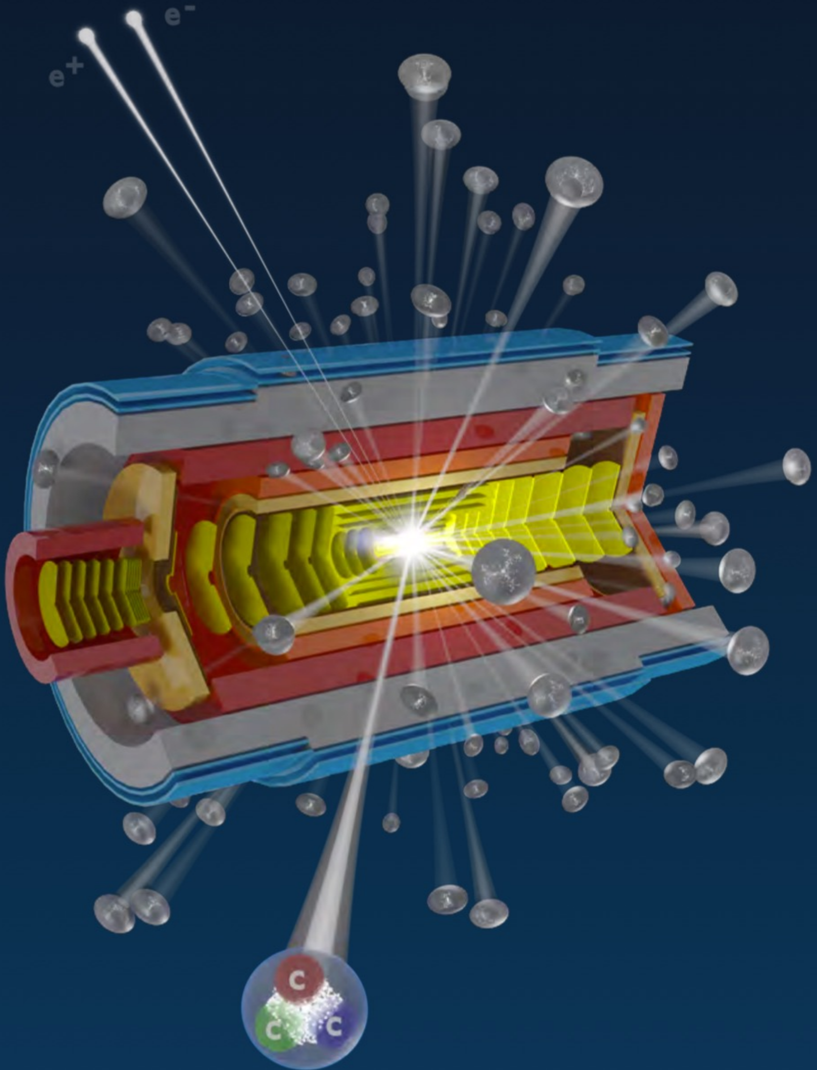


ALICE 3

Sanghoon Lim
for the ALICE Collaboration

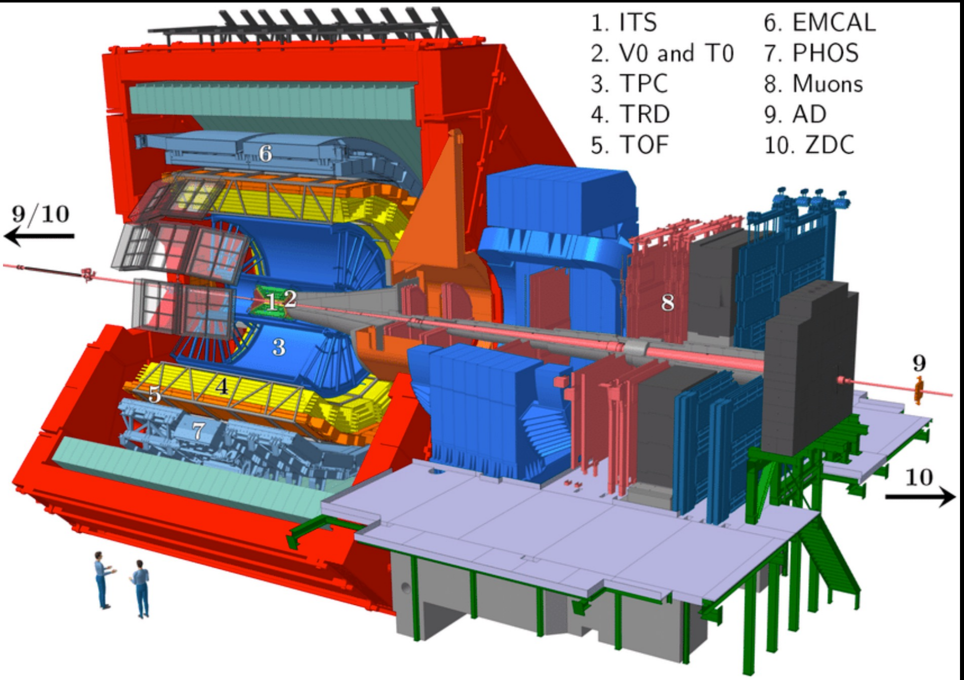
Pusan National University

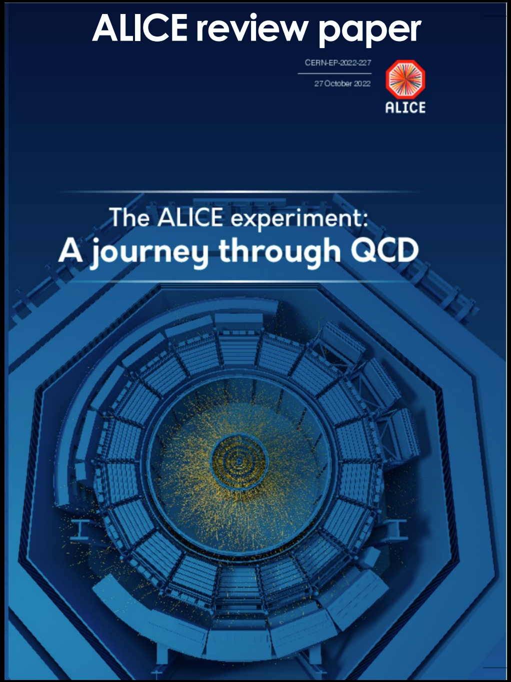
ATHIC2023

ALICE

PUSAN NATIONAL UNIV.
NPL
NUCLEAR PHYSICS LAB

ALICE



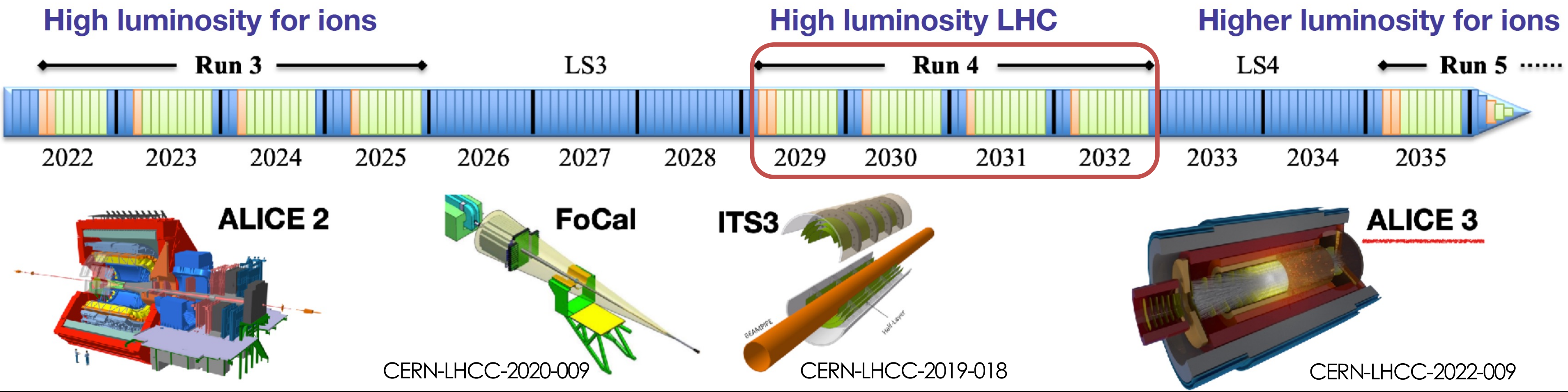


arXiv:2211.04384

- Central Barrel: tracking, particle ID, and EM calorimetry ($|\eta|<0.9$)
- Forward muon arm ($2.5<\eta<4.0$)
- Major upgrades in LS2: New inner tracking system, forward muon tracker, and TPC upgrade

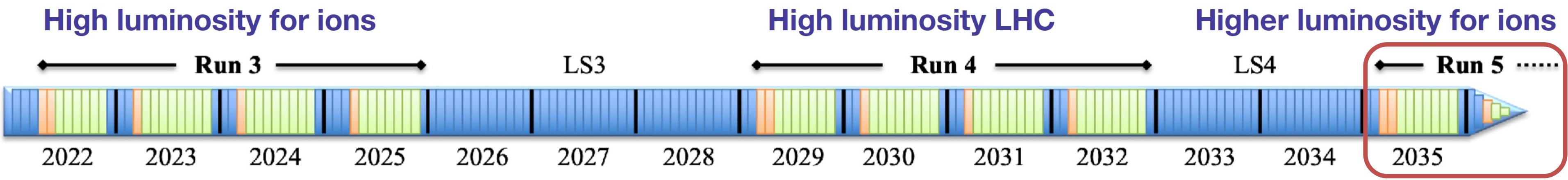
arXiv:2302.01238

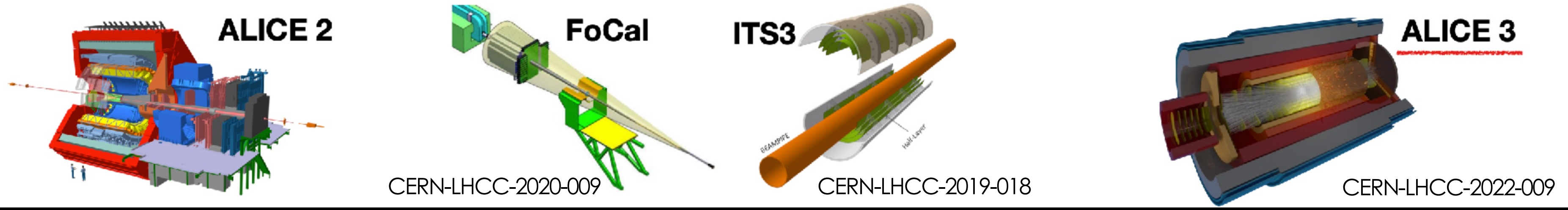
ALICE in the future



- FoCal
  - FoCal-E: 20 layers of W(3.5 mm≈1X_0)+Si sensors
    Two sensor types: pad and pixel (ALPIDE)
  - FoCal-H: conventional metal-scintillator sampling calorimeter
  - Parton distributions in protons and nuclei with photons and jets at forward rapidity
- ITS3
  - Replacement of 3 innermost layers of ITS2 with curved wafer-scale silicon sensors
  - low material budget: 0.05% X_0 per layer
  - Improved tracking precision and efficiency at low p_T

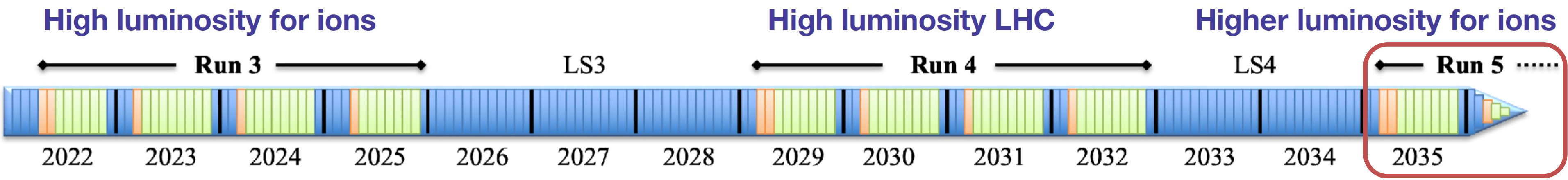
ALICE in the future

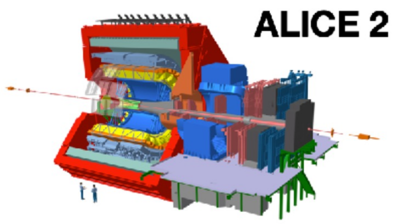


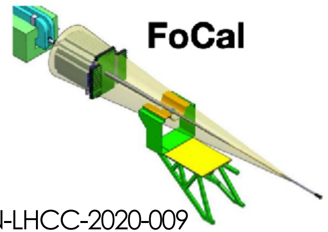


- Heavy-ion physics at the LHC beyond Run 4
  - Parton transport: high-precision beauty measurements
  - Formation of hadrons: multi-charm baryons, P-wave quarkonia, exotic hadrons
  - Bulk and shear viscosity: azimuthal asymmetry of electromagnetic radiation
  - Chiral symmetry restoration: low mass dileptons
  - Collectivity in small systems: high event rates and a large acceptance

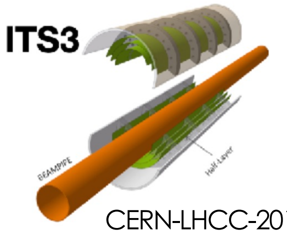
ALICE in the future



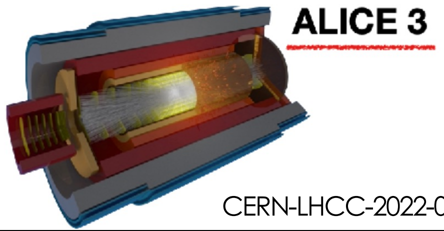




CERN-LHCC-2020-009



CERN-LHCC-2019-018



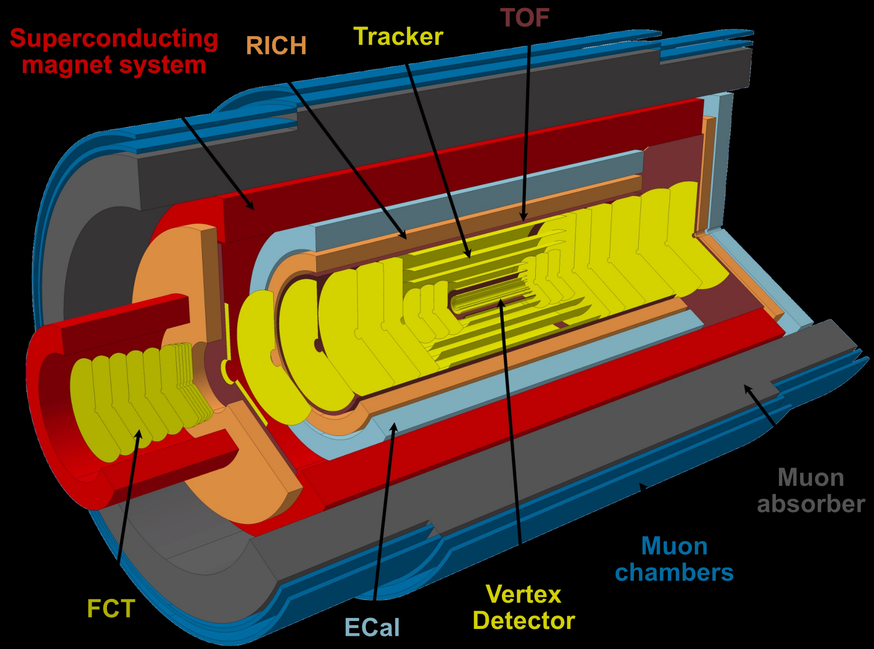
CERN-LHCC-2022-009

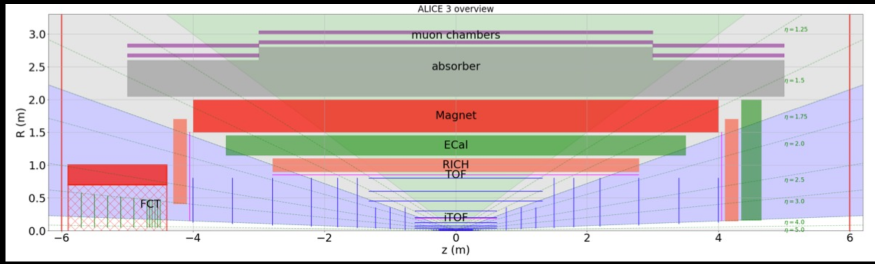
- ALICE 3
  - Next-generation heavy-ion experiment: first ideas at Heavy-Ion town meeting 2018 (arXiv:1902.01211)
  - Letter of Intent: very positive feedback from the LHCC in Mar. 2022 and recommended proceeding with R&D

System	$\mathscr{L}^{\text{month}}$	$\mathscr{L}^{\text{Run5+6}}$
pp	$0.5\,\text{fb}^{-1}$	$18\,\text{fb}^{-1}$
pp reference	$100\,\text{pb}^{-1}$	$200\,\text{pb}^{-1}$
A–A		
Xe–Xe	$26\,\text{nb}^{-1}$	$156\,\text{nb}^{-1}$
Pb–Pb	$5.6\,\text{nb}^{-1}$	$33.6\,\text{nb}^{-1}$

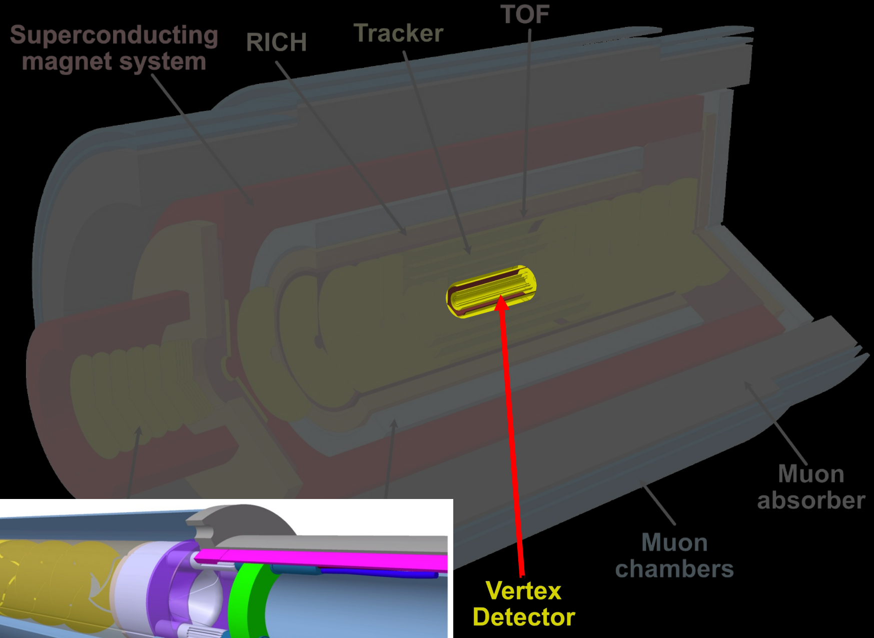
ALICE 3: Detector Overview

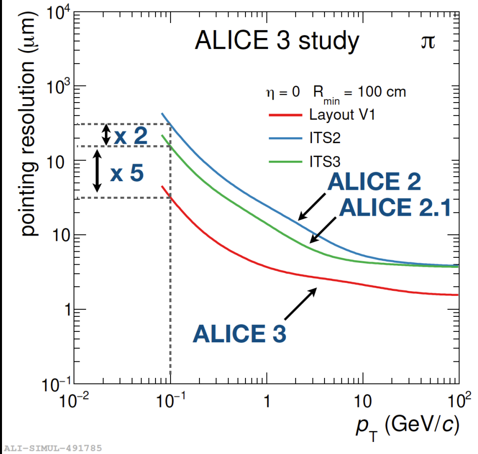
- Compact and large acceptance
  - $|\eta|<4$ and $p_T>0.02$ GeV/c
- Superconducting magnet system
  - Maximum field: B=2 T
- All silicon-based large acceptance tracker
  - ~10% X_0 overall material budget
  - ~10 μm pointing resolution at p_T~200 MeV/c
- Particle identification in a wide p_T and η range
  - Silicon-based TOF and RICH
  - Muon identification
- Continuous readout and online processing

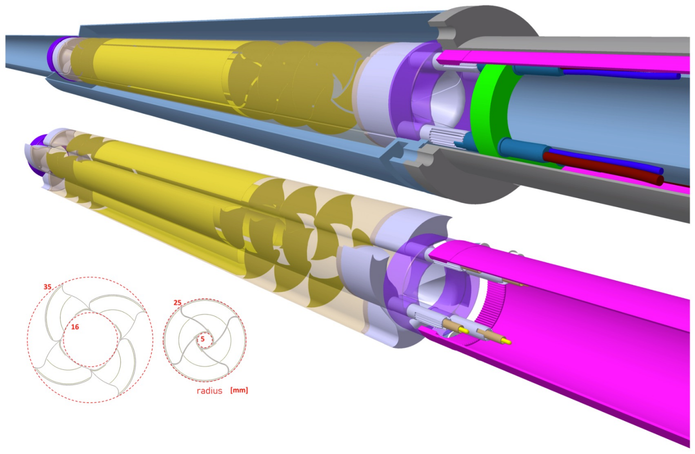




- In vacuum, retractable, tracker (3 layers + 3 disks)
- Wafer-size sensors based on CMOS Monolithic Active Pixel Sensors (MAPS) technology
- Extremely low material budget
  - 0.1% X_0 per layer
- Pixel pitch of ~10 μm for ~2.5 μm intrinsic resolution

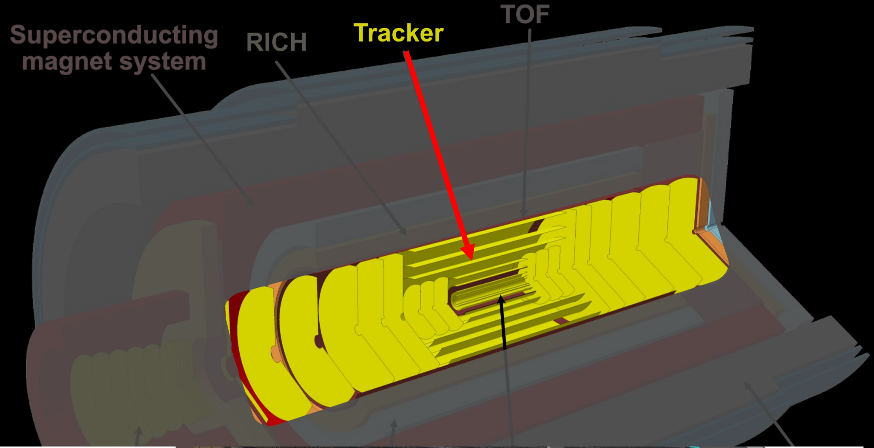


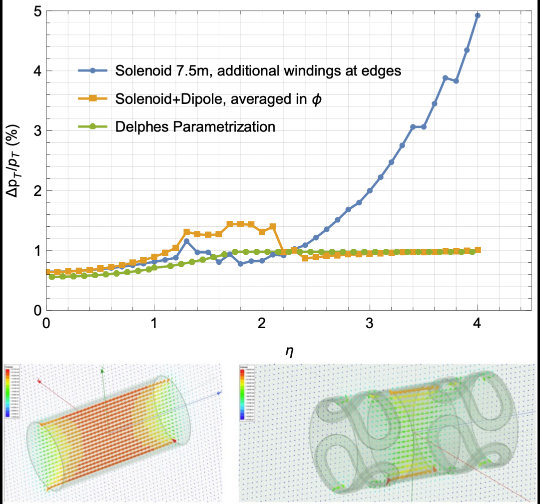




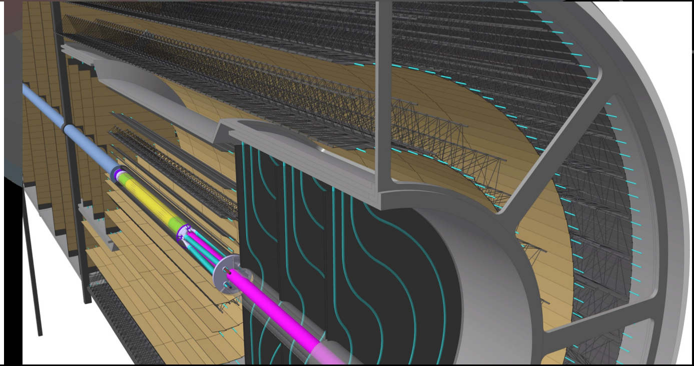
ALICE 3: Outer Tracker

- 8 layers and 9 disks based on MAPS
  - Total of ~67m² of silicon
  - Compact design (R<80 cm, |z|<4 m)
- Pixel pitch of ~40 μm for ~10 μm intrinsic resolution
- 1% X_0 per layer
- Low power: ~20 mW/cm²

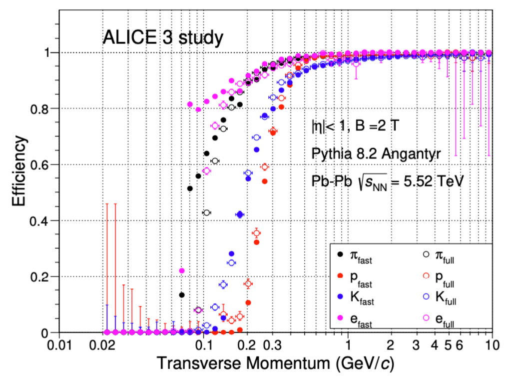




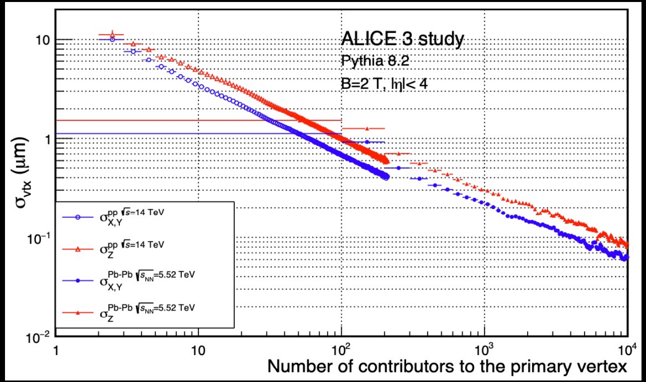
Layer	Material thickness (% X_0)	Intrinsic resolution (μm)	Barrel layers Length ($\pm z$) (cm)	Barrel layers Radius (r) (cm)	Forward discs Position ($\|z\|$) (cm)	Forward discs R_{in} (cm)	Forward discs R_{out} (cm)
0	0.1	2.5	50	0.50	26	0.50	3
1	0.1	2.5	50	1.20	30	0.50	3
2	0.1	2.5	50	2.50	34	0.50	3
3	1	10	124	3.75	77	5	35
4	1	10	124	7	100	5	35
5	1	10	124	12	122	5	35
6	1	10	124	20	150	5	80
7	1	10	124	30	180	5	80
8	1	10	264	45	220	5	80
9	1	10	264	60	279	5	80
10	1	10	264	80	340	5	80
11	1				400	5	80



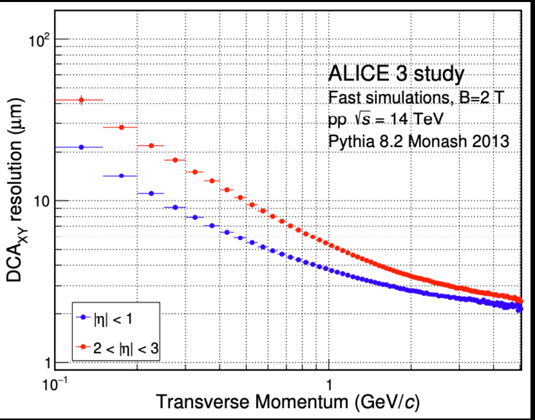
ALICE 3: Tracking Performance



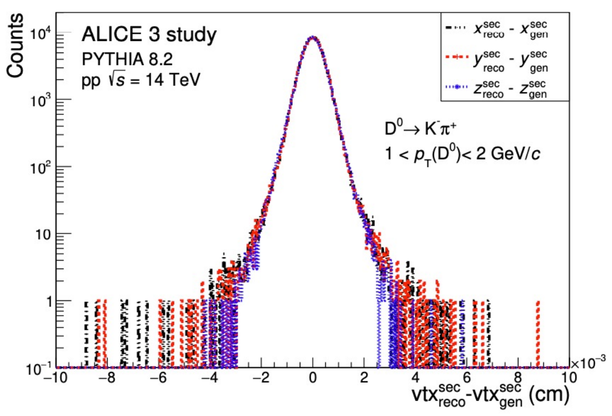
Tracking efficiency



Primary vertex resolution

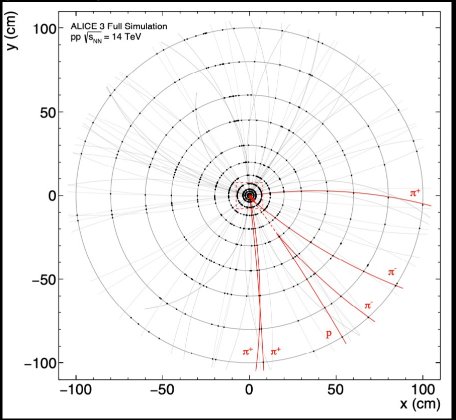


Impact parameter resolution



Secondary vertex residual

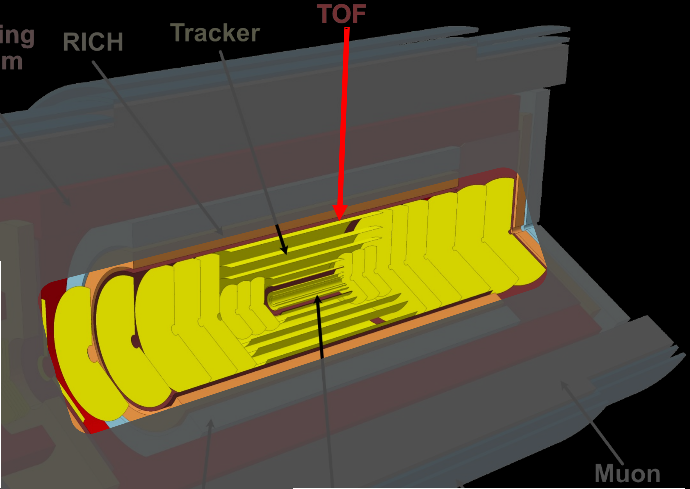
$\Xi^{++}_{cc} \to \Xi^+_c + \pi^+ \to \Xi^- + \pi^+ + \pi^+ + \pi^+$

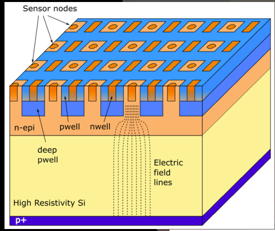


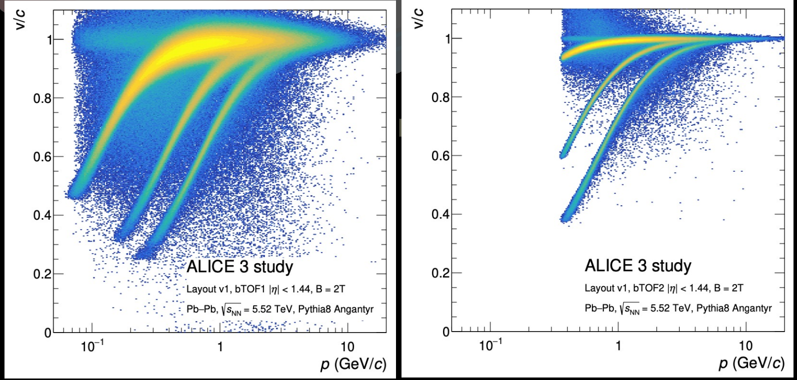
Strangeness tracking

ALICE 3: Time-of-Flight

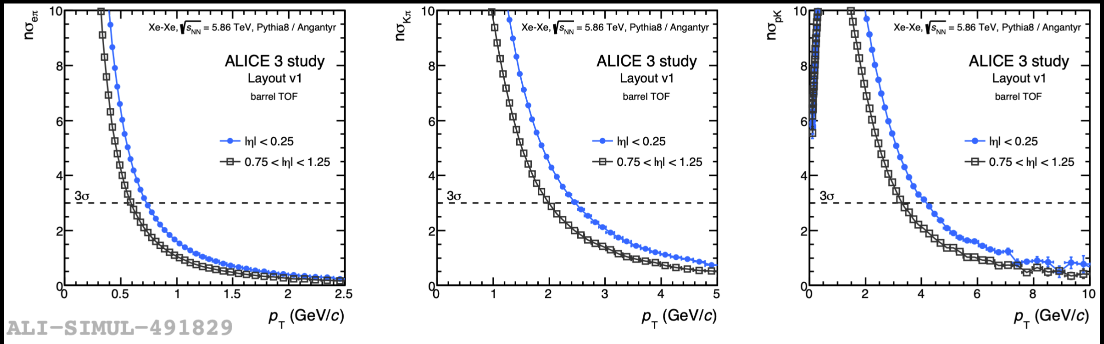
- 2 barrel layers ($|\eta|<1.75$)
  - Inner TOF at r=19 cm (surface: 1.5 m^2)
  - Outer TOF at r=85 cm (surface: 30 m^2)
- 2 forward layers ($1.75<|\eta|<4$)
  - R_{in}=15 cm and R_{out}=150 cm, z=±405 cm
- Silicon timing sensors
  - Baseline: CMOS sensor with gain





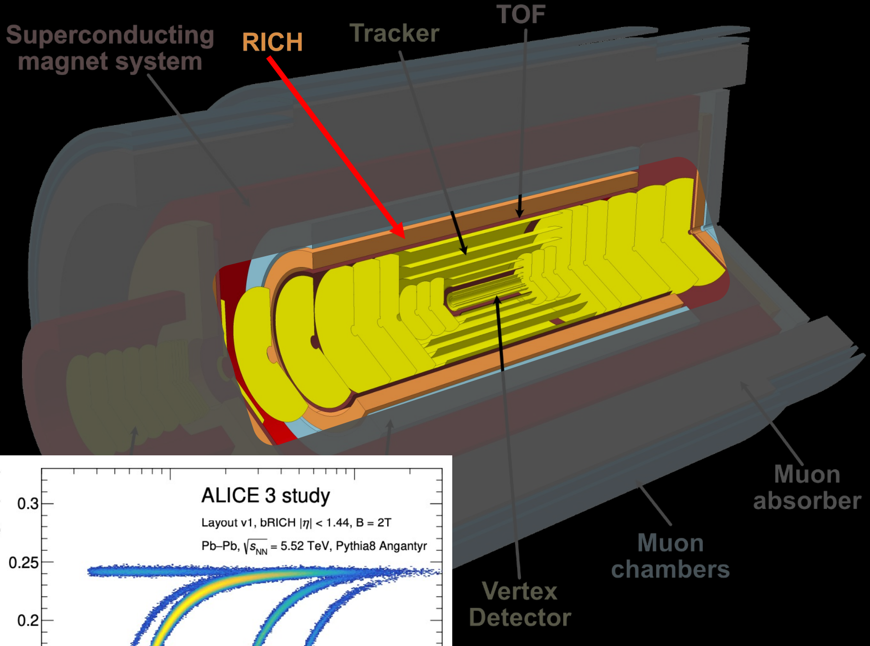


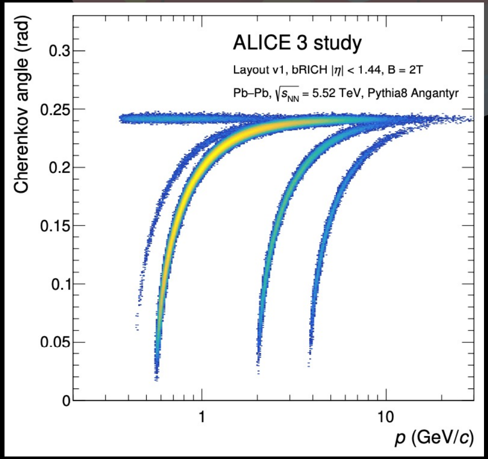
Performance of the outer TOF in Xe-Xe

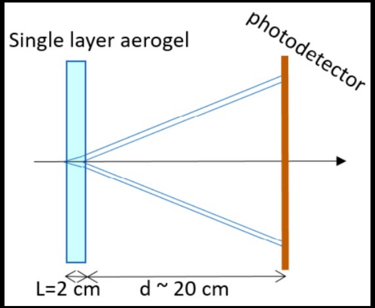


ALICE 3: RICH

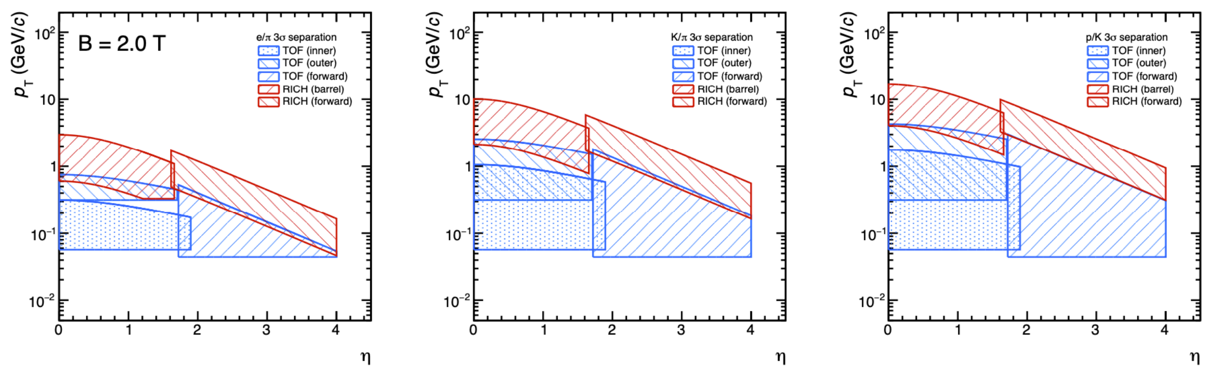
- Cherenkov detector to complement the TOF system for higher p_T reach
- 2 cm thick aerogel tile and photo-detection layer (SiPMs) at 20 cm from the radiator
  - n=1.03 at barrel and n=1.006 at forward
  - Total area of SiPM: ~60 m^2



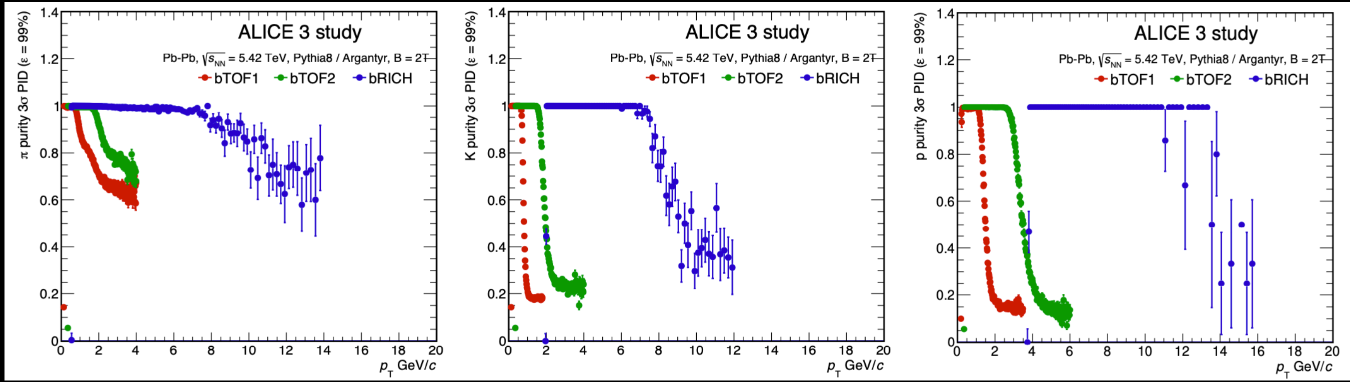




ALICE 3: PID Performance



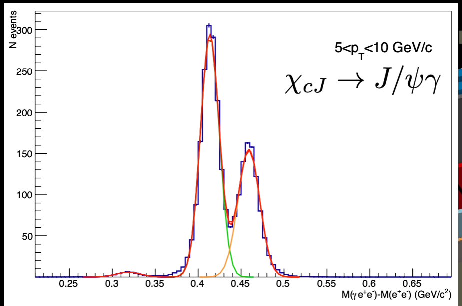
Kinematic region in which particles can be separated by at least 3σ

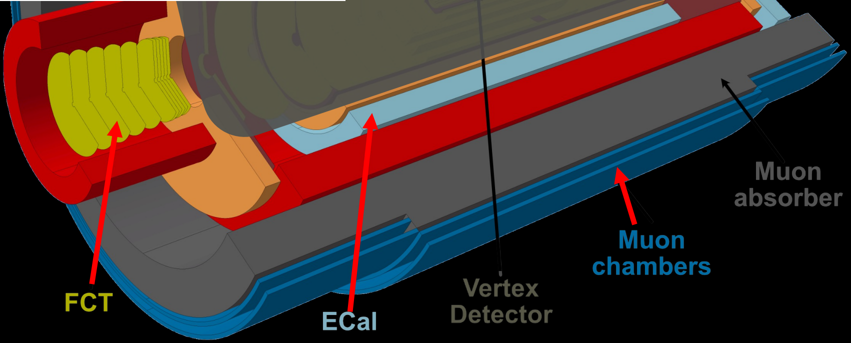


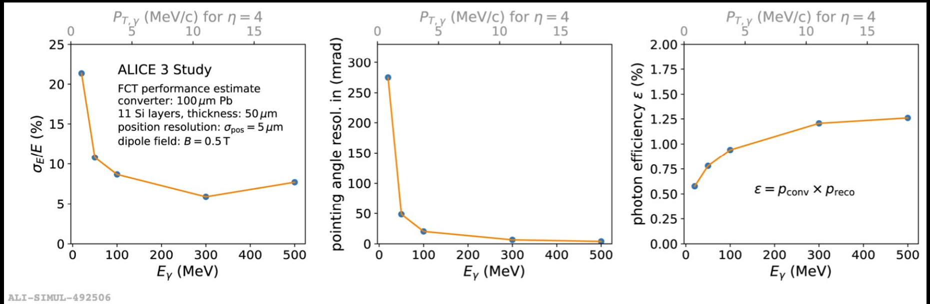
Purity of pions, kaons, and protons in Pb-Pb with a 3σ cut

ALICE 3: Additional particle identification

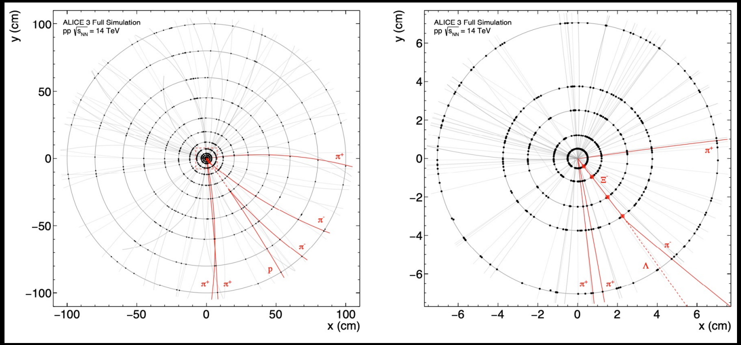
- Electromagnetic Calorimeter
  - Pb-scintillator sampling calorimeter + $PbWO_4$ crystals in $|\eta|<0.33$ for high precision
  - Photons and high-momentum electrons
- Muon Chambers
  - Absorber + 2 layers of muon detectors
  - Scintillator bars with SiPM readout or RPC
  - Muons down to p_T~1.5 GeV/c
- Forward Conversion Tracker
  - Thin tracking disks in $3<\eta<5$ in a dipole field
  - Very low p_T photons (<10 MeV/c)



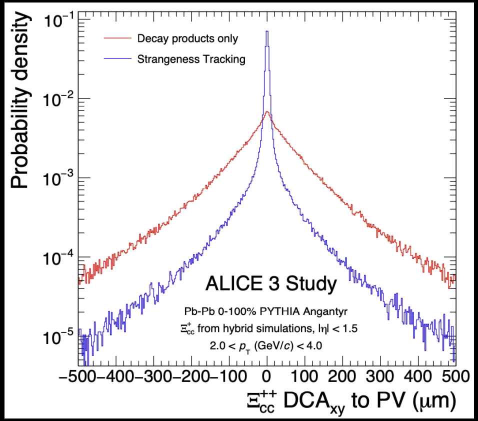


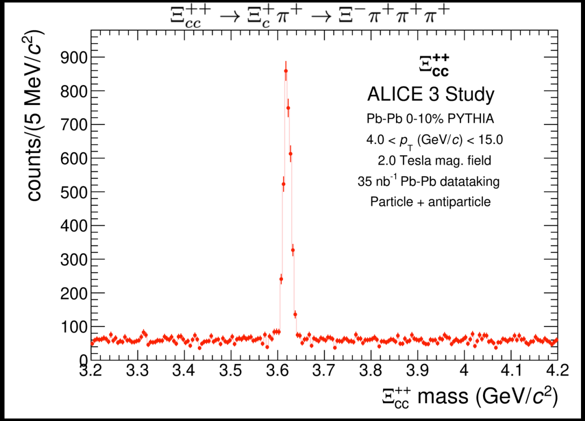


Physics performance: Multi-charm baryon

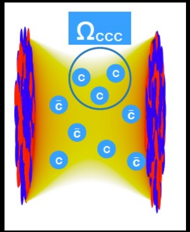


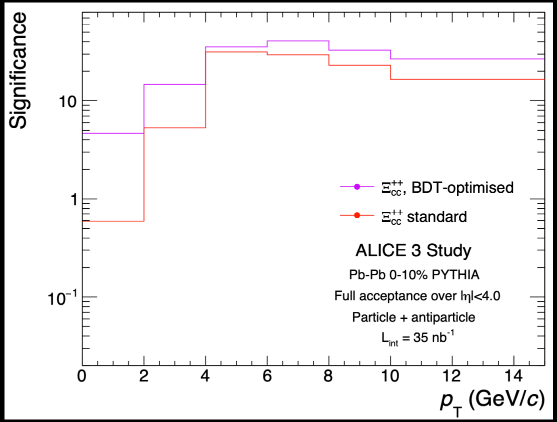
Strangeness tracking of the Ξ_{cc}^{++} decays

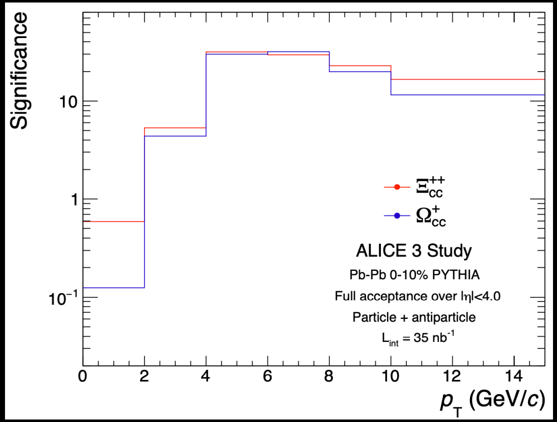




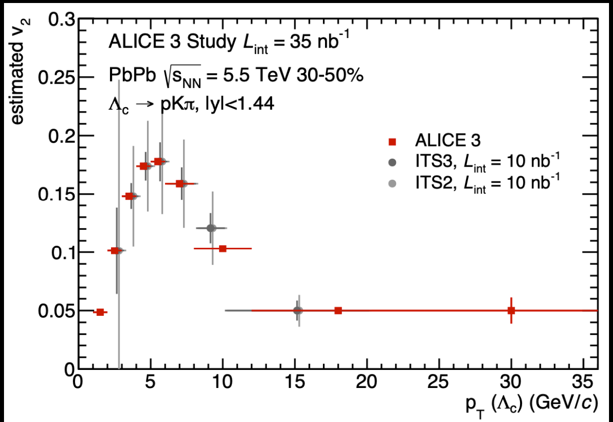
- Study of hadronization mechanisms and nature of exotic hadrons
  - Tracking of non-prompt strange baryon with inner tracking layers at r<5 mm

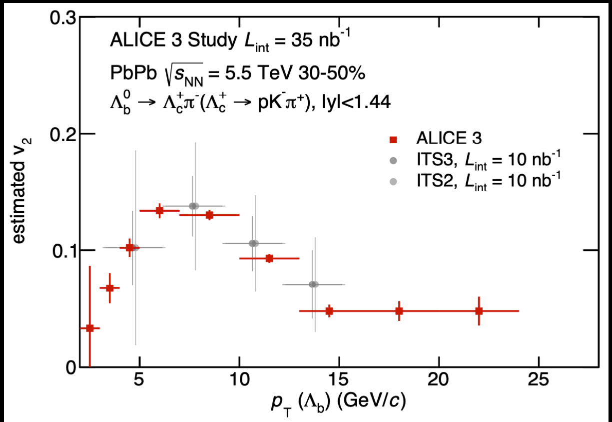


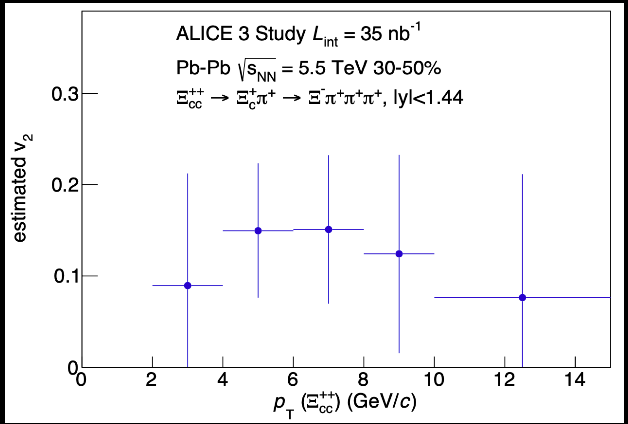




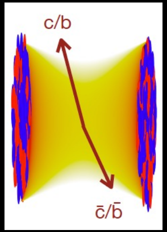
Physics performance: heavy-flavor baryon flow

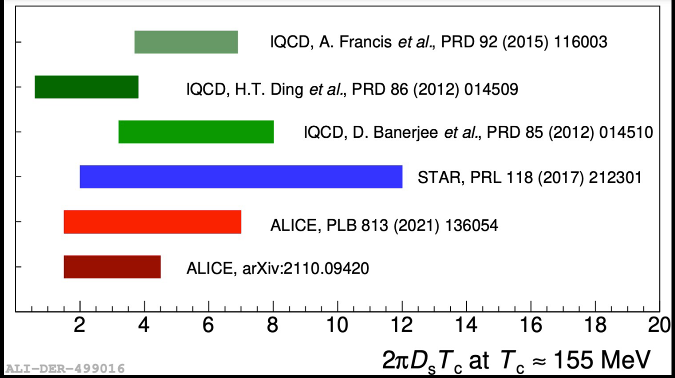




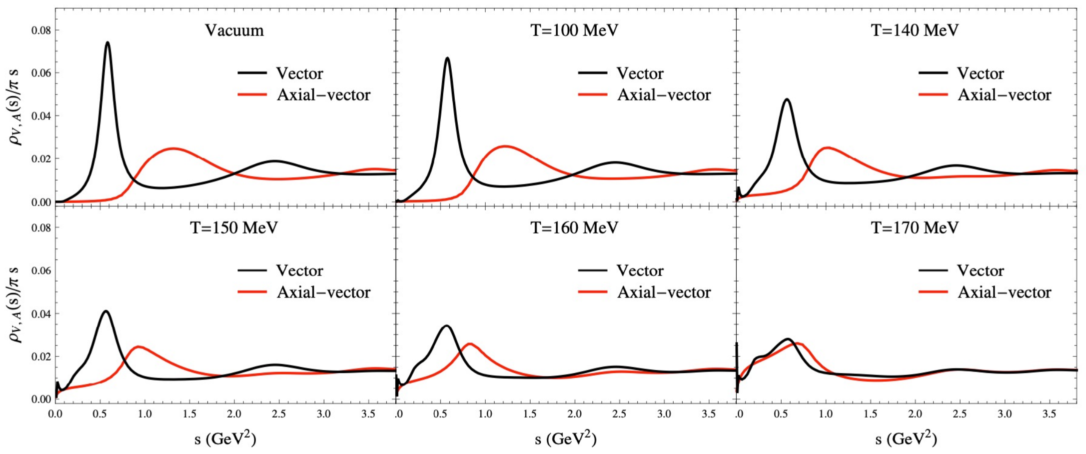


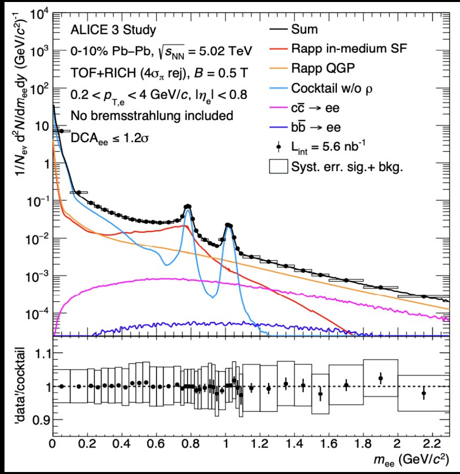
- Study of the medium response of heavy quarks
  - Constrain the Transport properties such as diffusion coefficient using R_{AA} and v_2 down to low p_T
  - Requires high-statistics of data with a large acceptance for precision measurement of v_2

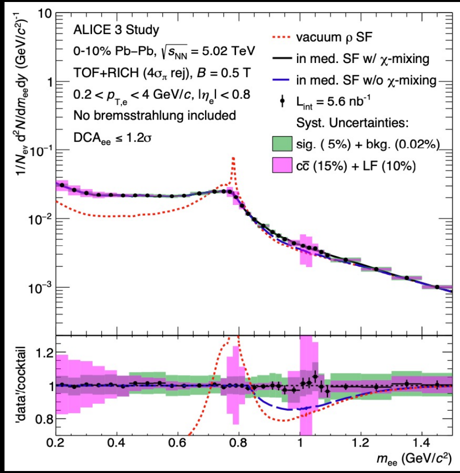




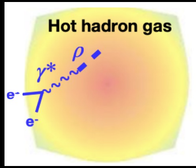
Physics performance: Thermal radiation and chiral symmetry



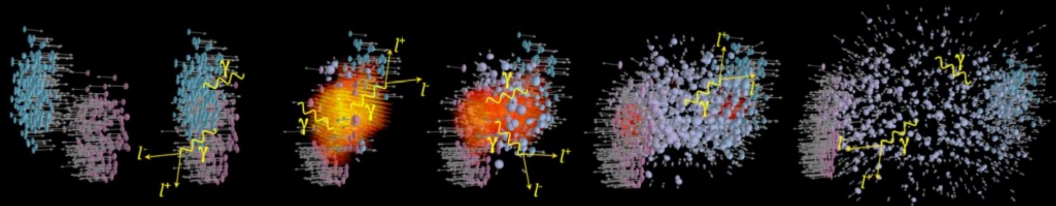




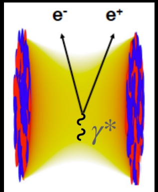
- Study of chiral symmetry restoration mechanisms using thermal dielectron spectrum
  - Thermal production of ρ
  - Modification of spectral function

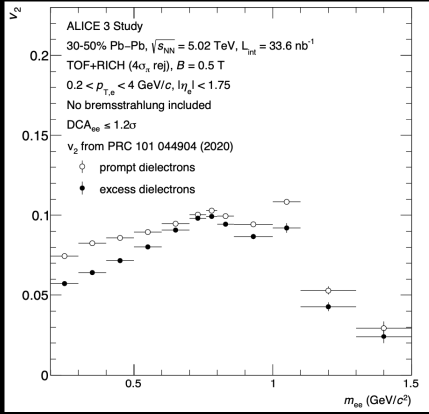


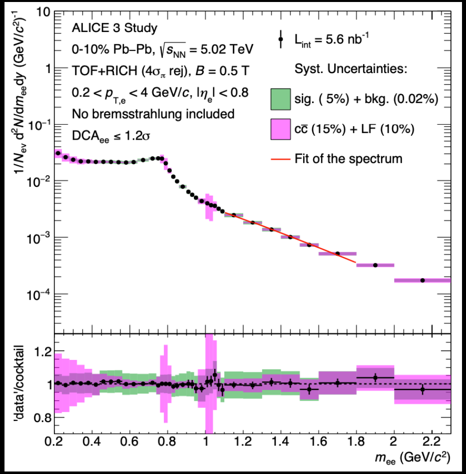
Physics performance: Thermal radiation and chiral symmetry

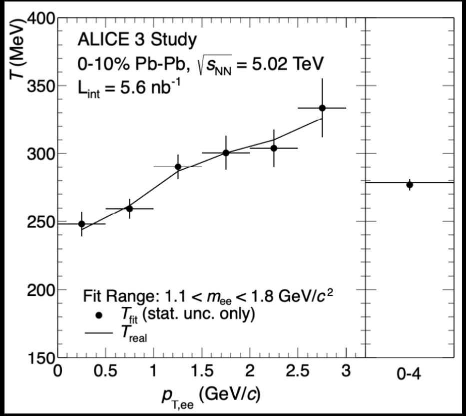


- Study of QGP temperature throughout the evolution using precision measurement of dielectrons (m_{ee}>1.1 GeV/c^2)
  - Main background:
    γ conversion (requires a small material budget)
    heavy-flavor (requires an excellent pointing resolution)
  - Differential measurements in m_{ee} and $p_{T,ee}$ provide information on the production time









- ALICE 3 will provide access to fundamental properties of QCD matter at the phase of extreme temperature
  - Heavy quark propagation and hadronization
  - Formation and dissociation of quarkonium states and exotic hadrons
  - Temperature and expansion with electromagnetic radiation
  - Chiral symmetry restoration

- Schedule
  - 2023-25: selection of technologies, small-scale R&D for proof of concept
  - 2026-27: large-scale engineered prototypes, Technical Design Reports
  - 2028-31: construction and test
  - 2031-32: contingency
  - 2033-34: installation and commissioning

BACKUP

Quantity	pp	O–O	Ar–Ar	Ca–Ca	Kr–Kr	In–In	Xe–Xe	Pb–Pb
$\sqrt{s_{NN}}$ (TeV)	14.00	7.00	6.30	7.00	6.46	5.97	5.86	5.52
L_{AA} ($cm^{-2}s^{-1}$)	3.0×10^{32}	1.5×10^{30}	3.2×10^{29}	2.8×10^{29}	8.5×10^{28}	5.0×10^{28}	3.3×10^{28}	1.2×10^{28}
$\langle L_{AA} \rangle$ ($cm^{-2}s^{-1}$)	3.0×10^{32}	9.5×10^{29}	2.0×10^{29}	1.9×10^{29}	5.0×10^{28}	2.3×10^{28}	1.6×10^{28}	3.3×10^{27}
$\mathscr{L}_{AA}^{month}$ (nb^{-1})	5.1×10^{5}	1.6×10^{3}	3.4×10^{2}	3.1×10^{2}	8.4×10^{1}	3.9×10^{1}	2.6×10^{1}	5.6
$\mathscr{L}_{NN}^{month}$ (pb^{-1})	505	409	550	500	510	512	434	242
R_{max} (kHz)	24 000	2169	821	734	344	260	187	93
μ	1.2	0.21	0.08	0.07	0.03	0.03	0.02	0.01
$dN_{ch}/d\eta$ (MB)	7	70	151	152	275	400	434	682
	at $R = 0.5$ cm							
R_{hit} (MHz/cm^2)	94	85	69	62	53	58	46	35
NIEL (1 MeV n_{eq}/cm^2)	1.8×10^{14}	1.0×10^{14}	8.6×10^{13}	7.9×10^{13}	6.0×10^{13}	3.3×10^{13}	4.1×10^{13}	1.9×10^{13}
TID (Rad)	5.8×10^{6}	3.2×10^{6}	2.8×10^{6}	2.5×10^{6}	1.9×10^{6}	1.1×10^{6}	1.3×10^{6}	6.1×10^{5}
	at $R = 100$ cm							
R_{hit} (kHz/cm^2)	2.4	2.1	1.7	1.6	1.3	1.0	1.1	0.9
NIEL (1 MeV n_{eq}/cm^2)	4.9×10^{9}	2.5×10^{9}	2.1×10^{9}	2.0×10^{9}	1.5×10^{9}	8.3×10^{8}	1.0×10^{9}	4.7×10^{8}
TID (Rad)	1.4×10^{2}	8.0×10^{1}	6.9×10^{1}	6.3×10^{1}	4.8×10^{1}	2.7×10^{1}	3.3×10^{1}	1.5×10^{1}

Observables	**Kinematic range**
Heavy-flavour hadrons	$p_T \to 0$, $\lvert\eta\rvert < 4$
Dielectrons	$p_T \approx 0.05$ to $3\,GeV/c$, $M_{ee} \approx 0.05$ to $4\,GeV/c^2$
Photons	$p_T \approx 0.1$ to $50\,GeV/c$, $-2 < \eta < 4$
Quarkonia and exotica	$p_T \to 0$, $\lvert\eta\rvert < 1.75$
Ultrasoft photons	$p_T \approx 1$ to $50\,MeV/c$, $3 < \eta < 5$
Nuclei	$p_T \to 0$, $\lvert\eta\rvert < 4$