



# Study of inclusive production ratio $\Psi(2S)/J/\psi$ versus charged particle multiplicity in pp collisions at $\sqrt{s} = 13$ TeV with ALICE experiment at LHC

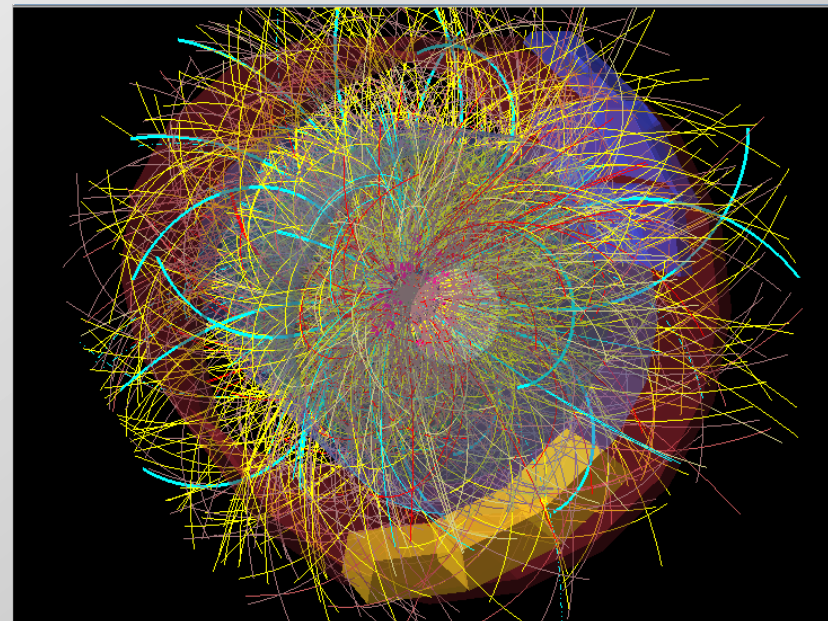


**Manuel Guittièrre**  
PhD Student at Subatech  
Nantes, FRANCE  
Master Internship  
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<http://alice-project-bestpictures.web.cern.ch>

- I      Physics motivations**
- II     ALICE experiment**
- III    Analysis**
- IV    Results**



<http://aliceinfo.cern.ch/public/en/Chapter1/news-nov2011.html>

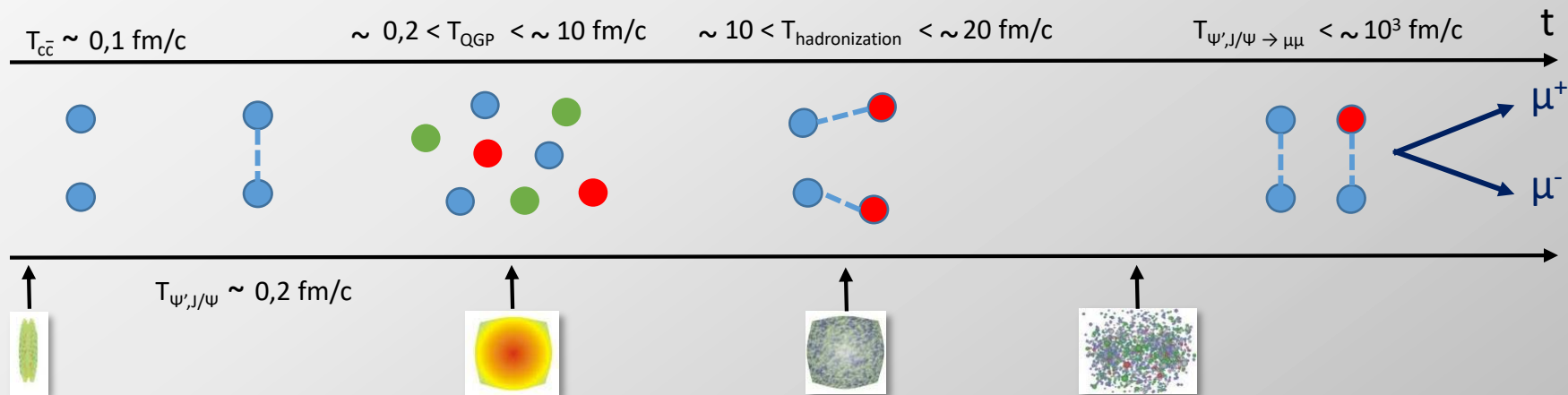


# I – Physics motivations



# Charmonia probes

- $\Psi'$  and  $J/\Psi$  :  $c\bar{c}$  bound states.
- Behavior in heavy-ion collisions :



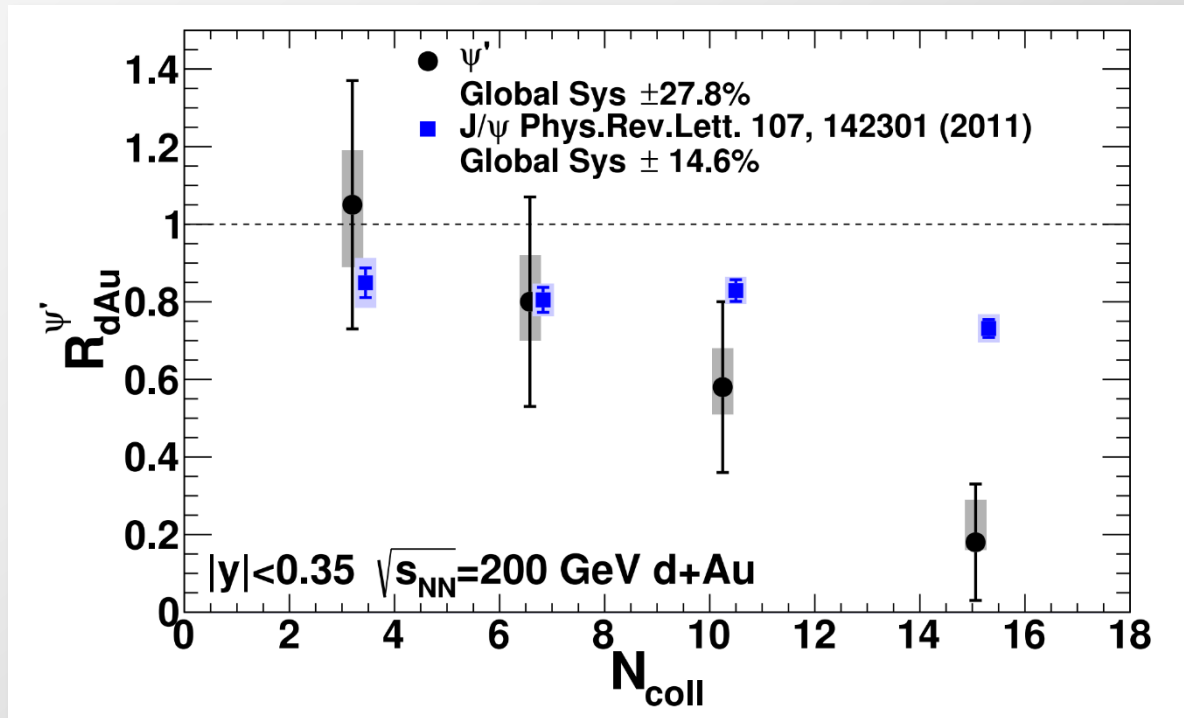
- Charmonia  $\Psi'$  and  $J/\Psi$  sensitive to QGP but also to cold nuclear effects (coherent parton energy loss, shadowing...).

➡ **Comparison with collisions where QGP is not expected (p-Pb and pp).**

- Production sources of  $\Psi'$  and  $J/\Psi$  :
    - Direct production.
    - Other charmonia bound state decays (ex :  $\chi_c$ ).
    - B-hadron decays (non-prompt).
- } prompt } **Inclusive measurement**

# Previous experimental measurements

PHENIX collaboration (2013) arXiv:1305.5516



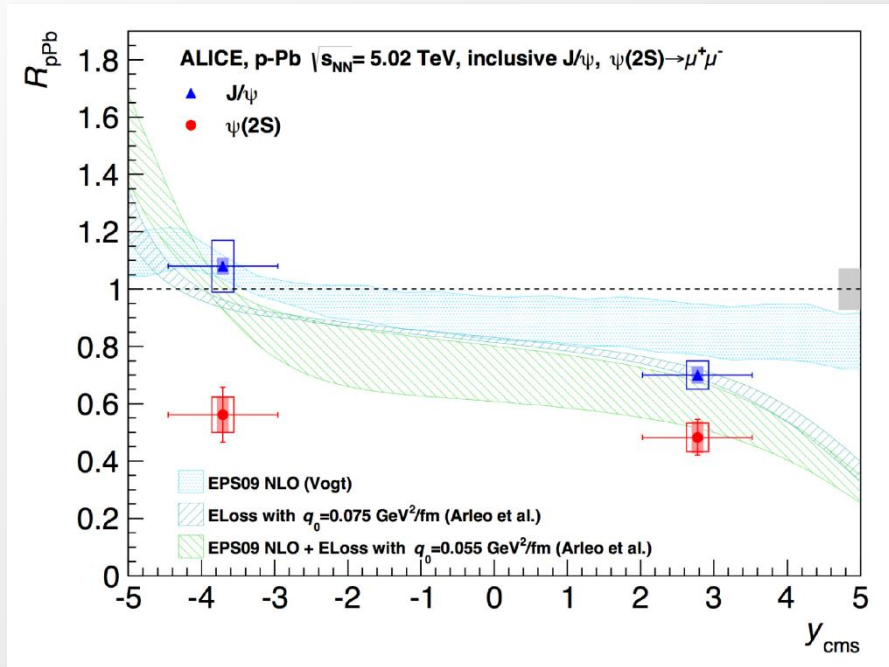
- $R_{dAu}$  (Nuclear modification factor) : Ratio of charmonia production yields measured in dAu and pp, normalized to the mean number of pp collisions.

$$R_{dAu}^{\psi'} = \frac{dN_{\psi'}^{dAu}/dy}{N_{\text{coll}} dN_{\psi'}^{pp}/dy}$$

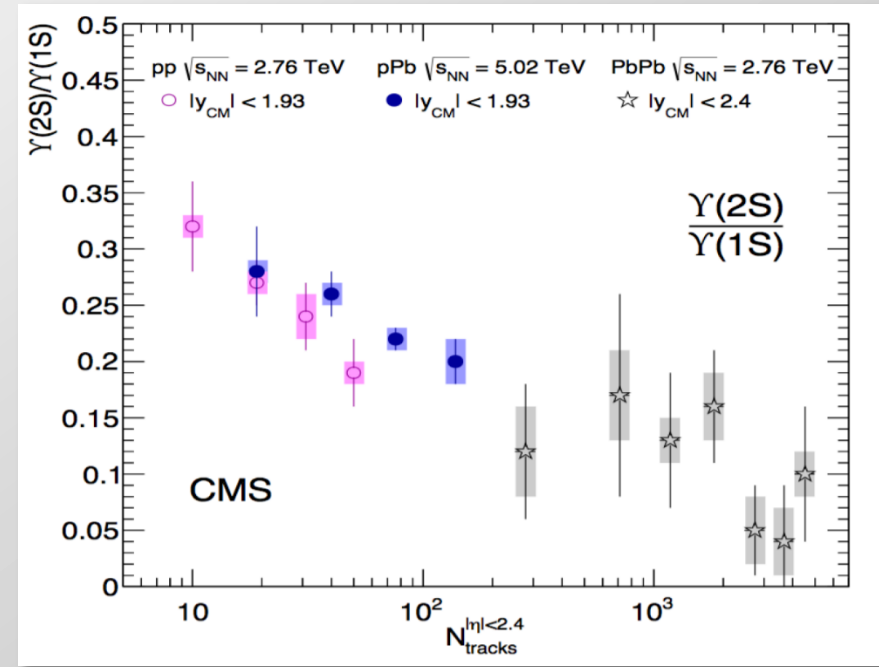
- Unexpected relative suppression of  $\Psi'$  observed.

# Previous experimental measurements

ALICE (2014) arXiv:1405.3796



CMS (2014) arXiv:1312.6300



➤  $\Psi'$  is more suppressed than  $J/\Psi$ . Shadowing and Energy loss cannot describe this result.

➤ CMS observed a relative suppression of  $Y(2S)$  compared to  $Y(1S)$  in pp, pPb and PbPb collisions.

➔ Study of  $\Psi'/J/\Psi$  production ratio in pp collisions



I – Physics motivations



## II – ALICE experiment

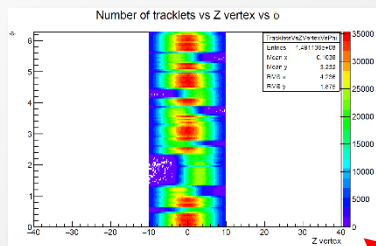
III – Analysis

IV – Results



ALICE

# ALICE detectors



## ITS (Inner Tracking System) :

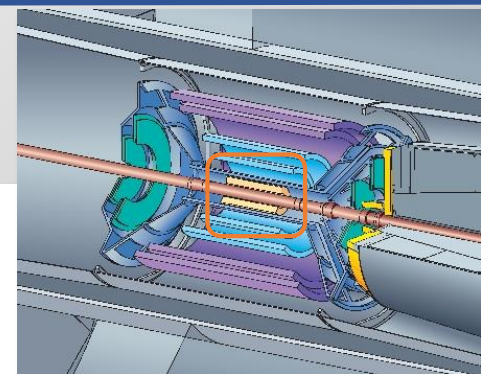
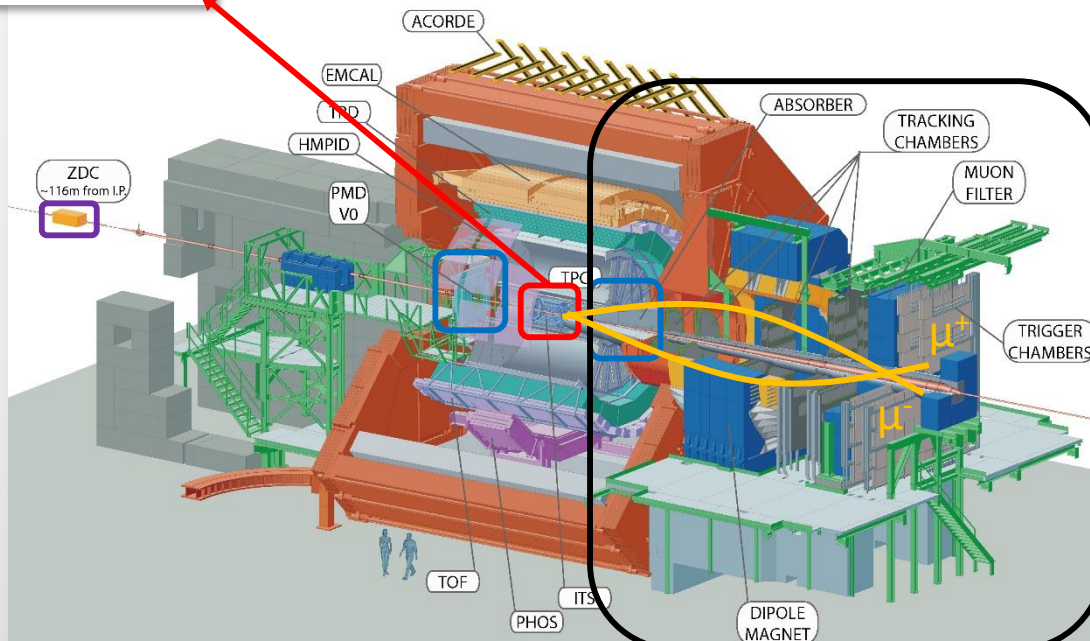
- ❖ Primary vertex reconstruction

## VO (VOA + V0C) :

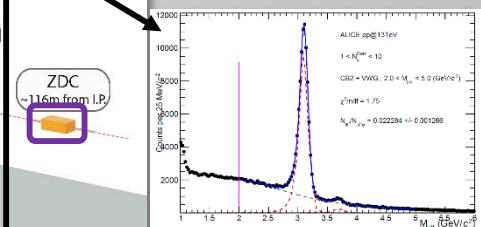
- ❖ Trigger signal to identify collisions (MB trigger)

## ZDC (Zero Degree Calorimeter)

- ❖ Reject EM interactions



## SPD (Silicon Pixel Detector)



## Muon Spectrometer:

- ❖ Detection and reconstruction of muon tracks
- ❖ Muon trigger
- ❖  $2.5 > y > 4$

- Dataset : pp at  $\sqrt{s} = 13$  TeV (2015)
- $L_{\text{int}} : 3.2 \text{ pb}^{-1}$



I – Physics motivations

II – ALICE experiment



## III – Analysis

IV – Results

# Charged particle multiplicity

- **Multiplicity  $N_{ch}$  : Number of primary charged particles produced during the collision**
- Measurement of observables as a function of multiplicity : Possible comparison between the results from different collision systems (pp, p-Pb, Pb-Pb).
- Reached multiplicities in pp at  $\sqrt{s} = 13$  TeV are comparable to p-Pb à  $\sqrt{s_{NN}} = 5.02$  TeV :
  - ➔ About 4 times mean multiplicity  $\langle dN_{ch}/d\eta \rangle^{pp} \approx 9$  (at 13 TeV) with respect to  $\langle dN_{ch}/d\eta \rangle^{pPb} \approx 20$  (at 5.02 TeV).
- Multiplicity measurement : track reconstruction of charged particles thanks to SPD (2 inner layers of ITS).



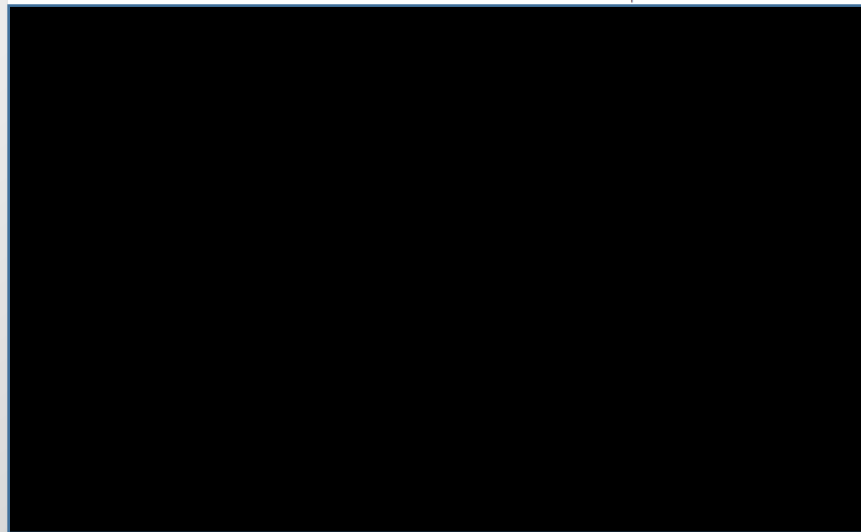
# Event selection

## ➤ Event selection criteria :

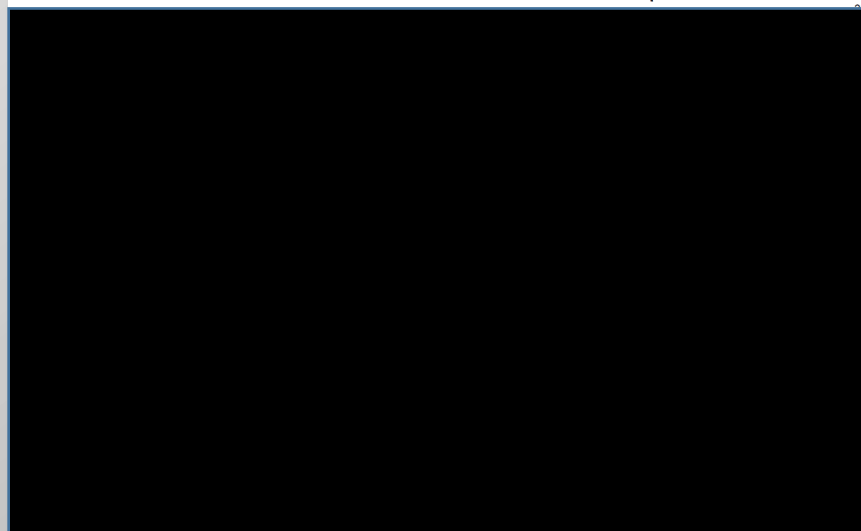
- ❖ Minimum Bias (MB : pp collision), signal measured in VOA and VOC
- ❖  $z_v$  coordinate of the reconstructed vertex :  $-10 < z_v < 10$  cm
- ❖ Reject EM interactions
- ❖ Reject beam-gas interactions
- ❖ Reject beam-pipe interactions
- ❖ Reject satellite collisions
- ❖ Pseudo-rapidity range :  $-1 < \eta < 1$

Defective parts in SPD (efficiency loss, not working modules...), a correction of reconstructed tracklets is necessary.

Number of tracklets vs Z vertex vs  $\phi$



Number of tracklets vs ZVertex vs  $\eta$



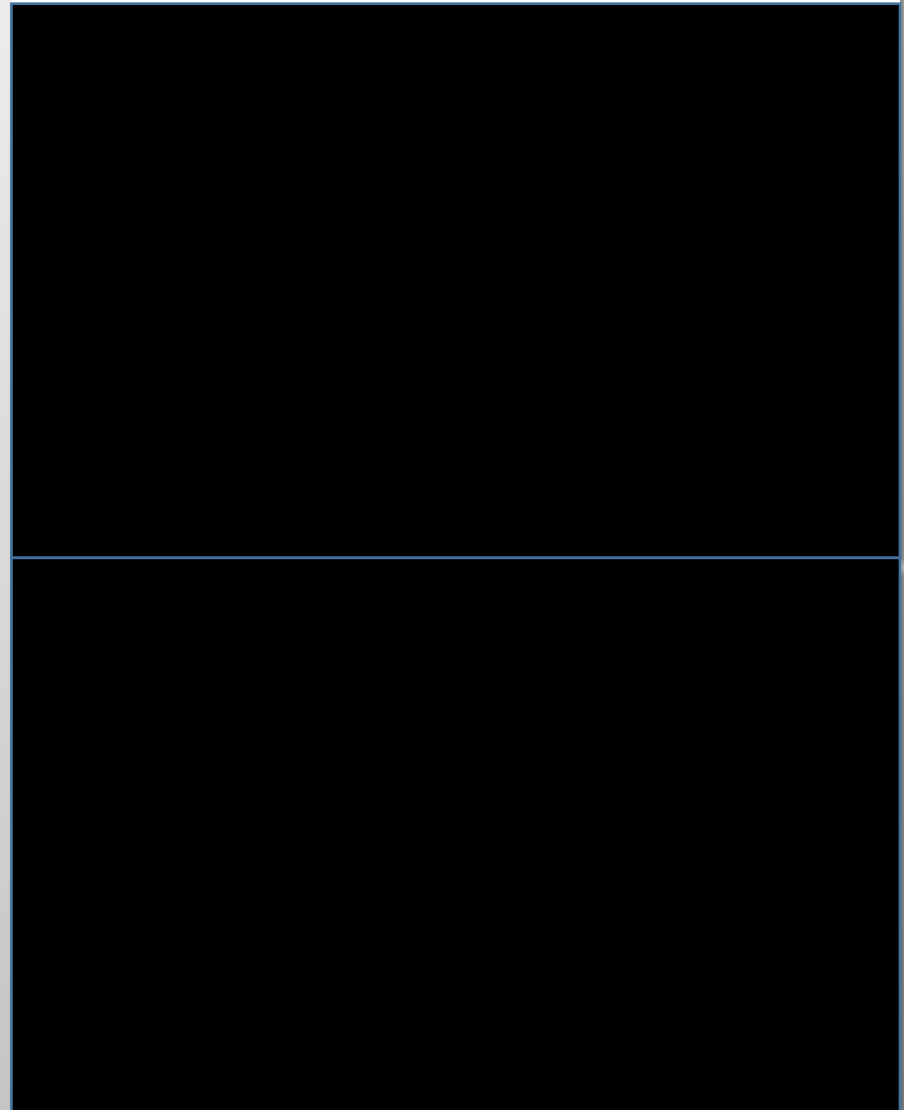
# Data-Driven Correction Method

- **DDCM** : data driven correction method based on the mean raw number of reconstructed SPD tracklets as a function of the interaction vertex coordinate ( $z_v$ ).
- **Advantage** : MC simulations not needed.
- **Basis** : equalization of the mean raw number of reconstructed SPD tracklets as a function of  $z_v$ , with respect to a reference value, and conversion of the number of corrected tracklets into a number of charged particles.
- **Condition** : normalization by the mean multiplicity to remove uncertainties due to AccxEff loss of the detector (undetermined by the method and assumed to be independent of multiplicity).

# Data-Driven Correction Method

- Distribution of the mean number of corrected tracklets uniform, mean multiplicity : 8.42 for  $1 < N_{trCorr} < 50$ .
- Reference value : minimum of mean raw number of reconstructed SPD tracklets.
  - ➔ Minimizes the correction effects on resolution.
- 4 ranges for number of corrected tracklets between 1 and 50.

Mean Number of corrected tracklets in  $|\eta| < 1.0$  vs Z vertex

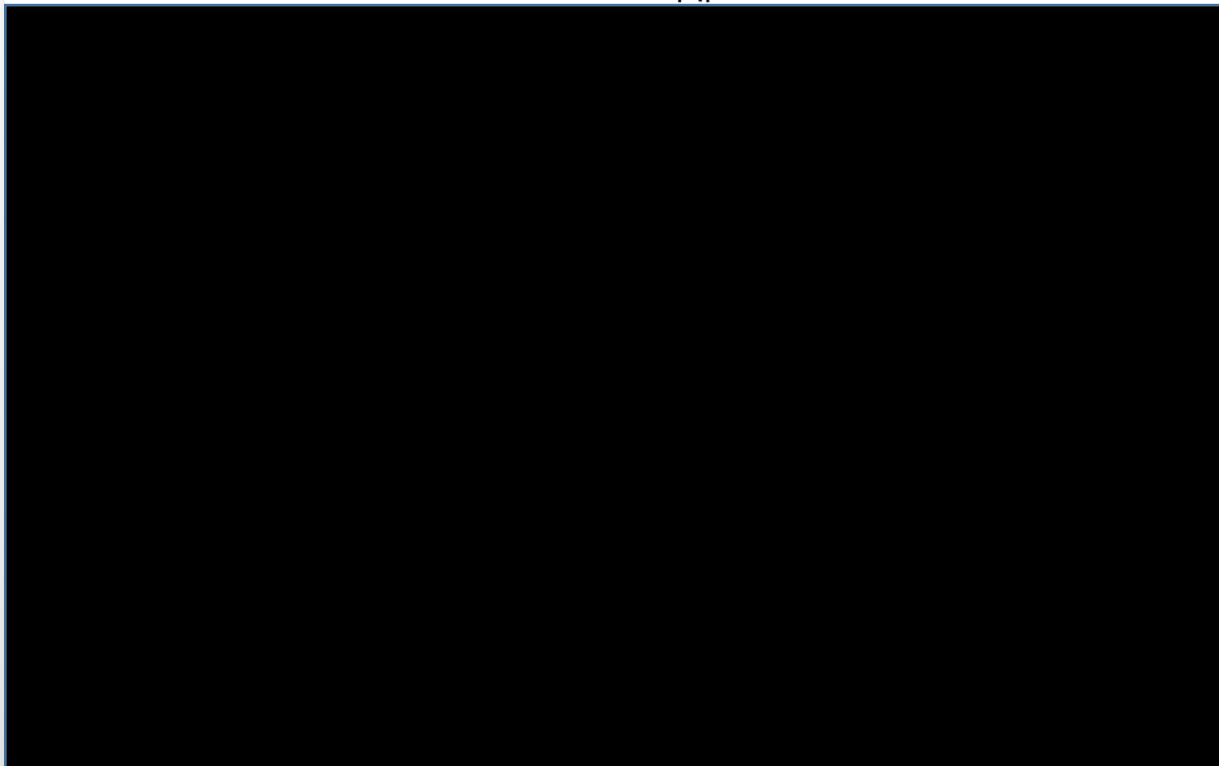






# Multiplicity distribution

Number of tracklets in  $|\eta| < 1.0$  distribution



- Expected decrease of the multiplicity distribution (correction effect).
- Choice of multiplicity ranges :  $N_{\text{events}} (N_{\text{tr}}^{\text{Corr}} > 50) < 0.1\%$ .

# Measurement of $\Psi'$ and $J/\Psi$ production

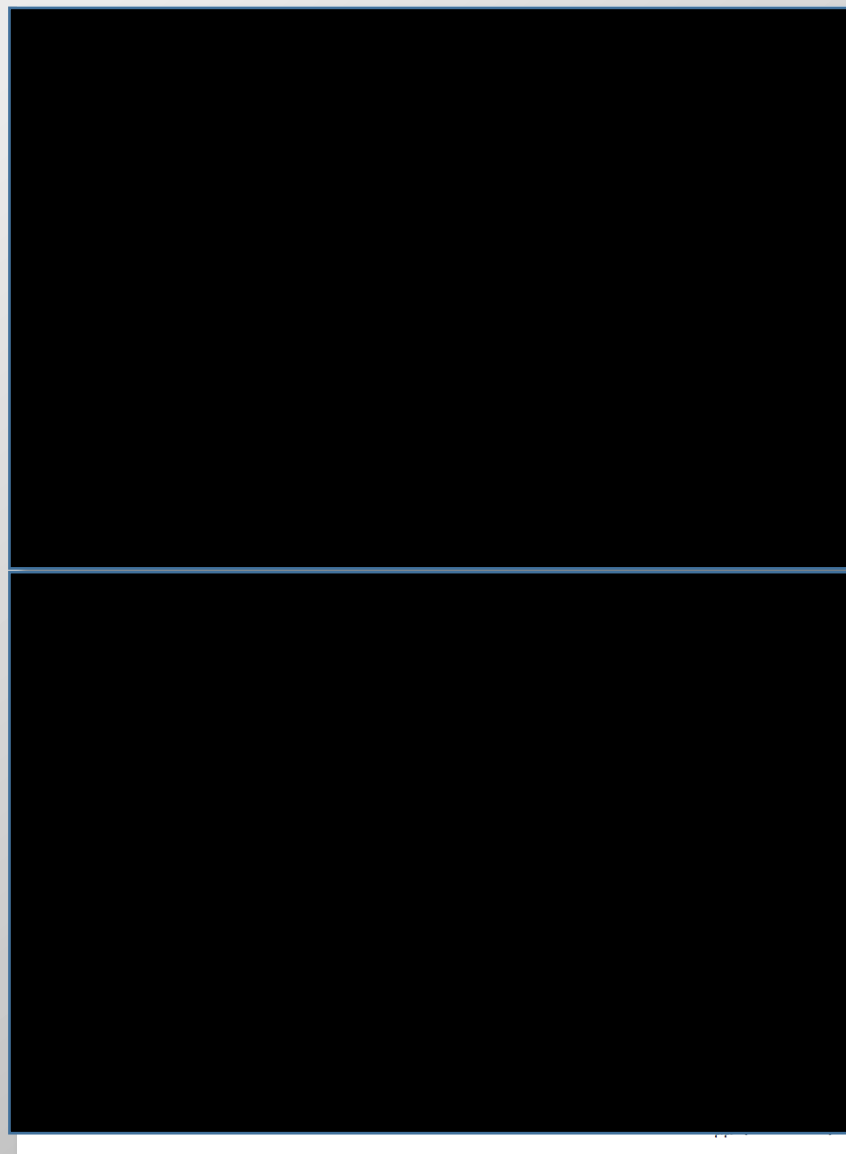
## Event and track selection :

- Trigger V0A and V0C, and dimuon unlike sign event identified (MTR) and reconstructed by the muon tracking system (MCH).
- Matching between the reconstructed track in MCH and a detected track in MTR above  $p_T > 1$  GeV/c threshold (reduction of pion and kaon contamination).
- Acceptance range of the spectrometer for single muon tracks (MS) :  
 $-4 < \eta < -2.5$
- Rejection of tracks passing through non-uniform parts of the front absorber.
- Rapidity range for muon pairs :  $2.5 < y < 4$

# Measurement of $\Psi'$ and $J/\Psi$ production

## Signal extraction :

- Invariant mass histograms filled with events corresponding to multiplicity ranges.
- Testing with convolutions of fit functions for signal and background.
- Each test is performed with 2 invariant mass ranges and 2 sets of parameters for the fit function distribution tails.
- Mean value of all fit tests, systematic uncertainty is given by RMS.



I – Physics motivations

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III – Analysis



## IV - Results

# Inclusive production ratio $\Psi(2S) / J/\psi$



- Uncertainties dominated by statistical uncertainties ( $\Psi'$ ).
- Central values : indication of a multiplicity dependance of the production ratio (relative suppression).
- Results of a preliminary study to be continued.



- Additional studies :
  - Improve the signal extraction (more tests with different signal functions).
  - Check the hypotheses with other multiplicity measurement methods (MC).
  
- Increase dataset (reduction of statistical uncertainties).
  - $L_{\text{int}} 2015 : 3.2 \text{ pb}^{-1}$  (this analysis)
  - $L_{\text{int}} 2016 : 8.3 \text{ pb}^{-1}$
  - $L_{\text{int}} 2017 : 7.4 \text{ pb}^{-1}$

➡ Expected reduction of statistical uncertainties  $\approx *1/2.5$
  
- Comparison with theoretical predictions.



# Thank you !