Permanent Magnets program for PETRA IV

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DESY / FS-US

II. InnovEEA Project Meeting :   WP3 – Magnet Technology (Riccardo Bartolini)
10th November 2021

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

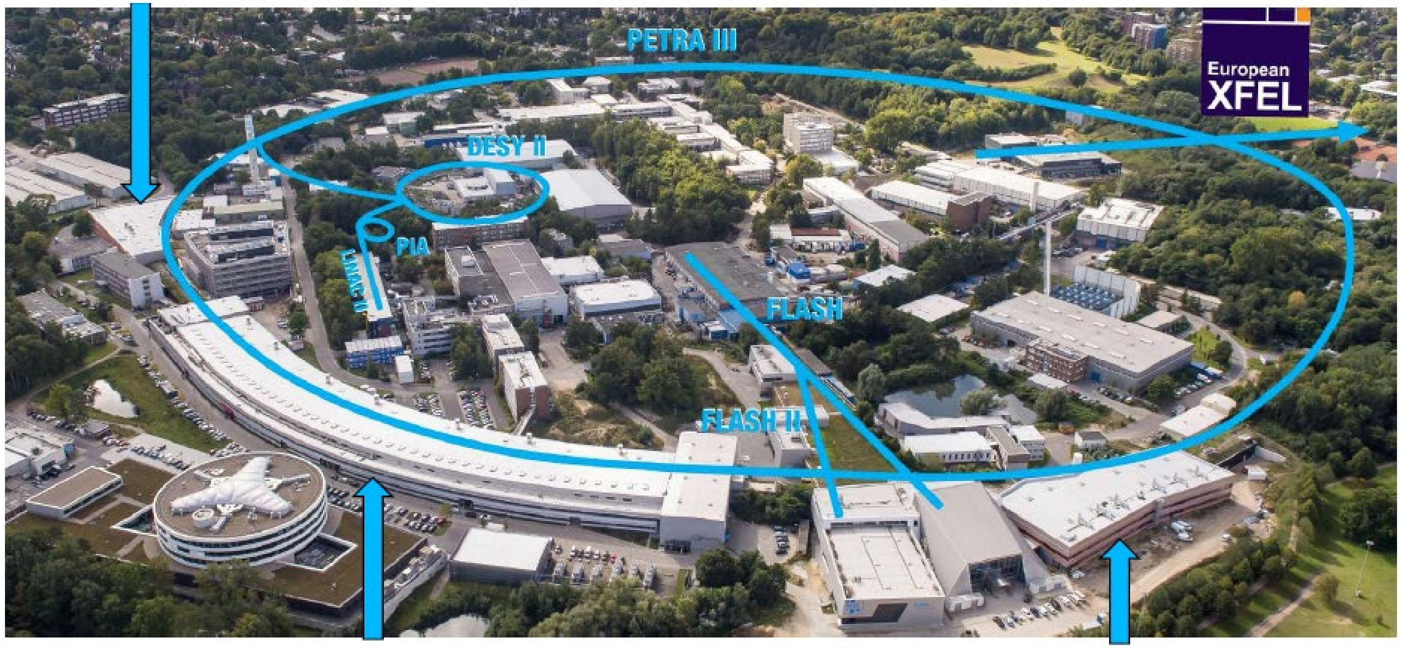
Outline

- Introduction and evolution of DL design
- Latest DLQ configurations
- Proposed DLQ design
- Present status and future tasks

PETRA III is one of the core facilities at DESY

Each year ~5000h users operation serve more than 2000 users

Ada Yonath Hall
Extension Hall East



Max von Laue Hall

Paul P. Ewald Hall
Extension Hall North

*Courtesy of **R. Bartolini***

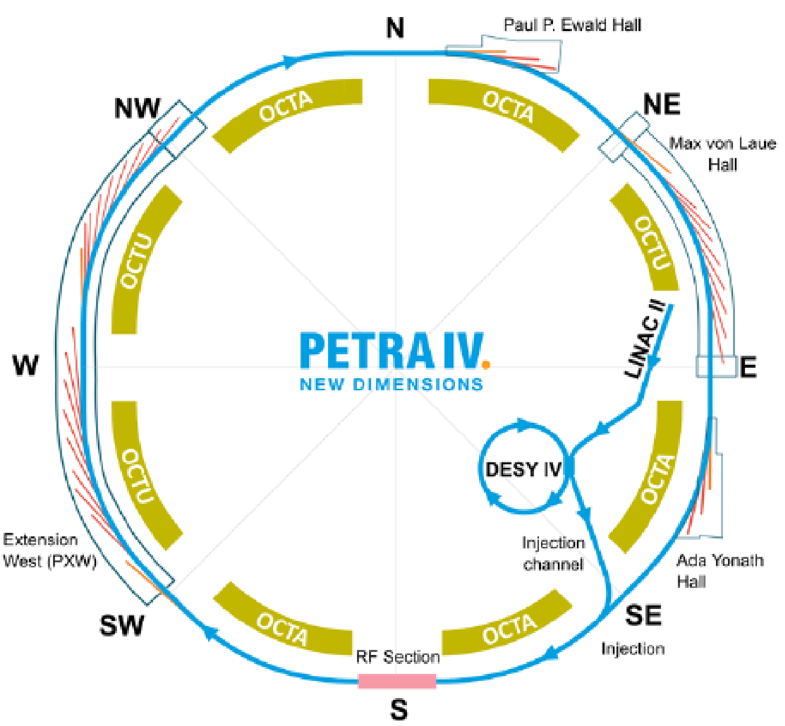
Parameter	PETRA III
Energy [GeV]	6
Circumference [m]	2304
Emittance (hor./vert.) [nm.rad]	1.3/ 0.013
Total current [mA]	100

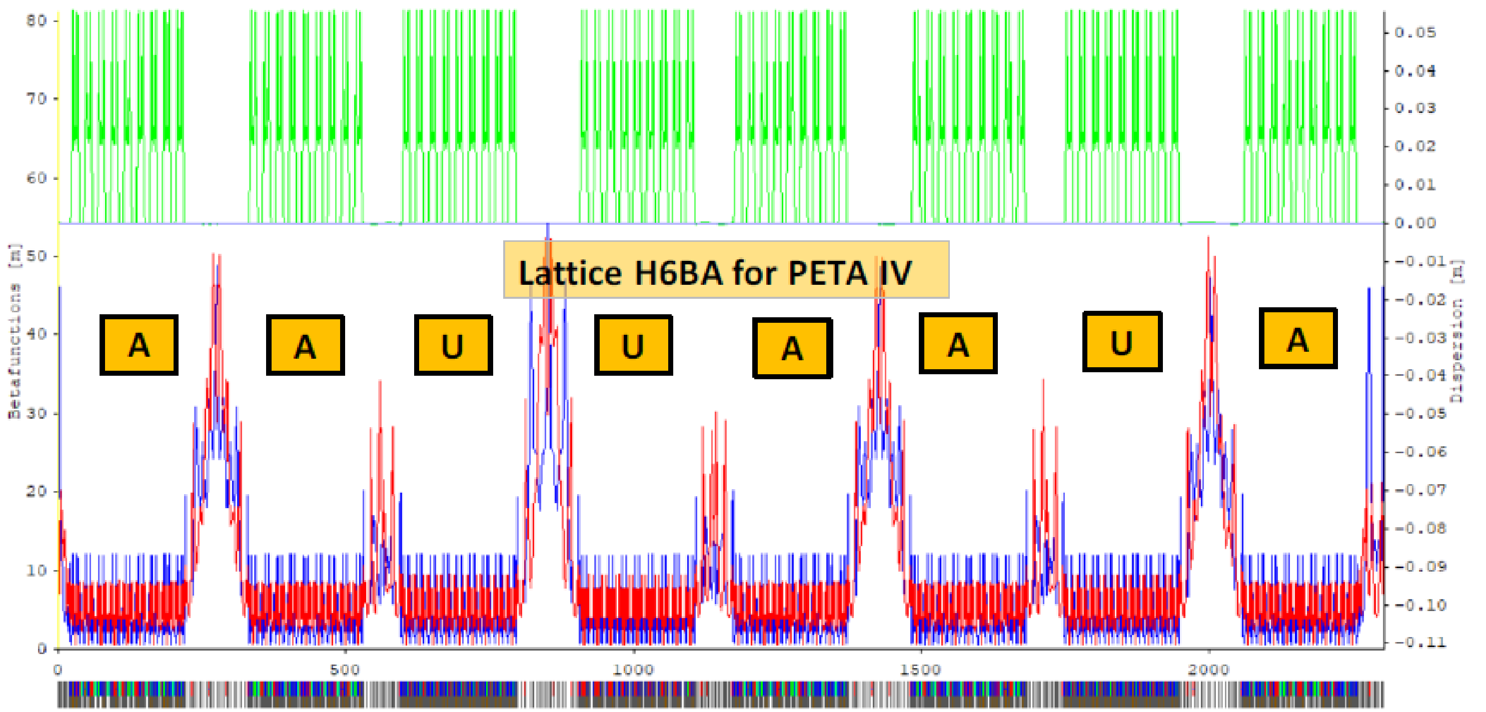
PETRA IV project:

replacing PIII with an ultra low emittance ring (20 pm) adding a new Experimental Halls in two more octants

A new lattice proposal was evaluated

There is a new lattice H6BA performing better than the previous one





Periods		1
Length	[m]	2304.00
Angle	[deg]	360.000
AbsAngle	[deg]	360.000
TuneX		135.182
TuneY		86.2357
ChromX		-233.07
ChromY		-156.91
Alpha	[xE-3]	0.033
Jx		1.24980
Energy	[GeV]	6.000
EmitXo	[nm rd]	0.019
dE/turn	[keV]	4090.7
Espread	[xE-3]	0.895
TauX	[ms]	18.039
TauY	[ms]	22.545
TauE	[ms]	12.881
EmitYo	[pm rd]	0.002
Location		START
Position	m	0.000
BetaX	m	46.148
AlphaX		0.0025
BetaY	m	6.838
AlphaY		0.0038
Disp.	m	0.0003
dD/ds	rad	0.0000

Courtesy of D. Einfeld

Based on H6BA cell – 8 octants with 9 cells each
Strongly favored as the present PIII-beamlines can be conserved

- In the octants “U” there is the lattice H6BA_23.00 m and in the octants “A” is the lattice H6BA_22.75 m (Same magnet arrangement, they only differ in the straight section length)
- There are overall 432 permanent Bendings, 1348 Quadrupoles, 432 Sextupoles, 286 Octupoles and 1126 Correctors. This makes overall 3626 magnets.
- In addition there are 40 damping wigglers in the octants A and 30 undulators for users in the octants U.

The H6BA outperforms the combi lattice

Justification and consequences of the changes investigated

H6BA lattice [9 cells per octant] vs combi lattice [modified H7BA 8 cells per octant]

Emittance kept to 20 pm albeit with a different concept,
Based on extensive use of DW in long straight sections (as now in PIII)

Pros

- Larger Dynamic Aperture (off axis injection and accumulation looks now feasible)
- Larger Momentum Acceptance (Touschek lifetime 2.5-fold improvement)
- More PM magnets (resistive DQs changed to PM based DQs – changed DLs to DLQs)
- Overall performance improved (sensitivity to errors and instabilities)
- One more beamline per octant
- Possibility of keeping the existing source point fixed in the Max von Laue Experimental Hall

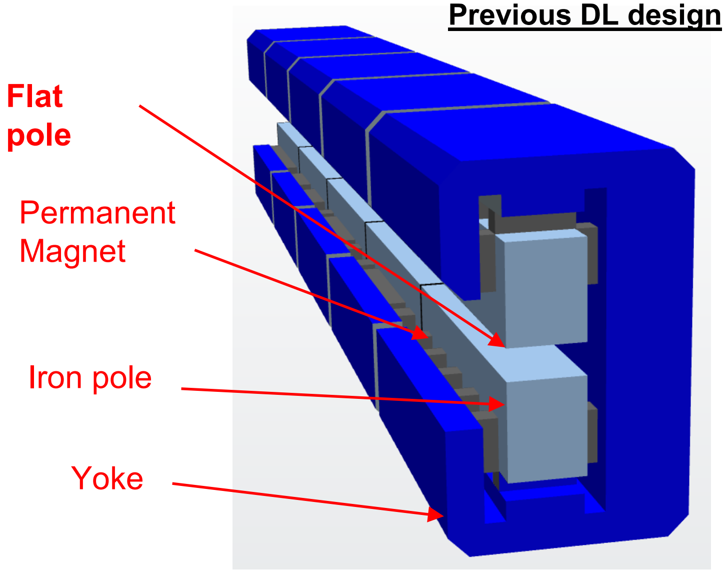
Cons

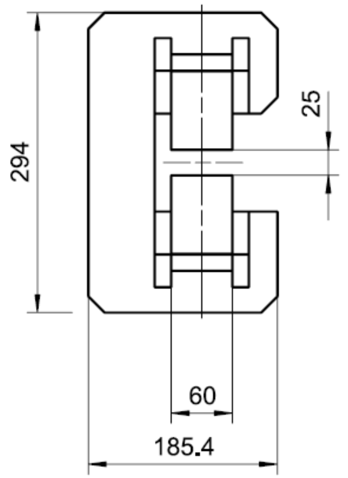
- Stronger focusing quadrupoles (max 115 T/m) but weaker sextupoles in dispersion bump
- Reduced straight section length 5.3 m to 4.7 m
- Reduced brightness, despite smaller and equal beta functions in the straight sections
- All bending magnets become more demanding combined-function magnets

Courtesy of R. Bartolini

Evolution of DL design

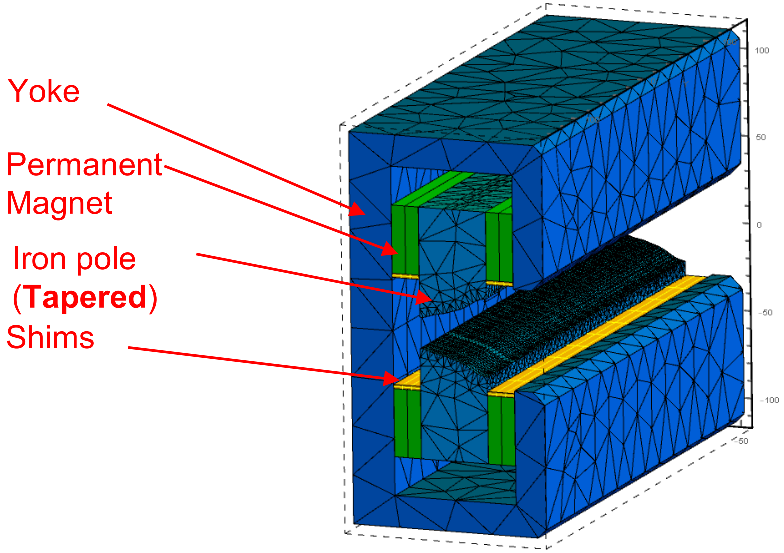
Previous DL design



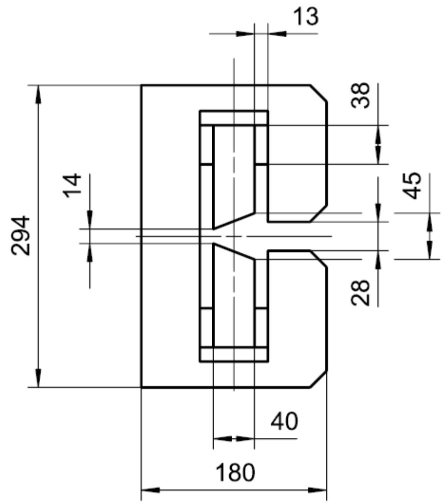


Cross section of the previous DL

Combi lattice
- Maximum field 0.38 T
- No transverse gradient
- "Flat" pole
- Uniform field along the transverse direction
- 2 types of DLs



New DLQ design



Cross section of the new DLQ

H6BA lattice
- Maximum field ~0.29 T
- Moderate transverse gradient ~11.7 T/m
- Tapered pole
- 3 types: 1 DLQ , 2 DQs

From the combi cell to H6BA cell

- 4 DLs and 3 central DQs substituted with 2 DLQs and 4 PM DQs
- Same cell structure replicated across all octants

Latest DLQ Configurations

Parameters for the 23m cell

	Element	Length (m)	Field (T)	Gradient (T/m)	x_0 = B/G (mm)
DLQ	DL1A_4	0.303	0.2771	-11.3144	24.5
	DL1A_3	0.303	0.2878	-11.7471	
	DL1A_2	0.303	0.2558	-10.4426	
	DL1A_1	0.303	0.2238	-9.1382	
DQ	DL2A	1.084	0.1907	-7.7184	24.7
DQ	DL3B	1.84	0.1901	-6.5972	28.8

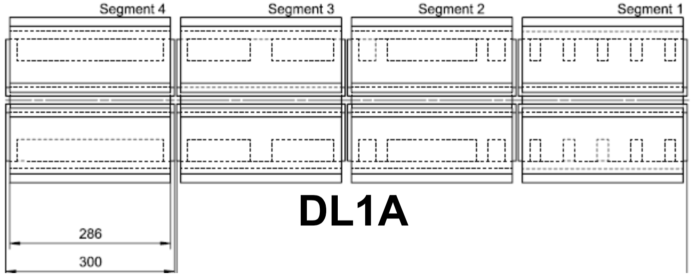
Difference to pure DLs (“Combi”)

- ~50% more PMs to build
- Modules are straight but must be placed on curve trajectory
- More challenging:
  - Magnetic and mechanical design
  - Measurement concept (curved)
  - Tuning and alignment

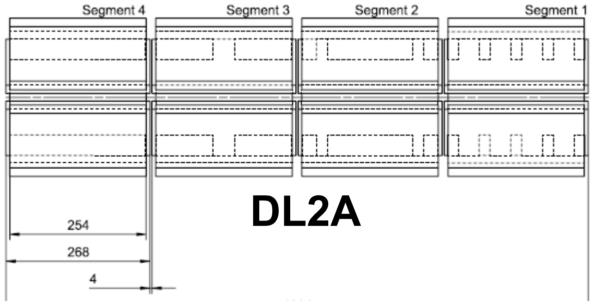
Intermediate Design for 26m H6BA cell: ✓

- Maximum gradient -9.7 T/m, achievable with previous 2-pole design
- 3 types of DLQs with same G/B
- Same modules length 0.414 m for all

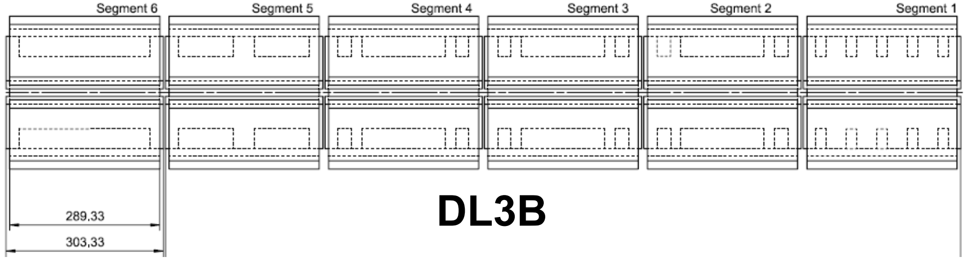
- Maximum gradient -11.7 T/m
- 50% higher G/B compared to “26m-version”
- Gradient hardly achieved (at the limit for a tapered 2-pole design)
- 3 types of DLQs (DQs), 432 magnets in total
- Different module length for each DLQ
- DL2A and DL3B will be split to 4 and 6 modules each



DL1A



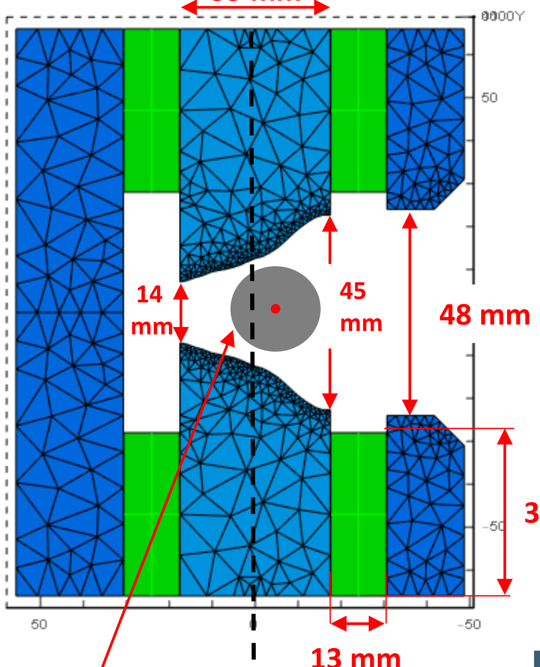
DL2A



DL3B

Proposed DLQ Design

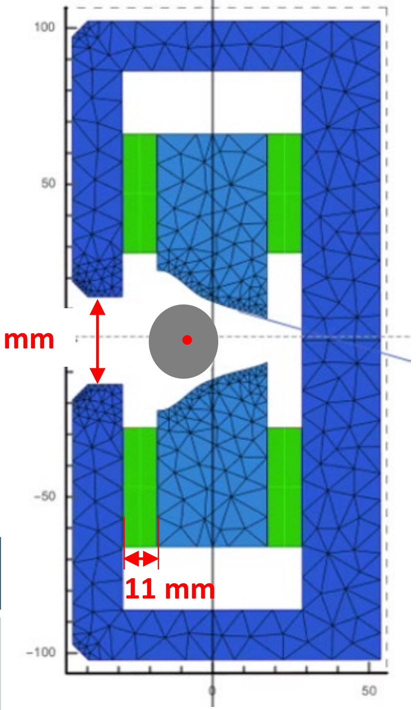
Open structure



Off axis vacuum chamber by 5 – 6 mm (ϕ 25 mm)

- GFR center: **-5.1 mm** with a range of **11 mm**
- Field and gradient at center of GFR: **0.334 T – 13.65 T/m**
- Gradient homogeneity ΔG/G0 in GFR: **0.000228**
- Pole Gap at center of GFR: **30 mm**
- Outer diameter of vacuum chamber: **25 mm**

Structure with yoke



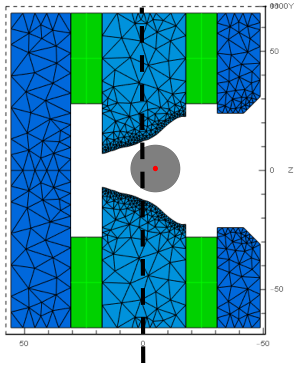
28 mm

- GFR center: **-6.3 mm** with a range of **10 mm**
- Field and gradient at center of GFR: **0.31 T – 12.68 T/m**
- Gradient homogeneity ΔG/G0 in GFR: **0.00036**
- Pole Gap at center of GFR: **32 mm**
- Outer diameter of vacuum chamber: **25 mm**

	Open structure	Structure with yoke
Advantages	- Good field quality enhanced - Larger GFR and center close to geometrical axis - More degree of freedom for tuning - Compactness - Larger opening for vacuum chamber	- Good feedback from ESRF-DL experience (measurement, thermal shimming…) - Less challenging in terms of mechanical assembly - Less sensitive to ambient field changes
Drawbacks	- Mechanical magnet assembly more challenging : assembly errors, magnetic forces… - Higher sensitivity to magnet block errors - Field tuning needs to be revisited due to decoupled poles - More sensitive (magnetic behavior)	- Tighter opening for Vacuum chamber - Smaller GFR (present optimization state)

Preliminary Results

Open structure



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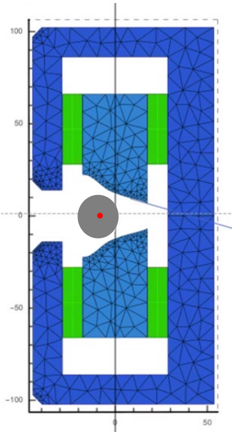

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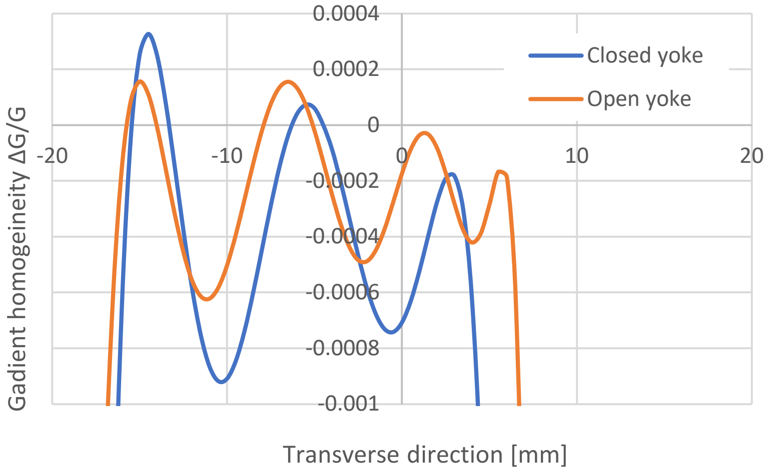

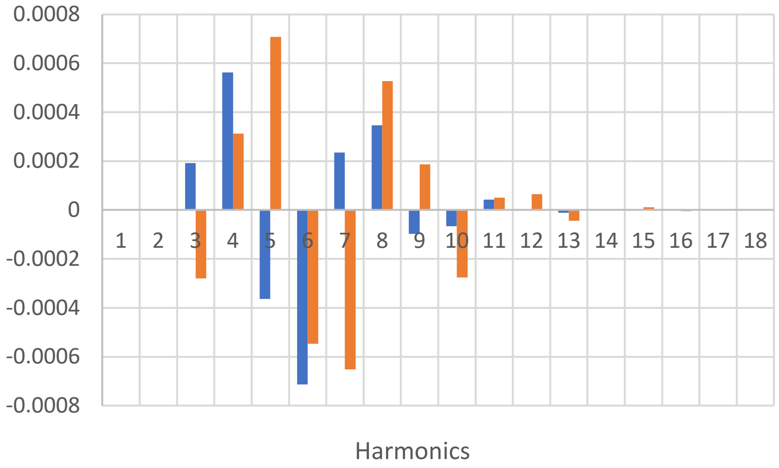

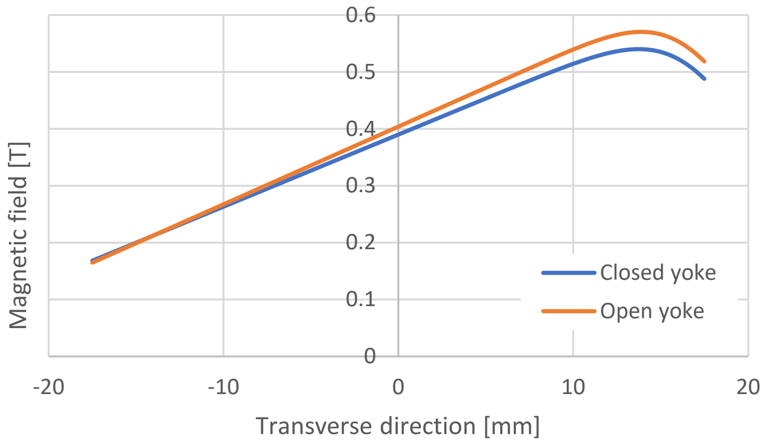

Present status and future tasks

Design status

- 1st solution (2D) achieved in August 2021
- Present preliminary results of new DLQs are promising
- Mechanical design can start with some overlap to magnetic refinement
- Collaboration with ESRF is well established
- Schedule for the WP needs adjustment due to lattice change

Next Tasks

- 3D model needs to be worked out
- Cross-talk, magnetic and mechanical error assessments
- Launch prototype(s)
- Elaborate alignment concept
- Develop assembly and measurement procedures
- Work out logistics for production phase

Personnel

- InnovEEA-related PostDoc will start soon (Nov.21)

Thank you for your attention!