CERN
European Organization for Nuclear Research

THE LHC Collimators

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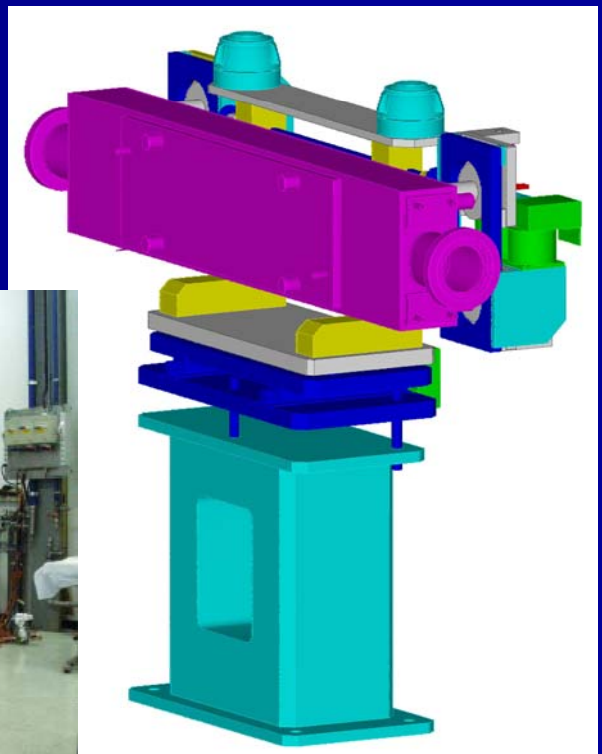

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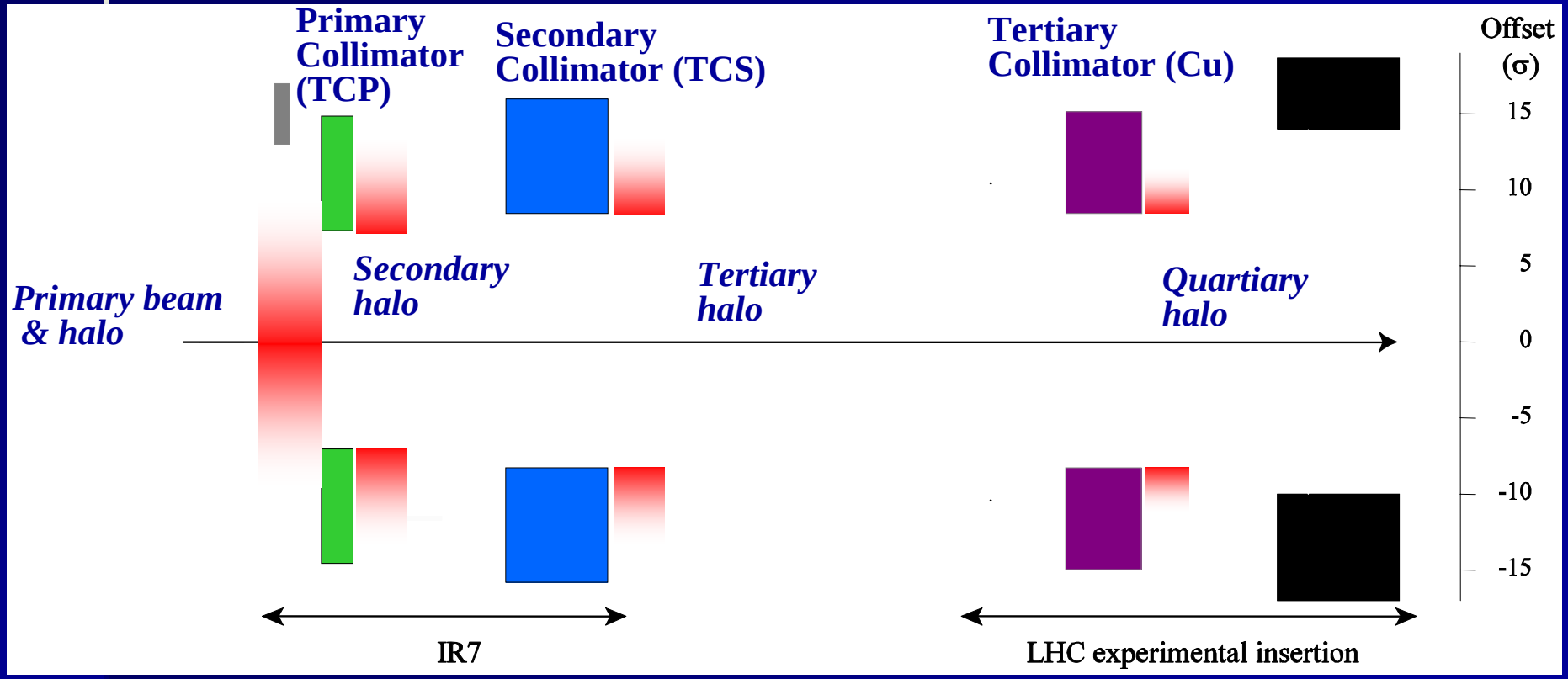
1st TS department Workshop
4-6 May 2004, Archamps, France

OUTLINE

- The LHC Collimator Project
- Collimator Work-package at TS dept.
- Project Requirements
- Design strategy
- Technical design
- Thermal and Mechanical Calculations
- Experimental validation
- Conclusions

COLLIMATION PRINCIPLE



Phase 1 TCP+TCS (2 stage concept)

IR3 (2 primary 8 secondary)
IR7 (6 primary 22 secondary)

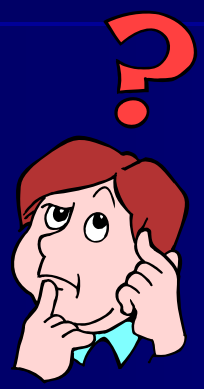
LHC COLLIMATORS AT TS

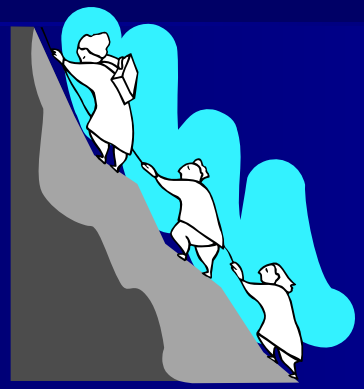
- **Work-Package taken by TS department:**
  - Mechanical engineering and analysis
  - Mechanical design
  - Prototype follow-up and production for SPS tests
  - Drawings for series production …
- **Design Activity started in September ’03**
- **Prototype manufacturing: ongoing**
- **Involved specialties:**
  - Design office
  - Workshop
  - Brazing, Surface Coatings, Metrology
  - CV, IC …

PROJECT REQUIREMENTS

- **Functional specification (TCS excerpts):**
  - High absorbed heat load (up to 32 kW)
  - Very accurate precision (25μm on 1200mm)
  - High robustness in accident cases (up to 700°C)
  - Maximum flexibility (adjustable jaw)
  - Limited maximum temperatures (<~50° C)
- **Schedule**
  - First full prototype by May 2004
  - Installation in SPS ring (LSS5) and TT40 in Aug. 2004
  - Drawing for Series production by September 2004

DESIGN STRATEGY





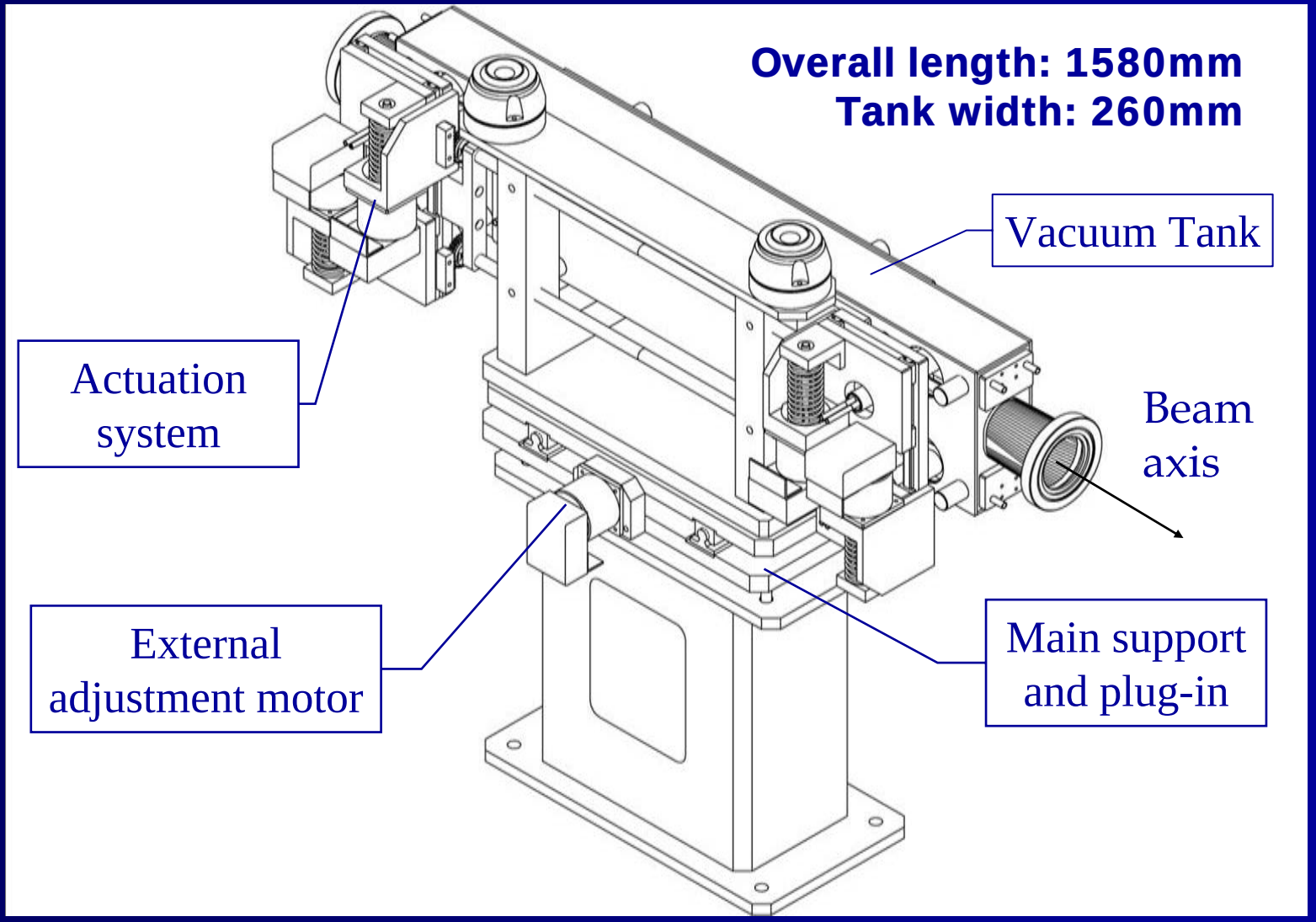
How to meet the challenging requirements ?

- Highest priority to Secondary Collimators (TCS) …
- Contribution of many experts …
- Wide exploitation of LEP experience …
- Many concepts and solutions analyzed …
- Mix of traditional and innovative technologies.
- Advanced Materials (C/C composites, GlidCop® …).
- Specific tests to validate most critical technologies (Clamping)

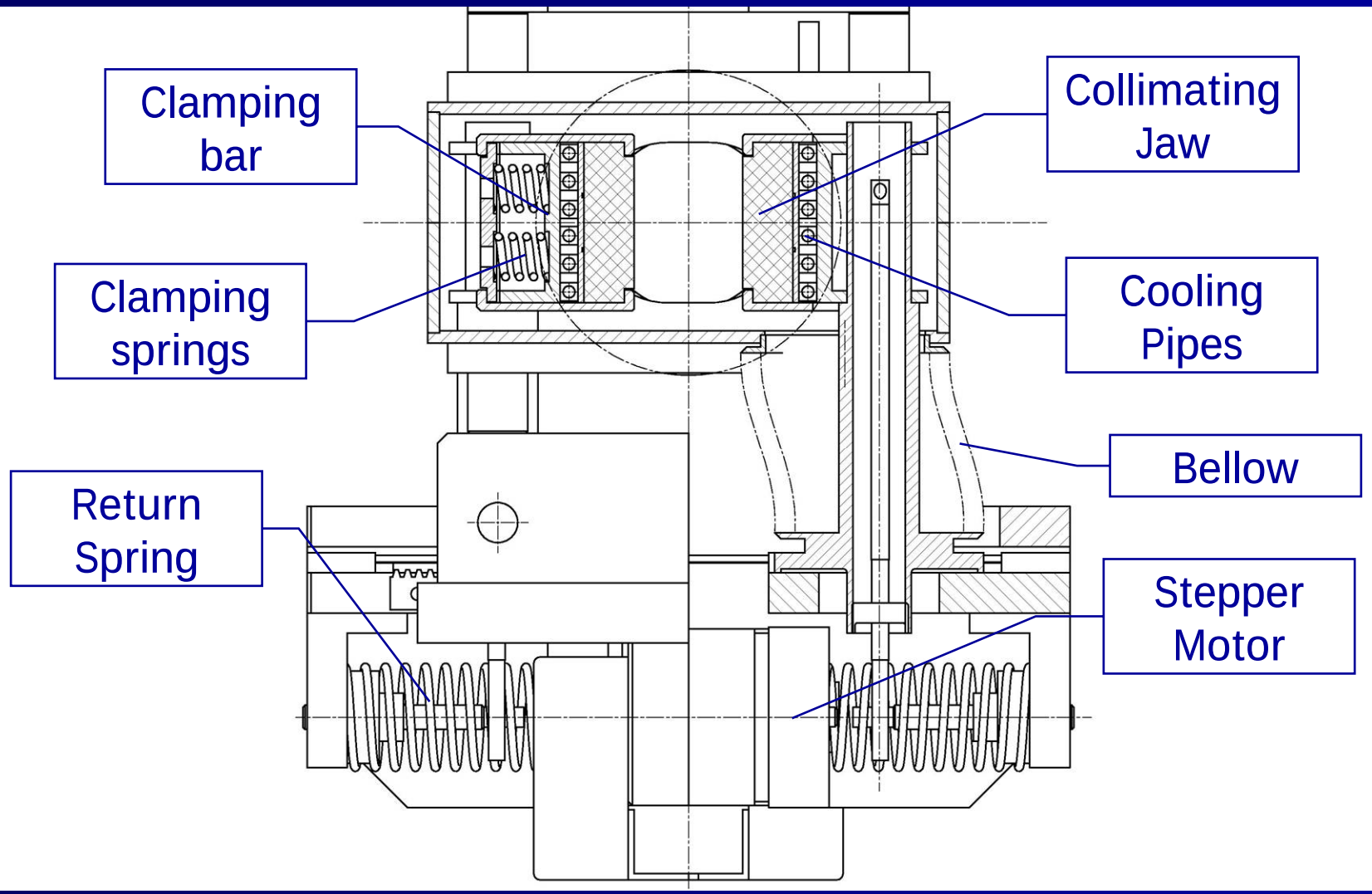
Main Features

- Multi-DoF internal alignment system
- Jaw clamping system
- Compensation of thermal deformations
- Cooling system
- RF contacts for low impedance
- Actuation system
- External alignment system and plug-in
- Misalignment prevention
- Motorization and electronic controls

TECHNICAL DESIGN
Mechanical Assembly

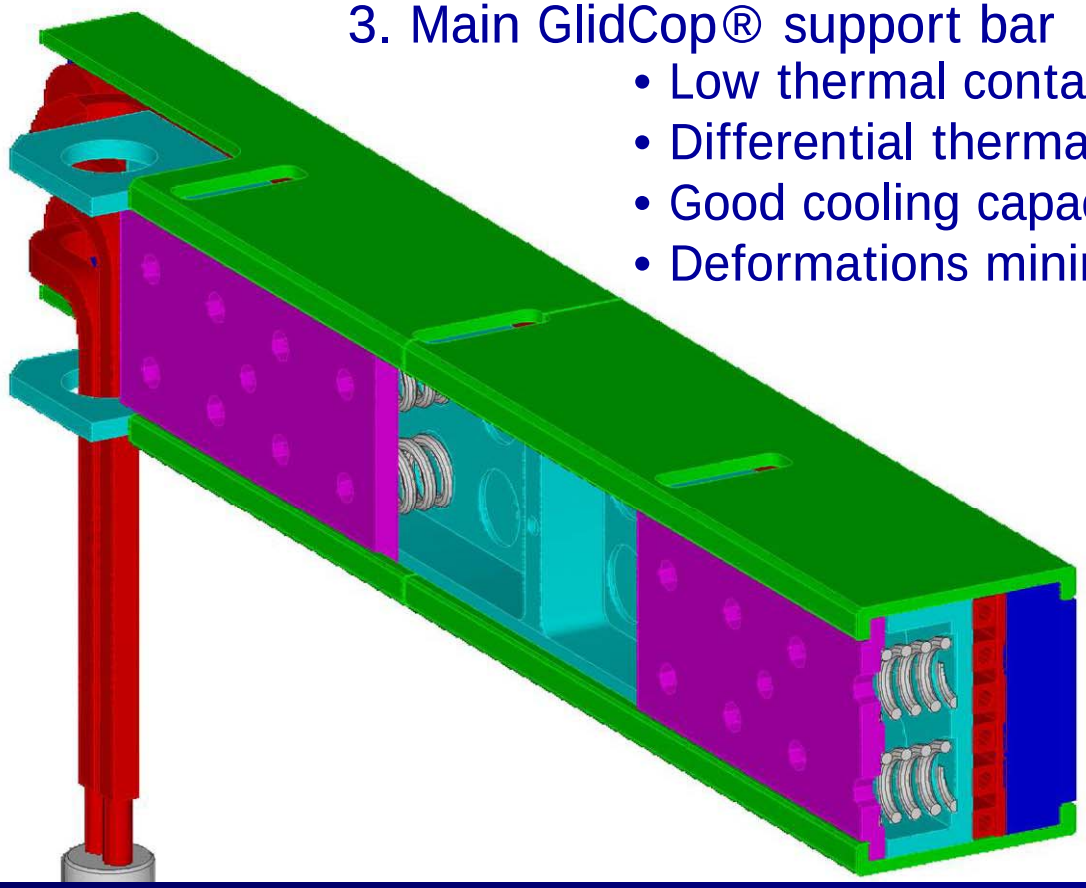


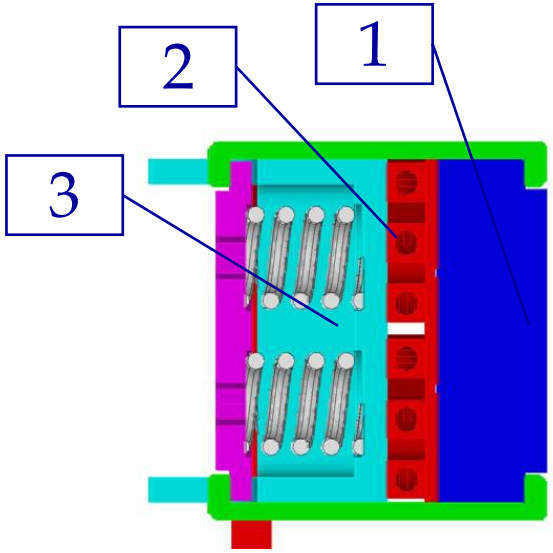
TECHNICAL DESIGN
Collimator Cross-section



TECHNICAL DESIGN
Collimator Bloc

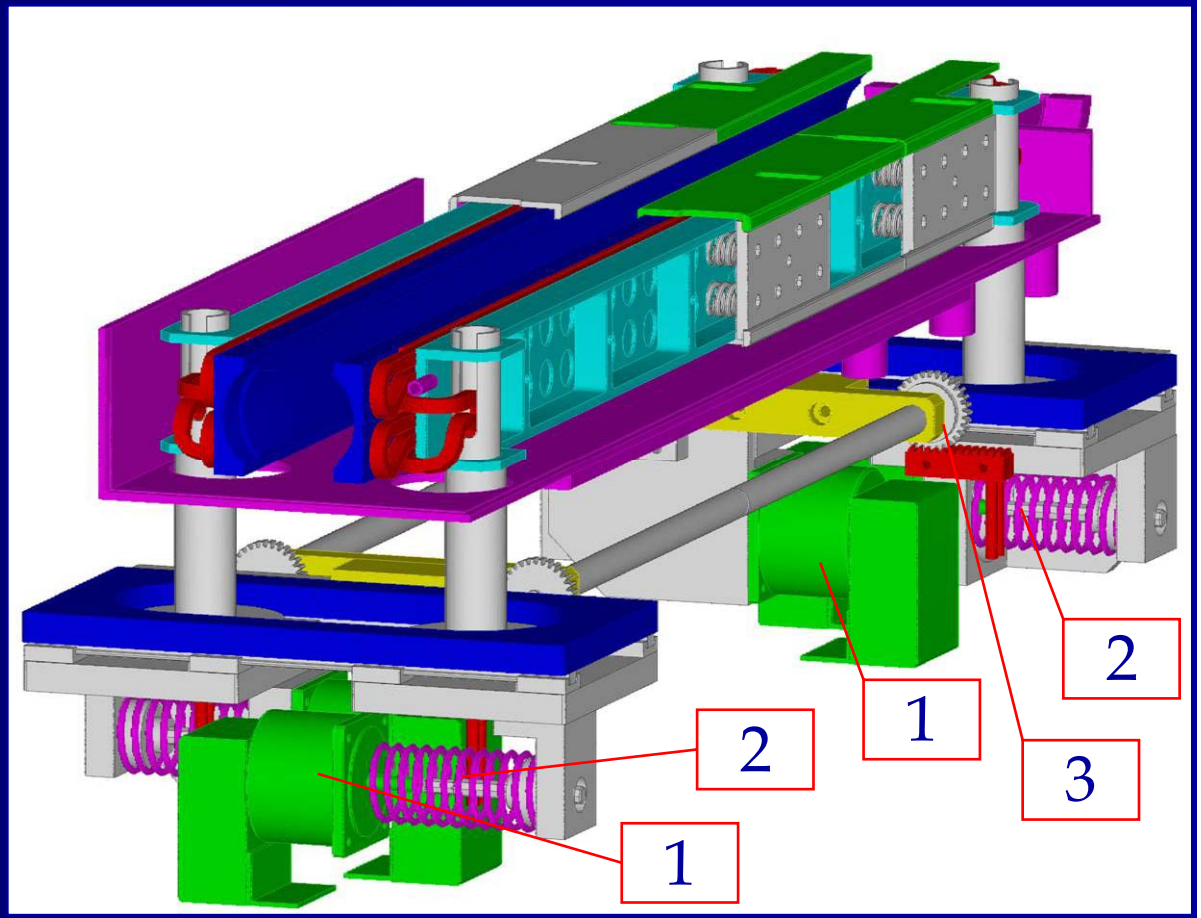
1. Jaws in C/C or graphite
2. Cooling Cu-pipes (2 x 3 turns) and plate pressed against the jaw, brazed to the bar.
3. Main GlidCop® support bar
   - Low thermal contact resistance (P=5 bar)
   - Differential thermal expansion allowed
   - Good cooling capacity (5 l/min per pipe)
   - Deformations minimized (compensation)





TECHNICAL DESIGN
Actuating System

1. Jaw actuated by 2 stepper-motors via a roller screw (10 μm/step)
2. Return spring for semi - automatic pullback and play recovery
3. Rack-pinion system to prevent misalignments (max 2 mm)
4. Sliding of the jaw surface (+/- 10mm)



THERMOMECHANICAL CALCULATIONS

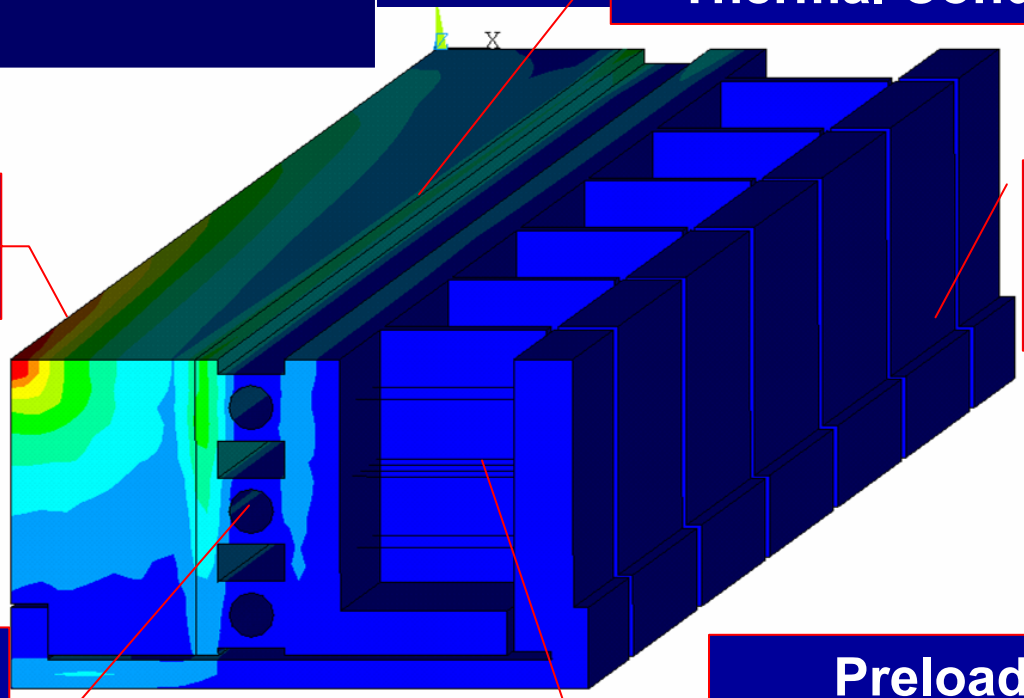
- Extensive analytical and numerical calculations.
- Semi-analytical models for Thermal contact resistance, Convection, Thermal bending …
- Many FE models (ANSYS®) of the TCS were studied:
  - 2- and 3-dimensional …
  - Different materials (C/C, C, Cu, Steel, Glidcop®)…
  - Input thermal load imported from FLUKA simulations …
  - Different load cases (nominal, accident, transient)
  - Complex boundary conditions …

THERMOMECHANICAL CALCULATIONS

FEM Model for 3-D analysis

Temperature - dependent properties

Contact elem. (Friction + Thermal Conductance)



Deposited Heat Power (W/m^3)

Geom. B.C.: Pinned + Free expansion

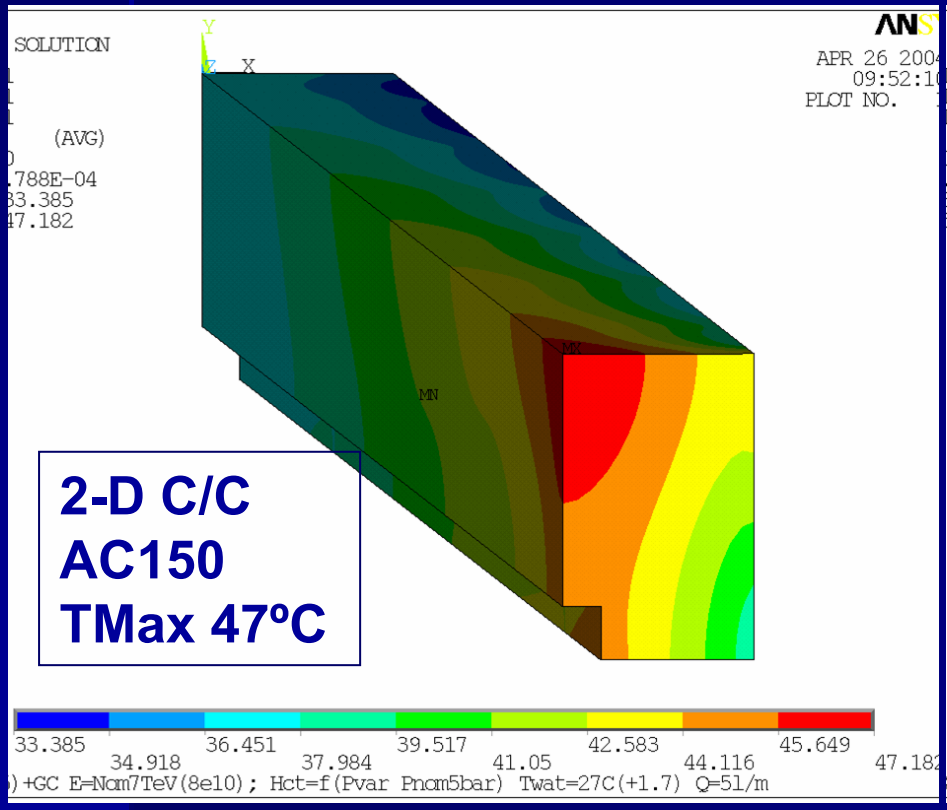
Convection (12360W/m2/K) + inlet temp. (27ºC)

Preloaded Springs (5 bar)

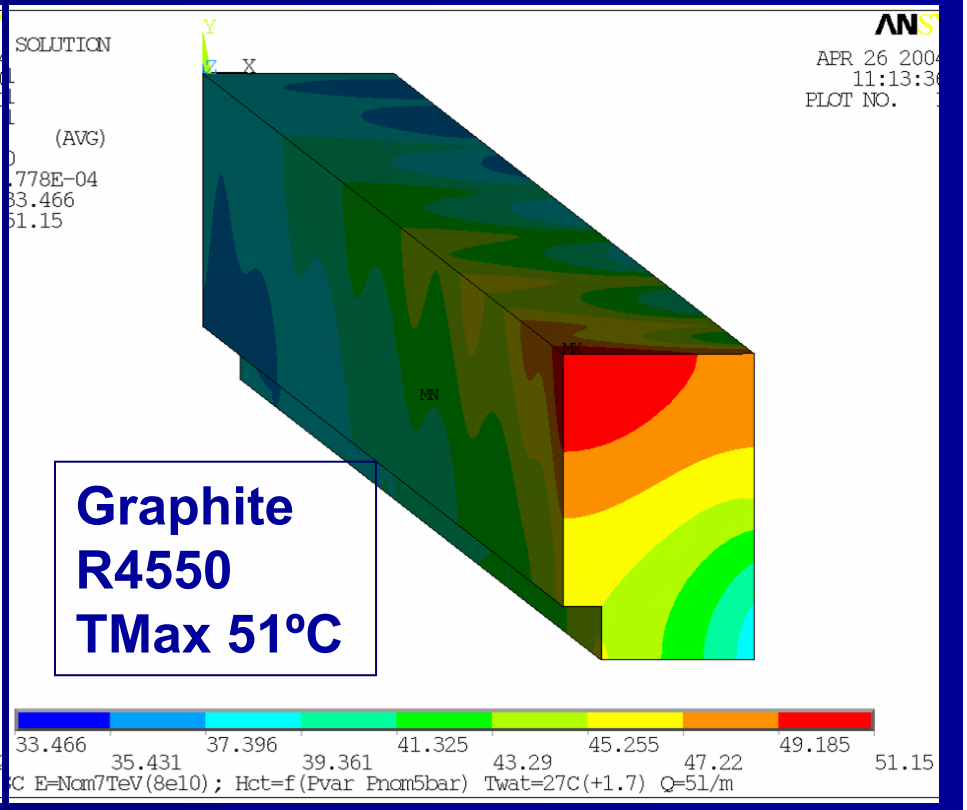
THERMOMECHANICAL CALCULATIONS

Thermal analysis

Nominal Conditions 7 TeV 8e10 p/s Steady-state



2-D C/C
AC150
TMax 47ºC

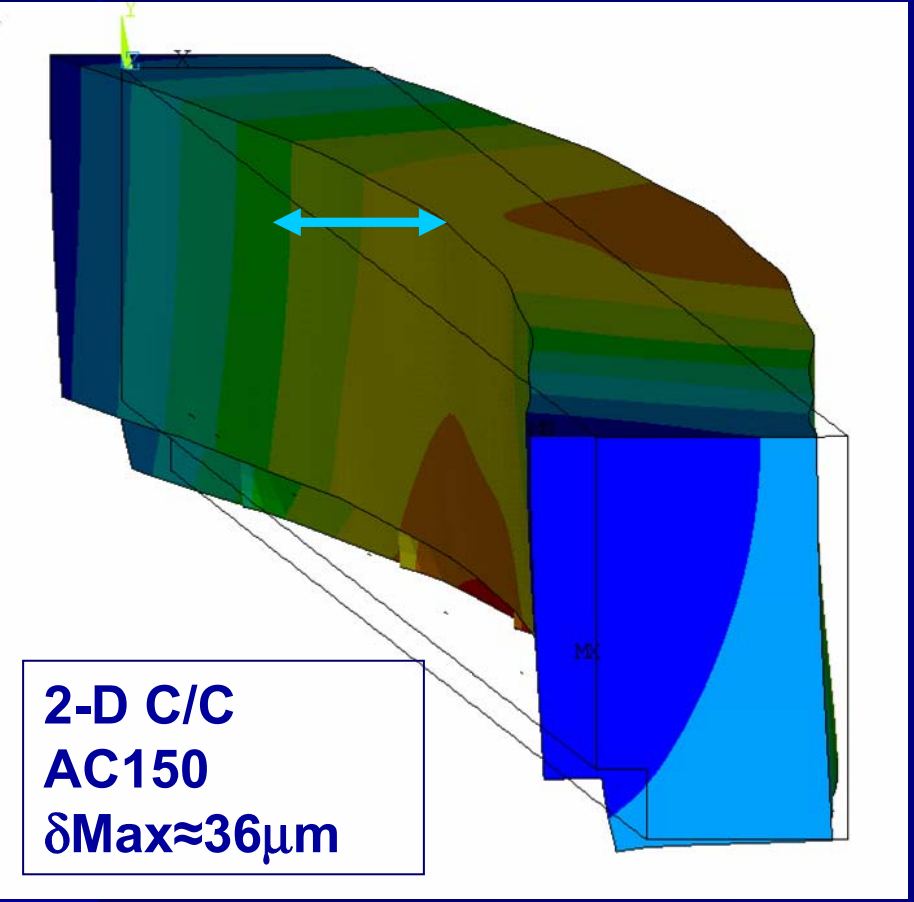


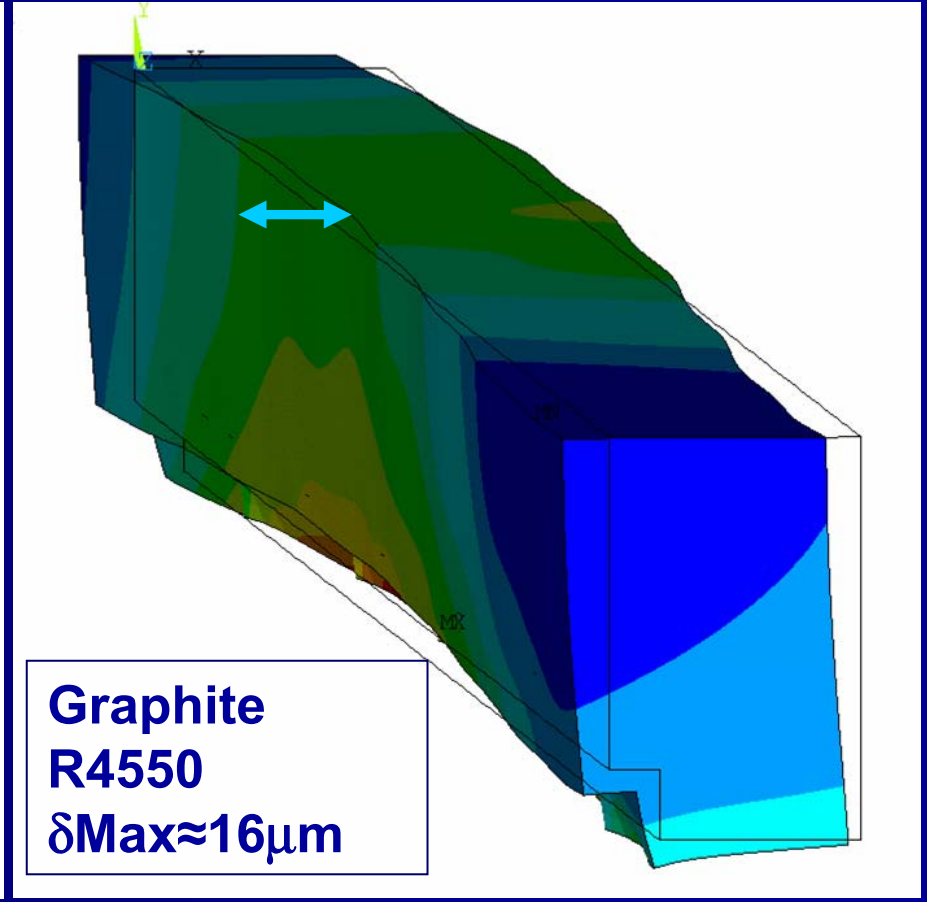
Graphite
R4550
TMax 51ºC

THERMOMECHANICAL CALCULATIONS

Displacement analysis

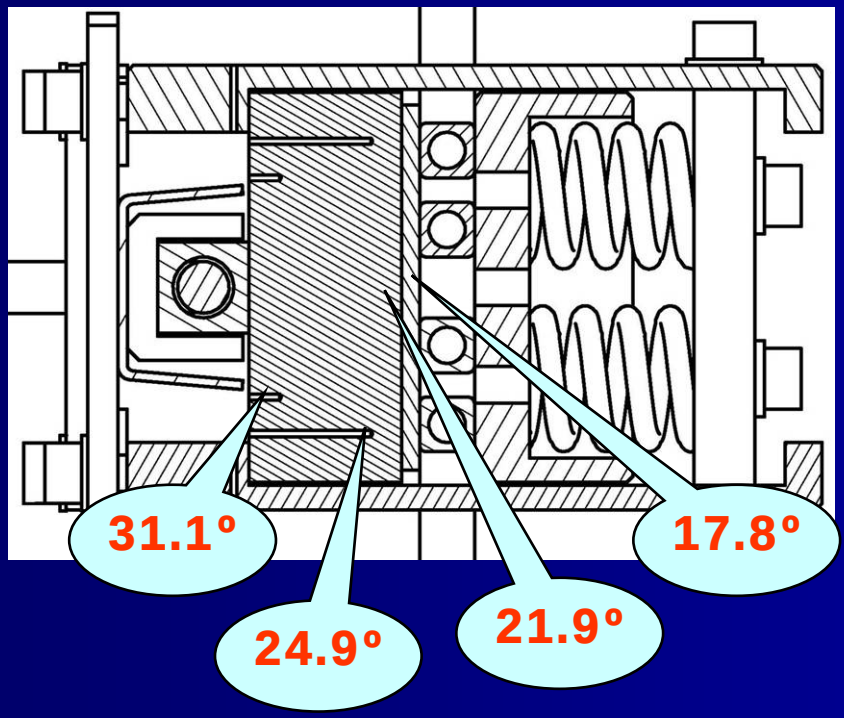
Nominal Conditions 7 TeV 8e10 p/s Steady-state

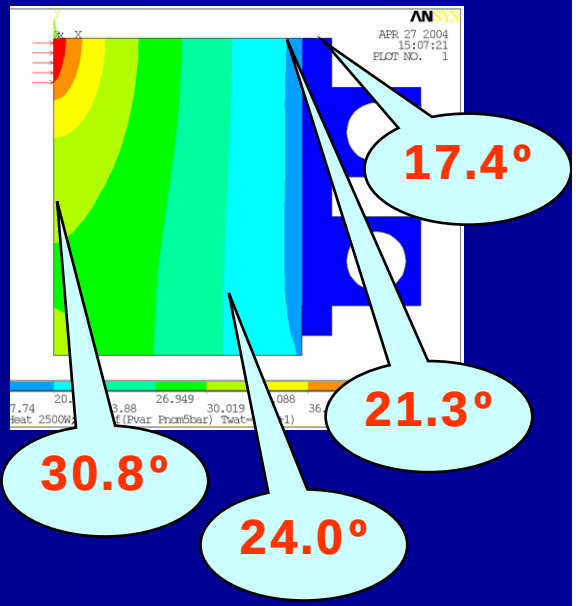




EXPERIMENTAL VALIDATION

Equivalent Heating Test of collimator bloc
2500 W Water inlet temperature 11°C





Very good agreement between measured and calculated data!!

CONCLUSIONS

- A mix between traditional and innovative solutions chosen…
- Prototype design finalized and series design activity starting up …
- Extensive thermo-mechanical analyses results predict that tough specification should be attained … (within reasonable limits and provided material data are correct!)
- Experimental data confirm thermal calculations and model used …
- Manufacturing of 3 prototypes is ongoing and running on schedule for SPS installation (August, 11th) …
- … nevertheless meeting Project production deadlines remains extremely difficult (series drawing by September!) … lot of work still ahead!

CONCLUSIONS

Many thanks for contribution to:

J.P. Bacher, C. Benvenuti, S. Calatroni, L. Favre, L. Ferreira, D. Gasser, J.M. Geisser, G. A. Izquierdo, T. Kurtyka, D. Lombard, S. Mathot, M. Mayer, N. Mézin, M. Polini, S. Sgobba, T. Tardy … **and many more from TS and AB Department.**

Thank You for your attention