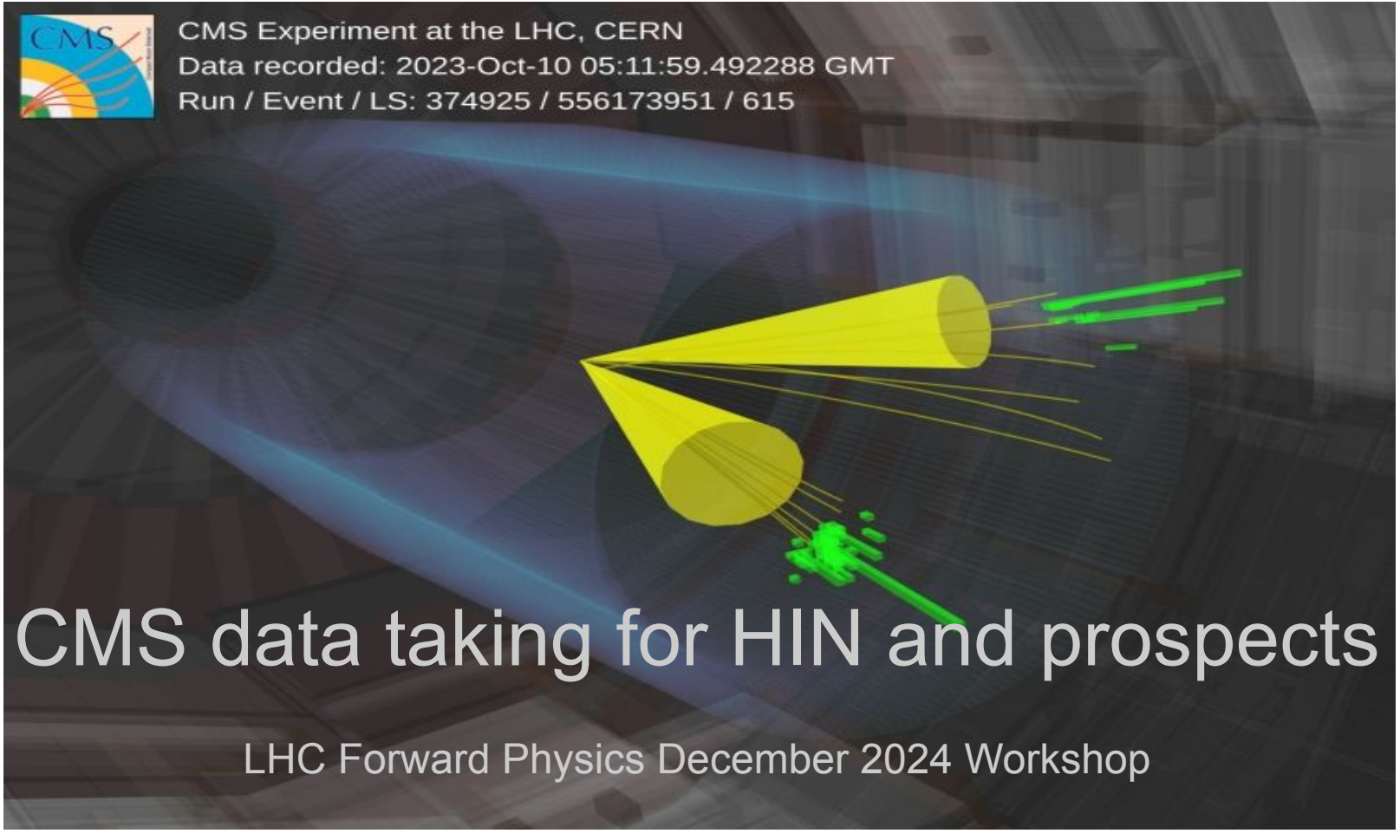


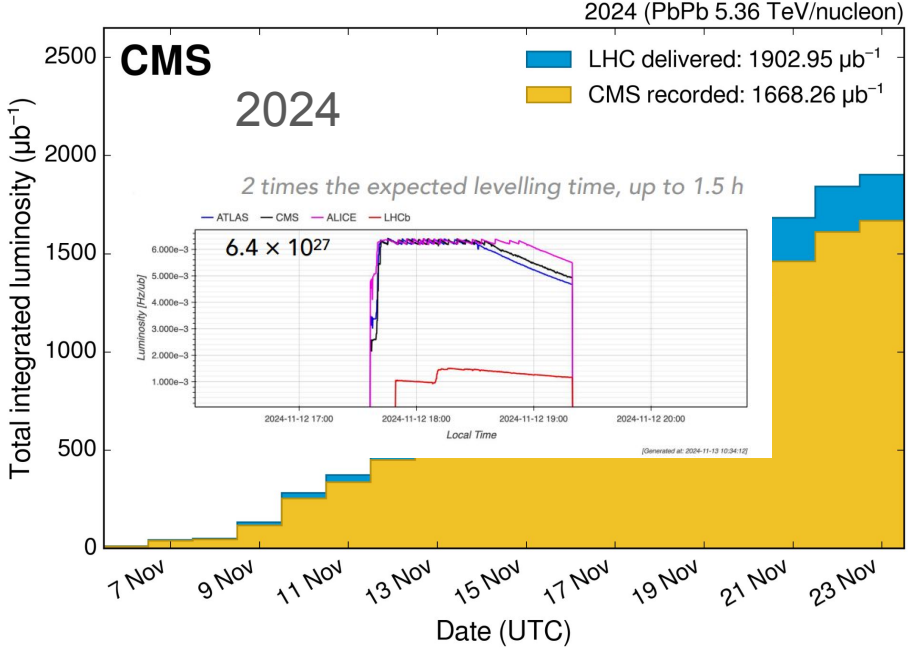
CMS data taking for HIN and prospects

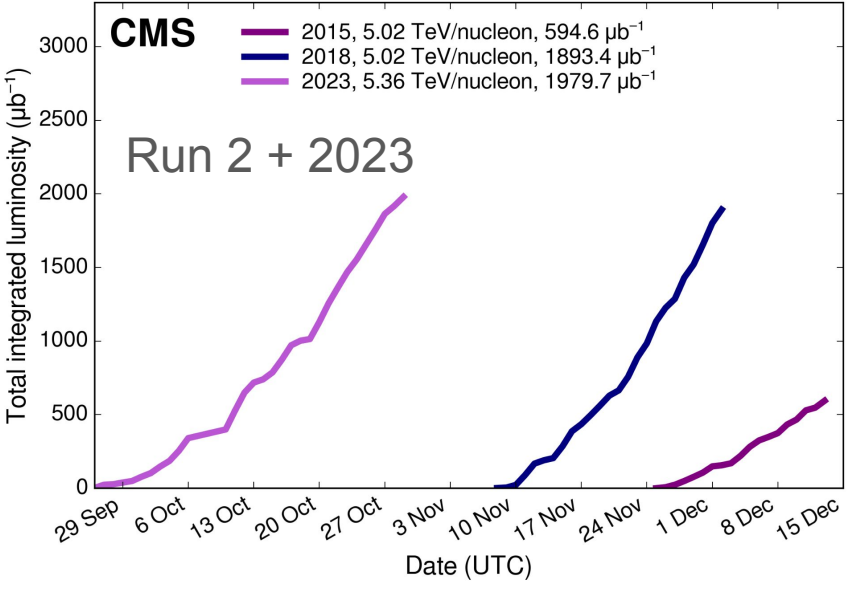
LHC Forward Physics December 2024 Workshop

PbPb Runs 2 and 3

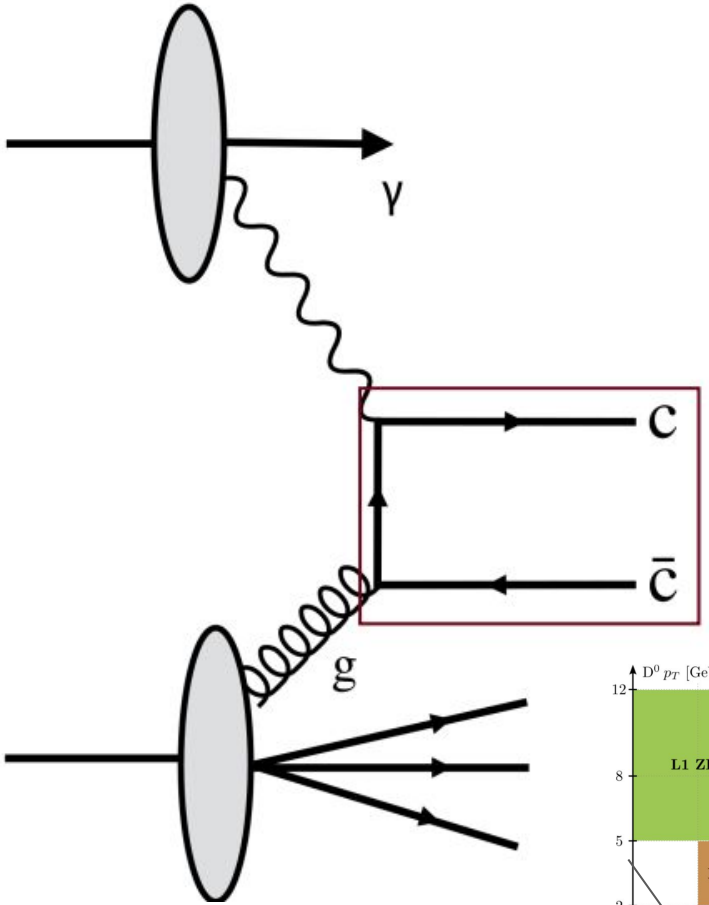
Bumpy but another successful PbPb run in 2024

- Less than three weeks of data taking
- Machine performance better than last year
- Run 3 lumi > 1.5 × Run 2 lumi

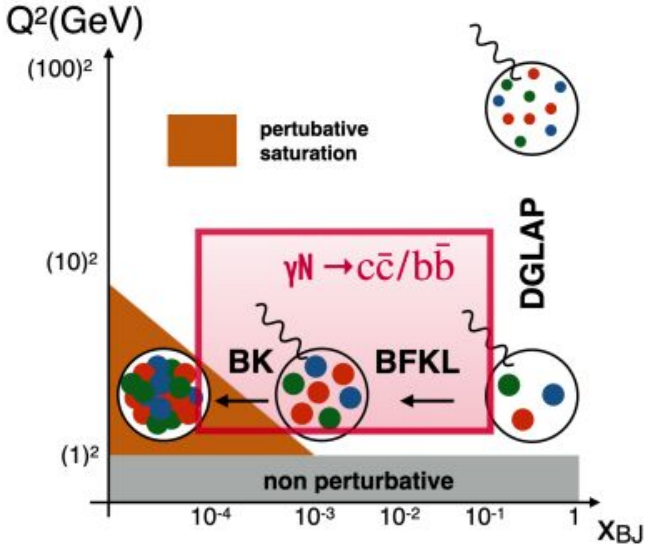


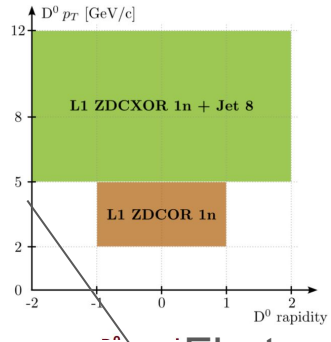


Open Heavy Flavor in UPCs



- Mass of charm gives perturbative control down to p_T 0
- Probes $Q^2 \sim$ charm/bottom mass
- Probes x from anti-shadowing, to shadowing and potentially saturation regimes!



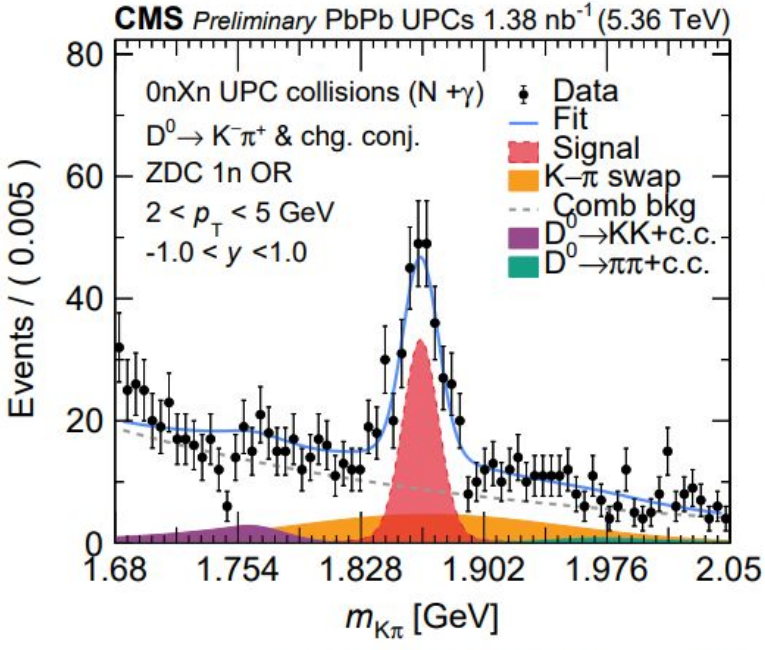


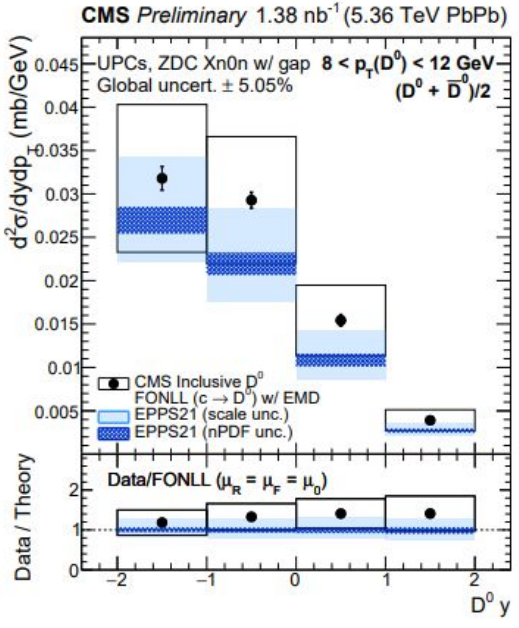
First measurement at LHC

Possible thanks to ZDC inclusion at L1 trigger

CMS-PAS-HIN-24-003

Exceptionally clean events!

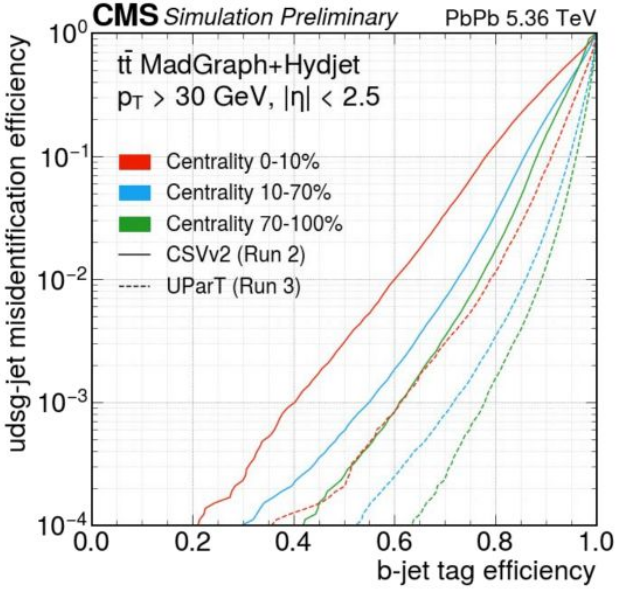


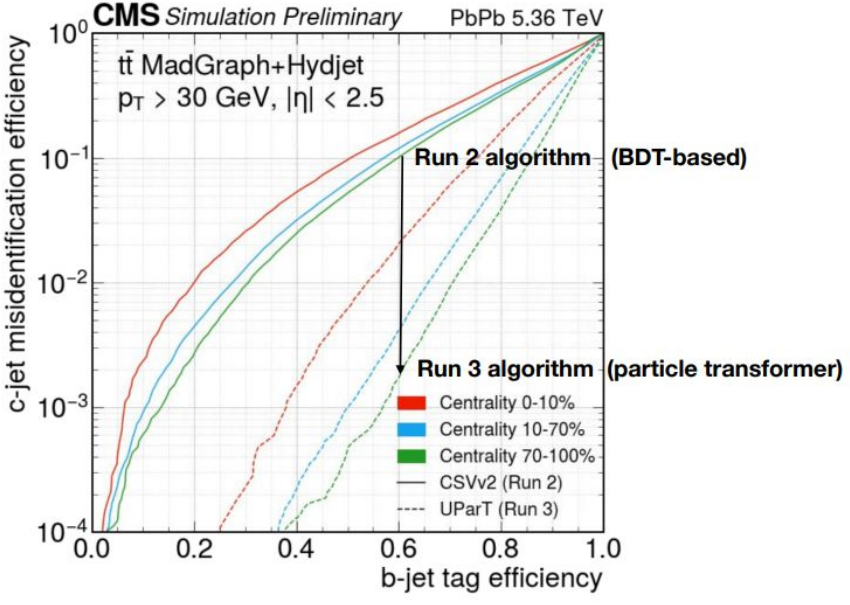


- **First measurement of UPC D^0 differential cross sections at the LHC**
- **New sensitivity to nPDFs over a broad x with a pQCD controlled probe**
- **Opening a new program at CMS**

CMS-DP-2024-088

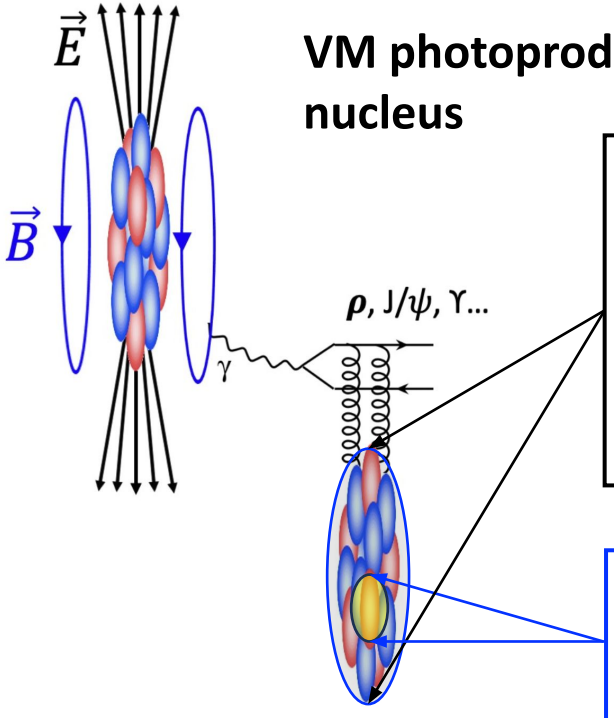
B-tagging performance in 2023 PbPb data





Significantly improved b-jet tagging performance in Run 3 (2023) PbPb collisions compared with Run 2

Vector Meson Photoproduction in UPCs



VM photoproduction is sensitive to the gluonic structure of target nucleus

Coherent photoproduction:

- Photon **interact with entire nucleus**
- **Target** nucleus remains **intact**
- VM $\langle p_T \rangle$ ~ **50 MeV**
- Probing the **averaged gluon density**

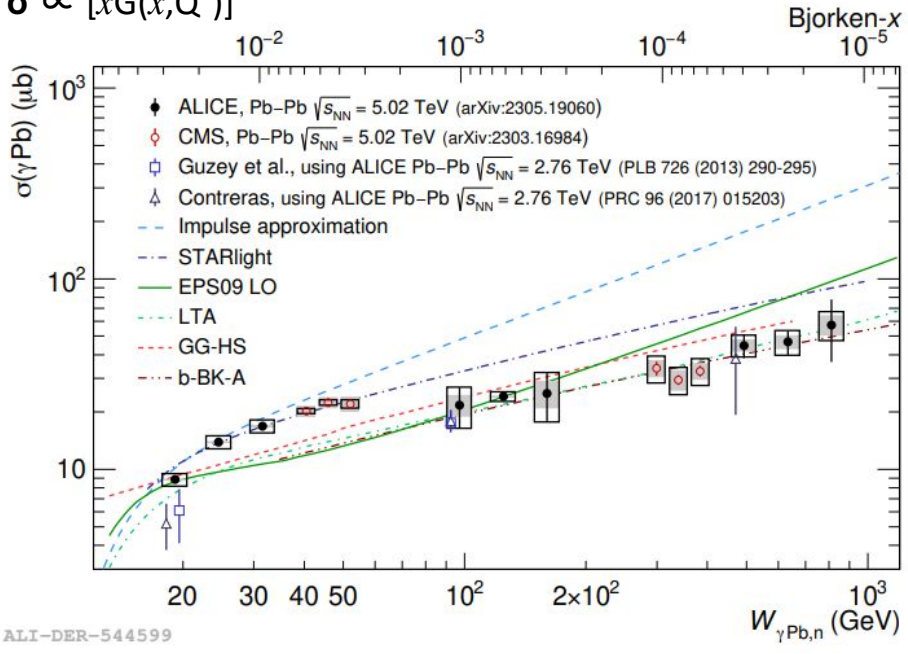
Incoherent photoproduction:

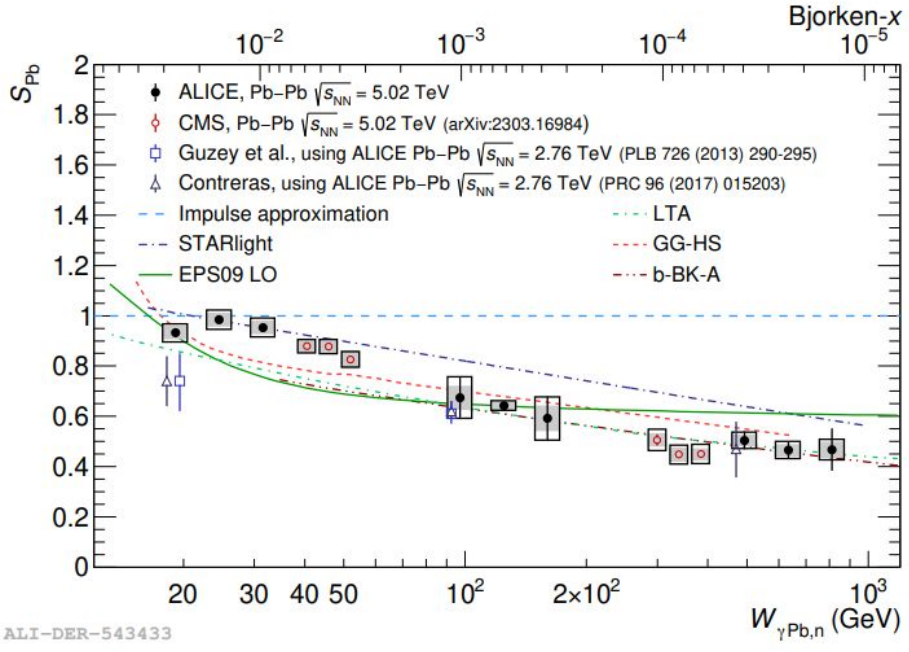
- Photon interact with **individual nucleon** or **sub-nucleon**
- **Target** nucleus usually **breaks**
- VM $\langle p_T \rangle$ ~ **500 MeV**
- Probing the **local gluon density** and **fluctuations**

Recent coh. J/ψ photoproduction off Pb nucleus

$$S^{J/\psi} = \frac{\sigma^{exp}_{\gamma Pb \to J/\psi Pb'}}{\sigma^{IA}_{\gamma Pb \to J/\psi Pb'}}$$

$\sigma \propto [xG(x,Q^2)]^2$

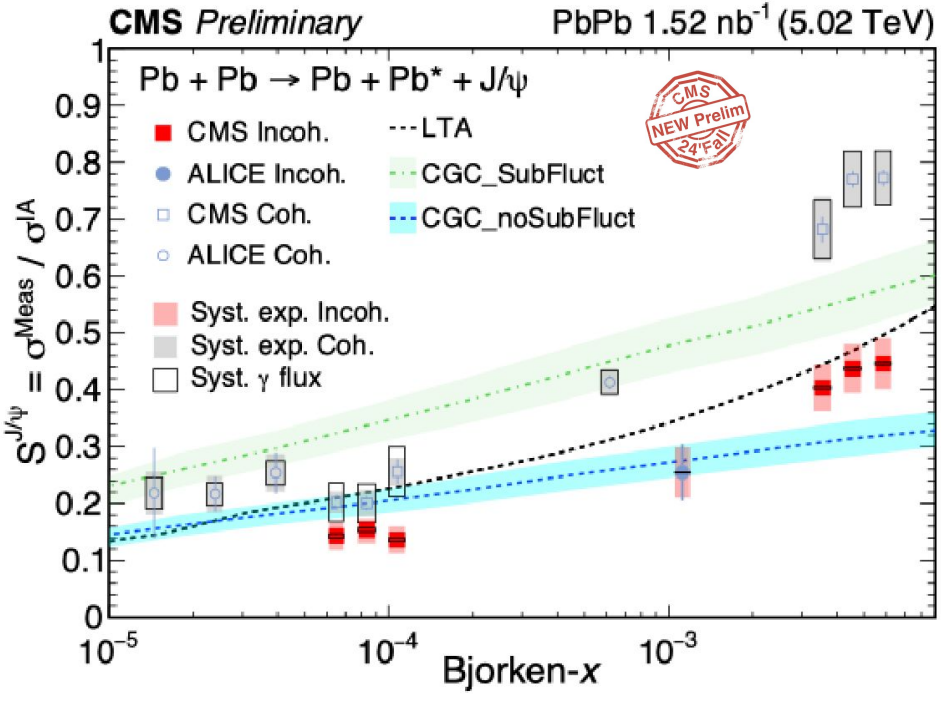




Saturated cross section?

Strongly suppressed gluon density (see also J. Penttala, C. Royon)

Nuclear Suppression



$$S^{J/\psi} = \frac{\sigma^{exp}_{\gamma Pb \to J/\psi Pb'}}{\sigma^{IA}_{\gamma Pb \to J/\psi Pb'}}$$

No nuclear effects

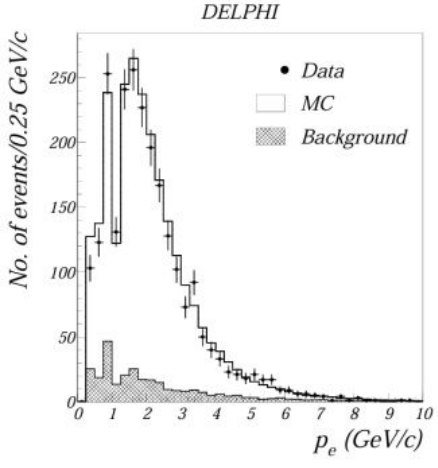
- Stronger suppression towards lower x, and eventually flattens out
- ALICE data follows CMS data trend
- Incoh. J/Ψ is more suppressed than Coh. J/Ψ
- Incoh. J/Ψ gets closer to Coh J/Ψ for $x<10^{-4}$
- No model can describe the data

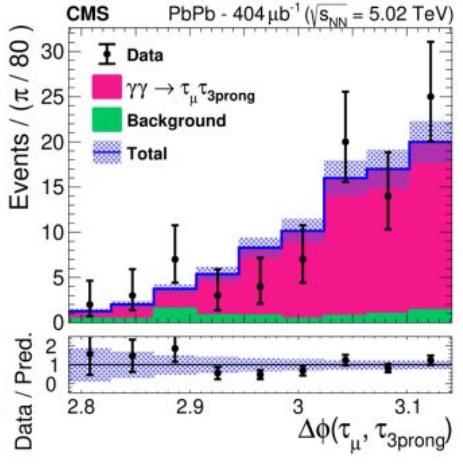
CMS-PAS-HIN-23-009 Coh: CMS, PRL 131, 26201 (2023); ALICE, JHEP 10, (2023) 119

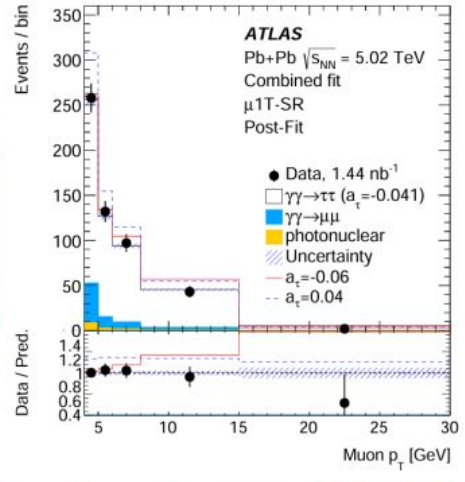
$$S^{J/\psi}_{coh}(x, \mu^2) = (R_g)^2$$

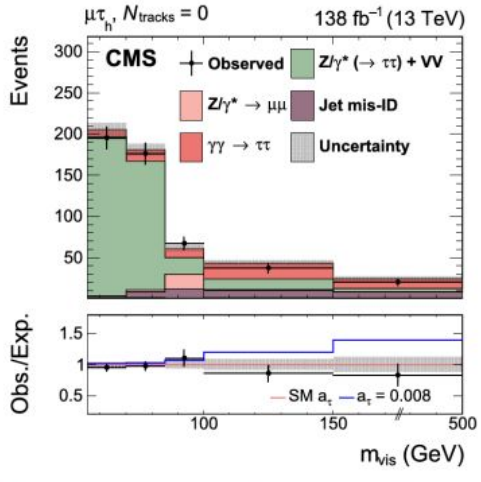
$\gamma\gamma \rightarrow \tau\tau$ to measure a_τ

- DELPHI had the best measurement of a_τ for 21 years.
- First LHC observations by CMS (2015 data) and ATLAS (2018 data) in PbPb
- CMS measurement in pp improved the previous best a_τ measurement by ATLAS & DELPHI by exploiting the high a_τ sensitivity in high $\tau\tau$ mass







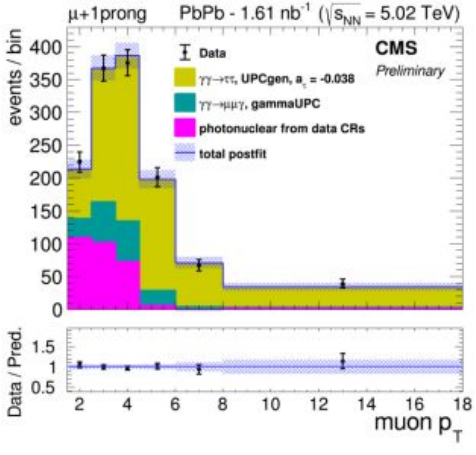


Eur.Phys.J.C 35 (2004) 159-170 | Phys. Rev. Lett. **131**, 151803 | Phys. Rev. Lett. **131**, 151802 | Rep. Prog. Phys. 87 107801

Kinematics consistent with signal

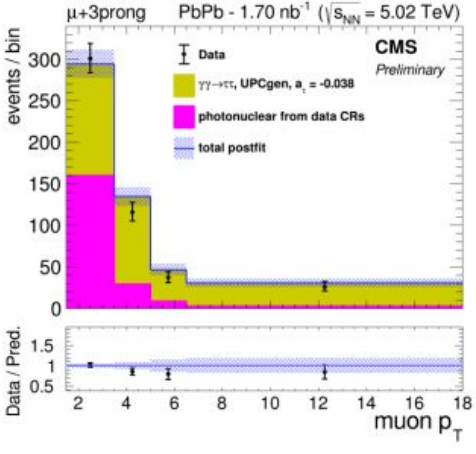
CMS-PAS-HIN-24-011

- Signal: $\gamma\gamma \rightarrow \tau\tau$ generated with UPCgen
- Signal stacked on top of background(s), compared to data
- Good agreement between data and the signal+background model

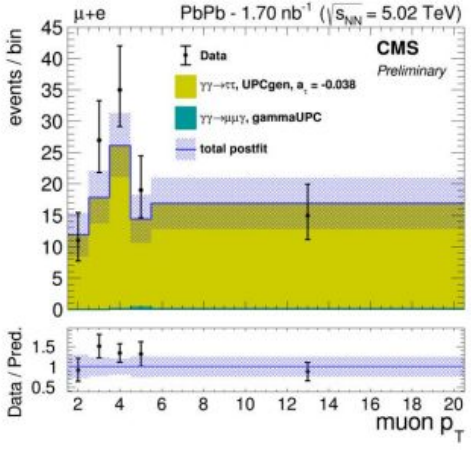


μ+1prong

(most a_τ sensitivity)

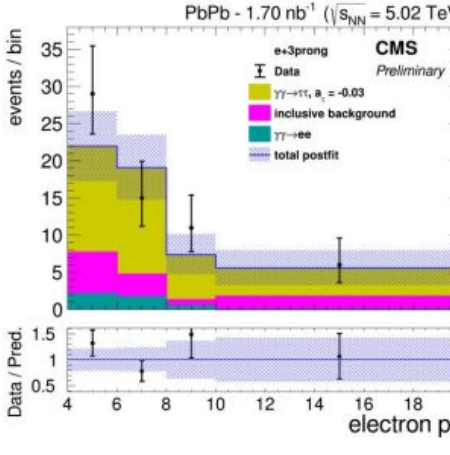


μ+3prong



μ+e

(cleanest)

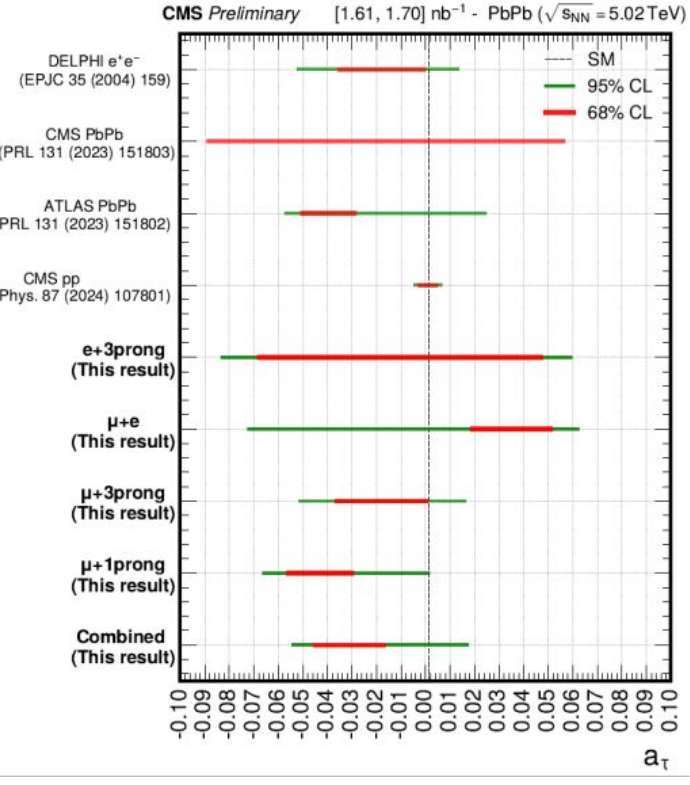


e+3prong

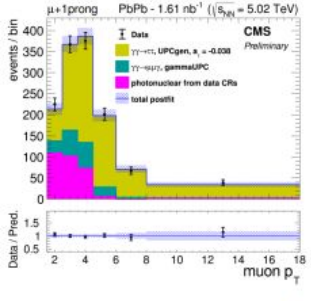
A dedicated a_τ program in CMS

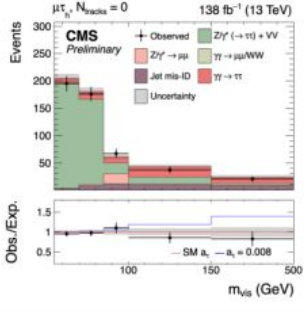
- Precision measurement of a_τ at CMS in three complementary phase spaces
- $a_\tau = -35^{+11(stat)+18(stat+sys)}_{-3(stat)-10(stat+sys)} \times 10^{-3}$
- The most precise measurement of $\gamma\gamma \to \tau\tau$ cross section.
  - $\sigma_{fiducual}(ub) = 447^{+18(stat)+16(stat+sys)}_{-5(stat)-11(stat+sys)}$

CMS-PAS-HIN-24-011



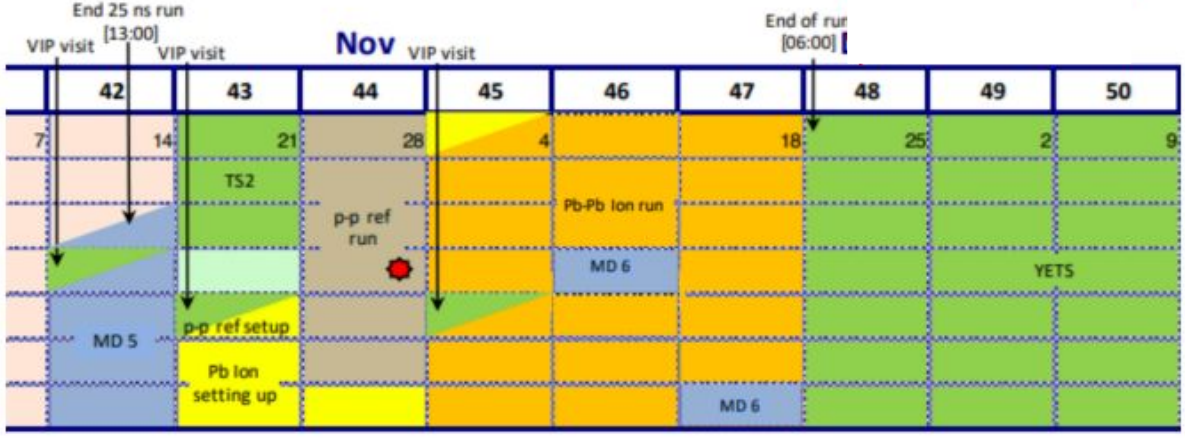
- Heavy ion runs
- pp runs with track counting
- pp runs with proton tagging





PPS approved for Run-4

2024, a year not to be missed for the HIN program!



First (and single?) proton-proton ``reference" data taking of Run 3

☛ initial target: 60 pb^{-1} per nb^{-1} of PbPb data

☛ reduced to 50 pb^{-1} per nb^{-1} of PbPb data

Second campaign of PbPb data taking

☛ goal: recording *all* hadronic interactions (`minimum-bias" events) + always larger samples of ultraperipheral collisions (UPC)

Data Collected

- Total: **33.72 B** events
- MB+HP (RAW'): **15.11 B** events
- UPC (RAW): **17.98 B** events

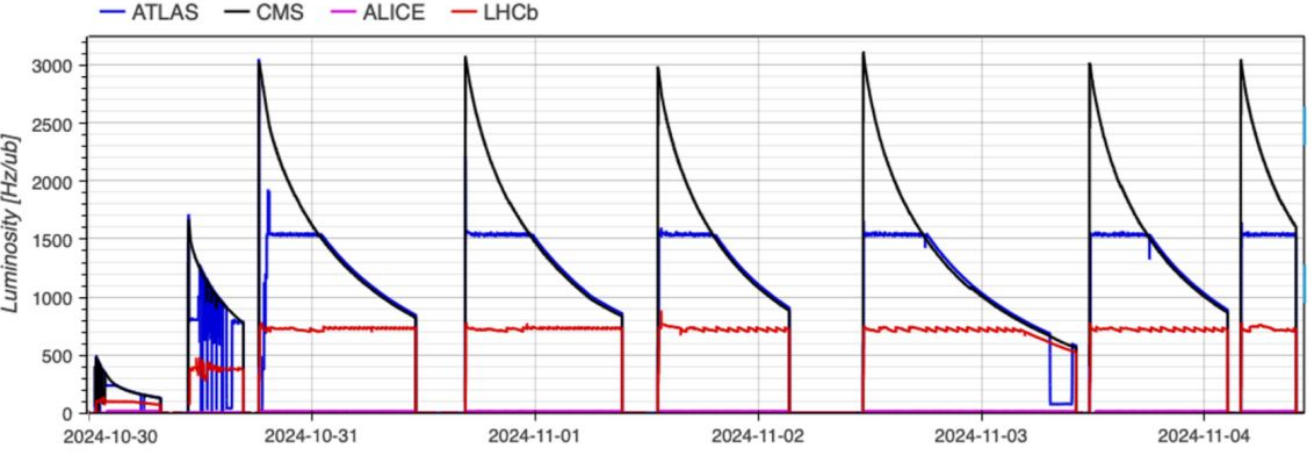
pp reference run

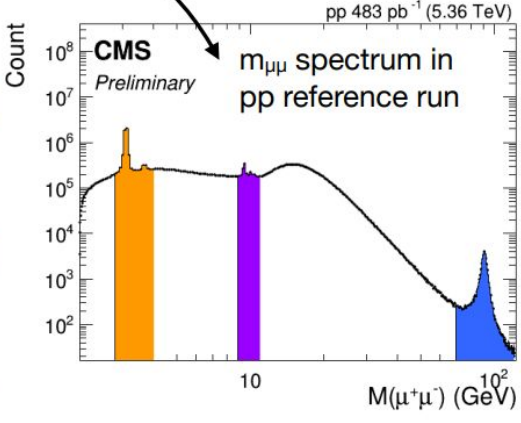
Very efficient pp reference run at 5.36 TeV and smooth VdM session

Long fills starting at PU=8 and then decaying to PU 1-2

For CMS, half the fill duration would have been optimal

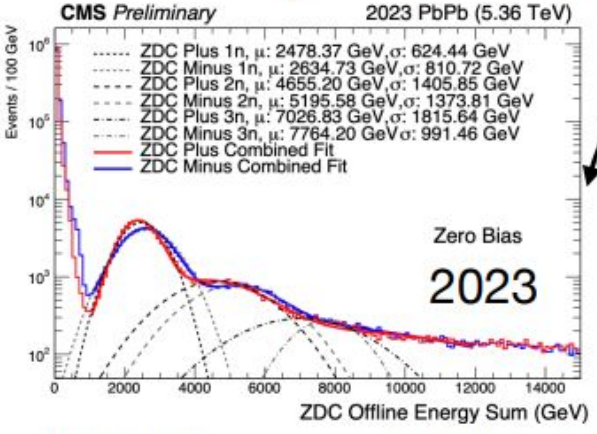
520 pb^{-1} delivered to CMS, **92.3%** efficiency (~480 pb^{-1} recorded)

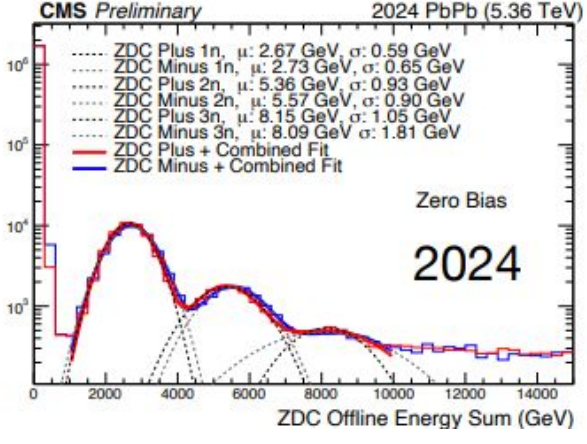




Included ZDC too

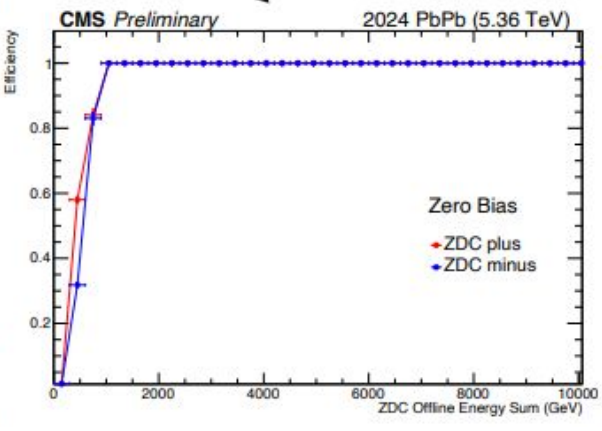
PbPb performance in 2024

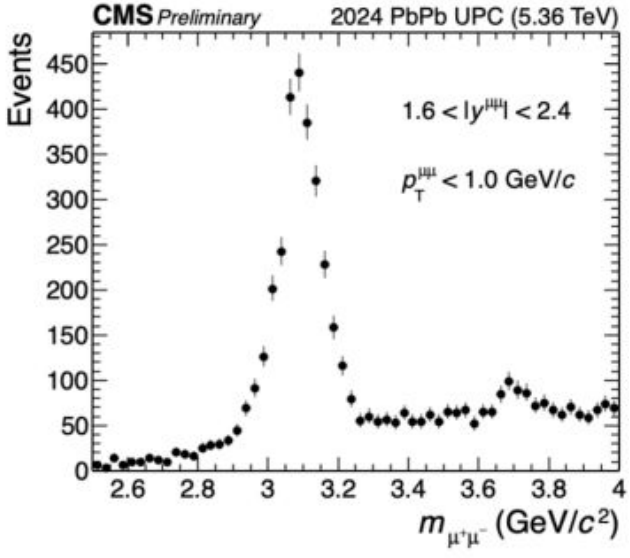




Much better ZDC performance compared with 2023

Minimum-bias trigger efficiency significantly improved





$m_{\mu\mu}$ performance in ultra-peripheral collisions

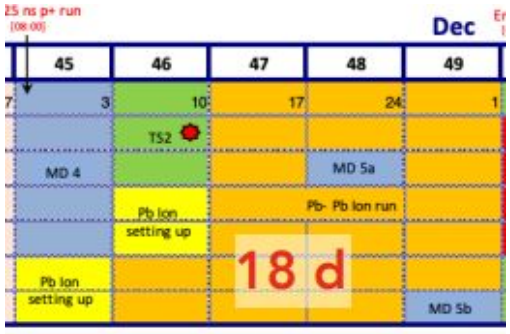
Outlook

- Almost 15 new physics results released by CMS since the last workshop
  - 3 related to forward physics
  - 1 to CERN News (D^0 photoproduction in PbPb, Run 3 data)

- Successful year both for ppref and PbPb
  - the largest ppref sample so far (~0.5 /fb)
  - Run 3 lumi > 1.5 × Run 2 lumi

- Preparing for 2025 and 2026
  - 1.8 (2025) + 1.8 (2026) /nb (optimistic: +50%) → Total Run 3: ~7 / nb
  - OO and pO in July 2025 (low-mass VMs in UPC possible)

All HIN results here



2025

2026