ALICE - A Large Ion Collider Experiment
and
EIC - Electron-Ion Collider

Jian Liu (University of Liverpool)

on behalf of the Liverpool ALICE/EIC group

Liverpool Particle Physics Annual meeting 2024

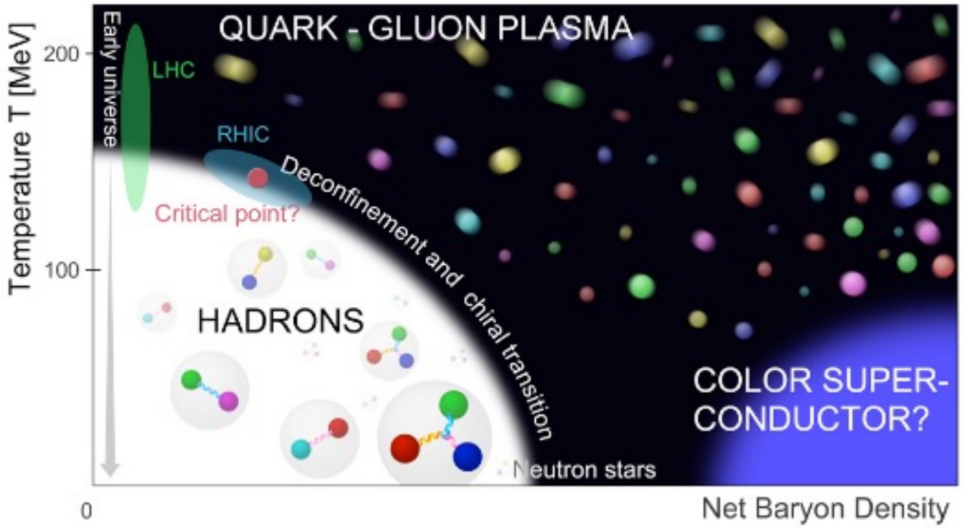
23-24 May 2024

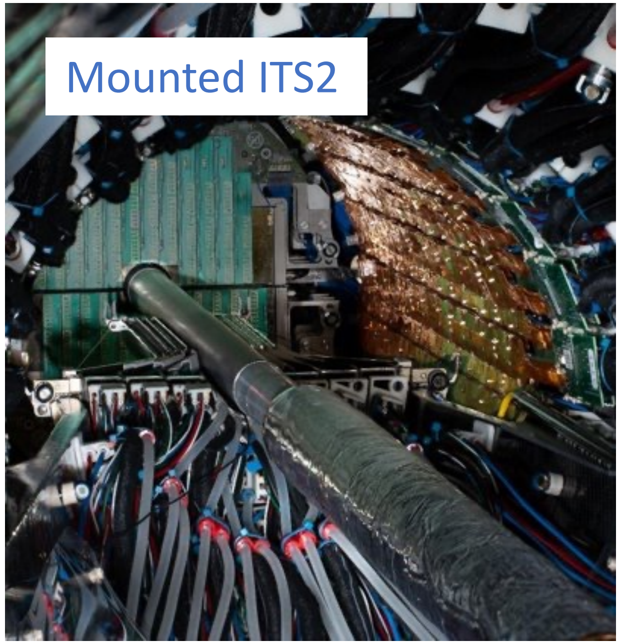
Upgraded ALICE for Run 3 and 4

- Major upgrades underwent for ALICE during LHC long shutdown 2 (2019-2022)

- Physics goals → high-precision measurements of QGP properties
  - Heavy-flavor hadrons, jets and quarkonia at very low p_T
  - Vector mesons and low-mass di-leptons
  - High-precision measurements of light nuclei and hypernuclei

- The new Inner Tracking System (ITS2) currently operational and showing excellent performance in LHC Run 3





Heavy-ions were back in the LHC!

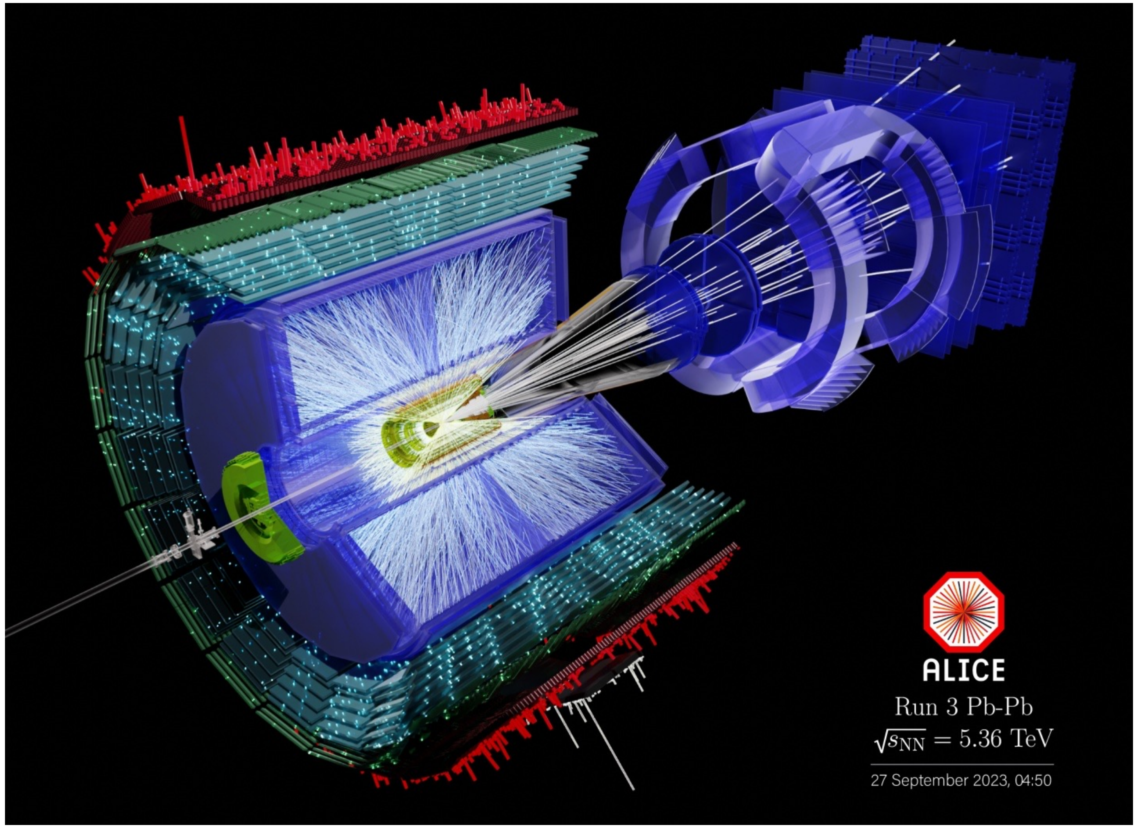
Heavy-ion LHC Run 3 started on 26/09/23

- Vastly upgraded ALICE detectors and subsystems ready for data taking

LHC intensity ramp up to maximum number of bunches 1240b by 06/10/23

- Successful data taking at ~50 kHz interaction rate proceeded smoothly until end of run on 30/10/23, routinely processing 700 GB/s of data

https://alice-collaboration.web.cern.ch/2023_Dec_heavy_ion



Run 1+2 (2010-18): 1.5 nb^{-1} Pb-Pb collisions delivered at 2.76 and 5.02 TeV

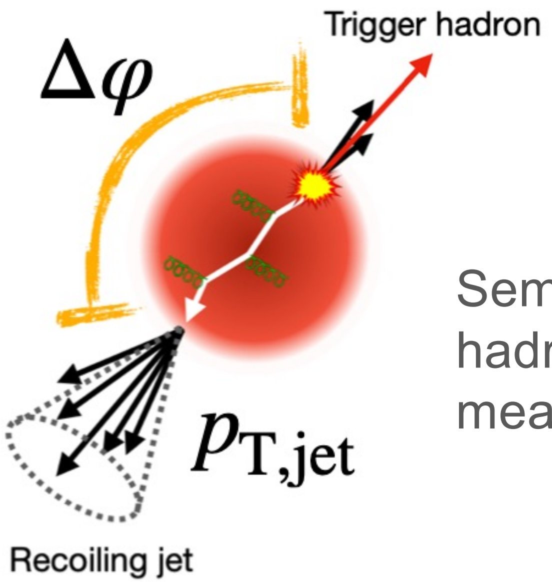
Run 3 (2023): ~ 2 nb^{-1} Pb-Pb collisions delivered at 5.36 TeV

➔ Recorded Minimum Bias sample of ~ 12 billion collisions, ~ 40 times larger than Run 1+2

(Also recorded **~ 30 pb^{-1} pp collisions** during 2022-23 at 0.9 and 13.6 TeV)

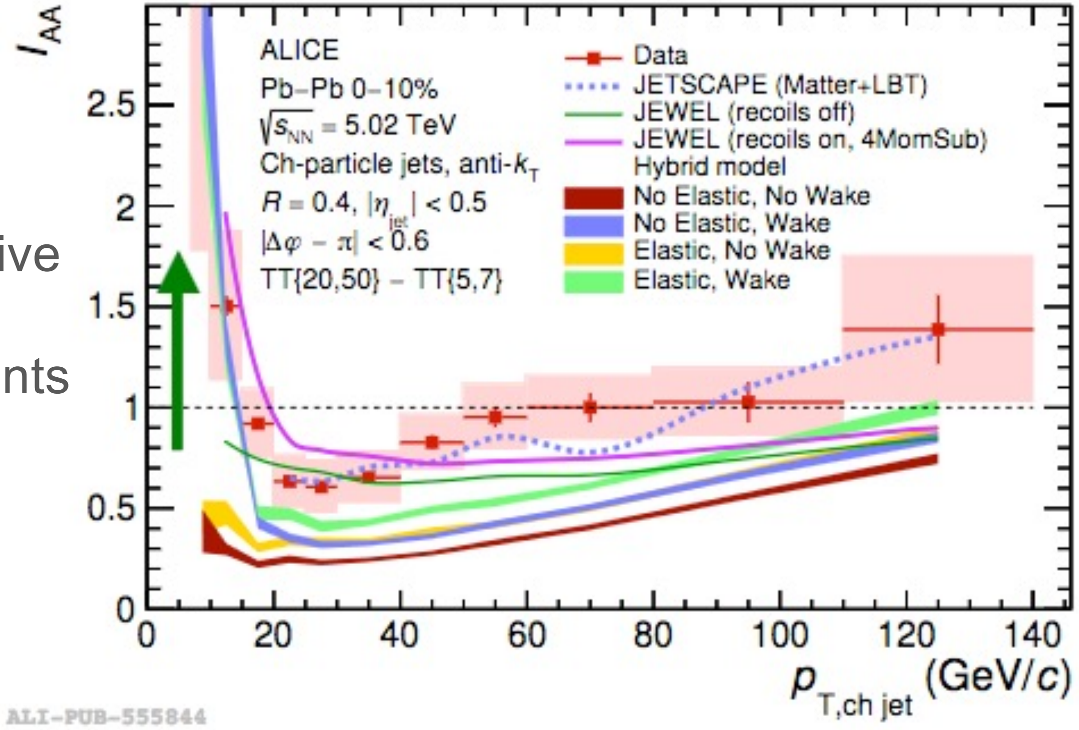
Jet broadening and deflection in Pb-Pb collisions

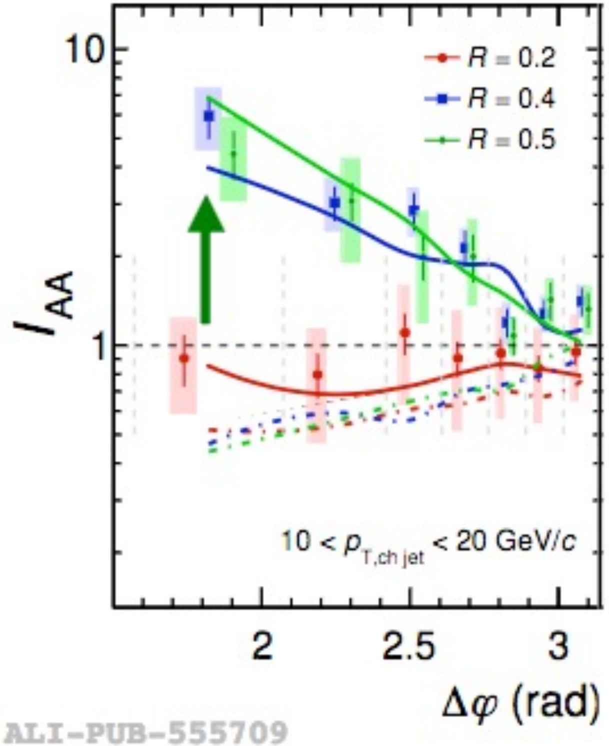
Main contributors: Jaime Norman, Roy Lemmon



Semi-inclusive hadron+jet measurements

$$I_{AA} = \frac{\Delta_{recoil}(\mathrm{Pb-Pb})}{\Delta_{recoil}(\mathrm{pp})}$$





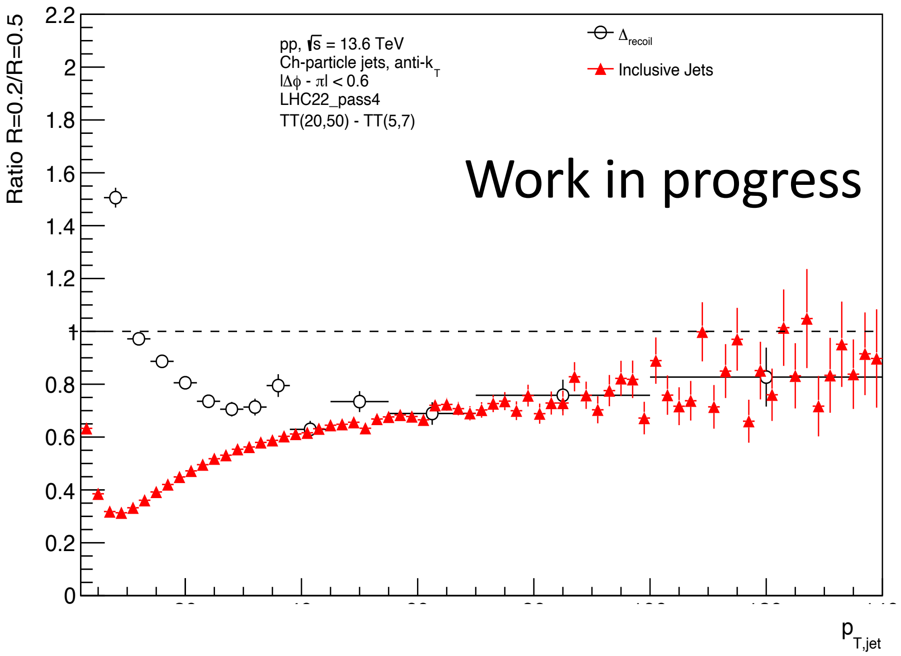
arXiv:2308.16128 (accepted in PRC), arXiv:2308.161131 (accepted in PRL)

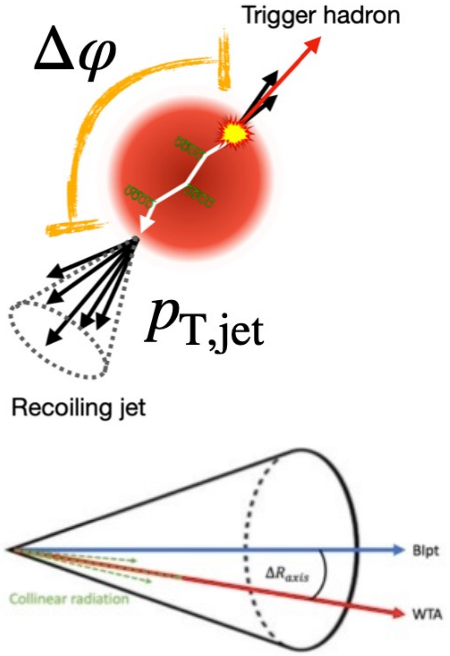
- First observation of significant medium-induced yield enhancement and acoplanarity broadening of low-p_T jets from measurements in pp and central Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE (Run 2 data).
- Medium response or medium-induced soft radiation favoured as cause for both measured effects.

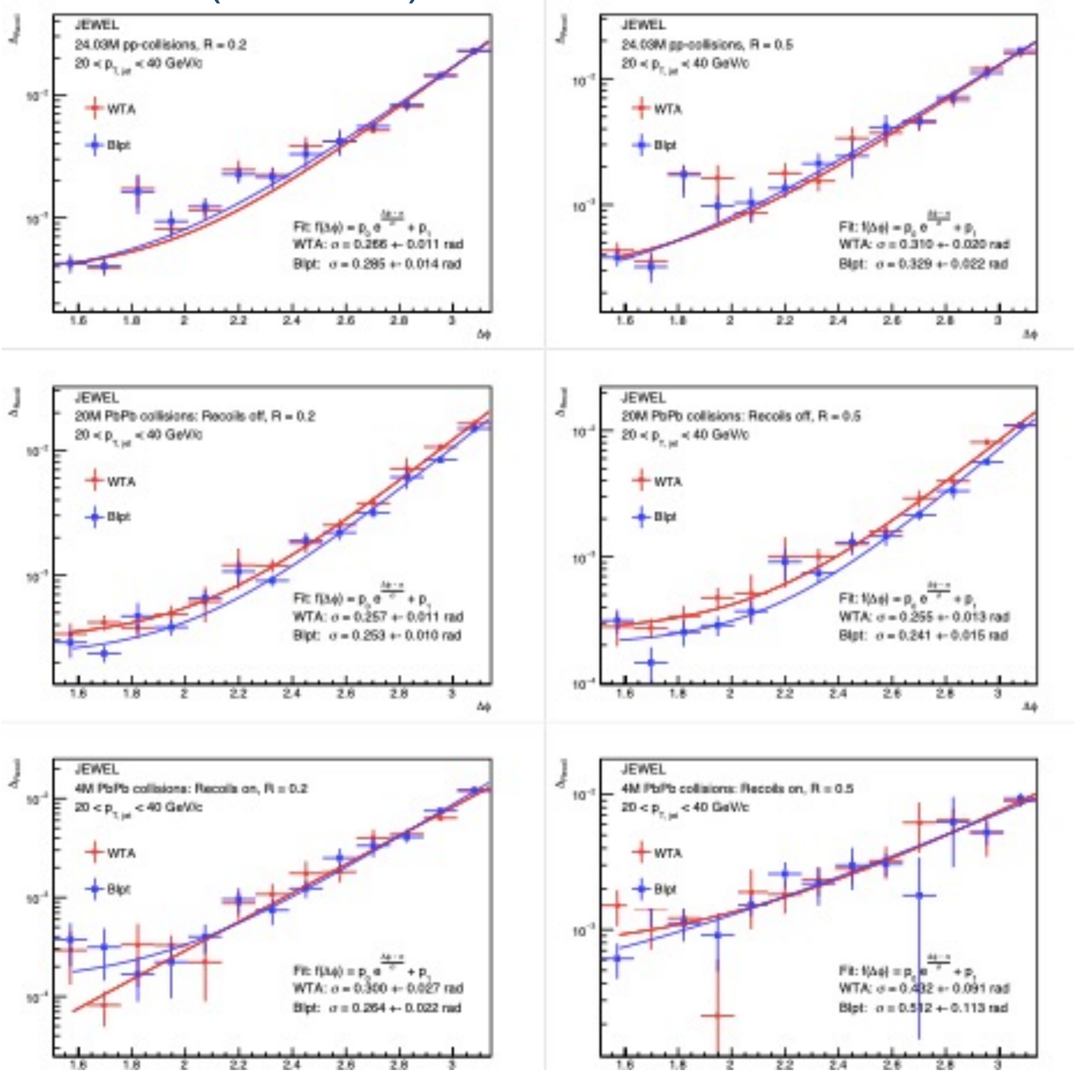
See Jaime’s HEP seminar for more details

Hadron-Jet Correlations – Run 3 data analyses in progress

Main contributors: Danny Jones (PhD), Jaime Norman, Matt Ockleton (MPHYS)







- Ratio of R=0.2 jets to R=0.5 jets for inclusive jets (red) and recoil jets (white)
  - Not full data sample analysed yet
- Investigations of origin of broadening with JEWEL MC simulations https://jewel.hepforge.org/

Congratulations to Dr Clara Bartels!

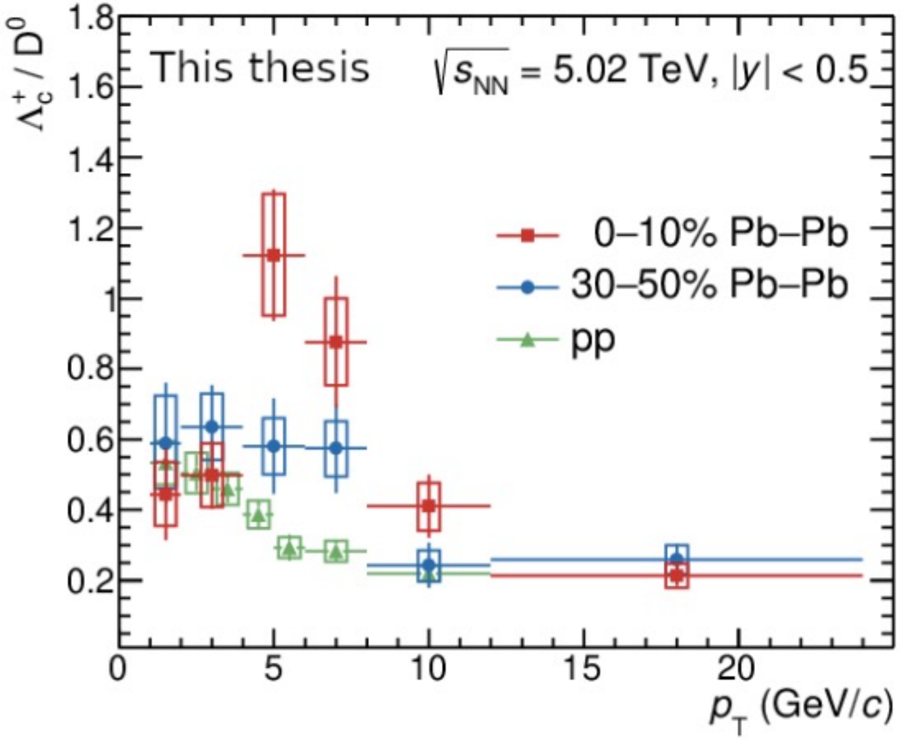
Measurement of Λ_c^+ production in Pb–Pb collisions at √sNN = 5.02 TeV with the ALICE experiment at the LHC.

PhD examiners: Tara Shears and Pietro Antonioli (Bologna IT)
Supervisors: Jaime Norman, Marielle Chartier, Roy Lemmon

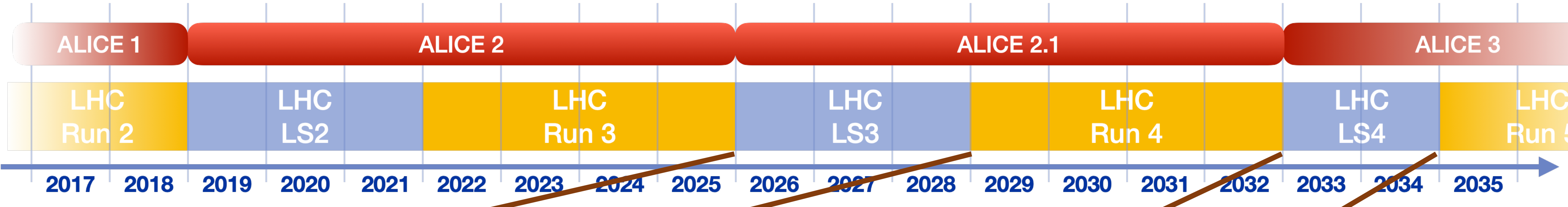
$$\Lambda_c^+ / D^0 := \frac{\mathrm{d}^2\sigma^{\Lambda_c^+}}{\mathrm{d}p_T\mathrm{d}y} \Big/ \frac{\mathrm{d}^2\sigma^{D^0}}{\mathrm{d}p_T\mathrm{d}y}$$

First measurements of the production cross section of the charmed baryon Λ_c^+ via the $\Lambda_c^+ \to pK^-\pi^+$ decay channel, as a function of transverse momentum (p_T) in Pb–Pb collisions (in two collisional centrality classes, central and semi-central).

Probe hadronisation in the Quark Gluon Plasma through charm hadron / baryon-to-meson production ratios.

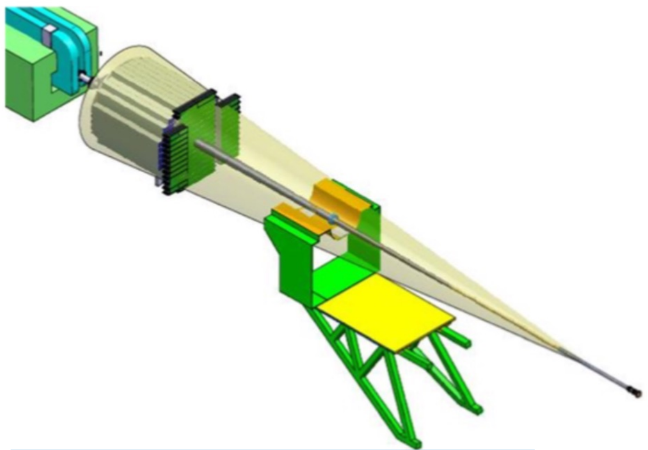


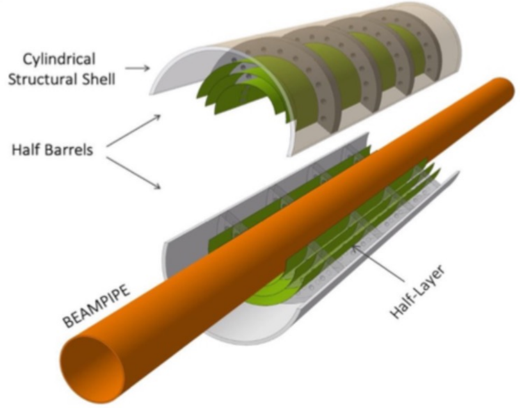
ALICE upgrades timeline

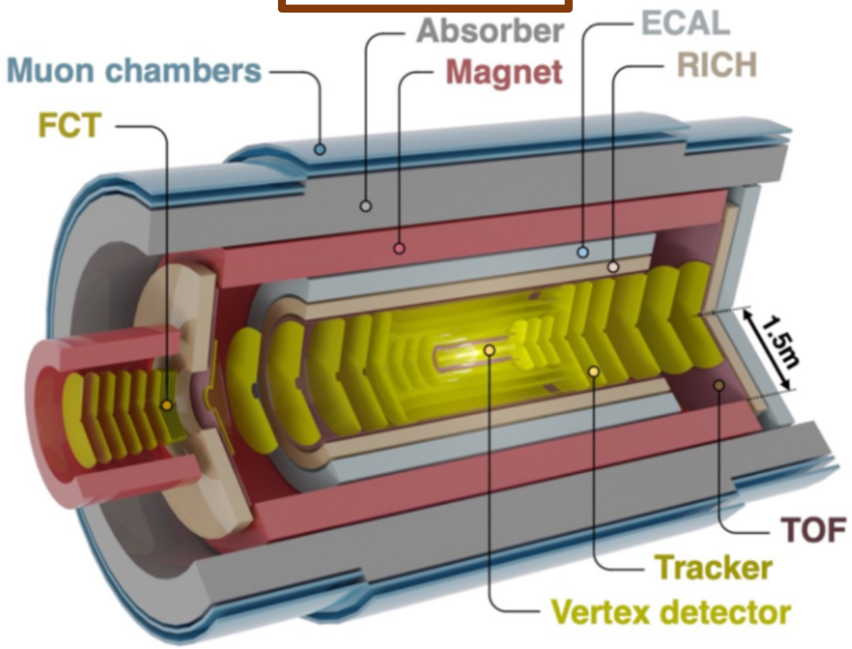


LS3: FoCal and ITS3

LS4: ALICE 3







FoCal LoI: CERN-LHCC-2020-009
FoCal TDR: ALICE-TDR-022
Not covered in this talk

ITS3 LoI: CERN-LHCC-2019-018
ITS3 TDR: ALICE-TDR-021

ALICE 3 LoI: CERN-LHCC-2022-009

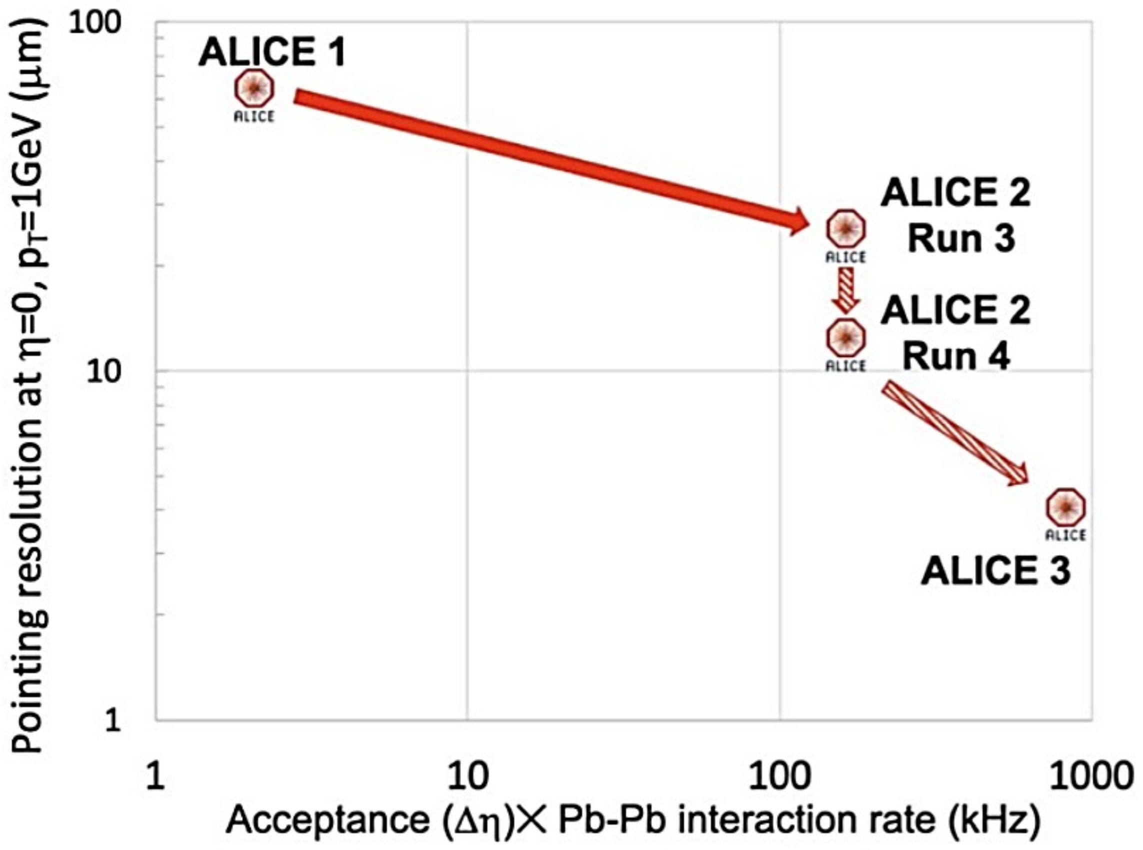
Upgrade motivations and requirements

Main physics motivations

- Heavy flavours hadrons at low p_T (charm and beauty interaction and hadronisation in the QGP)
- Quarkonia down to $p_T = 0$ (melting and regeneration in the QGP)
- Thermal dileptons, photons, vector mesons (thermal radiation, chiral symmetry restoration)
- Precision measurements of light (hyper)nuclei and searches for charmed hypernuclei

Main requirements

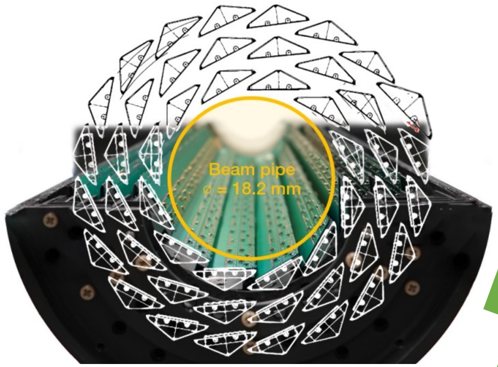
- Increased effective acceptance (acceptance x readout rate)
- Improved tracking and vertexing performance at low p_T for background suppression
- Preserve in ALICE 2 and enhance in ALICE 3 particle identification (PID) capabilities



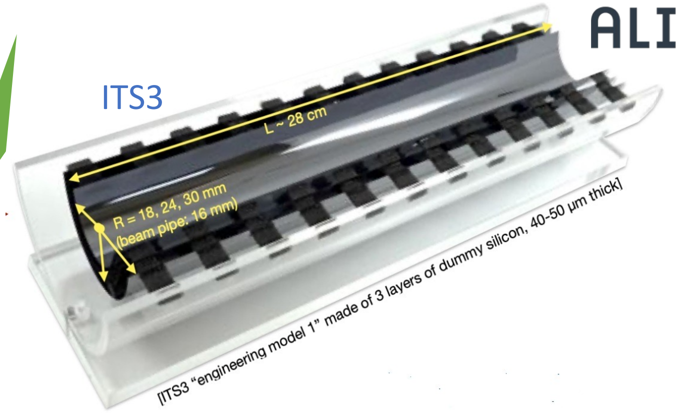
ITS3

Replacing the 3 innermost layers with new ultra-light, truly cylindrical layers

- Reduced material budget (from 0.36% to 0.07% X_0 per layer) with a very homogenous material distribution by removing water cooling, circuit boards and mechanical support
- Closer to the interaction point (from 23 to 19 mm)



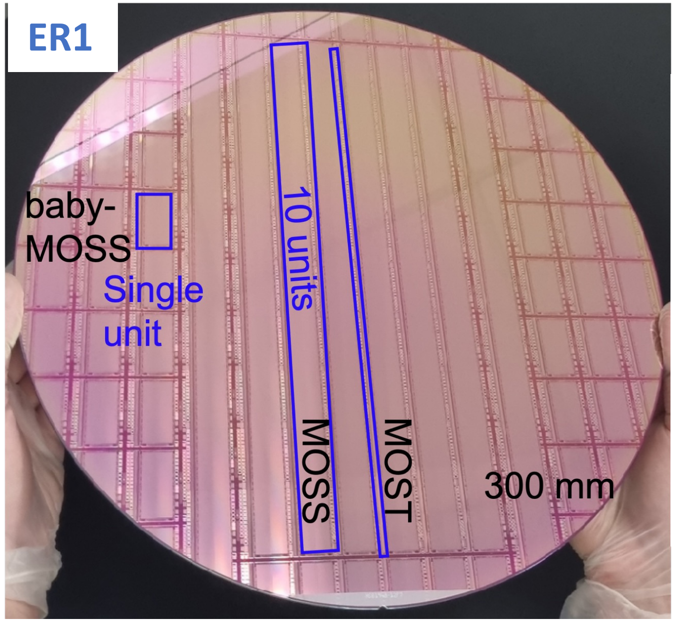
ITS2 Inner Barrel



ITS3

Sensor design roadmap

- **2021** MLR1 (Multi-Layer Reticle 1): first MAPS in TPSCo 65 nm
  - Successfully qualified the 65 nm process for ITS3 (and much beyond)
- **2022**
- **2023** ER1 (Engineering run 1): first stitched MAPS
  - Large design "exercise", stitching was new
  - Tests ongoing
- **2024** ER2: first ITS3 sensor prototype
  - Specifications frozen
  - Design ongoing
- **2025** ER3: ITS3 sensor production




MLR1 test system in LSDC

Liverpool involvement with sensor characterisation

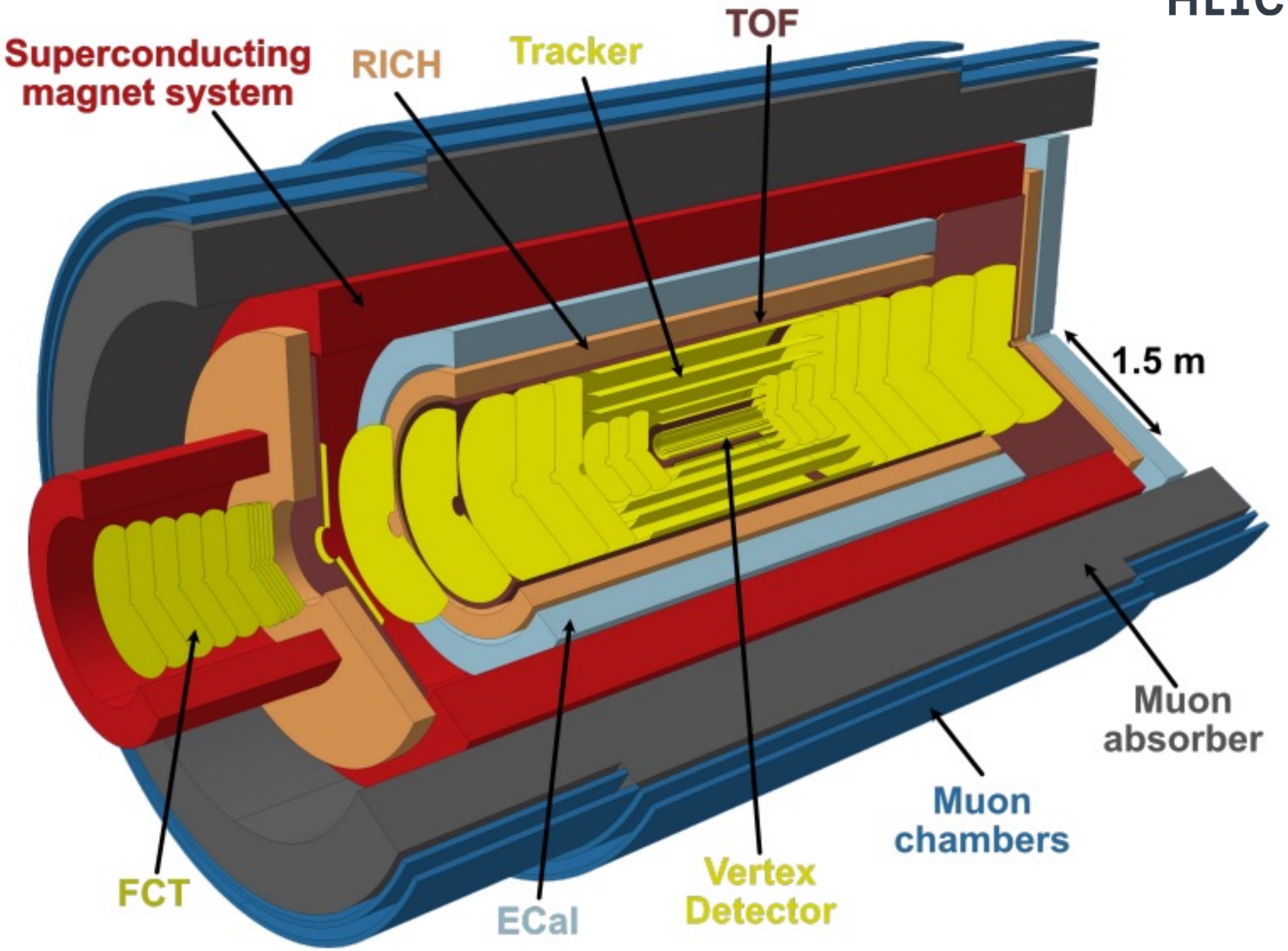
- MLR1 prototype and ER1 babyMOSS laboratory tests in LSDC with ^{55}Fe and ^{90}Sr
- Beam tests at CERN PS and SPS
- Software development and test beam data analysis

Analogue Pixel Test Structure (APTS): arXiv:2403.08952

ALICE 3

ALICE 3 LoI: CERN-LHCC-2022-009

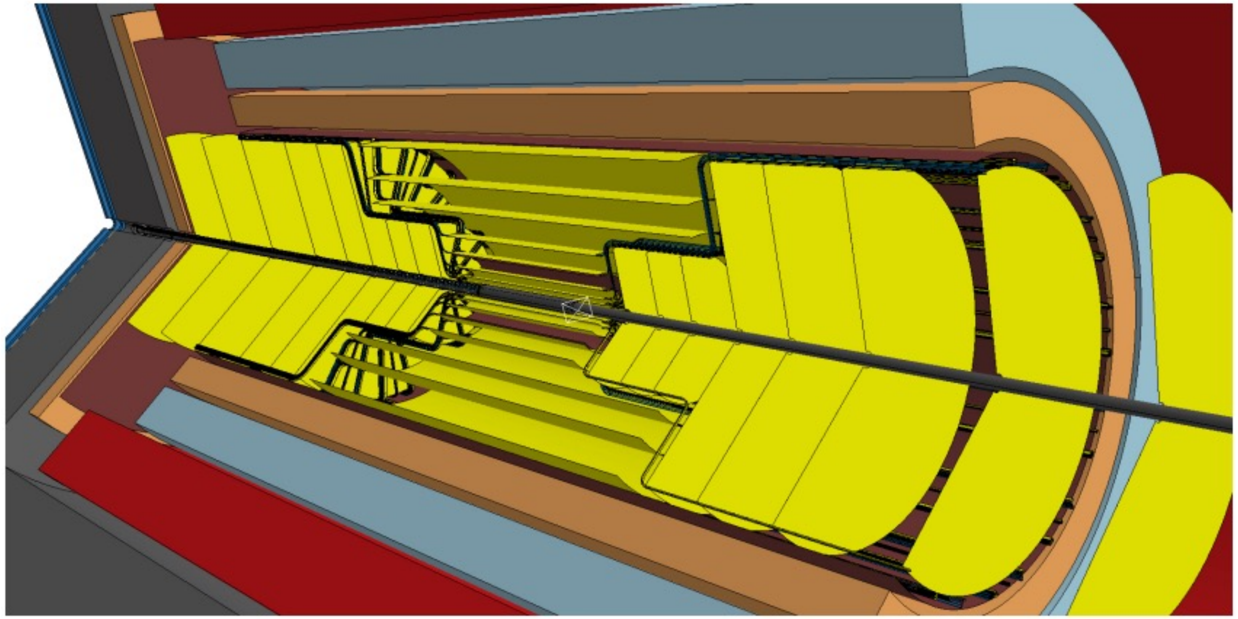
- Compact and lightweight all-silicon tracker
  - p_T resolution better than 1% @1 GeV/*c* and ~1-2% over large acceptance
- Retractable vertex detector with excellent pointing resolution
  - About 3-4 μm @ 1 GeV/*c*
- Large acceptance: $-4 < \eta < 4$, $p_T > 0.02$ GeV/*c*
- e/π/K/p particle identification over large acceptance
- Superconducting magnet system
- Continuous readout and online processing
  - Large data sample to access rare signals
- Muon Identification system
- Large-area ECal for photons and jets
- Forward Conversion Tracker for ultrasoft photons



UK proposed involvement in **outer tracker** and **triggering**

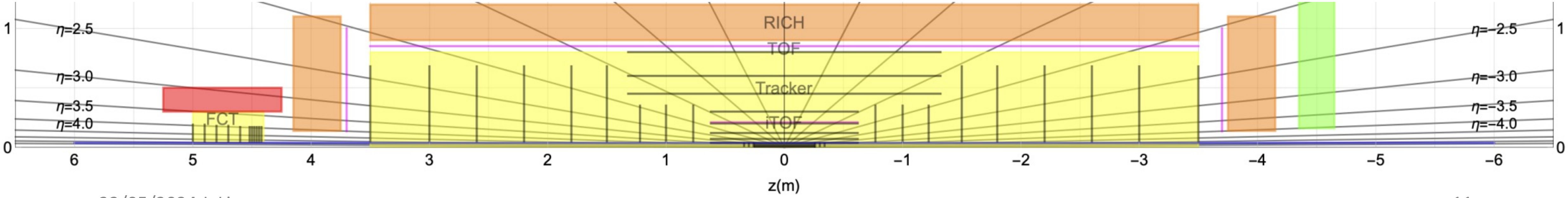
ALICE 3 - Tracker

- 8 + 2 x 9 tracking layers (barrel + disks)
- 60 m^2 silicon pixel detector based on CMOS MAPS technology
- Compact: r_{out} ~80 cm, z_{out} ± 3.5 m
- Large coverage: ± 4 η
- Time resolution: ~100 ns
- Sensor pixel pitch of ~50 µm for σ_{POS}= 10 µm
- Low power consumption: ~ 20 mW/cm^2
- Low material budget: ~1% X_0 per layer



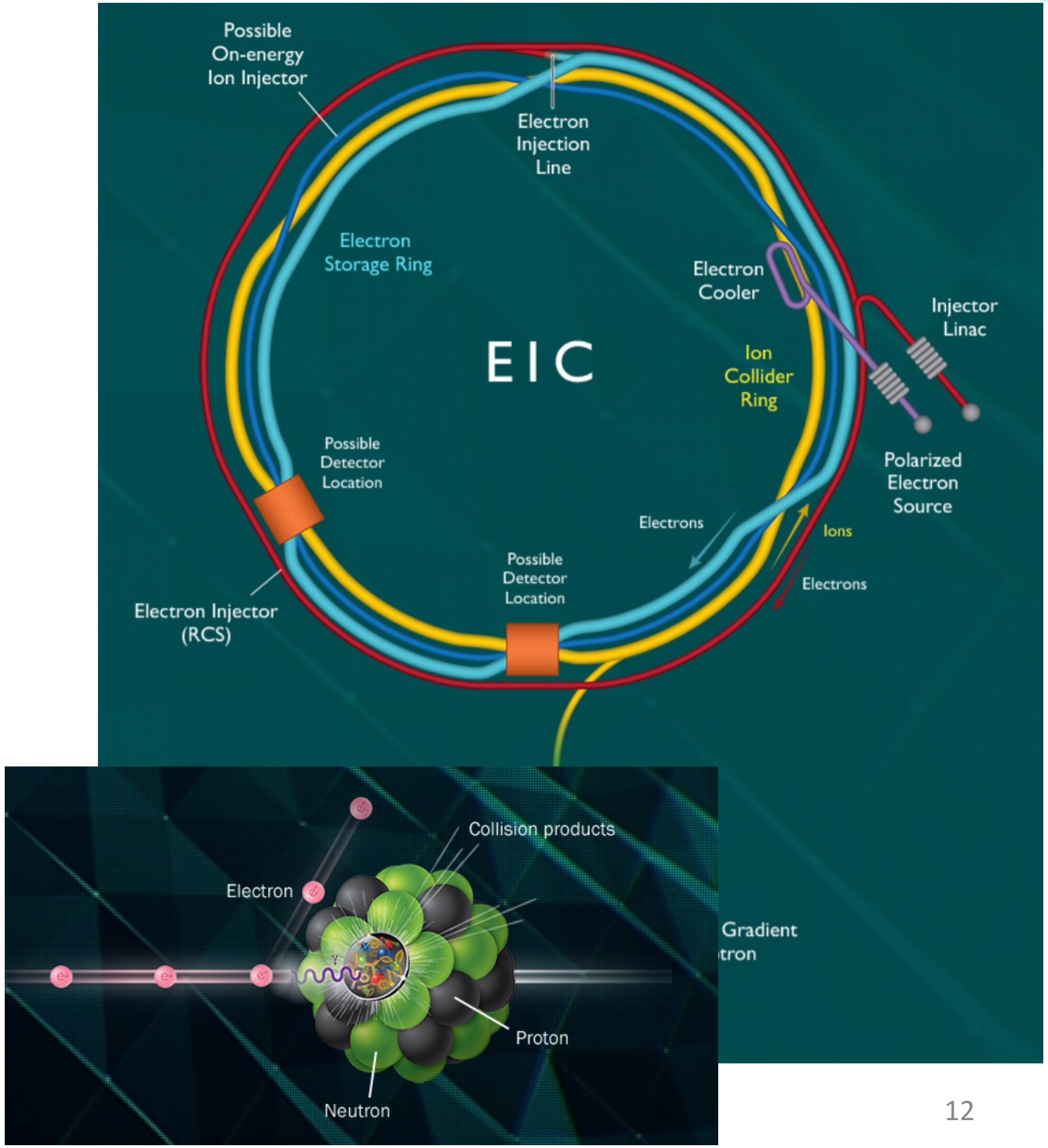
R&D challenges: module integration, timing performance and material budget

UK collaboration including Liverpool: seeking larger strategic O(20M) investment in view of complementary development and synergies in detectors for future colliders



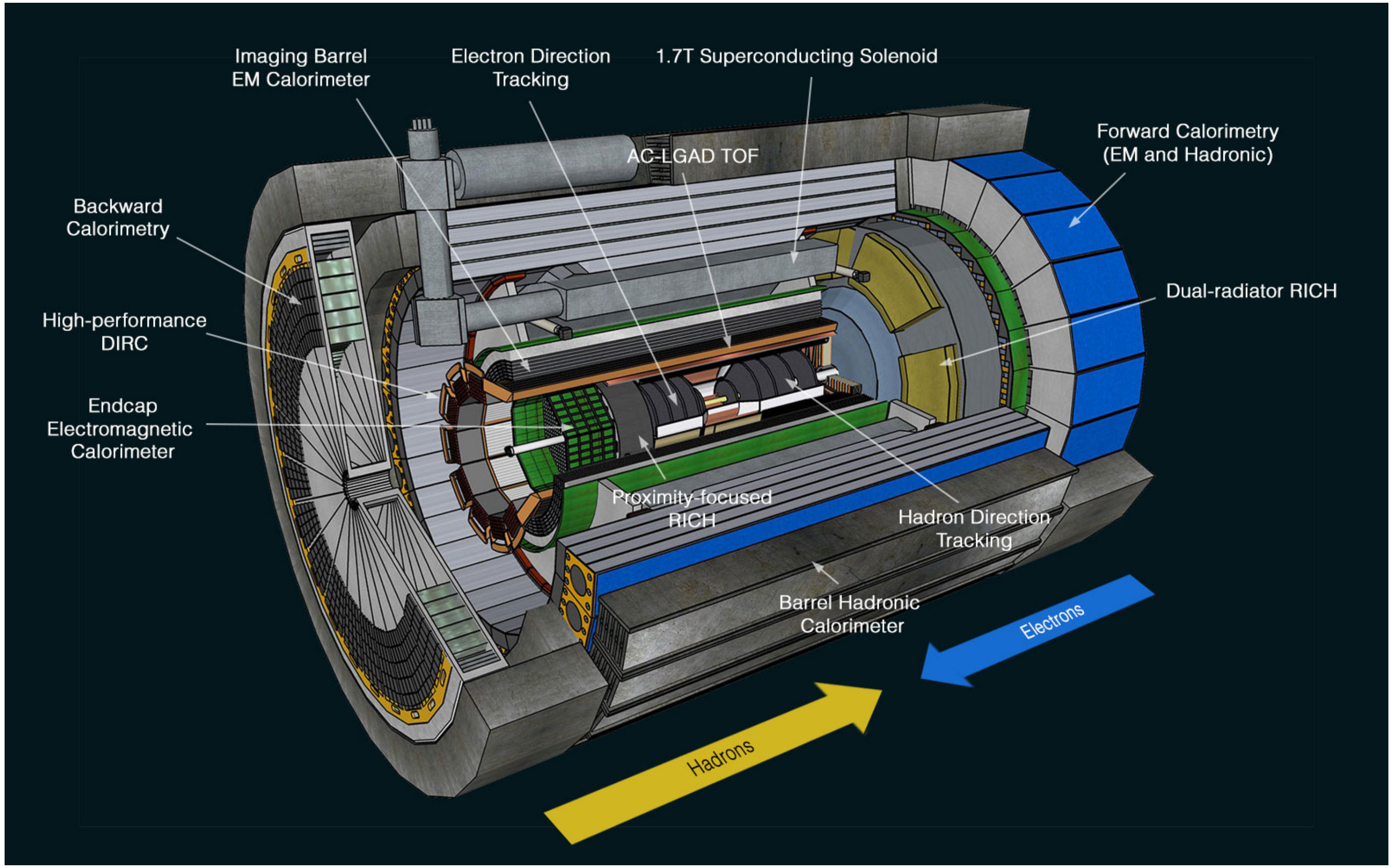
EIC - Electron-Ion Collider

- Facility
    - To be built at the Brookhaven National Laboratory (BNL) incorporating the existing Relativistic Heavy Ion Collider (RHIC)
    - Two intersecting accelerators, one producing an intense beam of electrons, the other a high-energy beam of protons or heavier atomic nuclei
- Uniqueness
    - World's first polarized electrons and ions collider
- Science questions to be answered
    - How do the nucleon properties like mass and spin emerge from quarks and their interactions?
    - What are the emergent properties of dense systems of gluons?
- Timeline
    - Dec 2019: EIC Project approved
    - Apr 2025: EIC Project Detector TDR
    - Apr 2032 – Apr 2034: Transition to Operations



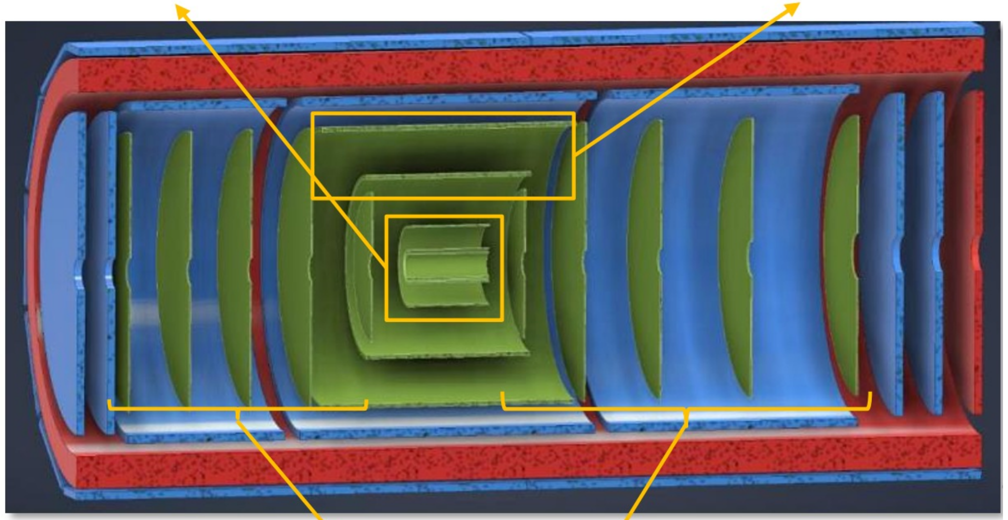
ePIC detector

- The Electron-Proton/Ion Collider (ePIC) Collaboration was formed to design, build, and operate the first experiment at the EIC
- Detector details
  - High-precision tracking, PID, EM and hadronic calorimetry in all directions, covering equal rapidity areas ($-4 < \eta < 4$), high-precision polarimetry
  - Asymmetric beam energies, different electron and hadron endcaps
  - A 1.7 T superconducting magnet for curving the trajectories of charged particles
  - Streaming readout approach and AI-powered data collection



ePIC Silicon Vertex Tracker (SVT)

- Well integrated, large acceptance, high precision SVT based on large area, low power MAPS in 65 nm CMOS imaging technology
  - Spatial resolution: σ_{pos} ~ 5 µm
  - Power consumption: < 40 mW/cm^2
  - Framing rate: ≤ 2 µs
- 5 barrel layers and 10 endcap discs (~ 8.5 m^2)
  - 3 Inner Barrel (IB) layers – same curved, wafer-scale stitched MAPS used within ITS3
  - 2 Outer Barrel (OB) layers – stave-based, optimised sensor for EIC
    - Focus of EIC-UK WP1 (MAPS)
  - 5 discs for Electron and Hadron Endcaps (EE/HE)
    - Same optimised sensor as OB
- EIC-LAS (Large Area Sensor)
  - Optimised sensor variant based on the ITS3 sensor
  - Minimise the material required due to service (data/power/control) connections
  - Improve yield for large area coverage



- Liverpool involvement under discussion with the UK collaboration (incl. Birmingham, Oxford, STFC Daresbury and RAL) – opportunities in sensor characterisation, mechanical design, stave tooling and assemblies, QA/QC etc.
- £ 58m investment from UKRI Large Infrastructure fund approved.

A Good Year for our group!

Jian Liu

- **ALICE ITS System Run Coordination**
  Jan. 2021 – June 2023
- **ALICE Data Preparation Group**
  Asynchronous QC coordinator from Jan. 2023
- **ALICE ITS Technical Director (Deputy)**
  from Jan. 2024
- **LHCP Conference**, Belgrade, May 2023
- **IWORID Conference**, Oslo, June 2023
- **Tracking and Vertexing technologies Workshop**, London, Nov. 2023
- **HSTD'13 Symposium**, Vancouver, Dec. 2023
- **Joint APP, HEPP and NP IOP Conference**, April 2024

Jaime Norman

- **ALICE Physics Convener (jets & hard photons analyses)** Nov. 2021 – Nov. 2023
- **Quark Matter Conference**, Houston, Sep. 2023
- **LHC Physics Seminar**, CERN, Oct. 2023
- **ALICE Editorial Board member** from Nov. 2023
- **Joint APP, HEPP and NP IOP Conference**, April 2024
- **Rencontres de Moriond**, April 2024

Marielle Chartier

- **Chair ALICE Collaboration Board** 2022-2025
- **ACHEP Conference**, Rabat, Oct. 2023
'Recent highlights and future plans with ALICE at the LHC'

Roy Lemmon
(STFC Daresbury)

- **IPPP Durham Associate** 2021-2023 (Higgs self coupling using EFTs at future e+e- colliders)
- **Honorary Visiting Professor** from 2023

Summary

- Successful Heavy-Ion data taking in 2023, leading roles in detector operation and data assurance, achieved a data-taking rate of 50 kHz and recorded 2 nb-1 of Pb-Pb collisions
- Great results and leading new physics analyses in heavy-flavour and jet measurements; ongoing analyses using Run 3 data
- Strong involvement in future upgrade projects, e.g., ALICE ITS3, EIC ePIC SVT, and ALICE 3, focusing on advanced CMOS sensor R&D and detector construction

Summary

- Successful Heavy-Ion data taking in 2023, leading roles in detector operation and data assurance, achieved a data-taking rate of 50 kHz and recorded 2 nb-1 of Pb-Pb collisions
- Great results and leading new physics analyses in heavy-flavour and jet measurements; ongoing analyses using Run 3 data
- Strong involvement in future upgrade projects, e.g., ALICE ITS3, EIC ePIC SVT, and ALICE 3, focusing on advanced CMOS sensor R&D and detector construction

Special thanks to our HEP colleagues for their invaluable help and support in setting up the upgrade projects in LSDC!

Backup

Strongly interacting matter

The place of chromodynamics in the SM of the Universe

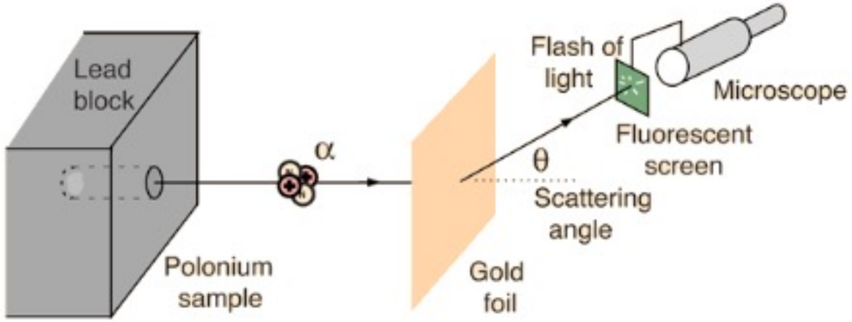
QCD is asymptotically free, and we expect at high enough temperature to find a gas of weakly interacting quarks and gluons.

However, at temperatures accessible in a lab, the QGP is strongly coupled (liquid with very low viscosity).

What is the nature of the QGP constituents?

➔ Determine the quasi-particle structure of the QGP and study how a strongly-coupled liquid emerges from its constituent degrees of freedom.

These are just some of the open questions!



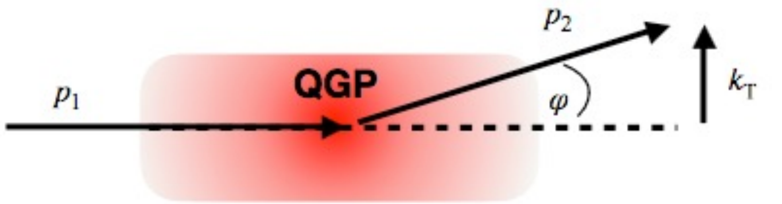


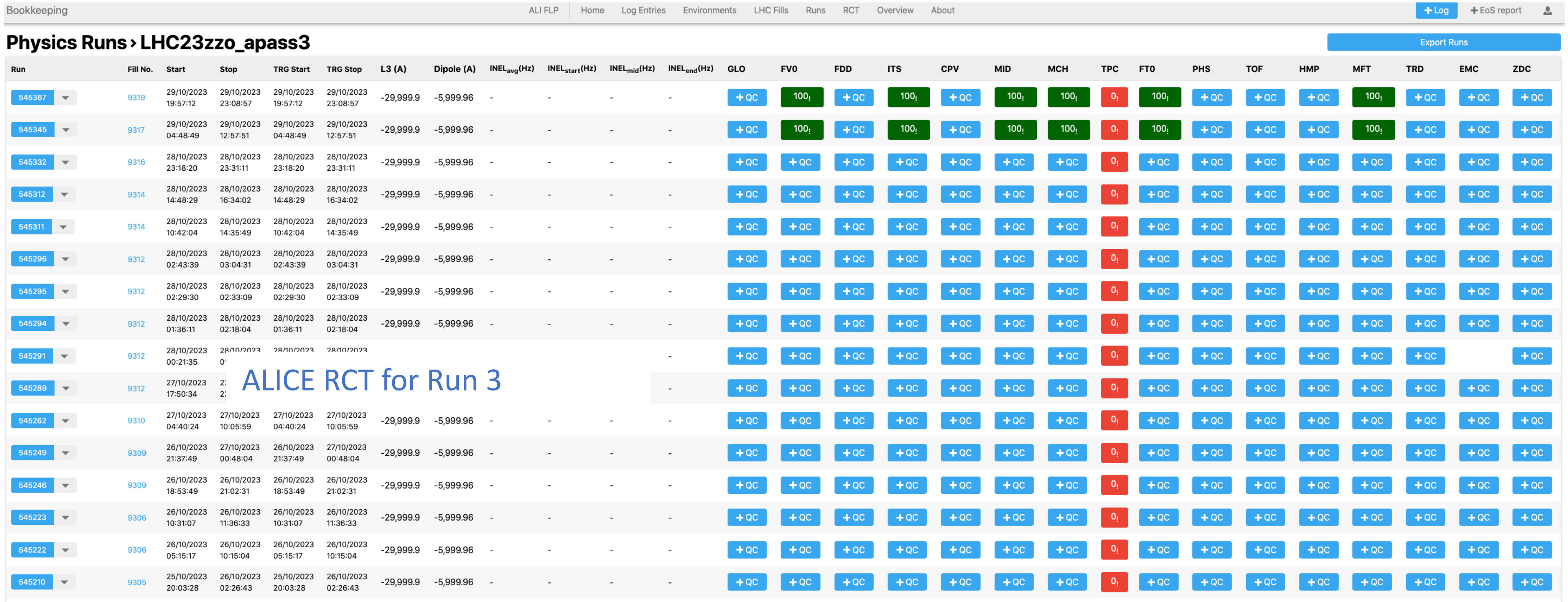
Fig. modified from F. D'eramo, K. Rajagopal, Y. Yin *JHEP* 01 (2019)

Can we probe its short distance structure?

Can a Rutherford scattering experiment be performed in the QGP?

ALICE Data Preparation

- Coordination of Asynchronous Quality Control (A-QC) in Data Preparation Group (DPG)
  - Review of data reconstruction quality from sub-detectors and PWGs
  - A-QC workflow maintenance
  - Coordination of ALICE Run Condition Table (RCT) development
    - JavaScript based framework for automatically run quality aggregation

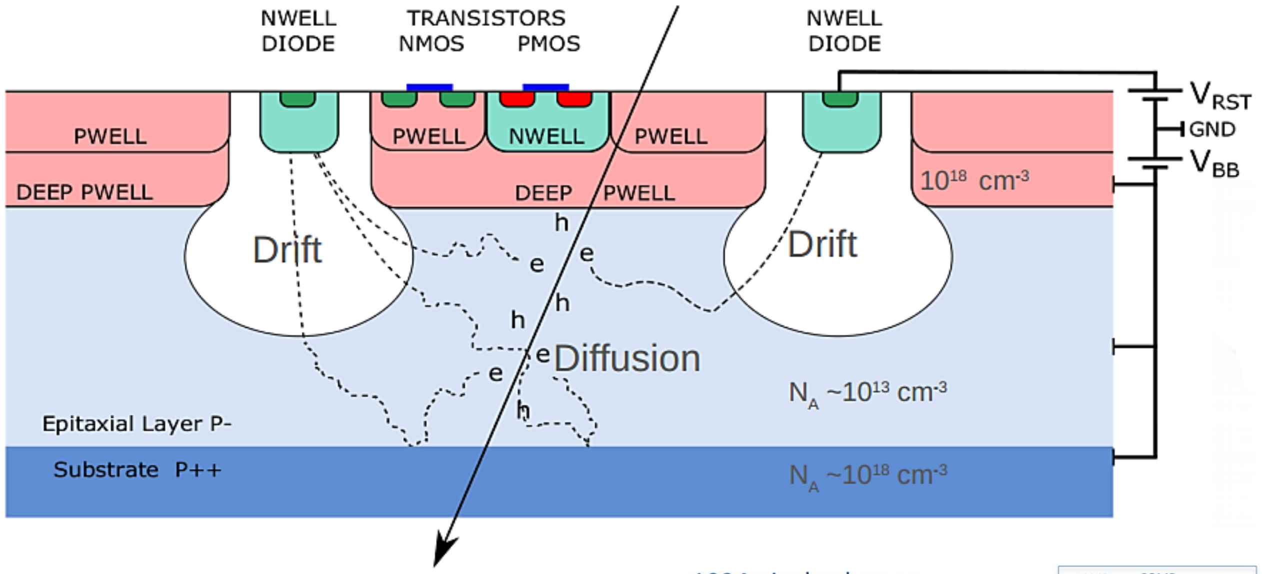


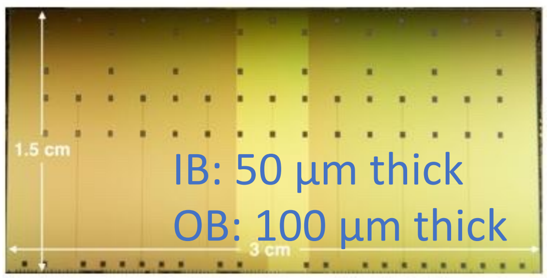
Run	Fill No.	Start	Stop	TRG Start	TRG Stop	L3 (A)	Dipole (A)	$INEL_{avg}$(Hz)	$INEL_{start}$(Hz)	$INEL_{mid}$(Hz)	$INEL_{end}$(Hz)
545367	9319	29/10/2023 19:57:12	29/10/2023 23:08:57	29/10/2023 19:57:12	29/10/2023 23:08:57	-29,999.9	-5,999.96	-	-	-	-
545345	9317	29/10/2023 04:48:49	29/10/2023 12:57:51	29/10/2023 04:48:49	29/10/2023 12:57:51	-29,999.9	-5,999.96	-	-	-	-
545332	9316	28/10/2023 23:18:20	28/10/2023 23:31:11	28/10/2023 23:18:20	28/10/2023 23:31:11	-29,999.9	-5,999.96	-	-	-	-
545312	9314	28/10/2023 14:48:29	28/10/2023 16:34:02	28/10/2023 14:48:29	28/10/2023 16:34:02	-29,999.9	-5,999.96	-	-	-	-
545311	9314	28/10/2023 10:42:04	28/10/2023 14:35:49	28/10/2023 10:42:04	28/10/2023 14:35:49	-29,999.9	-5,999.96	-	-	-	-
545296	9312	28/10/2023 02:43:39	28/10/2023 03:04:31	28/10/2023 02:43:39	28/10/2023 03:04:31	-29,999.9	-5,999.96	-	-	-	-
545295	9312	28/10/2023 02:29:30	28/10/2023 02:33:09	28/10/2023 02:29:30	28/10/2023 02:33:09	-29,999.9	-5,999.96	-	-	-	-
545294	9312	28/10/2023 01:36:11	28/10/2023 02:18:04	28/10/2023 01:36:11	28/10/2023 02:18:04	-29,999.9	-5,999.96	-	-	-	-
545291	9312	28/10/2023 00:21:35	28/10/2023 [illegible]	28/10/2023 [illegible]	28/10/2023 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
545289	9312	27/10/2023 17:50:34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
545262	9310	27/10/2023 04:40:24	27/10/2023 10:05:59	27/10/2023 04:40:24	27/10/2023 10:05:59	-29,999.9	-5,999.96	-	-	-	-
545249	9309	26/10/2023 21:37:49	27/10/2023 00:48:04	26/10/2023 21:37:49	27/10/2023 00:48:04	-29,999.9	-5,999.96	-	-	-	-
545246	9309	26/10/2023 18:53:49	26/10/2023 21:02:31	26/10/2023 18:53:49	26/10/2023 21:02:31	-29,999.9	-5,999.96	-	-	-	-
545223	9306	26/10/2023 10:31:07	26/10/2023 11:36:33	26/10/2023 10:31:07	26/10/2023 11:36:33	-29,999.9	-5,999.96	-	-	-	-
545222	9306	26/10/2023 05:15:17	26/10/2023 10:15:04	26/10/2023 05:15:17	26/10/2023 10:15:04	-29,999.9	-5,999.96	-	-	-	-
545210	9305	25/10/2023 20:03:28	26/10/2023 02:26:43	25/10/2023 20:03:28	26/10/2023 02:26:43	-29,999.9	-5,999.96	-	-	-	-

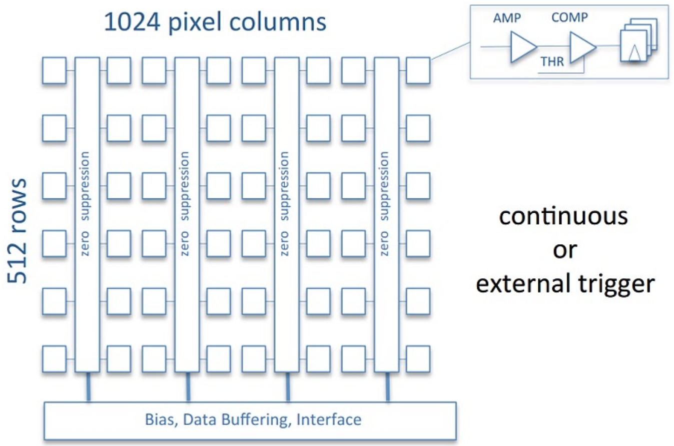
Run	GLO	FV0	FDD	ITS	CPV	MID	MCH	TPC	FT0	PHS	TOF	HMP	MFT	TRD	EMC	ZDC
545367	+ QC	100!	+ QC	100!	+ QC	100!	100!	0!	100!	+ QC	+ QC	+ QC	100!	+ QC	+ QC	+ QC
545345	+ QC	100!	+ QC	100!	+ QC	100!	100!	0!	100!	+ QC	+ QC	+ QC	100!	+ QC	+ QC	+ QC
545332	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545312	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545311	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545296	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545295	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545294	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545291	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC		+ QC
545289	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545262	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545249	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545246	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545223	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545222	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC
545210	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	0!	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC	+ QC

ALICE RCT for Run 3

ALPIDE: ALICE PIxel DEtector







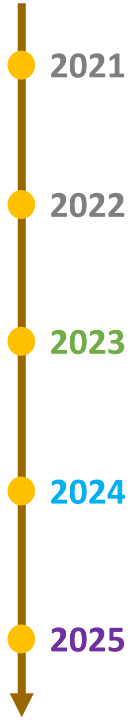
ALPIDE technology features:

- TowerJazz 180 nm CiS Process, full CMOS
- Deep P-well implementation available
- High resistivity epi-layer (>1 kΩ·cm) p-type, thickness 25 μm
- Smaller charge collection diode → lower capacitance → higher S/N
- Possibility of reverse biasing
- Substrate can be thinned down

Sensor specification:

- Pixel pitch 27 μm x 29 μm → spatial resolution 5 μm x 5 μm
- Priority Encoder Readout
- Power: 40 mW/cm^2
- Trigger rate: 100 kHz
- Integration time: < 10 μs
- Read out up to 1.2 Gbit/s
- Continuous or triggered read-out

ITS3 chip development roadmap

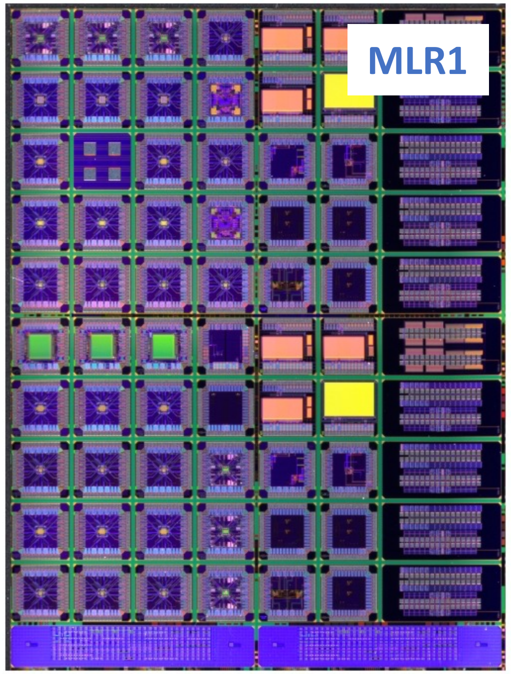


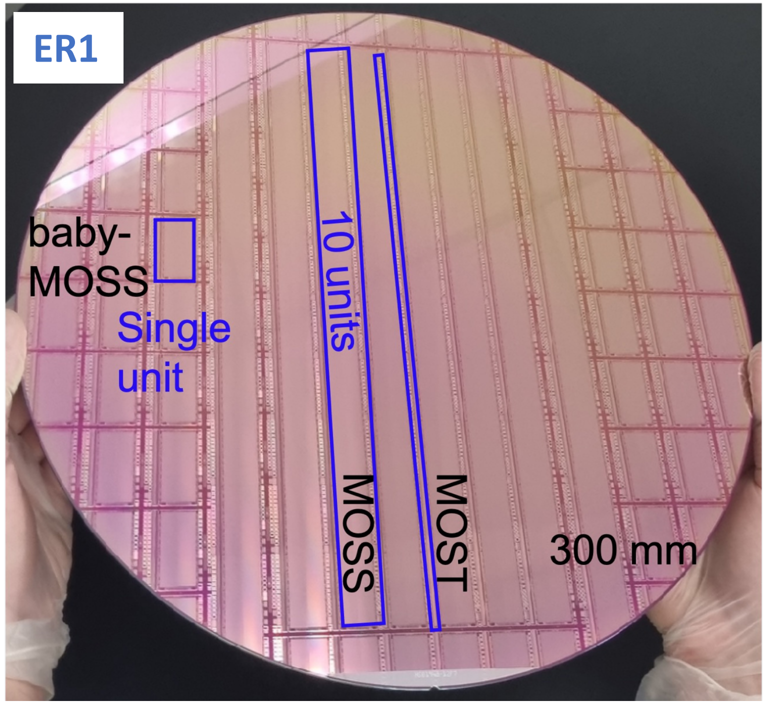
MLR1 (Multi-Layer Reticle 1): first MAPS in TPSCo 65 nm
- Successfully qualified the 65 nm process for ITS3 (and much beyond)

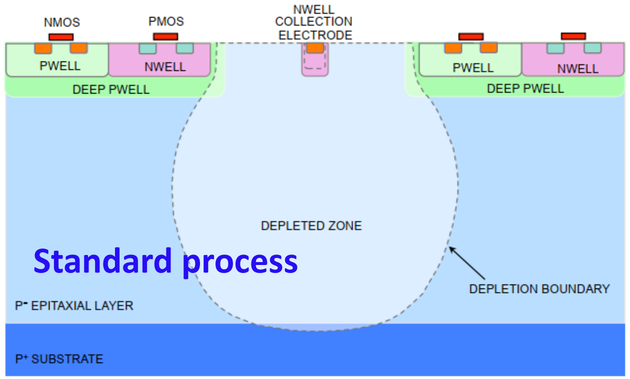
ER1 (Engineering run 1): first stitched MAPS
- Large design "exercise", stitching was new
- Tests ongoing

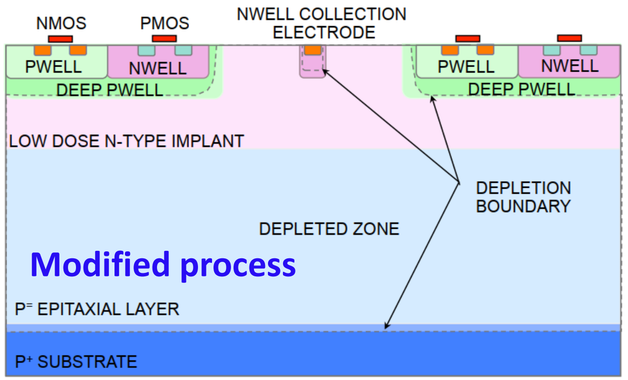
ER2: first ITS3 sensor prototype
- Specifications frozen
- Design ongoing

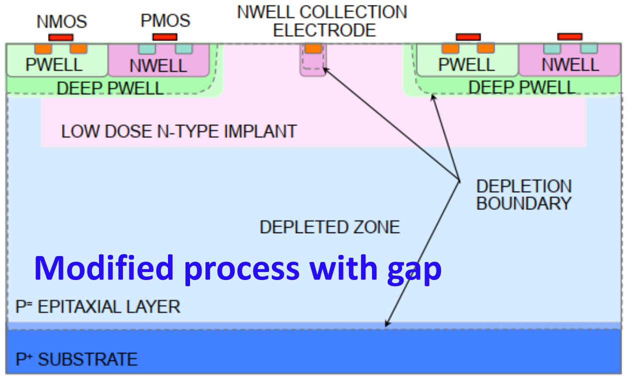
ER3: ITS3 sensor production



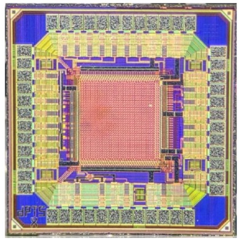




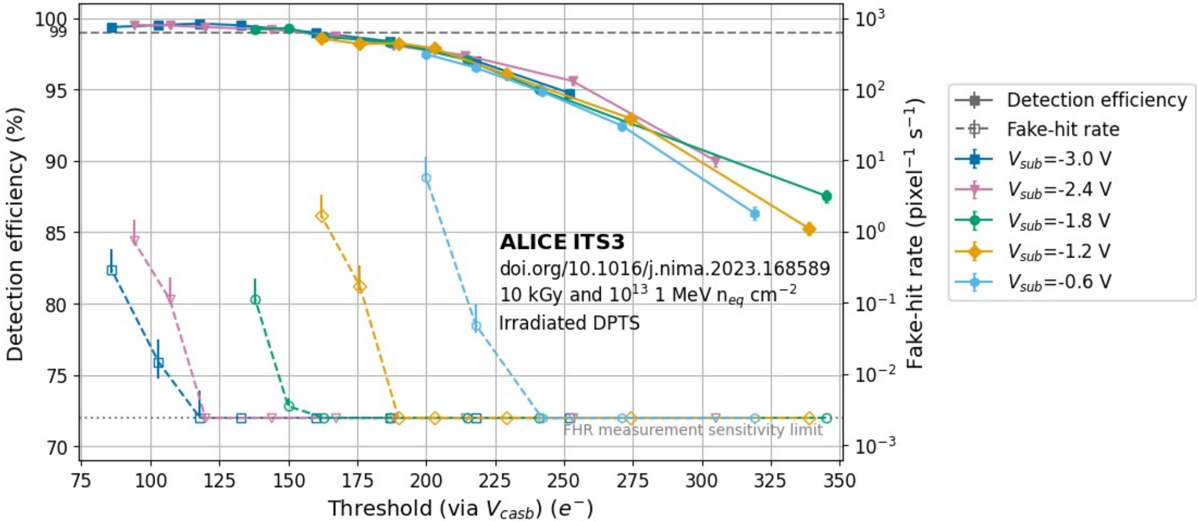


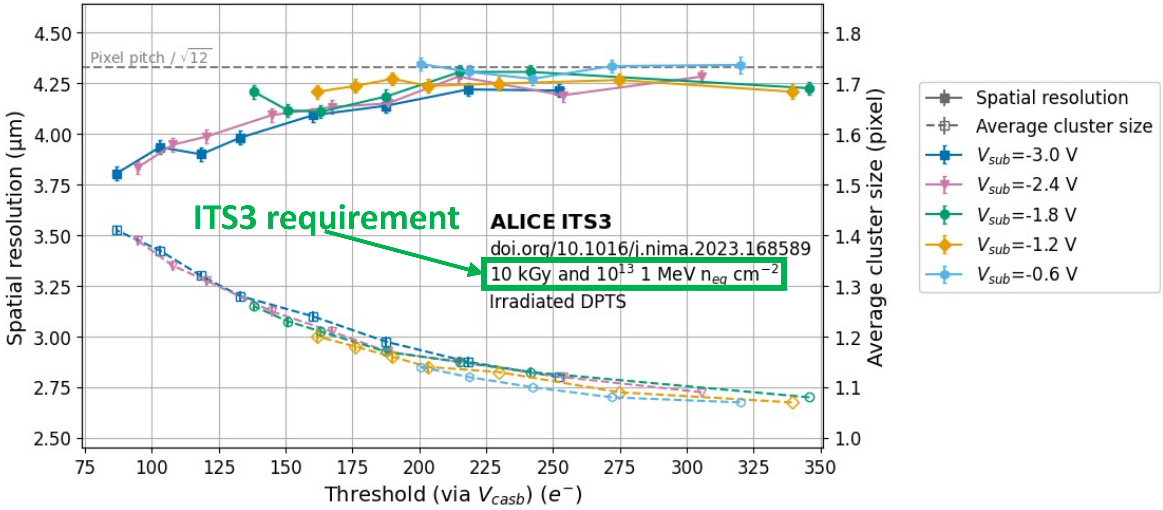


ITS3 MLR1 characterization

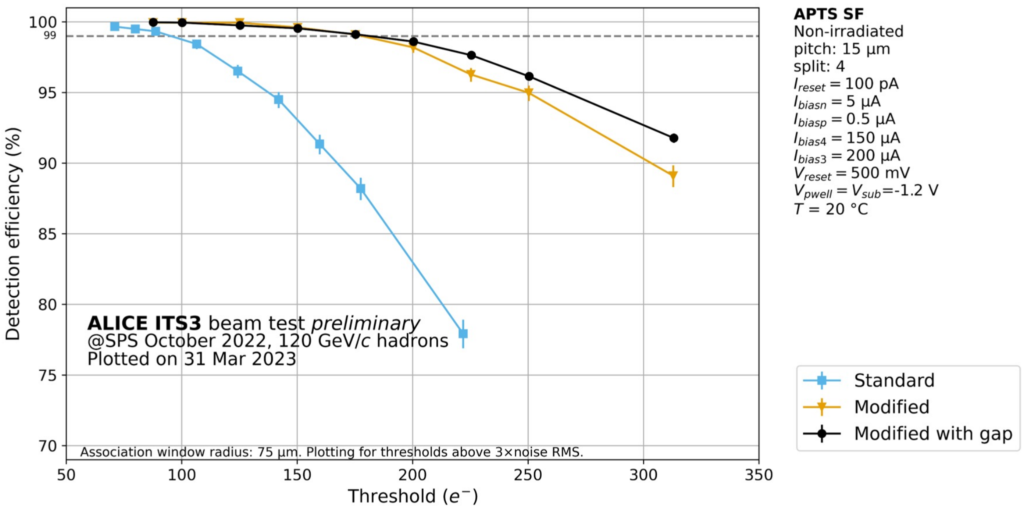


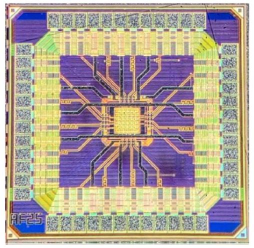
Digital Pixel Test Structure (DPTS)
- 32x32 pixel matrix
- Asynchronous digital readout with Time-over-Threshold information
- Pitch: 15 µm
- Only "modified with gap" process





DPTS: NIM A.2023.168589





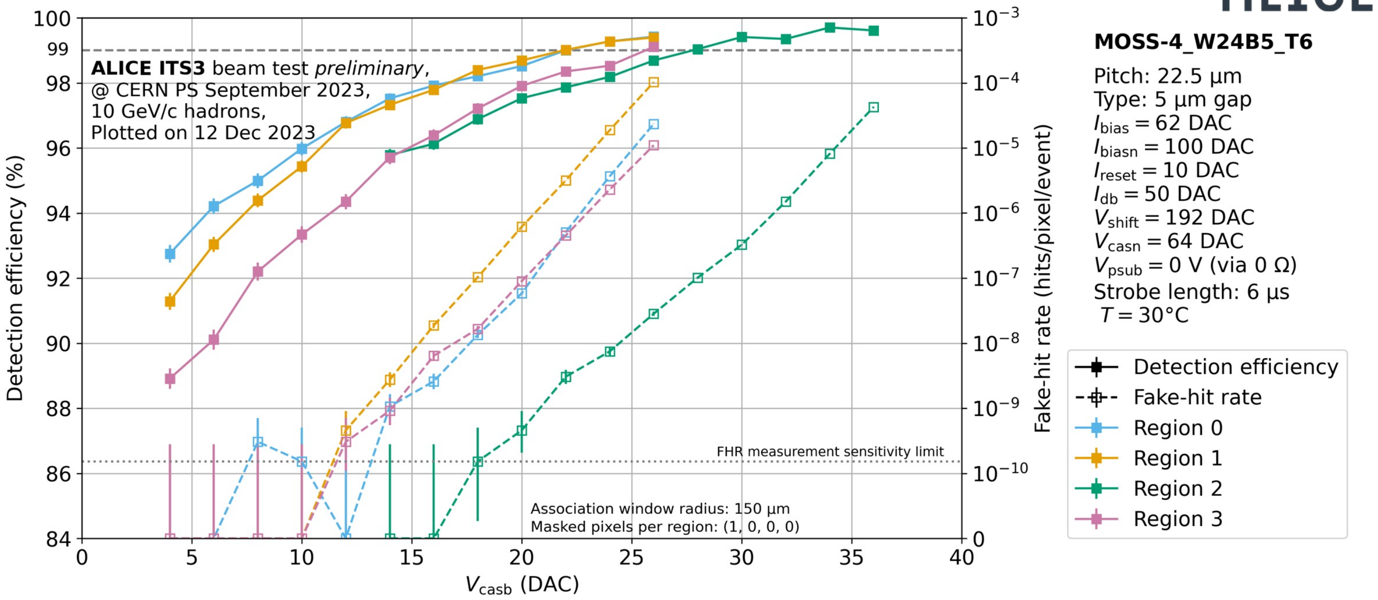
Analogue Pixel Test Structure (APTS)
- 6x6 pixel matrix
- Direct analog readout of central 4x4 pixels
- Two types of output drivers
  - Source follower (APTS-SF)
  - Fast OpAmp (APTS-OA)
- Pitch: 10, 15, 20 and 25 µm

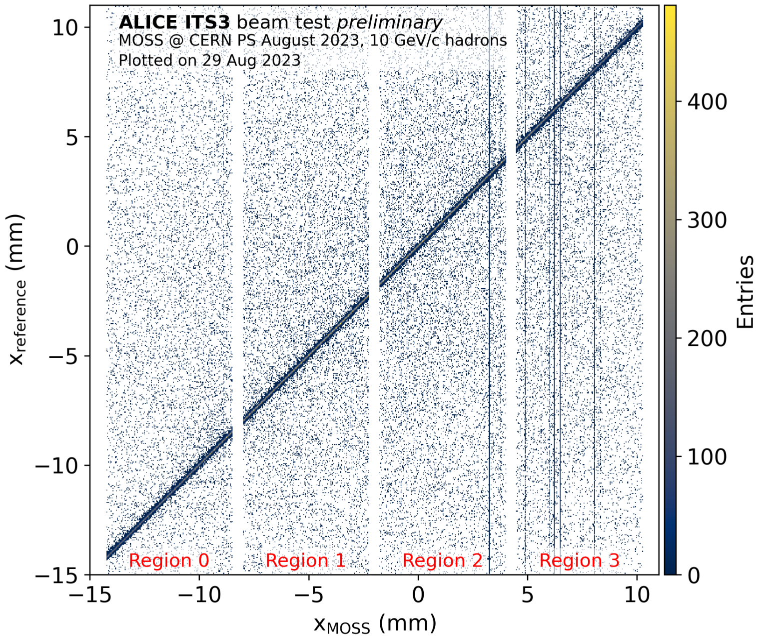
APTS: arXiv:2403.08952

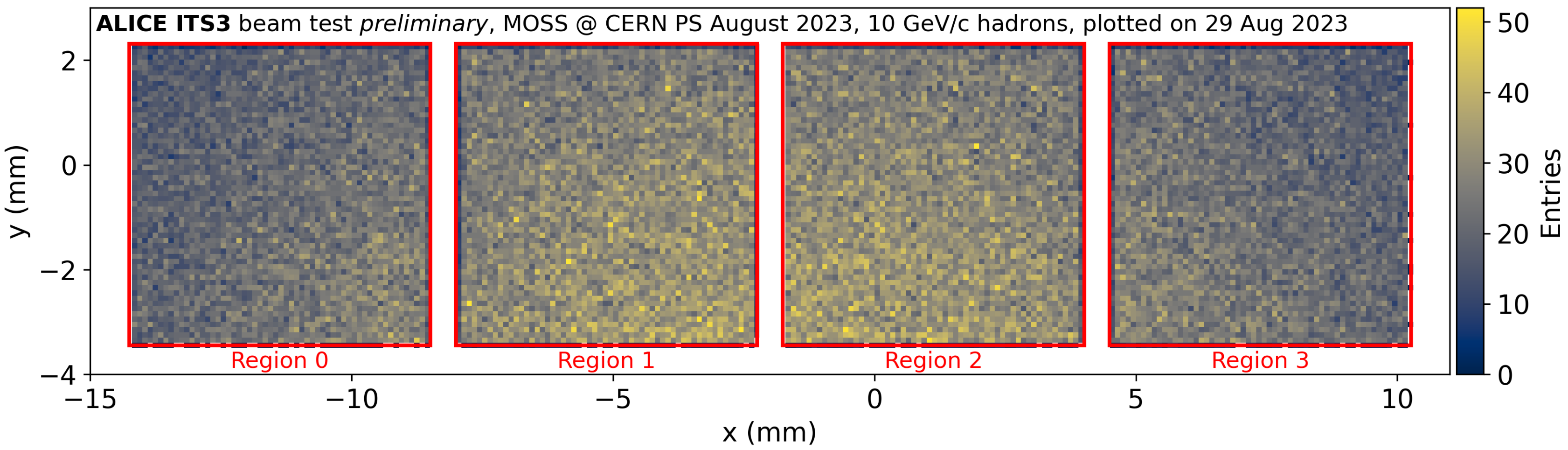
- Validated in terms of charge collection efficiency, detection efficiency and radiation hardness
- Several pixel variants (pitch 10 - 25 µm) were tested both in laboratory and in beam tests
- Excellent detection efficiency over large threshold range for the ITS3 radiation hardness requirement (10 kGy + 10^{13} 1MeV n_{eq} /cm^2)

ITS3 MOSS test beams

- Wafer probing and systematic lab tests: verified all basic functionalities, ongoing full characterization to assess yield of different sensor sections
- Three campaigns: July, August and September at PS in 2023
- Data analysis in progress and parameters to be further optimised

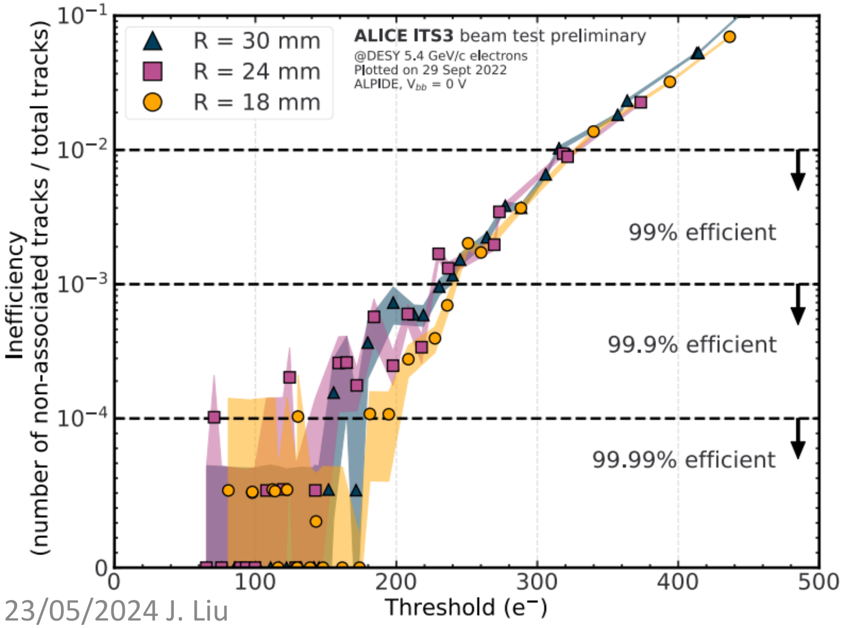


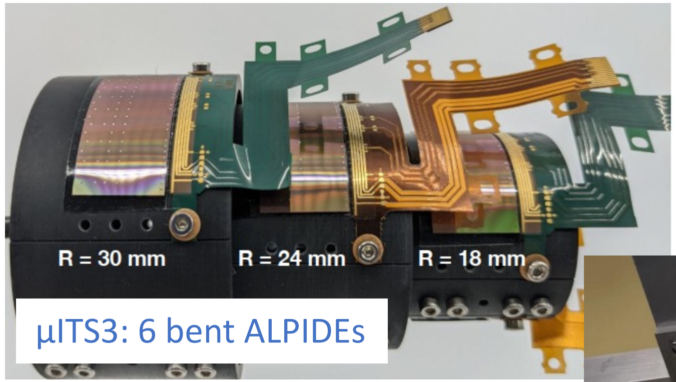




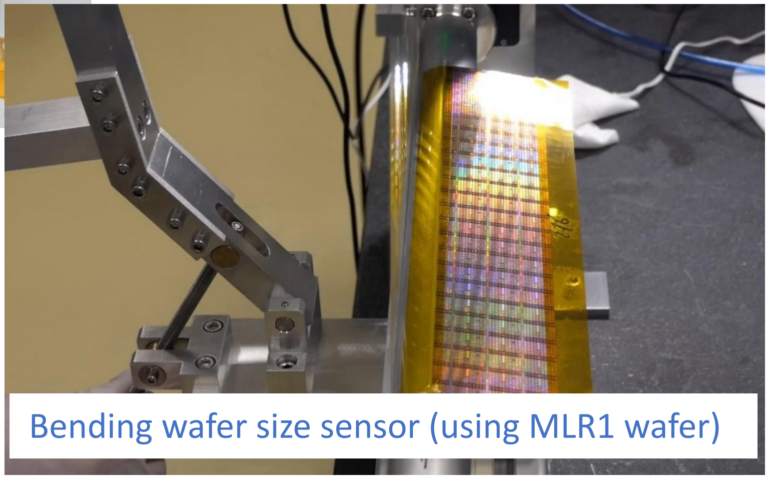
ITS3 sensor bending

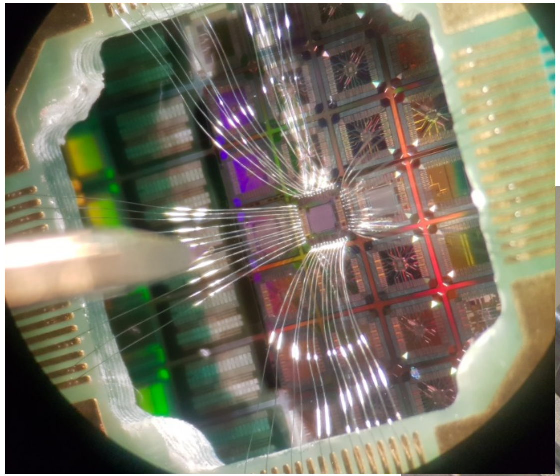
- Functional chips (ALPIDEs) and MLR1 sensors are bent routinely at different labs)
- Full mock-up of the final ITS3, called "µITS3"
  - 6 ALPIDE chips, bent to the target radii of ITS3 tested
- The sensors continue to work after bending
  - Spatial resolution of 5 µm consistent with flat ALPIDEs
  - Efficiency > 99.99 % for nominal operating conditions and compatible with flat ALPIDEs
- Bent MLR1 prototypes are being tested

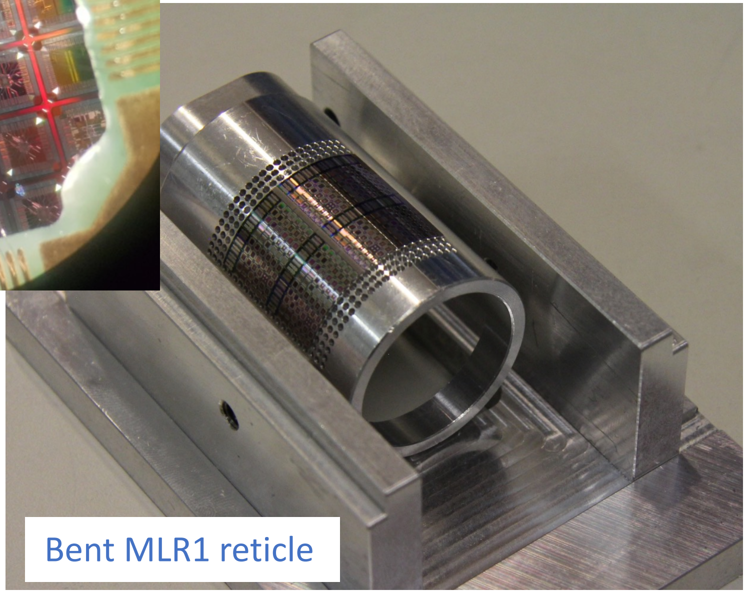




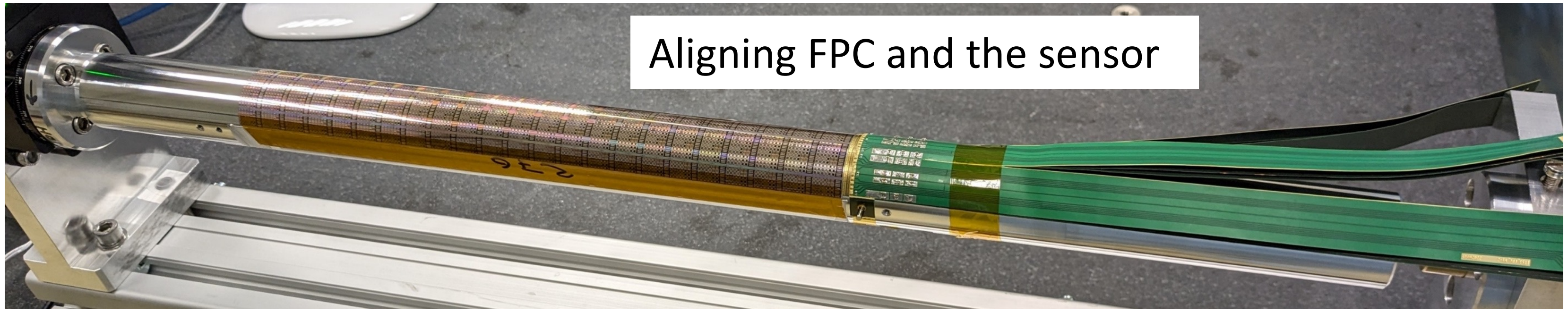
µITS3: 6 bent ALPIDEs

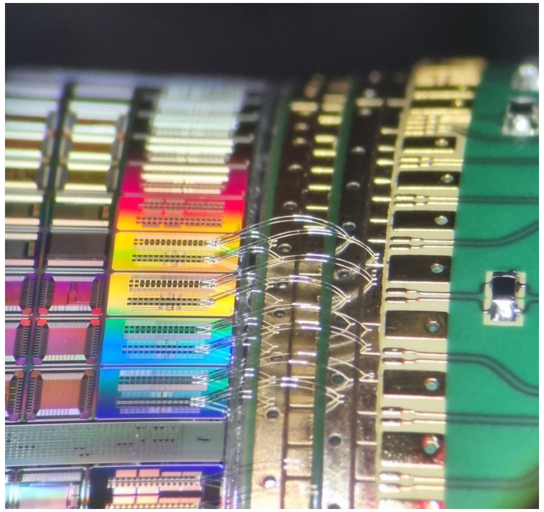

Bending wafer size sensor (using MLR1 wafer)



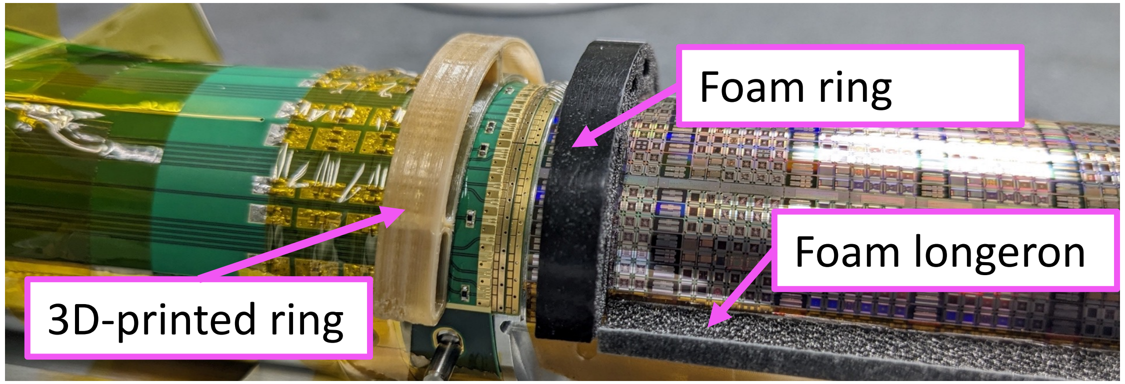

Bent MLR1 reticle

ITS3 assembly practicing

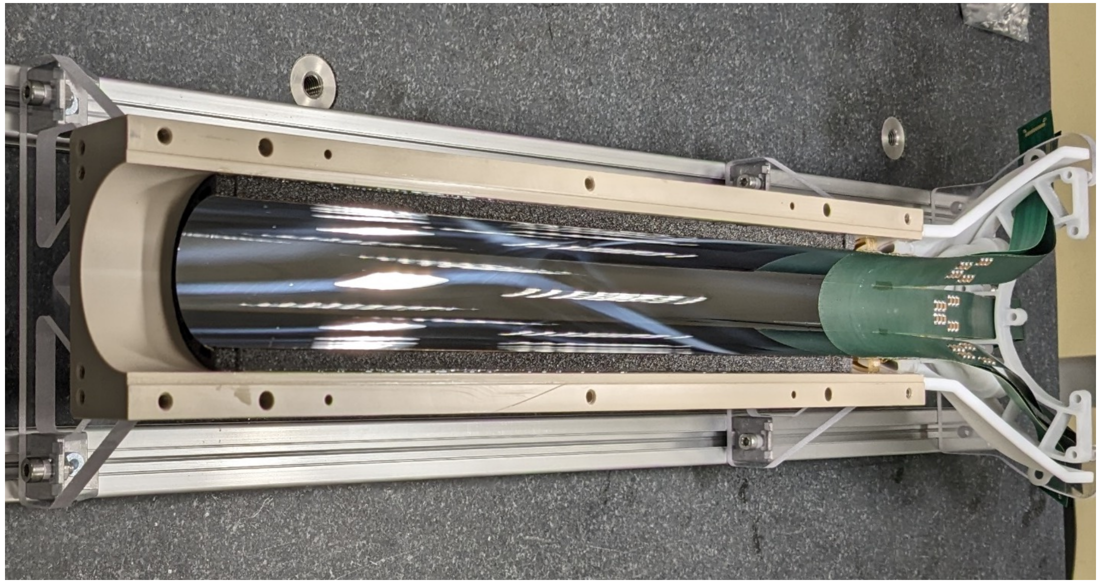




Wire-bonding for the curved sensor

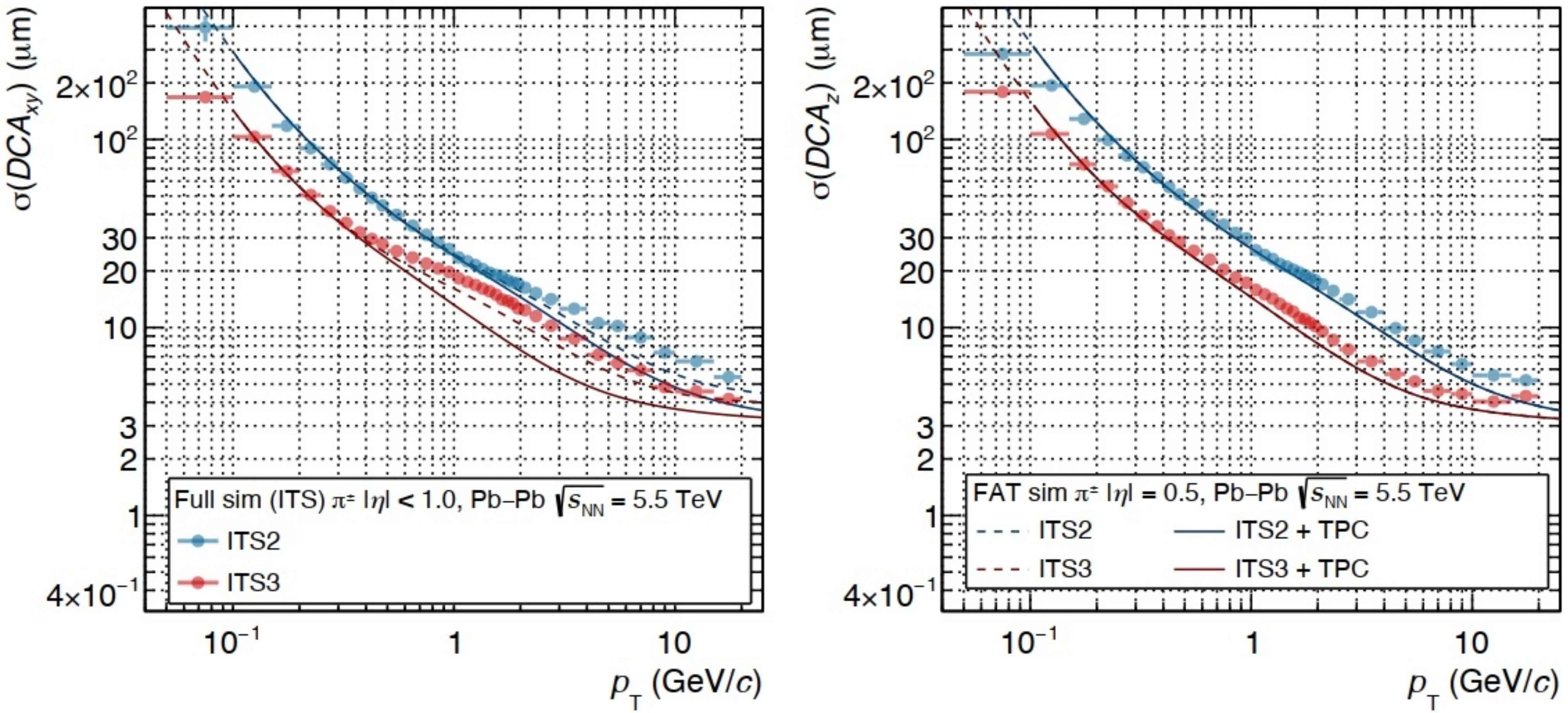


Gluing of foams and additional supports



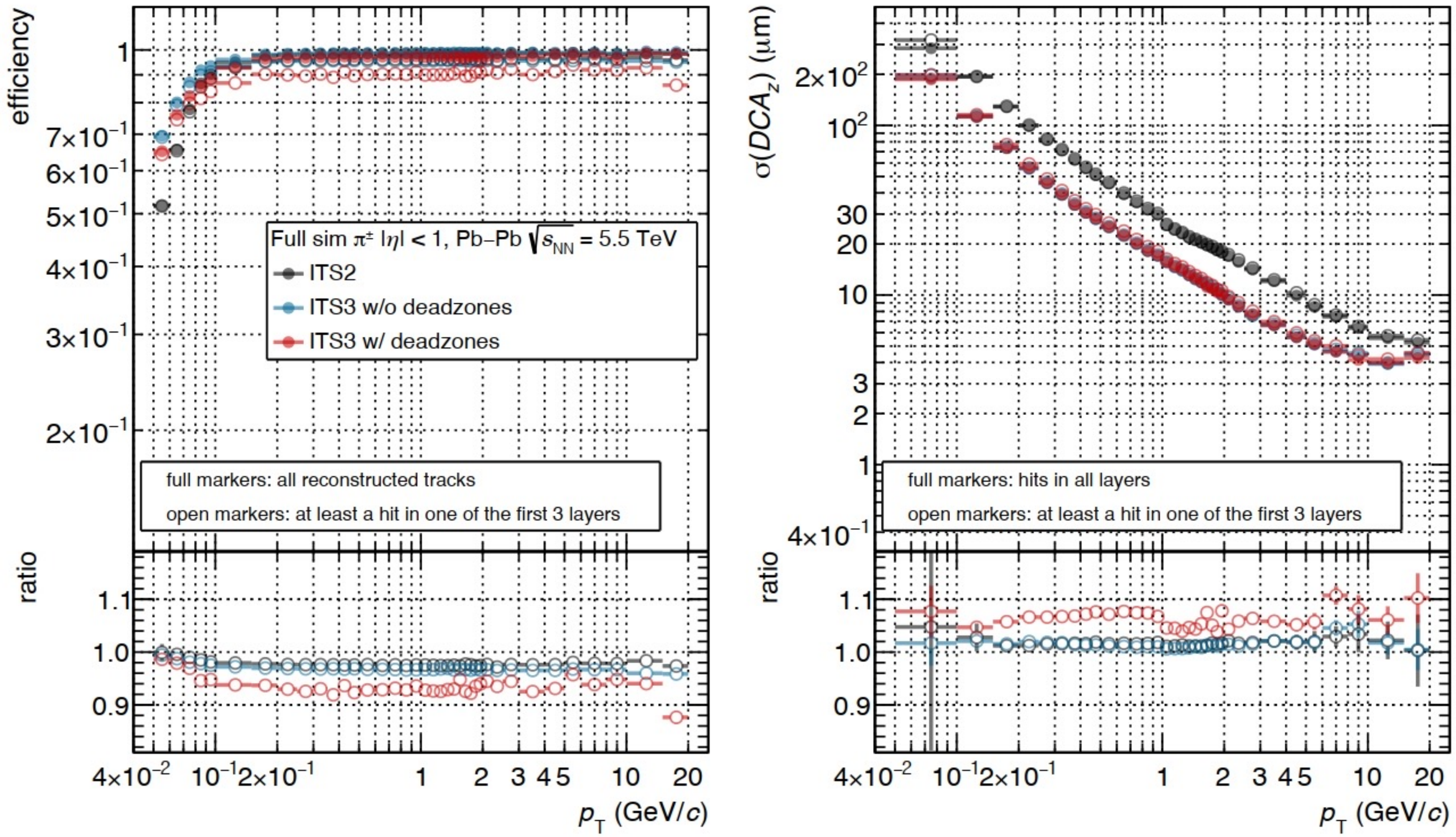
Assembled first layer of ITS3

ITS3 performance – pointing resolution



- Improvement in pointing resolution by a factor of 2 over all momenta
- Increase of tracking efficiency for low-p_T particles and extension of the low-p_T reach

ITS3 performance – impact on dead zones

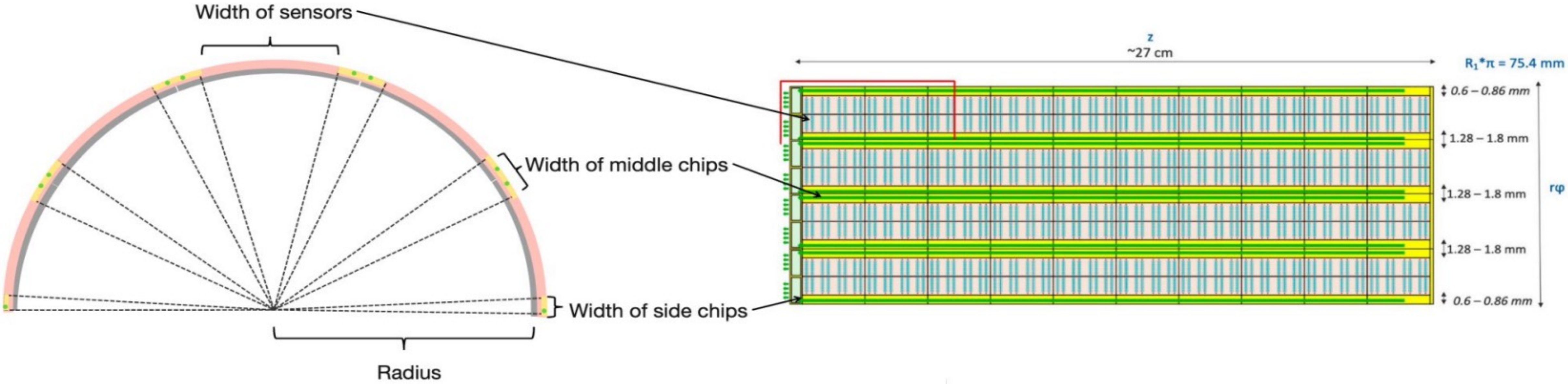


Assumptions here:

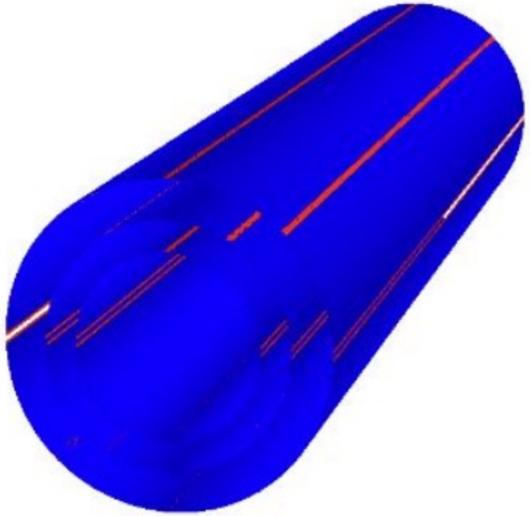
- 1mm gap between top and bottom
- Total: 8-9% dead area

- Dead zones (on chip and between halves) have direct impact on efficiency → important to optimise mechanics and chip design in this parameter

ITS3 geometry - dead zones



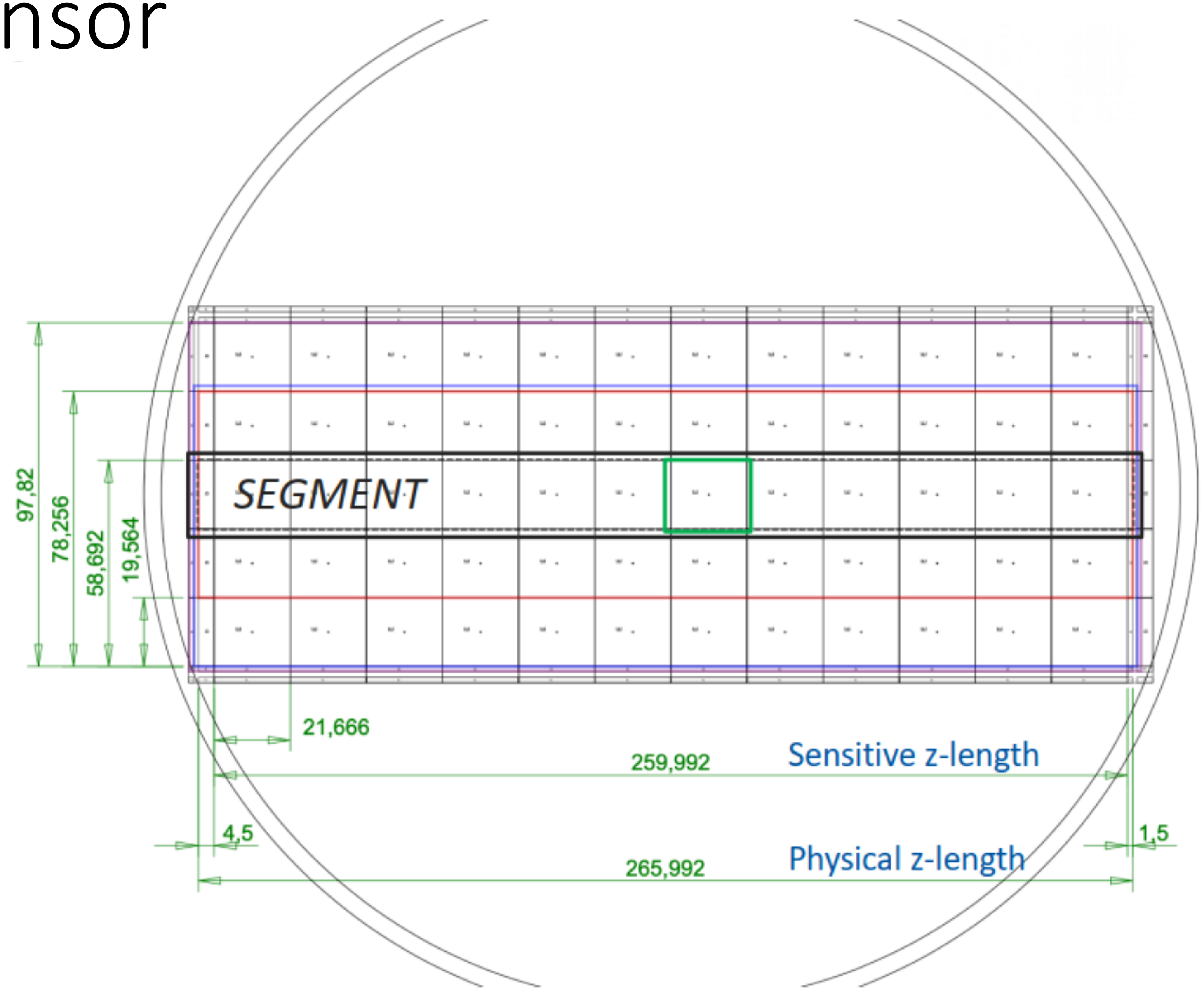
- Blue: sensitive areas
- Red: dead areas
- Gap between the two hemicylinders



ITS3 ER2 stitched sensor

Layer 0: 12 x 3 repeated units+endcaps
Layer 1: 12 x 4 repeated units+endcaps
Layer 2: 12 x 5 repeated units+endcaps

Repeated (Stitched) Sensing Unit



ITS3 ER1

First MAPS for HEP using stitching

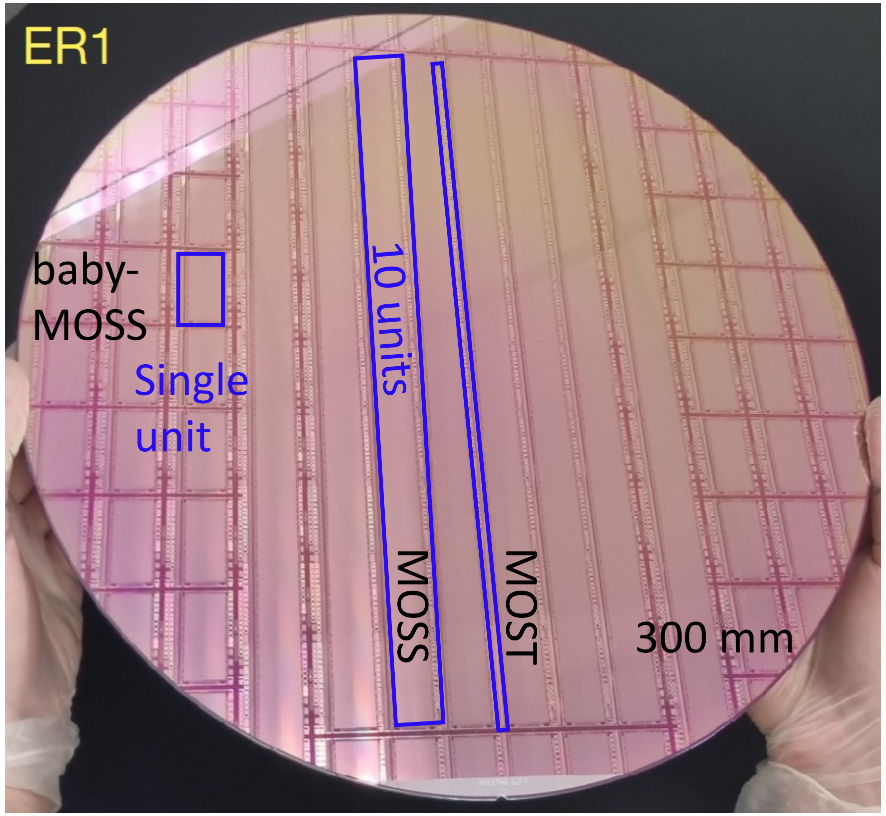
- One order of magnitude larger than previous chips

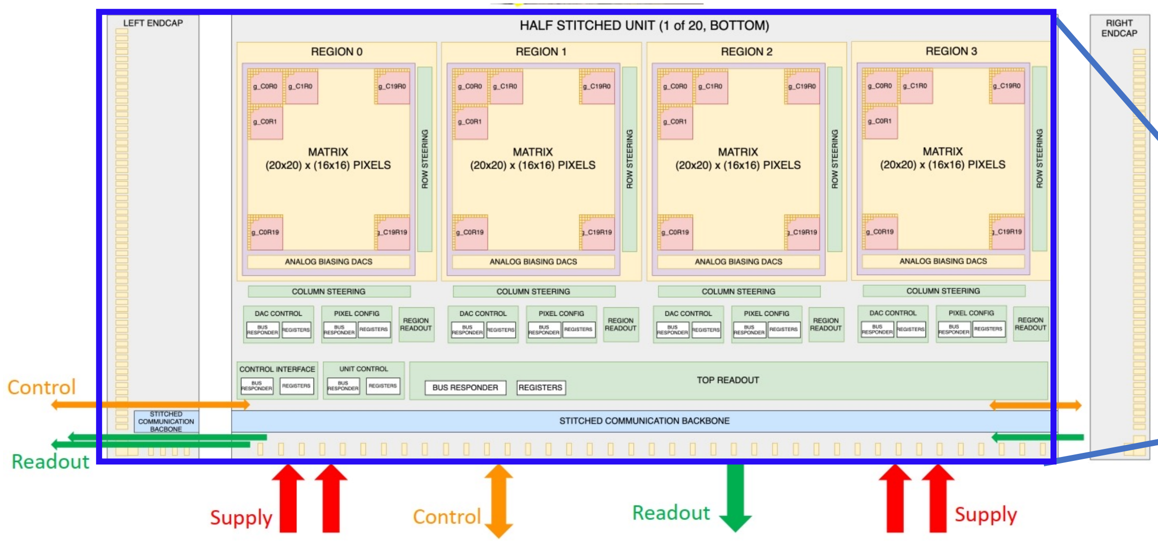
"MOSS": 14 x 259 mm, 6.72 MPixel (22.5 x 22.5 and 18 x 18 μm^2)

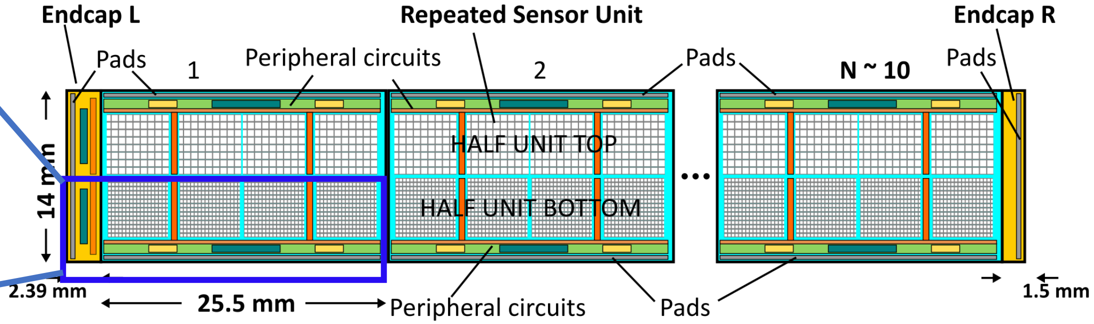
- Conservative design, different pitches

"MOST": 2.5 x 259 mm, 0.9 MPixel (18 x 18 μm^2)

- More dense design

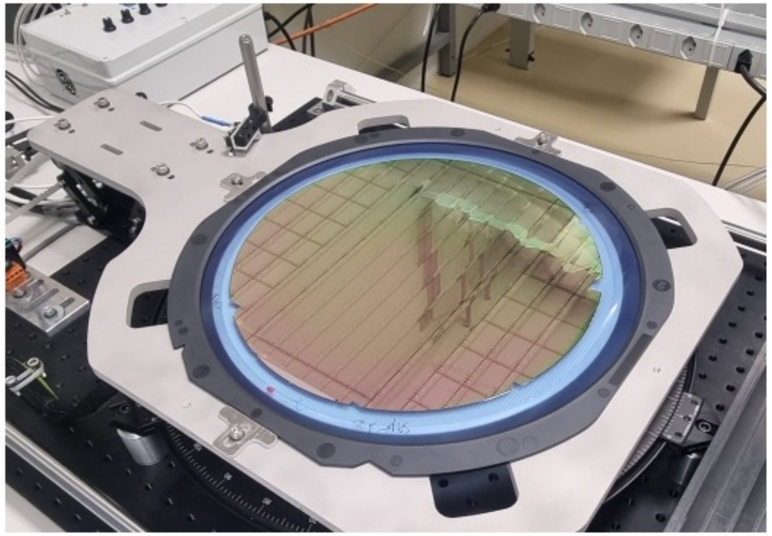


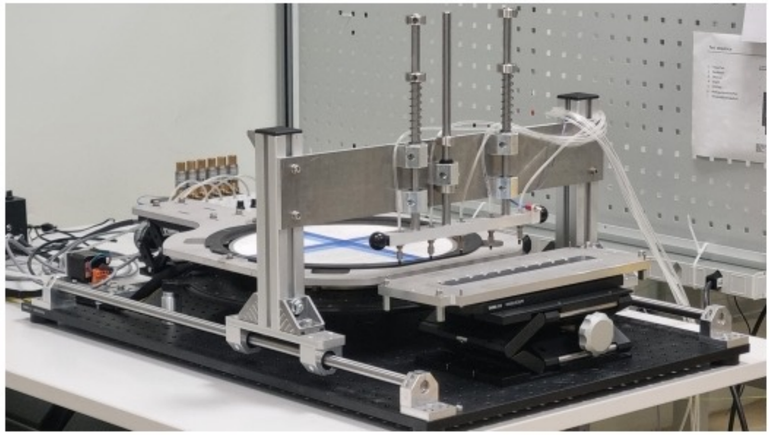


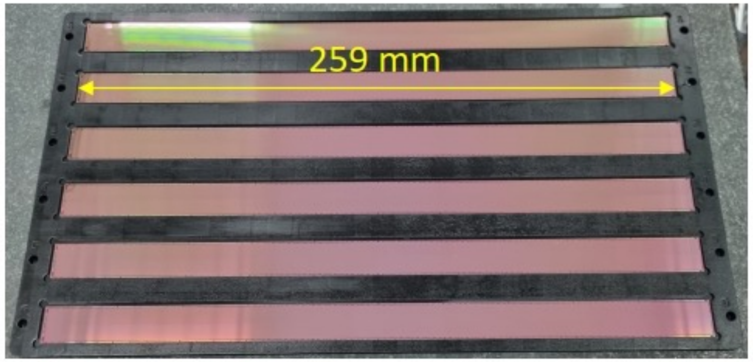


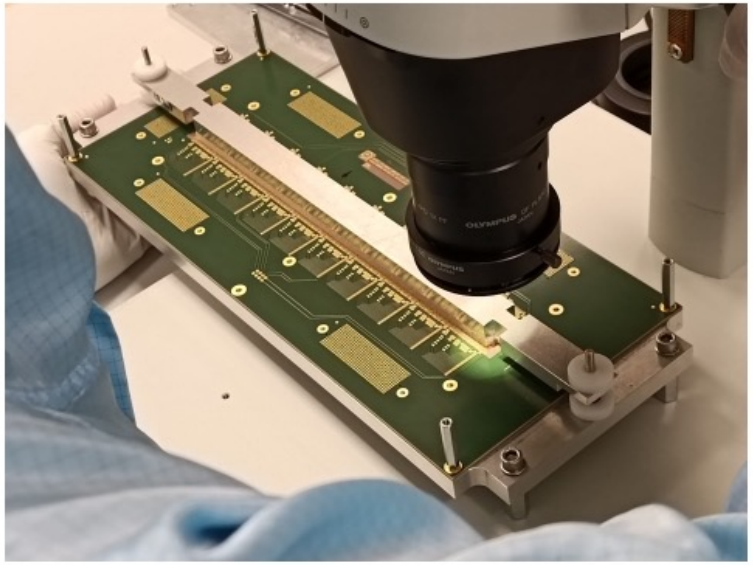
ITS3 ER1 postprocessing

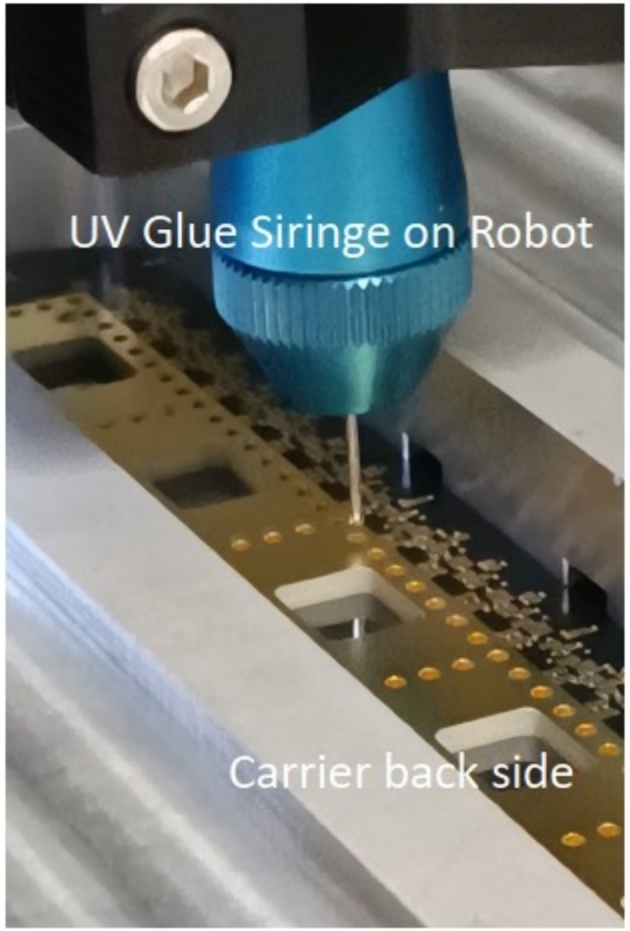
Pick, align, glue MOSS on Carrier





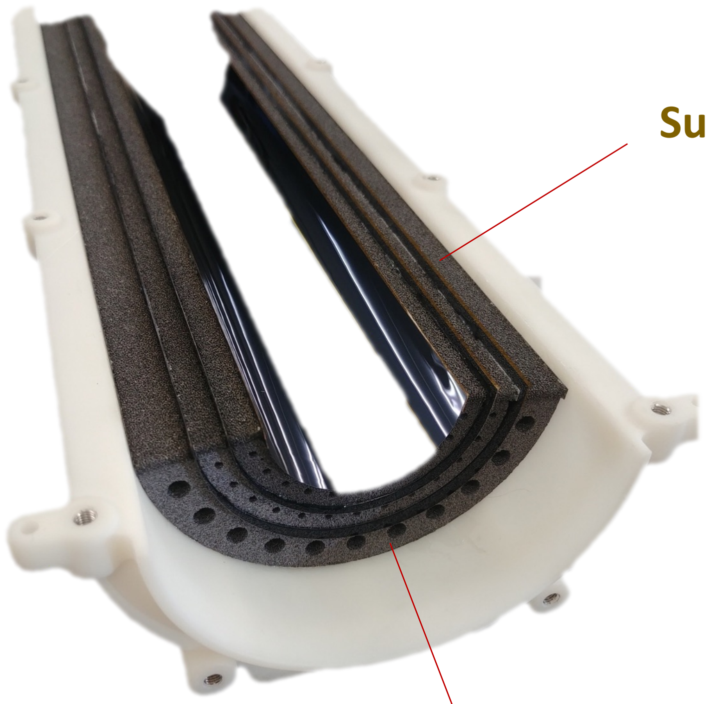






ITS3 mechanics and cooling solutions

- The limited dissipated power allows for the use of air cooling at ambient temperature (colder gas are also being considered as back up)
- The material budget requirement call for a unpalpable support structure i,.e. carbon foam used as support and radiator (carbon fiber truss support being considered as backup)



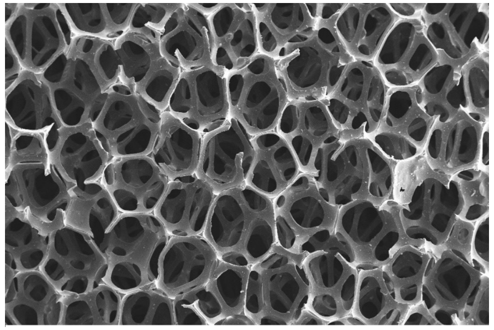
Support

ERG Carbon

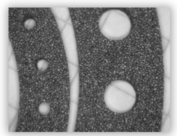
@Duocel

ρ = 0.045 kg/dm^3

k = 0.033 W/m·K



Support & cooling

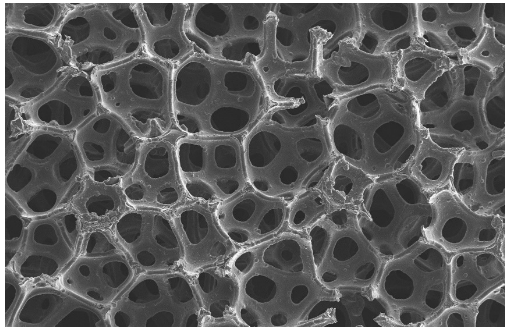


K9

Standard Density

ρ = 0.2-0.26 kg/dm3

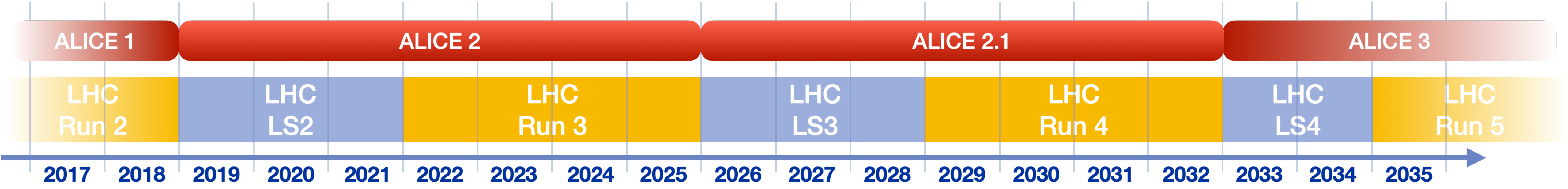
k = >17 W/m·K



ALICE 3 timeline

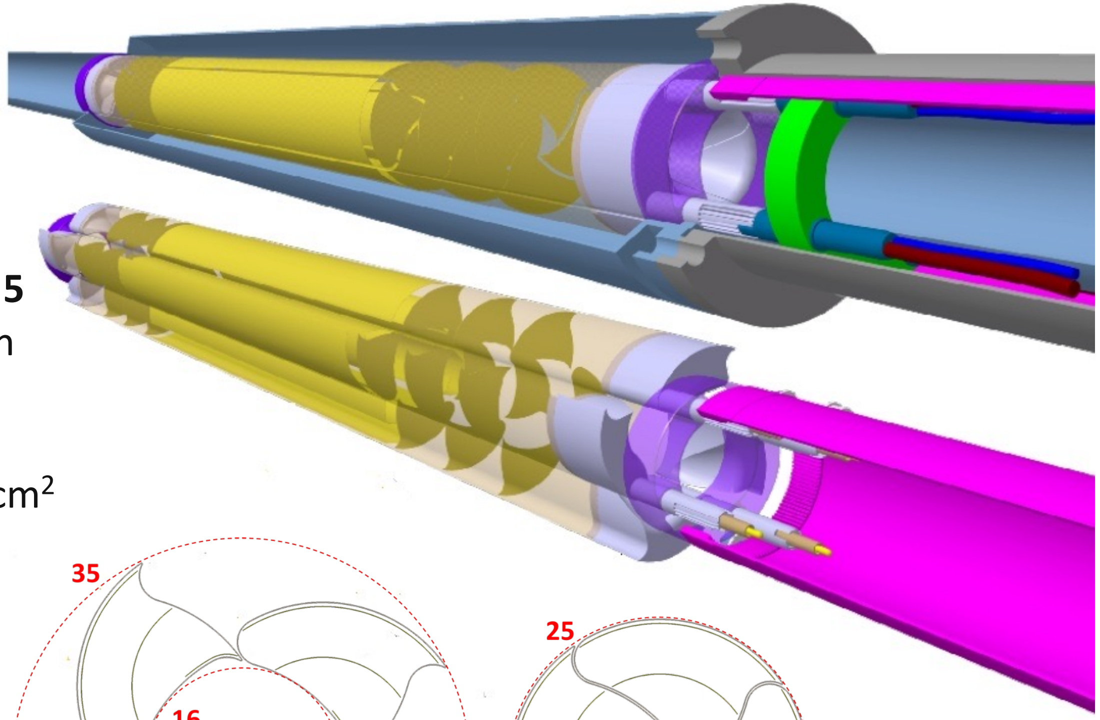
Long-term schedule

- **2023-25**: selection of technologies, small-scale proof of concept prototypes (~25% of R&D funds)
- **2026-27**: large-scale engineered prototypes (~75% of R&D funds) → Technical Design Reports
- **2028-30**: construction and testing
- **2031-32**: contingency and pre-commissioning
- **2033-34**: preparation of cavern, installation

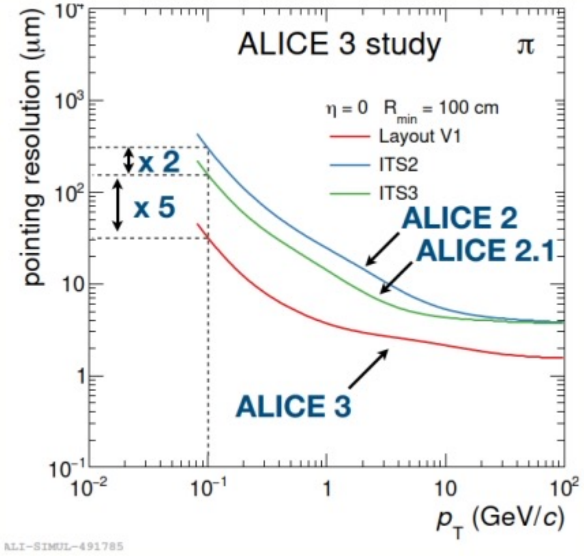


ALICE 3 - Vertex detector

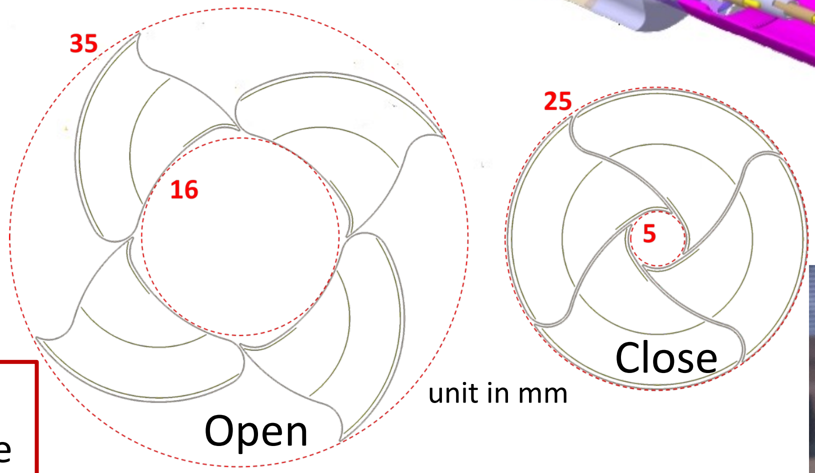
- 3 layers of wafer-size, ultra-thin, curved, CMOS MAPS **inside the beam pipe** in secondary vacuum
- **Retractable** configuration thanks to **movable petals**: distance of **5 mm** from beam axis for data taking and **16 mm** at beam injection
- Unprecedent spatial resolution: $\boldsymbol{\sigma_{pos}}$ **~ 2.5 µm**
- Extremely low material budget: **0.1% per layer**
- Radiation tolerance requirements: 10 Mrad + 2x10^{15} 1MeV n_{eq} /cm^2 (from FLUKA simulations; safety factor to be decided)



ITS3 prototype already achieved 10^{15} 1MeV n_{eq} /cm^2

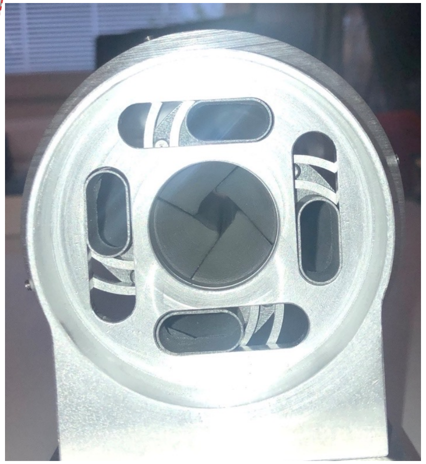


R&D challenges: radiation hardness, technology feature size and cooling



Plans in 2024: new irradiation tests (NIEL, TID), sensor specs, lab tests (mechanics, services, vacuum, etc.)

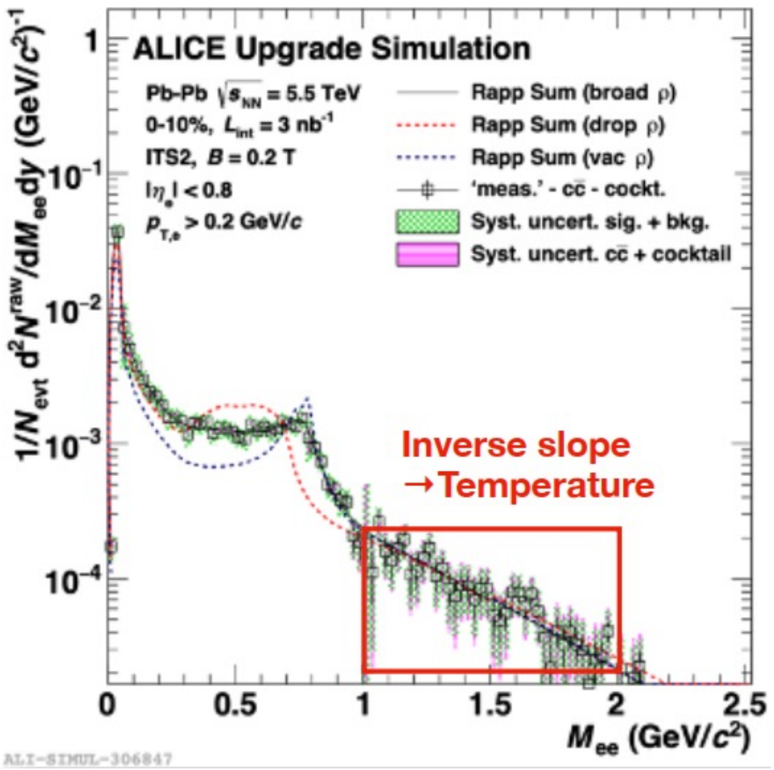
Bread-Board Model 3
3D-printed aluminium petals
0.5 mm wall thickness

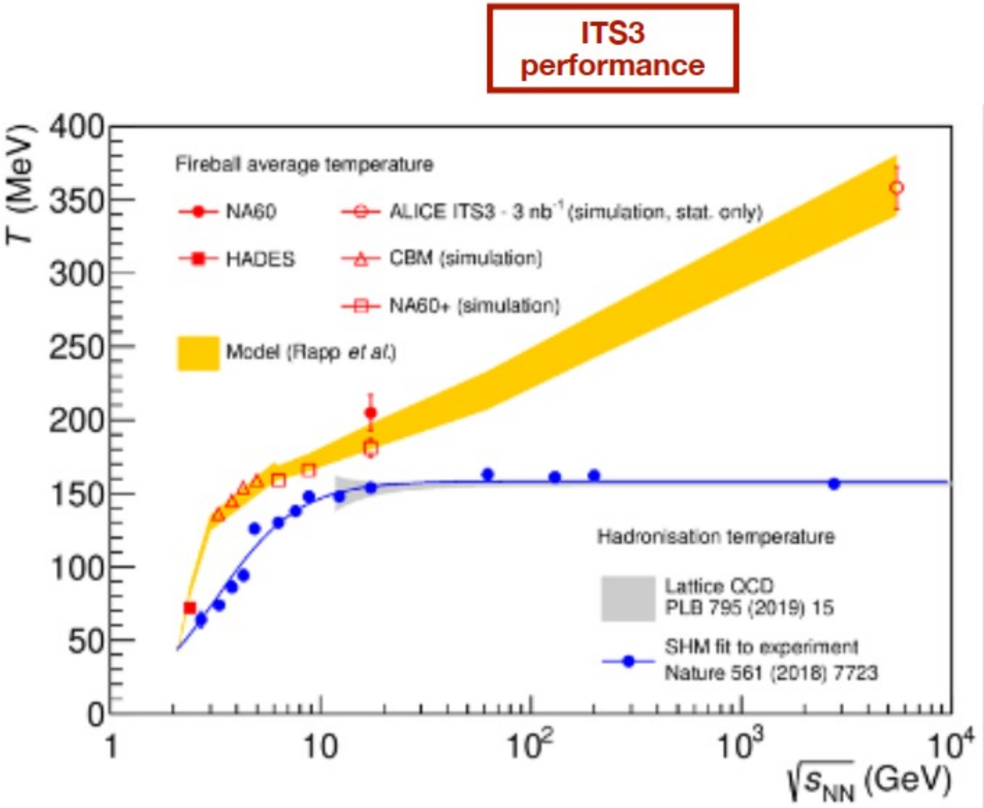


ITS3 - Physics goals - Dileptons

Thermal dileptons, photons, vector mesons (thermal radiation, chiral symmetry restoration)

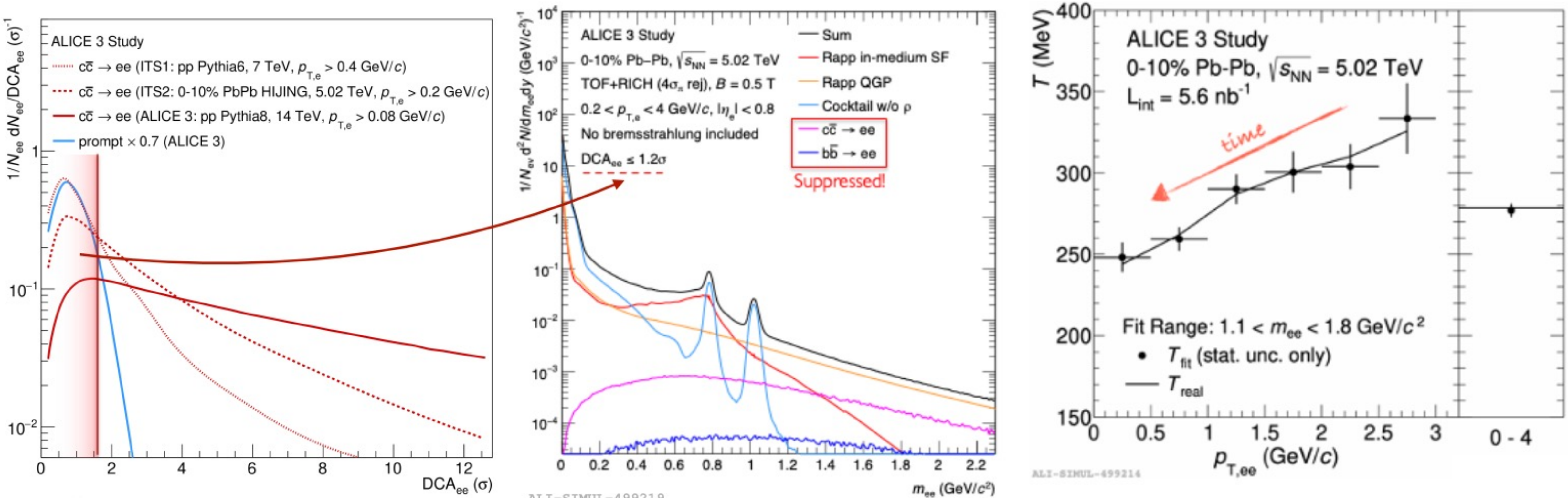
- High precision measurement of temperature in mass region $1<M_{ee}<2$ GeV/c^2





ALICE3 - Physics goals - Dileptons

- ALICE 3 high precision tracking results in an unprecedented HF rejection and low-p_T electron ID → background suppression allows a very precise temperature measurement
- Differential analysis in $p_{T,ee}$: **only** accessible with ALICE 3



ALICE3 - Physics goals - Heavy flavours

- **Heavy flavour** hadrons at low p_T (charm and beauty interaction and hadronisation in the QGP)
- SHM: hierarchy with **n** number of charms (**g_c^n**) → multicharm hadrons (e.g., Ξ^{++}_{cc})
- Silicon layers inside the beam pipe allow for **direct tracking** of **Ξ/Ω** baryons (**strangeness tracking**) -> full reconstruction of multi-charm baryon decay vertices