MAPS@Nikhef

And the role of FASTER

Nikhef

ALESSANDRO GRELLI
JORY SONNEVELD

From FASTER WP1.1

However, to progress to a fully functional, low-power chip with 20 picoseconds time resolution coping with the extreme radiation environment of the high luminosity LHC [4], a large R&D effort is still necessary where characterisation is one of the pillars. The characterisation work is envisaged to be subdivided in two main branches:

- Detailed in-house lasers studies on the timing performance of available MAPS analog pixel structures developed in the 65 nm technology node. The work will be followed by a **detailed** characterisation of the structures discussed in detail in **research line 2**.
- Characterisation at accelerator facilities and x-ray irradiation facilities of the already available and future timing structures. On this point we aim to exploit the existing collaborations with ALICE and CERN EP R&D WP 1.2 to profit of joint test-beam campaigns and therefore rationalising the efforts.

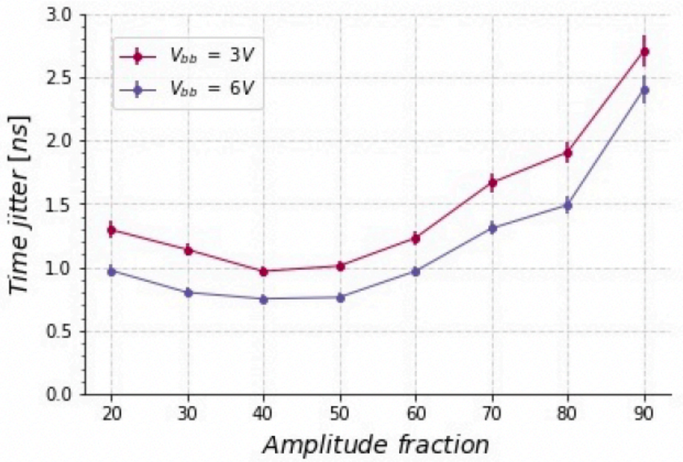

Figure 6: Temporal resolution for various percentages of total signal for the ALICE investigator chip.

The combination of the laser, x-ray an accelerator beam studies in realistic conditions of fluence, performed at different temperatures will grant viable information on the degradation of the sensor. The results of the characterisation will be used to benchmark detailed simulations and, therefore, to improve modelling with the final goal of gathering fundamental insight on the necessary design improvements in order to meet the timing requirement while keeping high-spatial resolution and low-power.

☑ MAPS In house characterisation for timing and radiation hardness

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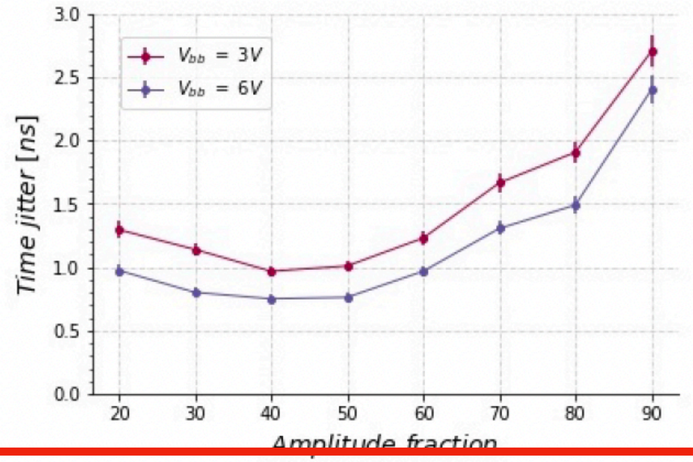

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- ☑ MAPS In house characterisation for timing and radiation hardness
- ☑ MAPS characterisation for timing and radiation hardness at beam facilities

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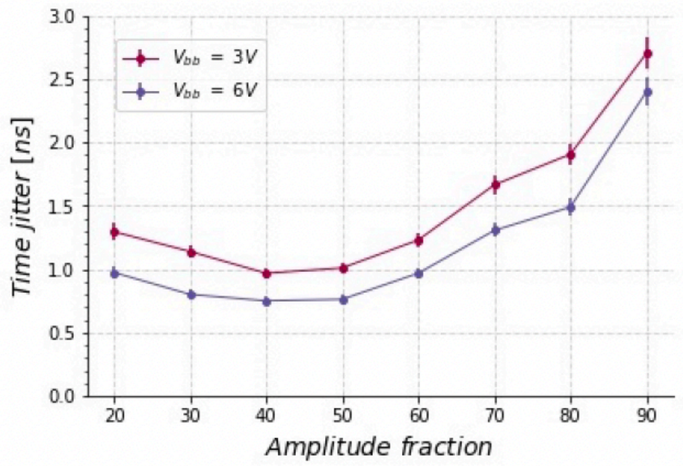

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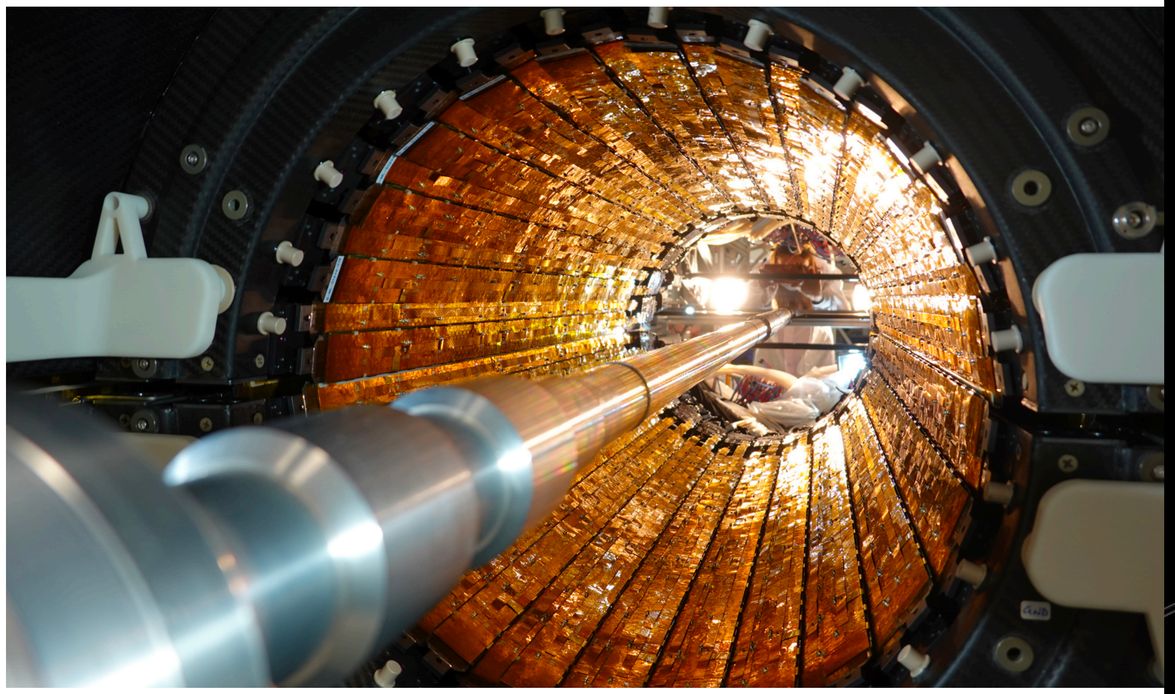
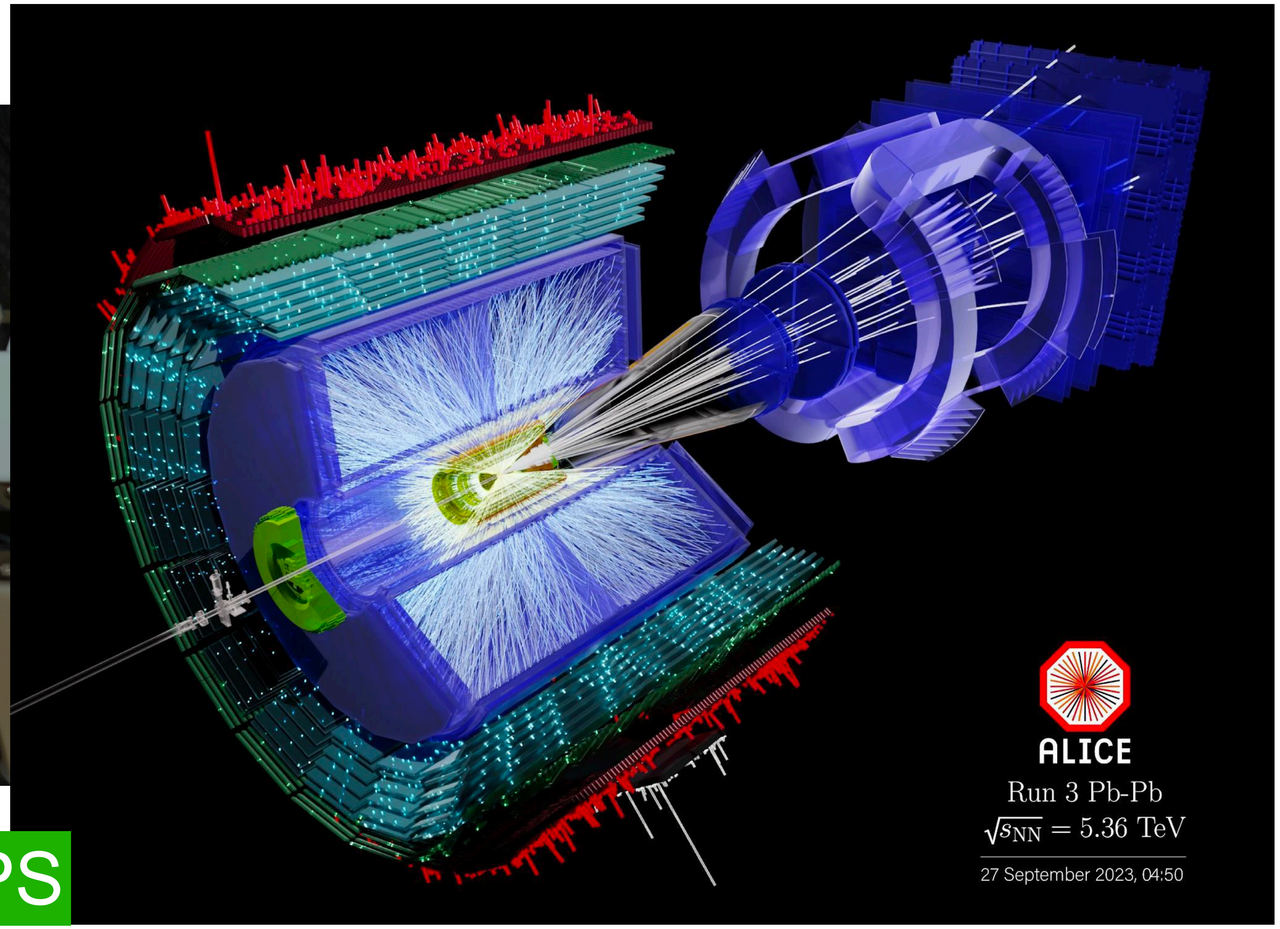
- ☑ MAPS In house characterisation for timing and radiation hardness
- ☑ MAPS characterisation for timing and radiation hardness at beam facilities
- ☑ Applications for ALICE3 and beyond (blue sky)

MAPS @ALICE

Status in 2020: ALICE ITS2



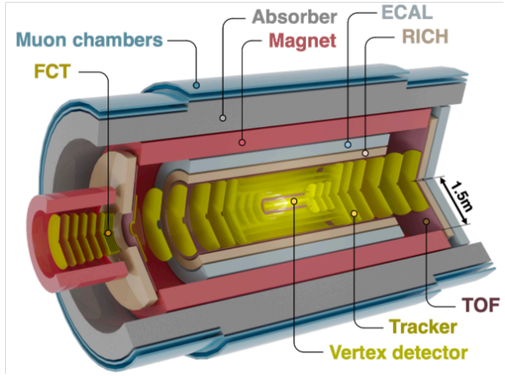


Largest tracker ever built with MAPS

Long term goal: ALICE3

Status in 2020

2034



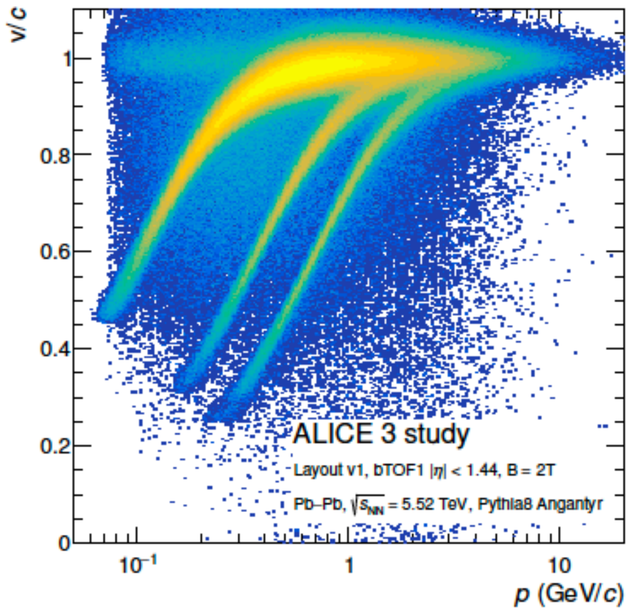
Requirements: Radiation >~5x10^{15}, 20-50 ps, xy pointing resolution @1 GeV/c of 4μm

Why those requirements?

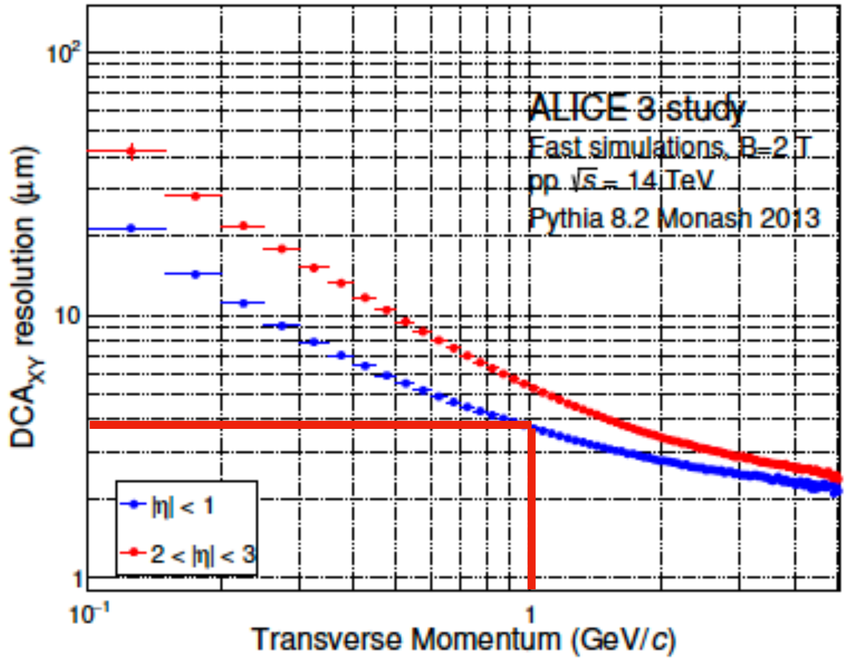
☑ Among the others ALICE3 aims to:

- ✓ Investigate chiral symmetry restoration (*you need very low momentum tracks*)
- ✓ Investigate multi-charm hadrons (*you need state of heart pointing resolution and particle identification, PID*)

PID via time-of flight, 20-50ps resolution

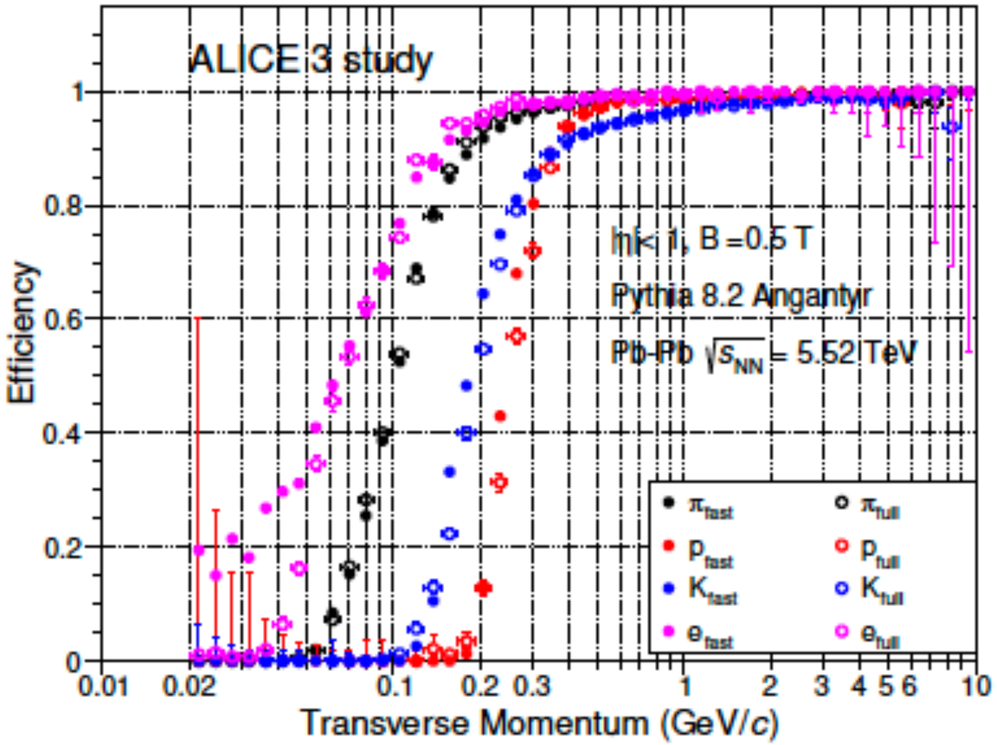


Pointing @~4mum at 1 GeV, need low material budget

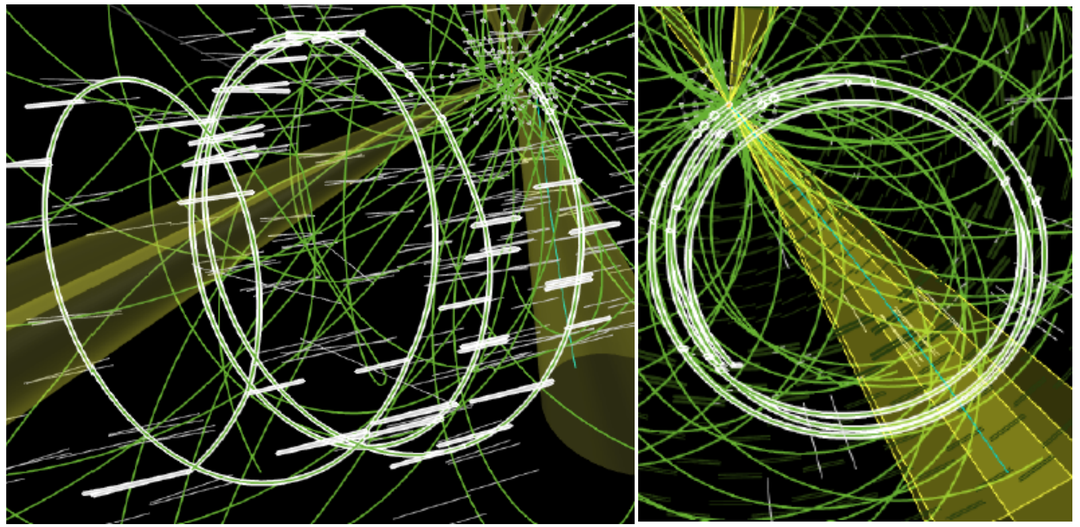


Why those requirements?

☑ And, most importantly needs to track till unprecedented low momentum (*requires low material budget, timing(?)*)



Just an example of loopers … actually from CMS



☑ Can time information help? i.e can we tag loopers?

Status (ALICE related MAPS)

Status in 2020

2021 - ….

R&D radiation hardness/speed

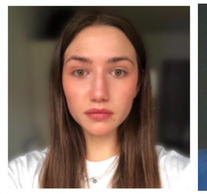
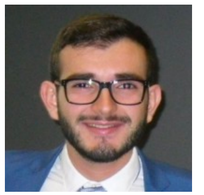
Our PhDs



2021 - ….

R&D timing

Our PhDs

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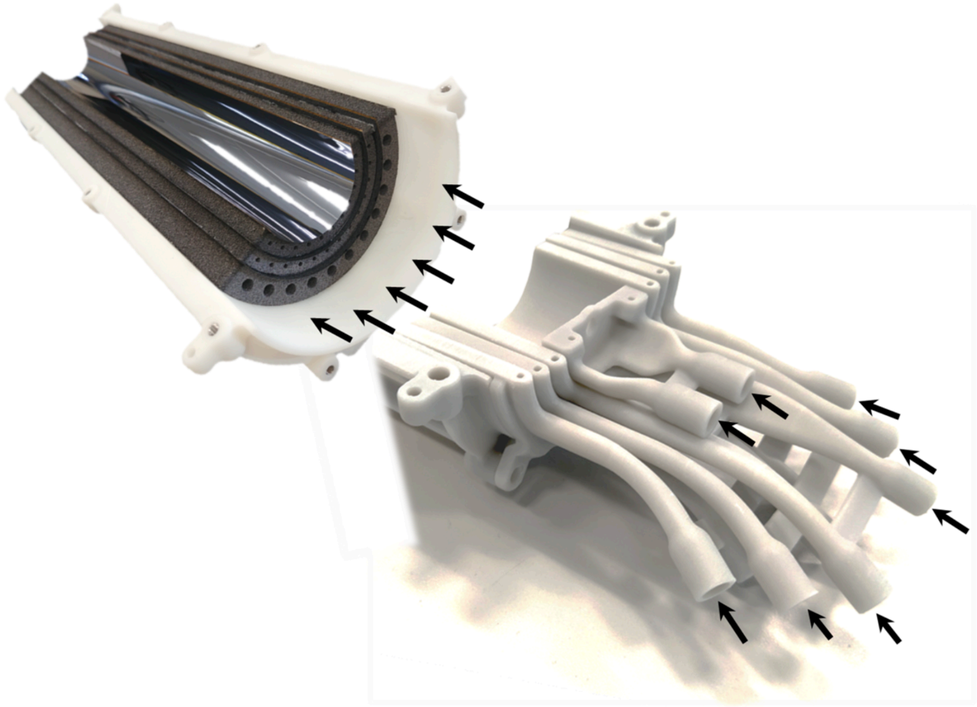
And of course thanks to all the R&D, ET and UU staff involved!

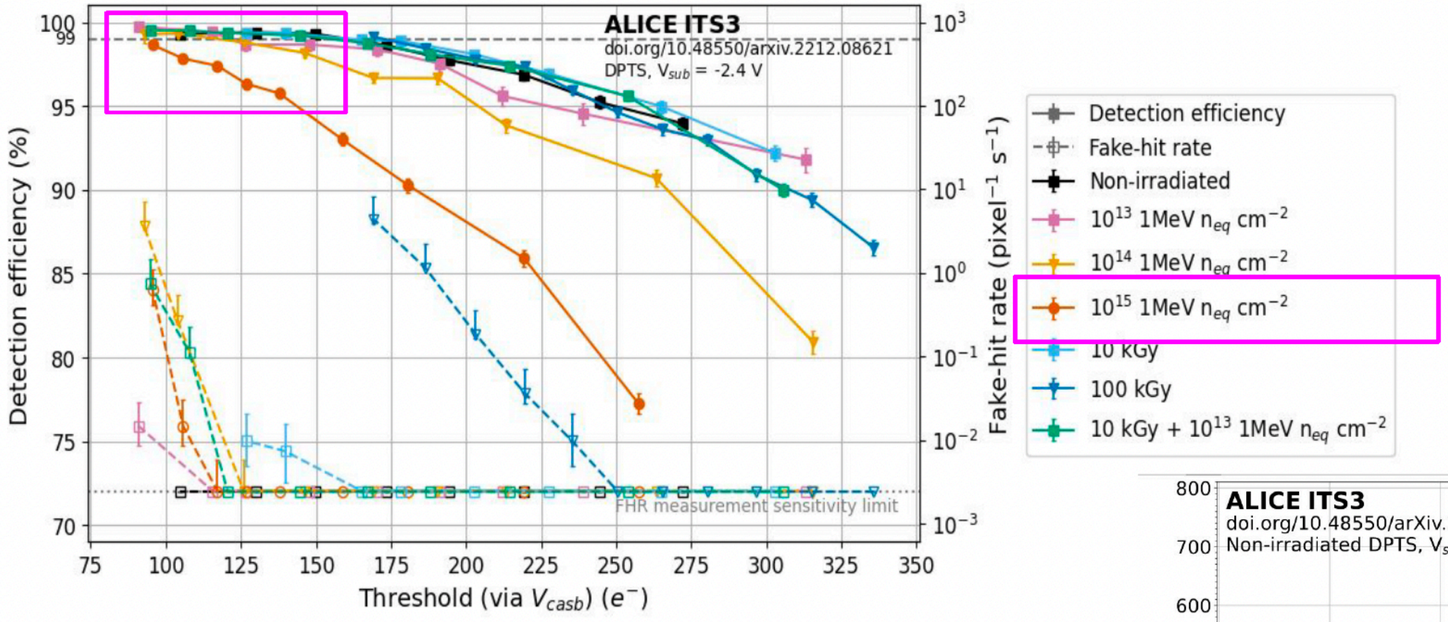
Radiation hardness and time resolution

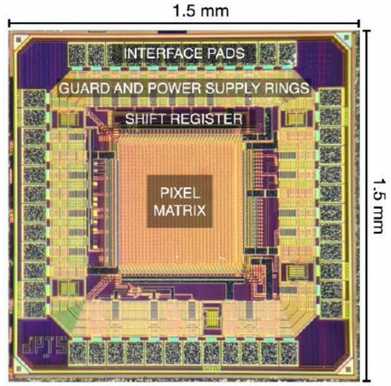
The impulse behind R&D: ITS3



- ☑ ITS3: 3 layers of vertex tracker
- ☑ Material budget: 0.05%X_0
- ☑ 15μm at p_T = 1 GeV/c pointing resolution
- ☑ Low power -> air cooling
- ☑ Truly cylindrical: minimal support frame

Status at Nikhef (DPTS)



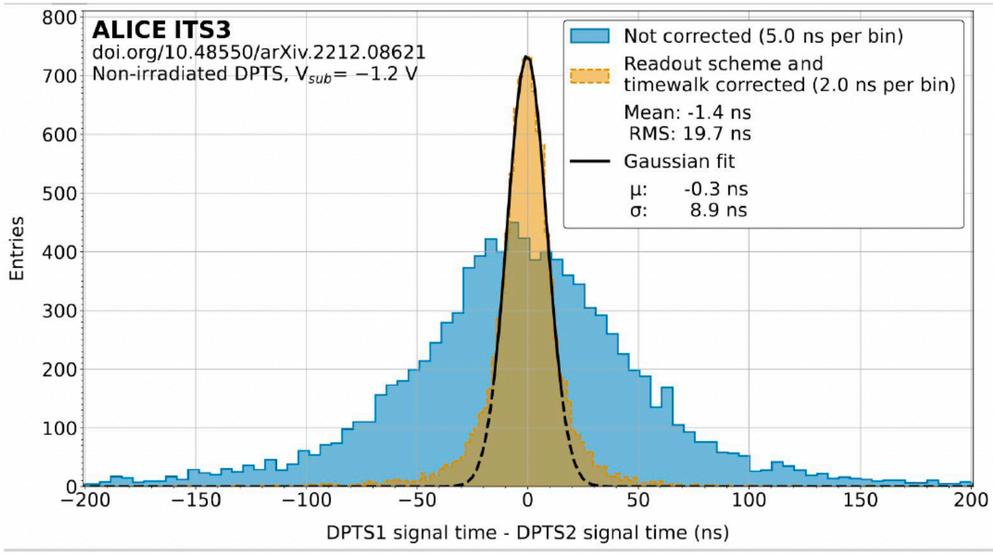


Results published in

doi:10.48550/arXiv.2212.08621

Efficient at room temperature after 100 ✕ ITS3 fluence

- Operated at room temperature!
- 100% efficient after ITS3 fluence
- **Sensor still operable at 99% efficiency at 20°C after $\Phi_{eq} = 10^{15}$ / cm^2**



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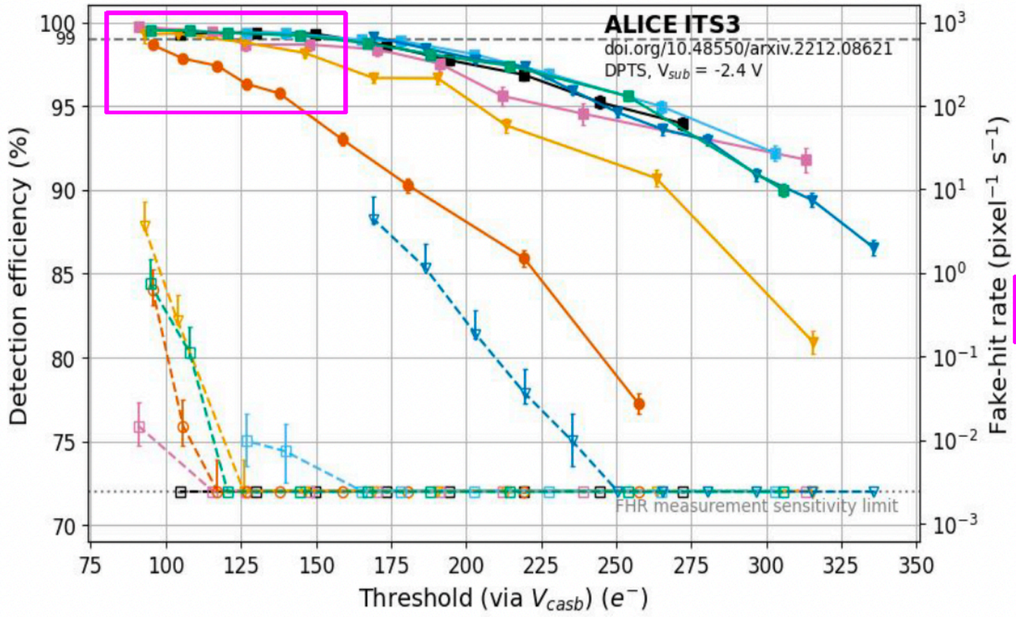

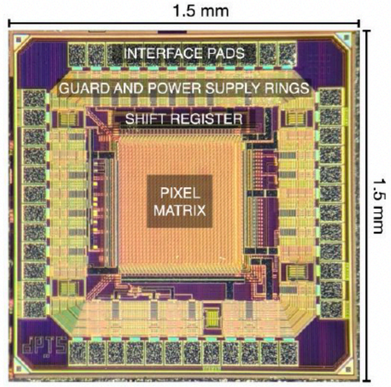

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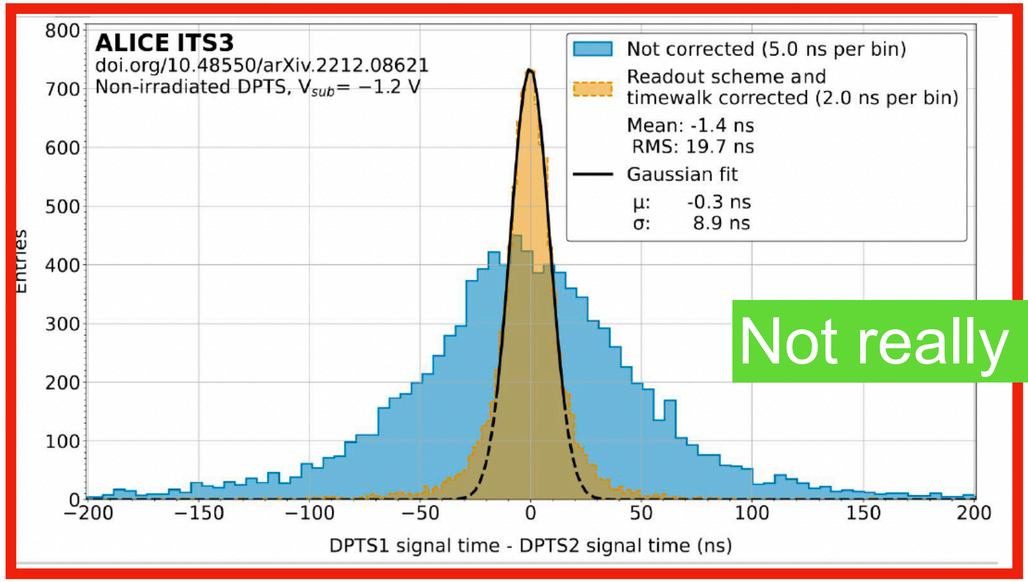
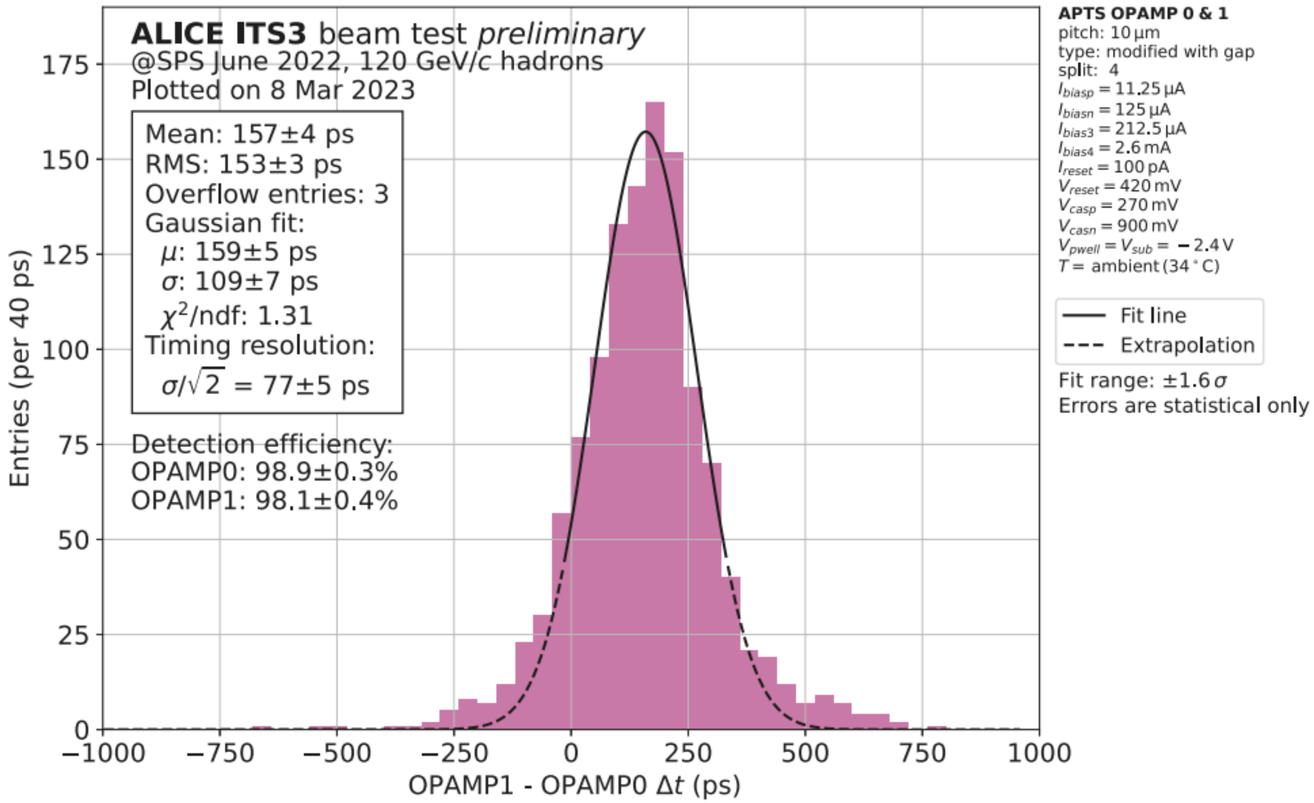
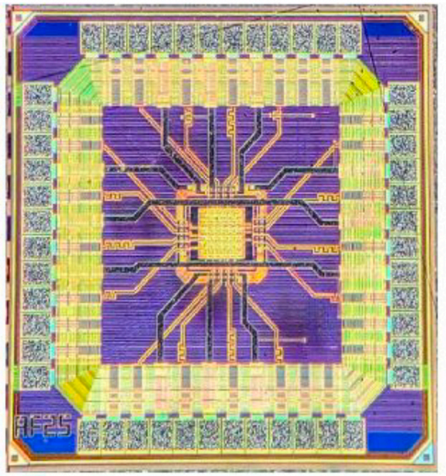


Not really that fast

Status at Nikhef (APTS)





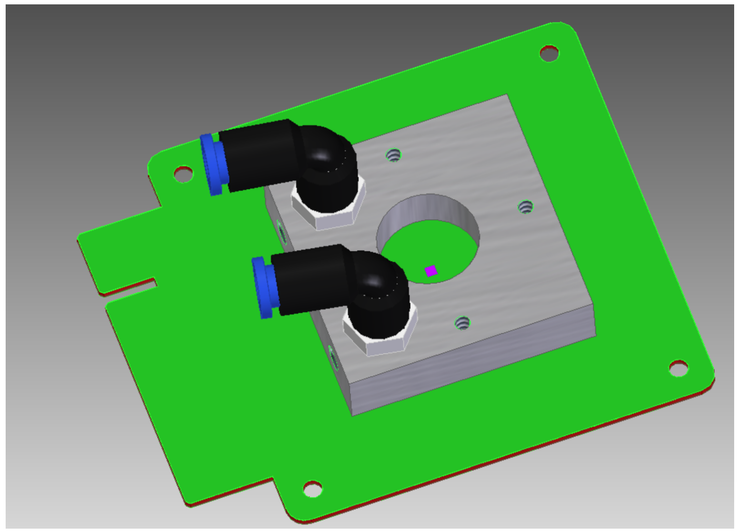
matrix: 6x6 pixels
readout: direct analogue readout of central 4x4
pitch: 10, 15, 20, 25 µm
process: all 3 variants
total: 34 dies

☑ ~70 picoseconds resolution at pixel level

Status at Nikhef (APTS)

Isis @faster

- ☑ APTS opamp sensors irradiated at 5x10^{15} and 10^{16} sent @Nikhef. *Are they alive?*
  Quite an interesting characterisation ahead



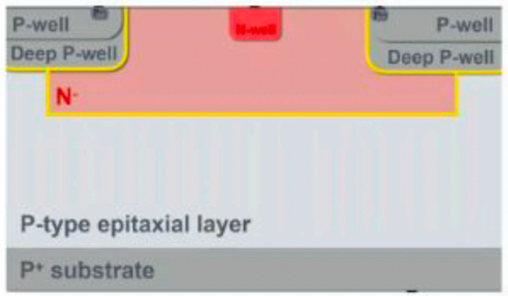
- ☑ And a nice startup project!

Status at Nikhef (TCad)

Can we find a smart way to be below 20ps?

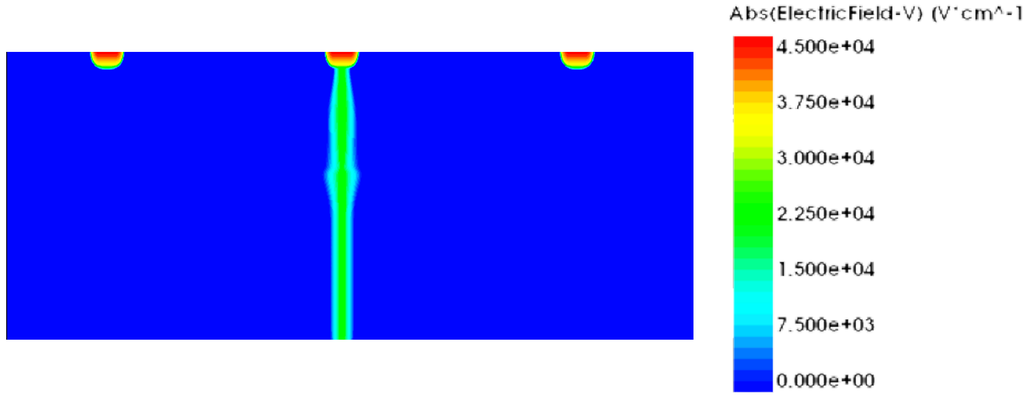
- ☑ With the actual production process seems ~70ps (pixel level) is close to the limit.
- ☑ How to progress further?

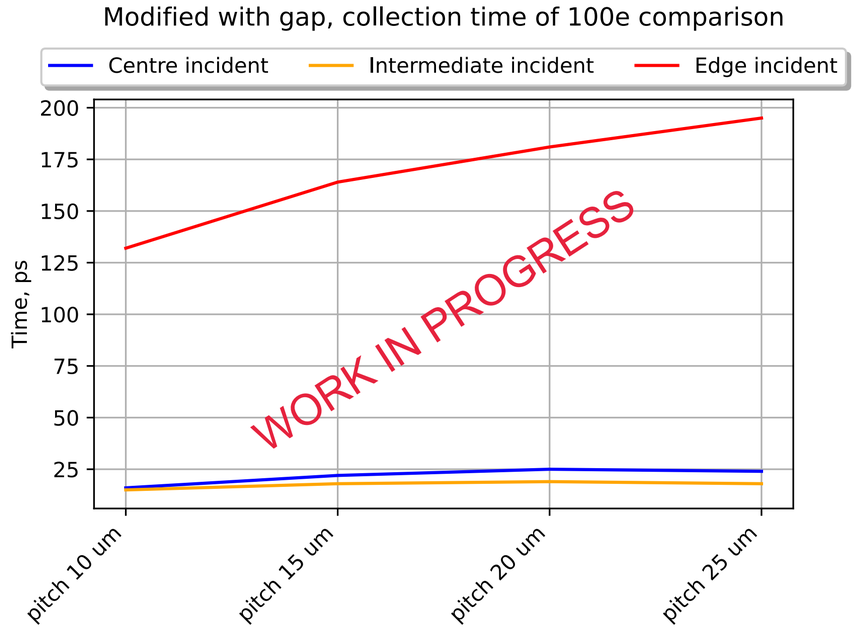
70 ps ⟶ <~20 ps

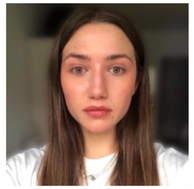


Gap in deep n-implant, 65nm :

?

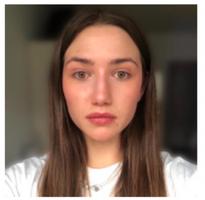




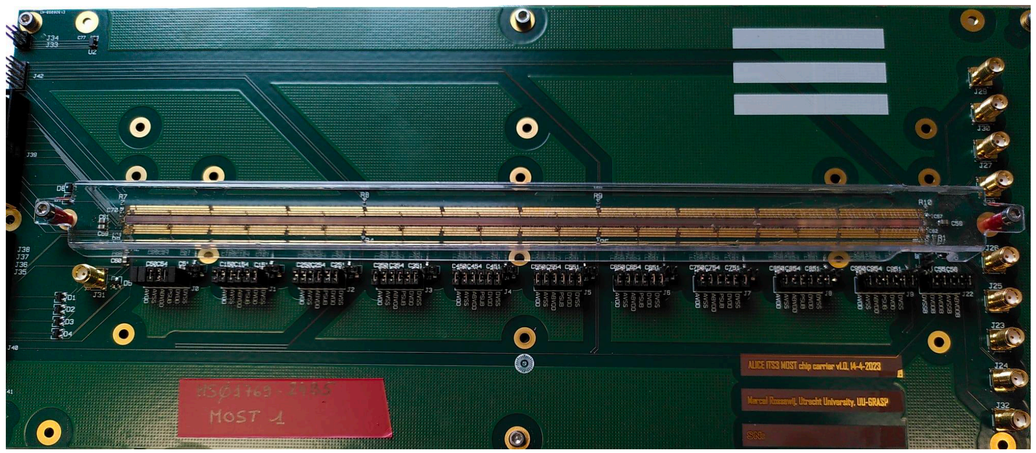


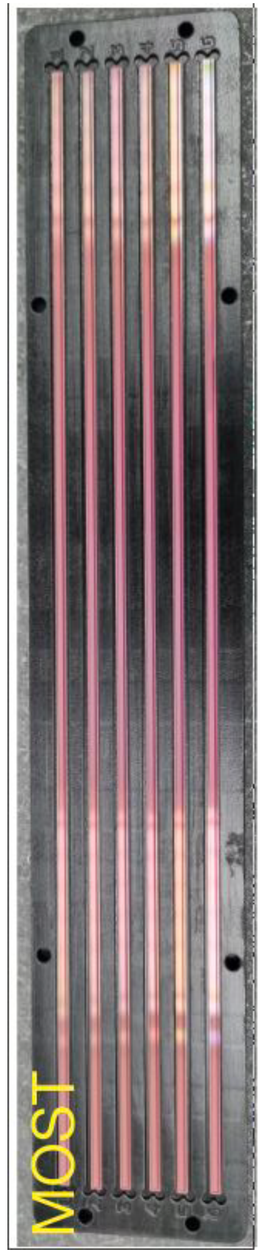
- ☑ Investigate new geometries for improved/faster charge collection

Status at Nikhef (MOST)



- First MAPS for high energy physics using stitching
- First full structures at Nikhef
- “MOST”: 2.5 x 259 mm, 0.9 MPixel (18 x 18 μm^2)
- Carrier board designed at Nikhef/Utrecht





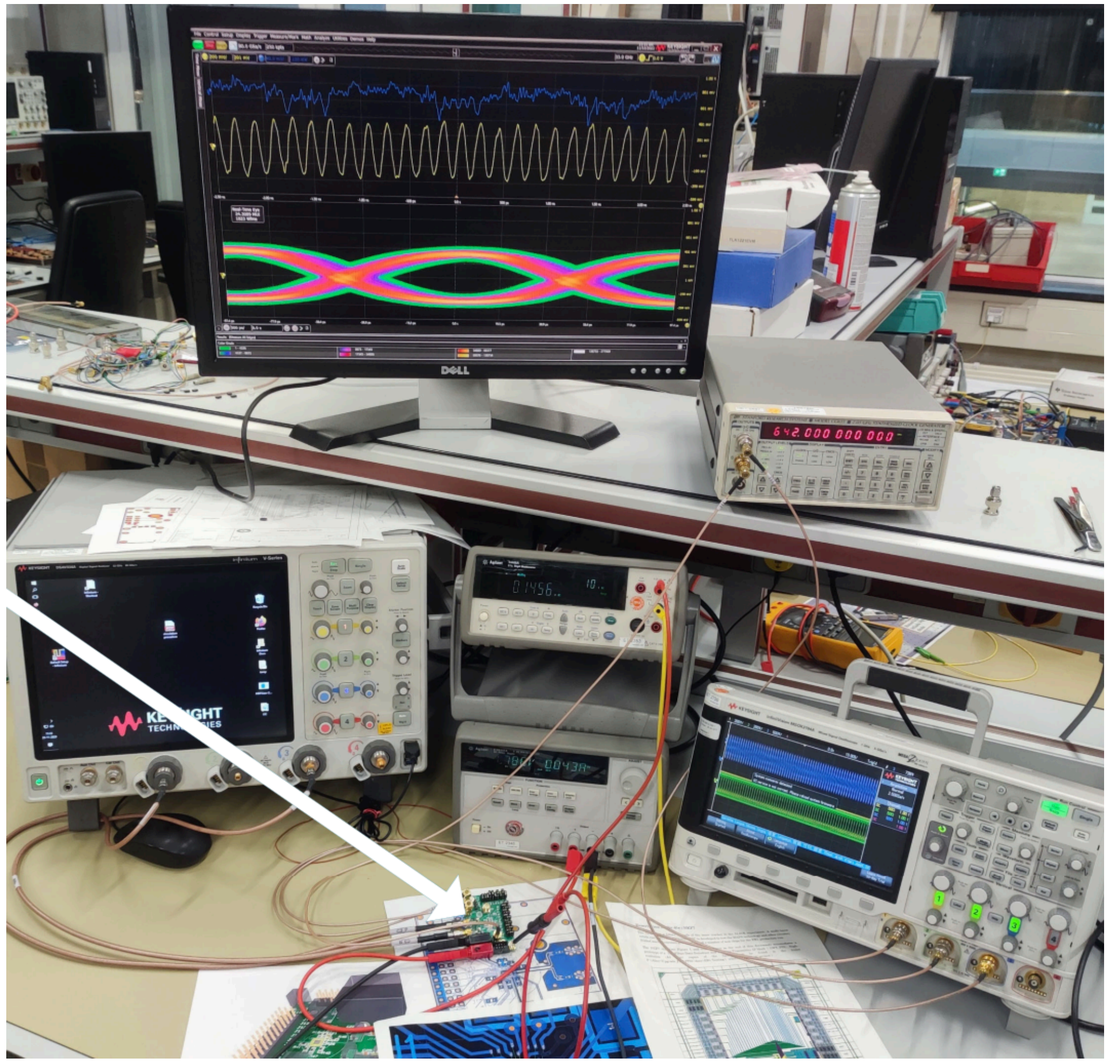
☑ Characterisation of MOST starting at Nikhef: does the stitching process work? How powering works on 20cm lines? What is the time performance?

Data rate

Serialiser @10Gb/s

- ☑ Nikhef responsible for the ITS3 serialiser (10 Gb/s)
- ☑ Analog blocks designed last submission and under characterisation
- ☑ Full serialiser to be completed by 2024

Thanks to the ET team!



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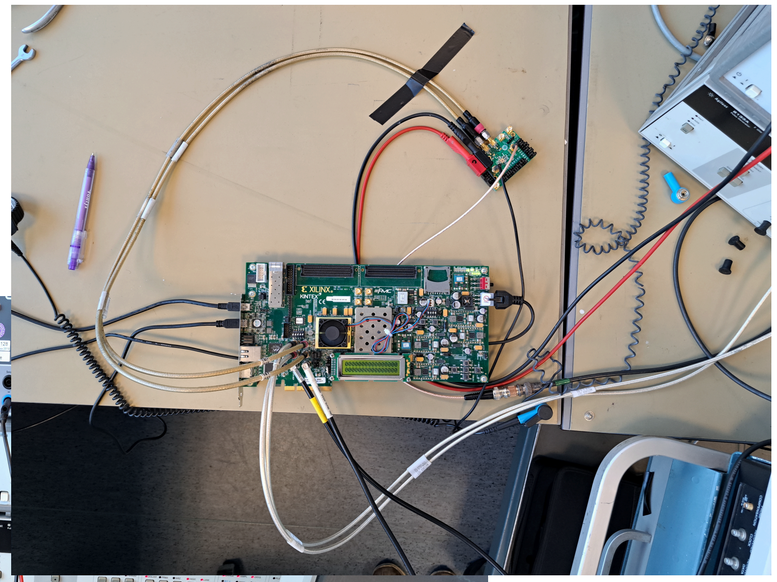
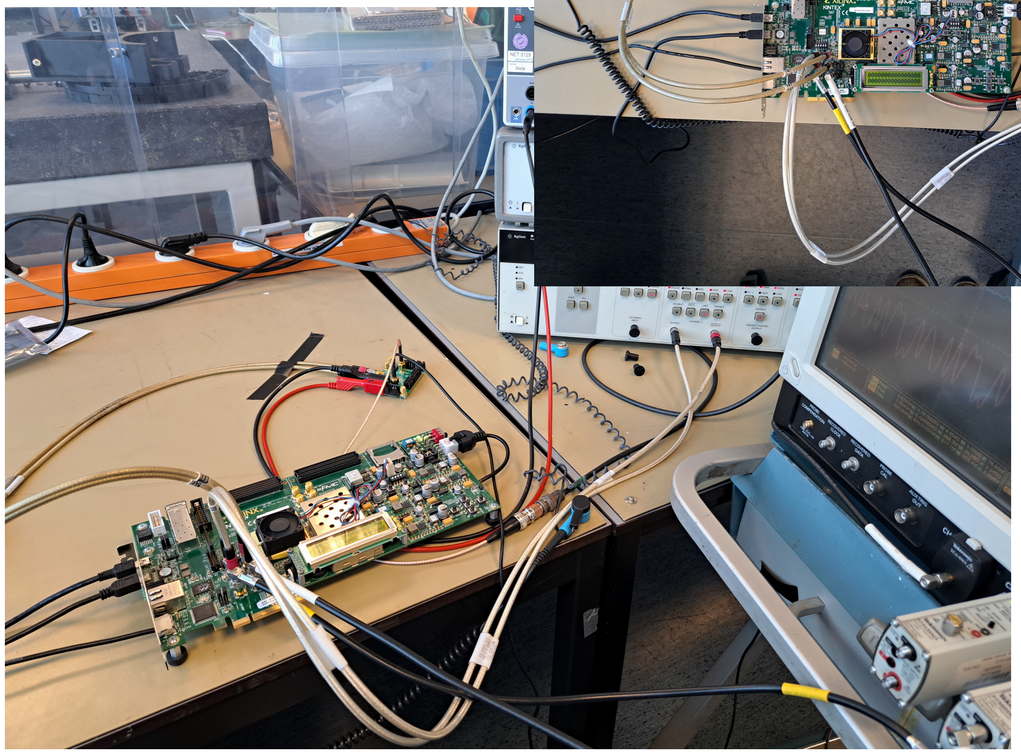




- ☑ Bit error rate tested in ideal situation (no jitter), proved to be **< 10^{-15}**
- ☑ Jitter simulation will be included as soon as the new structures will be bonded (~this week)
- ☑ Test beam for single event upset under preparation

In summary

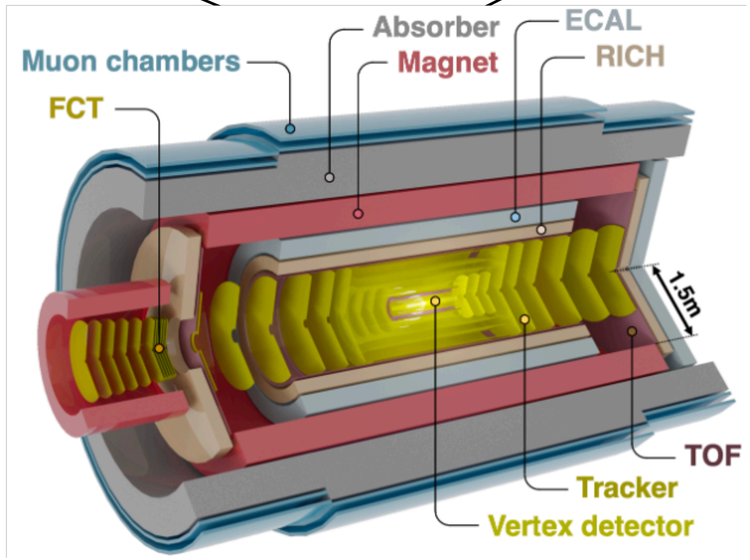
Long term goals

2021 - ….

R&D radiation hardness/speed

2021 - ….

R&D timing



2034

Long term goals

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R&D radiation hardness/speed

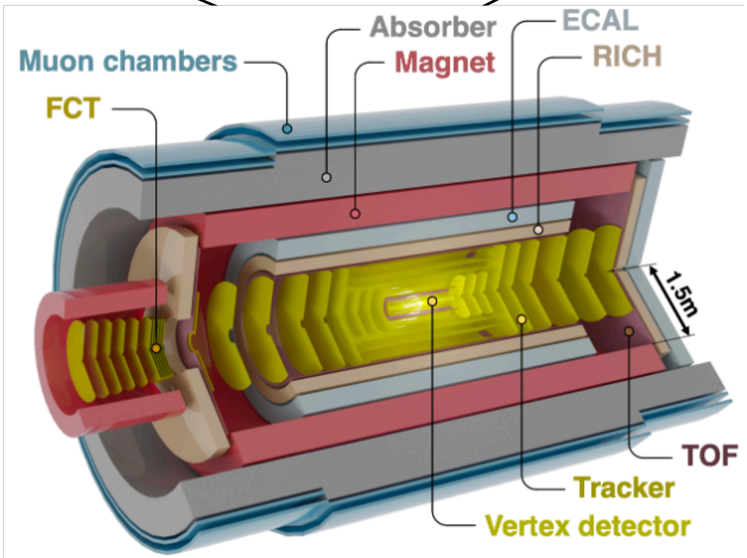
2021 - ….

R&D timing

Algorithmic developments

@FASTER

But this is a story for WP3



2034

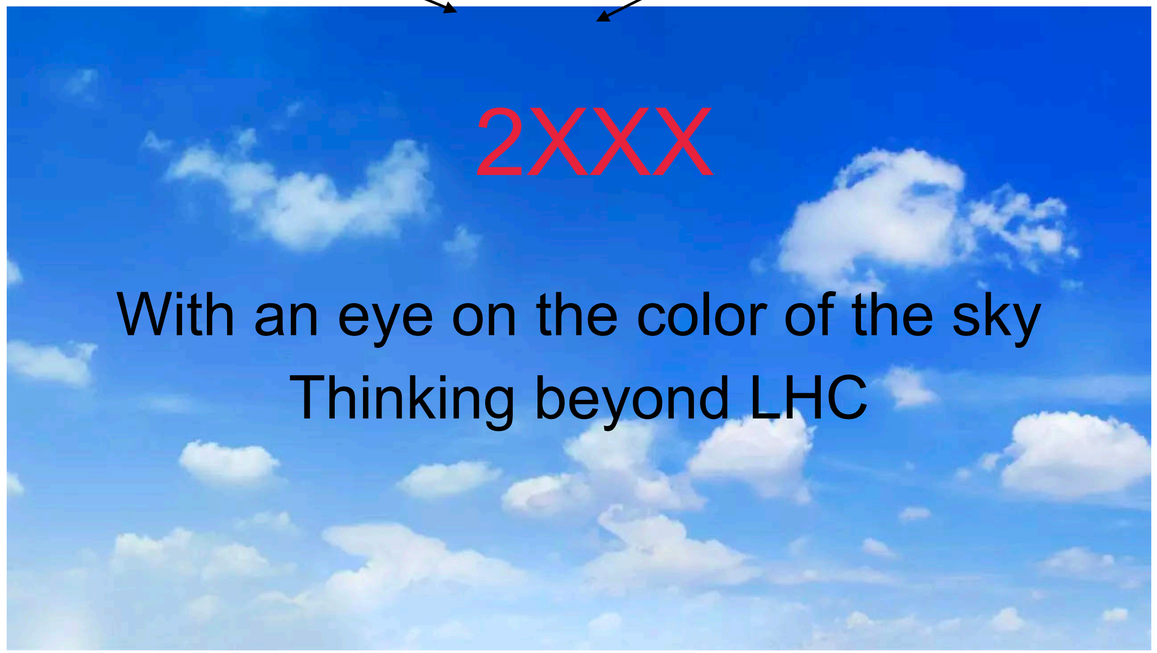
Status in the field (MAPS)

2021 - ….

R&D radiation hardness/speed

2021 - ….

R&D timing



Concluding

☑ Large R&D work ahead to match requirements

☑ Faster PhD students folded in the MAPS group and already starting the first projects

☑ Their support fundamental to secure the future of MAPS R&D and algorithmic development expanding the reach of Nikhef MAPS research.