A Slinky Approach to MANX

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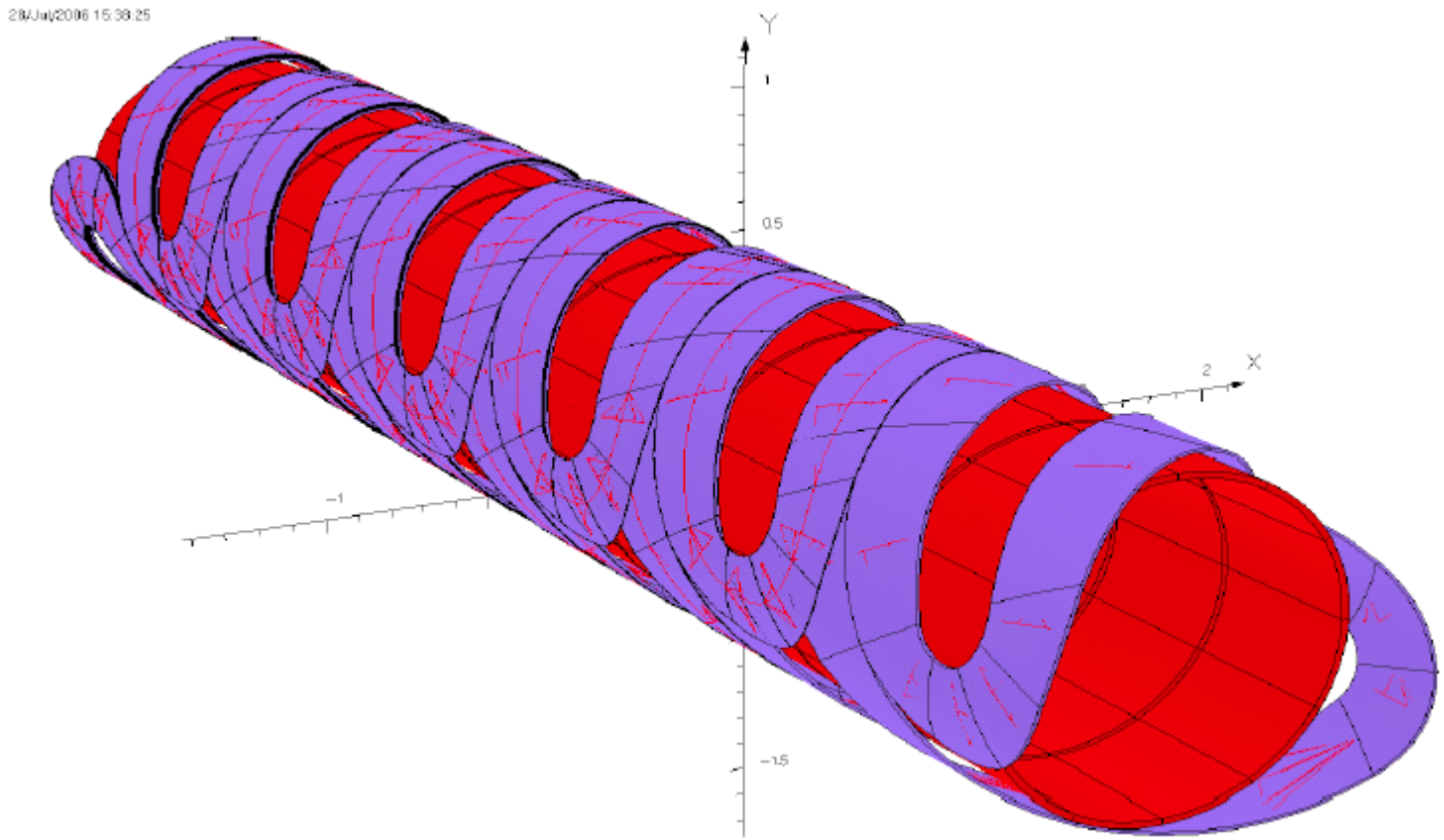
Why the Slinky Approach

- The *Helical Cooling Channel* relies on the superposition of helical dipole, helical quadrupole fields on top of a solenoid field.
  - MANX is a short 4 meter long demonstration channel.
- The traditional approach would be to wind helical dipole and quadrupole coils around solenoid coils.
  - The helical coils need to be on the outside of the solenoid to minimize the forces between the solenoid and the helical coils.
  - The downside of this approach is that the helical fields can be quite large since the fields grow as $I_n(nkr) \sim e^{nkr}$
- The muon beam only occupies a small part of the aperture since it moves in a helix.

The Snake Approach: Helical Dipole Wound around a Solenoid



Ring Magnet Geometry

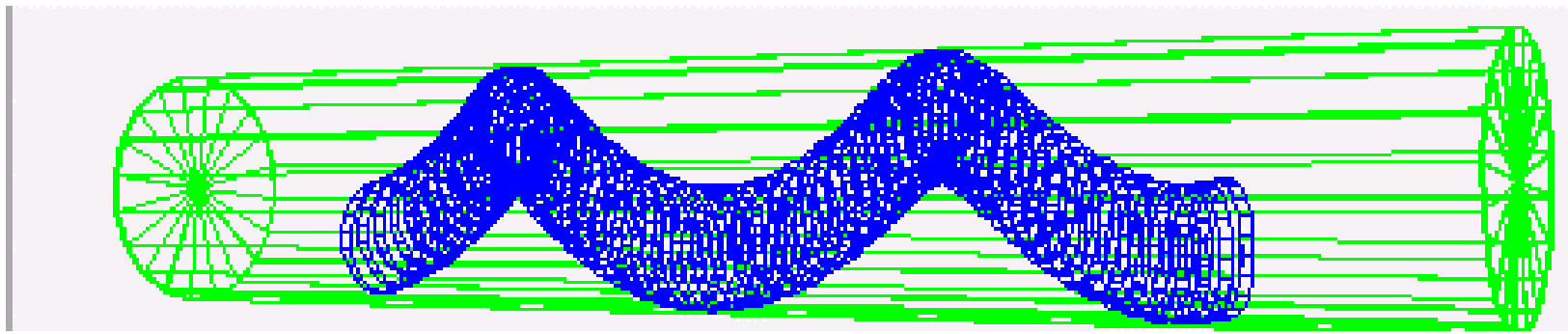
- MANX magnet channel is made up of 64 rings. Each ring has a diameter of 2a=51 cm.
- The field for the computations use the elliptic integral description that is used in ICOOL.

See Smythe, Static and Dynamic Electricity, p266

$$A_\phi(r,\theta) = \frac{4Ia}{c\sqrt{a^2+r^2+2ar\sin\theta}}\left[\frac{(2-k^2)K(k)-2E(k)}{k^2}\right]$$

$$B_r = \frac{1}{r}\frac{\partial}{\partial r}(rA_\phi)$$

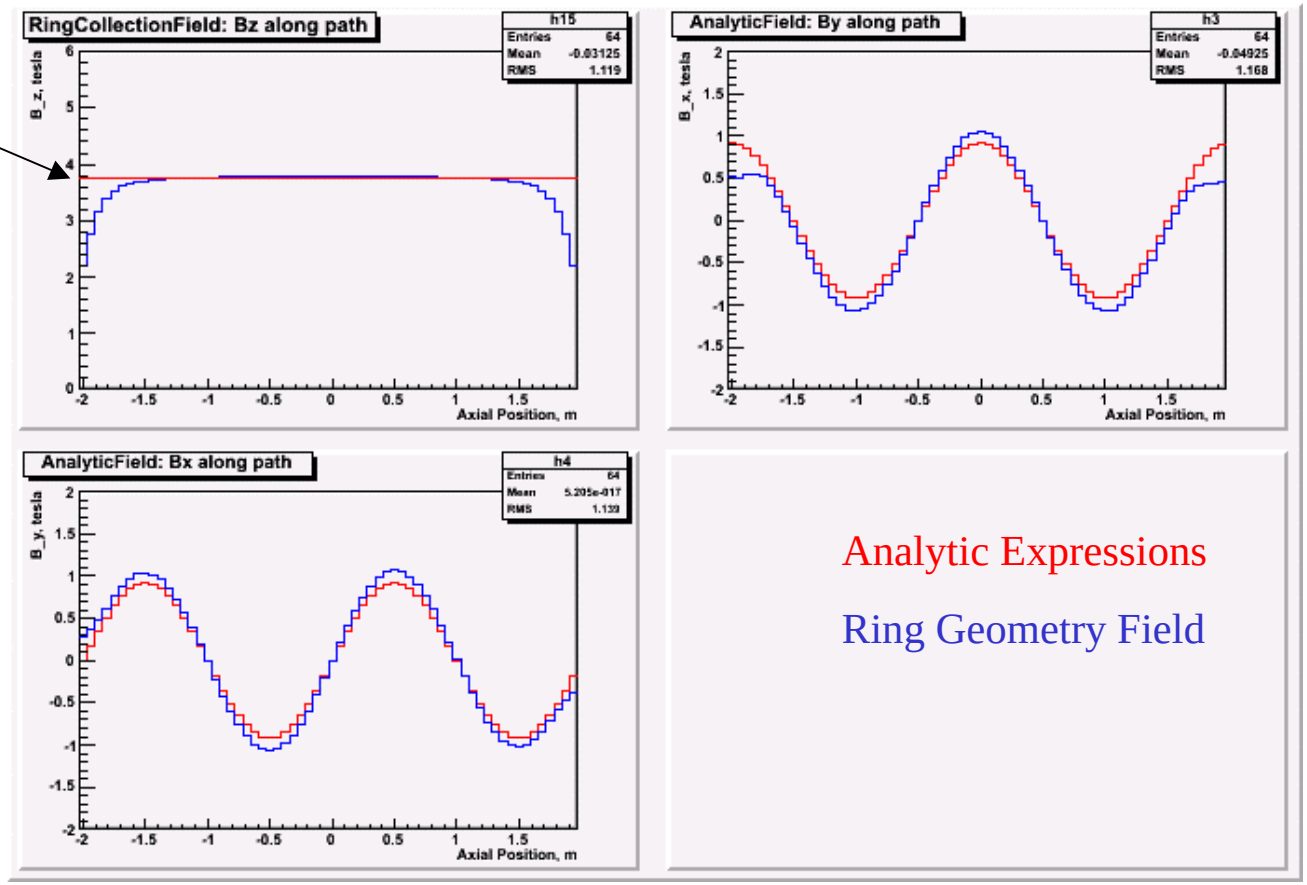
$$B_z = -\frac{\partial A_\phi}{\partial z}$$



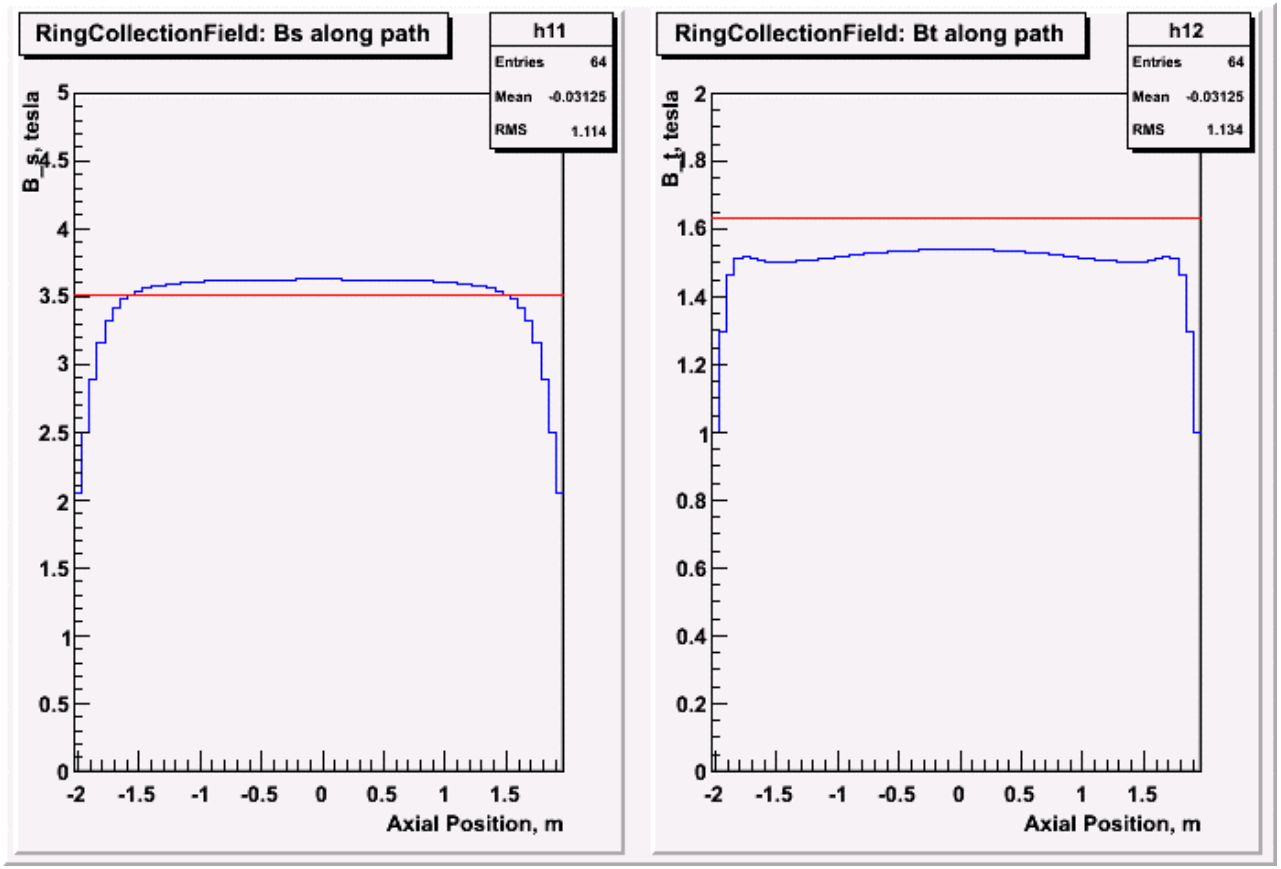
Comparison of Ring Geometry Field with Analytic Expressions

There are matching issues as we enter/leave the channel as we stop the rings abruptly

Field is along reference path



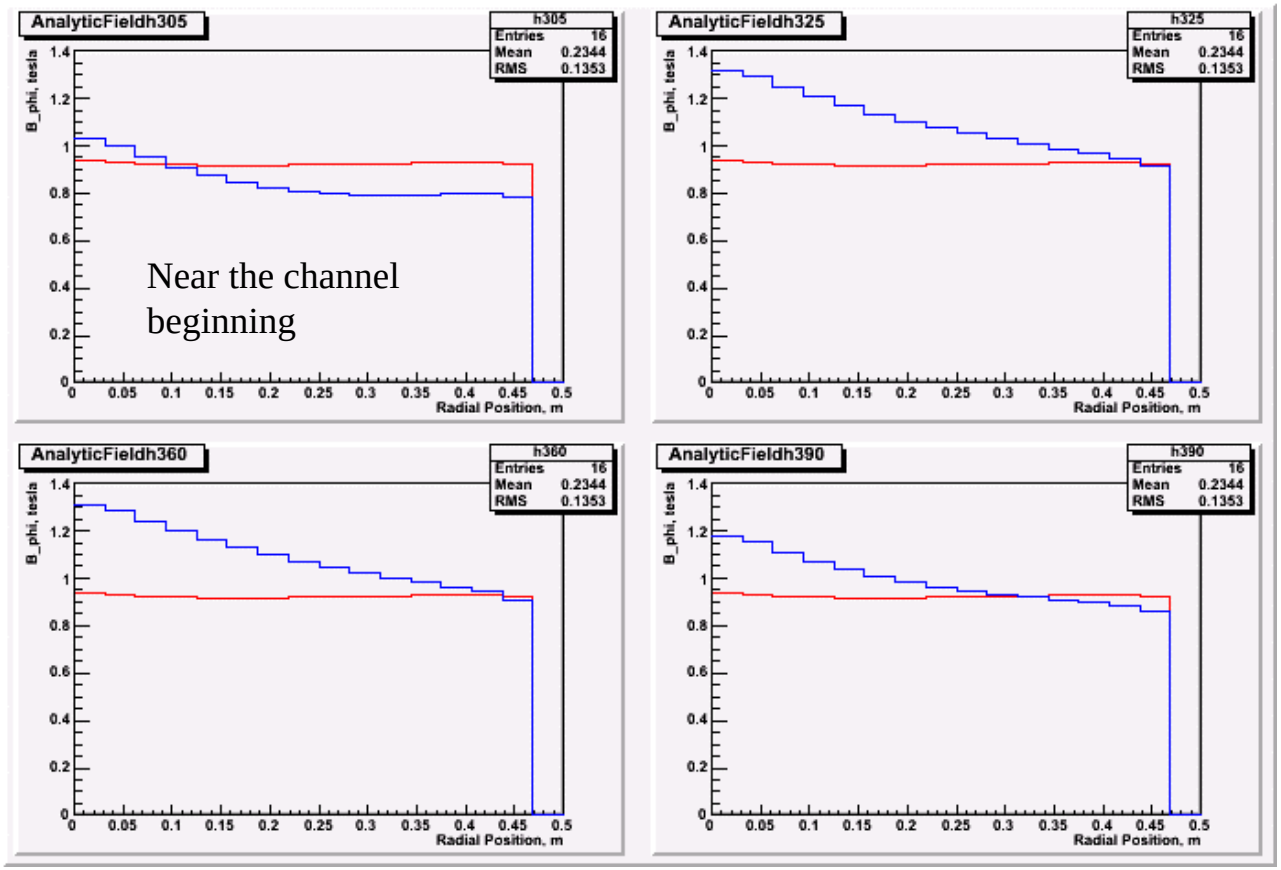
Comparison Made in the Helical Frame of Field Along and Transverse to Reference Path



Comments on Comparison of the Fields Produced by Rings with Analytic Field

- There is an overall normalization between the ring field and the analytic fields which is performed by setting the *ring current such that the B_z field is matched at z=0*.
- The correspondence between the *helical frame* and the lab frame is
  - The rings are oriented along the helical path, which may not be optimal for field match-up. $\hat{x} \equiv x_1 + ix_2 = (x + iy)e^{-ikz}$
- This does provide a tool for examining *slinky* field issues without *TOSCA* or field maps.
- These issues include
  - Quadrupole component from ring array.
  - Matching

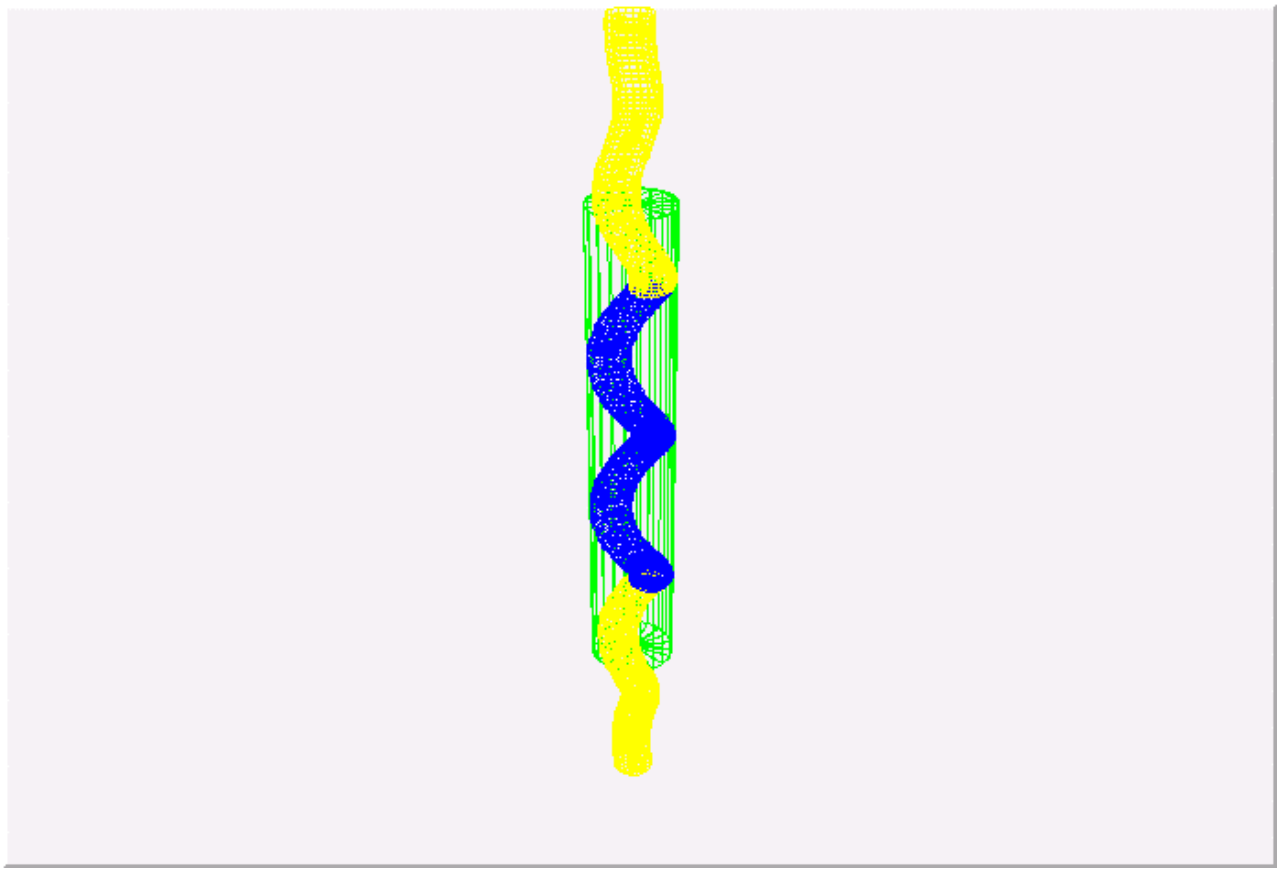
Visualizing the Quadrupole



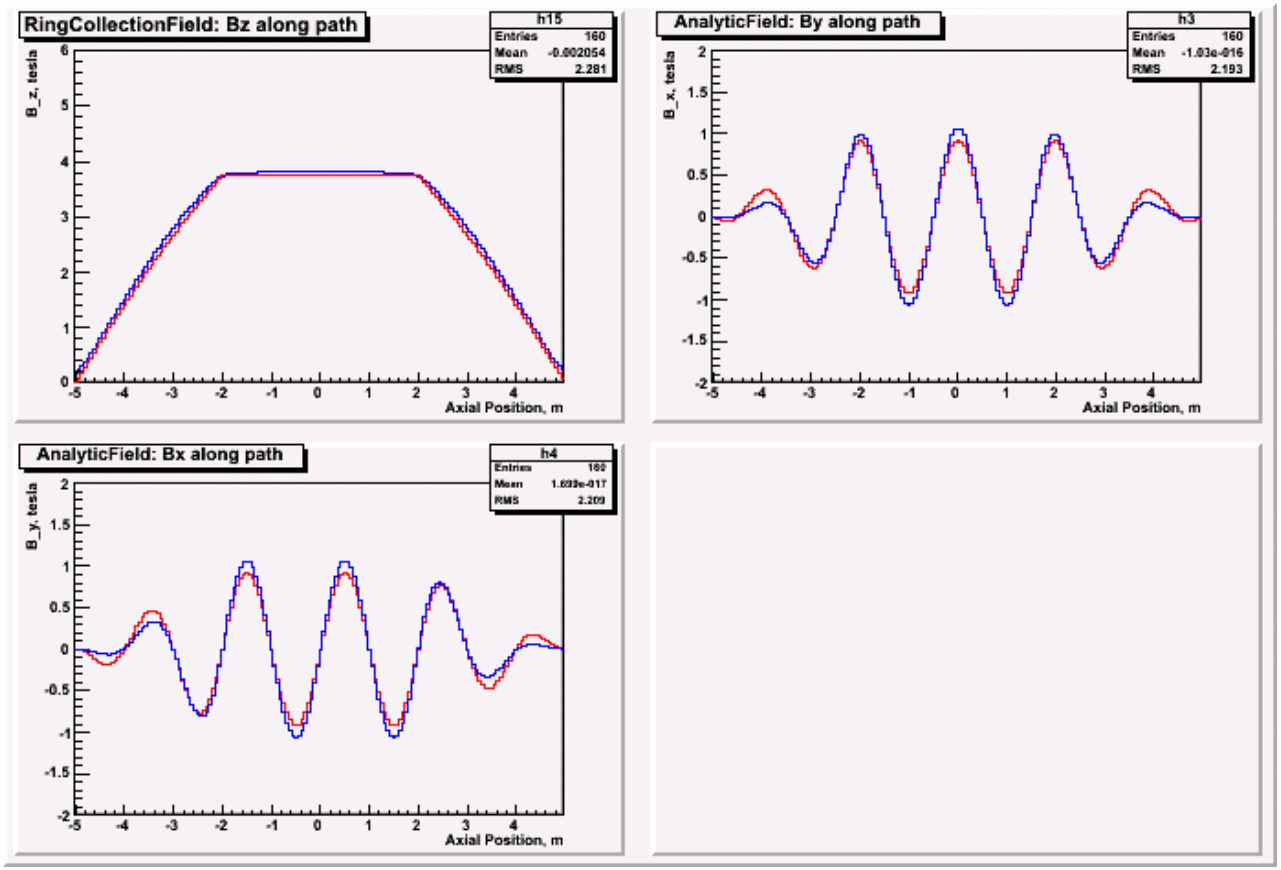
Can We Control the Quadrupole?

- The quadrupole is a measure of the left-right (along the radius) asymmetry of the field.
  - Note that relative to the center of any particular ring all of the other rings are on the inner radial side. This is why there is a natural quadrupole to a slinky arrangement.
- If we have chosen Λ and ring radius of a circular ring we have fixed the quadrupole component.
- Is there anything that can be done to influence the quadrupole?
  - Varying the ring size (keeping Λ constant) may have an effect.
    - If $a \rightarrow \infty$, the quadrupole should go to zero.
  - Can we distort the circular shape of the ring to give a desired quadrupole? We need to investigate this.

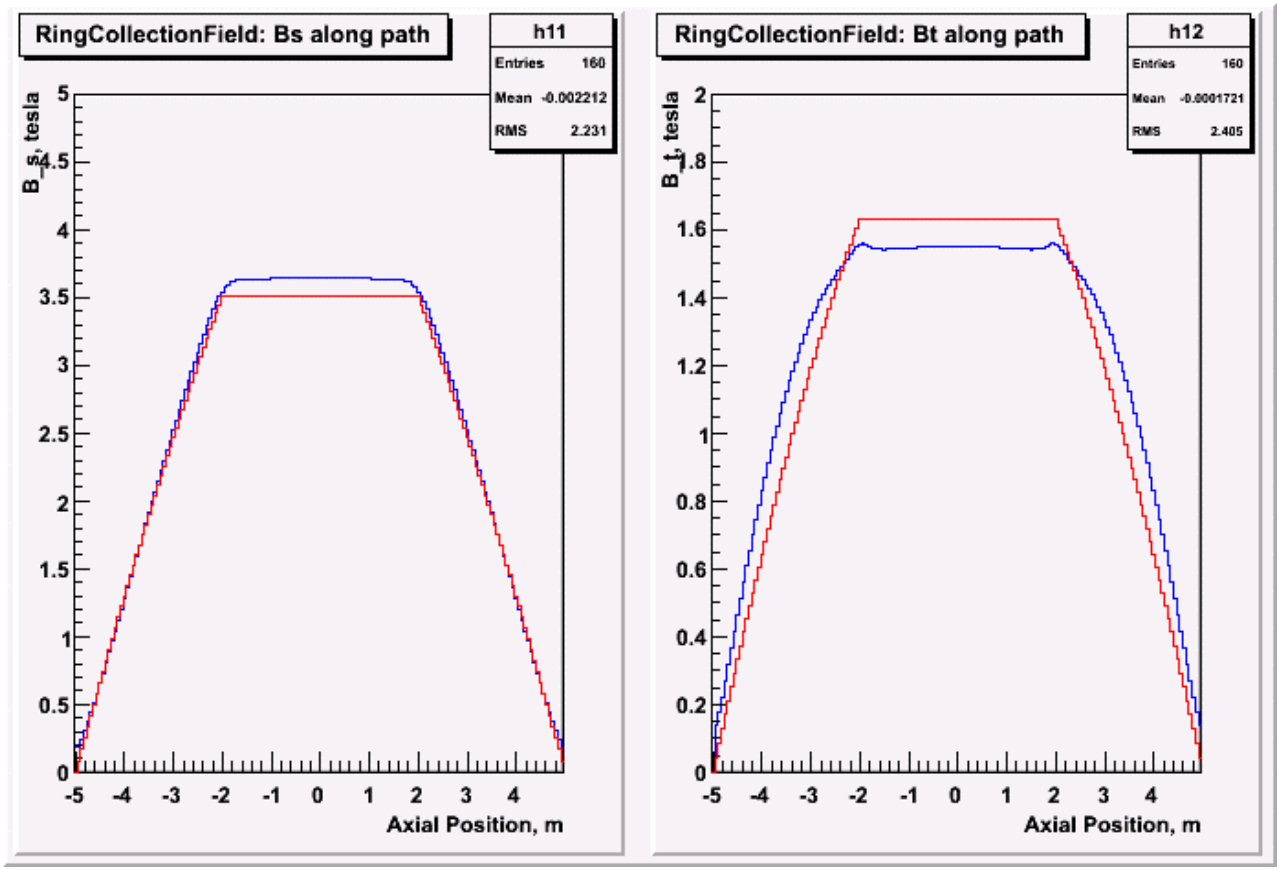
Adding the Matching Section with Rings



Field with Matching Sections: As Viewed in the Lab System



Fields Seen in the Helical System



Future Directions

- Integration into g4beamline:
  - Can provide a field map in the g4beamline format.
  - Can provide input to TOSCA, which can provide g4beamline map and verification of results.
    - We already have classes to do this.
  - This will provide rapid feedback of field effects on the muon beam cooling, emittance, etc.
- Evaluate the effects on the field by reducing the number of rings and by allowing free space in the helical lattice:
  - Can we produce an acceptable field with 16 rings/4 meter length?
  - Can we leave 50% of the space free (between rings) for RF?

Conclusions

- We have developed a useful tool to evaluate the field of the helical cooling channel with an analytical approach using current rings in a “slinky-like” arrangement.
- We have already shown that we can implement Katsuya’s matching scheme with a ring arrangement. This is a realistic design that can be implemented.
- This tool can be used to investigate other important issues for a helical cooling channel:
  - As mentioned, we can investigate reducing the number of rings and the inclusion of free space for RF.