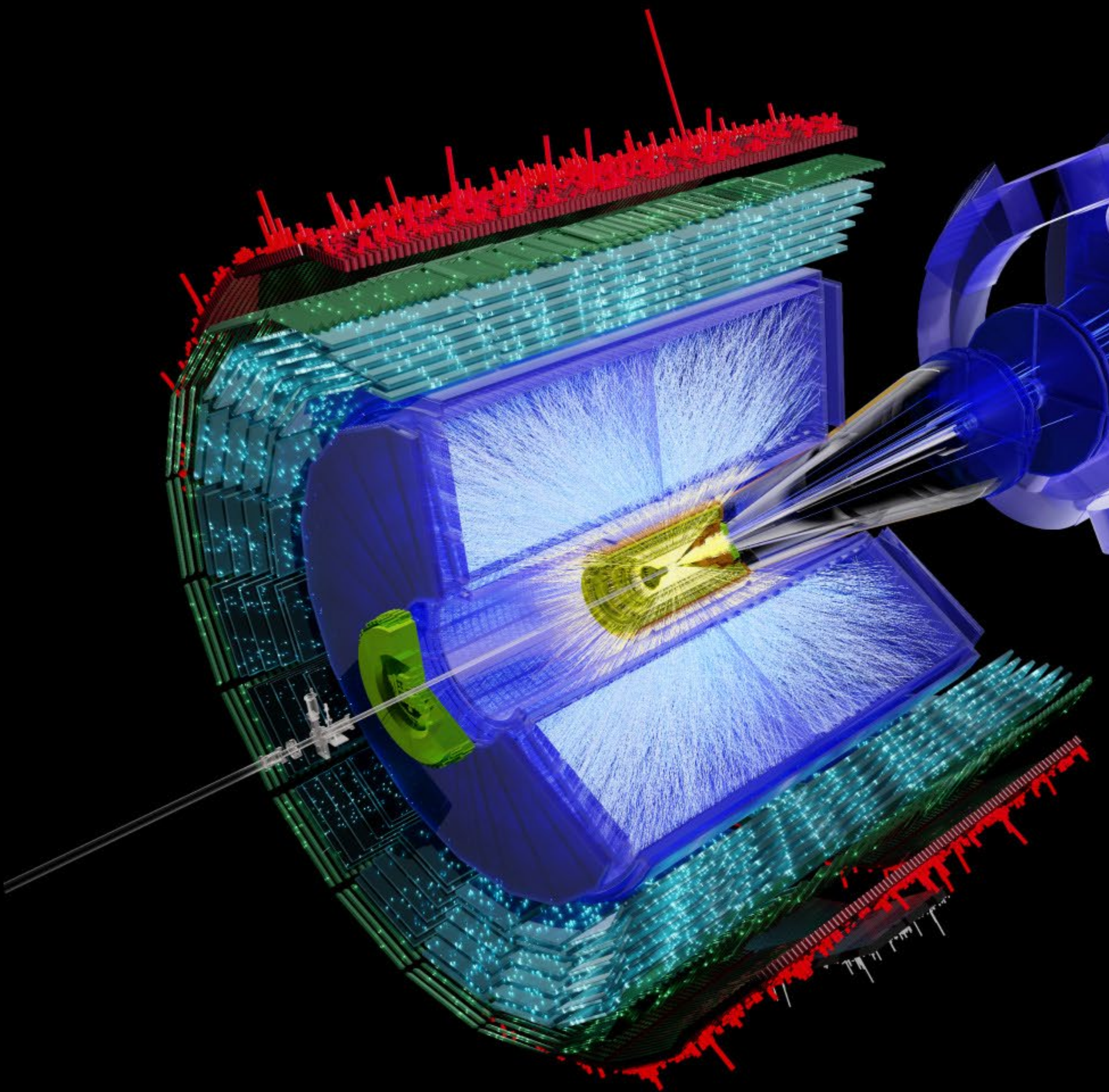


LUND UNIVERSITY

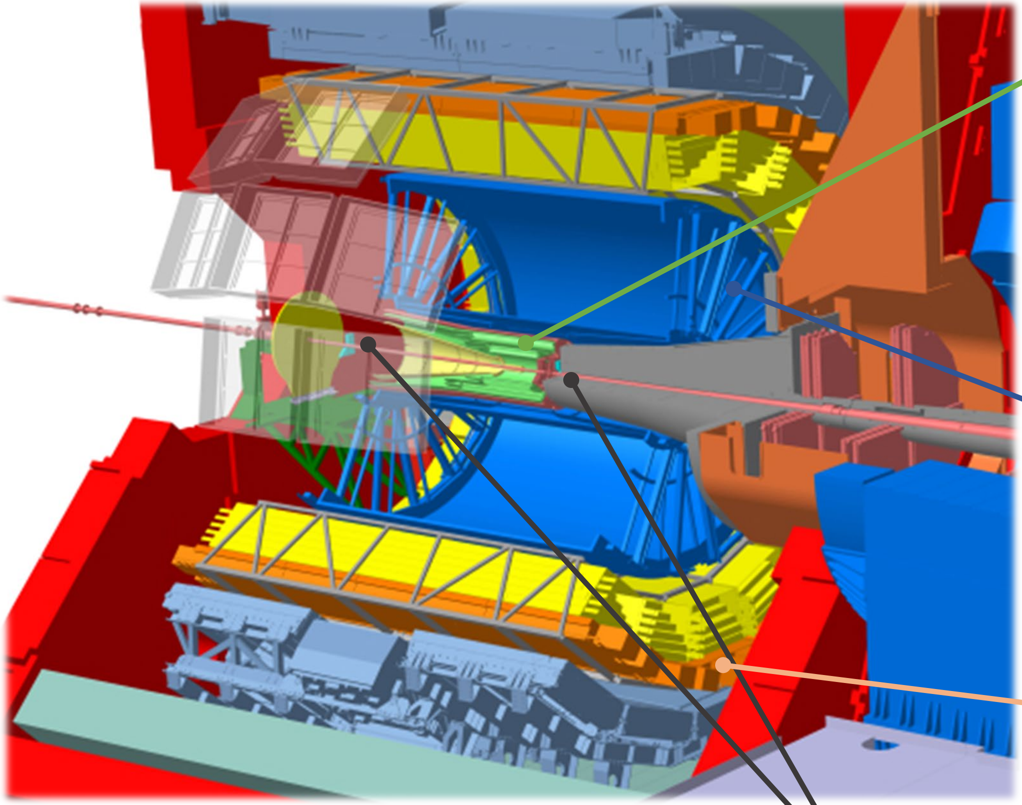
Analysis of Strangeness with ALICE detector at the LHC

PHD DAY @ LUND UNIVERSITY

Roman Nepeivoda* Lund University

*roman.nepeivoda@fysik.lu.se

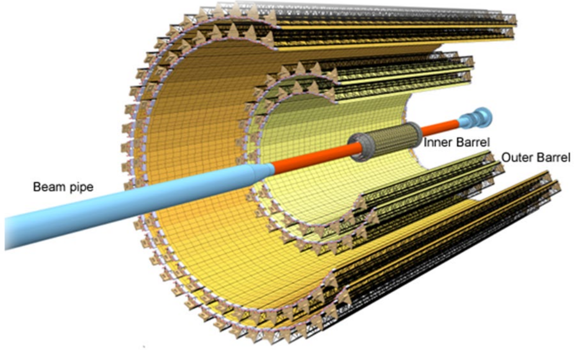
The ALICE Detector in Run 3



ITS upgrade

NIM 1032, 166632 (2022)

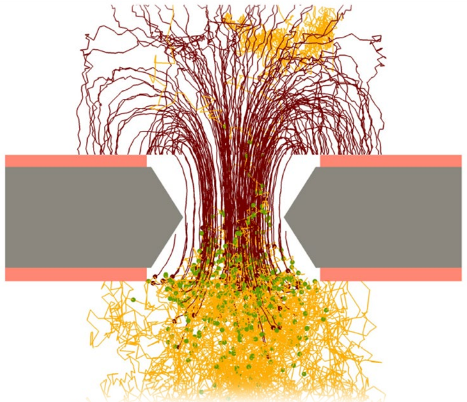
- 7 layers of silicon pixel detectors with reduced material budget
- First detection layer closer to IP + new beam pipe (ITS L0 at 22 mm)



Time **P**rojection **C**hamber (**TPC**)

JINST 16, P03022 (2021)

- Tracking, PID (*dE/dX*)
- MWPCs replaced with GEMs
- Continuous readout up to 50 kHz Pb-Pb interaction rate (x50 wrt Run 2)



Time **O**f **F**light (**TOF**)

- PID via Time-Of-Flight technique

New O^2 framework

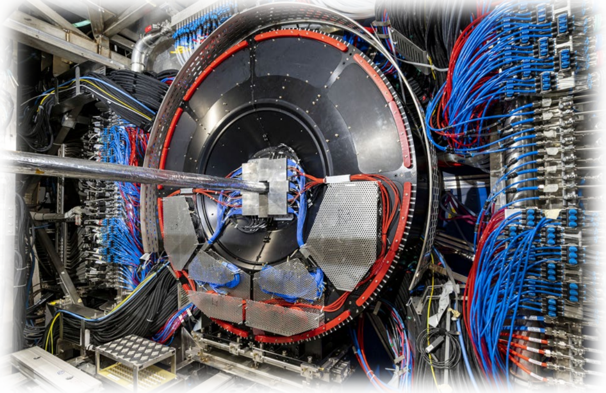
CERN-LHCC-2015-006, ALICE-TDR-019

- One common Online Offline (O^2) computing system
- Faster online and offline processing
- Increased data volume x100 wrt Run 2

NEW Fast Interaction Trigger (FIT)

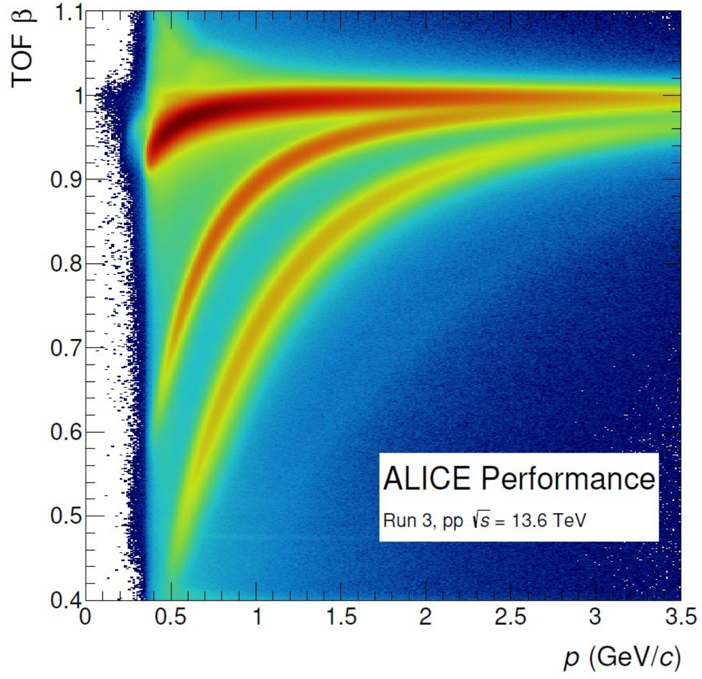
NIM 1039, 167021 (2022)

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

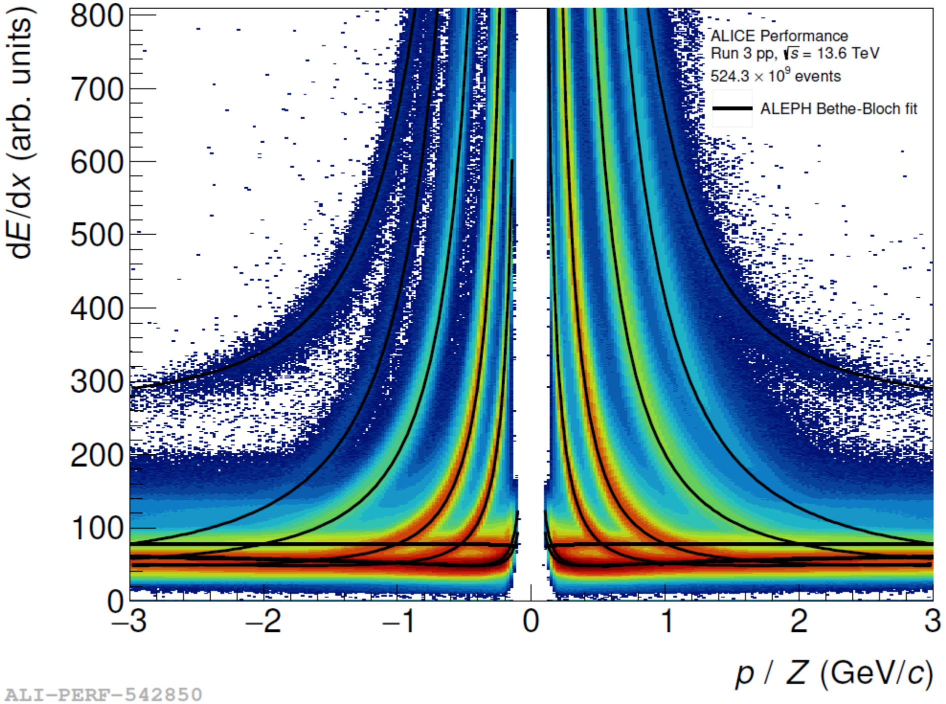


Performance of the ALICE detector in Run 3

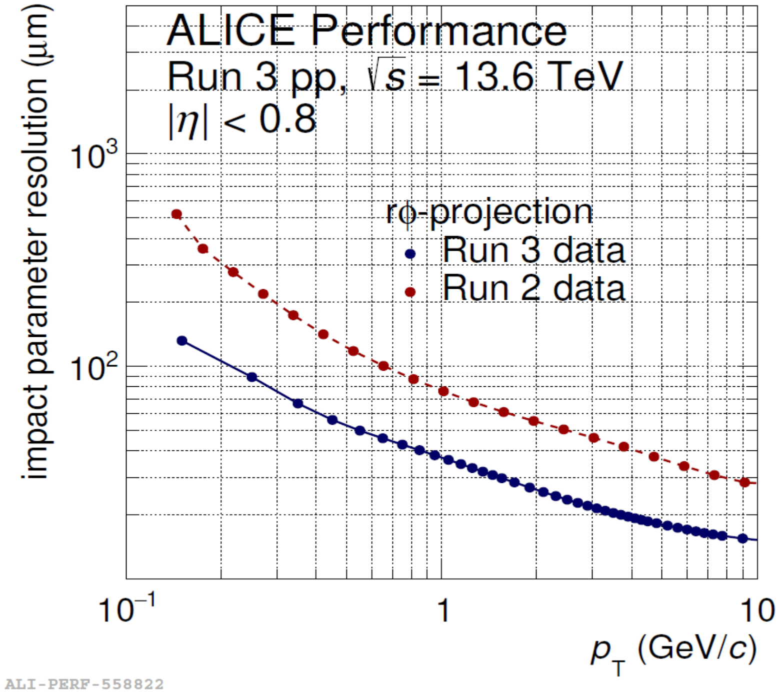
The LHC Run 3 started in 2022, so far ALICE collected almost **x1000** events wrt Run 2 in pp data taking at **~500 kHz** in continuous readout



ALI-PERF-537607



ALI-PERF-542850



ALI-PERF-558822

- Extend our studies further to higher multiplicities
- Increase our precision on existing studies
- Allows to conduct studies on rare species

Strangeness reconstruction with ALICE

The identification of (multi-)strange hadrons is based on two topologies:

V^0: neutral particle decaying weakly into a pair of charged particles (V-shaped decay)

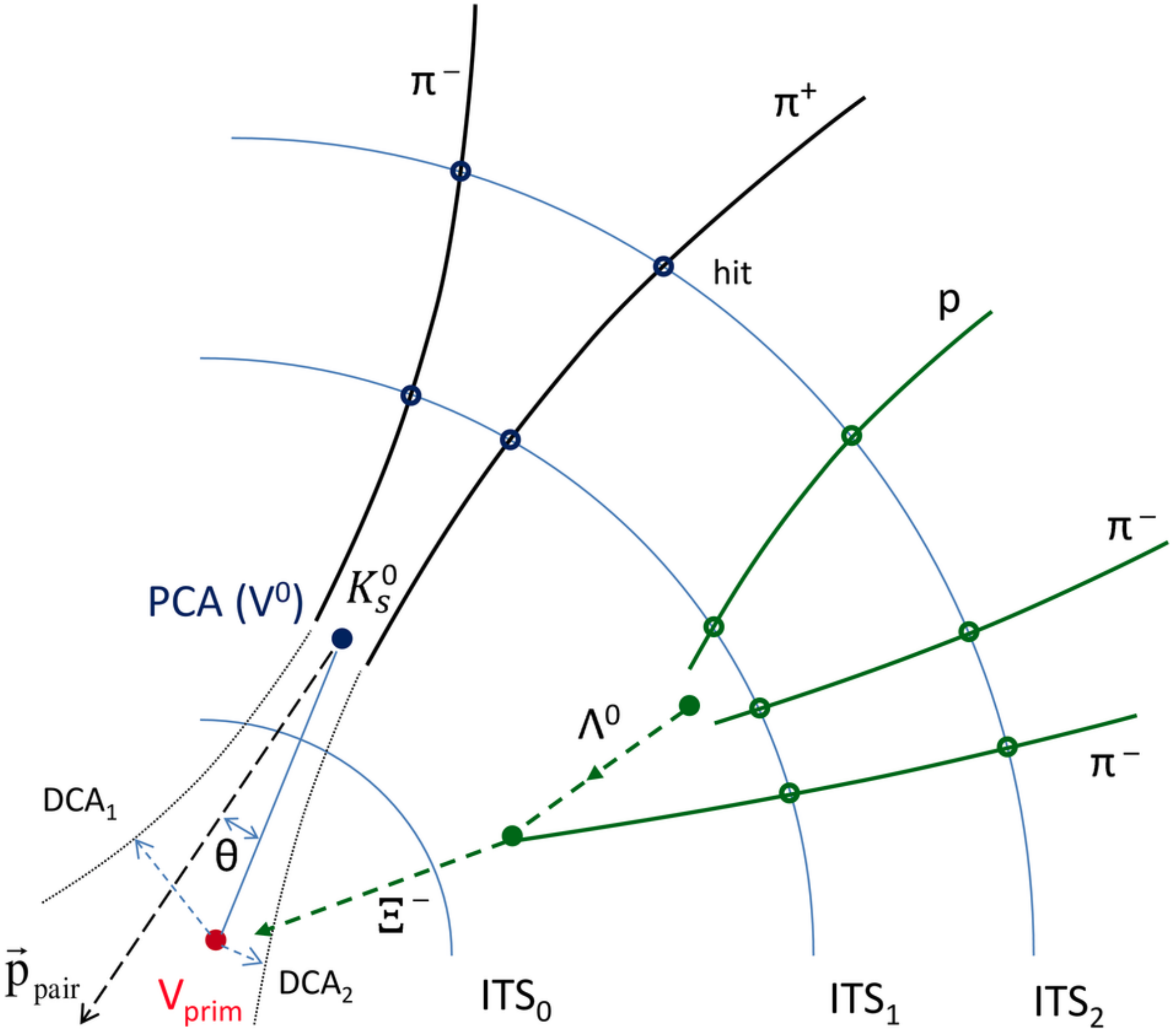
$$K_S^0 \rightarrow \pi^+ + \pi^- \quad (d\bar{s})$$

$$\Lambda\,(\bar{\Lambda}) \rightarrow p\,(\bar{p}) + \pi^-\,(\pi^+) \quad (uds)$$

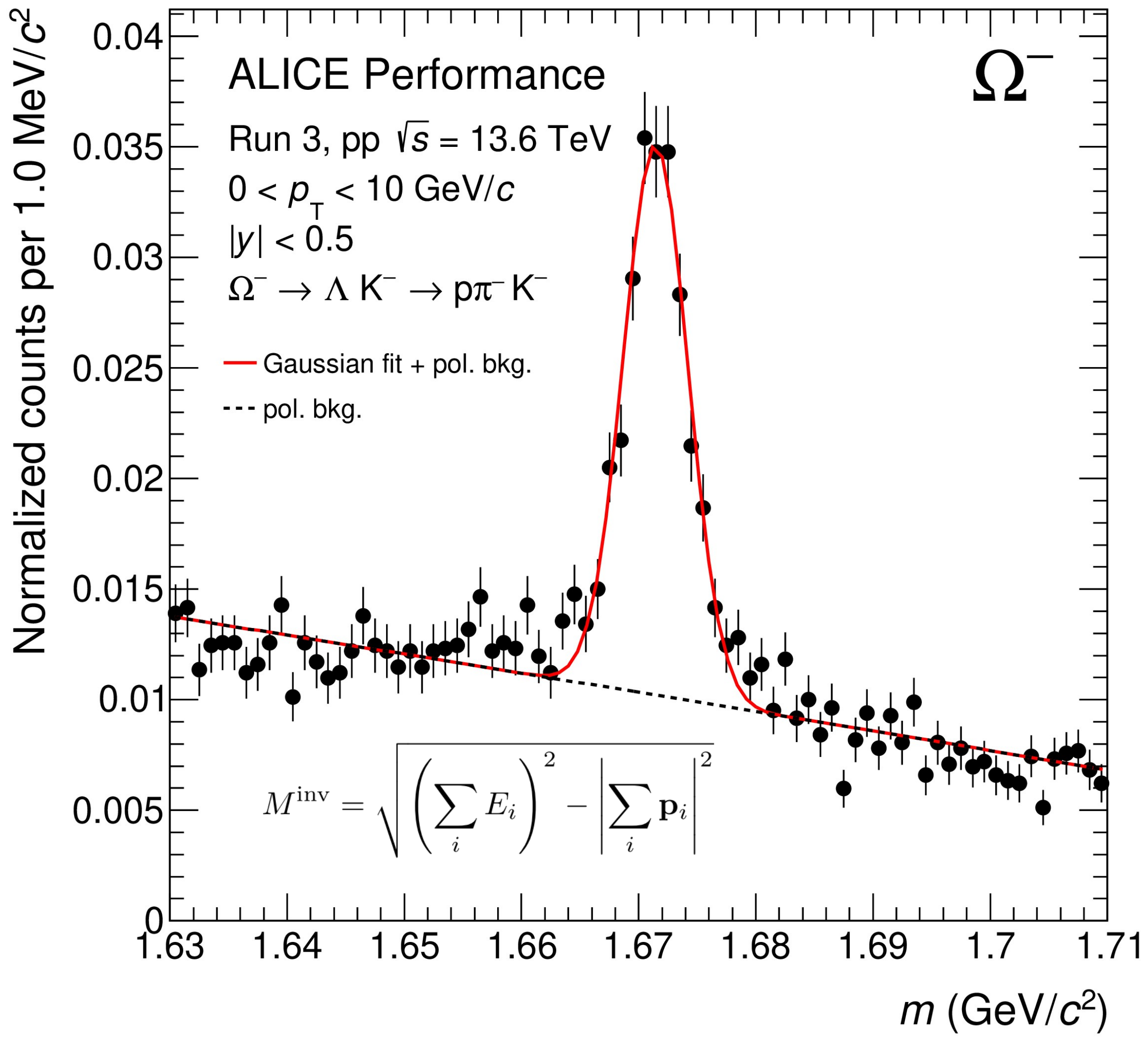
Cascade: charged particle decaying weakly into a V^0 + charged particle

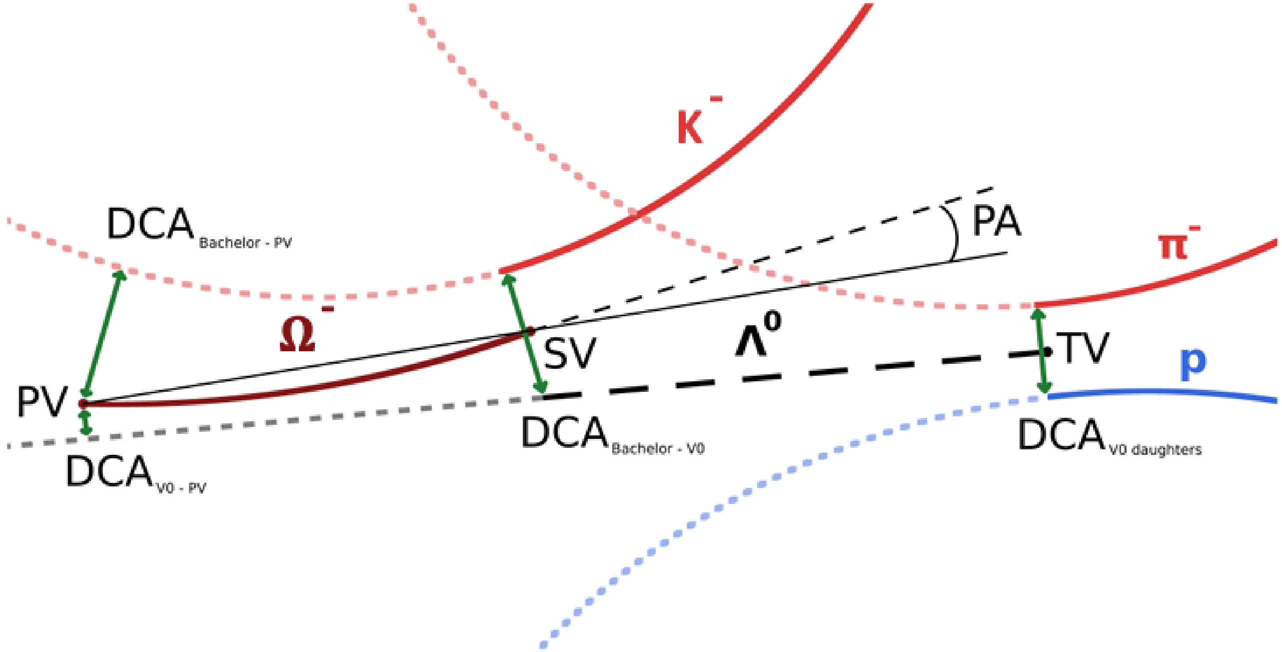
$$\Xi^-\,(\bar{\Xi}^+) \rightarrow \Lambda\,(\bar{\Lambda}) + \pi^-\,(\pi^+) \quad (dss)$$

$$\Omega^-\,(\bar{\Omega}^+) \rightarrow \Lambda\,(\bar{\Lambda}) + K^-\,(K^+) \quad (sss)$$



Cascade signal extraction





PV – primary vertex
SV – secondary vertex
TV – tertiary vertex

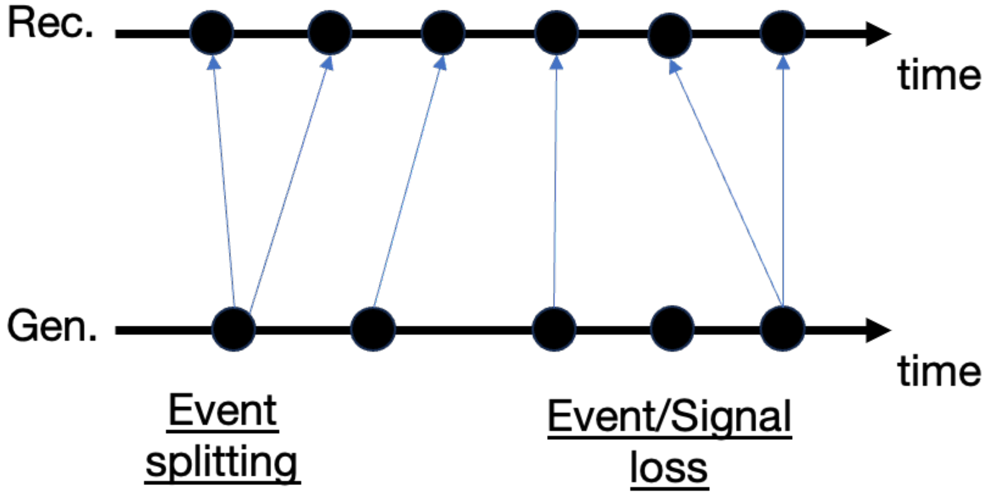
DCA – distance of closest approach
PA – pointing angle

> 20 topological and kinematic variables are used for the reconstruction, and optimized for a better signal purity

Event and signal loss corrections in Run 3

$$\frac{1}{N_{\text{events}}^{\text{true INEL}>0}(\%)}\frac{dN}{dp_{\mathrm{T}}} = Y_{\text{corr}}\left(\Delta p_{\mathrm{T}}, \%\right) =$$

$$= \frac{S\left(\Delta p_{\mathrm{T}}, \%\right)}{N_{\text{events}}^{\text{acc INEL}>0}(\%)} \cdot \frac{1}{\varepsilon_{\text{eff.x acc.}}\left(\Delta p_{\mathrm{T}}\right)} \cdot \frac{1}{\Delta p_{\mathrm{T}}} \cdot \frac{\varepsilon_{\text{event loss}}(\%)}{\varepsilon_{\text{signal}}\left(\Delta p_{\mathrm{T}}, \%\right) \cdot \varepsilon_{\text{event splitting}}(\%)}$$



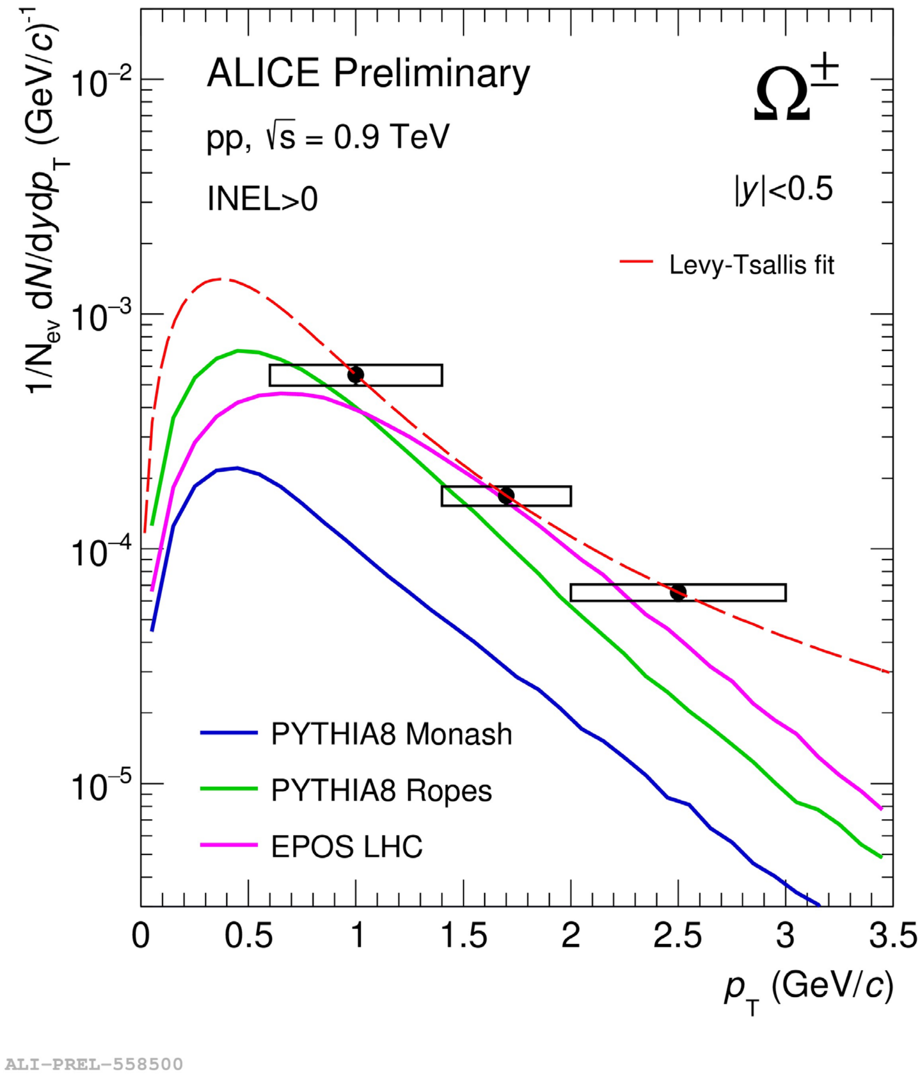
$$\varepsilon_{\text{event loss}}(\%) = \frac{N_{\text{gen events with at least 1 rec.event}}(\%)}{N_{\text{gen}}(\%)}$$

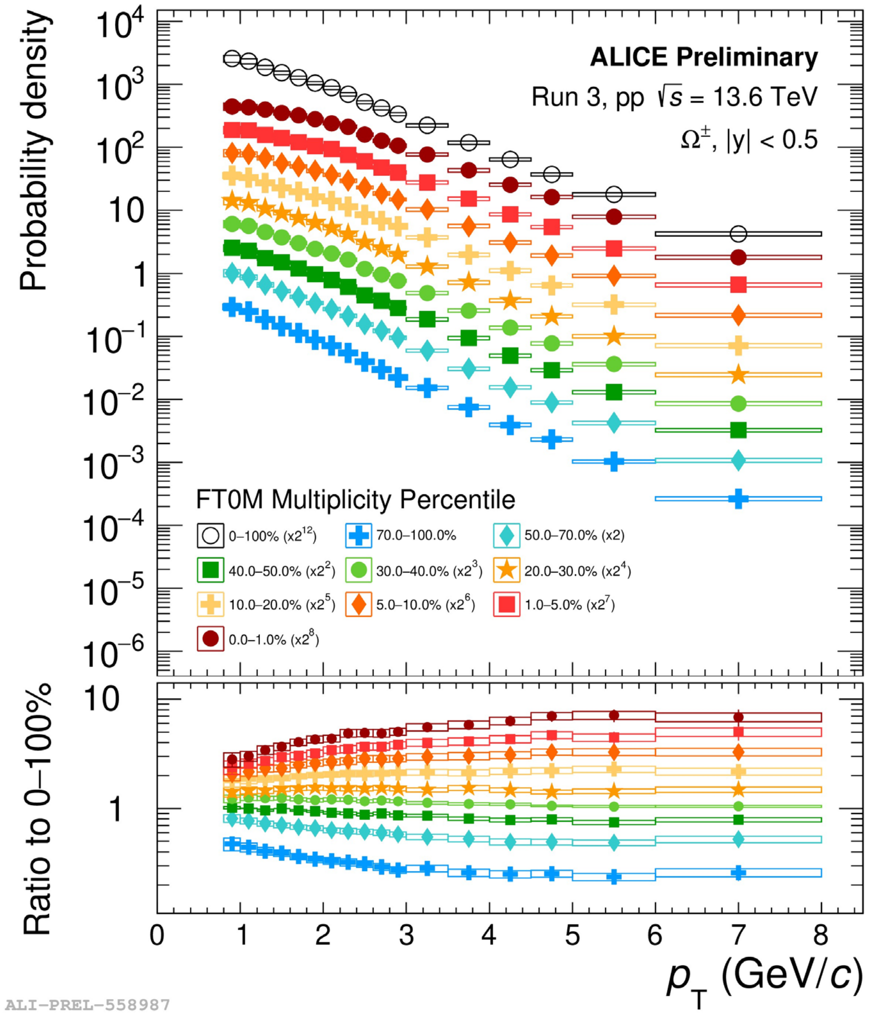
$$\varepsilon_{\text{event splitting}}(\%) = \frac{N_{\text{gen events with at least 1 rec.event}}(\%)}{N_{\text{rec}}(\%)}$$

$$\varepsilon_{\text{signal}}\left(\Delta p_{\mathrm{T}}, \%\right) = \frac{N_{\text{gen cascades, at least 1rec. event}}\left(\Delta p_{\mathrm{T}}, \%\right)}{N_{\text{gen cascades}}\left(\Delta p_{\mathrm{T}}, \%\right)}$$

$$\varepsilon_{\text{eff. }x\text{ acc.}}\left(\Delta p_{\mathrm{T}}\right) = \frac{N_{\text{rec casc.}}\left(\Delta p_{\mathrm{T}}\right)}{N_{\text{gen casc., at least 1 rec.event}}\left(\Delta p_{\mathrm{T}}\right)}$$

p_T Spectra in Multiplicity Classes





High multiplicity

Low multiplicity

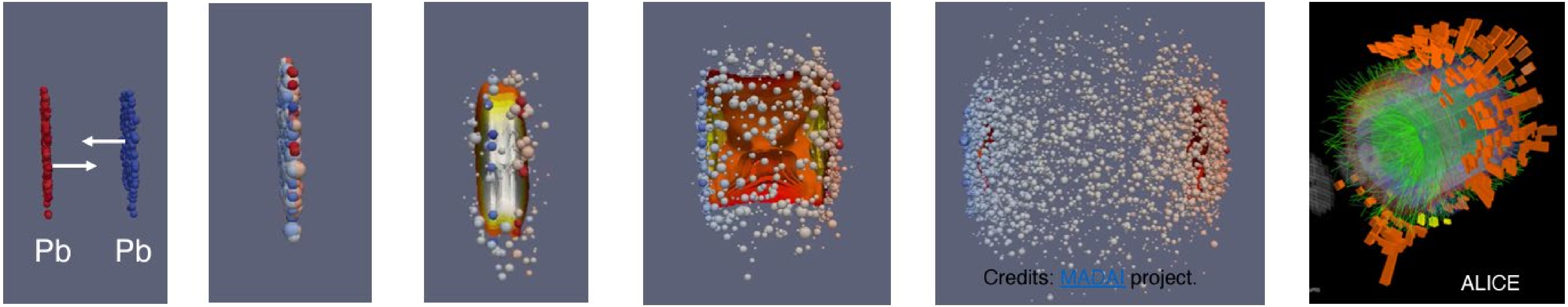
Multiplicity

Strangeness Enhancement Phenomenon

Strangeness as a signature of QGP in heavy-ion collisions

QGP

Initial state | Hard scatterings | QGP formation | Hydrodynamic expansion | Hadronization and freeze-out | Detection

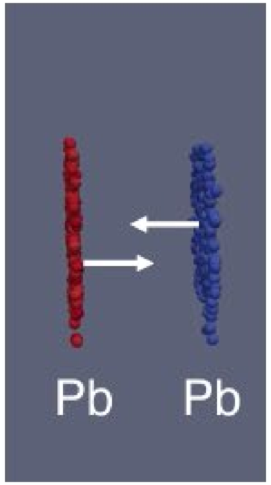


Strangeness Enhancement Phenomenon

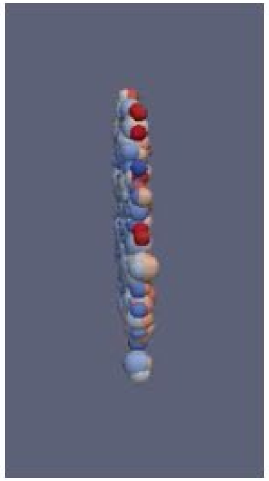
Strangeness as a signature of QGP in heavy-ion collisions

QGP → deconfinement

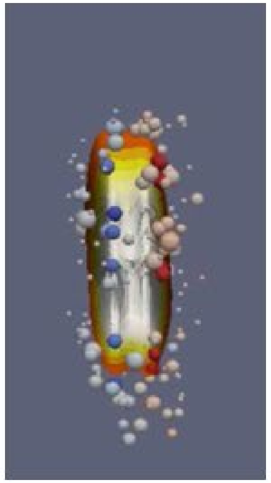
Initial state



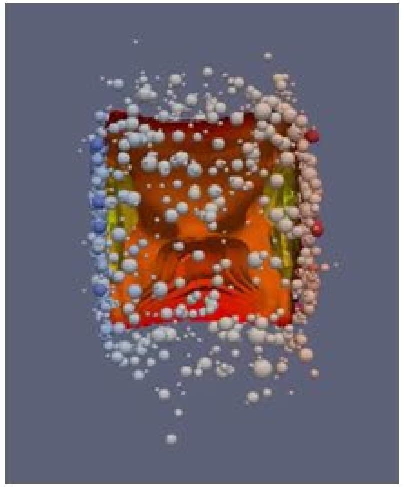
Hard scatterings



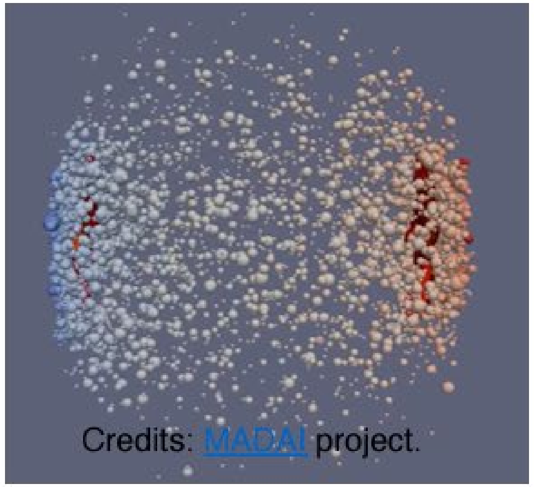
QGP formation



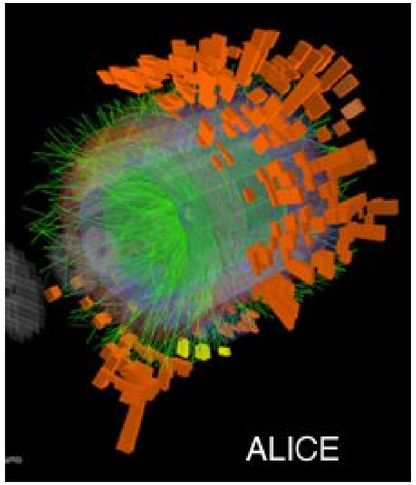
Hydrodynamic expansion



Hadronization and freeze-out



Detection

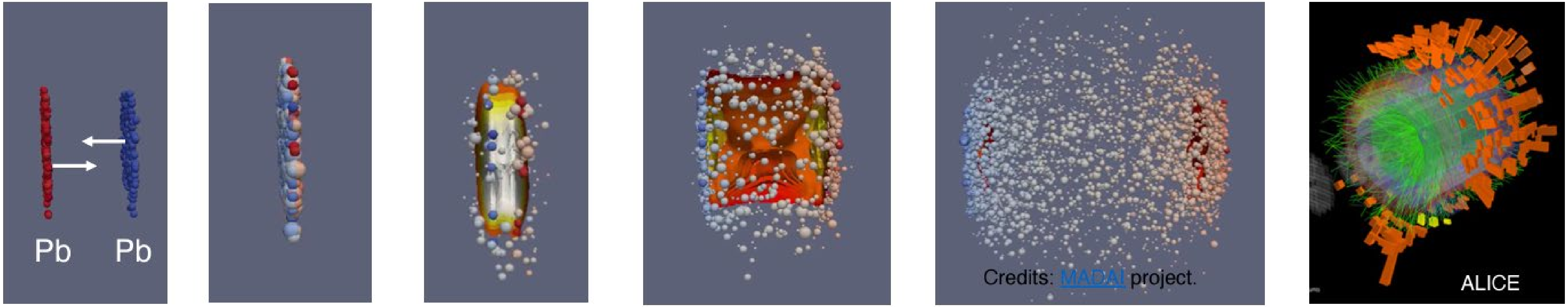


Strangeness Enhancement Phenomenon

Strangeness as a signature of QGP in heavy-ion collisions

QGP → deconfinement → lower effective s quark mass

Initial state | Hard scatterings | QGP formation | Hydrodynamic expansion | Hadronization and freeze-out | Detection

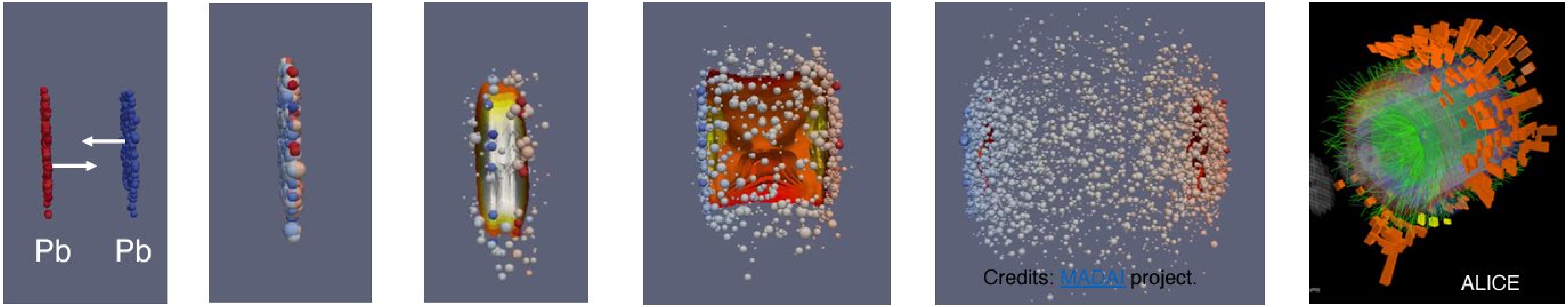


Strangeness Enhancement Phenomenon

Strangeness as a signature of QGP in heavy-ion collisions

QGP → deconfinement → lower effective s quark mass → more $s\bar{s}$ breakings

Initial state | Hard scatterings | QGP formation | Hydrodynamic expansion | Hadronization and freeze-out | Detection

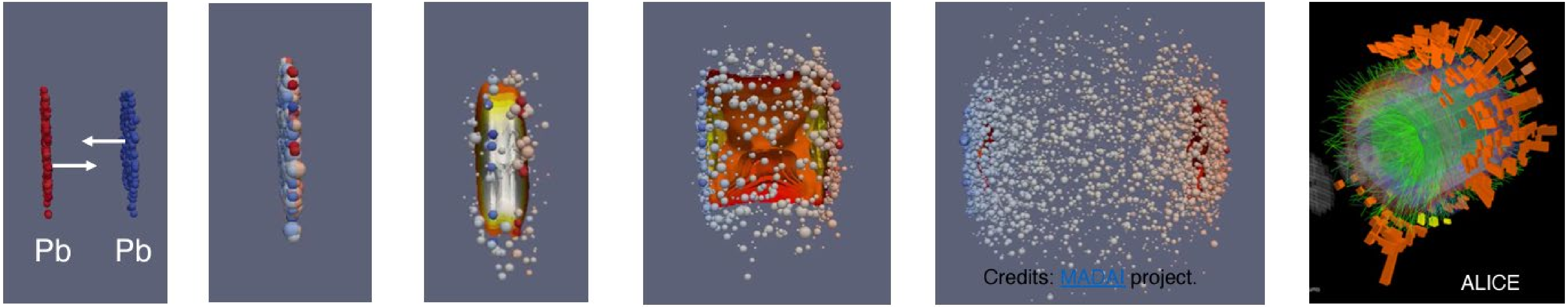


Strangeness Enhancement Phenomenon

Strangeness as a signature of QGP in heavy-ion collisions

QGP → deconfinement → lower effective s quark mass → more $s\bar{s}$ breakings → more (multi)strange hadrons

Initial state | Hard scatterings | QGP formation | Hydrodynamic expansion | Hadronization and freeze-out | Detection

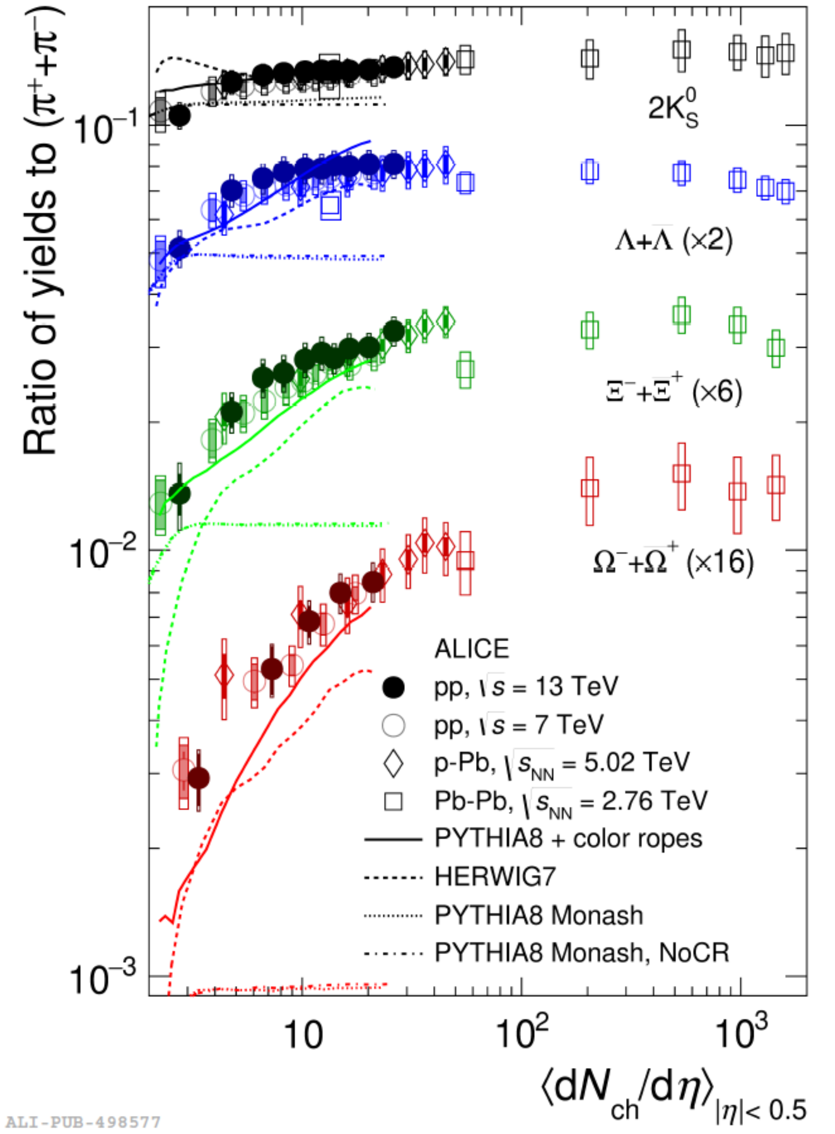


Strangeness Enhancement Phenomenon

Strangeness as a signature of QGP

QGP → deconfinement → lower effective s quark mass → more $s\bar{s}$ breakings → more (multi)strange hadrons

However, strangeness production increases with particle multiplicity **regardless** of collision system and energy!



Eur. Phys. J. C 80, 693 (2020)

Strangeness Enhancement Phenomenon

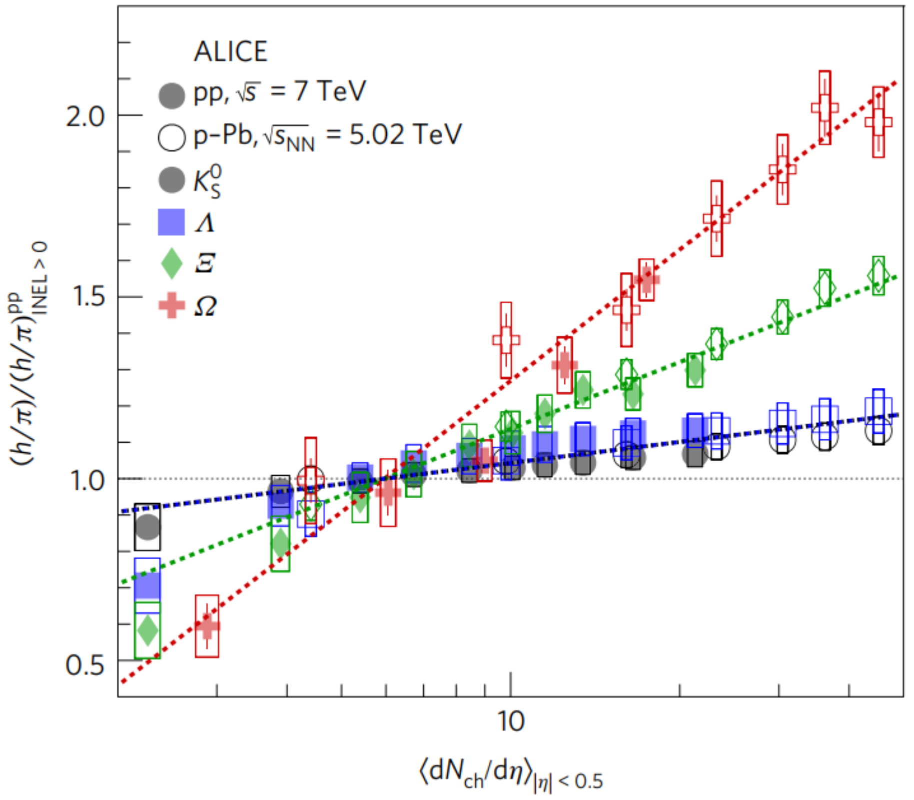
Strangeness as a signature of QGP

QGP → deconfinement → lower effective s quark mass → more $s\bar{s}$ breakings → more (multi)strange hadrons

However, strangeness production increases with particle multiplicity **regardless** of collision system and energy!

$$\frac{(h/\pi)}{(h/\pi)^{\mathrm{pp}}_{\mathrm{INEL}>0}} = 1 + a\, S^{b} \log\left[\frac{\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle}{\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{\mathrm{pp}}_{\mathrm{INEL}>0}}\right]$$

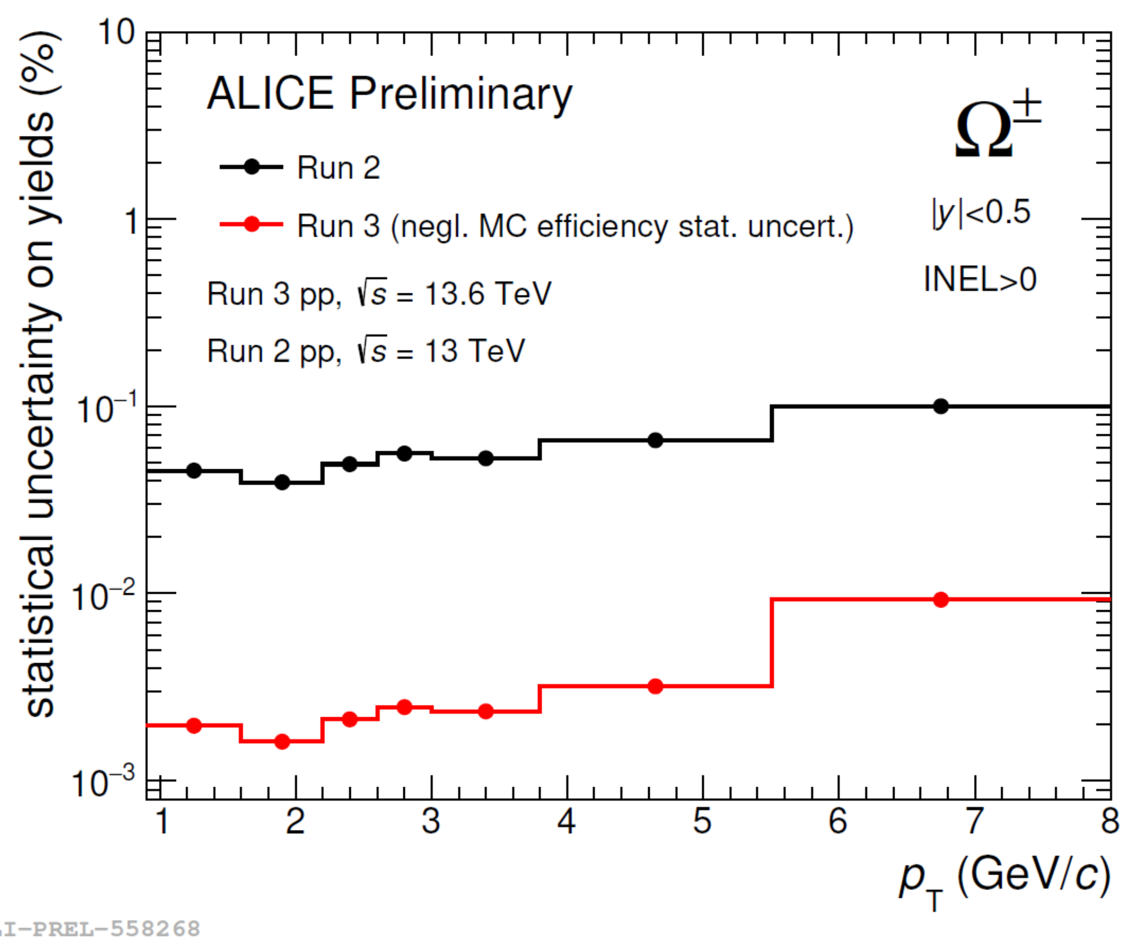
$$a = 0.083 \pm 0.006,\; b = 1.67 \pm 0.09,\; \frac{\chi^2}{ndf} = 0.66$$

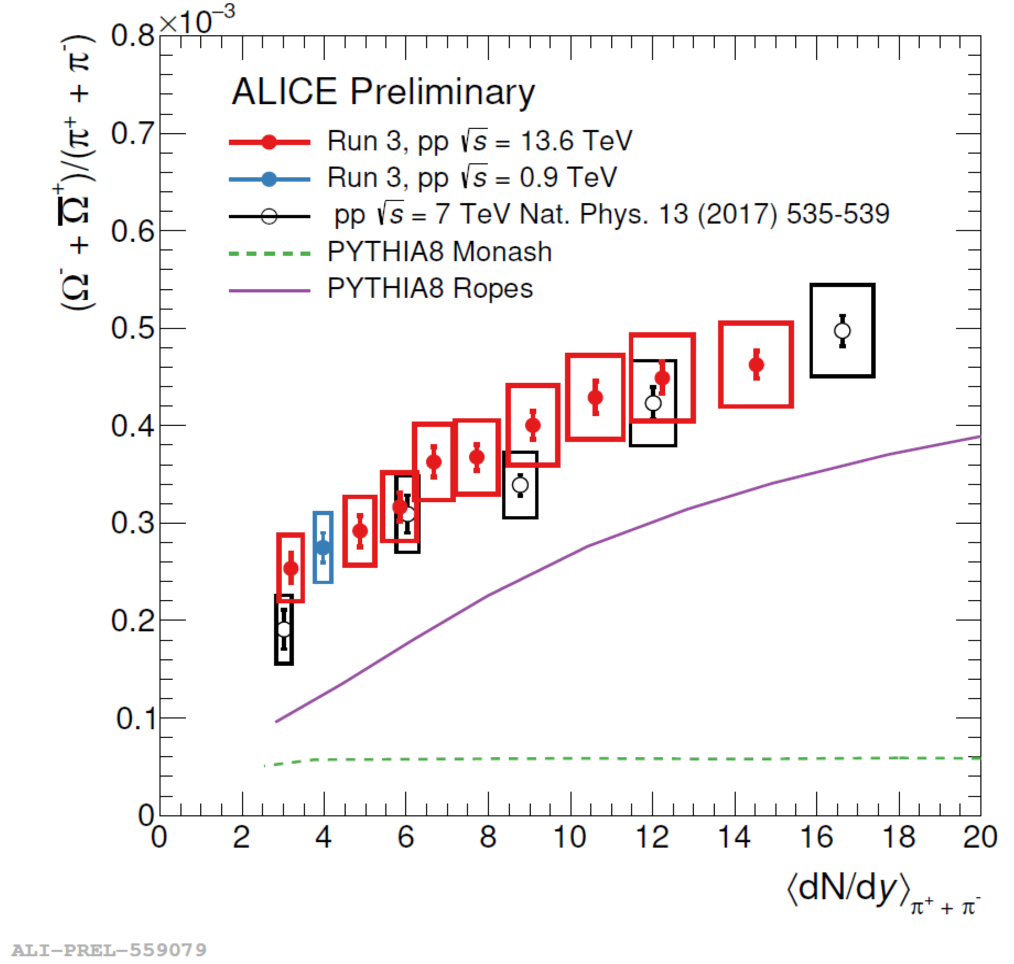


Particle yield ratios to pions normalized to the values measured in the inclusive inelastic pp sample

Nature Physics **13**, 535-539 (2017)

Ω/π ratio vs multiplicity



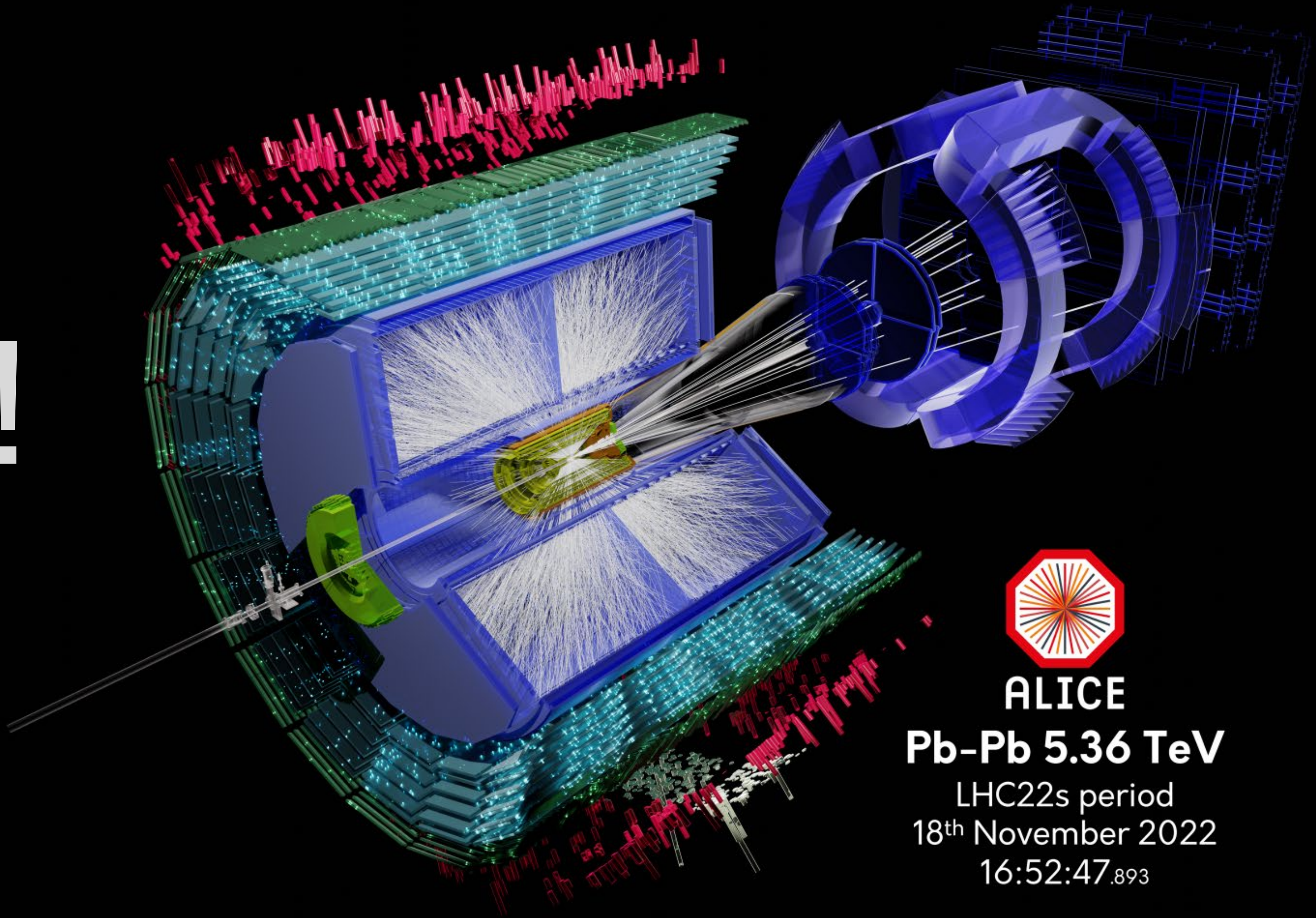


- Unprecedented multiplicity differential study of Ω/π production in pp collisions at $\sqrt{s}$ = **13.6 TeV**
- First Ω yield measured in INEL>0 pp collisions at $\sqrt{s}$ = **900 GeV** at the LHC

Summary

- **ALICE detector** stands as a testament to human ingenuity and scientific curiosity
- **Major upgrades** for **Run3** allow to increase the precision on existing studies and conduct studies on rare species, perform statistically-hungry analyses
- By understanding how **strange quarks** are produced and interact in the **QGP**, we can gain a deeper understanding of fundamental properties of matter
- First measurement of $\Omega^{\pm} - \mathrm{to} - \pi^{\pm}$ ratio in pp at $\sqrt{s} = 13.6$ TeV: **unprecedented multiplicity differential study**
- **Extension** of the $\Omega^{\pm} - \mathrm{to} - \pi^{\pm}$ ratio to the lowest collision energy (900 GeV) available at the LHC

Thank you!


ALICE
Pb-Pb 5.36 TeV
LHC22s period
18th November 2022
16:52:47.893