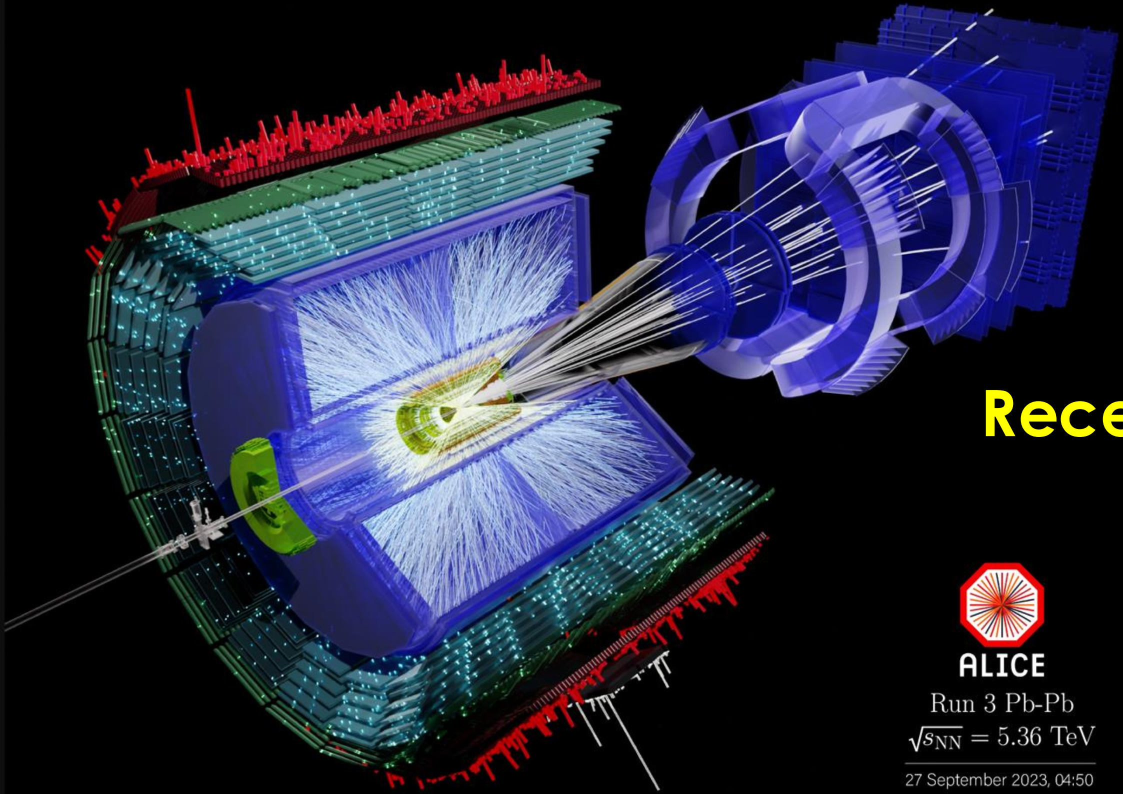
Recent activity from KoALICE

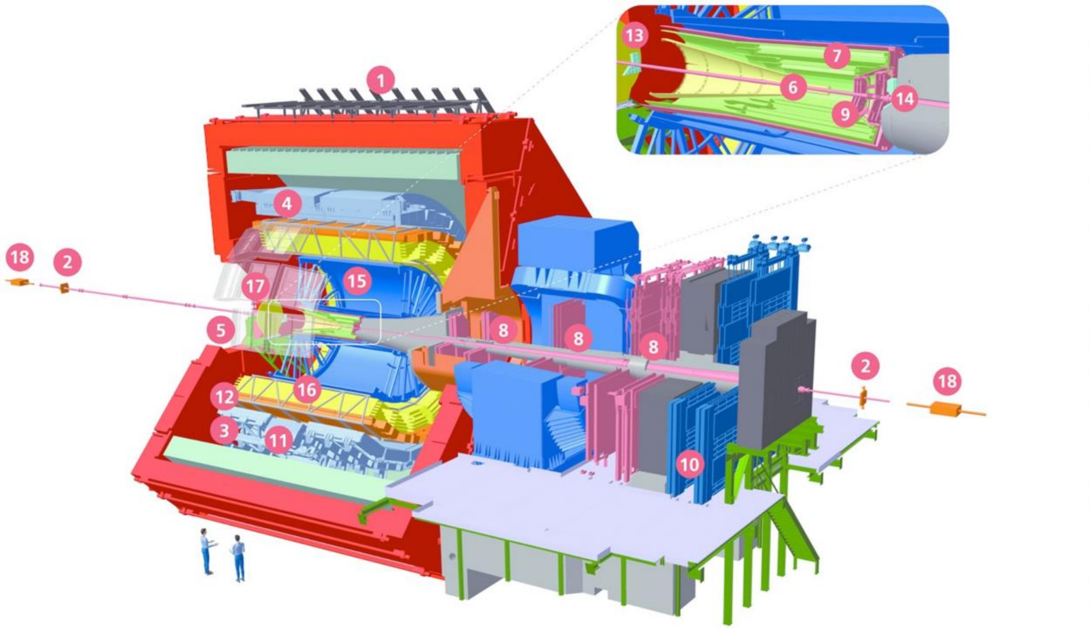


ALICE
Run 3 Pb-Pb
$\sqrt{s_{\mathrm{NN}}} = 5.36$ TeV
27 September 2023, 04:50

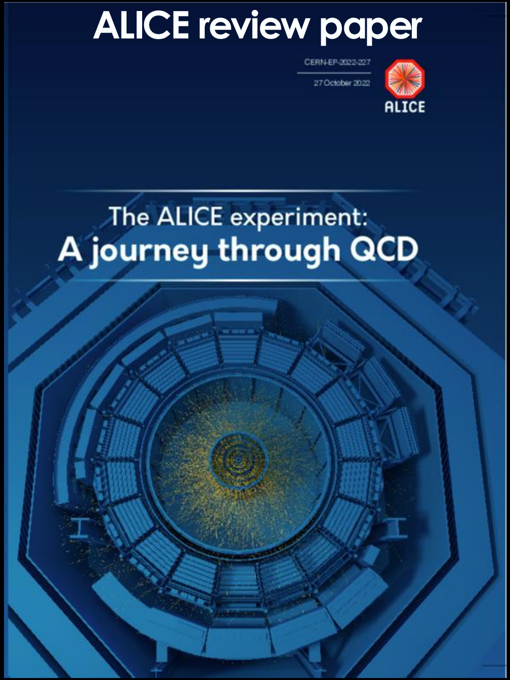
Sanghoon Lim
for the KoALICE group

Pusan National University

ALICE



①	**ACORDE** | ALICE Cosmic Rays Detector
②	**AD** | ALICE Diffractive Detector
③	**DCal** | Di-jet Calorimeter
④	**EMCal** | Electromagnetic Calorimeter
⑤	**HMPID** | High Momentum Particle Identification Detector
⑥	**ITS-IB** | Inner Tracking System - Inner Barrel
⑦	**ITS-OB** | Inner Tracking System - Outer Barrel
⑧	**MCH** | Muon Tracking Chambers
⑨	**MFT** | Muon Forward Tracker
⑩	**MID** | Muon Identifier
⑪	**PHOS / CPV** | Photon Spectrometer
⑫	**TOF** | Time Of Flight
⑬	**T0+A** | Tzero + A
⑭	**T0+C** | Tzero + C
⑮	**TPC** | Time Projection Chamber
⑯	**TRD** | Transition Radiation Detector
⑰	**V0+** | Vzero + Detector
⑱	**ZDC** | Zero Degree Calorimeter



ALICE review paper

CERN-EP-2022-227
27 October 2022
ALICE

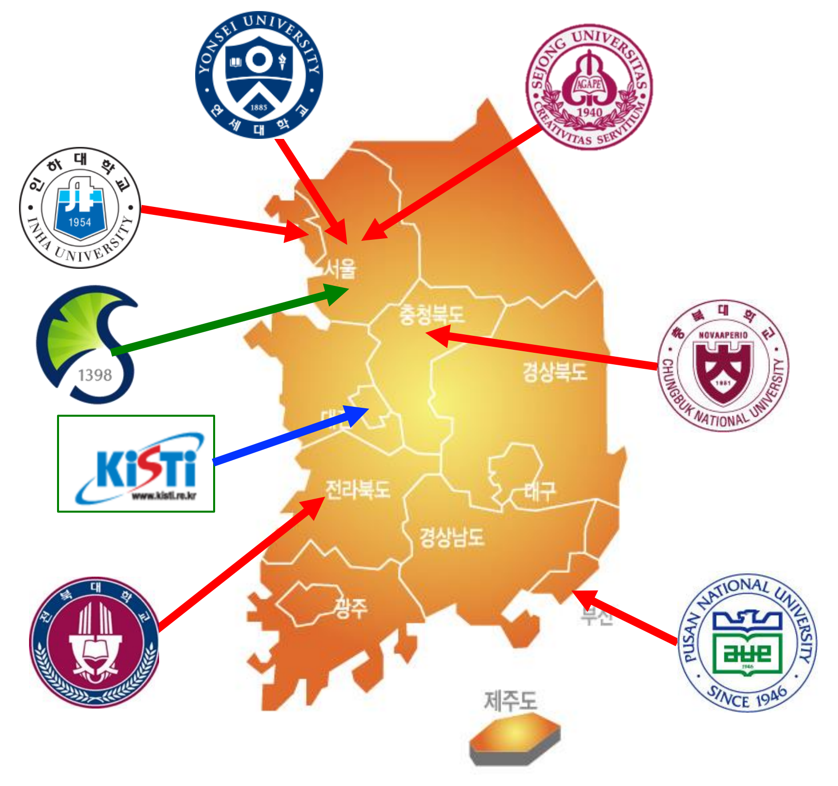
The ALICE experiment:
A journey through QCD

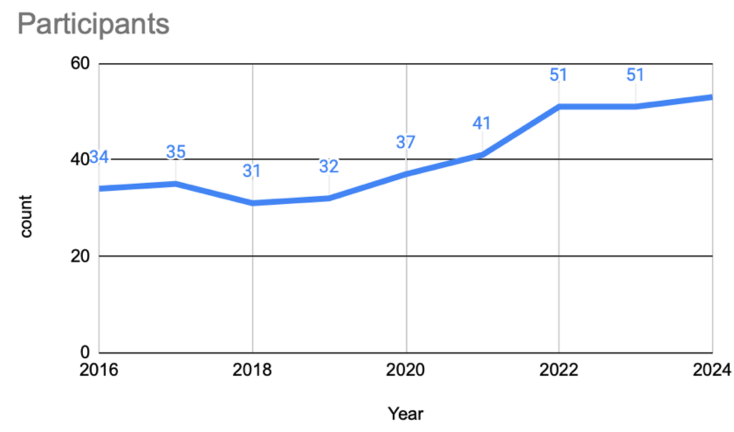
arXiv:2211.04384

- 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

KoALICE





KoALICE in numbers (53+1)

18 PhD Physicists (18 M&O-A)

10 PhD Students

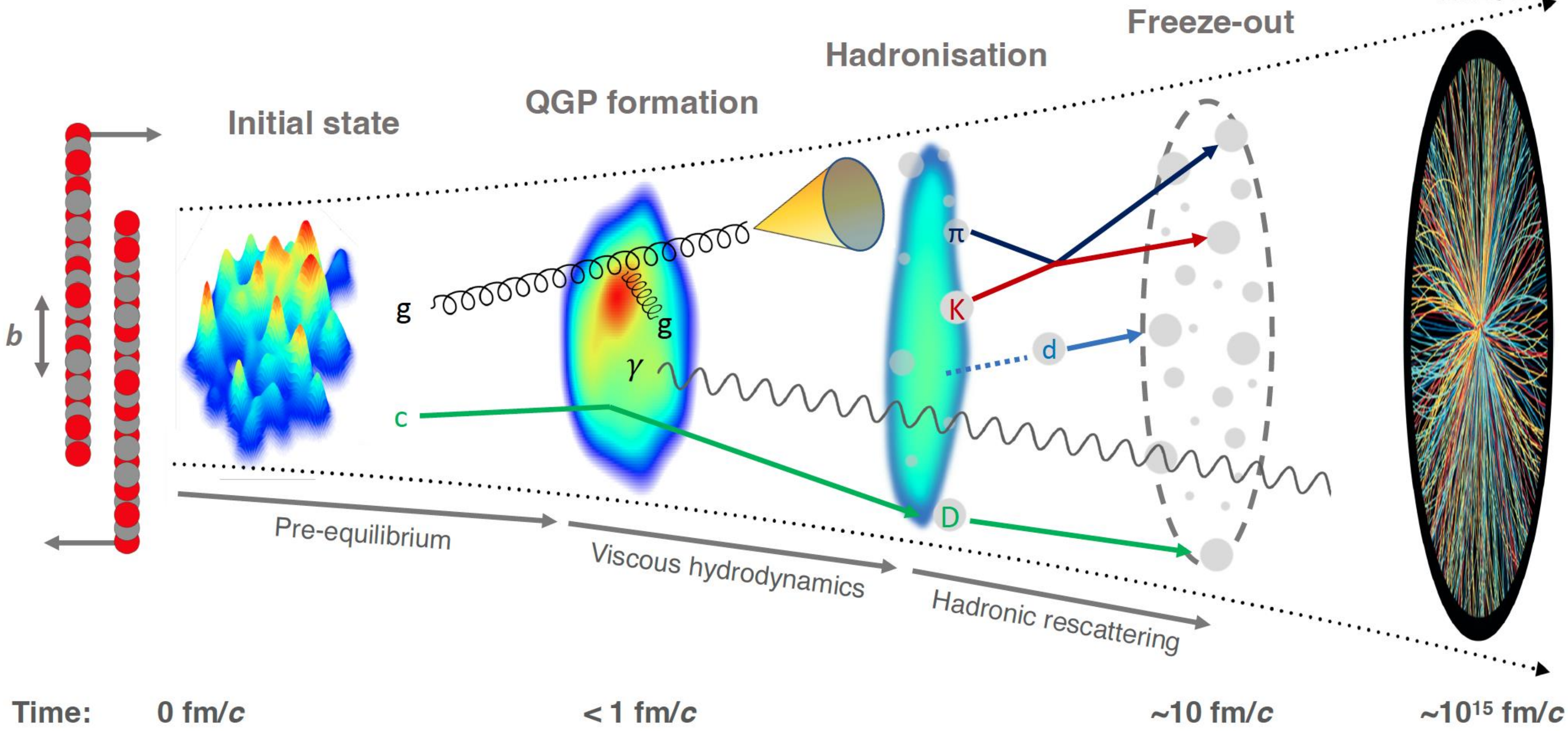
23 Master Students

1 researcher (post-MS degree)

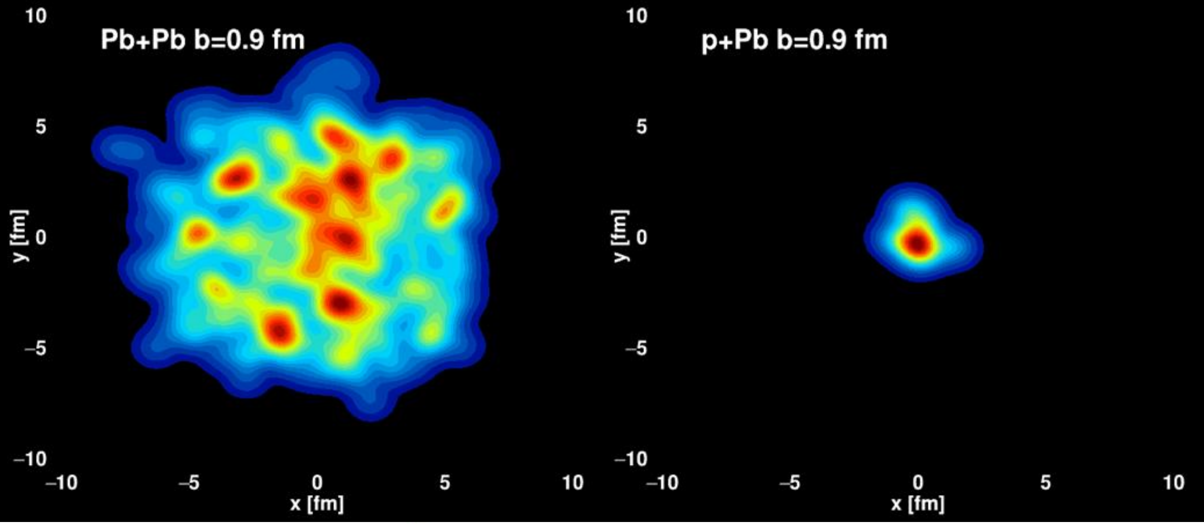
1 Administrative Assistant

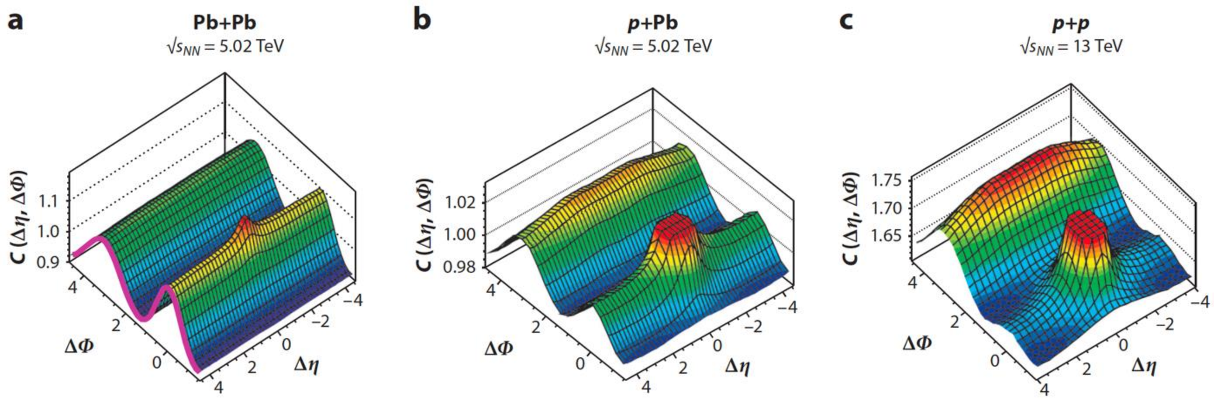
+1 PhD Physicists from KISTI (1 M&O-A)

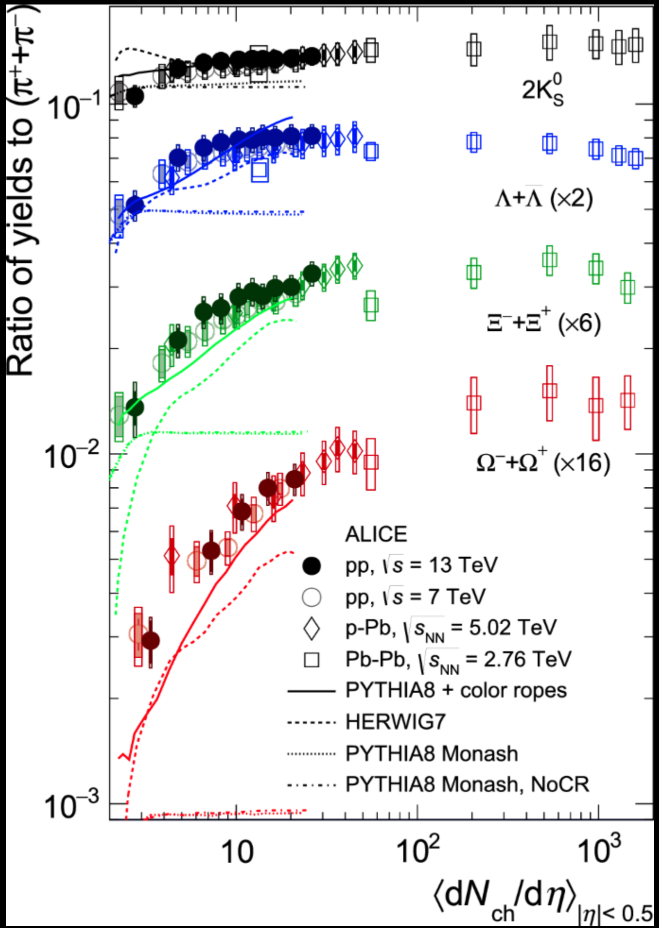
Primary research subject in ALICE



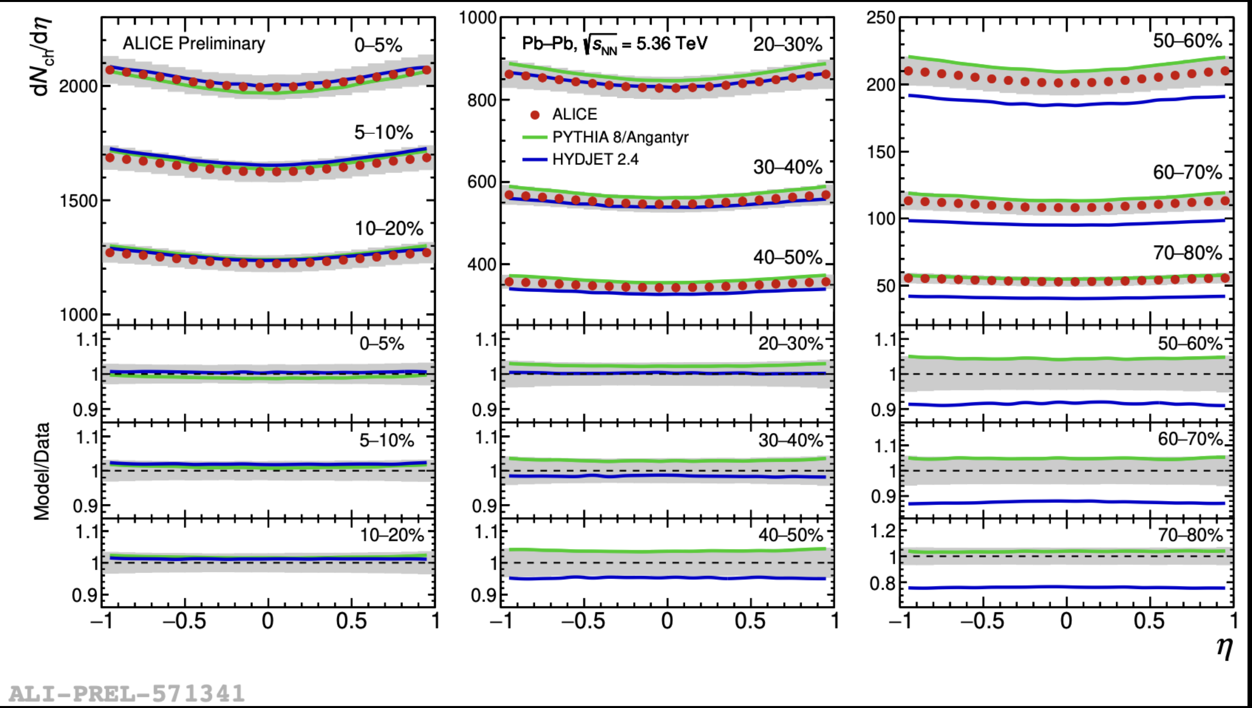
Searching for a droplet of QGP? Controlling the size of QGP?



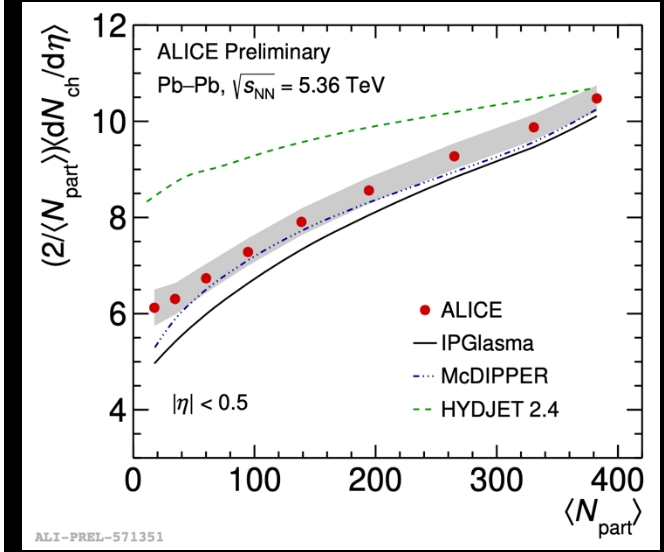




Searching for a droplet of QGP? Controlling the size of QGP?

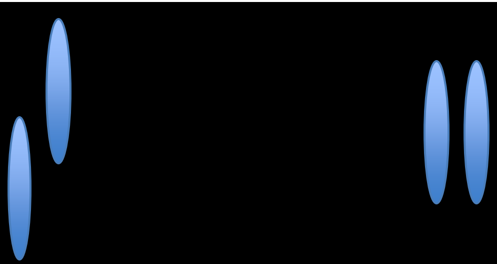


ALI-PREL-571341

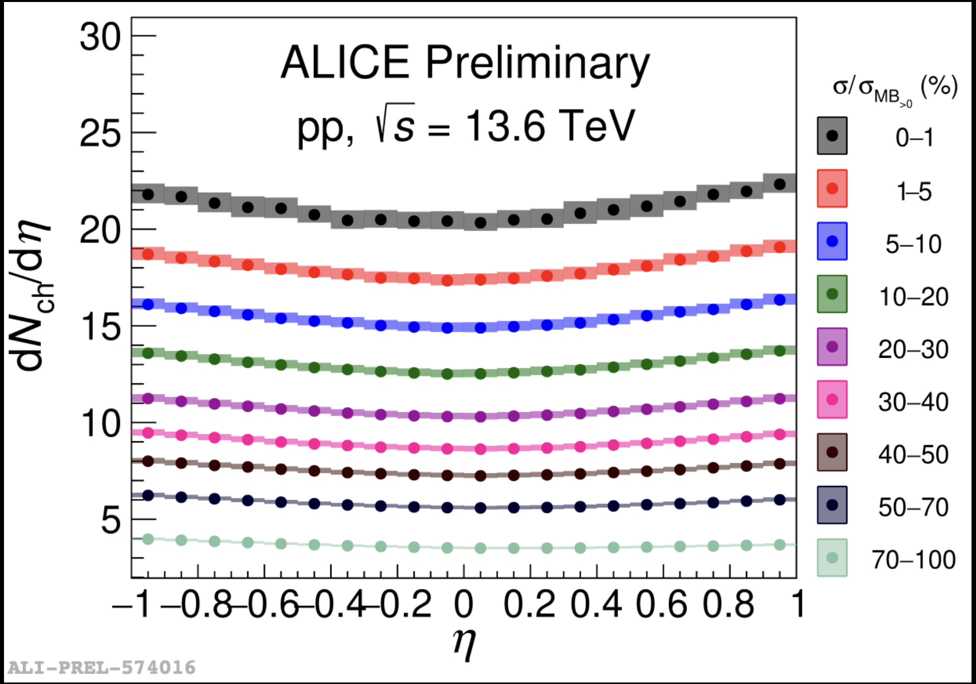


ALI-PREL-571351

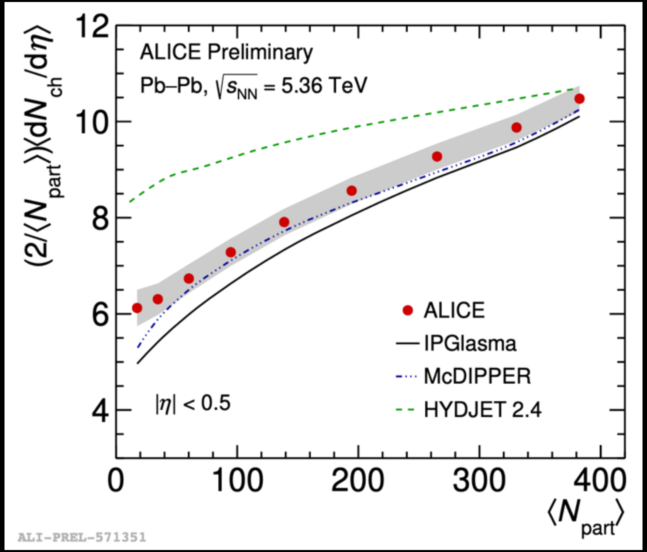
Charged particle pseudo-rapidity density in Pb-Pb at 5.36 TeV



Searching for a droplet of QGP? Controlling the size of QGP?

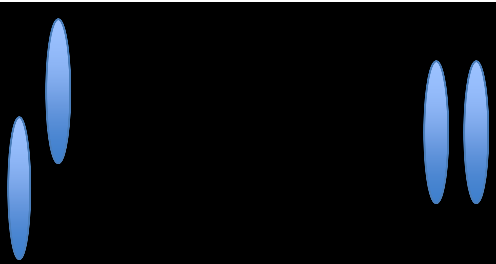


ALI-PREL-574016

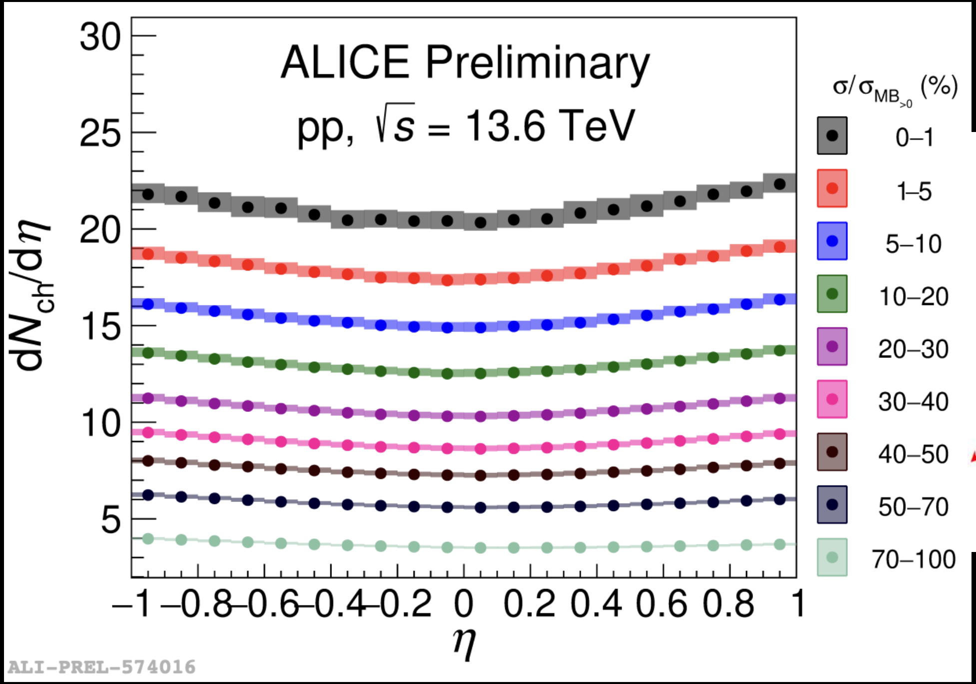


ALI-PREL-571351

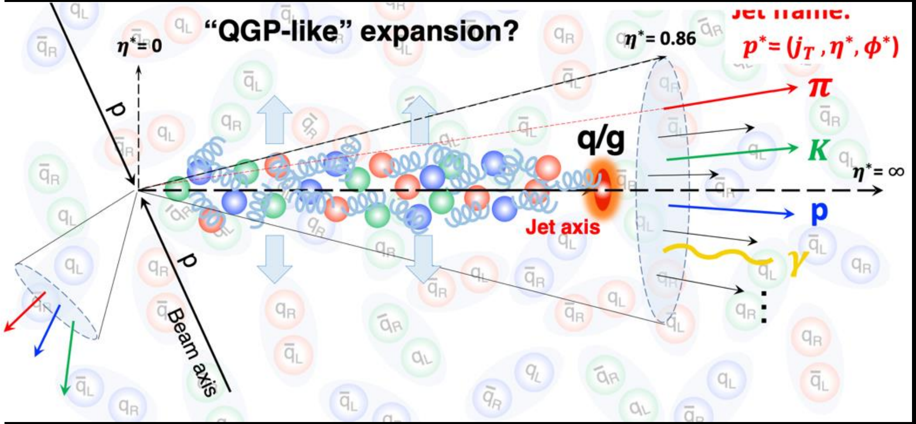
Charged particle pseudo-rapidity density in pp at 13.6 TeV



Searching for a droplet of QGP? Controlling the size of QGP?

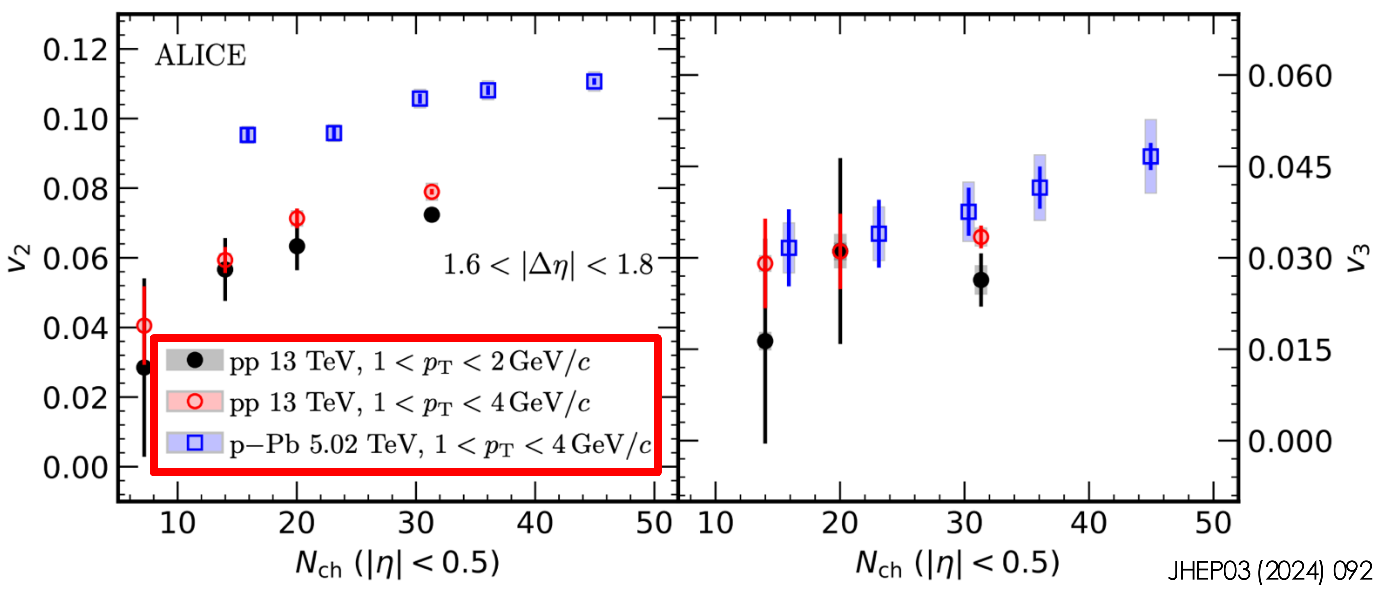


Charged particle pseudo-rapidity density in pp at 13.6 TeV

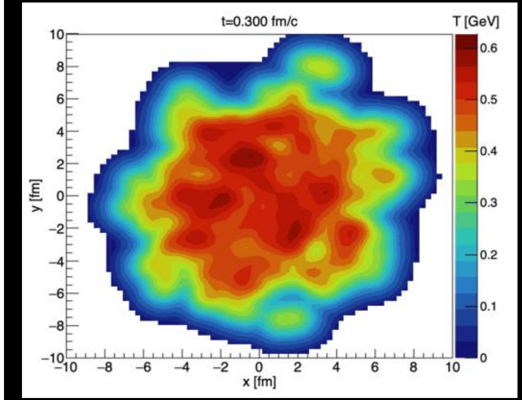


More extreme environment inside a jet?

Searching for a droplet of QGP? Controlling the size of QGP?

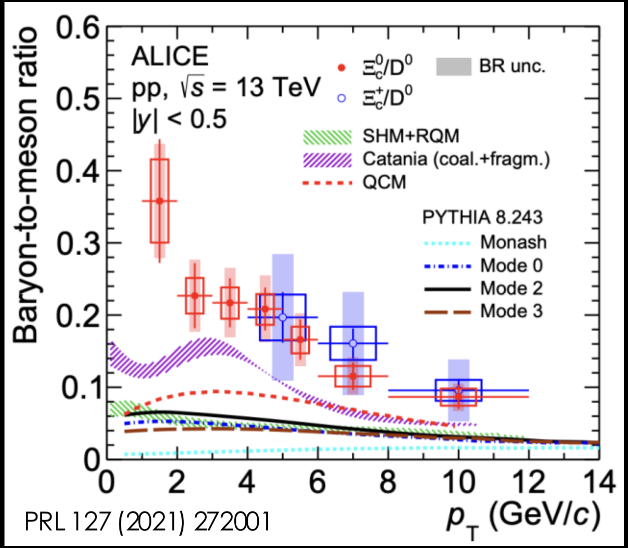


JHEP03 (2024) 092

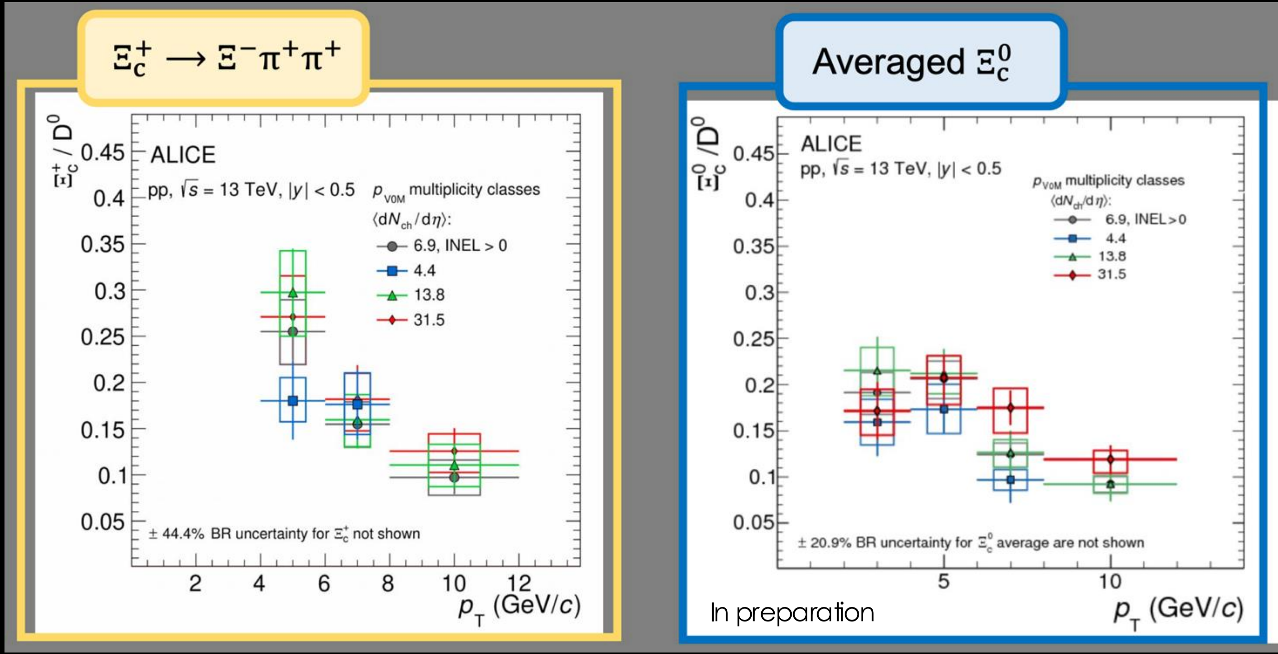


Clear collectivity in pp collisions

Searching for a droplet of QGP? Controlling the size of QGP?



PRL 127 (2021) 272001

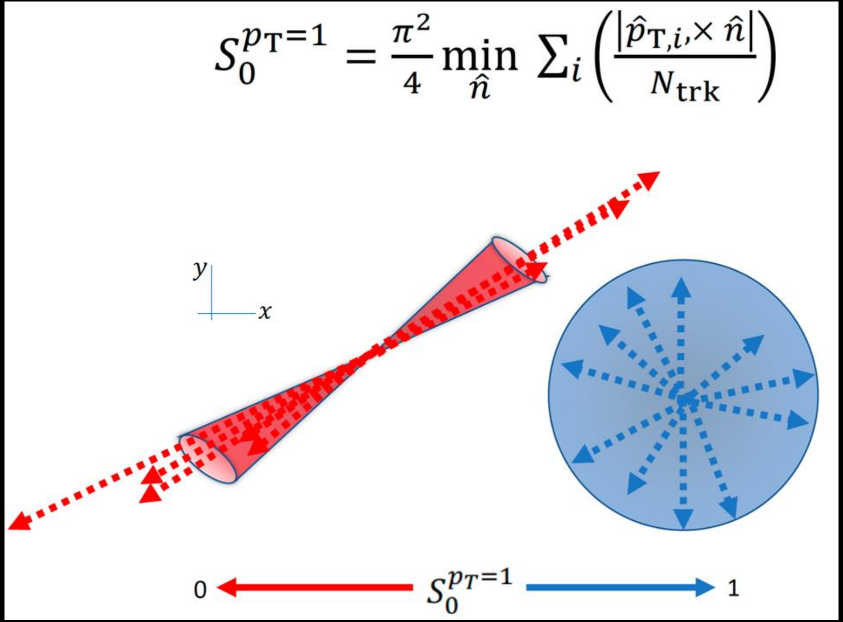


Integrated multiplicity

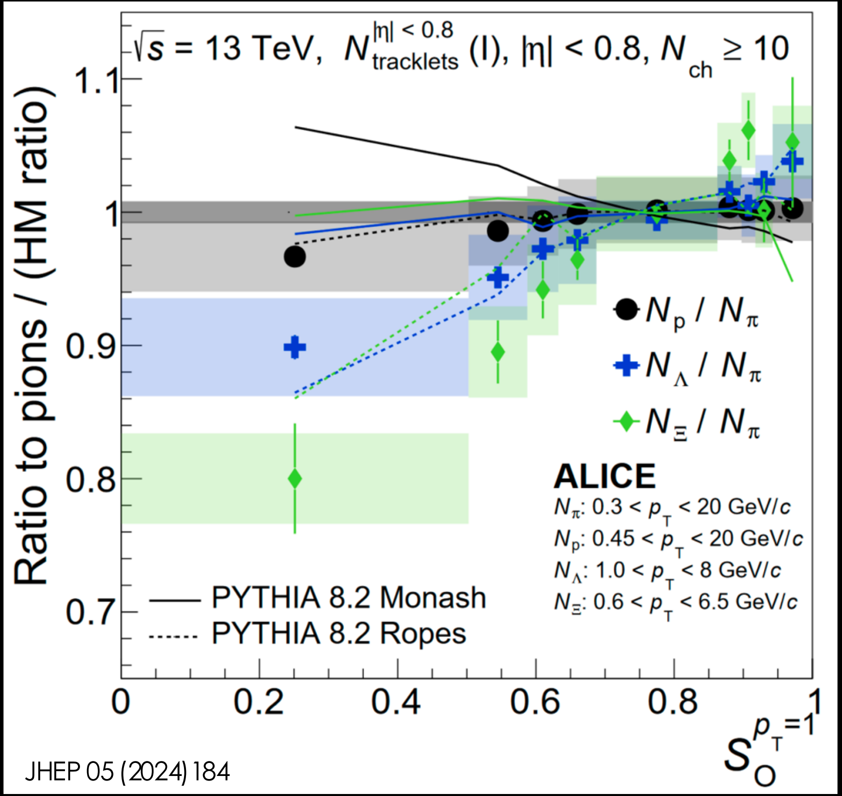
Multiplicity dependent

Charm fragmentation (hadronization) is not universal

Searching for a droplet of QGP? Controlling the size of QGP?



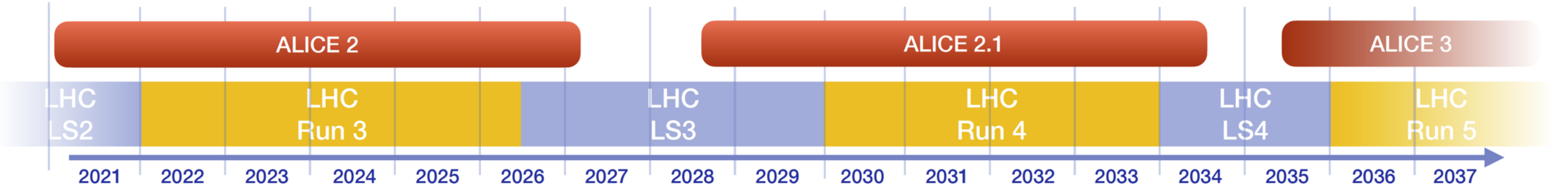
Event classification for the top 1% high multiplicity:
jet-like vs isotropic

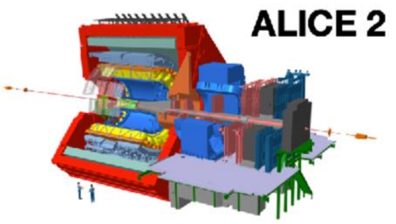


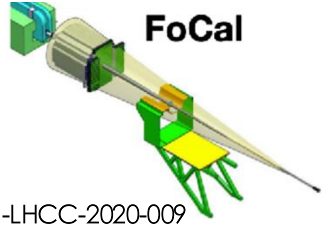
JHEP 05 (2024) 184

Strangeness enhancement is a property of underlying events

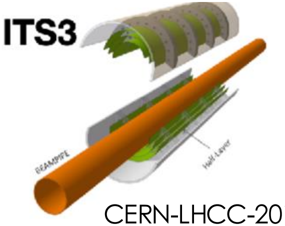
ALICE in the future



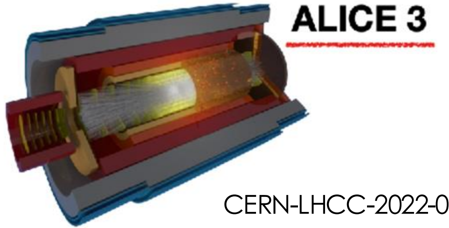




CERN-LHCC-2020-009



CERN-LHCC-2019-018

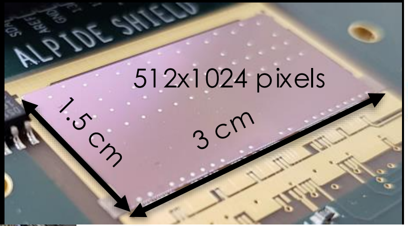


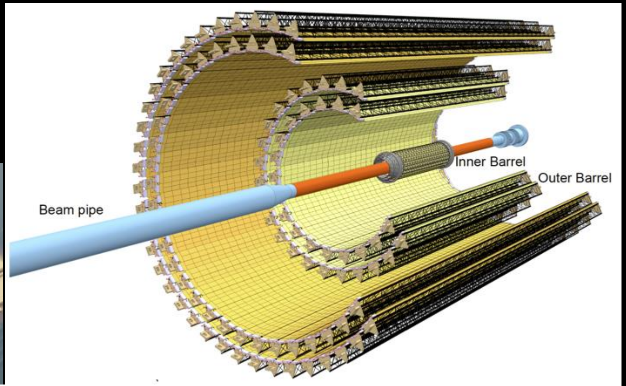
CERN-LHCC-2022-009

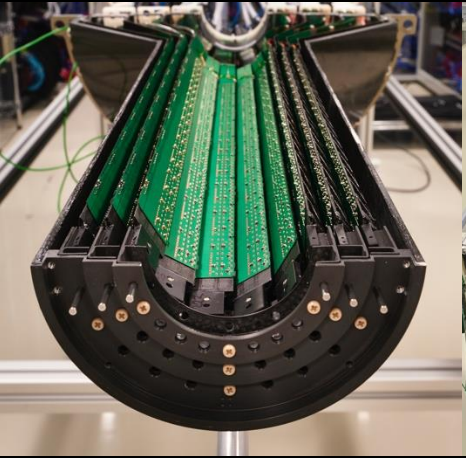
- **FoCal**
  - FoCal-E: 20 layers of W (3.5 mm≈1 X_0)+Si sensors Two sensor types: pad and pixel (ALPIDE)
  - FoCal-H: conventional metal-scintillator sampling calorimeter
  - Parton distributions in protons and nuclei with photons and jets at forward rapidity
- **ITS3**
  - Replacement of 3 innermost 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

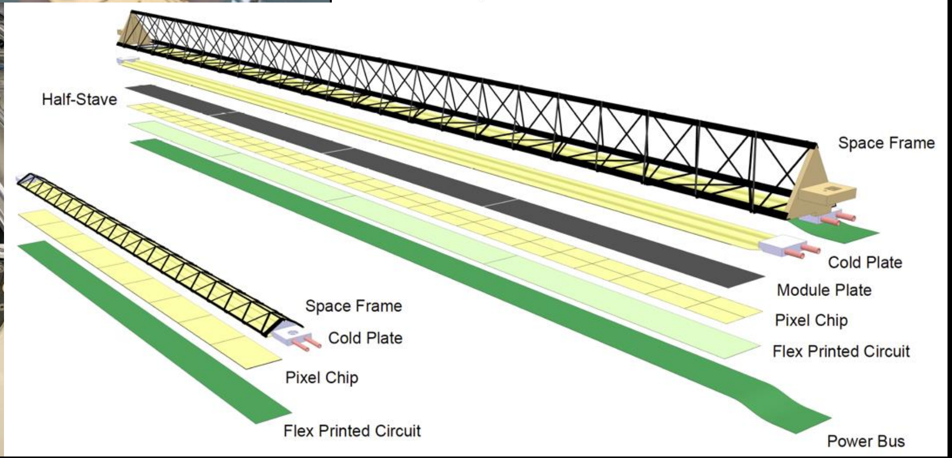
ITS2

- New inner tracking system (ITS2) for Run 3
  - 7 layers (3 inner + 4 outer)
  - Monolithic Active Pixel Sensor Technology
  - Pitch: 29 x 27 μm^2
  - Thickness: 50 μm for inner, 100 μm for outer
  - 5 μm position resolution, >99% hit efficiency

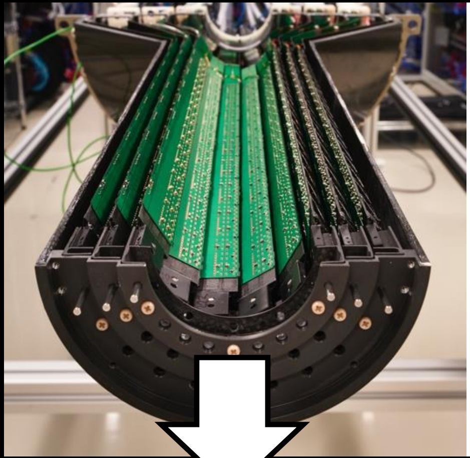


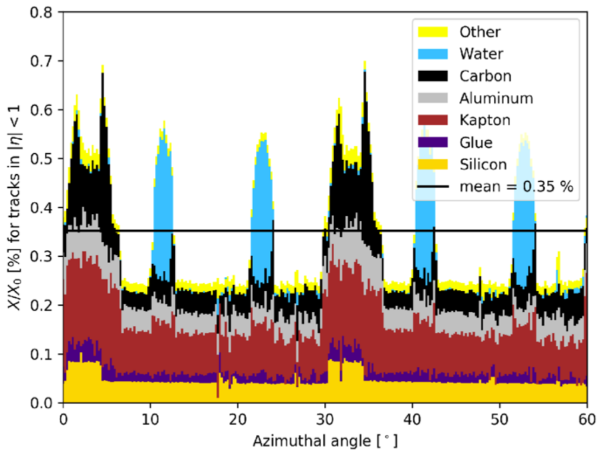


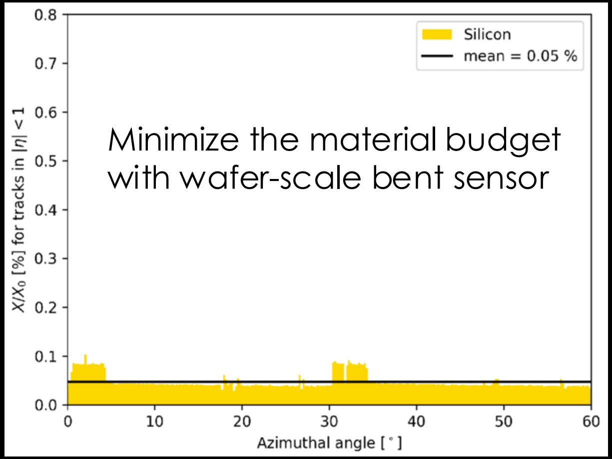




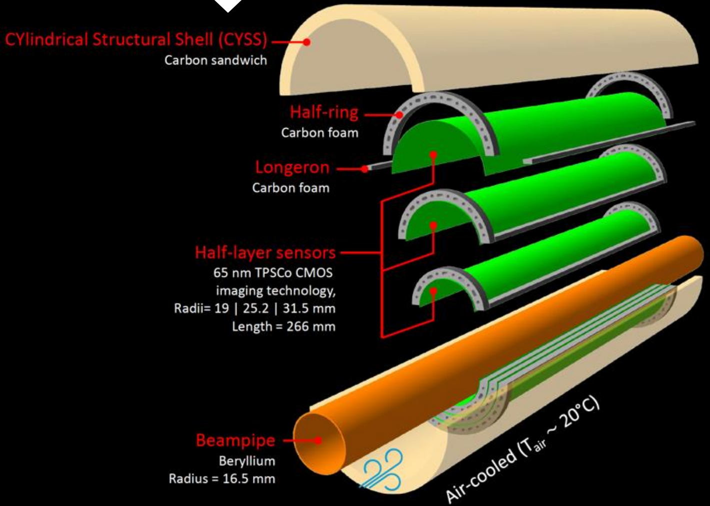
ITS3 in Run 4







Minimize the material budget with wafer-scale bent sensor



CYlindrical Structural Shell (CYSS)
Carbon sandwich

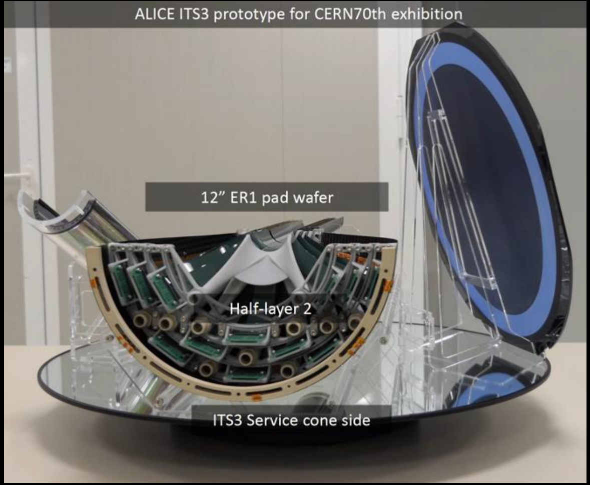
Half-ring
Carbon foam

Longeron
Carbon foam

Half-layer sensors
65 nm TPSCo CMOS imaging technology,
Radii= 19 | 25.2 | 31.5 mm
Length = 266 mm

Beampipe
Beryllium
Radius = 16.5 mm

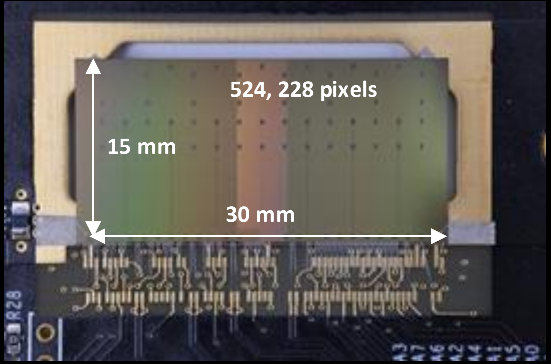
Air-cooled (T_{air} ~ 20°C)



ALICE ITS3 prototype for CERN70th exhibition

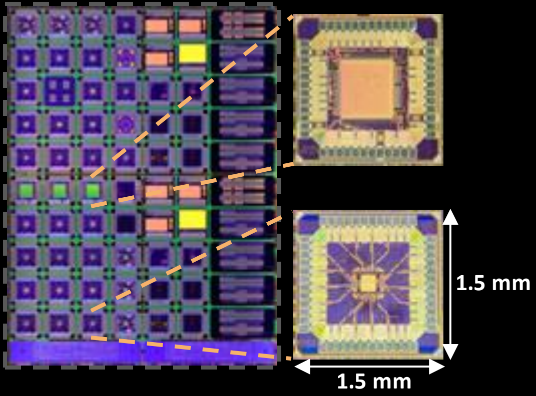
ITS3 in Run 4

ALPIDE (ITS2, 180 nm)



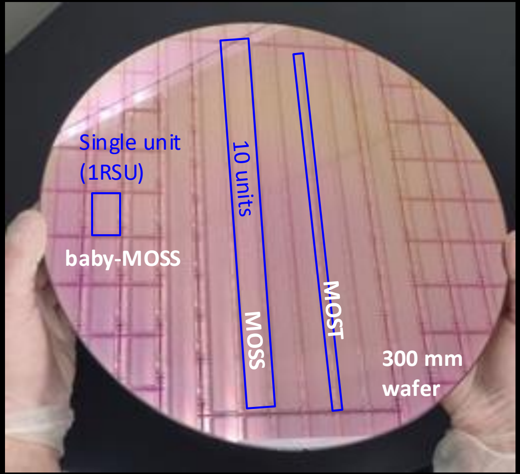
- **AL**ice **PI**xel **DE**tector
  - Manufactured with Tower Semiconductor 180 nm CIS
  - 1024 x 512 pixels
  - Used chip for ITS2
  - 50, 100 um thickness
  - > 99 % detection efficiency
  - Bent chip test + use reference planes detector in telescope

MLR1 (65 nm)



- **M**ulti-reticle **L**ayer **R**un **1**
  - Qualifying the TPSCo 65 nm CIS
  - 55 prototypes sensors
  - Analog Pixel Test Structure (APTS)
    - 6 x 6 pixels
    - Direct analog readout of central 4 x 4
    - 10, 15, 20, 25 um pitches
  - Digital Pixel Test Structure (DPTS)
    - 32 x 32 pixels
    - Asynchronous digital readout

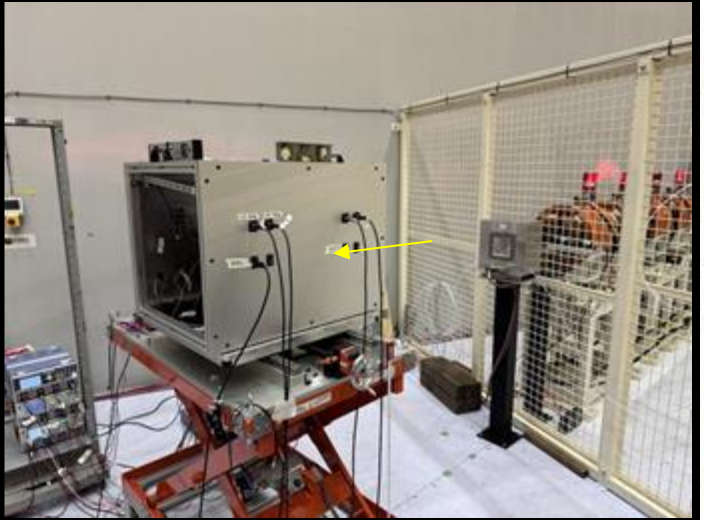
ER1 (65 nm)

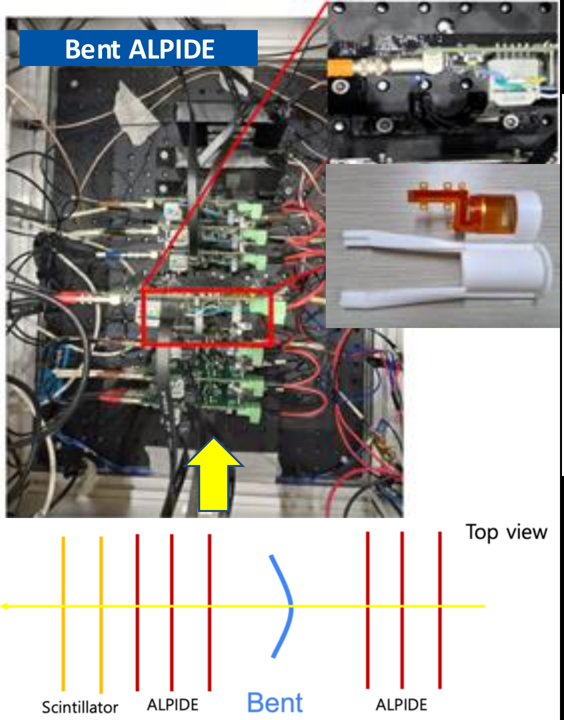


- **E**ngineering **R**un **1**
  - First MAPS for HEP using stitching
- MOSS: 14 x 259 mm, 6.72 MPixels (22.5 x 22.5, 18 x 18 um^2)
  - Conservative design
  - Different pitches
- MOST: 2.5 x 259 mm, 0.9 MPixels (18 x 18 um^2)
  - More dense design

Sensor performance study

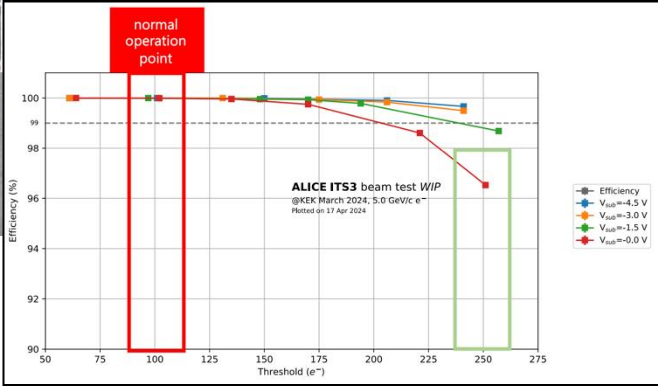
Develop a telescope and perform a beam test (KEK PF-AR)





- Collaboration with Japanese colleagues
- Electron beam @ 3 - 5 GeV/c
- Various DUT sensors have been studied
  - Bent ALPIDE
  - APTS-SF
  - CE65v2

Efficiency of the bent sensor



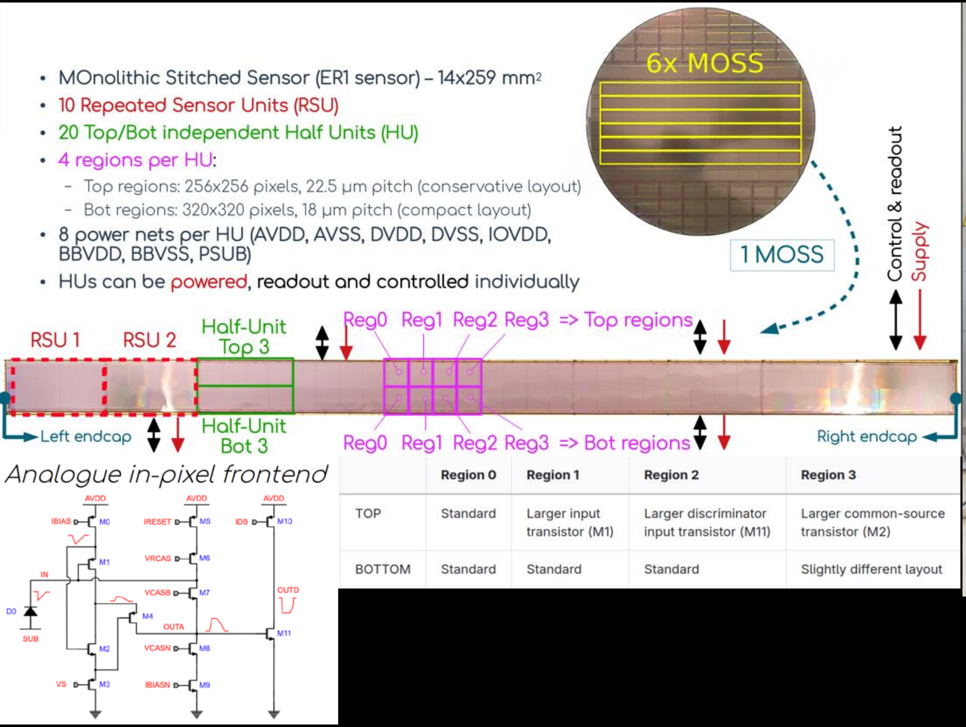
Still >99% efficiency after bending

Consistent results with the results from the ALICE ITS3 team

The paper is under preparation

Sensor performance study

Participation in babyMOSS lab test and beam test (CERN PS)
KoALICE group will produce a new telescope with babyMOSS
(beam test at KEK PF-AR in early next year)

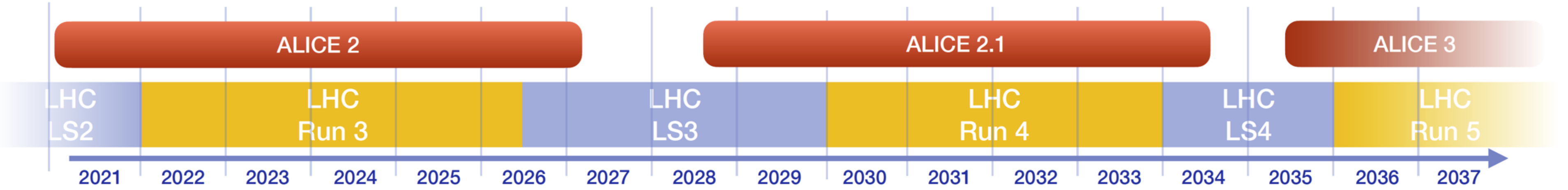


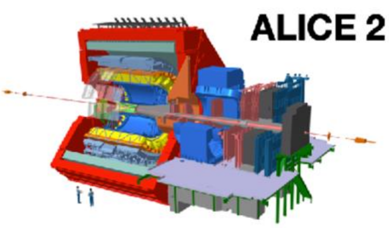
- MOnolithic Stitched Sensor (ER1 sensor) – 14x259 mm^2
- 10 Repeated Sensor Units (RSU)
- 20 Top/Bot independent Half Units (HU)
- 4 regions per HU:
  - Top regions: 256x256 pixels, 22.5 µm pitch (conservative layout)
  - Bot regions: 320x320 pixels, 18 µm pitch (compact layout)
- 8 power nets per HU (AVDD, AVSS, DVDD, DVSS, IOVDD, BBVDD, BBVSS, PSUB)
- HUs can be powered, readout and controlled individually

Analogue in-pixel frontend

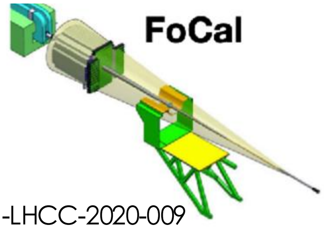
	Region 0	Region 1	Region 2	Region 3
TOP	Standard	Larger input transistor (M1)	Larger discriminator input transistor (M11)	Larger common-source transistor (M2)
BOTTOM	Standard	Standard	Standard	Slightly different layout

ALICE in the future



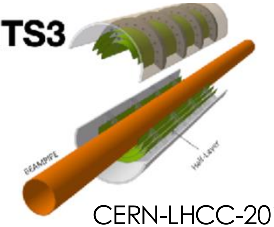


ALICE 2



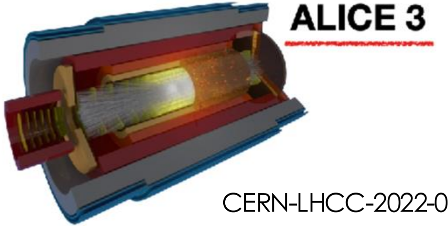
FoCal

CERN-LHCC-2020-009



ITS3

CERN-LHCC-2019-018



ALICE 3

CERN-LHCC-2022-009

- **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 3
Letter of intent

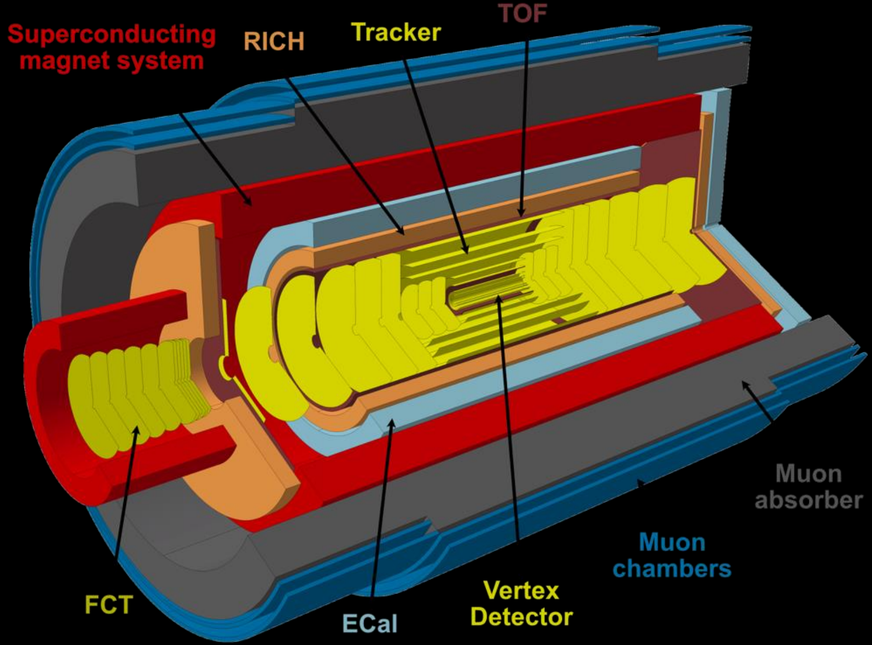
A next-generation heavy-ion experiment at the LHC

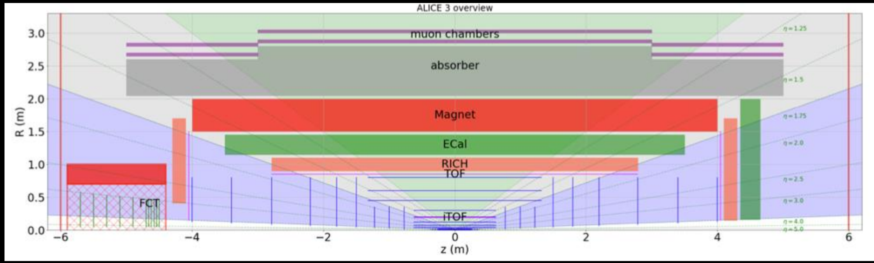
VERSION 2

arXiv:2211.02491

ALICE 3: Detector Overview

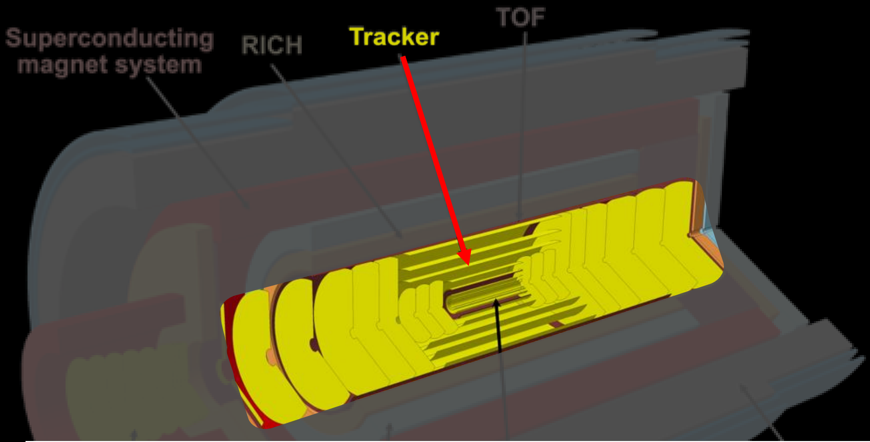
- Compact and large acceptance
  - $|\eta|<4$ and $p_T>0.02$ GeV/c
- Superconducting magnet system
  - Maximum field: B=2 T
- All silicon-based large acceptance tracker
  - ~10% X_0 overall material budget
  - ~10 μm pointing resolution at p_T~200 MeV/c
- Particle identification in a wide p_T and η range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

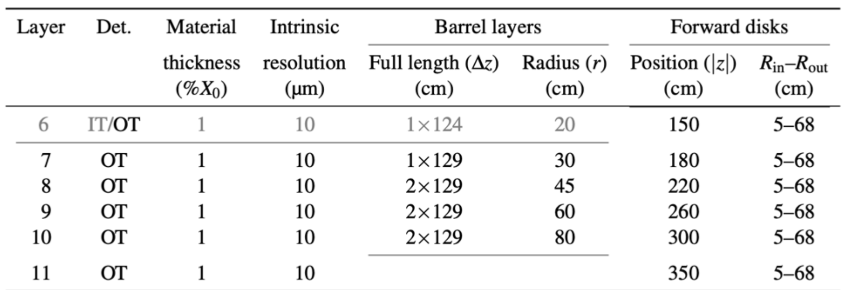




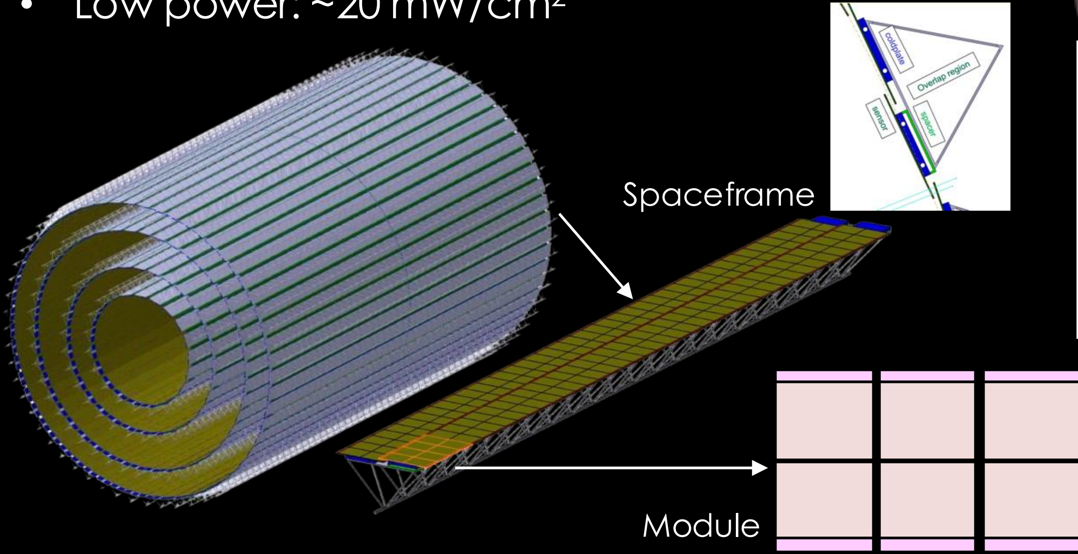
ALICE 3: Outer Tracker

- 8 layers and 9 disks based on MAPS
  - Total of ~60m^2 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/cm^2





Layer	Det.	Material thickness (%X_0)	Intrinsic resolution (µm)	Barrel layers		Forward disks	
				Full length (Δz) (cm)	Radius (r) (cm)	Position ($\lvert z\rvert$) (cm)	R_{in}–R_{out} (cm)
6	IT/OT	1	10	1×124	20	150	5–68
7	OT	1	10	1×129	30	180	5–68
8	OT	1	10	2×129	45	220	5–68
9	OT	1	10	2×129	60	260	5–68
10	OT	1	10	2×129	80	300	5–68
11	OT	1	10			350	5–68



Sensor: 3.2 × 2.5 cm^2

Path to the module after sensor fabrication

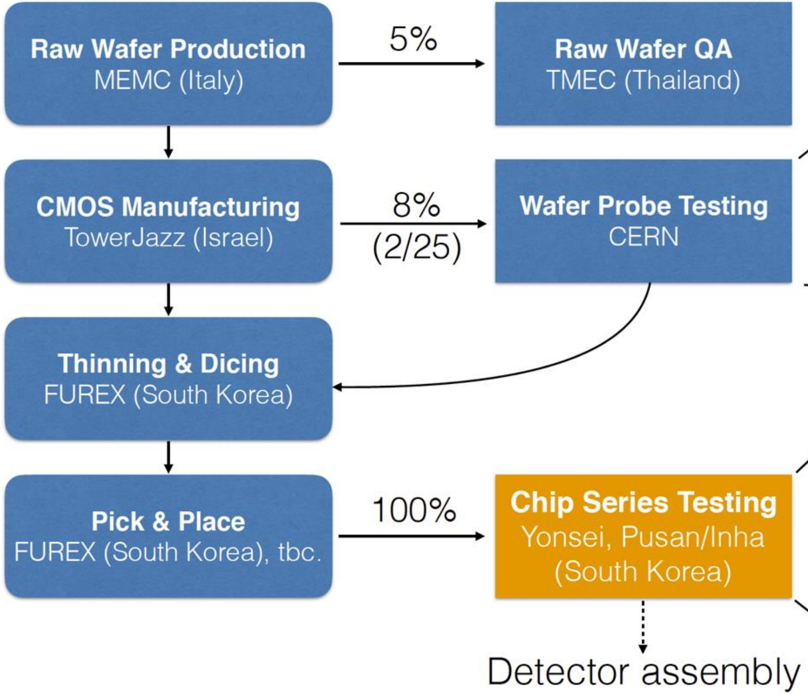
Sensor test procedure for ITS2

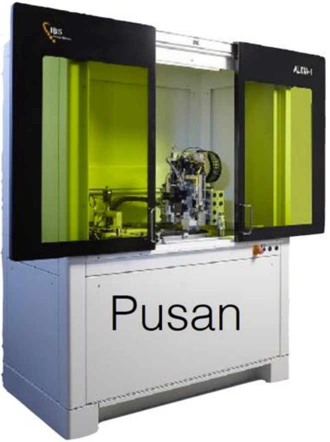
for ALICE 3 OT

1,500 raw wafers

1,200 CMOS wafers
1,920 CMOS wafers

55,000 sensors
109,200 sensors



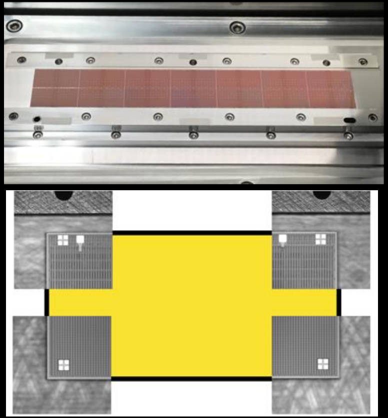


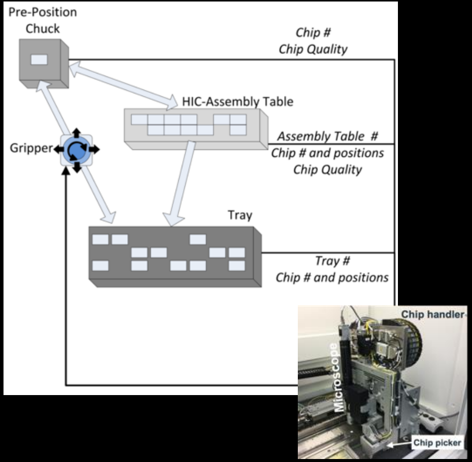
Chip-level or wafer-level test
Under discussion with a wafer probing company in Korea for a test run

Path to the module after sensor fabrication

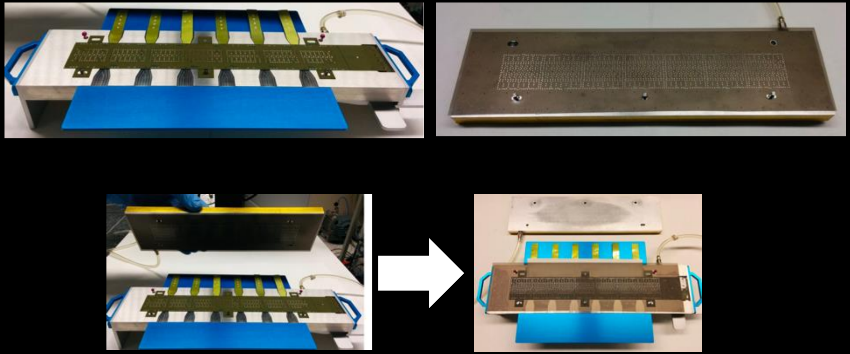
Module assembly procedure for ITS2 OB
2600 modules for ~2 years in 5 sites

1) Chips positioned on the HIC table



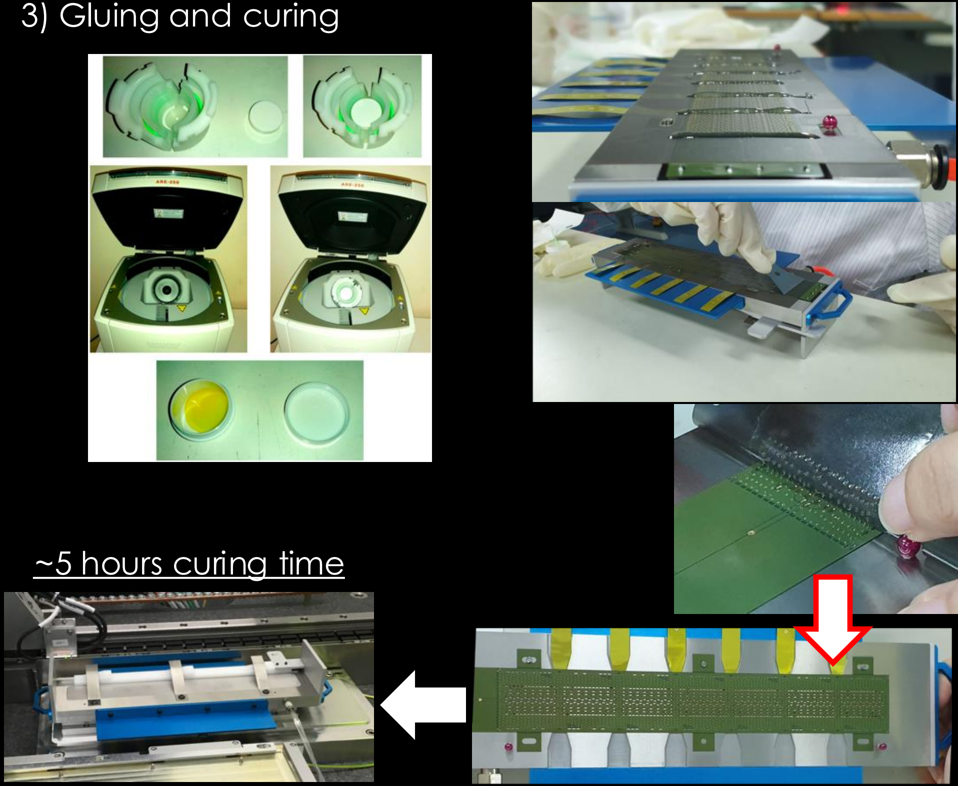


2) Glue mask on FPC



ALICE 3 OT:
5620 for barrel and 2688 for disks
~10000 modules considering yield and spares

3) Gluing and curing



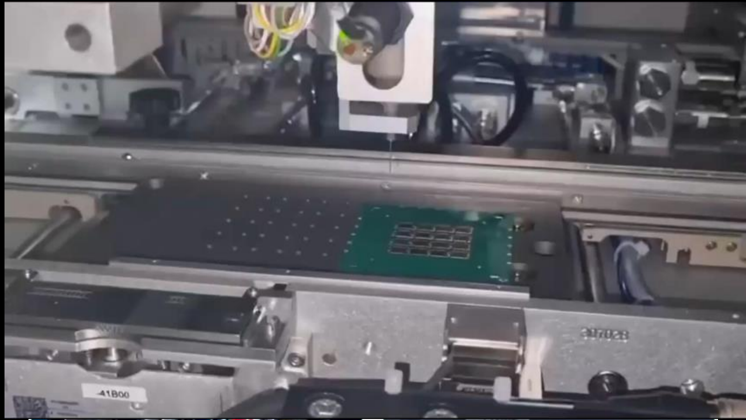
~5 hours curing time

Module assembly for ALICE 3 OT

- **Automatization and industrialization of module assembly**
  - Collaboration with MEMSPACK using a multi-purpose machine die bonder

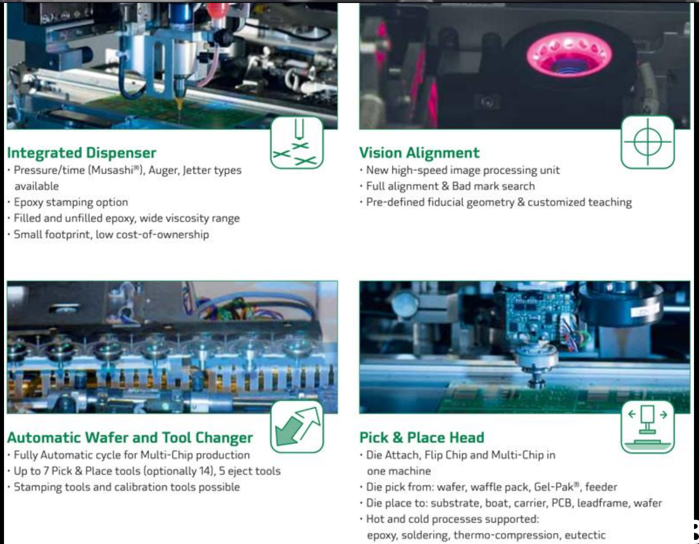
Datacon 2200 evo+

MRSI



Visit from Japan

Visit from Germany



Integrated Dispenser
- Pressure/time (Musashi®), Auger, Jetter types available
- Epoxy stamping option
- Filled and unfilled epoxy, wide viscosity range
- Small footprint, low cost-of-ownership

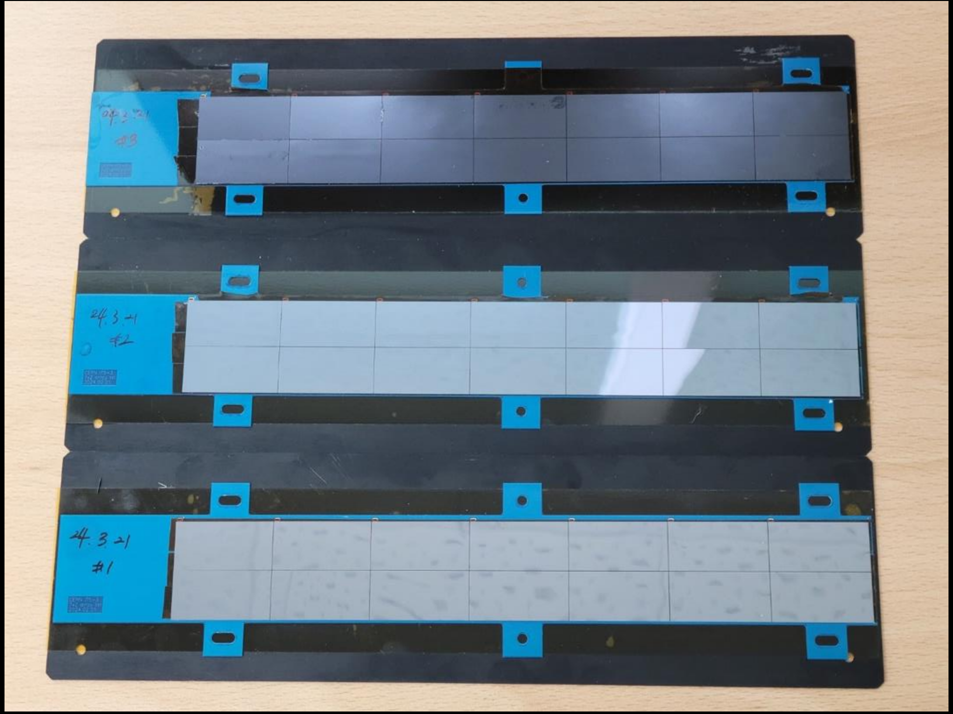
Vision Alignment
- New high-speed image processing unit
- Full alignment & Bad mark search
- Pre-defined fiducial geometry & customized teaching

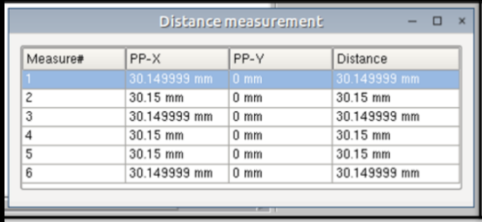
Automatic Wafer and Tool Changer
- Fully Automatic cycle for Multi-Chip production
- Up to 7 Pick & Place tools (optionally 14), 5 eject tools
- Stamping tools and calibration tools possible

Pick & Place Head
- Die Attach, Flip Chip and Multi-Chip in one machine
- Die pick from: wafer, waffle pack, Gel-Pak®, feeder
- Die place to: substrate, boat, carrier, PCB, leadframe, wafer
- Hot and cold processes supported: epoxy, soldering, thermo-compression, eutectic

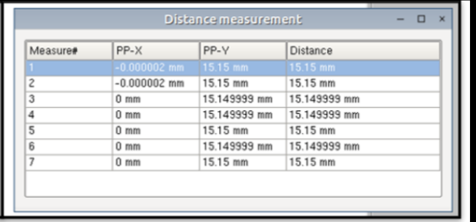
Dummy module assembly (2024 March)

- Machine validation using dummy chips and dummy boards
  - Both for ITS2 OB HIC design and ALICE 3 OT design
  - Thicker chip (50-100 µm) and board (0.3 mm) to validate the repeatability of position precision
  - Successfully produced five modules with good position precision (<u>using double-sided tape</u>)

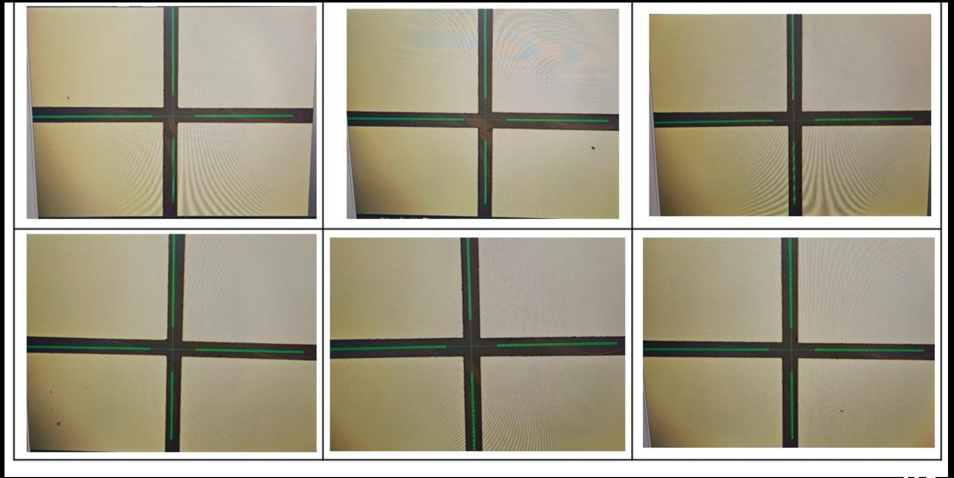



Distance measurement

Measure#	PP-X	PP-Y	Distance
1	30.149999 mm	0 mm	30.149999 mm
2	30.15 mm	0 mm	30.15 mm
3	30.149999 mm	0 mm	30.149999 mm
4	30.15 mm	0 mm	30.15 mm
5	30.15 mm	0 mm	30.15 mm
6	30.149999 mm	0 mm	30.149999 mm

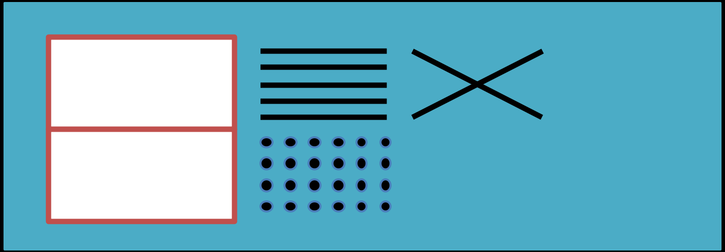

Distance measurement

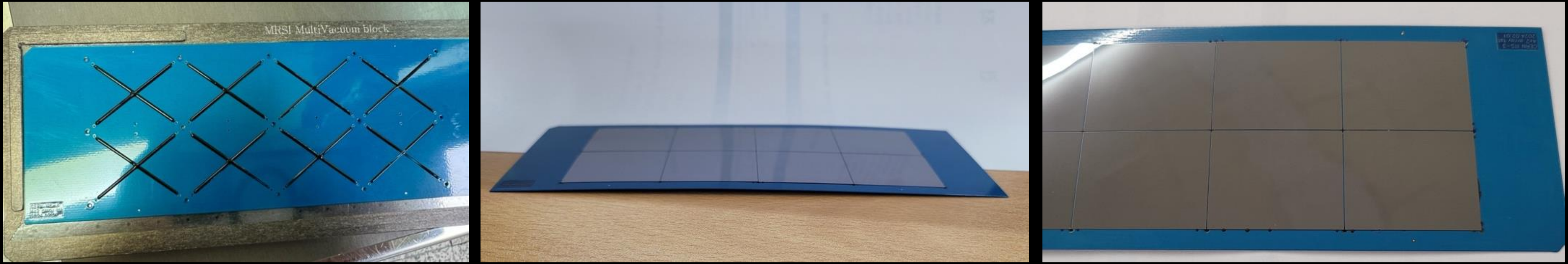
Measure#	PP-X	PP-Y	Distance
1	-0.000002 mm	15.15 mm	15.15 mm
2	-0.000002 mm	15.15 mm	15.15 mm
3	0 mm	15.149999 mm	15.149999 mm
4	0 mm	15.149999 mm	15.149999 mm
5	0 mm	15.15 mm	15.15 mm
6	0 mm	15.149999 mm	15.149999 mm
7	0 mm	15.15 mm	15.15 mm



Dummy module assembly (2024 June)

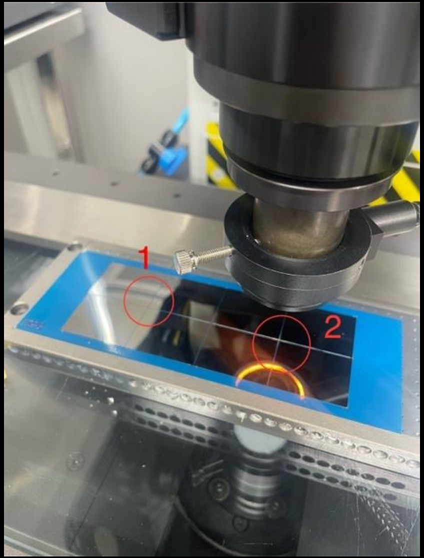
- Die bond with heat cure epoxy
  - Epoxy generally used by MEMSPACK
  - Heat cure condition: 100 ℃, 30 minutes (outside from the die bonder machine)
  - Dispense epoxy on the PCB (a few lines) and place chips
  - 0.3 mm thick chip (will reduce gradually)
  - Various dispensing patterns to minimize the position variation

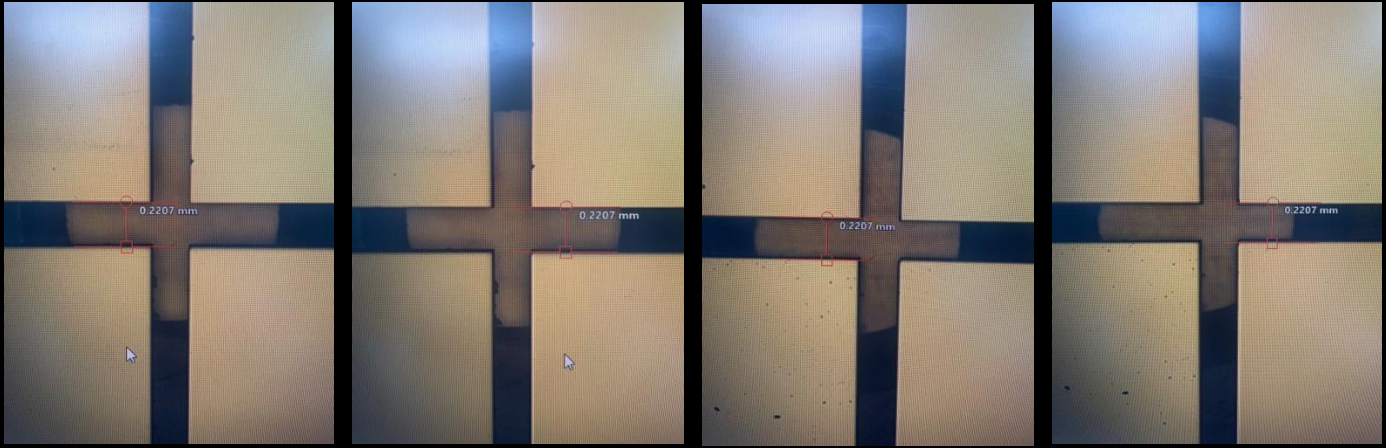




Dummy module assembly (2024 June)

- Die bond with heat cure epoxy
  - Epoxy generally used by MEMSPACK
  - Heat cure condition: 100 ℃, 30 minutes (outside from the die bonder machine)
  - Dispense epoxy on the PCB (a few lines) and place chips
  - 0.3 mm thick chip (will reduce gradually)
  - Various dispensing patterns to minimize the position variation
  - Reasonable position precision but needs to be optimized

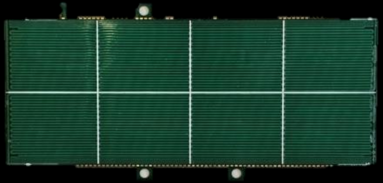


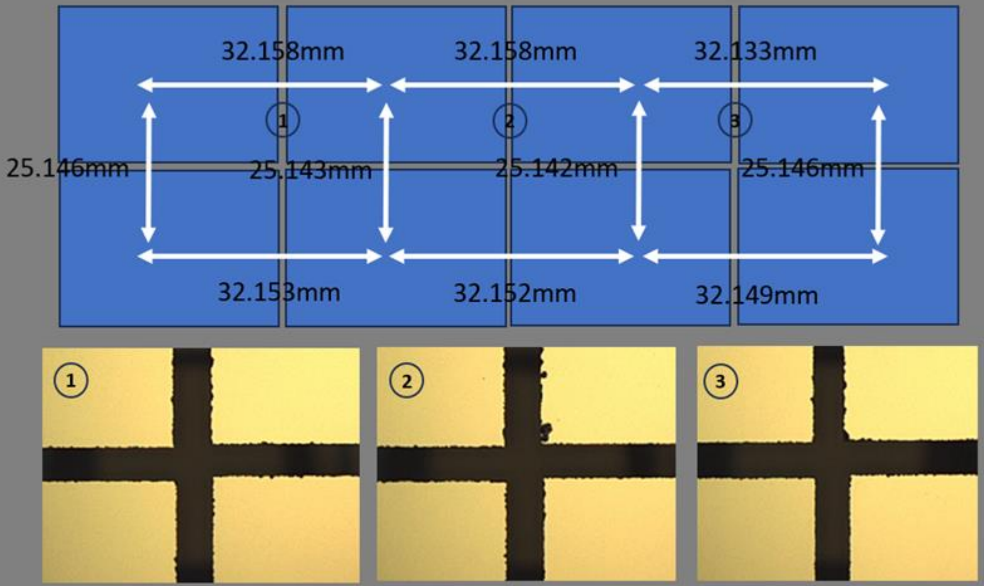


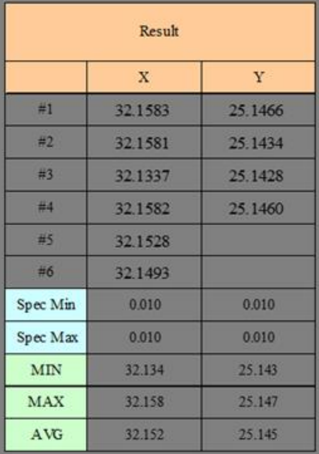
Dummy module assembly (2024 October)

- Die bond with heat cure epoxy
  - Epoxy generally used by MEMSPACK
  - Heat cure condition: 100 °C, 30 minutes (outside from the die bonder machine)
  - Dispense epoxy on the PCB (a few lines) and place chips
  - 0.3 mm thick chip (will reduce gradually)
  - **Confirmed a good position precision**

- To do
  - Thinner chip
  - Flexible PCB
  - Wire bonding
  - Epoxy (Araldite 2011)



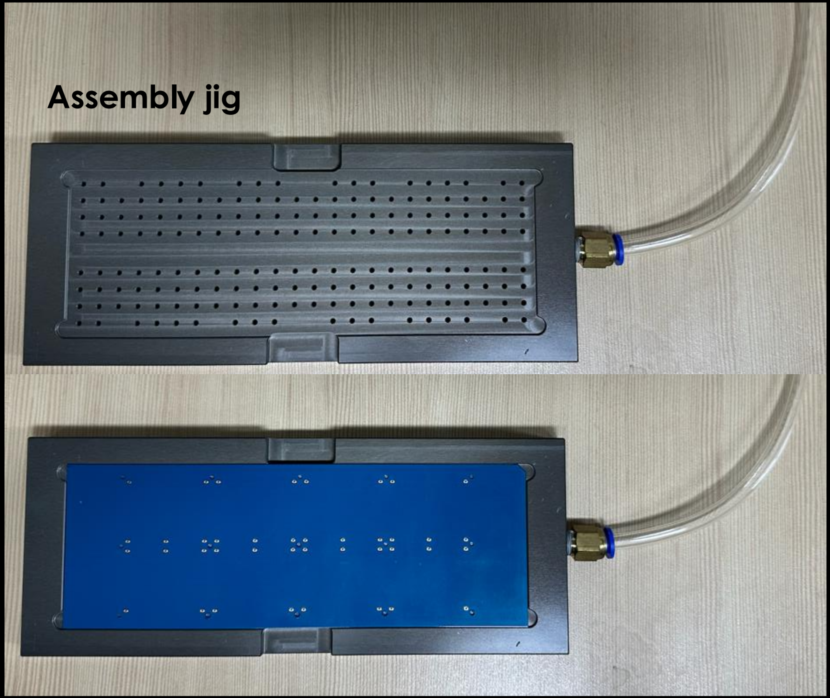


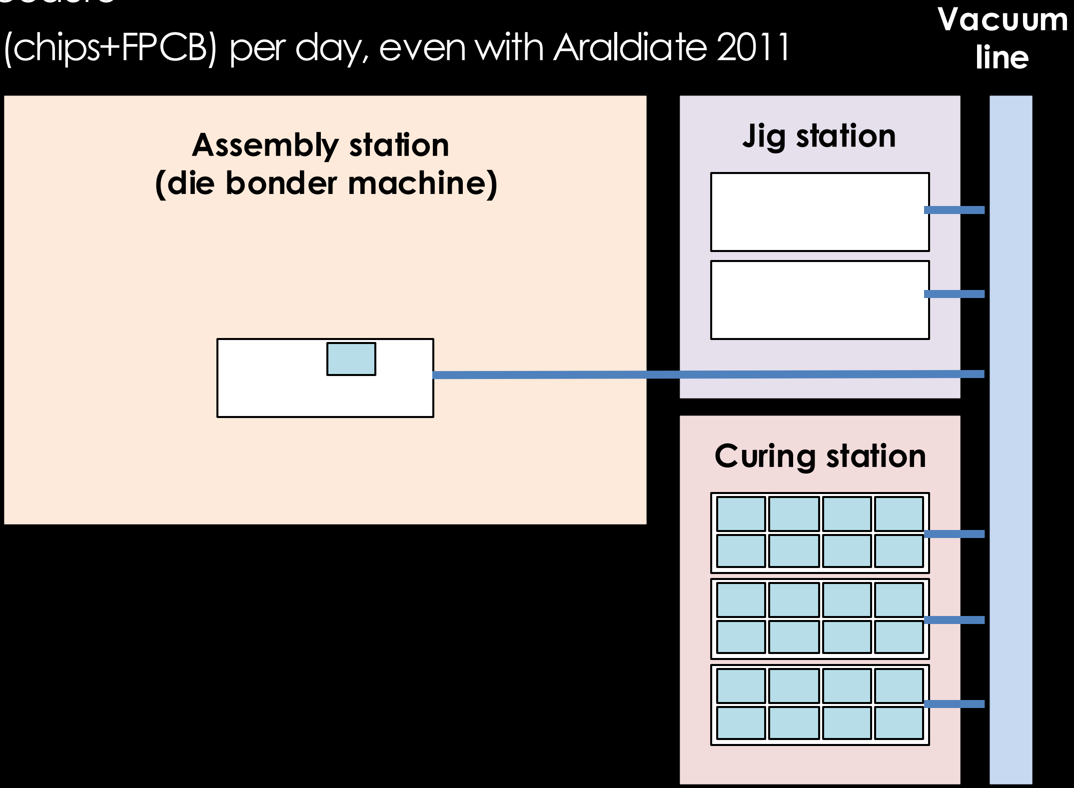


	Result	
	X	Y
#1	32.1583	25.1466
#2	32.1581	25.1434
#3	32.1337	25.1428
#4	32.1582	25.1460
#5	32.1528	
#6	32.1493	
Spec Min	0.010	0.010
Spec Max	0.010	0.010
MIN	32.134	25.143
MAX	32.158	25.147
AVG	32.152	25.145

Concept of mass production procedure

- Uses several assembly jigs to run the assembly station continuously
  - FPCB is held with a vacuum during curing
  - Plan to build the system and verify the procedure
  - Expected production rate: 20-30 modules (chips+FPCB) per day, even with Araldiate 2011




Vacuum line

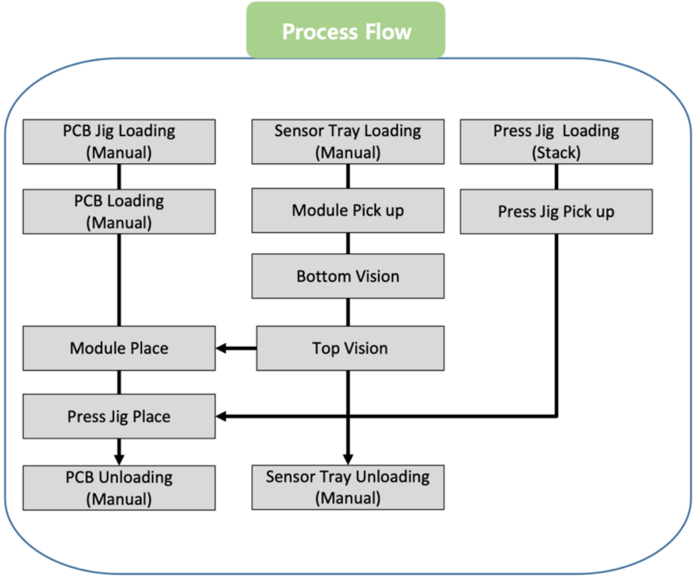
Assembly station (die bonder machine)

Jig station

Curing station

Customized module assembly machine (C-ON tech)

- Initial design for the customized machine
  - Chip handling system will provide an accurate position precision
  - Plan to produce a prototype machine in 2025

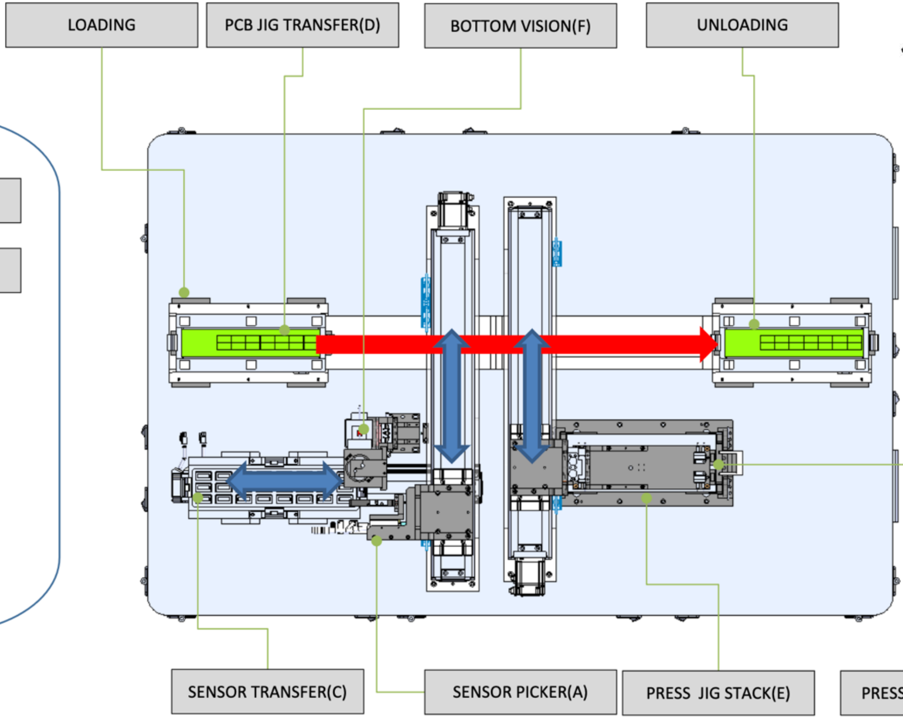


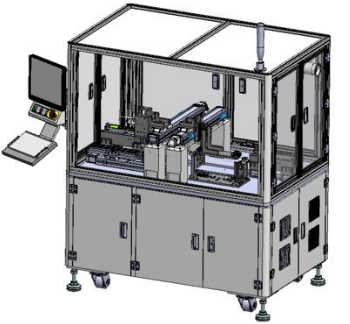
Process Flow

PCB Jig Loading (Manual)
PCB Loading (Manual)
Module Place
Press Jig Place
PCB Unloading (Manual)

Sensor Tray Loading (Manual)
Module Pick up
Bottom Vision
Top Vision
Sensor Tray Unloading (Manual)

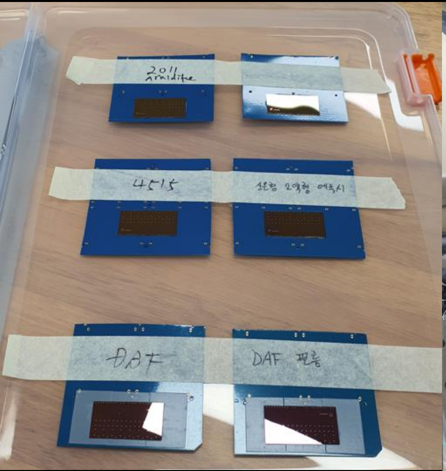
Press Jig Loading (Stack)
Press Jig Pick up

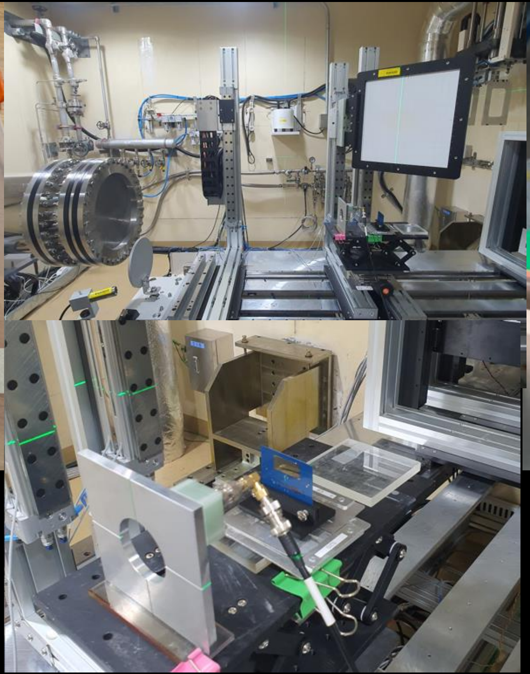


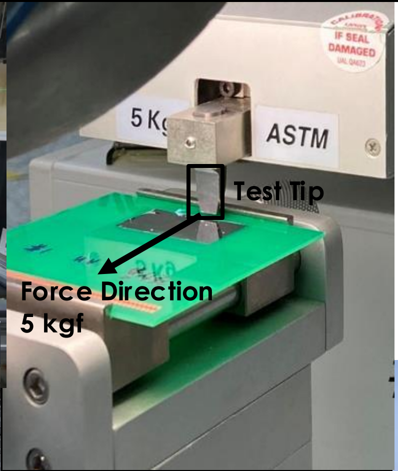


Radiation hardness test

- Proton beams (15~20 MeV) at KOMAC TR23 can be utilized for radiation hardness test of epoxies
  - High-intensity beams ($10^{10\text{-}11}$ #/cm^2 s)
  - Comparison between different epoxies, including Araldite 2011
  - First run in Oct/16-17 and second run in Dec/23-24







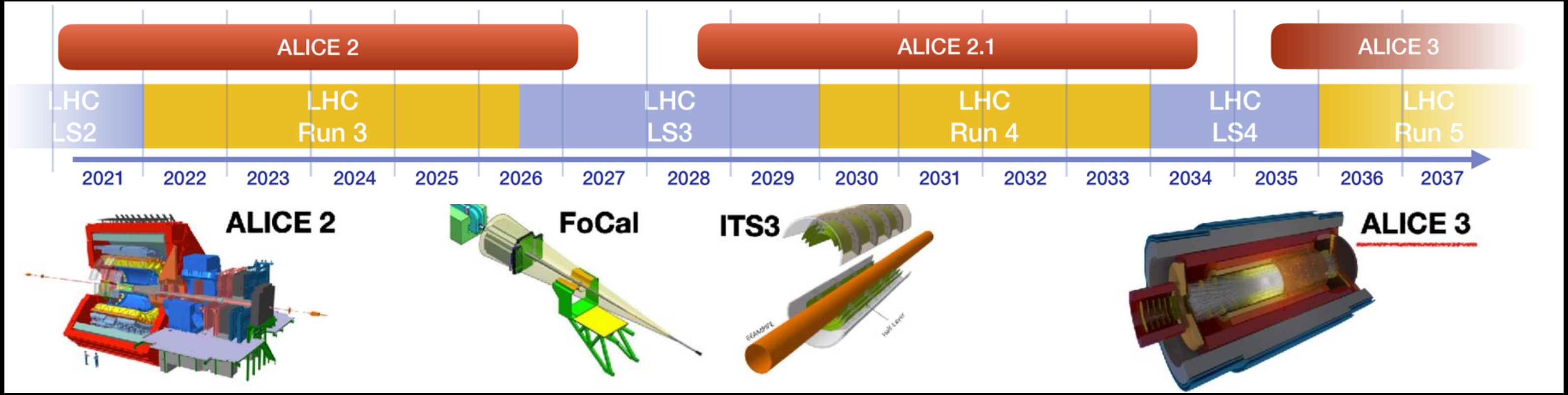
Test Tip

Force Direction
5 kgf


Automatic dispenser
E4V, PerformusX100

Summary

KEEP MOVING FORWARD



BACKUP