LOW-GAIN AVALANCHE DIODES FOR THE CMS ENDCAP TIMING LAYER

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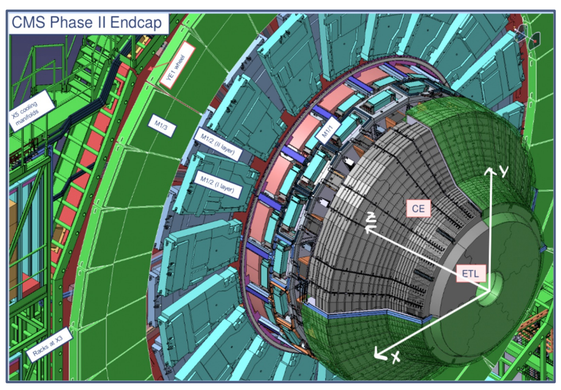
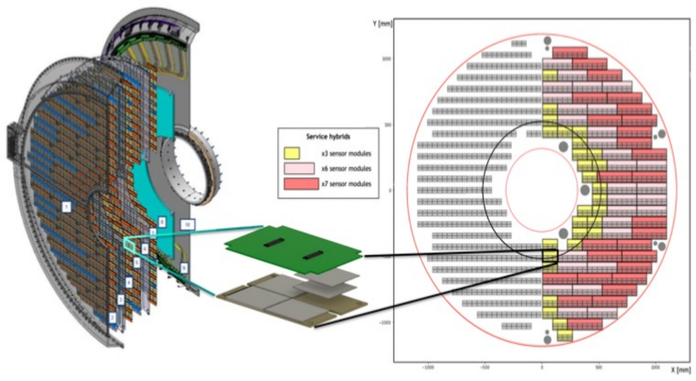
The CMS Endcap Timing Layer (ETL)

In order to preserve its present-day performance during HL-LHC the CMS detector will need an upgrade. Among many upgrades CMS will feature a new MIP timing detector (MTD), which will allow the timing of charged particles with a resolution of 30-40 ps





- **ETL will cover the two Endcap regions of the MTD**
- It will cover the **1.6 < |η| < 3.0 region**
- **Two disks on each side** for a total surface of ~14 m²
- Highest expected radiation fluence: $\phi = 1.5 \cdot 10^{15}$ neq/cm²

To achieve a time resolution of 30-40 ps, ETL will be equipped with Low Gain Avalanche Diodes (LGADs)

The LGADs for ETL

The final design for ETL LGADs will be a 16x16 pad array

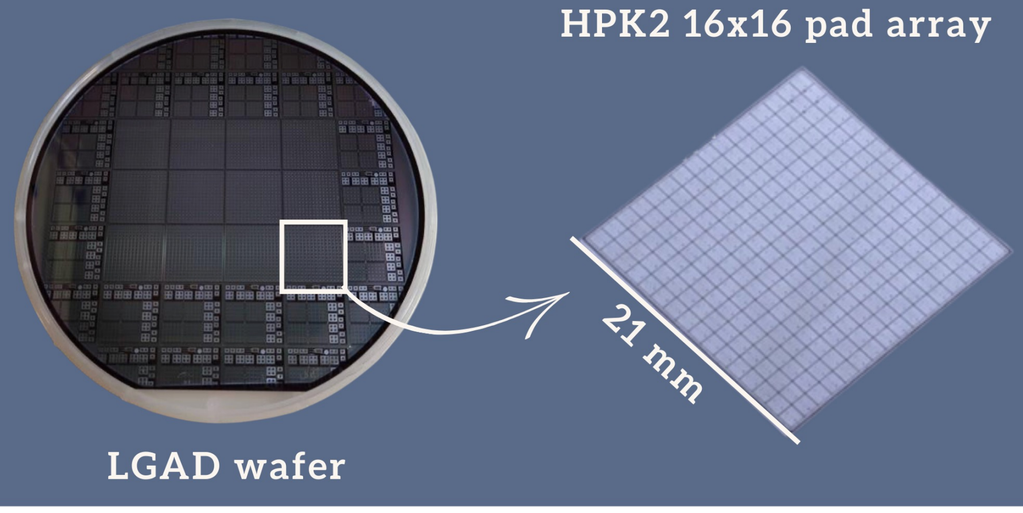
→ **1.3 x 1.3 mm²** pads for a total surface of 21x21 mm²

→ **39.000** sensors to cover the whole ETL surface

LGADs will be bump-bonded to the ETL read-out ASIC (ETROC). From the beginning to the end of HL-LHC lifetime, sensors expected to:

→ **> 8 fC** of delivered charge

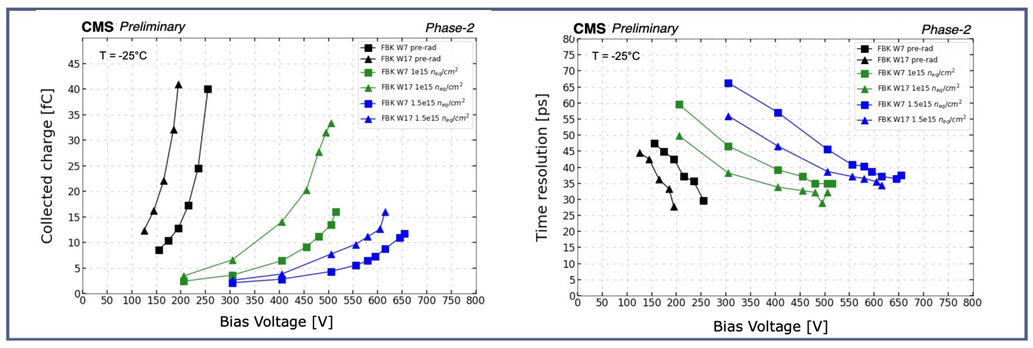
→ **< 50 ps** of time resolution when coupled to the ASIC (40 ps for the bare sensor)



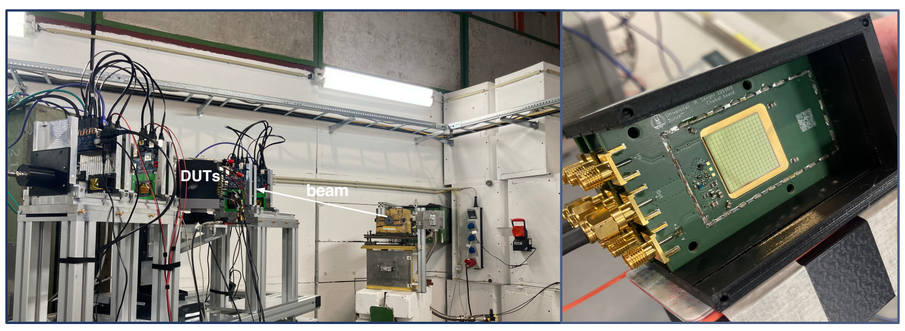
The LGAD performance

ETL sensors need to be **radiation-hard** to survive the harsh radiation environment at HL-LHC. The evaluation of their capacity to maintain unchanged performances after $\phi = 1.5 \cdot 10^{15}$ neq/cm² was performed:

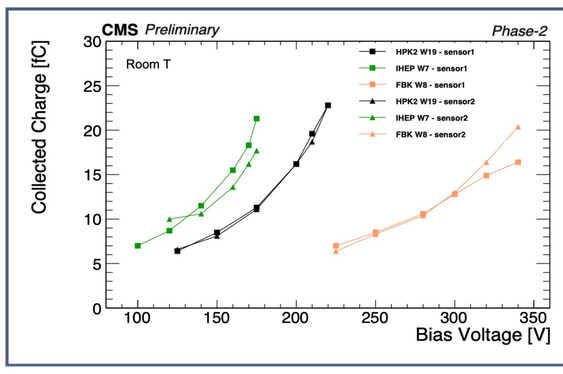
- Using a **^{90}Sr Beta source** in Turin Laboratory
- Calculating the **collected charge and the time resolution of 2x2 sensor arrays that received various irradiation fluences**



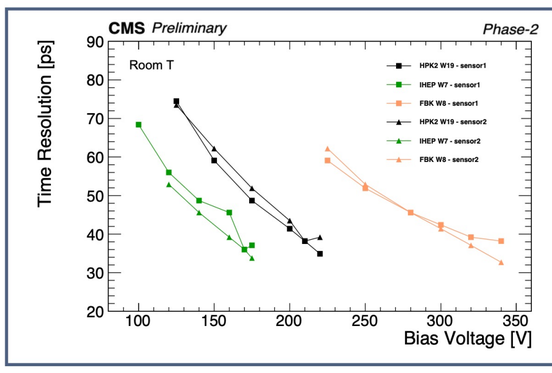
After testing 2x2 sensors **the performance of HPK, FBK and IHEP 16x16 arrays was verified at the DESY test beam facility.**



- **First test on 16x16 sensors with a high energy beam**
- 2 non-irradiated sensors tested for each vendor
- Electron beam with E = 5 GeV and ϕ = 1000 particle/s·cm²
- One pad read-out on each LGAD, 255 short-circuited and grounded
- MCP used as trigger and placed behind the DUTs
- LGADs glued on a single channel board (SC-UZH board)

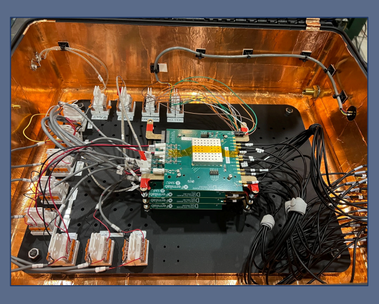


- Collected charge extraced by dividing the LGAD signal area [pWb] by the system trans-impedance (4700 Ω)
- **All sensors collected more than 8 fC of charge**

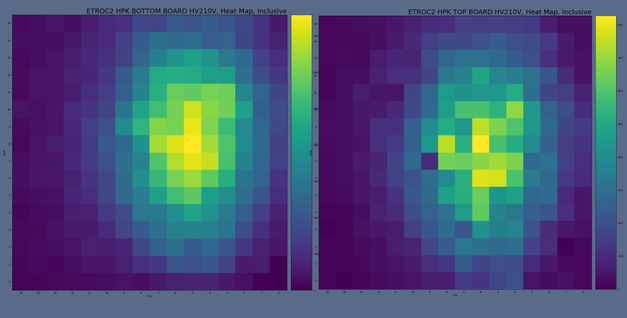


- Time resolution calculated using the MCP as a time reference (σ = 15 ps)
- **All sensors obtained a time resolution lower than 40 ps**

First ETROC + LGAD beam test



- **The LGADs bump bonded to ETROC chips were tested at SPS (CERN)**
- **Hadron beam** (2/3 π, 1/3 p) with **E = 120 GeV**
- **ETROC+LGAD hybrids demonstrated full functionality** as the beam spot was clearly visible
- A detailed analysis of the timing performance is ongoing



Conclusions and future plans

- LGAD sensors demonstrated to be the perfect solution to provide the requested time resolution until the end of HL-LHC lifetime
- The testing campaign of the LGADs bump bonded to ETROC started to give the first positive results. An intense schedule of test beams is foreseen in the near future to confirm these results and to investigate the performance of the sensors coupled with the ASIC

Acknowledgments: This work is the part of a collaborative effort. We acknowledge the support of the funding agencies involved in the design and construction of the CMS MTD.