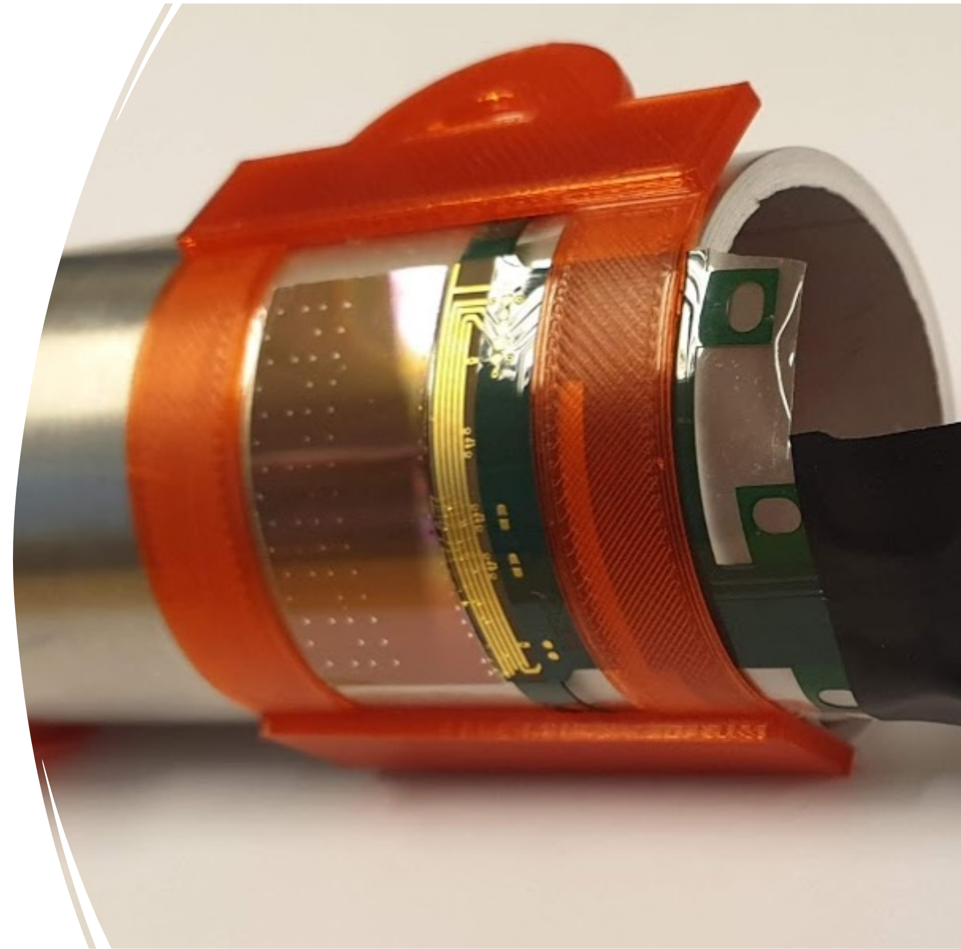
Detector R&D actvities –



ECFA Roadmap

Detectors for future colliders

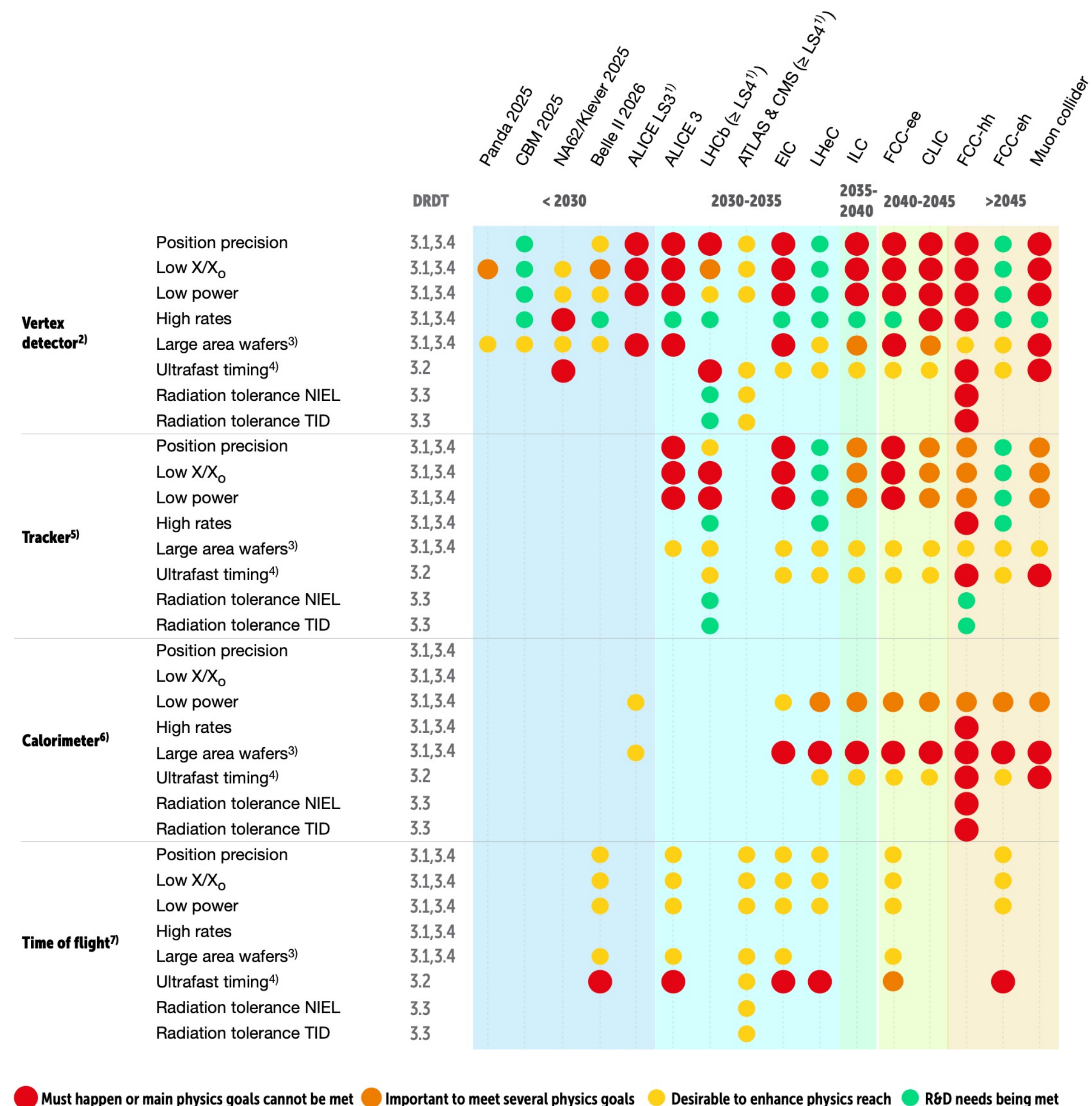
- low mass
- low power
- high-resolution trackers
- Sub-nanosecond timing
- increased radiation tolerance

3.5 Recommendations

3.5.1 Detector R&D Themes

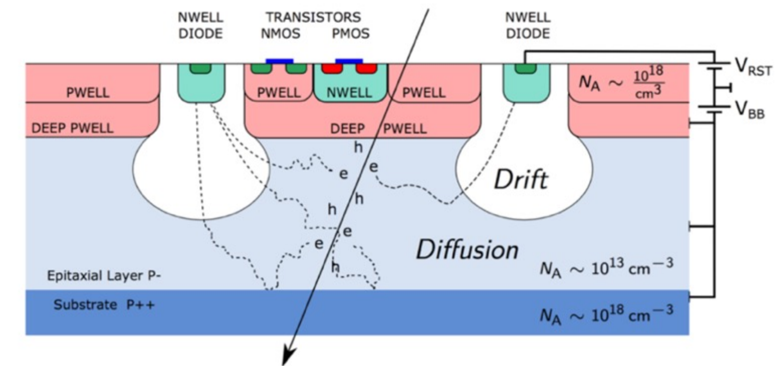
During the various ECFA Symposia (see Appendix C) and from the feedback through the National Contacts, four main areas of research were identified.

The further evolution of active monolithic sensors is considered key to achieving several of the goals at future facilities such as very small pixels, low material budget and large area. MAPSs are also in a position to benefit greatly from the further evolution of the main consumer electronics (DRDT 3.1).

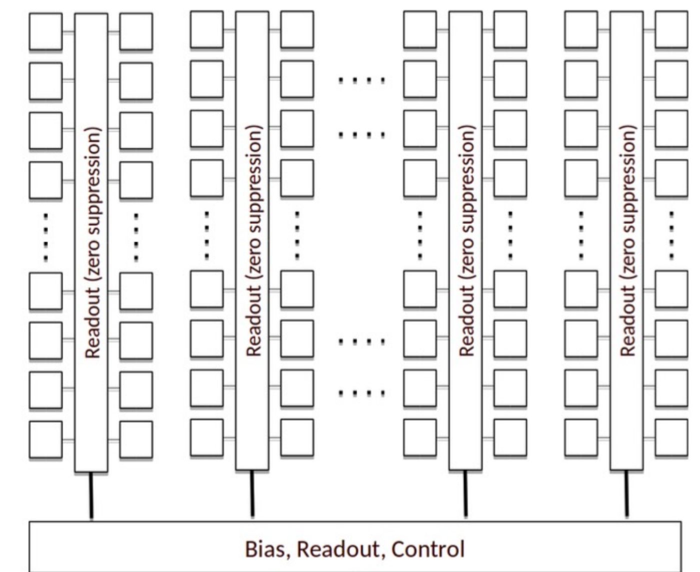


The 2021 ECFA detector research and development roadmap. Available: https://cds.cern.ch/record/2784893

Monolithic Active Pixel Sensor (MAPS)



- Readout electronics and sensor matrix on same silicon
  - no need for bump-bonding / flip-chip technology
- Commercial CMOS technology,
  - low cost
  - Small feature size, small pitches (pixels) and position resolution
  - Low power – reduced need for cooling



"Standard process" – charge collection by diffusion

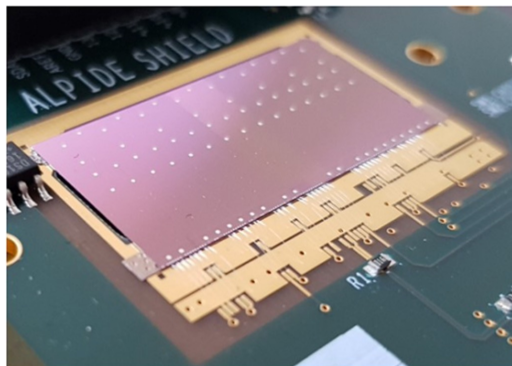
- radiation damage beyond 10^{12} –10^{13} 1 MeV n_{eq}/cm^2
- Slower collection signal, less precise timing

M. Šuljić, 'ALPIDE: the Monolithic Active Pixel Sensor for the ALICE ITS upgrade', *J. Inst.*, 2016, doi:10.1088/1748-0221/11/11/C11025
Snoyes et al., "A process modifiction for CMOS monolithic active pixel sensors for enhanced depletion, timing performance and radiation tolerance", https://doi.org/10.1016/j.nima.2017.07.046
M. Mager, "ALICE ITS3 – a next generation vertex detector based on bent, wafer-scale CMOS sensors, CERN Detector seminar 24. Sept. 2021 https://indico.cern.ch/event/1071914/

State-of-the-art

- ~12.5 Gpixels CMOS detector
- 24000 chips, 10 m^2
- Radial distance: 23 mm
- Material (mean X/X0): 0.3%
- ALICE Pixel Detector (ALPIDE) MAPS
  - 29 x 27 um^2, 1024 x 512 pixels
  - 1.5 x 3.0 cm^2
  - ~40 mW/cm^2,~4 us integration time

ITS2 installed @ P2 for Run3



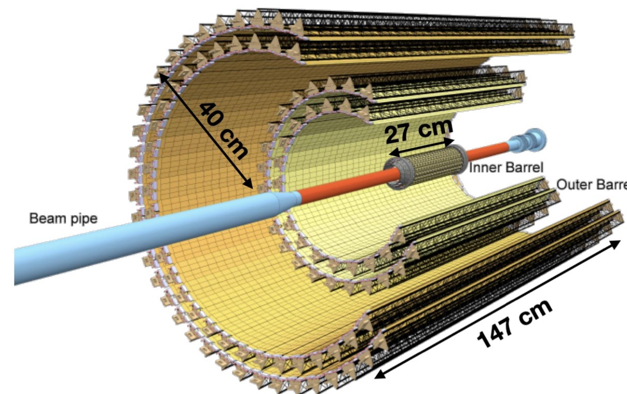
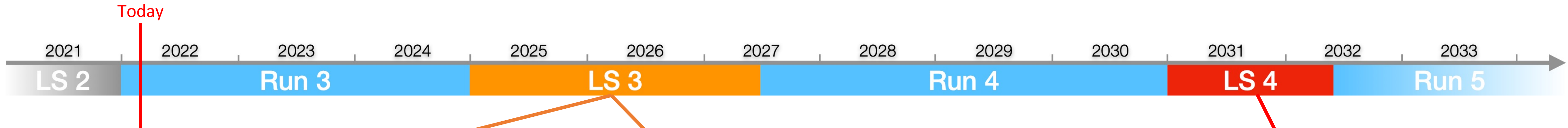
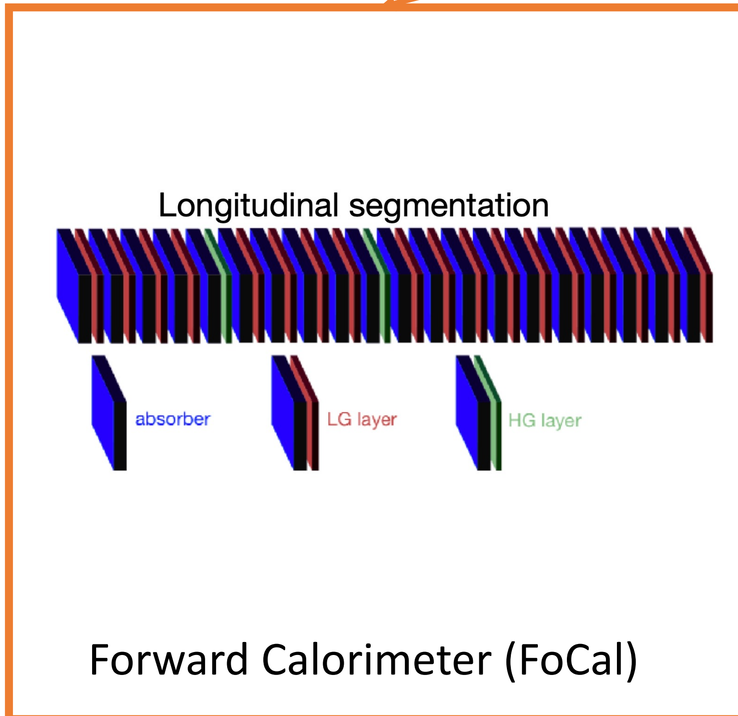


Photo credit: ALICE

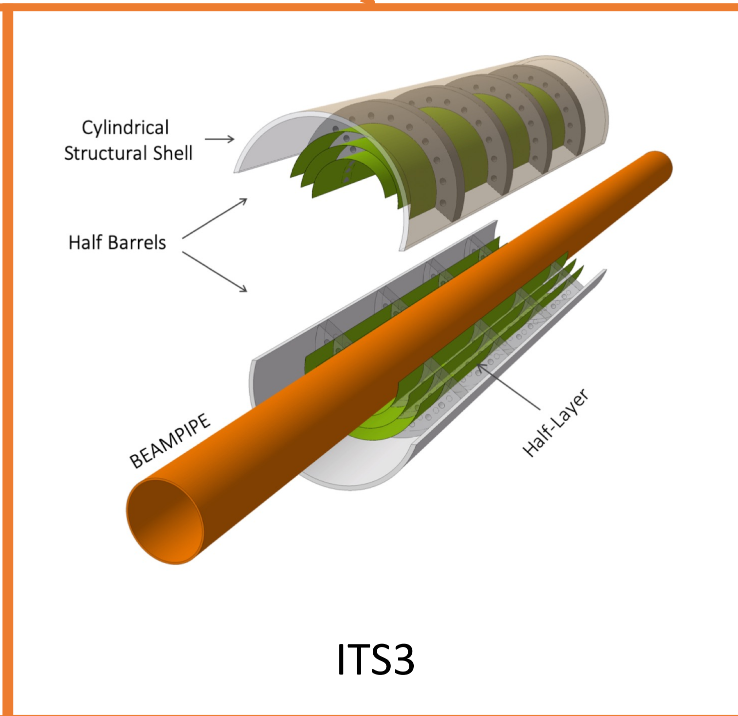
Mager et al. 2016, doi.org/10.1016/j.nima.2015.09.057; Rinella et al. 2017, doi.org/10.1016/j.nima.2016.05.016; ALICE collaboration ITS Upgrade TDR doi:10.1088/0954-3899/41/8/087002

Future upgrades using MAPS

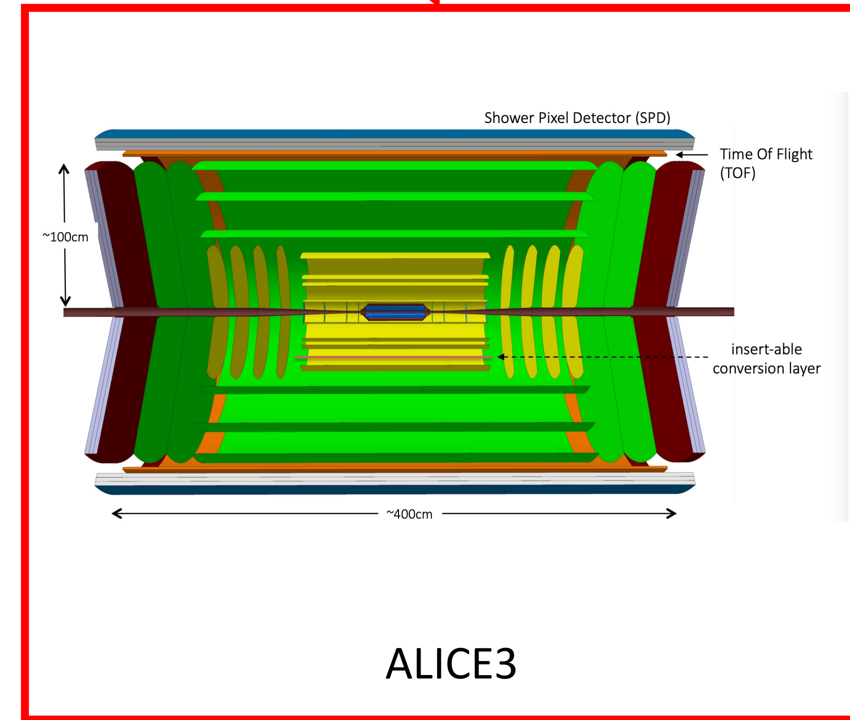




Forward Calorimeter (FoCal)



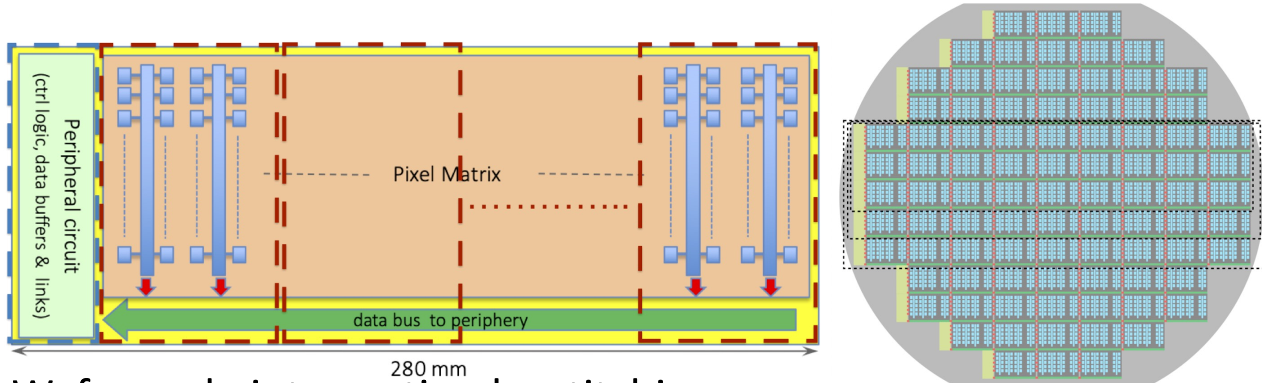
ITS3



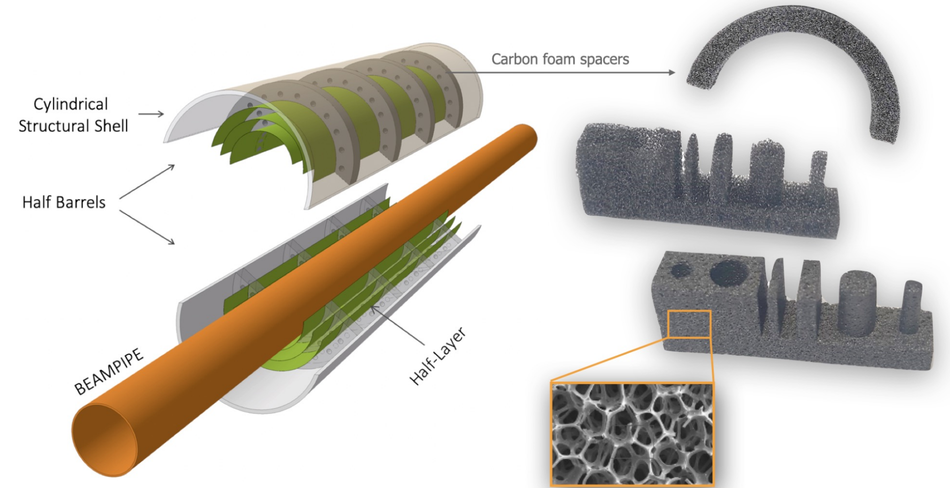
ALICE3

Letter of Intent for an ALICE ITS Upgrade in LS3, https://cds.cern.ch/record/2703140
Letter of Intent: A Forward Calorimeter (FoCal) in the ALICE experiment, https://cds.cern.ch/record/2719928?ln=en
A next-generation LHC heavy-ion experiment, http://arxiv.org/abs/1902.01211

Bent, wafer scale CMOS detector



Wafer-scale intergration by stitching
65 nm technology → smaller pixel size



ITS3: Replace inner layers with 3 layers of two halfs
Thinning to 20–40 um, 0.02–0.04 X/X0

Bending of single chip and dummy wafer proven,
wafer scale chip prototypes under development

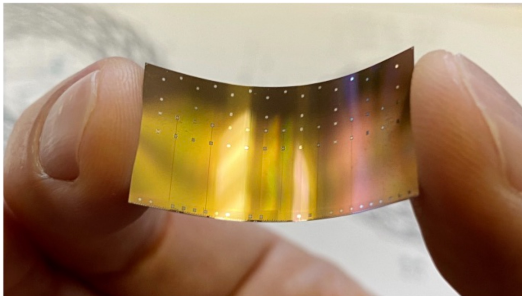
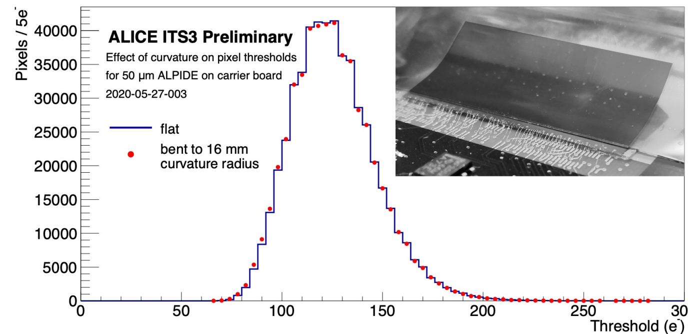
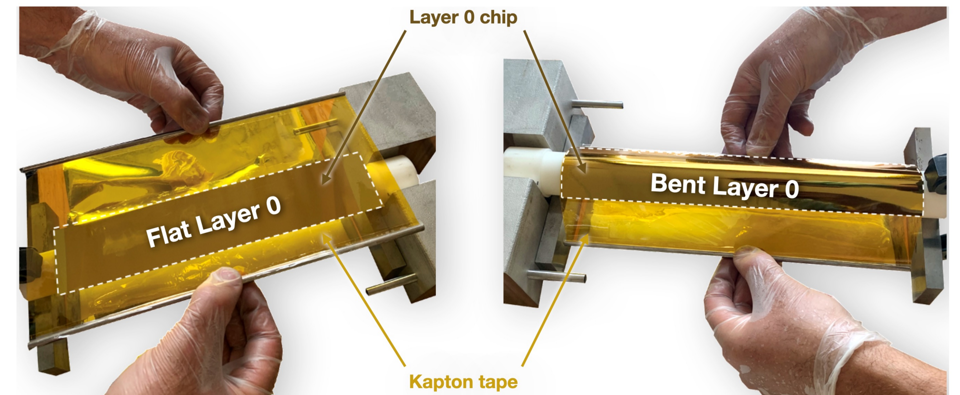


Photo credit: ALICE ITS3 https://alice-collaboration.web.cern.ch/menu_proj_items/ITS-3

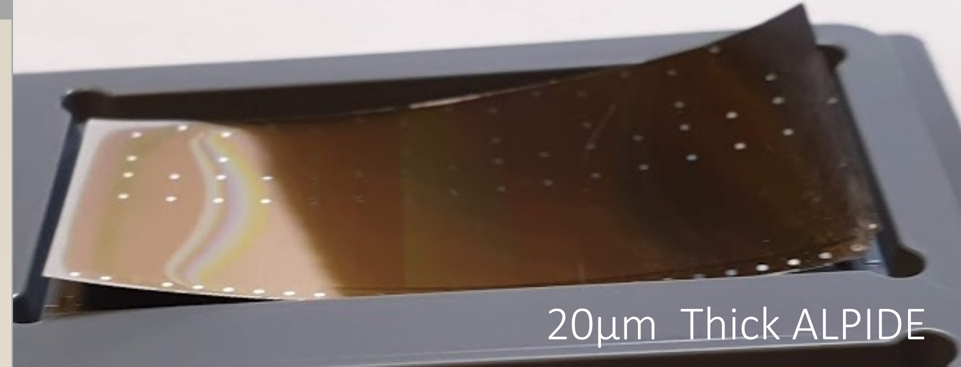




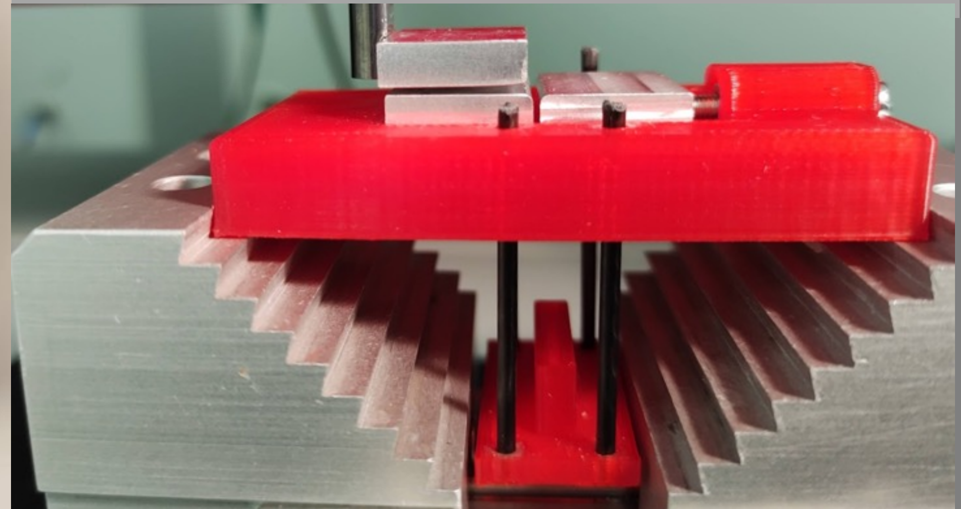
M. Šuljić, "The Novel ALICE Inner Tracking System (ITS3) Based on Truly Cylindrical, Wafer-scaled Monolithic Active Pixel Sensors, VERTEX2020, https://journals.jps.jp/doi/10.7566/JPSCP.34.010011

ALICE ITS3 WP4: thinning, bending, interconnect

University of South-Eastern Norway



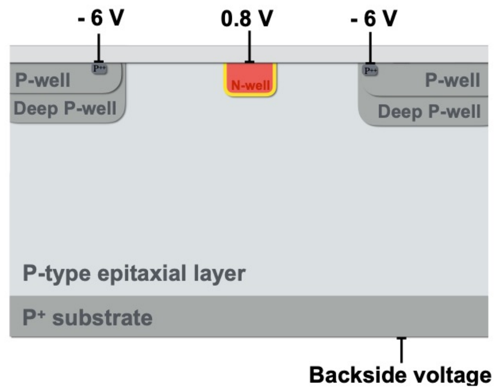
Silicon Deep Reactive Ion Etching (DRIE) in the ranges of 20,30,50,56μm

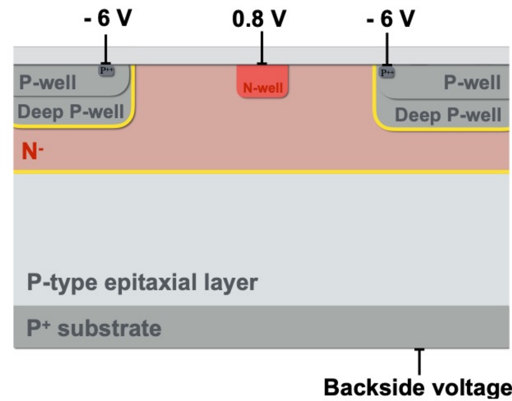


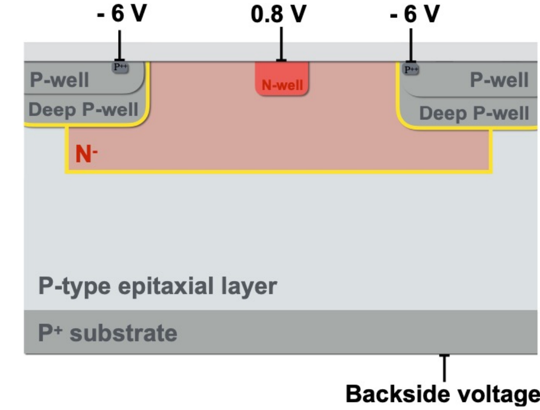
ALPIDE (Die) strength testing

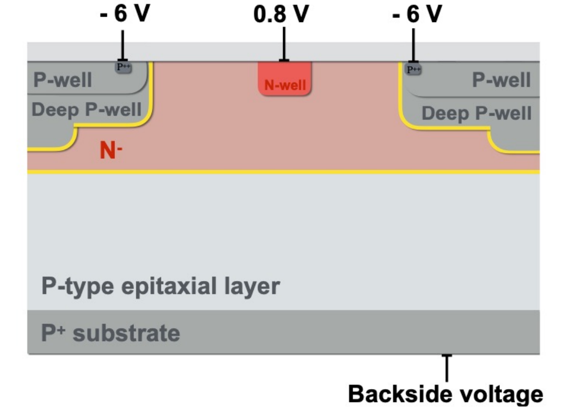
Curved and interconnected ALPIDE

Improved timing and radiation tolerance – full depletion





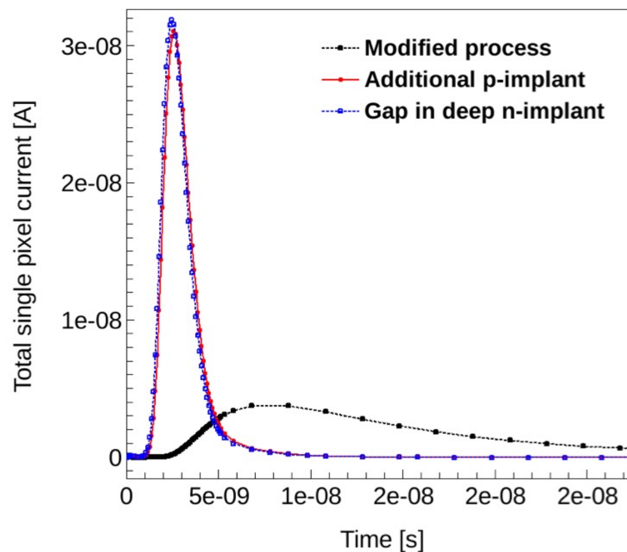


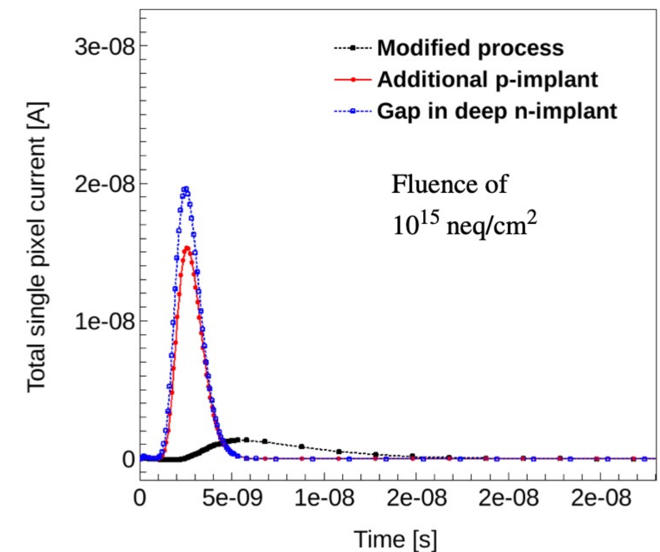


TCAD simulations for 180 nm process

10^{15} neq/cm^2 demonstrated for 180 nm

Needs to be verified for 65 nm





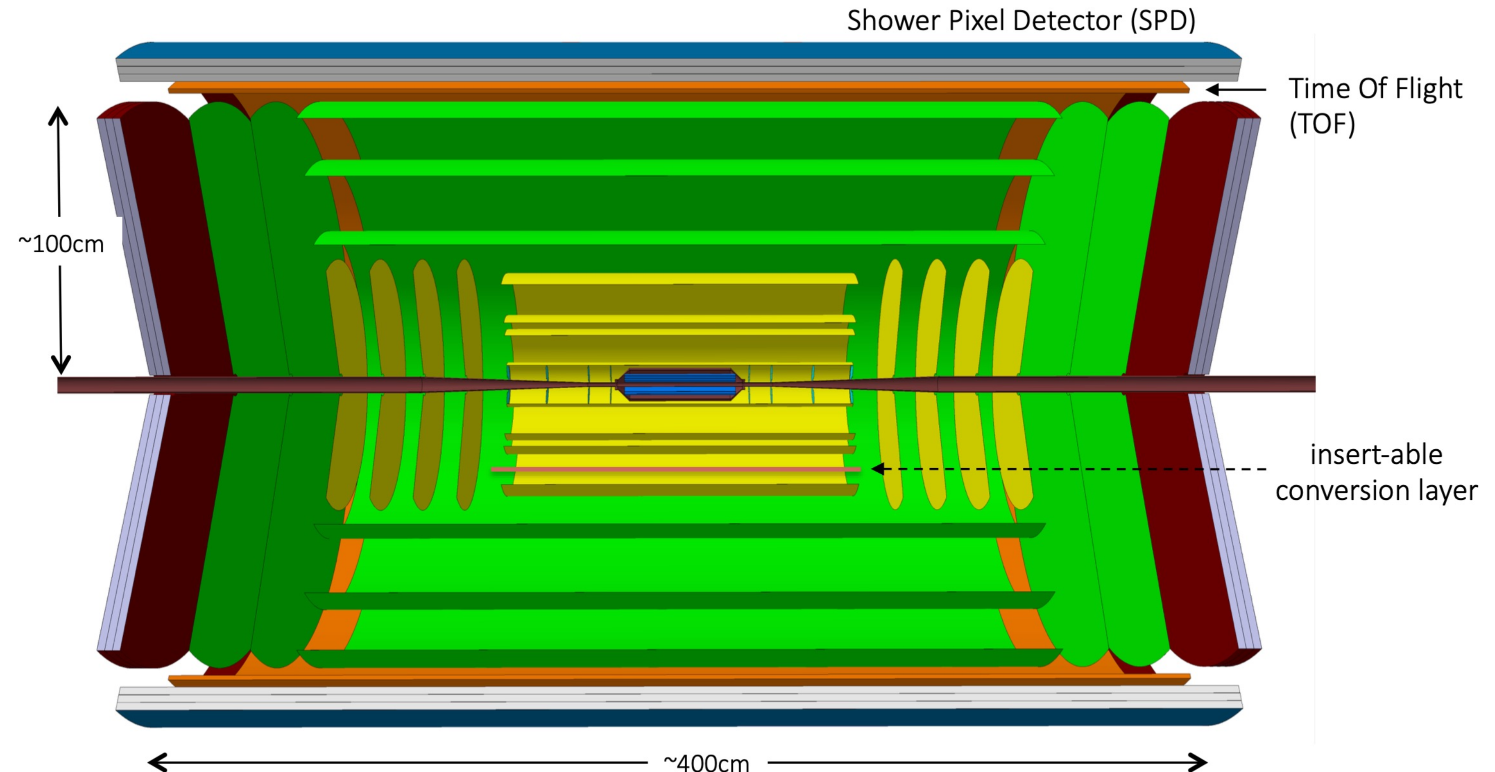
Munker et al., 2019 *JINST* **14** C05013
https://doi.org/10.1088/1748-0221/14/05/C05013
Pernegger et al., 2017 *JINST* **12** P06008
https://doi.org/10.1088/1748-0221/12/06/P06008

Long-term activites

- Participate in the R&D for FoCal, ITS3, ALICE3
- Increase access to and knowledge of this technology in Norway

- Characterization of single MAPS, as well as bent, wafer-scale CMOS MAPS (mechanical, electrical, timing, energy resolution, radiation tolerance, simulations)
- Complex readout electronics required, both on-sensor and off-sensor

- Be open to synergies/opportunities with
  - Future ee-/eh-colliders, medical, space



A next-generation LHC heavy-ion experiment, http://arxiv.org/abs/1902.01211