The Tail Clipper Collimator

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Acknowledgements: *H. Braun, R. Zennaro*

Outline

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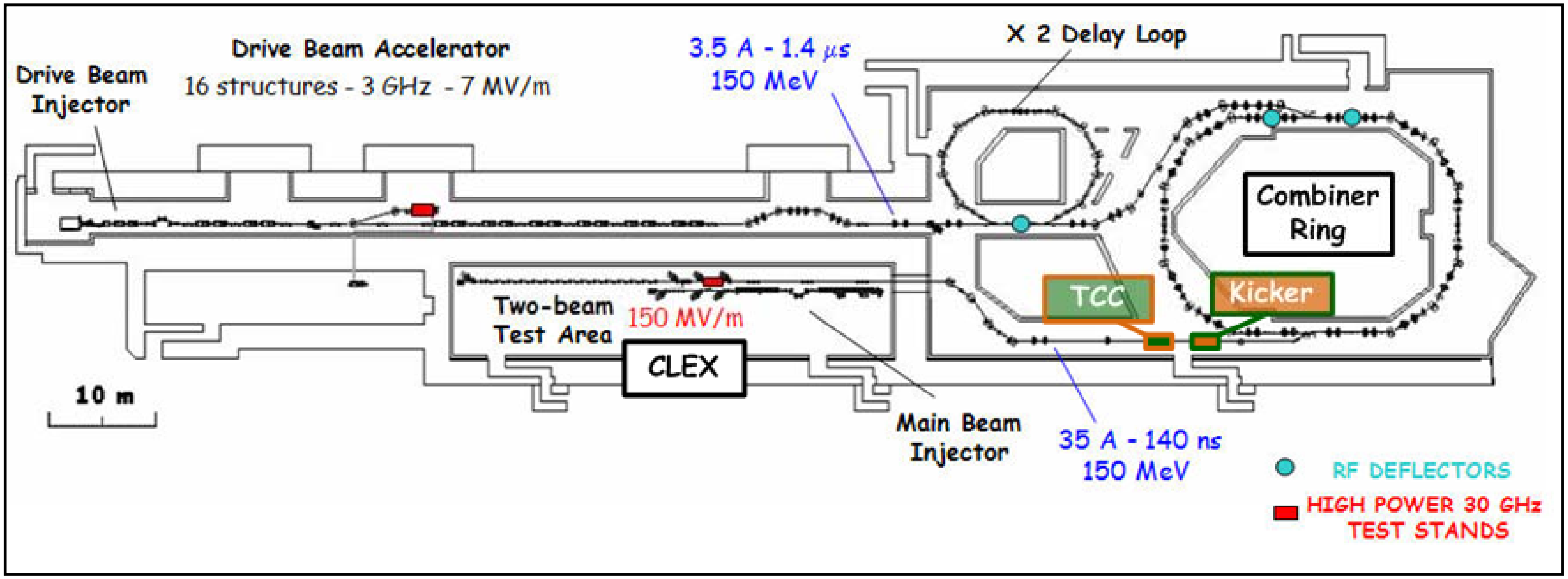
- **Mechanical design of the Tail Clipper collimator (TCC)**
  - **Design parameters**
  - **FLUKA and ANSYS thermo mechanical analysis**
  - **Design basics**
    - Thermal analysis
    - Protection issues ⇨ Absorbed doses
- **Range of movements**
- **Electronics and control for operation**
- **Integration issues**
- **Status**
- **Conclusions**

The Tail Clipper Collimator (TCC)

- **The Tail Clipper Collimator is a combined collimator/dump. It will operate in the CTF3 *TL2* line** *(transfer line between the Combiner Ring and CLEX)*



- **Two different operation modes:**
  - **Collimator mode ⇨ Absorb ~ half of the bunch train length deflected by the Tail Clipper Kicker (for RF conditioning in the CLEX)**
  - **Dump mode ⇨ Intercept the full beam arriving from the Combiner Ring (internal safety device & physical separation of CLEX and CR)**

TCC Design parameters

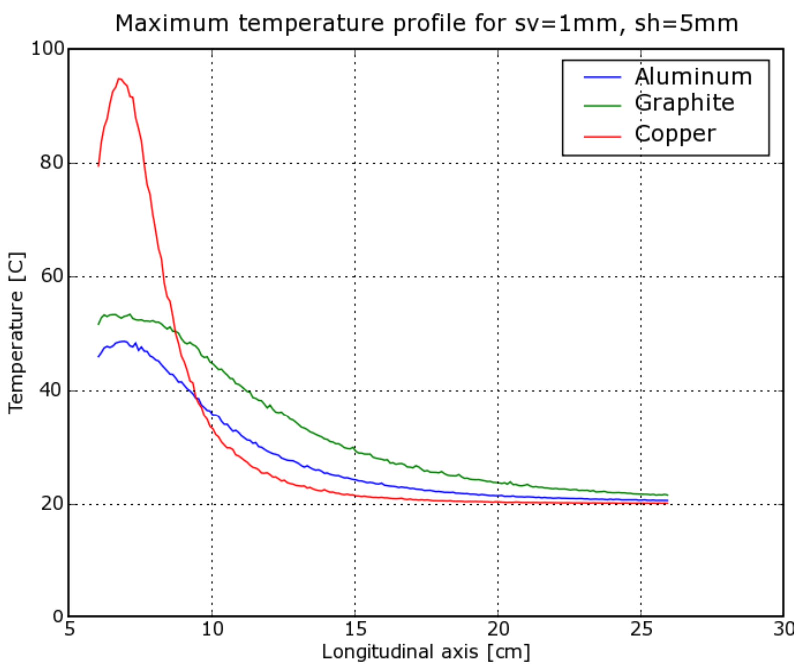
Particle type	**Electrons**
Beam energy	**100-300 MeV**
Repetition rate	**0.8-5.0 Hz**
Incoming pulse duration	**140 ns**
Maximum beam pulse current	**35 A**
Operation of the kicker	**Beam kicked upside, in the vertical plane**
Beam size range (rms, 1σ)	**2-5 mm (horizontal plane); 1 mm (vertical plane)**
Displacement of beam on the tailclipper entry face due to kicker action	**> 6 mm**
Average beam power	**3.7 kW**
Duty time	2000 h/year
Energy for maximum beam power	150 Mev
Length of the tailclipper (flange to flange)	1200 mm
Distance to the kicker (upstream to upstream)	3620.6 mm
Inner aperture of diameter of upstream and downstream beam pipe	40 mm
Flatness of the jaw	0.1mm
Positioning resolution in the movement of tailclipper	0.1 mm
Precision of tailclipper	0.3mm
Compatible with RF	No grooves; angles smaller than 20 deg.
Compatible with CTF3 dematerialized water line	Material of the cooling pipes: Cu, CuNi…
Compatible with CTF3 vacuum	~10^{-8} mbar
Compatible with radioprotection requirements	Radiation shielding if needed
Maximum time range to reach failsafe position	30 s

FLUKA & Thermo mechanical analysis

From FLUKA & ANSYS simulations

⇩

Graphite is the "safest" material choice for the core of the TCC



- **FLUKA and ANSYS Simulations ⇨ normal dump operation:**
  - **Materials studied: Al, Cu, graphite; Nominal beam size (σv=1mm, σh=5mm); Impact centered in the jaw**
  - **Hypothesis: E= 150MeV; 5 bunches/s; P=3.7kW (<=>735 J/pulse); No cooling**

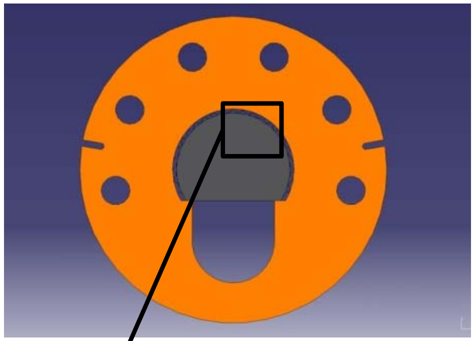
	Aluminum		Copper		Graphite	
	Simulation results	Tensile Yield Strength	Simulation results	Tensile Yield Strength	Simulation results	Tensile Yield Strength
Δt (140ns)	23 C	~ 55 MPa	70 C	~ 70 MPa	34 C	~ 30 MPa
Δt (200ms)	5 C		10 C		6 C	
Max. Stress (140ns)	37 MPa		136 MPa		1.2 MPa	

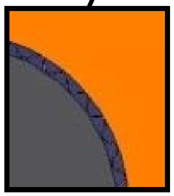
- **FLUKA and ANSYS simulations ⇨ worst dump case:**
  - **Beam size: (σv=1mm, σh=2mm) (during setting-up)**
  - **Beam dumped at 1.3mm from the surface of the jaw** (based on past calculations: *"Thermal and Mechanical Analysis of the LHC Injection Beam Stopper (TDI)"* , L. Massida and F. Mura)

	Aluminum		Graphite	
	Simulation results	Tensile Yield Strength	Simulation results	Tensile Yield Strength
Δt (140ns)	58 C	~ 55 MPa	78 C	30 MPa
Δt (200ms)	11 C		13 C	
Max. Stress (140ns)	79 MPa		2 MPa	

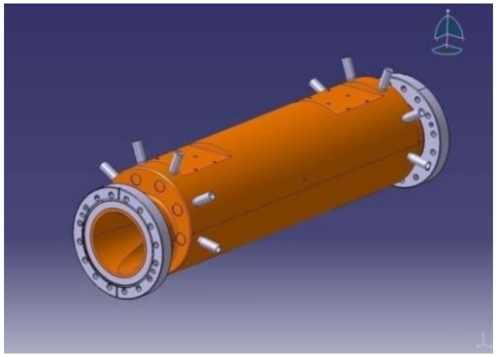
TCC Design basics: Core & Vacuum chamber

- **Core ⇨ Graphite (ρ=1.8 g/cm3)**
  - **Total stopping power (e^-, 150Mev) = 5.136 MeV cm^2/g : Range = 20cm**
  - **Vacuum requirements:**
    - **Cleaning and heat treatment** following specific vacuum procedures
    - **Bake out (300° C)** needed "in situ" to meet vacuum requirements (10^{-8}mbar in the TL2 line)



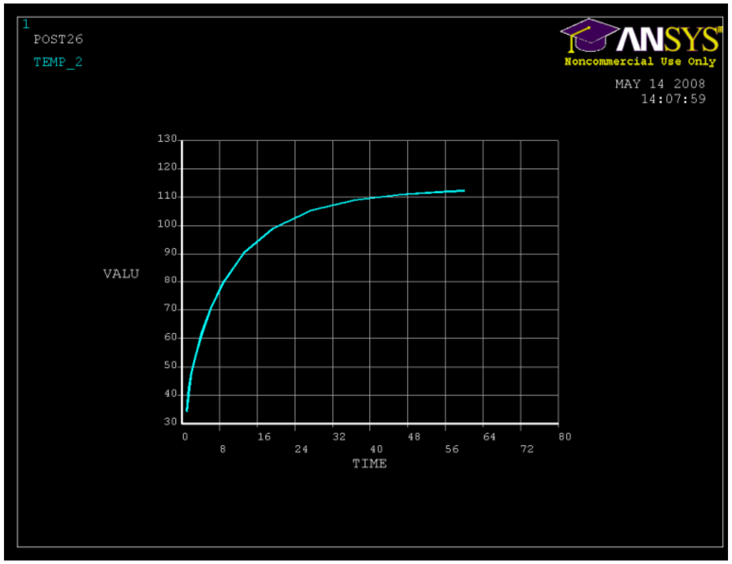


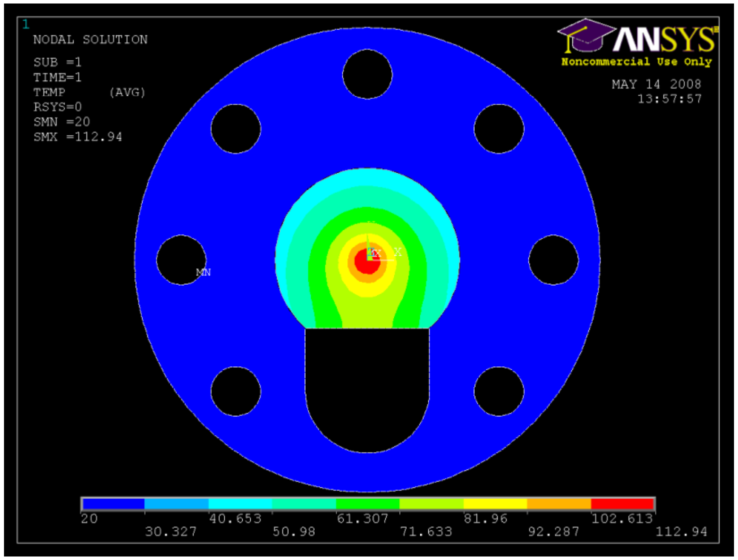
- **Vacuum chamber ⇨ CuOFE**
  - **Cooling: Water (6l/min)**
  - **The graphite is not constrained inside the vacuum chamber. It is held and kept in position by two CuBe foils acting as spring**
    - No internal stresses due to differences in the thermal expansion coefficient between CuOFE and Graphite
    - The open space between the graphite and the Cu envelope facilitates the out gazing recovery, while the CuBe foils guarantees the thermal conductivity
  - **RF studies performed by R. Zennaro (AB/RF) showed the compatibility of the design with the requirements in the TL2 line** (*R. Chamizo, H. H. Braun, N. Chritin, D. Grenier, J. Hansen, Y. Kadi, L. Massidda, Th. Otto, R. Rocca, R. Zennaro, "*Design of the Tail Clipper Collimator for CTF3*", LINAC'08, Victoria, October 2008*)



TCC Thermal analysis

- **A 2D model was used for the thermal analysis** ***(compatibility was checked with analytical calculations and a 3D model)***
- **During operation:**
  - **The contact loss due to the CuBe foil (spring) represents a small thermal resistance with minor impact in the maximum temperature reached in the graphite**
  - **The maximum temperature reached (steady state) is ~ 112 degrees**
  - **No constraints are induced in the graphite during operation or during the bake out: Open gap between the Cu envelope and the graphite**
- **During bake out:**
  - **Transient analysis: After 2 hours, the thermal equilibrium (300 degrees) is reached**
  - **The graphite is not stressed during the whole bake out process**
  - **A 22MPa VonMises equivalent stress is found on copper (tensile yield strength ~70MPa)**



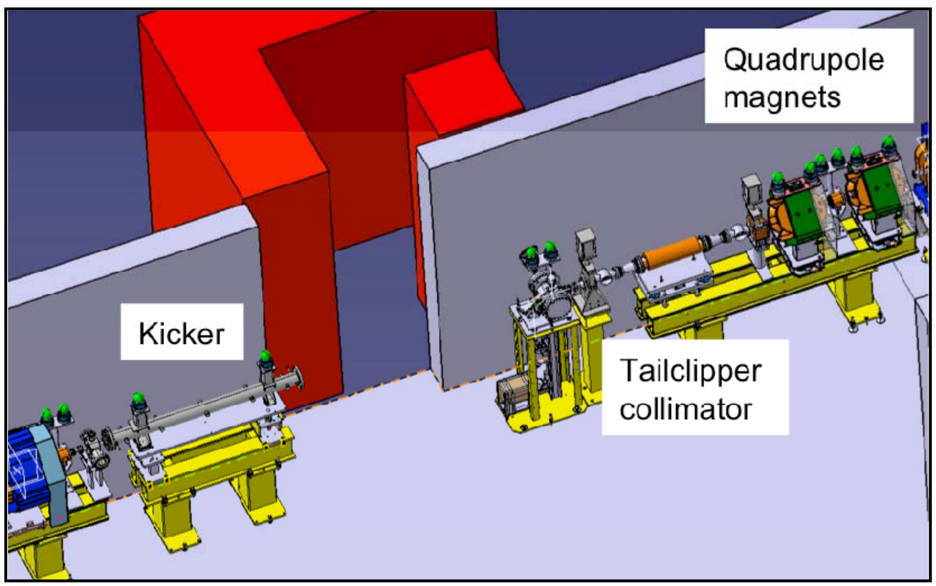


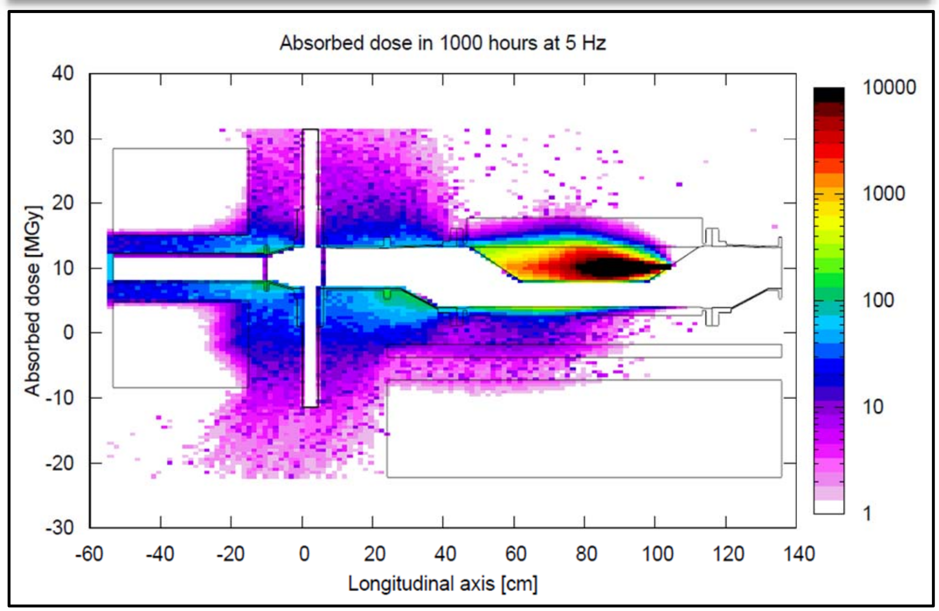
TCC Design: Protection issues I

- **The TCC will operate in the TL2 line, upstream of a set of quadrupole magnets**
  - **The absorbed dose in the magnets must be kept below a critical threshold in order to avoid damage of the insulating resin (Araldite) in the magnet coils**
  - **Experimental results show an important degradation of the mechanical properties of pure Araldite irradiated above 3 MGy (*CERN-TIS-2002-010-D1-PP*)**

Result from preliminary FLUKA analysis:

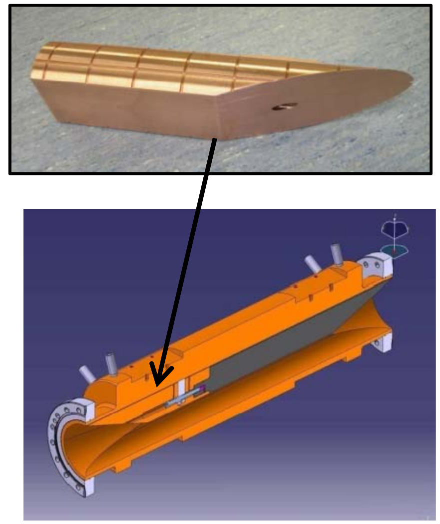
- **The absorbed dose on the quadrupole magnet downstream of the TCC was 27MGy after one year of TCC operation (1000h/year @ 5Hz)**
- **The design was reviewed in order to protect the elements downstream during the dump operation**

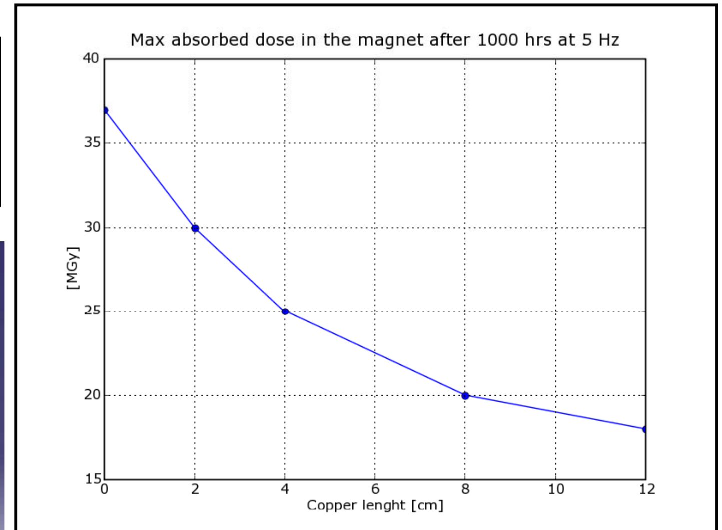




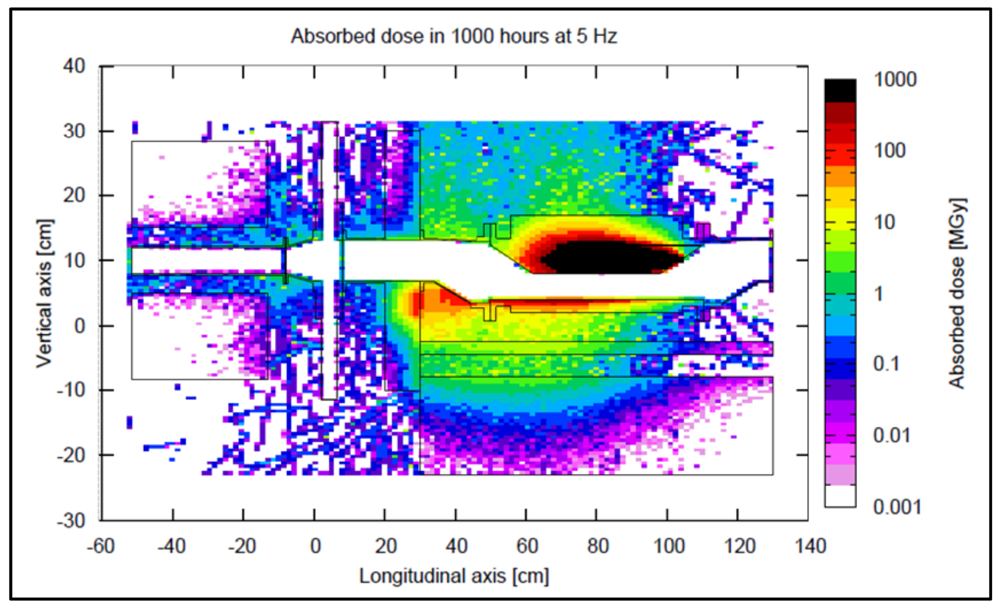
TCC Design: Protection issues II

- **A combination of internal and external shielding was implemented in the design:**
  - **Internal: A Cu absorber (12cm) was added downstream to the graphite core**
    - ***The absorbed dose in the quadrupole magnet was reduced to 18MGy after one year operation***
  - **External: 10cm-thick lead plate added downstream the TCC**





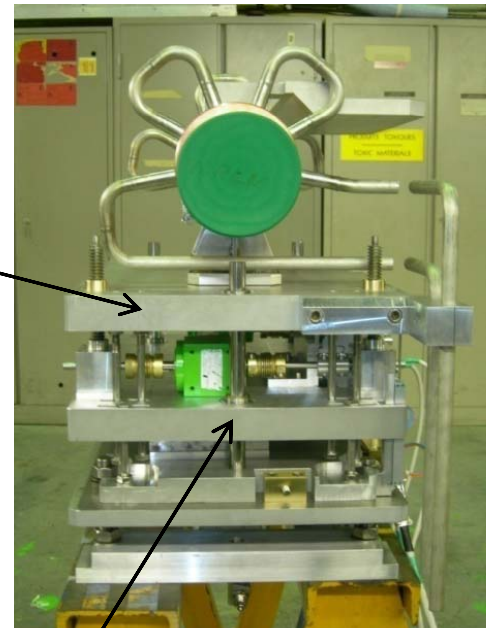
By combination of an internal absorber and a external shielding, the absorbed dose in the quadrupole magnet is reduced to 0.1MGy after one year operation

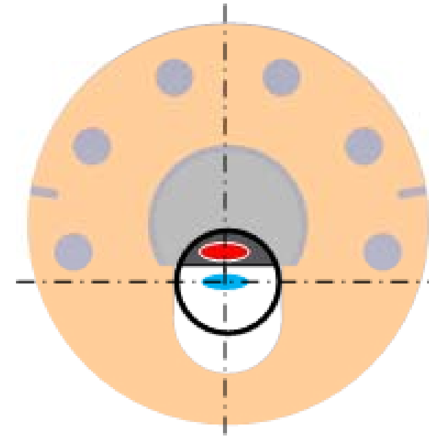


TCC Design: Movement ranges

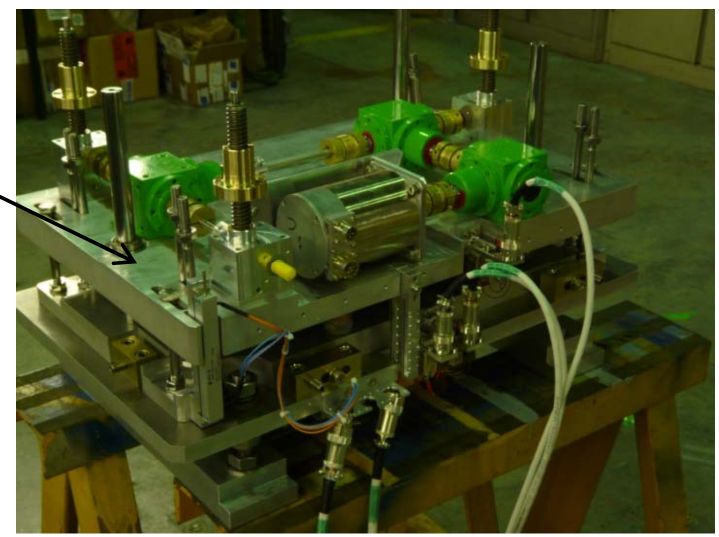
The Tail Clipper collimator is supported in two movable tables that provide the movement range needed for the collimator and dump modes:

1. *The upper table allows the movement ranges for the* collimator operation *with the required resolution and precision*
   - The movement range is procured by a stepper motor that commands 3 screw jacks
   - One potentiometer serves to monitor the displacement and detect a hypothetical motor failure.
   - The maximum and minimum range of movements are limited by end switches and mechanical stops
2. *The lower table guarantees the positioning of the collimator for* dump operation
   - A pneumatic system guarantees that the dump position can always be reached (TCC's own weight)
     - The rapidity of the system can be regulated. A safe movement is possible within 3s (safety requirements: within 30s)
   - The maximum and minimum range of movements are limited by end switches and mechanical stops





Collimator mode



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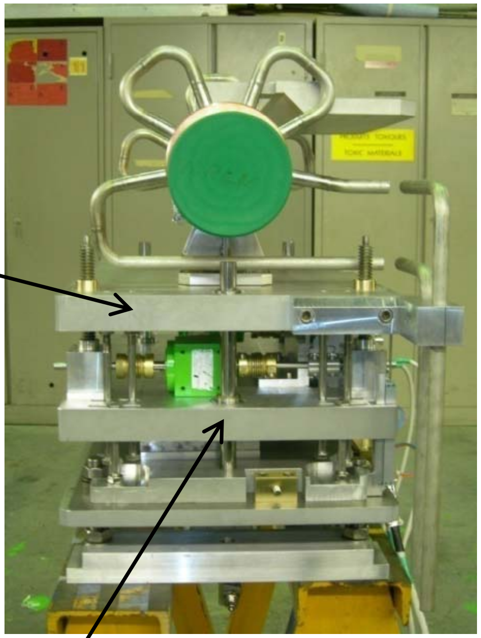
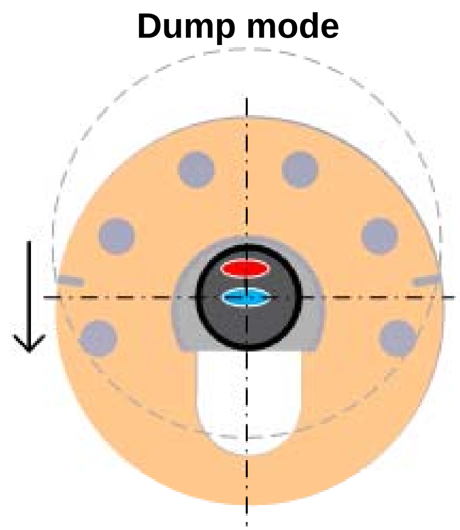
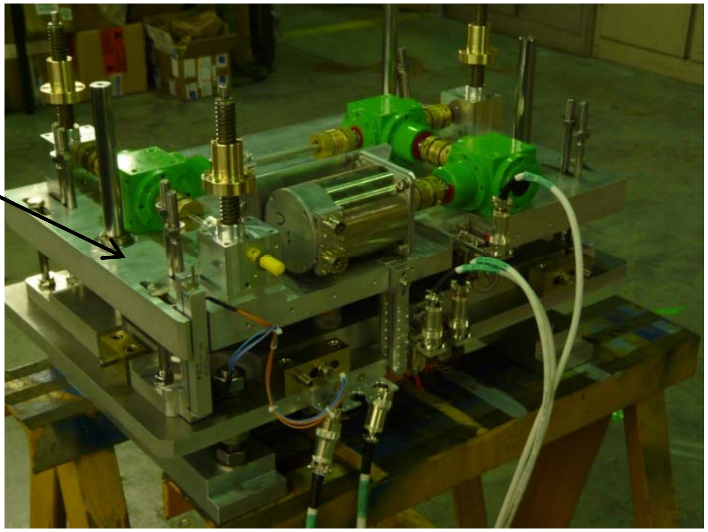


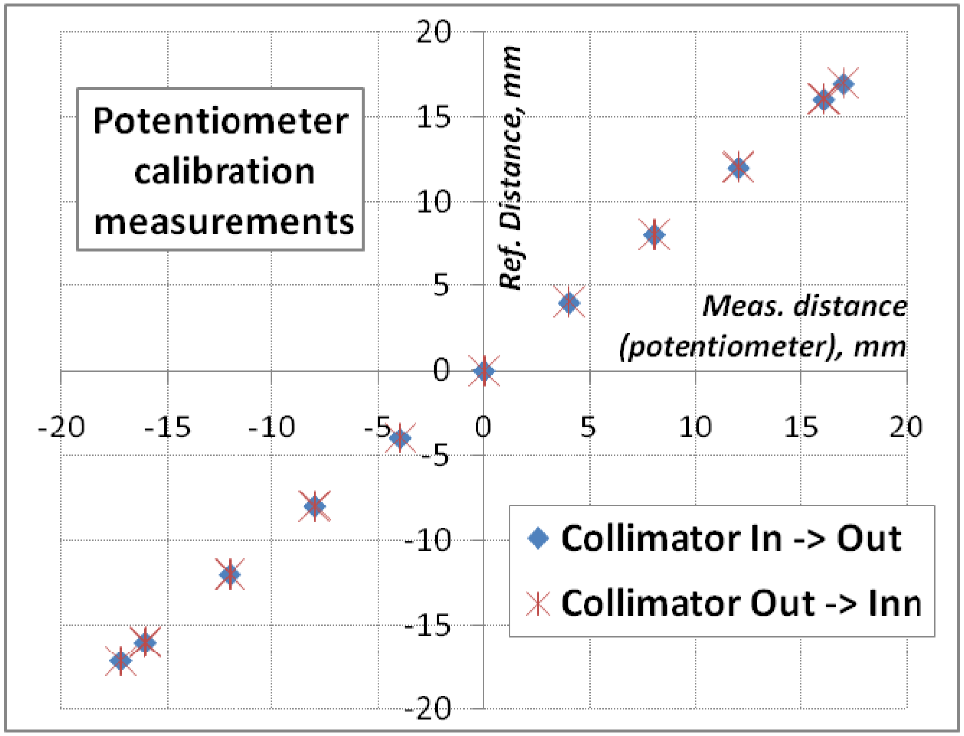




Electronics and control

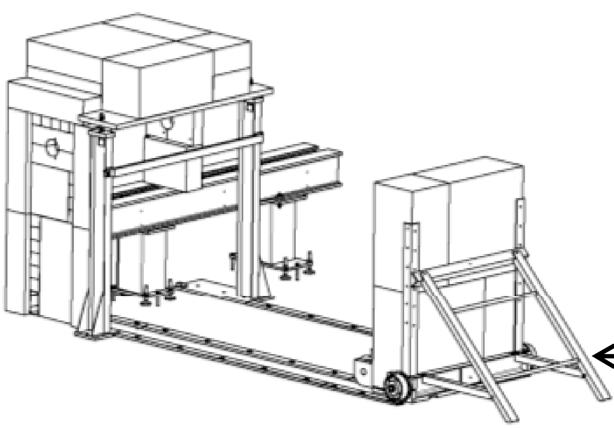
- All electronic components of the collimator (motors, local cables, potentiometer and switches) are **radiation hard resistant** (absorbed doses ~0.2MGy/year)
- An **external patch panel** makes the **interface** between local (radiation hard) cabling and general (non radiation hard) cabling to the control rack
- Range of movements:

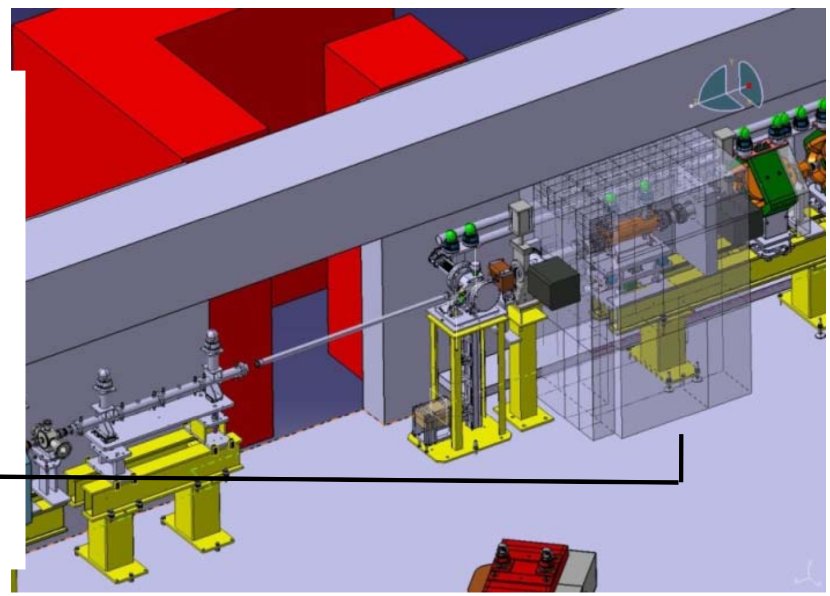
(mm)	Switch	Mechanical stop
Dump OUT (=collimator mode)	+17.2	**+18.06**
Dump IN	-20.8	**-23.30**
Collimator OUT	**+17.1**	+18.06
Collimator IN	**-17.12**	-23.30



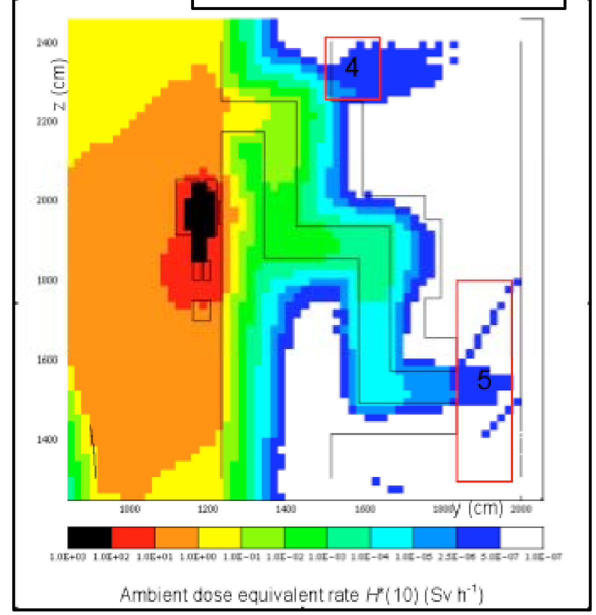
TCC: Integration issues

- **Two major issues resulted from the integration of the TCC in the TL2 line:**
  - **The TCC needs to be baked out “in situ” => Separated vacuum sector in the line (the rest of elements cannot be baked out)**
  - **The analysis of the ambient dose equivalent rates (Th. Otto, “Radiation Protection Shielding of the CTF3 Tail Clipper”, CERN-SC-2008-051-RP-TN) led to the design of an iron local shielding and further modifications in the line** *(i.e. extension of the access labyrinth, shielding of cable ducts and qualification of annex areas as supervised radiation areas)* **=> A mobile shielding has been designed**





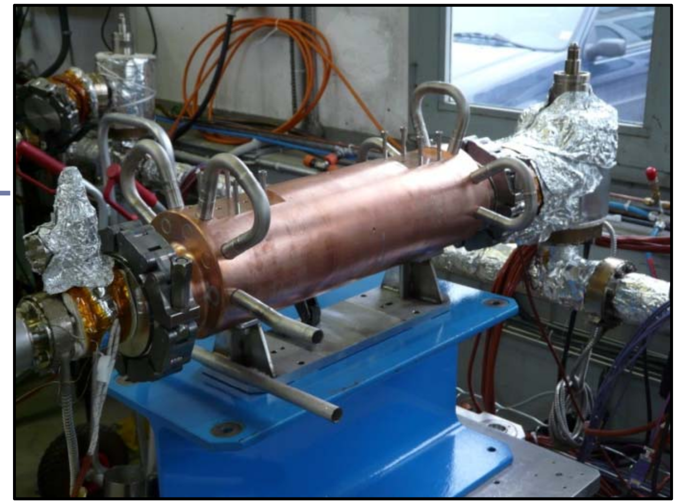
(Th. Otto, SC-RP)

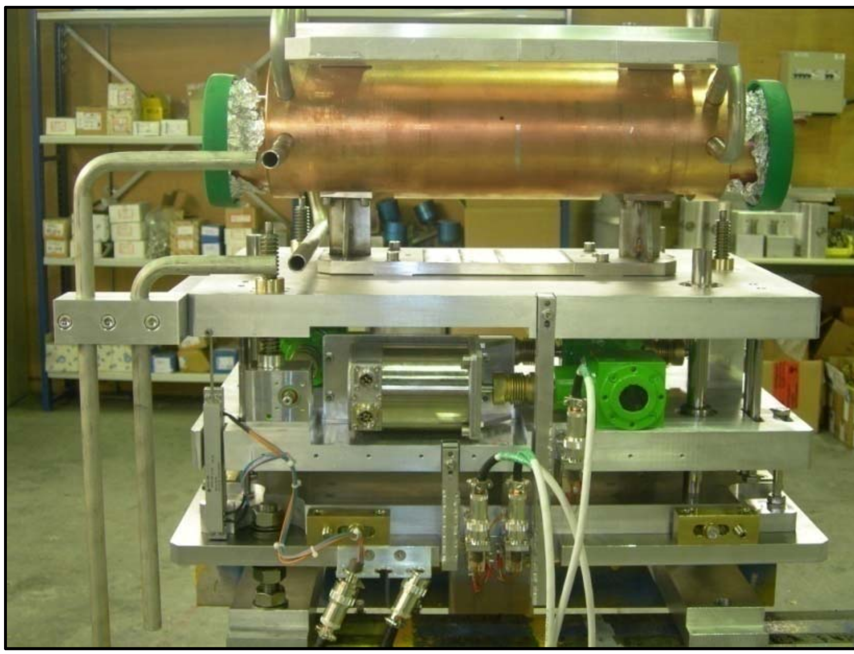


All integration issues have been addressed

Status I

- **Before installation (laboratory tests):**
  - **Bake out (300° C) ✔**
    - **Resulting vacuum: 5.1e^{-9}mbar (compatible for installation)**

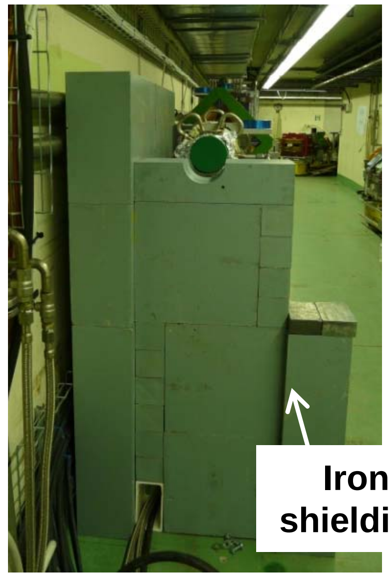


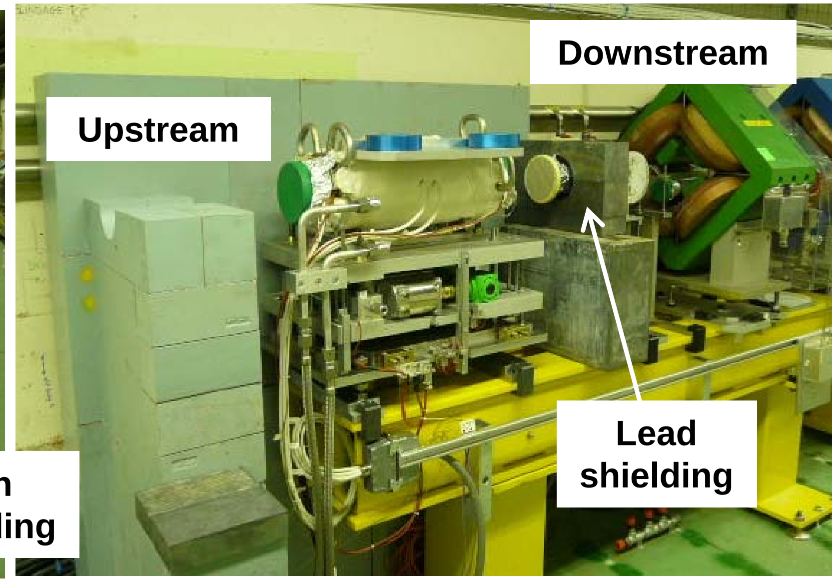


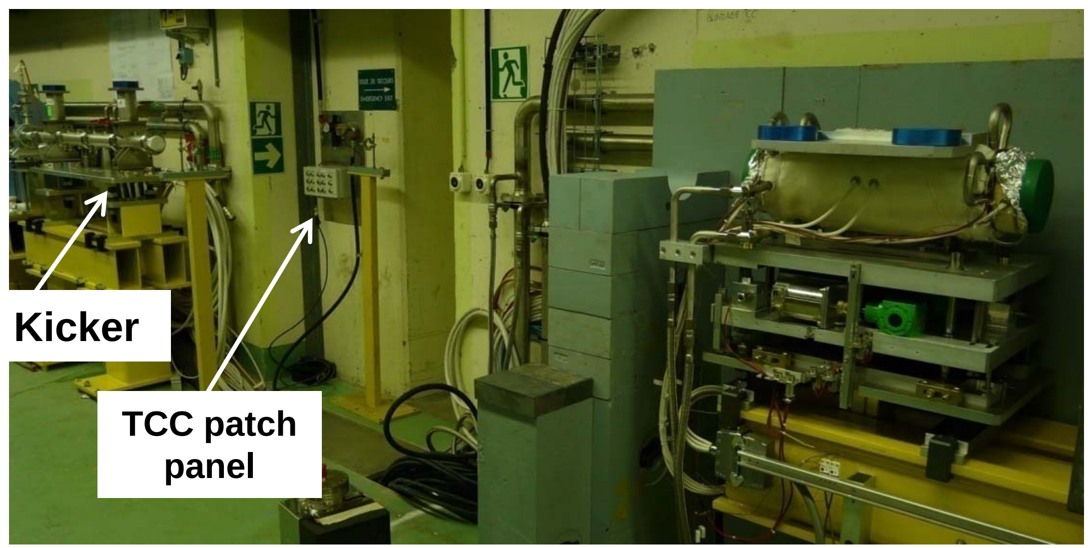
- **Mechanical stops and switches aligned ✔**
  - **The movement ranges in both collimator and dump mode are met**
- **Low level software has been finished and tested ✔**
  - **The calibration of the potentiometer is done**
  - **The interlock beam signals are generated**

Status II

- The TCC has been installed in Jan09 ✔
- The fix part of the local shielding (iron and lead) is installed ✔
  (major modifications of the environment were required)
- Air and water connections are finished and tested ✔
- The patch panel has been installed
  - Pneumatic system and electronics tested ✔







All activities are included in (and are compatible with) the CTF3 shut-down planning

Conclusions

- **The design, manufacturing and assembly, tests and installation of the Tail Clipper collimator have been finished within one year (major challenge!)**
  - **The thermo mechanical behavior of the TCC is validated by calculation for the worst case operation mode (dump mode) ✔**
  - **The design takes into account the requirements from RF and vacuum ✔**
  - **The implementation of an internal absorber and a local external shielding (lead) prevents any damage due to the absorbed doses in the downstream equipment s✔**
  - **All the elements to be placed inside the local iron shielding are radiation hard resistant. A patch panel has been designed as interface between radiation hard and standard components ✔**
- **All integration issues have been addressed**
  - **Vacuum sectoring of the TL2 line ✔**
  - **Local modifications in the line to allow the installation of the iron shielding and to meet RP requirements ✔**
- **The remaining activities (bake out and HWC) are in line with the CTF3 shut-down general planning ✔**

The TCC collimator will be fully operational by beginning March 09

Thank you for your attention…

Study of absorbed doses II

- **The absorbed doses are mainly due to photons:**
  - **Average energy: photons (9.7MeV), neutrons (1.8MeV)**
  - **Fluence: photons (10^{15} $cm^{-2}s^{-1}$), neutrons (10^{11} $cm^{-2}s^{-1}$)**