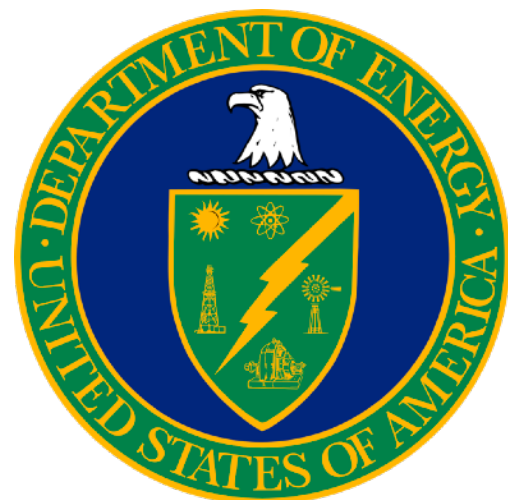


Overview of the latest UPC and photonuclear results in CMS

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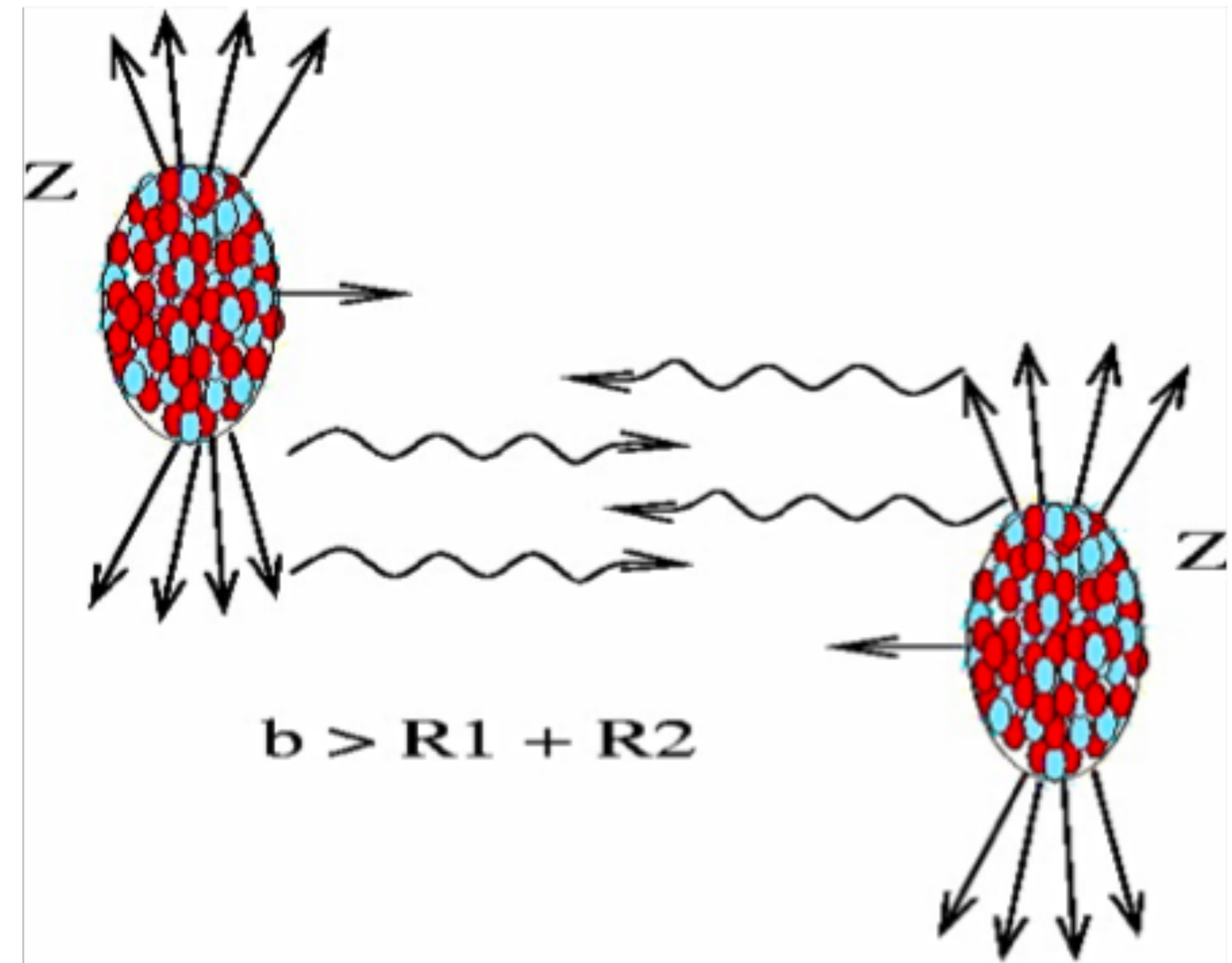
*Department of Physics & Astronomy
University of Kansas*



**Diffraction and Low-x 2024
Palermo, Italy
Sept. 8-14, 2024**

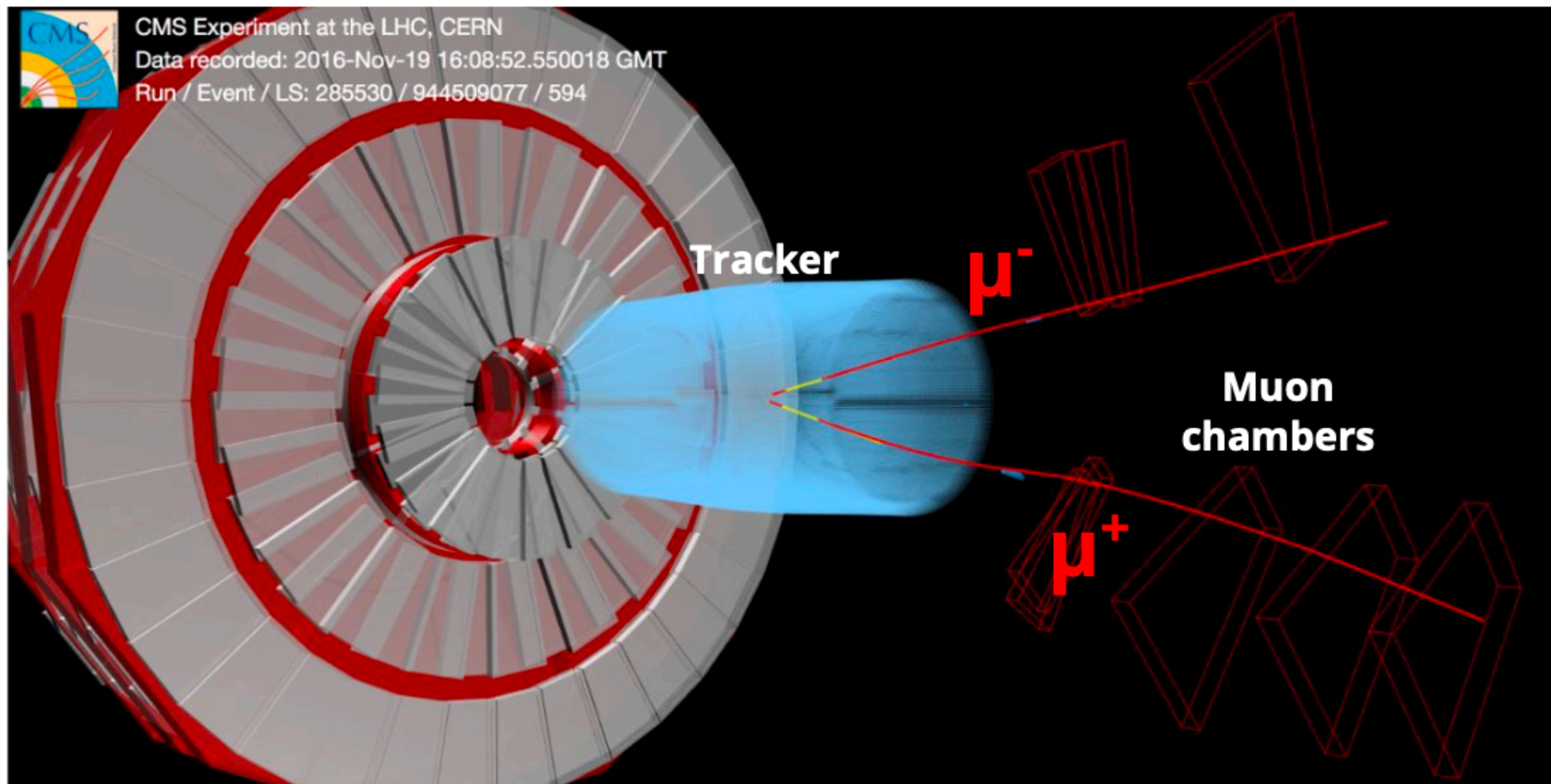
Ultrapipheral collisions (UPCs)

- When ions don't "touch" each other:
Impact parameter $b > R_1 + R_2$:
- These processes dominate nucleus-nucleus cross section.
- Electromagnetic (photon) interactions dominate.
- Photons are quasi-real: $Q^2 \lesssim 1/R_A^2$
- Large photon flux $\sim Z^2$ (Fermi/Weizsacker-Williams). In the case of Pb, probability 82^4 larger than proton!

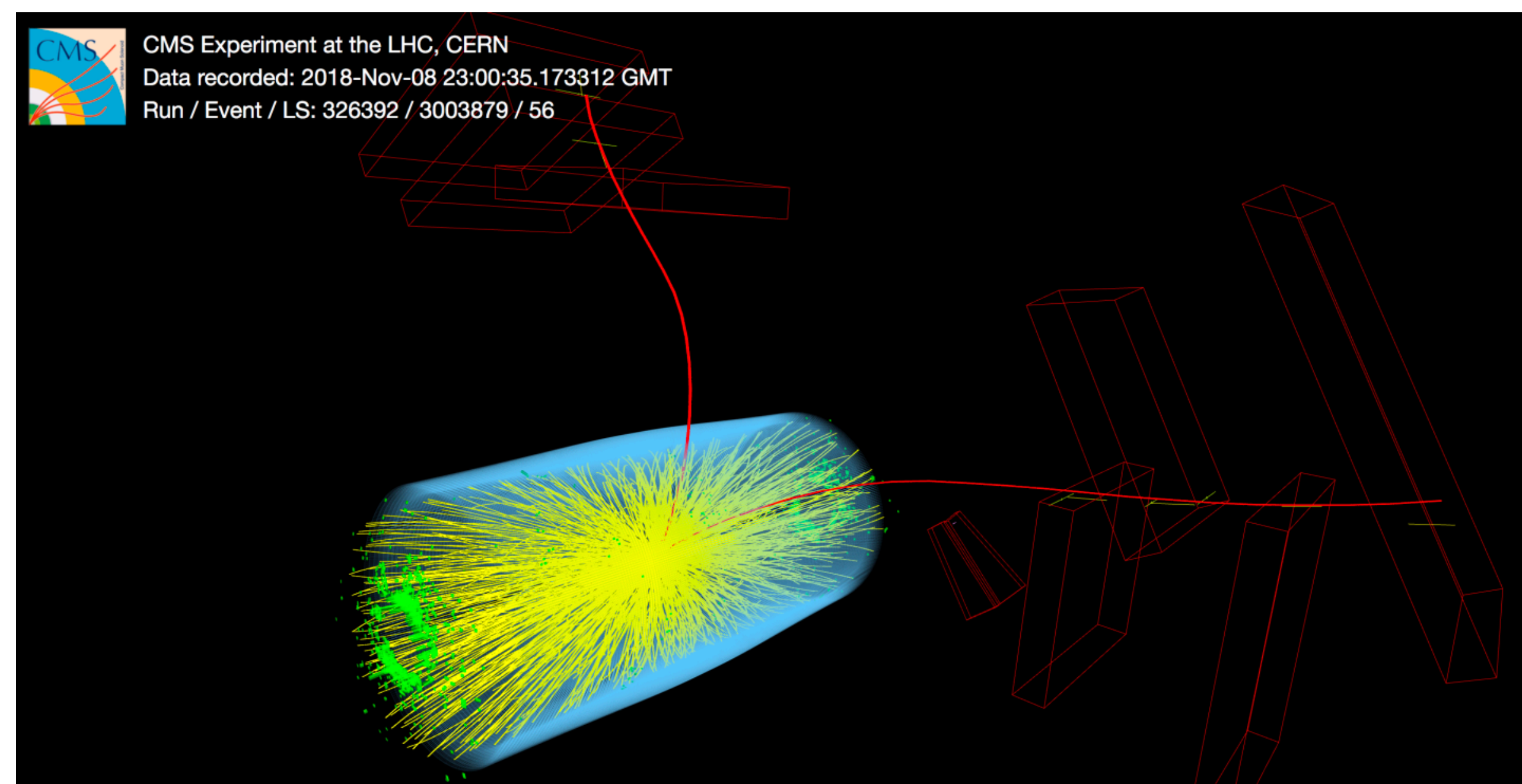


Ultrapерipheral collisions (UPCs)

UPC



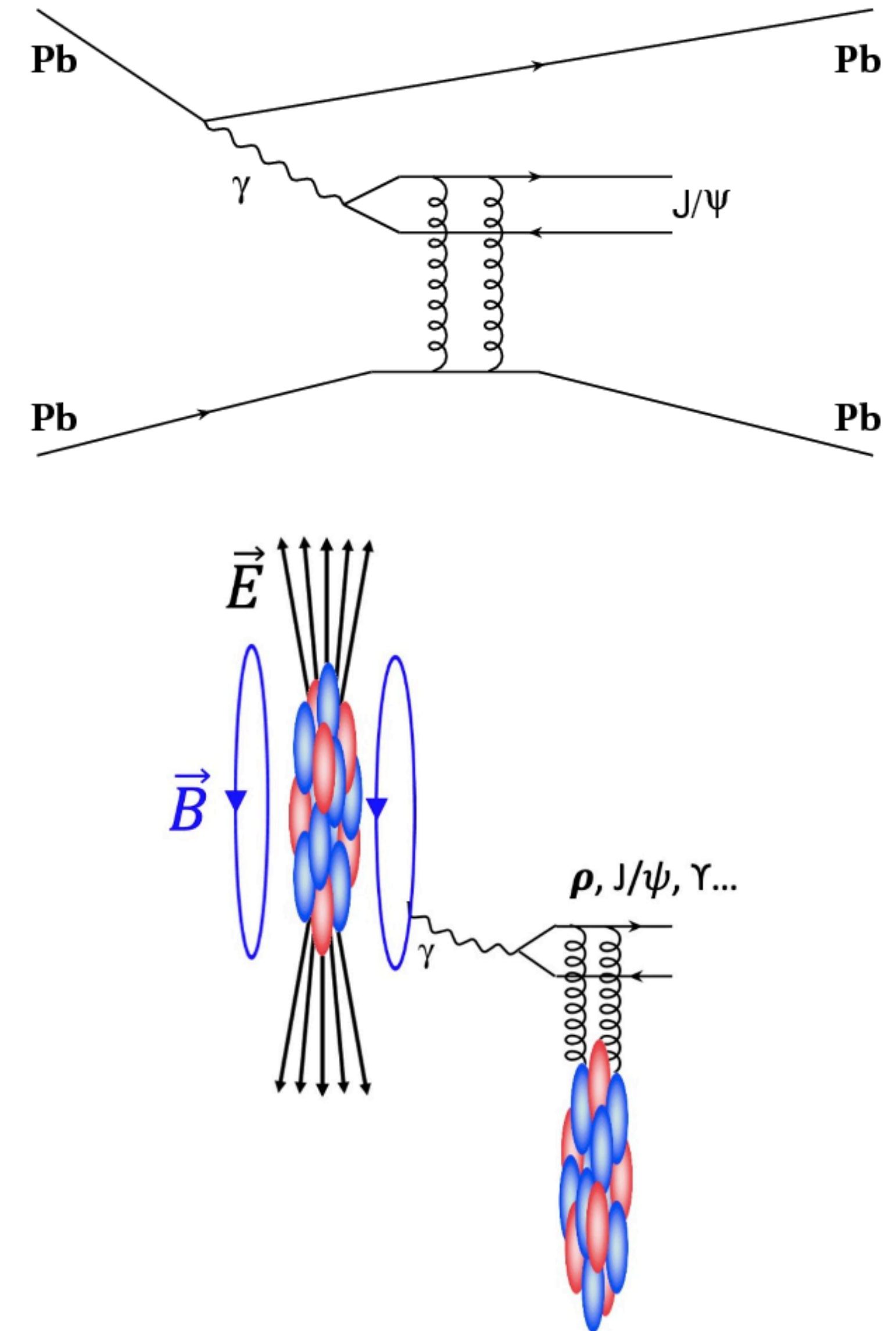
Central



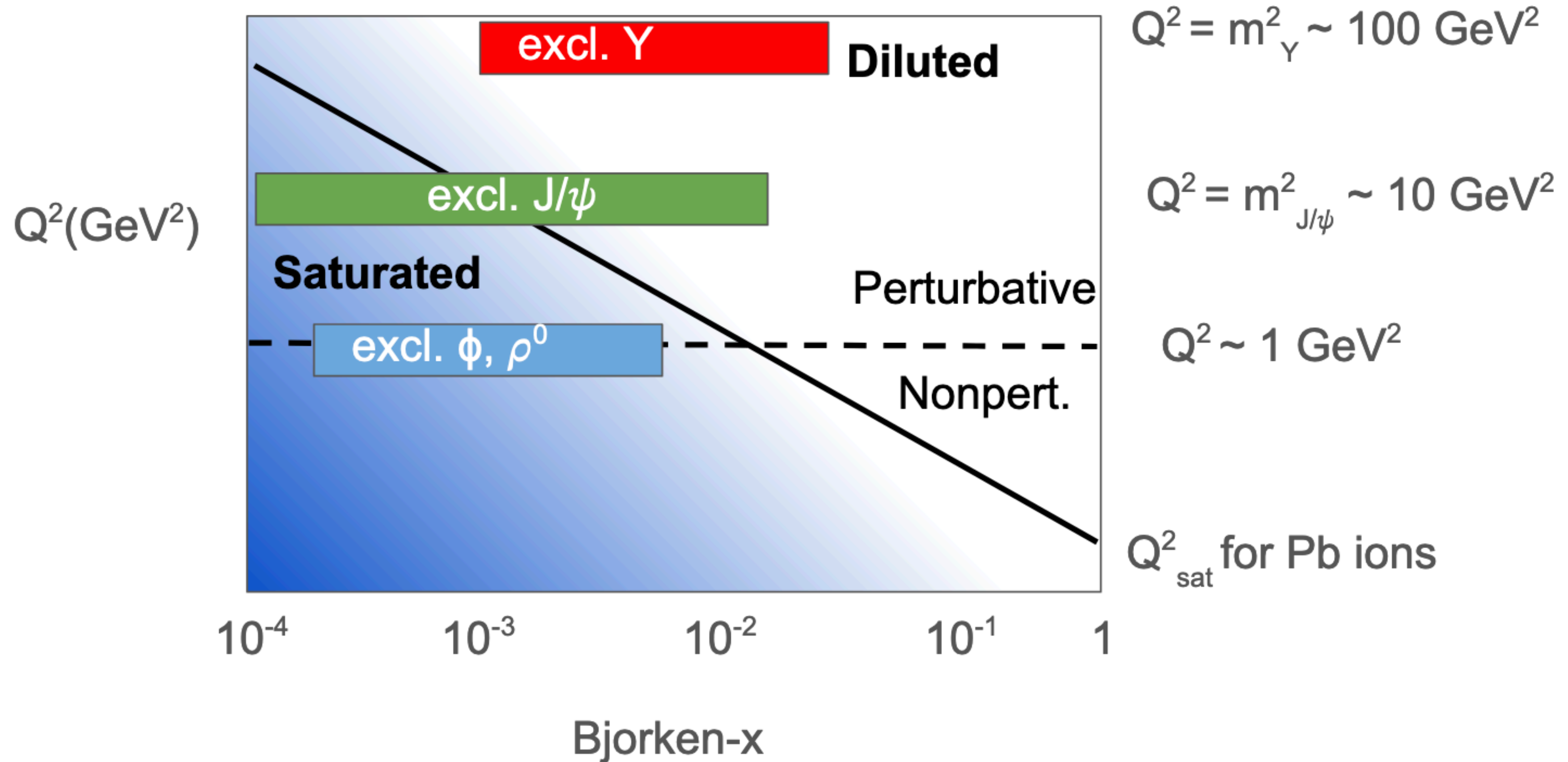
Experimentally very clean events !

Vector meson photoproduction

- Photon quantum numbers ($J^{PC} = 1^{--}$) same for VM \rightarrow highly likely a photon will fluctuate into a VM
- VM photoproduction cross section $\propto (xg(x, Q^2))^2$ at LO \rightarrow sensitive to the target's gluon distribution.
- Photoproduced VM cross section at small x can test gluon density

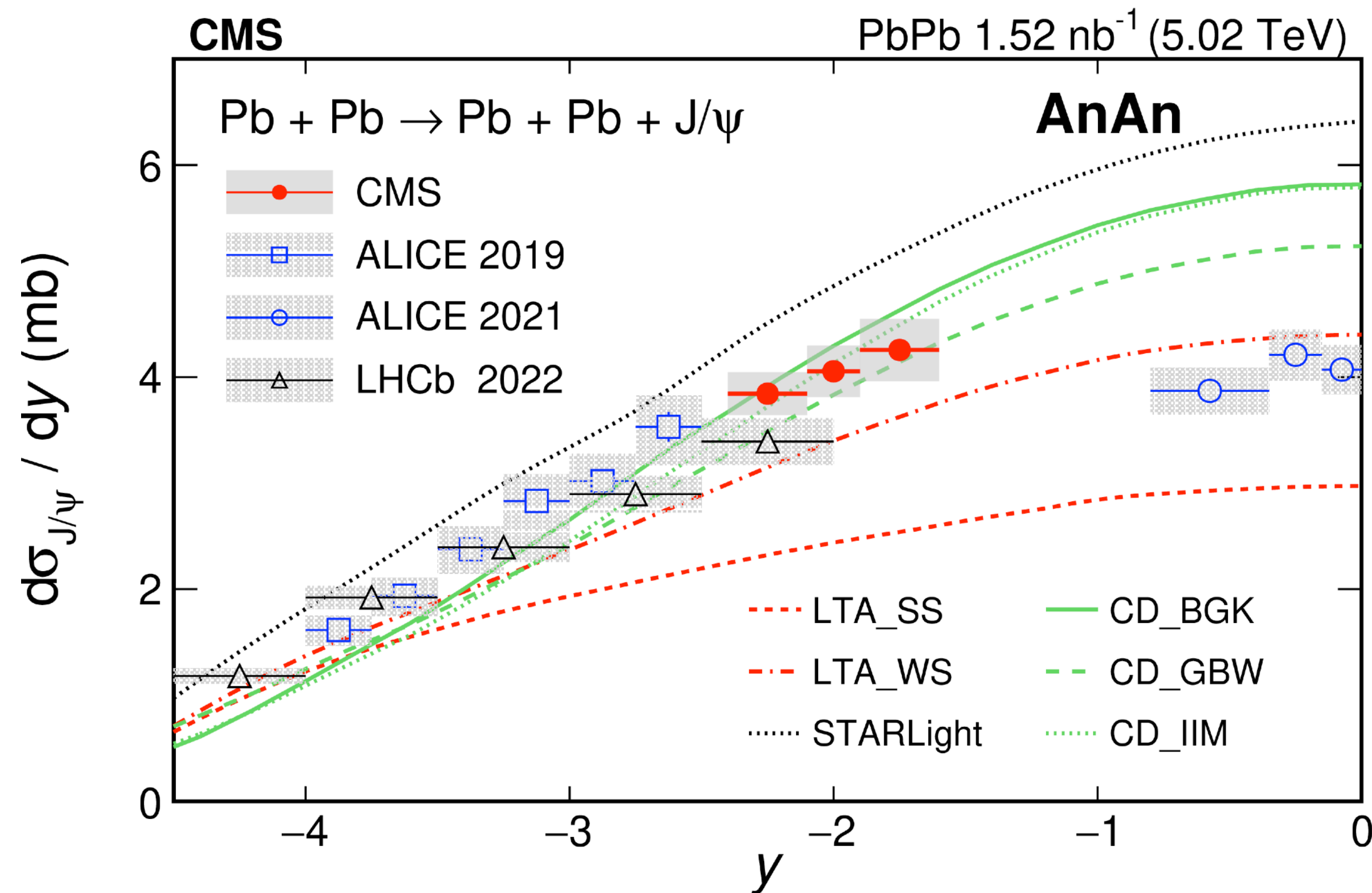
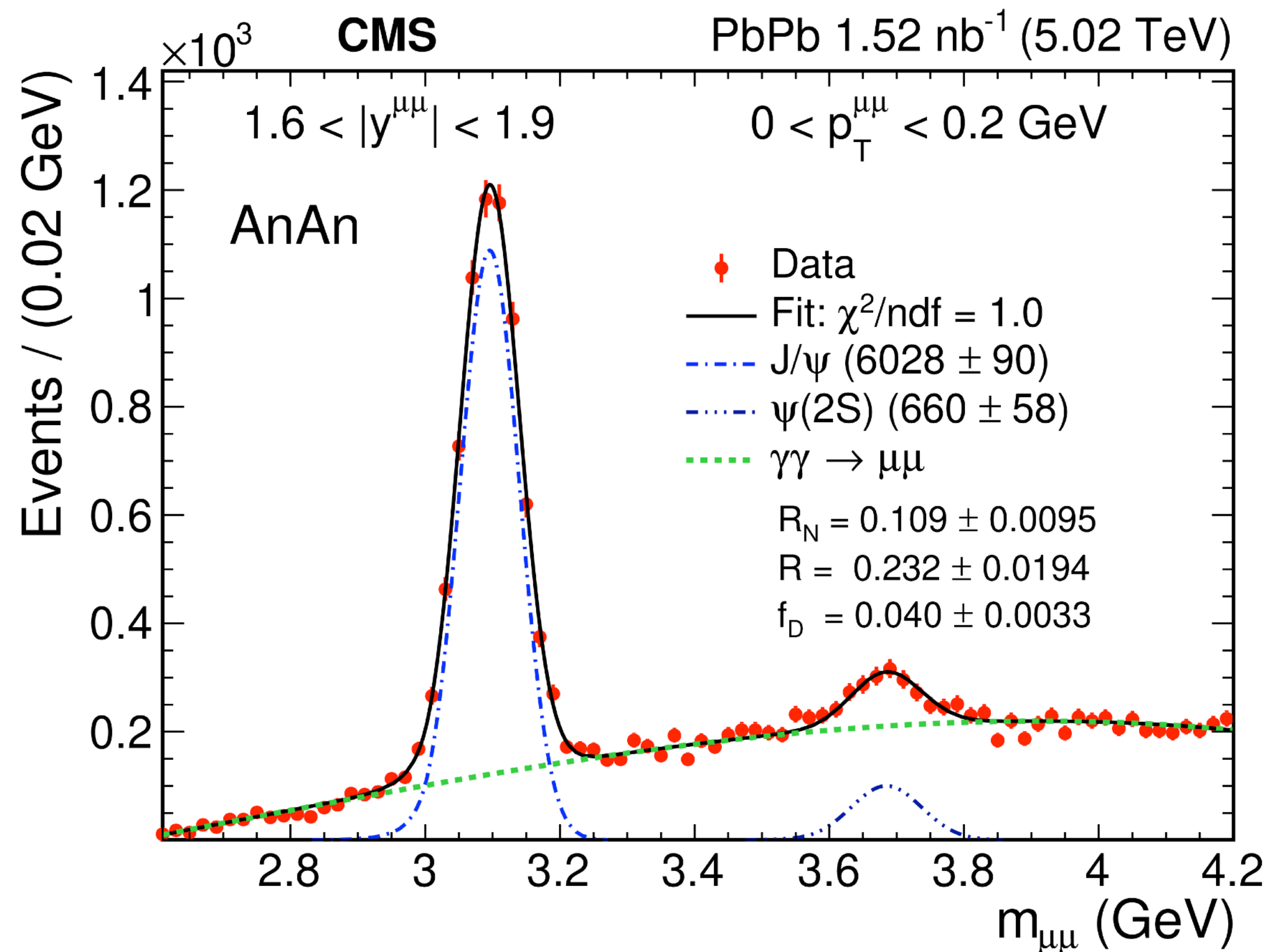


Vector meson photoproduction



- Different VM states map out the transition to the low- x regime.

Coherent J/ψ in PbPb

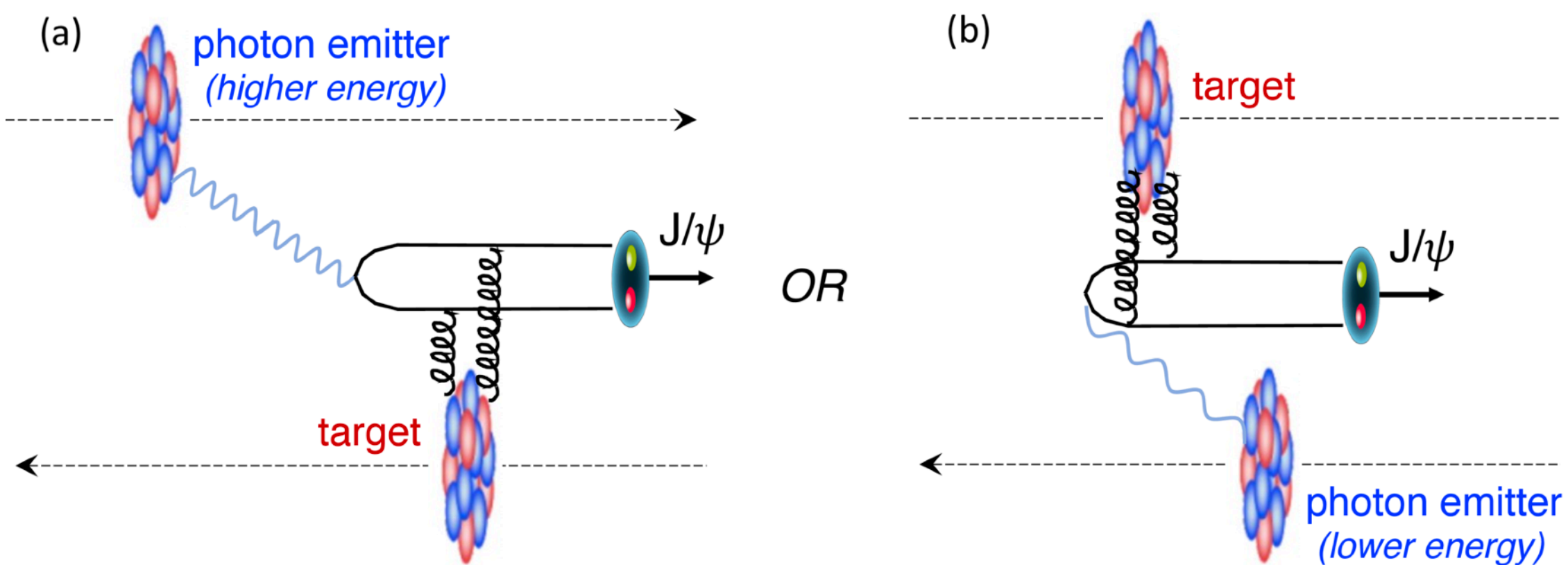


[Phys. Rev. Lett. 131, 262301](#)

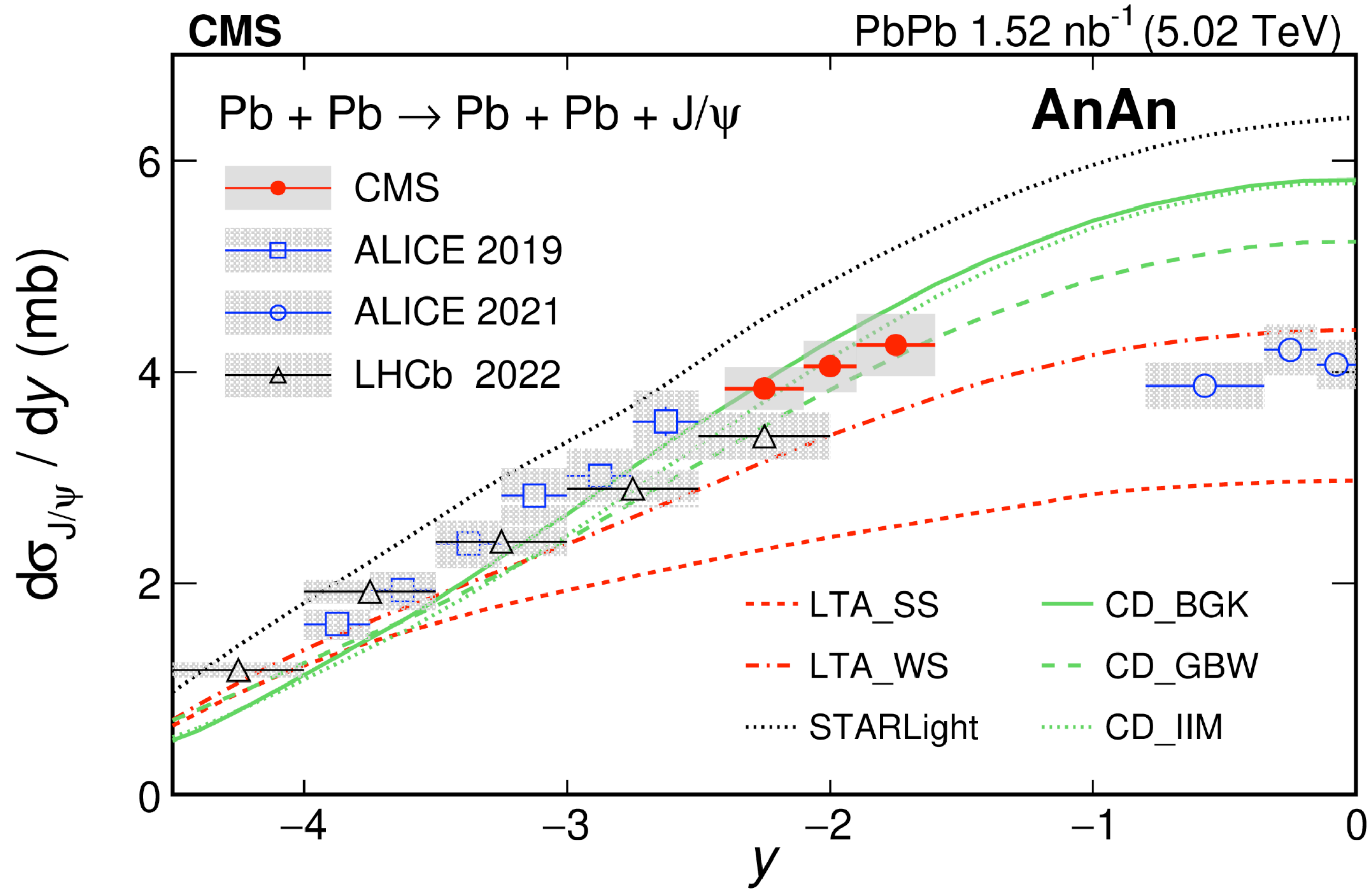
- J/ψ in PbPb UPCs measured by CMS with Run 2 data.
- High stats. allows precision measurements.

Coherent J/ψ in PbPb

- **Ambiguity in symmetric collisions:** either ion can serve as the emitter or target.
- Each data point has contributions from low and high energy photons.
- Solution: control impact parameter with **ZDC detector**.



$$\frac{d\sigma_{AA \rightarrow AA' J/\psi}}{dy} = N_{\gamma/A}(y) \cdot \sigma_{\gamma A \rightarrow J/\psi A'}(y) + N_{\gamma/A}(-y) \cdot \sigma_{\gamma A \rightarrow J/\psi A'}(-y)$$



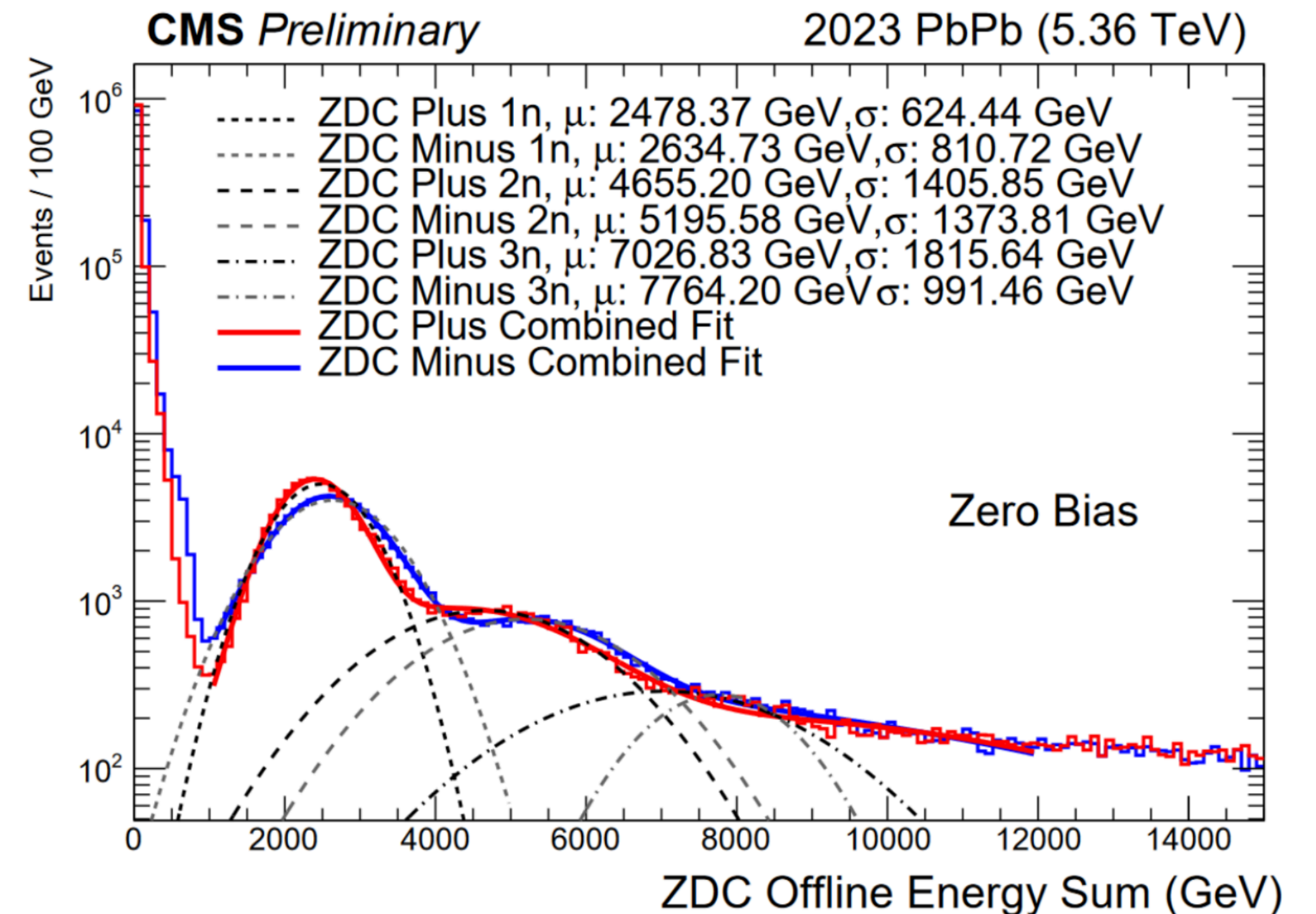
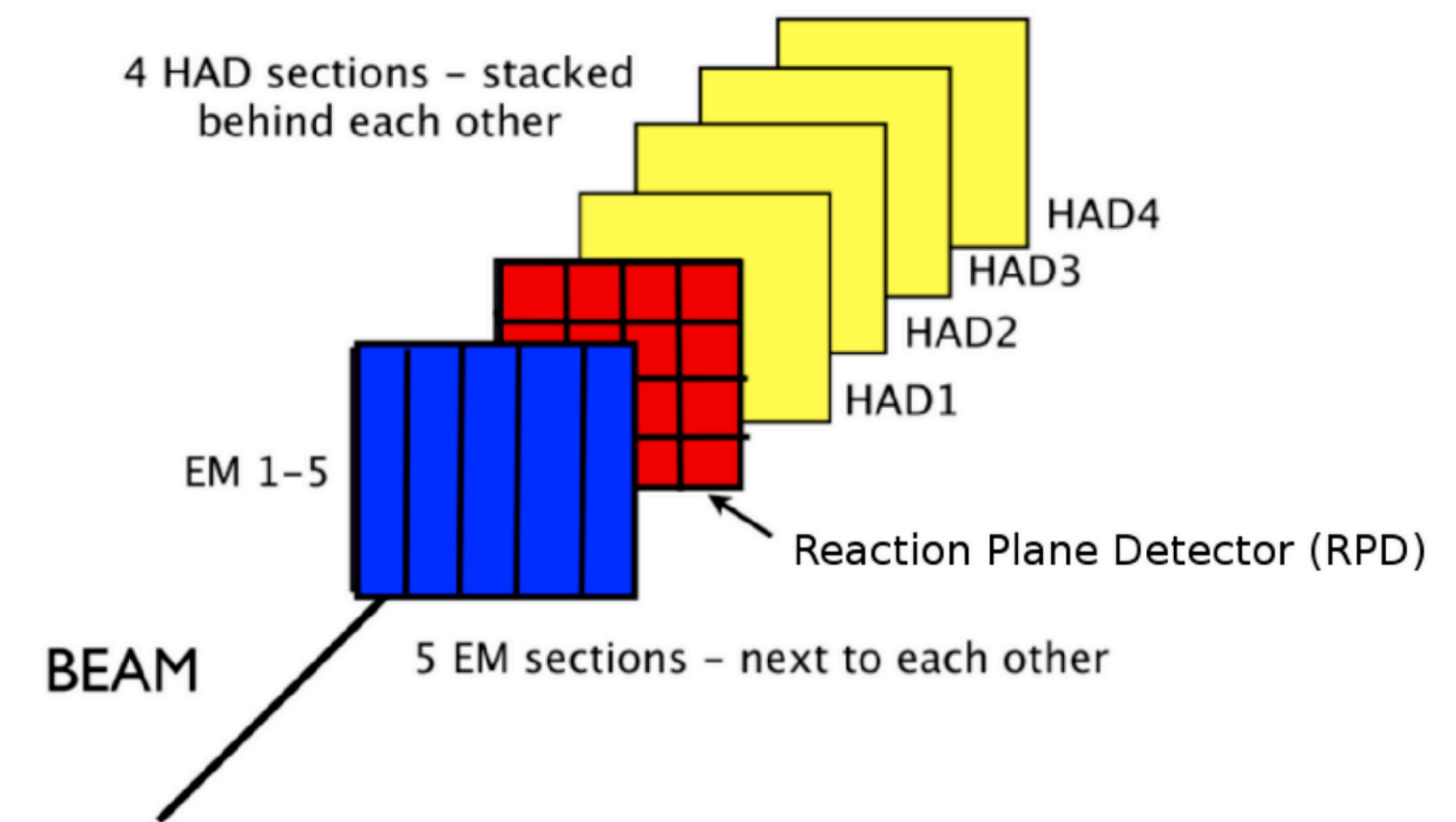
[Phys. Rev. Lett. 131, 262301](https://arxiv.org/abs/1808.07511)

$$x = \left(\frac{M_{J/\psi}}{\sqrt{s_{NN}}} \right) e^{\mp y}$$

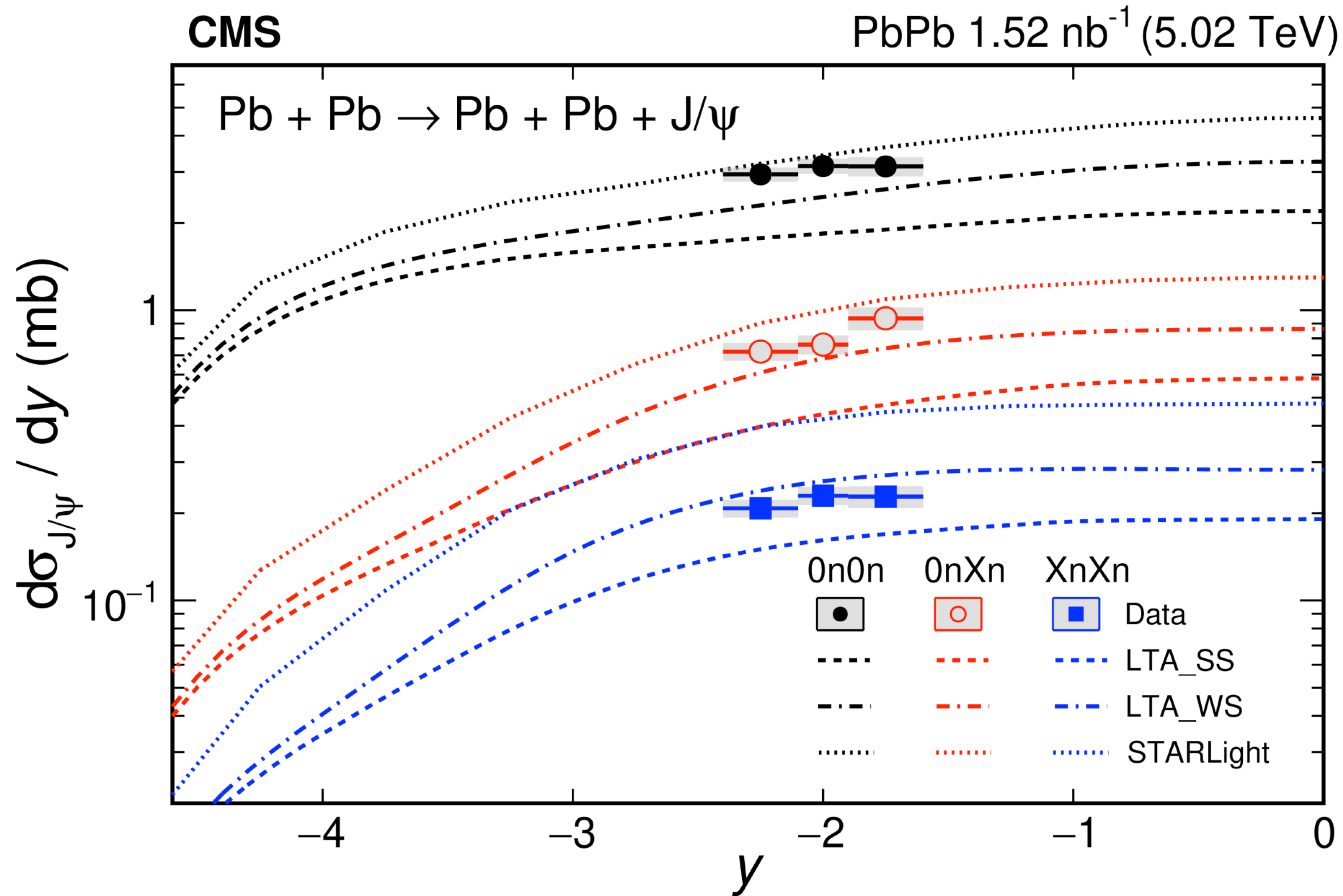
Zero-degree calorimeter

- Detects neutrons produced in nuclear break-ups at very forward $|\eta| > 8.3$.
- Measure by summing up energy depositions in the EM and HAD sections.
- In Run 3, for the first time included at trigger level.

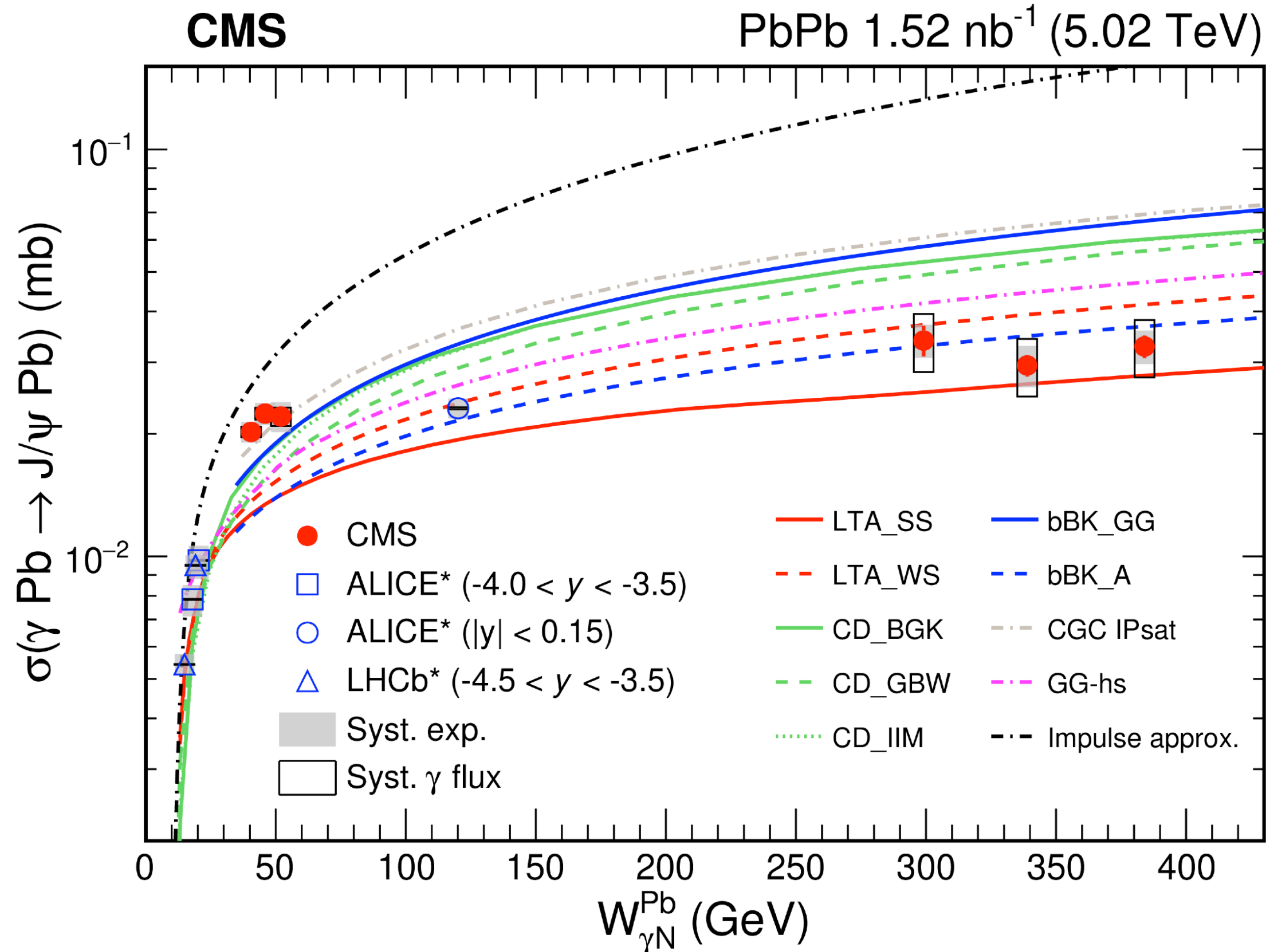
ZDC Layout



Coherent J/ψ in PbPb



- ZDC allows to classify events in neutron categories.
- Separation in different neutron categories.



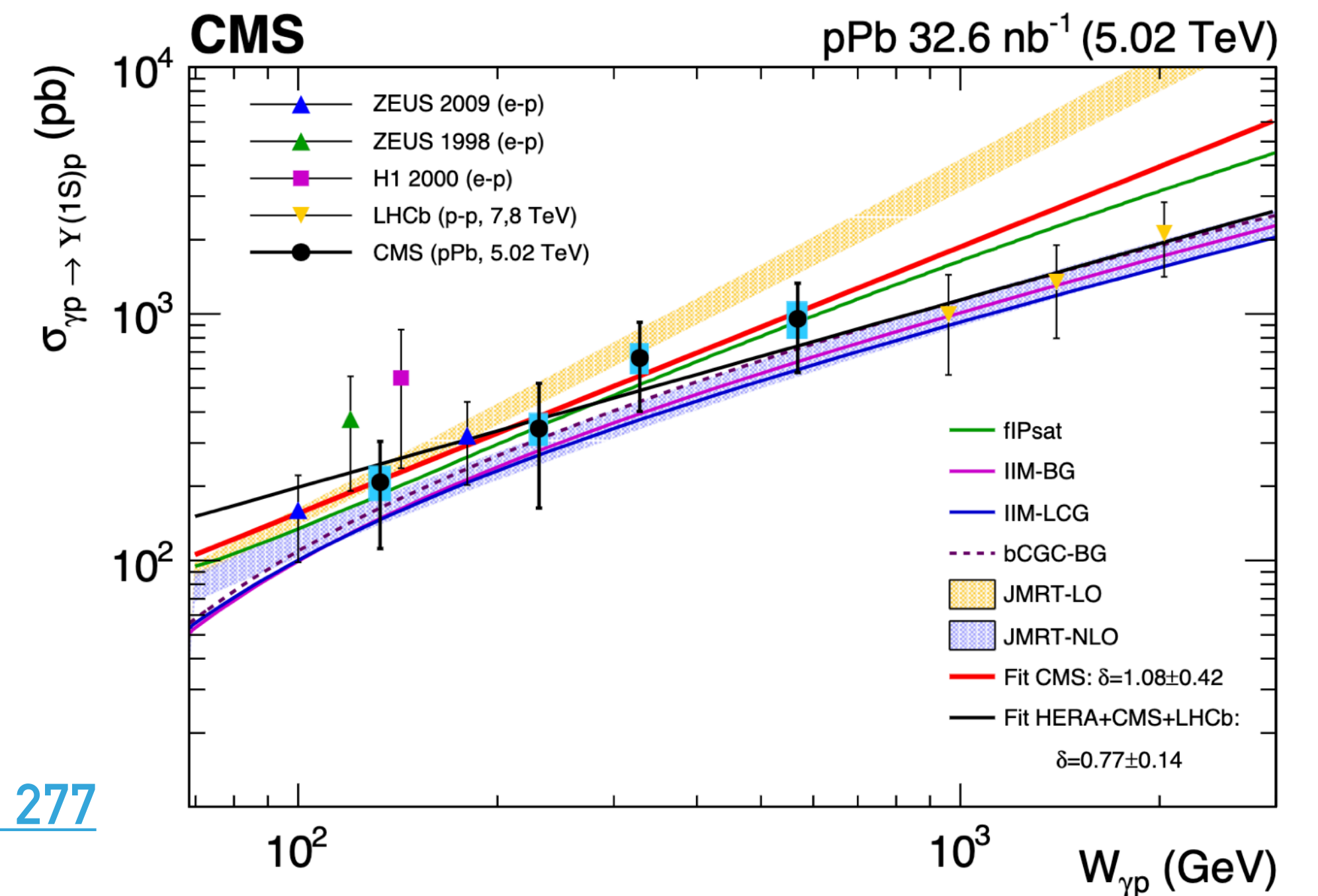
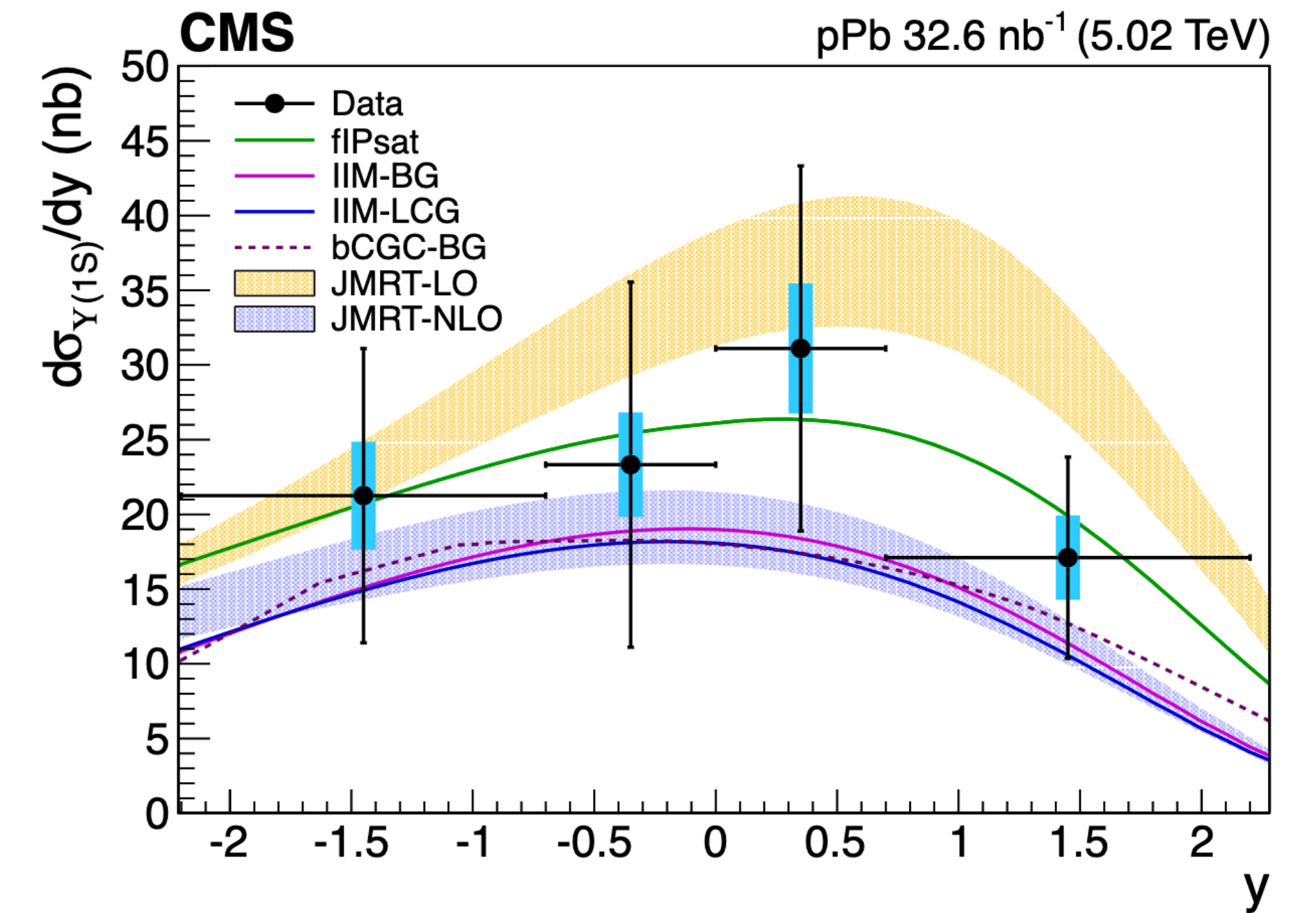
[Phys. Rev. Lett. 131, 262301](#)

- ZDC categories allow us to obtain the W dependence.
- $W < 40$ GeV: rapidly increasing
- Higher W : slow rise \rightarrow underlying physics changed!
- Clear suppression w.r.t IA at high W .

Exclusive $Y(1S)$ in pPb

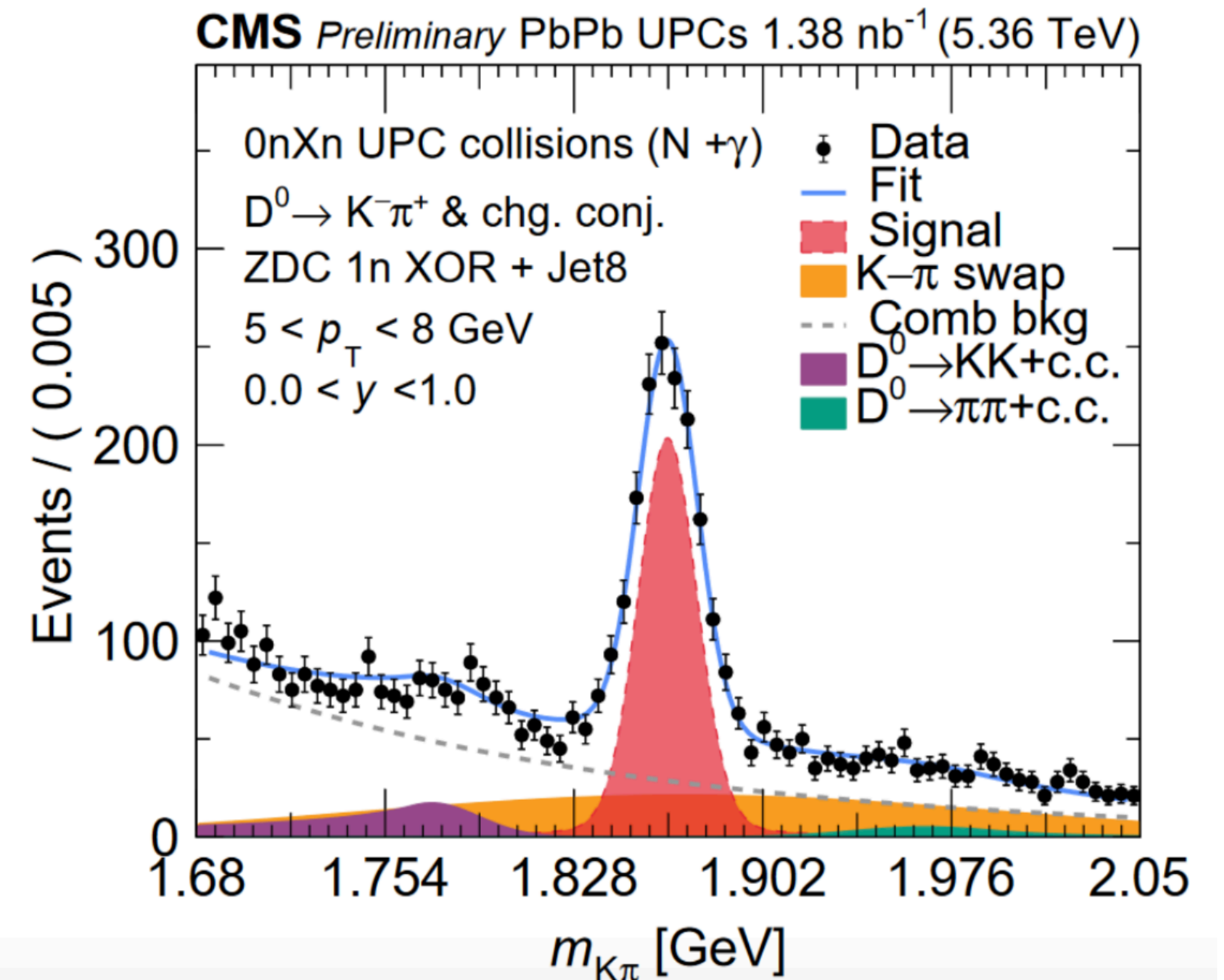
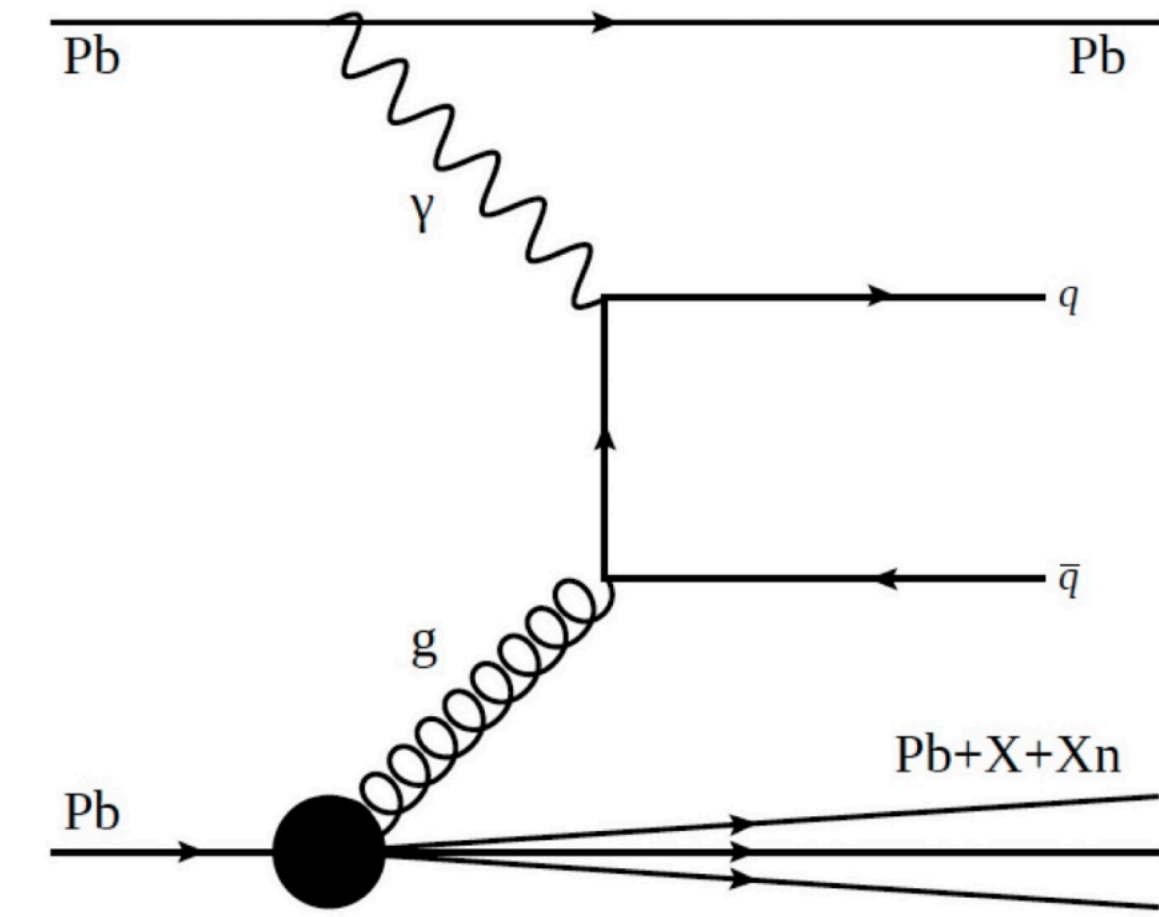
- Higher masses allows to probe at higher Q^2 .
- CMS measured this process in pPb at 5 TeV.
- This measurement probes the region $x \approx 10^{-4} - 10^{-2}$
- Ongoing effort in $Y(1S)$ measurement in PbPb.

[Eur. Phys J.C, Vol 79, 277](#)



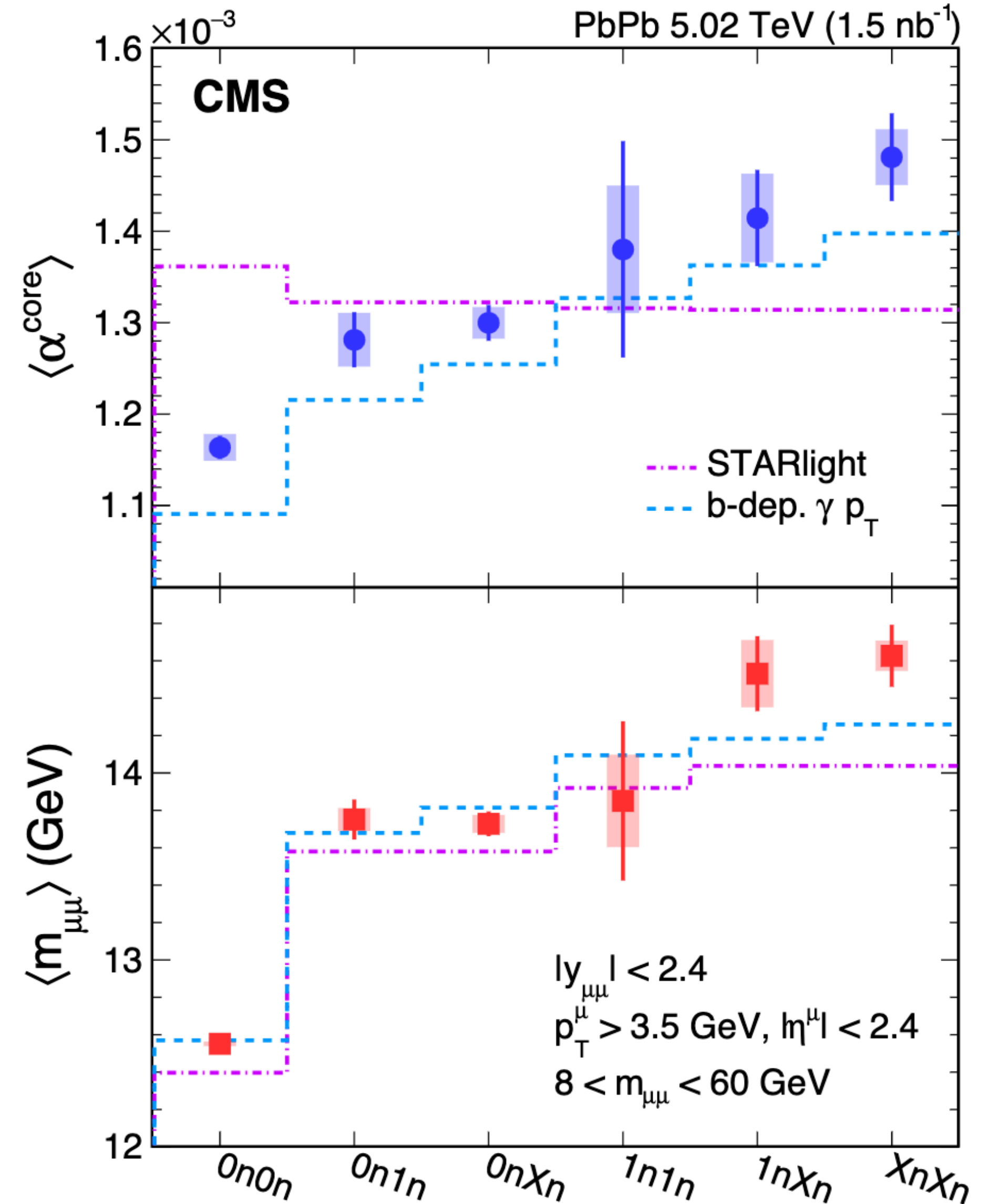
Open charm photoproduction in PbPb

- New ZDC capabilities have made possible new searches.
- New experimental probe to test QCD at low- x .
- See [talk](#) by G.M Innocenti and [poster](#) by B. Kovacs.



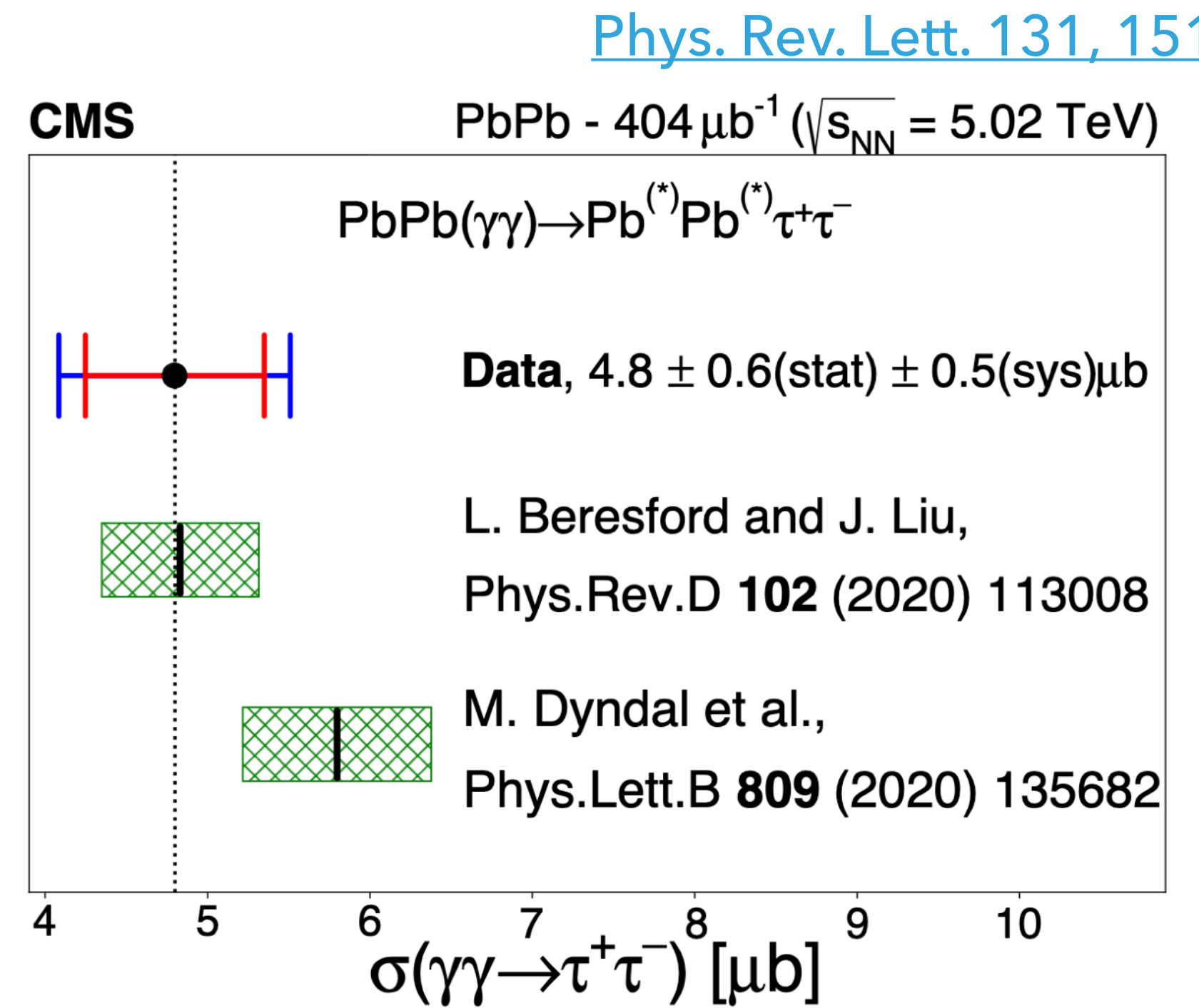
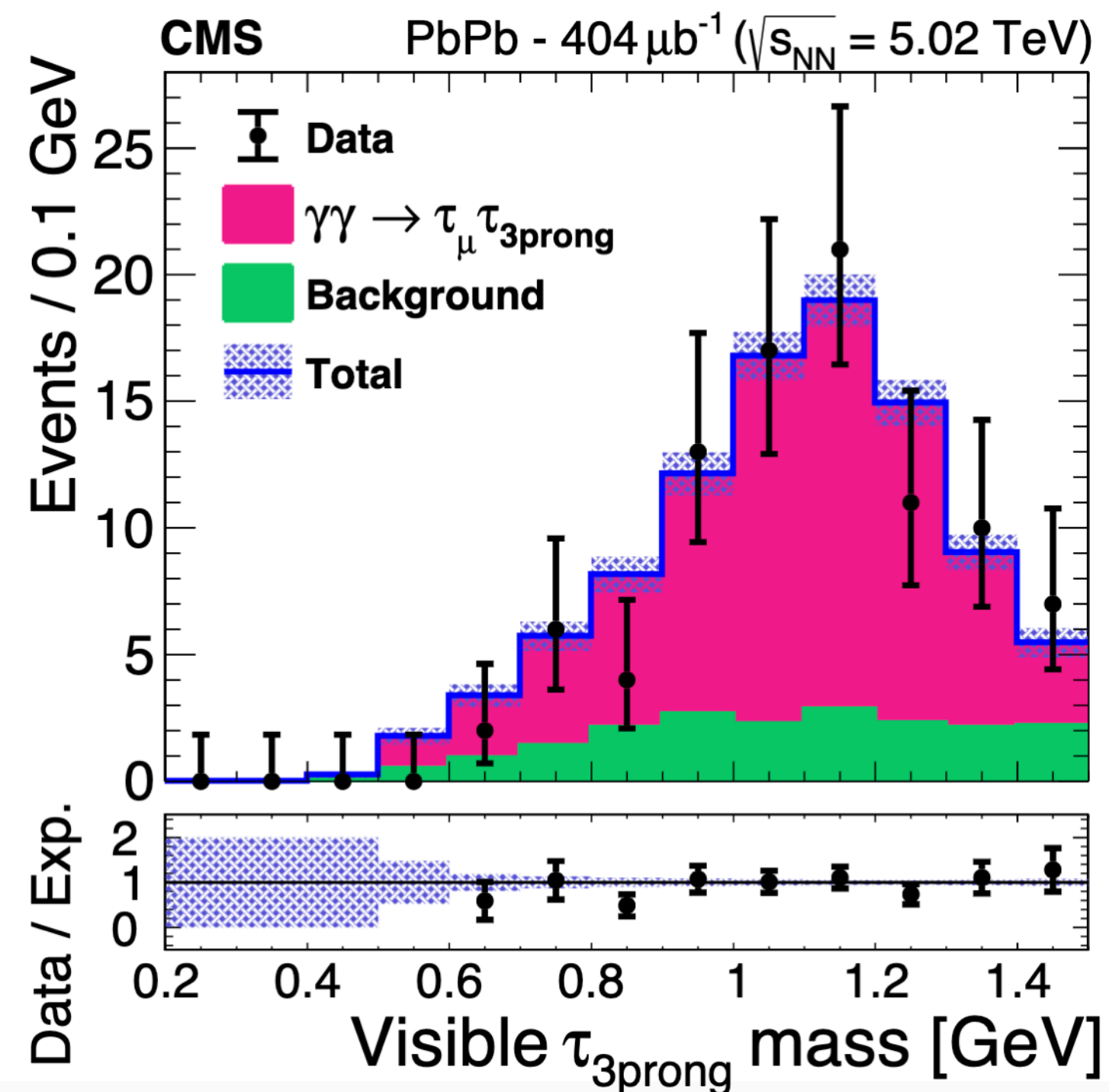
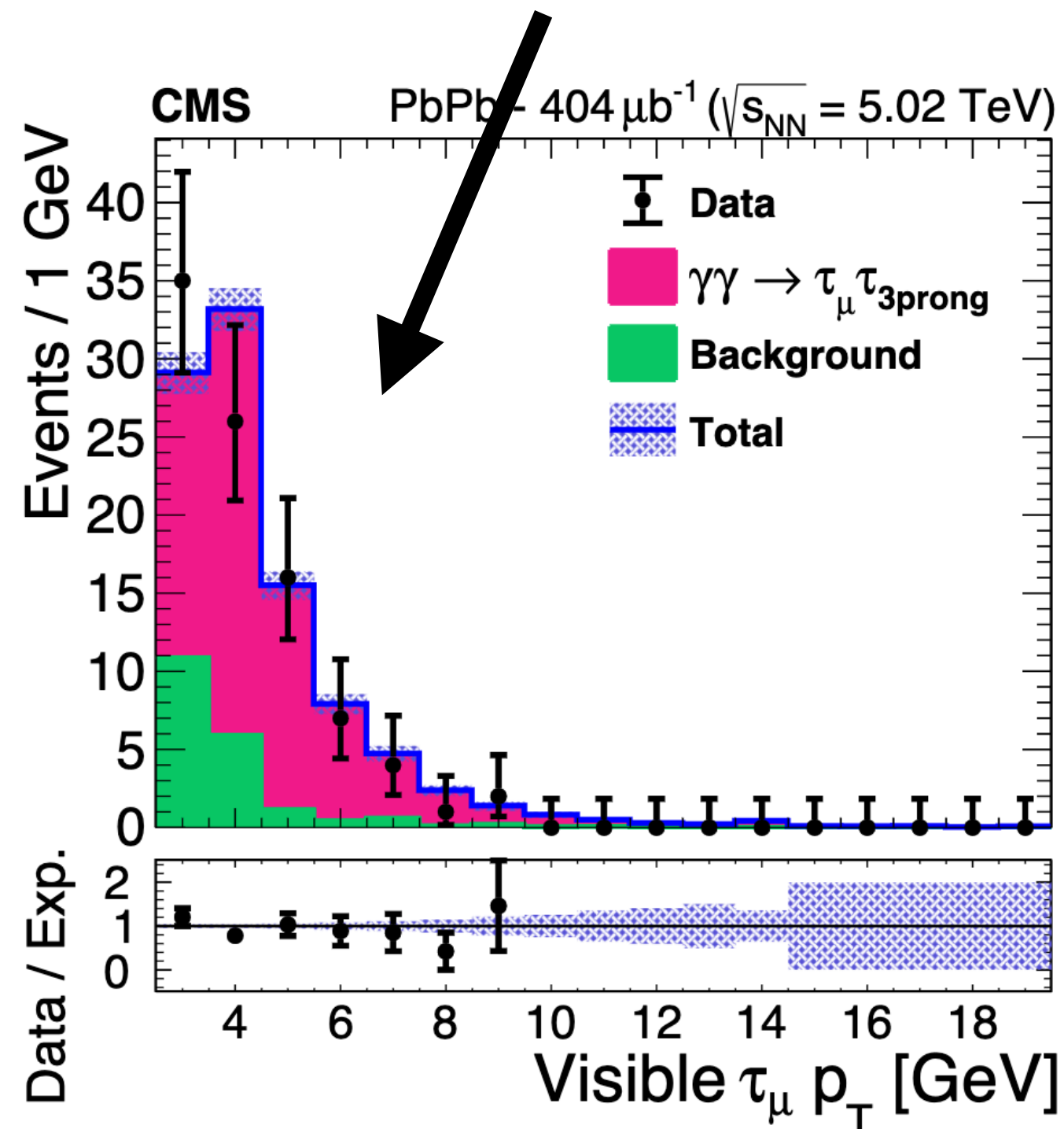
- Impact parameter dependence of $\gamma\gamma$ interactions can be tested with EM dissociation.
- Significant broadening observed for increasing forward neutron multiplicities.

$$\alpha = 1 - \frac{|\phi^+ - \phi^-|}{\pi}$$



$\gamma\gamma \rightarrow \tau\tau$ production in PbPb UPCs

- Good candidate to test tau g-2.
- $\tau \rightarrow \mu + 2\nu$ and $\tau \rightarrow 3\pi + \nu_\tau$
- We profit from the low p_T muon detection capabilities.
- Cross section in agreement with QED at LO.



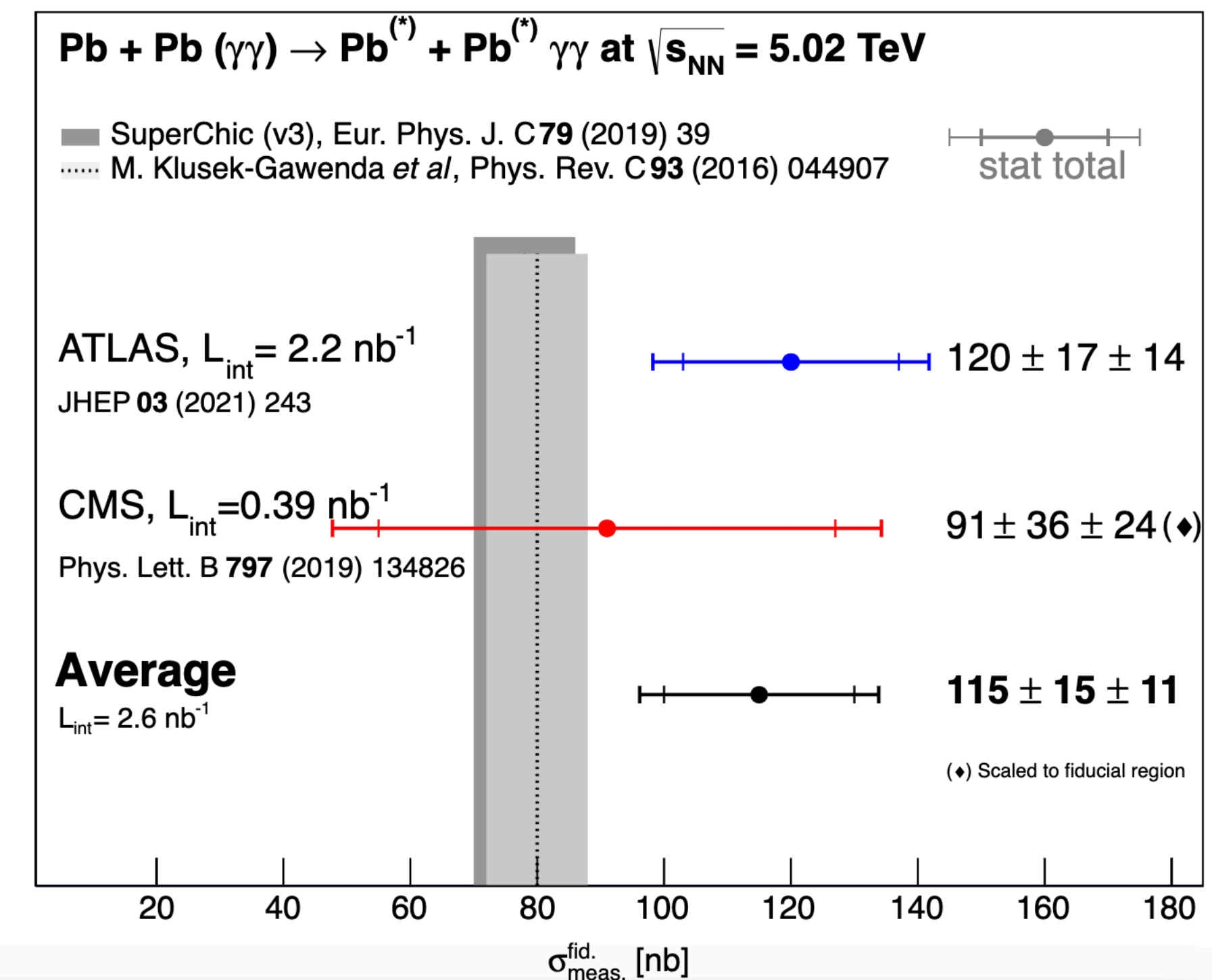
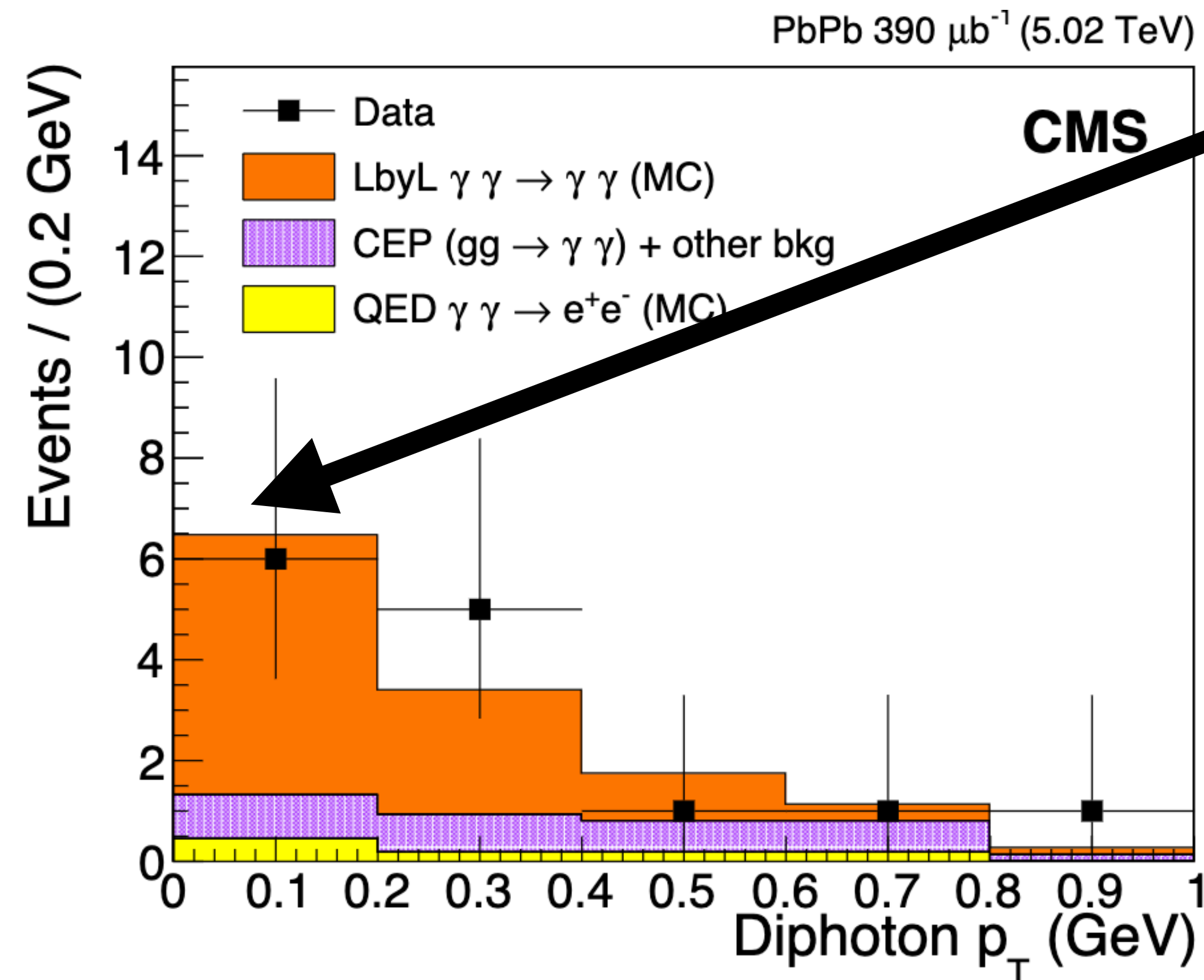
[Phys. Rev. Lett. 131, 151803](https://arxiv.org/abs/1907.07803)

$\gamma\gamma \rightarrow \gamma\gamma$ production in PbPb UPCs

- First observed by ATLAS and evidence by CMS.
- ATLAS+CMS combined
- A clear example of UPCs as a photon colliders! (still, very rare!)

[arXiv:1810.04602](https://arxiv.org/abs/1810.04602)

[arXiv:2204.02845](https://arxiv.org/abs/2204.02845)



- CMS undergoes a rich and dedicated UPC physics program, covering photonuclear and photon-photon physics.
- More data, detector upgrades and analysis techniques are/will bring further improvements.
- Many ongoing efforts UPC related to be unveiled very soon, so stay updated!

