High Resolution Separator

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HIE-ISOLDE Workshop
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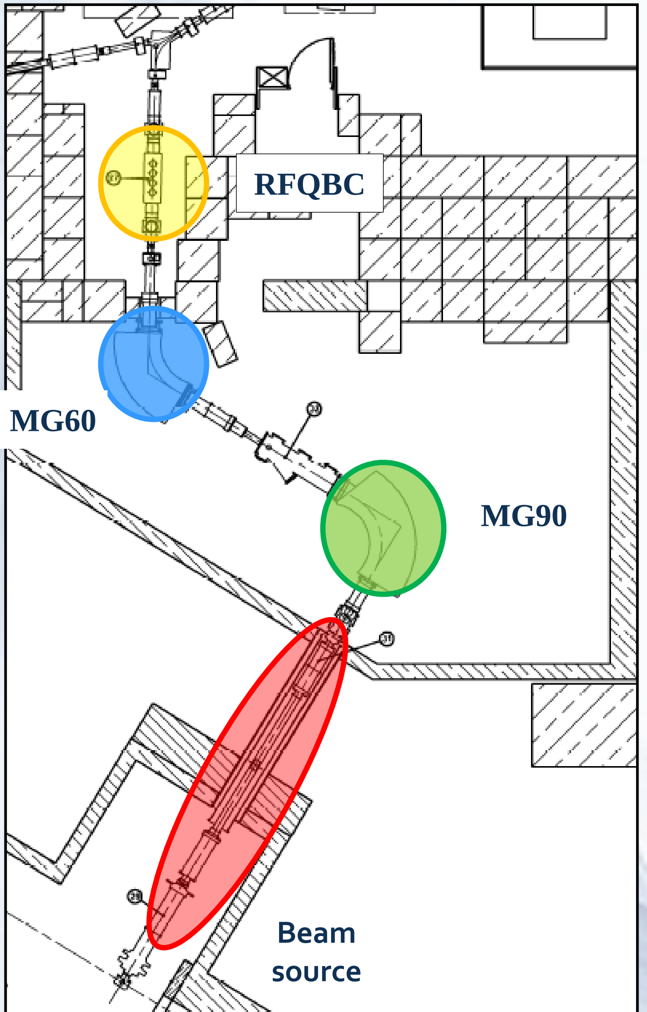
Outline

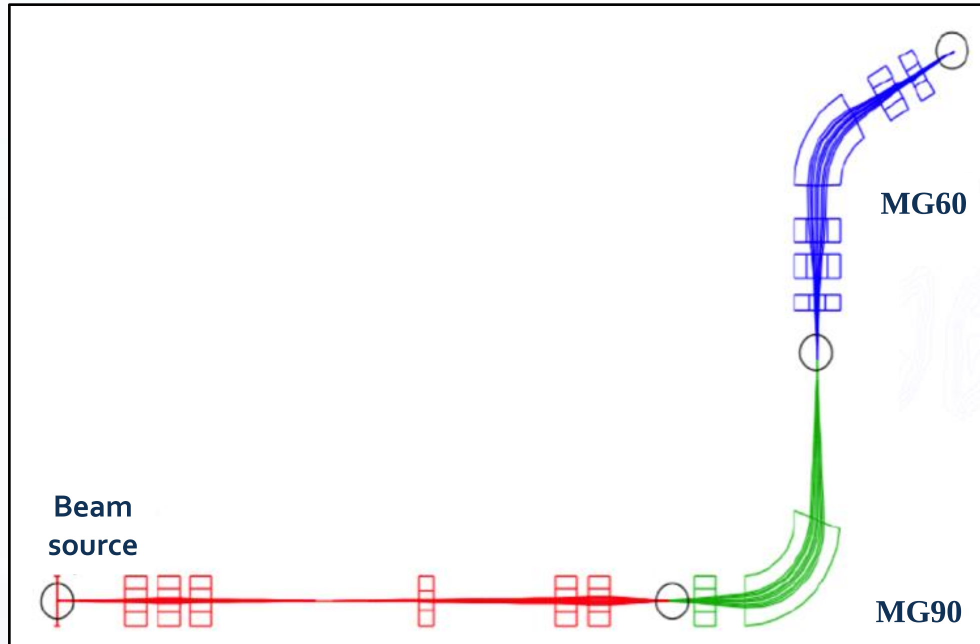
- ✓ The High Resolution Separator and its current situation
- ✓ The new constraints
- ✓ Design proposals
- ✓ Magnet features
- ✓ The technology: pole face winding coils
- ✓ The testbench

The High Resolution Separator

Current status



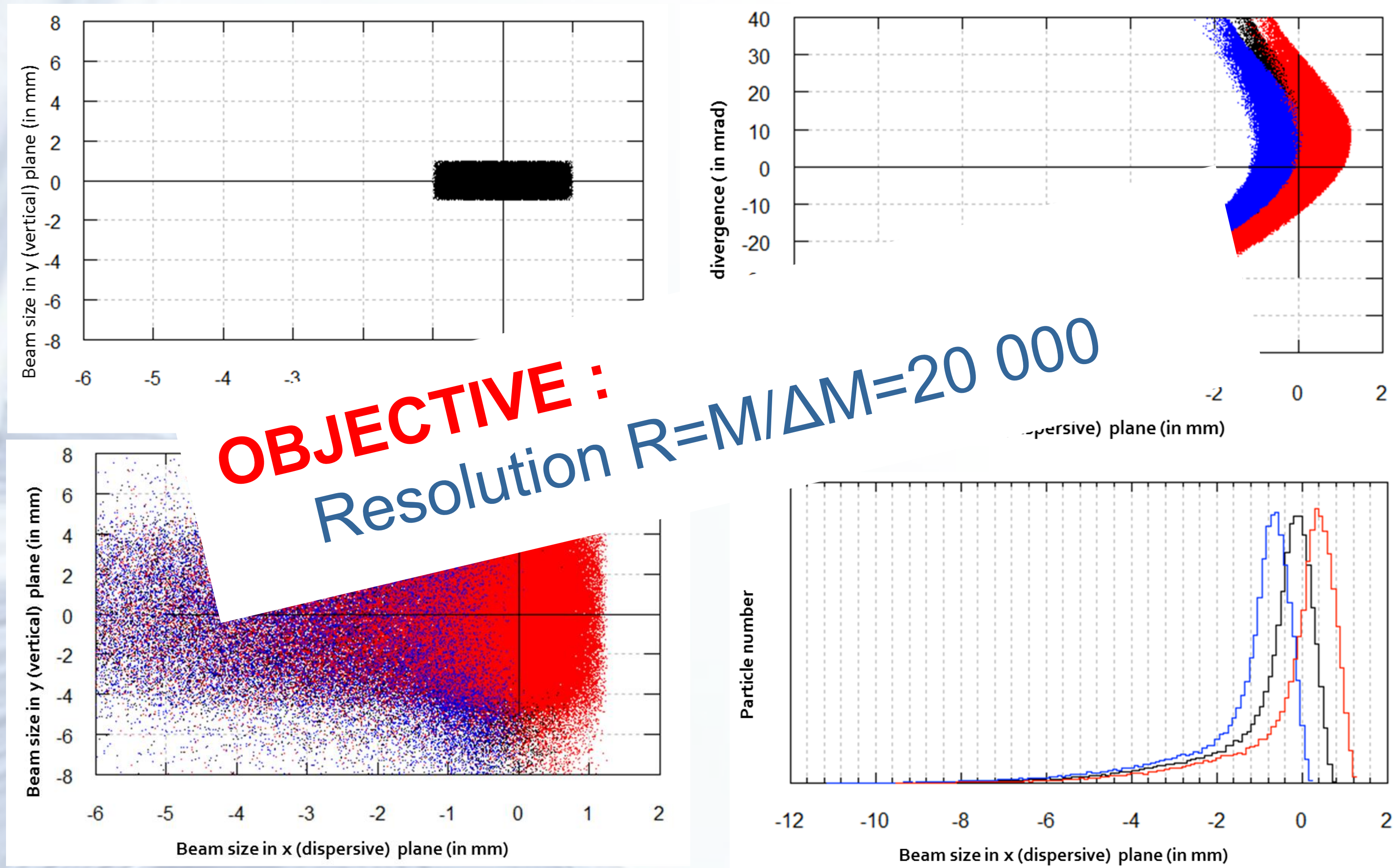
Layout view of the separator room



Optical layout of HRS (courtesy of T. Giles)

The High Resolution Separator

Current HRS optical performances



OBJECTIVE :

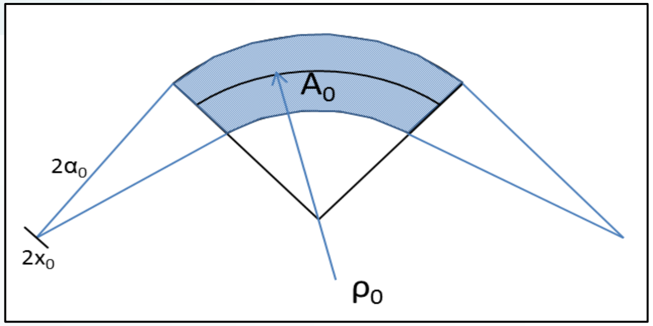
Resolution R=M/ΔM=20 000

Attainable mass resolution R=5000

for beam source of emittance ε=20π.mm.mrad

The High Resolution Separator

How to reach high resolution ?



Dispersion D

$$R = \frac{D}{2.x_0.M_x}$$

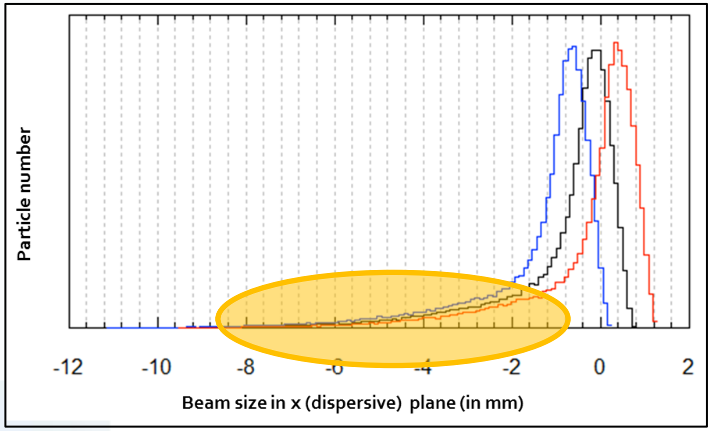
$$\varepsilon = \pi \cdot x_0 \cdot a_0$$

} Beam emittance

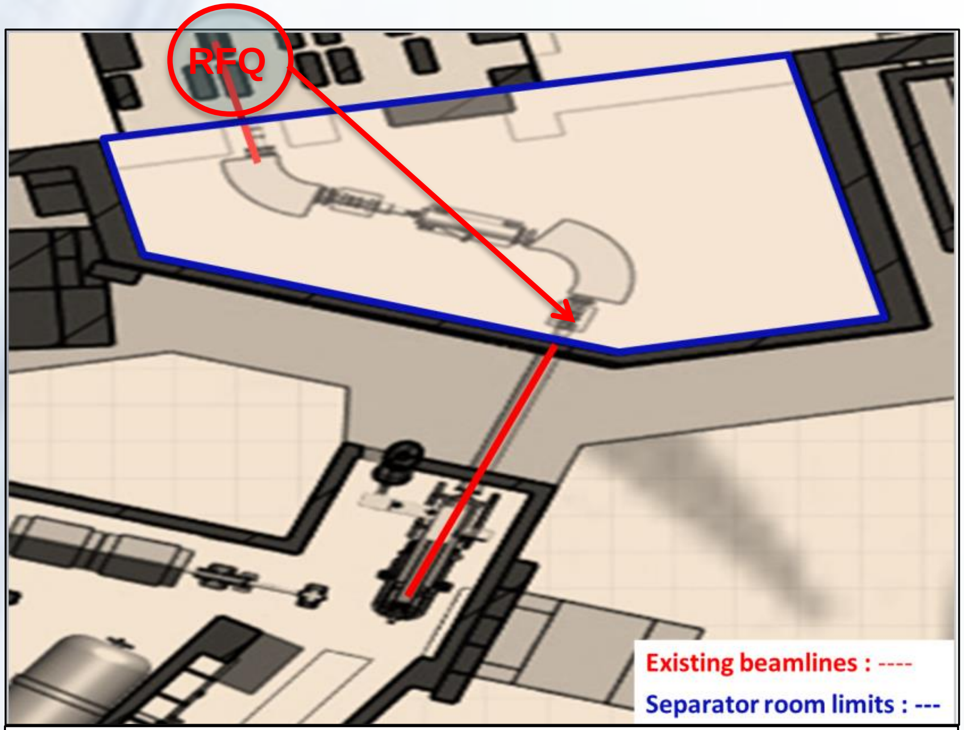
M_x magnif. Factor

x_0 beam size at source

Eliminate higher order terms (=aberrations)



The High Resolution Separator
RFQ-CB displacement



Layout view of the separator room

Moving of the RFQ-CB

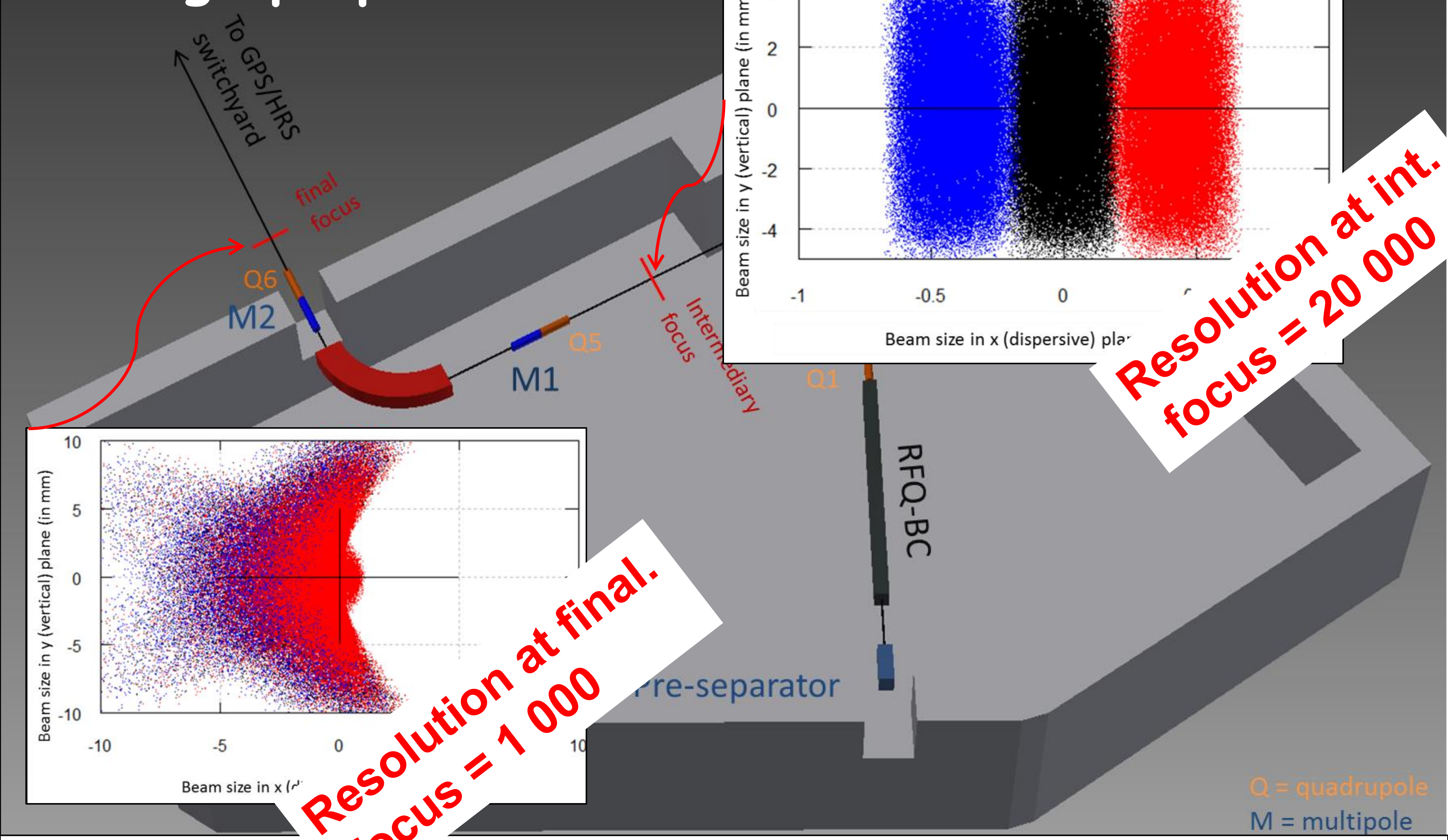
Ensuing constraints :

- Beamlines installations and positioning
- Separator room size

OBJECTIVE :

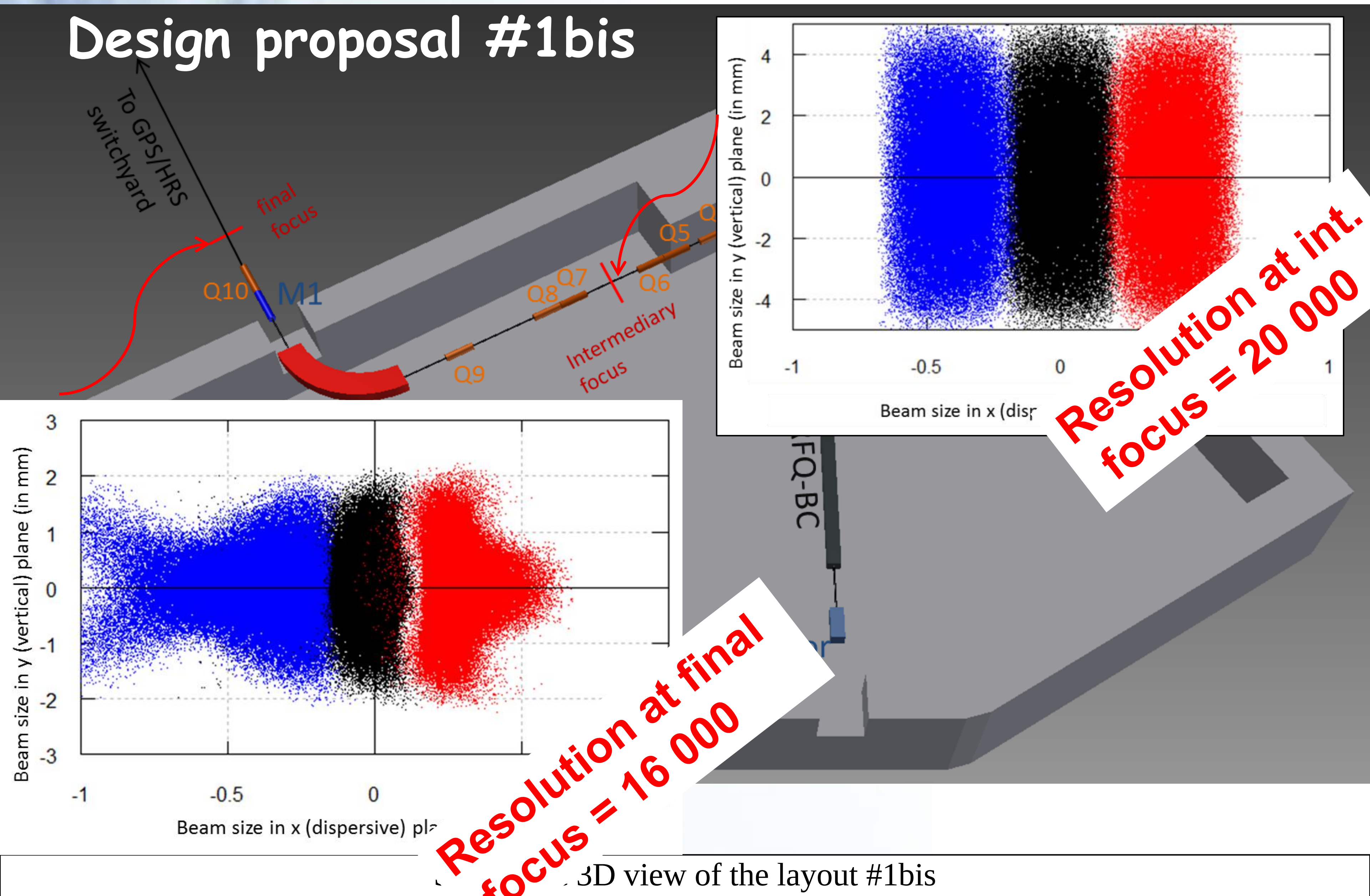
Resolution R=M/ΔM=20 000
for a beam source emittance ε=3π.mm.mrad

Design proposal #1



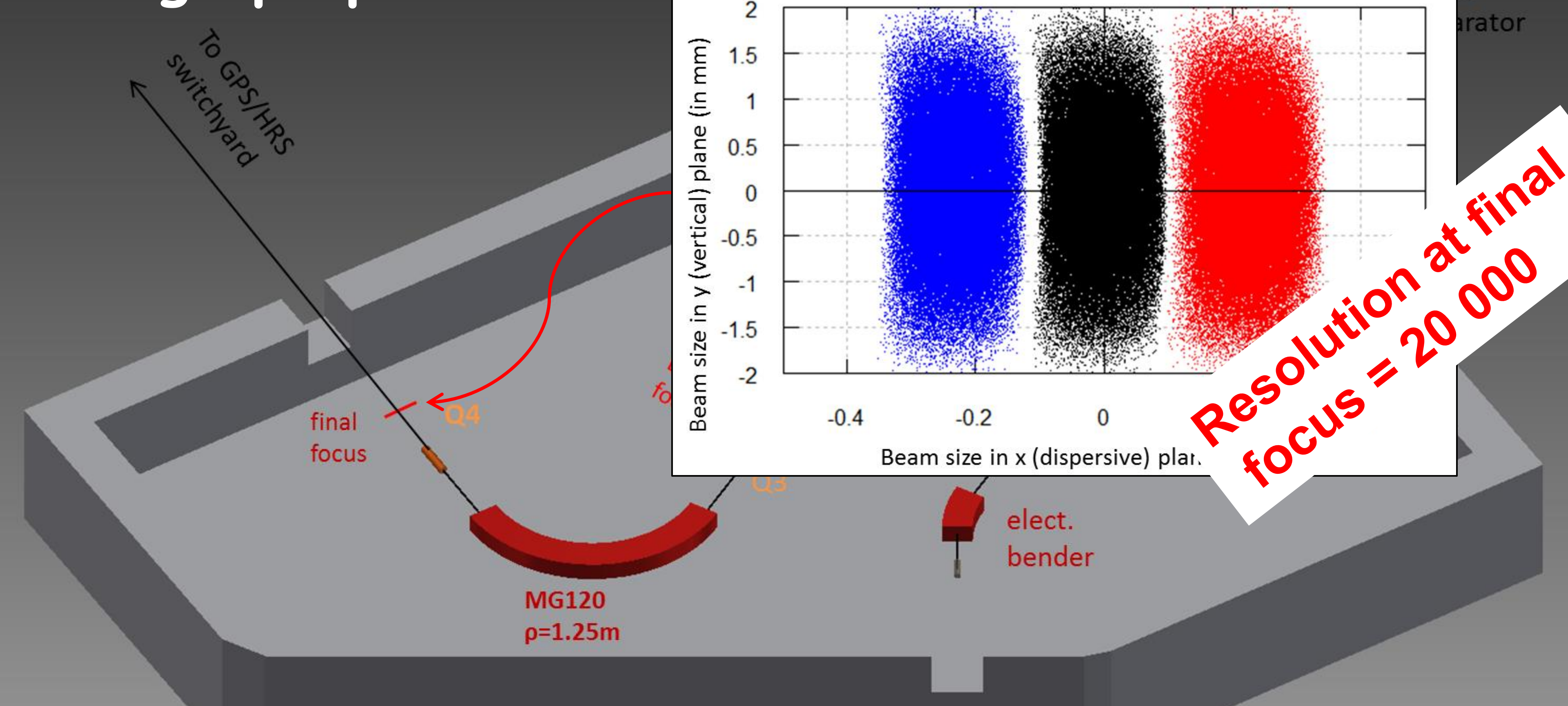
Schematic 3D view of the layout #1

Design proposal #1bis



3D view of the layout #1bis

Design proposal #2



Schematic 3D view of the layout #2

Beam emittance ε=3π.mm.mrad

R = 20 000 for more than 99% transmission of pure beam

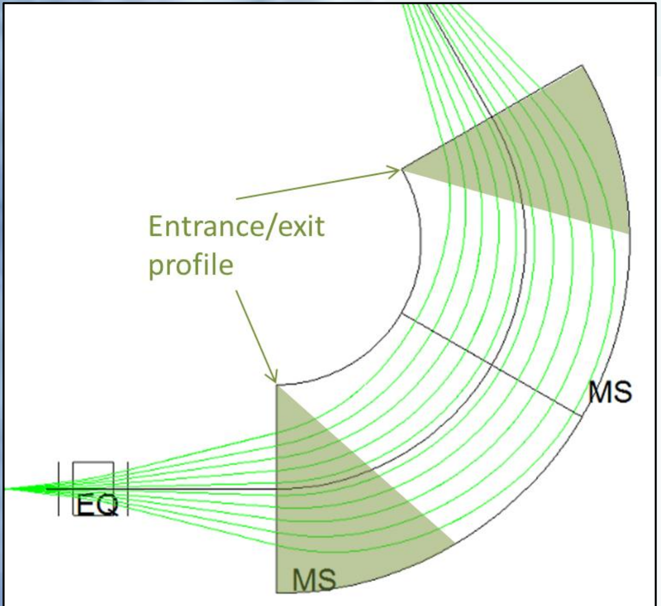
R ~ 23 000 for 90% transmission of pure beam

Magnet features
Optical parameters

Beam energy	60 keV
Maximum mass	300
Magnetic rigidity	0.6125
Bending radius	1.25 meter
Nominal magnetic field B	0.49
Bending angle	120 degrees
Vacuum chamber size on x-plane (dispersive)	350 mm
Vacuum chamber size on y-plane (vertical)	25 mm
Inhomogeneous field parameters	
α (quadrupole component)	0.25 (tolerable between 0.21 and 0.31)
β (hexapole component)	4.245e-2< 4.32E-2< 4.40E-2
Γ (octopole component	4.00E-3< 8.38E-3 < 1.30e-2

List of parameters for the mechanical design of the magnet

Magnet features : optical parameters

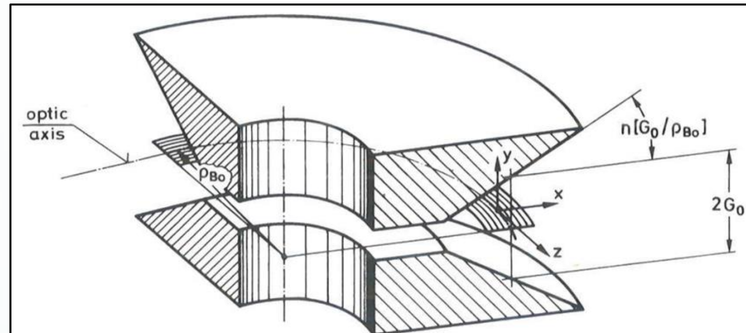


Beam enveloppe for design #2 in lab coordinates (x,z), featuring a magnet using entrance/exit profiles (producing a quadrupole component)

- No entrance/exit angular profile
- Radially Inhomogeneous Magnetic field :

$$B = B_0\left(1 - \alpha \cdot \frac{r - r_0}{r_0} + \beta \cdot \left(\frac{r - r_0}{r_0}\right)^2 - \gamma \cdot \left(\frac{r - r_0}{r_0}\right)^3\right)$$

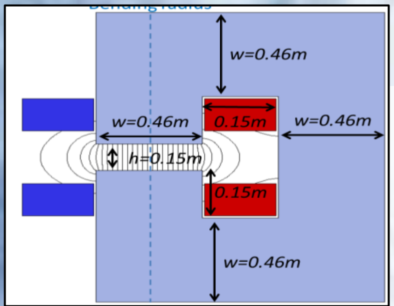
(with α, β and γ respectively being the quadrupole, sextupole and octopole components)



Example of magnet design, producing a radial inhomogeneous field, using inclined pole faces.

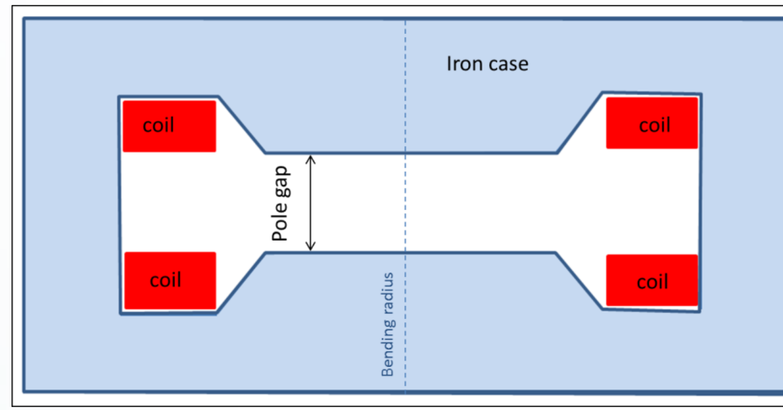
- Plane pole faces → easier to machine
- Inhomogeneous field produced with pole face windings

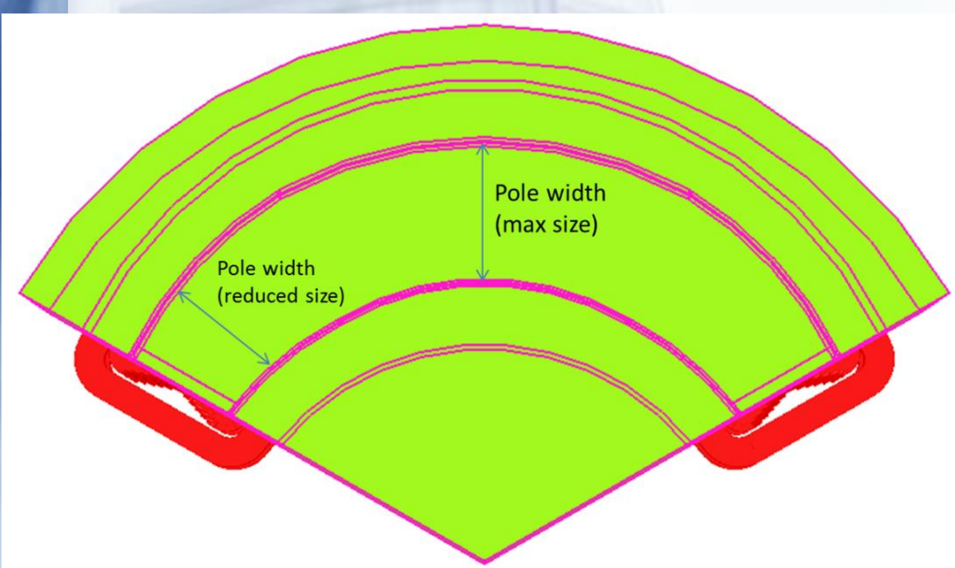
Magnet features



- H type magnet → mechanically more stable, possibility of better pole face machining

- Yoke made of laminated steel
  → reduction of eddy currents,
  allowing an increase in cycling speed
  (~1min VS 15min)

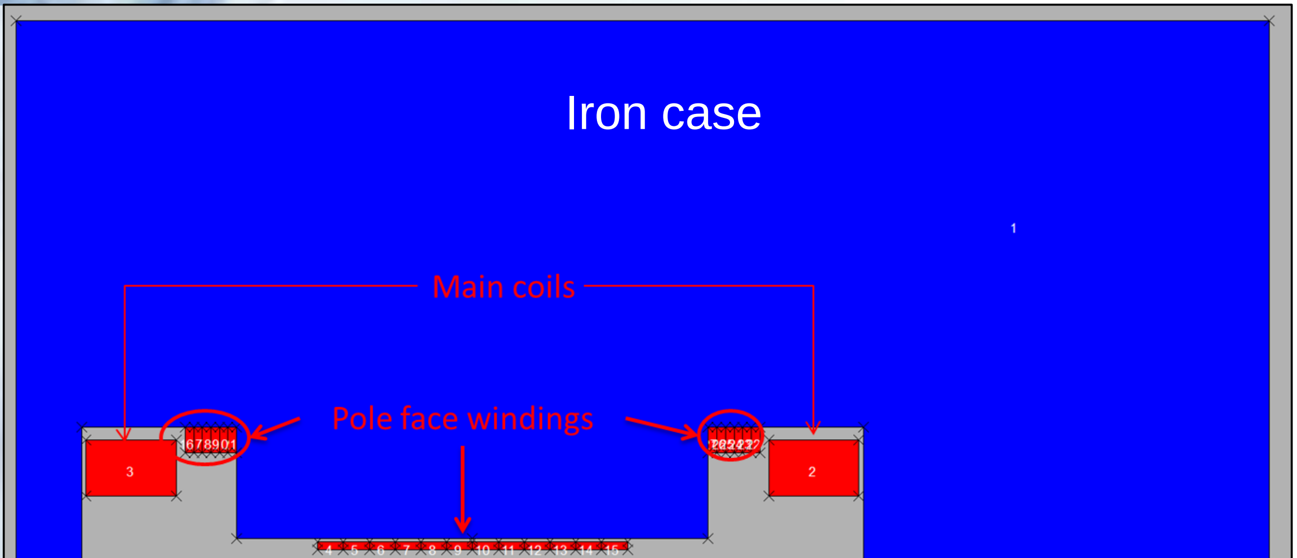




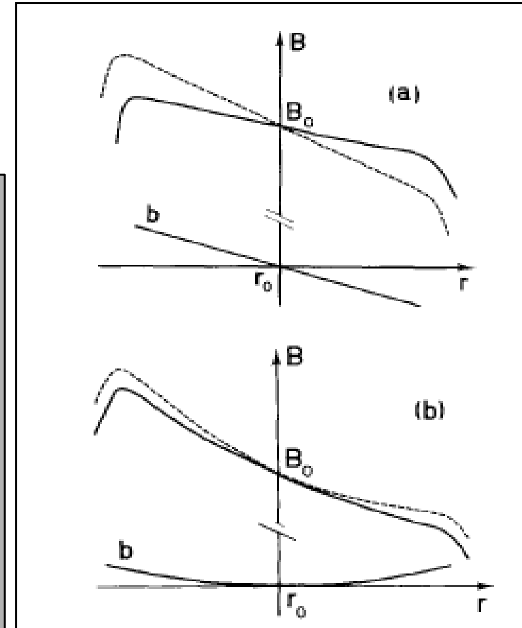
- Changing pole face width
  → saving of material (~8%)

The High Resolution Separator

Pole face windings



Schematid view in cross section of the new HRS magnet (H-type), featuring the pole face windings technology (picture credit to M. Breitenfeldt



Effect of pole face winding for α and β component in the main field distribution. Dashed curves represent the additional field necessary to modify α and β

- **Optimize currents in the conductors to match the field composition**

$$I = I_{quad} + I_{hex}\left(\frac{r-r_0}{r_0}\right)^2 + I_{octo}\left(\frac{r-r_0}{r_0}\right)^3 \rightarrow B = B_0\left(1 - \alpha\cdot\frac{r-r_0}{r_0} + \beta\cdot\left(\frac{r-r_0}{r_0}\right)^2 - \gamma\cdot\left(\frac{r-r_0}{r_0}\right)^3\right)$$

- **Current density in the conductor : up to 1A/mm2 (with air cooling)**

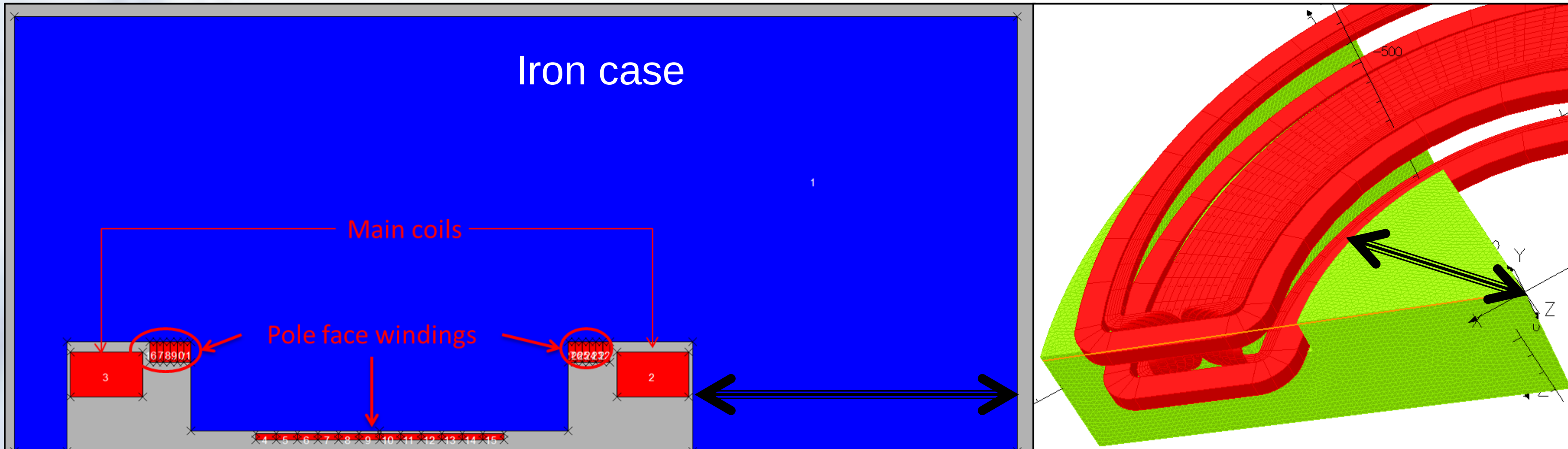
  ➔for the studied magnet : 0.2 A/mm2 were necessary

- **Higher order term coefficients are adjustable by changing current**

  ➔High degree of freedom

The High Resolution Separator

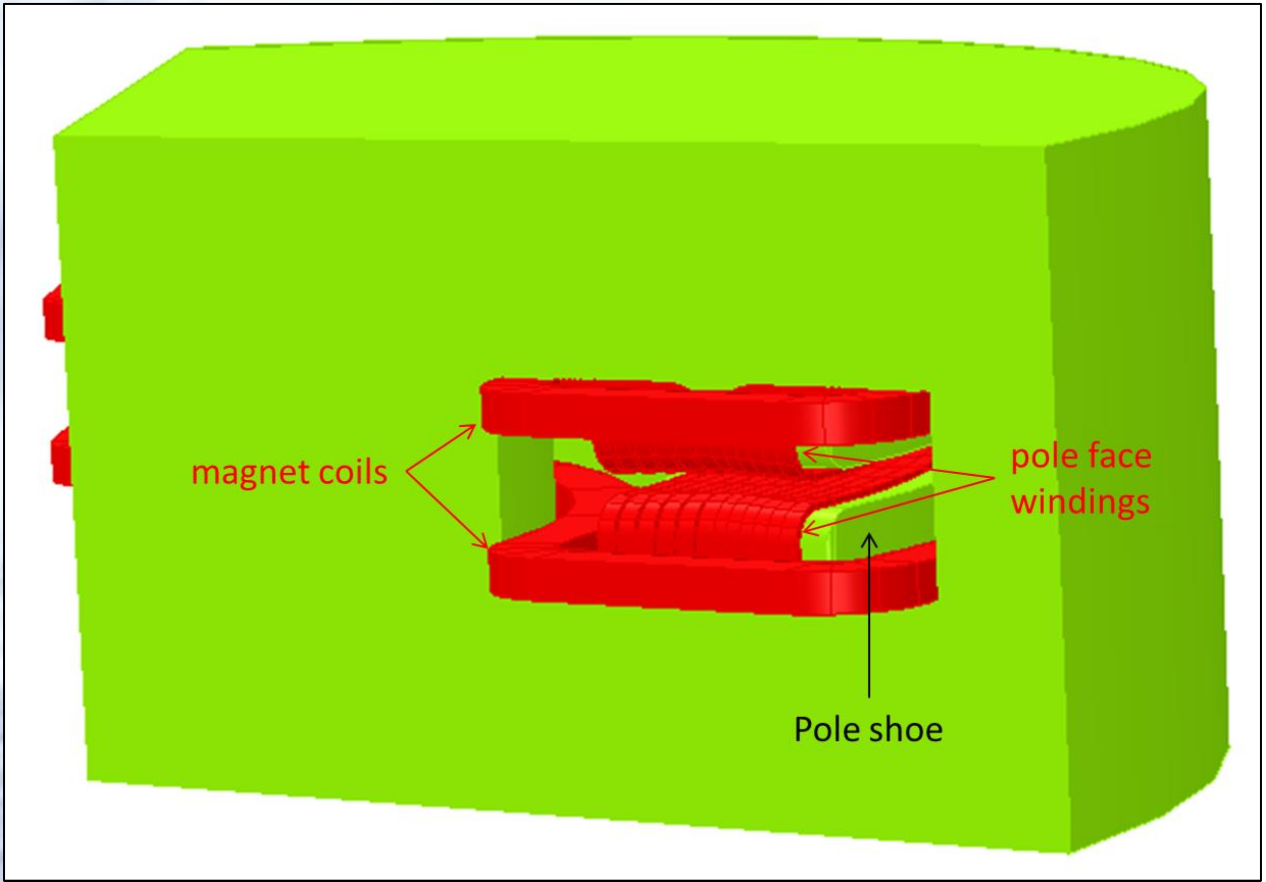
Pole face windings



Schematic view in cross section of the new HRS magnet (H-type), and partial view in 3D, featuring the pole face windings technology (picture credit to M. Breitenfeldt)

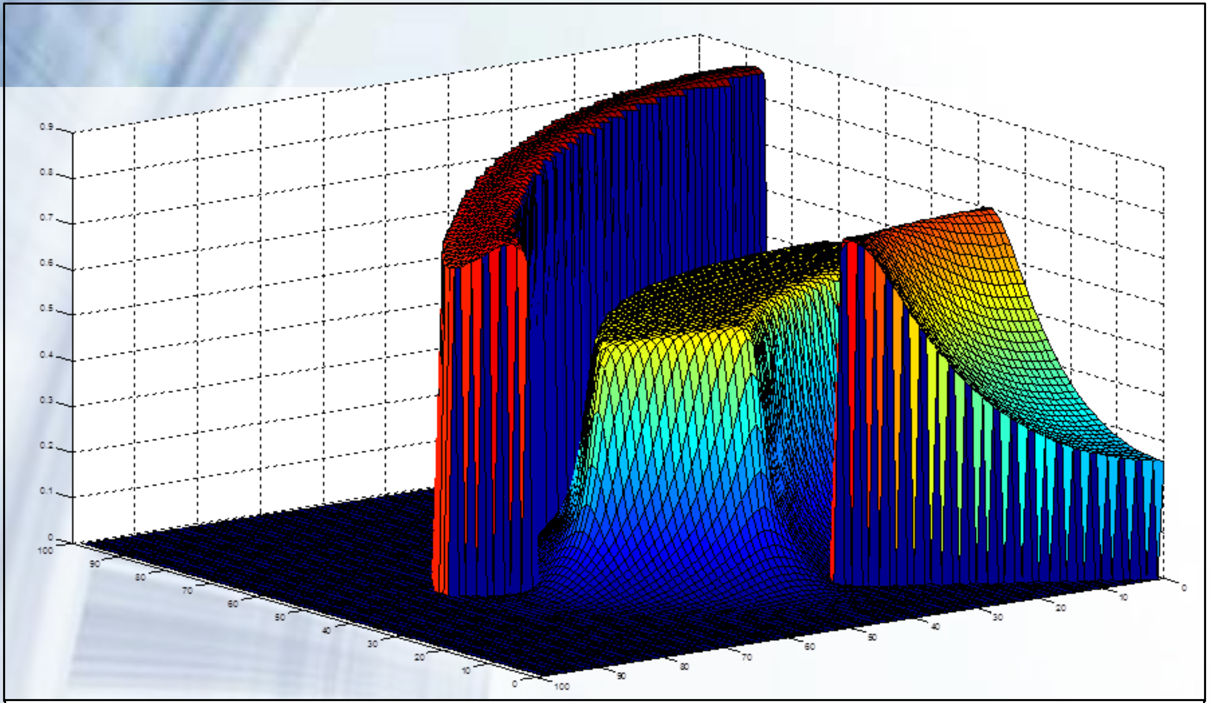
- **Avoid field lines saturation ➔ adapting the design**

The High Resolution Separator

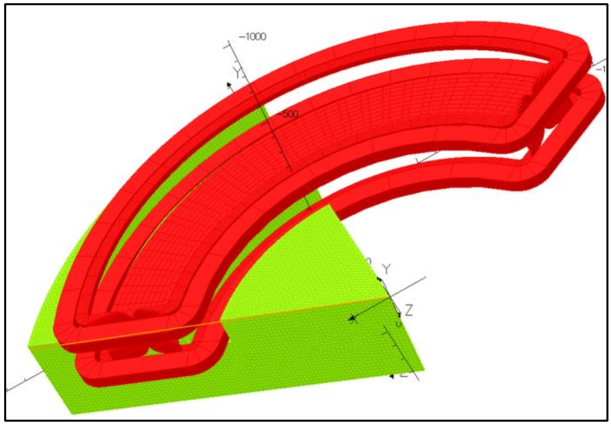


3D view of the new HRS magnet (H-type), featuring the pole face windings technology
(picture credit to M. Breitenfeldt)

The High Resolution Separator

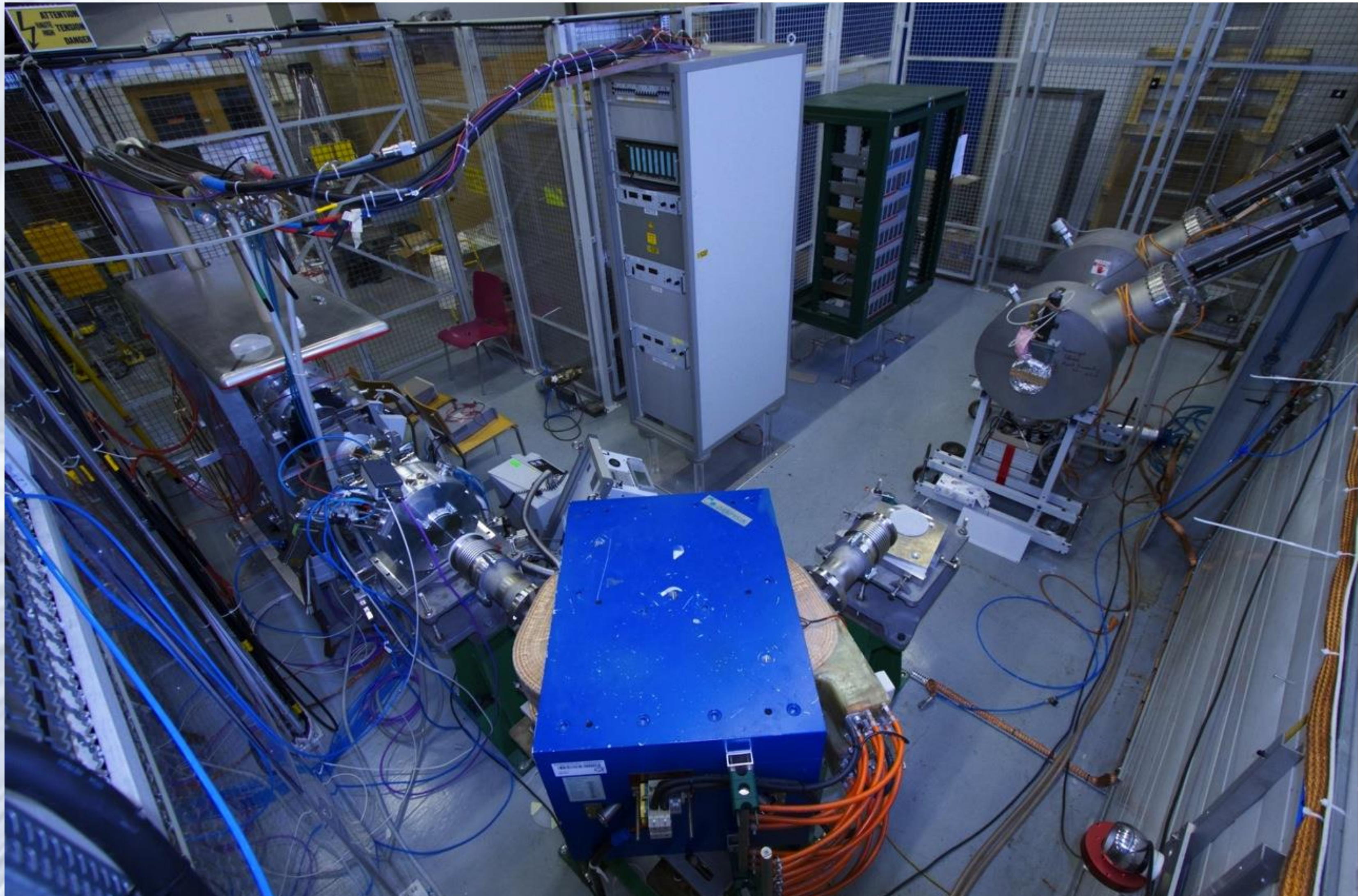


3D magnetic field map of the new HRS magnet for a section of a magnet, computed with Opera software (picture credit to M. Breitenfeldt)

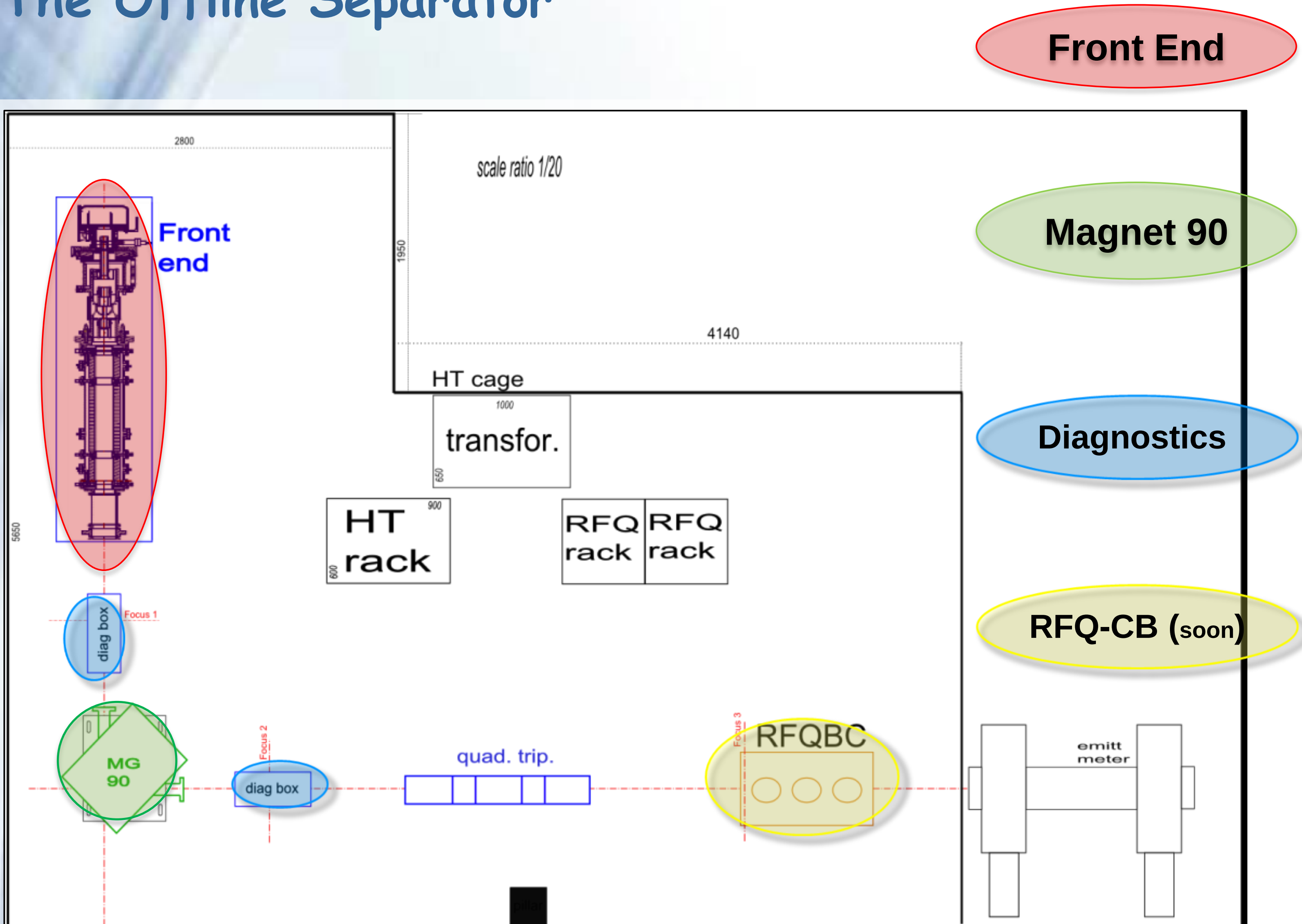


- Poleface windings allow the adjustment of the magnetic field along the beam axis.
- Rogovski profile at pole entrance and exit adjusts magnetic length.
- Excitation of return yoke is not exceeding 0.9T for max field at beam axis (0.5T)
  → the excitation is in the linear regime.

The Offline Separator

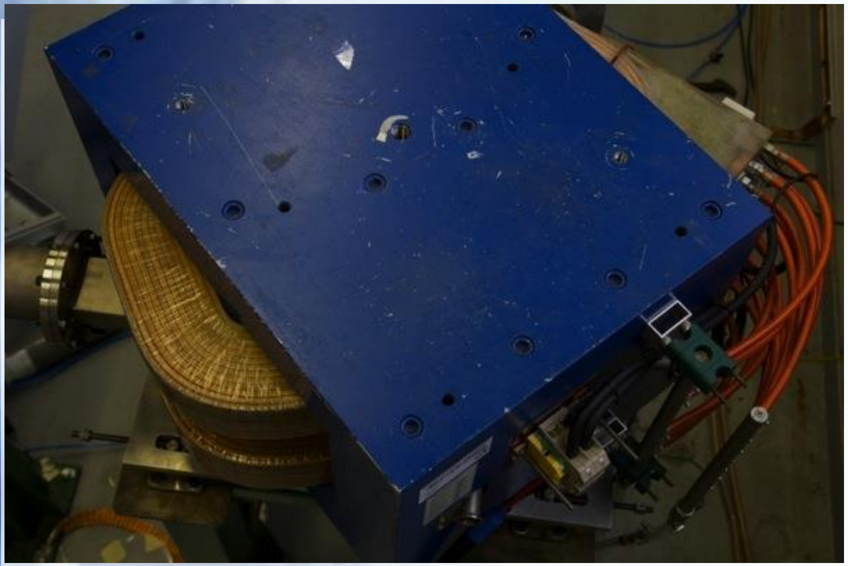


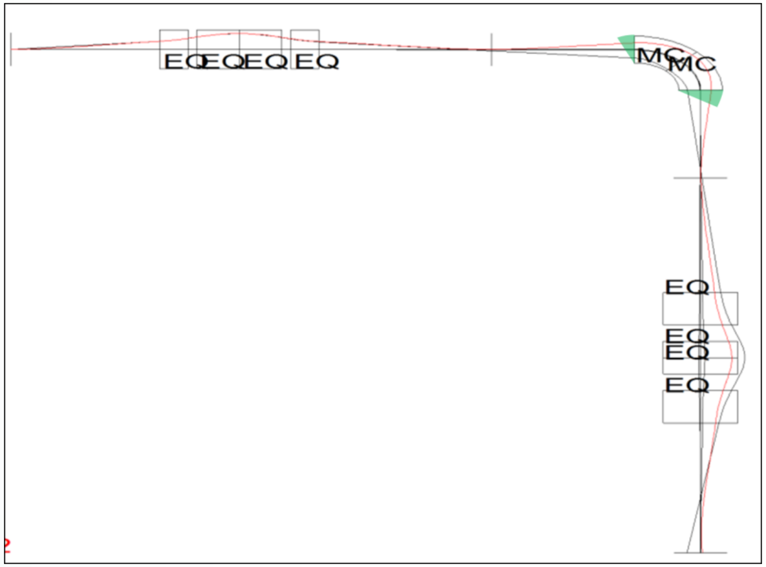
The Offline Separator



October 2013 : FE8 made its first beam : 30 nA at 40 kV with surface ion source !
March 2014 : First separation tests successful

The Offline Separator
Objectives





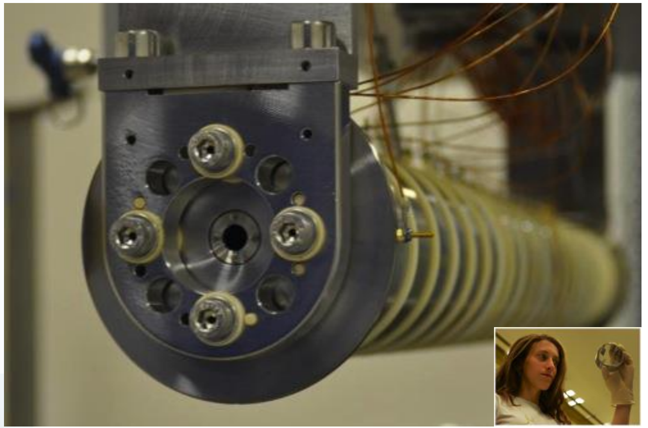
- Current magnet is of flat pole type, with entrance/exit profile (later used as pre-separator?)
- Design of a new offline magnet ongoing, featuring pole face windings

- **Objective : validate the technology**

The Offline Separator
Objectives

ISOLDE FRONT END 8
- Beam production
- Tests and characterization of different ion sources

THE RFQ-CB
- **Investigation of functional parameters :**
  - injection/extraction system efficiency
  - Emittance and beam parameters



Conclusion

ON THE ROAD TO A NEW HIGH RESOLUTION MAGNET…

- A workable layout, including all necessary items
- Design choice for the magnet features
- Functional test bench for validating the technology

  Pole face winding

  source parameters

Acknowledgements

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and CERN staff

The Marie Curie Actions

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Thank you for your attention