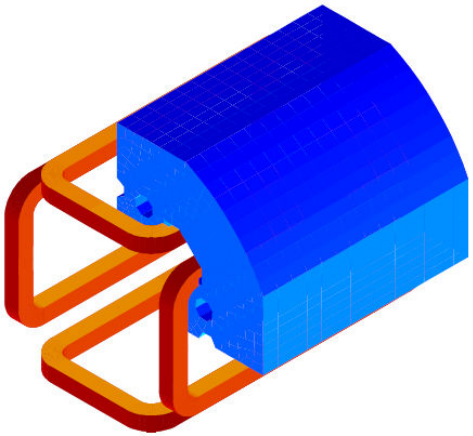
Accelerator activities at CIEMAT



GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

F. Toral on behalf of the Accelerator Group, CIEMAT

CIEMAT, 5/02/2010

Outline

- ✓ Group capabilities and facilities
- ✓ Collaboration with CERN: CTF3-CLIC, SLHC, EUCARD
- ✓ XFEL collaboration
- ✓ IFMIF collaboration
- ✓ FAIR collaboration
- ✓ RTM collaboration
- ✓ Own developments

Group capabilities

In the year 2008, CIEMAT created a Particle Accelerators Unit with 28 people up to now. It absorbs the former Applied Superconductivity Group and the facilities located at another Institute, CEDEX. Our group also keeps ongoing activities concerning kynetic energy storage.

There is a number of collaborations with other accelerator centres. The oldest one is with **CERN**, since 1989. Future plans aim to build an accelerator here.

Capabilities

- **Calculations**: electromagnetic, thermal and mechanical numerical simulations
- **Engineering design**
- **Prototyping**: fabrication and assembly of magnets, RF structures and other accelerator devices
- **Tests**: two vertical cryostats, one cryocooler and low power RF measurements

Group facilities

CEDEX Superconductivity Laboratory

CIEMAT Winding Machine

CEDEX Flywheel Pit

CEDEX Assembly Hall

Outline

- ✓ Group capabilities and facilities
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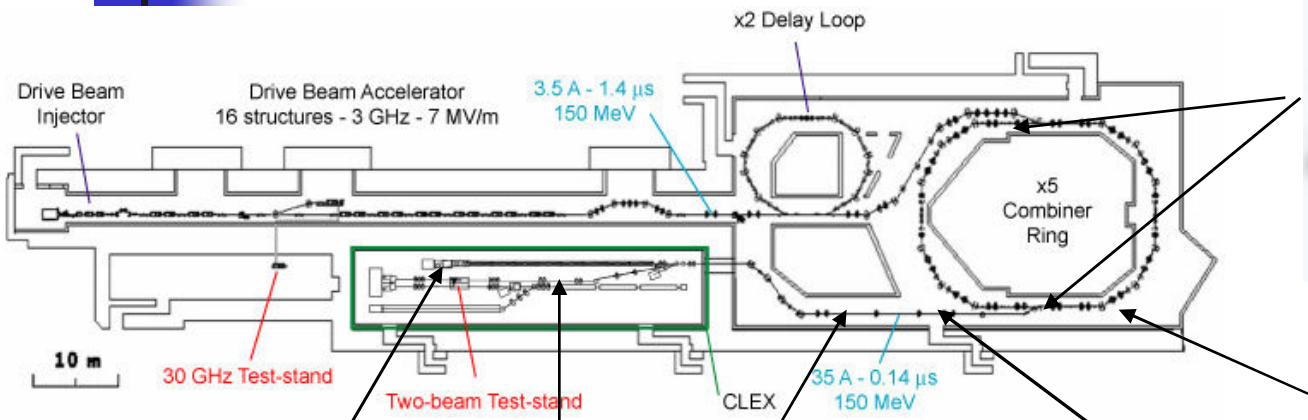
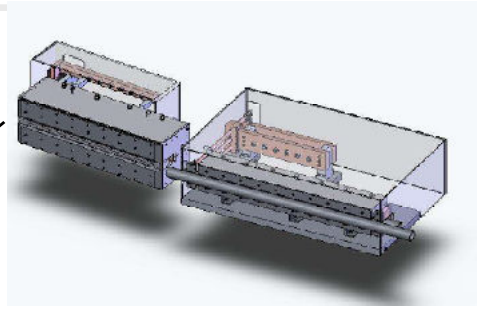
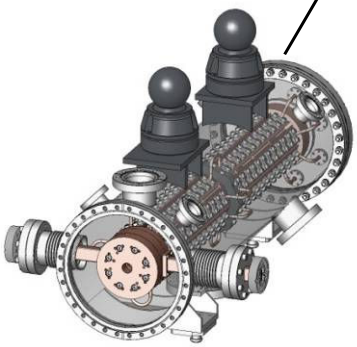
Contribution to CTF3



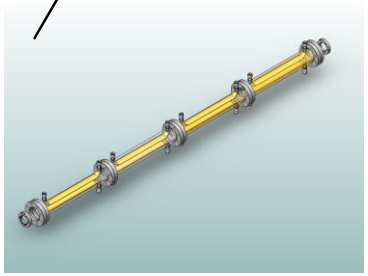


Thin and Thick Septa

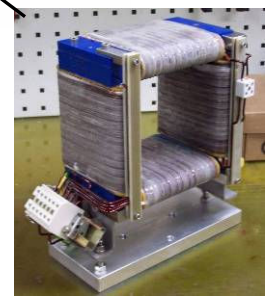


4 TBL PETS

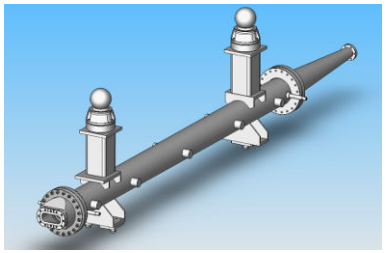
16 TBL quad Movers



Tail Clipper Kicker



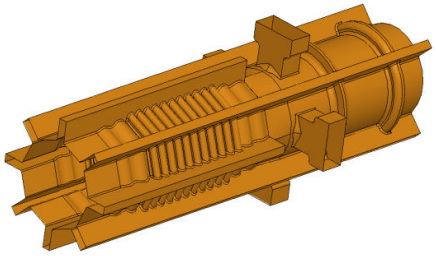
33 Horizontal/Vertical Correctors



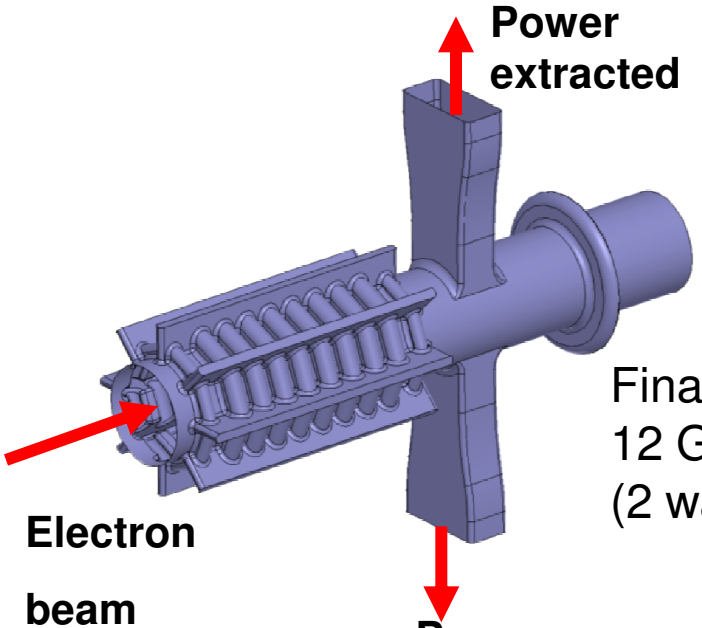
Fast Kicker

*** In 2004, CIEMAT joined the CTF3 experiment to test the feasibility of CLIC(CERN). Our contribution consists of the delivery of different components for the Combiner Ring and also for the Transfer Lines and the Test Beam Line. In this participation, with an overall budget of around 1,5M€, we had an important industrial contribution.**

RF design of TBL PETS

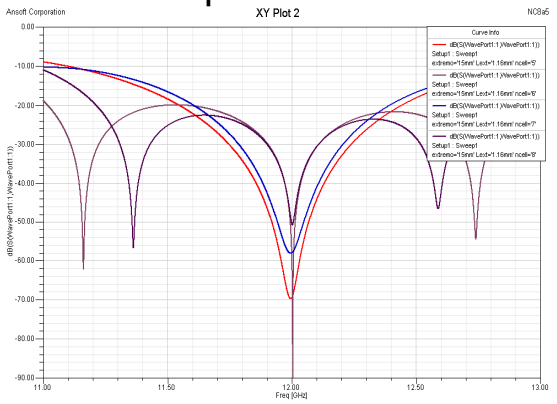


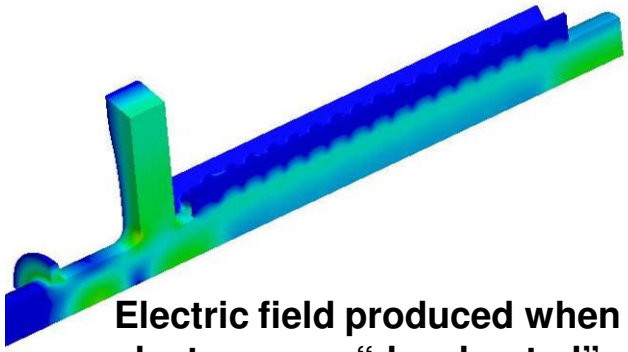
Previous design
30 GHz PETS
(4 waveguide extractor)



Final version:
12 GHz PETS
(2 waveguide extractor)

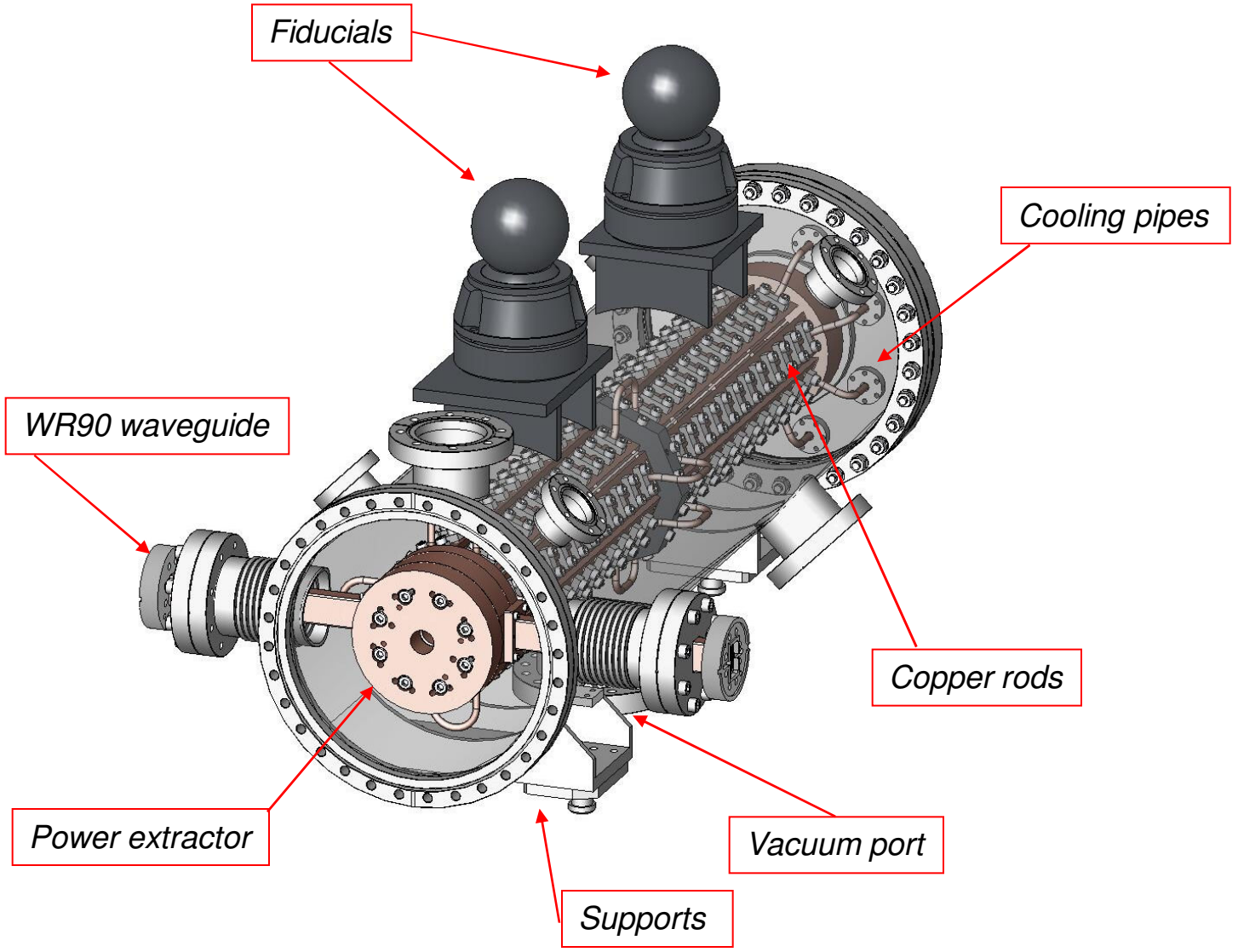
RF optimization





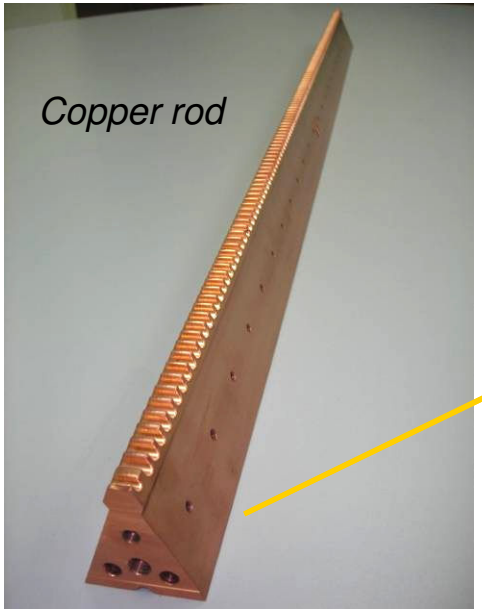
Electric field produced when electrons are "decelerated"

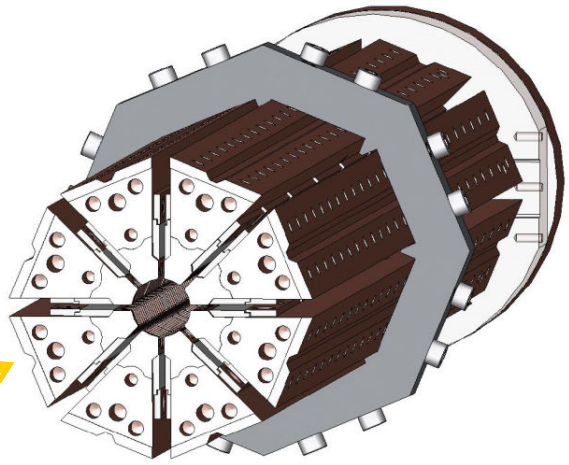
General layout of TBL PETS

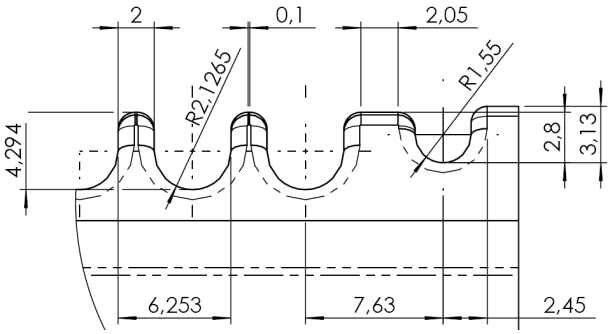


Copper rods production

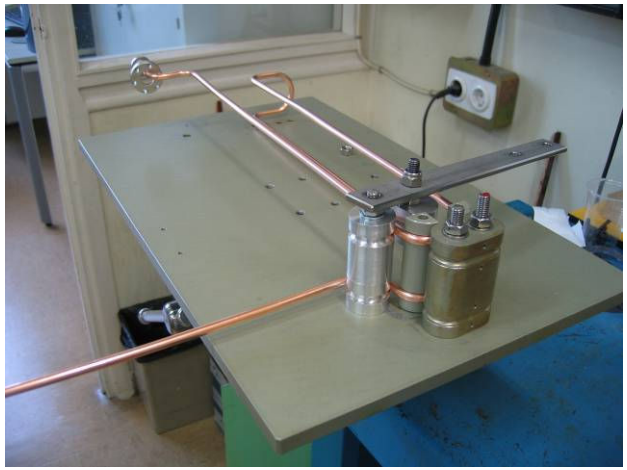
- Each PETS was made of eight OFE copper rods (800 mm long).
- These were the most difficult parts to fabricate: profile tolerance is +/- 0.02 mm and roughness R_a should be better than 0.4 micron.
- The coupling cell is smaller: two different milling tools were necessary.
- Two intermediate thermal treatments for stress relaxation.

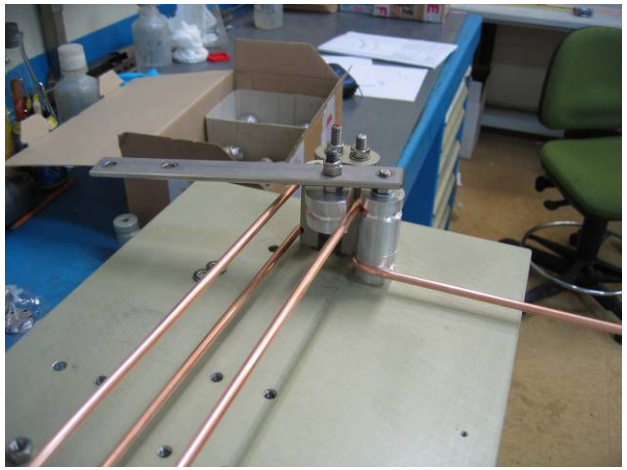


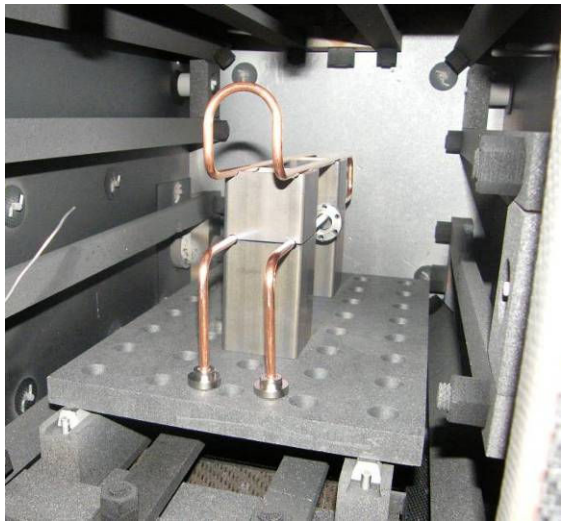


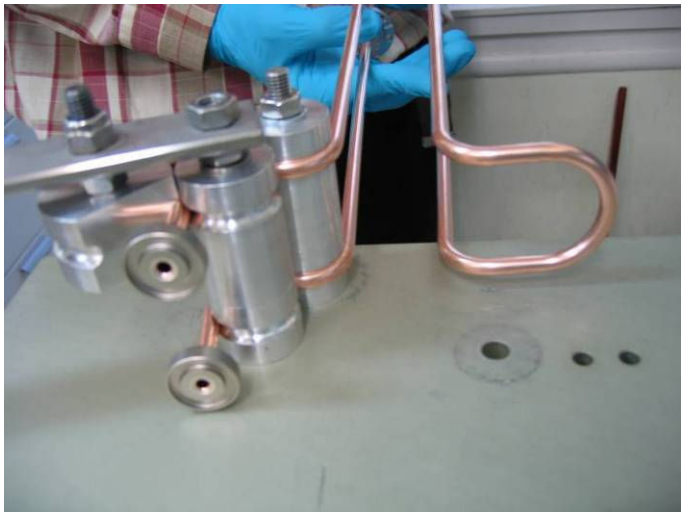


Cooling pipes production

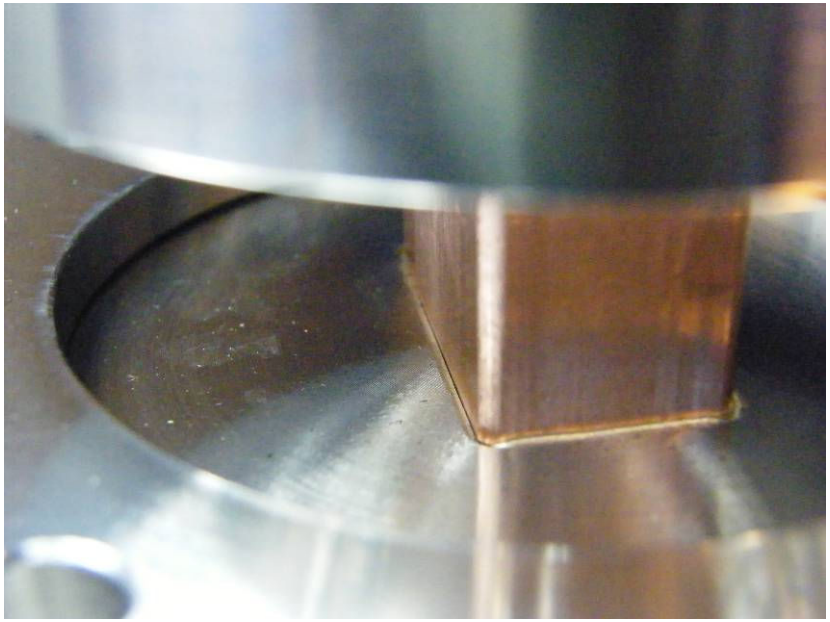


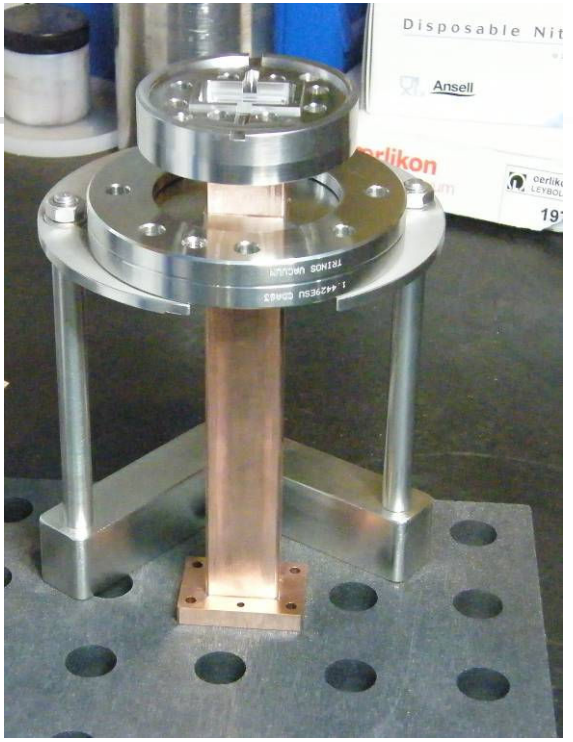


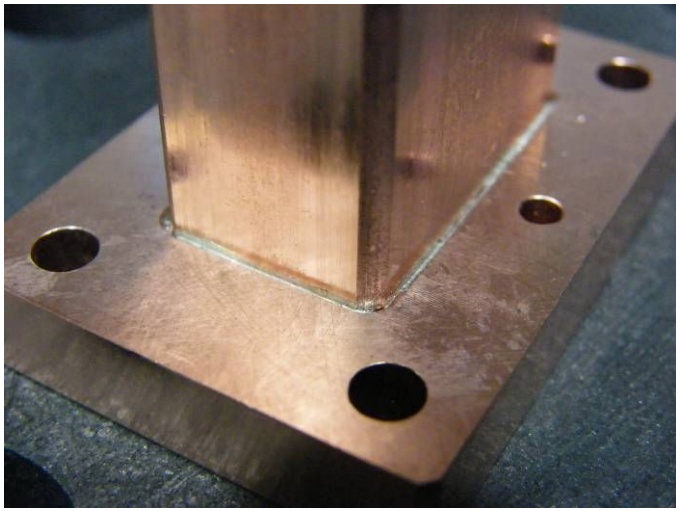


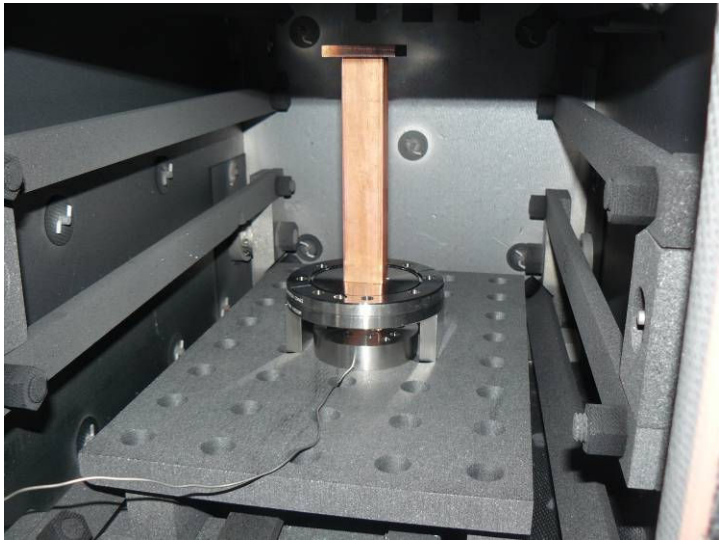


Waveguides

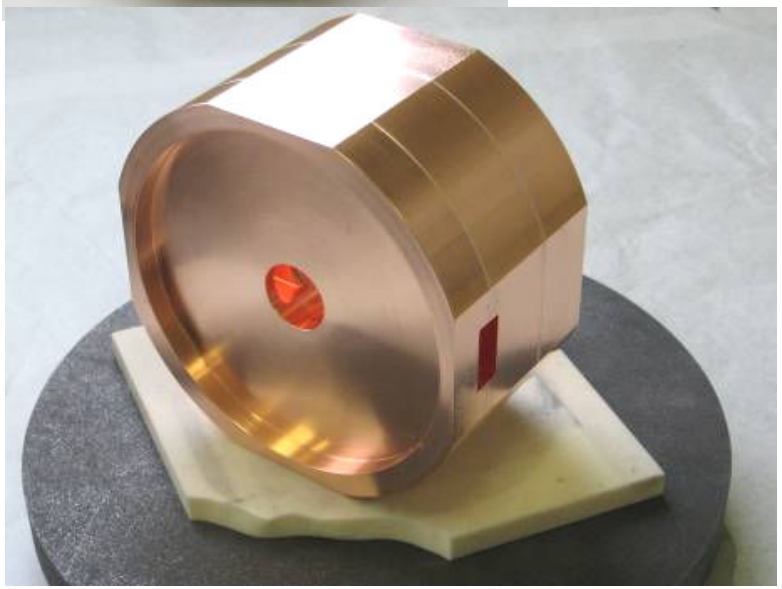


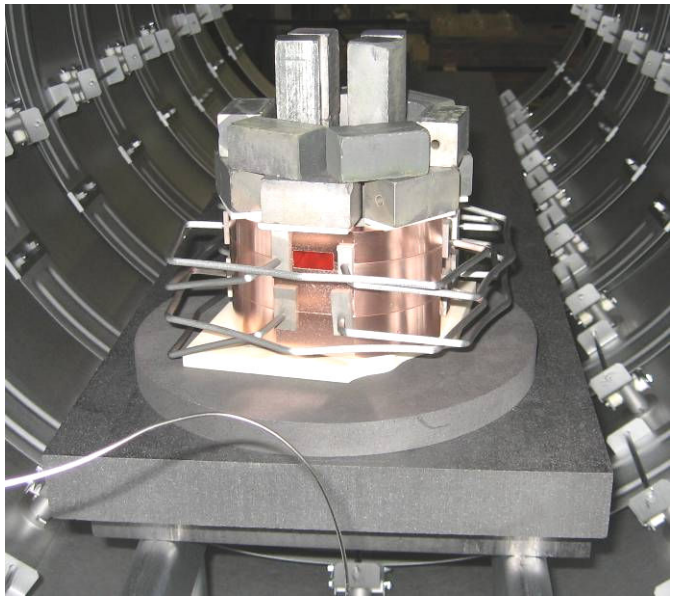






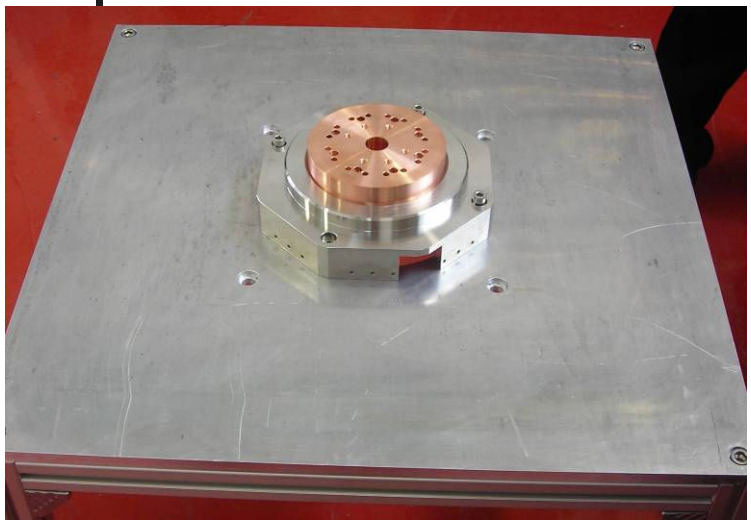
Power extractor

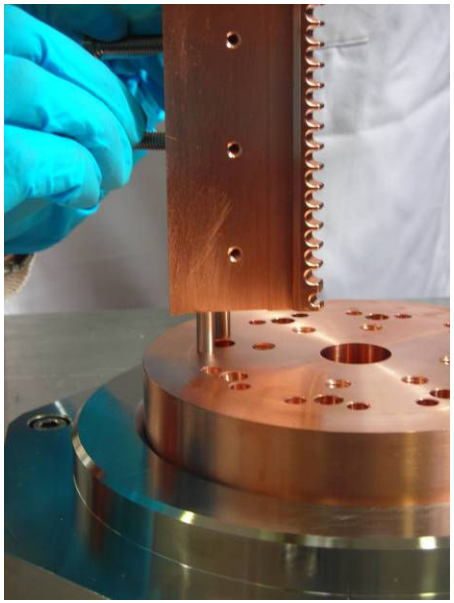


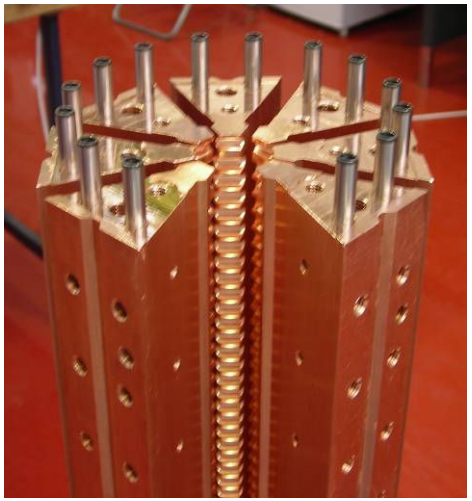


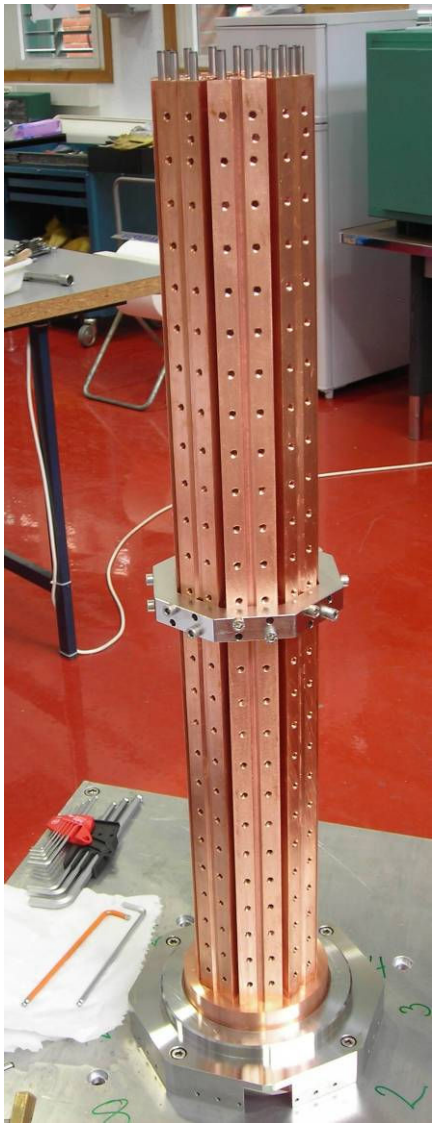
Courtesy Serge Mathot, CERN

RF structure assembly









Mechanical measurements

Before shims

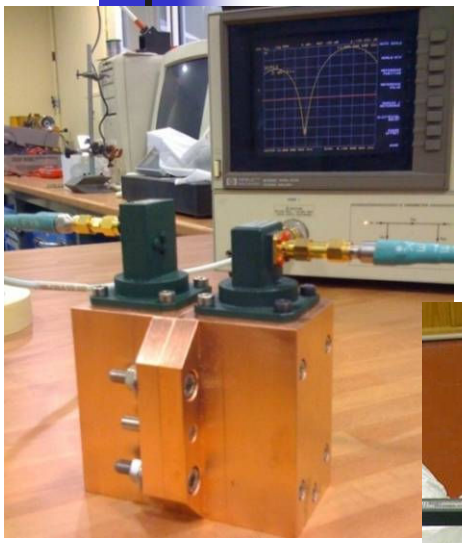
	ROD 1-5		ROD 4-8		ROD 7-3		ROD 6-2		AVERAGE
	R	L	R	L	R	L	R	L	
DOWN	113.045	113.035	112.950	112.990	113.045	113.010	112.950	112.950	112.997
MID-DOWN	113.040	113.040	112.960	112.980	112.930	112.925	112.955	112.960	112.974
BELOW RING	**113.055**	**113.040**	**113.045**	**113.055**	**113.035**	**113.010**	**113.045**	**113.035**	113.040
ABOVE RING	**113.040**	**113.020**	**113.045**	**113.060**	**113.070**	**113.050**	**113.065**	**113.055**	113.051
MID-UP	112.965	112.980	112.990	112.995	112.980	112.985	113.035	113.020	112.994
UP	112.990	113.010	113.040	113.050	112.970	112.940	113.080	113.060	113.018
AVERAGE	113.023	113.021	113.005	113.022	113.005	112.987	113.022	113.013	113.012

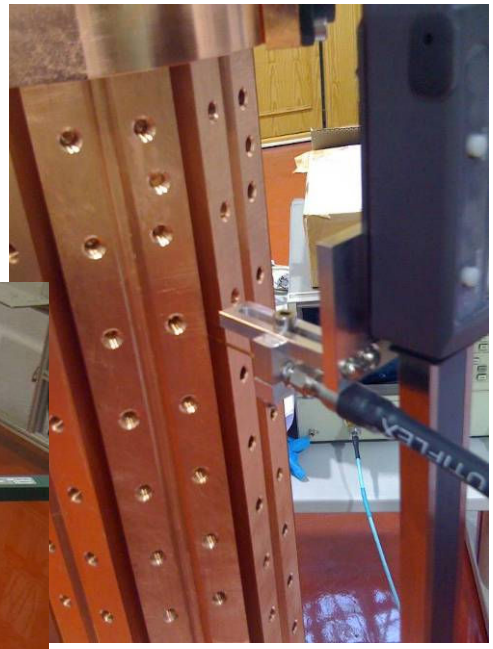
After shims

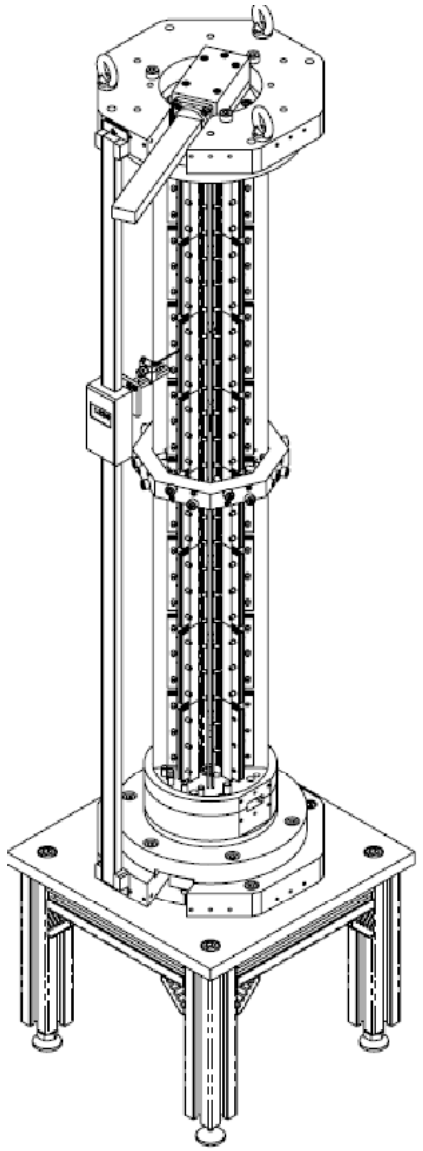
	ROD 1-5		ROD 4-8		ROD 7-3		ROD 6-2		AVERAGE
	R	L	R	L	R	L	R	L	
DOWN	113.040	113.035	113.000	112.945	113.015	113.040	112.950	112.950	112.997
MID-DOWN	113.015	113.015	112.960	112.925	**112.885**	**112.890**	112.940	112.945	112.947
BELOW RING	**113.025**	**113.010**	**113.015**	**112.980**	**112.970**	**112.985**	**113.000**	**113.005**	112.999
ABOVE RING	**113.010**	**112.995**	**113.010**	**112.980**	**113.005**	**113.025**	**112.995**	**113.010**	113.004
MID-UP	112.955	112.940	112.950	112.930	112.930	112.955	112.975	112.990	112.953
UP	112.990	113.000	113.045	113.045	112.955	112.975	113.050	113.065	113.016
AVERAGE	113.006	112.999	112.997	112.968	112.960	112.978	112.985	112.994	**112.986**

Nominal distance between the back sides of opposite rods is 113.00 mm

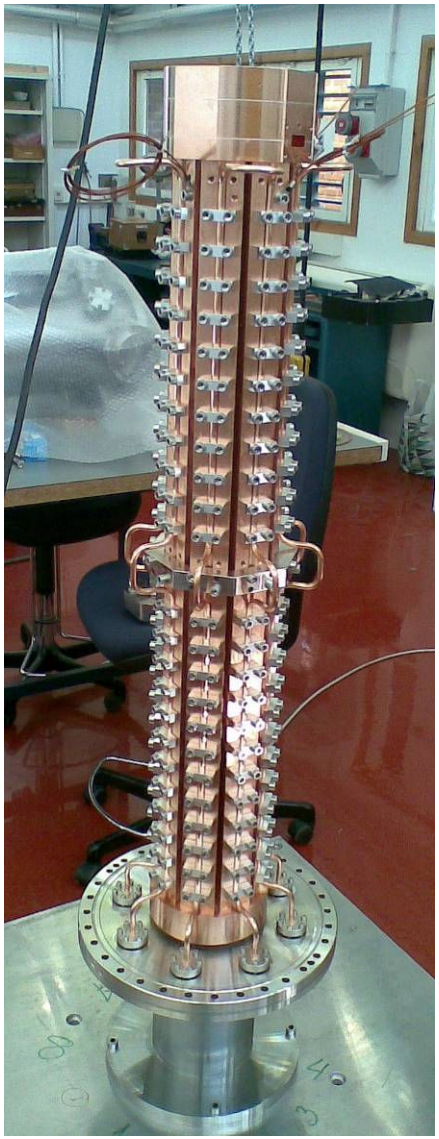
PETS RF measurement bench

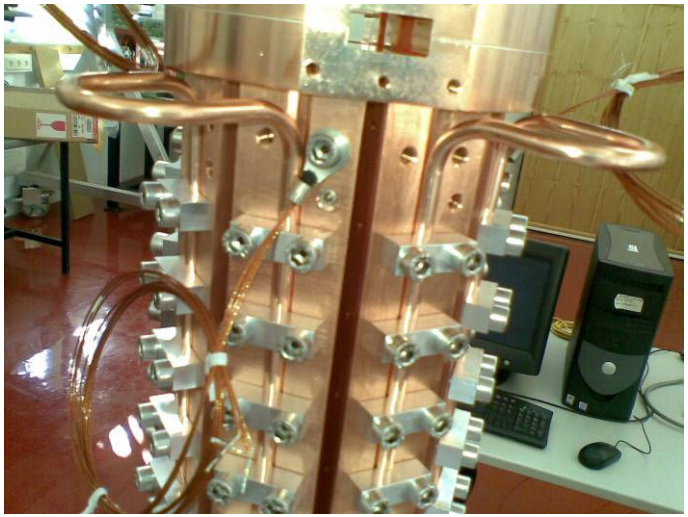


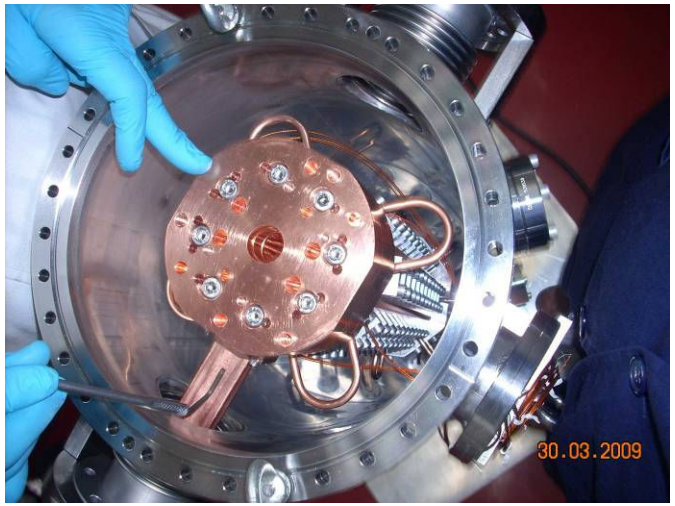


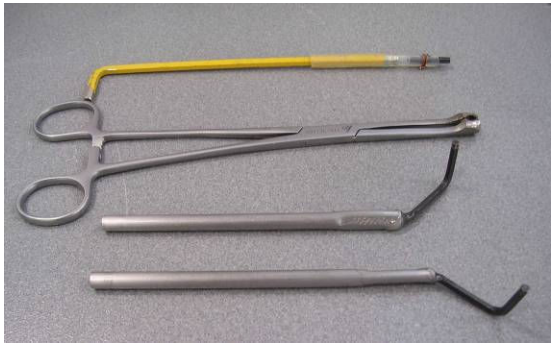


PETS tank assembly (I)

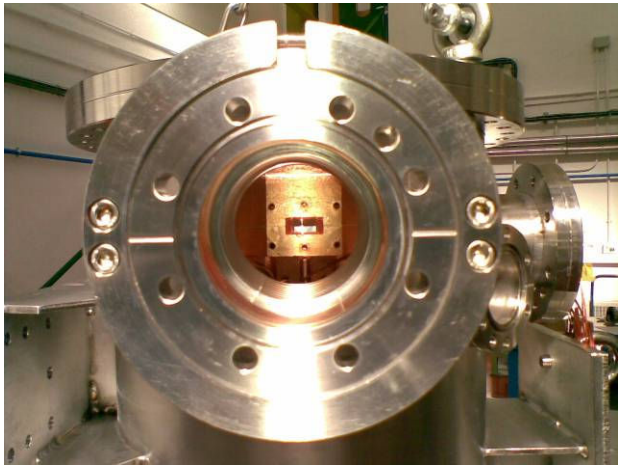






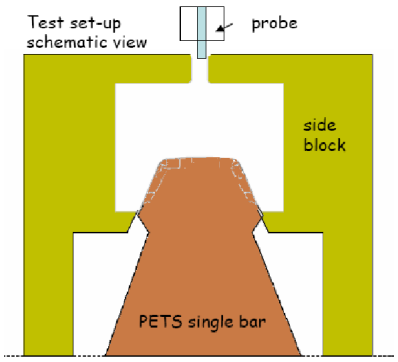


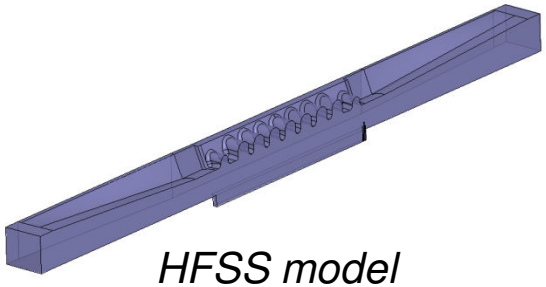
PETS tank assembly (II)



Single rod RF test bench

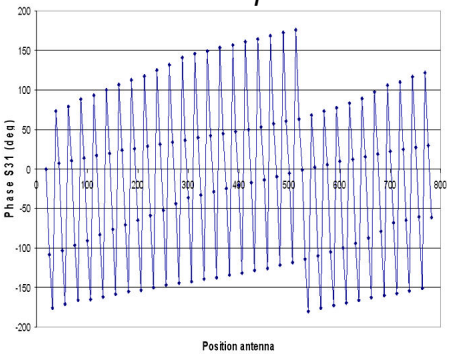
- A special test bench has been designed to do RF measurements on each rod
- It consists of two side blocks put together with a single PETS bar in order to create inside a mode with same properties as the decelerating mode
- Results agree with 3-D mechanical measurements

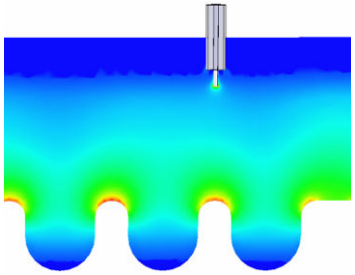




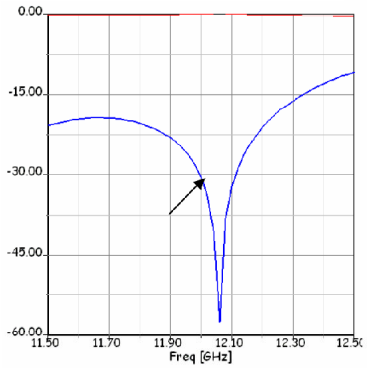
HFSS model

Phase S31 vs position

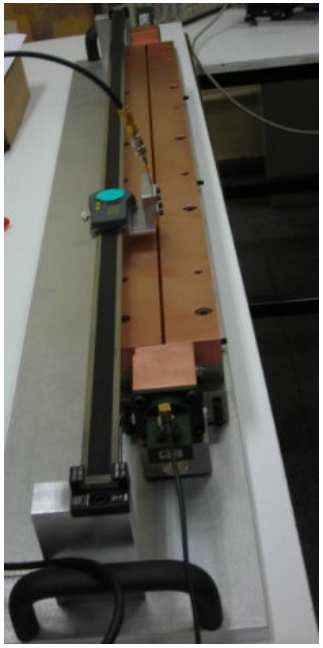


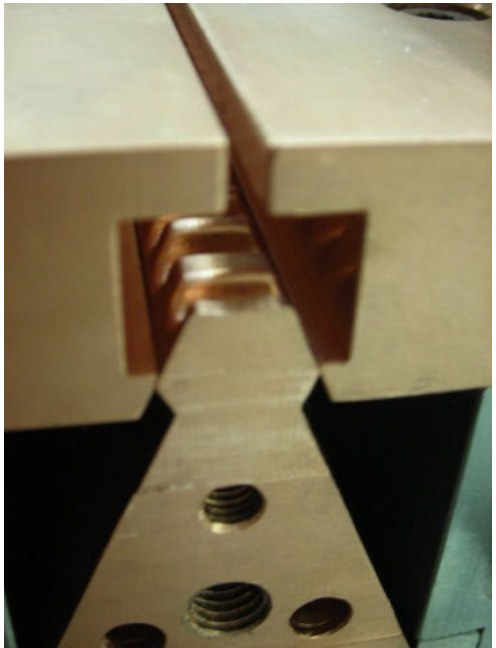


E field and probe

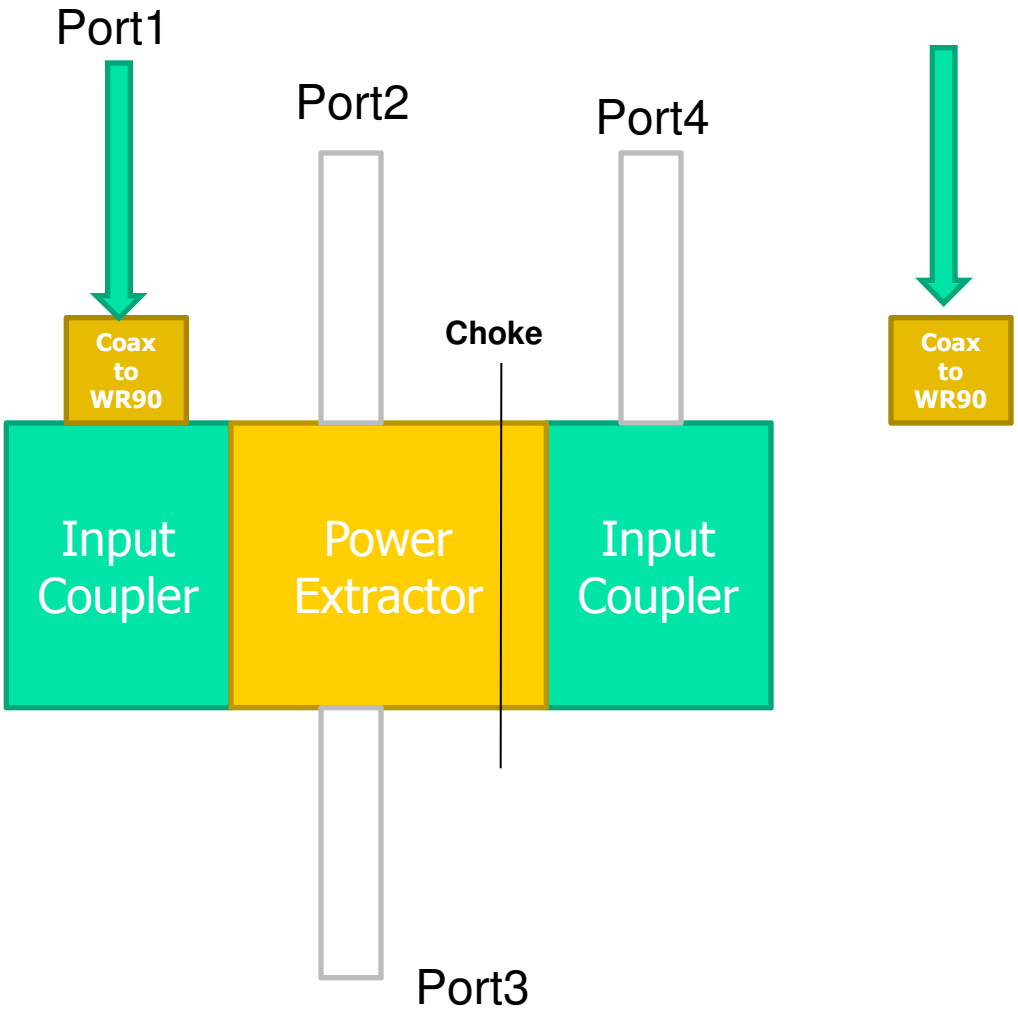


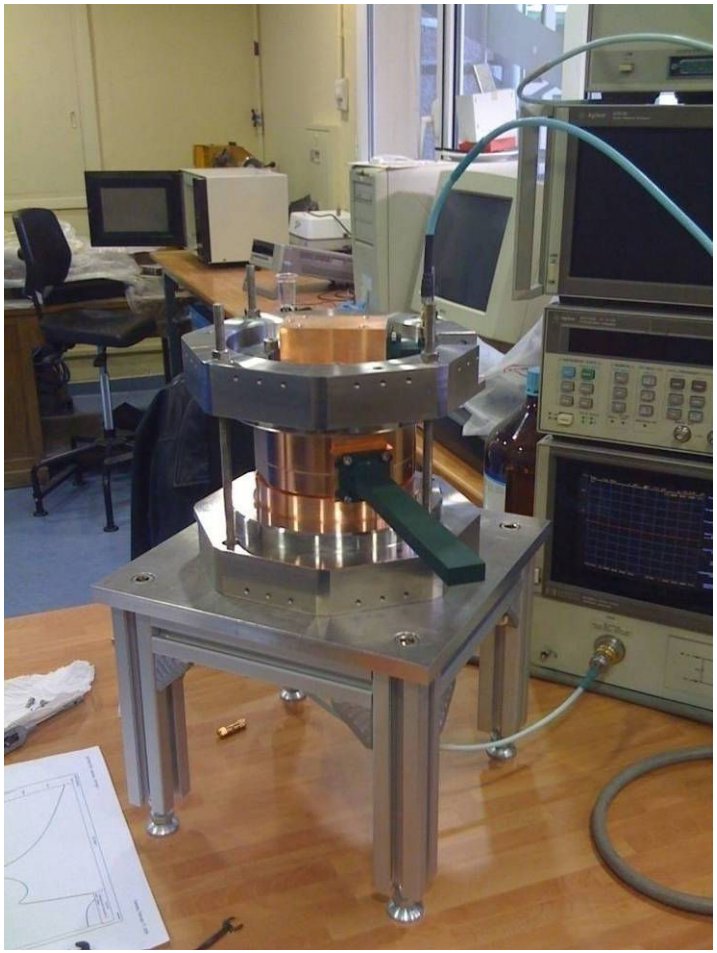
Mode TE_{10}





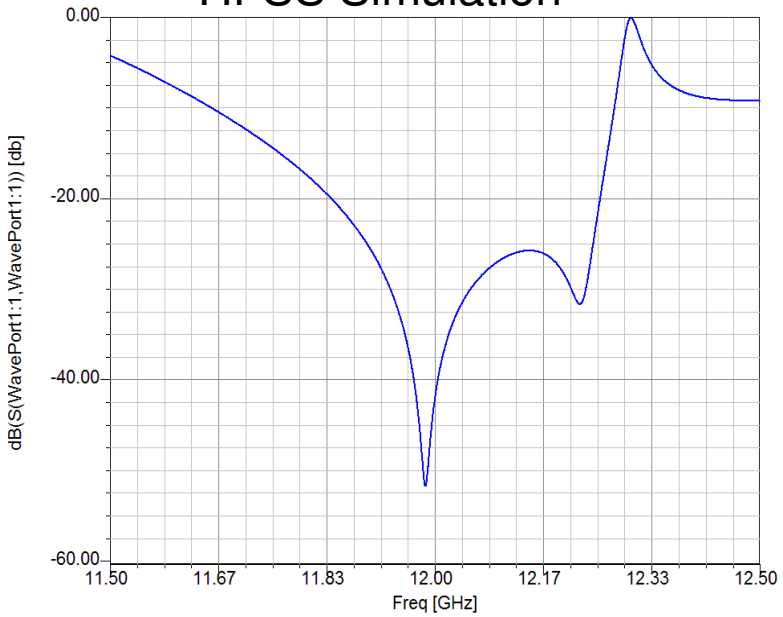
Power extractor RF measurements (I)



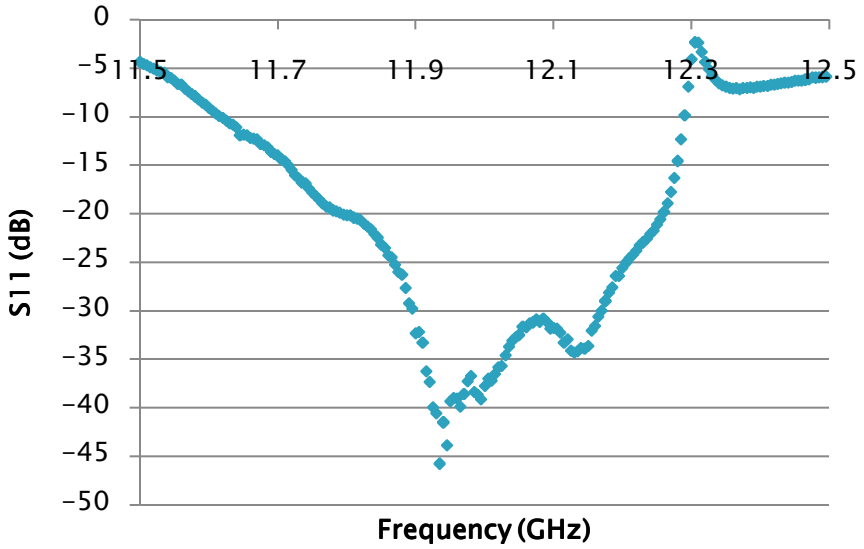


Power extractor RF measurements (II)

S11
HFSS Simulation



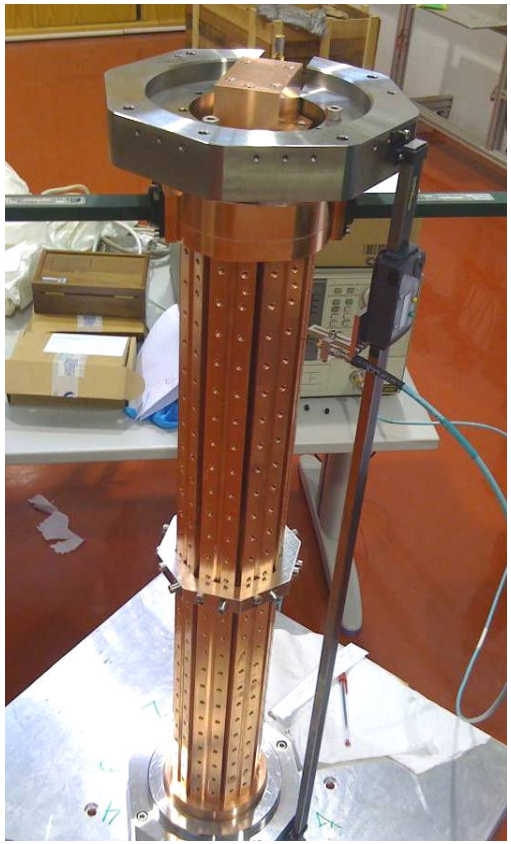
S11
Experimental results

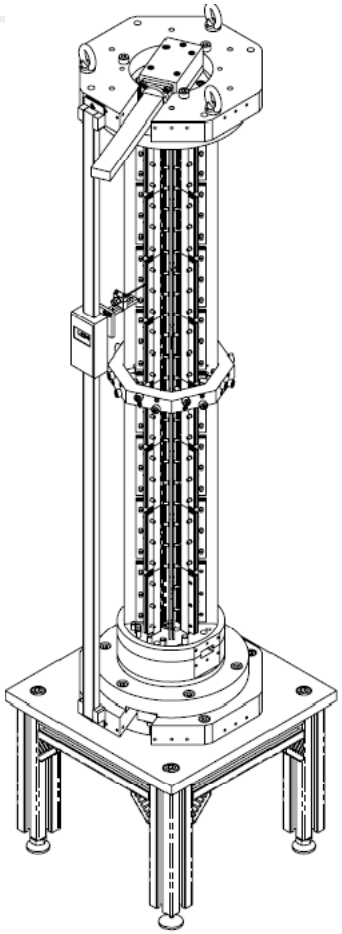


No visible change in S11 when removing wire or absorber from port 4

Both S21 and S31 are aprox. -3dB at 12 GHz

PETS RF measurement bench

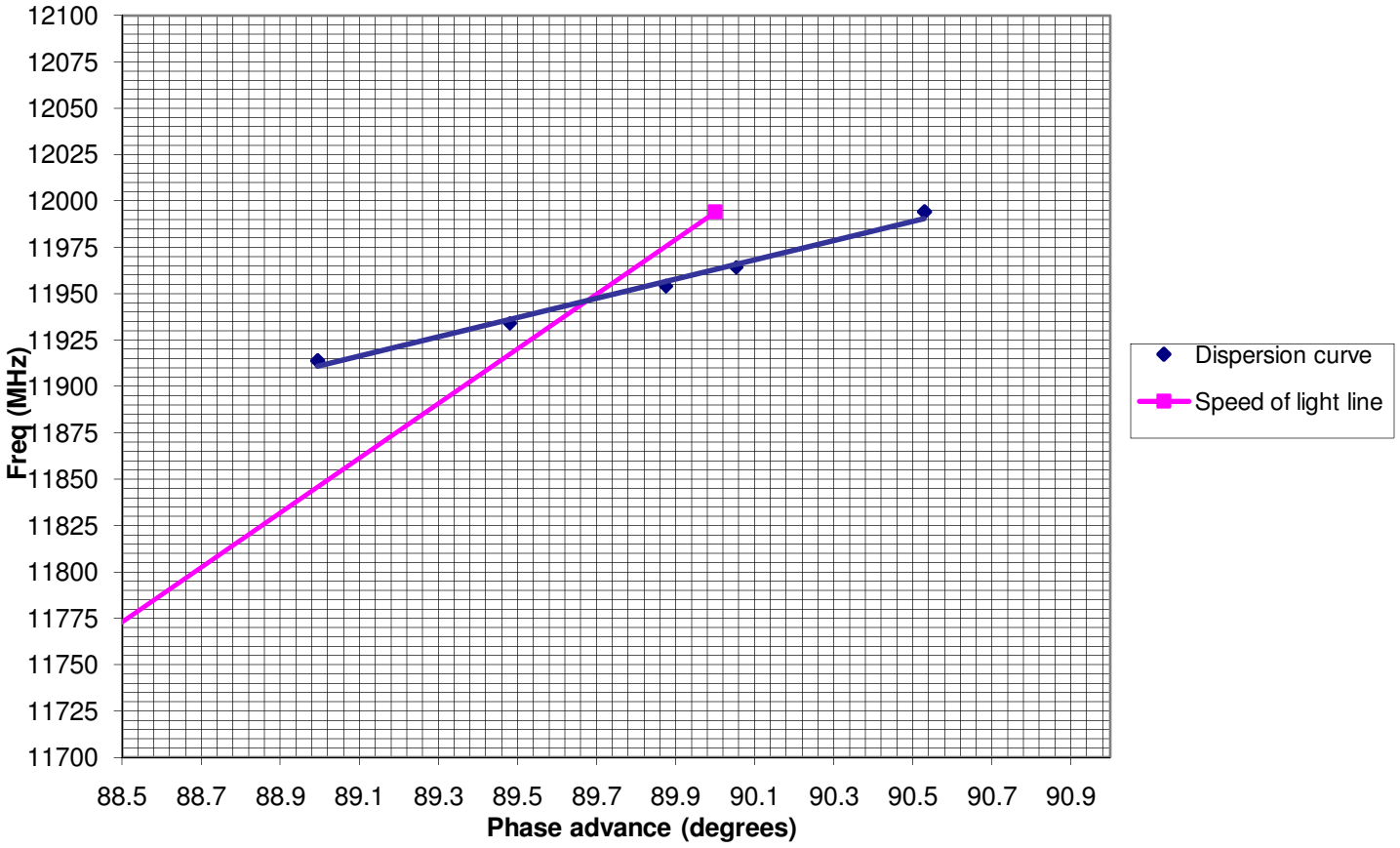




- A special test bench was designed to measure the assembly of rods
- A coaxial antenna was used to measure the field through the slots between the rods

PETS dispersion curve

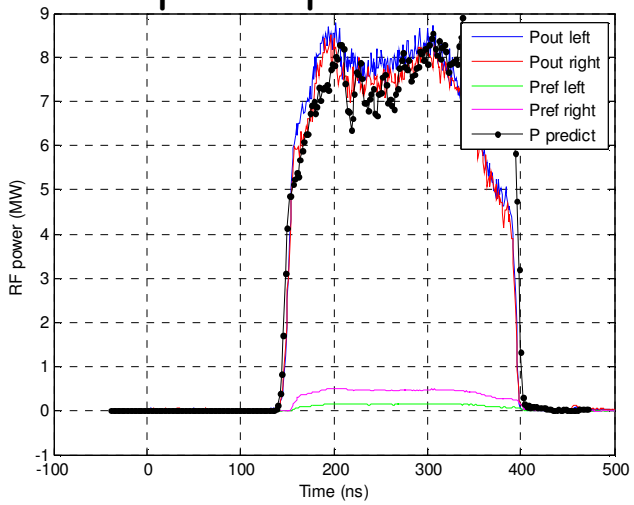
In the worst case, a 10% loss of extracted power is expected



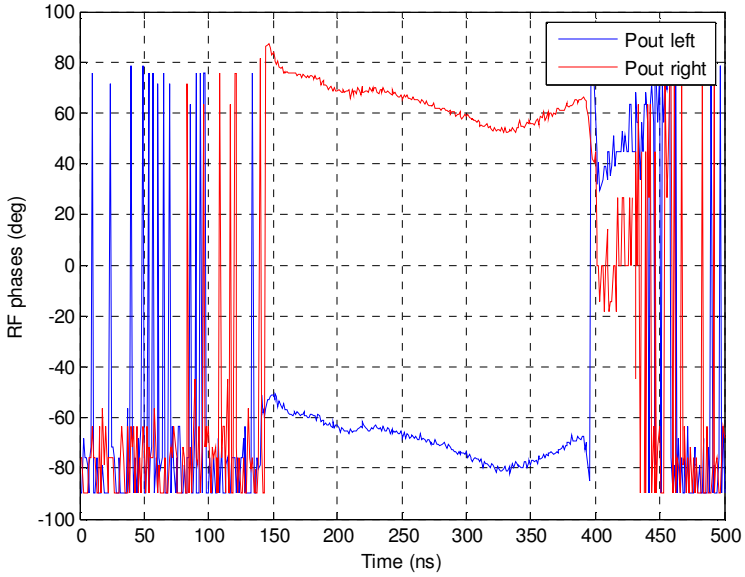
11944 MHz ⇒ 50 MHz detuning

TBL PETS commissioning

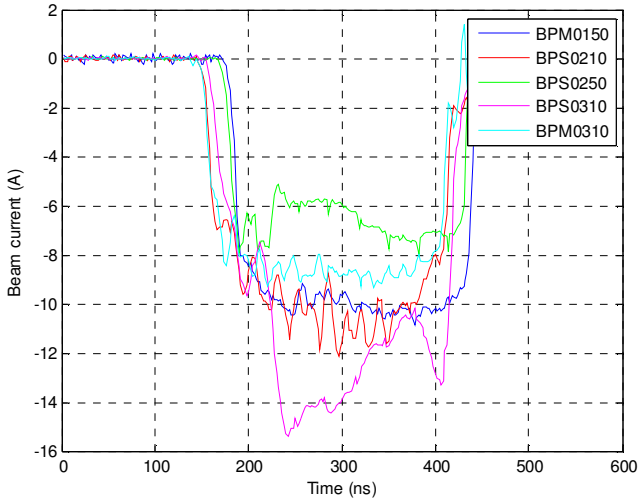
RF power produced



RF pulse phase



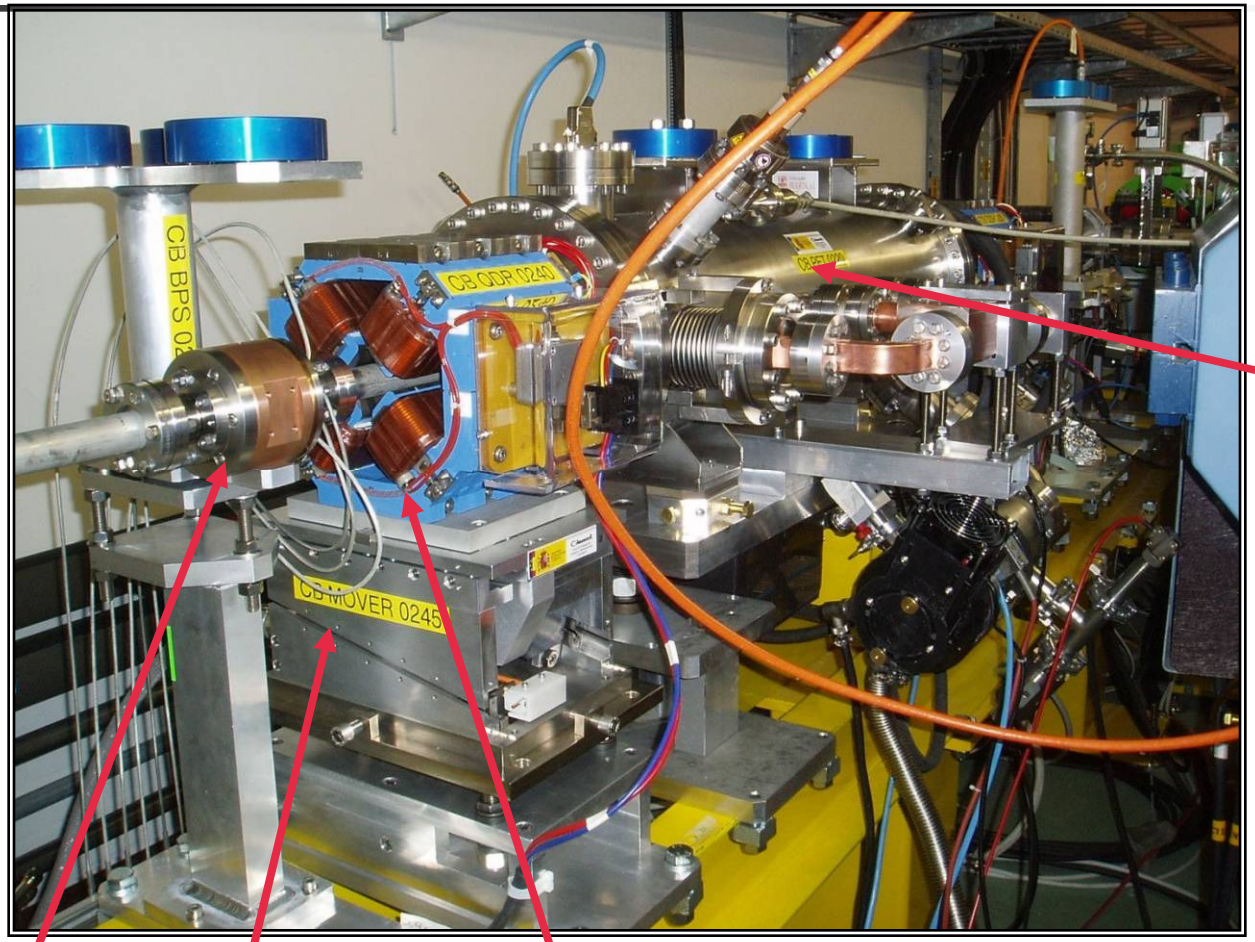
Beam current along the line



- up to 10 A through PETS
- 20 MW max produced at a pulse length of 280 ns
- Power production consistent assuming a form factor of 0.9
- PETS series production launched jointly by CERN and CIEMAT(series of 8)

Courtesy Steffen Doebert, CERN

PETS tank at CLEX (spring 2009)



PETS tank

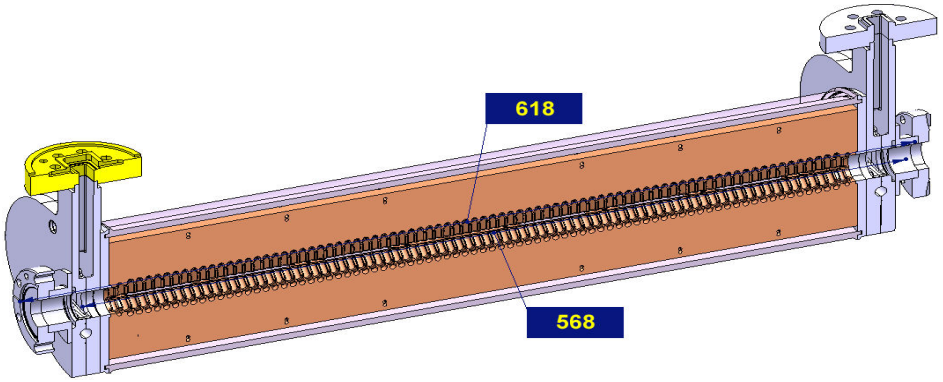
BPM

Mover

Quadrupole

Courtesy Steffen Doebert, CERN

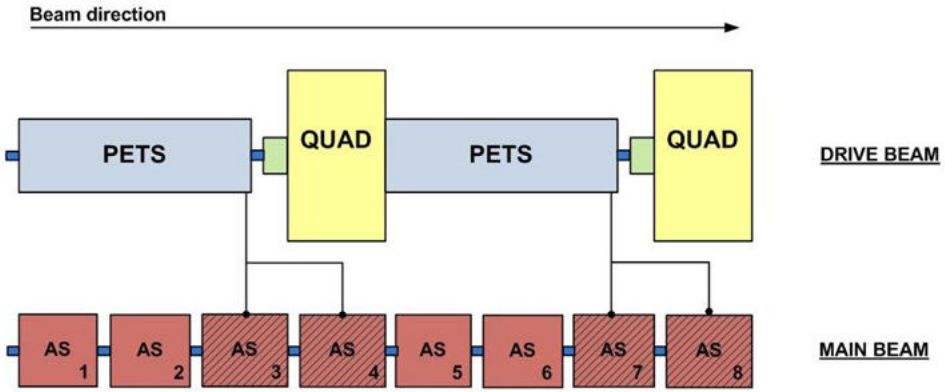
Next steps: EUCARD

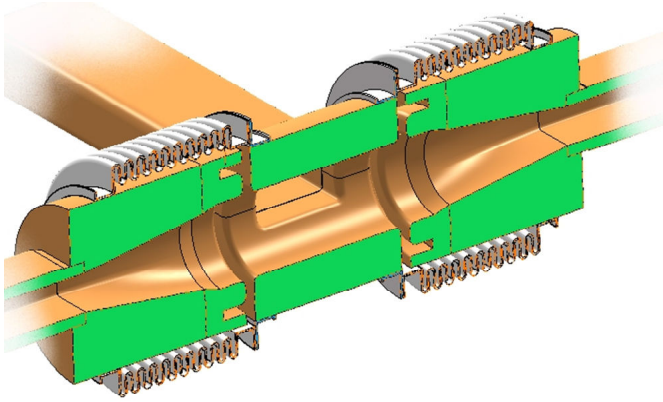


CIEMAT commitment consists of the engineering design, fabrication and low power testing of:

+ **double-length 11.424 GHz PETS** with damping material for the CLEX modules

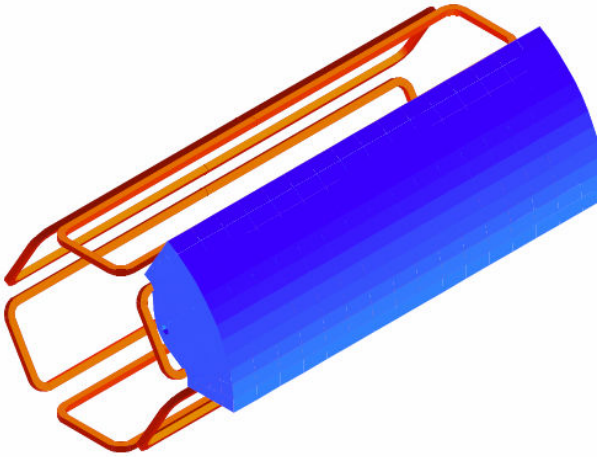
+ **compact 3-dB splitter** with two integrated choke mode flanges

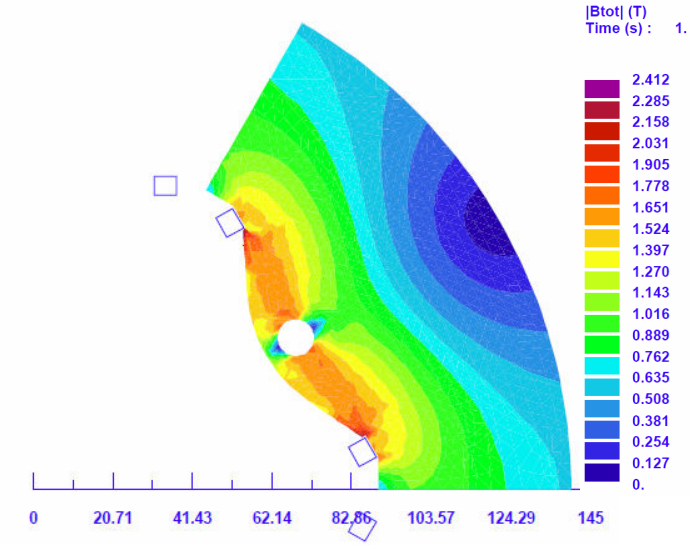




Contribution to SLHC-PP

CIEMAT commitment consists of the calculation, design and fabrication of a corrector magnet for LHC upgrade.





More information yesterday in talks by S. Russenschuck (Plenary) and I. Rodriguez (WP6)

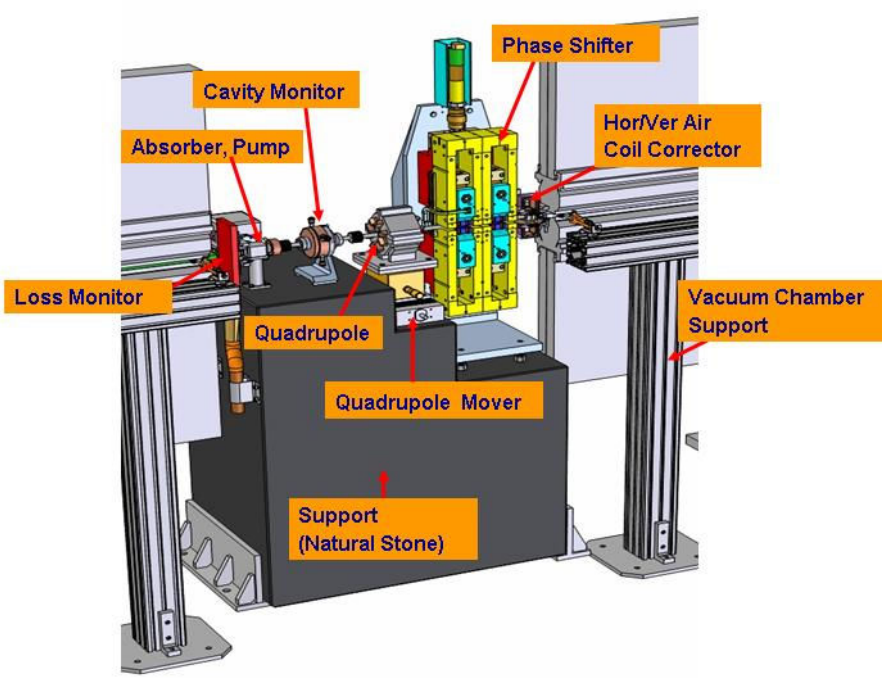
Outline

- ✓ Group capabilities and facilities
- ✓ Collaboration with CERN: CTF3-CLIC, SLHC, EUCARD
- ✓ XFEL collaboration
- ✓ IFMIF collaboration
- ✓ FAIR collaboration
- ✓ RTM collaboration
- ✓ Own developments

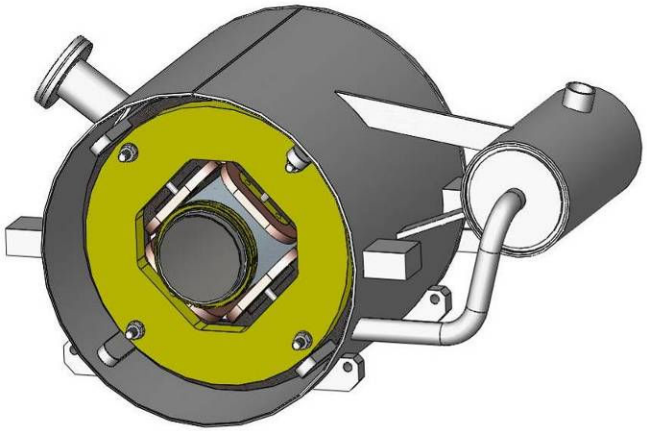
Contribution to XFEL

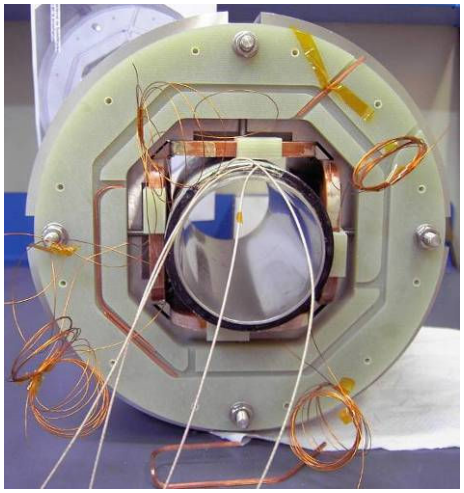
Our contribution is valued at about 12 M€ and our commitment consists of the delivery of the following systems:

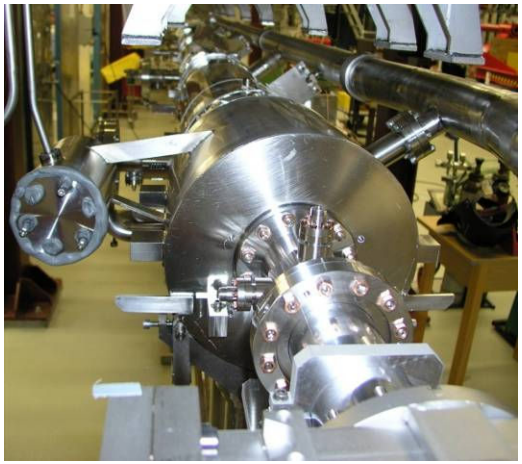
- **120 Superconducting Nested Magnets plus their Power Supplies.**
- **Different components for 91 Intersections between undulators: phase shifter, precision quadrupole mover & support.**



XFEL main linac magnets



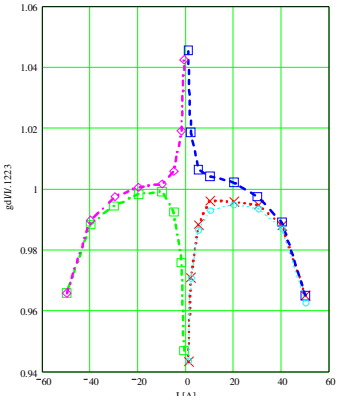




Combined Superconducting Magnet for XFEL Installed in the "XFEL String" (2007)

Within the first contribution, our group has developed a short series of four superconducting combined magnets (one quadrupole + two dipoles) while the remaining 100 magnets will be developed by industry.

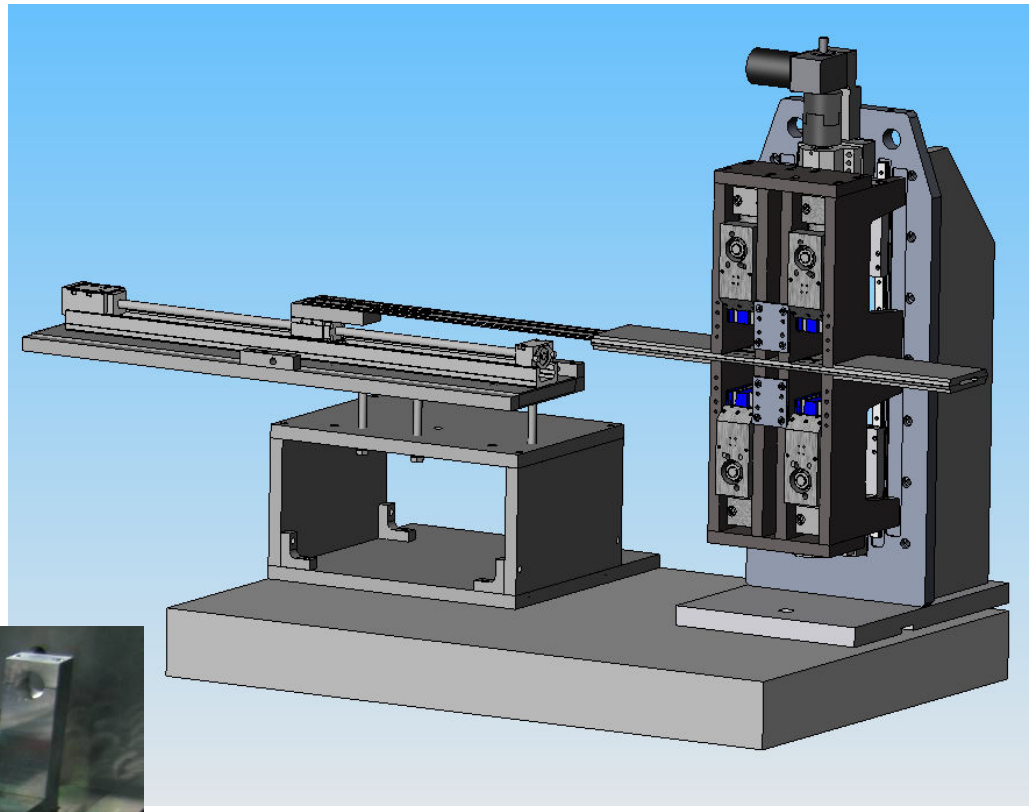
The design is being reviewed to decrease the series cost and the magnetization effects and a new prototype is under fabrication.



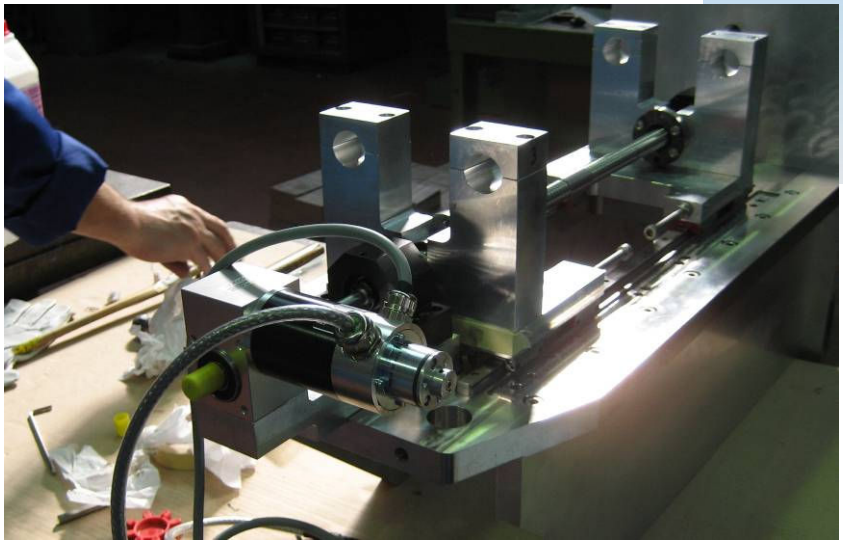
Magnetization Measurements for the Combined Superconducting Magnet for XFEL (2007)

XFEL intersections components

Prototype mover



3D model of measurement bench for phase shifter



Prototype phase shifter assembly

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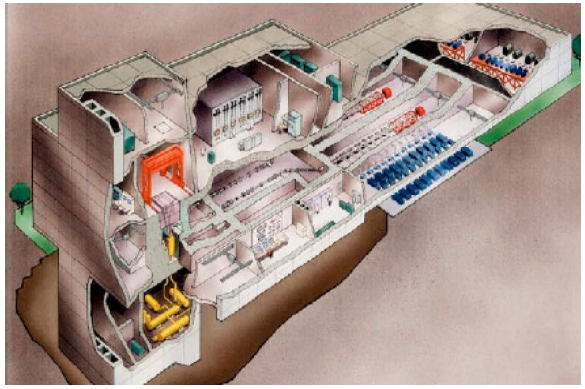
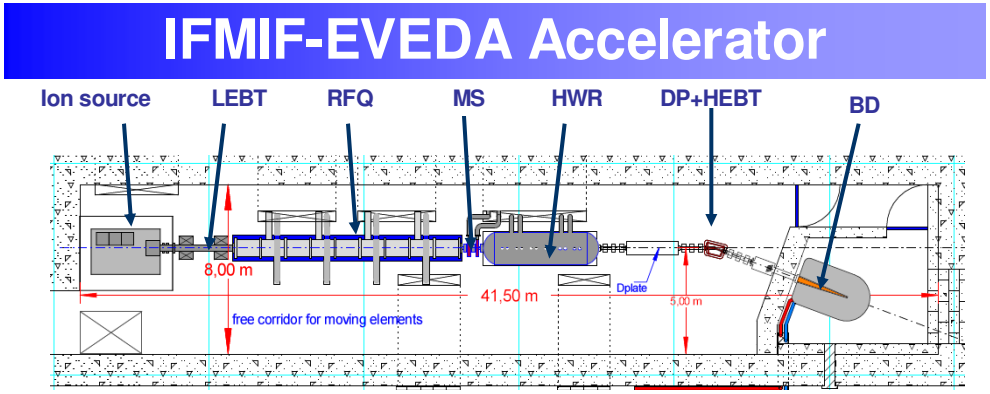
Contribution to IFMIF

The Accelerators Unit also collaborates in the IFMIF project: a 40 MeV, 125 mA deuteron accelerator acting on a lithium target to generate neutrons to test materials for the first commertial fusion reactor : the DEMO



Original IFMIF Project



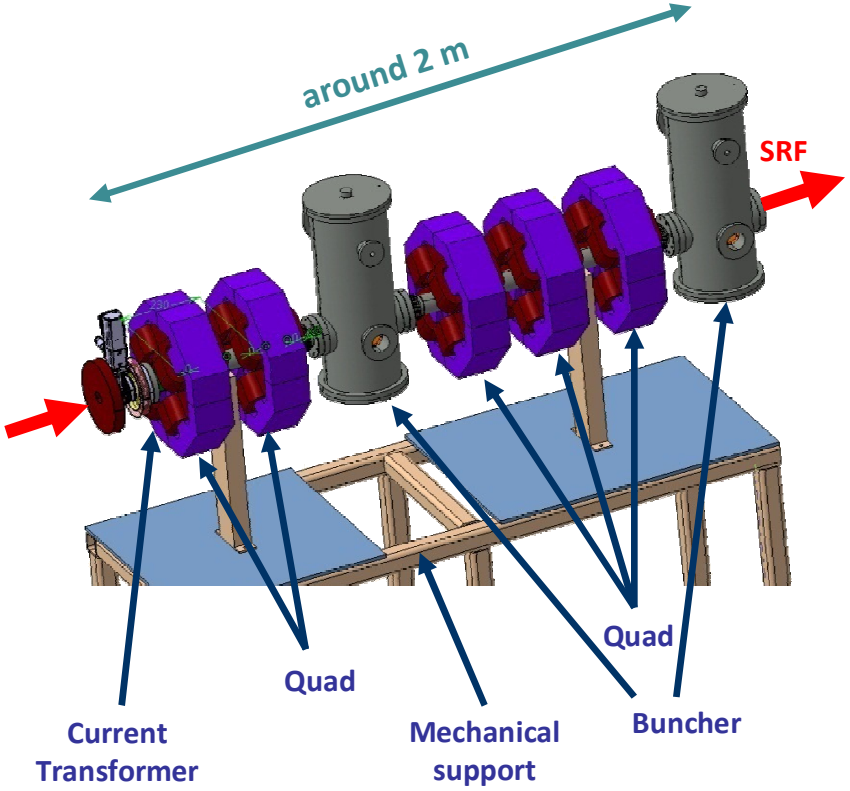
IFMIF-EVEDA phase Accelerator Scheme

To validate the IFMIF concept, the so called EVEDA phase has been launched with a current of 125 mA and an energy of 9 MeV. It is a collaboration between CEA, INFN, CIEMAT, SCK-CEN and JAEA.

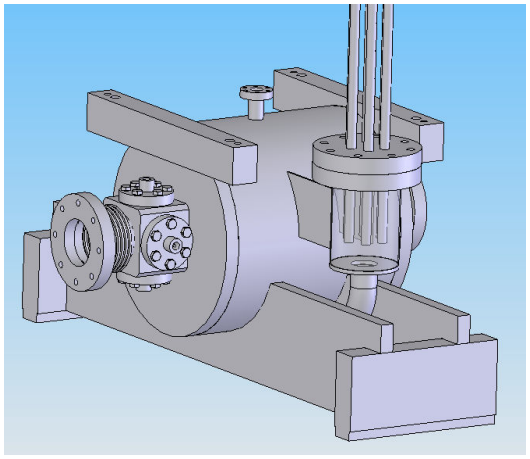
CIEMAT contribution is: DTL magnet package, transport line and 1.2 MW beam dump, 175 MHz RF systems, local control systems and beam instrumentation

Most of these packages are being developed by the Fusion group.

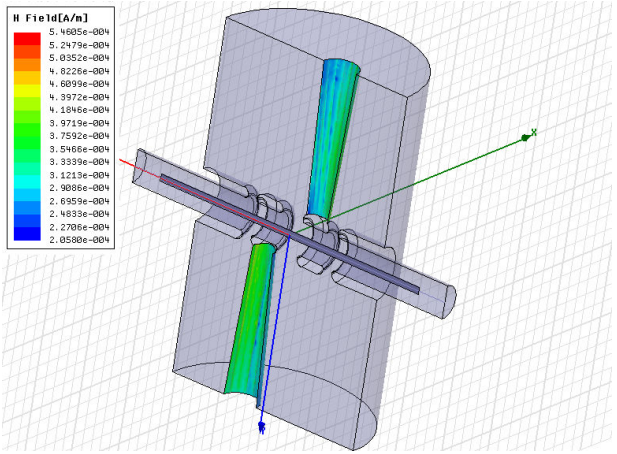
Some IFMIF components



Ongoing design of the matching section



DTL superconducting magnet package with BPM



Magnetic fields in the stems of a 3 gap QWR buncher

Outline

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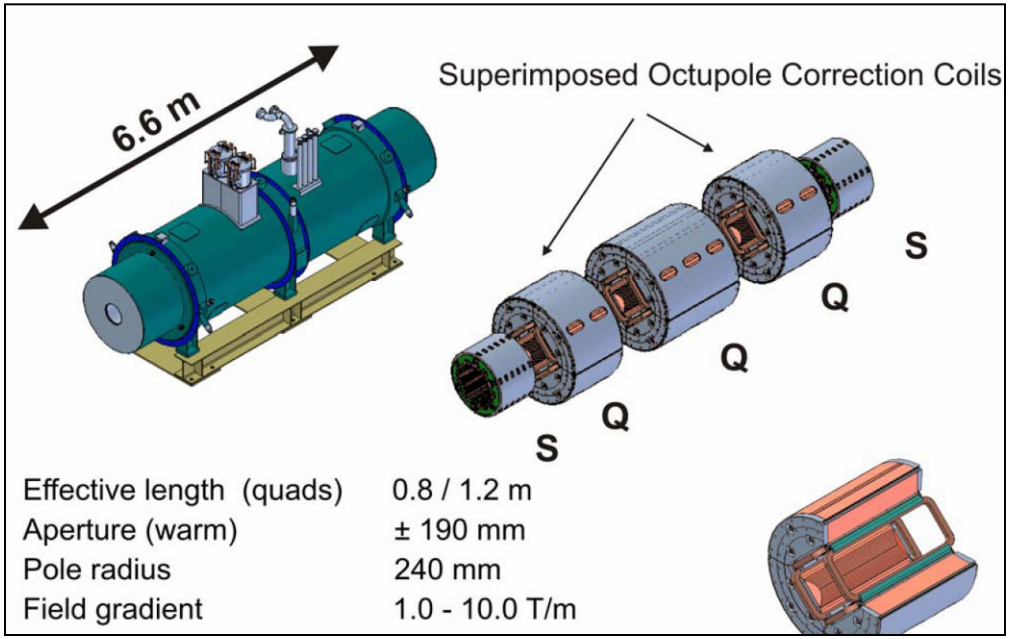
- ✓ RTM collaboration
- ✓ Own developments

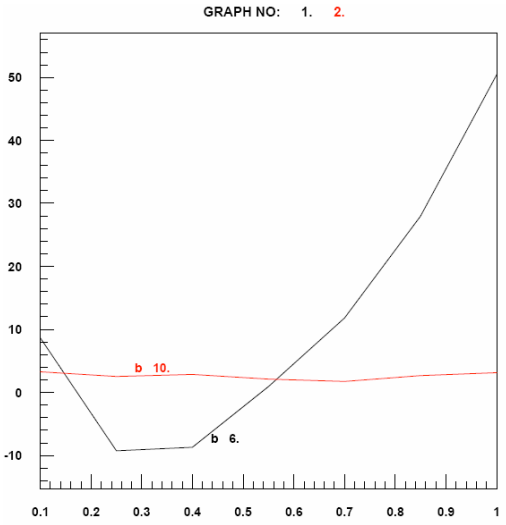
Contribution to FAIR

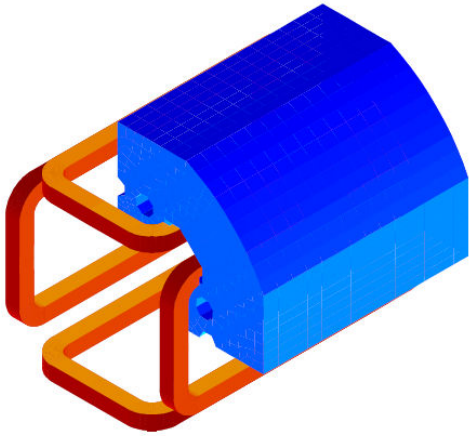
*** CIEMAT will lead the Spanish Contribution to FAIR (Facility for Antiproton Ion Research) coordinating the delivery (in cooperation with Saclay) of the superconducting multiplets for the Super Fragment Separator (SFRS).**

This contribution is valued in 20 M€ and will be funded by the Ministry of Science & Innovation.

At the moment, two alternatives for these magnets are under study and CIEMAT is developing the superferric solution.







Superferric Quadrupole for the SFRS at FAIR

Outline

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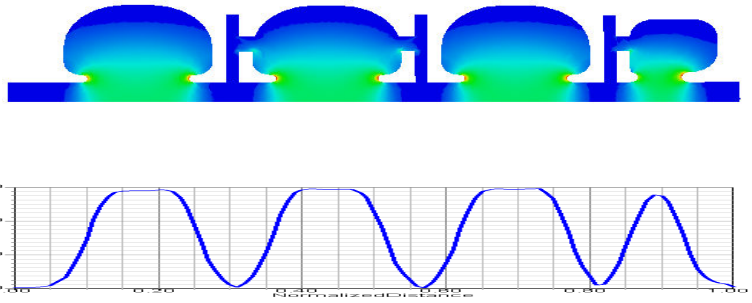
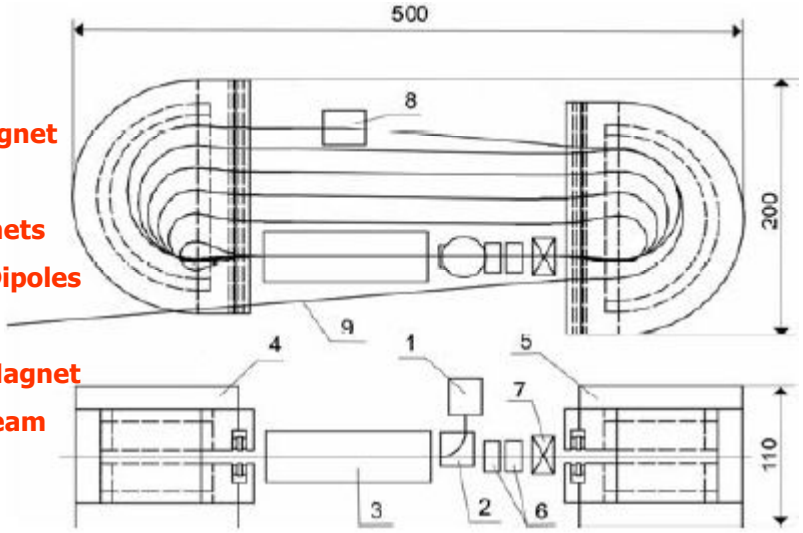
- ✓ RTM collaboration
- ✓ Own developments

Contribution to RTM

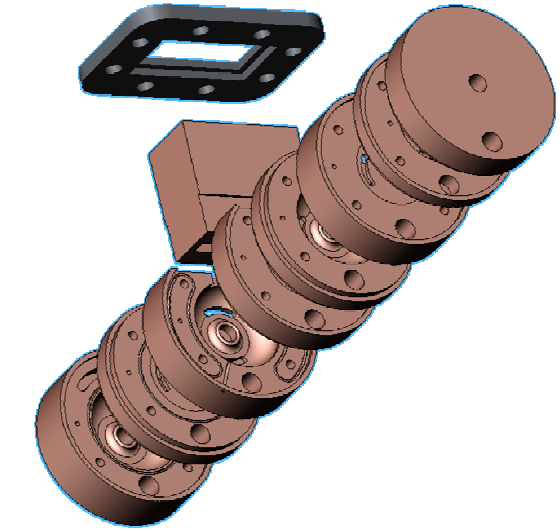


Accelerating Cavity and Electrical Field Distribution

1.-Electron Gun
2.-Injection Magnet
3.-LINAC
4&5.- End Magnets
6.- Correcting Dipoles
7.- Quadrupole
8.- Extraction Magnet
9.- Extracted Beam



Scheme of the working principle for a "Racetrack" Microtron



Conceptual Design of the LINAC

The CIEMAT Accelerator Unit participates in a project with other partners for the development and fabrication of a racetrack microtron for Intra Operative Surgery. It is a 12 MeV, 1 μA machine for which the Unit is developing the LINAC.

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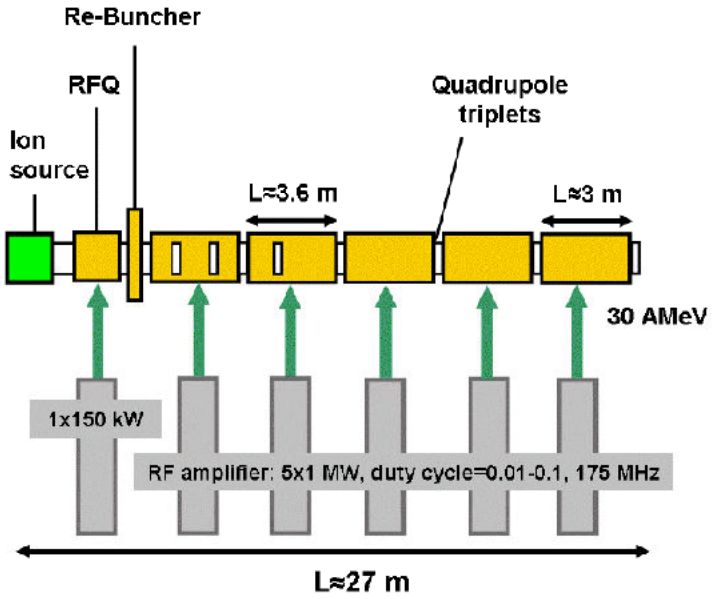
CIEMAT linac proposal

APLICACION	Partículas	Energía (Mev)	Corriente (μA)
TRANSMUTACION	p,d	200	100-1500
INSTRUMENTACION NUCLEAR	p,d	15-30	100
MATERIALES	p,He	5-50	10
FUSION	p,d,He	20-60	1-10
DOSIMETRIA	p	100	1
MEDICINA NUCLEAR	p,d,He	7-200	0,01-100
ELECTRONICA	p	5-60	0,01-1

CIEMAT is considering to install a multipurpose accelerator to study some of the applications presented in this table. A first analysis has been performed at Bevatech.

Proposal for a LINAC-CIEMAT based on IH Cavities at room temp.



ION SOURCE	Parameter
Ion Species	H,D,He A/q=2
Beam Current	Up to 1 mA
Beam Emittance	0.4-0.8
Extraction voltage	3-20 kV
RFQ	**Parameter**
Input Energy	3-10 (AkeV)
Output Energy	300-1000 (AkeV)
Operation RF Frequency	175 MHz
Duty cucle	>1% (possibility cw)
DTL	Parameter
Input Energy	300-1000 (AkeV)
Output Energy	30 (AMeV)
Operation RF Frequency	175 MHz
Upgrade option	Yes, up to 50 (AMeV)
Energy variability	Yes in 5 steps

Superconducting cyclotron study

- Development of a Compact Superconducting Cyclotron for Isotope production, mainly 18F and 11C.
- The energy is in the order of 14 MeV and the current around 10 microamps.
- Maximum magnetic field in the center of the machine will be 4T and, for the moment, both a HTc superconducting coil or a LTc one are open options…