Swedish activities in ALICE

Peter Christiansen, Alice Ohlson, David Silvermyr
Lund University

Partikeldagarna 2019, Linköping

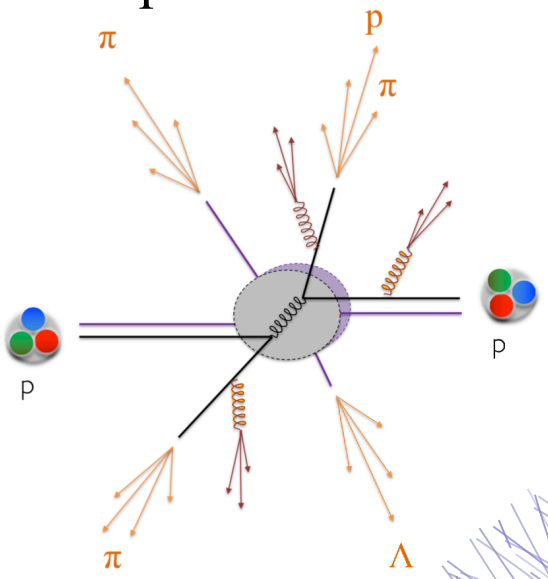
Lund Heavy-Ion Group

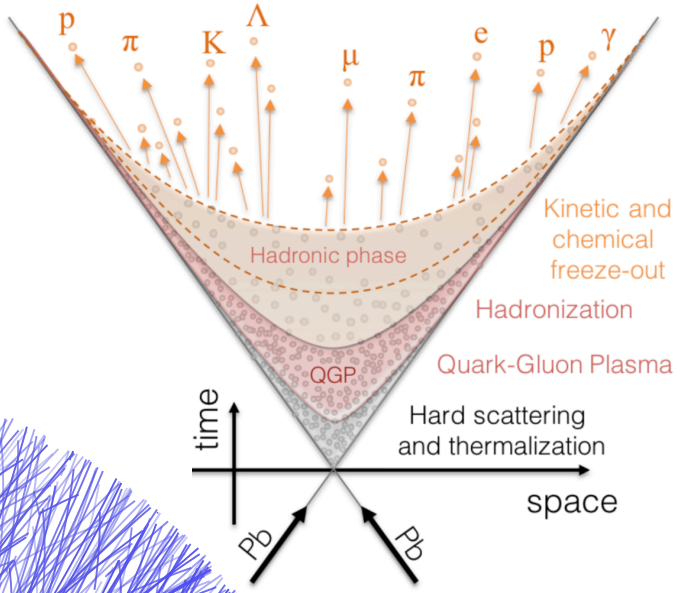
- 3 Seniors
  - Peter Christiansen, David Silvermyr, Alice Ohlson
  - Emeriti: Anders Oskarsson, Evert Stenlund
- 1 Postdoc
  - Tuva Richert (VR international postdoc, at NBI)
- 4 Ph.D. Students
  - Jonatan Adolfsson, Adrian Nassirpour, Omar Vazquez Rueda, Oliver Matonoha
- Member of the ALICE Collaboration at the LHC
- Individuals also work on detector R&D for: ILC, ESS, ESSνSB, sPHENIX

From small to large systems

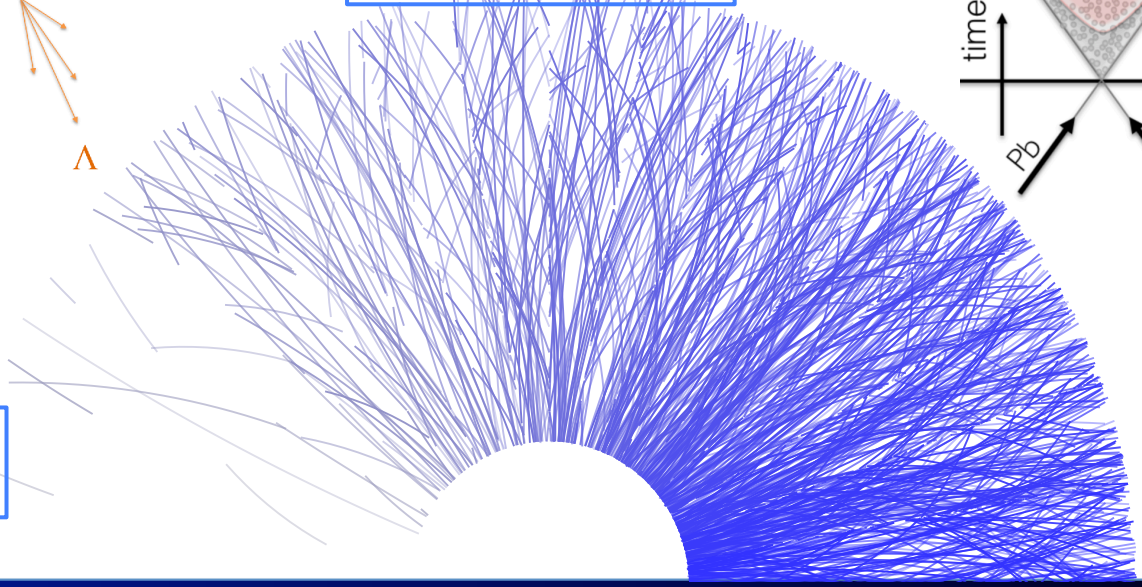
particle production mainly from 2→2 scatterings (LO), multi-parton interactions

high-energy and high-density limit of QCD, equilibrated system governed by thermodynamics and hydrodynamics





high-mult pp, pPb



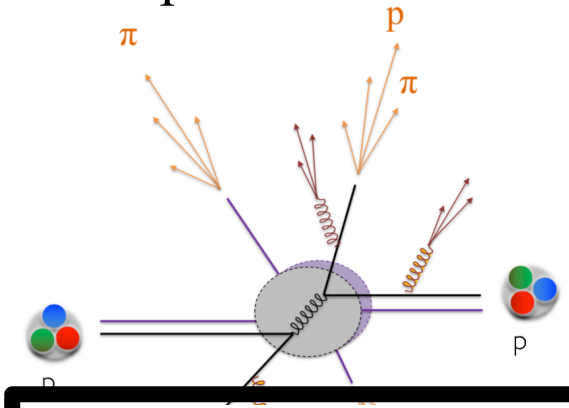
pp

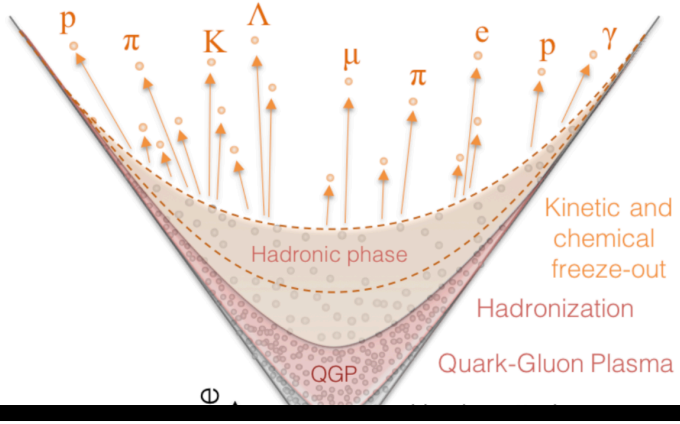
PbPb

Collectivity: long-range correlations

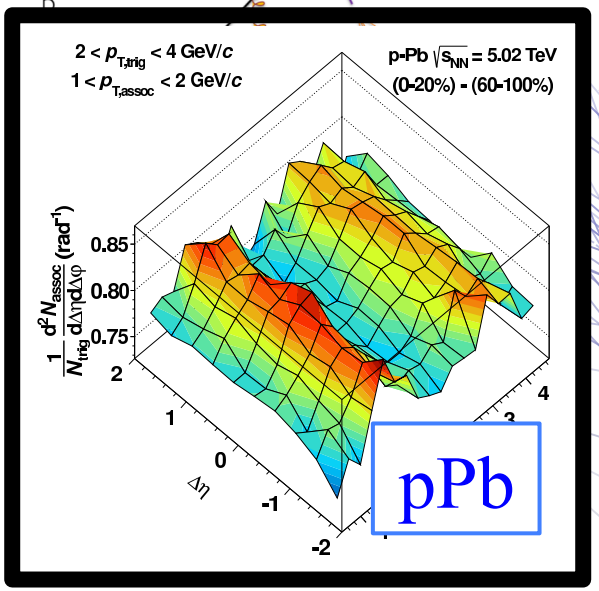
particle production mainly from 2→2 scatterings (LO), multi-parton interactions

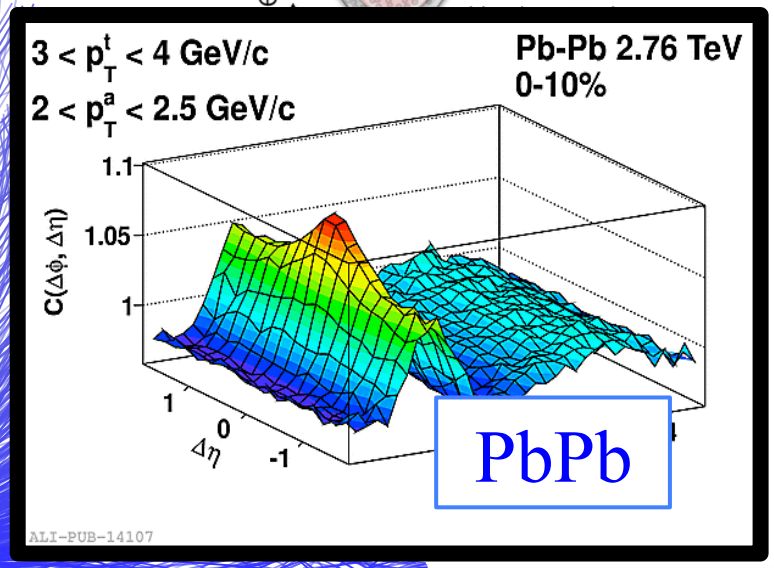
high-energy and high-density limit of QCD, equilibrated system governed by thermodynamics and hydrodynamics





high-mult pp, pPb

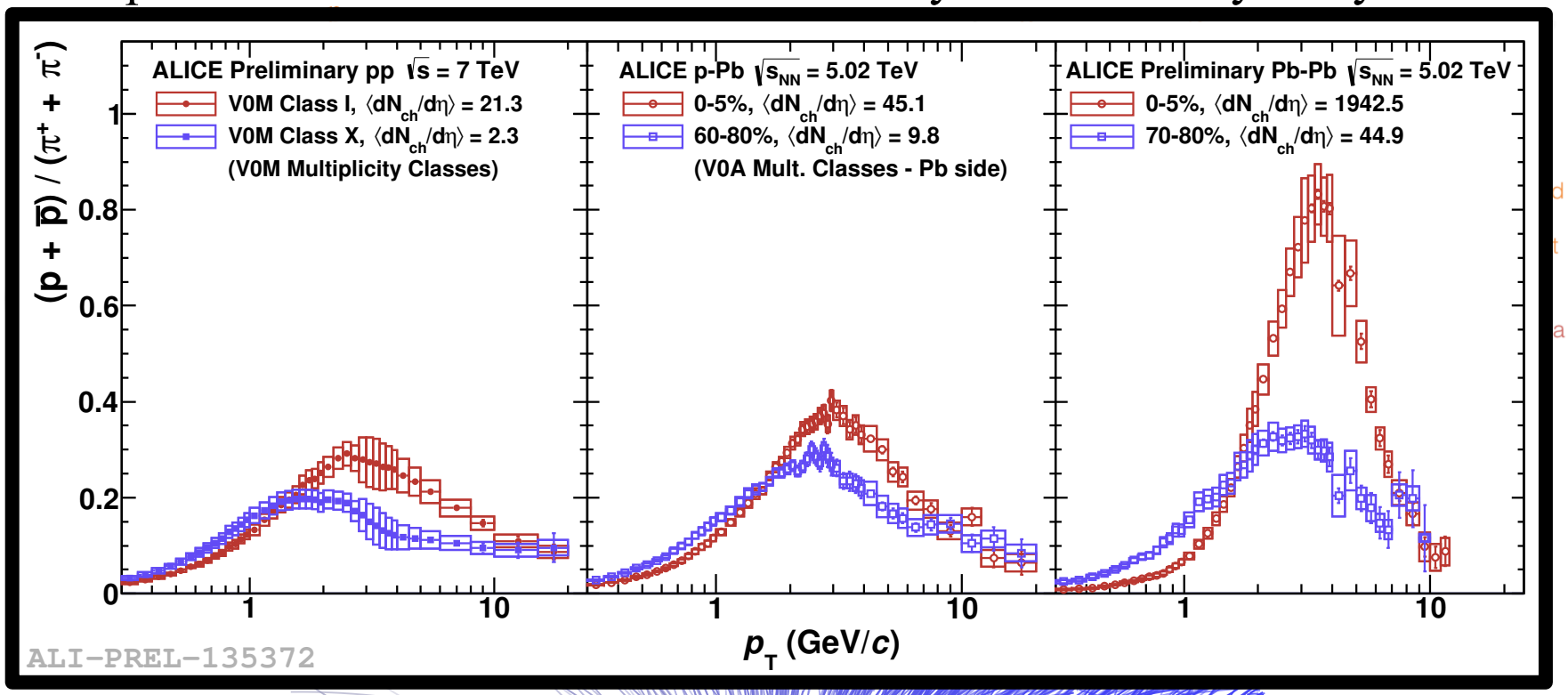




p/π ratio, radial flow

particle production mainly from 2→2 scatterings (LO), multi-parton interactions

high-energy and high-density limit of QCD, equilibrated system governed by thermodynamics and hydrodynamics



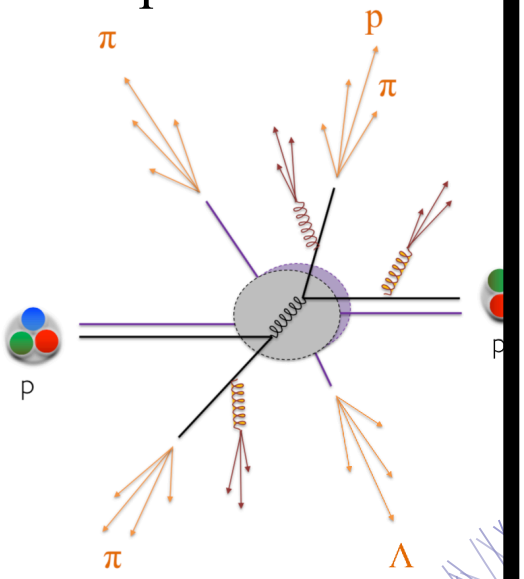
pp

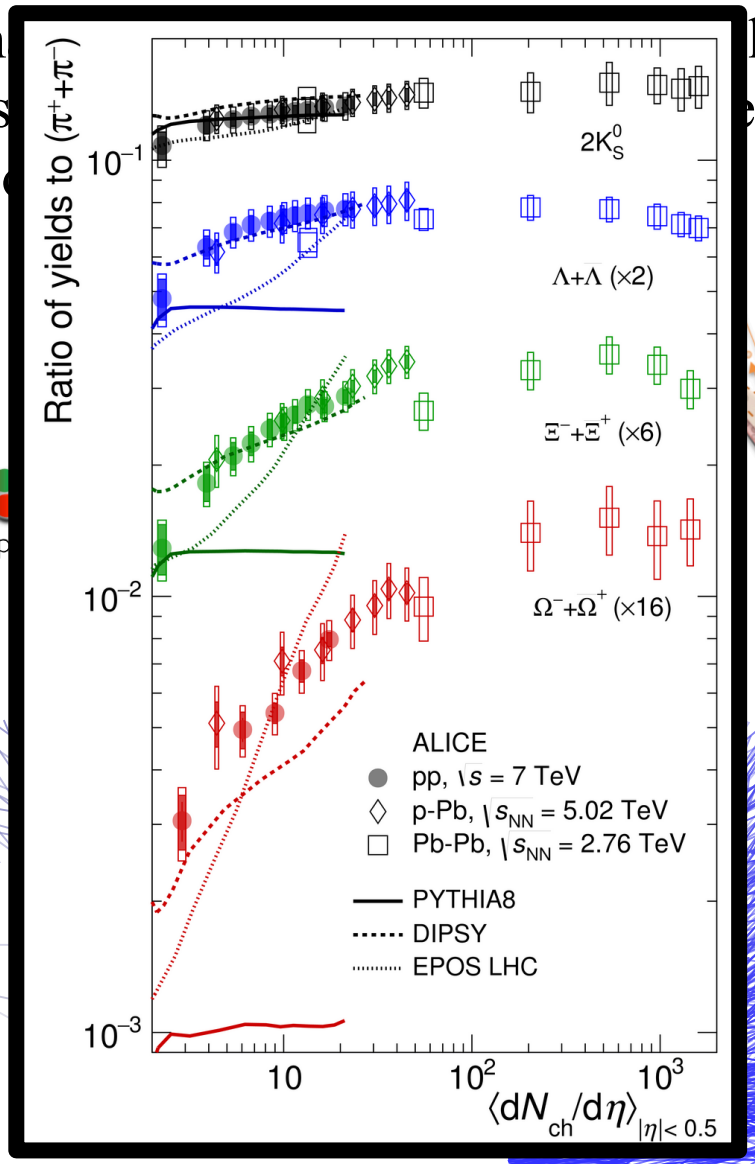
pPb

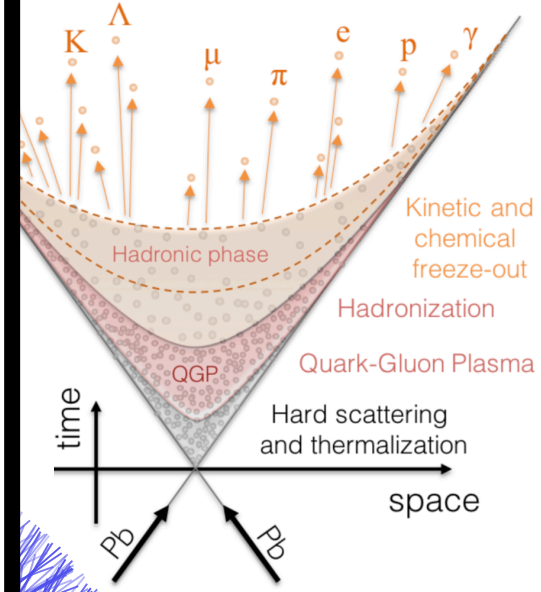
PbPb

Strangeness enhancement

particle production m… high-density limit of
from 2→2 scatterings … d system governed by
multi-parton interacti… and hydrodynamics







pp

PbPb

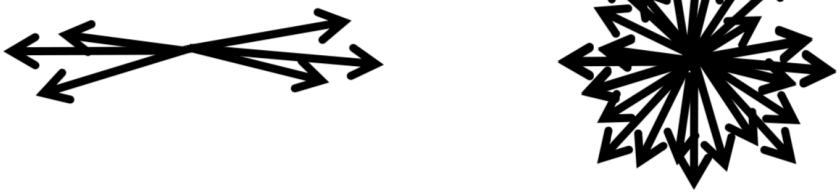
Event shape studies

- What is the origin of strangeness enhancement and collective effects in small systems?
- Select pp collisions that are dominated by soft particle production

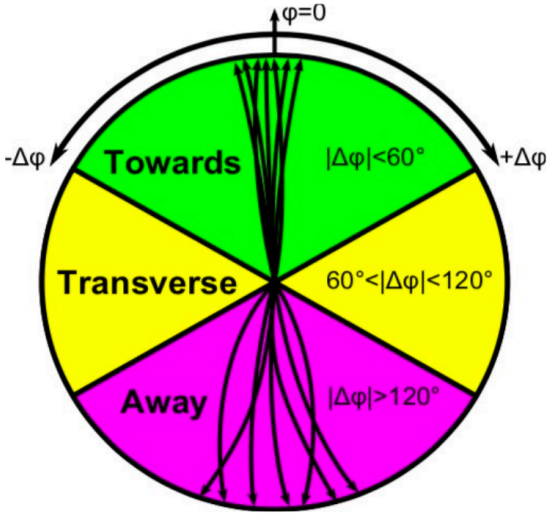
Spherocity

$$S_O = \frac{\pi^2}{4} \min_{\hat{n}} \left(\frac{\sum_i \vec{p}_{T,i} \times \hat{n}}{\sum_i p_{T,i}} \right)^2$$

Jetty: $S_O \rightarrow 0$ **Isotropic: $S_O \rightarrow 1$**

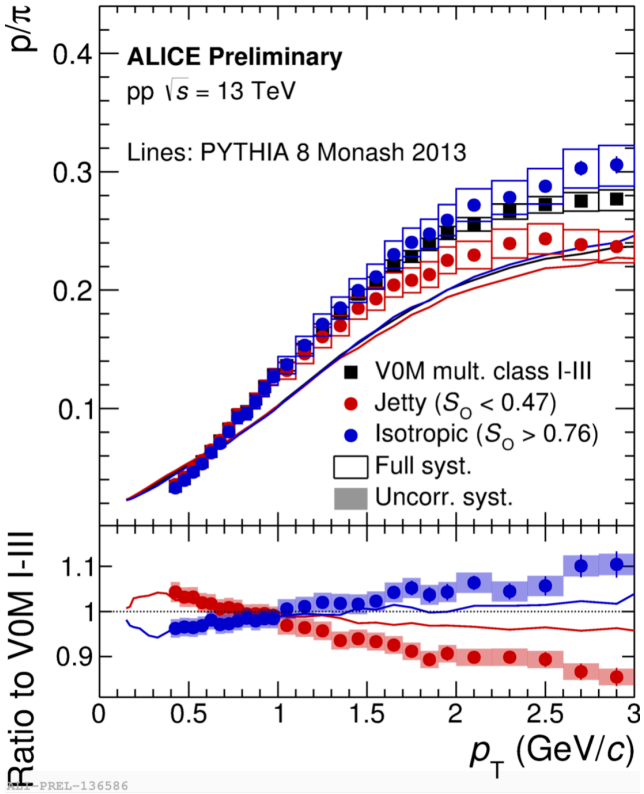


$R_T = N_T / \langle N_T \rangle$

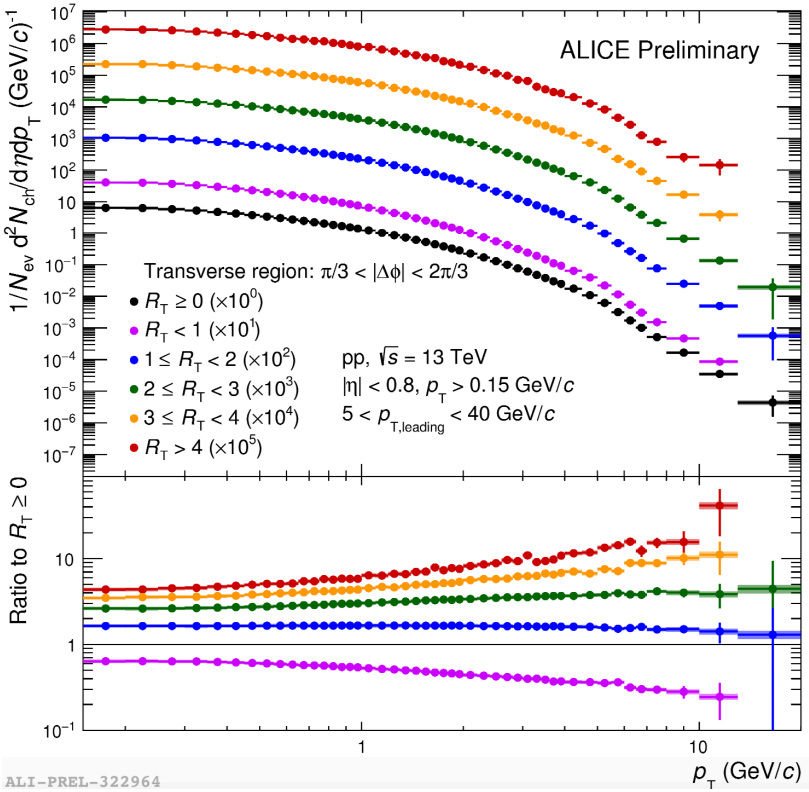


Spherocity and R_T

- p/π ratio vs S_O



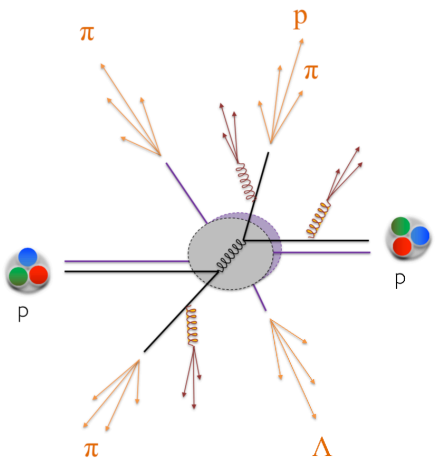
- spectra vs R_T



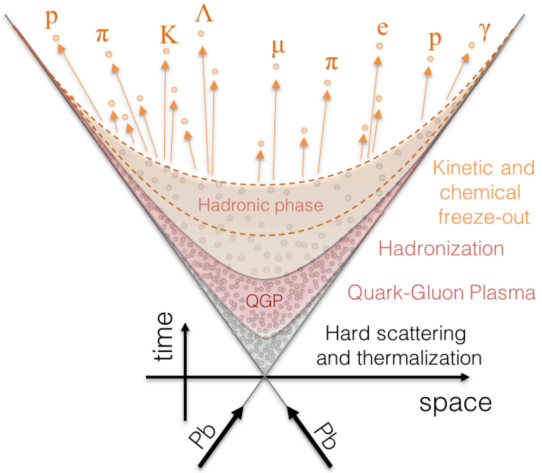
Identified particle spectra vs S_O and R_T → QM19:
π, K, p (O. Vazquez Rueda), K^0_S, Λ (O. Matonoha),
ϕ (A. Nassirpour), Ξ (P. Christiansen)

Strangeness production

- Is strangeness produced locally or globally in small systems?
  - Ξ-π, Ξ-K, Ξ-p correlations (J. Adolfsson) → QM19



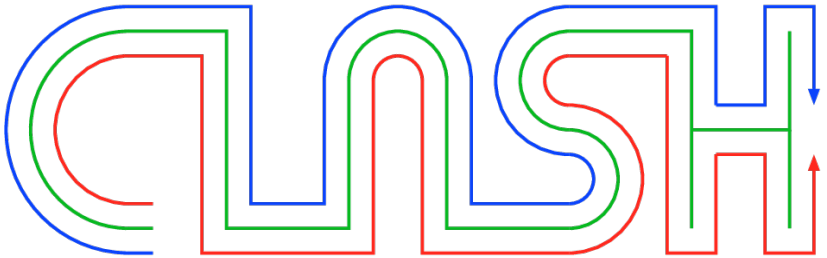
or



- Correlated fluctuations of net-strangeness number and net-baryon number
  - Net-Λ fluctuations in PbPb collisions (A. Ohlson)

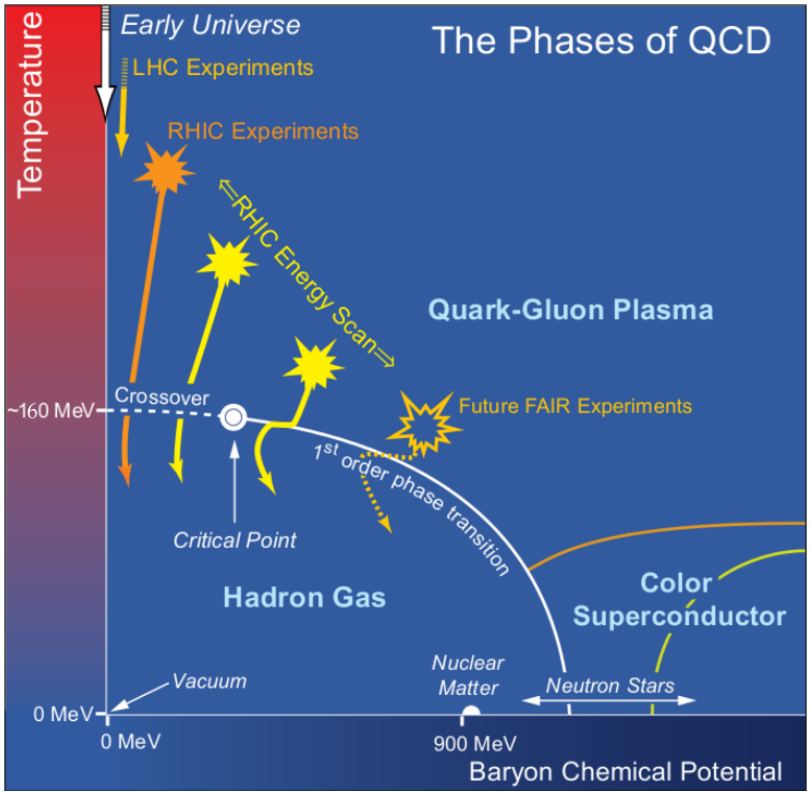
Collaboration with theorists

- Lund theory group developing Angantyr – extending Pythia to heavy-ion collisions, no QGP
- KAW grant: “Pinning down the origin of collective effects in small collision systems”
- CLASH workshop
  - 19-23 August
  - 40 participants in 6 working groups
  - almost entirely discussion-based
  - purpose : to identify/clarify open questions and propose key experimental measurements and theoretical calculations



Fluctuations in heavy ion collisions

- Event-by-event fluctuations of particle multiplicities are used to study properties and phase structure of strongly-interacting matter



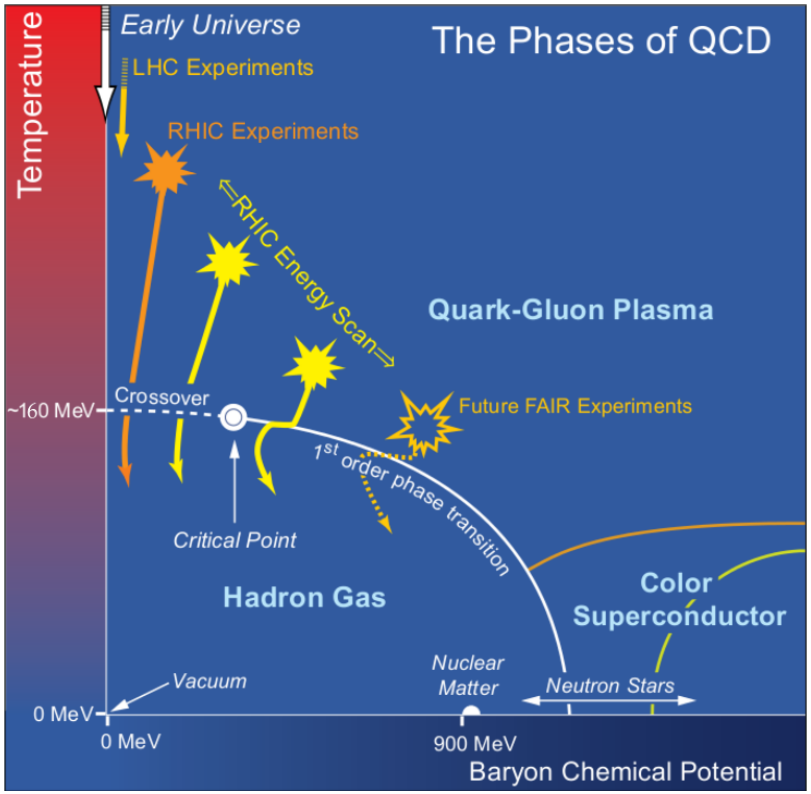
- Fluctuations grow in the region near a phase transition and/or critical point

Critical opalescence in CO_2 (2^{nd} order PT)
J.V. Sengers, A.L Sengers, Chem. Eng. News, June 10, 104–118, 1968

$T > T_c$ $T >\sim T_c$ $T <\sim T_c$ $T < T_c$

Fluctuations in heavy ion collisions

- Event-by-event fluctuations of particle multiplicities are used to study properties and phase structure of strongly-interacting matter



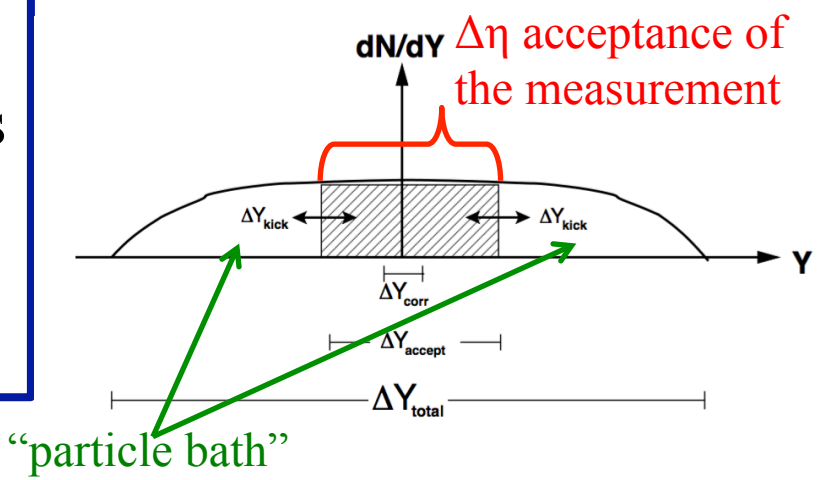
- Fluctuations grow in the region near a phase transition and/or critical point
- Fluctuations of conserved charges can be related to susceptibilities calculable in lattice QCD
  - precision test of LQCD at $\mu_B \approx 0$

Connecting theory to experiment

- Thermodynamic susceptibilities χ
  - can be calculated within lattice QCD
  - within the Grand Canonical Ensemble, are related to event-by-event fluctuations of the number of conserved charges

Theory: susceptibilities

$$\chi_n^B = \frac{\partial^n \left(P/T^4 \right)}{\partial \left(\mu_B / T \right)^n}$$



Experiment: moments of net-charge, net-strangeness, net-baryon number distributions

$$\Delta N_B = N_B - N_{\bar{B}}$$

Connecting theory to experiment

- Thermodynamic susceptibilities χ
  - can be calculated within lattice QCD
  - within the Grand Canonical Ensemble, are related to event-by-event fluctuations of the number of conserved charges

Theory: susceptibilities

$$\chi_n^B = \frac{\partial^n \left(P/T^4\right)}{\partial \left(\mu_B/T\right)^n}$$

$$\langle \Delta N_B \rangle = VT^3 \chi_1^B$$

$$\left\langle \left(\Delta N_B - \langle \Delta N_B \rangle\right)^2 \right\rangle = VT^3 \chi_2^B = \sigma^2$$

$$\left\langle \left(\Delta N_B - \langle \Delta N_B \rangle\right)^3 \right\rangle \Big/ \sigma^3 = \frac{VT^3 \chi_3^B}{\left(VT^3 \chi_2^B\right)^{3/2}} = S$$

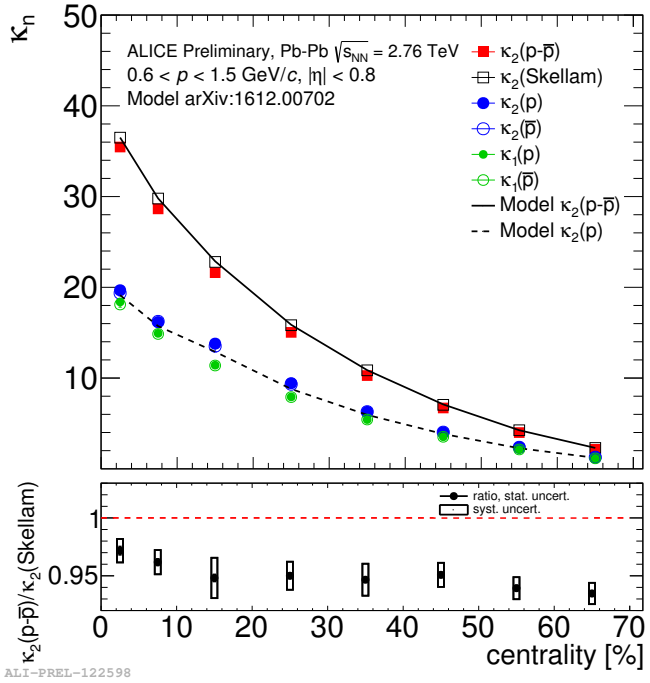
$$\left\langle \left(\Delta N_B - \langle \Delta N_B \rangle\right)^4 \right\rangle \Big/ \sigma^4 - 3 = \frac{VT^3 \chi_4^B}{\left(VT^3 \chi_2^B\right)^2} = \kappa$$

Experiment: moments of net-charge, net-strangeness, net-baryon number distributions

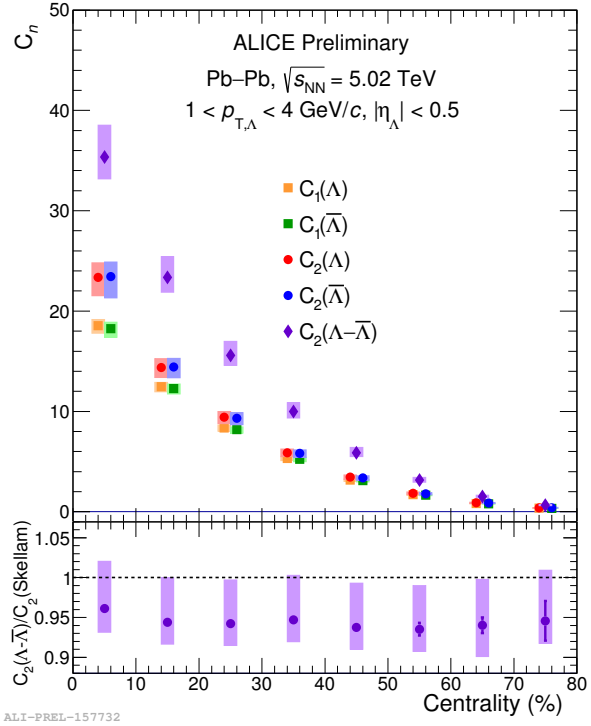
$$\Delta N_B = N_B - N_{\bar{B}}$$

Second moments

- Net-proton fluctuations



- Net-Λ fluctuations

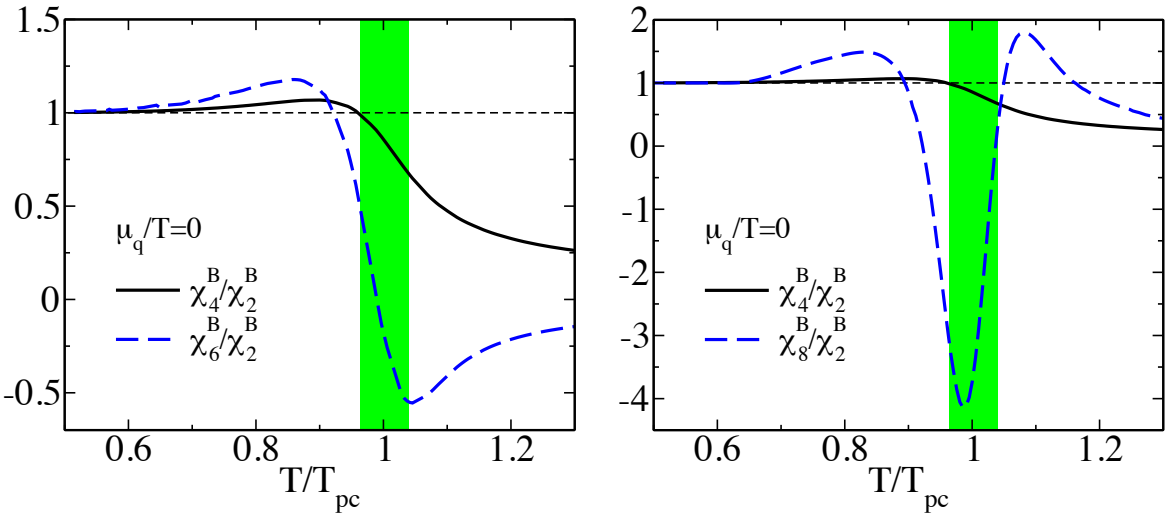


- Net-baryon number fluctuations

- Correlated fluctuations of net-baryon and net-strangeness number

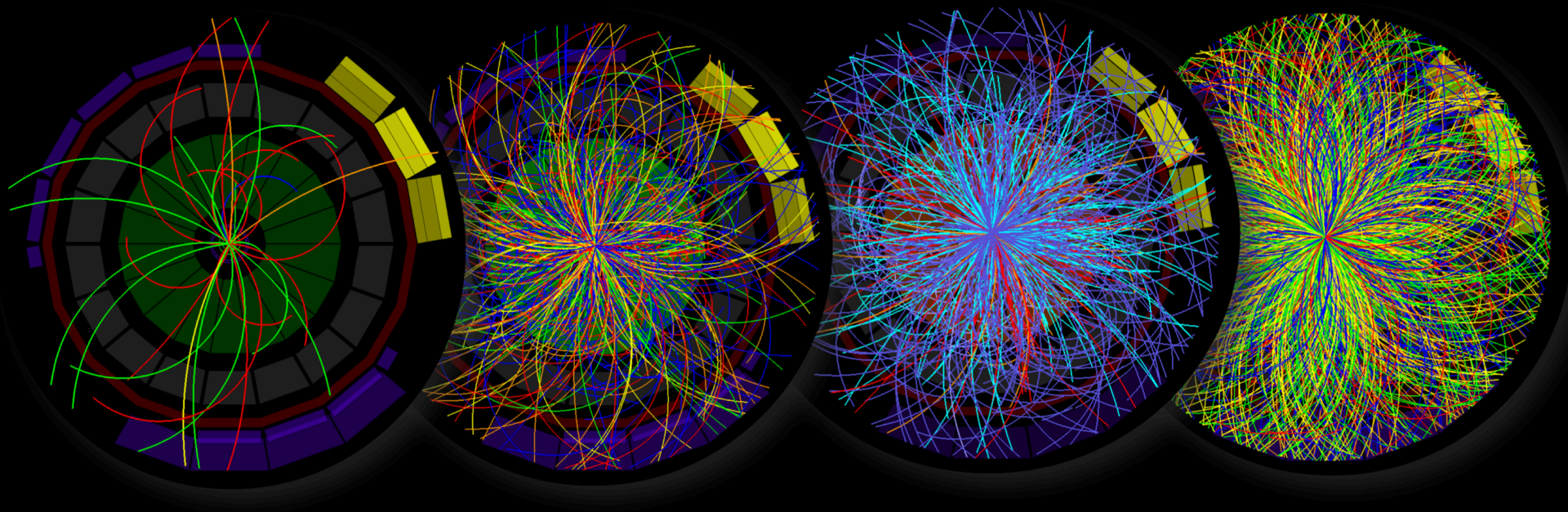
Future prospects – tests of LQCD

- Deviation from the baseline not observed (nor expected) for the second moments
- Deviations from unity and signs of criticality are greatly enhanced for the higher moments (4^{th}, 6^{th}, 8^{th},...)



Friman, B., et al. Eur. Phys. J. C 71 (2011) 1694, arXiv:1103.3511 [hep-ph]

- But huge statistics are needed → Run 3 and Run 4 at the LHC → ALICE will run at least until 2029!



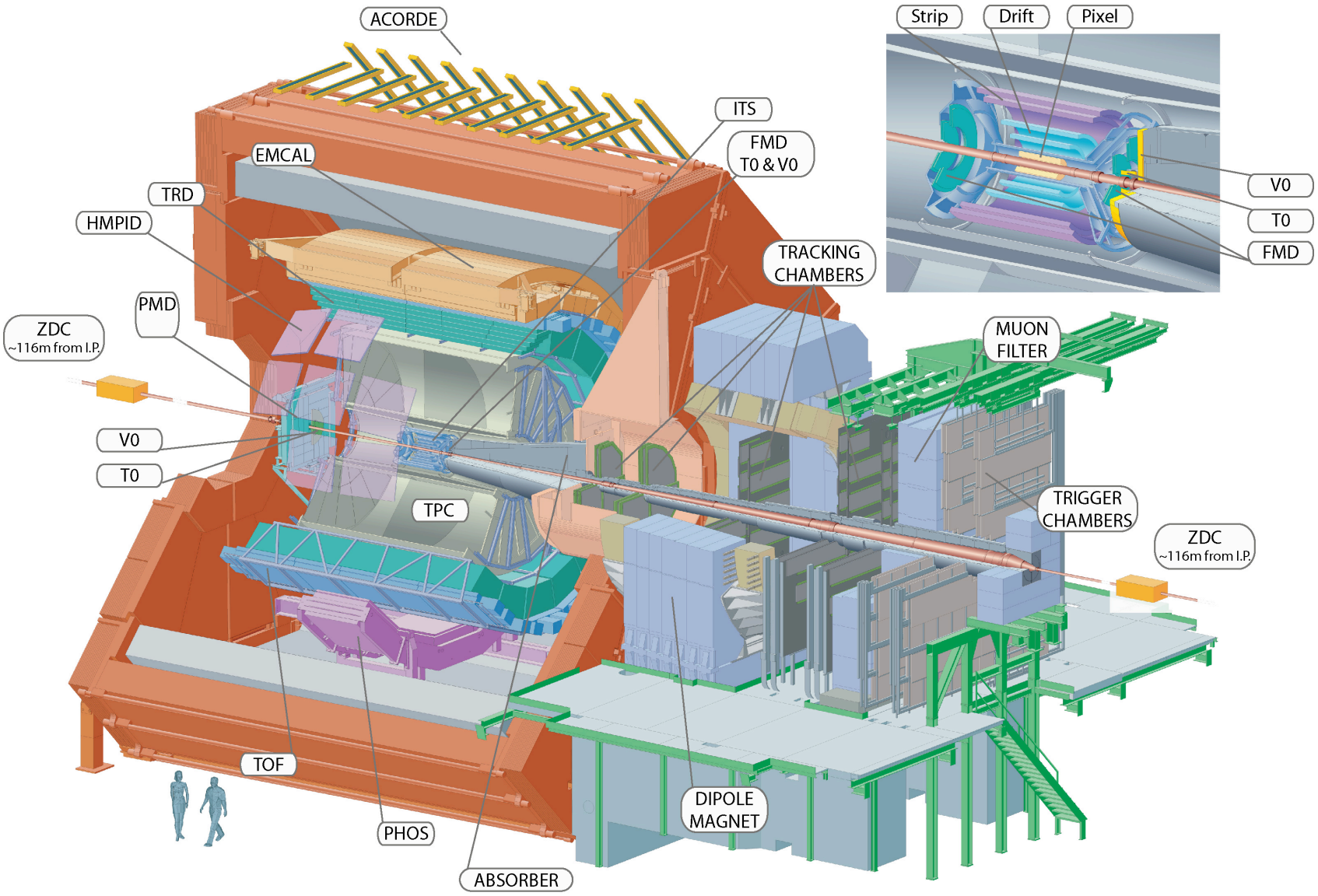
pp
13 TeV

p-Pb
5.02 TeV

Xe-Xe
5.44 TeV

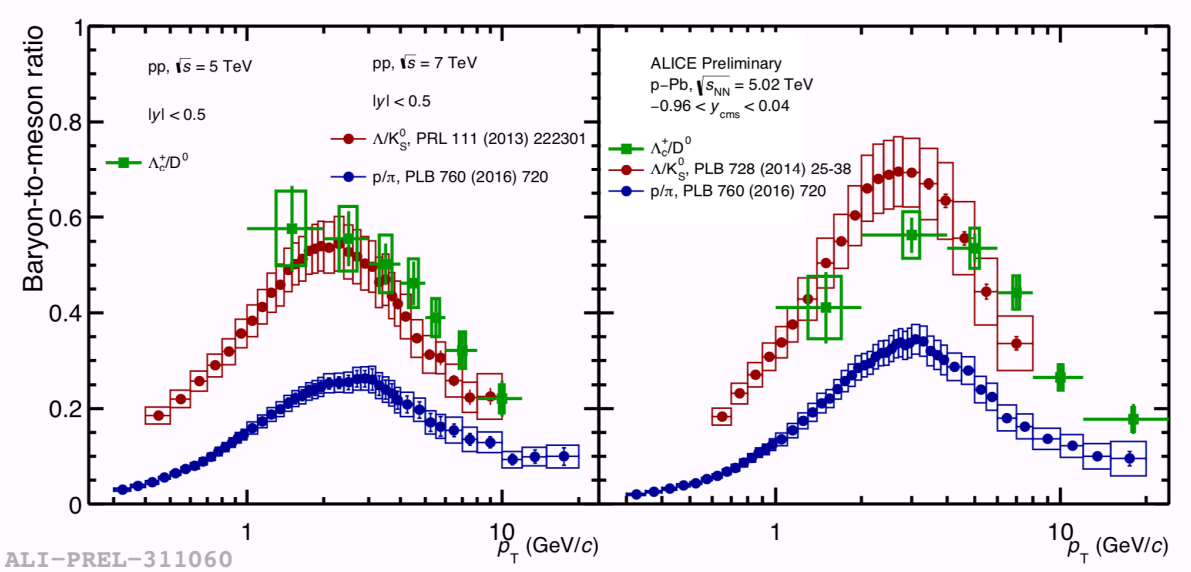
Pb-Pb
5.02 TeV

A Large Ion Collider Experiment



Aiming towards Run 3

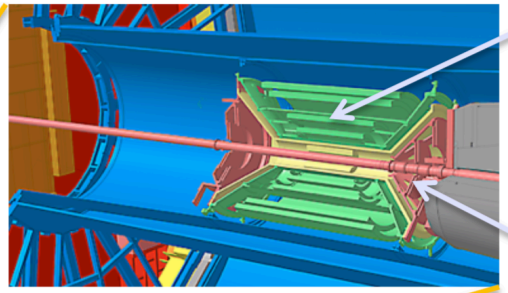
- Collision rate at ALICE IP will increase to 50 kHz
  - upgrade TPC chambers for continuous readout
- Improve vertexing and tracking at low p_T for measurements of low p_T particles, including heavy flavor and short-lived states, in high multiplicity environment



Upgrades during Long Shutdown 2

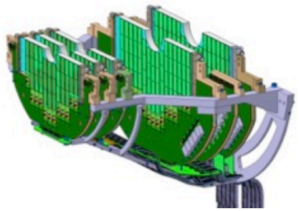
New RO architecture
(TPC, Muon Spectrometer, TRD, TOF, PHOS, EMCAL/DCAL, ZDC)

New MB trigger
(FIT)

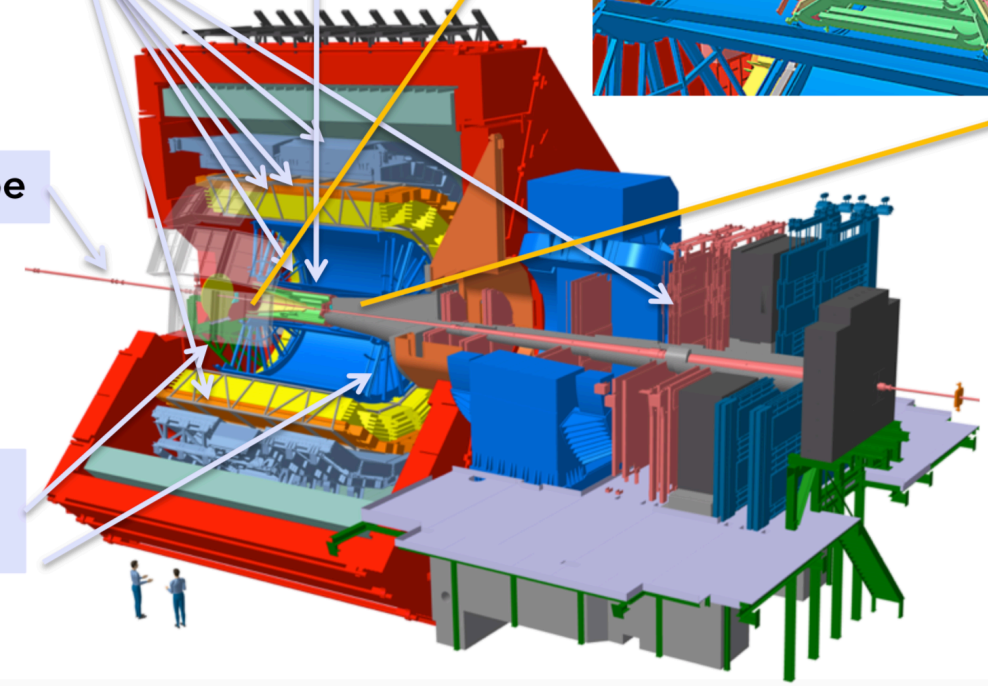


New Inner Tracking System

New Muon Forward Tracker



New Be beam-pipe



New TPC GEM-based chambers

Computing O^2

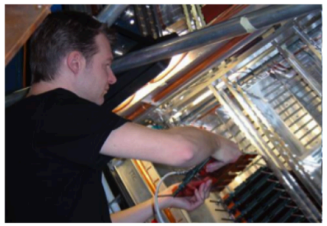
TPC upgrade status

TPC upgrade status

Remove Services and FEE (outside cleanroom)

Uninstall MWPC ROC

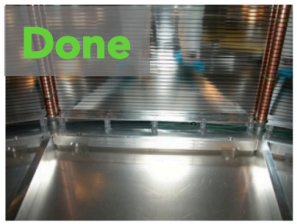
Install GEM ROC



Install new FEC + test

Ready for transportation to SX2

TPC in cleanroom. Cleaning & irradiation tests



FC HV infrastructure modification

Survey, shimming, sealing

Pre-commissioning with cosmic, Laser, pulser, Xray

7 Mar

11 Apr

25 Apr (A)
5 Aug (C)

13 May (A)
16 Aug (C)

14 Jun (A)
25 Aug (C)

5 Jul (A)
16 Sep (C)

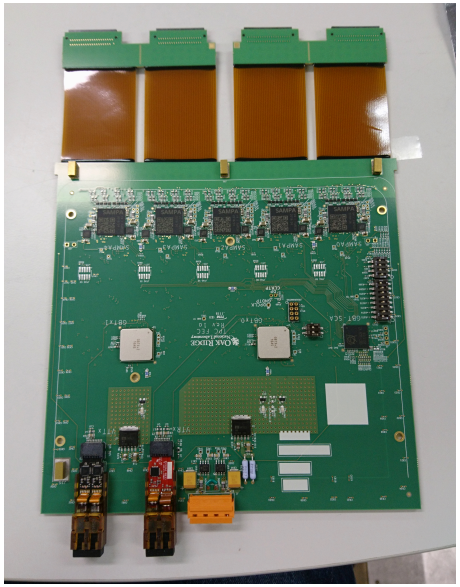
14 Oct (A)
31 Oct (C)

31 Oct (A)
4 Dec (C)

18 Feb 2020

Readout electronics for the TPC and MCH

- Development and testing of SAMPA chip for the front-end cards at Lund
- Completed robotic testing of 30k (TPC) + 60k (MCH) chips ✓
- In ALICE TPC :
  5 SAMPAs/FEC
  91 FECs/sector
  36 sectors
  = 16380 SAMPAs
- Also testing chips for STAR, NICA, FAIR, Rutherford, sPHENIX



Lund activities in ALICE

- Analysis : exploring the origins of collective effects in small systems and strangeness production
  - How do our measurements of pp collisions inform our understanding of AA, and vice versa?
- Hardware : participation in TPC upgrade
  - SAMPA chip campaign successfully completed
  - FEC installation and pre-commissioning about to start
- Coordination : Convenor of Physics Working Group on Correlations and Fluctuations (A. Ohlson)


Lots more interesting
physics to come!
ALICE
Run: 244918
Time: 2015-11-25 10:36:18
Colliding system: Pb-Pb
Collision energy: 5.02 TeV


Thank you for your attention!
Any questions?
ALICE
Run: 244918
Time: 2015-11-25 10:36:18
Colliding system: Pb-Pb
Collision energy: 5.02 TeV