Quark Matter 2023
The 30th International Conference on Ultrarelativistic Nucleus-Nucleus Collisions

Shedding light on light flavour particle production in small systems at the LHC with ALICE

Francesca Ercolessi on behalf of the ALICE Collaboration

University and INFN, Bologna

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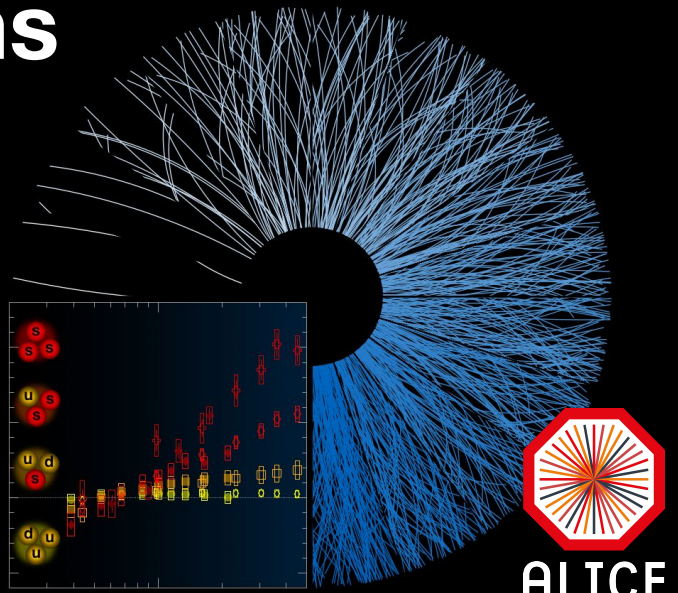
ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

INFN
Istituto Nazionale di Fisica Nucleare



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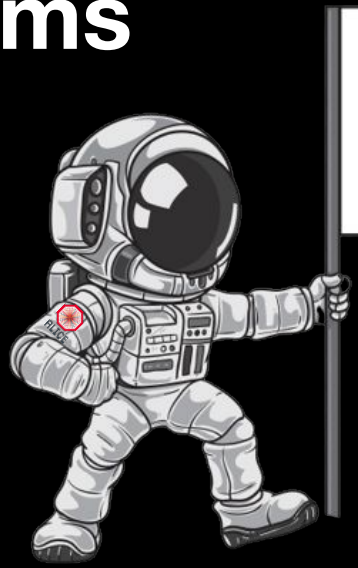


ALICE

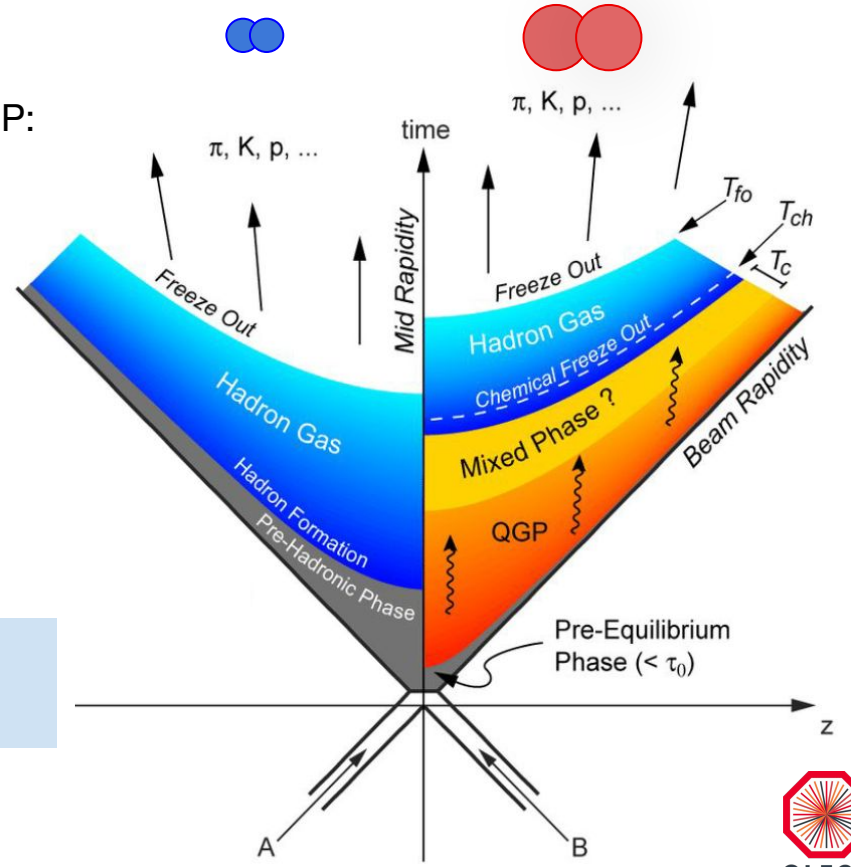
From large to small collision systems

Light flavor (u, d, s) quarks **thermally produced** in the QGP: soft probes are key to study the properties of the medium

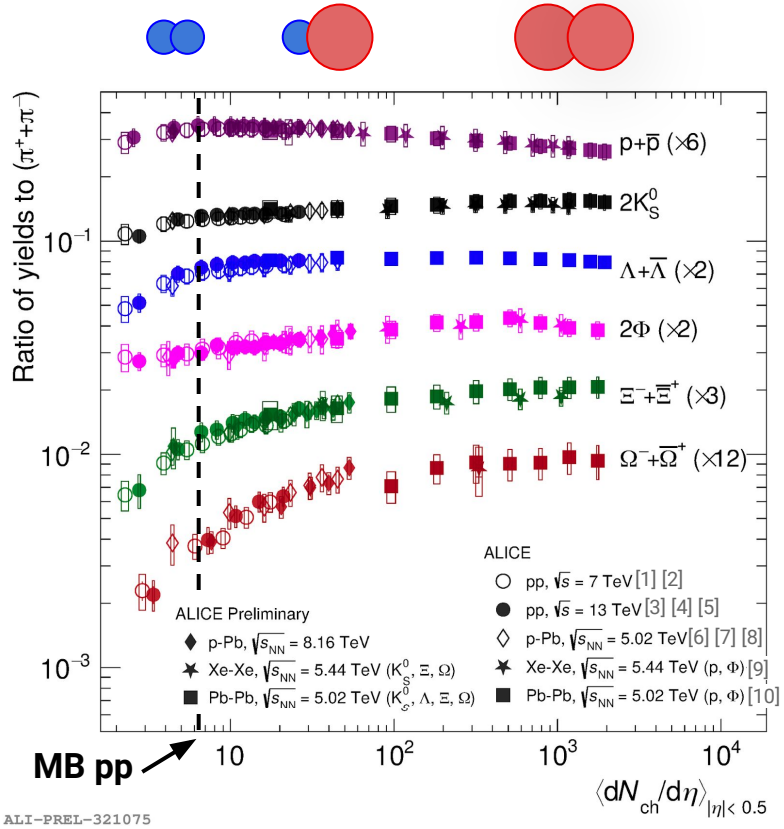
Expected **strangeness suppression in small systems**
→ MB pp collisions historically used as reference to study **strangeness enhancement in AA**

Recent observations in **small systems show striking similarities to heavy-ion collisions**

Is there a way to coherently describe particle production across collision systems?



Particle production across collision systems



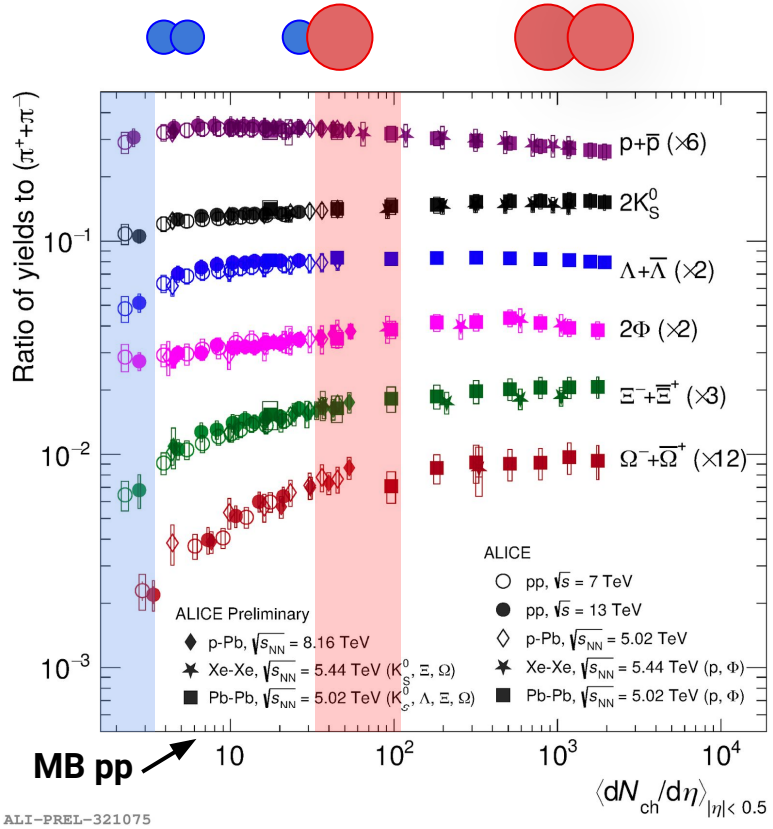
Continuous evolution of light flavour yield ratios to pions **with the charged-particle multiplicity** observed at the LHC, smoothly connecting different collision systems and energies

Strangeness production **increases with** particle **multiplicity** wrt MB pp, saturating for central Pb–Pb

Strange content **hierarchy**: $|S_{\Omega^\pm}| > |S_{\Xi^\pm}| > |S_\Lambda| \approx |S_{K^0_S}|$

[1] Nature Phys. 13, 535-539 (2017)
[2] PRC 99, 02490 (2019)
[3] EPJC 80, 167 (2020)
[4] EPJC 80, 693 (2020)
[5] PLB 807, 135501 (2020)
[6] PLB 728, 25-38 (2014)
[7] PLB 758, 389-401 (2016)
[8] EPJC 76, 245 (2016)
[9] EPJC 81, 584 (2021)
[10] PRC 101, 044907 (2020)

Particle production across collision systems



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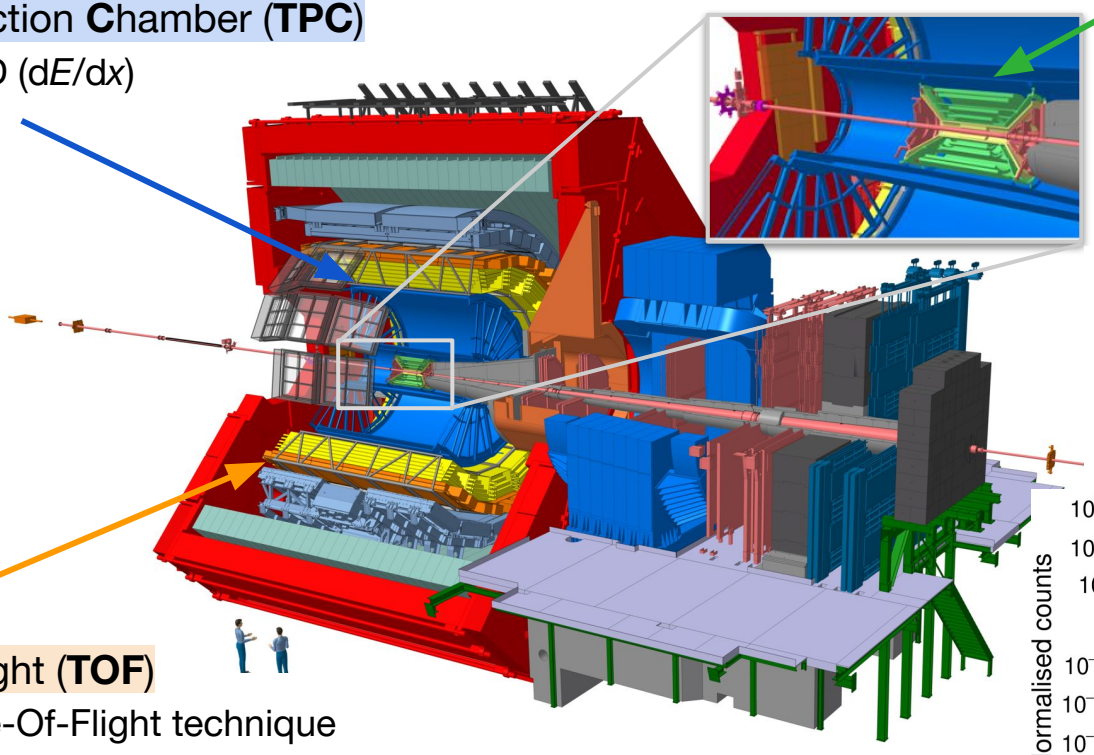
Recent ALICE results focus on:

connecting results in **small systems at high multiplicity** compatible **to semi-central AA** collisions

explore particle production in the **lower multiplicity** region

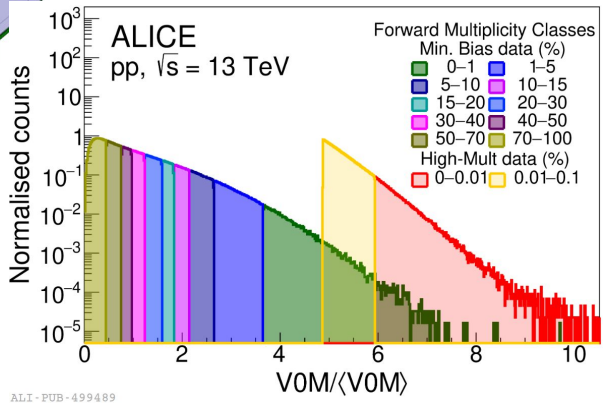
ALICE in Run 2

Time **P**rojection **C**hamber (**TPC**)
tracking, PID (d*E*/d*x*)
$|\eta| < 0.9$



Inner **T**racking **S**ystem (**ITS**)
tracking, triggering, vertexing, PID (d*E*/d*x*)
$|\eta| < 0.9$

V0 detectors (**V0A** & **V0C**)
triggering, multiplicity estimator
$2.8 < \eta < 5.1$ (V0A)
$-3.7 < \eta < -1.7$ (V0C)



Time **O**f **F**light (**TOF**)
PID via Time-Of-Flight technique
$|\eta| < 0.9$

from Run 2

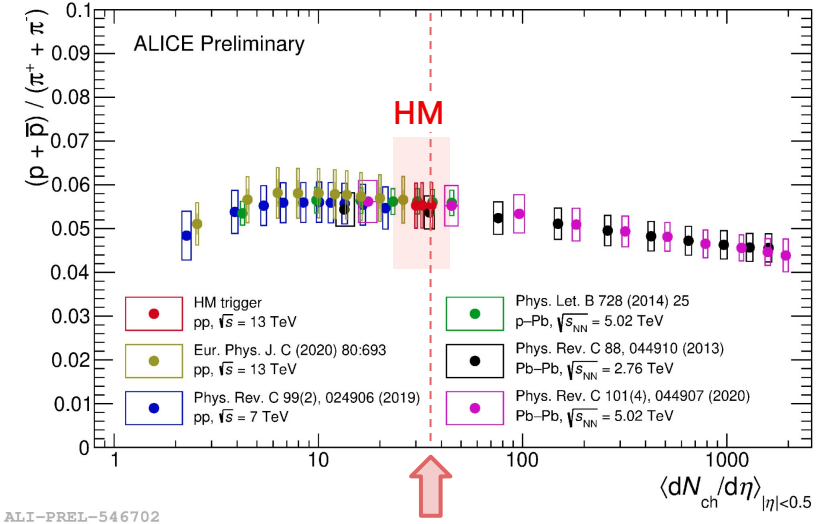
Particle ratios in high multiplicity (HM) events

New measurements in HM pp collision events

Results follow the **smooth trend with multiplicity** observed for other pp, p–Pb and Pb–Pb collisions

Results in **pp** now **reach semi-peripheral Pb–Pb collisions**

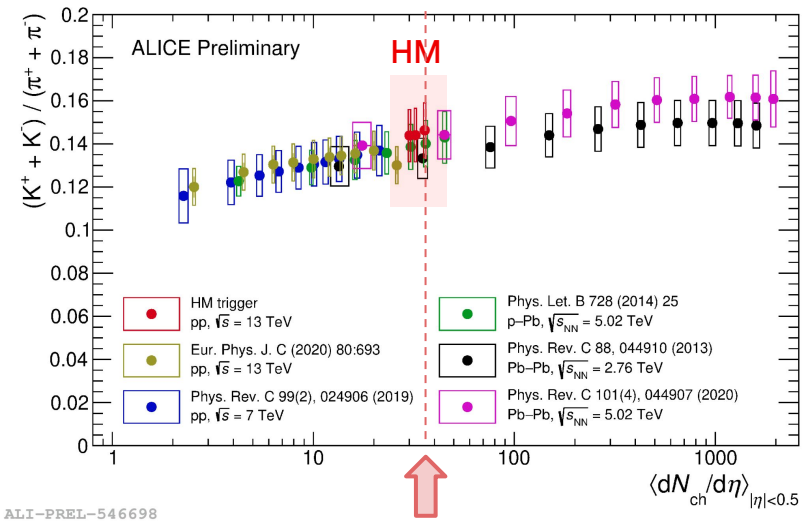
NEW!



ALI-PREL-546702

Max multiplicity in Run 2 pp

NEW!



ALI-PREL-546698

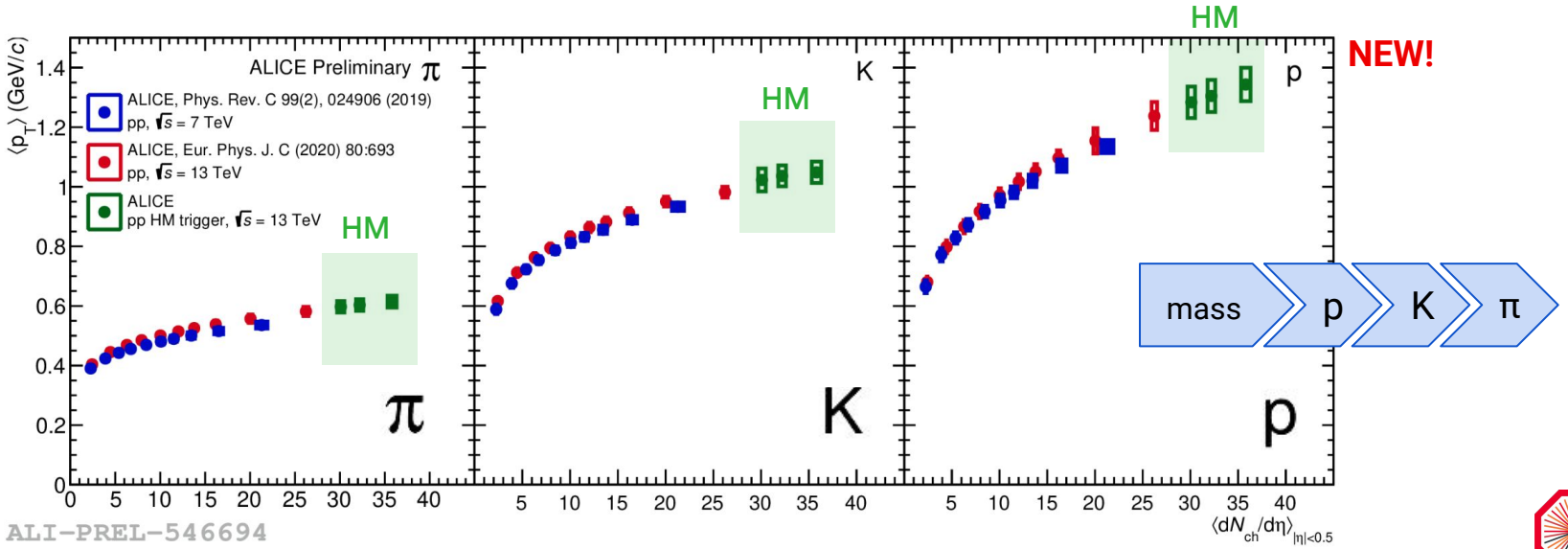
Max multiplicity in Run 2 pp

from Run 2

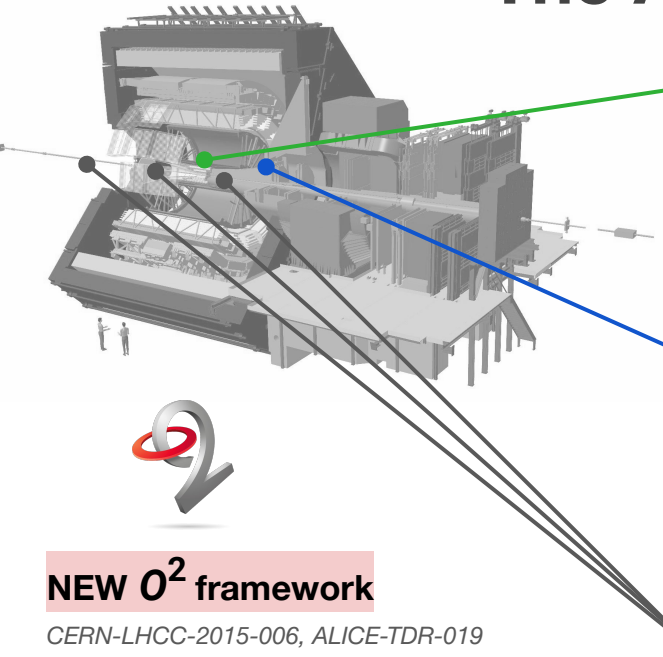
$\langle p_T \rangle$ vs multiplicity in pp collisions

In Pb–Pb collisions expected mass-dependent hardening of the soft part of the spectra with increasing multiplicity
→ collective expansion of the medium

Multiplicity dependent $\langle p_T \rangle$ increases also in pp systems with a **steeper** trend for **higher hadron masses**
→ supports the picture of a collective evolution in small systems (similar to radial flow)



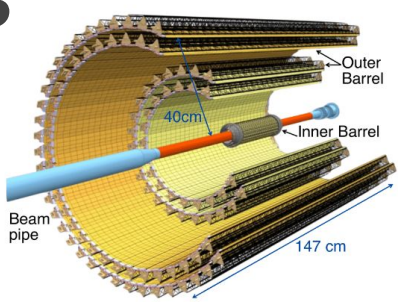
The ALICE detector in Run 3



ITS Upgrade

NIM 1032, 166632 (2022)

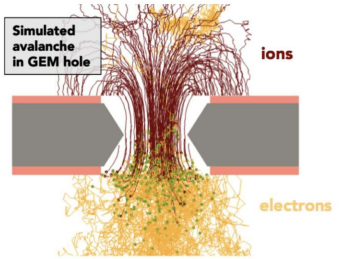
- 7 layers of silicon pixel detectors with reduced material budget
- First detection layer closer to IP + new beam pipe (ITS L0 at 22 mm)



TPC Upgrade

JINST 16, P03022 (2021)

- MWPCs replaced with GEMs
- Continuous readout up to 50 kHz Pb-Pb interaction rate (×50 wrt Run 2)



NEW O^2 framework

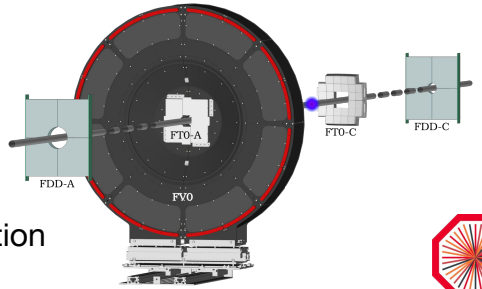
CERN-LHCC-2015-006, ALICE-TDR-019

- One common Online Offline (O^2) computing system
- Faster online and offline processing
- Increased data volume ×100 wrt Run 2

NEW Fast Interaction Trigger (FIT)

NIM 1039, 167021 (2022)

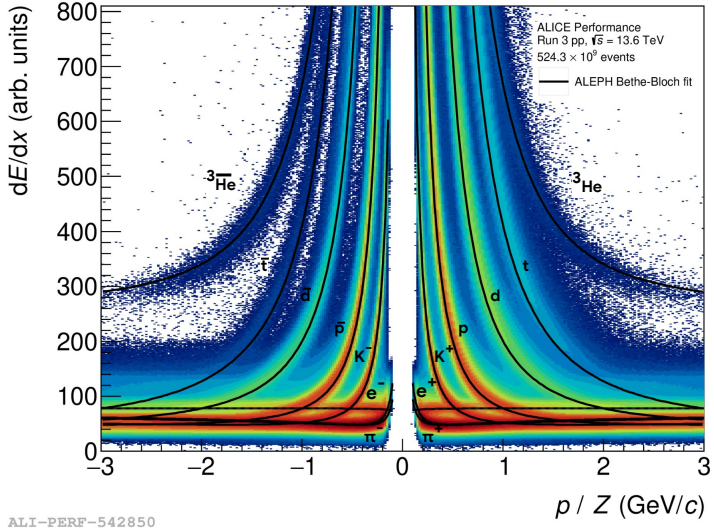
- 4 arrays of Cherenkov detectors and scintillators
- Triggering, collision time, centrality estimation

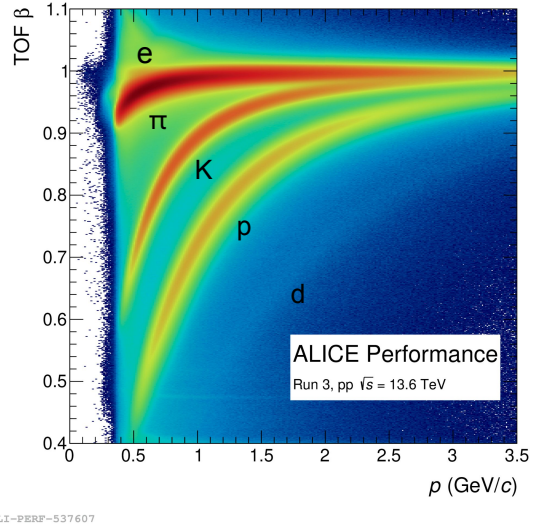


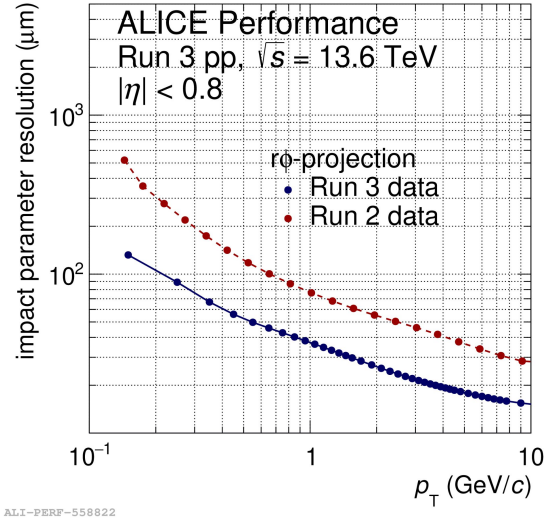
Performance of the ALICE detector in Run 3

The LHC Run 3 started in 2022, so far ALICE collected almost **×1000** events wrt Run 2 in pp data taking at **~500 kHz in continuous readout**

Excellent PID performance of the ALICE detector in Run 3!







Only ~10^{-3} will be stored: **minimum-bias sample** + samples selected by **software triggers** based on specific physics cases (e.g. events with multi-strange hadrons, nuclei) [1]

[1] *ALICE-PUBLIC-2020-005*

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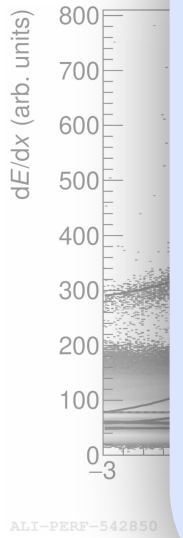


Run 3 targets ~**200 pb^{-1} of high-multiplicity pp collisions** at $\sqrt{s}$ = 13.6 TeV:

- **extend** our studies **to higher multiplicities**
  → $dN_{ch}/d\eta \approx 100$ (reached by Pb–Pb with centrality ~65%)
- **increase our precision** on existing studies and **allow for new ones**

Run 3 provided a large sample of **pp collisions at $\sqrt{s}$ = 900 GeV** (×300 wrt Run 1) the lowest center of mass energy at the LHC!

- **explore** particle production at **low multiplicity**

Only ~1 … c physics cases (e.g. events with multi-strange hadrons, nuclei) [1]

[1] *ALICE-PUBLIC-2020-005*

ALICE

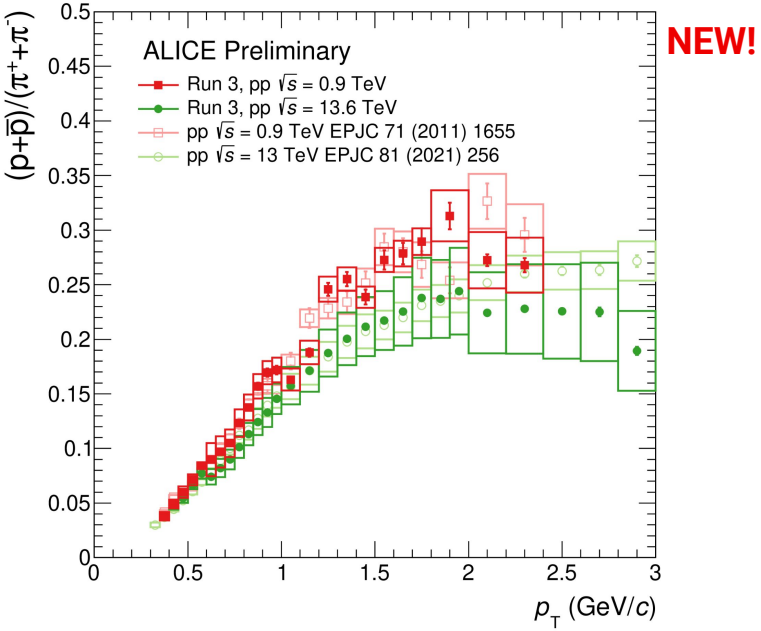
from Run 3

K/π and p/π p_T-dependent yield ratios

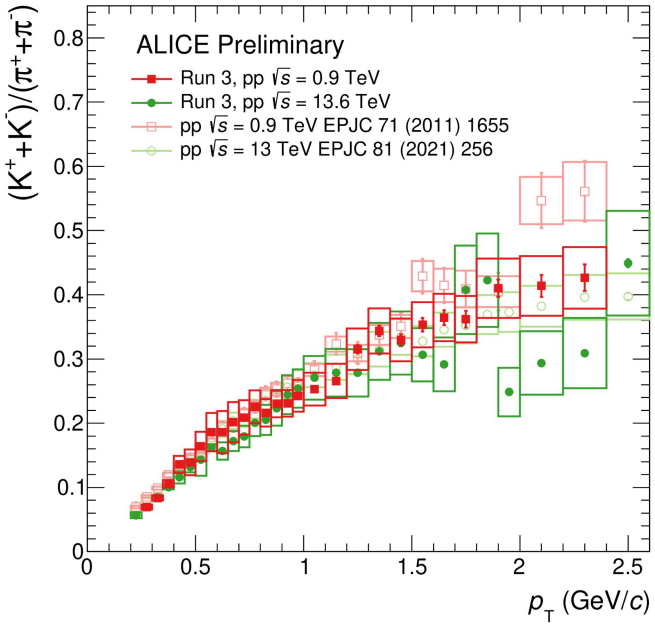
K/π and p/π yield ratios in pp collisions at 13.6 TeV and 900 GeV collected in **Run 3**

→ **900 GeV** yields in **agreement** with published results + **improved statistical uncertainty**

→ **13.6 TeV** yields **consistent with expectations**



NEW!

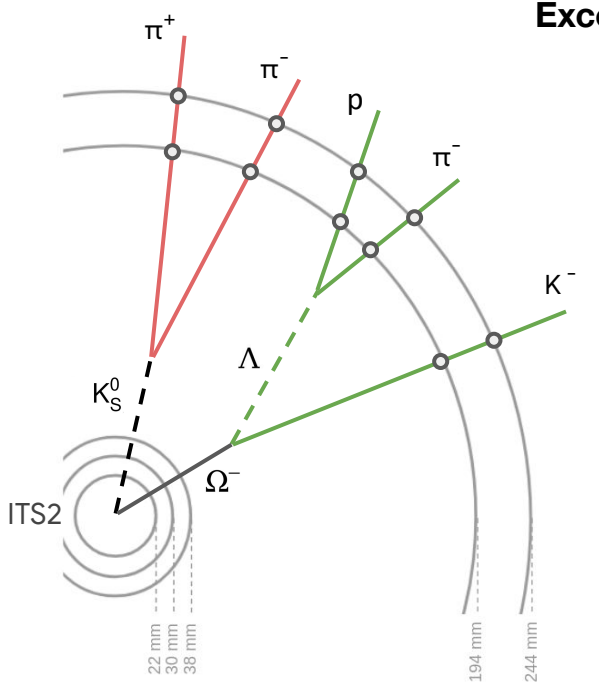


NEW!

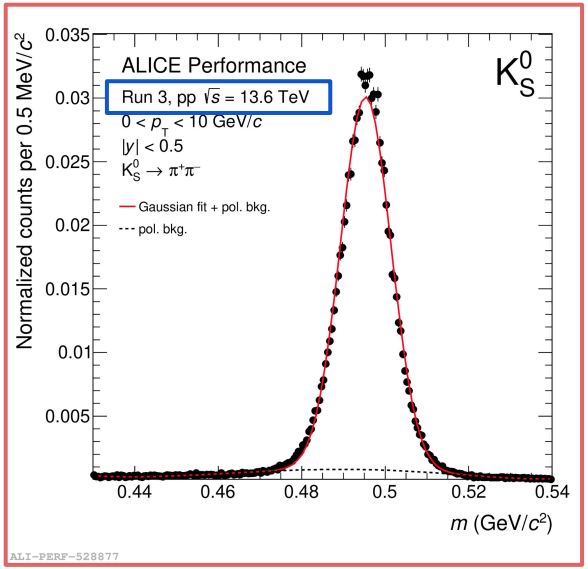
Strangeness production in Run 3

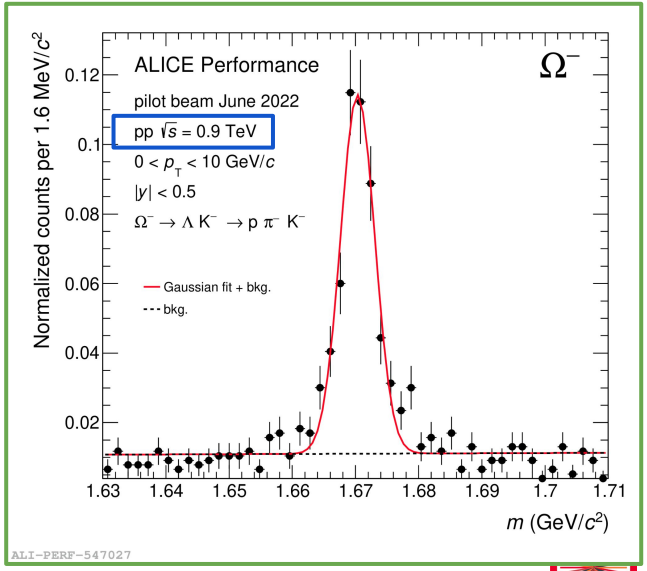
Kinematical and geometrical criteria are used to reconstruct candidates for strange hadrons

Identification based on two topologies: V^0 and **Cascade**



Excellent performance for strange hadron reconstruction with ALICE in Run 3





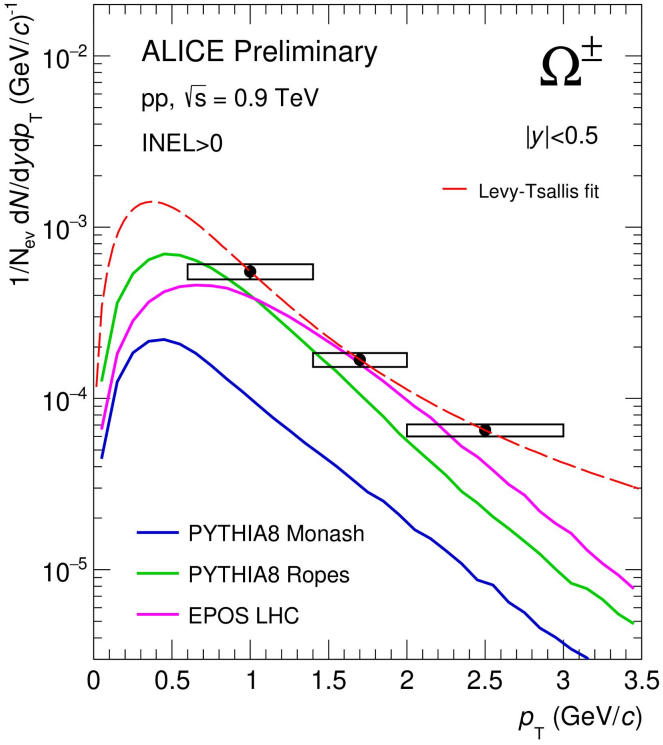
from Run 3

Ω production in pp collisions at 900 GeV

First measurement of Ω production in pp collisions at 900 GeV at the LHC, complementing ALICE results from Run 1 [1]

The p_T-dependent yields are compared to different MC models
→ overall discrepancy with data is observed for all models

NEW!



[1] Eur. Phys. J. C (2011) 71

C. De Martin (Poster) 5 Sept 17:30

from Run 3

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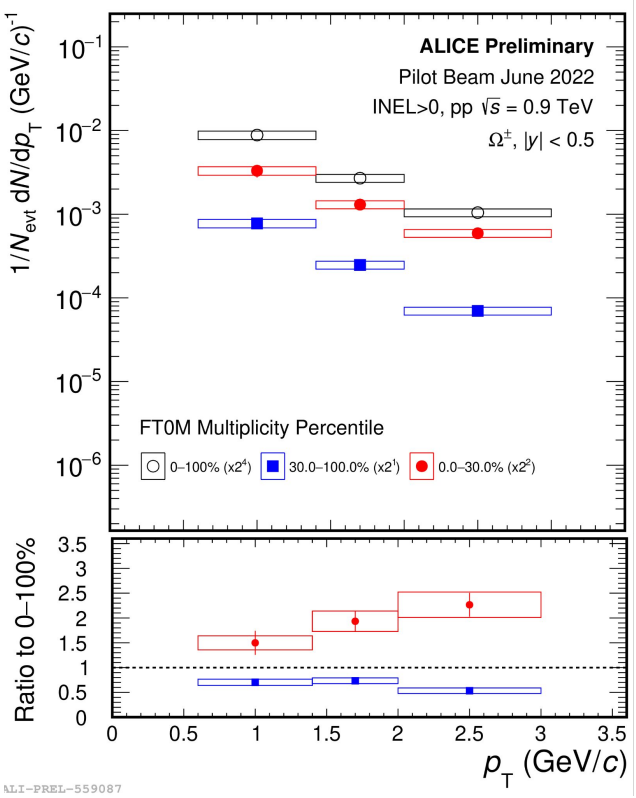
The p_T-dependent yields are compared to different MC models
→ overall discrepancy with data is observed for all models

The Ω **spectra** are studied for the **first time in multiplicity classes** (FT0A+FT0C) in pp collisions at $\sqrt{s}$ = 900 GeV

Hardening of the spectra with increasing multiplicity is observed in pp collisions at the lowest center of mass energy at the LHC



[1] Eur. Phys. J. C (2011) 71

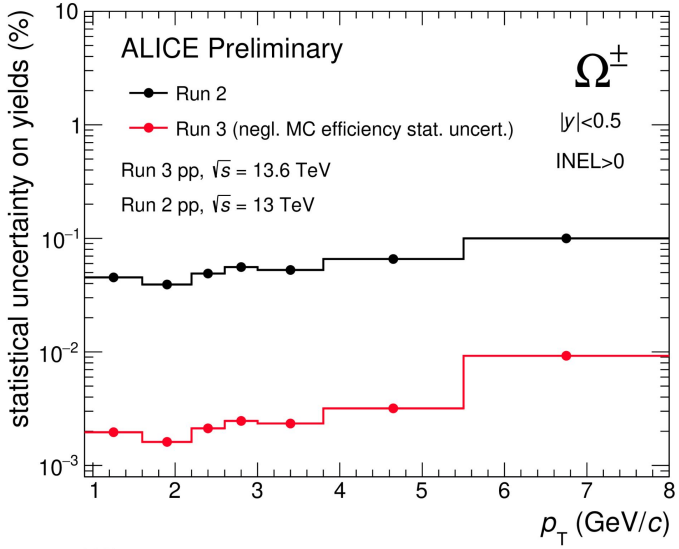
C. De Martin (Poster) 5 Sept 17:30

from Run 3

Ω production in pp collisions at 13.6 TeV

The Ω measured probability density vs p_T in pp collisions at $\sqrt{s}$ = **13.6 TeV** is studied in multiplicity classes (FT0A+FT0C)

Minimum bias Run 3 sample now **×1000 wrt Run 2**
Allows to improve the statistical uncertainty of a factor > 10



NEW!

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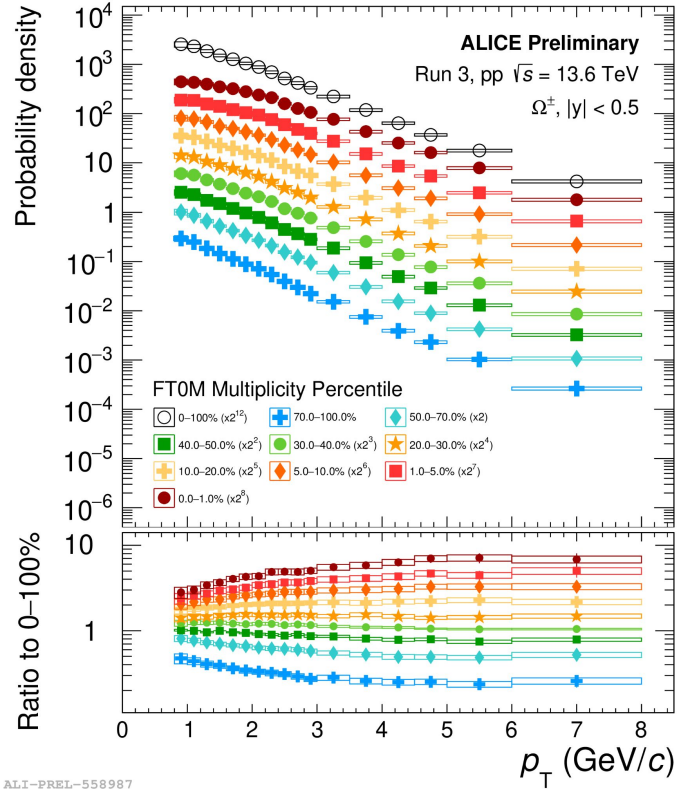


C. De Martin (Poster) 5 Sept 17:30

from Run 3

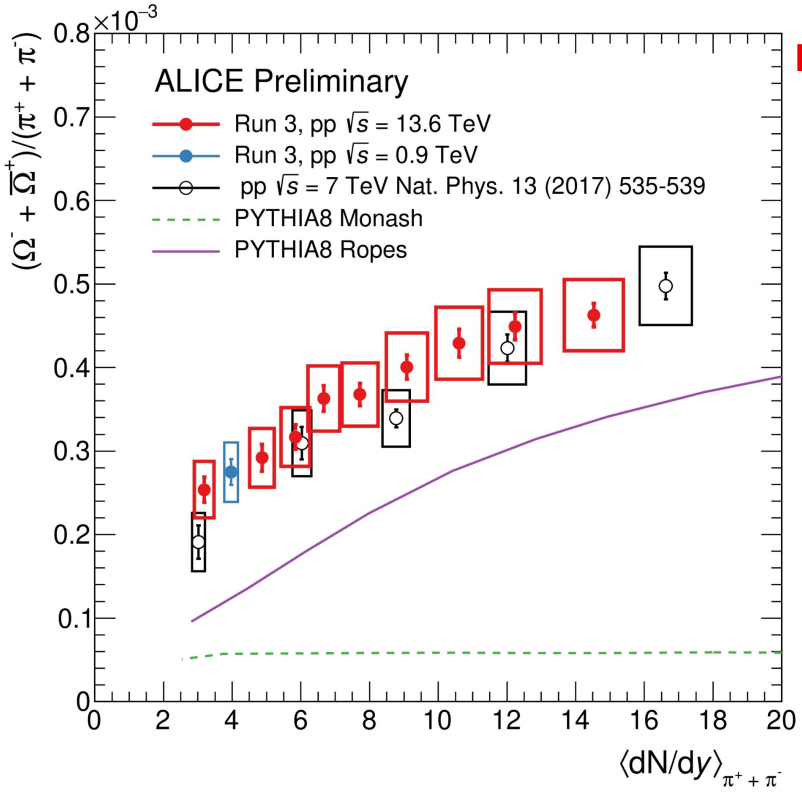
Ω/π ratio vs multiplicity

Unprecedented multiplicity differential study of Ω/π production in pp collisions at $\sqrt{s}$ = **13.6 TeV**

First Ω **yield** measured in INEL>0 pp collisions at $\sqrt{s}$ = **900 GeV** at the LHC

Run 3 statistics will allow to extend this study to higher multiplicities!

MB pp sample (this analysis) + **software triggers** to select events containing multi-strange hadrons



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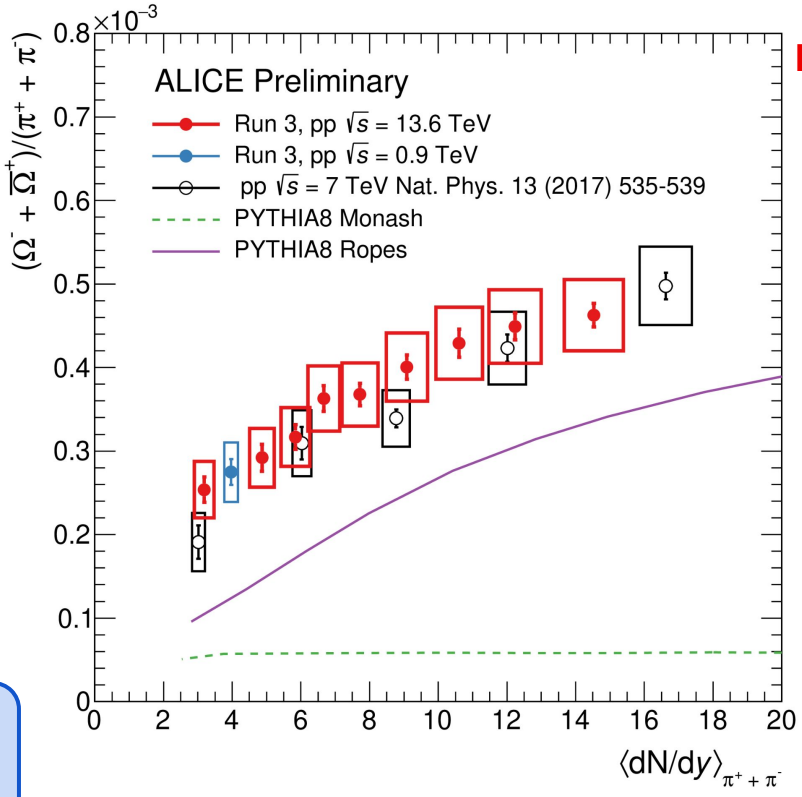

NEW!

New results on strangeness production with Run 2 data in **S. Pucillo's talk (408) → 6 Sept 2023, 17:30**

ALICE

Summary

NEW!

from Run 2

ALICE new results exploit **high-multiplicity** pp triggered events to study light flavour production in small systems at high multiplicities compatible to semi-peripheral Pb–Pb collisions

Summary

NEW!

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ALICE is smoothly **transitioning from Run 2 to Run 3 results**!

Summary

from Run 2

NEW!

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from Run 3

NEW!

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First measurement of Ω/π ratio in pp at $\sqrt{s}$ = 13.6 TeV: **unprecedented multiplicity differential study**

First results on Ω production in pp collisions at **900 GeV** were presented also in multiplicity classes, complementing ALICE results from Run 1

Summary

NEW!

from Run 2

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NEW!

from Run 3

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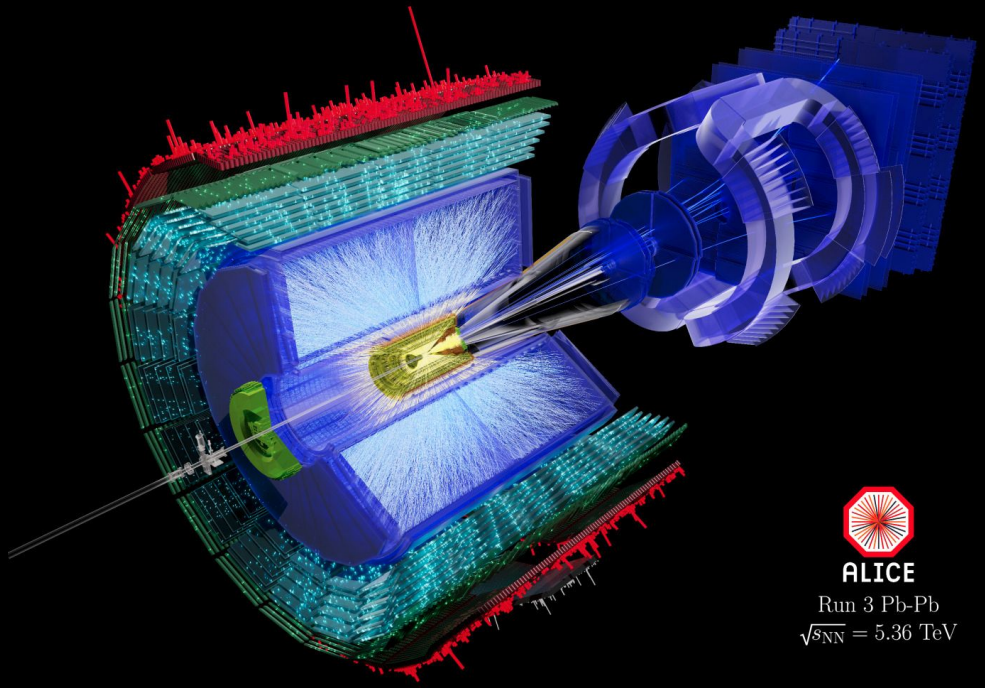
In a few weeks Pb ions will be back at the LHC
ALICE is ready to collect Pb–Pb collisions at 5.36 TeV!

ALICE

Thank you!

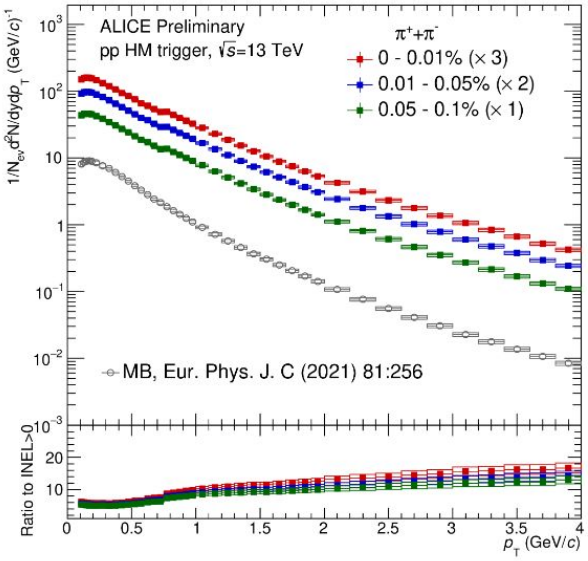


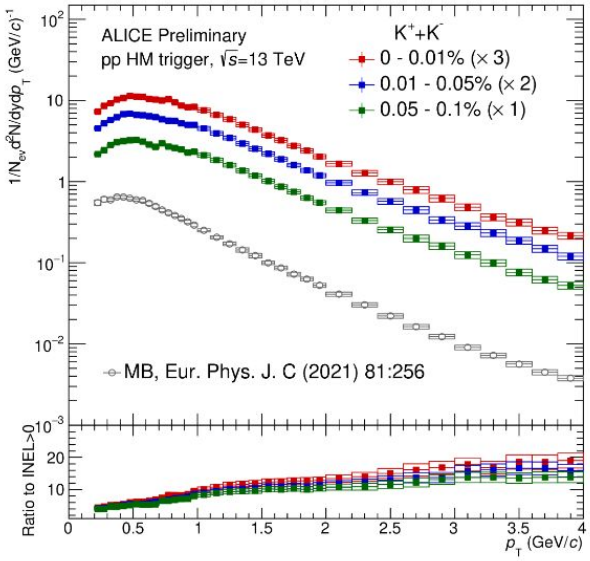
from Run 2

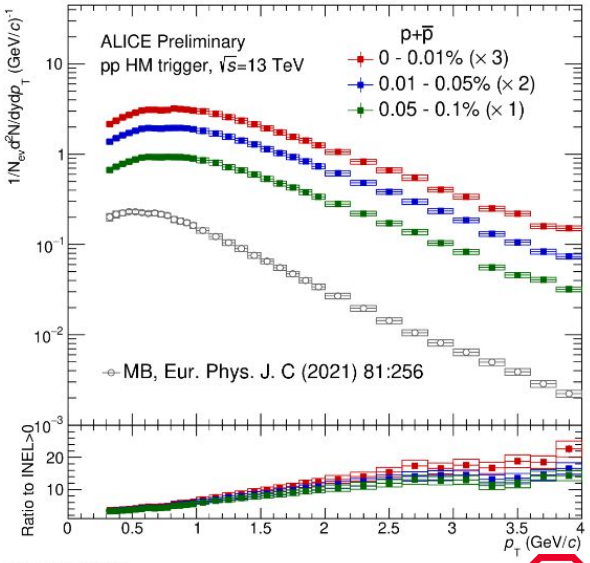
Light flavor spectra in HM pp events

p_T spectra of π, K and p for pp collisions at 13 TeV in HM classes compared to the INEL>0 spectra

Mass dependent + **slight centrality** dependent **hardening** of the spectra is observed







from Run 2

K/π and p/π yield ratios vs p_T in HM pp events

K/π and p/π p_T differential yield ratios compared among HM, INEL>0 and low multiplicity events

The ratio of HM to V0M-X class (*low multiplicity*) shows an **enhancement of p/π with increasing p_T**
→ similar effect to collective expansion (radial flow?)