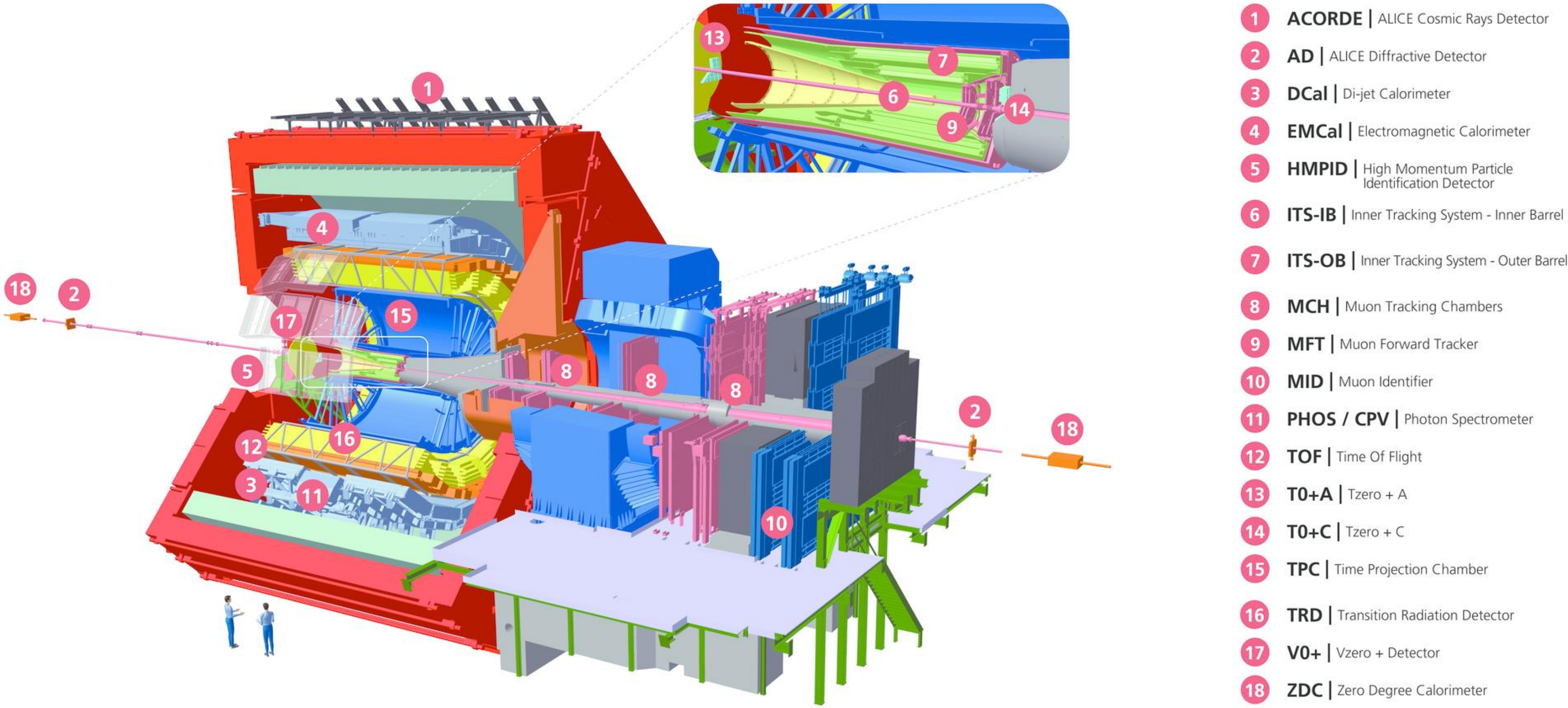
The heavy-ion group in Lund

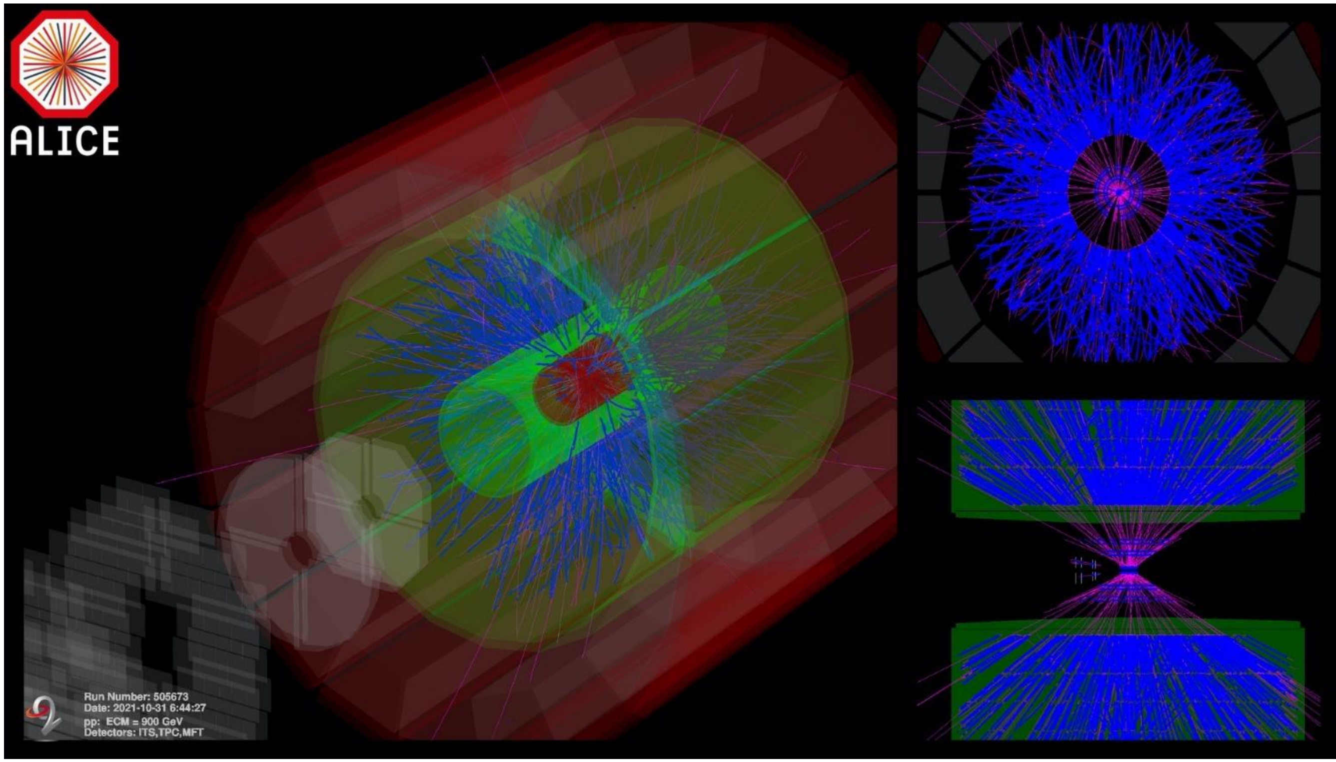
- 3 Seniors
  – Alice Ohlson, David Silvermyr, Peter Christiansen
- 2 Postdoc
  – Sumit Basu, Vytautas Vislavicius (after 3 years at NBI)
  – (Tuva Richert left to pursue a career in journalism)
- 3 Ph.D. Students
  – Adrian Nassirpour, Oliver Matonoha, Omar Vazquez Rueda
- Activities
  – Group: ALICE
  – Individuals works on preparations for: sPHENIX, HIBEAM/NNBAR experiment at ESS, ESSνSB

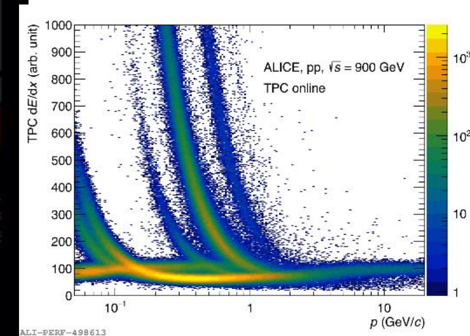
The upgraded ALICE experiment for Run 3 and 4



- Continuous readout (factor 10-100 gain for signals that cannot be triggered on)
- Main new features
  - New ITS2: 7 layers of monolithic active pixel sensors (MAPS)
  - GEM continuous readout for TPC (Lund group involvement)

First pilot beam collisions (proton-proton, $\sqrt{s}$ = 900 GeV)

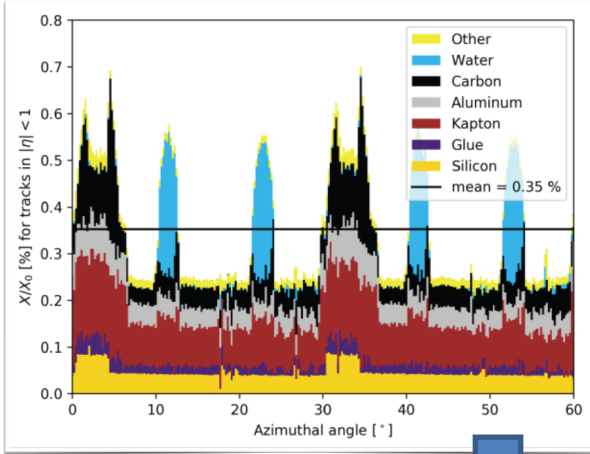




- A lot of work to be done to get ready for Run 3 but first results are very promising

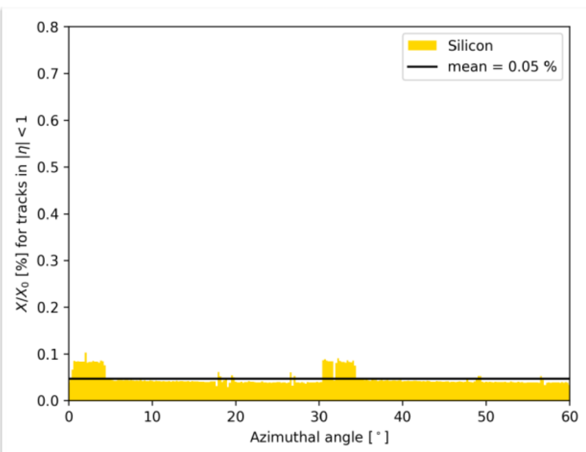
New ITS3 for Run 4

Motivation for ITS3



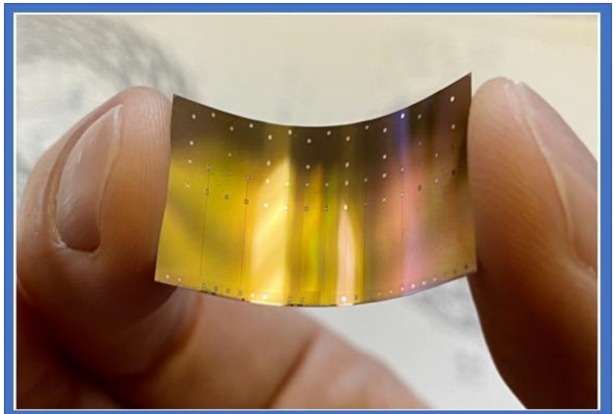
- Observations:
  - Si makes only **1/7th** of total material
  - **irregularities** due to support/ cooling

Motivation for ITS3



- Observations:
  - Si makes only **1/7th** of total material
  - **irregularities** due to support/ cooling
- Removal of water cooling
  - **possible** if power consumption stays below 20 mW/cm²
- Removal of the circuit board (power+data)
  - **possible** if integrated on chip
- Removal of mechanical support
  - **benefit** from increased stiffness by rolling Si wafers

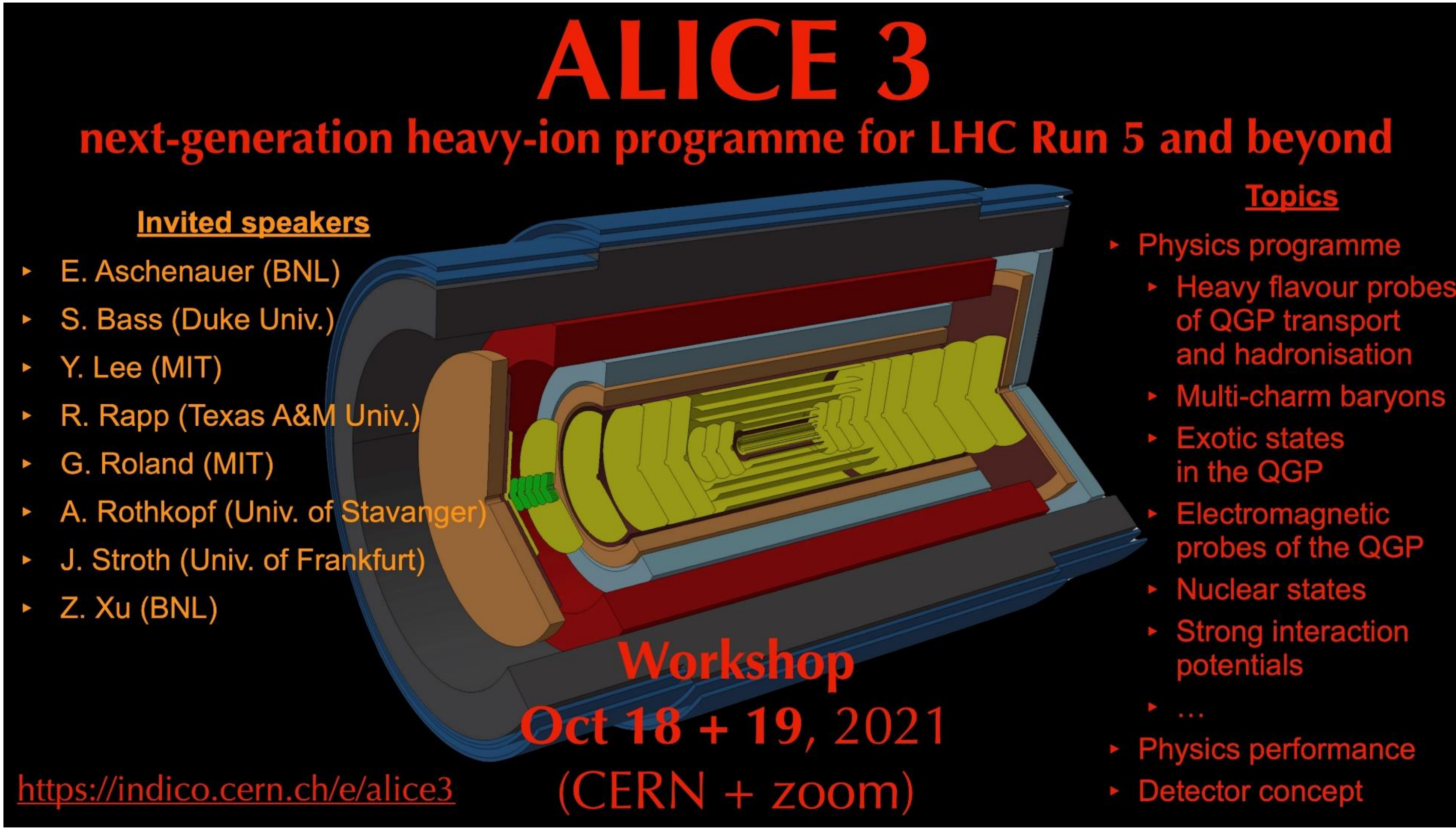
Magnus Mager (CERN) | MAPS R&D in 65 nm | LCWS2021 | 18.03.2021 | 7



ITS3

The Lund ALICE group has obtained funding from RFI to join the ITS3 upgrade project

ITS3 can lead on to a completely new ALICE 3 experiment



- Low p_T oriented/rare probes programme (where the medium “sits”)
- Indico link: https://indico.cern.ch/event/1063724/timetable/

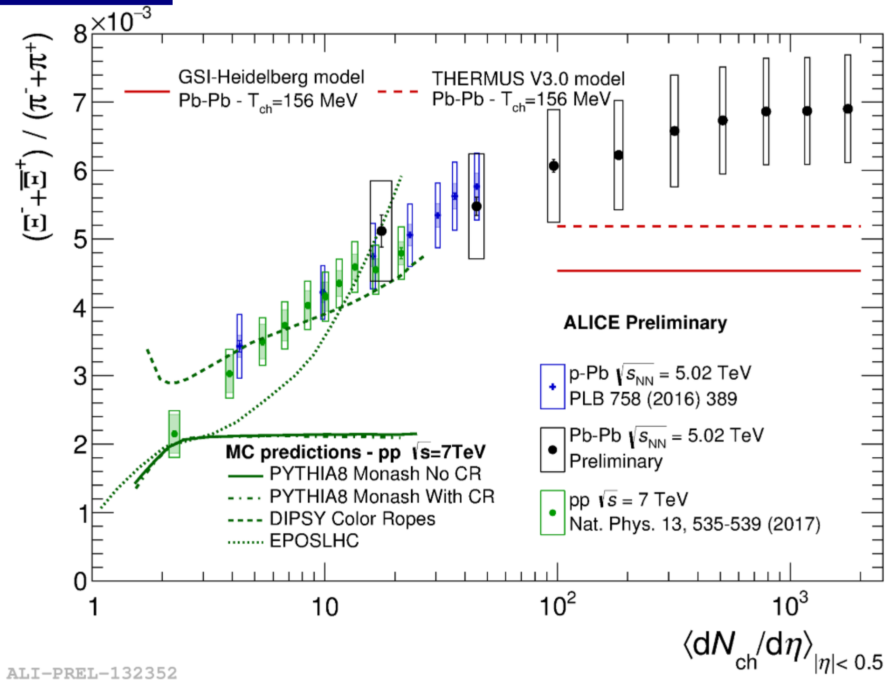
Lund ALICE data analyses

- A lot of activities (mainly around KAW CLASH)
- Many activities are focused on a single large data set
  - $>10^9$ MB pp 13 TeV events
- Have a complete set of identified particles
  - $\pi, K, p, \phi, K_s^0, \Lambda, \Xi$, (and still hope to do Ω)

Lund ALICE data analyses

- A lot of activities (mainly around KAW CLASH)
- Many activities are focused on a single large data set
  - $>10^9$ MB pp 13 TeV events
- Have a complete set of identified particles
  - $\pi, K, p, \phi, K_s^0, \Lambda, \Xi$, (and still hope to do Ω)
- Several papers in progress using this data
  - Spherocity (Oliver Matonoha)
  - R_T (was covered last year by Adrian Nassirpour)
  - Ξ-identified hadron correlations (more details here)

The main result that lead to CLASH



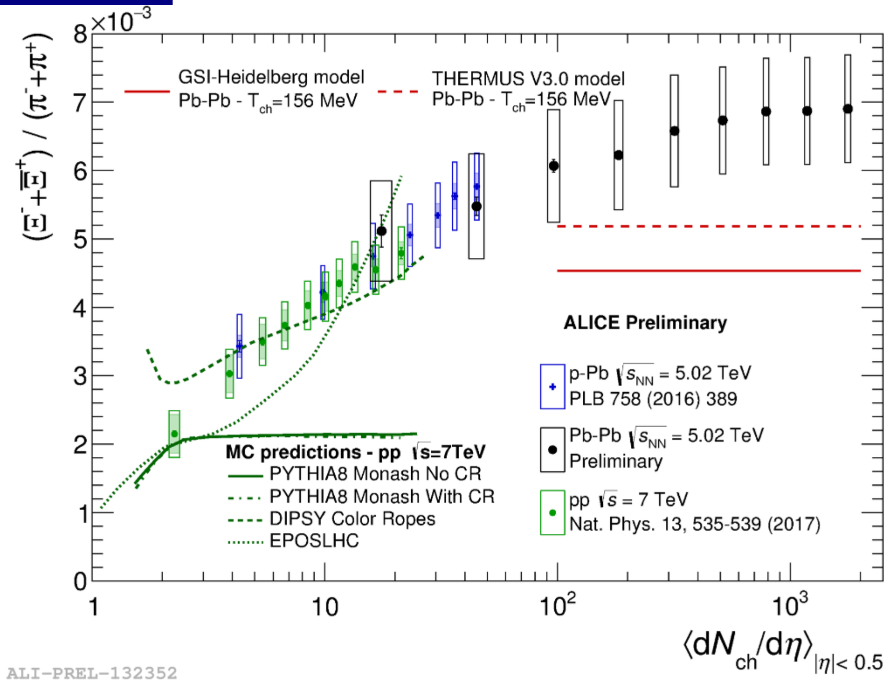
PYTHIA:
pp
$\sim \sum_{MPI}$ parton−parton interactions

https://www.hep.lu.se/clash/

predicts "more of the same" as one would expect from jet universality and "asymptotic freedom" (lack of significant final state interactions).

ALICE "revelation" is that this is wrong!

The main result that lead to CLASH



PYTHIA:

pp

$\sim \sum_{\mathrm{MPI}} \text{parton}-\text{parton interactions}$

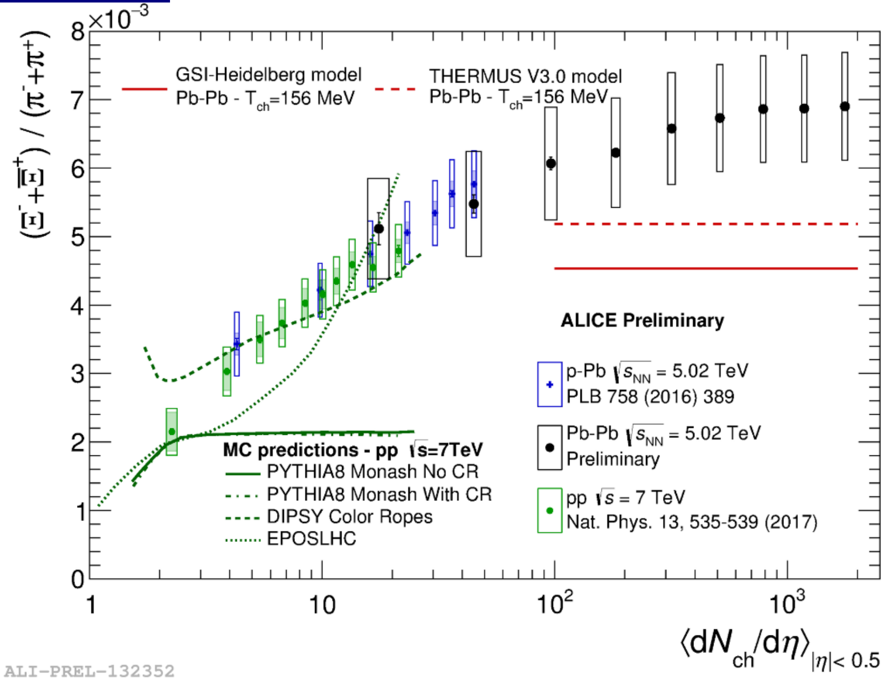
https://www.hep.lu.se/clash/

predicts "more of the same" as one would expect from jet universality and "asymptotic freedom" (lack of significant final state interactions).

ALICE "revelation" is that this is wrong!

- Irreversible change in understanding of pp collisions

The main result that lead to CLASH



https://www.hep.lu.se/clash/

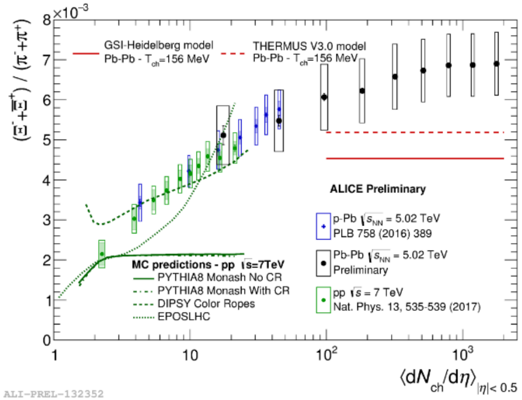
PYTHIA:
pp
$\sim \sum_{MPI}$ parton−parton interactions

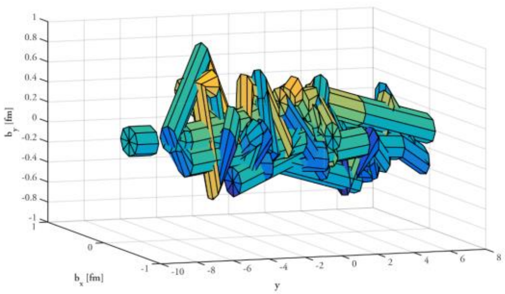
predicts "more of the same" as one would expect from jet universality and "asymptotic freedom" (lack of significant final state interactions).

ALICE "revelation" is that this is wrong!

- Irreversible change in understanding of pp collisions
- A new world of physics has been opened by ALICE:
  - DIPSY/Angantyr: "Microscopic extension of PYTHIA"
    - Can even challenge our AA paradigms (Pandora's box!)
  - QGP in small systems? (One fluid to rule them all?)
  - Something else?

Strangeness enhancement: Color rope explanation

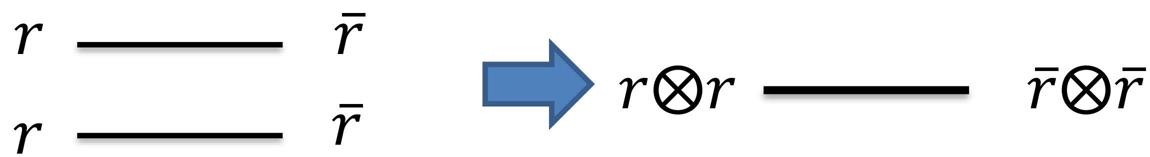




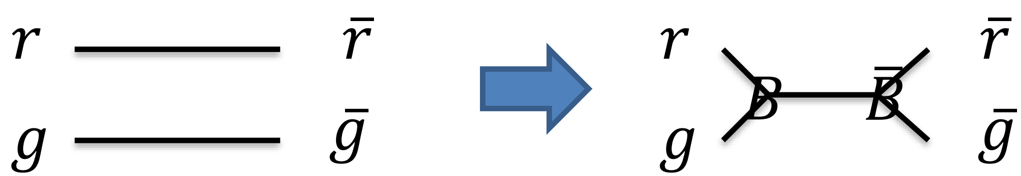
Picture from C. Bierlich
(string radii ~3.5 times too small!)

C. Bierlich, G. Gustafson, L. Lönnblad, A. Tarasov, JHEP 03 (2015) 148

String interactions: rope formation



String interactions: junction formation



- Increase strangeness and/or baryon production
  - Ropes have increased string tension $\rightarrow$ Produces more strangeness
  - Junctions produces more baryons
- Importantly: quarks and hadrons still produced together locally

Strangeness enhancement: EPOS explanation

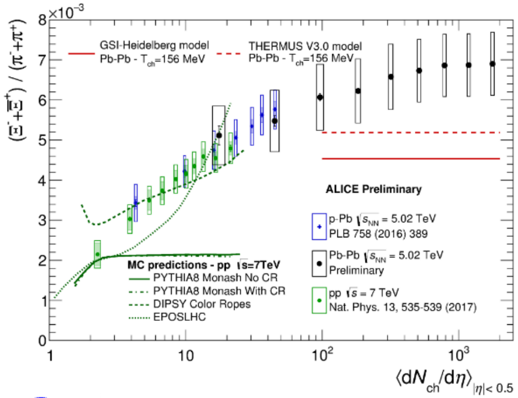
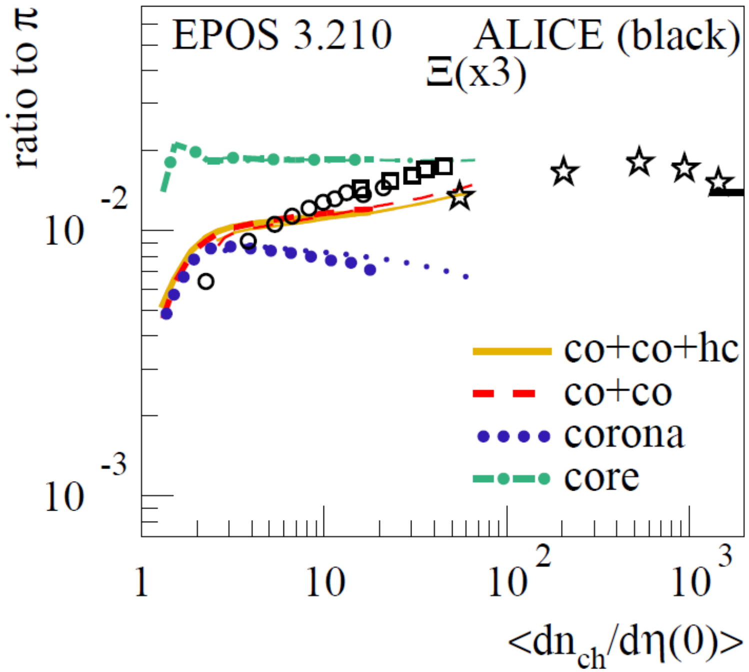
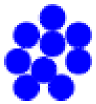


Figure from "QCD Challenges, ECT, Feb 2017, Klaus Werner"

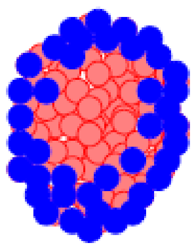


thick lines = pp (7TeV)
thin lines = pPb (5TeV)
circles = pp (7TeV)
squares = pPb (5TeV)
stars = PbPb (2.76TeV)



Low mult pp

High mult



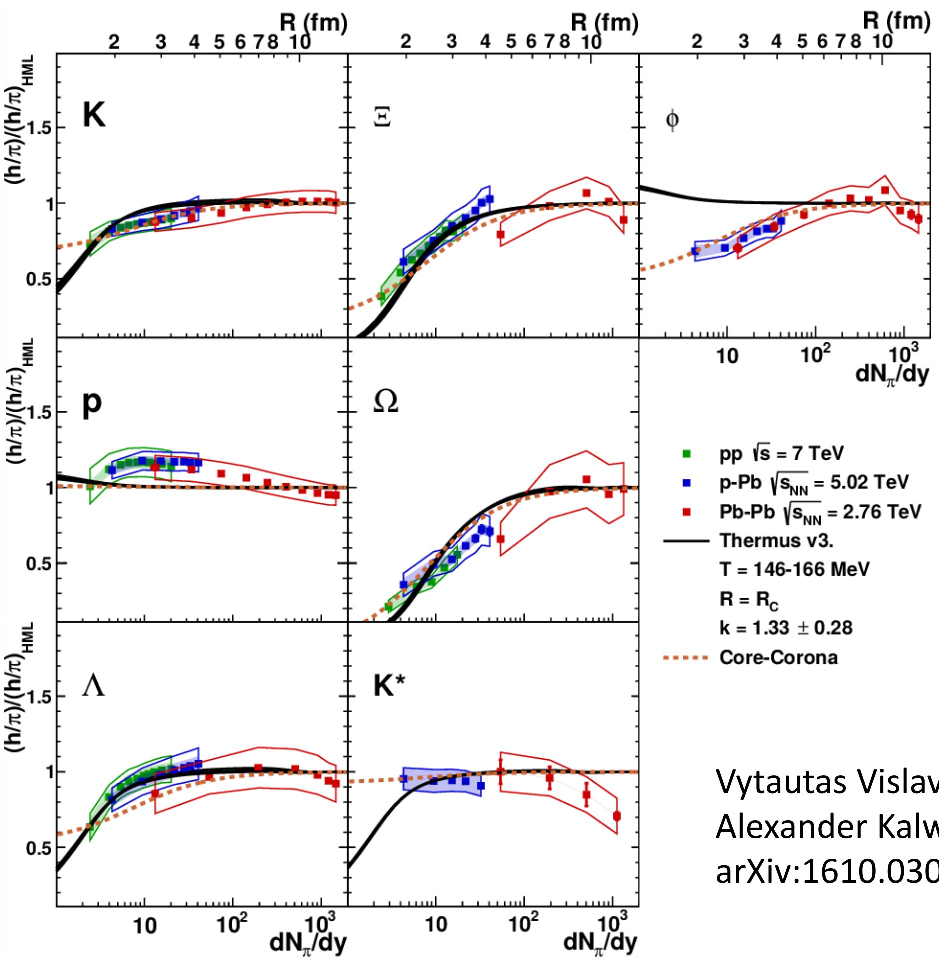
corona

core

Pictures from K. Werner

- Corona is more or less like basic PYTHIA
- Core is modelled as a QGP where particle production is described by grand canonical ensemble
  - Strangeness is produced thermally and only conserved globally

Strangeness enhancement: full thermal description



Vytautas Vislavicius,
Alexander Kalweit,
arXiv:1610.03001

Treat evolution as a change from canonical to grand canonical.
“Opposite” picture: strangeness suppressed in small system!

Qualitative picture

Similar pictures:
EPOS and PYTHIA agrees.
Thermal model has minor differences.

PYTHIA/pp models:
Local enhancement!

EPOS and thermal "agrees":
Enhancement is due to change from local to global conversation of strangeness (+ thermal prod. in EPOS).

Multiplicity

Qualitative picture

Similar pictures:
EPOS and PYTHIA agrees.
Thermal model has minor differences.

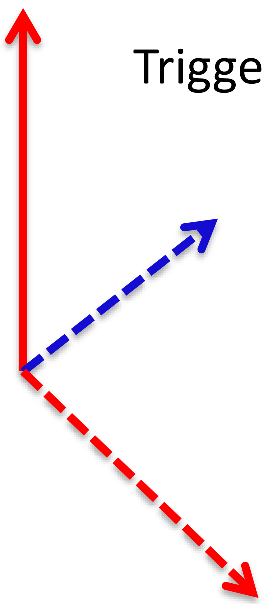
PYTHIA/pp models:
Local enhancement!

EPOS and thermal "agrees":
Enhancement is due to change from local to global conversation of strangeness (+ thermal prod. in EPOS).

Multiplicity

- But this is in some sense also directly related to also to question of deconfinement?
  - We want to observe that quarks are "free" in the QGP
  - I want to show you how we try to measure this
- Caveat: microscopic processes are local

Measure how strangeness is balanced in $\Delta\eta$, $\Delta\varphi$



Trigger on strangeness: $\Xi\ (ssd)$

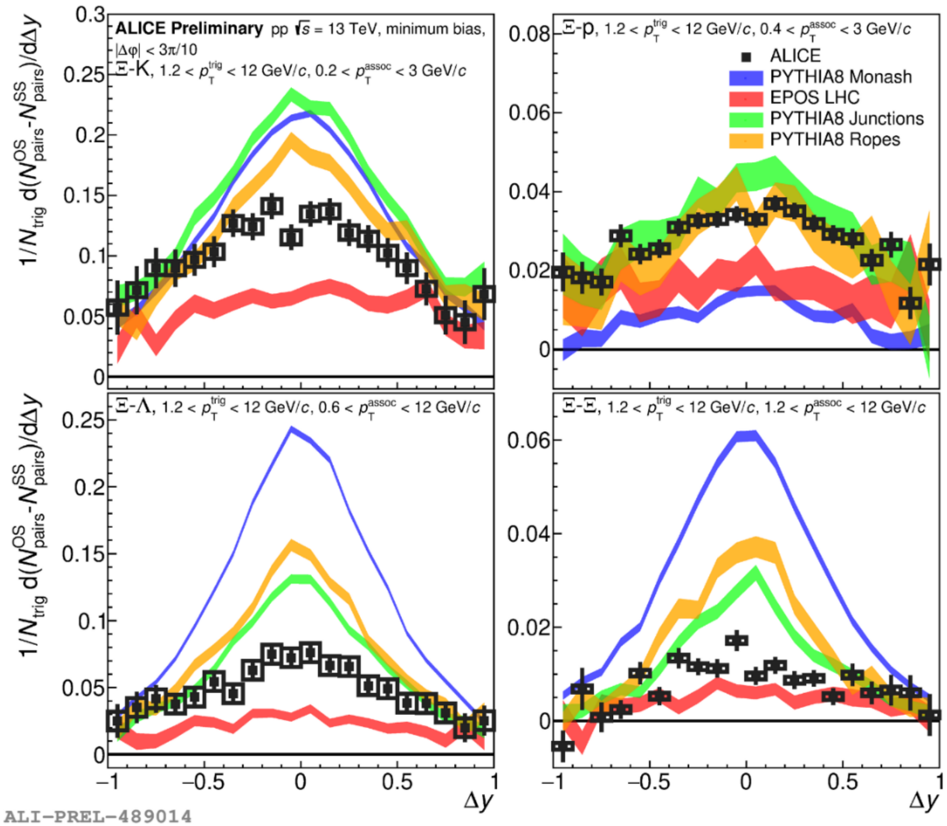
Measure where the anti-strangeness (baryon number, charge) that balances the strangeness ends up:
$K^+\ (u\bar{s}), \bar{p}\ (\bar{u}\bar{u}\bar{d}), \bar{\Lambda}\ (\bar{u}\bar{d}\bar{s}), \bar{\Xi}\ (\bar{s}\bar{s}\bar{d})$

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

Results near side (after subtraction of uncorrelated production)

Ξ-K

Ξ-p



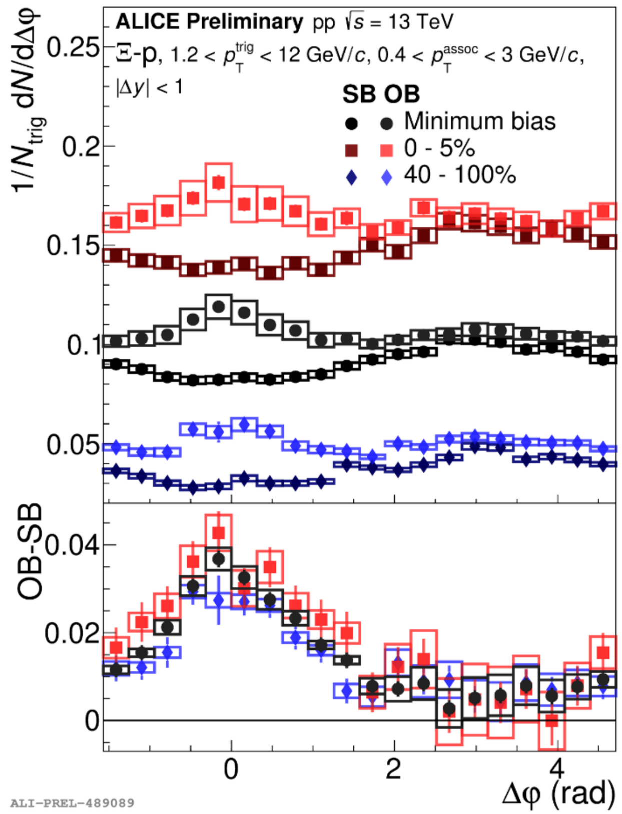
Ξ-Λ

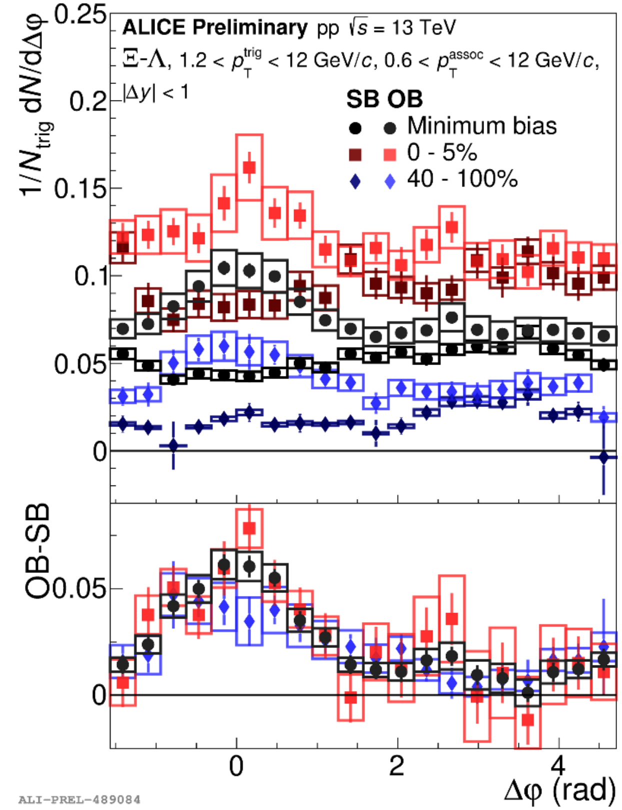
Ξ-Ξ

- Normal strings are disfavoured as main production mechanism
- Junctions describes well protons but not so well Λ and Ξ
- EPOS LHC (QGP) limit: no microscopic picture of deconfinement.
    - A feature (grand canonical limit postulates this – only correlations are from resonance decays)

Little or no multiplicity dependence

Ξ-p





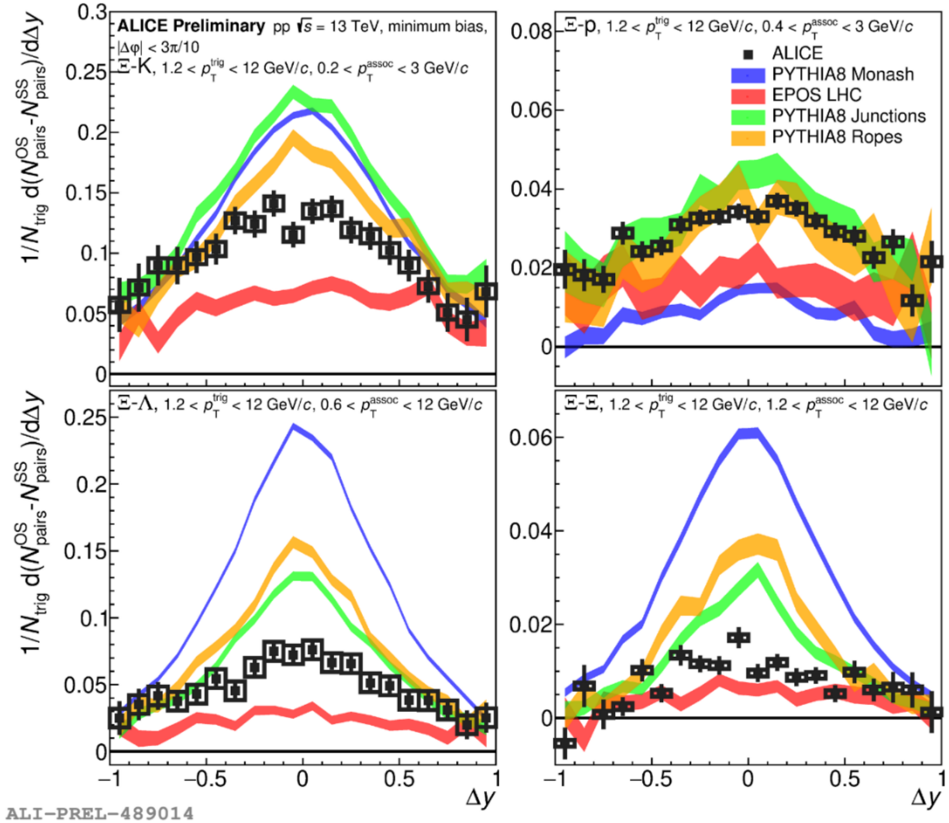
Ξ-Λ

- No strong signals for change in production mechanism or increasing diffusion
  - In some sense goes against all models… (?)

Results (near side) *continued*

Ξ-K

Ξ-Λ



Ξ-p

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

Ξ-Ξ

- Normal strings are disfavoured as main production mechanism
- Junctions describes well protons but not so well Λ and Ξ
- **IF we want to be able to test QGP in small systems directly with data on similar terms as we can test PYTHIA (and other pp generators)**
  - **THEN we need to develop a microscopic model of QGP deconfinement**

Insights from CLASH and outlook

- Original idea: microscopic (PYTHIA++) vs macroscopic (QGP)

Insights from CLASH and outlook

- Original idea: microscopic (PYTHIA++) vs macroscopic (QGP)

- Main insights:
  - Microscopic is misleading because strings are macroscopic objects and we need microscopic QGP models to describe small systems
  - Lund string model is "confined" meaning that most soft quarks are created together with the hadrons
    - This is the much bigger difference IMO
  - We need in the AA community to develop small system QGP generators. Only way we can make comparison between "pp" and "AA" descriptions that are apples-to-apples!
    - Some local ideas presented at "Offshell-2021" (with Sumit Basu, Alice Ohlson, and David Silvermyr): https://arxiv.org/abs/2110.05134
    - Ideas for Run 3&4 measurements!

Insights from CLASH and outlook

- Original idea: microscopic (PYTHIA++) vs macroscopic (QGP)

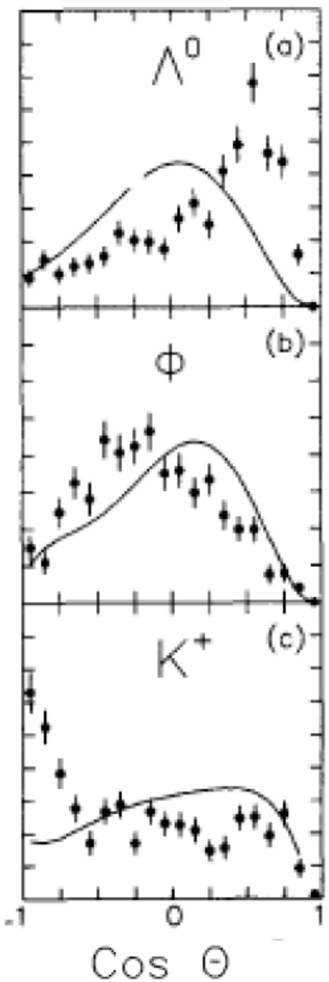
- Main insights:
  - Microscopic is misleading because strings are macroscopic objects and we need microscopic QGP models to describe small systems
  - Lund string model is “confined” meaning that most soft quarks are created together with the hadrons
    - This is the much bigger difference IMO
  - We need in the AA community to develop small system QGP generators. Only way we can make comparison between “pp” and “AA” descriptions that are apples-to-apples!
    - Some local ideas presented at “Offshell-2021” (with Sumit Basu, Alice Ohlson, and David Silvermyr): https://arxiv.org/abs/2110.05134
    - Ideas for Run 3&4 measurements!

Thank You!

Backup

Strangeness correlations / confinement: an old idea

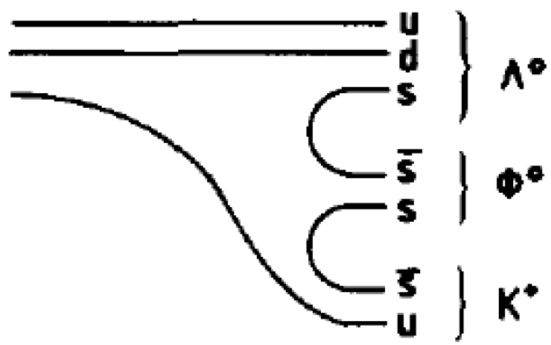
Phys.Lett. 163B (1985), 267



Solid lines are calculations for isotropic phasespace

EVIDENCE FOR POMERON SINGLE-QUARK INTERACTIONS IN PROTON DIFFRACTION AT THE ISR

R608 Collaboration



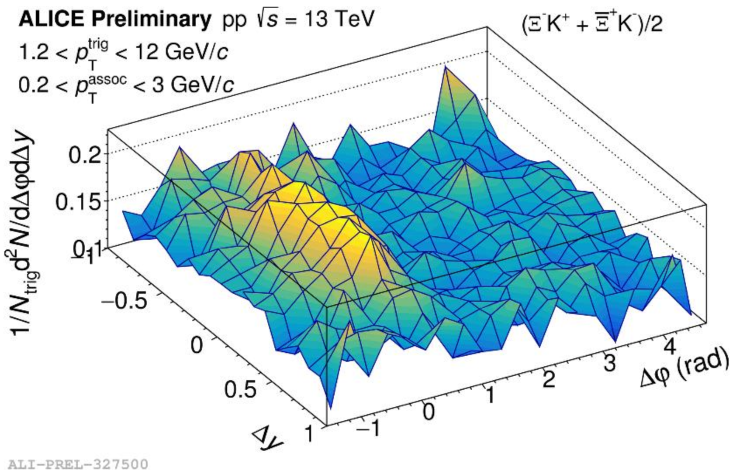
In pp collisions we can ask the question:
Where is the anti-strangeness (strangeness) associated with production of Ξ^-/ssd ($\Xi^+/\bar{s}\bar{s}\bar{d}$) recovered?

PYTHIA/Angantyr: expect strangeness to be recovered locally (as shown to the left).

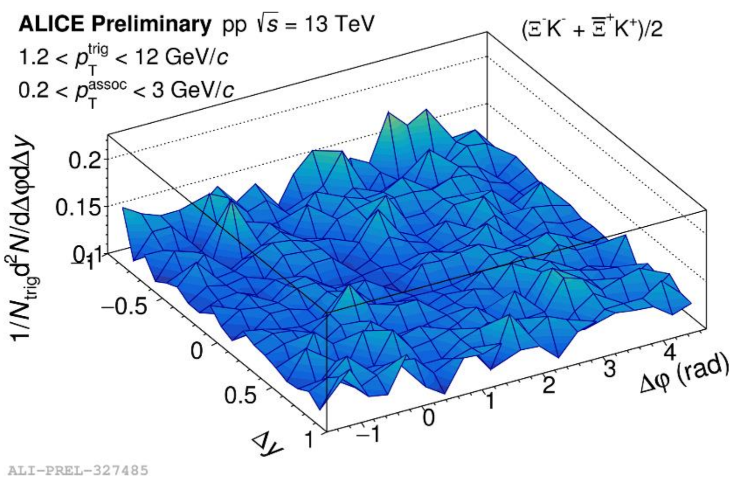
EPOS LHC: expect strangeness enhancement to be associated with a grand canonical (global) reservoir. Microscopic picture?

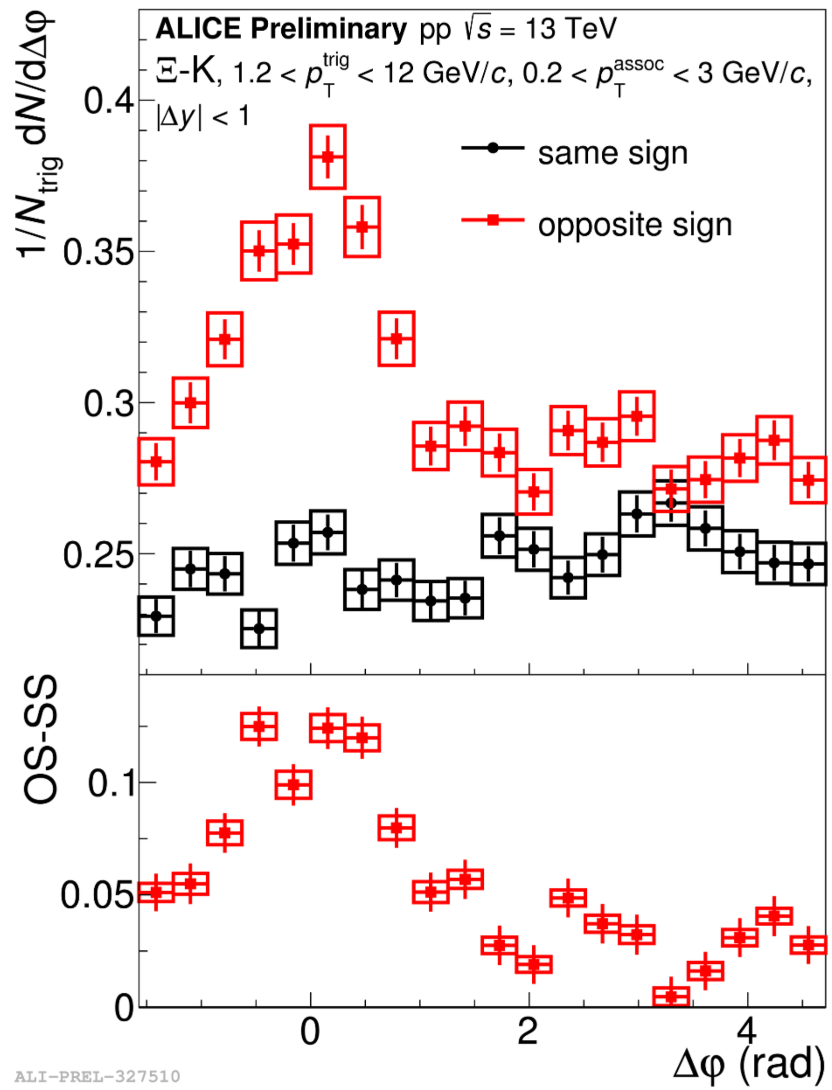
How do we measure that: Ξ-K correlation functions

Opposite sign (OS), e.g., $\Xi^-/ssd - K^+/\bar{s}u$

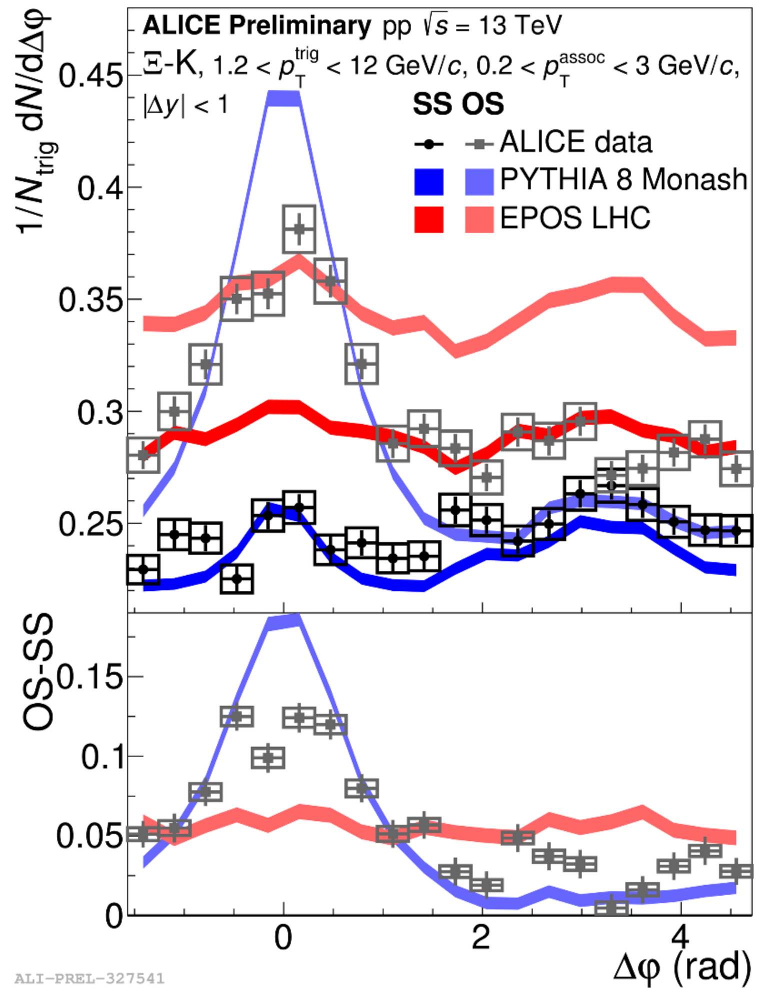


Same sign (SS), e.g., $\Xi^-/ssd - K^-/\bar{u}s$



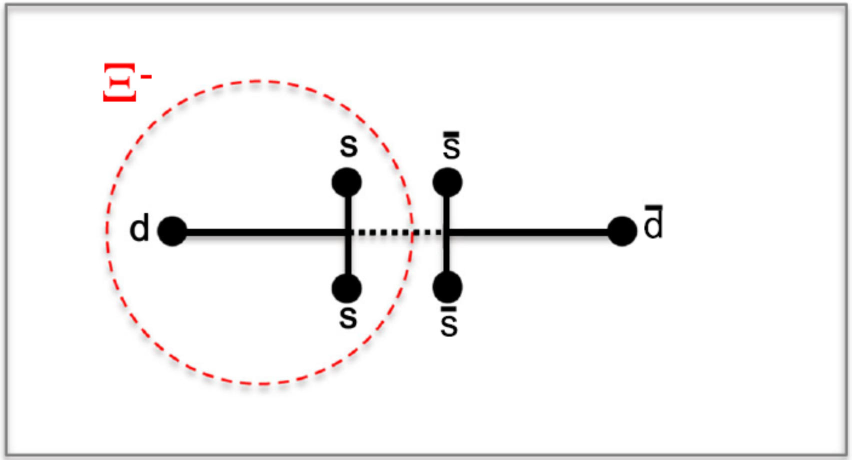


Ξ- K correlation functions

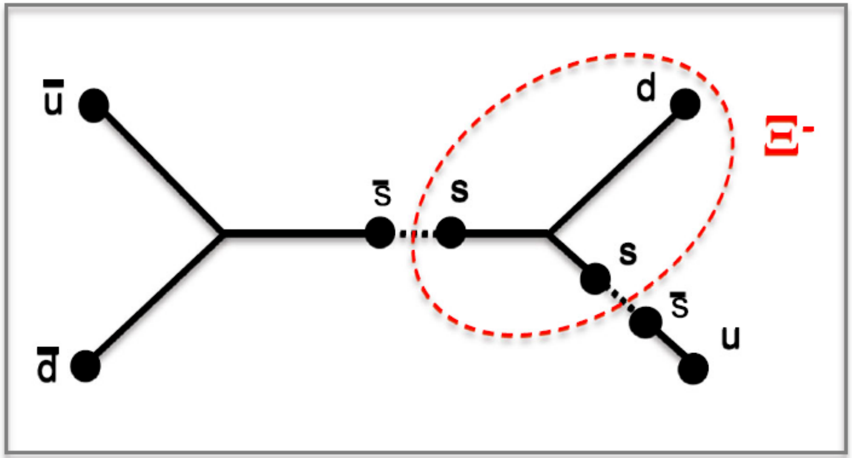


- EPOS LHC (QGP) limit: no microscopic picture of deconfinement.
- This is as I understand it a feature (grand canonical limit postulates this – only correlations are from resonance decays)

"Confinement" of baryon number in Lund strings



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



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"