IPBPM piezo-mover system and plans for in situ monitoring of calibration and stability

Current status and plan for ATF2

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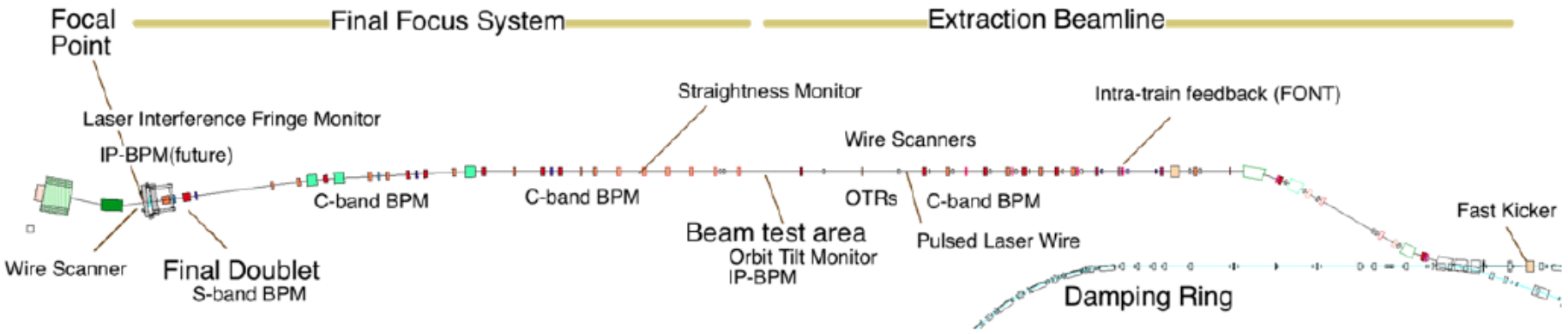
Motivation

- Small vertical beam size (goal 1)
  - Achieve $\sim$ 37nm
  - Validate Local chromaticity correction
- Stabilization of beam center (goal 2)
  - down to $\sim$ 2nm

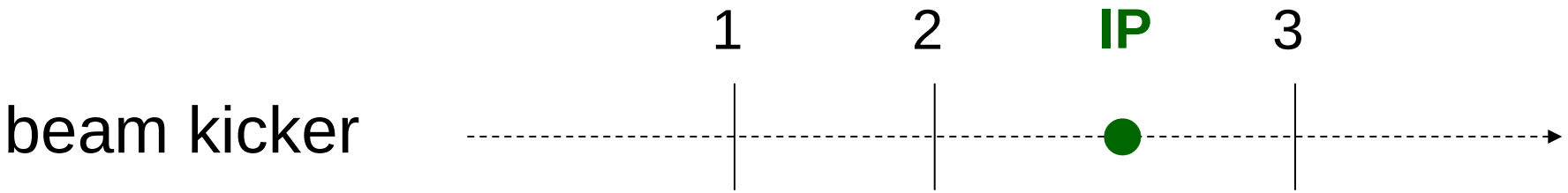
Methodology for stabilization



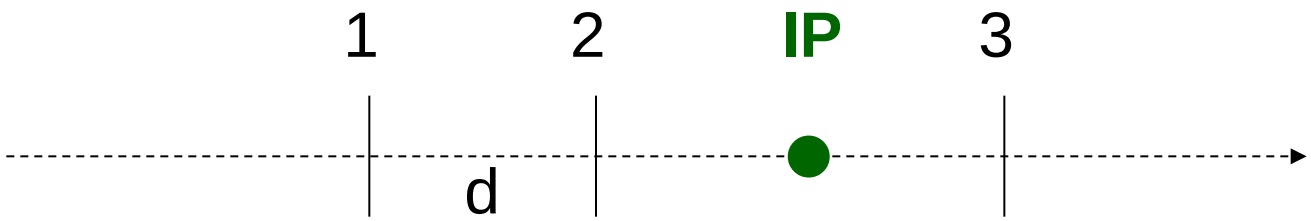
Goal 1 (beam size ~ 37 nm) **beam jitter < 10 nm**
Goal 2 (nm-scale stability with feedback) **beam jitter ~ 2 nm**

1. Measure stability at one of IP-BPMs after shifting the beam waists there
2. Infer position from measurements at the two other IP-BPMs
3. Use fast kicker just upstream to correct second bunch within ATF2 train
4. Optional: use fast feedback upstream to check for improved IP stability
5. Optional: use fast kicker upstream for corrections based on IP-BPMs
6. Optional (goal 1): correct data if second bunch in IP-BSM beam size analysis

in all cases ➔ must first calibrate scale factors and study system resolution



Required precision on relative IP-BPM scale factors depends on beam parameters



d ~ 0.1 m
ε_y ~ 12 pm
σ_{jitter} / σ ~ 10%

$\theta_{IP} = (y_2 - y_1) / d$
$y_{IP} = 2\, y_2 - y_1$

ξ = calibration error of 1 relative to 2
→ $2\, y_2 - y_1 \sim y_{IP} + 2\, \xi\, \theta\, d$

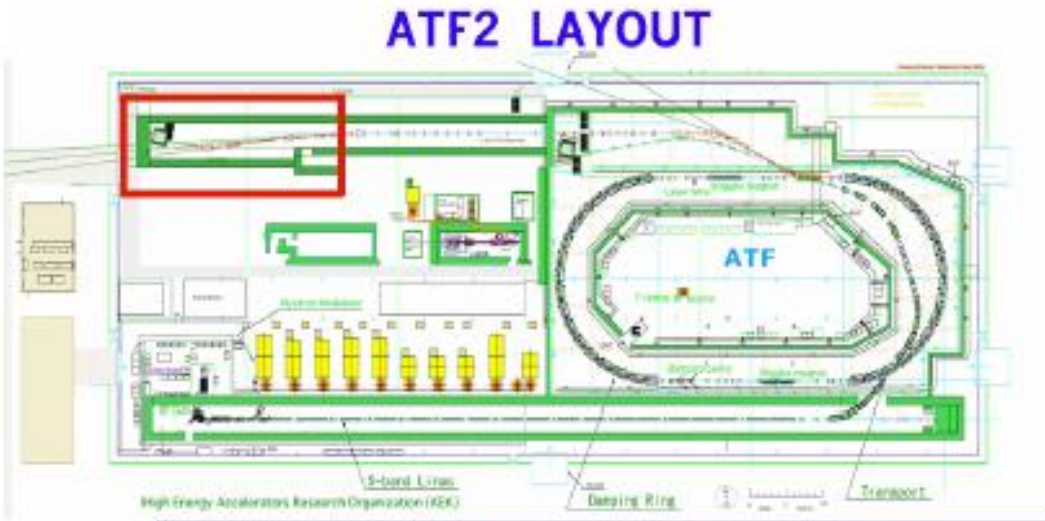
1. **Determination of resolution**
2. **Feedback to IP or to 3rd IP-BPM**

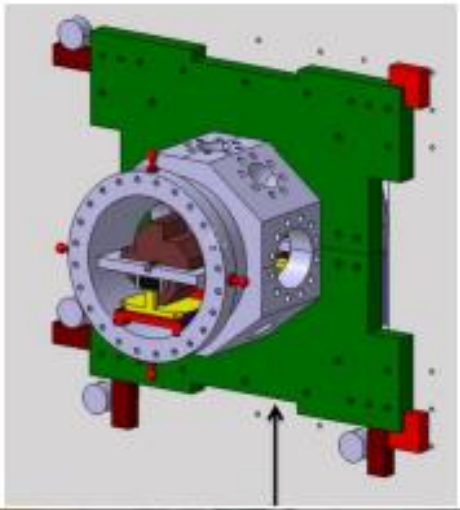
β ~ 1 m (e.g. diagnostic section)

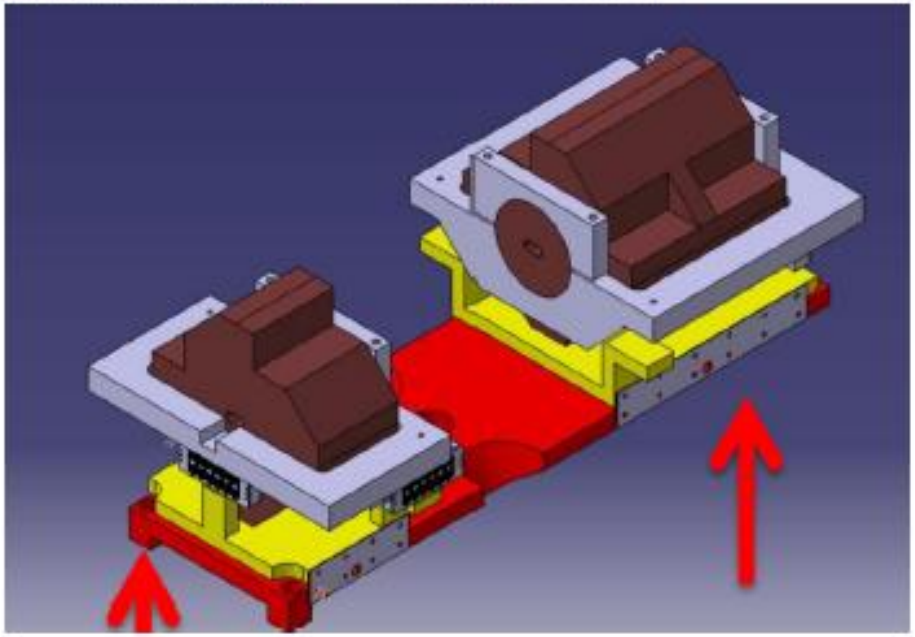
Residual ~ $2\, (\varepsilon / \beta)^{0.5}\, d\, (\sigma_{jitter} / \sigma)\, \xi \sim 10^{-7}\, \xi$ → $\xi \sim 10^{-2}$ for 1 nm error

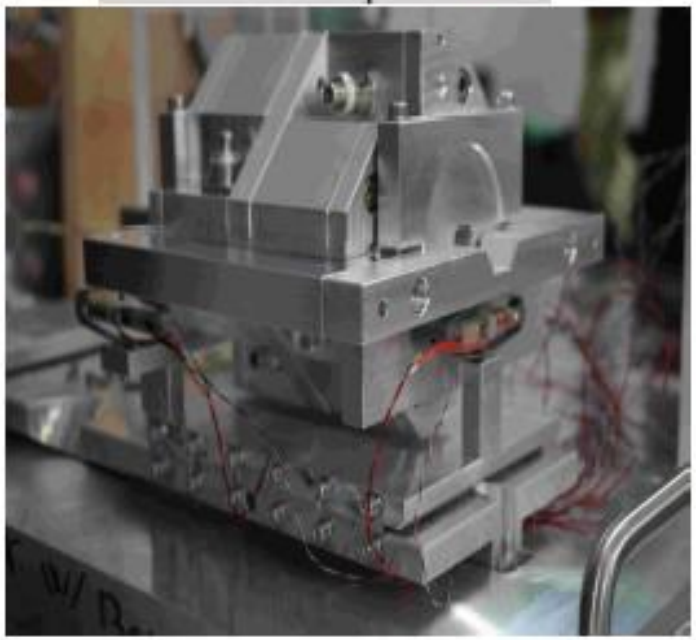
$\beta \sim 10^{-4}$ m (interaction point : nominal optics)

Residual ~ $2\, (\varepsilon / \beta)^{0.5}\, d\, (\sigma_{jitter} / \sigma)\, \xi \sim 10^{-5}\, \xi$ → **$\xi \sim 10^{-4\,/\,-3}$ for 1 / 10 nm error**


ATF2 LAYOUT
ATF
S-band Linac
Damping Ring
Transport





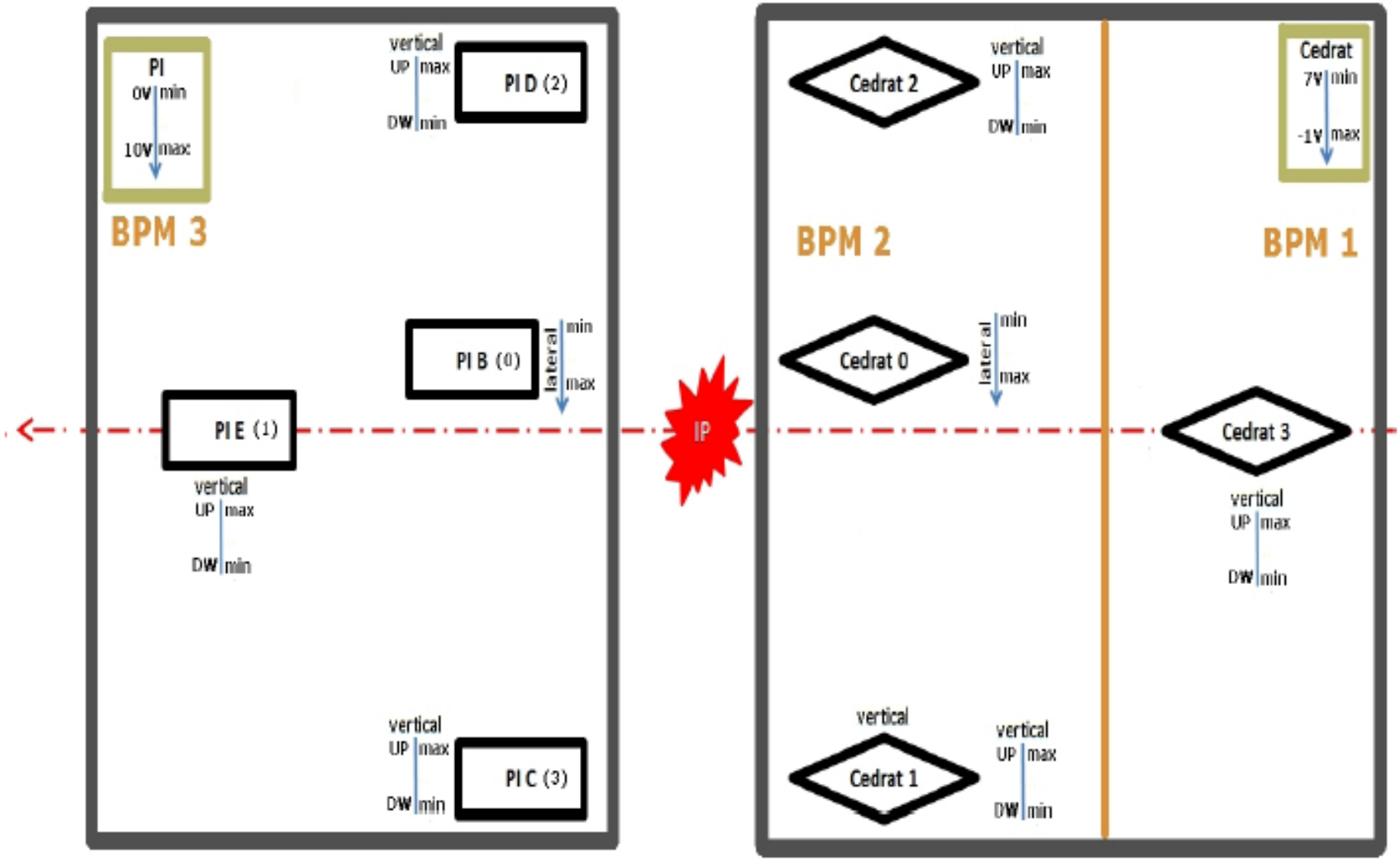


Motivation (cont.)

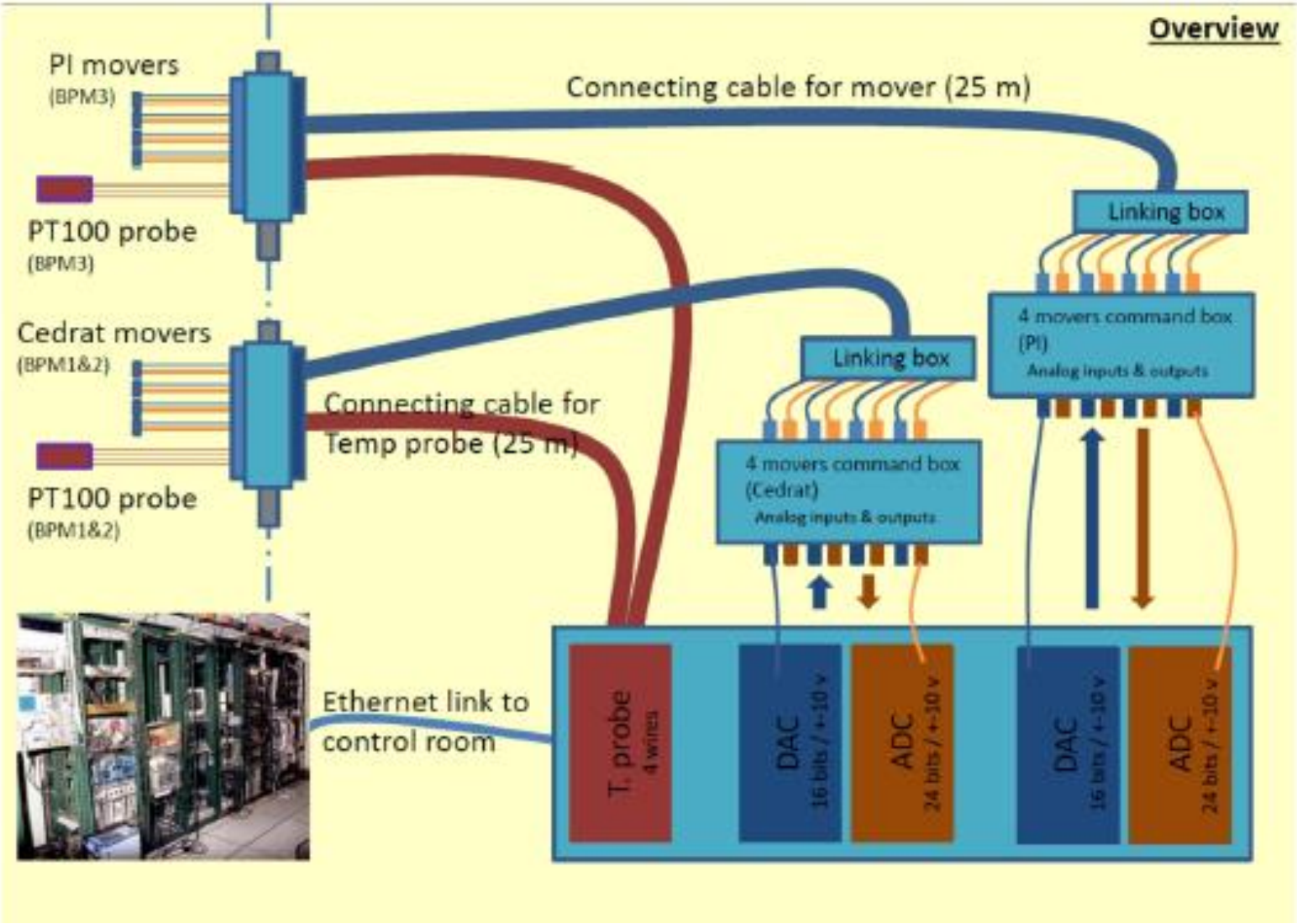
- Locate BPMs to enable the **maximum possible** beam position resolution
- Precision $\sim 5\mu$m
- Calibration $\sim 10^{-4}$

$\Downarrow$

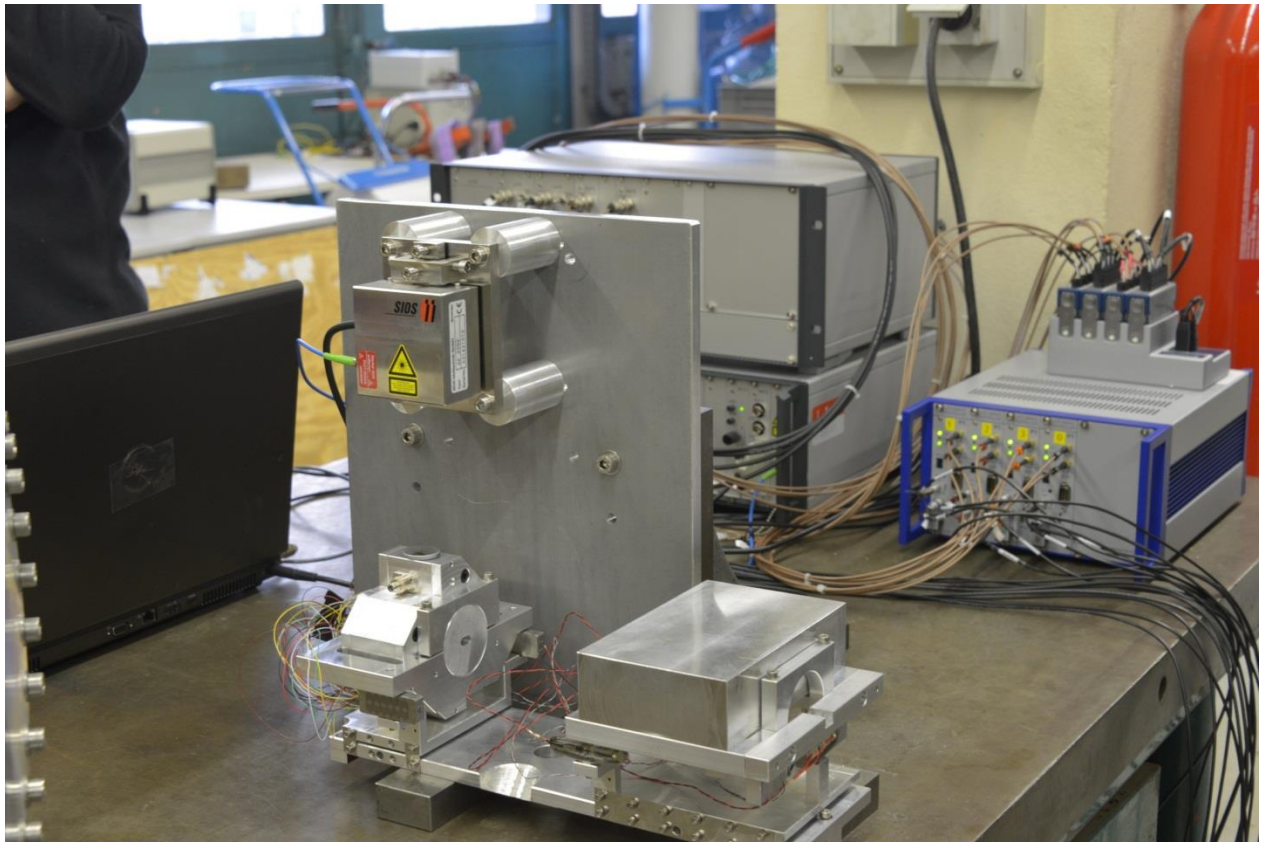
Displace each BPM block **independently**


PI
0V min
10V max
BPM 3
vertical
UP max
DW min
PI D (2)
PI B (0)
lateral
min
max
PI E (1)
vertical
UP max
DW min
vertical
UP max
DW min
PI C (3)
IP
Cedrat 2
vertical
UP max
DW min
BPM 2
Cedrat 0
lateral
min
max
vertical
Cedrat 1
vertical
UP max
DW min
Cedrat
7V min
-1V max
BPM 1
Cedrat 3
vertical
UP max
DW min

How to control the piezo movers?



Piezo-mover performance checks performed at LAL before installation used Sios interferometer, with a weight representing IP-BPM block 1&2 and identical cabling



- Closed-loop stability
- Open-loop stability

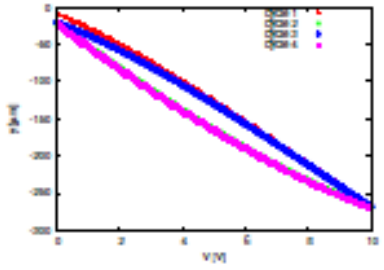
- Setting accuracy
- Calibration

- Thermal effects
- Vibration mitigation

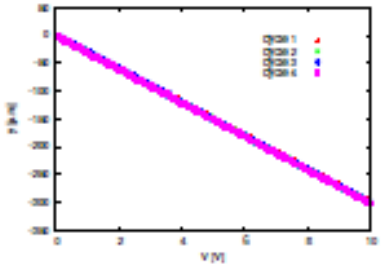
Linearity over 300 / 250 μm range → 10^{-3} – 10^{-4}
(much better by parameterizing calibration curve)

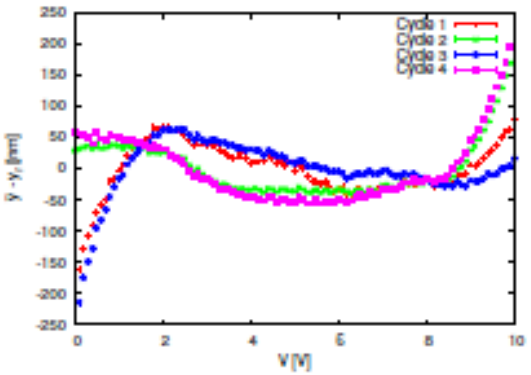
Four cycles,range (0∼10V, 0∼300μm)

PI without fb



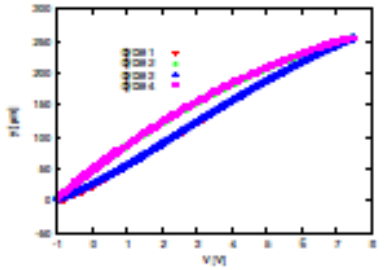
PI with fb



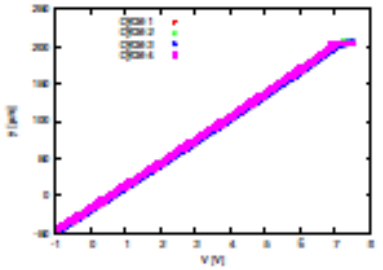


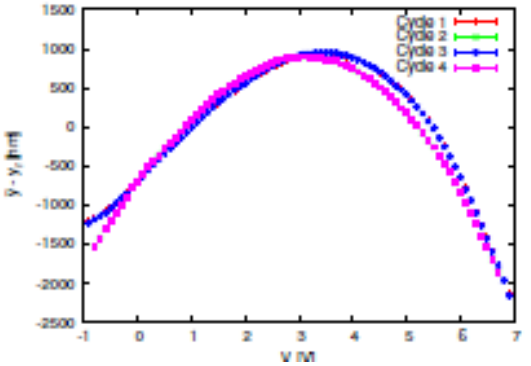
Four cycles, range (-1∼7V, 0∼250μm)

Cedrat without fb



Cedrat with fb

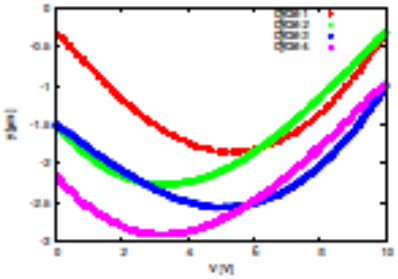




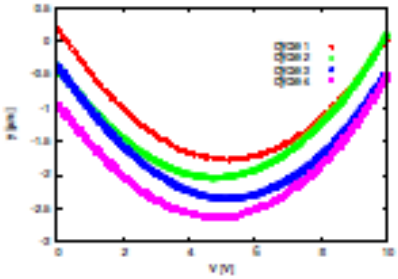
Coupling of horizontal motion into vertical over 300 / 250 μm range → 10^{-2}

Four cycles, range (0∼10V, 0∼300μm)

PI without fb



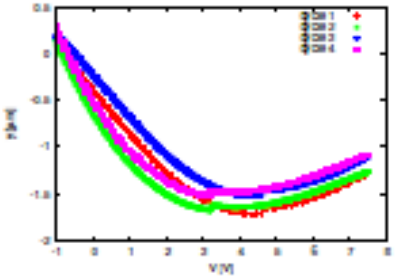
PI with fb



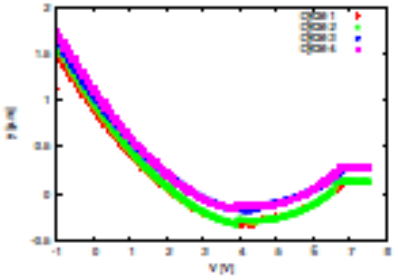
Coupling of 3μm over all lateral range, equivalent to (1%)

Four cycles, range (-1∼7.0V, 0∼250μm)

Cedrat without fb



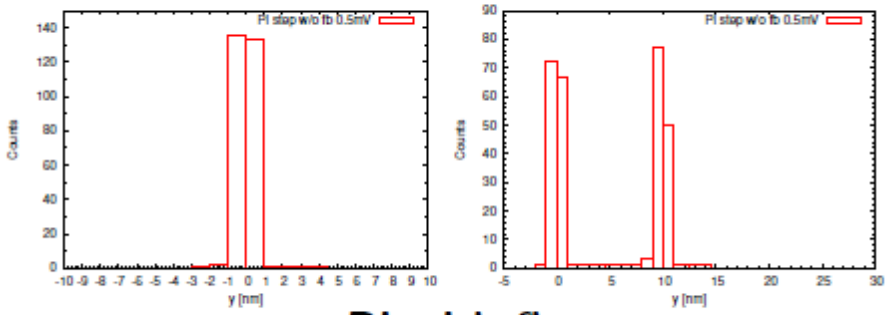
Cedrat with fb



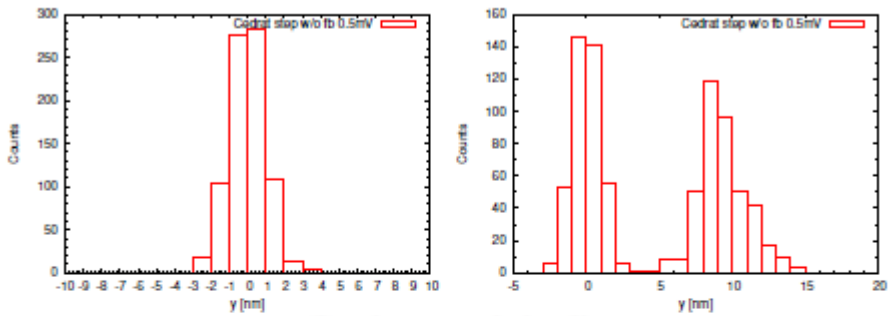
Coupling of 2.5μm over all lateral range, equivalent to (1%)

Stability ~ 1 nm in with feedback
Resolution < 10 nm

PI without fb

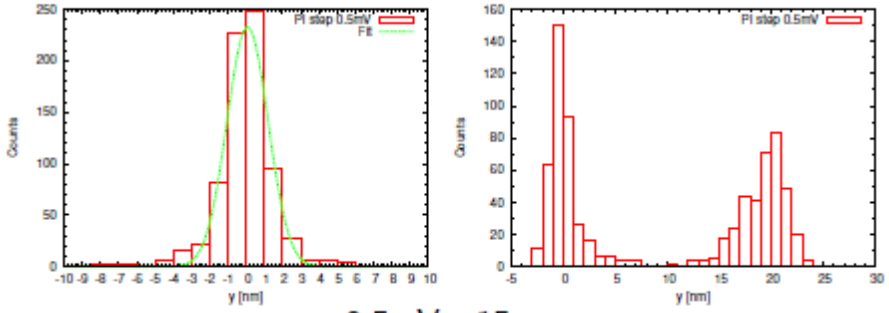


Cedrat without fb



PI with fb

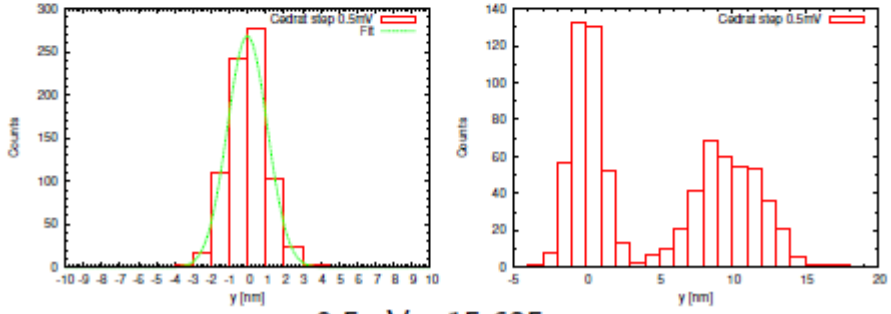
σ = 1.13 nm



0.5mV→15nm

Cedrat with fb

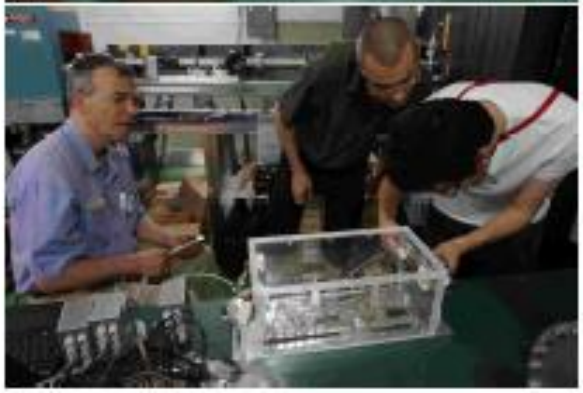
σ = 1.1 nm

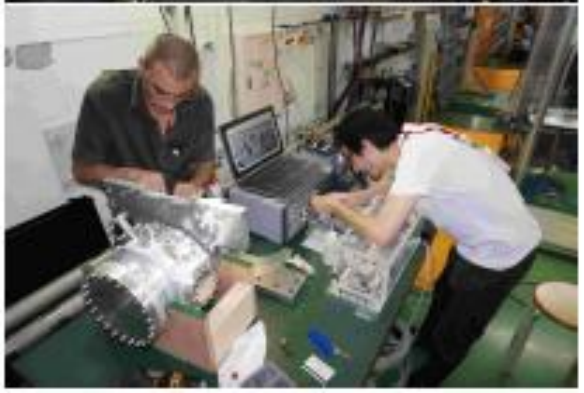


0.5mV→15.625nm

Unpacking and setting up

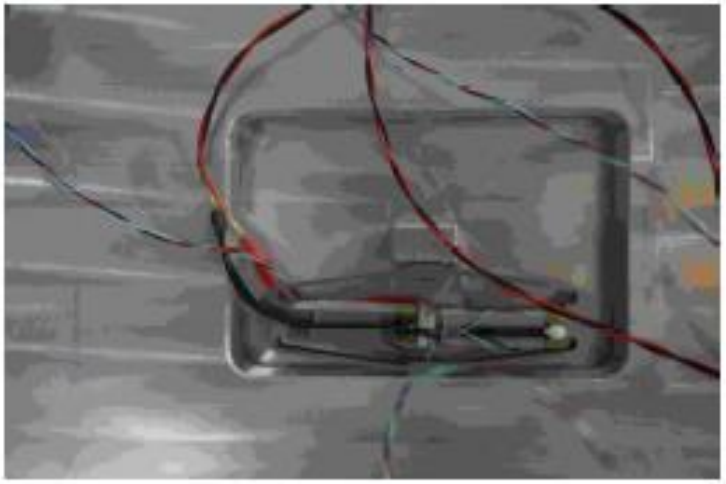


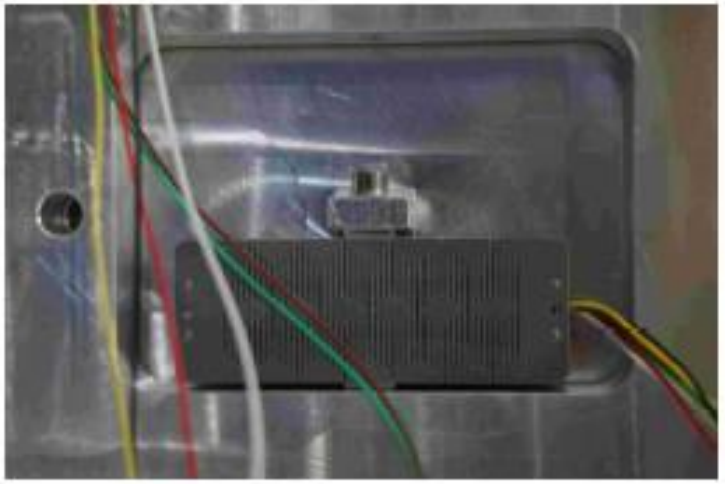





Mechanical Alignment

Lateral





Vertical

Rotation

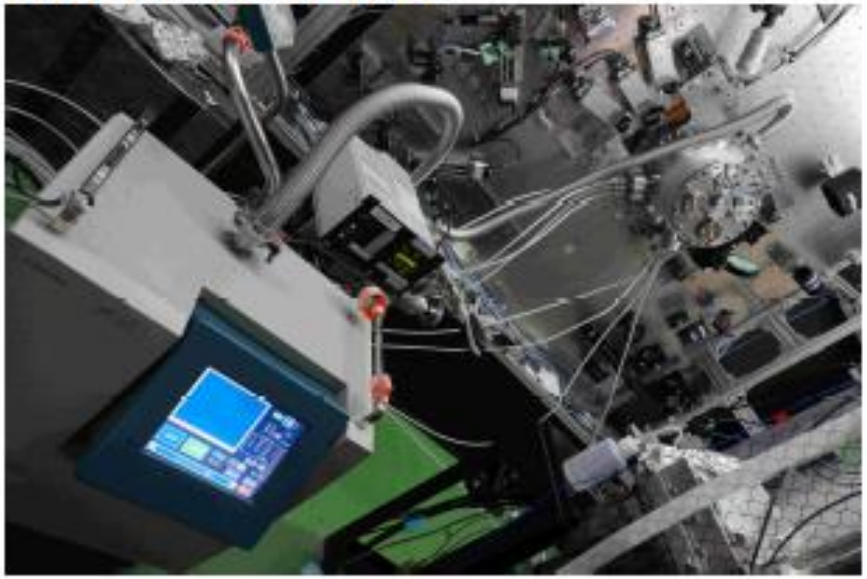
Chamber installation and system first insertion

Cable modifications

Flanges installation



and vacuum test

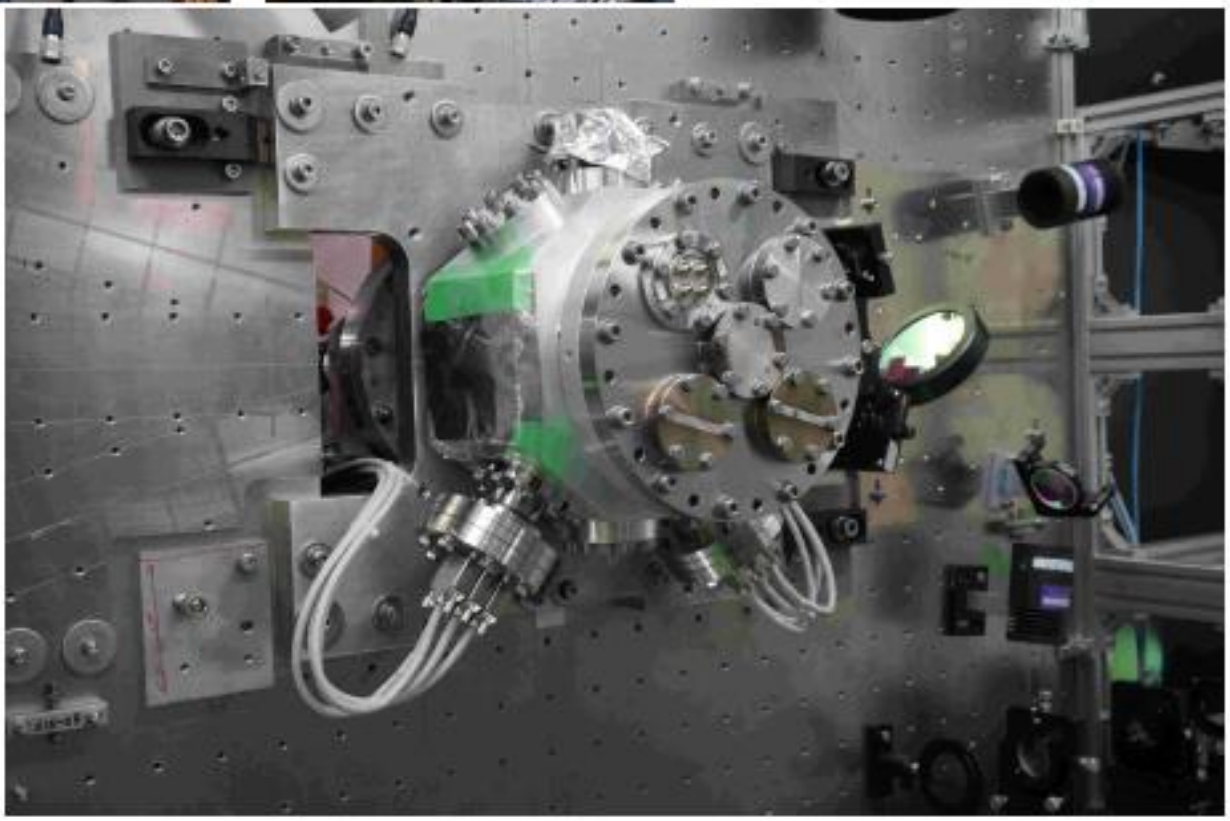


Pressure 2.8×10^{-3} Pa $\rightarrow 10^{-4}$Pa

Damping ring pressure 10^{-6}Pa

Positioning test was performed with readback from strain gauges

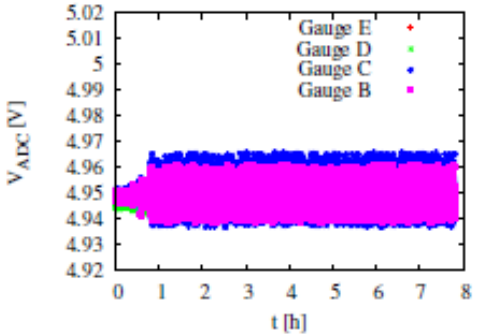
Cabling outside IP

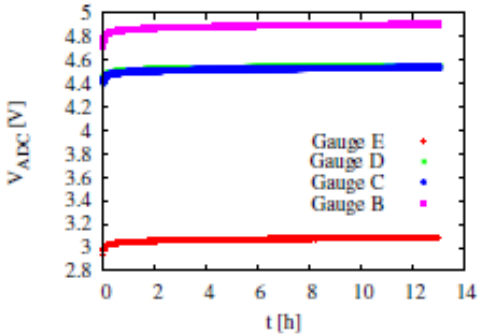


Issue after installation: suddenly increased noise in strain gauge read-back on all PI piezo-movers

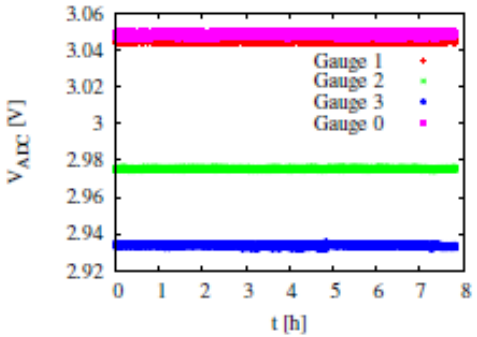
Stability (PI 1mV∼30nm, Cedrat 1mV∼31.25nm)

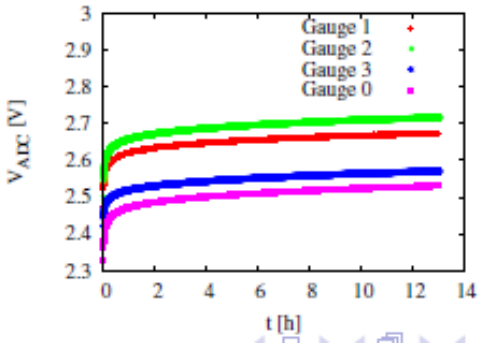
PI at 5V (fb, σ <= 1.4mV→5.3mV) (no fb, σ <=1.6mV)





Cedrat at 3V (fb, σ <= 0.8mV) (no fb, σ <= 0.6mV)





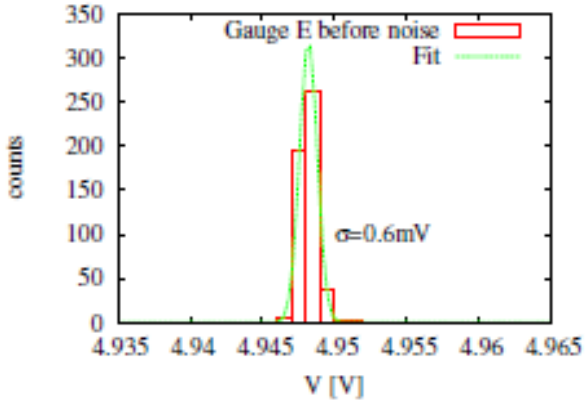
Before installation: 1-2 mV on all PI and Cedrat channels

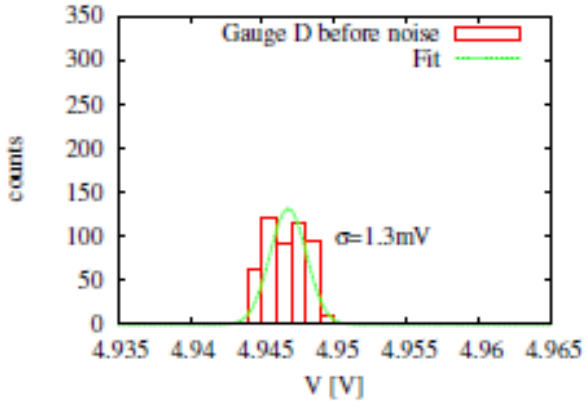
PI Strain Gauges – After Installation

VERTICAL MOVERS

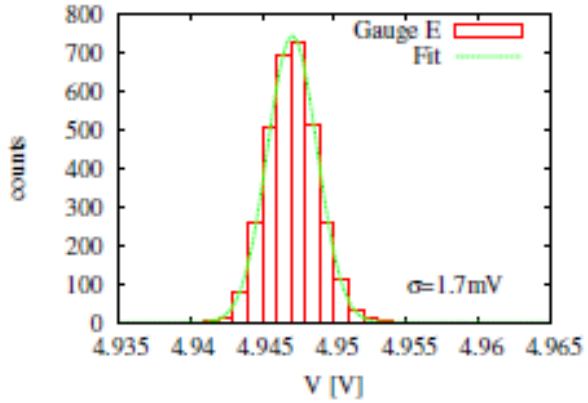
Remotely

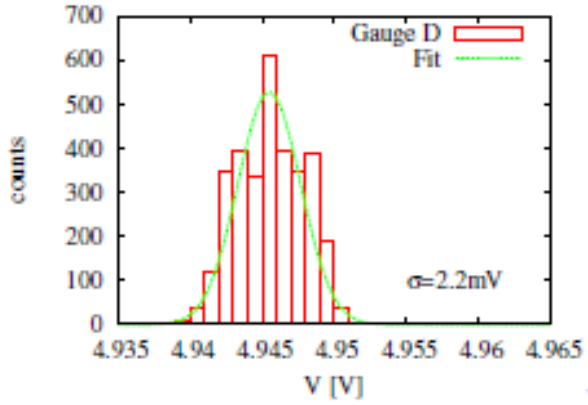
Before noise



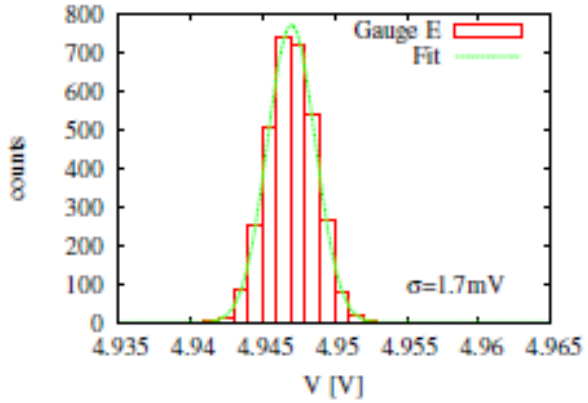


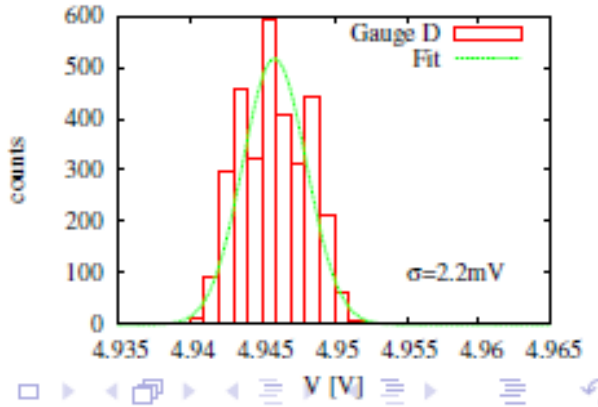
First test

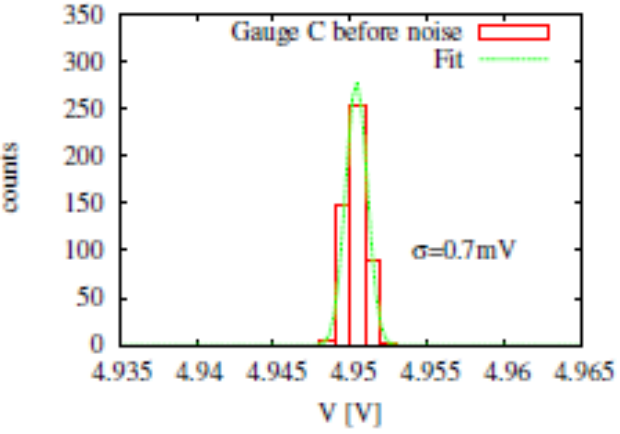


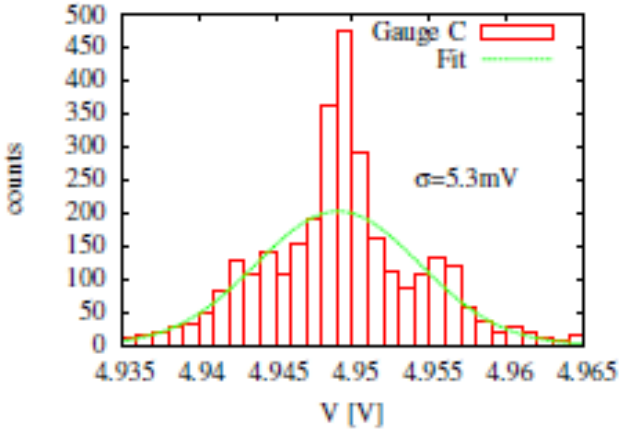


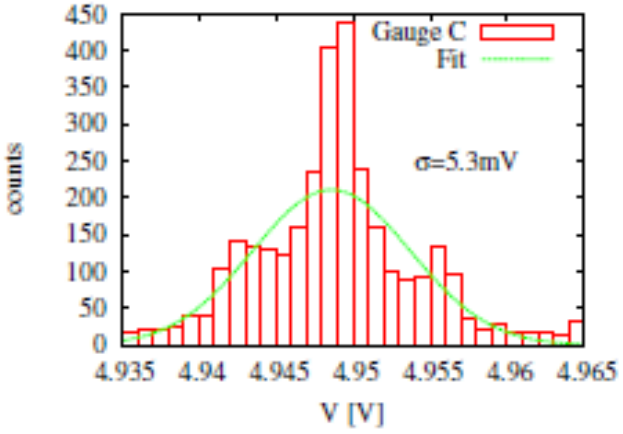
Second test (swap)



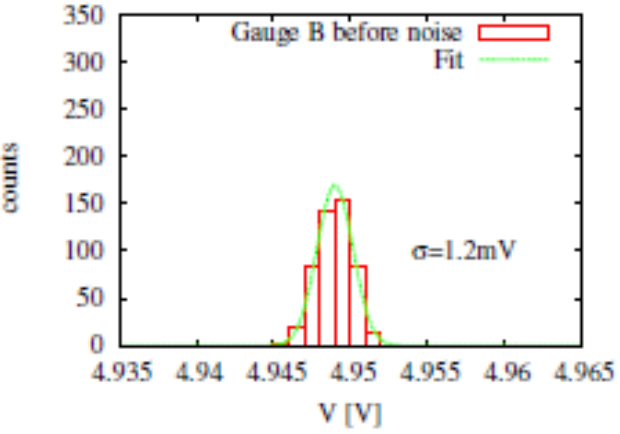


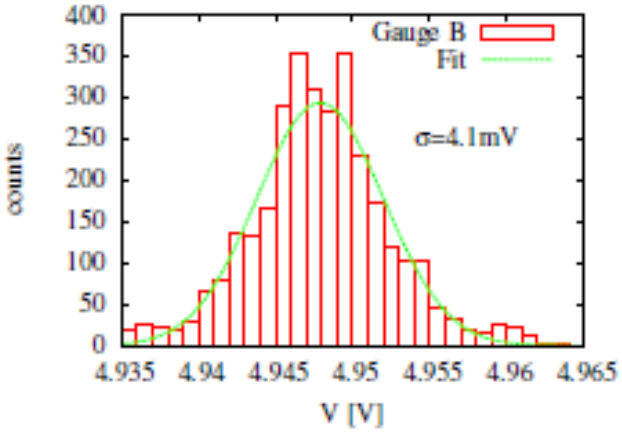


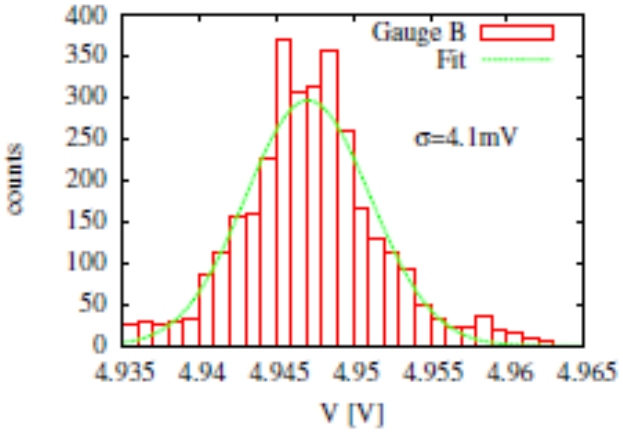




LATERAL MOVER





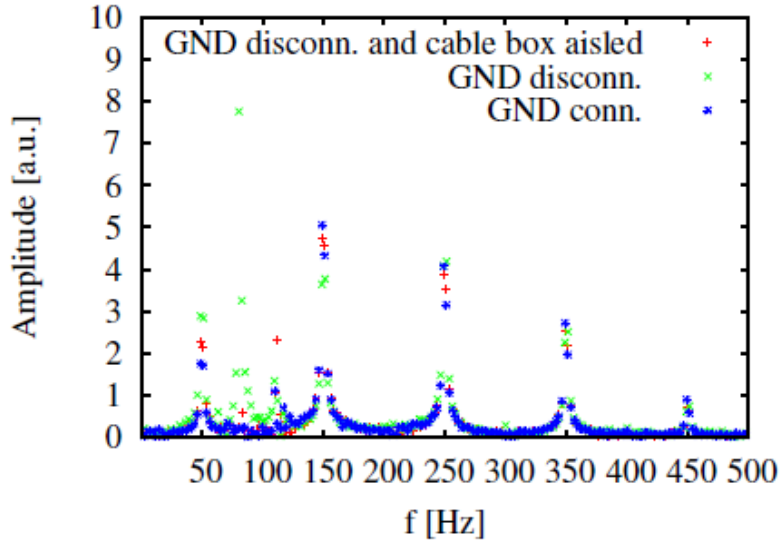


Will revisit the connection of grounds (and do a number of other checks)

GND connection

Just one channel was analyzed (PI E)

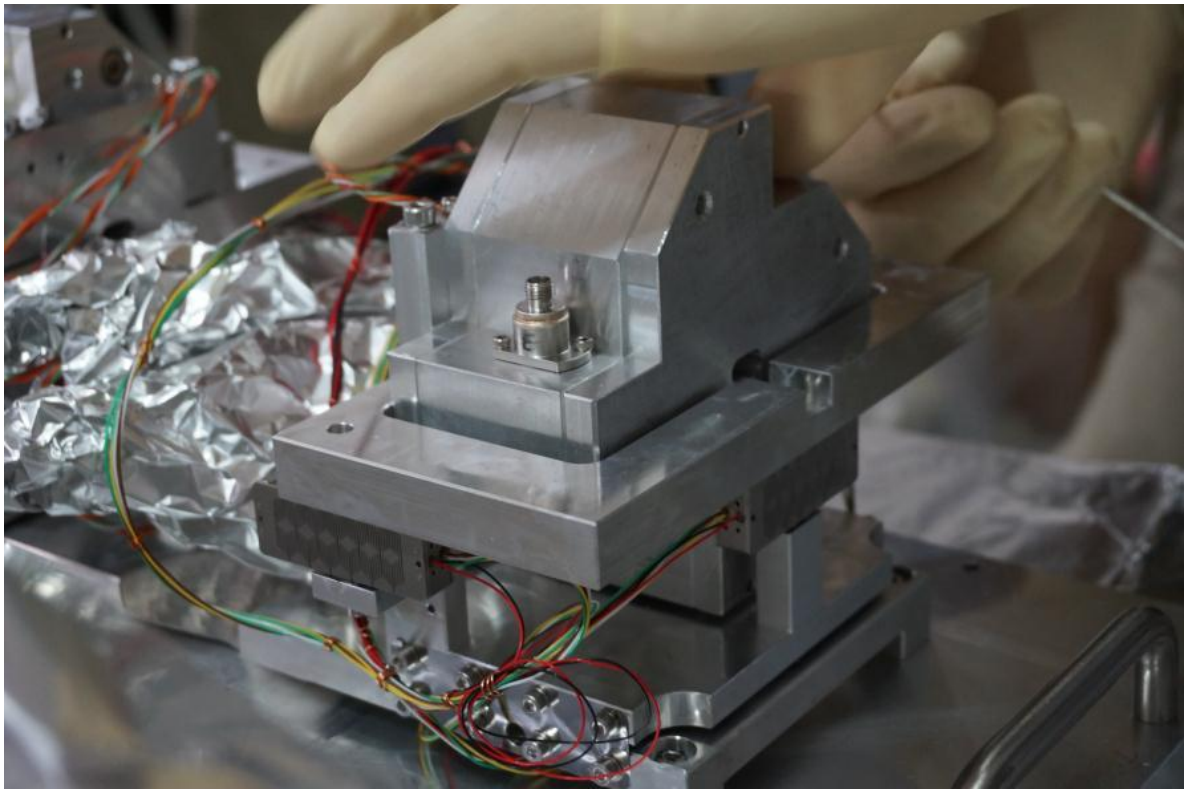
When GND is disconnected, additional frequency components were present.



We chose GND connected.

Increased noise in strain gauge read-back does not necessarily affect actual position stability

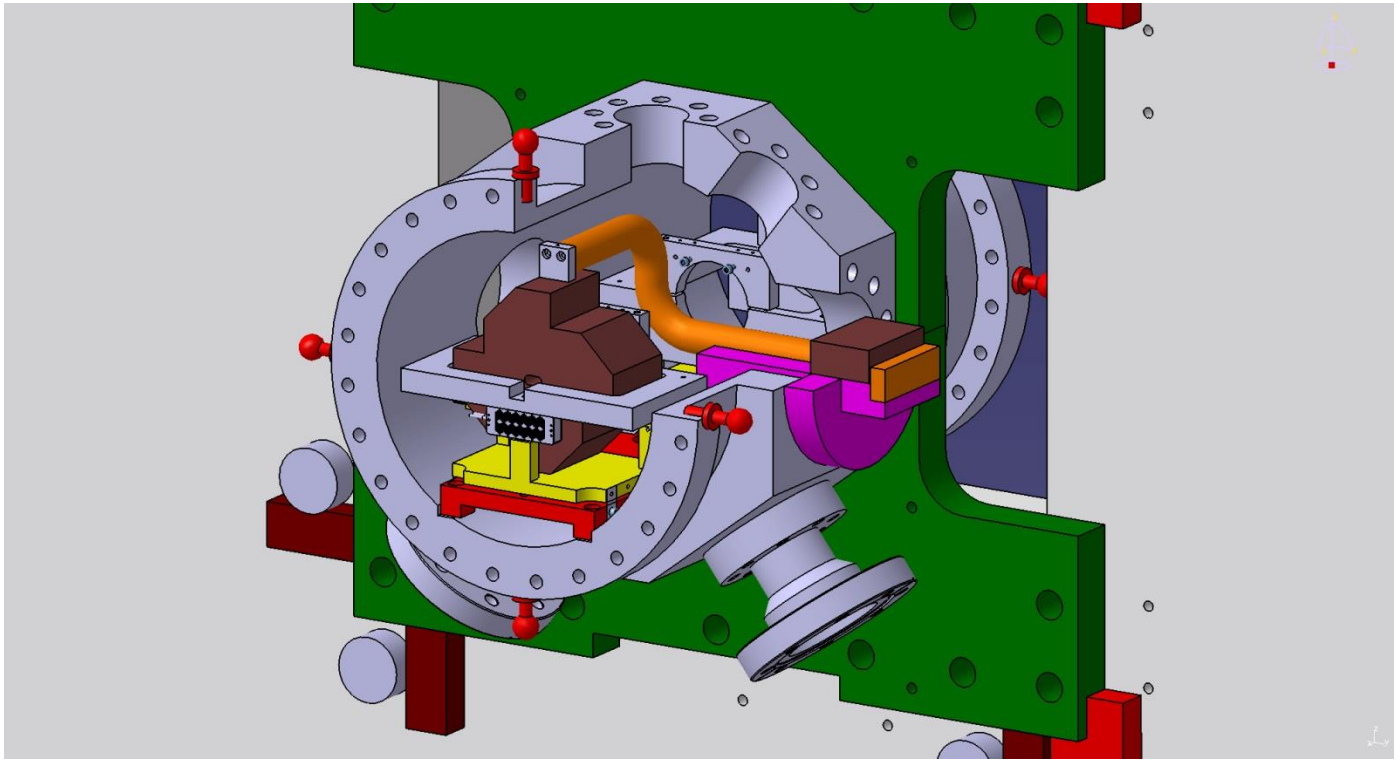
Pre-design for in situ measurements stability and calibration of strain gauge readout



BPMs are moved with a set of piezo actuators

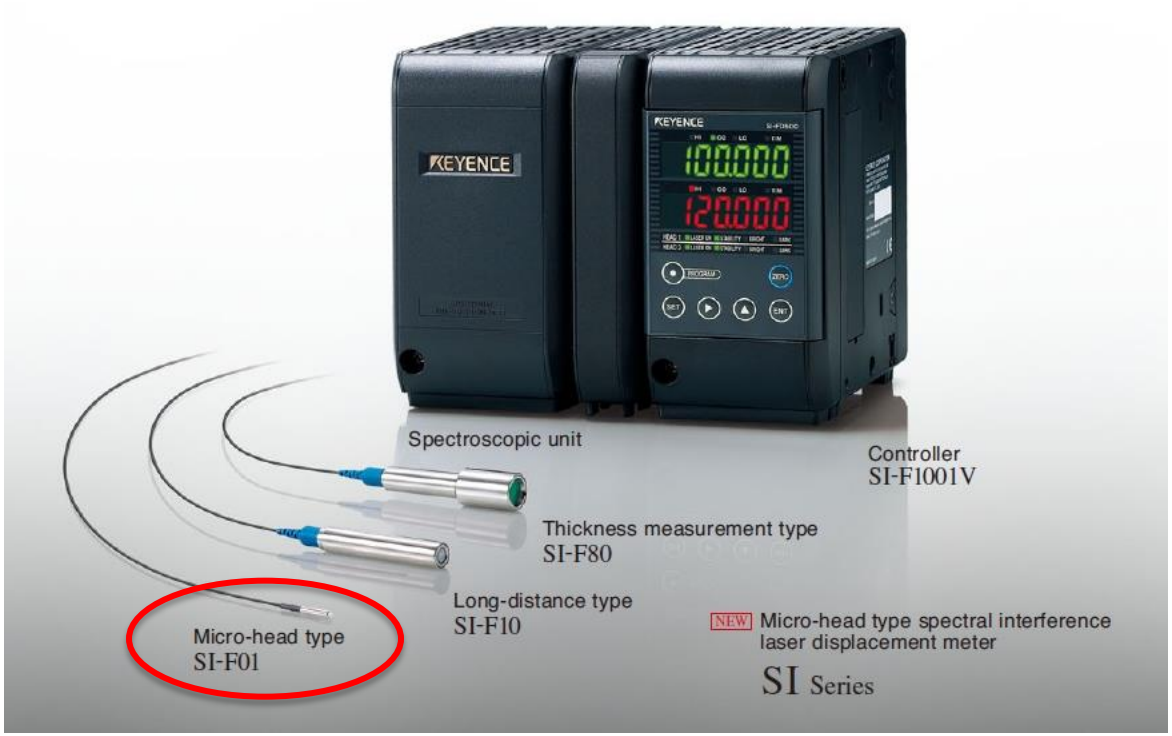
Feedback given by strain gauges
→ expected resolution : typically 20-30 μm
→ Strain gauges do not provide a feedback of actual BPMs displacement, but dilatation of a part of piezo elts stacking

A 1st way to measure the true BPMs vertical displacement



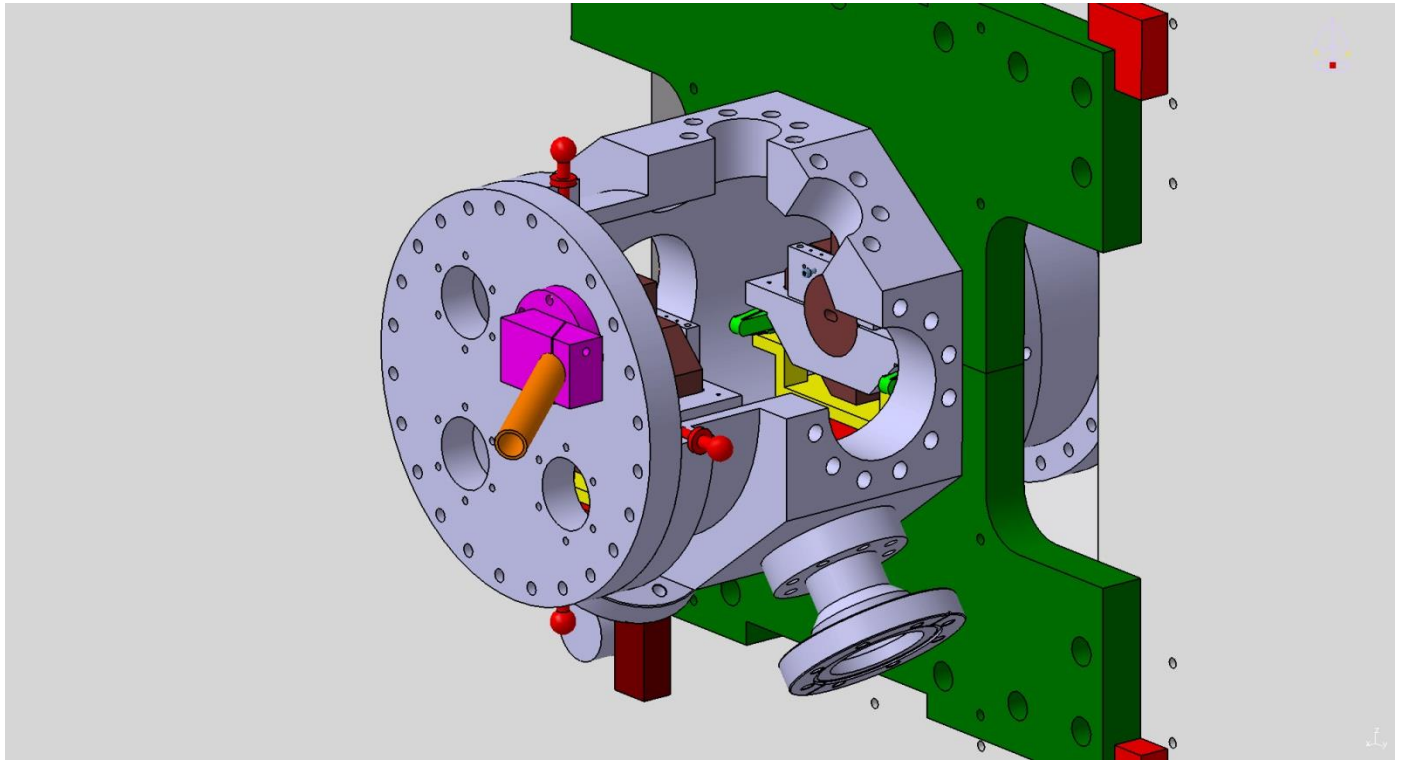
→ Access : lateral viewport
→ Stiff bent arm (no joint)
→ Miniature interferometer probe w/ fiber optic (Keyence)

A 1st way to measure true BPMs vertical displacement



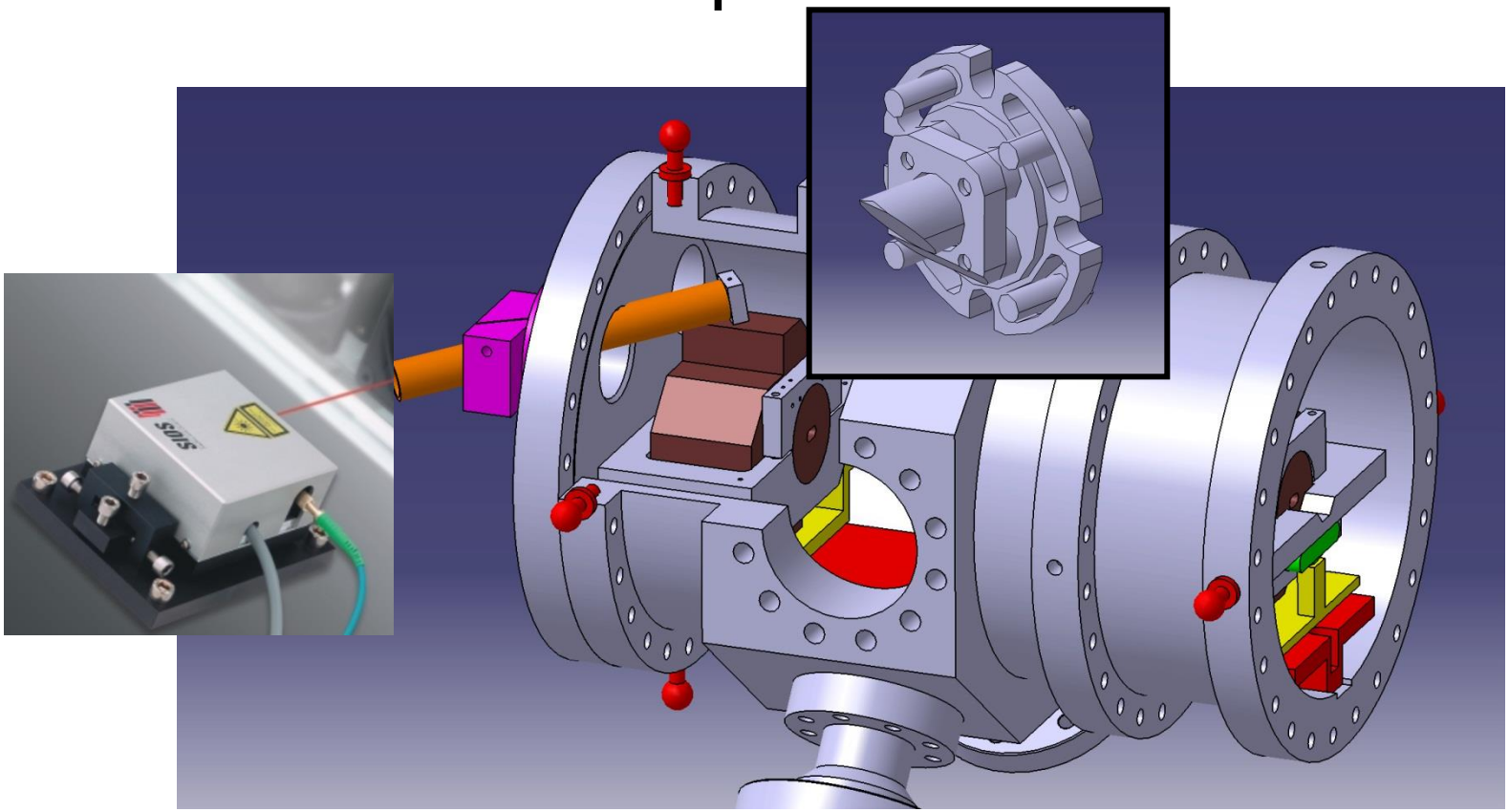
→ 2 mm diameter miniature interferometer probe
→ 1 nm resolution / 0.2 μm linearity

A 2nd way to measure the true BPMs vertical displacement



→ Access : big end flange
→ Miniature interferometer probe (Keyence)
→ Or existing interferometer (SIOS) with 45 deg mirror

A 2nd way to measure the true BPMs vertical displacement



→ Access : big end flange
→ Miniature interferometer probe (Keyence)
→ Or existing interferometer (SIOS) with 45 deg mirror

Pros and cons

Design	Access	Interferometer	Pros	Cons
1	Viewport 2-8-30 deg	Keyence	No mirror to place inside chamber Seems user friendly Very small and light (< 1 kg) 1 nm resolution	Viewport to remove 0.05 to 1.1 mm range Cost : 20000 €
2	End flange(s)	Same	Same	How to reach BPM1&2 : long arm (carbon fiber)? Mounting at upstream flange (awkward)?
3	End flange(s)	SIOS	0.1 nm resolution Already used, tested and bought Lab device with Press. & Temp. correction and invar head → high stability for long time measurements	Same as 2 plus : Mirror to place on BPM Cannot aim BPM central top surface Large electronic / power supply unit (150 x 450 x 40 cm ; 9.5 kg) to export

Conclusions and prospects

- A precise mover system, needed for goal 2, has been installed at the IP of ATF2
  - → precise remote mechanical alignment of IP-BPMs
  - → mechanical calibrations of IP-BPM scale factors with required precision, complementing determinations based on measuring beam fluctuations
- Experienced and studies using the setup in next runs
- Preparing in situ interferometer based monitoring for stability and strain gauge calibration
  - → Tests to perform with existing interferometer (using 45 deg. mirror)
  - → Purchase of new interferometer under consideration (if budget allows)
  - → Plan for possible installation / implementation in summer 2014

Stay tuned for goal-2 results with the IP-BPMs !