HZB BESSY II Light Source

PERMANENT MAGNET DEVELOPMENTS

for BESSYII+ and BESSYIII

Low Emittance Rings – Permanent Magnets

2023 Nov 14.

J. Völker

HZB BESSY II Light Source

RF2.0

BESSYIII

BESSY II+

overview

RF 2.0 Project (EU Horizon 2023/2024) „Research Facility 2.0“

- funded 3 year project
- partner: ALBA, CERN, Commtia, Cryoelectra, DESY, Elytt, HZB, KIT, MAX-IV, Zaphiro
- development of components for more sustainable accelerators:

-> **Highly efficient Novel Permanent Magnets for accelerator storage rings (WP2.1)**
-> Energy efficient Solid State Amplifiers (WP2.2)
-> Phasor Measurements Units for fast dynamic energy management (WP4.1)
-> Green High Power Computing centers for accelerators (WP4.3)

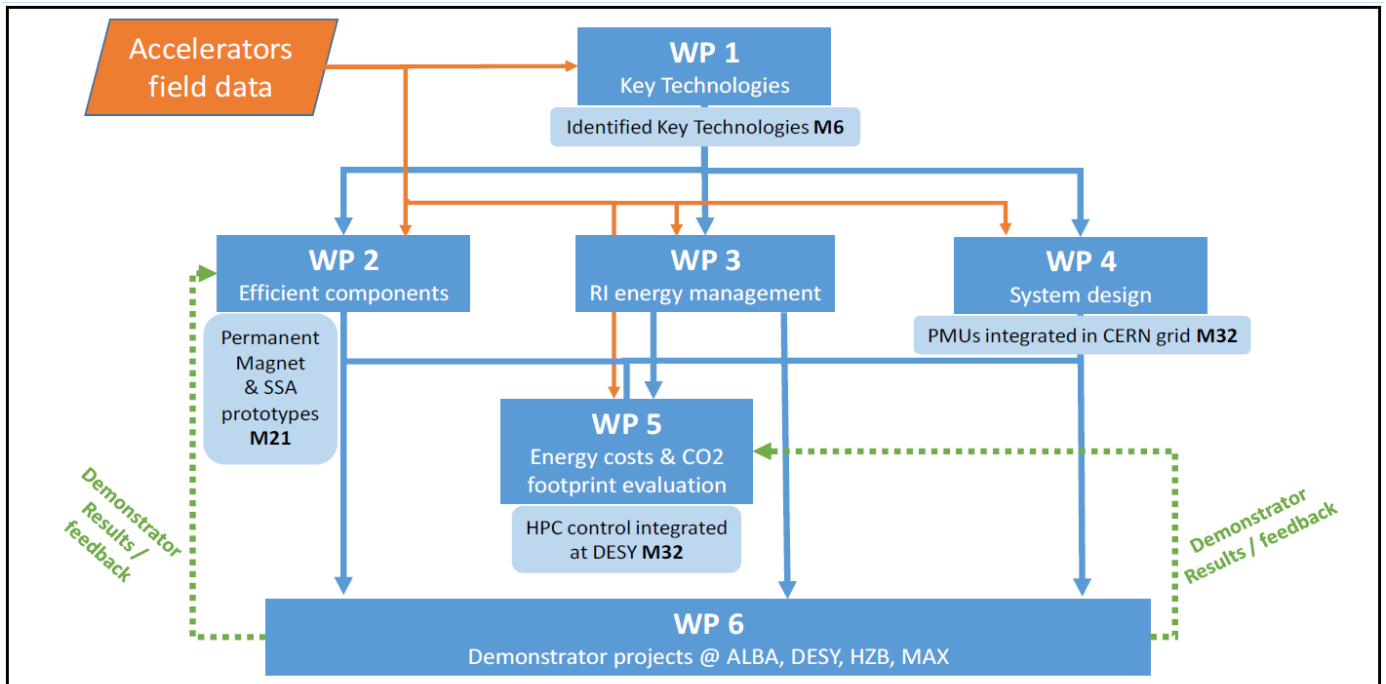


Fig.3, Work Flow of RF2.0 Consortium, with interaction among Working Packages

RF 2.0 Project (EU Horizon 2023/2024) „Research Facility 2.0“

PM Workpackage 2.1 (coordinated by HZB)
partners: **ALBA, Elytt, HZB, MAX-IV**
Total budged for the workpackage: approx. 1.5M€
three main topics:

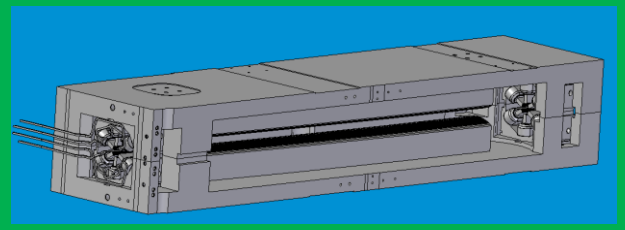
⇒ **refurbishment of electro magnets in an accelerator to PM driven magnets (MAX-IV)**

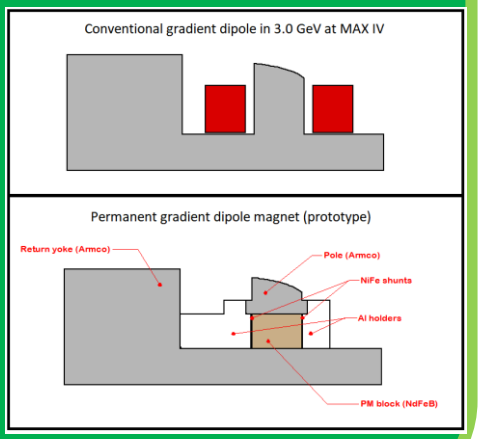
⇒ **investigation thermal shim parameter as function of thermal and mechanical stress (HZB)**

⇒ **prototyping of a variable high gradient PM-QP magnet concept, usable for ALBAII and BESSYIII (ALBA, Elytt, HZB)**

Dipole refurbishment @ MAX IV

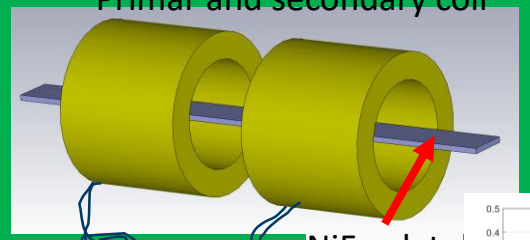
-> replace coils in dipole magnets (3GeV ring) with PM blocks
-> energy reduction of 45%
-> more space for further NL-magnets





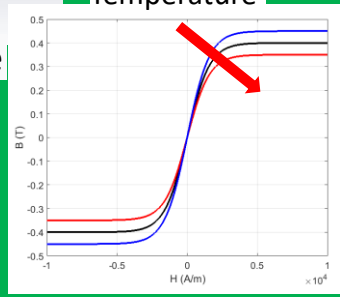
NIFe Test bench @ HZB

Primar and secondary coil

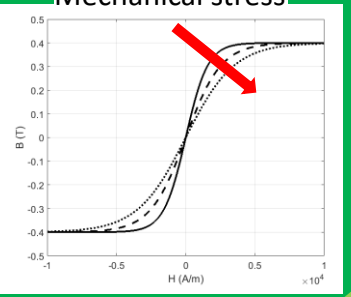


-> test bench for thermal shims
-> temperature effects
-> mechanical history

Temperature

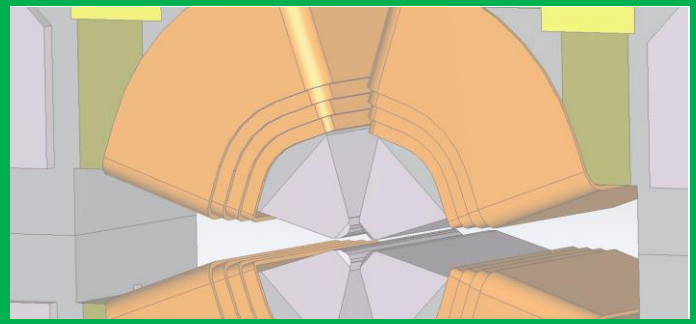


Mechanical stress



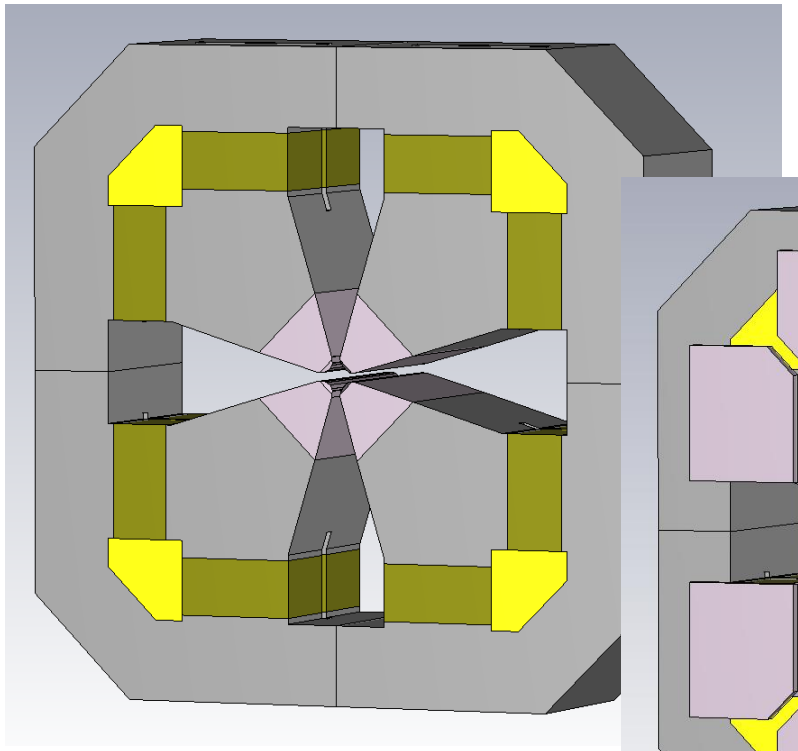
S-VPHM QP demonstrator @ ALBA+HZB

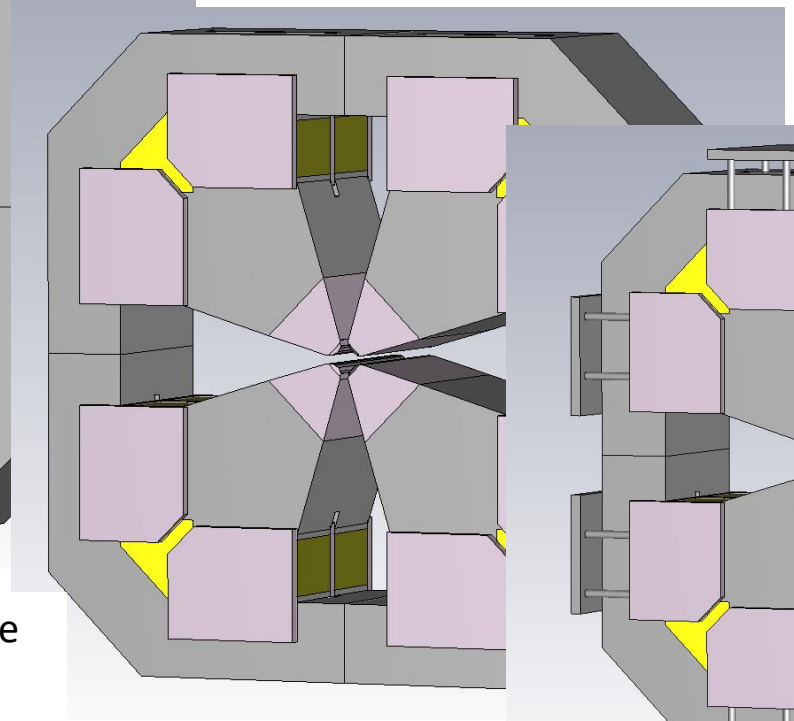
-> motorized PM QP magnet
-> gradients tuning between 80 and 120 T/m
-> slow mechanical, fast electrical tuner

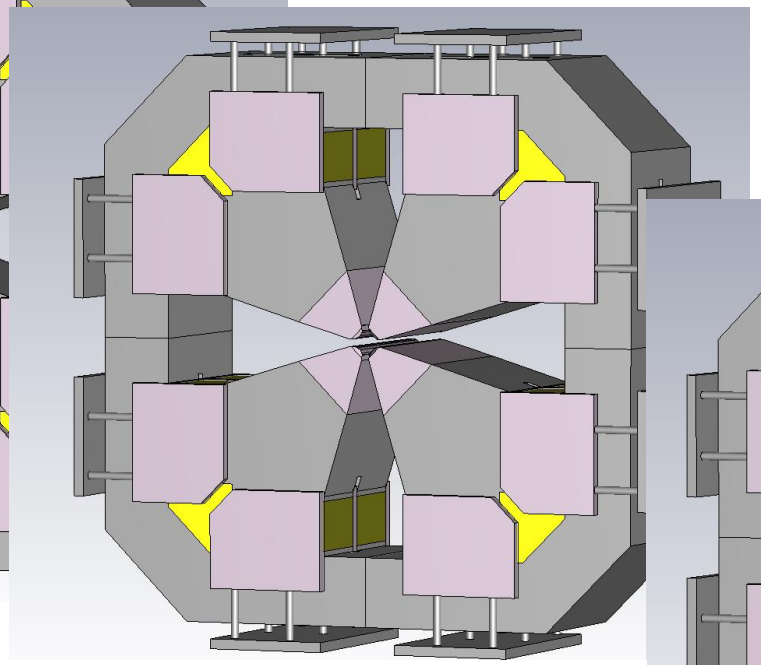


RF 2.0 Project (EU Horizon 2023/2024) „Research Facility 2.0“

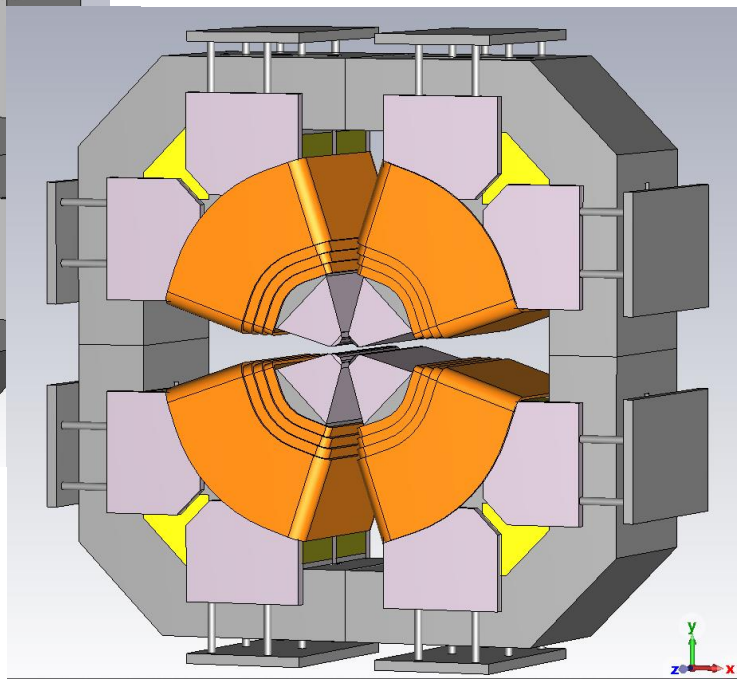
-> up 24 tuning plates (10mm thick CoFe) will be installed in parallel to the PM blocks
-> position of these plates reduces the max. magnetic flux (short circuit)







-> small corrector coils can be used for fast (up to 1Hz) gradient adjustment
-> also thermal shims are possible



-> PM driven QP magnet with CoFe Pole Shoes (gradient up to 120T/m)
-> Pole Shoe Tip and chamfer are numerical optimized to maximize b2 (quadrupole) and to minimize central and/or integrated b6, b10 and b14

-> the plates are mechanical connected
-> position inside yoke can be changed via motors (slow)
-> field strength can be reduced by approx. 40% ($\sim 0.5\%/\mathrm{mm}$) (or $\pm 20\%$ to operating point)

HZB BESSY II Light Source

RF2.0

BESSYIII

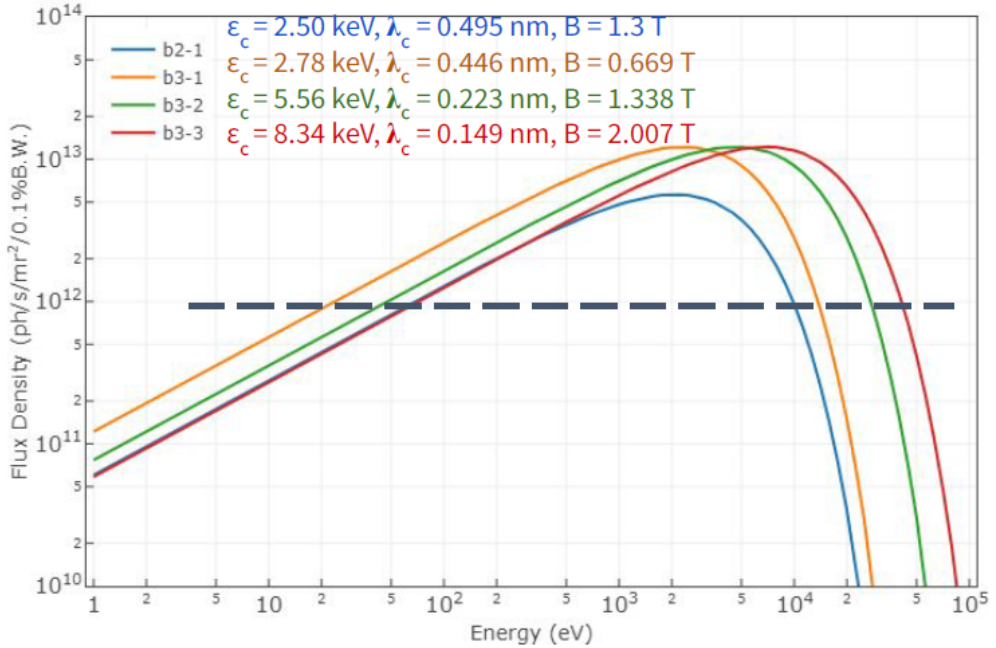
BESSY II+

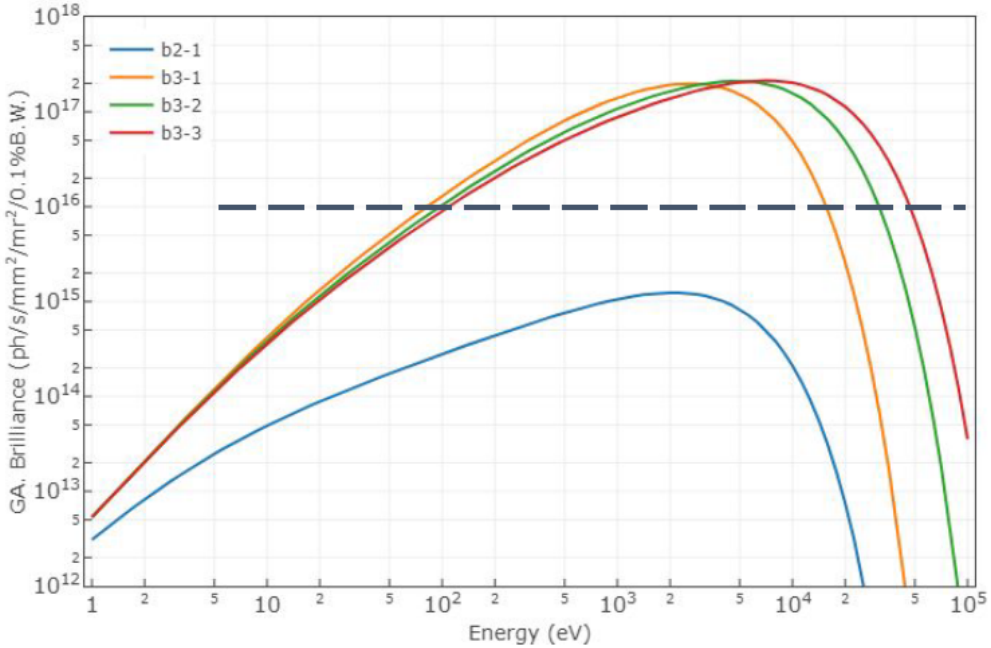
overview

Dipole Magnets for BESSYIII

- additional to the undulator sources for SR, user wants to have 1-2 dipole sources per arc
- one soft X-Ray source for metrology (homogeneous bend with high accuracy) -> **Type A/B**
- one tender to hard X-ray source -> **Type C**

- Two/Three applications:
  - PTB, Metrology, similar to BESSY II (primary radiation standard): **2.5 keV**
  - Tender X-rays bends: **> 3, 5, 10 keV**
  - Hardest X-rays bends, 20 keV and beyond: ?





P. Goslawski, The BESSY 3 Lattice, 9th MT Meeting, October 2023, KIT, Karlsruhe, Germany

Dipole Magnets for BESSYIII

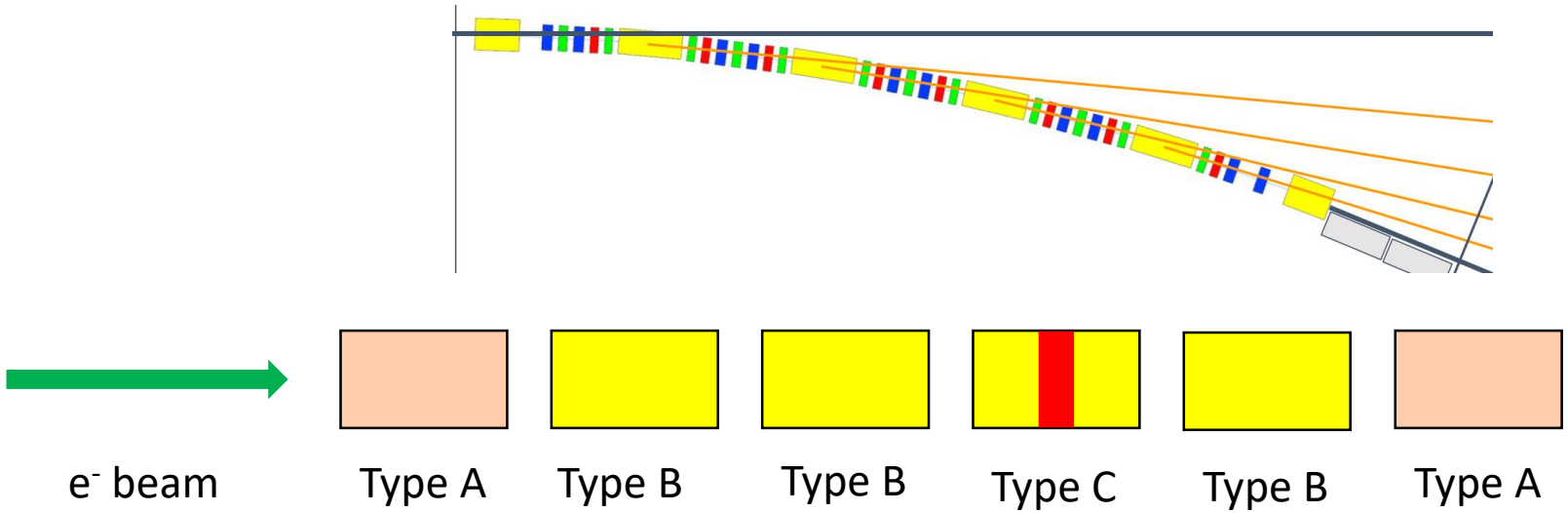
- additional to the undulator sources for SR, user wants to have 1-2 dipole sources per arc
- one soft X-Ray source for metrology (homogeneous bend with high accuracy) -> **Type A/B**
- one tender to hard X-ray source -> **Type C**

- open discussion which dipole magnet of the six bends per arc should be used for this
- Type A and B will have a length of one meter or less, B~0.75T

-> straight long dipole magnet with larger pole shoe width for increased good field region
-> moderate magnetic flux density for a gap of 25mm

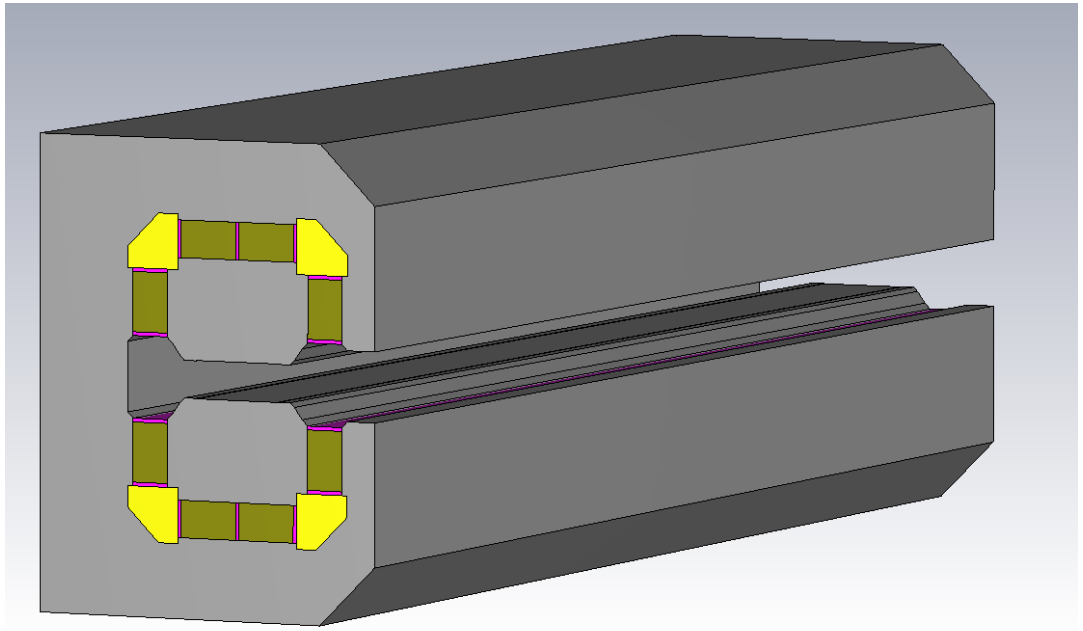
- Type C superbend option: straight 3-step LGB with central peak field >2T

=> field quality in this region is less important as for Type A/B



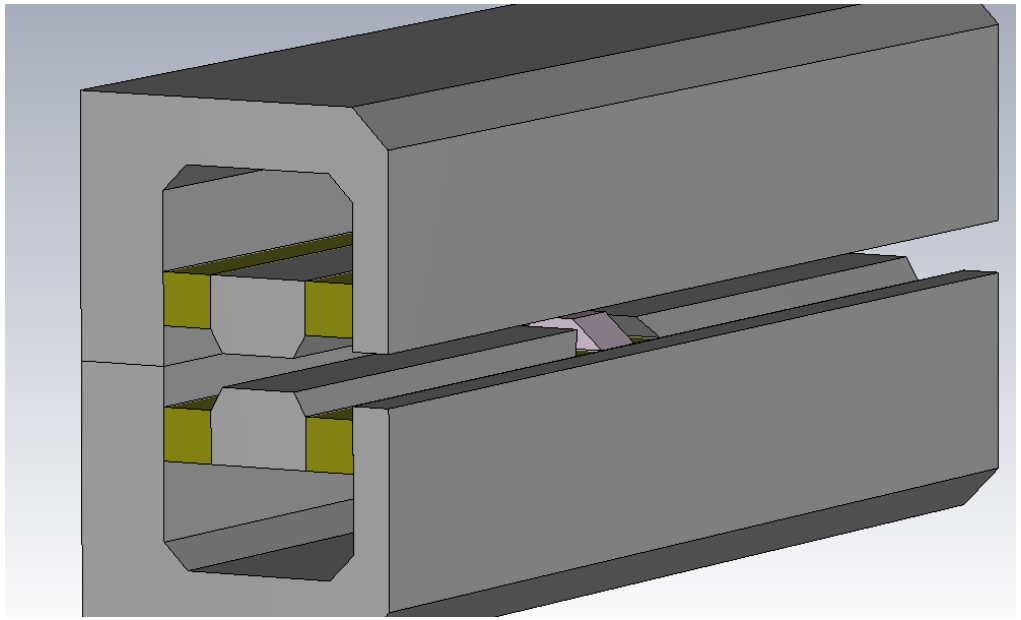
Homogeneous PM-Dipole (Type A/B)

-> 1m long bending magnet (approx. 0.75T)
-> homogenous field in vertical and longitudinal direction
-> can be build as a straight 1m block
-> simplifies construction and measurement

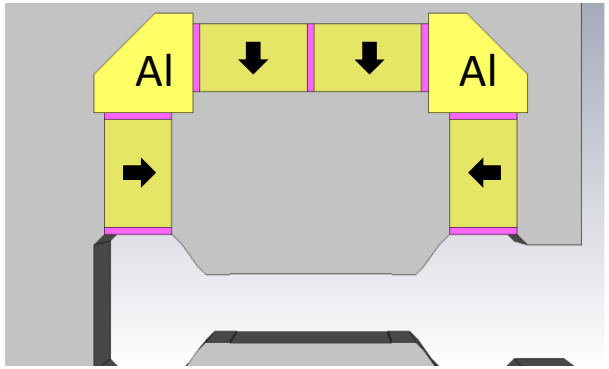


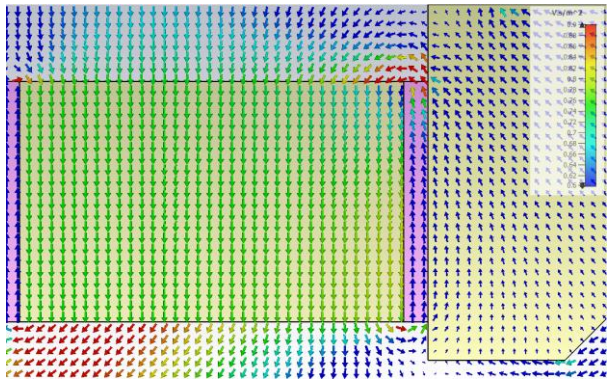
Super Bend option (Type C)

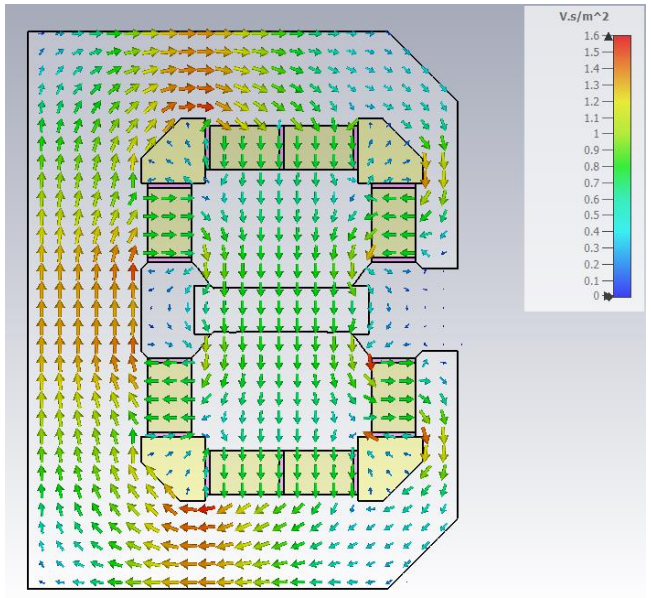
-> same length and integrated field as Type B
-> short high field region for hard X-ray source
-> central pin (CoFe) with surrounded PMs
-> similar design to Type B (consistent construction)



Homogeneous PM-Dipole (Type A/B)

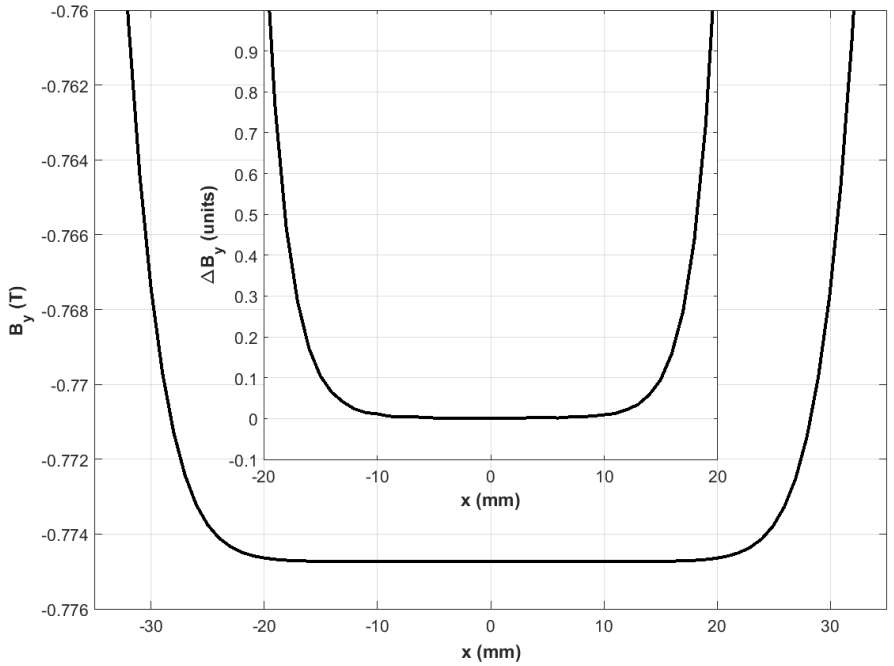






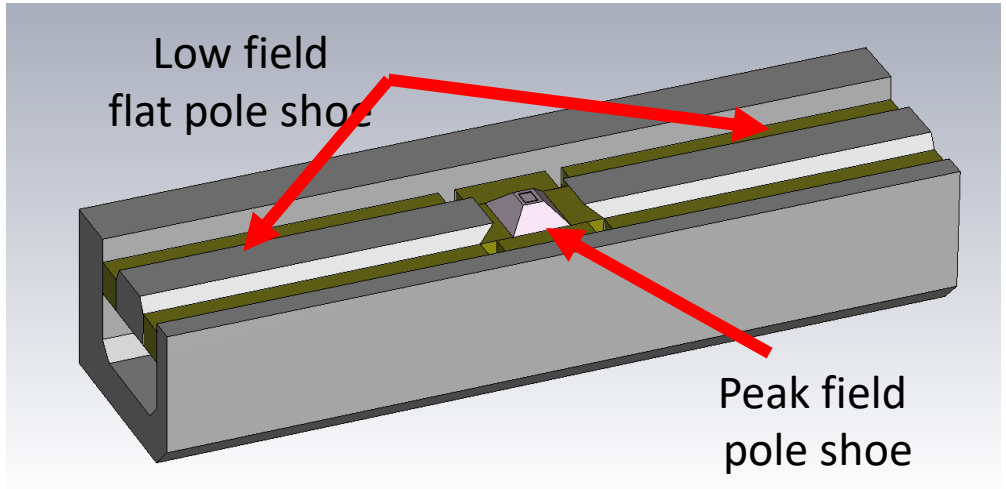
- Increased pole shoe width for straight magnet
- central notch to further flatten the field
  -> homogenous field for the full bended beam

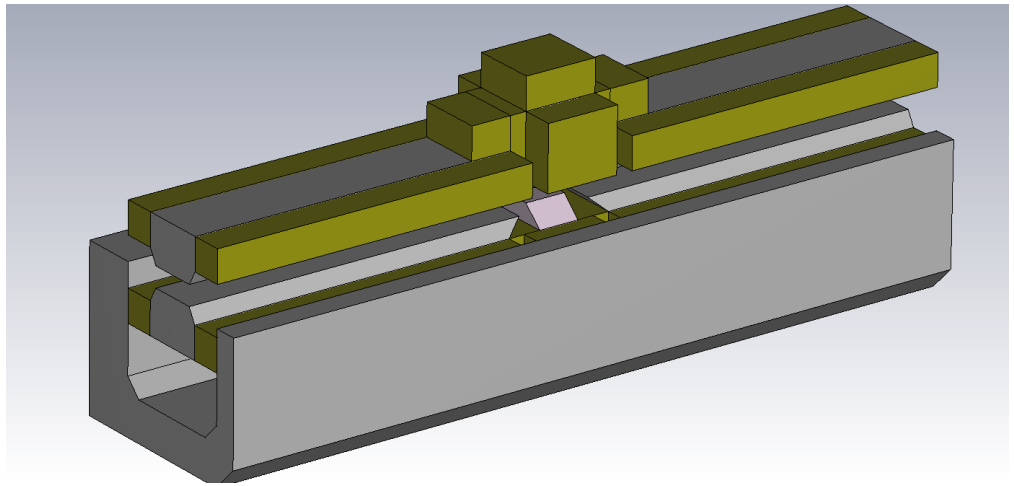
8 PM blocks (40mm x 25mm) in transverse plane
-> 14 thermal shim plates (< 4mm thickness)

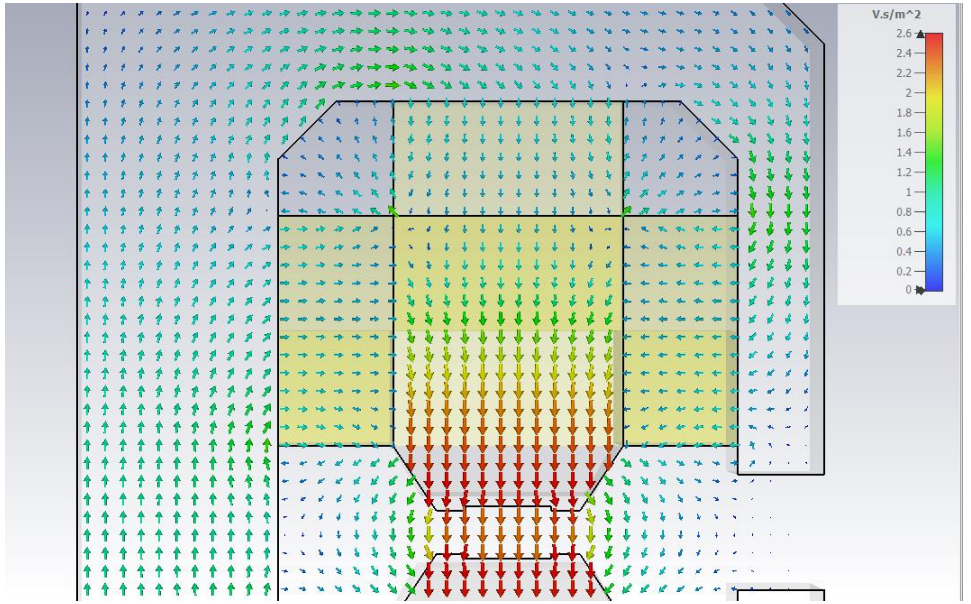


- Pole optimization to achieve field flatness of < 0.1 unit in 30mm and < 1 unit in 40mm

Super Bend option (Type C)







-> three pole shoes:

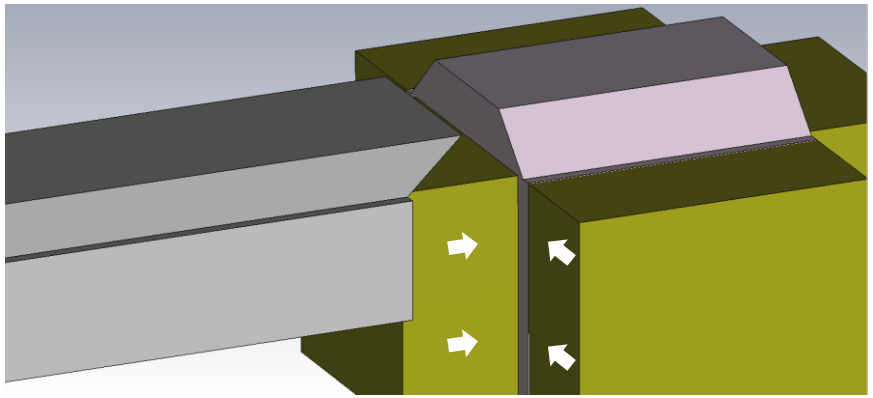
-> two outer (gap 25mm)

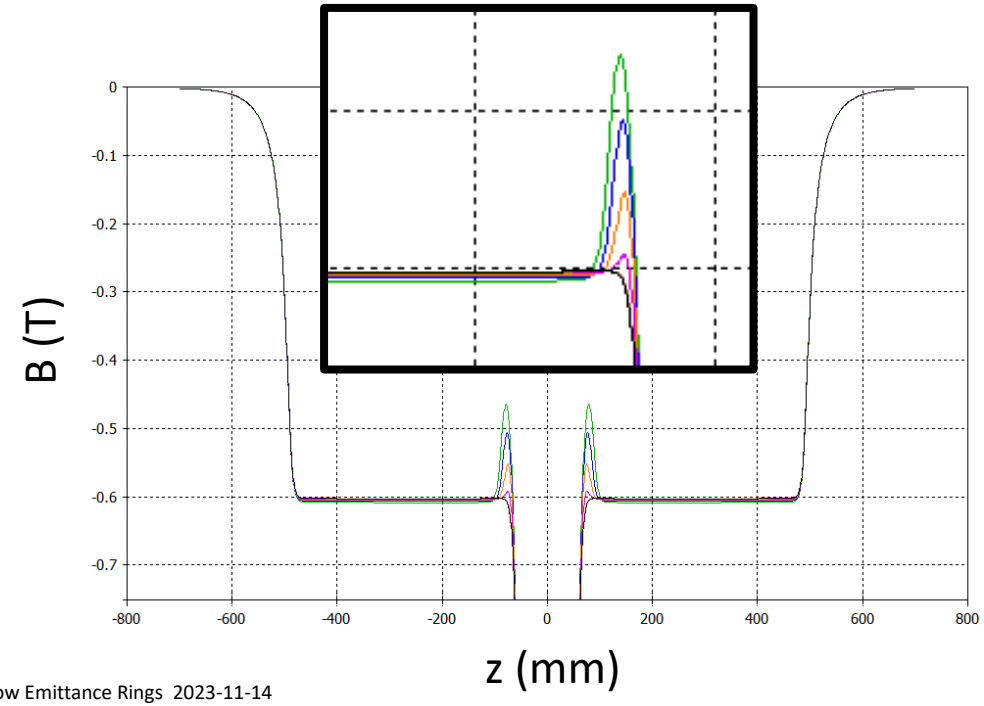
-> short central pole (gap ca. 15mm)

-> Central pole shoe made of CoFe for increased flux

-> PM blocks dimensions as similar as possible

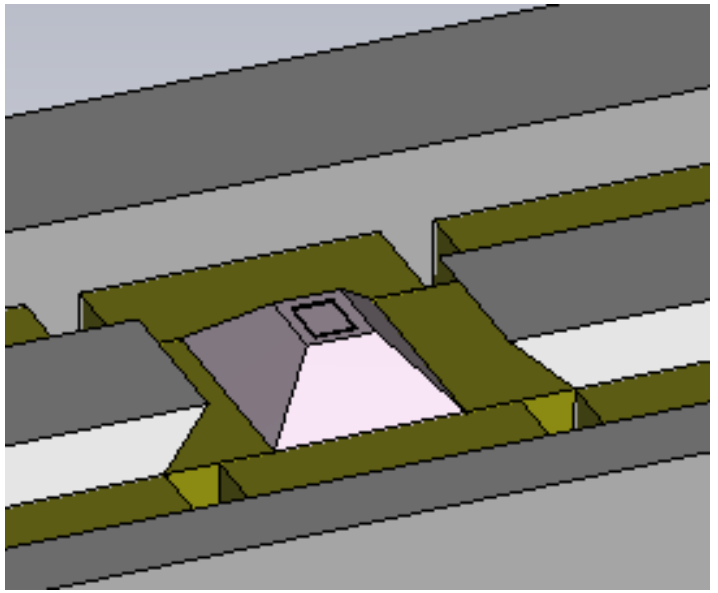
Super Bend option (Type C)





-> Additional nose at the outer pole shoe to smoothen the long. Field profile

- The sharp edge projects in the area of the long. PM block
- the length of the nose changes dip of the field between outer an central pole shoe



-> angles and indentation of the central pole were optimized to achieve highest field (up to 2.5T) and homogenous field region for a few millimeters next to the central region

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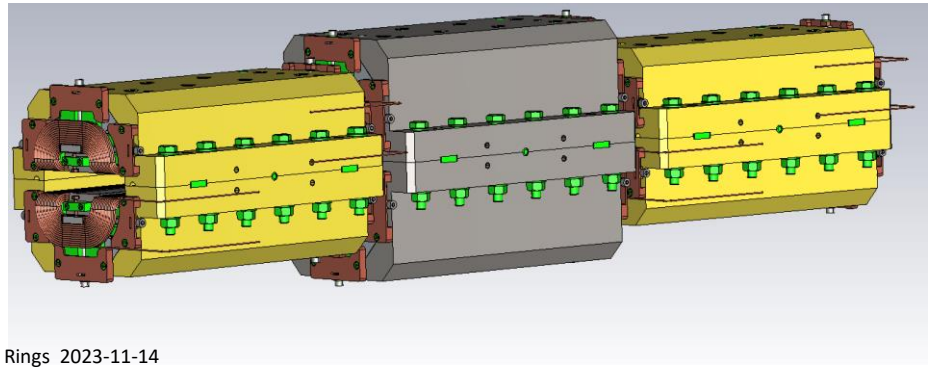
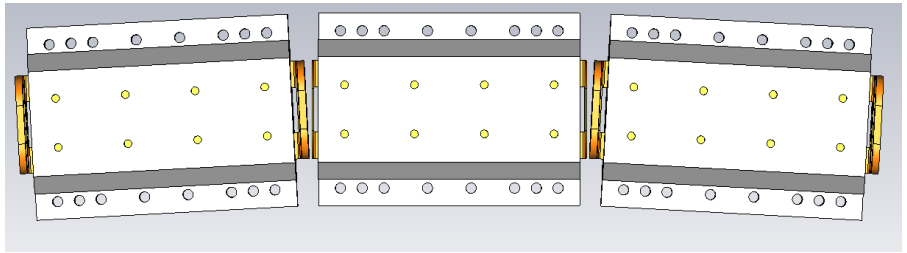
overview

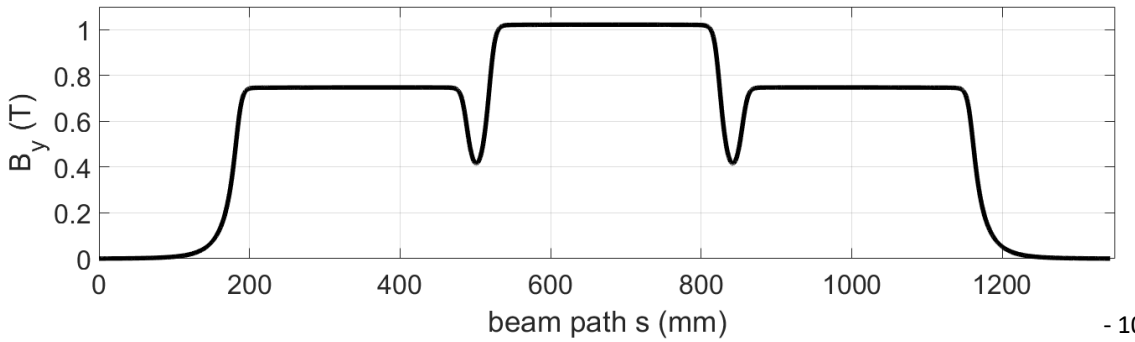
B2PT Replacement

BESSYII Injection-Line PM Dipole (B2PT)
-> three 300 mm long H-shaped dipols
-> field of 0.75T (outer regions)
1.08T (central region)
-> two types of PM blocks are necessary
-> corrector coils in the outer magnets
for small corections

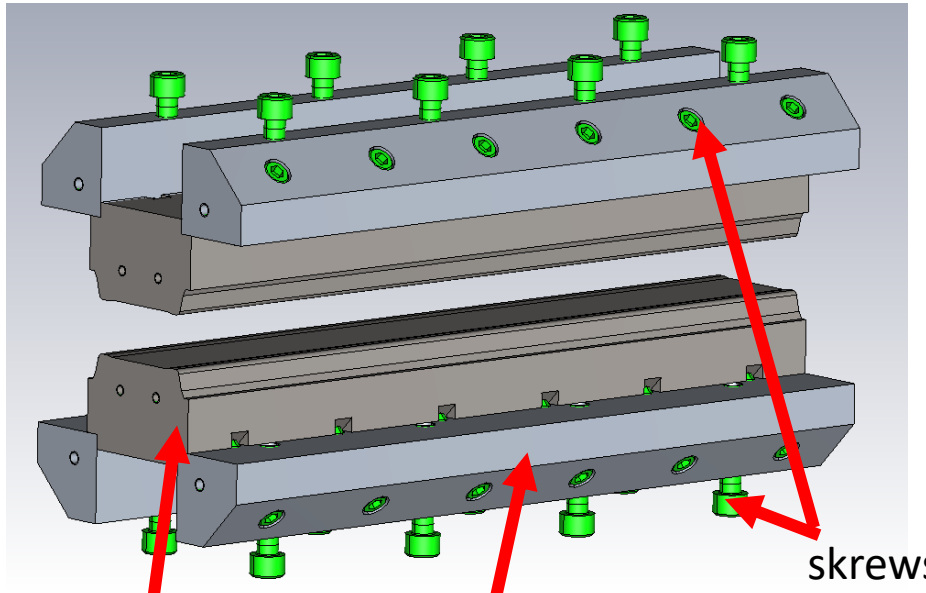


-> PM blocks were delivered (different than expected)
-> start of PM measurements
-> yoke design is finished
-> Corrector Coil production is ongoing but
(8mm thick , 30mm width , 300mm long)
fabrication is a little bit more complicated as expected
-> construction of the PM press tool



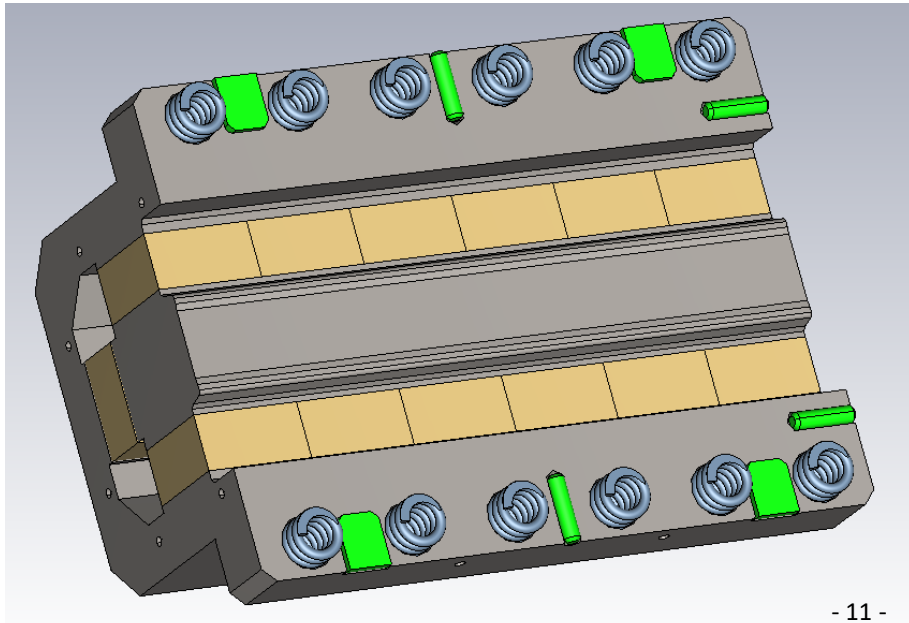


B2PT Replacement



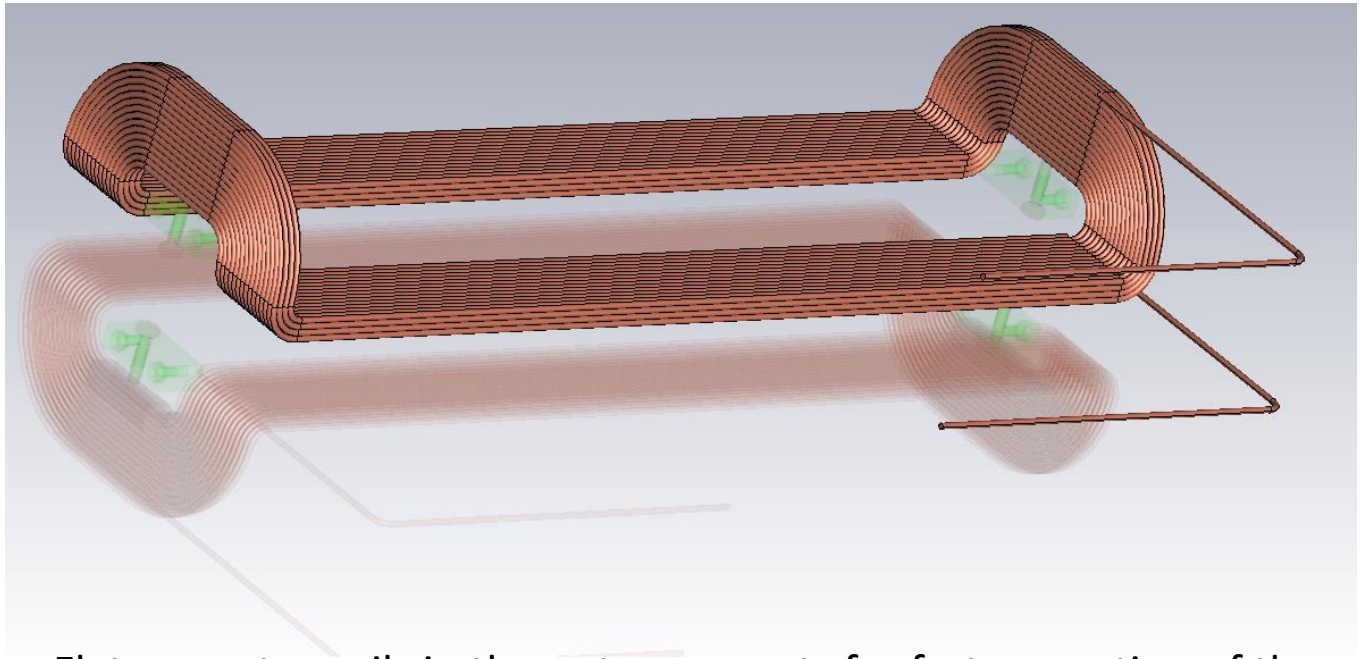
Pole shoes are fixed with the yoke in an Aluminum (μ_r=1) framework

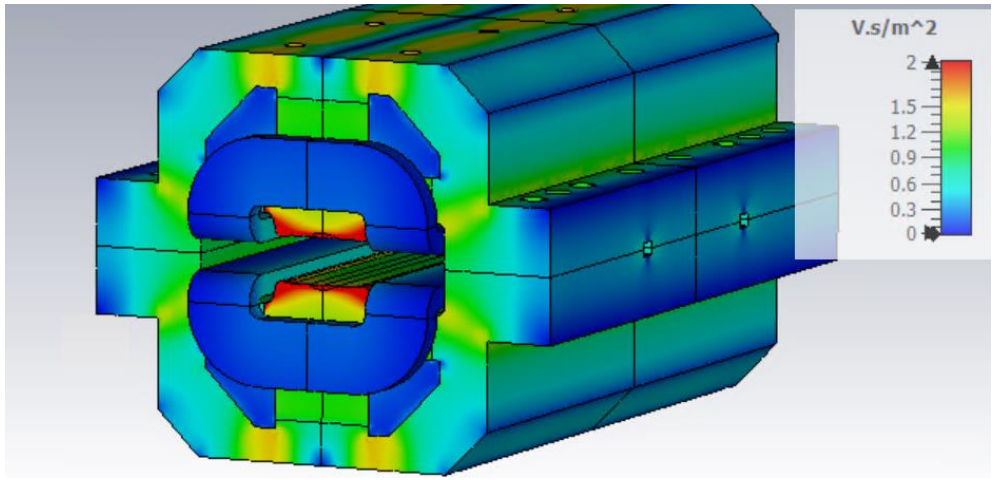
- align pole shoe
- space for PM block installation
- will be connected via skrews to the pole shoe and both to yoke



- Between both yoke pieces 12 springs are placed to reduce the magnetic forces during the installation of the full magnetized Half magnets
  -> magnets have to opened for beam pipe installation
- Steel pins are used for precision alignment of both half-magnet

B2PT Replacement





CST calculation for a 8mm x 30mm coil:

$$\text{-> } 1.68 \frac{\%}{\text{Amp}/\text{mm}^2}$$

Flat corrector coils in the outer magnets for fast correction of the magnetic field (bending angle)

-> no water cooling

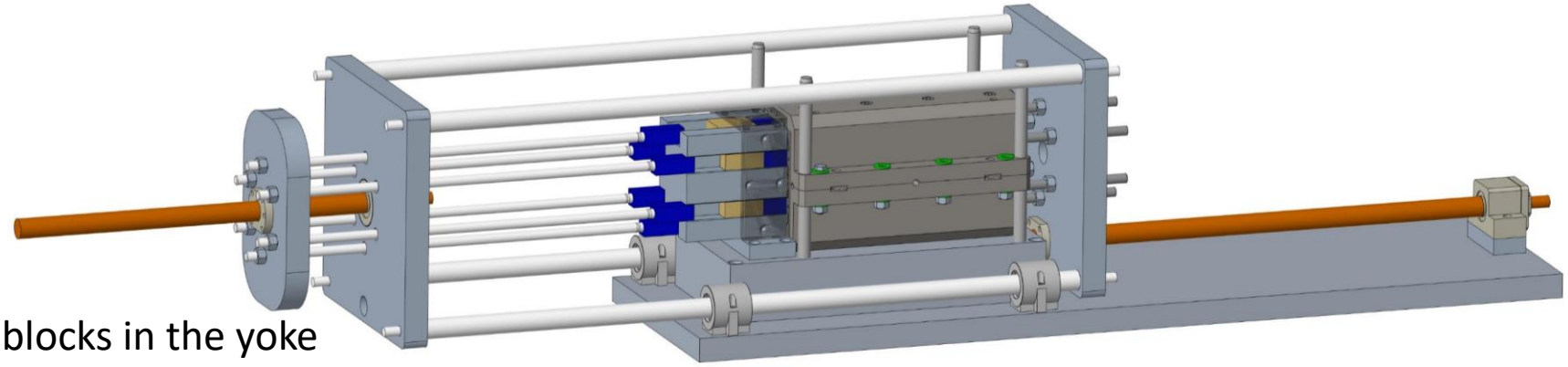
-> driver should be existing 8Amps Power Supply
(cable diameter in the range of 2-3 mm^2)

-> only 8-10mm thick coil to reduce the overall length of the magnet

-> width can be at least the same size as the PM blocks (25-30mm)

-> first Prototype development is ongoing with an external company

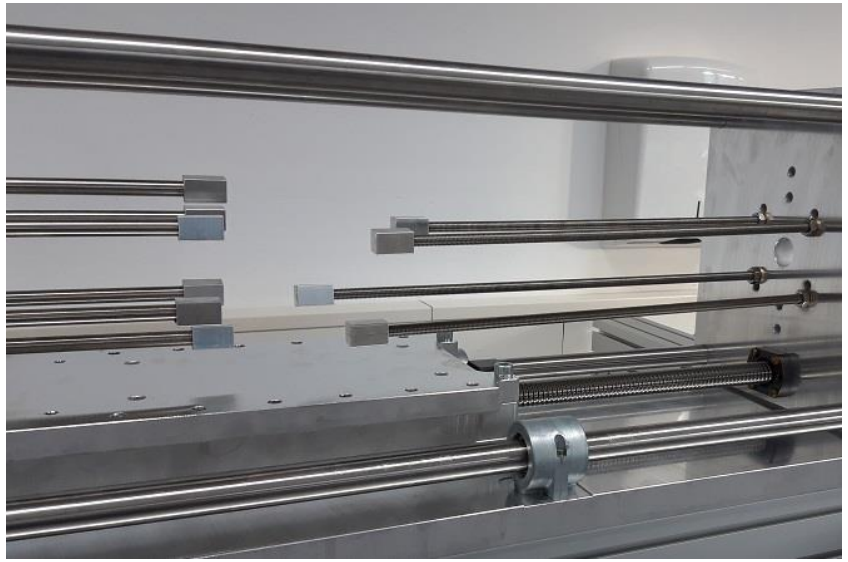
B2PT Replacement

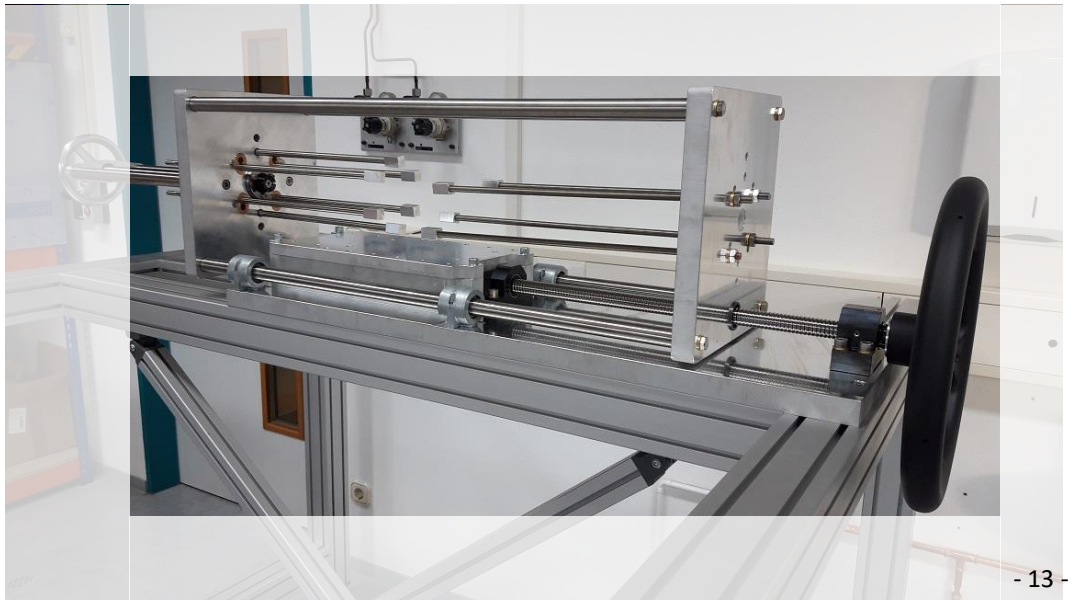


Press-Tool

-> for insertion of the PM blocks in the yoke
-> two Aluminum fingers per PM raw to guide the blocks in the yoke
-> minimum forces between PMs, if the installed PMs are nearly 10mm inside the yoke
-> first test of the tool with Aluminum-spacers (same size as PM blocks)

Aluminum blocks will also be needed as spacer between PMs in magnets with less PM blocks in the design





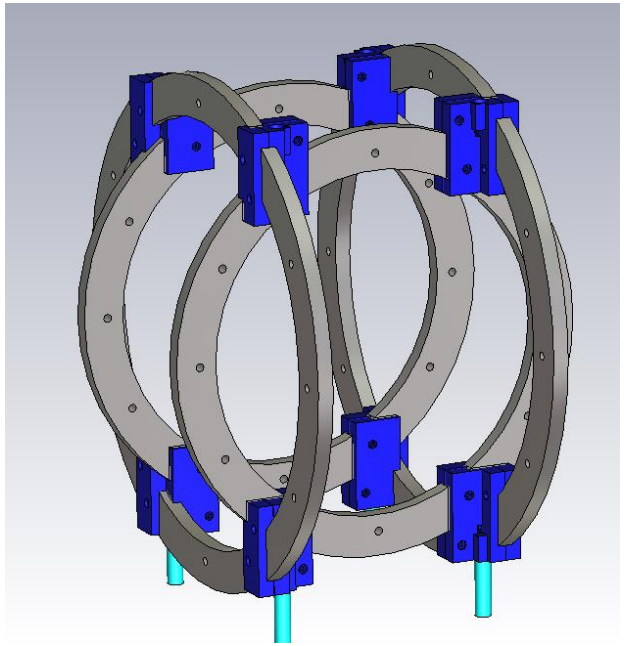
B2PT Replacement

PM Measurements via 2D-Helmholtz-Coils

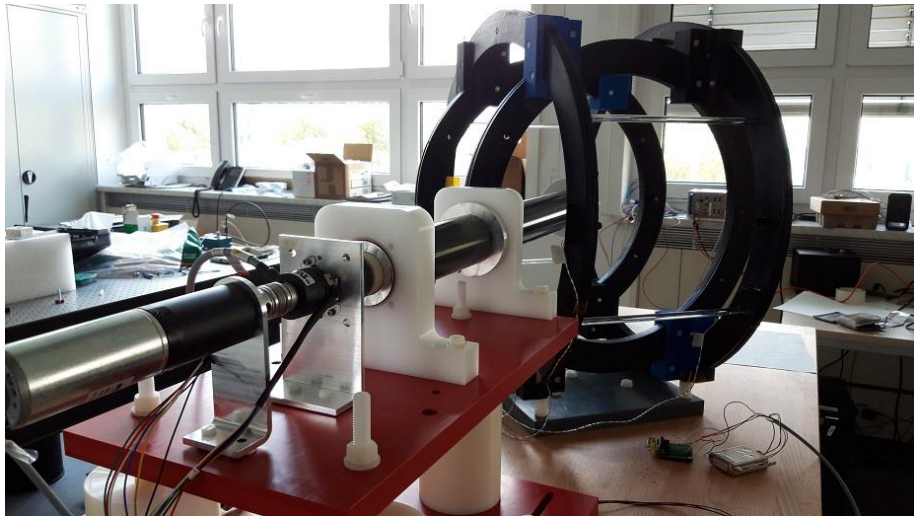
-> two 600mm and two 500mm Coil pairs

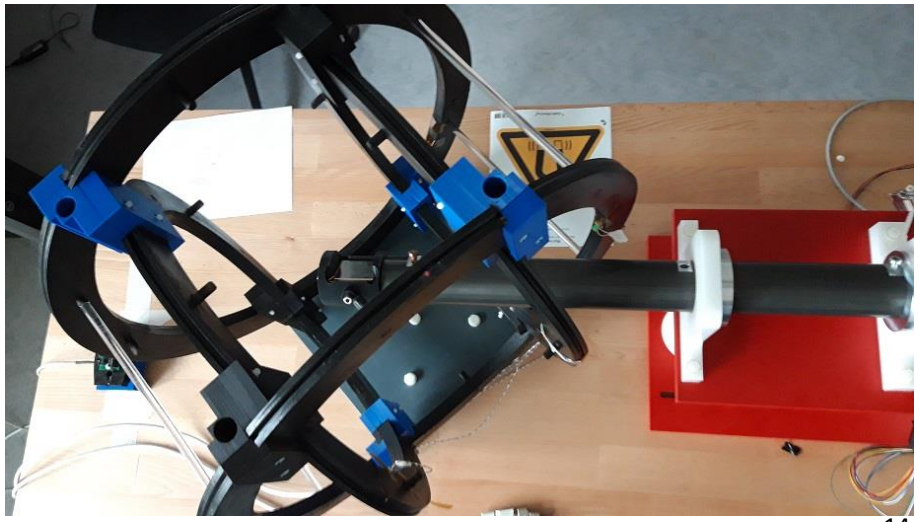
-> PM blocks will be rotated under 45° in the coil system

-> current/voltage measurement during rotation of the PMs



-> individual alignment test, magnetic field tests and PM tests are done





-> After the attack in June 2023, we had to stop the most work for more than 4 month

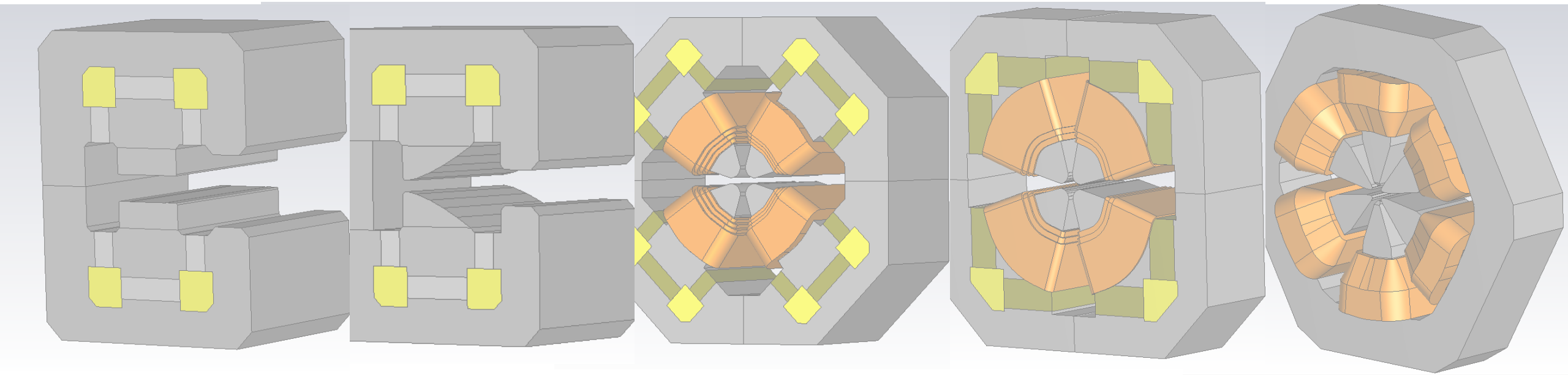
-> B2PT magnet work is ongoing (PM tests, Measurement system)
-> yoke and Corrector-Coils scheduled for January 24

-> first design ideas for a BessyIII superbend as 10keV source

-> next step: implementation in a first draft for the vacuum system and the radiation-extraction design

-> Start of the EU-Horizon project „RF2.0“ in January 2024 with three dedicated PM topics

summary



Thank you.

Partners:

ALBA

ELYTT ENERGY

KIT Karlsruher Institut für Technologie

MAX IV

PerMaLIC