Measurements of coherent J/ψ production in ATLAS and the problem of exclusivity

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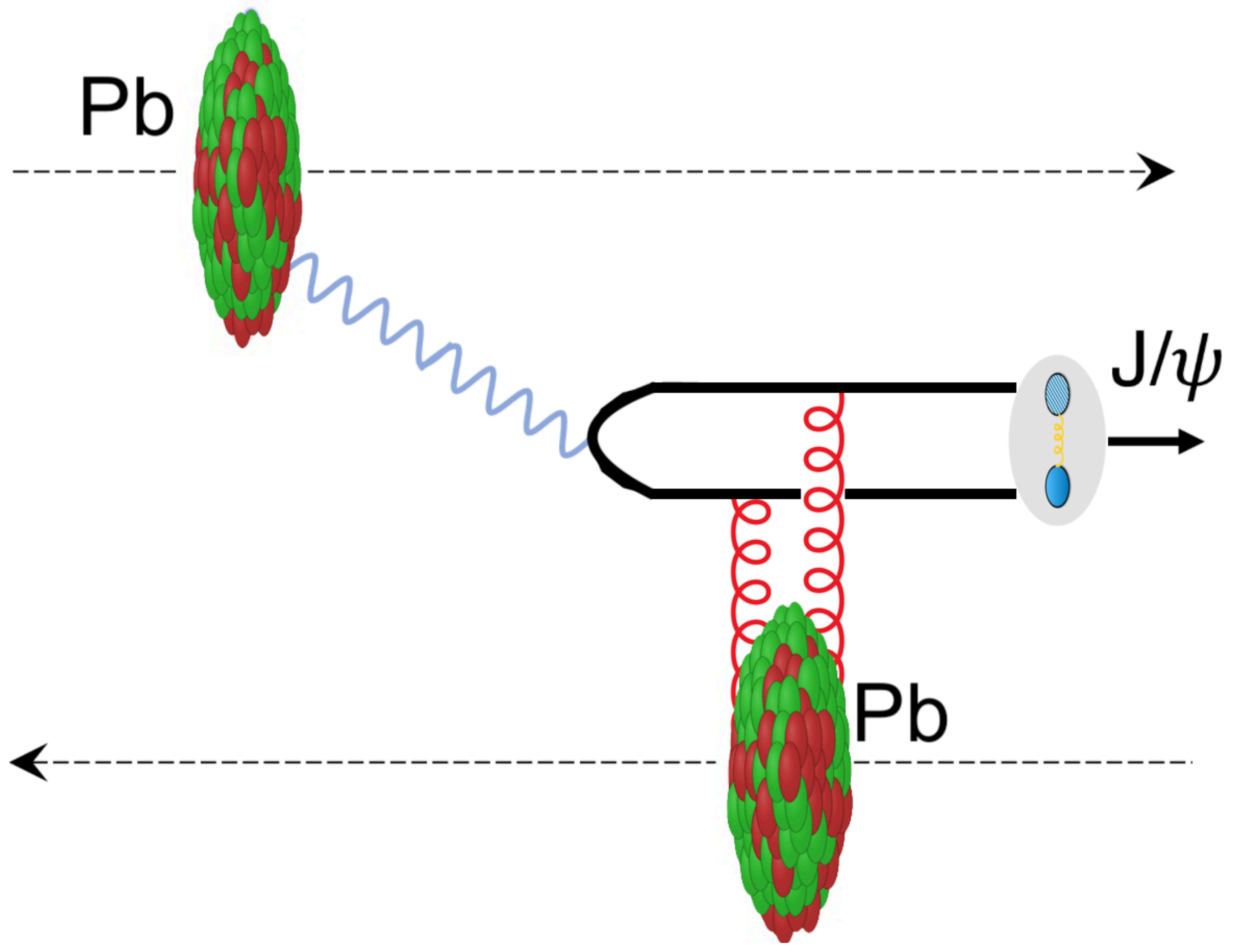
on behalf of the ATLAS Collaboration

EMMI workshop on saturation (2026)

Original motivation



- Coherent J/Psi production in UPC: process sensitive to nuclear parton dynamics at low-x

- Filling the gap in measurements for 0.8<|y|<1.6 (uncovered by previous studies)

- Focusing on **dimuon** decay channel

- Key experimental challenge in ATLAS:
  - Trigger on soft (**p_T ~1.5 GeV**) leptons

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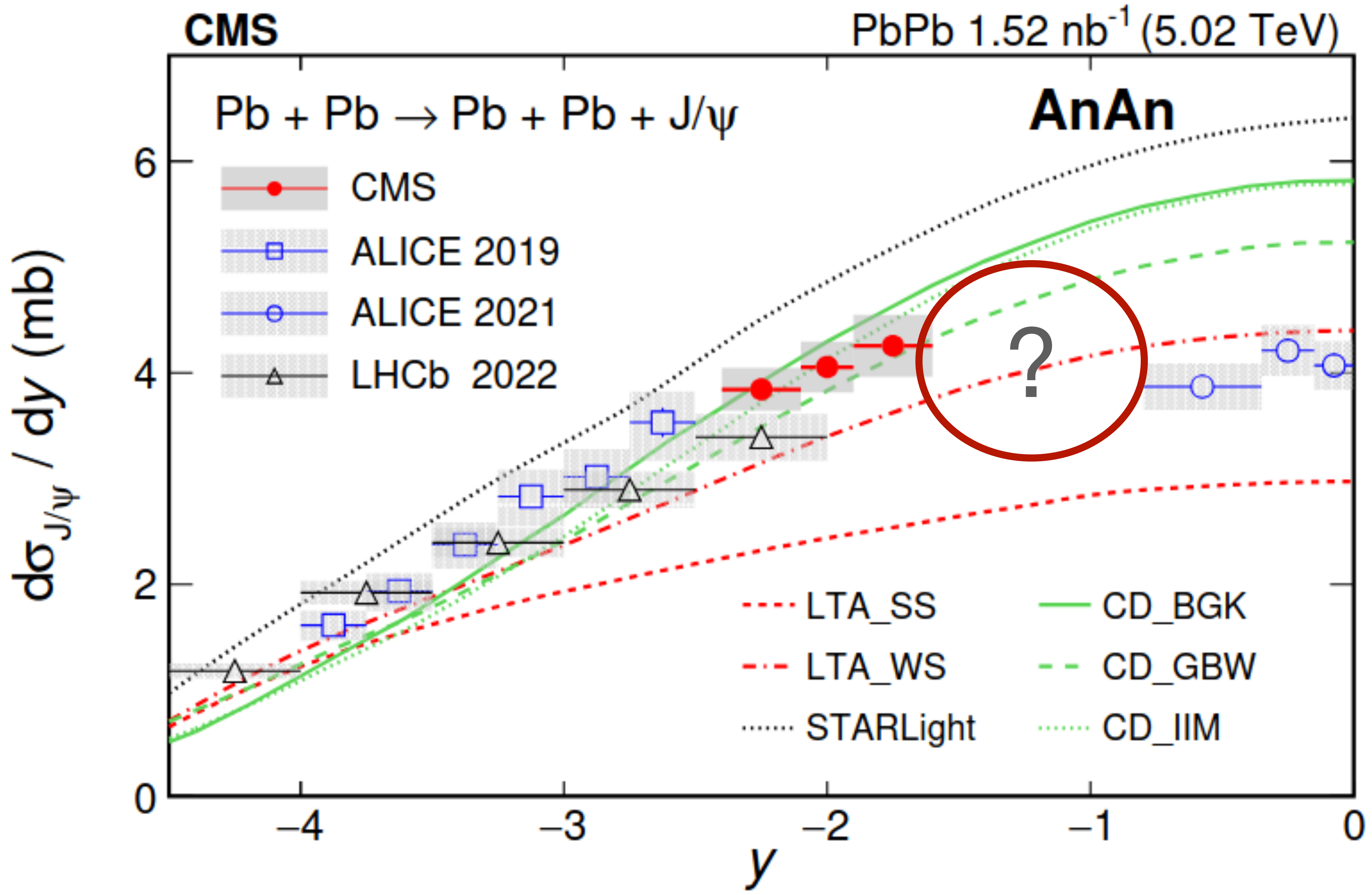


ATLAS Run 3 UPC game-changer

The L1TRT trigger (aka FastOR cosmic trigger): Track-sensitive trigger running at O(MHz)

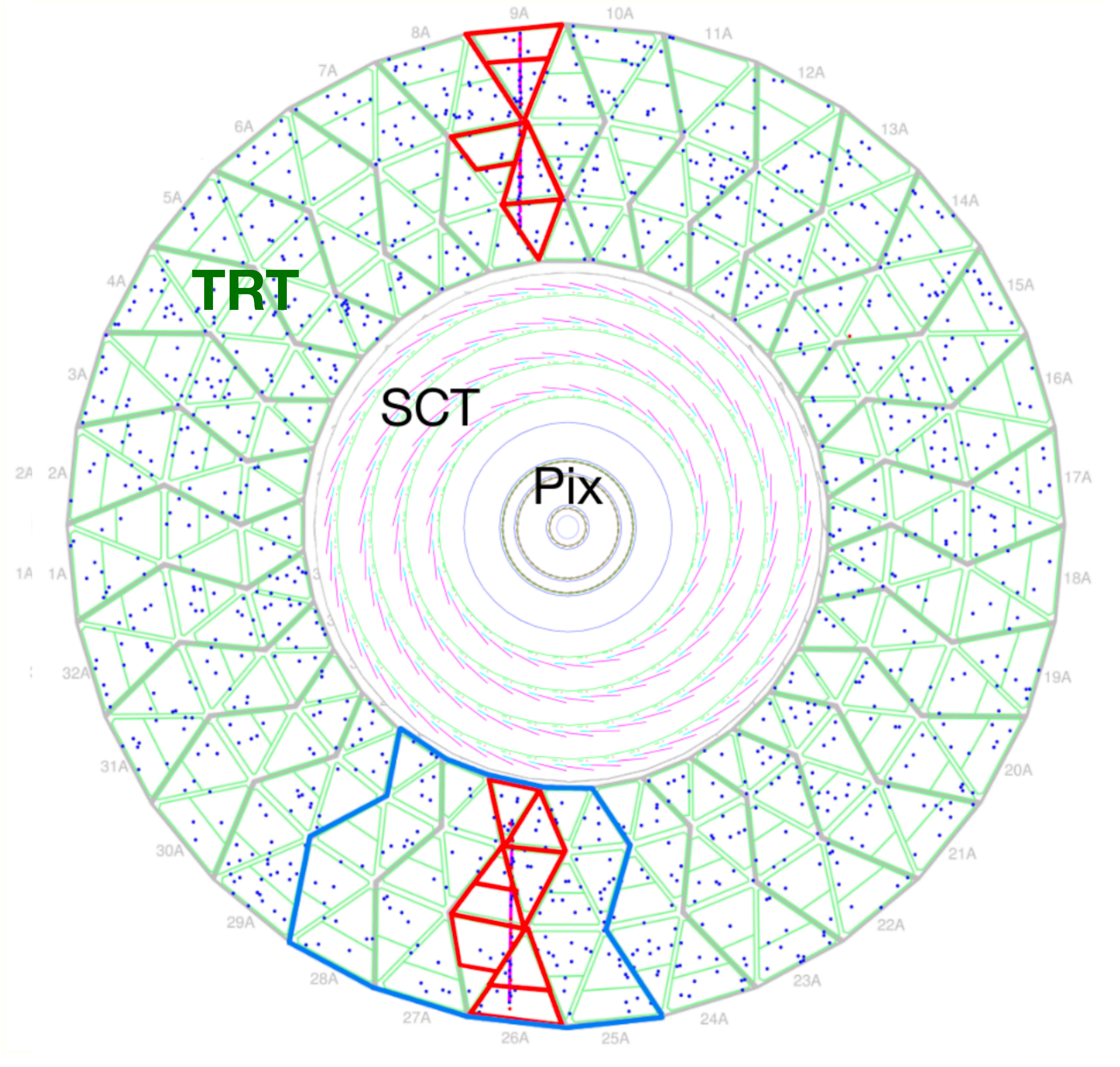
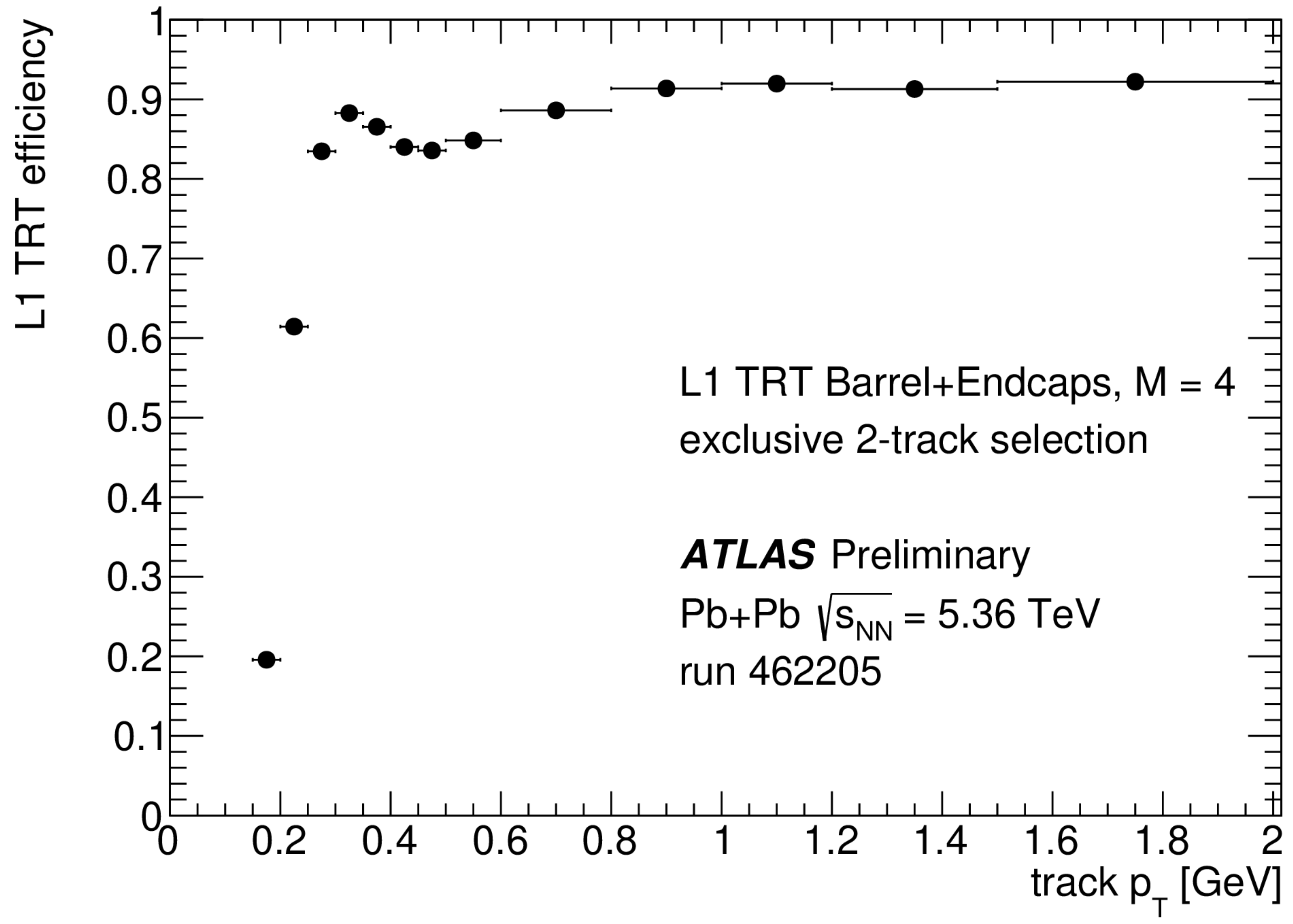


Figure 2.1: The L1TRT FastOR logic in the Barrel A region [17]. The Barrel TRT region is divided into 32 phi sectors (bold gray), each consisting of 9 TRT trigger segments (shown as green triangles/trapezoids). A trigger signal within a segment is formed if the transition radiation threshold is exceeded in any of TRT straws from this segment (shown as red triangles/trapezoids). Then, the trigger logic aggregates signals from all segments in a region formed from 4 adjacent phi sectors (shown in blue for example region), yielding an effective ϕ segmentation of 1/8. To form a global trigger decision, a given number of segments (multiplicity) with a trigger signal has to be reached in a given set of four sectors (each set of four sectors = 36 segments).

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/IDET-2023-01/

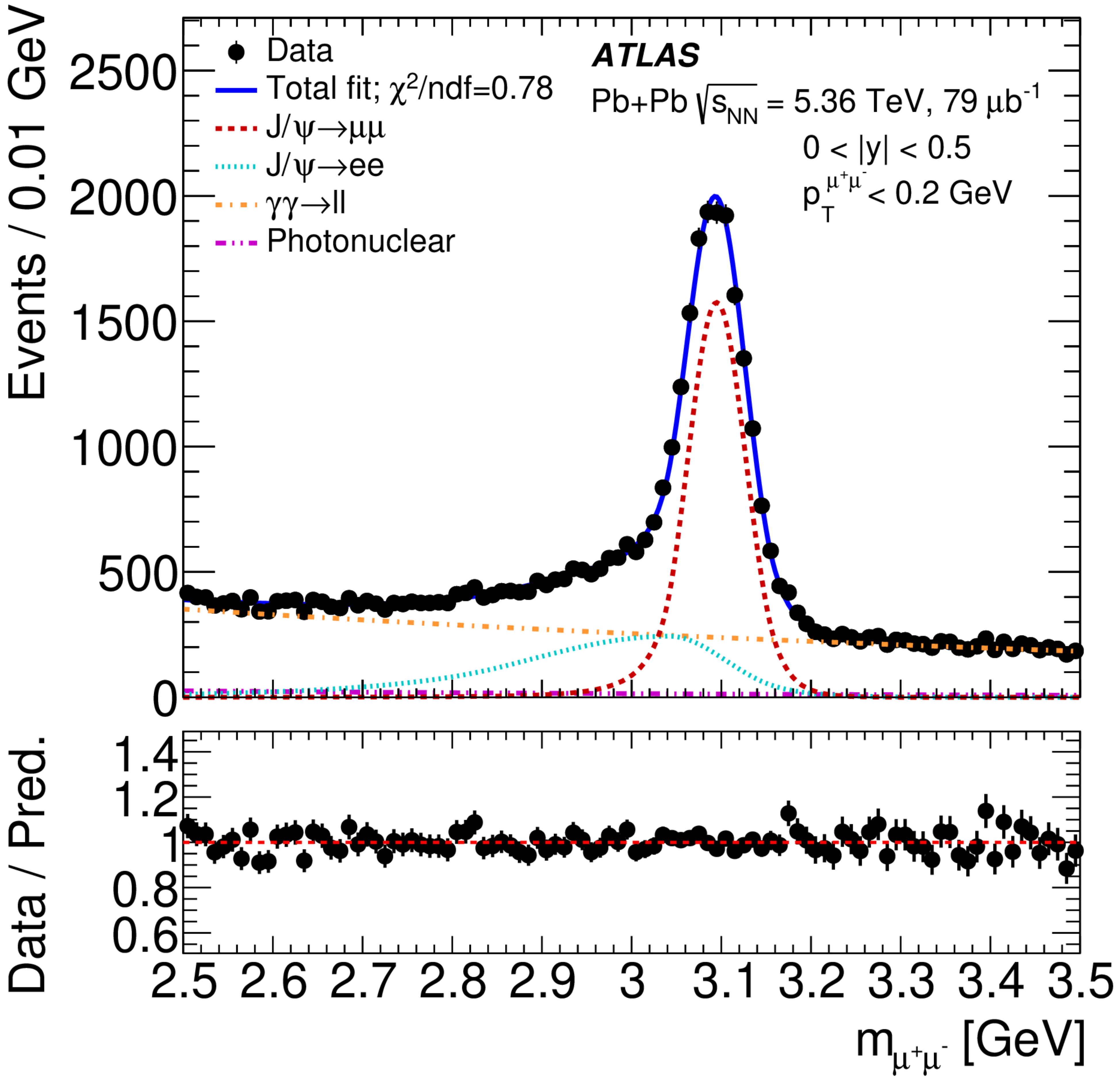


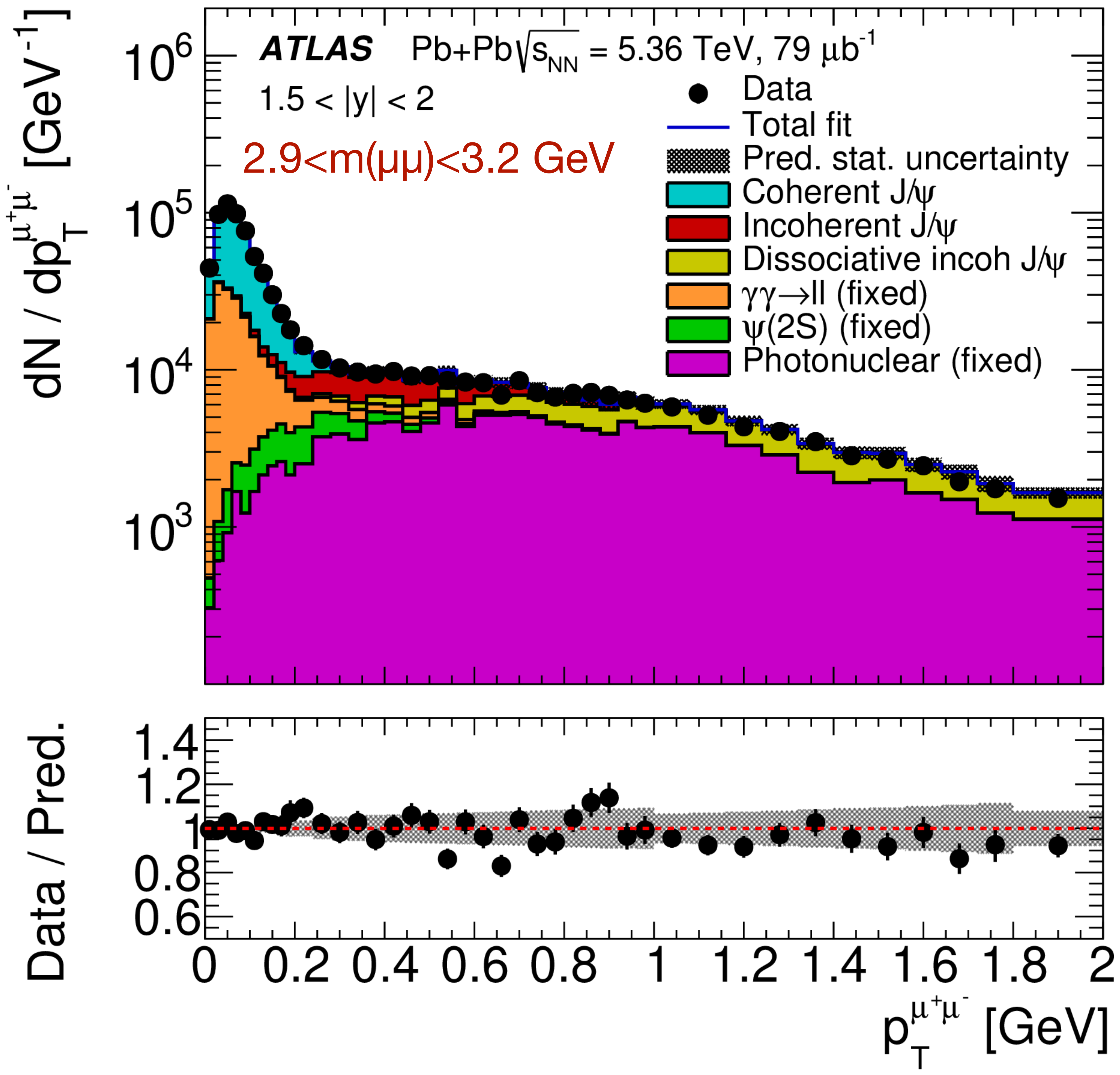
- In 2023, 79/ub of Pb+Pb data at 5.36 TeV was recorded with this trigger

JHEP 04 (2026) 020

Measurement of coherent J/ψ in UPC at 5.36 TeV

- Signal extraction
  - Template fits to **two-track invariant mass** and **system p_T**
  - No muon ID is used → **fits to mass lineshape**





Measurement of coherent J/ψ in UPC at 5.36 TeV

- Differential cross section measurement:

$$\boxed{\frac{d\sigma}{dy} = \frac{N^{\mathrm{coh}}_{J/\psi\to\mu^+\mu^-}}{A \times \epsilon_C \times BR \times \mathcal{L}_{\mathrm{int}} \times \Delta y}}$$

Raw coherent yield from p_T fits

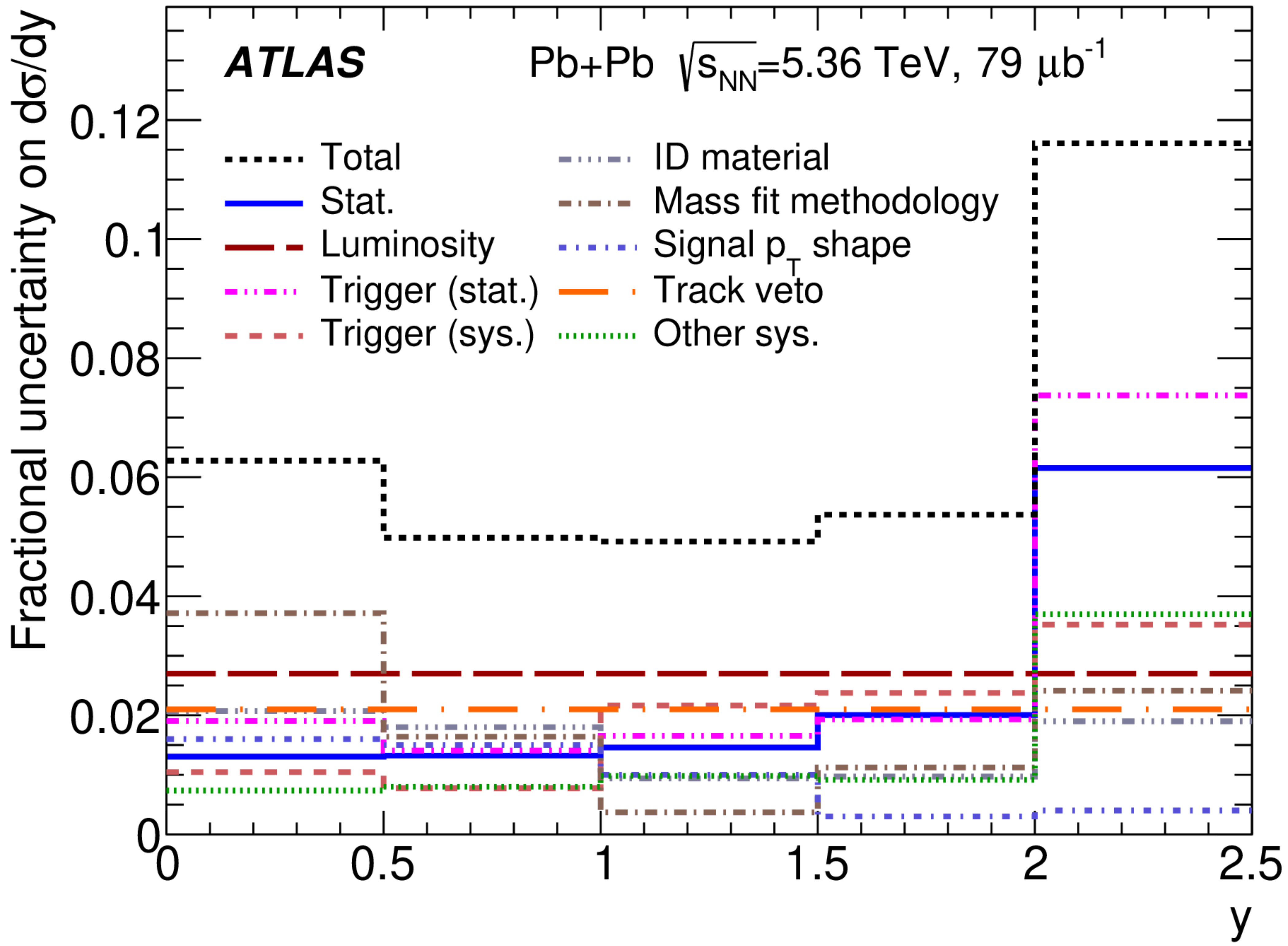
Acceptance correction (from MC)

Efficiency correction (from MC with data-driven corr. factors)

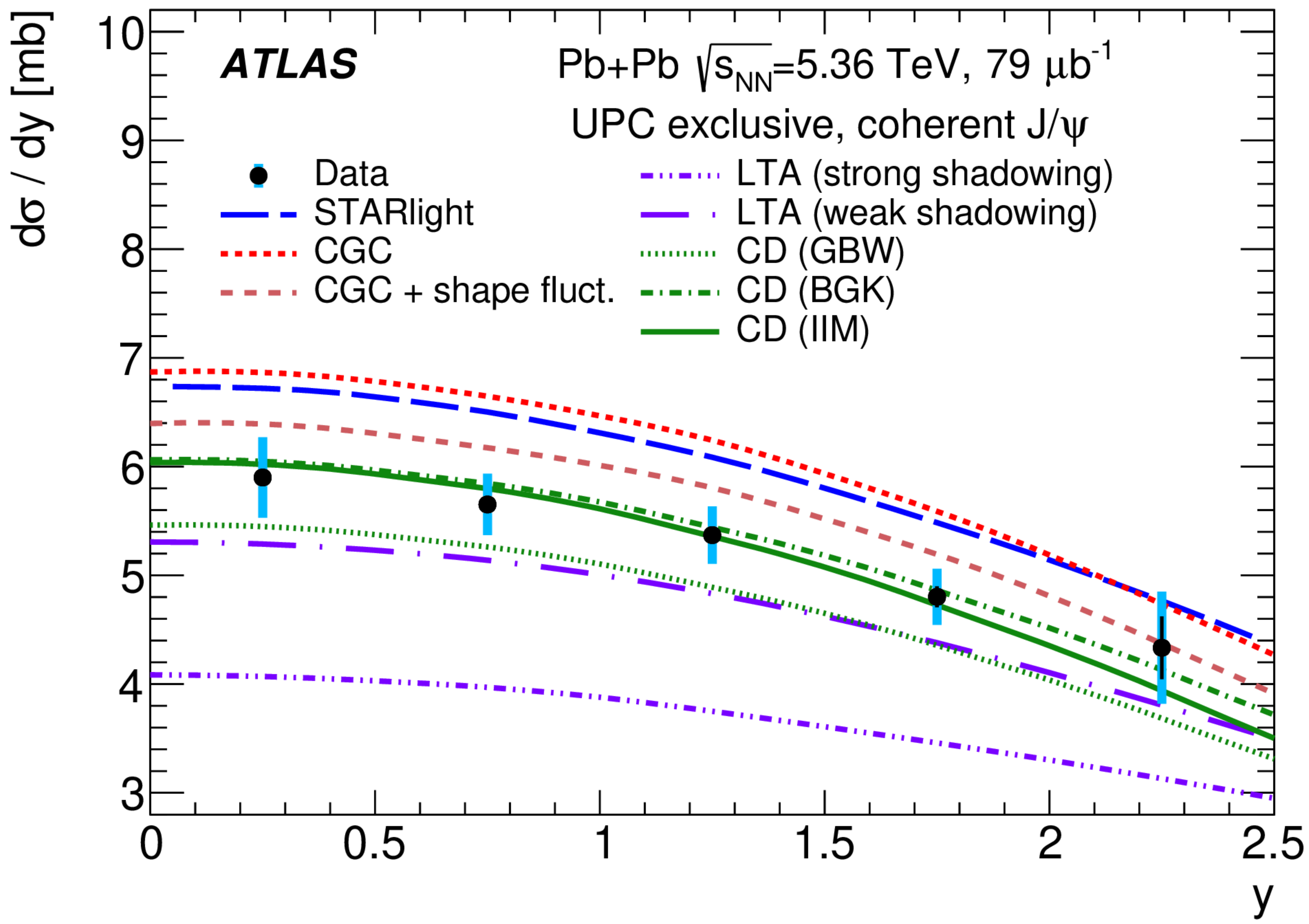
J/ψ →μμ BR

Integrated lumi

- Uncertainties
  - Dominated by **systematics** (lumi, fit methodology, …)



Measurement of coherent J/ψ in UPC at 5.36 TeV



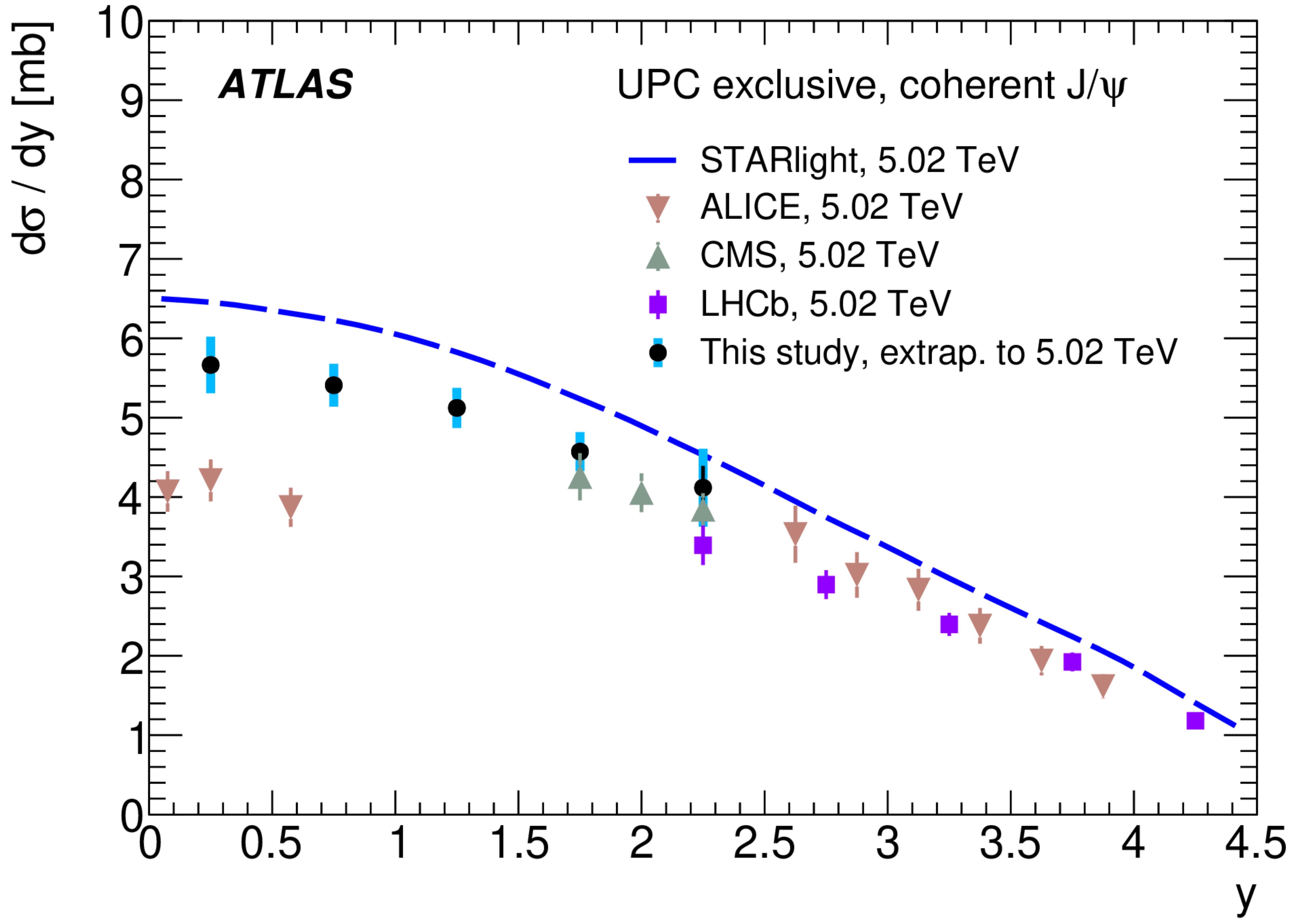
Results shown in a single hemisphere (averaged on the full -2.5<y<2.5 range)

Blue vertical bars = total uncertainty

- Results
  - Comparison with several theory predictions → **CGC and color dipole models reasonably describe data**

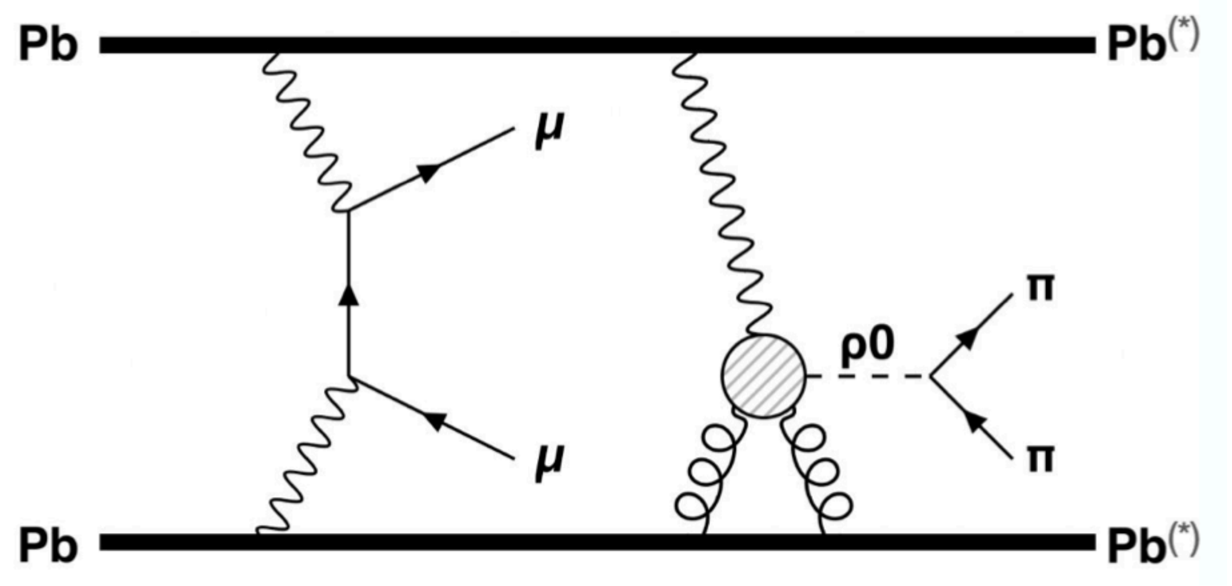
Measurement of coherent J/ψ in UPC at 5.36 TeV

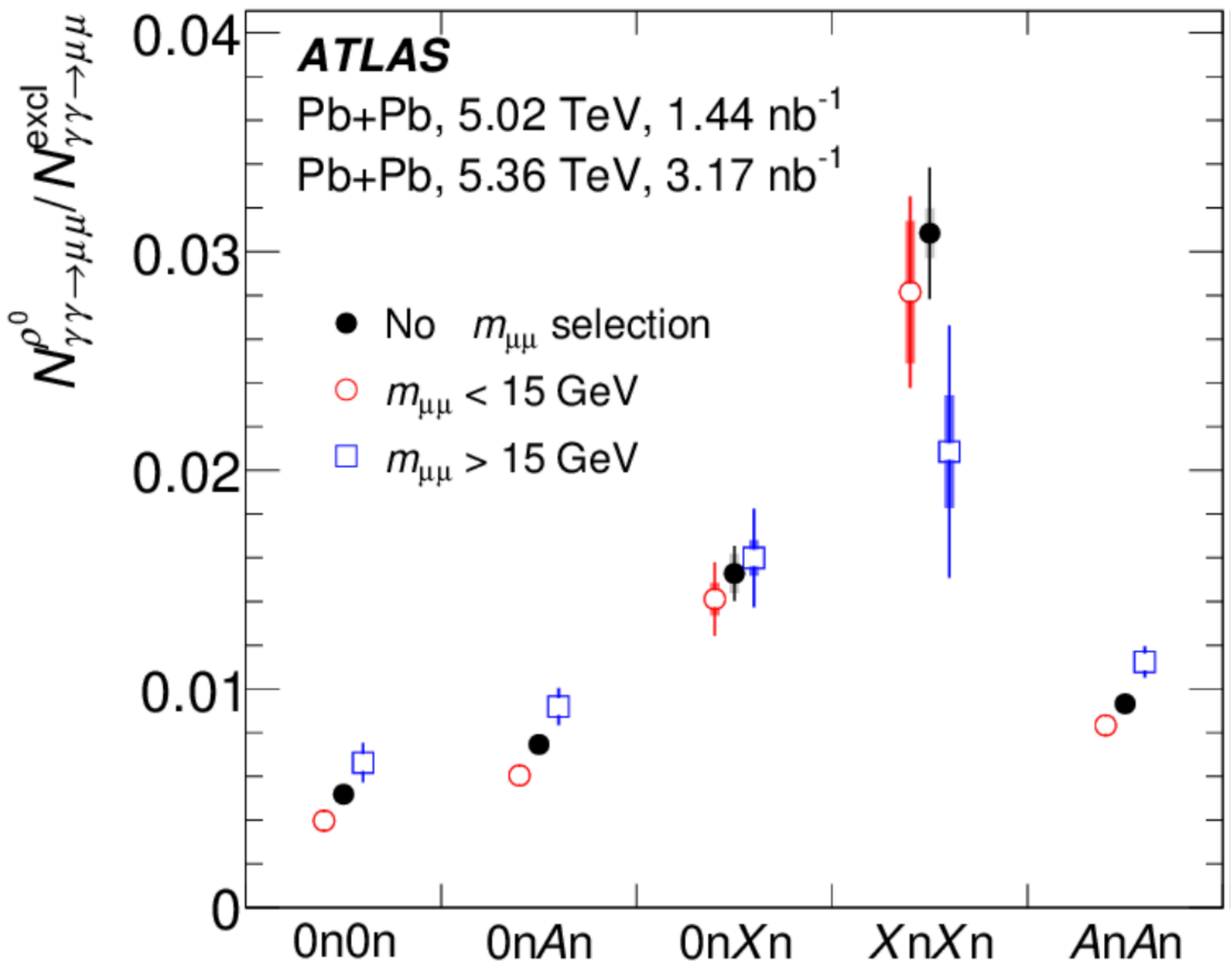
- **Extrapolation** to 5.02 TeV
  - -4-5% correction applied
  - At y~2 agreement w/ previous measurements (CMS, LHCb)
  - Tension w/ previous ALICE mid-rapidity measurement



The problem of exclusivity

- Traditionally, LHC UPC processes were assumed to be produced w/o any extra particles (exclusive production)
  - BUT: due to enormous EM Pb+Pb fields, extra particle pairs can be produced **in the same UPC interaction (ee, μμ, pi+pi-, …)**
  - The existence of such a coincident production is demonstrated recently by ATLAS, by exploring high-mass γγ→μμ + pi+pi- reaction [**arXiv:2504.07795**]
    - **Probability for the coincident process is not a static number. It evolves with Pb-Pb impact-parameter!**
  - How does this relate to ATLAS vs ALICE tension? A: different exclusivity veto criteria

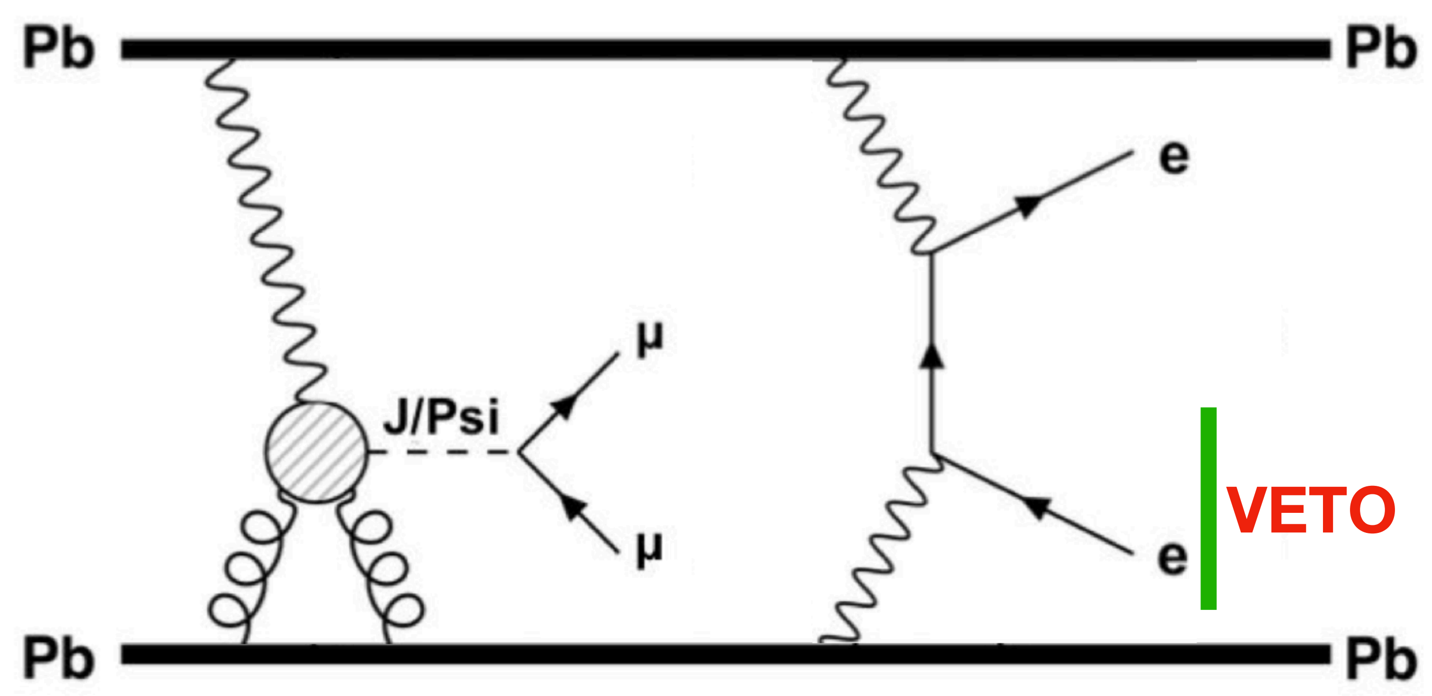




The problem of exclusivity

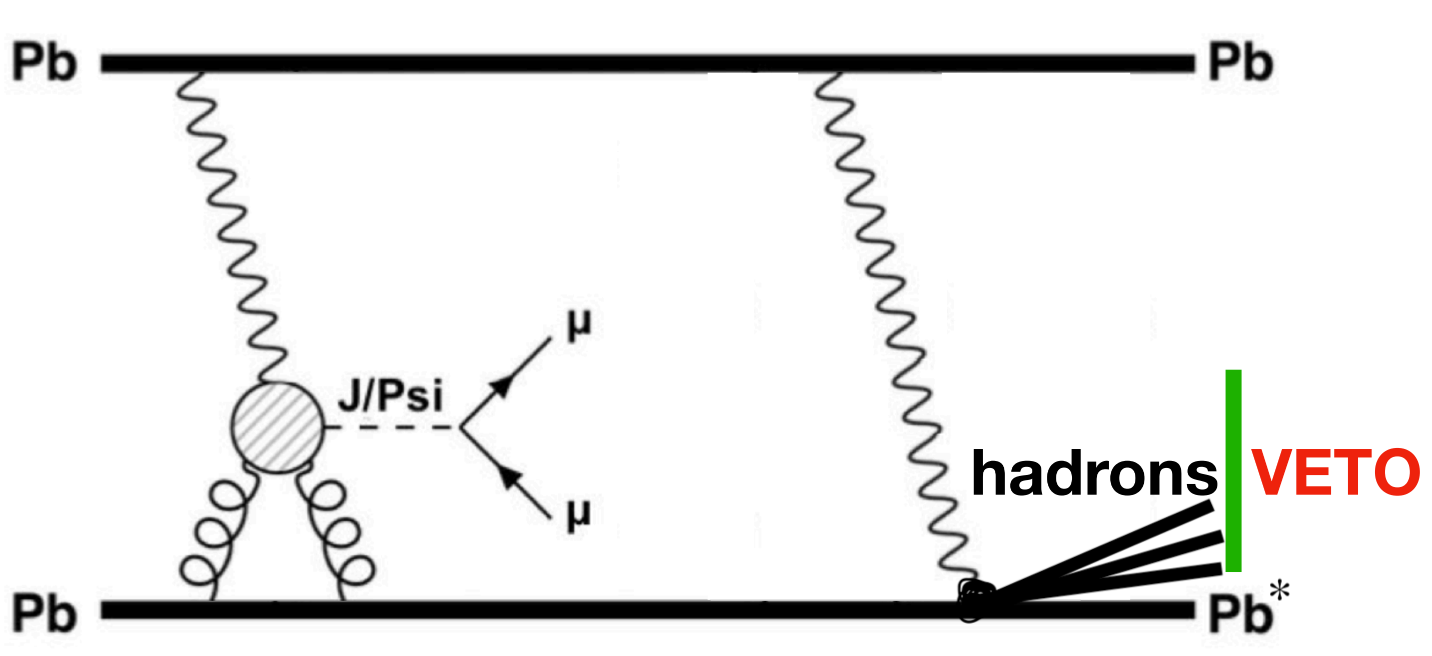
- ATLAS exclusivity veto (UPC J/ψ): no extra charged-particle tracks w/ p_T>100 MeV and $|\eta|$<2.5

- ALICE exclusivity veto (UPC J/ψ): veto on forward counters (V0A, V0C, …) plus some mid-rapidity requirements
  - Let's take V0C as an example: $-3.7<\eta<-1.7$ acceptance. What about its p_T acceptance? Theoretically if it sits at z=-90cm from the IP, assuming B=0.5 T, it should be around **p_T>3.5 MeV (!)** [neglecting material effects]
  - (we know that the cross section for **γγ→ee** process *explodes* at ultra-low p_T's, e.g. SuperChic predicts **σ ~1000 b** for at least one electron in the V0C 'theoretical acceptance')
    → can the signal contribution w/ extra coincident ee pairs be responsible for the observed tension?
    → Dedicated (MC) calculations are needed!

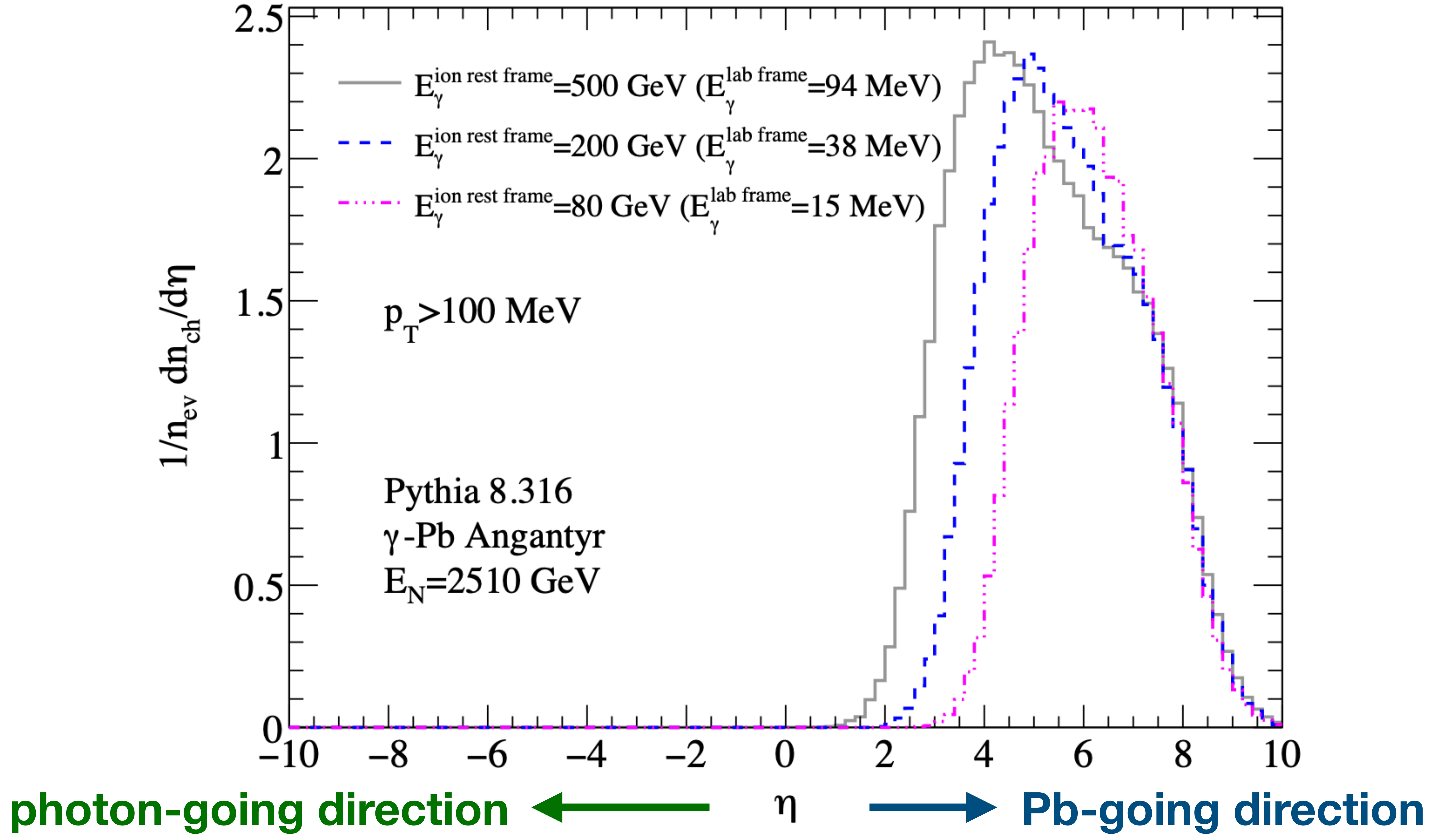


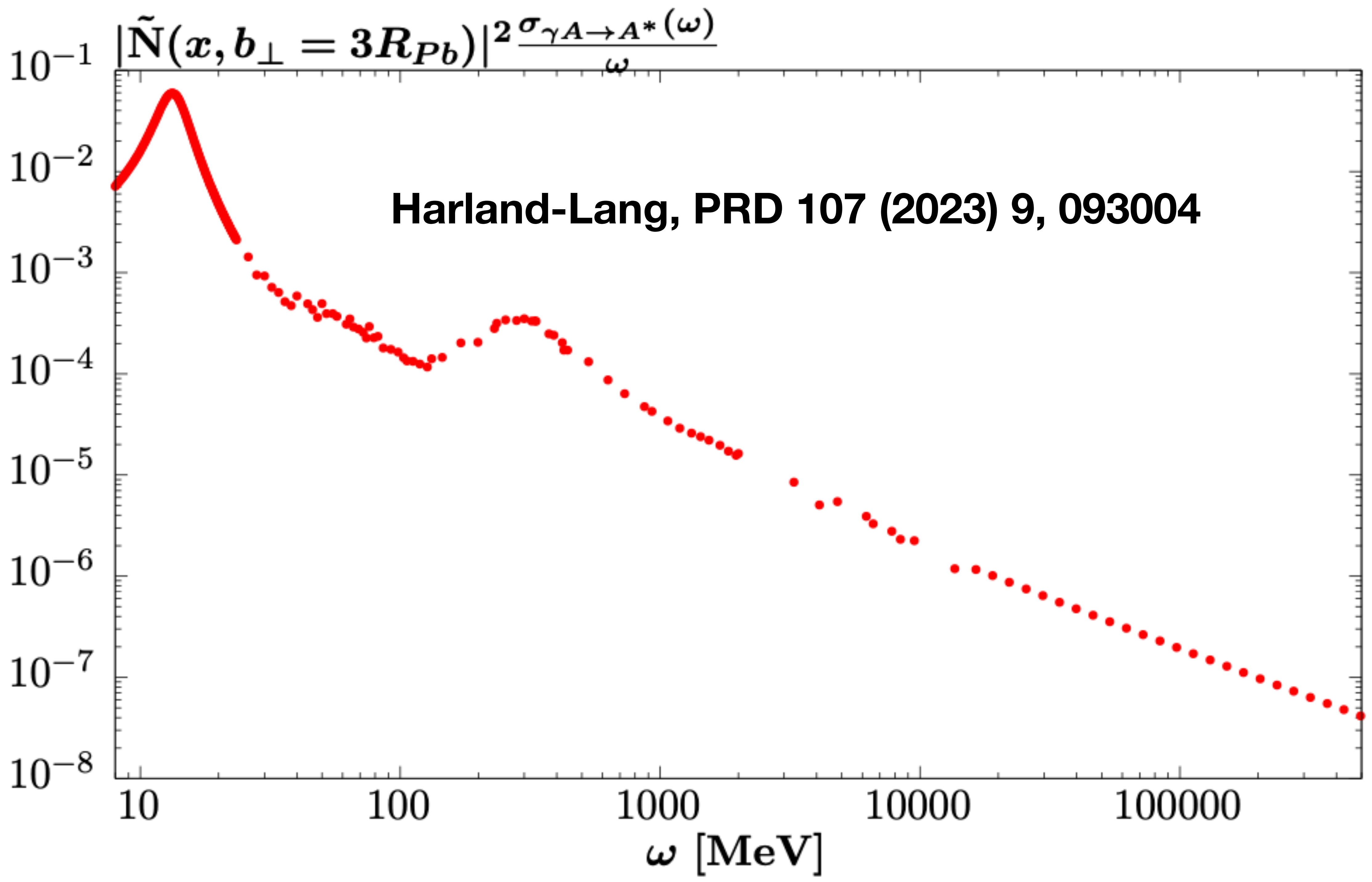
EMD as a coincident process

- What if **hadrons from accompanying EMD** (w/ high-energy photon) can also break the event exclusivity?



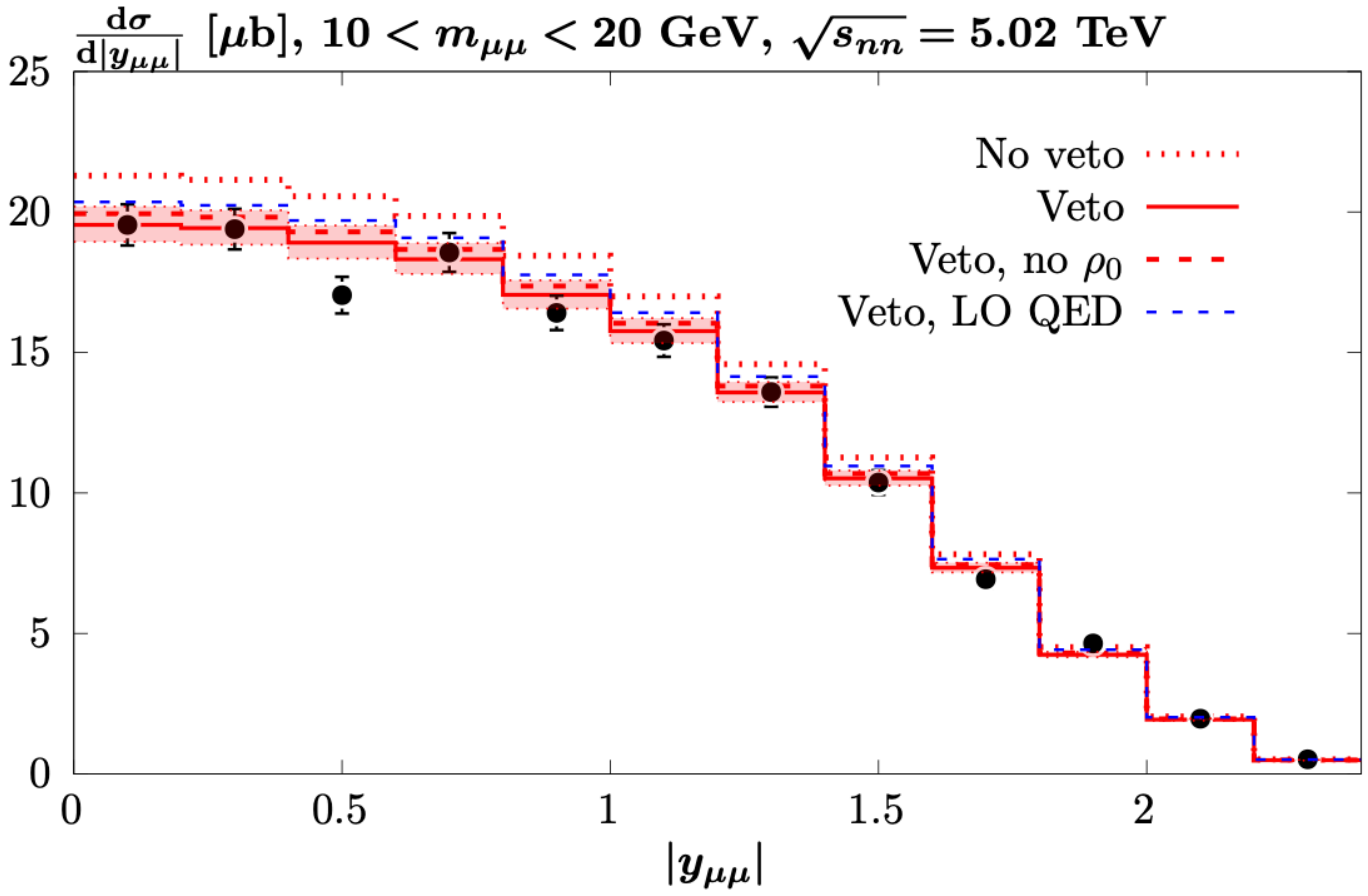
- We can simulate this process by using the existing MC tools (Pythia8+Angantyr) and 'fold it' w/ exclusive process MC model

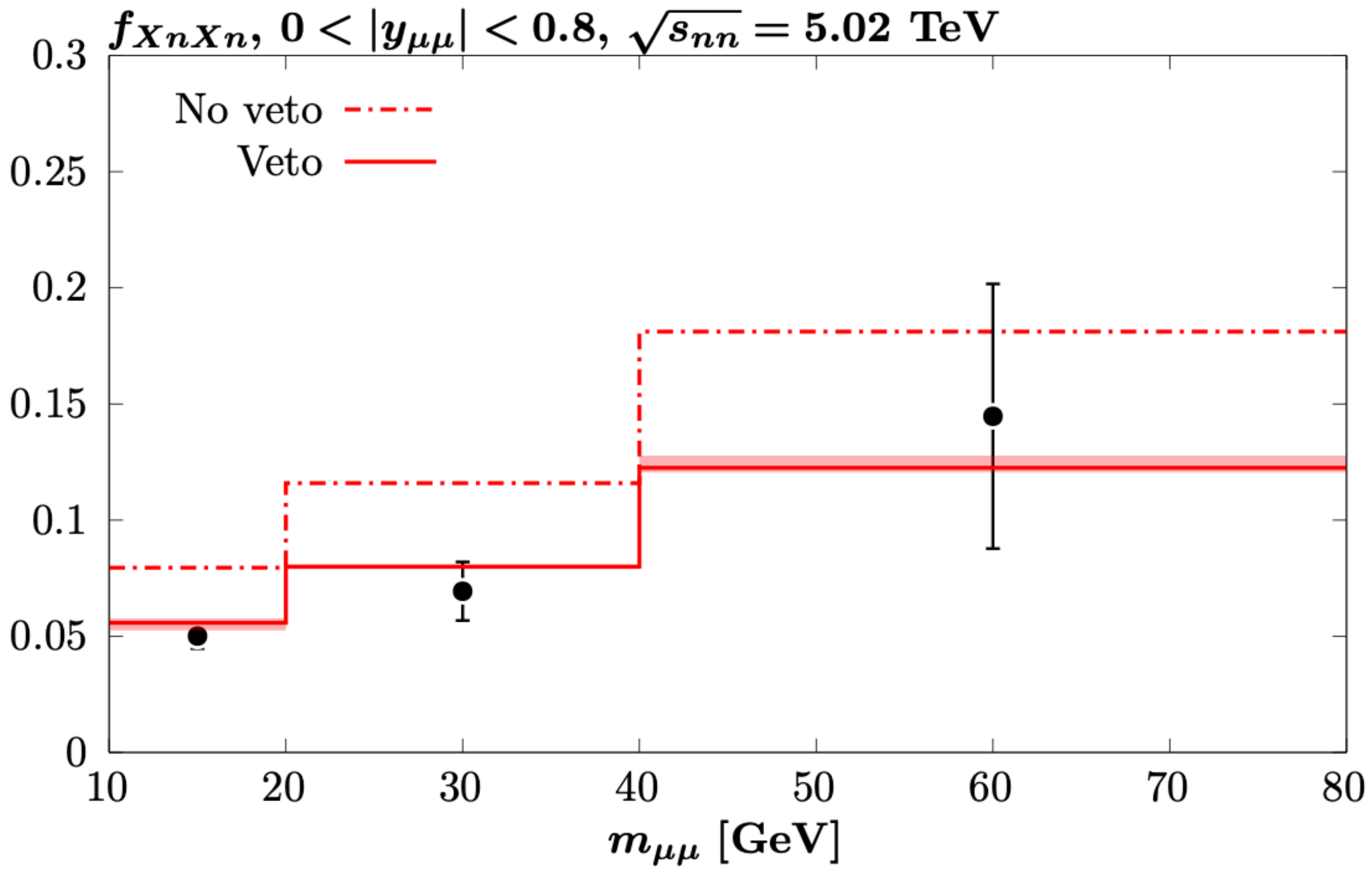




EMD as a coincident process

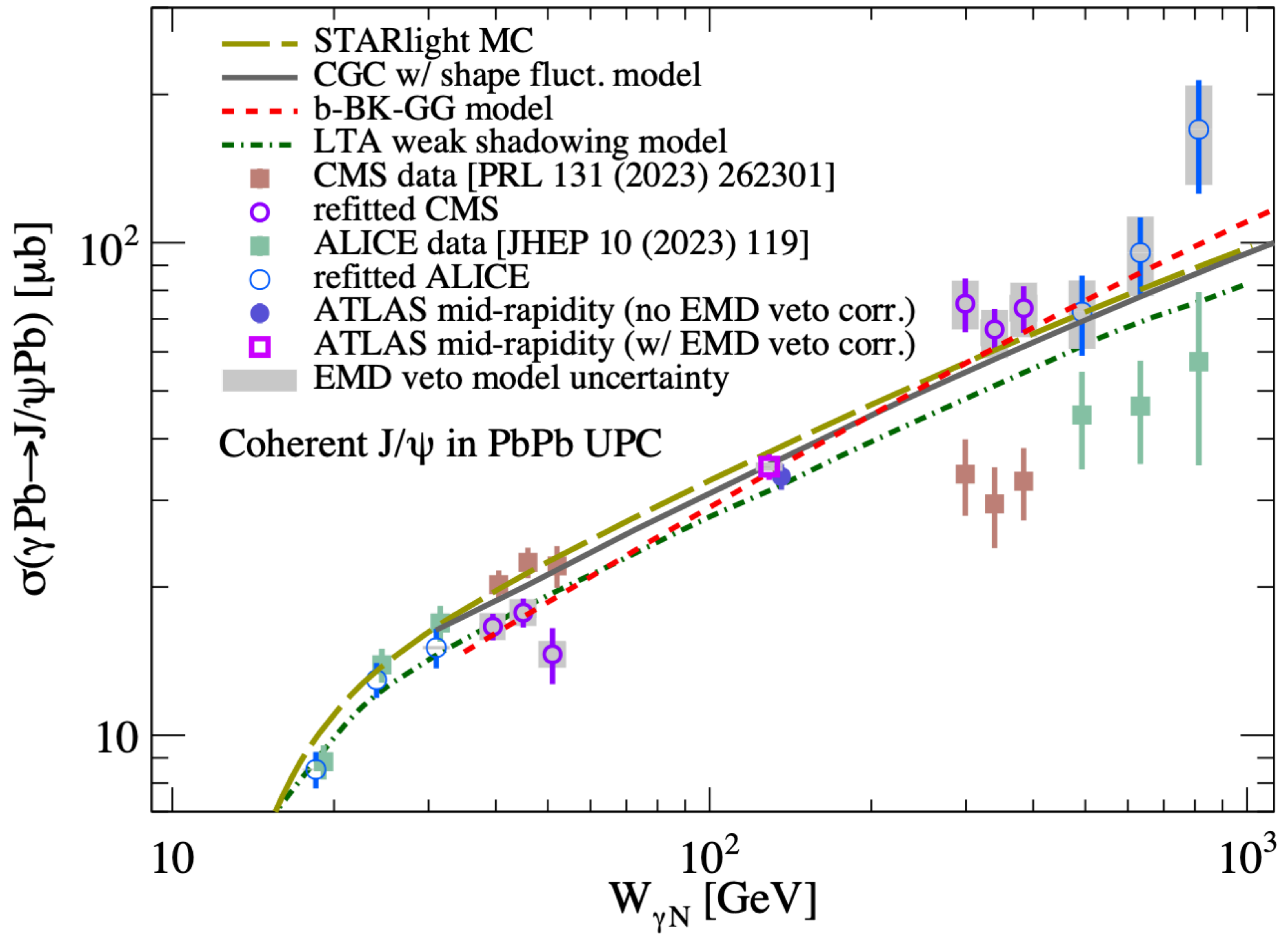
- Impact on ‘standard candle’ high-mass γγ→μμ ATLAS measurement
  - Good agreement w/ SuperChic (w/ NLO QED k-factors), after including *EMD veto* corrections
  - Resolving long-standing tensions :)





EMD as a coincident process

- Impact on LHC coherent exclusive J/ψ measurements
  - CMS and ALICE data re-fitted with modified photon fluxes from STARlight, taking into account exclusivity veto definition of each measurement
  - Large effect, esp. for XnXn fluxes (-50%) → translates directly into high-W behaviour
  - Resolving large data-theory tensions seen w/ the original data
  - Good agreement with b-BK-GG model [Bendova et al., PLB 817 (2021) 136306]
  - See also the impact on CGC-based Bayesian analysis: [arXiv:2606.20362]
  - Similar CMS study for rho0 may be affected in the same way…



EMD as a coincident process

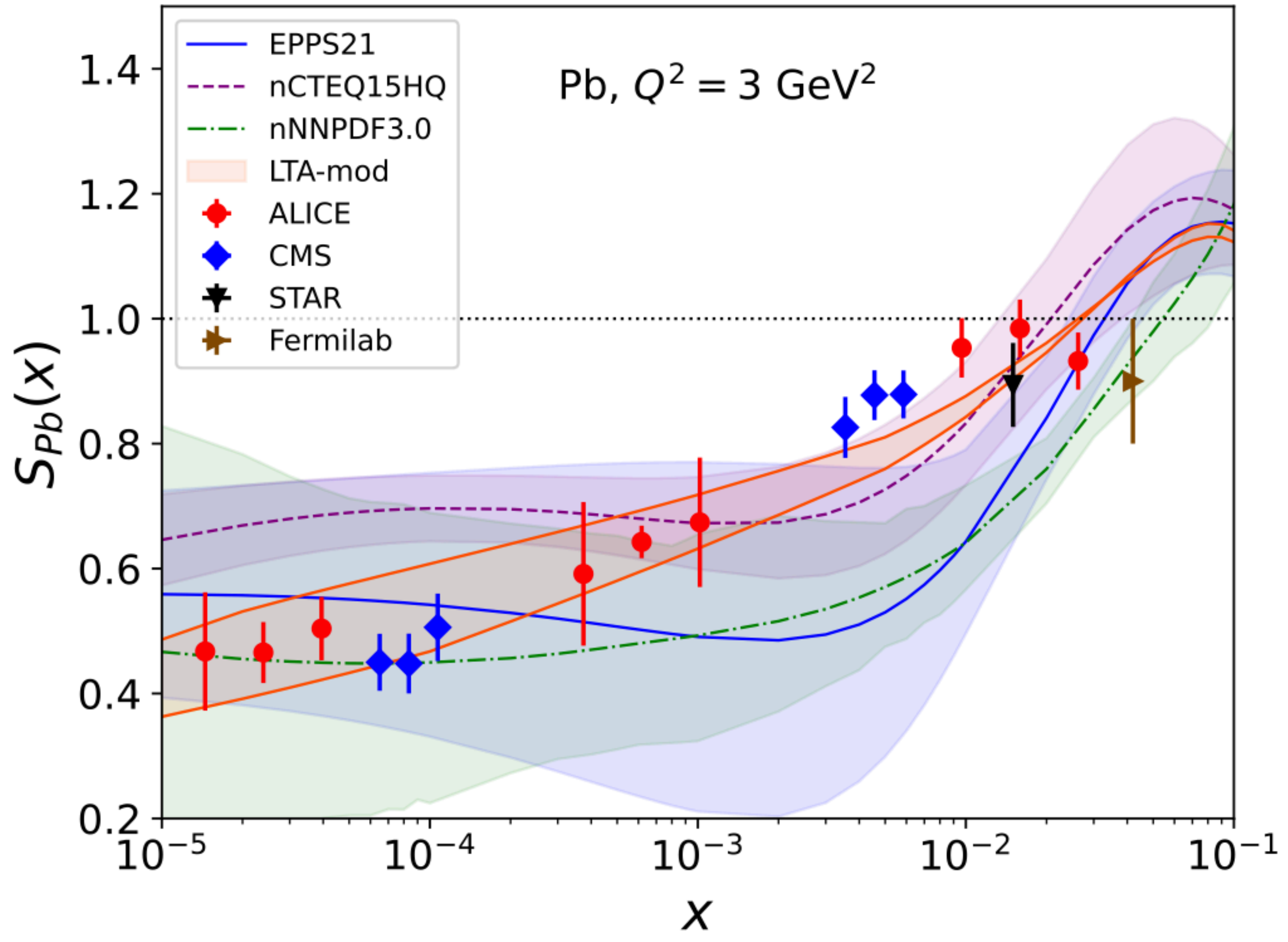
$$S_g(x) = \sqrt{\frac{\sigma(\gamma Pb \to J/\psi Pb)}{\sigma_{IA}(\gamma Pb \to J/\psi Pb)}}$$

- Analysis of nuclear suppression factor for UPC coherent J/ψ

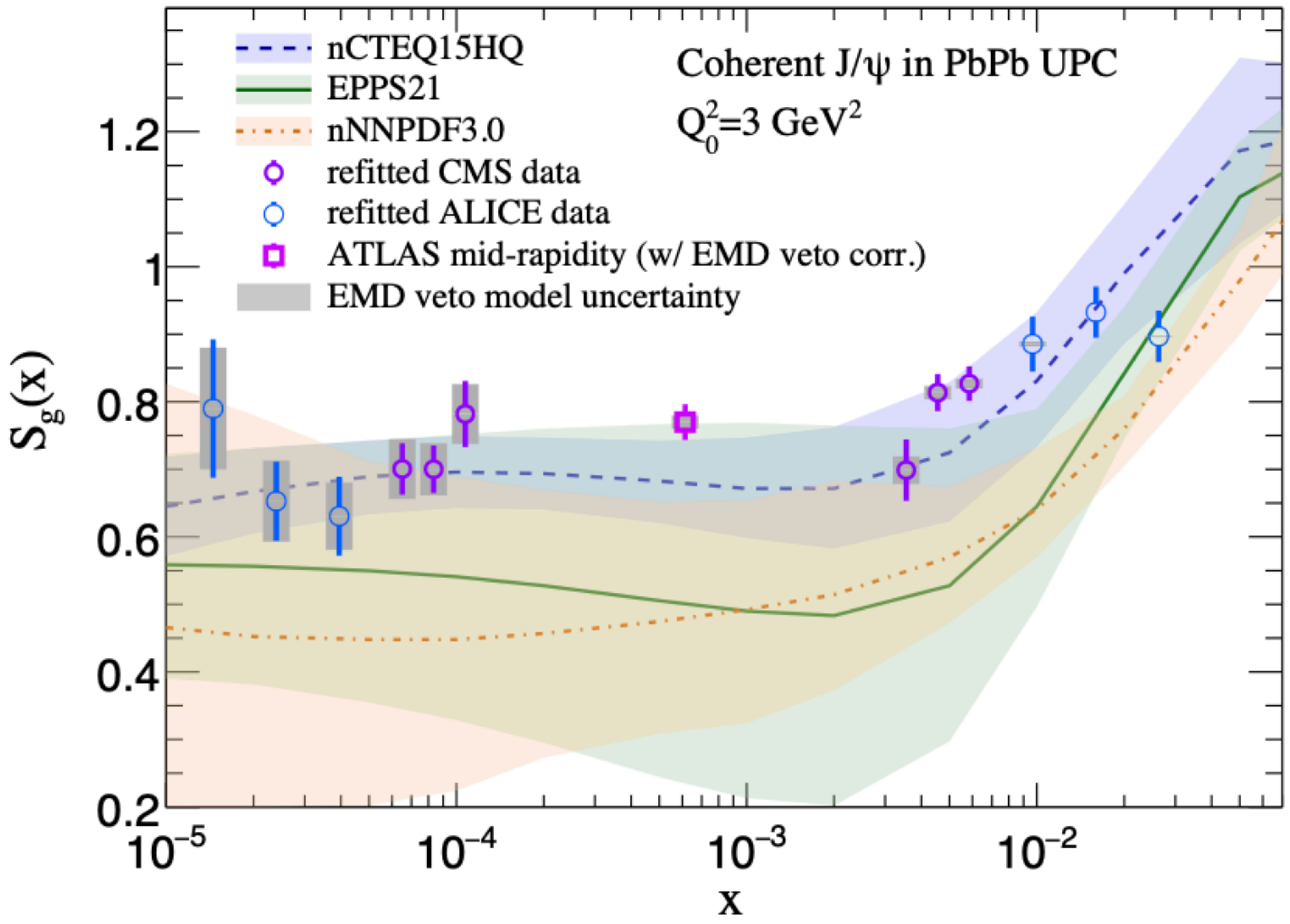
$$\sigma^{\rm IA} = \frac{d\sigma^{\gamma p}}{dt}(t=0)\int_{-t_{\rm min}} dt\, |F(t)|^2$$

  - Good agreement w/ nPDF predictions (NLO) after data corrections, in particular within nCTEQ15HQ's "small uncertainties"

Guzey, Strikman, PRC 110 (2024) 4, 045201 (original data trends)



after EMD veto corrections



Summary

- Coherent J/ψ production in UPC measured for the first time in ATLAS, using Run 3 data
  - Initially meant to be a clean 'demonstrator' for L1TRT trigger performance, but revealed interesting tensions

- The treatment of exclusivity is a physics issue, not merely an experimental background-rejection tool
  - Veto requirements modify the measured observables
    - Particle pairs "elastic contribution" → very sensitive to p_T threshold of the veto (ee pairs)
    - EMD hadrons -> |eta| thresholds are important
  - Associated effects must be modeled consistently for unbiased data–theory comparisons (incl. impact-parameter dependence for the process of interest)
  - This includes cross-experimental comparisons (different veto definitions → we do not measure the same thing at ALICE/CMS/ATLAS/LHCb and those differences start to be visible)
    - Recommendations for experiments and theory to what concern "exclusivity veto fiducial phase-space" needed?

Backup

What coherent rho0 measurements tell us?

- ALICE, JHEP 09 (2015) 095 [Run1, sqrt(s_NN)=2.76 TeV]
  - Coherent rho0:

decorrelated for the comparison. This gives a cross section $d\sigma/dy = 466^{+25}_{-25}$ mb for the sample taken with the TOF only trigger and $d\sigma/dy = 414^{+14}_{-16}$ mb for the sample taken with the SPD+TOF+VZERO

  - Exclusive yy->ee:

selection in invariant mass and pseudorapidity ($\sigma = 9.7$ mb). The cross sections for the individual trigger samples are $11.8 \pm 1.6\,(\text{stat.})^{+1.1}_{-1.4}\,(\text{syst.})$ mb (TOF only trigger) and $9.4 \pm 0.7\,(\text{stat.})^{+0.9}_{-1.1}\,(\text{syst.})$ mb (SPD+TOF+VZERO trigger).

What coherent rho0 measurements tell us?

- Coherent rho0 at 5.02/5.36 TeV
- AnAn cross sections "agree", but:
  - dsigma/dy (prelim. CMS, XnXn) ~ 13 mb
  - dsigma/dy (ALICE, XnXn) ~ 25 mb (https://arxiv.org/pdf/2002.10897)
  - dsigma/dy (prelim. CMS, 0nXn) ~ 70 mb
  - dsigma/dy (ALICE, 0nXn) ~ 90 mb (https://arxiv.org/pdf/2002.10897)