The CNGS Target

Expectation vs. Experience

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The CNGS Target
Expectation vs. experience

OUTLINE

1. Requirements & engineering approach
2. Material choices & target cooling
3. Engineering limits of the target
4. Handling overview
5. Summary

Physical requirements…

The CNGS Target has to …

… reliably intercept a 400 GeV proton beam every 6 s in a double fast extraction with 10.5 μs long spills at 50 ms distance. The nominal beam intensity is 4.8×10^{13} protons per cycle, but an ultimate intensity of 7×10^{13} protons must be considered in view of a possible beam upgrade. The beam has a $\sigma = 0.53$ mm.

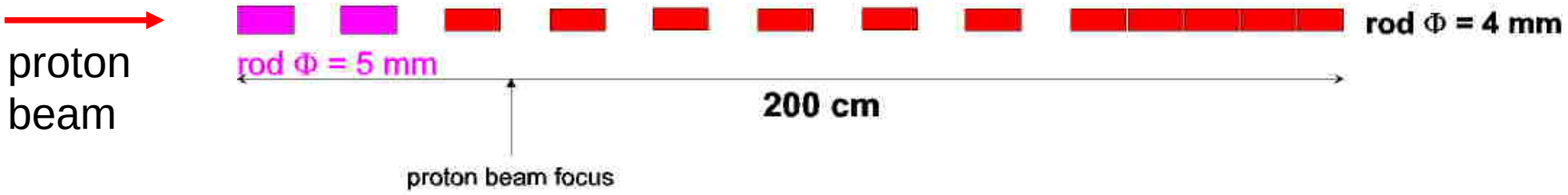
… and engineering requirements

The CNGS Target has to …

… interact with a high intensity, well focused fast extracted beam of 750 kW average power. The target must be located along the beam path within ±0.1mm in the transversal direction and must withstand the thermo-mechanical shock and evacuate the deposited thermal energy. Spare targets, remote alignment and monitoring are required.

The target elements

10 cm long carbon rods, Ø = 5mm and/or 4mm



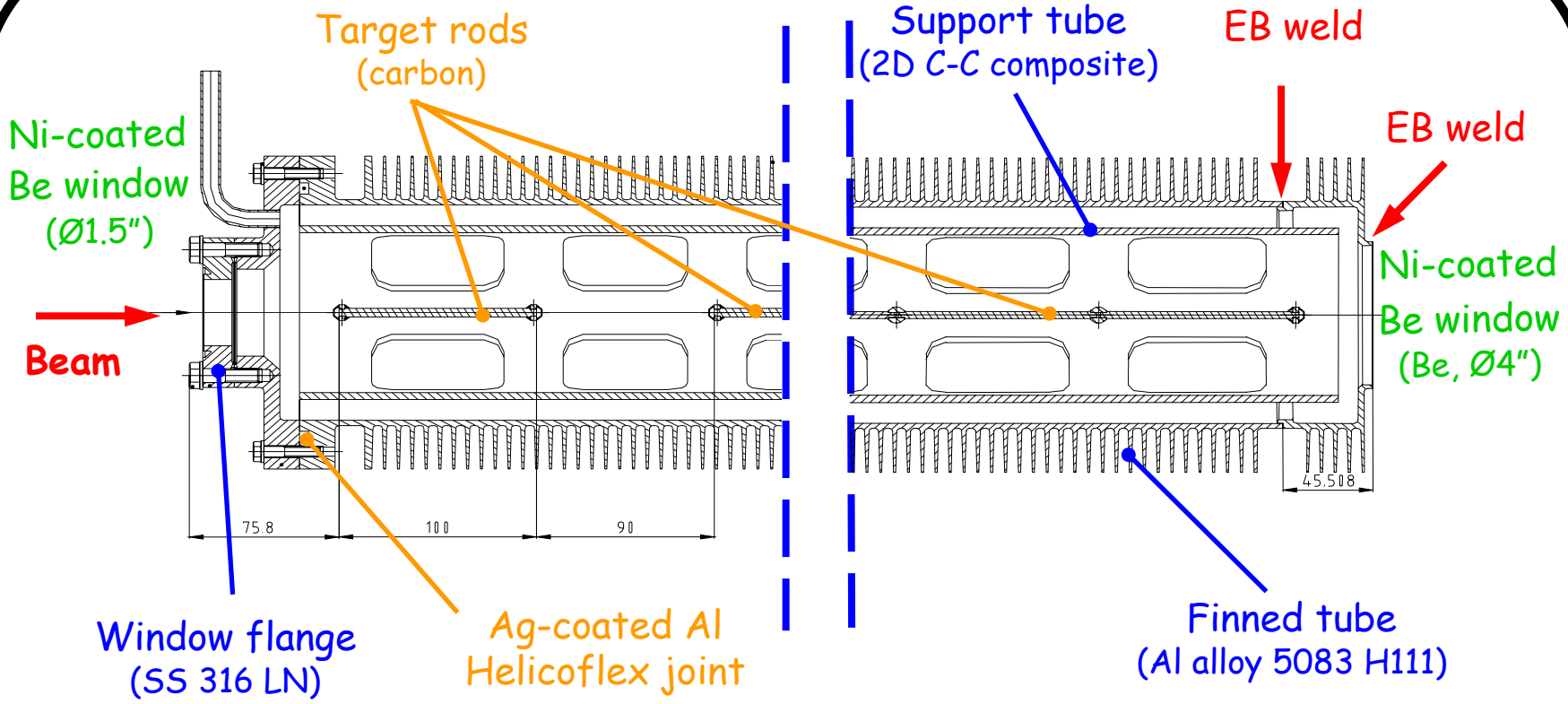
Note: - target rods thin / interspaced to "let the pions out"

- target shall be robust to resist the beam-induced stresses
- target needs to be cooled (particle energy deposition)

Engineering approach

- The target should NOT be cooled by water, in order to avoid mechanical shocks.
- Material choices should minimize the absorbed beam power and maximize radiation resistance.
- The target should be a consumable item with in-situ spares.
- The target station should allow remote handling by the crane.
- The target station should allow remote calibration of the displacement system.

Material choices



The target unit is conceived as a static sealed system filled with 0.5 bar of He.

The tube has annular fins to enhance convective heat transfer.

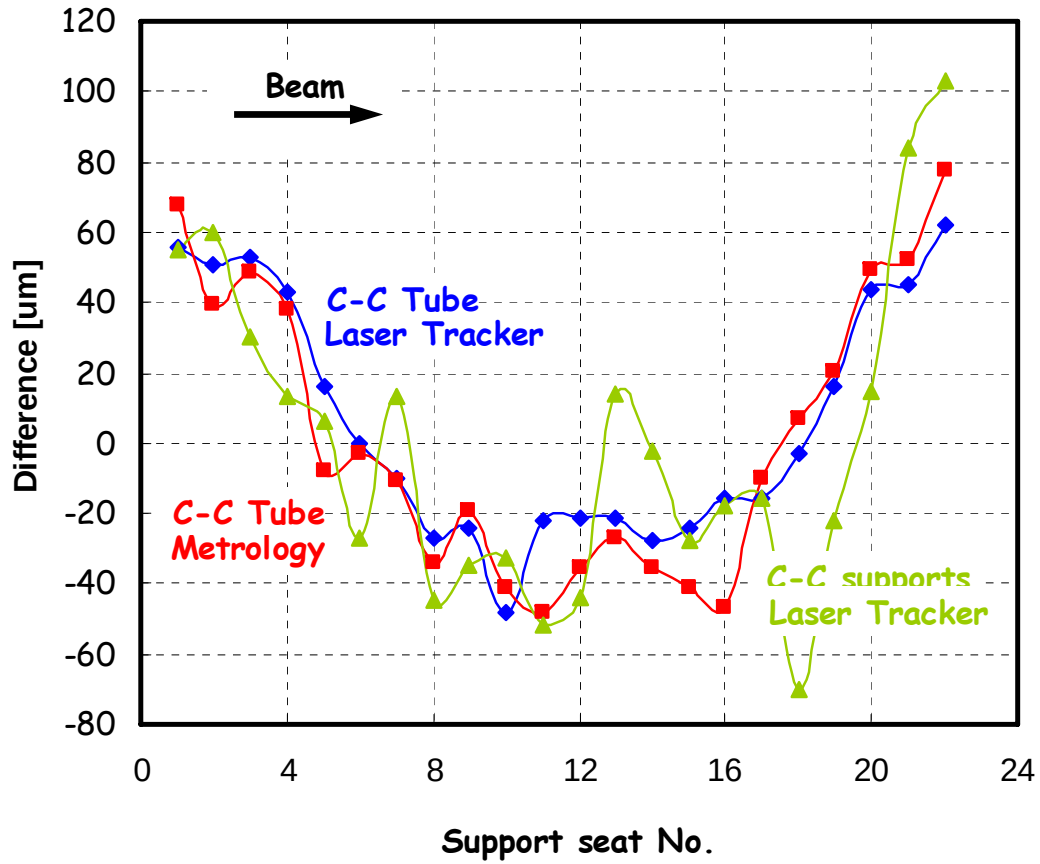
The choice of light materials limits the absorbed design power to less than 5 kW.

The target units

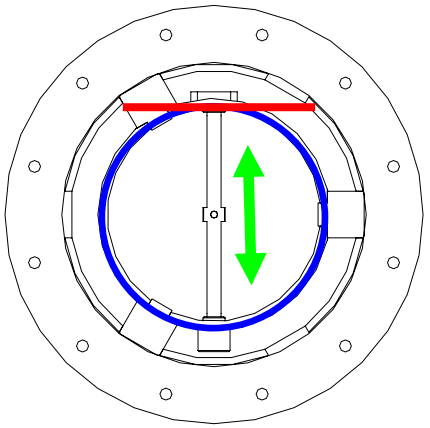
Ten targets (+1 prototype) have been built. They are assembled in two magazines worth 500 kCHF each.

Target rod alignment

Results of the lab measurements

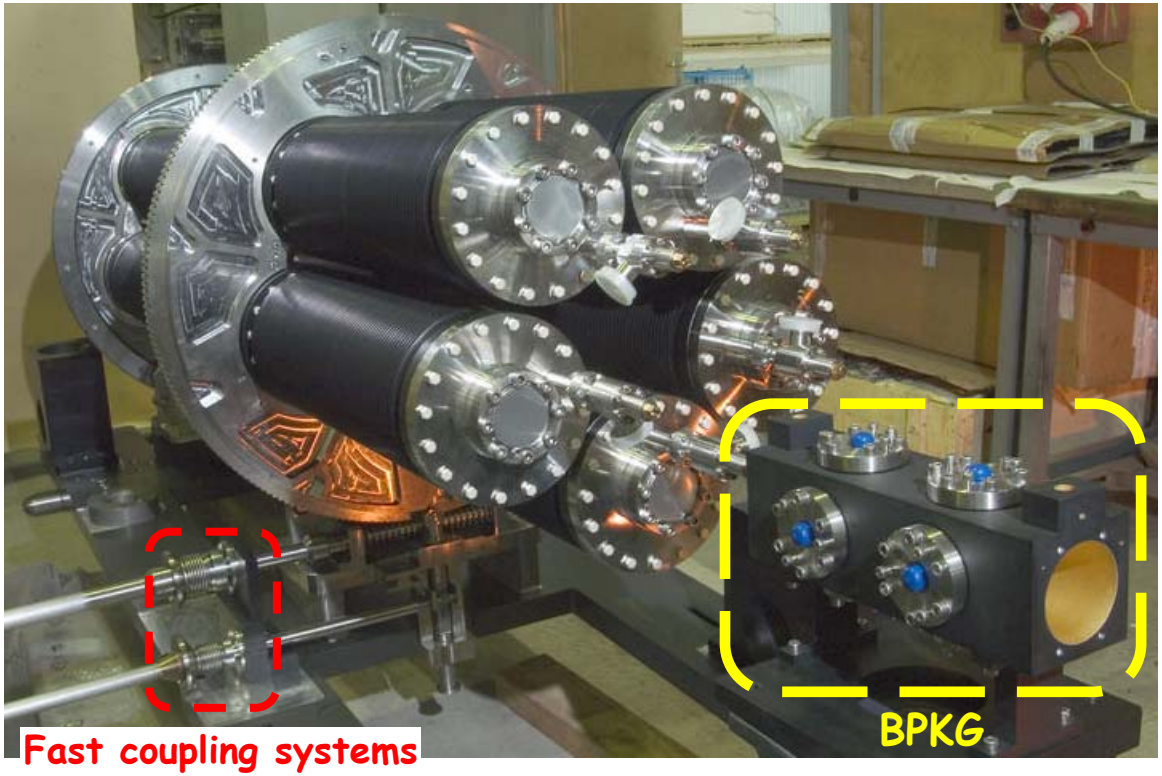


Reference surface



Lab tests have proven that a monolithic 2D carbon-carbon structure can be built with a high precision. This is a major achievement of the project.

The target magazine



Indexing finger

The commissioning experience has proved that the active target unit can be changed with an in-situ spare within 15 min. Still, an erratic time-out when disengaging the indexing finger has been detected which requires a reset of the exchange system. This is being investigated on the target spare.

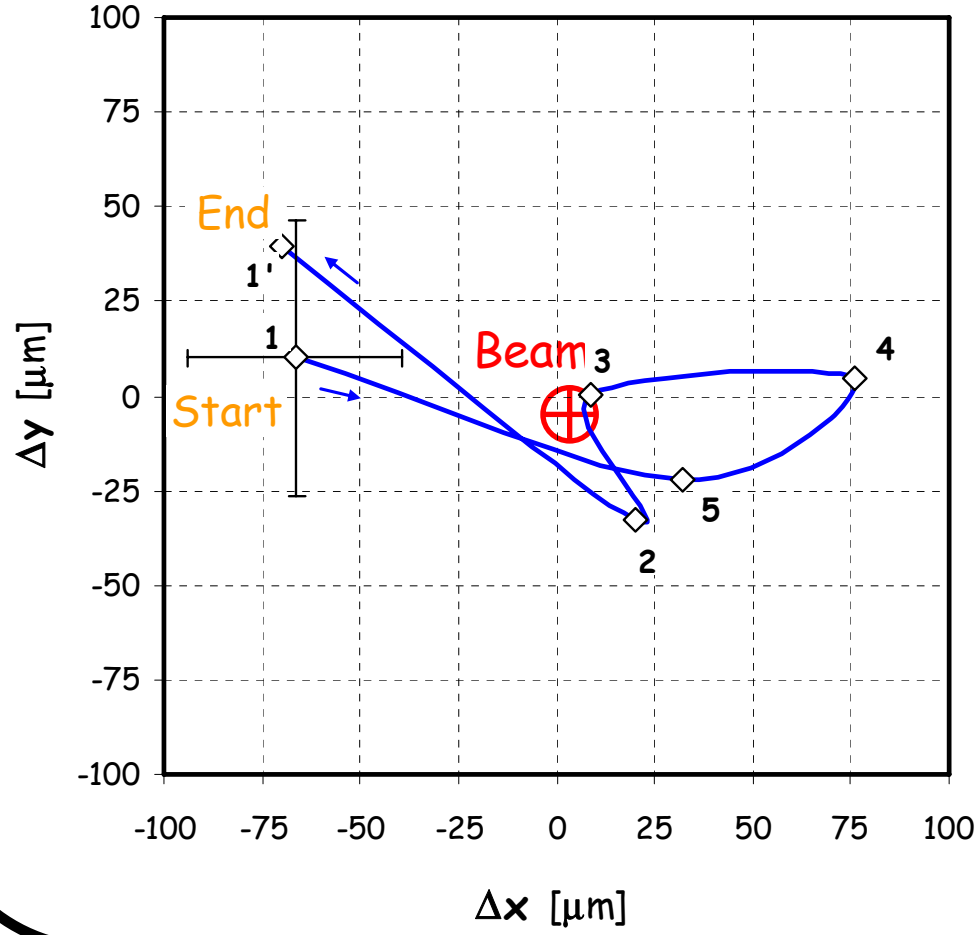
The first target magazine…

…Is equipped as follows:

1. Graphite target with baseline geometry under helium (Graphite 2020PT by Carbone Lorraine);
2. Carbon target with baseline geometry under helium (Sintered Carbon SC24 by Sintec Keramik);
3. C-C composite target with baseline geometry under helium (Aerolor A035 by Carbone Lorraine);
4. Carbon target with baseline geometry under vacuum (Sintered Carbon SC24 by Sintec Keramik);
5. "*Safe" target:* Graphite target with all ∅5mm rods under helium (possibility to increase the beam size, 2020PT);.

Measured rotation precision

of the target magazine



The location of the active target has been measured by a laser-tracker during a complete rotation of the target magazine.

The discrepancies shown in the diagram cumulate the local machining tolerances and the global precision of the target rotation mechanism.

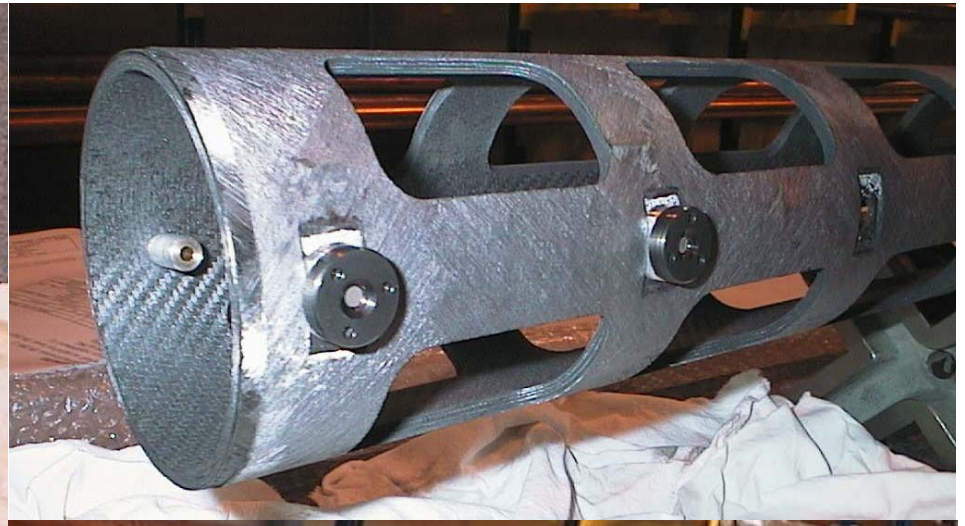
The results are within the required precision of ±100 µm.

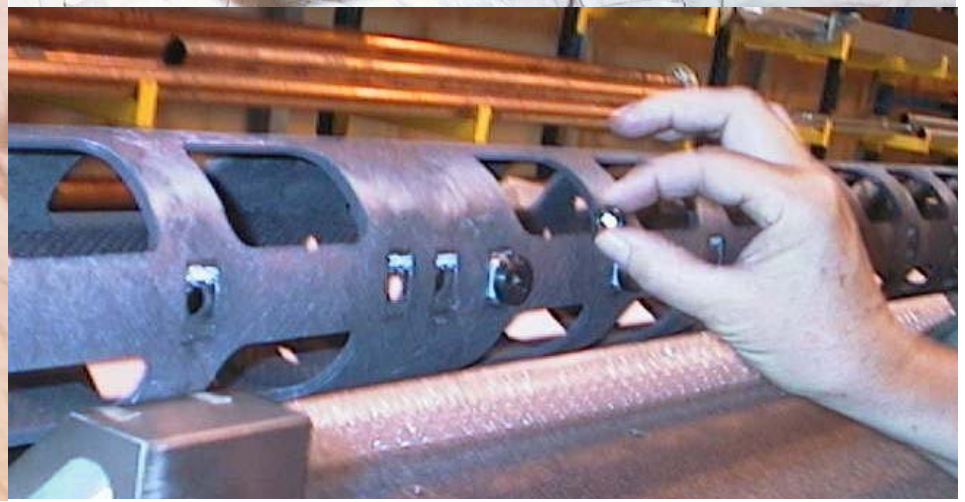
CNGS target rod alignment

Control by the laser tracker

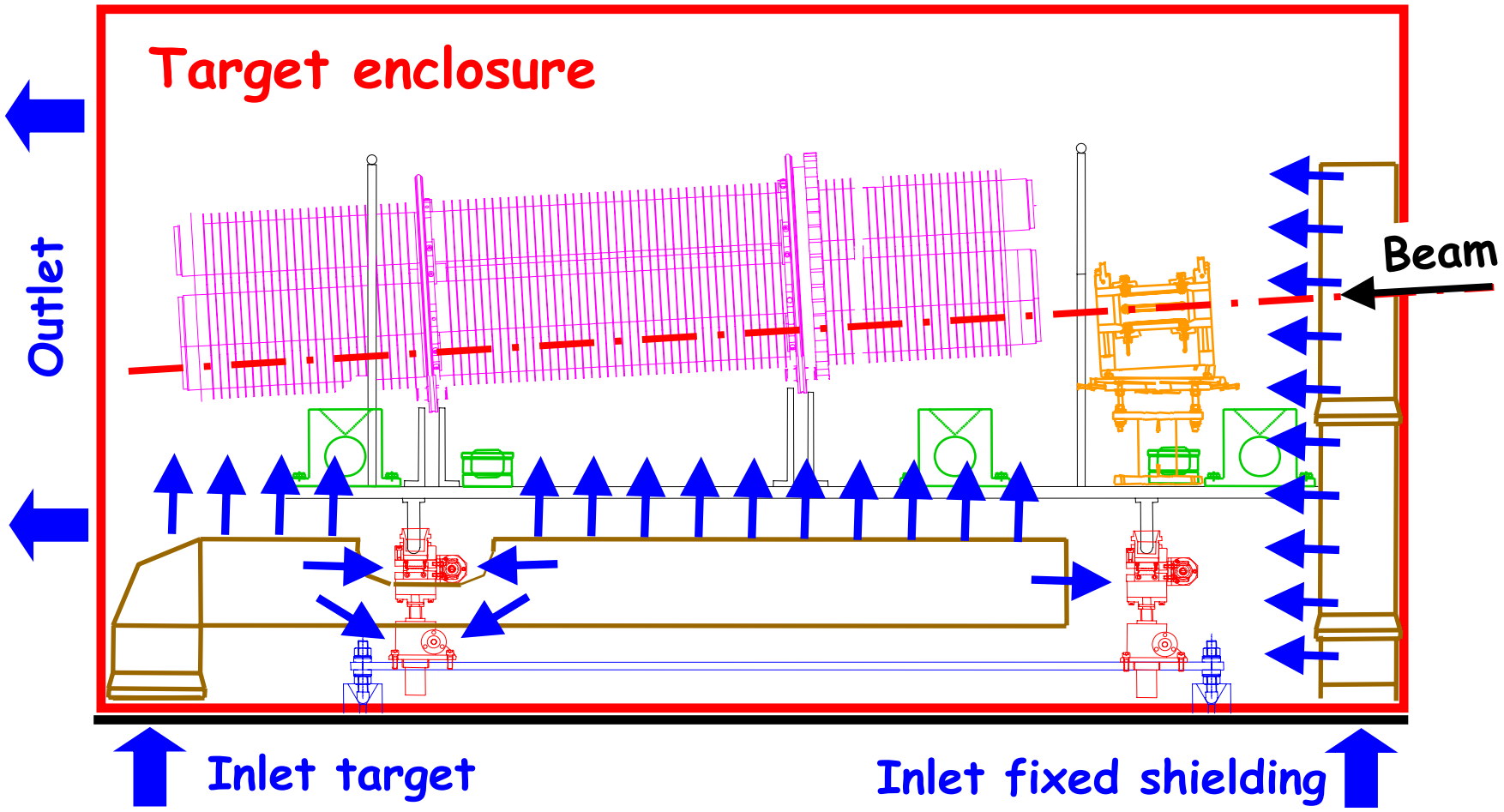
C-C Tube prototype

Control at CERN – August 2004

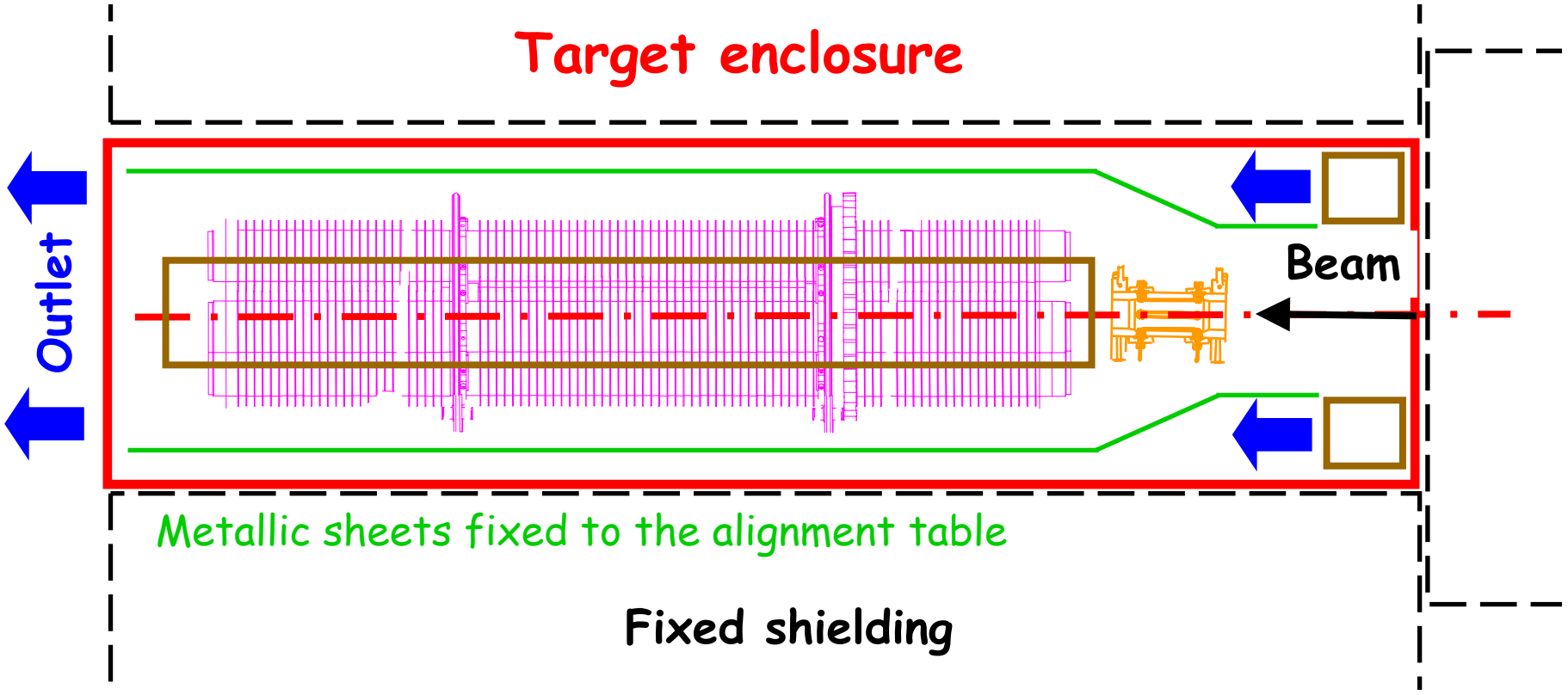




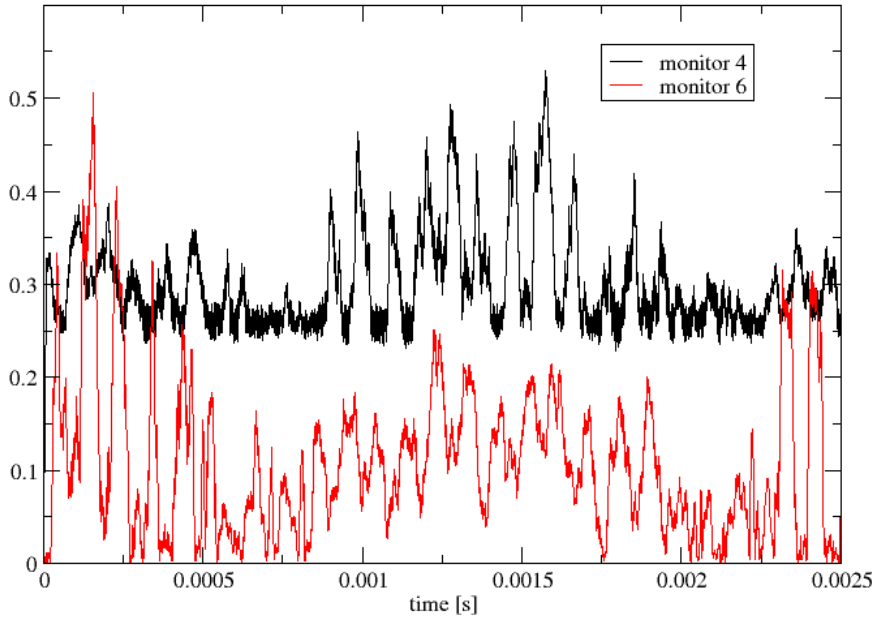
Air cooling
Schematic side view



Air cooling
Schematic top view



Engineering limits of the CNGS target



Presently, **the limit of the CNGS target is set by the dynamic stresses**. Spreading the extracted protons more batches and increasing the spacing of the proton extractions would allow to increase the proton beam intensity beyond 1 MW.

Mechanical Limits

- Dynamic stresses (beam time-structure)
- Static stresses (beam profile)

Thermal limits

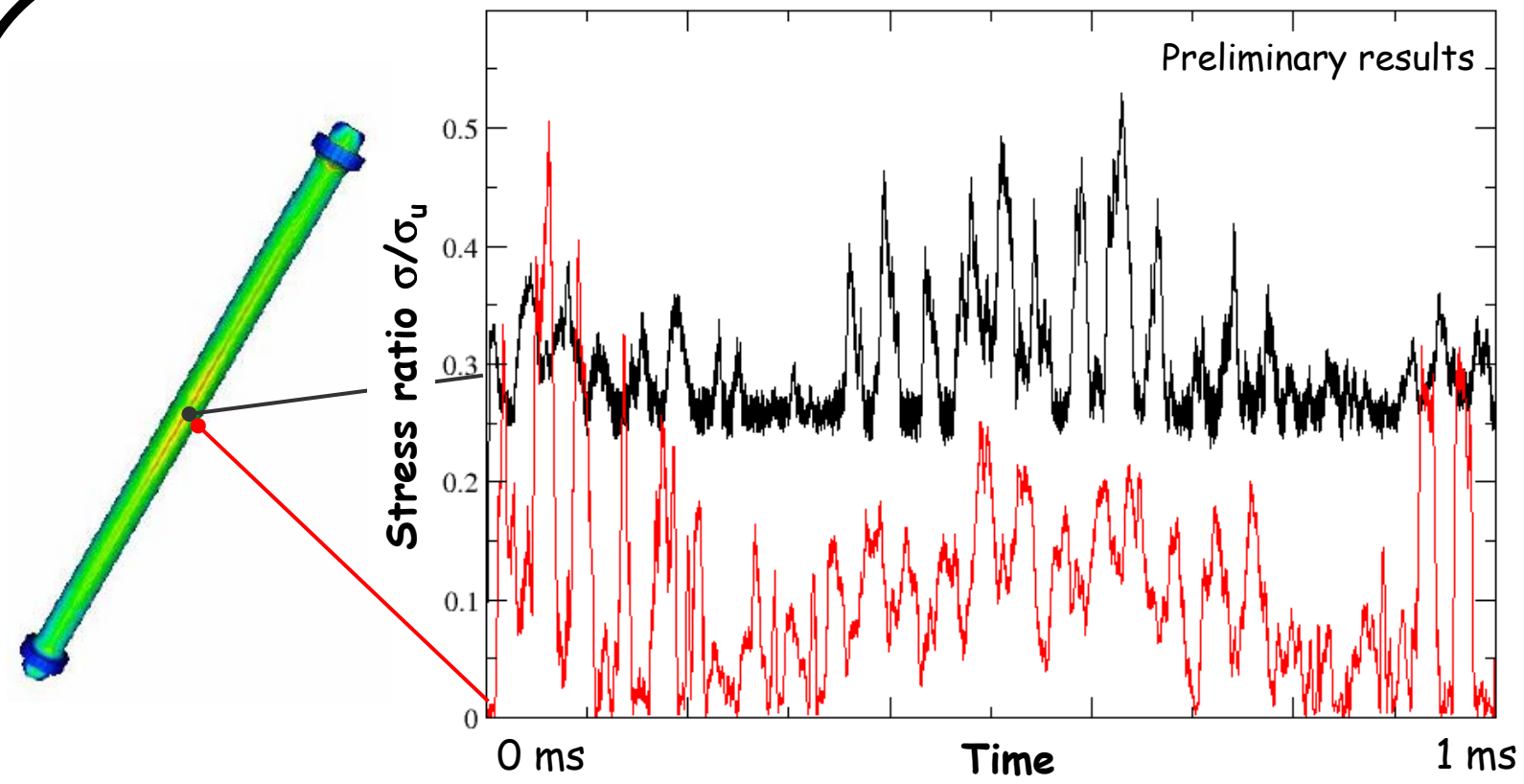
- Cooling (target density, thermal load dilution)

Radiation damage

- Defects (annealing at high T)
- Target failure (quick exchange, in-situ spares)

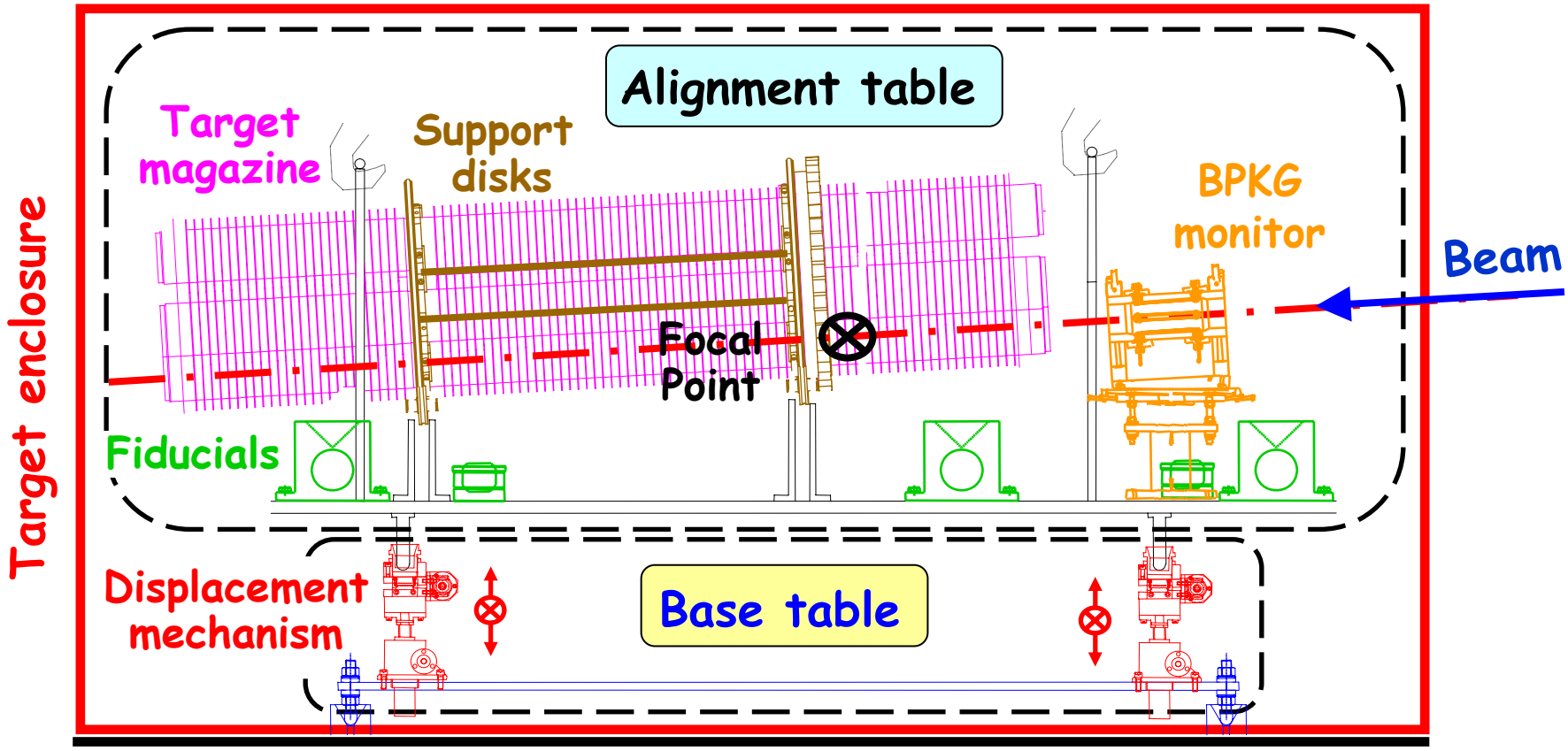
Estimated Target Stress

Measured material properties



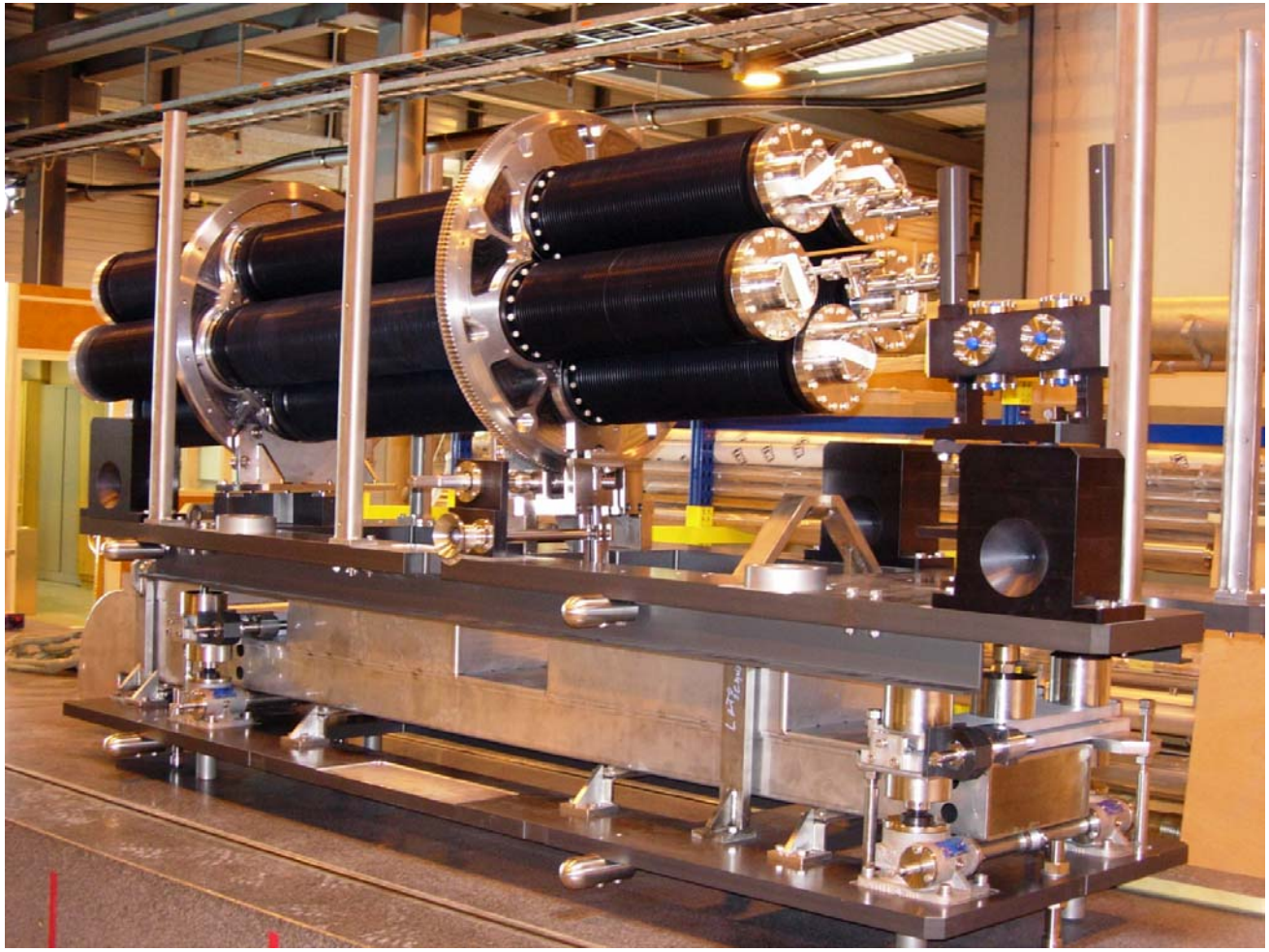
Based on the measured material properties, the estimated stress values are within the allowables under worst loading conditions (1.5mm off-axis, ultimate proton spill on a cold baseline target without damping).

Handling principles

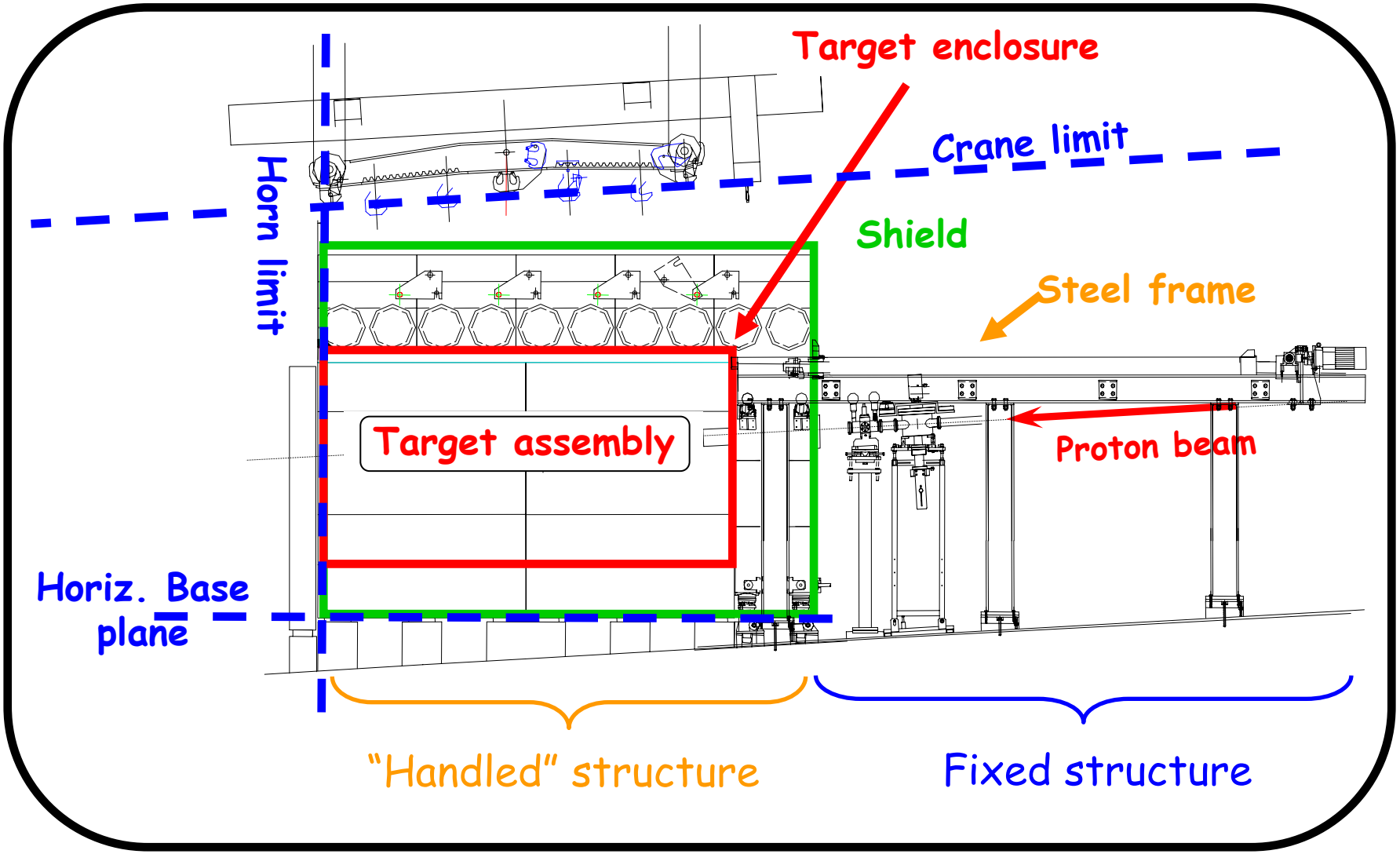


The target magazine is mechanically coupled to the BPKG monitor. They are aligned in the lab and are remotely handled as a single component (the « alignment table »). They rest on the « base table », bearing the displacement mechanisms. The cooling manifold is not shown.

The Target Assembly

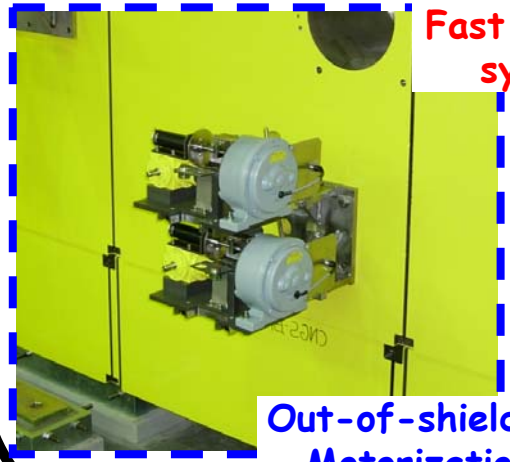


T40 - Schematic Vertical view



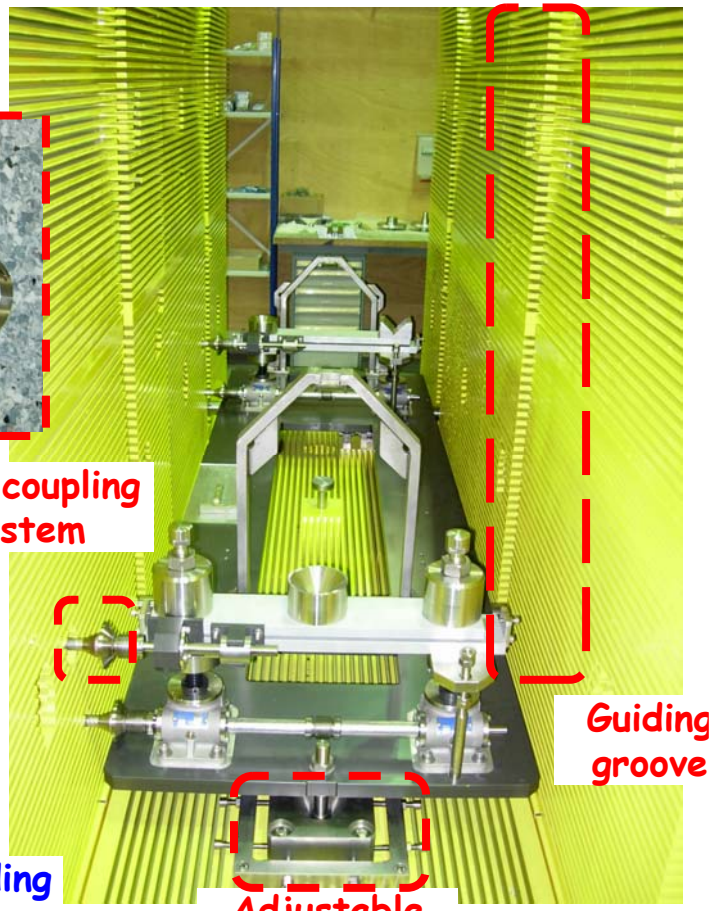
The target within its shielding

The base table



Fast coupling system

Out-of-shielding Motorization



Guiding groove

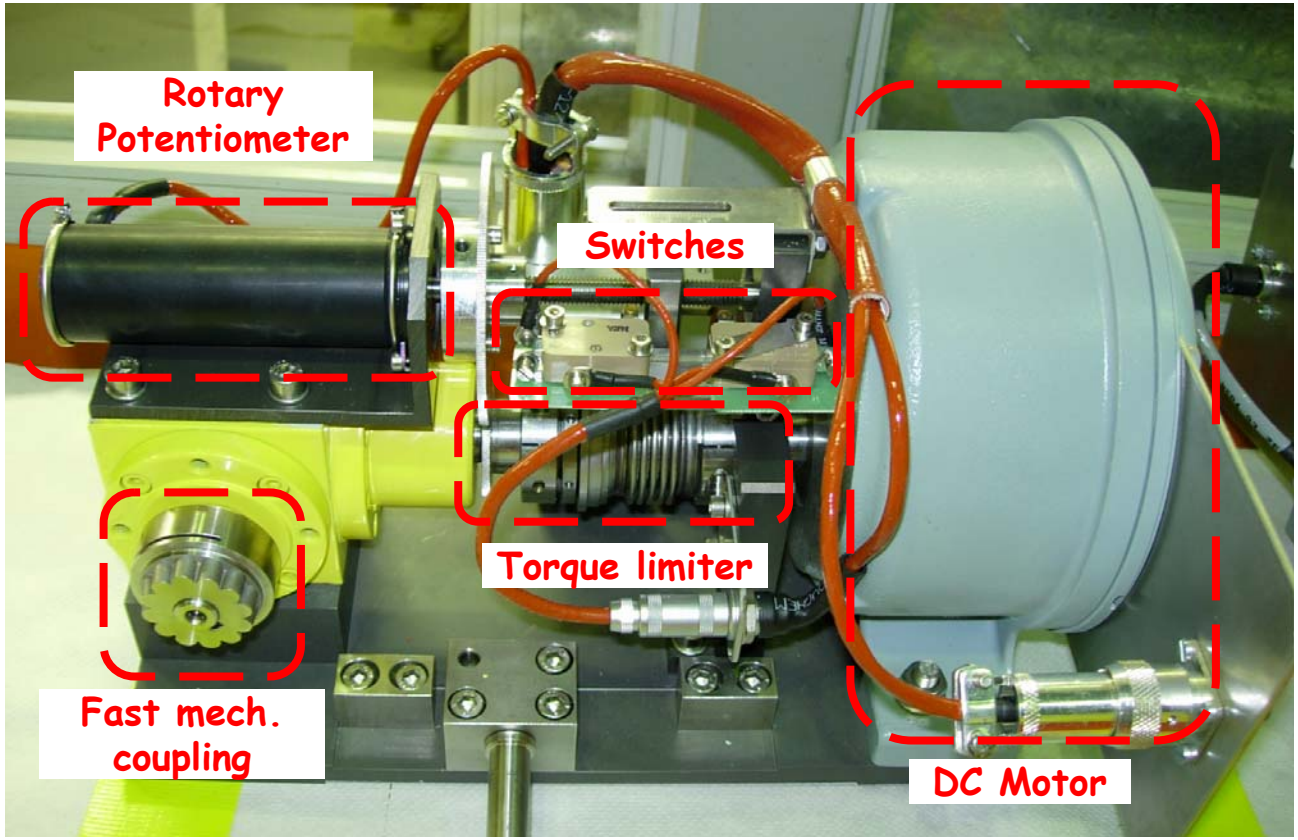
Adjustable Table seat

The base table is placed automatically by guiding grooves on three adjustable seats.

The motorization driving the table mechanisms is located out of the shielding.

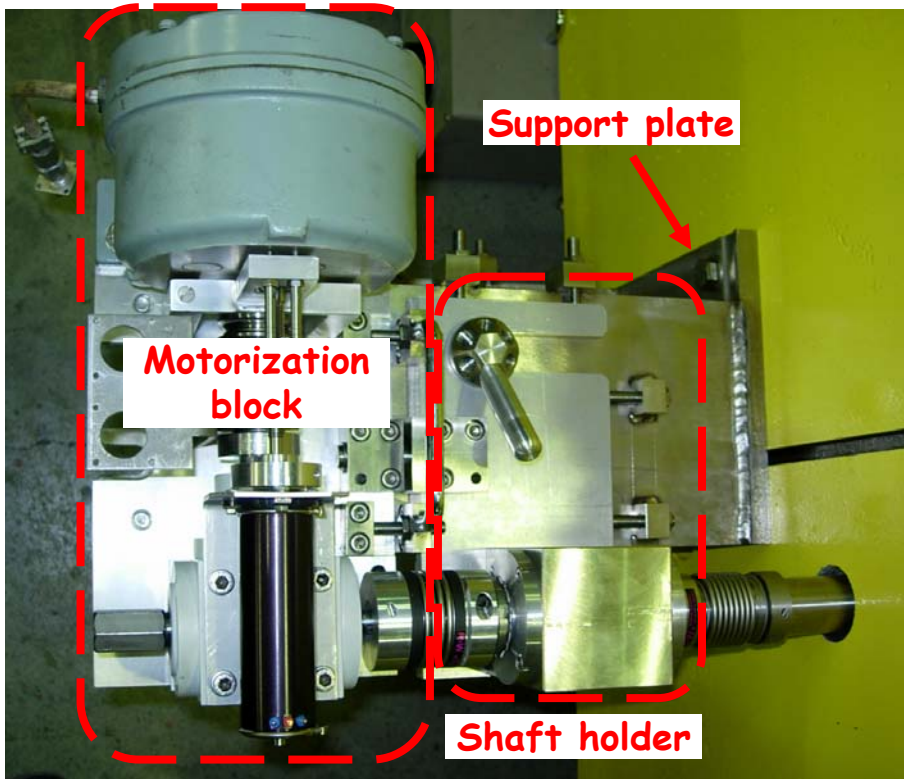
The connection is realized through the shielding by shafts provided with fast coupling systems.

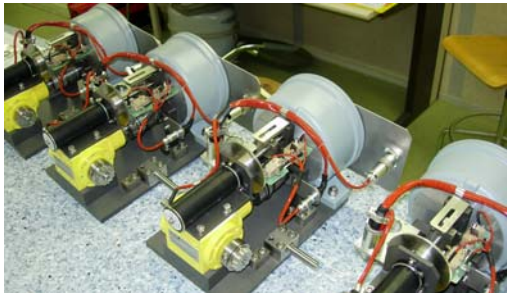
Alignment Motorization
Main parts

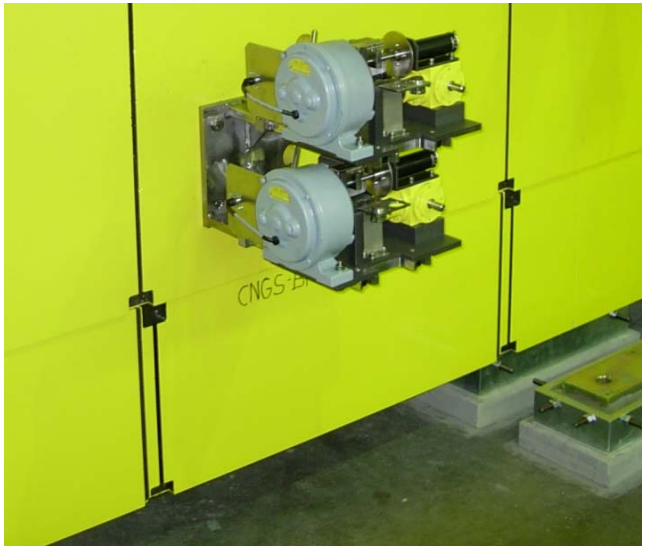


The four alignment motorizations have been assembled, cabled and successfully tested in the lab with the final local electronic control system.

Alignment Motorization Assembly







Each motorization block is mounted together with a shaft holder on a support plate fixed to the shielding. The motorization and the holder can be easily (de)mounted (< 60 sec) for maintenance.

Summary

The project has delivered…

- **A new operational target station**
  - Complying with the specifications at "ultimate" beam intensity;
  - Successfully tested (mechanics, electronics, in local and remote);
- **Spare sub-assemblies**
  - A complete spare target assembly ("base+alignment tables");
  - A double of all motorizations and potentiometers;
  - A double of electronic components (rack, cables);
- **A set of tools to maintain it**
  - "Hardware" tools (handling, alignment, transport, testing);
  - "Software" tools (detailed procedures for testing and handling);
- **Trained personnel to operate the target**
  - Preventive and exceptional maintenance
    4 technicians (2 Mech. + 2 Electr)
  - Alignment (2 Geometers);
  - Remote operation (1 Engineer);
  - Radiation protection (2 Technician);
  - Handling (2 crane/transport operators).