

Hybrid FCaI magnetic shielding for crystals

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Hybrid FCal Design

Hybrid FCal design:

- Insert crystals to the central part of FCal (aka HCal)

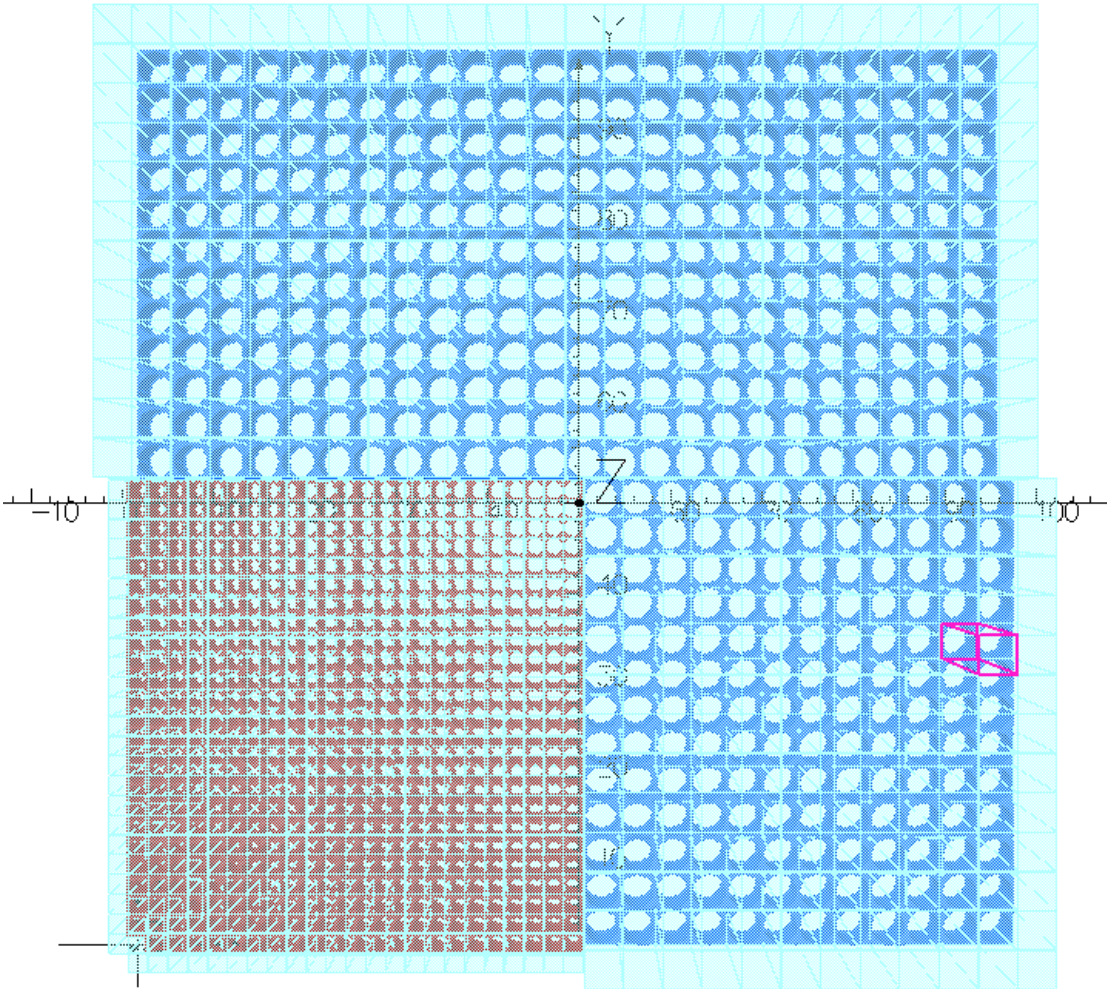
"crystals" part is $\sim 1 \times 1 \text{m}$

Crystal size: $2.05 \times 2.05 \times 18 \text{cm}$

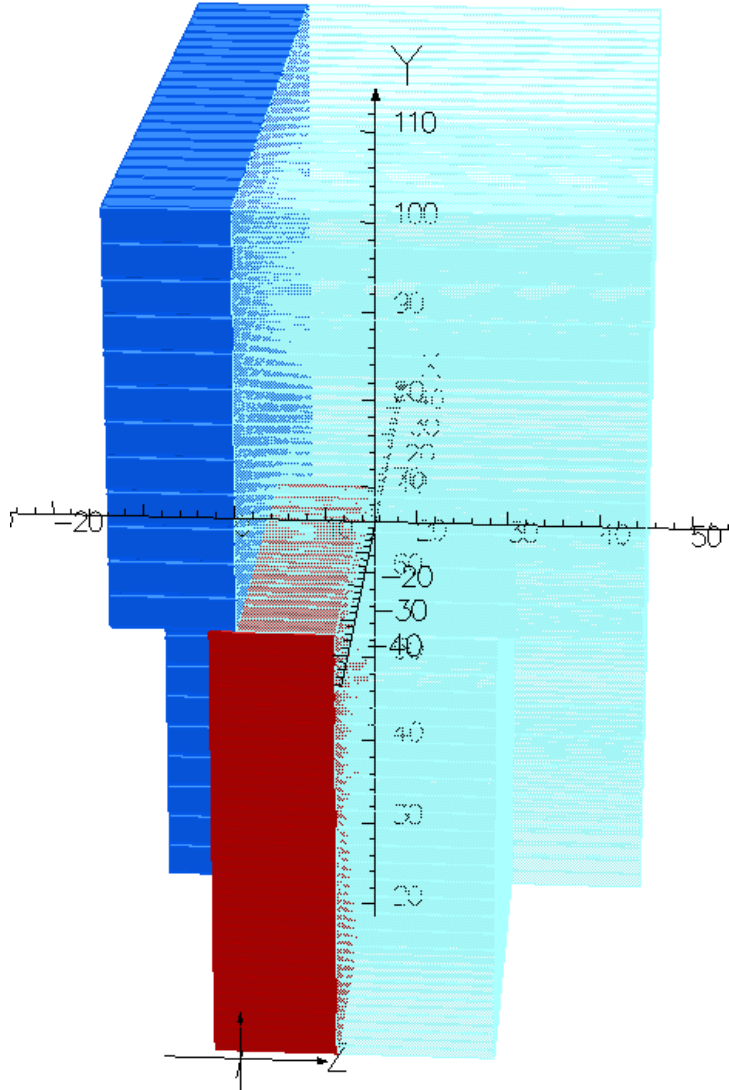
Magnetic field in the Hall D (measurements from Simon Taylor)

| Z, cm | R, cm | H _z , Oe | H _r , Oe | Comments |
|-------|-------|---------------------|---------------------|-----------------|
| 608 | 2 | 110 | 2 | Face of TOF |
| | 50 | 95 | 33 | |
| 670 | 2 | 54 | 0 | Back of FCal |
| | 50 | 50 | 13 | |

Hybrid FCal Quarter



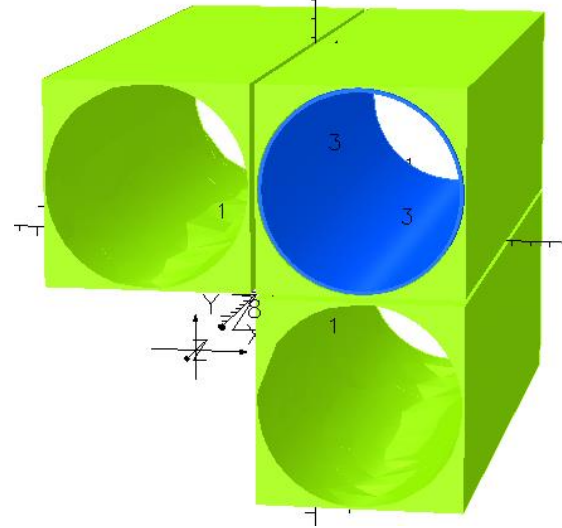
TOSCA can't calculate full scale model!



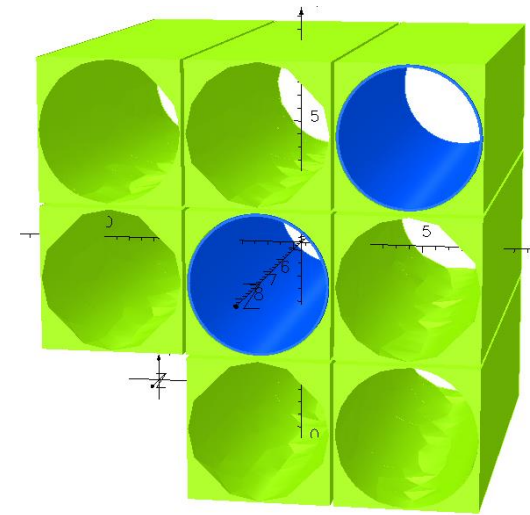
Models to Compare

Green - AISI-1010
Blue - Co-Netic

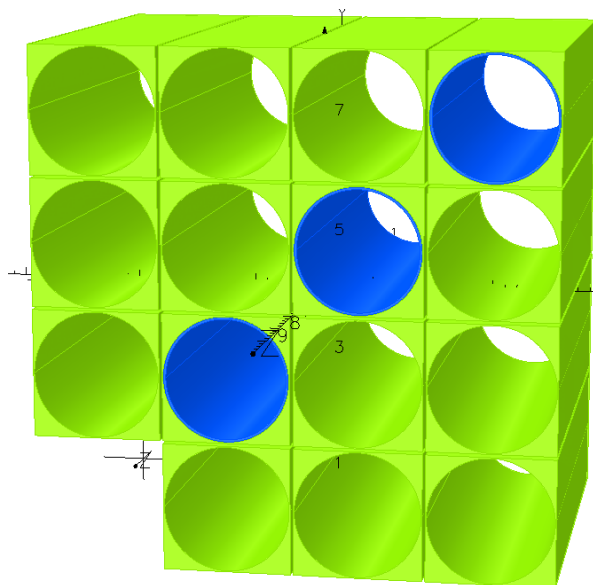
2X2



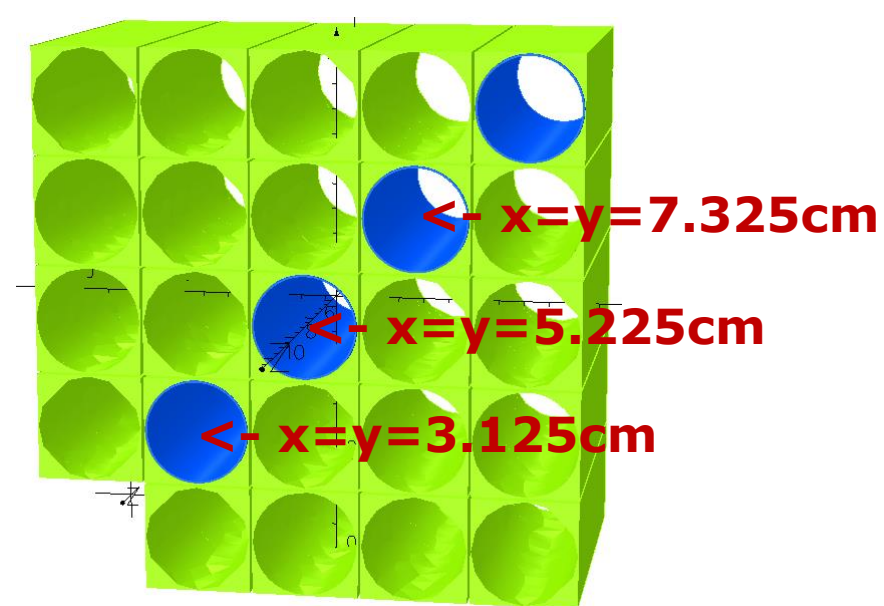
3X3



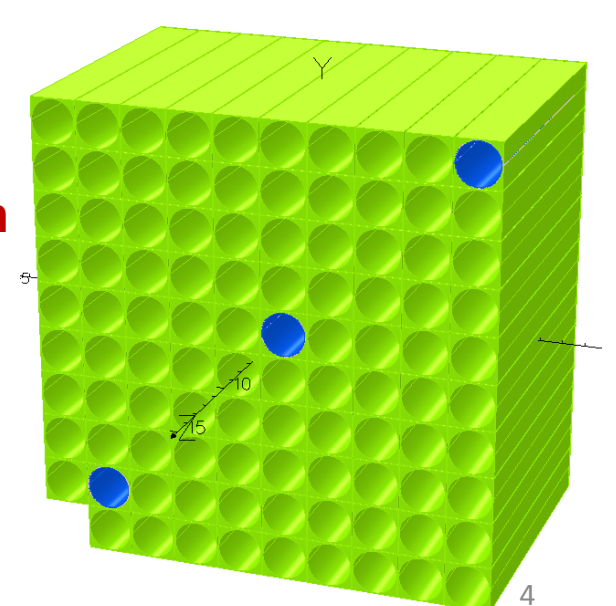
4X4



5X5

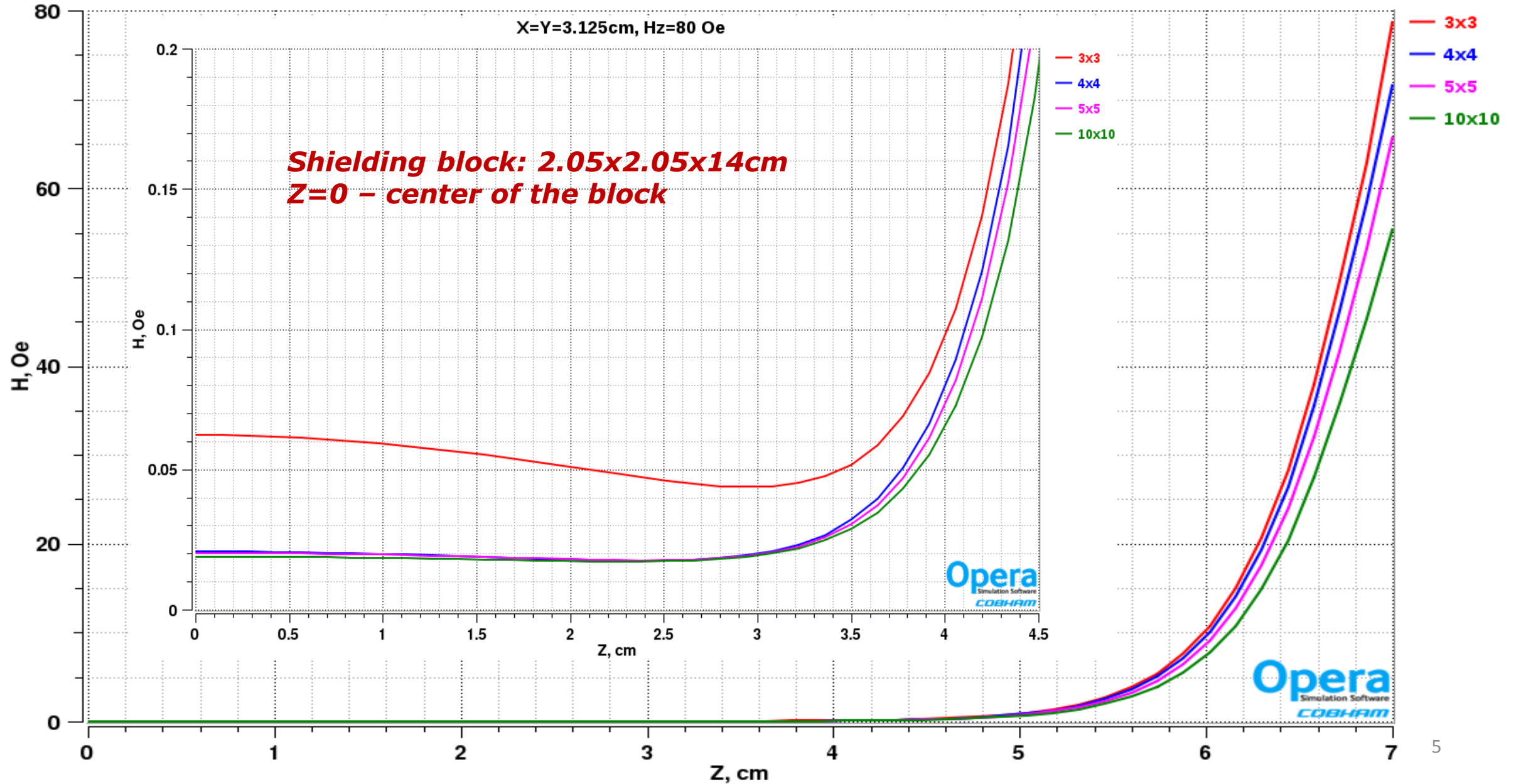


10X10



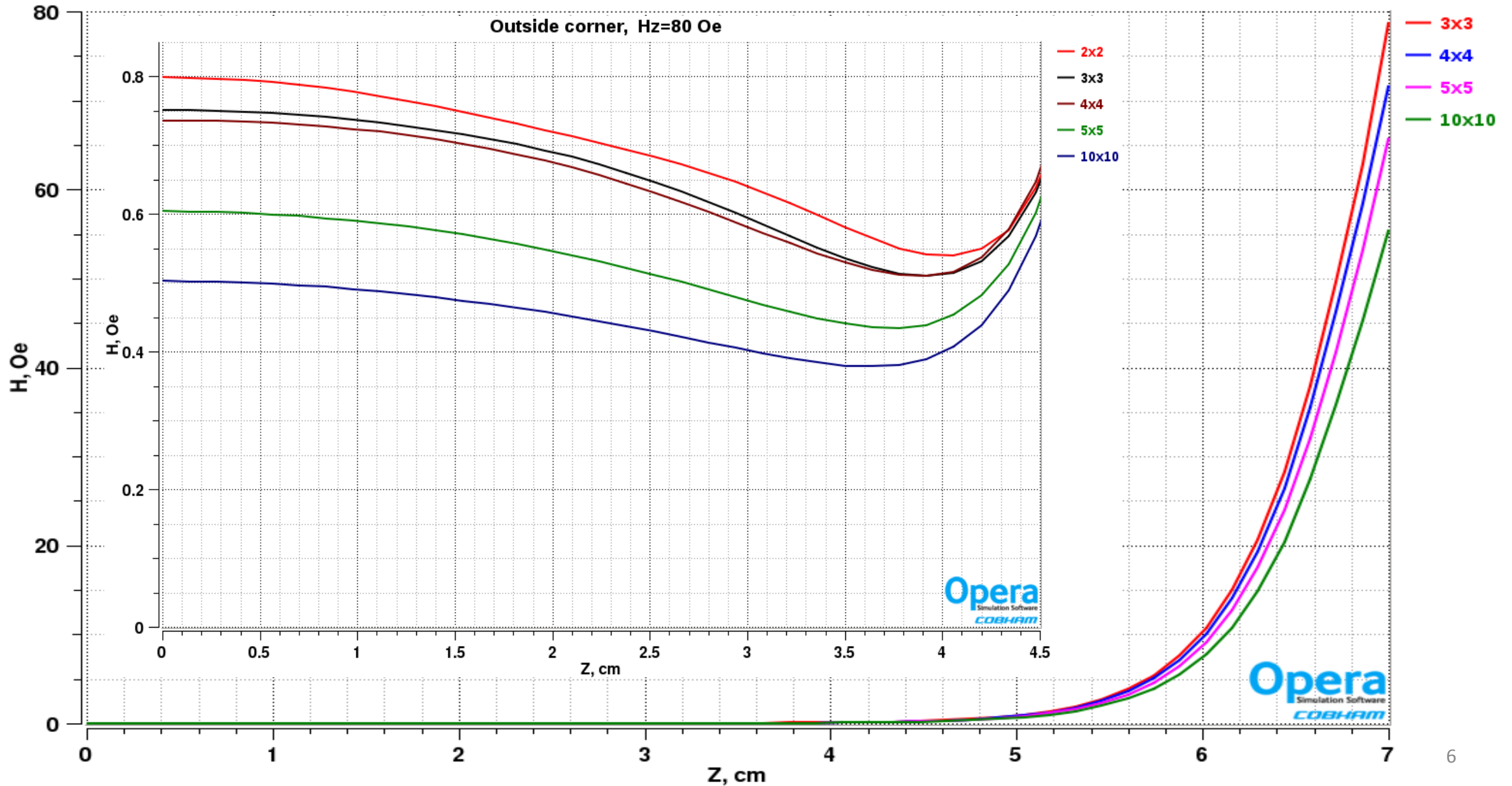
Block Closest to the Beam

$X=Y=3.125\text{cm}$, $H_z=80\text{ Oe}$



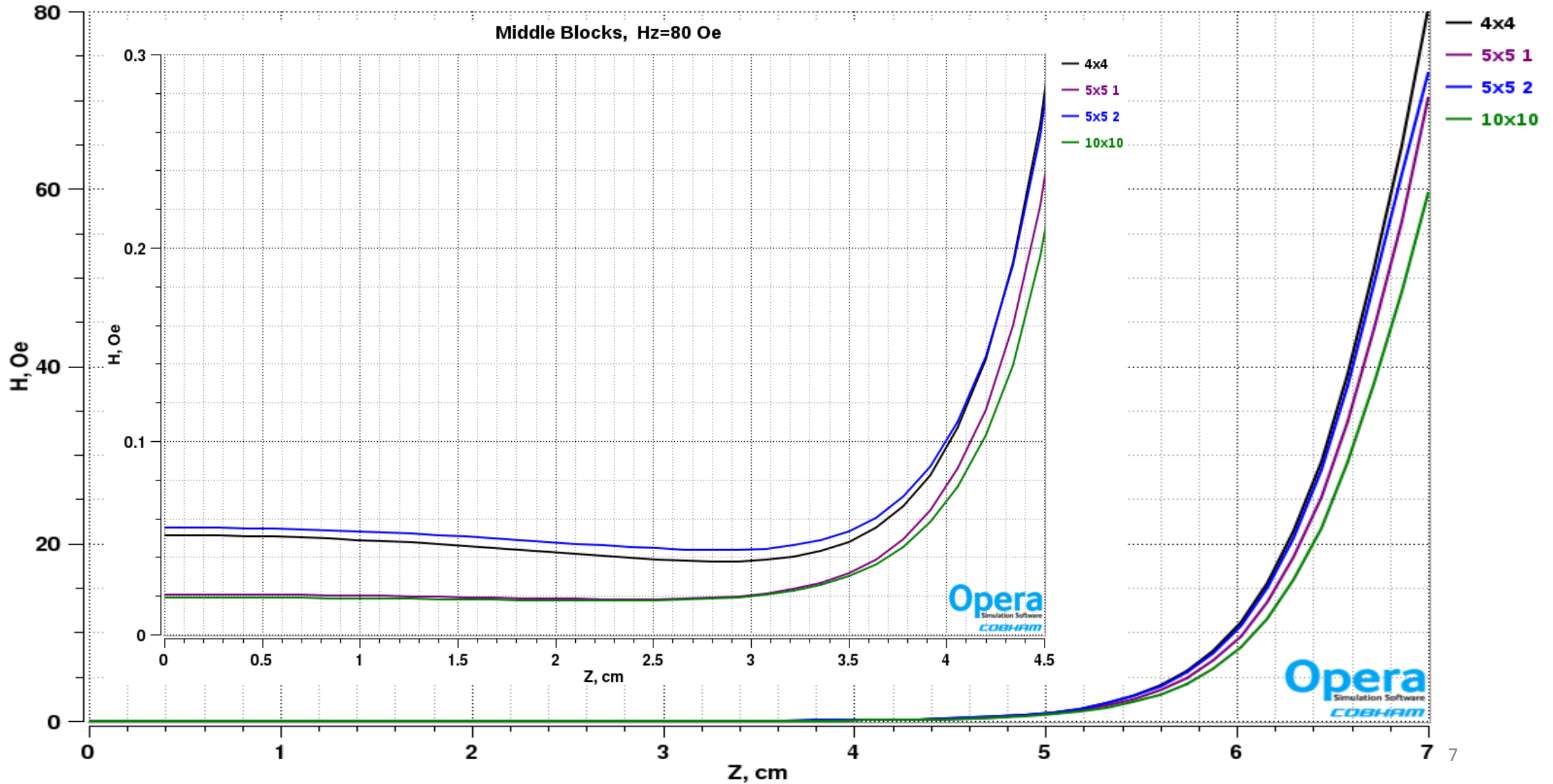
Outside Corner Block

X=Y=3.125cm, Hz=80 Oe

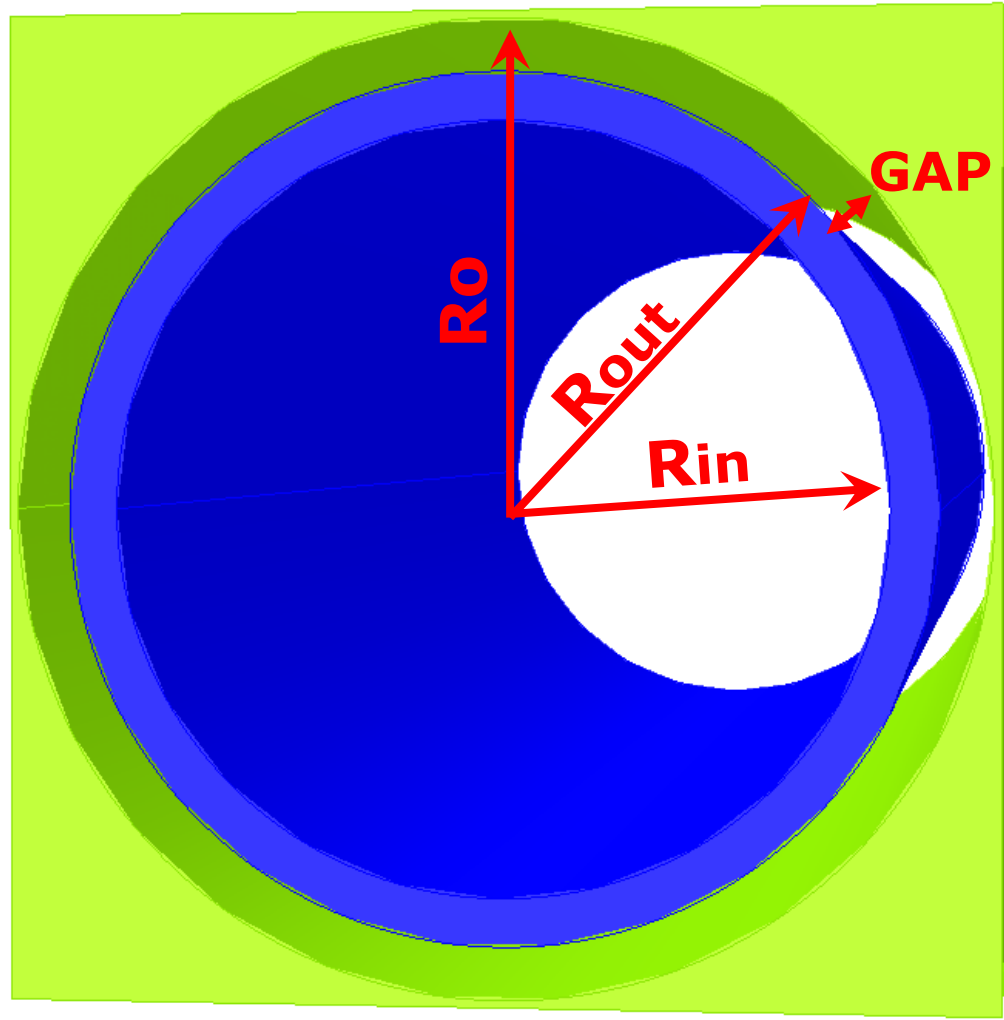


Middle Blocks

Middle Blocks, Hz=80 Oe



Co-Netic Configuration Optimization



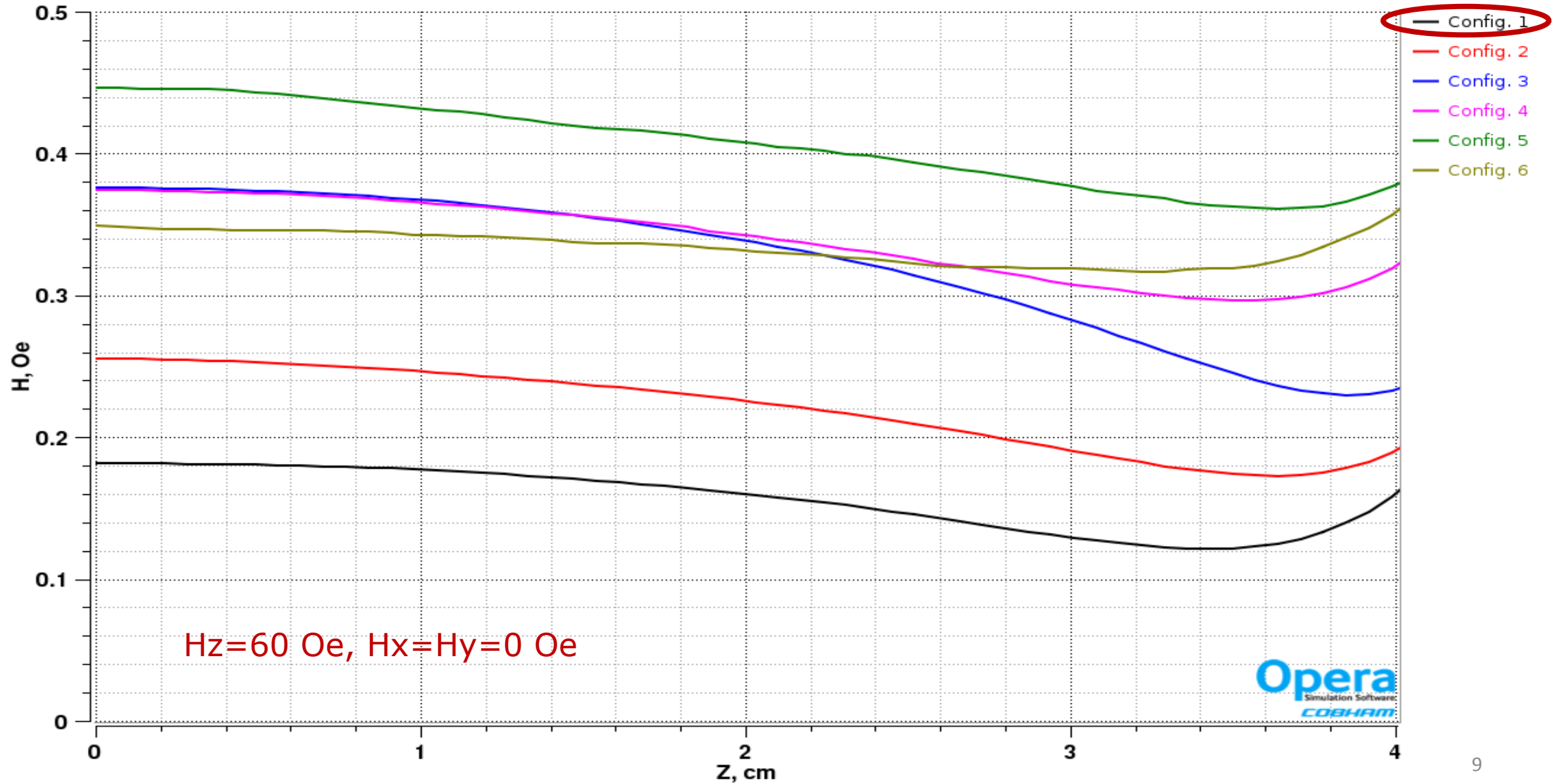
Rectangular block – iron AISI-1010
Cylinder – Co-Netic from Mu-shield Co.

| Conf. | Ro, cm | Air gap, μm | Rin, cm | Rout, cm | Co-netic, μm |
|----------|--------------|------------------------|--------------|--------------|-------------------------|
| 1 | 1.01 | 100 | 0.965 | 1.0 | 360 |
| 2 | 1.01 | 200 | 0.965 | 0.99 | 250 |
| 3 | 1.0 | 100 | 0.965 | 0.99 | 250 |
| 4 | 1.0 | 200 | 0.965 | 0.98 | 150 |
| 5 | 0.99 | 100 | 0.965 | 0.98 | 150 |
| 6 | 0.985 | 100 | 0.965 | 0.975 | 100 |

$R_{pmt} = 0.96\text{cm}$

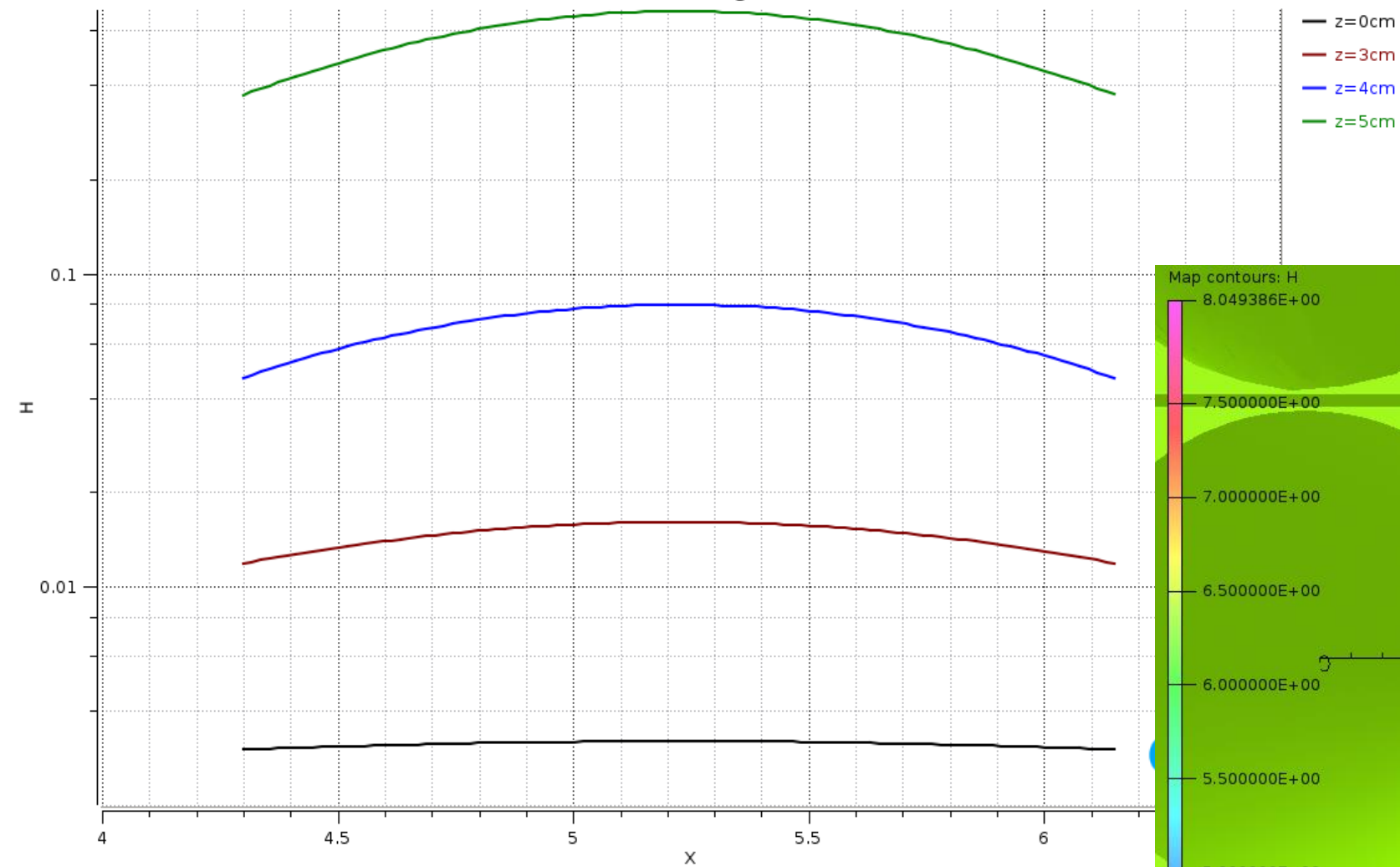
Co-Netic Configuration Comparison

Co-Netic Configuration Comparison

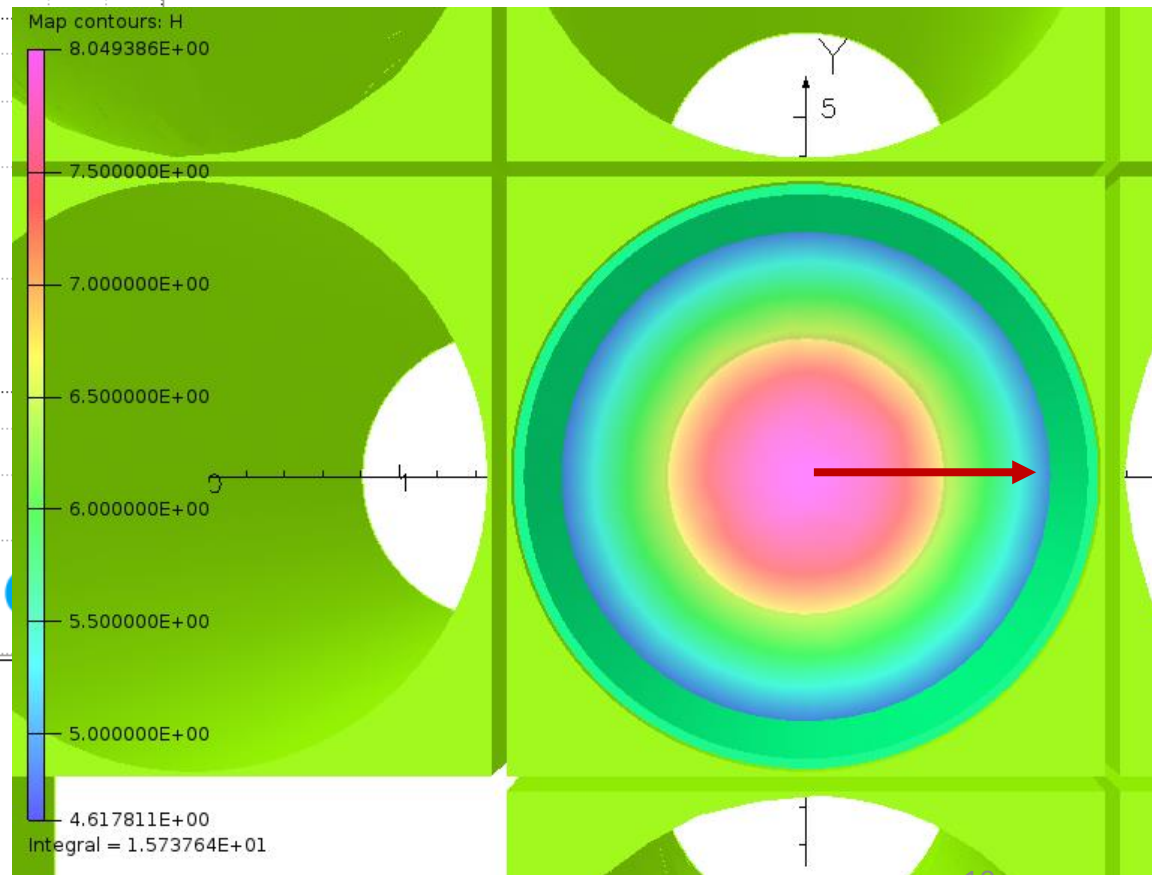


Field Dependence of R

Field Along X

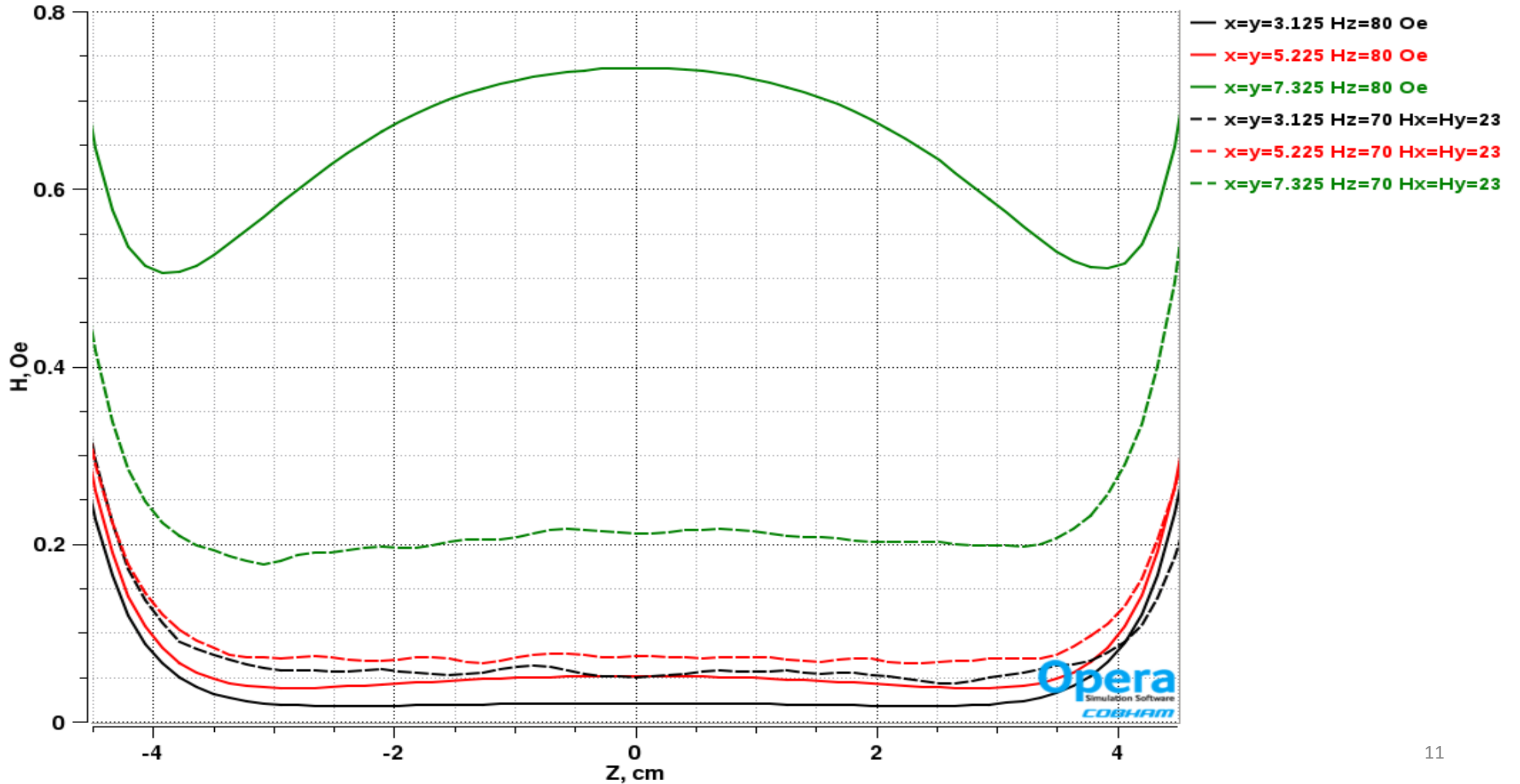


$H_z=60\text{ Oe}, H_x=H_y=0\text{ Oe}$

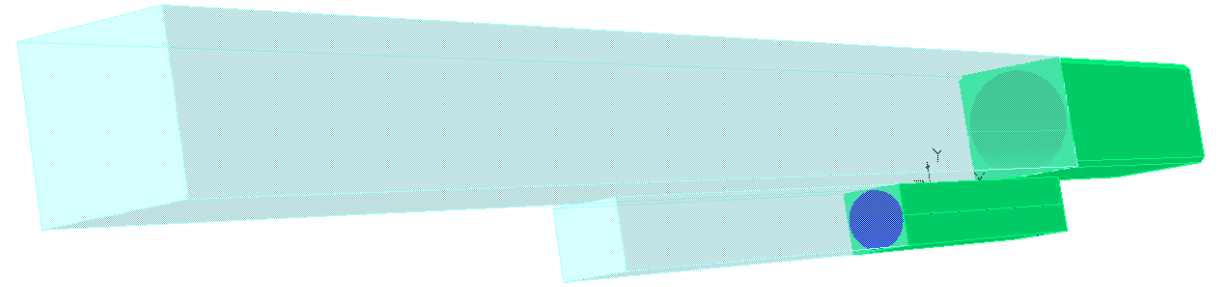
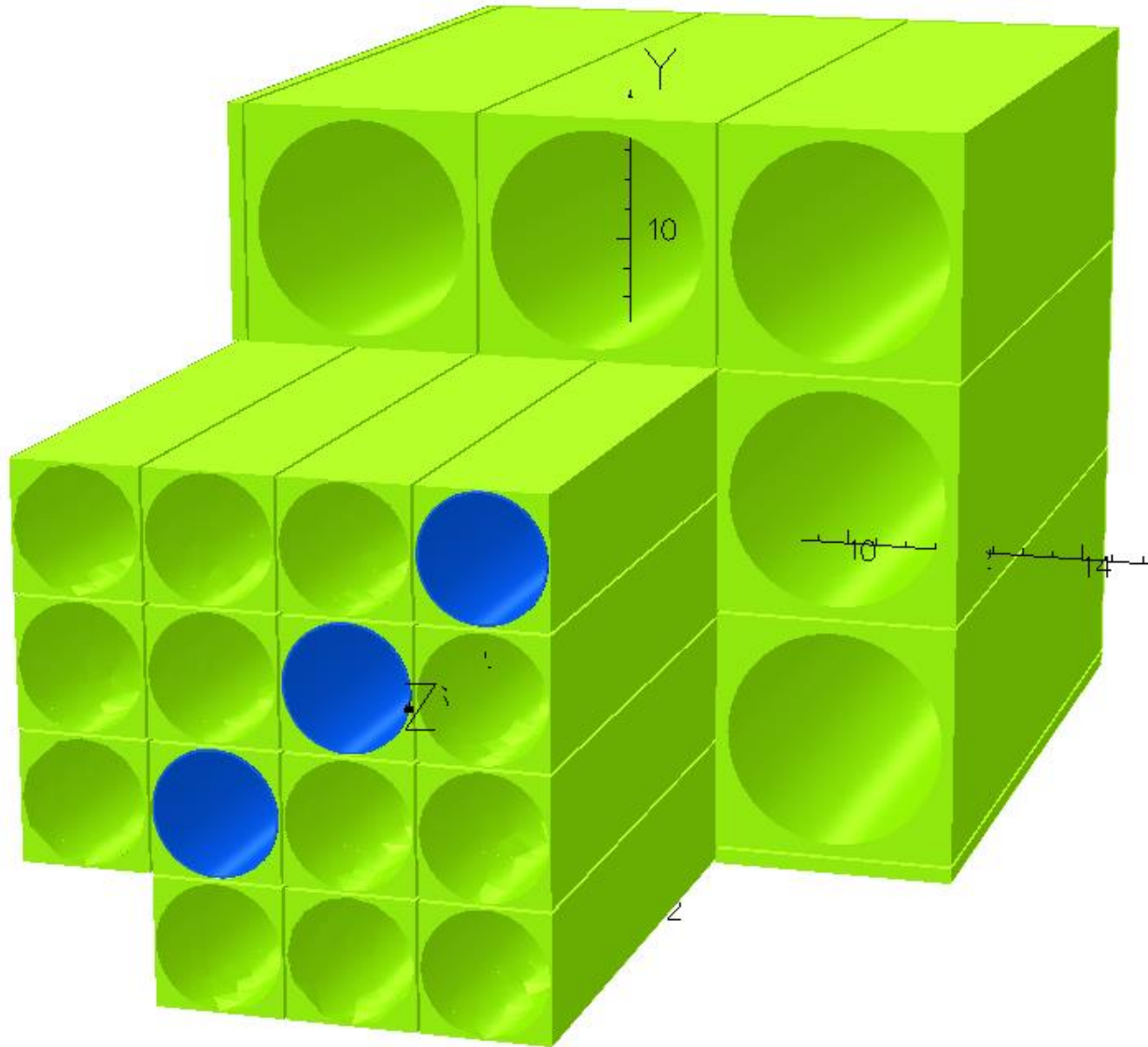


4x4 Transverse Component

Hz=80 Oe vs Hz=70 Hx=Hy=23 Oe



4x4 Hybrid FCal

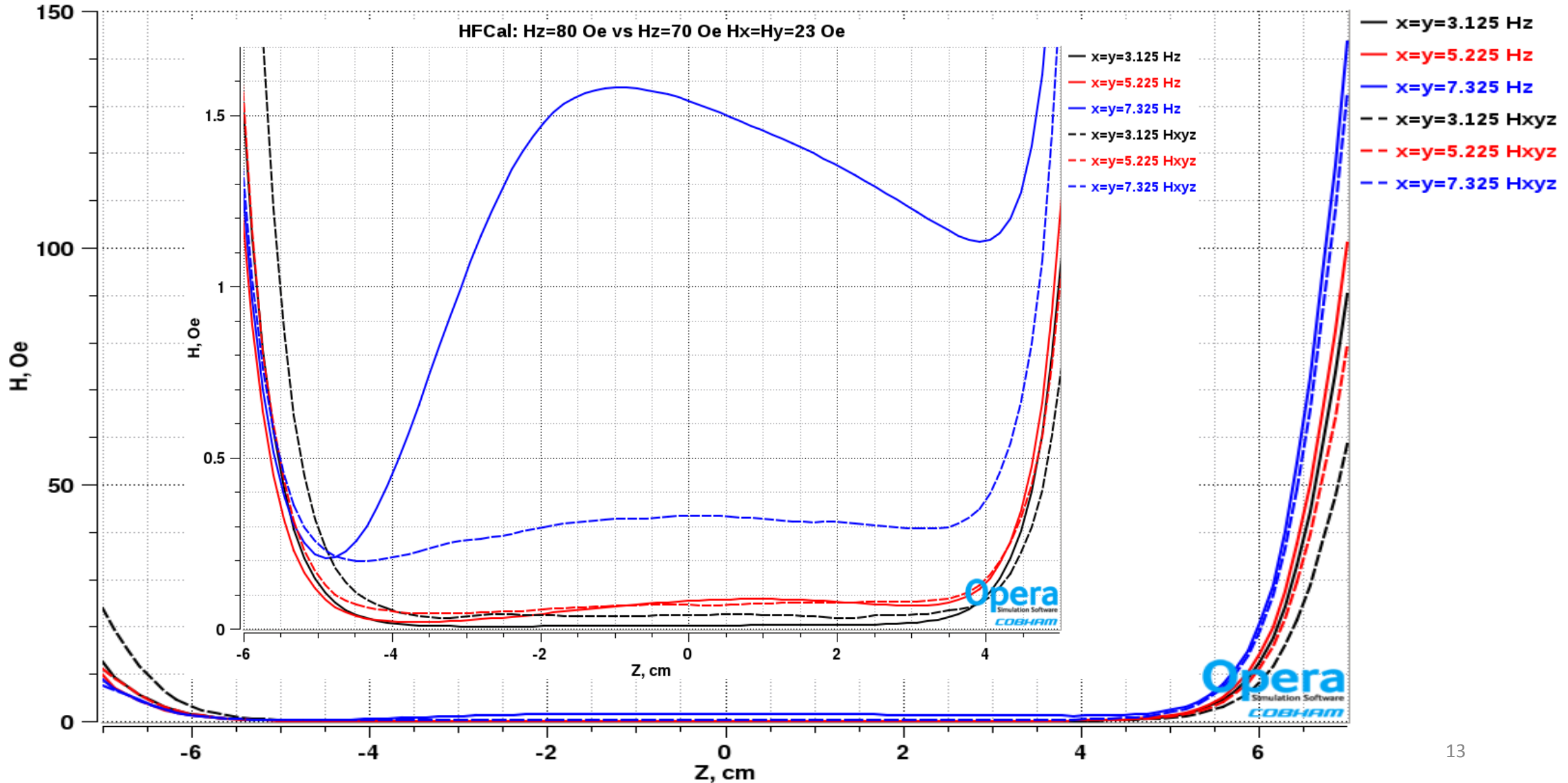


Lead Glass: 4x4x45 cm
LG shield: 4x4x14 cm

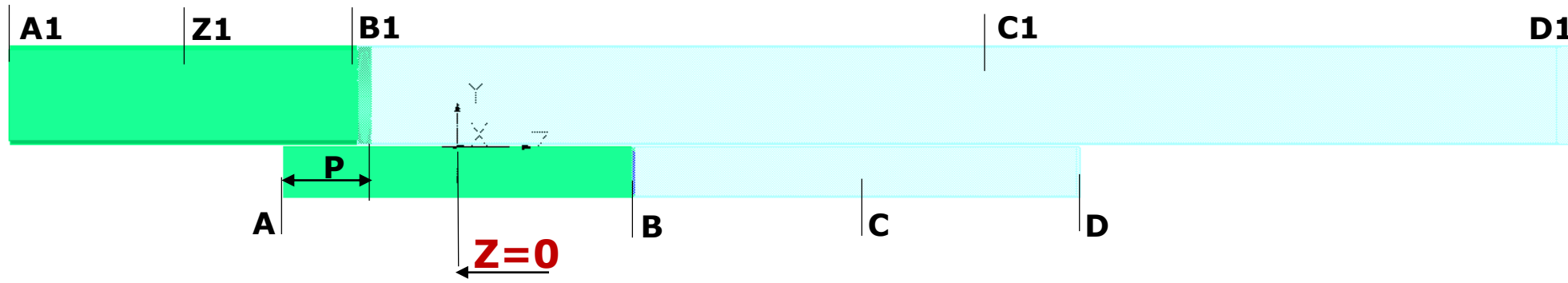
Crystal: 2.05x2.05x18 cm
Crystal shield: 2.05x2.05x14 cm

Hybrid FCal Transverse Component

HFCal: Hz=80 Oe vs Hz=70 Hx=Hy=23 Oe



LG and Lead Tungsten Overlapping Parameter



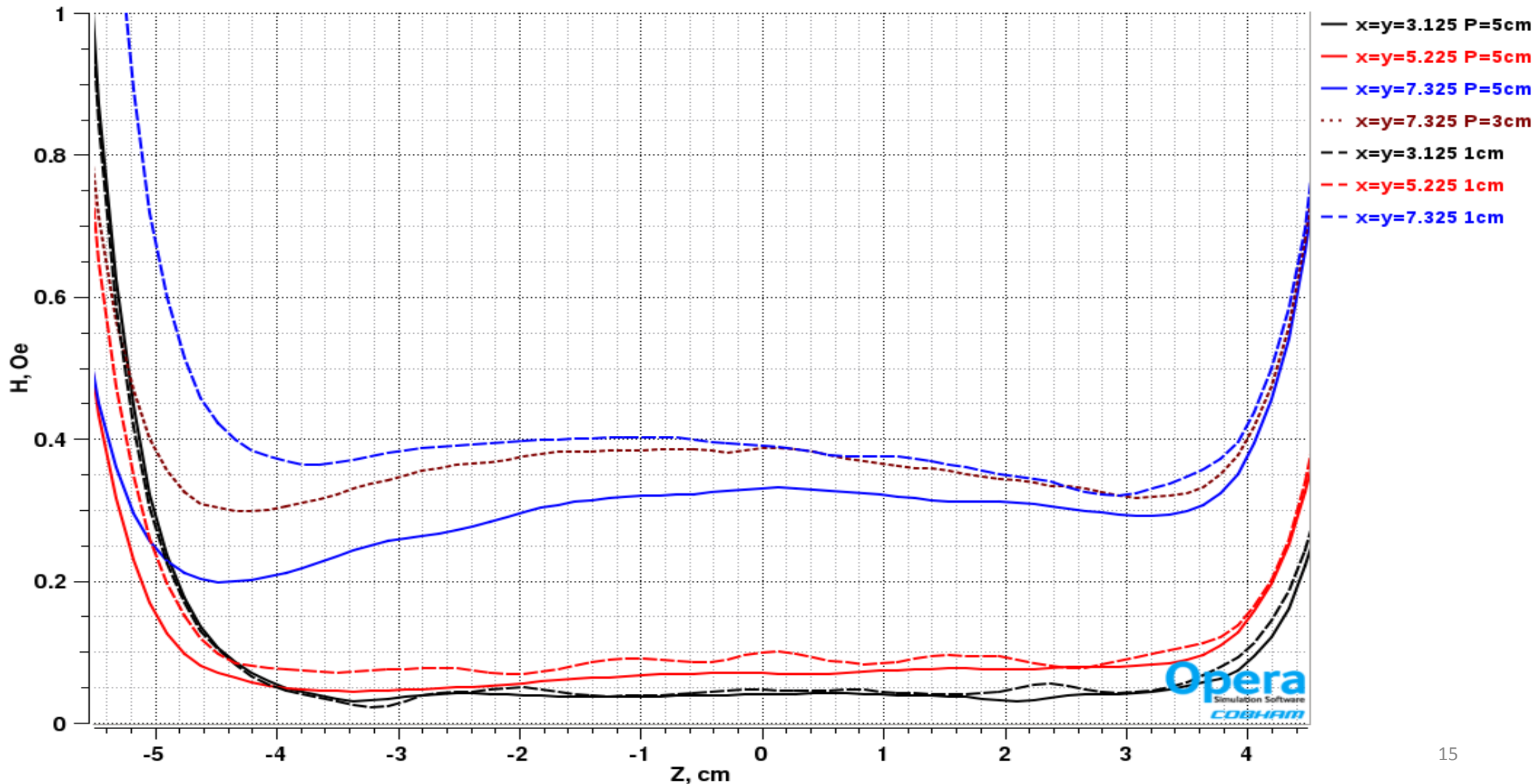
| P, cm | Crystal + Shield | | | | LG + Shield | | | | |
|----------|------------------|----|----|----|-------------|-----|----|------|----|
| | A | B | C | D | Z1 | A1 | B1 | C1 | D1 |
| 1cm | -7 | +7 | 16 | 25 | -13 | -20 | -6 | 16.5 | 39 |
| 3cm | -7 | +7 | 16 | 25 | -11 | -18 | -4 | 18.5 | 41 |
| 5cm | -7 | +7 | 16 | 25 | -9 | -16 | -2 | 20.5 | 43 |

Lead Glass: 4x4x45 cm
 LG shield: 4x4x14 cm

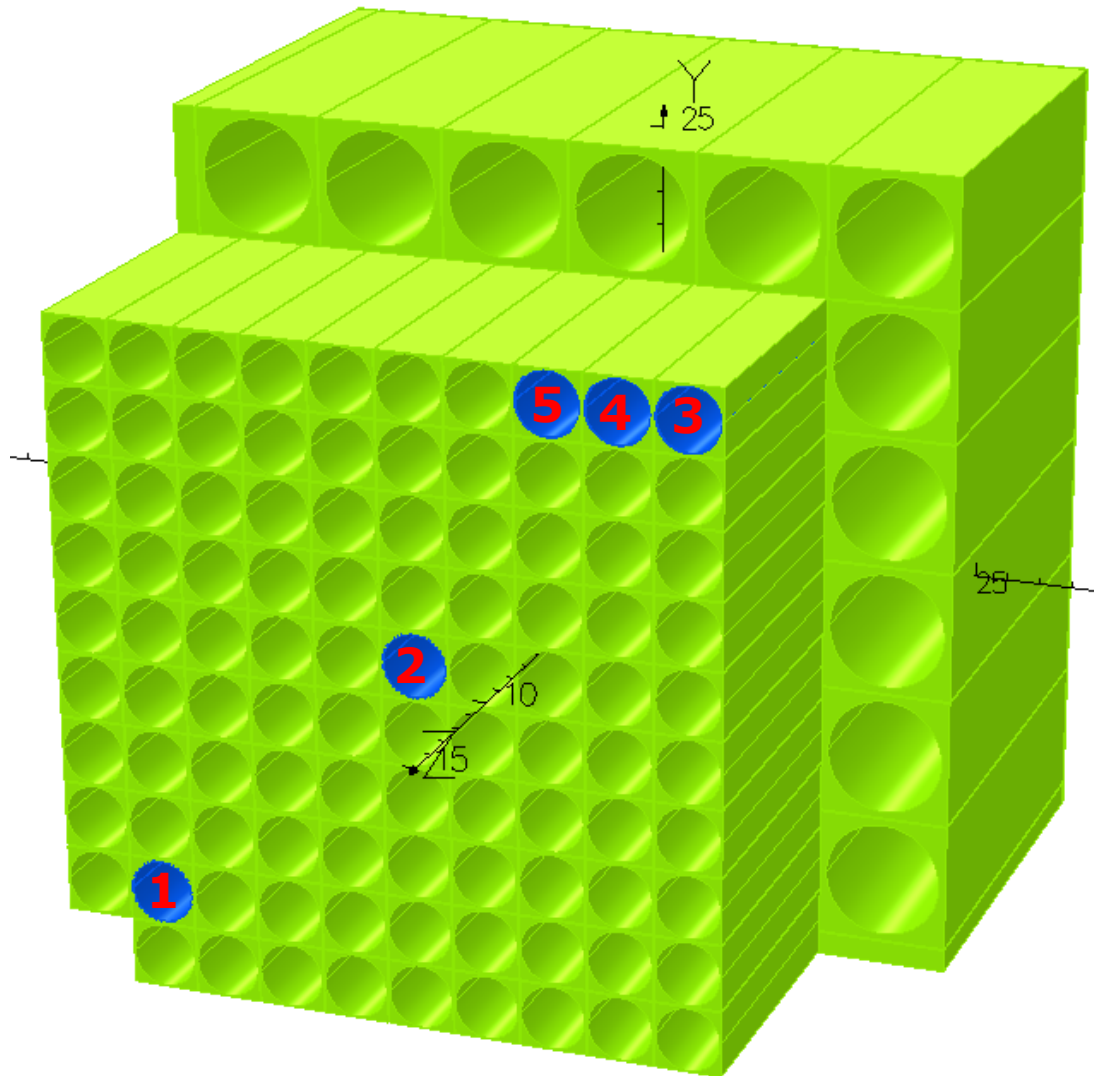
Crystal: 2.05x2.05x18 cm
 Crystal shield: 2.05x2.05x14 cm

LG and Lead Tungsten Overlapping Parameter

HFCal: P=5/3/1cm, Hz=70 Oe Hx=Hy=23 Oe



Realistic Magnetic Field



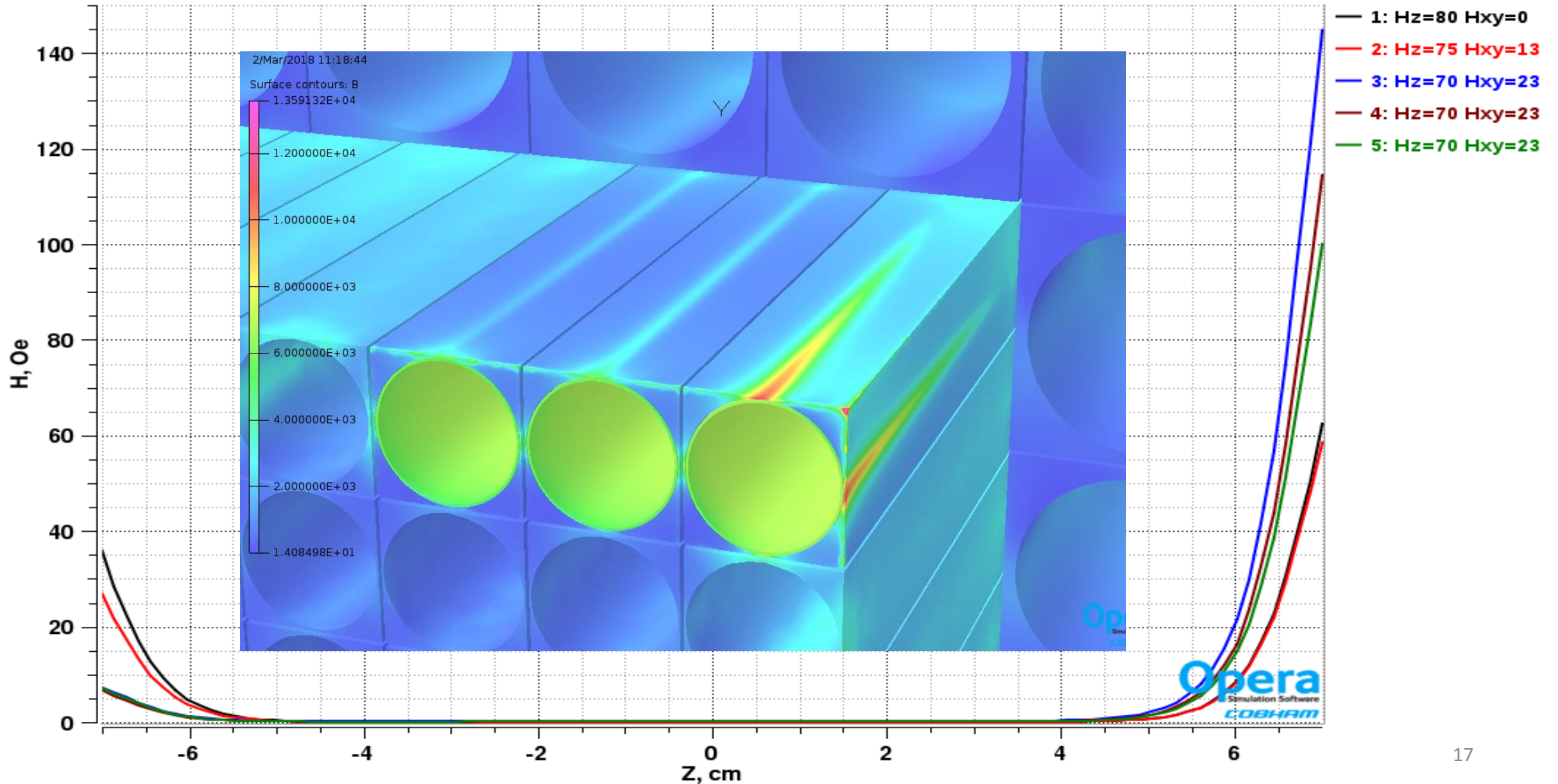
10x10 crystals:

- 1 - $H_z=80$ Oe, $H_x=H_y=0$ Oe
- 2 - $H_z=75$ Oe, $H_x=H_y=12$ Oe
- 3 - $H_z=70$ Oe, $H_x=H_y=23$ Oe
- 4 - $H_z=70$ Oe, $H_x=H_y=23$ Oe
- 5 - $H_z=70$ Oe, $H_x=H_y=23$ Oe

| Z, cm | R, cm | H_z , Oe | H_r , Oe | Comments |
|-------|---------|------------|------------|--------------|
| 608 | 2 50 | 110 95 | 2 33 | Face of TOF |
| 670 | 2 50 | 54 50 | 0 13 | Back of FCal |

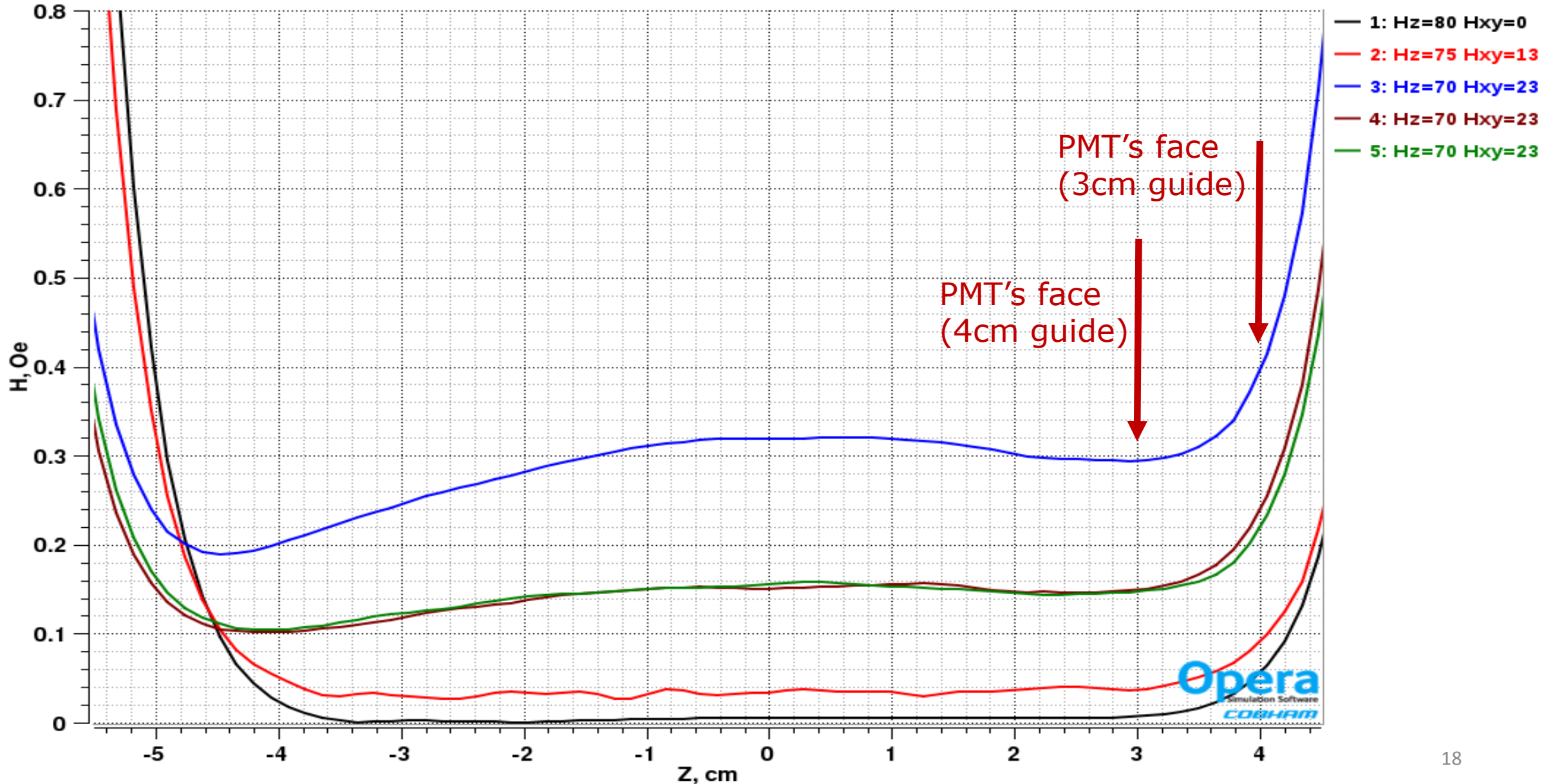
Hybrid FCal: Realistic Fields (P=5cm)

Hybrid FCal 10x10 blocks



Hybrid FCal: Realistic Fields ($P=5\text{cm}$)

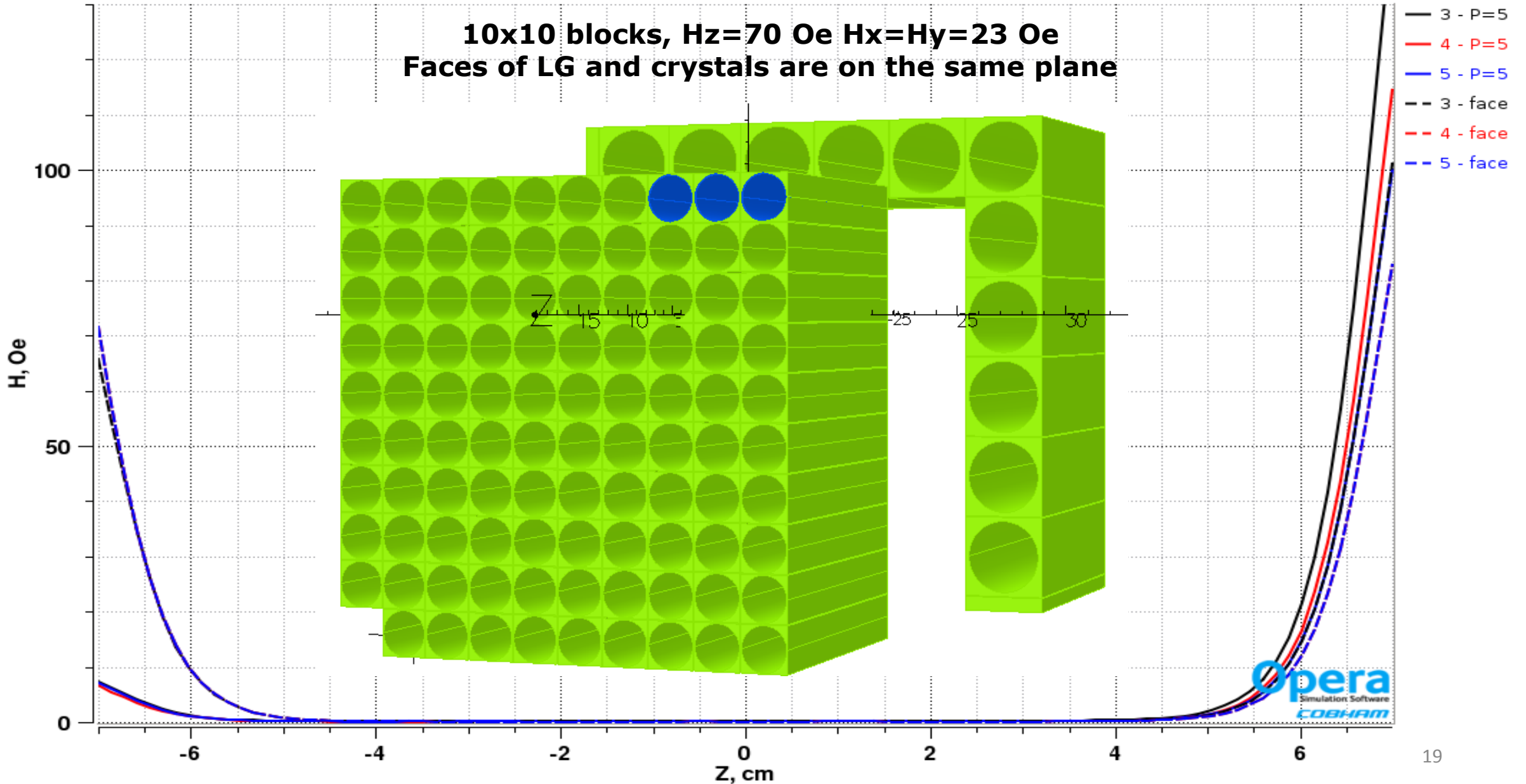
Hybrid FCal 10x10 blocks



LG and Lead Tungsten Overlapping Parameter

HFcal: P=5cm vs Face to Face

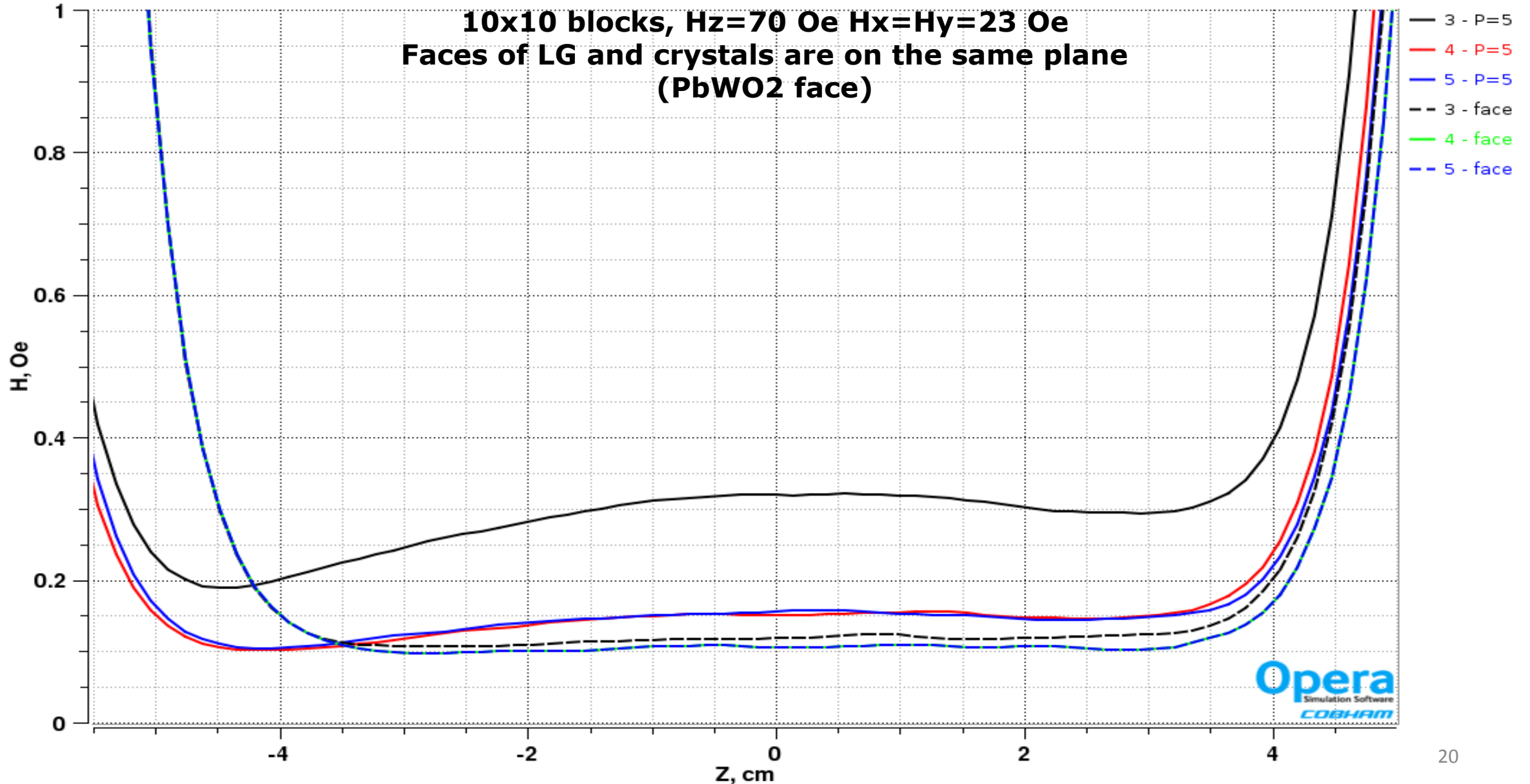
10x10 blocks, Hz=70 Oe Hx=Hy=23 Oe
Faces of LG and crystals are on the same plane



LG and Lead Tungsten Overlapping Parameter

HFcal: P=5cm vs Face to Face

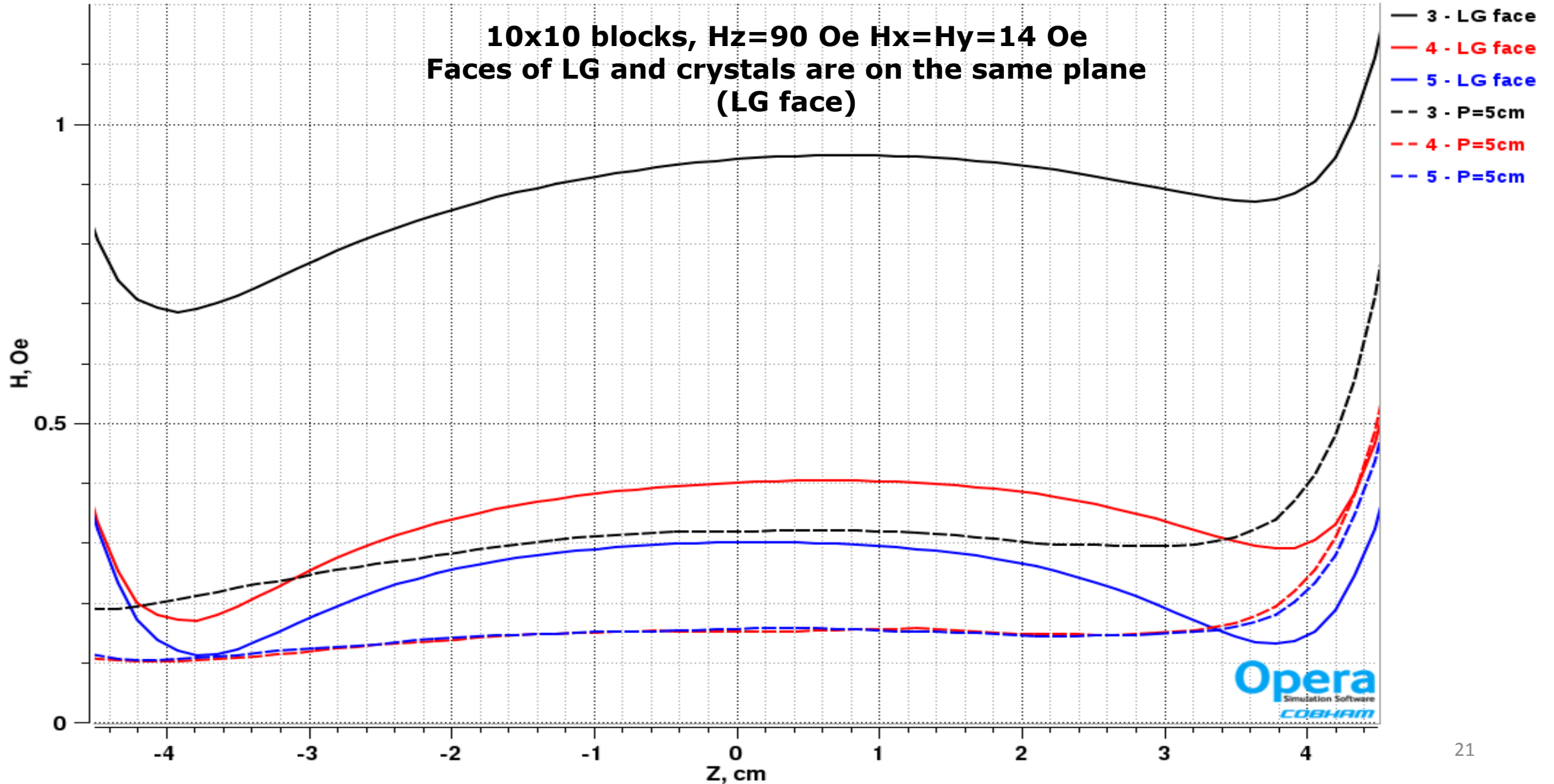
10x10 blocks, $H_z=70$ Oe $H_x=H_y=23$ Oe
Faces of LG and crystals are on the same plane
(PbWO₂ face)



LG and Lead Tungsten Overlapping Parameter

PbWO4 moved forward to LG face

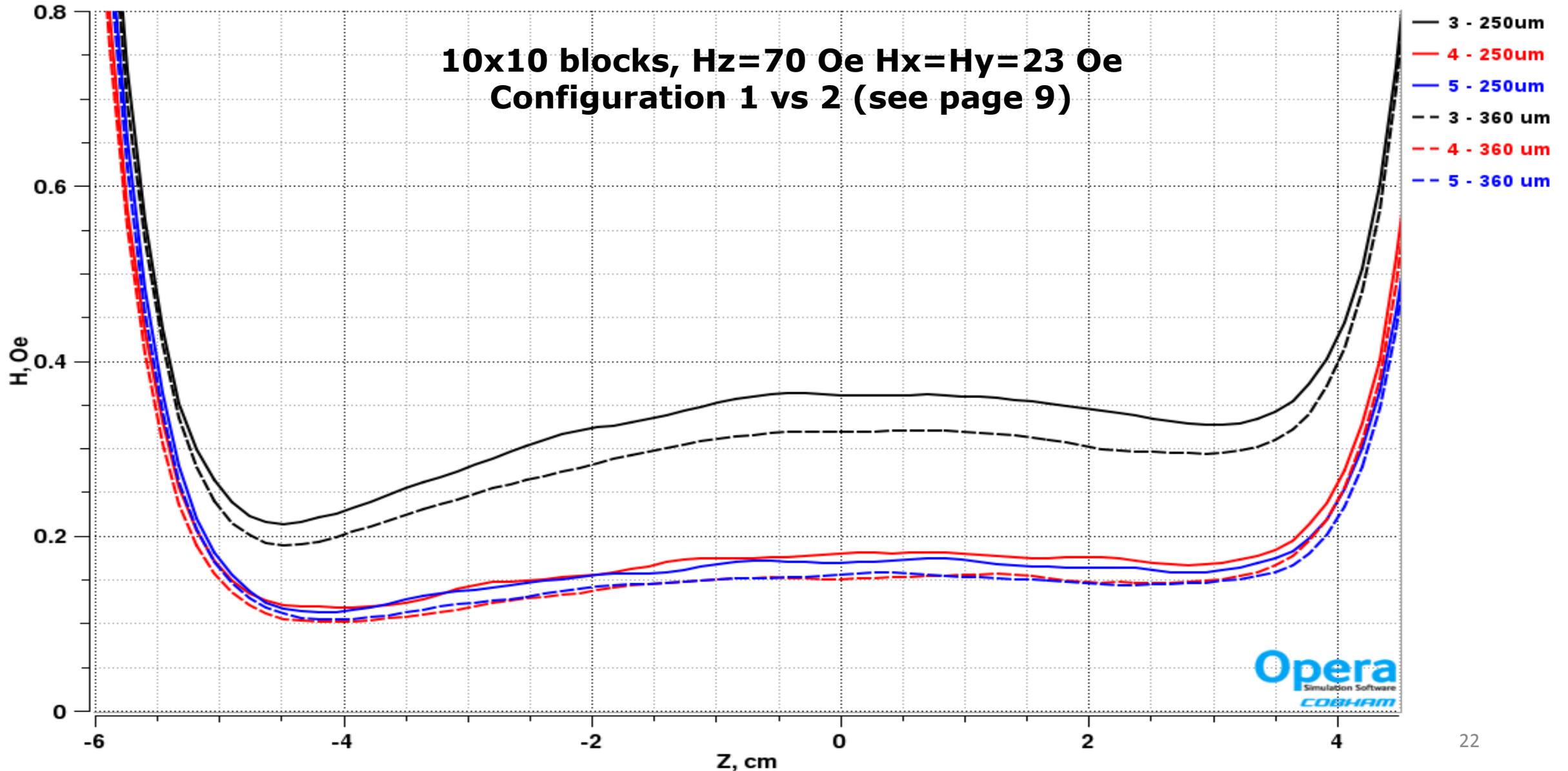
10x10 blocks, $H_z=90$ Oe $H_x=H_y=14$ Oe
Faces of LG and crystals are on the same plane
(LG face)



Co-Netic Configuration Optimization

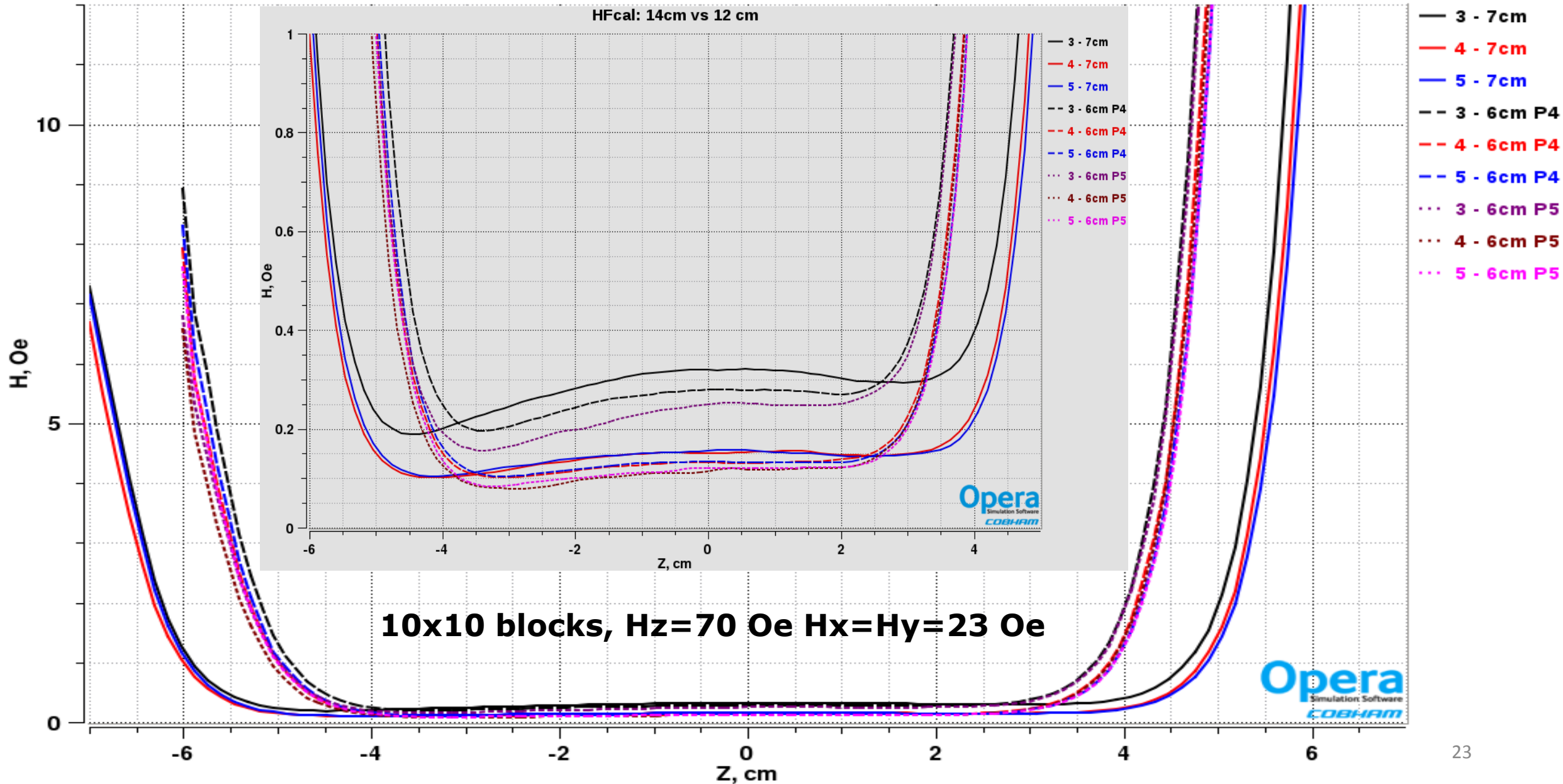
Co-Netic: 250um vs 360um (Configuration 2 vs 1)

10x10 blocks, $H_z=70$ Oe $H_x=H_y=23$ Oe
Configuration 1 vs 2 (see page 9)



Length of PMT's Housing/ μ -shield cylinder

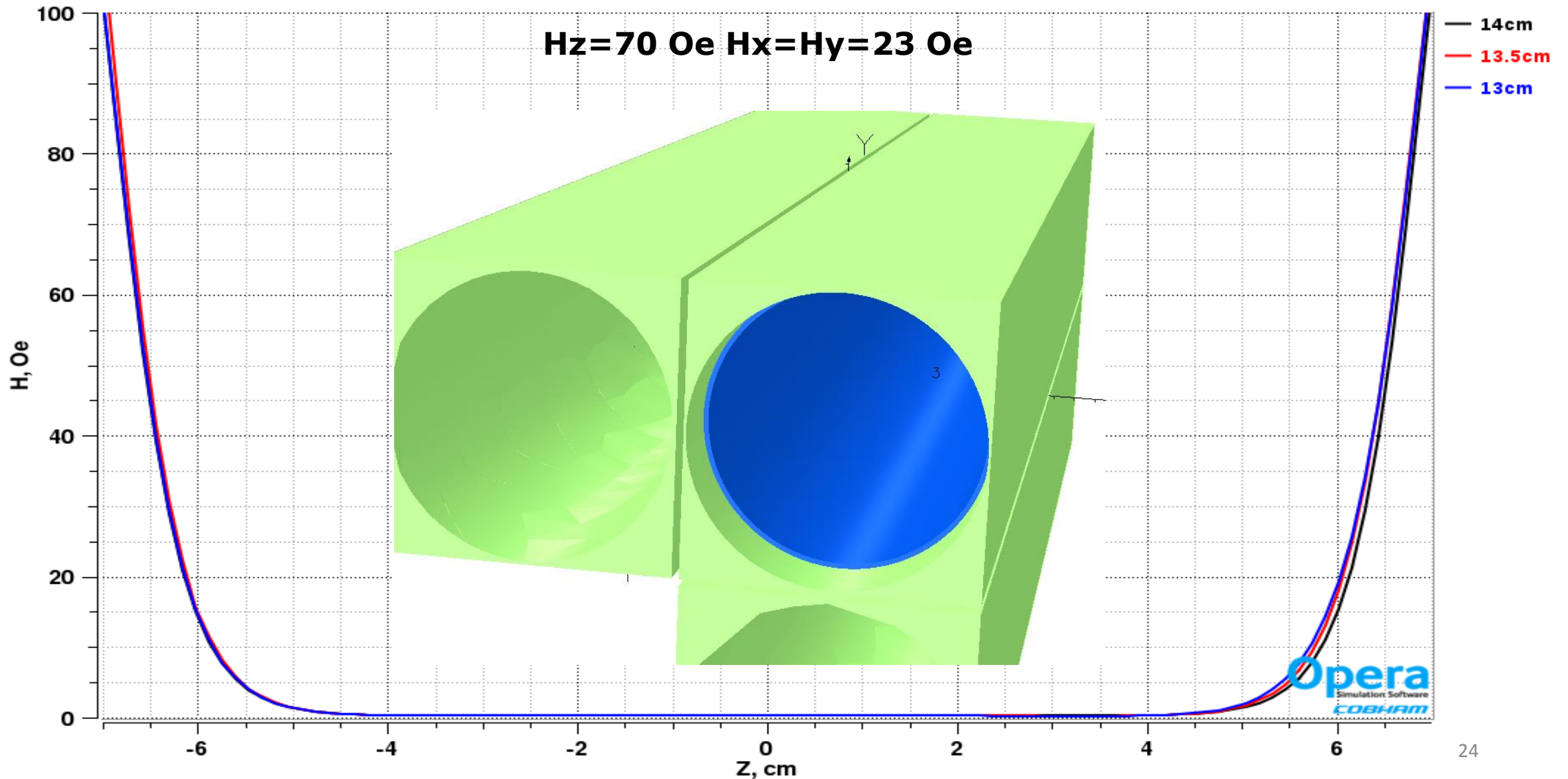
HFcal: 14cm vs 12 cm



Co-Netic Length Optimization

Co-Netic 14 / 13.5/ 13cm length

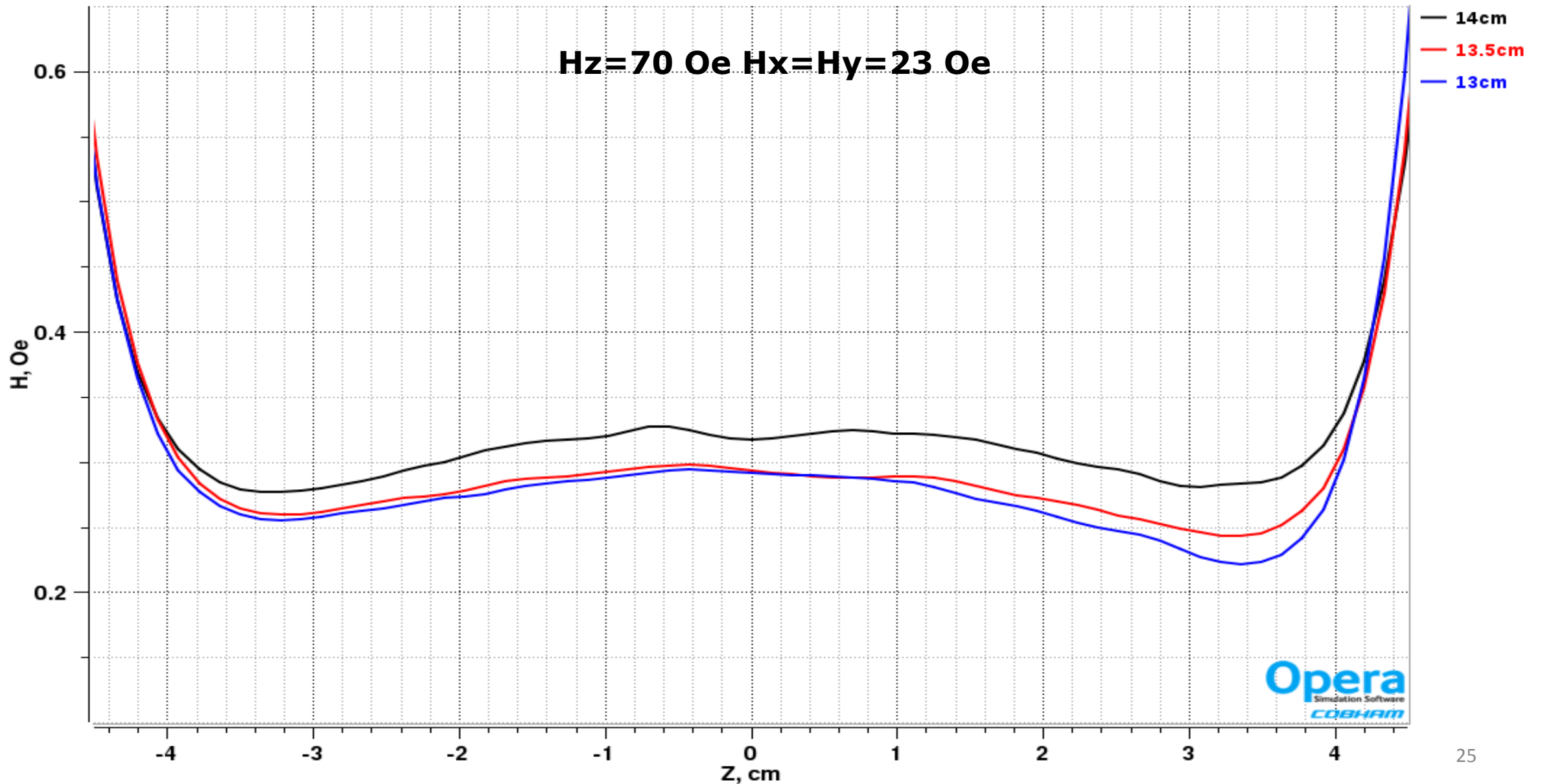
$H_z=70$ Oe $H_x=H_y=23$ Oe



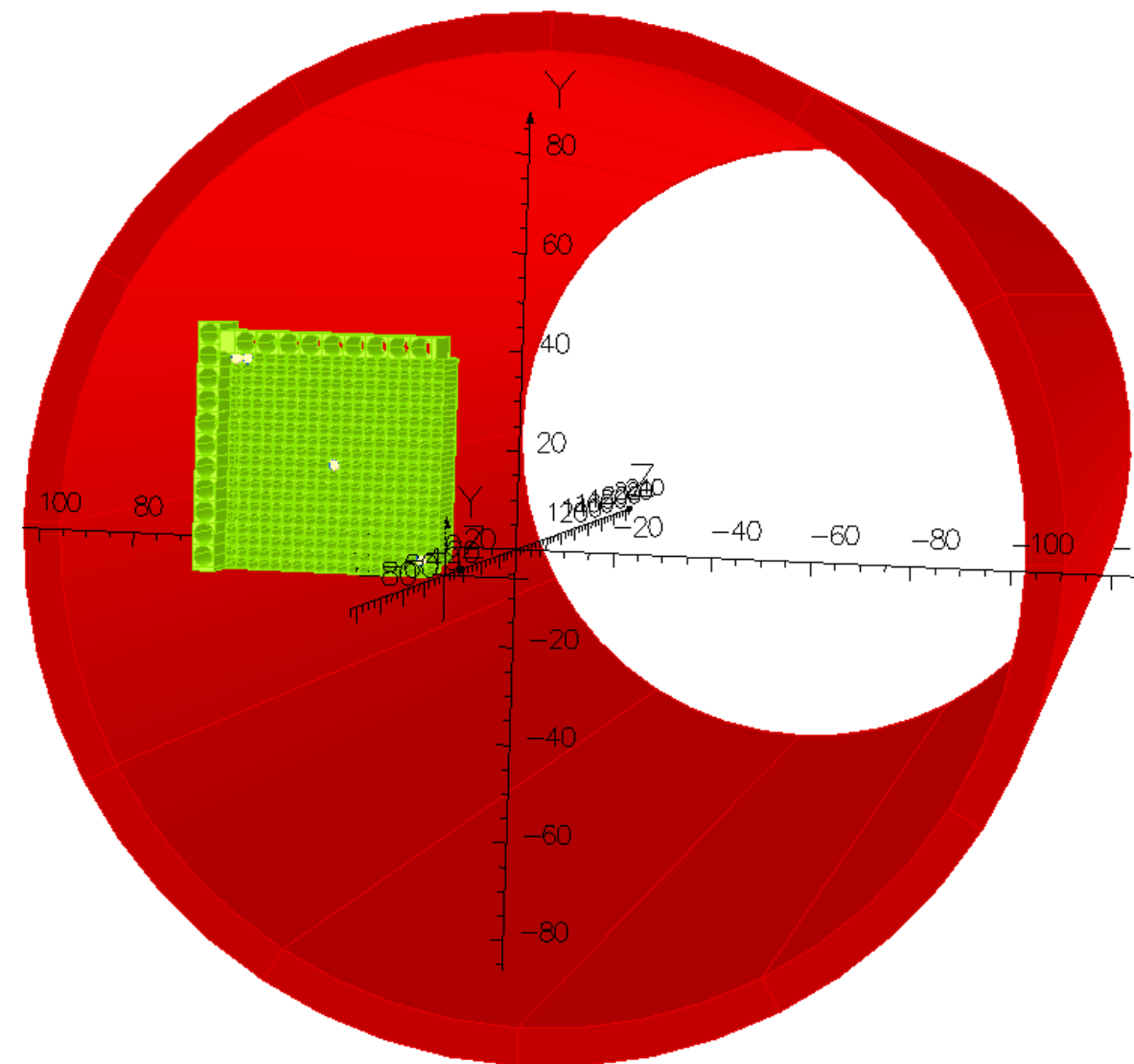
Co-Netic Length Optimization

Co-Netic 14 / 13.5/ 13cm length

$H_z=70.0e$ $H_x=H_y=23.0e$

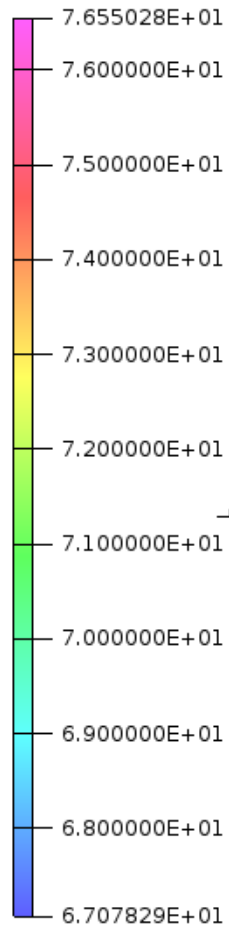


19x19 blocks, $P=5\text{cm}$, Solenoidal Field

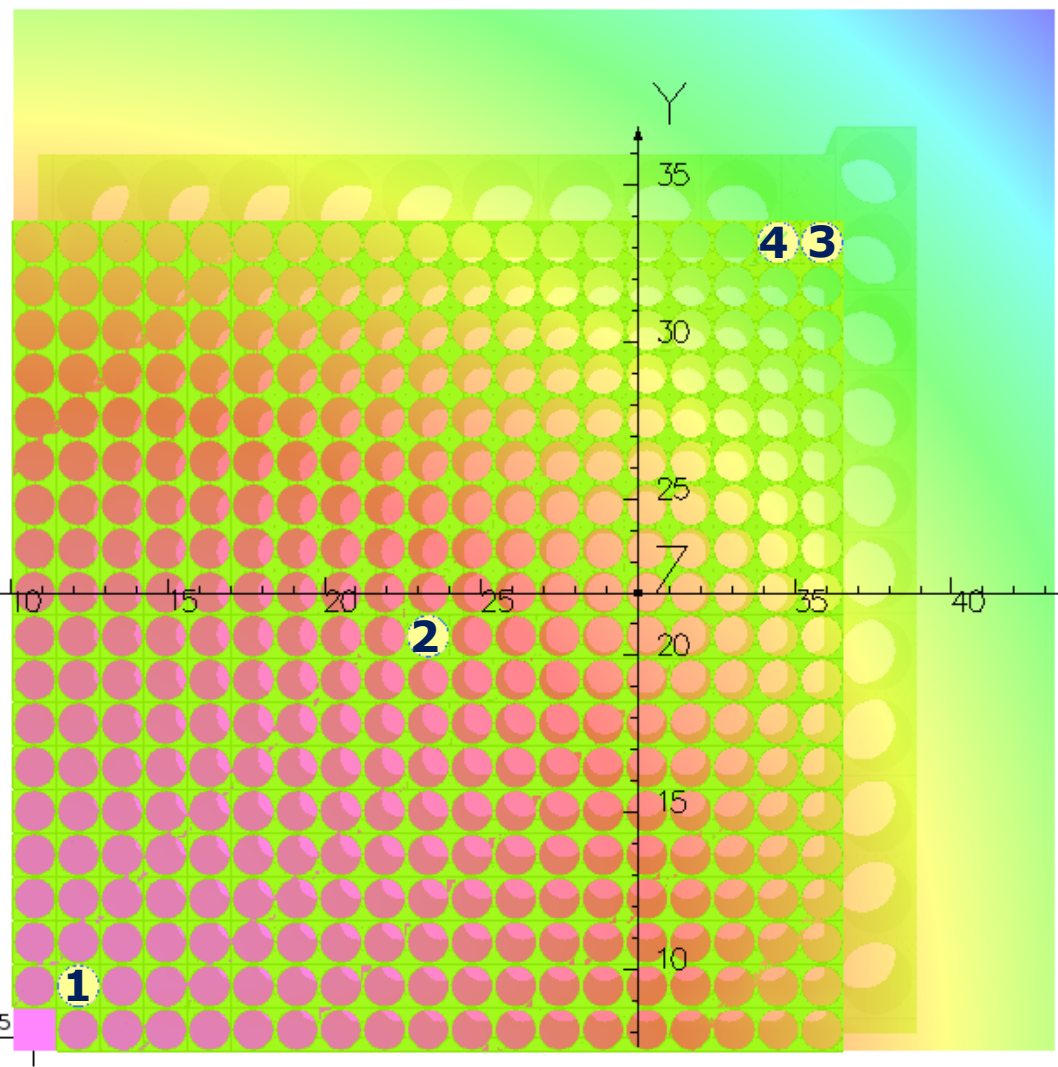


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Map contours: H



Integral = $1.834633\text{E}+05$



Fields Comparison

Magnetic field in the Hall D (measurements from Simon Taylor)

Magnetic field from TOSCA model with solenoid

| Z, cm | R, cm | Hz, Oe | H _R , Oe | Comments |
|------------|---------|-----------------------|---------------------|--------------|
| 608 43 | 2 50 | 110 / 119 95 / 107 | 2 / 1.5 33 / 36 | Face of TOF |
| 670 -19 | 2 50 | 54 / 56 50 / 51 | 0 / 0.6 13 / 14 | Back of FCal |

Magnetic field on face of PMT's shield Z=7cm

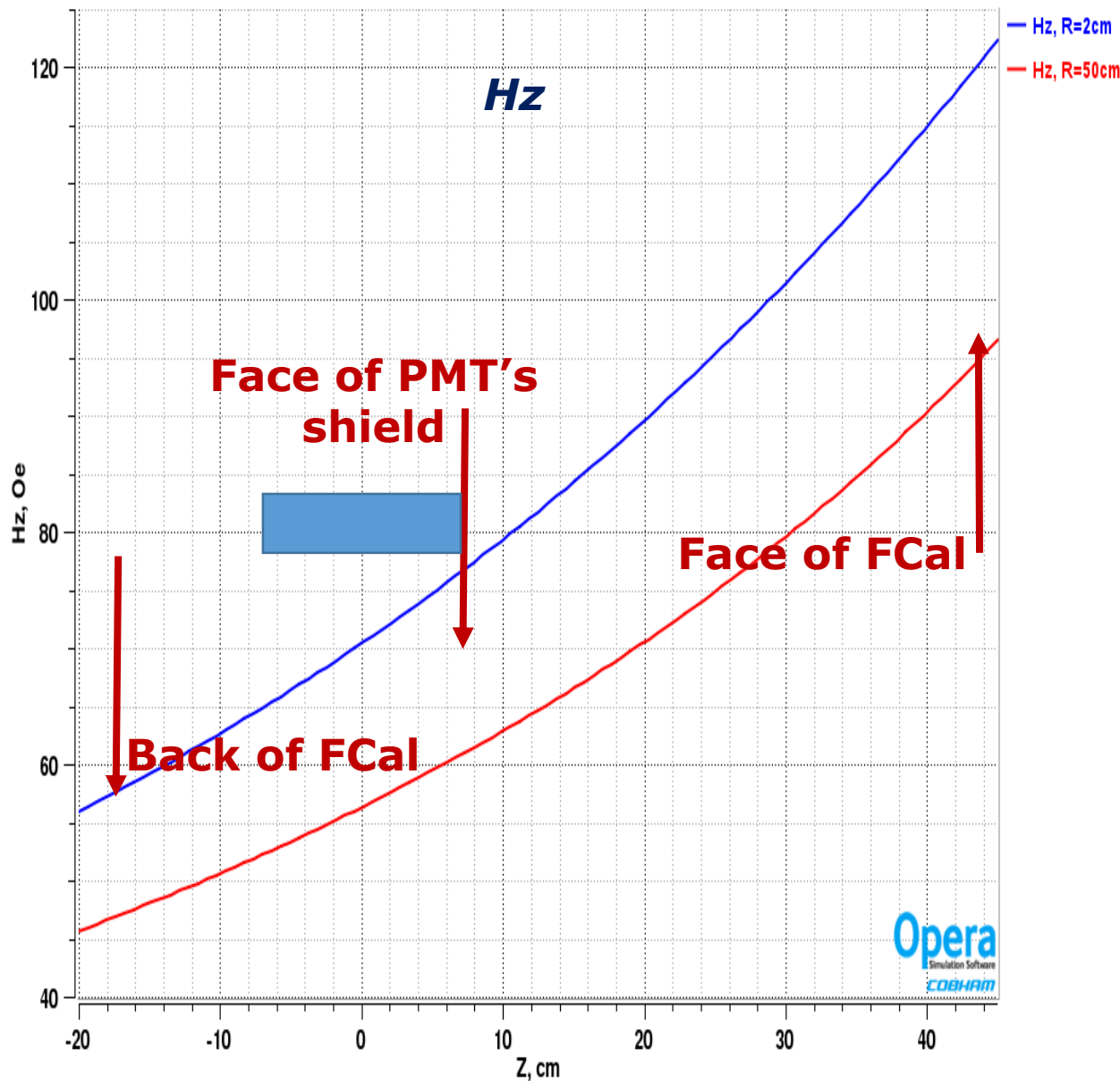
Black – constant field: TOSCA with no solenoid

Red – gradient field: TOSCA with solenoid

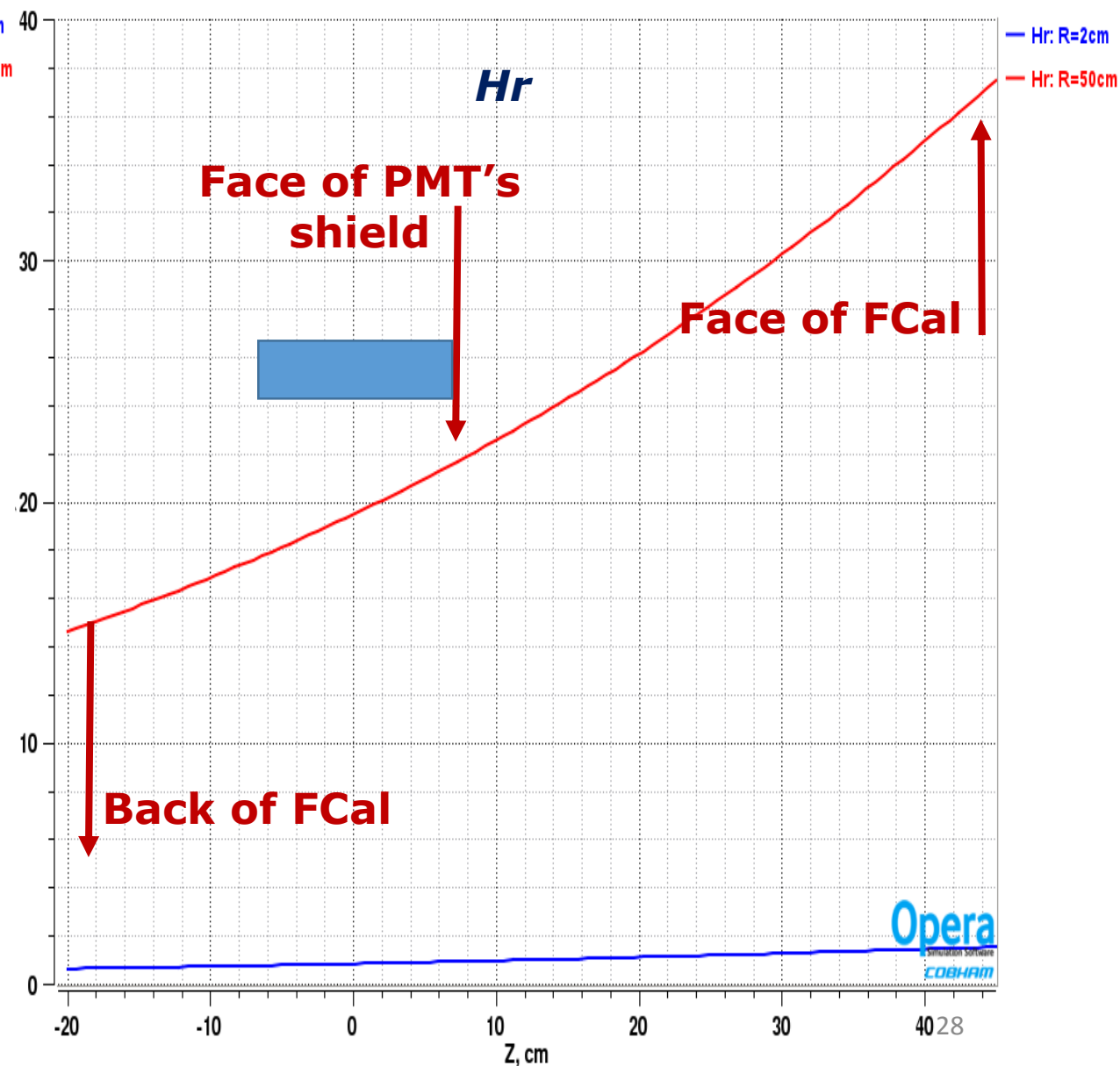
| R,cm | Hz, Oe | H _R , Oe | Comments |
|------|---------|---------------------|---------------|
| 2 | 80 / 77 | 0 / 1 | Near the beam |
| 25 | 75 / 72 | 13 / 11 | Middle |
| 50 | 70 / 61 | 23 / 20 | Outside Layer |

Field in HFCal with Solenoid

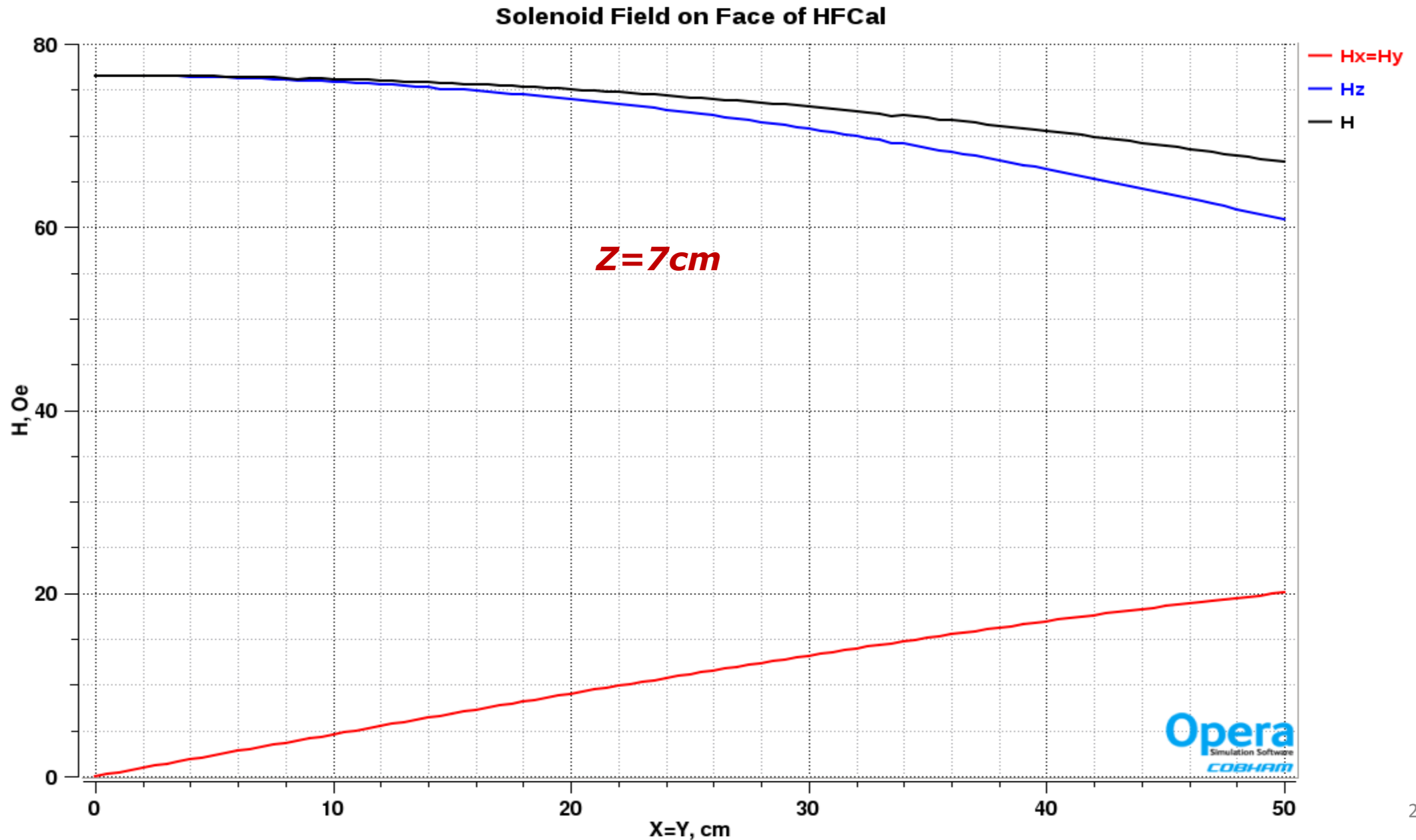
Solenoid Field in HFCal



Solenoid Field in HFCal

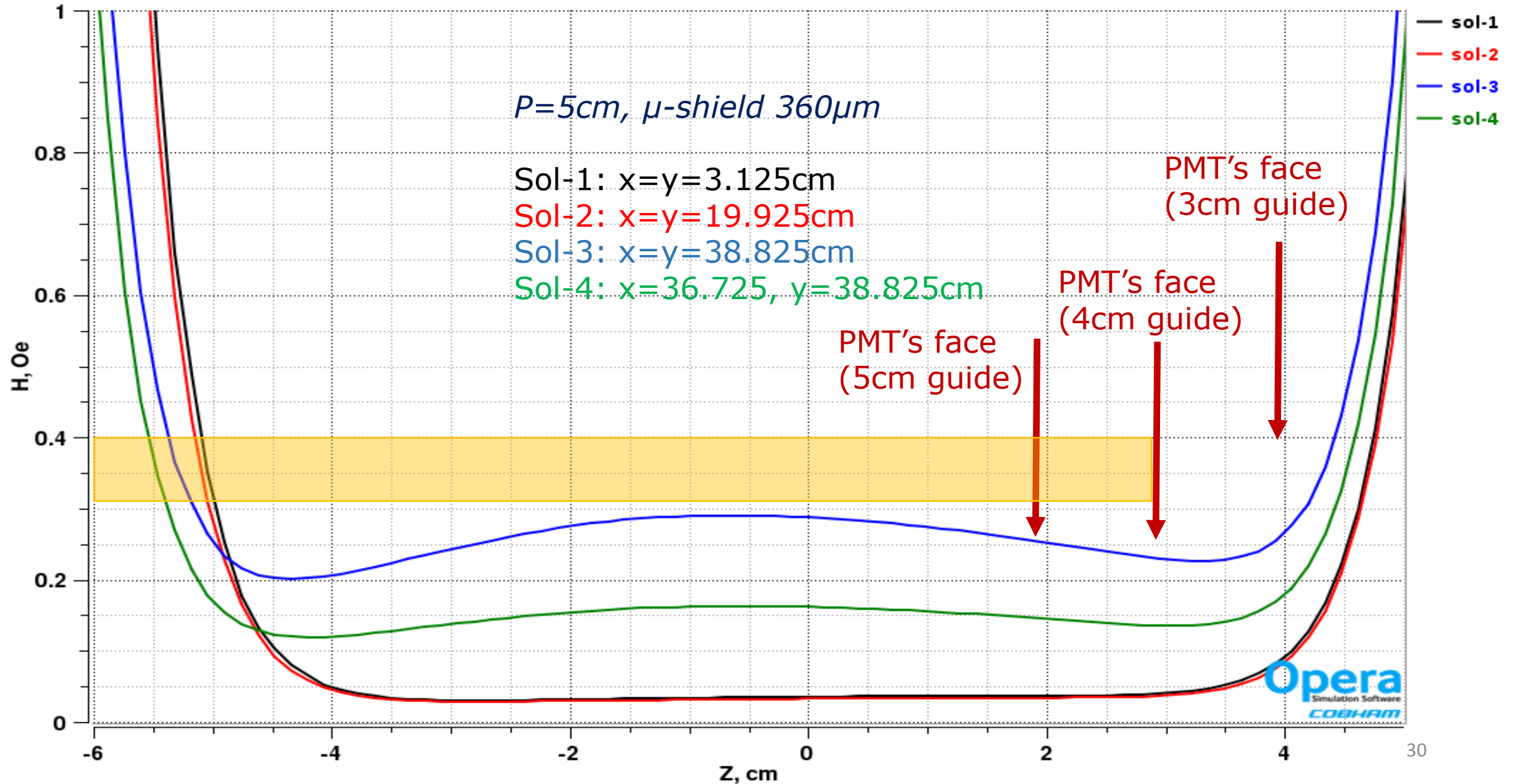


Field on Face of HFCal with Solenoid



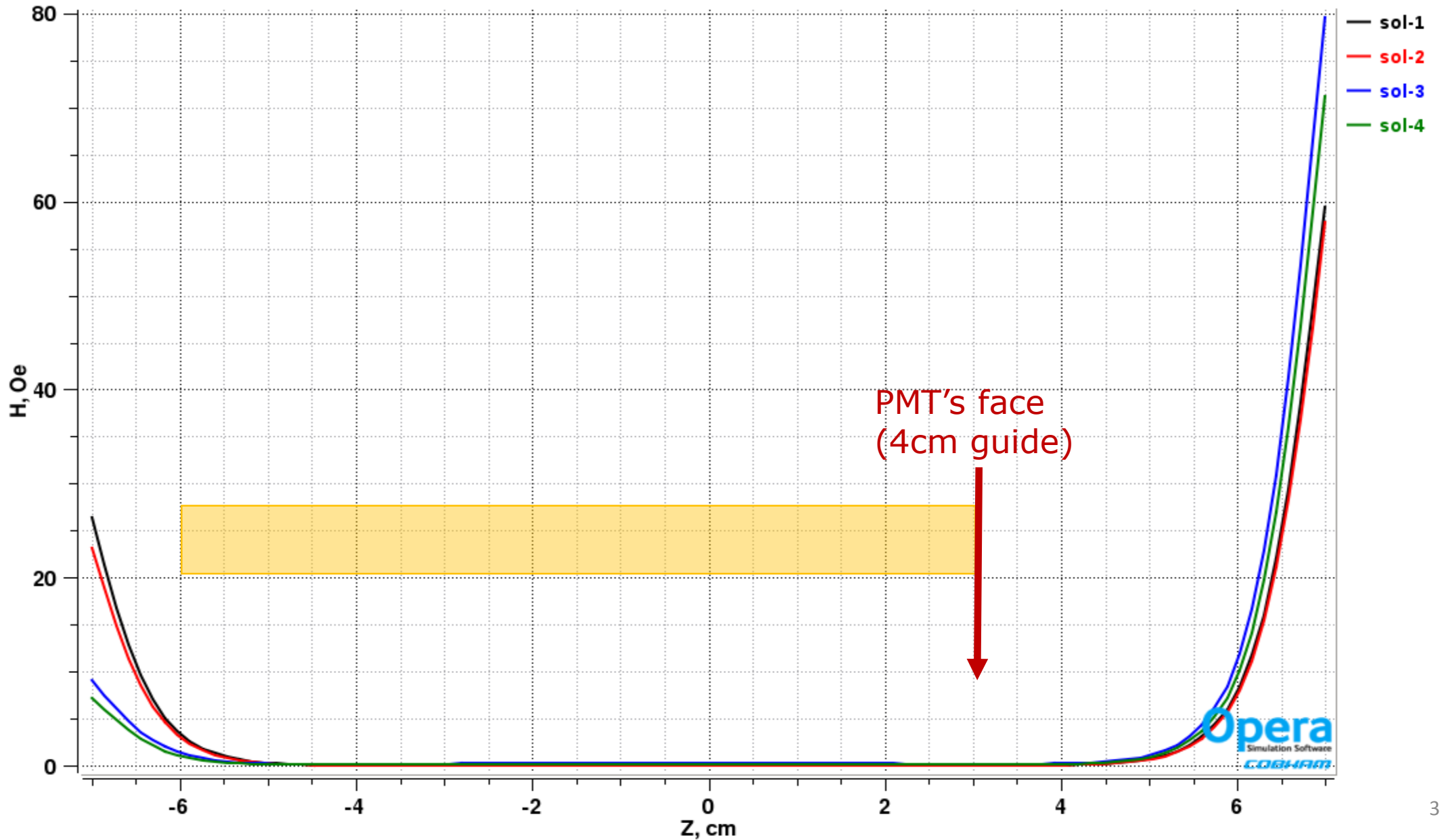
19x19 Hybrid FCal with Solenoid

19x19 HFCal with Solenoid



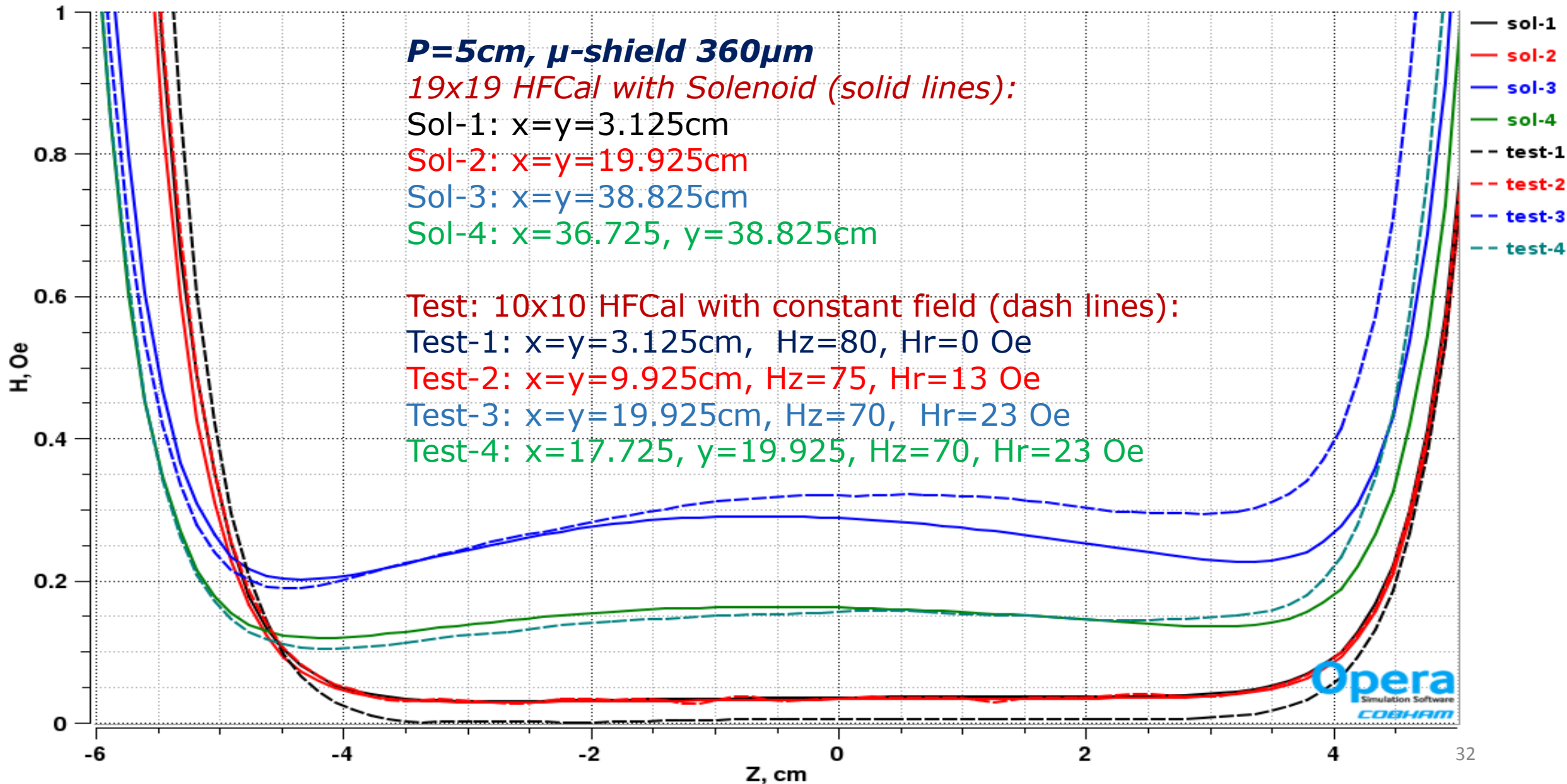
19x19 Hybrid FCal with Solenoid

19x19 HFCal with Solenoid



Comparison Solenoid vs Realistic Field

19x19 HFCal with Solenoid



TOSCA/OPERA Model Precision

Overestimates:

- *Zero tolerances*
- *Perfect annealing*
- *Perfect alignment*
- *No welding*

Underestimates:

- *19x19 crystals model vs ~24x24*
- *More LG shielding layers*
- *Field on PMT axes is maximal*

Reasonable conservative result!

RECOMENDATIONS

PMT's block:

Steel AISI-1010: 2.05x2.05x14cm, $R_{in}=1.01\text{cm}$

μ -shield:

Co-netic: $L=14\text{cm}$, $R_{in}=0.965\text{cm}$, thickness= $360\mu\text{m}$

Co-netic thickness = $250\mu\text{m}$ is acceptable

Welded cylinder

Cylinder magnetically separated of 1010-block (painted?)

Overlapping parameter(LG – crystal PMT's housing): 5cm

Face to face geometry is possible

Light guide: 3-4cm

AISI-1010 / co-netic length: 14 cm. If length is too long use

Longer light guide instead shorter shield

Co-netic cylinder shorter AISI-1010 block is more complex in assembly without essentially lower field