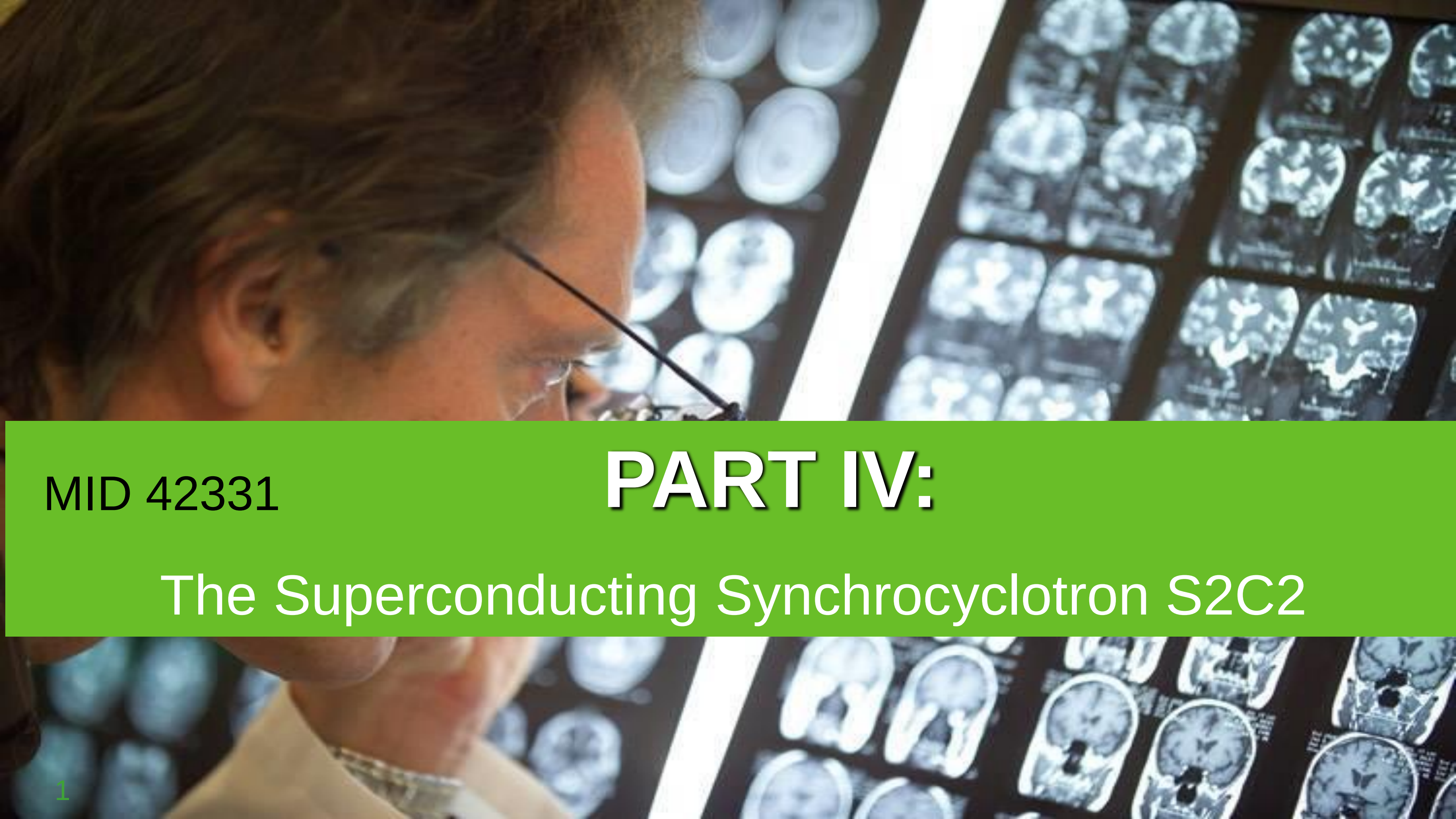

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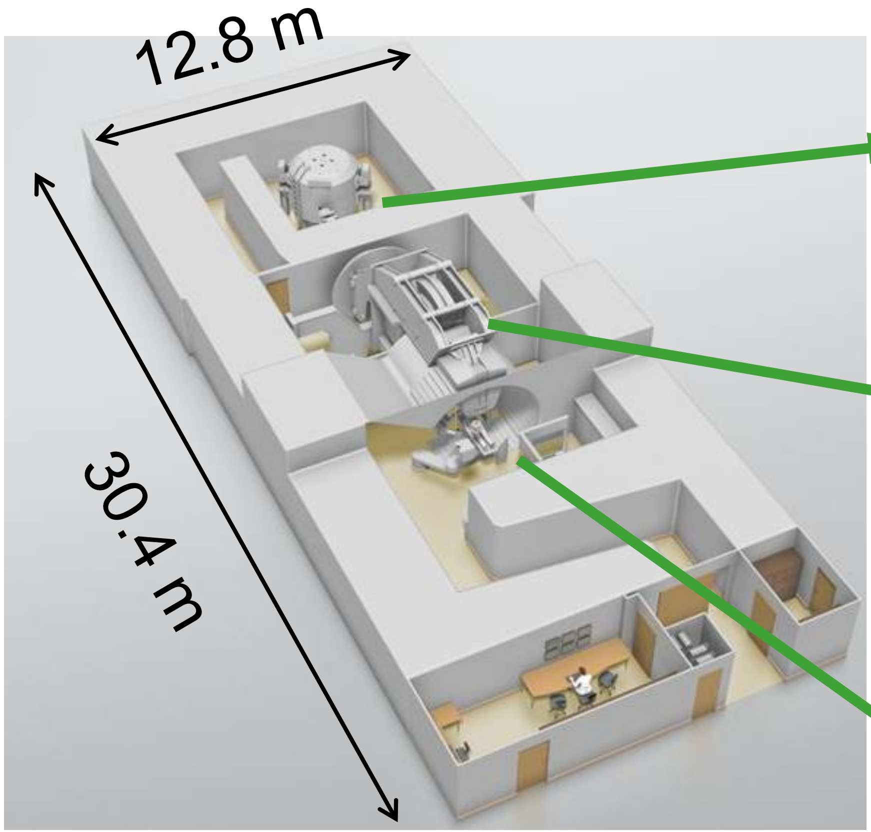
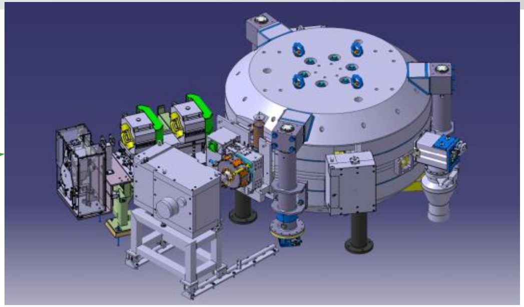
PART IV:

The Superconducting Synchrocyclotron S2C2

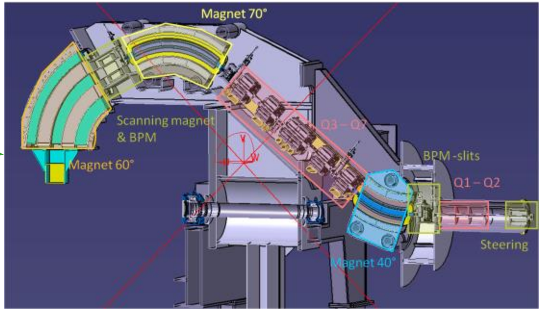
The New IBA Single Room Proton Therapy Solution: ProteusONE®

High quality PBS cancer treatment: compact and affordable





Synchrocyclotron with superconducting coil: S2C2



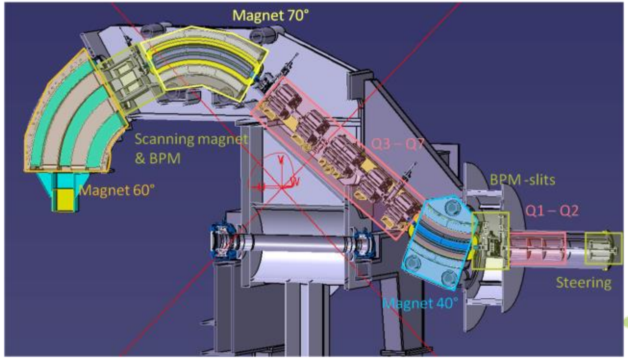
New Compact Gantry for pencil beam scanning

Patient treatment room

The new compact gantry for pencil beam scanning

Design aimed at reducing footprint and cost

- Scanning magnets are placed upstream of the last bending magnet
- ESS integrated in the 45 deg inclined part
- Rotation angle 220° => more compact treatment room
- Transport and installation in one part
- The prototype has been fully manufactured and tested and is installed at the customer site in Shreveport where the beam was succesfully transported to the gantry isocenter.
- Patients are treated since September 2014



How a Synchrocyclotron differs from a Cyclotron

Isochronous cyclotron:

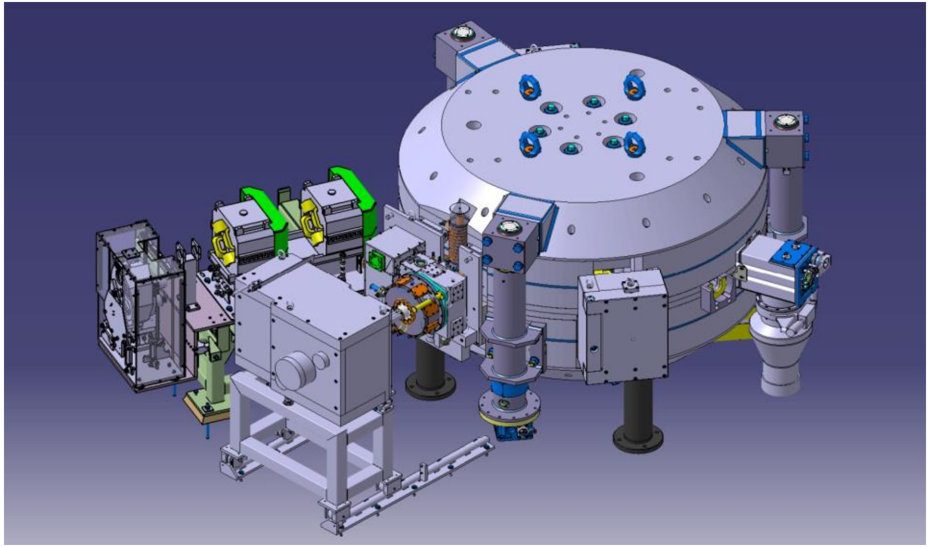
- Requires B to increase proportionally to m.
- Requires sector focusing for vertical stability.
- This leads to a smaller average magnetic field, thus a larger structure.
- All parameters being constant, operation is CW.

Synchro cyclotron:

- Requires B to decrease for weak focusing.
- Requires f to decrease during acceleration.
- Smaller structure due to high average magnetic field.
- Acceleration being frequency dependant, operation is pulsed.

S2C2 overview

General system layout and parameters

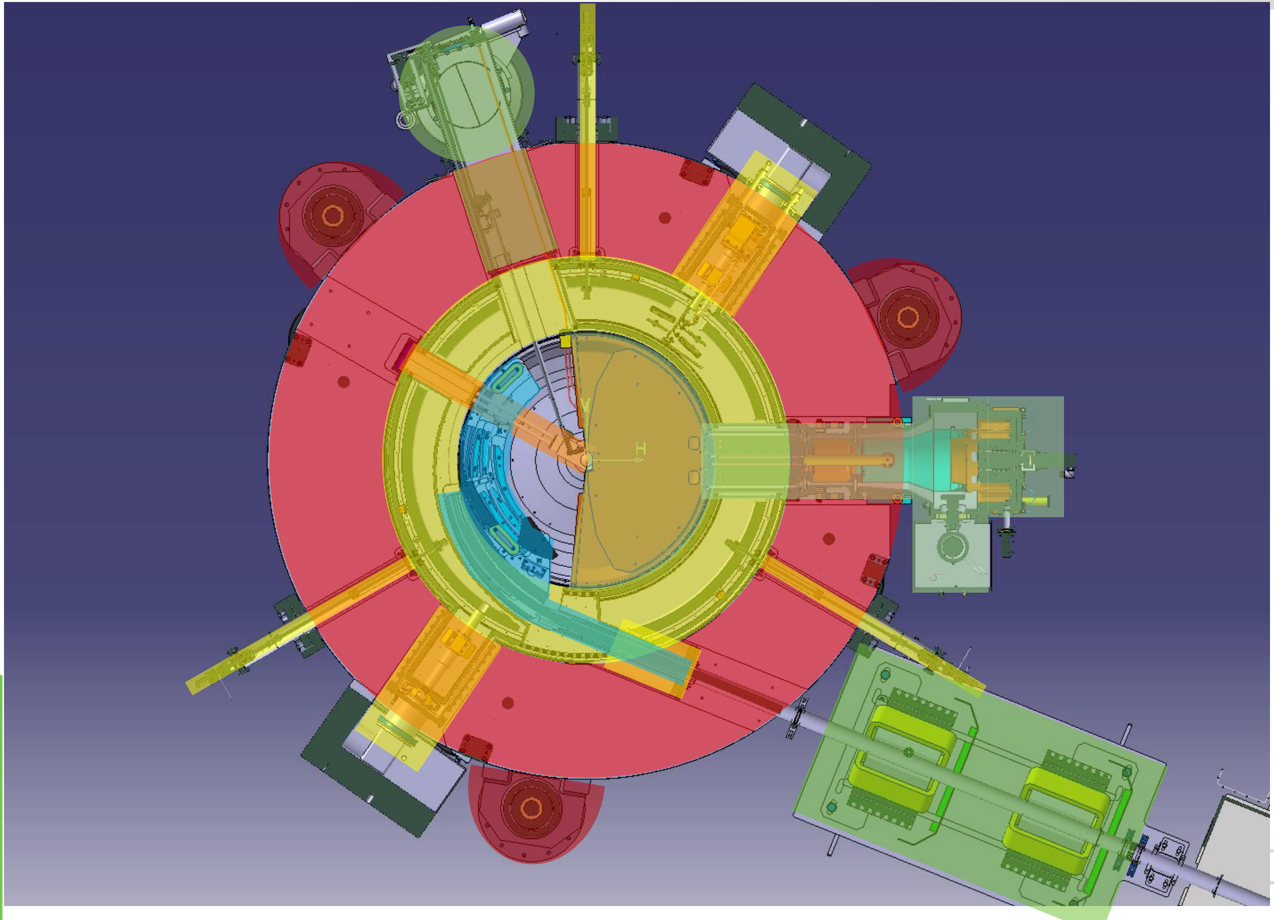


Maximum Energy	230/250 MeV
Size	
yoke/pole radius	1.25 m/0.50 m
weight	50 tons
Coil	NbTi - wire in channel
ramp up rate / time	2-3A/min / 4 hours
windings/coil	3145
stored energy	12 MJ
Magnetic field	
central/extraction	5.7 T/5.0 T
Cryo cooling	conductive
	4 cryocoolers 1.5 W
initial cooldown	12 days
recovery after quench	less than 1 day
Beam pulse	
rate/length	1000 Hz/7 μsec
RF system	self-oscillating
frequency	93-63 MHz
voltage	10 kV
Extraction	Passive regenerative
Ion source	PIG cold cathode
Central region	removable module

- An invited talk on this project was presented at the 2013 cyclotron conference in Vancouver
- Several contributions can be found on the ECPM2012-website

S2C2 overview

Main subsystems



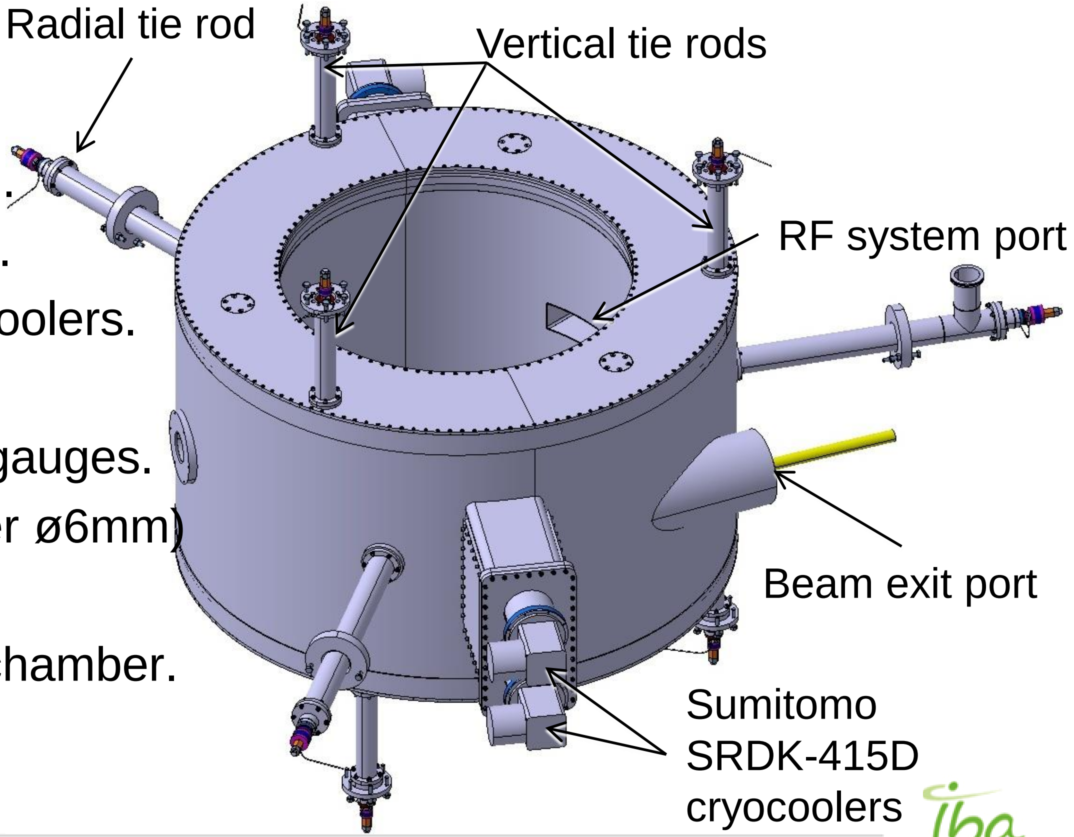
- Magnet return yoke
- Cryostat with coil
- RF system
- Ion source+central region
- Extraction system
- Vacuum system
- Yoke lifting system
- Extracted beam line

Superconducting coil

Designed and manufactured by ASG (Genua, Italy)

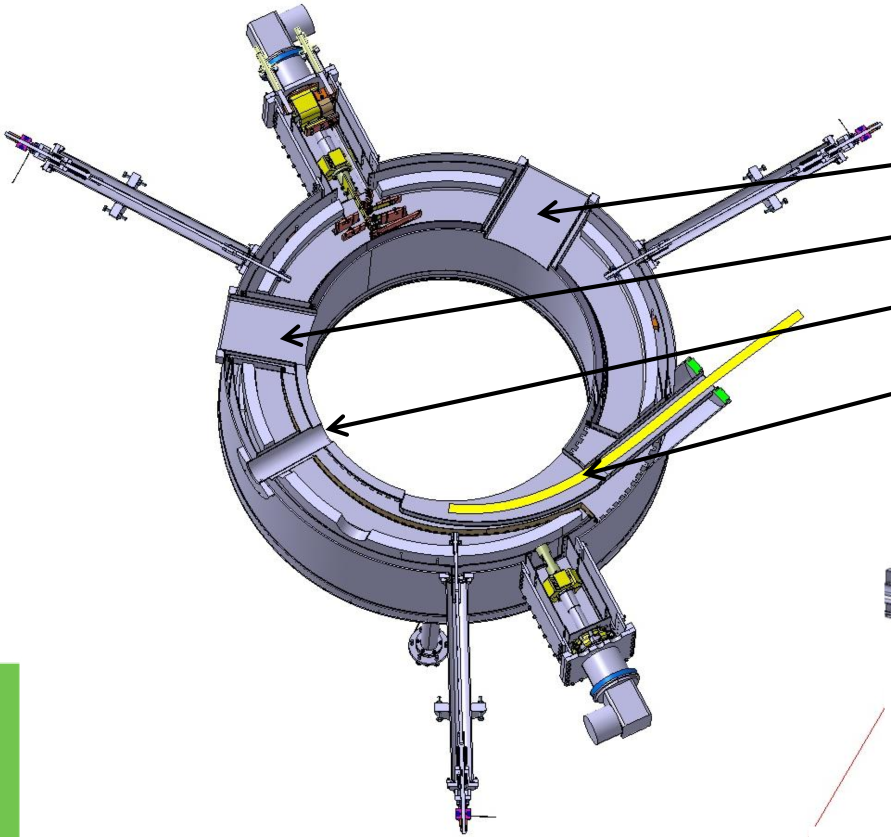
- NbTi wire in channel coil.
- Suspended cold mass: 3tons.
- Nominal current: 650A (56 A/mm²).
- Nominal ampere-turns: $4.3 \times 10^{+6}$At.
- Conduction cooled by 4 SHI cryocoolers.
- Overall weight: 4tons.
- 9 Inconel tension rods with strain gauges. (radial ø14mm; upper ø8mm; lower ø6mm)

- Cryostat is the cyclotron vacuum chamber.

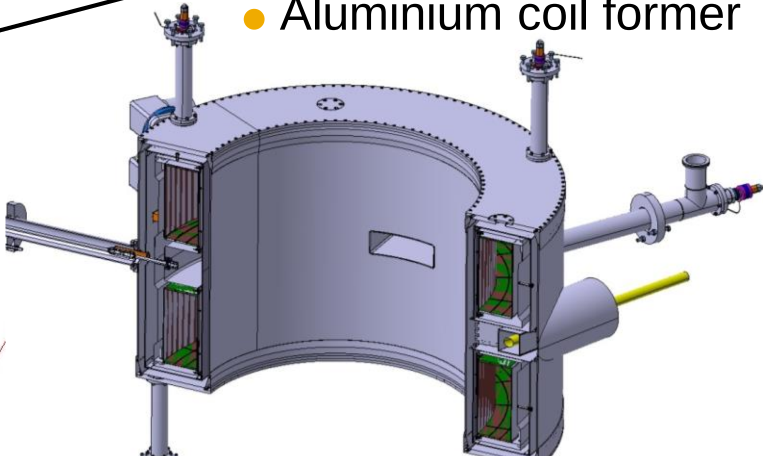


Superconducting coil

Cryostat penetrations

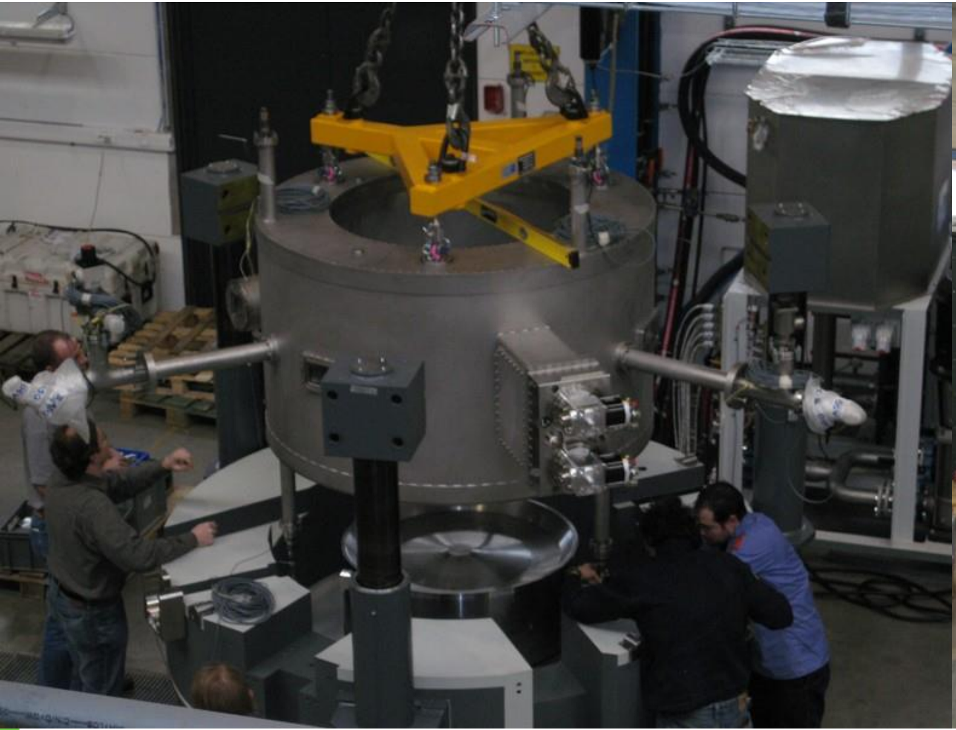


- Four cryostat penetrations
  1. RF port
  2. Vacuum pumping/radial probe
  3. Ion source
  4. Beam extraction
- Aluminium coil former



Superconducting coil

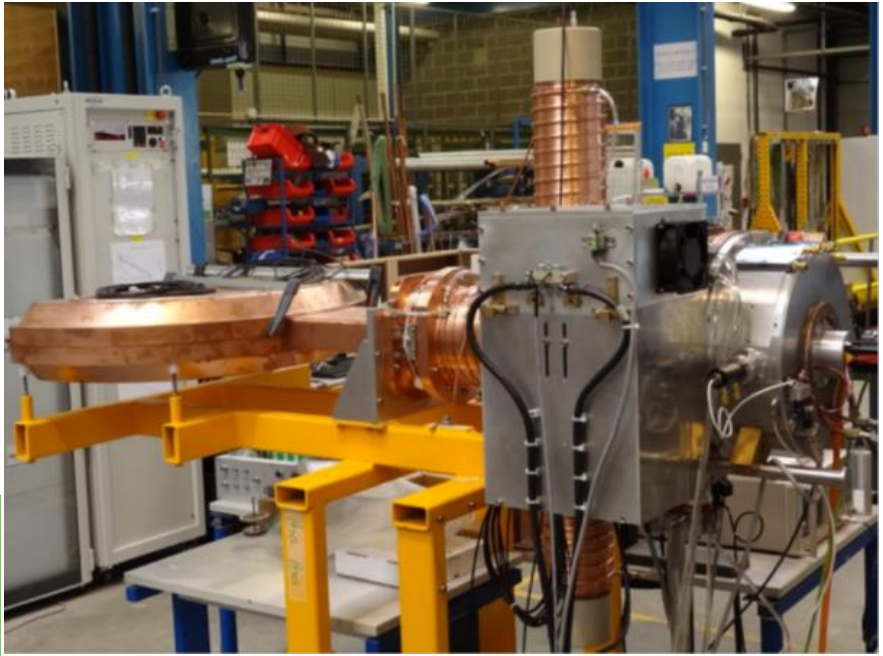
Installation of the cryostat in the yoke



RF-system

A triode-based self-oscillating RF system

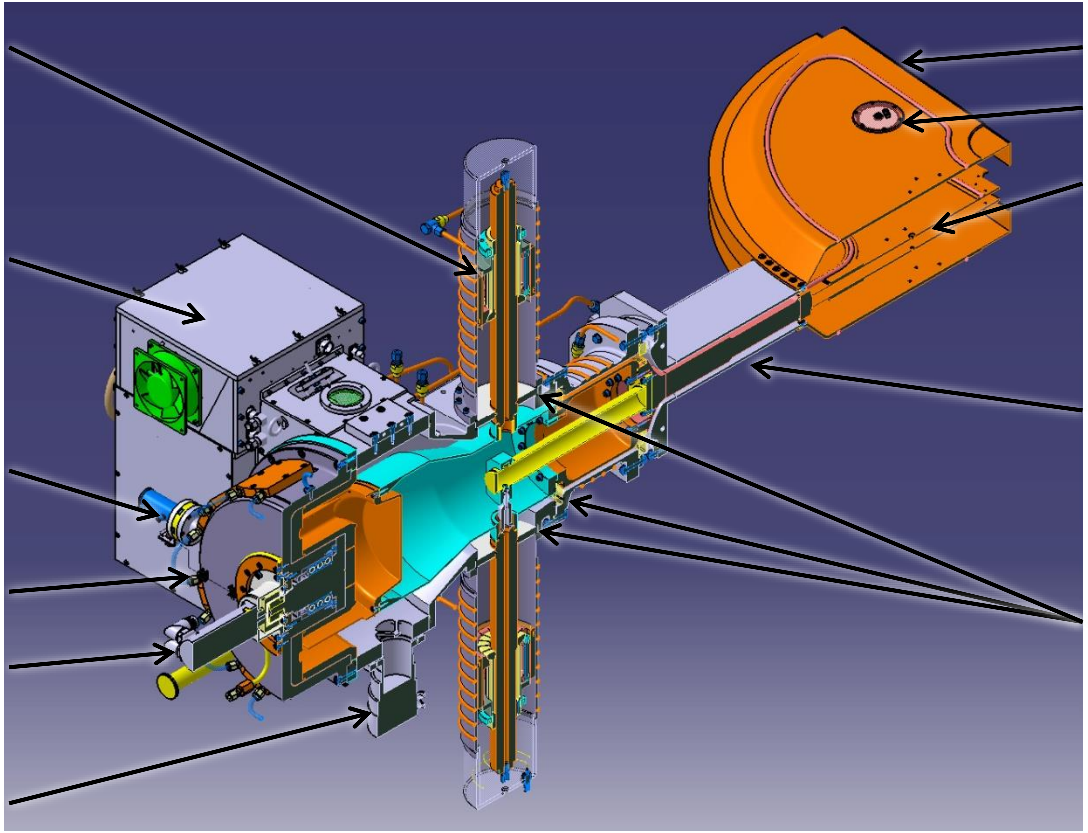
RF system on the test bench



- $\lambda/2$-structure operating in 1^{th} harmonic mode: terminated by the 180° dee on one side and the rotco on the other side
- Biased at 1 kV DC to supress mulipactor
- Two side stubs provide fine-tuning of df/dt during capture
- RF Frequency: 60~90MHz
- Modulation frequency: 1kHz
- Dee voltage: 3~12kV
- Extensively modeled with CST
- Placed outside yoke in shielded volume

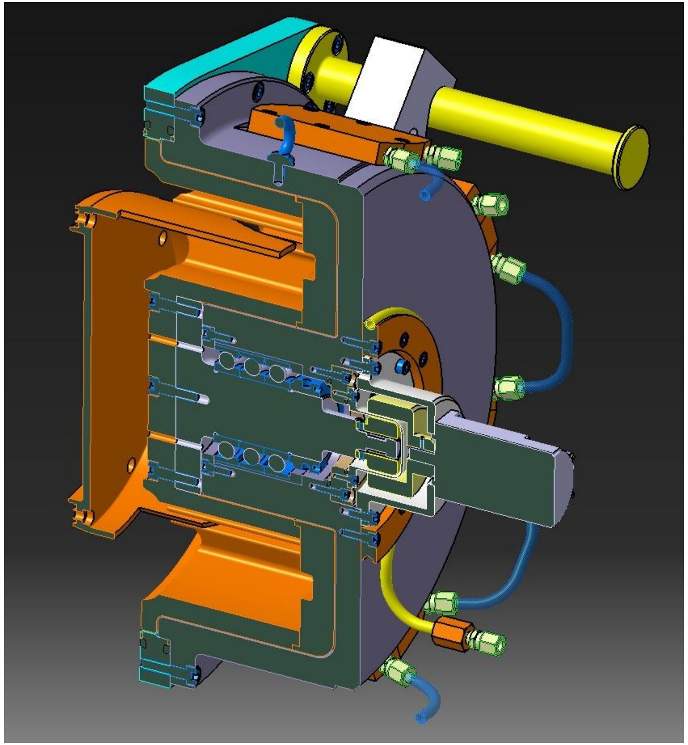
RF-system

layout



RF-system

Rotco=> Coaxially mounted with 8-fold symmetry

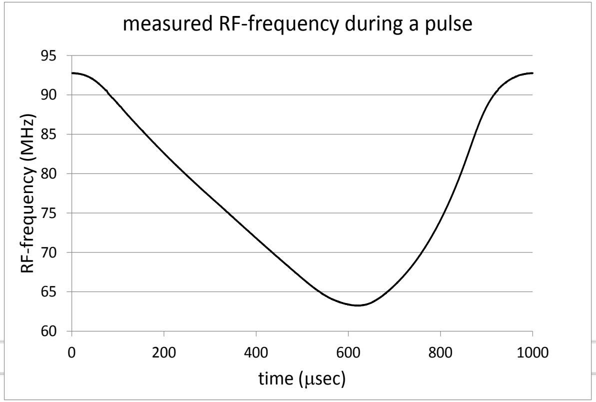


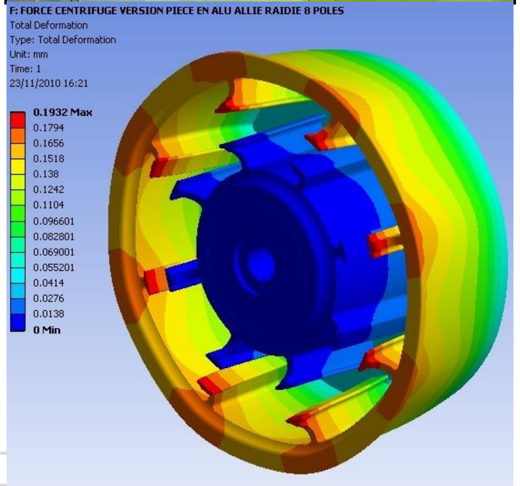
Innovative/patented design:

excellent mechanical stability and good pulse reproducibility

Stator: 8 blades with a carefully designed profile to have the desired df/dt curve.

Rotor: wheel with 2x8 electrodes turning at 7500rpm (1 kHz pulse)





External beam line

layout

- A variable energy degrader is placed at 2 meters from the yoke exit
- A permanent magnet quad matches the beam phase space with respect to the beam line optics
- A quadrupole doublet provides a 1 mm double waist (1-sigma) on the degrader.
- A variable horizontal collimator between the two quads cuts the horizontal divergence providing constant optics independent of gantry angle
- Full assembly can be shifted aside for access to the quads in the shielding wall