Energy, multiplicity and event shape dependence of ϕ production in pp collisions with ALICE at the LHC

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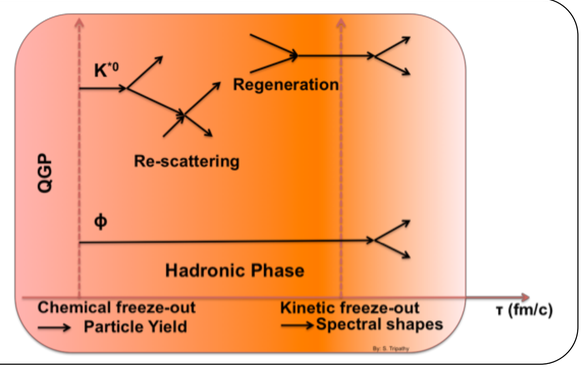
1. Physics Motivation

1. Find whether there is a dependence of the relative $\phi(1020)$ production on the collision energy.
2. Search for onset of collective effects in small collision systems by a double differential study with multiplicity and event shape.
3. Investigate whether there is any effect of re-scattering and re-generation for the long-lived ϕ (lifetime: 46.3 fm/c) in high multiplicity pp collisions, where the density and the volume of the system are expected to be larger.
4. An insight into strangeness using $\phi(1020)$ production in small systems.

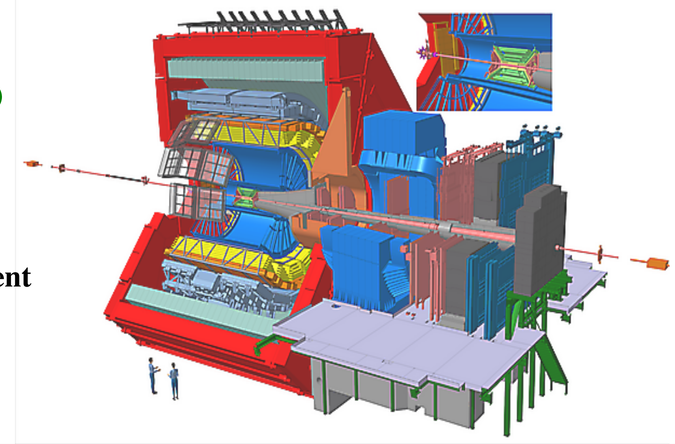


2. A Large Ion Collider Experiment (ALICE)

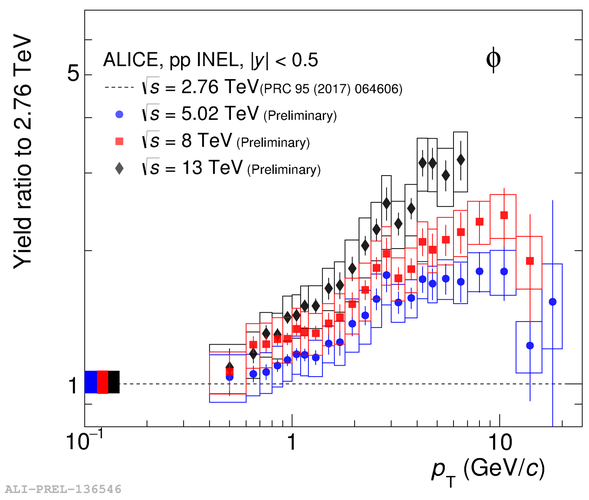
- At the LHC, ALICE has collected data in pp collisions at $\sqrt{s}$ = 0.9, 2.76, 5.02, 7.0, 8.0 and 13.0 TeV.
- In order to improve the global momentum resolution, tracks are accepted only in the range $|\eta| < 0.8$ and with $p_T > 0.15$ GeV/c.

Detectors used

- **Inner Tracking system (ITS)**
  - Tracking
  - Vertexing
- **Time Projection Chamber (TPC)**
  - Main tracking detector
  - Particle identification (dE/dx)
  - Momentum measurement
- **Time of Flight (TOF)**
  - PID via time of flight measurement
- **V0**
  - Trigger
  - Multiplicity estimator



3. p_T spectra, integrated yield and $\langle p_T \rangle$



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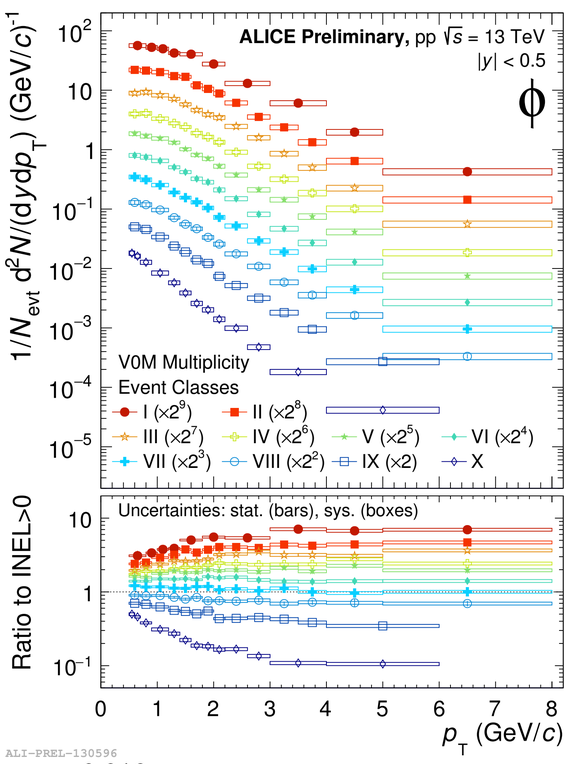

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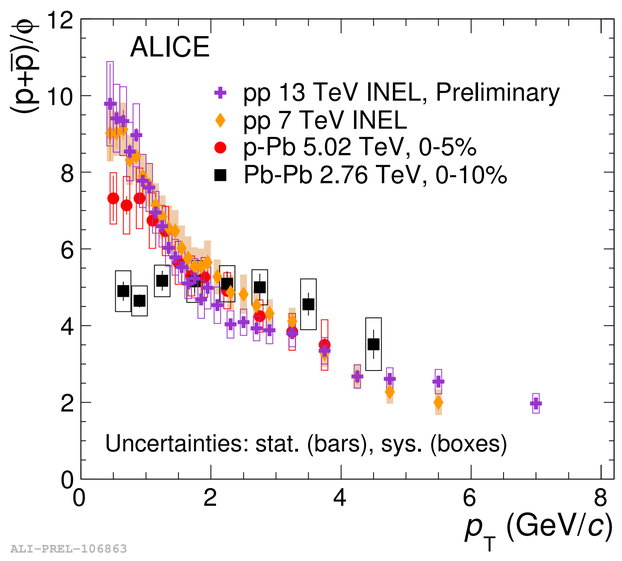
- Bulk production seems to be independent of collision energy.
- p_T spectra get harder with increasing collision energy.
- Evolution of the spectral shape with increasing multiplicity for $p_T < 5$ GeV/c.



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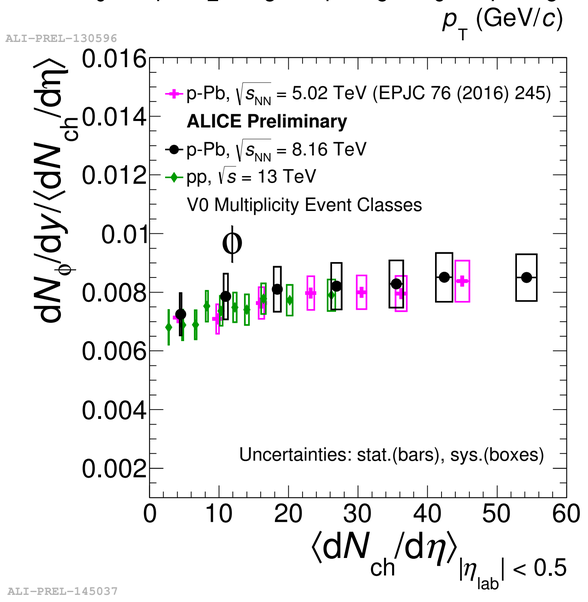

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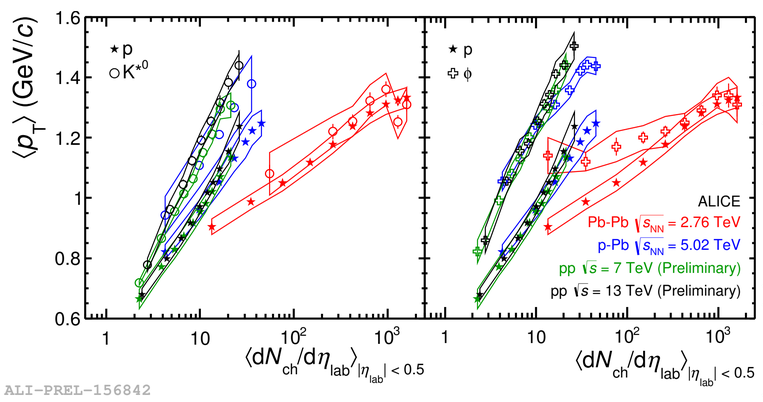
- After $p_T > 2$ GeV/c, proton and ϕ production seem to be similar for pp, p-Pb and Pb-Pb collisions.



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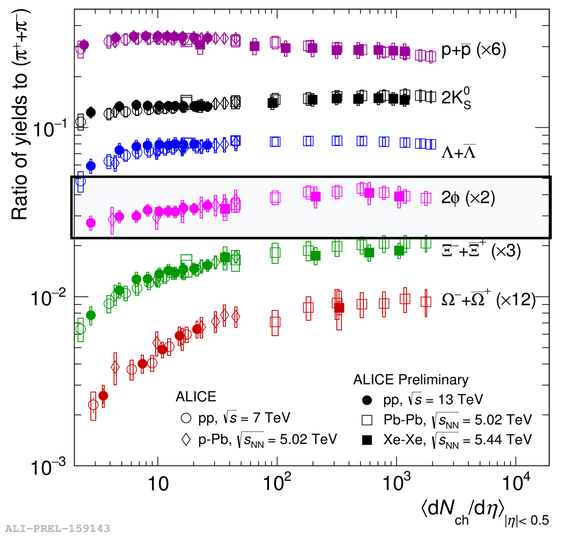
- **Event multiplicity drives** the particle production irrespective of collision energy and colliding system.
- Similar $\langle p_T \rangle$ for protons, K^{*0} and ϕ in central Pb-Pb collisions: expected from hydrodynamics as they have similar masses.
- **Mass ordering violated** for small colliding systems.
- Steeper increase of $\langle p_T \rangle$ with multiplicity in small systems.

4. Particle Ratios



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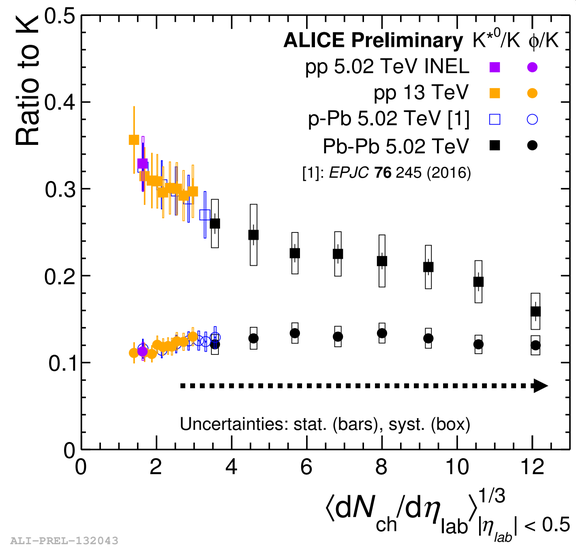

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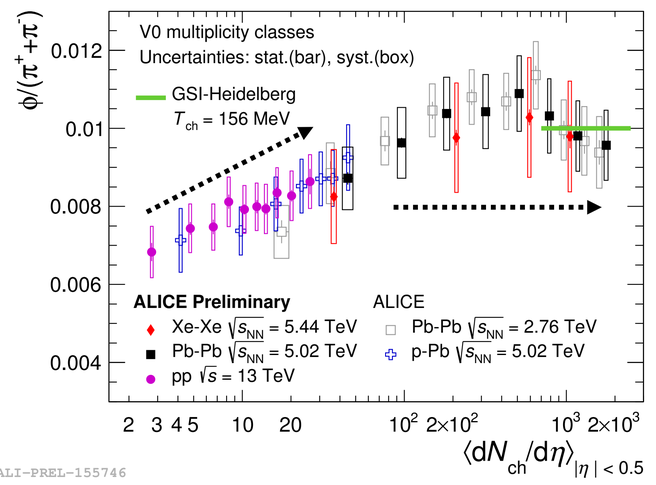

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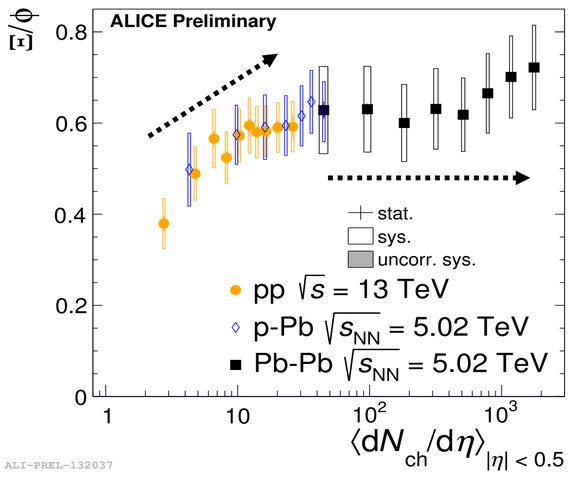

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ϕ/π (|S|=0/|S|=0)

- No sign of energy dependence for small colliding systems.
- **Large systems:** Consistent with the predictions from thermal model.
- **Small systems:** Increase with multiplicity, in contrast to the canonical suppression of strangeness.

ϕ/K (|S|=0/|S|=1)

- No sign of **re-scattering effects** on ϕ.
- Fairly **flat or slight increase** across wide multiplicity range, which hints that ϕ behaves like a particle with |S| =1 units.

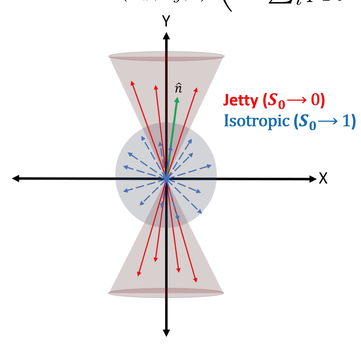
Ξ/ϕ (|S|=2/|S|=0):

- Fairly **flat or slight increase** across wide multiplicity range, indicating ϕ behaves like a particle with $|S| \approx 1$ or 2 units.
- ϕ behaving as if it has 1-2 units of open strangeness may be consistent with expectation from rope-hadronization models (e.g. DIPSY).

5. Event shape studies (Spherocity)

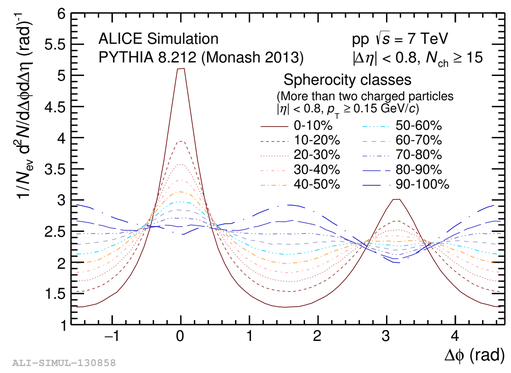
Spherocity (S_0) is defined for a unit vector $\hat{n} = (n_x, n_y, 0)$

$$S_o = \frac{\pi^2}{4} \min_{\hat{n}=(n_x,n_y,0)} \left(\frac{\sum_i |\vec{p}_{Ti} \times \hat{n}|}{\sum_i p_{Ti}} \right)^2$$



Spherocity can help to discriminate hard and soft processes.

- Jetty: back-to-back structure, indication of hard QCD
- Isotropic: enhanced UE, soft QCD



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Currently measurements of resonances as function of spherocity is ongoing. Stay tuned!

6. Summary

- ALICE has measured ϕ in different collision energies and colliding systems.
- For small systems, event multiplicity drives the particle production irrespective of collision energies and colliding systems.
- No sign of re-scattering effects on ϕ.
- ϕ behaves like a particle with strangeness $\approx$ 1 or 2 units.

7. References

1. B. Abelev et al., Eur. Phys. J. C72, 2183 (2012).
2. J. Adam et al., Phys. Rev. C95, 064606 (2017).
3. J. Adam et al., Eur. Phys. J. C76, 245 (2016).

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