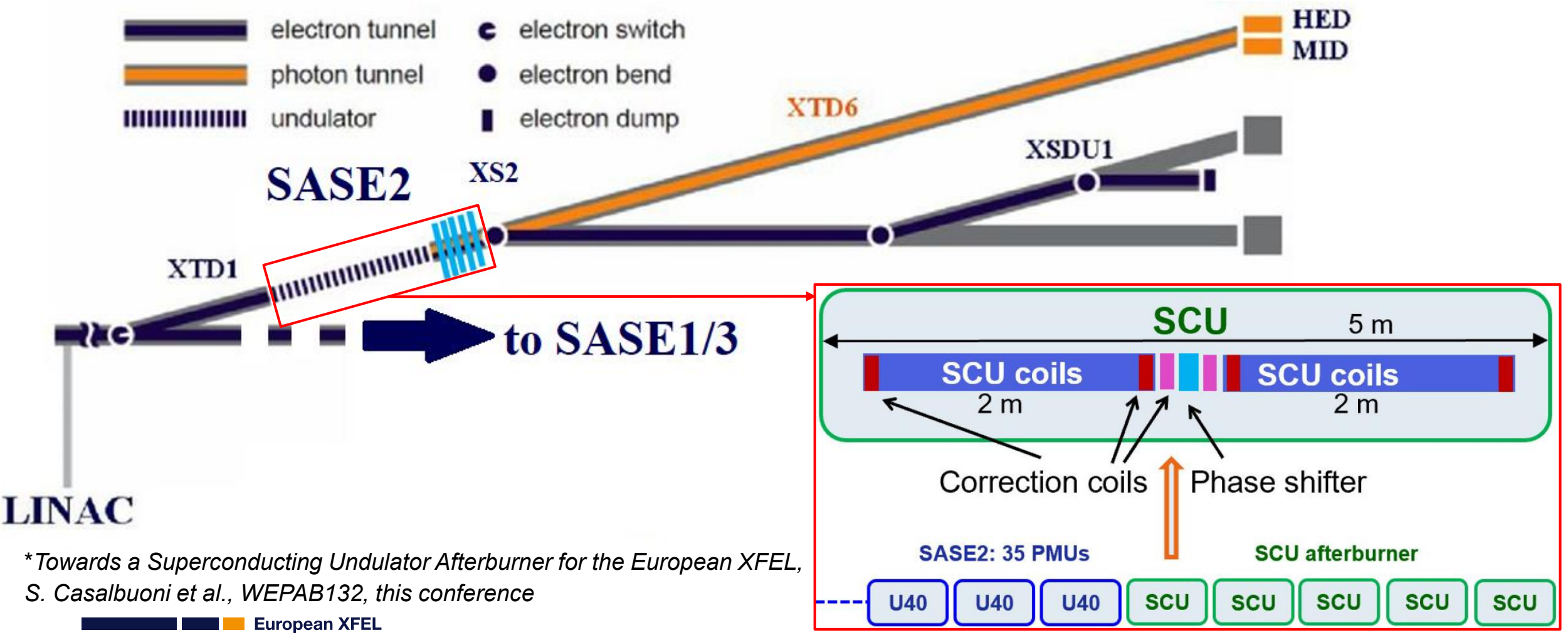
THPAB036

Superconducting Phase shifter design for the afterburner at the European XFEL

Authors: V. Grattoni, J. E. Baader, S. Casalbuoni

Abstract: At the European XFEL, a superconducting afterburner is under design for the SASE2 hard X-ray beamline. It will consist of 5 undulator modules. One module corresponds to two superconducting undulator (SCU) coils of 2 m length plus one phase shifter. Such an afterburner will enable photon energies above 30 keV. Superconducting (SC) phase shifters will be installed in each undulator module to keep the correct phase delay between the electron beam and photon beam. In this contribution, we present the required SC phase shifter parameters to enable operation in the electron beam energy range 11.5-17.5 GeV. We also analyze different magnetic designs satisfying the calculated specifications.

The Afterburner* at the European XFEL

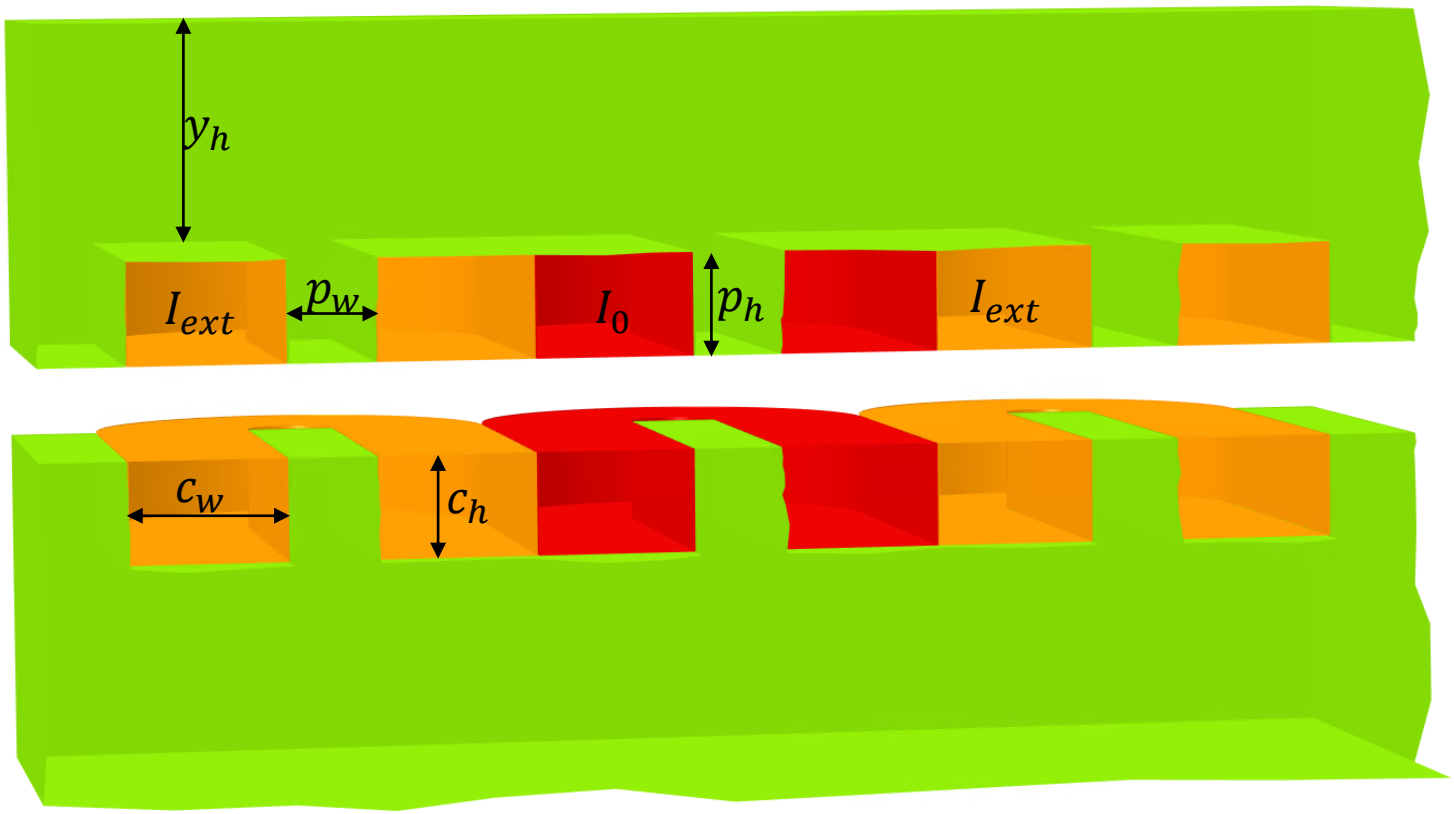


*Towards a Superconducting Undulator Afterburner for the European XFEL, S. Casalbuoni et al., WEPAB132, this conference

Superconducting Phase Shifter Specifications

- Needed phase integral of $\mathrm{PI} \geq 1.5 \times 10^{-5}\, T^2 m^3$ for continuous tunability in the photon energy ranges 28 -100 keV and 12.3 - 60 keV for the electron beam energy of 17.5 GeV and 11.5 GeV respectively
- In order to have a compact magnetic structure, the magnetic length of the phase shifter should be minimized
  - We define the magnetic length to include all magnetic fields except for $1.5 \times 10^{-4}\, Tm$ of first field integral at each end of the phase shifter
- The interference with the magnetic field of the undulators should be avoided
- To limit the heat load from the current leads, a maximum current of $I_w = 20\ \mathrm{A}$ is considered
- First field integral $I_1 < 1.5 \times 10^{-4}\, Tm$ and second field integral $I_2 < 10^{-4}\, Tm^2$ at the exit of the phase shifter

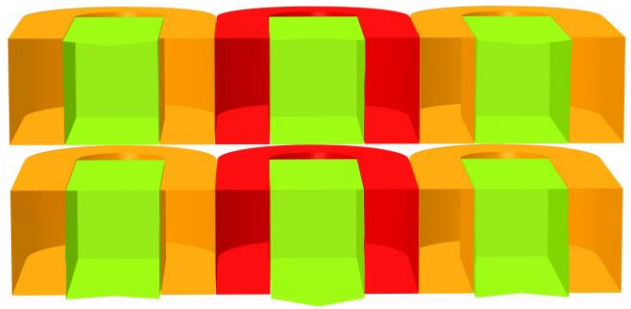
Phase Shifter Geometry



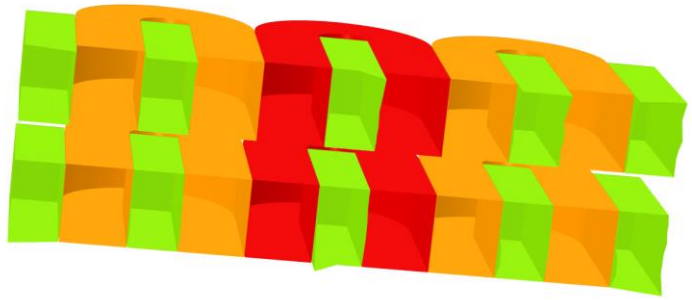
- y_h: yoke height
- p_w: pole width
- p_h: pole height
- c_w: racetrack width
- c_h: racetrack height, it is equal to p_h
- I_{ext}, I_0: respectively current in the external and central racetrack
- The racetracks are build from an insulated round wire with a total diameter (conductor+insulation) of $0.254\ mm$

Simulated Designs

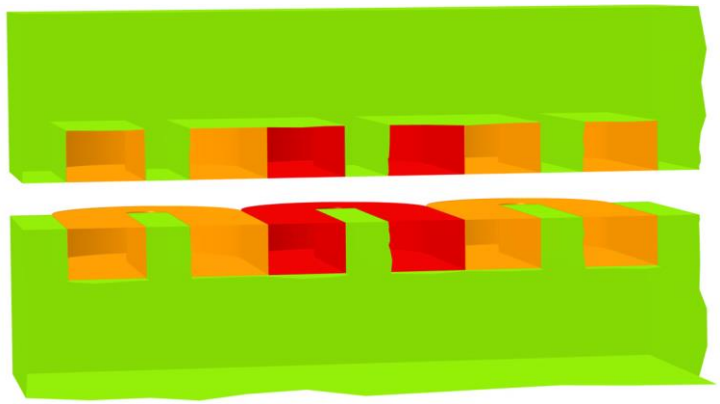
CASE 1



CASE 2



CASE 3



	N_{turns}	c_w $[mm]$	c_h $[mm]$	p_w $[mm]$	y_h $[mm]$	I_0 [A]	I_1 [A]	Mechanical length [mm]	Magnetic length [mm]	PI $[T^2m^3]$
Case 1	1733	7.112	13.892	12.176	–	20	6.527	80	168	1.520×10^{-5}
Case 2	2173	10.16	12.132	7.608	–	20	7.654	100	158	1.539×10^{-5}
Case 3	1185	10.16	6.633	5.608	15	20	7.72	90	80	1.616×10^{-5}

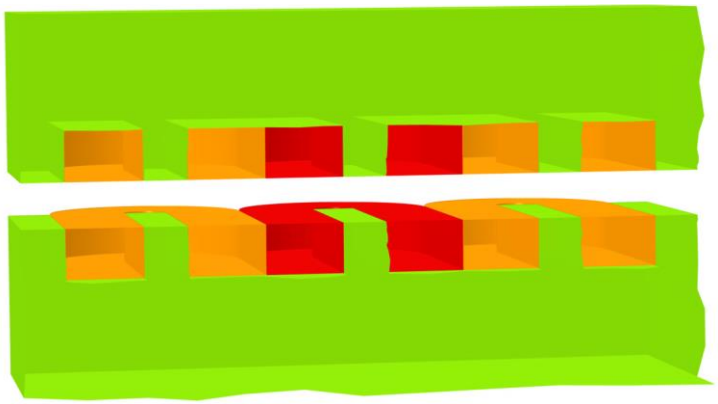
N_{turns}: total number of wire turns in the racetrack

Simulated Designs

CASE 4

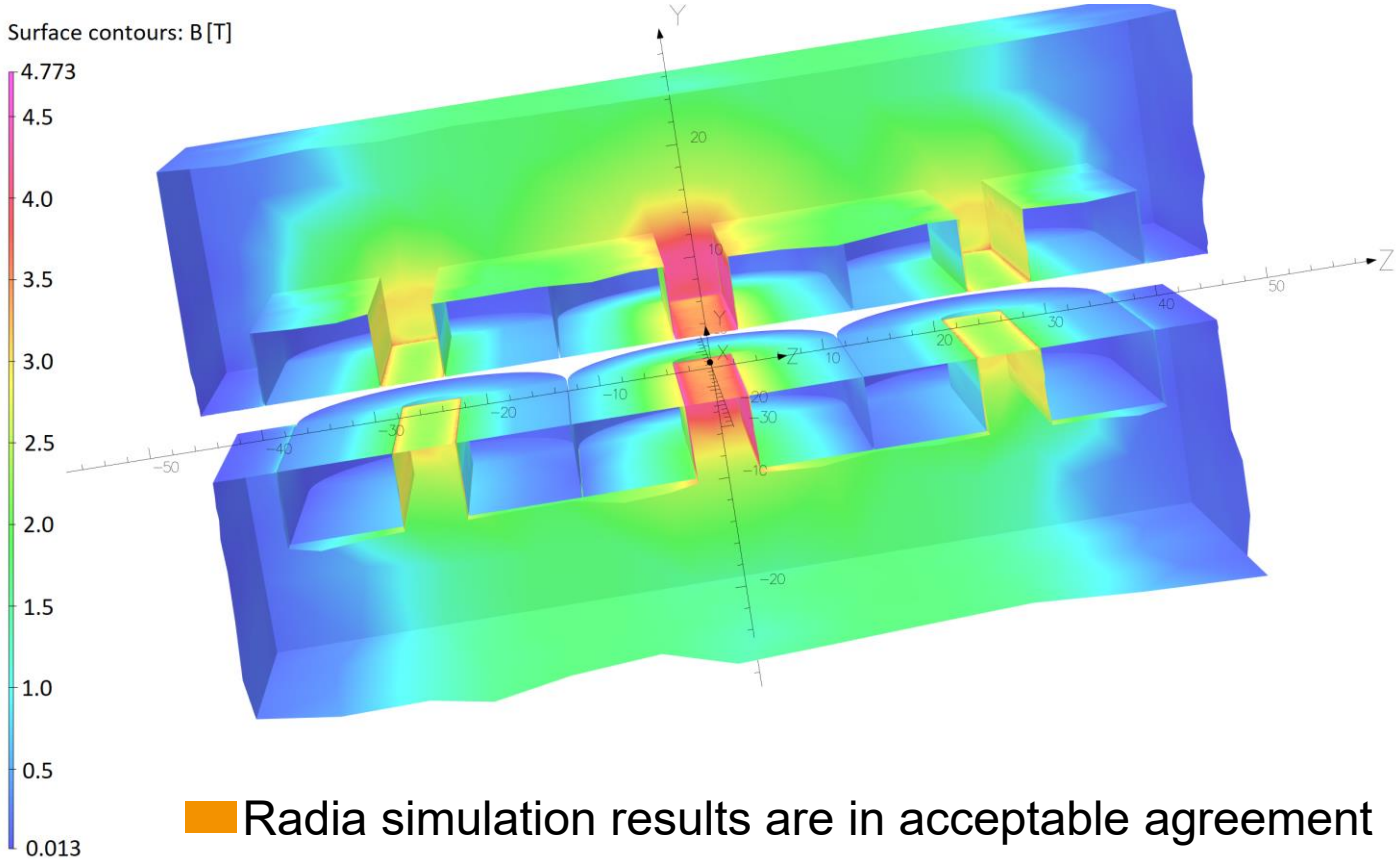
CASE 5

CASE 3



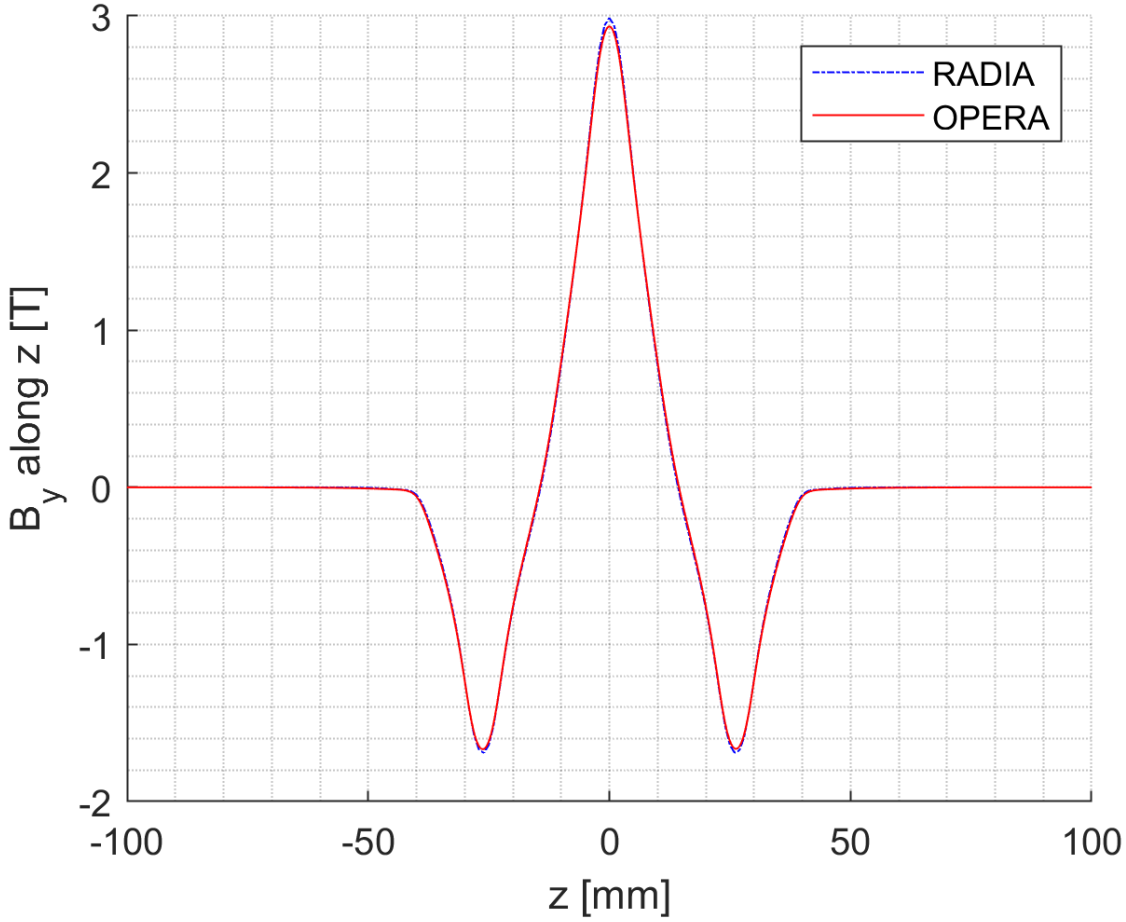
	N_{turns}	$c_w\ [mm]$	$c_h\ [mm]$	$p_w\ [mm]$	$y_h\ [mm]$	$I_o\ [A]$	$I_1\ [A]$	Mechanical length [mm]	Magnetic length [mm]	$PI\ [T^2m^3]$
Case 4	1185	10.16	6.633	–	–	20	10	78.584	146	3.136×10^{-6}
Case 5	2780	13.97	11.252	–	–	20	10	93.62	202	1.502×10^{-5}
Case 3	1185	10.16	6.633	5.608	15	20	7.72	90	80	1.616×10^{-5}

Magnetic Properties of the Selected Case



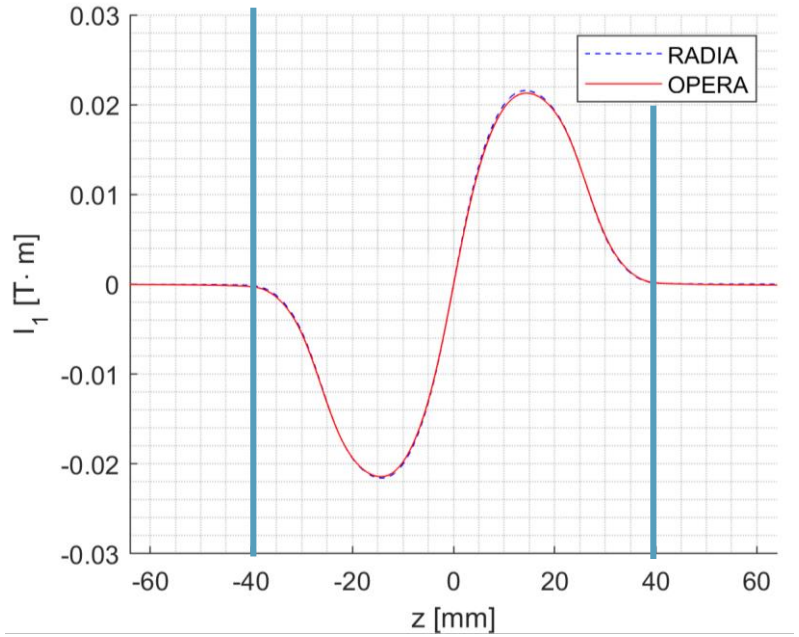
- Radia simulation results are in acceptable agreement with the OPERA-3d outcome

y-projection of the magnetic field along z

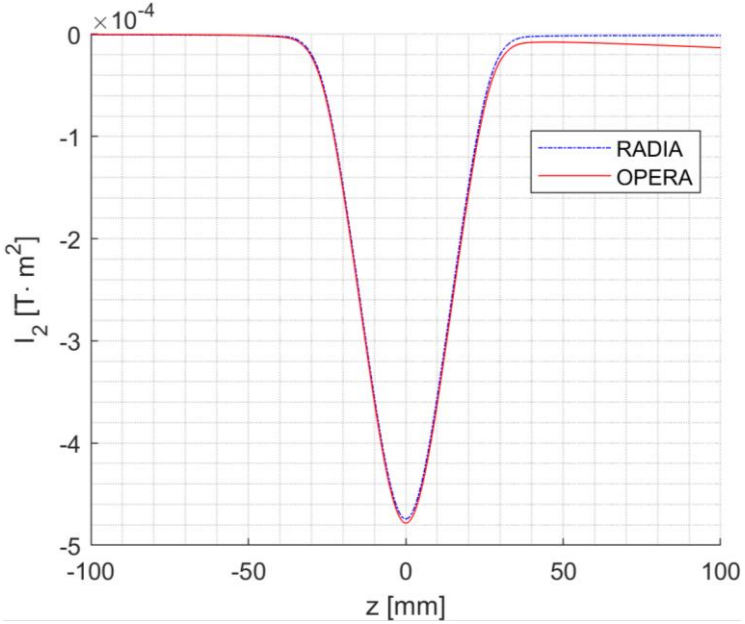


Field Integrals and Phase Integral

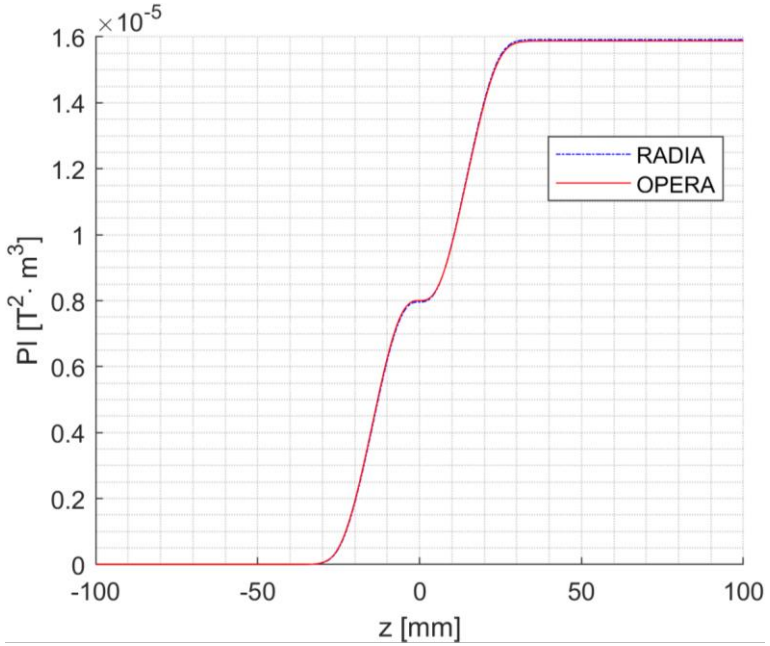
First field integral



Second field integral



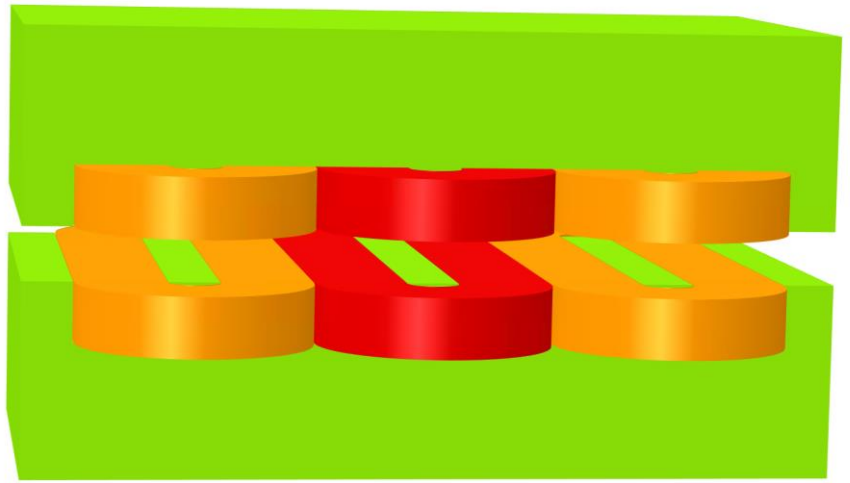
Phase integral



magnetic length: $80\ mm$

Conclusions

- The SCU afterburner under investigation at the European XFEL is characterized by five cryomodules (cryostats). Within each module there are two SCU coils, correction coils and a SC phase shifter
- The best design in terms of compactness and magnetic length is:
  - magnetic length: $80\ mm$
  - mechanical length: $90\ mm$



- The requirements for the phase shifter have been achieved:
  - $I_1 < 1.5 \times 10^{-4}\ Tm$ and $I_2 < 10^{-4}\ Tm^2$
  - $\mathrm{PI} \geq 1.5 \times 10^{-5}\ T^2 m^3$
- The contribution of the iron in the design is fundamental to confine the magnetic field, therefore reducing the magnetic length and helping to keep a moderate number of wire turns