Intensity and beam quality upgrade

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Base line parameters

- Linac 4
  - Linac 4 will be able to provide 5 x 10^{13} ppp = 1.25 x 10^{13}/ring
    - Based on 40mA from the ion source
  - Could possibly go beyond this value with a combination of different options
    - Increase in source current output
    - An increase in pulse length
    - Chopping factor
  - All need to be in place for testing

- Booster RF upgrade
  - CO2/CO4 upgrade would limit protons to 1.4 x 10^{13}/ring
    - Could be increased with a power amplifier upgrade after LS2
  - Finemet upgrade (+MOSFET amplifiers) = 2.5x10^{13}/ring
  - Depends on the upgrade solution chosen

Protons/pulse	Intensity (µA)	Energy (GeV)	Cycle (s)	Power (kW)
3.3x10^{13}	2.2	1.4	1.2	3.1
5.0x10^{13}	3.3	1.4	1.2	4.7
5.6x10^{13}	3.7	1.4	1.2	5.2
1x10^{14}	6.7	1.4	1.2	9.3
1x10^{14}	6.7	2.0	1.2	13.3

Based on 50% of available protons for ISOLDE

Base line parameters

- Linac 4
  - Linac 4 will be able to provide 5 x 10^{13} ppp = 1.25 x 10^{13}/ring
    - Based on 40mA from the ion source
  - Could possibly go beyond this value with a combination of different options
    - Increase in source current output - and/or output current out of the RFQ working at it, mostly on reducing emittance
    - An increase in pulse length-tested at linac4 source, this is possible
    - Chopping factor – to be studied by PSB team
  - All need to be in place for testing

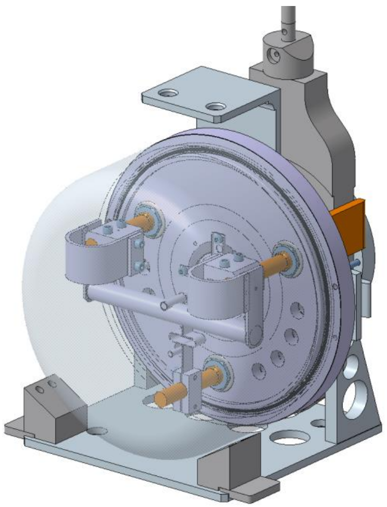
- Booster RF upgrade
  - CO2/CO4 upgrade would limit protons to 1.4 x 10^{13}/ring
    - Could be increased with a power amplifier upgrade after LS2
  - Finemet upgrade (+MOSFET amplifiers) = 1.6x10^{13}/ring
  - due to aperture restrictions in the PSB recombination/ejection lines

Protons/pulse	Intensity (μA)	Energy (GeV)	Cycle (s)	Power (kW)
3.3x10^{13}	2.2	1.4	1.2	3.1
5.0x10^{13}	3.3	1.4	1.2	4.7
6.4x10^{13}	4.3	1.4	1.2	6
6.4x10^{13}	4.3	2.0	1.2	8.6

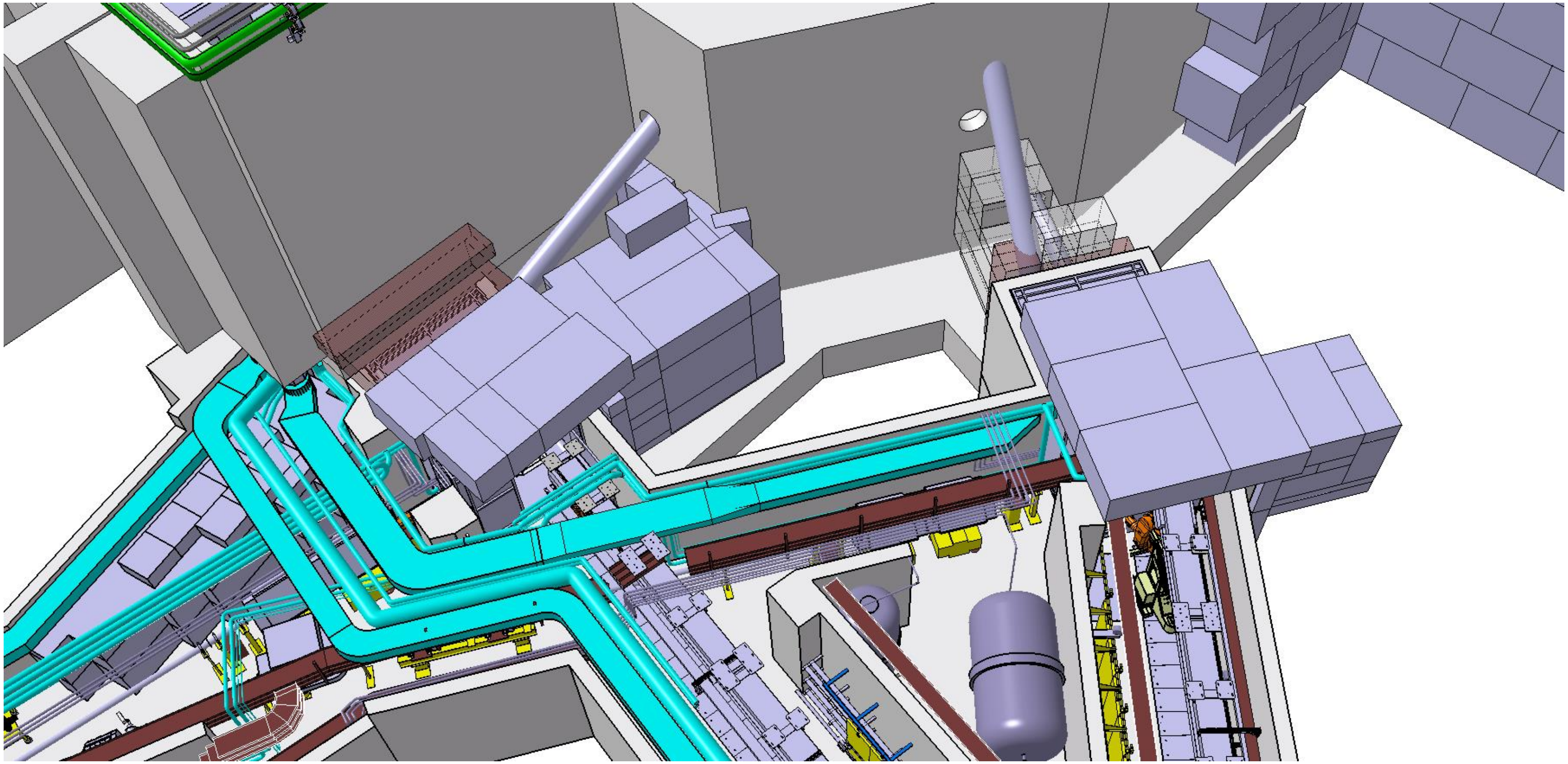
Based on 50% of available protons for ISOLDE

Consequences

- A factor of 2 increase in intensity can be absorbed by existing target units
  - Less dense (more porous) target materials
  - New design (without orings)
- Frontend design can be improved
  - Following a recent FE design review
    - Improve design for reliability.
- New HT modulator tests are very promising from an air ionisation aspect.



ISOLDE Beam Dumps



ISOLDE Beam dumps

- Beam dumps not according to drawings
  - GPS in 2 parts
  - Little cooling by convection
  - Clear signs of corrosion
  - Condensation problems

GPS beam dump

HRS beam dump

Photos taken at the end of LS1

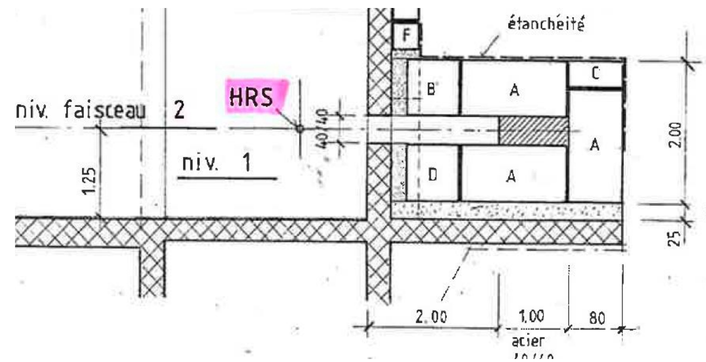
Beam Dump Characteristics

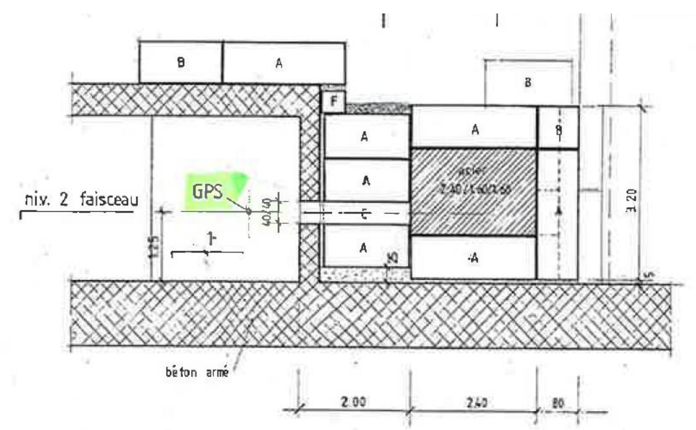
- Installed by the PS Division in 1991
- Dump material: not fully defined
  →carbon steel A36 (S275)

- Dimensions (WxHxL) [m]:
  -HRS: 0.4x0.4x1
  -GPS: 1.6x1.6x2.4

- Shielding: concrete blocks

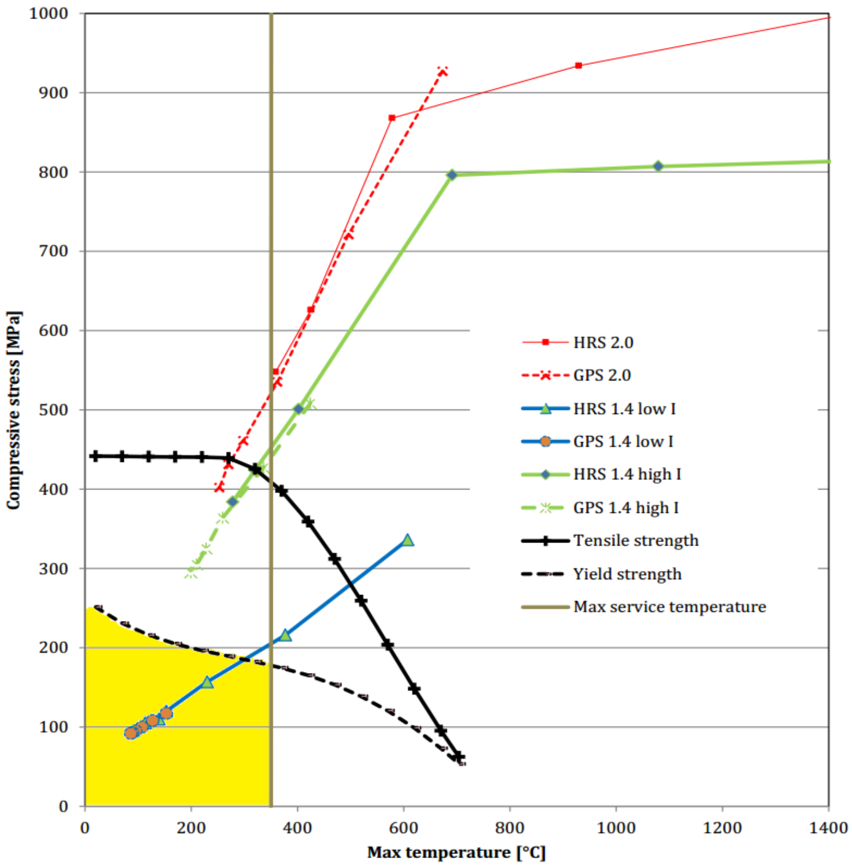
- State of contact shielding/dump: unknown heat transfer coefficient

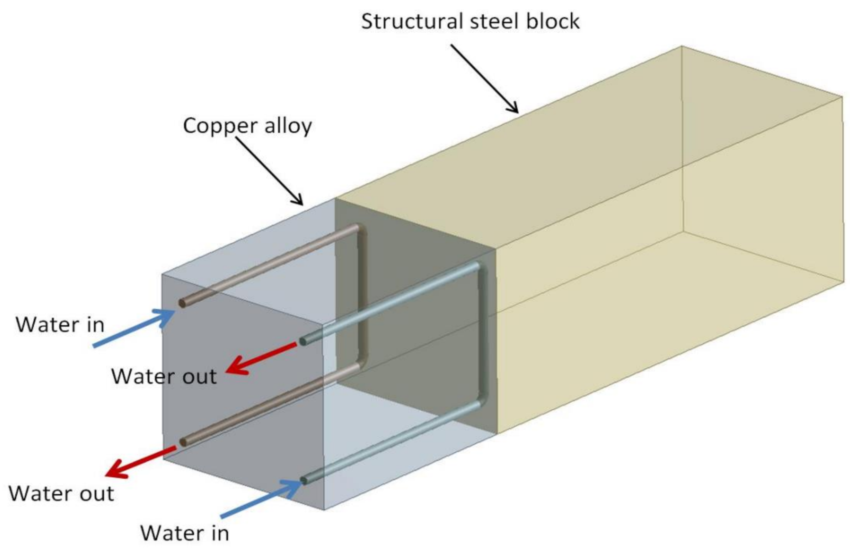




ISOLDE Beam Dumps

- Estimations made for different heat transfer coefficients
- New design based on PSB design





Valentina Venturi

ISOLDE Beam Dumps

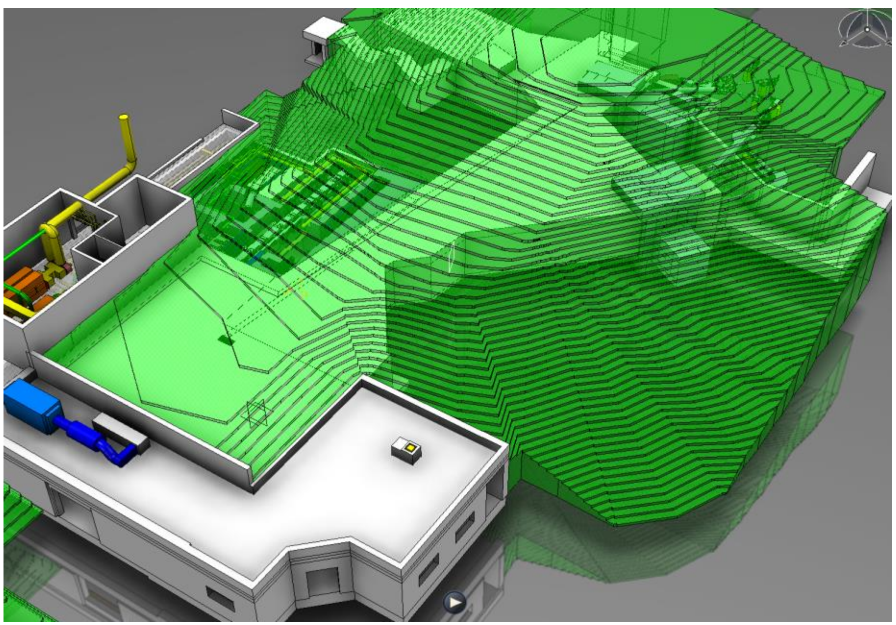
- Replace existing beam dumps
- Advantages
  - Lower dose rate for installation
  - Take advantage to improve shielding (see next slides)
  - Reduction in air activation through new design
- Disadvantages
  - Removal, storage and replacement of ~3500m^3 of earth, about half of which is activated.
    - *But this can be minimised*
  - Handling and storage of radioactive beam dump
  - Requires cooling and its associated disadvantages

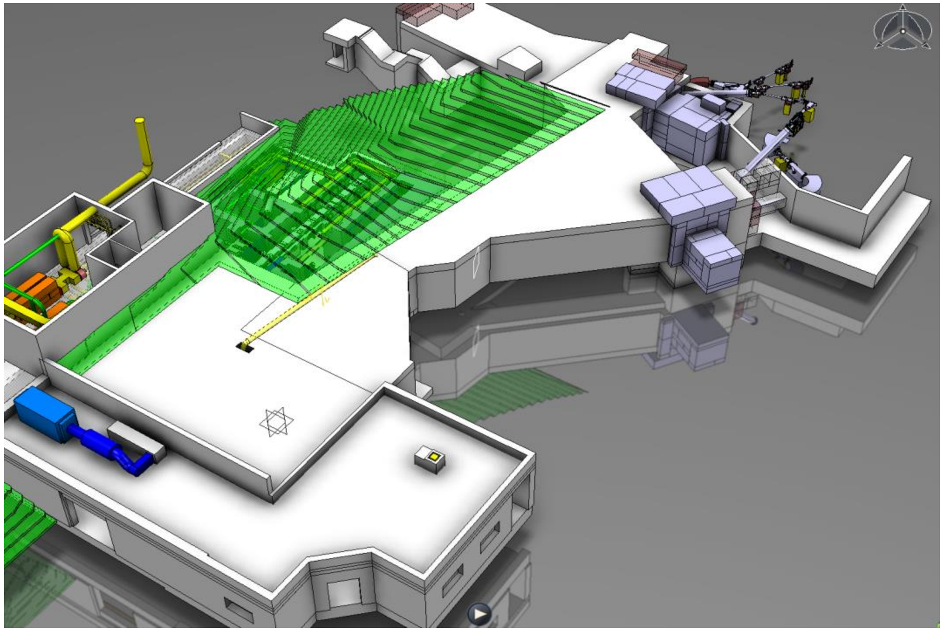
Shielding

- Further shielding required to attenuate dose rates observed during operation and under certain conditions:
  - 2uA of p-beam on thick ISOLDE targets (>50gcm-2)
- Identified by RP in https://edms.cern.ch/document/1142606/1 **CERN-DGS-2010-006-RP-SN**
  - Impact of p-beam intensity and energy increase on radiation dose rates outside the CERN perimeter to be assessed
- Can be combined with an upgrade of the ISOLDE beam dumps

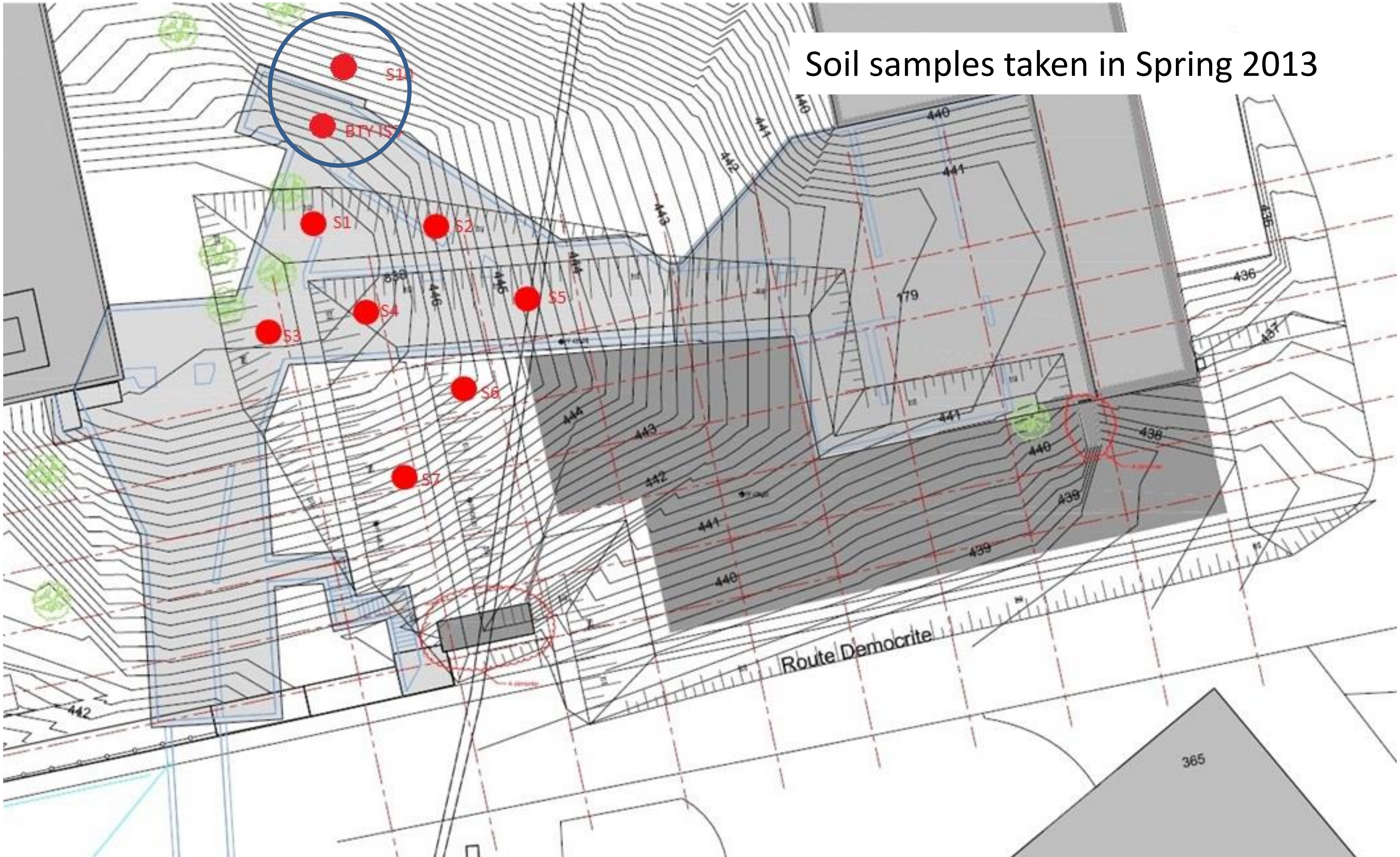
Shielding

- ~18μSvh^{-1} measured on top of ISOLDE hill above HRS dump
- ~100μSvh^{-1} (from neutrons) measured in experiment hall above the GPS separator shielding
- ~500kBqh^{-1} from released activated air during operation
  - To be confirmed following ventilation modifications done this year.





Activated Earth



Courtesy J. Vollaire

Soil Sampling Results

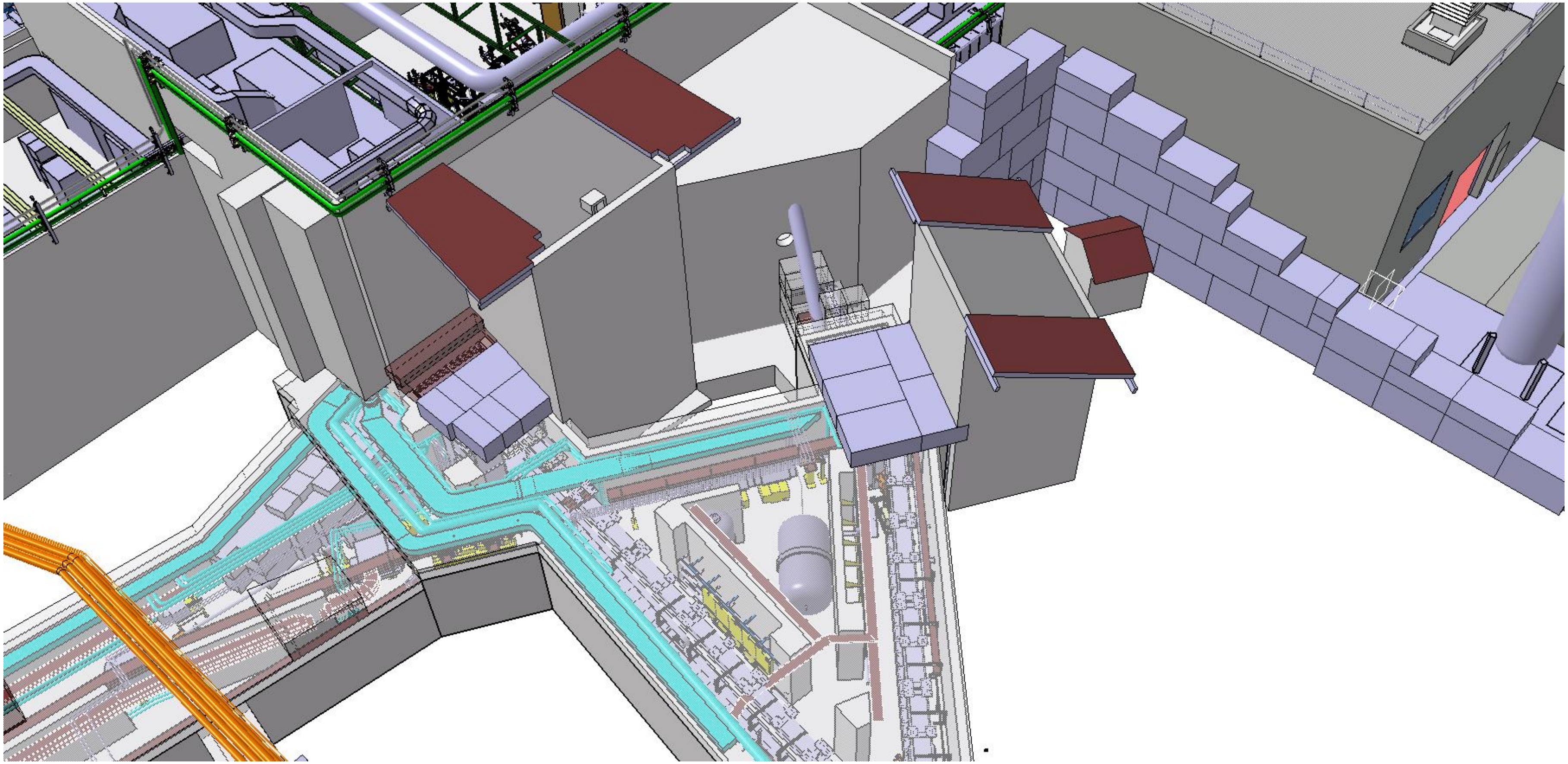
Echantillon	Nuclide	A Total (Bq/g)	A Total (Bq/kg)	LE (Bq/kg)	Multiple LE
S10 Profondeur carotte 4.55 - 4.70 m Masse échantillon 1.31 kg	Be-7	2.36E-01	2.36E+02	4.00E+05	5.90E-04
	Na-22	6.81E-01	6.81E+02	3.00E+03	2.27E-01
	Sc-46	4.27E-02	4.27E+01	7.00E+03	6.10E-03
	Mn-54	2.90E-01	2.90E+02	1.00E+04	2.90E-02
	Co-60	4.25E-02	4.25E+01	1.00E+03	4.25E-02
	Y-88	1.75E-03	1.75E+00	8.00E+03	2.19E-04
	Cs-134	9.79E-03	9.79E+00	5.00E+02	1.96E-02
	Eu-152	4.50E-02	4.50E+01	7.00E+03	6.43E-03
				Somme	3.31E-01

BTY IS3 Profondeur carotte 4.95 - 5.10 m Masse échantillon 1.535 kg	Be-7	1.95E-01	1.95E+02	4.00E+05	4.88E-04
	Na-22	5.78E-01	5.78E+02	3.00E+03	1.93E-01
	Sc-46	3.47E-02	3.47E+01	7.00E+03	4.96E-03
	Mn-54	2.74E-01	2.74E+02	1.00E+04	2.74E-02
	Co-57	3.81E-03	3.81E+00	5.00E+04	7.62E-05
	Co-60	3.94E-02	3.94E+01	1.00E+03	3.94E-02
	Y-88	1.61E-03	1.61E+00	8.00E+03	2.01E-04
	Cs-134	8.68E-03	8.68E+00	5.00E+02	1.74E-02
	Eu-152	3.88E-02	3.88E+01	7.00E+03	5.54E-03
				Somme	2.88E-01

Courtesy J. Vollaire

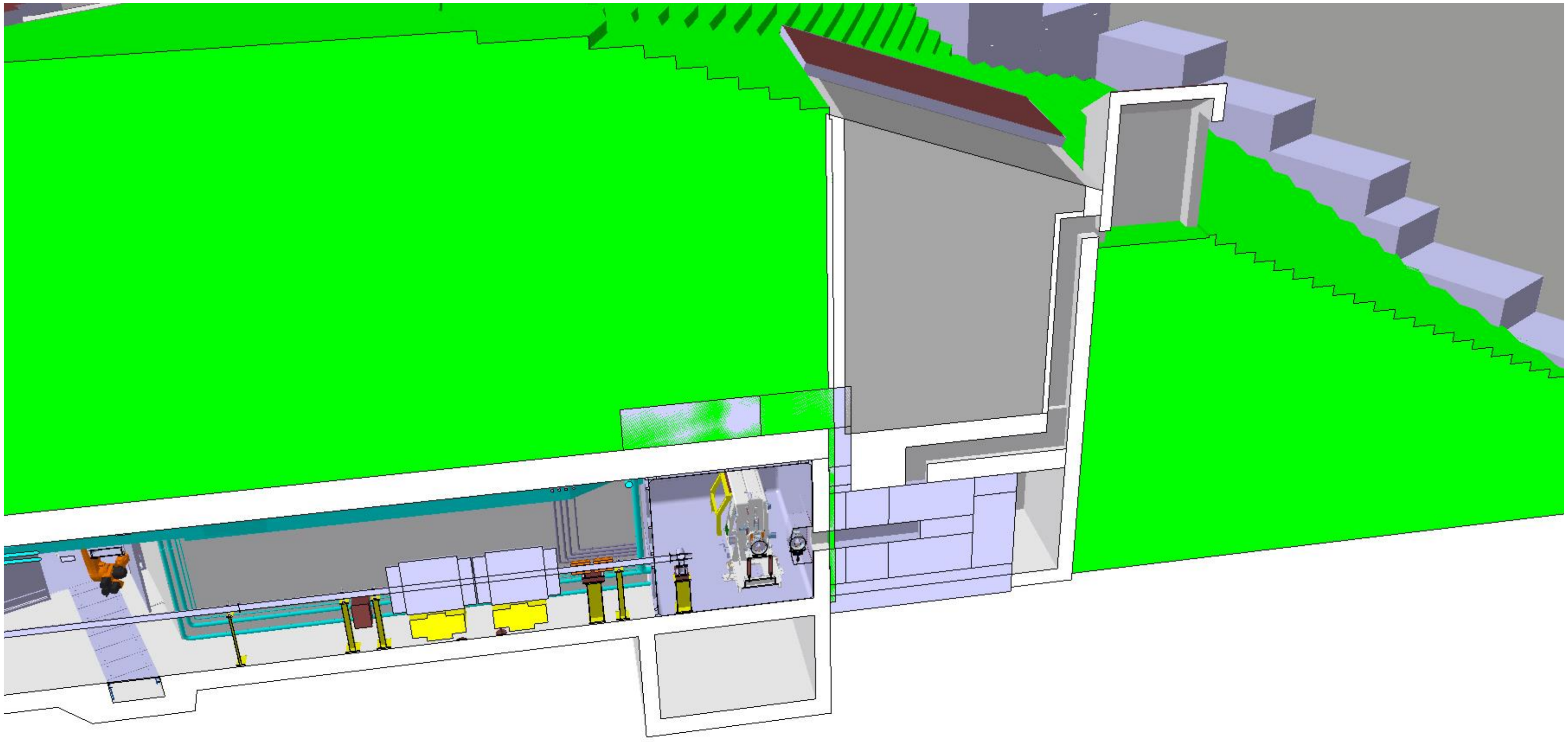
Bored Pile Shafts

- A possible solution to minimize the amount of earth to be removed
  - $300m^3$ instead of $3500m^3$



Bored Pile Shafts

- Chicane for the passage of cooling tubes and other services.
- Optimize collimation in front of beam dump
- Improved access for eventual long term disposal



V. Barozier

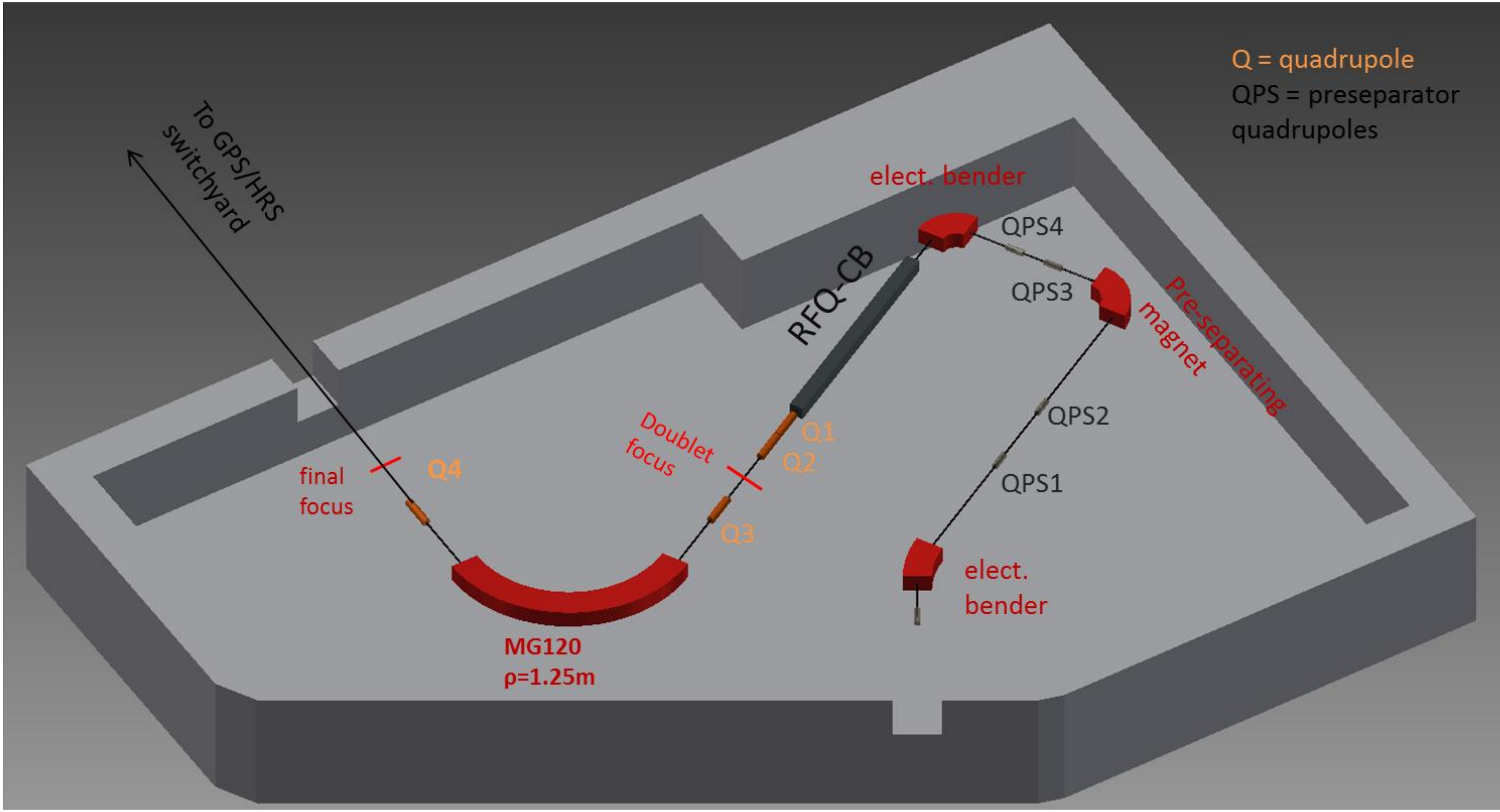
HIE Status

- An upgrade of the beam dumps and BTY line to accommodate 2GeV would cost in the order of 10MCHF
- For financial reasons, an eventual upgrade has been postponed until LS3 (2024?)
  - The work has to be done during a long shutdown period.

Beam Purification

- RFQ Cooler upgrade
- Now that funding has been secured through the consolidation project, work will continue on the Off-Line Separator 2
  - Removes bottleneck for target testing and R&D
  - Allows for testing and improvements of RFQ Cooler

HRS upgrade: Schematic layout

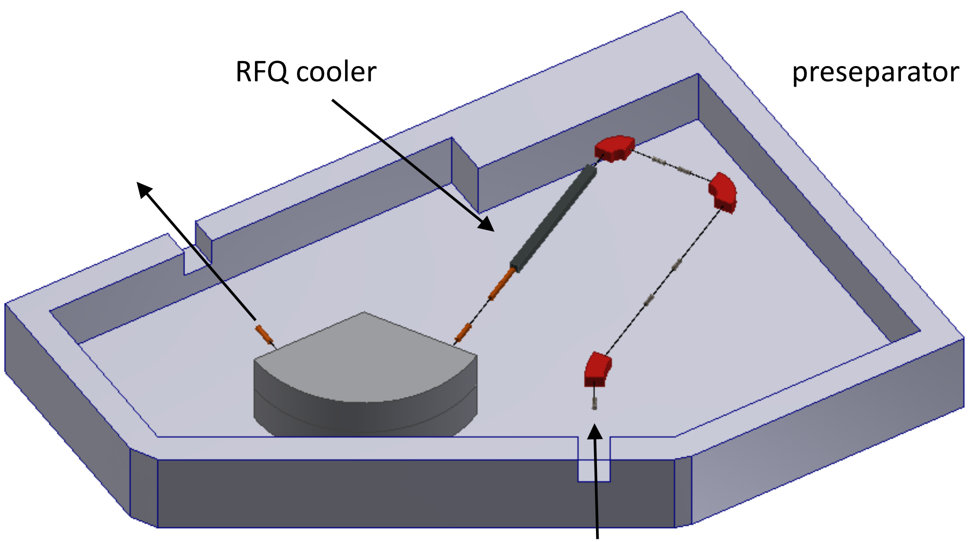


T. Giles & M. Breitenfeld

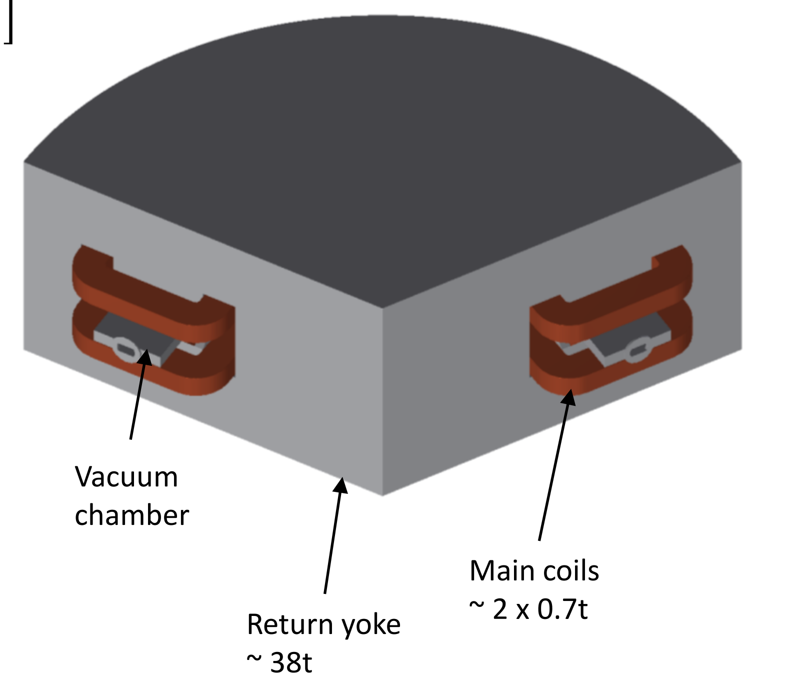
HRS upgrade

- Replace 2 magnets with a pre-separator, a RFQ cooler and a single magnet.
- Careful COSY infinity studies for misalignments and electrostatic imperfections (M. Augustin and G.M. Tveten)
- Single magnet requires wide beam in the centre
  → aberration correction by higher order
  (α–γ from COSY, δ for compensation of finite pole width)

$$B = B_0\left[1 - \alpha\left(\frac{\rho-\rho_0}{\rho_0}\right) + \beta\left(\frac{\rho-\rho_0}{\rho_0}\right)^2 - \gamma\left(\frac{\rho-\rho_0}{\rho_0}\right)^3 + \delta\left(\frac{\rho-\rho_0}{\rho_0}\right)^4\right]$$



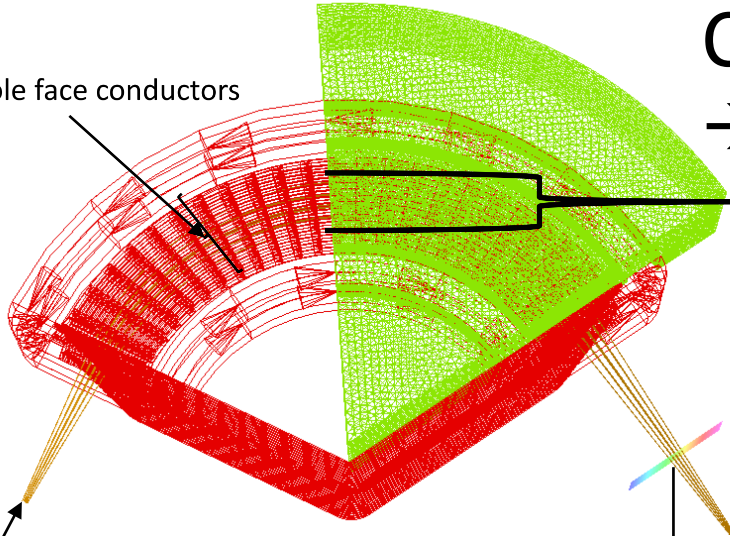
Room of the HRS



M. Breitenfeld, T. Giles, G.M. Tveten

Conceptual magnet design

→ Pole face conductors



Pole face conductors

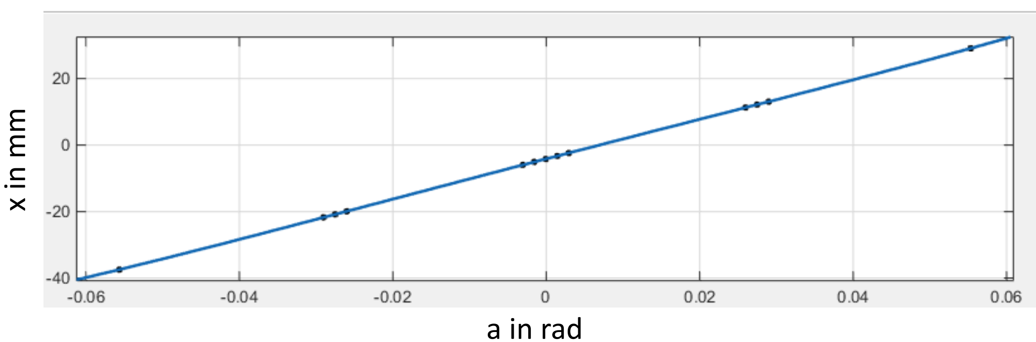
Beam width in the centre 220mm

Radial emittance 2π mm mrad

Read out coordinates

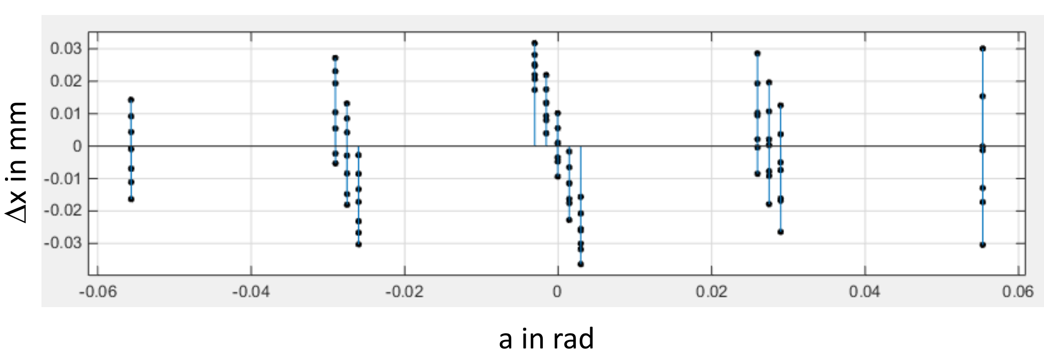
$$\begin{pmatrix} I_0 \\ I_q \\ I_h \\ I_o \\ I_d \end{pmatrix} \begin{pmatrix} a_{00} & a_{0q} & a_{0h} & a_{0o} & a_{0d} \\ a_{q0} & a_{qq} & a_{qh} & a_{qo} & a_{qd} \\ a_{h0} & a_{hq} & a_{hh} & a_{ho} & a_{hd} \\ a_{o0} & a_{oq} & a_{oh} & a_{oo} & a_{od} \\ a_{d0} & a_{dq} & a_{dh} & a_{do} & a_{dd} \end{pmatrix} = \begin{pmatrix} dip_{fit} \\ quad_{fit} \\ hex_{fit} \\ oct_{fit} \\ dec_{fit} \end{pmatrix}$$

None-diagonal elements are present as each type of correction current is influencing the others due to finite size of the magnet



Fit of 4th order residuals
→ Width in the focal point

Max. width in focal point for mass separation of Δm/m = 20000 is Δx = 0.1mm



Calculation shown for mass ~ 200u
Behaves the same in mass range 20u

Still to be done: Produce a calculation with focussed beam without requiring the fit (hex_{fit}, oct_{fit} and dec_{fit} are 0!).

First discussion of the magnet
M. Breitenfeldt et al. NIMB 376 (2016) 116-119

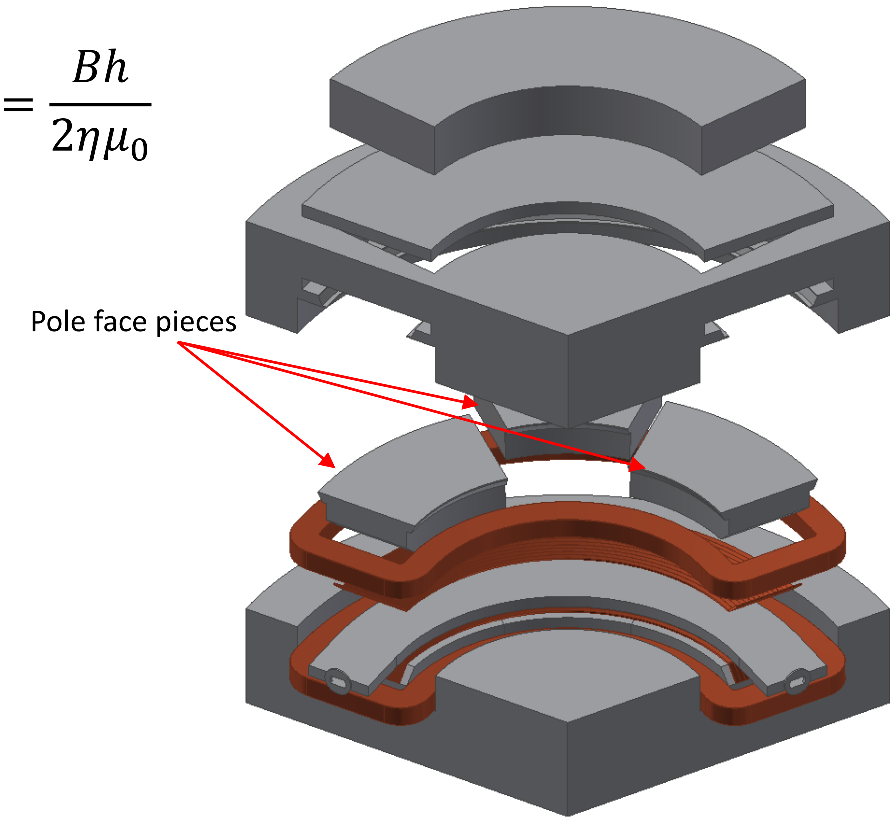
Mechanical design

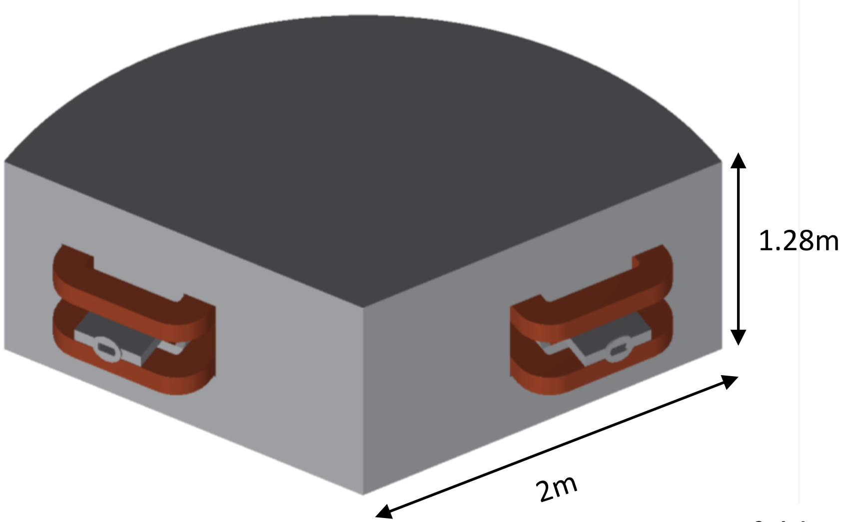
→alignment and pole face machining

Pole faces to be machined with a precision of better than 6μm to allow for R = 20000 (gap height 12cm) to avoid “heating effect” on the spread-out beam

- → Pole faces have to be divided into pieces of max 1mx1.1mx0.7m as the best machines on the market have these acceptance
- → Pole face pieces are aligned by machined gradients and gravity

$$NI = \frac{Bh}{2\eta\mu_0}$$





Huge part of the yoke will be laminated, to increase cycling speed
Different BH curves for the lamination material (ARMCO pure iron) have been checked

M. Breitenfeld, T. Giles, G.M. Tveten