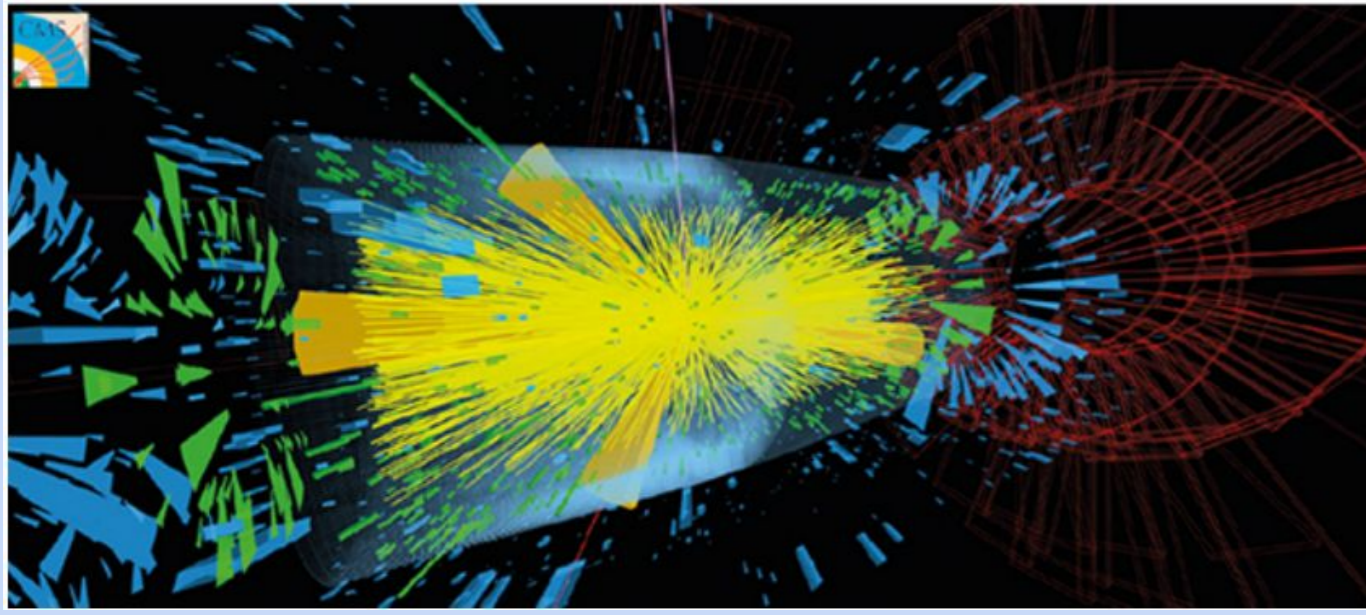
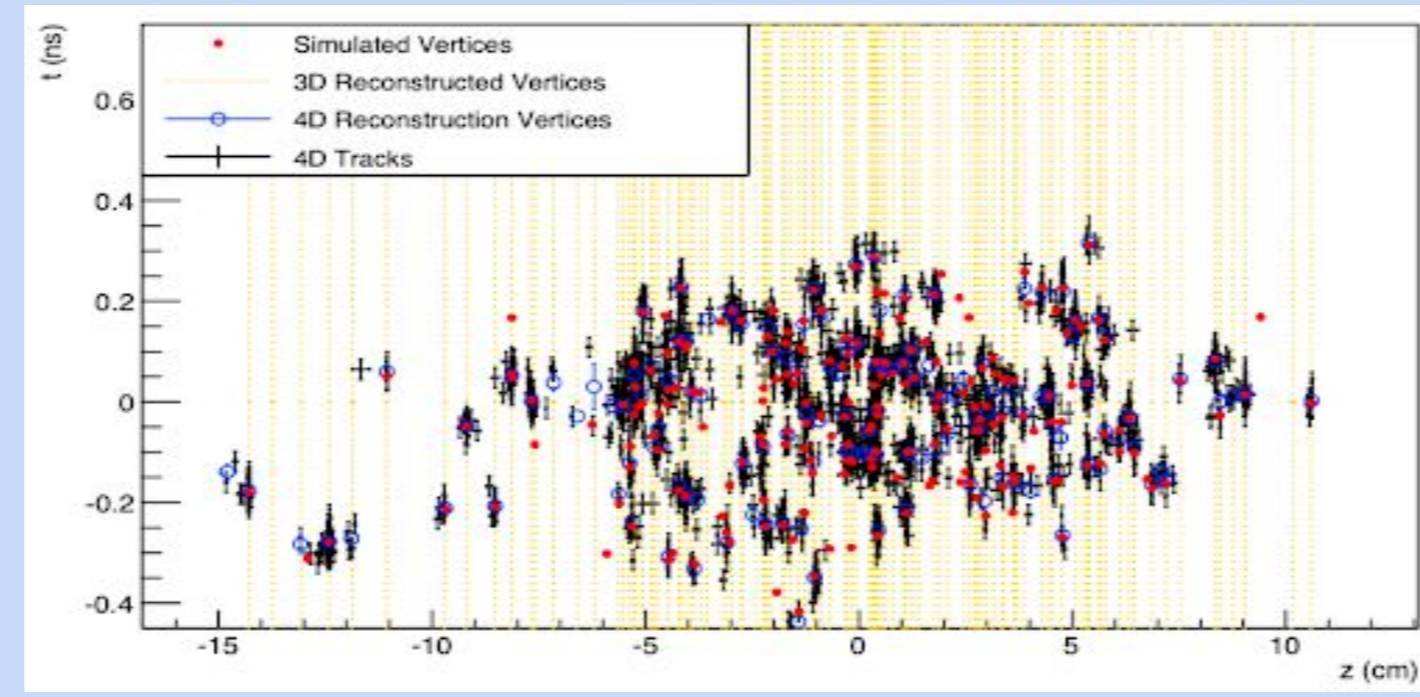


Lazar Markovic on behalf of the CMS Collaboration

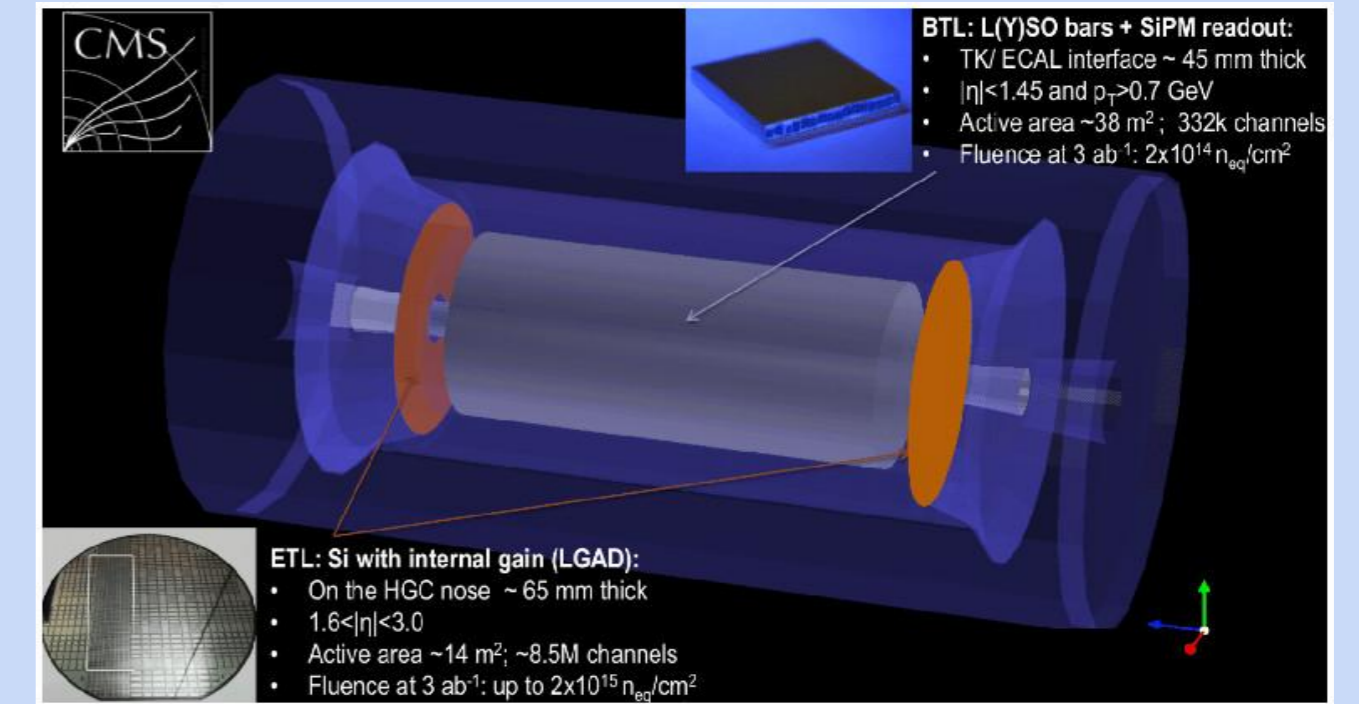
## Motivation



Simulation of a VBF  $H \rightarrow \tau \tau$  in 200 pp pile-up collisions



With **35 ps** time resolution vertex merging is reduced, from **15 %** in space to **1 %** in space-time, as in present LHC operation



Starting from Run 4 (2029)<sup>[1]</sup> CMS will be equipped with MIP Timing Detector<sup>[2]</sup>

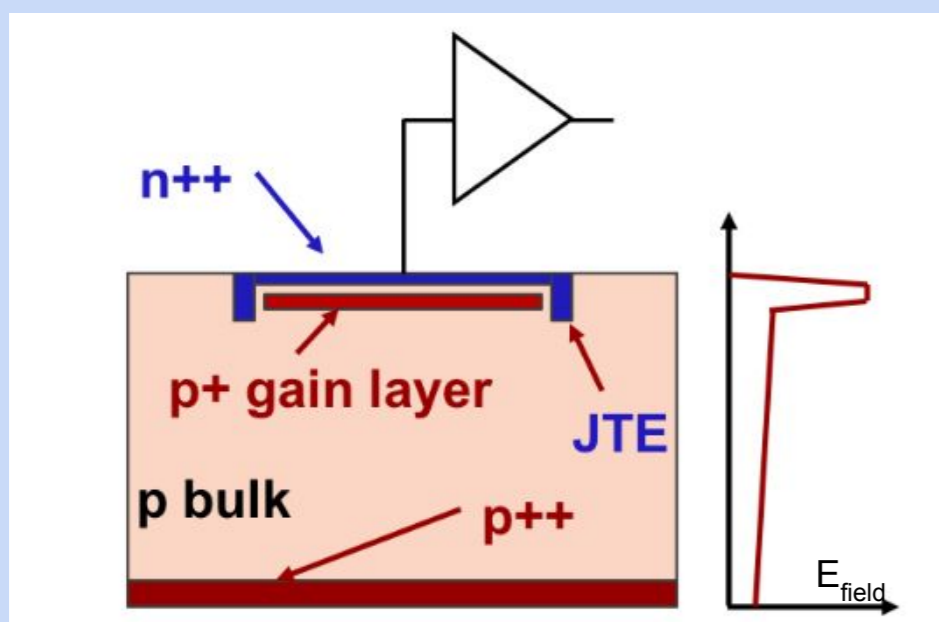
The Endcap part will be equipped with Low-Gain Avalanche Diodes<sup>[3]</sup>

Harsh and challenging conditions at **HL-LHC**  
→ pushed to the limit of performances

Spread of **~180 ps** in time collisions  
→ slices of **35 ps**

Timing increases the CMS physics reach at **HL-LHC** by reducing the negative effects of the pile-up

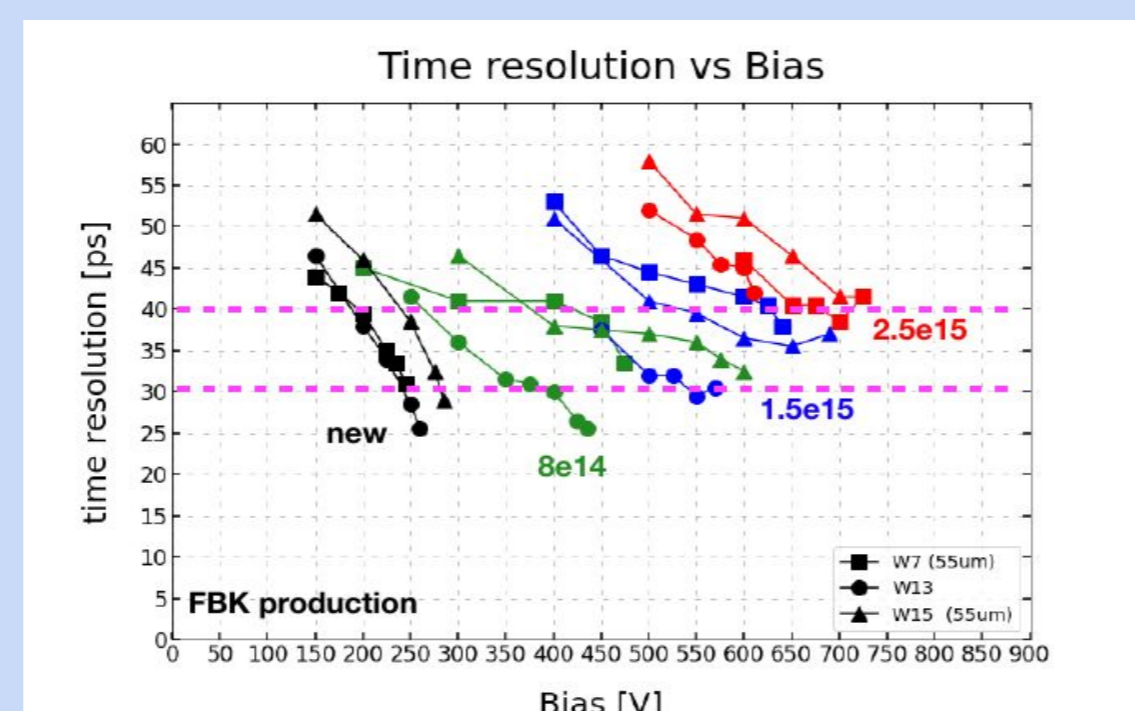
## Sensors



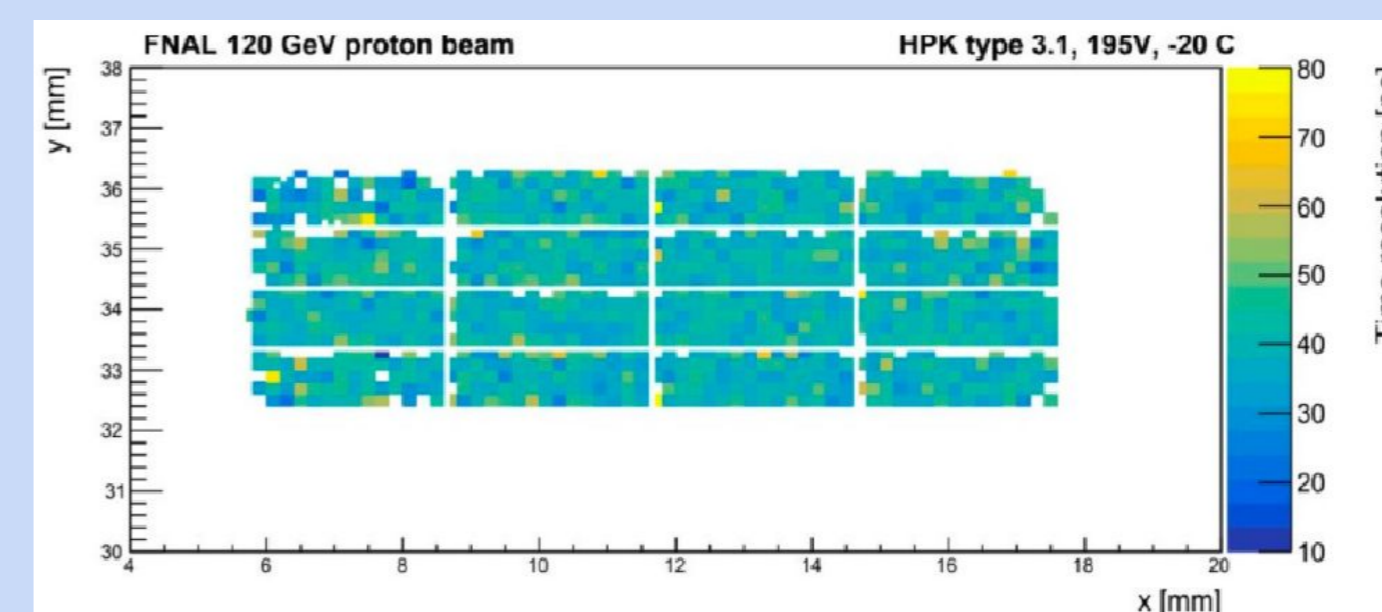
Low-Gain Avalanche Diode (LGAD)

Moderate gain factor **10-30**  
 $E_{field}$  is well controlled by  $V_{bias}$

Active thickness of **~50  $\mu\text{m}$** ,  
timing resolution is of **~30 ps**<sup>[4]</sup>

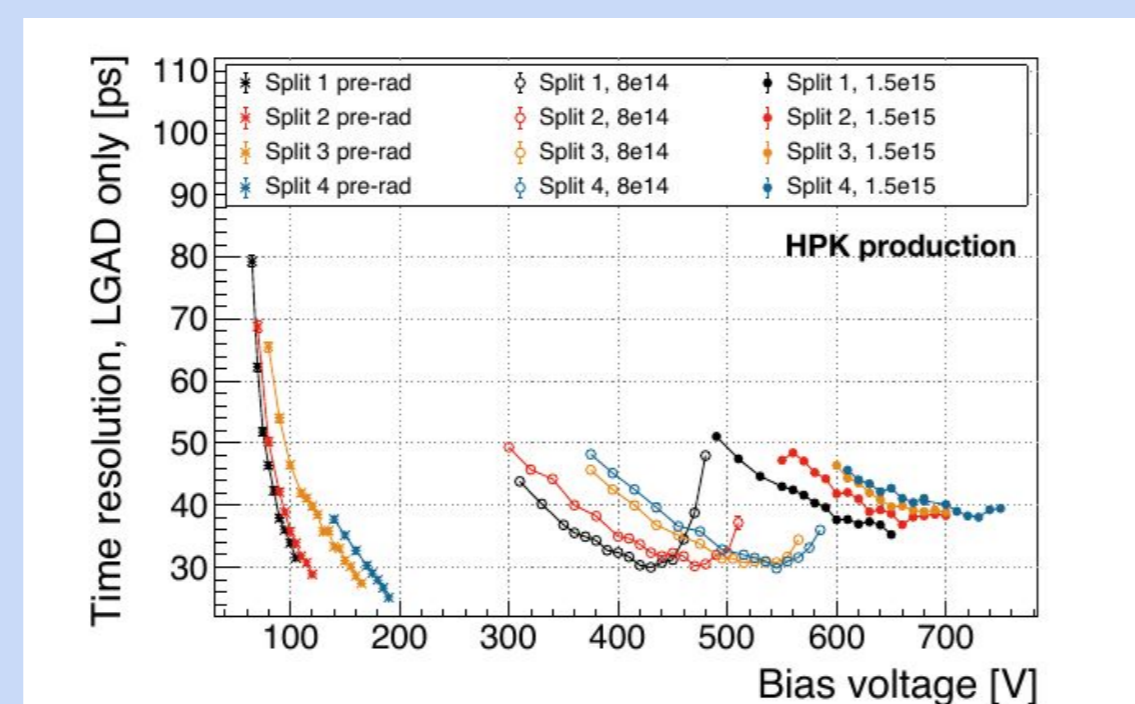


Time resolution as a function of applied bias for **FBK** sensors for different irradiation levels



Uniform timing resolution of **HPK** sensors

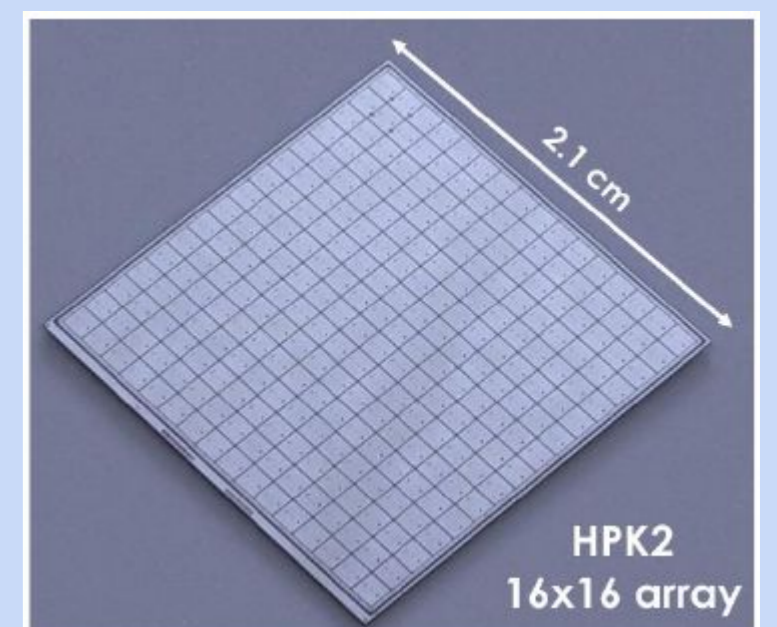
For **ETL**:  
**16x16** pad sensors,  
**1.3x1.3 mm<sup>2</sup>** pad area



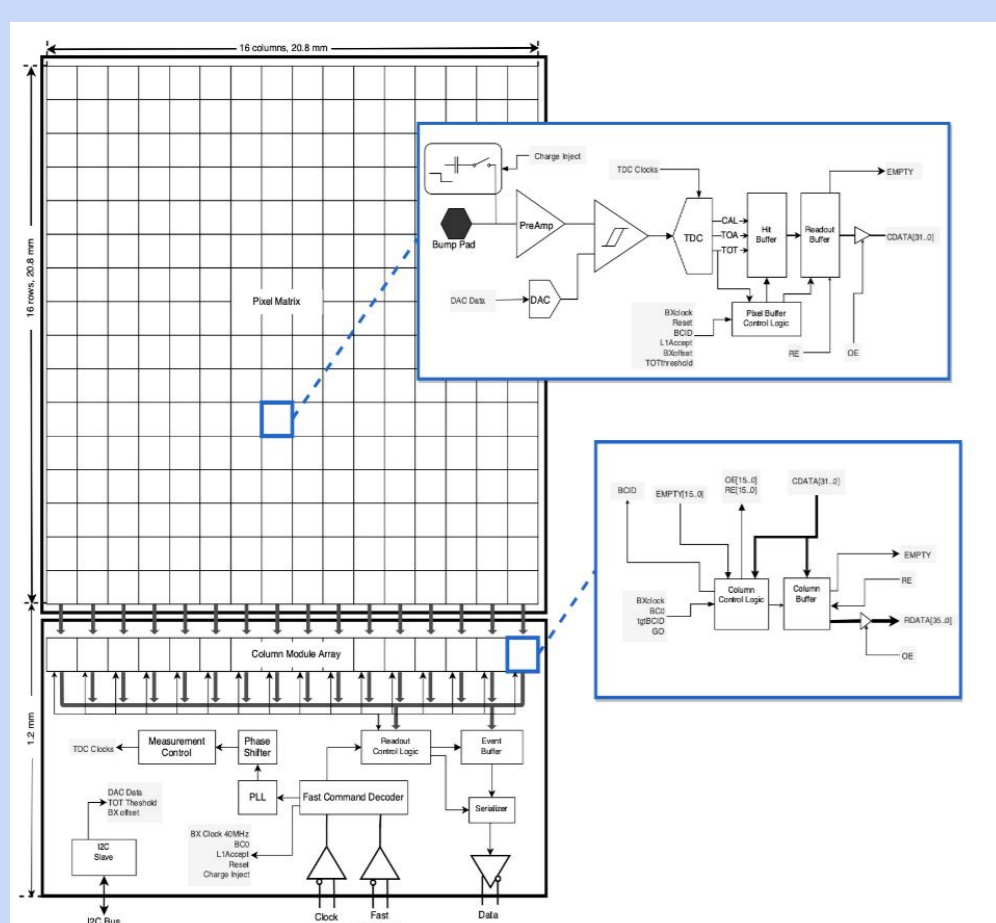
Time resolution as a function of applied bias for **HPK** sensors for different irradiation levels

### Ongoing tests to:

- ❖ define the production parameters
- ❖ enhance the radiation tolerance
- ❖ check the production quality
- ❖ control the uniformity over big areas

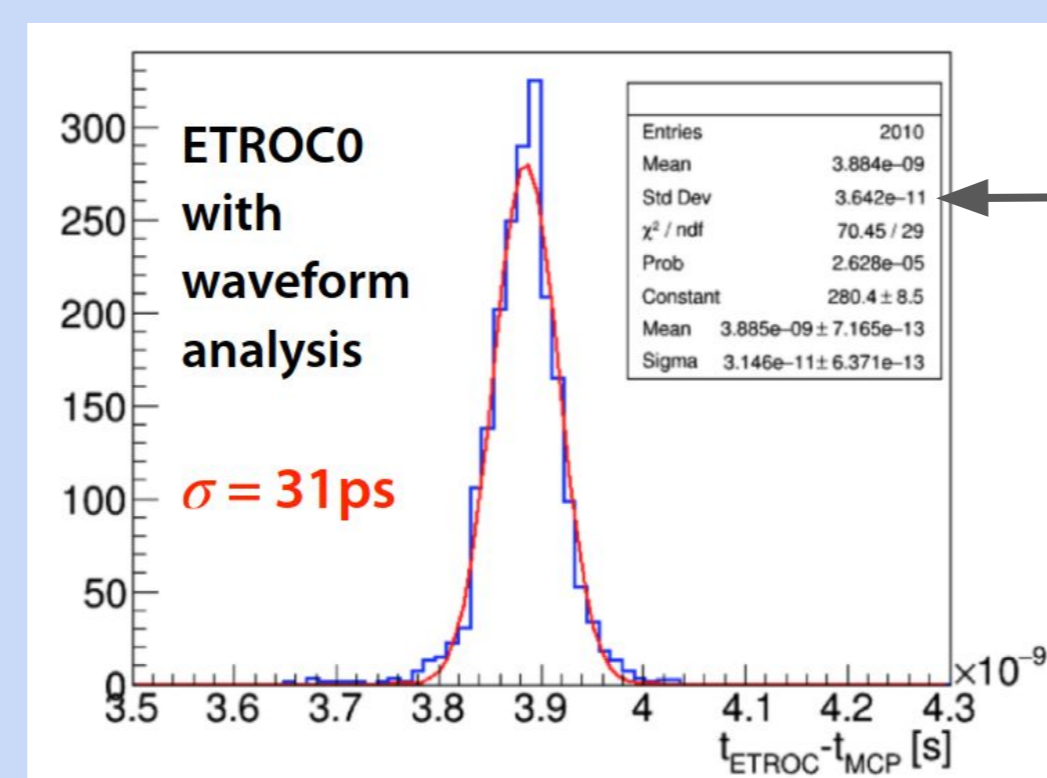


## Electronics



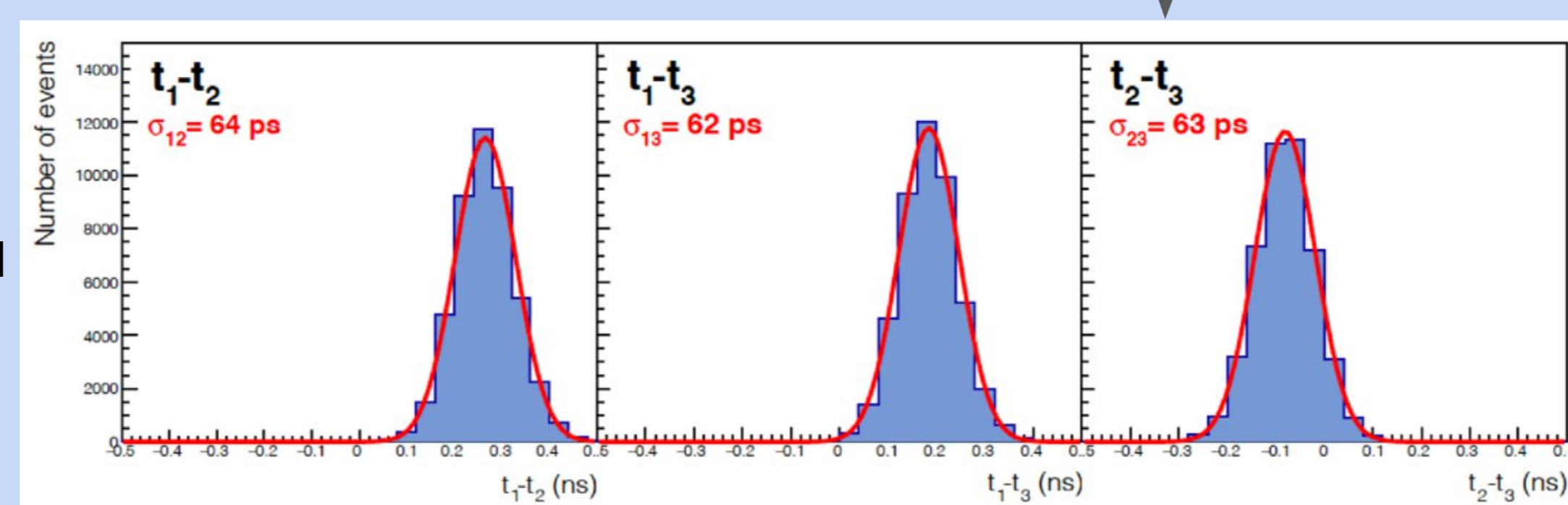
Endcap Timing ReadOut Chip (ETROC)<sup>[5]</sup>

- ❖ Extract precision timing for small signals
- ❖ Low power budget
- ❖ Contribution to time resolution **< 40 ps**



ETROC0:  $\sigma_t \sim 30$  ps

ETROC1:  $\sigma_t \sim 42-46$  ps



With LGAD  $H_V=230$  V for all three channels

### Timeline

- ETROC0**: Submission Dec. 2018, - single analog channel
- ETROC1**: Submission Aug. 2019, - 4x4 pixel array with full front-end - TDC brand new design
- ETROC2**: Submission 2022, - 16x16 full size - H-tree clock distribution
- ETROC3**: Submission 2024 - pre-production chip

### References:

- [1] High Luminosity LHC Project, available at <https://hilumilhc.web.cern.ch/content/hl-lhc-project>
- [2] CMS Collaboration, A MIP Timing Detector for the CMS Phase-2 Upgrade, CERN-LHCC-2019-003, CMS-TDR-020, <https://cds.cern.ch/record/2667167>
- [3] G. Pellegrini et al., Technology developments and first measurements of Low Gain Avalanche Detectors (LGAD) for high energy physics applications, Nucl. Inst. Meth. A 765 (2014) 12, doi:10.1016/j.nima.2014.06.008
- [4] N. Cartiglia et al., Beam test results of a 16 ps timing system based on ultra-fast silicon detectors, Nucl. Inst. Meth. A 850 (2017) 83, doi:10.1016/j.nima.2017.01.021
- [5] Q. Sun et al., The Analog Front-end for the LGAD Based Precision Timing Application in CMS ETL, doi:10.48550/arXiv.2012.14526