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Calibration of the Collimator Motors for the SPS and TT40 prototypes

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+ addition man power from AB-ATB

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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 (5-10 µm) 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
- LVDT

Different sensor installation for SPS and TT40 prototypes…
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

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

High-resolution palmer (res = 1 μm)
At first borrowed from A. Marin, EST-SU

Calibrated with A. Cherif

![Graph showing the difference between calibrated and measured positions.](image-url)
Resolver and palmer readings versus motor settings

- **Resolvers** show typical **absolute errors** of up to 80 \( \mu m \) (5 \( \mu m \) expected!!)
- Resolver measurements are **reproducible**
  (systematic error due to mechanical plays between resolver and motor?)
- **Motor** are better! Typical error: \( \approx 0.5 \! \mu m/mm \Rightarrow \text{error} \leq 15 \! \mu m \) (full range)
- **BUT**: we do not know if we lose steps! (always some jump at zero)
4. Measurements with open collimator

Before…

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

…after!
- 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)

[Graph showing SPS data with Palmer, LVDT, and Resolver readings.]

SPS: typical play ≈ 30-40 µm

**Typical TT40**

[Graph showing TT40 data with Motor 1, Motor 2, Motor 3, and Motor 4 readings.]

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 \(\approx 3 \, \mu m\)
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!!)

The fitting constants of the linear fit $F = A \times V + B$
are given. The dimension of $A$ is [mm/V] while $B$ is given in [mm].

Po1: $A = +17.4584 ; B = -34.4252$  
Po2: $A = +17.4369 ; B = -32.4034$  
Po3: $A = -17.4695 ; B = +32.8810$  
Po4: $A = -17.4225 ; B = +36.1236$

LVDT up: $A = +3.00520 ; B = +22.7898$
LVDT dn: $A = +2.98320 ; B = +23.0921$

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: $A = -0.0036850 ; B = 63.5484$

SPS prototype

TT40 prototype
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
Conclusions

✓ Resolvers: absolute error \(\approx 80\ \mu m\) (expected \(5\ \mu m\)).
   In any case, *not enough* because measure on the other side of the mechanical structure

✓ Potentiometers: Resolution \(\approx 40-50\ \mu m\) (some sensor better, \(\approx 20\ \mu m\))

✓ LVDT’s: Resolution \(\leq 15\ \mu m\) in laboratory tests. However, too delicate?
   (re-calibrations regularly needed - feasible for > 500 sensors in radiation environment?)

✓ Palmer: Resolution \(\leq 1\ \mu m\); test with radiation will tell if it can be okay.

✓ Mechanical response:
   ♦ Mechanical play: \(40\ \mu m\) for SPS prototype
   \(\leq 10\ \mu m\) for TT40 prototype
   ♦ Minimum step for jaws = \(10\ \mu m\)

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 $\mu$m ?

Surface flatness:

40-60 $\mu$m

Total control/knowledge in laboratory:

$\approx 100 \, \mu m = 0.5 \, \sigma$ (LHC, top energy)

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

???