Cold Magnets and Current Leads

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Topics

- Introduction
- Cold Magnets in Accelerator Modules (Cryomodule)
- Current Leads
- Status and Future Plans

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Magnets in different Sections

Accelerator magnets are used for bending and focussing of the electron beam

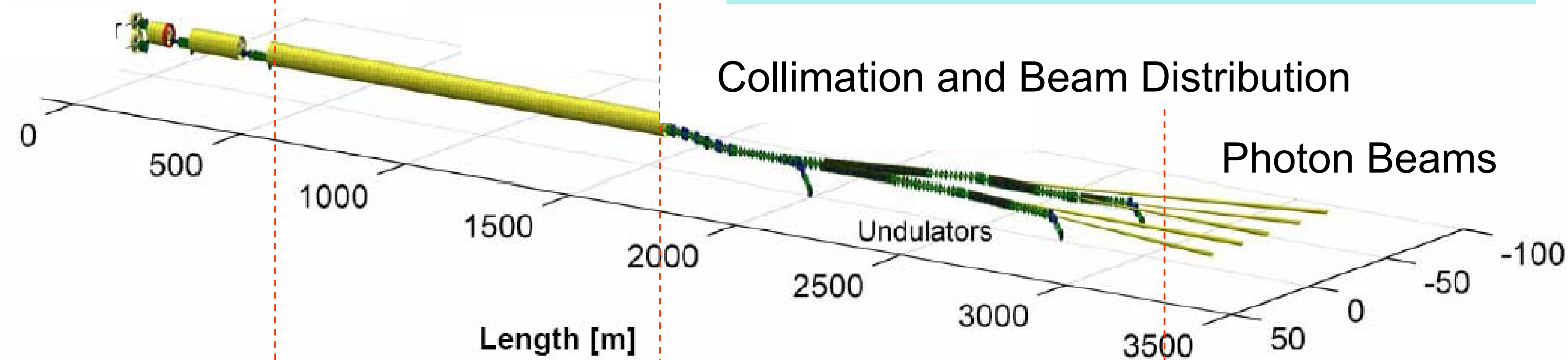
- 116 superconducting Magnets Packages in the Accelerator Modules
  - Cold Quadrupoles and 2 correction magnets
- Warm magnets
  - 60 dipoles
  - 400 quadrupoles
  - 40 sextupoles/octupoles
  - 530 correction magnets
- Undulators with permanent magnets
  - In total about 650m

Injector and Bunch Compressor

Main LINAC

Collimation and Beam Distribution

Photon Beams

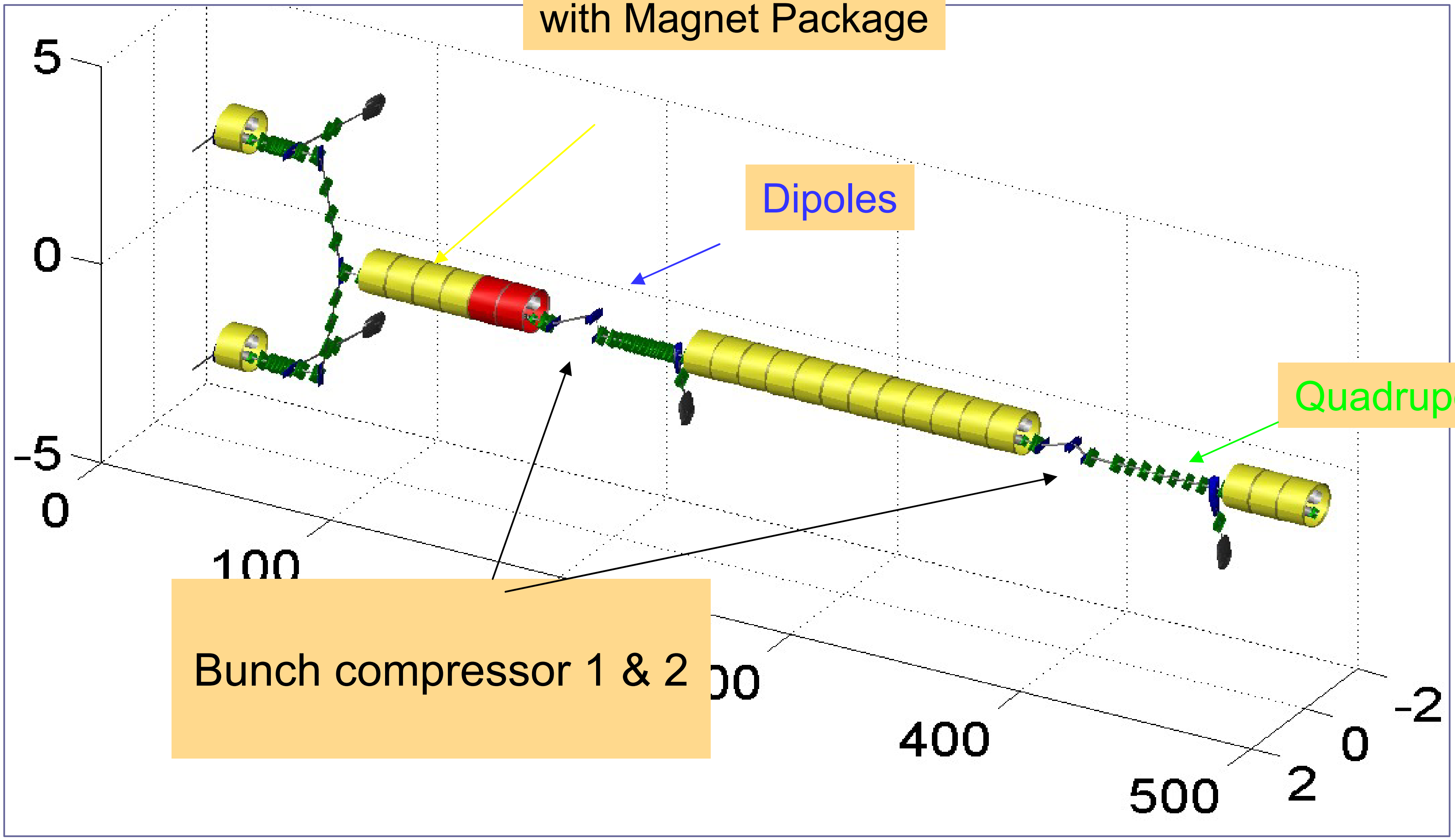


warm and cold magnets

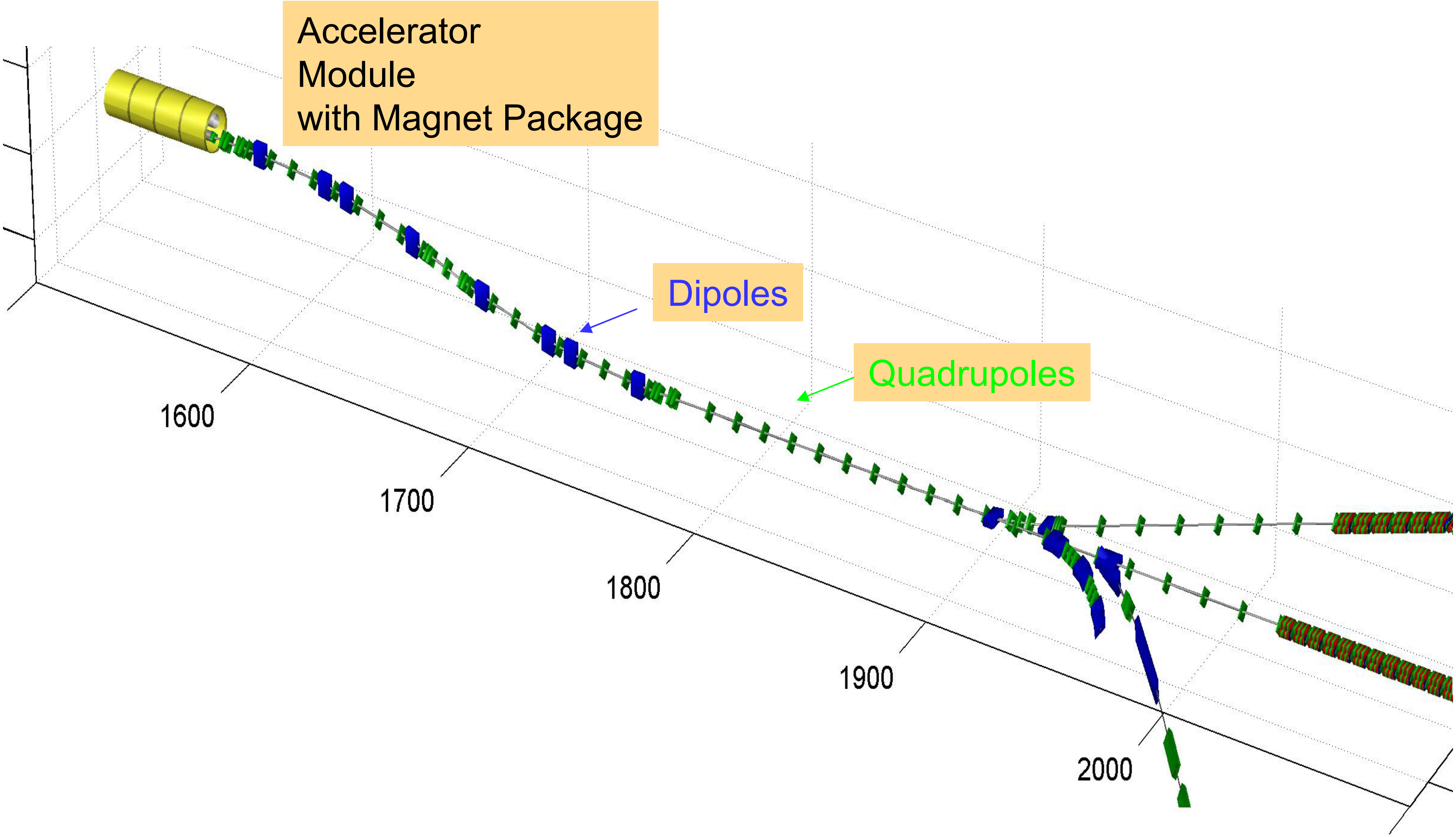
cold magnets

warm magnets and permanent magnets

Injector and Bunch Compressor Area

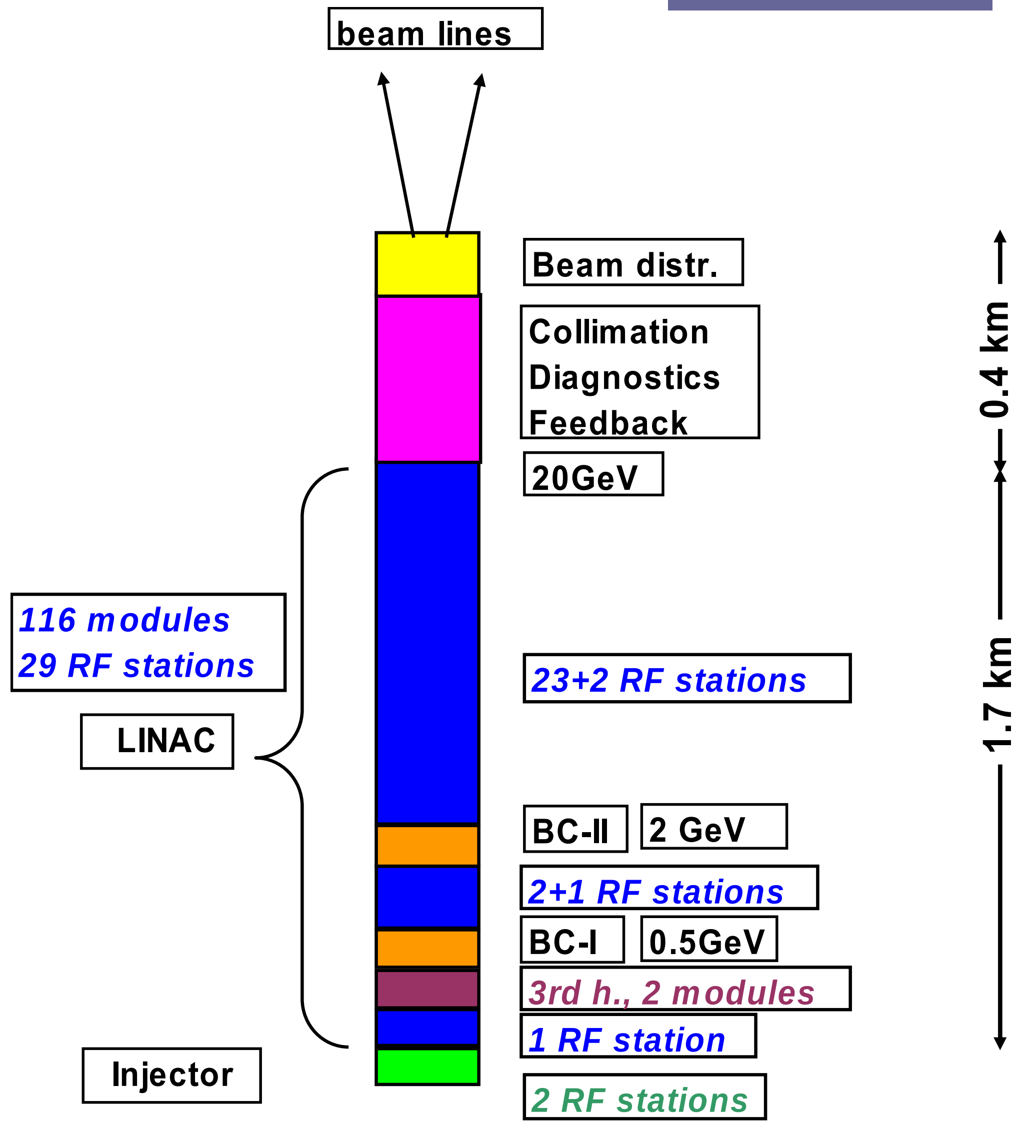


Collimation and Beam Distribution



Cold Magnets

- The Linear Accelerator consists of 116 cold Accelerator Modules (Cryo Modules).
- Connected in in long string, cryo by-pass at BC1&2.
- → The necessary focusing and correction magnets must be cold.
- They are operated at 2K, 30mbar with 2-phase Helium like all the cavities.
- → This implies: no gas cooled leads can be used.

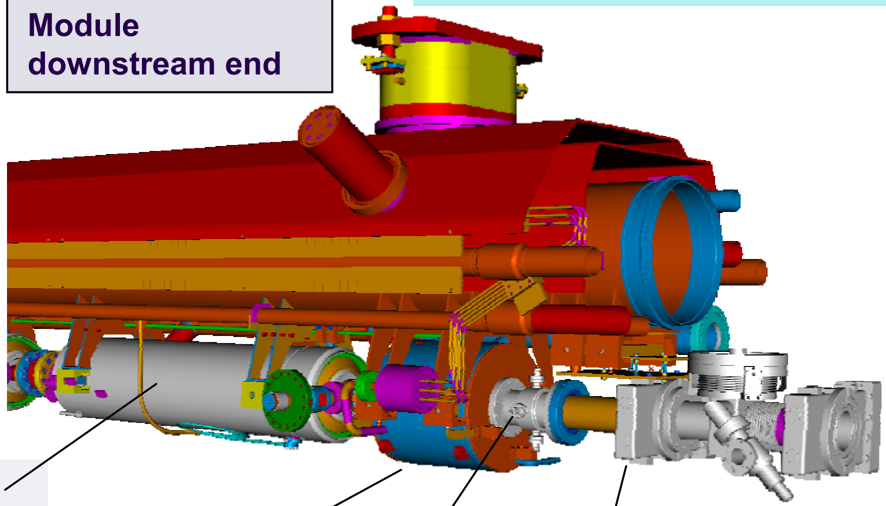


Accelerator Modules

A real Accelerator Module at the “Tesla Test Facility” now called “FLASH”

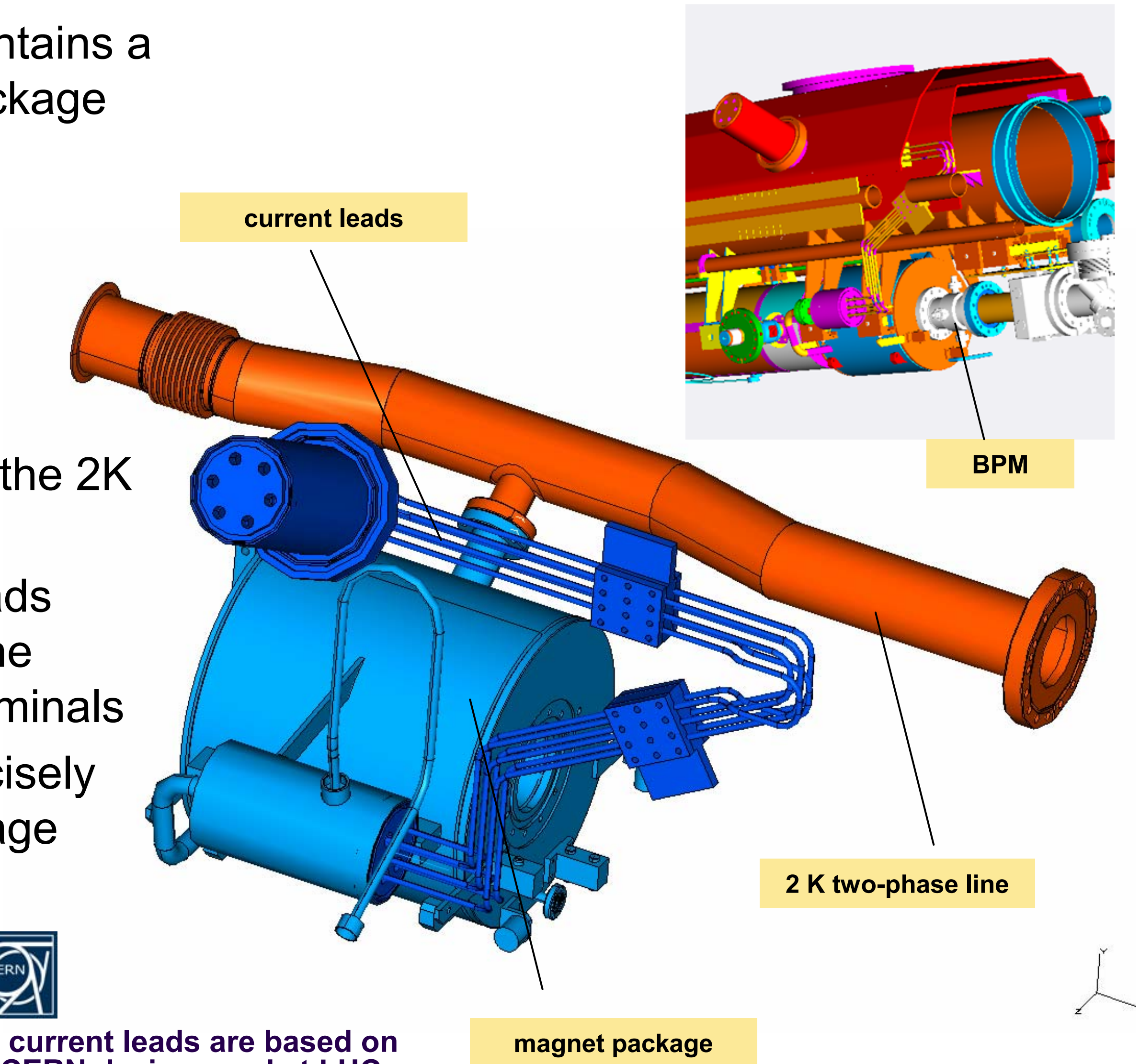
Model of a Prototype Module
(Vacuum tank and other parts removed)

Module downstream end



Magnet Package Overview

- ❑Each accelerator module contains a superconducting magnet package at the downstream end
- ❑Consisting of:
  - ➢A superferric quadrupole
  - ➢Two correction dipoles
- ❑The magnet package is cryogenically integrated into the 2K circuit
- ❑An assembly of 6 current leads (non gas cooled) connects the magnets to warm current terminals
- ❑A beam monitor (BPM), precisely coupled to the magnet package



The magnet design is done in collaboration with CIEMAT

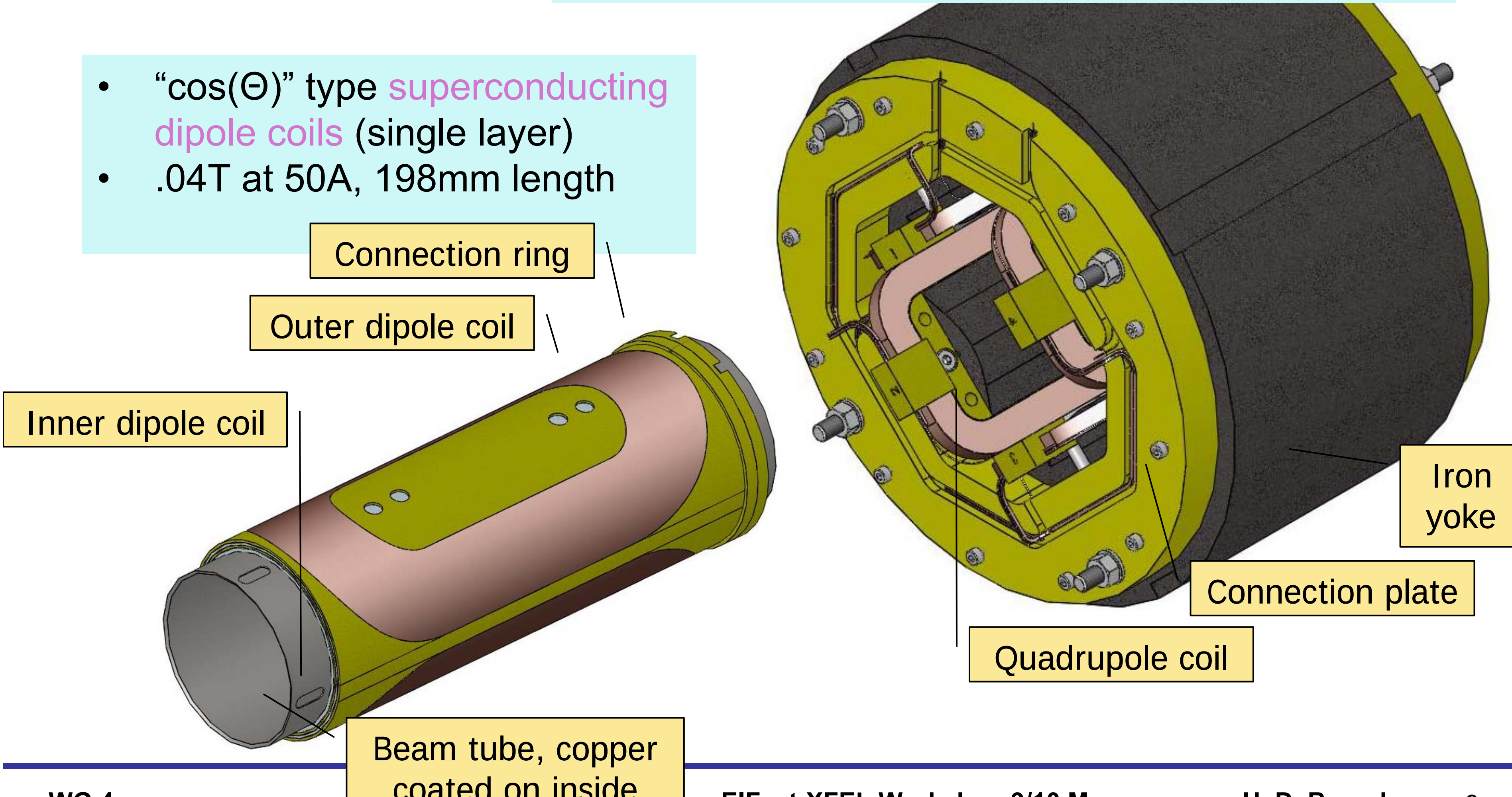
The current leads are based on the CERN design used at LHC

Magnet assembly

The magnet design is done in collaboration with CIEMAT

- A “superferric” quadrupole is a conventional iron based quadrupole with superconducting coils
- 35T/m at 50A, 170mm length

- “cos(Θ)” type superconducting dipole coils (single layer)
- .04T at 50A, 198mm length



Quadrupole Parameters

Winding type	Superferric	
Iron yoke inner diameter	94.4	mm
Iron yoke outer diameter	270	mm
Nominal current	50	A
Nominal gradient	35	T/m
Magnetic length	169.6	mm
Number of turns	646 (34x19)	
Wire diameter (bare/insulated)	0.4/0.438	mm
Copper to superconductor ratio	1.35	
RRR	>70	
Filament diameter	35	micron
Twist pitch	50	mm
Iron yoke length	145	mm
Coil length	200.6	mm
Stored magnetic energy at 50A	1462	J
Self inductance at 50A	1.17	H
Integrated gradient at 50A	5.976	T
Integrated b6 at 50A	1.87	units
Integrated b10 at 50A	-2.75	units
Coil peak field	2.47	T
Working point on load line at 4.2 K	45	%
Integrated gradient at 5 A	0.621	T
Integrated b6 at 5 A	-1.79	units
Integrated b10 at 5 A	-2.71	Units
Saturation at 50 A (integrated)	3.9	%

Unit: $10^{-4} \cdot b_2$ at 30mm

- Field quality very good
- Saturation at 50A only 3.9%

Dipoles Parameters

Dipole	INNER	OUTER	
Winding type	cos-θ	cos-θ	
Inner diameter	83.6	88.5	mm
Outer diameter	85.66	90.56	mm
Nominal current	50	50	A
Nominal field	0.04	0.04	T
Magnetic length	203.7	205	mm
Number of turns	36	37	
Wire diameter (bare/insulated)	0.7/1.03		mm
Copper to superconductor ratio	1.8		
RRR	<100		
Filament diameter	<20		micron
Twist pitch	~25		mm
Iron yoke length	140		mm
Coil length	230	230	mm
Self inductance	0.96	1.07	mH
Integrated field at 50A	0.00815	0.00820	Tm
Integrated field at 50A, quad@50A	0.00748	0.00745	Tm
Saturation at 50A (integrated)	9.0	10.1	%

One vertical and one horizontal deflecting dipole

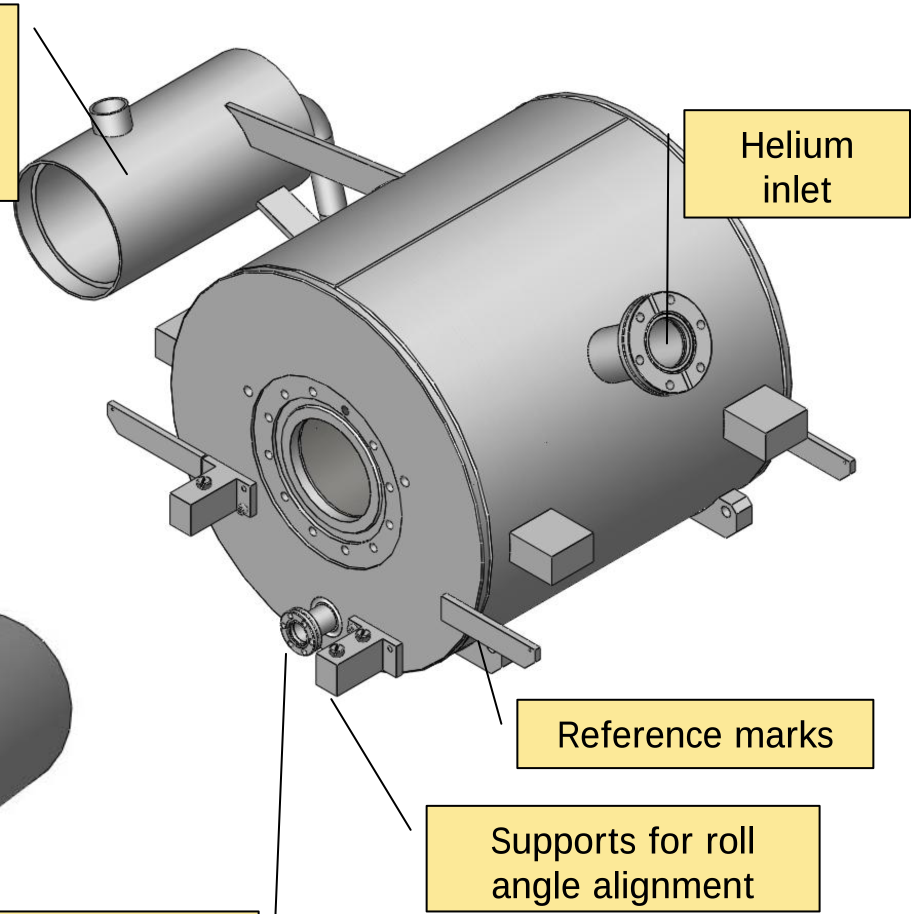
Helium Vessel Assembly

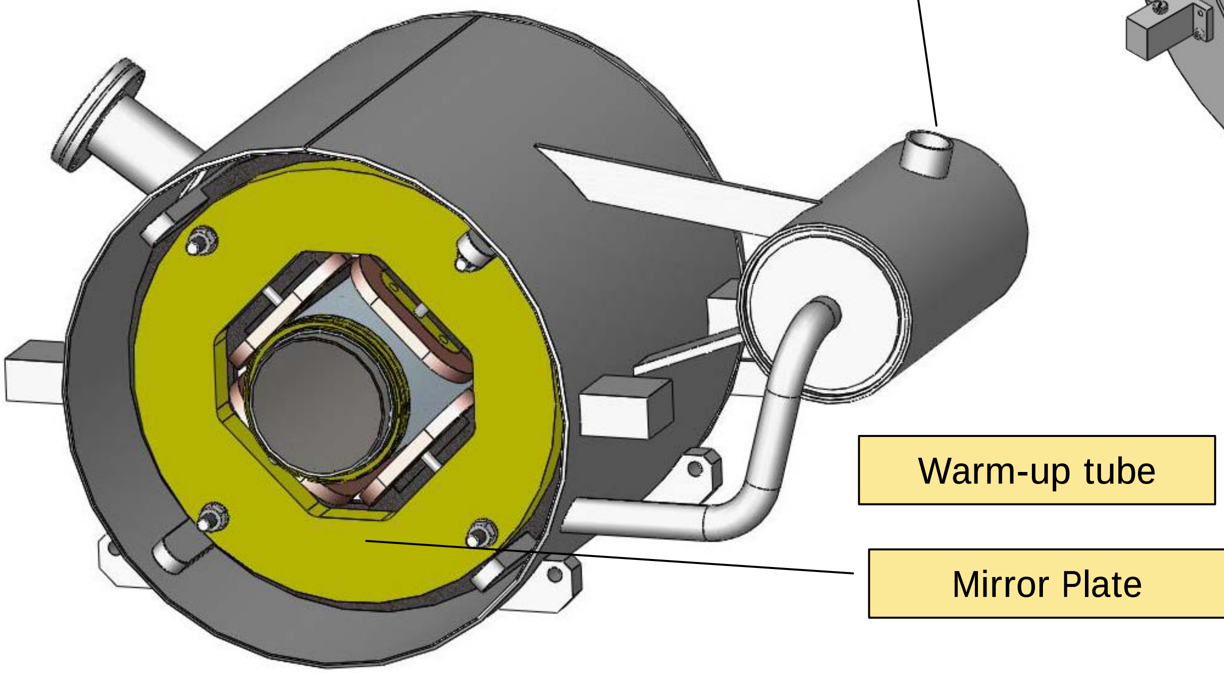
MINISTERIO DE CIENCIA Y TECNOLOGÍA

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

The magnet design is done in collaboration with CIEMAT

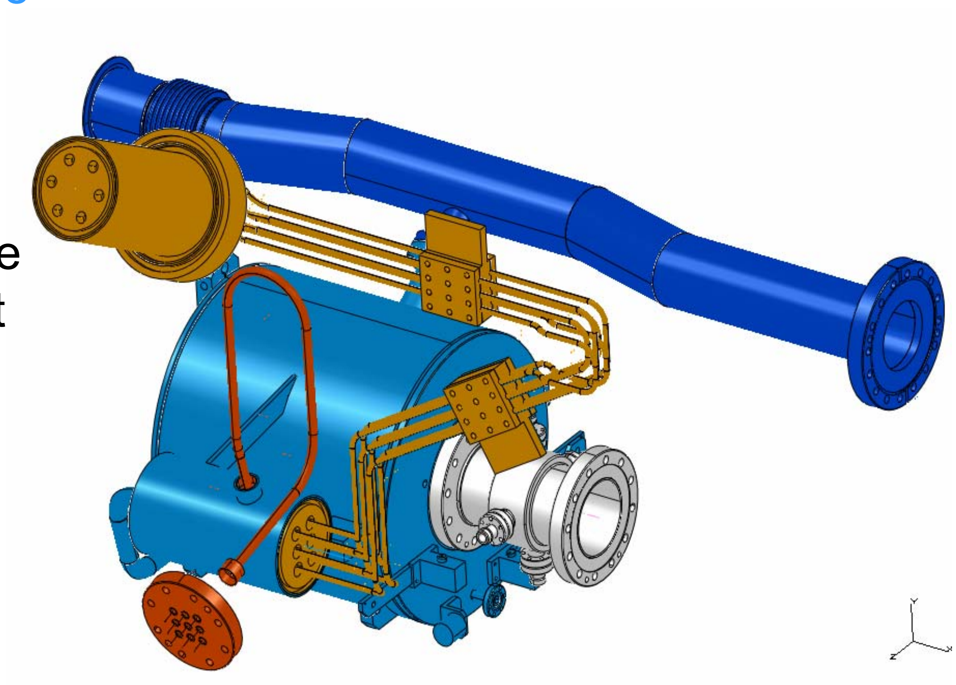
He vessel material stainless steel, eventually Titanium, 300mm long





Alignment and Measurements

- Alignment errors between Quadrupole and BPM below
  - 0.3mm for x,y
  - 3 mrad for roll angle
- Magnetic axis and field angle must be measured for each individual magnet
  - Will be done warm
- Dowel pins holes in magnet package drilled on basis of magnetic measurements results
- **Any** BPM-Magnet pair can then be built



Current Leads

- XFEL requirements are very similar to current leads for CERN LHC corrector magnets (60A, from room temperature to 2K)

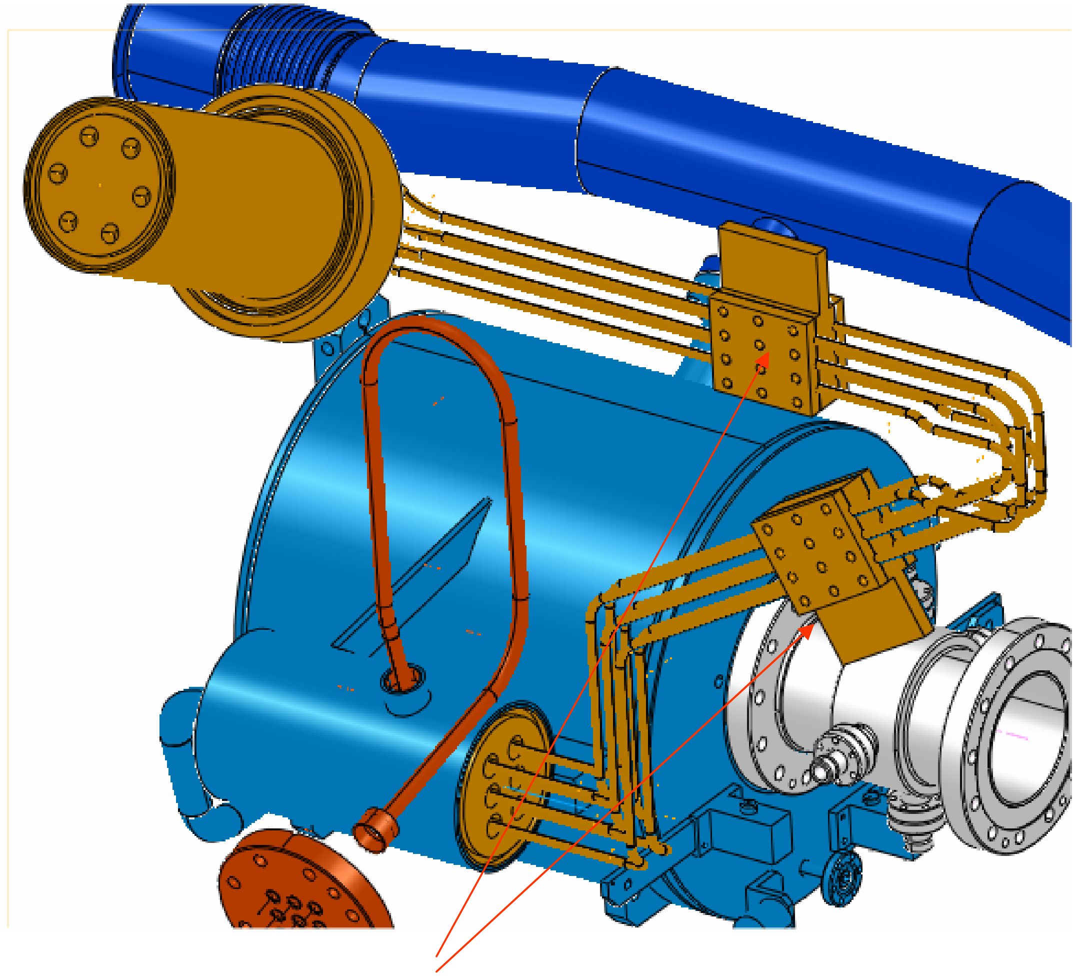
- CERN Design: Conduction cooled leads with 2 heat sinks
  - Heat sinks
    - 4-20K
    - 50-75K
  - Hybrid conductor
    - Brass rod with cupper coating with isolating Capton® tube inside a stainless steel tube

- Contract with CERN made for the design and production of a prototype assembly

The current leads are based on the CERN design used at LHC

Conduction Cooled Current Leads

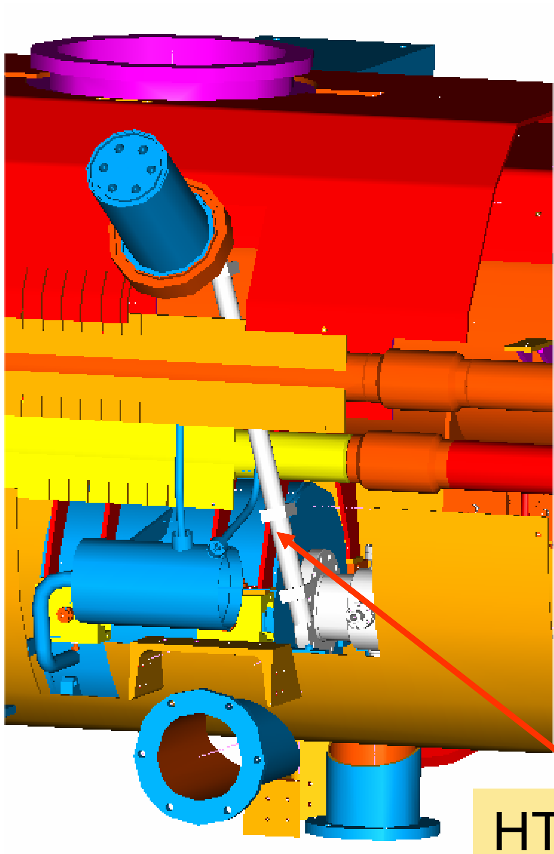
- Modified design by CERN especially for our requirements
- Heat sinks at 4-8K and 40-80K
- Heat load at maximum current:
  - 16 W at 70 K,
  - 3.5 W at 4.5 K,
  - 240 mW 1.9 K with the maximum length
- Advantage
  - No gas flow control
  - 2K volume extents up to the warm feed through



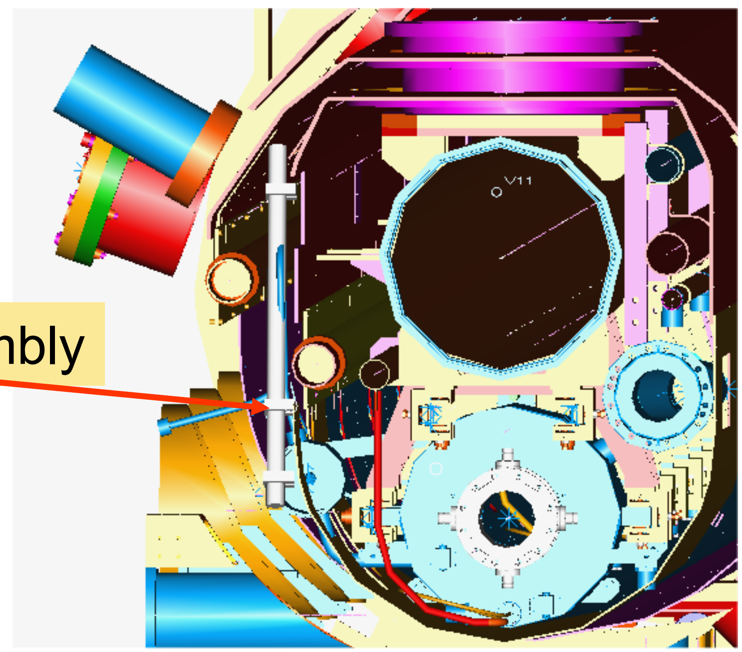
Heat sink
Connection to He tube by copper braide

Alternative: HTS Current Leads

- ❑ Alternatively we consider HTS leads
- ❑ Advantage
  - ➢ very low heat loads onto the 2K level
  - ➢ No gas flow control
- ❑ Disadvantage:
  - ➢ cold feed throughs necessary (2K, 30mbar to insulation vacuum), which might be risky! A failure would stop the accelerator for a long time
  - ➢ Experience?



HTS Leads assembly

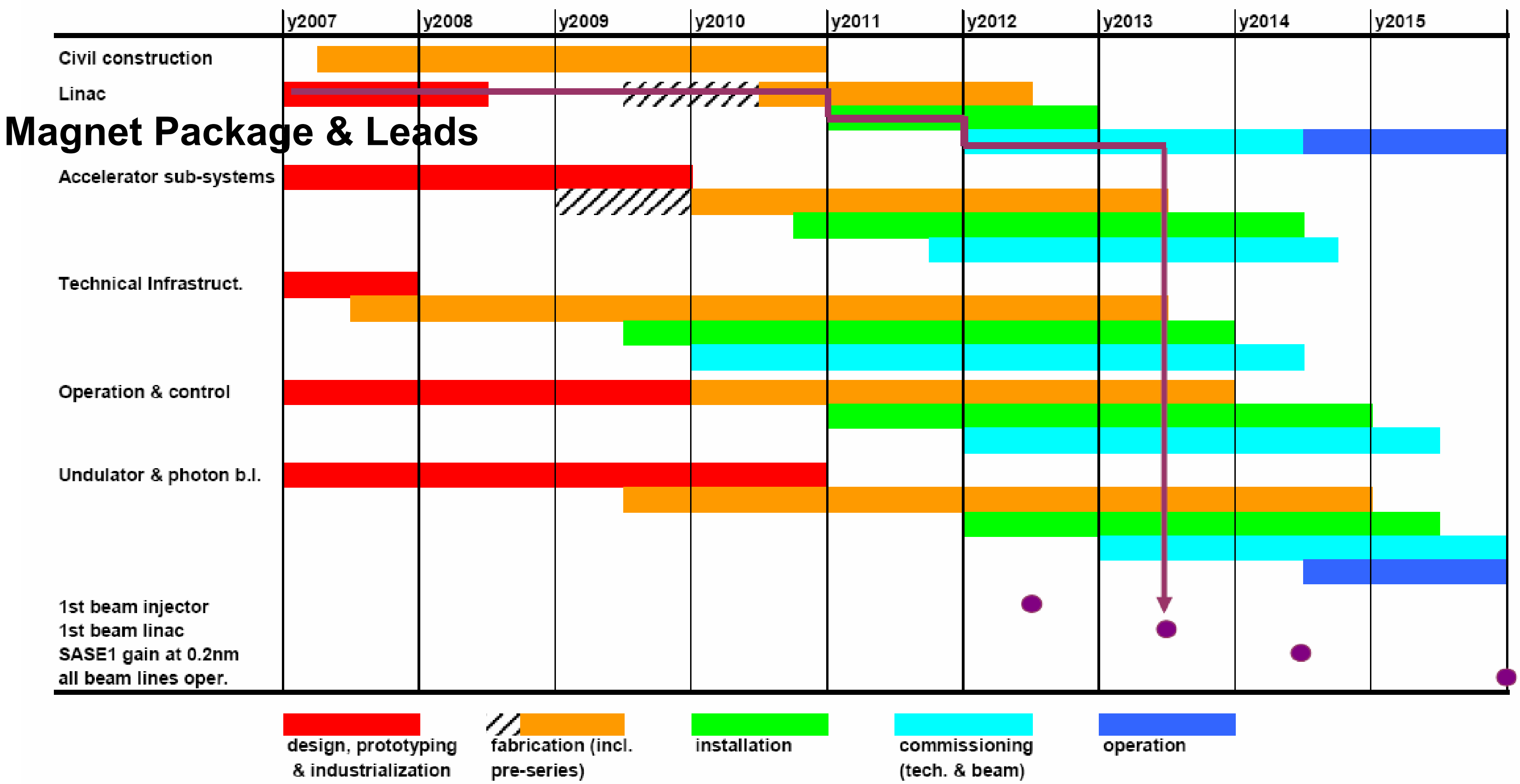


for the six leads combined
leak to 80 K 8 - 16 W (at 50 A and 0 A).
leak to 4.2 K approximately 120 mW (at any current)
leak to 1.9 K approximately 25 mW (at any current)

Plan for the Series

- ❑ Production of magnets and leads in industry
- ❑ Tests and detailed measurements at DESY of each magnet package
  - ➢ Test in the magnet test hall warm and cold
    - ❖horizontal cryostat especially designed for magnet tests
  - ➢ Cold: Integrated field strength, performance…
  - ➢ Warm: Magnetic axis and roll angle
- ❑ Final assembly into the Accelerator Module by industry
- ❑ Final cold tests of magnets and leads on module test stand in the AMTF
- ❑ Installation in tunnel

Time Schedule



Status & Outlook

- Where we are
  - Building prototype Magnets at CIEMAT for 3 prototype Accelerator Modules
    - ready in summer 2006
  - Building a prototype lead assembly at CERN, a 2nd later at DESY
  - We will Order a prototype HTS lead soon
  - Extensive tests of magnet and leads starting end of 2006
  - Horizontal cryostat specifications end 2006, ready end 2007?
- Outlook (based on assumed project start 2007)
  - Series Production of ~116 magnet packages & leads
  - Tender&Selection 2007-2008
  - Pre-series 2009
  - Production start 2010
    - One complete set per week
  - Installation in tunnel until end 2012