Next-Generation MAPS Sensor for ALICE 3 Outer Tracker

Project ID: D_RD_38

JPN Co-PI: Yorito Yamaguchi (Hiroshima Univ.)

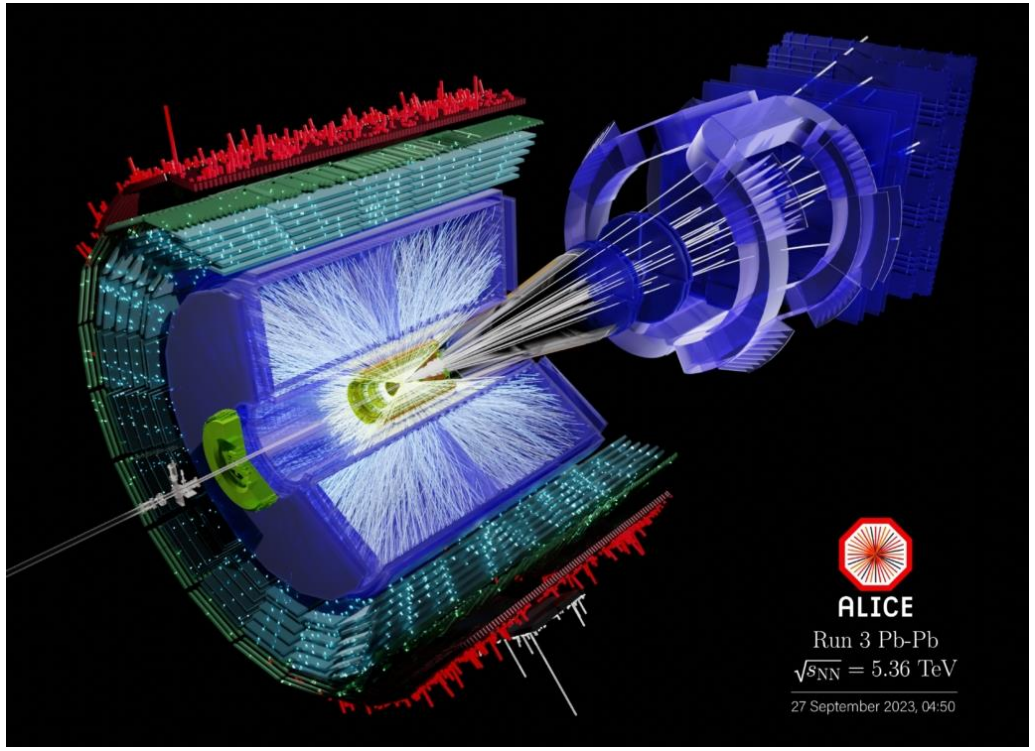
FRA Co-PI: Rachid Guernane (LPSC Grenoble)

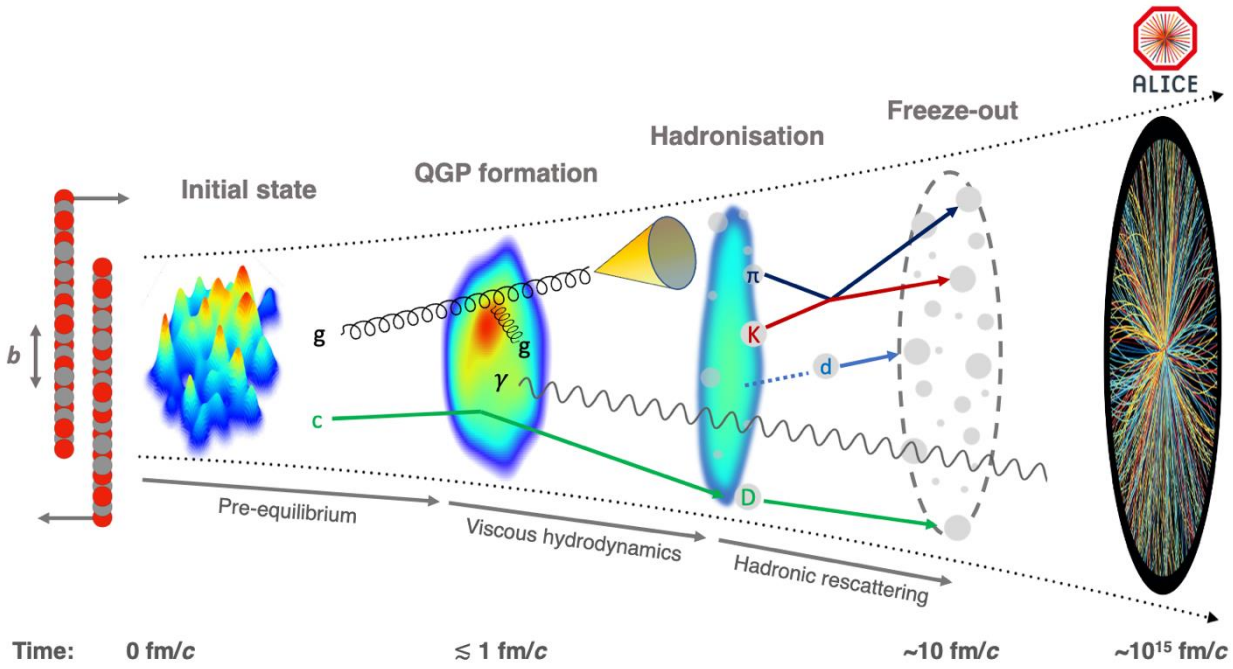
Joint workshop of TYL/FJPPN and FKPPN 2026

May 19, 2026

Heavy ion collisions

- Exploration of hot QCD matter
  - Deconfined state of quarks and gluons = Quark Gluon Plasma (QGP)
  - Discoveries of unique QGP properties, but still mysteries remain



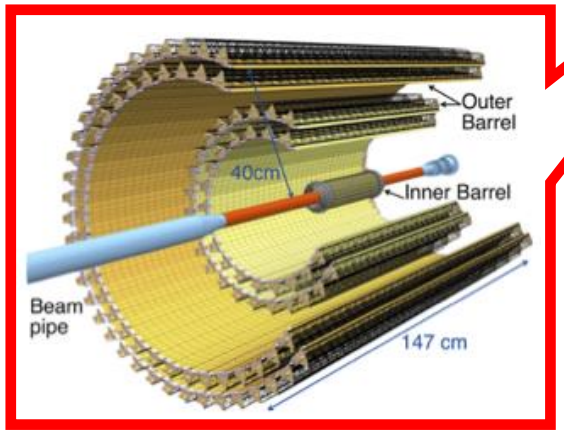


- Multi-probe approach to disentangle complex space-time evolution of collision history
  - New insights from heavy quark and dilepton measurements

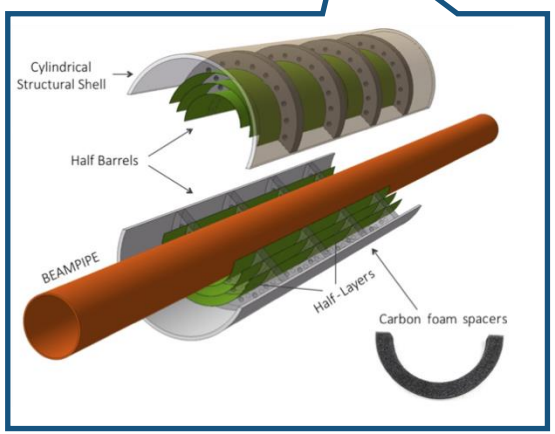
→ Vertexing & tracking performance: Crucial in extremely high multiplicity environment

ALICE upgrade roadmap

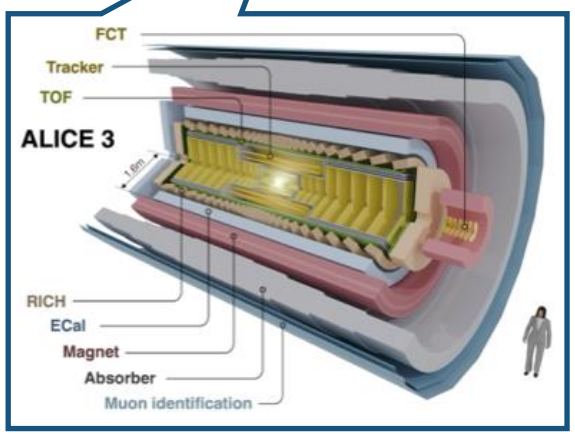
ITS2



ITS3

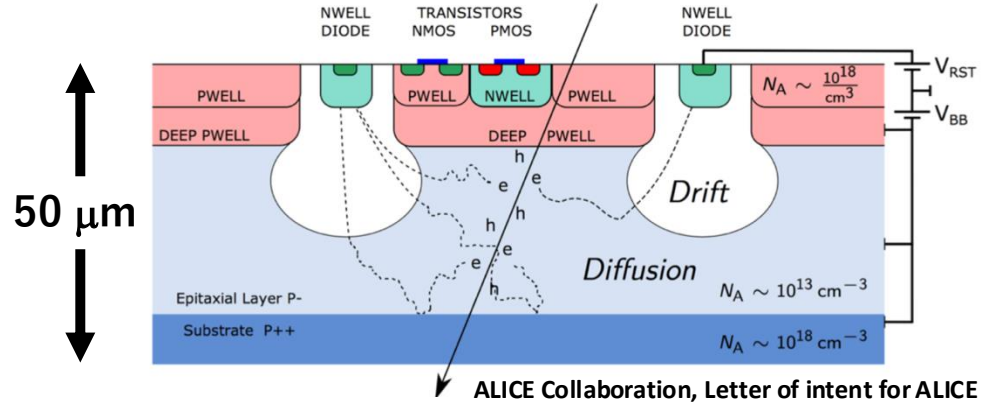


ALICE 3



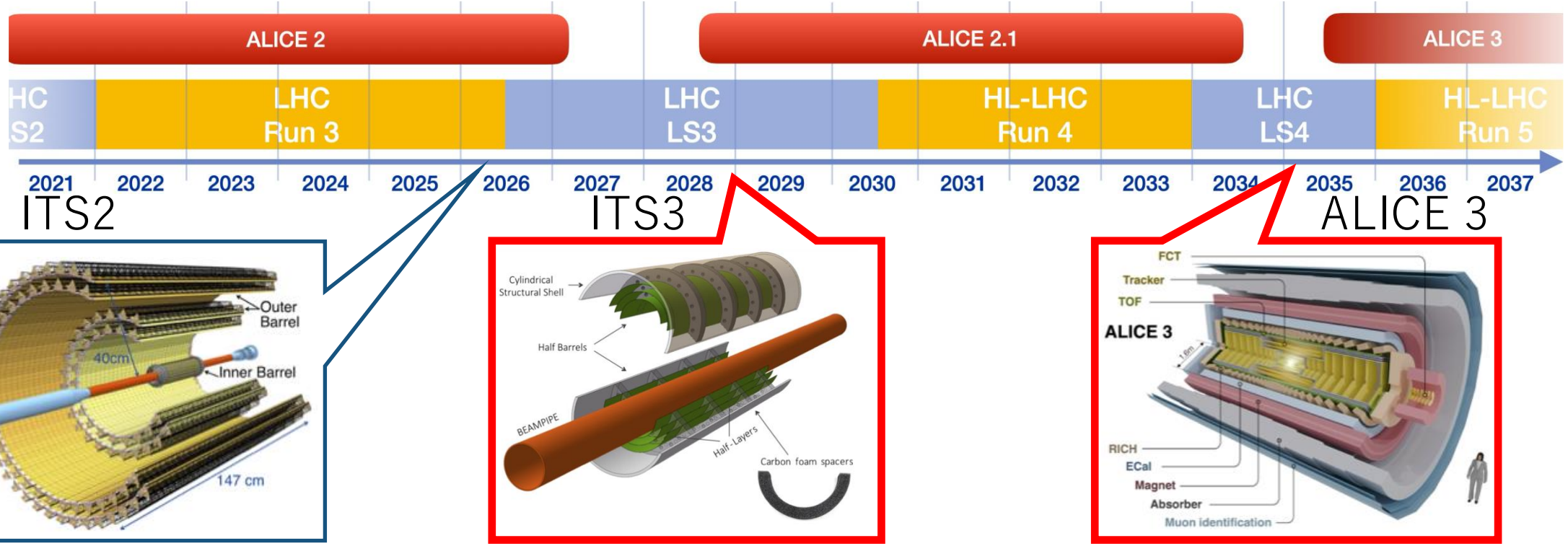
ALPIDE for ITS2

- State-of-art MAPS detector w/ TJ 180 nm-CMOS process
- 27x29 μm^2 pixel & reticle size chip
- Room for improvement on charge collection



ALICE Collaboration, Letter of intent for ALICE 3

ALICE upgrade roadmap



ALPIDE for ITS2

- State-of-art MAPS detector w/ TJ 180 nm-CMOS process
- 27x29 μm^2 pixel & reticle size chip
- Room for improvement on charge collection

Challenge w/ TPSCo 65nm-CMOS process

- Truly cylindrical detector w/ stitched wafer-size sensor
- Smaller pixels & better charge collection thanks to improved inner structure

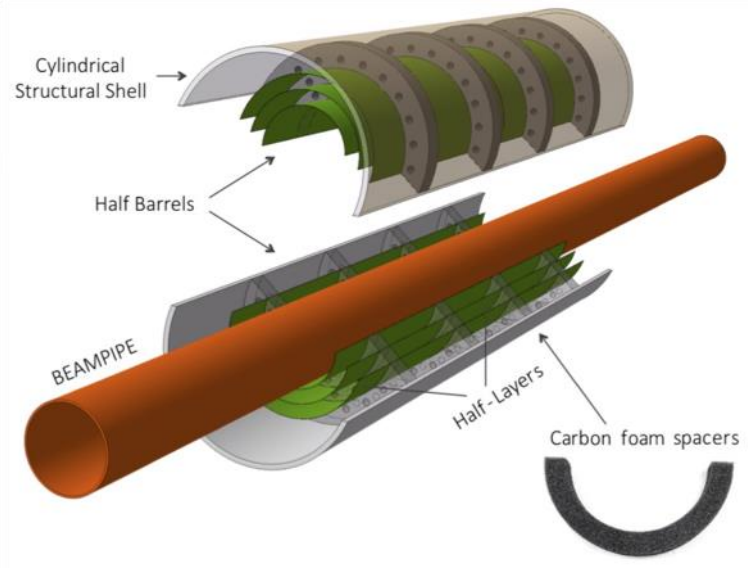
→ Sharing basic R&D for ITS3 and ALICE 3

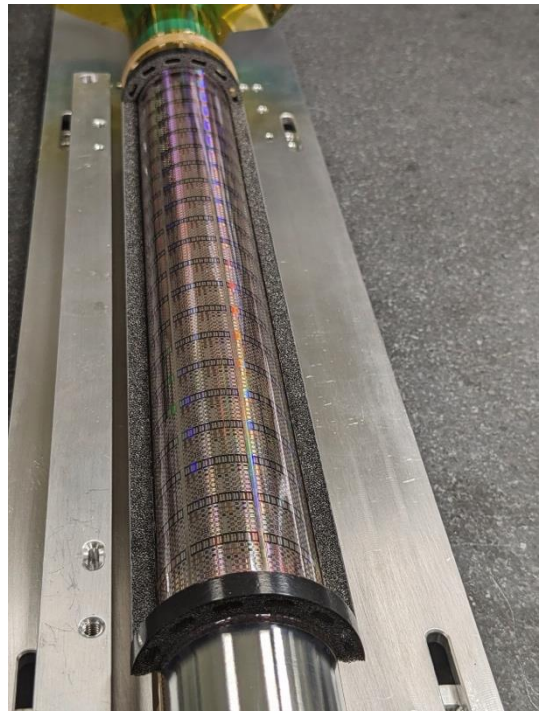
ITS3

- Replacement of 3 inner-most layers into truly cylindrical detector
  - Pointing resolution $\propto r_0 \cdot \sqrt{X/X_0}$

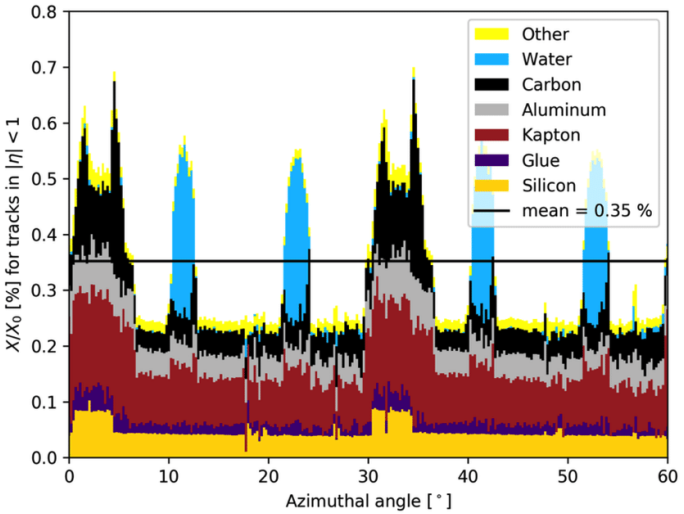
1. Reduction of material budget
   - ➢ Water → Air cooling
   - ➢ Higher integration of on-chip circuits by FPC elimination
   - ➢ Reduction of support structure
2. Putting 1st layer closer to IP
   - ➢ Reduction of beam pipe radius: 18 mm → 16 mm

Essential to make wafer-size sensors with TPSCo 65nm-CMOS process

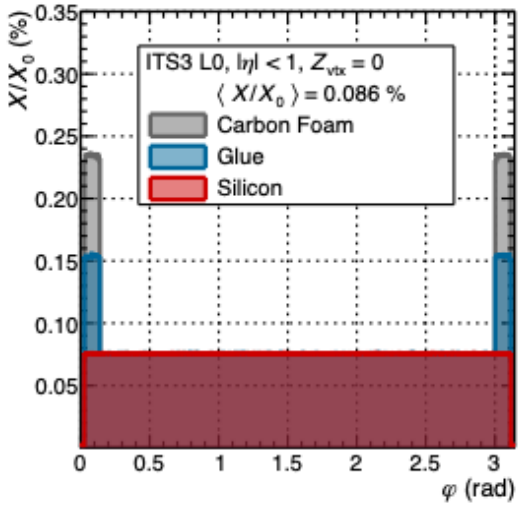




ITS2

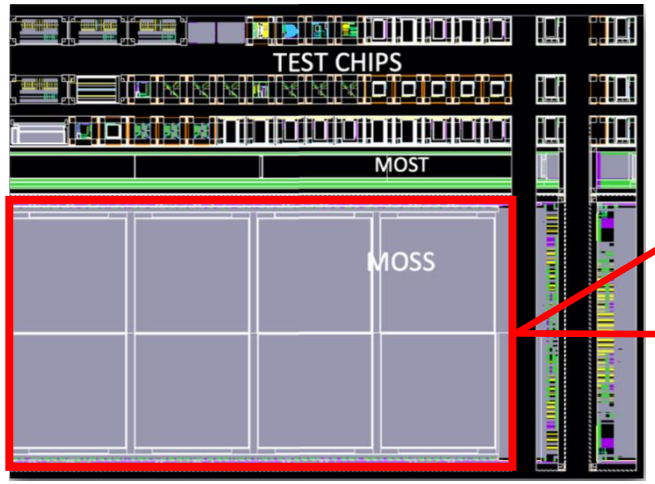


ITS3

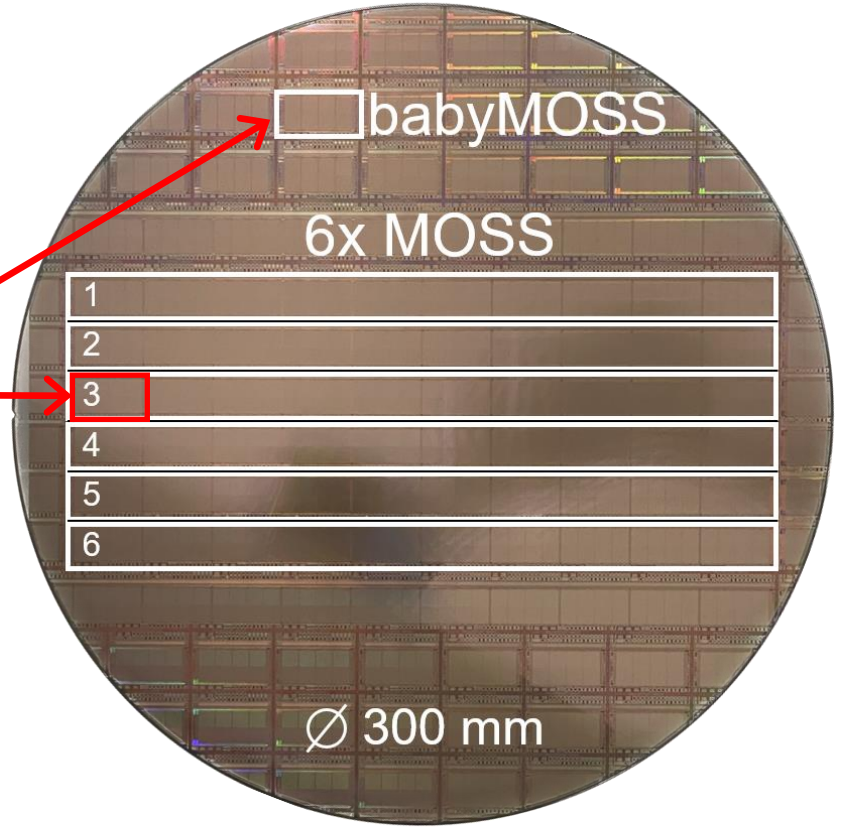


Wafer-size stitched sensor

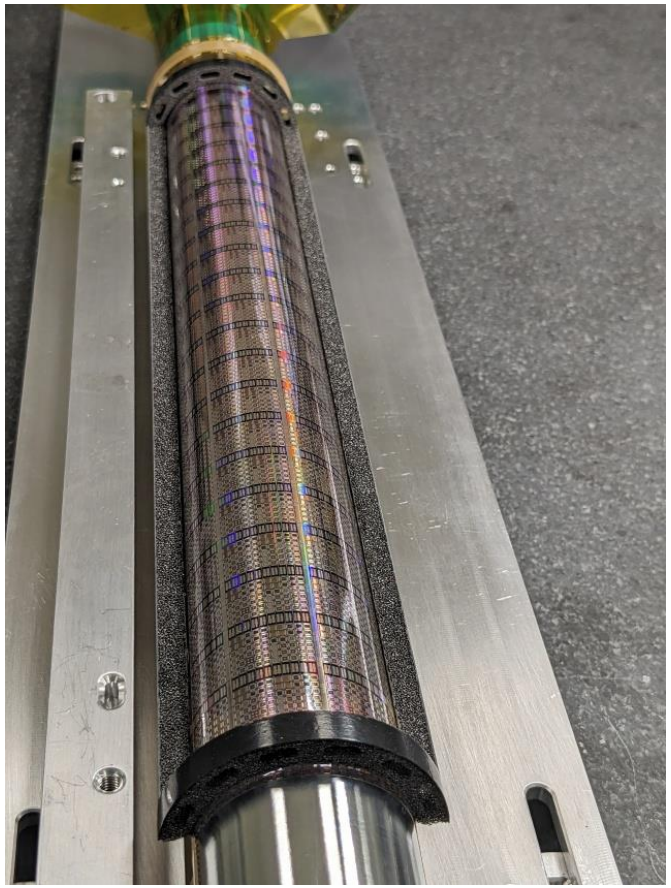
Reticle mask (1RSU)



12-inch wafer



bending

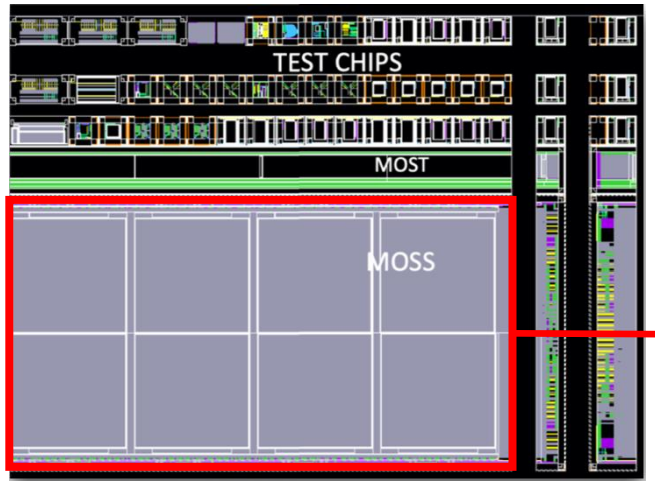


- 1 Repeated Sensor Unit = babyMOSS sensor for tests

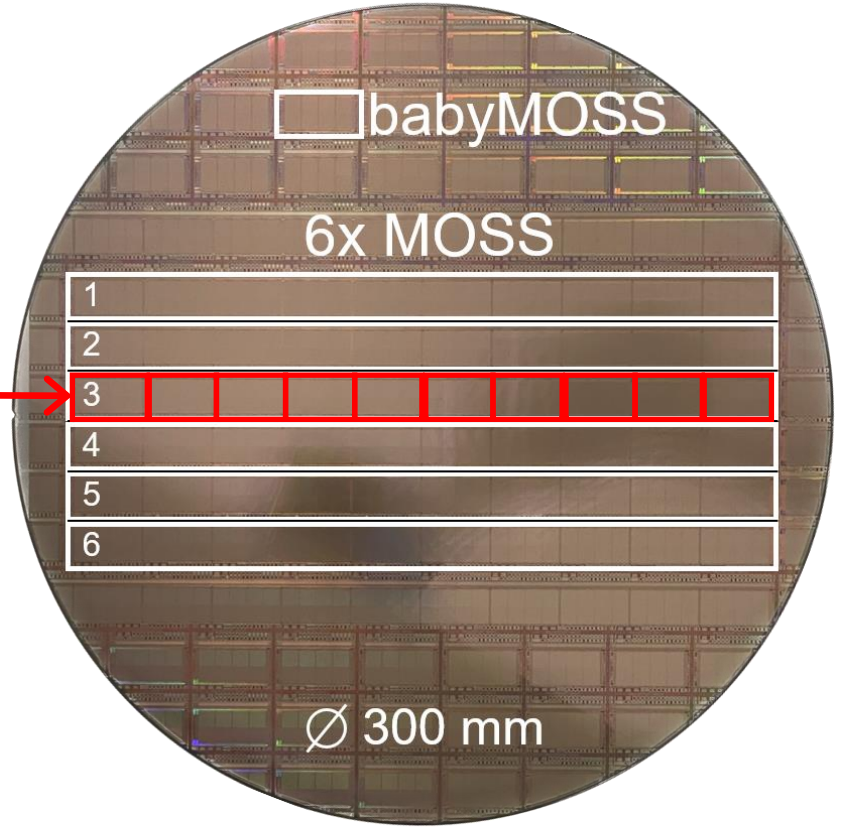
→ 10 Repeated Sensor Units w/ stitching = 1 wafer-size sensor

Wafer-size stitched sensor

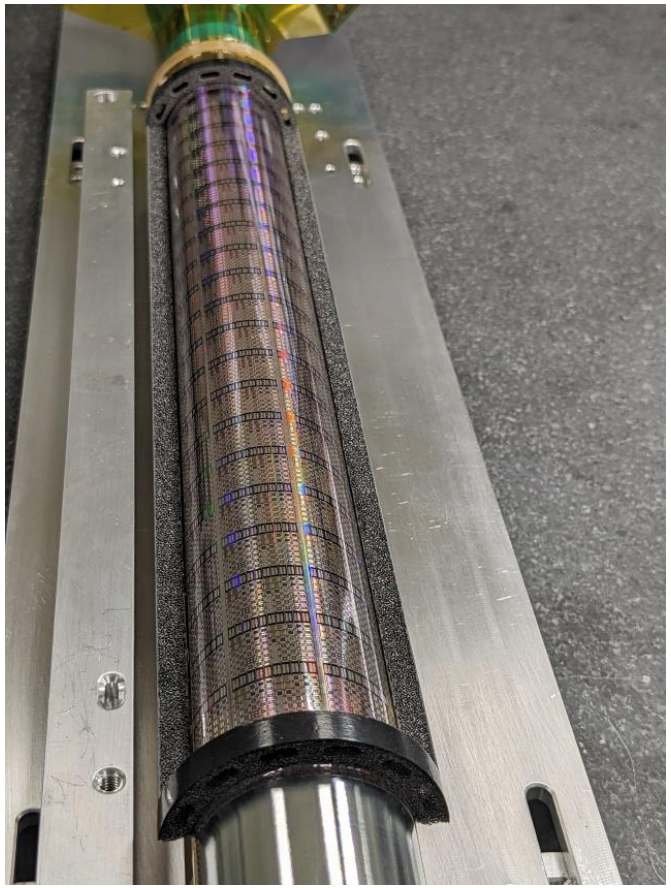
Reticle mask (1RSU)



12-inch wafer



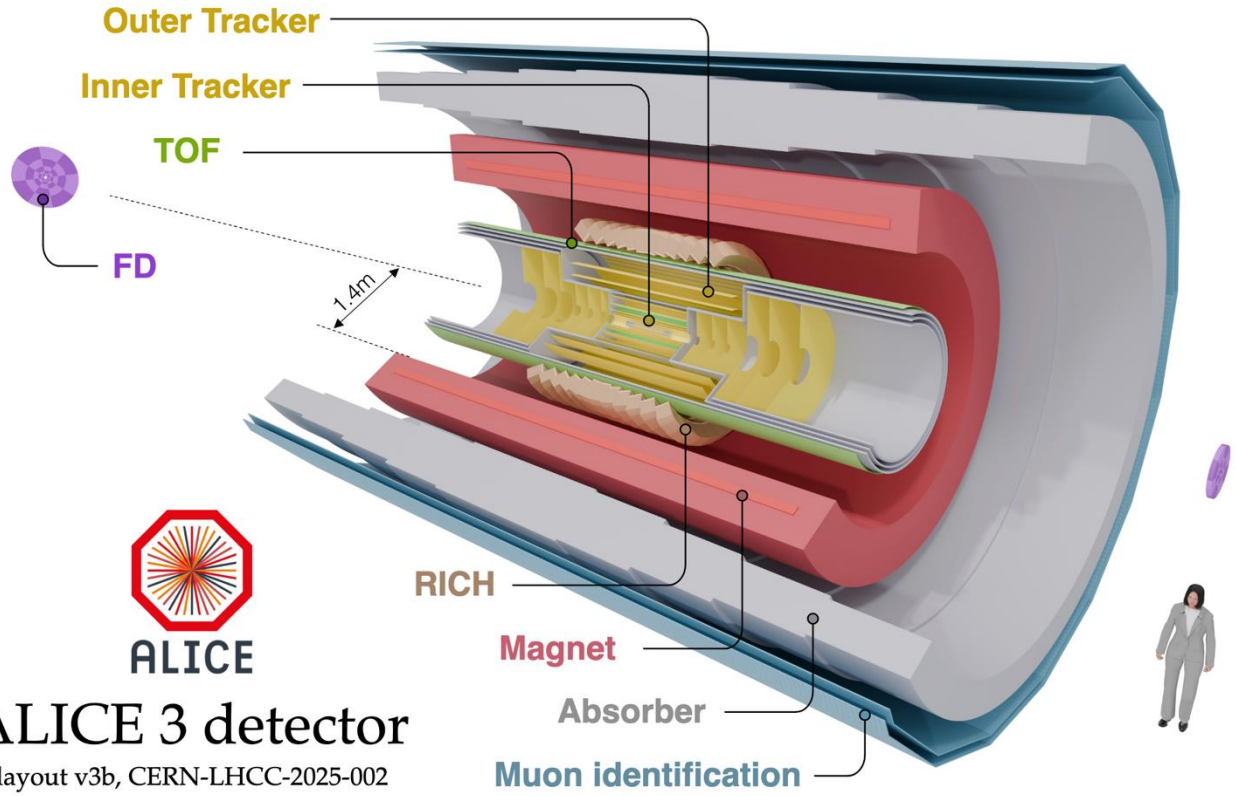
bending



- 1 Repeated Sensor Unit = babyMOSS sensor for tests

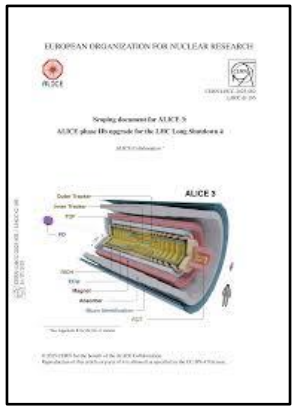
→ 10 Repeated Sensor Units w/ stitching = 1 wafer-size sensor

ALICE 3



Letter of intent
CERN-LHCC-2022-009

Scoping document
(2025)



- ALICE 3 as a next-generation HI experiment
  - Address open fundamental questions remaining even after Run 4
  - LoI (2022), Scoping document (2025)
- Key detector concepts
  - Compact & ultra-light all-silicon tracker
    - ✓ 65nm-CMOS MAPS
  - Retractable vertex detector
  - Excellent PID capability
  - Superconducting magnet, $B = 2T$
  - Continuous readout and online processing

ALICE 3 IT & OT

Inner Tracker (IT)

- Retractable with 3 (barrel) + 3 (disk) layers in beam pipe
  - 1st layer at 5 mm from IP
  - Wafer-size & bent sensors leveraging ITS3 R&D

→ σ_{pos}~2.5 μm w/ 10 μm pixel pitch

  - Radiation tolerance

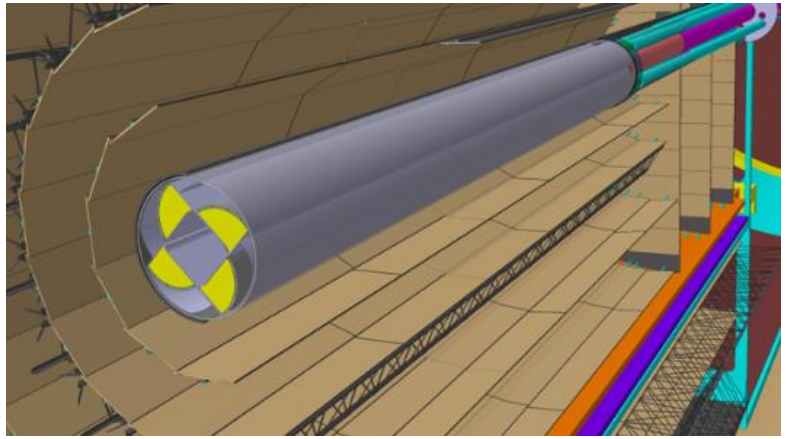
Outer Tracker (OT)

- 8 (barrel) + 3 (disk) layers covering by 8×10^4 sensors = 50 m^2
  - Manufacturing challenges in mass module production

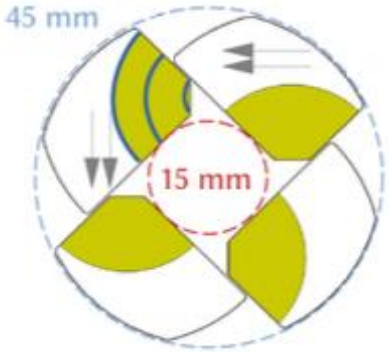
→ Low power density 20 mW/cm^2

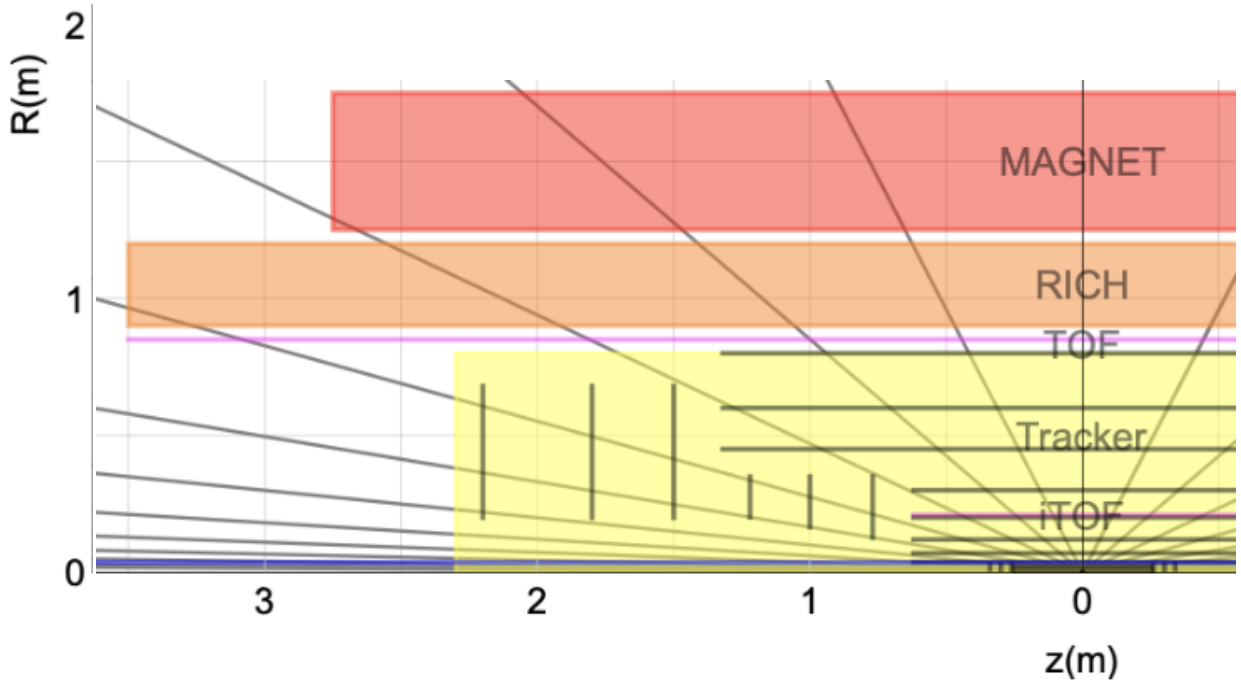
  - σ_{pos}~10 μm w/ 20-50 μm pitch

Beam injection / Stable beams



Open / Close





ALICE 3 IT & OT

Inner Tracker (IT)

- Retractable with 3 (barrel) + 3 (disk) layers in beam pipe
  - 1st layer at 5 mm from IP
  - Wafer-size & bent sensors leveraging ITS3 R&D

→ σ_{pos}~2.5 μm w/ 10 μm pixel pitch

  - Radiation tolerance

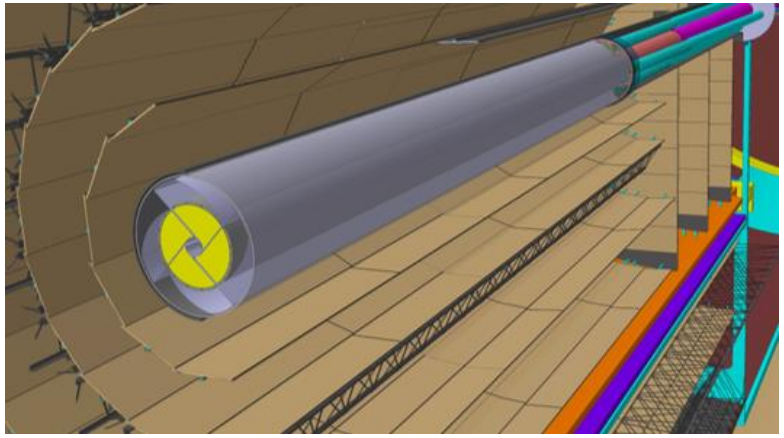
Outer Tracker (OT)

- 8 (barrel) + 3 (disk) layers covering by 8×10^4 sensors = 50 m^2
  - Manufacturing challenges in mass module production

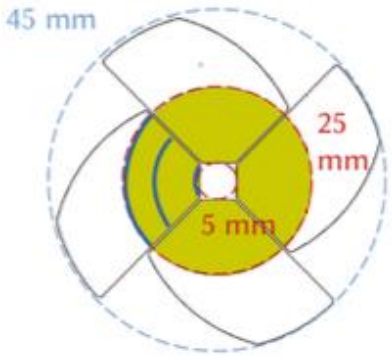
→ Low power density 20 mW/cm^2

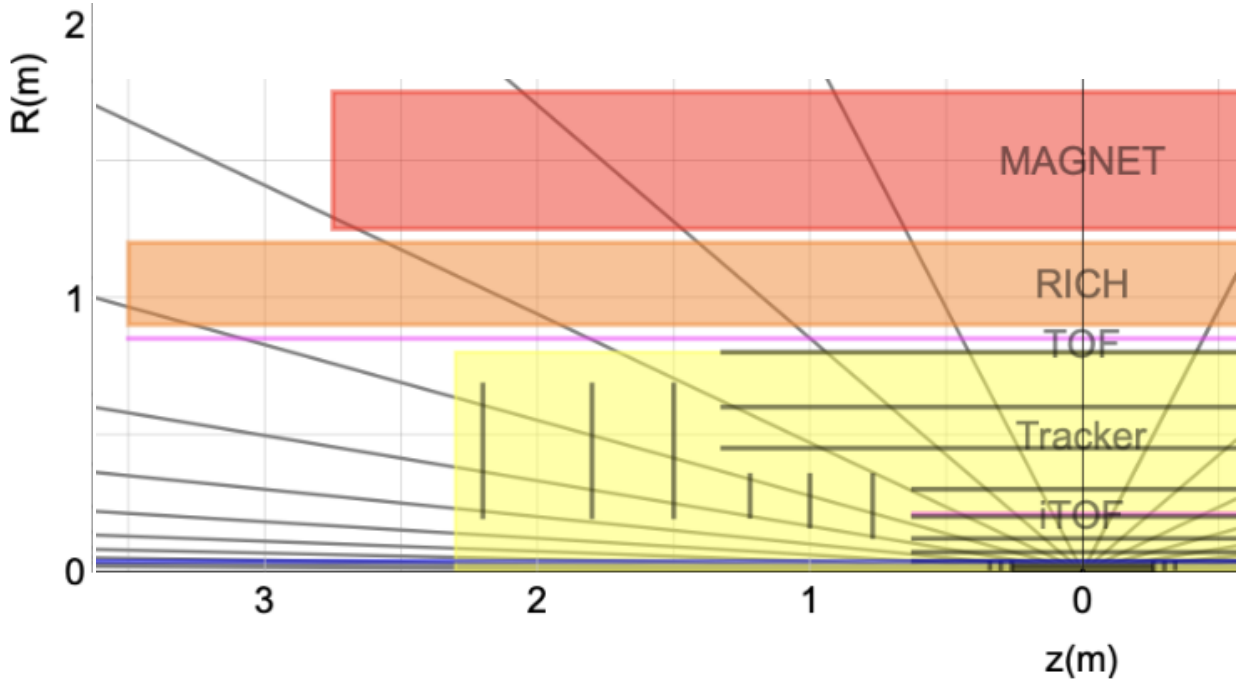
  - σ_{pos}~10 μm w/ 20-50 μm pitch

Beam injection / Stable beams



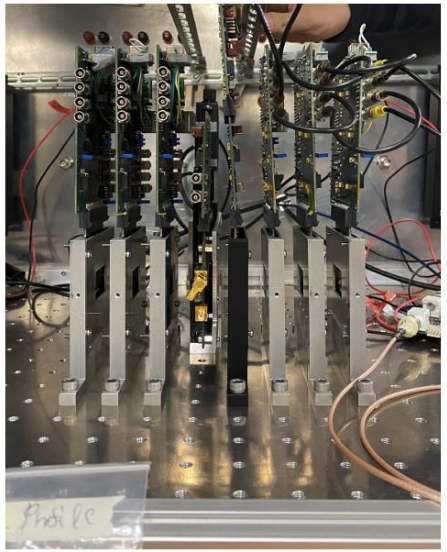
Open / Close

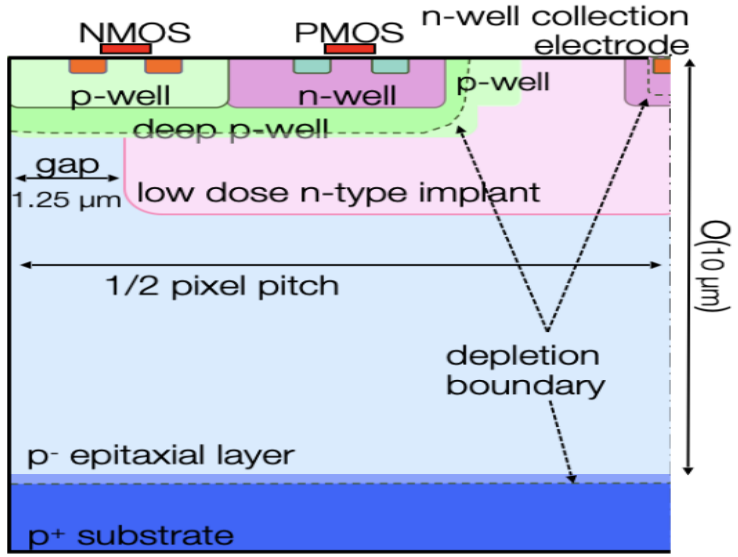




Beam test at PF-AR

- 4th beam test in Frence-Japan-Korea collaboration
  - ER1 sensor characterization
  - Connection to FJPPN D_RD_29 “BASHI” project
  - Practical training for new students through the beam test



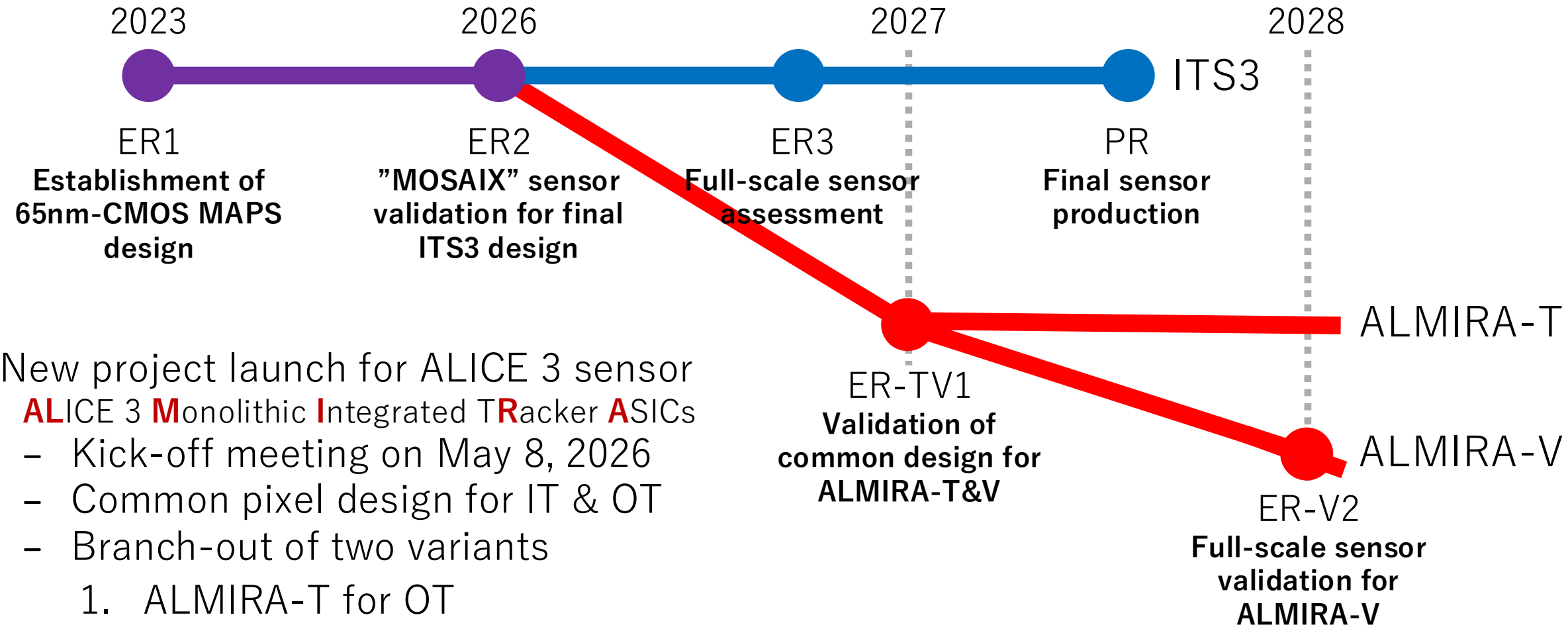


- Test items
  1. babyMOSS with ALPIDE telescope
     - Threshold scans
     - Variation of gap space
  2. babyMOSS telescope validation

→ Confirmation of expected performance

✓ Consistent with other tests

Prototyping runs



- New project launch for ALICE 3 sensor
  ALICE 3 **M**onolithic **I**ntegrated T**R**acker **A**SICs
  - Kick-off meeting on May 8, 2026
  - Common pixel design for IT & OT
  - Branch-out of two variants
    1. ALMIRA-T for OT
       Low power consumption & serial powering
    2. ALMIRA-V for IT
       High position resolution & radiation tolerance

Activities in FY2026

1. Beam tests at PF-AR
   - Upcoming beam test in June 3-8 for bent babyMOSS and ALICE 3 OT prototype sensor characterization
   - Plan of beam tests for ER2 prototype sensor characterization in fall and winter
     ✓ Irradiation test at RIKEN too
   - Great exercise for students to get expertise of MAPS
2. Sensor design
   - Formation of dedicated team with engineering experts for ALMIRA
   - Simulation study of full readout chain of MAPS
   - Detailed discussions at CERN/IPHC Strasbourg
3. Student exchanges between Japan and France
   - Student from Hiroshima to CERN & IPHC Strasbourg: May - June
   - Student from Tsukuba to CERN & LPSC Grenoble
   - Student from LPSC Grenoble to Tsukuba

Summary

- ALICE upgrade program with state-of-art MAPS technology
  - Extensive R&D efforts for development of 65 nm-CMOS MAPS shared in ITS3 and ALICE 3 trackers
  - FY2026 activities:
    [FR → JP] Beam test campaigns at PF-AR for ER2 sensor characterization
    [JP → FR] Sensor design discussions for ALMIRA with full readout chain simulation
- FJPPN & FKPPN collaborations as the essential driving force of the project
  - Encouraging student exchanges for future MAPS expert