



ALICE

# UPC physics with ALICE in Run 3

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The University of Kansas

**UPC 2023: International workshop on the physics of  
Ultra Peripheral Collisions  
Playa del Carmen  
15/12/2023**



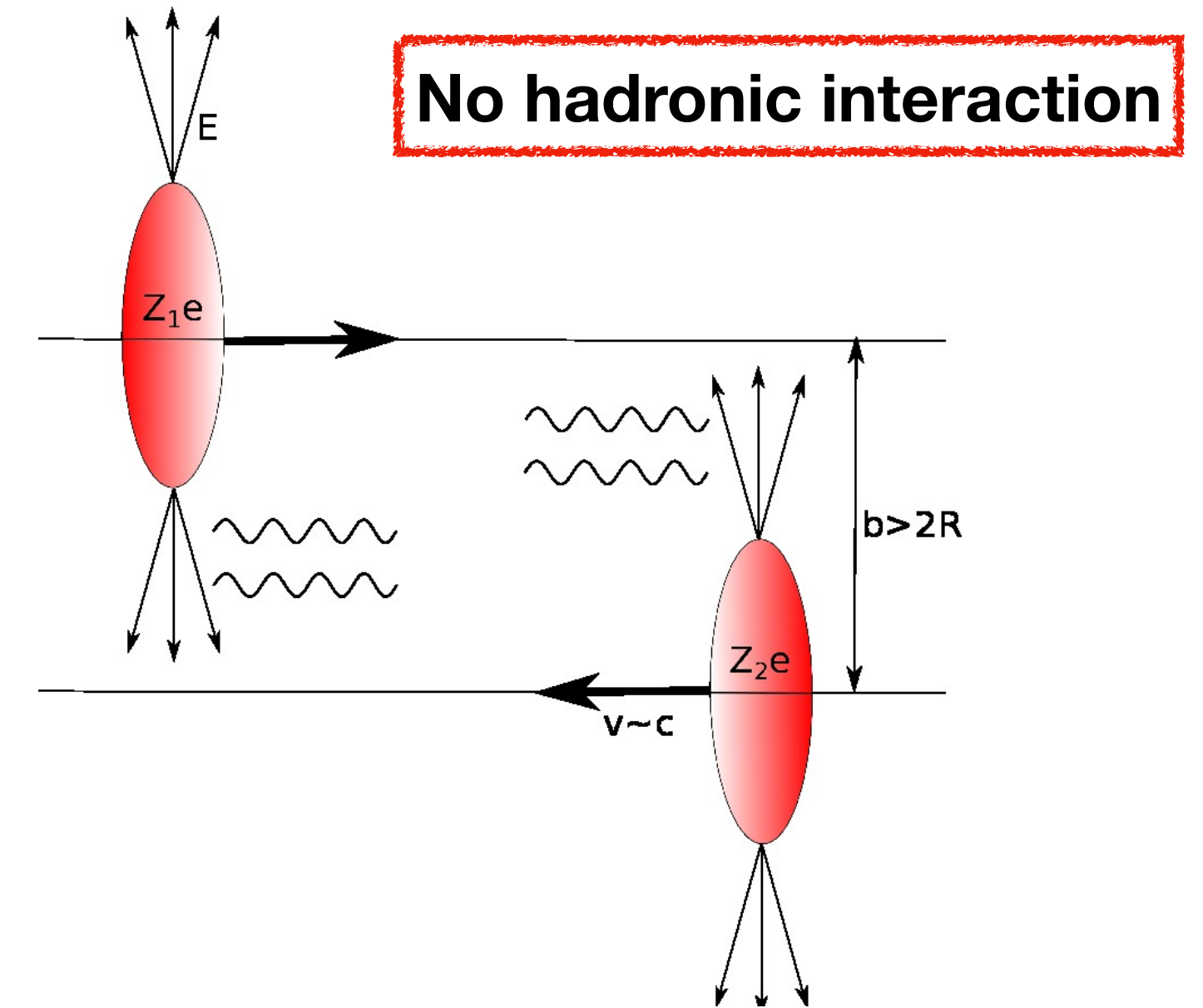
U.S. DEPARTMENT OF  
**ENERGY**

Office of Science



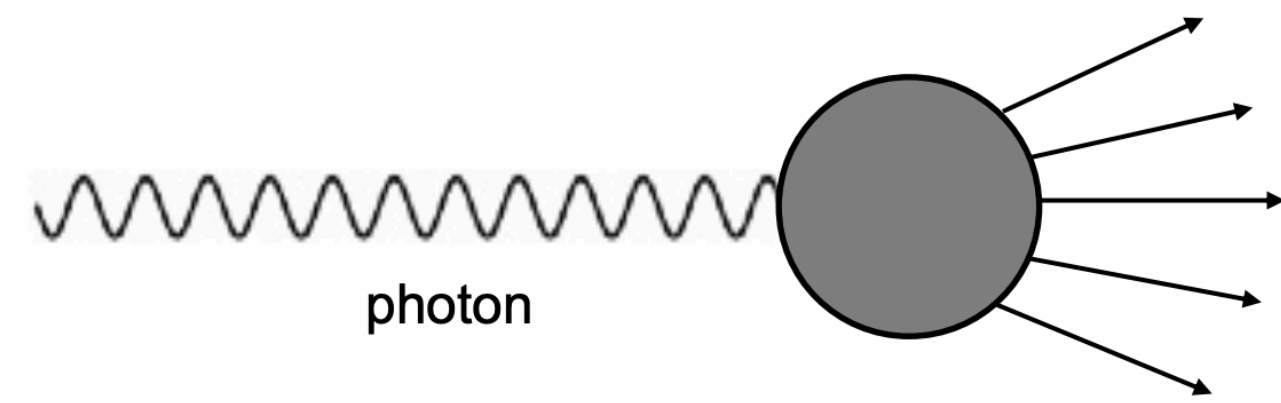
**KU** THE UNIVERSITY OF  
KANSAS

- ✓ Ultra-Peripheral Collisions (UPCs) provide a tool to probe the nucleus and nucleons
- ✓ ALICE is developing a comprehensive physics program [ALICE, [arXiv:2211.04384](https://arxiv.org/abs/2211.04384)]
- ✓ Unique in ALICE: Good acceptance for both charged particles, photons at low  $p_T$  and excellent particle identification at midrapidity
- ✓ Run 3 opens a new window to explore novel physics processes

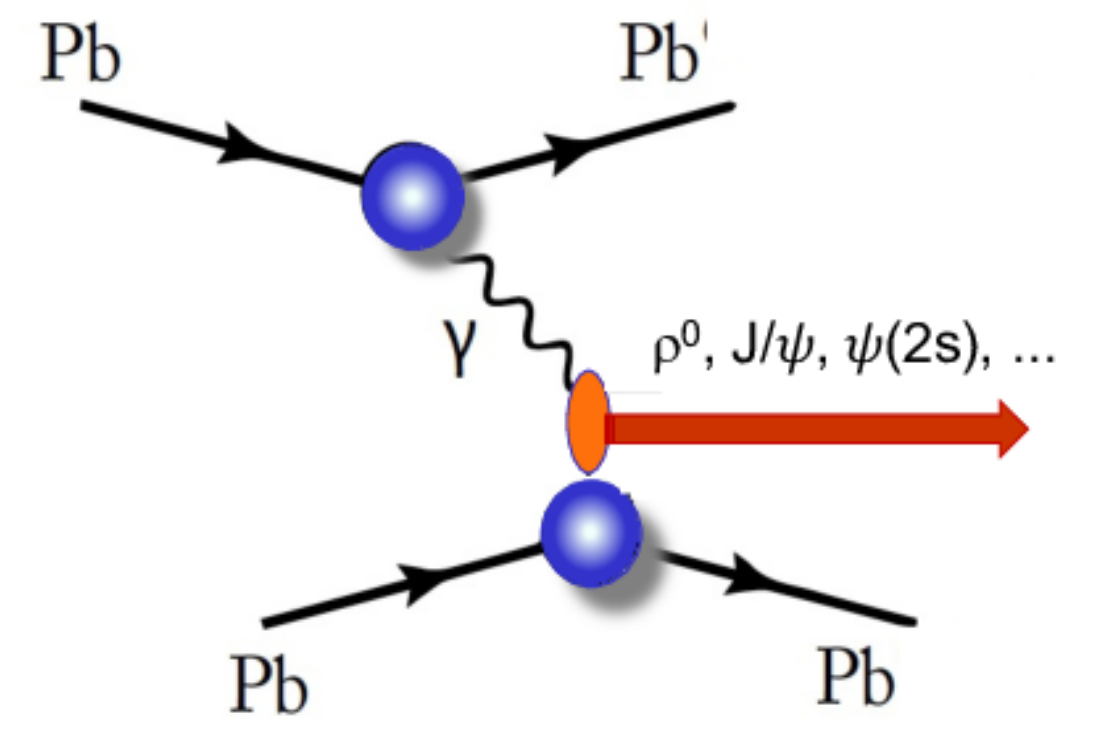


Ions still interact via electromagnetic processes

Photon breaks up target nuclei



Typical exclusive VM production in UPC



# The ALICE experiment in Run 3

FT0-A :  $3.8 < \eta < 5.0$

FT0-C :  $-3.4 < \eta < -2.3$

FV0 :  $2.2 < \eta < 5.0$

FDD-A :  $4.7 < \eta < 6.3$

FDD-C :  $-6.9 < \eta < -4.9$

**ZDC**  
Zero Degree  
Calorimeter

ITS :  $-1.22 < \eta < 1.22$

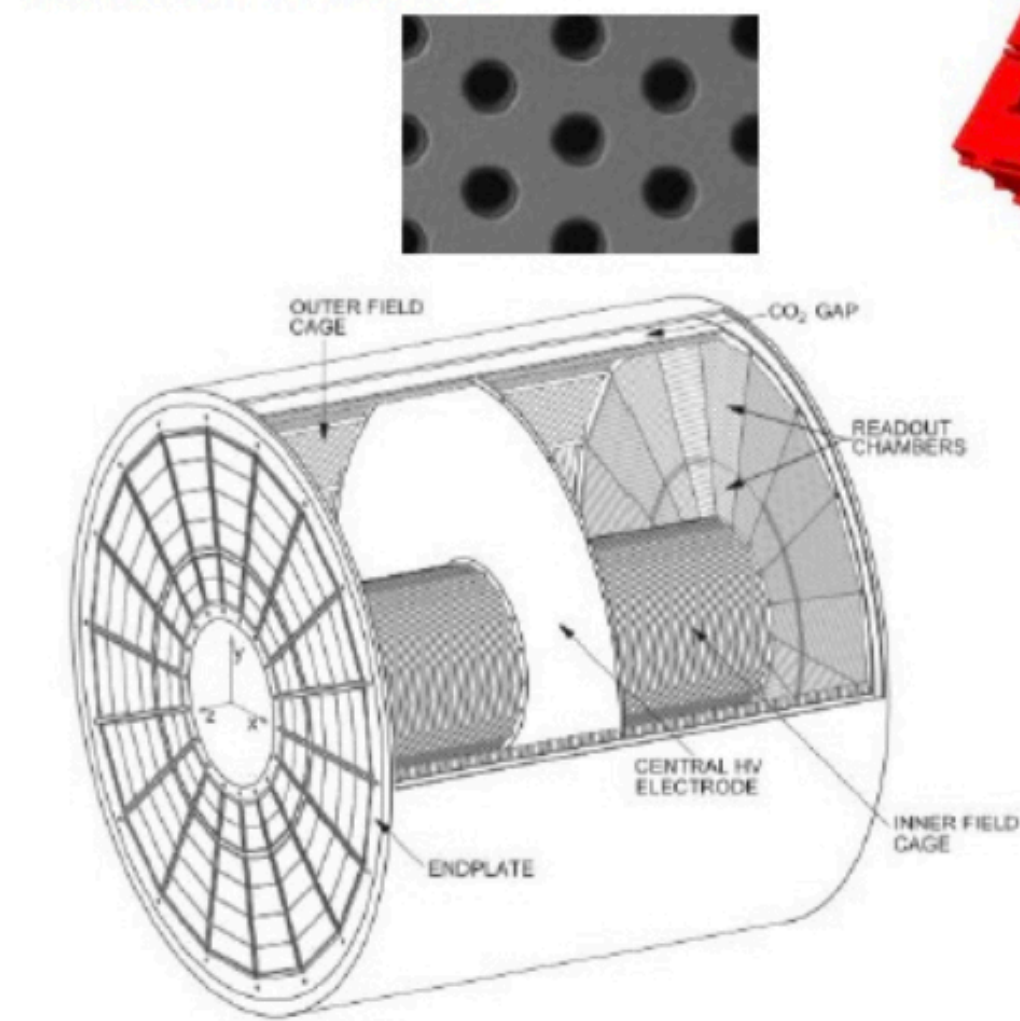
TPC :  $-0.9 < \eta < 0.9$

New Forward Interaction  
Trigger (FIT) to replace  
the V0 and T0 detectors  
and also AD

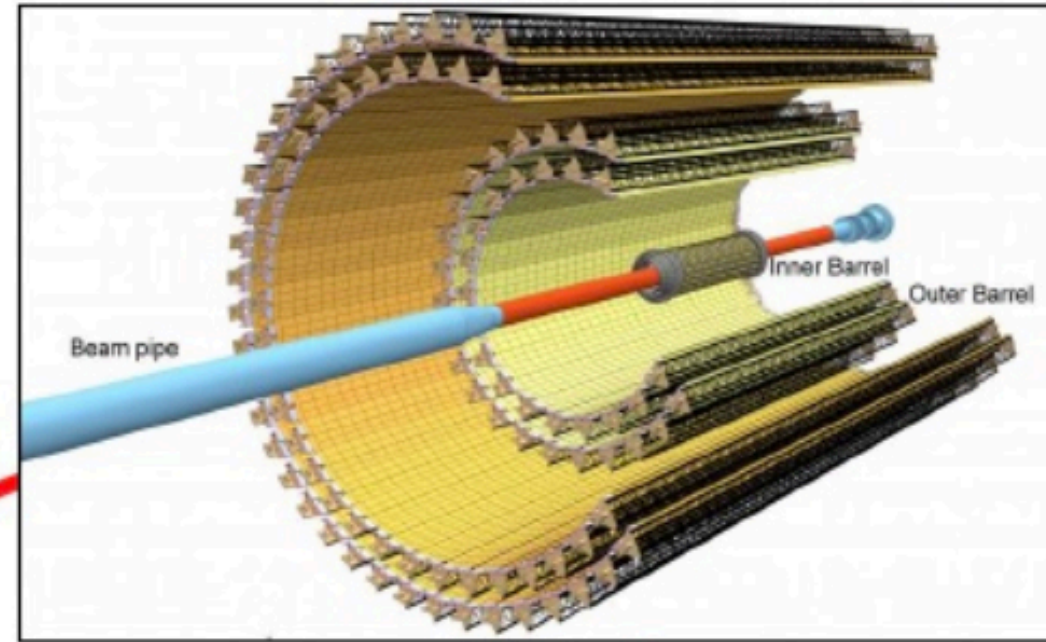
**MCH**  
Muon Trackers

New Inner Tracking System (ITS)

TPC with GEM  
based readout



+ improved readout for TOF, ZDC,  
TRD, MUON ARM  
+ new Central Trigger Processor  
+ new DAQ/Offline architecture



Both based on Monolithic  
Active Pixel Sensors  
(MAPS)

Muon Forward Tracker (MFT)

**MID**  
Muon Identifier

ZDC :  $4.8 < \eta < 5.7$

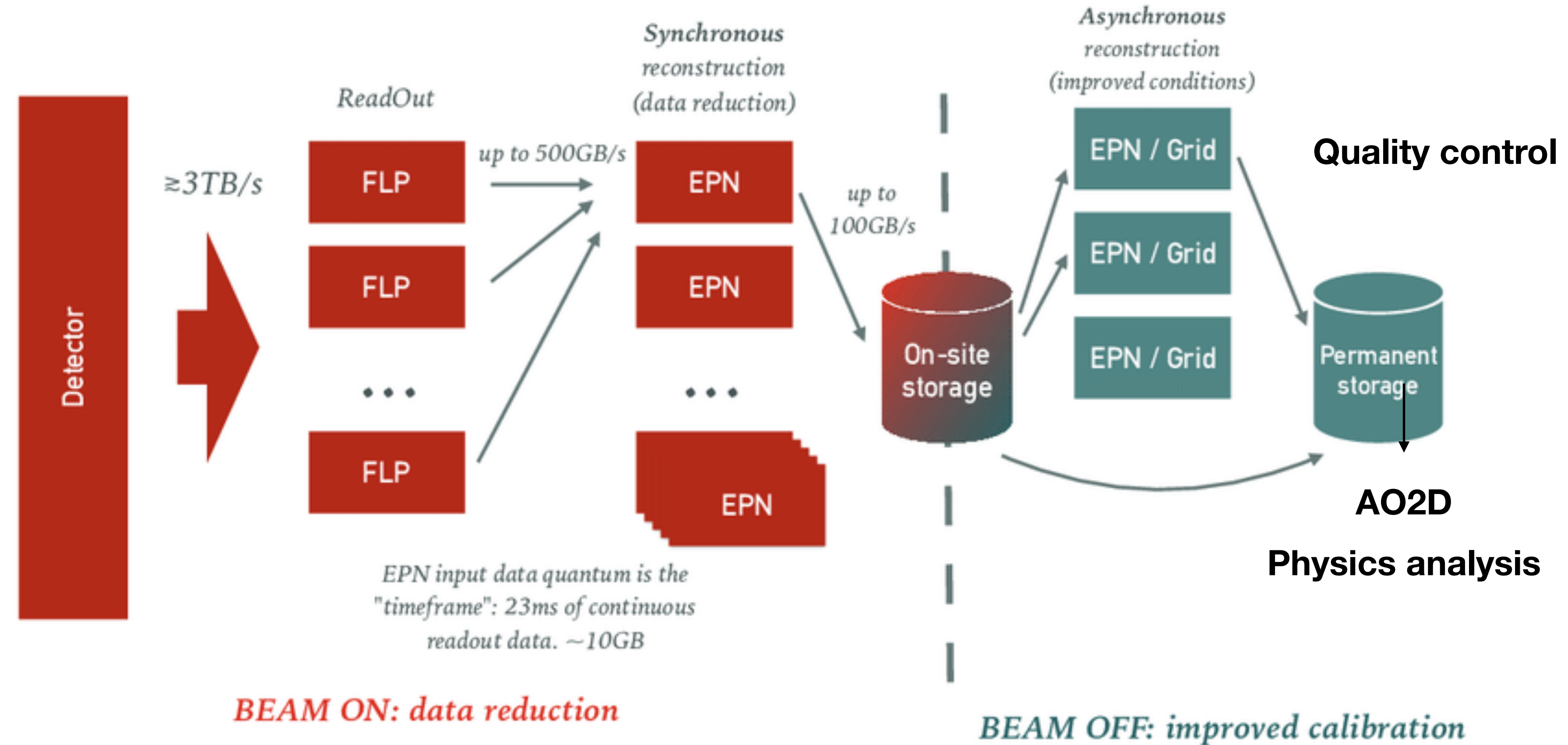
**ZDC**  
Zero Degree  
Calorimeter

MCH :  $-4.0 < \eta < -2.5$

MFT :  $-3.6 < \eta < -2.5$

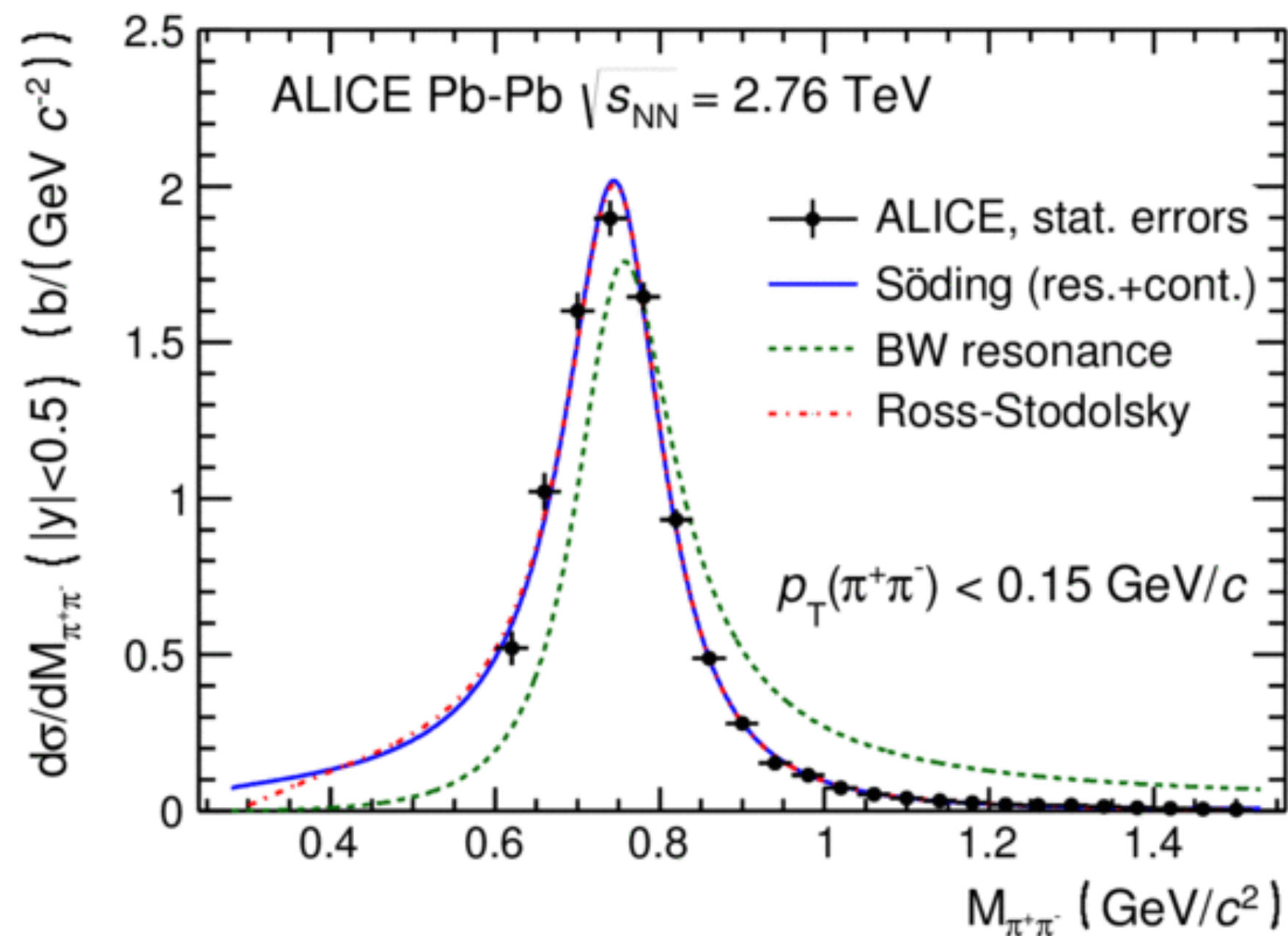
## New common online-offline computing system

- ✓ The designed interaction rate was 8 kHz for Pb–Pb and 100 kHz for pp collisions in Run 2
- ✓ To cope up with an increased interaction rate of up to 50kHz for Pb–Pb, 500 kHz for p–Pb and 1 MHz for pp collisions in continuous readout mode
- ✓ To collect a data sample more than 10 times larger than the combined Run 1 and Run 2 samples



[G. Eulisse, et al, EPJ Web of Conferences 214, 05010 (2019) CHEP 2018]

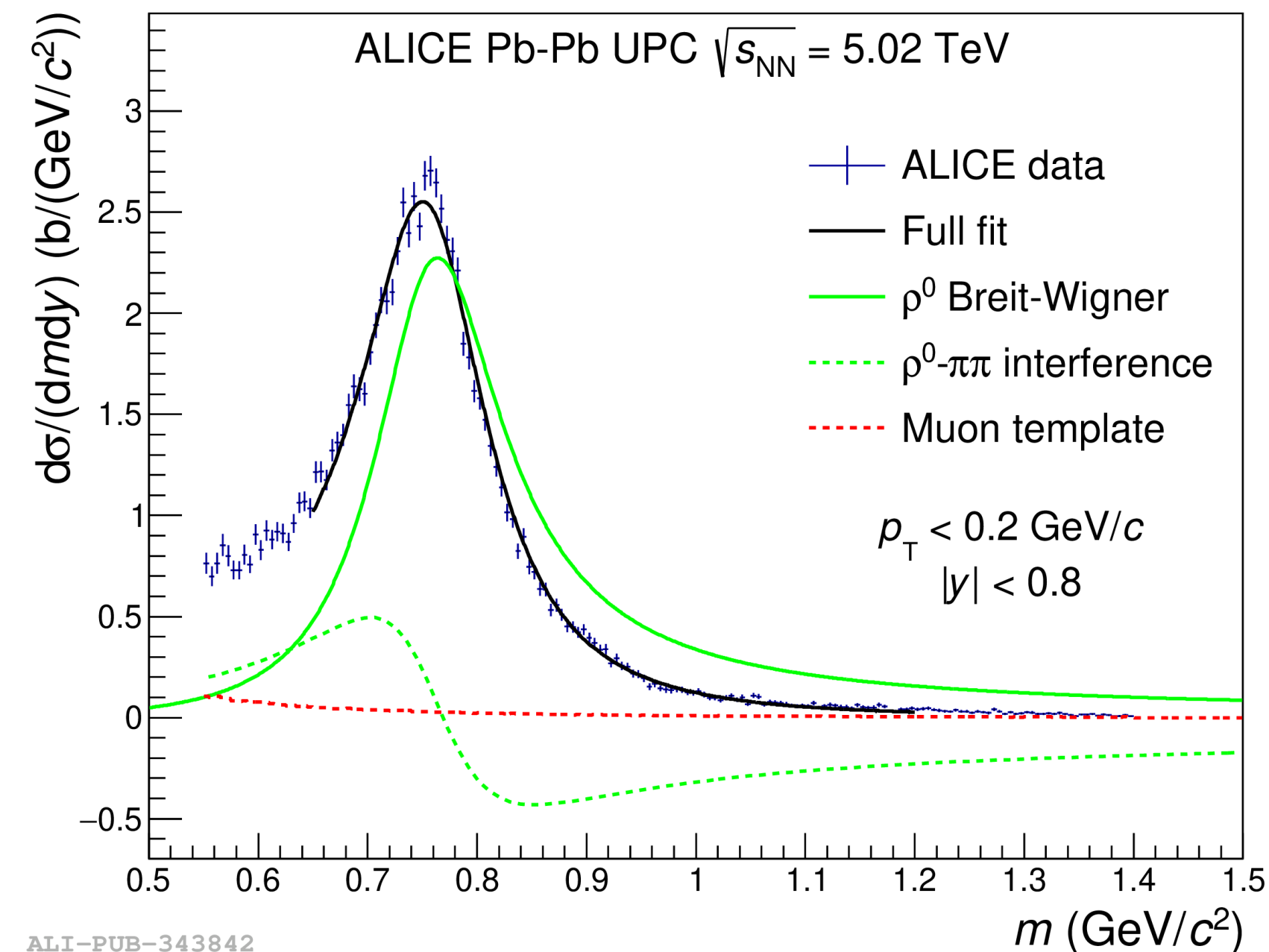
Run 1 : ~ 7k events



ALI-PUB-92319

ALICE, JHEP 09 (2015) 095

Run 2 : ~ 60k events



ALI-PUB-343842

ALICE, JHEP 06 (2020) 035

| Meson                                    | $\sigma$    | PbPb               |                      |
|--|-------------|--------------------|----------------------|
|  |             | Central 1<br>Total | Forward 1<br>Total 1 |
| $\rho \rightarrow \pi^+\pi^-$            | 5.2b        | 5.5 B              | 4.9 B                |
| $\rho' \rightarrow \pi^+\pi^-\pi^+\pi^-$ | 730 mb      | 210 M              | 190 M                |
| $\phi \rightarrow K^+K^-$                | 0.22b       | 82 M               | 15 M                 |
| $J/\psi \rightarrow \mu^+\mu^-$          | 1.0 mb      | 1.1 M              | 600 K                |
| $\psi(2S) \rightarrow \mu^+\mu^-$        | 30 $\mu$ b  | 35 K               | 19 K                 |
| $Y(1S) \rightarrow \mu^+\mu^-$           | 2.0 $\mu$ b | 2.8 K              | 880                  |

$|y| < 0.9$   $2.5 < y < 4$

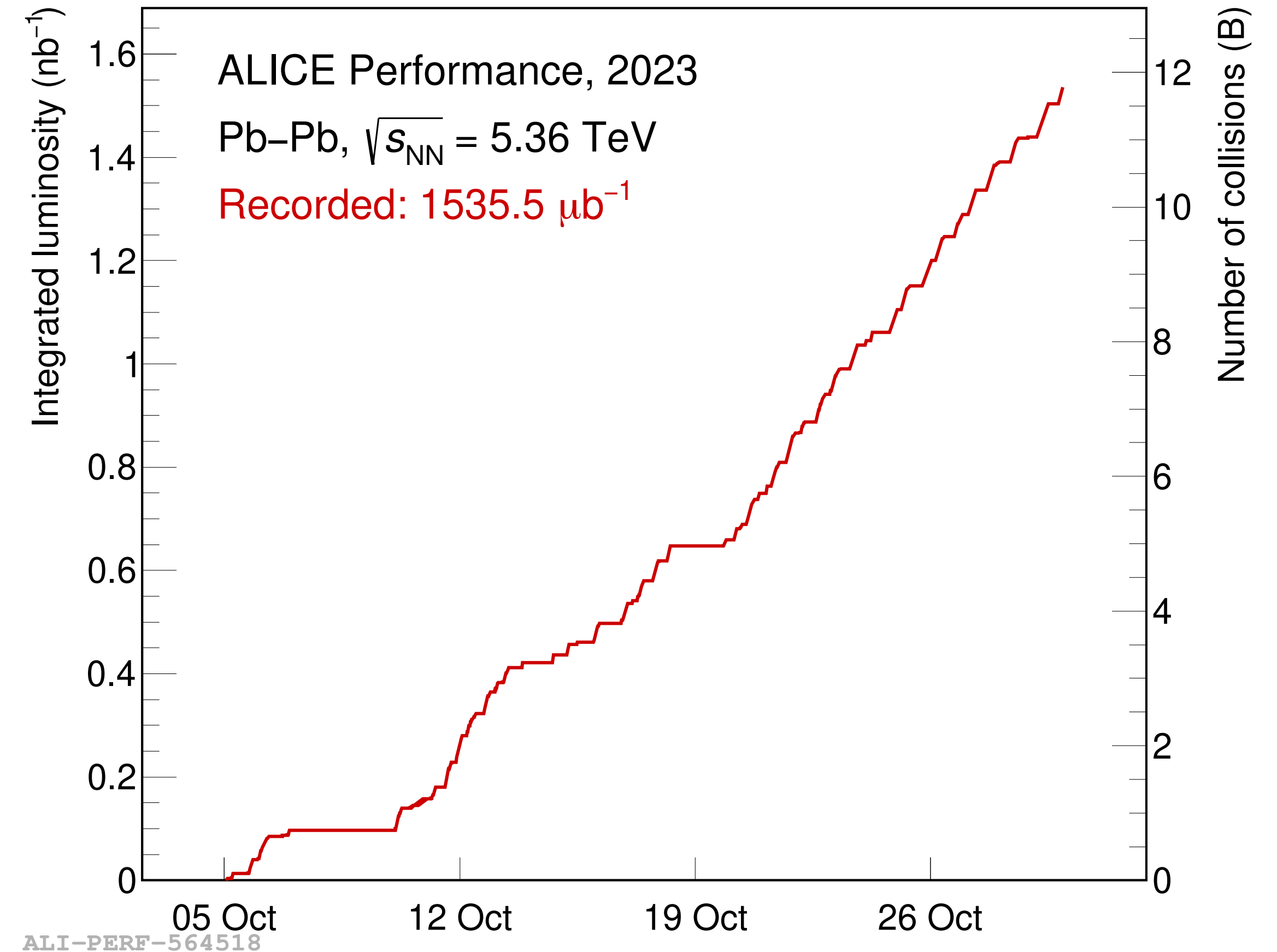
**Possible with continuous readout !**  
**Significant increase in statistics in Run 3!**  
**Integrated luminosity:**  
**1nb<sup>-1</sup> (Run 2) -> 13 nb<sup>-1</sup> ( Run 3 + Run 4)**

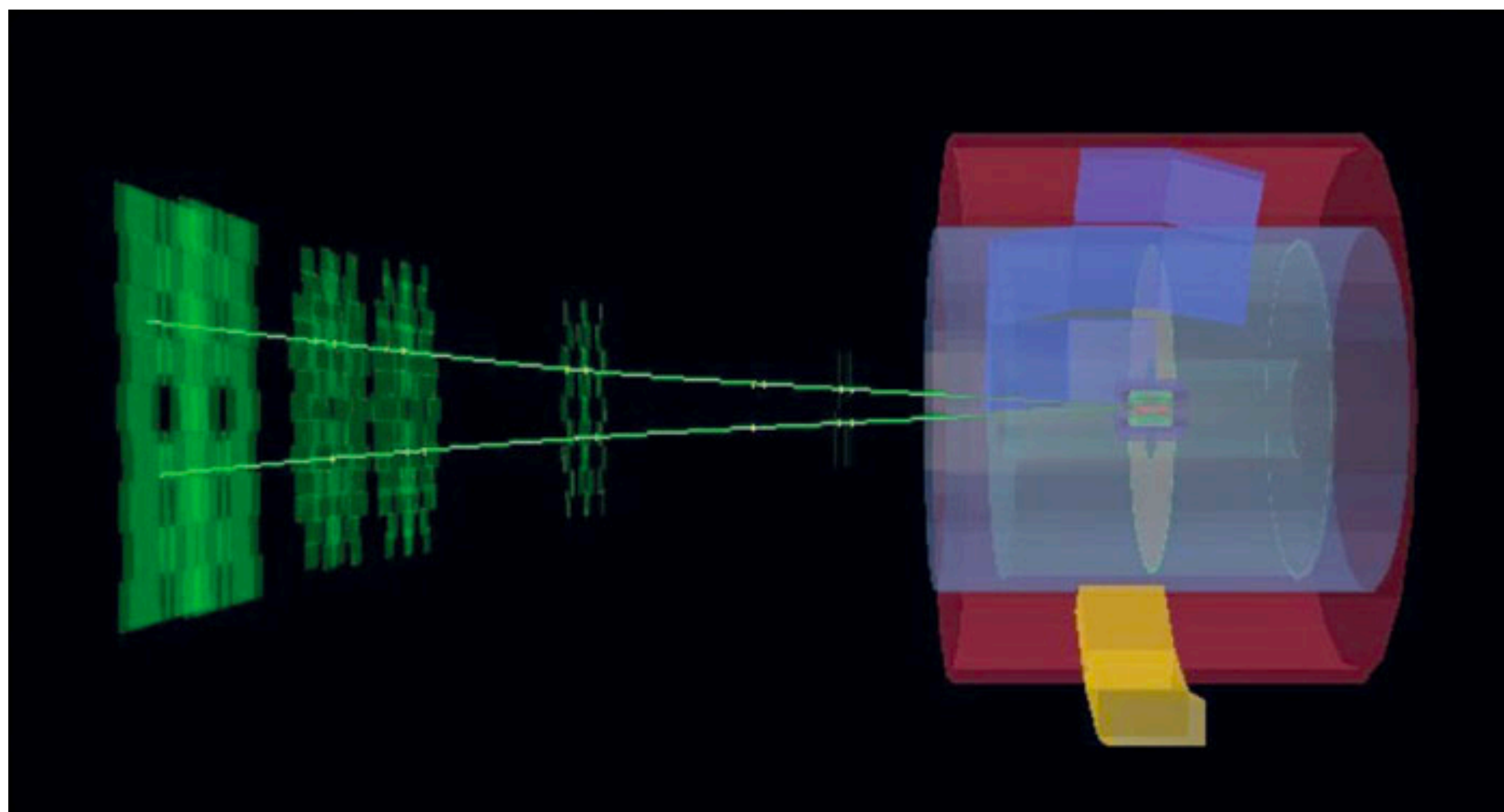
CERN Yellow Rep. Monogr. 7 (2019) 1159-1410

# UPC program in Run 3 so far

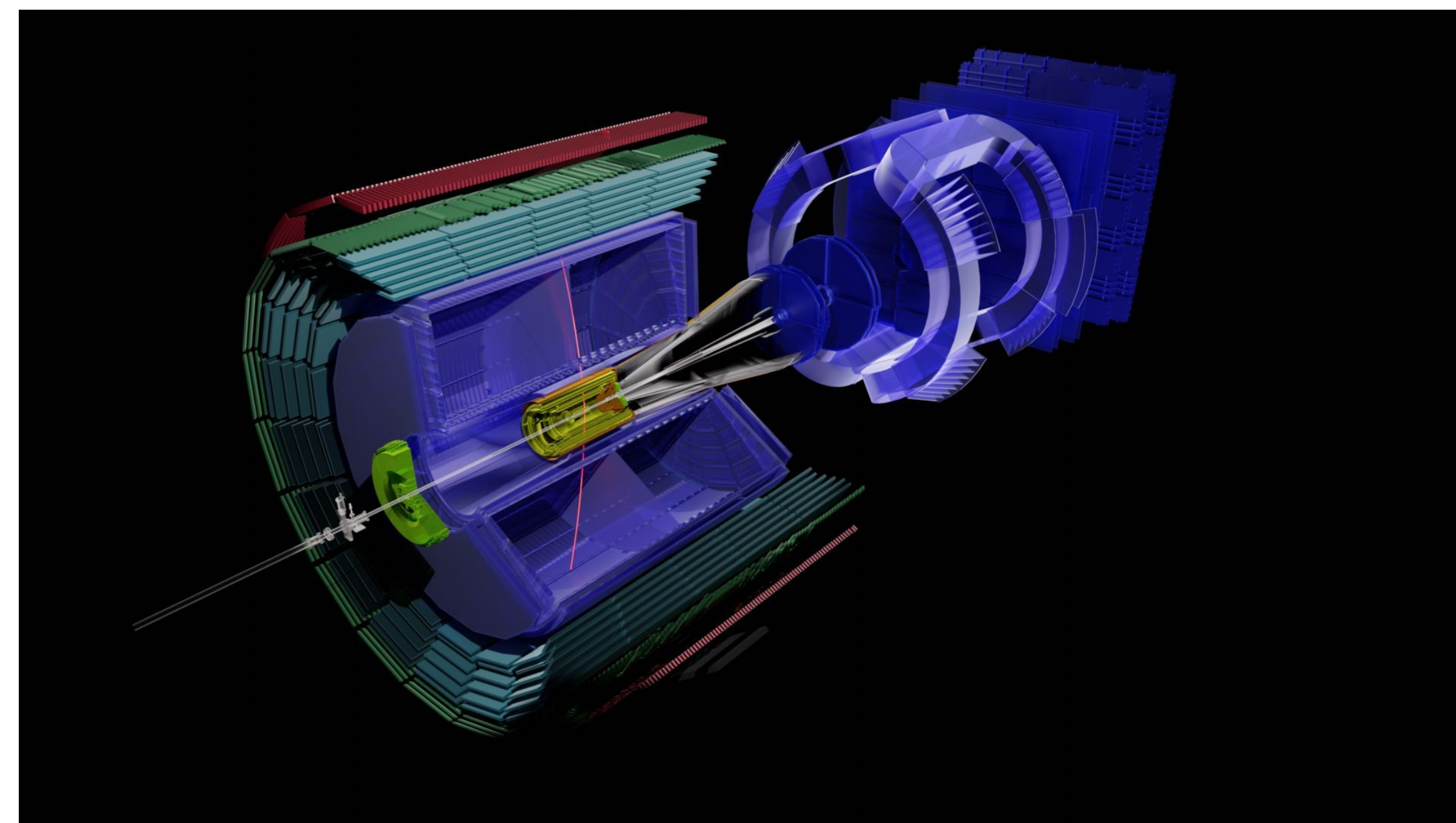
- ✓ LHC faced cryo incident affected pp data taking
- ✓ Despite the issues we were able to collect large sample pp data (see next slides for details)
- ✓ LHC faced vacuum incident and postponed pp reference data taking for 2024
- ✓ First Pb-Pb data taking with 2 kHz hadronic interaction rate recorded on 26th September
- ✓ Data is taken successfully with 45 kHz Hadronic Interaction Rate !

- ✓ About 1.5 nb<sup>-1</sup> of integrated luminosity in 2023
- ✓ Collected x40 larger sample of minimum bias events in Run 3 compared to Run 1 + Run 2!
- ✓ 1.5 nb<sup>-1</sup> is x3000 larger than integrated luminosity used in  $\rho^0$  analysis of Run 2 data



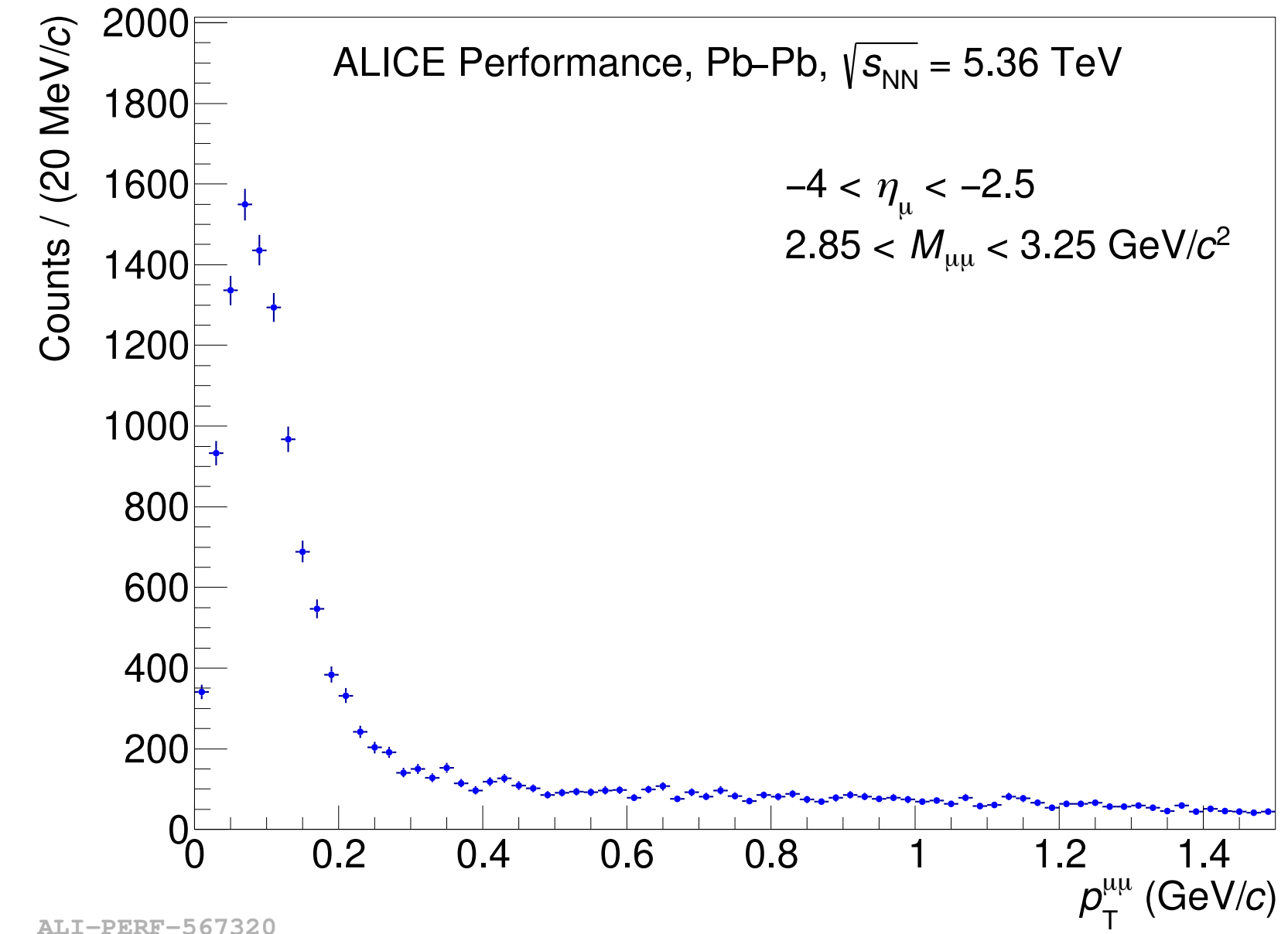
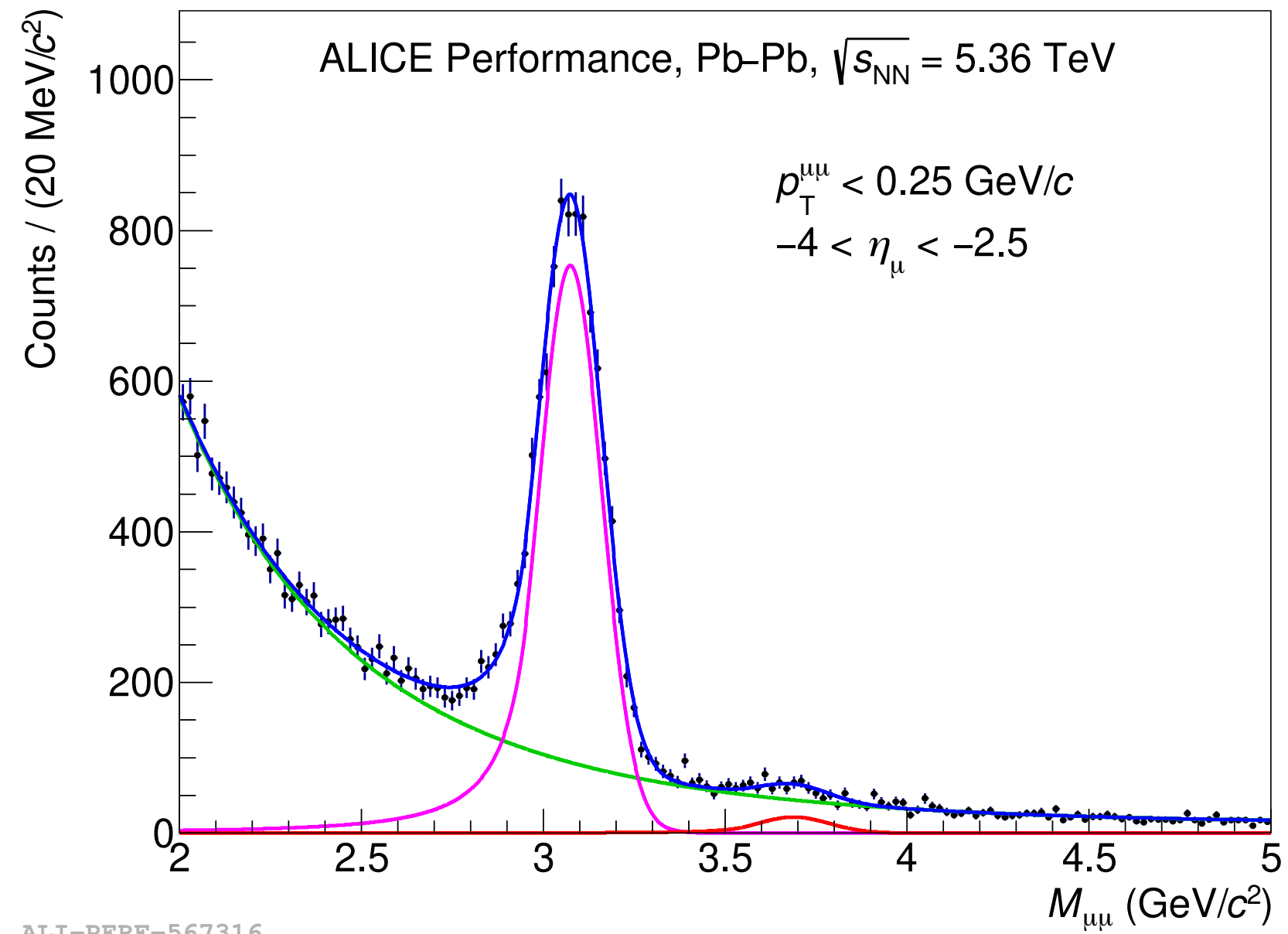
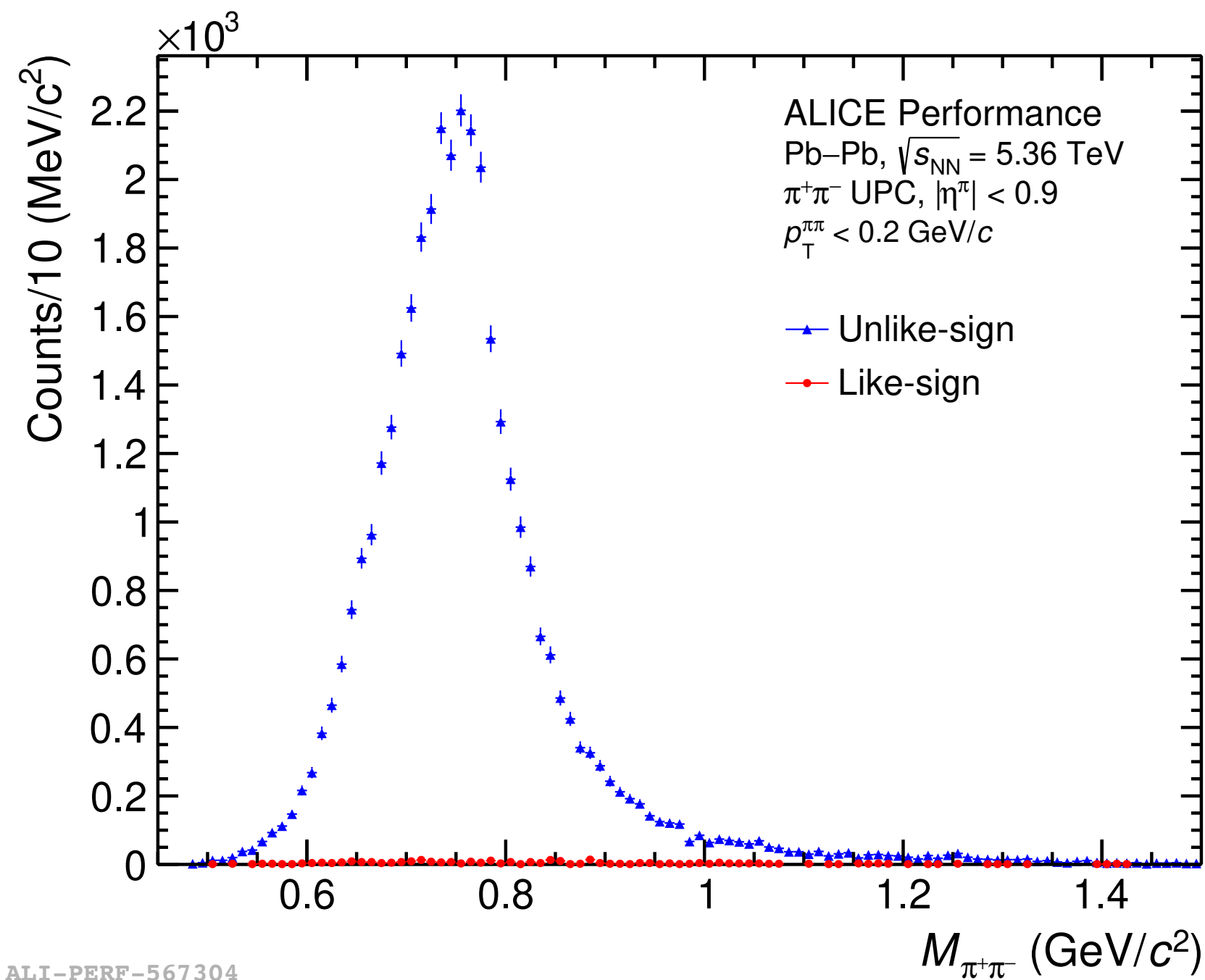


**RUN 2 UPC event**



**RUN 3 UPC event**

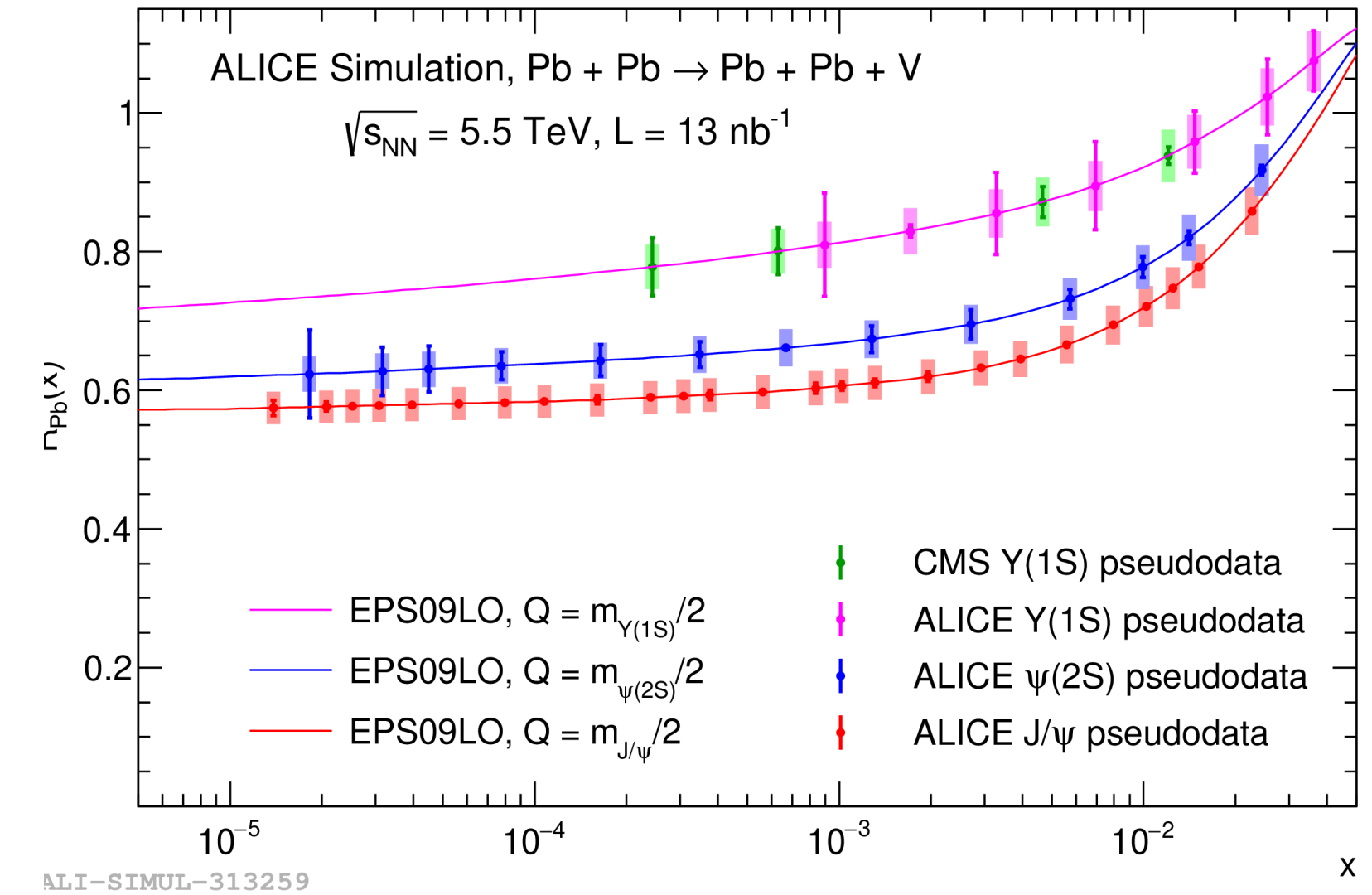
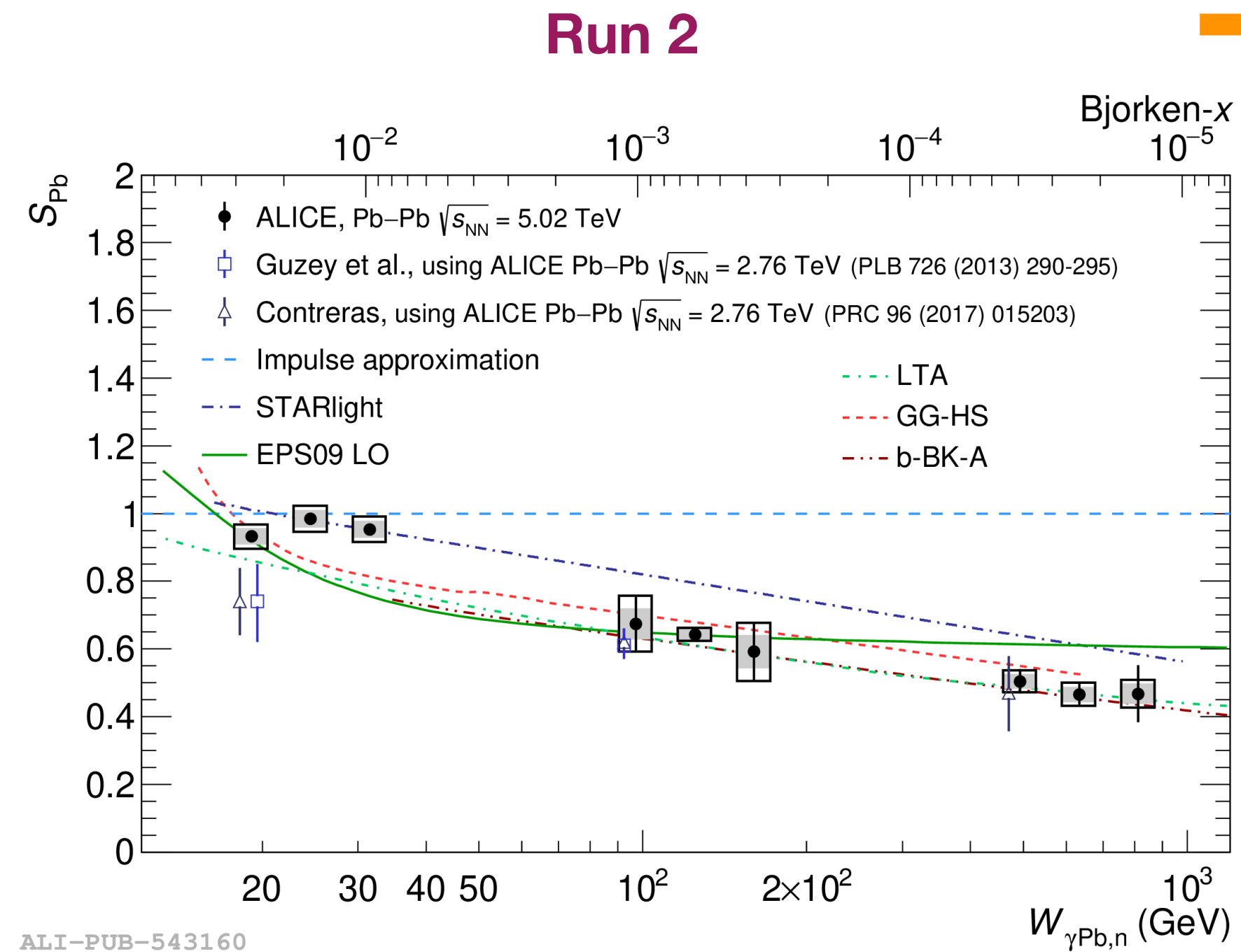
- As in Run 2, to select a exclusive vector meson UPC event
- we require no signal in the FIT and further empty ZDCs
- Possible to veto signals in individual detectors in Run 3
- More flexibility, possible to select inclusive, semi-inclusive UPC events



- Clear peak of coherent  $\rho^0$  and  $J/\psi$  in Pb-Pb UPCs at  $\sqrt{s_{NN}} = 5.36$  TeV
- Both coherent and incoherent are shown in the transverse momentum distribution



- ✓ Precision study of vector meson photoproduction in UPCs with significant increase in integrated luminosity
- ✓ Uncertainties for nuclear suppression factor are expected to be at the level of 4% [CERN Yellow Rep. Monogr. 7 (2019) 1159-1410]. Double vector meson photoproduction
- ✓ UPC bottomonia production [arXiv:2303.03007v1]
- ✓ Exclusive  $\phi$  production in the dikaon channel (currently done with Run 2 data in ALICE [arXiv:2311.11792] - See talk by Minjung Kim)
- ✓ Exclusive production of a much wider range of particles, including excited vector mesons and searches for exotica- e.g. X(3872)

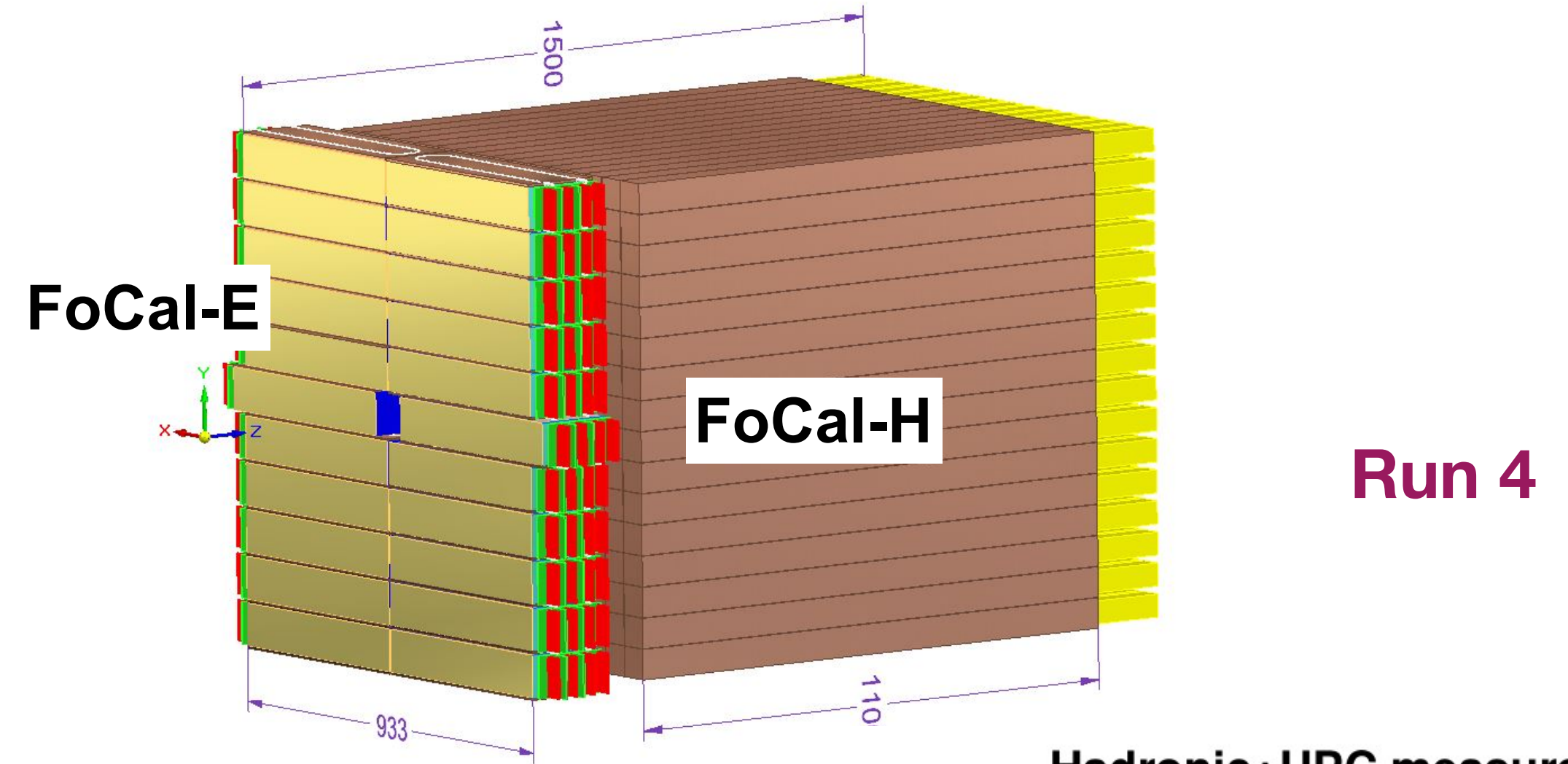


ALICE, JHEP 10 (2023) 119

# UPC Physics prospects in Run 3 and beyond : Exclusive vector meson photoproduction with FoCal

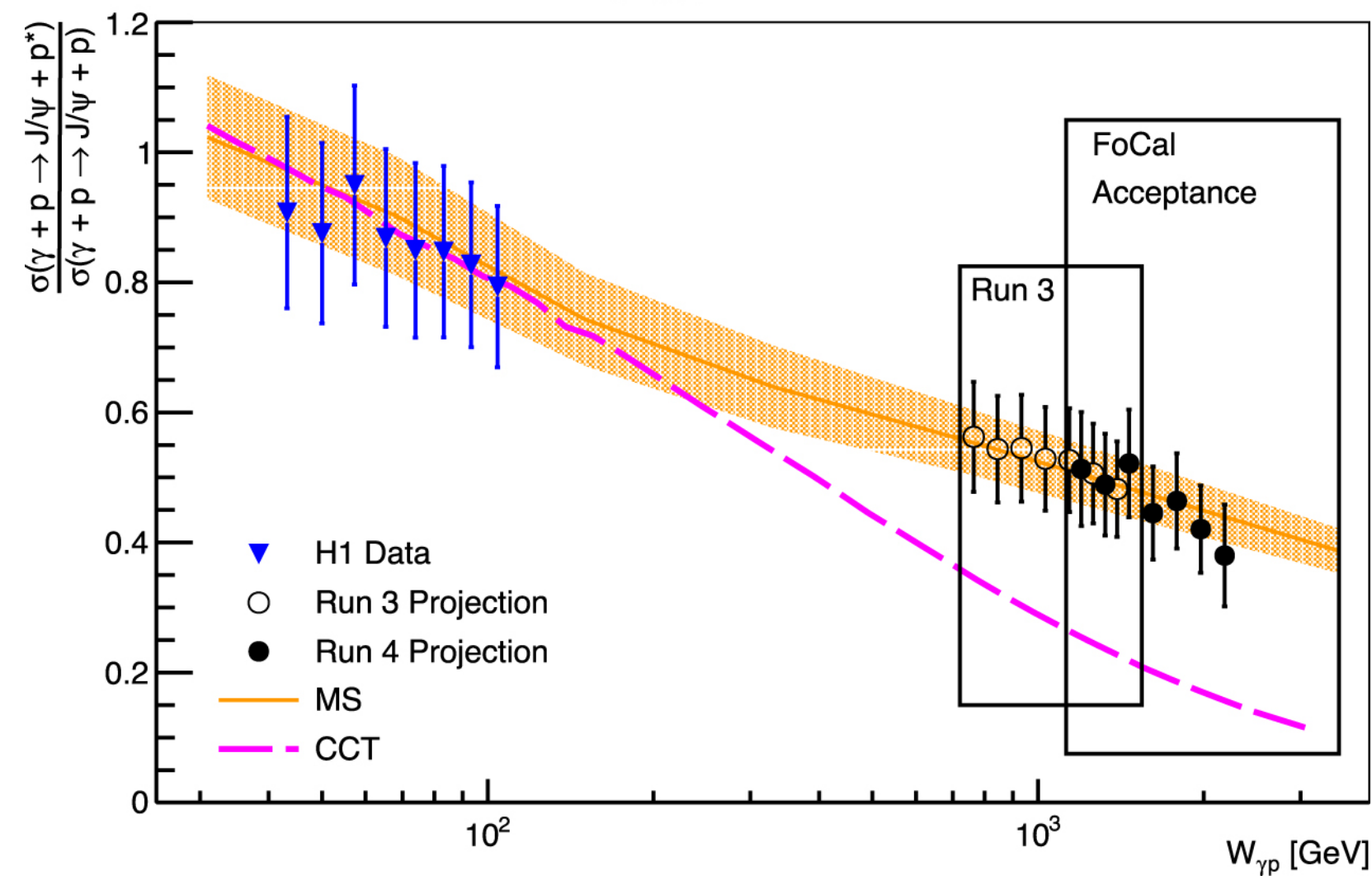


- ✓ **FoCal**: Part of ALICE upgrade for Run 4 (starting from 2029)-  
See talk by Ionut Cristian Arsene
- ✓ Positioned 7 m from IP2 (A-side), covering  $3.4 < \eta < 5.8$
- ✓ Dissociative  $J/\psi$  in Run 3 with FOCAL acceptance in Run 4  
[J. Phys. G: Nucl. Part. Phys. **50** 055105]
- ✓ Exclusive  $J/\psi$  and  $\psi(2S)$  (+ Run 4 with Focal acceptance) in p-Pb UPCs [J. Phys. G: Nucl. Part. Phys. **50** 055105]

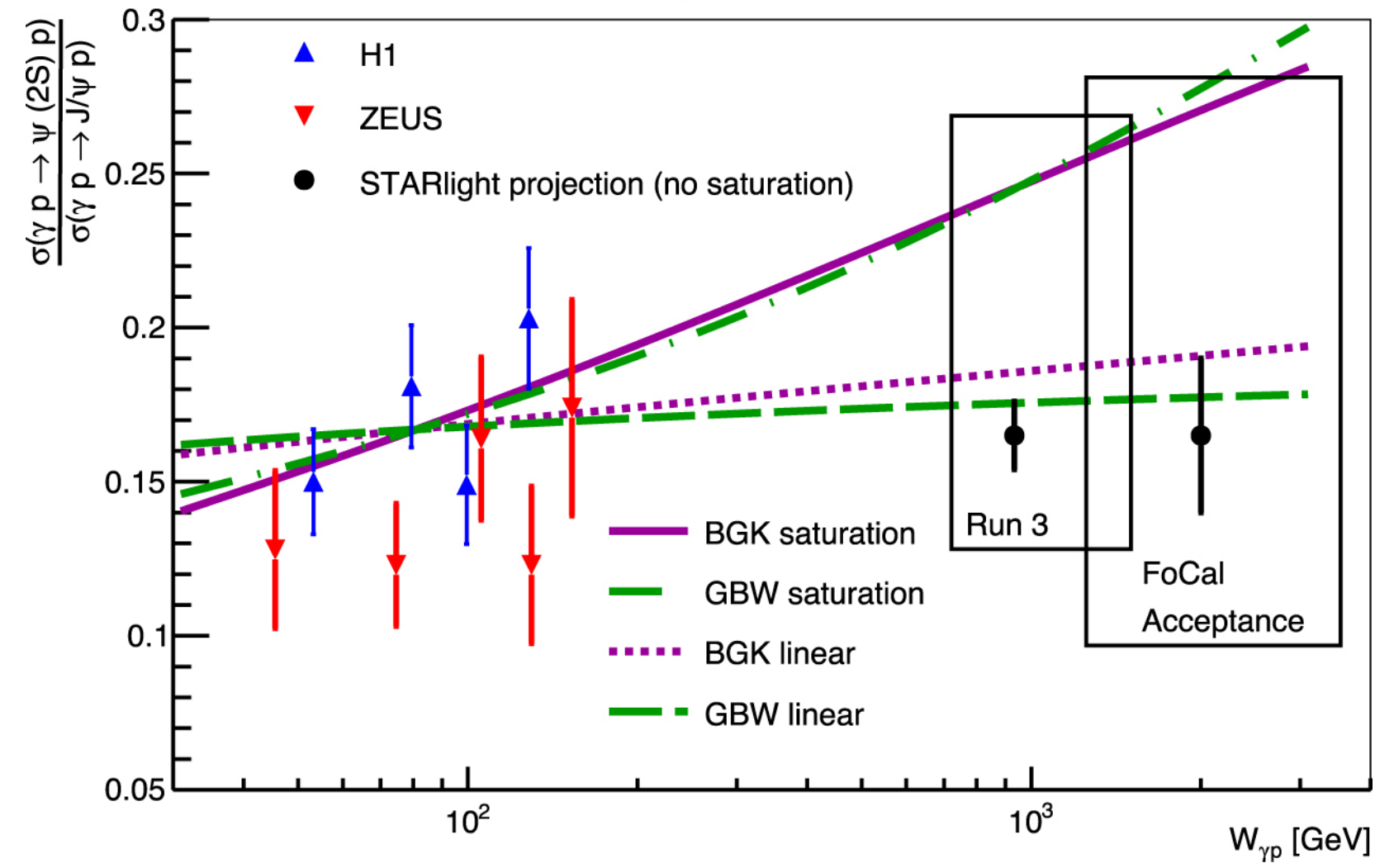


Run 4

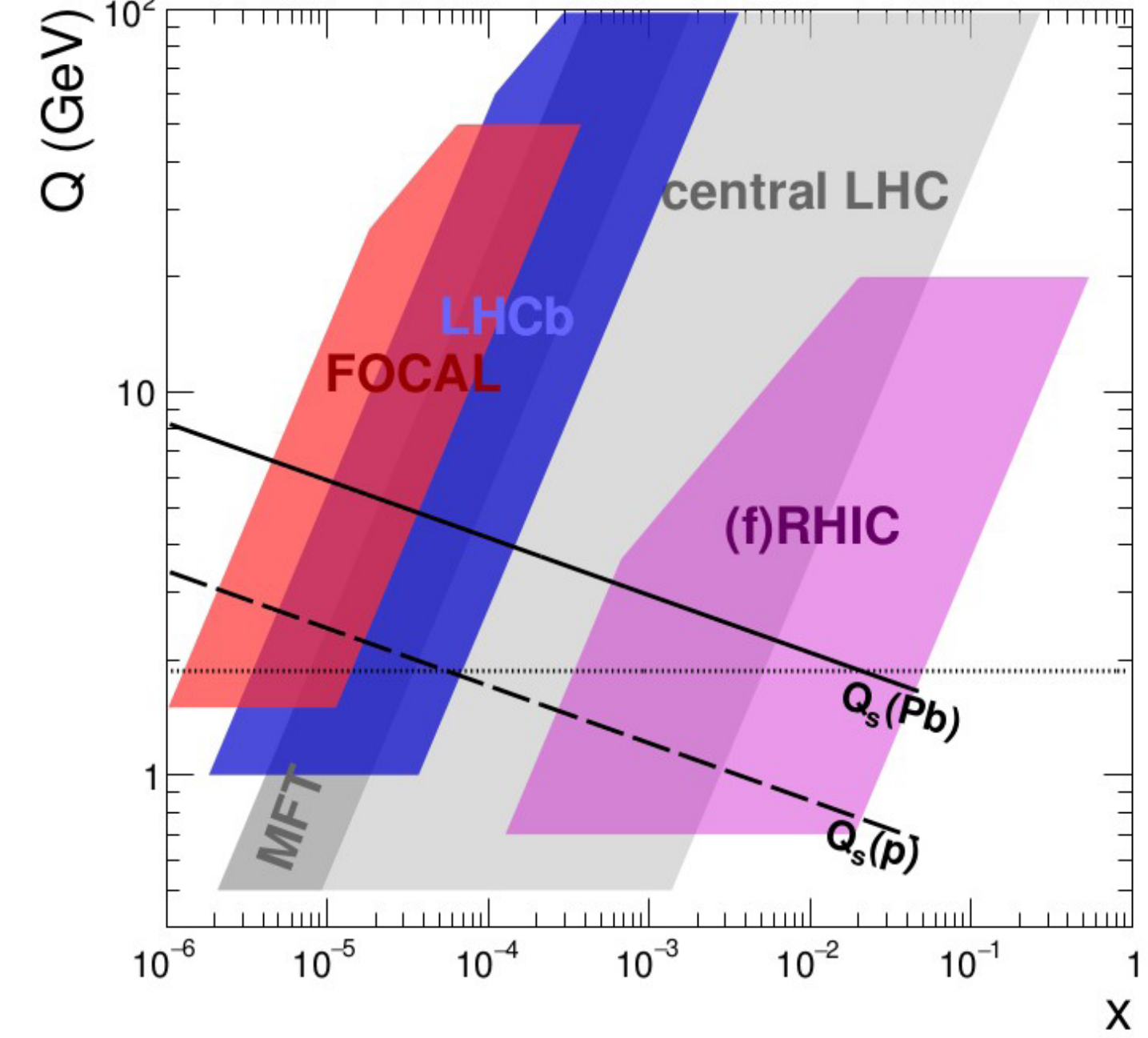
UPC p-Pb  $\sqrt{s_{NN}} = 8.16$  TeV,  $150 \text{ nb}^{-1}$



UPC p-Pb  $\sqrt{s_{NN}} = 8.16$  TeV,  $150 \text{ nb}^{-1}$



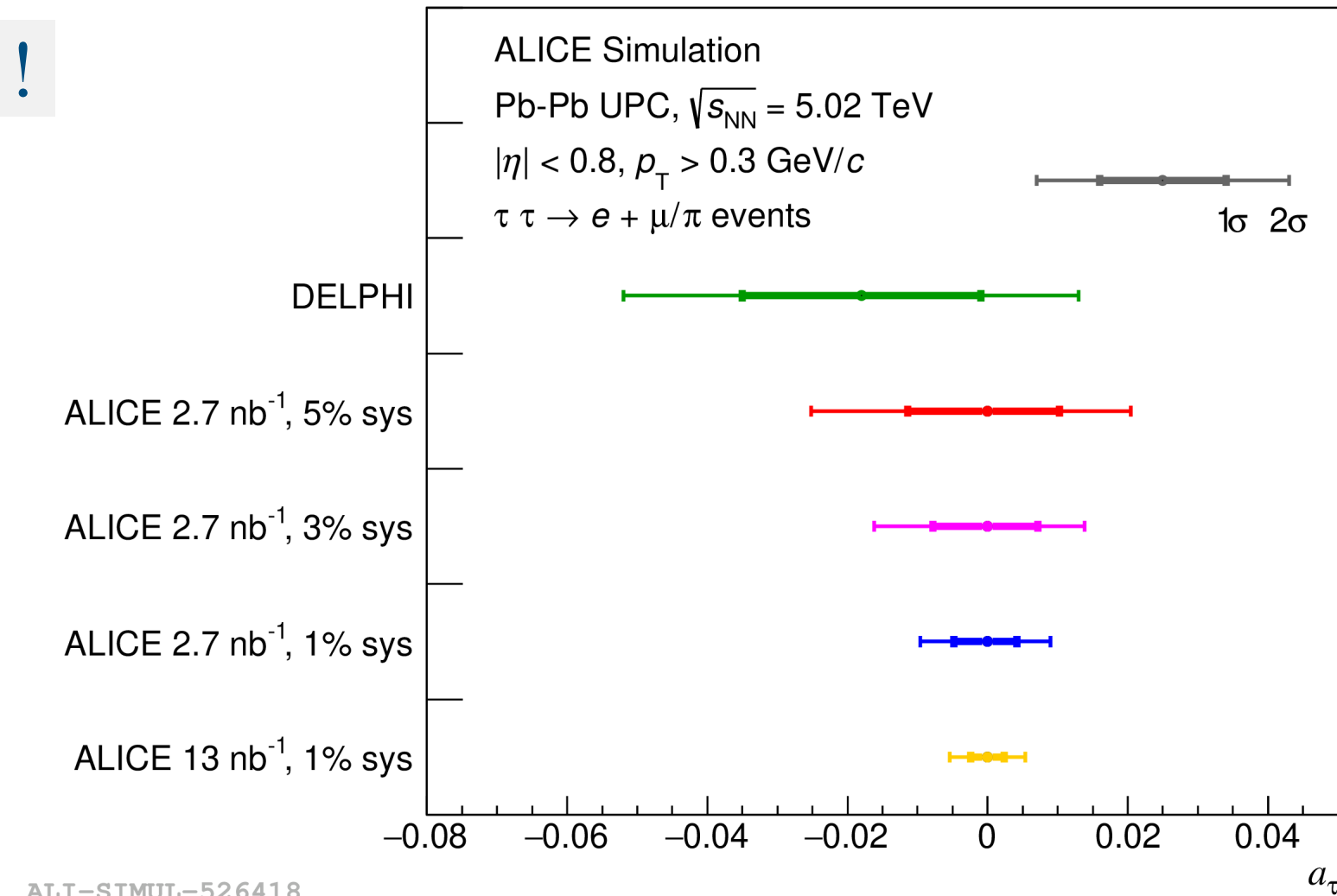
Hadronic+UPC measurements



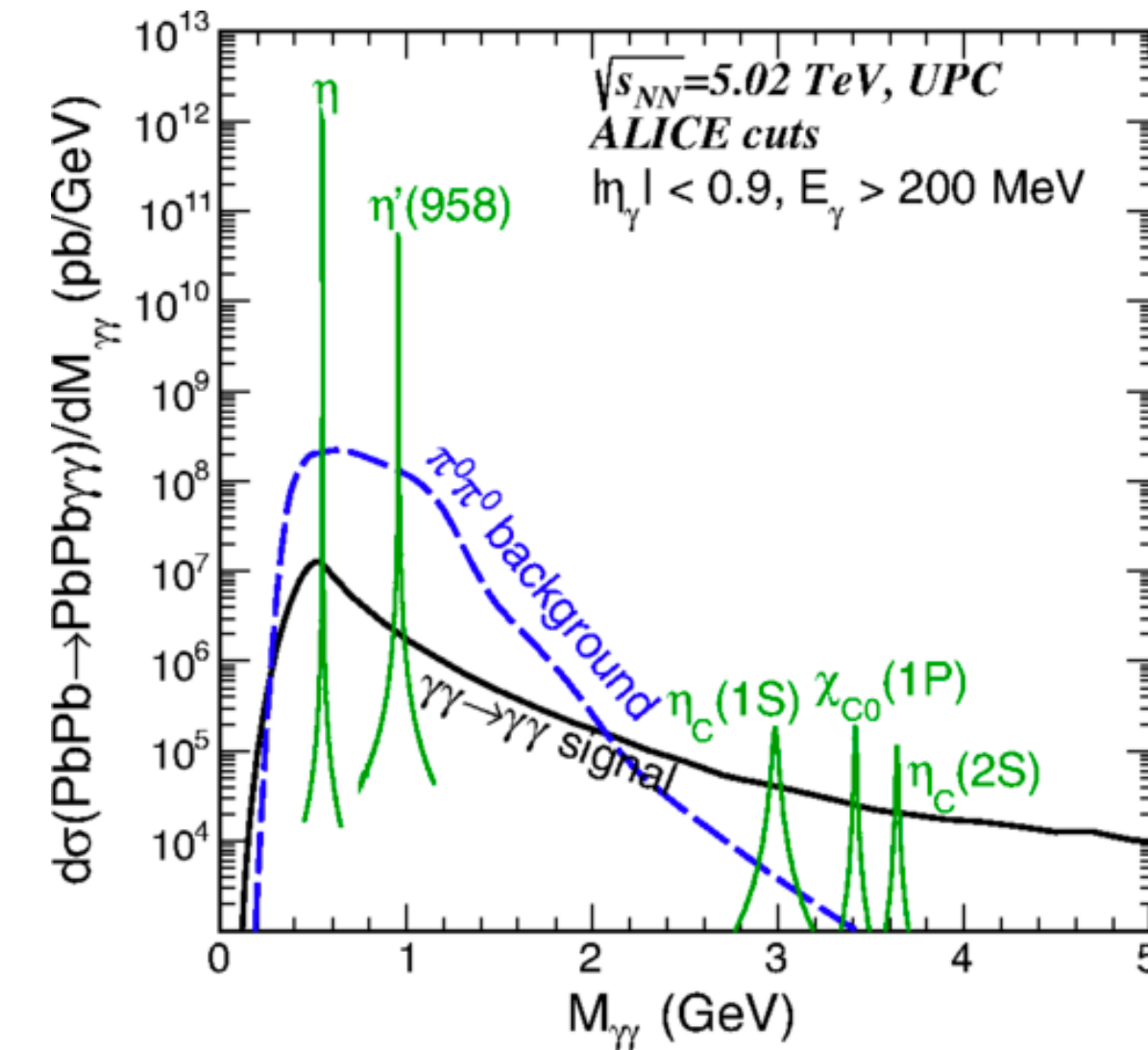
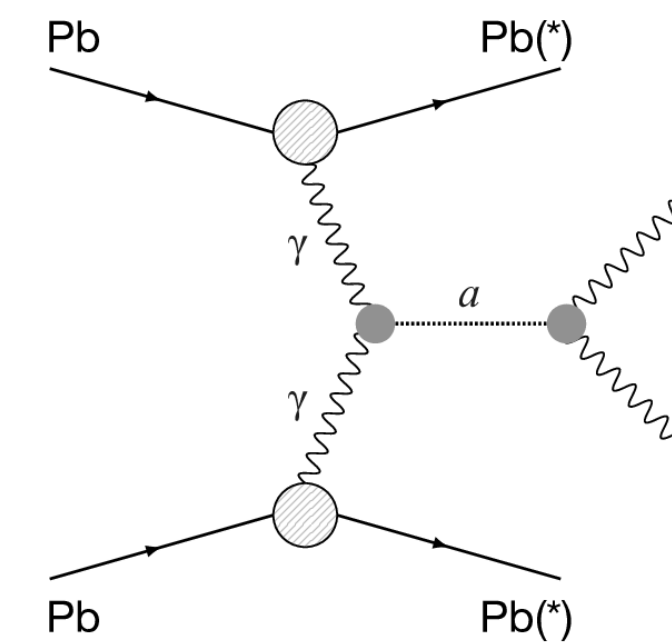
[J. Phys. G: Nucl. Part. Phys. **50** 055105]

## What one could possibly do in ALICE? A personal wish list !

- ☑ Open heavy flavour in UPCs: Possible with triggerless data taking, cross section much larger than charmonia [ [Phys. Rev. C66, 044906 \(2002\)](#), [Nucl. Phys. A 976 \(2018\) 33-45](#)]. Only a single gluon is involved unlike vector meson photoproductions
- ☑ Measurement of  $\tau$  anomalous magnetic moment
- ☑  $\gamma\gamma$  interaction in UPC: Measuring light-by-light scattering in Pb-Pb and looking for resonances in the invariant mass distributions -> Axion Like Particles (ALPs) [[ATLAS, JHEP 11 \(2021\) 050](#)]
- ☑ Axions are likely lighter particles, ALICE can potentially push down the search to 1 GeV with focus on low invariant masses [[PRD 99 \(2019\) 9, 093013](#)]
- ☑ Tetraquarks :  $\gamma\gamma \rightarrow T_{4c} \rightarrow 4l$  [[PLB 816 \(2021\) 136249](#)]
- ☑ Inclusive/semi inclusive UPCs e.g. inclusive  $J/\psi$ , jets in UPCs



ALI-SIMUL-526418

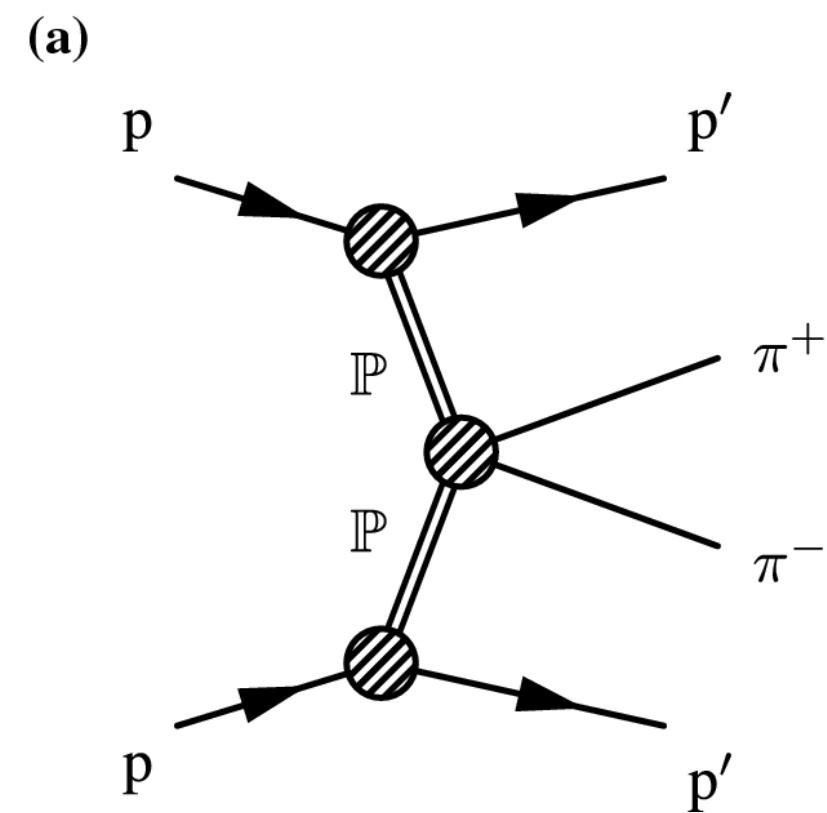


[[PRD 99 \(2019\) 9, 093013](#)]

# Central Exclusive Production (CEP) at ALICE

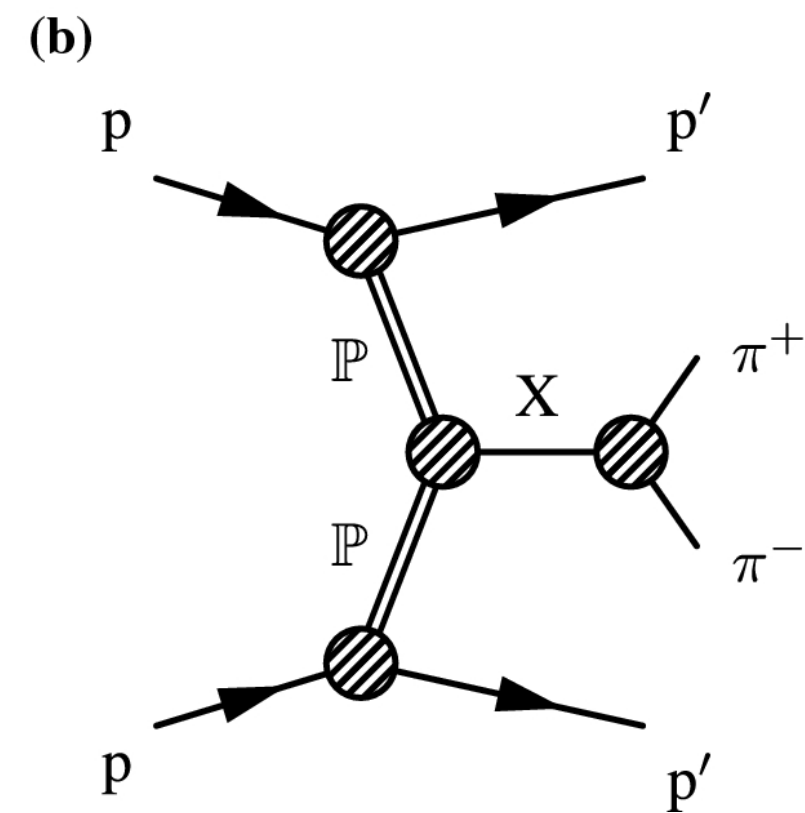
Study of diffraction reactions (exchange of colourless objects)

## $\gamma\gamma$ interaction



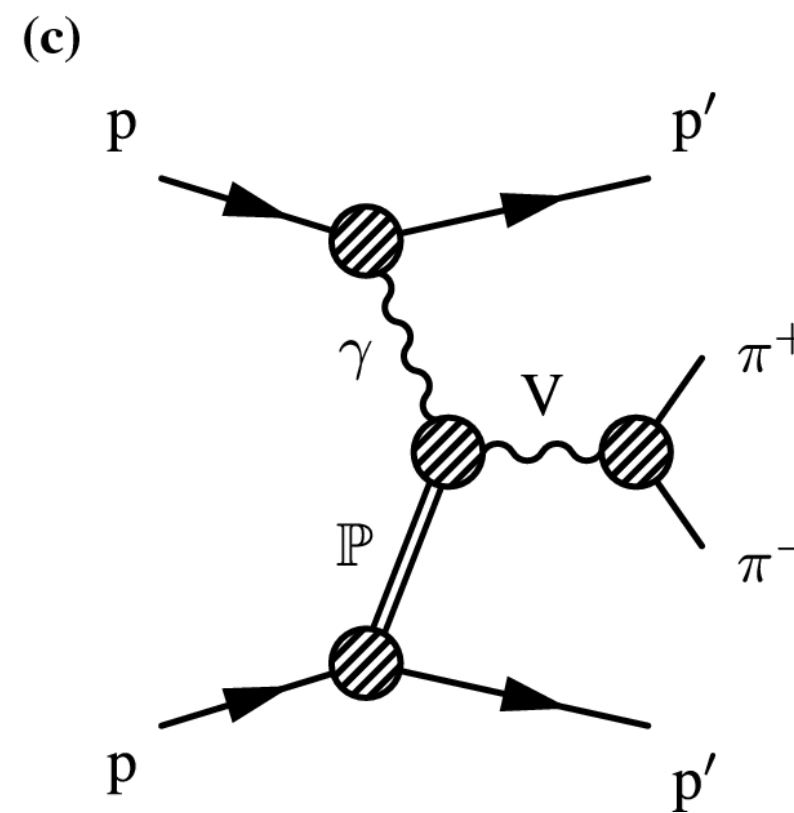
Final state:  $l+l^-$ , meson or photon pairs (light-by-light scattering)

## Double-pomeron exchange

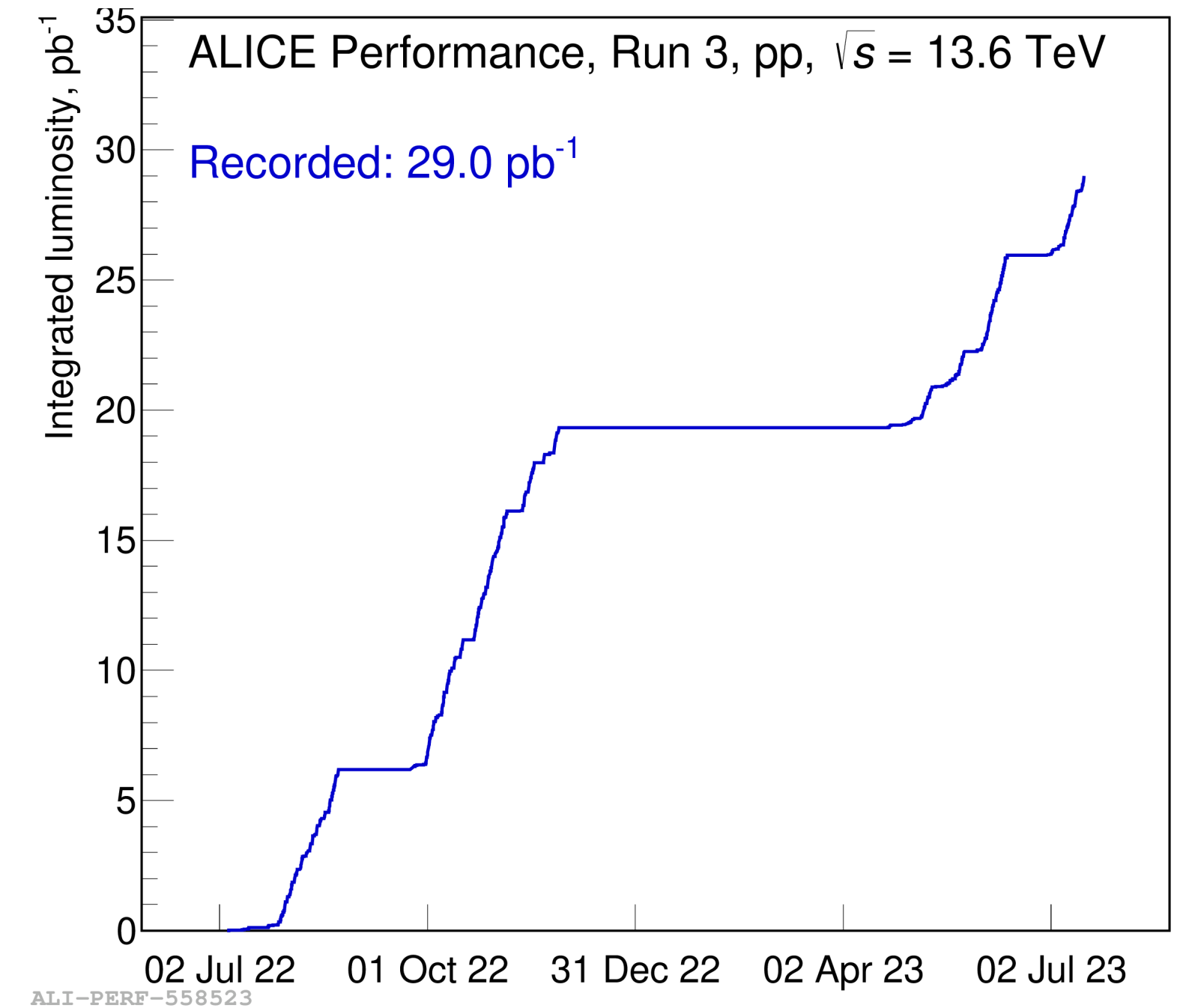


Final state: enhanced production of gluon-rich final states

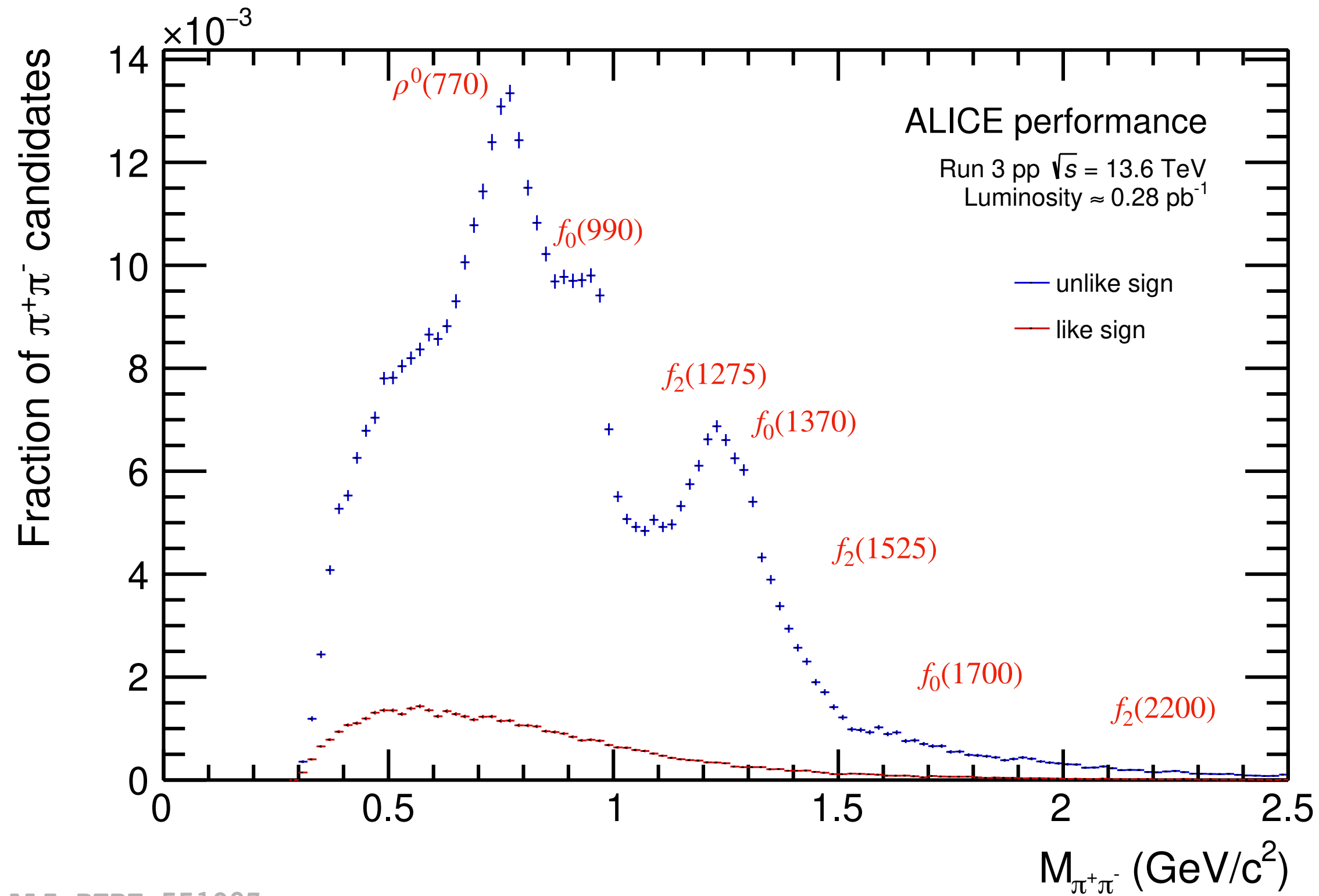
## $\gamma$ pomeron interaction



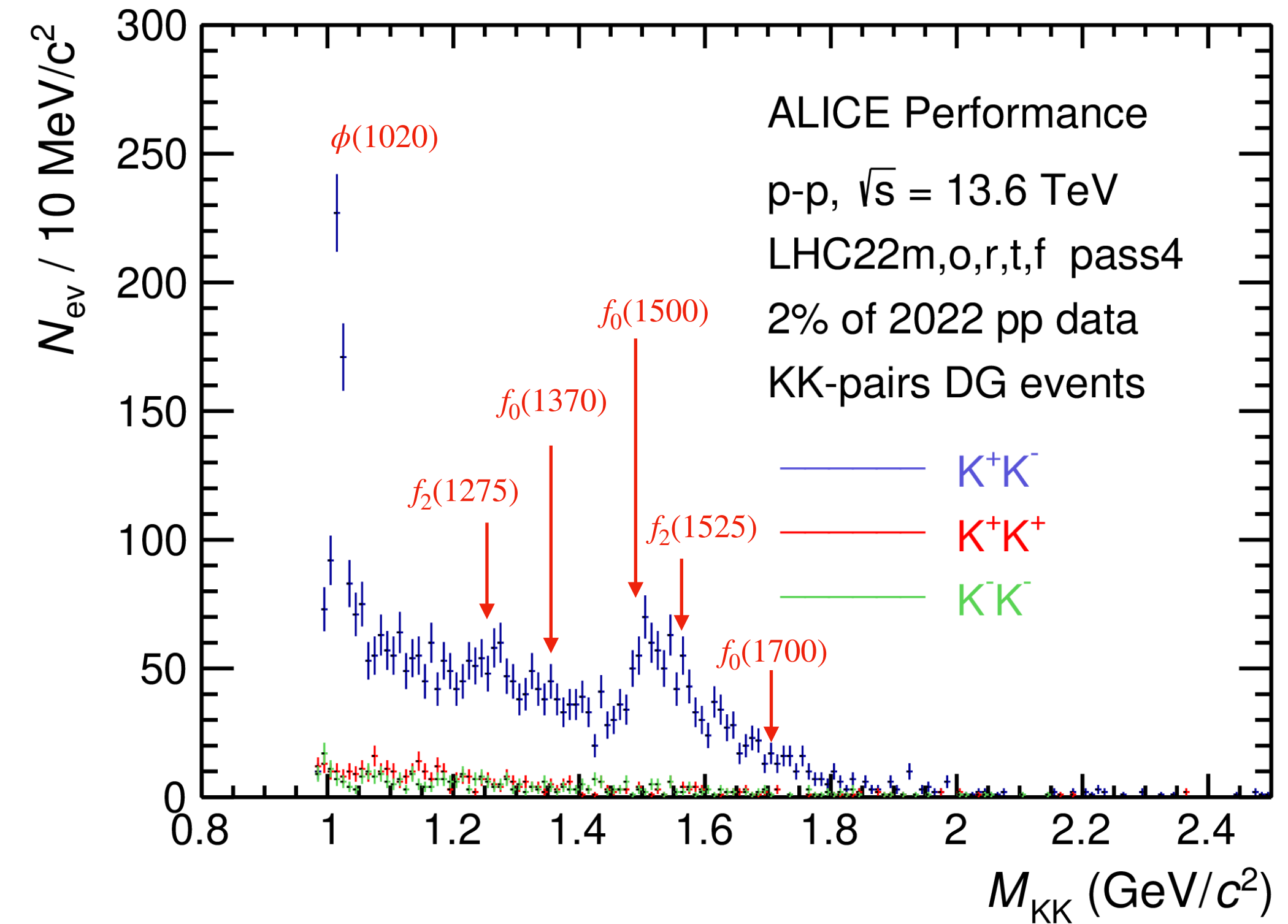
Final state: vector mesons or dijets



- ✓ CEP events are studied using double-gap topology in ALICE central barrel at mid rapidity
- ✓ The tracks are selected within central barrel having no signal at the FIT detectors
- ✓ About 29 pb<sup>-1</sup> of integrated luminosity recorded in pp collisions at  $\sqrt{s} = 13.6$  TeV in 2022 and 2023. ( We collected ~8 pb<sup>-1</sup> in Run 2 ! )



ALI-PERF-551097



ALI-PERF-545710

- ☑ Particle Identification carried by TPC down to low  $p_T$  based on specific energy loss (pion, kaon hypothesis)
- ☑ The events are selected with two opposite charge tracks
- ☑ Visible resonance in raw invariant mass distributions of opposite-sign pions and kaons
- ☑ It will be possible to study strangeness in double gap events with  $\phi(1020)$  and  $f_2(1525)$  states

- ☑ Exciting time for UPCs in Run 3 and Run 4
- ☑ ALICE already collected interesting data in both Pb-Pb and pp collisions. Also prospects for p-Pb data in the near future
- ☑ Precision measurements, new resonances as well as new physics!
- ☑ Strangeness, heavy-quarkonia (Upsilon), open charm in UPCs
- ☑ New physics searches: ALPs, Tetraquarks
- ☑ Inclusive UPCs
- ☑ New analysis framework capable of handling the event rates expected during Run 3 and beyond!
- ☑ Work and development in progress, stay tuned!



**Gracias!**