Swedish activities in ALICE

Peter Christiansen, Alice Ohlson, David Silvermyr
Lund University

Partikeldagarna 2022, Lund

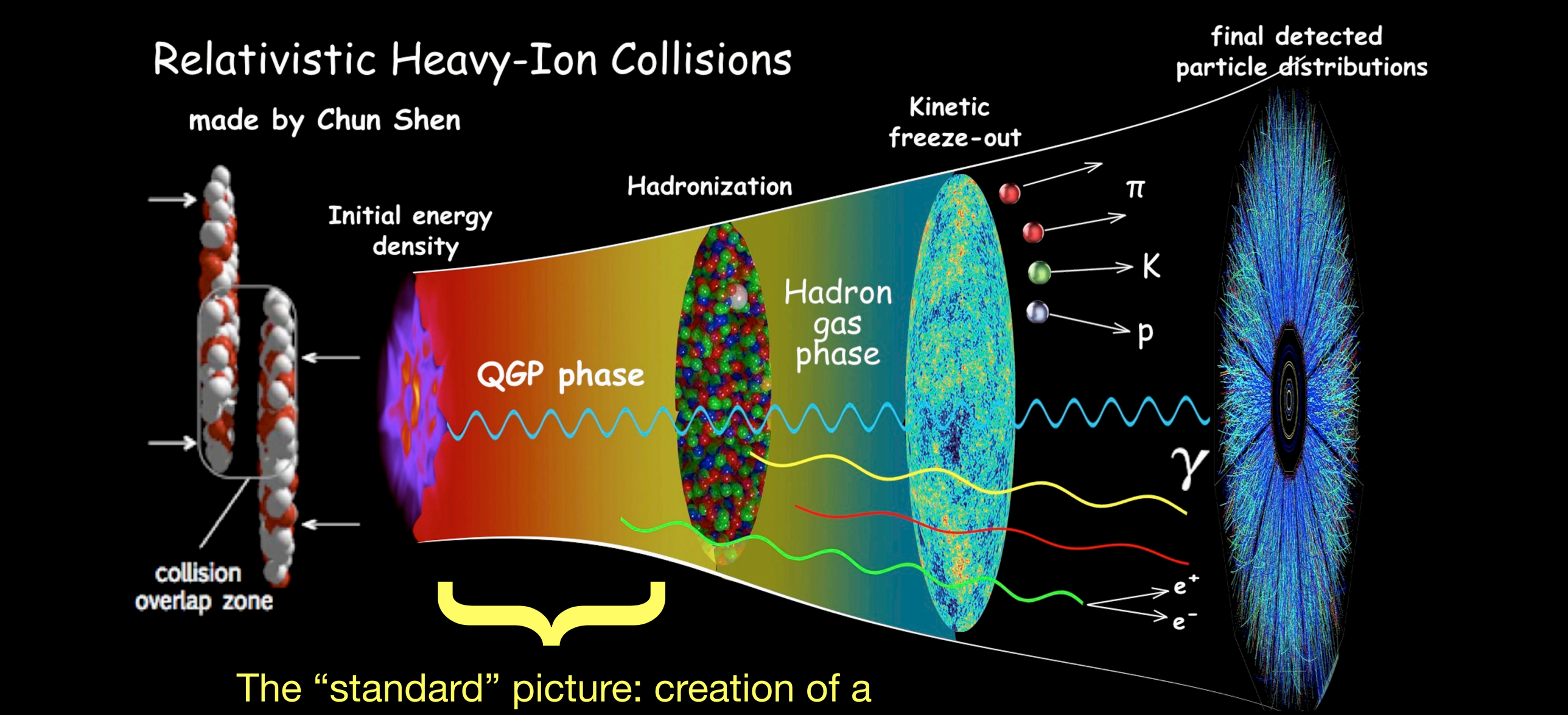
The Lund ALICE group: Heavy-ion physics in Sweden 🇸🇪

- 3 seniors
  - Peter Christiansen, Alice Ohlson, David Silvermyr
    + emeriti: Anders Oskarsson, Ingvar Otterlund, Evert Stenlund
- 2 postdocs
  - Sumit Basu, Vytautas Vislavicius
- 4 PhD students
  - Oliver Matonoha, Adrian Nassirpour, Joey Staa,
    Omar Vazquez Rueda (defended 10/6)
    + 3 more arriving soon!
- Main activity: Analyzing p+p and Pb+Pb collisions with ALICE at the LHC
- Individuals also work on detector R&D for ILC, ESS, ESSvSB, sPHENIX

SQM2022

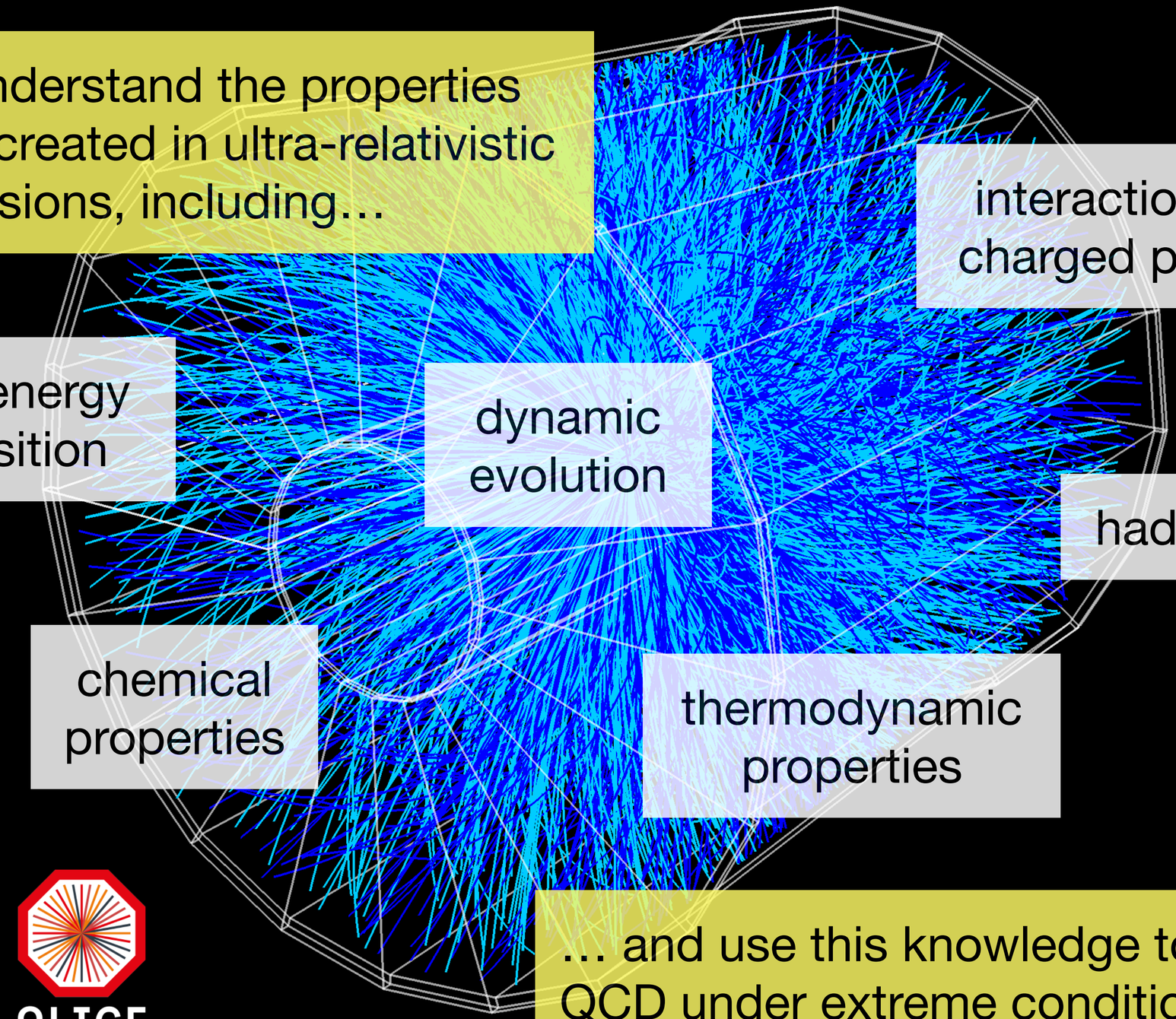
The 20th International Conference on Strangeness in Quark Matter
13-17 June 2022 Busan, Republic of Korea

https://sqm2022.pusan.ac.kr/



The “standard” picture: creation of a hot, dense, deconfined state of matter
→ the **Quark-Gluon Plasma (QGP)**

Our goal: to understand the properties of the system created in ultra-relativistic heavy-ion collisions, including…



interactions of charged probes

initial energy deposition

dynamic evolution

hadronization

chemical properties

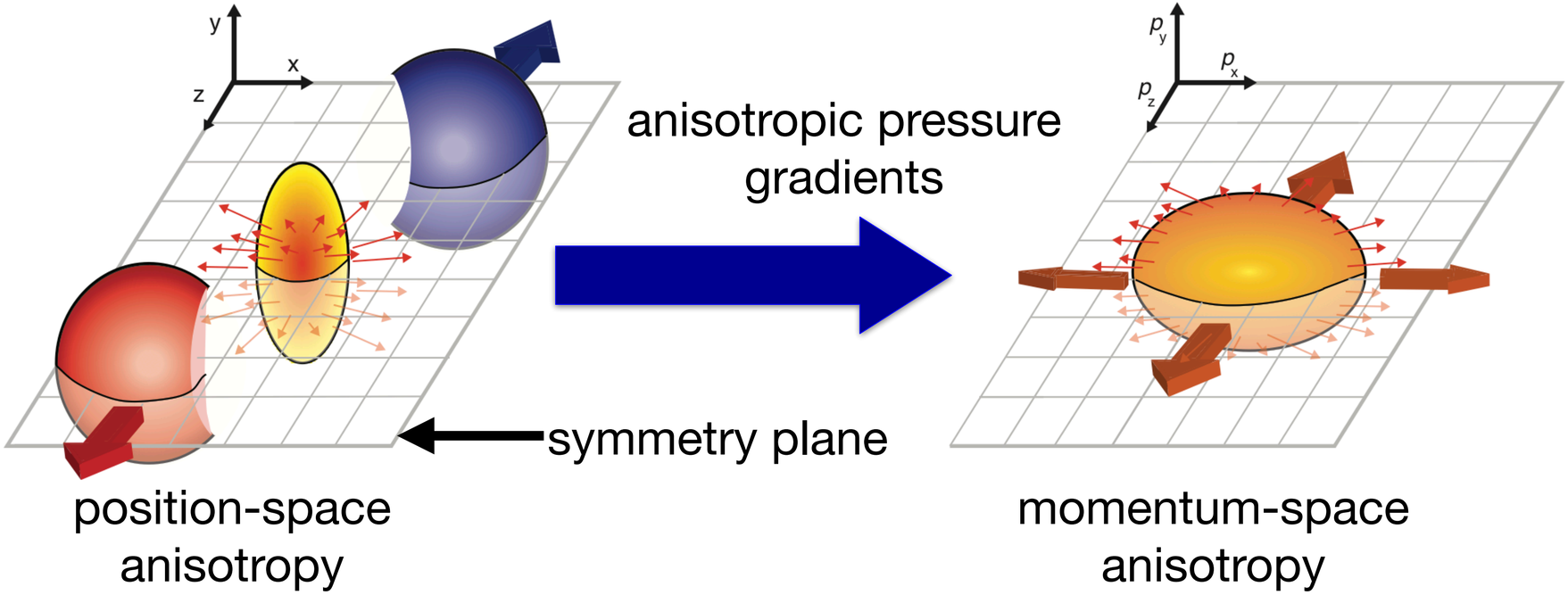
thermodynamic properties

ALICE

… and use this knowledge to understand QCD under extreme conditions

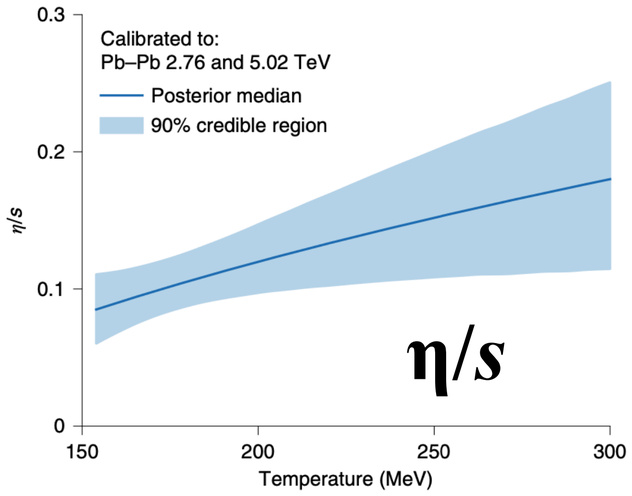
How does the system geometry evolve?

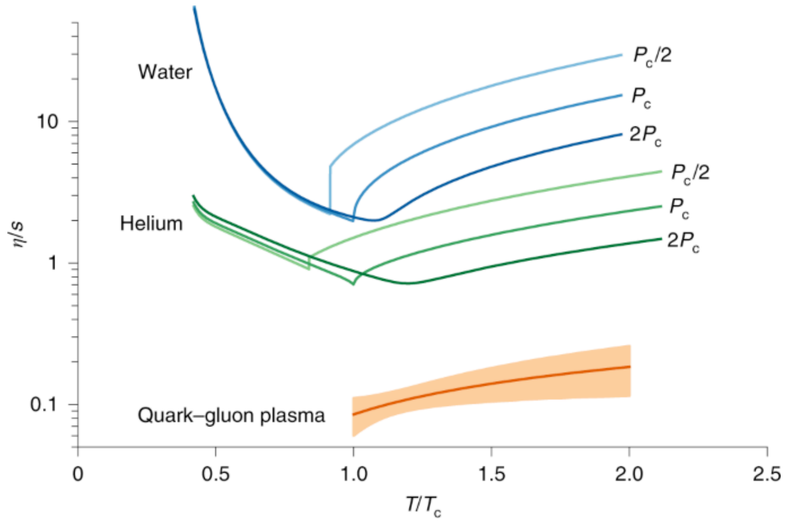
- Isotropic expansion: radial flow
  - Pressure gradients build up in the fireball → boost particles in the radial direction, indicated by an increase in $\langle p_T \rangle$
- Anisotropic expansion: elliptic (v_2), triangular (v_3), quadrangular flow (v_4),…

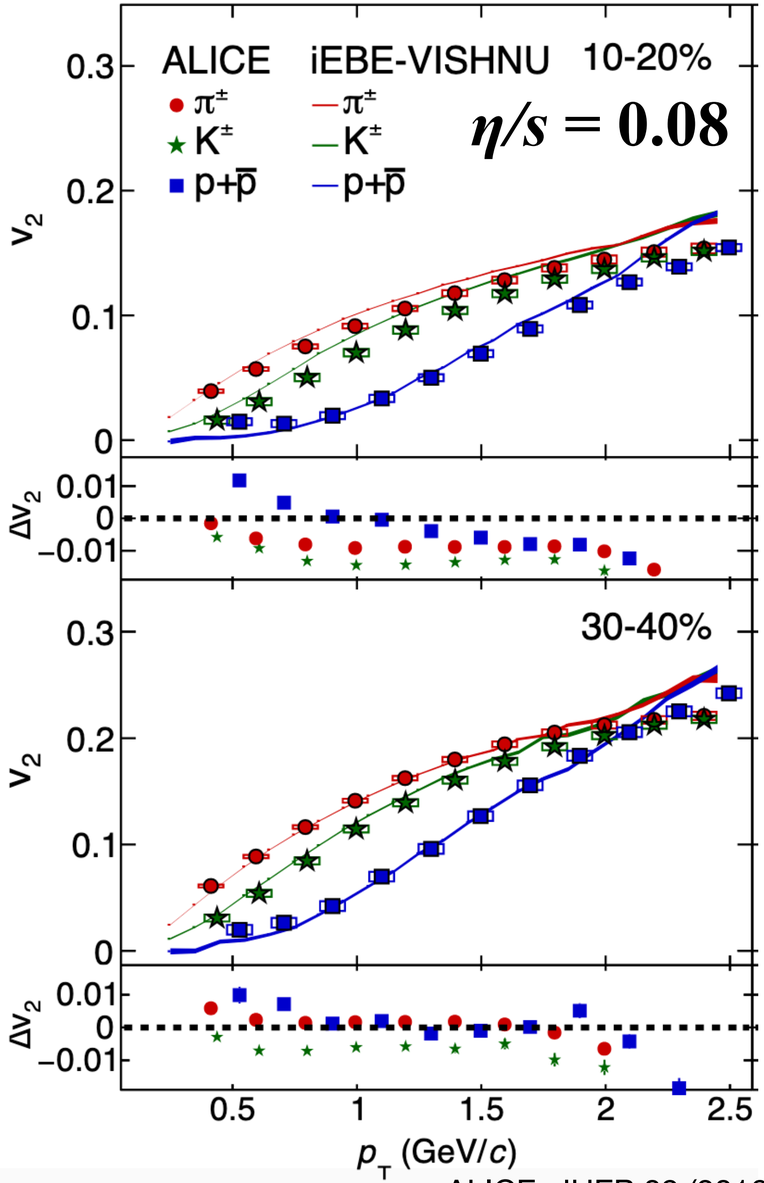


What are the thermodynamic properties of the QGP?

- v_n coefficients are sensitive to the initial state and properties of the QGP (η/s, ζ/s)
  - measurements are well described by a hydrodynamic description
  - viscosity very close to the quantum lower bound
- QGP is the “perfect liquid”







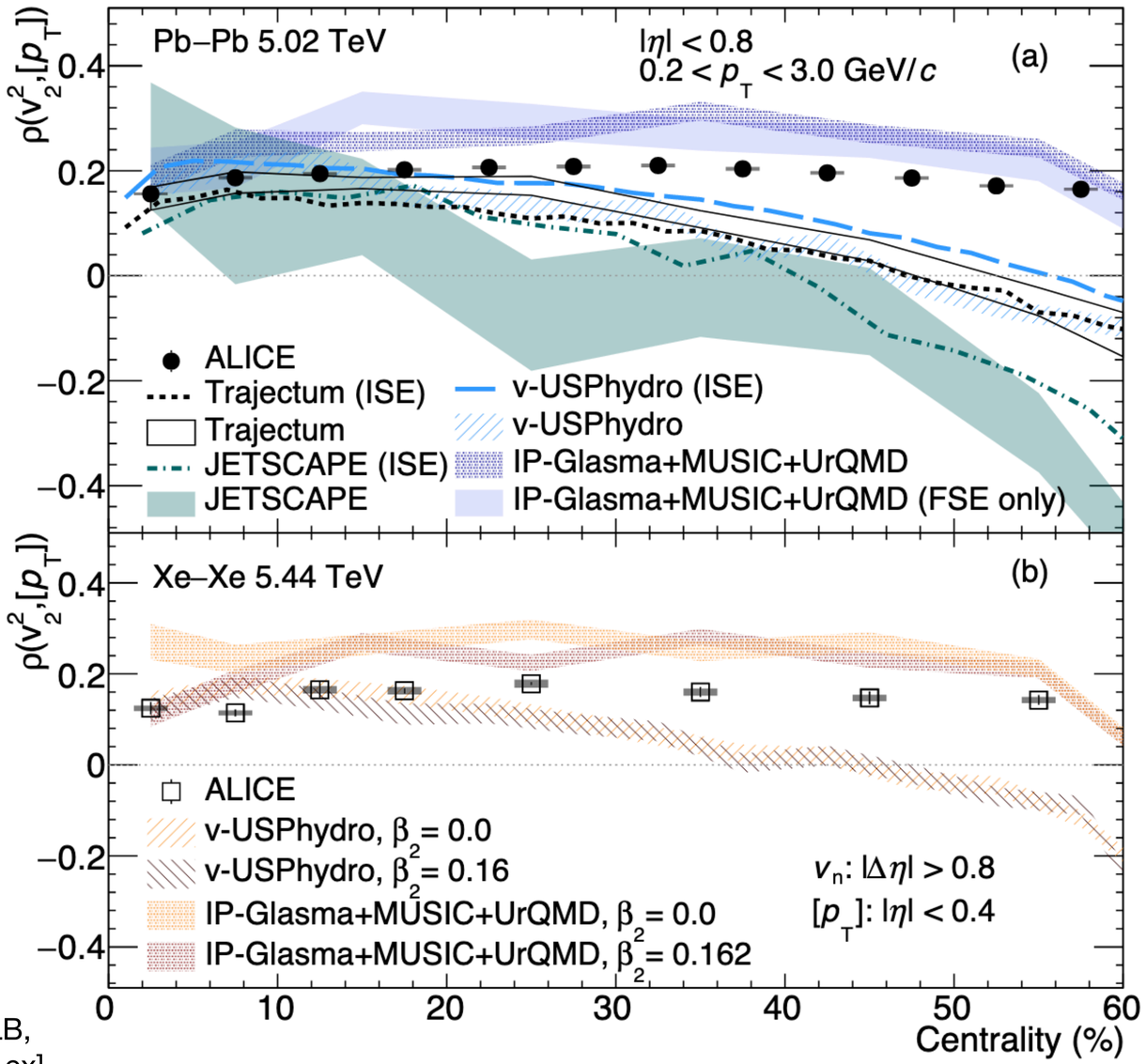
J. E. Bernhard, J. S. Moreland, S. A. Bass, Nature Physics 15 (2019) 1113
J. S. Moreland, J. E. Bernhard, S. A. Bass, PRC 101 (2020) 024911, arXiv:1808.02106 [nucl-th]
Similar analyses from Trajectum [PRL 126 (2021) 202301, arXiv:2010.15130], JETSCAPE [PRL 126 (2021) 242301, arXiv:2010.03928]

ALICE, JHEP 09 (2016) 164, arXiv:1606.06057 [nucl-ex]

What does the initial state look like?

- We can go beyond measuring v_2, v_3, v_4,…
- Correlations between flow harmonics can untangle interplay between initial state and hot nuclear matter effects
- Ex. correlation between radial flow and elliptic flow

$$\rho_n\left(v_n^2, \langle p_T \rangle\right) = \frac{\mathrm{cov}\left(v_n^2, \langle p_T \rangle\right)}{\sqrt{\mathrm{var}\left(v_n^2\right)}\sqrt{\mathrm{var}\left(\langle p_T \rangle\right)}}$$

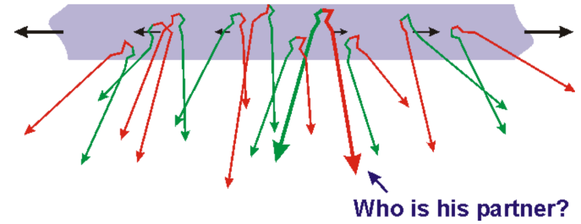


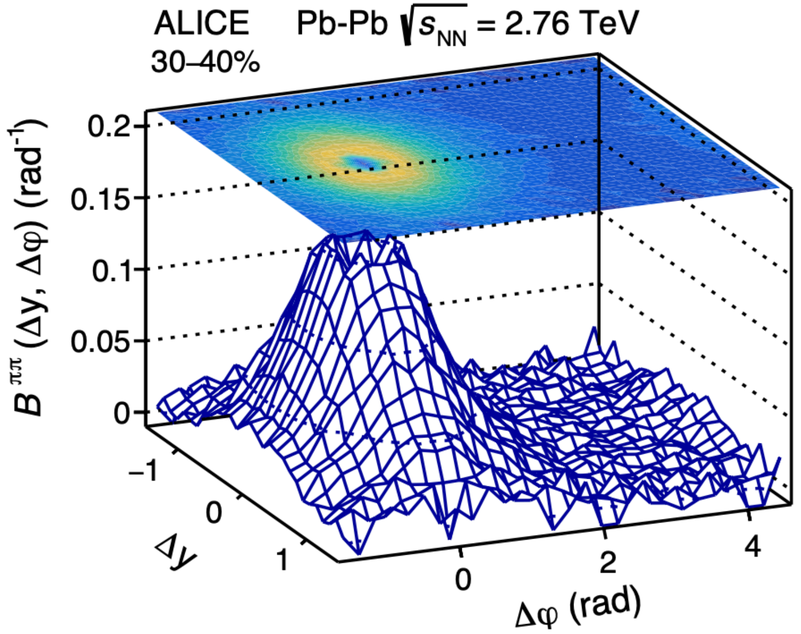
ALICE, submitted to PLB, arXiv:2111.06106 [nucl-ex]

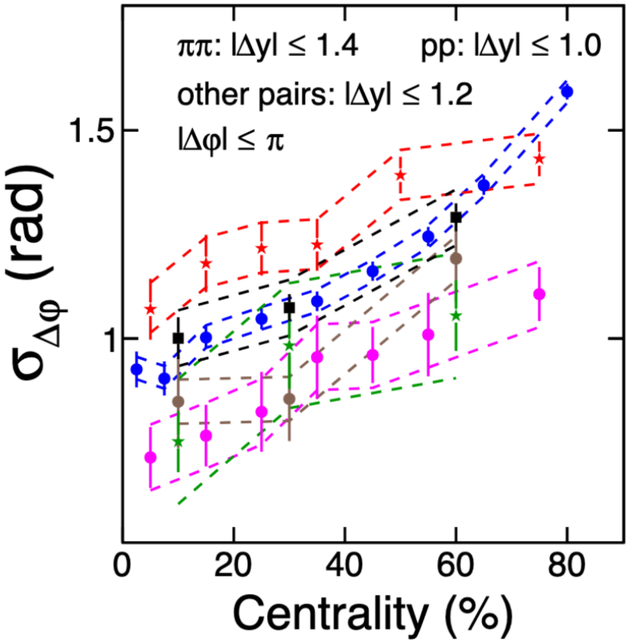
S. Basu

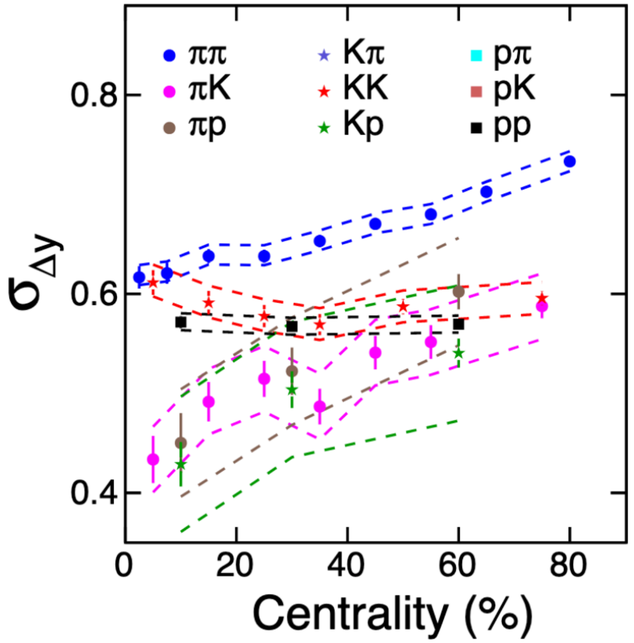
How are charges produced and dissociated?

- Balance functions: correlation functions indicate where balancing charges end up in ($\Delta\varphi$, $\Delta\eta$)









- Increasing width in $\Delta\varphi$ → a signature of radial flow

- Increasing width in $\Delta\eta$ for pions, constant for kaons → potential indication of a two-stage production of u,d quarks compared to s quarks

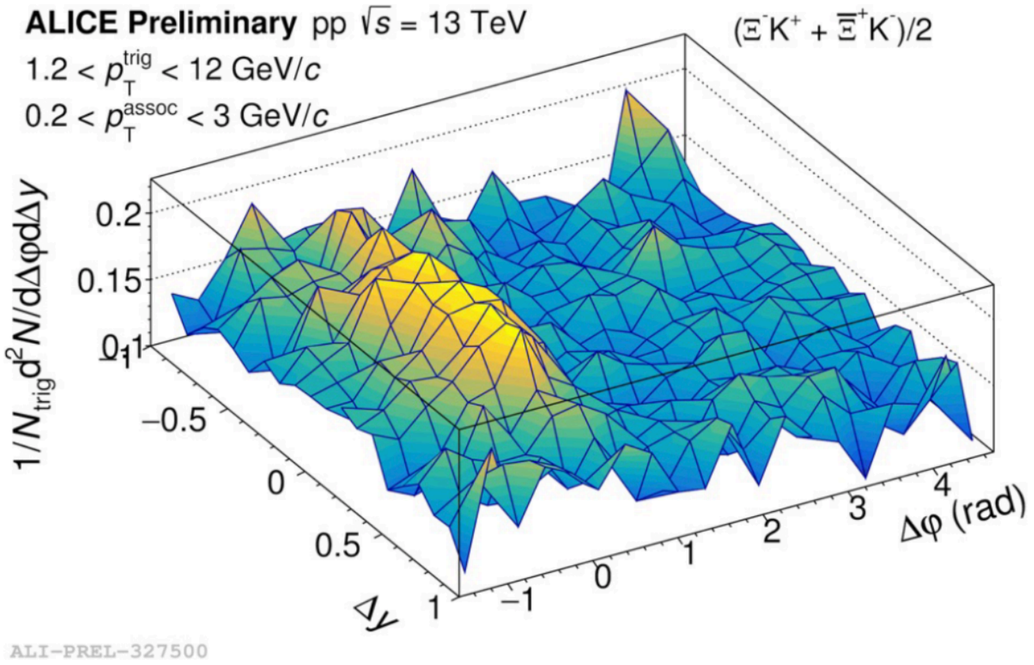
ALICE, submitted to PLB, arXiv:2110.06566 [nucl-ex]

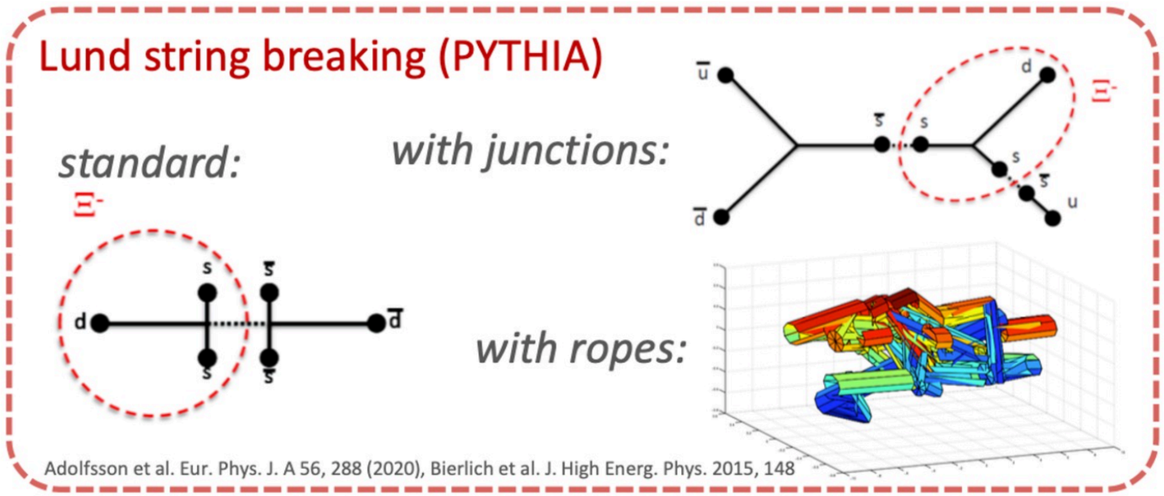
How is strangeness produced in p+p?

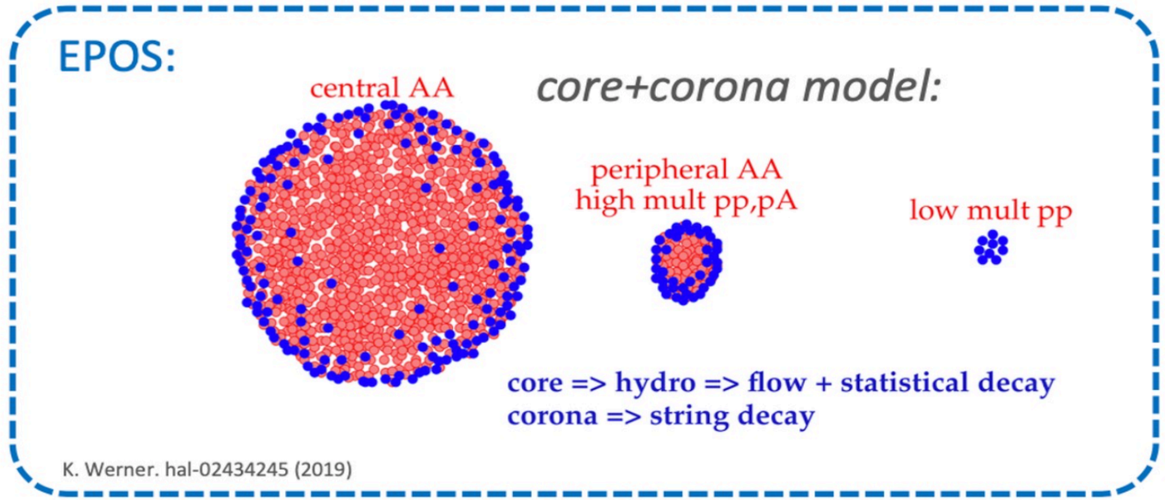
J. Adolfsson

ALICE Thesis Award 2021

- Balance functions: correlation functions indicate where balancing charges end up in ($\Delta\varphi$, $\Delta\eta$)







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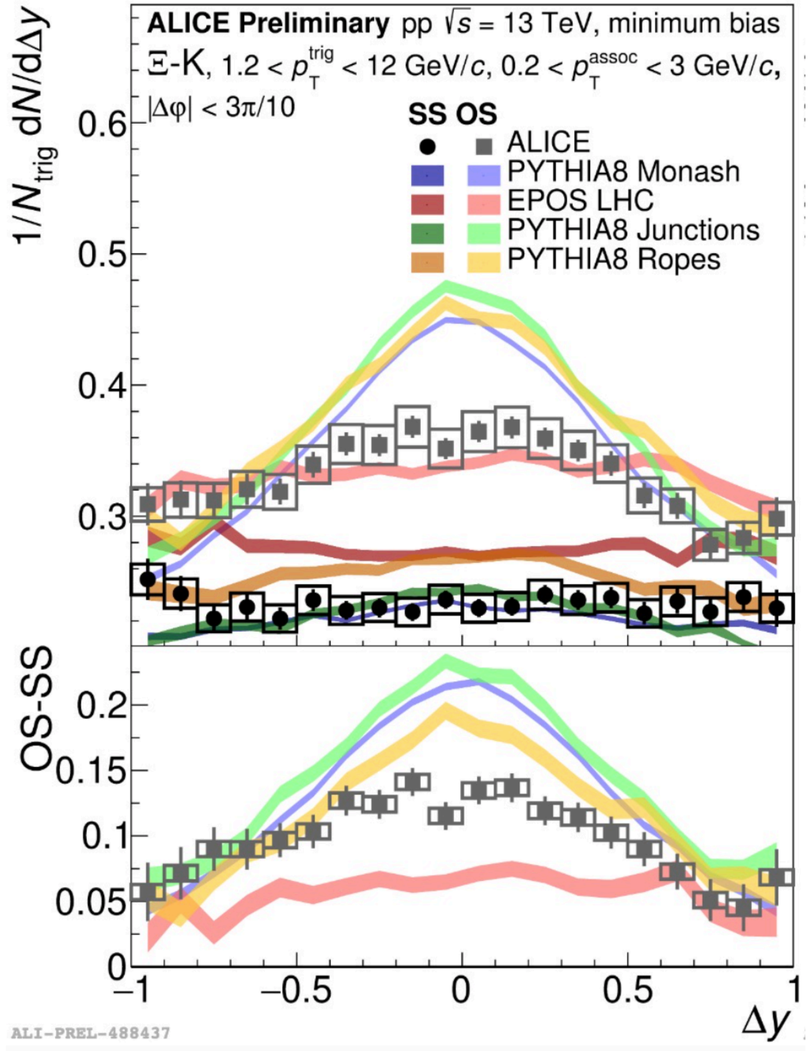
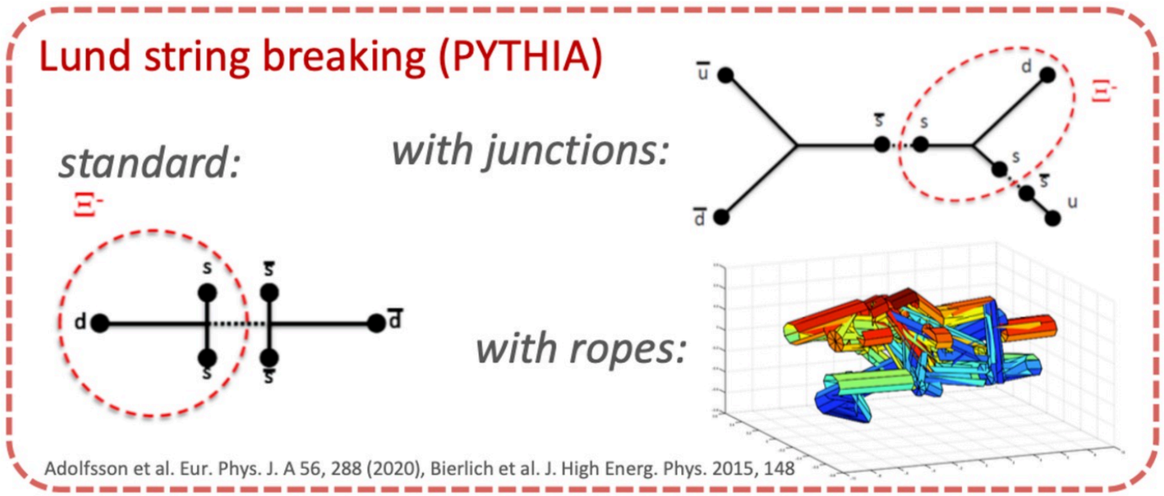
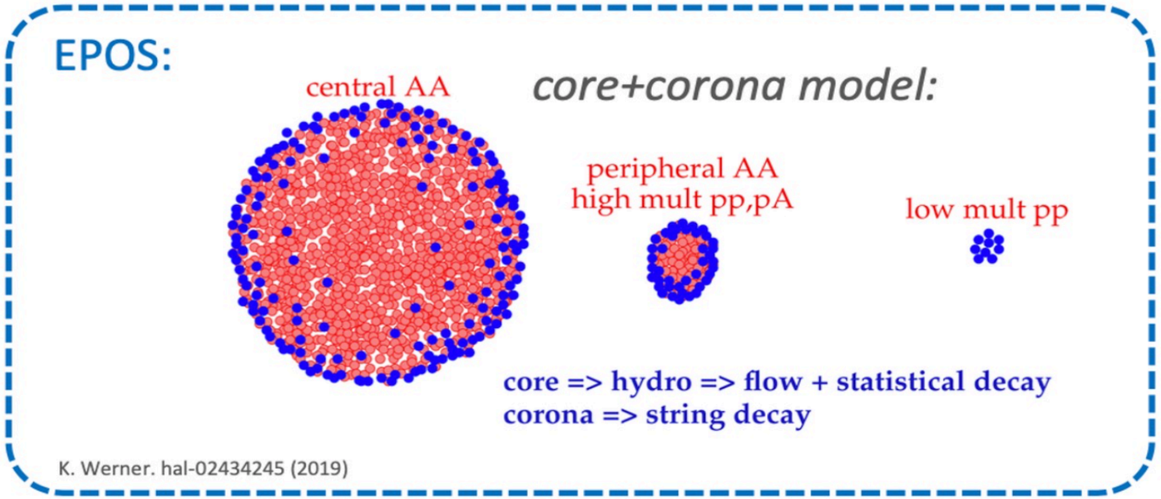




Adolfsson et al. Eur. Phys. J. A 56, 288 (2020), Bierlich et al. J. High Energ. Phys. 2015, 148



K. Werner. hal-02434245 (2019)

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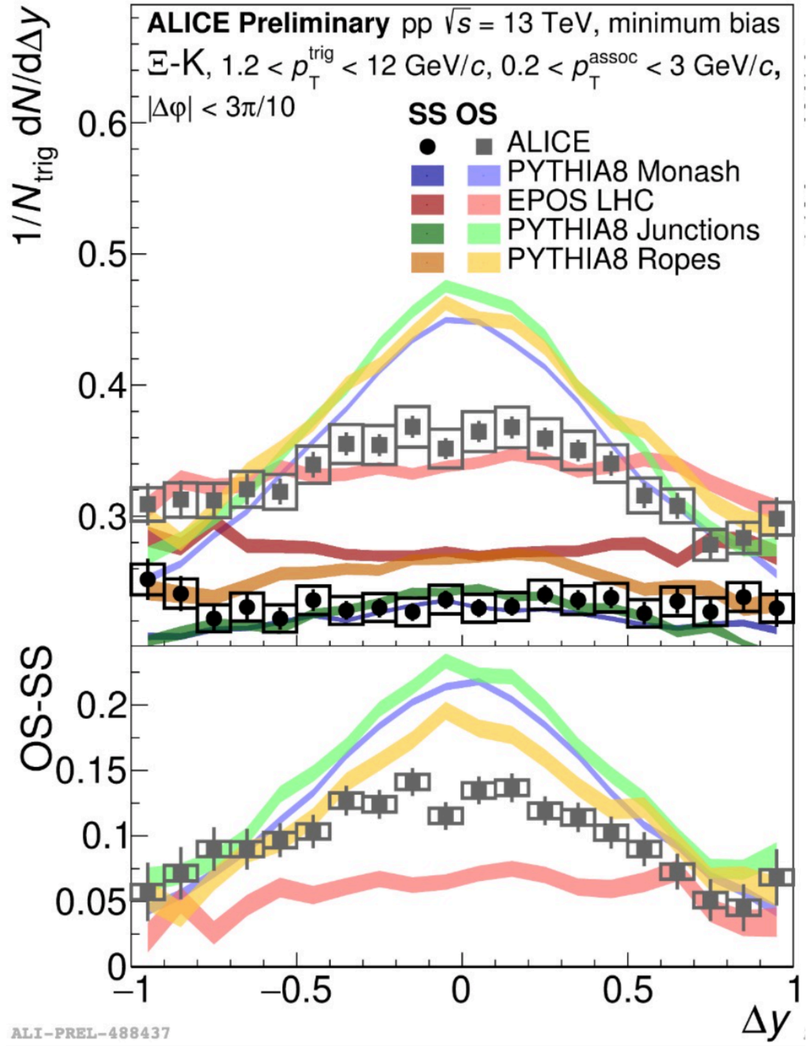
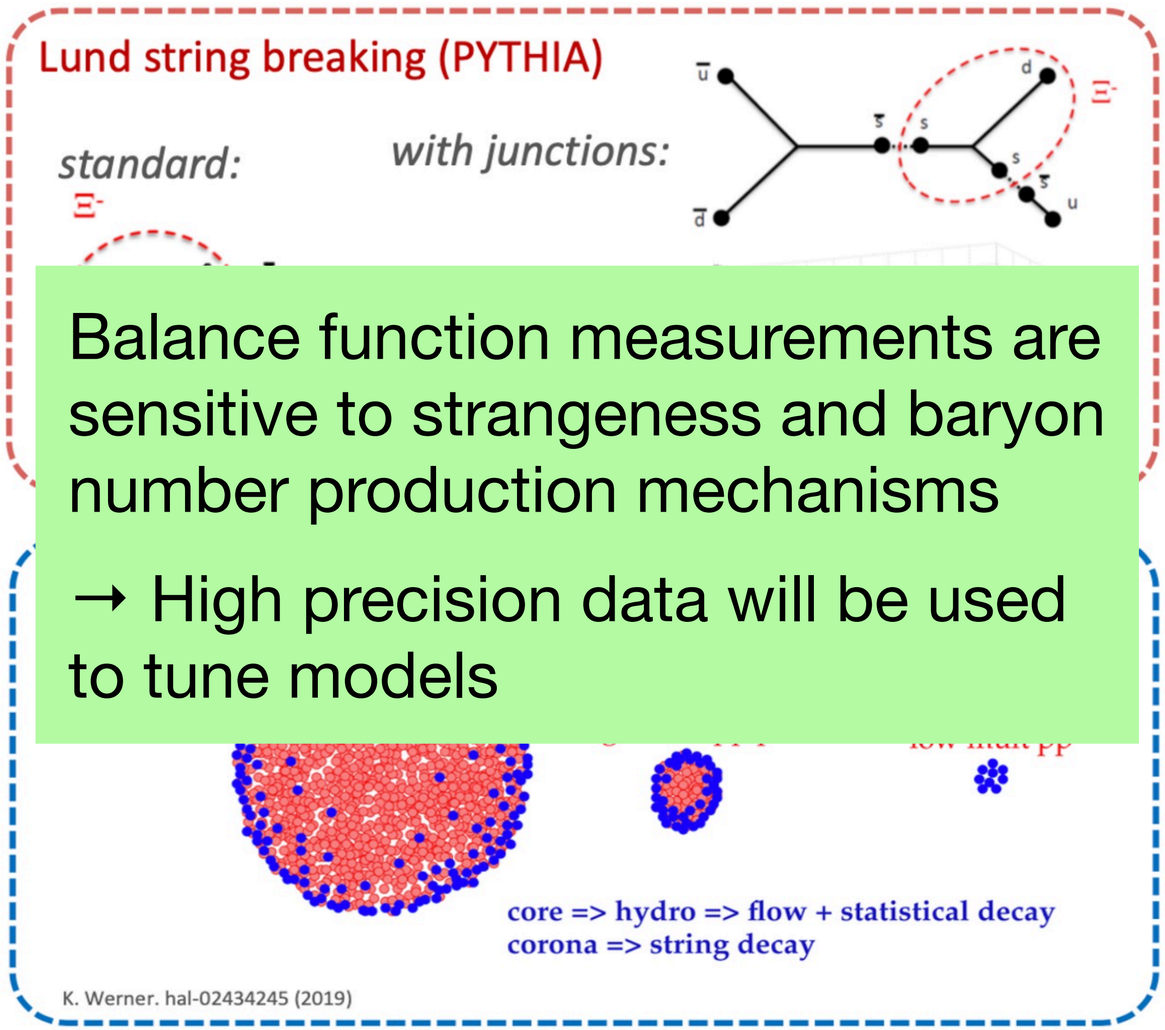


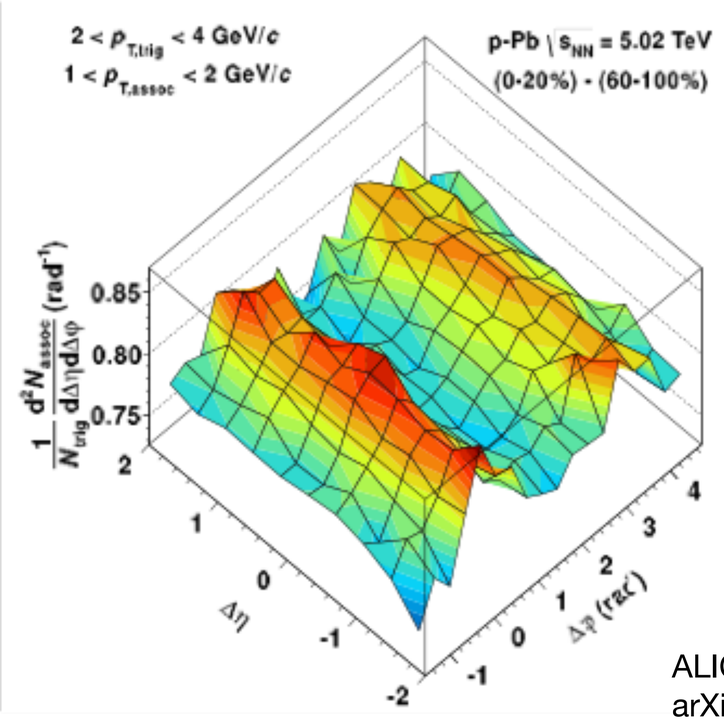


Balance function measurements are sensitive to strangeness and baryon number production mechanisms

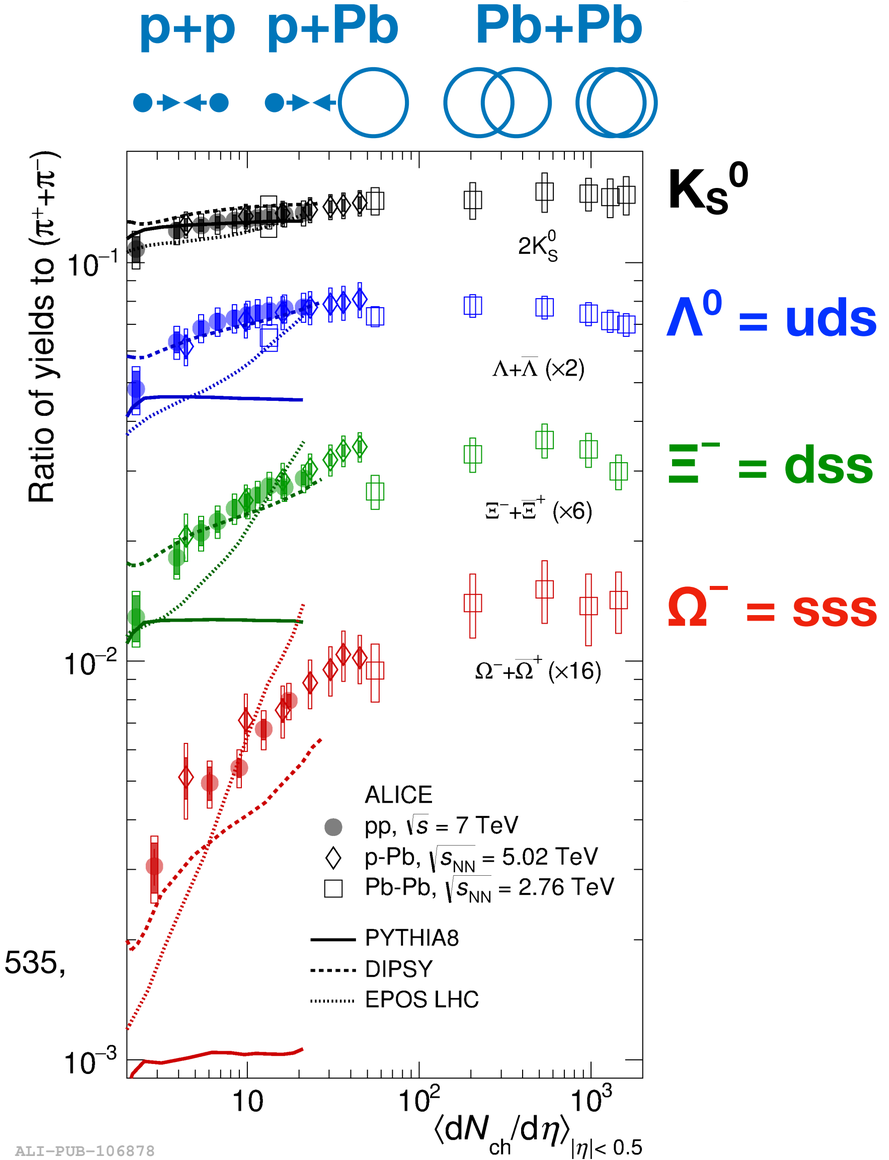
→ High precision data will be used to tune models

QGP-like signals in p+p collisions!

- Signatures, thought to be indicative of QGP formation, also observed in p+p and p+Pb collisions:
  - Enhancement of strange particle yields (w.r.t. pions) with multiplicity
  - Long-range correlations in Δη, looks like flow (v_n)



ALICE, PLB 719 (2013) 29,
arXiv: 1212.2001 [nucl-ex]



K_S^0

Λ^0 = uds

Ξ^- = dss

Ω^- = sss

ALICE, Nature Physics 13 (2017) 535,
arXiv: 1606.07424 [nucl-ex]

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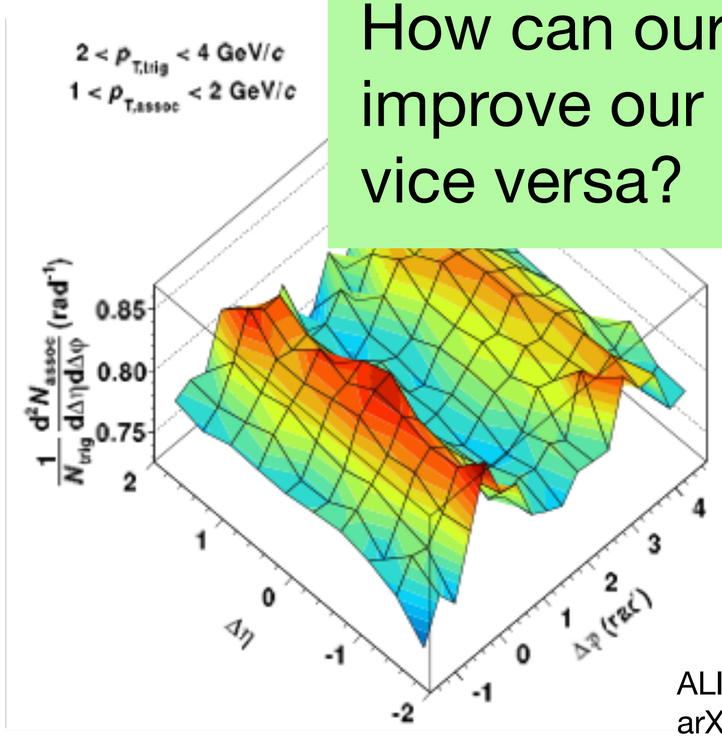
How can our knowledge of heavy-ion collisions improve our understanding of p+p physics, and vice versa?



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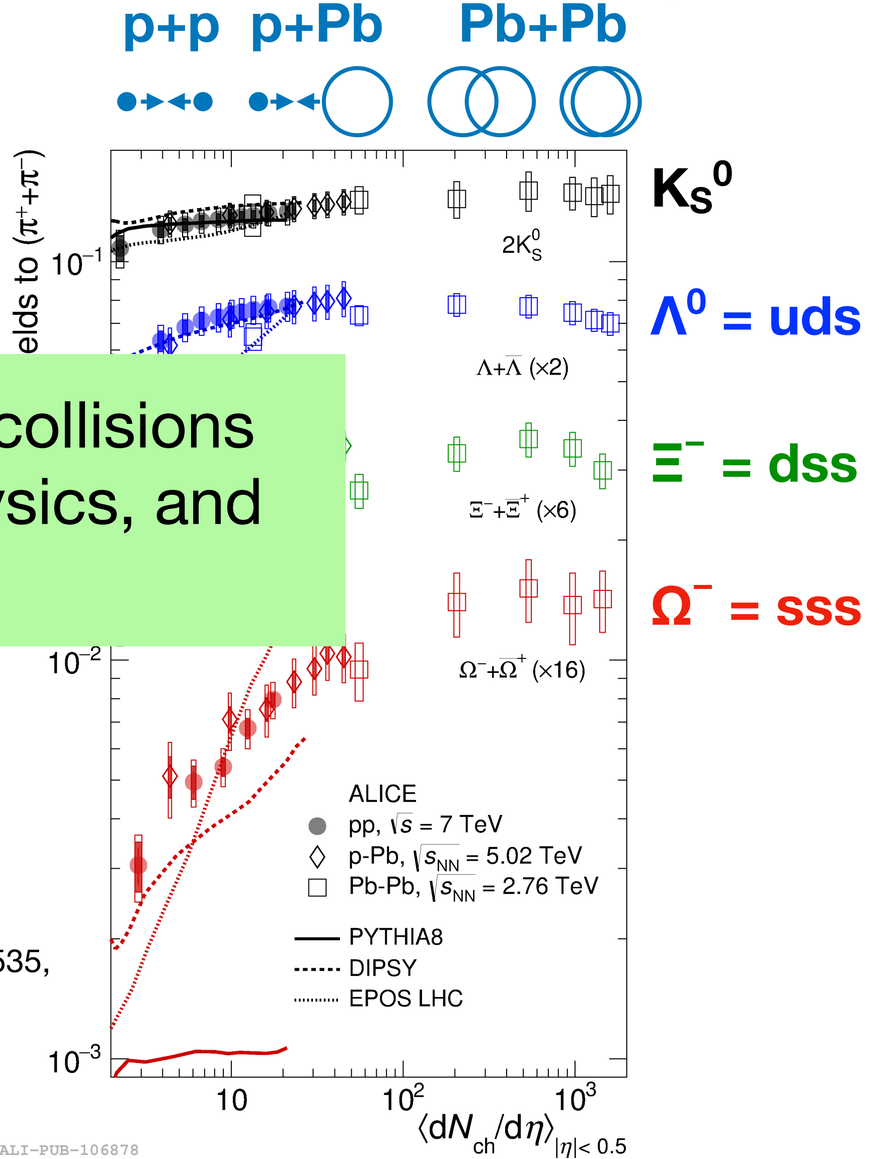

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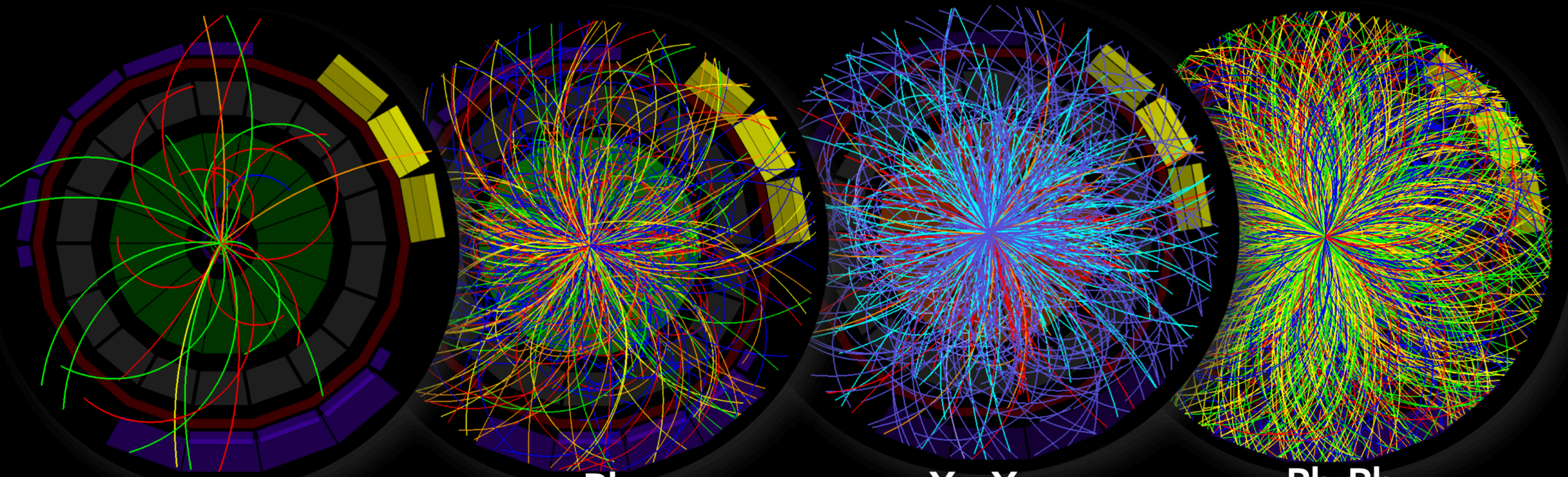
From large to small systems…



pp
13 TeV

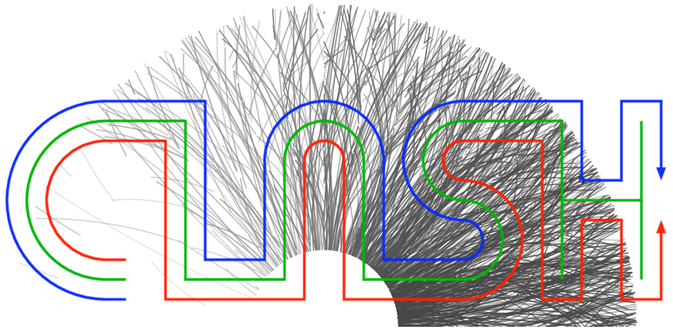
p-Pb
5.02 TeV

Xe-Xe
5.44 TeV

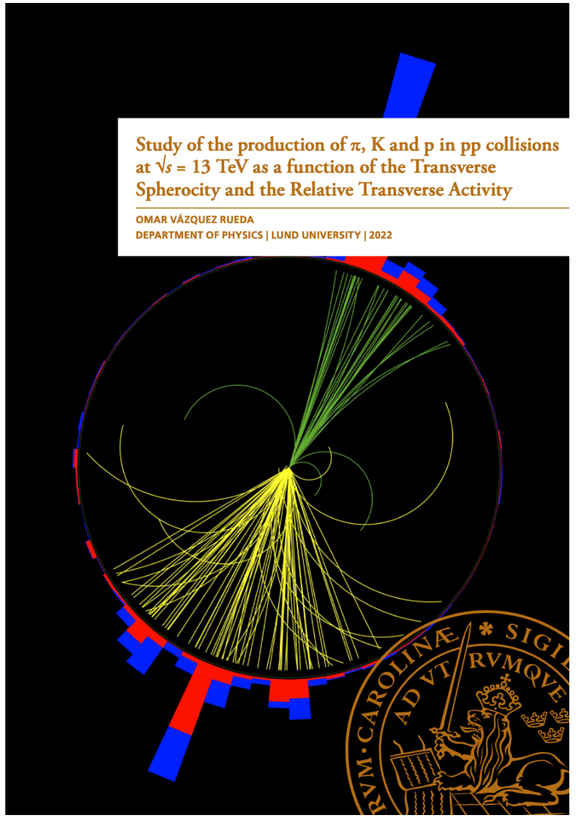
Pb-Pb
5.02 TeV

… and back again

The CLASH project



- Supported by KAW project grant,
  PIs: Peter Christiansen & Leif Lönnblad
- Collaboration between theorists and experimentalists to develop understanding of collisions from small to large systems
- Main experimental focus:
  - Using event shape observables, can we isolate the mechanisms leading to strangeness enhancement and multiplicity-dependent hadrochemistry?
  - Measure $\pi^{\pm}$, $K^{\pm}$, p, K^0_S, Λ, ϕ, Ξ spectra as a function of R_T and spherocity
    - see previous Partikeldagarna talks for more information [1] [2] [3]
    - and coming soon to a journal near you!



O. Vazquez Rueda
Ph.D. thesis

O. Vazquez Rueda (π, K, p)
O. Matonoha (K^0_S, Λ)
A. Nassirpour (ϕ)
P. Christiansen (Ξ)

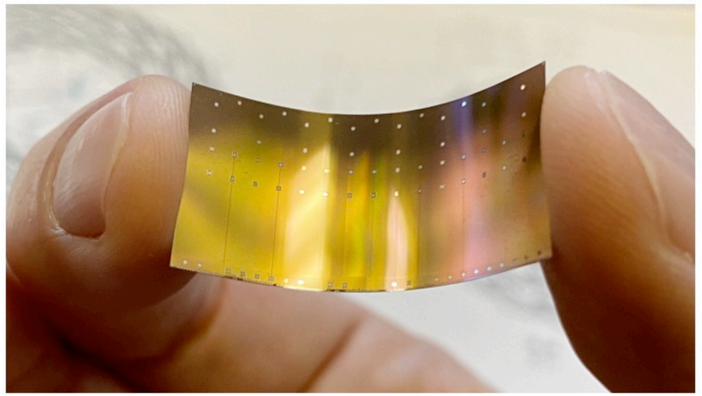
Looking towards the future…

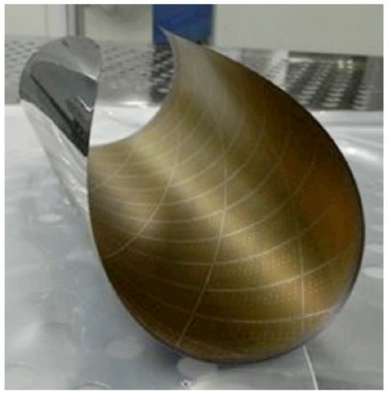
- Extend balance function studies into the charm sector
  - Contribution to Offshell-2021: Probing the QGP with Charm Balance Functions
    arXiv:2110.05134 [nucl-ex]

- ALICE → ALICE 3 in Run 5
  - an ultra-light silicon tracking system with suite of PID detectors
  - LoI to be released soon

- ALICE is back online with a new tracking paradigm!

- Upgrading the Inner Tracking System (ITS) with bent silicon wafers (after LS3) [4]
  - Lund ALICE group supported by VR/RFI to join the ITS3 project






Thank you for coming to Lund!
Safe travels home!