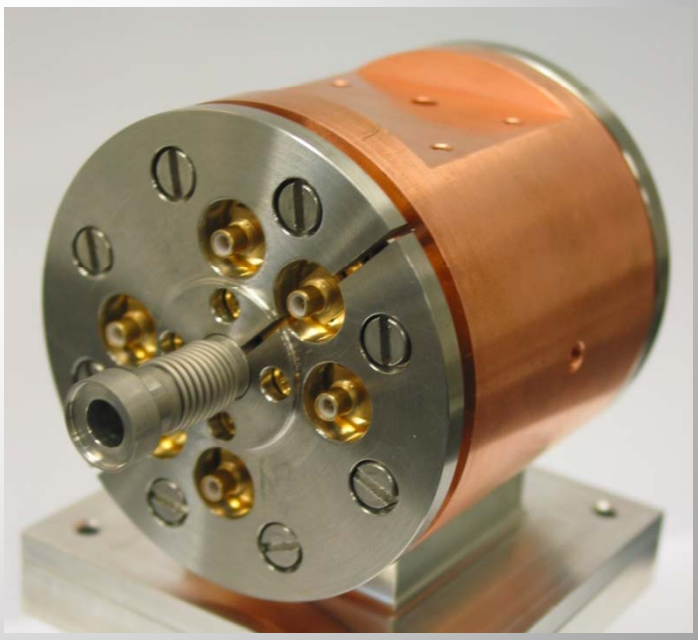
Precision Beam Position Monitor

- Deliverables
- Design
- Bench tests
- Beam tests
- Summery

On the behalf of:
I. Podadera
F. Guillot-Vignot



PBPM- deliverables

- **Prototype PBPM:**
  - Design and build prototype.
- **Report on bench tests:**
  - Design and build high resolution (100nm). mechanical stable test bench.
- **Report on beam tests:**
  - **Build 3 PBPMs and test with (CTF3) beam.**

Specifications

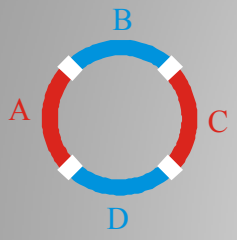
EUROTeV	Aperture	4mm (6mm)
	Resolution	100nm
	Absolute precision	10µm
	Rise time	<15ns
Extended specifications	Dynamic range	±1.5mm (15 bits)
	Linearity error	< 1% (±1.5mm)
	24H stability	1µm
	Droop	< 5%
	Low frequency cutoff	100kHz *(3.6% droop, CLIC 158ns pulse)*
	High frequency cutoff	30MHz
	CMRR	>90dB
	Bake out temperature	150ºC
	Vacuum	10^{-9} Torr
	Operating temperature	~20°C

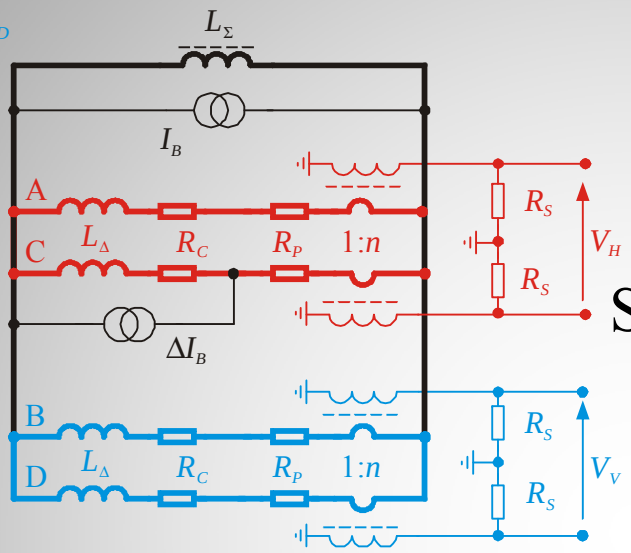
Inductive pick-up: basic scheme

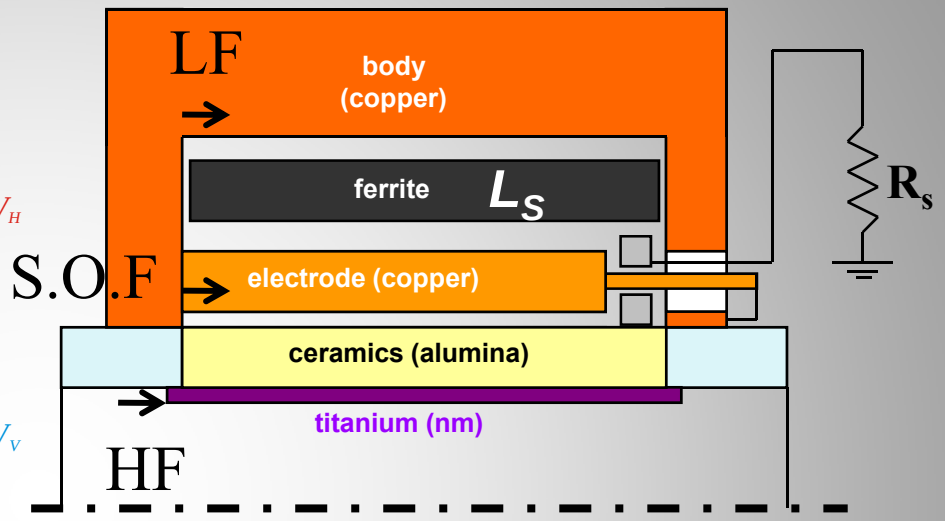
$V_\Sigma = V_A + V_B + V_C + V_D$

$V_{\Delta H} = V_A - V_C$

$V_{\Delta V} = V_B - V_D$







Coupling impedance

$$V_\Sigma = \frac{R_s}{n} I_B$$

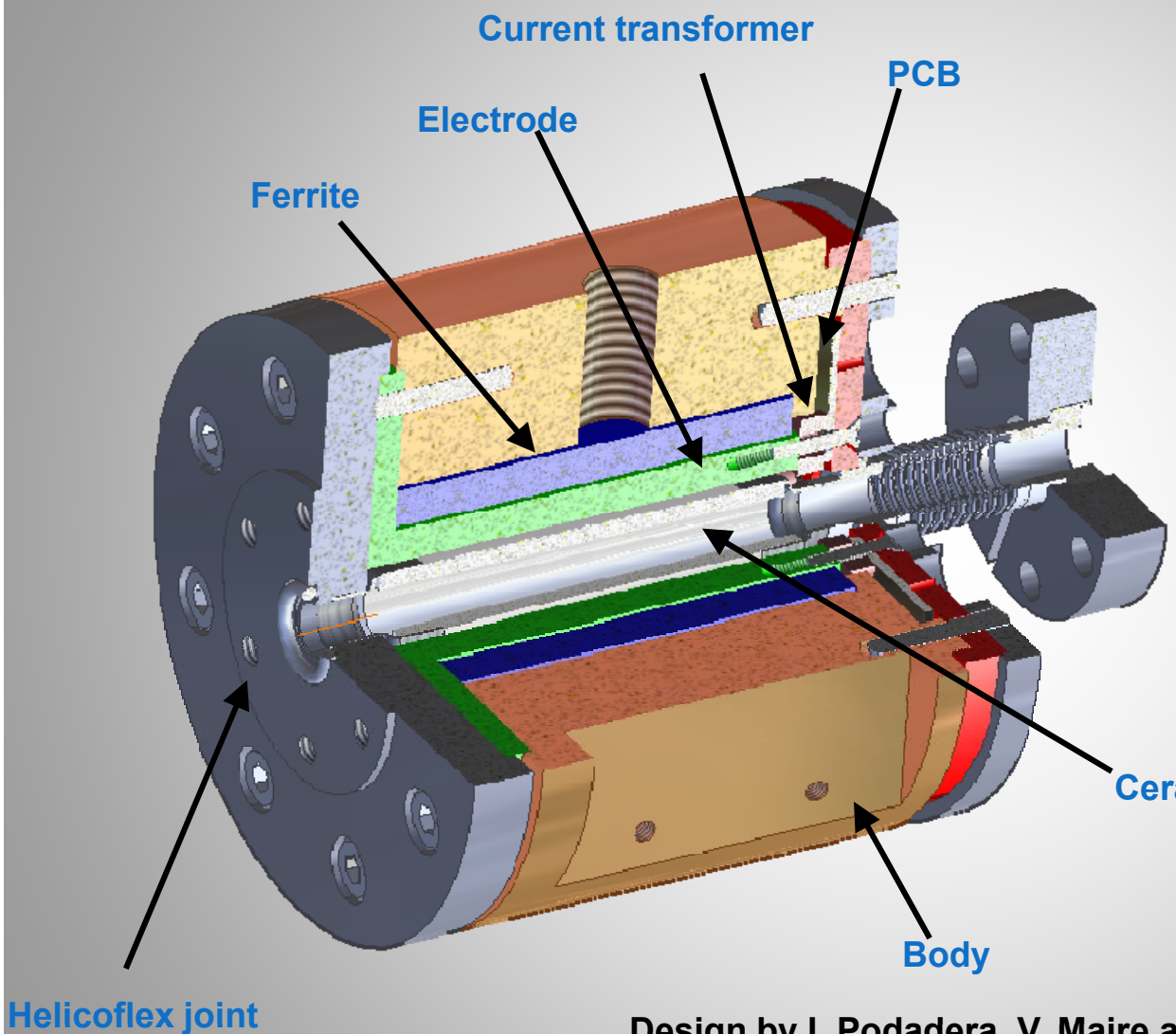
Low cutoff (difference signal)

$$f_{L_\Delta} = \frac{R_s / n^2}{2\pi L_\Delta}$$

Low cutoff (sum signal)

$$f_{L_\Sigma} = \frac{R_s / n^2}{2\pi L_\Sigma}$$

Final design

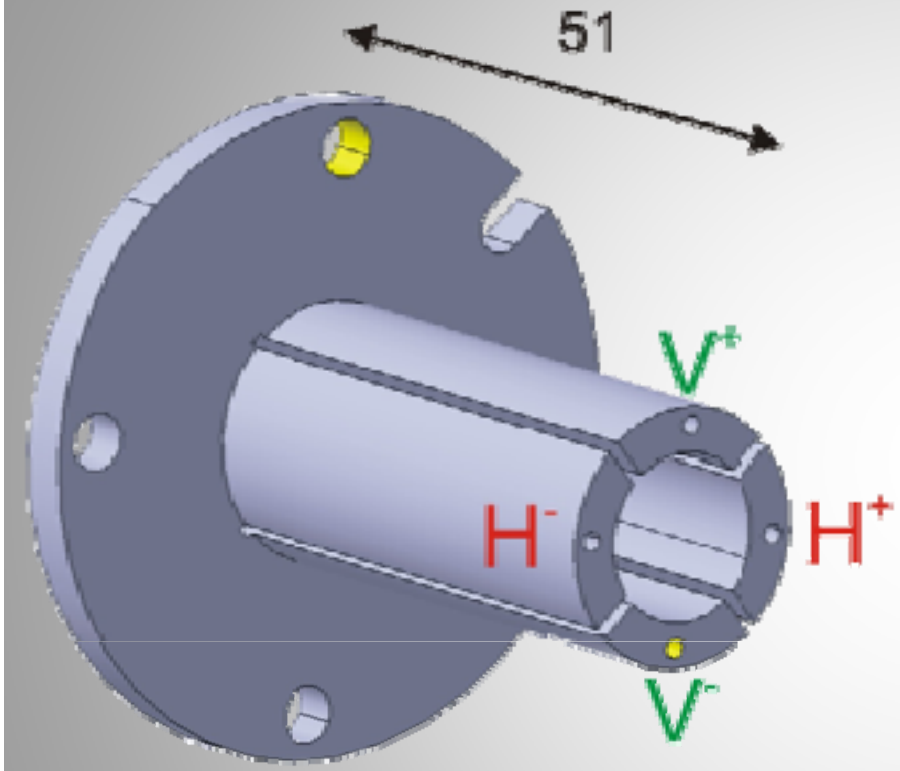


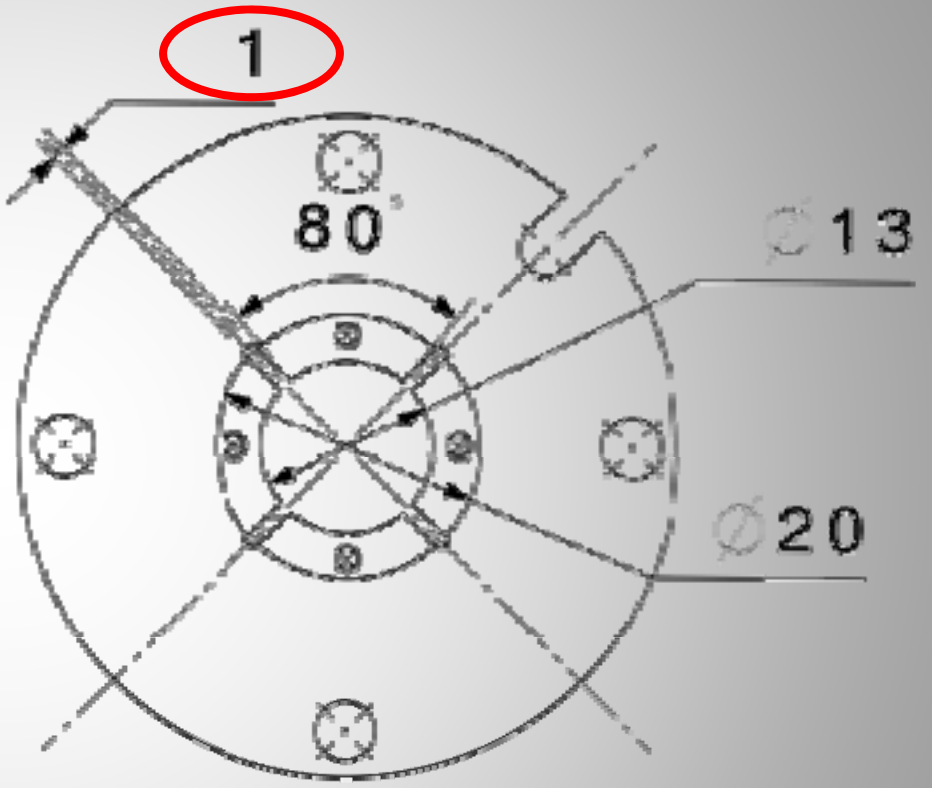
- Length: 99.7mm
- Overall diameter: 68mm
- Vacuum tube ID: 6mm
- Thickness ceramic: 2mm
- Electrode length: 51mm
- Electrode ID: 12mm
- Electrode OD: 19mm
- Electrode width: 60º
- Ferrite : 46, 21, 30mm

Design by I. Podadera, V. Maire and B. Favrat.

Different electrodes

Also tests with 2mm (70º) 3mm (60º), 4mm (50º), 5mm (40º),



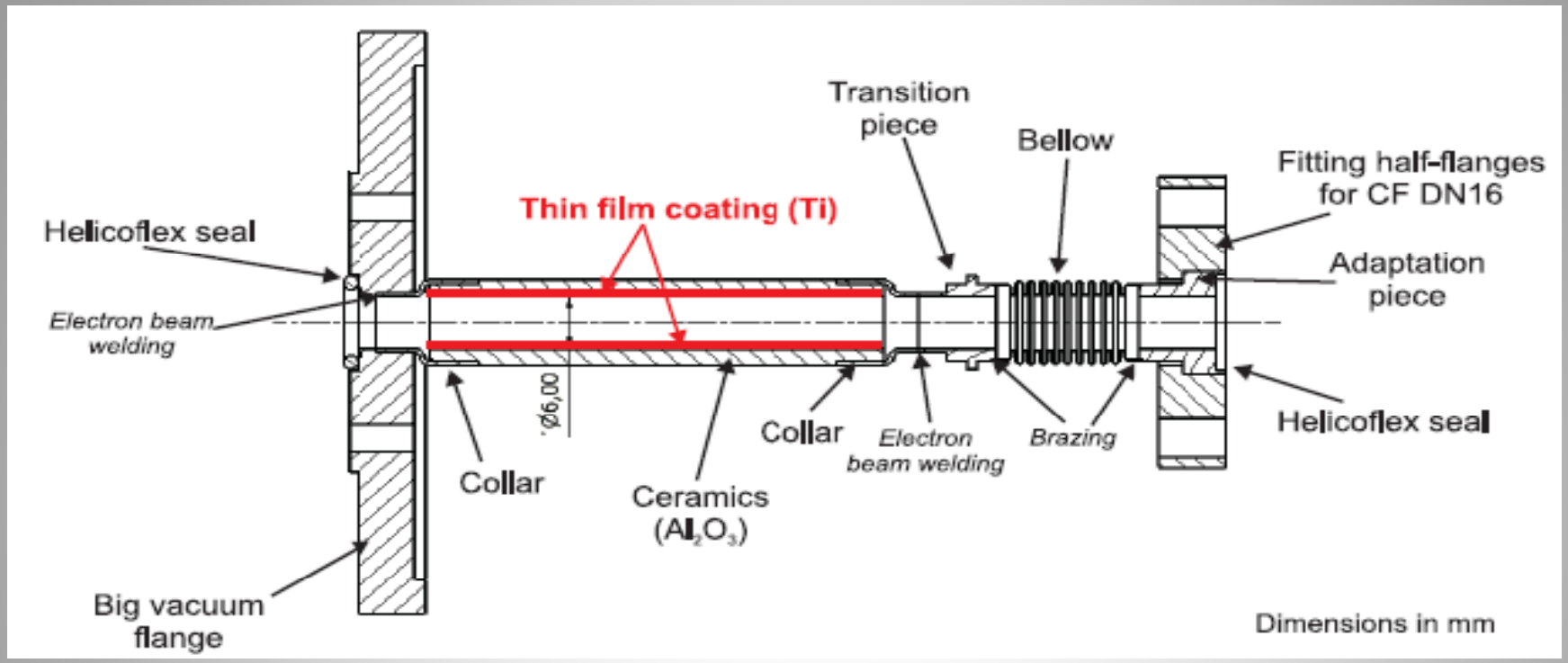


$\Delta_H = H^+ - H^-$

$\Delta_V = V^+ + V^-$

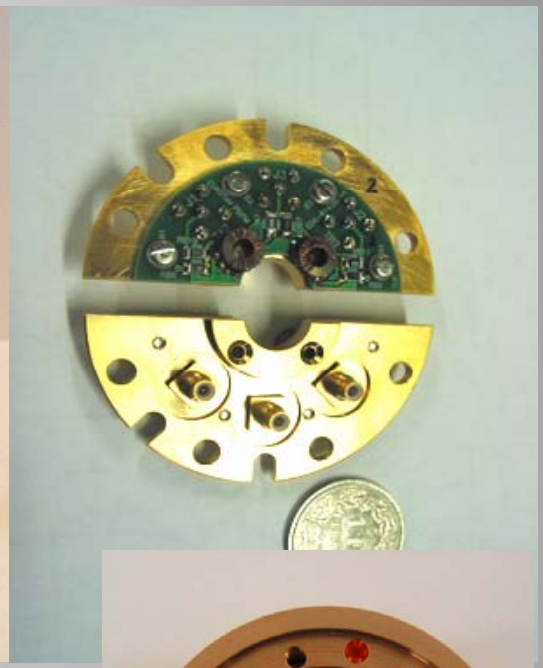
Dimensions in mm

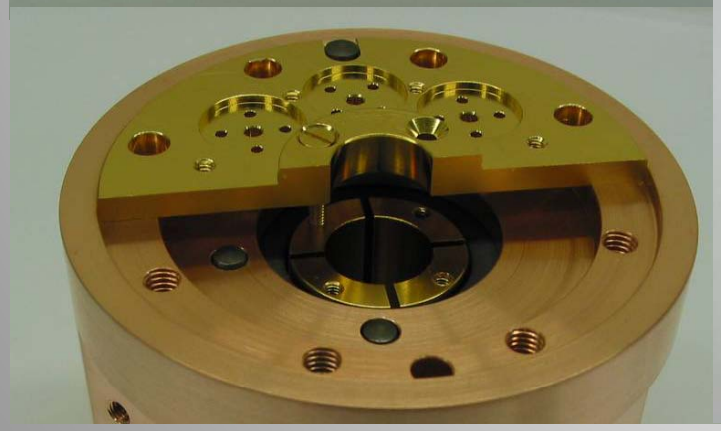
Vacuum assembly



- Sputtering technique requires homogenous plasma inside the tube. Simulations showed that a magnetron was needed .
- But our first test samples had collars made of Covar!
- With stainless steel collars coating is still not homogeneous. But end to end resistance of 10-15 ohms have been obtained.
- Small is difficult!

PBPM assembly





PBPM bench tests

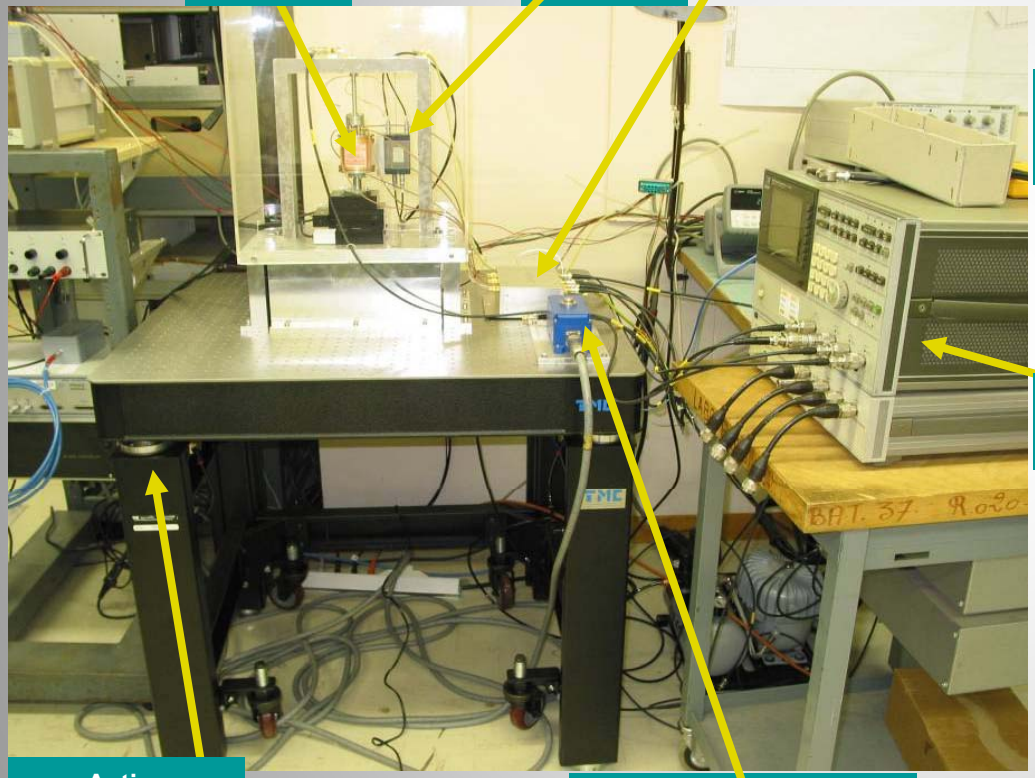
- Sensitivity
- Linearity
- Resolution
- Long-term stability
- Bandwidth
- Electrical offset
- Longitudinal impedance

→ **Network analyzer**
CW 1-10MHz, 100mA, narrow band

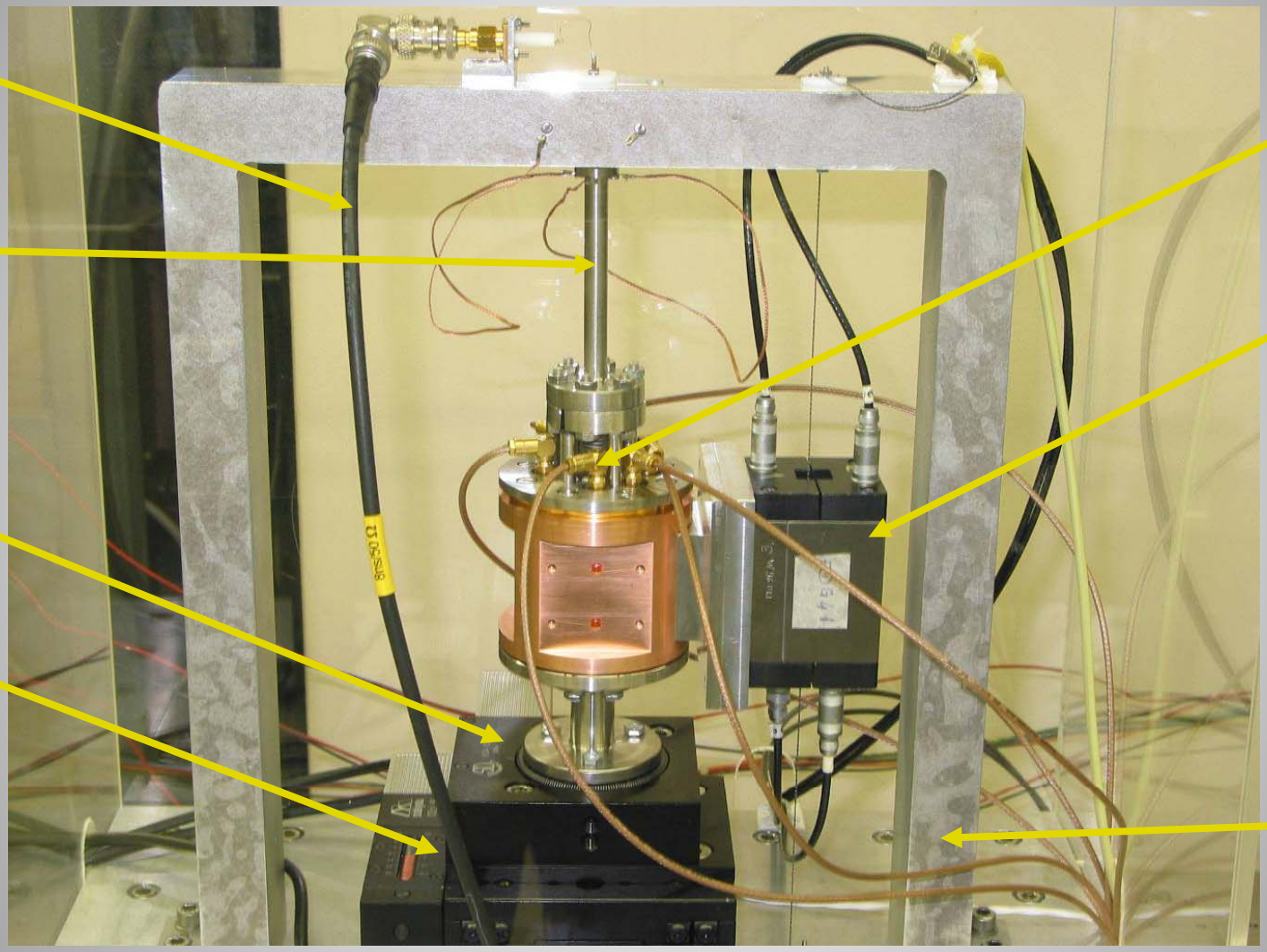
- Resolution
- Linearity

→ **Function generator and oscilloscope**
200ns, 200mA pulse, 25MHz BW

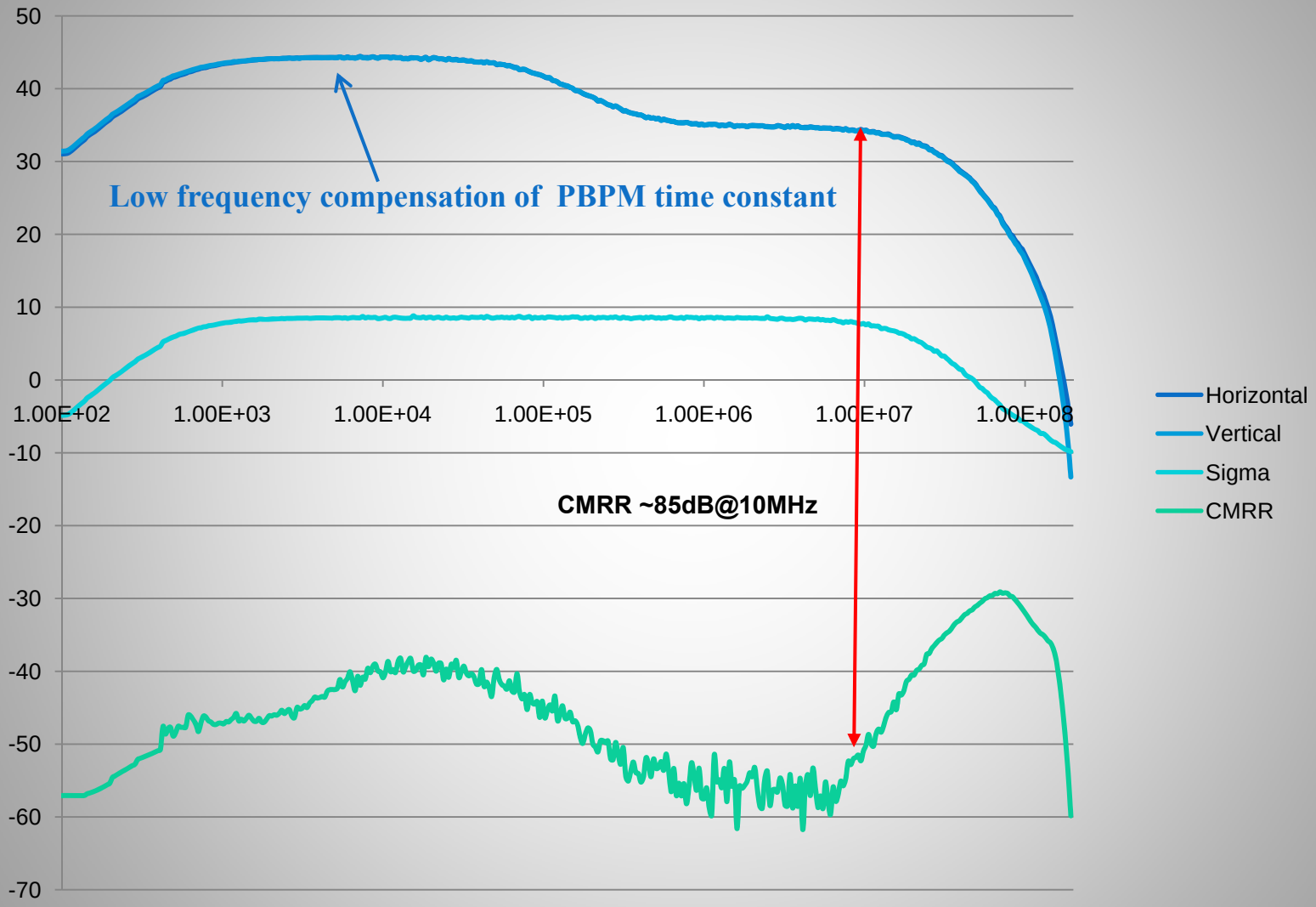
Test bench assembly



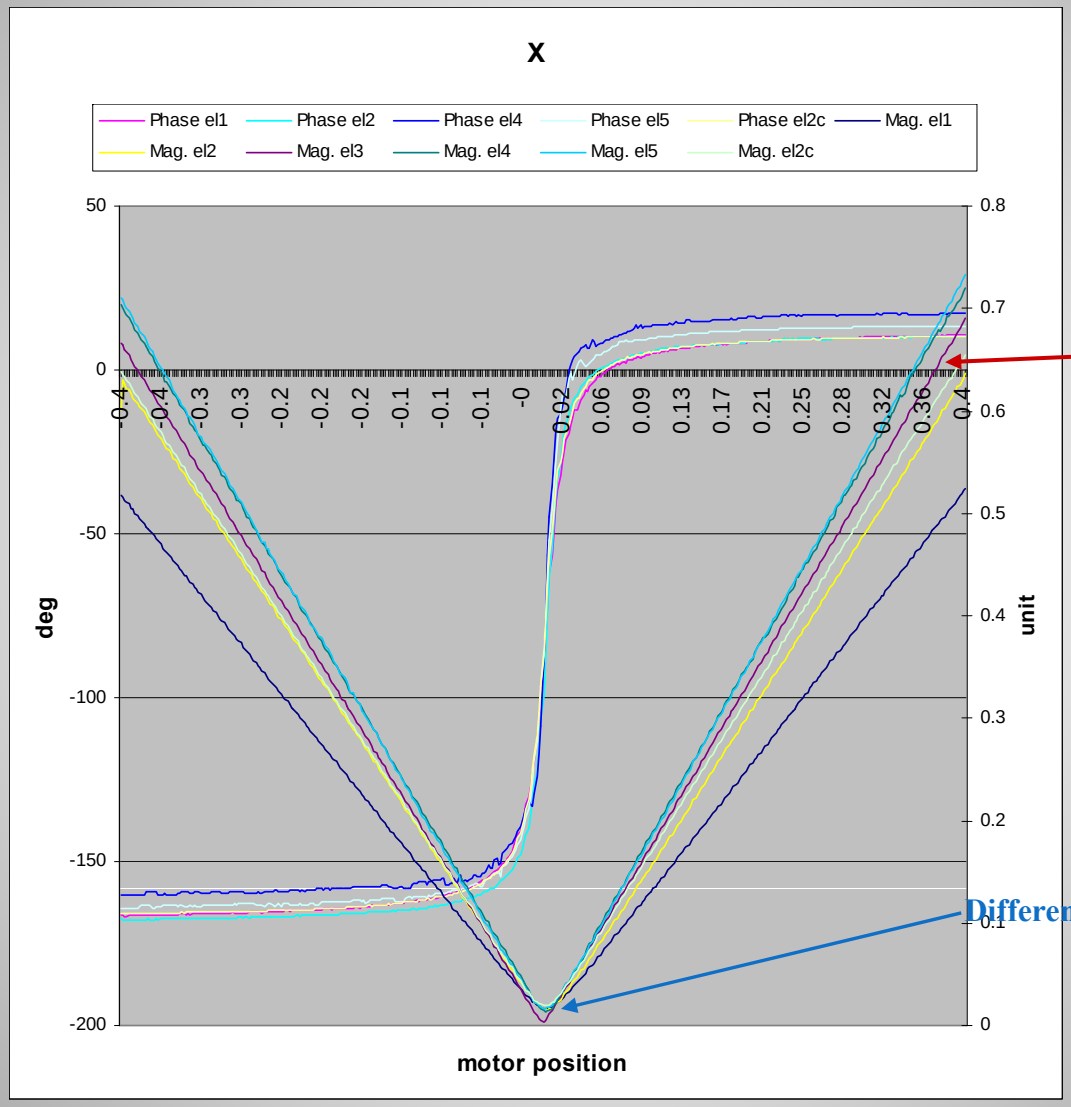
Test bench assembly



Difference amplifier



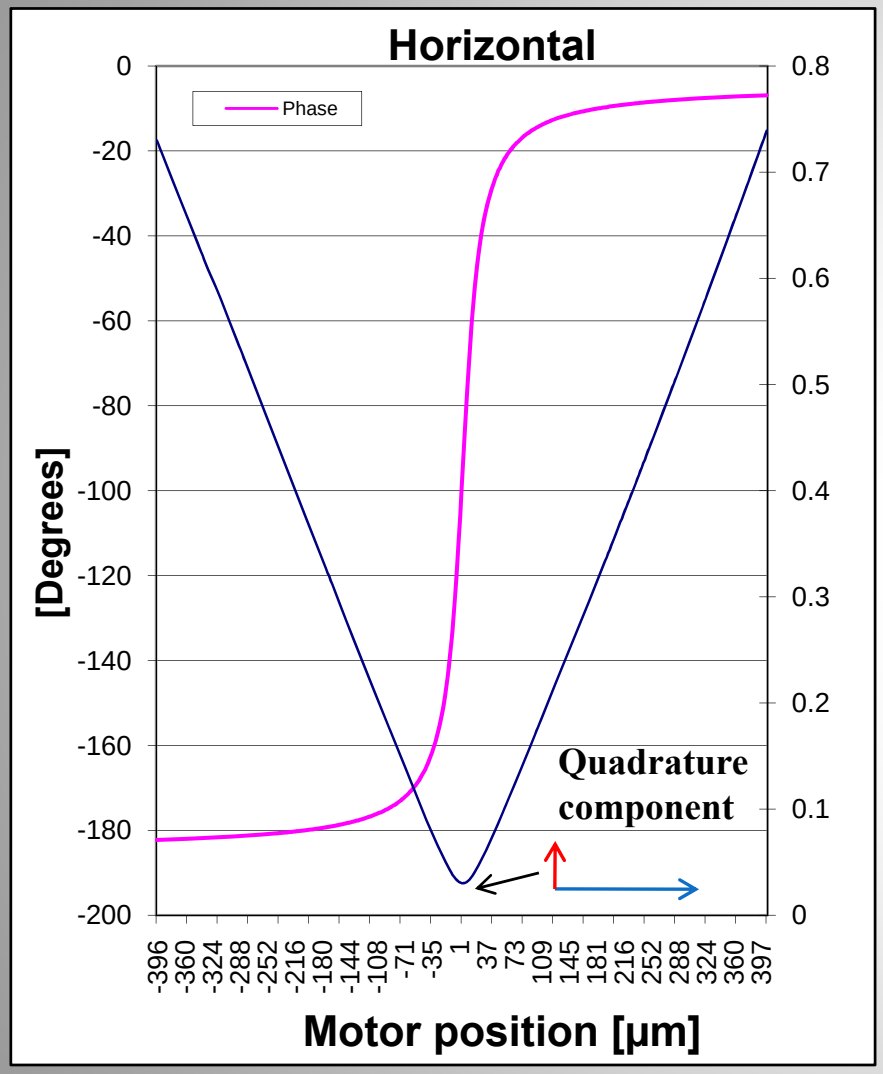
Sensitivity-different electrodes

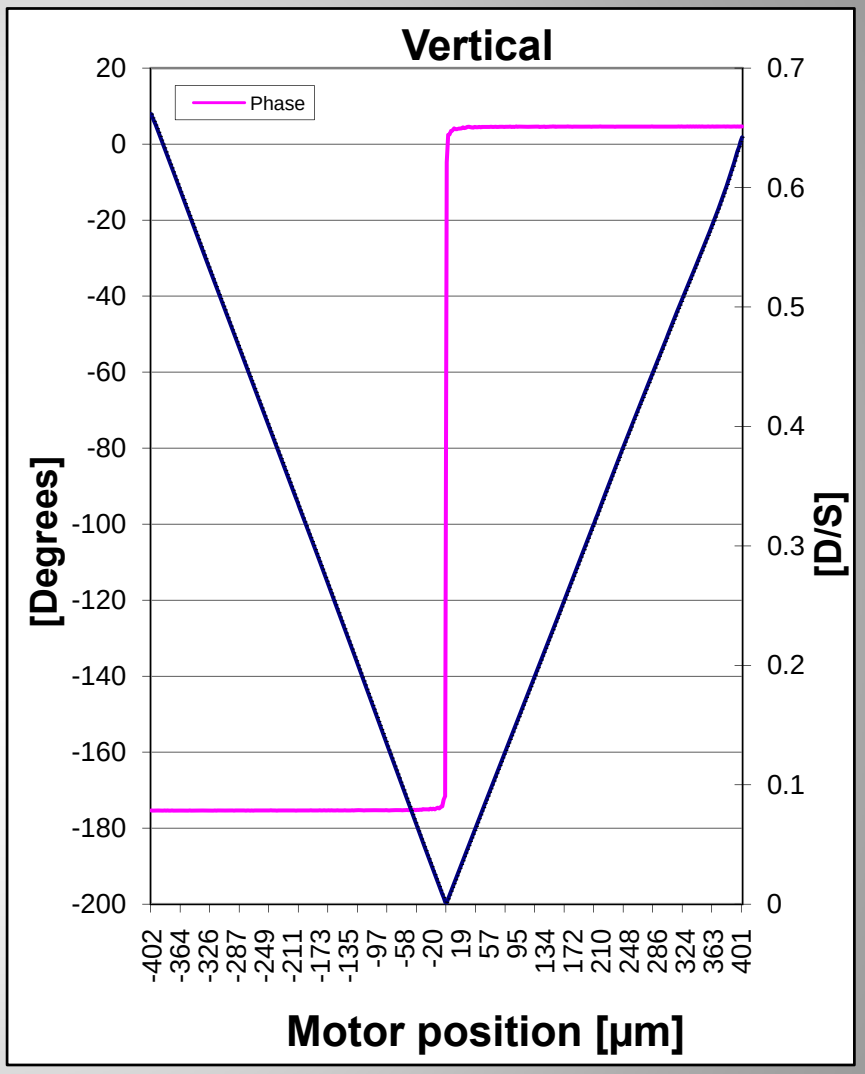


60 deg electrode
(3mm spacing)

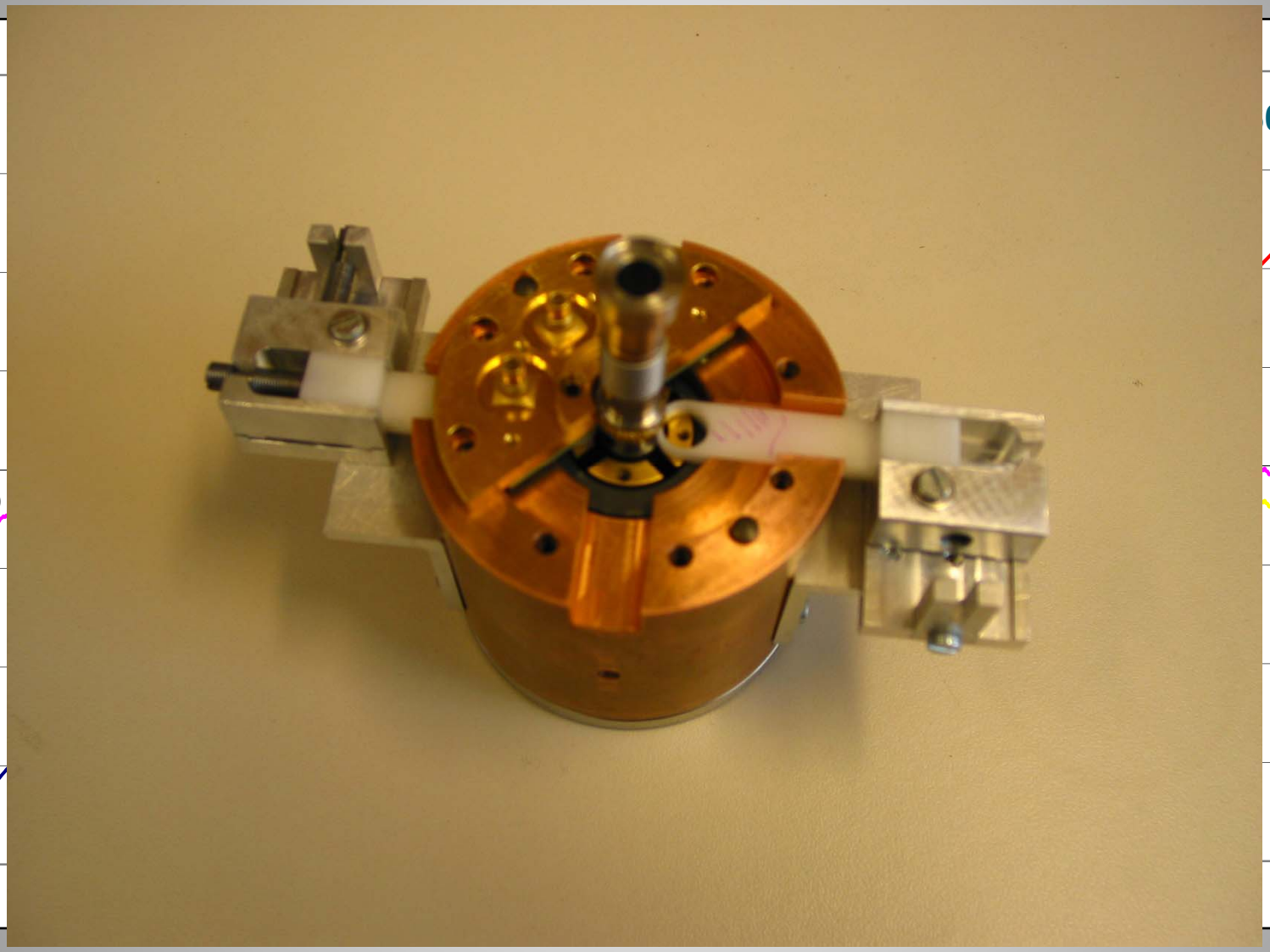
Different residuals from setup to setup

Sensitivity

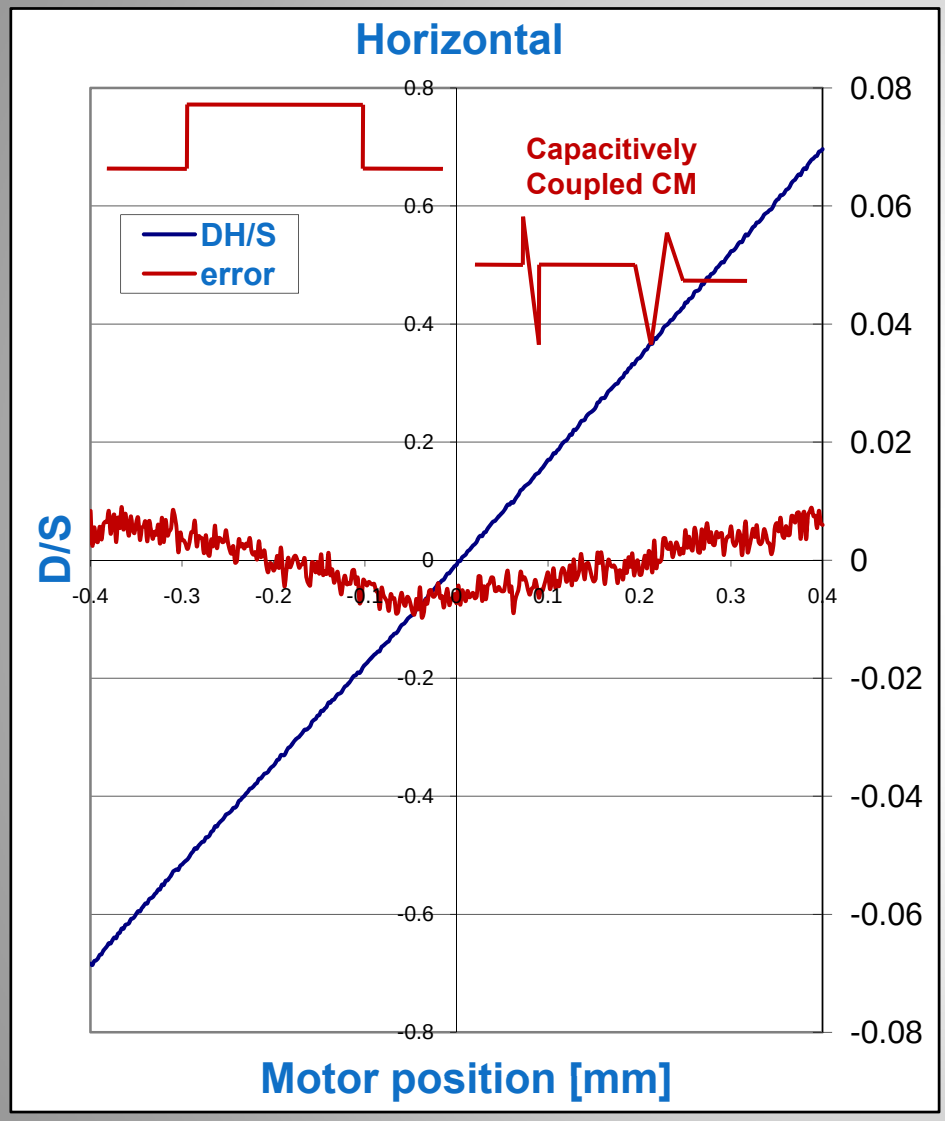


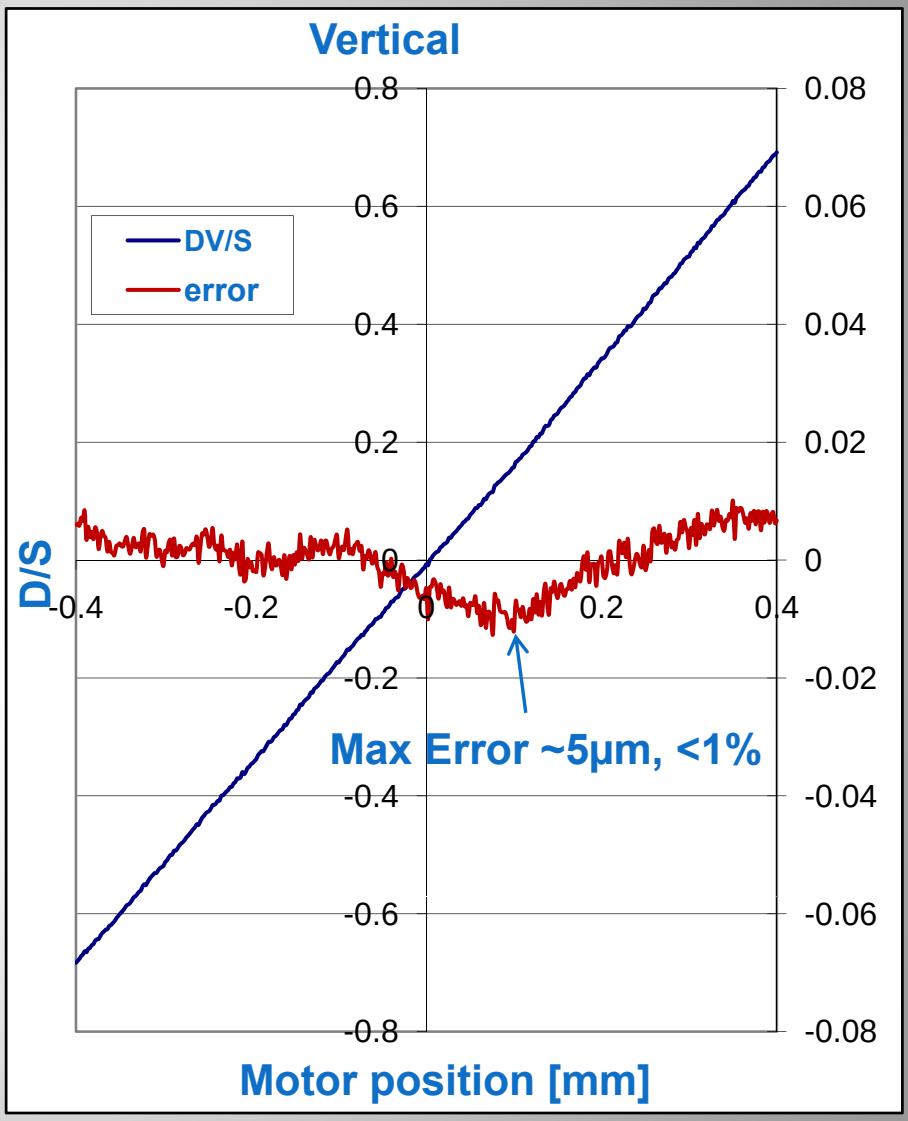


Bench tests-Linearity

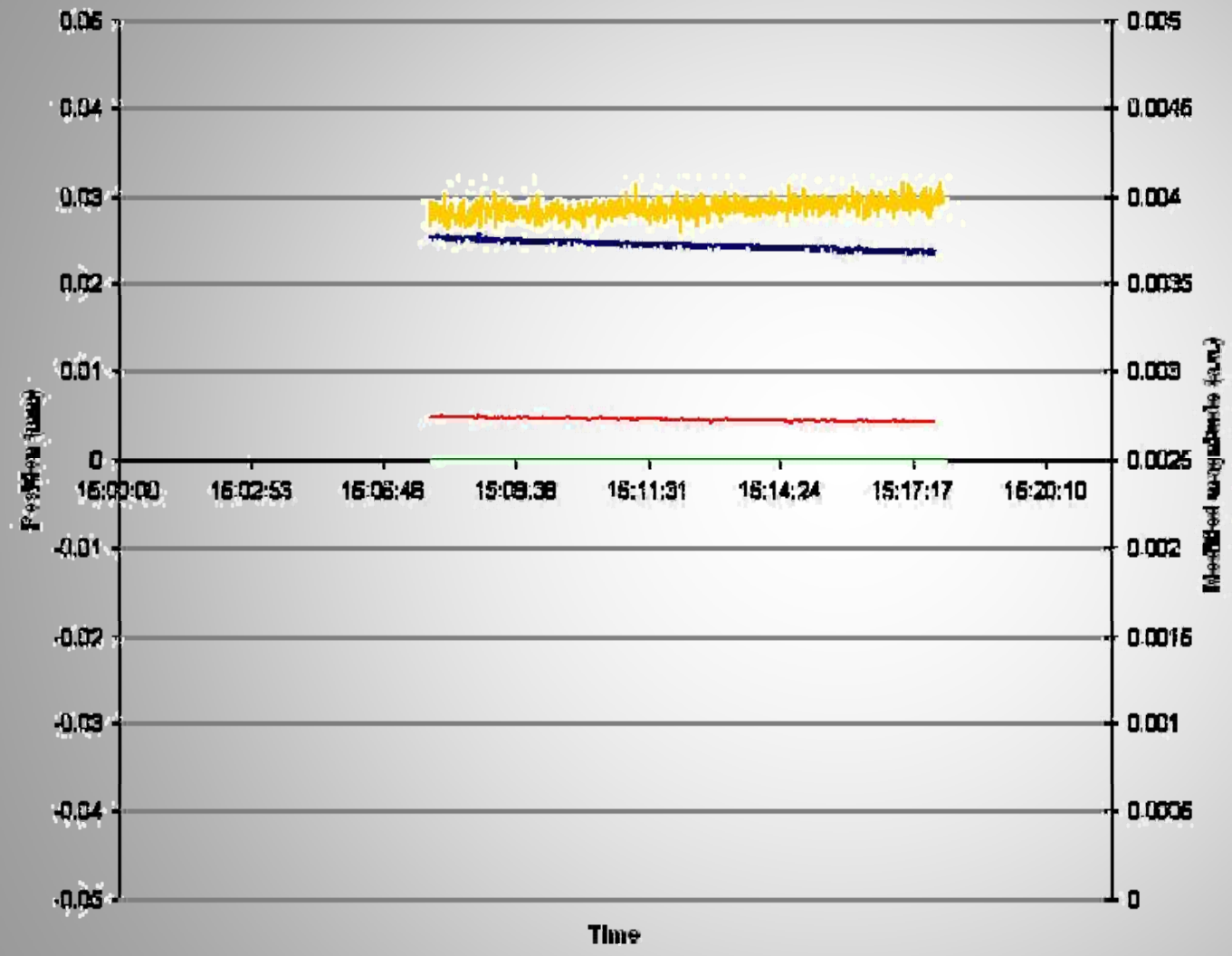


Linearity - time domain





Resolution



f=10 MHz
Gap spacing 3 mm
P = 25 dBm
3 kHz bandwith

1000 samples

σ_H=36 nm
σ_V=36 nm

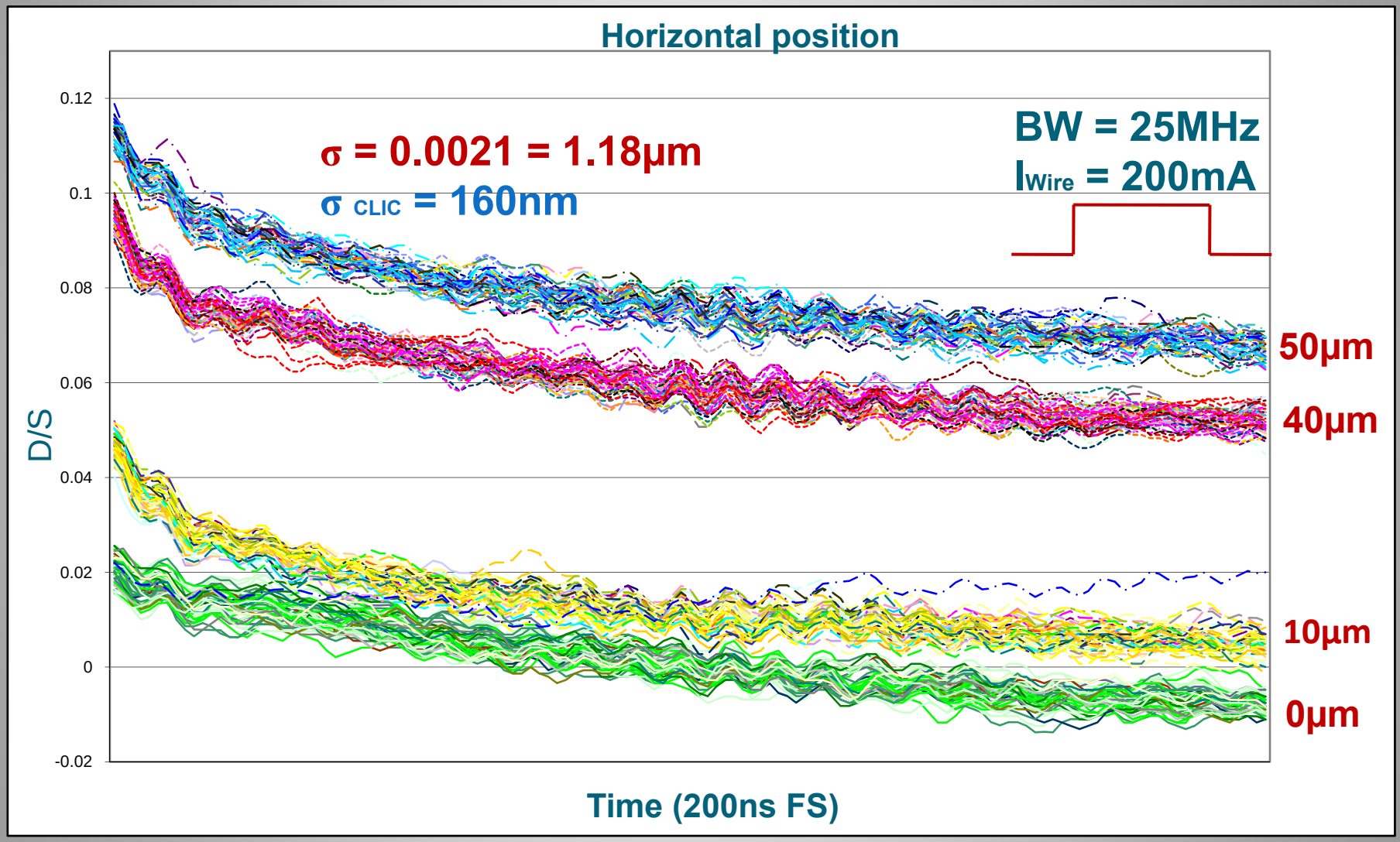
scaling noise to
same current at 25 MHz BW

σ_H=3.2 μm

CLIC (1.5 A)

σ_H=220 nm

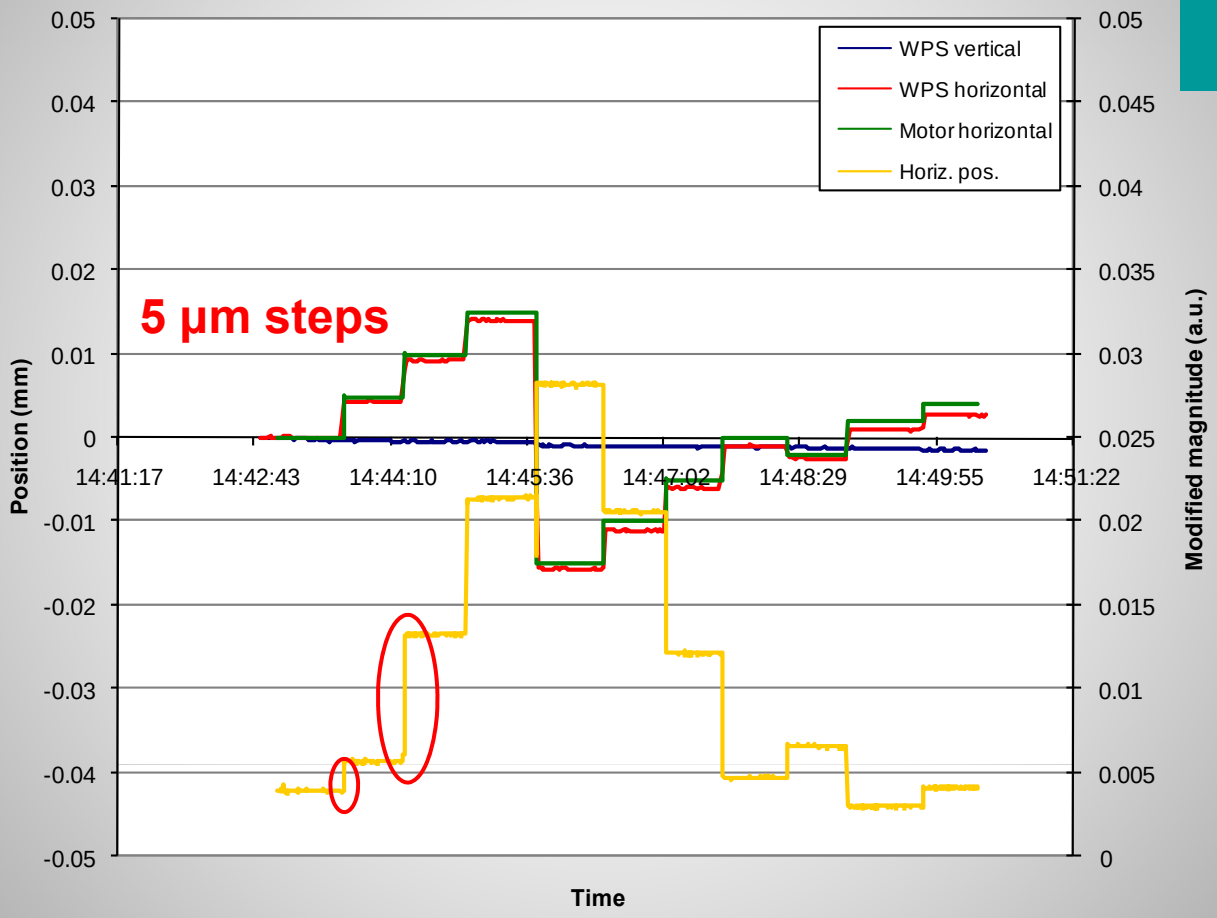
Resolution -Time domain



Resolution with movement

Correlation between x movements and monitoring signals

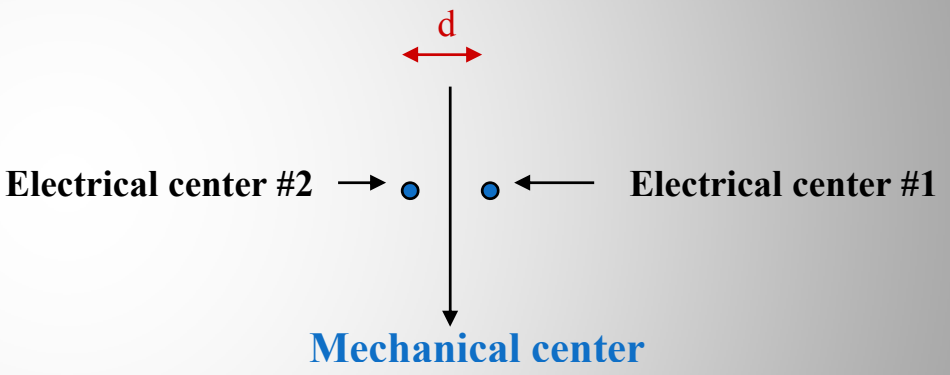
f=10 MHz
Gap spacing 3 mm
P = 25 dBm
3 kHz bandwith



Electrical offset

Difficult to know exactly where the wire is (inside) with respect to external reference.

1. Find electrical center #1
2. Rotate 180º
3. Find electrical center #2
4. Offset = d/2



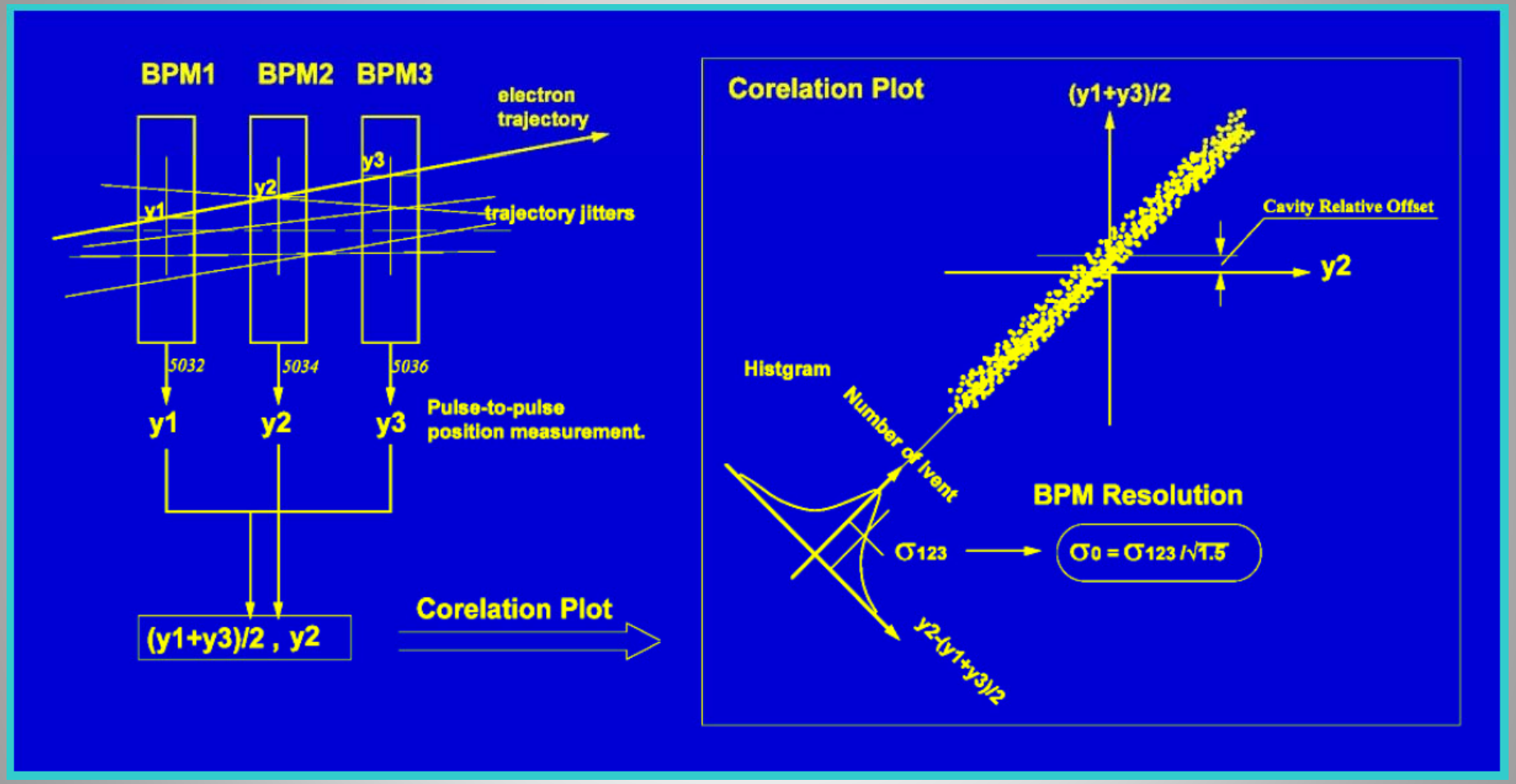
The electrical offset was measured to ~50µm.

The reason for this was due to in precise alignment of the PBPM on the rotation stage, and assembly of the setup.

Bench test-results

BPM Sensitivity Δ=Σ	11.8mm
Linearity error [±500µm]	1%
Electrical offset	~50µm
Meas. resolution (100mA, 3kHz BW)	σ = 36nm
Resolution CLIC (1.5A, 25MHz BW)	σ = 160nm / 220nm
Resolution ILC (55mA , σ=14ns, 25MHZ BW)	σ = 5.8um
24H stability/ 5 deg. C	2µm
BPM bandwidth	Δ = 300kHz-80MHz Σ = 5kHz-80MHz

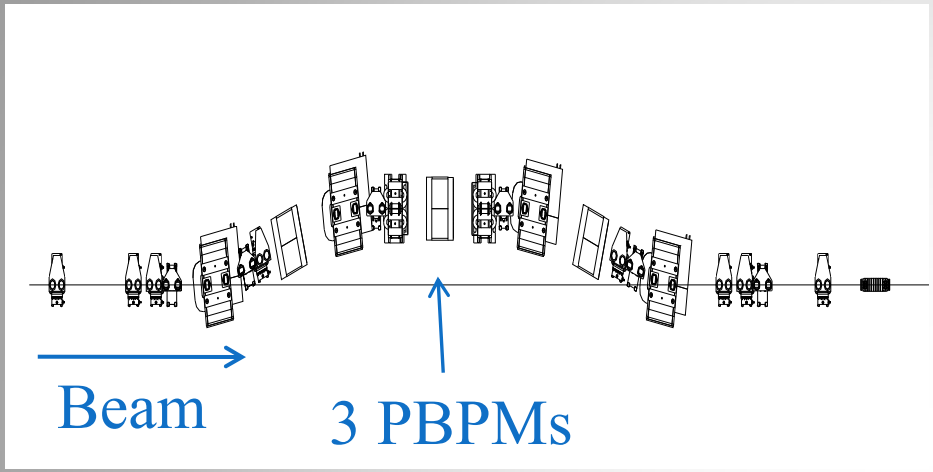
Beam tests



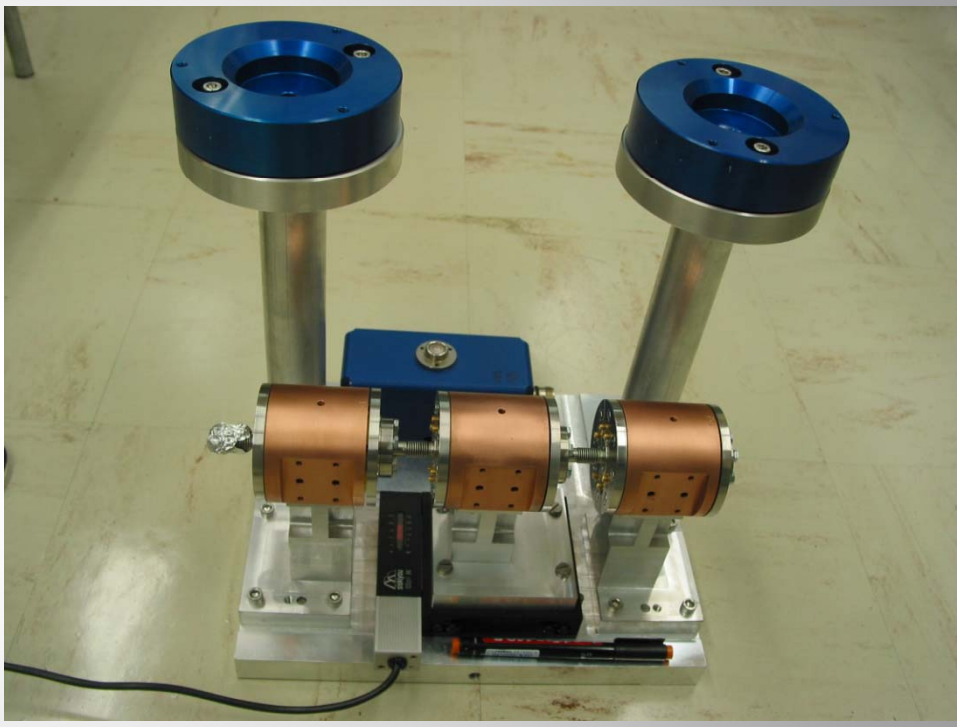
Courtesy T. Shintake

Beam tests in CTF3

Magnetic chicane CTF3 Linac



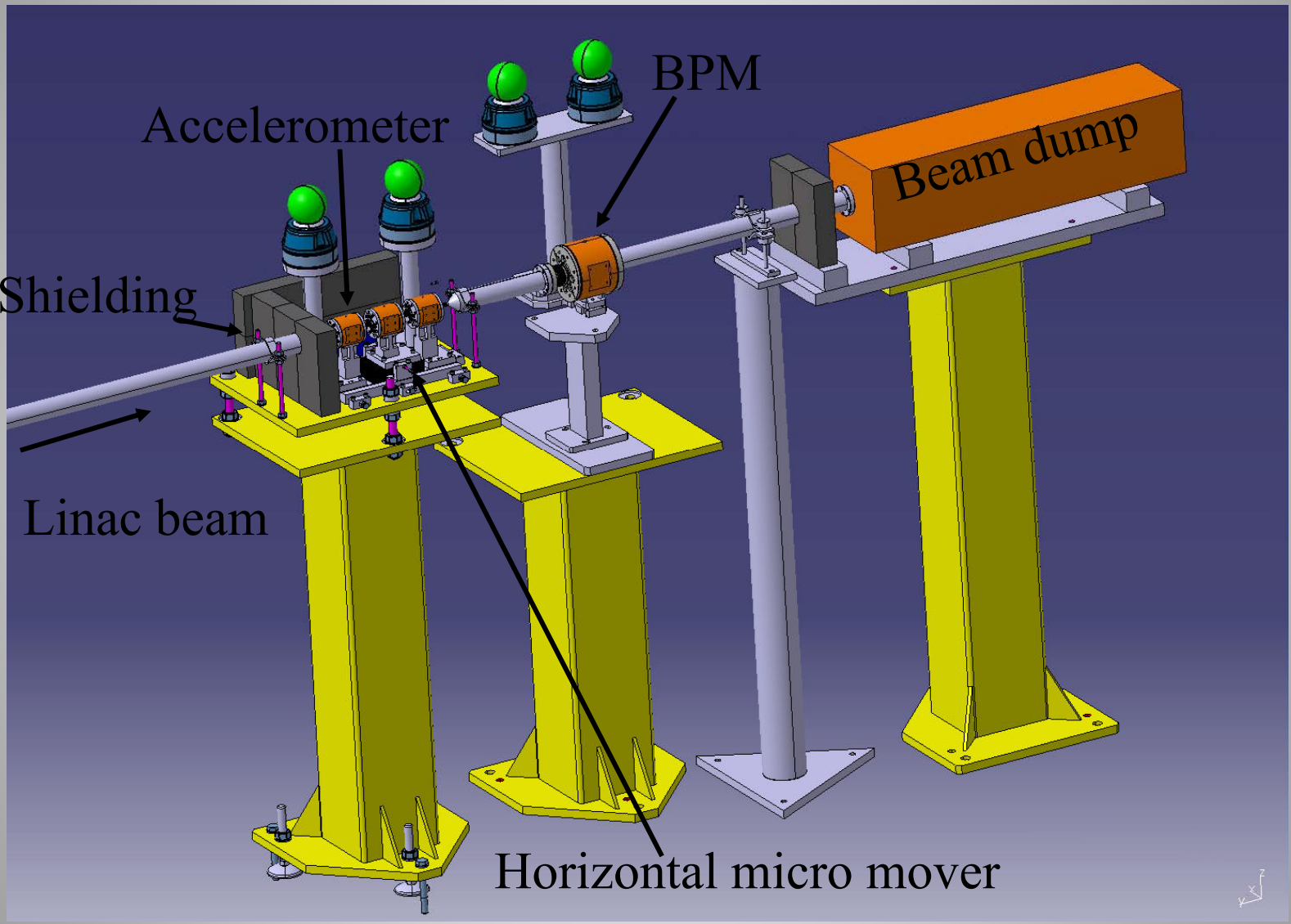
Installation of 3 PBPM in CTF3 November 2007



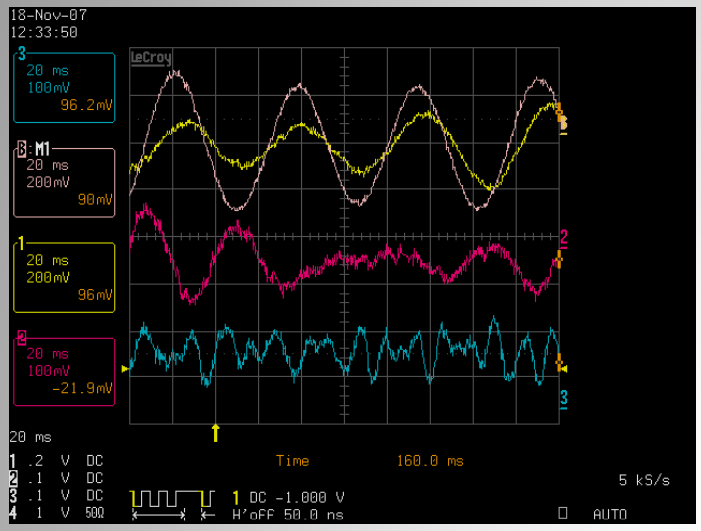
CTF3 beam properties

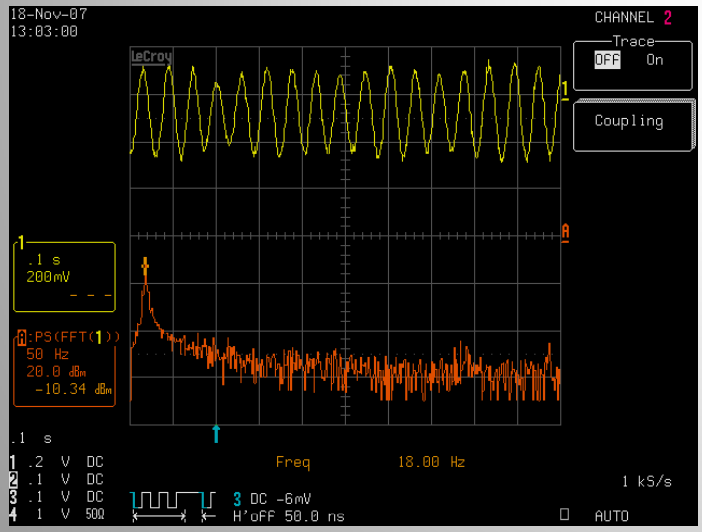
Beam current	**1.5 A**
Pulse width	**200 ns**
rms-Transverse beam size	**0.7 mm**
Beam angle	**1.25 mrad** *(0.5 mm offset at 400 mm length)*
Tranversal position jitter	**100 to 200 μm**

Beam tests


BPM
Accelerometer
Beam dump
Shielding
Linac beam
Horizontal micro mover

Beam tests-vibrations



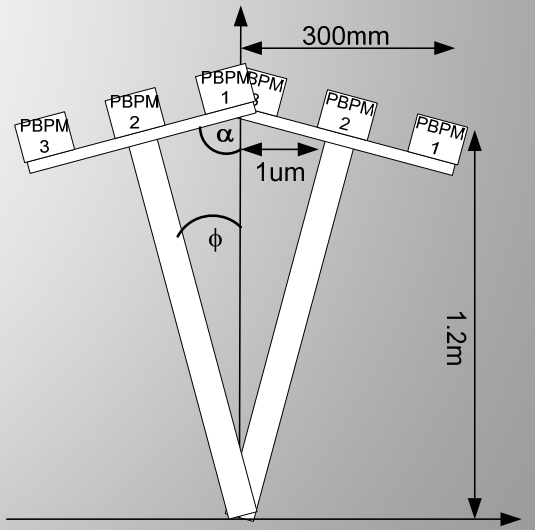


Longitudinal =Yellow, Violet = ± 1µm

Horizontal=Red = ± 500nm

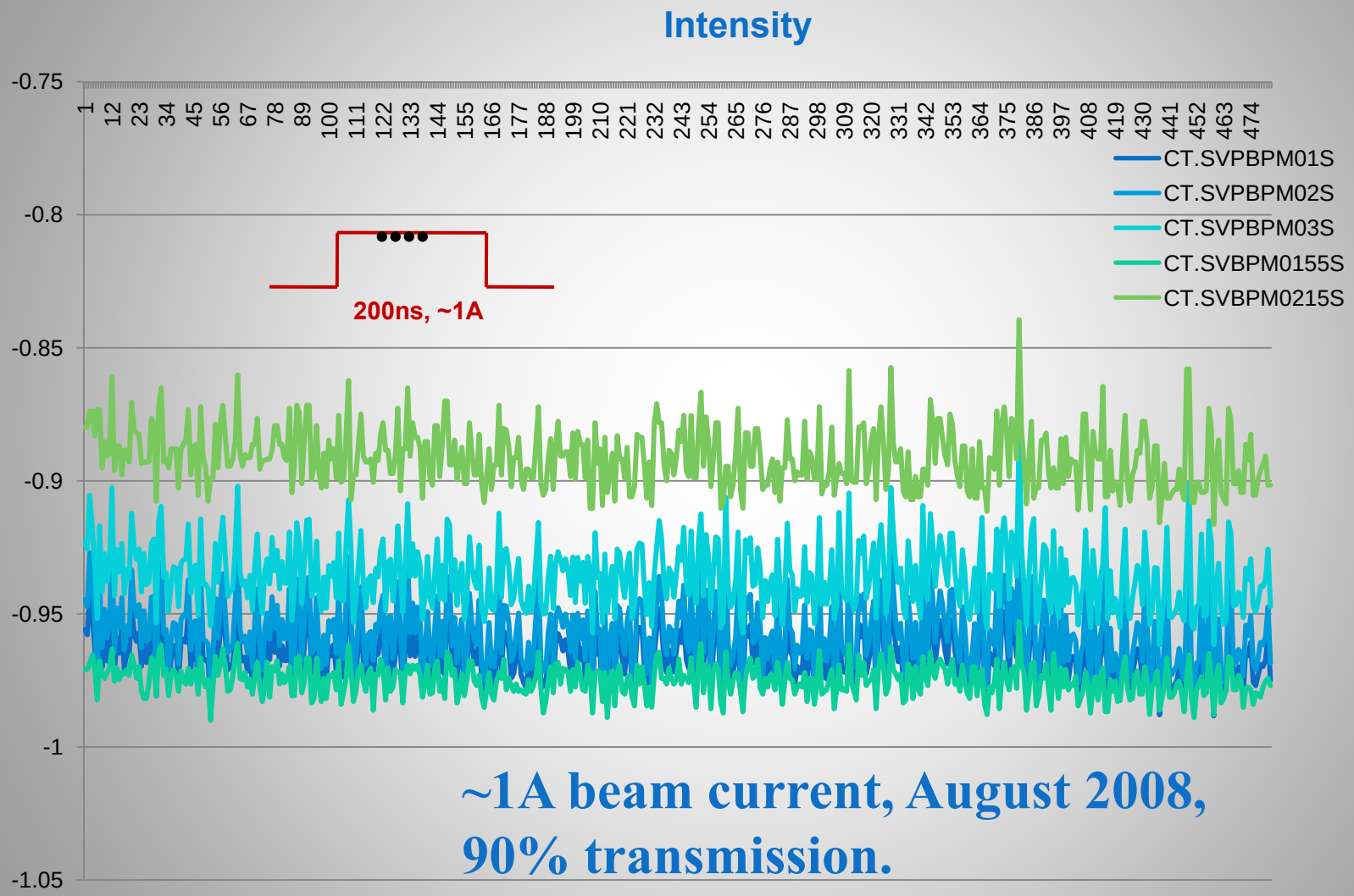
Vertical=Blue = ± 50nm

Longitudinal movement, gives vertical displacement of 125nm, of opposite signs on PBPMs 1 and 3, and zero on center PBPM.



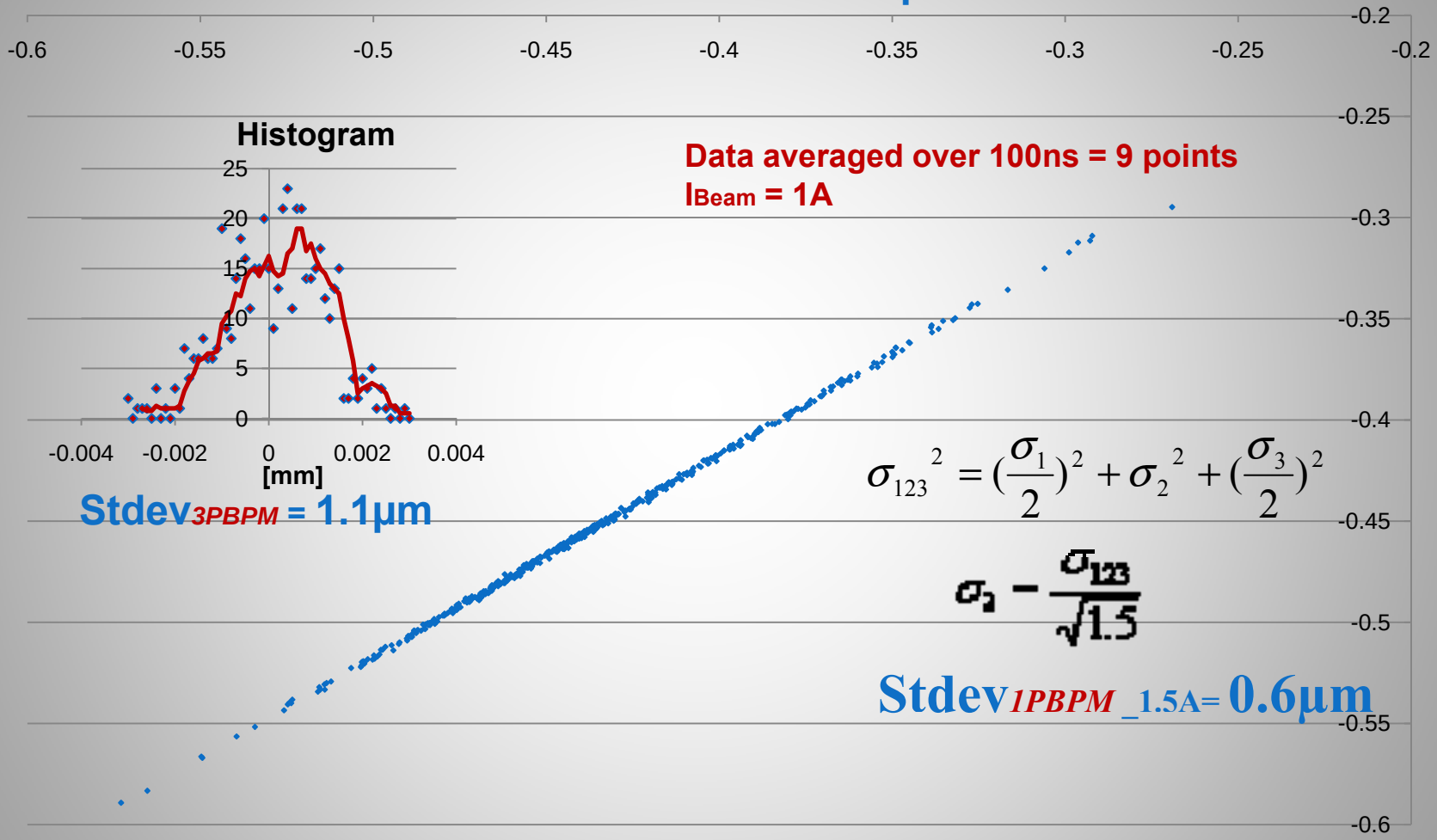
Longitudinal movement ~18Hz

Beam tests August 2008



Beam tests, August 2008

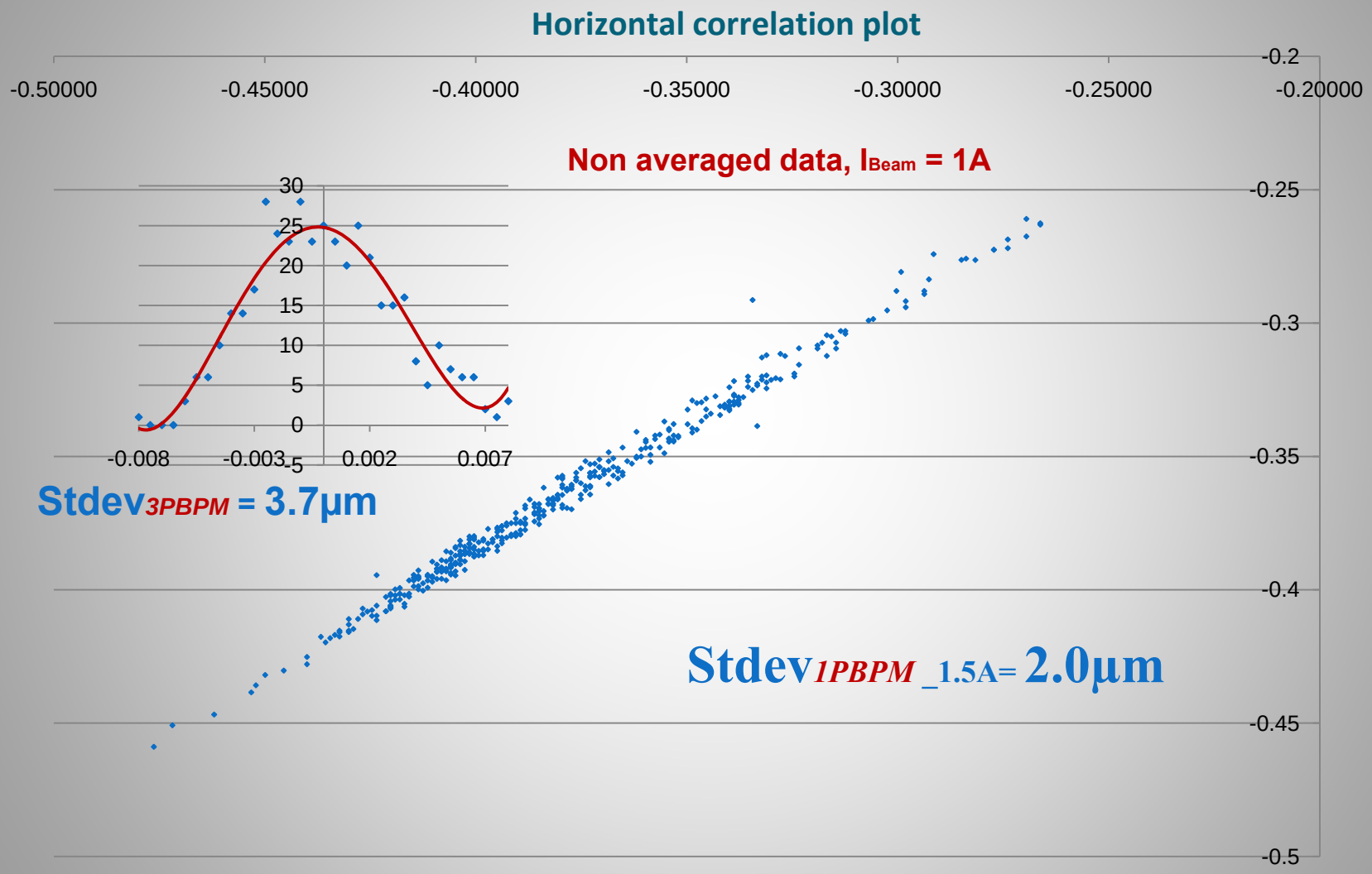
Horizontal correlation plot



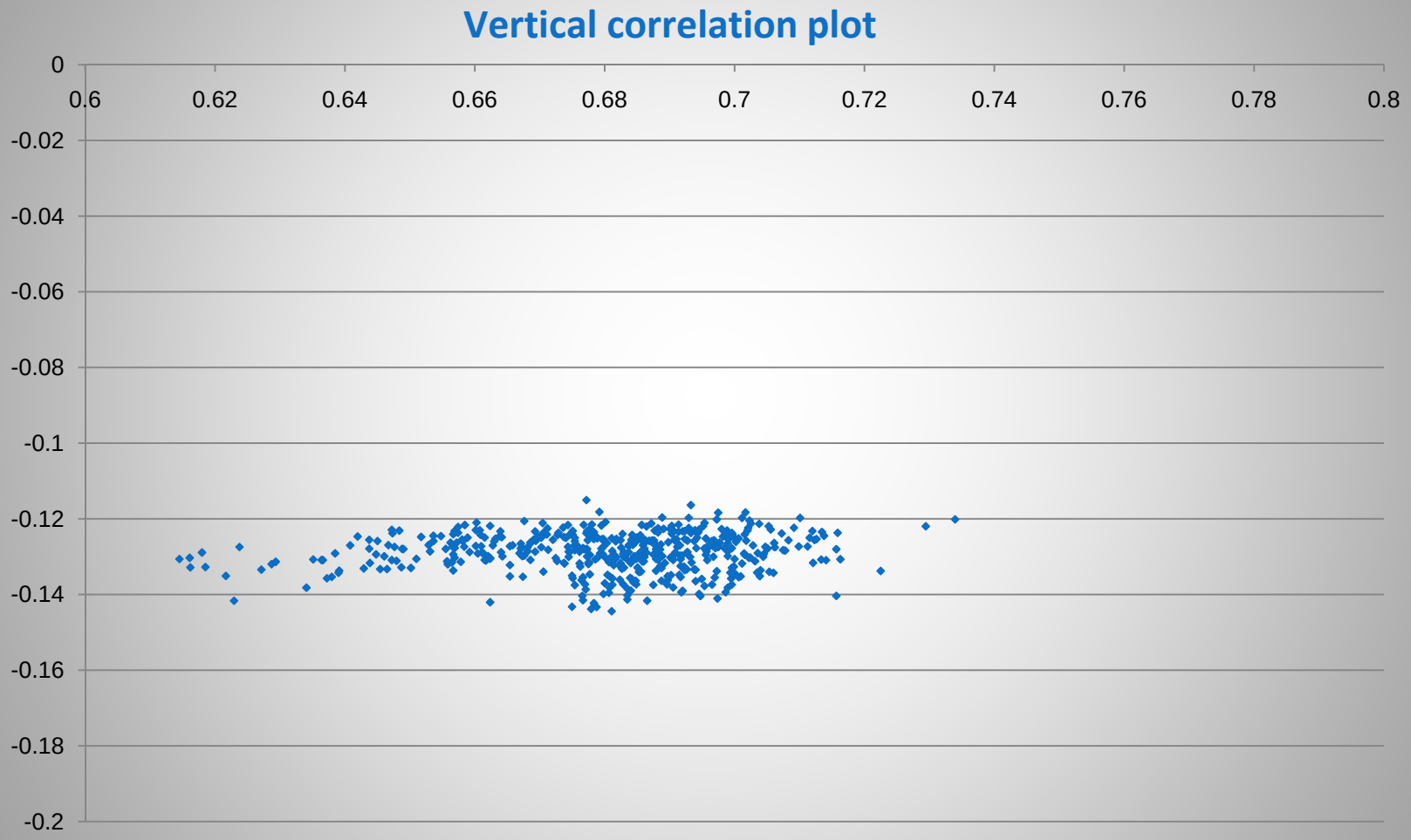
Stdev$_{3PBPM}$ = 1.1µm

Stdev$_{1PBPM_1.5A}$ = 0.6µm

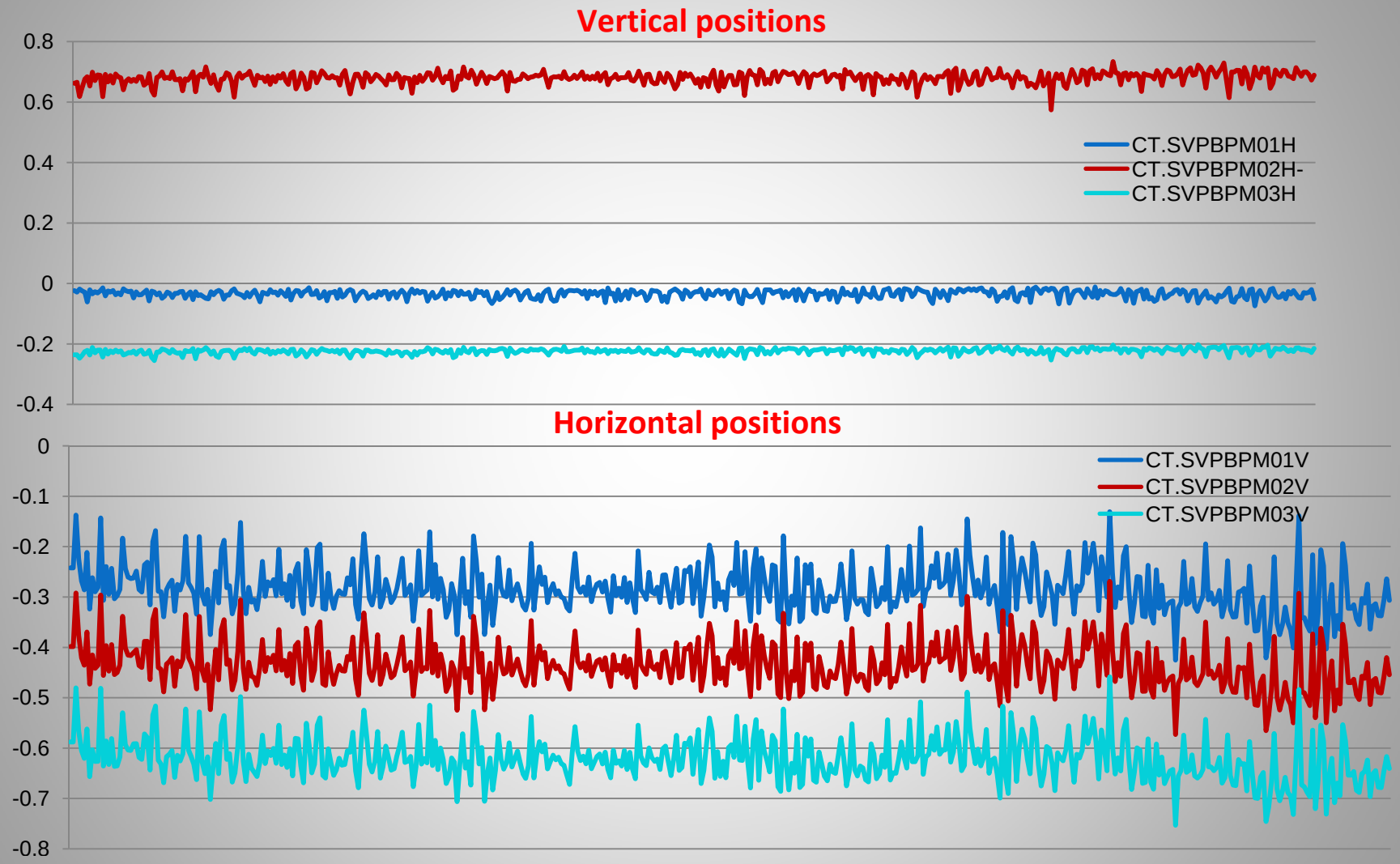
Beam tests, August 2008



Beam tests, August 2008



Beam tests, August 2008



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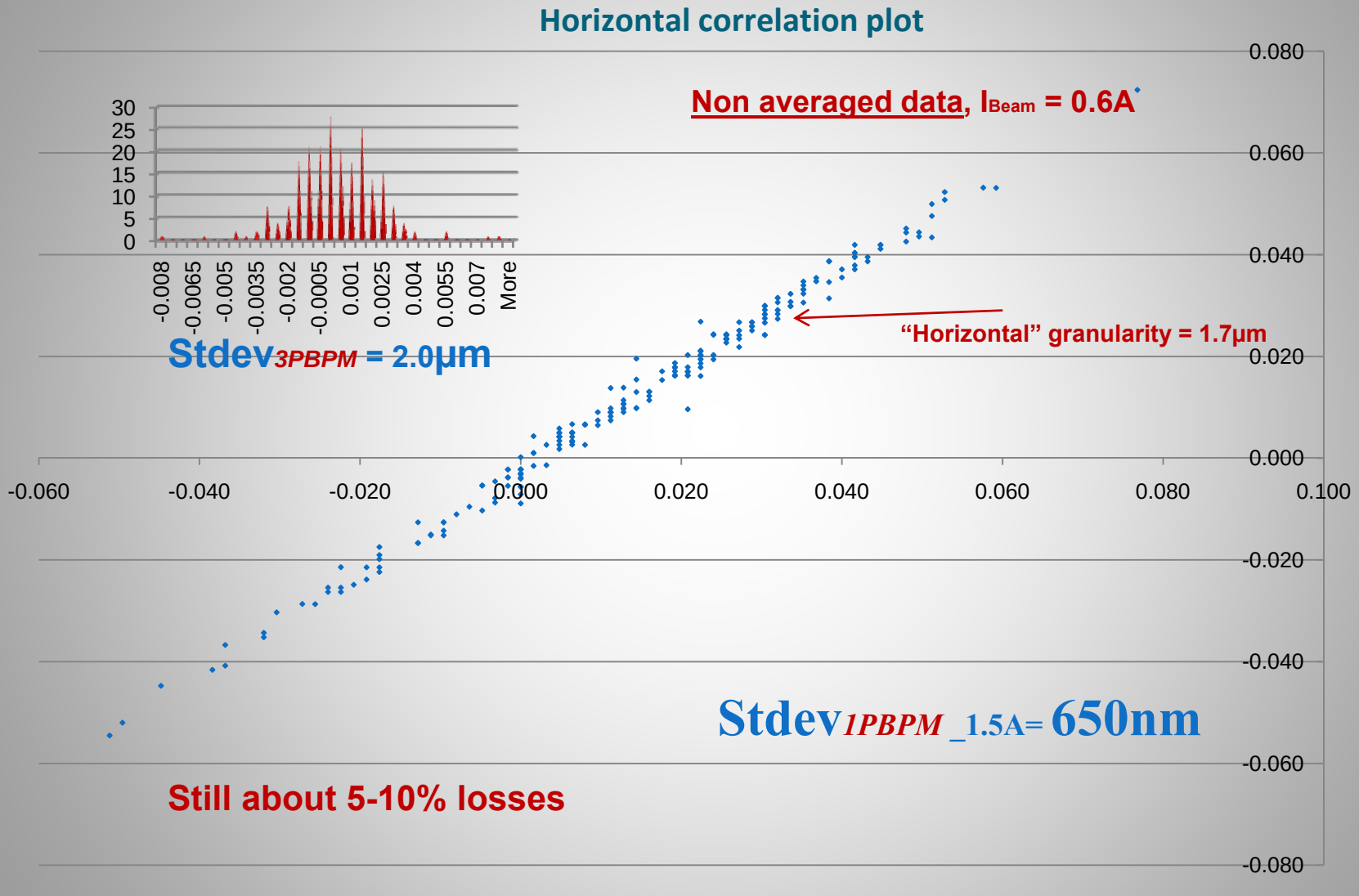

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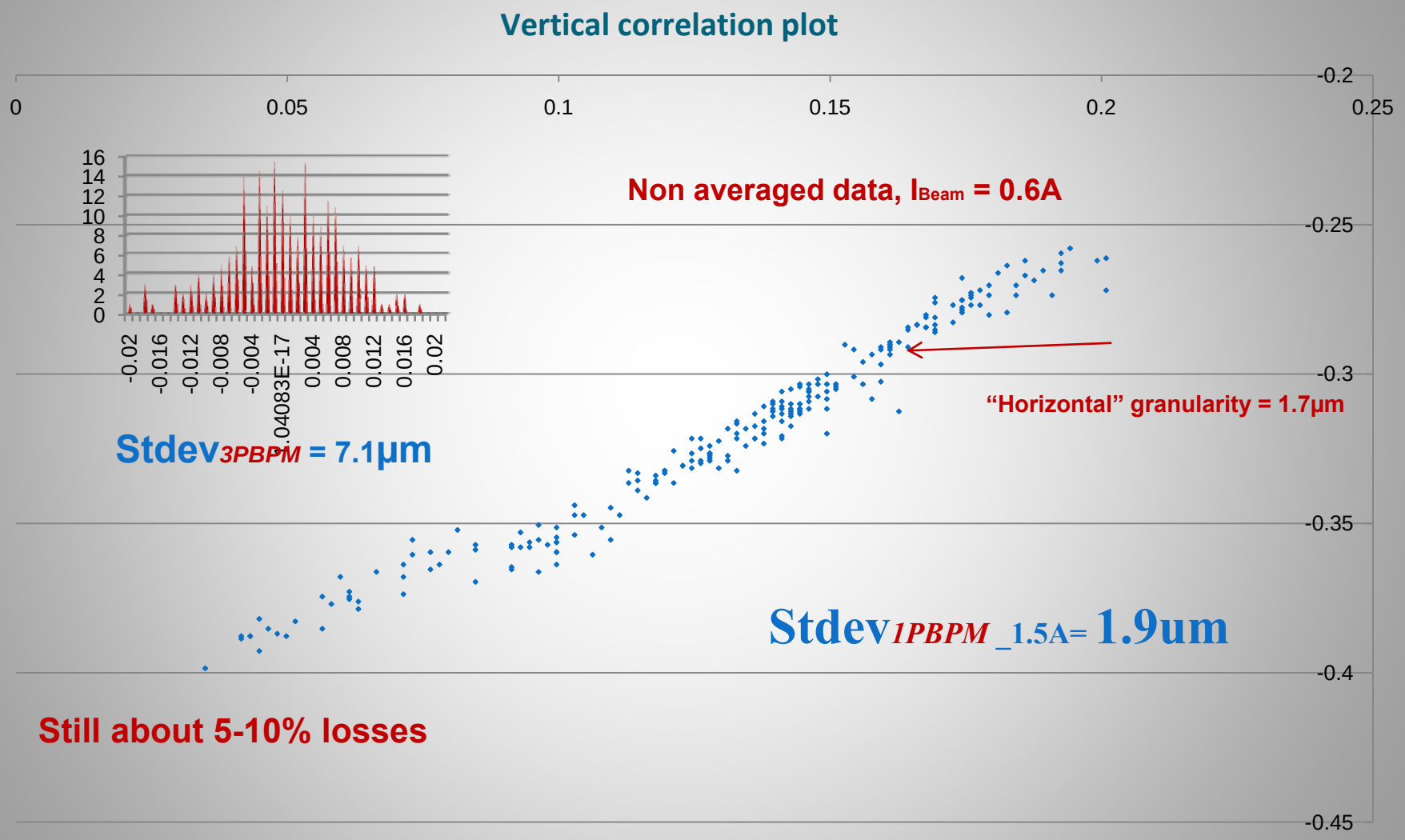

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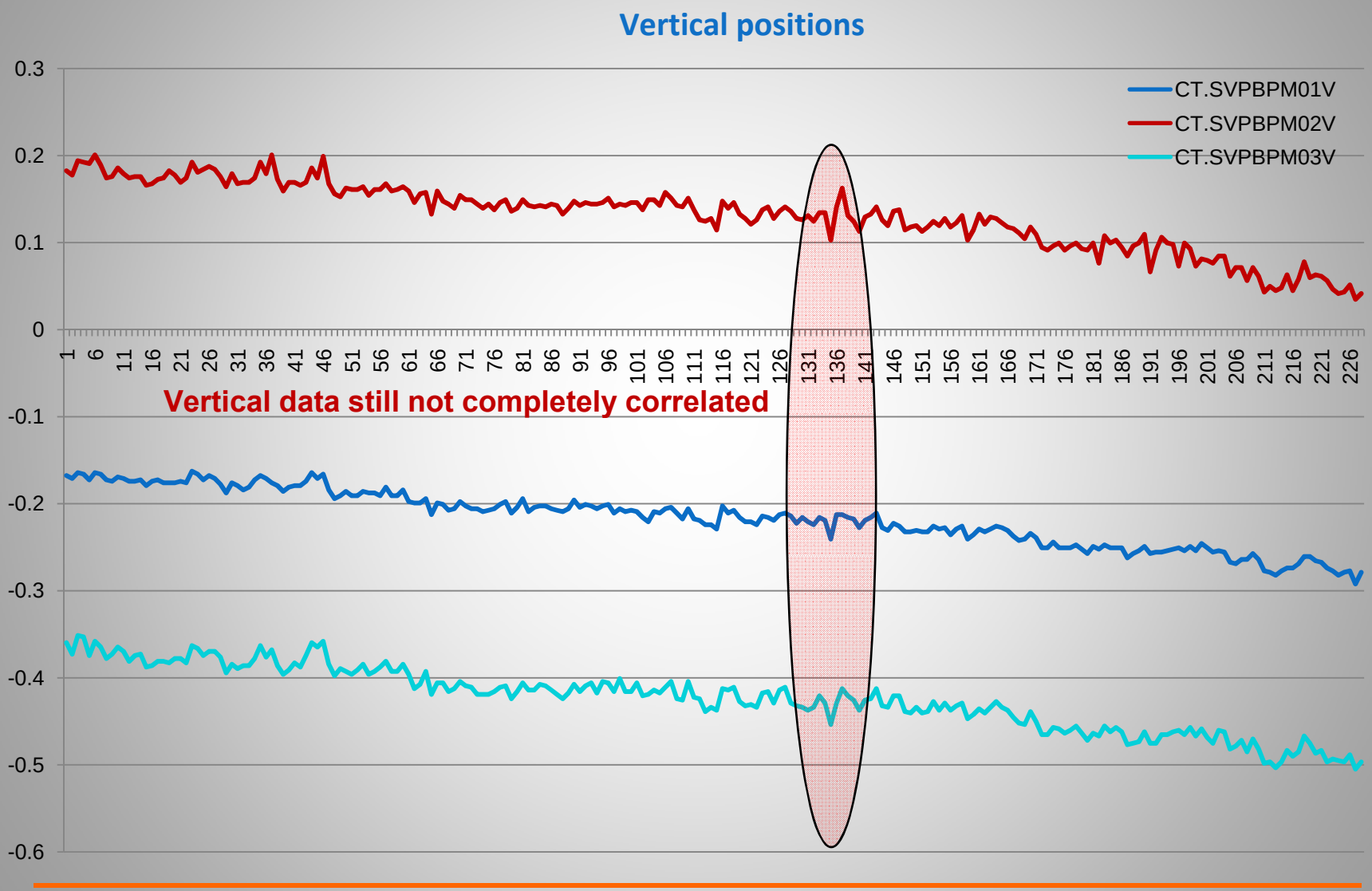

Conclusion and outlook

- The design of the PBPM has been reported in : **EUROTeV-Report-2007-008**
- Bench measurements are just finished and will be reported on in an EUROTeV Report in November 2008. Preliminary results were reported in: **EUROTEV-Report-2007-046, DIPAC TUPB03**
- The bench measured resolution for CLIC (1.5A) of 160nm / 220nm is close to the calculated one of 130nm.
- Big electrical offset has been measured, as well as a big centre residuals **(CW only)**. This hampers the centre resolution and accuracy. This is presently being studied.
- Beam tests in CTF3 has showed promising results, but beam losses in the vertical plane still has to be understood and corrected. A resolution down to 600nm has been measured. **Increasing the FE gain by ~ 10 should also help.**
- Further beam tests, **with >1A beam current**, are foreseen before the end of the year, followed by an EUROTeV report.