New insights into strange-quark hadronization measuring multiple (multi-)strange hadron production in small collision systems with ALICE

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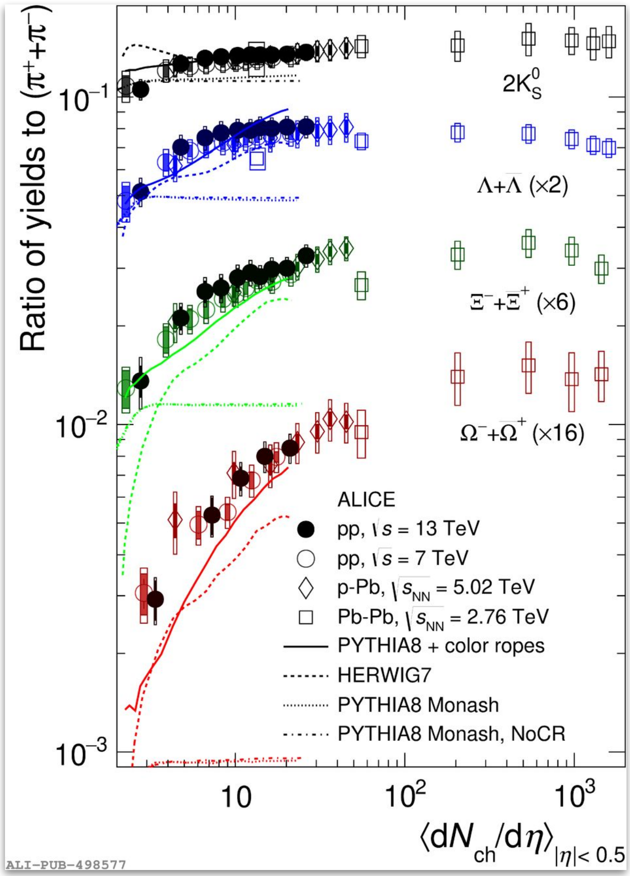
3-7 June

1. Università degli Studi di Torino

2. INFN Torino

Strangeness Enhancement: [1,2]

- S/π increases as a function of multiplicity identically across different energies and collision systems.
- Enhancement proportional to the strangeness content in the hadron



ALICE Coll., Eur. Phys. J. C 80 (2020) 2, 167

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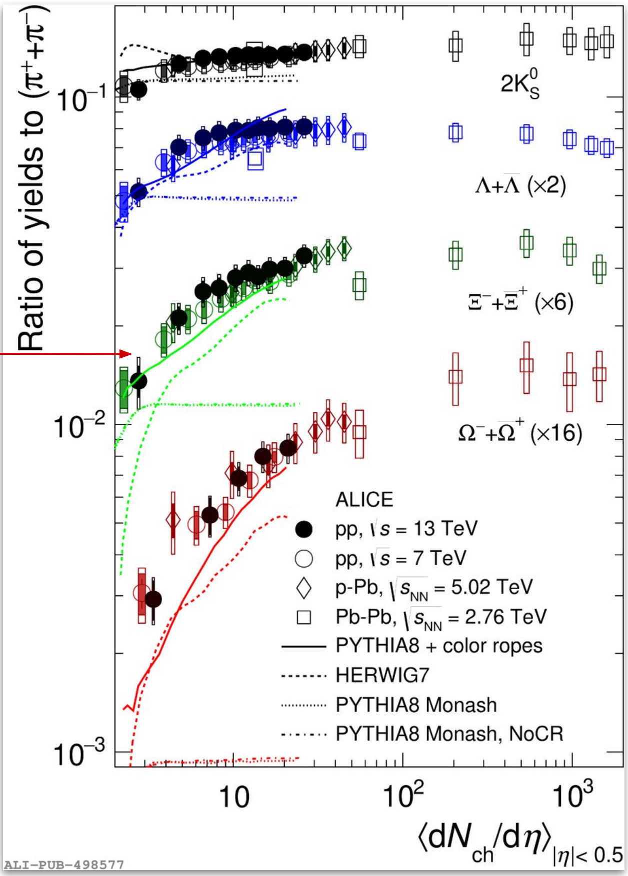
Published results: **average value of production rate**

$$\frac{<N_{\Xi}>}{<N_{\pi}>}$$



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For the first time:

- Strange particle multiplicity distribution $P(n_S)$ for K^0_S, Λ, Ξ, Ω
  - extend beyond the average of the distribution
  - new test bench for production mechanisms, probing events with a large imbalance between strange and non-strange content
  - powerful tool for MC tuning

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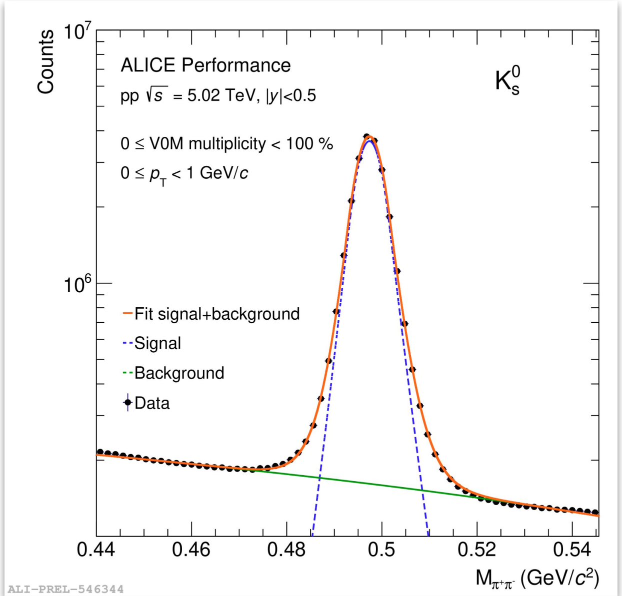
Analysis based on counting the number of strange particles event-by-event in pp collisions at $\sqrt{s}$ = 5.02 TeV



Each candidate weighted by P(sig) or P(bkg) estimated by 1D invariant mass fit in p_T/multiplicity bins

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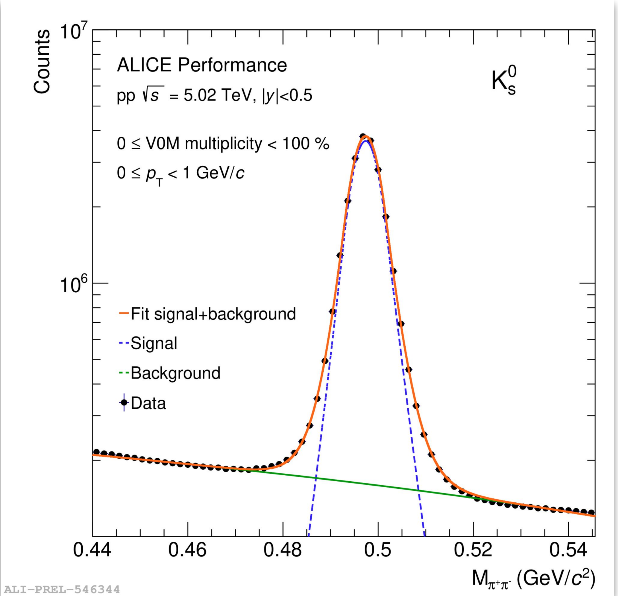

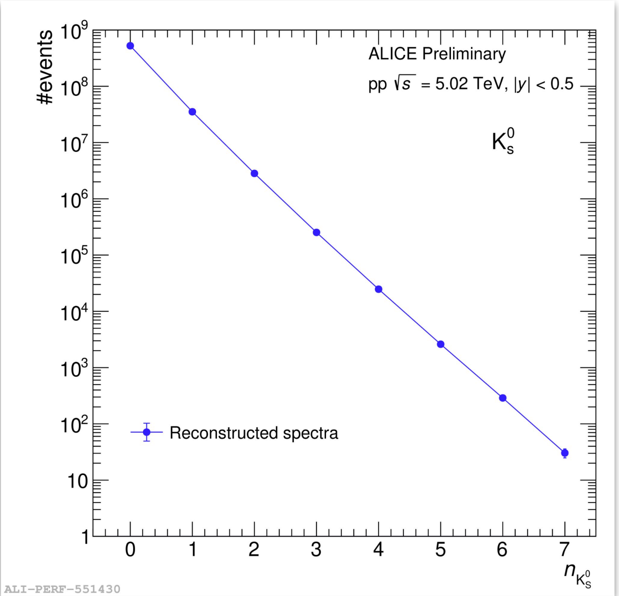

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Weights associated to each of the N candidates combined to obtain: P(all-sig), … , P(all-bkg)

For each event: full probability spectrum spanning from 0 to N

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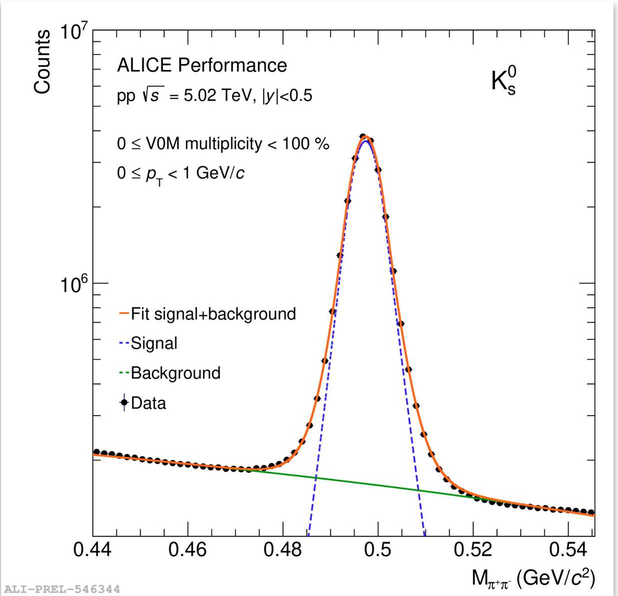

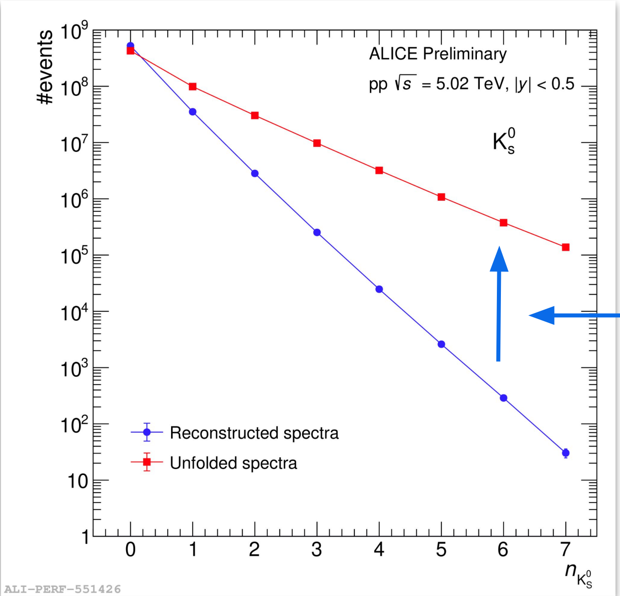

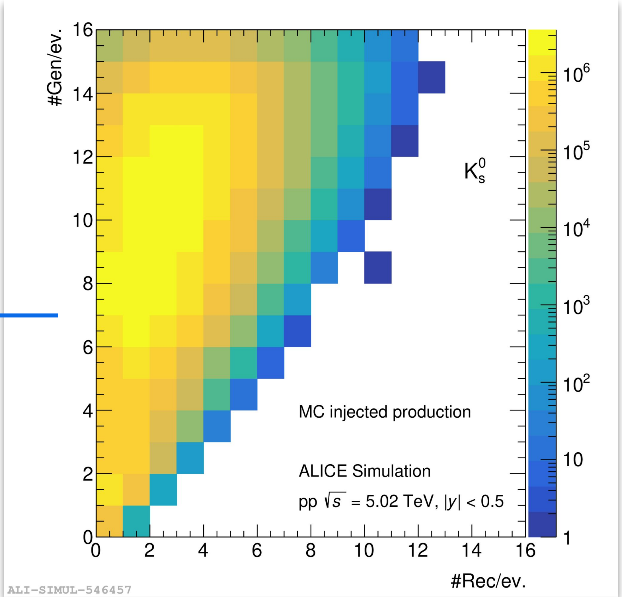

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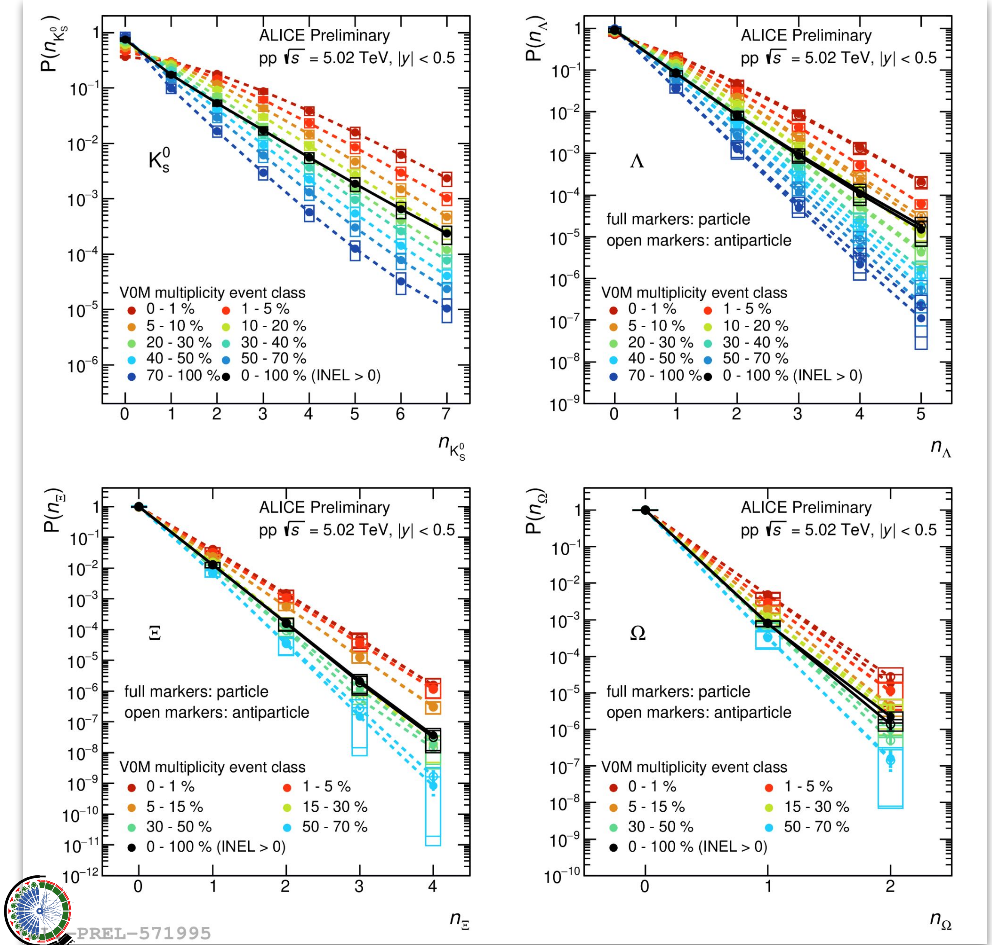
Correction for detector response (MC production featuring realistic p_T distribution)

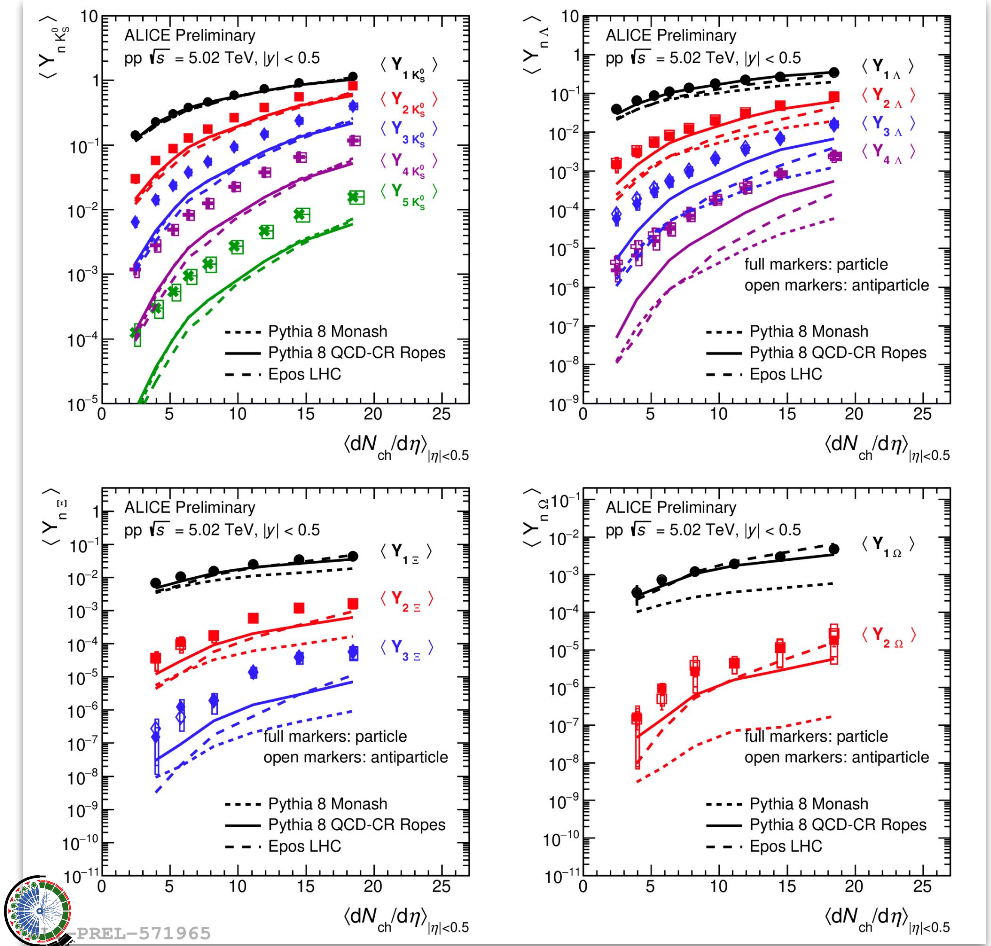
Bayesian unfolding procedure applied



Probability to produce *n* particles of a given species per event $P(n_S)$

- As expected at the LHC energies, a good agreement between particle and anti-particle was obtained from the highest to the lowest multiplicity class
- Spanning across large ranges of strange/multiplicity variations, all the way to very "extreme" situations (e.g. 7 K^0_S at low average charged-particle multiplicity, 0 K^0_S at high average charged-particle multiplicity)

Unique opportunity to test the connection between average charged and strange particle production



Average production yield of 1, 2, 3, ... particles/event:

$$< Y_{k-part} >= \sum_{n=k}^{\infty} \frac{n!}{k!(n-k)!} P(n)$$

- The increase with multiplicity of the probability for multiple strange hadrons is more than linear
- NOTE: very good agreement between $<Y_{1\text{-part}}>$ and previous results ([1,2])
- Model comparison:
  - K^0_S: no difference between Pythia 8 Monash and Pythia 8 QCD-CR Ropes
  - for baryons: Pythia 8 QCD-CR Ropes approaches the data at high multiplicity; Epos LHC does a rather good job at high multiplicity, but shows larger discrepancy at low multiplicity

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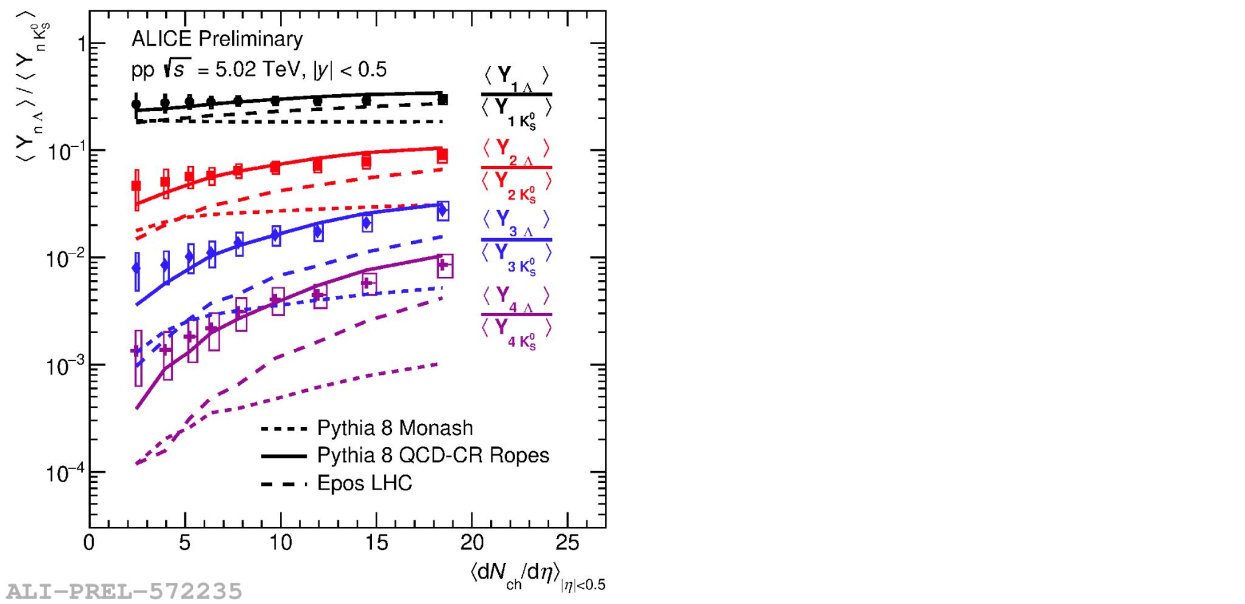
Yield ratios with ΔS = 0

$n\Lambda/nK^0_S$ - important to factor-out non strangeness related contribution

- Increase of Λ/K^0_S vs multiplicity when looking at multiple production!
- Is it baryon enhancement?



Yield ratios with $\Delta S = 0$

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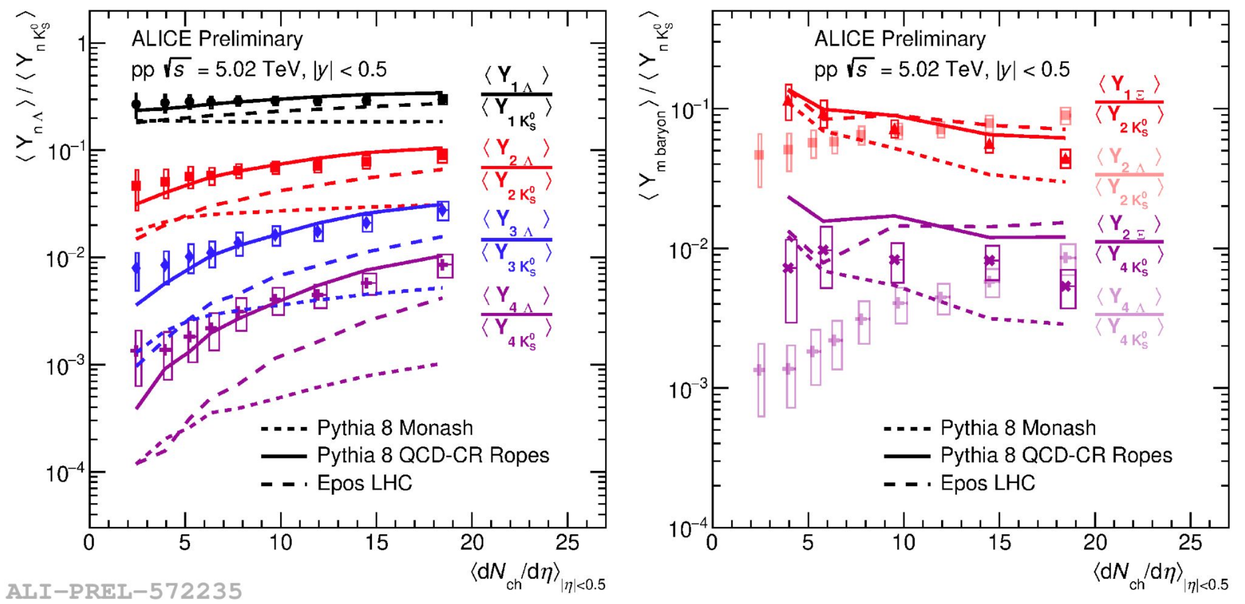

m baryons/nK^0_S - testing hadron production at fixed S and with different light quark content

- larger number of light quarks involved in the denominator → decreasing trend
  - High multiplicity: it is simpler to pair s-quarks with light quarks (very abundant)
  - Low multiplicity: the shortage of light quarks enhances the probability of multi-strange baryon formation

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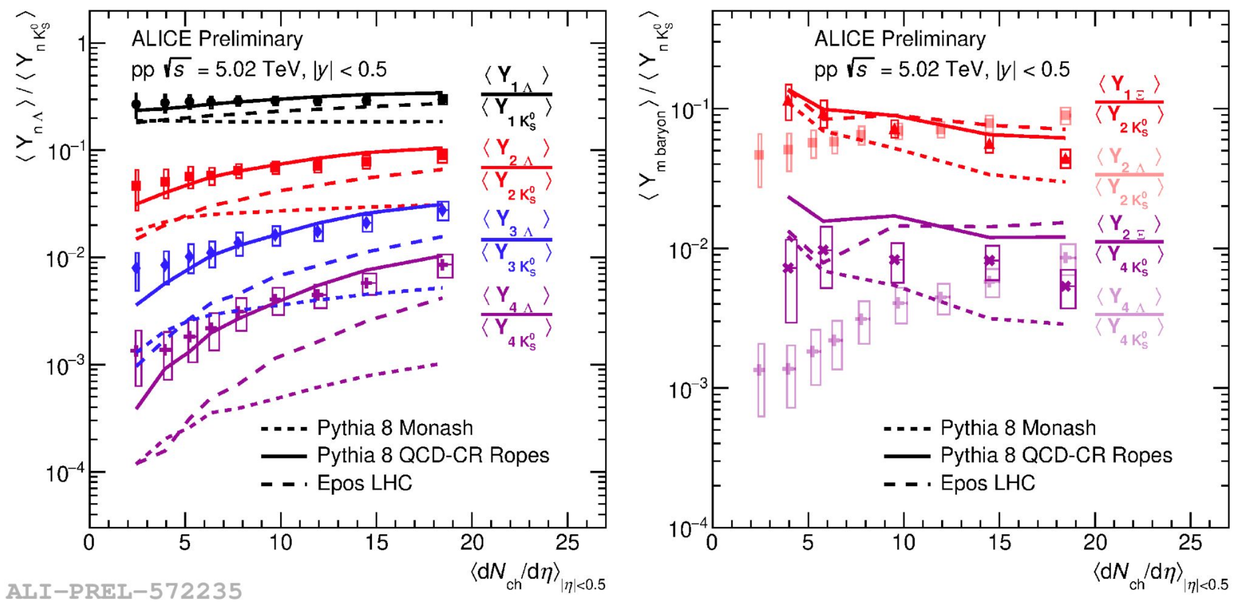
Model comparison:
All trends are rather well reproduced by Pythia 8 QCD-CR Ropes
→ strange quark production rate remains a puzzle, but once S is created the model of re-connection with light quarks catches the trends observed in the data

Would partonic coalescence be a viable approach here?



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Summary and Outlook

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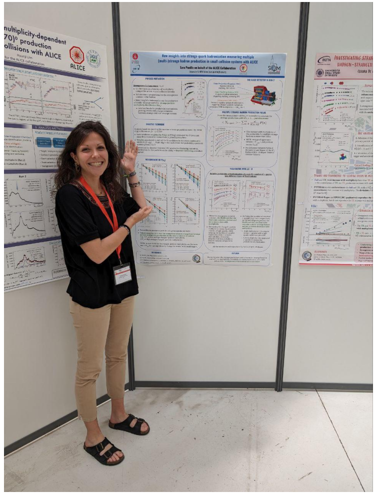
SQM poster

- First measurements of (multi-)strange particle multiplicity distribution
  - perfect benchmark to test production models in events spanning between extreme unbalances between of charged and strange particle multiplicity
  - it is a relevant extension of the traditional yield determination, as it tests at a higher order the strange hadron production mechanism

- Multiple strange hadron production yields ratio with $\Delta S = 0$:
  - 2-, 3-, 4- Λ/K^0_S yield ratios increase with multiplicity (baryon-related effect)
  - m multi-strange baryons/n K^0_S decrease with multiplicity → decreasing the charged-particle multiplicity means depleting the number of light quarks, while keeping the number of s quarks fixed in the event



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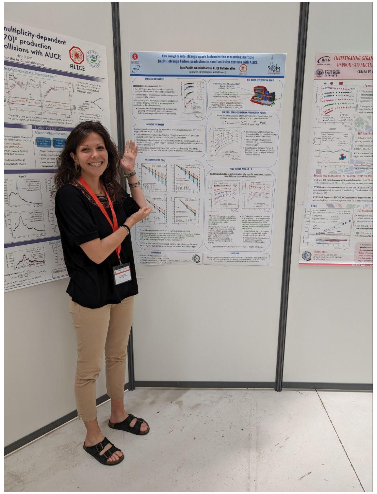

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Outlook:

- Ratios between the average production yield of m multi-strange baryons and n K^0_S vs multiplicity, for which ΔS moves from 2 to 5, are under preparation: strangeness enhancement at its extremes!
- Extension of the study to other colliding systems (e.g. Pb–Pb)
    - test the collision system invariance with multiplets of particles
    - test the trends up to extreme multiplicities and verify the relative importance of baryon/strangeness in a light-quark rich environment

Poster session award - SQM 2024