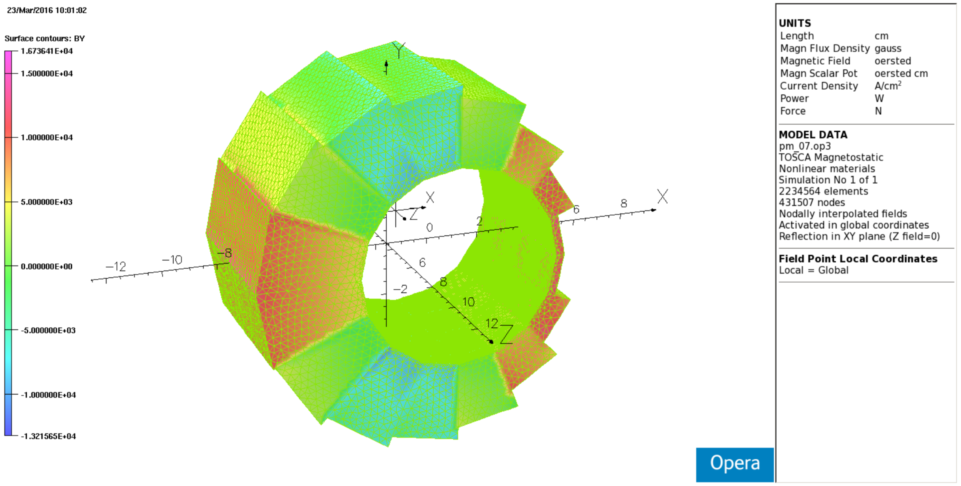
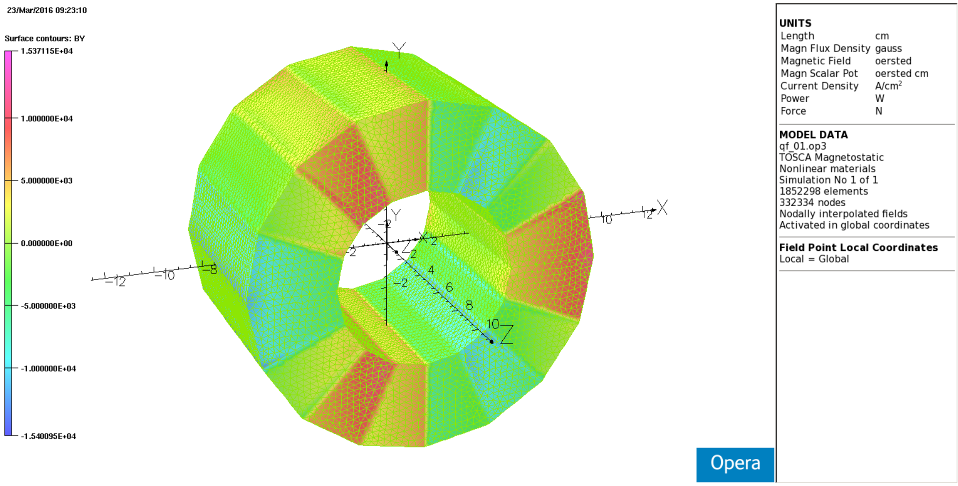
Cornell University
Laboratory for Elementary-Particle Physics

Model Development for the FFAG Cell BD, BDT and QF Magnets

-- Opera3D field tables, analysis and analytic parameterizations –

http://www.lepp.cornell.edu/~critten/cbeta/magnets





Jim Crittenden, Chris Mayes & David Sagan

(Original design and model development by Stephen Brooks and Nick Tsoupas)

CBeta Collaboration Meeting

25 March 2016

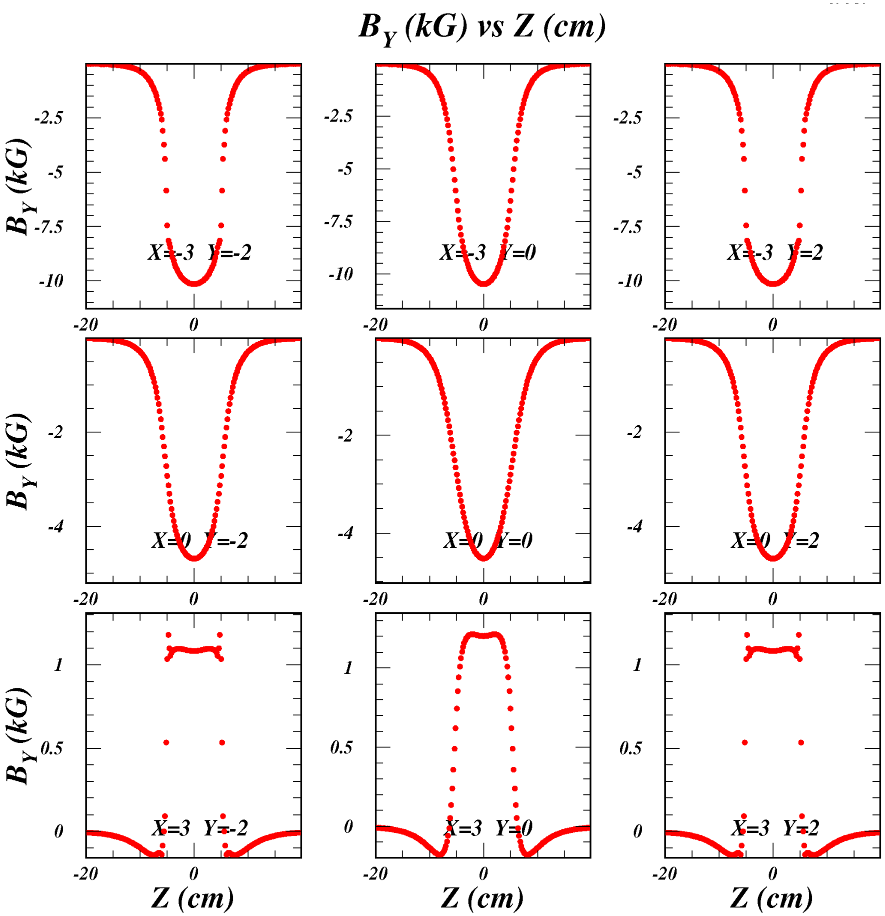
Summary of Recent Work

- ✫ **Start from NeFeCoN35 BH data from Nick and Stephen's csv geometry files.**
- ✫ **Write csv-to-Opera modeller translation python script.**
- ✫ **Develop Opera modeller command files, study finite-element mesh approximations.**
- ✫ **Develop Opera post-processor command files to write diagnostic plots and field tables.**
- ✫ **Apply analysis tools developed since 2002 for various CESR magnet projects.**
- ✫ **Generalize BMAD Maxwell-constrained field functions for quad/skew quad fields*.**
- ✫ **Adapt minimization codes to produce analytic descriptions of the fields*.**
- ✫ **Etienne Forest is now here at Cornell updating his polymorphic tracking code (PTC) for the new field parameterizations. This will allow use of faster, and symplectic, tracking algorithms via Taylor maps.**

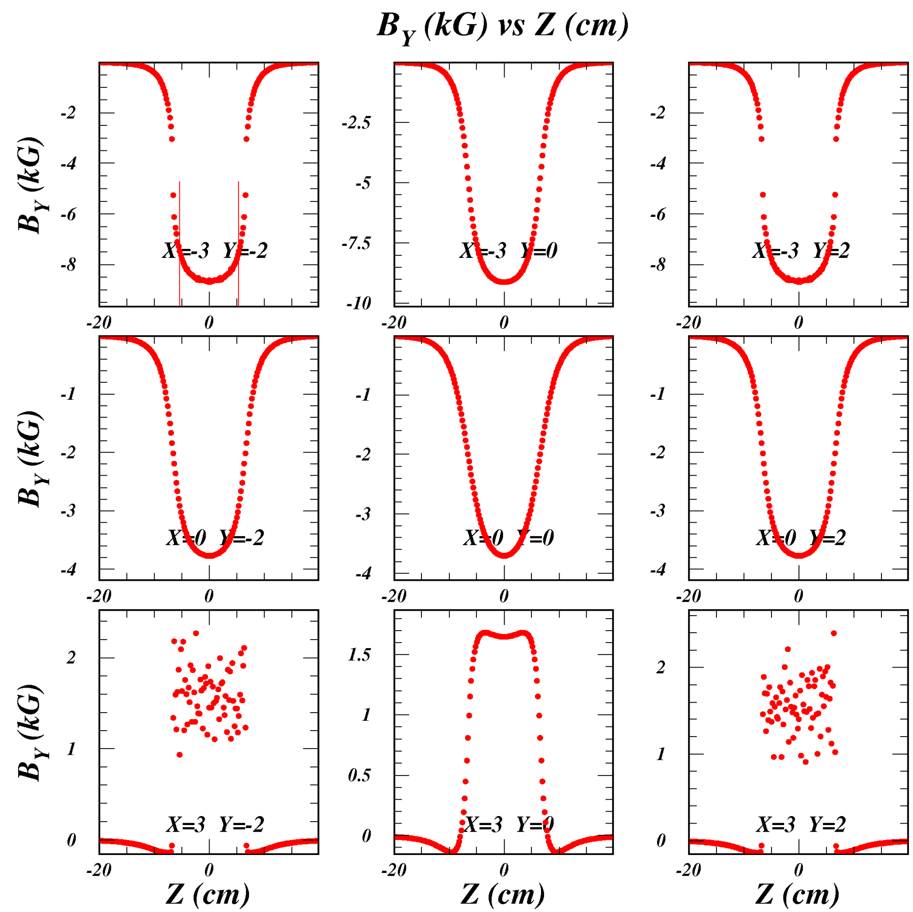
* Described in *A Magnetic Field Model for Wigglers and Undulators*,
D.Sagan, J.A.Crittenden, D.Rubin and E.Forest, proceedings of PAC2003, Portland, OR, 12-16 May, 2003

Field table plots

Nick's bdx3p0y2p0z40_step0p2_chris table



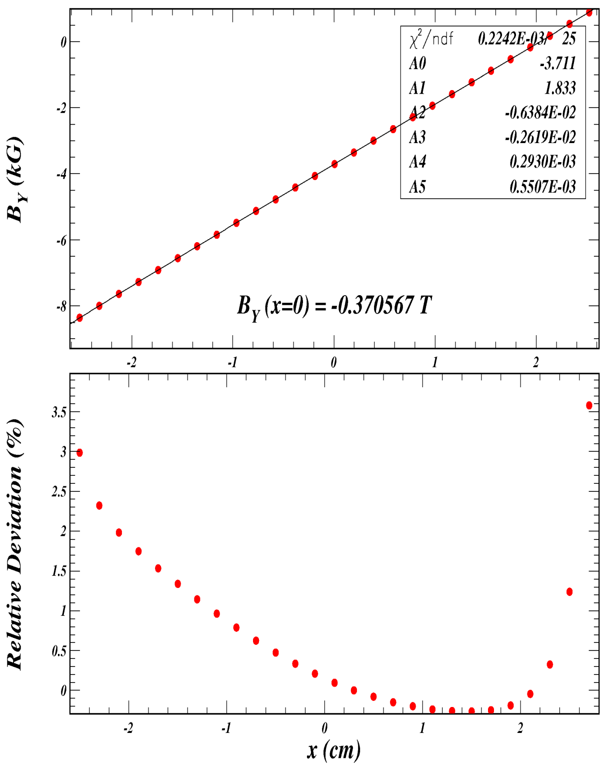
My first BD table



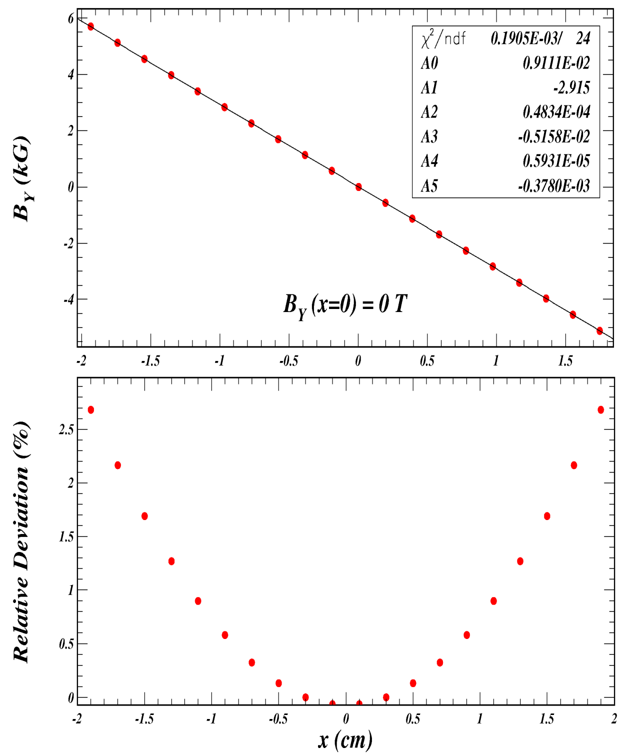
Such a comparison showed that I needed to refine the Opera mesh to match Nick's accuracy at the table edges.

Gradient uniformity

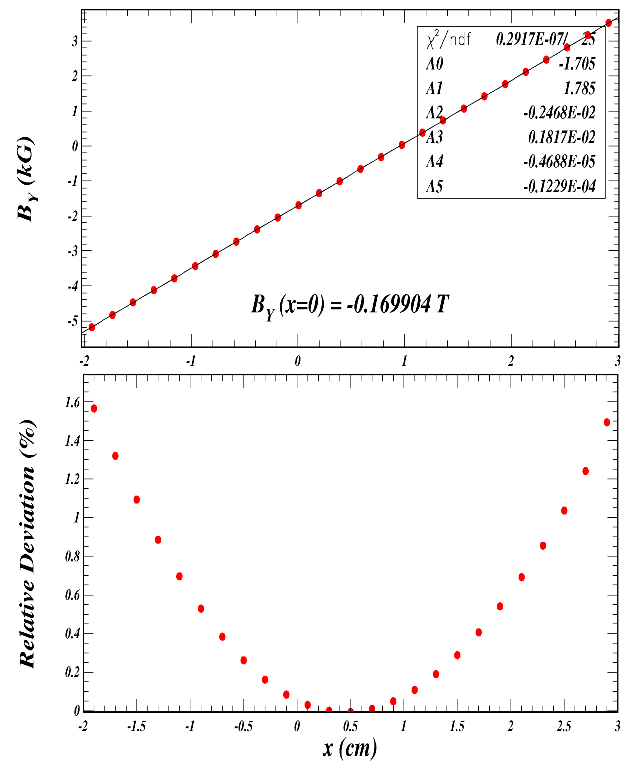
BD



QF



BDT



These relative deviations in the gradients are the 2D characteristics at the center of the magnet.

Also need to investigate the uniformity of the integrals. What are the specifications?

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Analytic form

Expansion satisfying Maxwell's equations term-by-term

Each family has three possible forms These are designated as "`hyper-y`", "`hyper-xy`", and "`hyper-x`".

For the `quad family` the `hyper-y` form is:

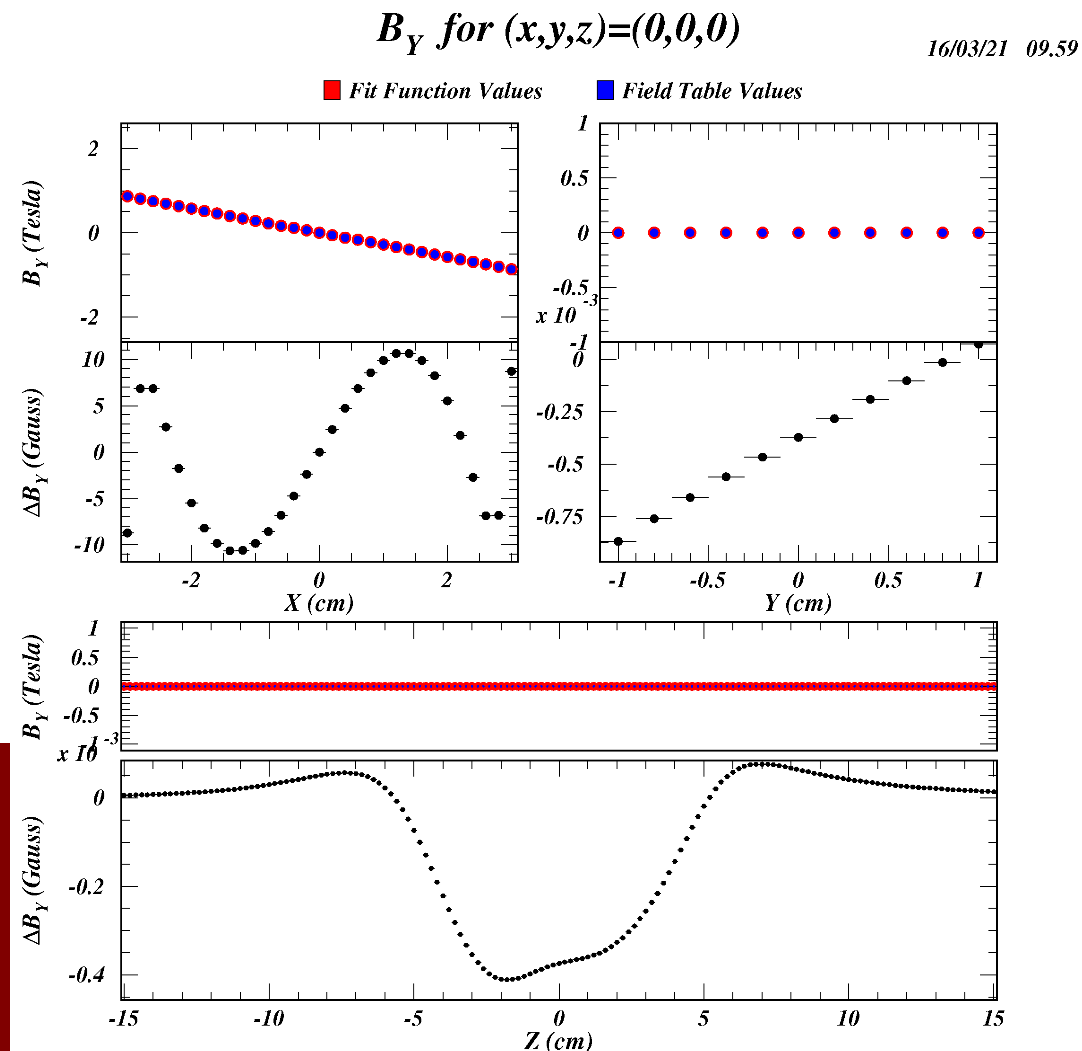
$$
\begin{aligned}
B_x &= \;\; A \frac{k_x}{k_y} \cos(k_x(x+x_0)) \sinh(k_y(y+y_0)) \cos(k_z z + \phi_z) \\
B_y &= \;\; A \; \sin(k_x(x+x_0)) \cosh(k_y(y+y_0)) \cos(k_z z + \phi_z) \\
B_s &= -A \frac{k_z}{k_y} \sin(k_x(x+x_0)) \sinh(k_y(y+y_0)) \sin(k_z z + \phi_z) \\
& \quad \text{with } k_y^2 = k_x^2 + k_z^2 \; .
\end{aligned}
$$

The `quad family hyper-xy` form is:

$$
\begin{aligned}
B_x &= \;\; A \frac{k_x}{k_z} \cosh(k_x(x+x_0)) \sinh(k_y(y+y_0)) \cos(k_z z + \phi_z) \\
B_y &= \;\; A \frac{k_y}{k_z} \sinh(k_x(x+x_0)) \cosh(k_y(y+y_0)) \cos(k_z z + \phi_z) \\
B_s &= -A \; \sinh(k_x(x+x_0)) \sinh(k_y(y+y_0)) \sin(k_z z + \phi_z) \\
& \quad \text{with } k_z^2 = k_x^2 + k_y^2 \; ,
\end{aligned}
$$

And the `quad family hyper-x` form is:

$$
\begin{aligned}
B_x &= \;\; A \; \cosh(k_x(x+x_0)) \sin(k_y(y+y_0)) \cos(k_z z + \phi_z) \\
B_y &= -A \frac{k_y}{k_x} \sinh(k_x(x+x_0)) \cos(k_y(y+y_0)) \cos(k_z z + \phi_z) \\
B_s &= -A \frac{k_z}{k_x} \sinh(k_x(x+x_0)) \sin(k_y(y+y_0)) \sin(k_z z + \phi_z) \\
& \quad \text{with } k_x^2 = k_y^2 + k_z^2 \; .
\end{aligned}
$$



Five parameters per term:
A, k_x, k_z, x_0, y_0, and ϕ_z
Maxwell's equations satisfied by the relationship between the scale parameters k_x, k_y, and k_z.
Numerical accuracy determined by number of terms/scales. This example for the QF magnet uses 26 terms.