Ideas related to testing coalescence

- An idea that can maybe work for both light and heavy flavour coalescence

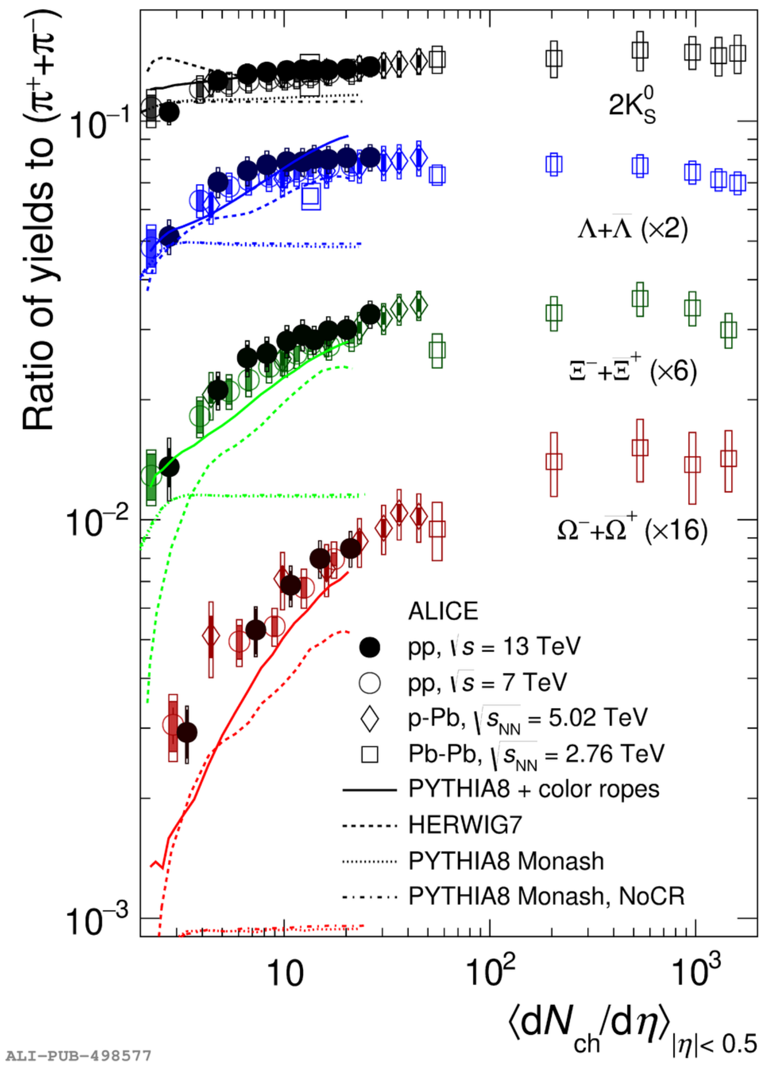
We are also a mix of explorers and gold diggers

We are also a mix of explorers and gold diggers

Sometimes, we need to use our intuition and guess

General problem

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

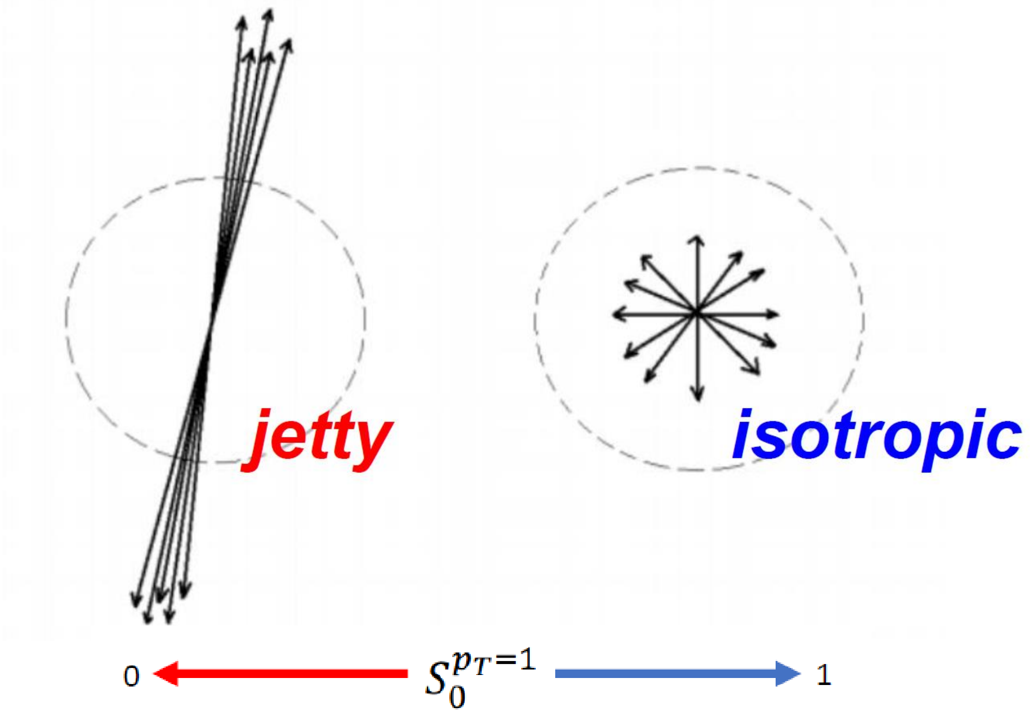


- Many models – especially after some time – can describe the same data
- Not even clear if discrepancies are problematic or just due to a necessary approximation

Transverse Spherocity S_O

Define the unweighted transverse spherocity:

$$S_O^{p_T=1} = \frac{\pi^2}{4} \min_{\hat{n}} \left(\frac{\Sigma_{tracks} |\hat{p}_T \times \hat{n}|}{N_{tracks}} \right)^2$$

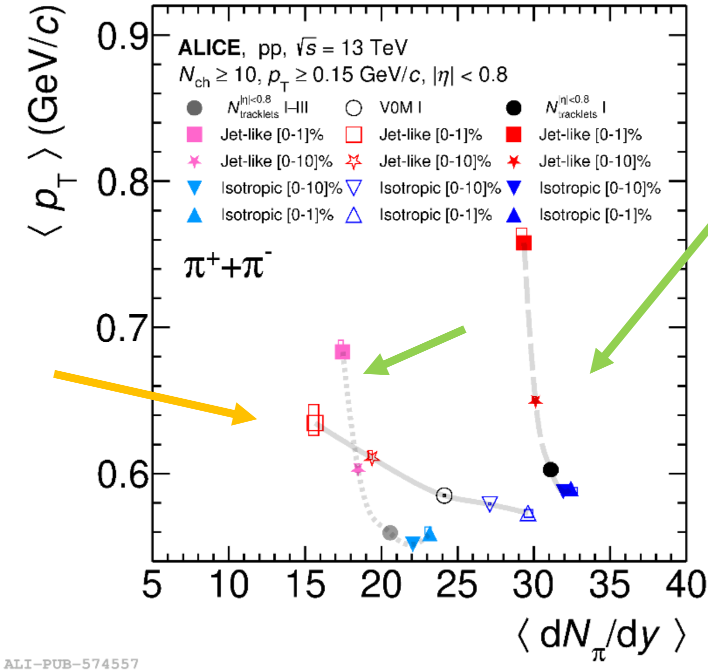


- Most other ALICE results were for the p_T-weighted S_O
  - We need this change because we study shortlived and neutral particles
  - Will call it S_O in the following

The effect of S_O selection for different multiplicity estimators

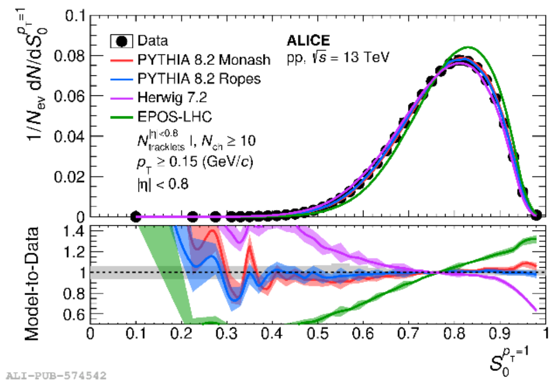
Forward estimator

Different region than where we measure S_O
Shown for top 10%.
(typically used in ALICE to avoid autocorrelations)



Mid-rapidity estimator

Same region where we measure S_O

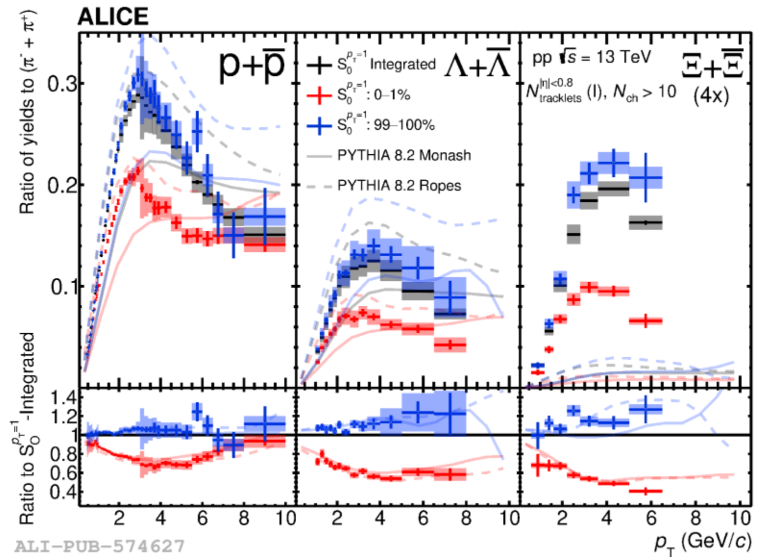


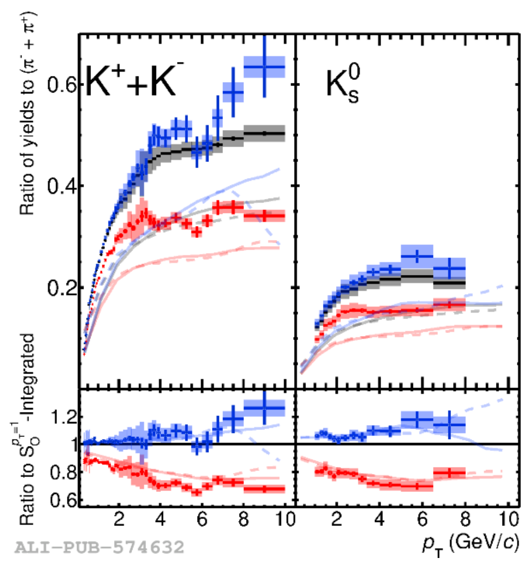
- Physics we can address with S_O depends on where we select the multiplicity
- The following results are all done with the mid-rapidity estimator
  - This ensures that multiplicity is almost constant so that we mainly select harder or softer events

Peter's questions (P. Christiansen, Lund)

Results top 1% multiplicity and top 1% S_O (0.01% of events)

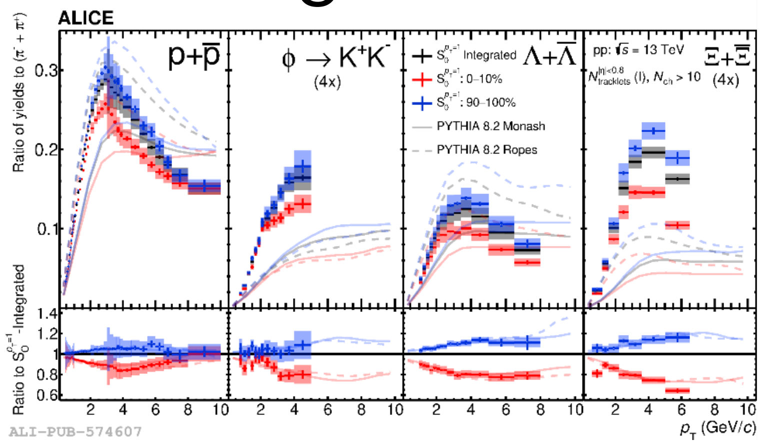
- Large differences between jetty and isotropic ratios ✓
- Events without S_O selection are similar to isotropic
  - QGP-like effects dominates
    - Perfect liquid?
  - Hard physics is outlier
- Jet-like events
  - Radial-flow "peaks" are reduced
  - Strangeness is significantly reduced at high p_T

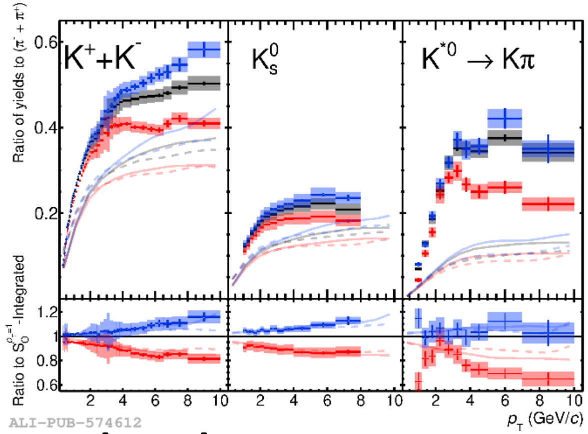




ALICE, JHEP 05 (2024) 184

Results top 1% multiplicity and top 10% S_O (0.1% of events)

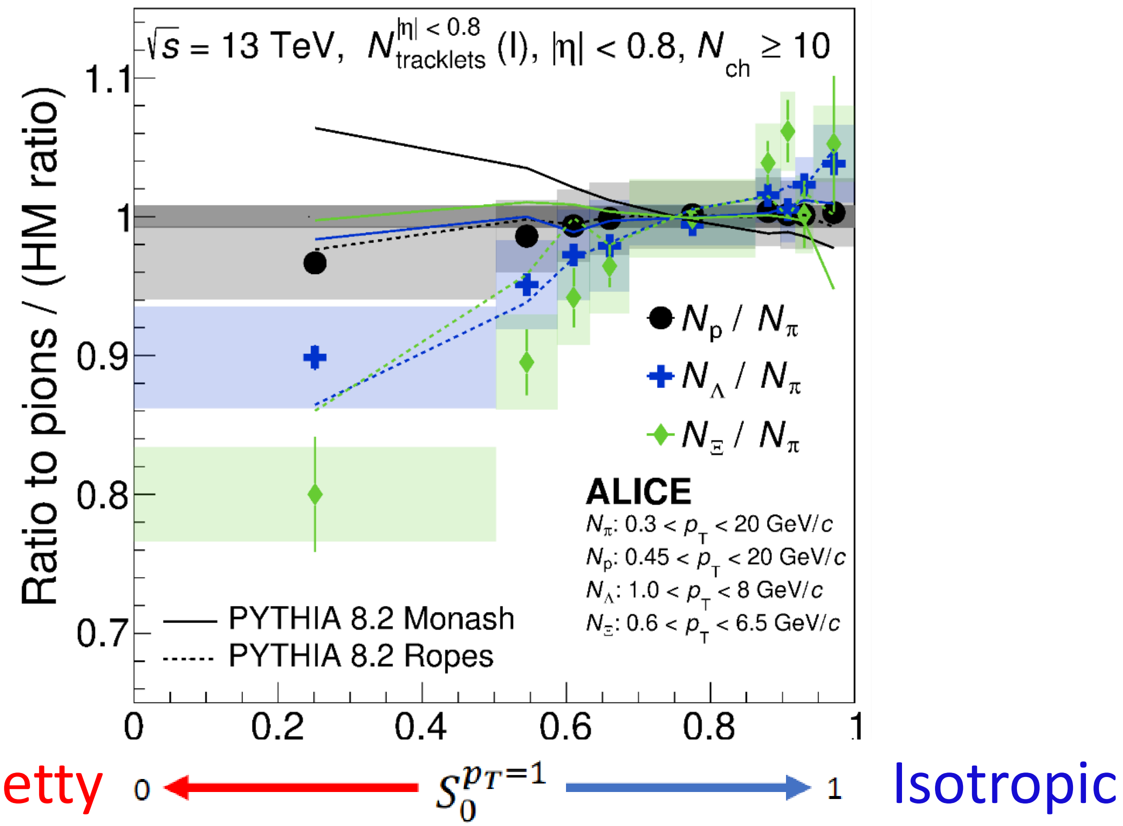




ALICE, JHEP 05 (2024) 184

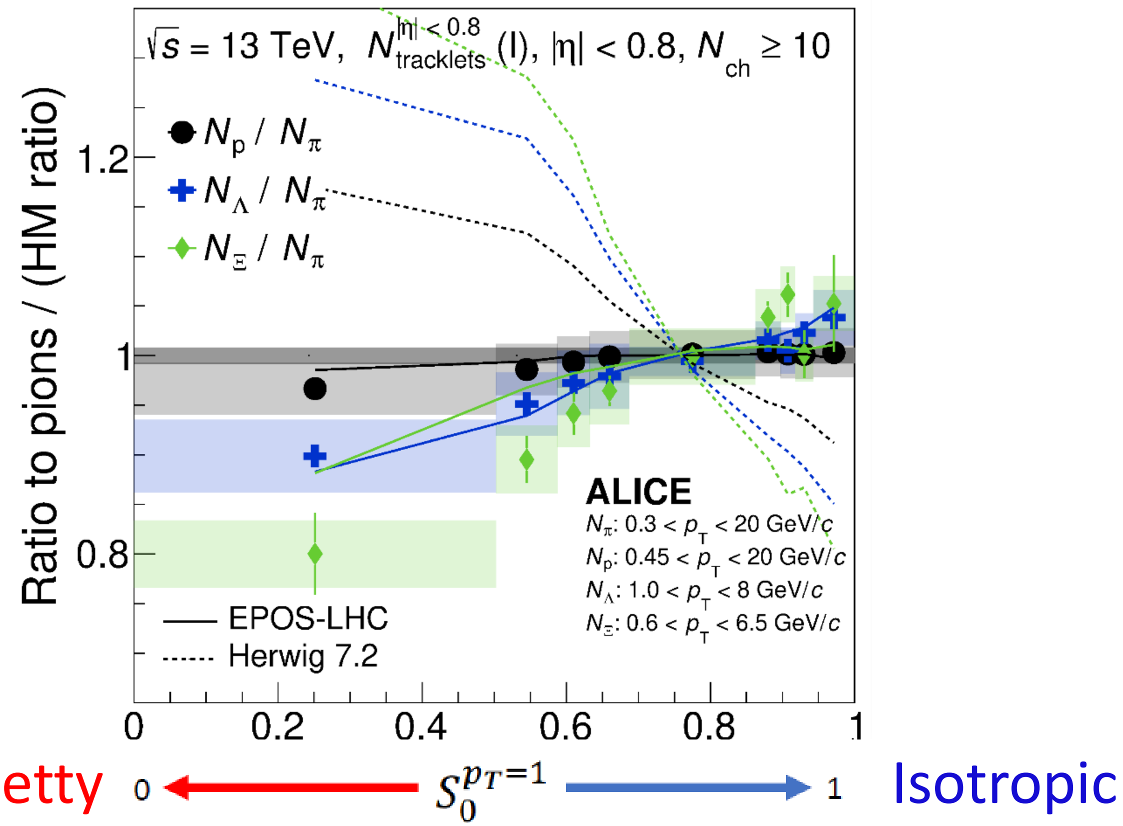
- For top 10% we also have resonances (ϕ and K^{*0})
  - Require more statistics due to event mixing background
- Vs top 1%: effects are reduced but trends are the same

Strangeness enhancement vs S_O (top 1% multiplicity)



- We can control the strangeness enhancement with S_O ✓
  - The effect is bigger for Ξ (S=2) than for Λ (S=1)
- Pythia ropes can describe the enhancement qualitatively

Strangeness enhancement vs S_O (top 1% multiplicity)

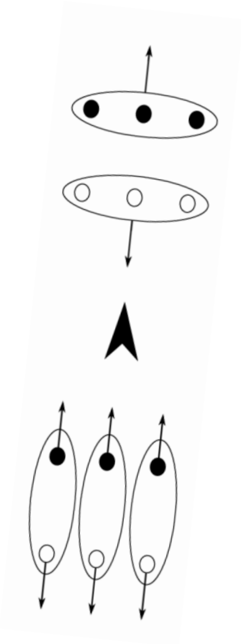


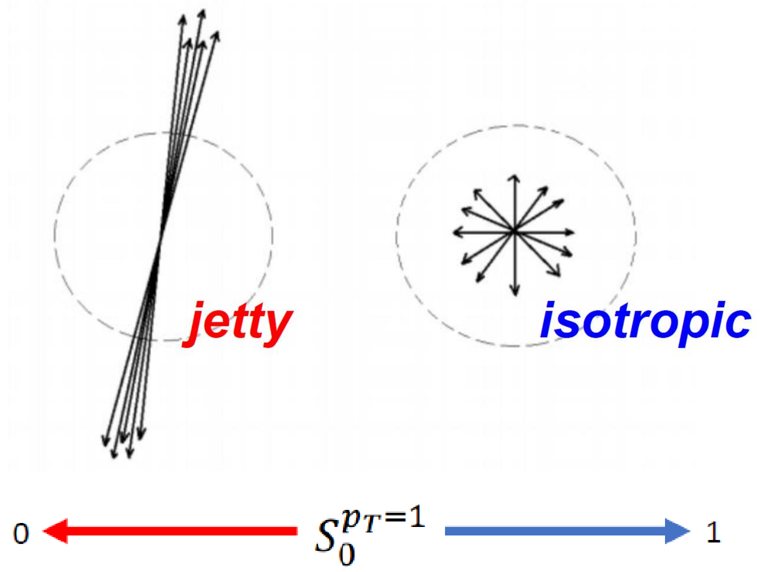
- EPOS LHC captures the trend
  - The QGP core is reduced in jetty events
- HERWIG has opposite trend?! (next slide)

Peter's questions (P. Christiansen, Lund)

Why Herwig is wrong

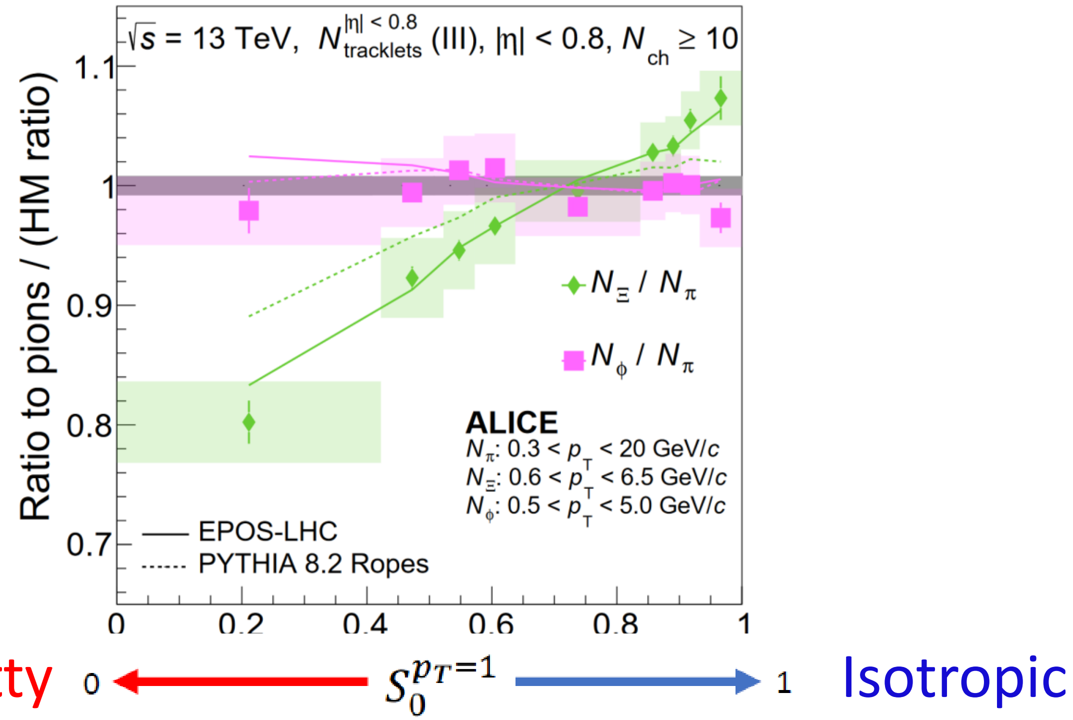
S. Gieseke,
P. Kirchgaeßer,
S. Plätzer
Eur.Phys.J.C 78 (2018) 2, 99





- Herwig produces a baryon enhancement by allowing 3 mesons close in phase space to form a baryon-antibaryon pair
  – But this will be more likely to happen in pencil-like events!
  – What about quark coalescence models?

Strangeness enhancement vs S_O (top 10% multiplicity)



- ϕ ($\approx s\bar{s}$) and Ξ (ssd) follows different trends
- Data and models agree

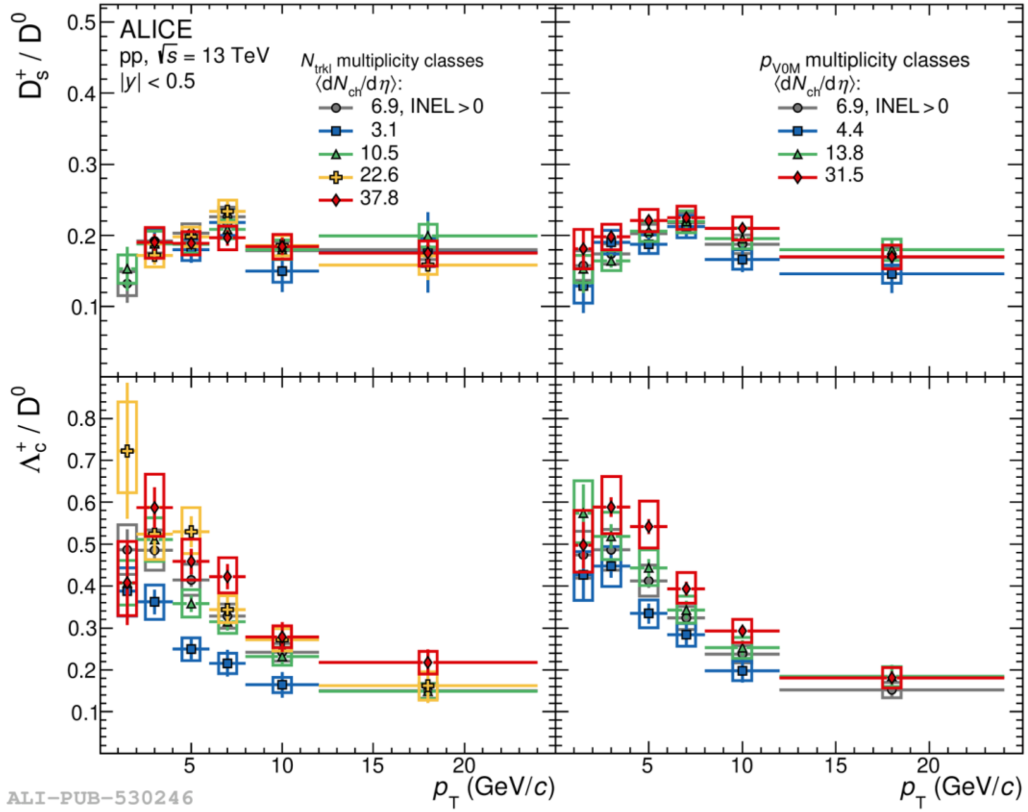
Several potential challenges to coalescence models

- Jetty events, which are here not defined with a pT cut, appears to be those where partons must be close in phase space
- But
  - No flow peak: p/pi flat vs pT
  - No strangeness enhancement
  - Different pattern for phi and Xi
- Problem: is there a generator implementation where we can test this?

Charm baryon production at very low multiplicity

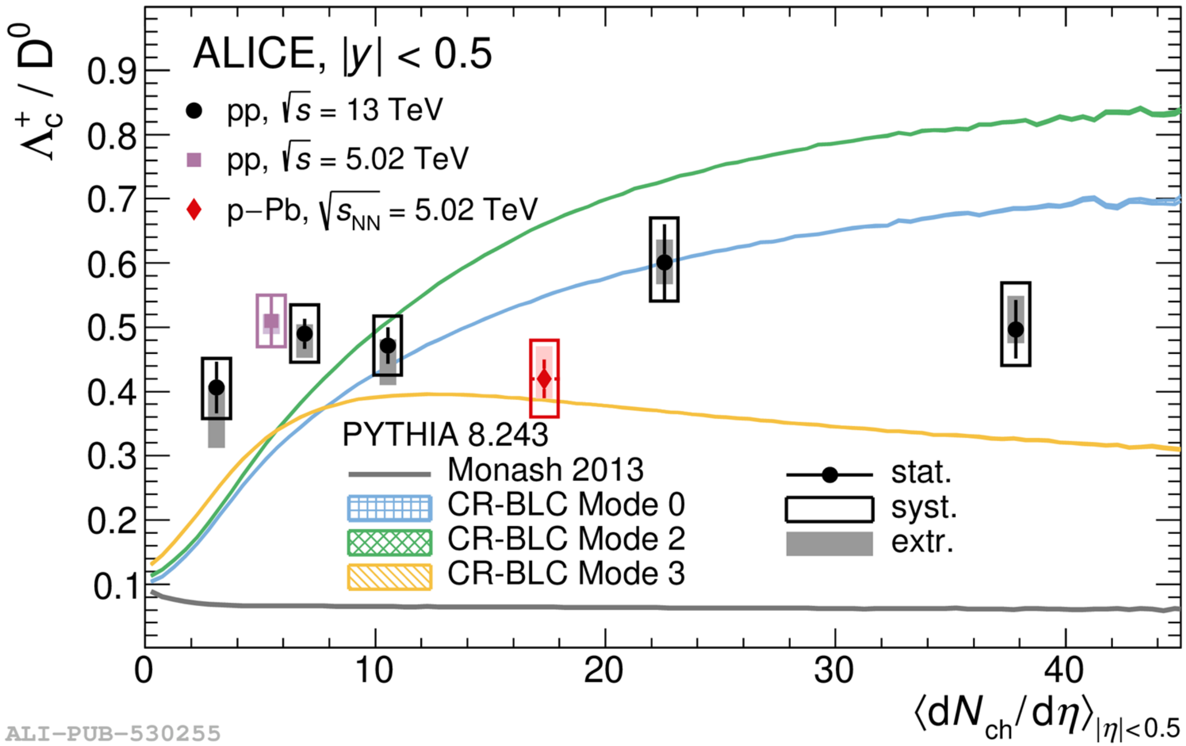
Ratios vs pT

ALICE
Phys. Lett. B 829 (2022) 137065



What is the limit at low mult?

ALICE, Phys. Lett. B 829 (2022) 137065

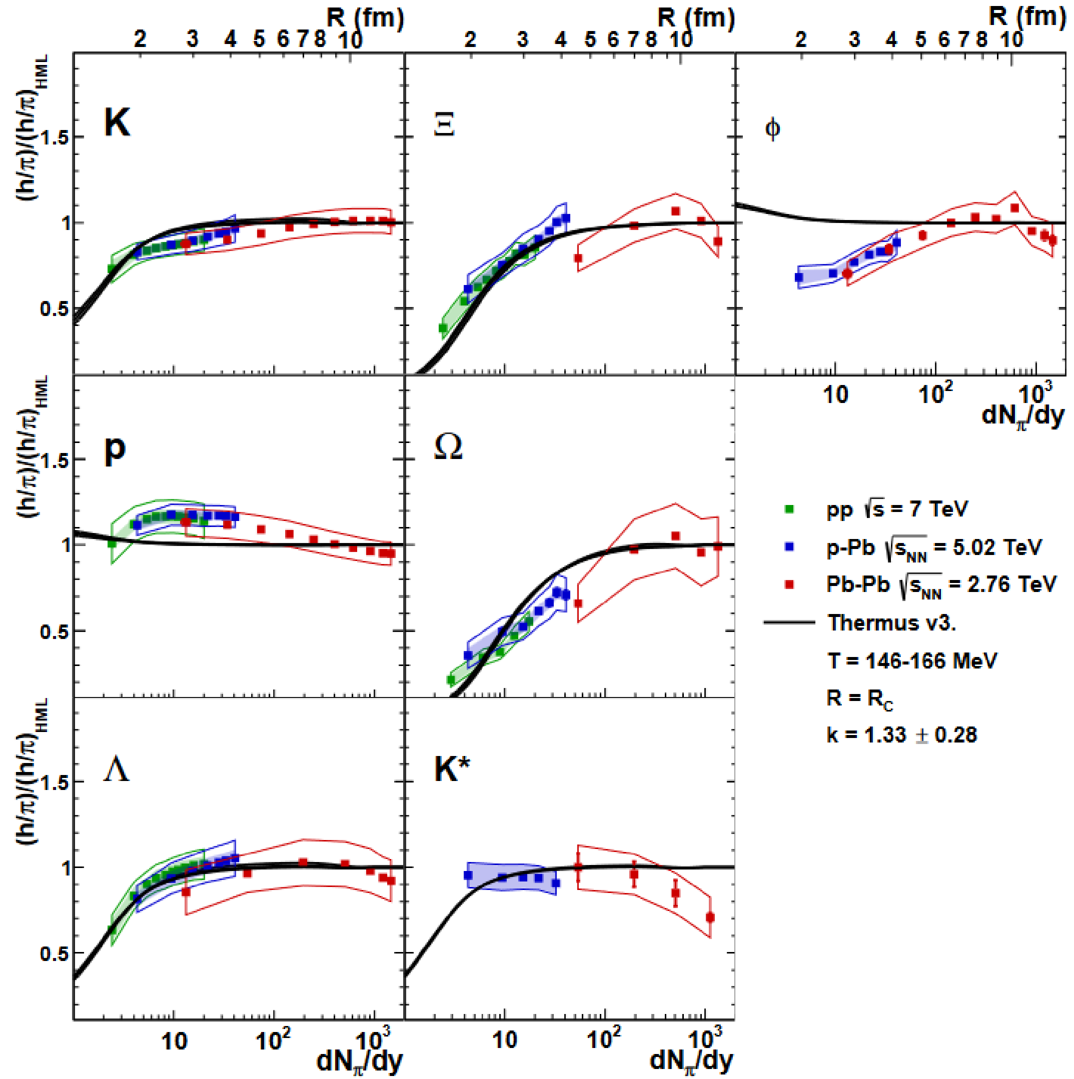


- Can models explain this?
  - And why does it not approach e+e-?!
    - Unlike strangeness enhancement

Is strangeness suppressed in small systems or enhanced in large systems?

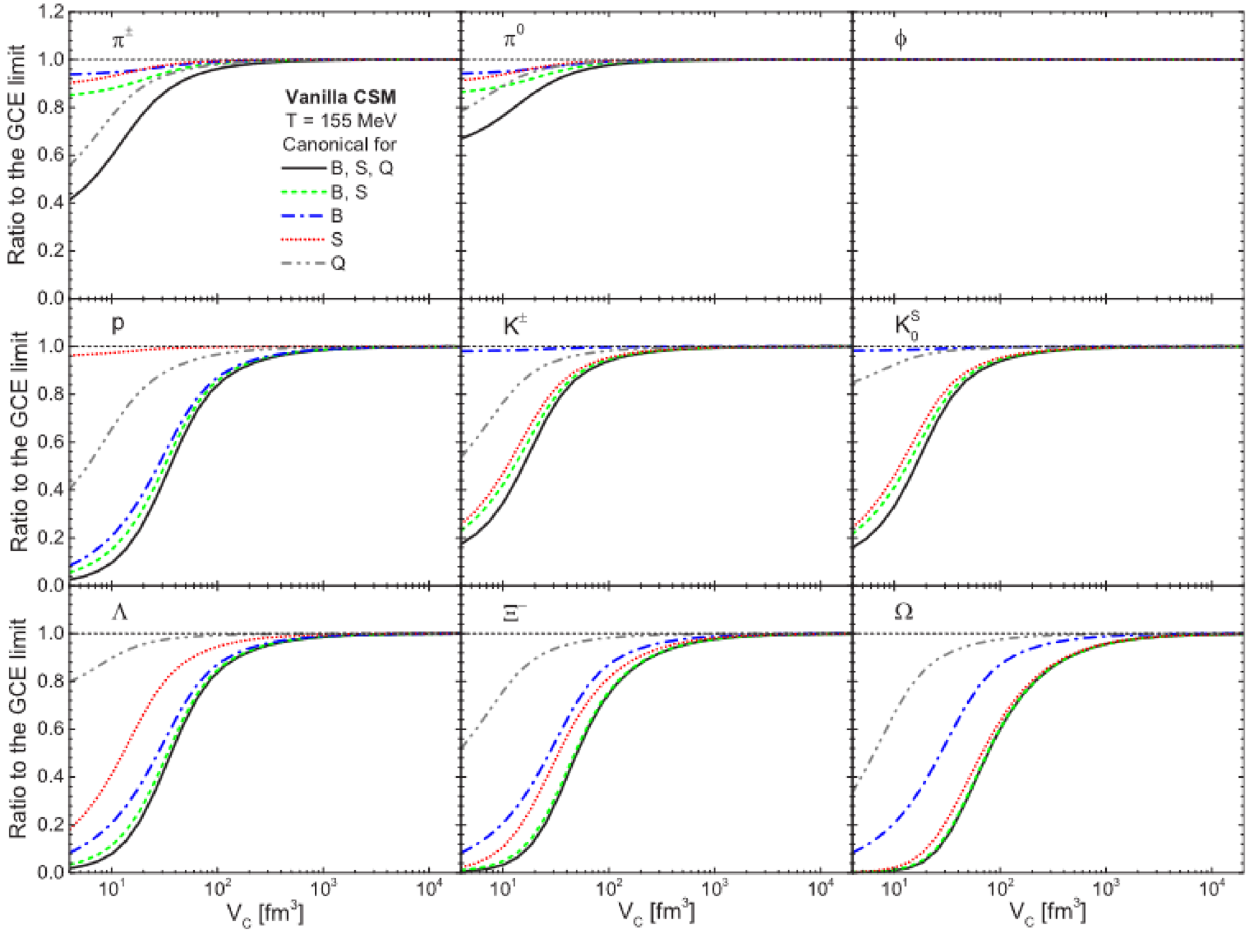
- Outline
  - Show some examples of "suppressed in small systems" data
  - Show some results on how Ξ is balanced by (anti)protons
  - Show some completely fresh results on balance in FIST

A purely statistical description of yields vs multiplicities



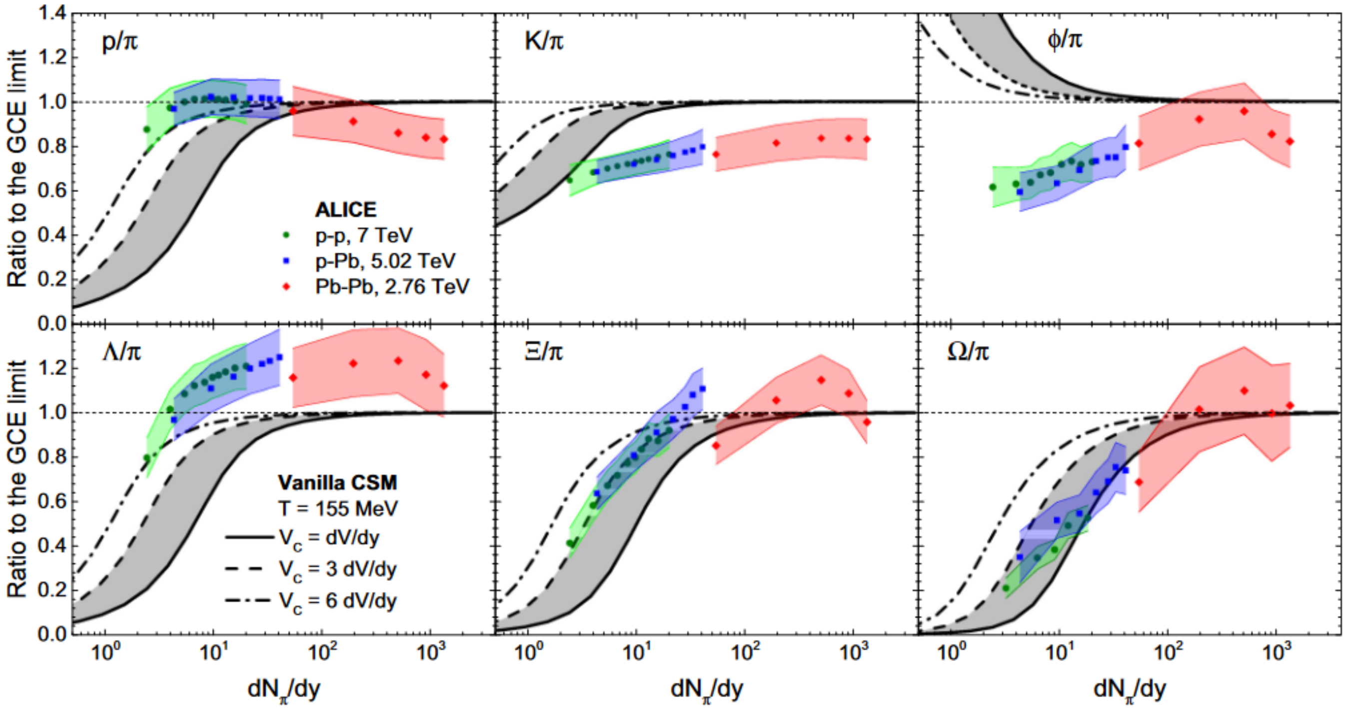
V. Vislavicius,
A. Kalweit,
arXiv:1610.03001

FIST
Full canonical treatment



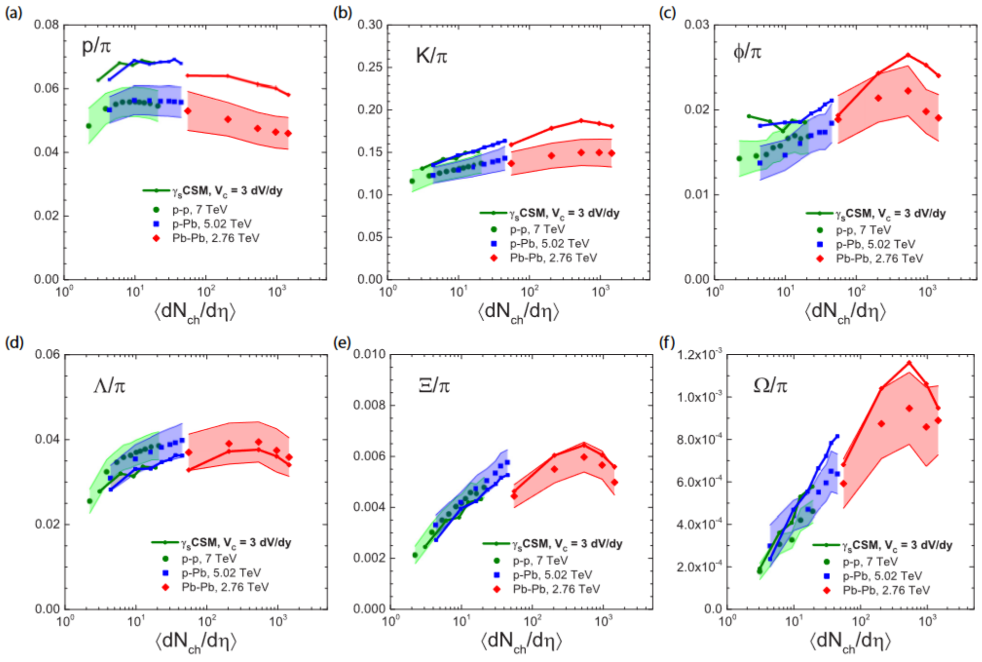
V. Vovchenko,
B. Dönigus,
H. Stoecker ,
Phys.Rev.C 100 (2019) 5, 054906

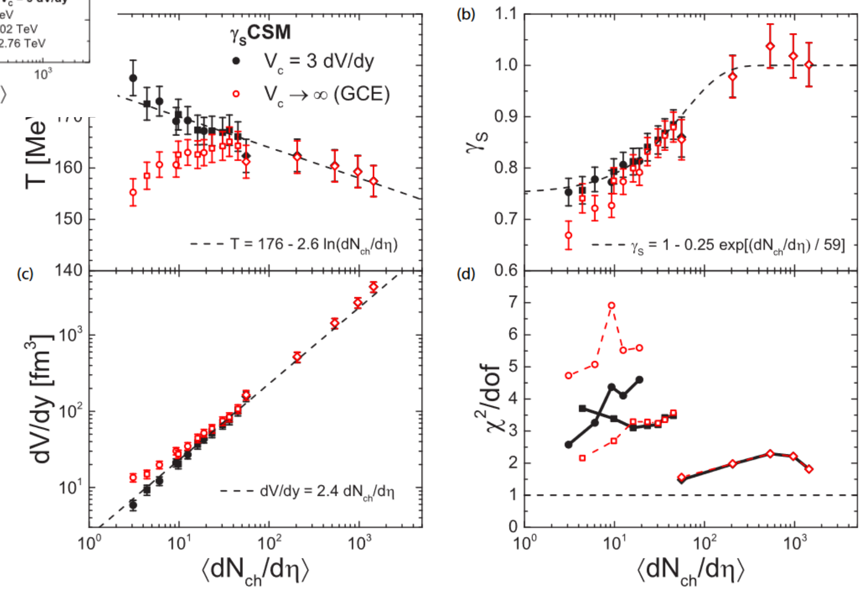
FIST: canonical description (no γ_s)



FIST: canonical description (with γ_s)

Peter's questions (P. Christiansen, Lund)





How to kill Pythia: two lessons from CLASH

1. No chemical or thermal equilibration
   - Kinetic equilibration via shoving but never chemical or thermal
   - However, this IMO also challenges the QGP paradigm: where is the direct microscopic evidence for chemical/thermal equilibration?
2. Quarks and hadrons are mainly produced together: it is not possible to have a large phase-space separation of balancing quantum numbers
   - This goes against some of the claims of ALICE of long-range balancing of baryon number. However, these are IMO only indirect claims.

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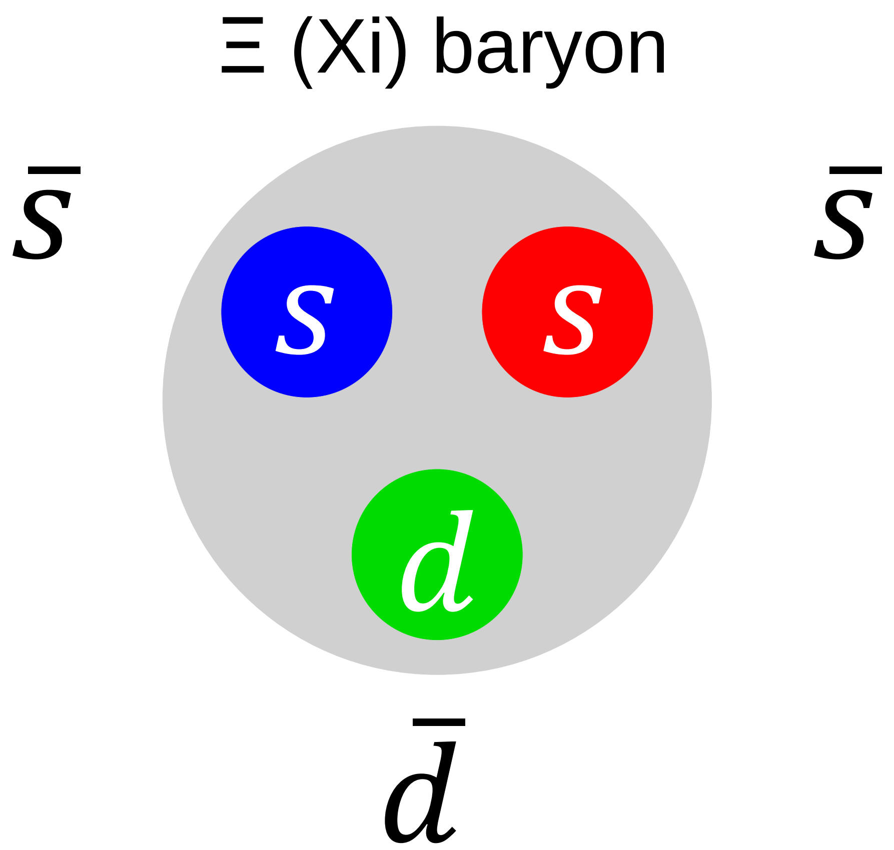
Idea: look at the how the strange quarks are balanced



QGP:
We naively expect that in a QGP the quarks will be deconfined and so eventually the quark pairs will drift apart in phase space.

Lund string:
Most quarks and antiquarks are produced together during hadronization.

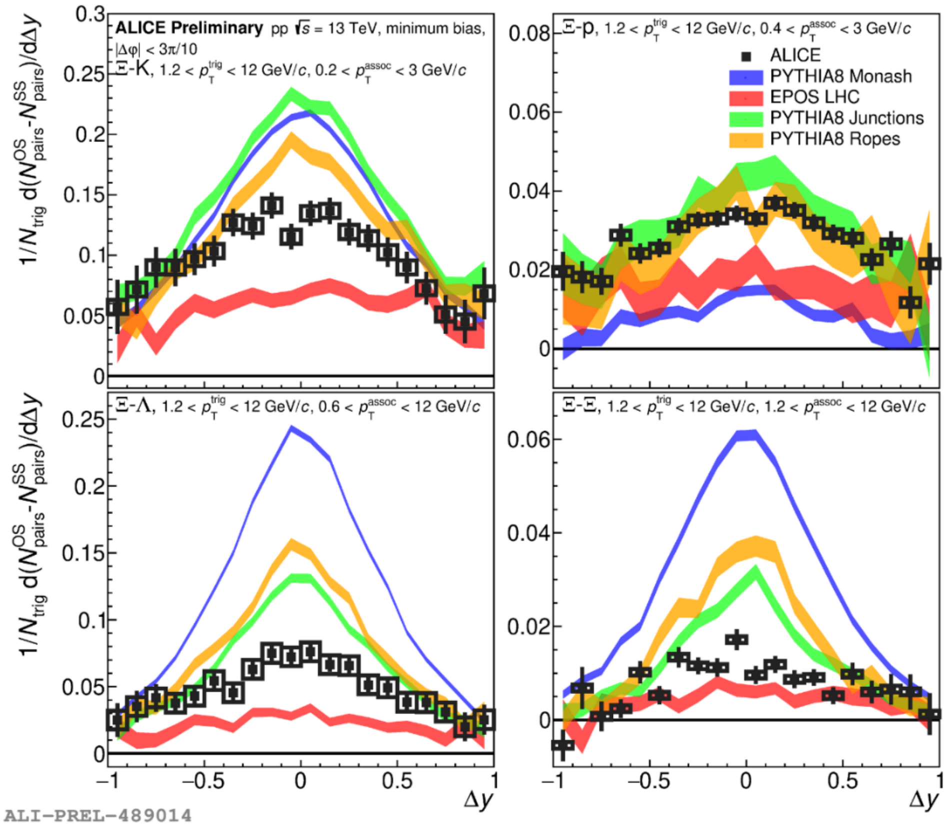
Part of the work of Jonatan Adolfsson's PhD Thesis

Ξ-K

Ξ-p

Ξ-Λ

Ξ-Ξ



ALICE congratulates its PhD thesis award winner

2 JULY, 2021

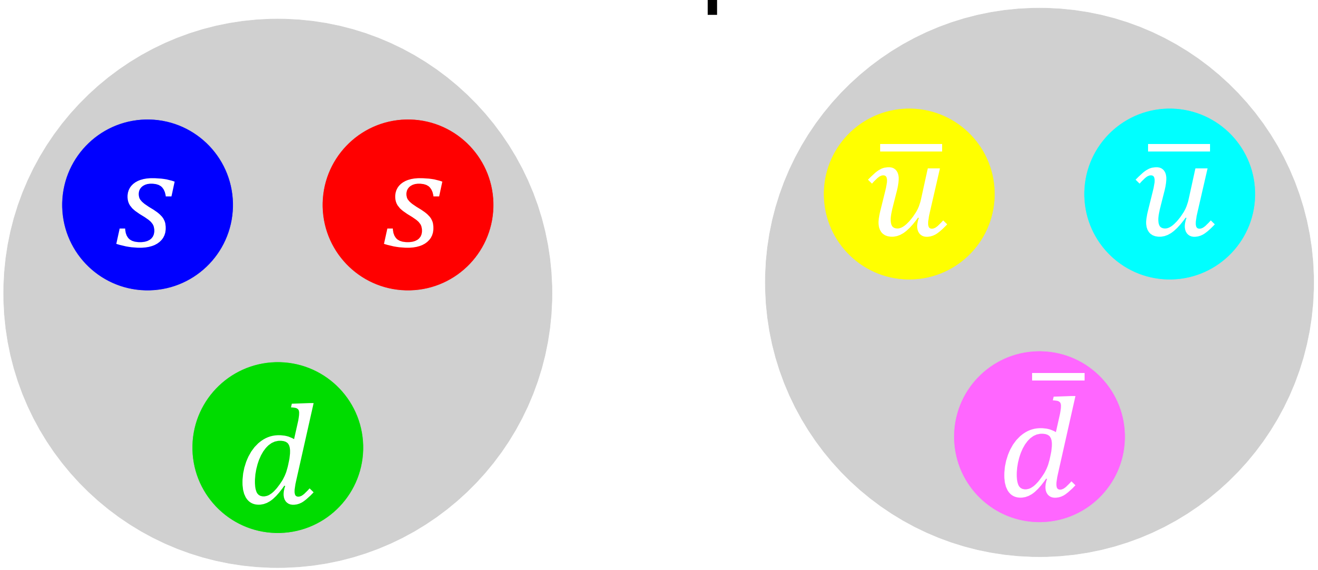
Jonatan Adolfsson (LU)

ALICE Spokesperson Luciano Musa (left) awards the prize to Jonatan Adolfsson (right) in the virtual presence of Collaboration Board Chair Silvia Masciocchi and the Chairs of the Thesis Award Committee, Giuseppe Bruno and Philippe Crochet (Image: CERN)

https://home.cern/news/news/cern/alice-congratulates-its-phd-thesis-award-winner

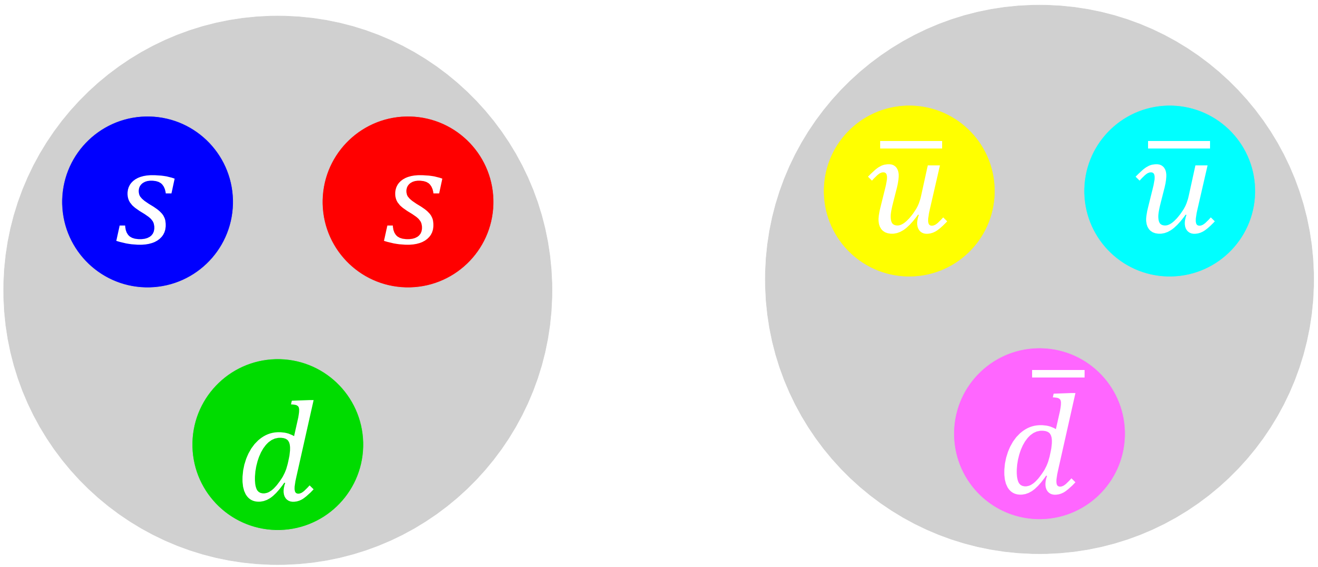
- He studied many combinations, see arXiv:2308.16706 (accepted by JHEP)

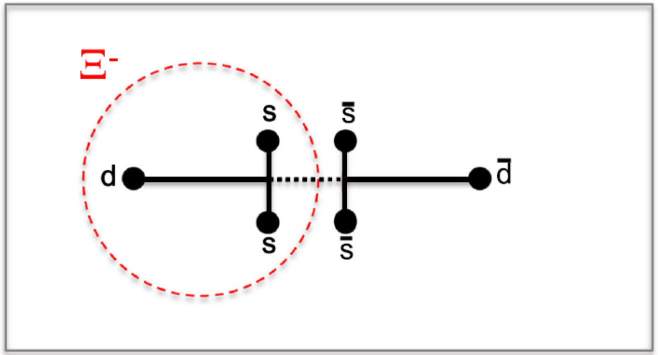
Focus on Ξ balanced by antiproton



- Ξ (s, s, d) balanced by p-bar (ubar, ubar, dbar)
  - Requires at least <u>two mesons</u> to balance strangeness, e.g., 2K+ (u, sbar) => Balance requires min. 3 particles
- I think one would expect this should be suppressed in a small system because one could balance with 1 or 2 particles only

Ξ balanced by antiproton: Monash

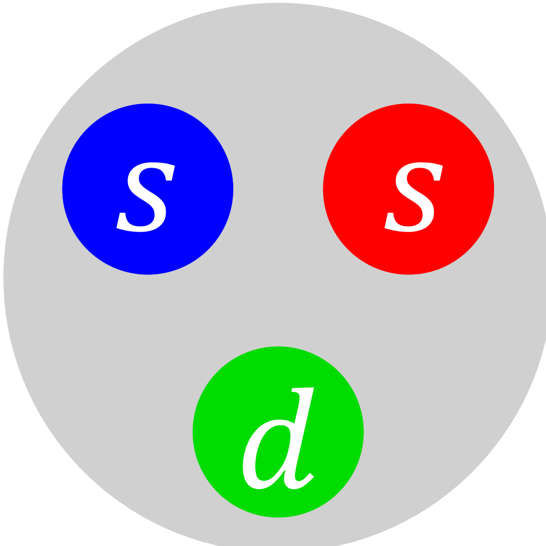


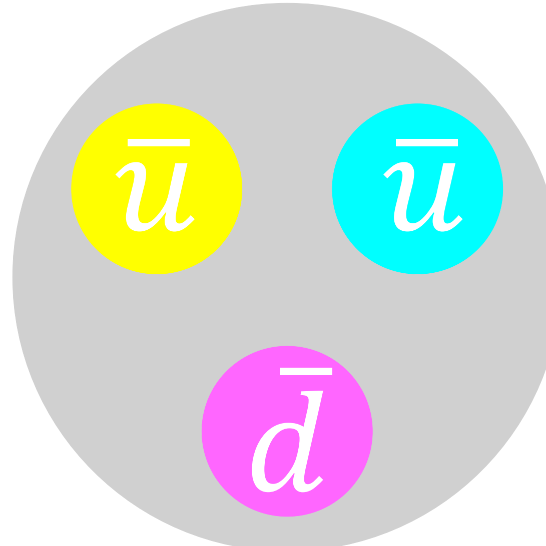


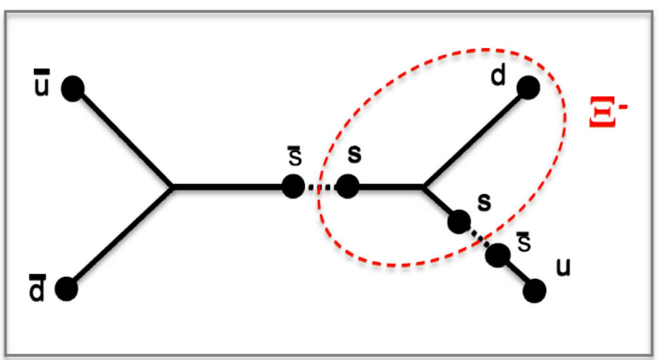
Normal Lund string and ropes: Ξ almost never balanced by antiproton but instead typically by antistrange baryons and even anti-Ξ!

Idea from CLASH workshop write up: J. Adolfsson et al, Eur. Phys. J. A 56 (2020) 11, 288, “QCD challenges from pp to A–A collisions”

Ξ balanced by antiproton: Junction



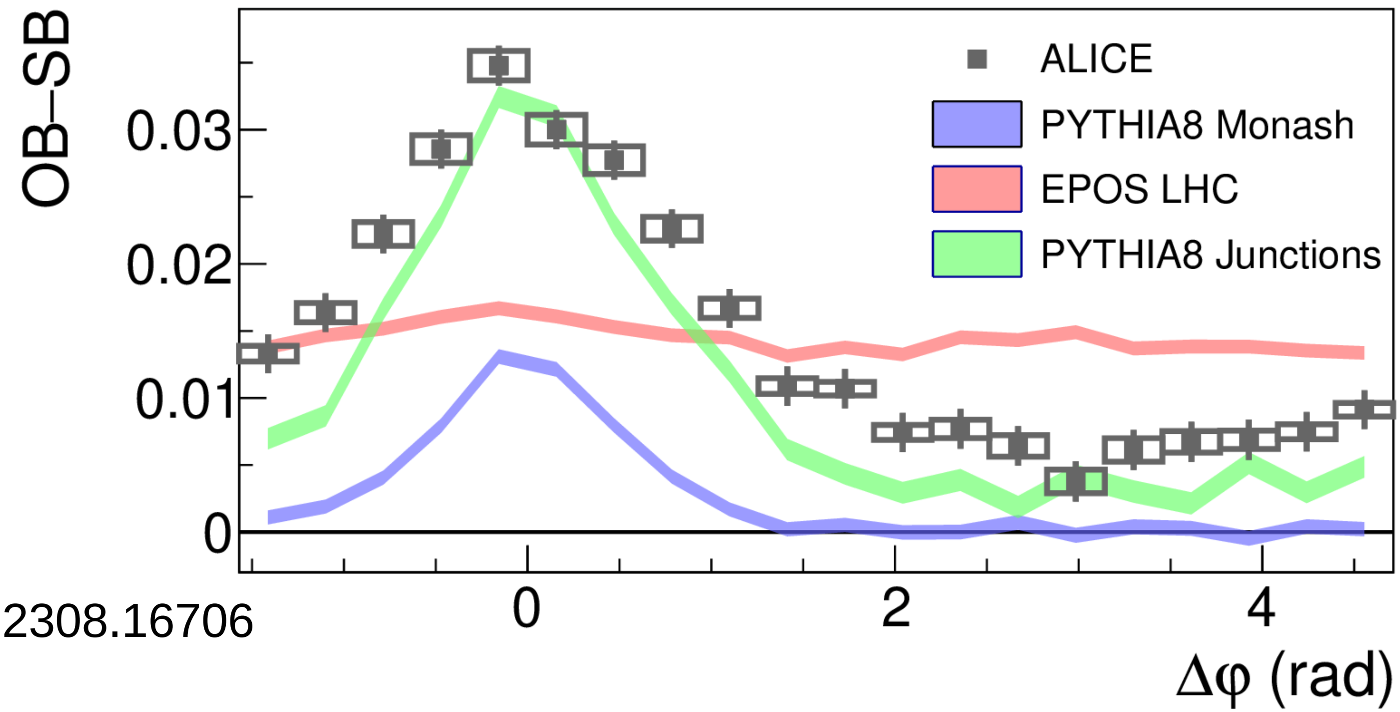




Junction:
Ξ balanced more by kaons and less by antistrange baryons.
Broader correlations in rapidity.

Idea from CLASH workshop write up: J. Adolfsson et al, Eur. Phys. J. A 56 (2020) 11, 288, “QCD challenges from pp to A–A collisions”

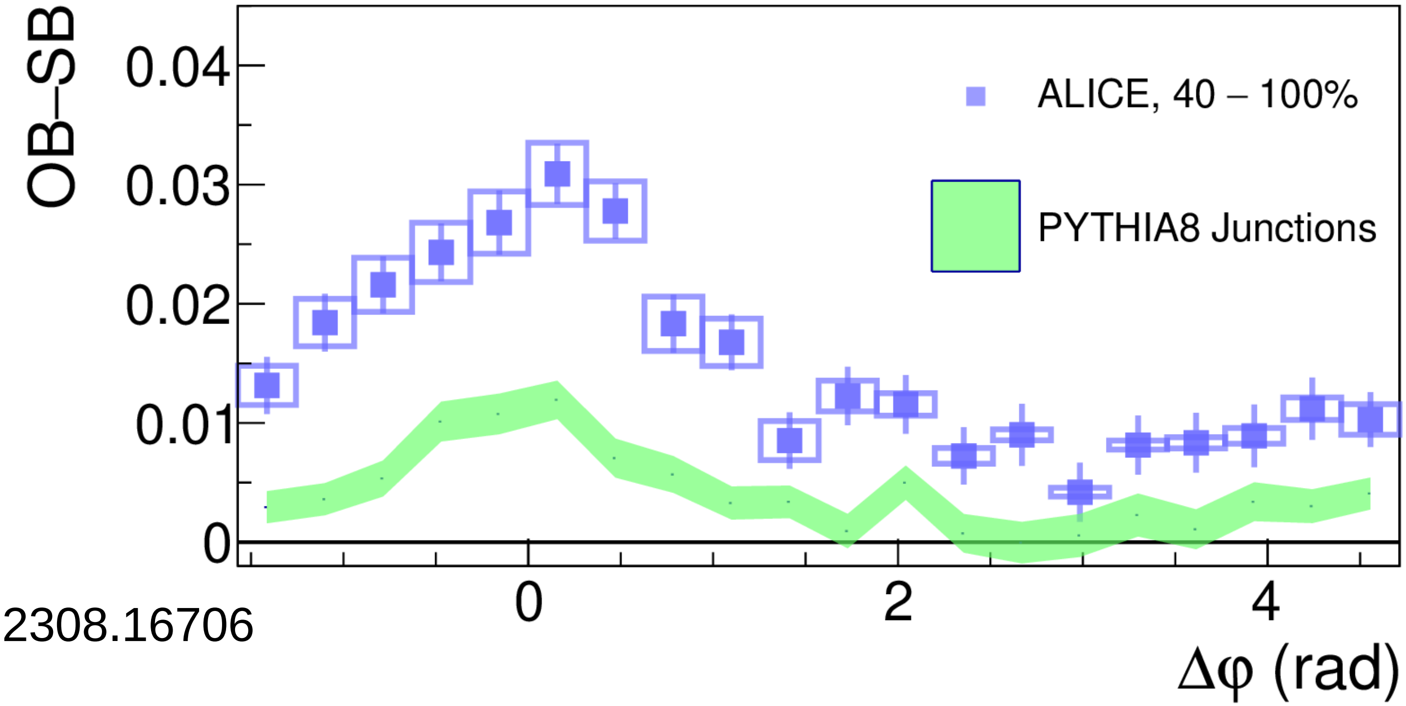
Microscopic balance of Ξ by antiprotons: MB results



arXiv:2308.16706

- EPOS (QGP) model: no structure due to extreme assumption of grand-canonical ensemble
- Pythia8 Monash: fails since this almost never happens
- Pythia8 Junctions: describes well the data

Microscopic balance of Ξ by antiprotons: low mult results

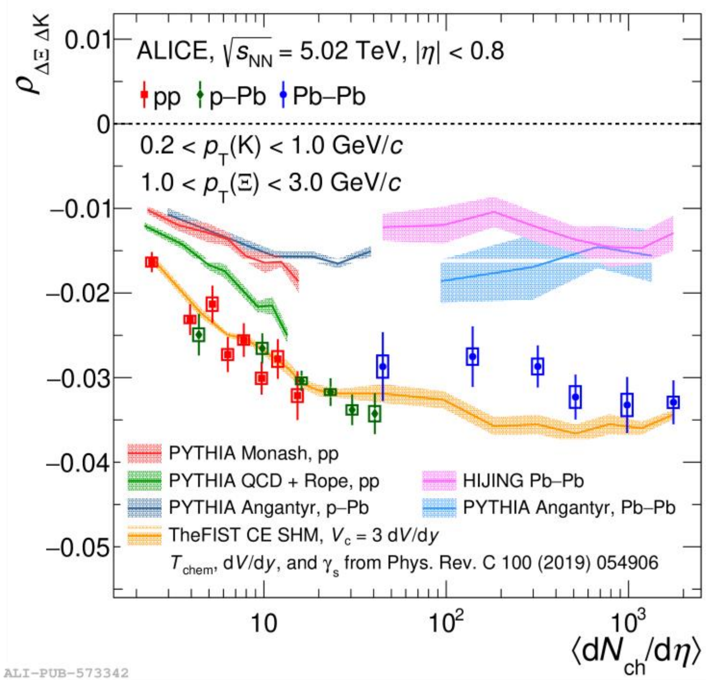


arXiv:2308.16706

- Pythia8 Junctions: fails to describe the data since in the low multiplicity limit it must agree with Monash (no CR)
- But why does nature prefer such a complicated process where strangeness is balanced by two mesons?

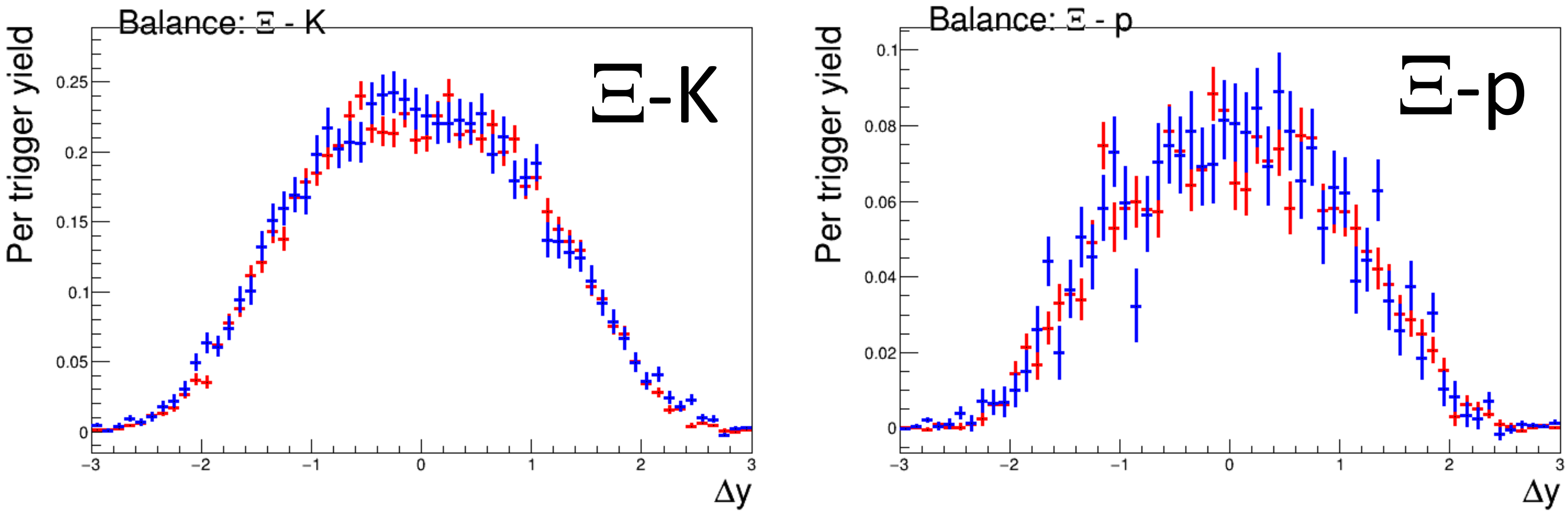
New simulation results from this morning

ALICE, arXiv:2405.19890



- Extract balance function in FIST
- Use the same simulations as done in paper above. Trigger on Ξ (same |η| and pT cuts). No eta or pT cut on balancing particle.

Balance functions: 0-1% vs 40-50% pp 13 TeV



- No difference observed even if I calculate the ratio Ξ/K I get ~2 times difference. (|η|<0.8 and pT cut on Ξ but not on K)
  - 0.1%: 0.018173282
  - 40-50%: 0.0098870056

My comments

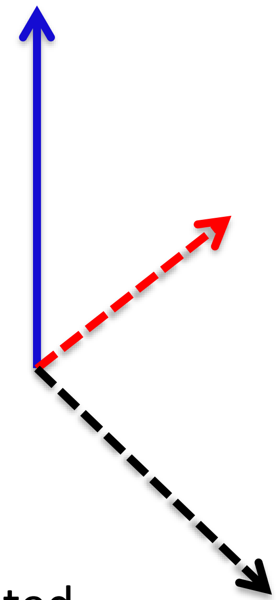
- Clearly too wide: correlation volume is too large to describe data
  - Is this a problem?
- But why does the balance not change: every time I create a Ξ I do it in the same way independent of system size…

Backup

Example: Ξ-K correlation functions

Trigger on : $\Xi\ (ssd)$

Measure where balancing QN ends up:
$K^+\ (u\bar{s}),\ \bar{p}\ (\bar{u}\bar{u}\bar{d}),$
$\bar{\Lambda}\ (\bar{u}\bar{d}\bar{s}),\ \bar{\Xi}\ (\bar{s}\bar{s}\bar{d})$



Subtract the uncorrelated production via the same QN correlations:
$K^-\ (s\bar{u}),\ \ p\ (uud), \Lambda\ (uds),$
$\Xi\ (ssd)$