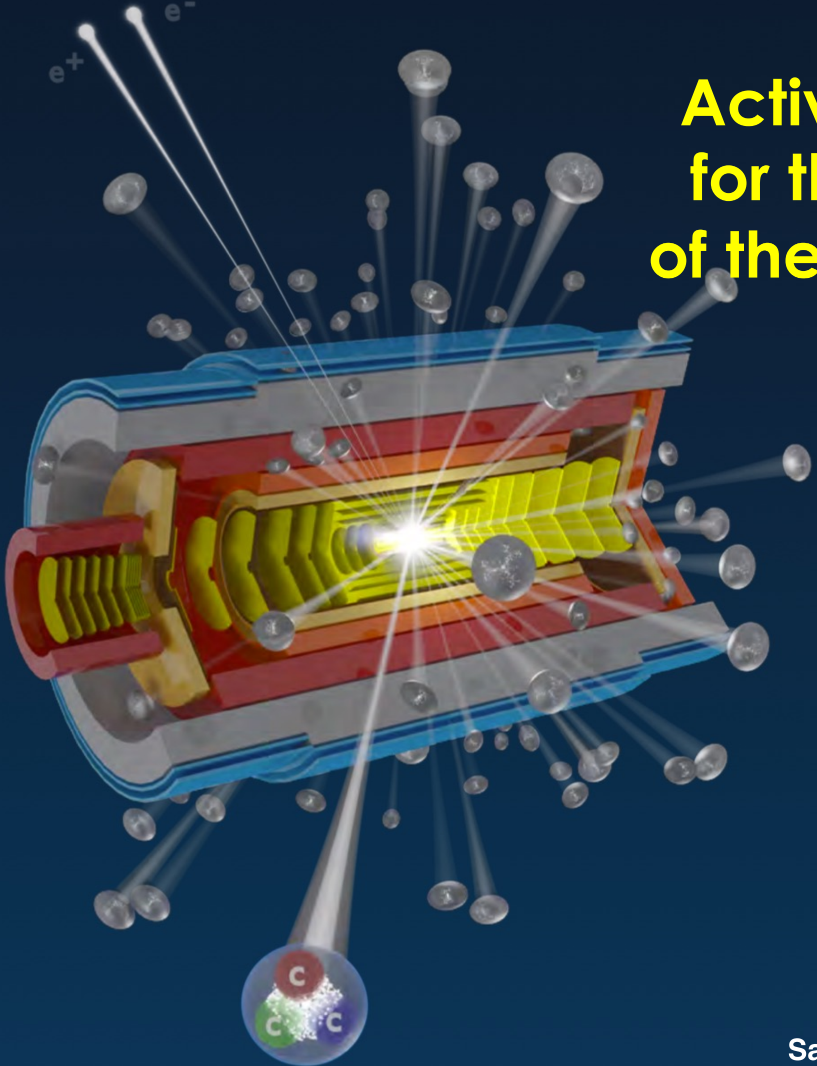


Activities from the Korea ALICE group for the development and production of the next generation of silicon tracker

Sanghoon Lim
for the ALICE Collaboration

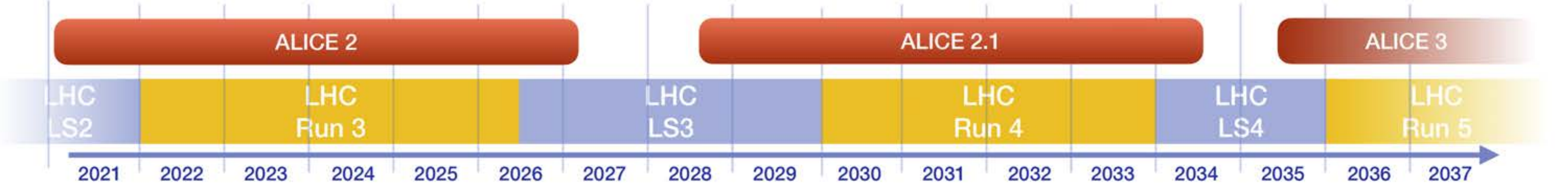
Pusan National University

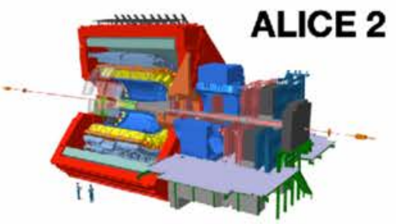
ALICE

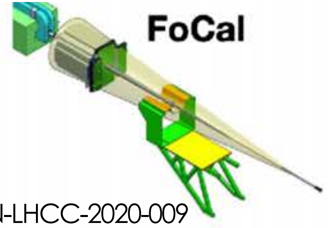
PUSAN NATIONAL UNIV.
NPL
NUCLEAR PHYSICS LAB

INPC 2025

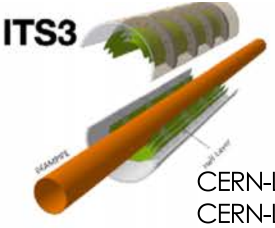
ALICE in the future



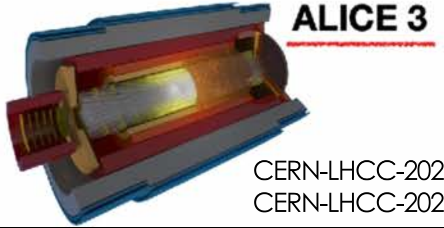




CERN-LHCC-2020-009



CERN-LHCC-2019-018
CERN-LHCC-2024-003

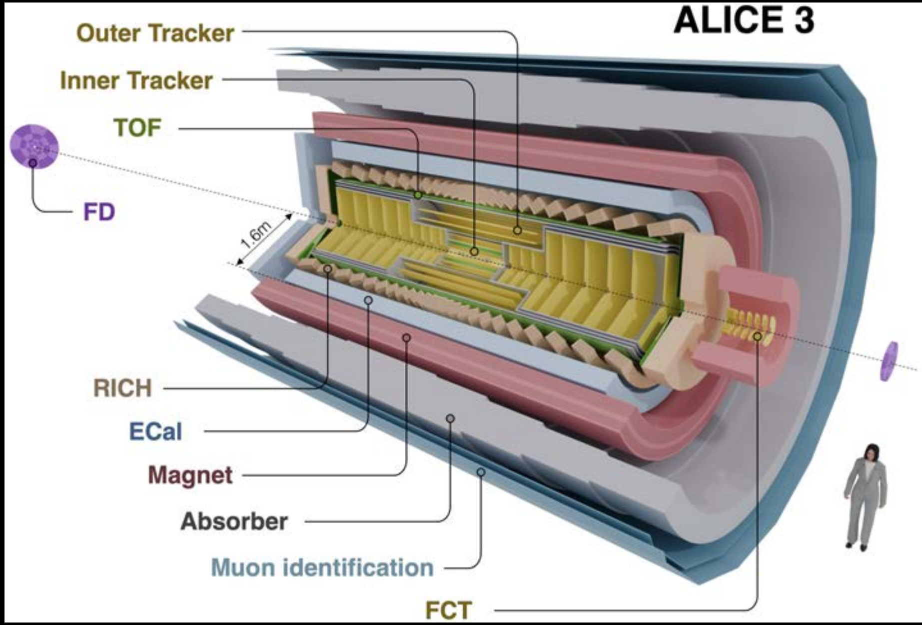


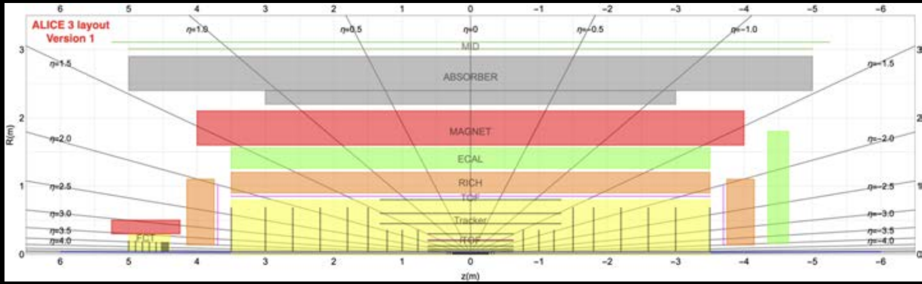
CERN-LHCC-2022-009
CERN-LHCC-2025-002

- **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

arXiv:2211.02491

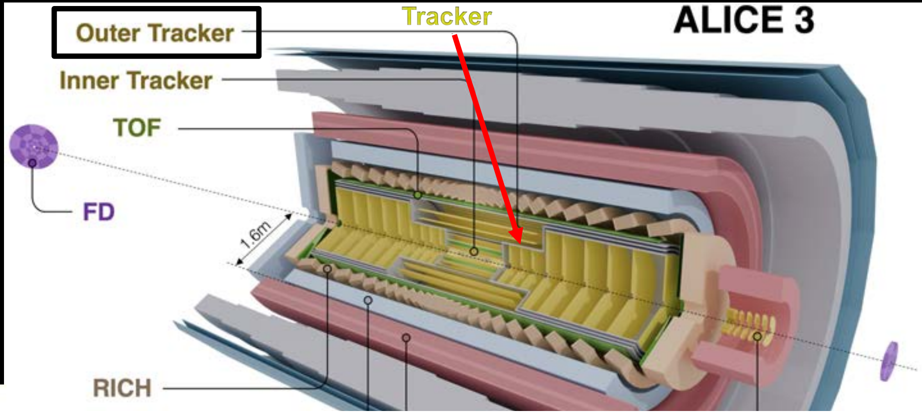
- Compact and large acceptance
  - $|\eta|<4$ and $p_T>0.02$ GeV/c
- Superconducting magnet system
  - Maximum field: B=2 T
- All silicon-based large acceptance tracker
  - ~10% X_0 overall material budget
  - ~10 μm pointing resolution at p_T~200 MeV/c
- Particle identification in a wide p_T and η range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

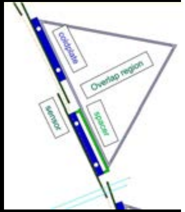




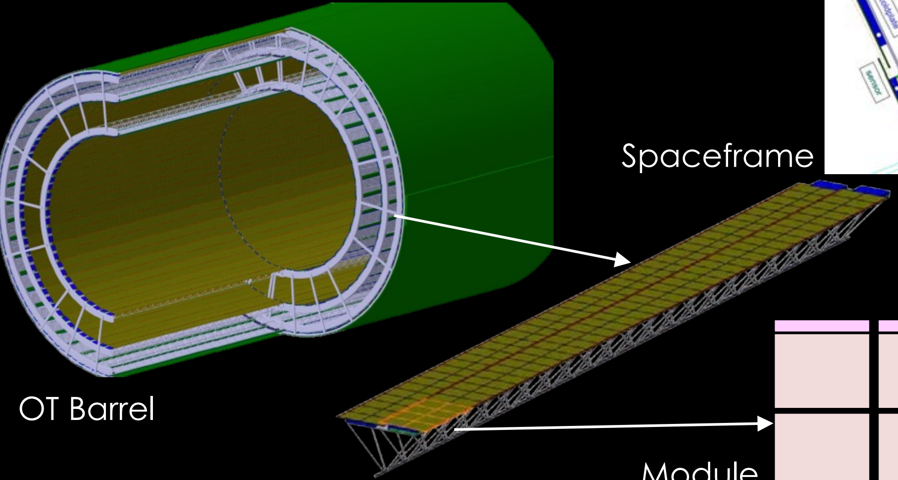
ALICE 3: Outer Tracker

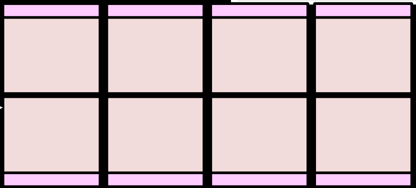
- 8 layers and 9 disks based on MAPS
  - Total of ~60m^2 of silicon
  - Compact design (R<80 cm, |z|<4 m)
- Pixel pitch of 50 μm for 10 μm intrinsic resolution
- 1% X_0 per layer
- Low power: ~20 mW/cm^2





Layer	Det.	Material thickness ($\%X_0$)	Intrinsic resolution (μm)	Barrel layers: Full length (Δz) (cm)	Barrel layers: Radius (r) (cm)	Forward disks: Position ($\|z\|$) (cm)	Forward disks: 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

ALICE 3: Outer Tracker

WP1 - Simulation and performance

WP2 - Sensor design

WP3 - Sensor post-processing & mass production Coordinator: MinJung Kweon

WP4 - Characterisation

WP5 - VD sensor integration

WP6 - Module design and production Coordinator: Sanghoon Lim

WP7 - Mechanics & Cooling

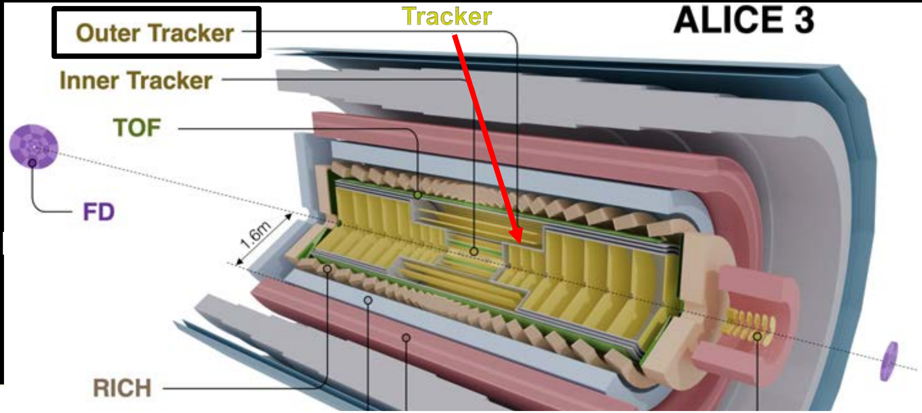
WP8 - Integration, Installation & cross-WP, cross-project actions

WP9 - Readout, Powering, Slow Control

WP10 - Calibration & Quality Assurance of detector data

Involved

Intersted



Layer	Det.	Material thickness (%X_0)	Intrinsic resolution (μm)	Barrel layers Full length (Δz) (cm)	Barrel layers Radius (r) (cm)	Forward disks Position (|z|) (cm)	Forward disks 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
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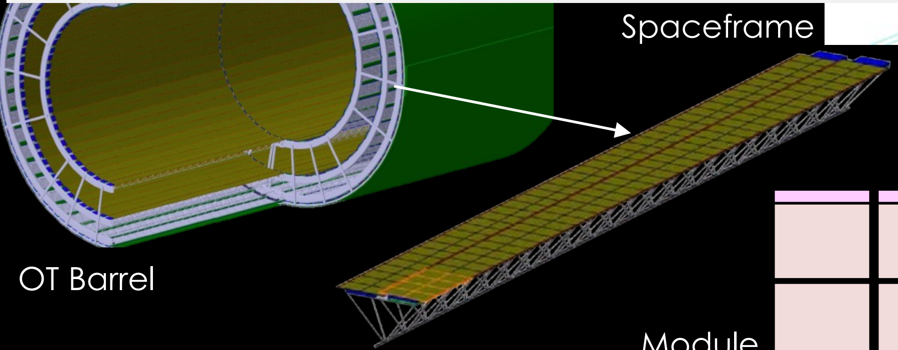
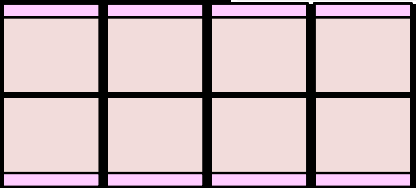
11	OT	1	10			350	5–68



Spaceframe

OT Barrel



Module

Sensor: 3.2 × 2.5 cm^2

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

Raw Wafer Production
MEMC (Italy)

5% → **Raw Wafer QA**
TMEC (Thailand)

CMOS Manufacturing
TowerJazz (Israel)

8% (2/25) → **Wafer Probe Testing**
CERN

Thinning & Dicing
FUREX (South Korea)

Pick & Place
FUREX (South Korea), tbc.

100% → **Chip Series Testing**
Yonsei, Pusan/Inha
(South Korea)

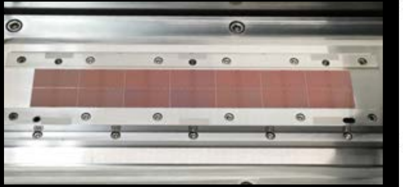
Detector assembly

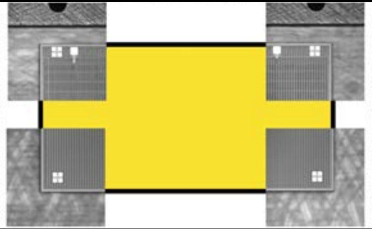
ALICE 3 OT is a factor of 6 wider area than the ITS2 (~10 m²)

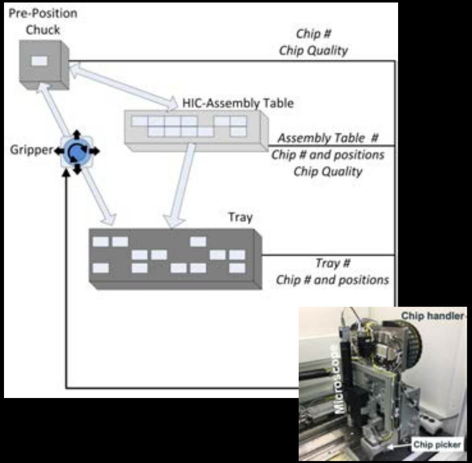
Path to the module after sensor fabrication

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

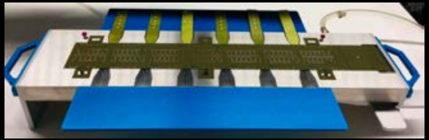
1) Chips positioned on the HIC table

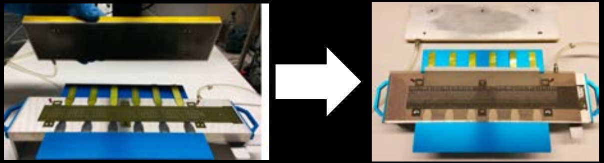






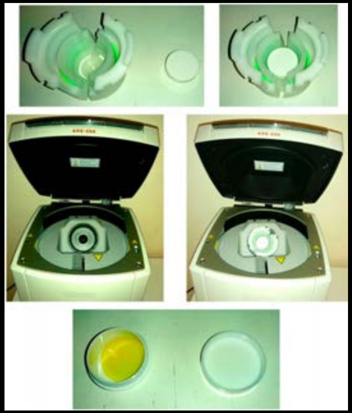
2) Glue mask on FPC

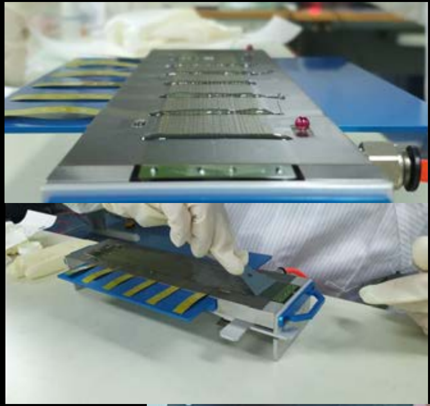




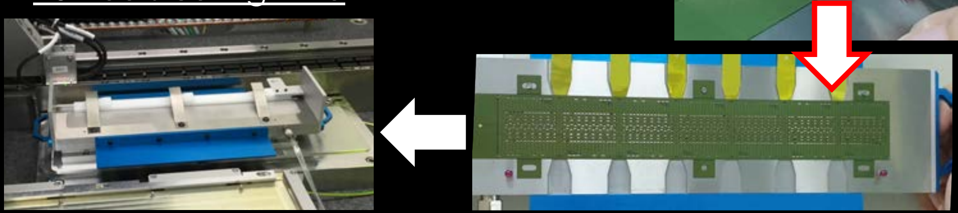
ALICE 3 OT:
5620 for barrel and 2688 for disks
~10000 modules considering yield and spares

3) Gluing and curing

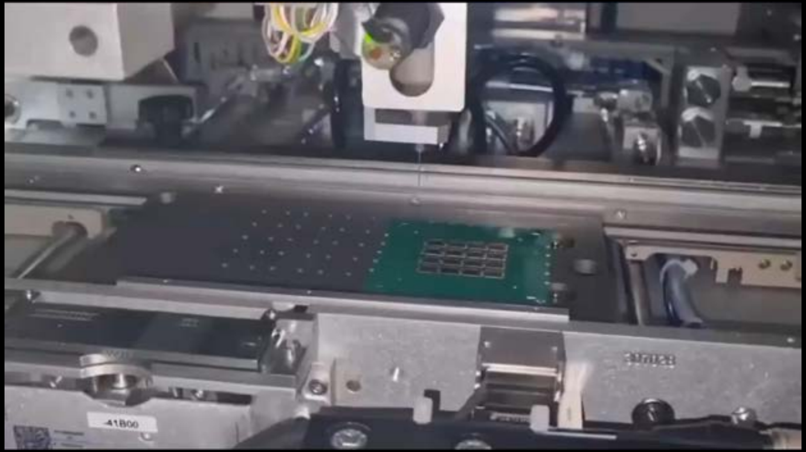




<u>~5 hours curing time</u>

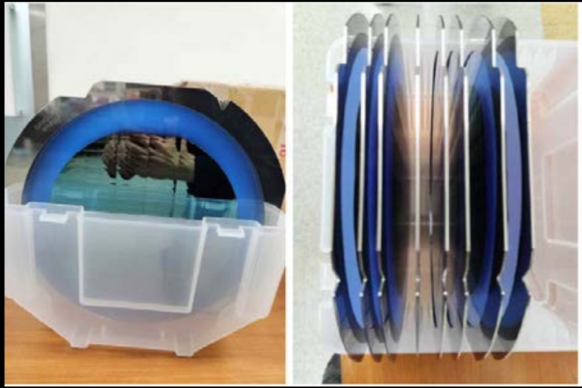


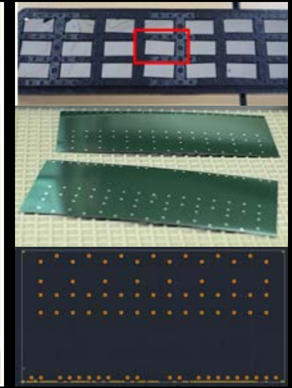
- Automation and industrialization of module assembly
  - Collaboration with MEMSPACK using a multi-purpose machine die bonder

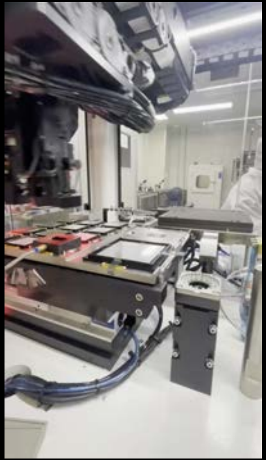


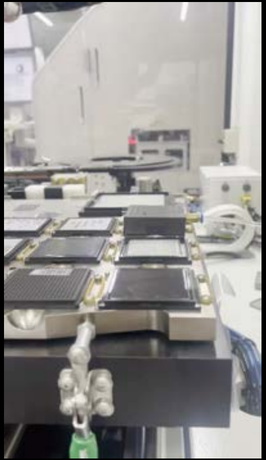
Dummy module assembly

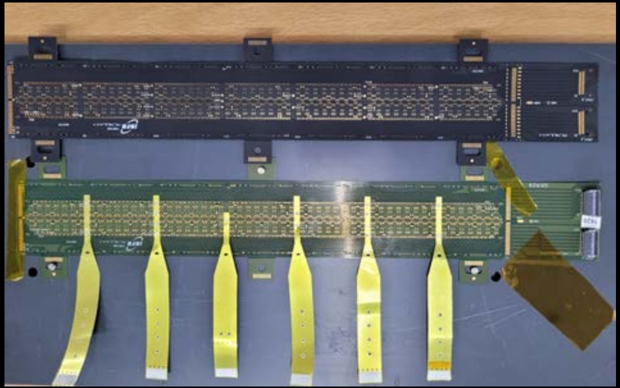
- Machine validation using dummy chips and dummy boards
  - Both for the ITS2 OB HIC design and the ALICE 3 OT design



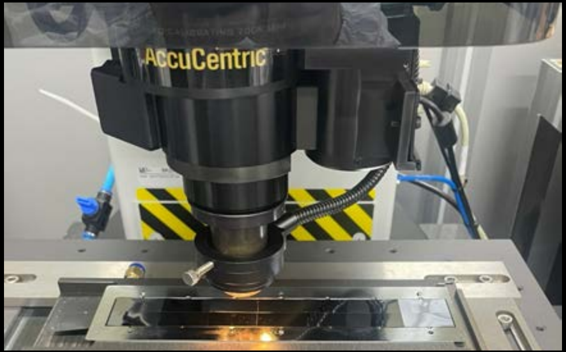






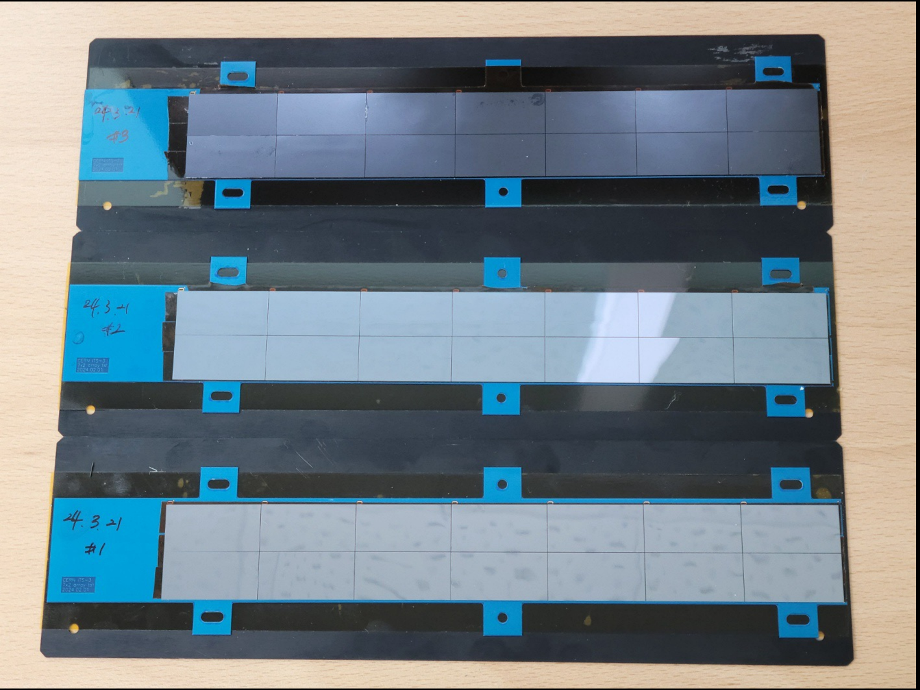


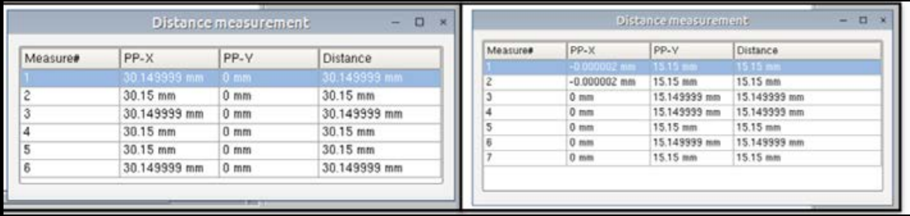
50 µm chip, flexible PCB



Dummy module assembly

- Machine validation using dummy chips and dummy boards
  - Both for the ITS2 OB HIC design and the 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>)



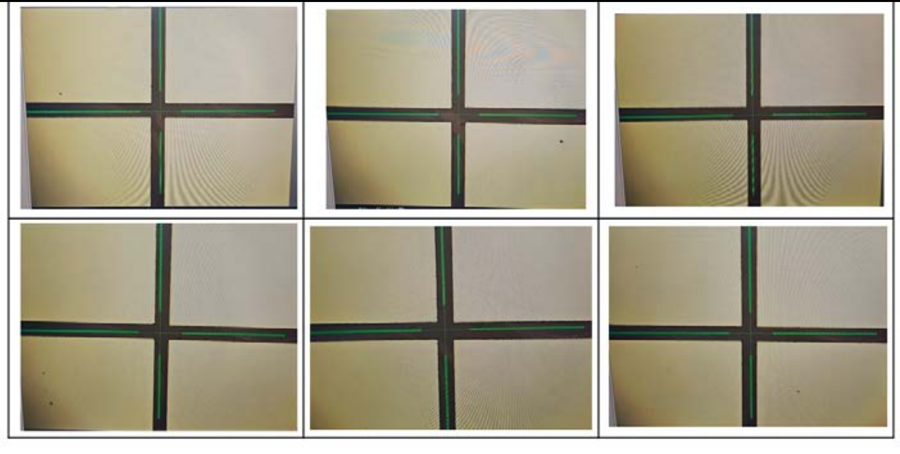


Distance measurement

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

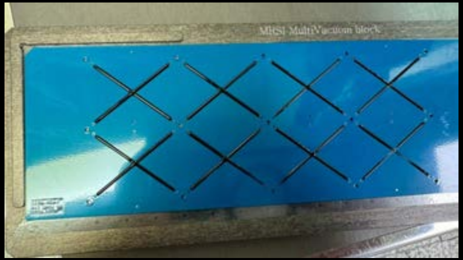
Distance measurement

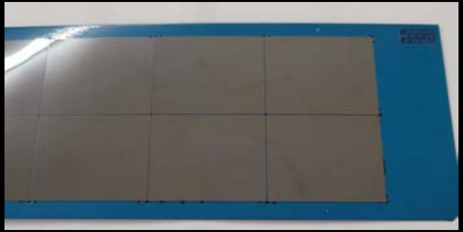
Measure#	PP-X	PP-Y	Distance
1	-0.000002 mm	15.15 mm	15.15 mm
2	-0.000002 mm	15.15 mm	15.15 mm
3	0 mm	15.149999 mm	15.149999 mm
4	0 mm	15.149999 mm	15.149999 mm
5	0 mm	15.15 mm	15.15 mm
6	0 mm	15.149999 mm	15.149999 mm
7	0 mm	15.15 mm	15.15 mm

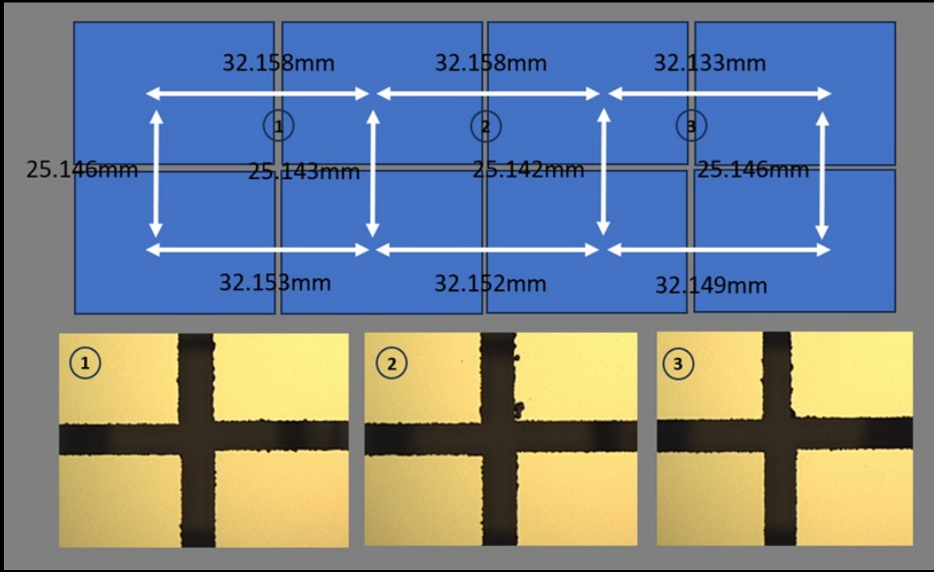


Dummy module assembly

- Die bond with heat-cure epoxy
  - Generally used in the industry
  - Heat cure condition: 100 ℃, 30 minutes (outside 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



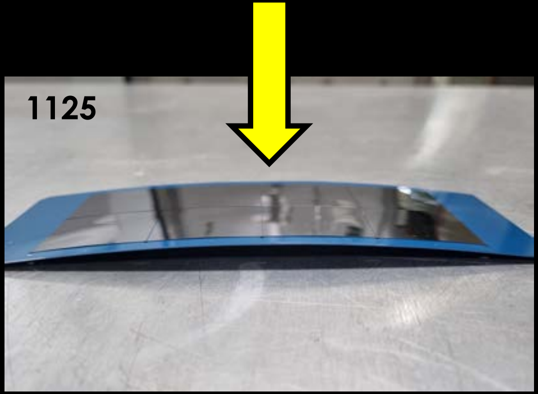




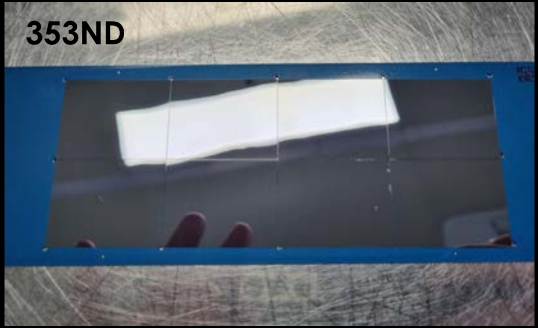
Result		
	X	Y
#1	32.1583	25.1466
#2	32.1581	25.1434
#3	32.1337	25.1428
#4	32.1582	25.1460
#5	32.1528	
#6	32.1493	
Spec Min	0.010	0.010
Spec Max	0.010	0.010
MIN	32.134	25.143
MAX	32.158	25.147
AVG	32.152	25.145

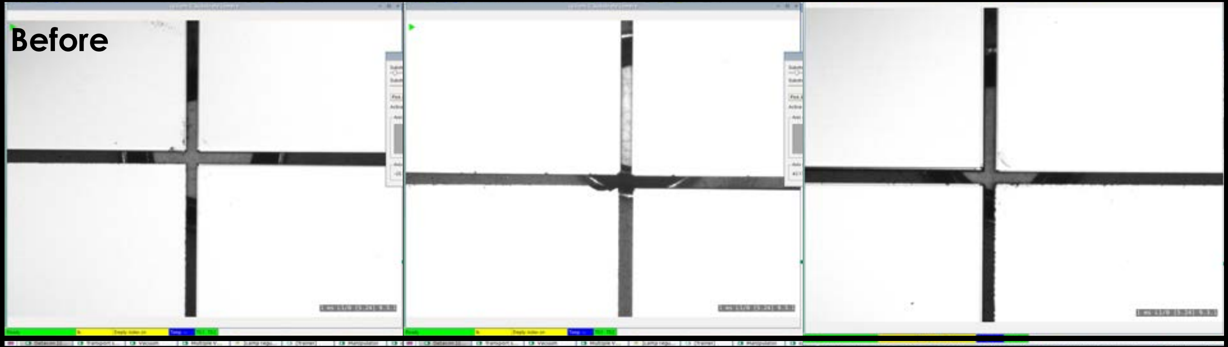
Dummy module assembly

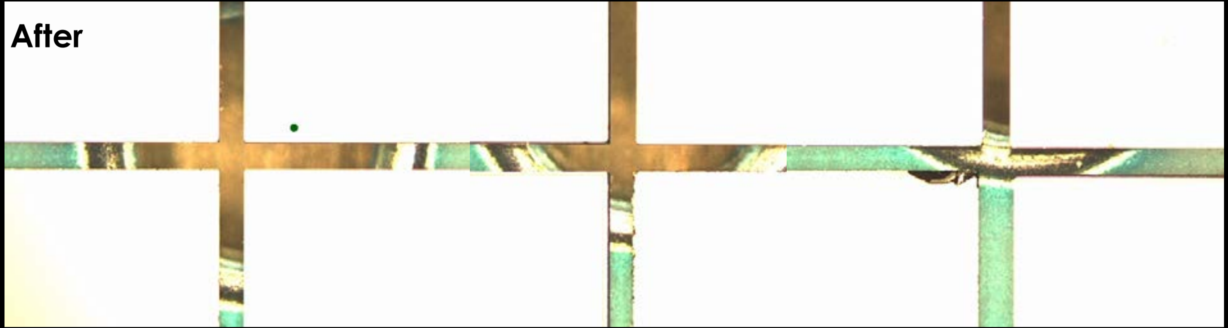
- Die bond with heat-cure epoxy
  - Generally used in the industry
  - Heat cure condition: 100 °C, 30 minutes (outside the die bonder machine)
  - Dispense epoxy on the PCB (a few lines) and place chips
  - 0.3 mm thick chip (will reduce gradually)
  - Confirmed a good position precision
  - However, bending is observed after curing



- Die bond with room temperature cure epoxy
  - Two-component epoxy (353ND), easier to handle than Araldite 2011
  - 100 μm-thick chip
  - **Confirmed a good position precision after curing**

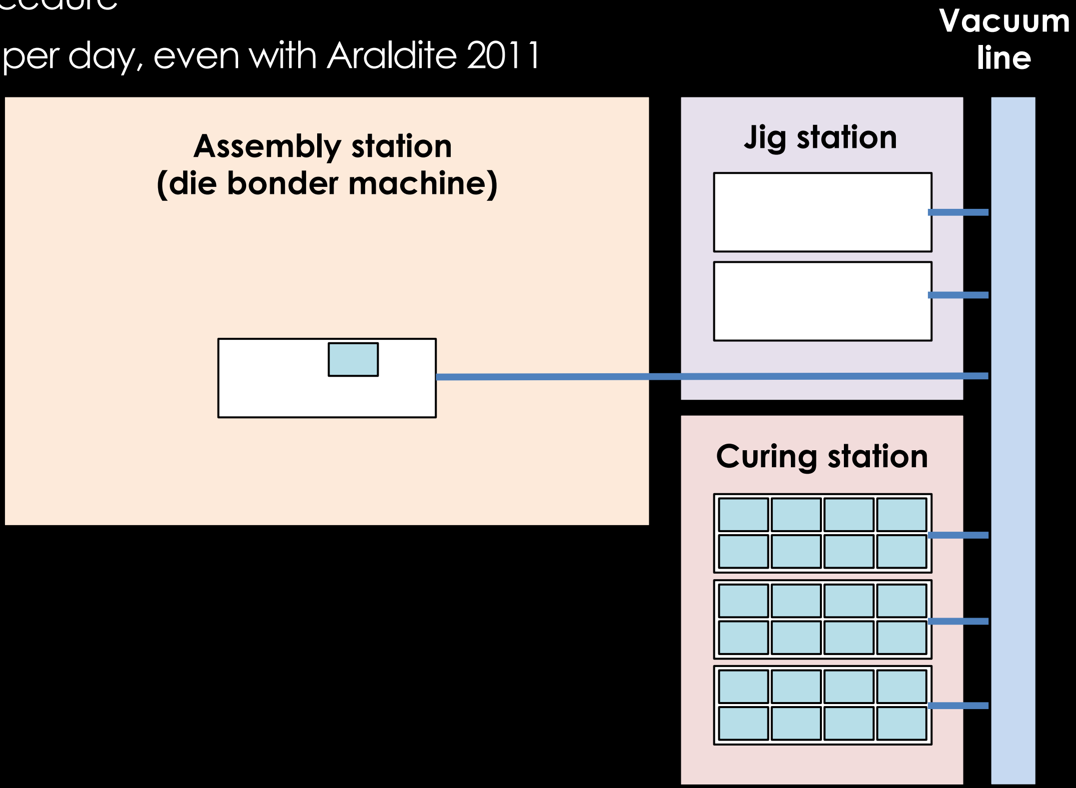






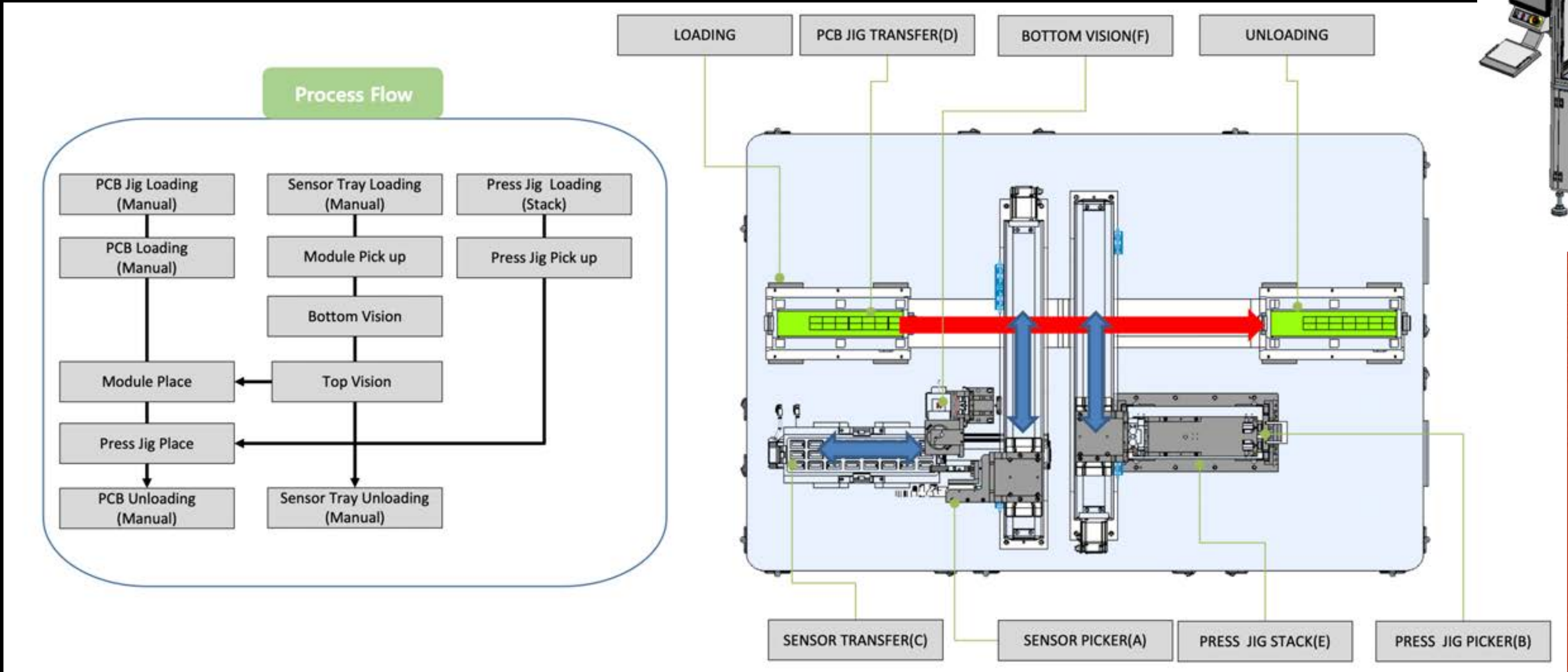
Concept of mass production procedure

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



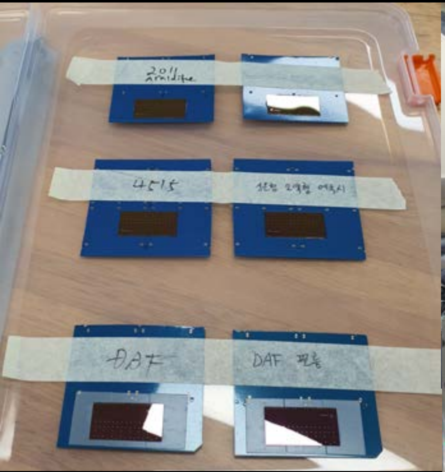
Customized module assembly machine

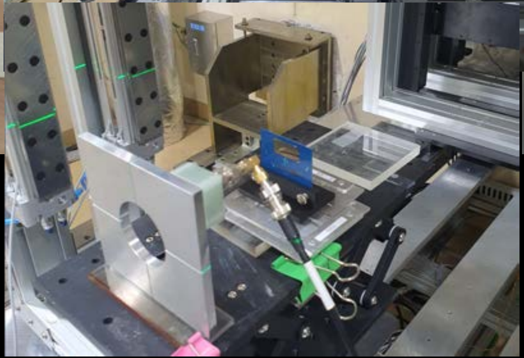
- Customized assembly machine for optimization of the assembly procedure
  - The chip handling system will provide an accurate position precision
  - Initial design with C-ON Tech produced a chip test machine for the ITS2 project

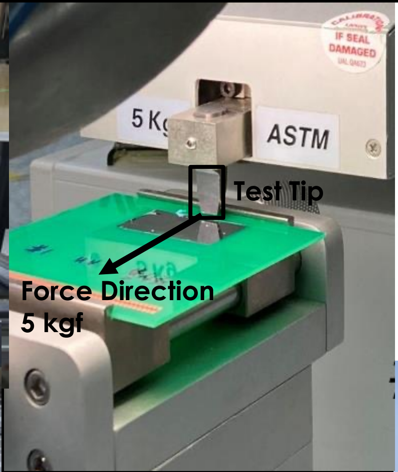


Radiation hardness test

- Proton beams (15~20 MeV) at KOMAC can be utilized for radiation hardness tests of epoxies
  - High-intensity beams ($10^{10\text{-}11}$ #/cm^2 s)
  - Evaluate different epoxies to select radiation-hard and easy-to-handle epoxies.
  - Requirement: 2.5×10^{12} NIEL (1 MeV n_{eq}/cm^2) and 0.1 Mrad TID for the innermost OT layer (r=30 cm)



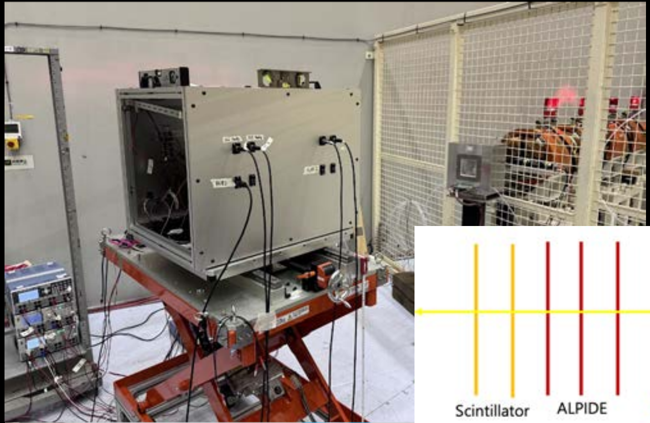




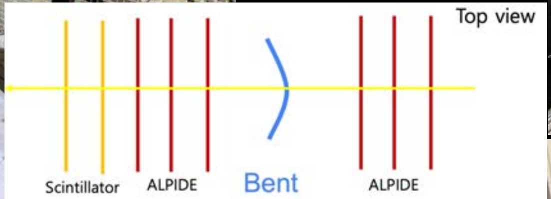
Test beam activity at KEK PF-AR

- The Korean ALICE group produced a telescope and performed several test beams of newly developed sensors for ITS3 at KEK PF-AR with Japanese and French colleagues

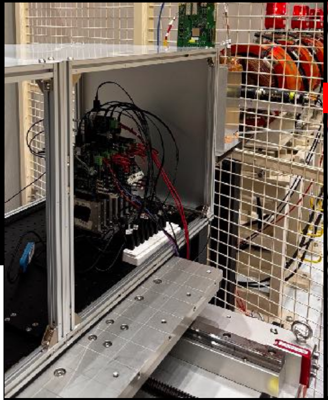
2024 March

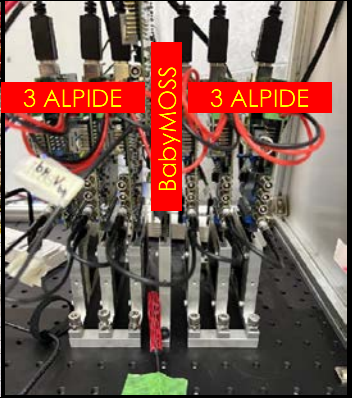


Bent ALPIDE



Korea: PNU, SKKU, Inha
Japan: Hiroshima, Tsukuba, Tokyo CNS
France: Grenoble

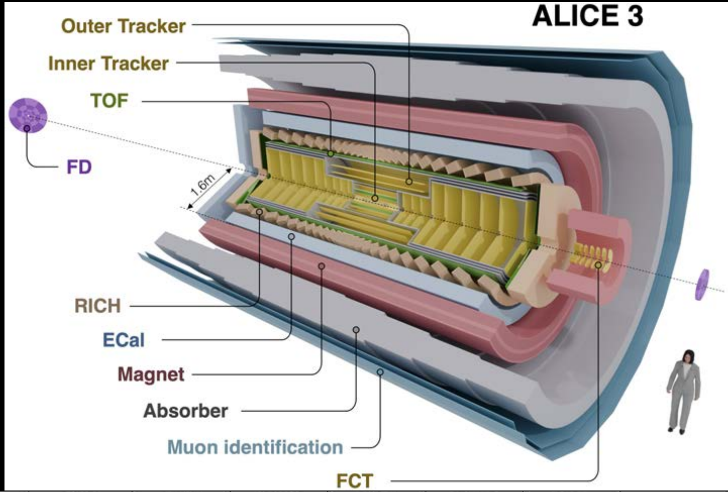


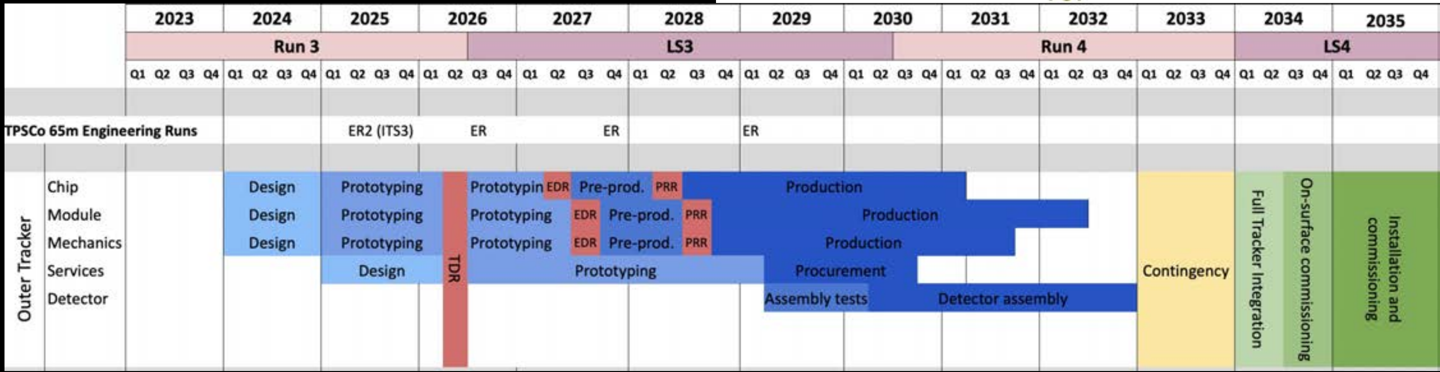


2024 December
2025 March

3D printed target for imaging

- **The Korean ALICE group is actively working on R&D for ALICE 3 OT**
  - R&D of module assembly by utilizing a general-purpose die attach machine for module assembly is ongoing
  - Developed an assembly procedure and achieved a good position precision from the dummy module production
  - Extending activities to post-processing, sensor characterization, automatic sensor test, and stave assembly





BACKUP