A novel temperature monitoring sensor for gas-based detectors in large HEP experiments

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Presented at TIPP 2011 by M.A. Caponero
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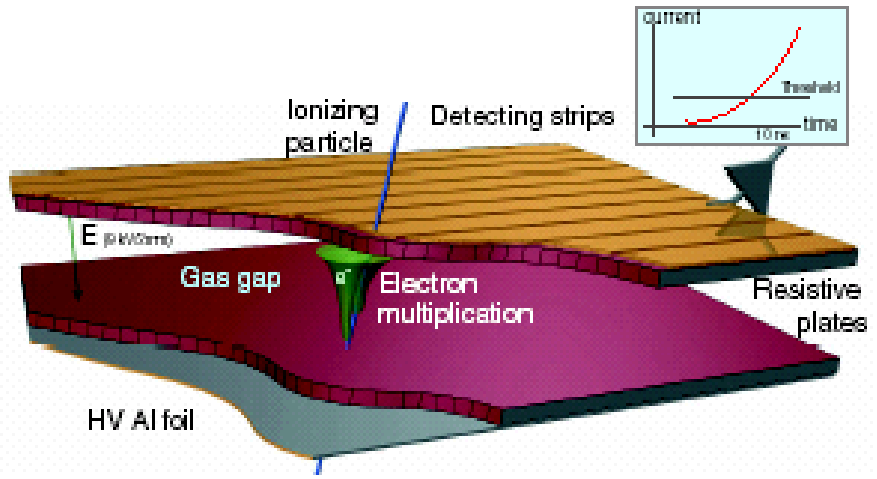
Gaseous detectors are widely used in HEP experiments as trackers, muon detectors, etc.

Detector response heavily depends on p, T, RH.



Case study:

Resistive Plate Counters (RPC)

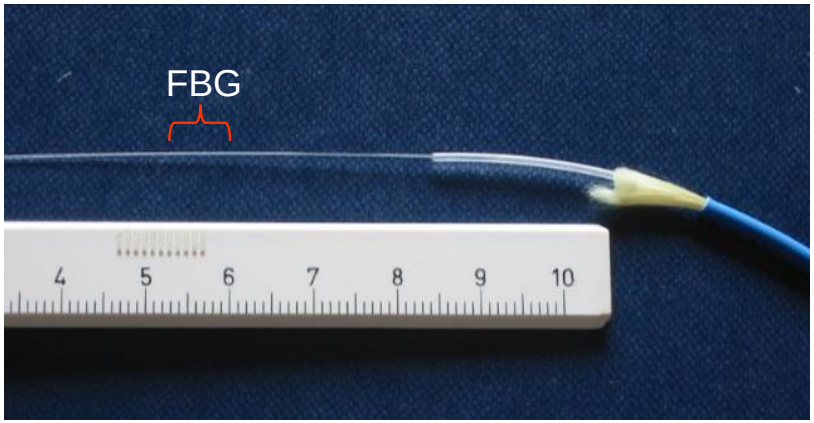
$V_{eff} = V\,(p/p_0)\,(T_0/T)$

Fibre Bragg Grating (FBG) optical sensors:

a novel technology that can allow developing real-time temperature monitoring sensor for gas-based detectors in large HEP experiments

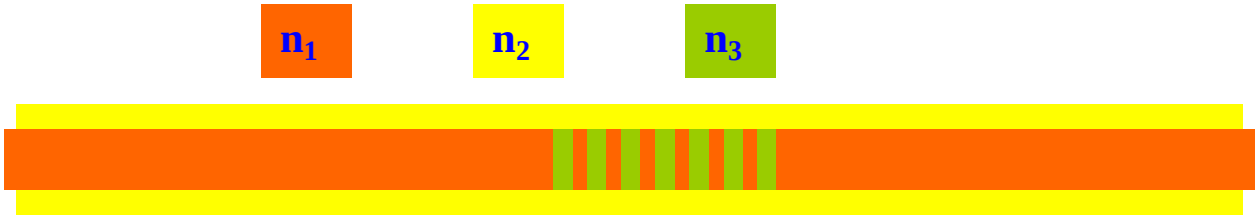
Fibre Bragg Grating (FBG) sensor: diffraction grating in the core of an optical fiber.

Diffraction grating is produced by modulation of the refractive index of the core.



Optical fibre before FBG production

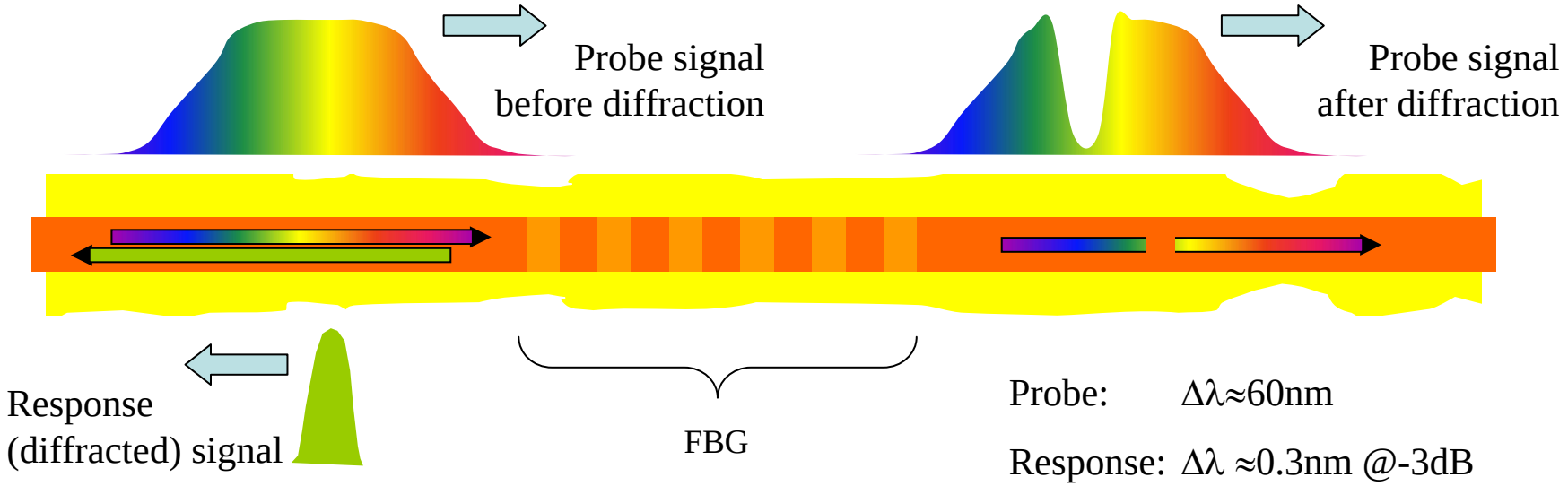
Core: constant refractive index (n_1)
Cladding: constant refractive index (n_2)



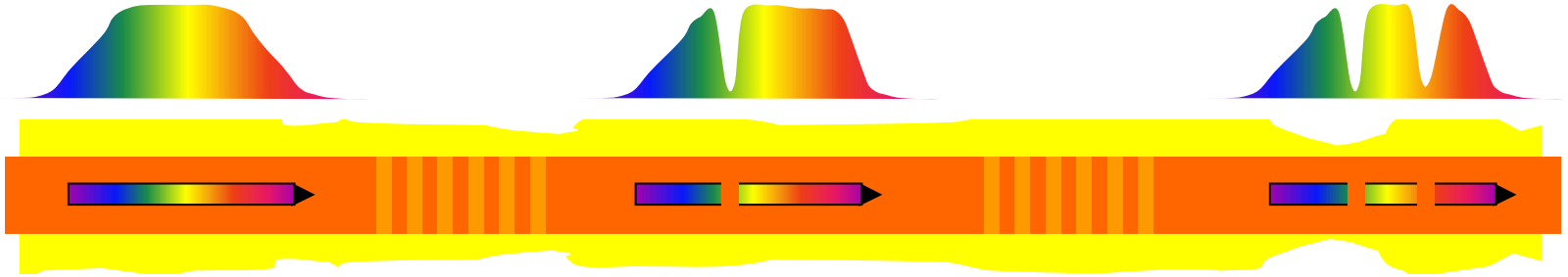
Optical fibre after FBG production

Core: local modulation of refractive index (n_1 & n_3)
Cladding: constant refractive index (n_2)

Light propagating along the optical fibre is diffracted (back-reflected) by FBG



Many FBGs at different λ_{BRAGG} can be arranged along one optical fibre



Diffracted wavelength depends on

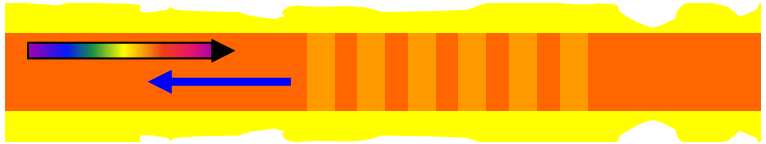
- FBG pitch
- effective refraction index

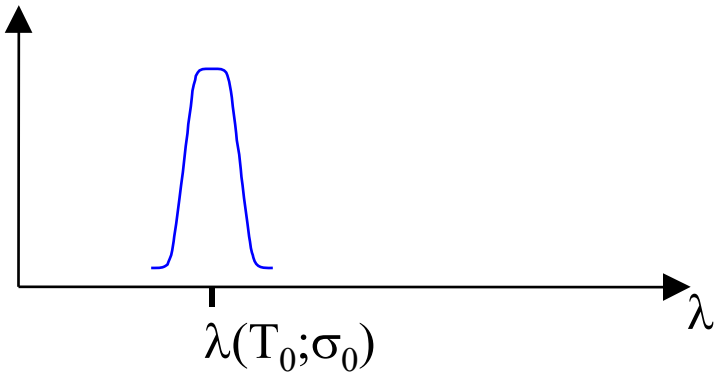
Both are affected by Temperature and Stress

$\Delta\sigma = 1\ \mu\varepsilon \quad \Rightarrow \quad \Delta\lambda = 1$ pm

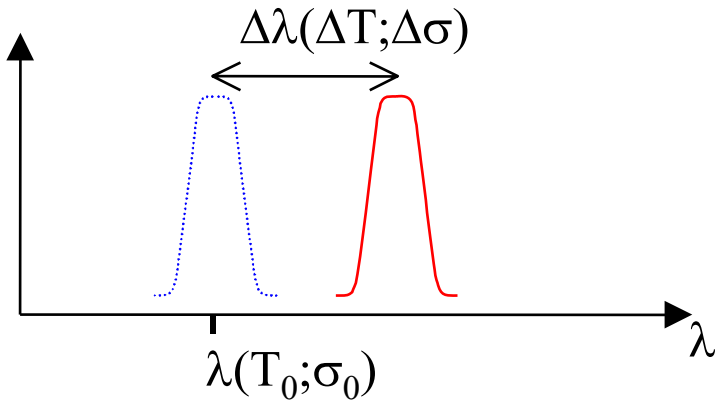
$\Delta T = 1\ °K \quad \Rightarrow \quad \Delta\lambda = 10$ pm

Fibre 'at rest' $(T_0;\sigma_0)$



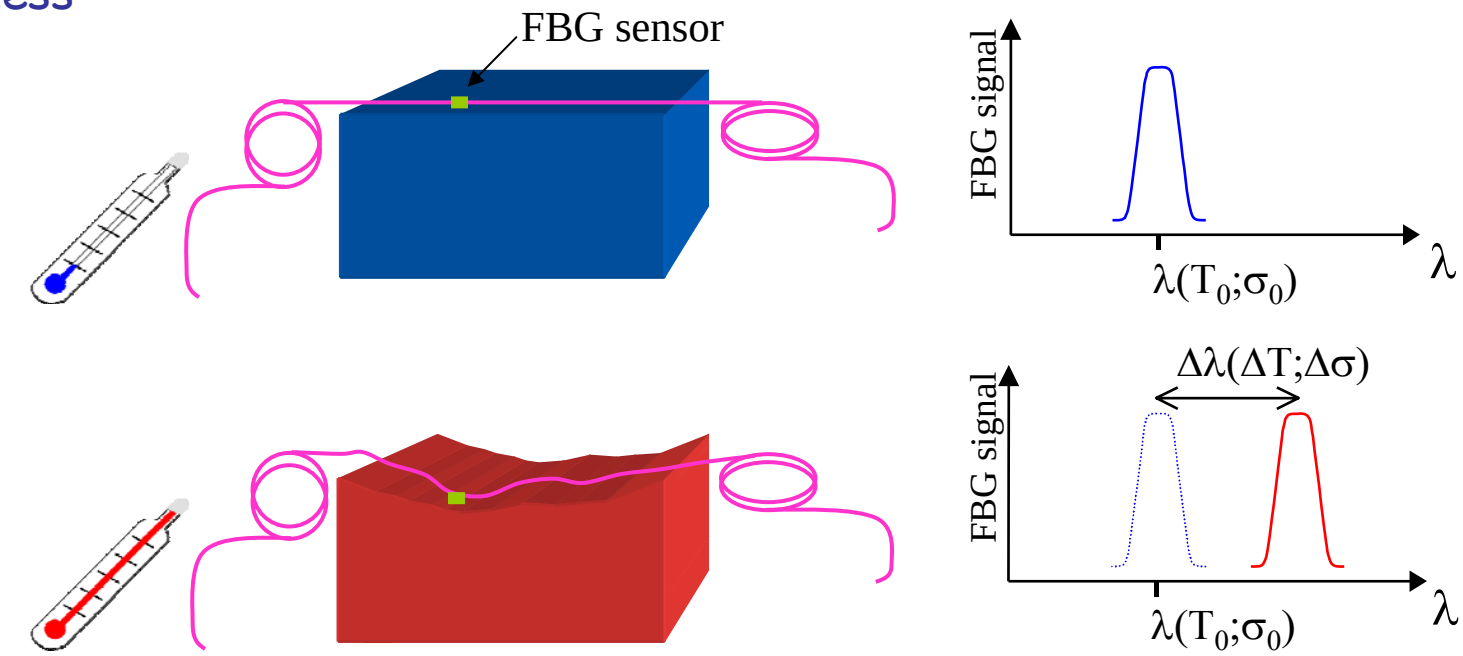


Fibre 'excited' $(T_0+\Delta T;\sigma_0+\Delta\sigma)$



Fibre Bragg Grating (FBG) sensor: optical Temperature and Strain Gauge.

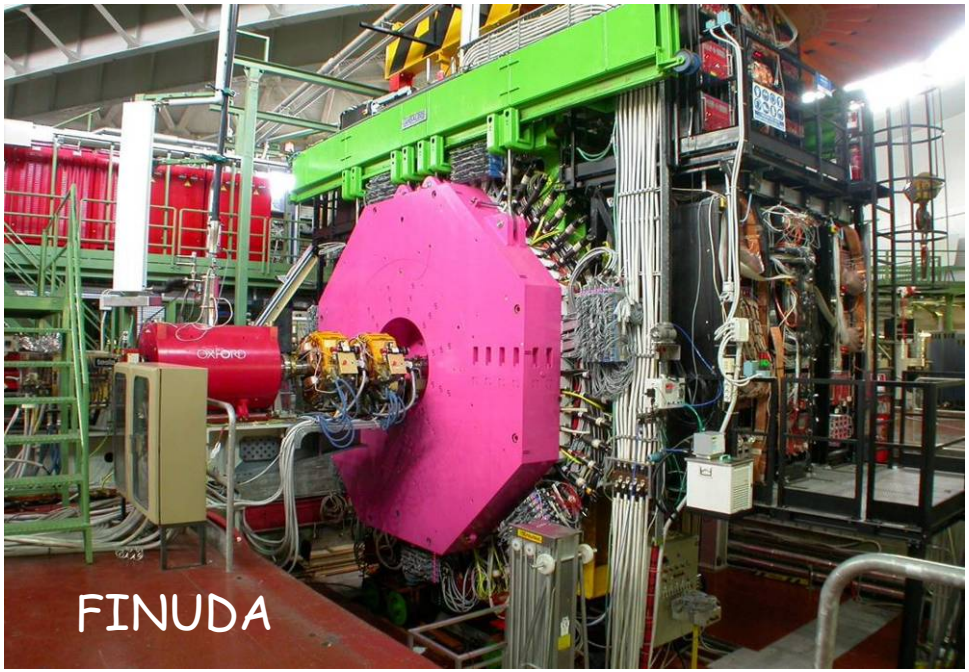
- Directly integrated in an optical fiber core
- Many sensors on the same optical fiber
- Long term stability
- Multiplexing read-out capability
- Electromagnetic field insensitivity
- Hostile environment endurance (Radiation Hardness)
- Mass lightness

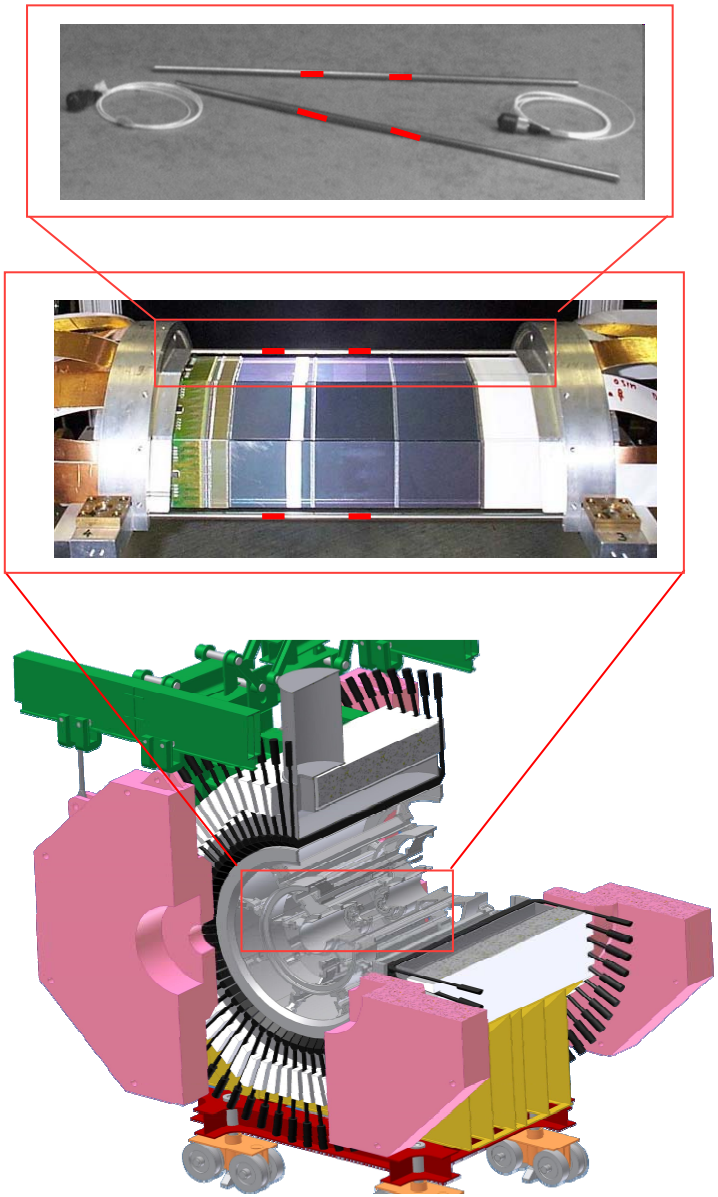


Fibre Bragg Grating (FBG): previous applications for HEP by the INFN-Frascati collaboration

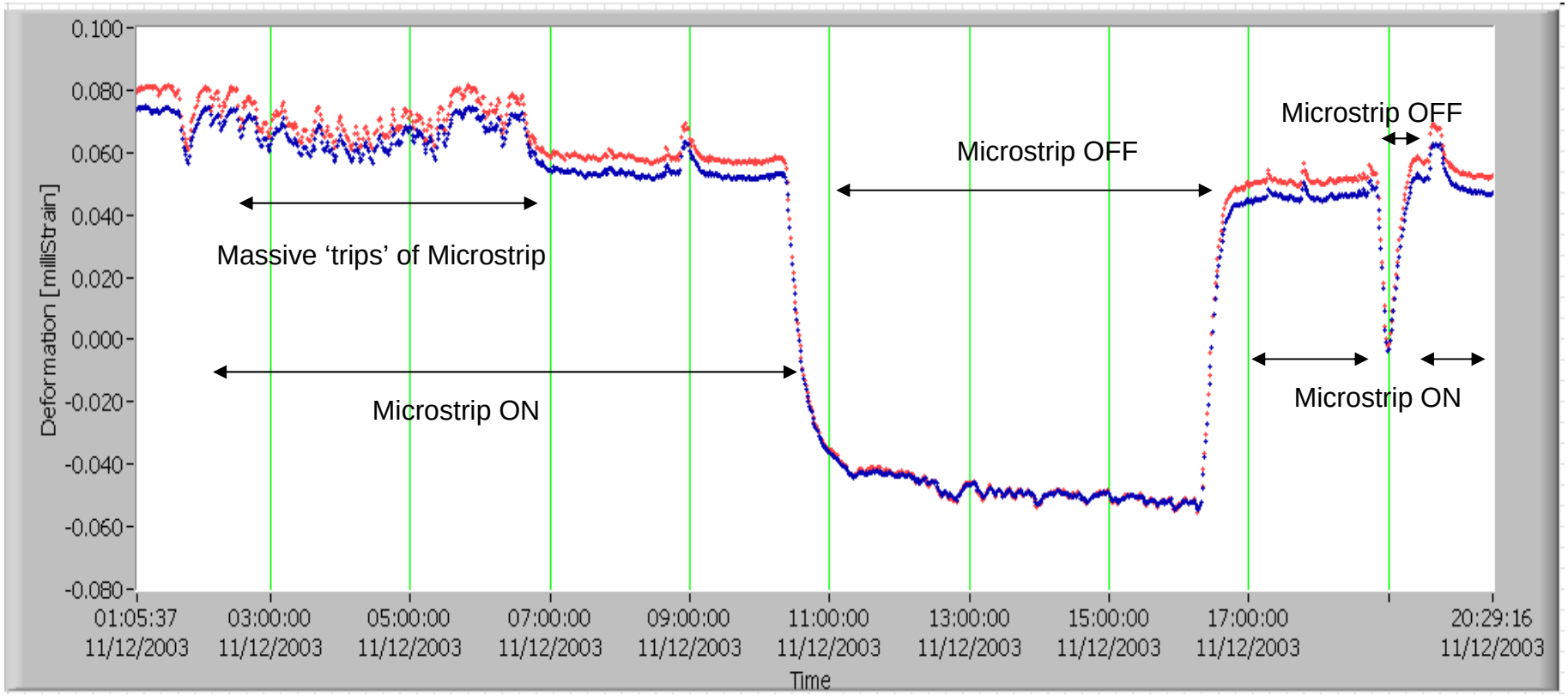
FBG sensors already used at
INFN – Frascati National Laboratory

FINUDA Experiment
Monitoring deformations of vertex detector mechanical structure

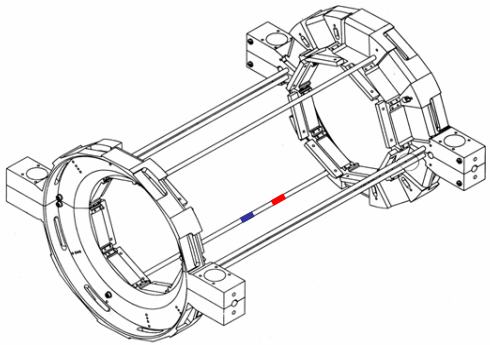




Fibre Bragg Grating (FBG): previous applications for HEP by the INFN-Frascati collaboration



11/Dic/2003 -03:08	Massive 'trips' for some time due to e^+ injection
10:10	DAΦNE machine development: Microstrip and Tofino off
16:15	Beam stable: Microstip and Tofino on
18:50	Microstrip (OSIM1) 'trip': recovery procedure
19:15	Microstrip stable: take data



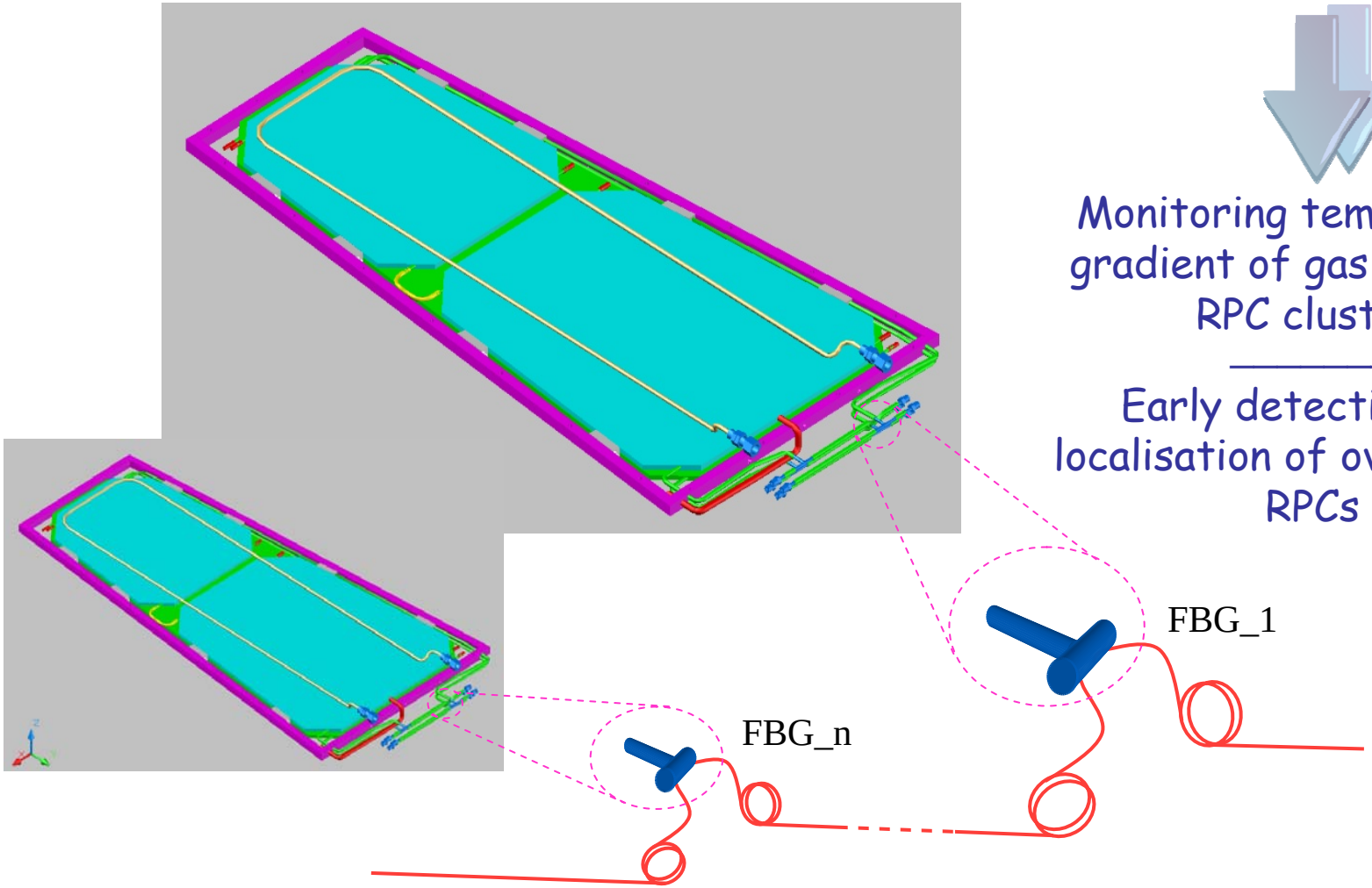
Proposing a distributed FBG sensing system for monitoring temperature of fluxed gas

Monitoring RPCs gas temperature

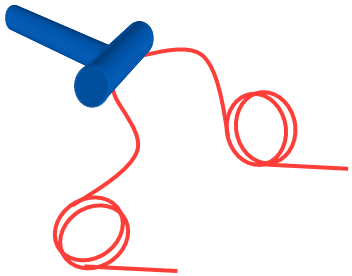
Array of FBG sensors inserted in gas conduit

Monitoring temperature gradient of gas fluxed in RPC clusters

Early detection and localisation of overheating RPCs

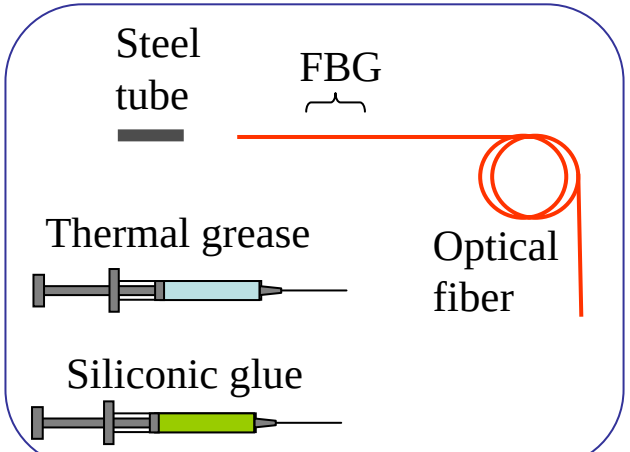


Production of a gas-pipe joint with built-in FBG sensor

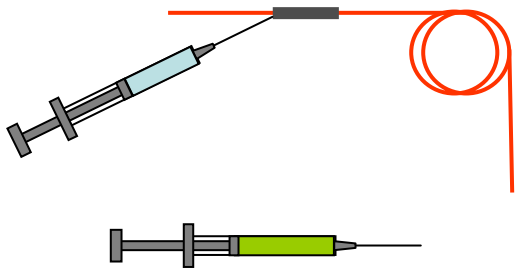


Step 1:

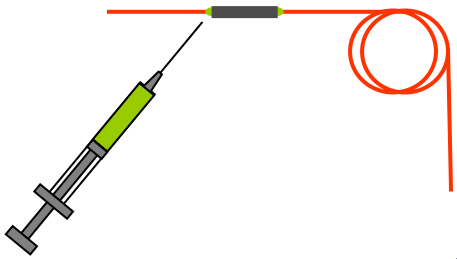
embedding the FBG sensor in a steel tube

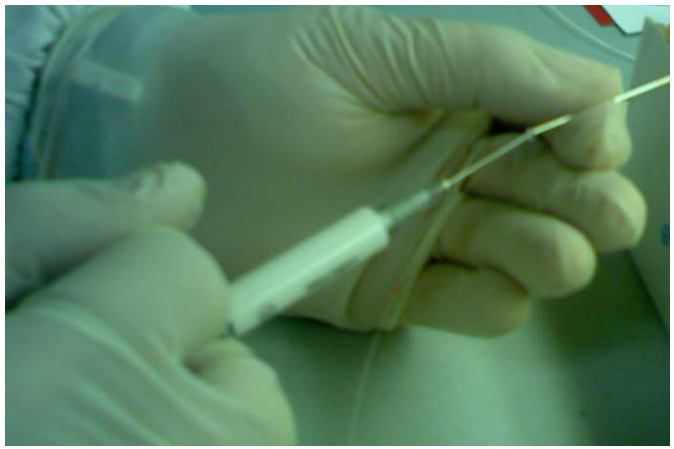


FBG inserted in Steel tube filled with thermal grease

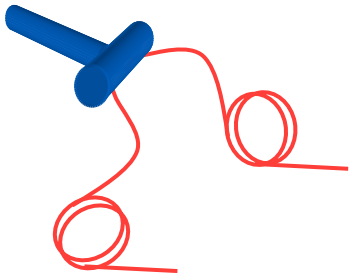


Steel tube openings sealed with siliconic glue





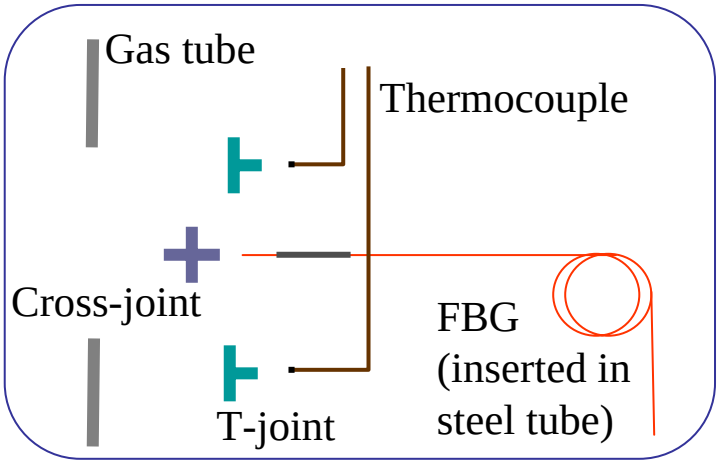
Production of a gas-pipe joint with built-in FBG sensor

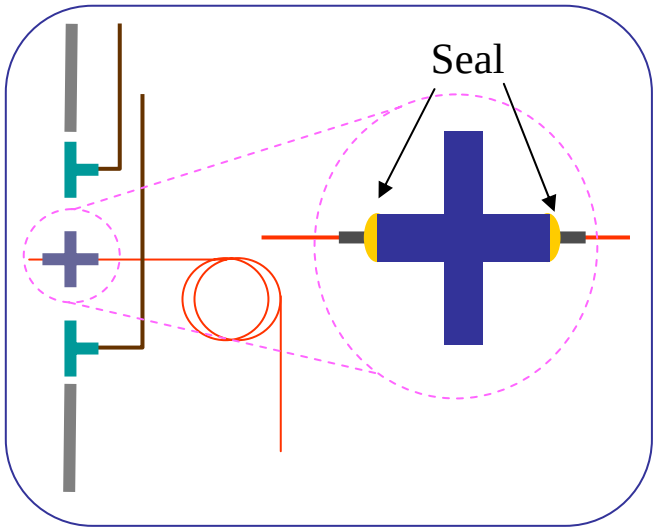


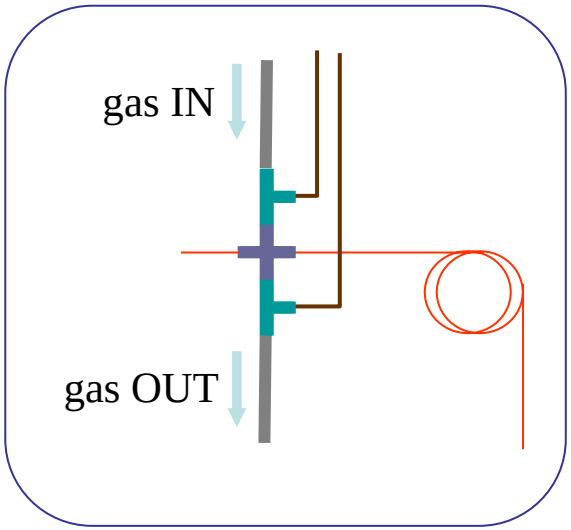
Step 2:

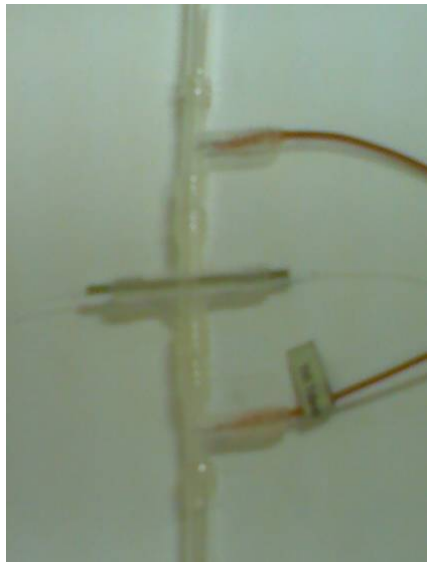
inserting the FBG sensor in the joint

(prototype provided with control thermocouples)

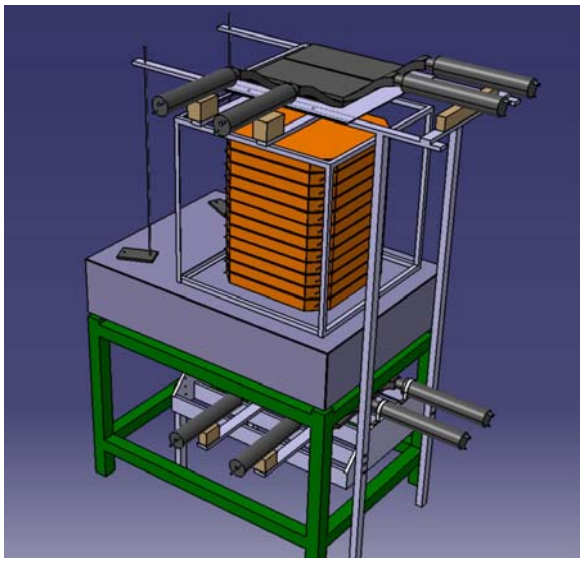








Testing sensor prototype



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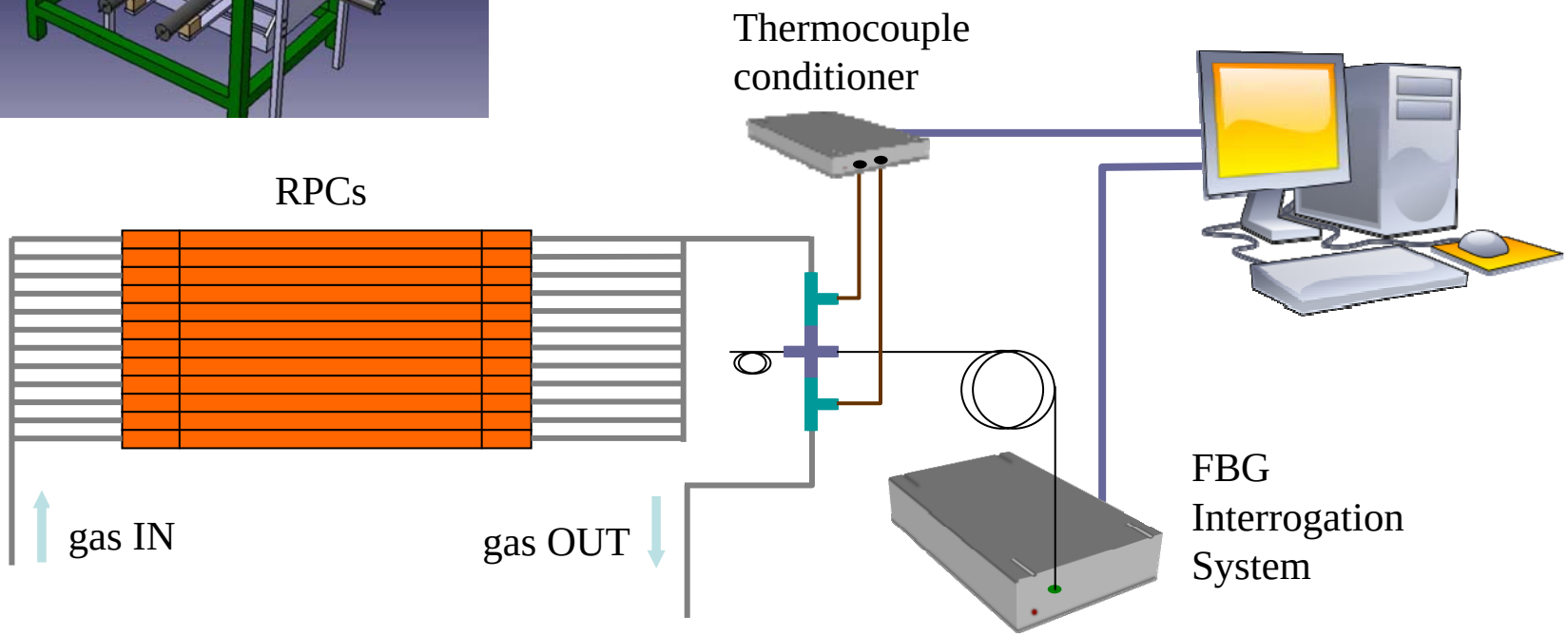
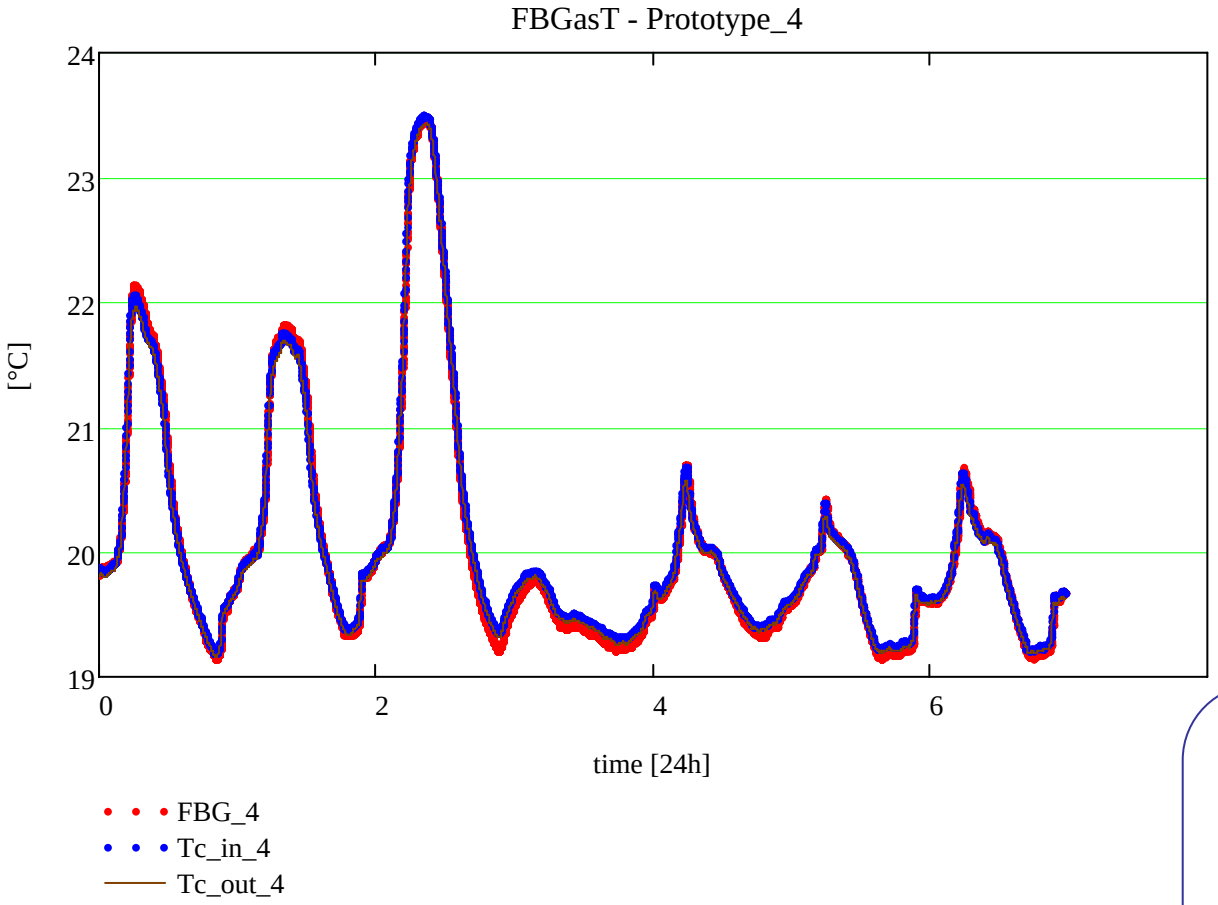
Experimental Hall 'ASTRA'
RPC Test Facility

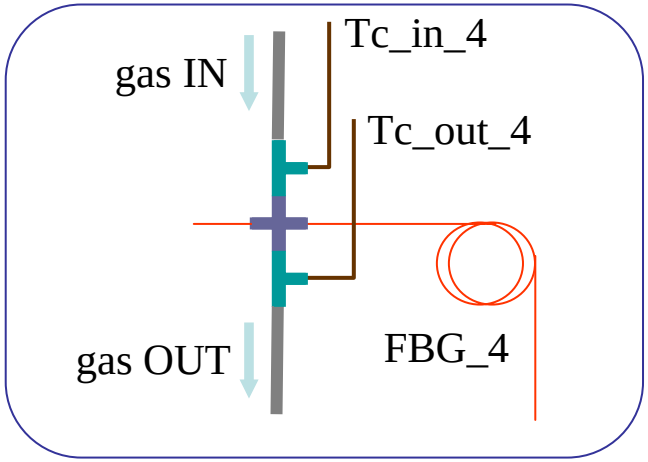
Test run: monitoring gas temperature of RPCs undergoing test measurements



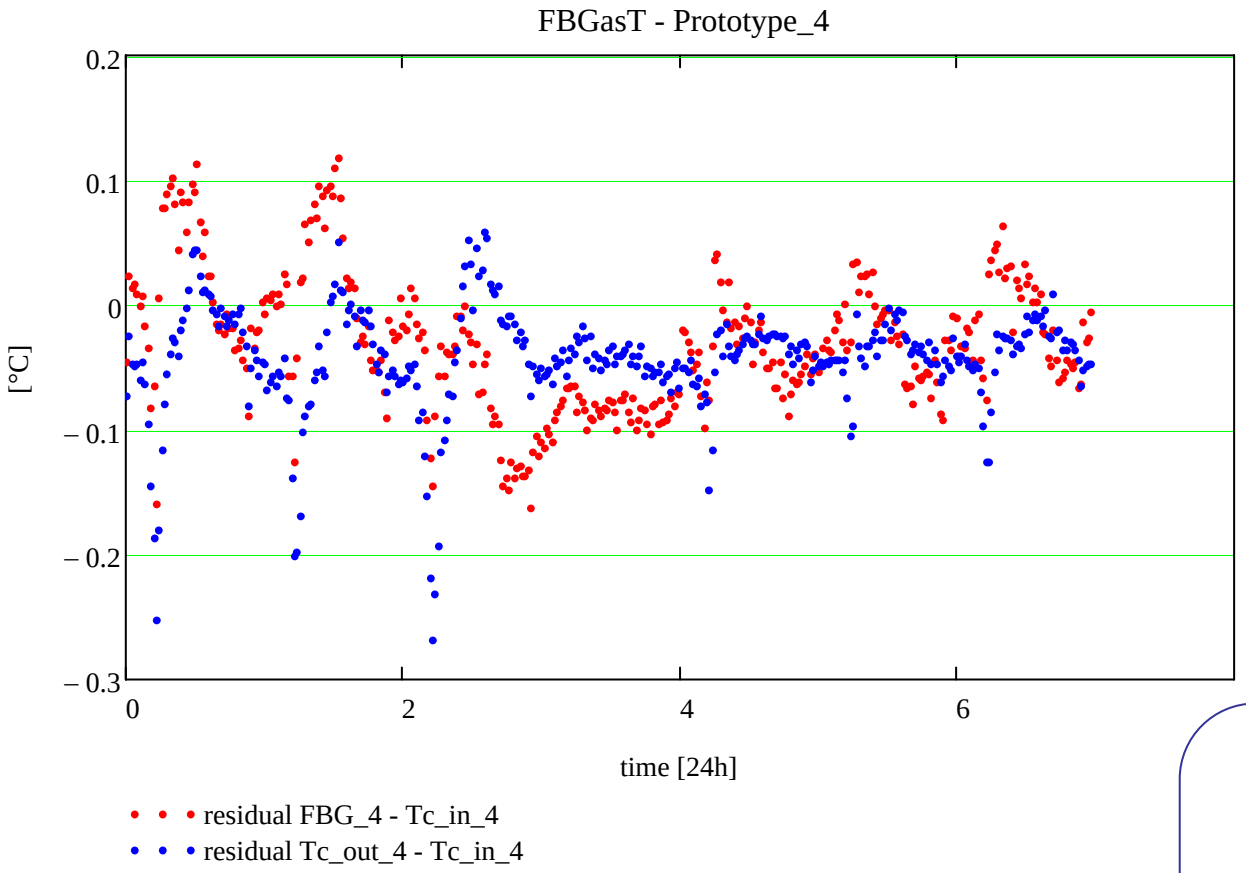
Sensor prototype testing



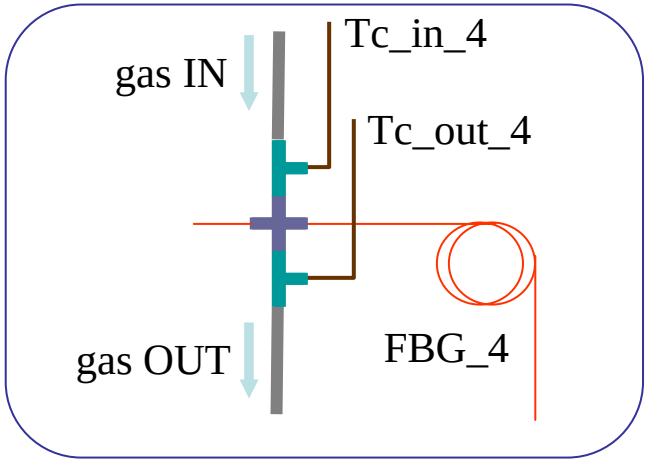
Prototype FBGasT_4: poor agreement with reference Tc



Sensor prototype testing



Prototype FBGasT_4: poor agreement with reference Tc



Adopted sensor prototype design: FBG subject to thermally induced mechanical stress

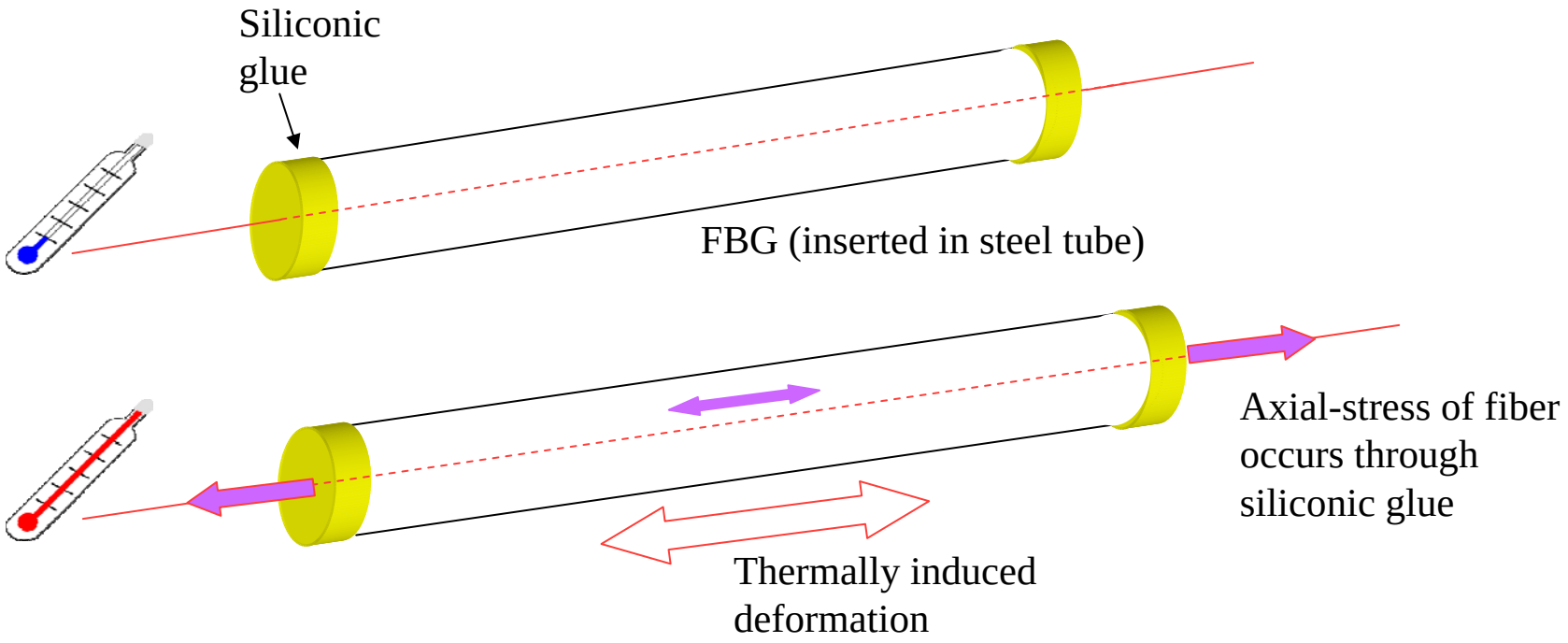
Heating:

thermal deformation of housing induces mechanical stress of FBG through siliconic glue seals

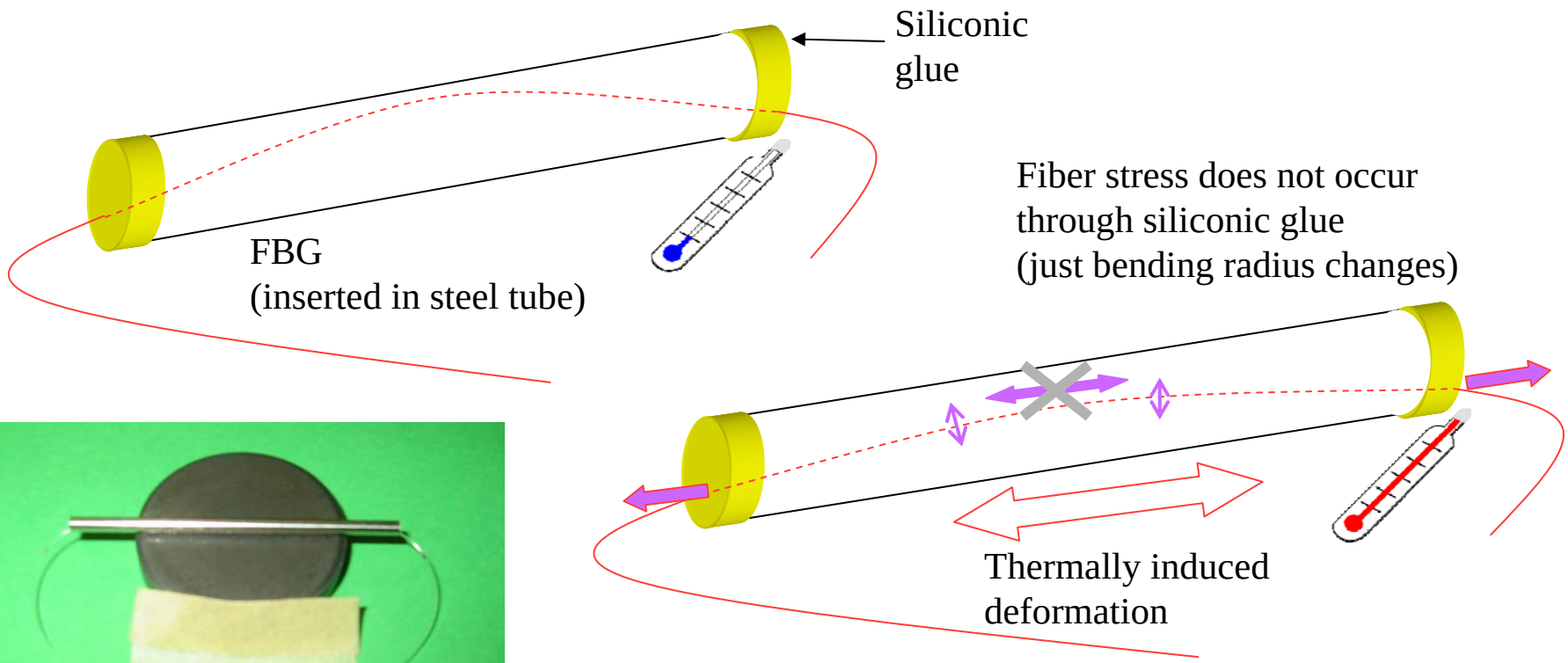
Siliconic glue:

poor elastic features

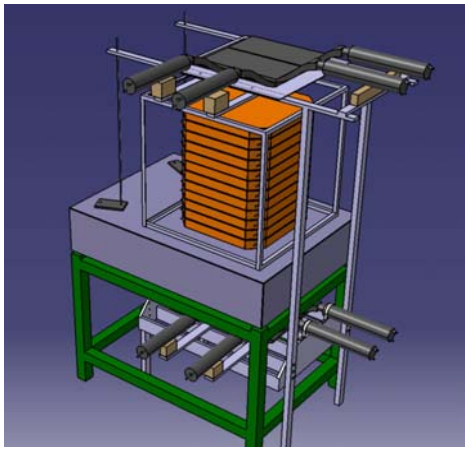
unstable/unrepeatable FBG mechanical stress (relaxation, slipping, …)



Adoption of a new design to avoid axial tensioning of FBG when thermal deformation of housing occurs: optical fiber sealed loose in the housing



Comparison of sensor prototypes



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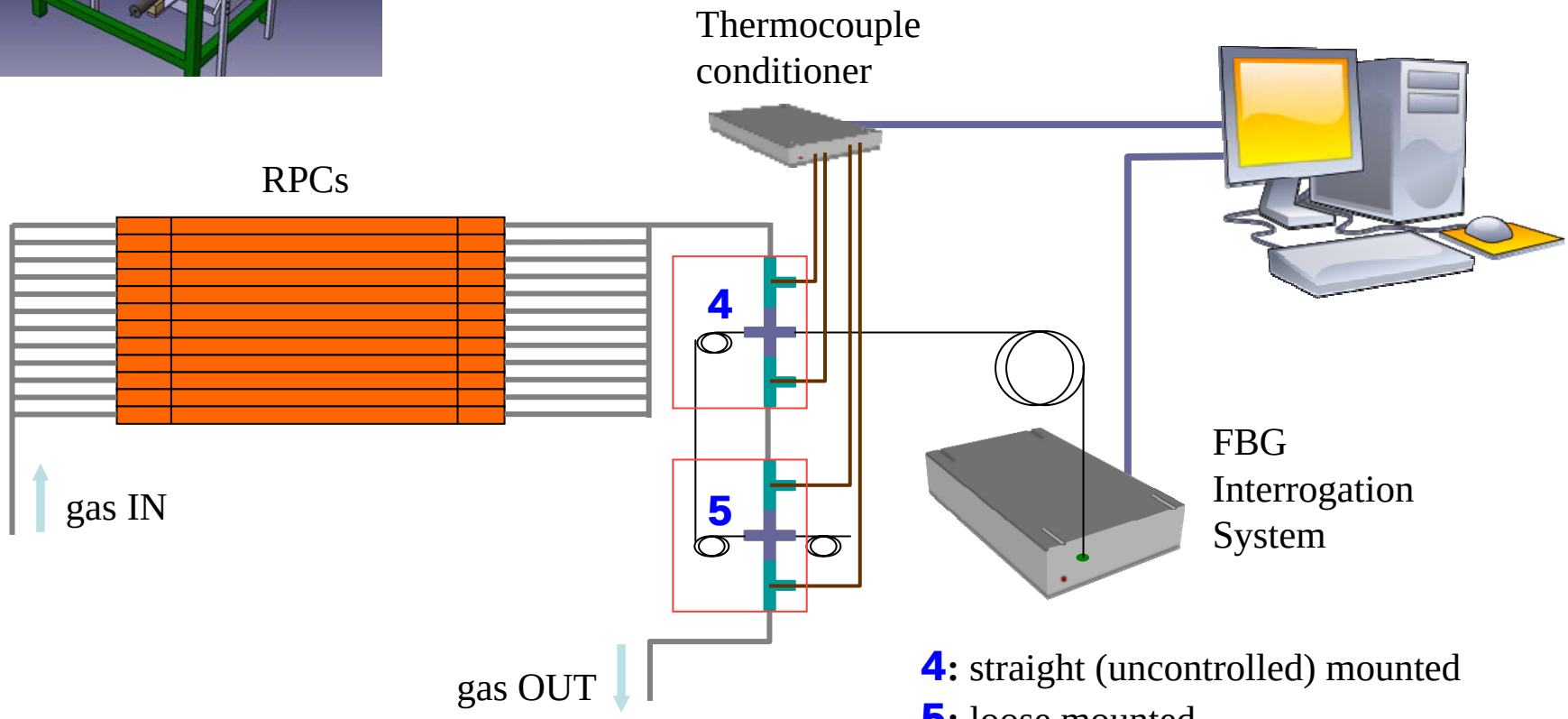
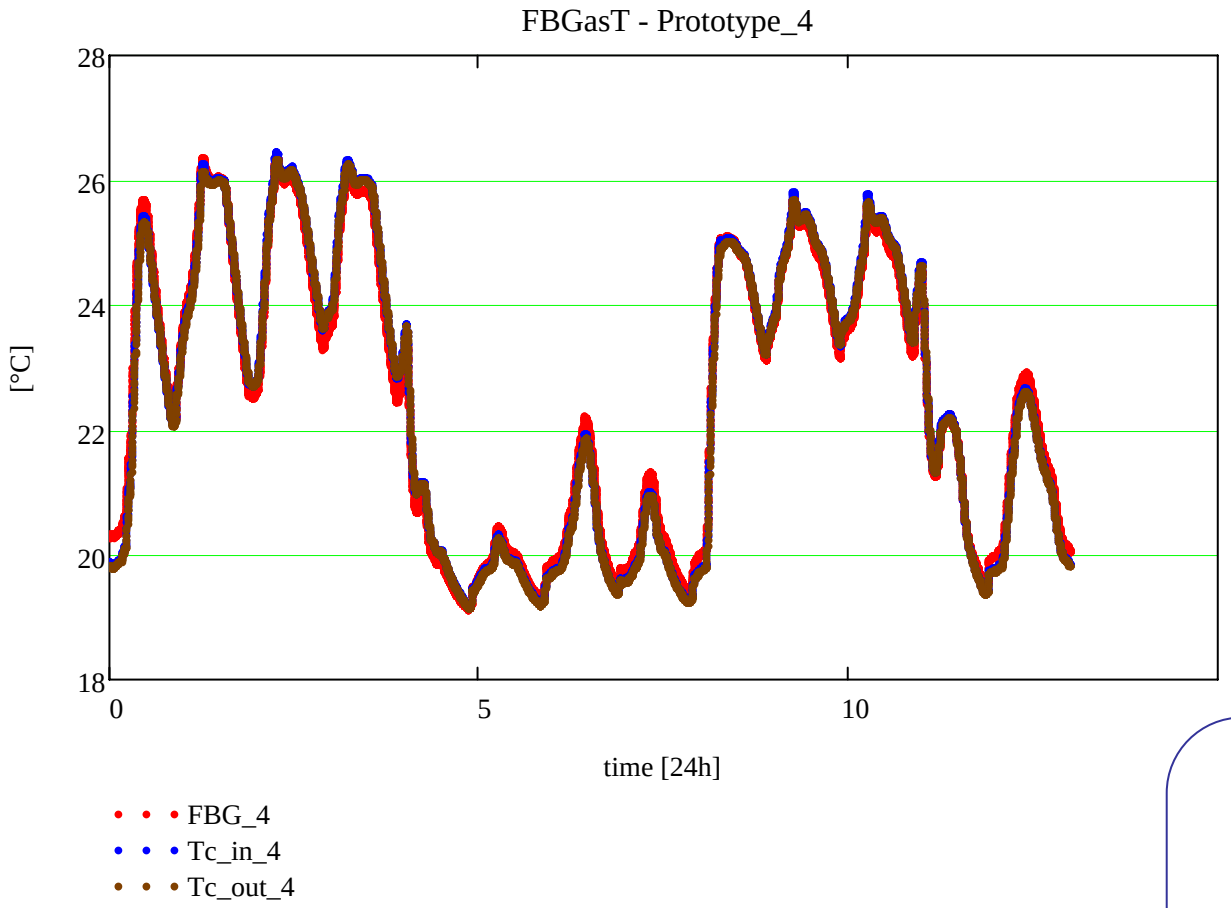
Experiment al Hall 'ASTRA'
RPC Test Facility

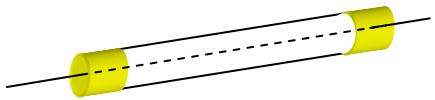
Test run: comparison test of 'straight mounted' and 'loose mounted' prototypes



4: straight (uncontrolled) mounted
5: loose mounted

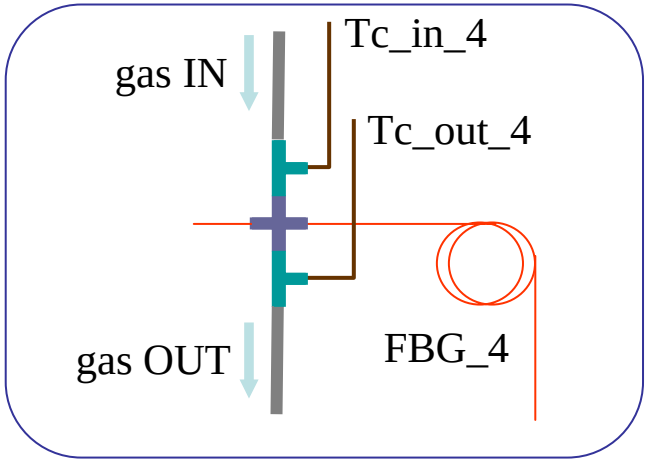
Comparison of sensor prototypes



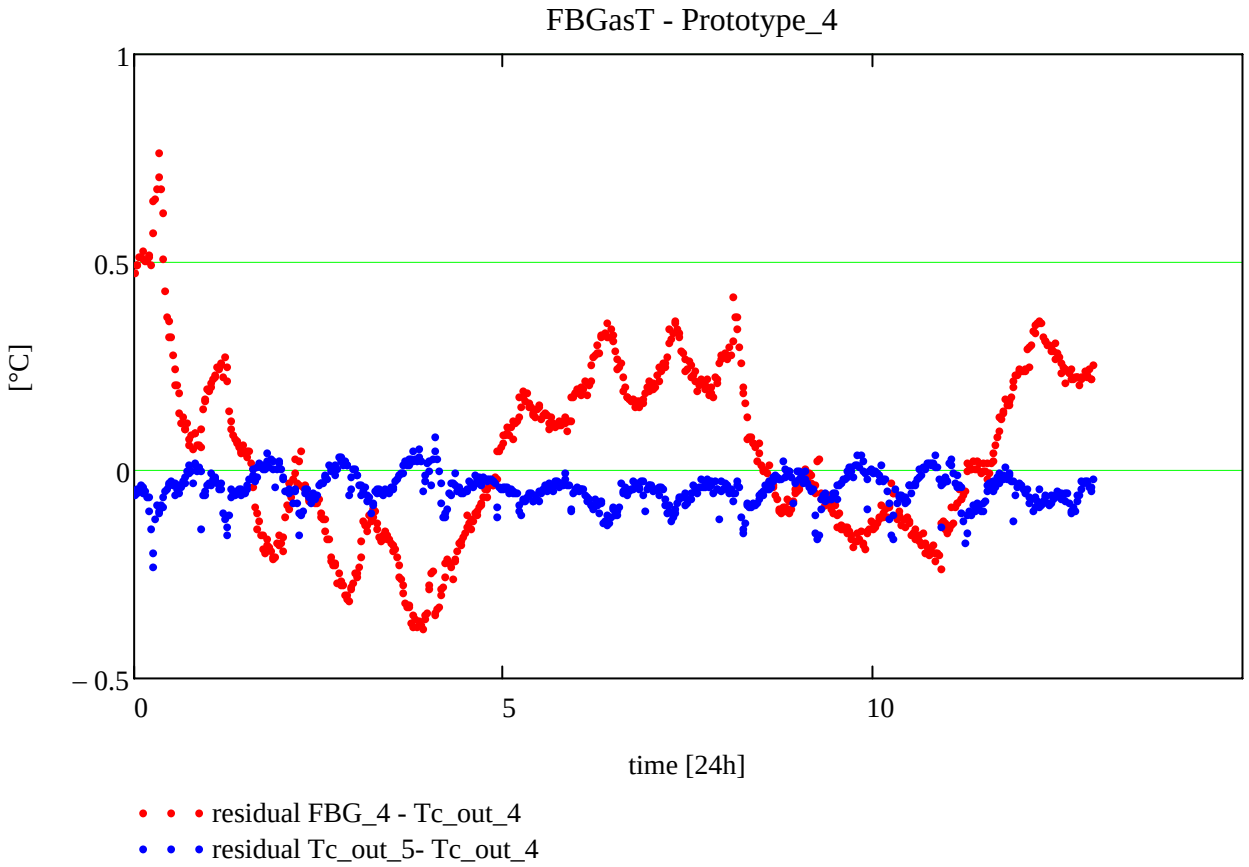


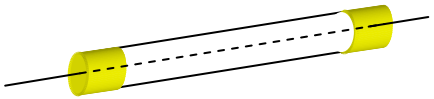
Prototype FBGasT_4:
FBG straight mounted

Prototype FBGasT_4: poor agreement with reference Tc

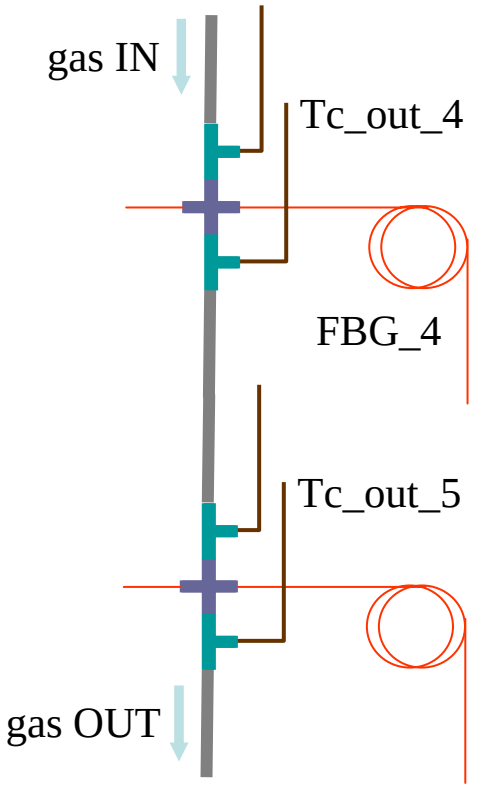


Comparison of sensor prototypes



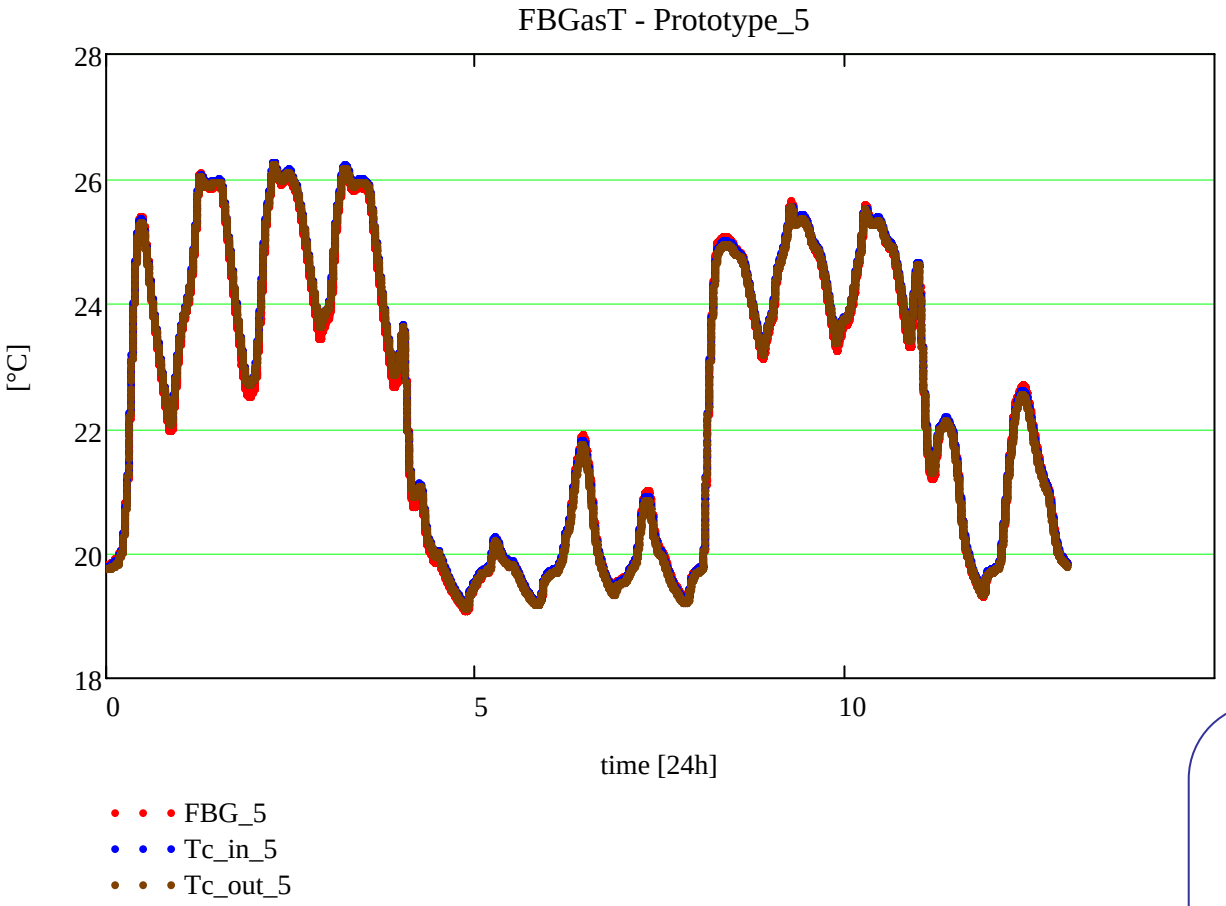


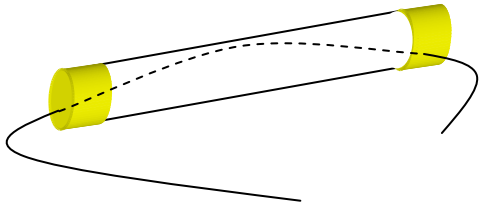
Prototype FBGasT_4:
FBG loose mounted



Prototype FBGasT_4: poor agreement with reference Tc

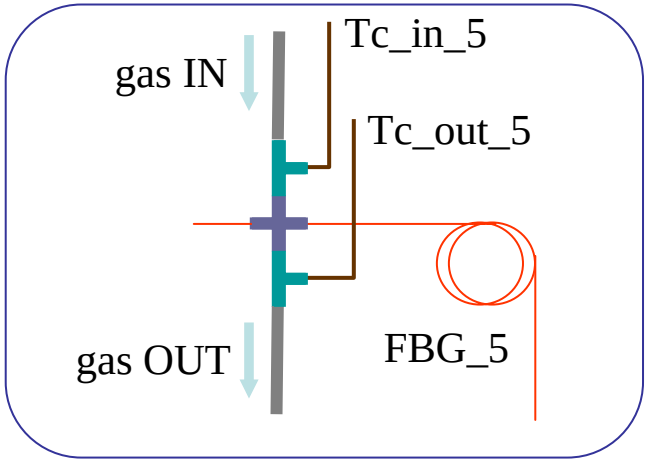
Comparison of sensor prototypes



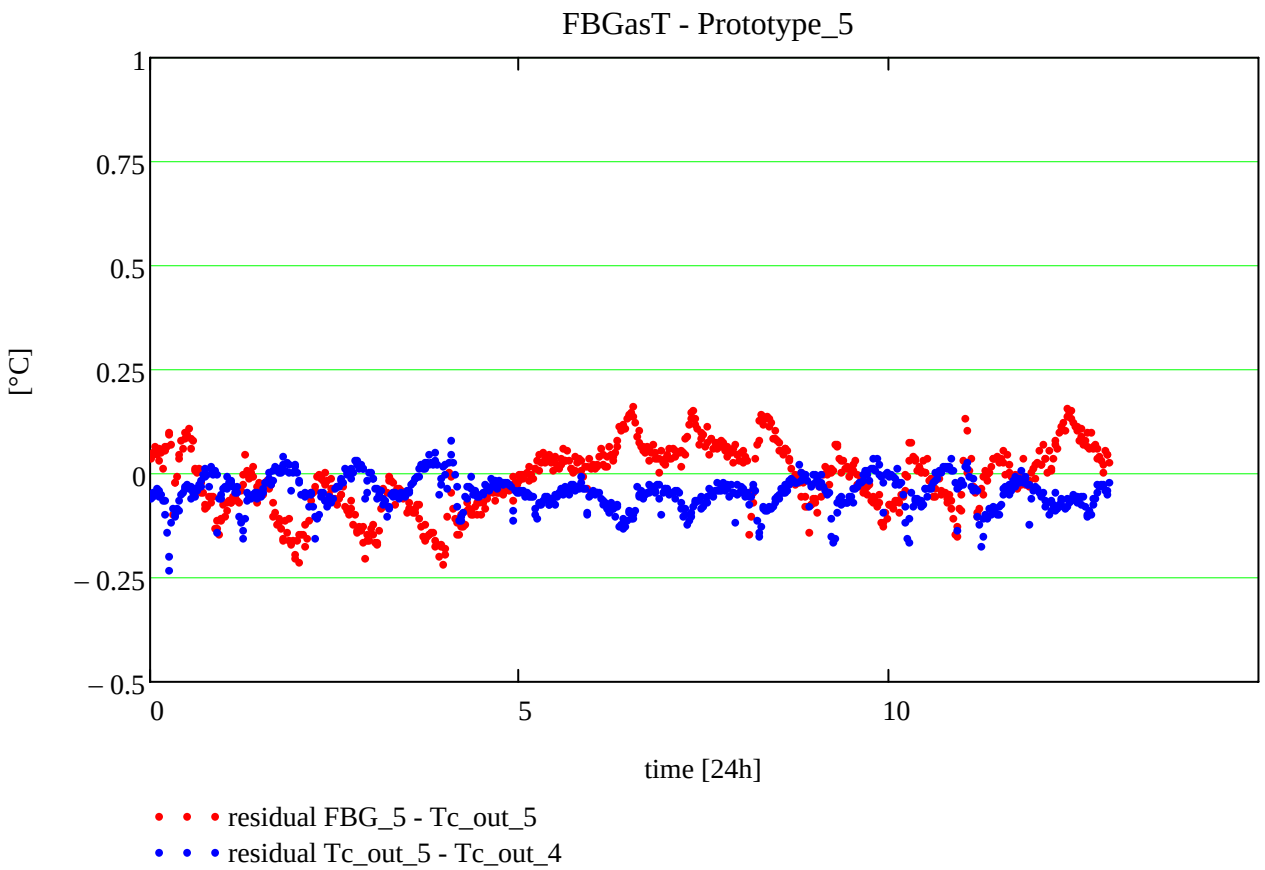


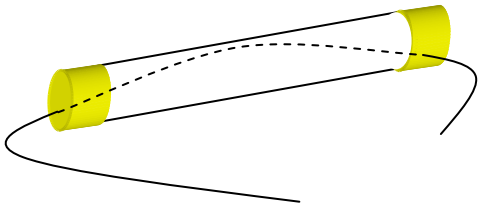
Prototype FBGasT_5:
FBG loose mounted

Prototype FBGasT_5: improved agreement with reference Tc

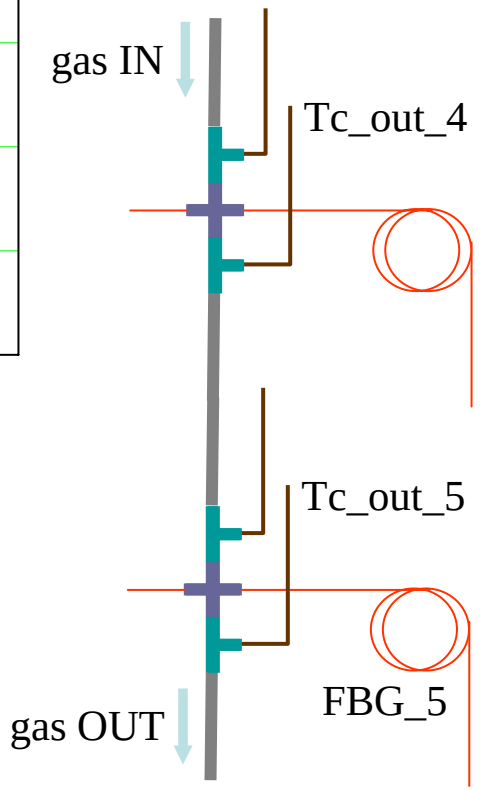


Comparison of sensor prototypes



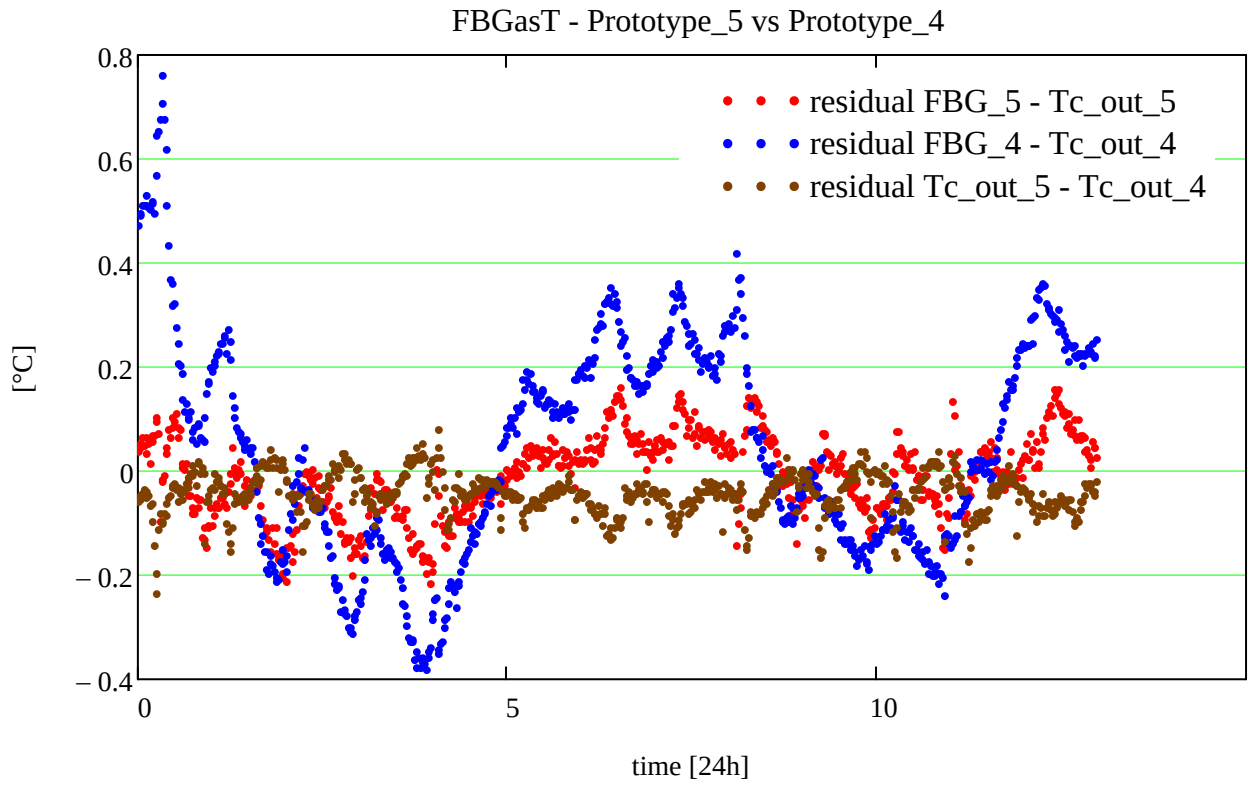


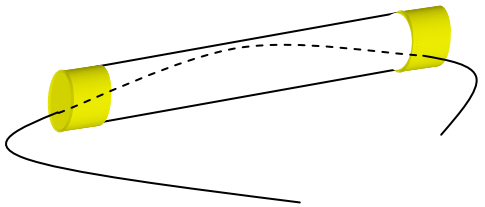
Prototype FBGasT_5:
FBG loose mounted



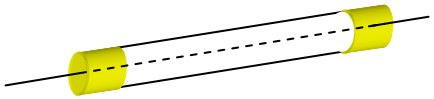
Prototype FBGasT_5: improved agreement with reference Tc

Comparison of sensor prototypes





Prototype FBGasT_5:
FBG loose mounted



Prototype FBGasT_4:
FBG straight mounted

Standard variation of residual
..but note that data show evident 'structure' related to temperature gradient..

$\sigma\_FBG4 = 0.21$

$\sigma\_FBG5 = 0.077$

$\sigma\_T = 0.04$

$\frac{\sigma\_FBG4}{\sigma\_T} = 5.316$

$\frac{\sigma\_FBG5}{\sigma\_T} = 1.956$

Conclusions and Future Work

- The goal of ±0.05K precision is close
- To improve both precision and accuracy a new housing design is planned

- Development of a custom tubing joint provided with openings for FBG
- Development of industrial-grade housing/cabling, suitable for large in-service chamber detectors