Swedish activities in ALICE

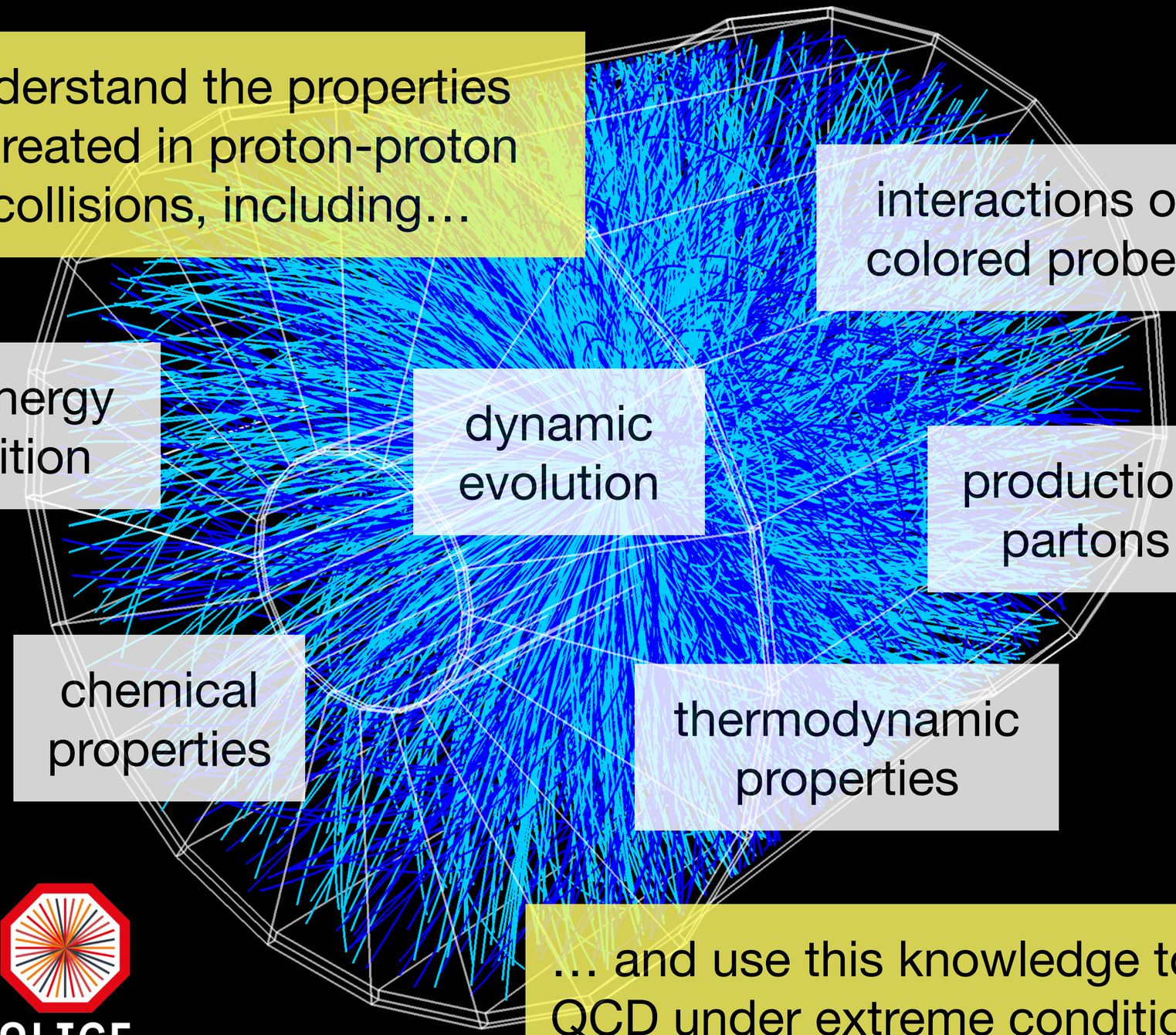
Peter Christiansen, Alice Ohlson, David Silvermyr
Lund University

Partikeldagarna 2026, 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
  - Iaroslav Panasenko, Sushanta Tripathy
- 4 PhD students
  - Joachim Hansen, Kaare Iversen,
    Roman Nepeivoda, Joey Staa (defended 12/6)
- 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

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



interactions of colored probes

initial energy deposition

dynamic evolution

production processes of partons and hadrons

chemical properties

thermodynamic properties

ALICE

… and use this knowledge to understand QCD under extreme conditions

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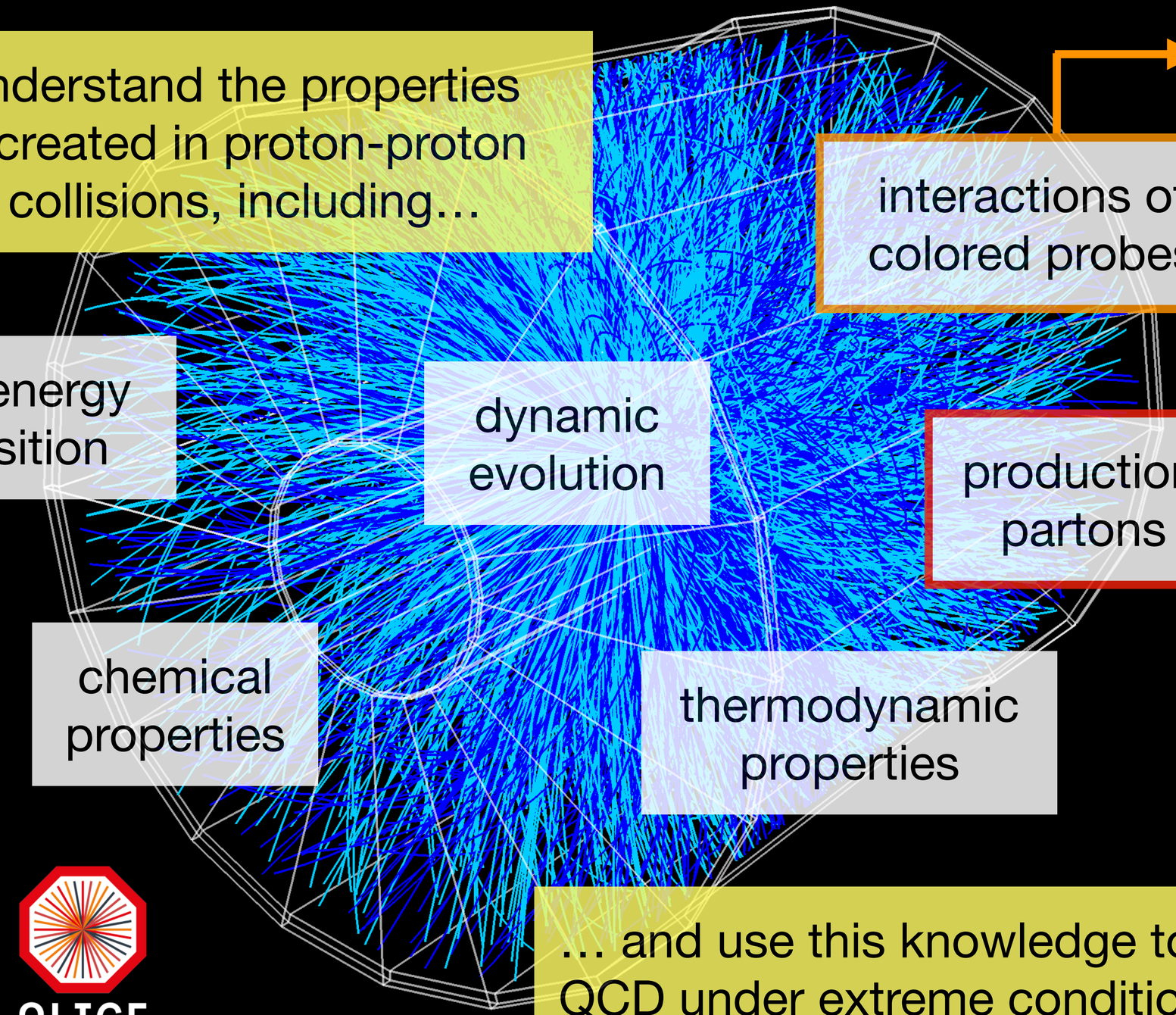

interactions of colored probes

See Joachim's talk next

initial energy deposition

dynamic evolution

production processes of partons and hadrons

chemical properties

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… and use this knowledge to understand QCD under extreme conditions

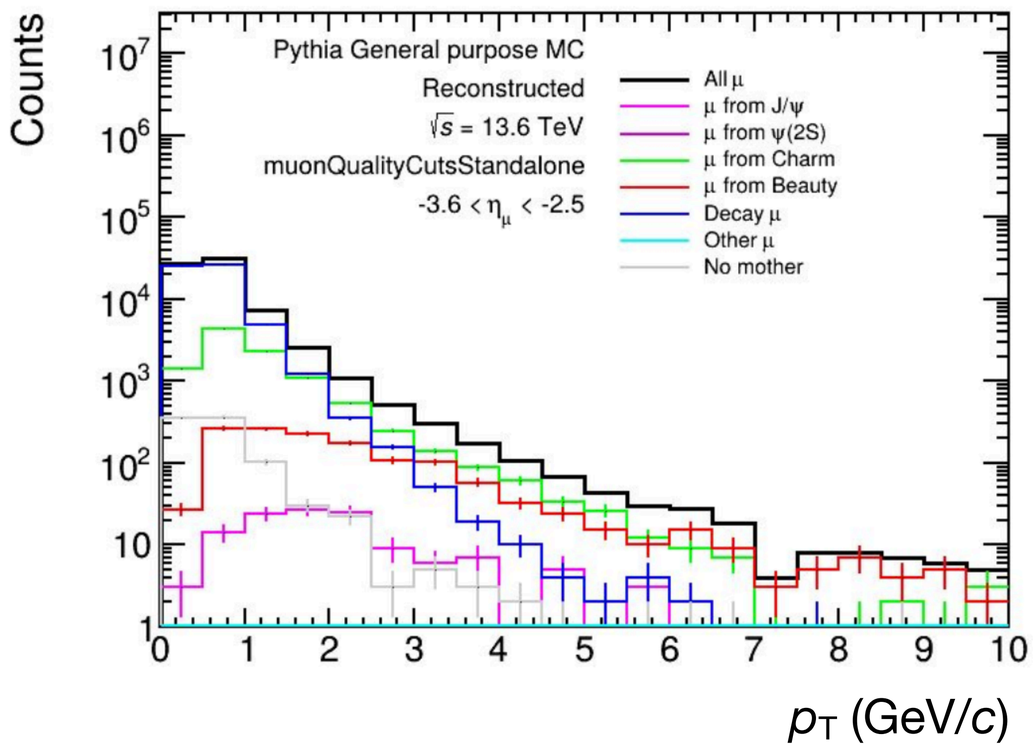
ALICE

K. Iversen

Charm production in p+p collisions

- Correlated production of J/ψ ($c\bar{c}$) and charm and beauty hadrons
  - → $\mu^+\mu^-$
  - → single μ as proxy

ALICE work in progress



- These correlations are sensitive to multi-charm production in p+p collisions
- Compare with LHCb J/ψ-D correlations: [JHEP 06 (2012) 141]

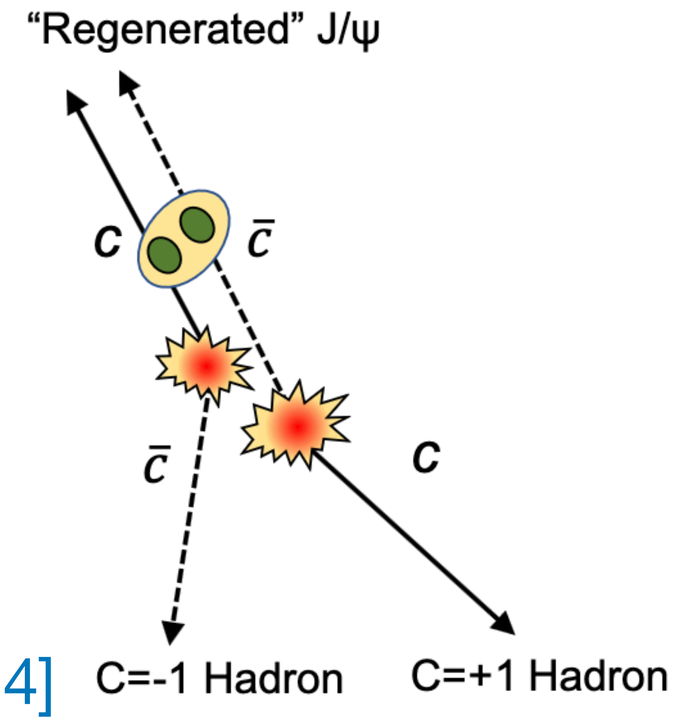
K. Iversen

Charm production in p+p collisions

- Correlated production of J/ψ ($c\bar{c}$) and charm and beauty hadrons

- Current p+p measurement serves as a baseline for future Pb+Pb measurement
- If charm can be “regenerated” in the quark-gluon plasma, we expect additional sources of correlations
  → strong signature of deconfinement

ALICE
work in progress

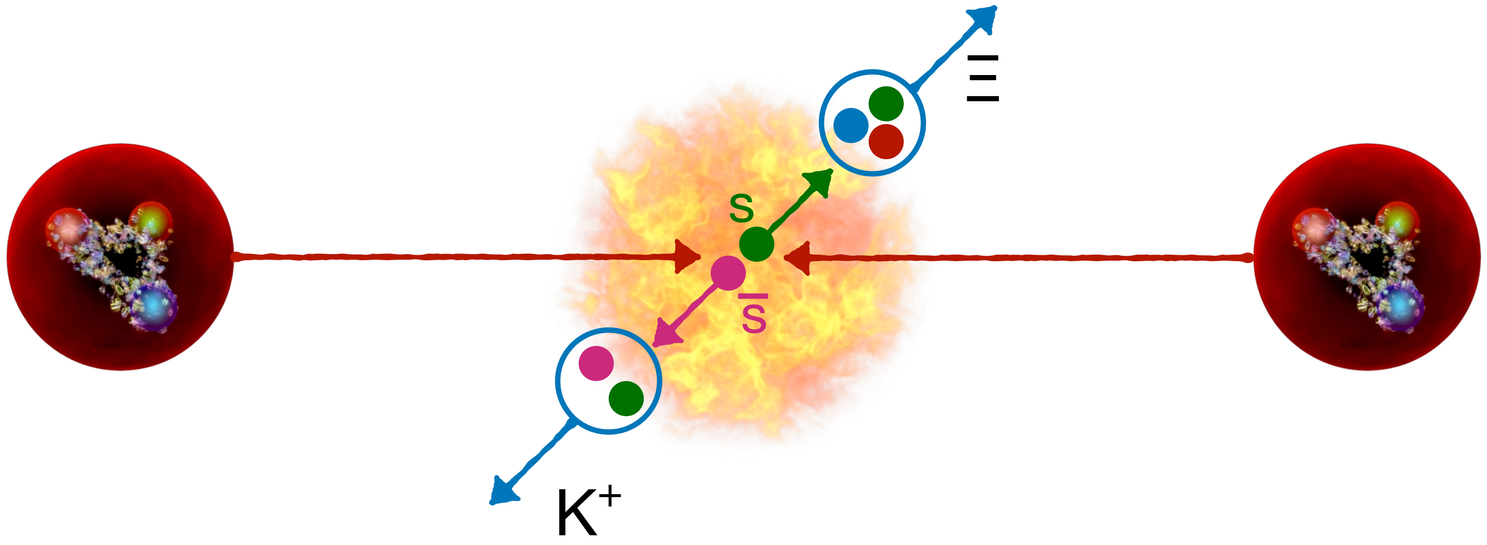


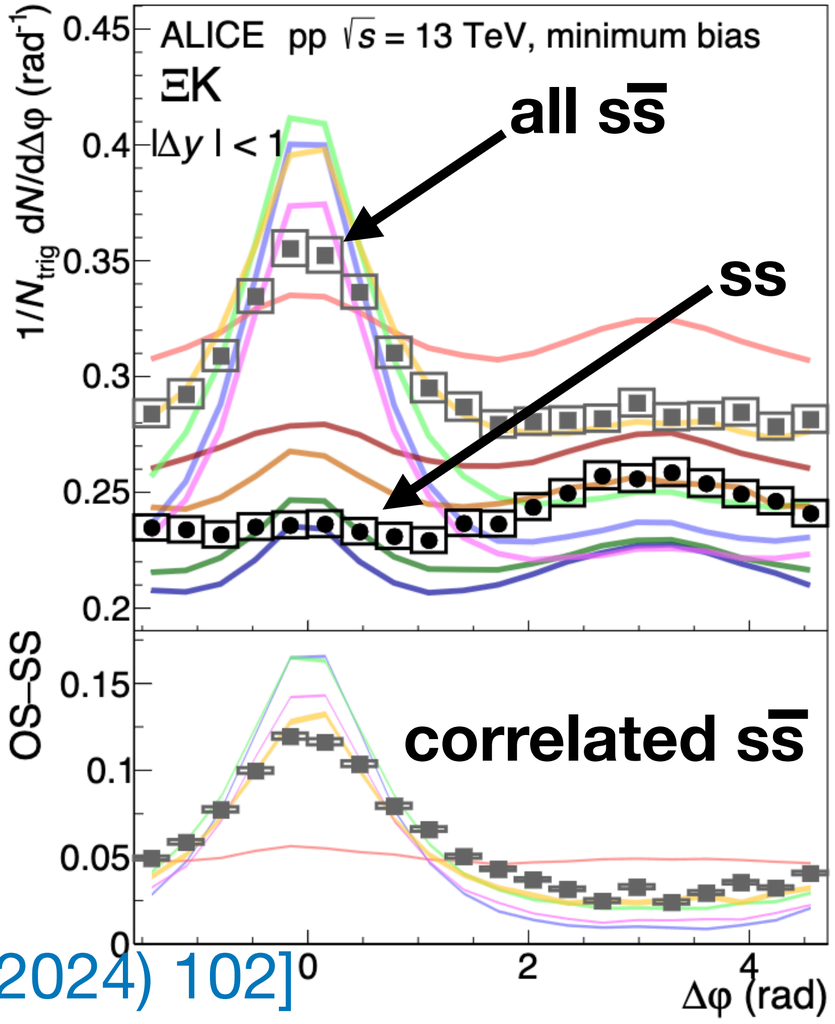
[EPJC 81 (2021) 1024]

How is strangeness produced in p+p?

J. Adolfsson
ALICE Thesis Award 2021

- How are strange and anti-strange quarks *produced in the same process* correlated? Is strangeness conserved locally or globally?





- Residual Ξ-K correlations indicate local strangeness conservation, not only global
- Additional string topologies in Pythia are necessary to describe data

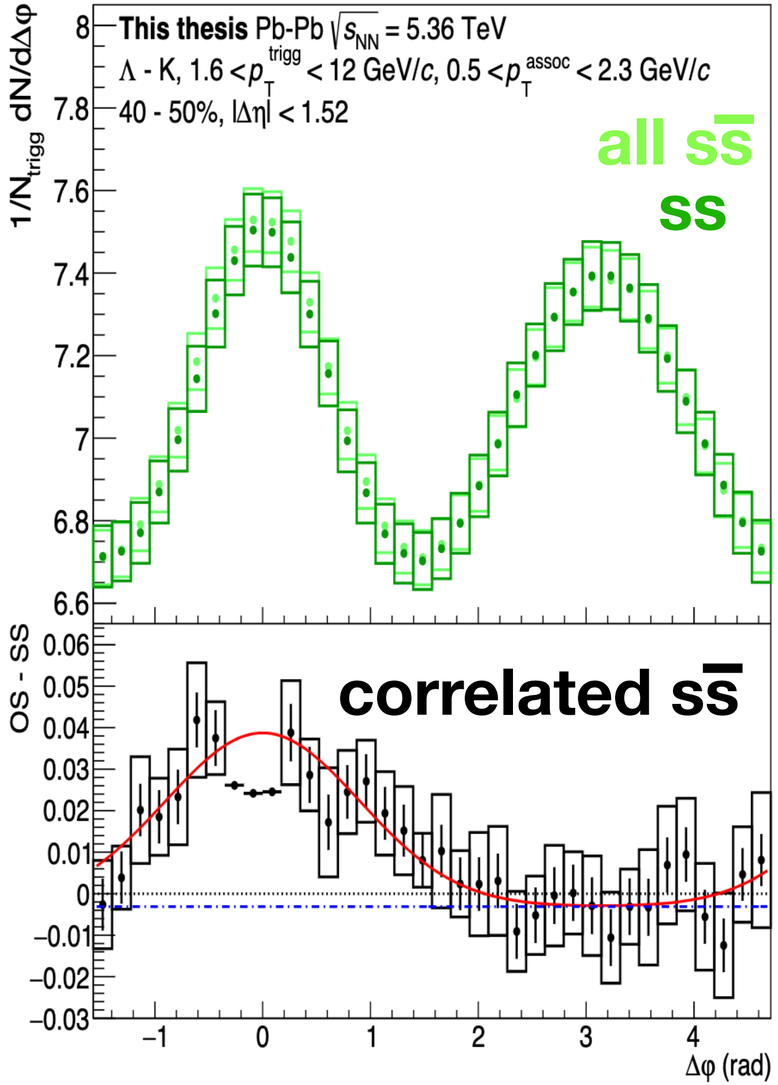
[JHEP 09 (2024) 102]

J. Staa

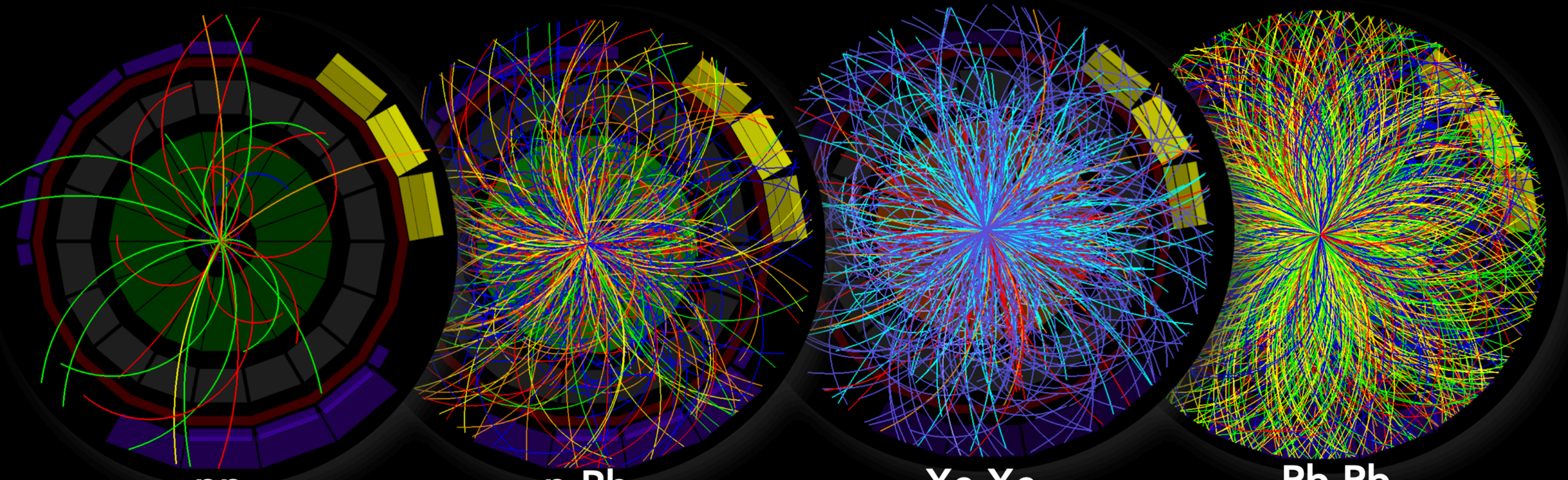
What about strangeness in Pb+Pb?

- New measurement of Λ-K balance functions in Pb+Pb collisions
- Correlations between balancing s and $\bar{s}$ remain, although small → evidence for local conservation of strangeness despite presence of hot, dense, thermalized QGP
- Similar results for baryon number in Λ-p balance functions [Joey's thesis]
- Balance functions also used to investigate coalescence and nuclei formation
  → see [Sushanta's talk] at Partikeldagarna 2025

[EPJC 86 (2026) 443]
[arXiv:2606.10668 hep-ex]



From small to large systems →



pp
13 TeV

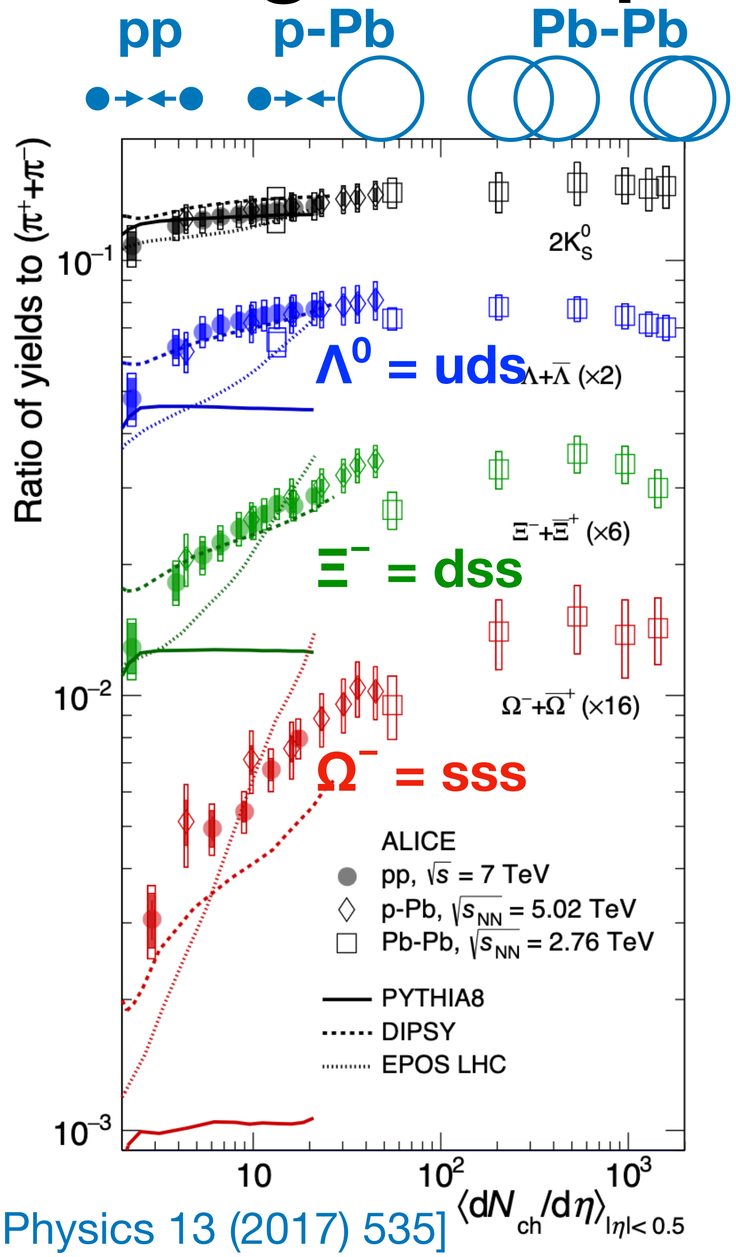
p-Pb
5.02 TeV

Xe-Xe
5.44 TeV

Pb-Pb
5.02 TeV

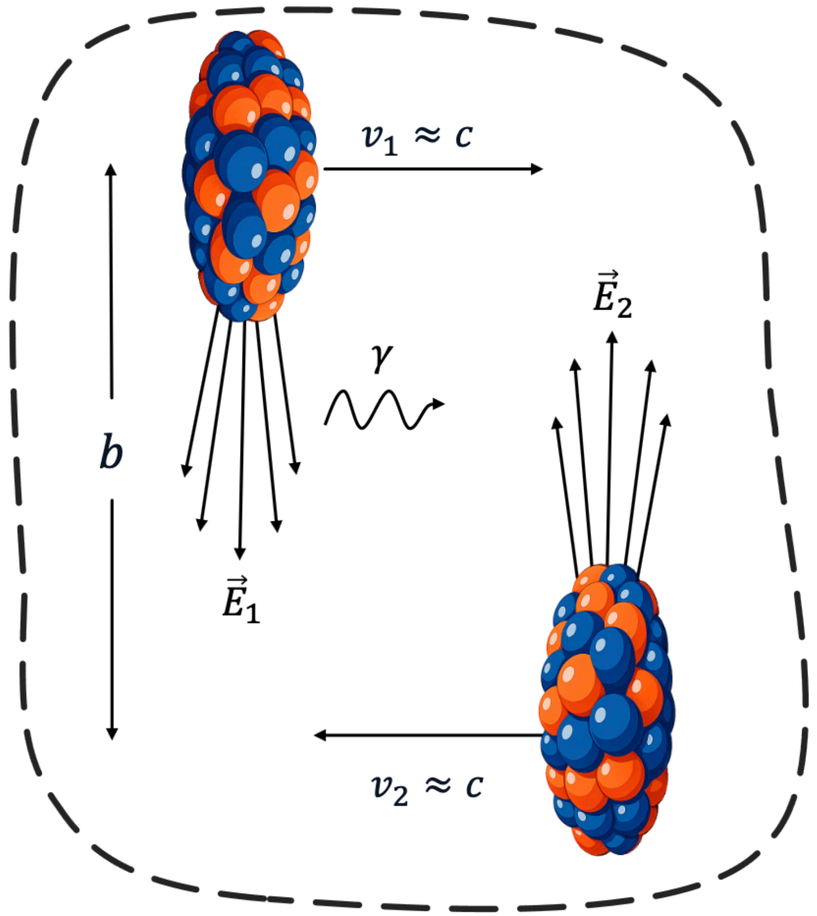
← and back again

Strangeness production in the smallest systems



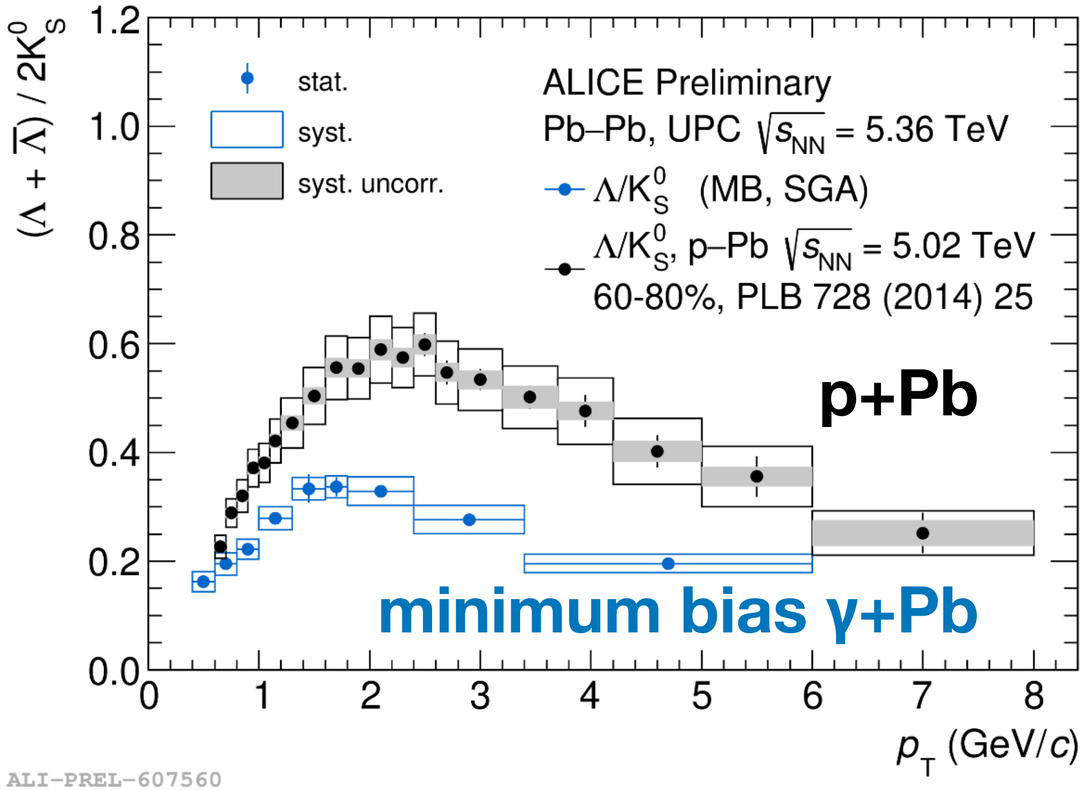
[Nature Physics 13 (2017) 535]

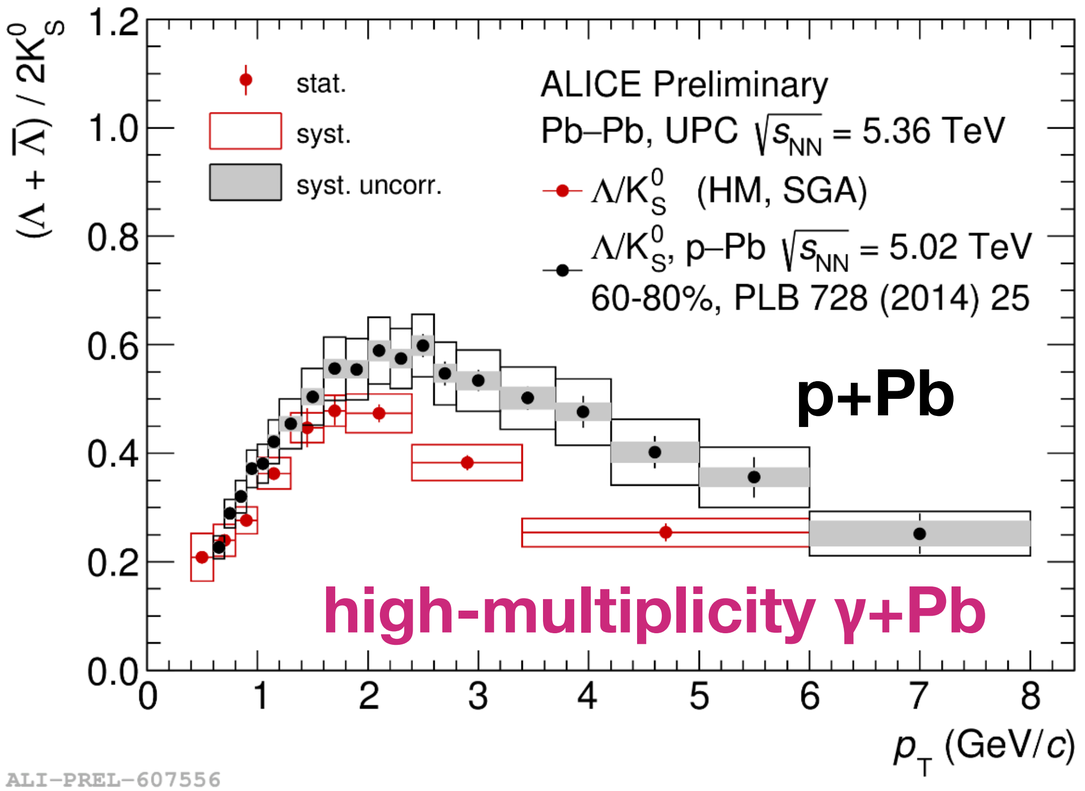
- Strangeness enhancement observed in Pb+Pb collisions, but also in p+Pb and p+p collisions!
- What about in even smaller systems like γ+Pb?



R. Nepeivoda

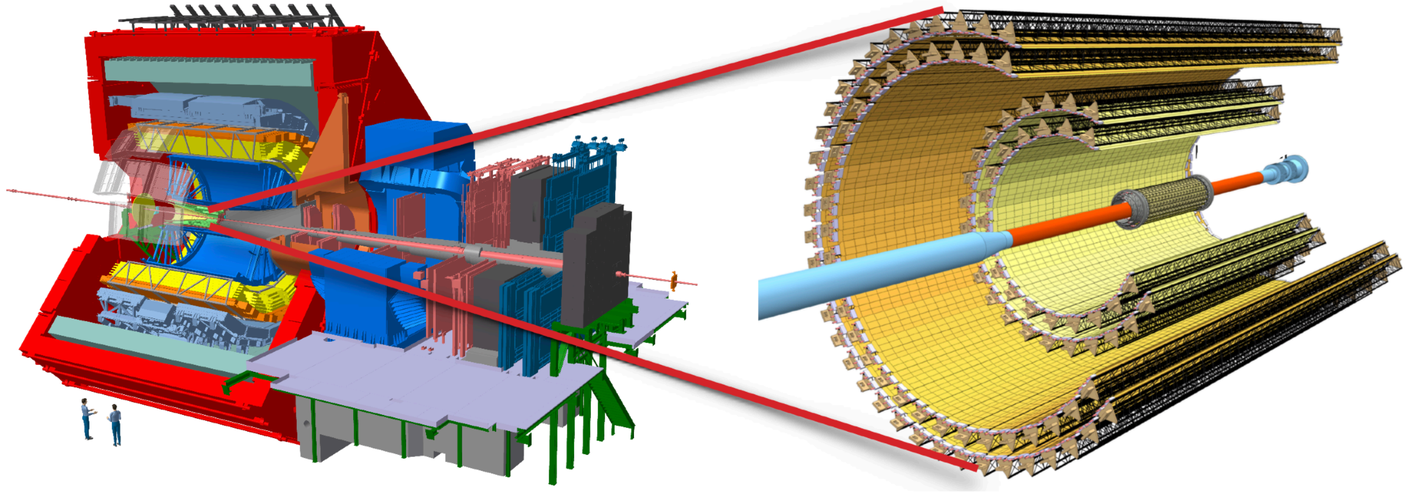
Strangeness production in the smallest systems

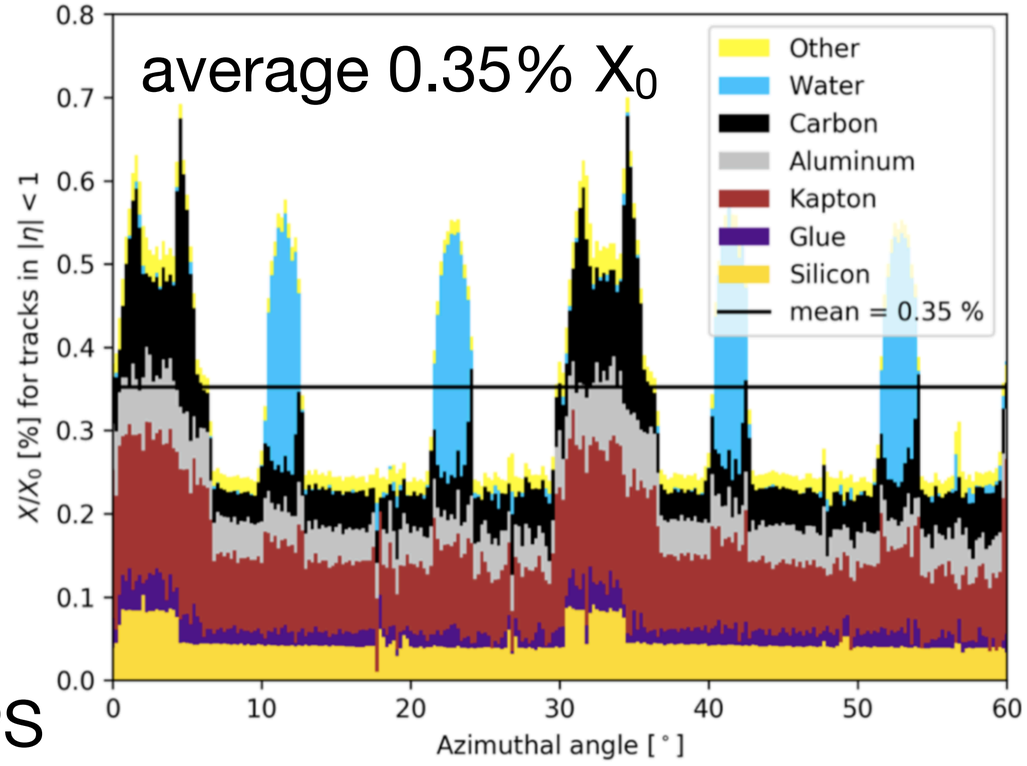




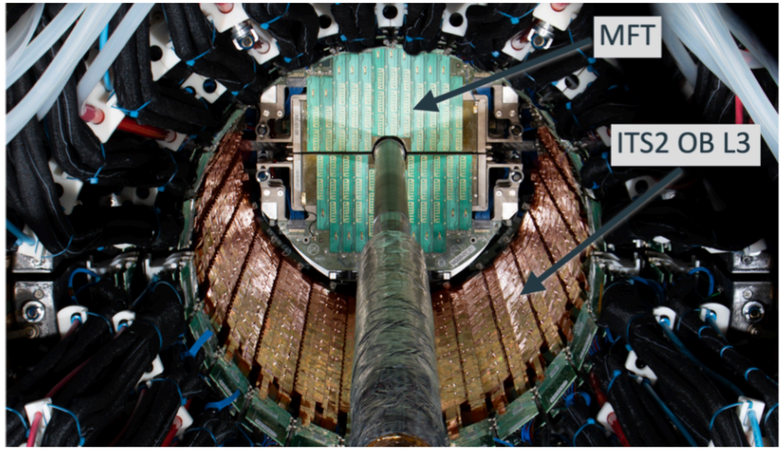
- Λ/K baryon-to-meson ratio is reminiscent of that measured in p+Pb collisions, and increases with multiplicity → possible indication of radial flow and strangeness enhancement

Upgrade from ITS2 to ITS3 (2027)



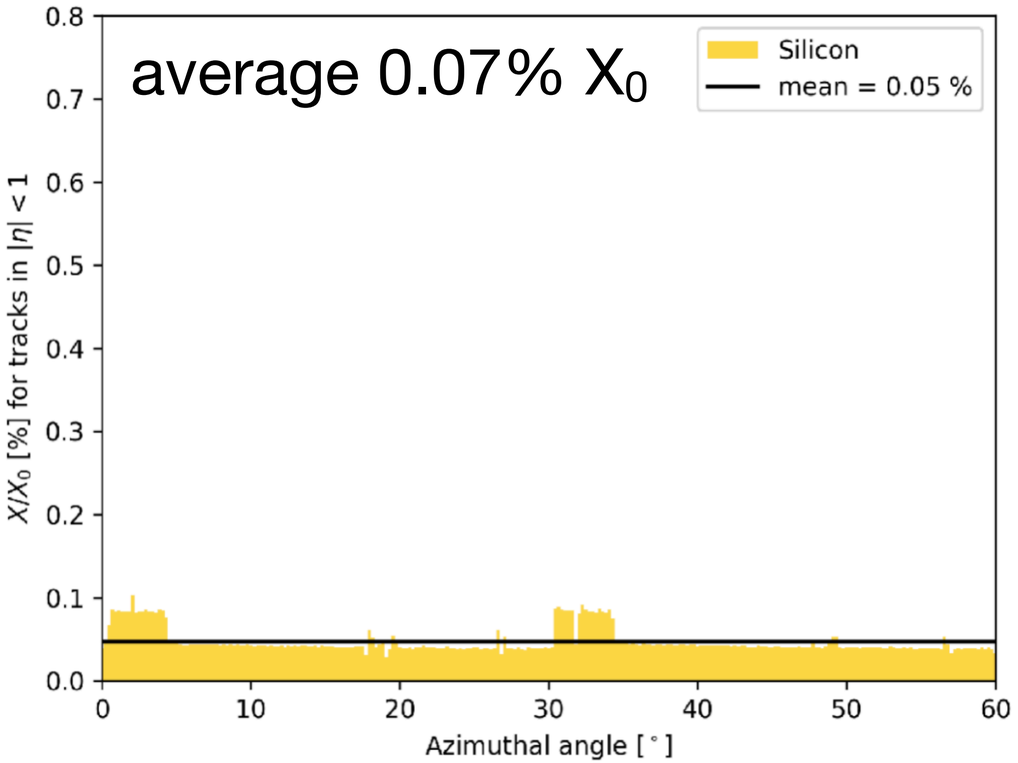


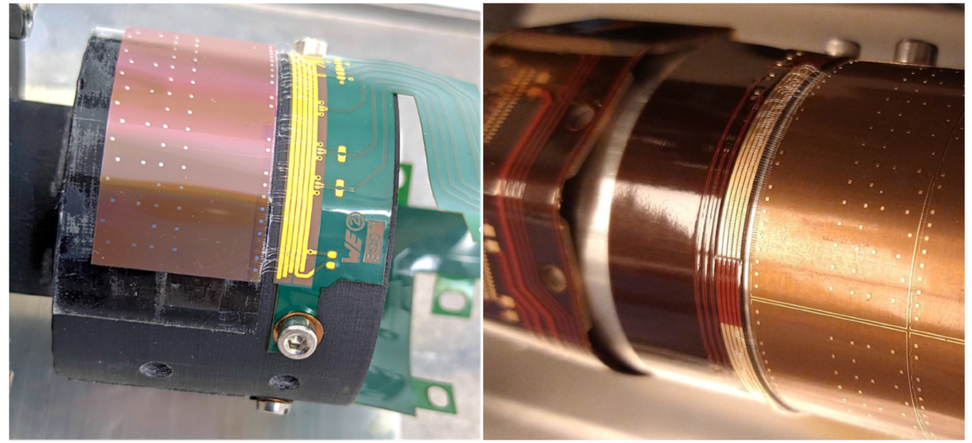
- Inner Tracking System in Run 3 (ITS2)
  - 7 layers of staves containing CMOS MAPS (ALPIDE) chips
  - Most of the material budget is non-sensitive material needed for cooling, support,…



Upgrade from ITS2 to ITS3 (2027)

- Inner Tracking System in Run 4 (ITS3)
  - Replace inner three layers of ITS2
  - Innermost layers are closer to the collision point
- Wafer-scale silicon CMOS MAPS stitched together, bent to radii of 18/24/30 mm
- Reduce material budget by replacing chips to lower power consumption and removing mechanical support

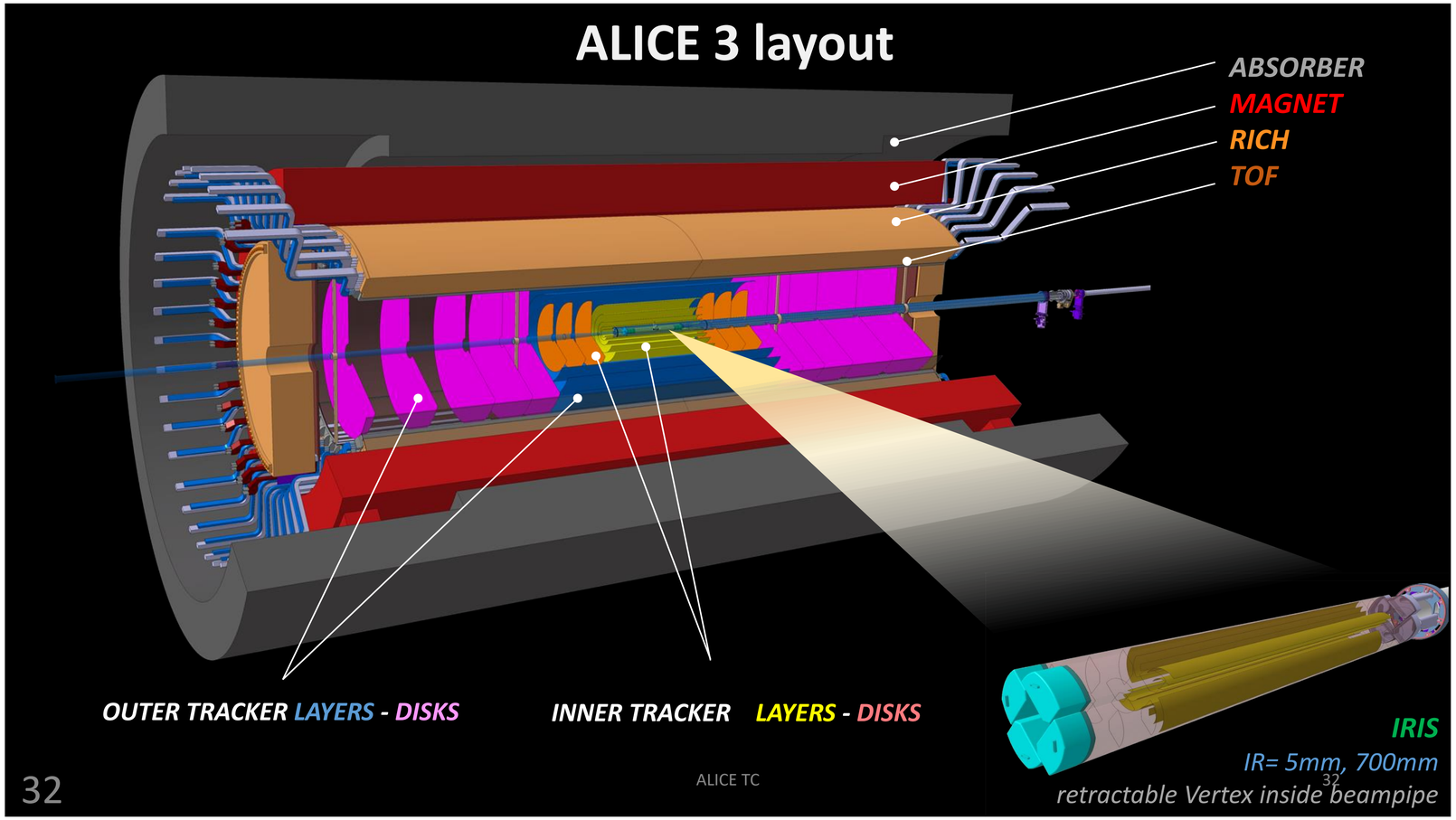




ALICE3: a next-generation heavy-ion detector (2030s)

- Physics goals:
  - Multi-heavy-flavour hadrons
  - Electromagnetic probes of chiral symmetry restoration
  - New physics in the soft (low-momentum) sector
- Novel detector concept
  - Full silicon tracking
  - Retractable inner layers
  - Surrounded by particle-identification detectors

[arXiv:2211.02491]



Summary

- In p+p and heavy-ion collisions at the LHC we study extreme nuclear matter in the high-temperature limit and the fundamental processes of QCD
- In the ALICE group at Lund University we are particularly interested in
  - The microscopic production mechanisms of strangeness and charm from small to large systems

	γ+Pb	**p+p**	**Pb+Pb**
strange	Λ/K ratios vs multiplicity	Ξ-h correlations	Λ-h correlations
charm		J/ψ-μ correlations	Future work!

  - Detector development and operations: tracking in high track-density environments, upgrades to ITS3 and ALICE3


We hope you enjoy Lund!

Strong support by CERN and several FAs

- CERN Directorate indicated phase IIb upgrades (ALICE 3 and LHCb-U2) as their next highest priority, after HL-LHC and ATLAS/CMS phase II upgrades
  - “Full exploitation of HL-LHC includes ALICE and LHCb upgrades in LS4”
  - “CERN is committed to investing in phase IIb upgrade..”
- Several Funding agencies expressed support and funding plans at April RRB

The European Strategy underpins CERN’s strategy

Top Priority – full exploitation of the LHC and HL-LHC
- HL-LHC and ATLAS and CMS upgrades are CERN’s top priority
- Full exploitation of HL-LHC includes the ALICE and LHCb upgrades during LS4

Highest long-term priority – FCC-ee as CERN’s next flagship collider
- Our aim is to be in the position for CERN Council to be able to take a decision on
  from June 2028 onwards

Non-collider physics at CERN will remains an important part of the programm
- Our aim is to develop a new roadmap for the future of the non-collider physics progra
  CERN by early 2027

Accelerator R&D – top priorities as recommended by the ESG:
- Advanced superconducting and normal-conducting Radio Frequency (RF) technology
- Efficient RF power supplies
- Accelerator quality magnets (14-20T), including High-Temperature Super-conductors

Mark Thomson | CERN: Present and Future 18 May 2026

M. Thomson, LHCP, 18 May

Scientific research

Main priorities
- **Completion of the ATLAS and CMS upgrades by 2030**
  - Alongside the HL-LHC, this is the top priority
  - To this end, CERN is strengthening the host-laboratory programme and will provide additional support to ATLAS and CMS to maximise the likelihood of success
- **Fully exploit the HL-LHC**
  - Progress the TDRs of the LS4 ALICE and LHCb upgrades and associated funding model
    - Need a plan compatible with the current LS4 schedule (2034-2035) and available funding
  - CERN is committed to investing in the Phase 2b ALICE and LHCb upgrades, and is putting in place a provisional budget line for host-laboratory support
- **Evolve the computing for the HL-LHC operation**
  - Working with the LHC collaborations and the WLCG to evolve the computing model for HL-LHC operation within the likely available resources

Mark Thomson | CERN: Present and Future 18 May 2026 34

ALICE 3 is now approved!

- **LHCC** (1-3 June):
  - concluded that the currently proposed scope for the ALICE 3 detector would enable the collaboration to achieve its key and unique physics objectives for Run 5 and to make full use of the HL-LHC in the heavy-ion collision sector
  - **recommended that ALICE proceeds to the phase of preparation of TDRs**
- **Research Board** (17 June) assessed the April RRB outcome and **approved the recommendation of the LHCC**

→ formal green light for ALICE to proceed to TDRs

Upgrade to the Inner Tracking System (ITS3)

Iaroslav, David + BSc/MSc students

- replace inner 3 layers of ITS2 with ITS3

  280 mm long sensor ASICs

  out of 300 mm long stitched (overlapping metal layers) wafers

  20-40 μm thick (0.02-0.04% X_0)

  15 x 15 μm^2 pixel size

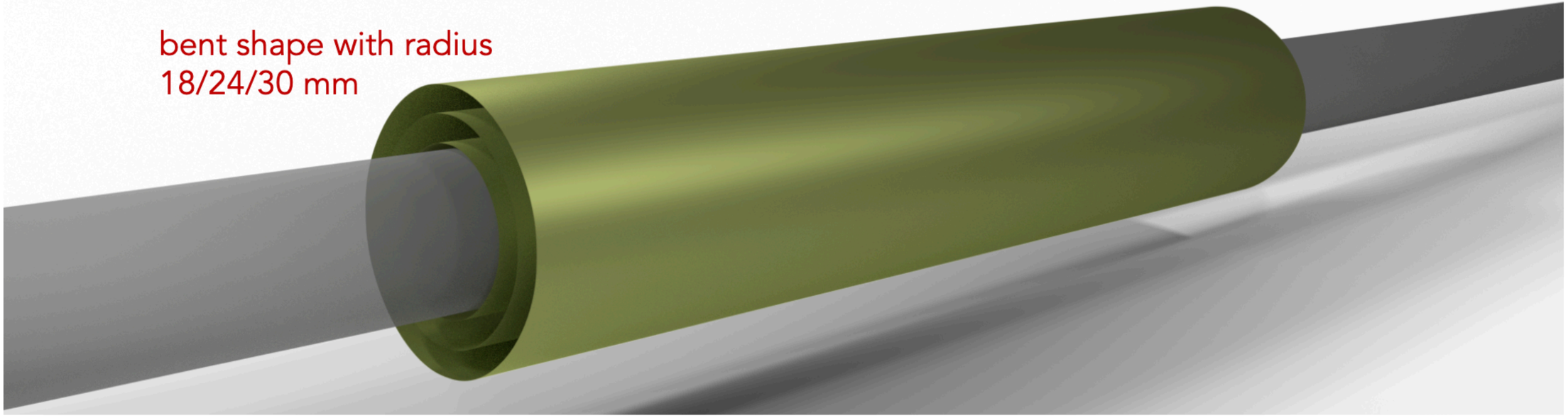
  bent shape with radius 18/24/30 mm

  carbon foam rib to hold ASICs in place

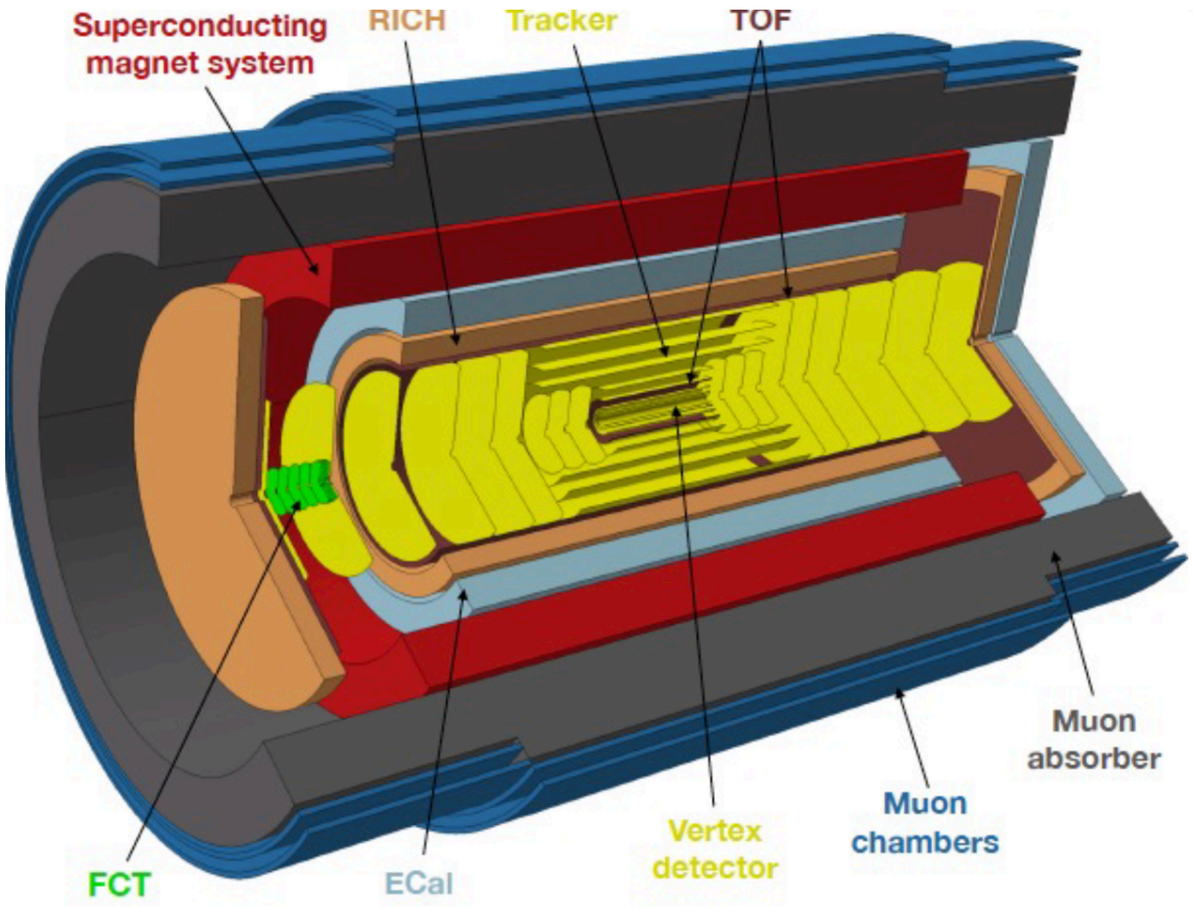
  air cooling

  homogenous material distribution

- 6 sensor ASICs
  - 2 halves * 3 layers



ALICE 3: a next-generation HI detector for LHC Runs 5+6 (2030s)



Fast and ultra-thin detector with precise tracking and timing

- Another factor 50x in luminosity
- Exploit higher LHC lumi with nuclei lighter than Pb
- Ultra-lightweight tracker based on CMOS pixels (MAPS), ~70 m^2 Si
- Si-based Time Of Flight determination: ~20ps time resolution
- Fast to sample large luminosity: 50-100x Run 3/4
- Large acceptance barrel + end caps $\Delta\eta = 8$

Ultimate performance for HF, thermal radiation and soft hadrons (p_T < 50 MeV/c)

- Multiply heavy flavour, hadron production, multi-quark states
- Chiral symmetry restoration (e.m. probes)
- Beyond HI (phase space complementary to other experiments)
  - Violation of fundamental properties of quantum field theories (emission of soft photons)
  - New physics in soft sector, e.g. dark photons

LoI : arXiv:2211.02491