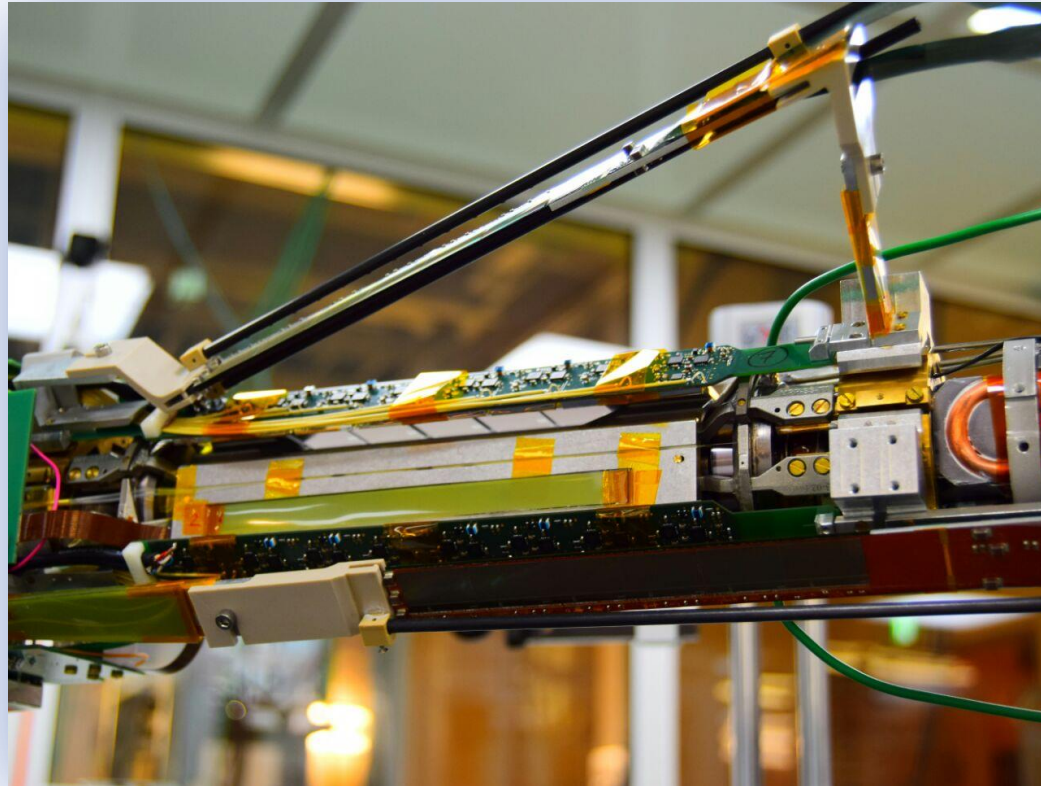


FOS system phase-2 status report



Belle-2 PXD Workshop
Castle Ringberg, April 2018



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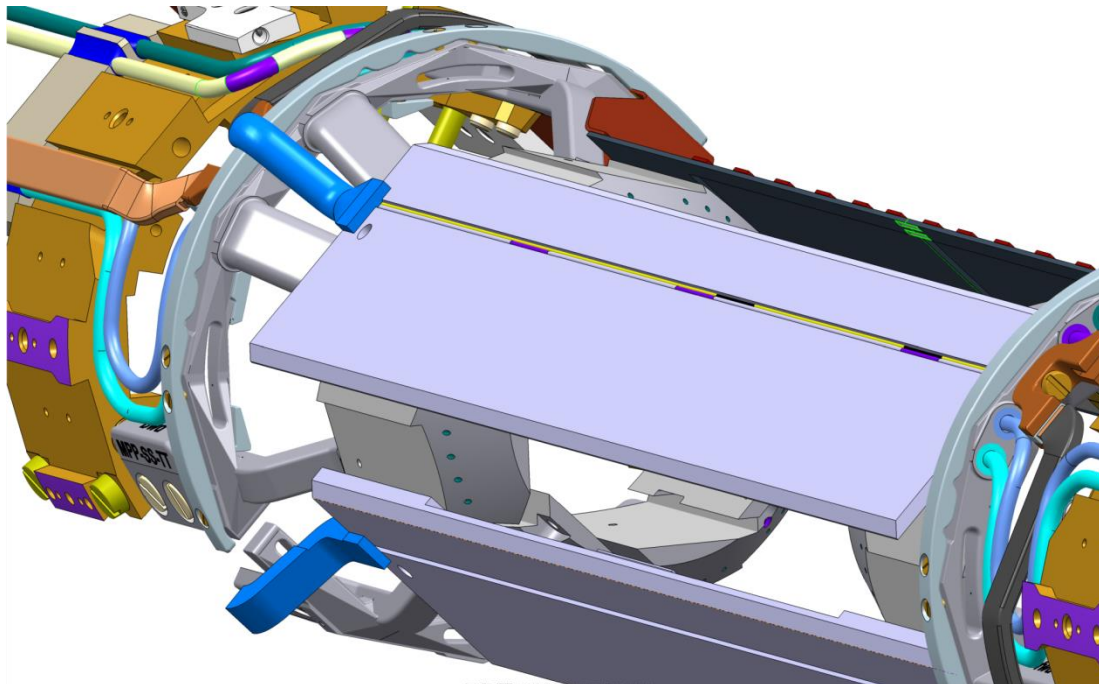
Outline



- Phase-2 Sensors layout
- Humidity initial studies on Low-Humidity Induced Off-set (LHIO)
- Phase-3 preparations.
- Summary

System Lay-out (1)

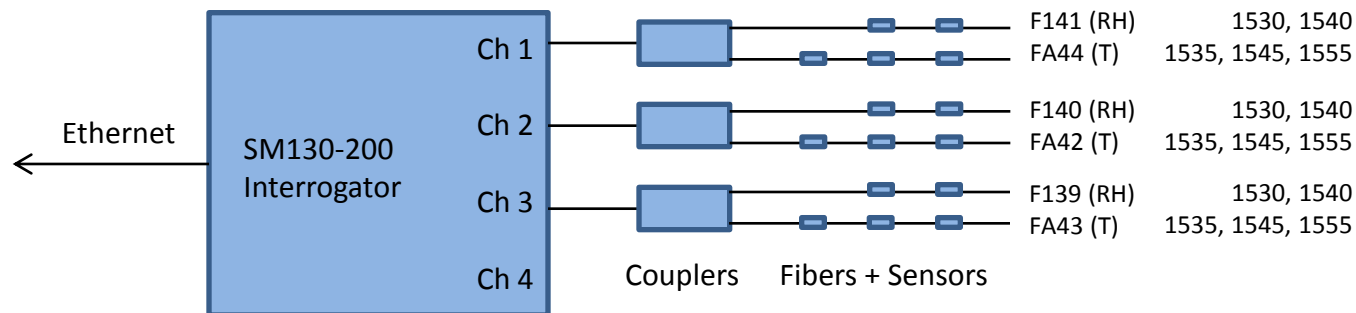
- _ Installation of pre-irradiated Fiber Bragg Grating sensors on the three FANGS arms for beast-II for temperature and humidity monitoring
- _ Focus on developing a FBG based humidity sensors.



System Layout (2)



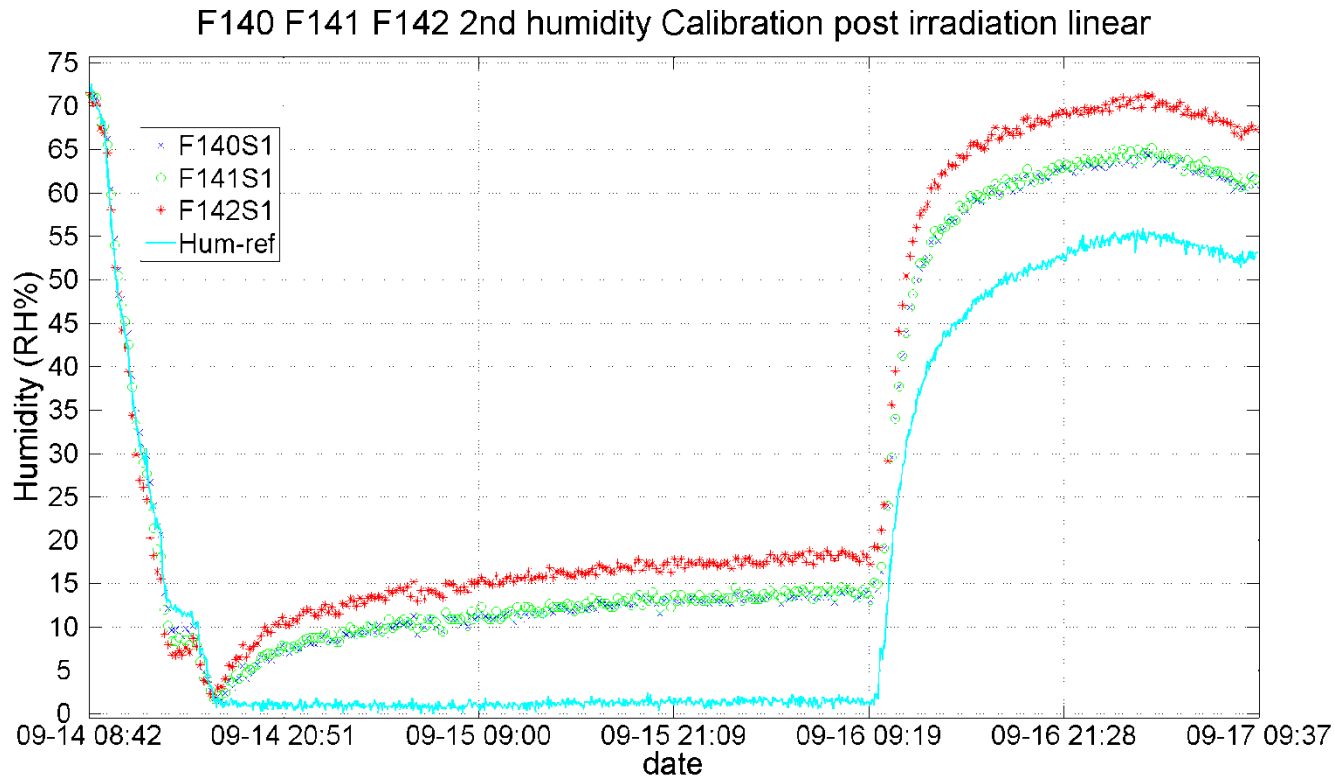
Fiber	Coating	Sensitive	Nº of sensors	Cable length
FA42	acrylate	T	3	3 meters
FA43	acrylate	T	3	3 meters
FA44	acrylate	T	3	3 meters
F139	polyimide	T+RH%	2	3 meters
F140	polyimide	T+RH%	2	3 meters
F141	Polyimide	T+RH%	2	3 meters



Preliminary Study of LHIO (1)



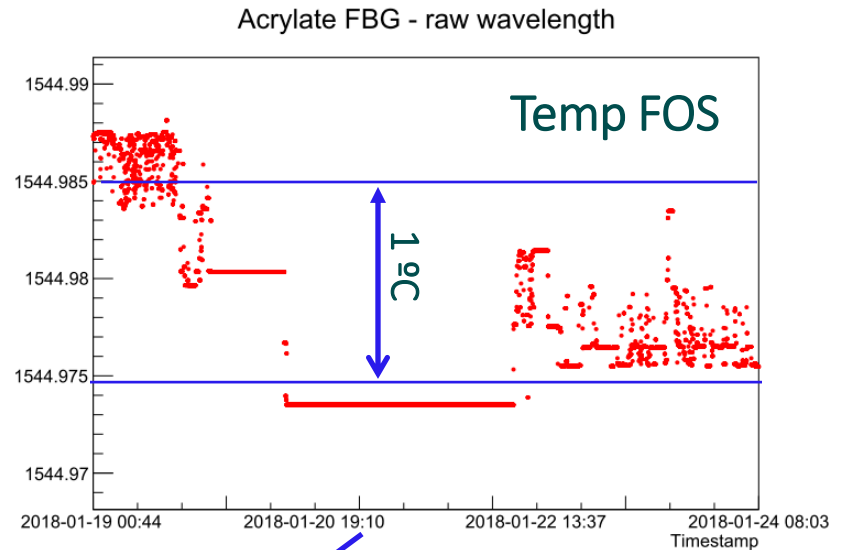
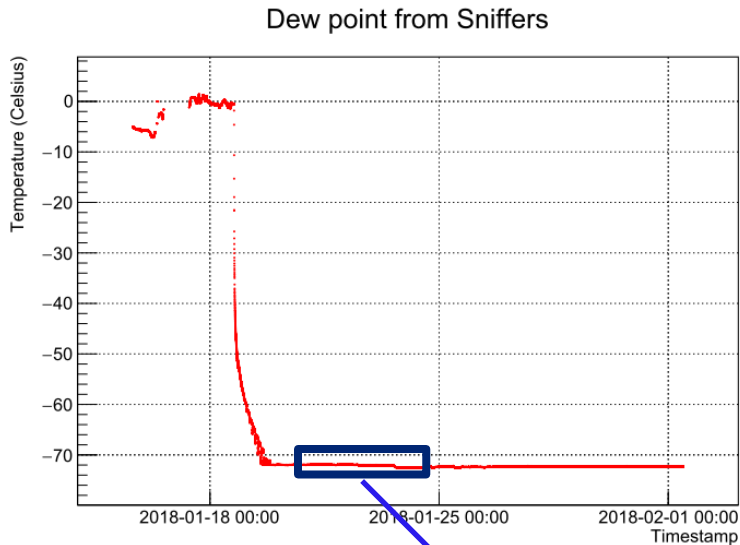
- **Major systematic** for the determination of the %HR
- During sensor calibrations: Observation of Low-Humidity-Induced Off-set (LHIO)
- In-situ long-term studies during phase-2.



Preliminary Study of LHIO (2)



- Extended period (~one week) with very stable temperature & very low humidity.
- Here raw data (wavelength) no calibration

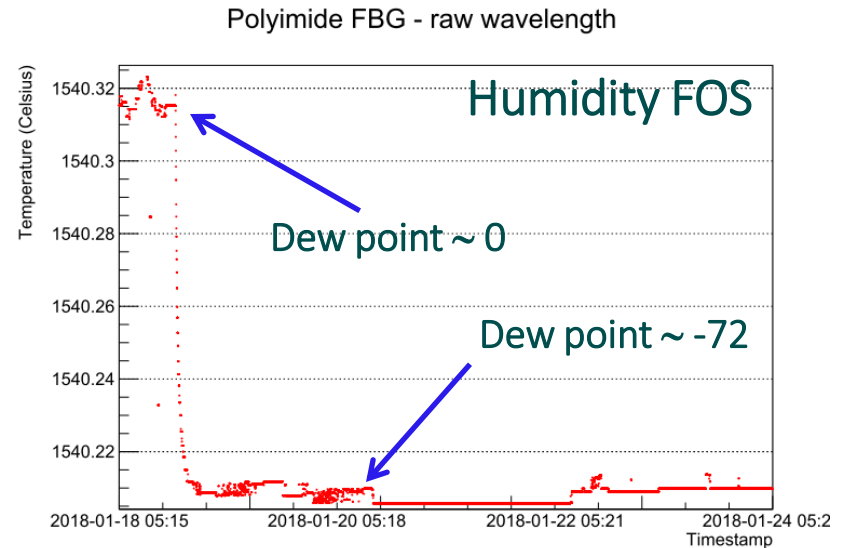
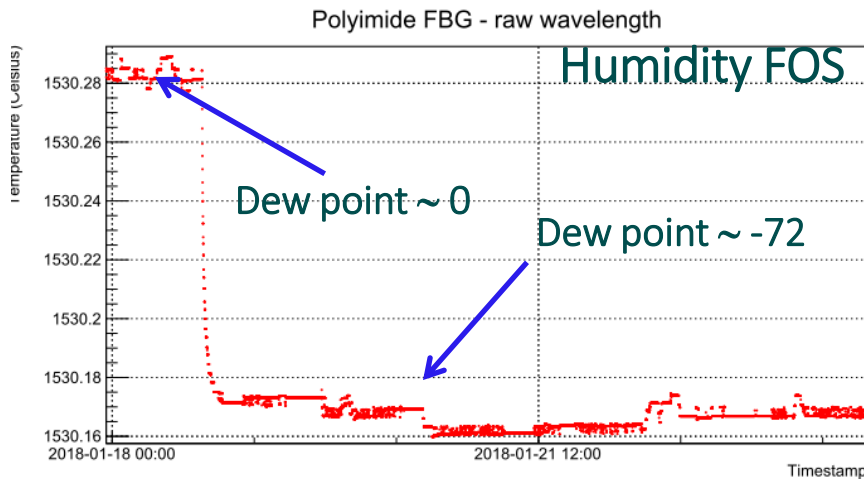


%HR ~ 0 and Temperature stable ~ 1 °C

Preliminary Study of LHIO (3)



- Extended period (~one week) with very stable temperature & very low humidity.
- Here raw data (wavelength) no calibration

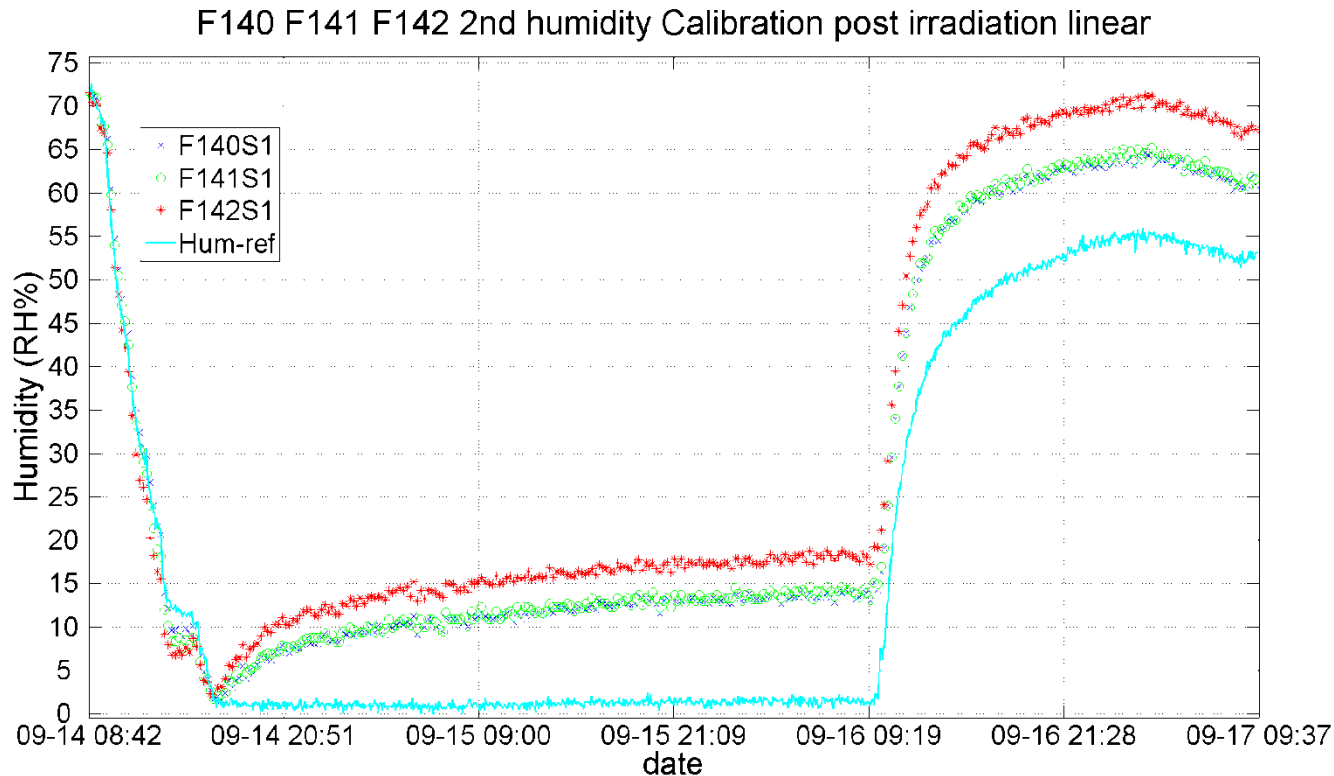


NO LHIO was observed (saturation effect?)

Preliminary Study of LHIO (1)



- During sensor calibrations: Observation of Low-Humidity-Induced Off-set (LHIO)
- In-situ long-term studies during phase-2.



Phase-3 progress



- _ Four temperature monitoring fibers in the PXD envelop + one additional spare
- _ Time line:
 - _ Fibers ordered (second half of April)
 - _ Irradiations (first/second week)
 - _ Re-calibration (2 weeks)
- Sensors should be ready on the fourth week of May.
- In parallel, qualification of non-recoatted FOS to mitigate the LHIO effect (to be proven).

Summary

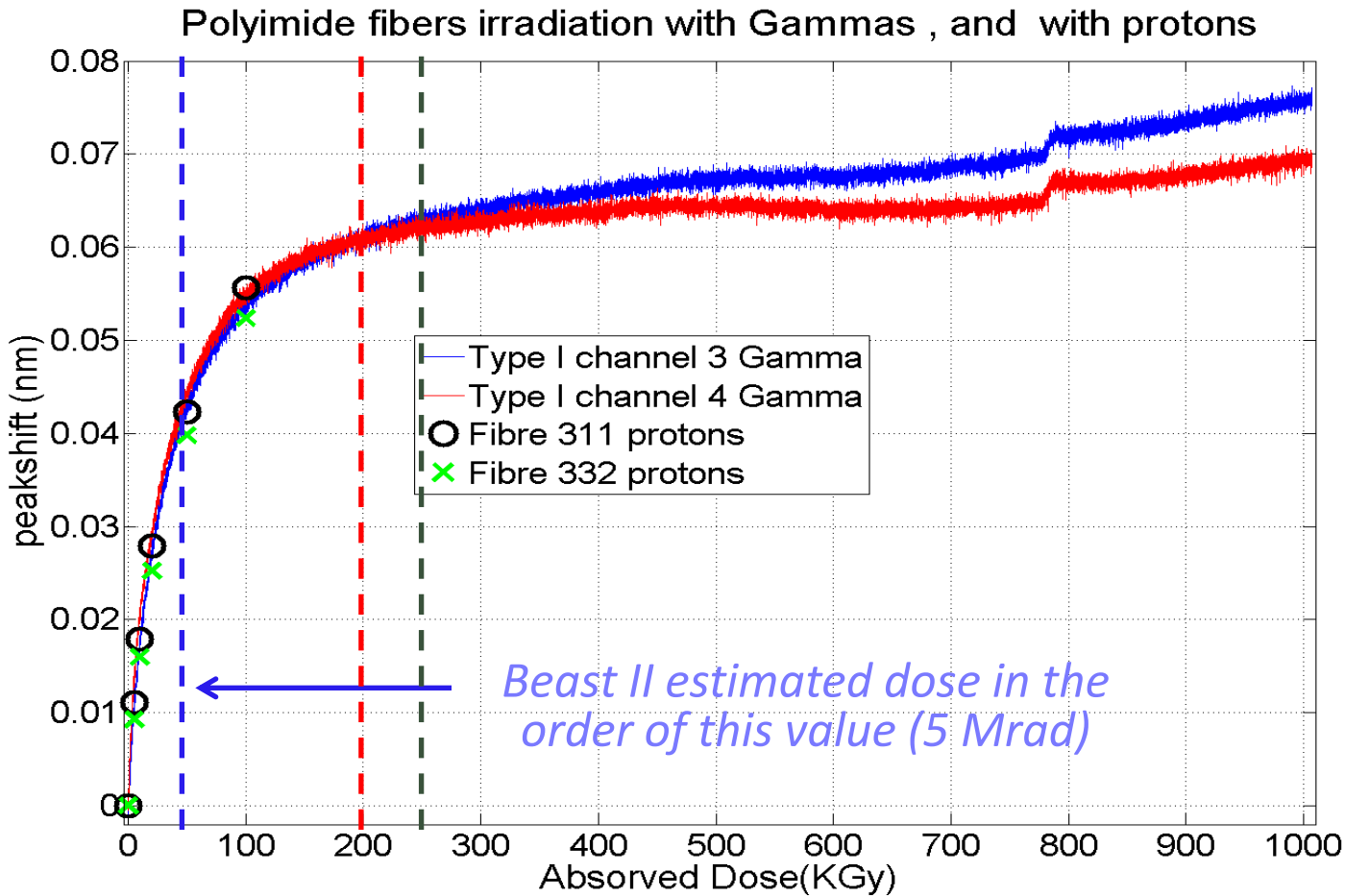


- FOS at Beast-II : all sensors alive and responsive.
- Readout goes smoothly with no incident
- Confirmed: absolute measurement of the humidity requires in-situ resetting of the off-set after what seems LHIO saturation reached.
- New humidity calibration constants taking in to account the previous effect on progress.

BACK-UP



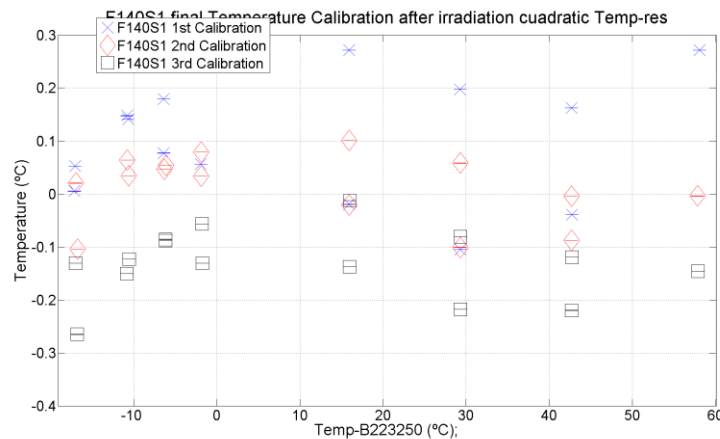
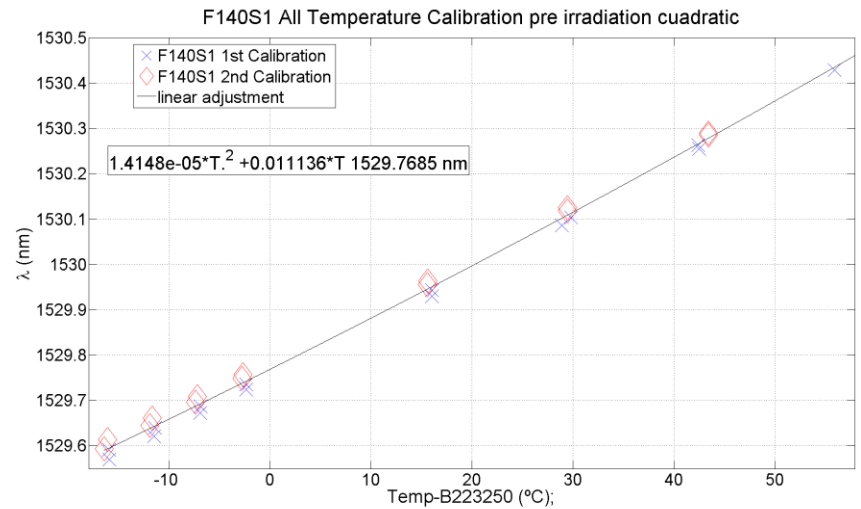
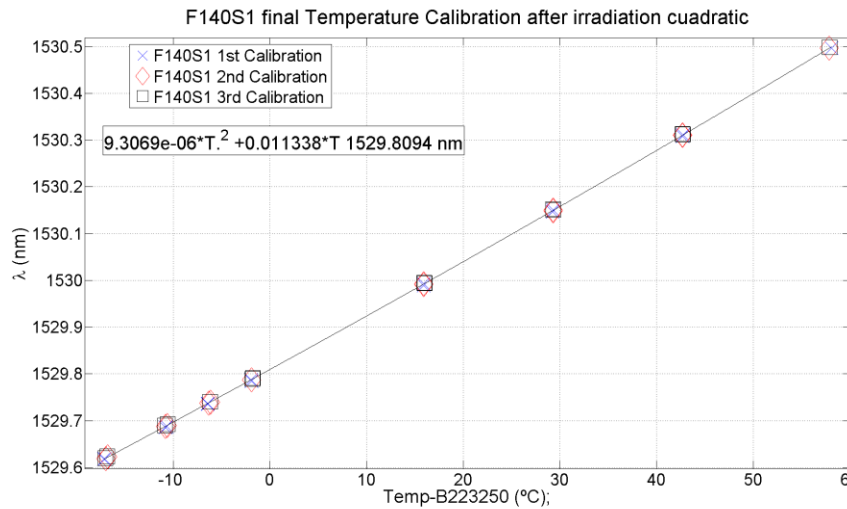
Pre-irradiation of sensors: motivation



Temperature calibration



- Temperature calibration carried out before and after the irradiation.



Humidity with FBGs 101

Water molecules absorbed by the hygroscopic coating



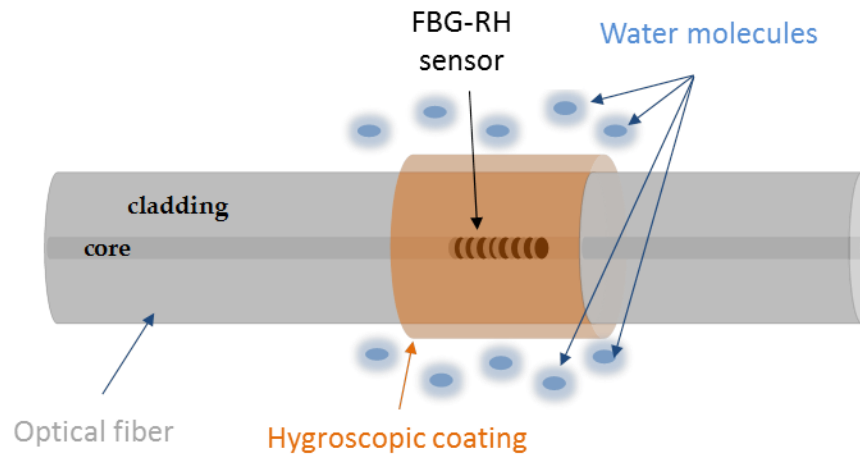
Coating expansion ("Swelling")



Strain induced on the FBG



Bragg wavelength shift ($\Delta\lambda_B$)



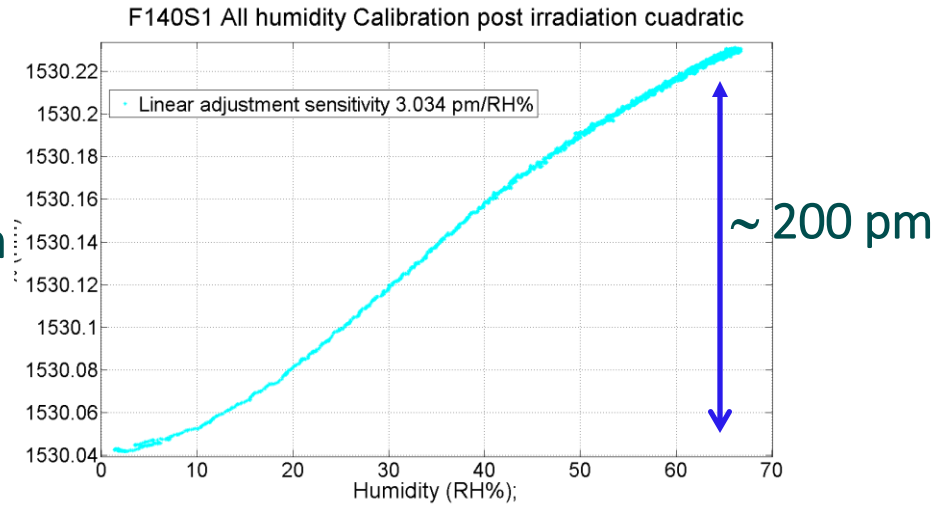
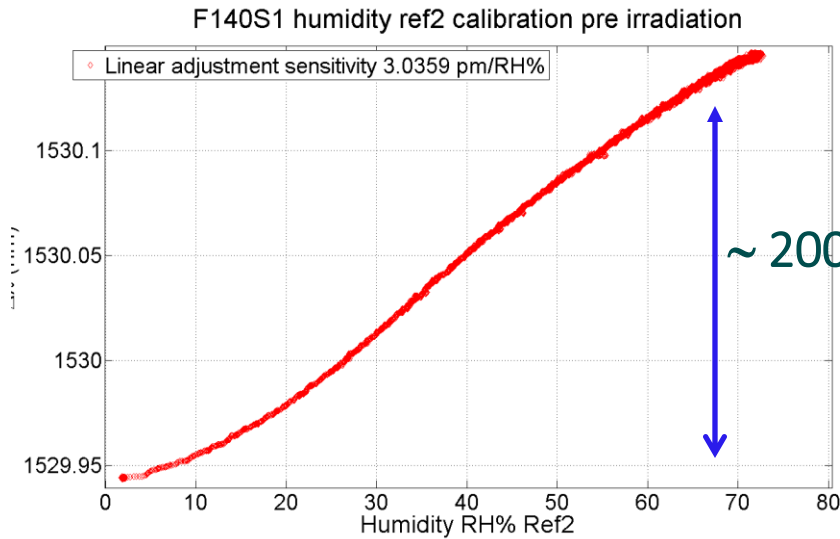
$$\Delta\lambda_B = f(\Delta T, \Delta RH) = S_T(T, RH) \cdot \Delta T + S_{RH}(T, RH) \cdot \Delta RH$$

- A temperature compensation scheme is required to extract RH measurements from the sensor readings

Radiation tolerance of the FBG sensitivity to the humidity.



Humidity sensitivity not affected by irradiation



Humidity systematics: Response latency

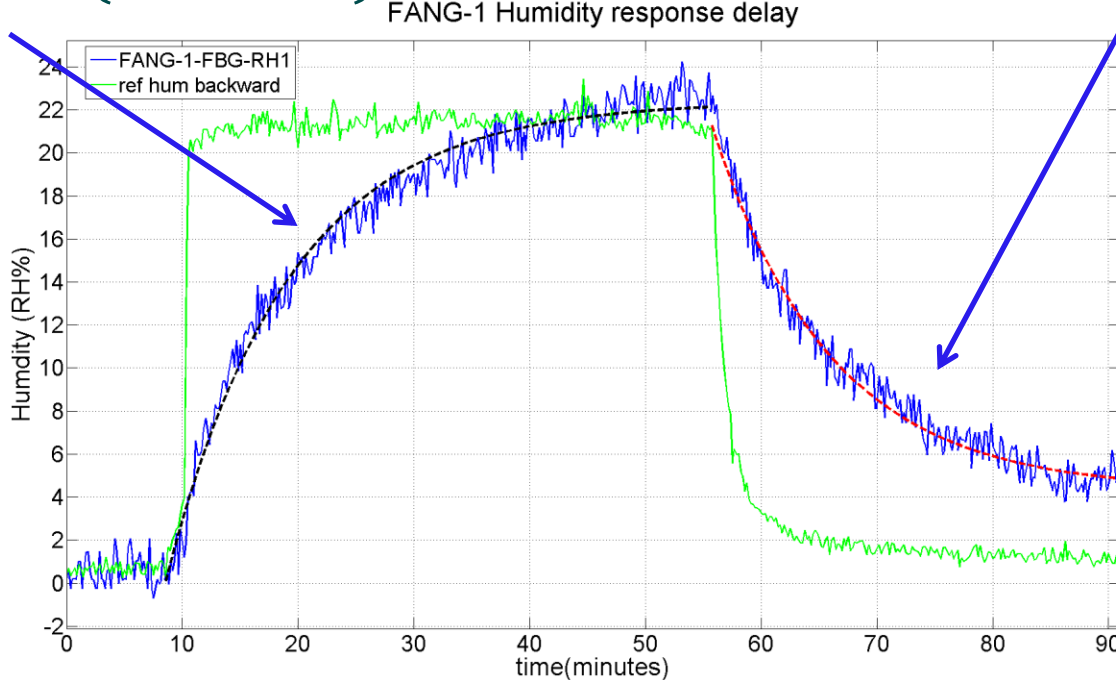


- Dynamic equilibrium of the water molecules in air and in the polyimide.

$$HR = K \left(1 - e^{-\frac{t}{\tau}}\right)$$

FANG-1 Humidity response delay

$$HR = e^{-\frac{t}{\tau}}$$



Time characteristics
 $\tau \sim 10$ minutes

Humidity systematics: Low-Humidity-Induced Off-set (LHIO)



F140 F141 F142 2nd humidity Calibration post irradiation linear

