Neutral meson production results in pp, p–Pb and Pb–Pb collisions in ALICE

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ALICE detector setup

Electromagnetic calorimeter (EMCal) + DCal

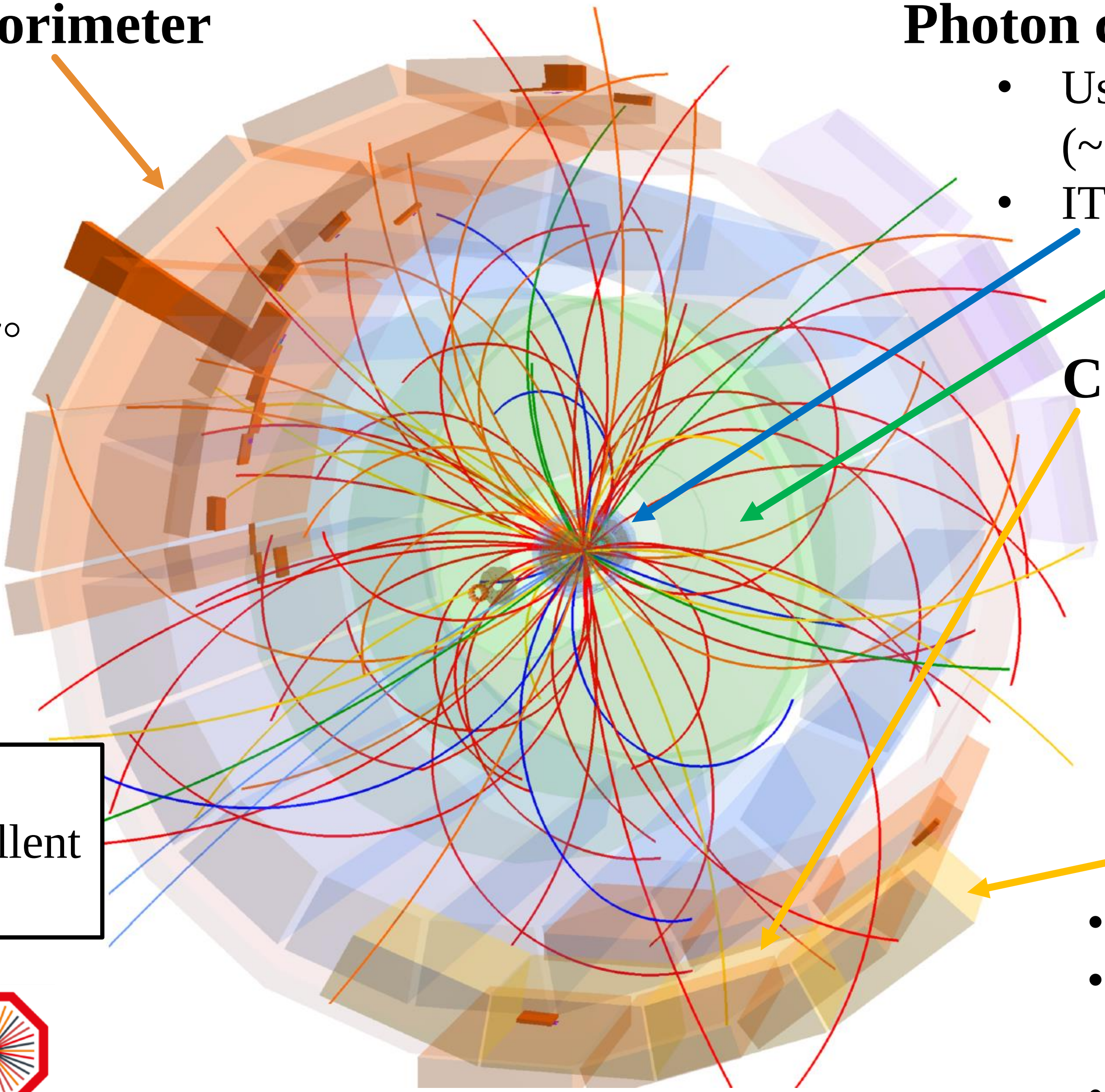
- Pb-scintillator sample calorimeter
- Cell size – 6×6 cm^2
- $|\eta| < 0.7$, $80° < \varphi < 187°$ (large acceptance)

Photon conversion method (PCM)

- Using photon conversion probability (~ 8%) in detector material
- ITS + TPC: $|\eta| < 0.9$, $0° < \varphi < 360°$

Charged-Particle Veto (CPV)

- Used for photon identification
- 2 additional CPV modules were installed prior to Run 3



Different techniques are combined to achieve excellent precision and p_T range.

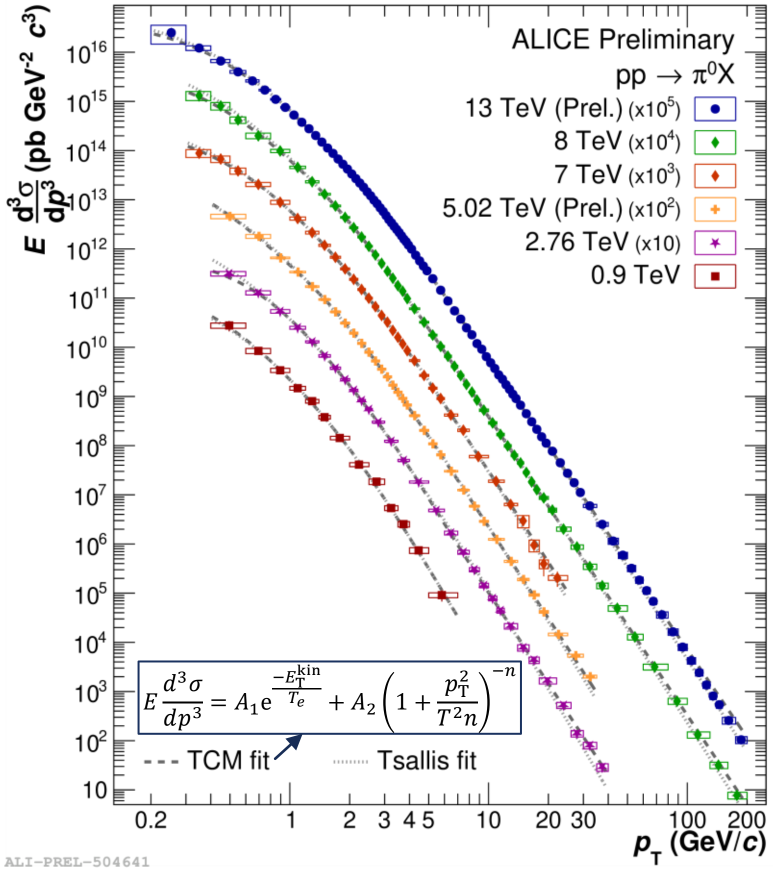
PHOS calorimeter

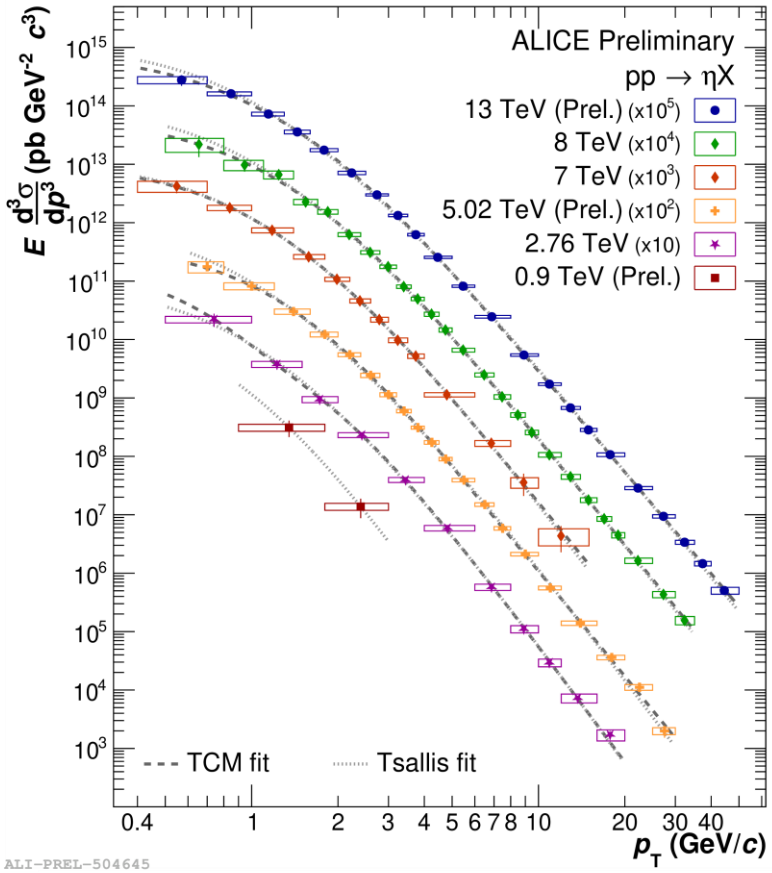
- $PbWO_4$ crystals
- High granularity (2.2×2.2 cm^2 cell size)
- $|\eta| < 0.12$, $260° < \varphi < 320°$

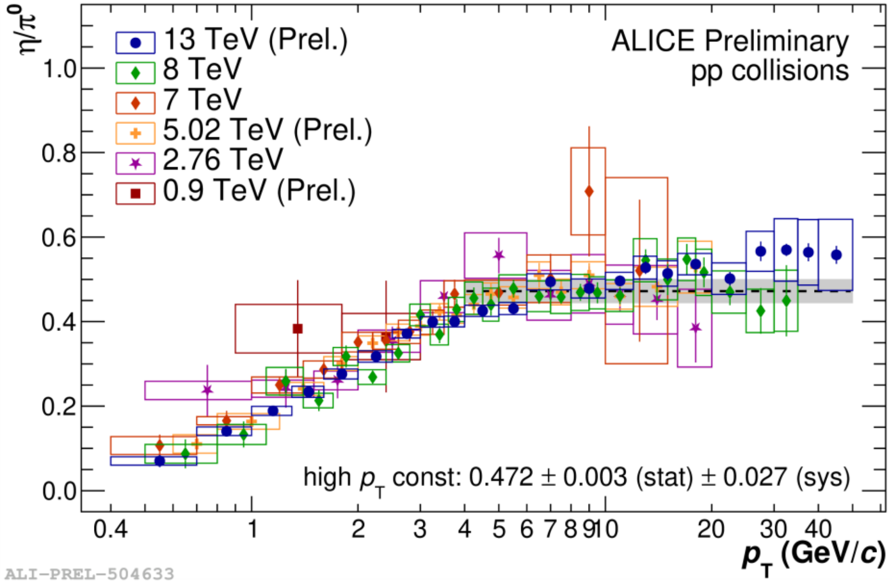
Run:266438
Timestamp:2016-11-26 17:56:16(UTC)
System: Pb-p
Energy: 8.16 TeV
EMCal L1 gamma and jet triggered event

ALICE

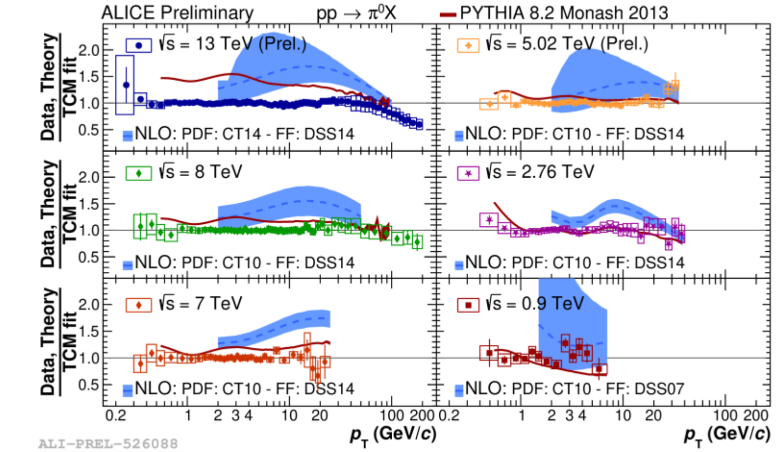
π^0 and η meson measurements in pp in Run 2

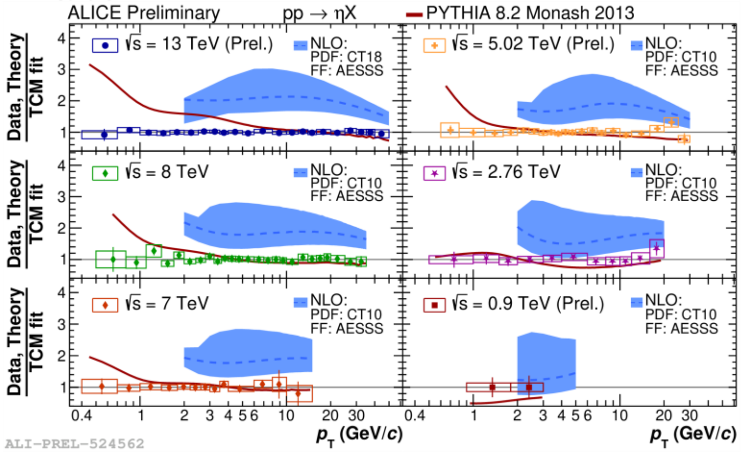






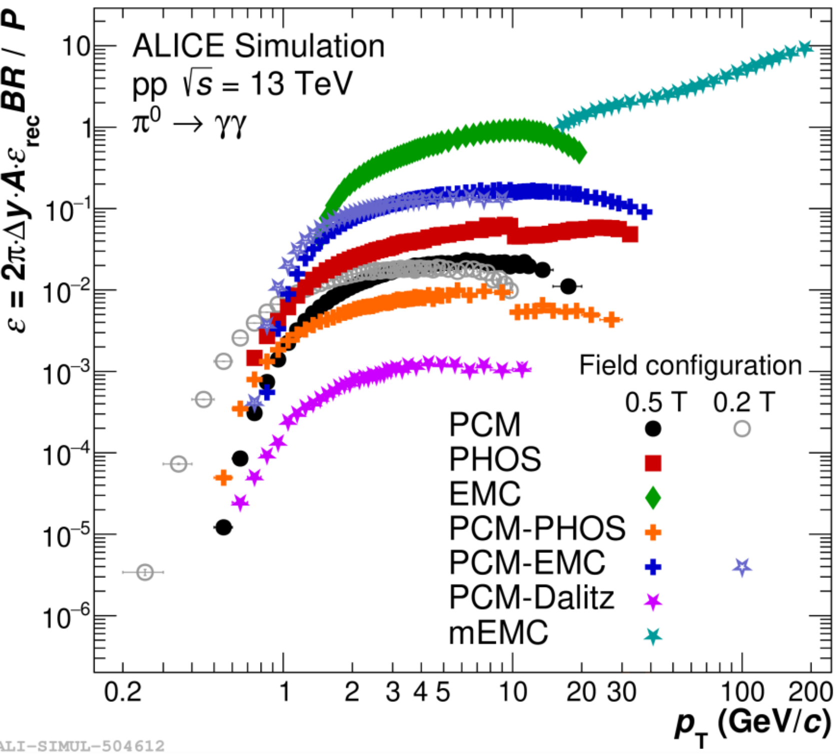
- Precise neutral meson measurements over wide p_T range help to **constrain FF and PDF + vital for direct photon measurements.**

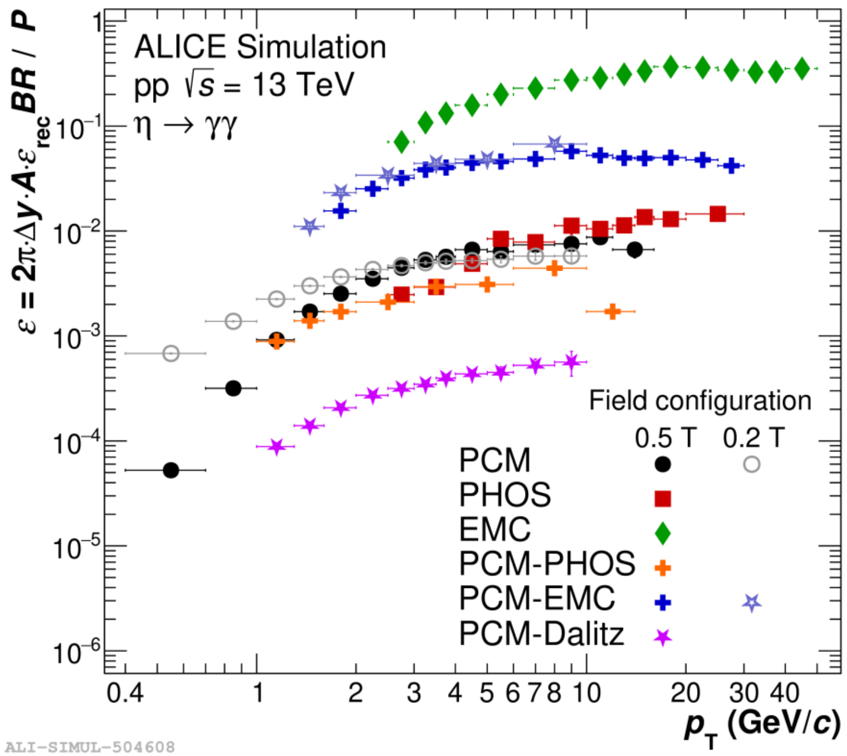


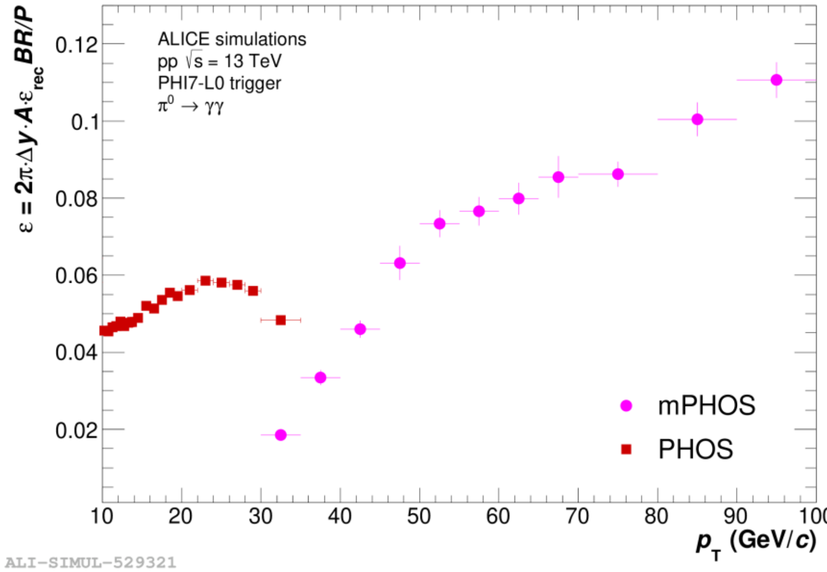


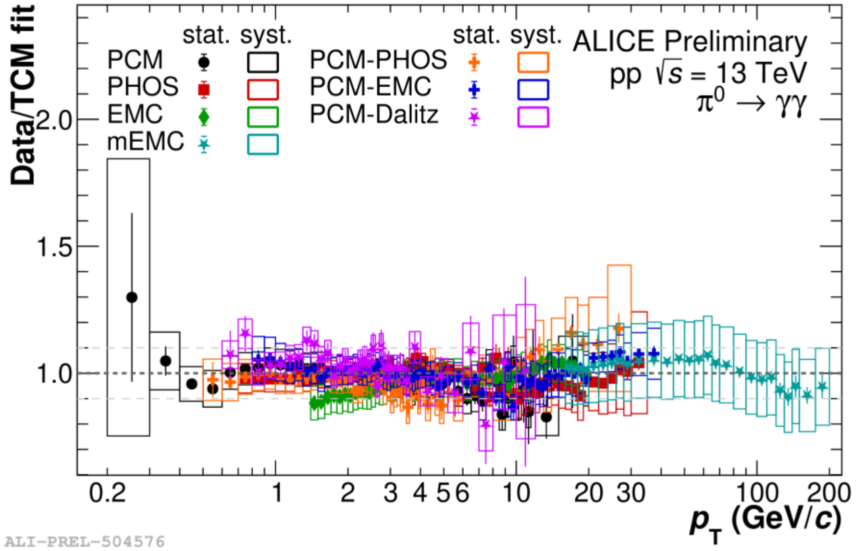
- Wide collision energies range (**0.9, 2.76, 5.02, 7, 8, and 13 TeV**) with combination of different reconstruction methods
- Both theory and PYTHIA 8 calculations tend to **overestimate** the data
- ***η/π^0***: No significant dependence on collision energy

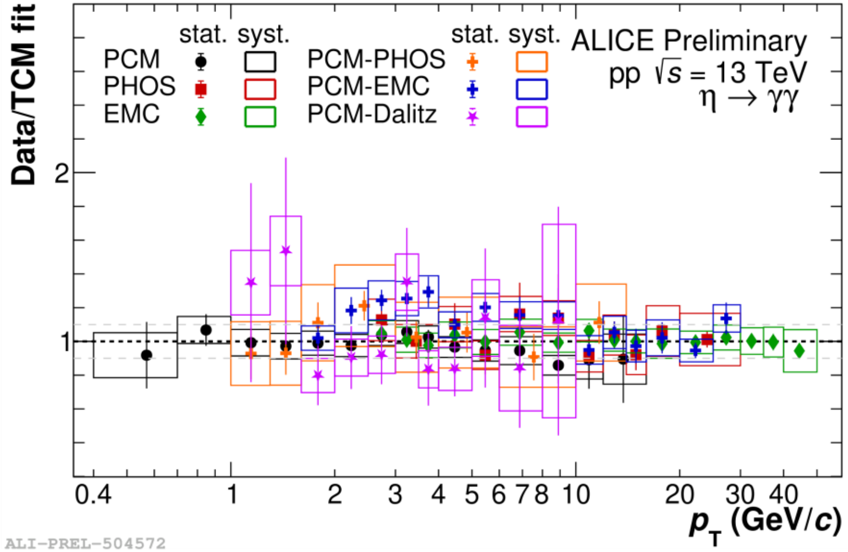
π^0 and η meson measurements in pp in Run 2









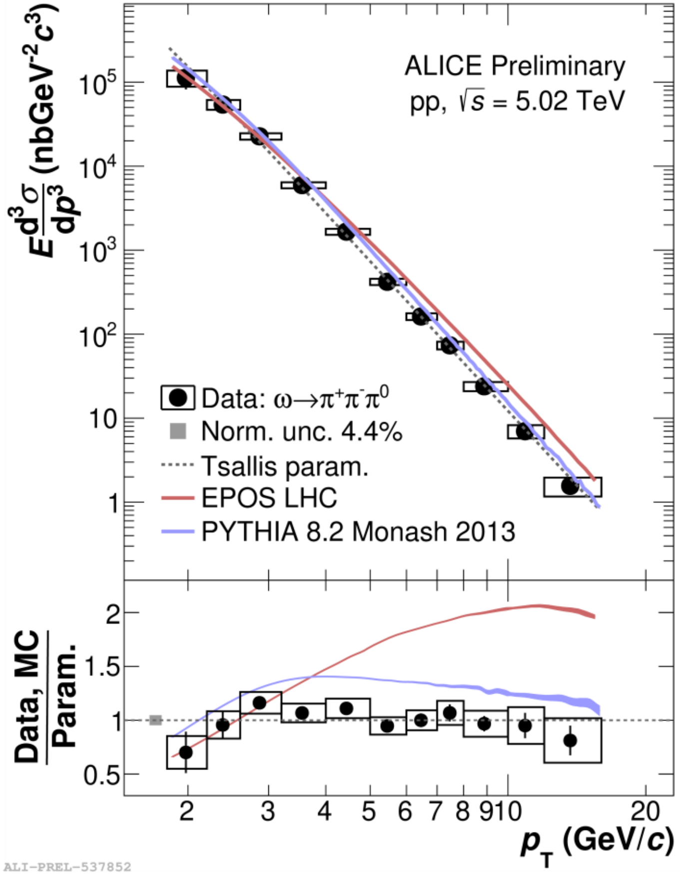


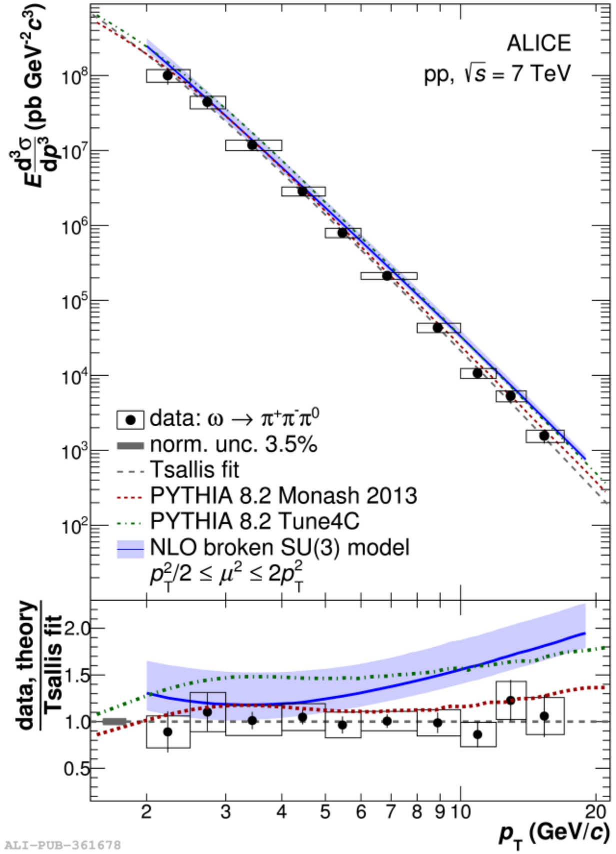
- Combined correction factors: p_T–dependent, **merged clusters** approach helps to extend π^0 spectra range up to 100 GeV/c for **mPHOS** and 200 GeV/c for **mEMC**.

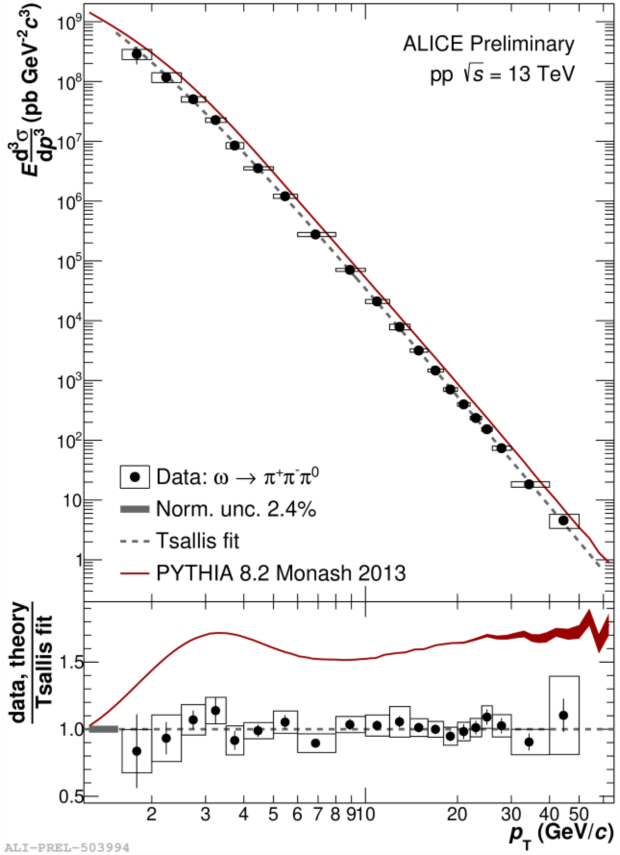
- Different measurement methods are statistically and systematically (PCM, PHOS, EMC) **uncorrelated** and are in **good agreement**.

$$E\frac{d^3\sigma}{dp^3} = \frac{1}{\varepsilon}\frac{1}{L_{\mathrm{int}}}\frac{N^{\pi^0(\eta)} - N^{\pi^0}_{\mathrm{sec}}}{\mathrm{TR}\, p_T\, \Delta p_T}$$

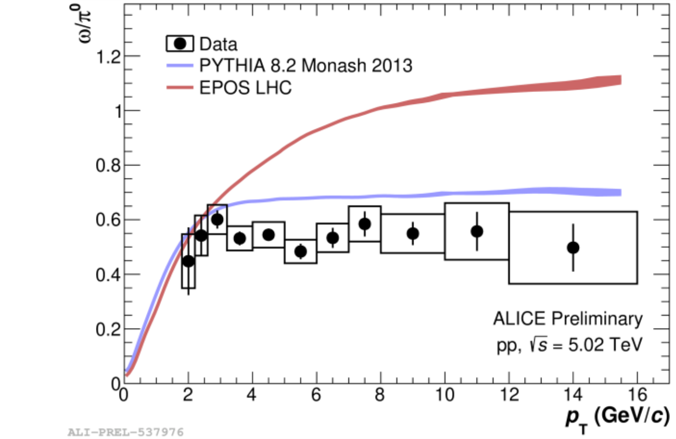
ω meson measurements in pp in Run 2

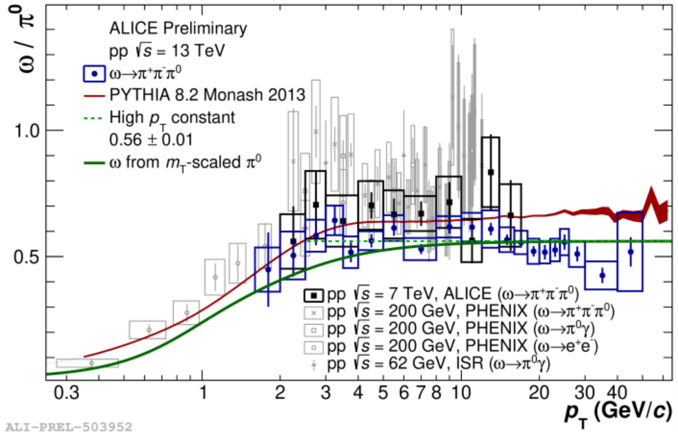






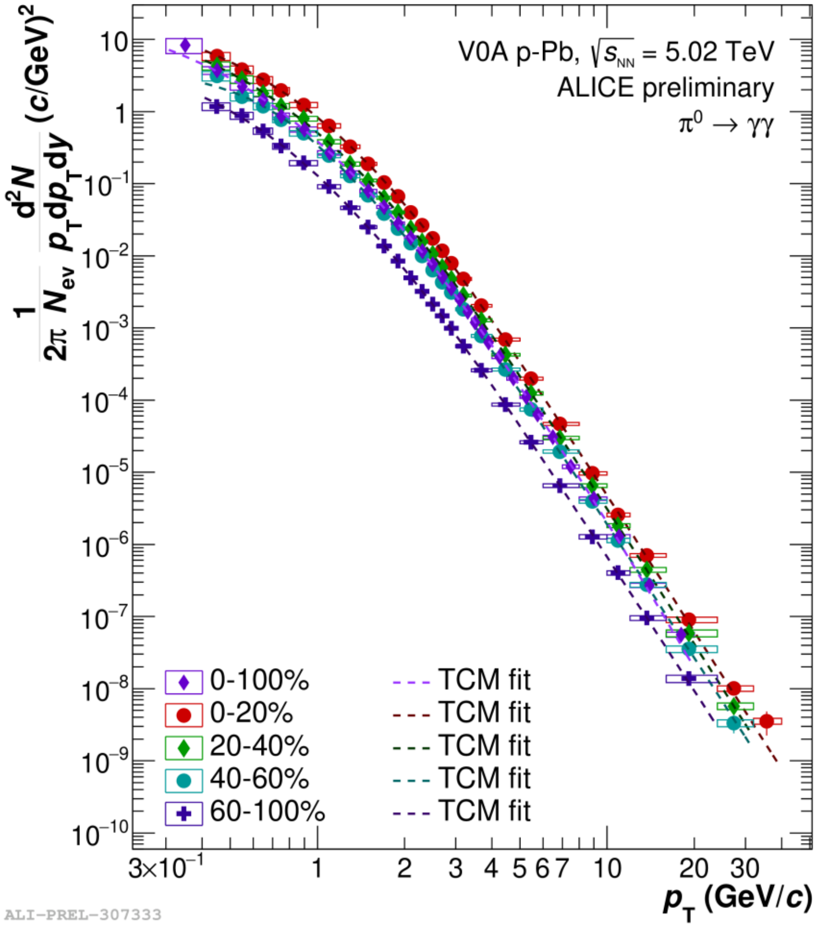
- The ω meson production measurement is crucial for **direct photon measurements** (3rd largest contributor to the background)
- Measured in **5.02, 7, and 13 TeV**
- $\omega \to \pi^+\pi^-\pi^0$, BR ≈ 89.2 %
- $\omega \to \pi^0\gamma$, BR ≈ 8.3 %

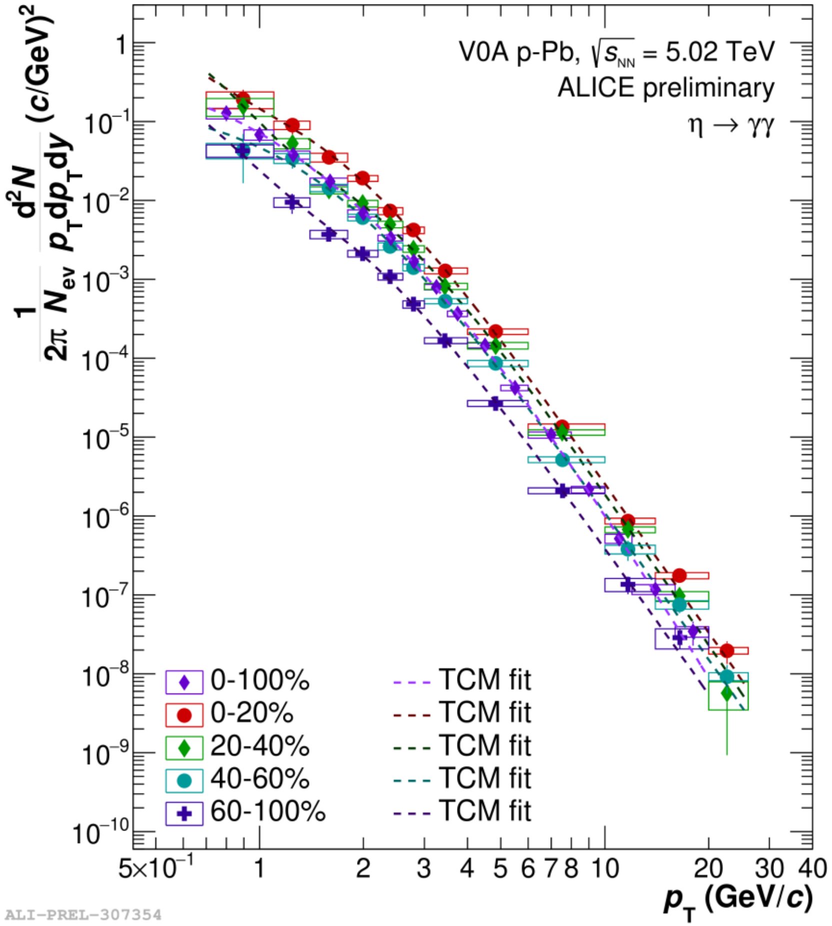


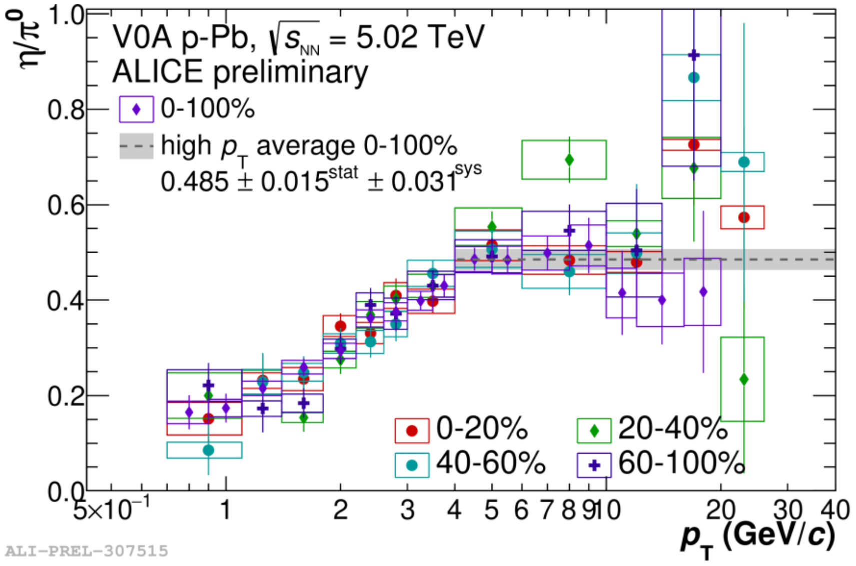


- **EPOS LHC overestimates** the pp data by up to 100% at $\sqrt{s}$ = 5.02 TeV, while **PYTHIA 8** calculations **overpredict** the data at $\sqrt{s}$ = 5.02 and 13 TeV and describes the data well at $\sqrt{s}$ = 7 TeV.
- ω/π^0: High p_T constant at $\sqrt{s}$ = 13 TeV is lower than measurements at $\sqrt{s}$ = 0.2, 7 TeV. However, it is consistent with the constant obtained at $\sqrt{s}$ = 5.02 TeV.

π^0 and η meson measurements in p–Pb in Run 2

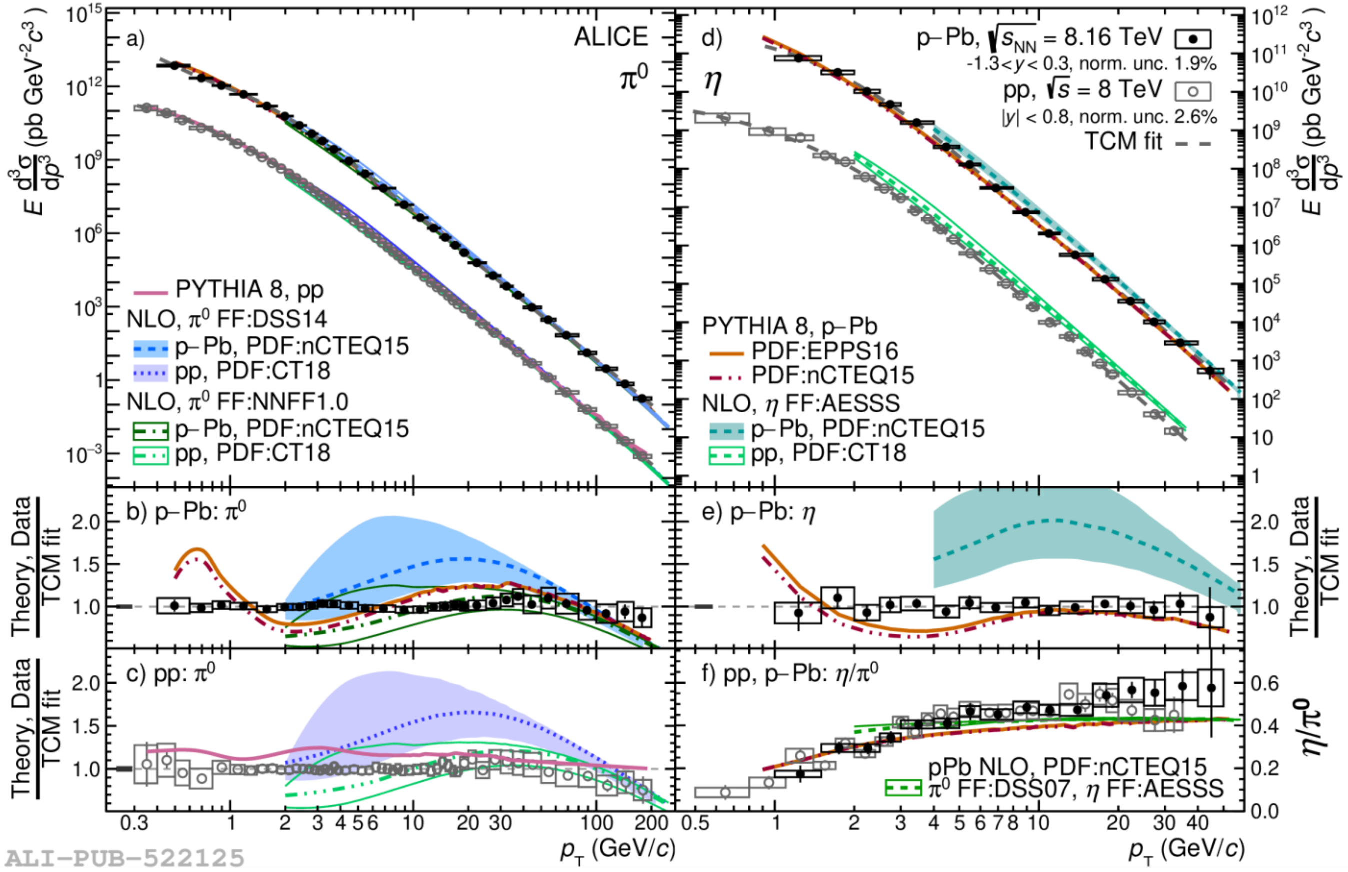


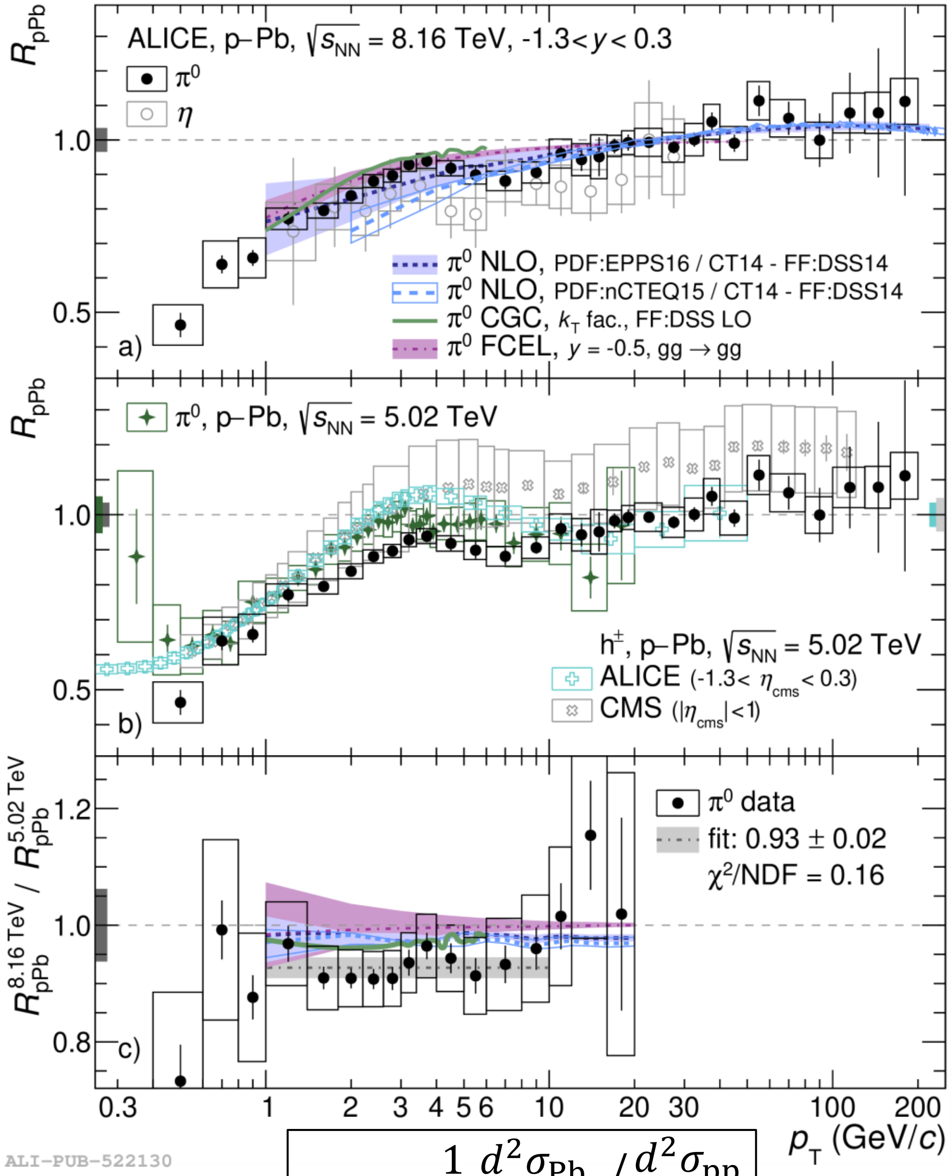




- π^0 and η spectra measured in **4 centrality classes** at $\sqrt{s}$ = 5.02 TeV in p–Pb: 0–20%, 20–40%, 40–60% and 60–100%.
- η/π^0: No significant centrality dependence.

π^0 and η meson measurements in p–Pb in Run 2

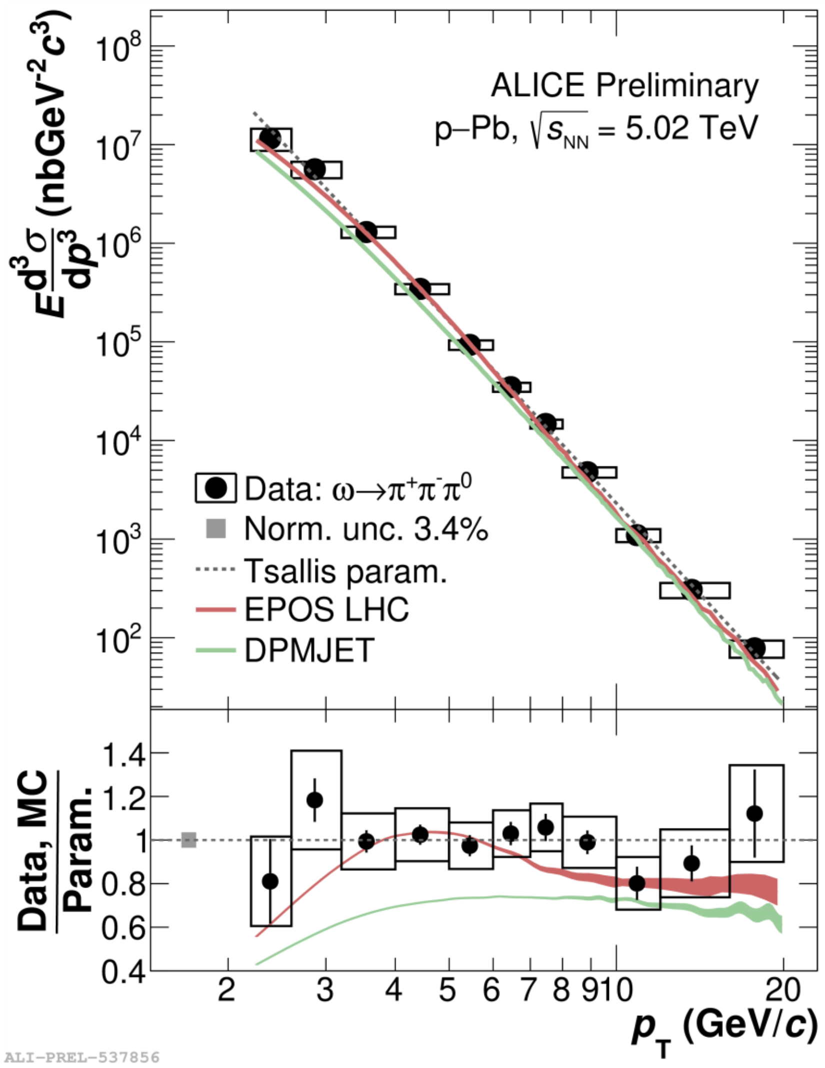


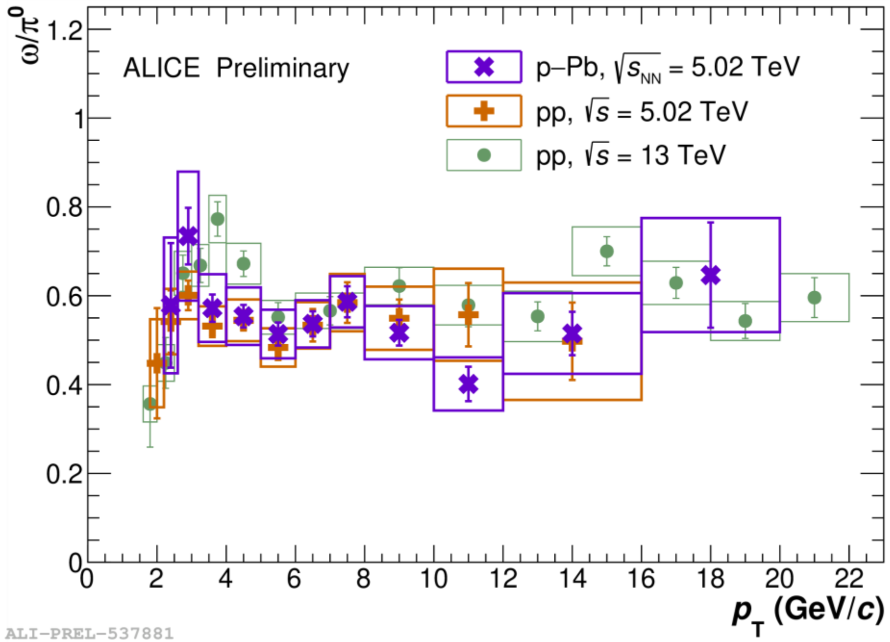


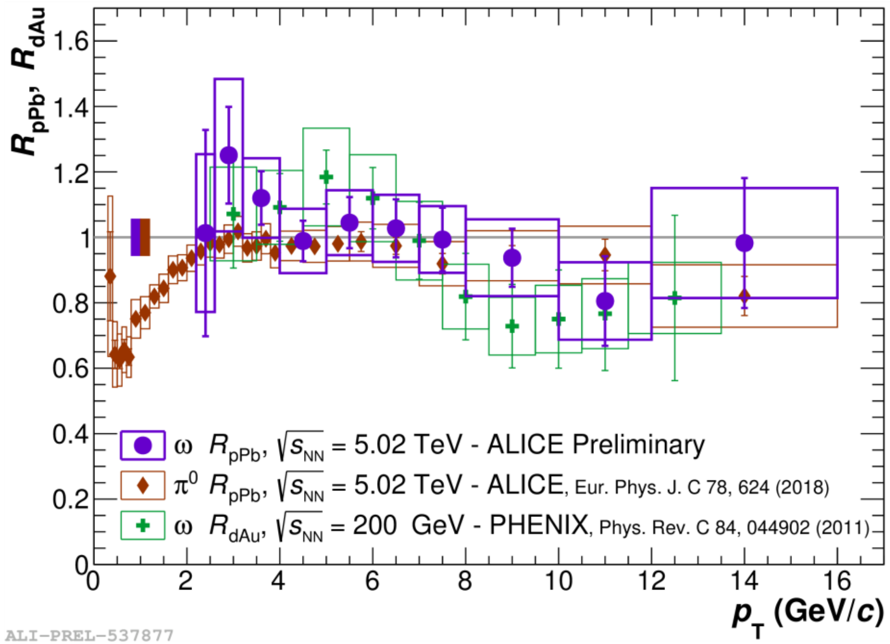
$$R_{\mathrm{pPb}} = \frac{1}{A}\frac{d^2\sigma_{\mathrm{Pb}}}{dp_{\mathrm{T}}dy} \Big/ \frac{d^2\sigma_{\mathrm{pp}}}{dp_{\mathrm{T}}dy}$$

- **NLO pQCD (FF:NNFF1.0)** calculations are in good agreement with the data above 2 GeV/*c*. **PYTHIA 8** generally reproduces π^0 and η spectra, but has problems describing the shape (low p_T, high p_T regions).
- $\boldsymbol{\eta/\pi^0}$: universal and independent of the colliding system – pp or p–Pb (high p_T constant is 0.48 ± 0.01 for pp and 0.47 ± 0.01 for p–Pb).
- $\boldsymbol{R_{pPb}}$: above 10 GeV/c – compatible with unity, at low p_T – strong suppression (CNM effects – CGC/FCEL calculations).

ω meson measurements in p–Pb in Run 2





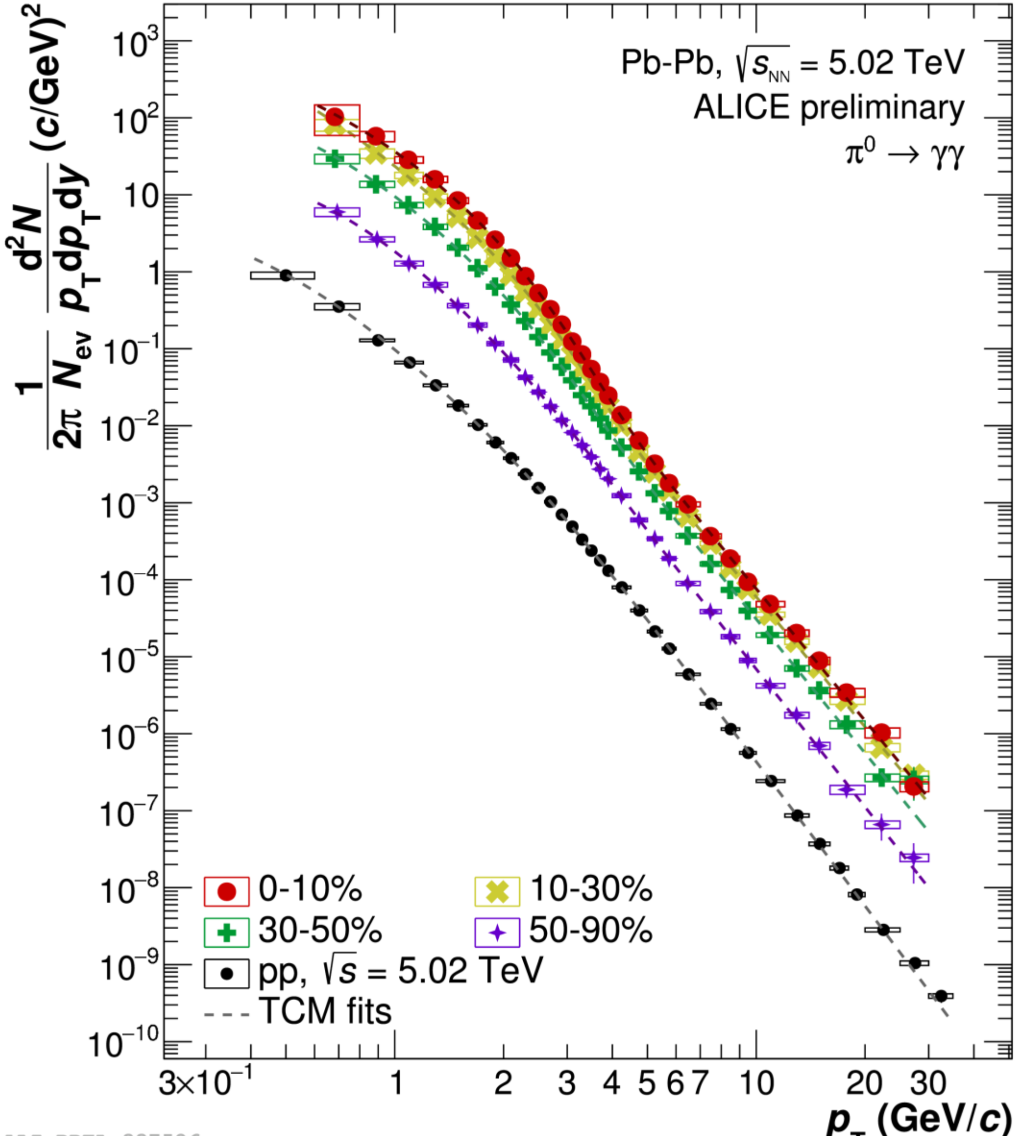


- **EPOS LHC** describes the p–Pb data well, while **DPMJET** calculations **underpredict** the data by 30–40% but overall describes the shape of the spectrum well.

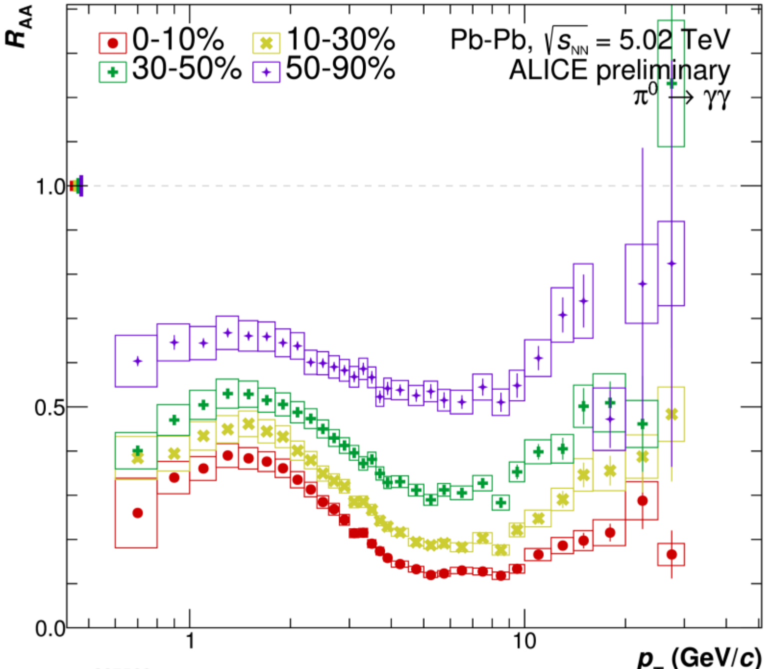
- $\boldsymbol{\omega/\pi^0}$: agreement between the pp data at $\sqrt{s}$ = 5.02 TeV and 13 TeV and the p–Pb data at $\sqrt{s_{NN}}$ = 5.02 TeV → independent of the collision system.

- $\boldsymbol{R_{pPb}}$: consistent with unity, no nuclear modification observed at $\sqrt{s_{NN}}$ = 5.02 TeV .

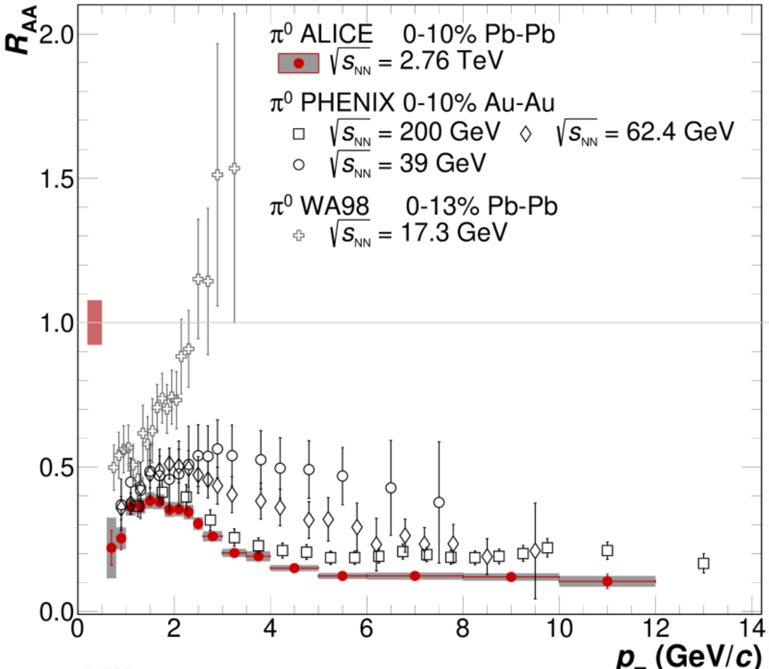
π^0 meson measurements in Pb–Pb in Run 2



ALI-PREL-337526



ALI-PREL-337593



ALI-PUB-81798

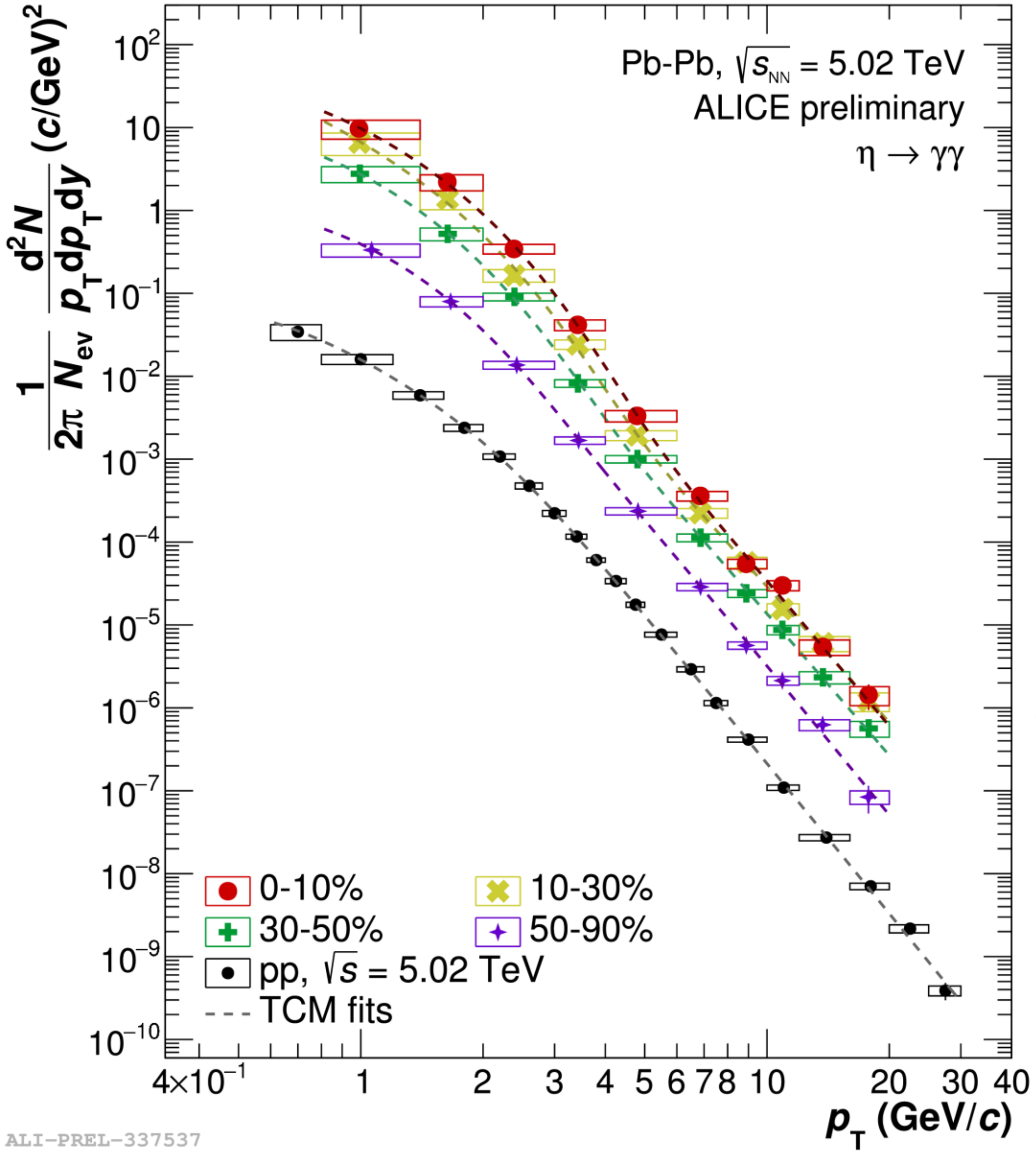
$$R_{AA} = \frac{d^2N_{AA}/dp_T dy}{\langle T_{AA}\rangle d^2\sigma_{pp}/dp_T dy}$$

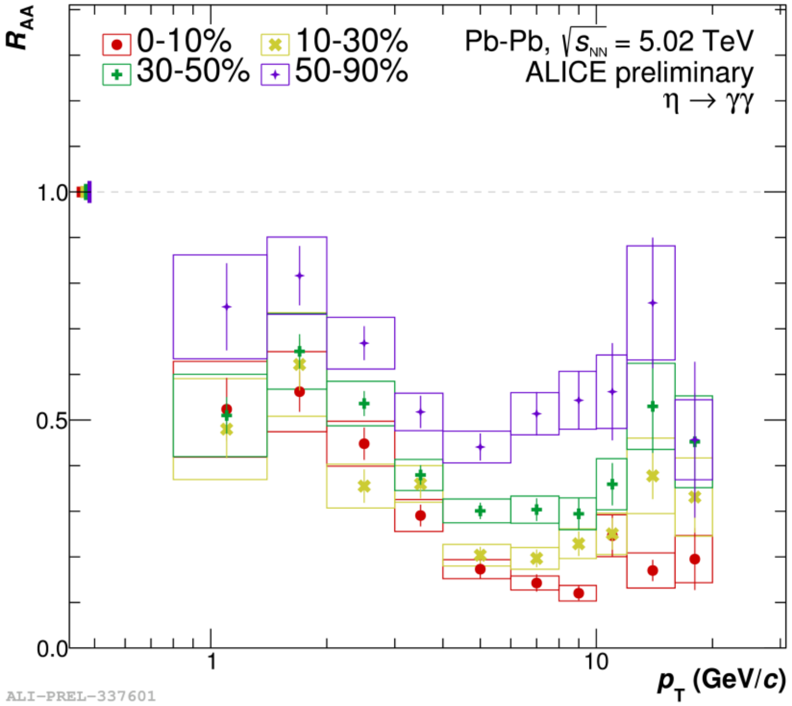
- ***π*⁰** spectra measured in **4 centrality classes** at $\sqrt{s_{NN}}$ = 5.02 TeV in Pb–Pb: 0–10%, 10–30%, 30–50% and 50–90%.

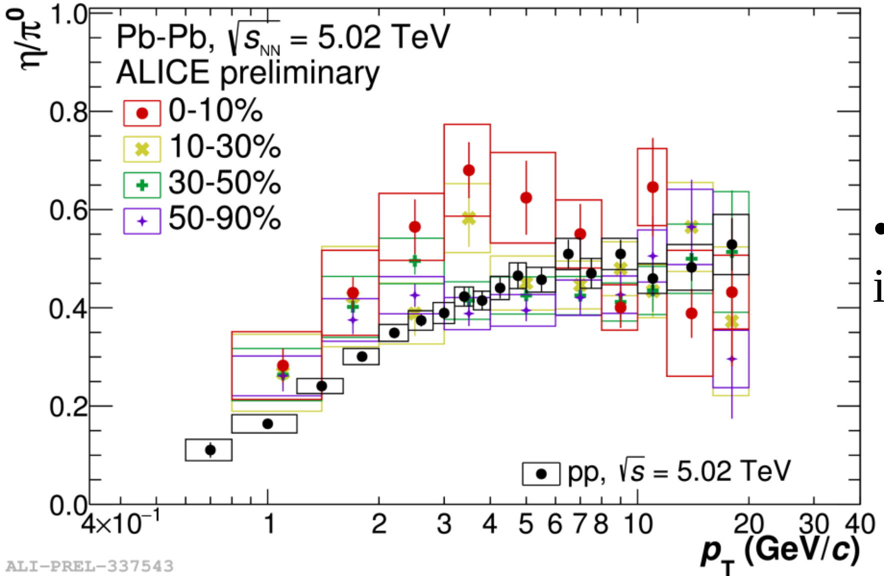
- ***R*_{AA}**: suppression is present in all centrality classes reaching the minimum value of ~ 0.1 at p_T ~ 7 GeV/c in the most central collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. The effect decreases in peripheral collisions.

- ***R*_{AA}**: The same magnitude of suppression at $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV. The suppression effect becomes less expressed at lower collision energies (for example, at $\sqrt{s_{NN}}$ = 17.3 GeV).

η meson measurements in Pb–Pb in Run 2





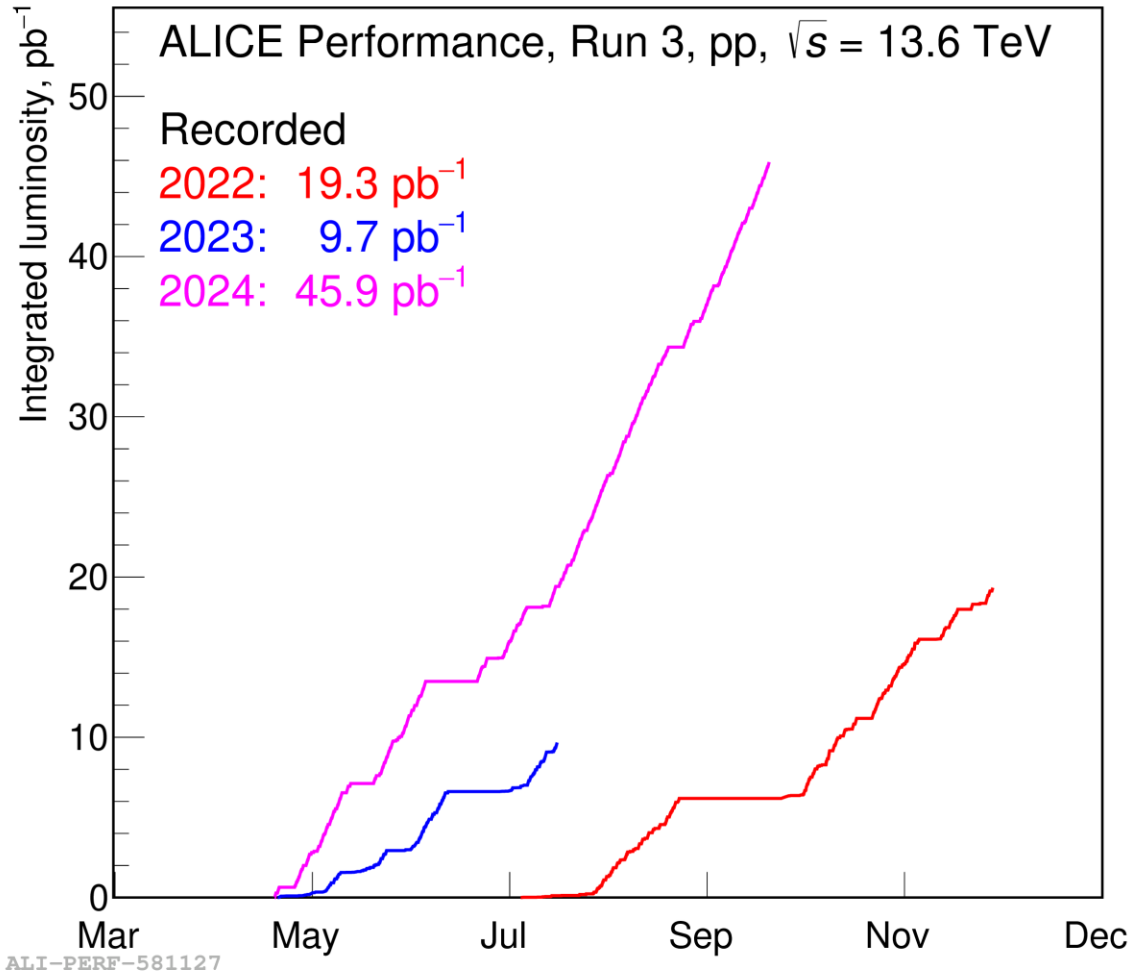


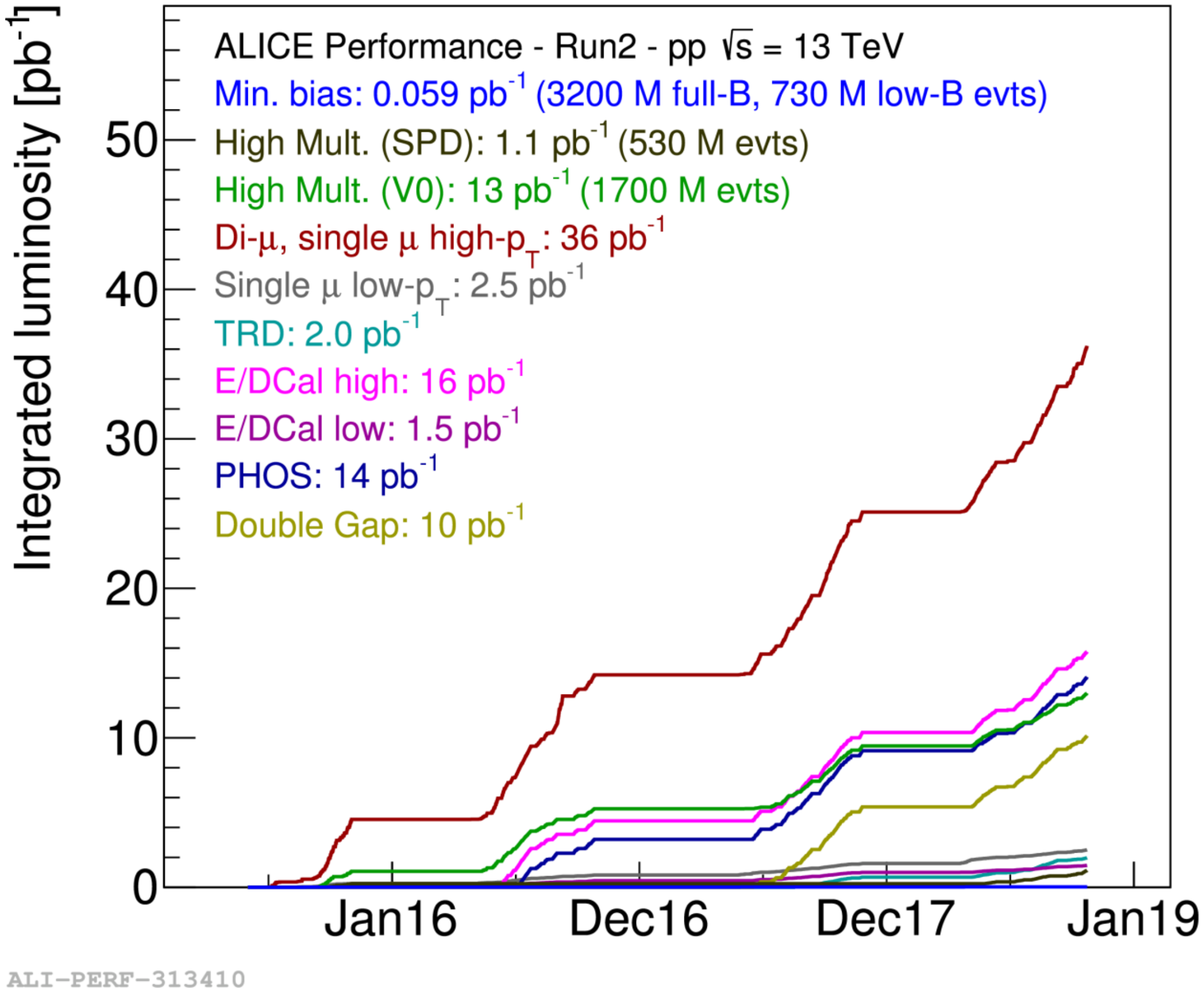
- ***η*** spectra measured in **4 centrality classes** at $\sqrt{s_{NN}}$ = 5.02 TeV in Pb–Pb: 0–10%, 10–30%, 30–50% and 50–90%.

- $\boldsymbol{R_{AA}}$: suppression is present in all centrality classes reaching the minimum value of ~ 0.1 at p_T ~ 9 GeV/c in the most central collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. The effect decreases in peripheral collisions.

- $\boldsymbol{\eta/\pi^0}$: significant modification in central collisions is observed.

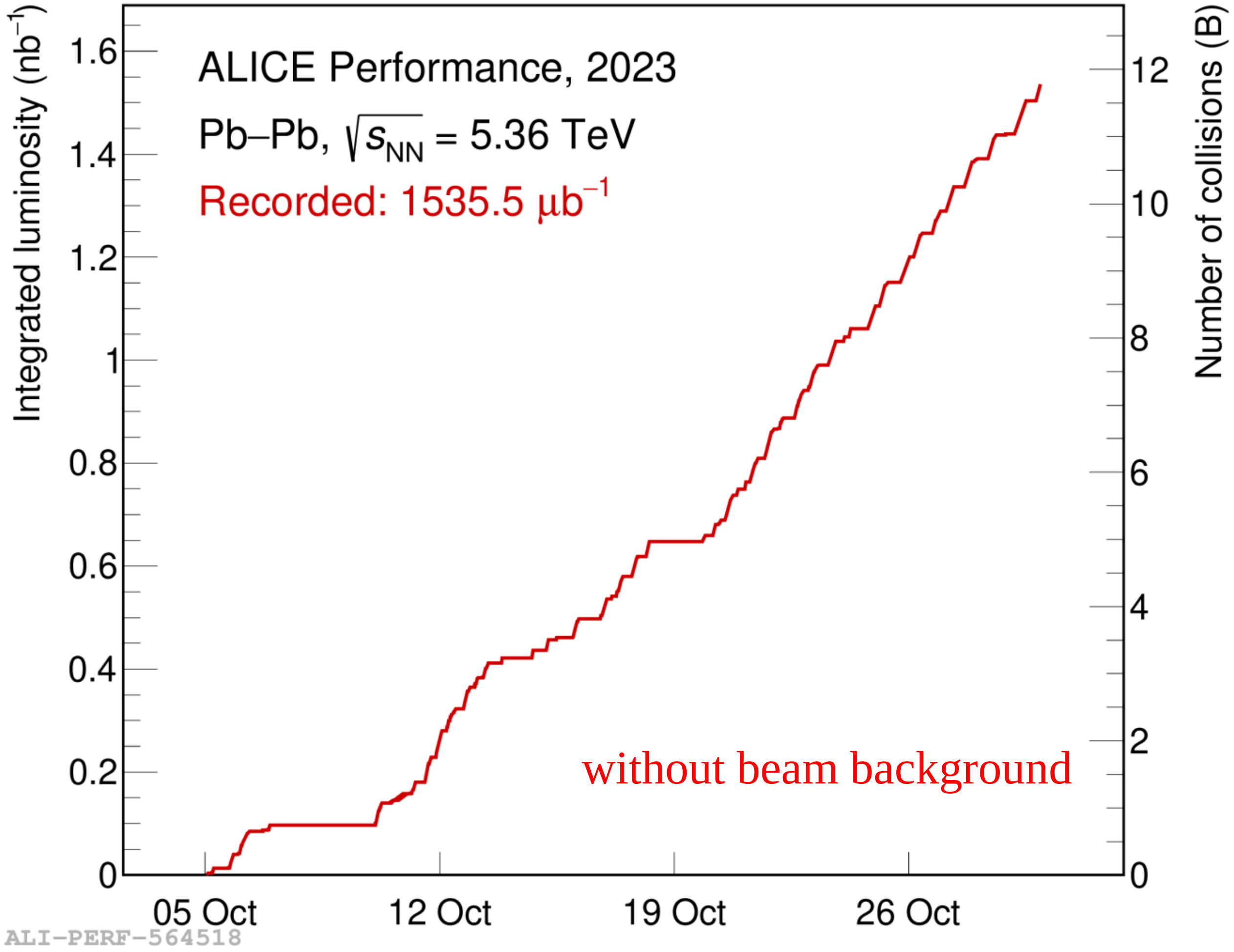
ALICE pp statistics in Run 3

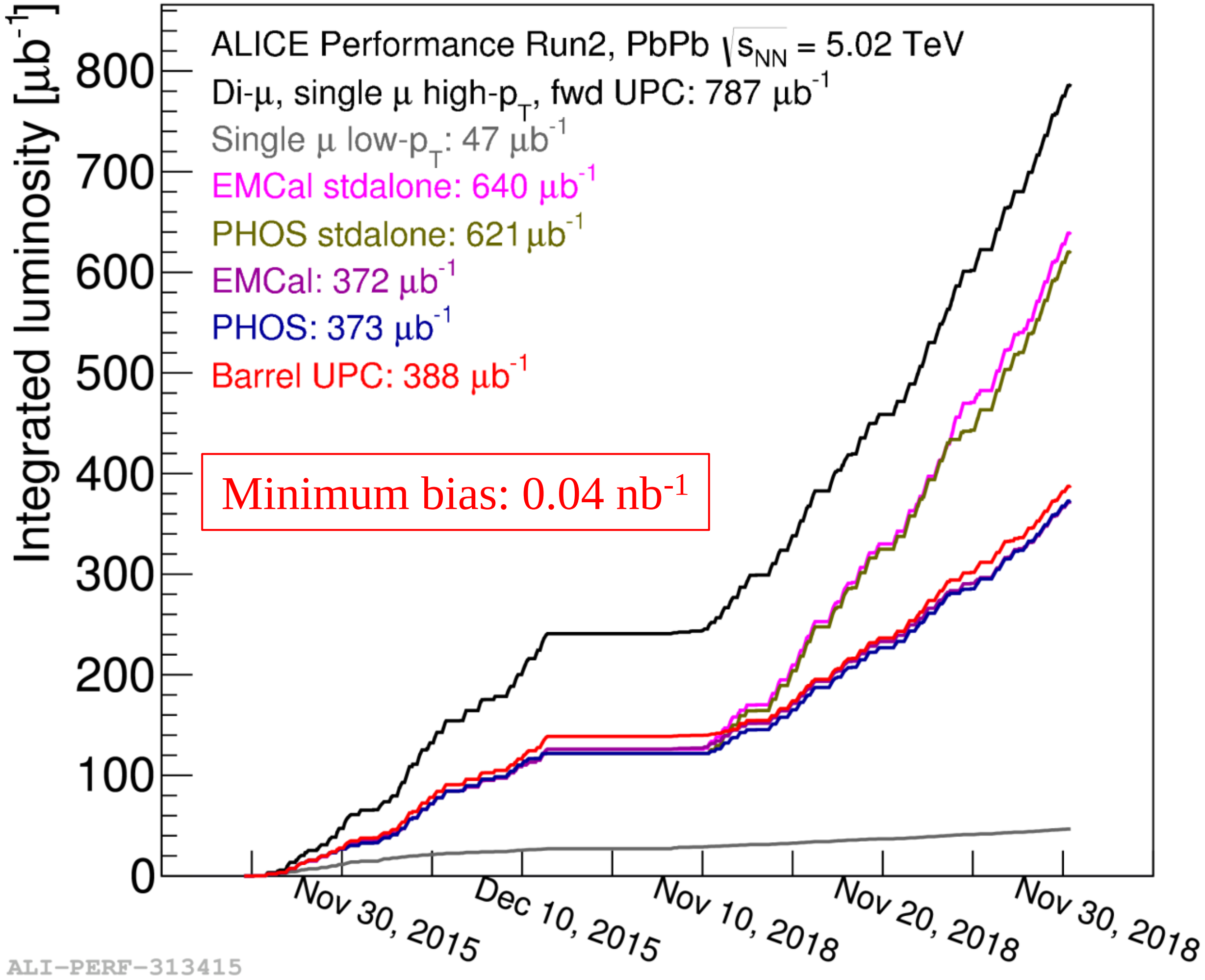




As of 19.09.24 the collected integrated luminosity exceeded **75 pb^{-1}**, which is equal to more than **5·10^{12}** minimum bias collisions. It is more than the total collected pp data during Run 1+2. In 2024 **about 55 pb^{-1}** pp collisions are expected.

ALICE Pb–Pb statistics in Run 3

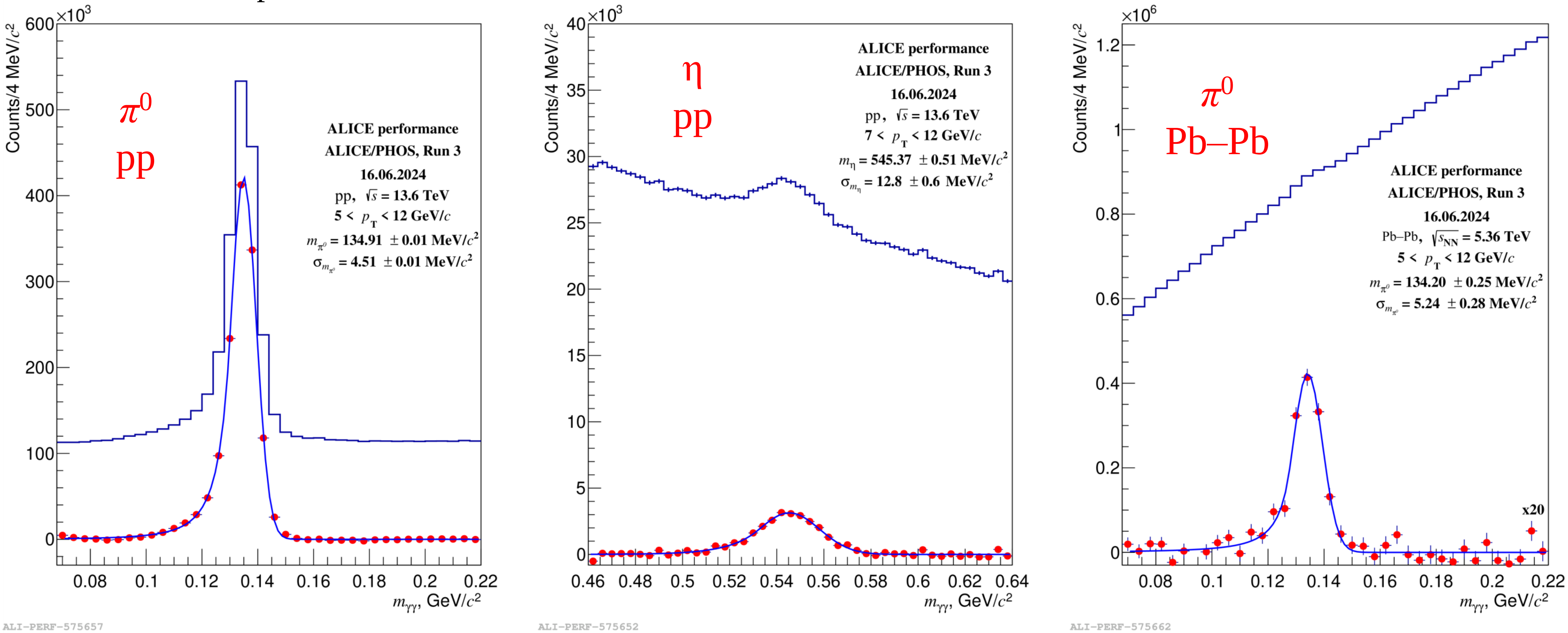




At the end of 2023 **1.54 nb^{-1}** of the Pb–Pb collisions were recorded, which is equal to more than **12·10^9** minimum bias collisions. It is **40 times** more than the total collected Pb–Pb data during Run 1+2. In 2024 **about 1.2–1.9 nb^{-1}** Pb–Pb collisions are expected.

PHOS performance in Run 3

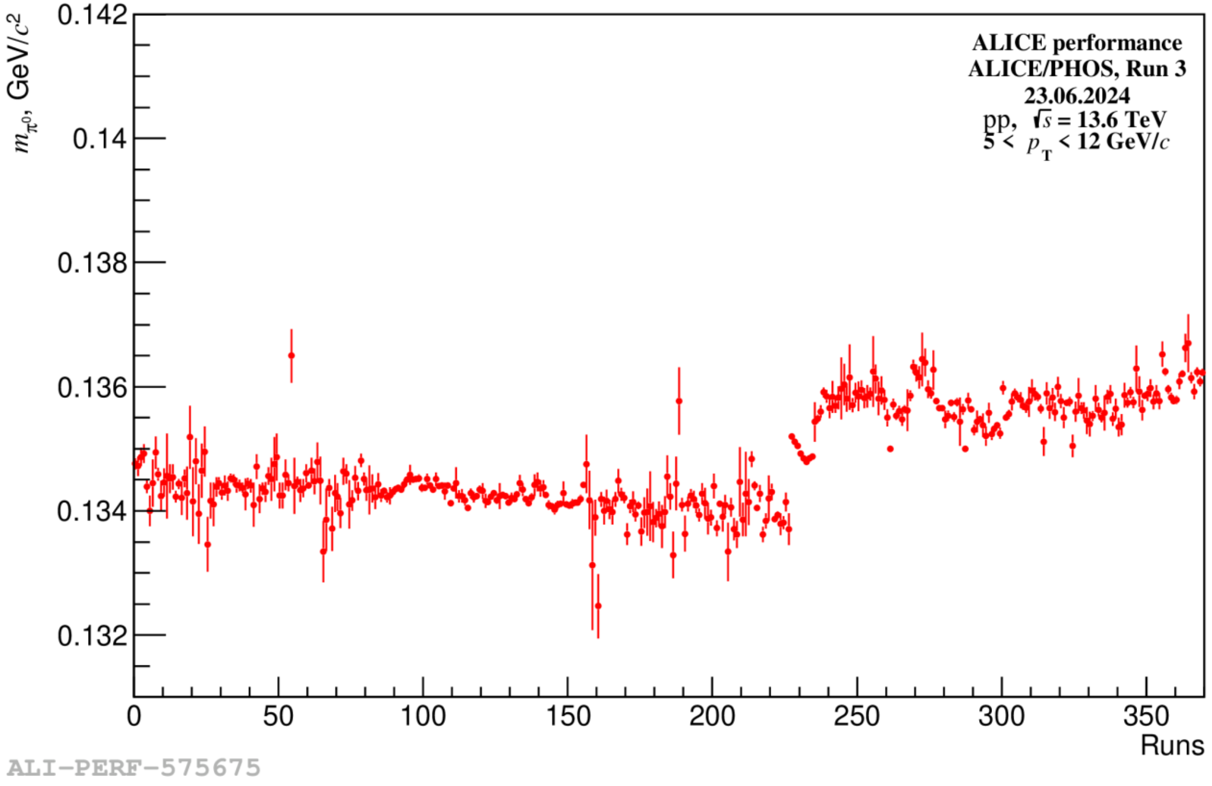
The best example invariant mass distributions



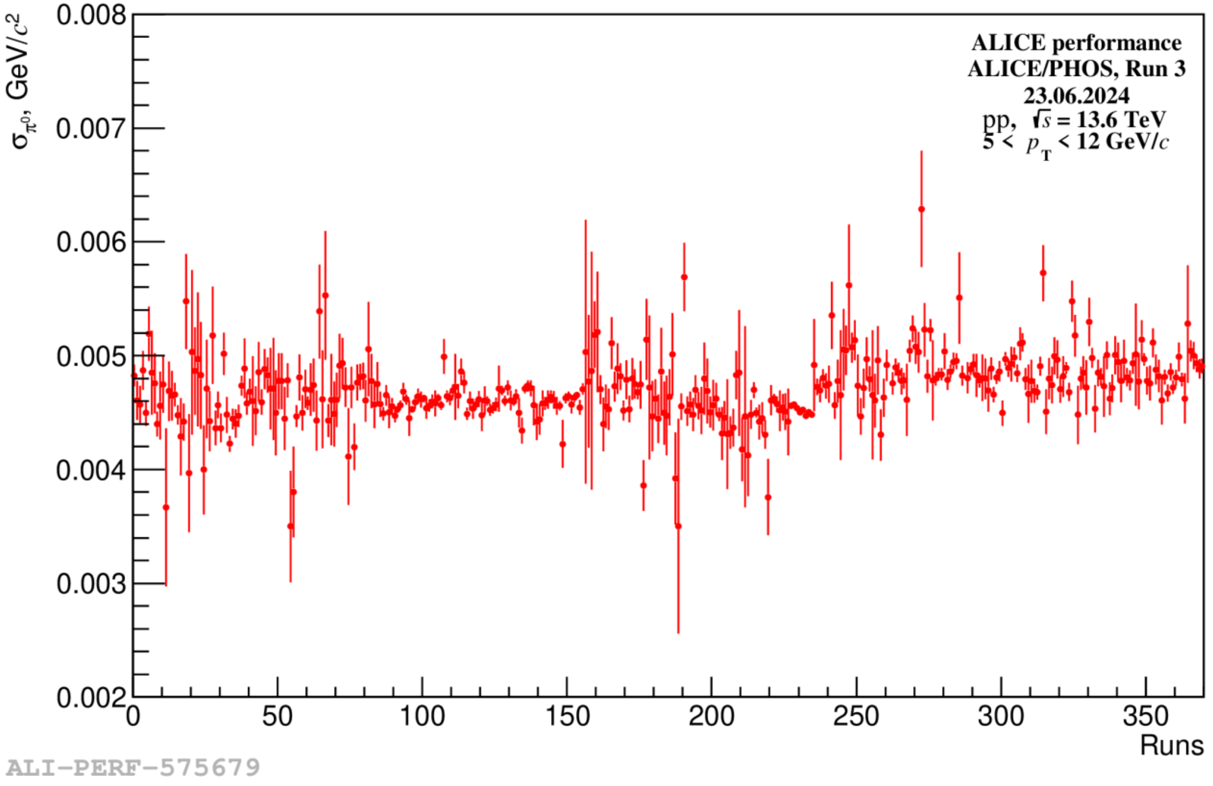
- Cluster selection is: E_{clu} > 0.3 GeV, t_{clu} ∈ [-50, 100] ns, p_T ∈ [5, 12] GeV/c.
- **Clear π^0 and η peaks** are observed in pp and Pb–Pb collisions.
- π^0 peak is at its PDG position (134.9 MeV/c^2) with good mass resolution (**$\sigma_m^{\pi^0}$ = 4.51 ± 0.01 MeV/c^2**).

PHOS performance in Run 3

π^0 peak position per run



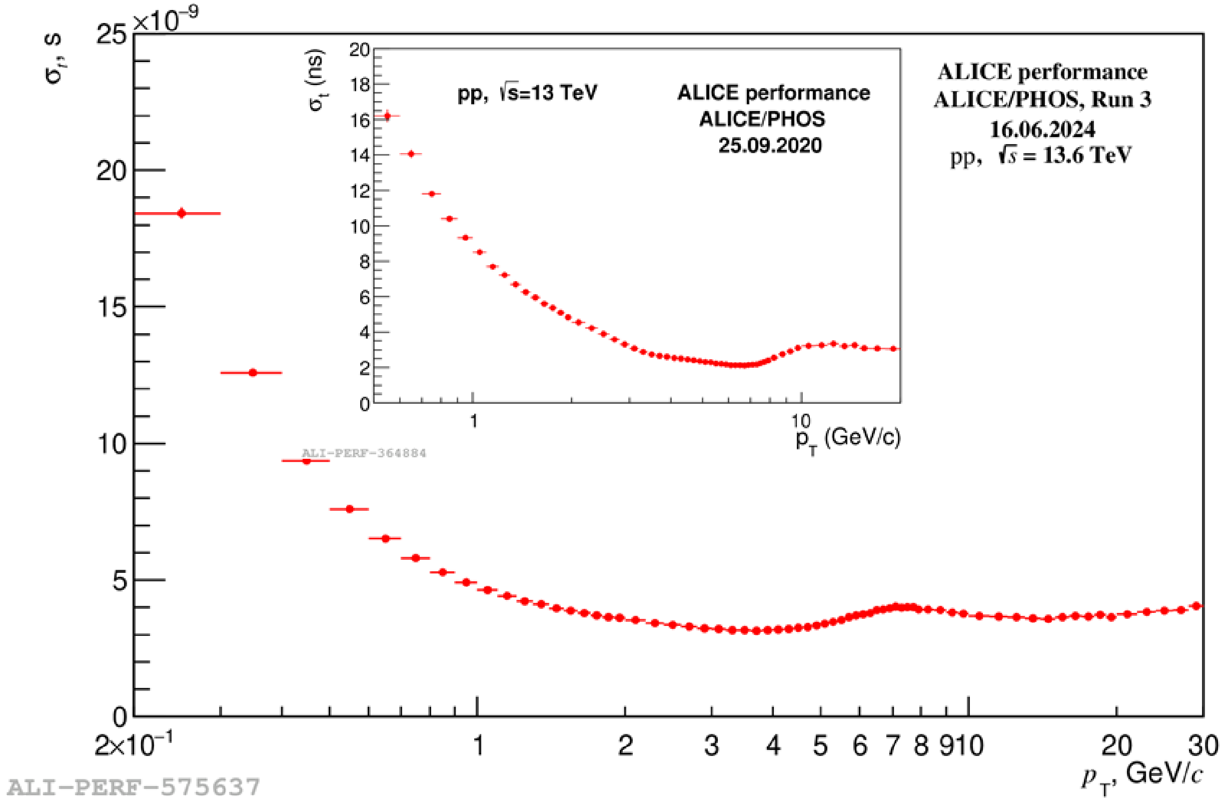
π^0 width per run



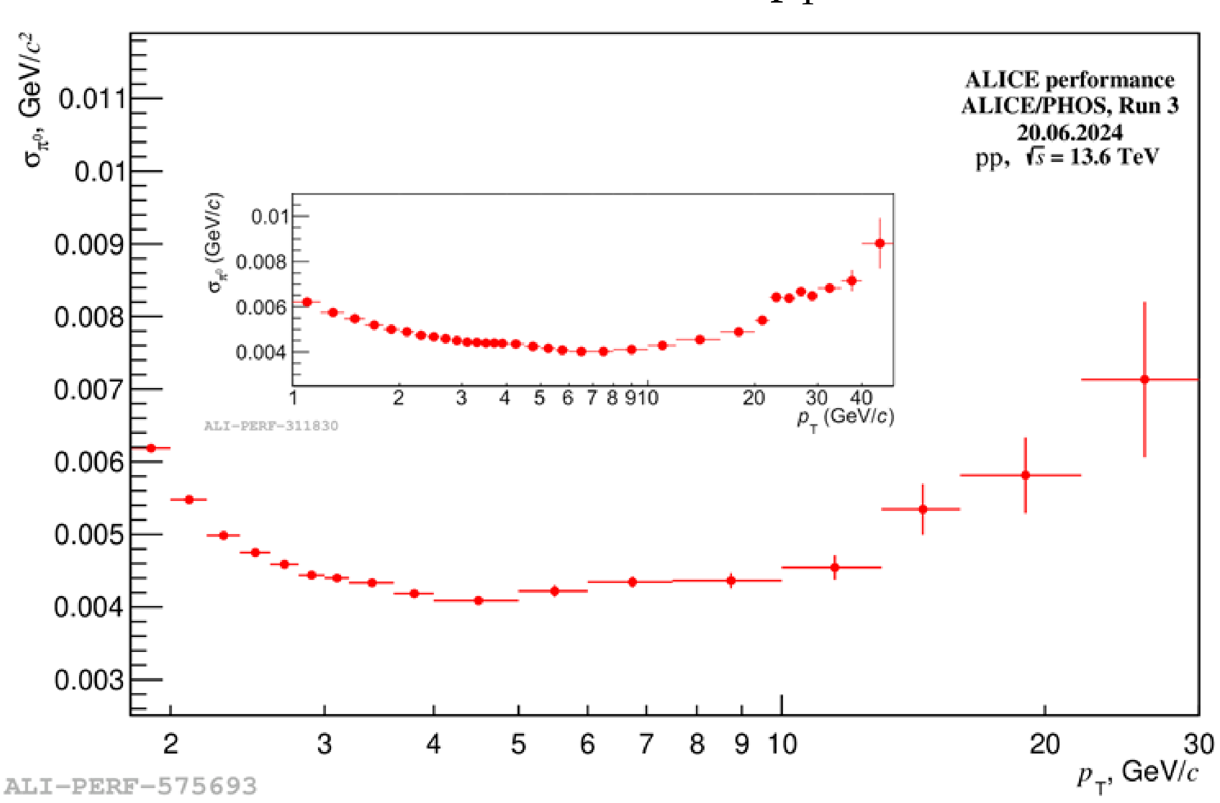
In order to check the long-term stability of the π^0 peak, its position and width were calculated in all available runs from 2023-2024. On average the π^0 peak position is stable (within **~ 0.5 MeV/c^2**), which is also true for its width **(~ 4.6 MeV/c^2**).

PHOS performance in Run 3

Time resolution



π^0 width vs. p_T



- **Time resolution** remains modest in Run 3 (only suitable for pileup rejection from subsequent bunch crossings)
- It improved below 2 GeV/*c* due to better signal fitting techniques: $\sigma_t^{\text{Run 2}} = 8.5$ ns, $\boldsymbol{\sigma_t^{\text{Run 3}} = 4.5}$ **ns** at $p_T = 1$ GeV/*c*.

- The minimum value **σ ≈ 4 MeV/*c*²** of the π^0 peak is reached at $p_T = 3.5 - 6$ GeV/*c*.
- The achieved mass resolution in Run 3 for $p_T > 1.7$ GeV/*c* is currently $\boldsymbol{\sigma_m^{\pi^0} = 5.34 \pm 0.01}$ **MeV/*c*²**, while in Run 2 it was $\boldsymbol{\sigma_m^{\pi^0} = 4.56 \pm 0.03}$ **MeV/*c*²**.

Conclusion

- Neutral meson spectra were measured in **pp, p–Pb and Pb–Pb** collisions in ALICE in Run 1+2 from 200 MeV to 200 GeV with different methods in various centrality classes.

- The data are fitted by the Tsallis and TCM parameterizations well, while MC generators and theory predictions generally **overestimate** experimental data.

- **A promising PHOS performance** is achieved in Run 3. The first results of neutral meson reconstruction in Run 3 using PHOS are presented.