Update from the Spanish future collider network

Micro-strip detectors with intrinsic gain

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Lessons from ILD-FTD design & mockup

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CLIC workshop, CERN, January 2015

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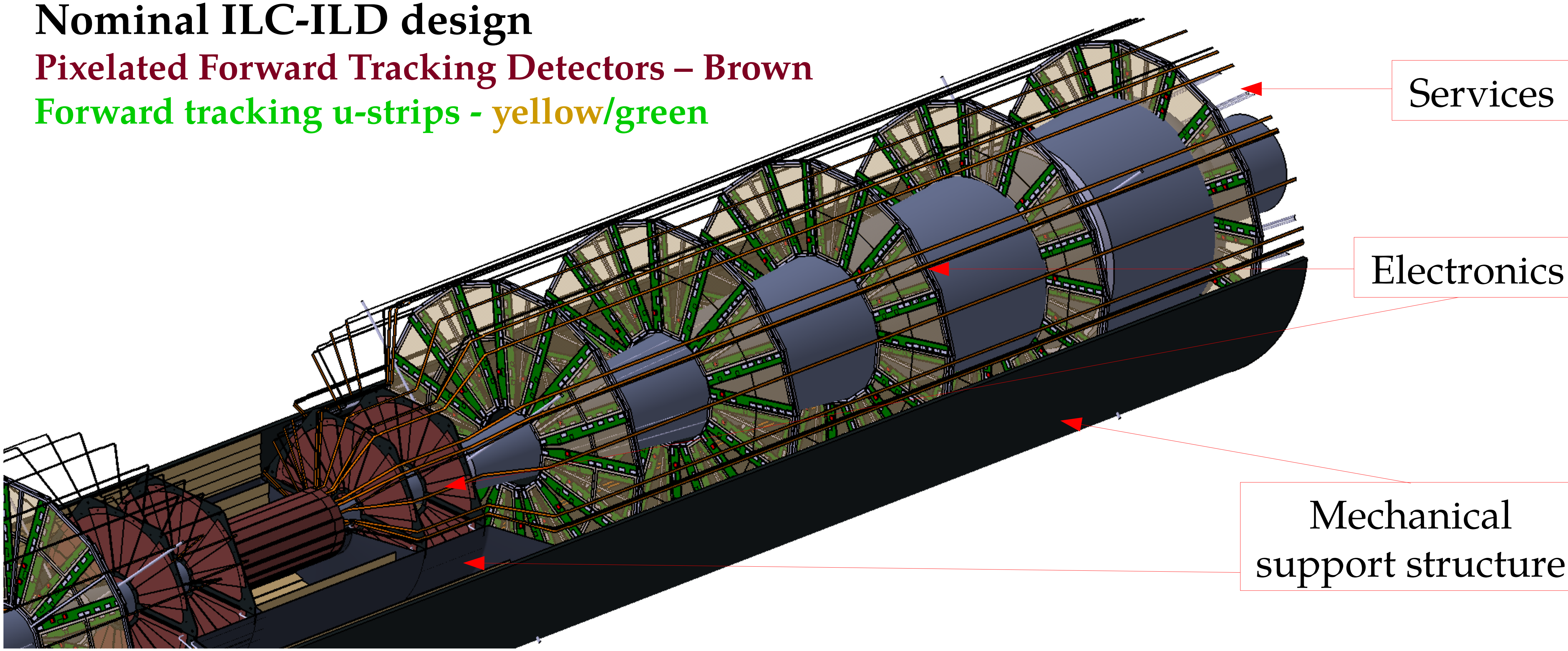
*with special thanks to Ladislav Andricek, José Deltoro, David Santoyo and Ivan Vila

Introduction

Nominal ILC-ILD design

Pixelated Forward Tracking Detectors – Brown

Forward tracking u-strips - yellow/green



Engineering studies to clarify:

Integration

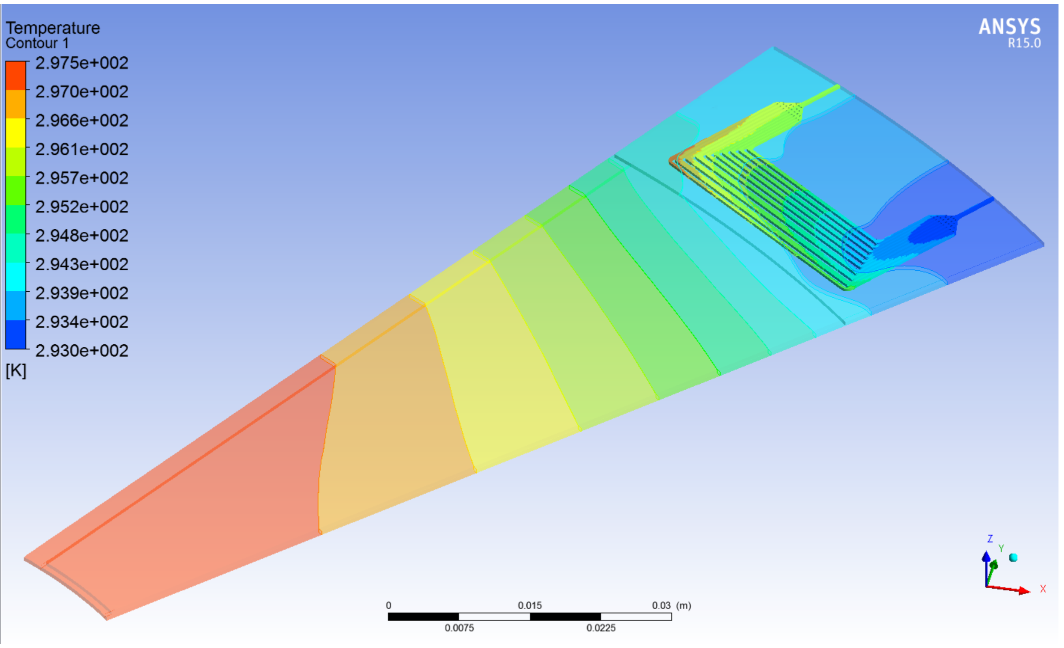
Materials
- Radiation length
- Mechanical properties
- Joints
- New materials
- ...

Services
- Power to deliver
- Cooling strategy
- Layout
- ...

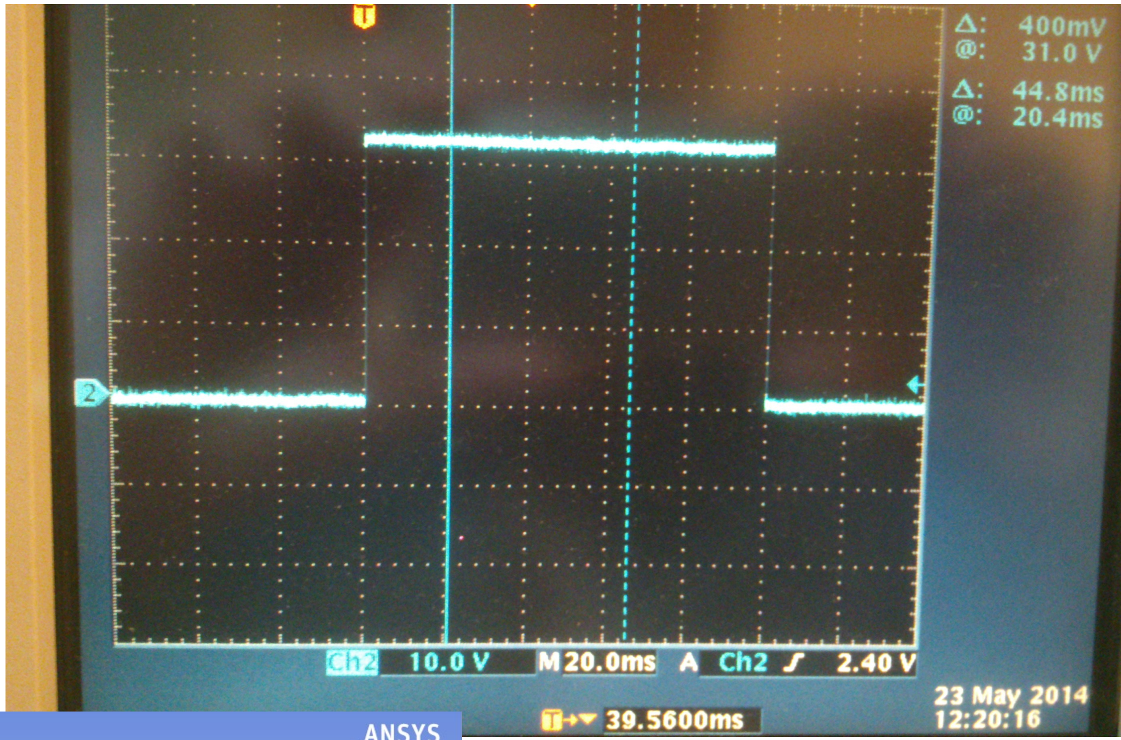
Cooling strategy

Micro Channel Cooling

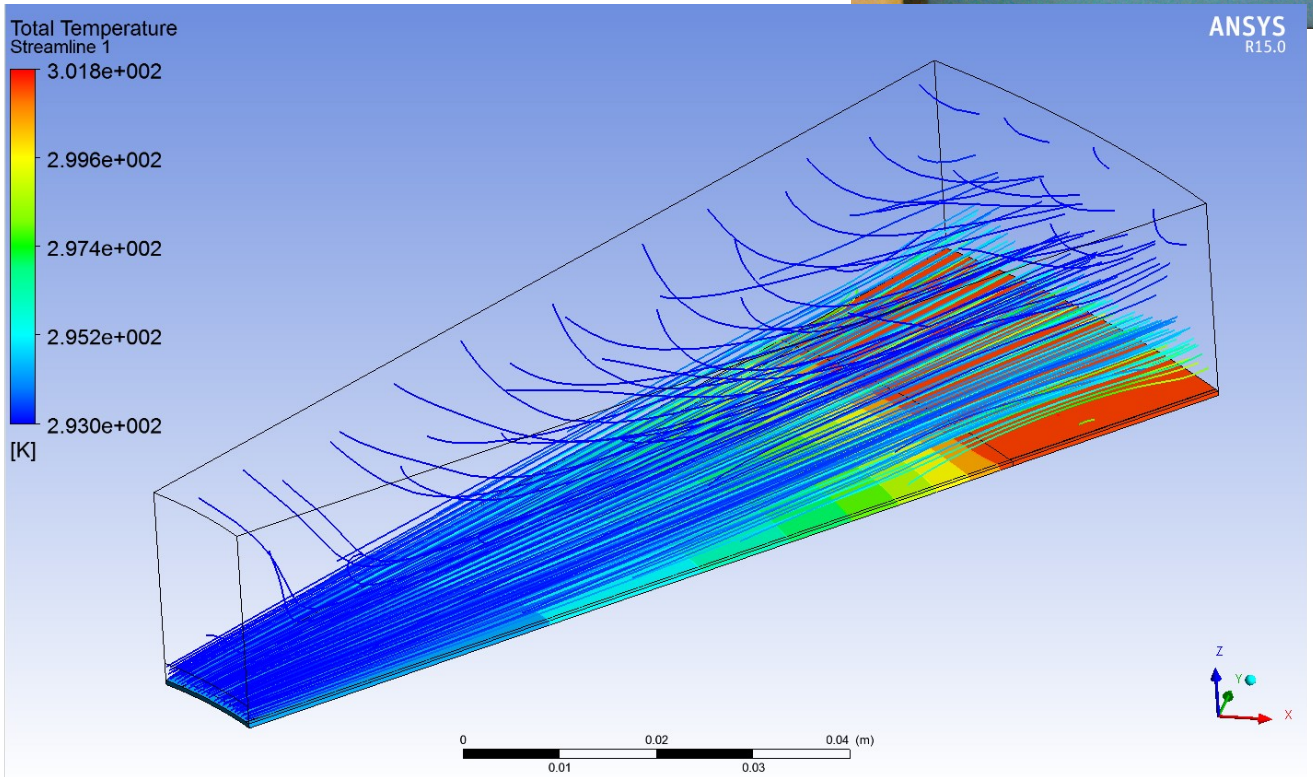
(IFIC-Bonn-HLL AIDA-H2020)



Power Pulsing

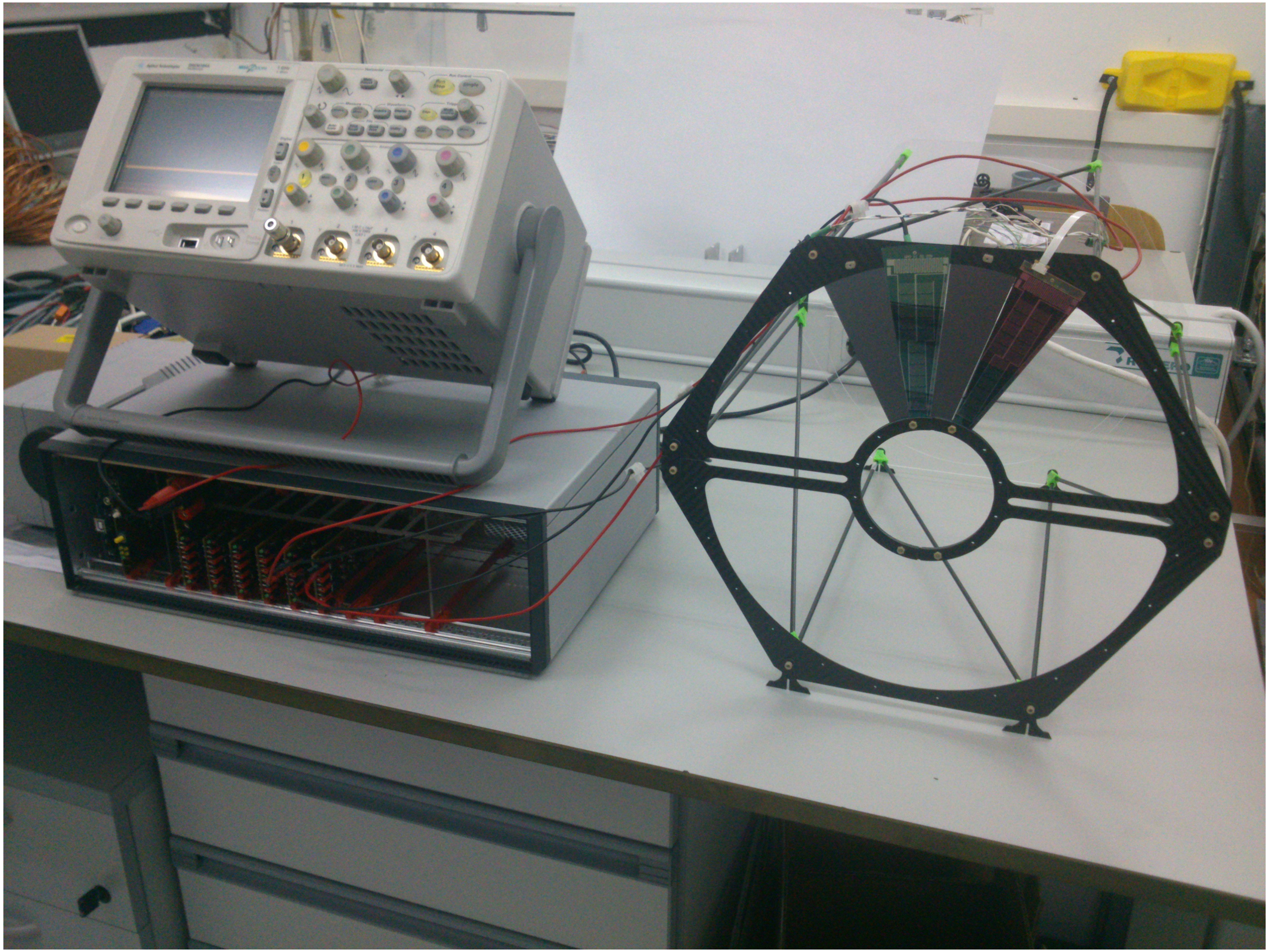


Air cooling

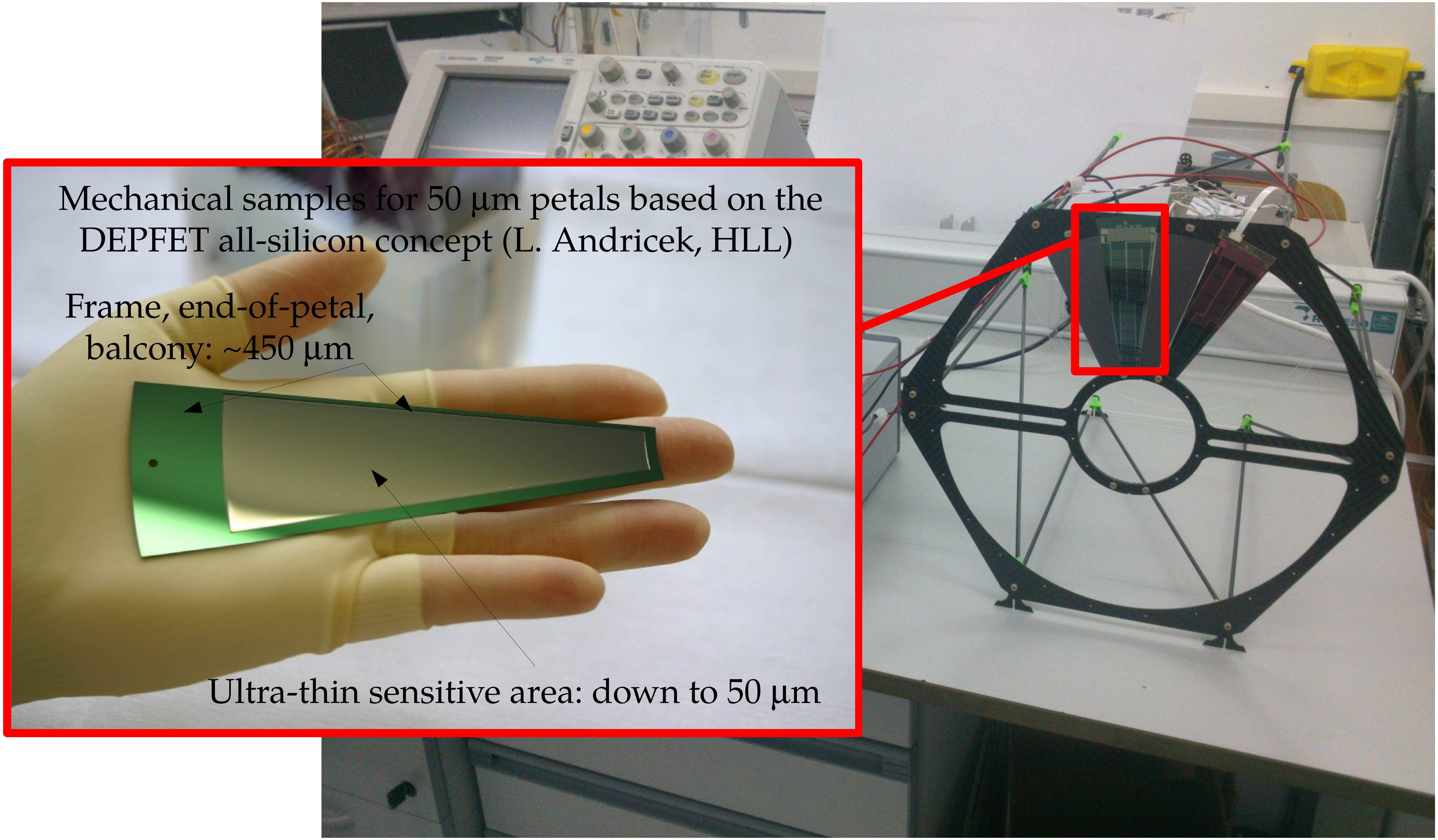


First generation mock-up

IFIC copy of the AIDA pulsing power supply (AIDA deliverable report)



First generation mock-up

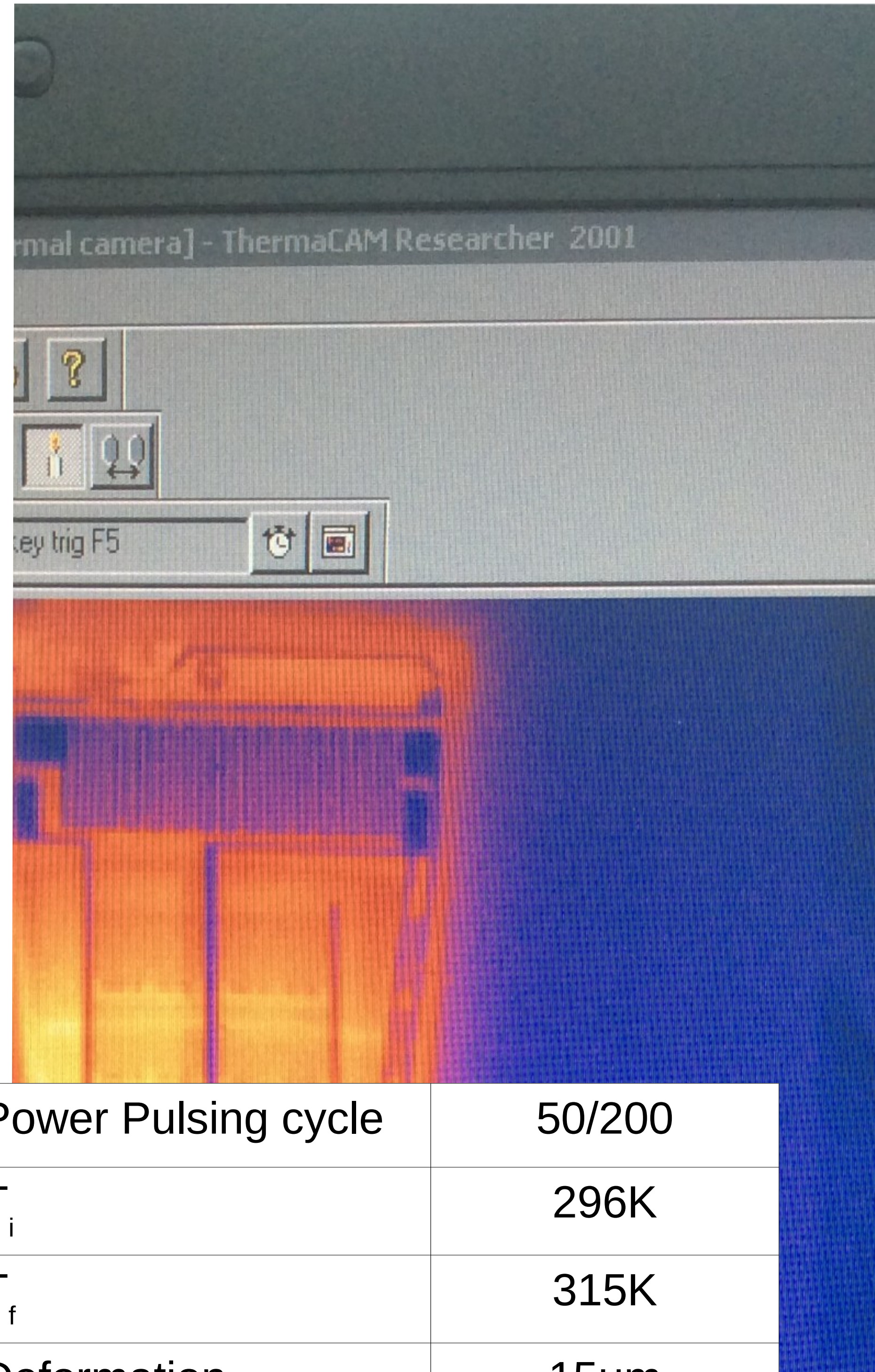


Heat load & deformation

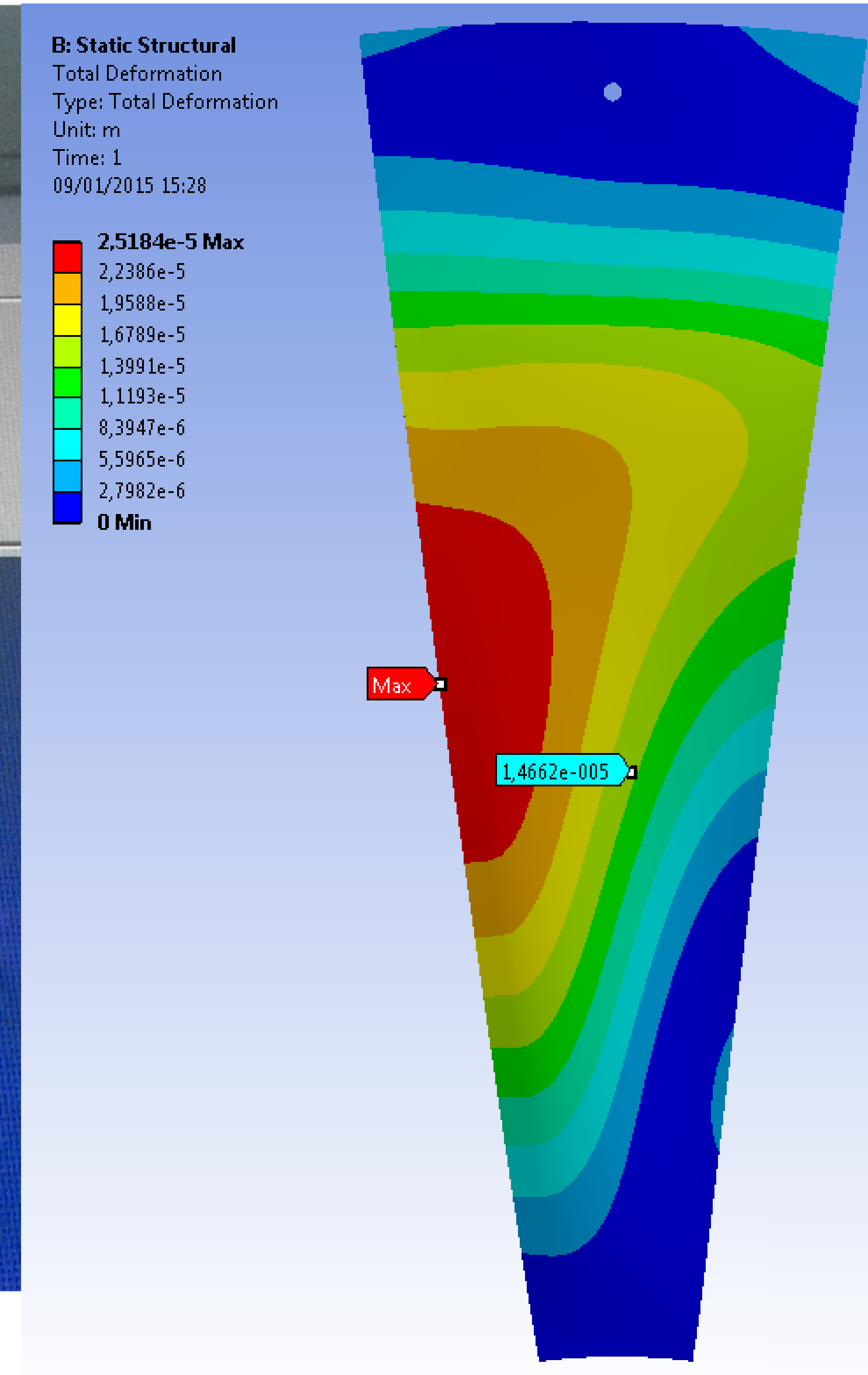
Nominal heat load (x2) without cooling leads to significant static deformation.

Extensive searches for dynamic deformations on ms time scale due to pulsed power (Bragg fibers, capacitative sensor, laser sensor)

No effect observed, seems negligible.

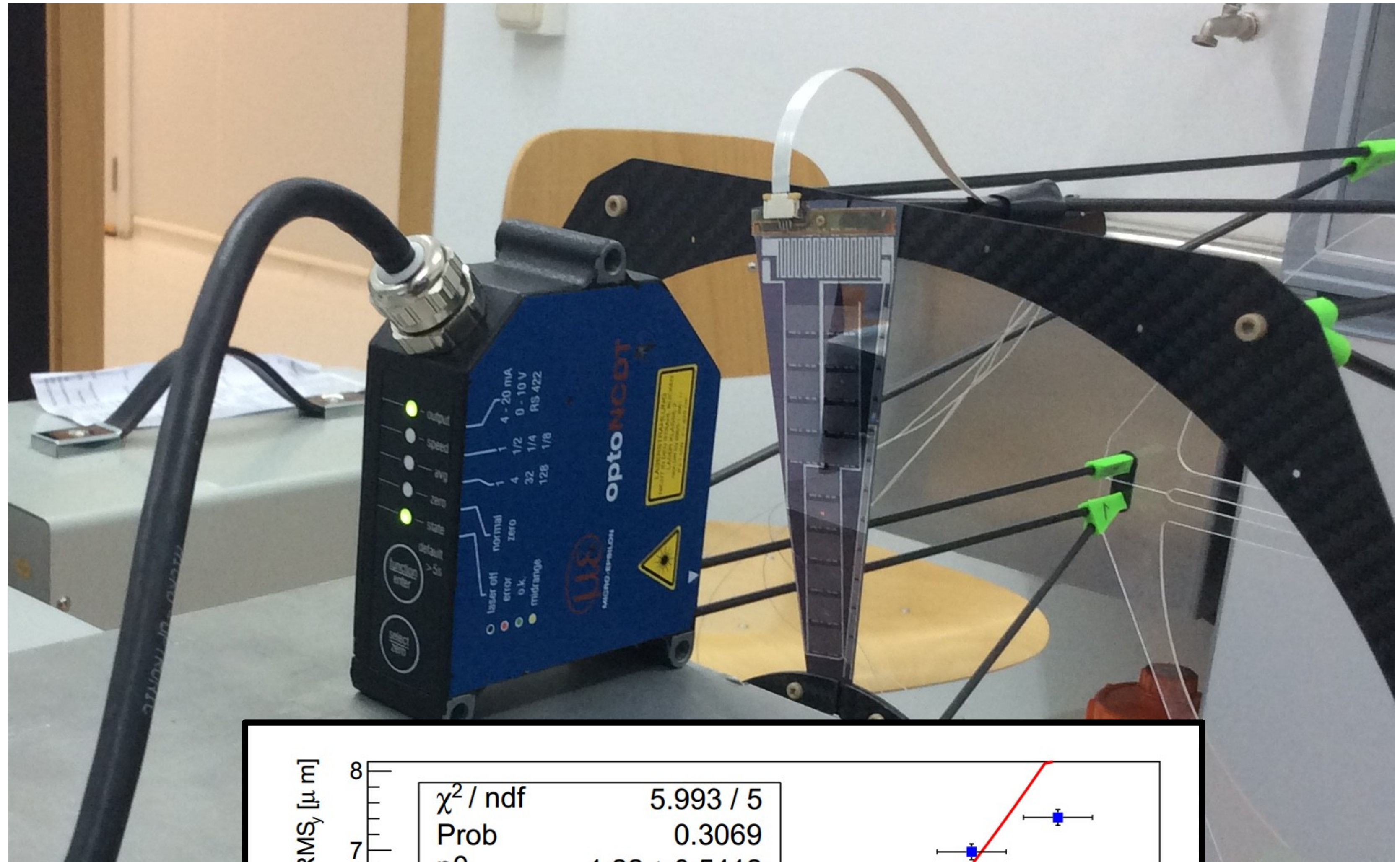


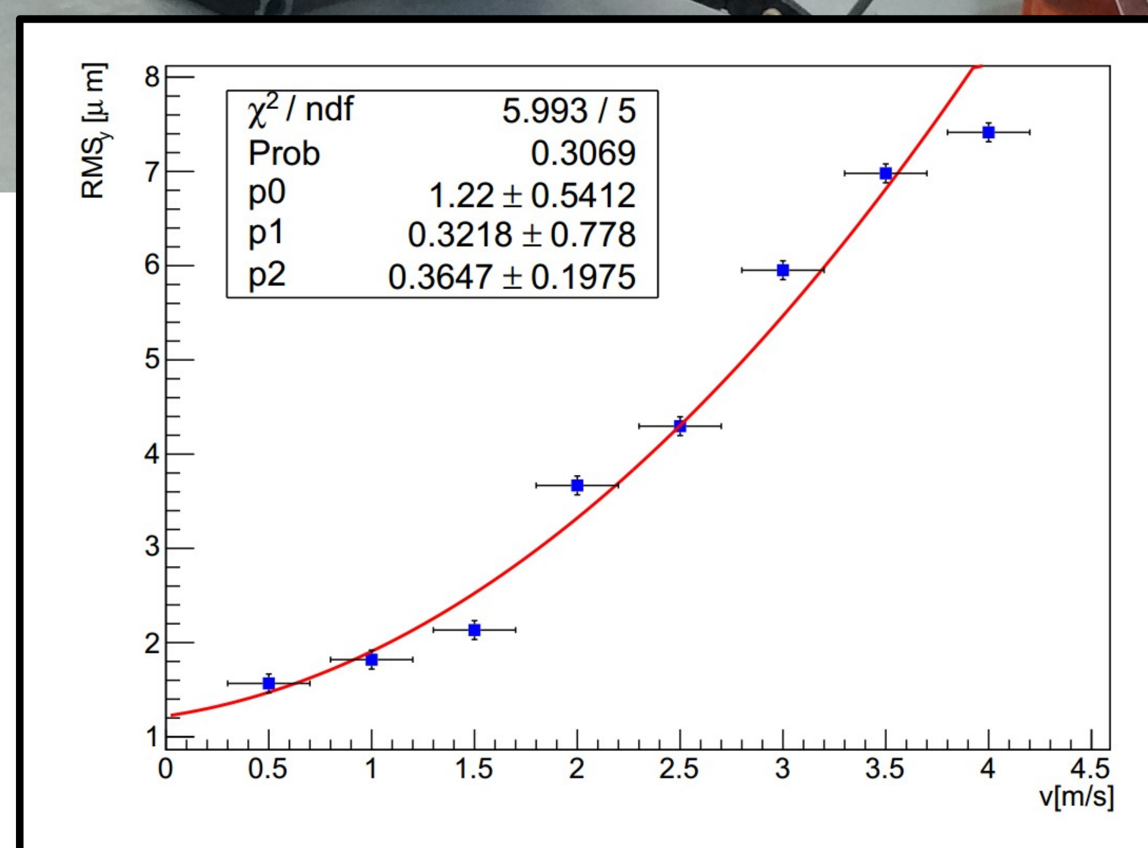
Power Pulsing cycle	50/200
T_i	296K
T_f	315K
Deformation	15µm



Air flow & deformation

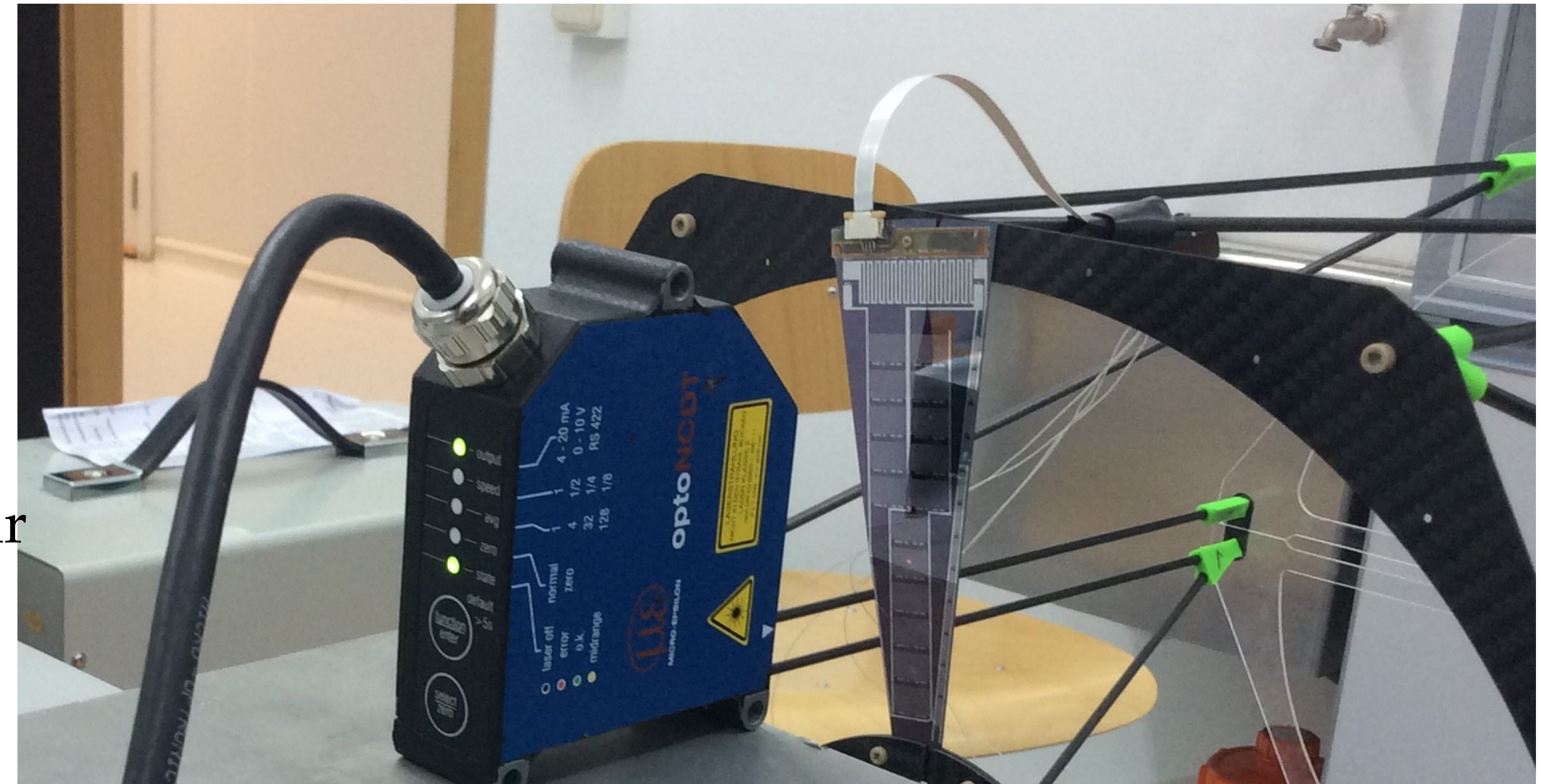
A laminar air flow in front of the disk, with a moderate speed of 1m/s, is sufficient to remove the nominal DEPFET heat load (assuming 1/25 duty cycle for power pulsing, IEEE TNS 60-2-2, arXiv:1212.2160)





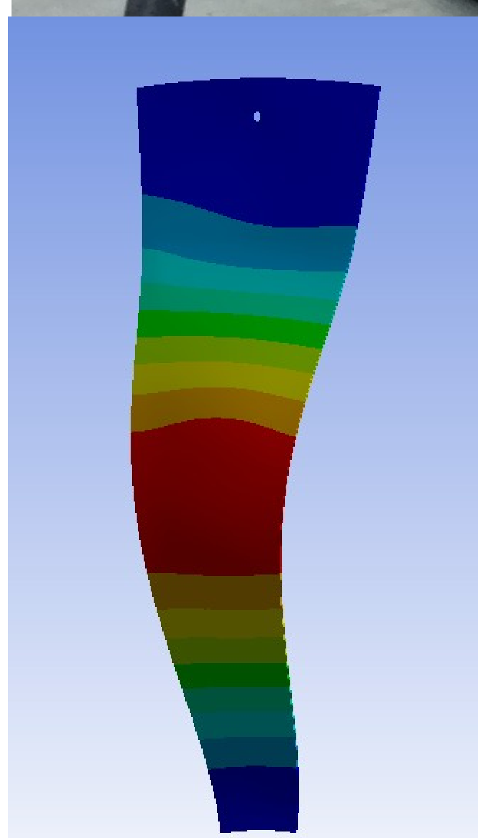
Air flow does introduce slight vibrations. For large air speed these become sizeable wrt the intrinsic resolution.

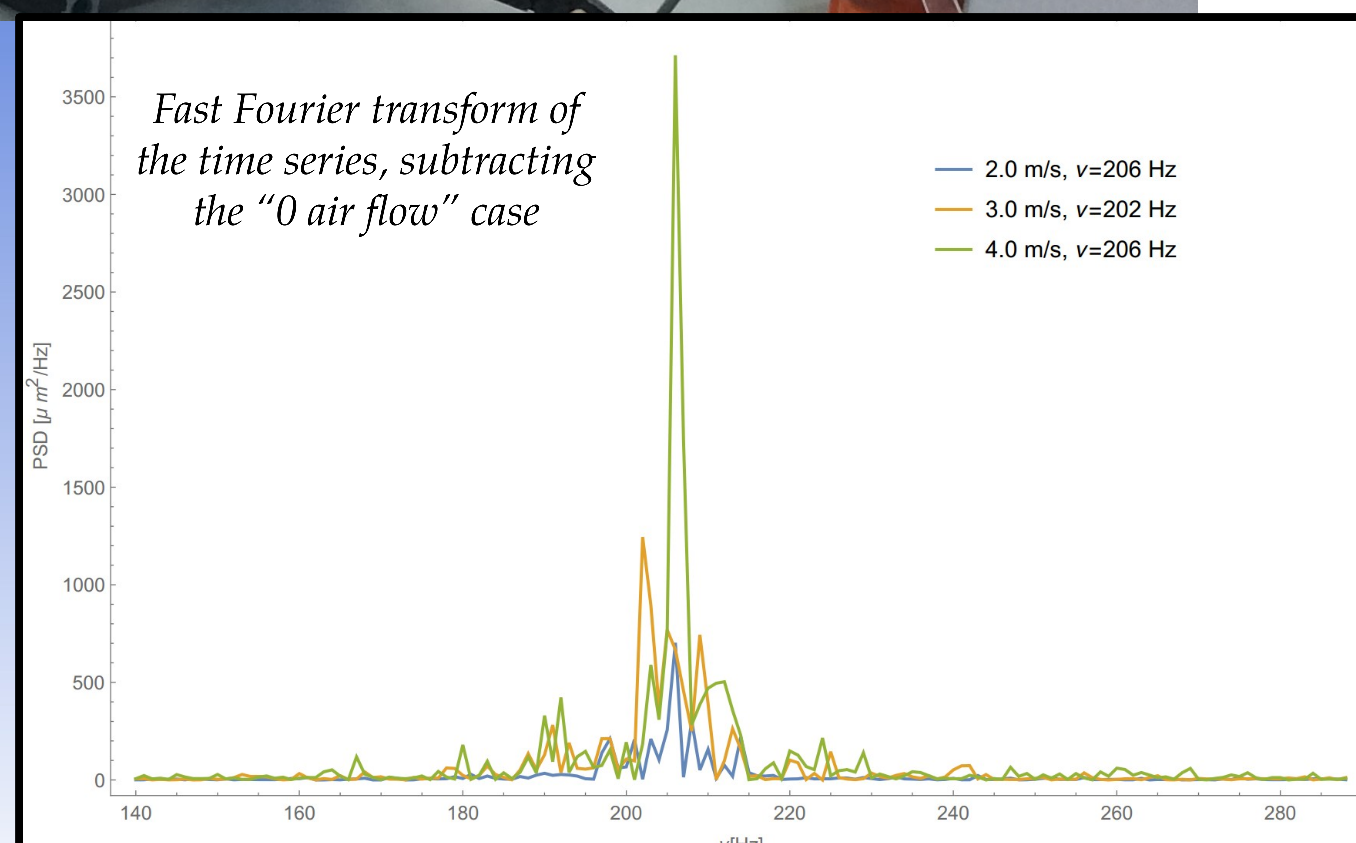
Air flow & deformation



Vibrations induced by air are at 200 Hz. Finite-element simulation of just the petal predict 300 Hz.

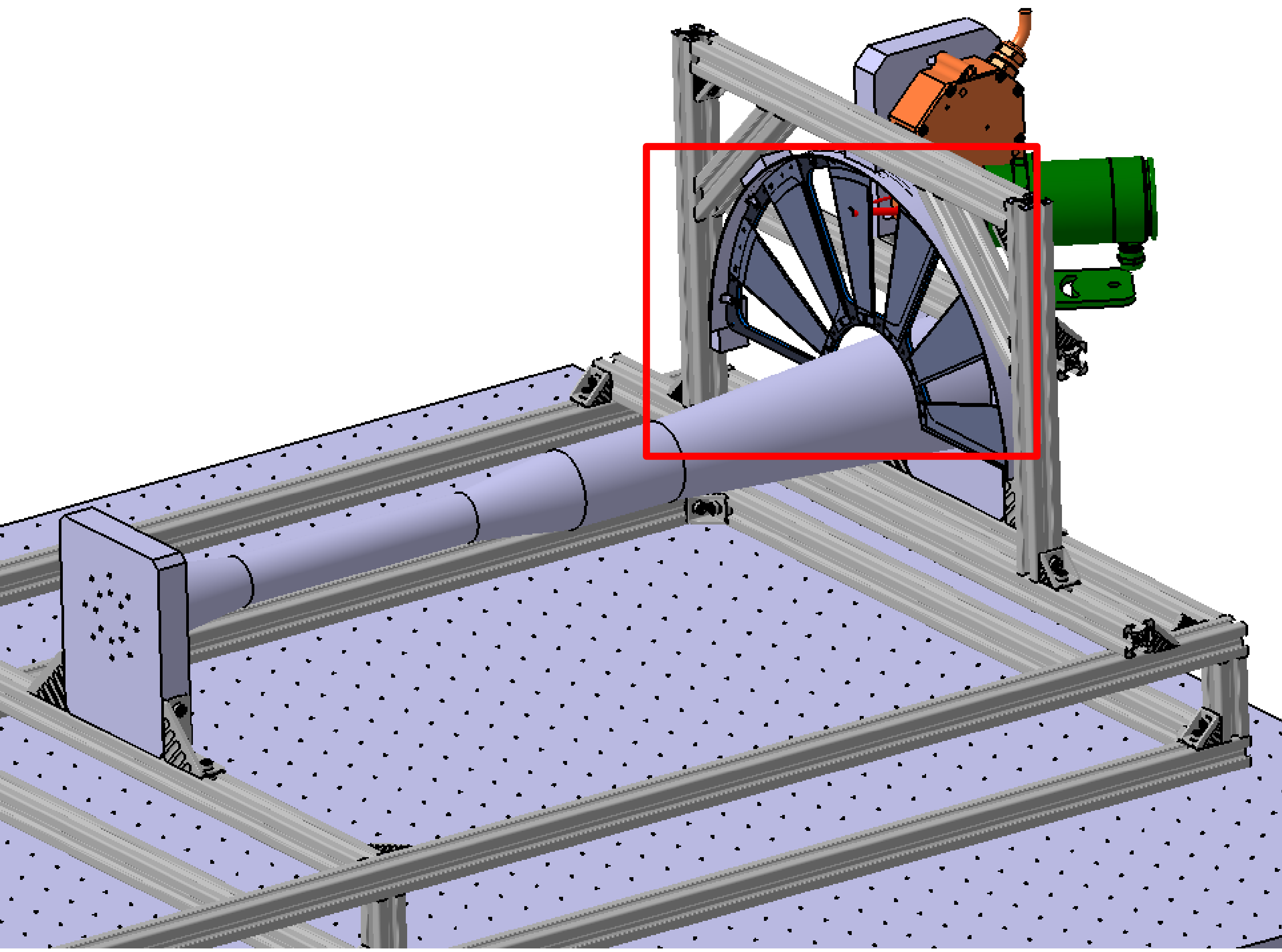
Work on petal design and CF support to raise the lowest eigenfrequency

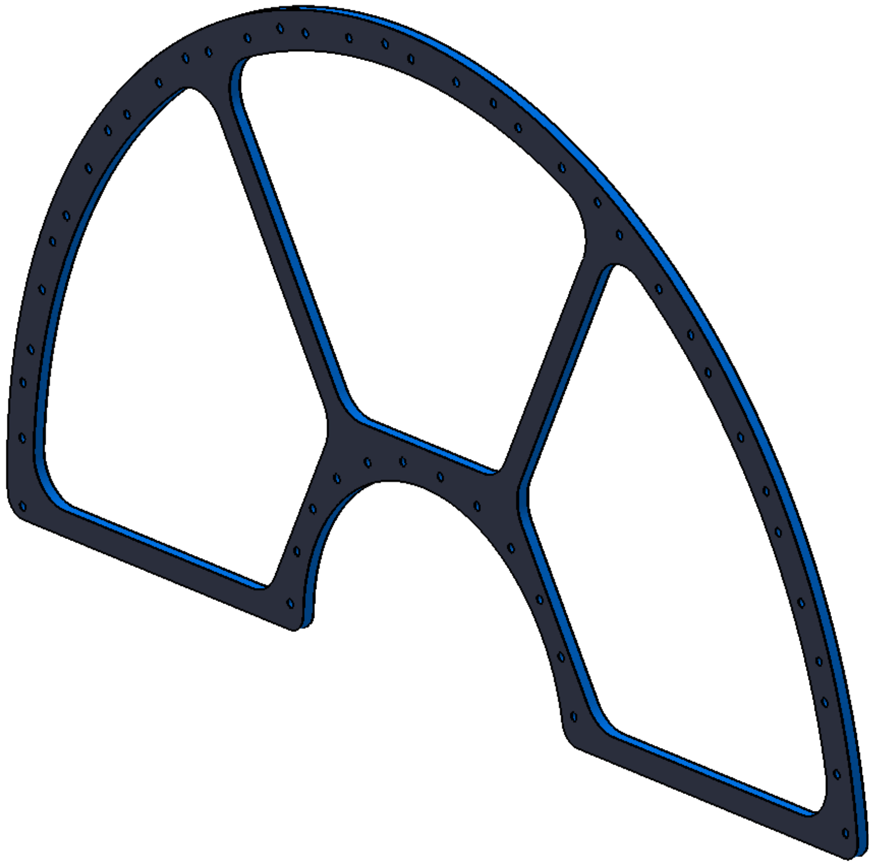




Second generation mock-up (first half 2015)

More sophisticated CF support structures are being designed and will be produced at INTA (Spanish Aerospace Institute)





Sandwich: [0(t=0,07),60(t=0,07),-60(t=0,07),$\overline{\text{core}}$(t=2-3)]

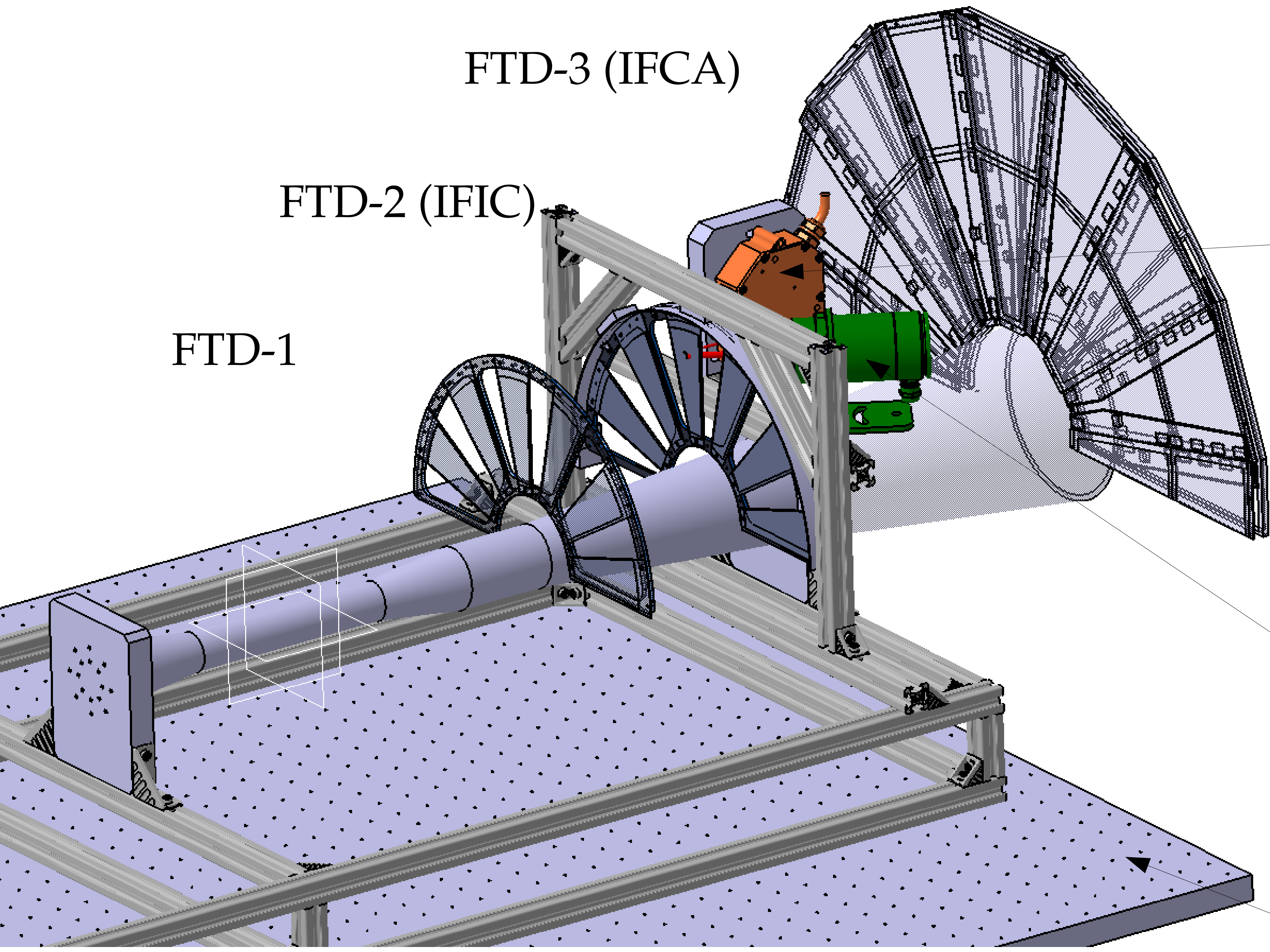
CFRP: M55J;
epoxy: cyanate-ester;
core: airex, nomex, rohacell
(mechanical and radiation tests needed)

R_{int} = 35mm; 45mm

R_{ext} = 150mm

m=10g (X/X_0~0,04%)

Complete FTD mock-up (2015+)



Avalanche Detectors with Low Internal Gain

- Exploit **avalanche** phenomenon of a **n+p junction** polarized **in reverse mode**.
  - **LGAD = Low Gain Avalanche Detectors**

Signal multiplication: *charge carriers accelerated in high electric field can release further carriers that add to the signal*

Linear regime: *signal remains proportional to primary ionization signal (avoid Geiger mode)*

- Higher **signal to noise ratio** (S/N)
- => Better spatial resolution
- => Less material
- => Rad-hard performance (RD50 LGAD)

Use CNM in-house processes: capability for thin 6" wafers, full custom implants and segmentation (pixel/strips)

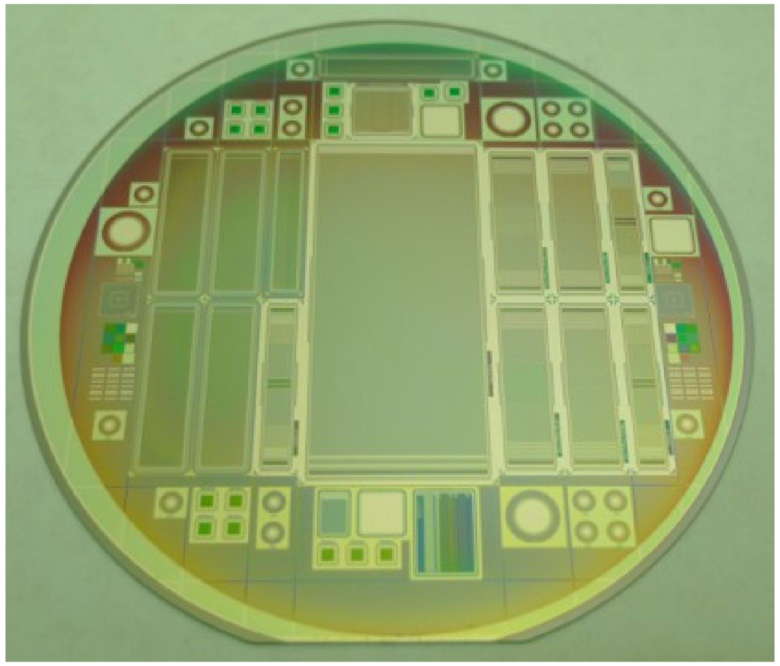


Figure 1. General view of a wafer with the new **resistive microstrip** detectors fabricated at IMB-CNM clean room

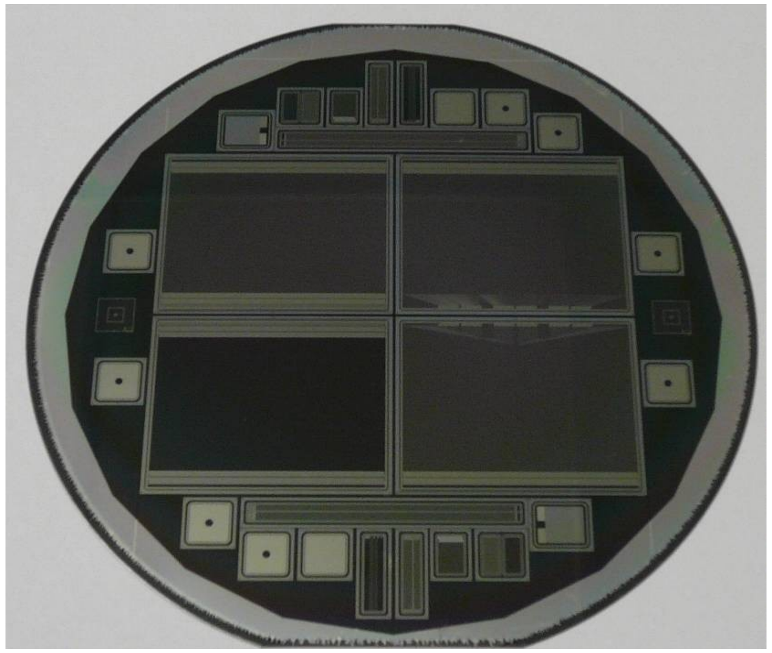


Figure 2. General view of a wafer with **thin substrate microstrips** detectors fabricated at IMB-CNM clean room

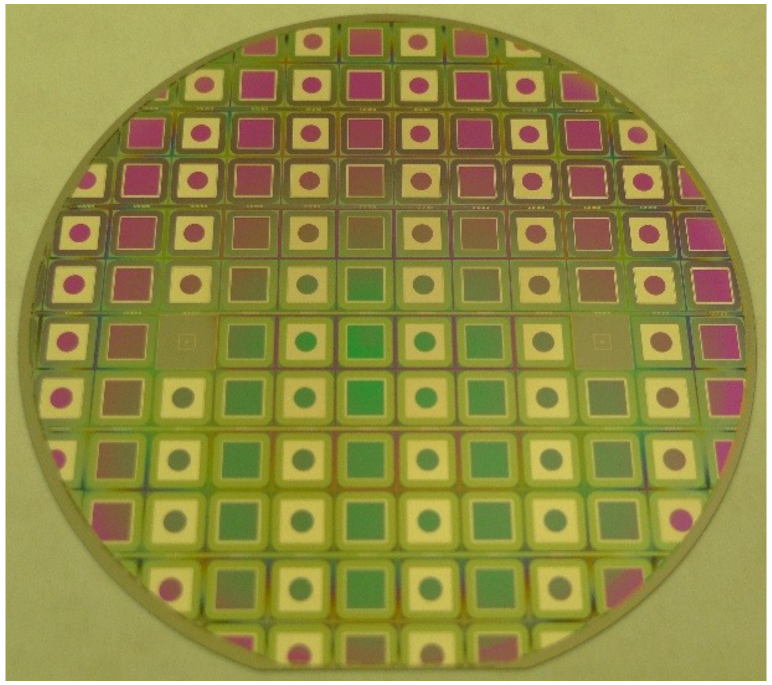
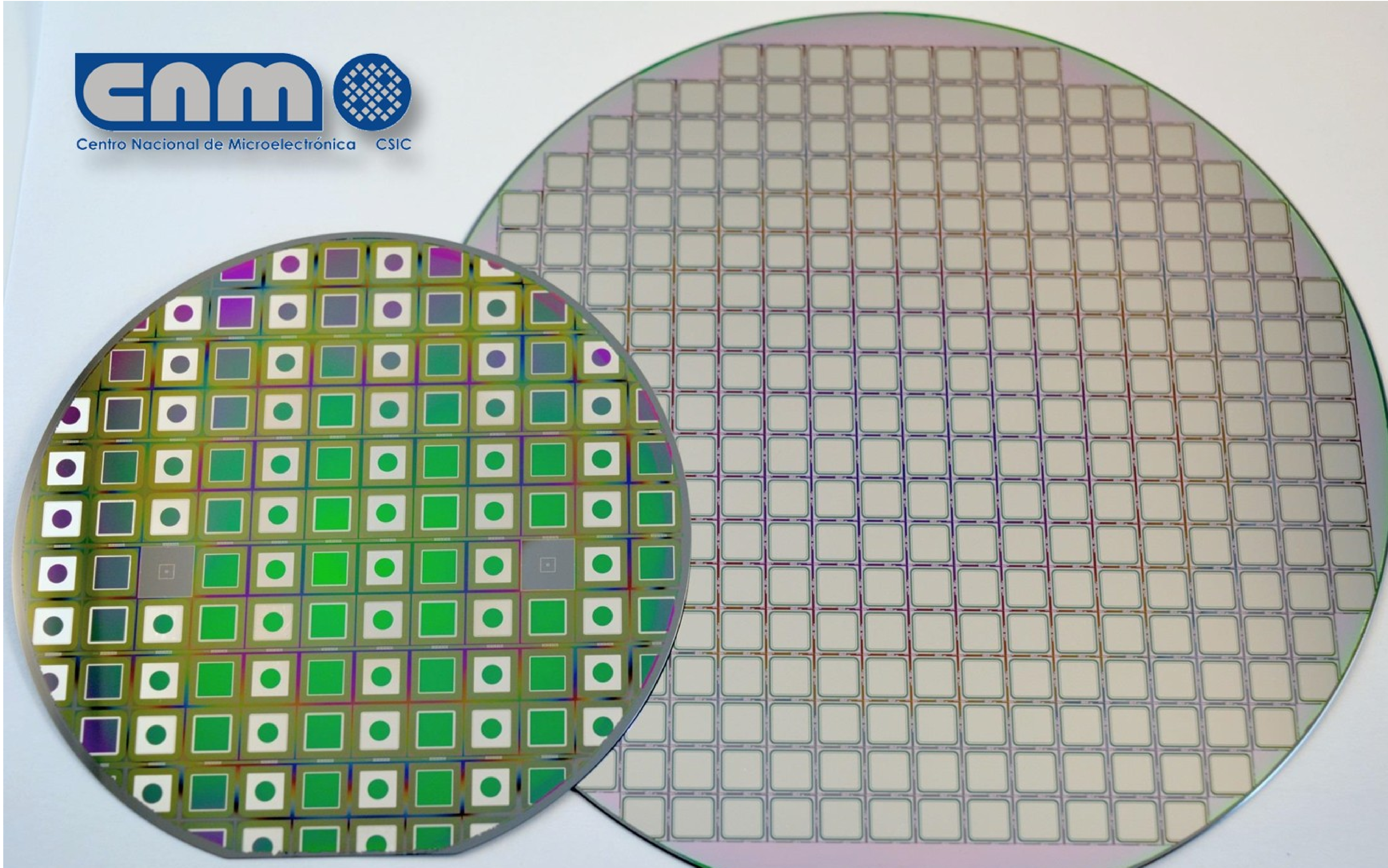


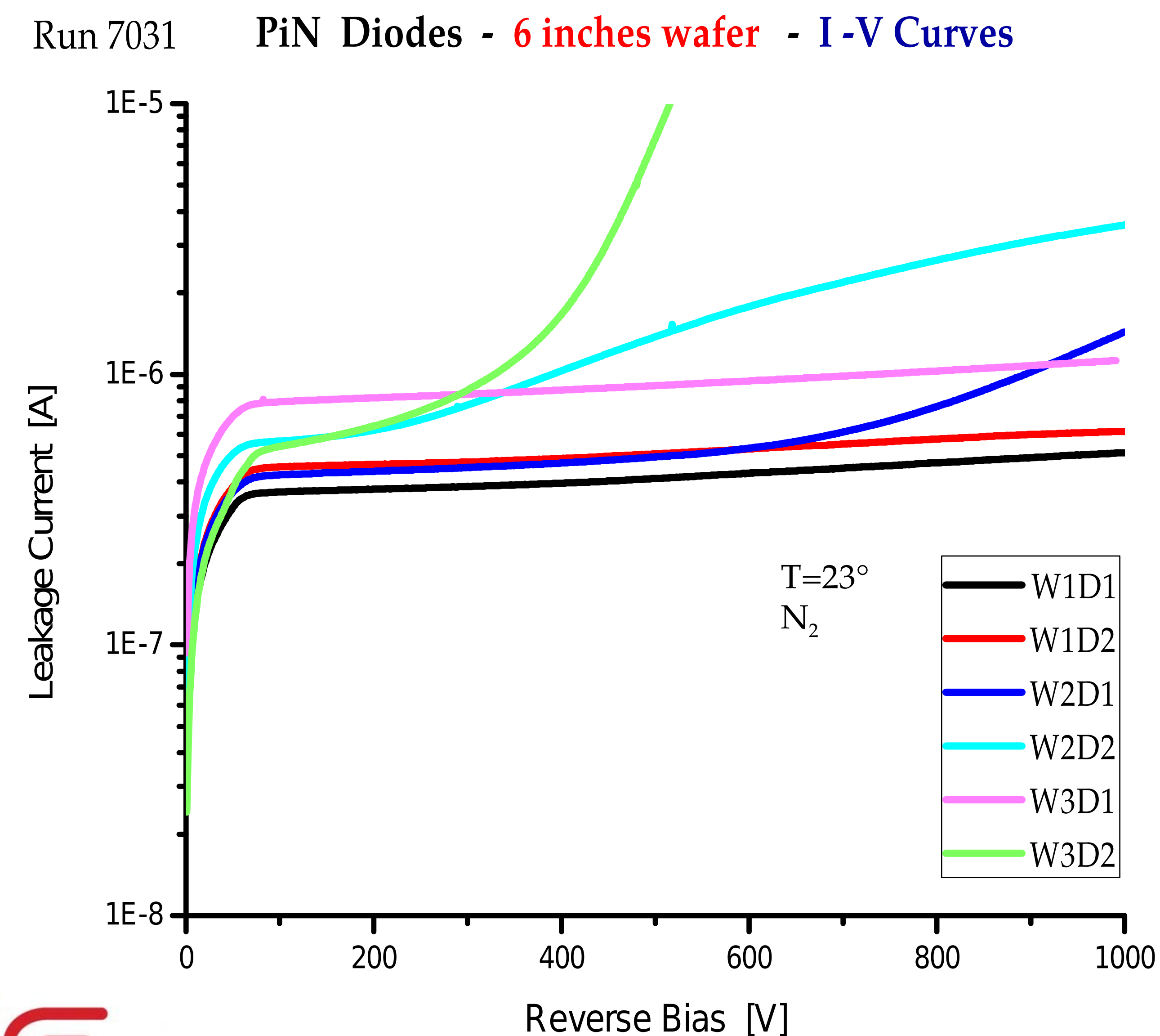
Figure 3. General view of a wafer with **LGAD** detectors (APD evolution) fabricated at IMB-CNM clean room

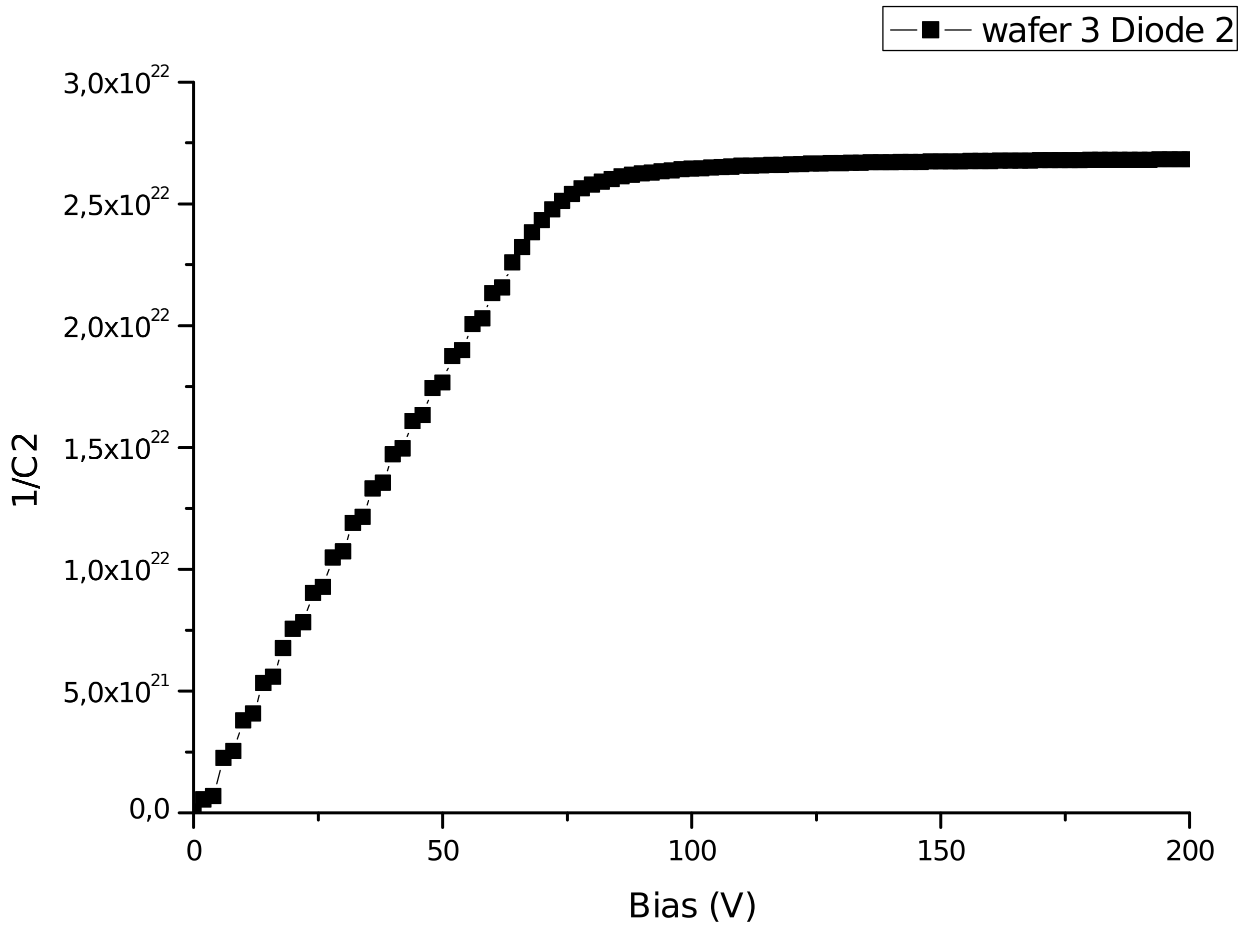
6 inch Technological Process



- ✓ First PiN Diodes On 6 Inches Wafers

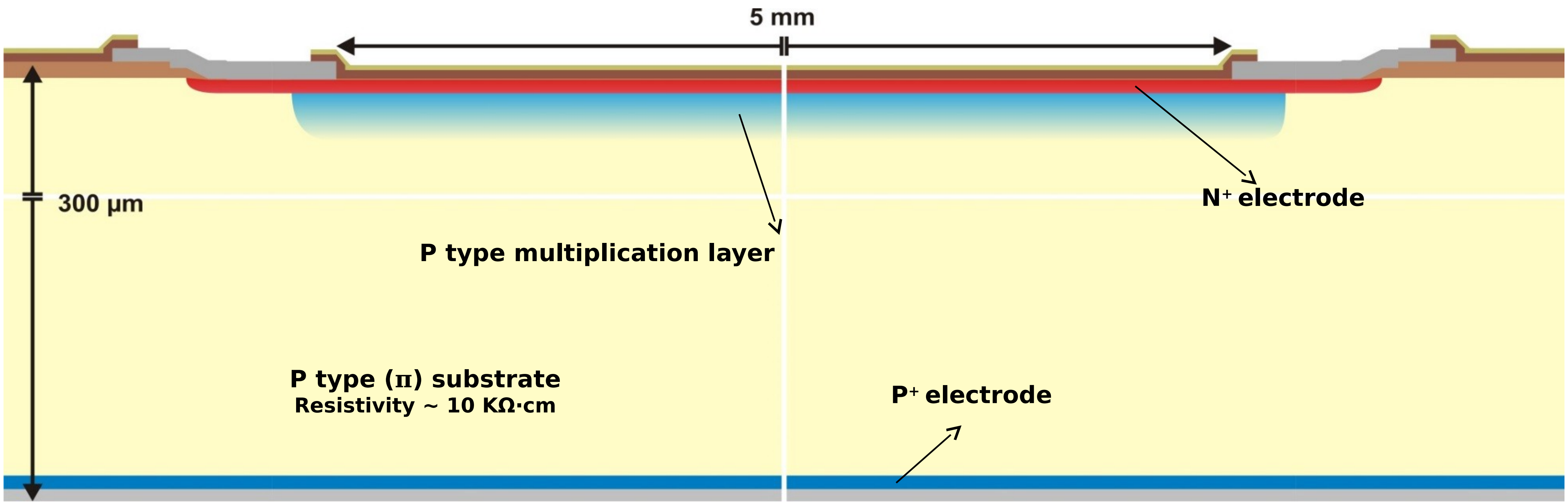
- First Results:
  - ✓ **Good** electrical performances
  - ✓ **Comparable** to **4 inch** technology PiN diodes





Low Gain Avalanche Detector (LGAD)

- The goal: a **diode with multiplication** working in linear mode (proportional response).



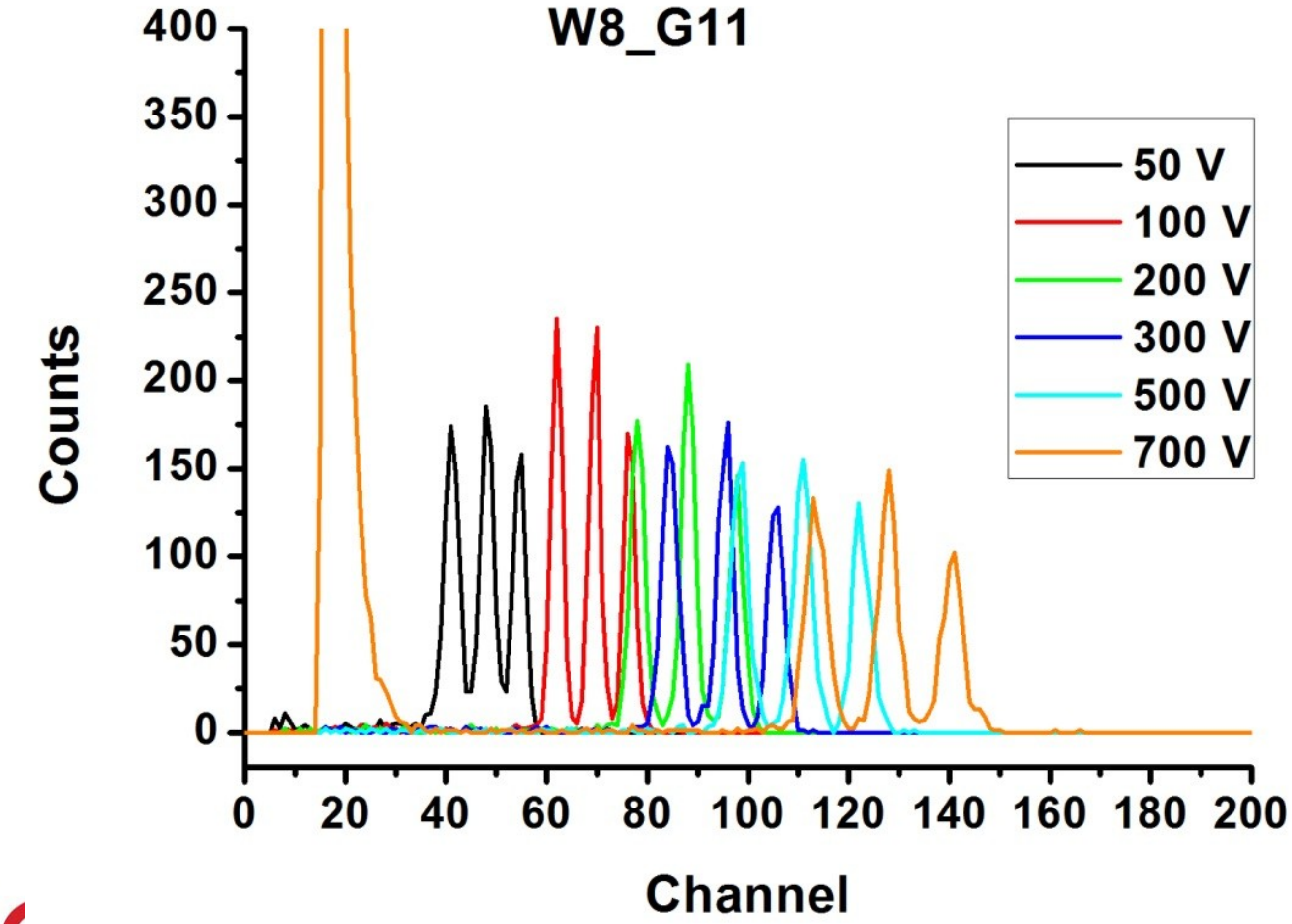
- Starting point : PiN-*pad* diode with an area of 5mm x 5mm.
  - **Structure**: highly resistive *p*-type substrate
    - ***n*+ and p+ diffusions** for the electrodes
    - ***p* diffusion** under the cathode

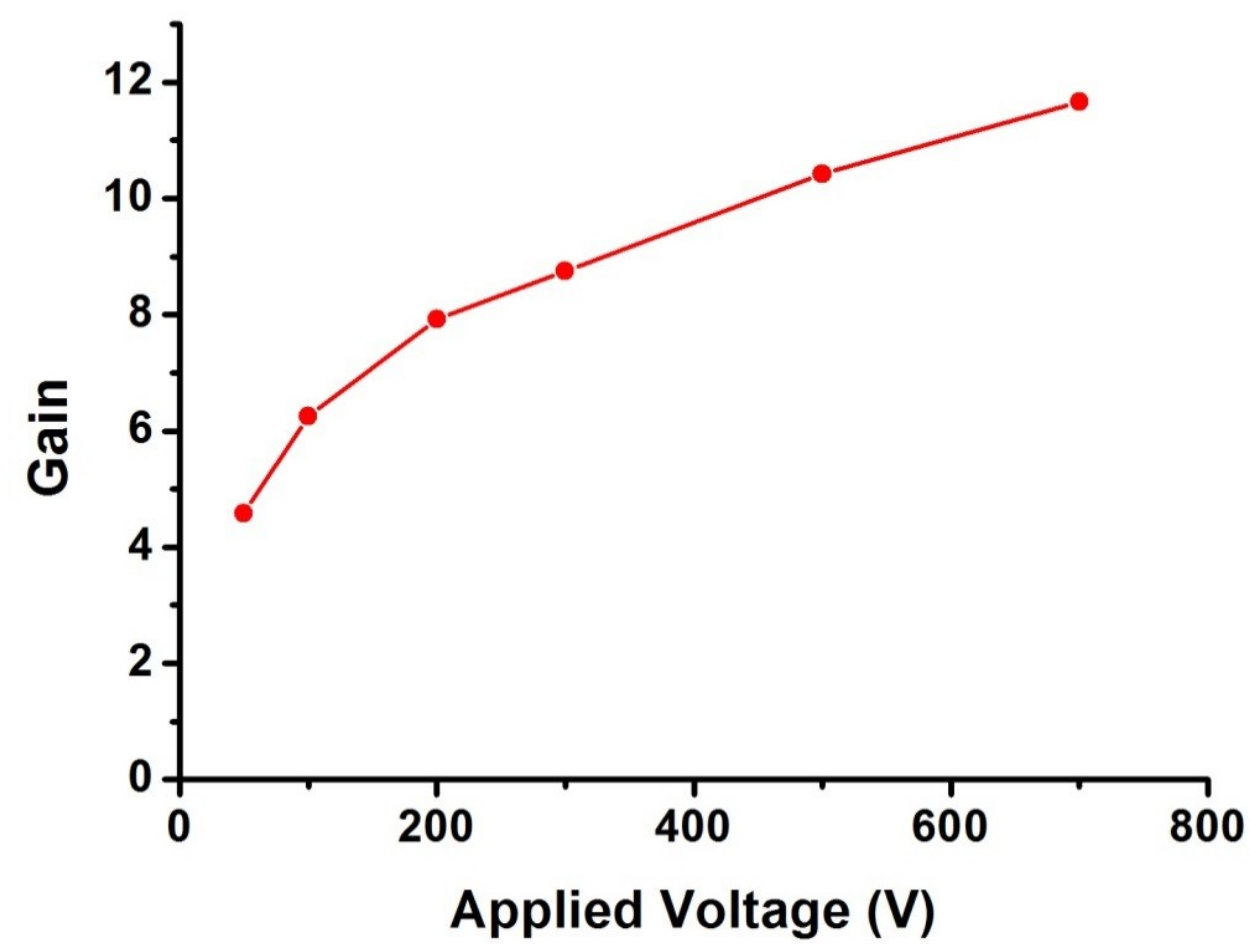
      => enhance electric field => **multiplication layer**

Charge Collection Measurements: Alpha Particles

- Multiplication factor measured with **tri-alpha radiation source** ($^{239}Pu/^{241}Am/^{244}Cm$)

$$Gain_{@V} = \frac{Central\ Peak\ Channel_{@V}}{Central\ Peak\ Channel_{No\ mult.}}$$



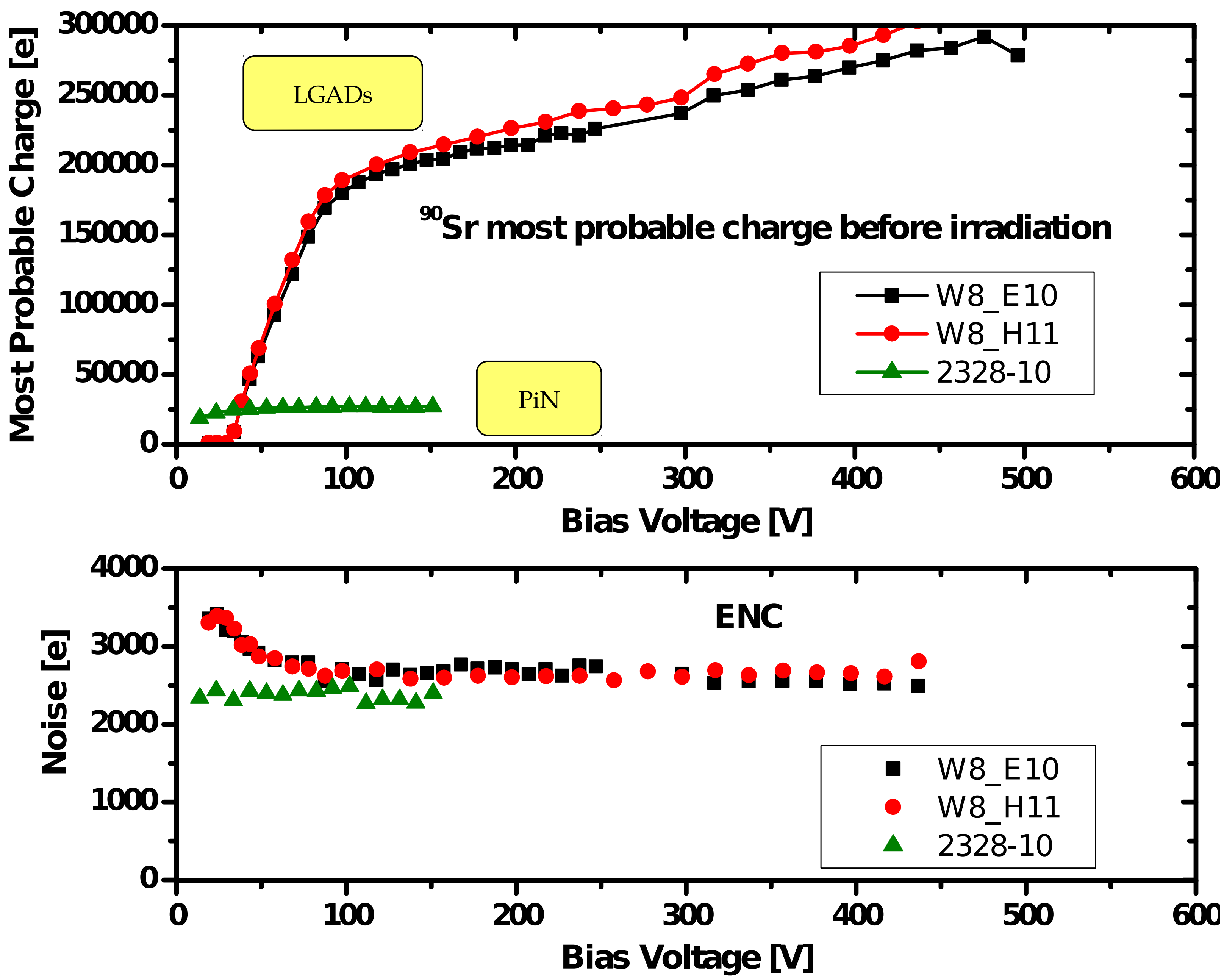


Charge Collection Measurements: Electrons (~mips)

- Charge collection measurements of *mips* with ^{90}Sr source

IJS

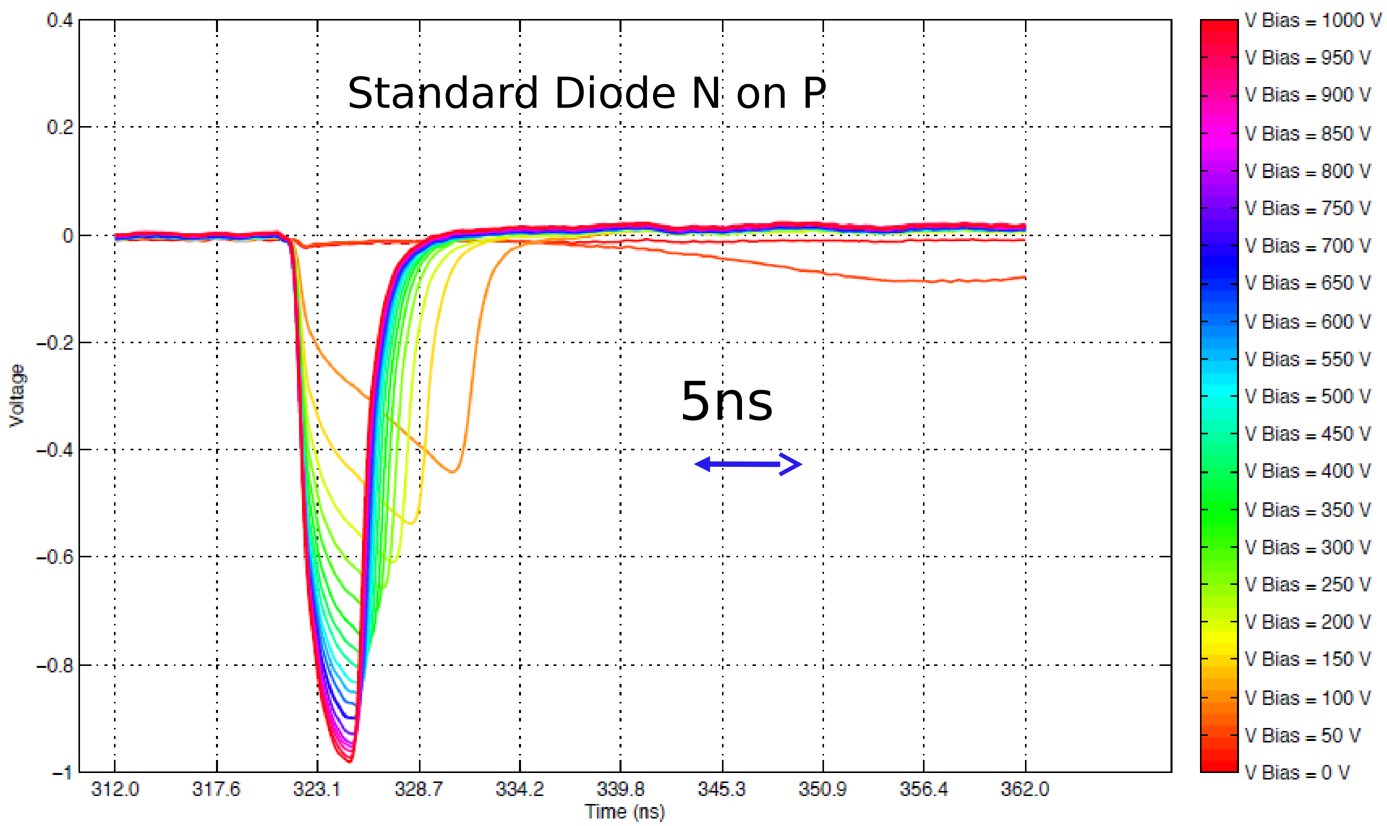
Measurements with LHC-style Front-End performed at the "Jozef Stefan" Institut, in Ljubljana, Slovenia

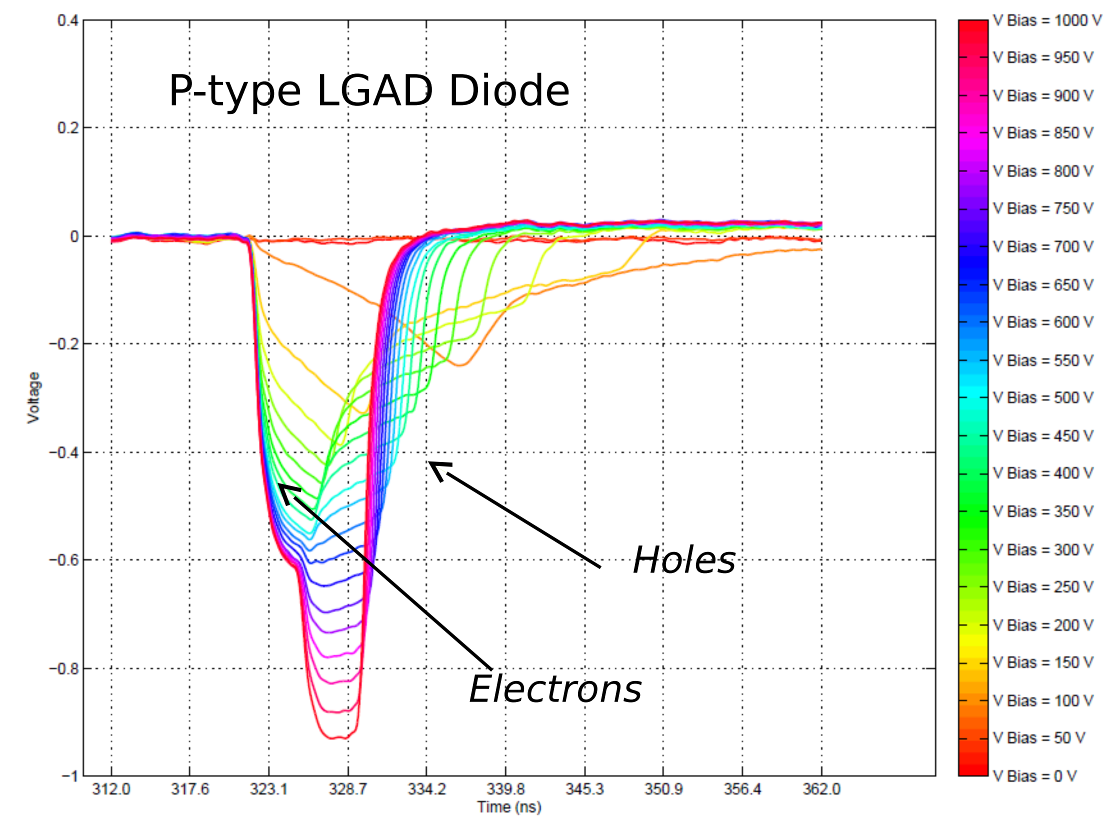


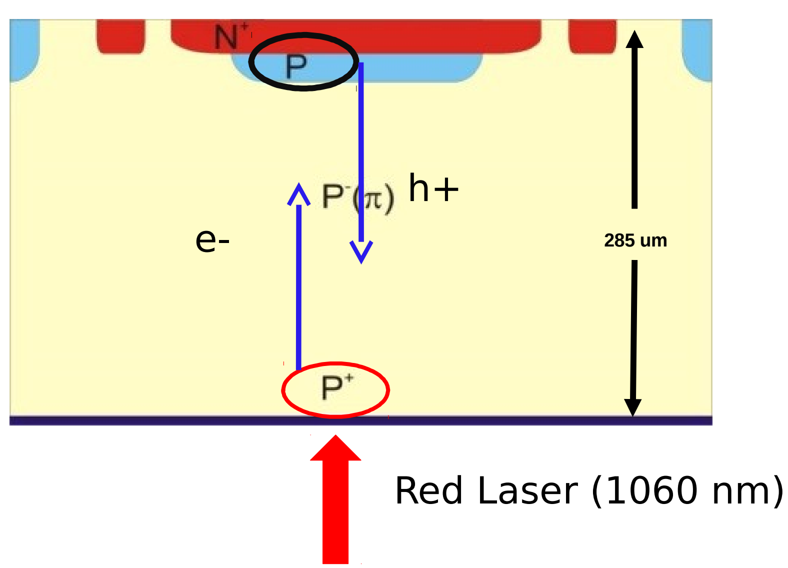
- Observed gain:
  Signal amplified by a factor 8 at 300V

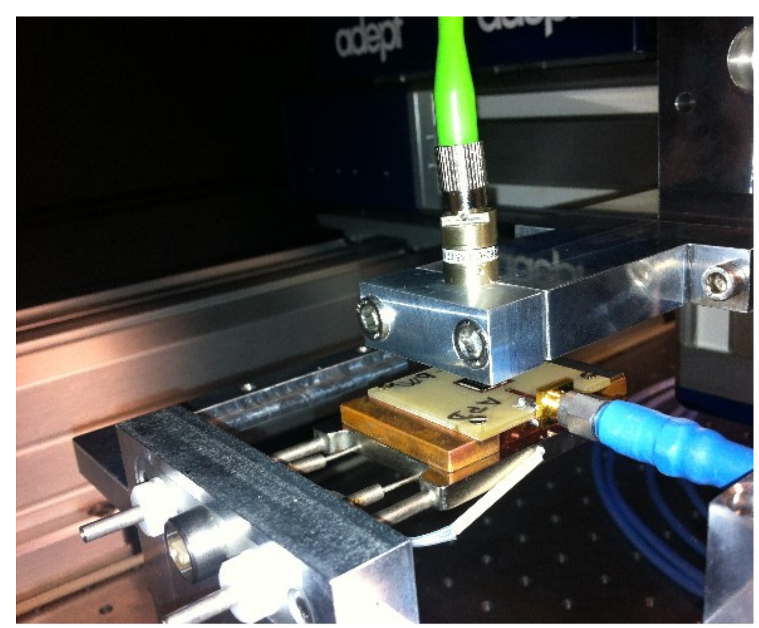
- Compare with a commercial PiN:
  no significant **increase of the noise**

o **Red Laser TCT** Characterization. **Bottom** Injection



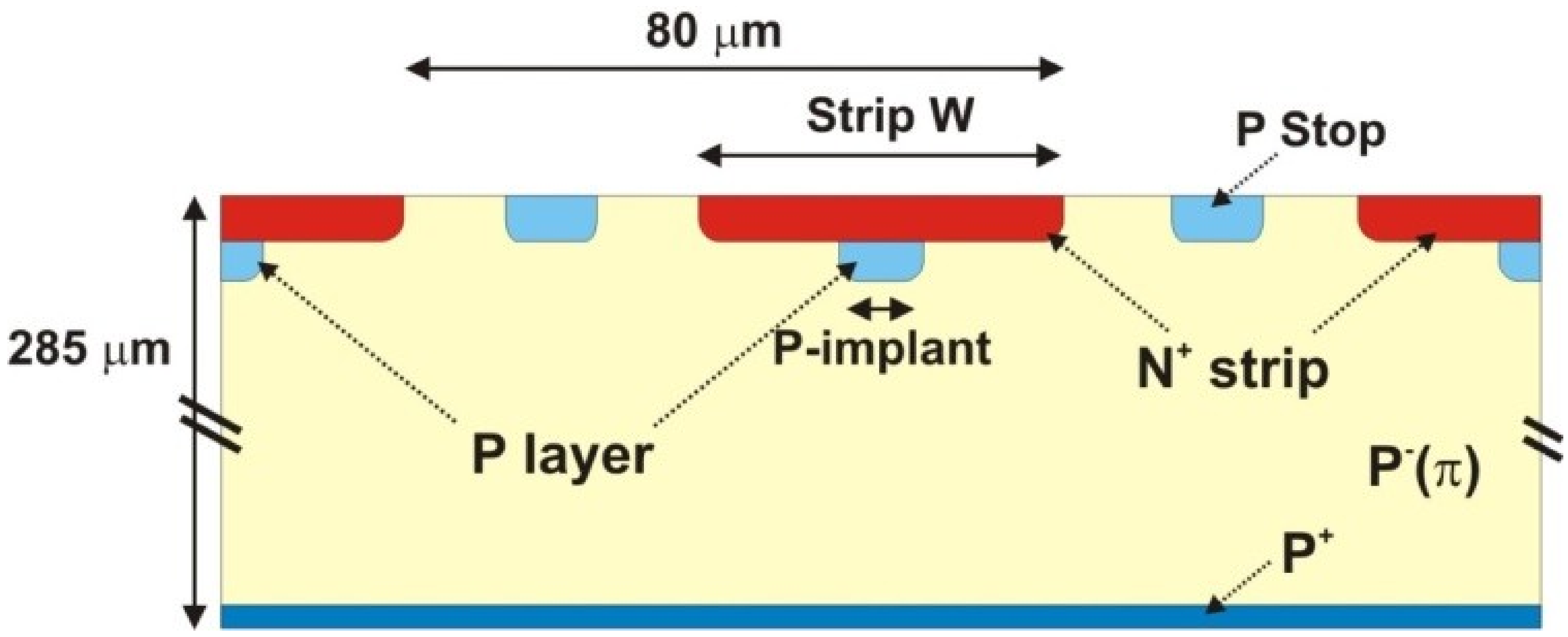


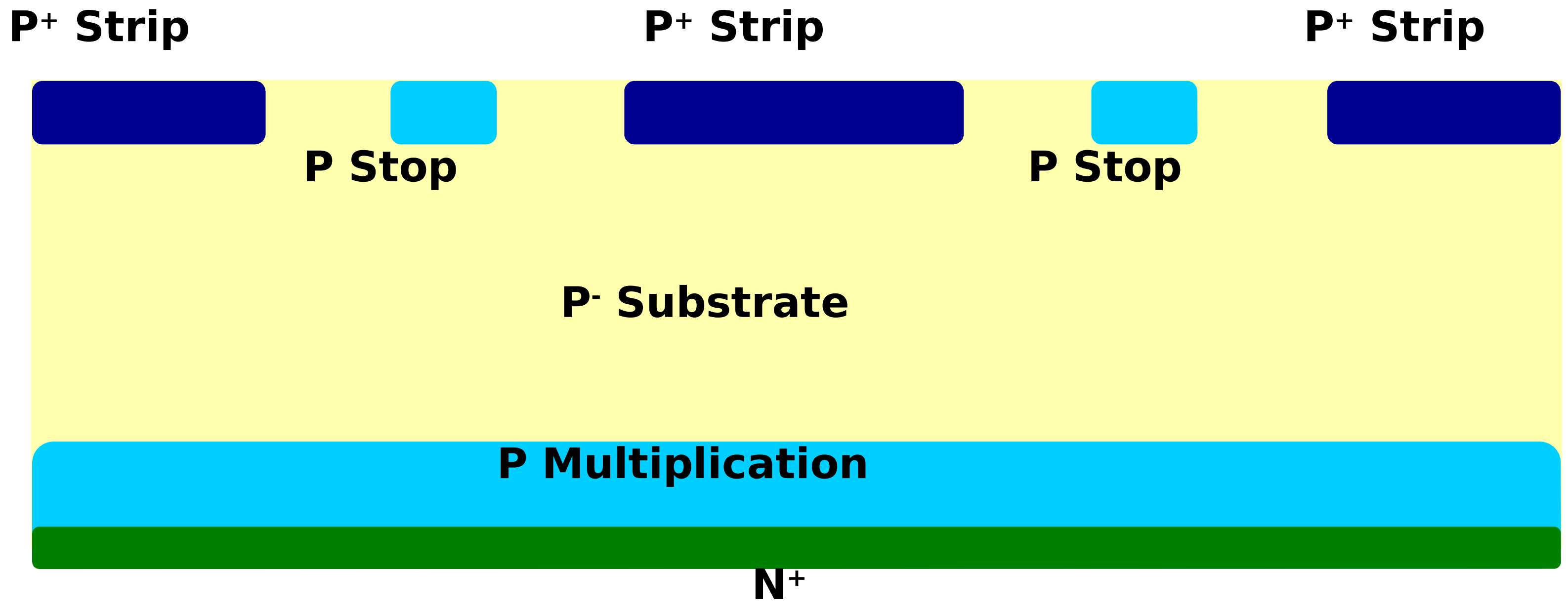




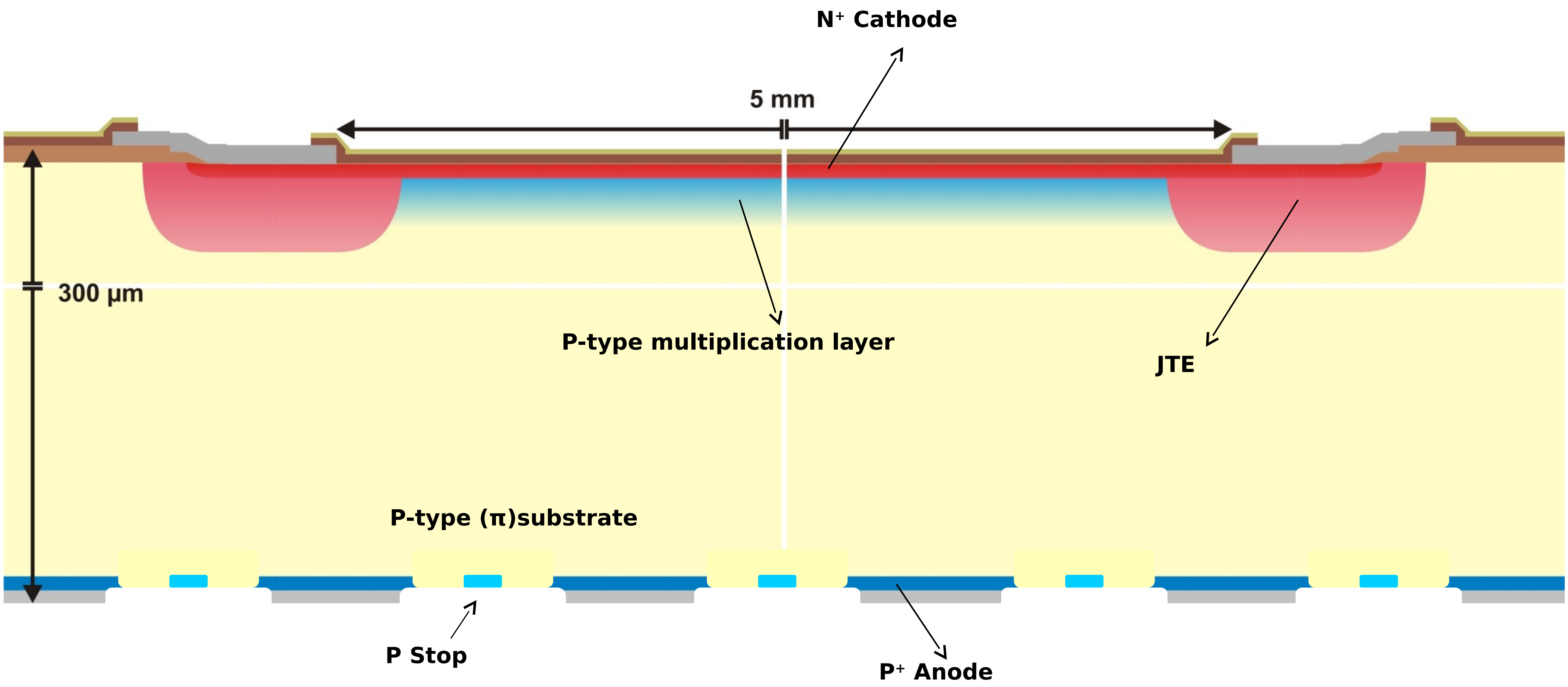
Performed at IFCA in Santander

- **N on P** vs **P on P LGAD** microStrips Comparison

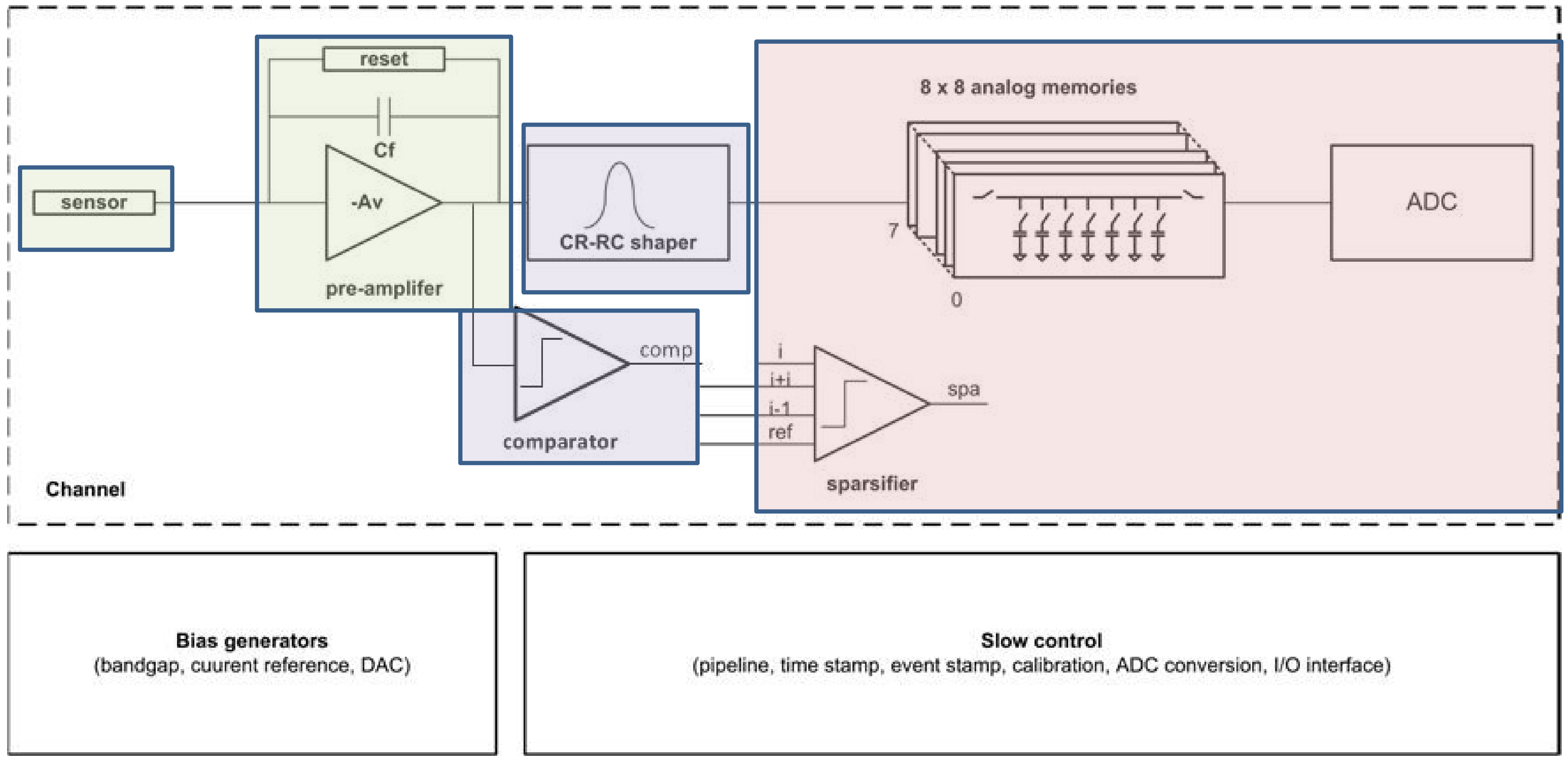




- **Pad Diodes LGAD** with P microStrips at Back Plane



Current status of FE design



- In progress
- To be designed
- Not included

Summary

Reported on just two activities, leaving for the next workshop the work on
CALICE (see calorimeter session),
EMC & in-situ power regulation
DEPFET progress & FE design

FTD engineered design & mock-up progressing steadily

DEPFET all-silicon petal prototypes : *Air flow at 1 m/s cools DEPFET, with 1/25 duty cycle pulsed power*
*D*ynamic deformations due to pulsed power: *none observed, definitively rule out impact this year*
Vibrations due to air flow: *vibrations at few-micron level, work ongoing to raise eigenfrequency above 200 Hz*

Diodes with intrinsic gain produced @ CNM in RD50/LGAD

Factor 8-10 signal amplification demonstrated
Noise unaffected → better S/N and/or less material

Now achieve the same on micro-strips

Small gain achieved; careful layout of amplification region needed