# Inclusive J/ψ production

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# Introduction

- Analysis already done - "*Measurement of the production cross-section of J/ψ and ψ(2S) mesons at high transverse momentum in pp collisions at √s=13TeV with the ATLAS detector*"*, main analyzer - Bakar Chargeishvili.
  - J/ψ and ψ(2S) cross-sections were measured;
  - Prompt and non-prompt contributions were separated;
  - Analysis was performed in high-pT bins, starting from 60 GeV reaching 360 GeV region for J/ψ.
- We continue to study inclusive onia production at lower pT range (8 < pT < 60 GeV).
- Low pt dimuon trigger is used:  HLT_2mu4_bJpsimumu_noL2

# Inclusive J/ψ production studies at low pt

- Used data: 2015 13 TeV data samples;

- Trigger: HLT_2mu4_bJpsimumu_noL2 (available unprescaled for 2015 data);

  – Integrated Luminosity about 2.6 fb$^{-1}$, but can reach the lowest J/ψ pT;

  – Sample extends up to ~150 GeV, but with low statistics;

- Acceptance cut: (pT1>4 && pT2>4);

- Use unweighted events for yield determination, with average per-bin efficiency and acceptance corrections applied at the next step.

# Fit function modification

The fit model is described by a sum of the following terms:

$$PDF(m, \tau) = \sum_{i=1}^{7} \kappa_i f_i(m) \cdot (h_i(\tau) \otimes R(\tau)) \cdot C_i(m, \tau). \qquad (4)$$

where $m$ is the dimuon invariant mass, while $\tau$ is the pseudo-proper lifetime of the dimuon. $R(\tau)$ in eq. (4) is the function describing the experimental resolution in pseudo-proper lifetime. It is parameterised as a weighted sum of three Gaussians, with $\sigma_2 = 2\sigma_1$ and $\sigma_3 = 3\sigma_1$, where the relative weights and $\sigma_1$ are free parameters.

**ω*CB$_1$(S$_1$*σ$_1$)+ (1-ω)*G$_2$(S$_2$*σ$_1$)**

**ω and S$_2$ are fit parameters – determined using MC fits**

| i | Type | P/NP | $f_i(m)$ | $h_i(\tau)$ | $C_i(m,\tau)$ |
|---|------|------|----------|-------------|----------------|
| 1 | $J/\psi$ | P | $\omega G_1(m) + (1-\omega)CB_1(m)$ | $\delta(\tau)$ | $BV(m,\tau,\rho)$ |
| 2 | $J/\psi$ | NP | $\omega G_1(m) + (1-\omega)CB_1(m)$ | $E_1(\tau)$ | 1 |
| 3 | $\psi(2S)$ | P | $\omega G_2(m) + (1-\omega)CB_2(m)$ | $\delta(\tau)$ | 1 |
| 4 | $\psi(2S)$ | NP | $\omega G_2(m) + (1-\omega)CB_2(m)$ | $E_2(\tau)$ | 1 |
| 5 | Bkg | P | $B$ | $\delta(\tau)$ | 1 |
| 6 | Bkg | NP | $E_4(m)$ | $E_5(\tau)$ | 1 |
| 7 | Bkg | NP | $E_6(m)$ | $E_7(|\tau|)$ | 1 |

| Notation | Function |
|----------|----------|
| $G$ | Gaussian |
| $CB$ | Crystal Ball |
| $E$ | Exponential |
| $B$ | Bernstein polynomials |
| $BV$ | Correlation term of the bivariate Gaussian dist. |

**ω*E(τ1) + (1-ω)*E(A*τ1) A – free fit parameter**

Table 1: Parameterisation of the fit model. Notation is explained in the text and in the table on the right.

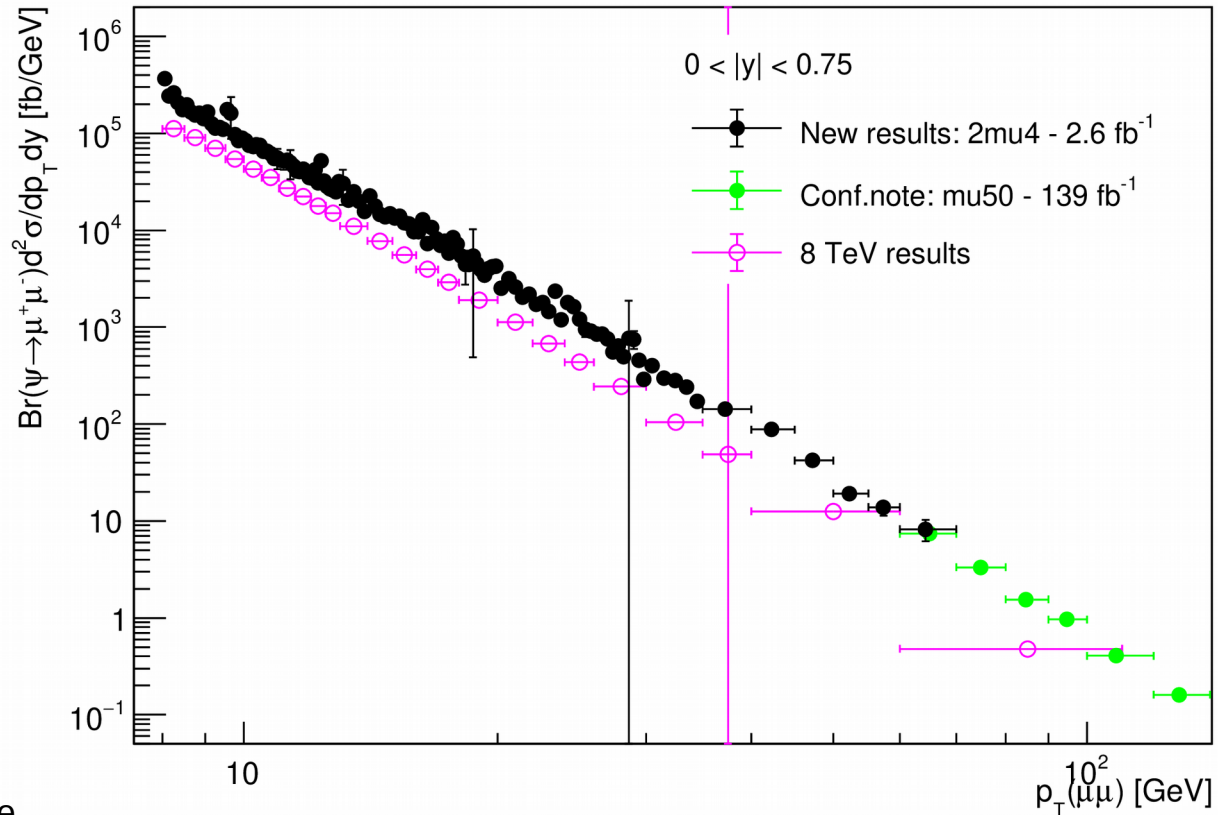- Fit yields are corrected with acceptance, trigger efficiency and reconstruction weights.

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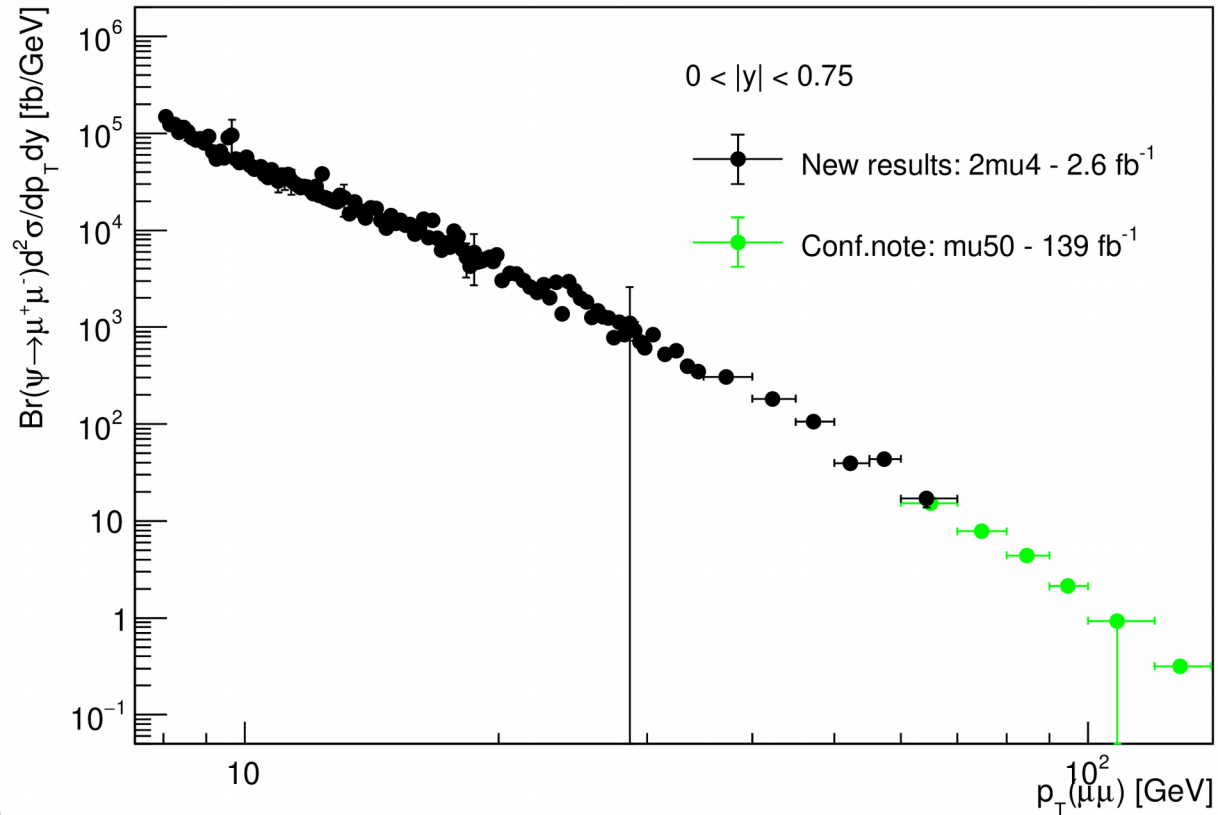# Prompt J/ψ cross-section

Systematic errors are
not displayed yet!

# Non-prompt J/ψ cross-section
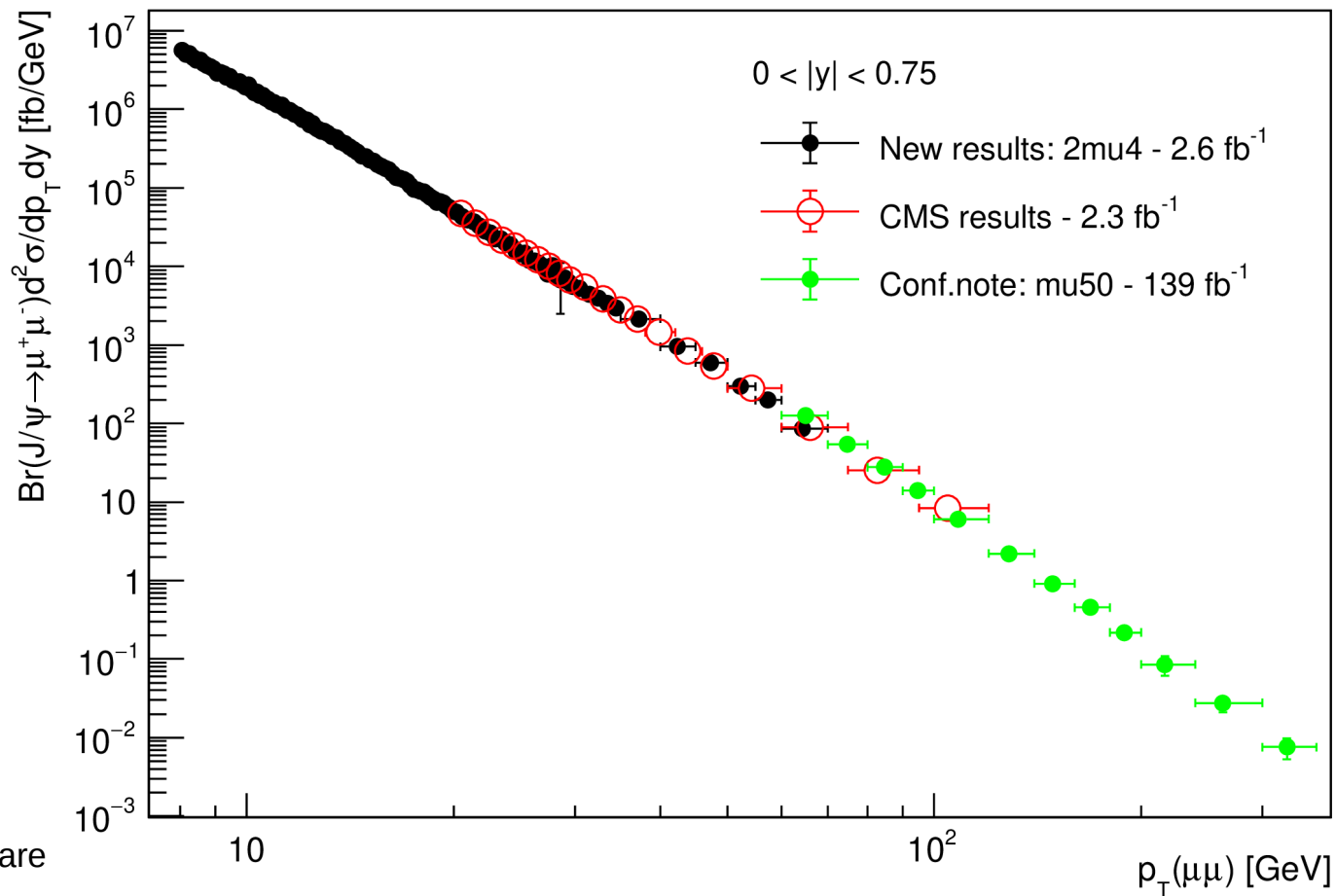
Systematic errors are
not displayed yet!

# Prompt ψ(2S) cross-section

Systematic errors are
not displayed yet!

# Non-prompt ψ(2S) cross-section

Systematic errors are
not displayed yet!

# Next few steps:

- Fits need attention in the region of $\psi(2S)$;

- Determine the trigger and reconstruction efficiency weights for $\psi(2S)$;

- Study other rapidity bins, systematics etc.

Thank you!

# Backup

# Fit function

In order to take into account possible correlations between mass $m$ and lifetime $\tau$ of a dimuon, in eq. 4 in the term with $i = 1$, the simple product of two Gaussians is replaced by a bivariate normal distribution (BVN), defined as:

$$BVN(m, \tau) = \text{Const} * \exp\left[\frac{1}{2(1 - \rho^2)}\left(\frac{(m - \mu_m)^2}{\sigma_m^2} - \frac{2\rho(m - \mu_m)(\tau - \mu_\tau)}{\sigma_m \sigma_\tau} + \frac{(\tau - \mu_\tau)^2}{\sigma_\tau^2}\right)\right] \qquad (5)$$

where $\rho$ is the correlation coefficient between $m$ and $\tau$.

# BPHY1 MC

- Lower $p_T$ range has much higher statistics, and more complex lineshapes.

- Allows moving to narrower binning, but additional shapes in the fit model still necessary.

- Too many parameters make fits unstable In order to fine-tune signal shapes, same fits were applied to signal-only MC distributions (mix of pp and bb)

- Aim to fix some parameters once fits move to data, with parameter varied at systematics stage

**MC: $bb{\rightarrow}J/\psi{-}{>}\mu\mu$** DAODs used:

1. mc16_13TeV.300203.Pythia8BPhotospp_A14_CTEQ6L1_bb_Jpsimu3p5mu3p5.deriv.DAOD_BPHY1.e4889_a875_r9364_p3648

**MC: $pp{\rightarrow}J/\psi{-}{>}\mu\mu$** DAODs used:

1. mc16_13TeV.300013.Pythia8B_A14_CTEQ6L1_pp_Jpsimu3p5mu3p5.deriv.DAOD_BPHY1.e7703_a875_r9364_p4277
2. mc16_13TeV.300000.Pythia8BPhotospp_A14_CTEQ6L1_pp_Jpsimu2p5mu2p5.deriv.DAOD_BPHY1.e3989_s3126_r9364_p4277

Description of MC produced ($pp{\rightarrow}J/\psi$):

- Derivation format: BPHY1
- AthDerivation cache used: 21.2.105.0
- Production: unskimmed production