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# Measurement techniques in HiRadMat Experiments

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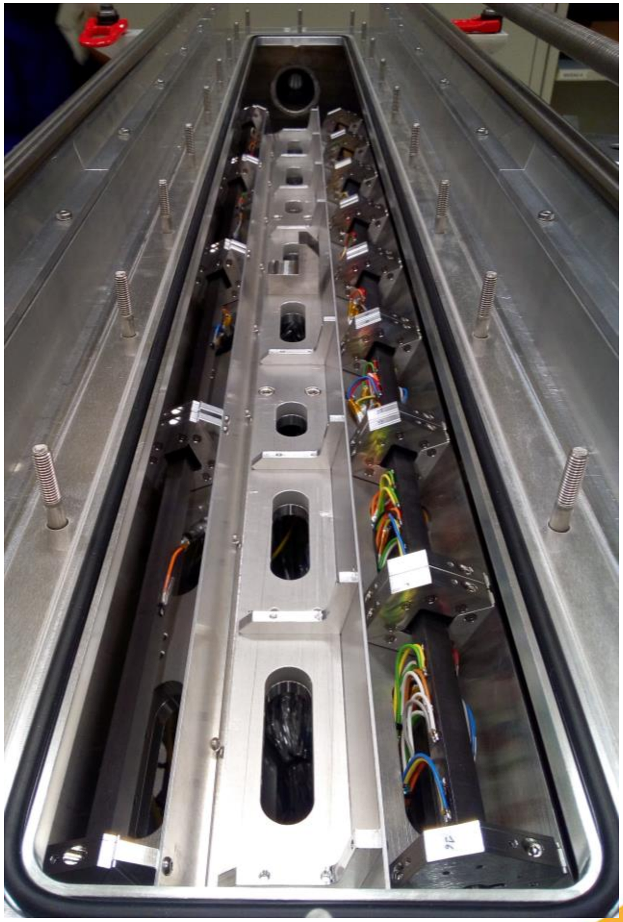
# Outline

1. Introduction
2. Motivations
3. Measurement techniques
4. Lessons learned
5. Conclusion



# **Hi**gh **Rad**iation to **Mat**erial Facility at CERN

HiRadMat is a facility designed to study the impact of intense pulsed beam on materials :

- Thermal management;
- Radiation Damage to materials;
- Thermal shock – beam induces pressure waves.

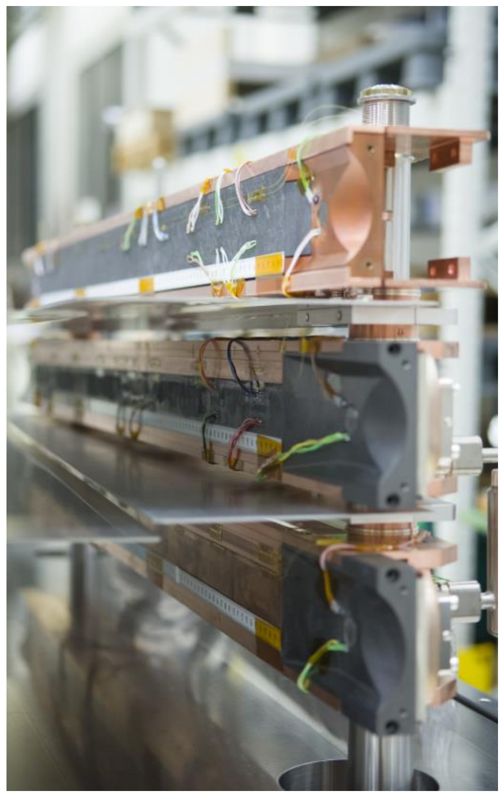
# Motivations for embarked measurements

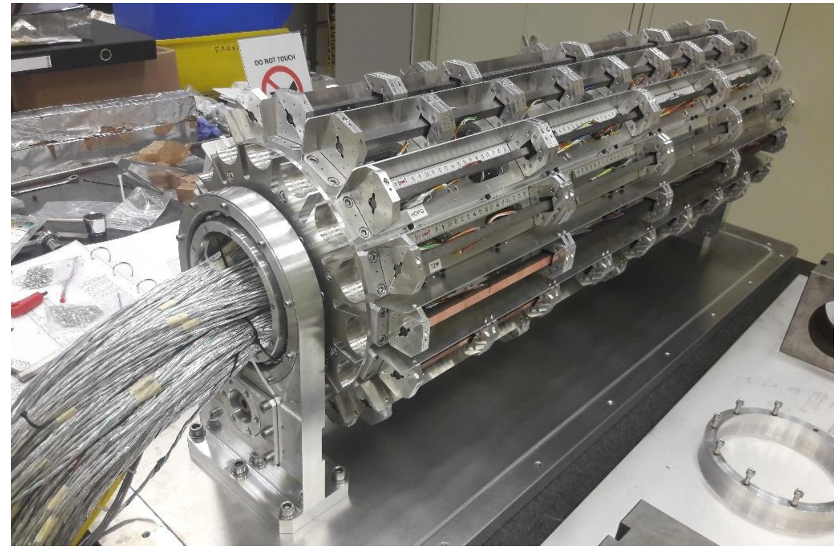
- Collect **data real time**.
- To **benchmark** advanced numerical simulations, powerful but based on limited and scarce literature data on **material constitutive models**.
- To optimize **design schedule** by collecting objective data sooner than the post-mortem analysis due to radiation aspect.
- For **safety reason**, with a complete vision of the integrity of the structures and material under tests.
- **Beam based alignment** in addition of beam instrumentation

# Measurement experiences in HiRadMat

**HRMT-14**
6 different materials
(Inermet, Glidcop, Mo, MoCuCd, CuCd, CFC)
Cylindrical and half-moon samples

**HRMT-23**
3 different materials
(CFC, MoGr, CuCd)
Collimator Jaws



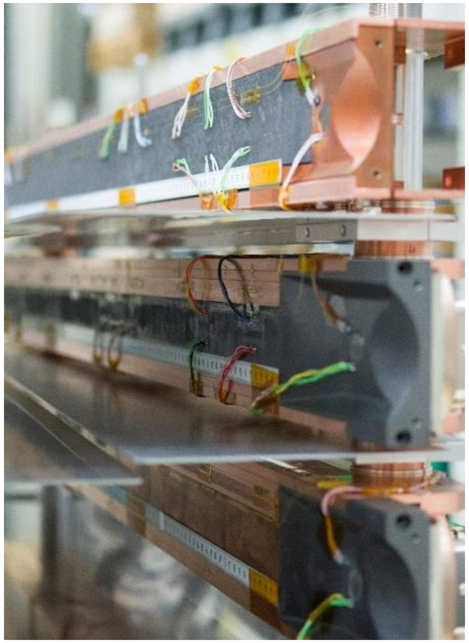


**HRMT-36**
16 Target stations
Sample with square or rectangular cross-section

And support on HRMT-12, HRMT-21, HRMT-24, HRMT-26.

# Measurement techniques

| Experiment Instrumentation | Sampling | HRMT-14 | HRMT-23 | HRMT-36 |
|---|---|---|---|---|
| Electrical strain gauges | 4 MHz | 168 | 126 | 336 |
| Optical strain gauges (FBG) | 1000 Hz | - | 60 | - |
| Laser Doppler vibrometer | 4 MHz | √ | √ | √ |
| Temperature probes | 100 Hz | 36 | 42 | 48 |
| Ultrasonic systems | - | - | √ | - |
| Inspection HD camera (4K) | - | √ | √ | √ |
| High speed camera | 20000 fps | √ | √ | - |

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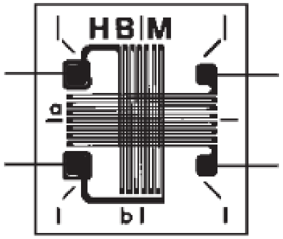
# Electrical strain gauges

$$\frac{\Delta R}{R} = k\frac{\Delta L}{L}$$

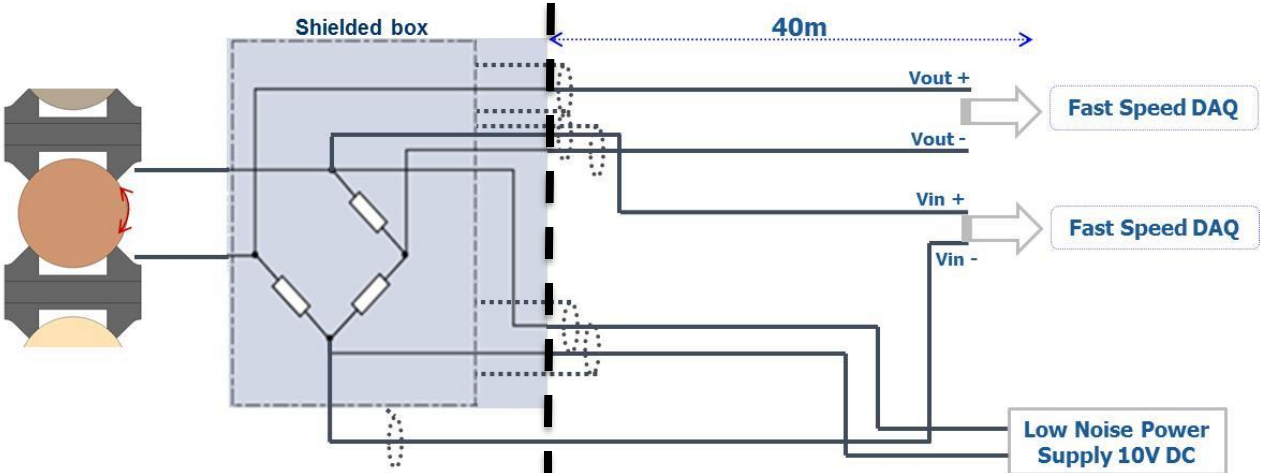
with k : Gauge factor

- Biaxial measurements, same spot
- Support : Polyimide (≈ 45 μm thickness)
- Grid : Copper-nickel alloys (5 μm thickness)
- Twisted and shielded pair cables




→ For 2000 μm/m, ΔR is equal to 11 μΩ !

→ Measurements inside a Wheatstone Bridge :

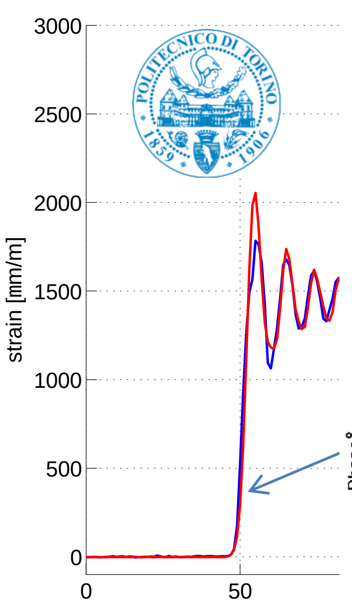


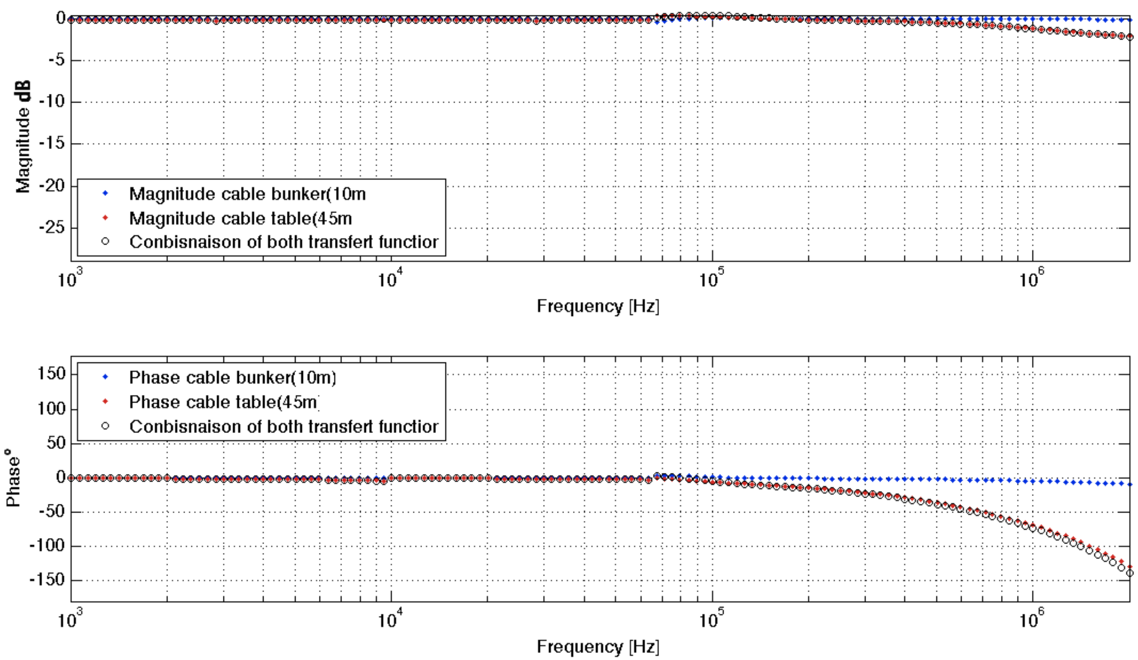
# Electrical strain gauges

Dynamic response of the strain gauges (Typically around 50 kHz) ?

**Hopkinson bars test bench to**

- ➔ Increase our knowledge for this bandwidth (higher than 50 kHz) ;
- ➔ Check the dynamic response of the gauges and the glue ;
- ➔ Evaluate the signal to noise ratio and the accuracy of the



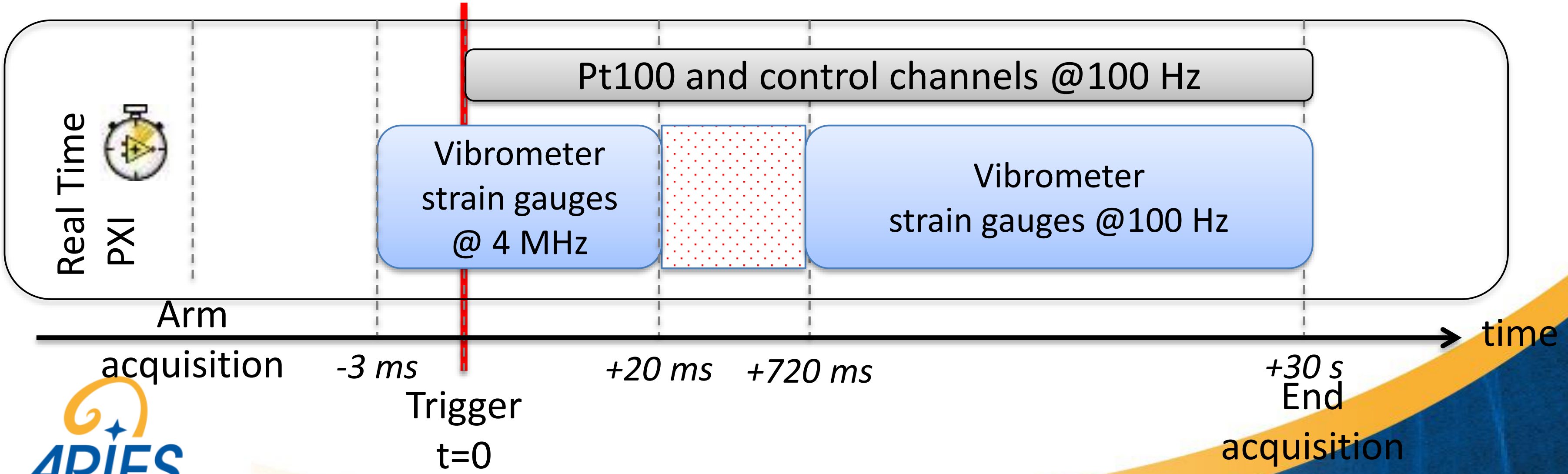
# Data acquisition and timing issue

Data acquisition system, actual configuration :

- 48 fast channels (PXIe-6124), 4 MS/s per channel, 16 bits, 1V
- 20 Pt100 channels at 100 S /s/ch
- 10 0-10V channels for system monitoring (Power supply, etc…)

Home made radiation hard switch :

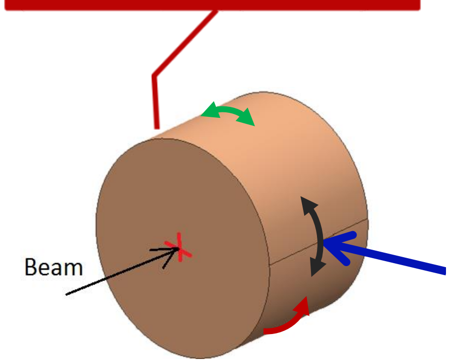
- 48 Channels over 8 positions (384 Channels)
- Wheatstone bridge integrated

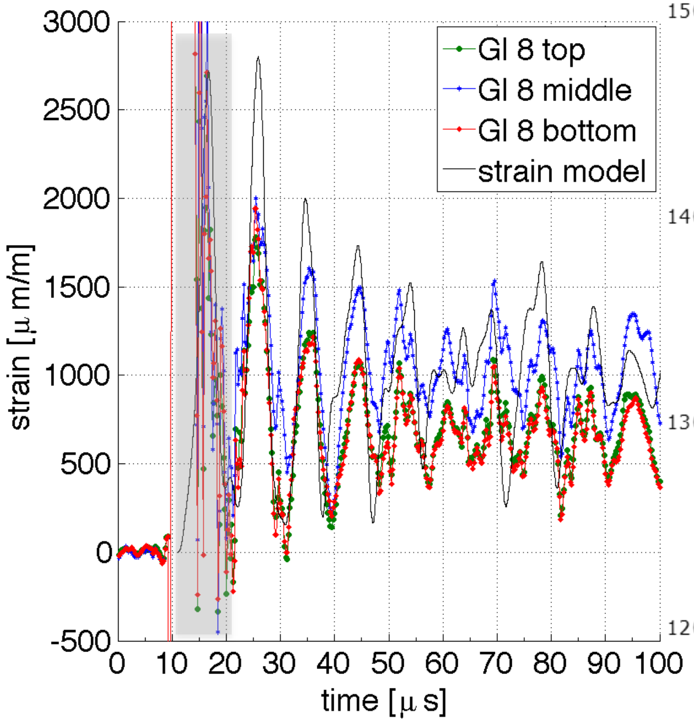


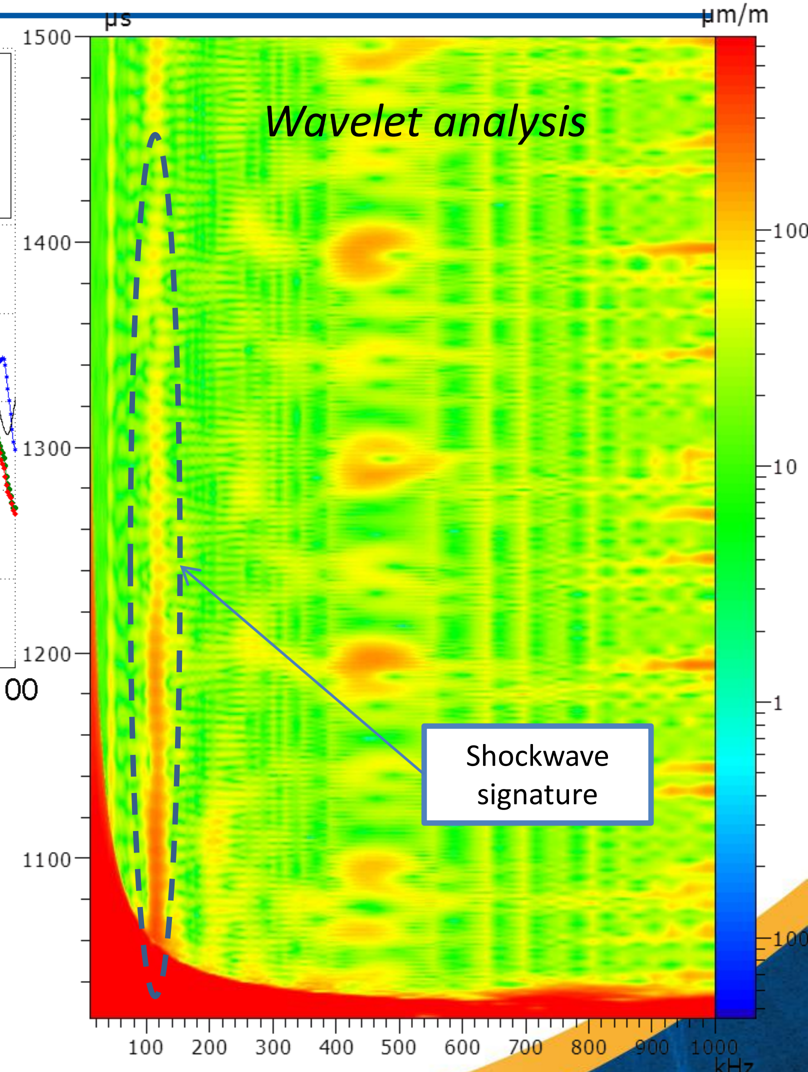
# Lesson learned (Strain gauges)

**HRMT-14**

Medium Intensity Tests:
Type 1 Sample
(Ø 40 mm  L30 mm)



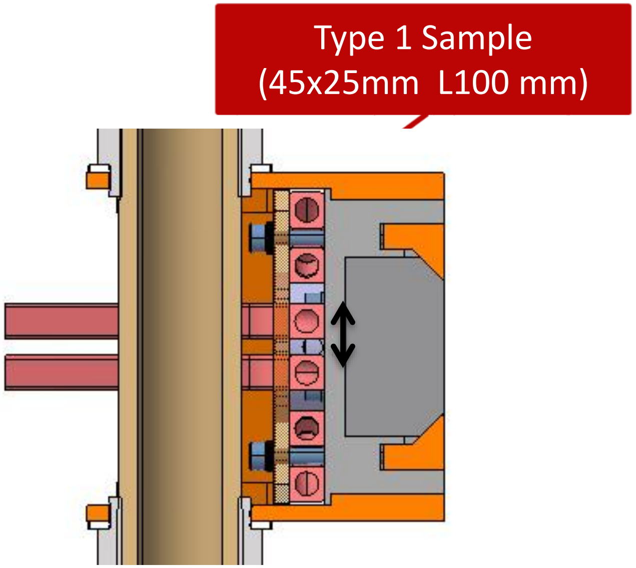



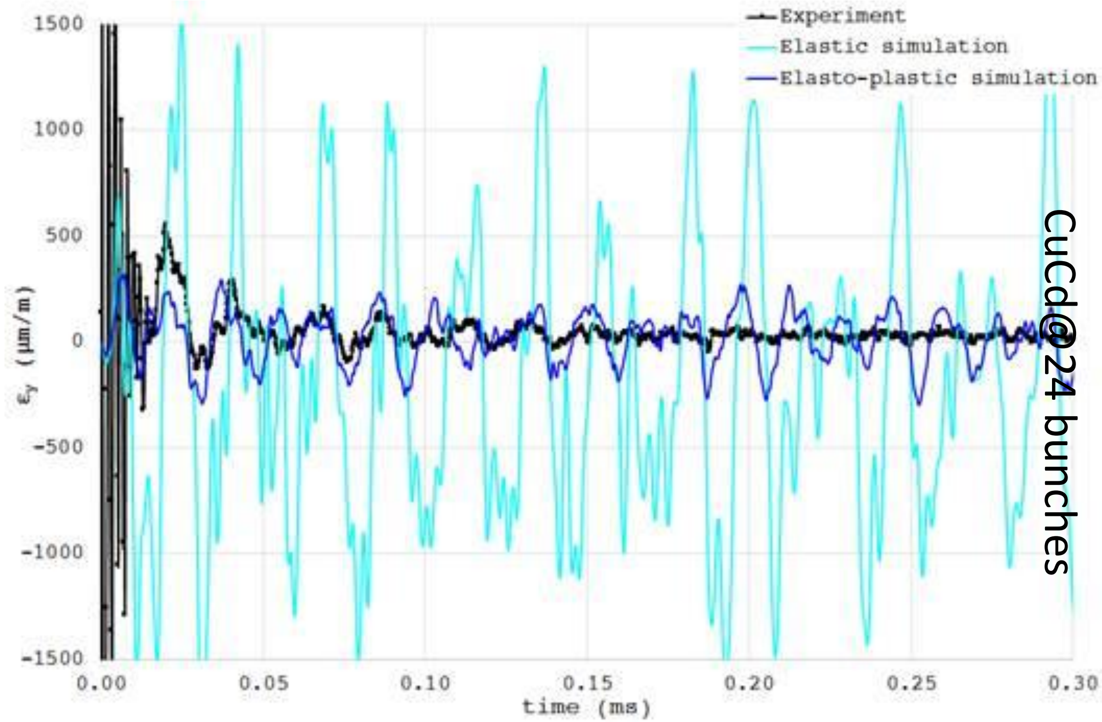




- Beam/Strain gauge distance : 20 mm
- Black-out during 10 μs after the beam
- Noise level : +/- 50 μm/m @4 MHz /42 m

# Lesson learned (Strain gauges)

HRMT-23

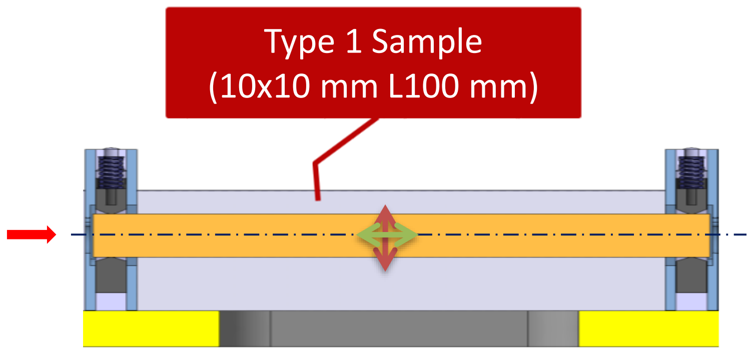


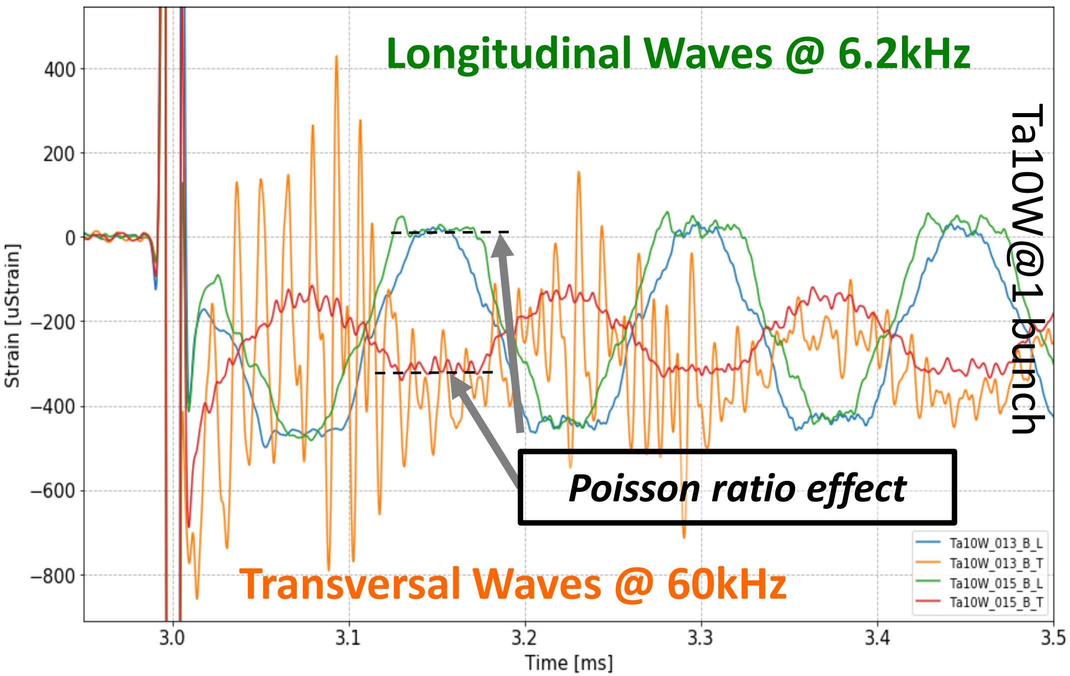




- Beam/Strain gauge distance : 25 mm
- Black-out during 10 µs after the beam
- Noise level : +/- 50 µm/m @4 MHz / 16 m

# Lesson learned (Strain gauges)

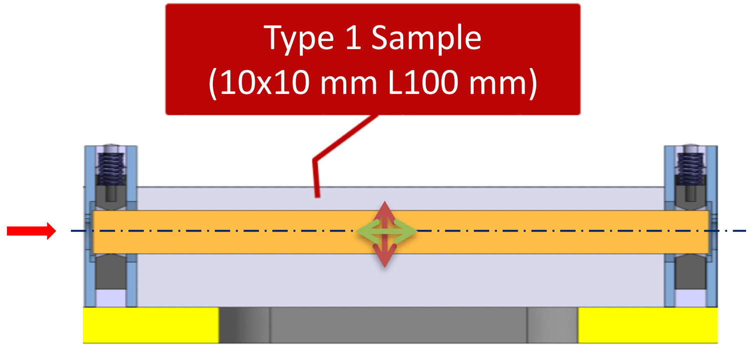
**HRMT-36**

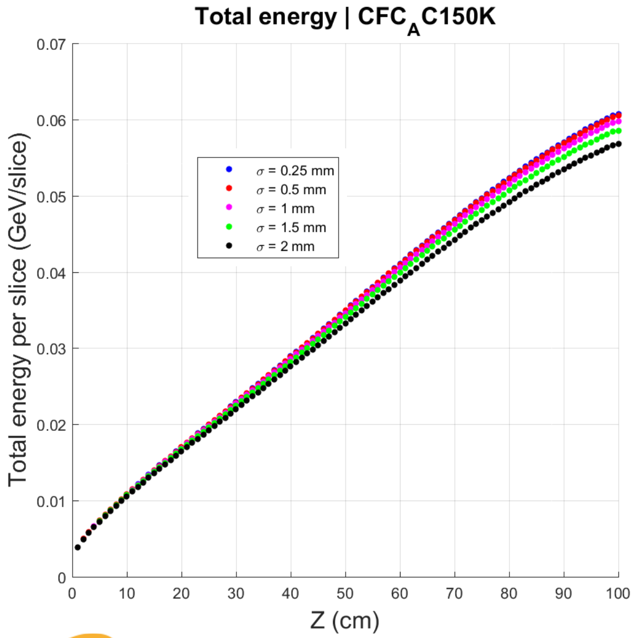


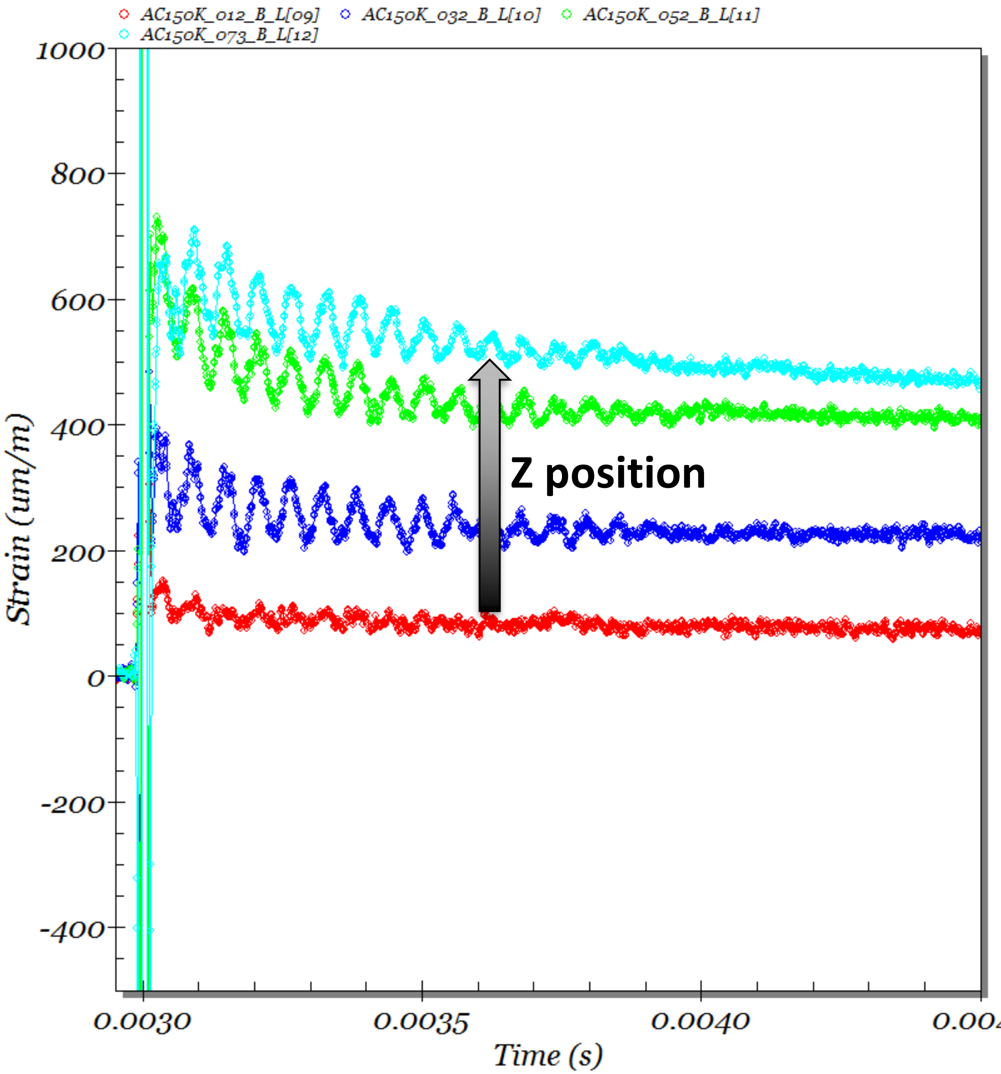




- Beam/Strain gauge distance : 5 mm
- Black-out during 25 µs after the beam
- Noise level : +/- 50 µm/m @4 MHz / 42m

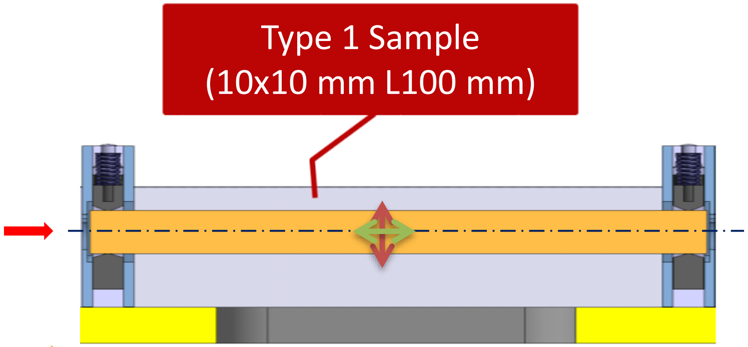
# Lesson learned (Strain gauges)



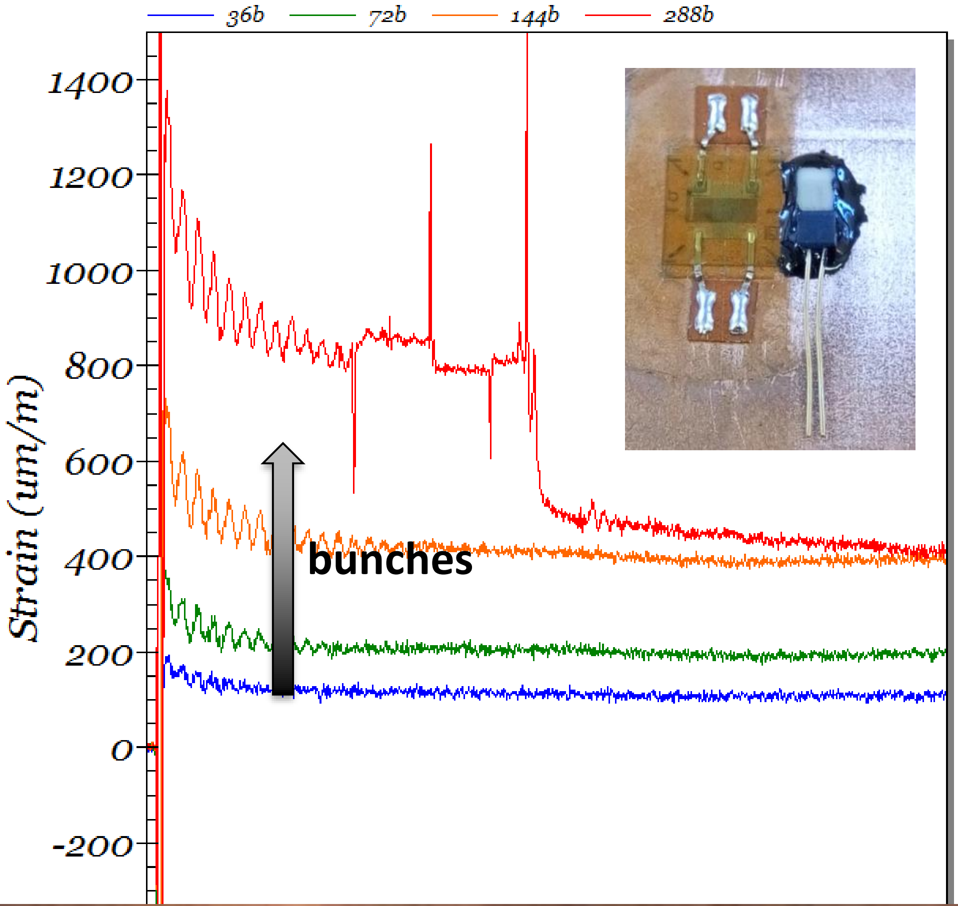



# Lesson learned (Strain gauges)




- Temperature effects expected on the tin connection pad induced by the particle shower, not by the materiel itself (<160°C)
- Tin-lead melting point probably achieved (184°C)

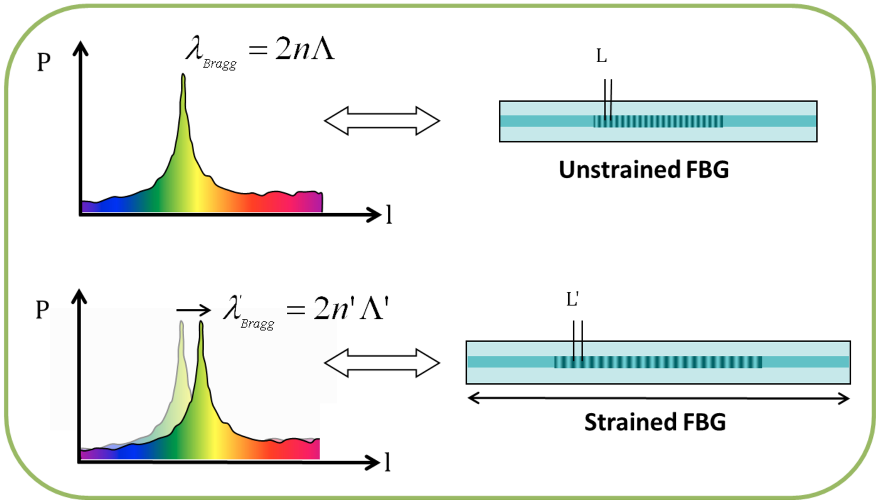



# Conclusion

- After 5 year's of HiRadMat experience, the best compromise between sample shapes (also shape ratio) and instrumentation capabilities was achieved in HRMT36.
- FEA and Measurement teams should work together during the design of the experiment.
- Some simulations should be launched to understand beam effects on the tin connection pad in order to calculate back the maximum temperature for the instrumentation.
- Developments are in progress to improve the bandwith of optical strain measurements based on Fiber Bragg technique.

# Conclusion

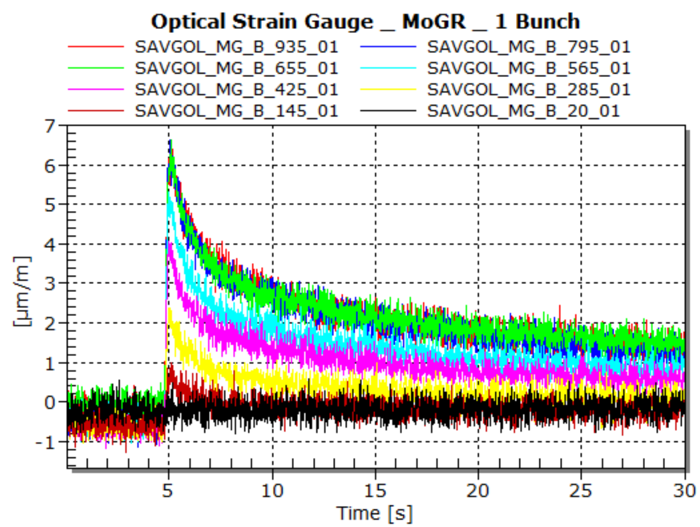
## Optical strain gauges:



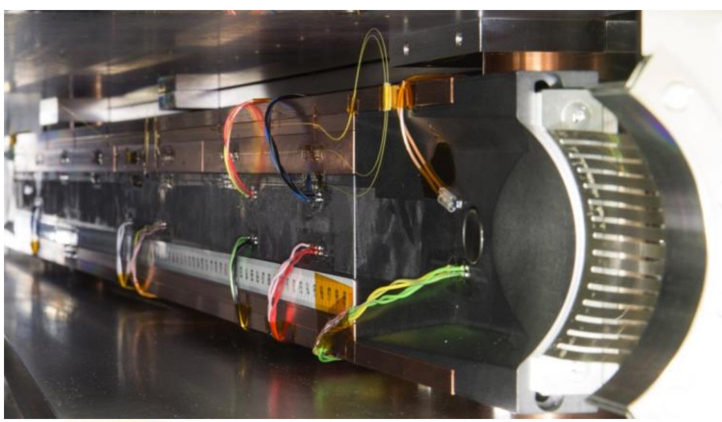

Several gratings on the same fiber

Less connections, low mass

Insensitivity to the particle beam




## Successfully used in HRMT23 :



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# Thank you !