In Vacuum High Accuracy Mechanical Positioning System of Nano Resolution Beam Position Monitor at the Interaction Point of ATF2

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On behalf of:

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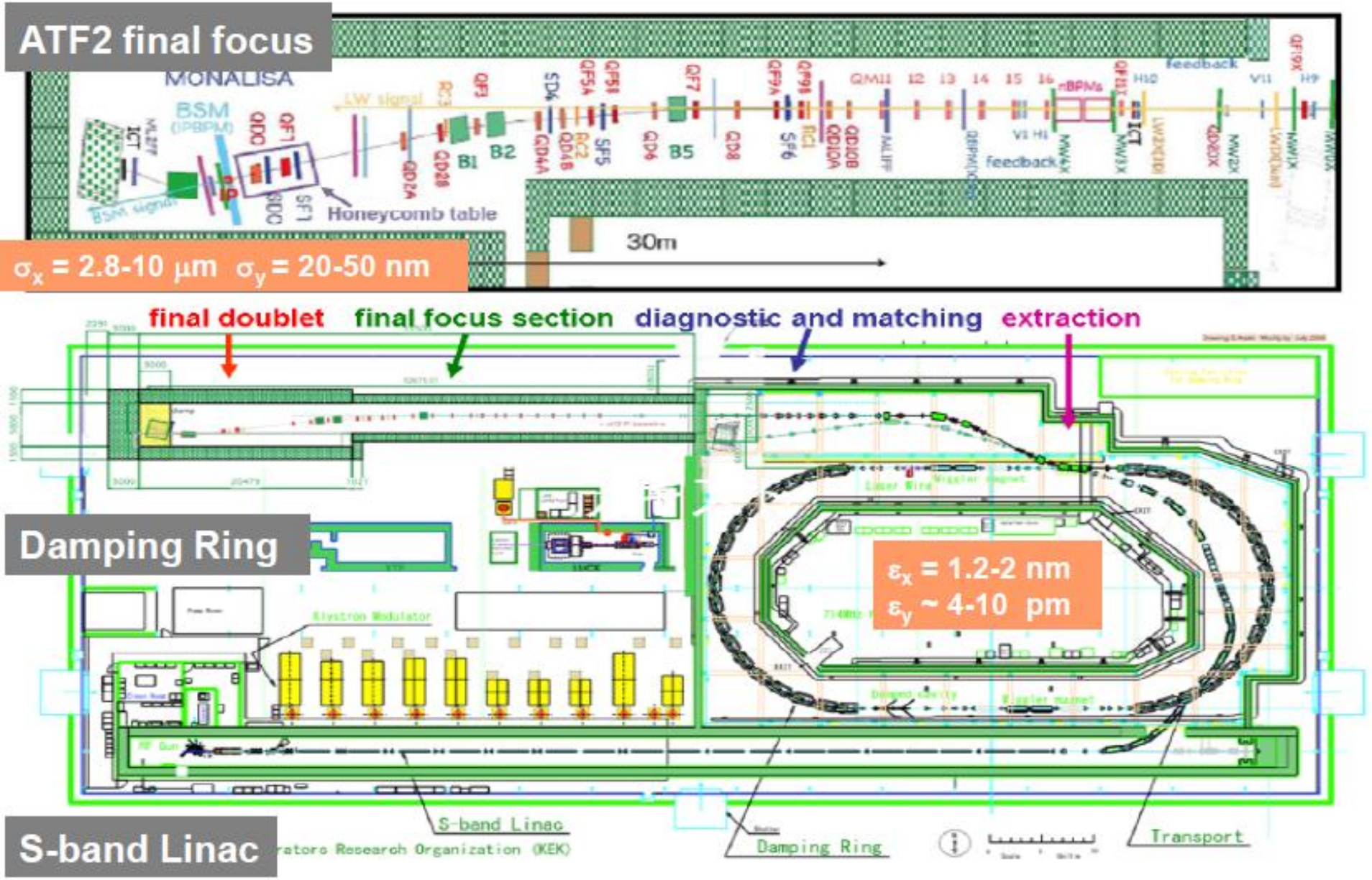
Acknowledgements:

LAL: Max DEMAREST, Bruno LELUAN, Bruno MERCIER

LAPP: Laurent JOURNET, Christine GASCQ

IPAC 2013 Shanghai, China, 12-17 May 2013

ATF & ATF2 R&D for linear colliders




IP


Shintake Monitor
Monitor
IP


Final Doublet

ATF / ATF2 Goals

- **Very small damping ring vertical emittance**
  - from ~10 pm → 4 pm (achieved !) → 1-2 pm

- **Small vertical beam size** *"goal 1"*
  - achieve σ_y ~37 nm (cf. 5 / 1 nm in ILC / CLIC)
  - validate "compact local chromaticity correction"

→ **Stabilization of beam center** *"goal 2"*
  - down to ~ 2nm
  - bunch-to-bunch feedback (~300 ns, for ILC)

- **R&D on nanometer resolution instrumentation**

- **Train young accelerator scientists on "real system"**
  - maintain expertise by practicing operation

→ *open & unique facility*

ATF International Collaboration

CERN
DESY
IN2P3
- LAL
- LAPP
- LLR

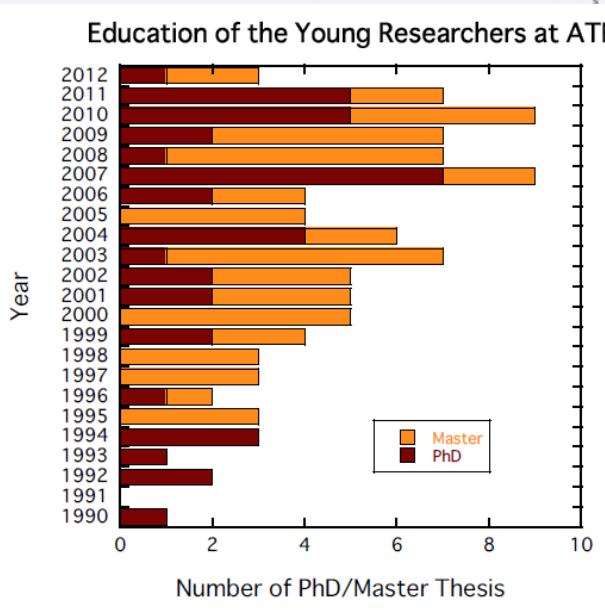
John Adams Inst.
- Oxford Univ.
- Royal Holloway Univ.

Cockcroft Inst.
- STFC, Daresbury
- Univ. of Manchester
- Univ. of Liverpool

University College London
INFN, Frascati
IFIC-CSIC/UV
Tomsk Polytechnic Univ.

KEK
Waseda U.
Nagoya U.
Tokyo U.
Kyoto U.
Tohoku Univ.
Hiroshima U.
IHEP
PAL
KNU
RRCAT

SLAC
LBNL
FNAL
Cornell Univ.
LLNL
BNL
Notre Dome Univ.

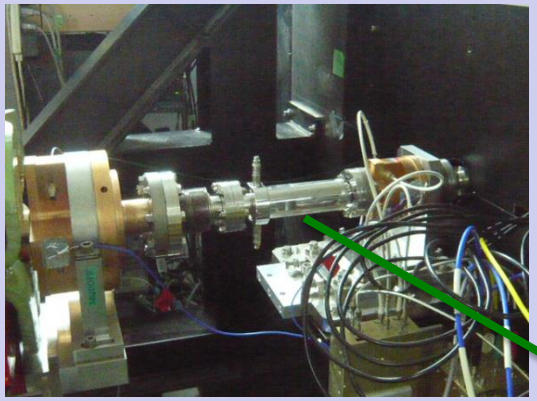


Overseas
25 Institutes,
~70 people,
~2000 people-days per year
+
KEK and Japanese Universities(6)

ATF2 goal 2 : nm-beam position stabilization

New FONT-kicker

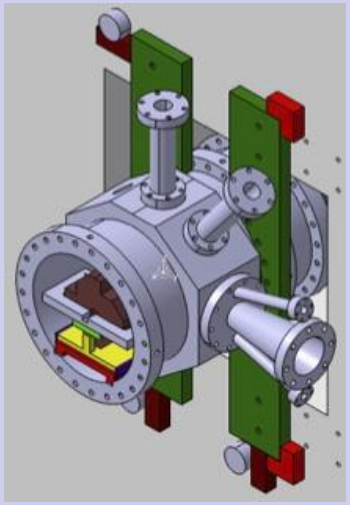
Installed near the ATF2-IP
Used since autumn 2012



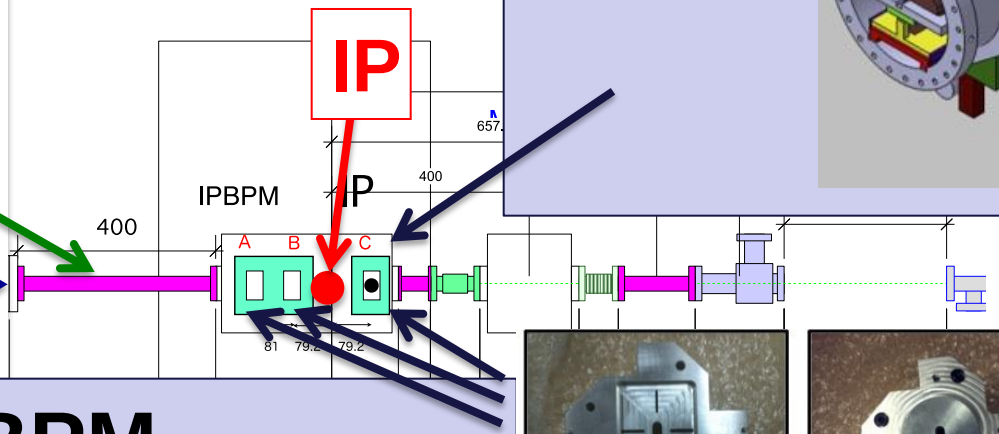
KEK
KNU
LAL
JAI/Oxford

New vacuum chamber

Precise positioning of IPBPM triplet

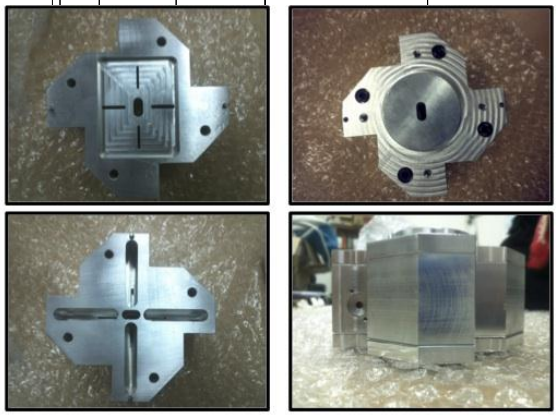


Beam

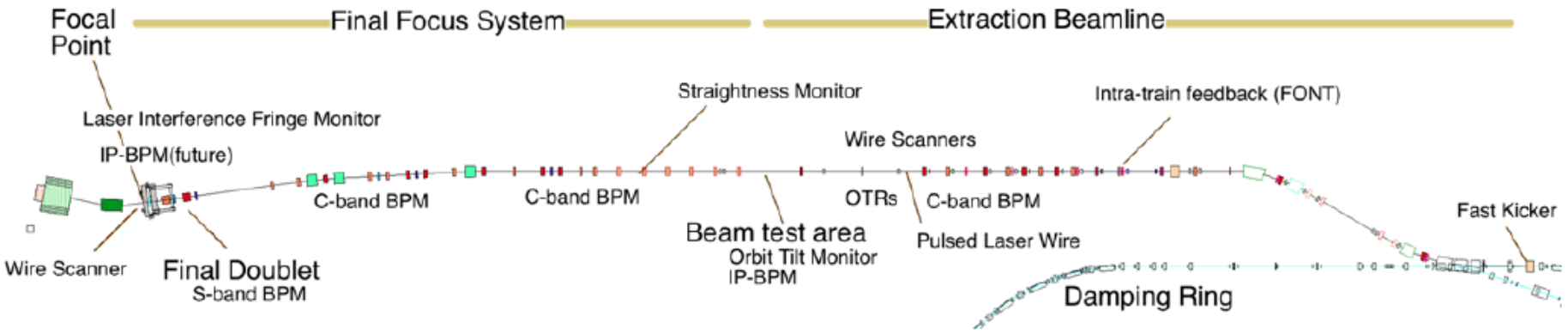


Triplet of New IPBPM

Low-Q short gap cavity light weight BPM
Sensitivity tested at ATF LINAC
Readout electronics tested at ATF2

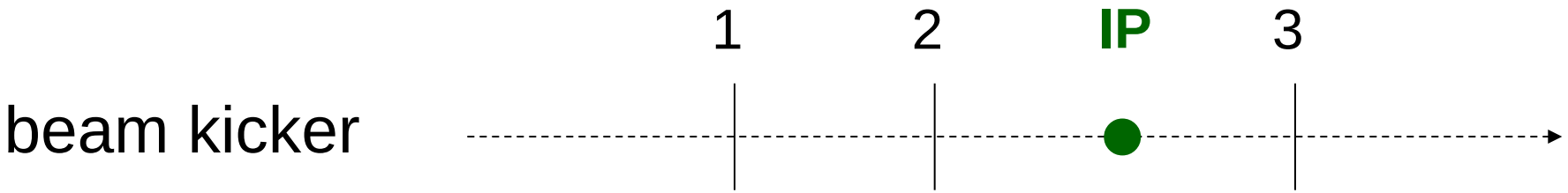


Methodology for stabilization

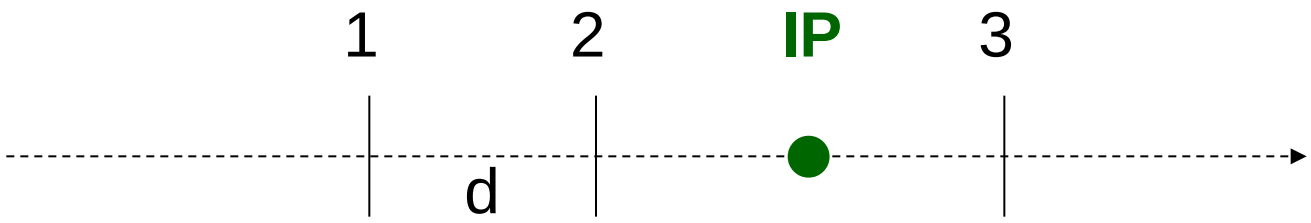


Goal 1 (beam size ~ 37 nm) **beam jitter < 10 nm**
Goal 2 (nm-scale stability with feedback) **beam jitter ~ 2 nm**

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
   ➔ Prior scale factor calibration and system resolution study



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)

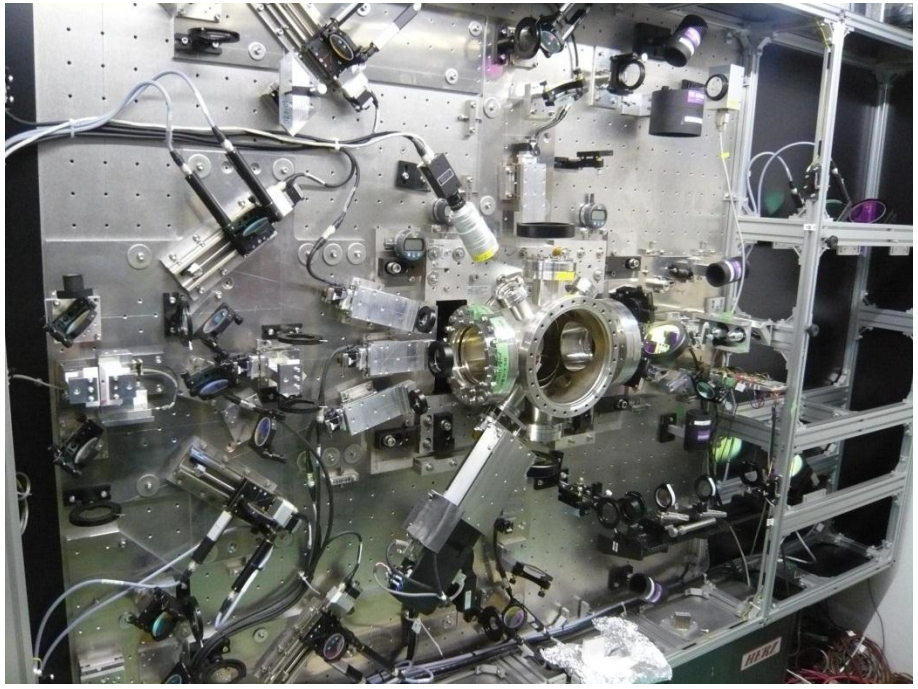
Residual ~ $2\, (\varepsilon / \beta)^{0.5}\, d\, (\sigma_{jitter} / \sigma)\, \xi \sim 10^{-7}\, \xi$ → $\xi \sim 10^{-2}$ for 1 nm error

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

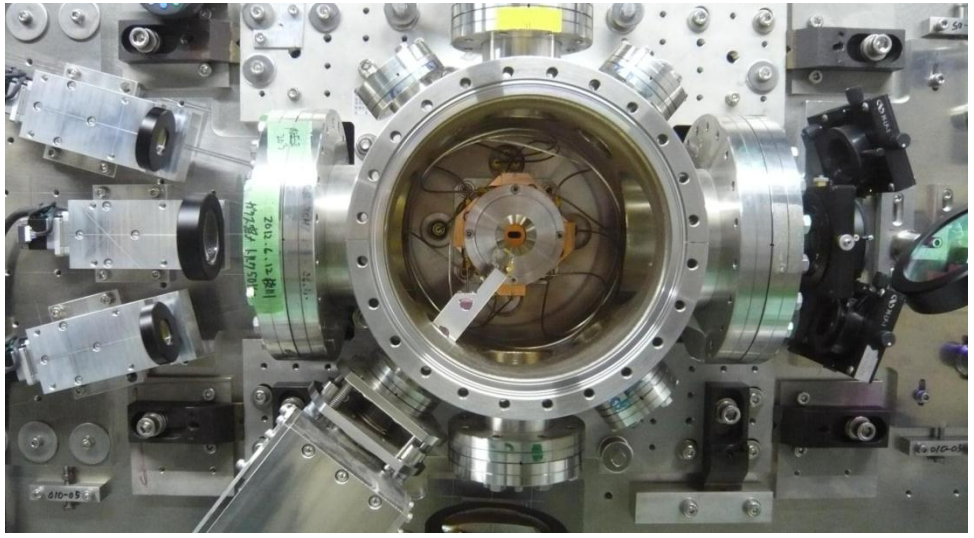
Residual ~ $2\, (\varepsilon / \beta)^{0.5}\, d\, (\sigma_{jitter} / \sigma)\, \xi \sim 10^{-5}\, \xi$ → **$\xi \sim 10^{-4\,/\,-3}$ for 1 / 10 nm error**

Requirements for new IP chamber

1. Pre-alignment of IP-BPM set with respect to rest of beam line < 200 μm
2. Internal pre-positioning accuracy ~ 50 μm
3. Remote relative positioning via beam based alignment within < 5 μm (dynamic range of IP-BPM electronics)
4. Mechanical calibration of IP-BPM scale factors → 10^{-4}
5. Compatibility with IP-BSM operation (viewports for lasers, wire-scanner, electron / laser beam alignment…)

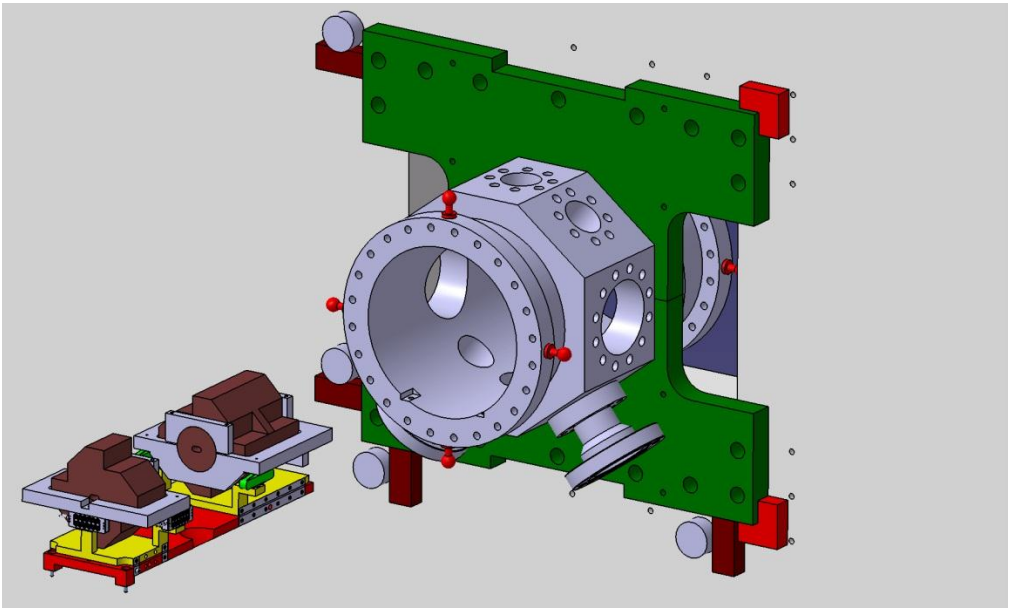


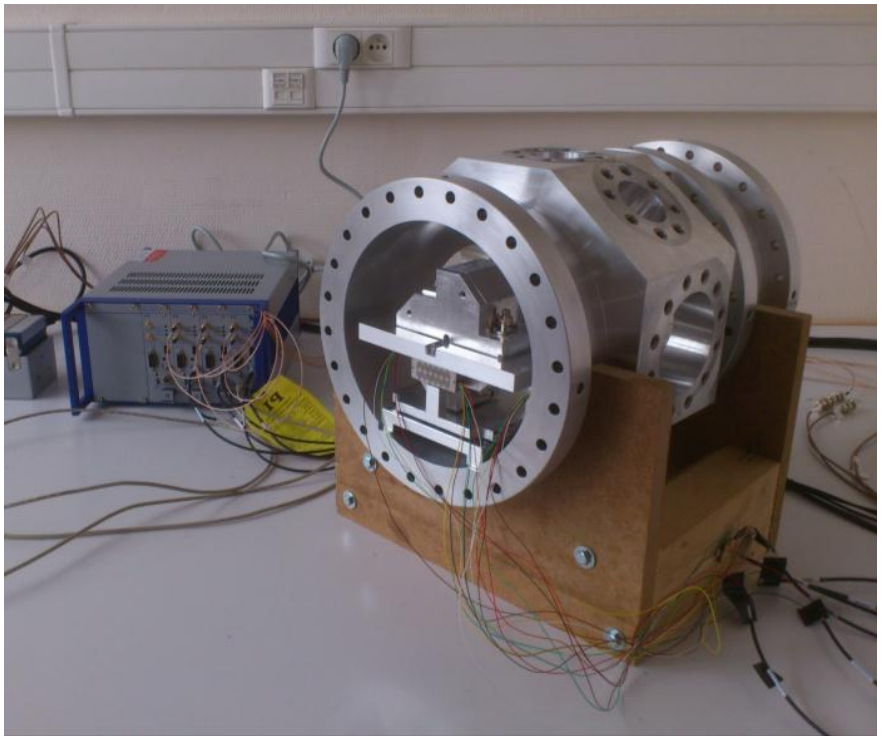
Present IP-chamber (FFTB)



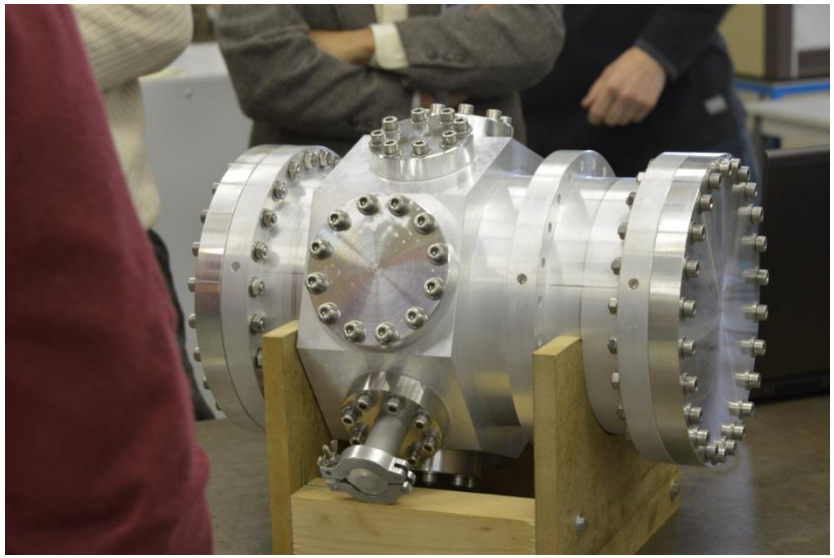
Main features of new IP chamber

1. Mechanical references for precise pre-positioning and alignment
2. Adjustable fixture for rigid mount on IP-BSM optical table
3. Base-plate + cradles support BPM1-2 and BPM3 in tripod configurations
4. Lateral & vertical adjustments with 8 piezo-movers in 230-300 μm range
5. Positioning within 10^{-4} of the range (strain gauges as input to feedback)
6. In-vacuum temperature monitoring
7. Remote electronics (25 meter cables)

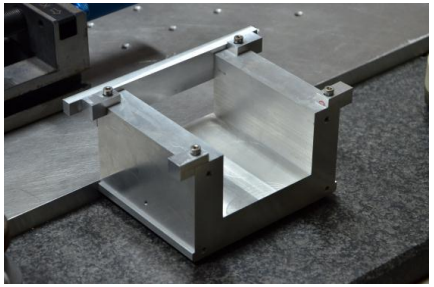


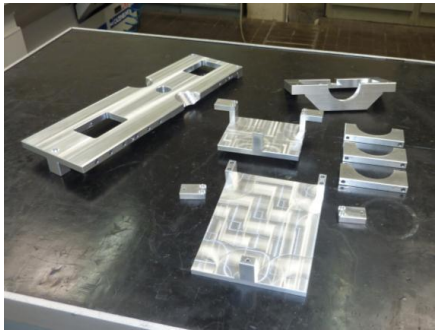


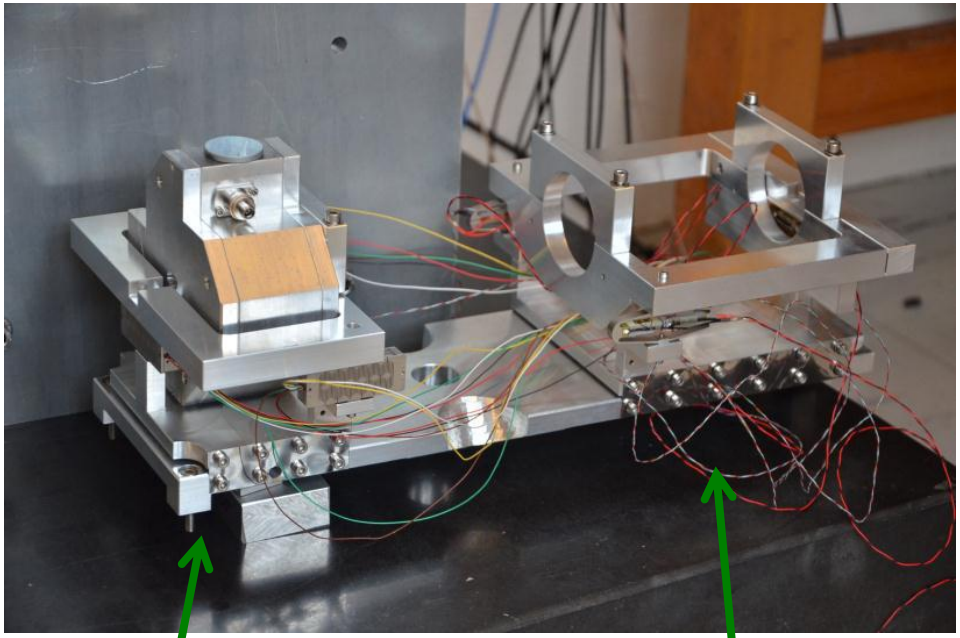
Mechanical parts almost completed



- Chamber and internal parts manufactured at LAPP
- Modifications, alignment tools and temporary flanges at LAL
- Mounting fixtures on IP-BSM vertical table and for vibration sensor on chamber at LAL
- Upstream chamber extension, viewports extensions, final upstream / downstream flanges and tool for in situ relative laser / beam / IP-BPM alignment in progress at KEK







4 PI piezo-actuators

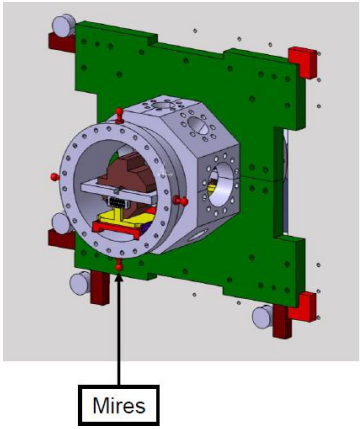
4 Cedrat piezo-actuators

Dimensional checks

Performed with 3D Mitutoyo machine (5 µm accuracy, 1 µm resolution)

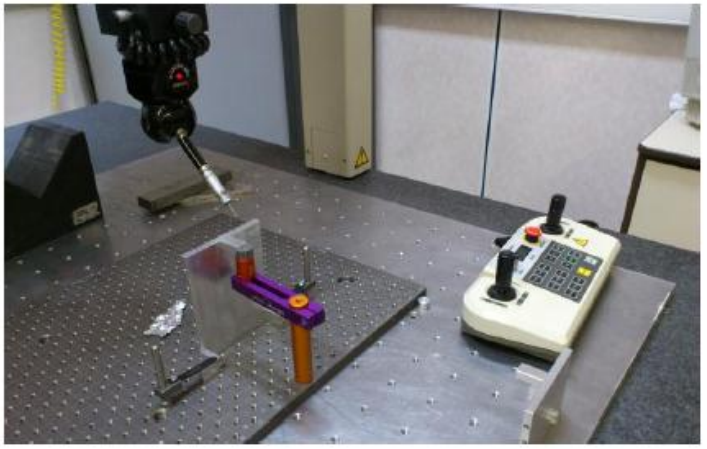
→ Chamber and internal parts : OK

→ Bruno Leluan, LAL Orsay

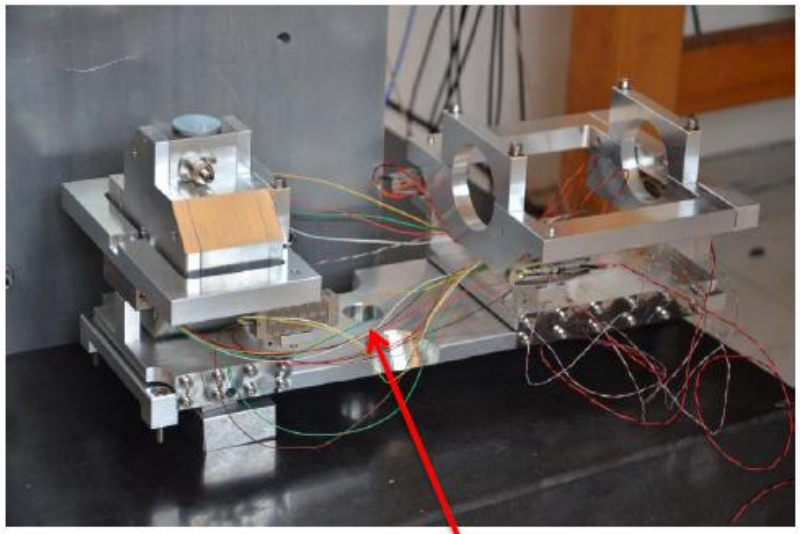


Position of internal references were measured with regard of external references (for mires)

→ Data useful for BPMs external pre-alignment



Adjustment of BPM positioning system

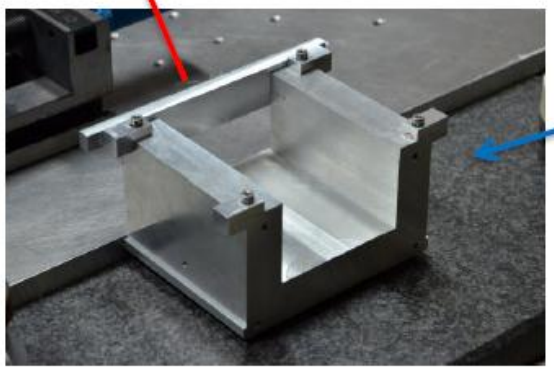


BPMs position will be adjusted with respect of interfaces « Chamber / BPMs displacement system »

- → Place shims (SS foil, 20 μm min. thick) below actuators
- → Check BPMs position / interfaces with 3D machine
- → Unmounting, remounting and recheck as repeatability test

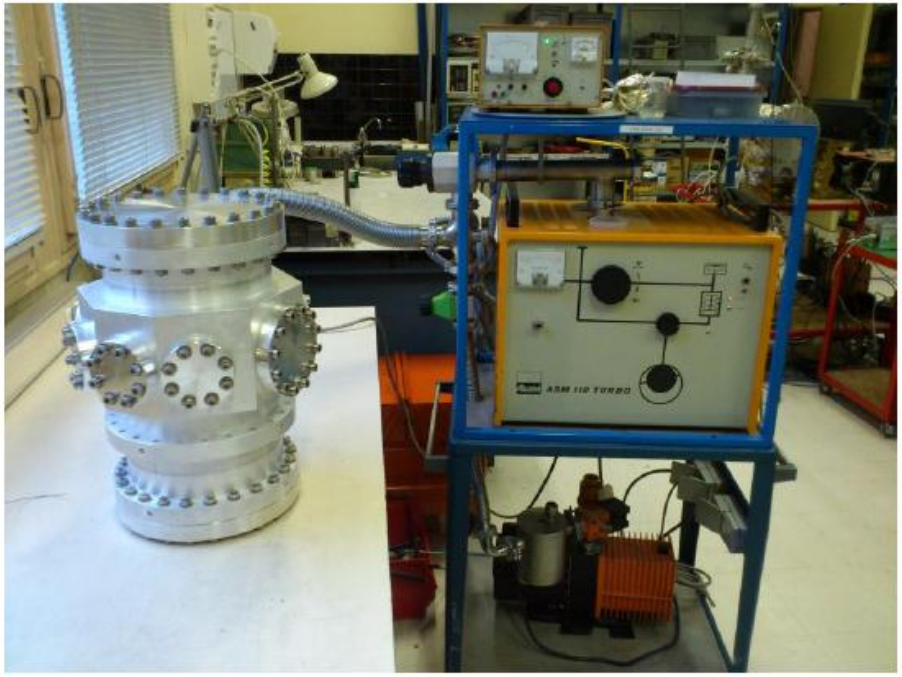
Delayed to May (availability of 3D machine)

→ Bruno Leluan & Sandy Wallon, LAL Orsay



BPMs positioning tool : give the right position to BPMs (distance to IP , lateral positioning, yaw, pitch (with third flat spot)).
Note : roll adjustment done when BPM is mounted to craddle/bracket

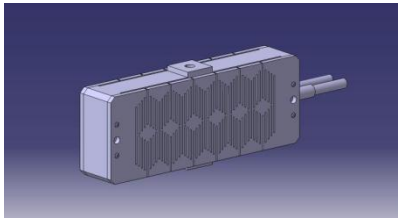
Vacuum test of chamber & piezo-actuators completed

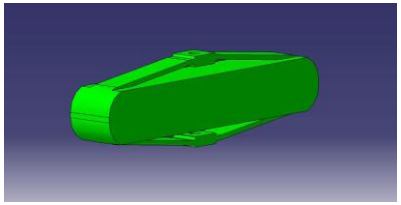


He leak test OK :

→ Flowrate at 3×10^{-8} Atm.cm^3/s
(suitable for UHV)

Data :
- All parts cleaned (SS insert removed and then reinstalled)
- 1.5 mm dia. indium seal (wire)
- Indium wire flaten up to 0.15 mm thickness (screws tightened at 6 Nm)
- Aluminum flanges with 0.7 mm dia. groove for wire positioning
- Test performed at 10^{-5} mbar





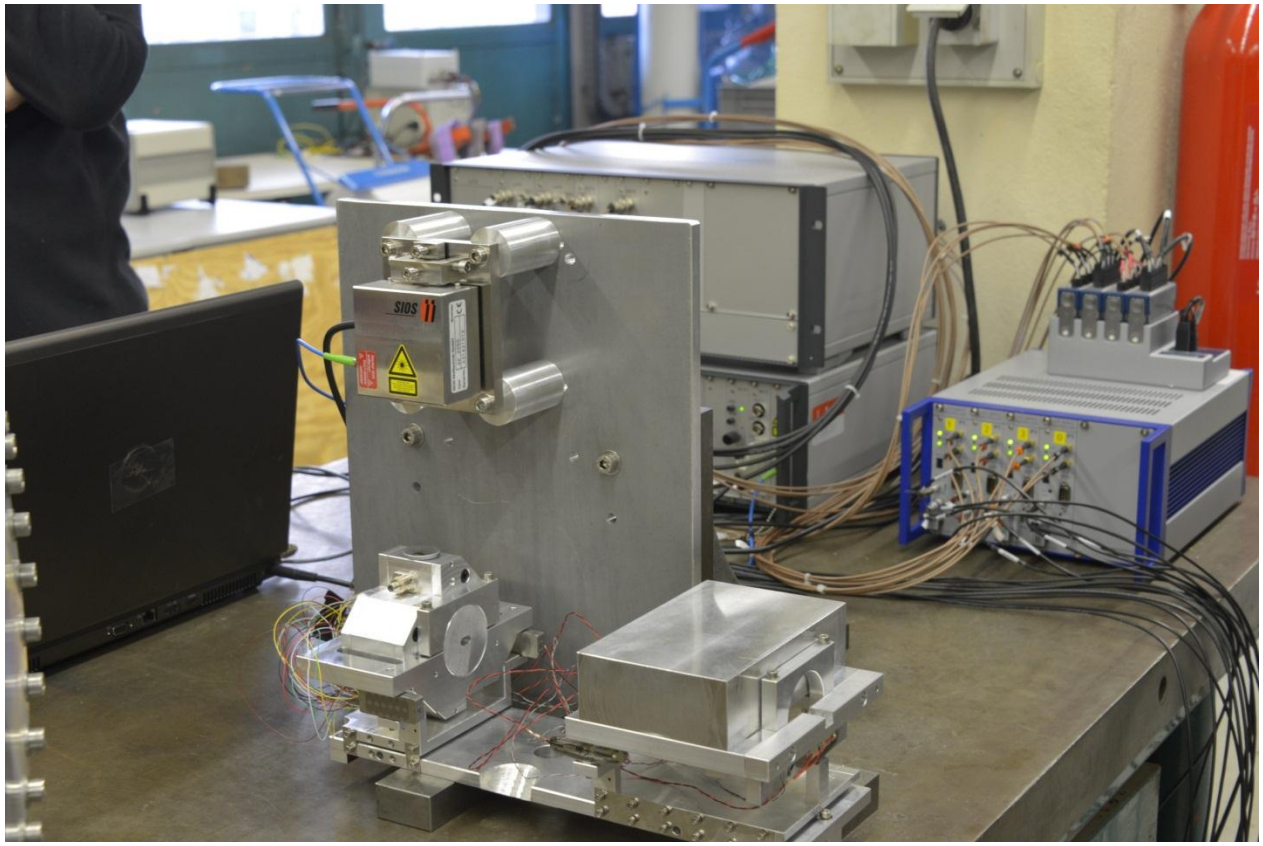
Outgasing of both PI and Cedrat with cables are OK :

➔ flowrate at 8x10-8 mbar.l/s (suitable for UHV)

➔ at 21° C and after 100 hours of pumping, no organic compound detected.

Piezo-mover performance checks :

- almost completed for PI
- started for Cedrat (noisy controller power supply was affecting read-back)

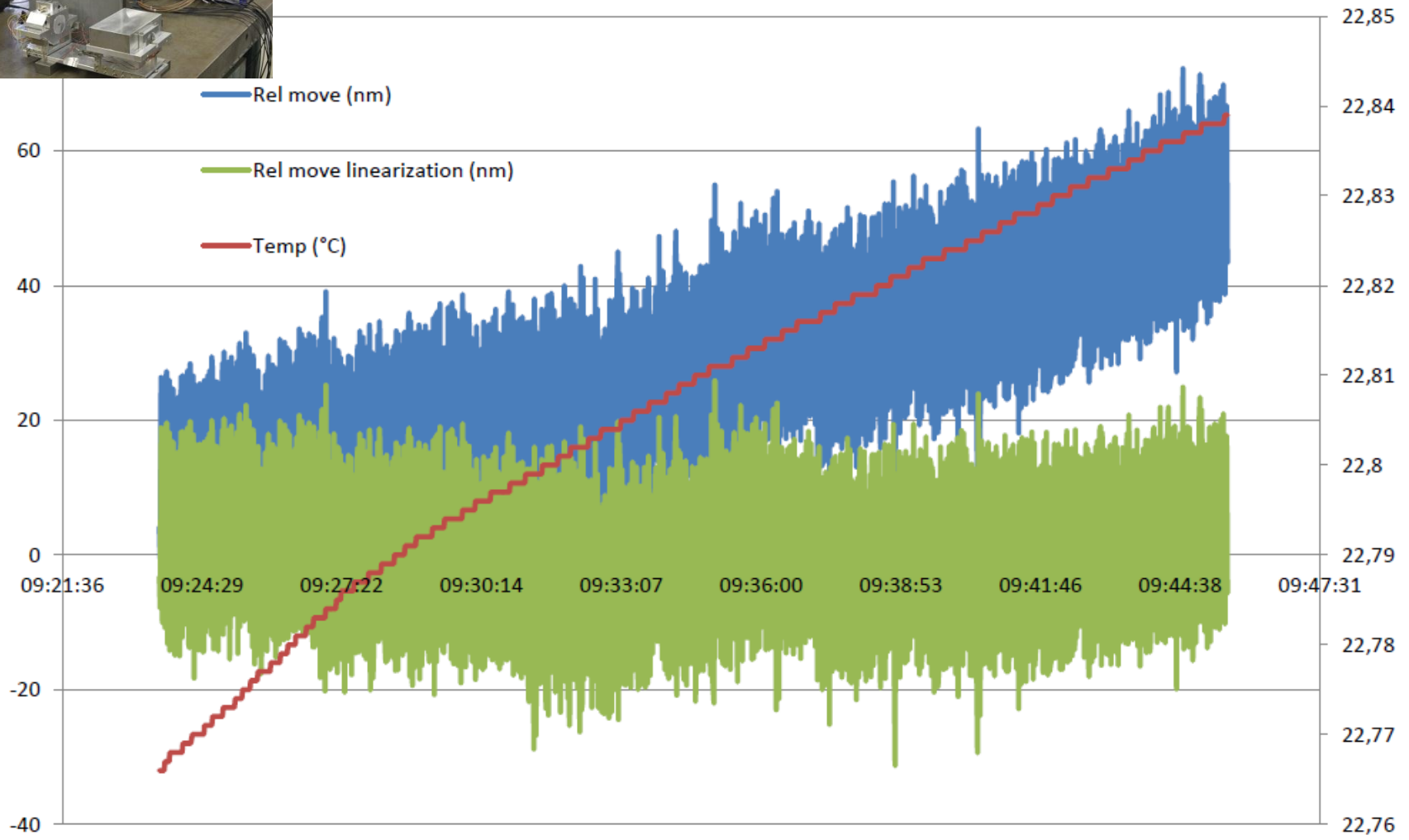


- Closed-loop stability
- Open-loop stability

- Setting accuracy
- Calibration

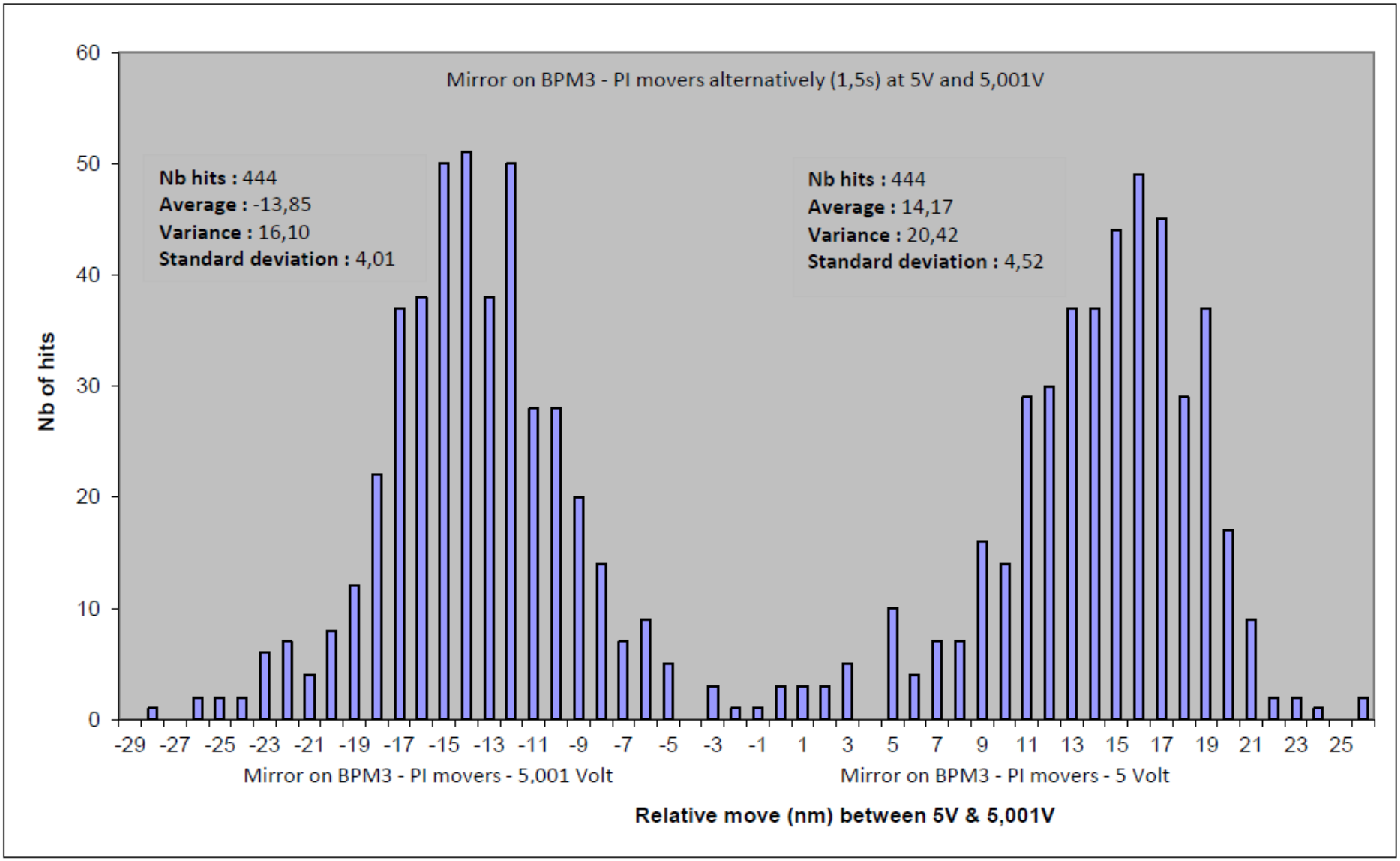
- Thermal effects
- Vibration mitigation

BPM3 – PI vertical movers – 5V / 5.001V alternatively

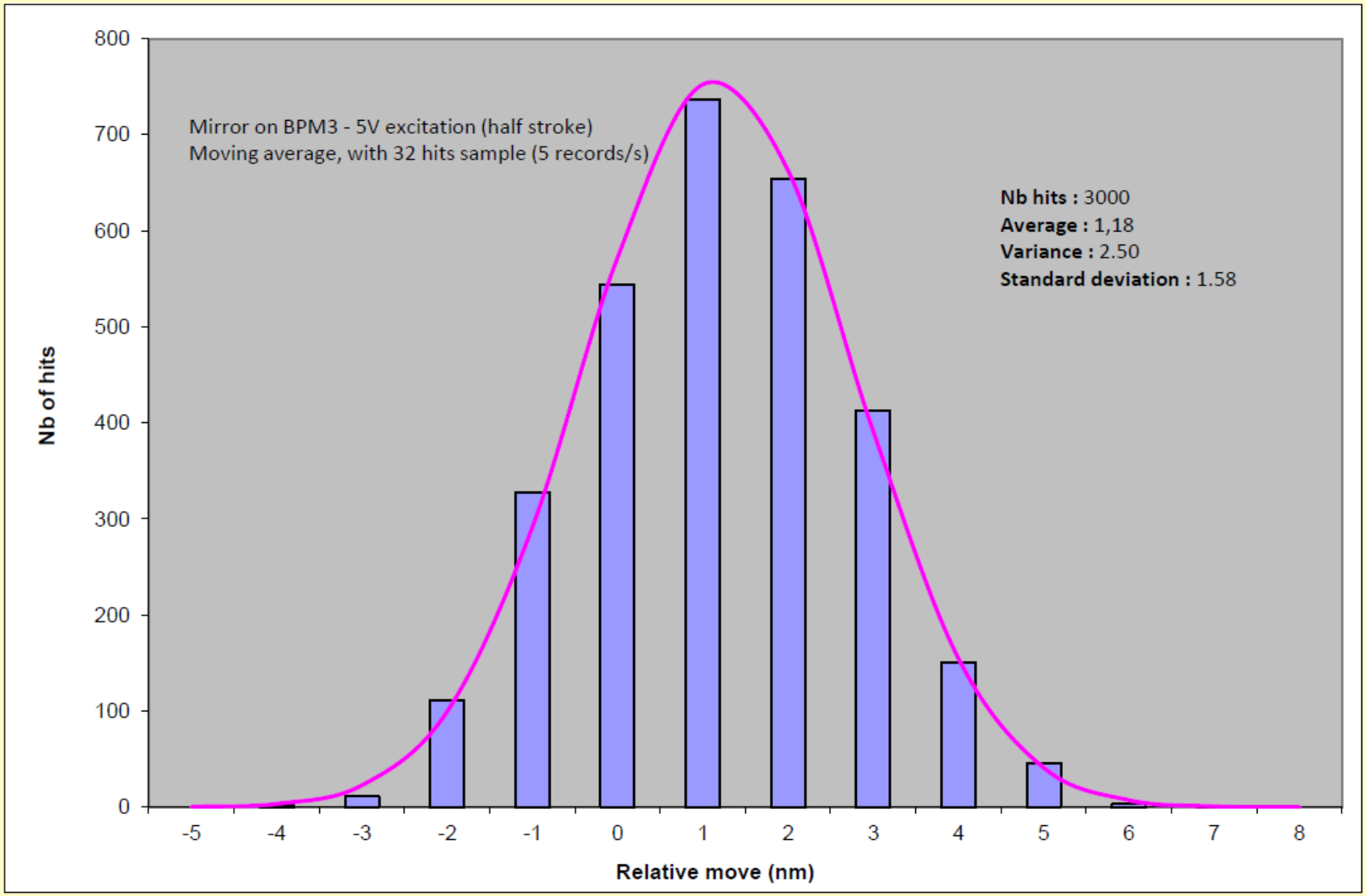


The 3 movers are stimulated at 5V (1,5s) then at 5.001 V (1,5s) during this experiment.

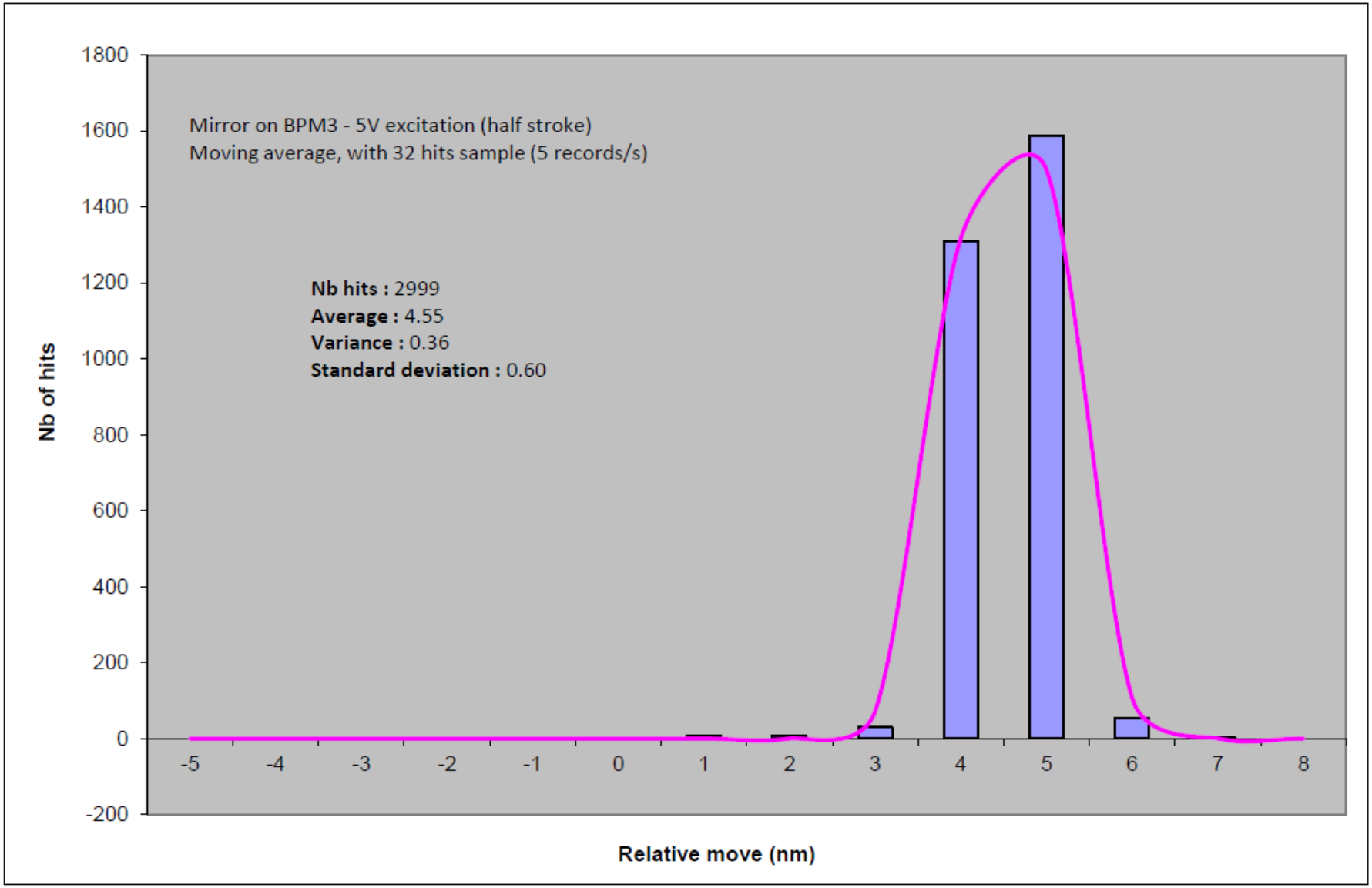
Results at 5V/5.001V alternatively during 1,5s



With feedback



Without feedback



Near term prospects

- Still some tests & adjustments: (de)mount, Cedrat performance
- Preparations for shipment (paperwork & packaging) end of May
- Delivery at KEK mid June
- Installation at KEK scheduled in first two weeks of July
- Commissioning with beam in Autumn 2013

Concluding remarks

- A mechanical support and positioning system prepared to meet the requirements of the IP-BPM project at ATF2
- Re-establish IP-BSM setup procedure with new IP chamber
- Overall vibration studies planned with help of LAPP-Annecy team
- Residuals from thermal effects will be important to consider
- Prospect of combined goal 1 + 2 operation

Stay tuned for very small & very stable beams at ATF2 !

ATF / ATF2 at IPAC 2013

- WEPME053 Latest Performance Results from the FONT 5 Intra Train Beam Position Feedback System at *ATF*
- MOPME058 Development of a cavity-type beam position monitors with high resolution for ATF2
- MOPWA058 Cavity Beam Position Monitor at Interaction Region of ATF2

- MOPME003 Development of Diamond Sensors for Beam Halo and Compton Spectrum Diagnostics after the Interaction Point of *ATF2*
- MOPWA052 Short Range Wakefield Measurements of High Resolution RF Cavity Beam Position Monitors at *ATF2*
- MOPWA053 Sub-Micrometre Resolution Laser-wire Transverse Beam Size Measurement System
- MOPWO023 Upgrade and Systematic Measurement Campaign of the *ATF2* Multi-OTR System
- TUPME030 Emittance Reconstruction from Measured Beam Sizes
- TUPWO017 Simulation on the Breaking of αx Multiknob Orthogonality in the Presence of Gradient and Coupling Errors and Experimental Investigation
- MOPME018 Beam oscillation monitor for the multi-bunch beam
- TUPME045 Turn-by-turn Measurements in the KEK-*ATF*