MAX IV magnet design

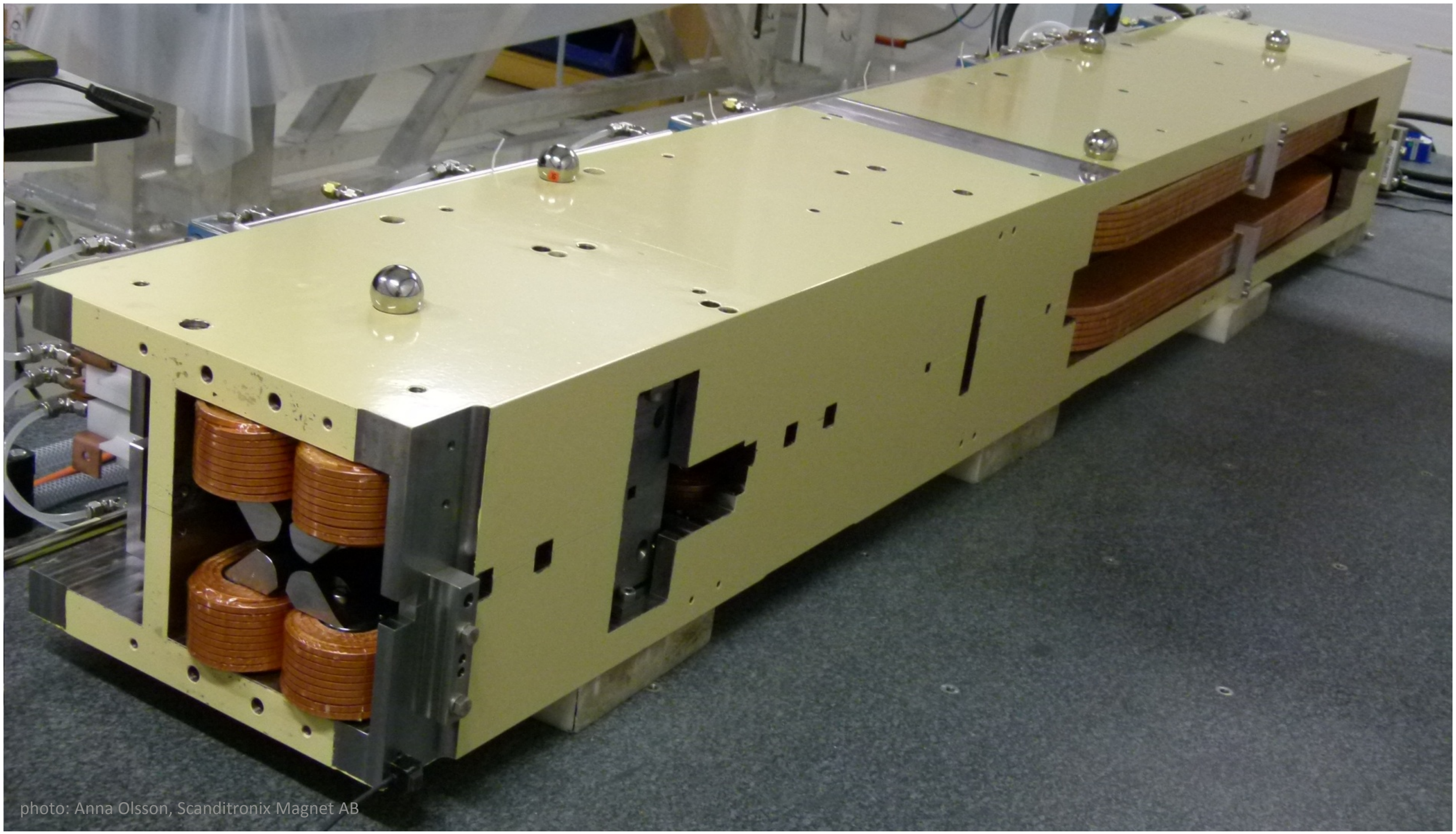
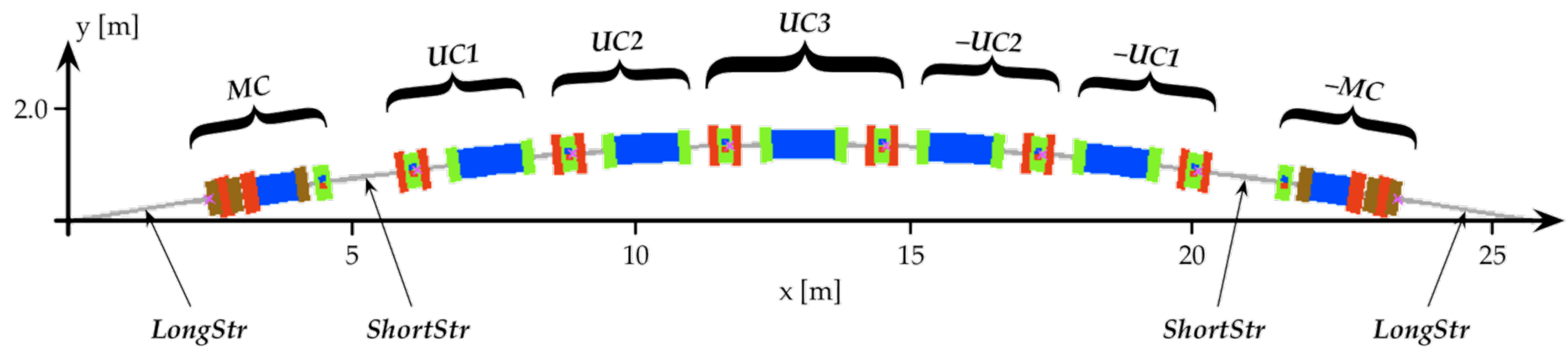


photo: Anna Olsson, Scanditronix Magnet AB

MAX IV magnet design

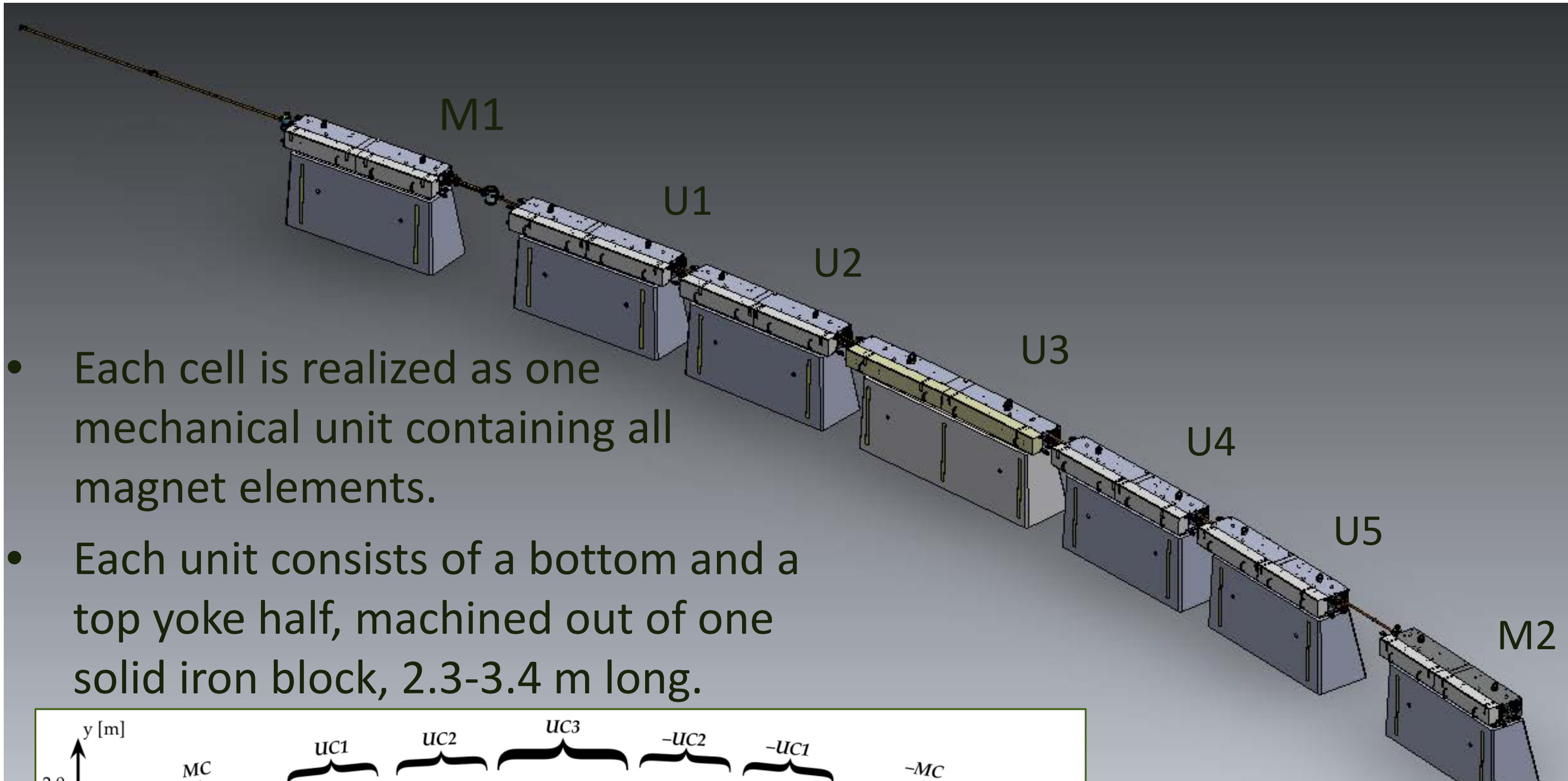
1) Presentation of the design concept.
2) Why have we done it like this?

MAX IV 3 GeV ring lattice:

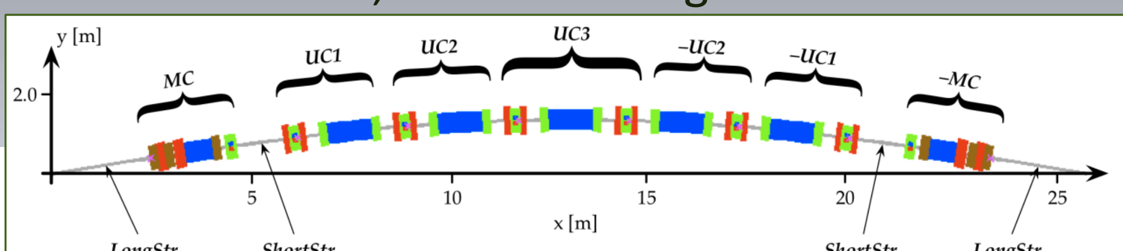


- Each achromat consists of five unit cells and two matching cells.
- 20 achromats x 7 cells = 140 cells total
- achromat length = 26.4 m
- ring circumference = 26.4 x 20 = 528 m

achromat 3D cad assembly:

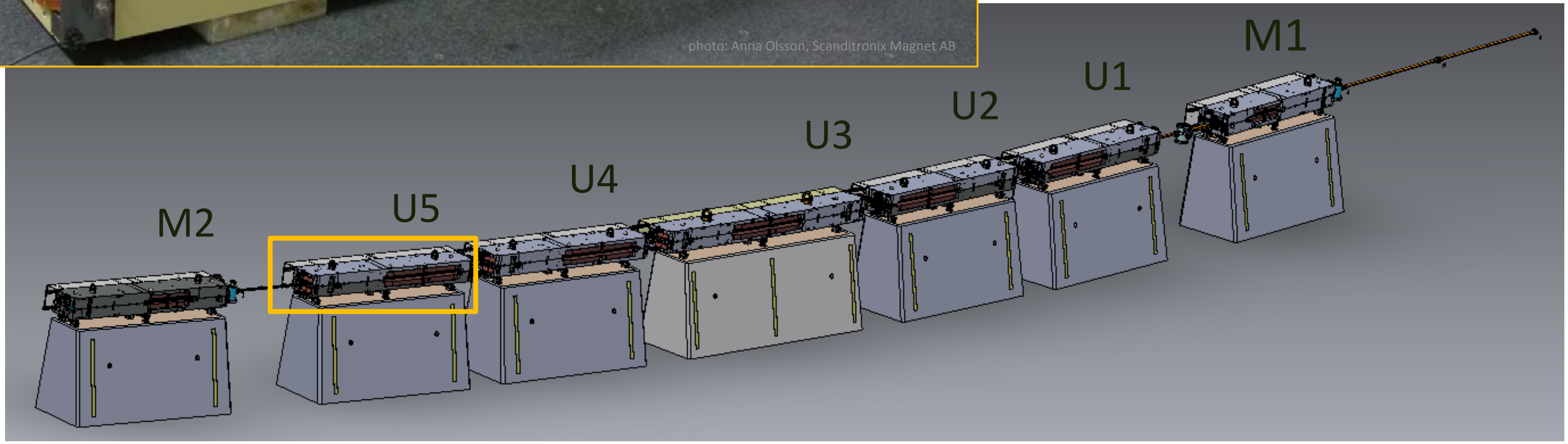


- Each cell is realized as one mechanical unit containing all magnet elements.
- Each unit consists of a bottom and a top yoke half, machined out of one solid iron block, 2.3-3.4 m long.



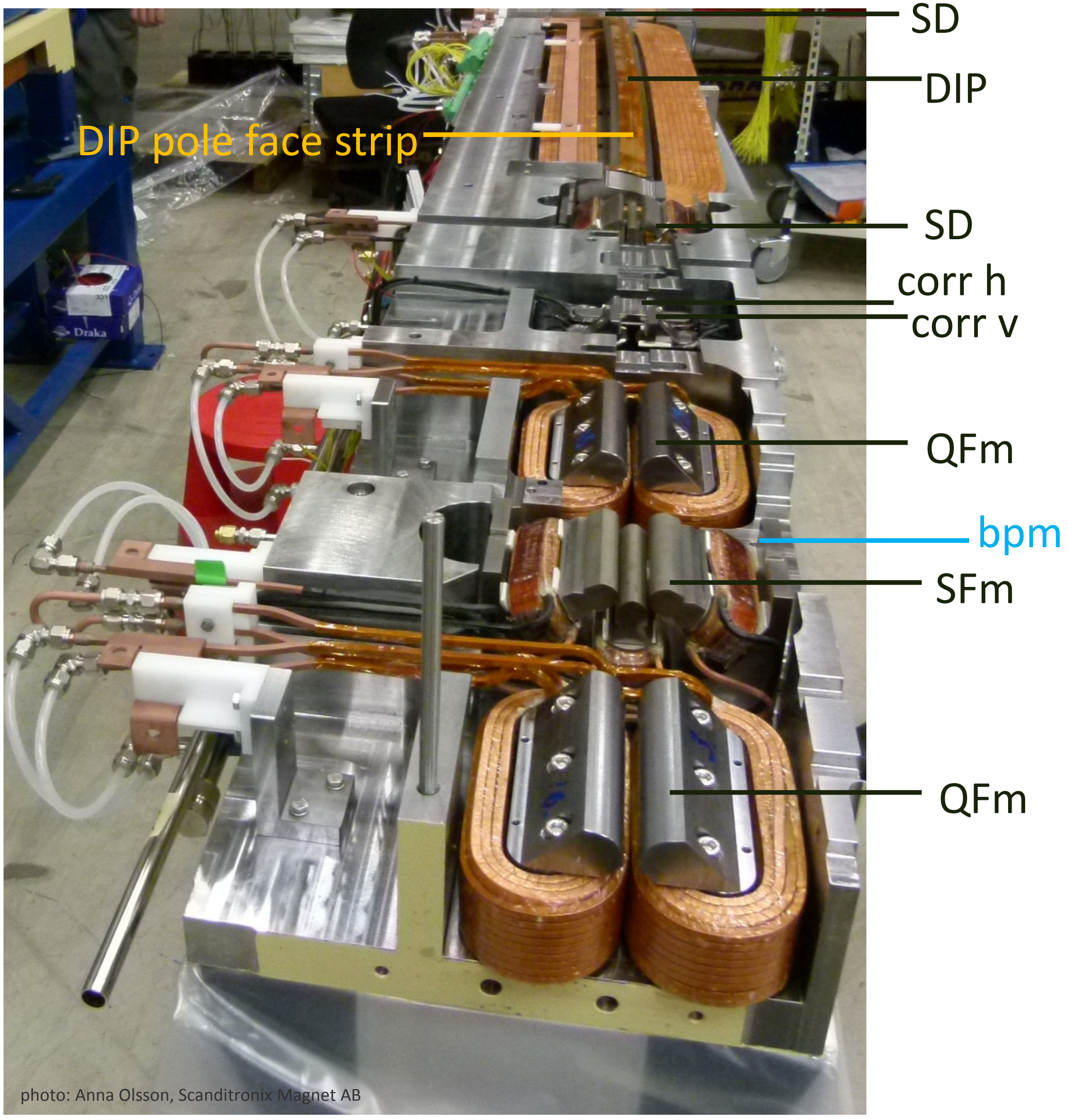
a MAX IV magnet block:

- a U5 bottom half →
- ↓ an assembled U5

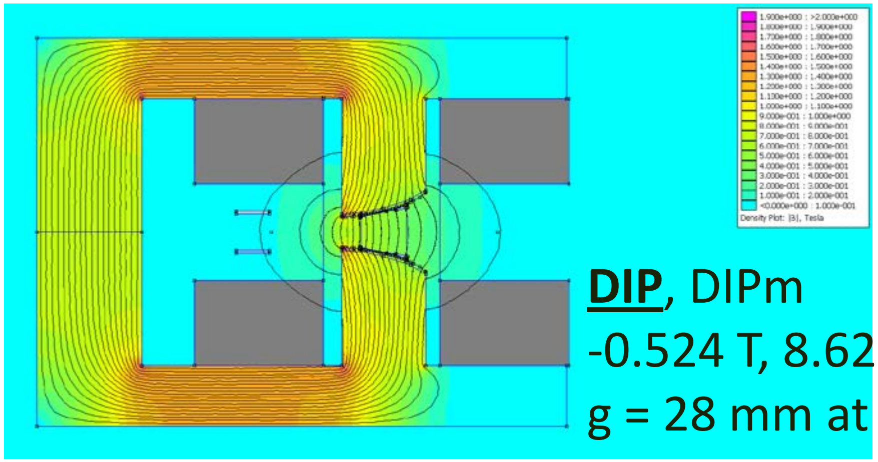


a MAX IV magnet block:

- Dismountable at horizontal midplane.
- all yoke parts = Armco low carbon steel.
- Quad and corr pole tips mounted over the coil ends.
- 6pole and 8pole magnet halfs mounted into guiding slots in yoke block.
- Electrical and water connections located towards inside.



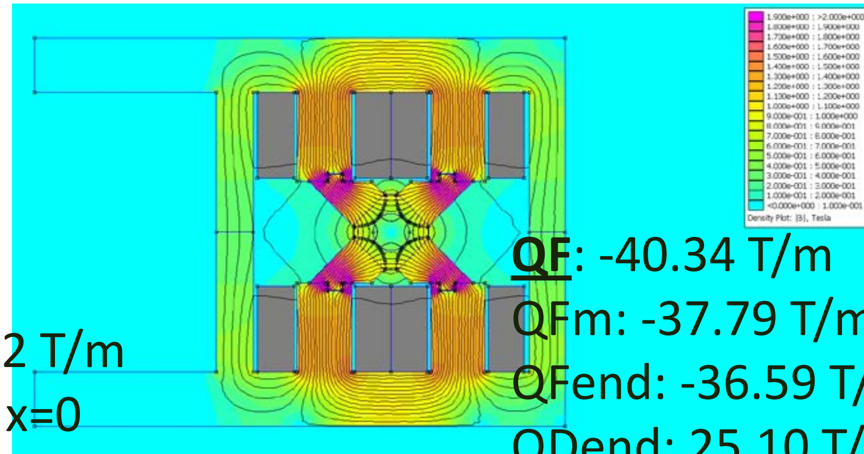
magnet elements:



DIP, DIPm

-0.524 T, 8.622 T/m

g = 28 mm at x=0



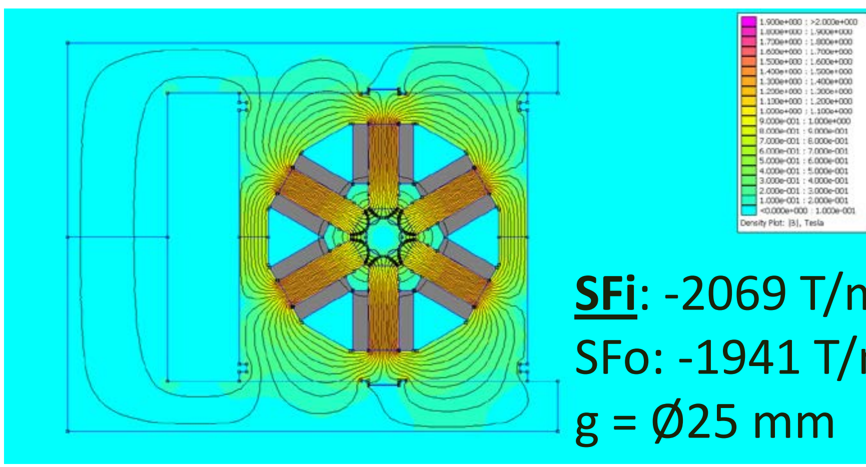
QF: -40.34 T/m

QFm: -37.79 T/m

QFend: -36.59 T/m

QDend: 25.10 T/m

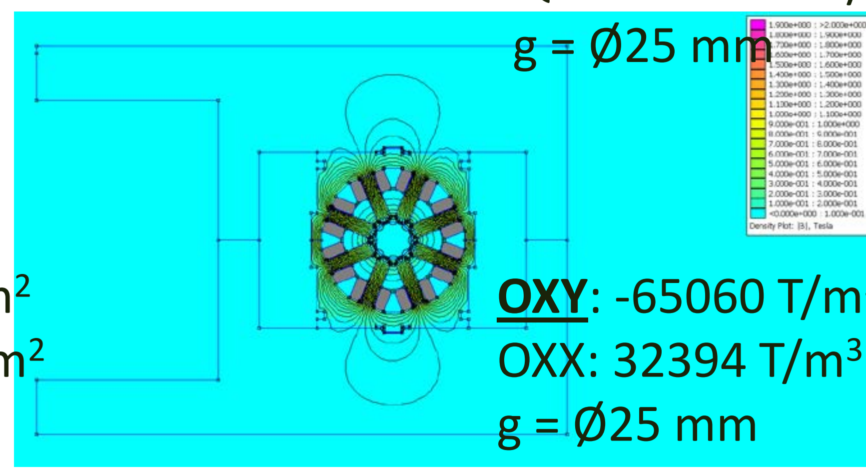
g = Ø25 mm



SFi: -2069 T/m^2

SFo: -1941 T/m^2

g = Ø25 mm



OXY: -65060 T/m^3

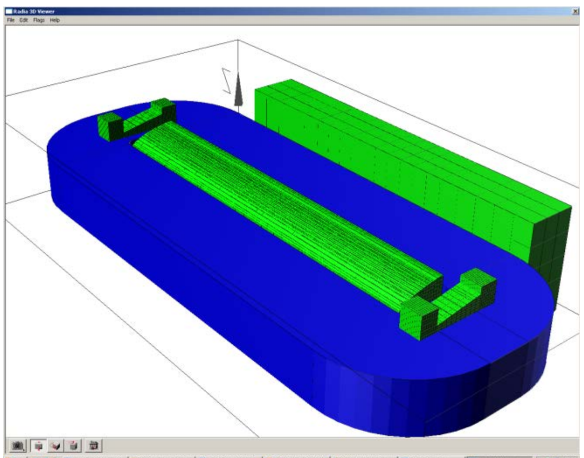
OXX: 32394 T/m^3

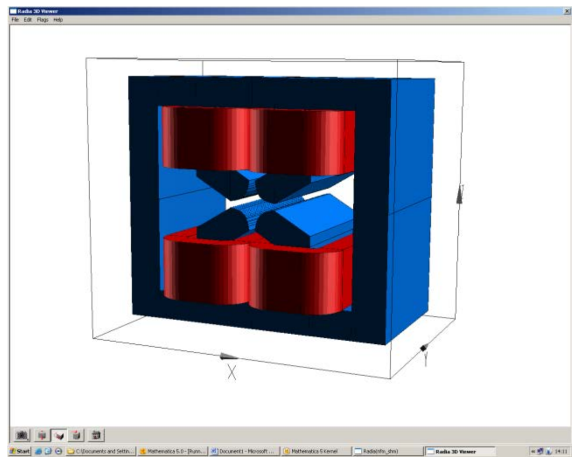
g = Ø25 mm

... + SFm, SD, SDend (g = Ø25 mm), OYY (g = Ø36 mm) and corr h/v (g = 25 mm)

design procedure:

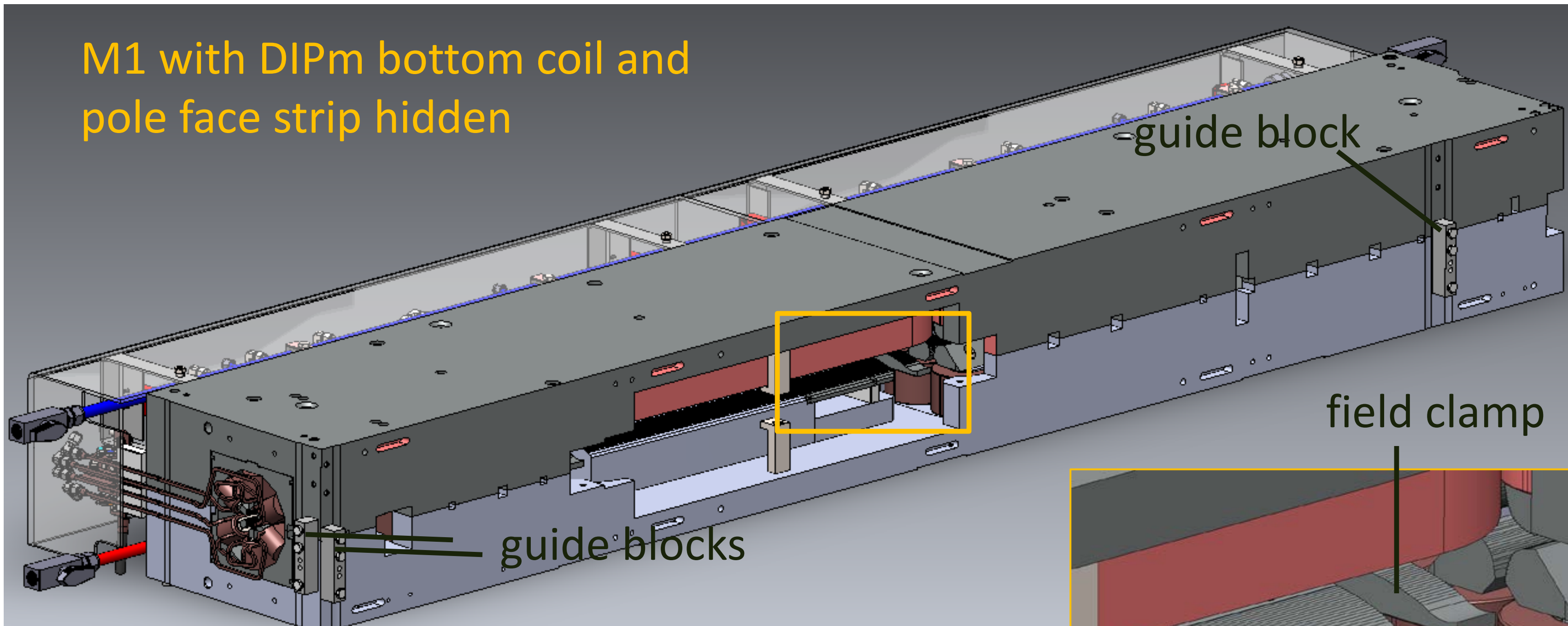
- 2D simulations were performed using FEMM for all magnet elements.
- 3D simulations were performed using Radia for dipoles and quads as standalone magnets, ie no 3D simulations of the full magnet blocks.

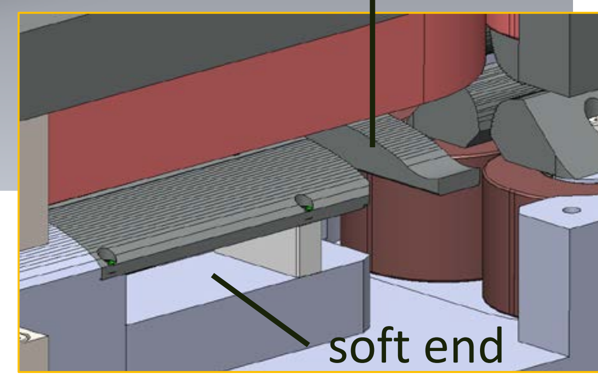




- The dipole was evaluated, and represented in the lattice, as consisting of 12 longitudinal slices.
- Lattice and magnet design were iterated against each other.

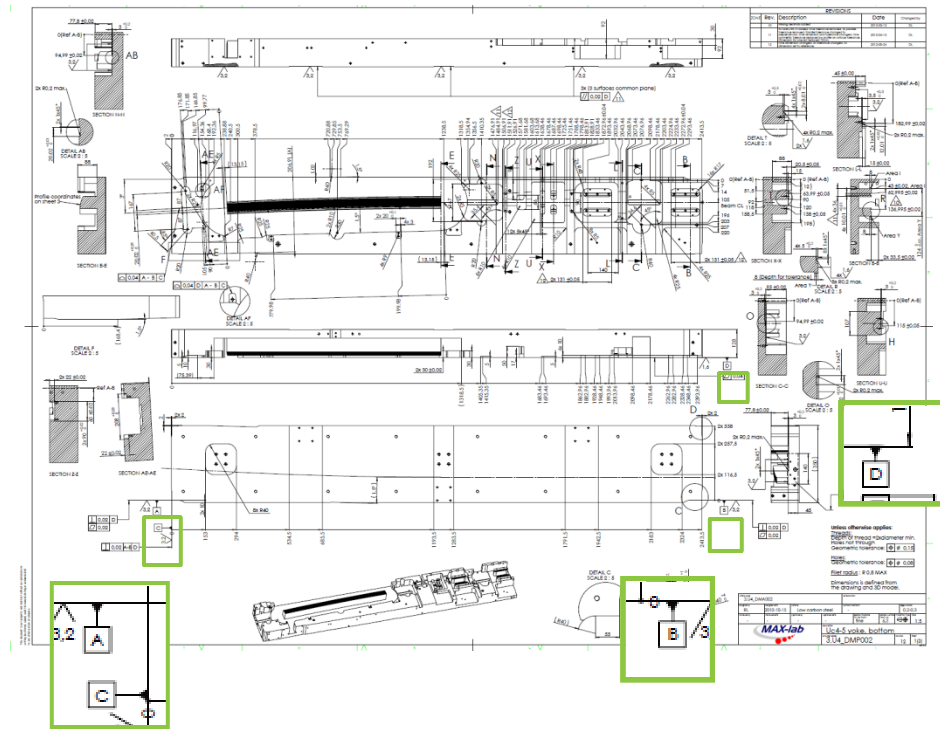
more details:





- Top half aligned to bottom half by 3 guiding blocks on bottom + top outer reference surfaces.
- Field clamps reduce the dipole fringe field distribution sensitivity to coil shape.
- M1/M2 DIPm soft end reduces thermal load to the long straight.

specification



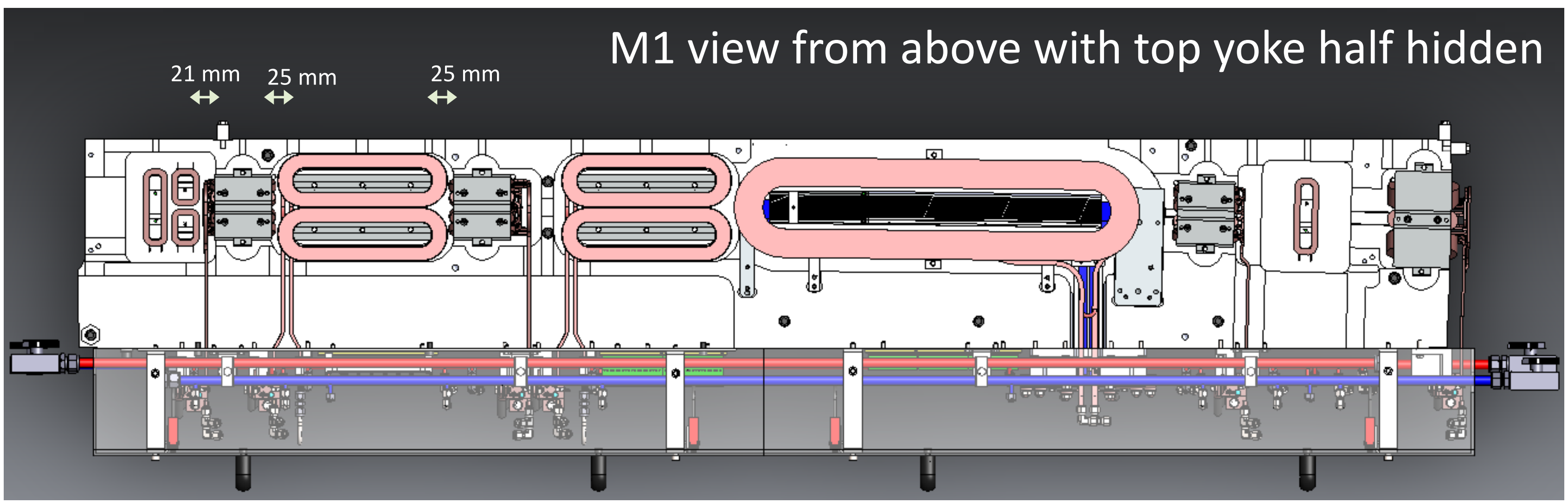
- Suppliers deliver magnet blocks fully assembled and wired, ready to put directly in ring tunnel and connect ps and water.
- Suppliers are responsible for mechanical tolerances on parts.
- MAX IV is responsible for magnetic design.
- Mechanical tolerances on the yoke bottom and top pieces are defined relative to reference planes A, B, C and D.
- Dipole surface and quad/6pole/8pole guiding surfaces have ±0.02 mm tolerance relative to D, A-B and C.
- Suppliers perform field measurements of all magnet elements to MAX IV instructions.

MAX IV magnet design

1) Presentation of the design concept.
2) Why have we done it like this?

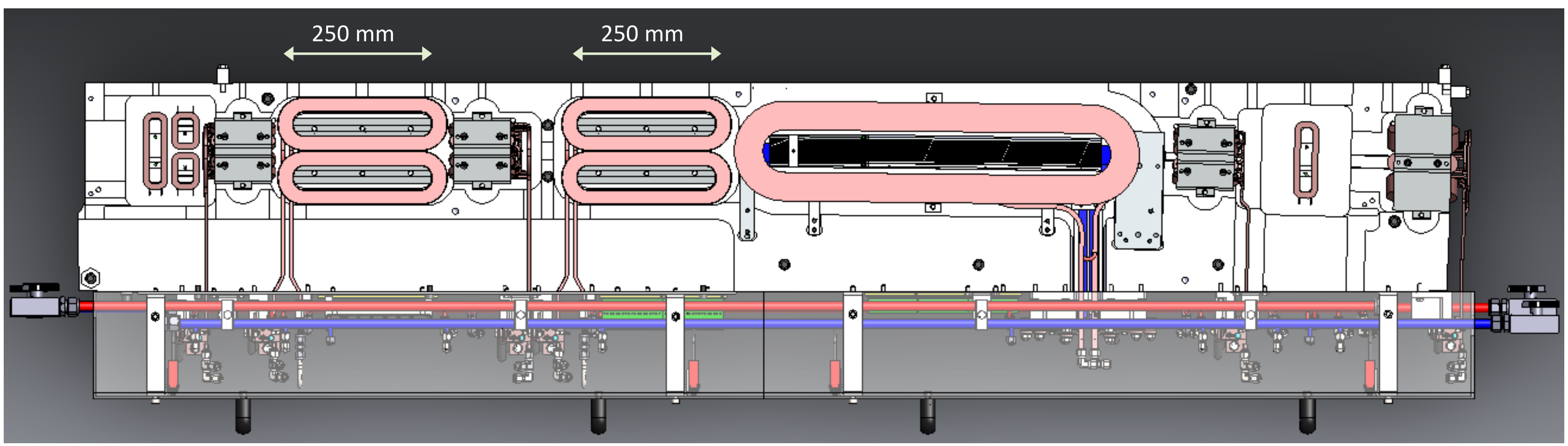
why Ø25 mm pole gap?

- The pole aperture has a direct influence on lattice compactness, by defining minimum distance between elements and minimum length for quads, 6poles, ...
- minimum distance between consecutive elements ≈ one pole gap
- If shorter, fringe fields overlap, destroying field quality.



why Ø25 mm pole gap?

- Assuming a fixed max pole tip field, B_{pt}, max quad gradient = B_{pt}/pole r
- We have chosen max Btp ≈ 0.5 T, which keeps the whole pole face in the linear region of the iron B(H) curve. Resulting max G ≈ 40 T/m.
- Our quads are at or close to this strength, so with larger pole radius, they would have needed to be longer.
- Our 6poles are in the same situation, at minimum length for this pole gap.



why Ø25 mm pole gap?

- The pole gap also has an indirect influence on lattice compactness through coil design, in that the required NI is proportional to g for dipoles, $(g/2)^2$ for quads, $(g/2)^3$ for 6poles, ... making it easer to fit the coil ends longitudinally between consecutive magnet elements for smaller pole gaps.
- A negative aspect is that with smaller pole gap, the relative strength of random field errors due to manufacturing tolerances increase, since the tolerances are fixed, constituting a larger fraction of the pole gap.
- Another consequence with smaller pole gap is that vacuum conductance decreases, in our case necessitating distributed pumping.

why the magnet block concept?

As opposed to standalone magnets not sharing a common return yoke...

- First of all, separate magnets on individual adjustment stands were never considered, because
  - we assumed that optical alignment would be less accurate between consecutive elements.
  - given the small footprint of our magnet elements, designing adjustment stands stiff enough to give the same level of vibration stability would have been difficult.
- So, from the perspectives of alignment and vibration stability, we were looking at a solution with several consecutive magnet elements in the same mechanical unit.
- Then there are two paths...

why the magnet block concept?

Two possibilities for girders

Based on field meas. data

for example NSLS-II girders:

↑ individual magnet vertical and sideways positions adjusted to stretched wire field meas. data.

Based on mech. tolerances

for example MAX II girders:

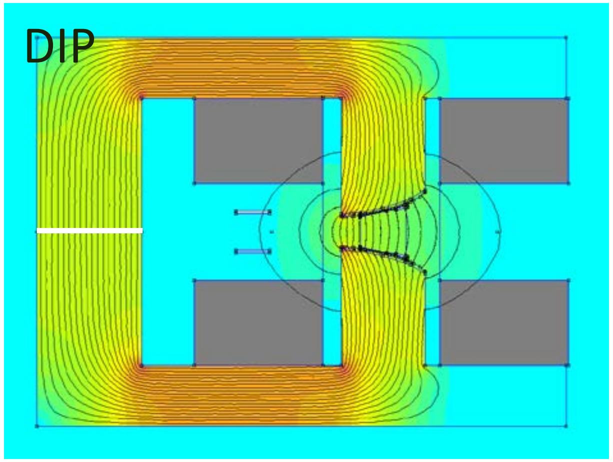
↑ Girders have precision machined fixed mating surfaces for each magnet element.

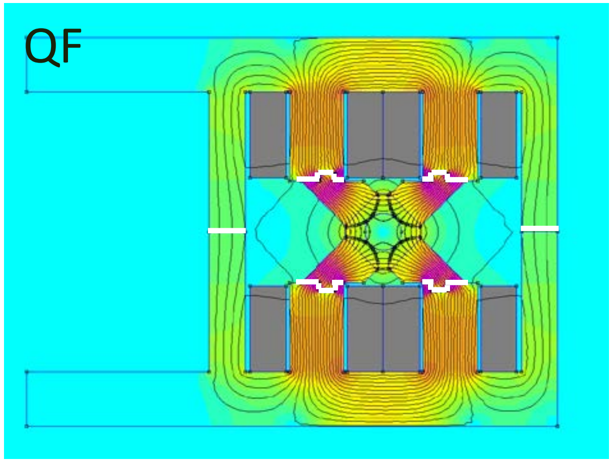
why the magnet block concept?

- At MAX IV, we typically want to subcontract as much work as possible to industry, minimizing the internal personnel need.
- We therefore chose an alignment concept based on mechanical tolerances over field meas. believing this is easier to subcontract to industry.

why the magnet block concept?

- DIP and QF cross sections →
- Separate magnets on a girder requires one more mating surface, decreasing the alignment accuracy. Therefore the magnet block concept.
- Expected rms alignment as sum of squares of parts, x,y = ±0.016,±0,020 for dipoles, = ±0.018,±0,021 for quads, = ±0.023,±0,025 for quads, with pessimistic assumption each part at max tolerance.
- Also, it is easier to achieve good vibrational stability with the magnet block concept. Lowest eigenfrequency ≈ 90 Hz for MAX IV, vs ≈ 30 Hz for MAX II.





Thank you for your attention!