

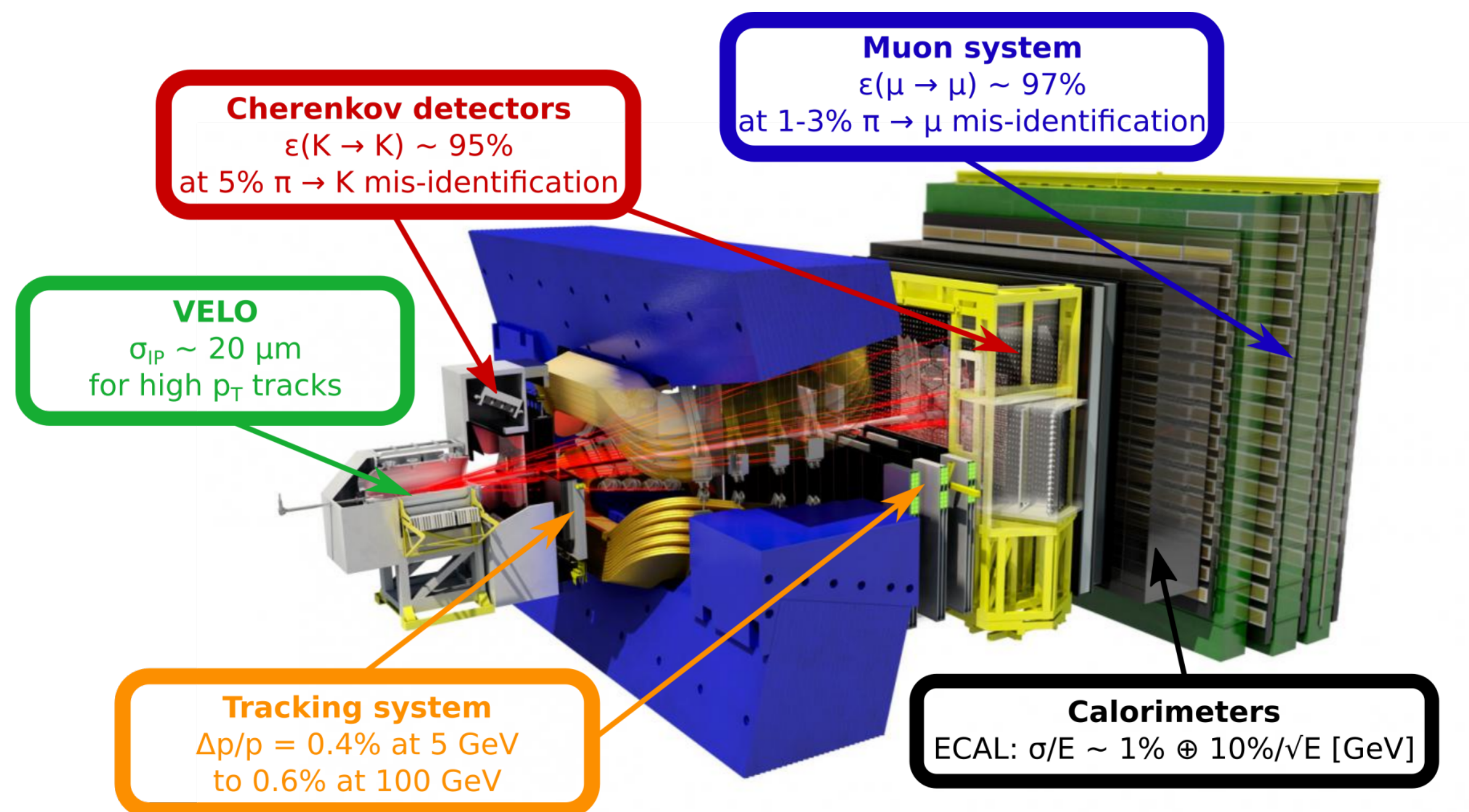
# Quarkonia production in pPb collisions at LHCb

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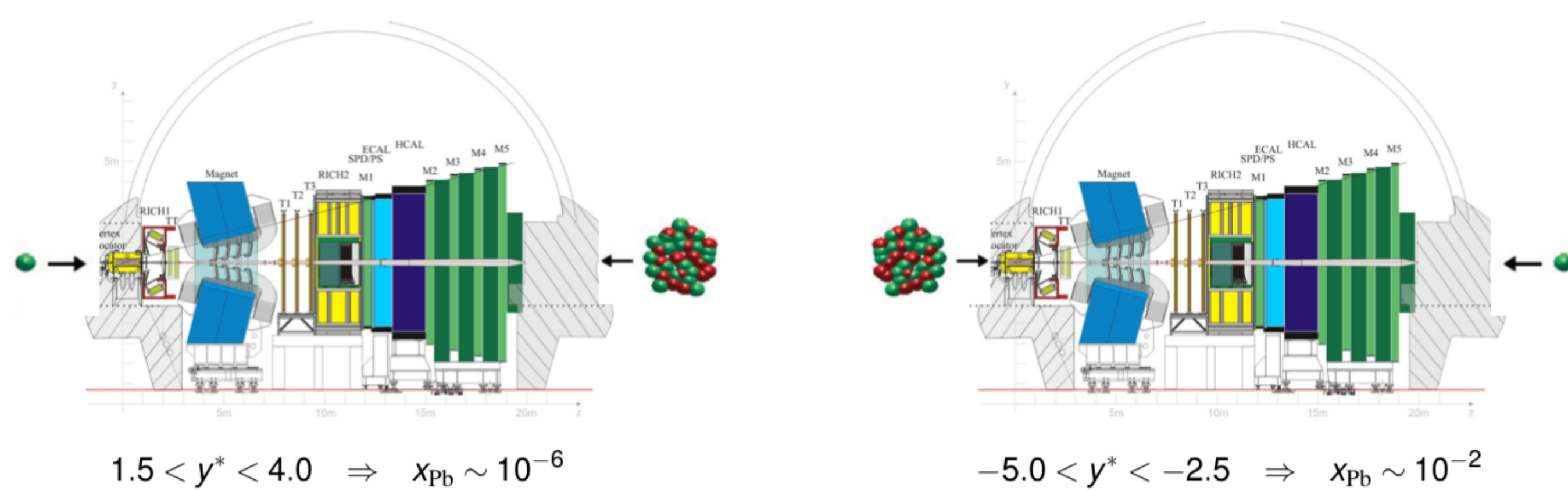
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## LHCb Detector

Single arm forward spectrometer fully instrumented in  $2 < \eta < 5$ .



LHCb collected data in 2016 for both pPb and PbPb configurations, which cover  $x_{Pb} \sim 10^{-6}$  and  $x_{Pb} \sim 10^{-2}$  respectively.

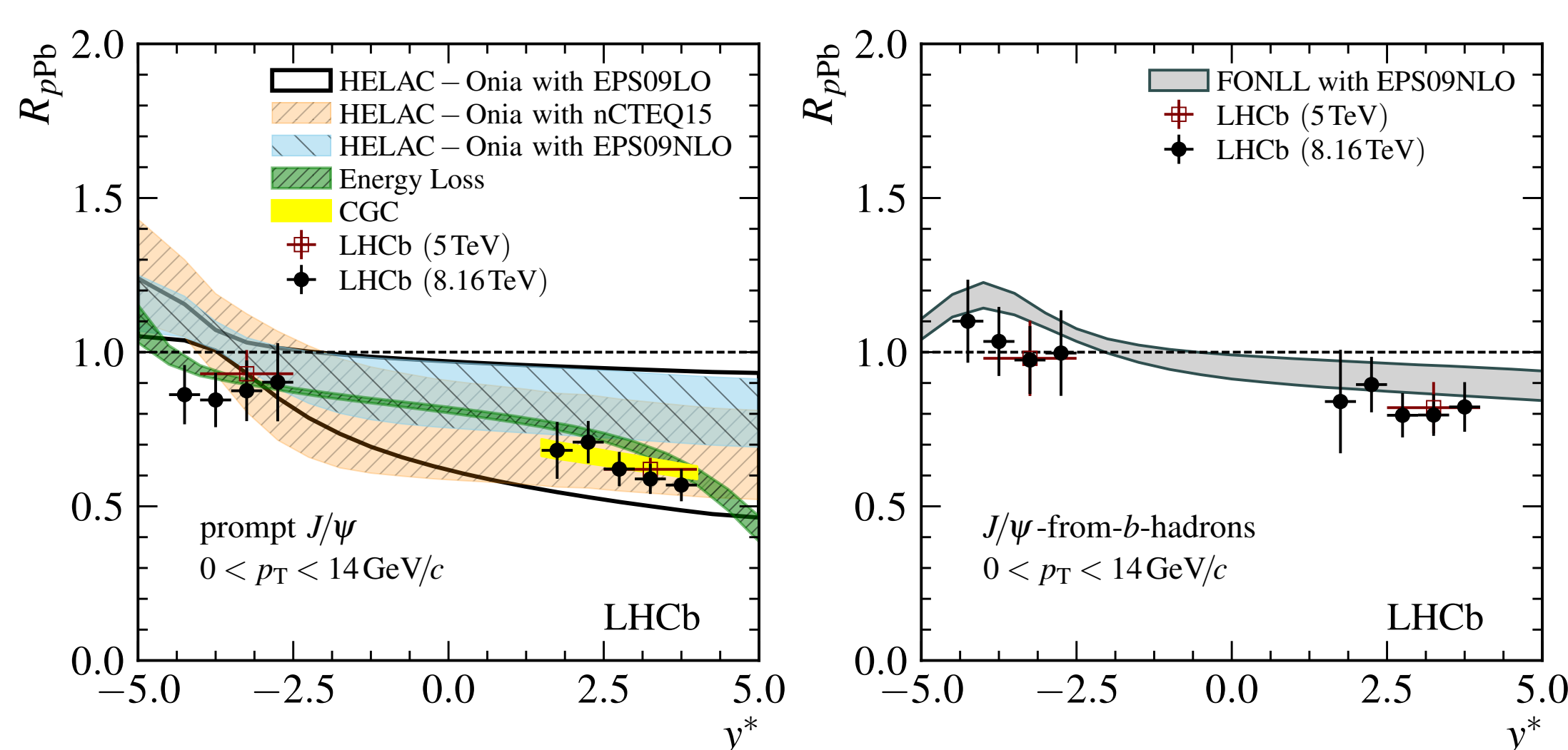


## Prompt & non-prompt J/ψ and ψ(2S) production

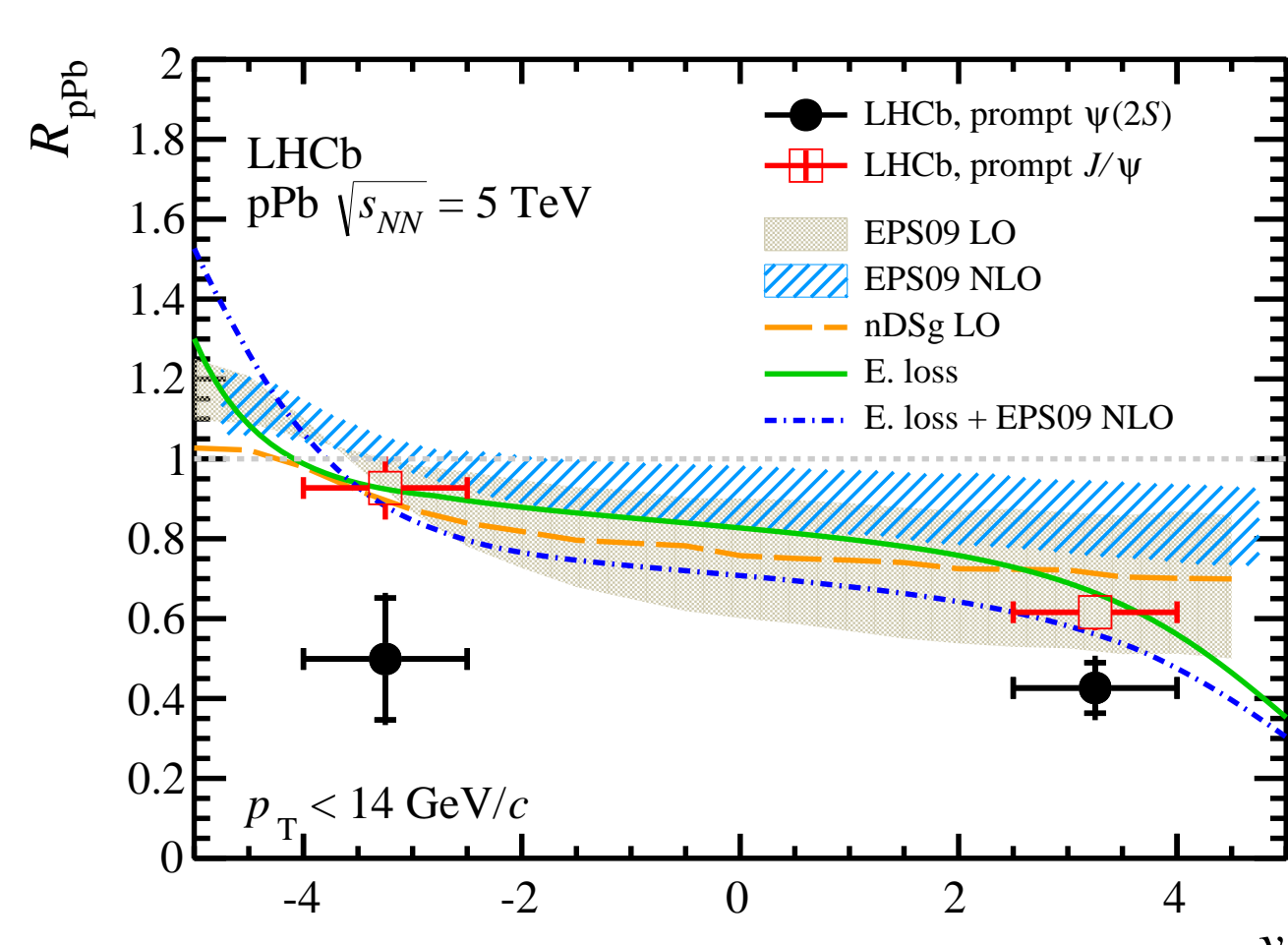
LHCb measured nuclear modification of  $J/\psi \rightarrow \mu^+\mu^-$  in pPb collisions at  $\sqrt{s_{NN}} = 8.16$  and 5.02 TeV [1, 2]:

$$R_{pPb}(p_T, y) = \frac{1}{208} \frac{d^2\sigma_{pPb}/dp_T dy}{d^2\sigma_{pp}/dp_T dy}.$$

- Suppression pattern described by calculations including modifications of nPDFs and coherent energy loss.
- No evidence of strong energy dependence of Cold Nuclear Matter (CNM) effects at the LHC energy scales.



$\psi(2S) \rightarrow \mu^+\mu^-$  has been measured in pPb at  $\sqrt{s_{NN}} = 5.02$  TeV [3].

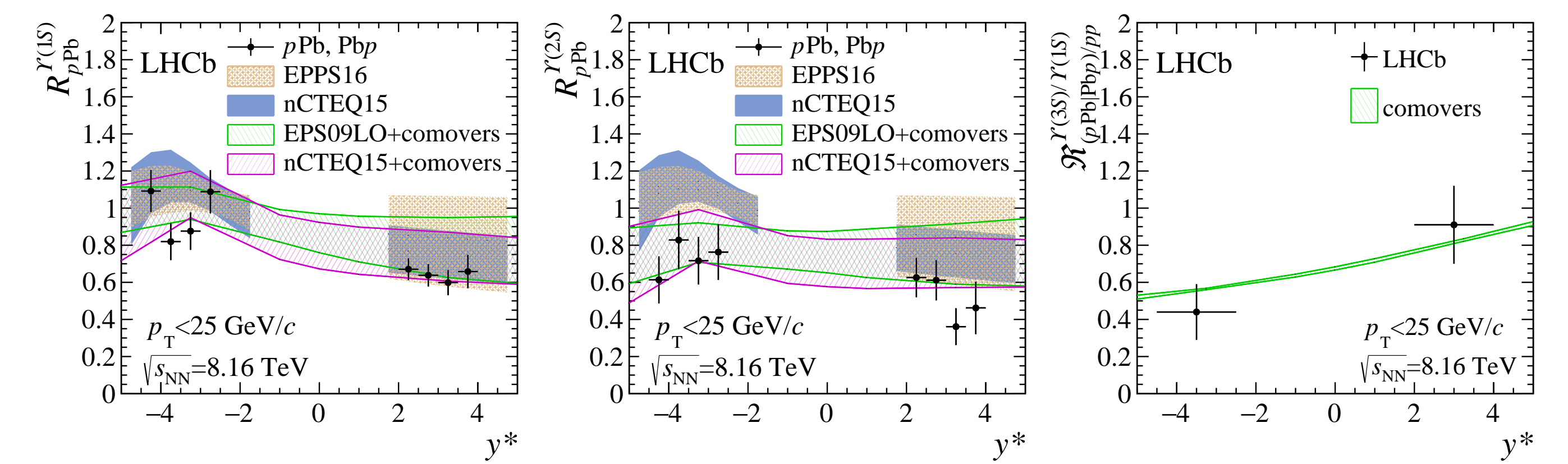


- Stronger suppression of  $\psi(2S)$  compared to  $J/\psi$ .

**The difference between the two  $c\bar{c}$  states cannot be explained by the same initial state effects.  $\Rightarrow$  Different final-state effects.**

## Υ(nS) production

LHCb measured nuclear modification of  $\Upsilon(nS) \rightarrow \mu^+\mu^-$  in pPb at  $\sqrt{s_{NN}} = 8.16$  and 5.02 TeV [4, 5]. The three peaks could be separated using the power of LHCb tracking.



- $\Upsilon(2S)$  shows hints of stronger suppression compared to  $\Upsilon(1S)$ .
- $\Upsilon(3S)$  clearly shows stronger suppression at backward rapidity.

**In general, the suppression of excited quarkonia cannot be described with the same initial-state effects as the ground state.**

## Outlook on quarkonia measurements in pPb

LHCb studied production of  $\chi_{c0}$ ,  $\chi_{c1}$ , and  $\chi_{c2}$  in pp collisions from their decays to  $\chi_{cJ} \rightarrow J/\psi \gamma$ . The cross-section ratio  $\sigma(\chi_{c2})/\sigma(\chi_{c1})$  was measured in pp at  $\sqrt{s} = 7$  TeV using calorimetric photons or photons converted in the detector material ( $\gamma \rightarrow e^+e^-$ ) [6, 7].

	mass (MeV)	$\Delta M(\chi_{cJ} - J/\psi)$ (MeV)	width (MeV)
$\chi_{c0}$	$3414.71 \pm 0.30$	$317.81 \pm 0.03$	$10.5 \pm 0.8$
$\chi_{c1}$	$3510.67 \pm 0.05$	$413.77 \pm 0.01$	$0.88 \pm 0.05$
$\chi_{c2}$	$3556.17 \pm 0.07$	$459.27 \pm 0.01$	$2.00 \pm 0.11$

Table: Basic characteristics of  $\chi_{cJ}$  states [8].

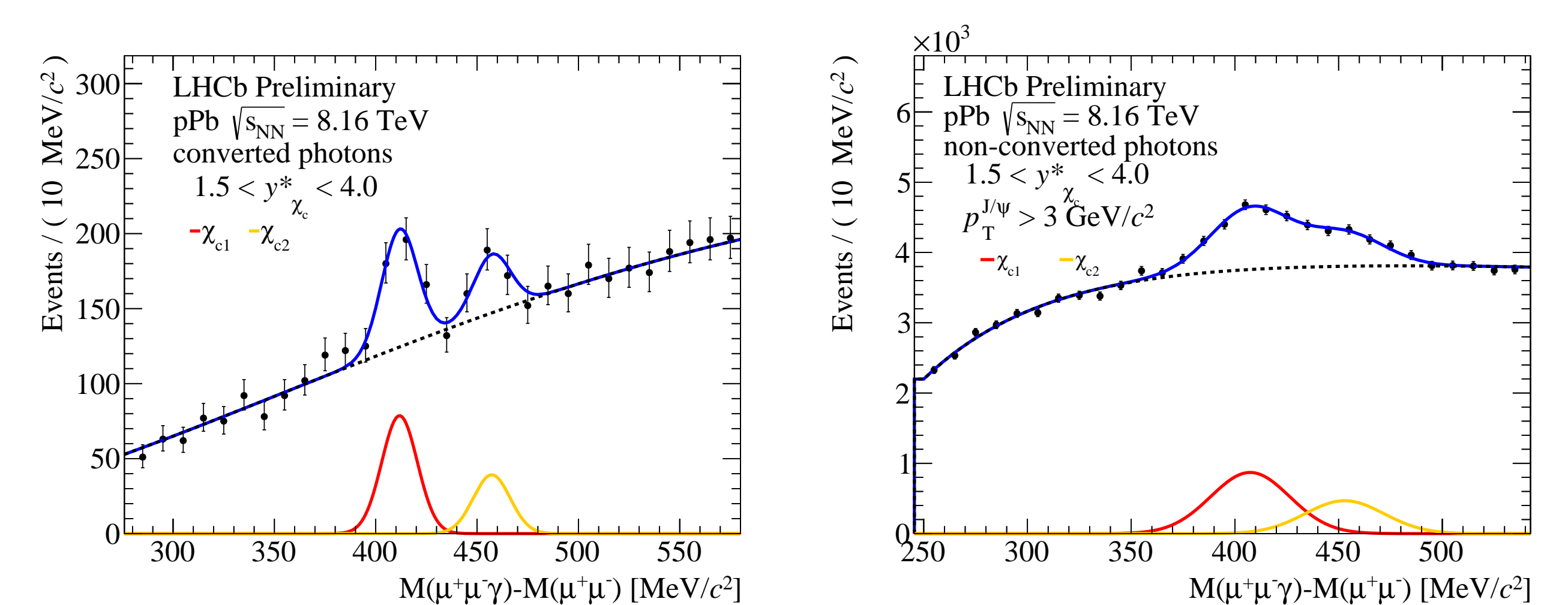
In pPb, the measurement presents another probe of CNM effects, as the masses of  $\chi_{cJ}$  states lie between  $J/\psi$  and  $\psi(2S)$ , and the mass difference between  $M(\chi_{c2}) - M(\chi_{c1}) \approx 50$  MeV.

**Does also the suppression lie between  $J/\psi$  and  $\psi(2S)$ ?  
Are the  $\chi_{c2}$  more suppressed than  $\chi_{c1}$ ?**

Furthermore, to control the  $J/\psi$  feed-down channel  $\chi_{cJ} \rightarrow J/\psi \gamma$  is important in order to correctly determine the direct  $J/\psi$  production.

Analysis of  $\sigma(\chi_{c2})/\sigma(\chi_{c1})$  in 2016 pPb data is ongoing.

LHCb tracking allows separation of the two  $\chi_c$  peaks using converted photons even in a nuclear environment (left plot). On the other hand calorimeters provide larger statistics (right plot).



## Acknowledgements

This work is supported by the US Department of Energy (DOE) Office of Science/Office of Nuclear Physics.

## References

- [1] LHCb Coll. PLB 774 (2017) 159.
- [2] LHCb Coll. JHEP 02 (2014) 72.
- [3] LHCb Coll. JHEP 03 (2016) 133.
- [4] LHCb Coll. JHEP 11 (2018) 194.
- [5] LHCb Coll. JHEP 07 (2014) 94.
- [6] LHCb Coll. PLB 714 (2012) 215.
- [7] LHCb Coll. JHEP 10 (2013) 115.
- [8] PDG Coll. PRD 98 (2018) 030001.