Magnetic field interference in RGH project[1]. Simulations using OPERA/TOSCA[2].

Outlook

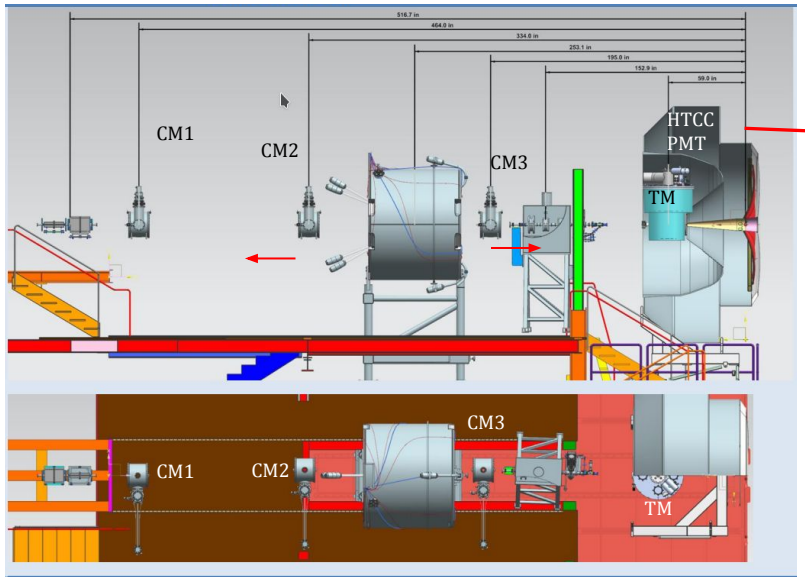
1. Beam Line configuration and focusing onto Cryo Target.
2. Maxwell forces between PMT shields and Beam Line Magnets.
3. Stray magnetic fields and performance of HTCC PMTs . Critical.
4. Positive Effect of Dynamic Magnetic Shield [3] .

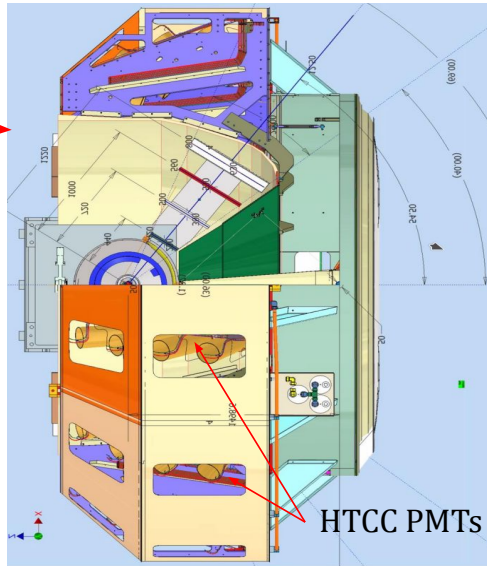
[1] J.S. Alvarado *et al.*, "CLAS12 Run-group H Experiments with a Transversely Polarized Target", https://www.jlab.org/exp_prog/proposals/24/J12-24-RunGroupH.pdf

[2] V. Baturin,"Reports to RGH group", https://clasweb.jlab.org/wiki/index.php/RGH_Meetings

[3] V. Baturin *et al.*, "Dynamic Magnetic Shield for the CLAS12 Central TOF Detector Photomultiplier Tubes", Nucl. Inst. and Meth. A 664, 11 (2012). (paper)

RGH beam line with 7T Chicain Magnets (CM1,2,3) and 5T Target Magnet (TM)

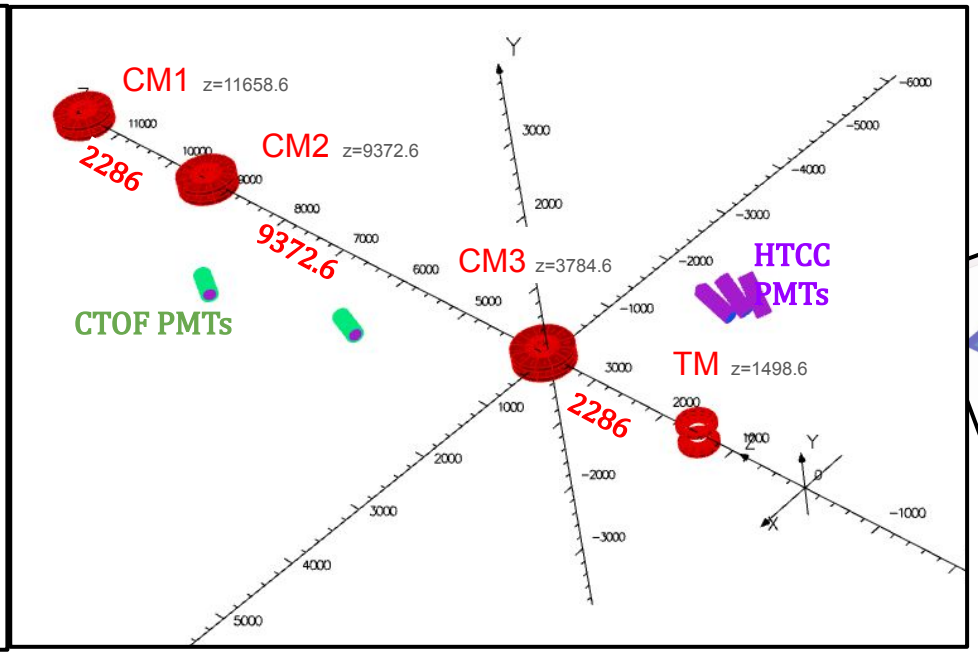


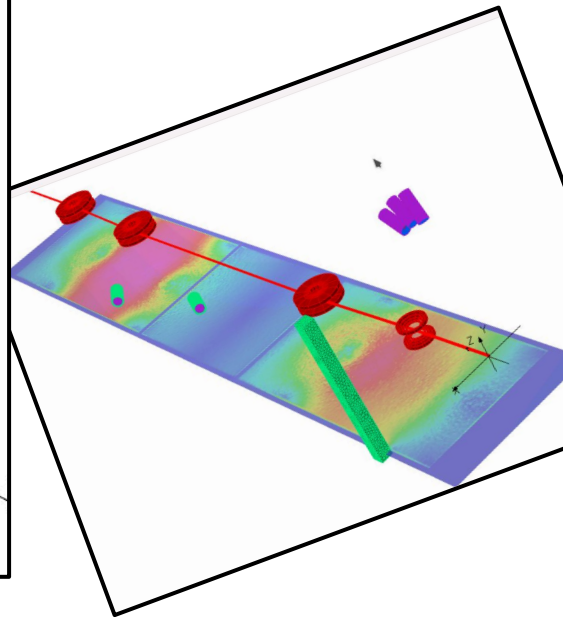


- Chicane line optimization to focus on the Target.
- Forces and torque to PMT shields and Cherenkov Light collection.
- PMT Shield design and PMT performance.
- Mutual forces between magnets and steel parts of the platform.

RGH beam line and Lorentz Forces on Magnets. OPERA/ TOSCA simulations.

Fx/Kg	FF_x/Kg	Fy/Kg	FF_y/Kg	Fz/Kg	FF_z/Kg	
0.0		1,545.5		-0.8		
0.0		2,863.7		-1.6		
0.0		5,125.3		-2.8		
0.0		10,126.8		-5.8		
0.0		164,981.4		-148.1		
0.0		-164,980.6		-148.1		CM1
0.0		-10,126.4		-5.8		
0.0		-5,124.9		-2.8		
0.0		-2,863.1		-1.6		
0.0	-0.003	-1,547.9	-0.184	0.9	-316.6	
0.0		1,545.5		0.9		
0.0		2,863.7		1.6		
0.0		5,125.3		2.9		
0.0		10,126.8		5.9		
0.1		164,981.2		150.7		
0.1		-164,980.4		150.7		CM2
0.0		-10,126.4		5.9		
0.0		-5,124.9		2.9		
0.0		-2,863.1		1.6		
0.0	0.129	-1,547.8	-0.136	-0.4	322.8	
0.0		1,545.5		-0.4		
0.0		2,863.7		-0.7		
0.0		5,125.1		-1.2		
0.0		10,126.4		-2.5		
0.0		164,972.5		-64.1		
0.0		-164,971.6		-64.1		CM3
0.0		-10,126.1		-2.5		
0.0		-5,124.7		-1.2		
0.0		-2,863.0		-0.7		
0.0	-0.012	-1,547.9	-0.110	-0.8	-138.2	
0.0		65,448.1		37.0		
0.0		2,368.6		18.4		
0.0		-11,091.2		7.8		
0.0		-6,532.8		2.6		
-0.1		-65,447.7		36.9		TM
0.0		-2,368.4		18.4		
0.0		11,091.2		7.8		
0.0	-0.268	6,532.8	0.650	2.6	131.4	

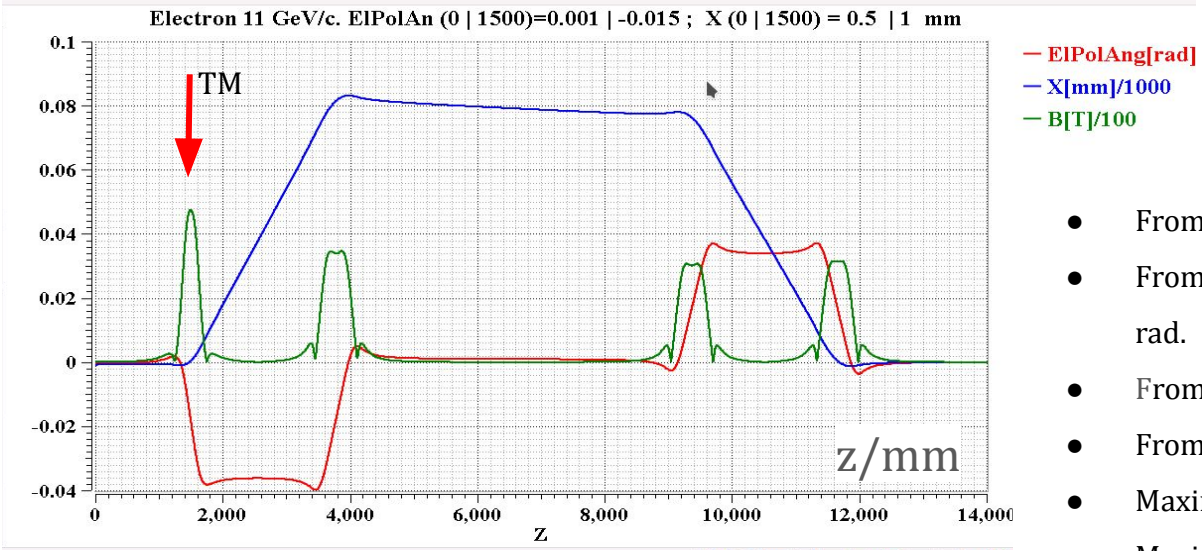


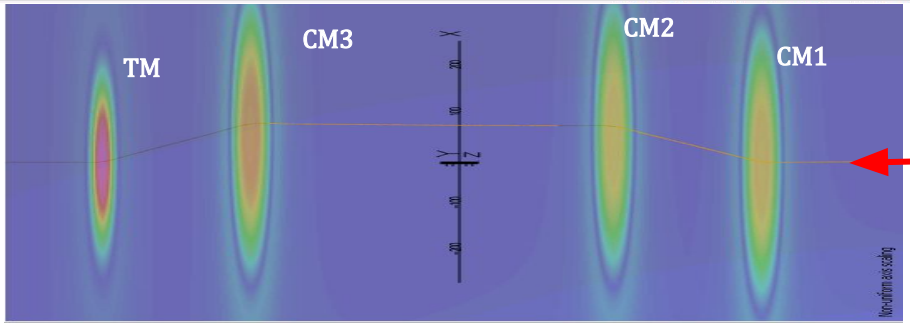


- Resulting $F_{x,y}$=~0 for all magnets, including TM, due to symmetry.
- Resulting **F_z =~±130 Kg** between TM & CM3 and = ~**±320 Kg b** etween CM1 & 2.
- Maximal **Internal vertical force inside Magnets** is of ~165,000 Kg.

“Symmetric” Beam Line. Trajectory of well focused Beam 11 GeV/c

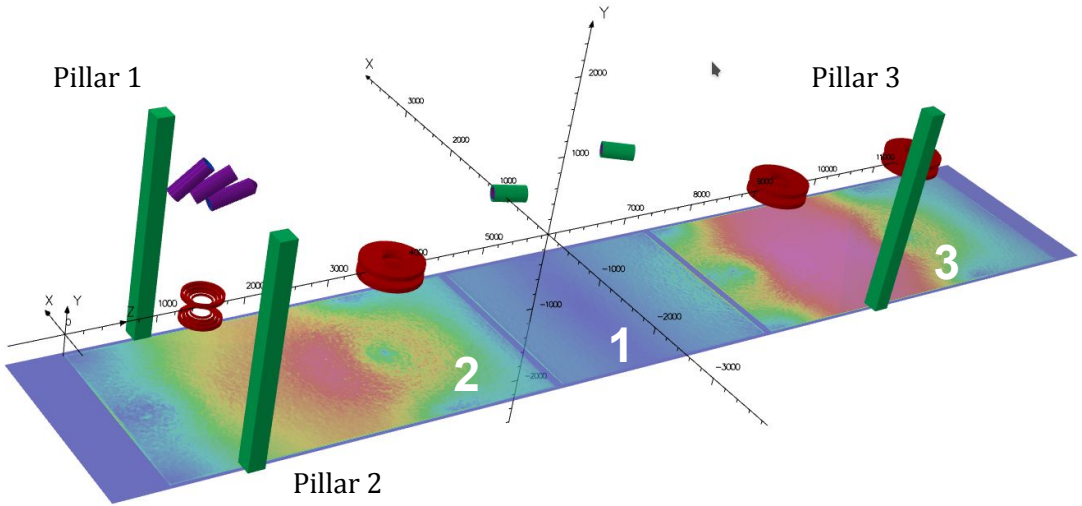
Model BEAMTRAJ-0d5CHIC+X6cm-M1-1d12.opc





- From **red plot** we read ElPolAng(z=0)=**~0.001 rad.**
- From **red plot** we read ElPolAng(Z_target)=~0.015 rad.
- From **blue plot** we read X(Z_target)=**-1 mm**!
- From **blue plot** we read X(0)=-0.5 mm!
- Maximum deviation from Beam Line **80 mm.**
- Maximal **Magnetic field** in chicane magnets <4T!
- Two BPMs between CM2&3 are required!

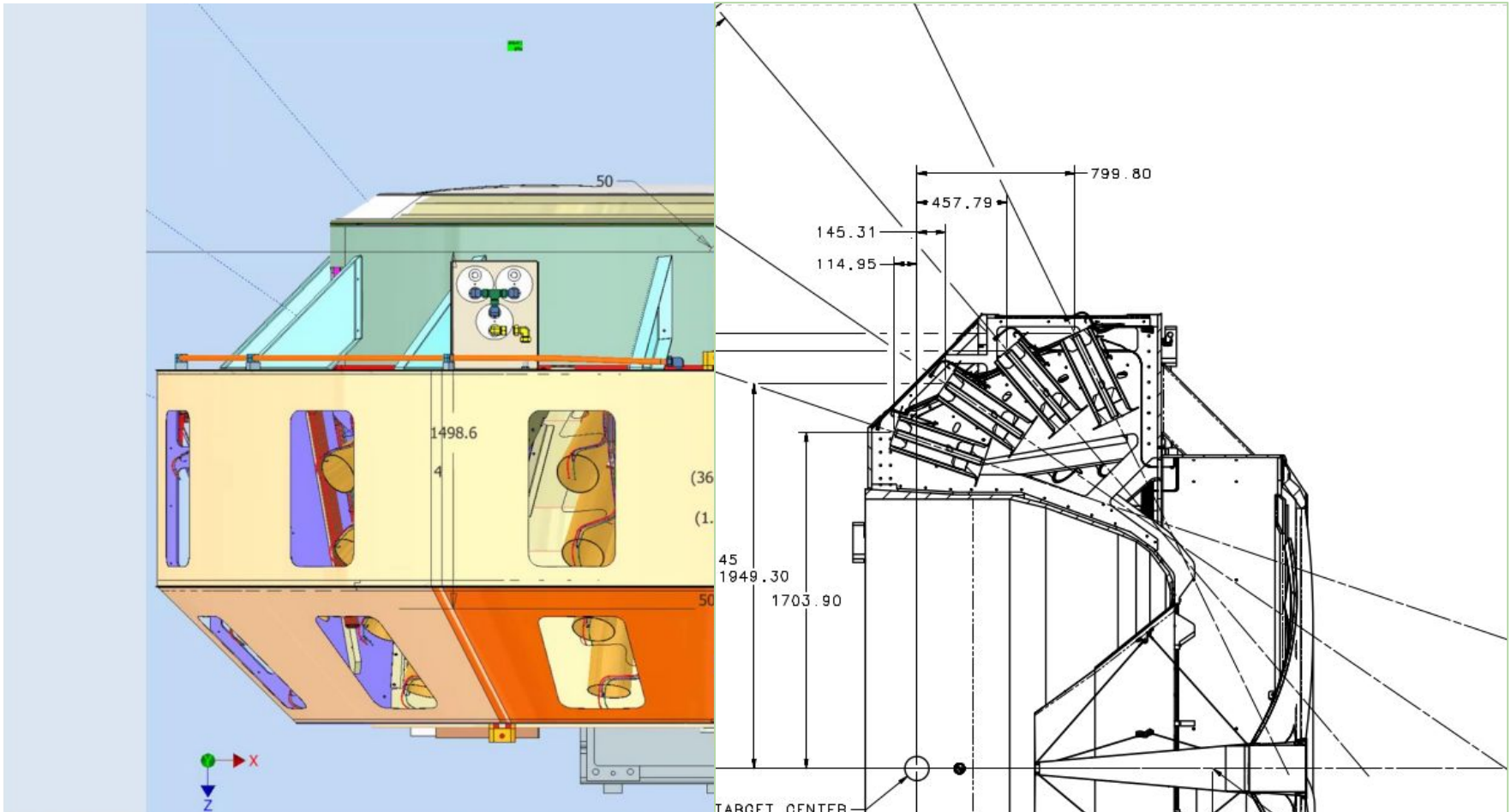
Maxwell forces to PMTs, Floor Segments, and Struts .



Part	V/mm^3	Fx/N	Fy/N	Fz/N
Floor 1	3.6E8	0	148	-1
Floor 2	5.7E8	0	5843	103
Floor 3	6.0E8	–5	9911	-13
PILLAR 1	1.08E8	–88	–4.4	–4.1
PILLAR 2	1.08E8	45	–1.7	–2.1
PILLAR 3	1.08E8	85	–6.5	–95.
DSEXT	3.49E6	-0.3	0	-3
USEXT	3.49E6	-0.7	0.4	0.3
HTCC Sh1	559E3	2.4	-4.7	13.6
HTCC Sh2	559E3	0.6	-1.7	1.0
HTCC Sh3	559E3	0.15	-0.5	0.15

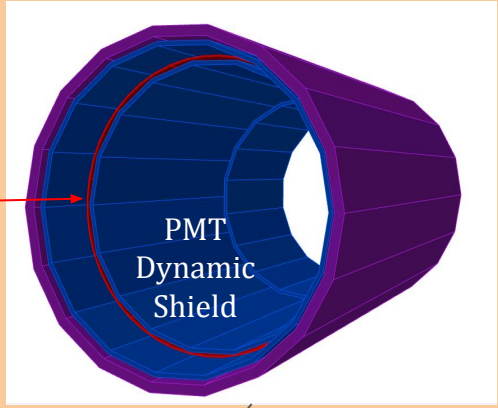
- Steel components of CTOF shields under < 3 N load;
- HTCC shields - under < 15 N load.
- A steel platform element (strut) inder load of < 90 N.
- Floor 2 (50 mm thick) and beamline magnets mutually attract with F_y= ~6,000 N
- Floor 3 and beamline magnets - with F_y=~10,000 N.

HTCC PMTs in Stray Magnetic field of 150 Gauss

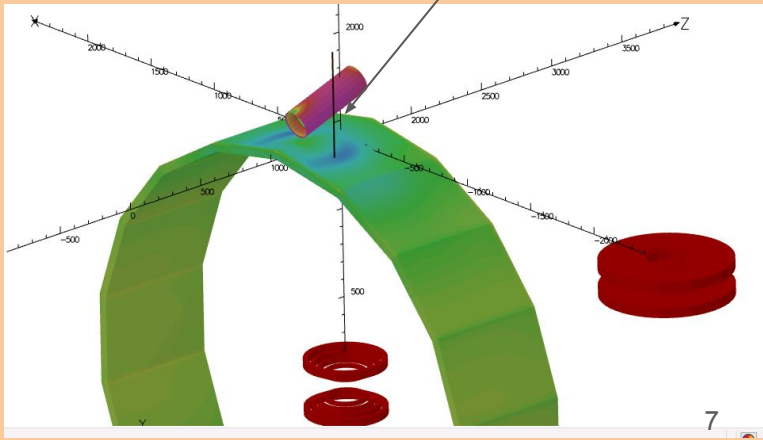


HTCC PMT performance in high magnetic fields and effects of

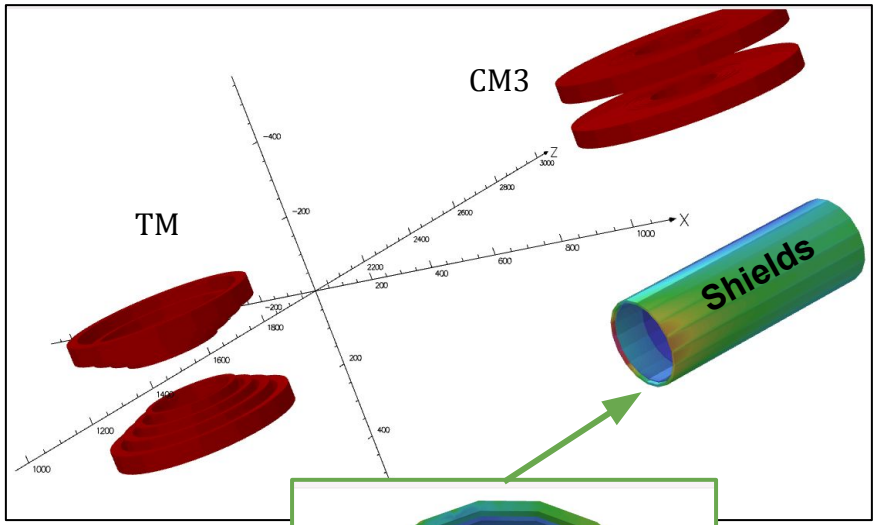
1. Barrel Shield (Green cylinder made of steel 1010).
2. Cylindrical extension from Readout (RO) side.
3. Conical extension from the RO side.
4. Dynamic Shield; active coil

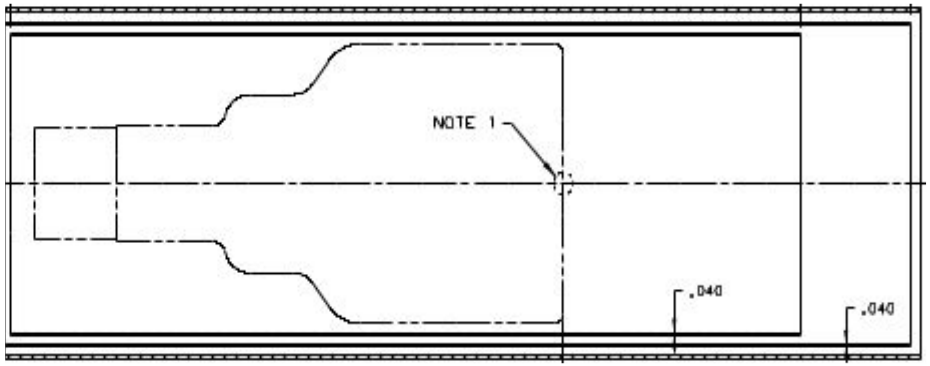


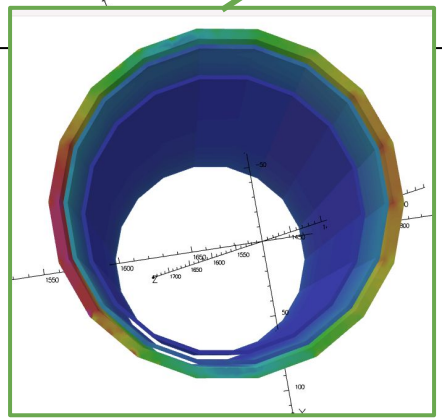




Ferromagnetic Shield for HTCC PMTs. Design and OPERA Model.

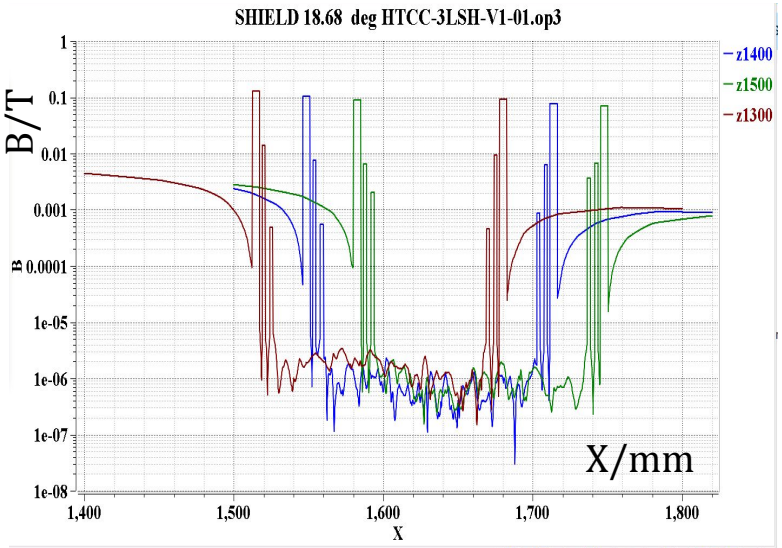


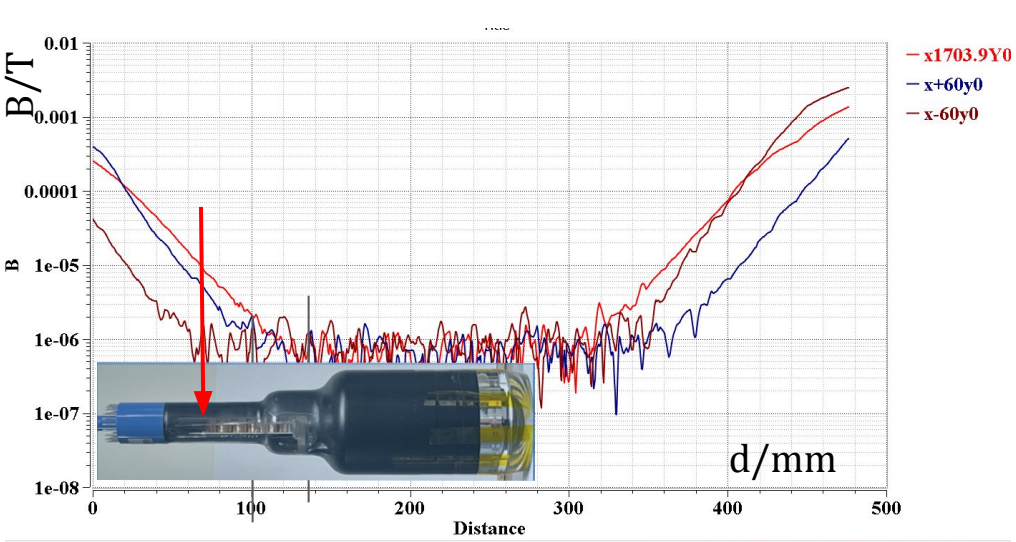




Layer	L/mm	OD/mm	ID/mm	Thick/mm	Material
External	457.20	163.83	159.00	4.826	Netic NS095
Middle	452.12	150.88	148.84	2.030	Co netic CP040
Inner	393.70	141.24	138.43	2.030	Co netic CP040

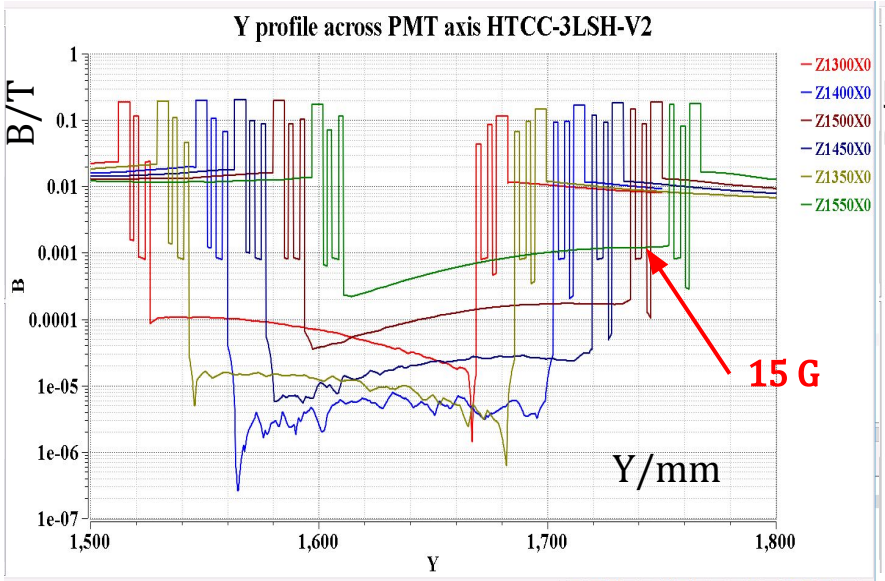
PMTs in Horizontal XZ-plane. Magnetic Field across (X) & along (d) PMT axis.

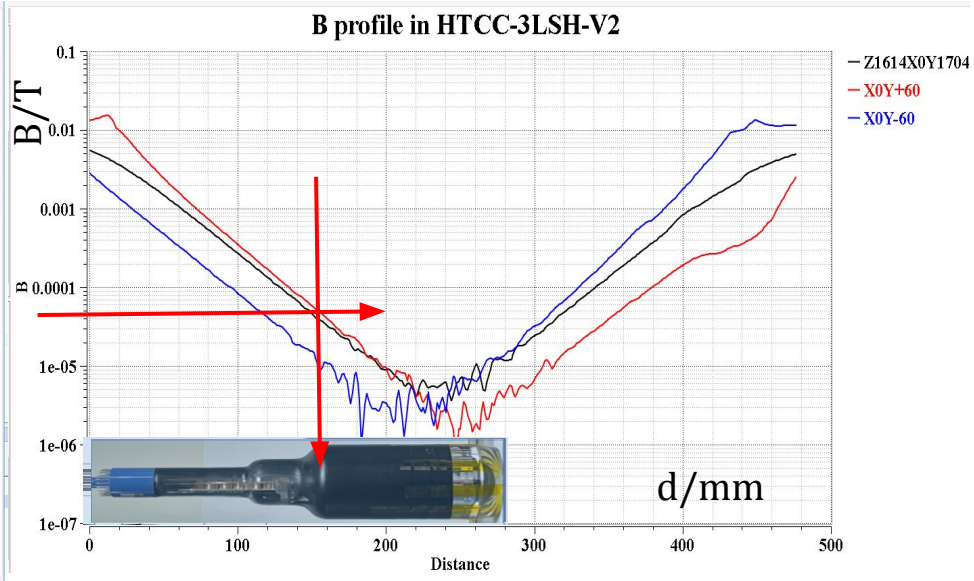




- External field is of 50 G. PMT inner field is of 0.01 Gauss.
- Comfortable conditions.

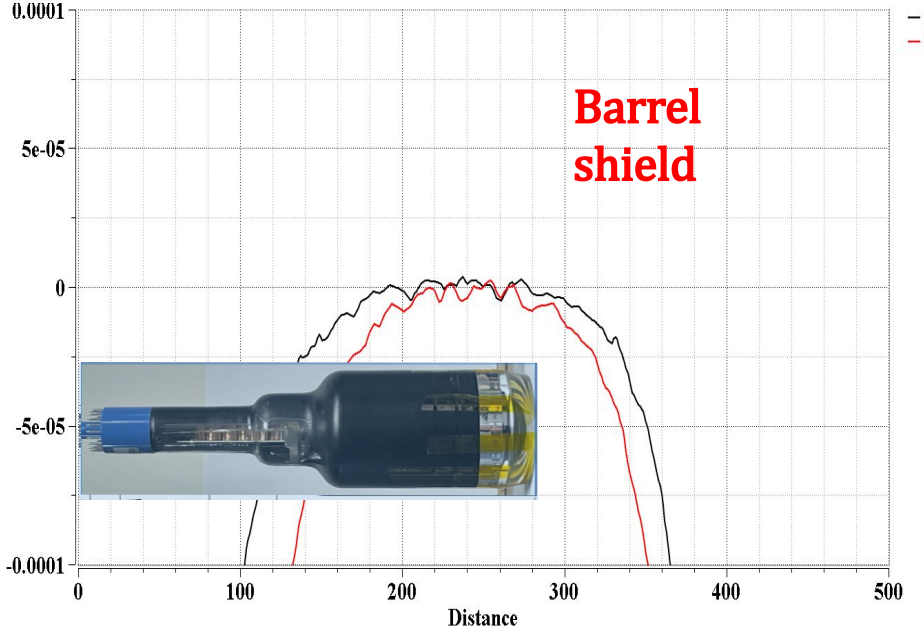
Problem with PMTs in YZ-plane. Magnetic Field across (Y) & along (d) PMT axis.





- External field is of 150 G. PMT inner B <0.1 Gauss at d >16 cm (12 cm from Photocathode).
- Problem: B > 0.5 Gauss at d <16 cm; **all dynodes at high field** !

Example. Effect of Very Large Barrel Shield (Steel 1010); field along PMT.

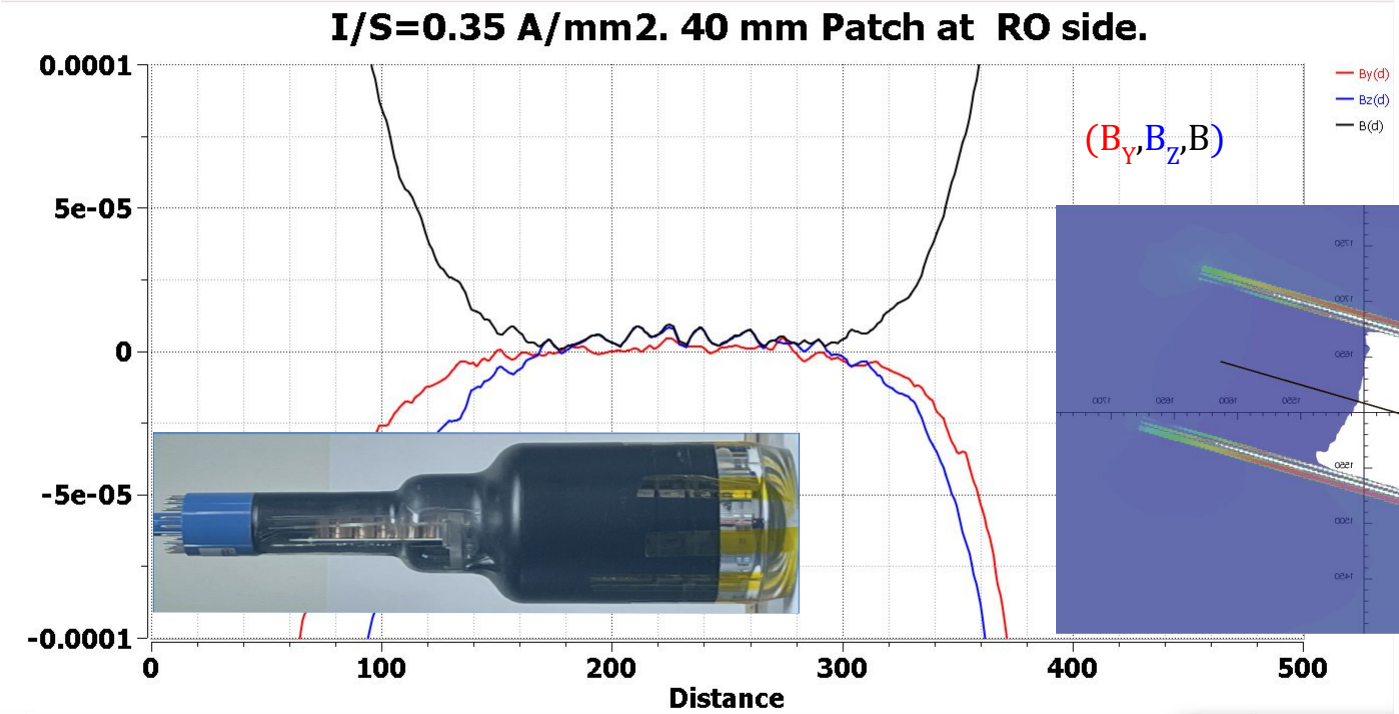


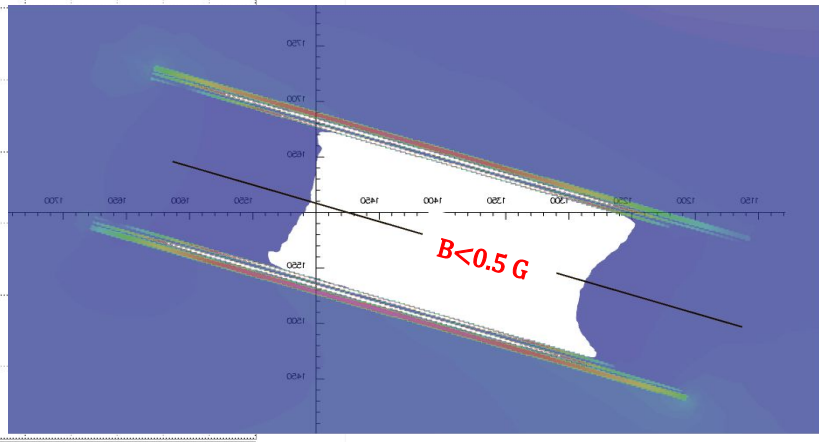


- Barrel Shield **does not help** .
- Even if we push PMT by 10 cm from RO side. (Y. Sharabian does not support).

Example. Active Coil and 4 cm shield extension from the RO side.

file:///C:/Users/baturin/RGHOPERA/HTCC-3LANDSSOLSH-V2-ROSH-01.OPC

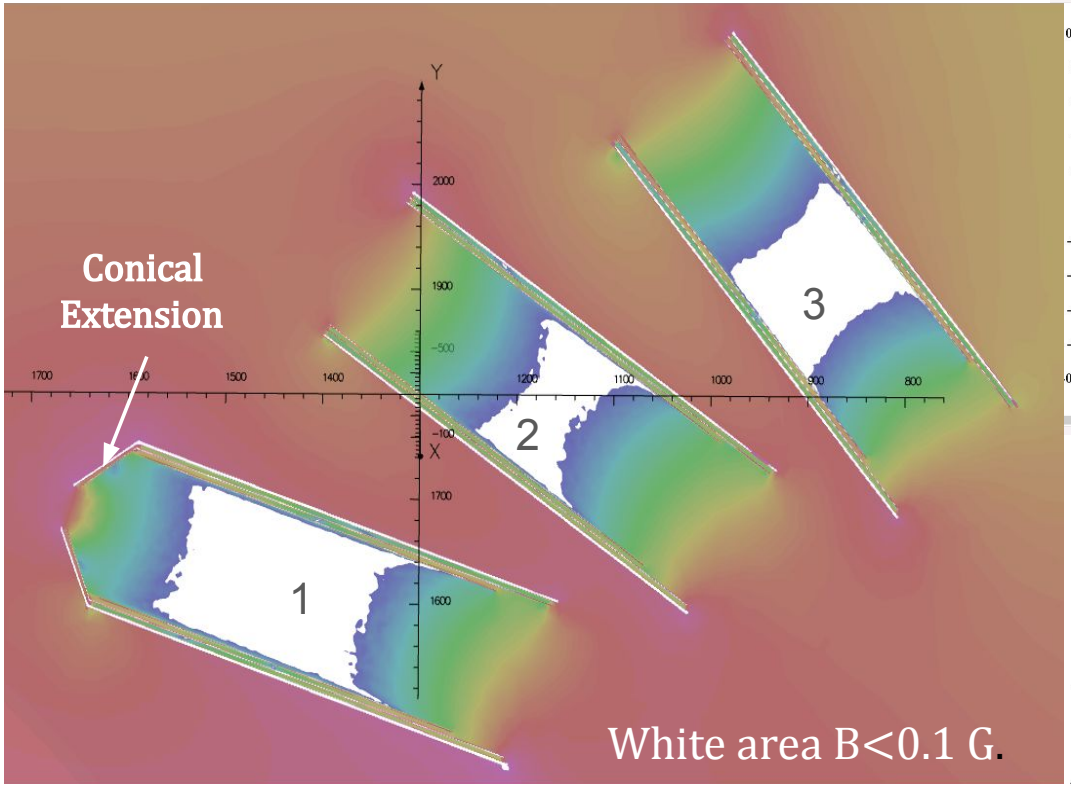


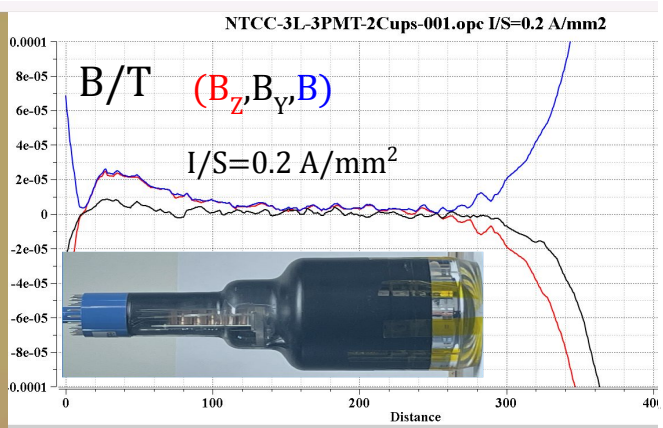


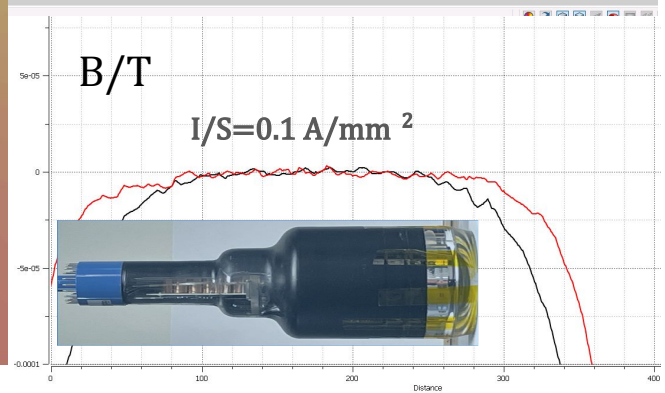
- Active coil with I/S $\leq$ 0.35 A/mm^2 and 4 cm extension guarantees sufficient shielding,
- Provided PMT pushed by ~5 cm from the RO side. But Y. Sharabian is not happy!

Conical Extension and Active Coil in PMT #1,3 is ON. PMTs at nominal position!

Model HTCC-3L-3PMT-2Cups-001.op3

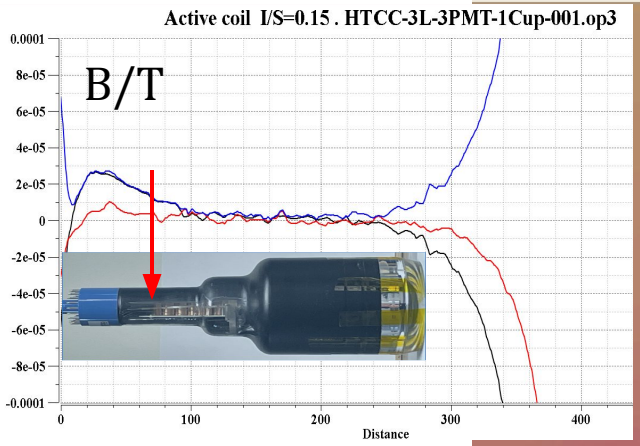


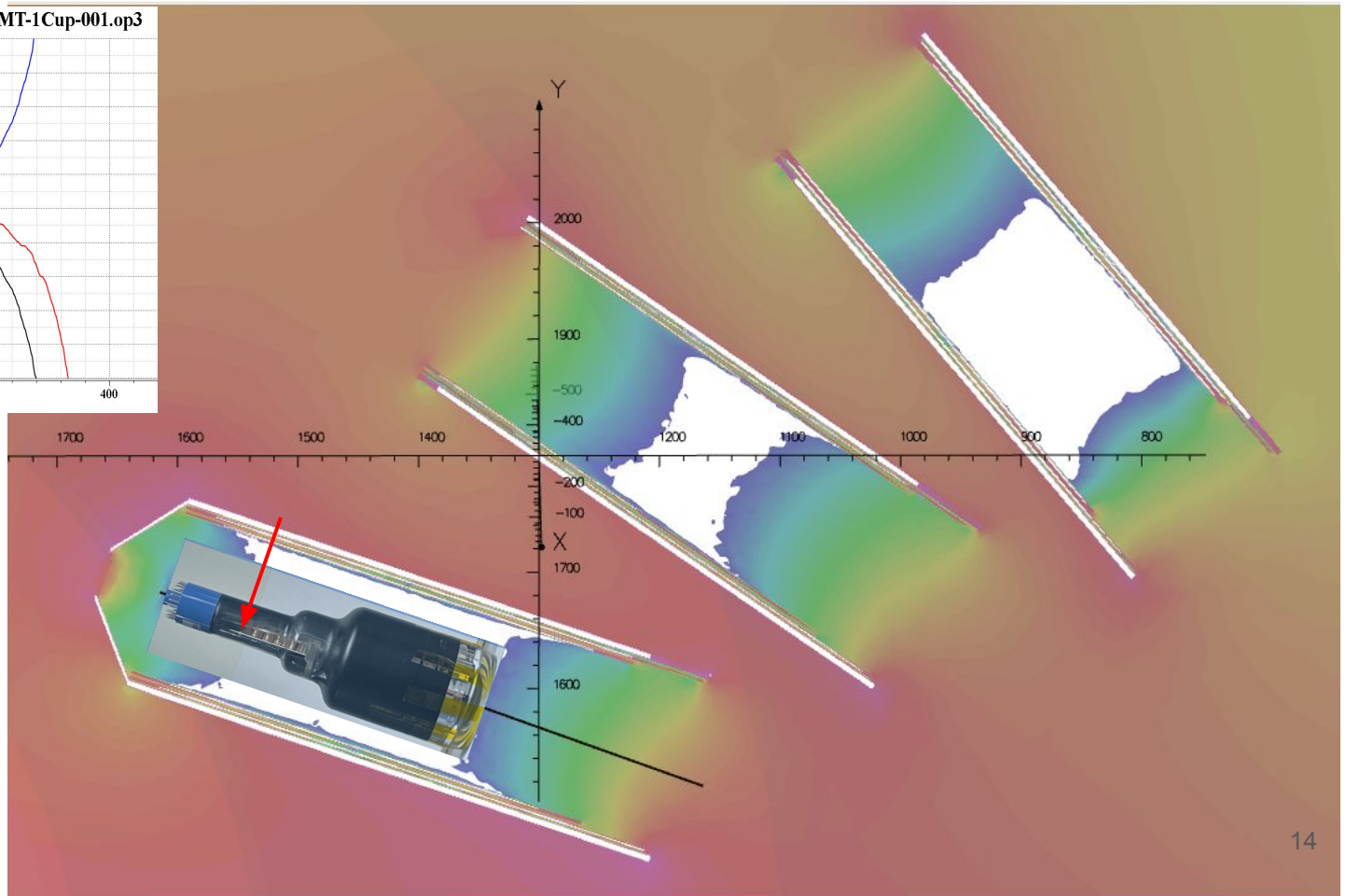




Active coil I/S=0.15 in PMTs 1&3 . White area B<0.1 G. PMT at nominal position!

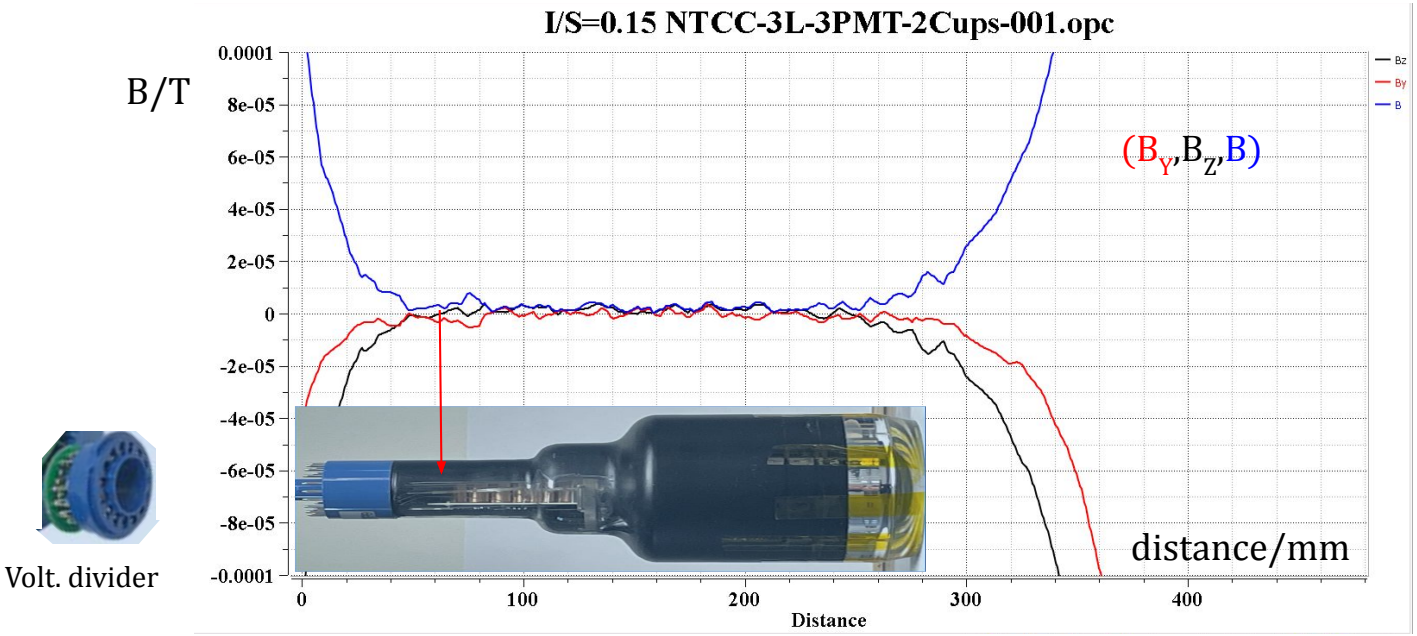
Model HTCC-3L-3PMT-1Cup-001.op3





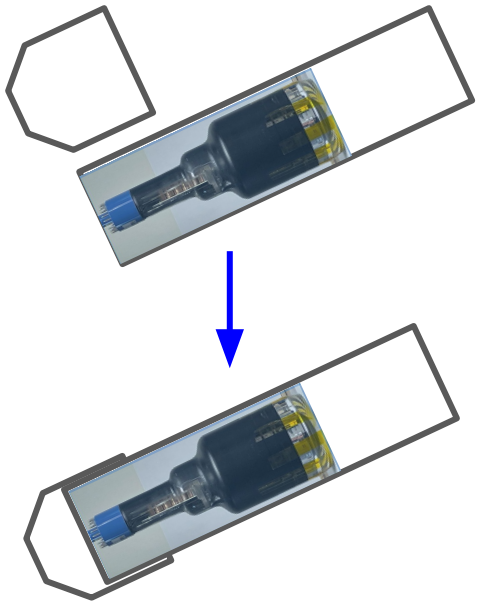
Final solution. 4 cm Conical Extension and Active coil I/S=0.15 A/mm^2. PMT at nominal position; inner B<0.05 G!

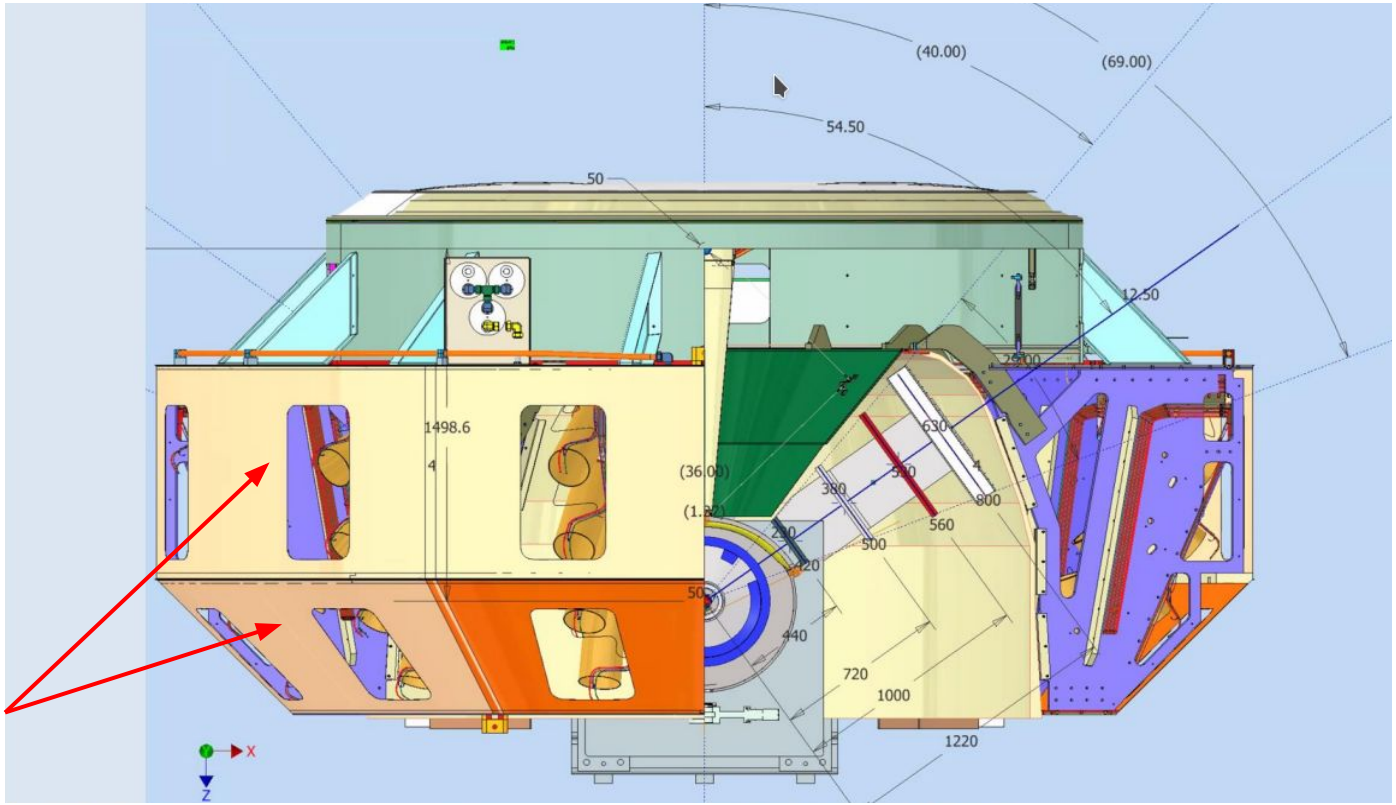
Model NTCC-3L-3PMT-2Cups-001.op3



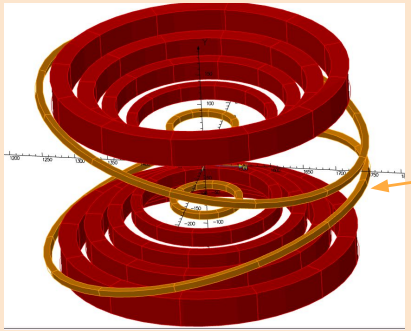
- Dynamic Magnetic Shield and conical extension solves the problem !
- PMT inner field B<0.05 G! Easy to modify existing Shields.

Conic Cap installation and Access to PMT shields from RO side.
NO shield dismount is required.



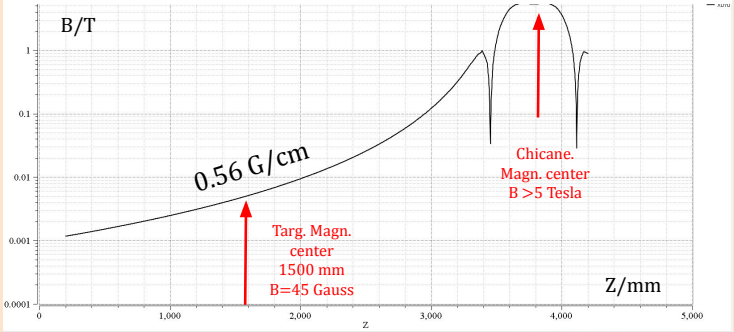


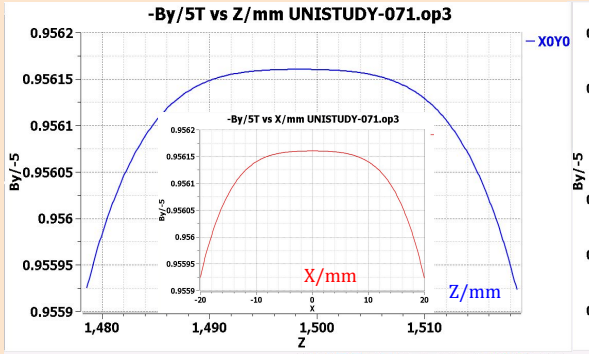
Compensation of Cryo Target Inner Field nonuniformity and Stray Field from Chicane Magnets.

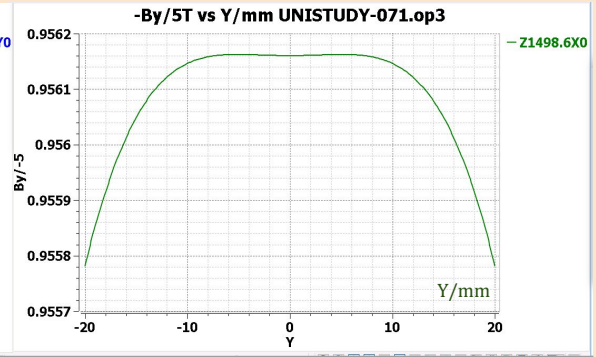


Warm Corrective Coils Outside Polarized Target Cryostat.

Stray field from upstream Chicane Magnets at beam axis.







Distance Interval From Tag. Center	Z Ref =1498.6	X Ref =0	Y Ref =0
Ref ±10 mm, B_{ZXY}/5T=	0.2 E-4	0.2 E-4	0.14 E-4
Ref ± 5 mm, B_{ZXY}/5T=	**0.03 E-4**	**0.03 E-4**	**0.03 E-4**

- **Very high and variable** B-field **uniformity inside the Target** **may be achieved** with external warm coils.
- **No redesign** of the Cryo Target Magnets and setup is required.

Future work with OPERA.

1. Support Engineering Design with detailed calculations of Maxwell forces between beam line magnets and magnetic elements of surrounding structure.
2. Support the Engineering Design of PMT shields.
3. Optimisation of currents in active coils of PMT shields.

Thanks for your attention.