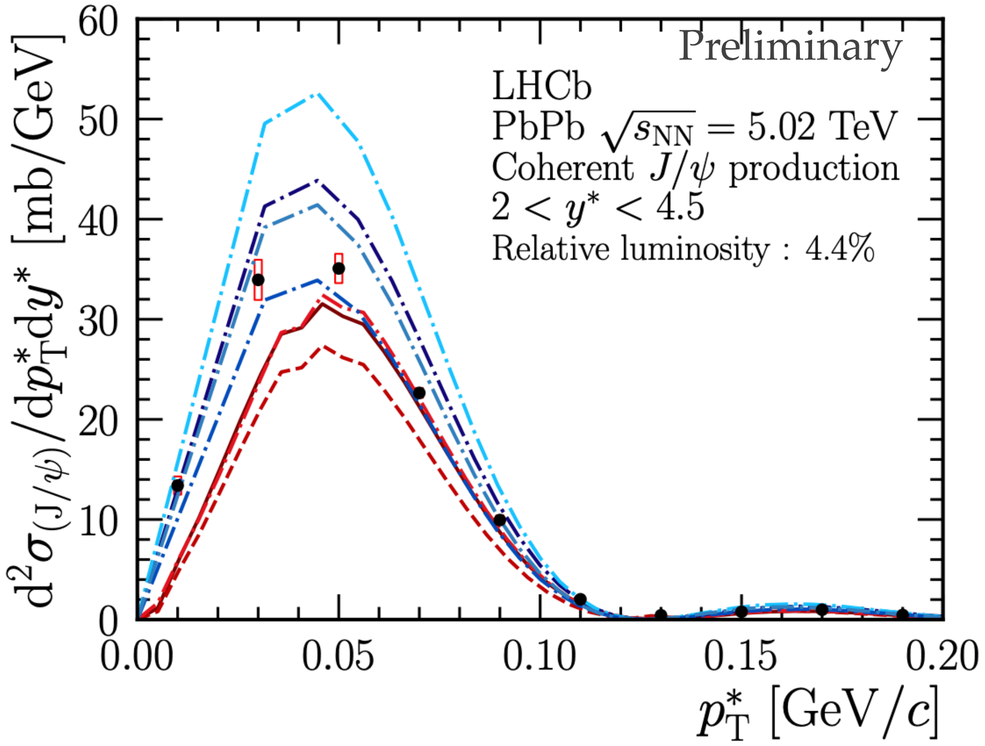


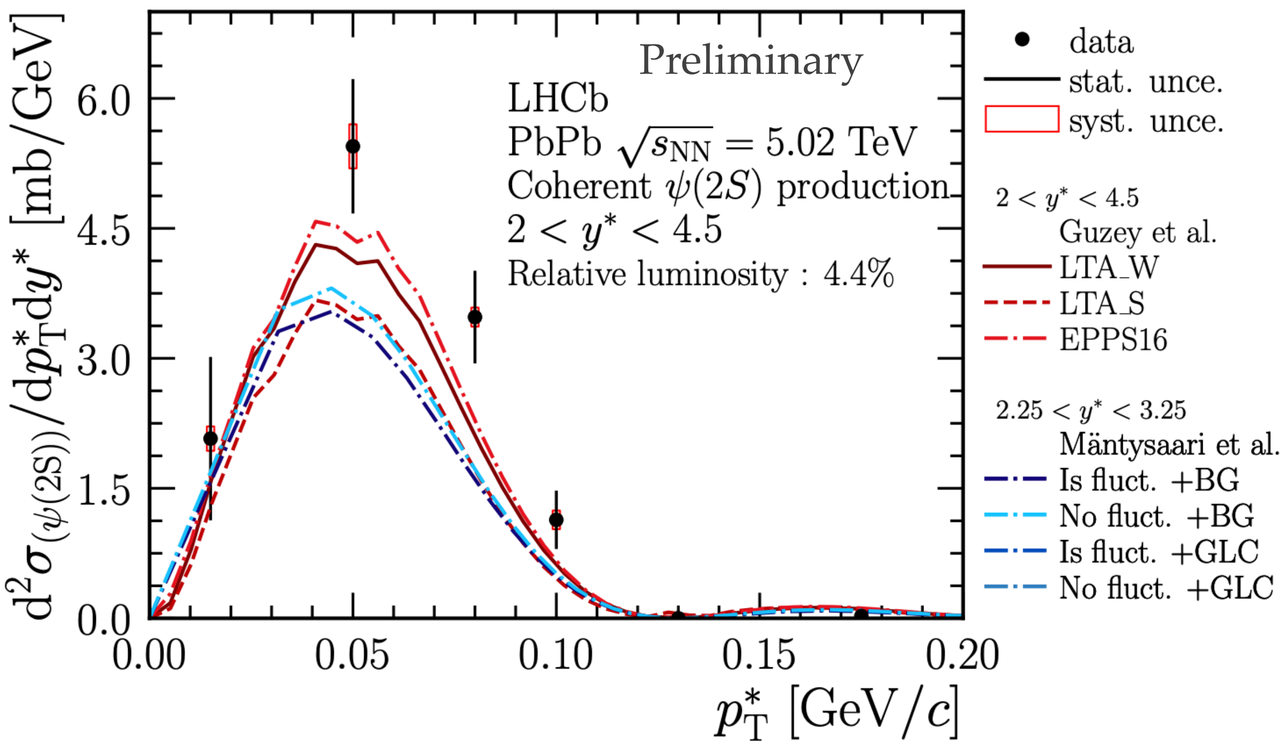


- Results compared with color-dipole and perturbative QCD based model
- No model precisely reproduces the data
- pQCD models have a slightly better agreement with the cross section ratio

NEW

J/ψ, ψ(2S) PbPb UPC @5TeV





- Overall shape well reproduced by models but the normalization is less accurate
- Peaking structure due to destructive interferences (cannot distinguish the photon emitter).

Phys. Rev. C **105**, L032201

First measurement in PbPb hadronic collisions !

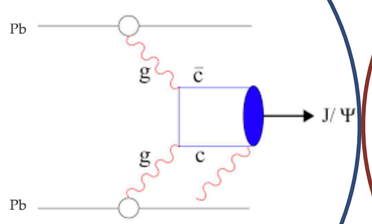
Coherent J/ψ in PbPb peripheral collisions

Coherent photo-production in peripheral collisions ? ($b<2R_{Pb}$)

- 2018 PbPb sample at 5.02 TeV, limited to 60-90% centrality

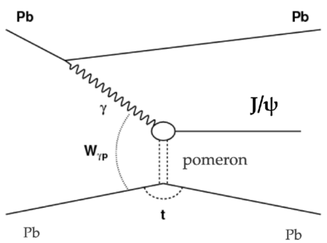
$\langle p_T \rangle$~1-2 GeV/c

Hadronic production



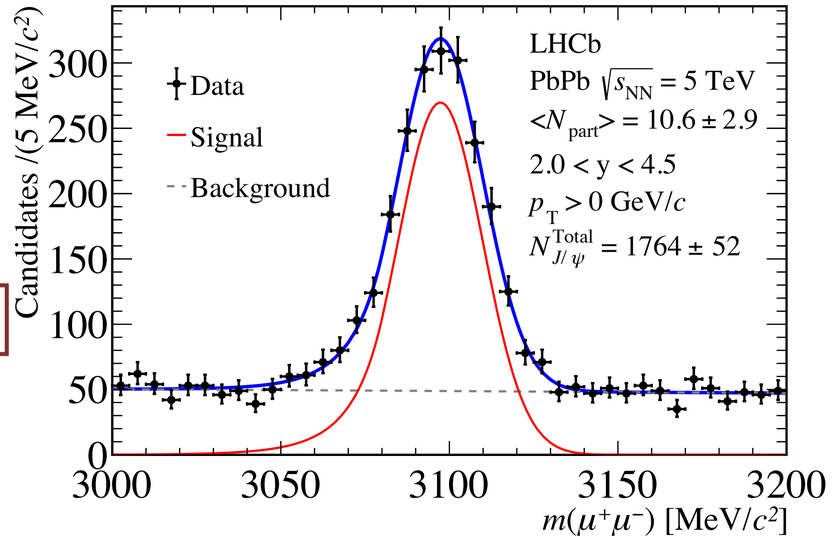
$gg \rightarrow J/\psi$

Coherent photo-production



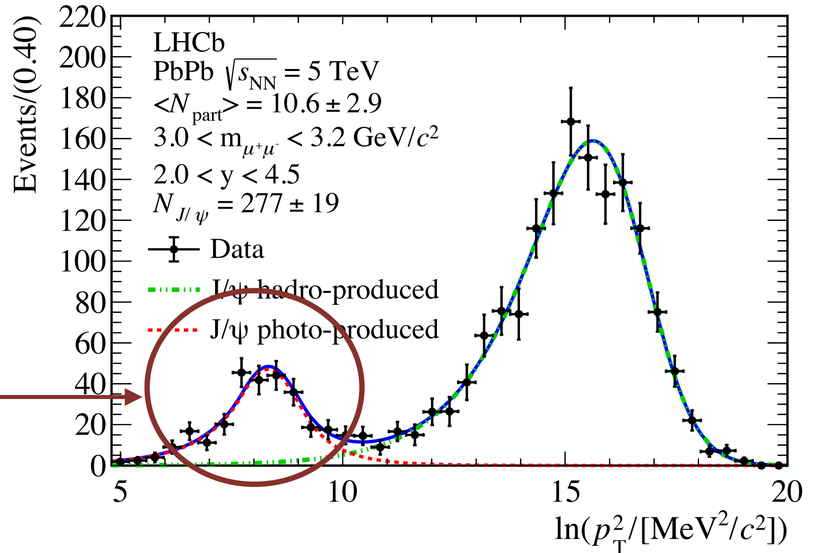
$\gamma(pomeron) \rightarrow J/\psi$

$\langle p_T \rangle < 100$ MeV/c



Separate the two contributions through the p_T distribution of the J/ψ

« Excess » of J/ψ with mean p_T around ~70 MeV/c
Compatible with coherent photo-production



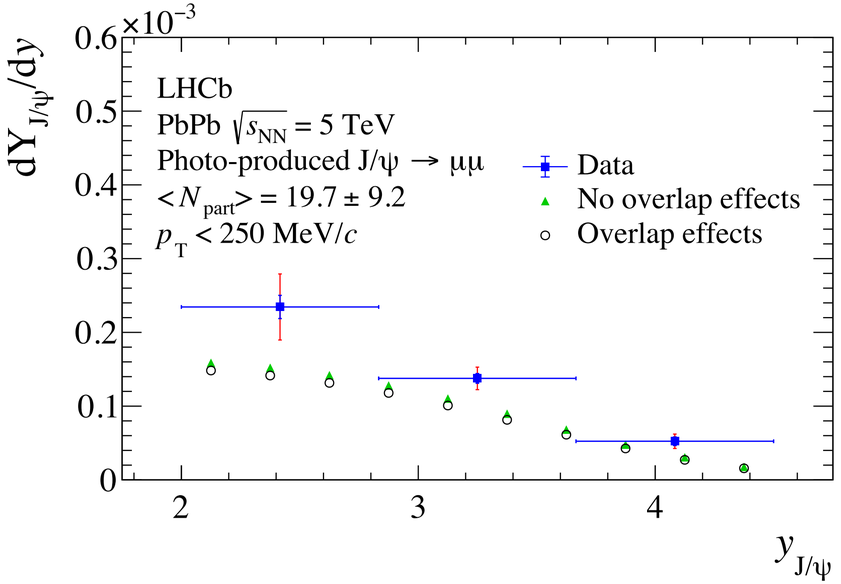
Phys. Rev. C **105**, L032201

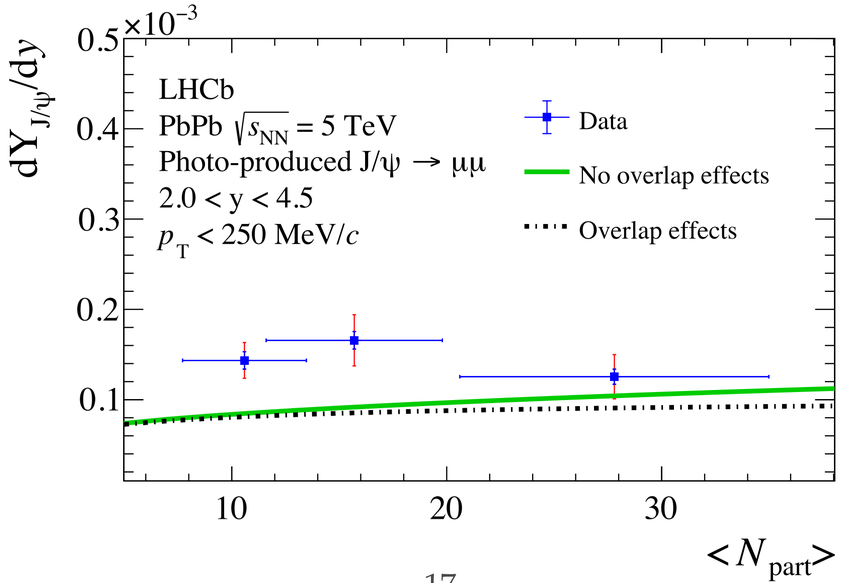
First measurement in PbPb hadronic collisions !

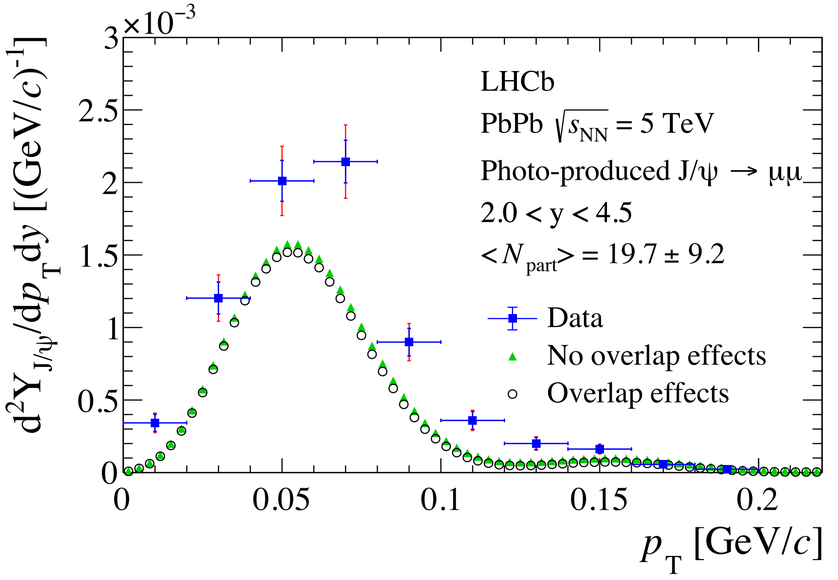
Coherent J/ψ in PbPb peripheral collisions

- Consistent with J/ψ photo-production in PbPb hadronic collisions
- Most precise p_T measurement to date
- Shape compatible with model, two assumptions:
  - No effect of the overlap between the nuclei (UPC-like but small IP)
  - Effect of the overlap

W. Zha et al. Phys. Rev. C97 (2018) 044910 / Phy. Rev. C99, 06901(R)



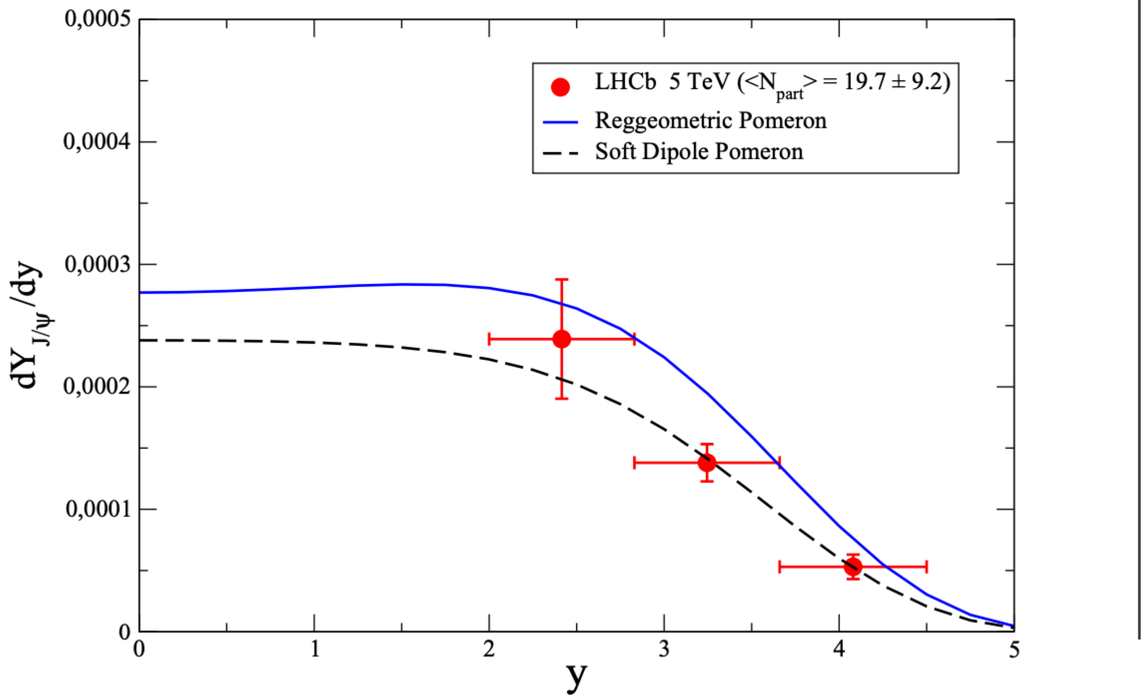


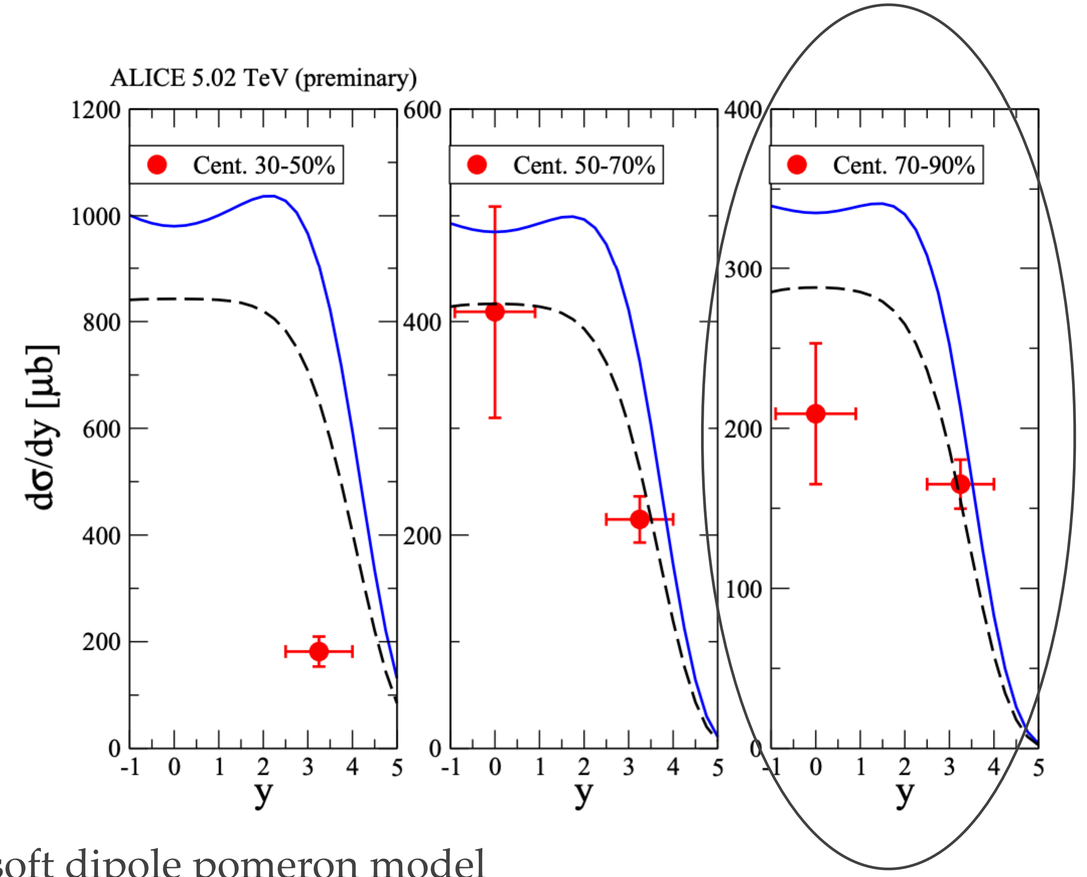


arXiv:2202.02162v2

Coherent J/ψ in PbPb peripheral collisions

Vector Dominance Model + Glauber multiple scattering formalism





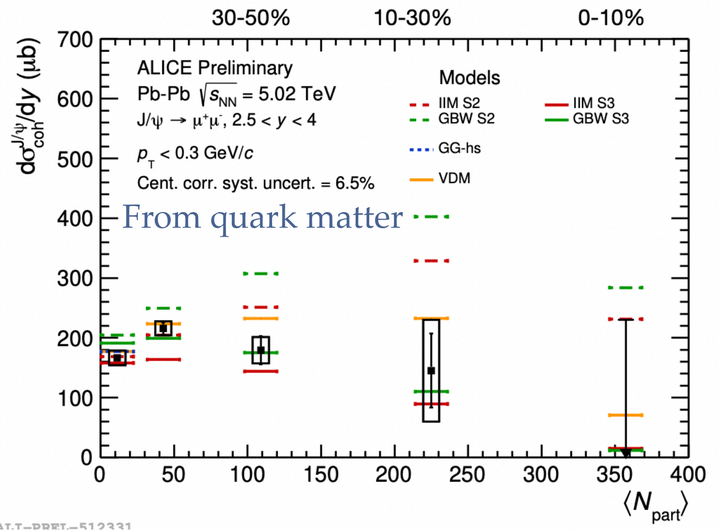
- Recent preprint shows good agreement with the soft dipole pomeron model
- Agreement with corresponding results from ALICE

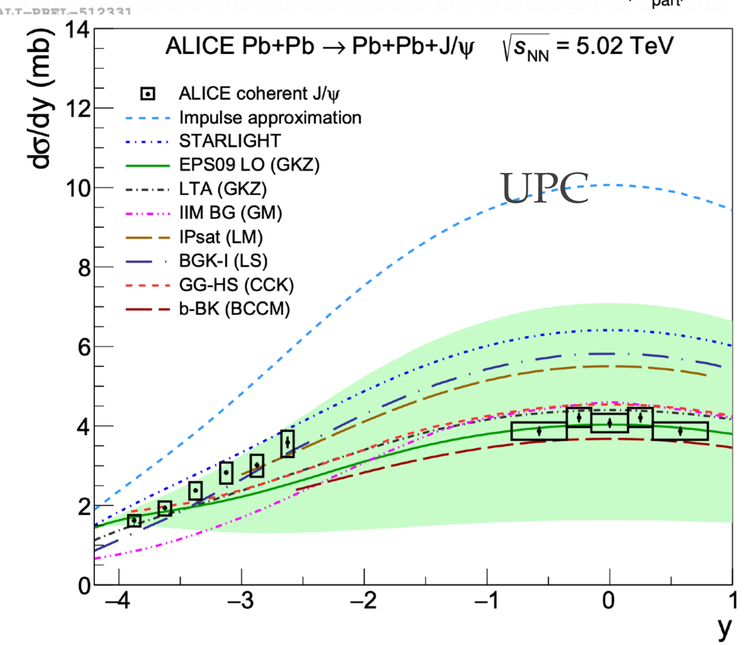
Coherent J/ψ in PbPb peripheral collisions

- ALICE as a lesser precision but central measurement
- Decrease here could be explain by:
  - Less accessible aera for the photon to interact
  - Melting of the photo produced J/psi, low-pt spectrum not repopulated by (re)combined

    Better thermometer for QGP ?
- Precise measurement with LHCb in run3/4
- However behavior not clearly understood even in UPC

Precise measurement with run3/4 !



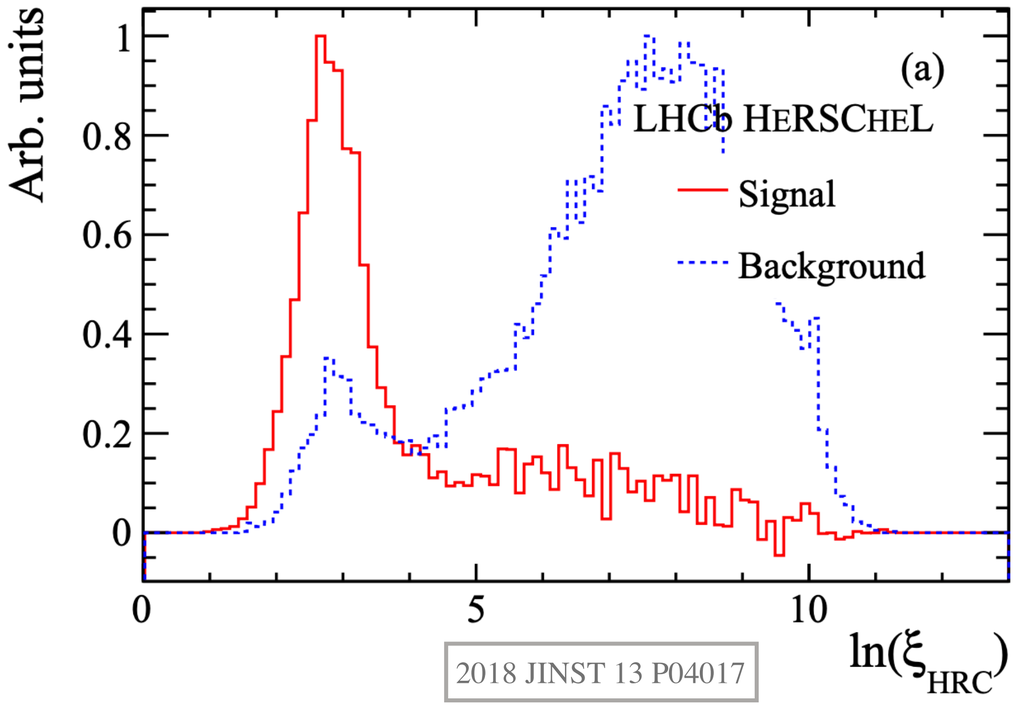


Conclusion

- First measurement of Λ_c/D^0 in PbPb collisions at forward rapidity
  - In agreement with previous LHCb results in pPb/Pbp
  - Confirm the difference between mid and forward rapidity
- Really precise measurement of coherent J/ψ and $\psi(2S)$ production in UPC PbPb collisions.
- Measurement of photo-produced J/ψ in peripheral PbPb collisions.
  - Consistent with photo-production in PbPb peripheral collisions.
  - Agreement with last model and ALICE results

J/ψ, ψ(2S) PbPb UPC @5TeV

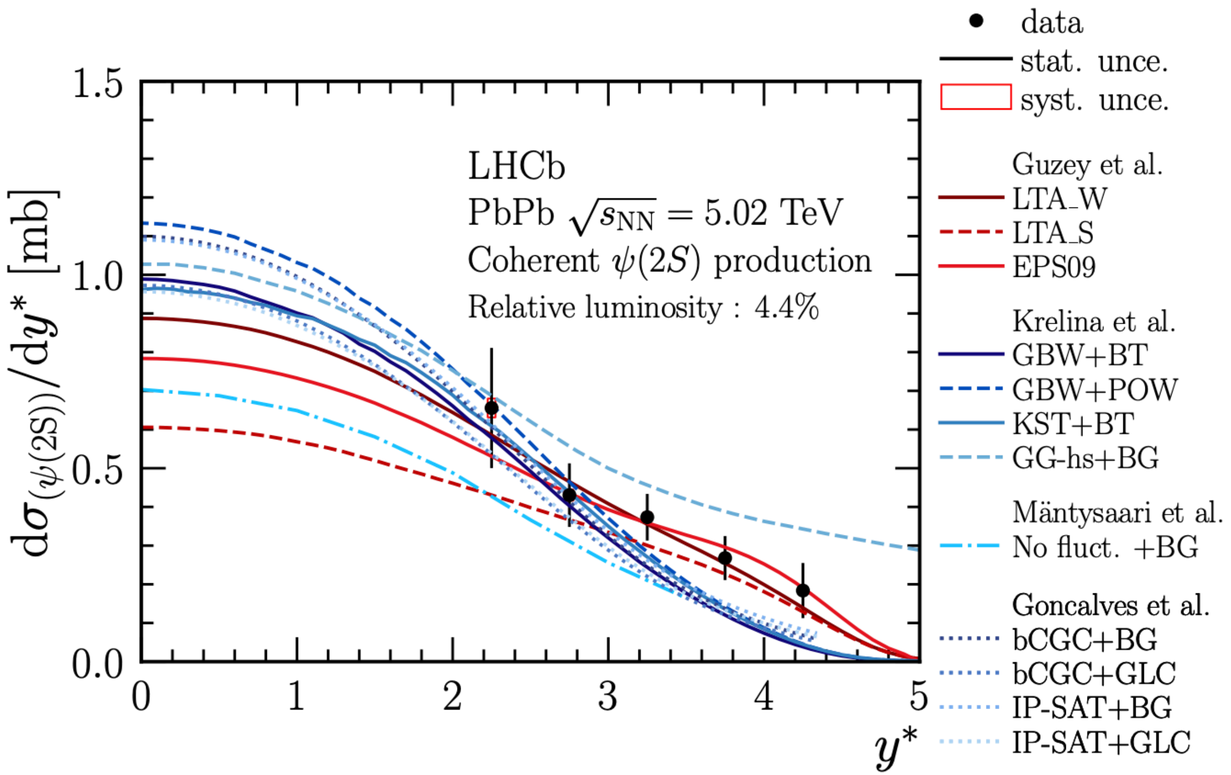
- PbPb data recorded by the LHCb detector in 2018 with in integrated luminosity of about $\mathscr{L}$=228±10μb
- UPC Event selection:
  - Veto events with more than 20 hits in the SPD
  - Veto events with more than 20 hits in the ξ_{HRC} calorimeter
  - Selection thanks to the HeRSCheL detector
- Candidates reconstructed with the dimuon channel
  - Two opposite sign μ with $p_T > 700$ MeV/c
  - $p_T^{\mu\mu} < 1$ GeV/c and $\Delta\varphi^{\mu\mu} > 0.9\boldsymbol{\pi}$



ξ_{HRC} is a $\chi_2$variable, ξ_{HRC} -> 0 corresponding to zero or little activity in HerRSCheL, compatible with UPC

Backup

References of models



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Λ_c/D^0 in PbPb @ 5TeV

- Large quark mass -> pQCD calculation
- Ratio to test pQCD factorisation
- Probe hadronization mechanisms:
  - Fragmentation functions
  - Coalescense:
    - Occuring in both small and large system?
    - Multiplicity dependent?

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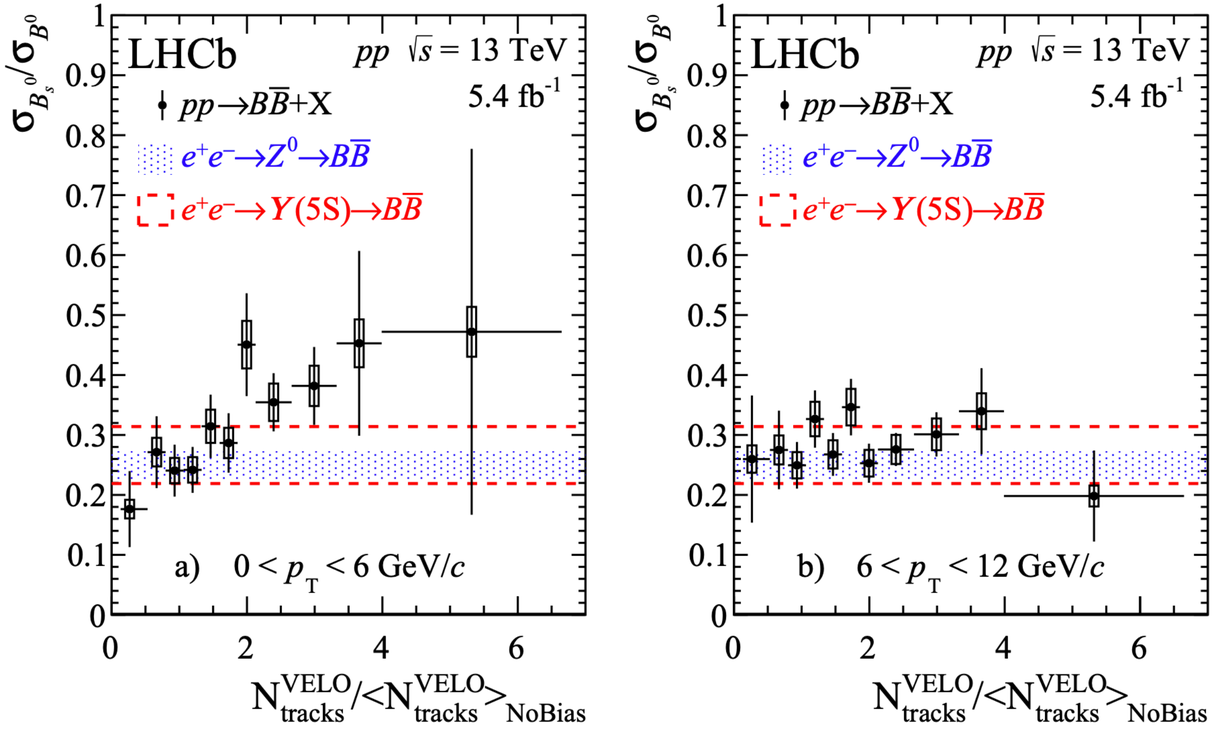
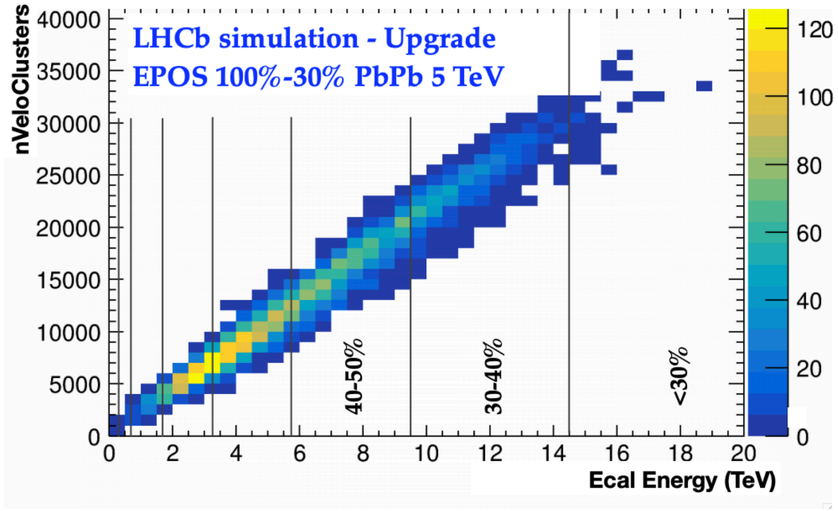
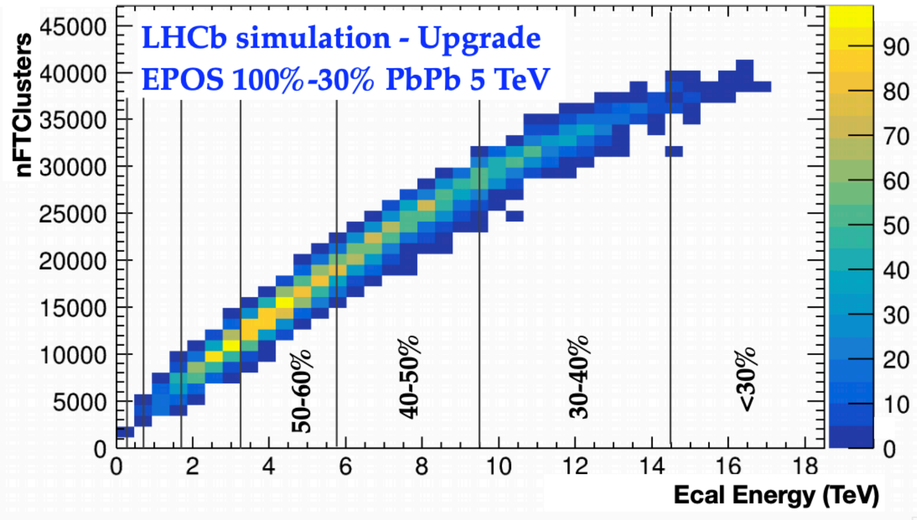


Performances Run 3 PbPb

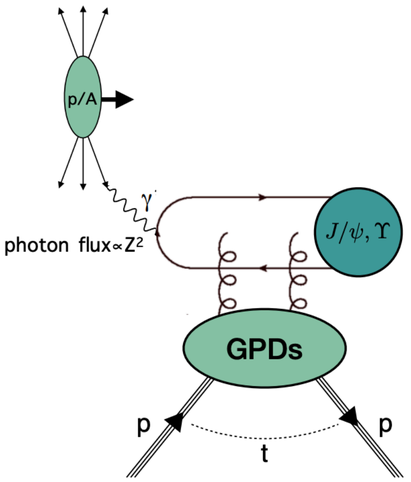
PbPb collisions

LHCB-FIGURE-2019-019





- No significant saturation for 70% most peripheral collisions (simulation for higher centralities are being produced), expect almost no saturation for Run4 (90% most peripheral) and no saturation for Run5.
- Semi-central PbPb collisions soon available : QGP studies for LHCb in run 3 !
- Increased statistics: improvement of UPC studies.



Exclusive meson production