31st International Workshop on Deep-Inelastic Scattering
8–12 Apr 2024, Grenoble, FRANCE

Energy dependence of coherent J/ψ production off lead with ALICE

Guillermo Contreras
Czech Technical University in Prague

On behalf of the ALICE Collaboration

FORTE
Co-funded by the European Union
MINISTRY OF EDUCATION, YOUTH AND SPORTS

Key questions we are interested in

What can we learn about the structure of hadrons at high energies with the LHC?

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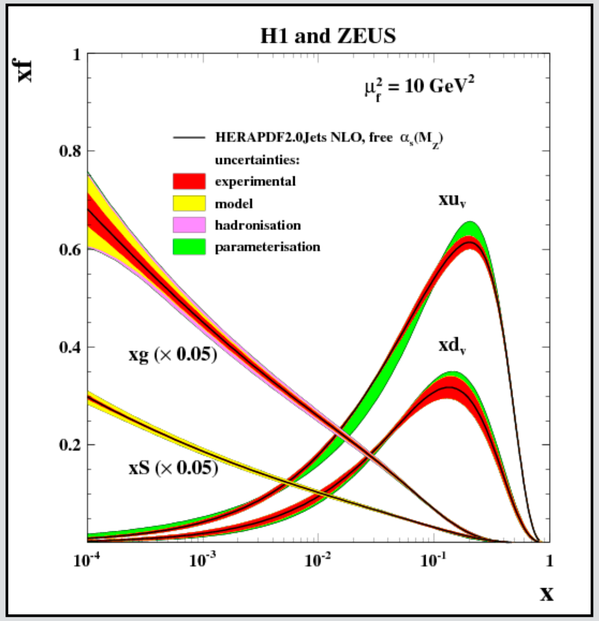
Measurements at HERA imply that, when seen with a high-energy probe, nucleons are made mainly of gluons



H1 and Zeus, EPCJ 75 (2015) 580

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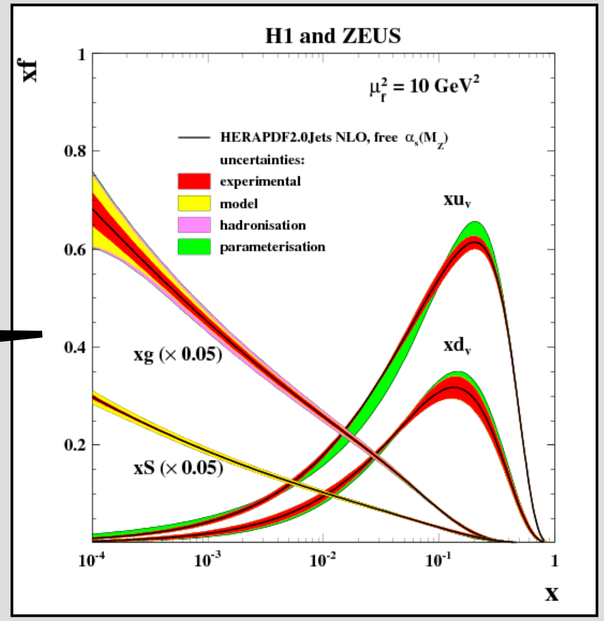

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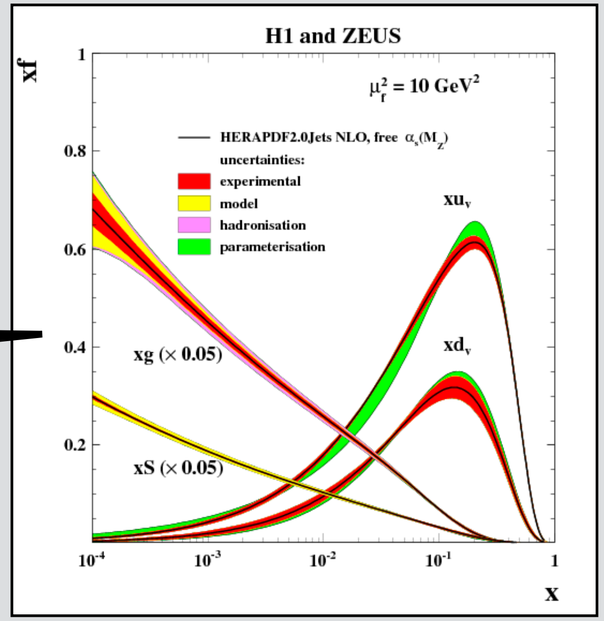

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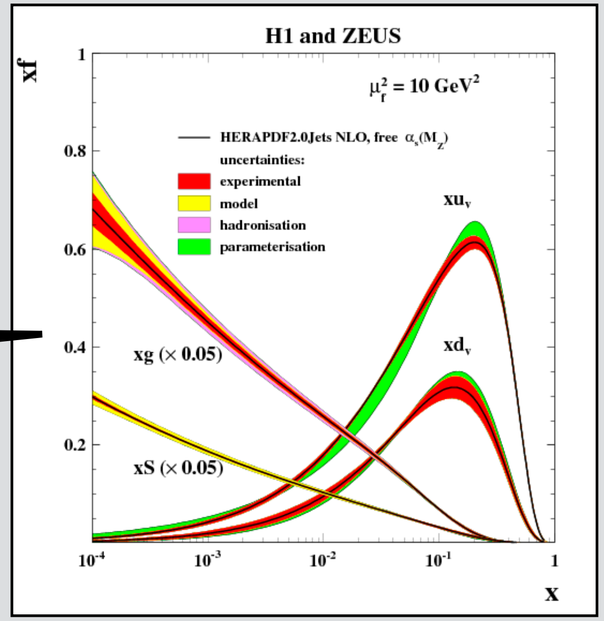

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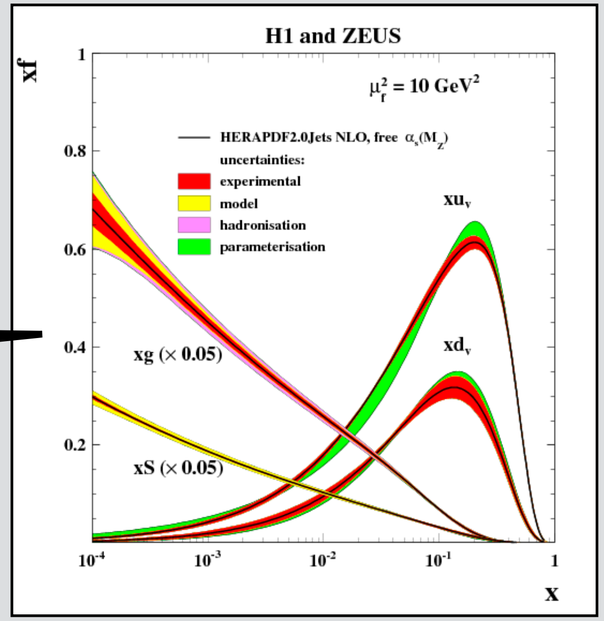

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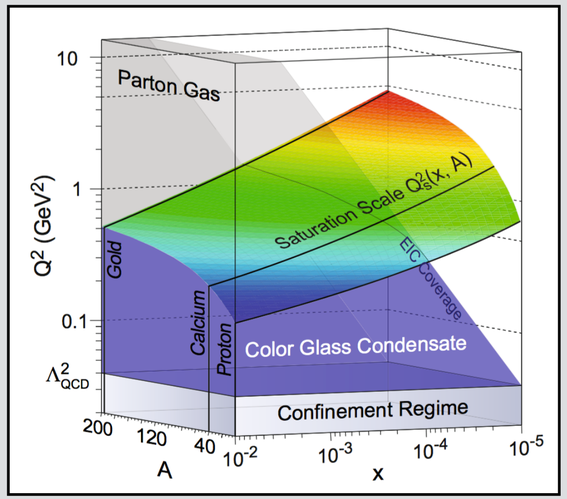
Saturation is expected to set at higher x in heavy nuclei



Accardi et al, EPJA 52 (2016) 268

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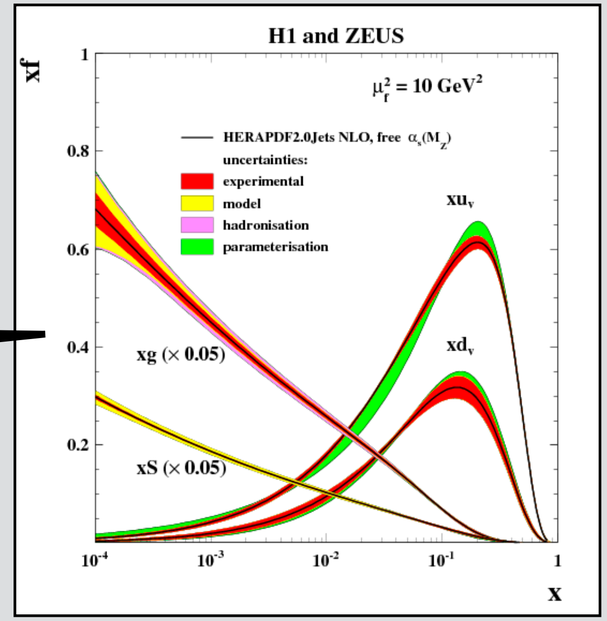

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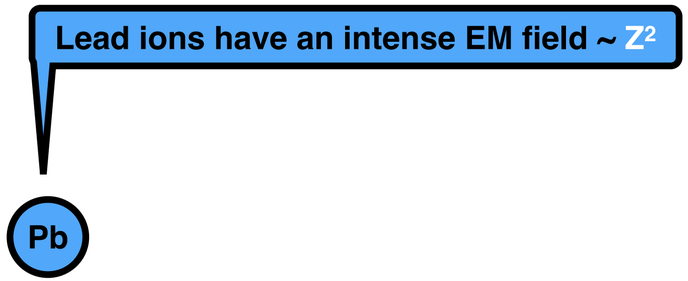
Photons at the LHC to understand QCD: coherent vector meson production



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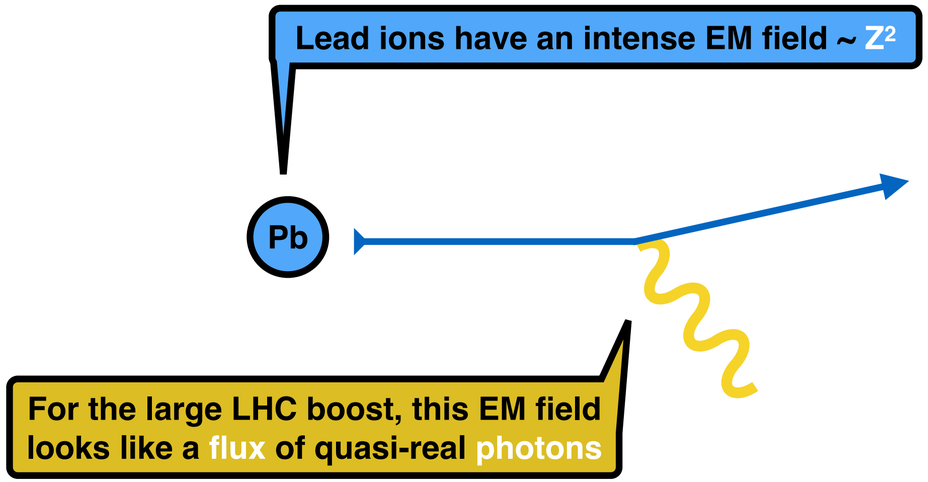

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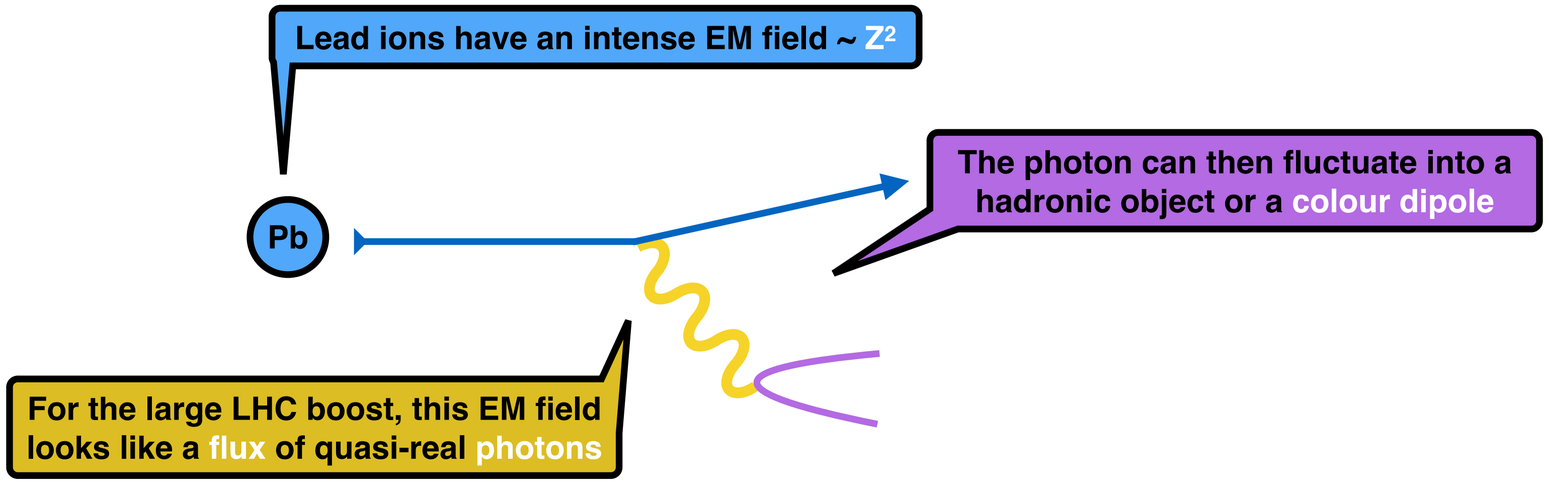

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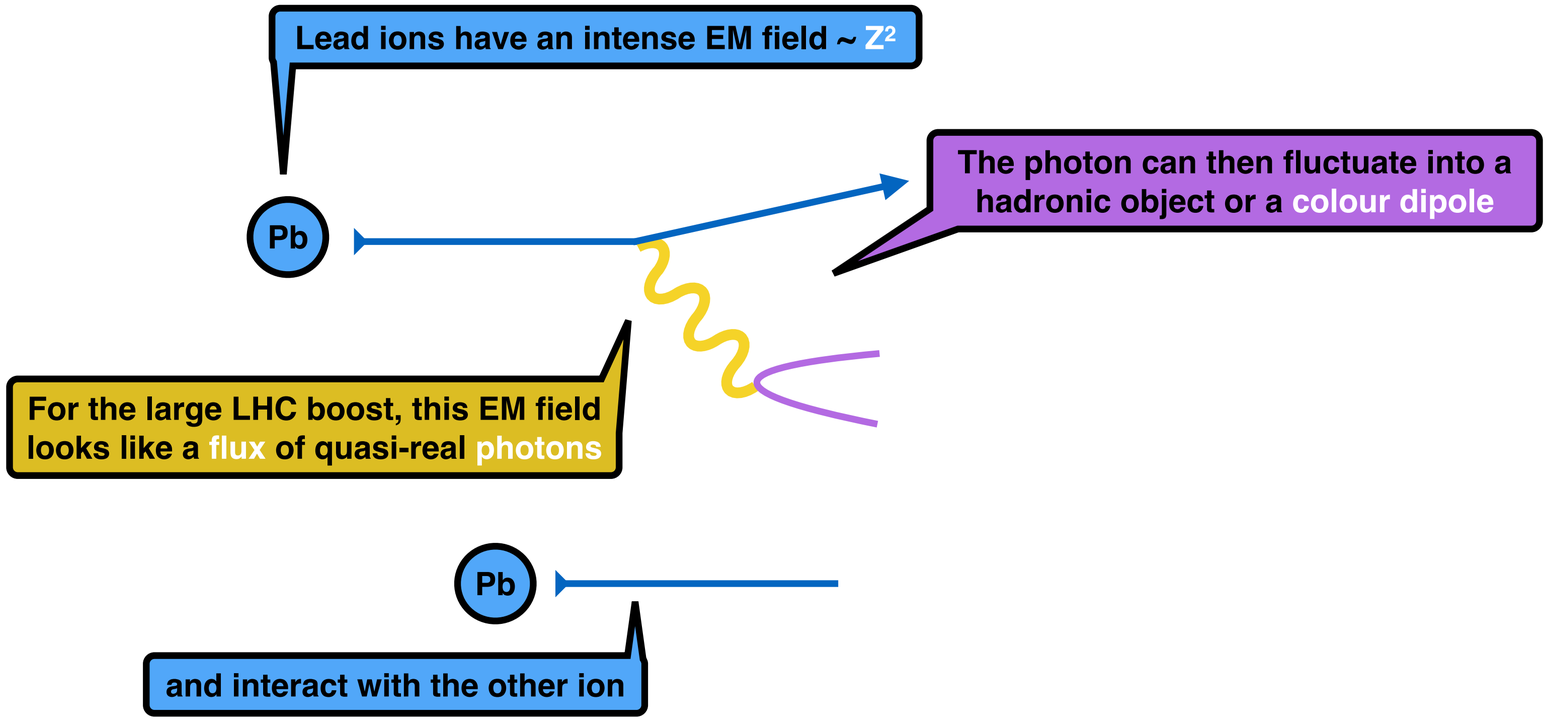

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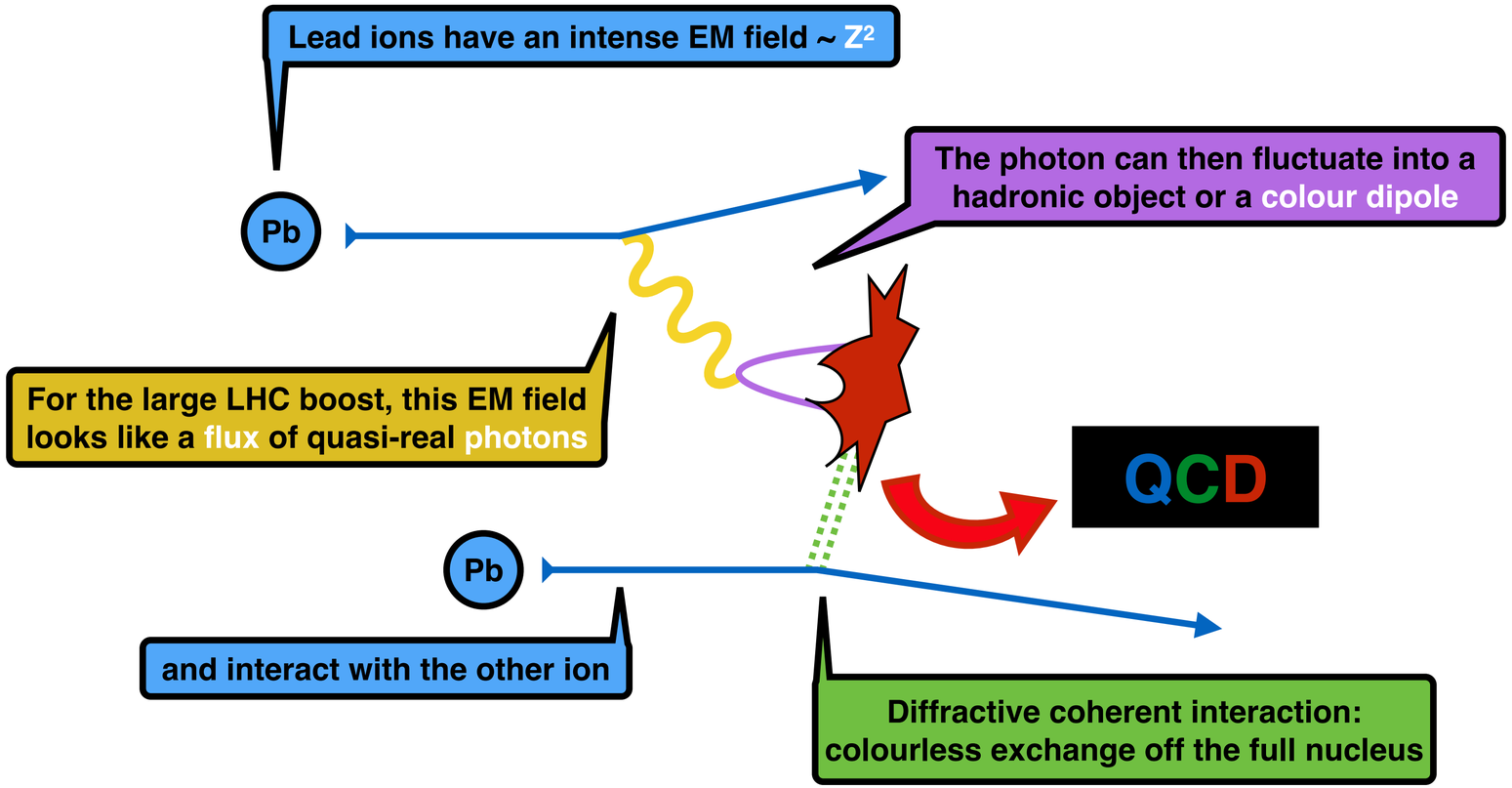

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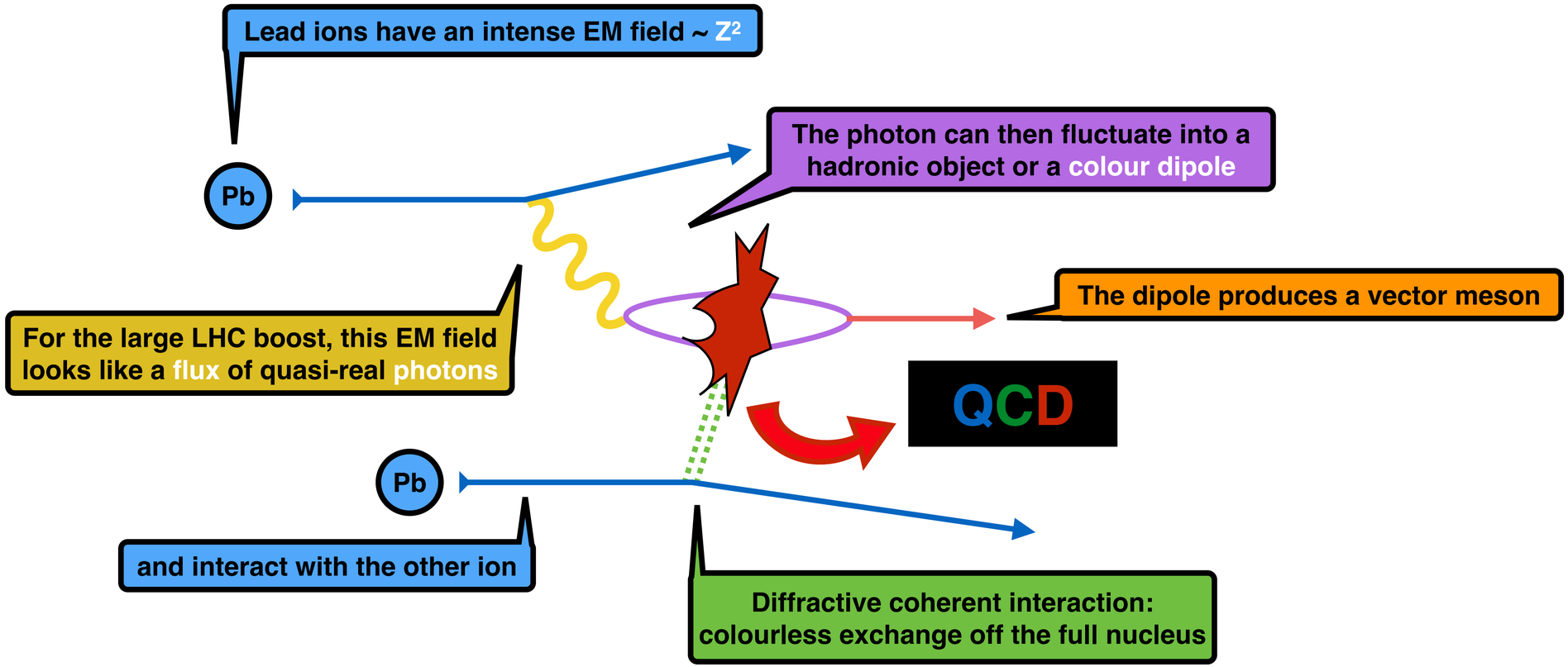

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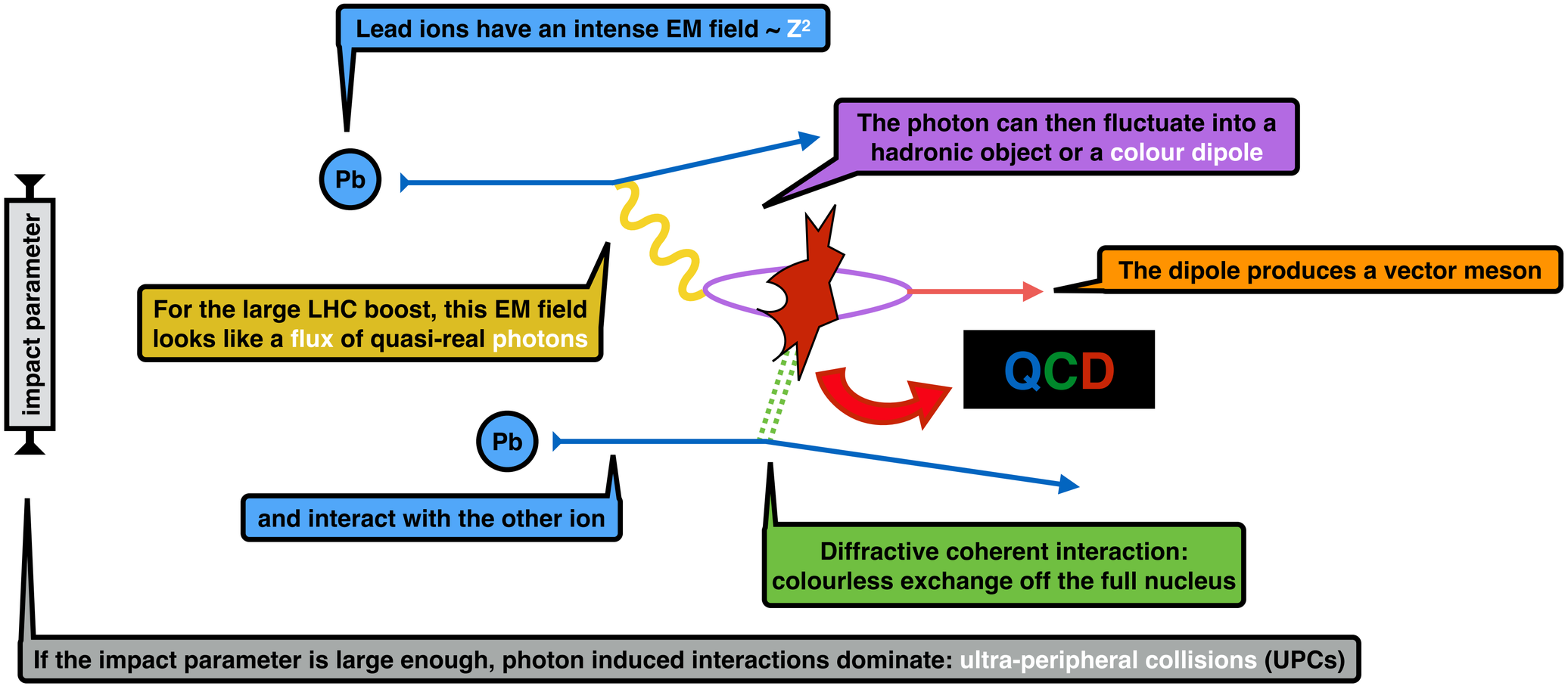

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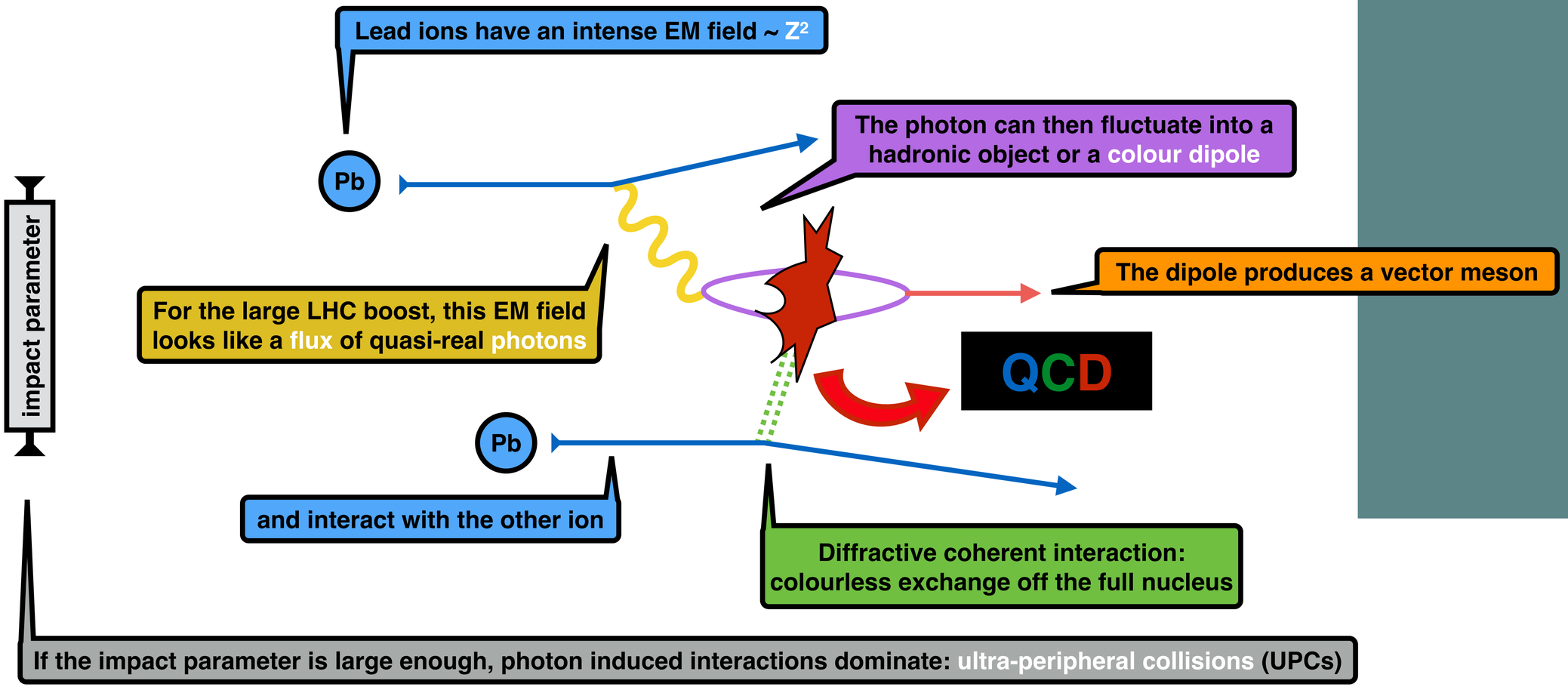
Rapidity (y), mass (m), and pT of the vector meson fully define the kinematics



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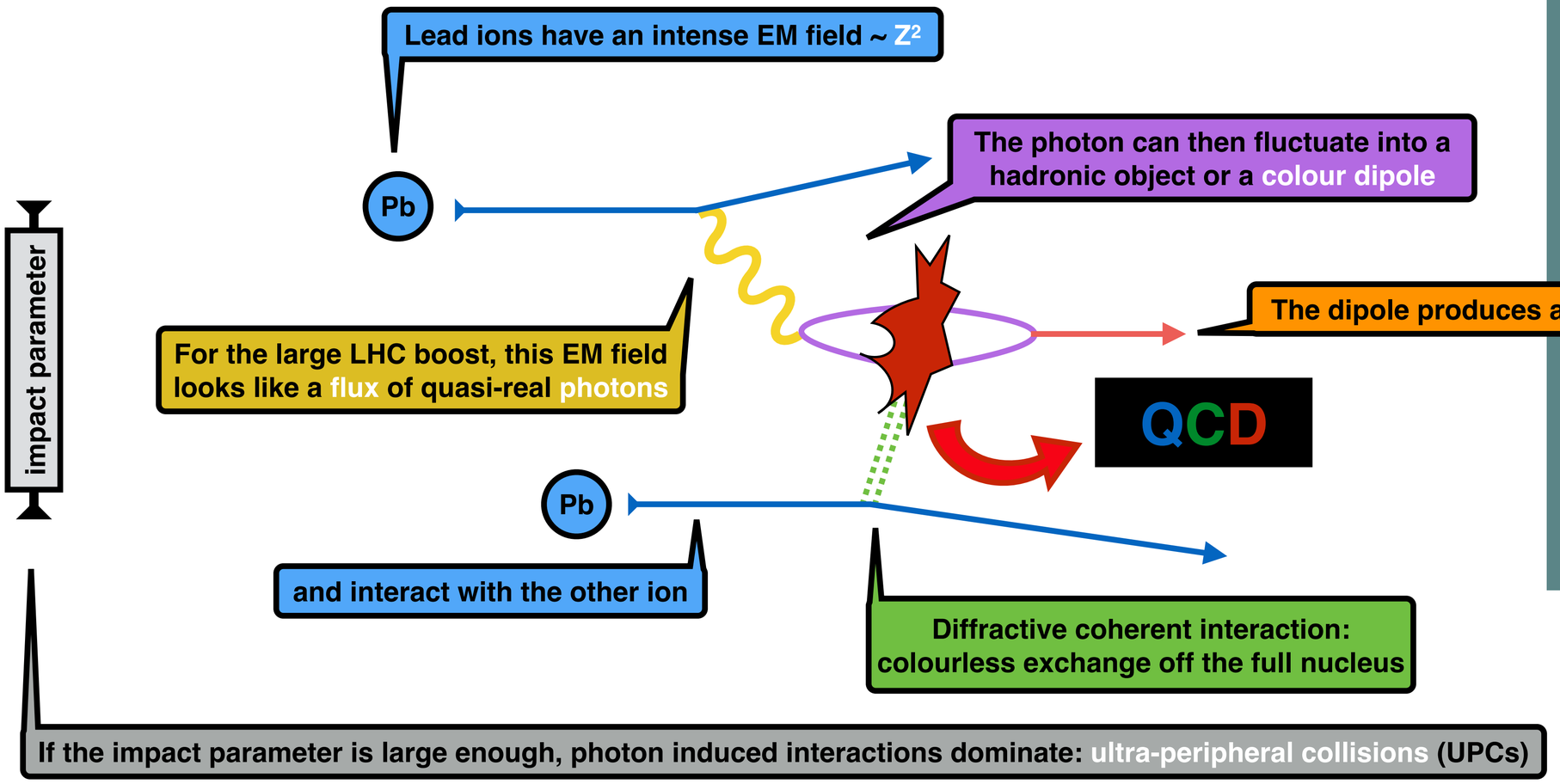

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$-t \approx p_T^2$

Mandelstam t, square of momentum transferred

Guillermo Contreras, CTU in Prague

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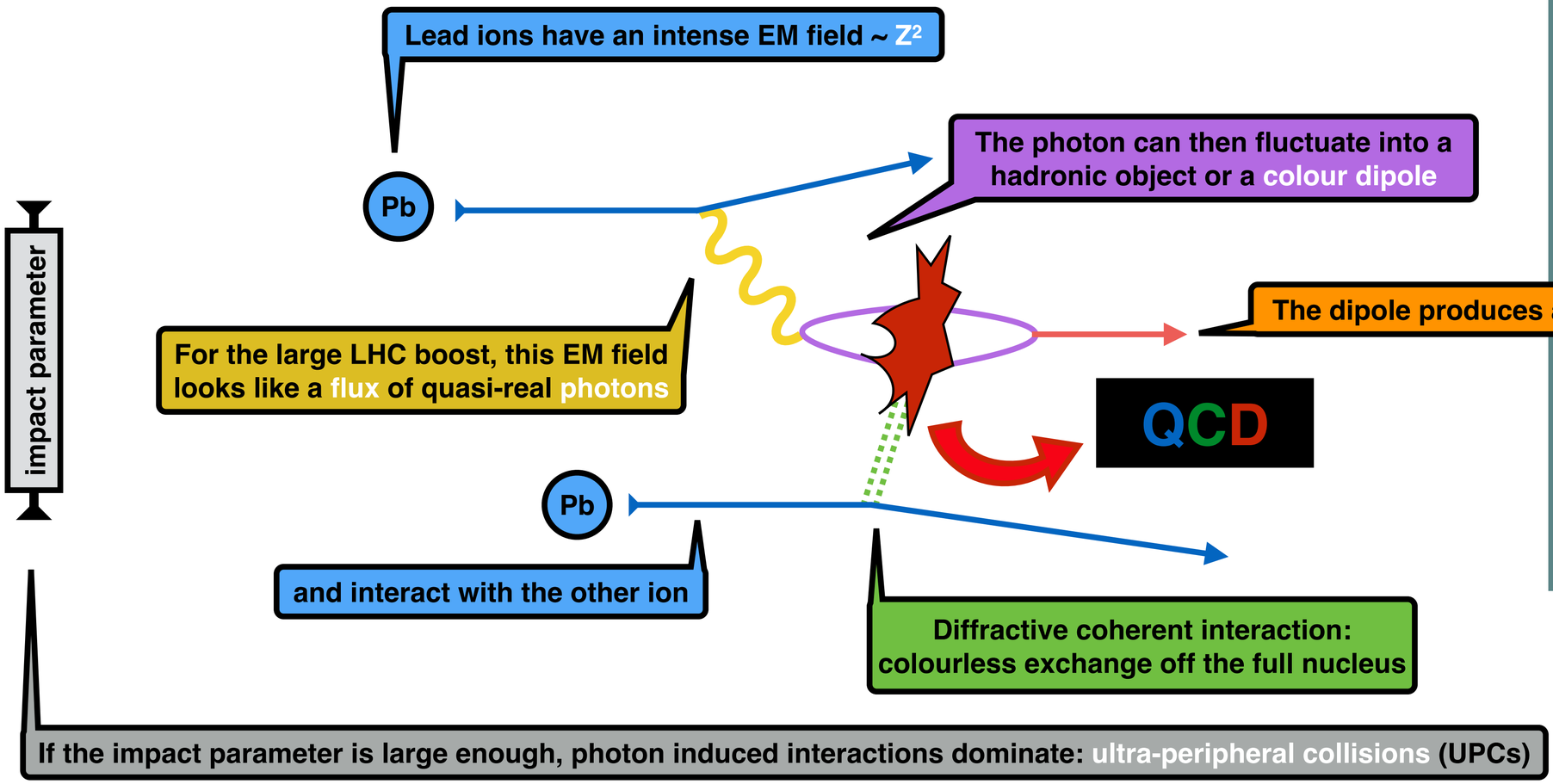

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$$x = \frac{m}{\sqrt{s}} e^{-y} = \frac{m^2}{W^2}$$

Centre-of-mass of the photon-Pb system

$$-t \approx p_T^2$$

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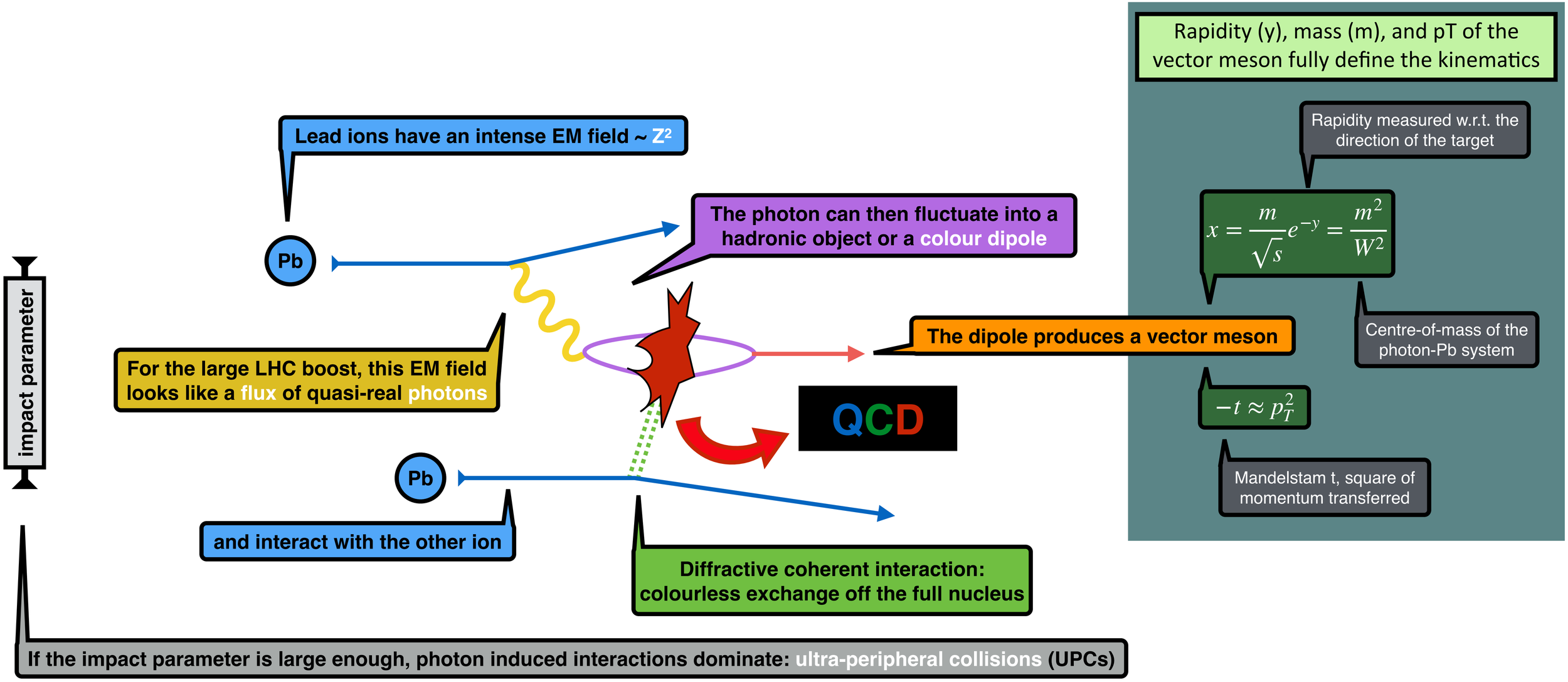

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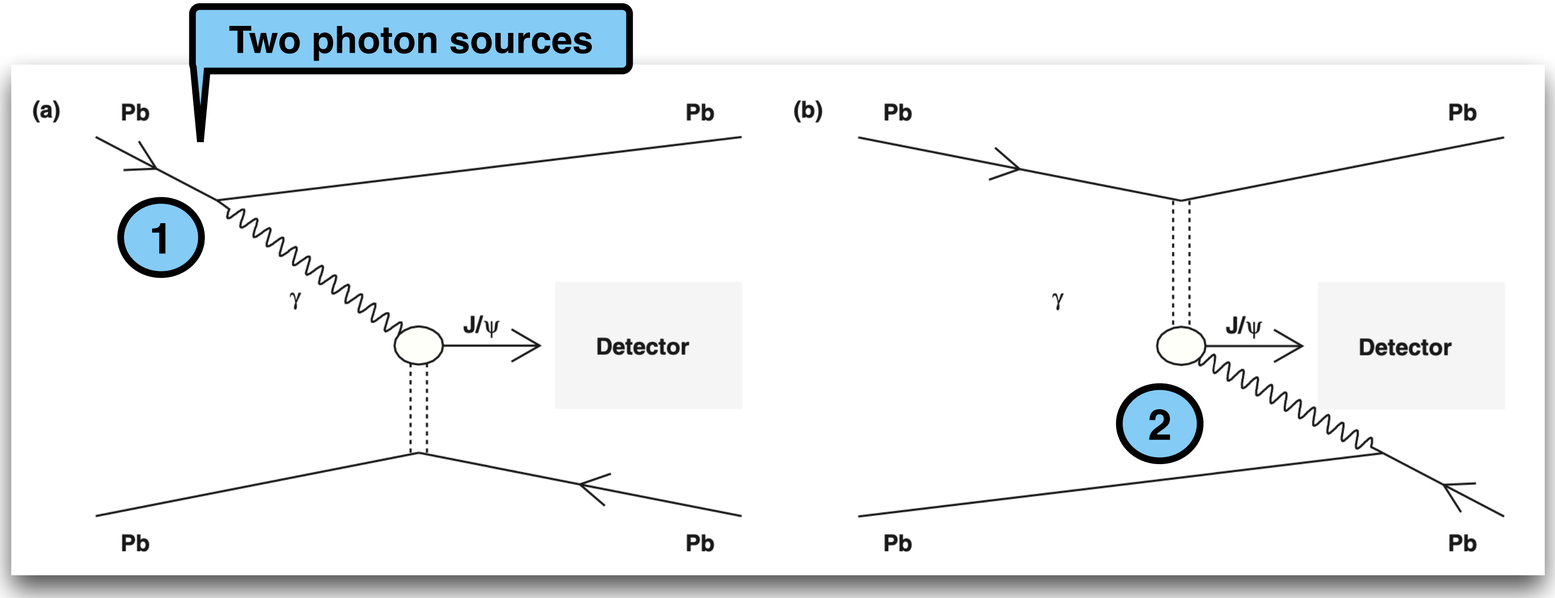
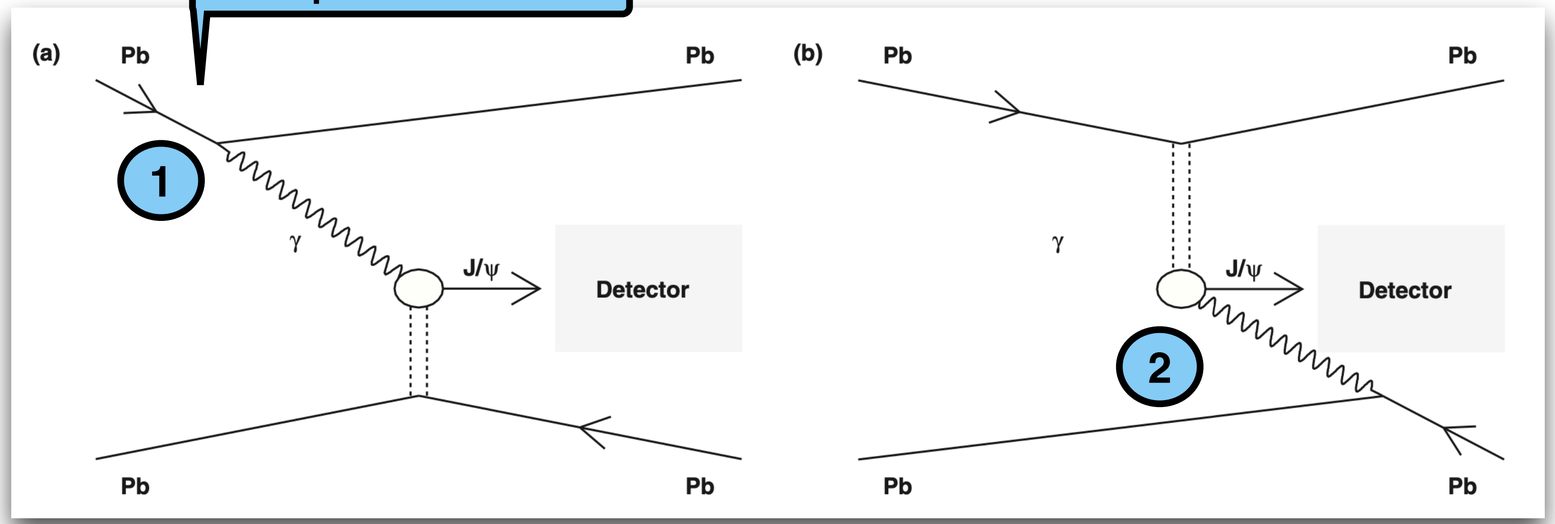
Ambiguity problem



Ambiguity problem

Two photon sources



1 2

$$\frac{d\sigma_{\mathrm{PbPb}}}{dy} = n_\gamma(y;\{b\})\sigma_{\gamma\mathrm{Pb}}(y) + n_\gamma(-y;\{b\})\sigma_{\gamma\mathrm{Pb}}(-y)$$

What we measure

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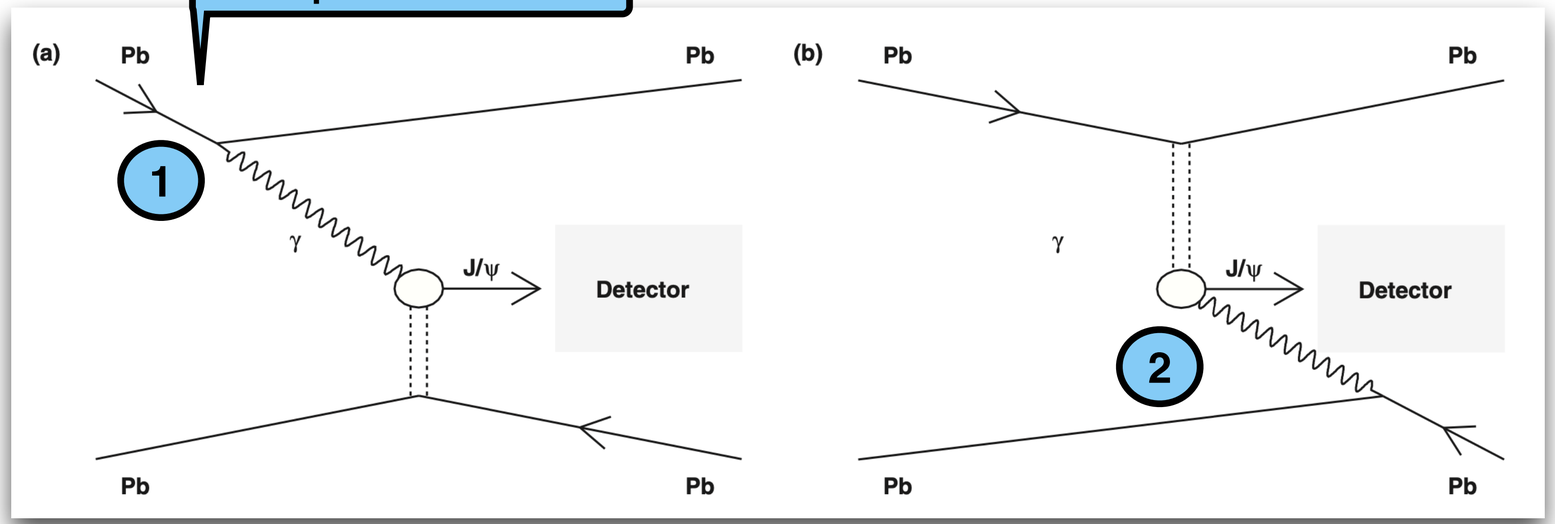

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Photonuclear cross sections at two rapidities, i.e. Bjorken-x

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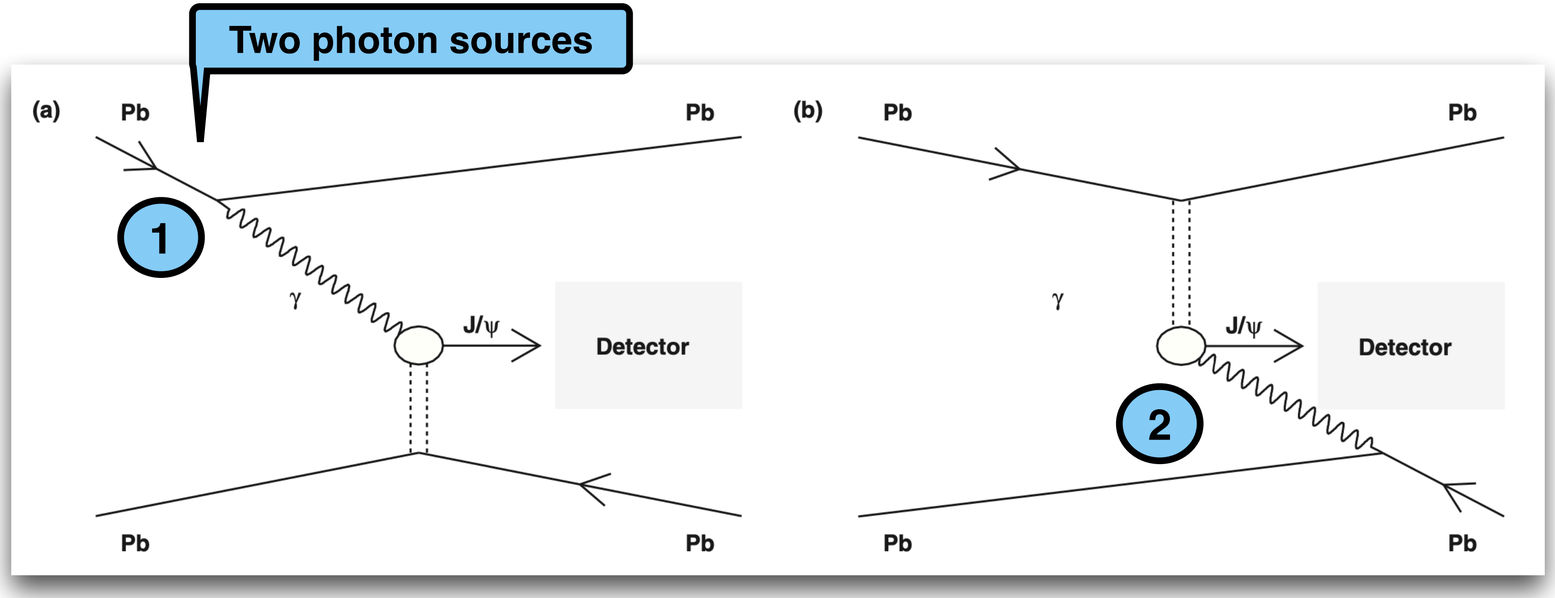

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What we measure

Photonuclear cross sections at two rapidities, i.e. Bjorken-x

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How to extract the photo-nuclear cross section if the photon fluxes are known?

Ambiguity problem: one solution, go to corners of phase space

At y=0 both contributions are equal, no ambiguity

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Use only 2 and correct for 1

Guzey et al, Phys.Lett. B726 (2013) 290-295

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Perform two independent measurements at the same rapidity, but different impact parameter, then solve the equations.

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For example, use peripheral and ultra-peripheral collisions

JGC, PRC **96**, 015203 (2017)

Measuring J/ψ in ALICE

To study the evolution of the nuclear structure in Bjorken-x, a large rapidity coverage is need

$$x = \frac{m}{\sqrt{s}} e^{-y} = \frac{m^2}{W^2}$$

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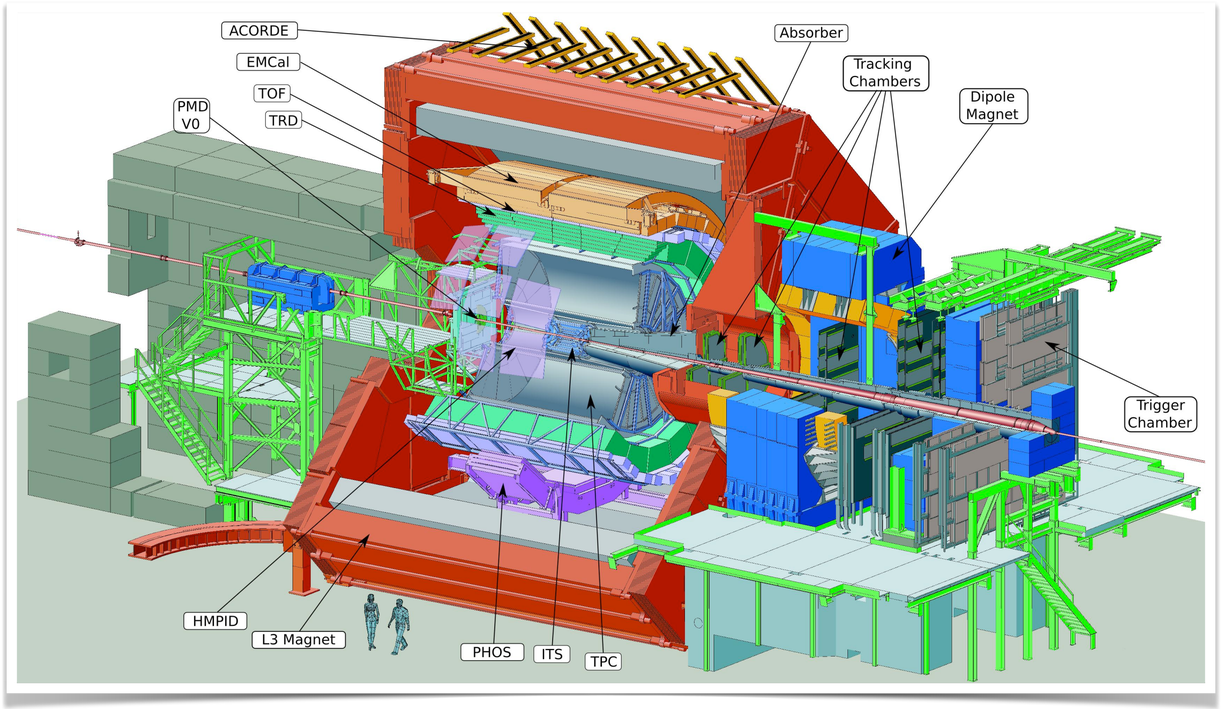

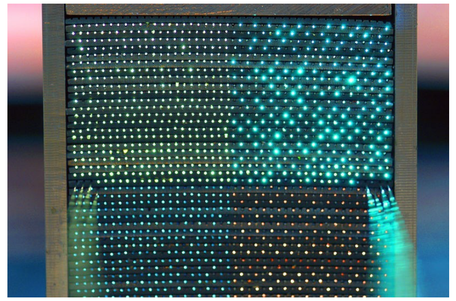

Zero degree calorimeters (ZDC) at ±112.5 m from the centre of ALICE

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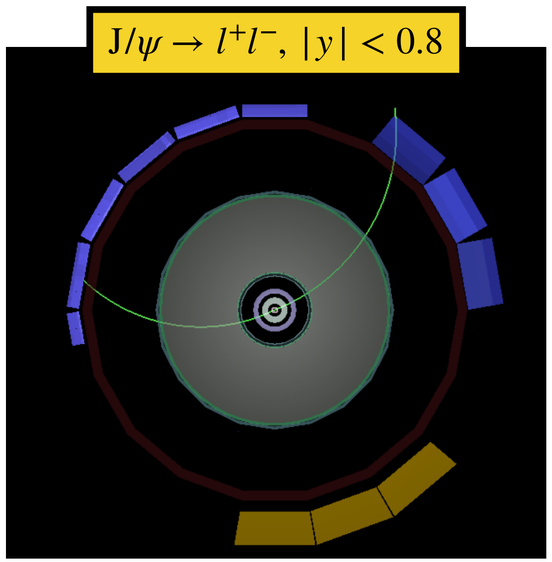

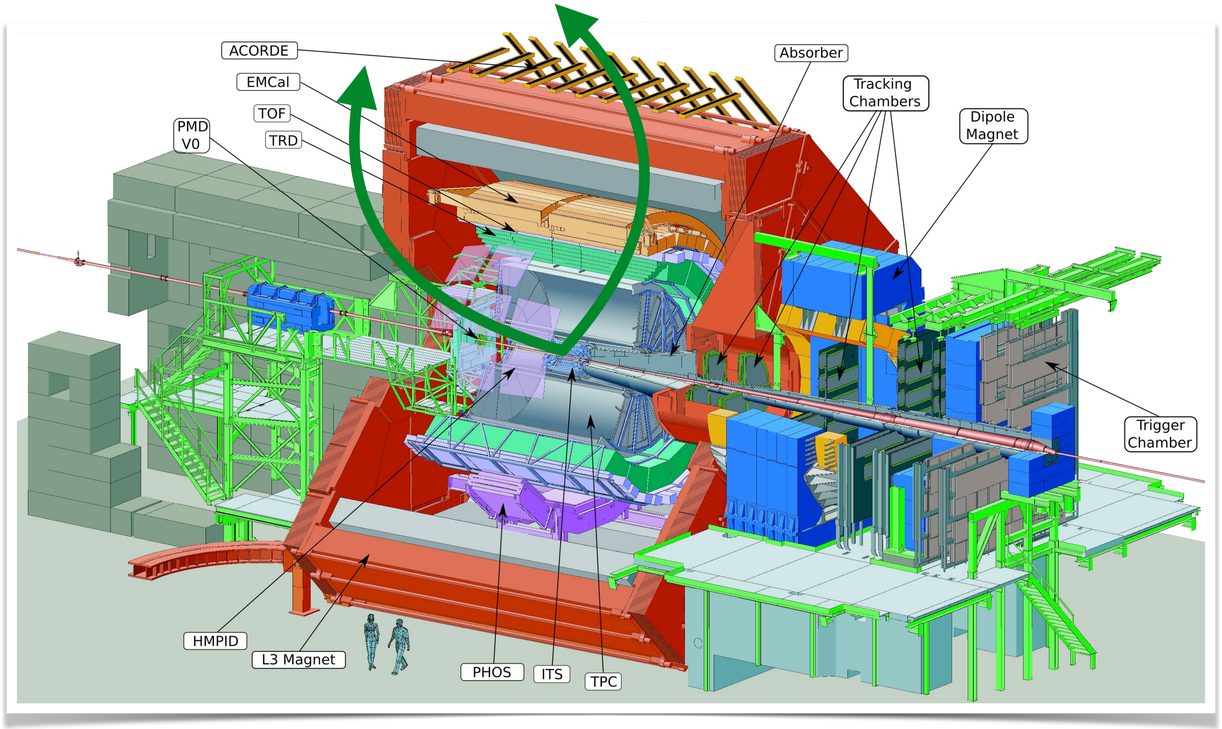

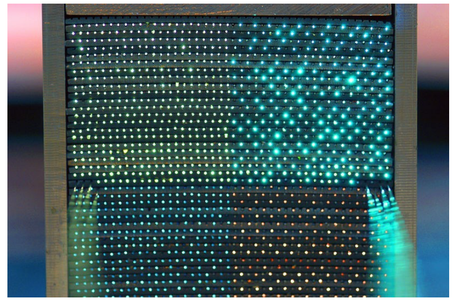

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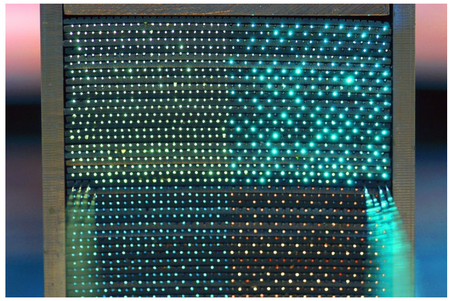

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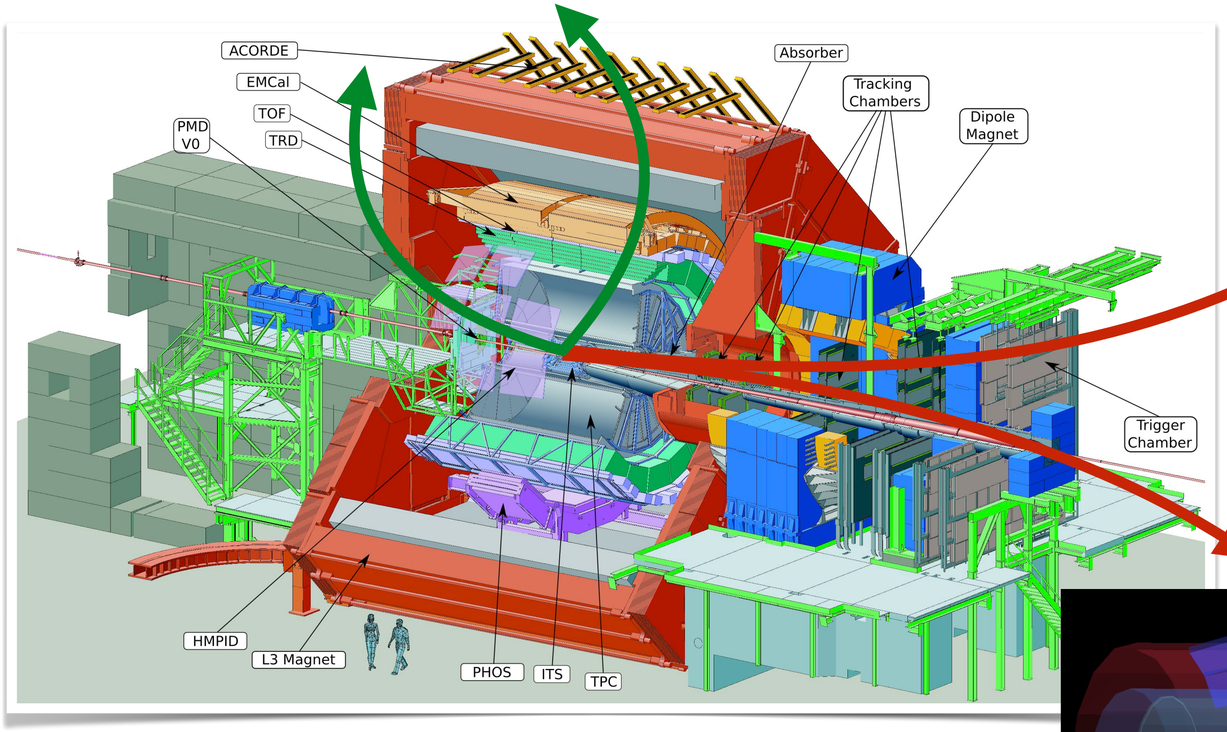
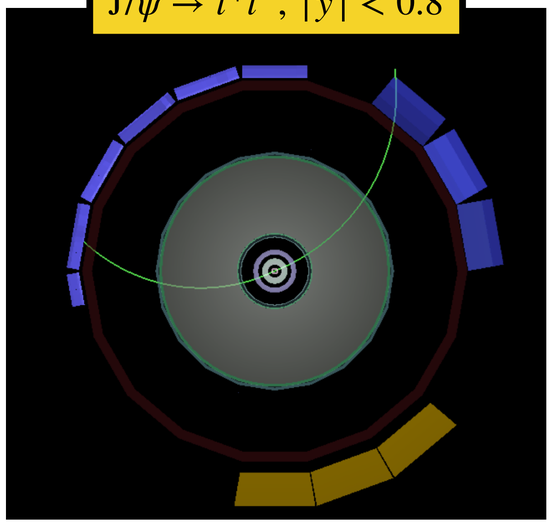
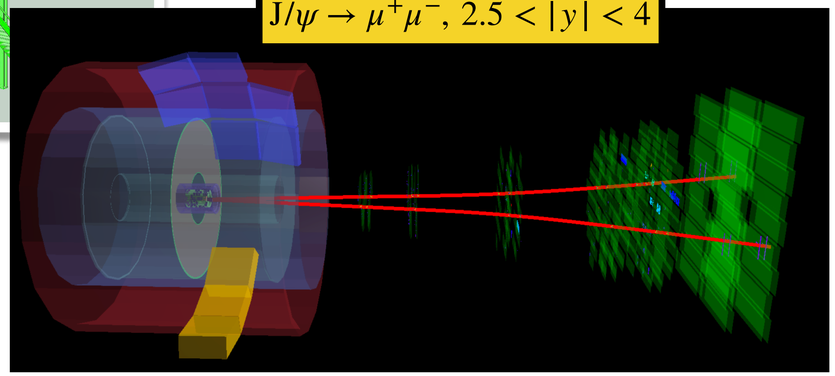


$J/\psi \rightarrow l^+l^-,\ |y| < 0.8$



$J/\psi \rightarrow \mu^+\mu^-,\ 2.5 < |y| < 4$



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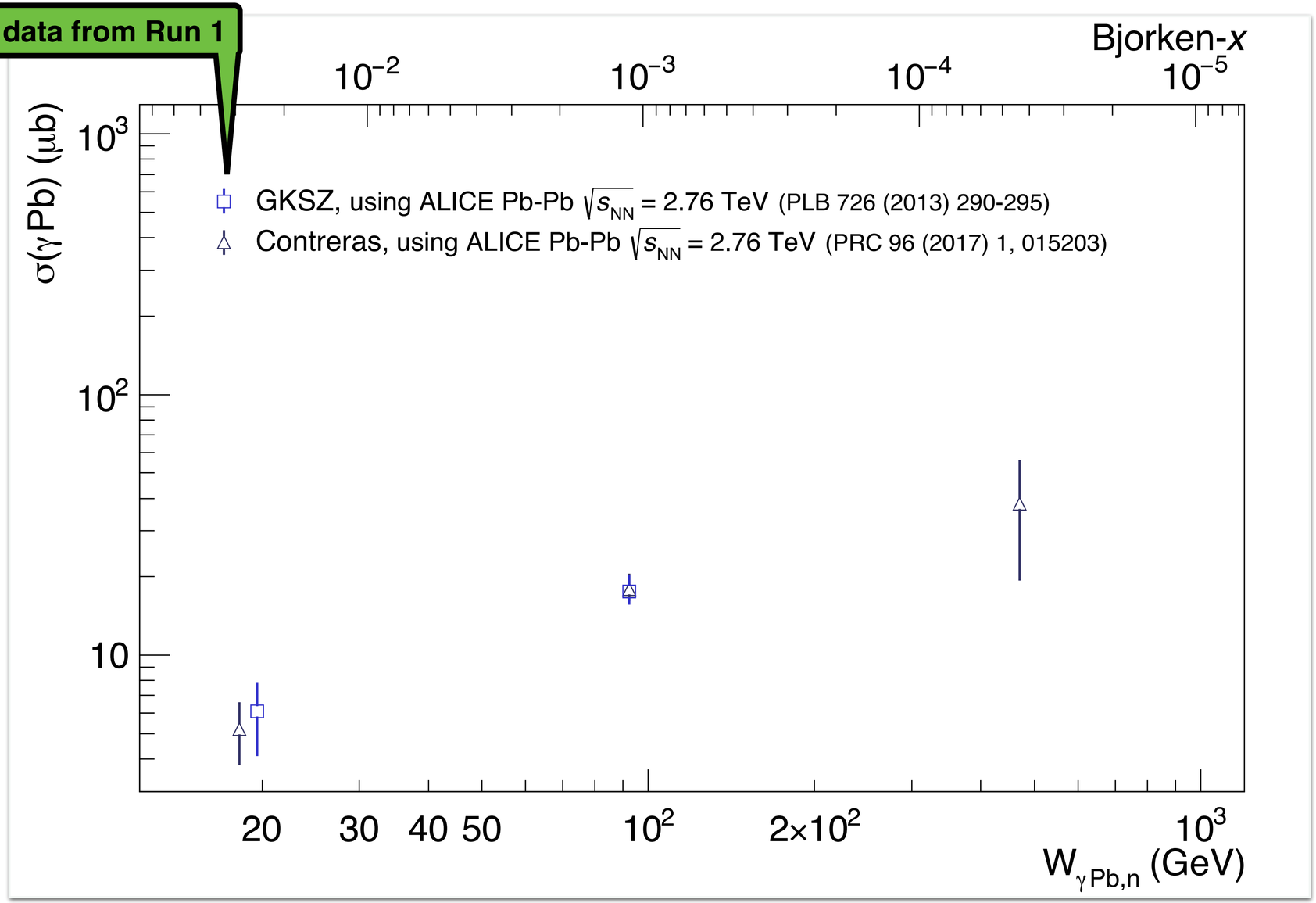
Energy/Bjorken-x dependence of coherent production from Run 1

Analyses using ALICE data from Run 1



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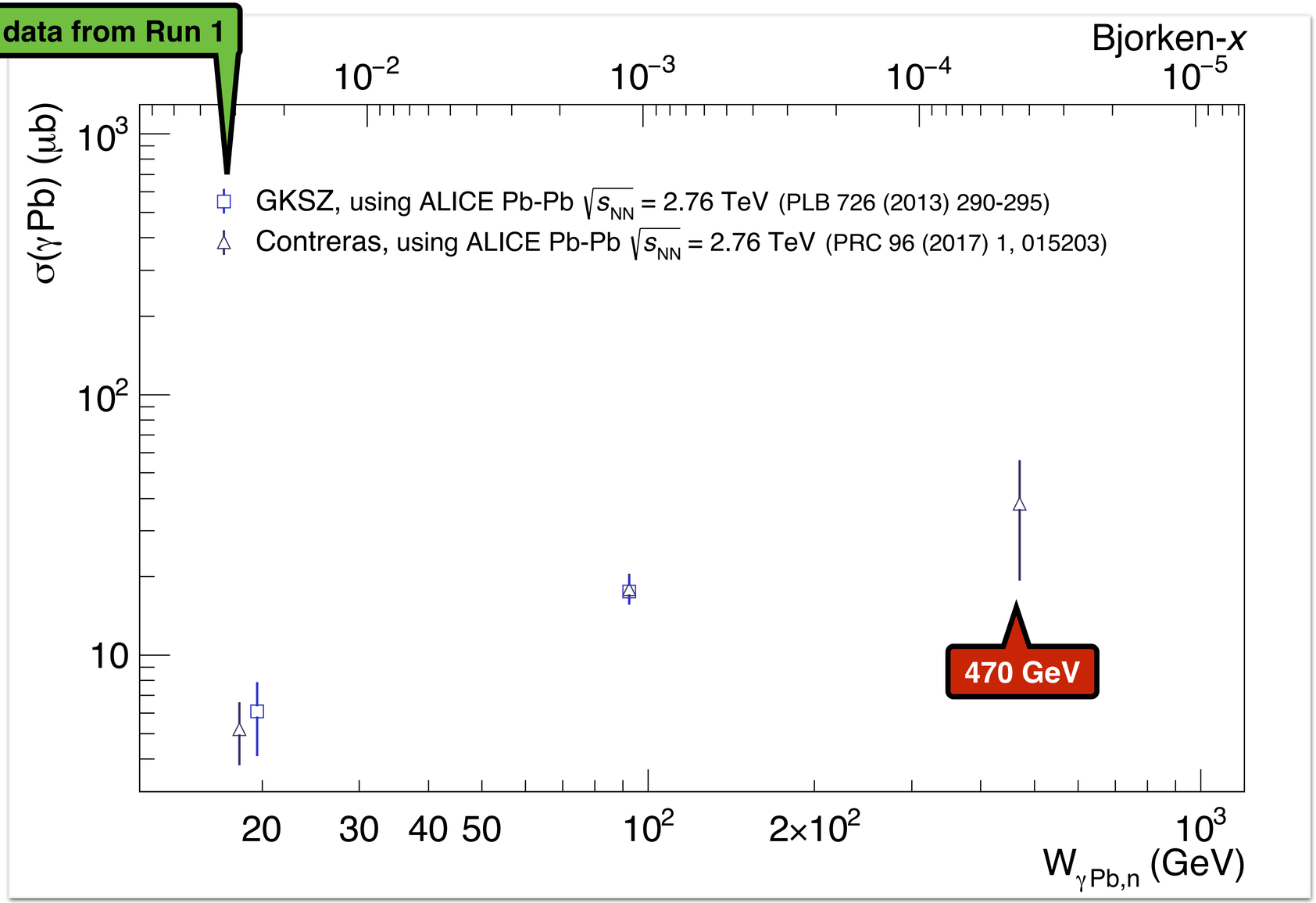

Ambiguity problem: perform independent measurements using EMD

Guzey, Strikman, Zhalov, EPJ C74 (2014) 2942

Very intense flux: impact-parameter-dependent possibility of multi-photon exchanges

Secondary photons may induce EMD of the nucleus, producing neutrons at zero degrees

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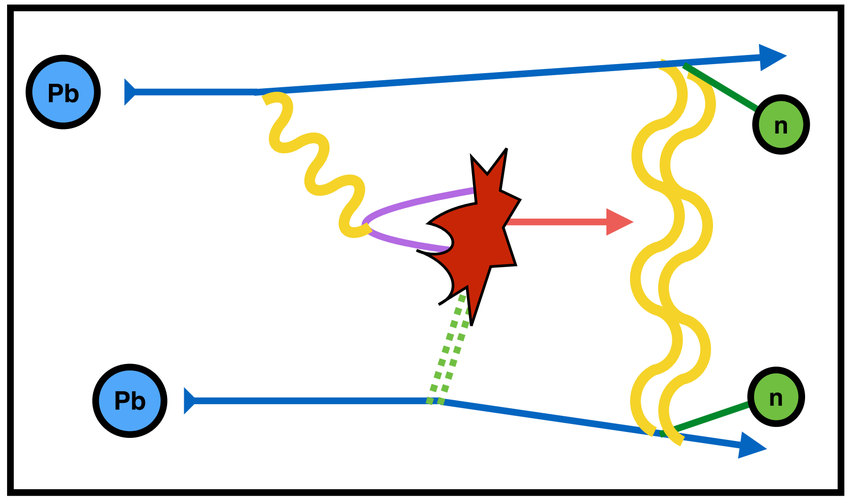

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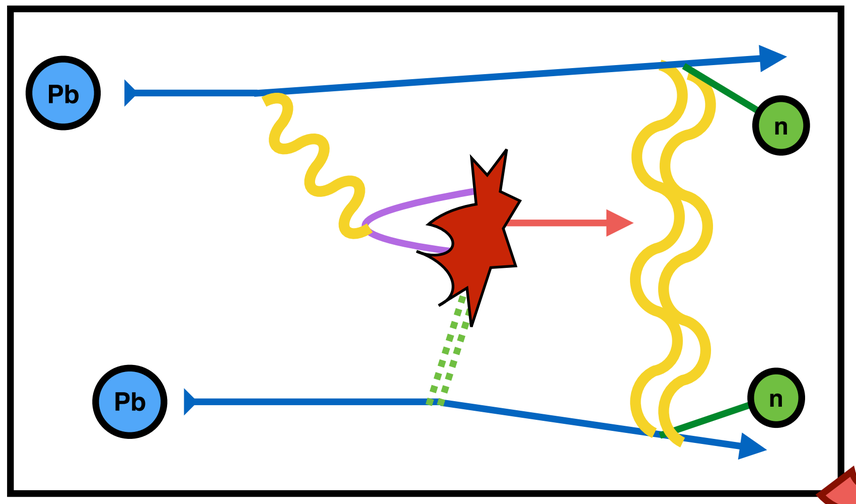
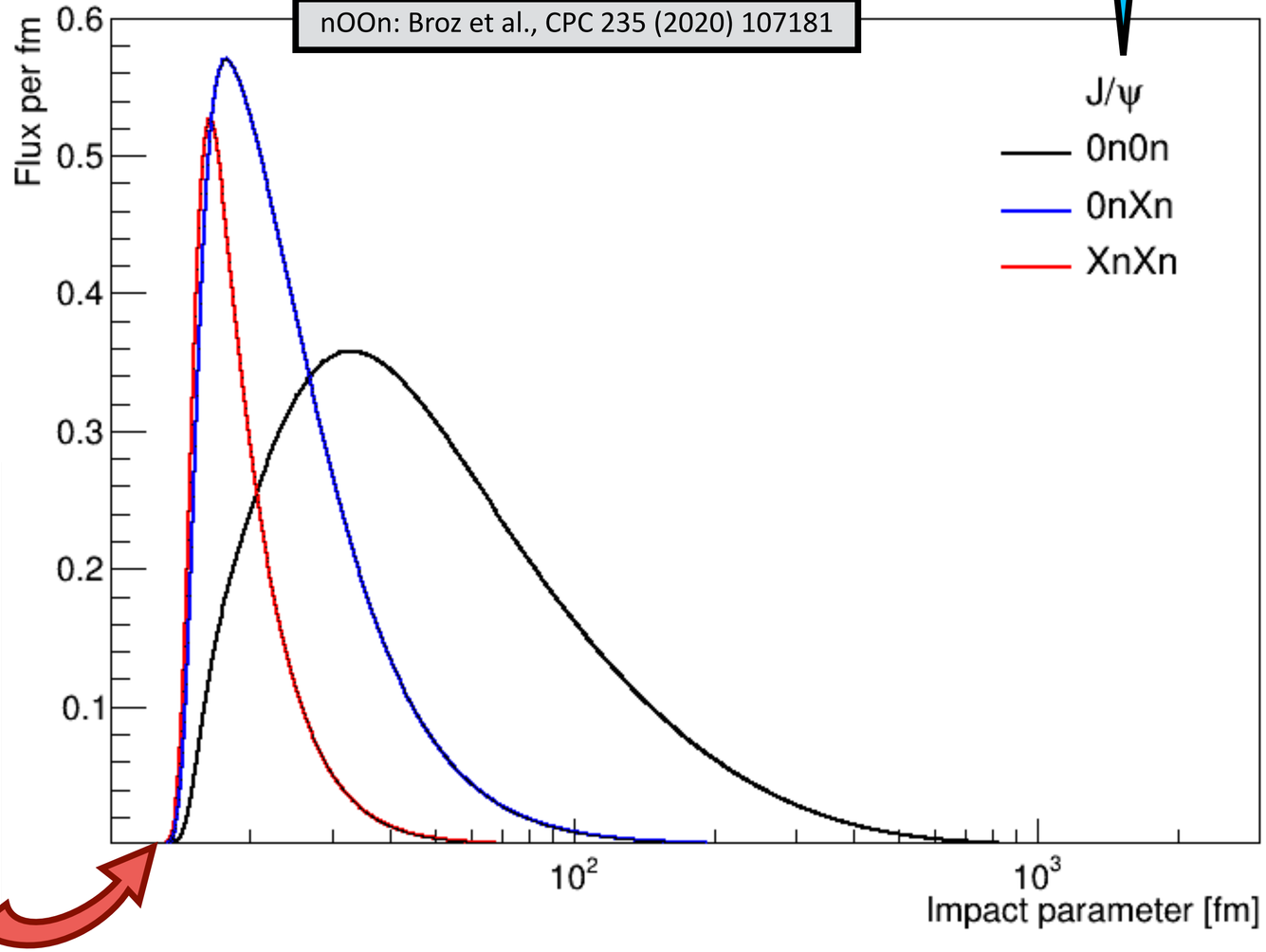


J/ψ at midrapidity

nOOn: Broz et al., CPC 235 (2020) 107181



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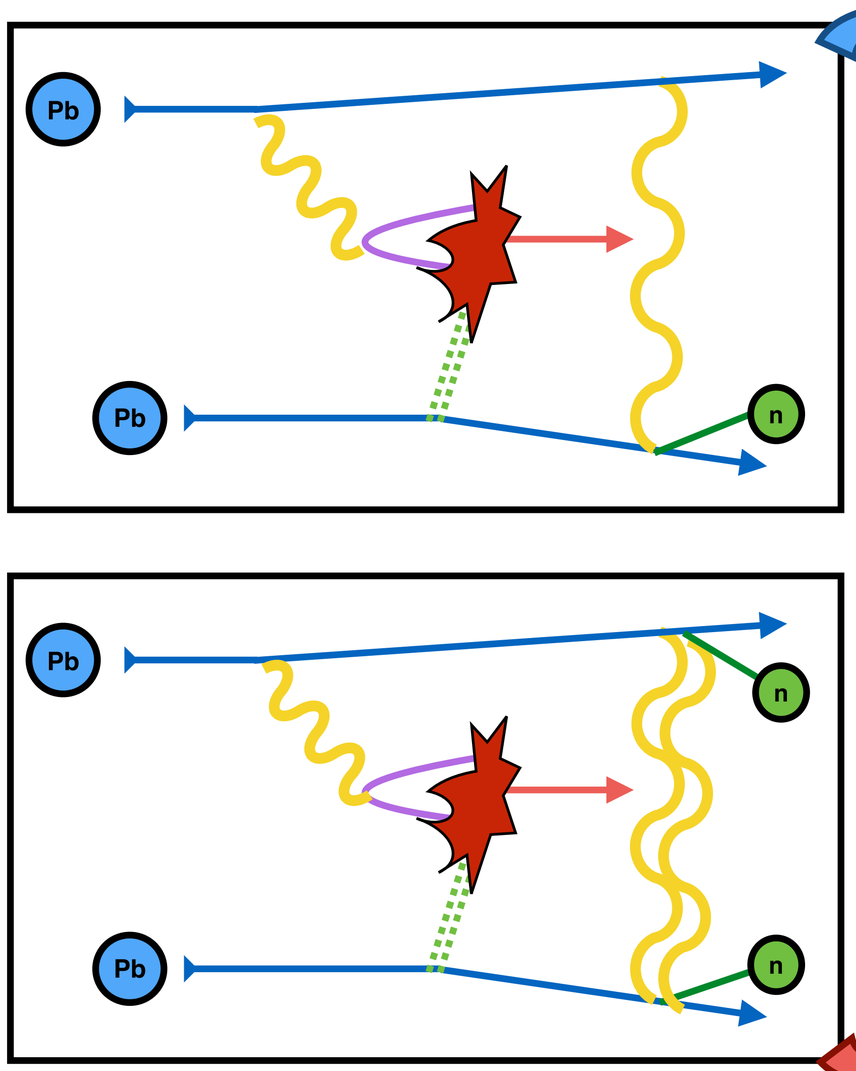

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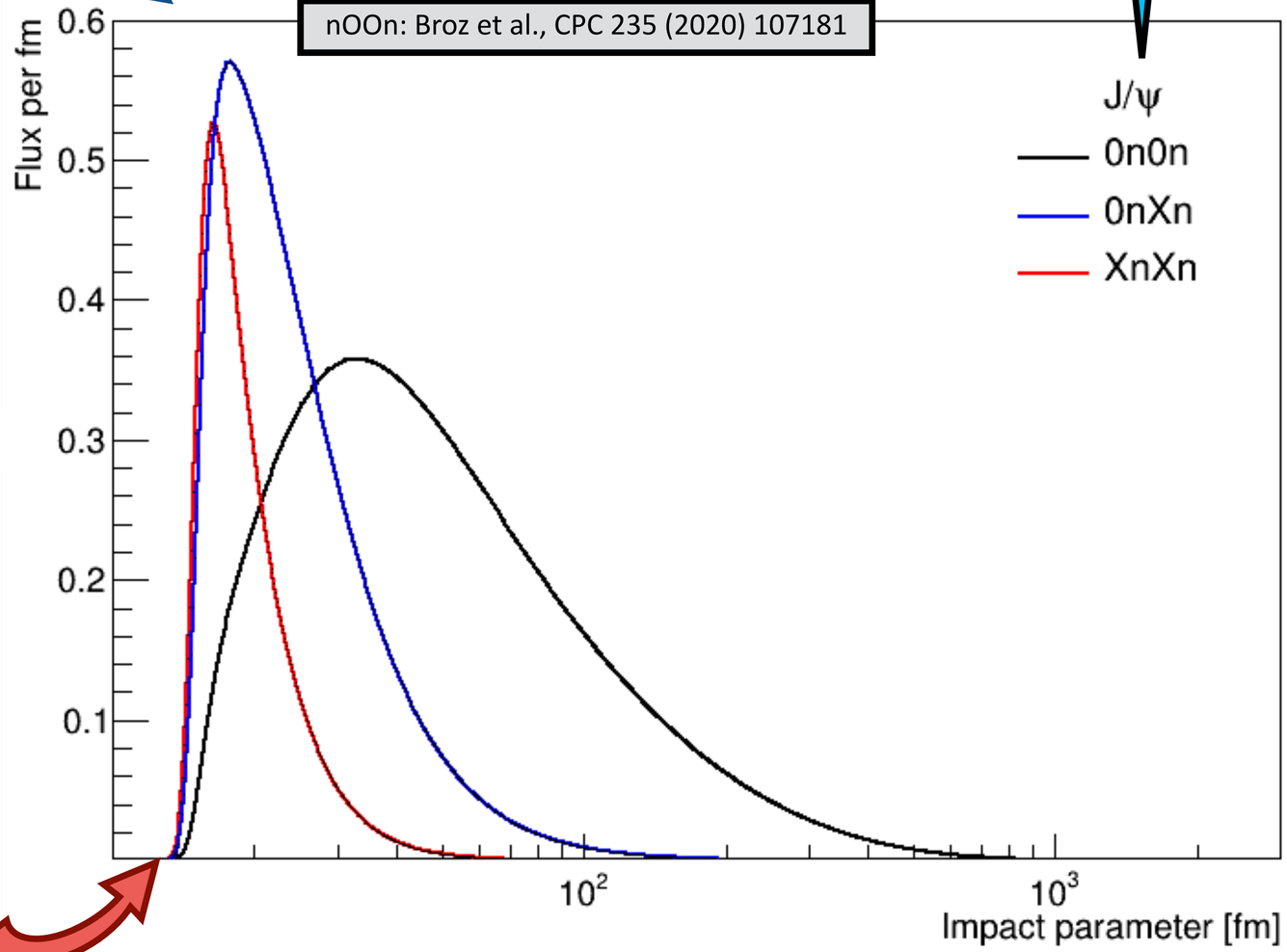

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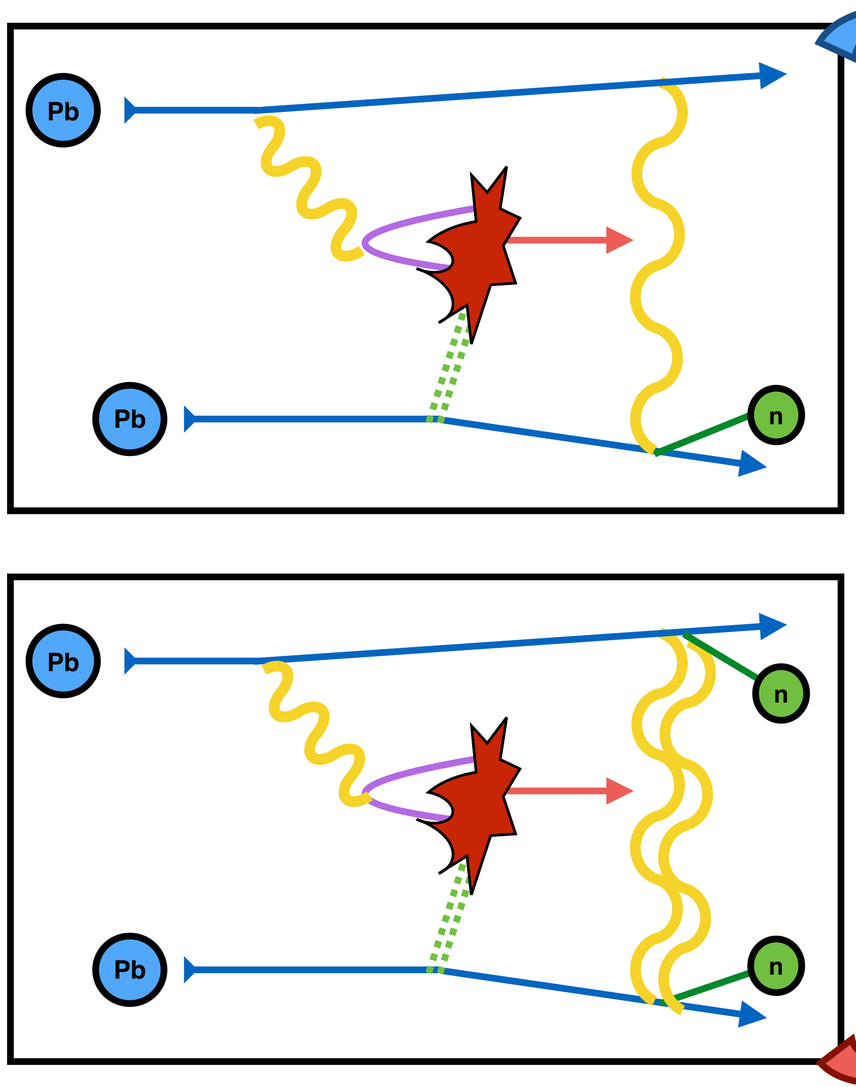

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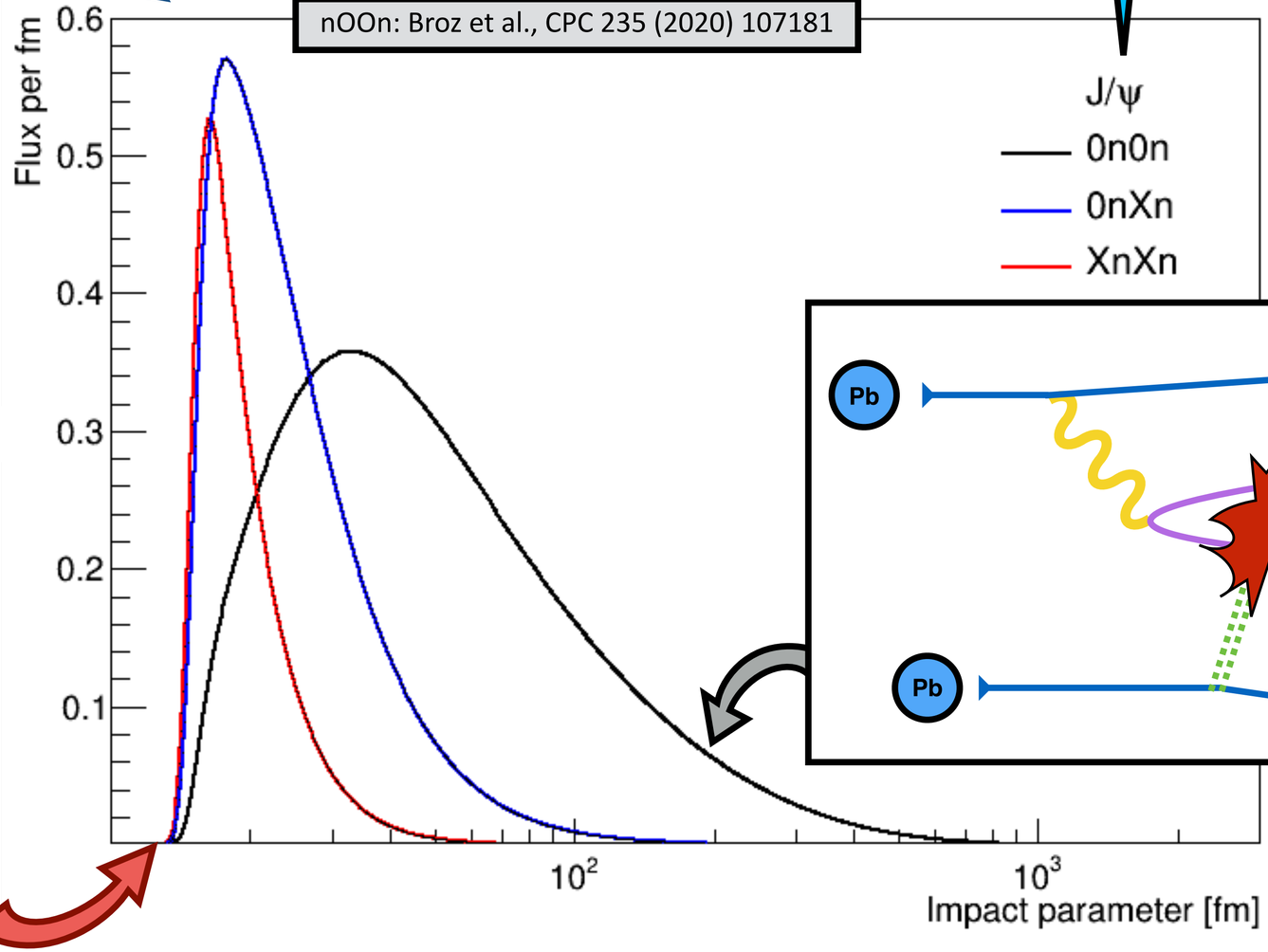
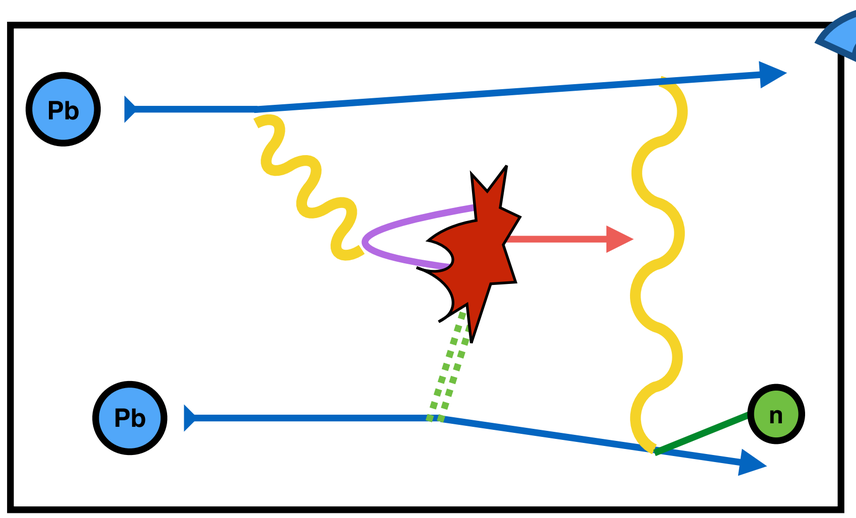


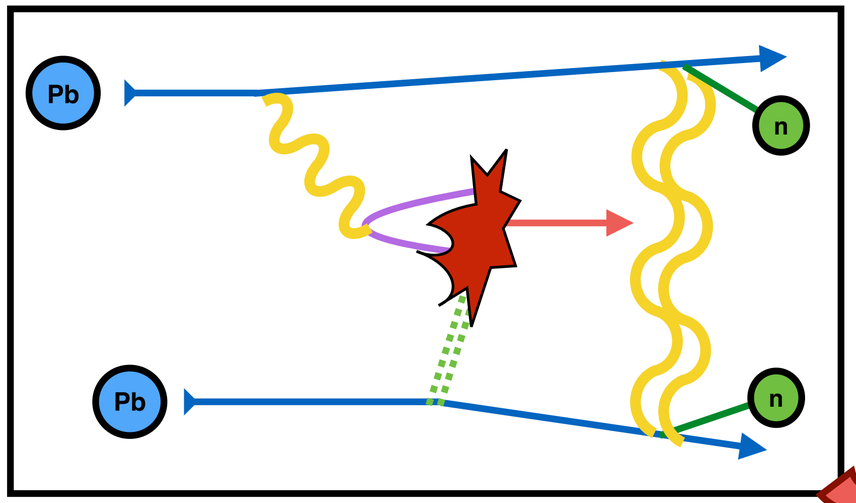
Ambiguity problem: perform independent measurements using EMD

Guzey, Strikman, Zhalov, EPJ C74 (2014) 2942

Very intense flux: impact-parameter-dependent possibility of multi-photon exchanges

Secondary photons may induce EMD of the nucleus, producing neutrons at zero degrees





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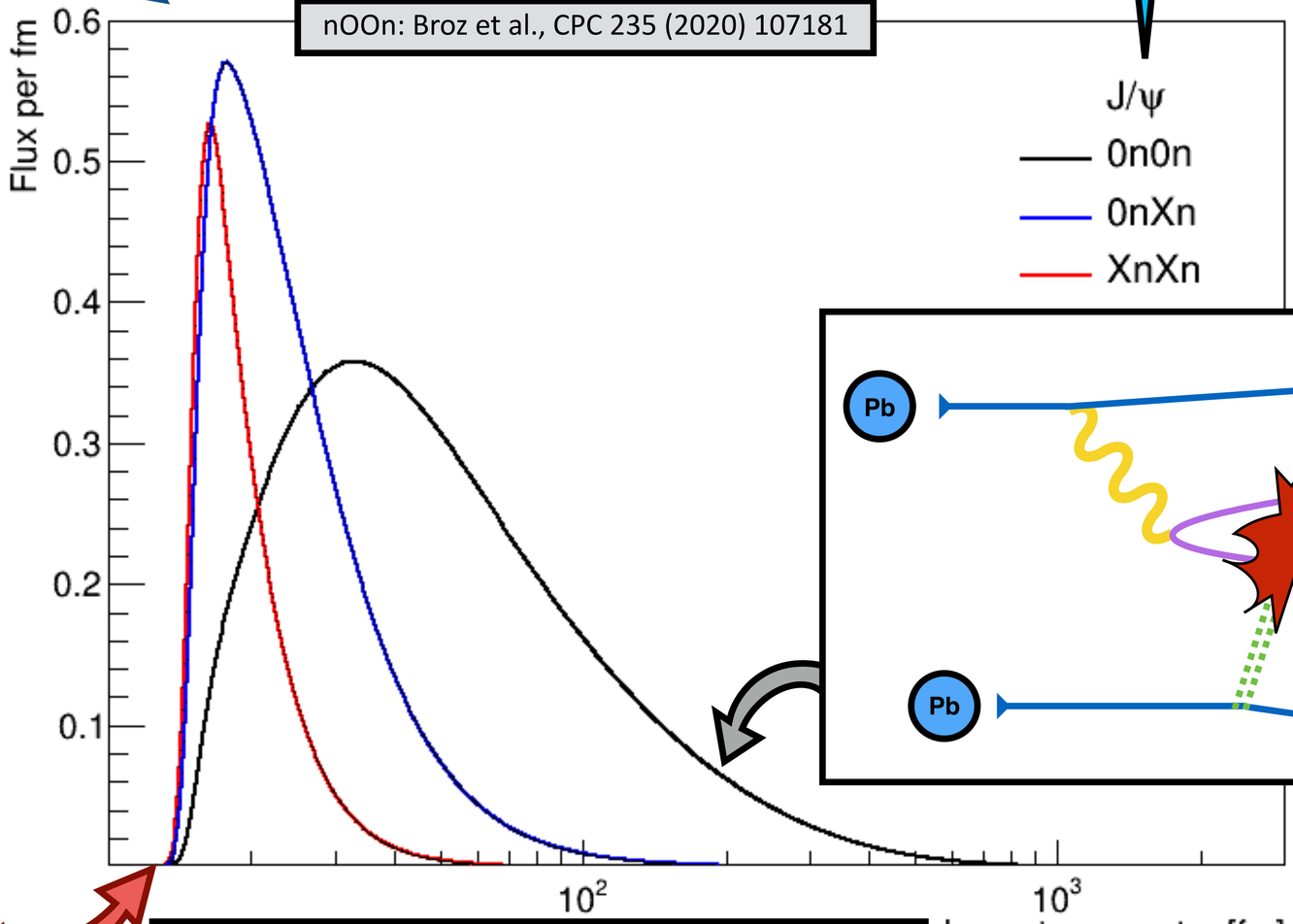
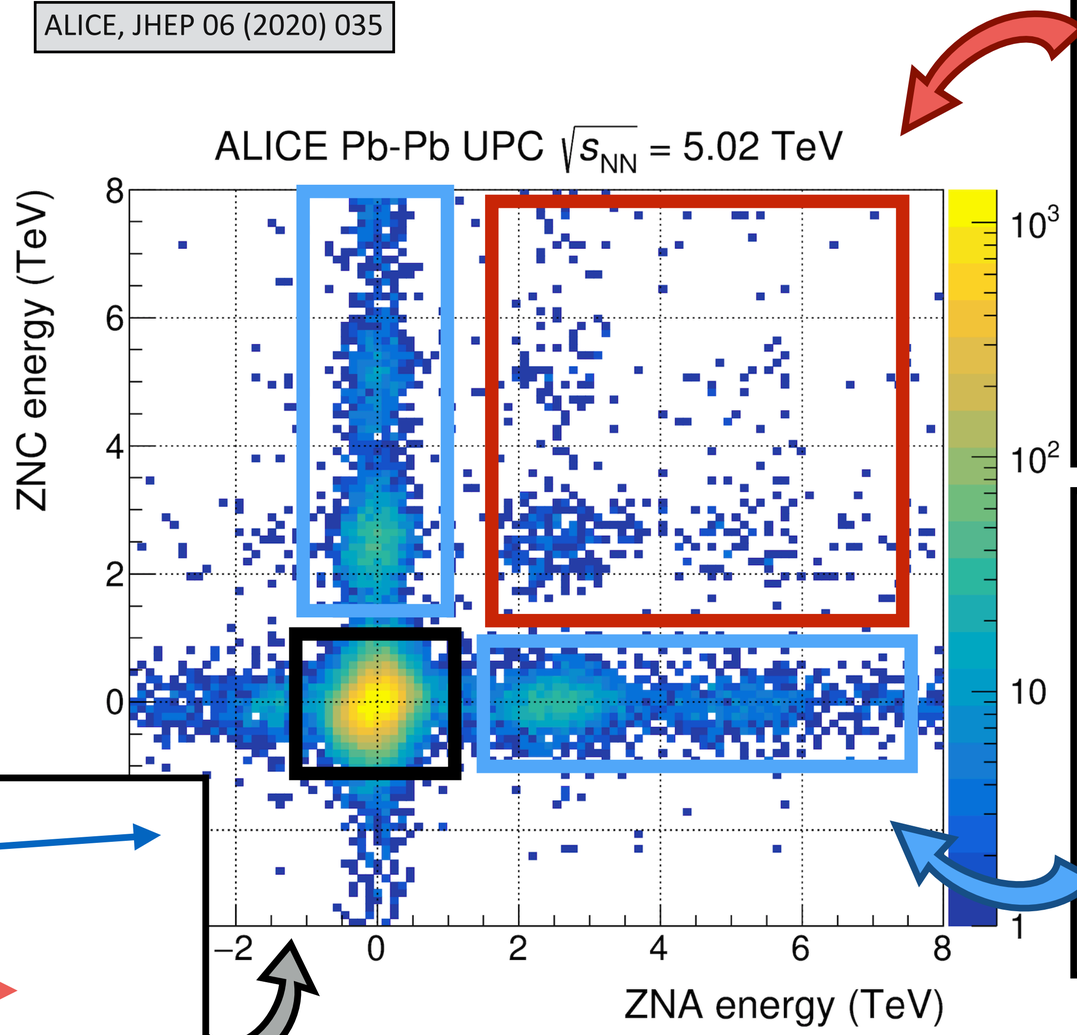
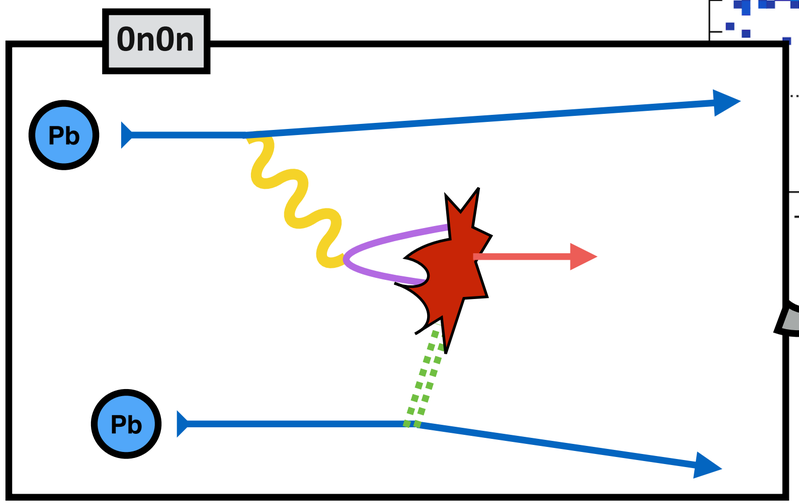


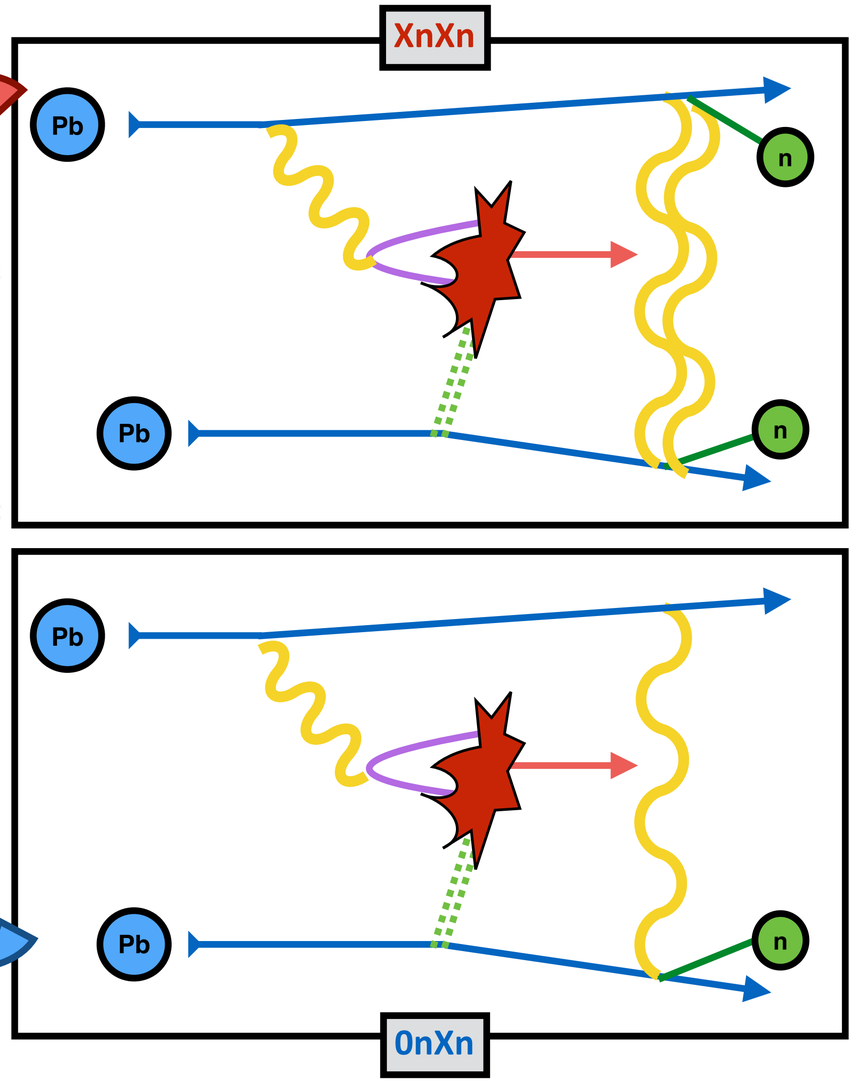
The neutrons are then measured with the ZDCs

EMD and ZDC

ALICE, JHEP 06 (2020) 035



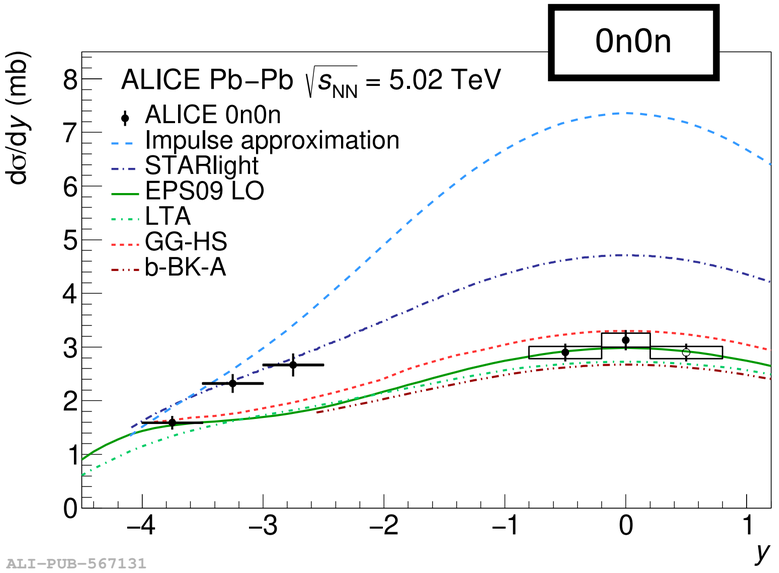


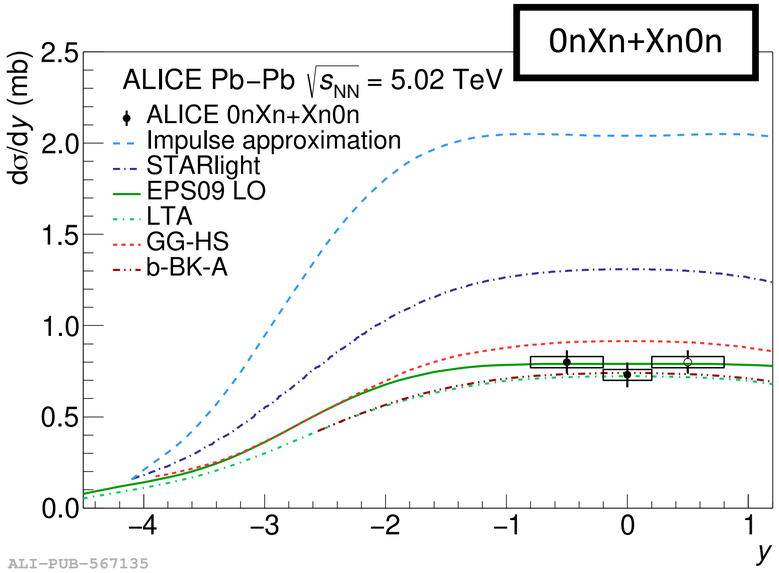


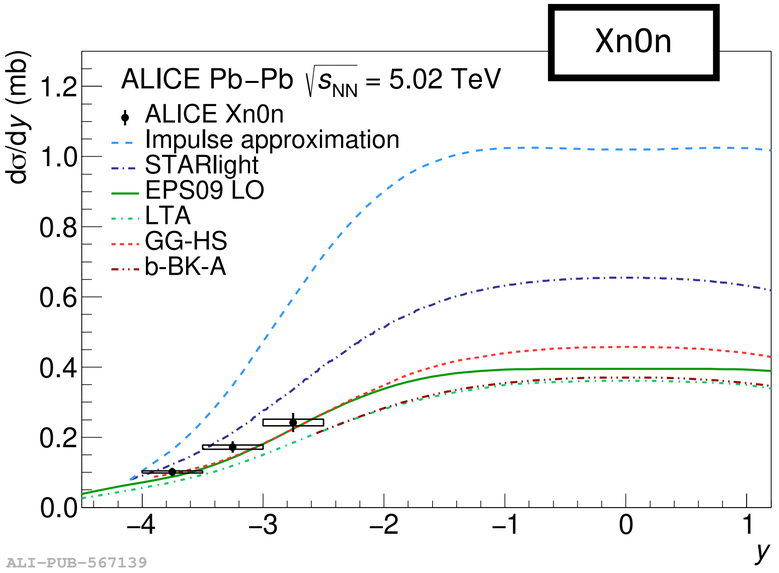
It is possible to cleanly separate the different event topologies, using the ZDC

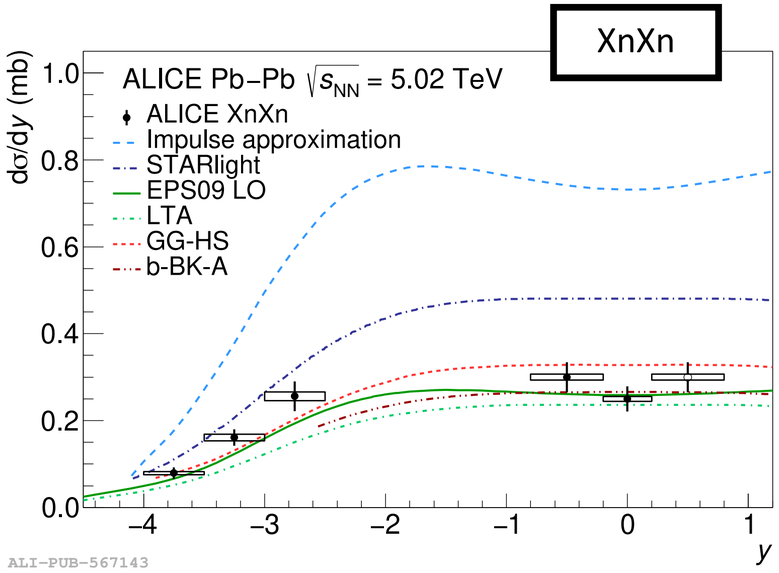
Run 2: rapidity dependence of J/ψ coherent production in EMD classes

ALICE, JHEP 10 (2023) 119





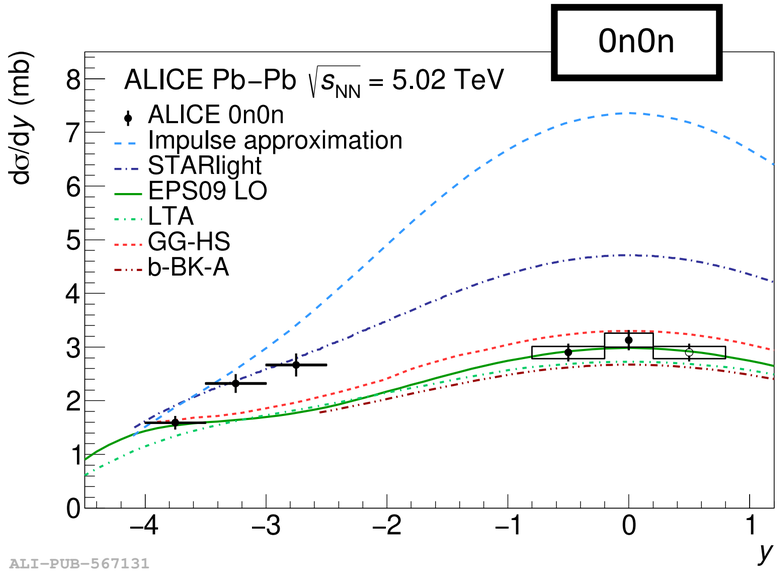


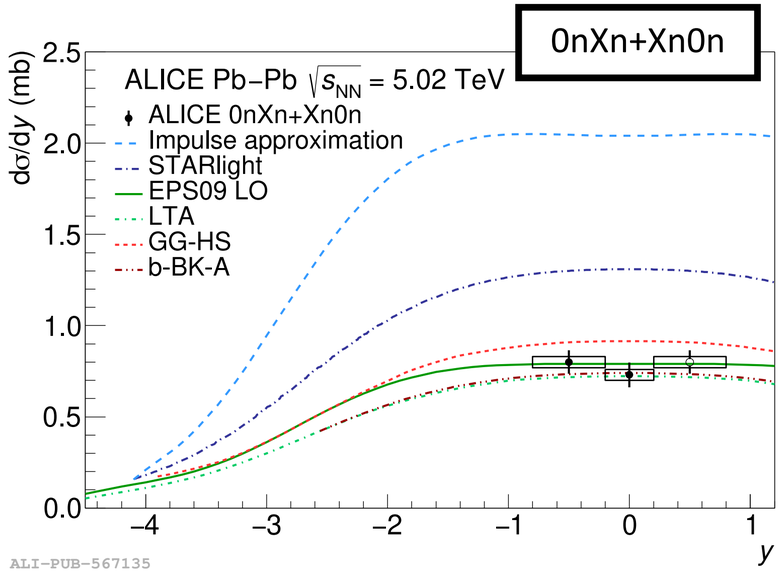


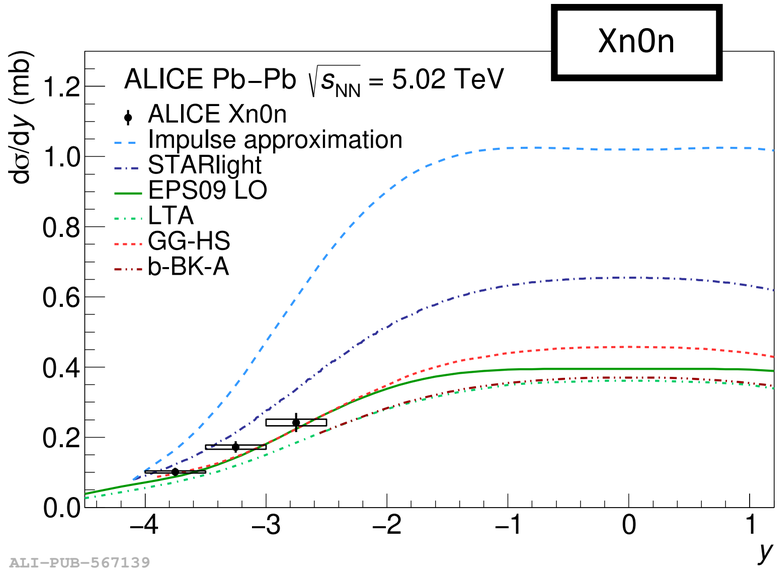
Guillermo Contreras, CTU in Prague

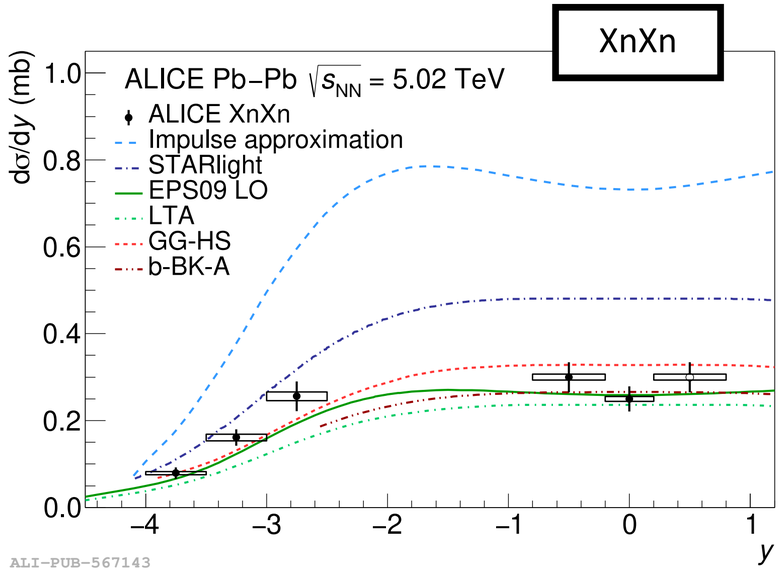
Run 2: rapidity dependence of J/ψ coherent production in EMD classes

ALICE, JHEP 10 (2023) 119









Several UPC measurements for each rapidity range → We can extract the photonuclear cross sections!

Flux at different rapidities

$$\frac{d\sigma_{\mathrm{PbPb}}}{dy} = n_\gamma(y;\{b\})\sigma_{\gamma\mathrm{Pb}}(y) + n_\gamma(-y;\{b\})\sigma_{\gamma\mathrm{Pb}}(-y)$$

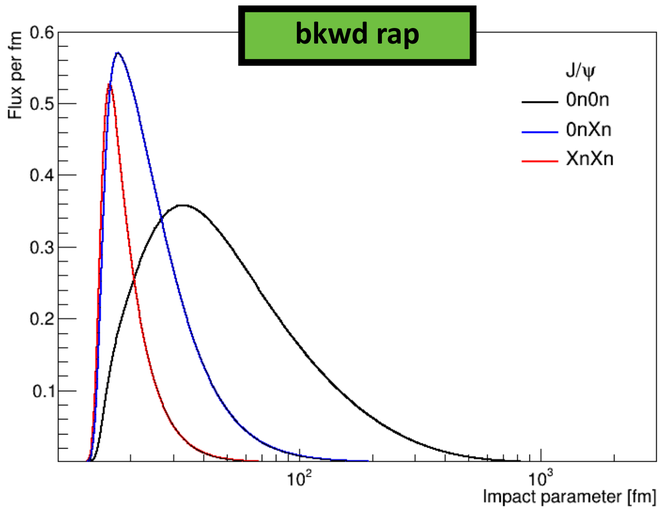
Flux at different rapidities

$$x = \frac{m}{\sqrt{s}} e^{-y} = \frac{m^2}{W^2}$$

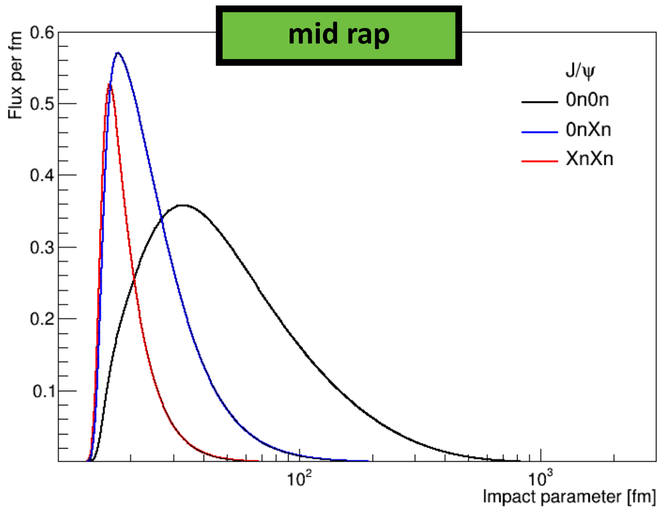
$$\frac{d\sigma_{\mathrm{PbPb}}}{dy} = n_\gamma(y;\{b\})\sigma_{\gamma\mathrm{Pb}}(y) + n_\gamma(-y;\{b\})\sigma_{\gamma\mathrm{Pb}}(-y)$$

Flux evolution

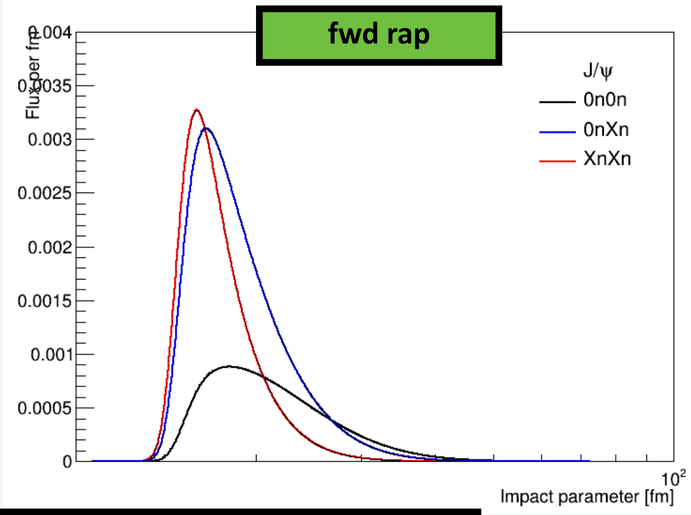
bkwd rap



mid rap



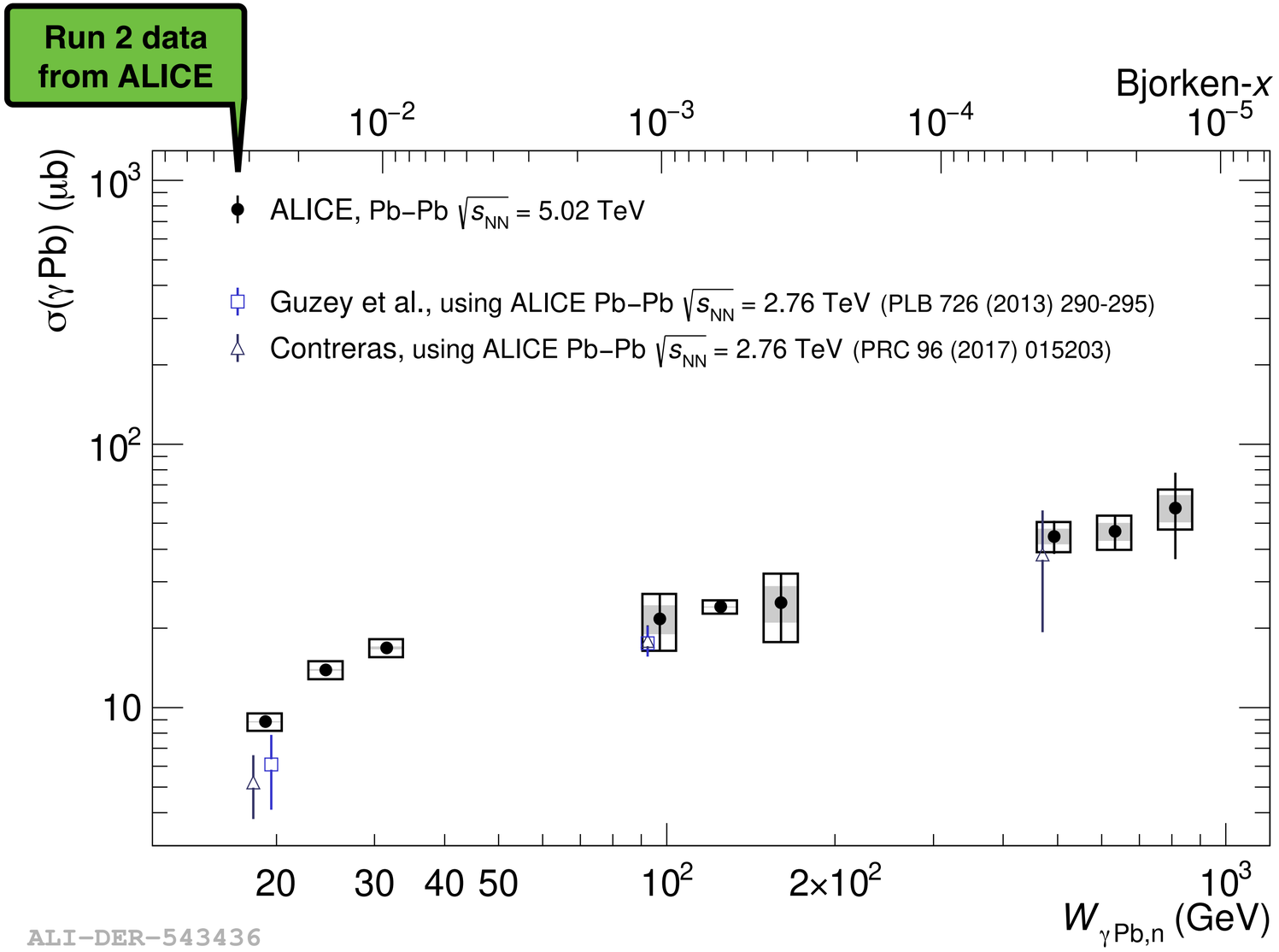
fwd rap



nOOn: Broz et al., CPC 235 (2020) 107181

At bkgd and mid rapidity, most of the flux in the 0n0n channel, at fwd rapidities (small x), all fluxes are small and similar

Energy/Bjorken-x dependence of coherent production from Run 2



ALICE, JHEP 10 (2023) 119

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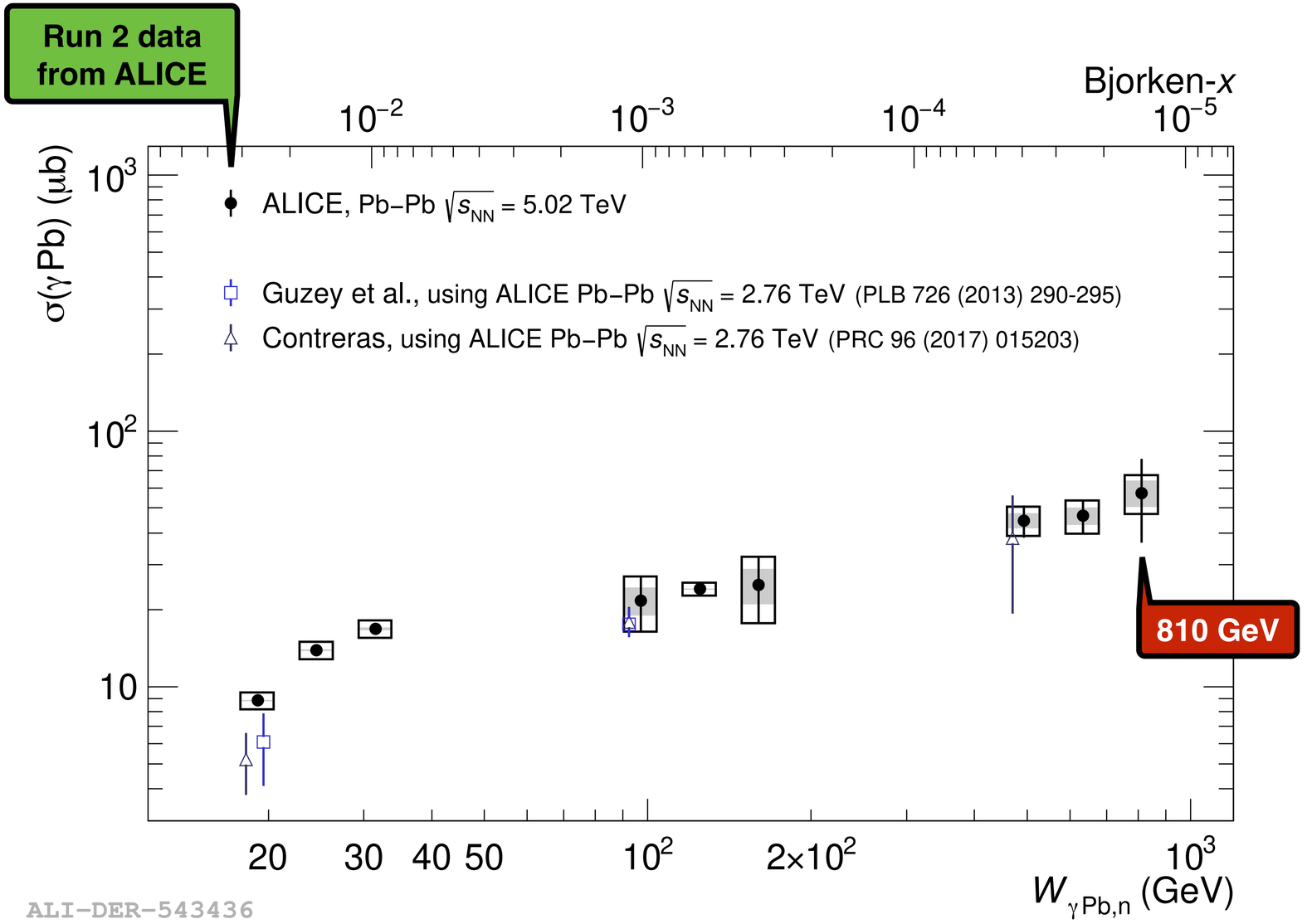

ALICE, JHEP 10 (2023) 119

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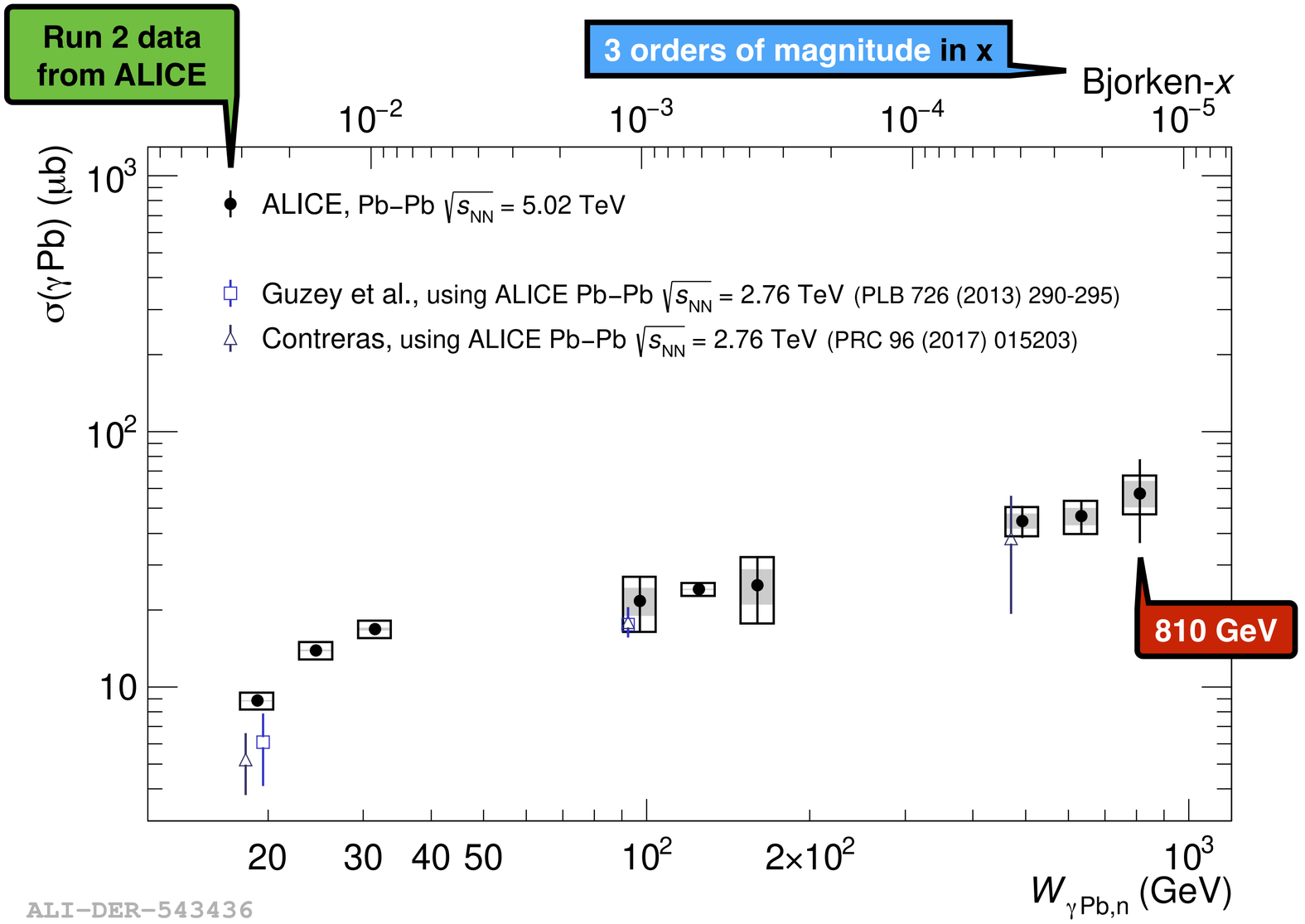

ALICE, JHEP 10 (2023) 119

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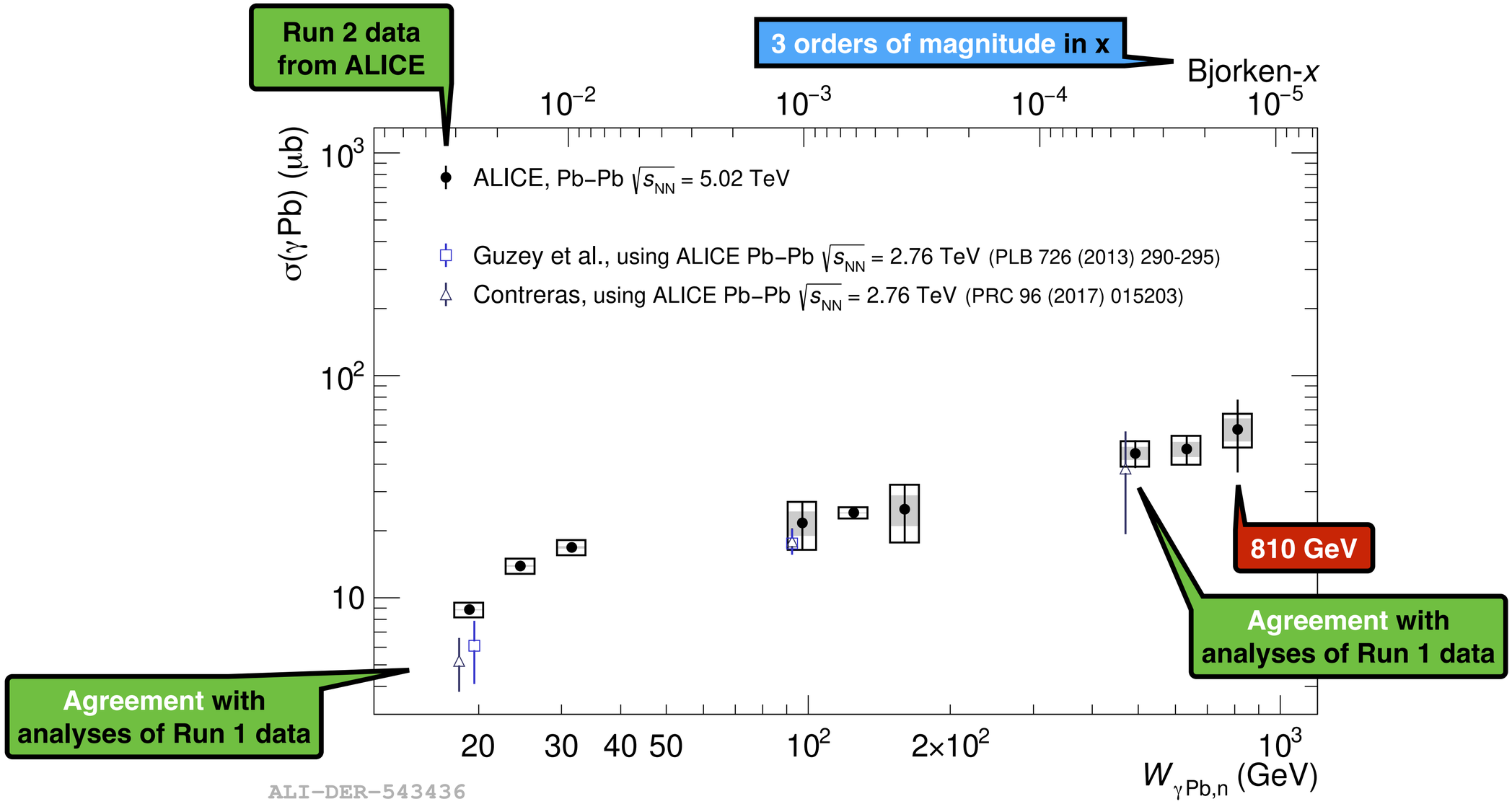

ALICE, JHEP 10 (2023) 119

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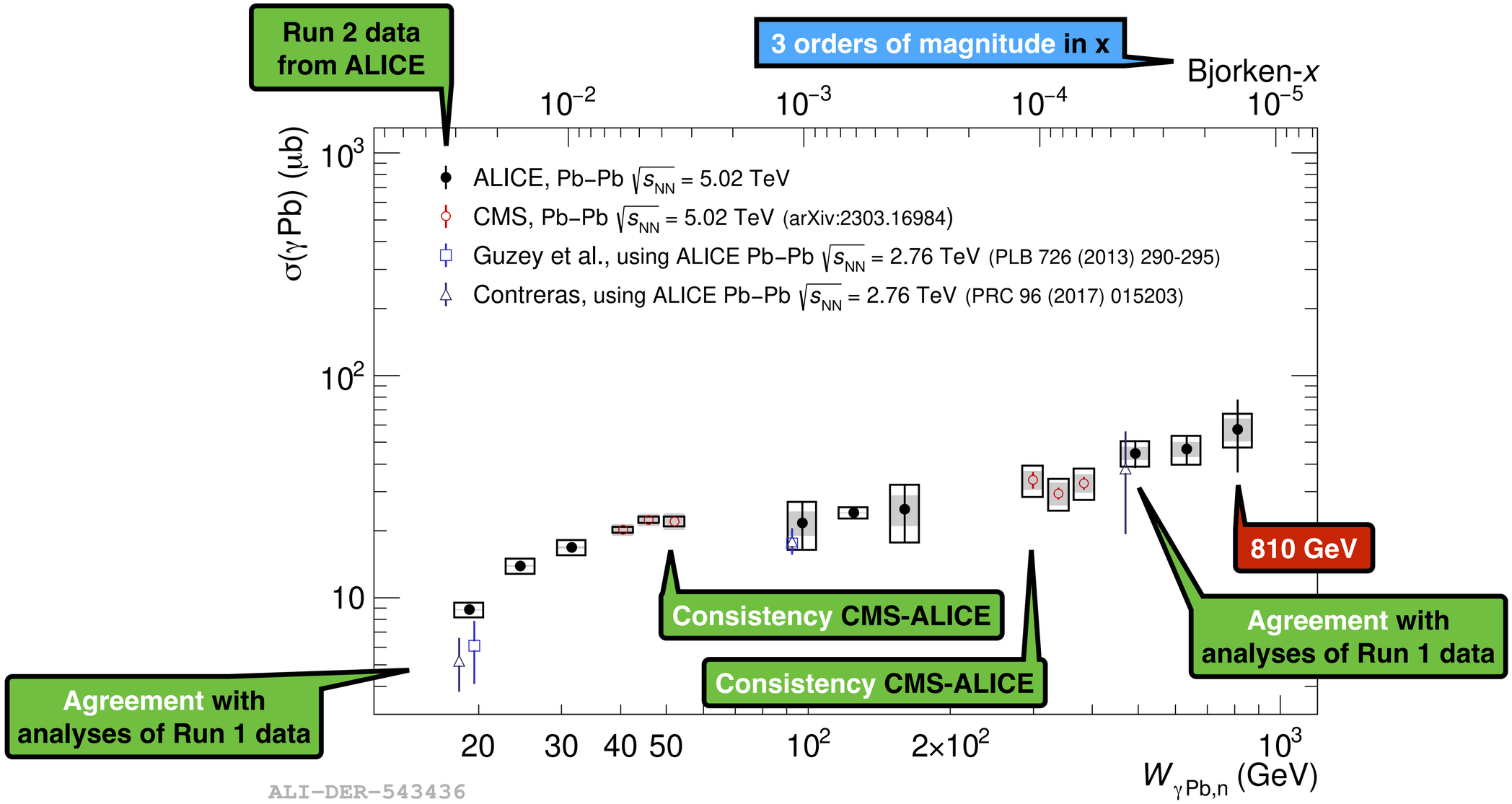

ALICE, JHEP 10 (2023) 119

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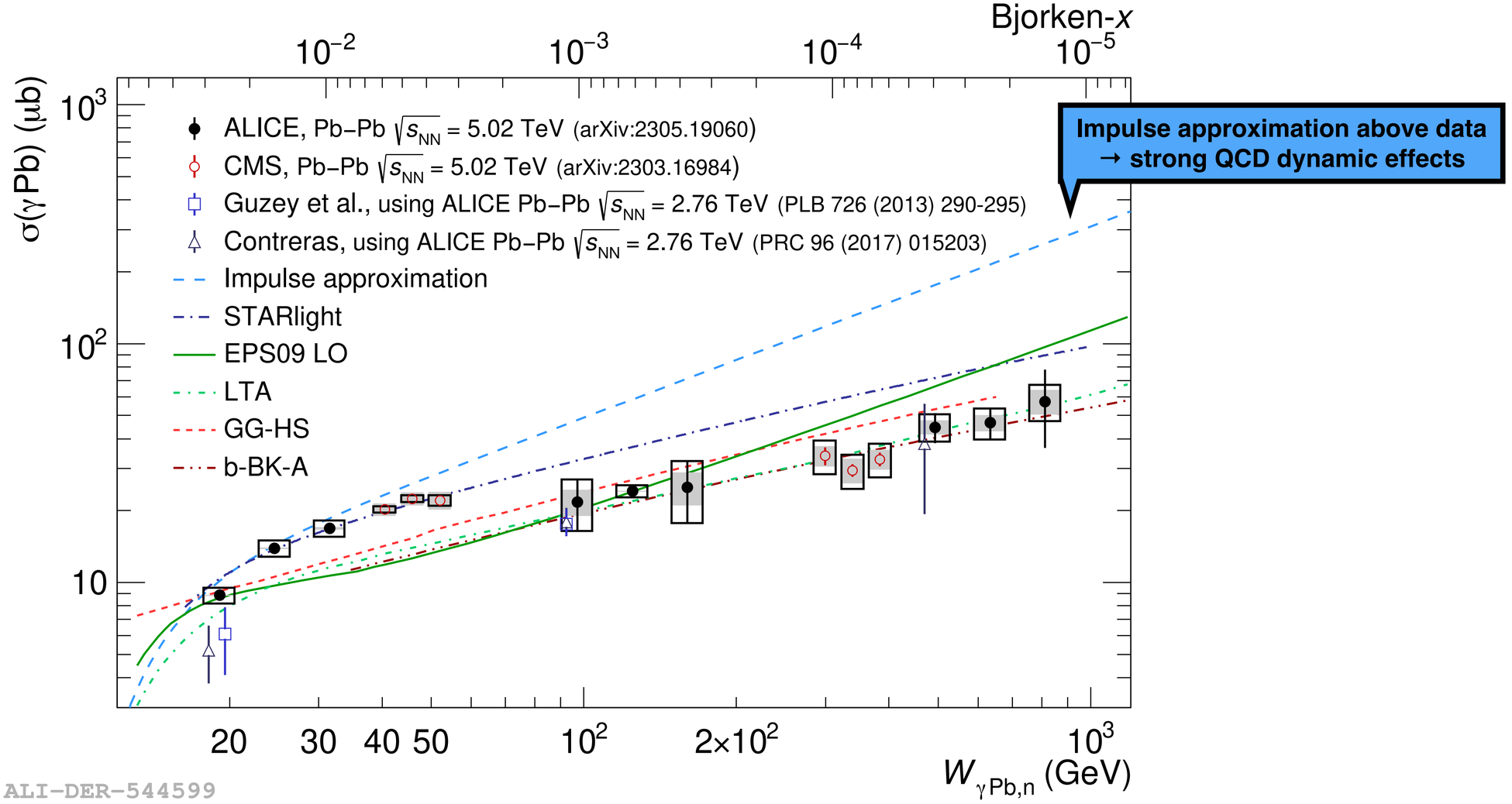

Impulse approximation above data → strong QCD dynamic effects

ALICE, JHEP 10 (2023) 119

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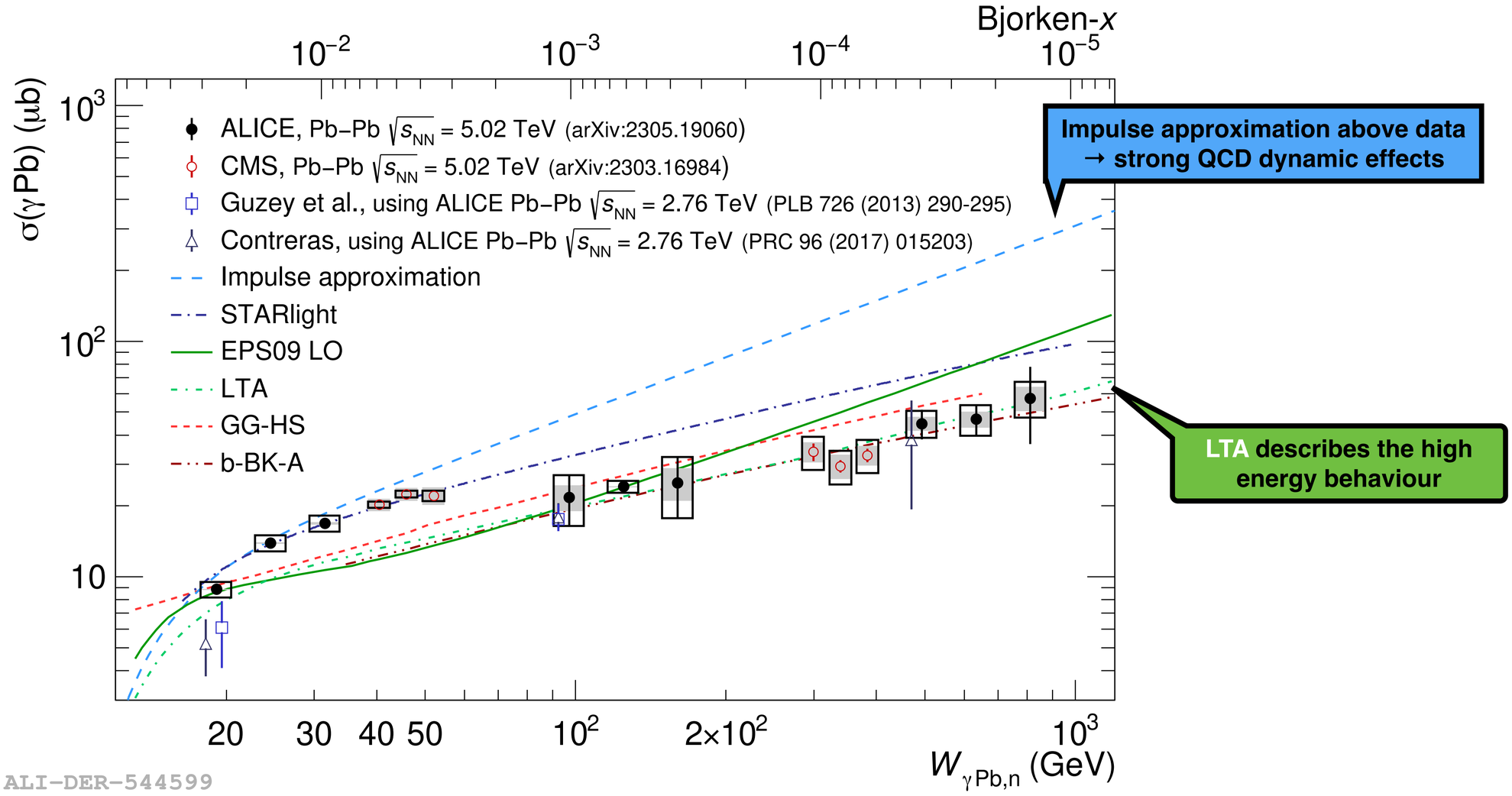

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LTA describes the high energy behaviour

ALICE, JHEP 10 (2023) 119

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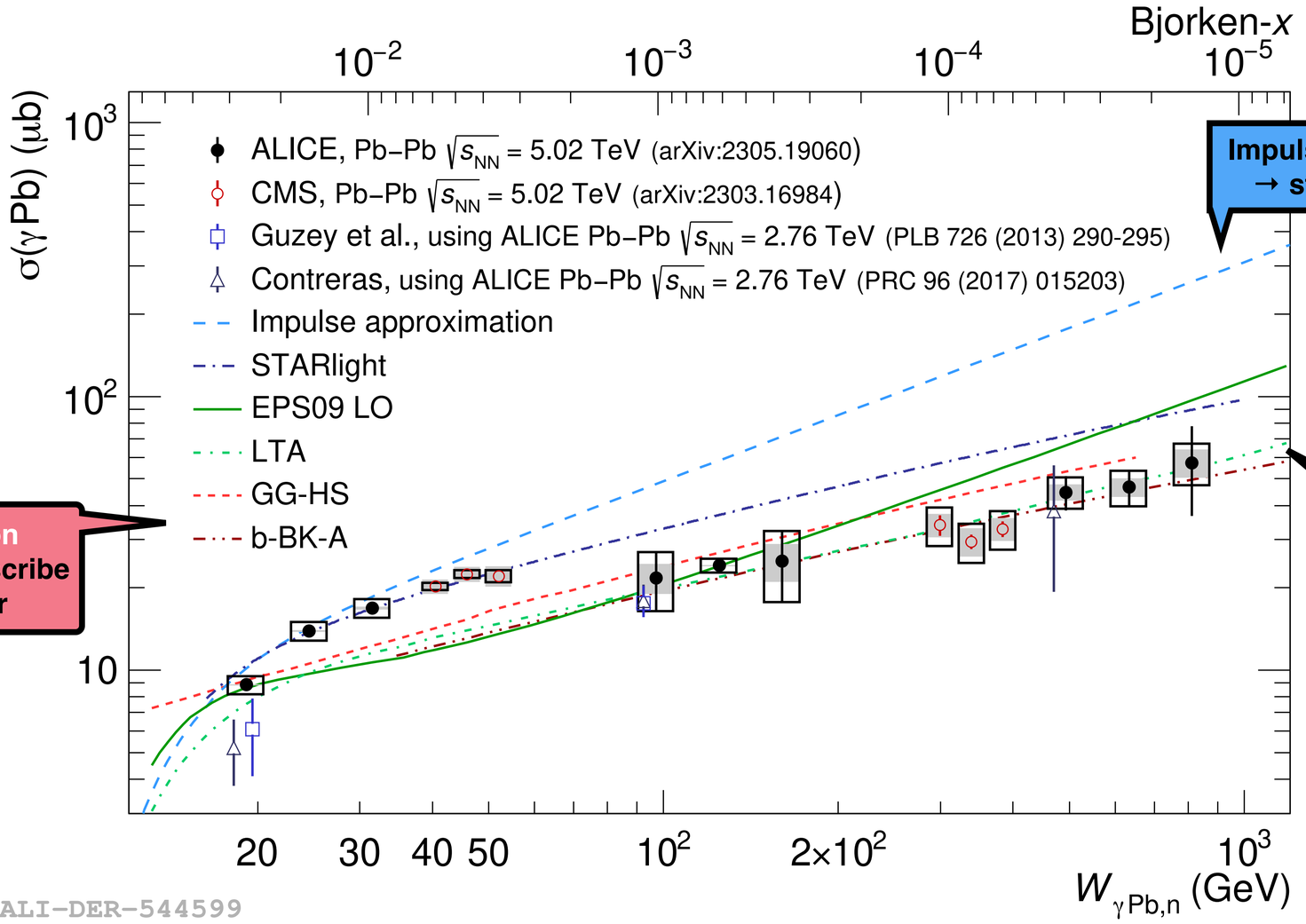

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ALICE, JHEP 10 (2023) 119

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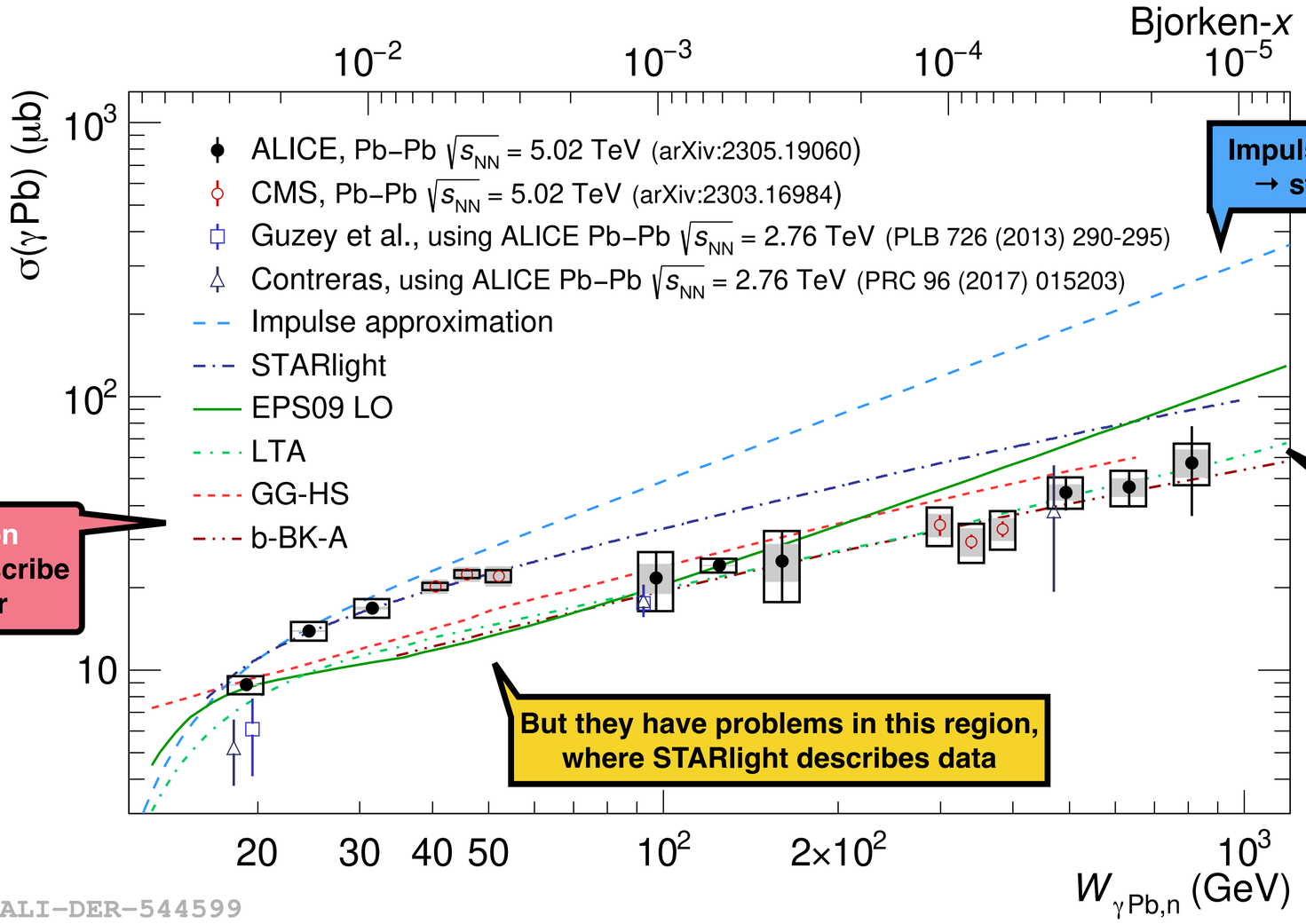

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But they have problems in this region, where STARlight describes data

ALICE, JHEP 10 (2023) 119

Energy/Bjorken-x dependence of coherent production from Run 2

Nuclear suppression factor

$$S_{\mathrm{Pb}} = \sqrt{\frac{\sigma_{\gamma\mathrm{Pb}}}{\sigma^{\mathrm{IA}}_{\gamma\mathrm{Pb}}}}$$

ALICE, JHEP 10 (2023) 119

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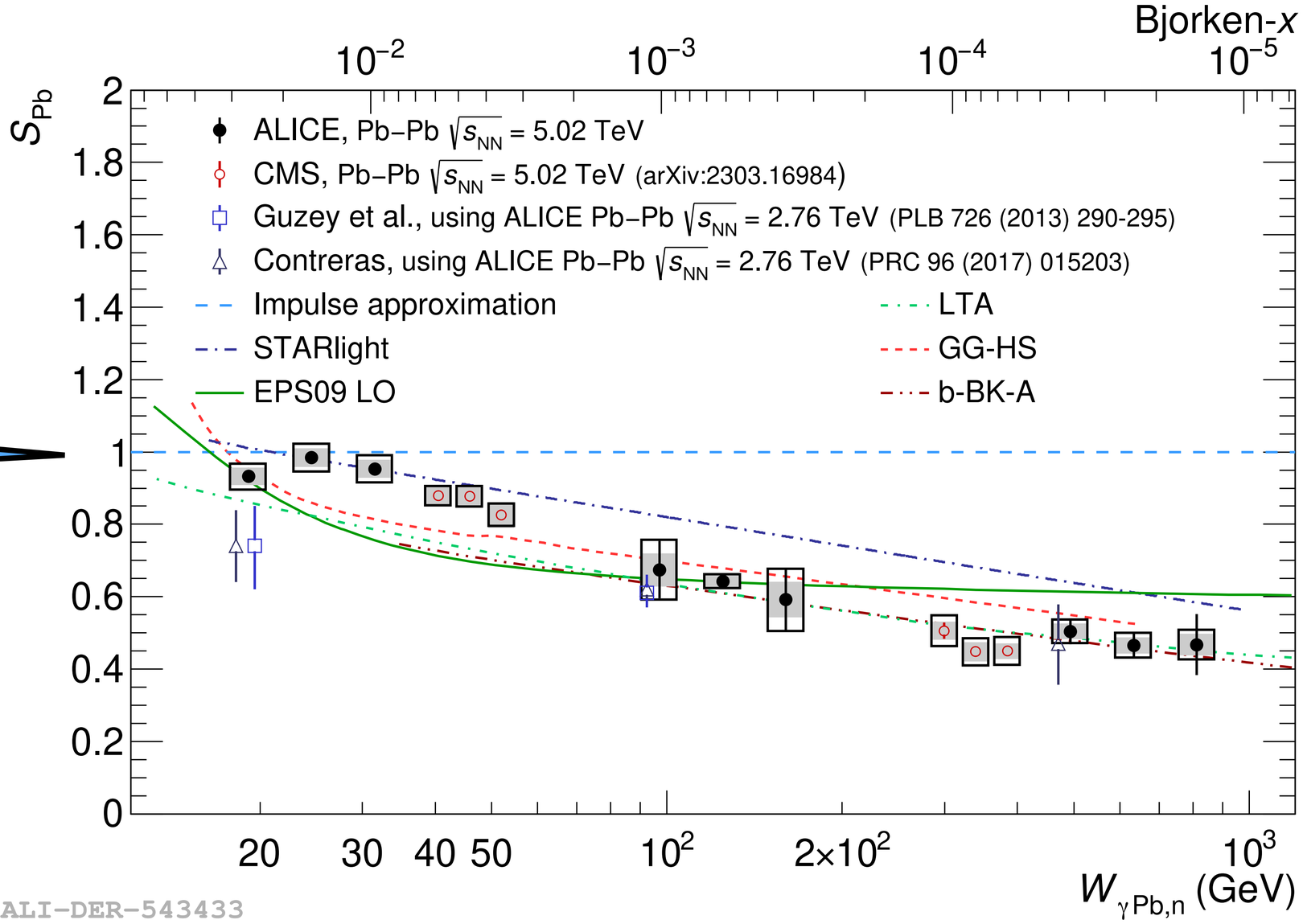

ALI-DER-543433

ALICE, JHEP 10 (2023) 119

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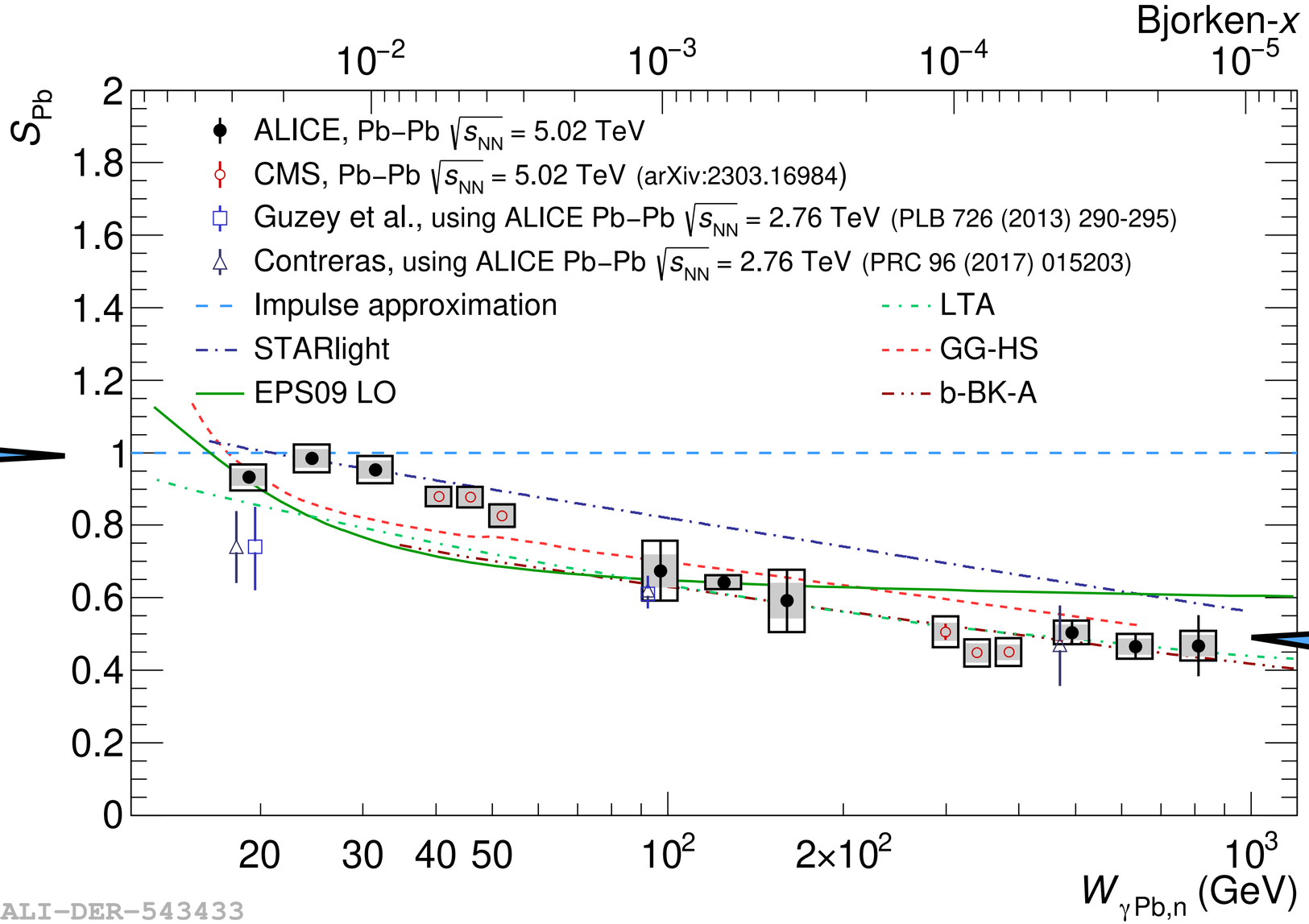

Flattening of suppression at high energies?

ALI-DER-543433

ALICE, JHEP 10 (2023) 119

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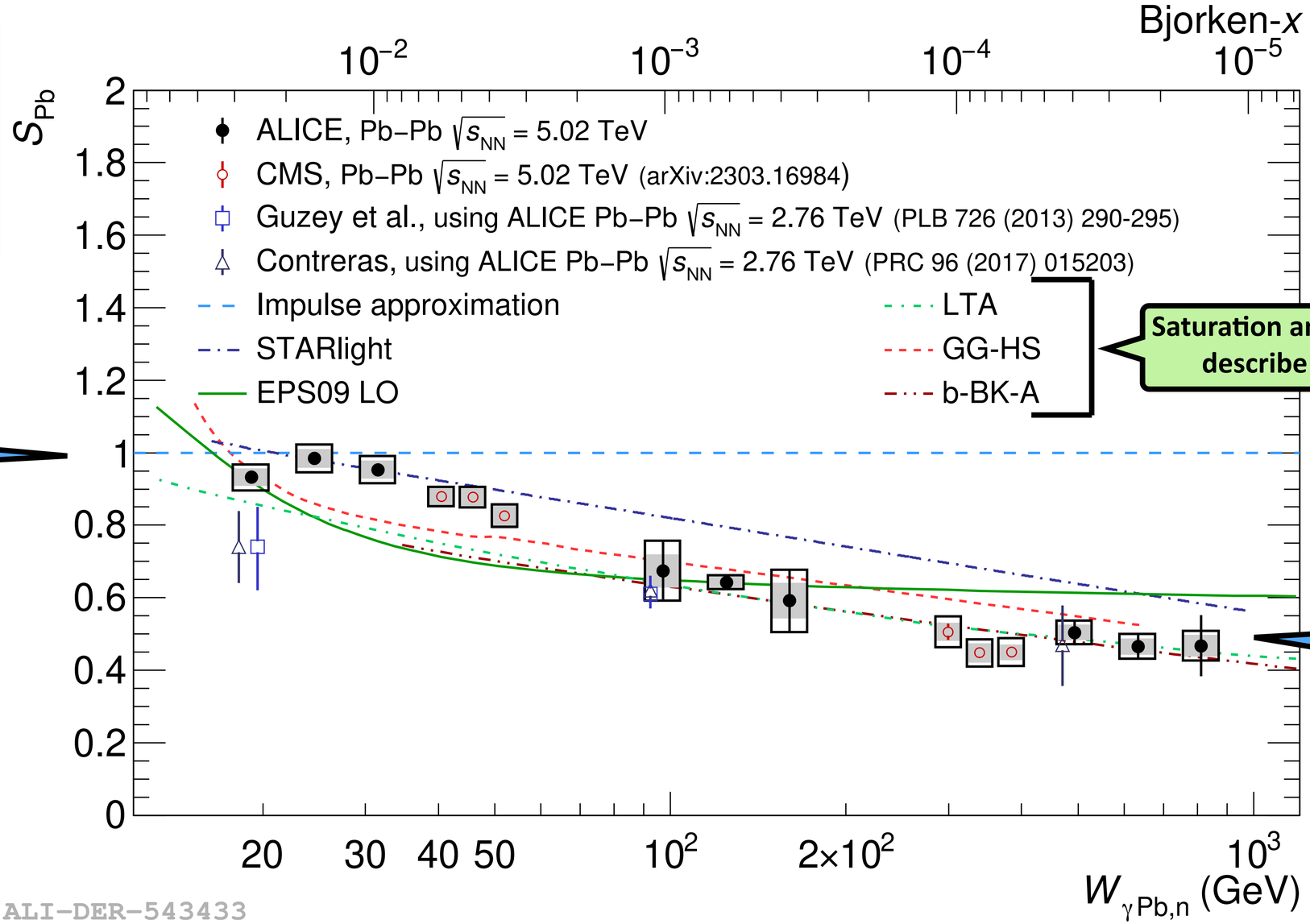

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Saturation and shadowing models describe data equally well

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ALI-DER-543433

ALICE, JHEP 10 (2023) 119

Summary and outlook

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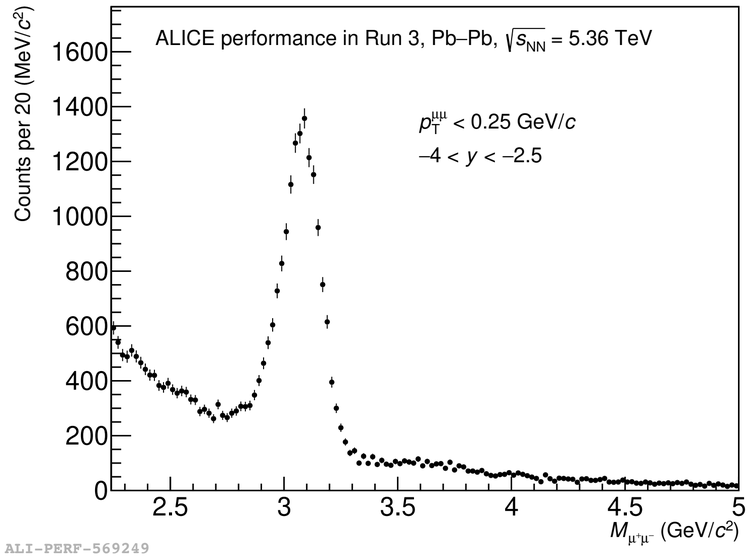

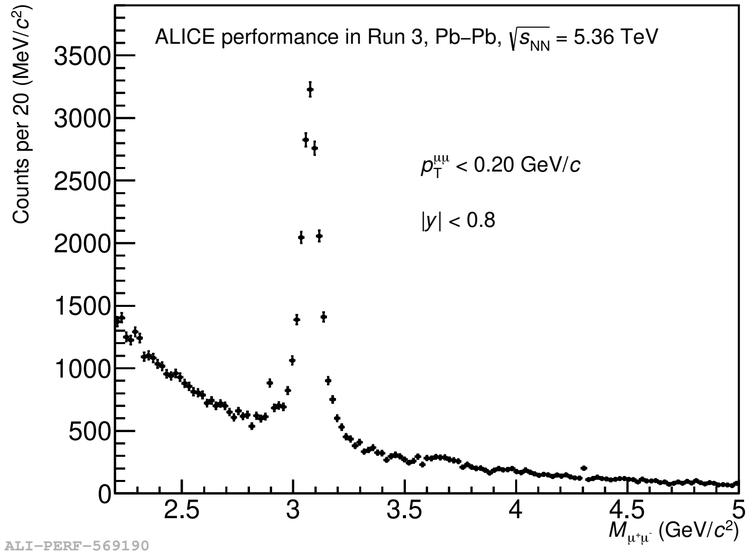

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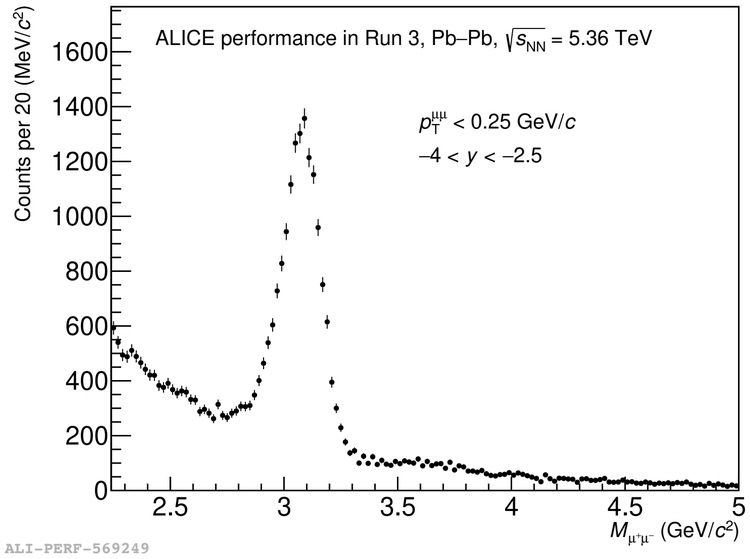

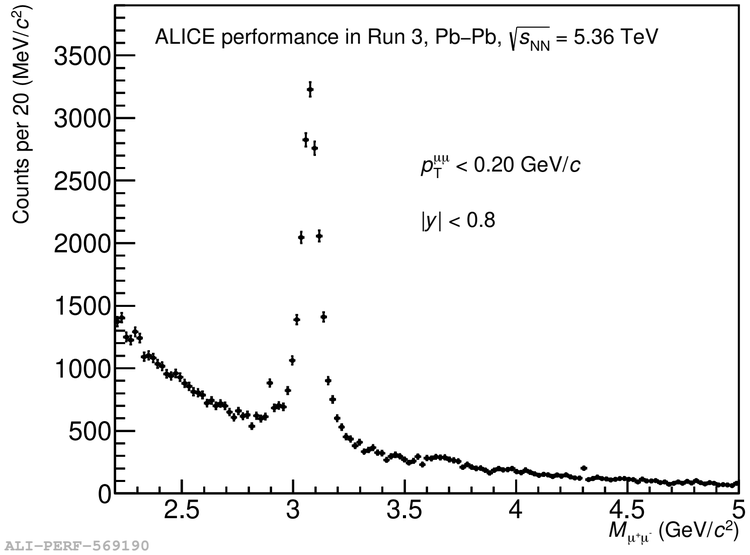

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Stay tuned :)