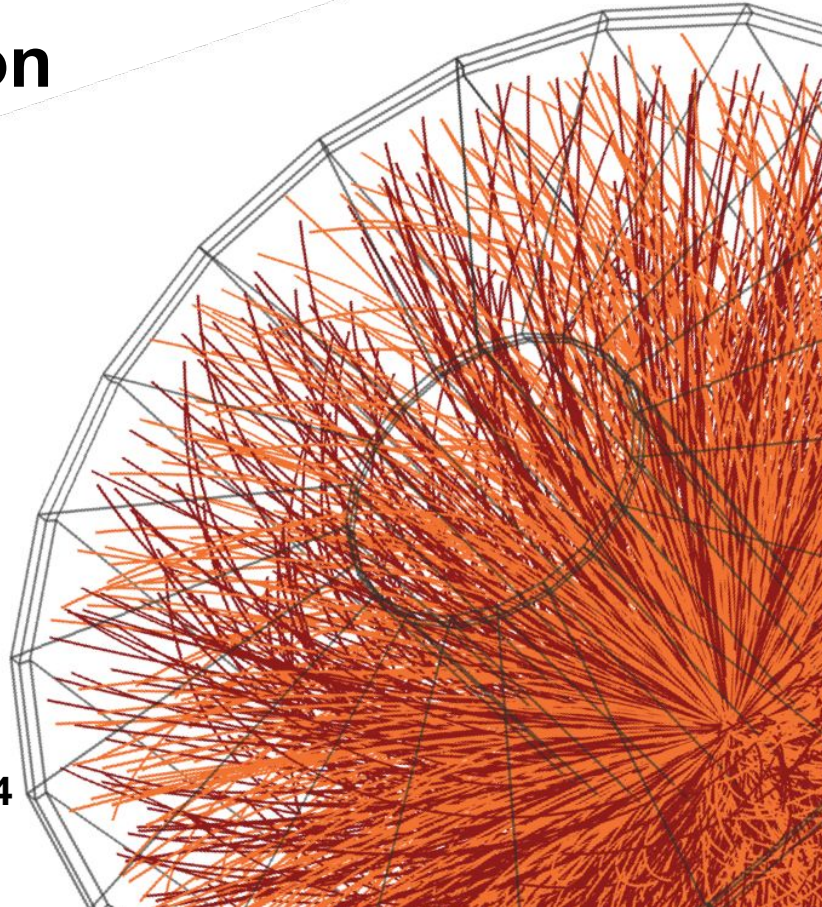
Light-flavour particle production as a function of transverse spherocity with ALICE

Adrian Nassirpour

Sejong University



Erice - International School for Subnuclear Physics 2024
17 June 2024

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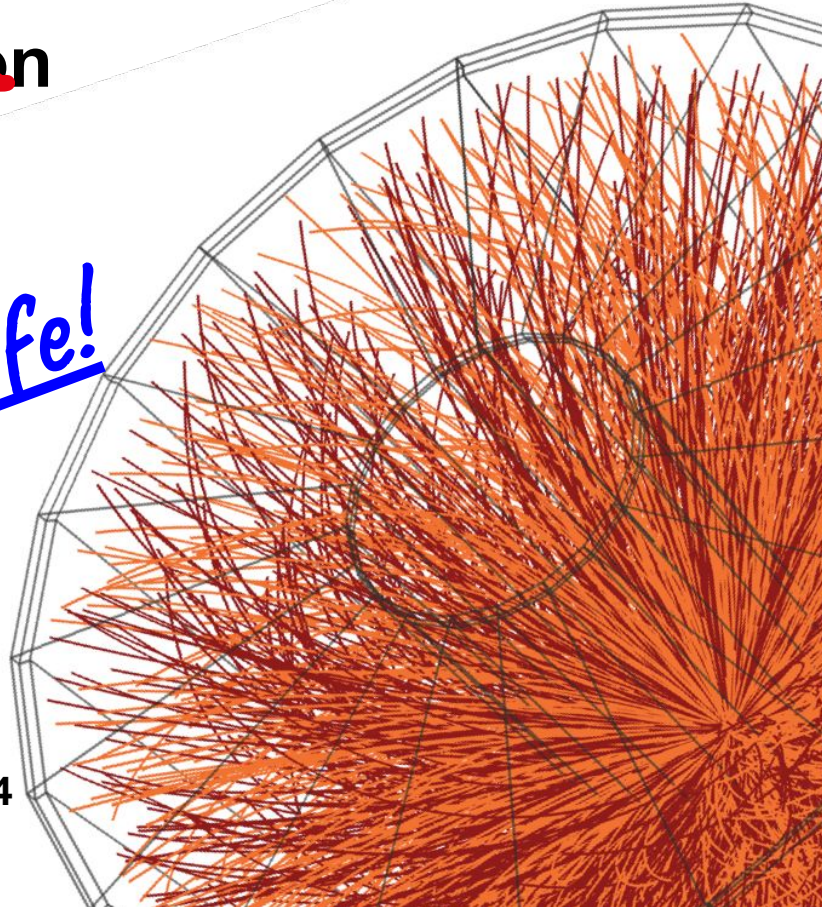
Heavy Ions 4 Life!



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  - QCD in vacuum - Confinement
    - QCD field lines modelled as strings
    - Cornell di-quark potential: $V(r) = -\frac{a}{r} + \sigma r$
    - Potential QCD transition: Non-perturbative in nature
      $T = 200\ \mathrm{MeV} \rightarrow E = 3k_B T = 600\ \mathrm{MeV} \approx 3\Lambda_{\mathrm{QCD}}$

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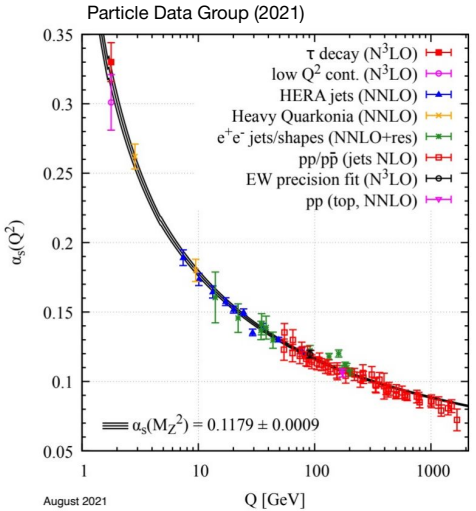

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  - QCD in quark-matter - Deconfinement
    - In Heavy-Ion collisions, we believe that the initial color fields undergo different stages
    - High Temp./Pressure possibly creating a strongly interacting medium of deconfined quarks and gluons
      - The **QGP!**
    - At higher temperature, the di-quark potential is screened (Debye screening)
    - Behaves like almost perfect liquid!

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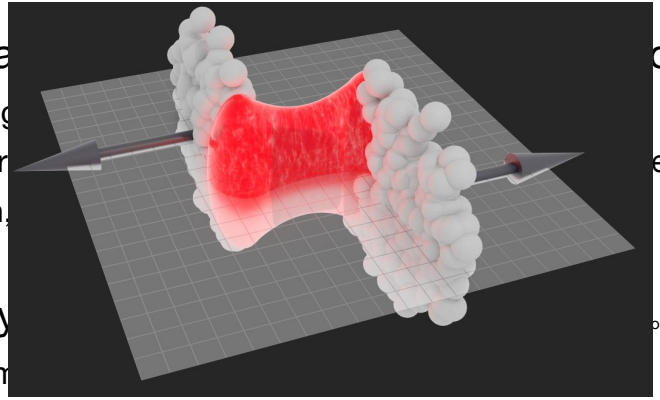

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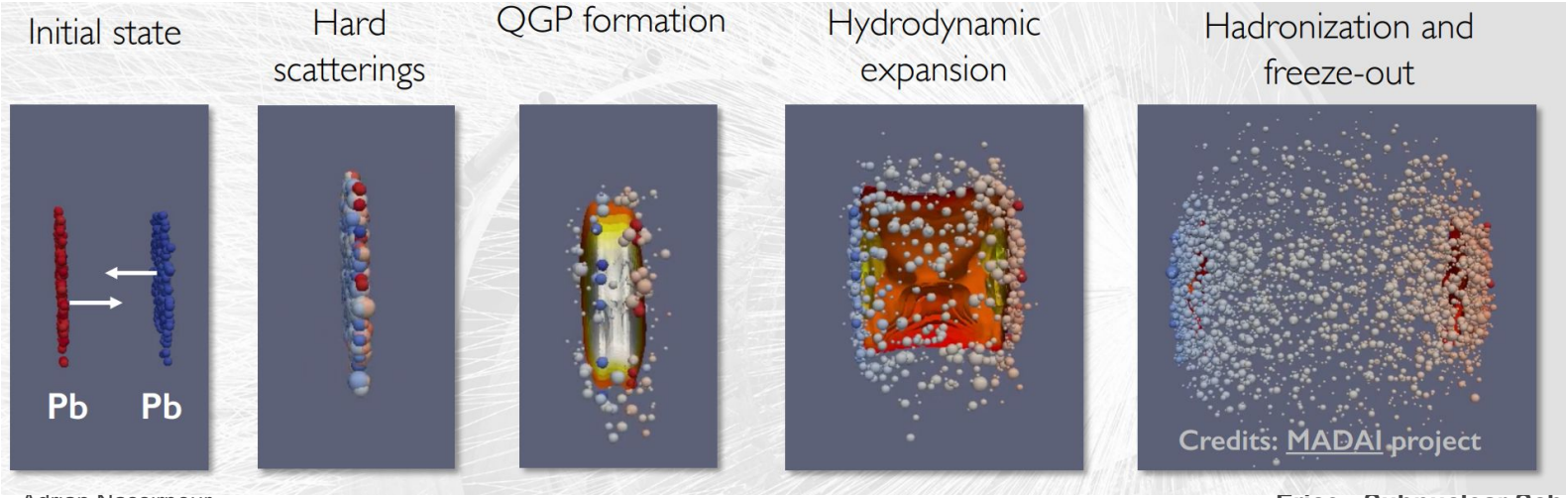

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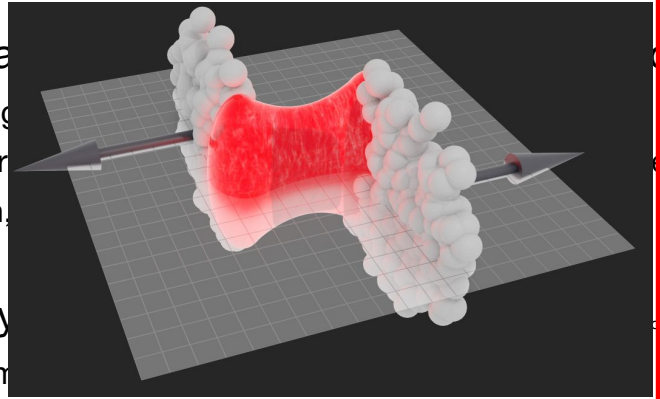
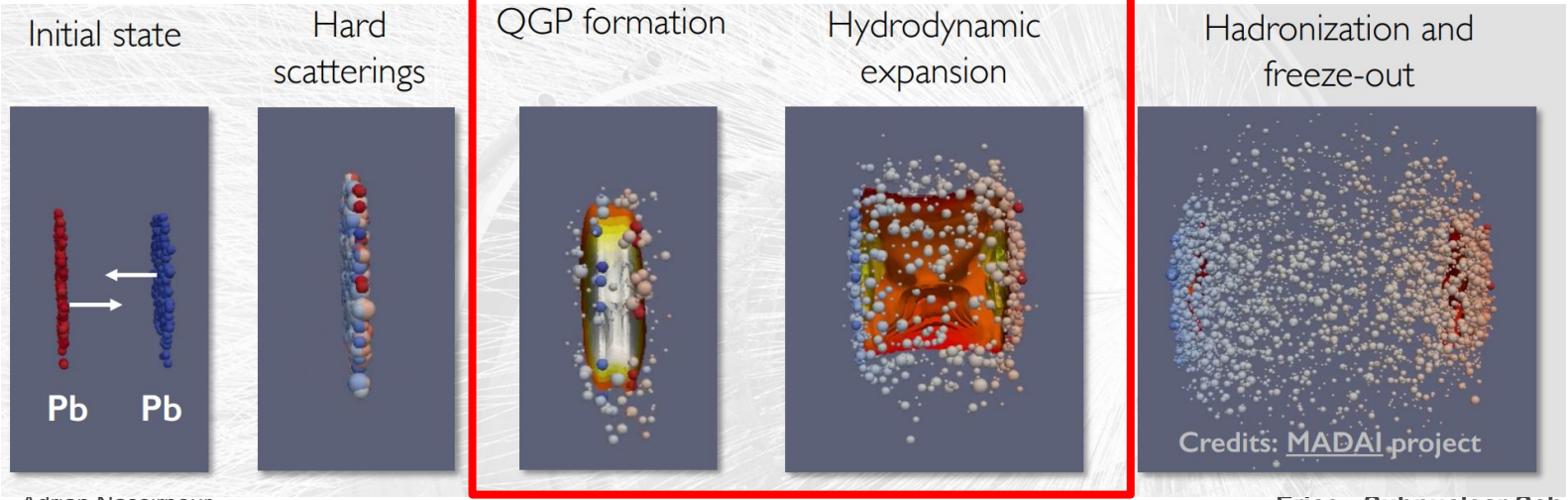


How do we measure this????



Introduction - Strangeness Enhancement

- One of the first suggested observables:

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  - Thermal production of strange quarks: $T_{\mathrm{QGP}} \approx \mathrm{M}_s$

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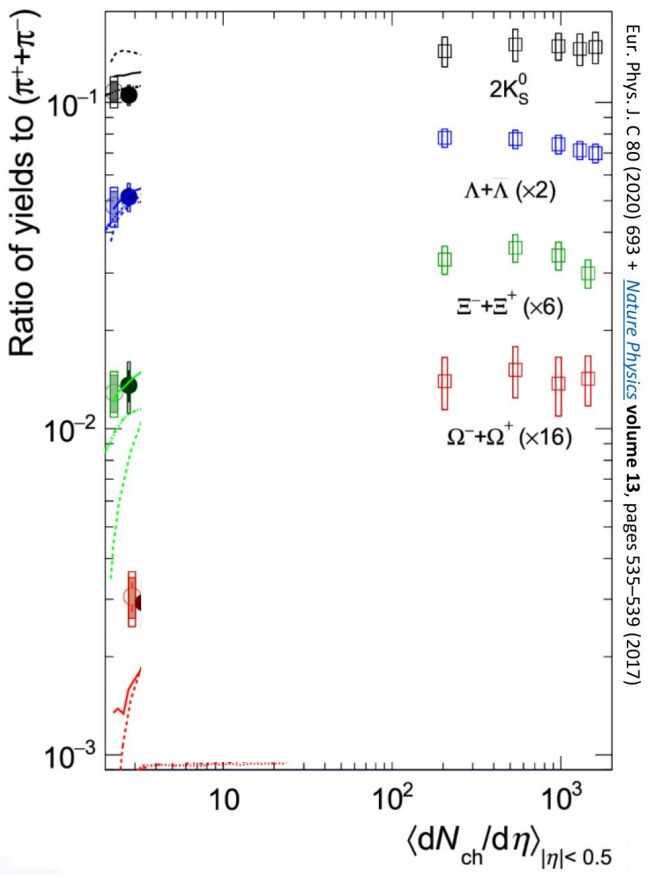

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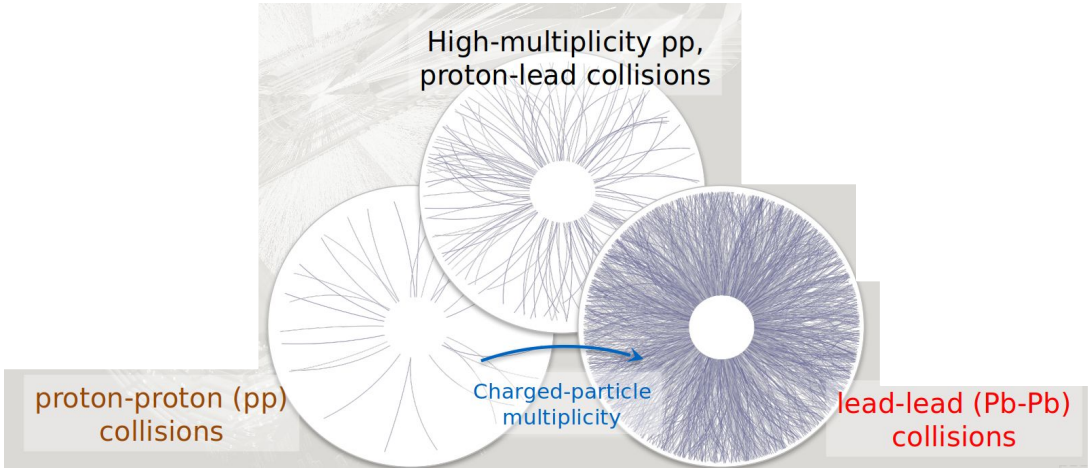
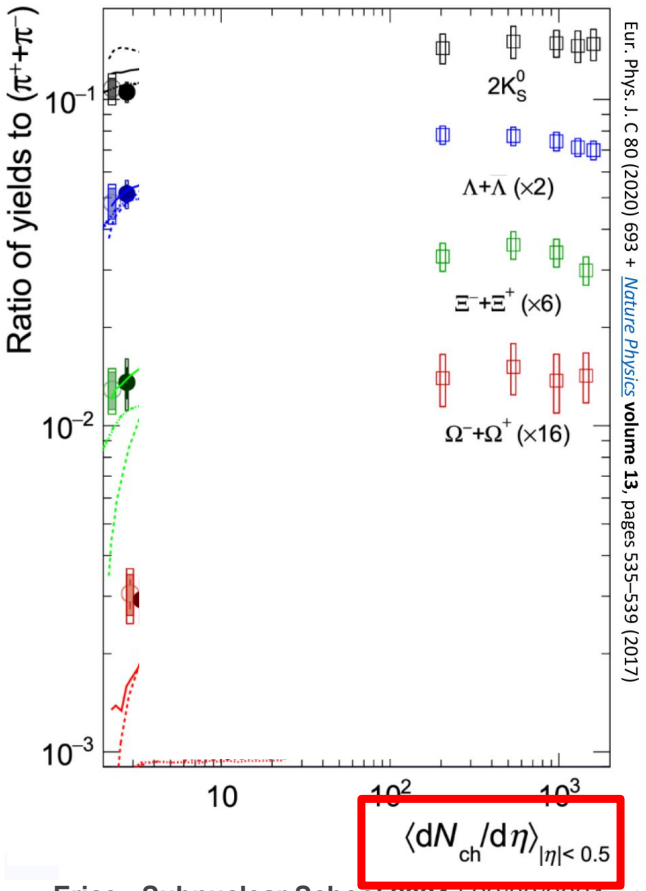


shamelessly stolen from D.D.Chinellato



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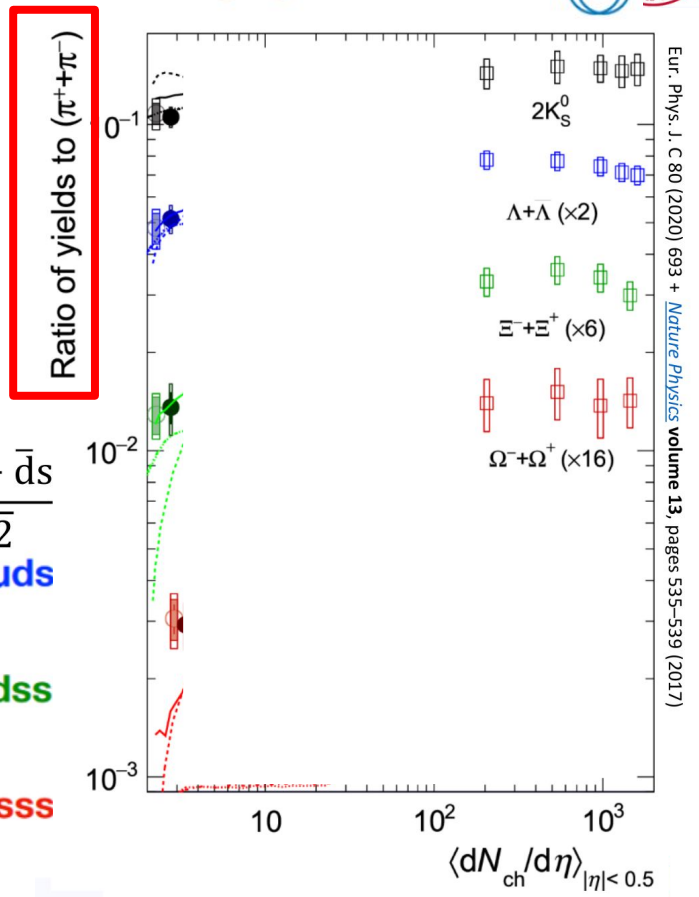

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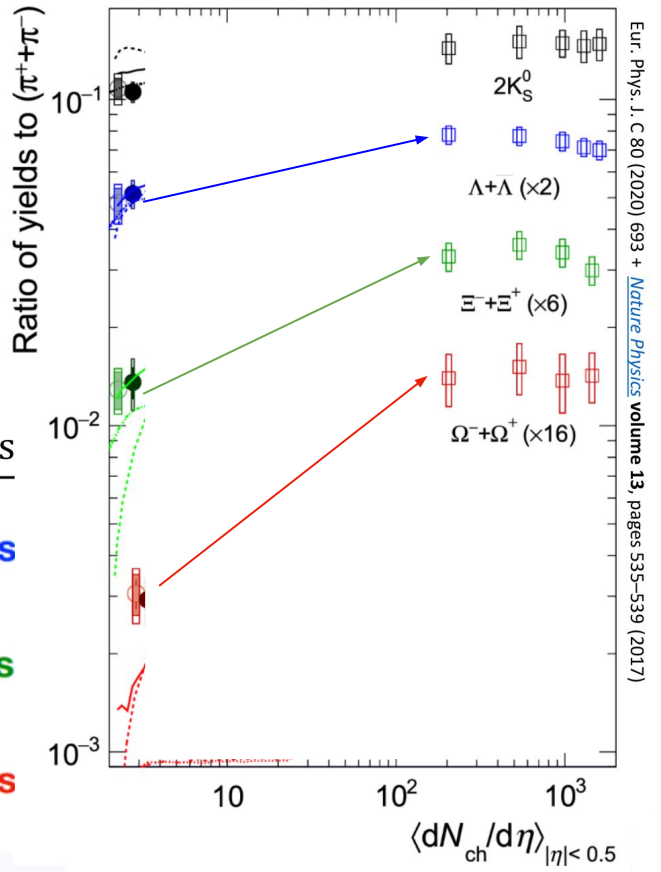

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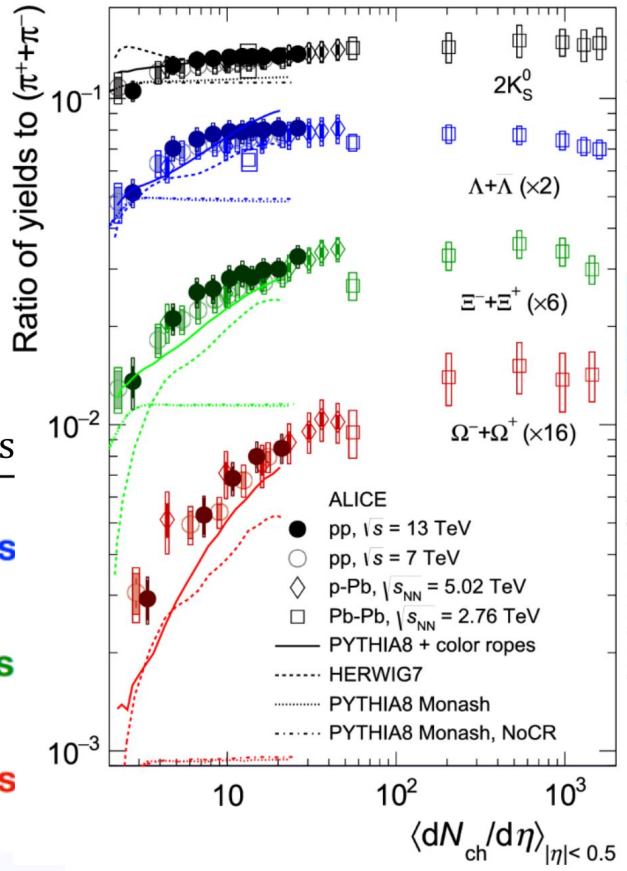

Eur. Phys. J. C 80 (2020) 693 + *Nature Physics* **volume 13**, pages 535–539 (2017)

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$$\mathrm{K}^0_{\mathrm{s}} = \frac{\mathrm{d}\bar{\mathrm{s}} + \bar{\mathrm{d}}\mathrm{s}}{\sqrt{2}}$$

- The main faction of enhancement

  occurs in high-multiplicity pp collisions

  - QGP in pp???!! QCD inspired

    models struggle to match data
  - This might be a signature of something else, and not QGP?

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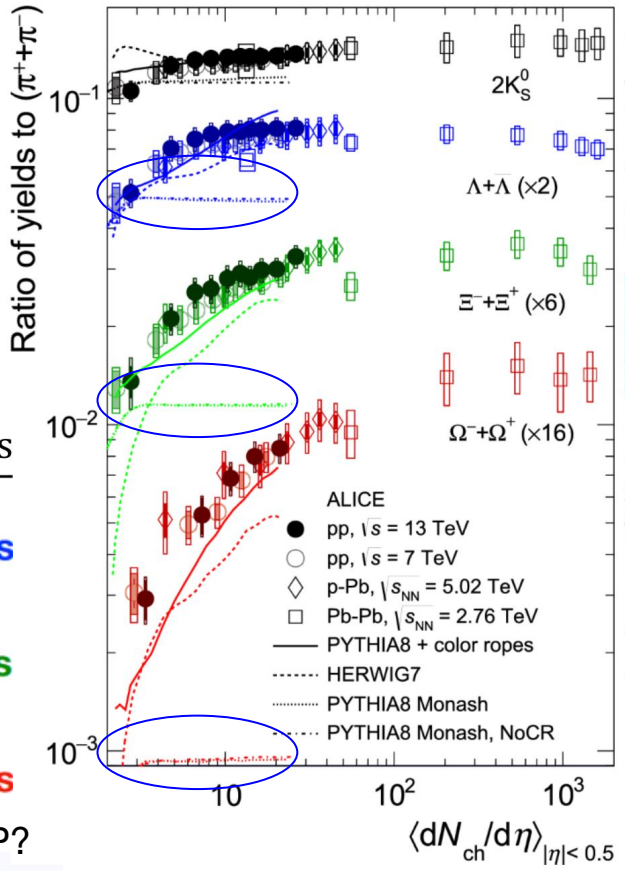

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Introduction - Transverse Spherocity $S_O^{p_T=1}$

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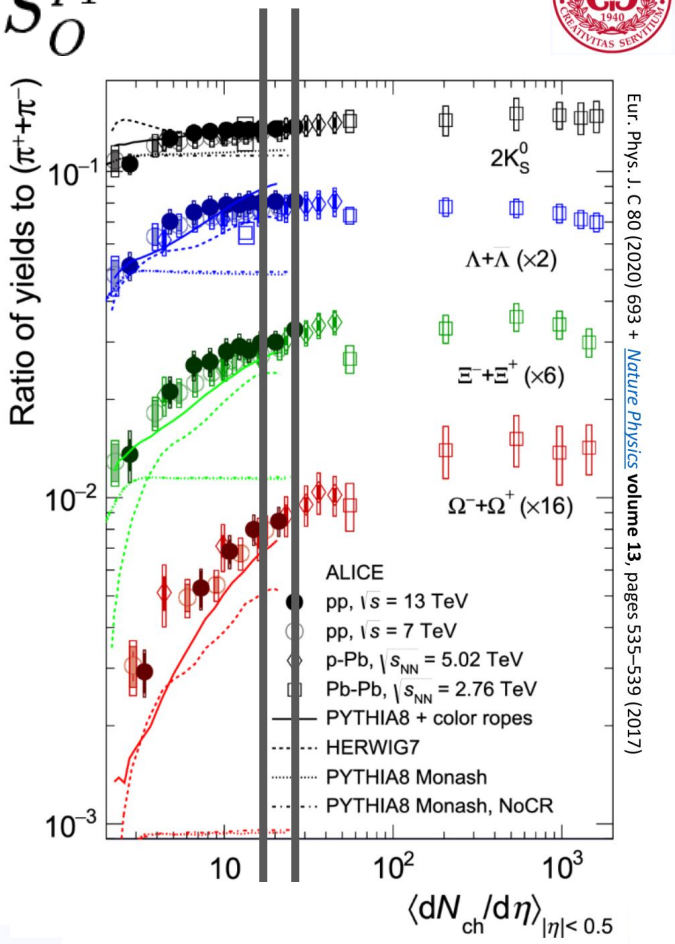
  - Idea: Classify top-1 % high-mult. pp events based on azimuthal event topology!



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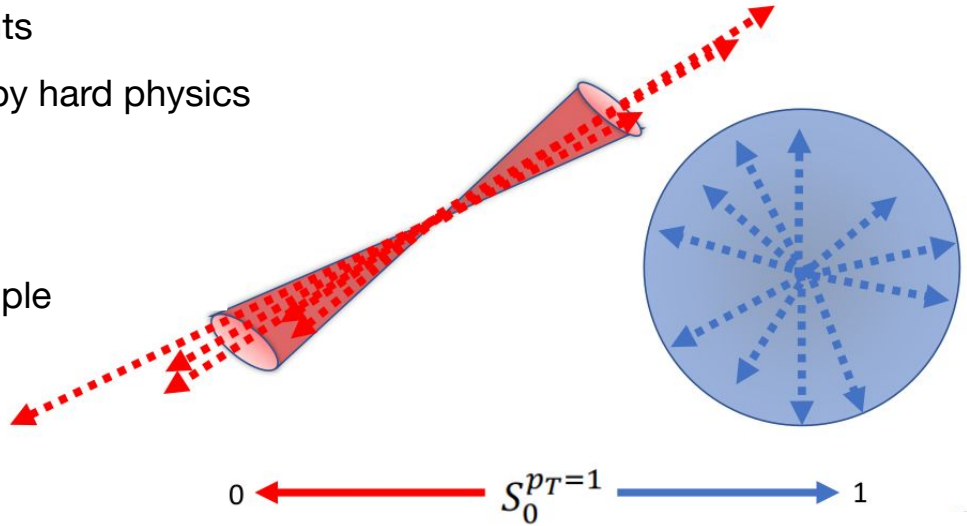

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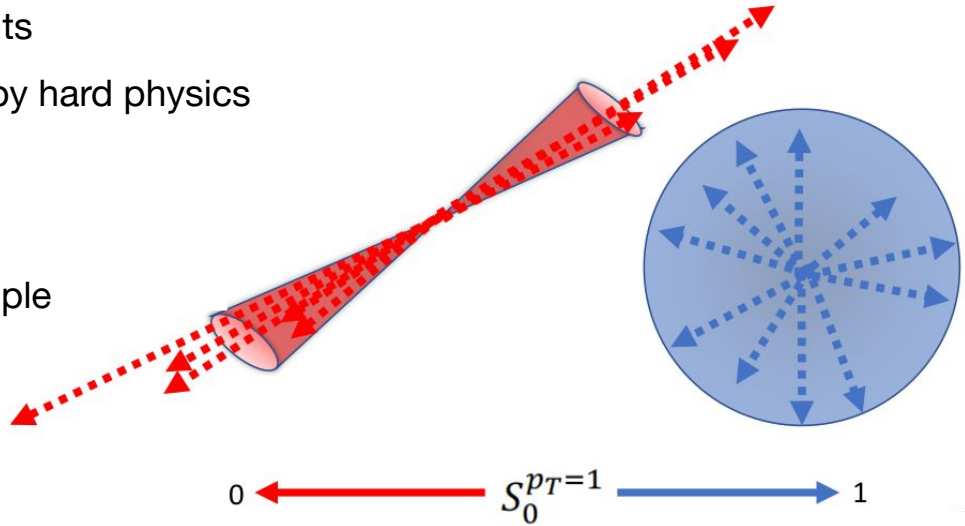

Newly published ALICE paper:
https://doi.org/10.1007/JHEP05(2024)184

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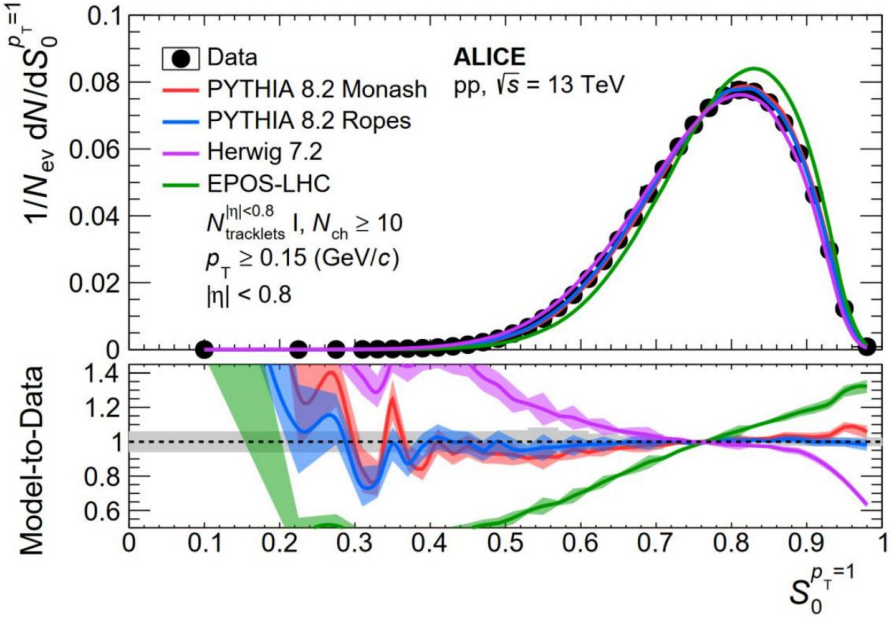

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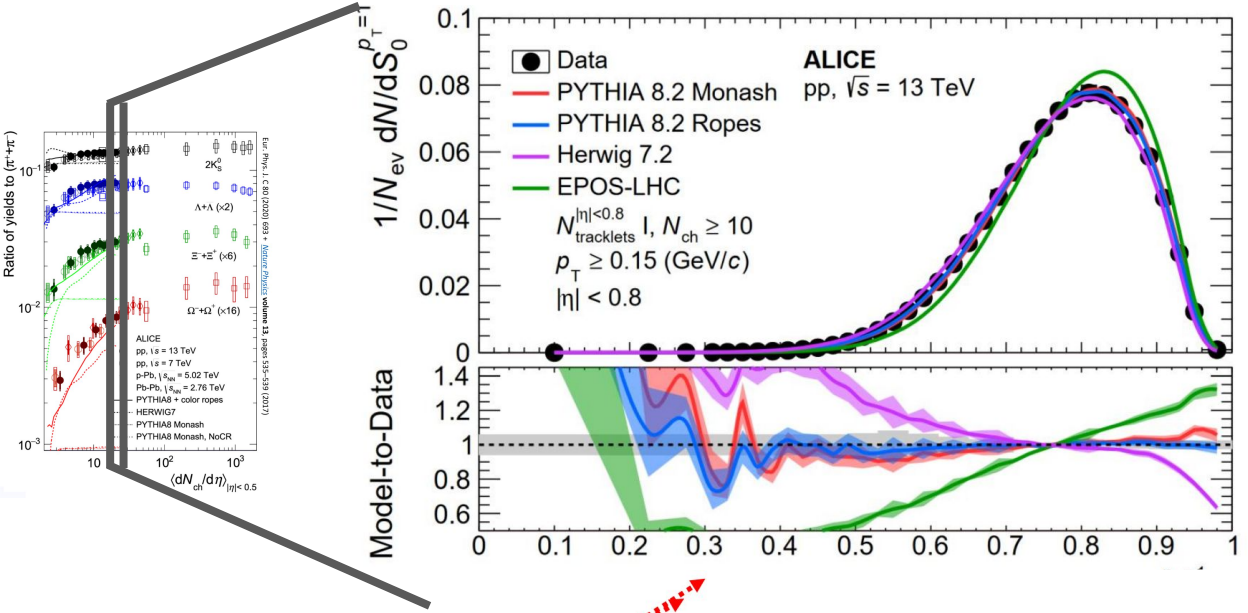

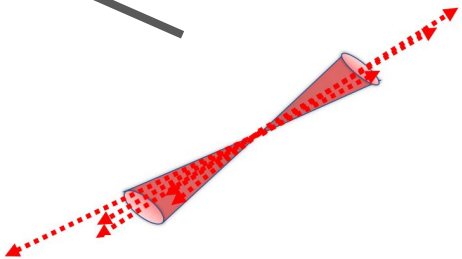

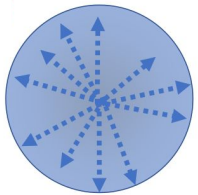

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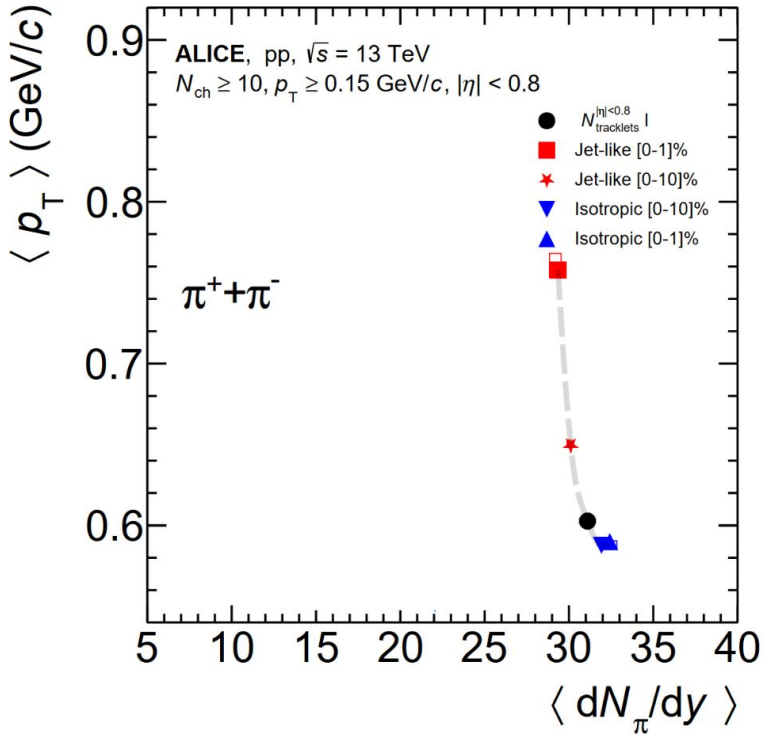

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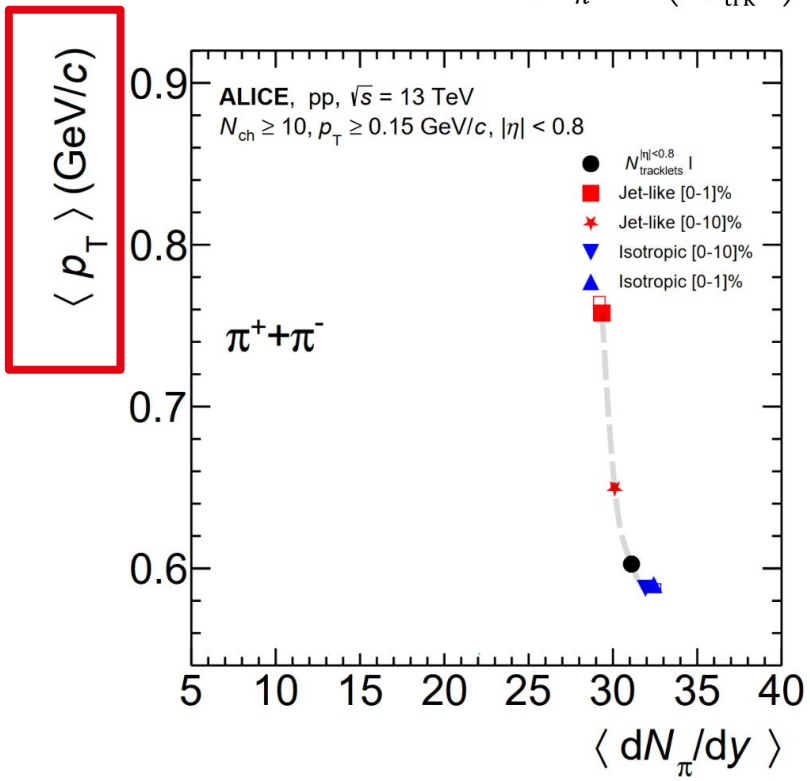

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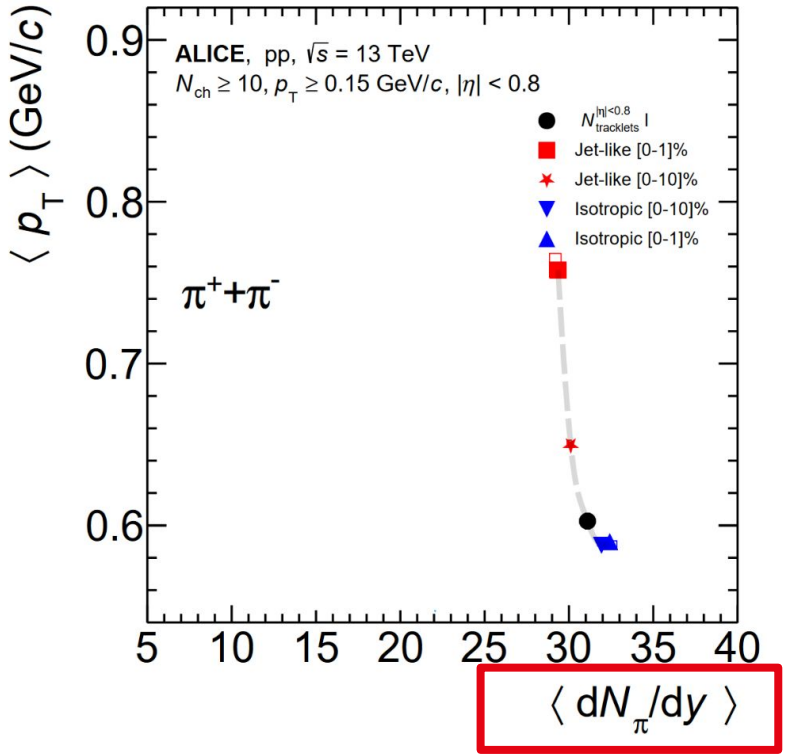

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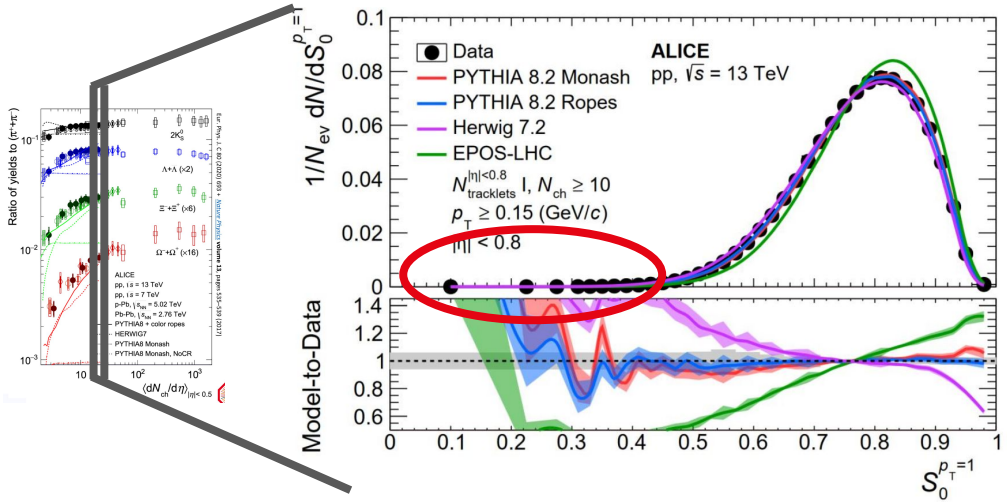

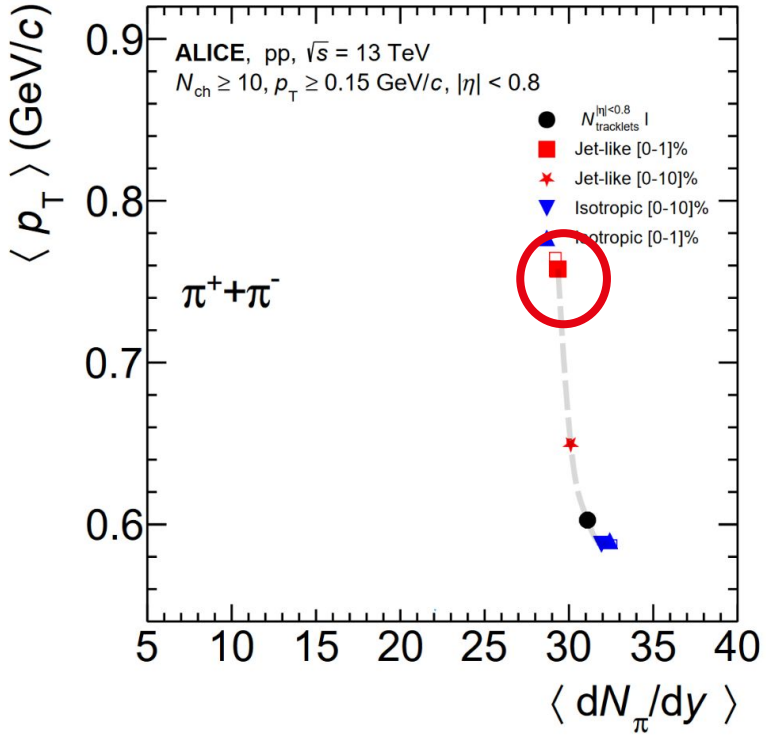

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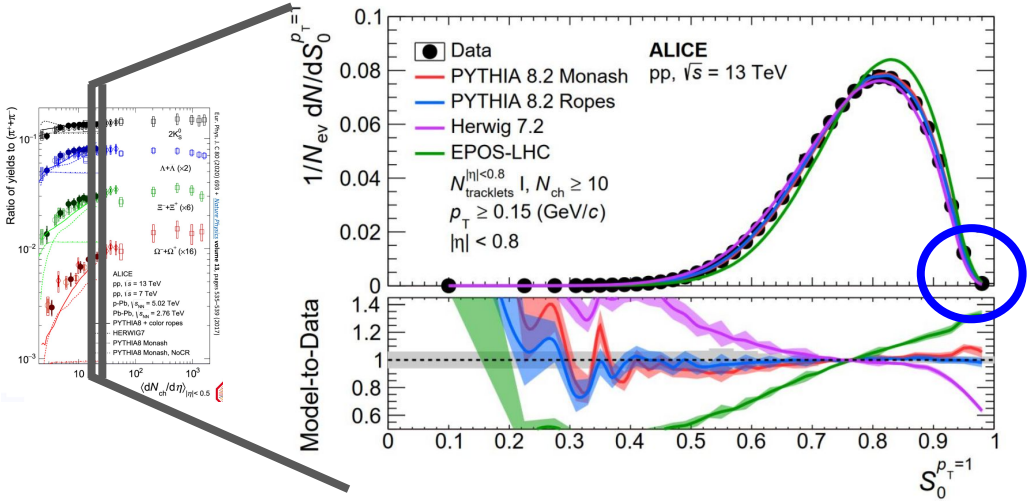

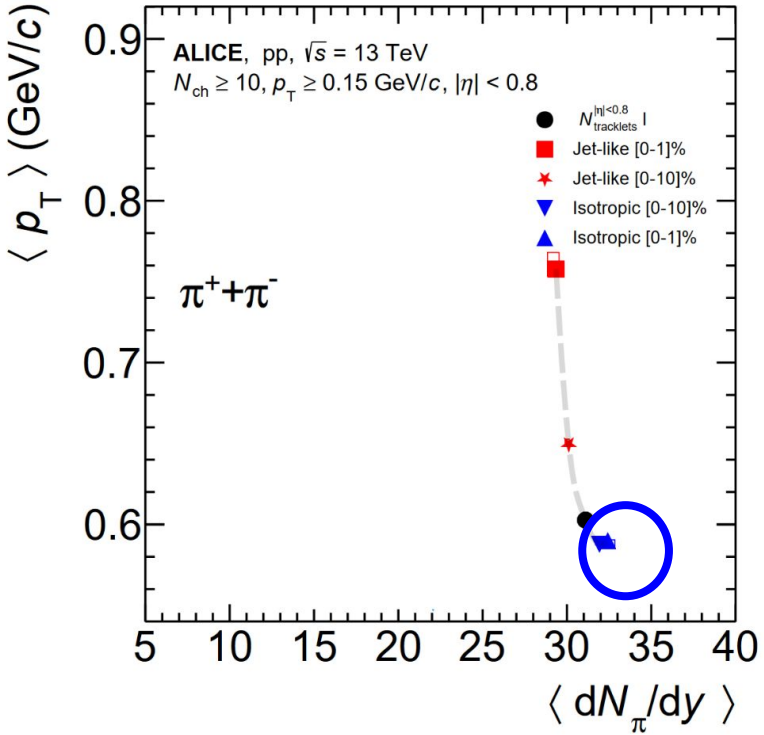

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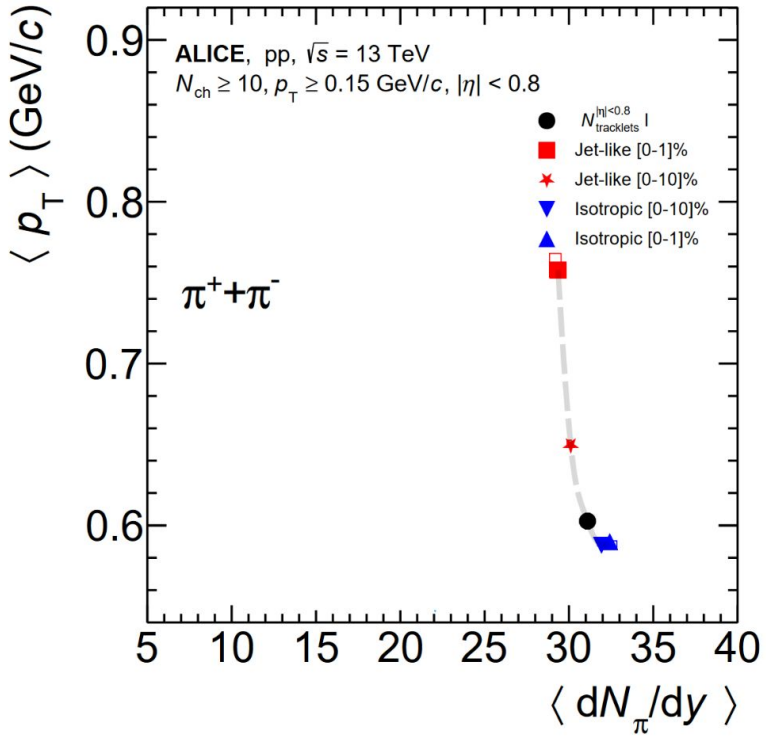

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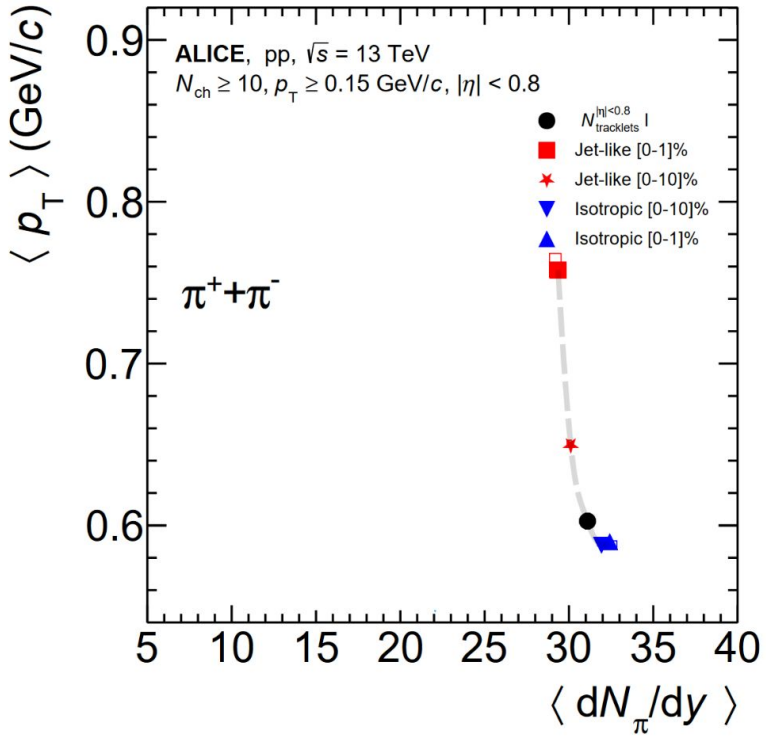
- Our jet-like selection really is able to capture hard structures, while the isotropic selection is not trivially isotropic

- These are the exact two paradigms we wish to contrast!



Results - $S_O^{p_T=1}$ integrated particle ratios

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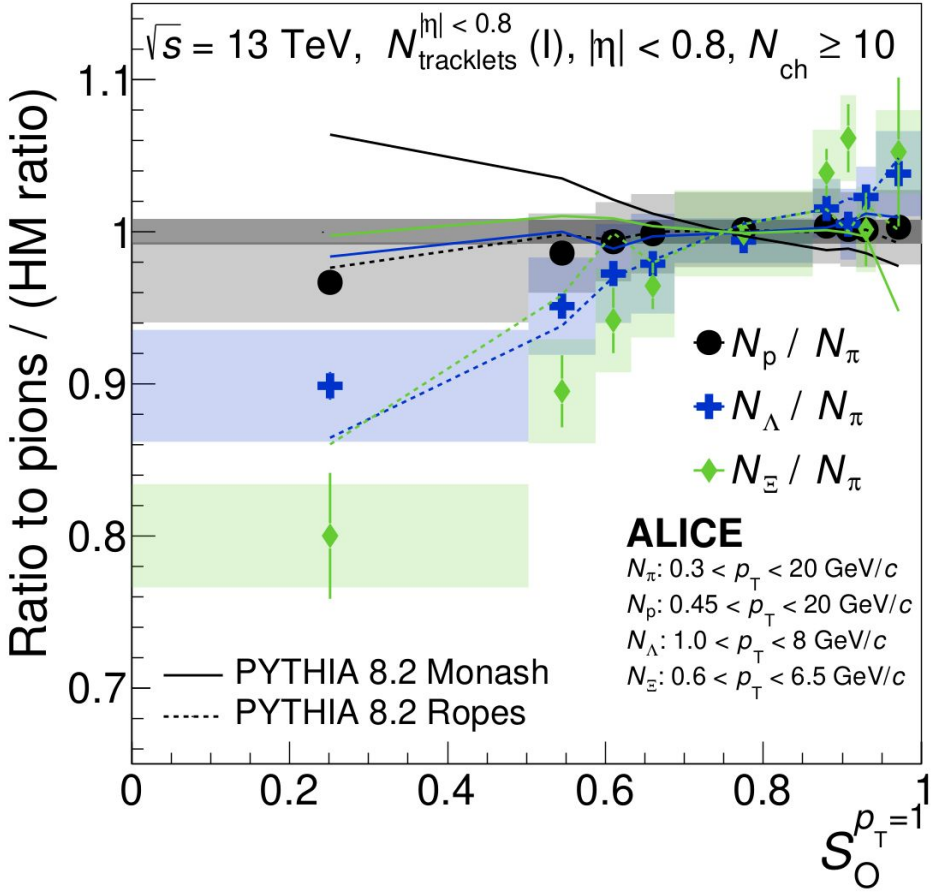

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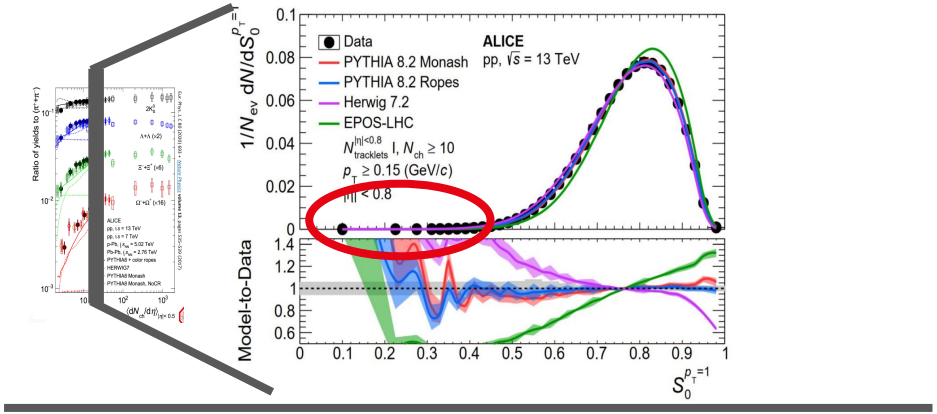
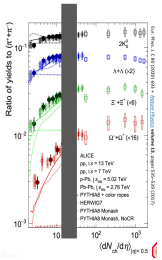
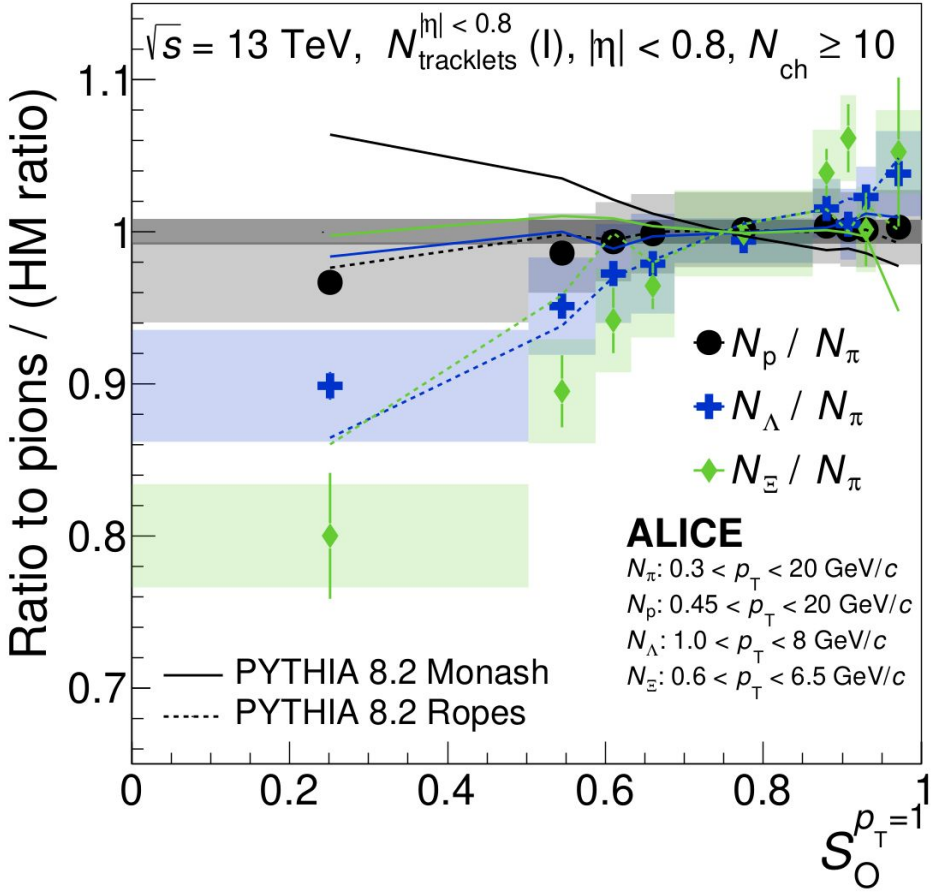
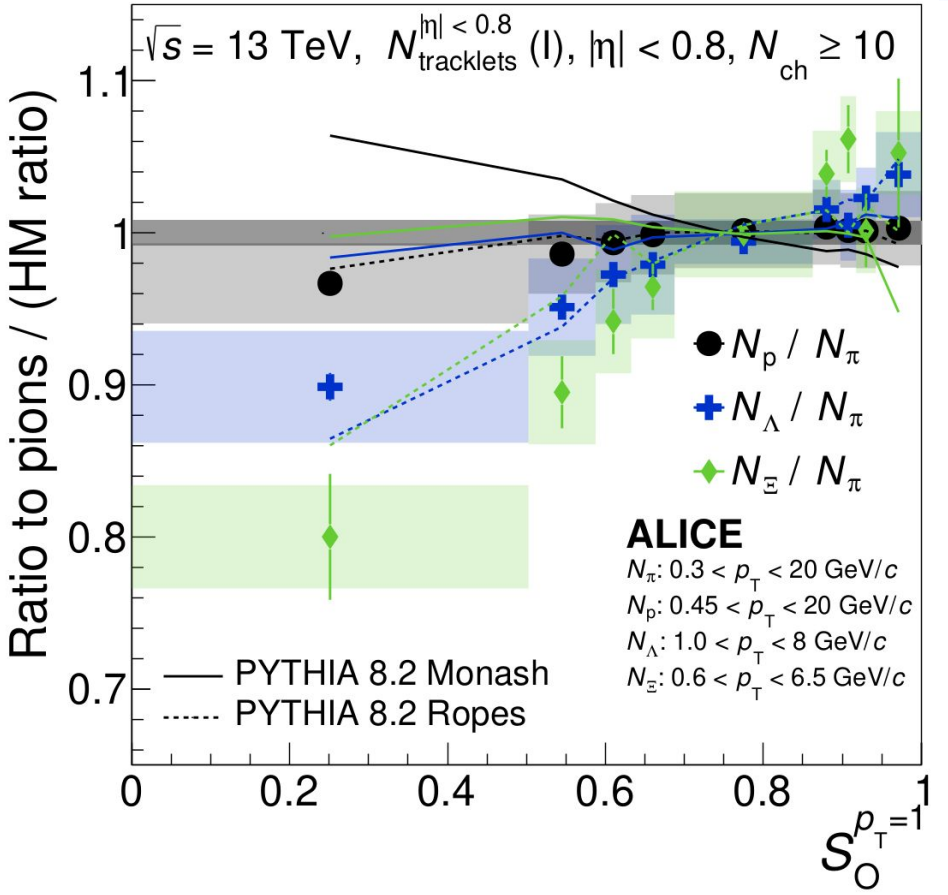






Results - $S_O^{p_T=1}$ integrated particle ratios

- Significant suppression of yields in jet-like events
  - Proton largely unmodified
  - Approximately 20% effect for Xi
  - Strength of suppression is ordered in strangeness
  - MC generators struggle to match data



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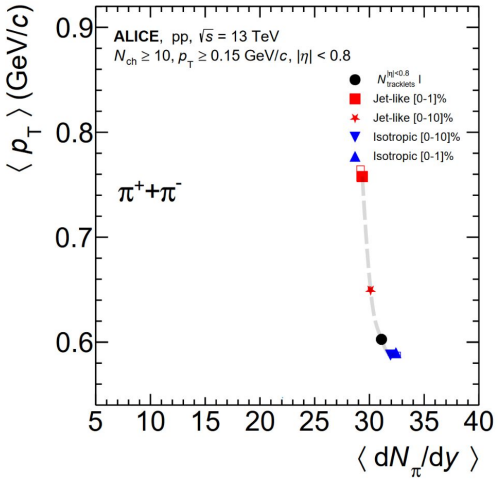
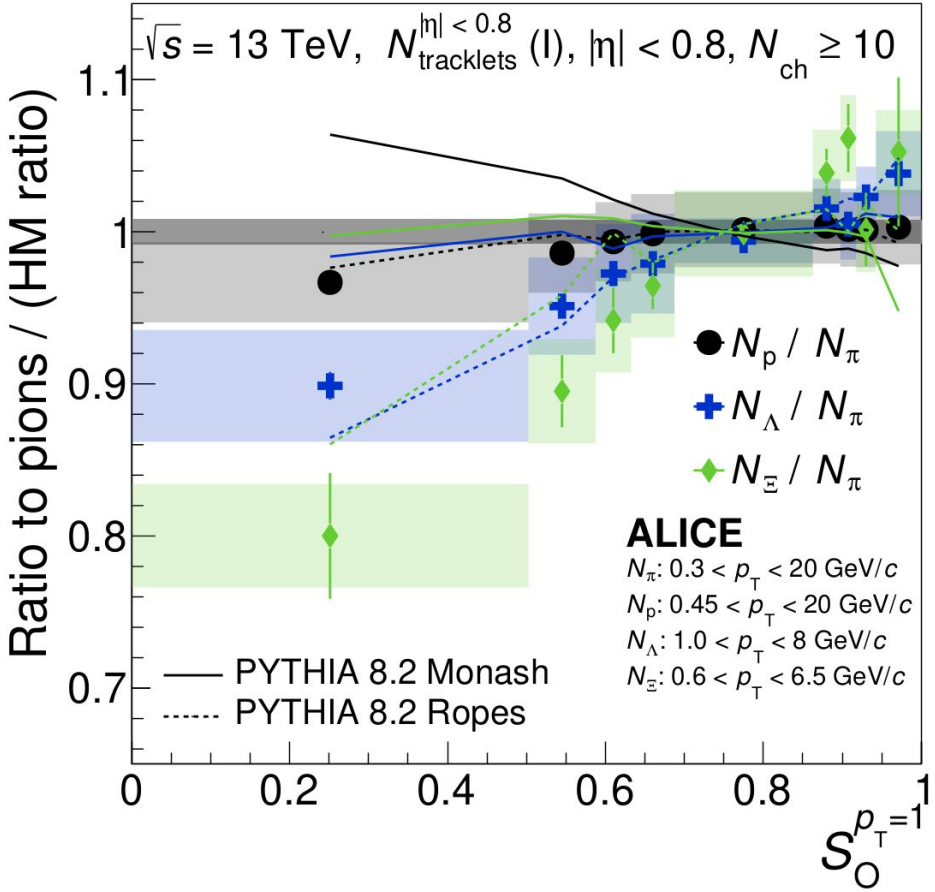


- Reminder, multiplicity

  is constrained at roughly 10%!!



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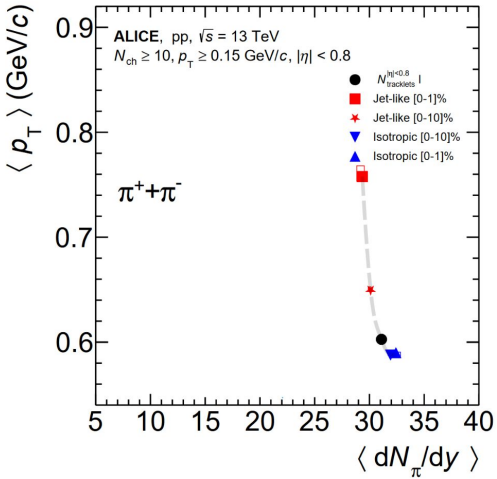

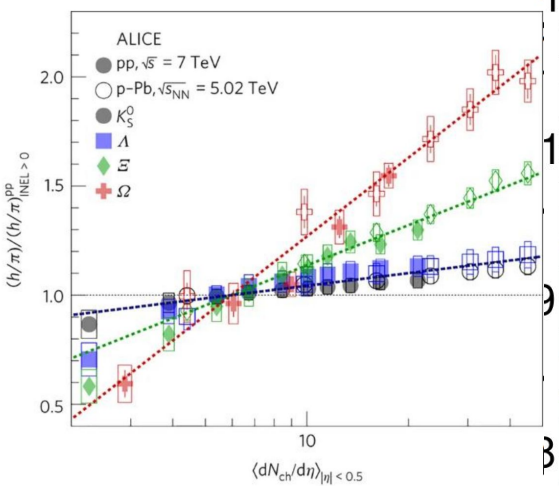

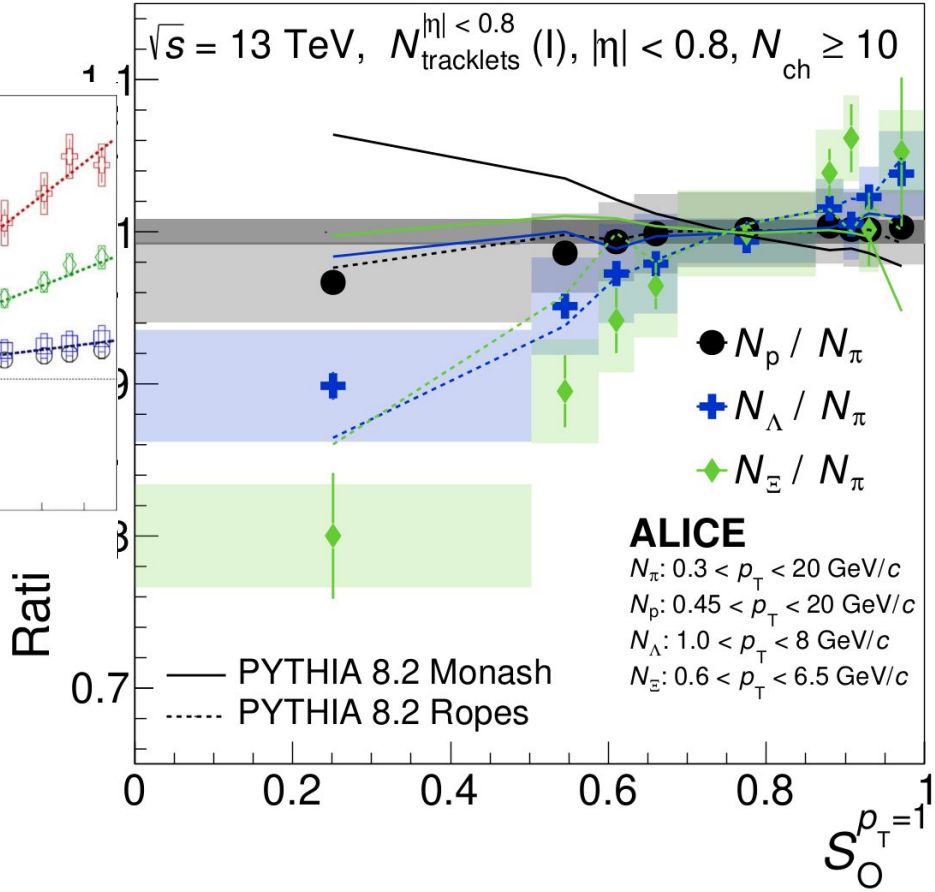

- Reminder, multiplicity is constrained at roughly 10%!!
  - Equivalent suppression by $\langle \mathrm{d}N/\mathrm{d}\eta \rangle$ alone require a 200-300% shift in multiplicity!

Results - $S_O^{p_T=1}$ integrated particle ratios

```
if(time < 120)
 goto summary;
else
 continue;
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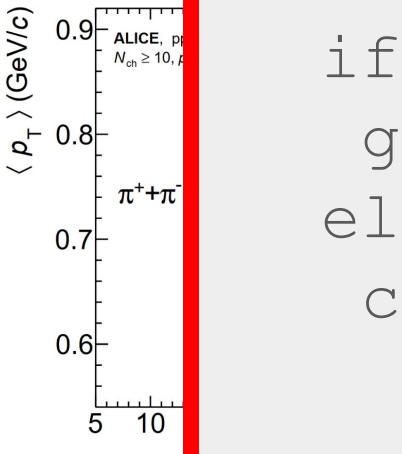

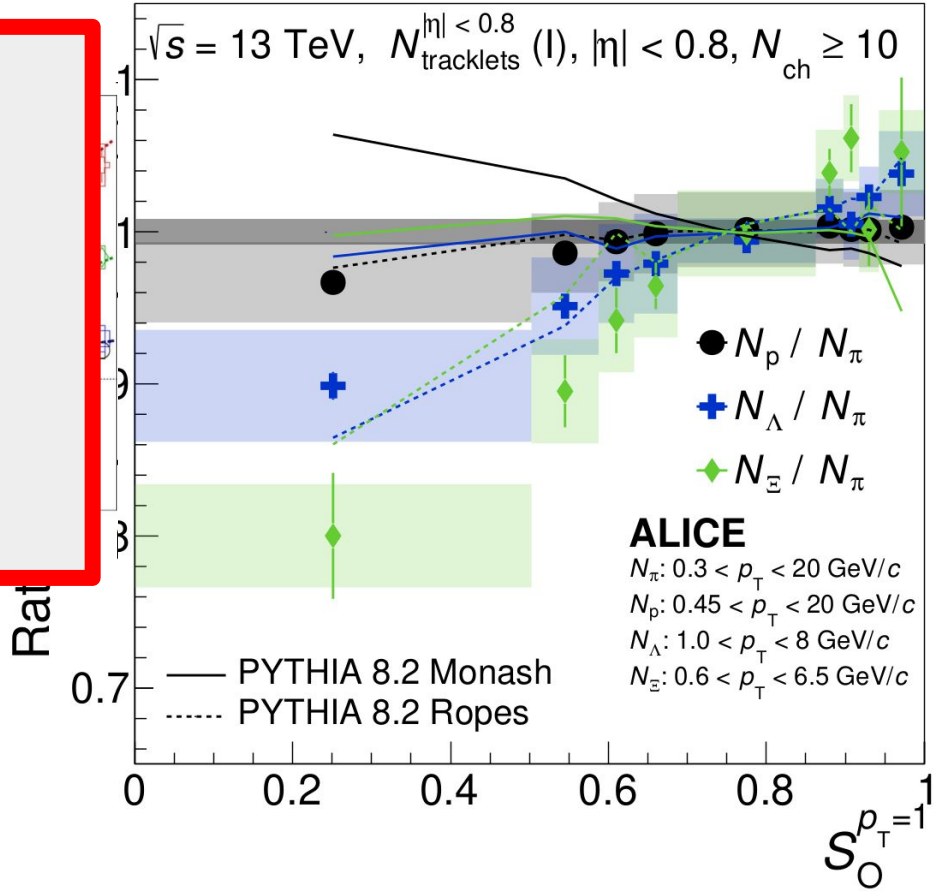

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- No modification at all

  for phi mesons in either

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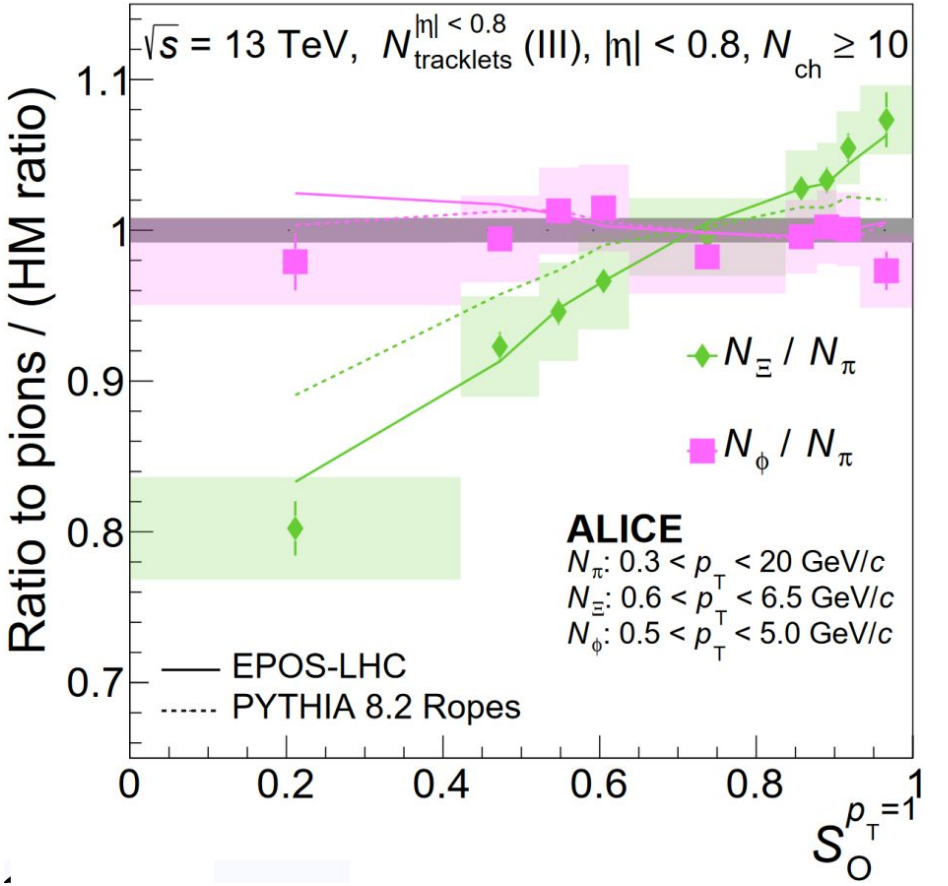

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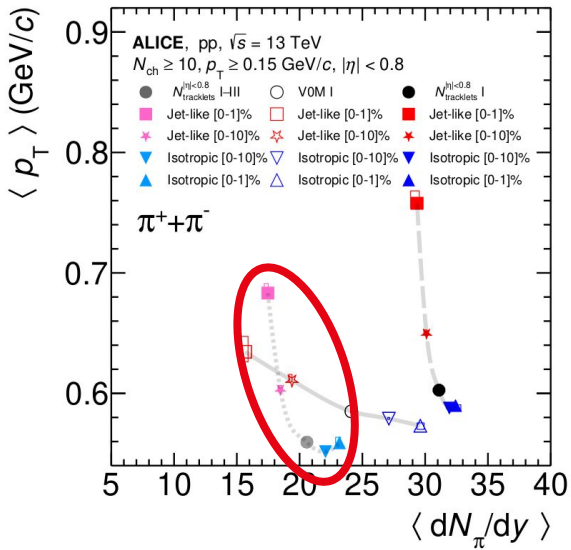

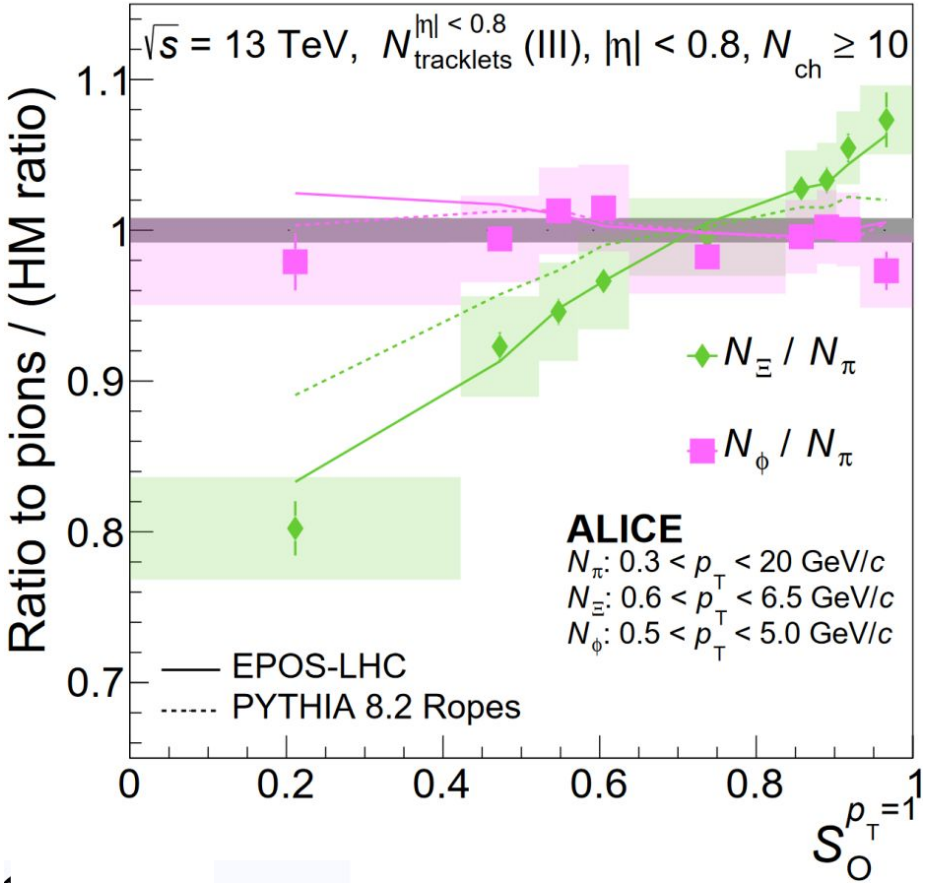

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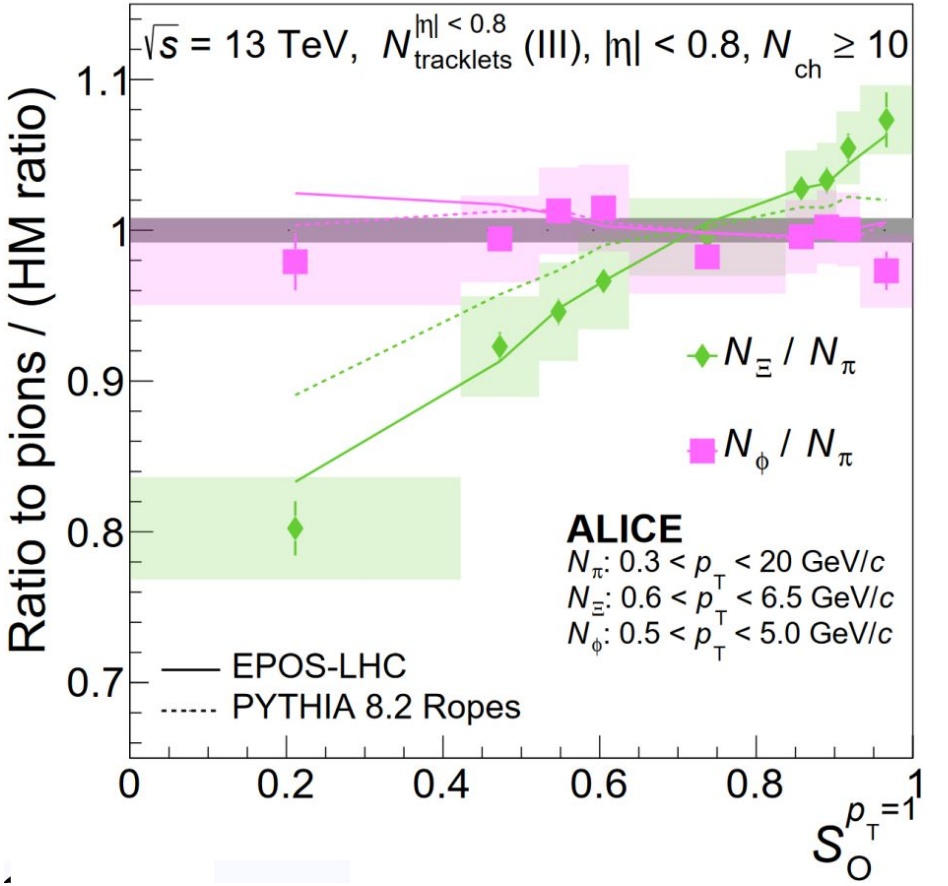
  - Behaves more like a proton

    (hadron mass) than the Xi

    (potentially same effective strangeness)



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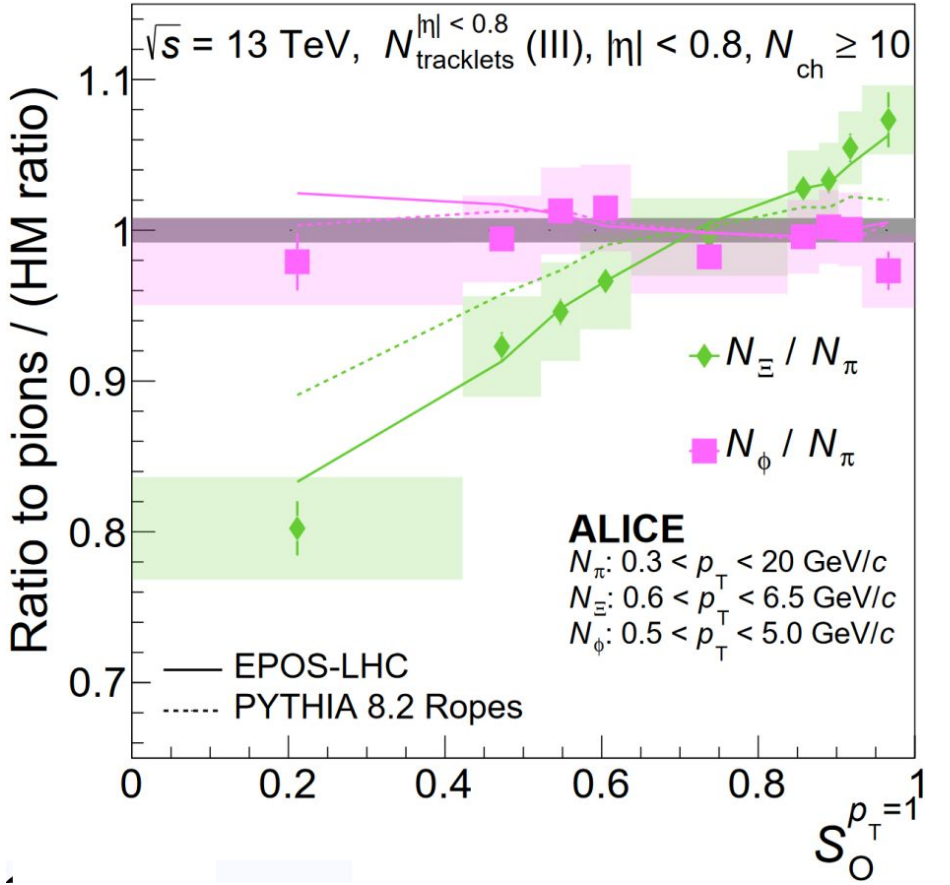

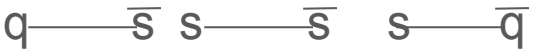

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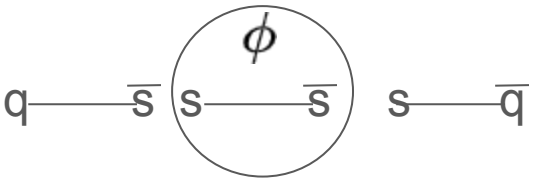
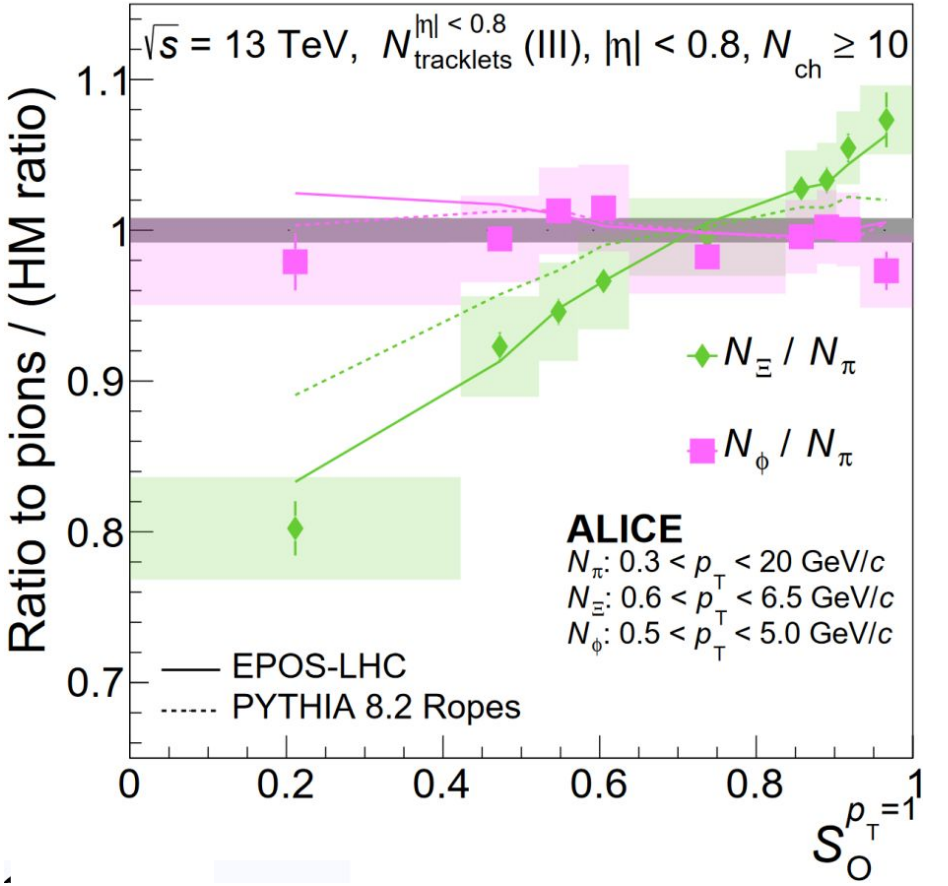
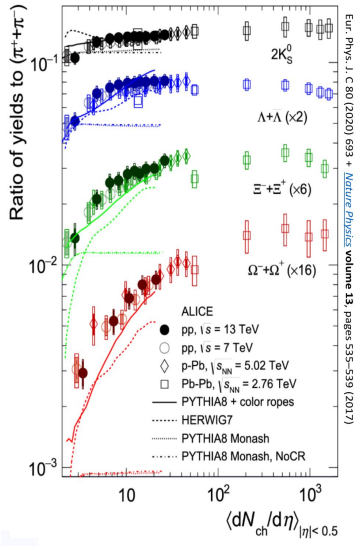




Summary

- Several heavy-ion like features have been found in high-multiplicity proton-proton collisions
  - Phenomenological, QCD-inspired solutions struggle to describe effects



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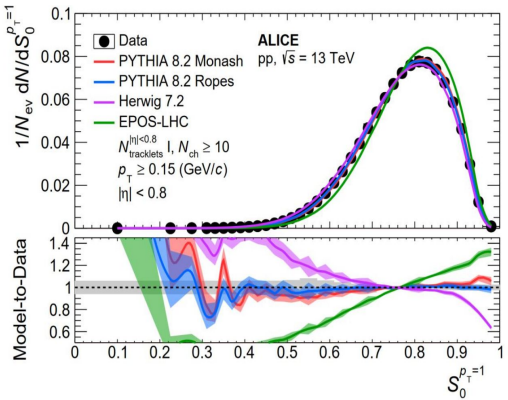
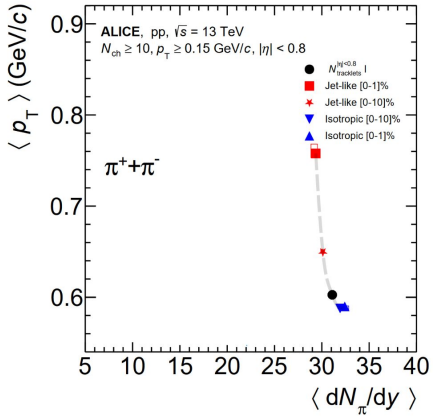
  - Isotropic topologies driven by soft physics agree well with the average high-multiplicity event
  - "Jet-like" topologies seem to be clear outliers





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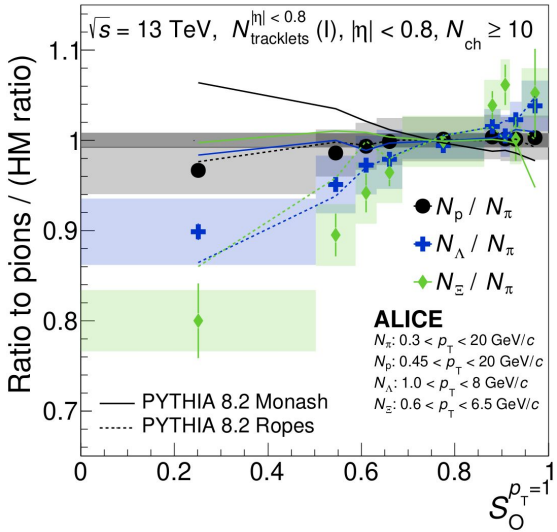
  - Phenomenological, QCD-inspired solutions struggle to describe effects
- How homogeneous are high-pp collisions?
  - Isotropic topologies driven by soft physics agree well with the average high-multiplicity event
  - “Jet-like” topologies seem to be clear outliers
- Can we delineate between soft/hard physics in this regime?
  - $S_O^{p_T=1}$ can be used to select strangeness enhanced/suppressed events
  - Hard, jet-like events seem to produce strange hadrons at a much lower rate than the average high-multiplicity event



BACKUP

Transverse Spherocity $S_O^{p_T=1}$

- What physics are our topological selection sensitive to?
  - We have a very large shift in mean pT
  - Very small (around 10%) shift in yield

$$S_0^{p_T=1} = \frac{\pi^2}{4} \min_{\hat{n}} \sum_i \left(\frac{|\hat{p}_{T,i} \times \hat{n}|}{N_{trk}} \right)$$

- Our jet-like selection really is able to capture hard structures, while the isotropic selection is not trivially isotropic

- These are the exact two paradigms we wish to contrast!