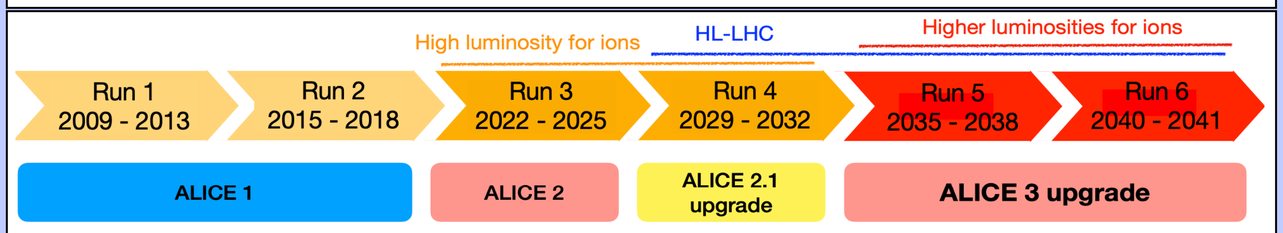
Physics program of ALICE 3: a next-generation heavy-ion detector for LHC Run 5 and beyond

Nicola Nicassio (University and INFN, Bari) on behalf of the ALICE Collaboration

ALICE 3 motivations



Main experimental goal of the ALICE Collaboration

Study the dynamics of strongly-interacting matter produced in heavy-ion collisions

Run 3+4 will allow systematic measurements of

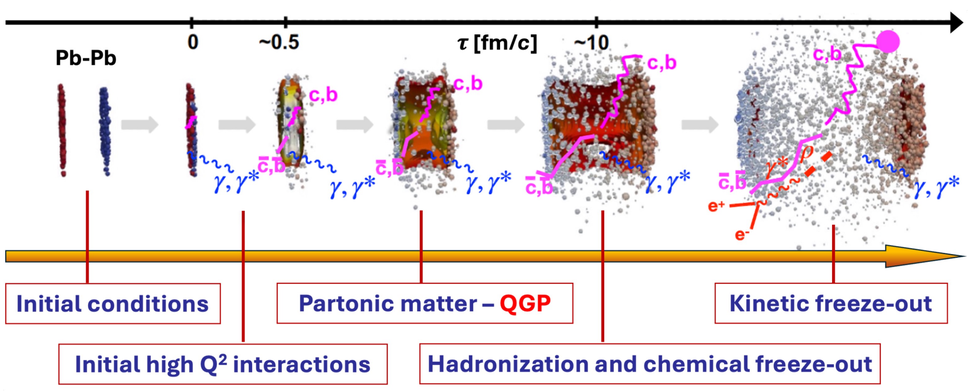
- Medium effects on heavy-flavour hadrons
- Time averaged thermal QGP radiation
- Collective effects from small to large systems

BUT

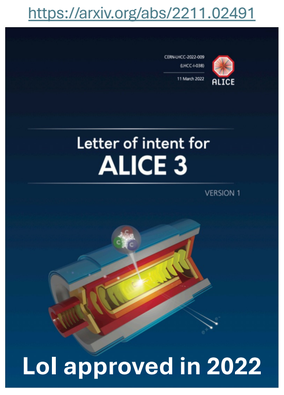
Fundamental questions will remain open

- QGP properties driving constituents to equilibrium
- The partonic EoS and its temperature dependence
- Underlying dynamics of chiral symmetry restoration
- Diffusion/hadronization mechanisms of the QGP

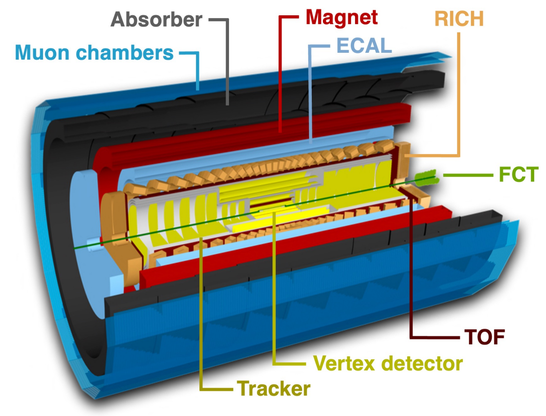
Need for unprecedented detector performance ➡ **Next-generation heavy-ion experiment: ALICE 3**



https://arxiv.org/abs/2211.02491



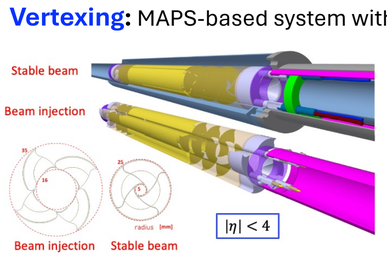
ALICE 3 detector concept

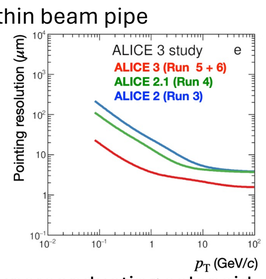


Processes	Observables
Early stages	Dilepton and photon production and flow
Diffusion	Heavy-flavour correlations and flow
Hadronization	Multi-charm baryons, quarkonia
Detector requirements	Pointing resolution: ≈ 10 μm at 200 MeV/c
	Tracking relative p_T resolution: ≈ 1-2 %
	Extensive identification of e, μ, π, K, p, γ
	Large pseudorapidity coverage: $\lvert\eta\rvert < 4$

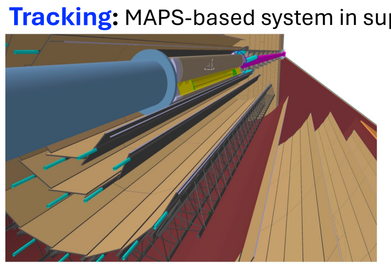
Efficient, fast, compact, light and hermetic apparatus
➔Si-based solid state sensors: MAPS, SiPMs, LGADs

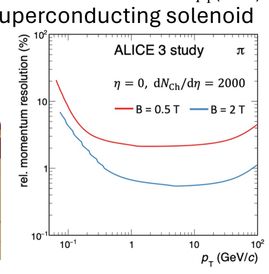
Vertexing: MAPS-based system within beam pipe





Tracking: MAPS-based system in superconducting solenoid

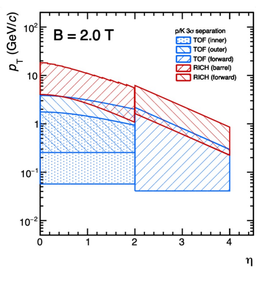


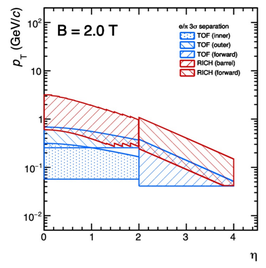


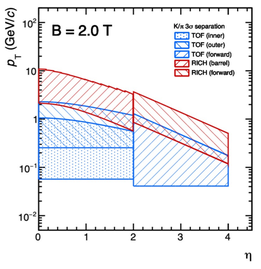
Particle identification
TOF & RICH:

- e/π sep. up to 3 GeV/c
- π/K sep. up to 10 GeV/c
- K/p sep. up to 16 GeV/c

MID: μ down to 1.5 GeV/c
ECAL: e, γ up to 100 GeV/c
FCT: γ down to 1-10 MeV/c







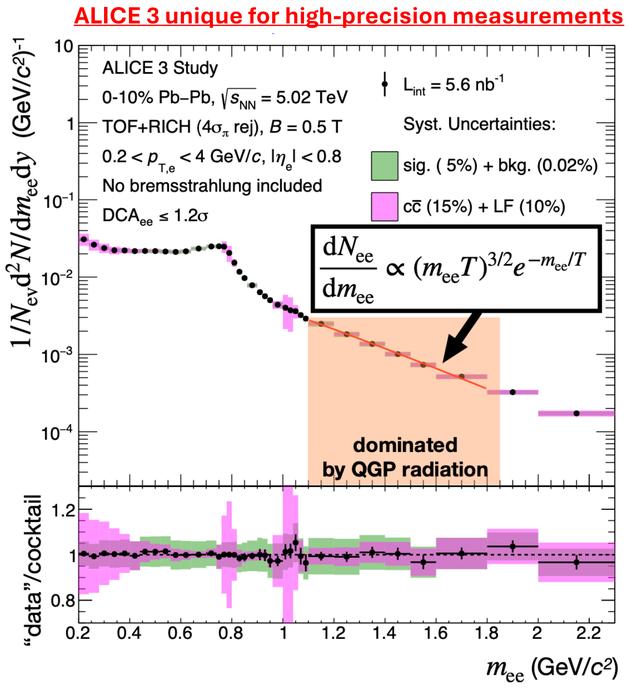
Dileptons

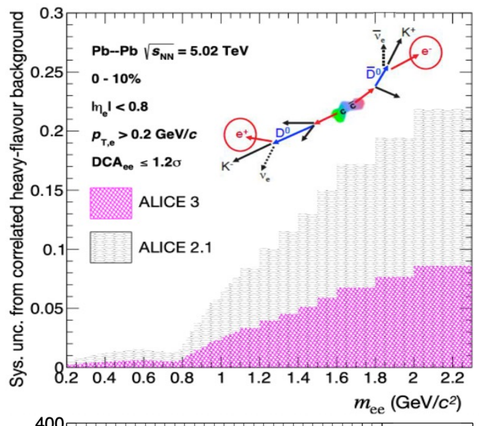
- Dileptons (virtual photons) are produced in all the different stages of a heavy-ion collision
- Since they are not interacting via the strong force, they leave the collision unscattered after production, making them ideal messengers to study the whole evolution of the collision

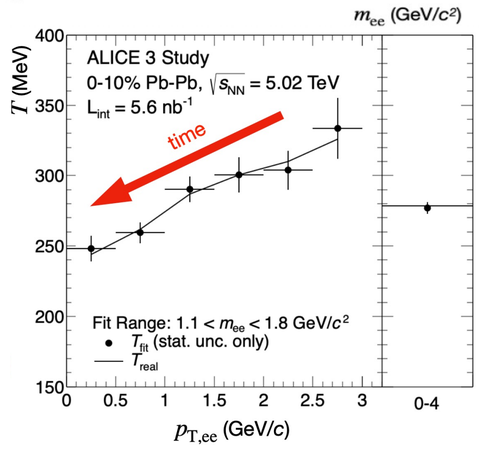
Time dependence of QGP temperature using double - differential spectra of m_{ee} and $p_{T,ee}$

Crucial requirements: $e^{\pm}$ PID, small material budget, excellent pointing resolution (HF bkg)

ALICE 3 unique for high-precision measurements



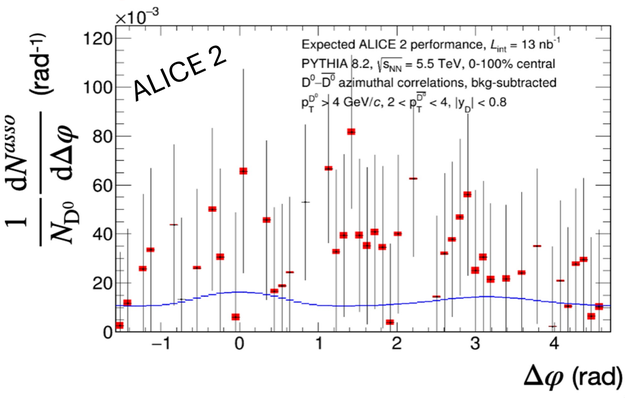


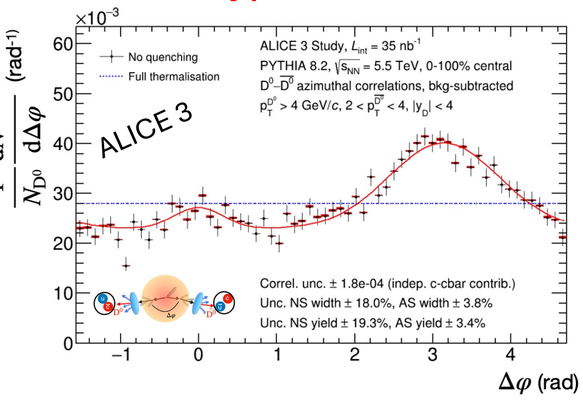


Heavy-flavour correlations

- The azimuthal correlation of associated heavy-flavour hadron pairs (e.g. $D^0\overline{D}^0$) is a probe of QGP scattering ⇒ Energy loss mechanisms and the degree of quark thermalization in the QGP
- Need for high identification purity, efficiency, statistics and acceptance down to low p_T

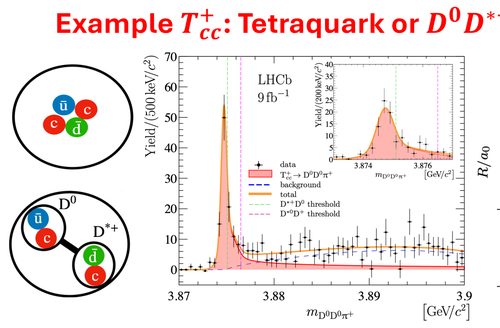
Heavy-ion measurement out of reach in LHC Runs 3 and 4: only possible with ALICE 3

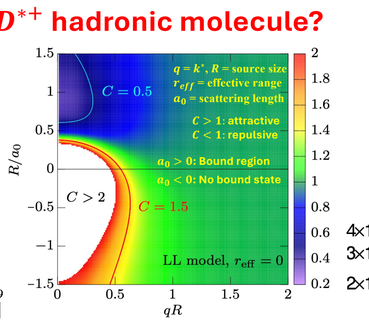


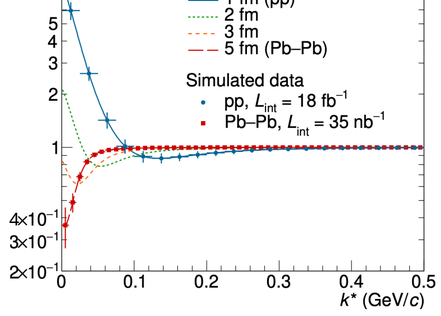


- The source size dependence of two-particle momentum correlation $C(k^*)$ probes nature of hadronic bound states

Example T_{cc}^+: Tetraquark or D^0D^{*+} hadronic molecule?





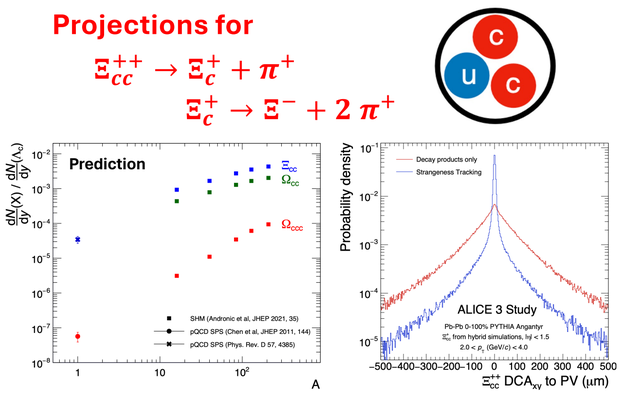


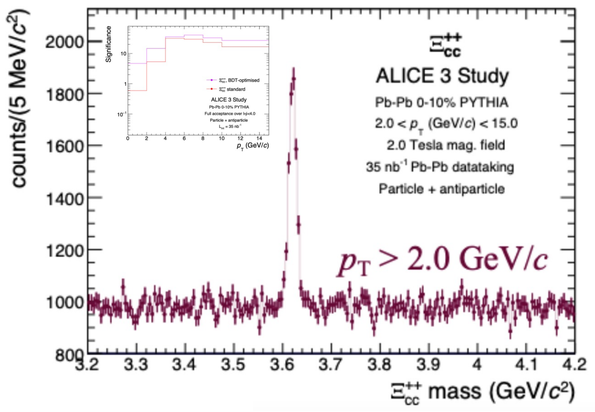
Multi-charm baryons

- Multi-charm baryon yields are powerful probes of the hadron formation mechanisms since they are produced by combination of uncorrelated charm quarks produced in the collision
- With the first tracking layer at 5 mm from the beam, strange particles (e.g. $\Xi^{\pm}$) are tracked before decaying ⇒ Capability to identify weak decays from primary and secondary sources

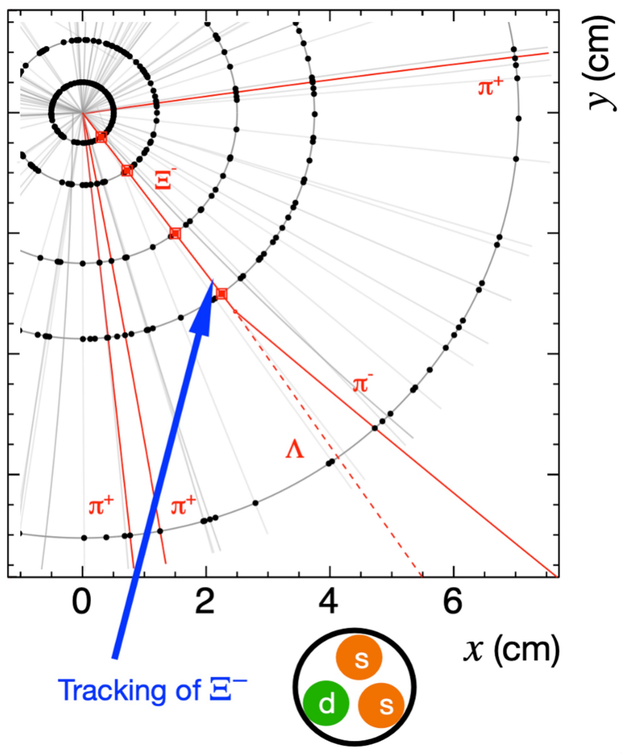
Projections for

$$\Xi_{cc}^{++} \rightarrow \Xi_c^+ + \pi^+$$
$$\Xi_c^+ \rightarrow \Xi^- + 2\,\pi^+$$



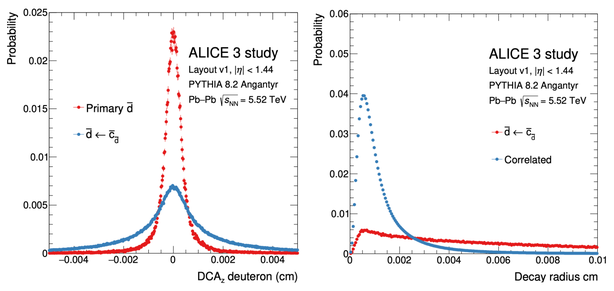


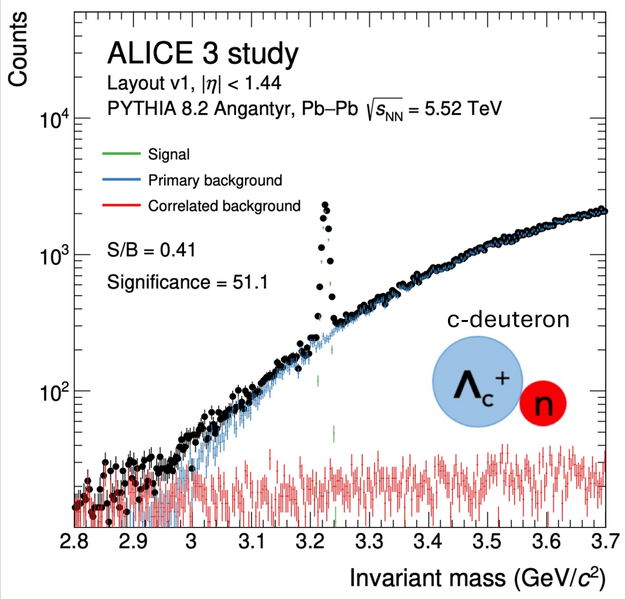
Strangeness tracking in Ξ_{cc}^{++} decay



Search for charm nuclei

Example c-deuteron: $d_c \rightarrow d + K^- + \pi^+$





Ultra-soft photons

- Low's theorem: soft inner Bremsstrahlung photon spectrum with a $1/E$ dependence
- Most past experiments show an excess by a factor 4-8 w.r.t. prediction Low's theorem

ALICE 3 aims to measure soft photons spectra with unprecedented precision