EDIPO: Comparison of the proposed designs

X. Sarasola

SWISS PLASMA CENTER

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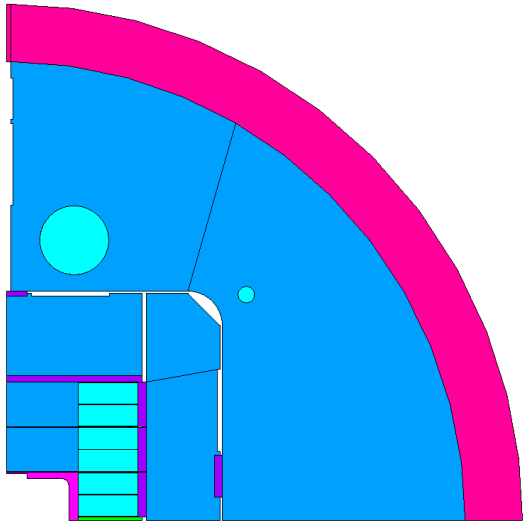
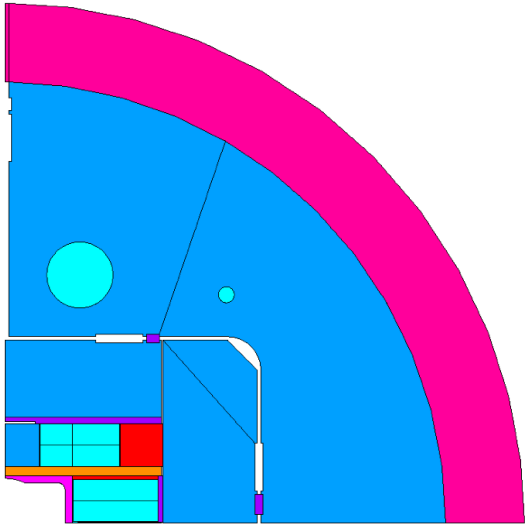
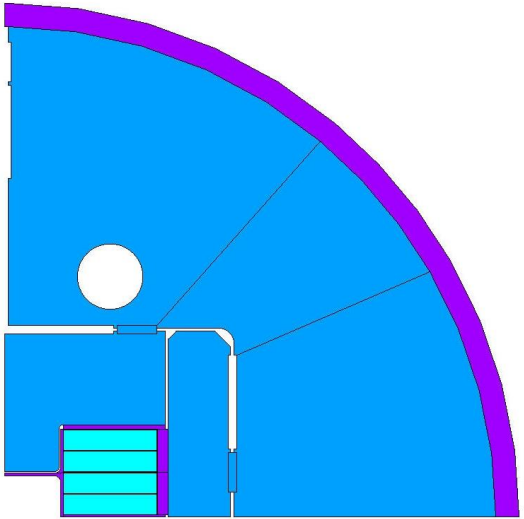
3 alternative designs of EDIPO

X. Sarasola

- Baseline design
- 4 staggered coils
- 4 aligned coils







Basic features

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	Baseline	4 staggered coils	4 aligned coils
Number of coils	6	4	4
Winding poles	Bonded	Bonded	Detachable
Ti pole	Yes	Yes	No
Mechanical structure	Shell based + keys and bladders	Shell based + keys and bladders + buffer steel plate btw coils	No pre-compression
Outer diameter	1260 mm (LD1)	1320 mm (max allowed by cryostat)	1320 mm (max allowed by cryostat)
Aperture	Rectangular 94×144 mm + Circular 106 mm diam	Rectangular 94×144 mm + Circular 106 mm diam	Rectangular 106×144 mm

Comparison of parameters (1/3)

	Baseline	4 staggered coils	4 aligned coils	Units
Operating current, I_{op}	14.00	14.43	11.53	kA
Total ampere-turns, I_{total}	5.38	5.14	4.71	MAt
B field in the aperture center, B_{center}	15.05	14.95	15.02	T
Peak field in the winding pack, B_{peak}	15.45	15.32	15.97	T
% of short sample limit at 4.2 K, I_{op}/I_{ss}	85%	85%	85%	%
% of critical current, I_{op}/I_c	45.5%	45.3%	42.6%	%
Temperature margin, ΔT_m	2.28	2.32	2.28	K
Total stored energy in the magnet, E_{total}	12.7	11.8	11.7	MJ
Magnet self inductance, L	129.6	113.3	175.9	mH
Current density insulated conductor, j_{eng}	224.0	230.8	184.5	A/mm^2
Copper current density, j_{Cu}	669.6	690.2	551.6	A/mm^2

Comparison of parameters (2/3)

	Baseline	4 staggered coils	4 aligned coils	Units
Winding type	Double pancake	Double pancake	Double pancake	
Number of coils, N_{coils}	6	4	4	
Number of turns per pancake, $n_{turns,pan}$	32	46/43	51	
Total number of turns, $n_{turns,total}$	384	356	408	
Turn insulation thickness, t_{ins}	0.2	0.2	0.2	mm
Ground insulation thickness, t_{ground}	0.5	0.5	0.5	mm
Cross-section of insulated conductor, $A_{cond,ins}$	24004	22254 (-7%)	25504 (+6%)	mm^2
Required cable length (whole magnet), L_{cable}	1683	1549 (-8%)	1758 (+4%)	m

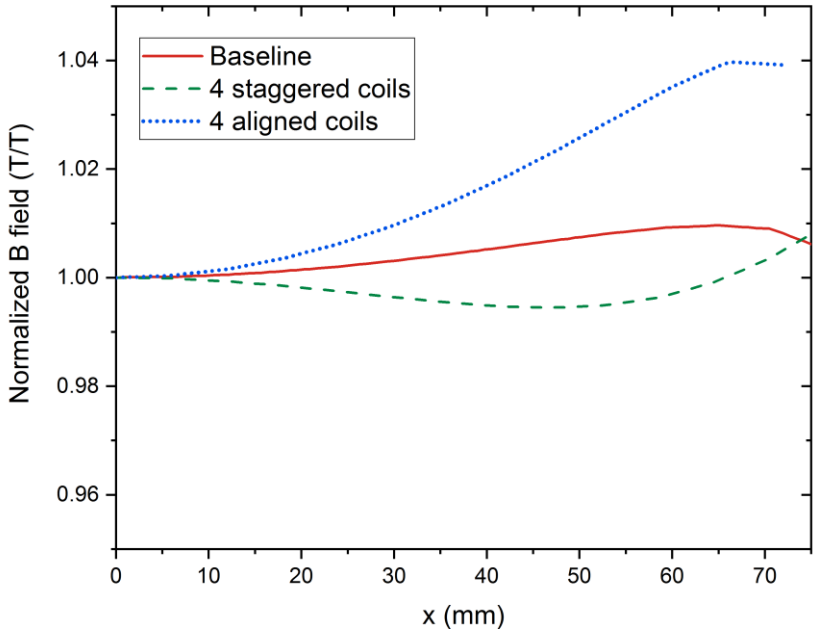
Comparison of parameters (3/3)

		Baseline	4 staggered coils	4 aligned coils	Units
Total Lorentz force in the coils	$F_{x,coils}$	14.48	13.35	11.83	MN
	$F_{y,coils}$	-5.60	-6.14	-5.72	MN
	$F_{z,coils}$	1.81	1.17	1.51	MN
Peak coil von Misses stress, $\sigma_{max\ coil}$		160	120 / 130	121	MPa
Magnetic field at the location of peak von Misses stress in the coil, $B_{\sigma max}$		15	12 / 8	5.02	T
Von Misses stress in the region of peak B field, σ_{Bmax}		160	70	76.5	MPa
Maximum coil horizontal displacement at nominal field, d_{max}		0.6 / 0.55 / 0.45	0.84 / 0.74	1.3	mm

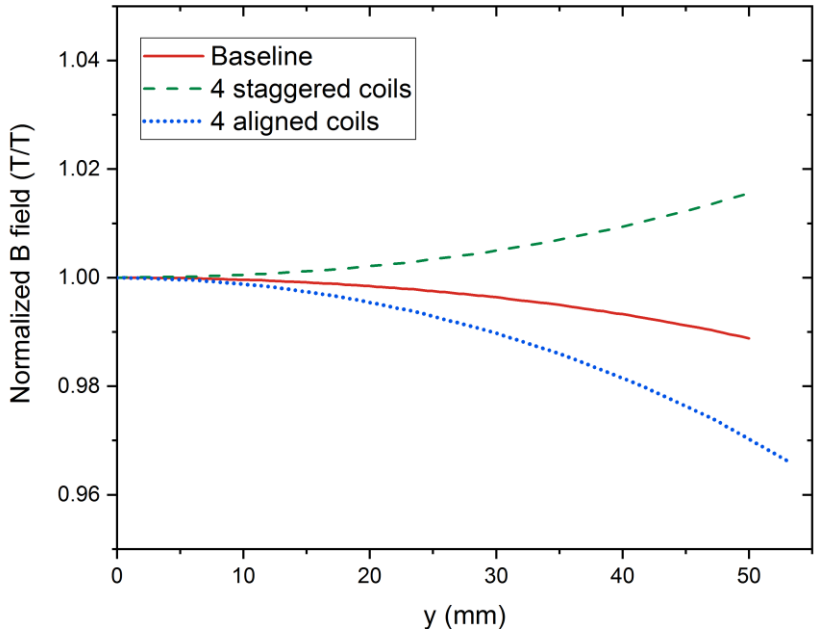
Field quality (1/2)

- Functional specification:
  - Uniformity along x and y axis: ±1%
  - Homogeneous field length along z: 1000 mm

Field in the aperture along the x axis



Field in the aperture along the y axis



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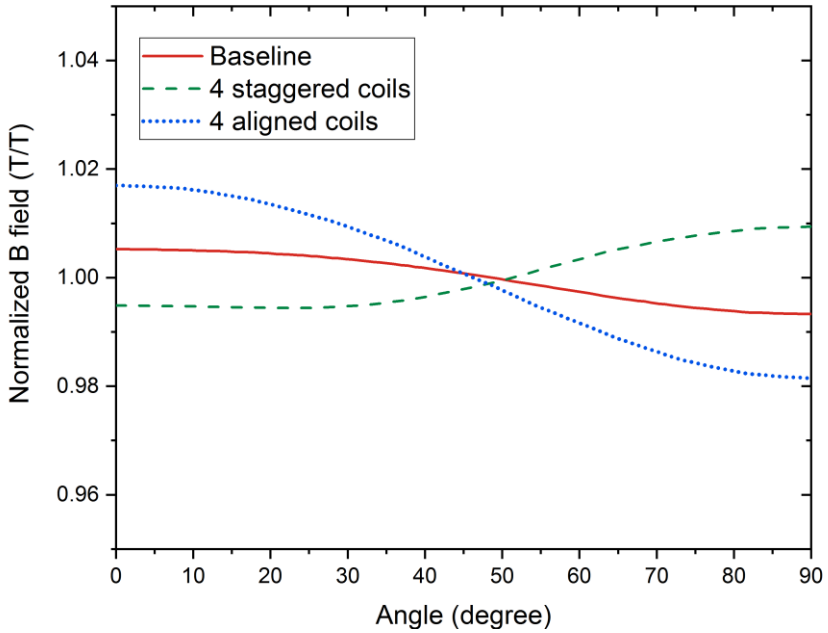
Field quality (2/2)

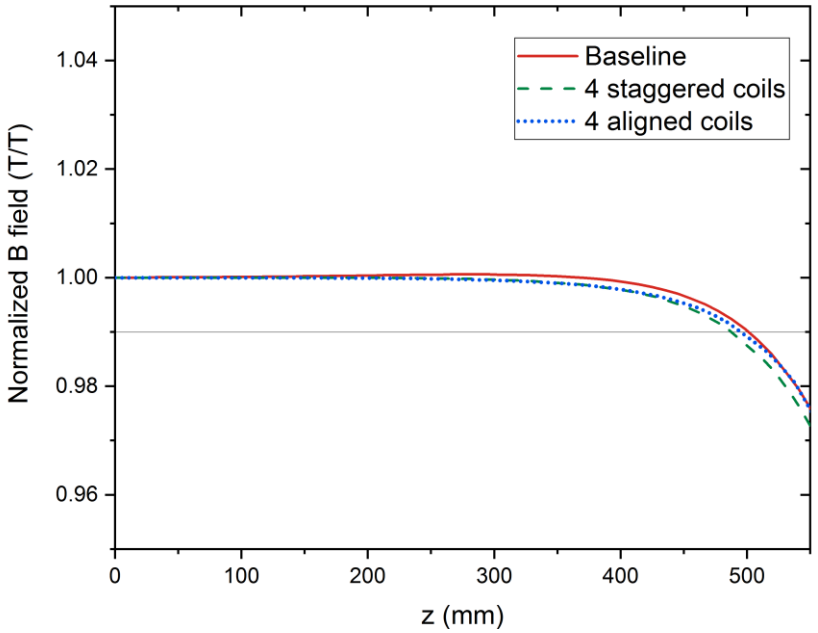
- Functional specification:
  - Uniformity along x and y axis: ±1%
  - Homogeneous field length along z: 1000 mm

Homogeneous field length (mm)	
Baseline	1001
4 staggered coils	973
4 aligned coils	989

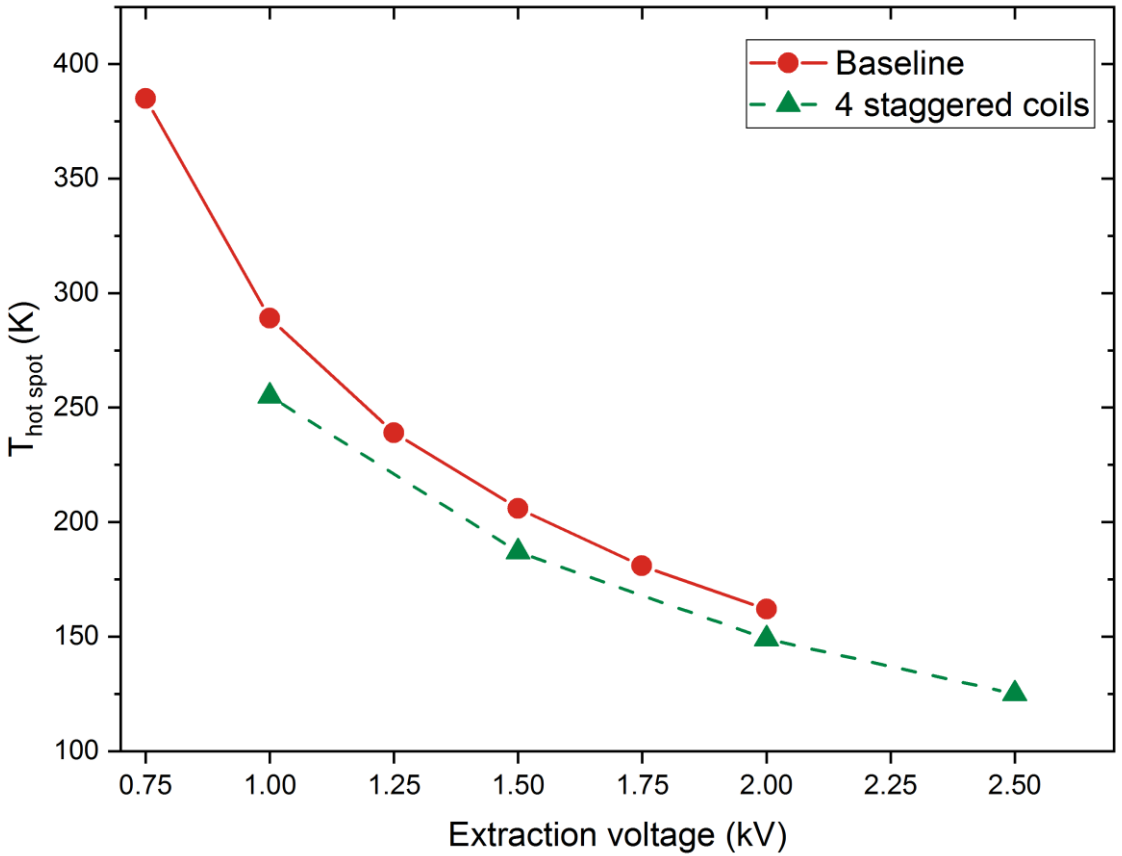
Field around R_{ref} = 40 mm



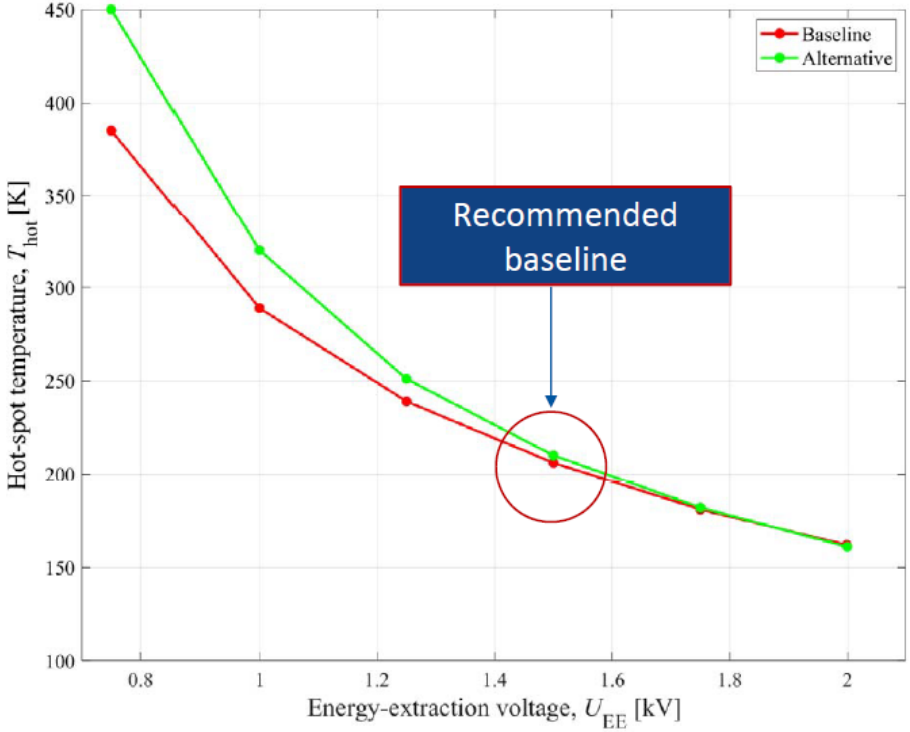
Field along the z axis



Quench analysis



Protection: baseline and alternative design



Small difference between quench protection performance for U_{EE}=1.5 kV

Thanks to E. Ravaioli

Additional considerations

- All 3 designs satisfy the functional specification
- No showstoppers found based on the performed analyses
- **Small differences** among the 3 designs:
  - **Margin in terms of I_{op}/I_c**: slightly larger for the **4 aligned coils**
  - Stress in the coils is low in all 3 designs.
  - **Field quality:** best in the current **baseline**
  - **Required conductor length: 1.7 km** (-8%/+4% depending on the option)
- **Baseline and 4 staggered coils:**
  - Rely on bonded contact between pole and coil
- **4 aligned coils:**
  - A **R&D program** is launched at CERN to study detachable poles in short racetrack coils.
- **Coil fabrication and tooling:**
  - The manufacturer has expressed **preference for a 4 coil design**.