Beam test results for the ALICE ITS3 prototype sensor

ITS3 babyMOSS beam tests at FNAL

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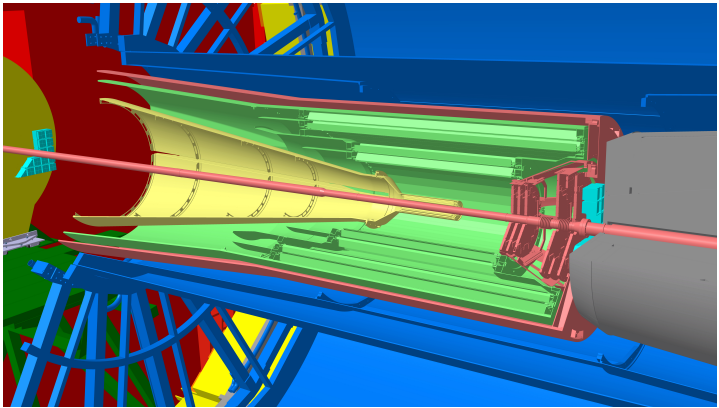
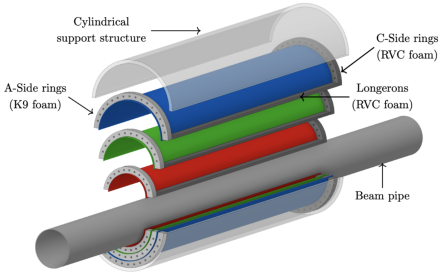
The ALICE ITS3 upgrade

- ITS2: Run 3 upgrade to 7 stave-supported MAPS layers



The ALICE ITS3 upgrade

- ITS3: Replace inner three layers with **curved**, **self-supporting**, **wafer-scale** sensors



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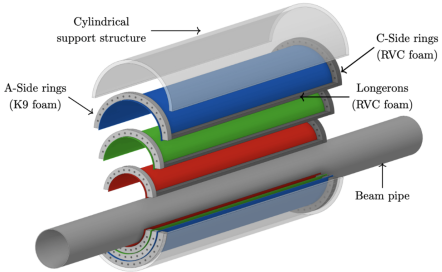
  - Improved **pointing resolution** and **tracking efficiency** at low p_T
  - Enhance ALICE's study of jets, heavy flavor, flow, low-mass dielectrons...



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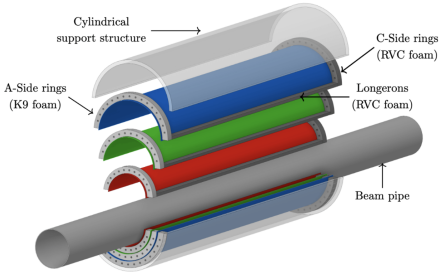
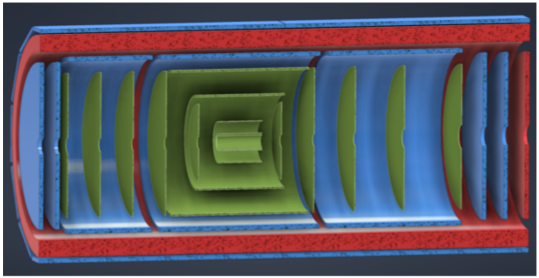
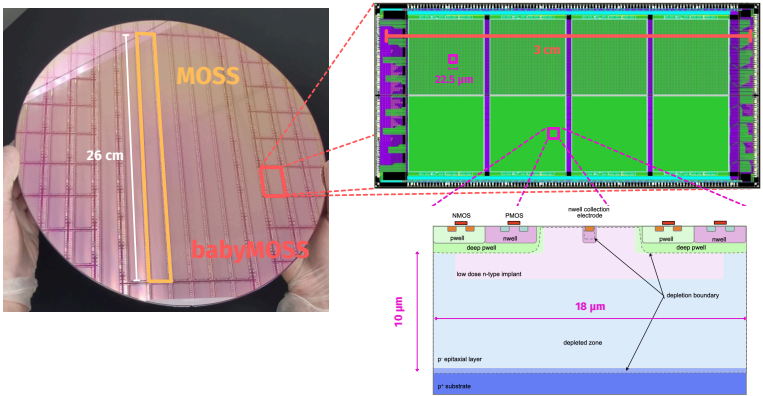
  - Improved **pointing resolution** and **tracking efficiency** at low p_T
  - Enhance ALICE's study of jets, heavy flavor, flow, low-mass dielectrons...
- Sensor design will be used as-is for the SVT IB, and a basis for the EIC-LAS (OB/disks)



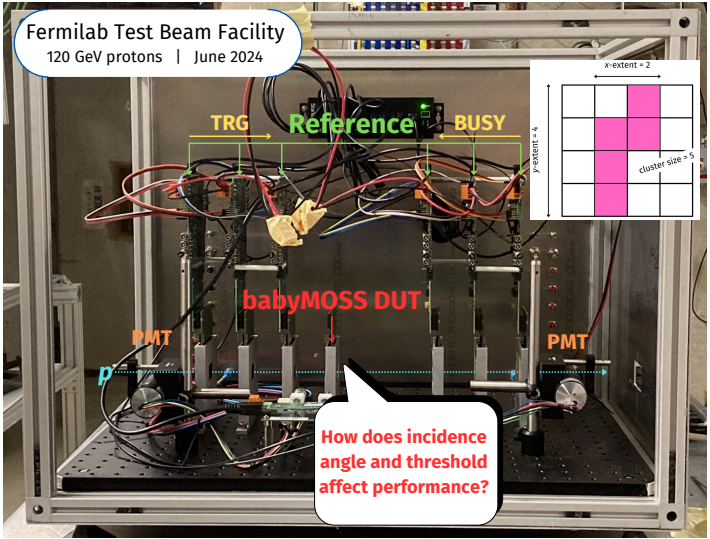


(baby)MOSS: a MOnolithic Stitched Sensor

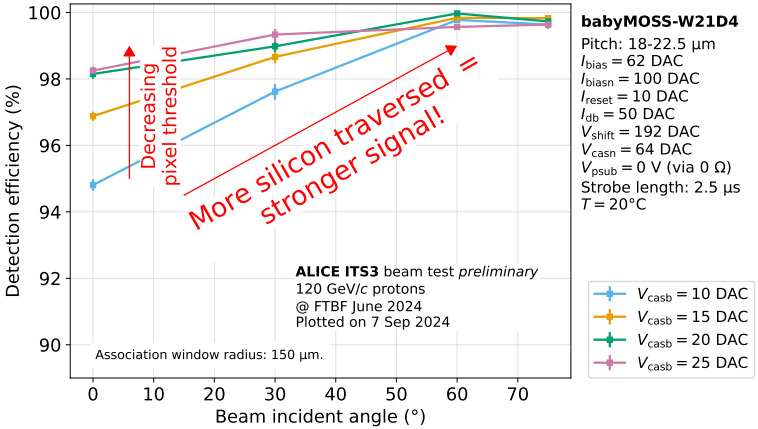
- MOSS: largest ER1 ITS3 prototype
- First testing of yield, layout, operating margin, etc. with a fully stitched sensor



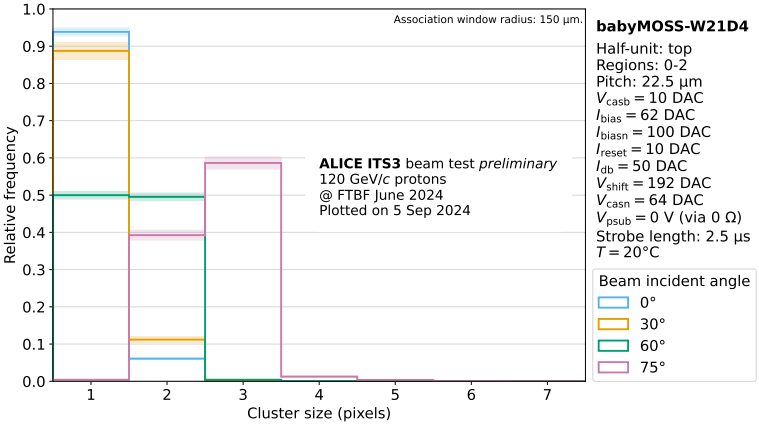
The beam telescope



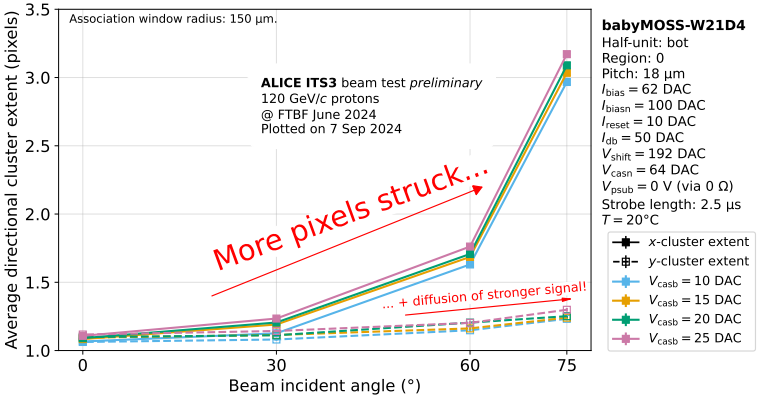
Sensor performance: efficiency



Sensor performance: average cluster size



Sensor performance: average cluster extent



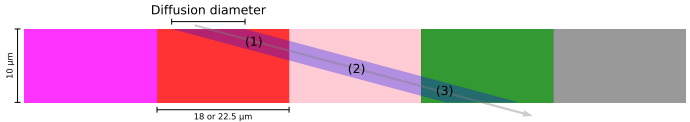
Geometry vs. diffusion: modeling cluster size

What is the main contributor to cluster size?

- *Track geometry*: particles passing through multiple pixels
- *Charge diffusion*: diffusion of electrons across pixel boundaries

GEANT4-based fast simulation:

1. Randomly select particle path at fixed angle, and determine pixels intersected
2. Determine length of silicon to traverse at fixed angle
3. Determine energy deposition from GEANT4
4. Convert to number of electron-hole pairs at 3.6 eV/pair
5. Divide among hit pixels in proportion to “area”
6. Impose *eh*-pair threshold and determine cluster extent



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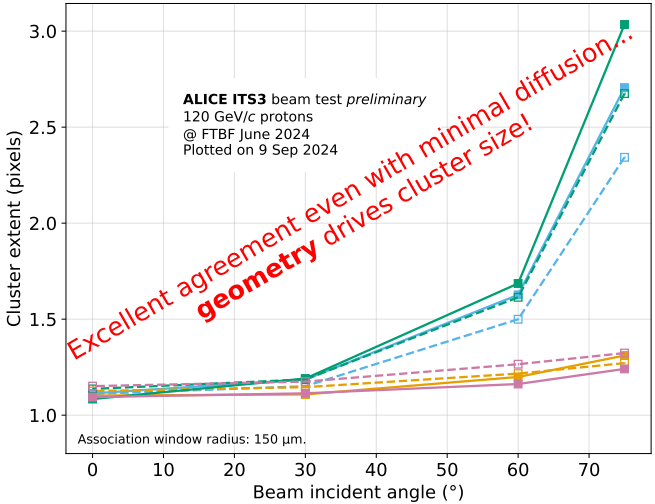


babyMOSS-W21D4

Region: 0
$V_{casb} = 15$ DAC
$I_{bias} = 62$ DAC
$I_{biasn} = 100$ DAC
$I_{reset} = 10$ DAC
$I_{db} = 50$ DAC
$V_{shift} = 192$ DAC
$V_{casn} = 64$ DAC
$V_{psub} = 0$ V (via 0 Ω)
Strobe length: 2.5 µs
$T = 20$°C

GEANT4 fastsim:
200 *eh*-pair threshold
9 µm diffusion diameter

- Data
- GEANT
- *x*-extent, top half
- *y*-extent, top half
- *x*-extent, bot half
- *y*-extent, bot half

Conclusions and outlook

From initial beam tests with the latest ITS3 prototype, we observe:

- an **increase in efficiency** from *longer path-length in active silicon*
- **strong cluster extent dependence** on track inclination angle
- that **track geometry**, not charge diffusion, determines cluster size, confirmed by fast simulation
  - implications on tracking and simulation

Future prospects:

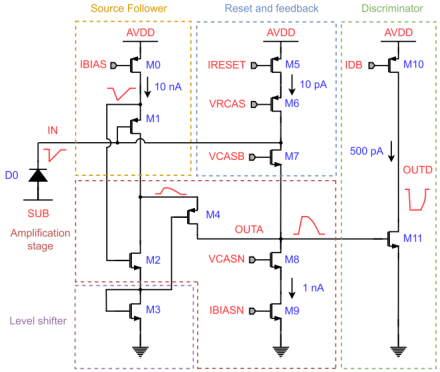
- Temperature and radiation dose dependence of fake-hit rate (LBNL climate chamber, UC Davis CNL cyclotron) - early 2025
- Temperature dependence of sensor performance @ FTBF or Jefferson Lab - mid-late 2025
- ITS3 project: MOSAIX (ER2) coming soon!

THANK YOU!

babyMOSS matrices and frontend

Matrices on MOSS

Top matrices, large pitch	M4 Standard	M5 Larger input transistor	M6 Larger discriminator input transistor	M7 Larger common-source transistor (M2)
Bottom matrices, fine pitch	M0 Standard	M1 Standard	M2 Standard	M3 Smaller feedback capacitance



Right figure taken from CDS-2876300

Data-taking and analysis

- Threshold (via V_{casb}) set remotely, but angle changed by hand
- Four values of V_{casb} scanned for each angle

Data-taking procedure:

1. Noisy pixel masking
2. Alignment with linear fit and least-squares χ^2 minimization
3. Calculate:
   - detection efficiency: impose 1 cluster per reference plane + 20 um residual cut. Project track to DUT: if cluster within 50um of projected point, track is efficient and vice versa
   - cluster size: size of cluster for efficient tracks

The Fermilab Test Beam Facility (FTBF)

- Located at Fermi National Accelerator Laboratory; Batavia, IL, USA
- The beam:
  - 120 GeV/c protons at variable intensity (1-300 kHz)
  - Also possibility of secondaries: pions, muons, electrons
  - 1 spill (4.2s) every 60 seconds
  - Event rate: 300/600 events recorded per spill
- "Two-party" system:
  - Primary user swaps every twelve hours (day and night shifts)
  - Beam properties, access times under sole control of primary user
  - Other detectors can be placed in beam as secondary users and take data in parasitic mode