



ALICE

# Physics prospects and data preparation for UPC studies with ALICE in Run 3

Anisa Khatun (for the ALICE Collaboration)

The University of Kansas

798. WE-Heraeus Seminar

Physikzentrum Bad Honnef

25/10/2023

WILHELM UND ELSE  
HERAEUS-STIFTUNG



U.S. DEPARTMENT OF  
**ENERGY**

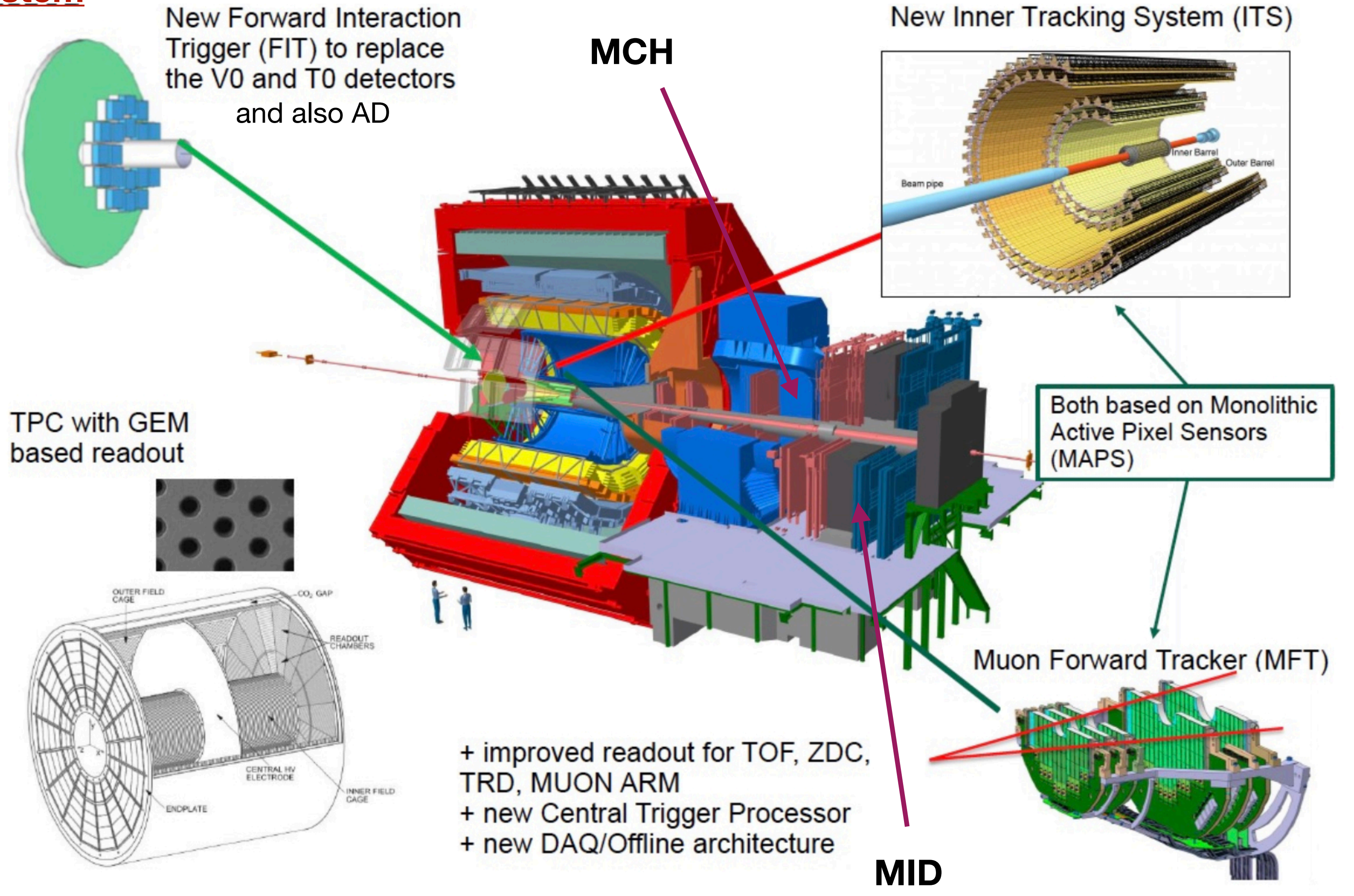
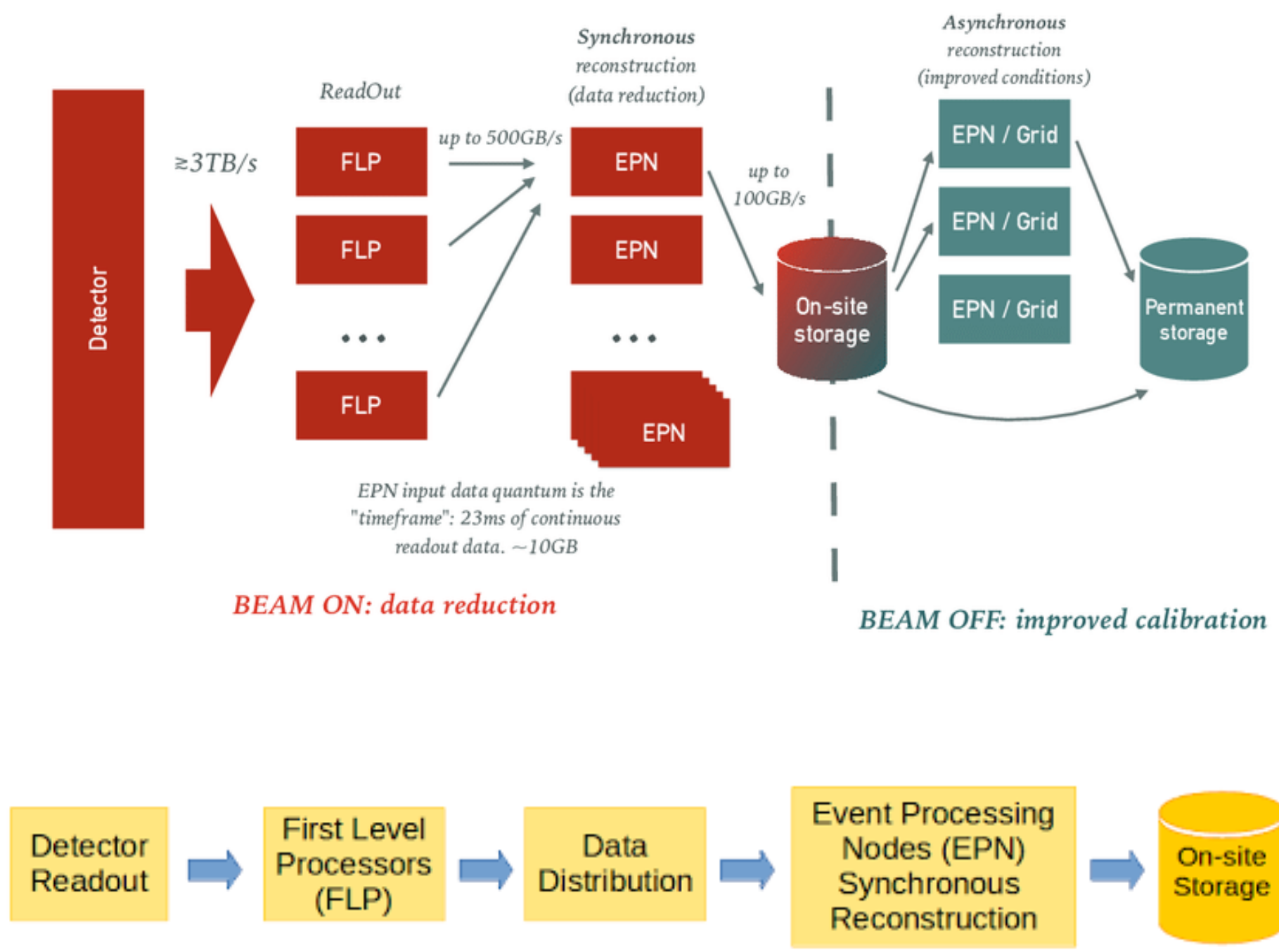
Office of Science



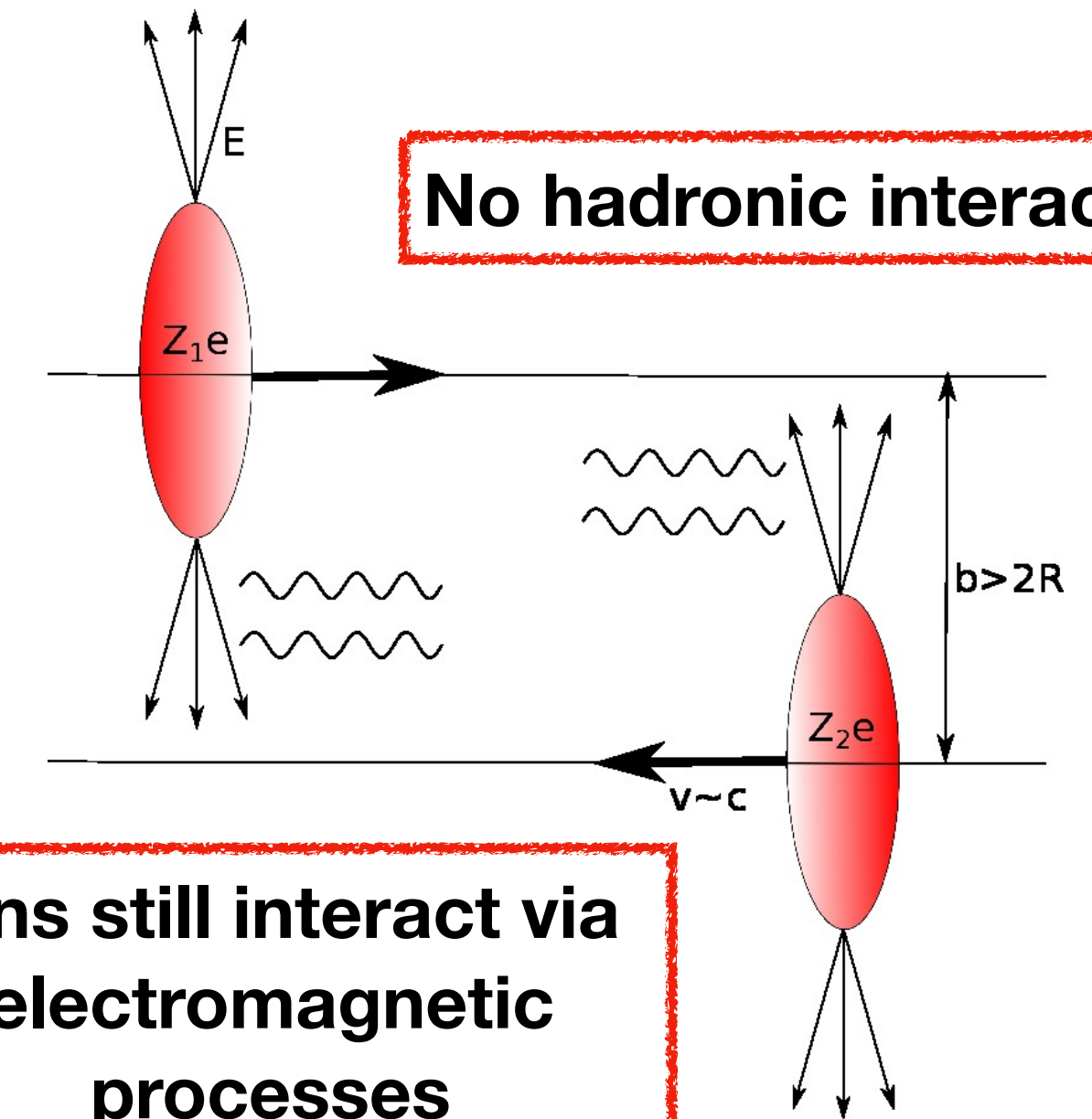
**KU** THE UNIVERSITY OF  
KANSAS

## New Common Online-Offline (O2) Computing system

- ✓ To cope up with an increased interaction rate of up to 50 kHz for Pb-Pb collisions in continuous readout mode
- ✓ To collect a data sample more than 10 times larger than the combined Run 1 and Run 2 samples.

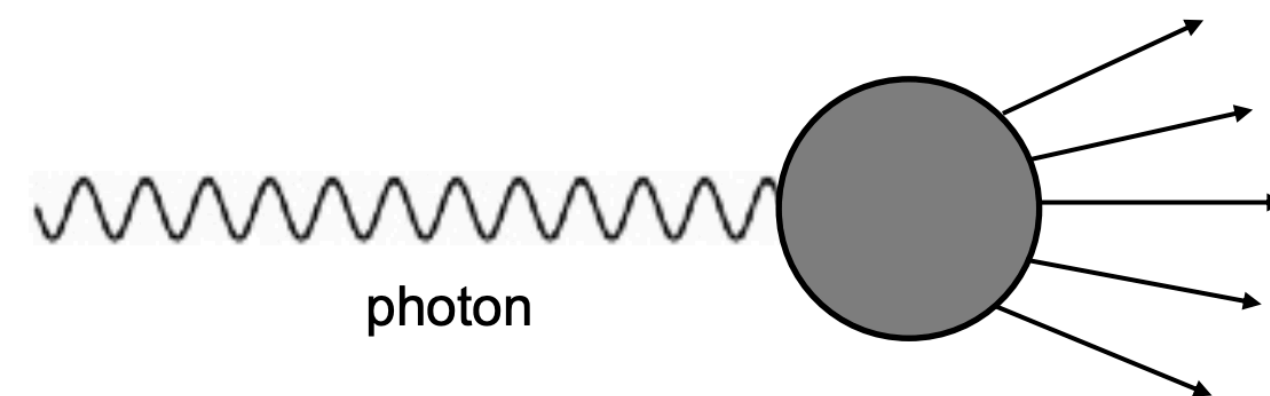


- ✓ Ultra-Peripheral Collisions (UPCs) provide a tool to study photoproduction at the LHC.
- ✓ Possible maximum CM energy ( $W_{\gamma p}$ ) reaches upto  $\sim 3$  TeV (5-10 times higher than that was available at HERA) at the LHC for pp collisions.
- ✓ Possible to study nuclear shadowing and saturation region of gluon distribution ( Bjorken-x values down to  $\sim 10^{-6}$  ).
- ✓ Photoproduction of vector mesons is sensitive to the gluon distribution in the target nucleus [*IJMPA 30 (2015) 1542012*]
- ✓ ALICE (at the LHC) has come a long way with the UPCs since Run 1 [*ALICE, arXiv:2211.04384*]
- ✓ Run 3 opens window to explore new regimes e.g search for axions-like particles and inclusive UPCs!

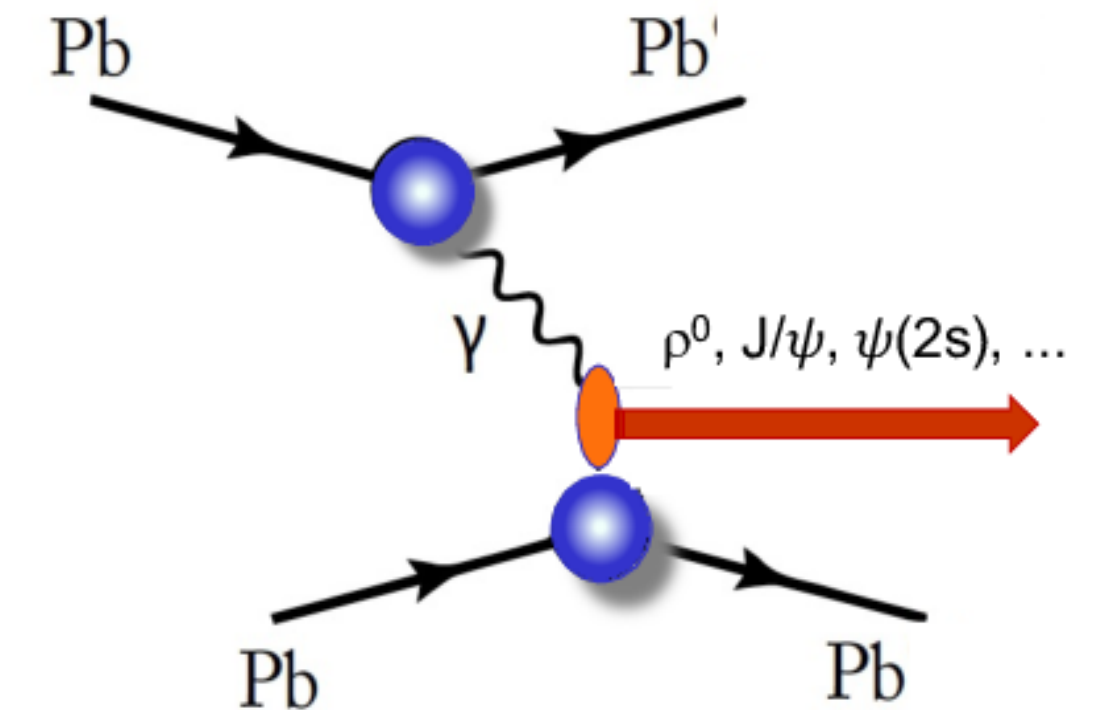


**Ends up in various rare processes -> Exclusive/Semi-Inclusive/Inclusive**

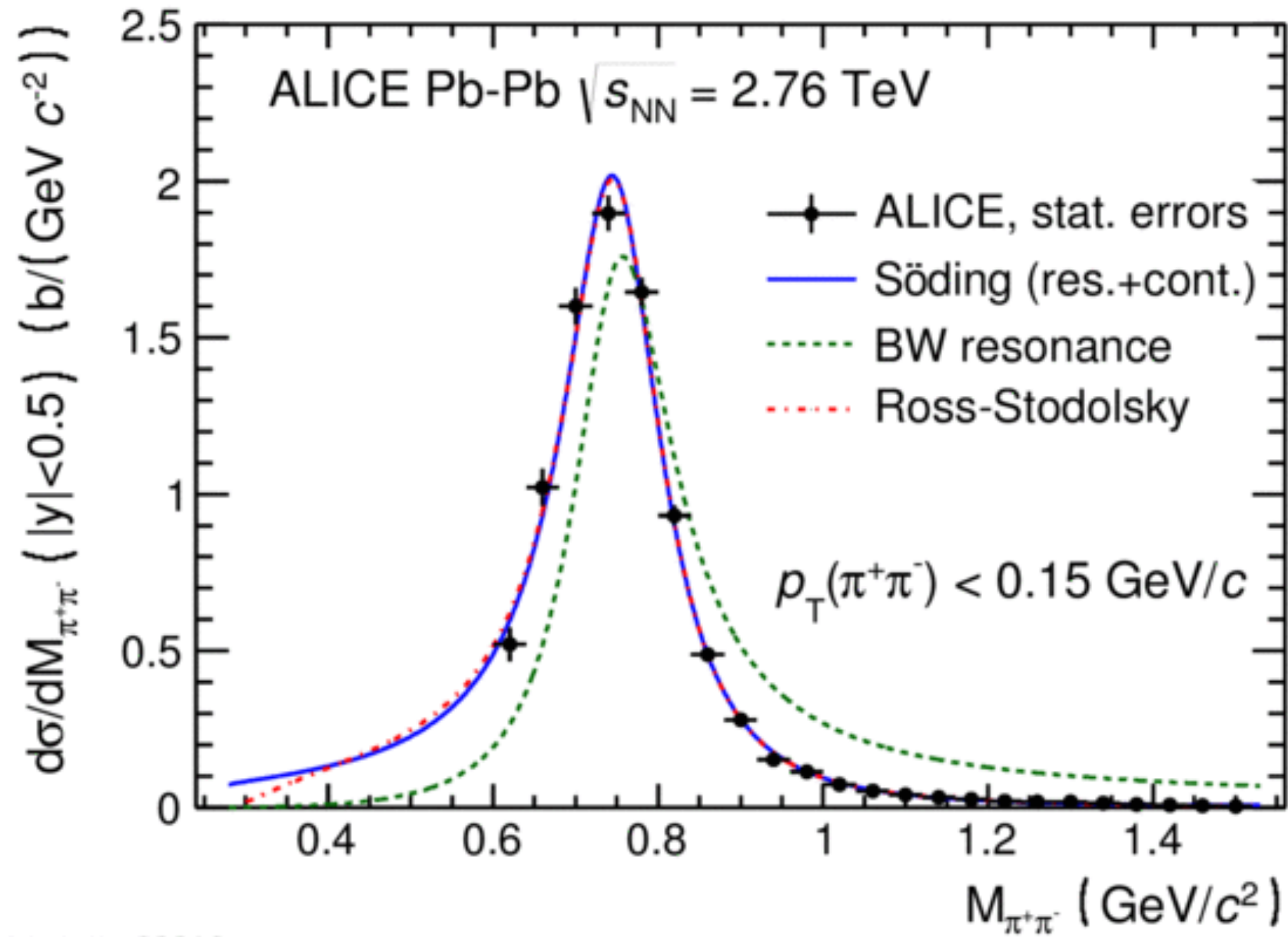
**Photon breaks up target nuclei**



**Typical exclusive VM production in UPC**



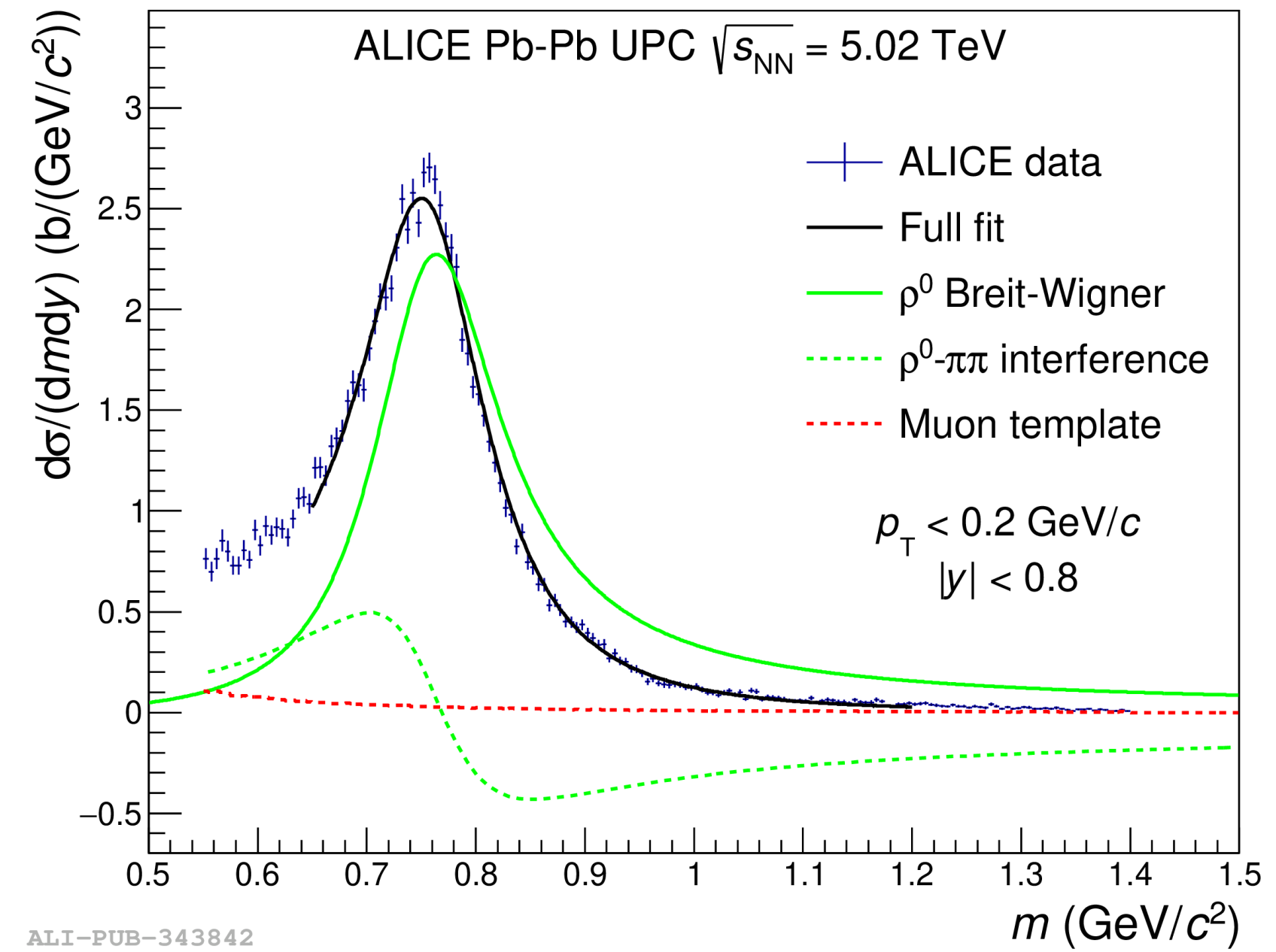
Run 1 : ~ 7k



ALI-PUB-92319

ALICE, JHEP 09 (2015) 095

Run 2 : ~ 60k



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)**

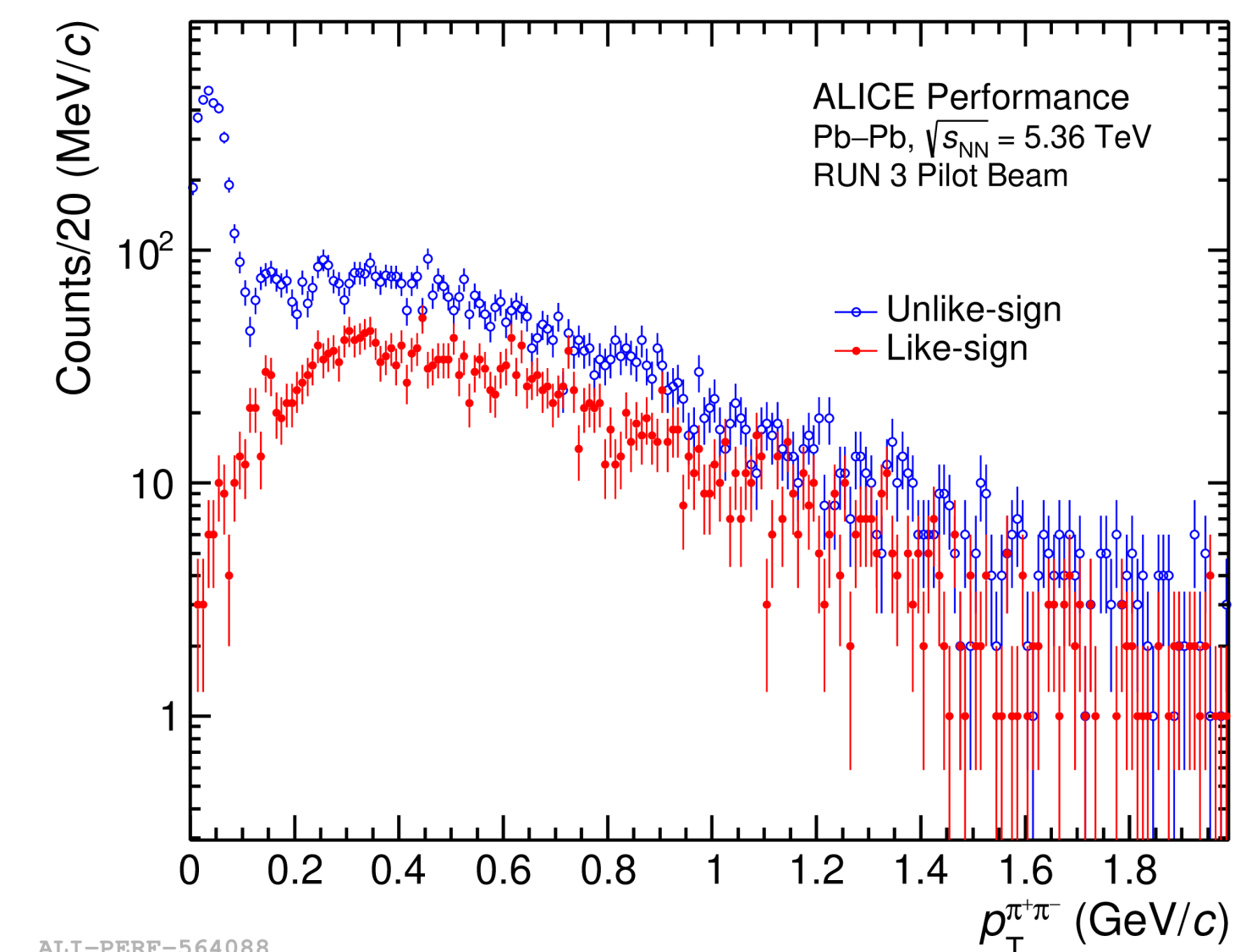
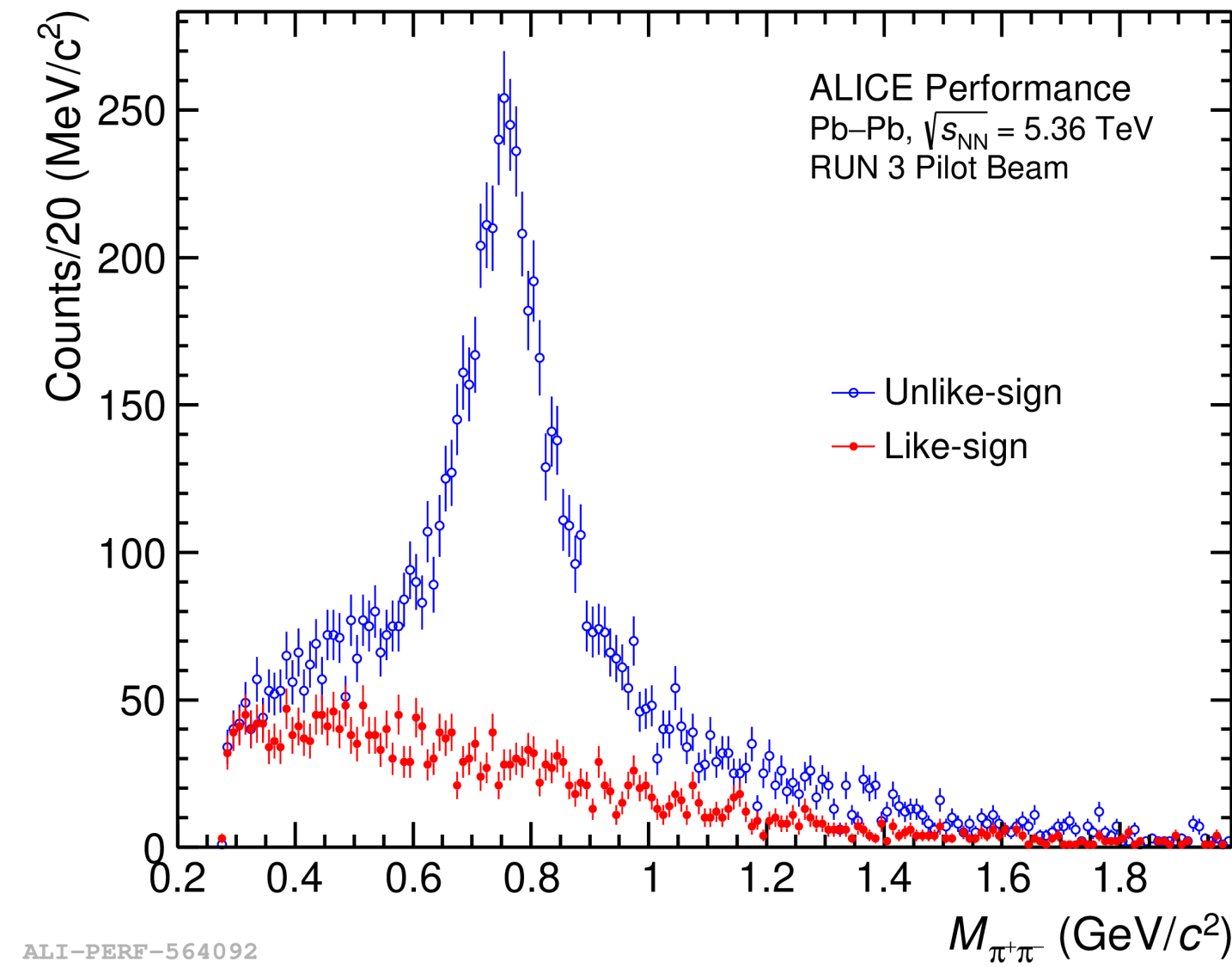
CERN Yellow Rep. Monogr. 7 (2019) 1159-1410

## Currently Run 3 heavy-ion data taking is ongoing !

Clear peak of coherent  $\rho^0$  in Pb-Pb  
UPCs at  $\sqrt{s_{NN}} = 5.36$  TeV

Example corresponds to pilot beam data taking  
in 2022 with integrated luminosity  $\sim 140$  mb $^{-1}$

Naturally things don't go as expected!



ALI-PERF-564092

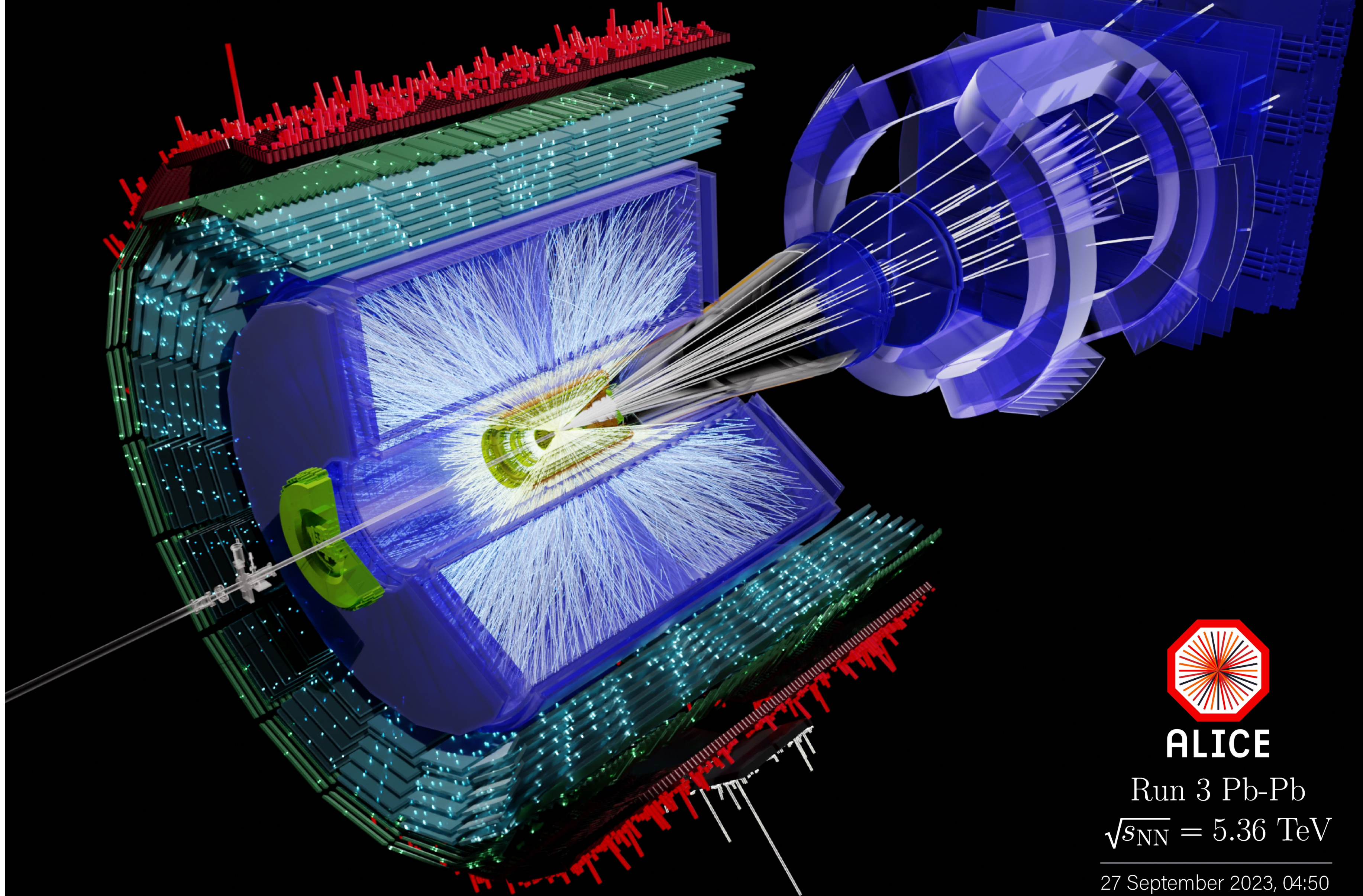
ALI-PERF-564088

With more data comes more challenges!!

- 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 :)

- ✓ ITS affected with beam background
- ✓ Issue is fixed with dedicated background study
- ✓ Now successful data taking ongoing with 45 kHz Hadronic Interaction Rate !
- ✓ Lack of trigger makes reconstruction process challenging-> alignment, track to collision association, vertex finding, TPC distortion map etc
- ✓ Higher rates, larger distortions and larger time uncertainties due to the continuous readout
- ✓ Back to square one with new analysis framework!
- ✓ Work and development in progress, stay tuned!

# Event display



**ALICE**

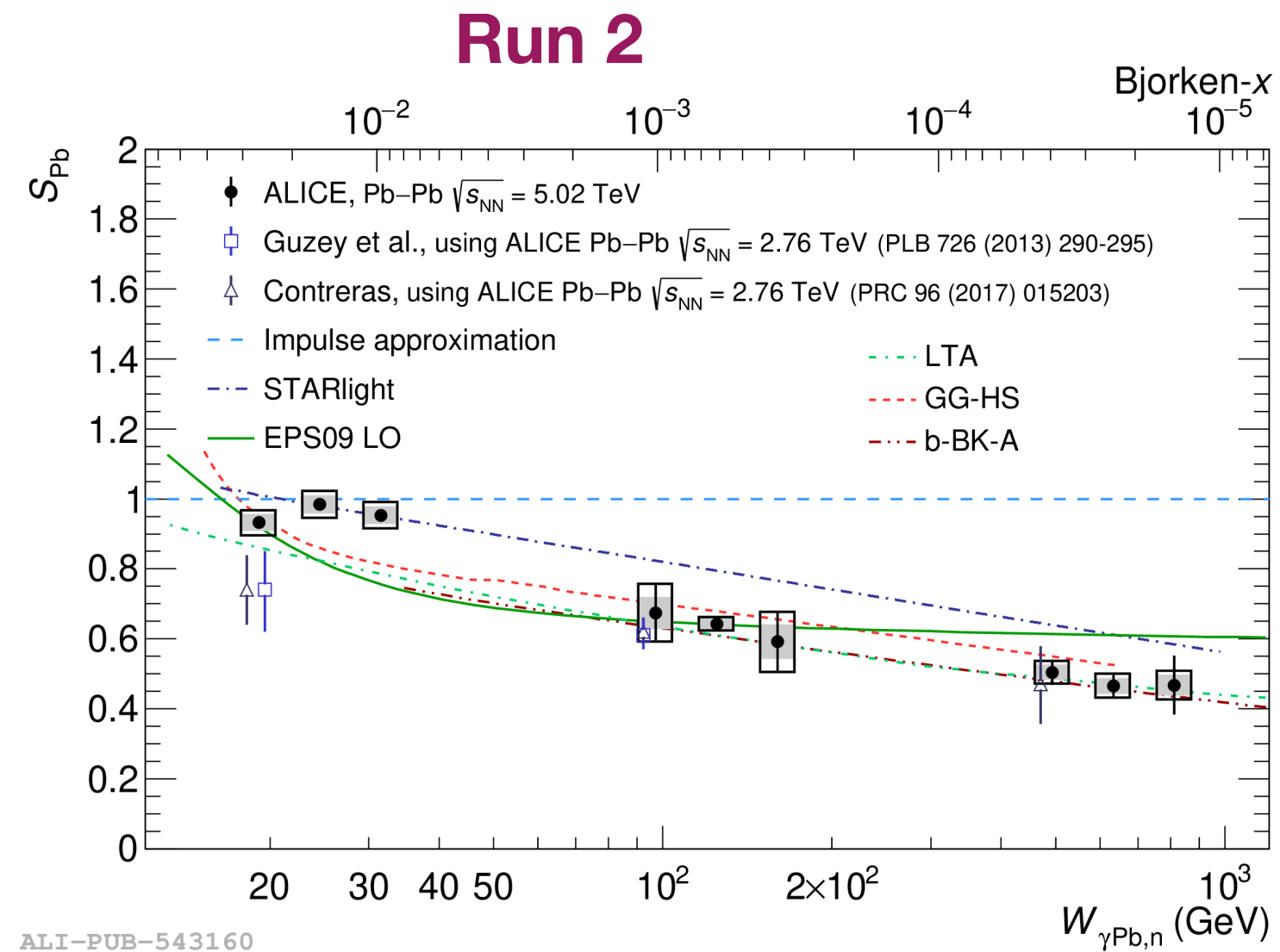
Run 3 Pb-Pb  
 $\sqrt{s_{NN}} = 5.36 \text{ TeV}$

27 September 2023, 04:50

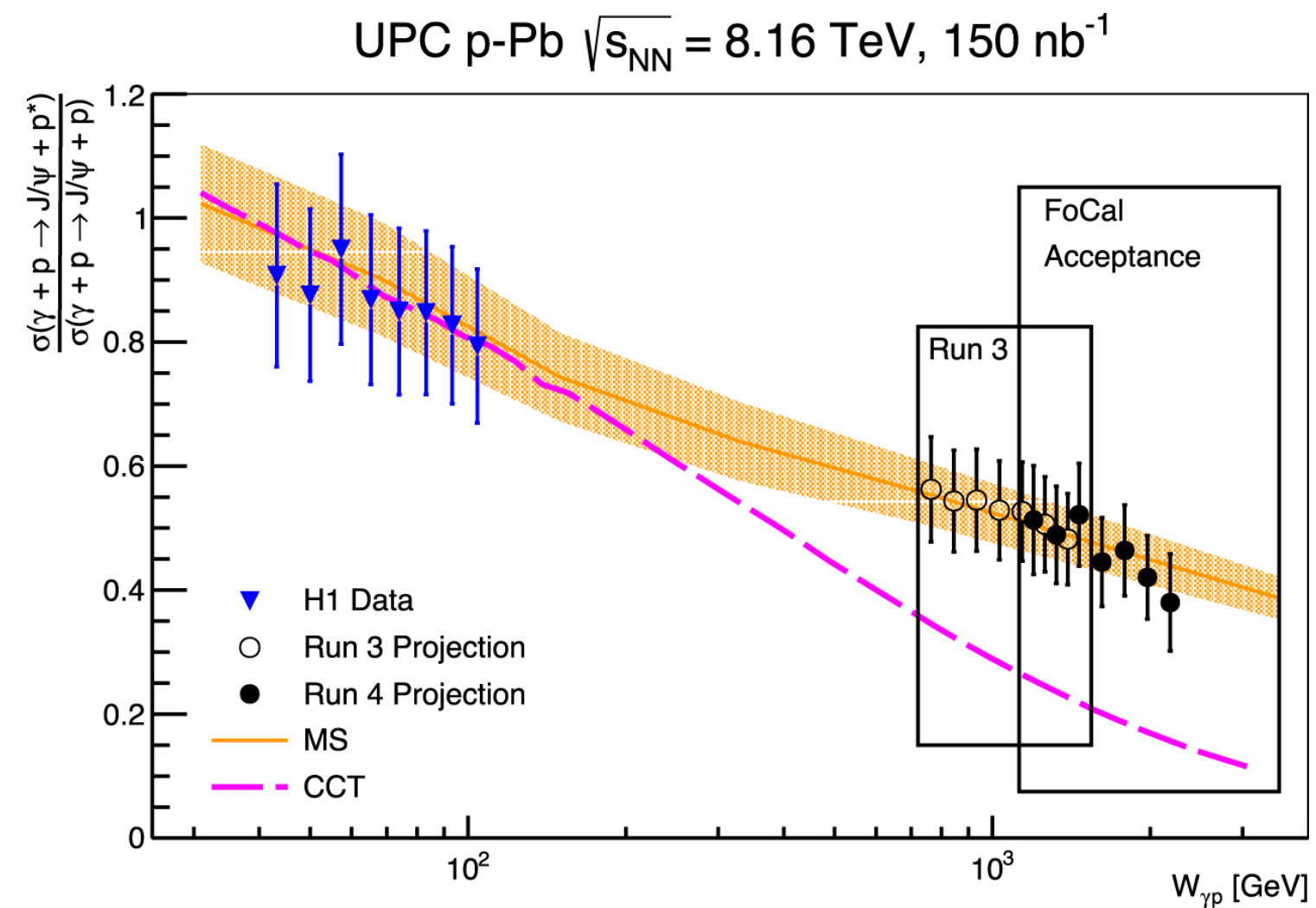
# UPC Physics prospects in Run 3 and beyond : Exclusive vector meson photoproduction



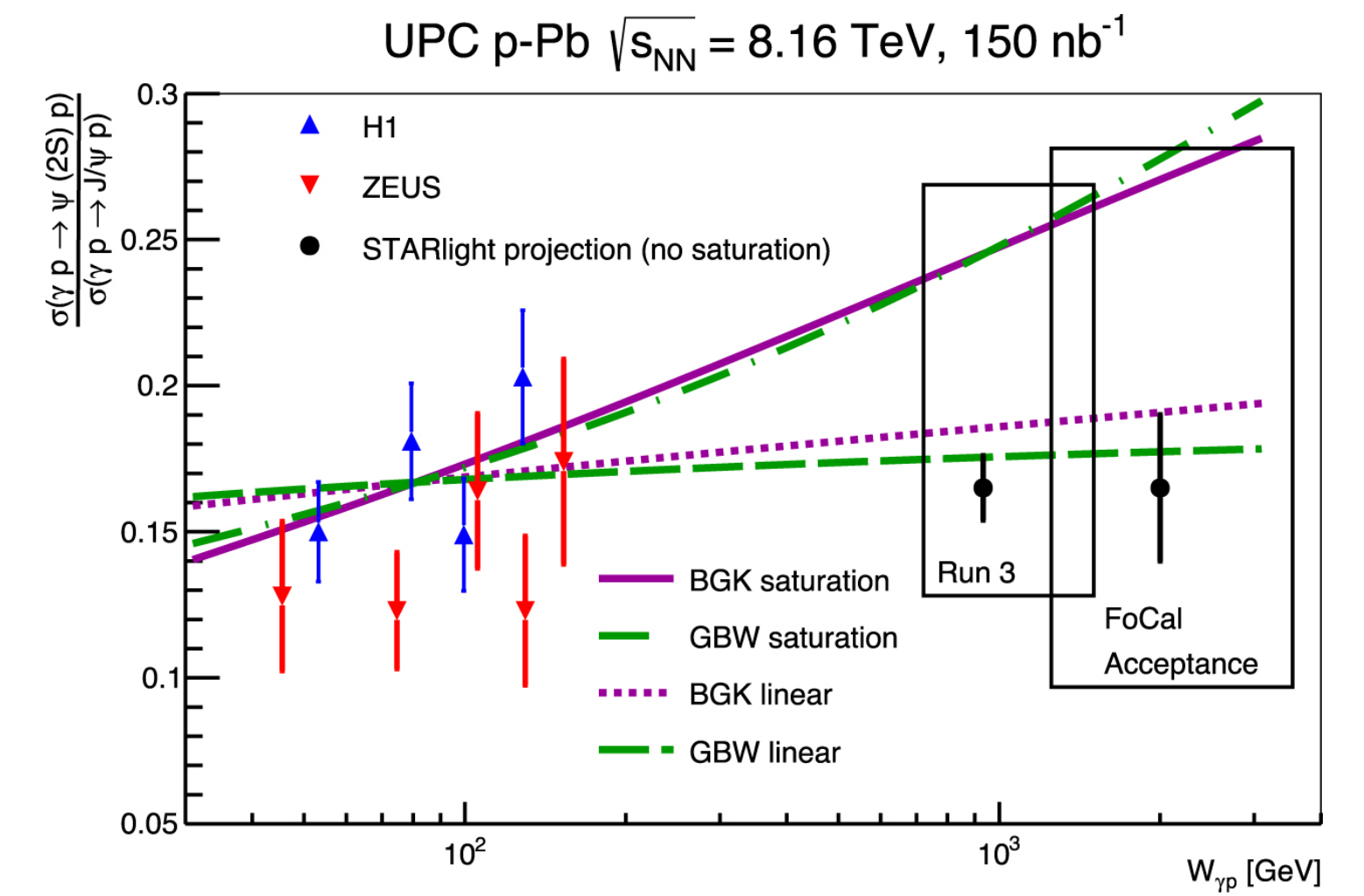
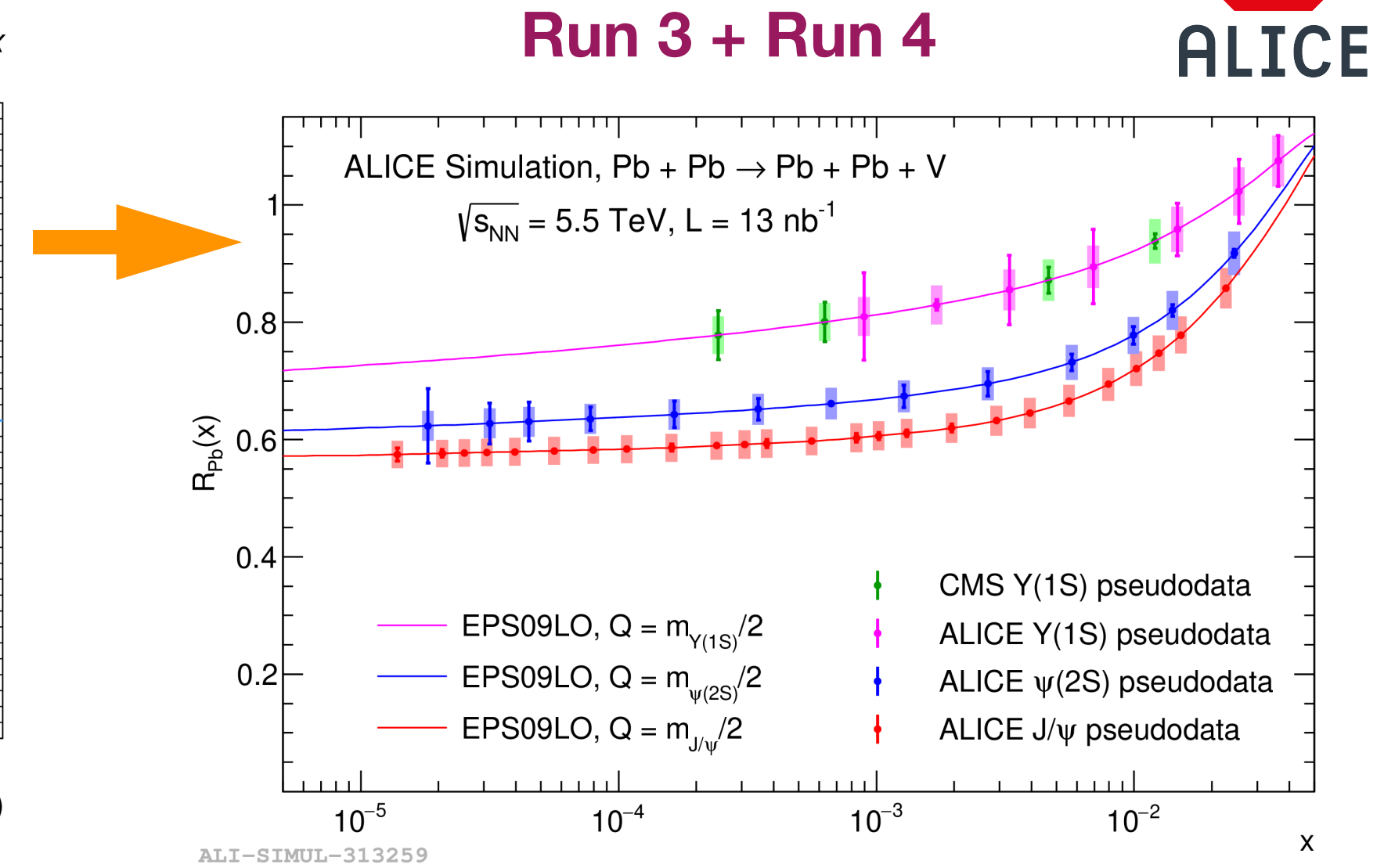
- ✓ Precision study of vector meson photoproduction in UPCs with significant increase in integrated luminosity.
- ✓ Uncertainties for nuclear suppression factor are expected to be at the level of 4%. [CERN Yellow Rep. Monogr. 7 (2019) 1159-1410]. See poster by Simone Ragoni.
- ✓ Double vector meson photoproduction.
- ✓ UPC bottomonia production. [arXiv:2303.03007v1]
- ✓ Exclusive  $\phi$  production in the dikaon channel (currently done with Run 2 data in ALICE -> Results awaiting).
- ✓ 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]



ALICE, arXiv:2305.19060

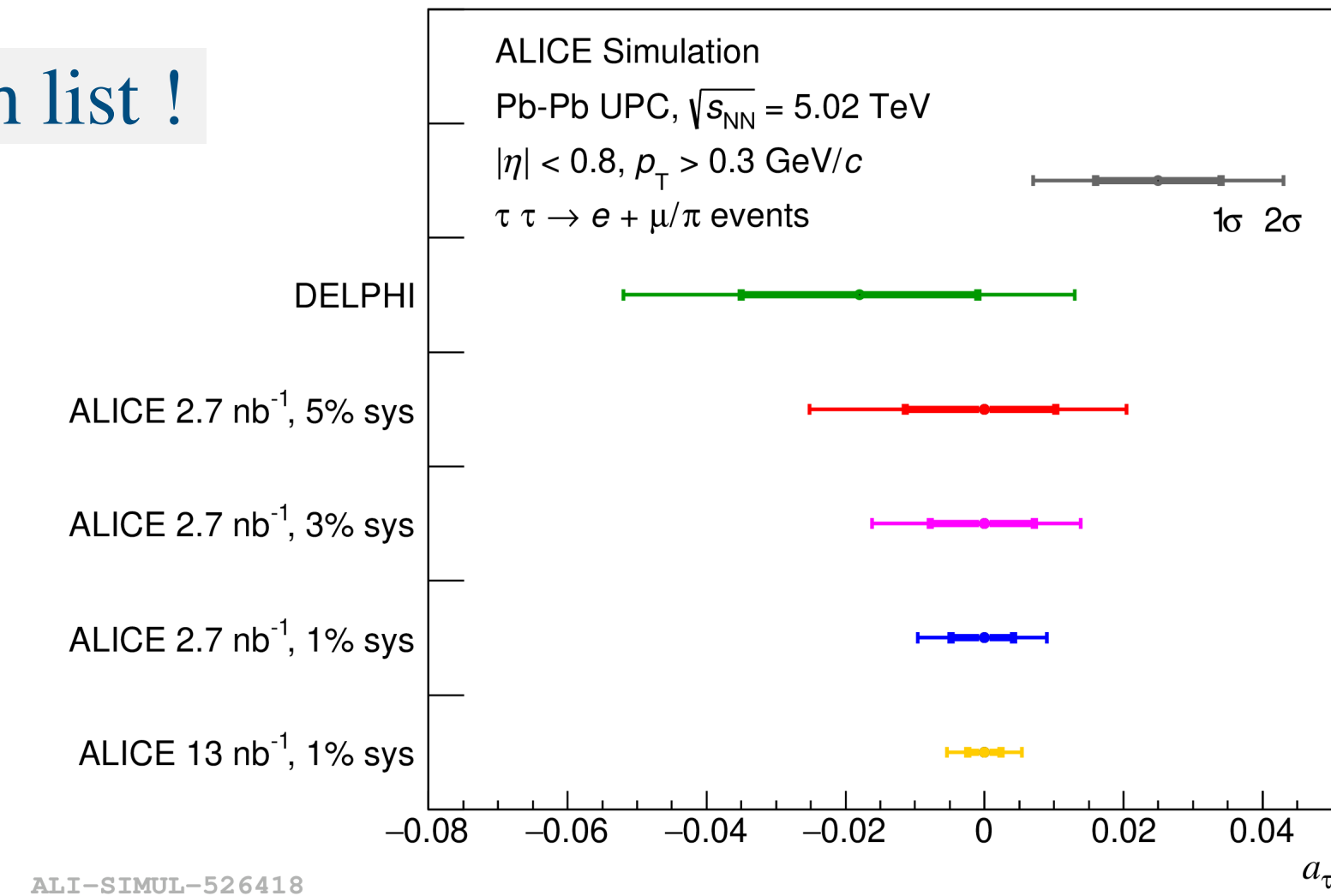


[J. Phys. G: Nucl. Part. Phys. 50 055105]

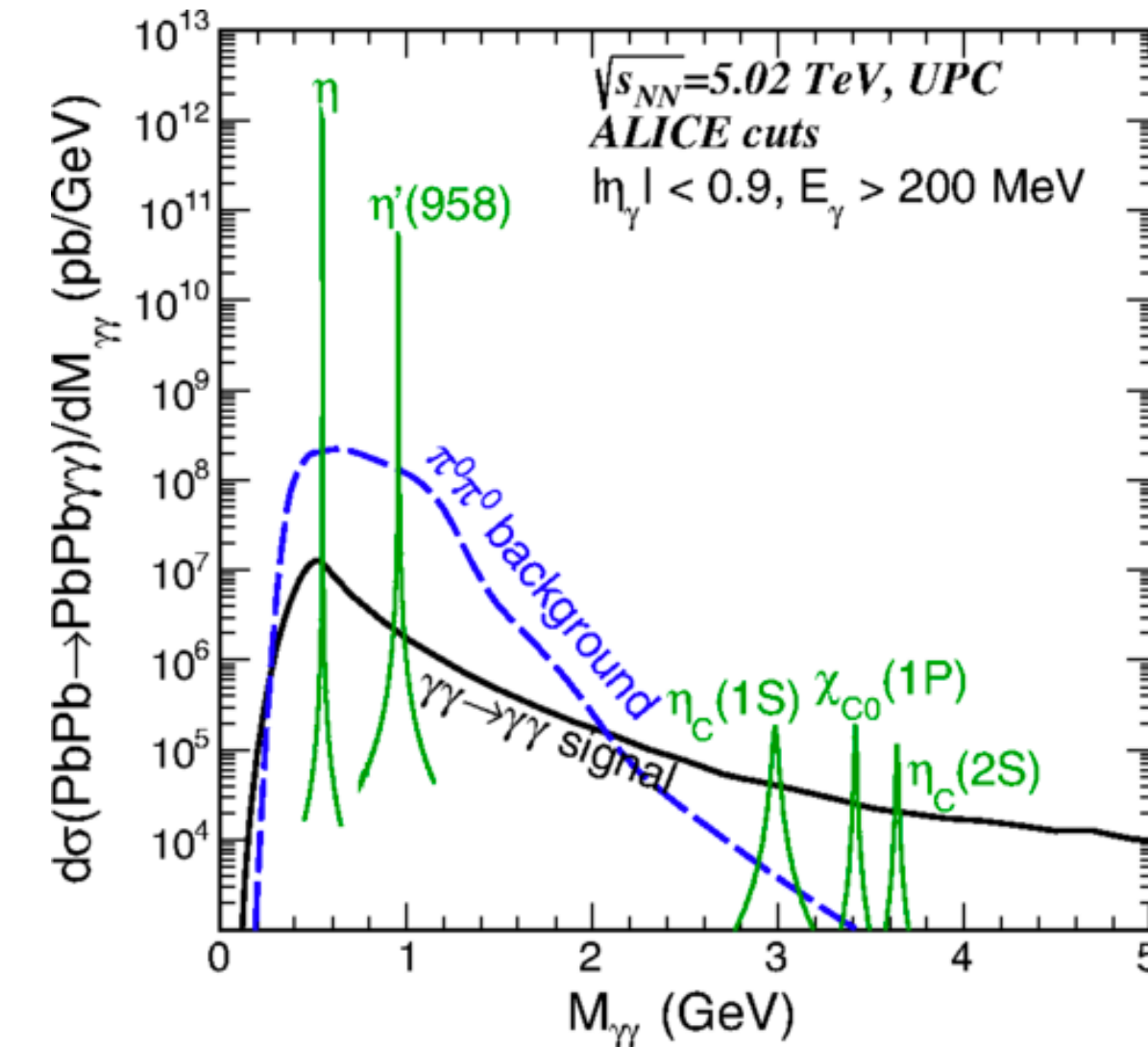
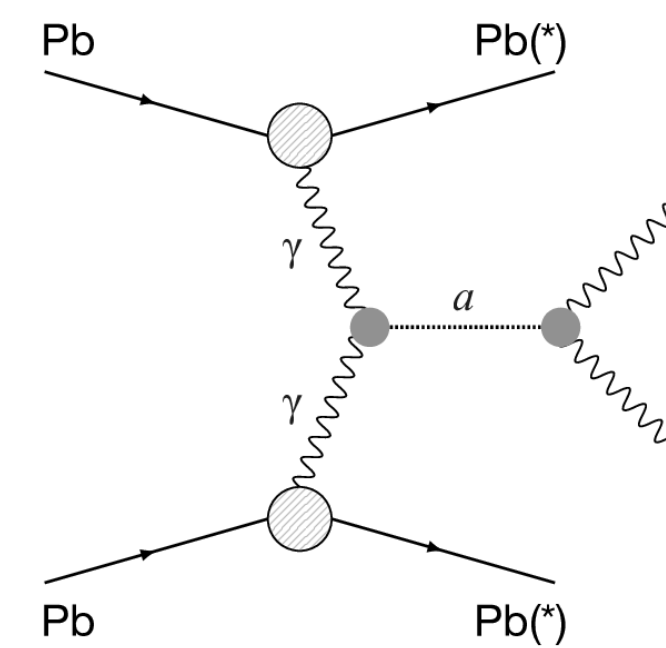


## What one could possibly do in ALICE? A personal wish list !

- ✓ Open heavy flavour in UPCs : Possible with triggerless data taking, cross section much larger than charmonia [Nucl. Phys. A 976 (2018) 33-45]. Only a single gluon is involved unlike vector meson photoproductions.
- ✓ Direct 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.
- ✓ Challenging but possible to study at the LHC.



ALI-SIMUL-526418

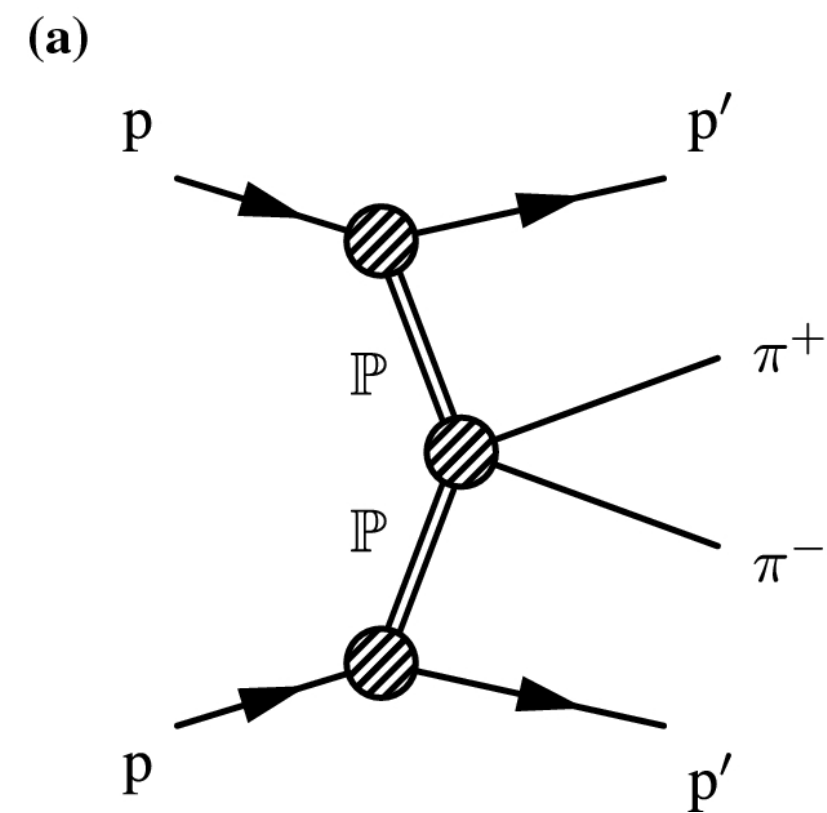


[PRD 99 (2019) 9, 093013]



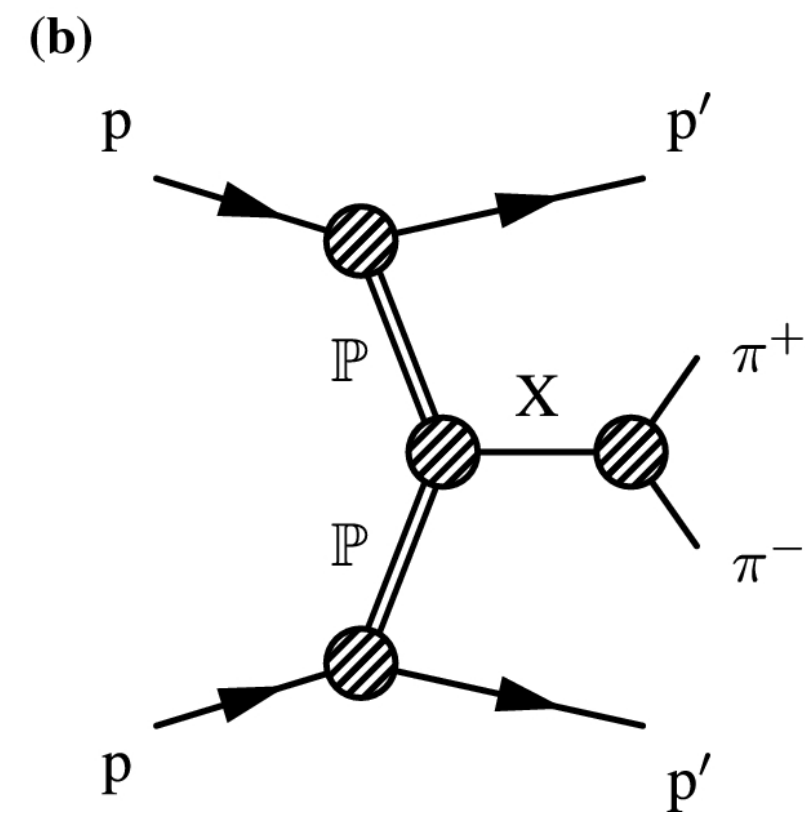
## Study of diffraction reactions (exchange of colourless objects)

### $\gamma\gamma$ interaction



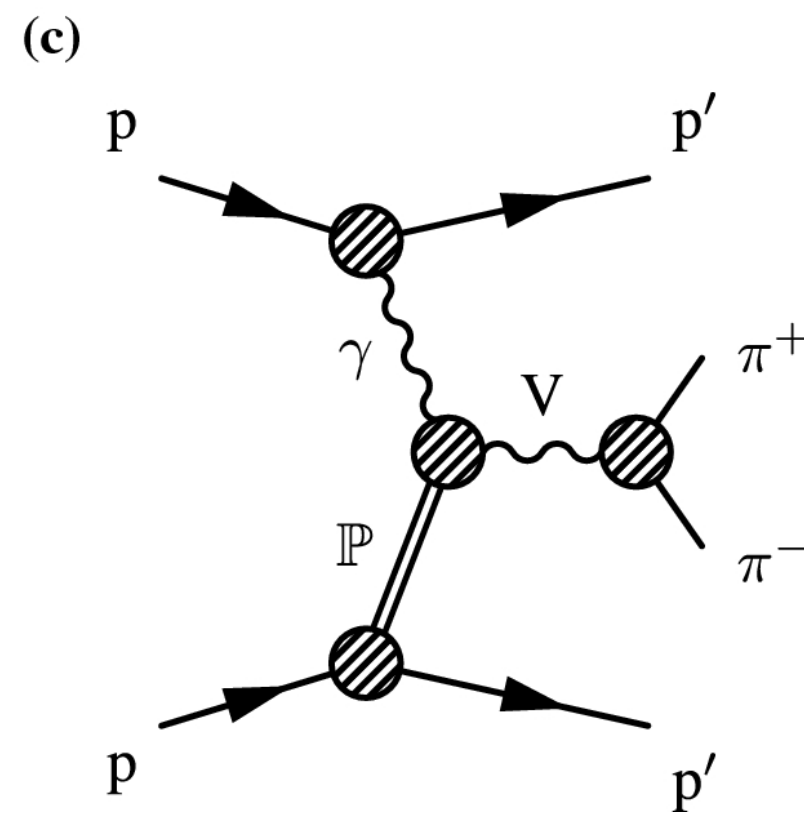
**Final state:  $l+l^-$ , meson or photon pairs (light-by-light scattering)**

### Double-pomeron exchange

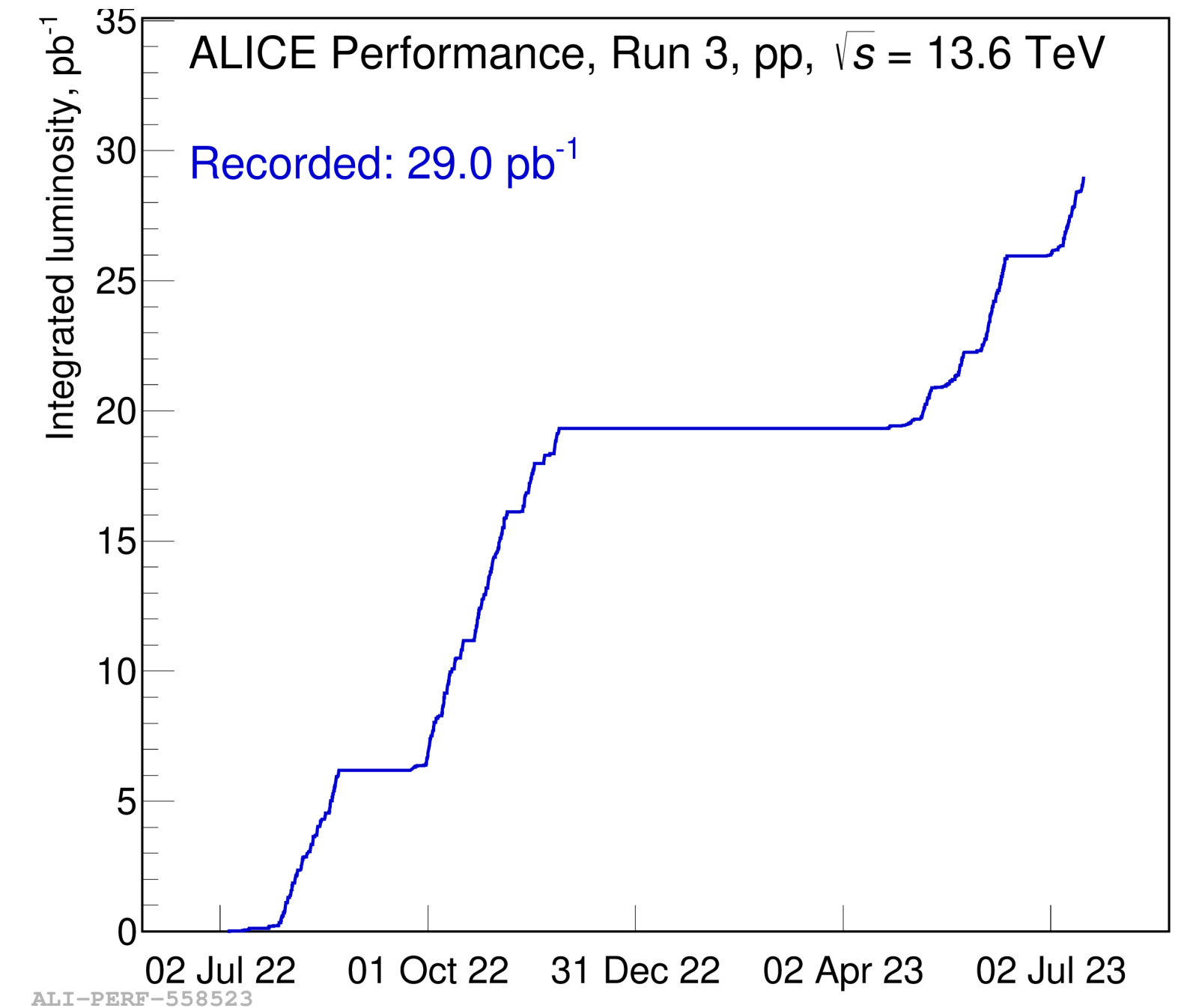


**Final state: enhanced production of gluon-rich final states**

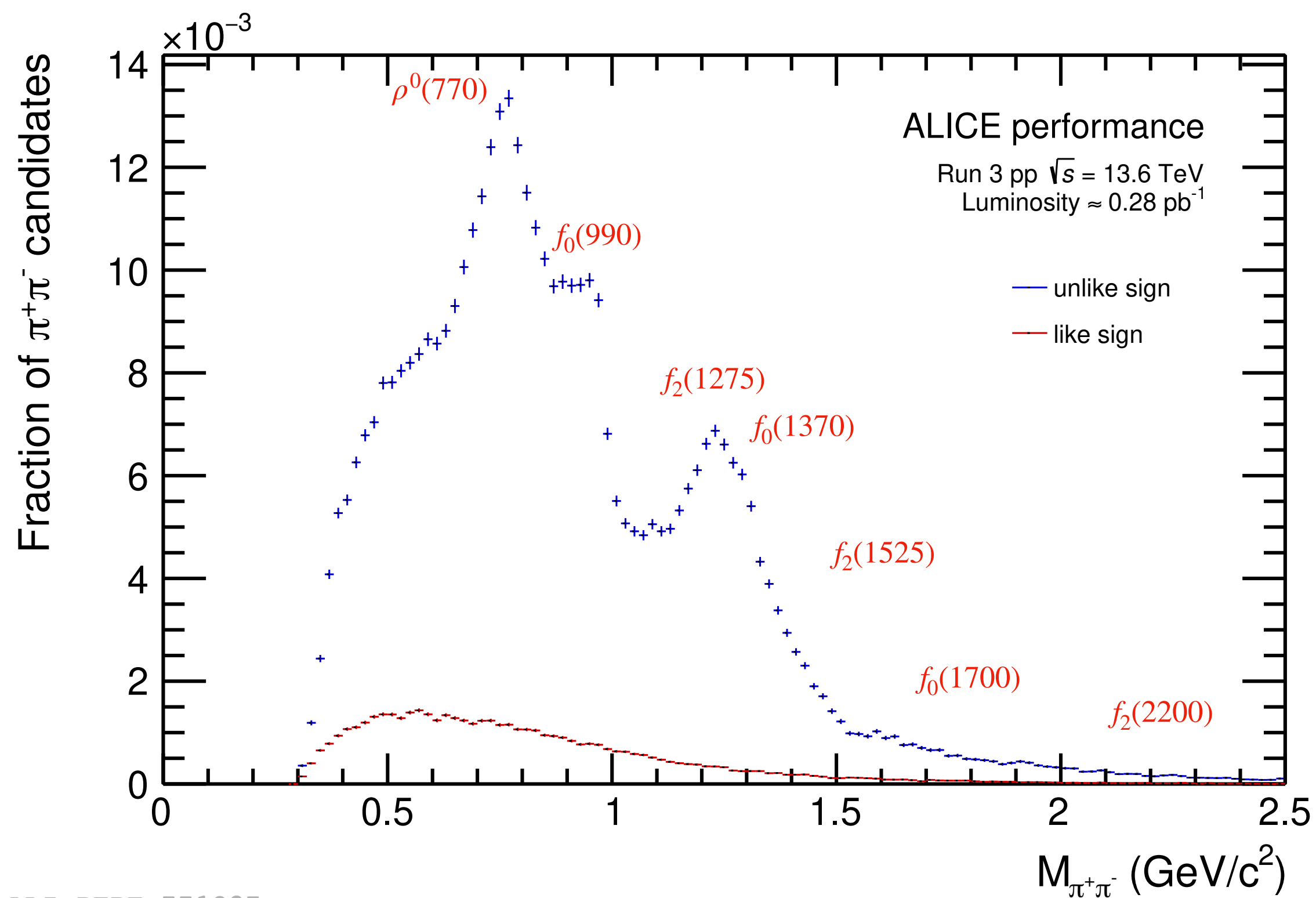
### $\gamma$ pomeron interaction



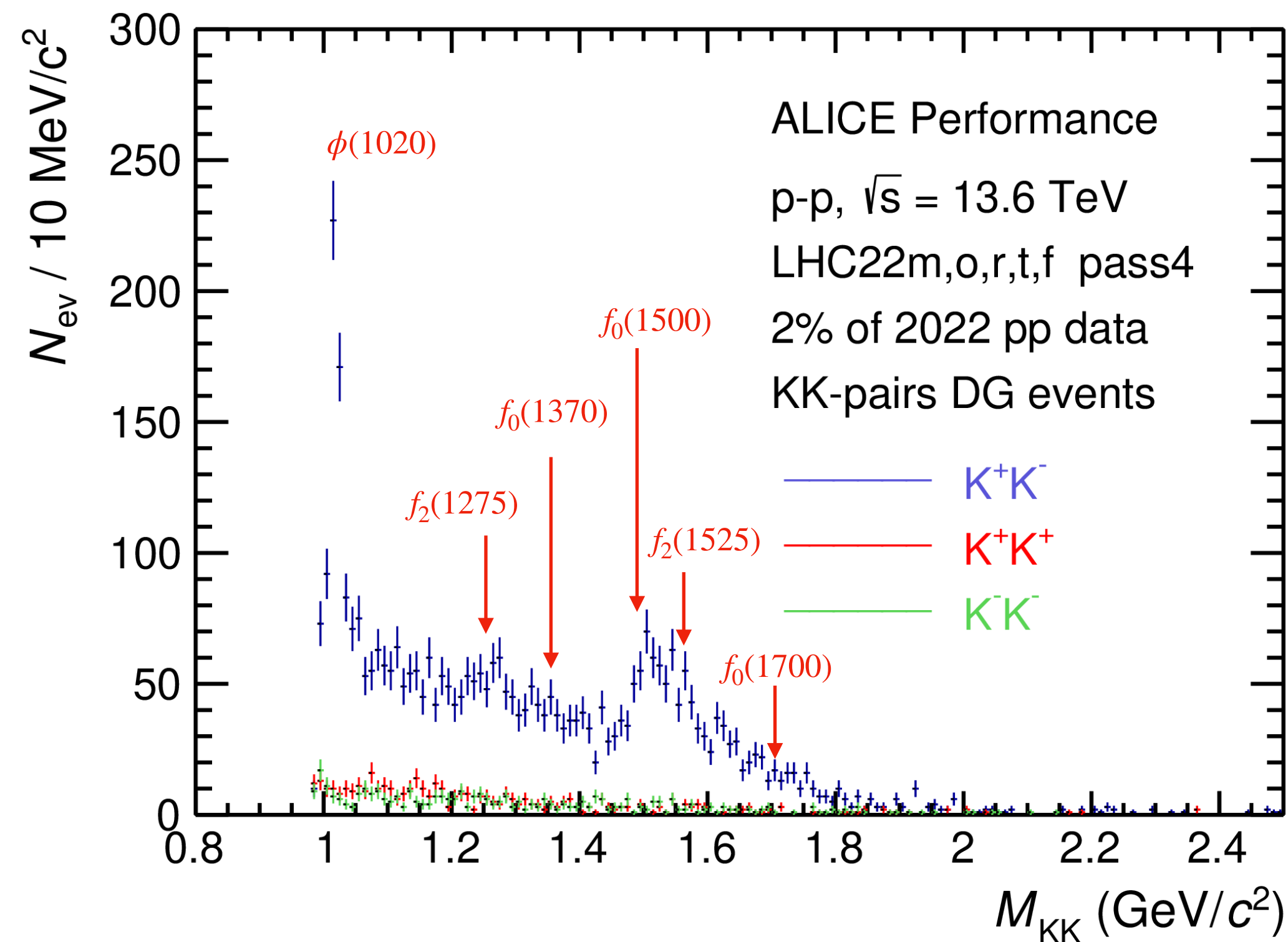
**Final state: vector mesons or dijets**



- ✓ 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  $\sim 8$  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.
- ✓ Evidence of strangeness in double gap events with  $\phi(1020)$  and  $f_2(1525)$  states.

# Physics prospects and data preparation for UPC studies with ALICE in Run 3

Anisa Khatun<sup>1,2</sup> for the ALICE Collaboration  
 1. The university of Kansas, Lawrence, USA  
 anisa.khatun@cern.ch

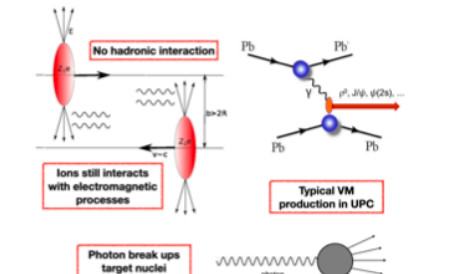


ALICE



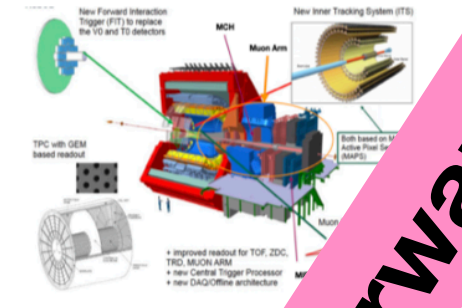
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## Physics of Ultra-peripheral collisions (UPCs)



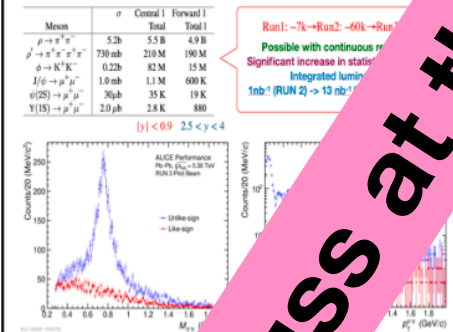
- Ultra-Peripheral Collisions (UPCs) provides a tool to study photo-production at LHC.
- Possible maximum CM energy reach  $\sim 3$  TeV (5 - 10 times higher than that was available at HERA).
- Possible to study nuclear shadowing and saturation region of gluon distribution (Bjorken  $x$  values down to  $\sim 10^{-6}$ ).
- Photo-production of vector mesons are sensitive to the gluon distribution in the target nucleus [1].
- ALICE has come a long way with UPCs since RUN 1 [2].
- RUN 3 opens a window to explore new regimes like search for axions and inclusive UPCs.

## The ALICE experiment in RUN3

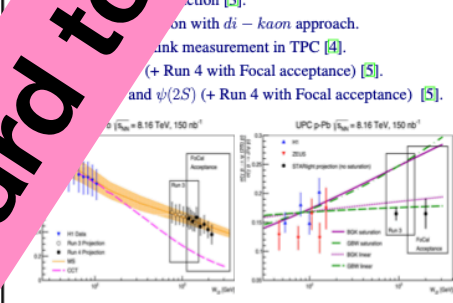


- To cope up with an increase in collision rate to 50 kHz for Pb-Pb collisions in core.
- To collect a data sample larger than the combined Run 1 and Run 2.
- First Pb-Pb data recorded on 20th September 2022.

## Progress of UPCs at ALICE

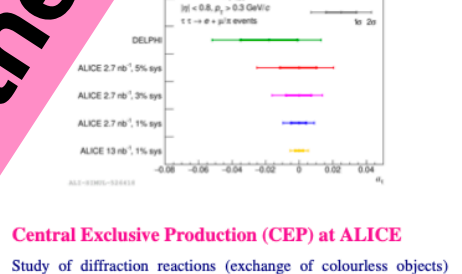


- Now successful data taking for hadronic interaction.
- Work and development for UPCs.

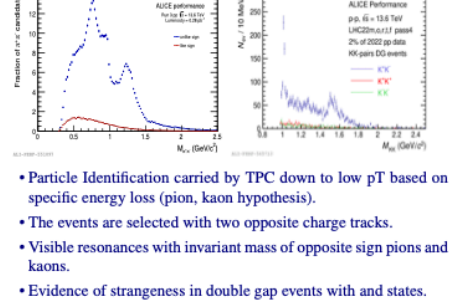


- $\gamma\gamma$  interaction in UPC: Axion Like particles (ALPs) by measuring light-by-light scattering and resonances.
- Axions are likely lighter particles. ALICE can potentially push down the search to 1 GeV with focus on low invariant masses [6].
- Direct measurement of  $r$  anomalous magnetic moment [7, 8].
- Tetraquarks:  $\gamma\gamma \rightarrow T_{cc} \rightarrow d\bar{d}$  [9].
- Open Heavy-flavour in UPCs [10].
- Inclusive/Semi Inclusive UPCs: Inclusive  $J/\psi$ , Jets in UPCs.
- Challenging but possible to study at LHC.

## Central Exclusive Production (CEP) at ALICE



- CEP 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 29.0 pb<sup>-1</sup> of integrated luminosity recorded in pp collisions at  $\sqrt{s} = 13.6$  TeV in 2023 + 2022. (More than 50 times data as compare to RUN 2)



- Particle Identification carried by TPC down to low pT based on specific energy loss (pion, kaon hypothesis).
- The events are selected with two opposite charge tracks.
- Visible resonances with invariant mass of opposite sign pions and kaons.
- Evidence of strangeness in double gap events with and states.

## References

- [1] JHEP 03 (2015) 1542012
- [2] CERN Yellow Rep. Monogr. 7 (2019) 1159 - 1410
- [3] Nucl. Phys. C 81 (2003) 6 - 706
- [4] PRL 768 (2017) 299-304
- [5] J. Phys. G: Nucl. Part. Phys. 50 055105
- [6] PRD 99 (2019) 9, 093013
- [7] arXiv:2208.09192v2
- [8] arXiv:2204.1476v4
- [9] PRL 816 (2021) 136249
- [10] Nucl. Phys. A 976 (2018) 33-45

Looking forward to discuss at the poster session!

Thank You !