



Hard probe production in $p\text{Pb}$ collisions at 8.16 TeV

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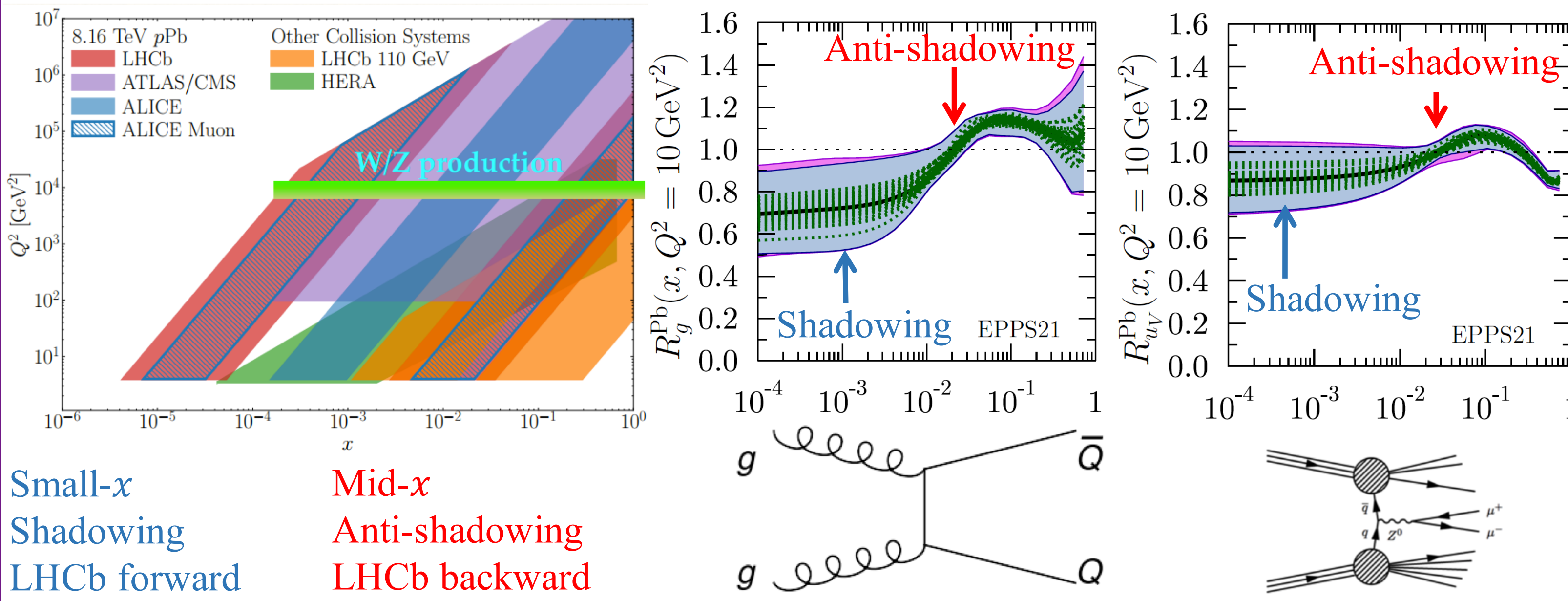
On behalf of LHCb collaboration



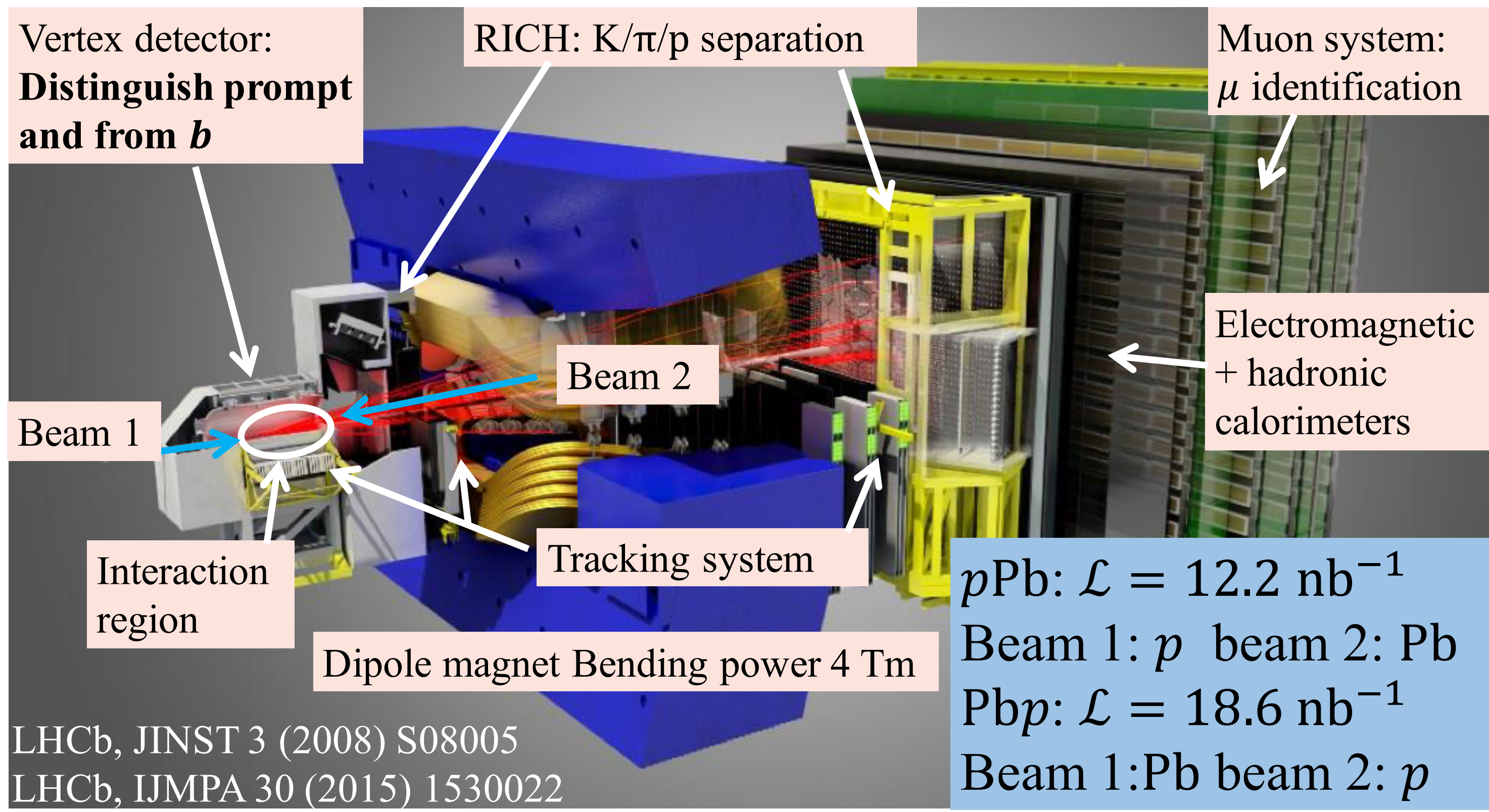
Introduction

- Cold nuclear matter effects (CNM) are assumed to be dominant in $p\text{Pb}$ collisions.
 - Nuclear parton distribution function (nPDF). $R_i^{\text{Pb}}(x, Q^2) = f_i^{\text{Pb}}(x, Q^2) / [A f_i^p(x, Q^2)]$.
 - Other initial/final states effects.
- Open heavy flavor charm pair, and Z boson are used to probe CNM and constrain nPDF at **small- x** and **mid- x** region in LHCb $p\text{Pb}$ collisions.

arXiv:2106.13661



LHCb detector and data set

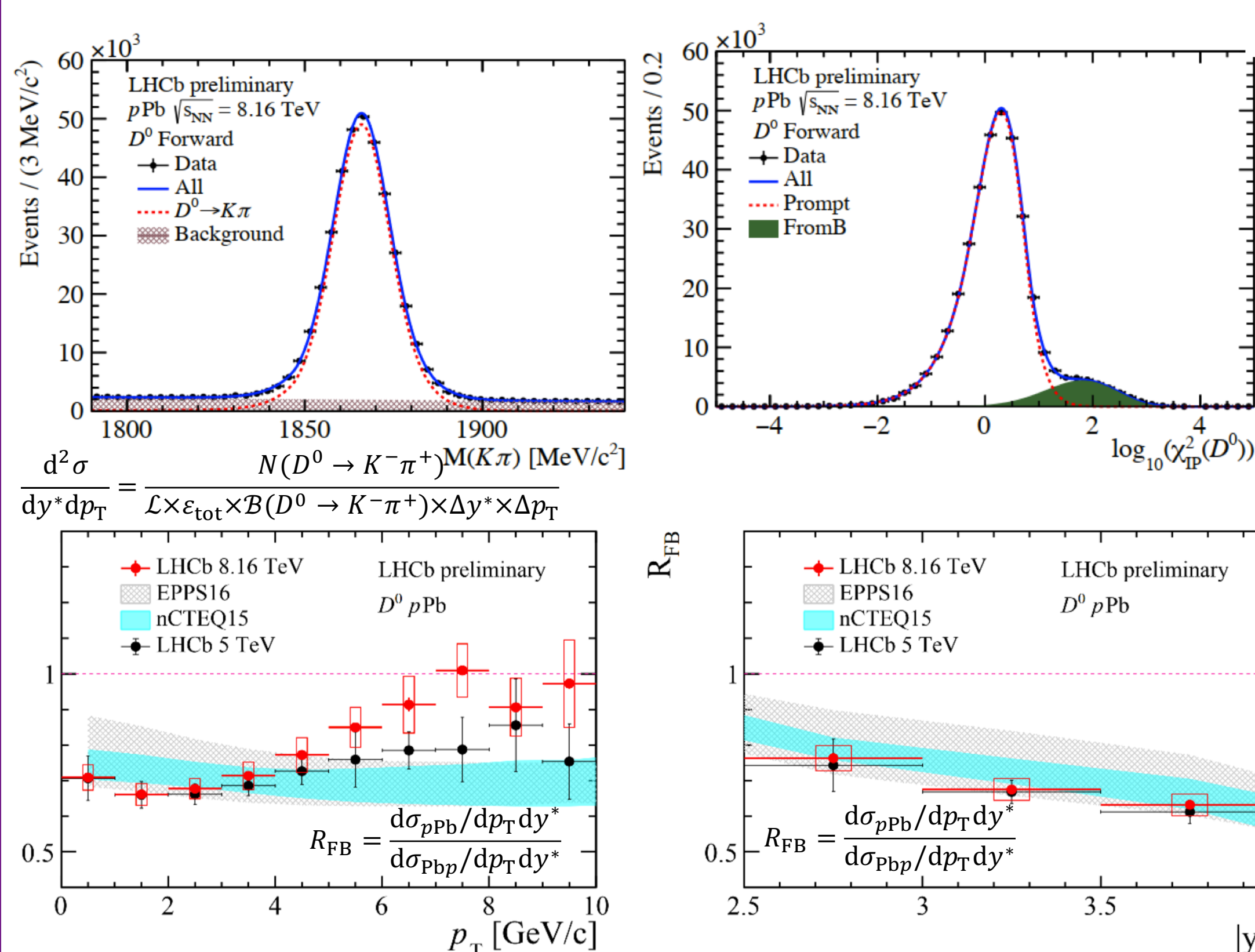
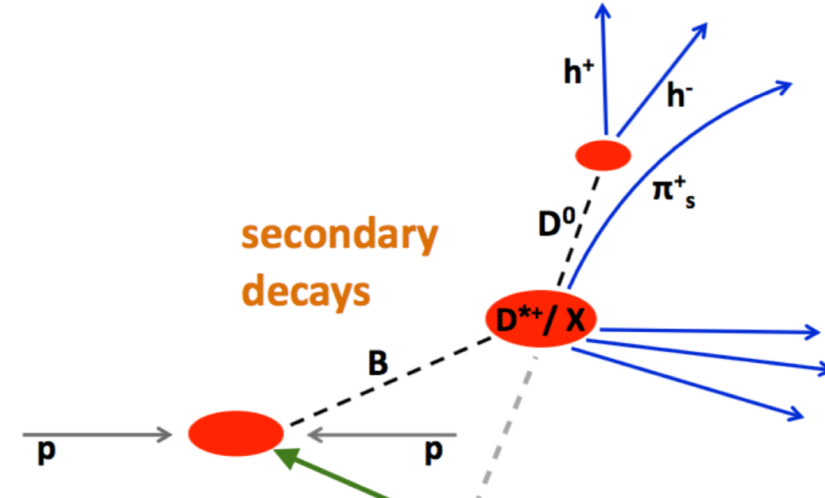


- LHCb is a single-arm general purpose detector at forward rapidity.
- Pseudorapidity acceptance $2 < \eta < 5$, p_T down to 0.
- Forward ($p\text{Pb}$): $1.5 < y^* < 4.0$
- Backward ($\text{Pb}p$): $-5.0 < y^* < -2.5$
- Common region: $2.5 < |y^*| < 4.0$

Prompt D^0 meson production in $p\text{Pb}$ at 8.16 TeV

- Decay mode: $D^0 \rightarrow K^- \pi^+ \text{ \&c.c.}$
- D^0 yields are extracted from $K^- \pi^+$ mass fit.
- Prompt and secondary D^0 are separated using impact parameter (IP).

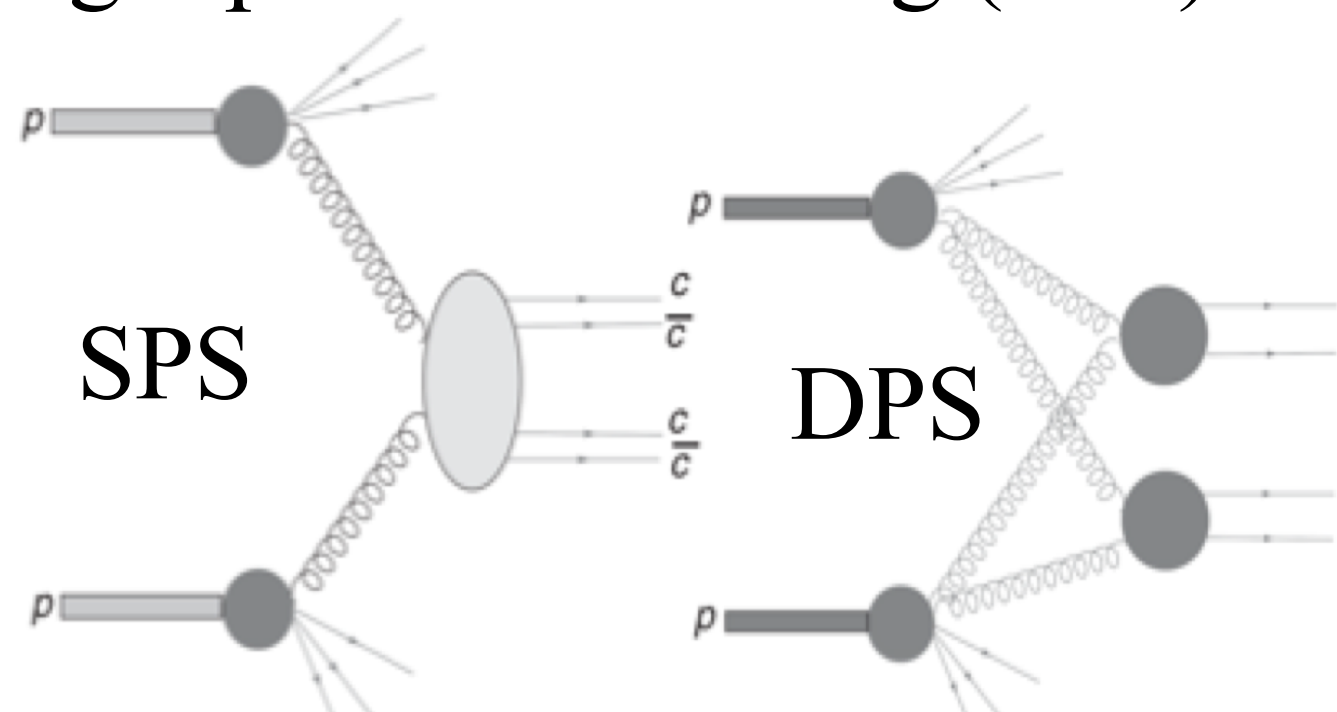
LHCb-CONF-2019-004



- R_{FB} increase with increasing p_T :
 - Low p_T : consistent with 5.02 TeV results and nPDF calculation.
 - High p_T : above nPDF calculation.
- R_{FB} decrease with increasing y^* .
 - Consistent with nPDF and 5.02 TeV results.

Charm pair production in $p\text{Pb}$ at 8.16 TeV

- First measurement of charm pair production in heavy-ion collisions.
- Single parton scattering (SPS) vs. double parton scattering (DPS).

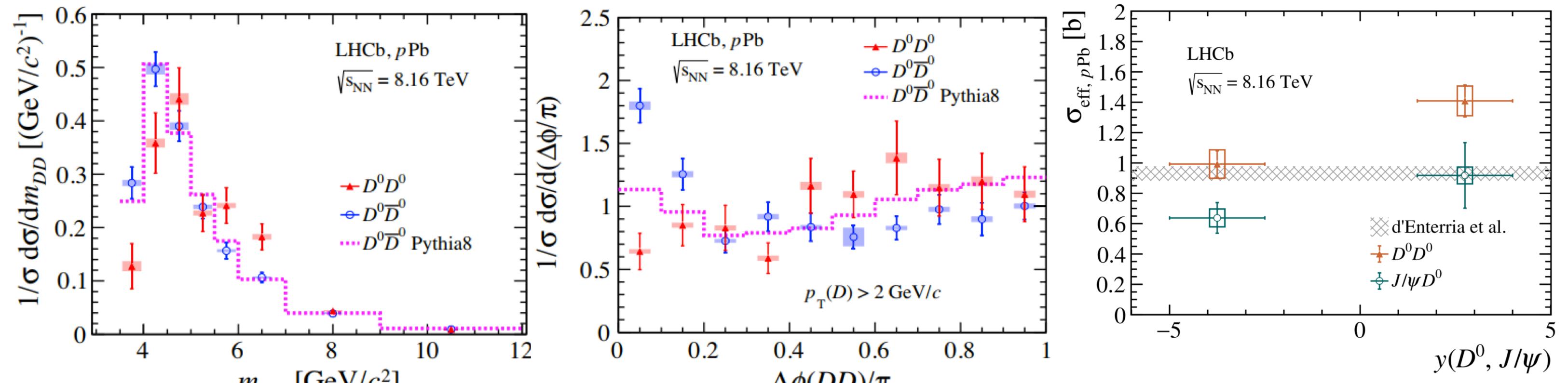


$$\sigma_{\text{eff}} = \frac{1}{1 + \delta_{\text{AB}}} \frac{\sigma_A \sigma_B}{\sigma_{\text{DPS}}}$$

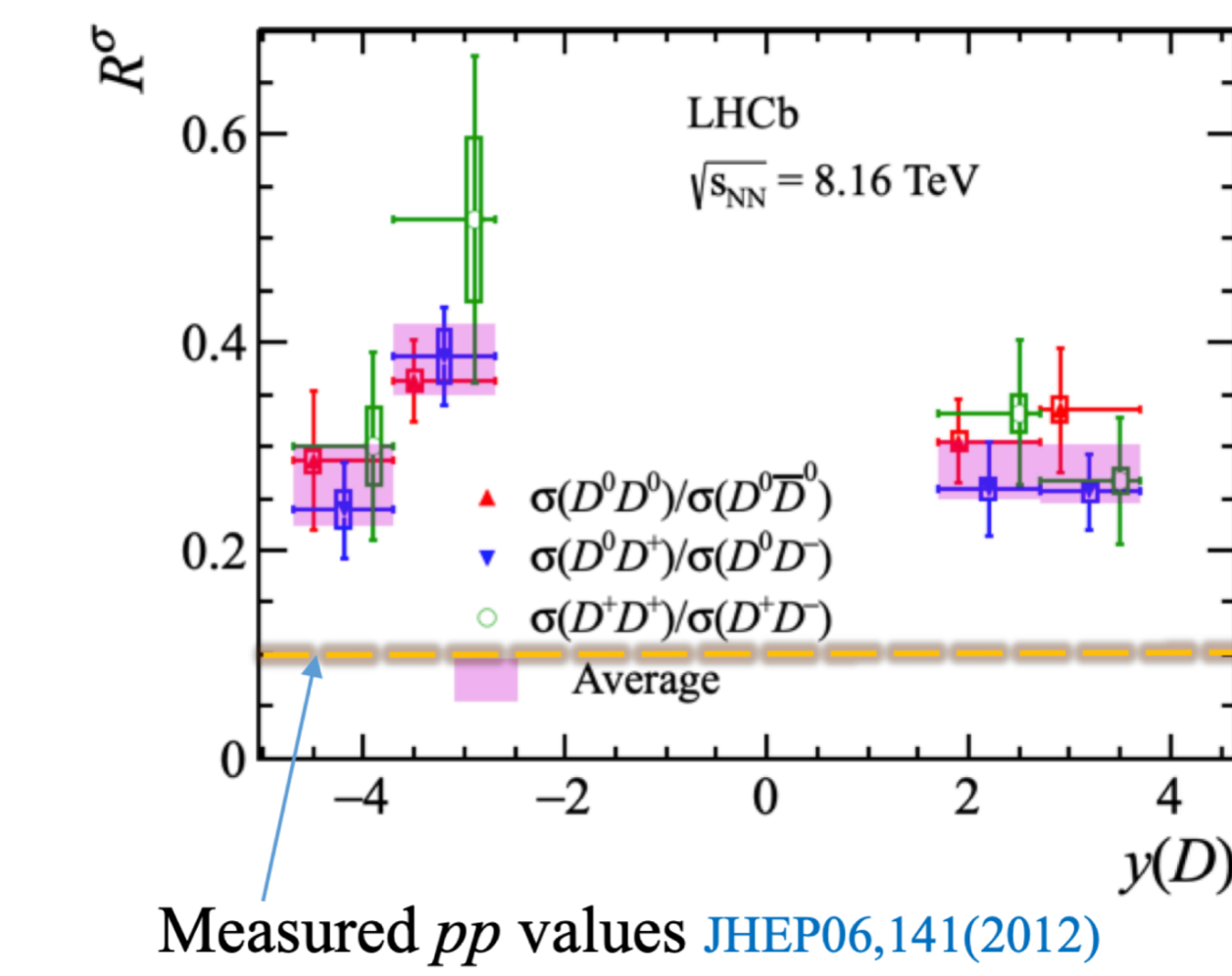
A, B: D^0 or $\bar{D}^0$, e.g.
 $\delta_{\text{AB}} = 1$, if A=B, else 0

PRL 125 (2020) 212001

- In $p\text{Pb}$, σ_{SPS} is expected to scale with mass number, σ_{DPS} is enhanced compared to mass number.
 - Like-sign (LS) (e.g. $D^0 \bar{D}^0$): DPS enrich, uncorrelated.
 - Opposite-sign (OS) (e.g. $D^0 D^0$): SPS enrich, correlated.



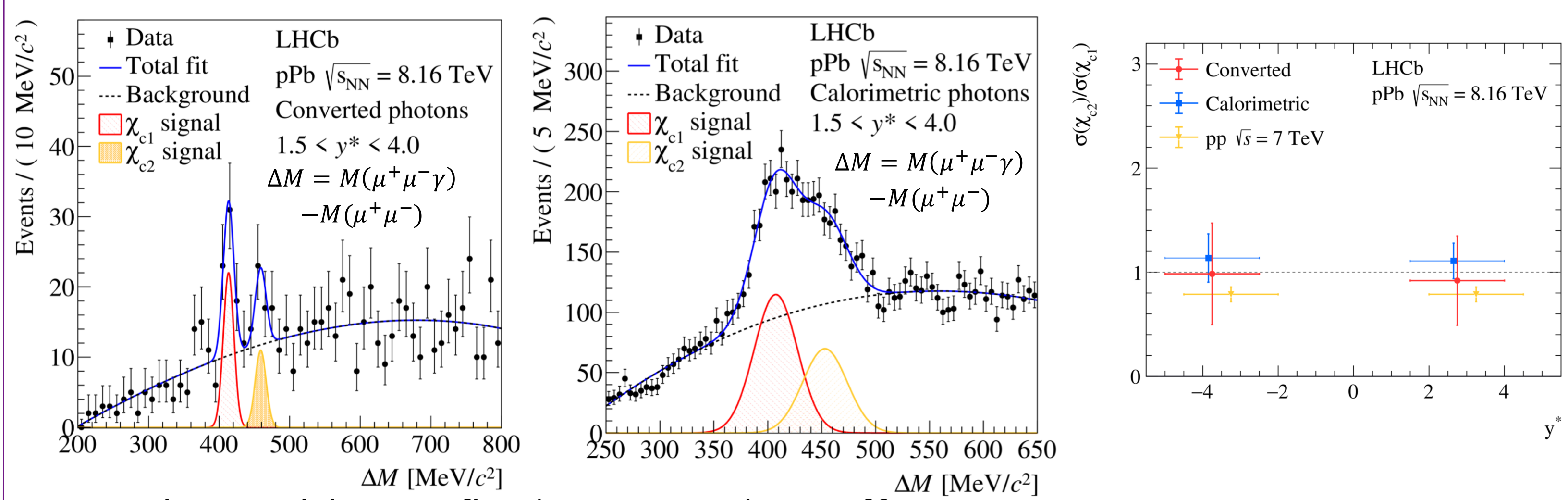
- Double charm hadron invariant mass $m_{D\bar{D}}$. PRL 125 (2020) 212001
 - Hints of difference between LS and OS pairs. OS consist with Pythia8.
- Azimuthal angle between the charm hadron pair $\Delta\phi(DD)$
 - Different between LS and OS pairs.
 - OS pair favor $\Delta\phi \sim 0$ (near side peak), LS pair consist with flat distribution (uncorrelated).
- σ_{eff} consist with excepted factor ~ 3 enhancement.



- LS/OS ratio R^σ are enhanced in $p\text{Pb}$ compared to pp .
- Suggesting DPS/SPS enhanced by a factor ~ 3 .

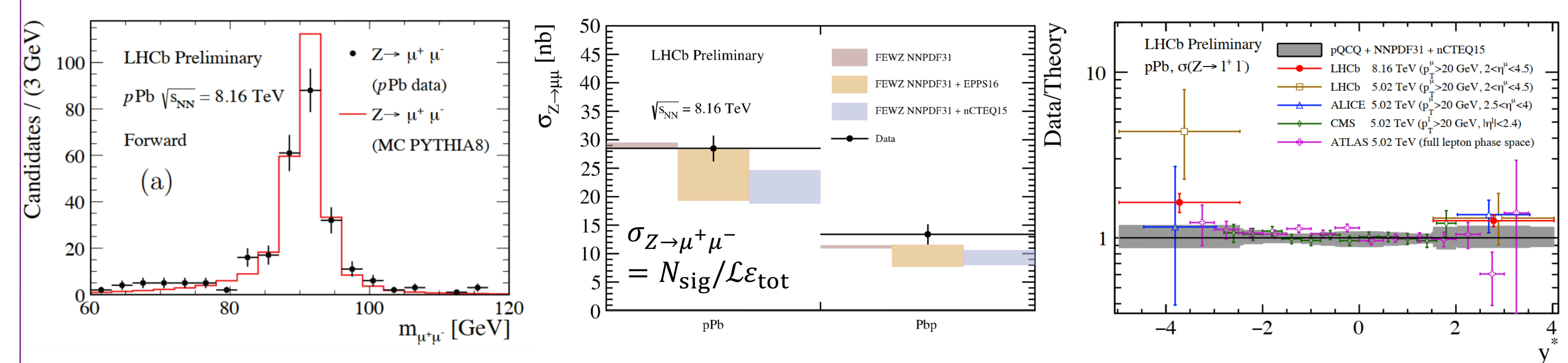
PRL 125 (2020) 212001

Prompt $\sigma(\chi_{c2})/\sigma(\chi_{c1})$ ratio in $p\text{Pb}$ at 8.16 TeV



- χ_{cj} is sensitive to final state nuclear effects. PRC 103 (2021) 064905
- Reconstruction via $\chi_{cj} \rightarrow J/\psi \gamma$, followed by $J/\psi \rightarrow \mu^+ \mu^-$, selection prompt through pseudo-decay time t_z .
 - Converted photons: $\gamma \rightarrow e^- e^+$ reconstructed in tracking system.
 - Calorimetric photons: $\gamma \rightarrow e^- e^+$ reconstructed in electromagnetic calorimetric.
- $\sigma(\chi_{c2})/\sigma(\chi_{c1})$ is larger in $p\text{Pb}$ than in pp , although they are consistent with unity within uncertainties.

Z boson production in $p\text{Pb}$ at 8.16 TeV



- The Z production in $p\text{Pb}$ can be used to probe CNM for $x \sim 10^{-4}$ to ~ 1 at $Q^2 \sim 10^4 \text{ GeV}^2$. LHCb-CONF-2019-003
- Data are compatible with theoretical predictions using NNLO pQCD and NNPDF3.1 for p and nCTEQ nPDF for Pb .
- Results are compatible with 5 TeV results from various experiments.

Summary

- Prompt D^0 production and R_{FB} in $p\text{Pb}$ at 8.16 TeV.
 - Hints an increasing trend at high p_T .
- Charm pair production in $p\text{Pb}$ at 8.16 TeV.
 - Observes 3 times DPS/SPS enhancement in $p\text{Pb}$ compared to pp .
- Prompt $\sigma(\chi_{c2})/\sigma(\chi_{c1})$ ratio in $p\text{Pb}$ at 8.16 TeV.
 - $\sigma(\chi_{c2})/\sigma(\chi_{c1})$ consist with unity within uncertainties in $p\text{Pb}$ and pp .
- Z boson production in $p\text{Pb}$ at 8.16 TeV.
 - compatible with theoretical predictions and 5TeV results.
- More results are on upcoming.
 - D^+ , D_s^+ mesons and Λ_c^+ baryon in $p\text{Pb}$.