Geneva, 20 September 2004

43rd LHC Collimation Working Group meeting

Calibration of the Collimator Motors for the SPS and TT40 prototypes

O. Aberle, R. Assmann, A. Bertarelli, A. Cherif, E. Chiaveri, F. Decorvet,

F. Mançon, A. Marin (EST-SU), R. Perret, S. Redaelli, G. Spiezia

+ addition man power from AB-ATB

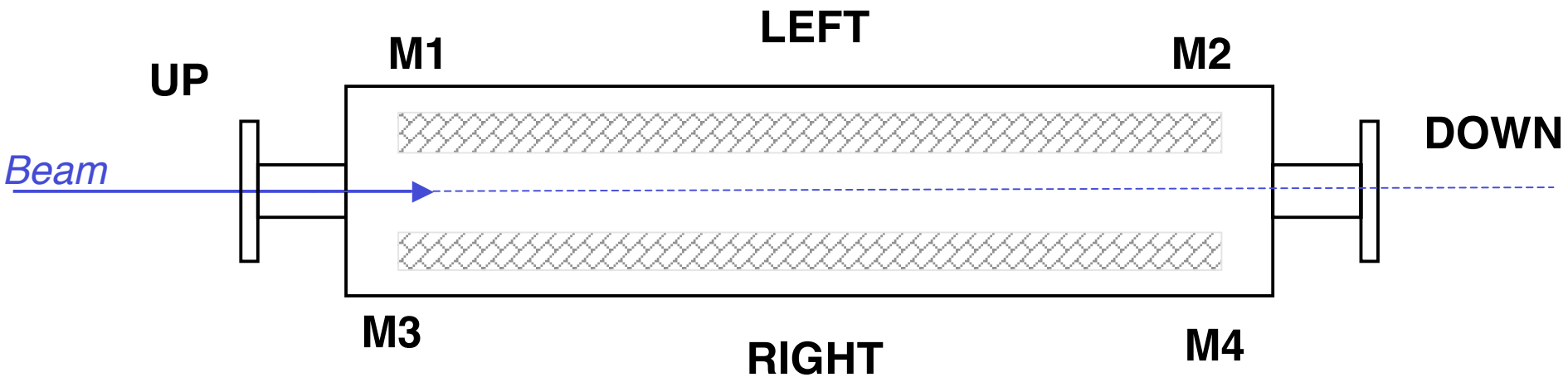
CERN AB-ABP

Switzerland

Overview of my talk:

1. Introduction - Sensor installation
2. List of required measurements
3. Measurements of single motor
4. Measurements with open collimators
5. Measurements at the metrology
6. Calibration curves
7. Palmer to test in the TT40 collimator
8. Conclusions

1. Introduction



For each collimator: 4 motors + 4 Resolver + 4 jaw positions + 2 gaps

⇨ 14 devices to move / control jaw positions and gap opening

Stepping motors Precise in relative (5-10μm) but may loose step (no absolute position)

Resolvers Count the steps of motor. Decoupled from mechanical structure (cannot see mechanical plays!)

External measurements (potentiometers, LVDT's, palmers): measure directly jaws

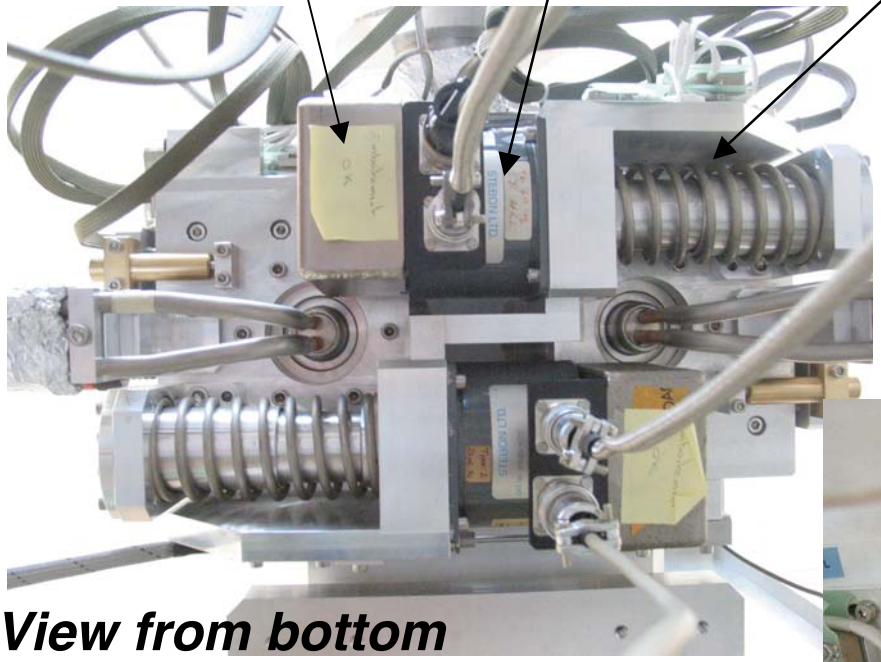
Our approach: Adjust the motor settings. Use the (calibrated) external measurement devices as a reference in the control room.

Some pictures:

Resolver

Motor

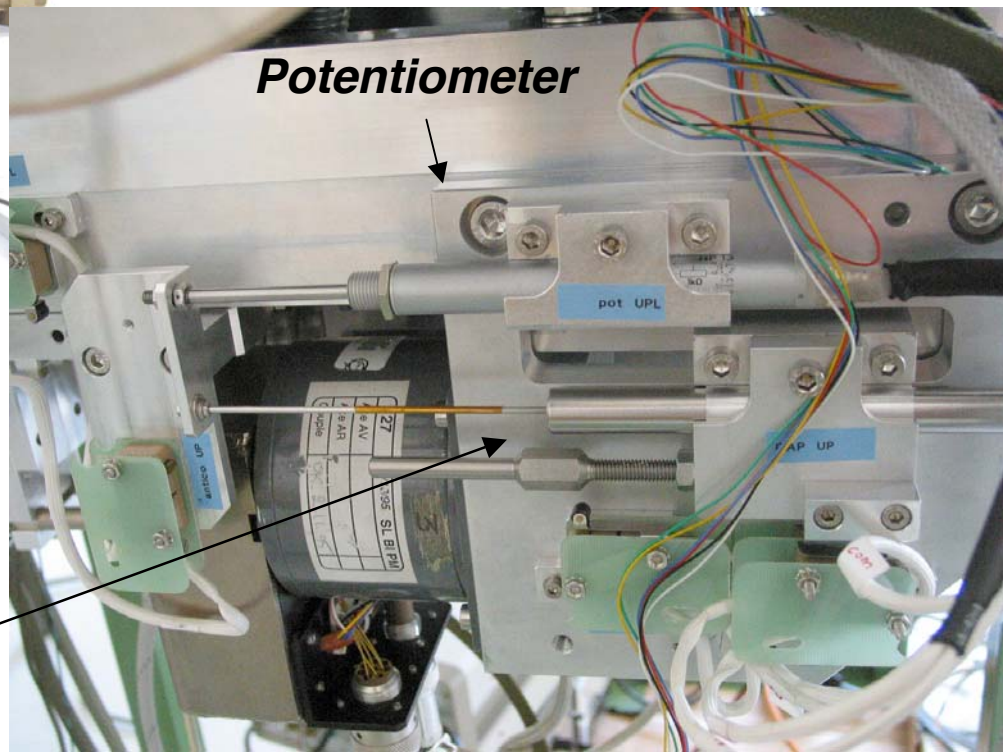
Transmission to jaw



View from bottom

Side view

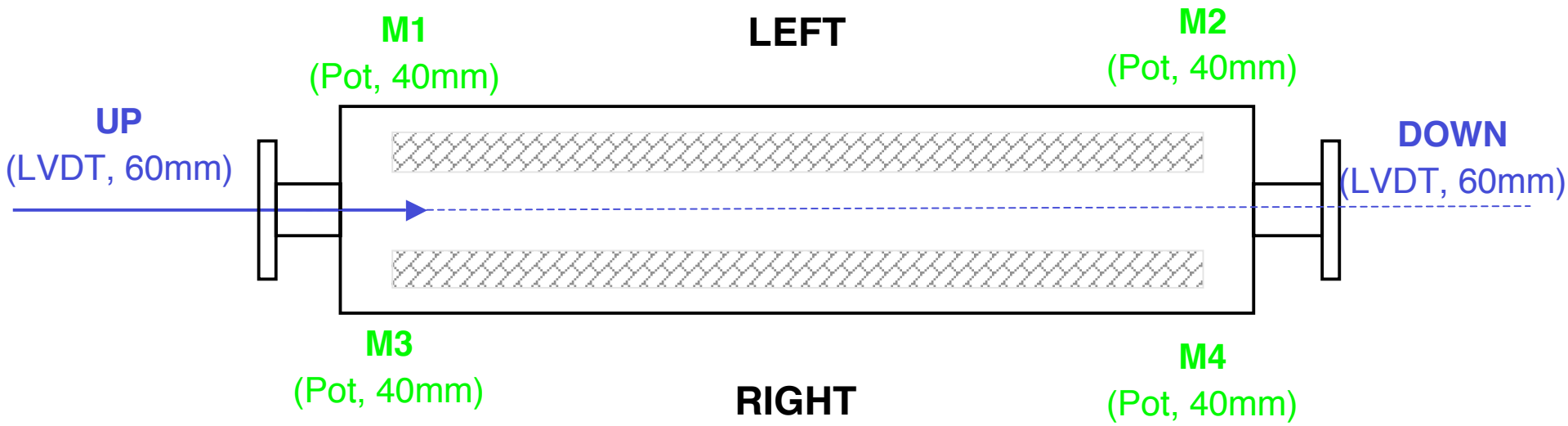
Potentiometer



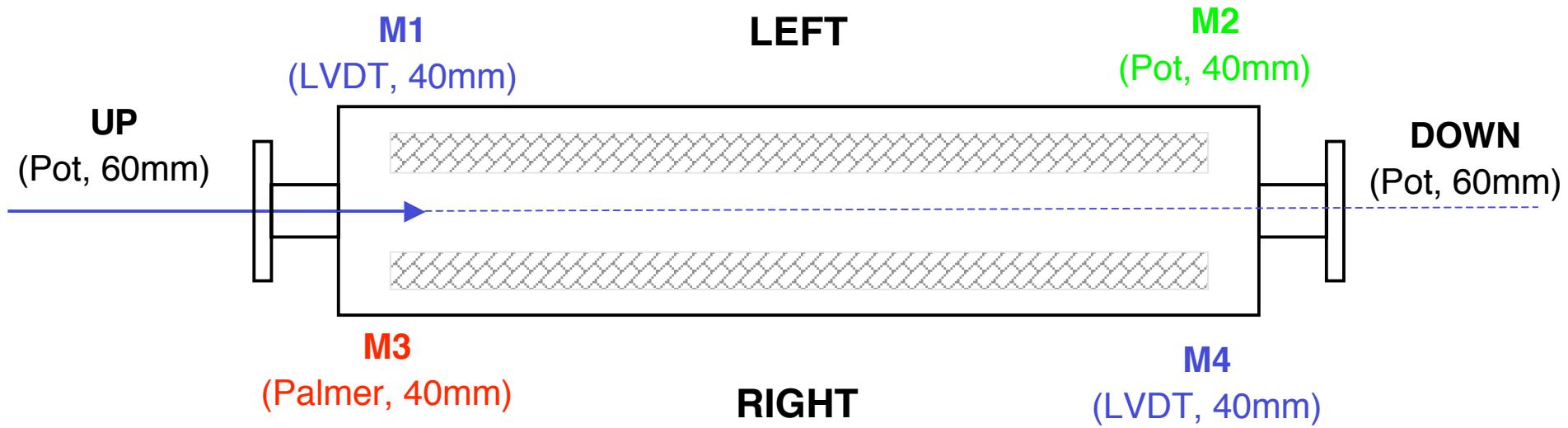
Different sensor installation for SPS and TT40 prototypes…

LVDT

SPS prototype



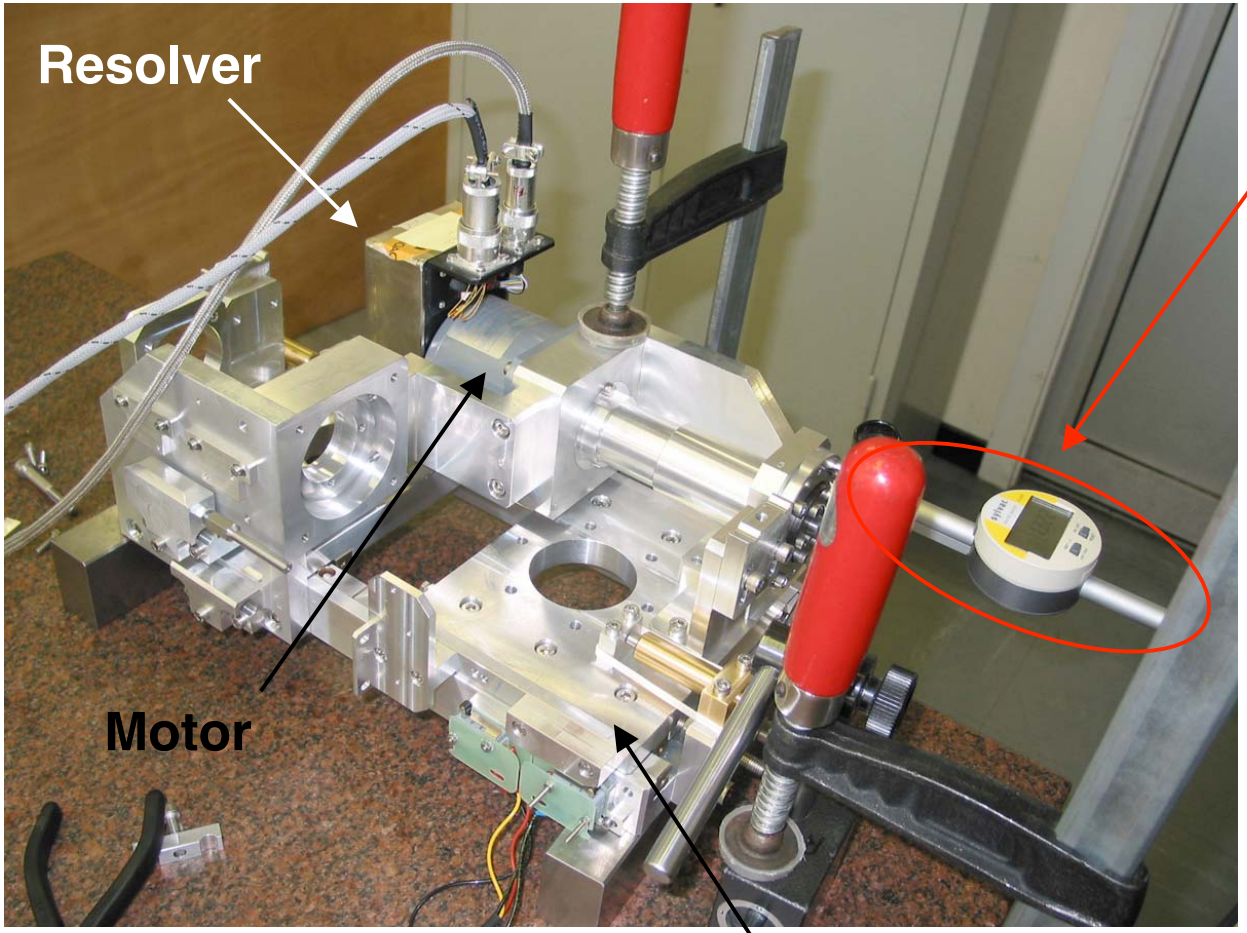
TT40 prototype



2. List of required (desired) measurements

Calibration of single motor (test bench)	• Verify correct functioning of motor and resolver • Verify step/resolver calibration
Calibration with open collimator	• Calibration of jaw displacement versus motor setting / resolver readings • Measure mechanical plays • Measure minimum jaw step
Calibration at the metrology (with close collimator)	• Provide the absolute reference with respect to the beam trajectory (fiducialization), with final sensor configuration
Calibration with long cables (300 m)	• Verify the electronics response • Possibly re-calibrate sensors (LVDT's)

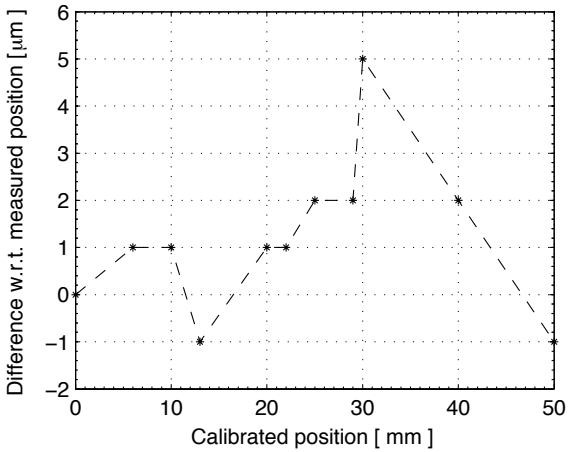
3. Measurements of single motors



High-resolution palmer (res = 1 μm)

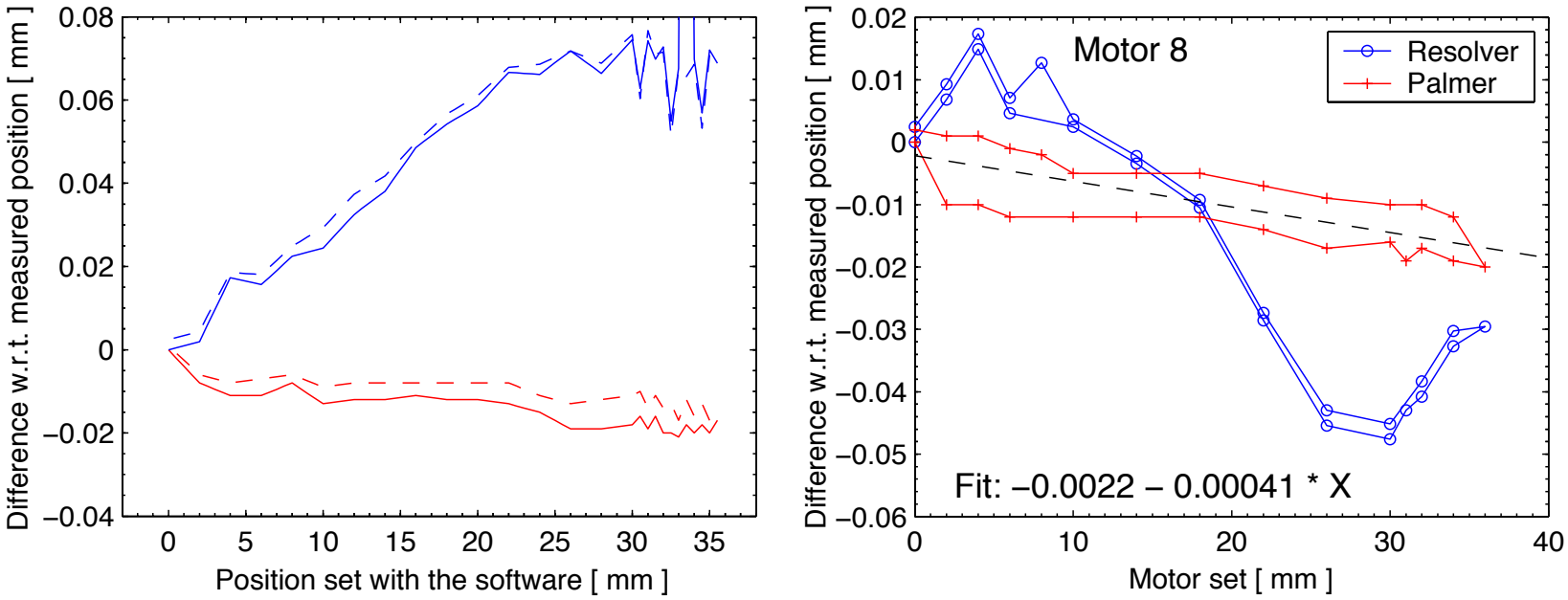
At first borrowed from
A. Marin, EST-SU

Calibrated with A. Cherif



Mechanical structure as mounted on the prototypes (also load with springs)

Resolver and palmer readings versus motor settings

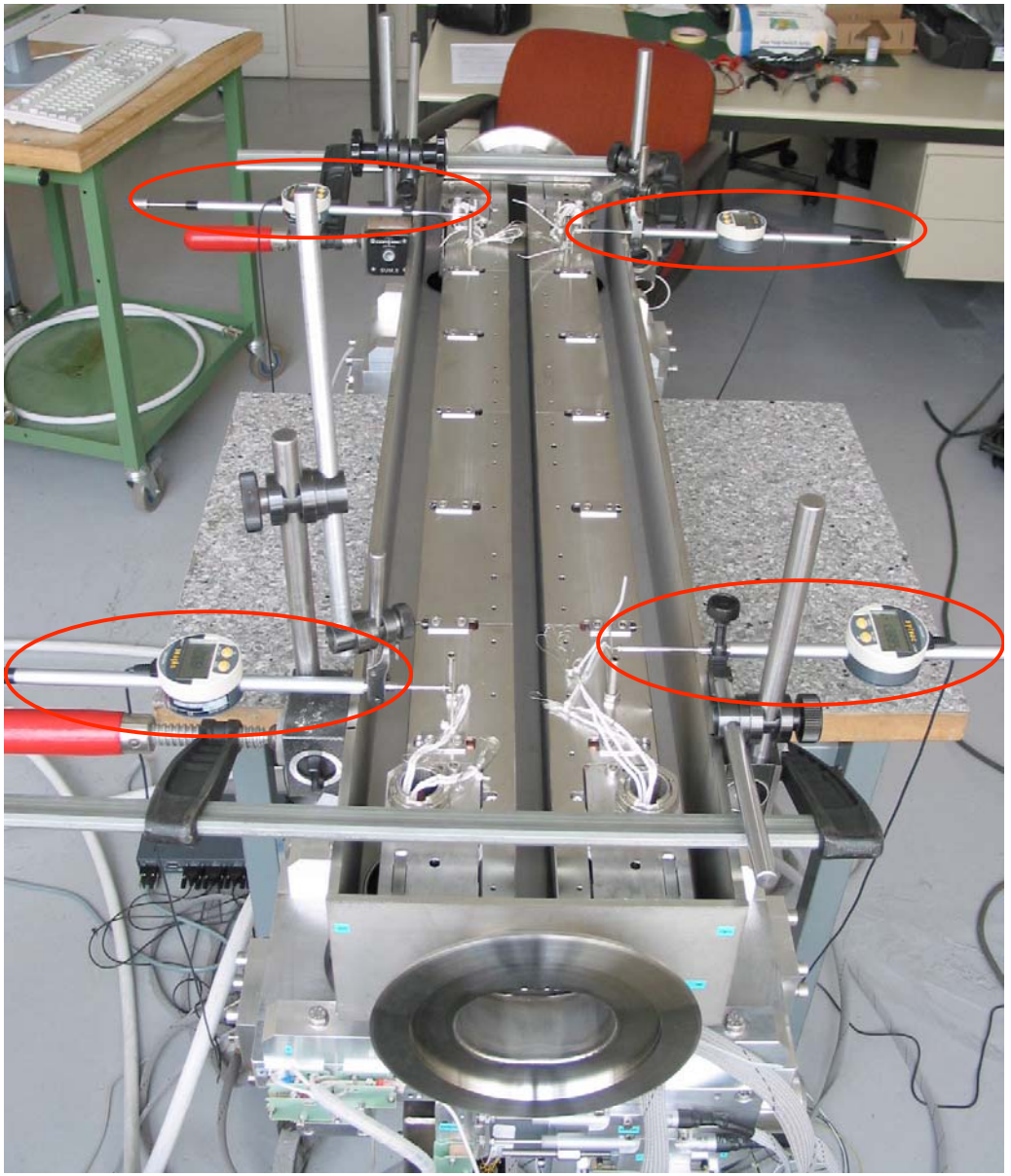


- **Resolvers** show typical **absolute errors** of up to **80 μm** (5 μm expected!!)
- Resolver measurements are reproducible
  (systematic error due to mechanical plays between resolver and motor?)
- **Motor** are better! Typical error: ≈ 0.5 μm/mm ⇒ **error ≤ 15 μm** (full range)
- *BUT*: we do not know if we loose steps! (always some jump at zero)

4. Measurements with open collimator

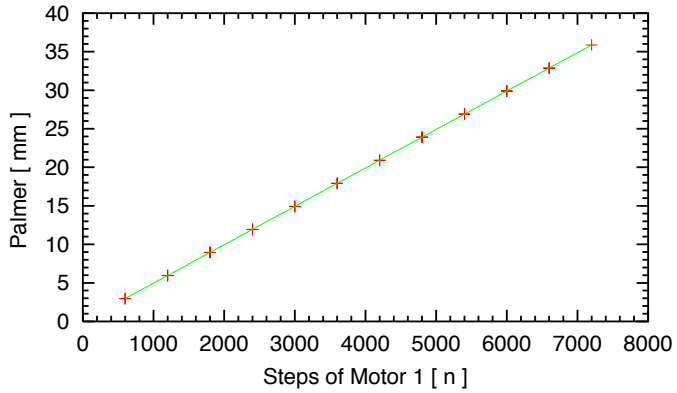
Before…

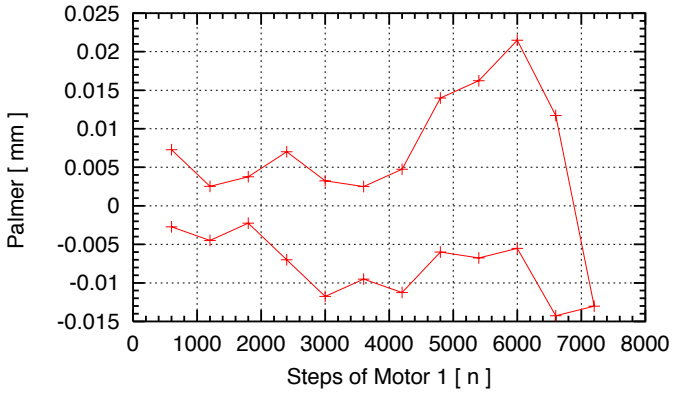
…after!

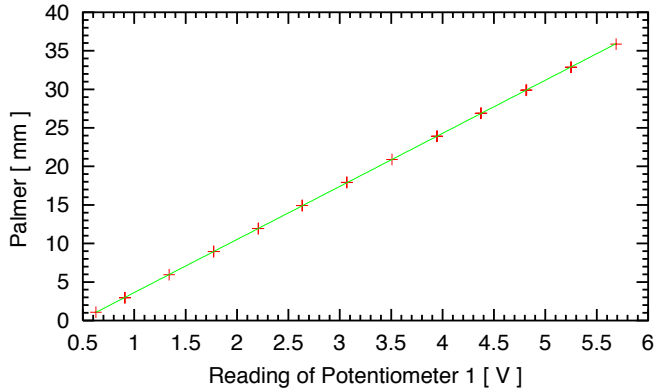


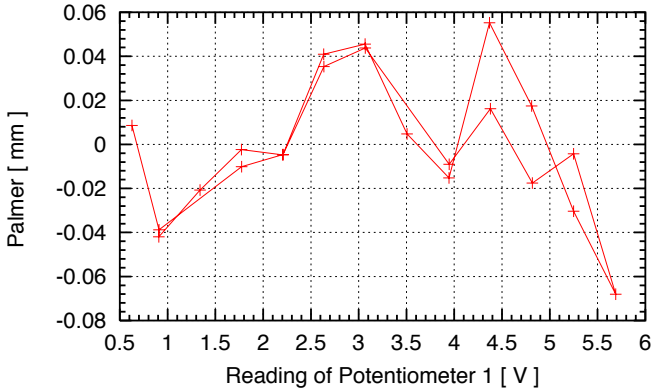
Four palmers (100 mm range, resolution ≈ 1 μm), acquisition integrated on a PC

- Calibration of motor settings, resolver readings and external devices against actual displacements independently measured on the jaws!
- Quantify response for small steps and mechanical play
- Identify problems in sensor installation



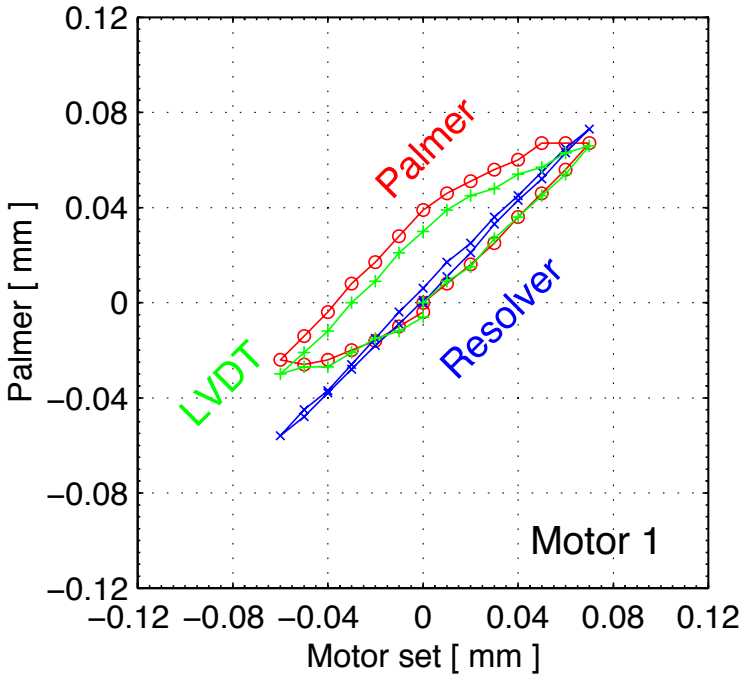




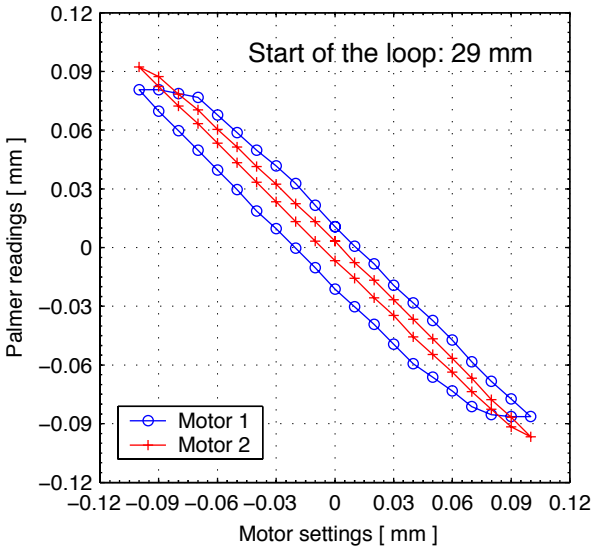


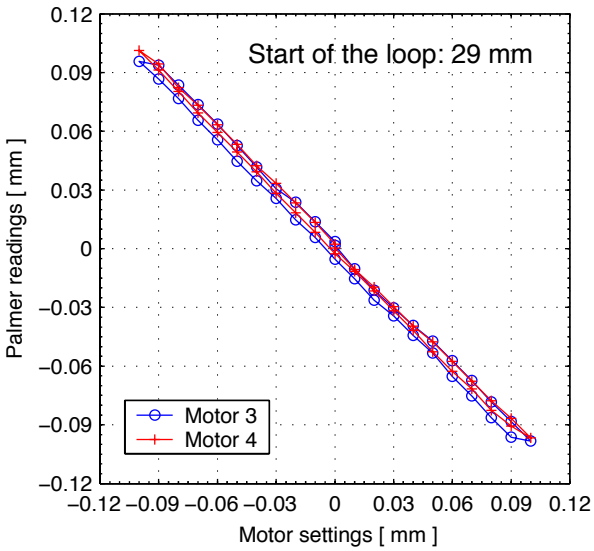
Mechanical plays quantified with hysteresis loops (±100 μm, Δ=10 μm)

Typical SPS
(less measurements)



Typical TT40

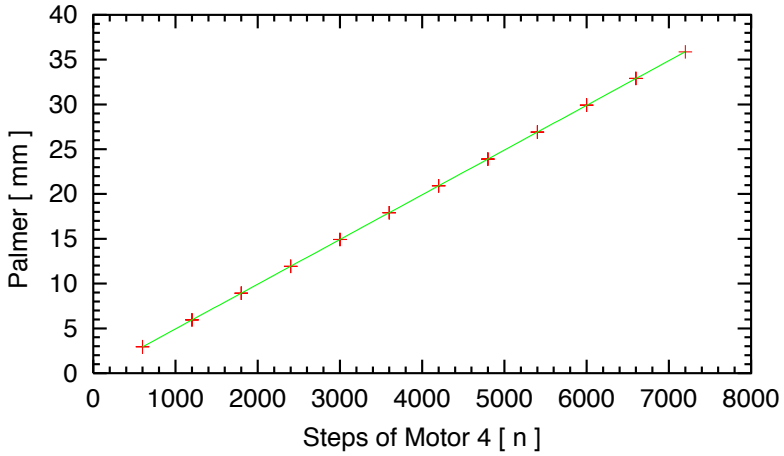


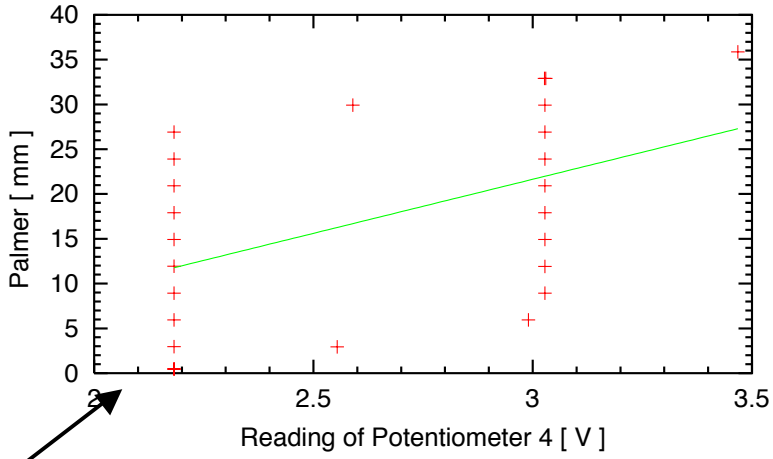


SPS: typical play **≈ 30-40 μm**

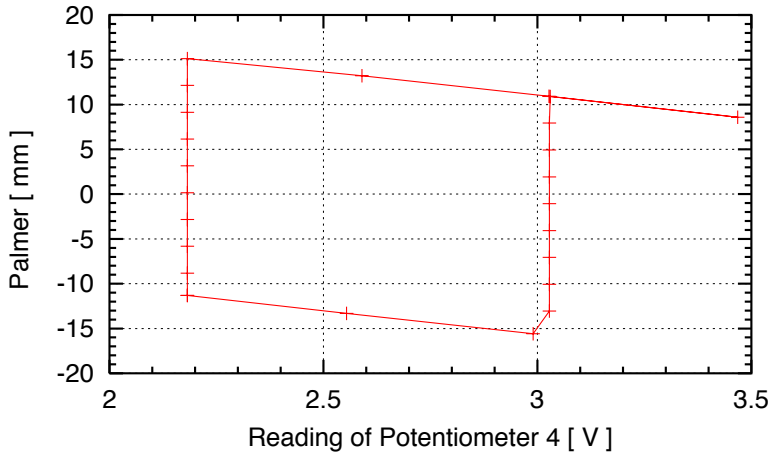
TT40: typical play **≤ 10 μm** (3 out of 4)

Lab tests are useful, indeed: found a badly fixed potentiometer



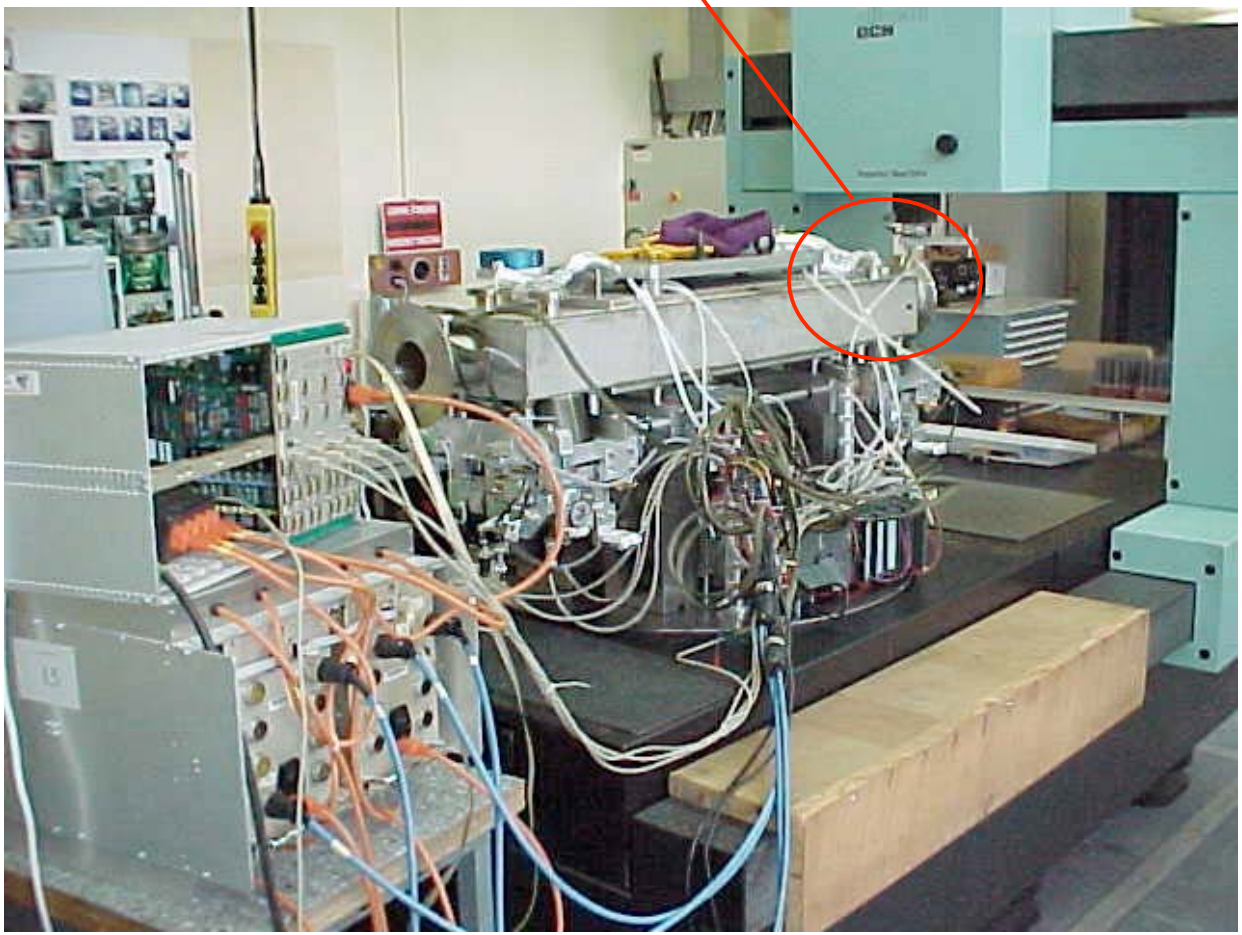


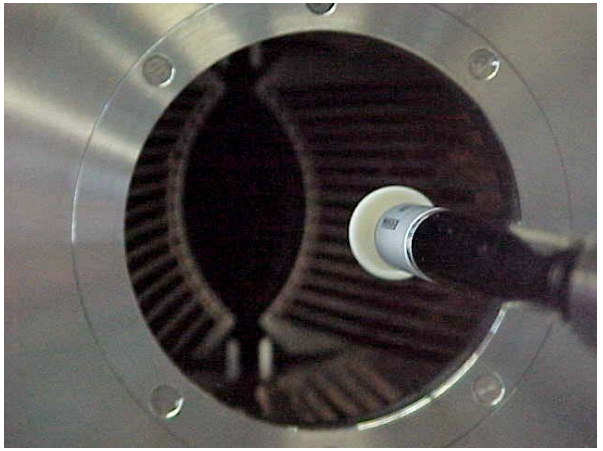
Found one potentiometer noon firmly fixed.

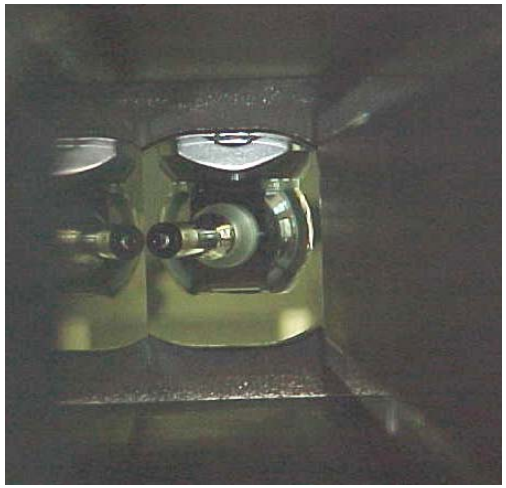


5. Measurements at the metrology

Absolute error with this setup ≈ 3 μm

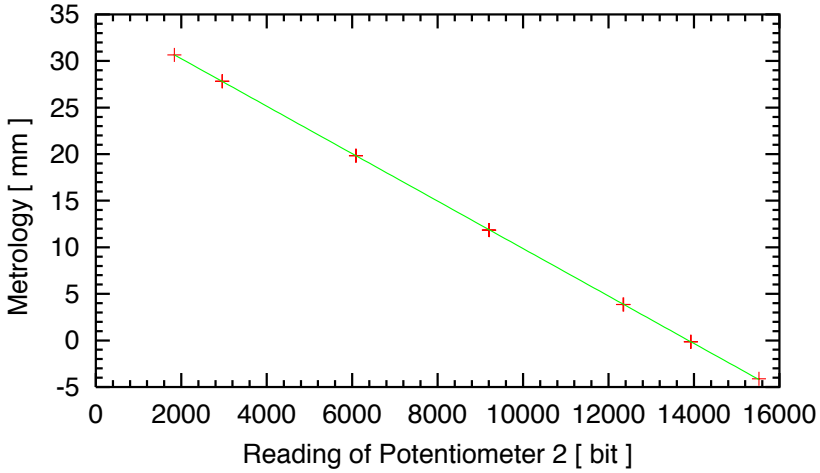


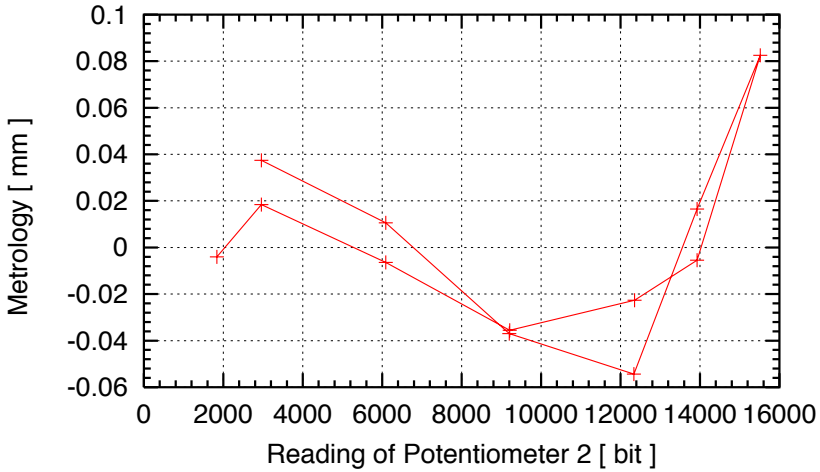




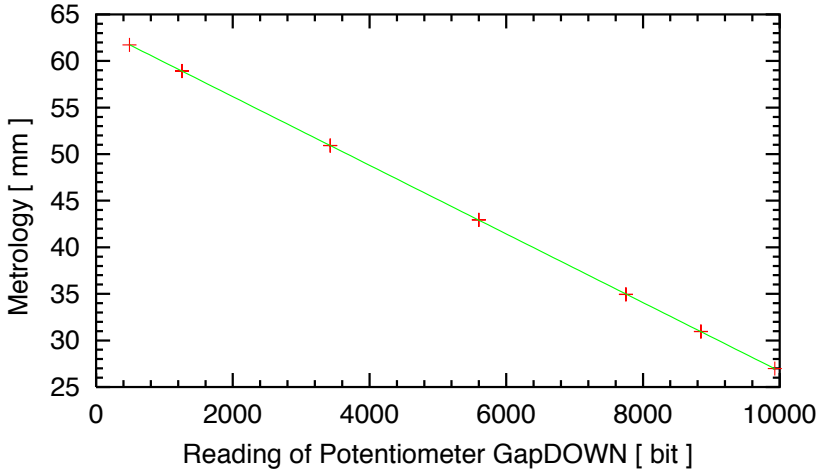
Now final calibration referred to the ideal beam trajectory in the tunnel (fiducialization)!

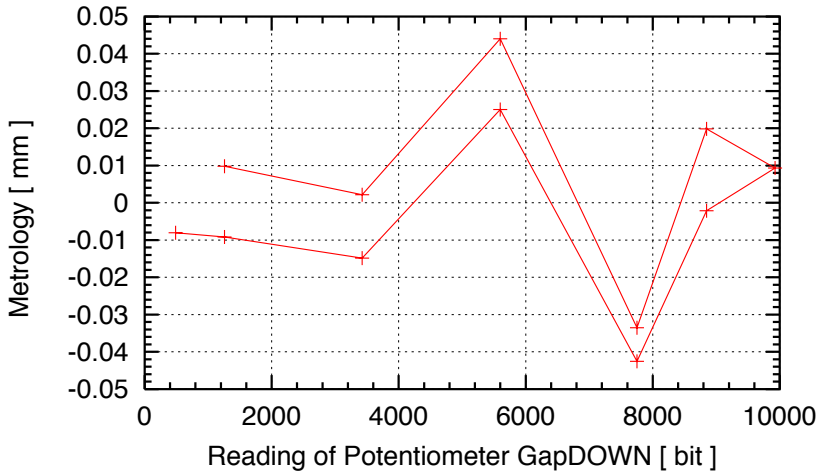
One jaw - calibration of a potentiometer





Calibration of the gap (potentiometer)





6. Calibration curves

Provided for all motors, resolvers and - in particular - for potentiometers and LVDT's.

To be implemented in the software for the data analysis, to be used in the control room (high priority!!)

SPS prototype

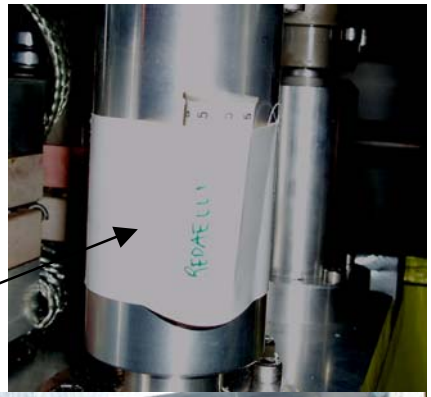
```
The fitting constants of the linear fit
F = A x V + B
are given. The dimension of A is [mm/V]
while B is given in [mm].
Pot1:     A = +17.4584 ; B = -34.4252
Pot2:     A = +17.4369 ; B = -32.4034
Pot3:     A = -17.4695 ; B = +32.8810
Pot4:     A = -17.4225 ; B = +36.1236
LVDT up:  A = +3.00520 ; B = +22.7898
LVDT dn:  A = +2.98320 ; B = +23.0921
```

TT40 prototype

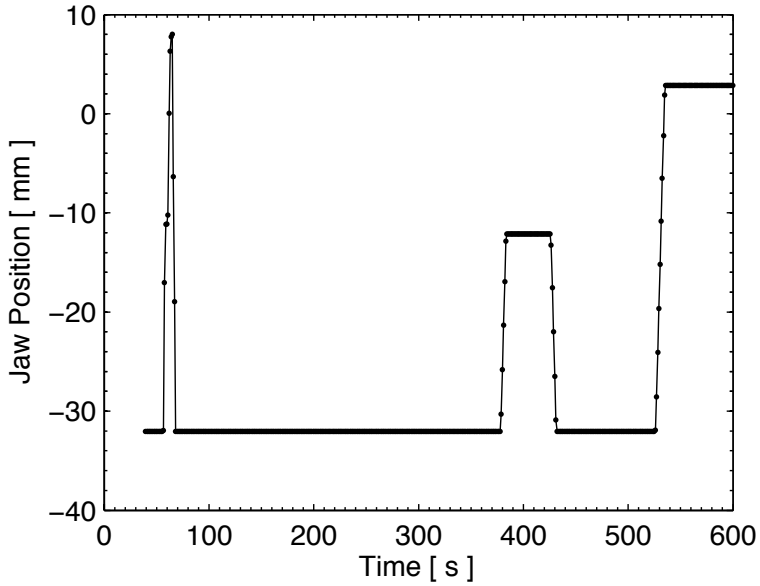
```
Point 1 (LVDT): A = +1.9918 ; B = +13.3360
Point 2 (Pot) : A = -0.0025477 ; B = 35.3418
Point 4 (LVDT): A = -1.9926 ; B = -13.4796


Gap up        : A = -0.0036982 ; B = 63.6387
Gap down      : A = -0.0036850 ; B = 63.5484
```

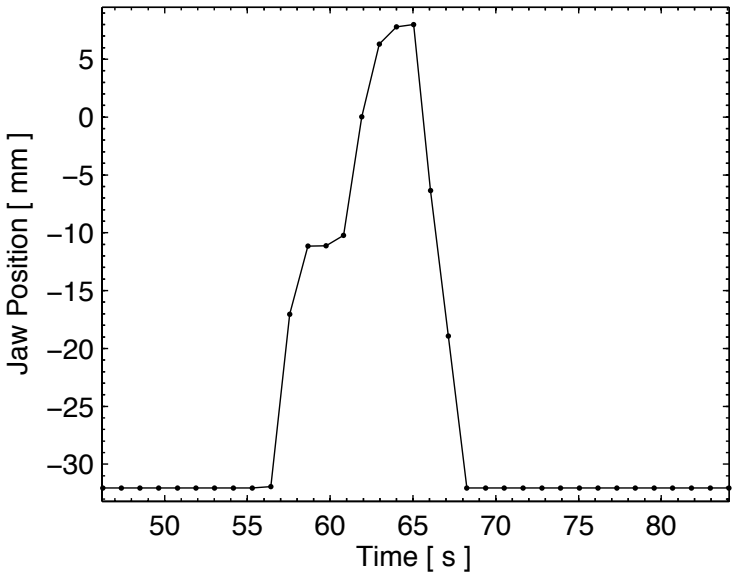
7. High-resolution palmer tested in the TT40 experiment

- Offered (almost) for free by Sylvac (HHW)
- Calibrated for us with long cable (30 m); measurement range of **50 mm**
- Maximum error ≈ **3 μm**, reproducibility **0.35 μm**, resolution **0.1 μm**
- Software for remote reading prepared by **G. Spiezia**: continuous data acquisition and remote control of acquisition box (zeroing, change resolution)
- Successfully tested on 06/09 (installation, acquisition, software)
- Correct functioning with radiation to be assessed



Dosimeter





Conclusions

✓ Resolvers: absolute error ≈ 80 μm (expected 5 μm).

In any case, *not enough* because measure on the other side of the mechanical structure

✓ Potentiometers: Resolution ≈ 40-50 μm (some sensor better, ≈ 20 μm)

✓ LVDT's: Resolution ≤ 15 μm in laboratory tests. However, too delicate?

(re-calibrations regularly needed - feasible for > 500 sensors in radiation environment?)

✓ Palmer: Resolution ≤ 1 μm; test with radiation will tell if it can be okay.

✓ Mechanical response: ♦ Mechanical play: 40 μm for SPS prototype
≤ 10 μm for TT40 prototype
♦ Minimum step for jaws = 10 μm

Issues for future

Implementation of the calibration curves!

Re-calibration of the LDVT's with long cables (some not working)

Problem with reading of the potentiometers?

Updates of MIDI software

Prototype 3: Do we have enough motors?
Man power for the calibration?

How well can we control and know and REPRODUCE the jaw positions of the prototype in the laboratory?

50 μm ?

Surface flatness:

40-60 μm

Total control/knowledge in laboratory:

≈ 100 μm = 0.5 σ (LHC, top energy)

How can we control / know the collimator in the tunnel??

???