2nd TCT Workshop – Ljubljana, October 17 2016

# Laboratory results on LGADs

Marco Ferrero at. All

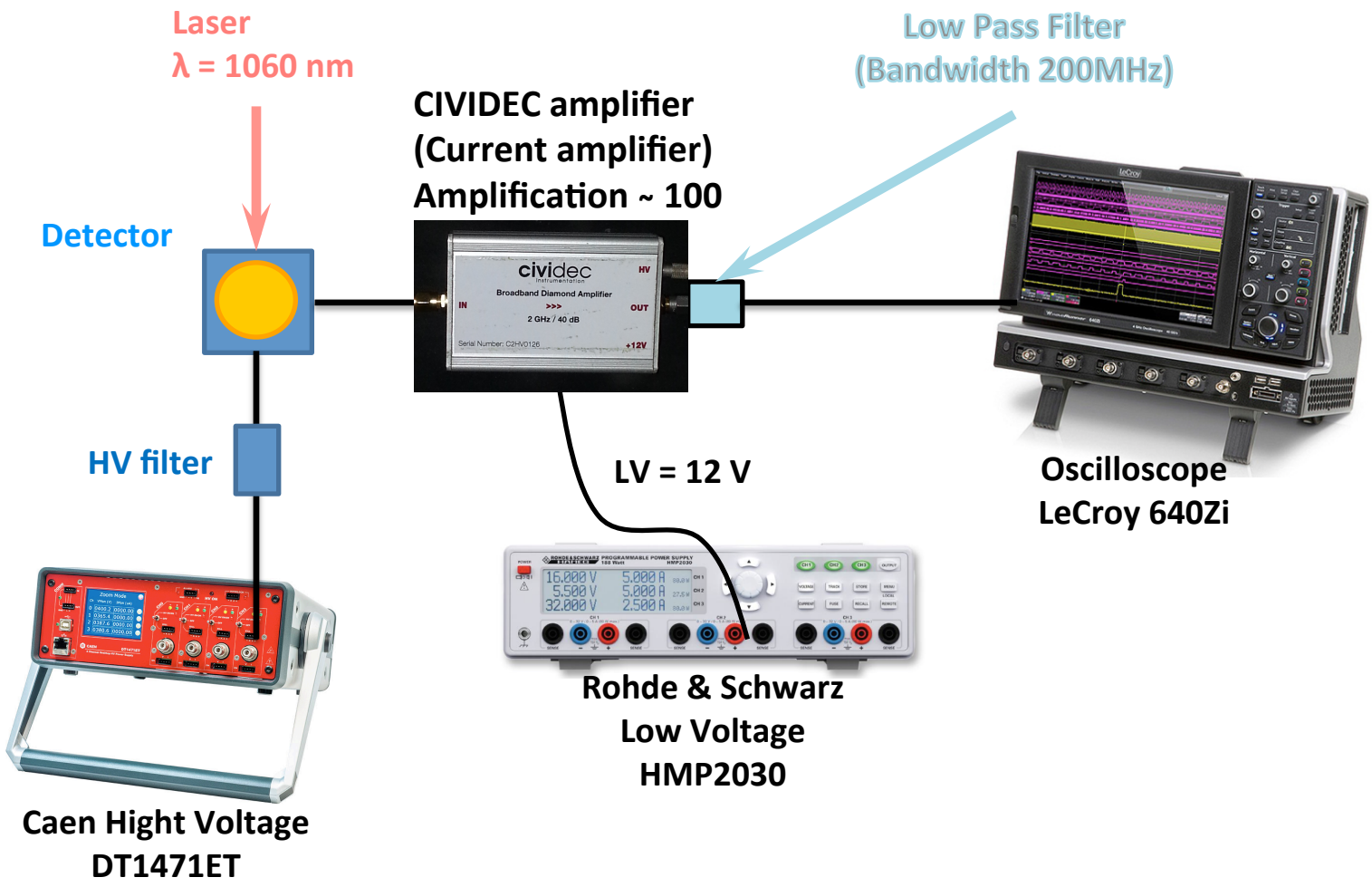


# Outline

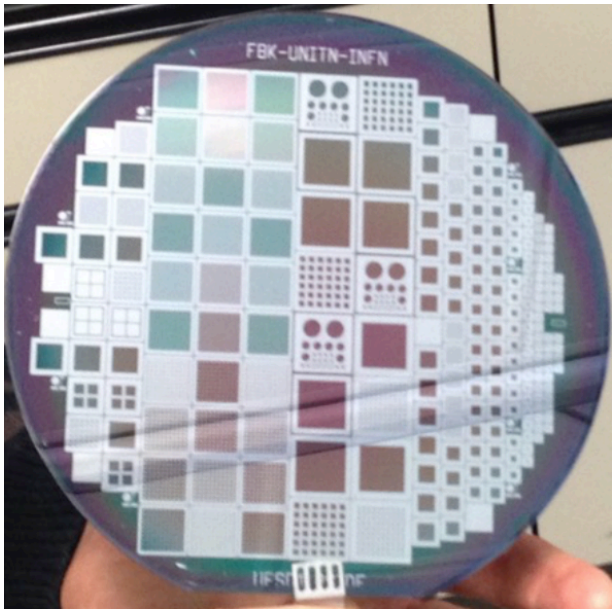
- Gain measurements:
  - CNM sensors (300µm and 50 µm);
  - FBK sensors (300µm);

- Evaluation of the time resolution Jitter and Landau components:
  - Simulation;
  - Beam test and Laboratory measurements comparison;

# Laboratory laser setup

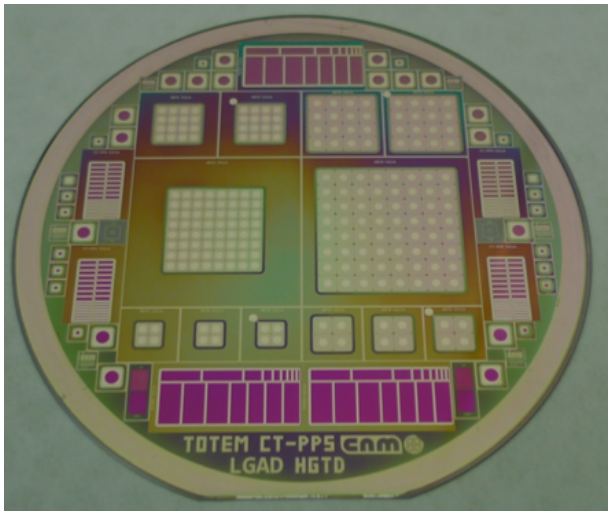


# FBK & CNM Sensors




**FBK Production:**

- Thickness 300µm;
- 13 Wafers produced;
- 5 Splits of gain in 2% steps;
- Multiple structures (single pad, multi-pad, array, strip);
- n-side segmentation;
- p-side segmentation;



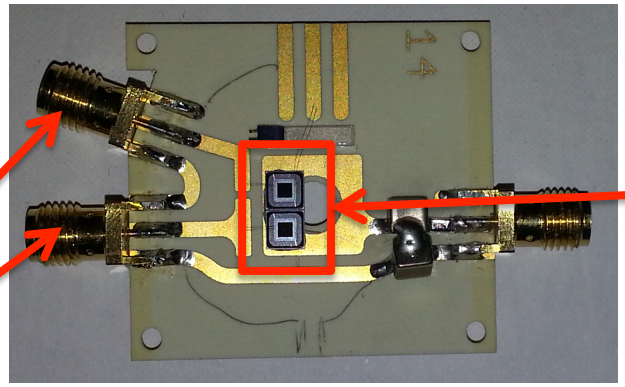

**CNM Production (Run 9088):**

- SOI wafers
- Thickness 50µm;
- 3 Gain Doses:
  - $1{,}8 \cdot 10^{13} cm^{-2}$
  - $1{,}9 \cdot 10^{13} cm^{-2}$
  - $2{,}0 \cdot 10^{13} cm^{-2}$

# FBK Sensors tested

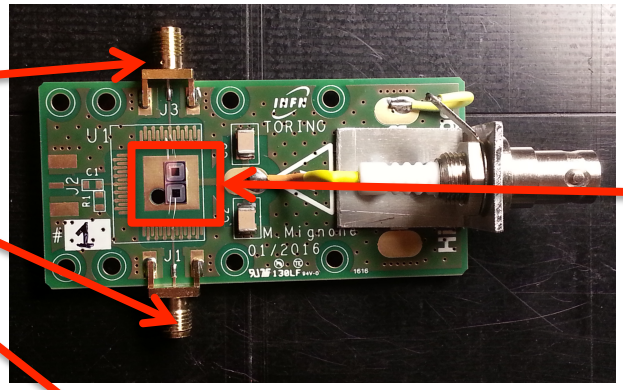


Read out channels



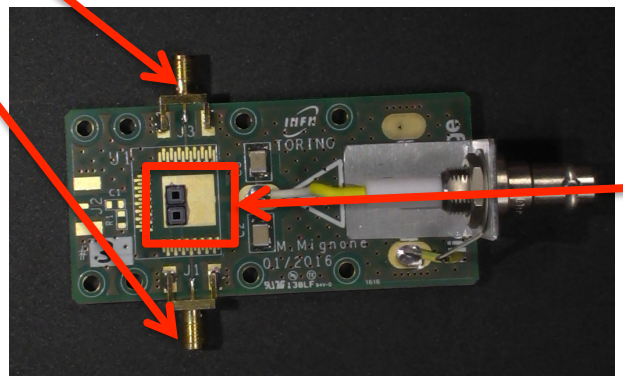
PCB developed by CERN

***Wafer 3-Split 2 of gain***
***Detector Single Pad***
***(LGAD + DIODE)***
***Area 4 mm²***
***Thickness = 300µm***




PCB developed by INFN, Turin (Marco Mignone)

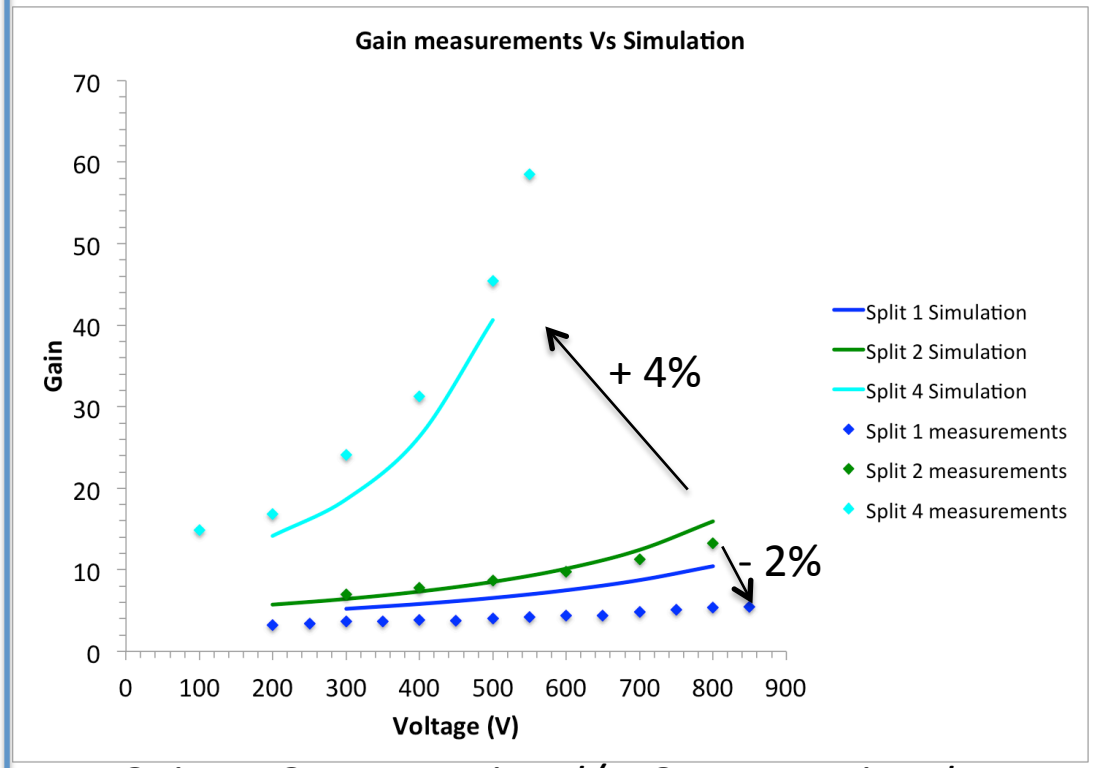
***Wafer 10-Split 4 of gain***
***Detector Single Pad***
***(LGAD + DIODE)***
***Area 4 mm²***
***Thickness = 300µm***




PCB developed by INFN, Turin (Marco Mignone)

***Wafer 1-Split 1 of gain***
***Detector Single Pad***
***(LGAD + DIODE)***
***Area 4 mm²***
***Thickness = 300µm***

# Gain Measurements Vs Simulations (FBK Sensors)




*Gain = LGAD area signal/DIODE area signal*

**Measurements**

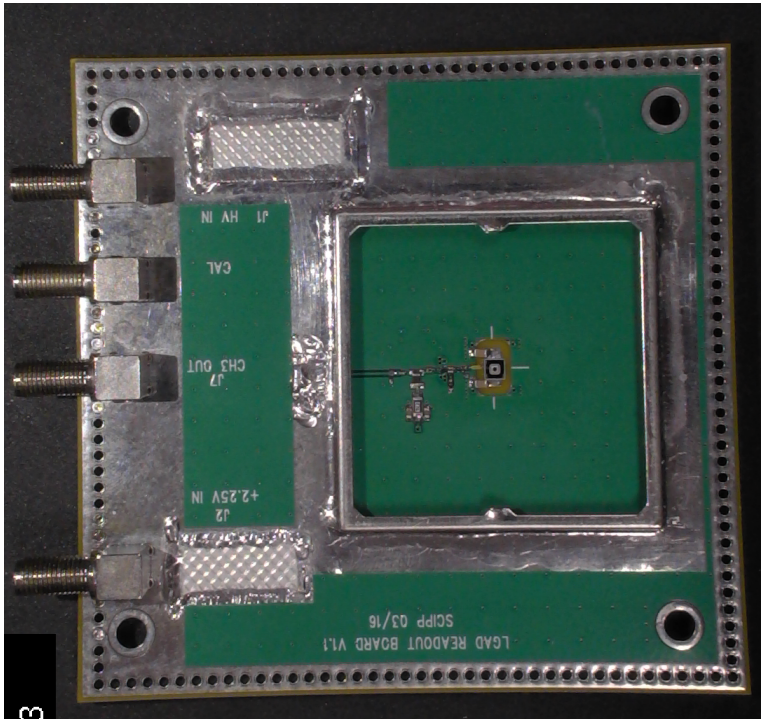
- Laser attenuation to replicate 1 MIP in agreement with Weightfield2;
- Ideal condition (laser in the center of the pad);
- Laser wavelength = 1060 nm
- Measurements performed at room temperature (about 300K);
- Laser not focalized;

**Simulations**

- TCAD Simulation;
- IR Laser;
- Simulations performed with diffusive optical generation;
- Temperature Simulations =300K;

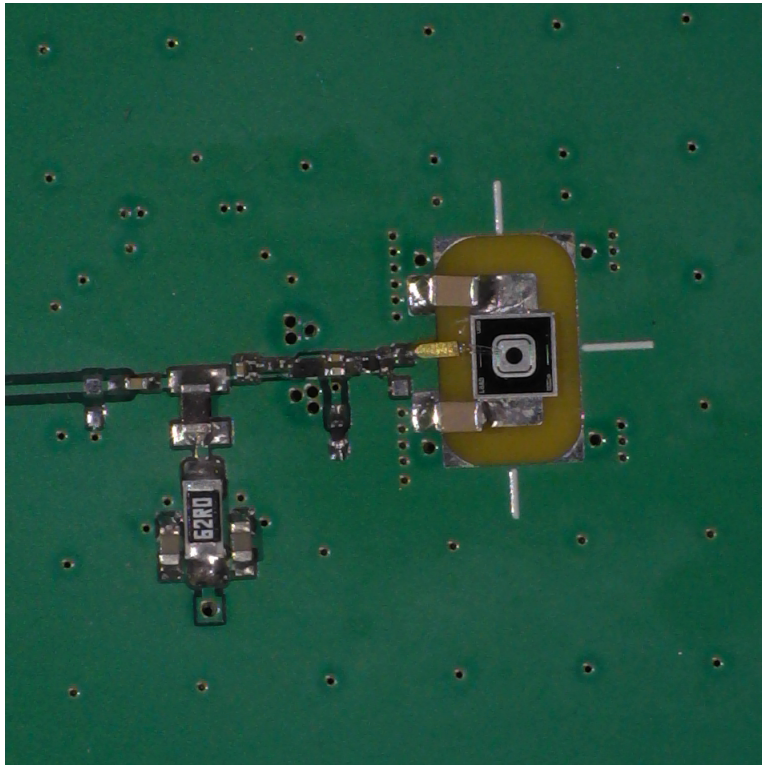
***The Simulations was performed by Lucio Pancheri of the University of Trento.***

# CNM Sensors tested

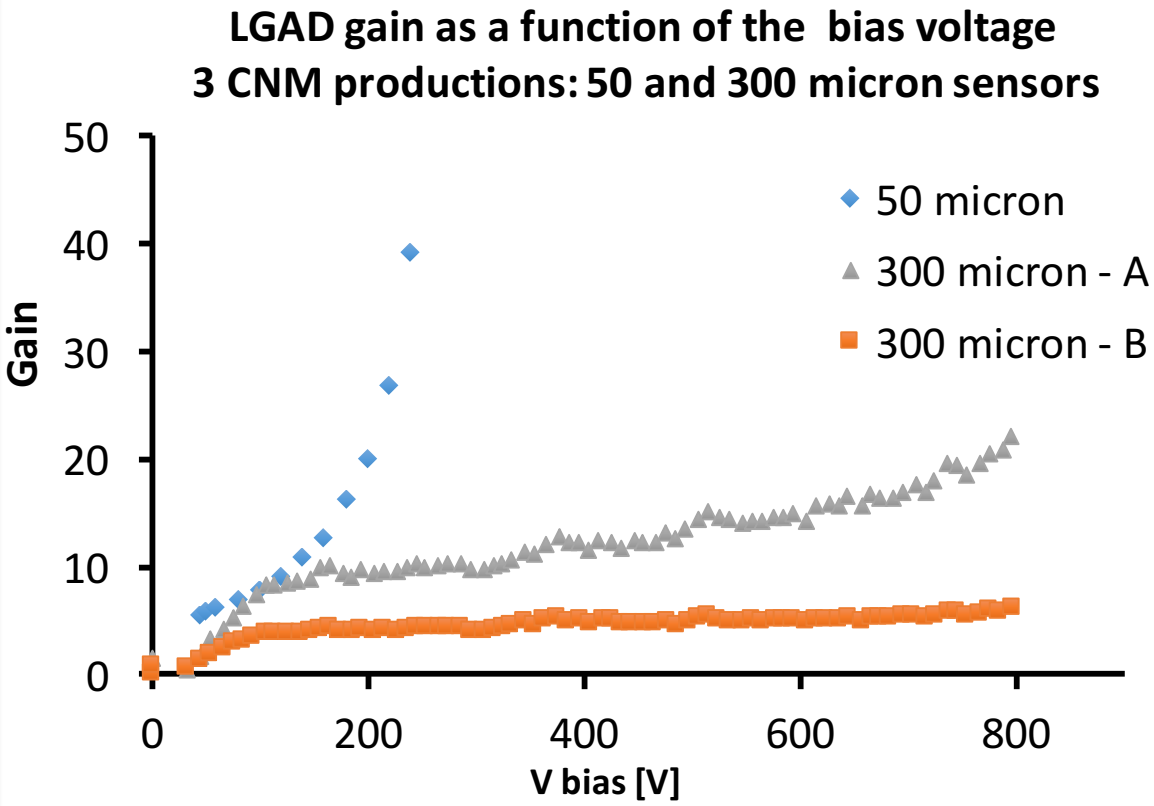



*SantaCruz Board*

***CNM Run 9088-Wafer 5***
***Gain Dose 1,9•$10^{13}$cm$^{-2}$***
***Detector Single Pad***
***Area 1,7 mm$^2$***
***Thickness = 50µm***



# Gain Measurements (CNM Sensors)

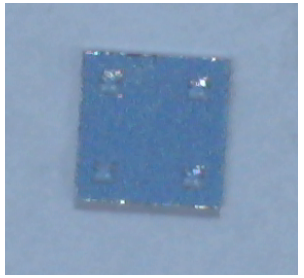



**Measurements:**

- Measurements of gain performed in Santacruz;
- B Source $^{90}Sr$;
- 50µm Sensors of the wafer 5 (Dose = $1{,}9 \cdot 10^{13} cm^{-2}$;

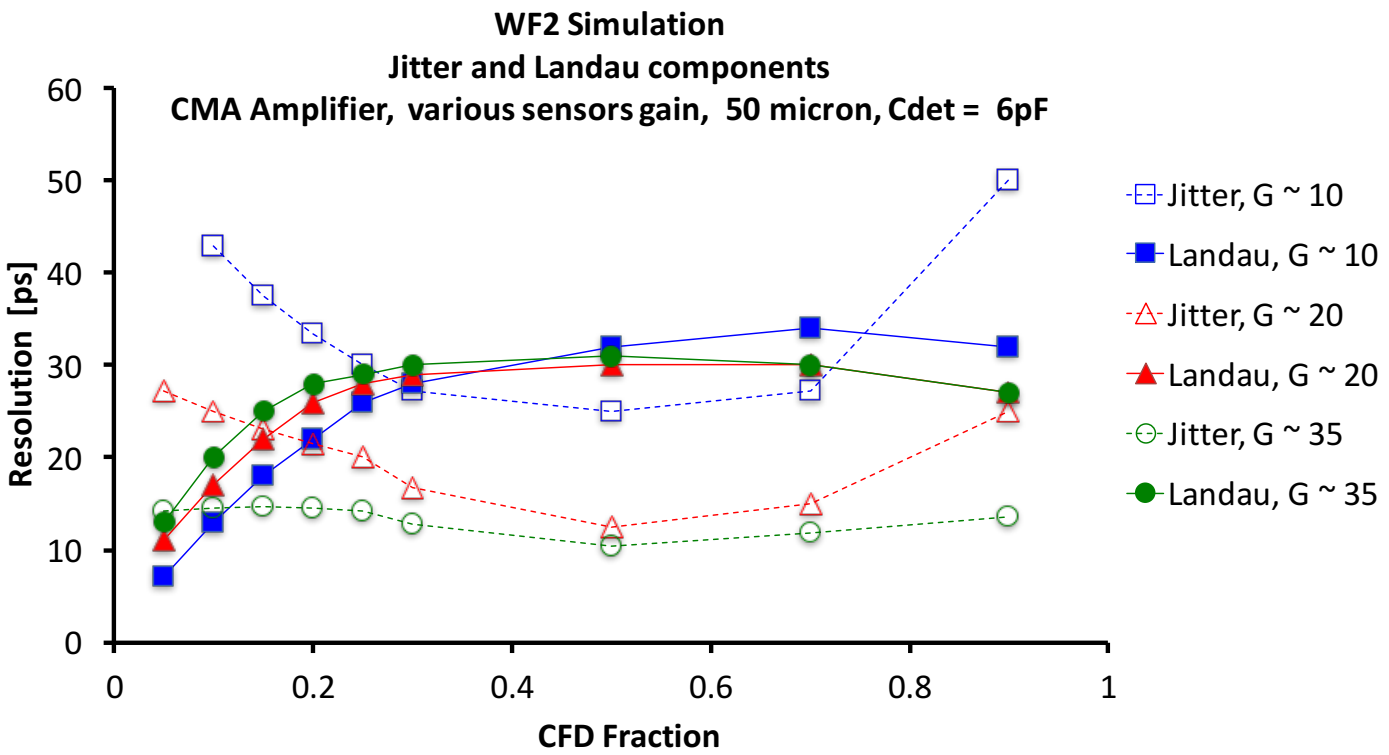
**ISSUE:**
The metallization on the back of the sensor doesn't permit to perform the same measurement using a laser source.
**Laser reflection**

*Sensor back plate metallization*



# Time resolution
# Jitter and Landau components

$$\sigma_t^2 = \sigma_{jitter}^2 \overset{?}{+} \sigma_{landau}^2 + \sigma_{TDC}^2$$



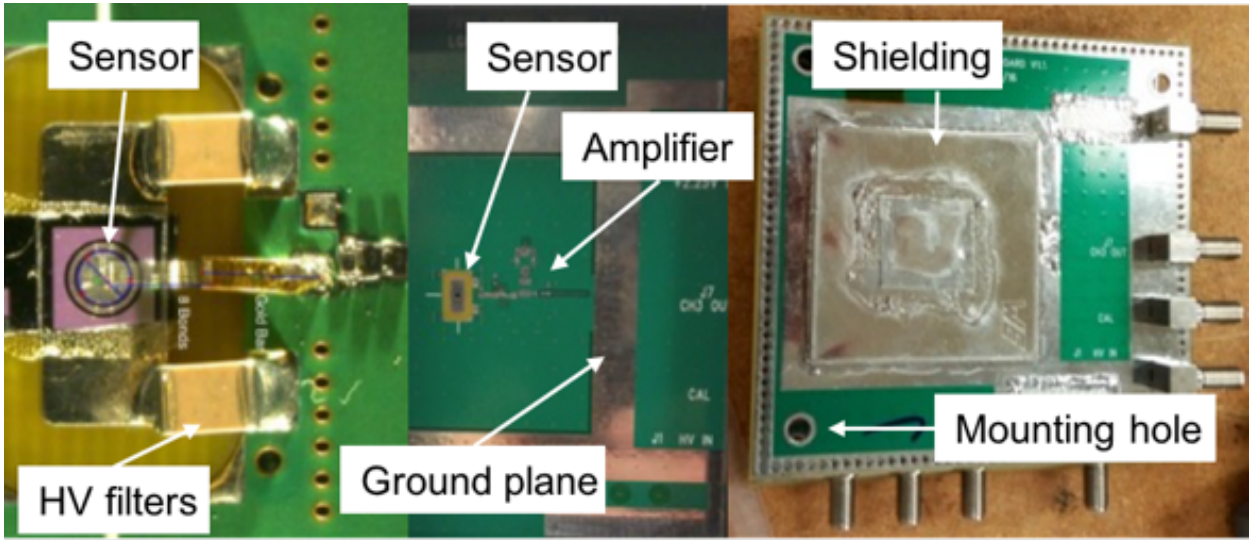

**Weightfield2 Simulations**

- 50µm Sensors;
- Cdet = 6pF;
- Sensor with various gain (10-20-35)

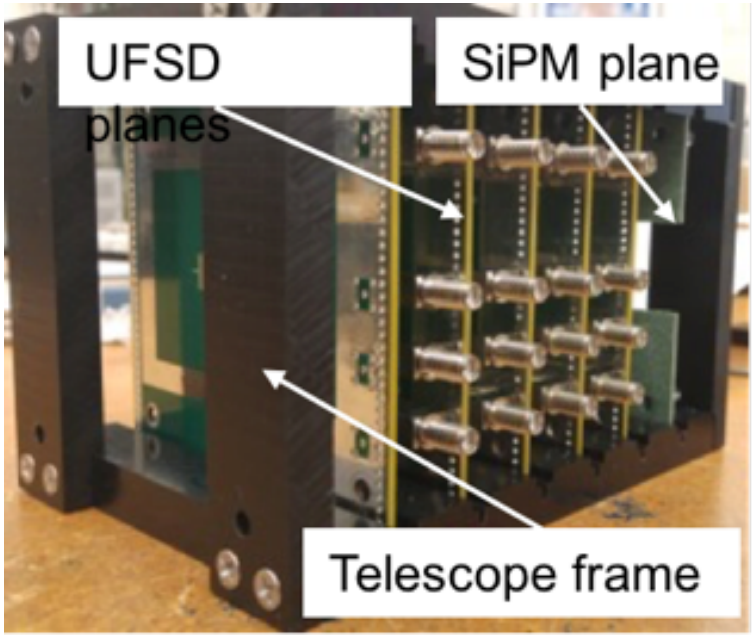
**Jitter components decrease with the gain increasing**

**Landau component predominates over the Jitter for high gain and CFD**

# Beam test setup




Fully custom made
UFSD readout (UCSC)

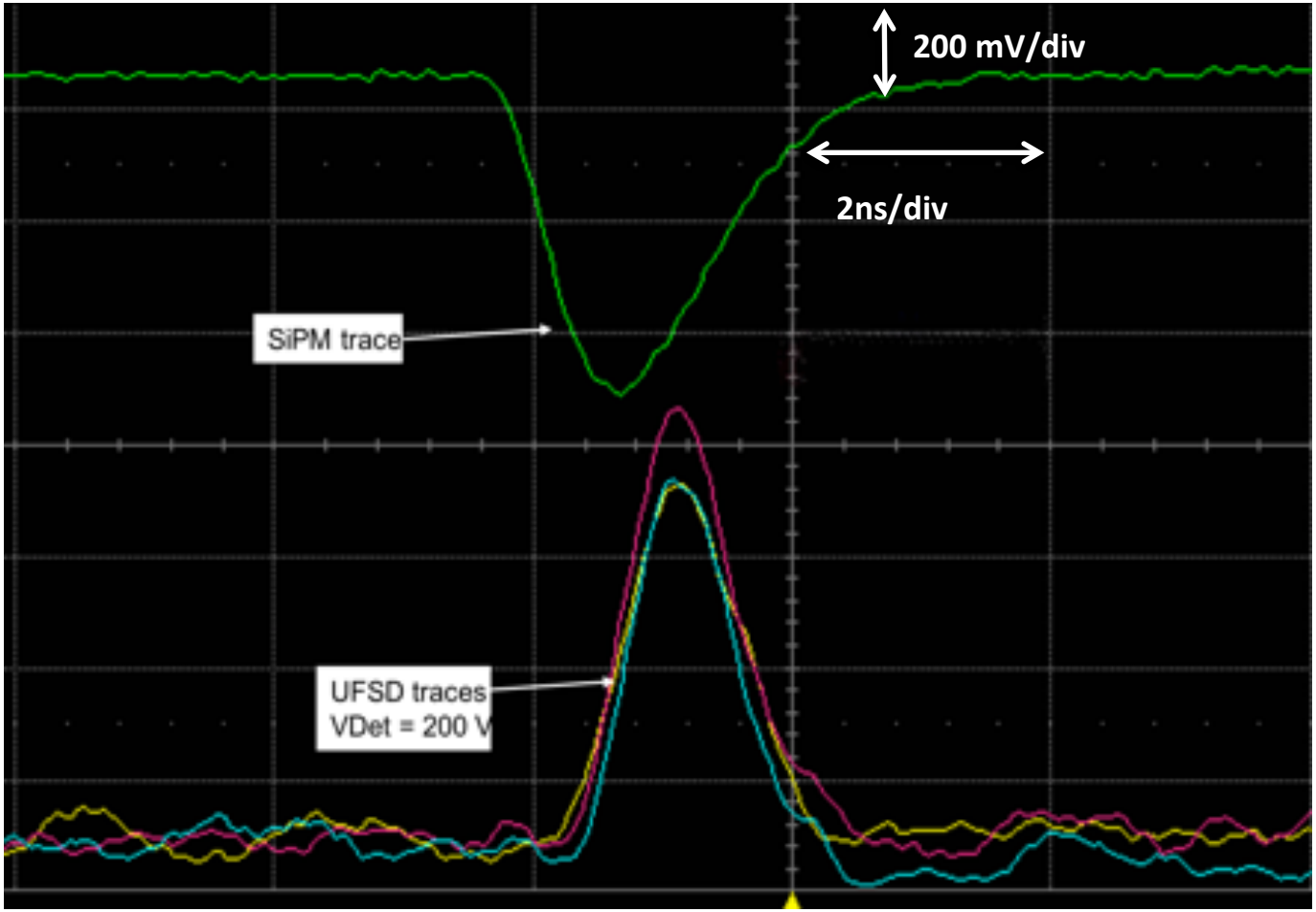



CNM production
of thin sensors
**50 µm**

**Beam Test @ SPS H8 area**
**(180 GeV/c pions)**

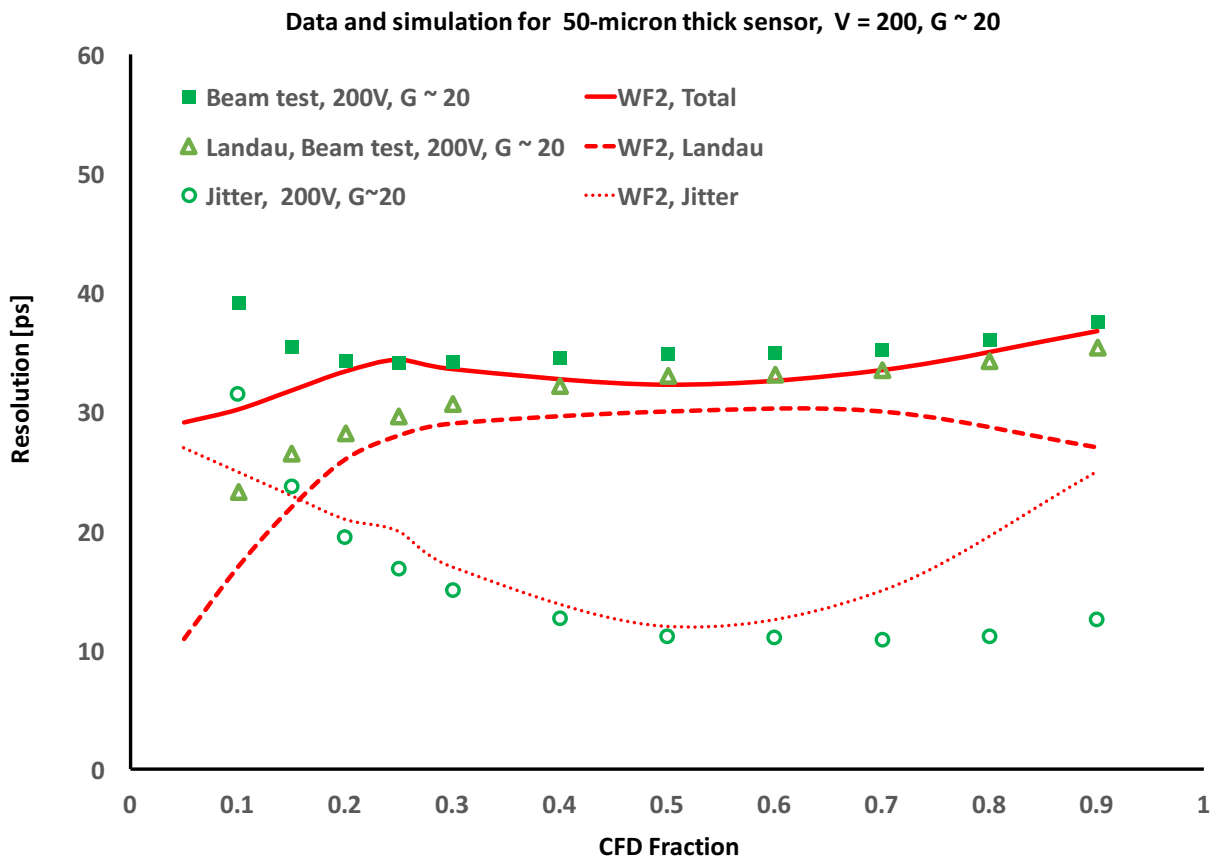
# Beam test signal example

**Fast, low noise signal, ideal for timing**



# Time resolution-Jitter and Landau components Data Vs Simulation

$$\sigma_t^2 = \sigma_{jitter}^2 + \sigma_{landau}^2 + \sigma_{TDC}^2 \quad ?$$



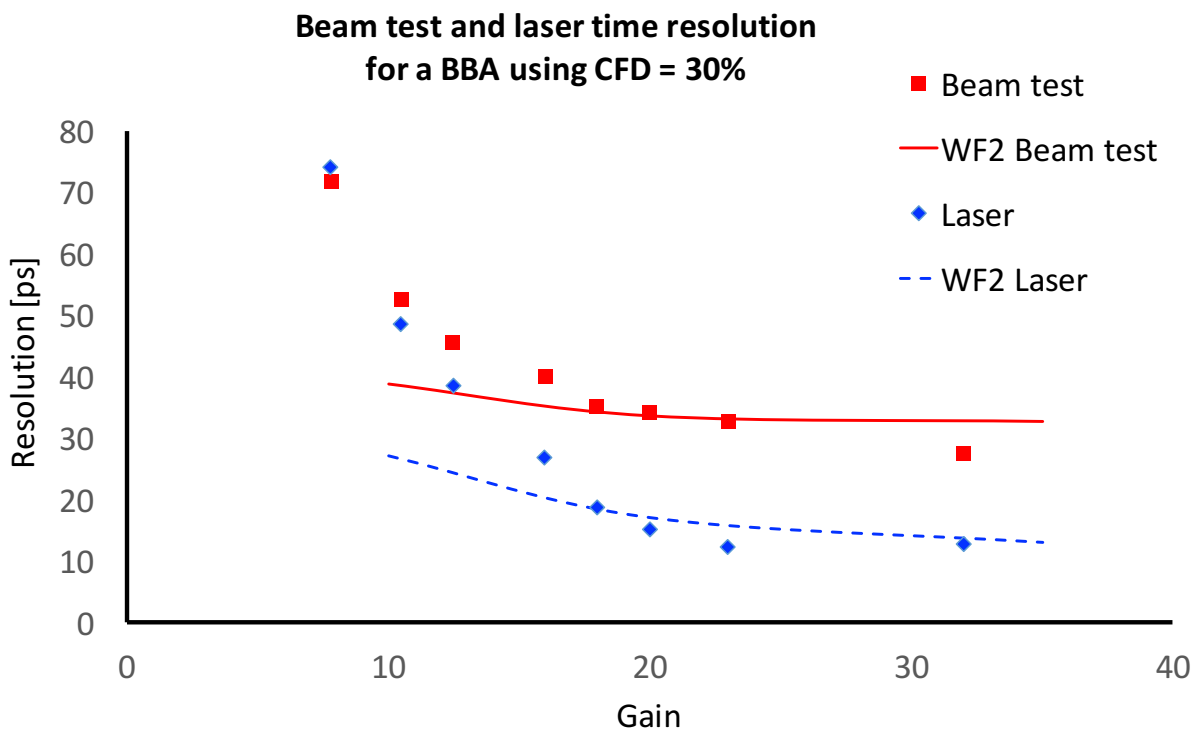

- Beam test data has jitter and Landau contribution
- Laser data has only Jitter contribution

**The landau contribution was extrapolated by the beam test and laser data**

**Good agreement between weightfield2 simulations and experimental data**

# Time resolution-Beam Test and Laser

$$\sigma_t^2 = \sigma_{jitter}^2 + \sigma_{landau}^2 + \sigma_{TDC}^2 \quad ?$$



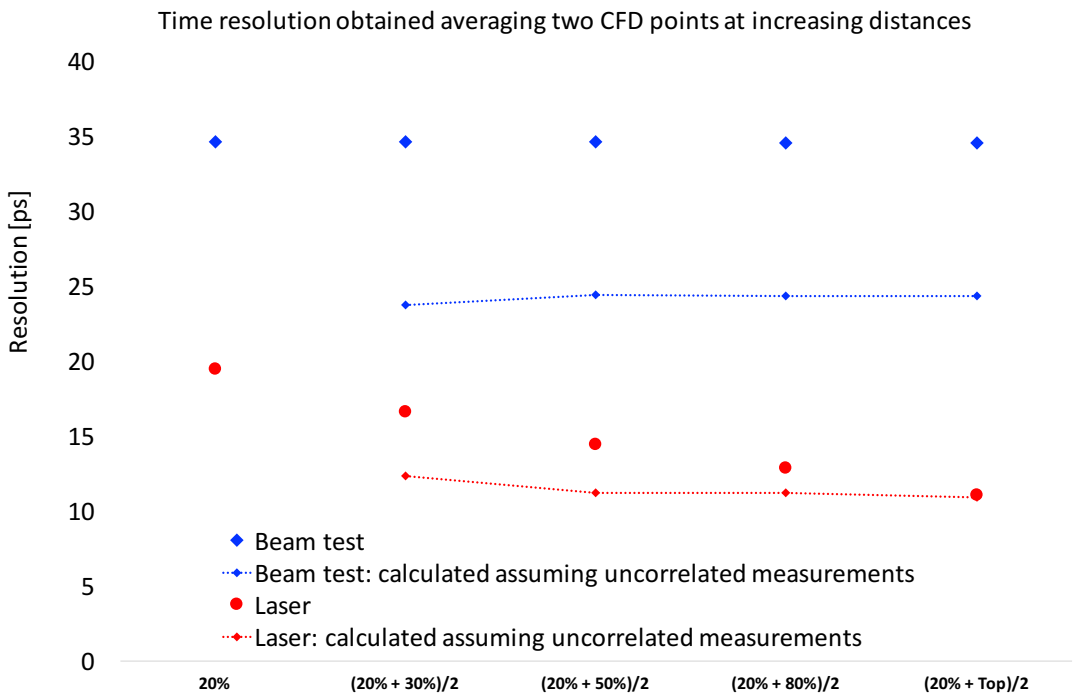

**Time resolution is flat for high value of gain**

**The different between beam test and laser data is due to only the landau fluctuation**

**Good agreement between weightfield2 simulations and experimental data**

# Correlation between time resolution and Jitter/Landau fluctuation

**Landau fluctuation cause a correlation for different points of the rising edge of the signal?**




**The beam test data (Landau) are correlated for all the rising edge of the signal (~400ps):**

*The Time Resolution of the average of two CFD points is the same of the single CFD point*

**The laser data (Jitter) are uncorrelated after all the rising edge of the signal (~400ps):**

*The Time Resolution of the average of two CFD points is better than the single CFD point*

# Conclusion

**Measurements of gain:**

- For FBK Sensors the gain measured in laboratory are in agreement with the TCAD simulation;
- For CNM Sensors there is the issue of the metallization that doesn't permit to perform the measurement with laser;

**Time resolution:**

- The landau fluctuation are predominant than the jitter for sensor with high gain and for CDF above 30%;
- The extrapolation of time resolution landau component and jitter component are in agreement with the Weightfiel2 simulation;
- Landau fluctuation induce a correlation between point for all the rising edge of the signal;

# Acknowledgements

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- RD50, CERN

# Backup

# Santacruz Board saturation