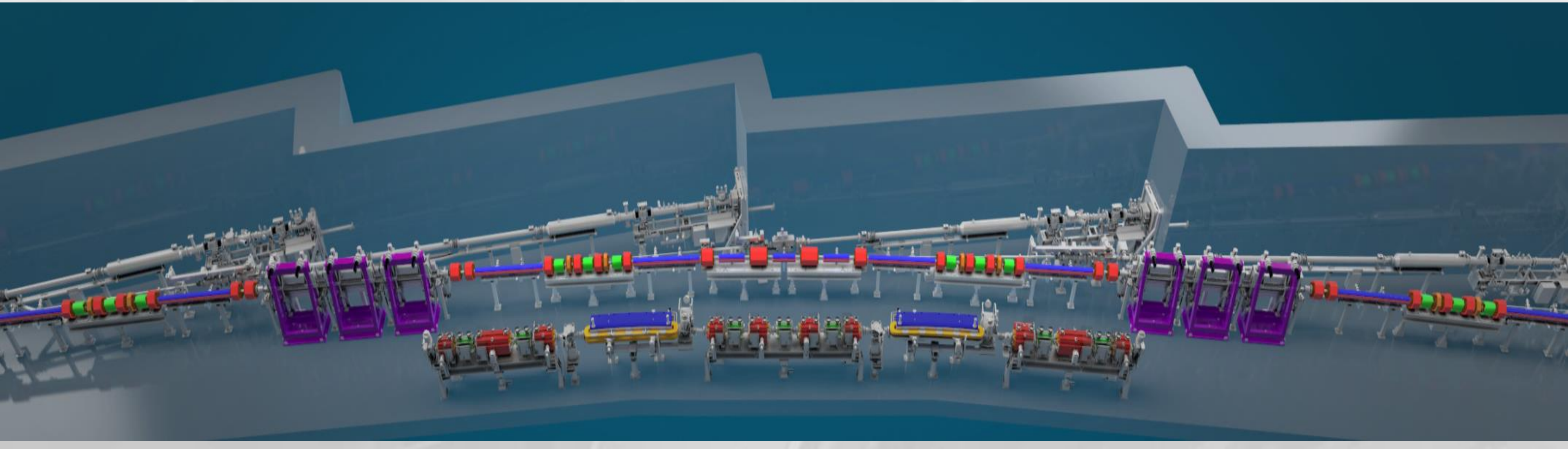
Boosting accelerator electrical efficiency at the ESRF

Geneva, October 23th, 24th & 25th 2013



Power Supply & Electrical Engineering for sustainable science

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On behalf of the ESRF Accelerator Program Phase II Team

European Synchrotron Radiation Facility

Global cost computation

- **Power Supply & Electrical Engineering ->**Electrical supply engineering
- Organisation:

J-F Bouteille
Power Quality and magnets power procurement

Joel Chavanne
Magnet group head

Y Gouez
Electrical infrastructure and consumption

Gael Le Bec
Magnet group deputy

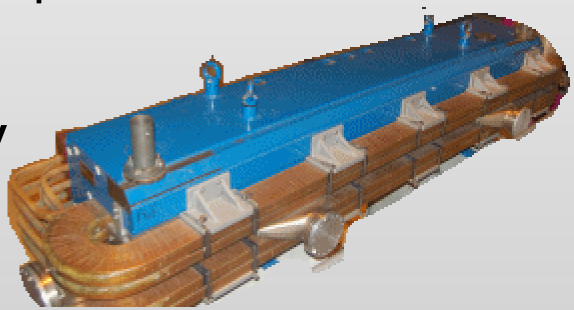
Work Package 1.4 of the Technical Design Study

- Goal of the package:
- Prepare the cost and the procurement planning of the power supplies.
- Evaluate the matching of each PS+Magnet pairs.
- Review of the cabling and cooling constraints of each of the PS+Magnet pairs. AC and DC wise they will be touched on as a global evaluation.
- Compatibility with the existing energy infrastructure; What needs to be adapted, in which direction and prepare the consequences of running costs.
- Compare many solutions with a global cost computation over 15 years including electrical energy cost increase.

Comparison dipole magnet technologies

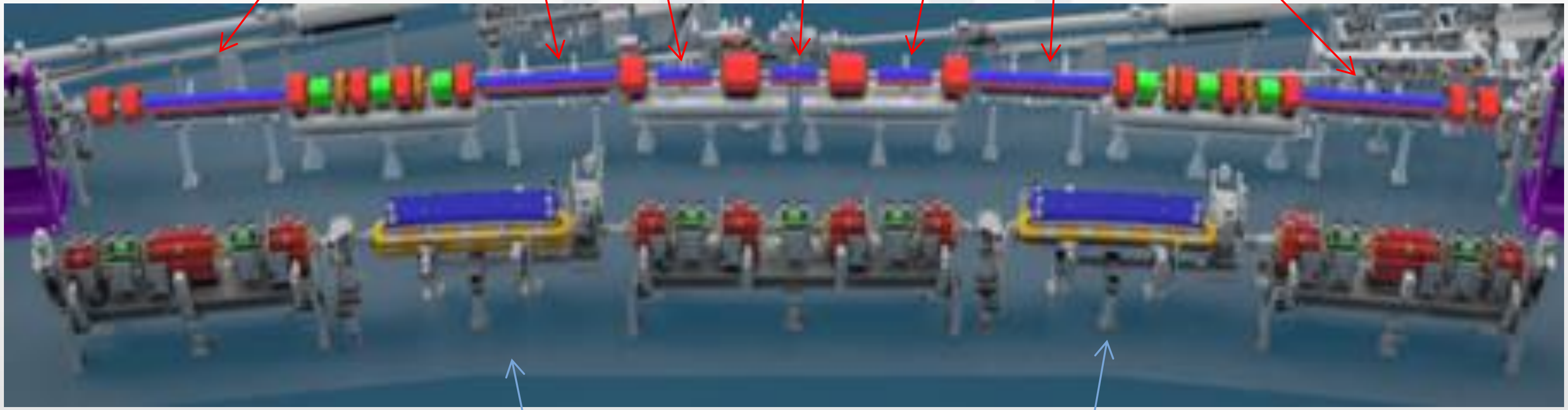
Present situation:

- Power per magnet = 10kW used for 160 000h
- Procurement cost of 64 magnets : 1.5 M€ in 1990,
- Running cost for 64 magnets : 5 M€ since 1992
  - Electrical for the magnet current : Joule losses.
  - Electrical for auxiliaries: PS + AC 50Hz transport and distribution
  - Electrical for cooling needs: water and air
- 5 year power and energy cost tendency
  - 3 main parts: energy, transport, taxes: €/MWh, €/MW, VAT+additional taxes.



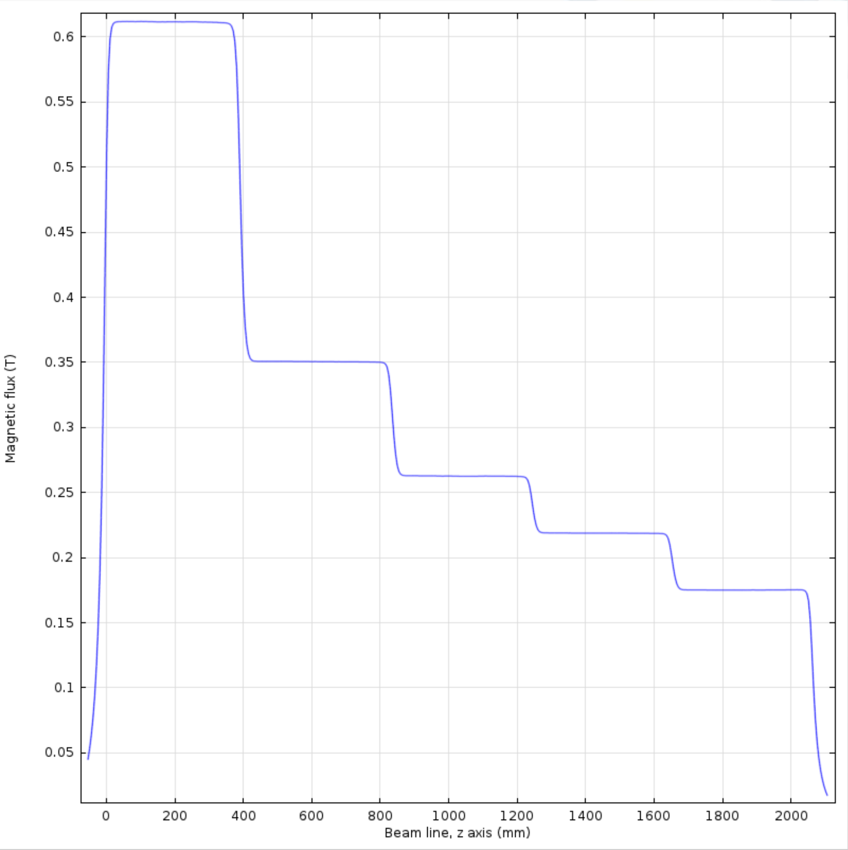
  - Announcement of 30% global increase for the 5 years to come.
  - General tendency of 3% per year over 15 years seems very optimistic.

New lattice with 7 dipoles



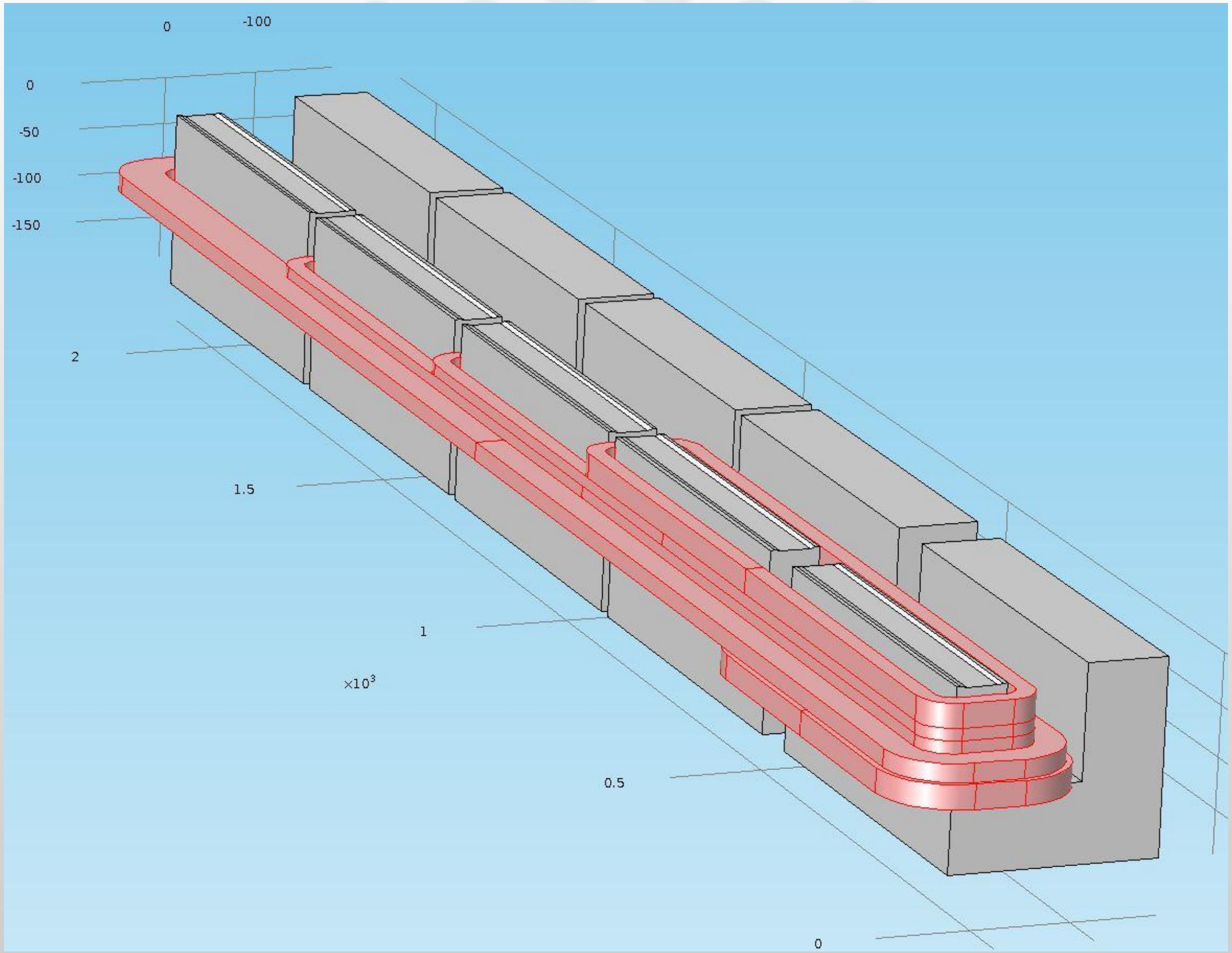
Old lattice with 2 dipoles

New lattice magnetic field profile



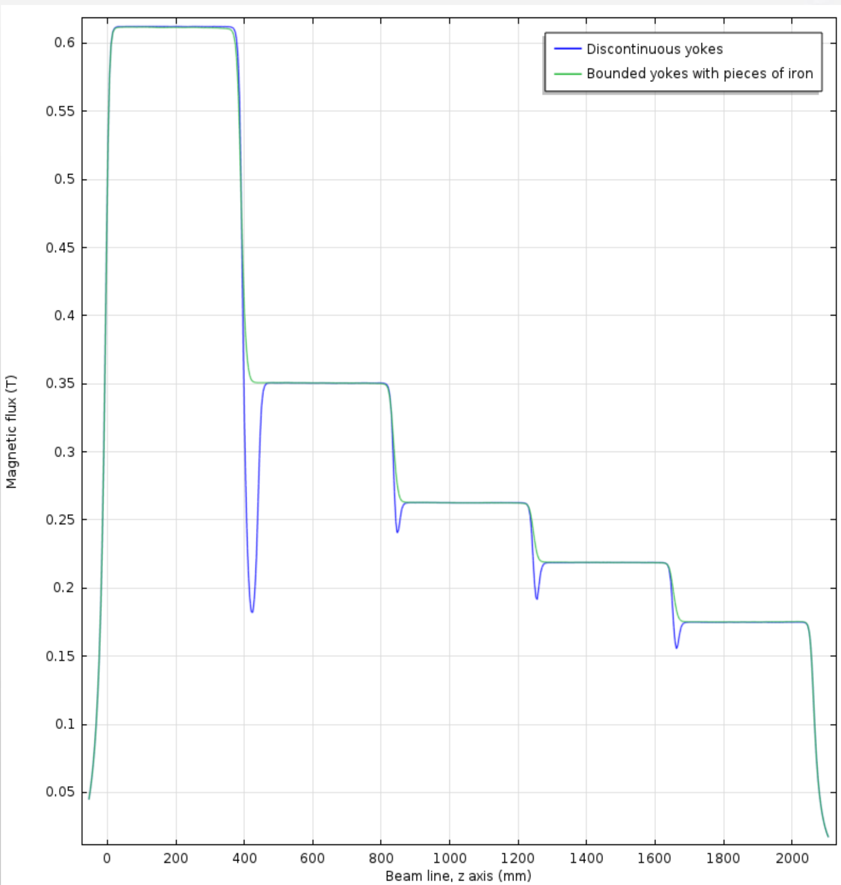
- The profile of the magnetic field is decreasing along the path of the electrons.
- The gap of the dipole is adjusted to the vacuum chamber height in order to minimize the magnetic volume.
- The number of coil turns is chosen to approach the ideal curve.
- The power to perform 4 / 7 of the dipole function is 2.6kW leading to a total of 336kW!
- The 3 other combined function dipole-quadrupole electromagnets are forecasted to 4.5kW/cell => 144kW

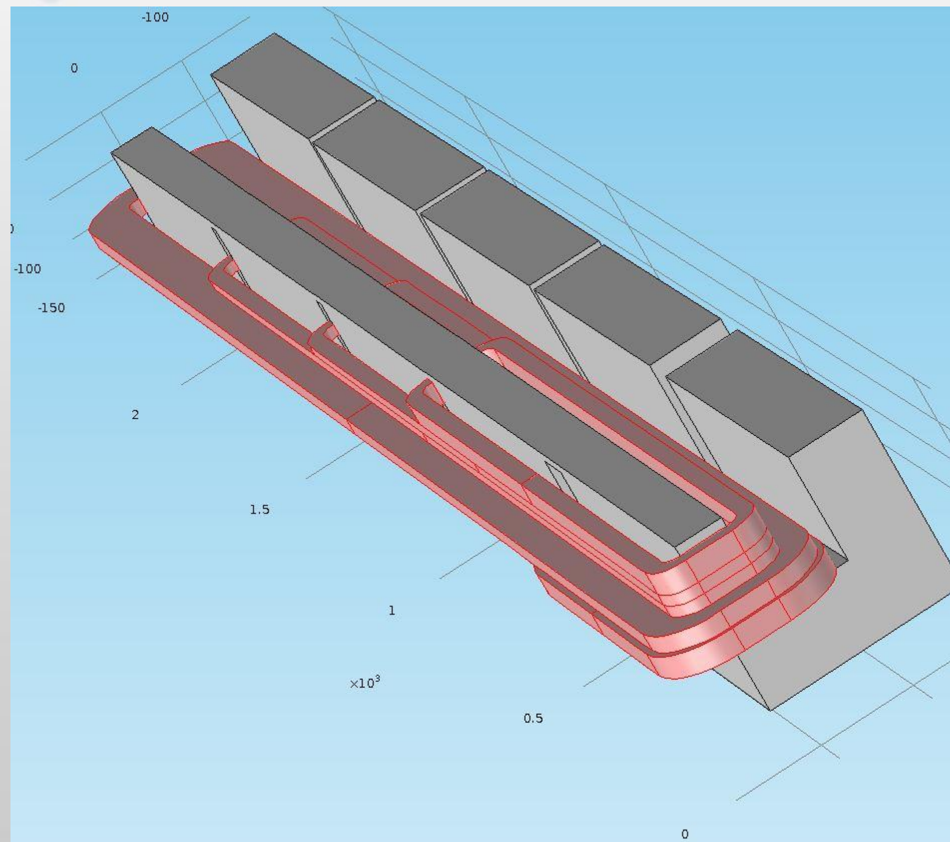
Longitudinal Gradient Dipole electromagnet



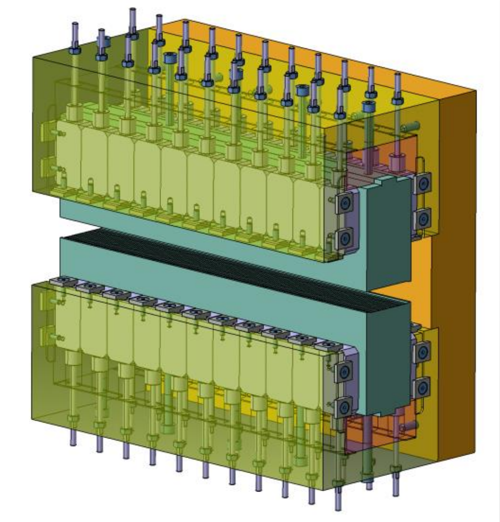
Pole extensions

- To avoid the loss of efficiency coil extremities: pole extensions to be engineered.



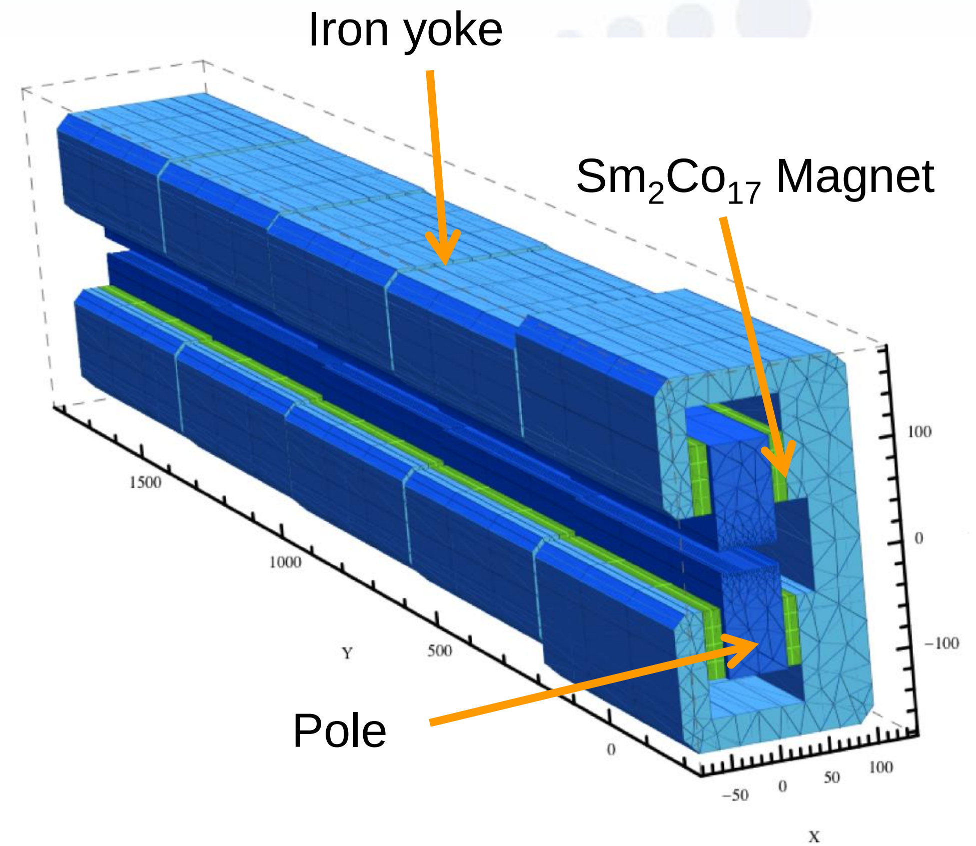


Comparison dipole magnet technologies

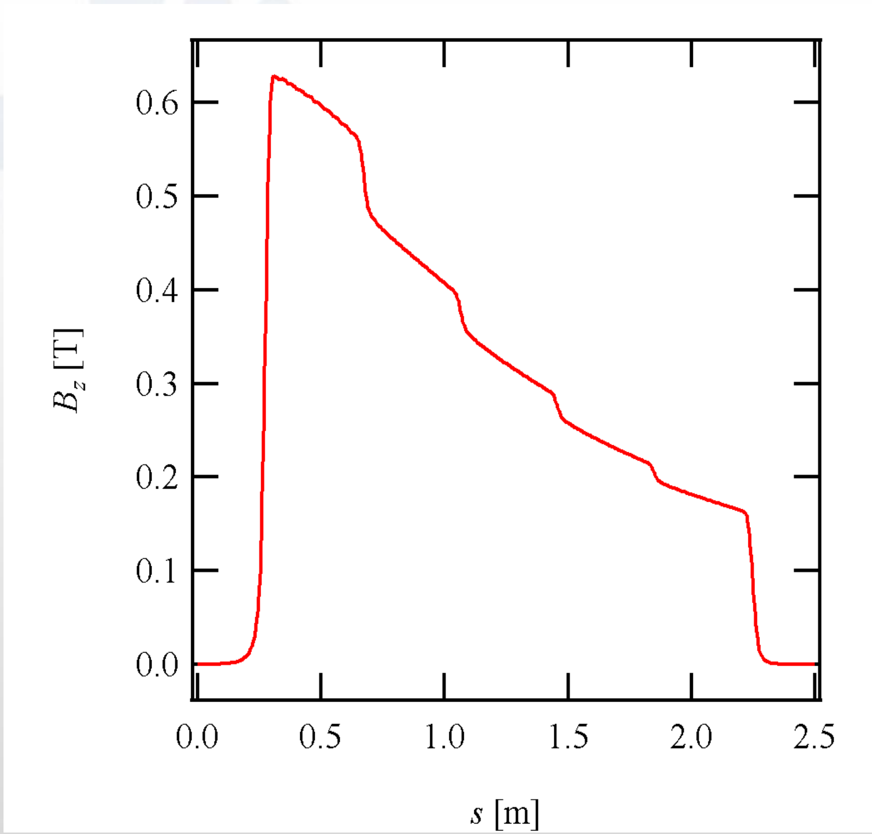


- Hybrid dipole magnet mixed with Permanent Magnets
  - Needs temperature and lattice correction coils
  - Cost of the correction function imposed by the technology and the alignment
  - Air cooled coils is today the best approach
  - Global cost over 15 years of the correction function
- Discussion on the added value of the correction function in electromagnet design,
  - Family connection compared to individual connection.

Dipole with longitudinal gradient



Magnetic design view

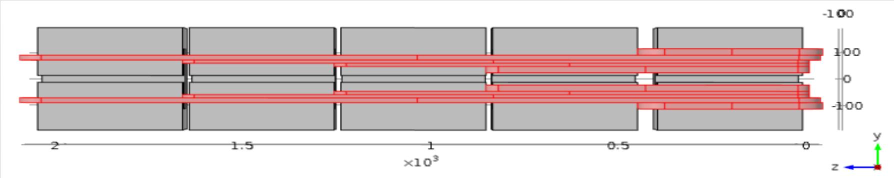


Vertical field along beam path

Fair comparison of two technologies we foresee

Electromagnet

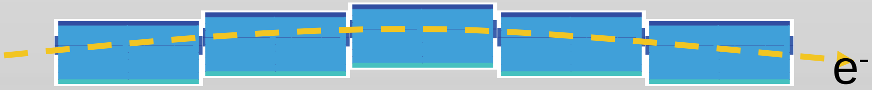
- Global length= 2.16m
- Pole extension and coils: engineering difficulties.
- Tunability: one power supply no local correction accessible
- Power = 2.6kW
- Energy for 15 years : 330MWh -> 28k€ **per magnet!**
- Safety: No risk when powered off



Electromagnet dipole modules (front view)

Permanent magnet

- Global length= 2.08m
- Pole extension: assembled before end. Mechanical forces to be mastered.
- Tunability: correction for temperature drift within +/- 3% of the field
- Power = few watts only.
- Energy for 15 years : less than 1MWh.
- Safety: Magnetic forces always present!



Arrangement of PM dipole modules (top view)

Comparison electro-magnet and permanent magnet

- The limited aperture of the pole gives severe constraints on the coils and pole designs.
- The total length is affected such that the crosstalk with neighbor magnets is yet not solved.
- The permanent magnet is not only cost effective but also able to be more compact
- The tunability of each step is accessible without any major constraints or changes.

Present power footprint of the storage ring

- The power to run the storage ring depends on the modes:
  - Multibunch uniform : 5.7MW->5.4MW for 200mA -> 161mA
  - 7/8 + 1 filling : 5.3MW->5.0MW for 200mA -> 164mA
  - 90 mA 16 bunches : 4.5MW -> 4.3MW for 91mA -> 59mA
  - 40 mA 4 bunches : 4.22MW -> 4.14MW for 43mA -> 31mA
- Most of the power variation is driven by the RF part
- The electromagnet part is measured to : 1.86MW
- The tech. gallery and General UTility for the accelerator is 0.92MW
- The RF part is therefore the complement : This varies from 2.92MW to 1.36MW

New low emittance lattice ring power footprint

- The lattice magnet part is foreseen to be 1.25MW instead of 1.86MW -> 33% reduction
- The RF reduces losses per turn from 5.4 to about 3.6 MeV/turn -> 30% reduction at least : function of the cavities impedances.
- Cooling needs for the accelerator will be reduced by 30% which represents half of the general utility 0.92MW: -> 0.78MW
- The SR will therefore have a power demand of 4.1MW instead of the 5.7MW for uniform 200mA which represents a 28% reduction of peak power demand.
- The injector in topup mode will also benefit from 4 cavities in the booster and optimized ramping power supplies:
  - Reduction of the SYRF power demand by nearly 50%; wall plug energy increase due to the topup repetition rate.
  - Booster Magnet power demand will be similar, energy to be discussed depending on the MDT yearly multicycle demand.

Conclusion

- The new lattice proposed is a big opportunity to think on a better efficiency of the accelerator complex.
- By enlarging the dipole length from 4m to 11m the emittance will decrease and consequently the RF losses.
- This is also the global cost computation over the estimated life time of the instrument which is guiding the technology which has to be used for a sustainable engineering. Many magnets will benefit from this computation
- Even if the electromagnetic solution would be chosen, the actual 640kW for the dipole electric function will be reduced to 480kW, many other facilities have power needs much above this value for lower electron energy!

Many thanks for your attention