A 20 ps SILICON DEVICE FOR THE ALICE 3 TIMING LAYERS

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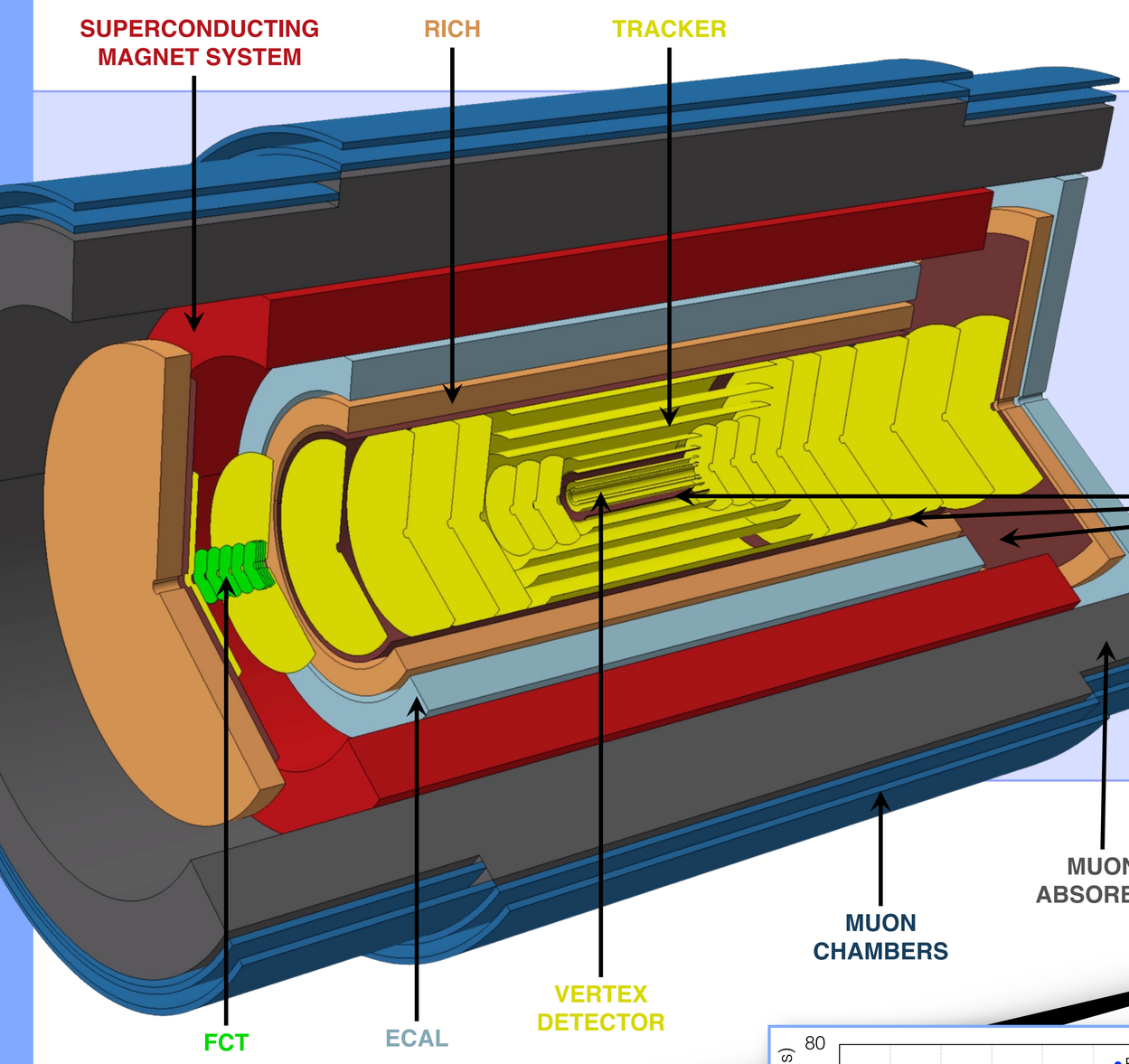


📍 LHC Interaction Point 2, Run 5 (2035) and 6

ALICE 3 - A next-generation heavy-ion experiment

https://arxiv.org/abs/2211.02491

ALICE 3 is a future experiment proposed by the ALICE Collaboration, which will utilize **cutting-edge silicon technologies** to

- study heavy-ion collisions with **unprecedented impact parameter resolution,**
- collect significantly **higher luminosities** compared to those collected with the current detector during Runs 3 and 4,

going to a pseudorapidity region up to **|η| < 4**.

TIME OF FLIGHT (TOF) DETECTOR

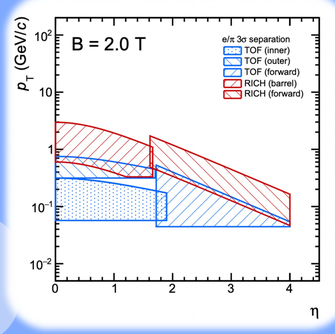
- outer TOF $R \approx 85$ cm
- inner TOF $R \approx 19$ cm
- forward TOF $z \approx \pm 405$ cm

Requirements:

- Rad. hardness
  - outer TOF: NIEL ~ $6.2 \cdot 10^9$ MeV n_{eq} /cm^2 /month
  - inner TOF: NIEL ~ $1.3 \cdot 10^{11}$ MeV n_{eq} /cm^2 /month
- Time resolution of **20ps**

Extensive R&D on the most advanced silicon technologies

LGADs - SiPMs - CMOS sensors

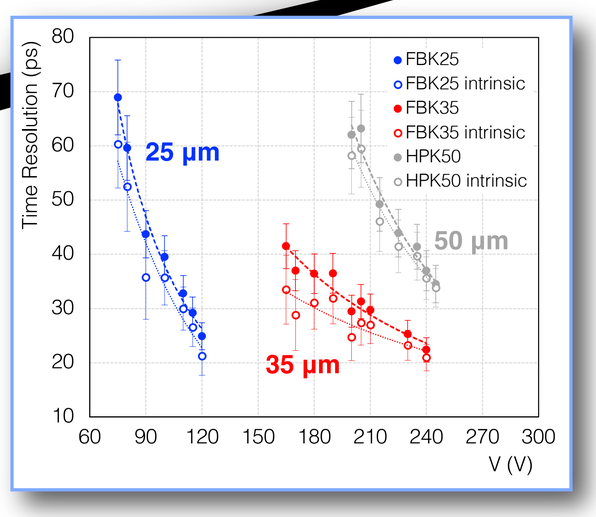


LGAD Low Gain Avalanche Detectors

https://doi.org/10.1140/epjp/s13360-022-03619-1

→ **Improvement of the time resolution by** going to a **thinner LGAD** design:

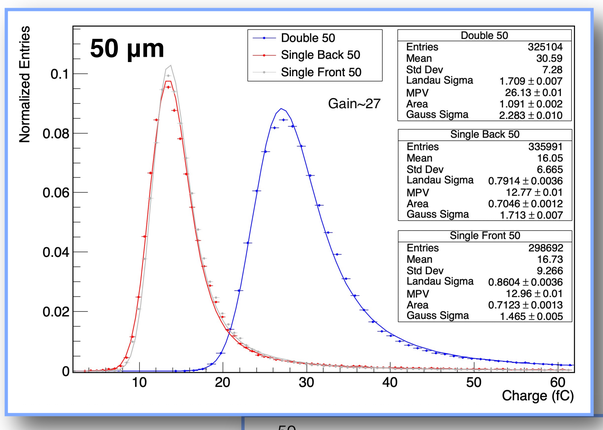
- 25 µm → 25 ps (120 V)
- 35 µm → 22 ps (240 V)



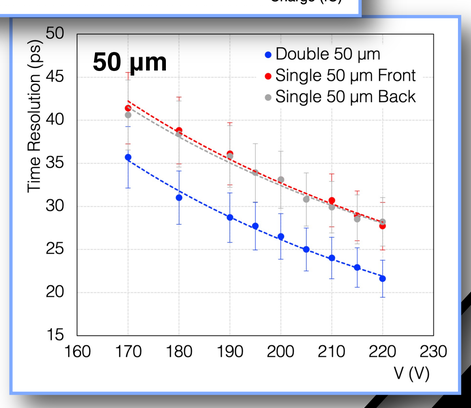
Very thin LGAD (25 & 35 µm) were tested for the first time in a test beam setup.

The new double-LGAD concept was introduced and tested for the first time. It consists of summing up the signals generated by two layers of LGAD using a single front-end amplifier.

https://doi.org/10.1140/epjp/s13360-023-04621-x



→ **higher** (doubled) **charge at the input of the amplifier** for all the thicknesses
→ advantage for the electronics.



→ consistent **improvement of the time resolution for the d-LGAD** compared to the single LGADs

→ time resolution of **~20 ps for all thicknesses** (25, 35, 50 µm)

Ongoing: study of even thinner LGADs (**15 & 20 µm**) in single and double config.

Additional gain layer to a standard CMOS sensor

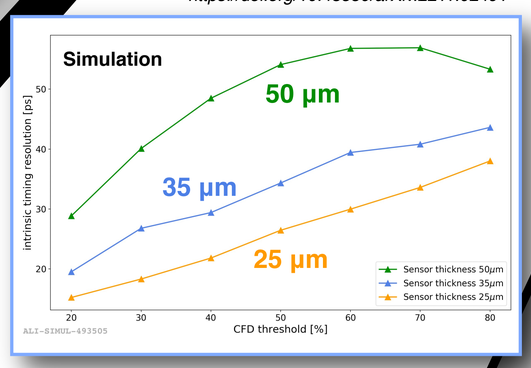
Potential to offer both the time resolution required and a complete coverage in a single layer with a **monolithic design → simpler and cheaper assembly.**

A System based on SiPMs may allow the **merging of TOF and RICH barrel detectors.**

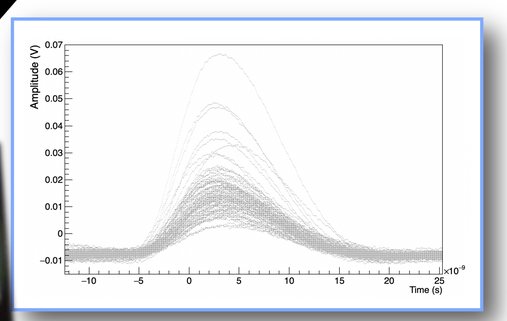
Extensive R&D with the goal to significantly pushing the time resolution well beyond current values.

A detailed **simulation work** is already ongoing to optimize the sensor design.

https://doi.org/10.48550/arXiv.2211.02491



→ Simulations show that **thinner layouts** with a **gain layer** could allow this technology to reach the ALICE 3 **time performance requirements** while maintaining a **reasonable power consumption**.



Ongoing: analysis of data taken with the first structures produced.

The direct response of SiPMs being traversed by a MIP charged particle was studied for the first time.

10.1088/1748-0221/17/06/P06007

→ unexpected **higher crosstalk**
→ **higher efficiency** w.r.t. fill factor

SiPMs with different protection layers (thickness & material) were tested and compared.

https://doi.org/10.1140/epjp/s13360-023-03923-4

→ **increased response** is **related to Cherenkov light** produced in the protection layer

→ Possibility to **detect and distinguish photons & MIPs at the same time**

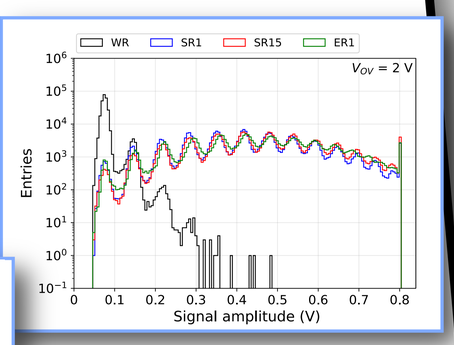
In-deep investigation on the Cherenkov effect

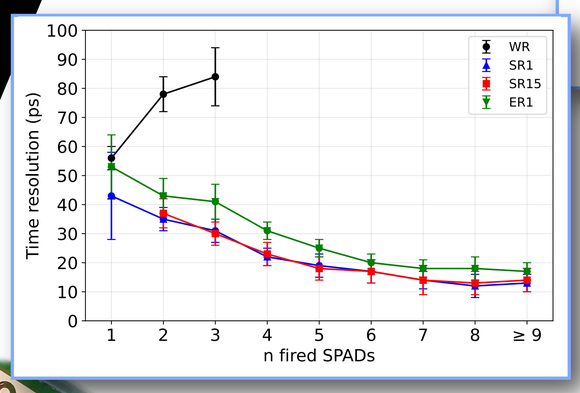
https://doi.org/10.1140/epjp/s13360-023-04397-0

→ **Time res. ~20-30 ps** at 4-6 V of OV

→ prod. of photons > in the thicker layer

→ **efficiency > 99%**, independent on fill factor

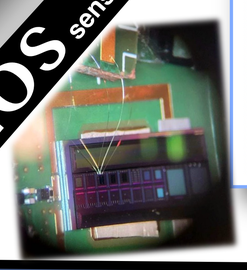




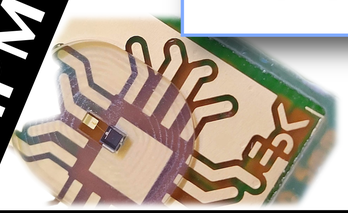
→ Improvement as a function of the number of fired pixels

→ **Time res. < 20 ps** for fired pixels ≥ 6 (majority of cases)

CMOS sensors



SiPM Silicon PhotoMultipliers



Ongoing: study of SiPMs with a larger area and pitch to cover the full Cherenkov cone, considering different resins.