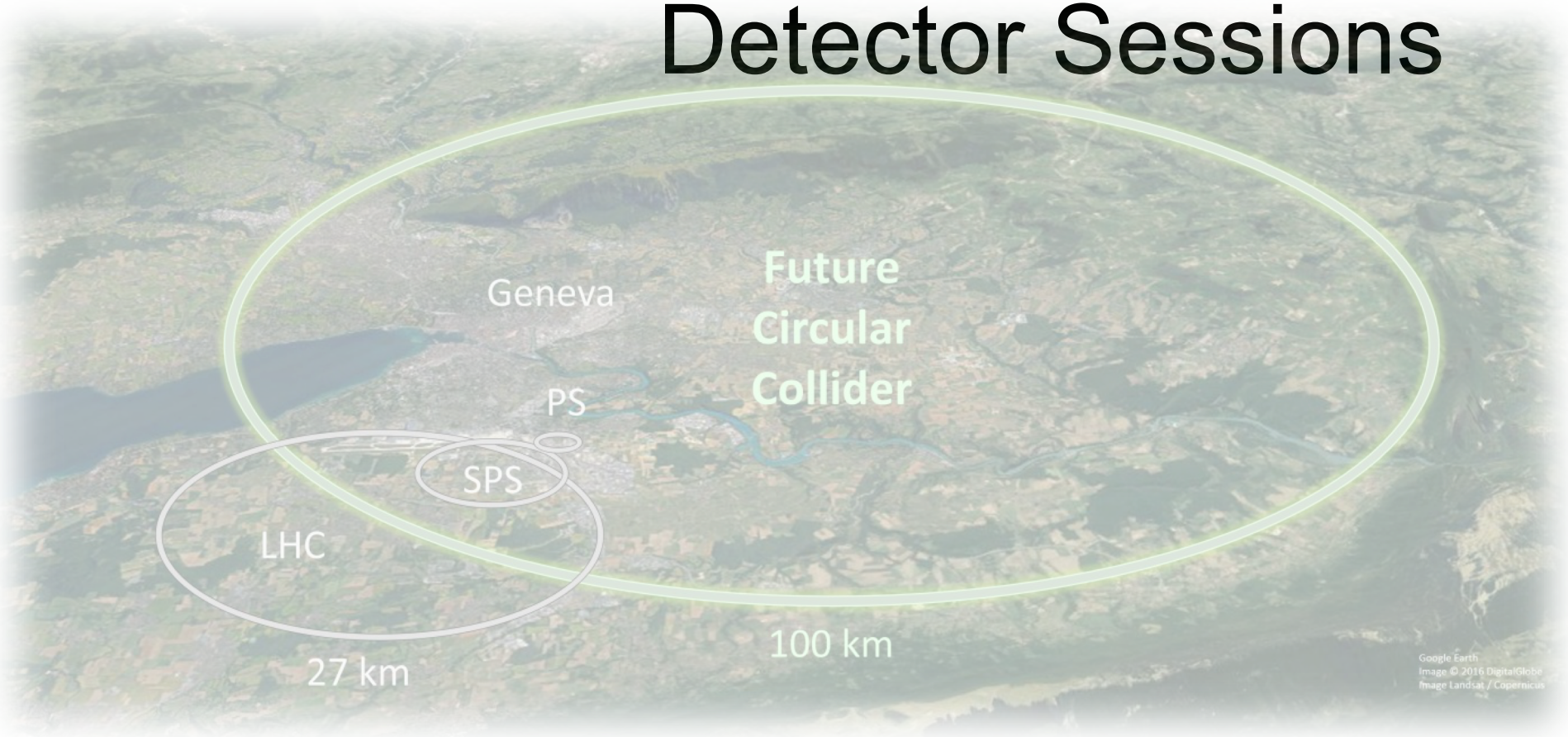
FUTURE CIRCULAR COLLIDER

Highlights of the Vertex Detector Sessions



4th FCC Physics & Experiments workshop

Auguste Besson, Paula Collins, Andreas Jung

Many thanks to all speakers of the sessions!

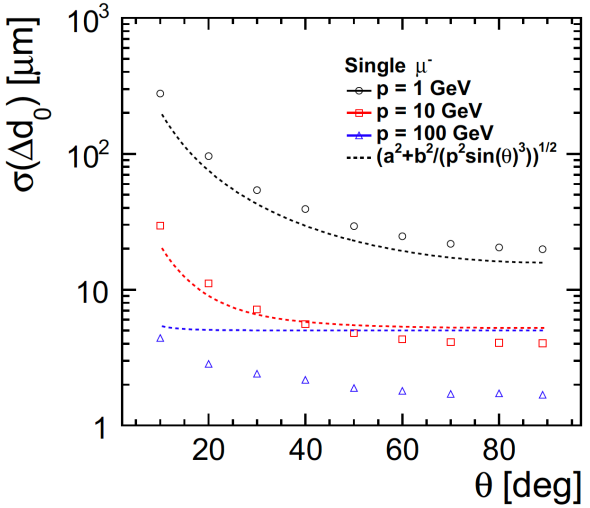
PURDUE UNIVERSITY

Nov 13th , 2020

Physics Drivers – see talks of P. Azzi, E. Perez during Monday's session

The challenge…

- ee experiment target track p_T and impact parameter resolutions of ≃ 1/5 LHC
  - → $\sigma(p_T)/p_T^2 \simeq 3 \times 10^{-5}$ GeV^{-1} (p ≤ 100 GeV)
  - → $\sigma(d_0)/d_0 \simeq$ 2 / 3-5 / 10 - 20 μm (100/10/1 GeV at 90°)
- R&D challenge
  - → ≃ 3 μm hit resolution with ≃ 0.2 % X_0 per layer (low multiple scattering) in pixel vertex detector
  - → Low power (no power pulsing); readout electronics integrate over < O(1 μs)
  - → New paradigm for stability/alignment/calibration due to immense statistics
- Starting point concepts: CLD and IDEA
  - → Typical quoted performance numbers for impact parameter resolution:



Impact parameter resolution:

$$\sigma_{d_0} = a \oplus \frac{b}{p \sin^{3/2}\theta}$$

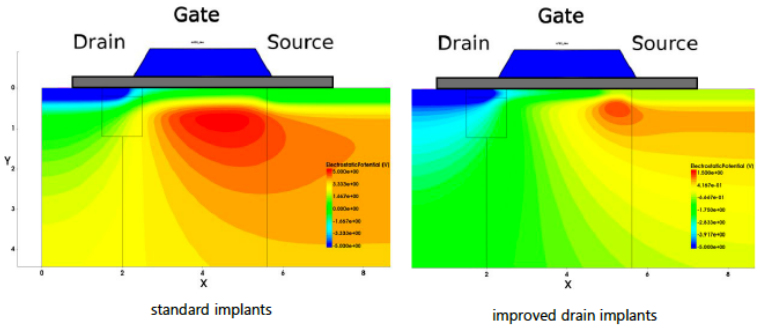
CLD: a ≃ 2 μm; b ≃ 20 μm

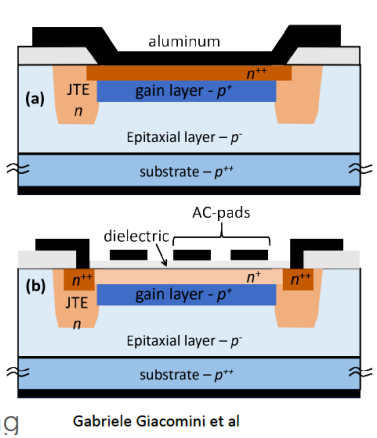
IDEA: a ≃ 2 μm; b ≃ 15 μm

ILD: a ≃ 5 μm; b ≃ 15 μm

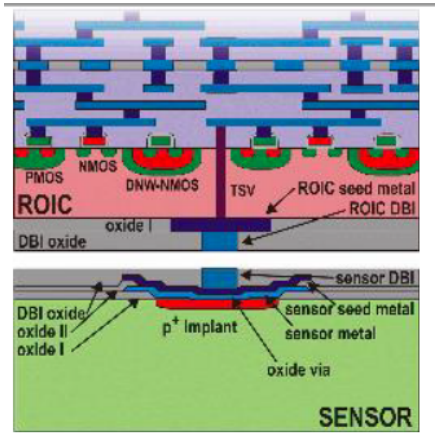
Strong ties to Foundries, allows…

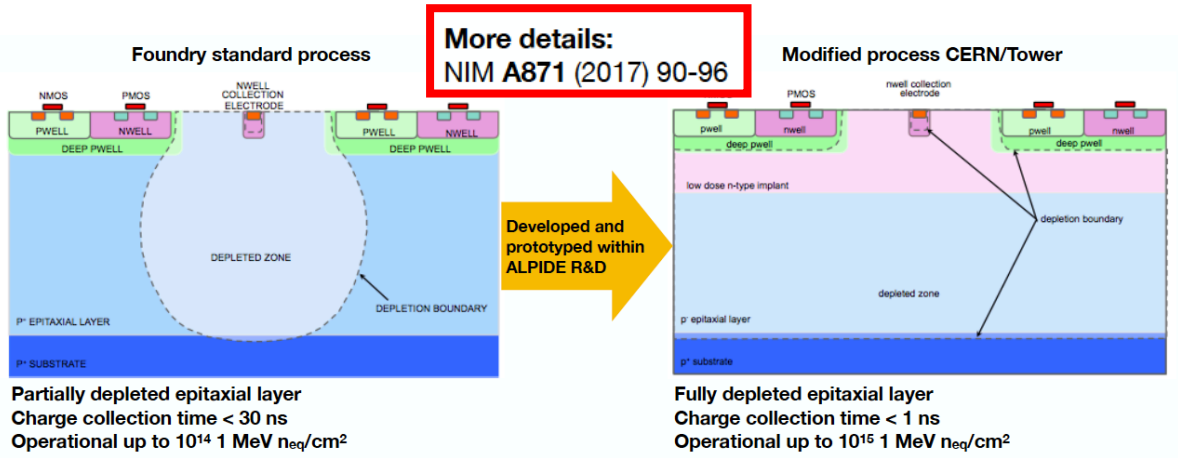
- Manipulation of the CMOS process to boost technology
  - Uniform epitaxial layers → speed & radiation hardness
  - Usage of larger wafers & stitching
  - 65nm technology: charge collection properties uncertain with thinner epitaxial layers
- DEPFET improvements: Better drain implants
- 3d integration (not 3D technology)
- LGADs and inverted LGADs
  - Smaller pixel possible but lots of power for time resolution → cooling ? mass ?





Gabriele Giacomini et al



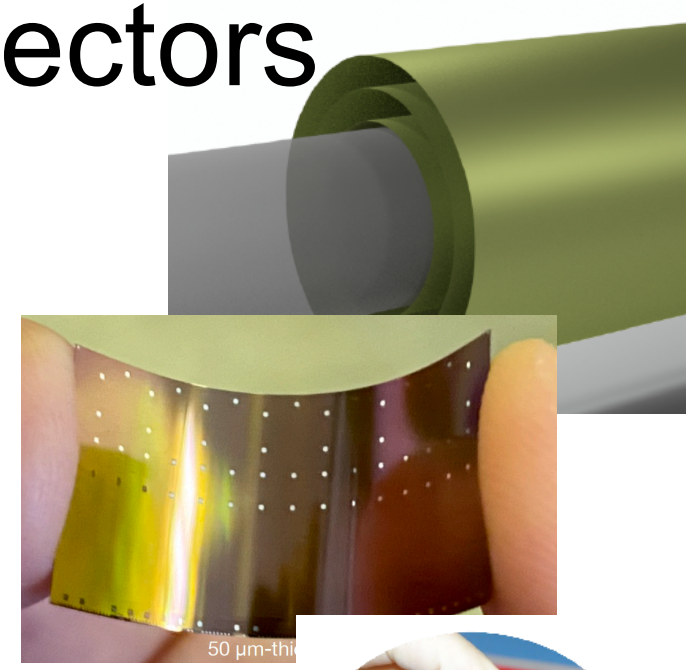


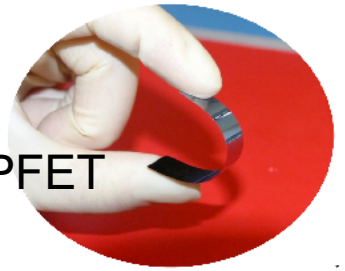
Partially depleted epitaxial layer
Charge collection time < 30 ns
Operational up to 10^{14} 1 MeV n_{eq}/cm^2

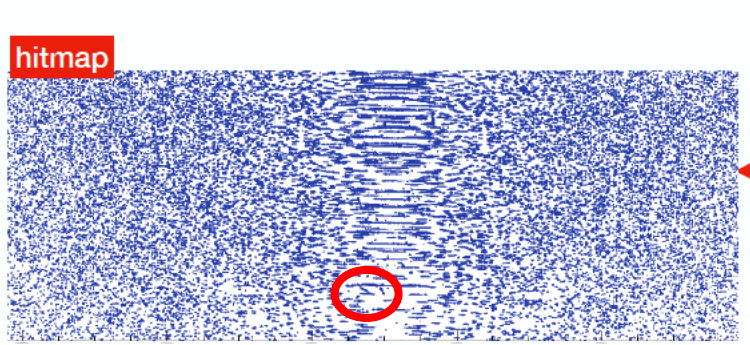
Fully depleted epitaxial layer
Charge collection time < 1 ns
Operational up to 10^{15} 1 MeV n_{eq}/cm^2

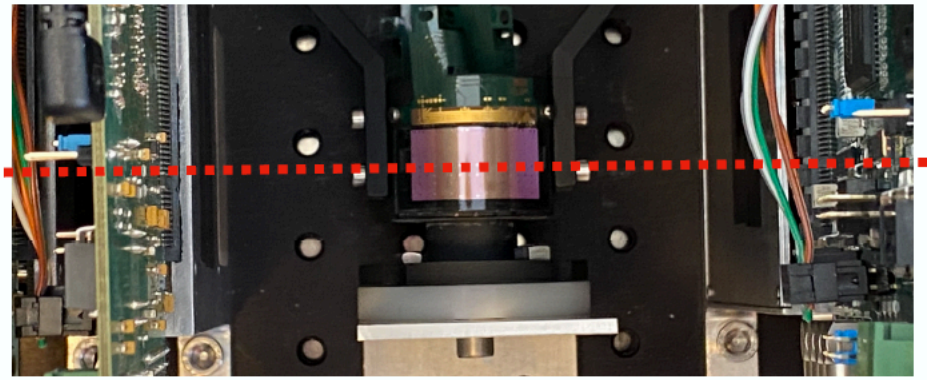
Very thin silicon detectors

- Bent ALPIDE (M. Mager) and the “golden detector” (ITS3)
- ALPIDE: amazing test beam results
  - Challenges remain, bending influences electric parameter
- DEPFETs are also bendable (L. Andricek)
- Allows very minimalistic support structures, i.e. almost “none”



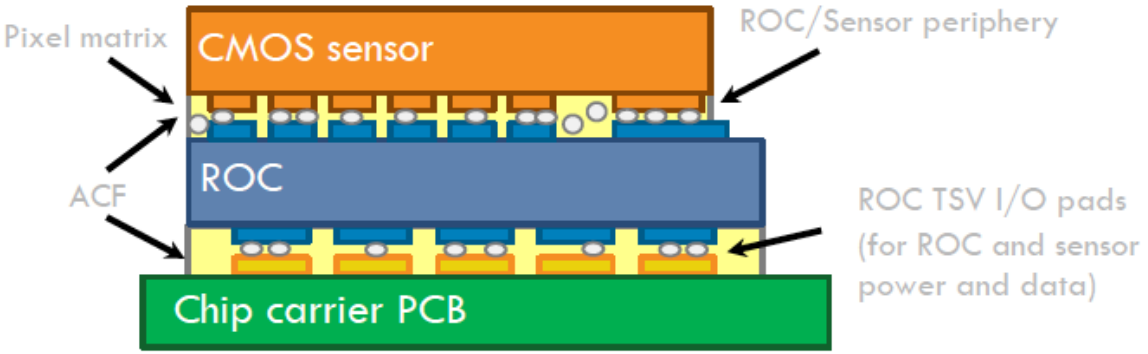


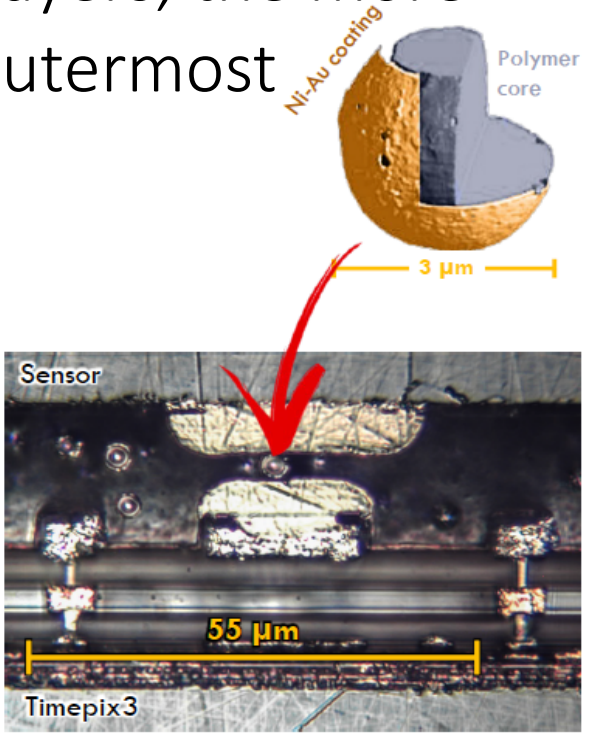




Hybridization

- While MAPS/CMOS is perfect for innermost layers, the more "classic" hybrid detectors still an option for outermost
  - Bonding forces doable, but yield remains low for now
  - Very small bond layers, almost like 3D integration…





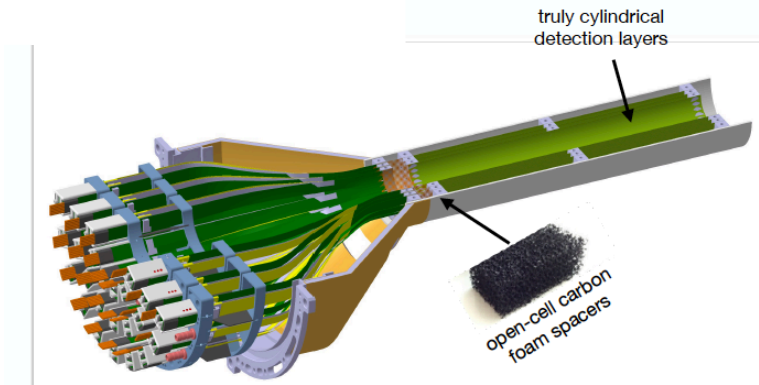
- Can this technology be a solution for interconnecting the ends of ALPIDE ladders?

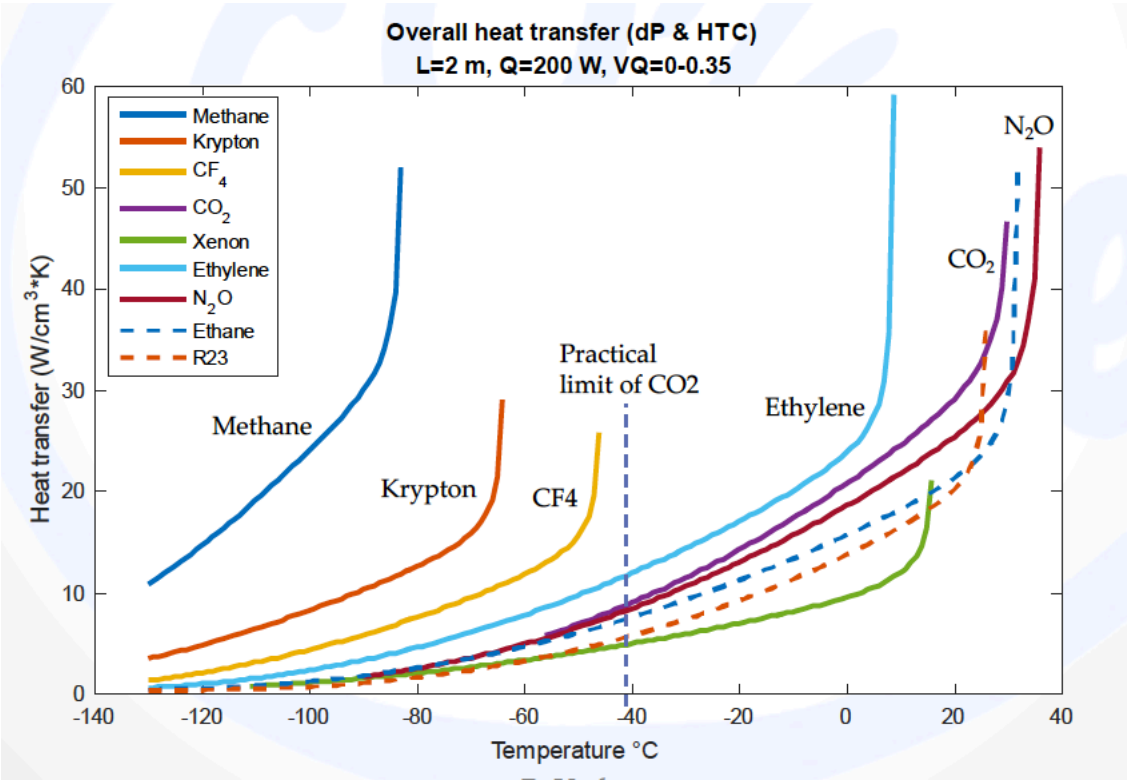
Cooling & support structures

- Reached the limit for cold CO2 technology
- Further improvement if power densities require it:
  - Super-critical krypton cooling (around -60C)

•…but air cooling the “weapon of choice” as long as power densities are low enough (see talk by M.Vos)

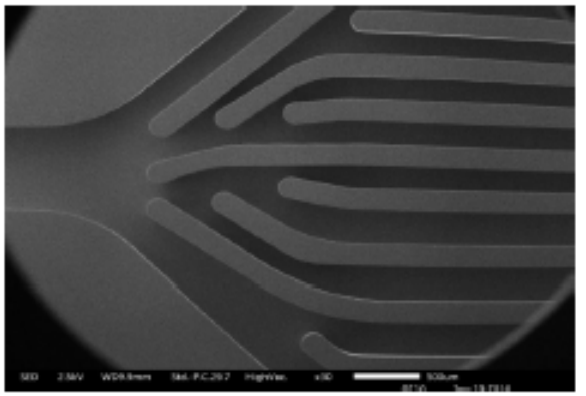
- Little to no support mass needed, example ALICE ITS3
- Can we dream ? 1st layer of vertex detector into beam pipe
- Beam current shield vs. beam pipe mass

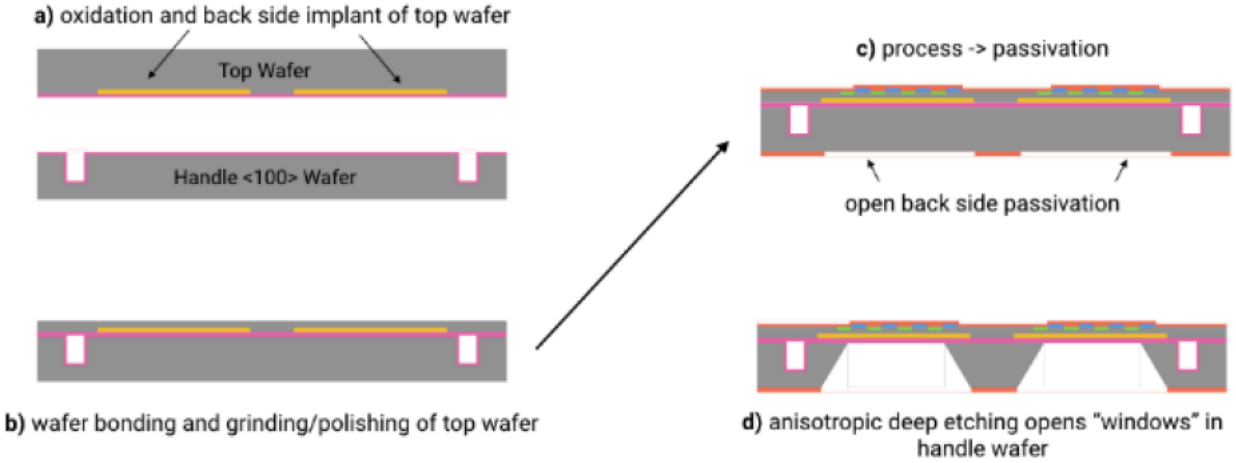


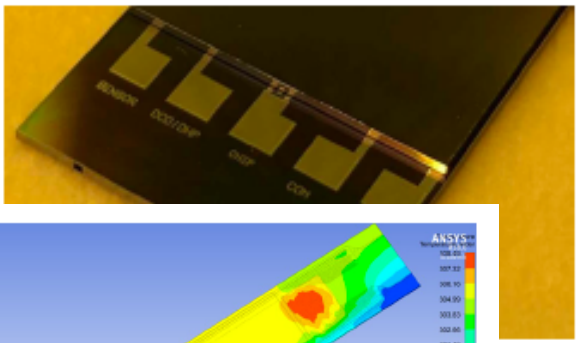


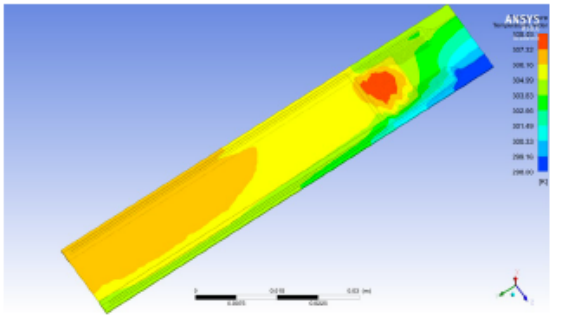
Micro-channel cooling

- Microchannel cooling is established to perform as expected by LHCb, now possible to consider for
  - DEPFETs (L. Andricek)
  - SOI (M.Vos in tracker session)









Cavity SOI process: can be adapted to any traditional silicon detector

Summary^2

- Really shouldn't do another summary, but truly exciting new technologies – very impressive progress
    - Technologies are up for the challenge…

Many thanks to Paula for input and a speedy recovery for Auguste!