

**NSLS2 Dipole
with
Electromagnetic (EM) Tooth**

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EM Dipole Tooth Studies

Active tooth (coil around small pole) with various axial pole width for 35 mm pole gap

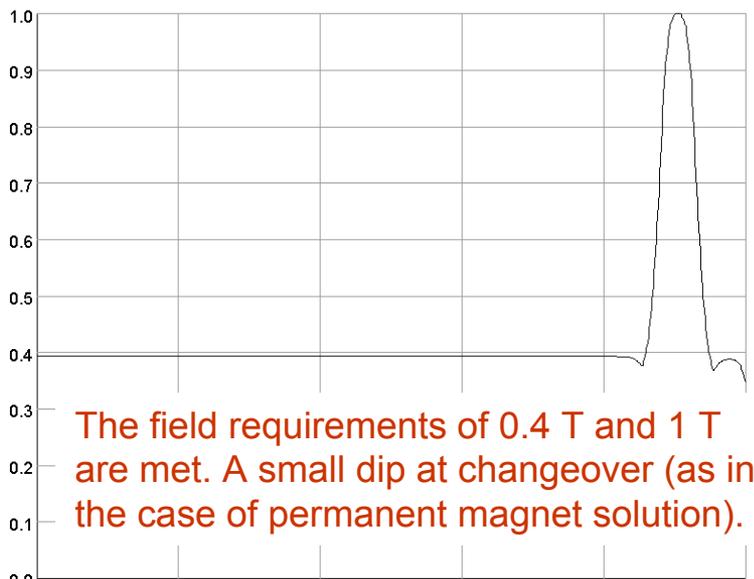
- ↓ **100 mm** : Starting point - Too large deflection ~10 mrad (initially desired ~2 mrad) - ***OUT***
- **50 mm** : Seems to work (but with larger than initially desired deflection)
- ↘ **20 mm** : Seems to be too small - ***Almost OUT (will not be discussed today)***
- ↗ **35 mm** : Why not examine this as a possible solution - **looks promising ...**

Passive tooth – Adjust pole gaps to generate 1 T field step in a nominal 0.4 T dipole.

For this meeting, rather than field quality, we would examine field profile (field, peak field, half width, etc.). First work on the basic design, then on harmonics.

Also a brief comparison of EM and PM tooth options.

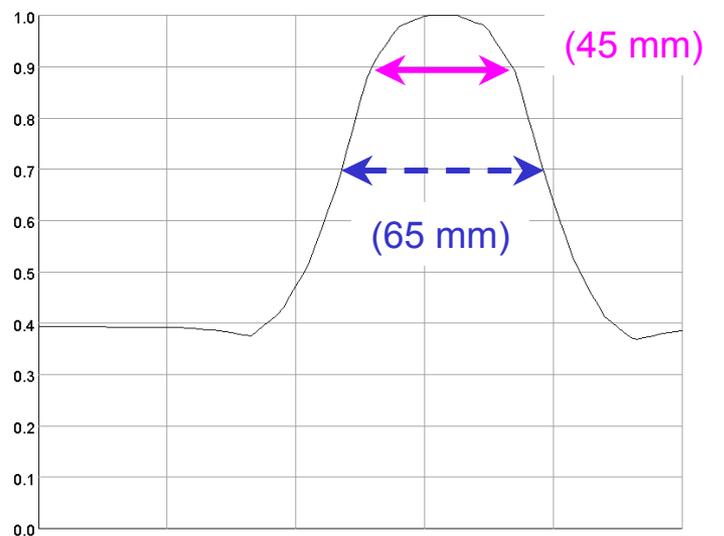
50 mm Wide Pole (plus 50 mm space either side for coil)



The field requirements of 0.4 T and 1 T are met. A small dip at changeover (as in the case of permanent magnet solution).

Component: BMOD, Integral = 557.400551705338

X coord	50.0	51.3758176	55.5031187	62.3814485	72.010049	84.387859
Y coord	0.0	0.0	0.0	0.0	0.0	0.0
Z coord	0.0577E-12	262.114928	524.200971	786.229246	1048.17088	1309.997



Component: BMOD, Integral = 127.829681847211

X coord	73.8190481	75.7684628	77.7943272	79.8966351	82.0753801
Y coord	0.0	0.0	0.0	0.0	0.0
Z coord	1091.67515	1135.34515	1179.01167	1222.67458	1266.33374

Magn Flux Density T
Magn Field A m⁻¹
Magn Scalar Pot A
Magn Vector Pot Wb m⁻¹
Elec Flux Density C m⁻²
Elec Field V m⁻¹
Conductivity S mm⁻¹
Current Density A mm⁻²
Power W
Force N
Energy J

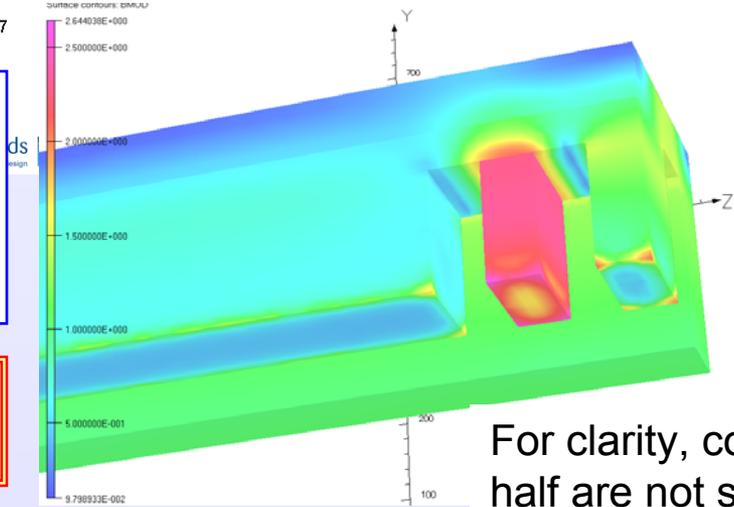
PROBLEM DATA
Is2-cu4+5a3_1-coil2-5_4.op3
TOSCA Magnetostatic
Nonlinear materials
Simulation No 1 of 1
122857 elements
210066 nodes
4 conductors
Nodally interpolated fields
Activated in global coordinate

Field Point Local Coordin
Local = Global

Deflections:

- ~4.3 mrad in 0.9 T – 1 T region (~45 mm).
- ~4.7 mrad additional deflection from the entire tooth region (~130 mm).

**What is the relevant parameter of merit?
Above or any other?**



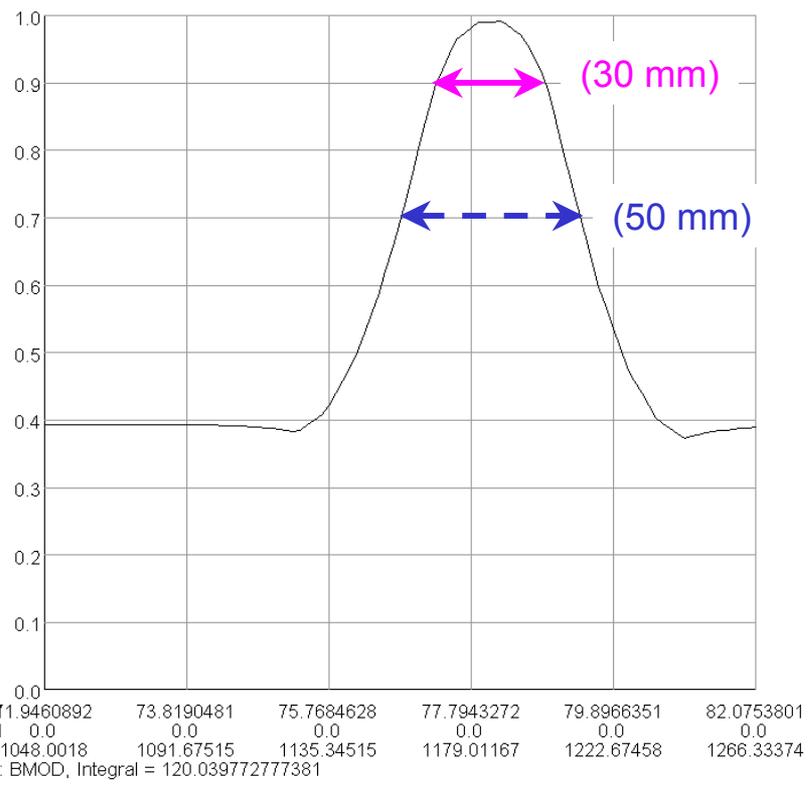
Magn Field A m⁻¹
Magn Scalar Pot A
Magn Vector Pot Wb m⁻¹
Elec Flux Density C m⁻²
Elec Field V m⁻¹
Conductivity S mm⁻¹
Current Density A mm⁻²
Power W
Force N
Energy J

PROBLEM DATA
Is2-cu4+5a3_1-coil2-5_4.op3
TOSCA Magnetostatic
Nonlinear materials
Simulation No 1 of 1
122857 elements
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Field Point Local Coordinates
Local = Global

For clarity, coil and lower half are not shown.

35 mm Wide Pole (plus 50 mm space either side for coil)



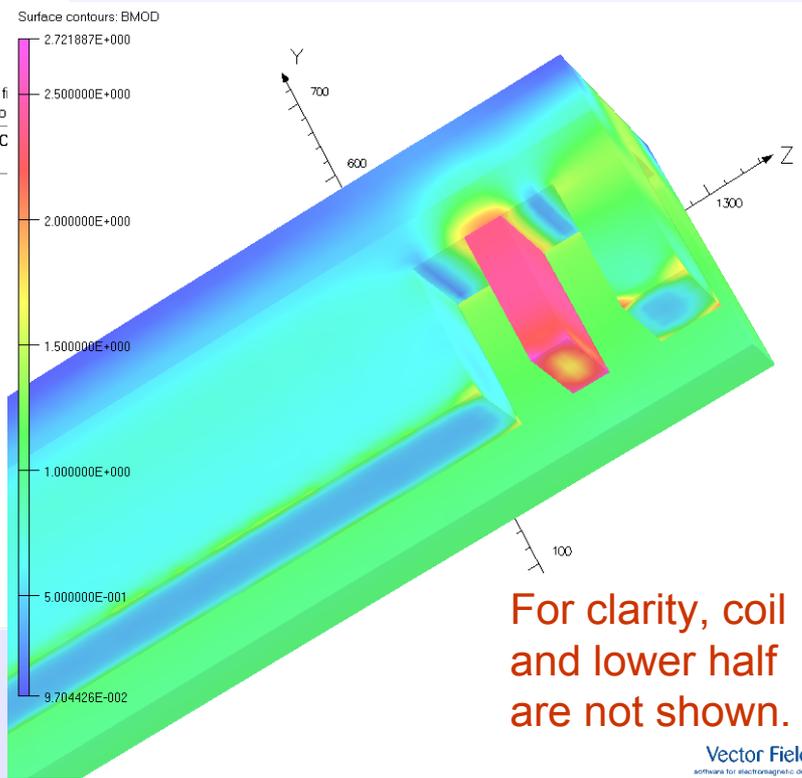
UNITS

Length	mm
Magn Flux Density	T
Magn Field	A m ⁻¹
Magn Scalar Pot	A
Magn Vector Pot	Wb m ⁻¹
Elec Flux Density	C m ⁻²
Elec Field	V m ⁻¹
Conductivity	S mm ⁻¹
Current Density	A mm ⁻²
Power	W
Force	N
Energy	J

PROBLEM DATA
 Is2-cu4-35mm-coil2-7_0.op3
 TOSCA Magnetostatic
 Nonlinear materials
 Simulation No 1 of 1
 1245825 elements
 213015 nodes
 4 conductors
 Nodally interpolated fi
 Activated in global co

Deflections:

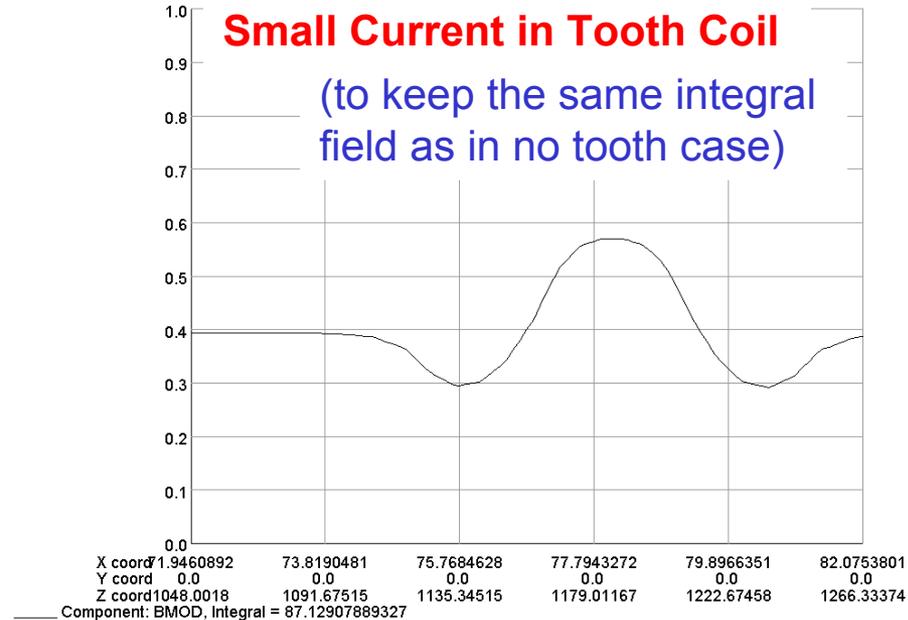
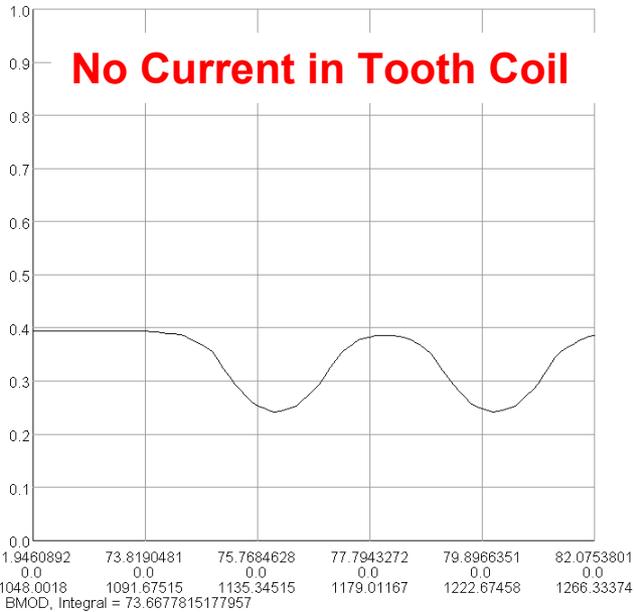
- ~3 mrad in 0.9 – 1 T region (~30 mm).
- ~3.3 mrad additional deflection from the entire tooth region (~100 mm).



Remember now we have:
35 mm long powered tooth, 35 mm pole gap and 100 mm pole width.

For clarity, coil and lower half are not shown.

Turning off (sort off) EM Tooth



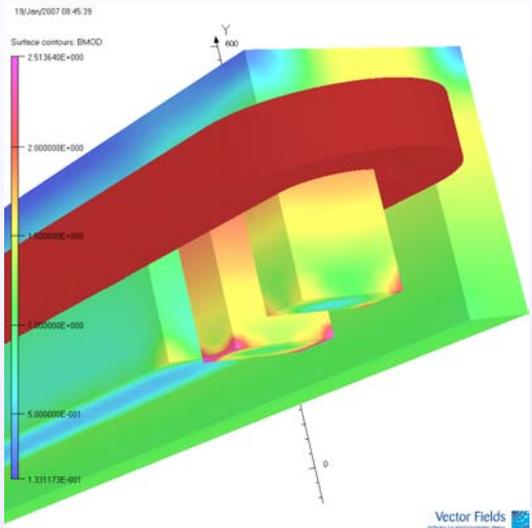
Magn Flux Density
 Magn Field
 Magn Scalar Pot
 Magn Vector Pot
 Elec Flux Density
 Elec Field
 Conductivity
 Current Density
 Power
 Force
 Energy
PROBLEM DATA
 Is2-cu4-35mm-coil2-1,
 TOSCA Magnetostat
 Nonlinear materials
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 1245825 elements
 213015 nodes
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Field Point Local C
 Local = Global

To obtain the same integral field as in no tooth case, one can

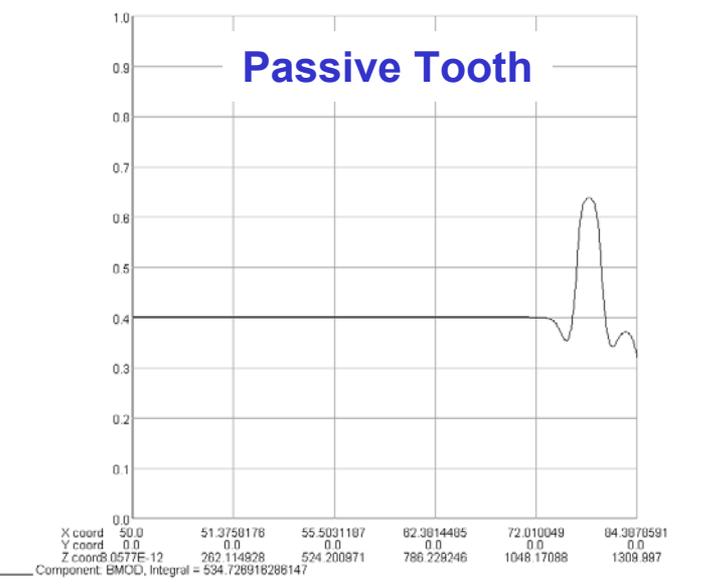
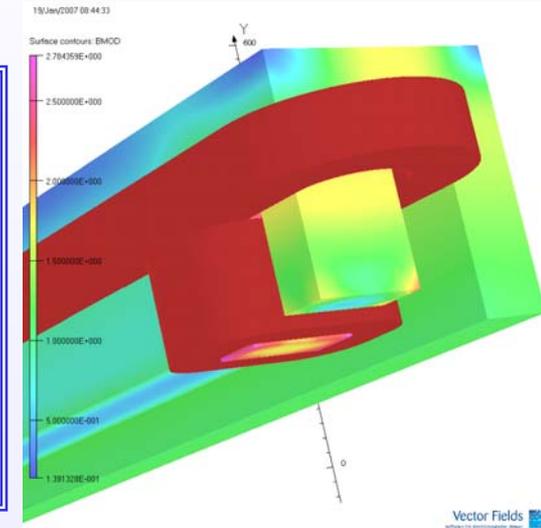
- (a) either switch off the tooth coil and adjust the current in main coil
- or (b) can adjust the current in tooth coil.

- Small iron “cap” can be inserted under coil to homogenize the field, if wiggle is not desired (such mechanical operations are easy in non-magnetized EM tooth)
- Can small adjustment in tooth coil may be used to serve as corrector dipole?

Passive Tooth (sort off) (35 mm tooth and in nominal 63 mm gap)



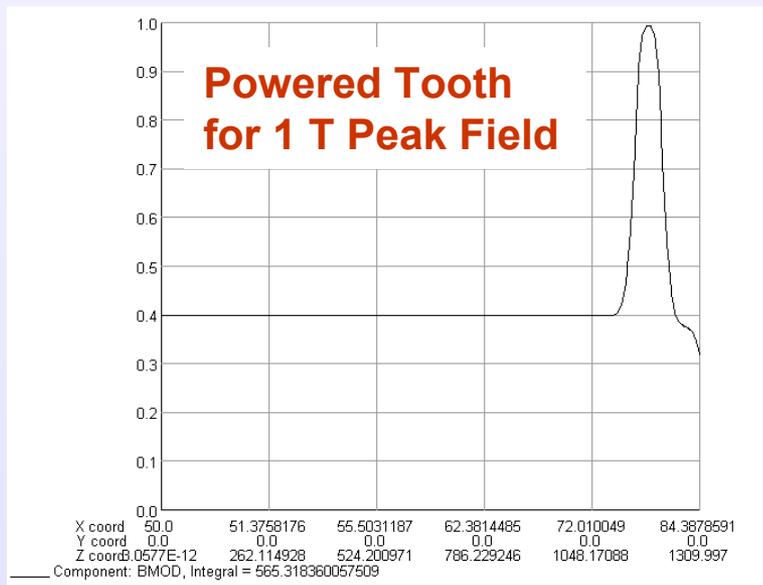
- For a passive tooth with a pole gap of 35 mm in a dipole with a nominal gap of 63 mm, the gap ratio is not right for 1 T and 0.4 T respective fields.
- Additional coil is used to obtain the desired 1 T to 0.4 T ratio. Thus, it is not a fully “Passive Tooth” any more.



Magn Flux Density	T
Magn Field	A m ⁻¹
Magn Scalar Pot	A
Magn Vector Pot	Wb m ⁻¹
Elec Flux Density	C m ⁻²
Elec Field	V m ⁻¹
Conductivity	S mm ⁻¹
Current Density	A mm ⁻²
Power	W
Force	N
Energy	J

PROBLEM DATA
Is2-r63mm-50mm-tooth-3.op3
TOSCA Magnetostatic
Nonlinear materials
Simulation No 1 of 1
1199293 elements
204948 nodes
3 conductors
Nodally interpolated fields
Activated in global coordinates

Field Point Local Coordinates
Local = Global



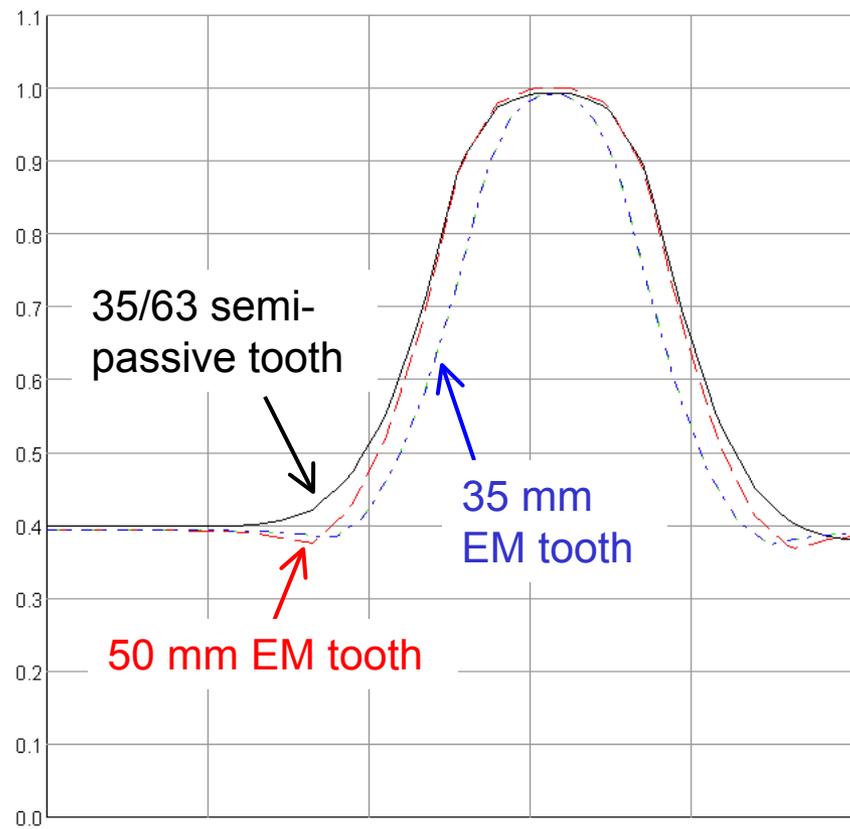
Magn Flux Density	T
Magn Field	A m ⁻¹
Magn Scalar Pot	A
Magn Vector Pot	Wb m ⁻¹
Elec Flux Density	C m ⁻²
Elec Field	V m ⁻¹
Conductivity	S mm ⁻¹
Current Density	A mm ⁻²
Power	W
Force	N
Energy	J

PROBLEM DATA
Is2-r63mm-50mm-tooth-5.op3
TOSCA Magnetostatic
Nonlinear materials
Simulation No 1 of 1
1199293 elements
204948 nodes
4 conductors
Nodally interpolated fields
Activated in global coordinates

Field Point Local Coordinates
Local = Global

Comparison of Field Profiles in Various Solutions

19/Jan/2007 09:09:53



X coord	71.9460892	73.8190481	75.7684628	77.7943272	79.8966351	82.0753801
Y coord	0.0	0.0	0.0	0.0	0.0	0.0
Z coord	1048.0018	1091.67515	1135.34515	1179.01167	1222.67458	1266.33374
Component: BMOD, Integral =	130.815147705064					
Component: BMOD, Integral =		127.829681847211				
Component: BMOD, Integral =			120.039772777381			
Component: BMOD, Integral =				120.039772777381		

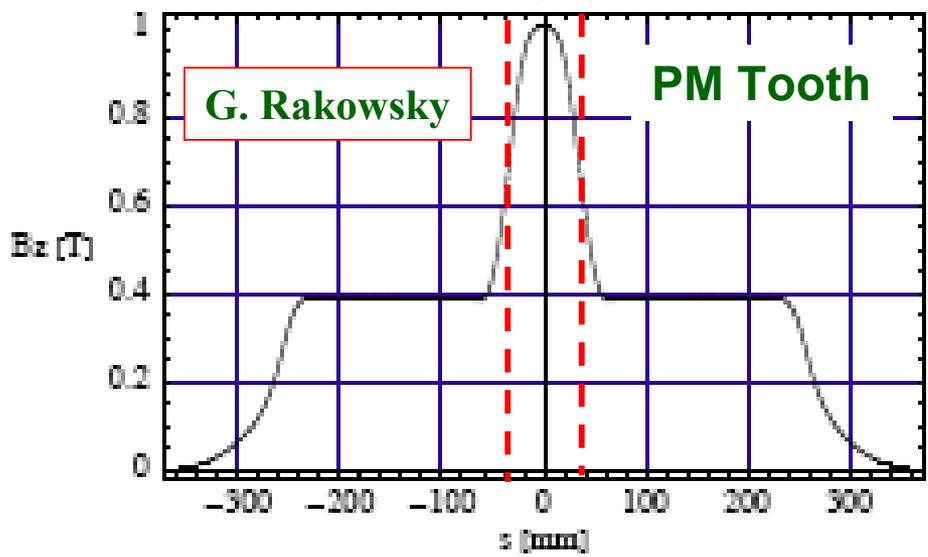
**35 mm EM powered
tooth seems to be
promising in keeping
width and hence
deflection small

(3 mrad?)**

Comparison of PM and EM Solutions for 50 mm Pole

Electron energy: 3. GeV

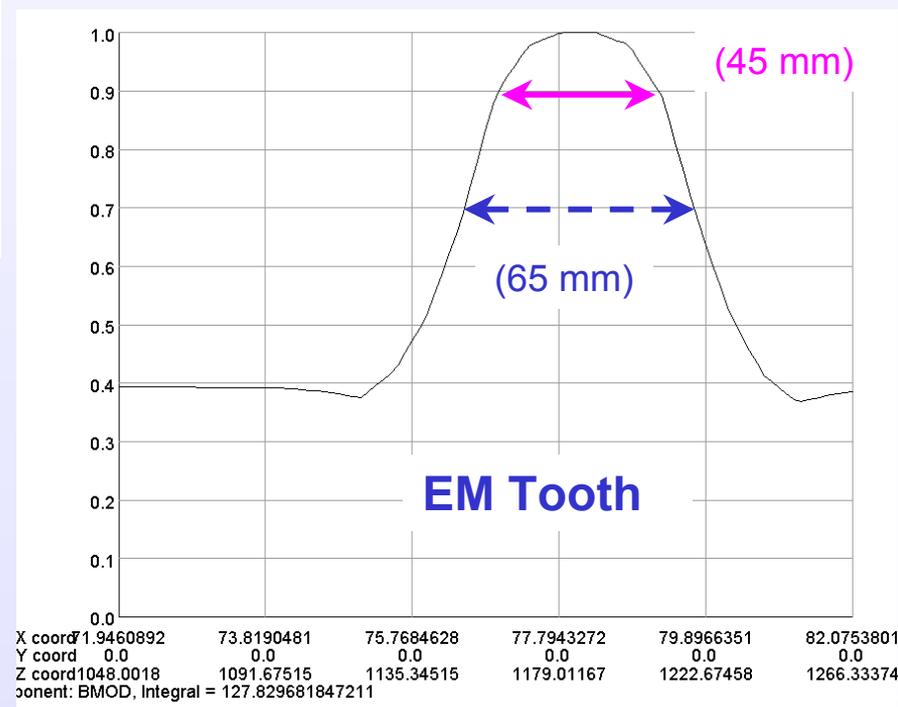
X = 0 mm, Z = 0 mm



~75 mm

- Both Permanent magnet and electromagnet tooth generate similar axial field profile (electromagnet tooth may be a little better).
- PM does not need additional power supply.
- The electromagnet tooth can be adjusted electrically – I.e. turn it off (almost), tune it (for axial wiggle profile) or mechanically cap it.

Question
Which one offers a better technical and operational solution?



Conclusions

- Pole length to pole gap ratio is an important design consideration. Pointed pole create high field locally but not high field in the gap.
- 35 mm long electromagnetic tooth with $\sim 3\text{mrad}(\?)$ deflection may turn out to be a working solution.
- If acceptable, the next step would be to work on specifying and optimizing field quality (field harmonics).
- At this stage, one should also briefly look at some creative variations to the design to explore if even a better solution exist.
- However, soon we should soon be able to make an informed decision on the fate of the "Tooth Option".