Review on collimator movement with stepping motors

Mechanical design and SPS results

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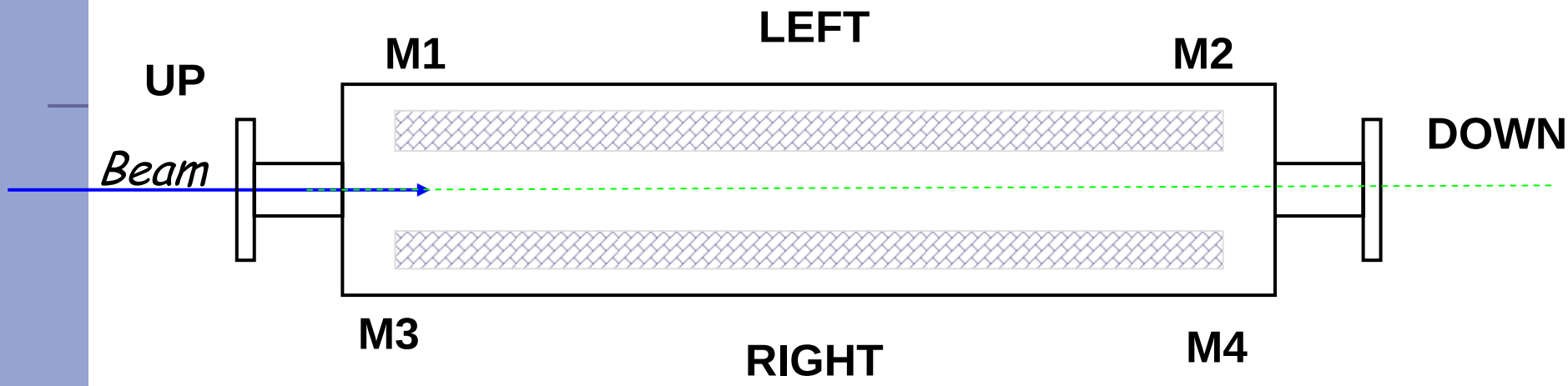
Design work from many colleagues in TS/MME,
Stefano Redaelli for the SPS test results
Photos from P. Francon

Overview

- Mechanical design
- Motion of collimator jaws
- Auto retraction
- SPS tests
- Results from SPS tests
- Results on Prototype No. 3
- Conclusions

Mechanical design



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

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

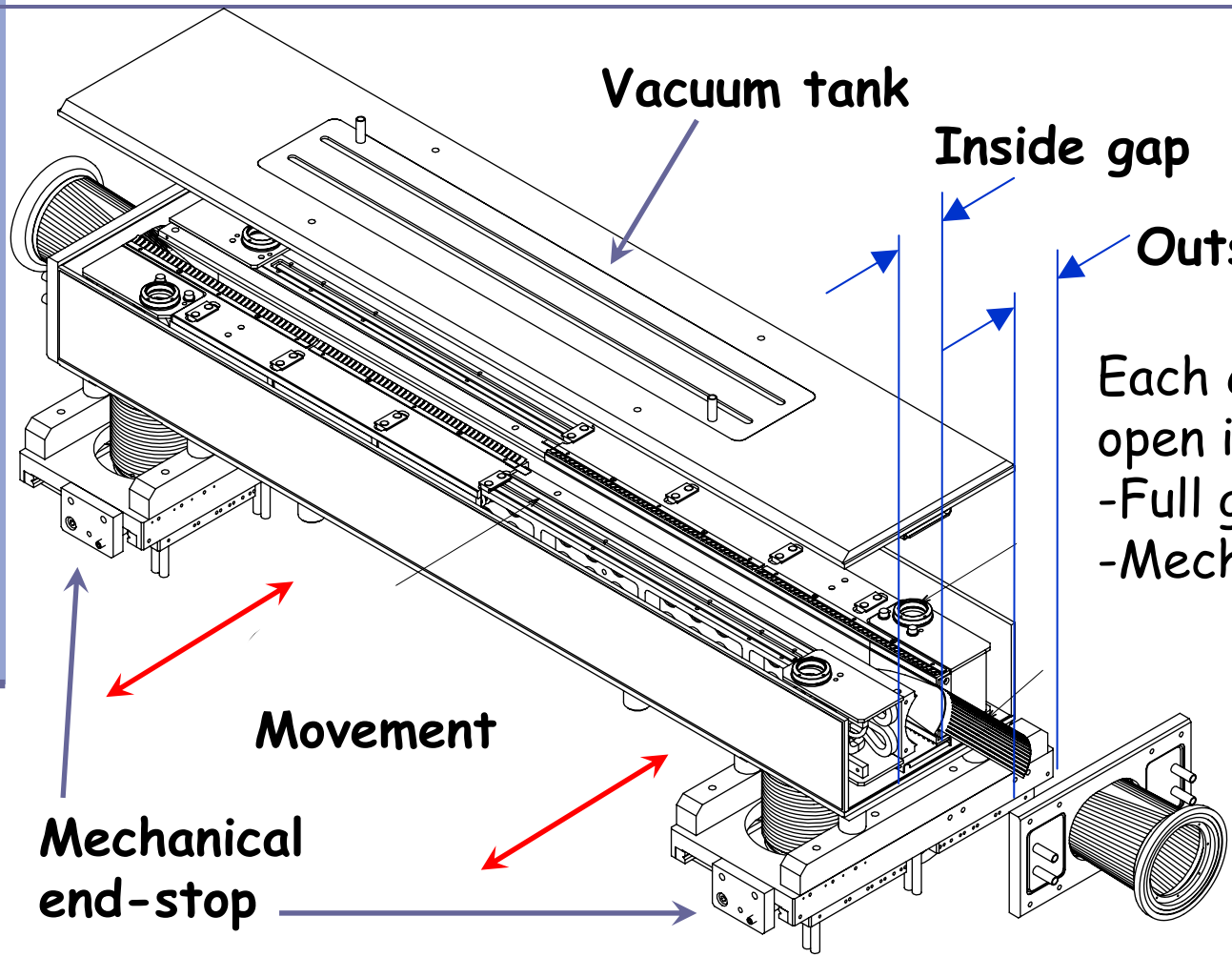
Stepping motors Precise in relative (5-10μm) but may loose steps

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

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

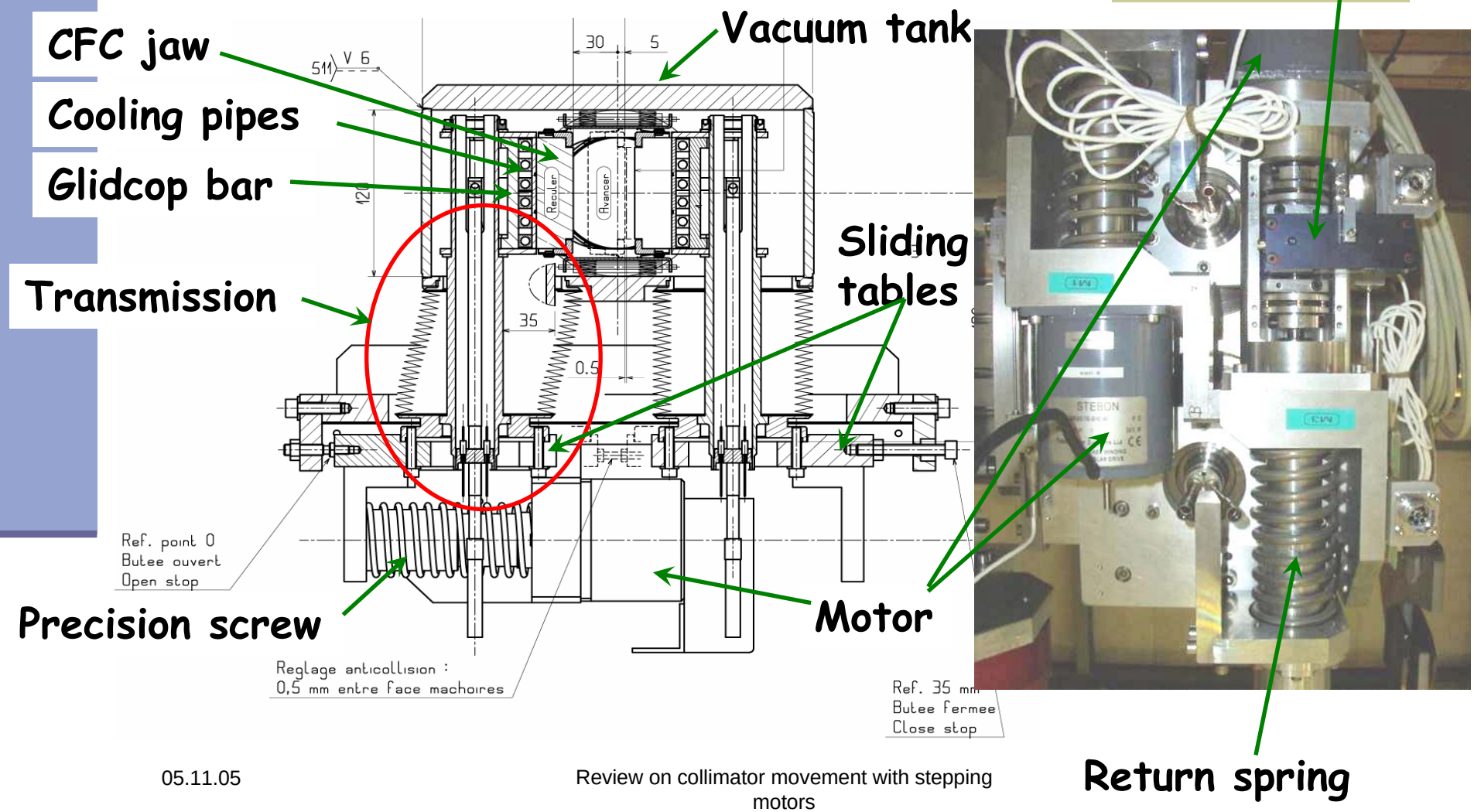
Our approach: Adjust the motor settings. Use the (calibrated) external measurement devices as a reference in the control room.

Mechanical design

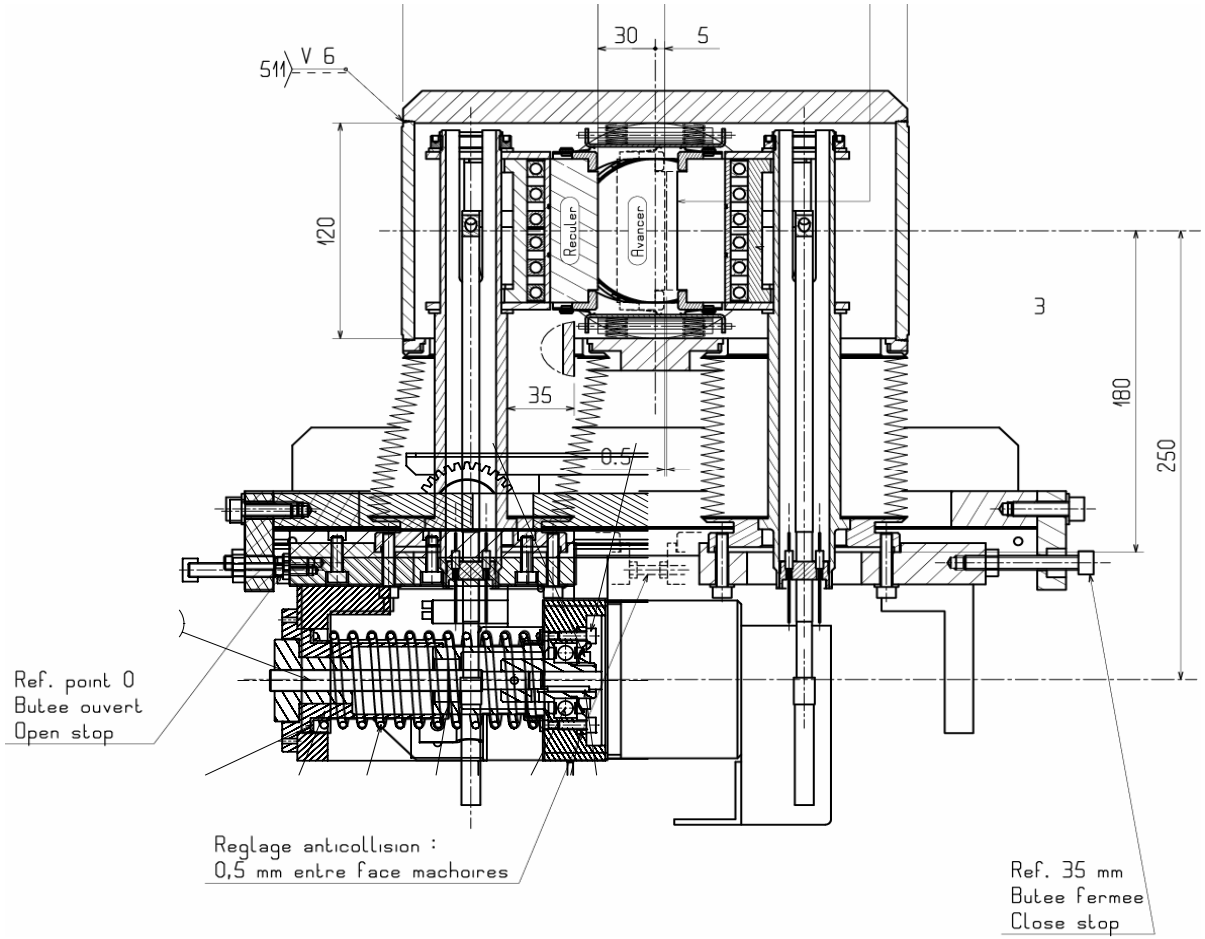


Each collimator measured open in metrology:
-Full gap
-Mech. stop/Jaw surface

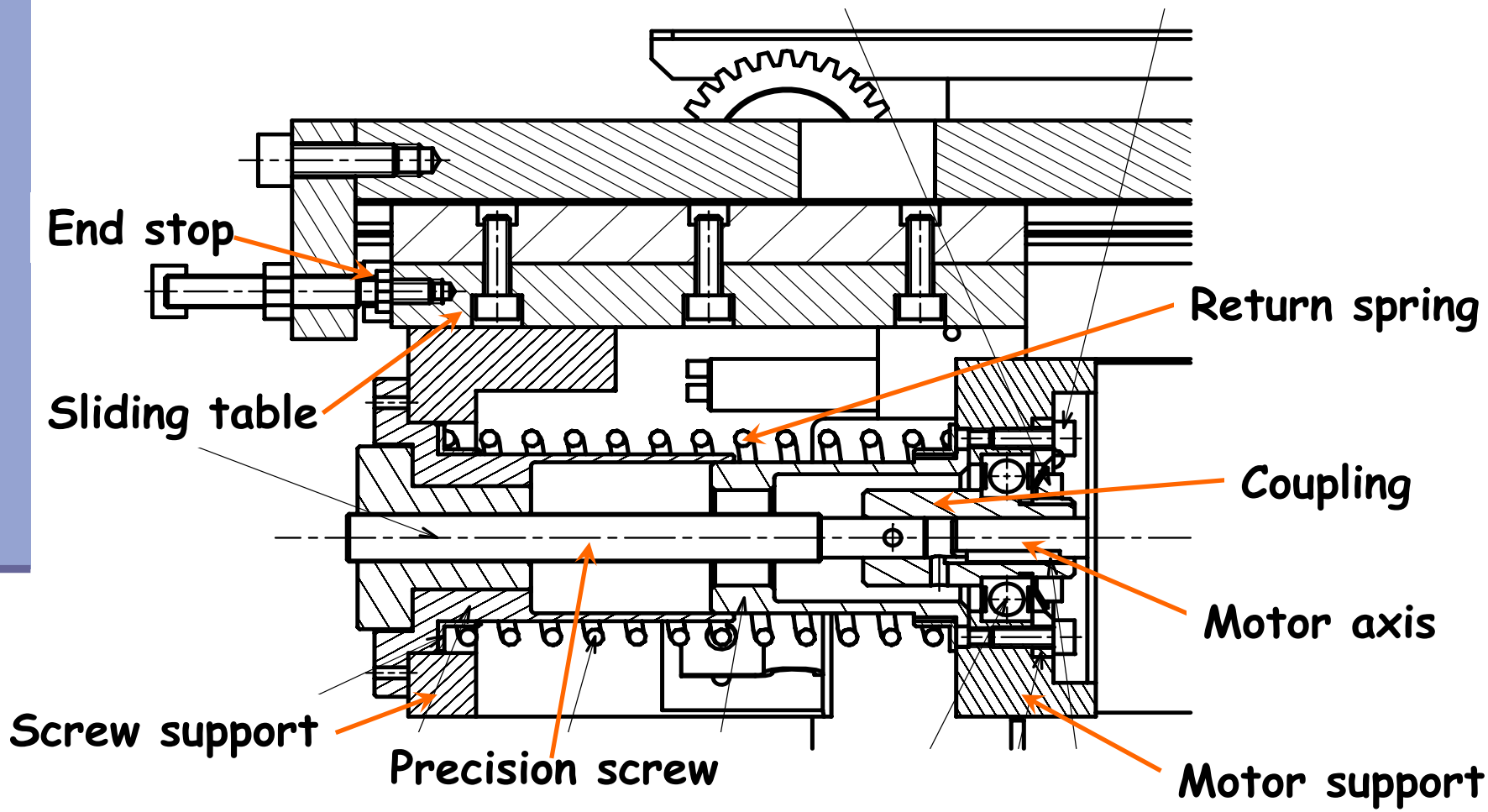
Motion of collimator jaw



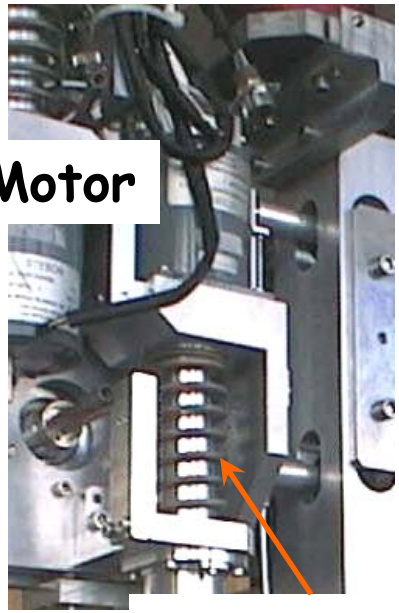
Motion of collimator jaw

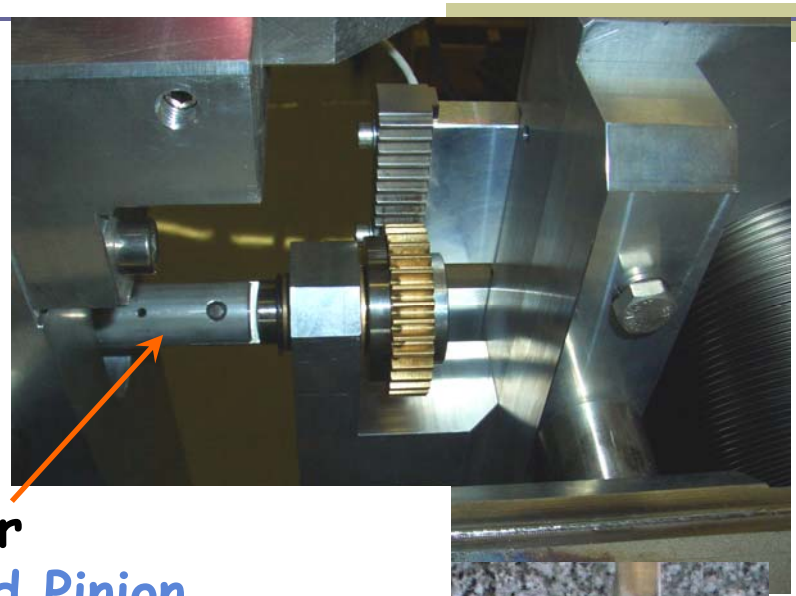


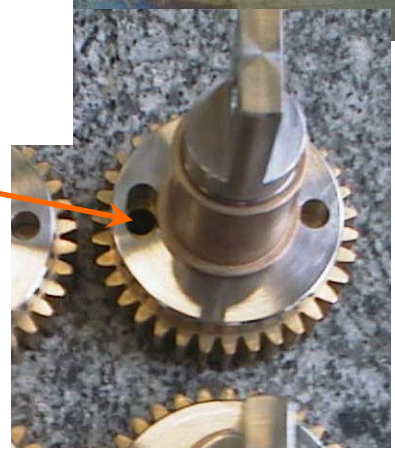
Motion of collimator jaw



Auto retraction, Angle limitation







Auto retraction, Angle limitation

Auto retraction

- One system: 2 sets of springs (dia. 5 and 6.3 mm) available
- for 3 types of collimators (CFC, CU and W jaw material)
- for 4 different orientations (0, 90, 45 and 135 °)
- Works in case of power cut (condition: Mechanics Ok)
- Tested vertically with 15 kg loaded (Tungsten case)
- Limitations: To start movement, minimum spring pre-load needed
- Back up: One motor can drive the jaw out against the angle limitation system

Angle limitation

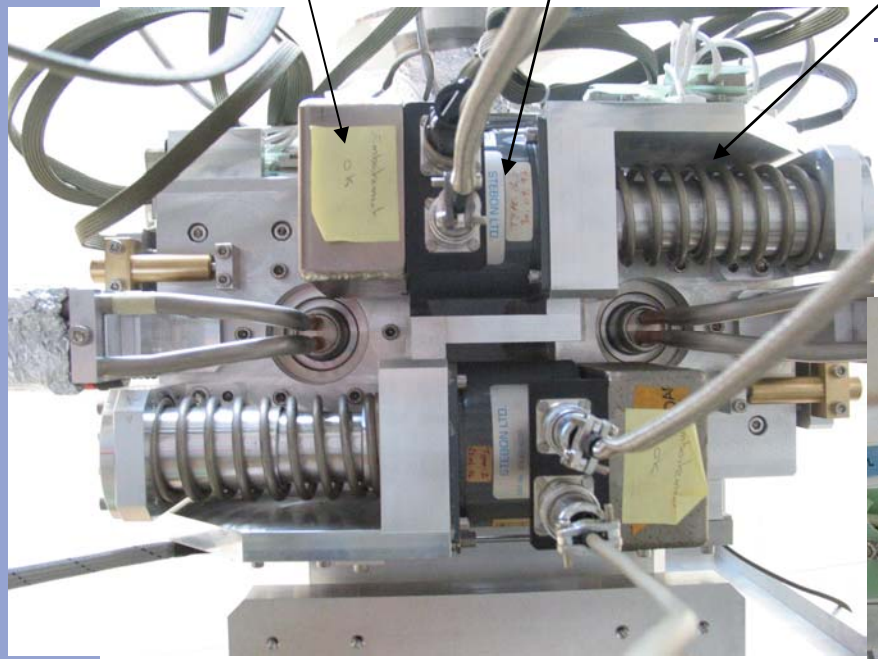
- Given by the mechanical play (3 mm on 1 m jaw length)
- Blocks the angle (with powered motor)

SPS tests

Resolver

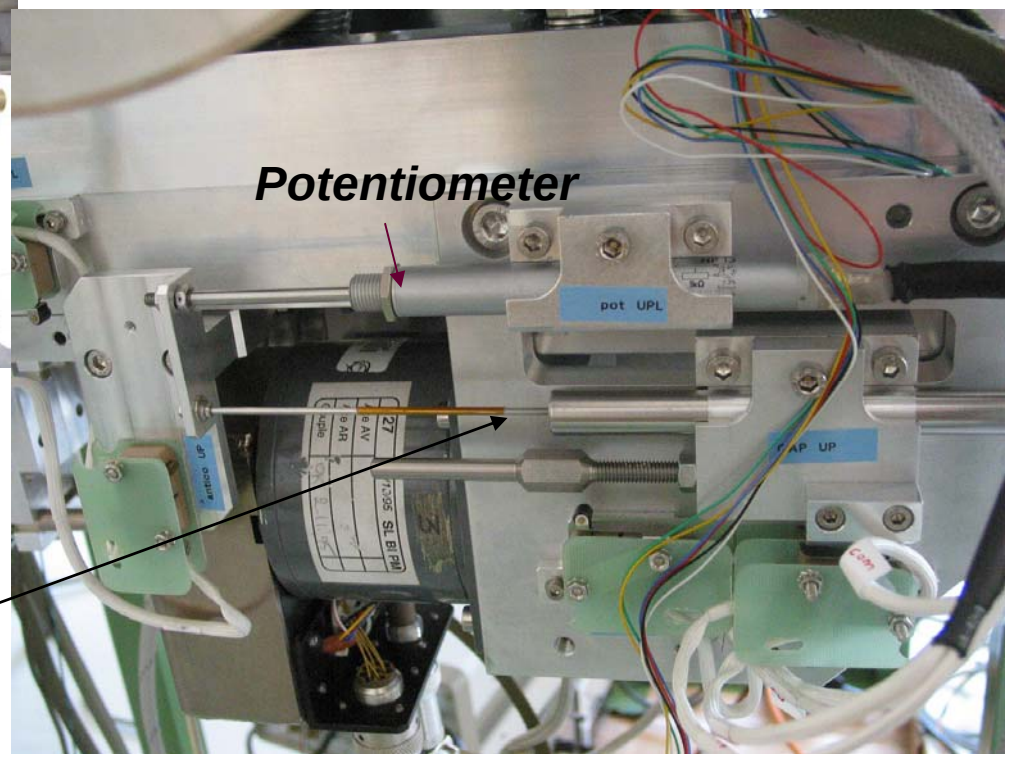
Motor

Transmission to jaw



View from bottom

Side view



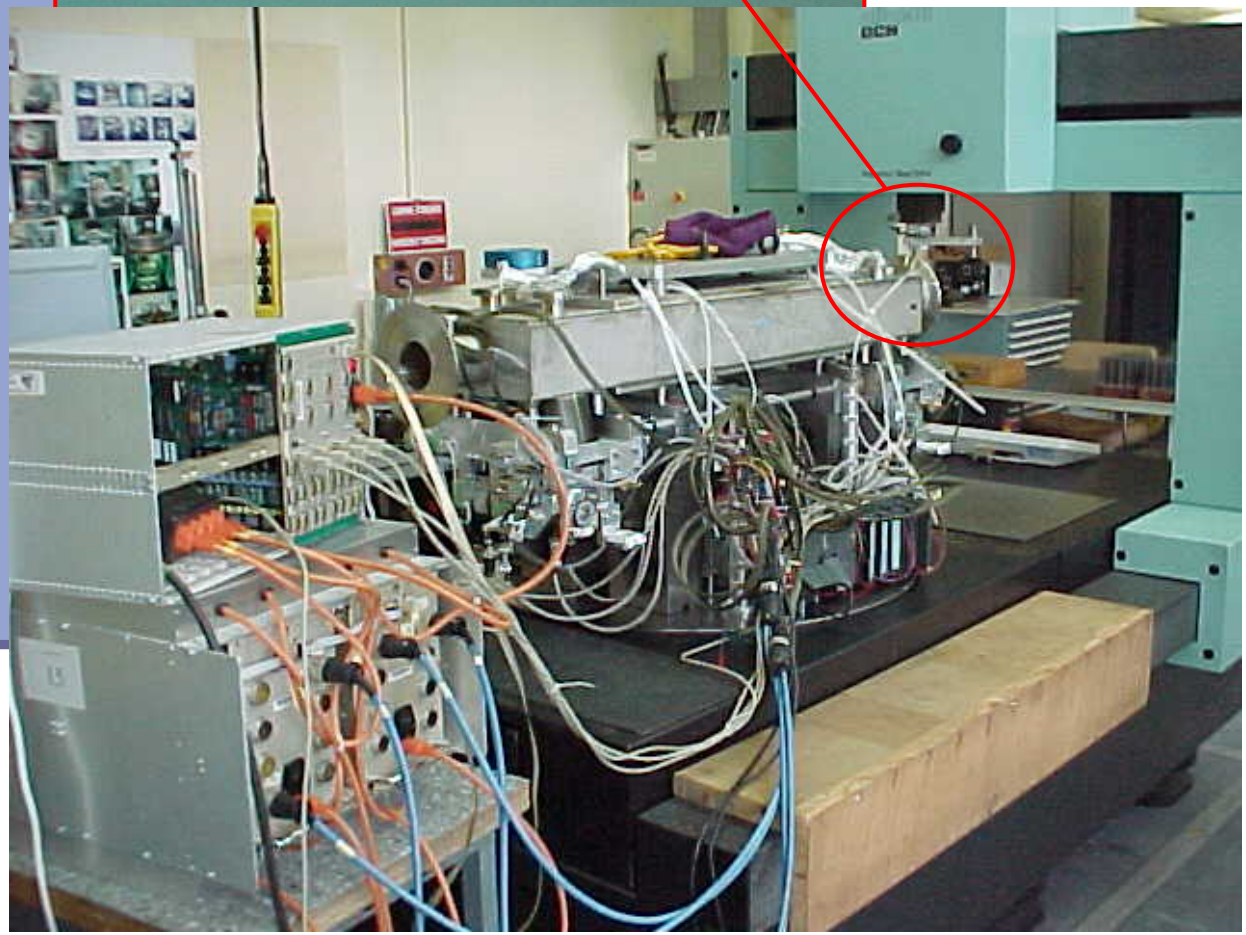
Different sensor installation for SPS and TT40 prototypes…

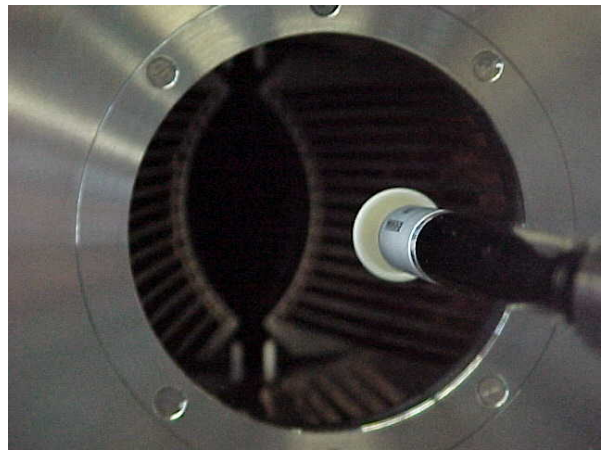
Results from SPS tests

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 with final sensor configuration

Measurements at the metrology

Absolute error with this setup ≈ 3 μm



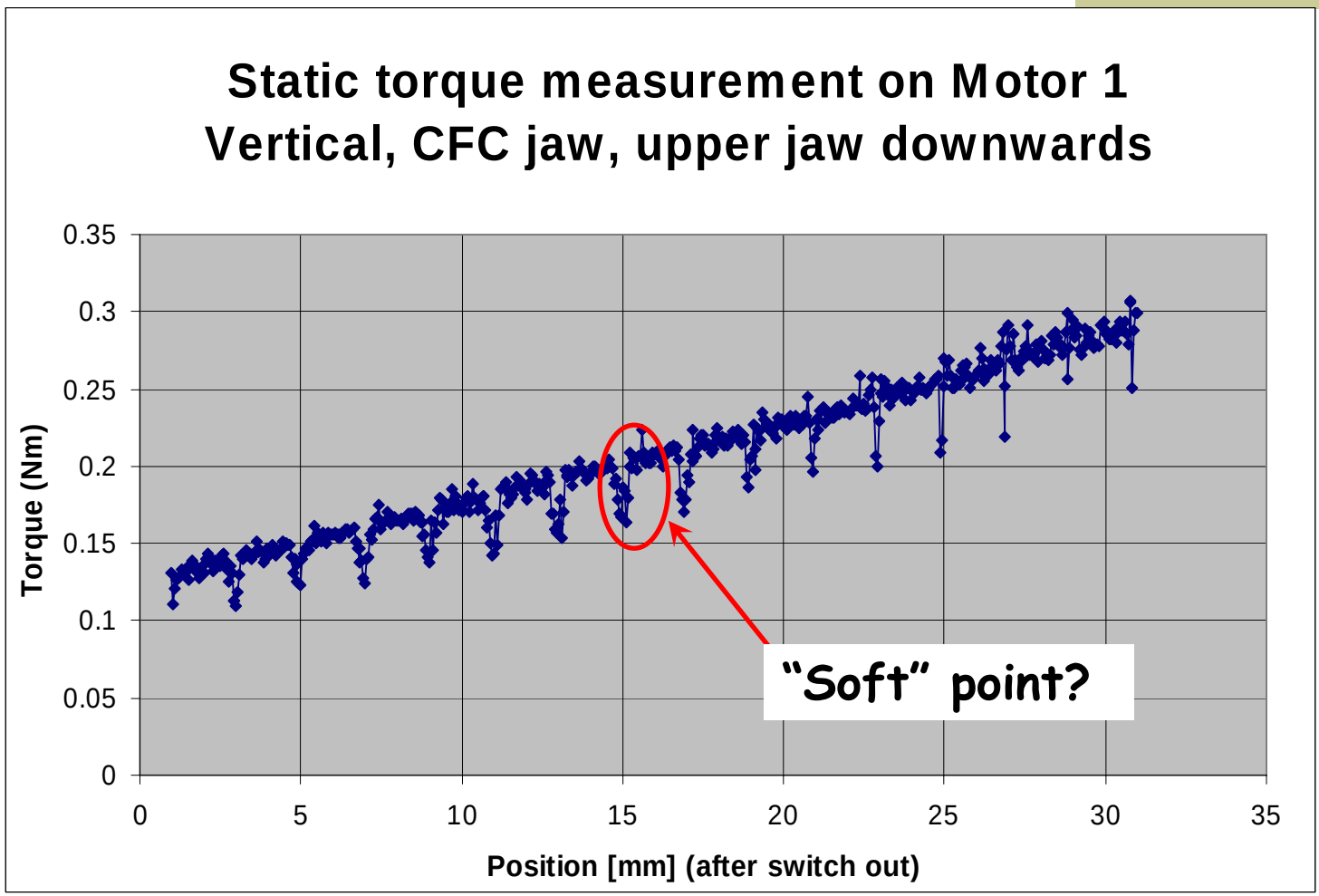


Results from SPS tests

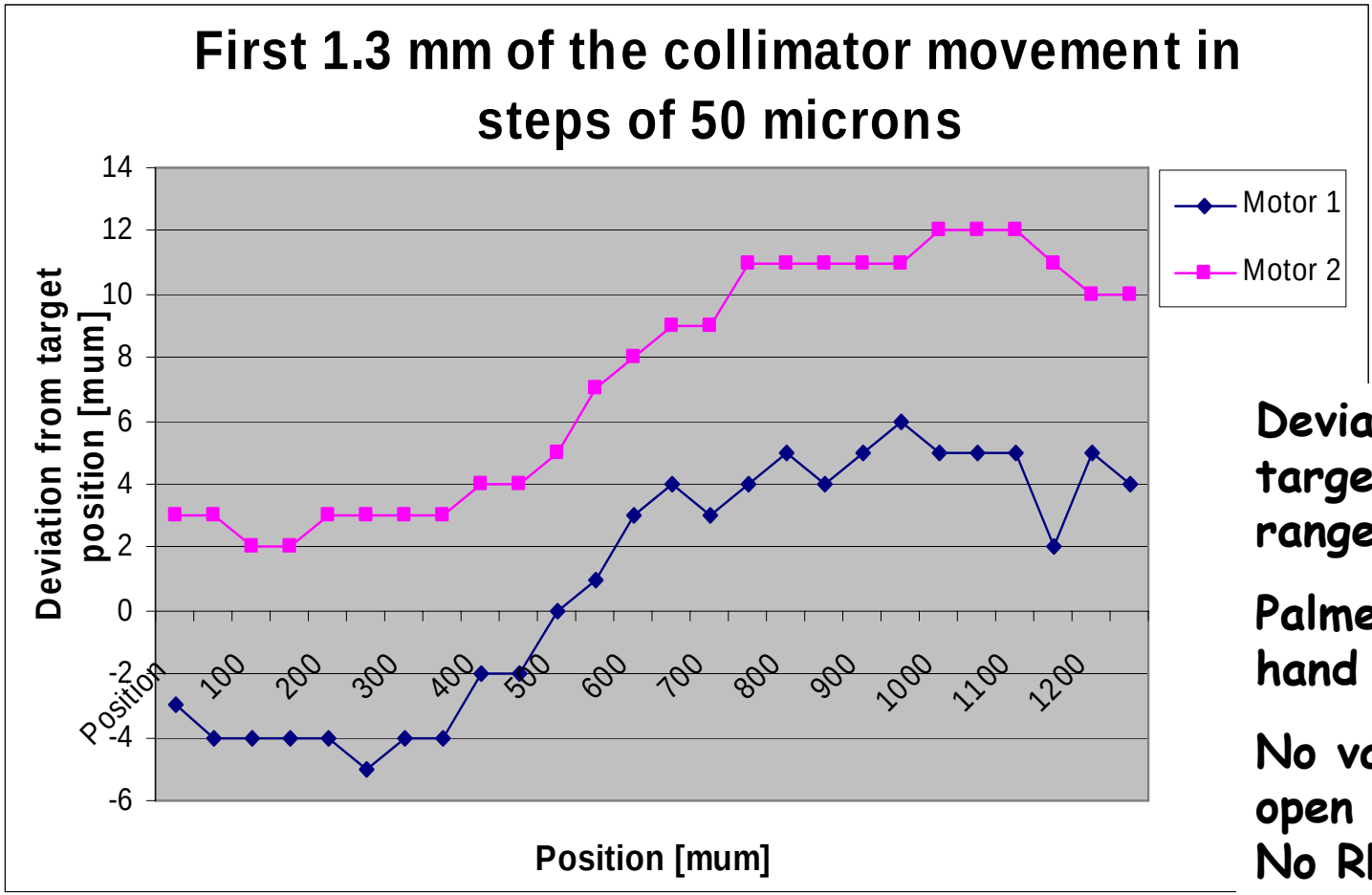
- ✓ Potentiometers: Resolution ≈ 40-50 μm (some sensor better, ≈ 20 μm)
- ✓ Resolvers: absolute error ≈ 80 μm (expected 5 μm).
  For motor control (lost steps?)
- ✓ LVDT's: Resolution ≤ 15 μm in laboratory tests.
  (re-calibrations regularly needed - feasible for > 500 sensors in radiation environment?)
- ✓ Capacitive sensor: Resolution ≤ 1 μm; not radiation resistant

- ♦ Mechanical play: 40 μm for SPS prototype
  ≤ 10 μm for TT40 prototype
- ♦ Minimum step for jaws = 5 μm

Preliminary results from Prototype 3



Preliminary results from Prototype 3



Deviation from target over full range: 50 μm

Palmer (±3 μm), hand aligned

No vacuum, open collimator, No RF contacts

Conclusions

- Reproducibility of the jaw position: **<10 μm**
- Mechanical play: **≈ 20 μm**
- Absolute position knowledge in laboratory: **≈ 100 μm = 0.5 σ** (LHC, top energy)
  (full mechanical chain)
- Alignment in tunnel: **0.1 to 0.2 mm**

Each axis might need a calibration curve

Open points:
Test the different orientations
Life time/ cycling
Effect vacuum
Determine safety margin for each type and orientation

Risks: Alignment screw/motor, wear and aging, limitation in auto-retraction,

Safety factor of 2 desirable