Update On QD0 Design

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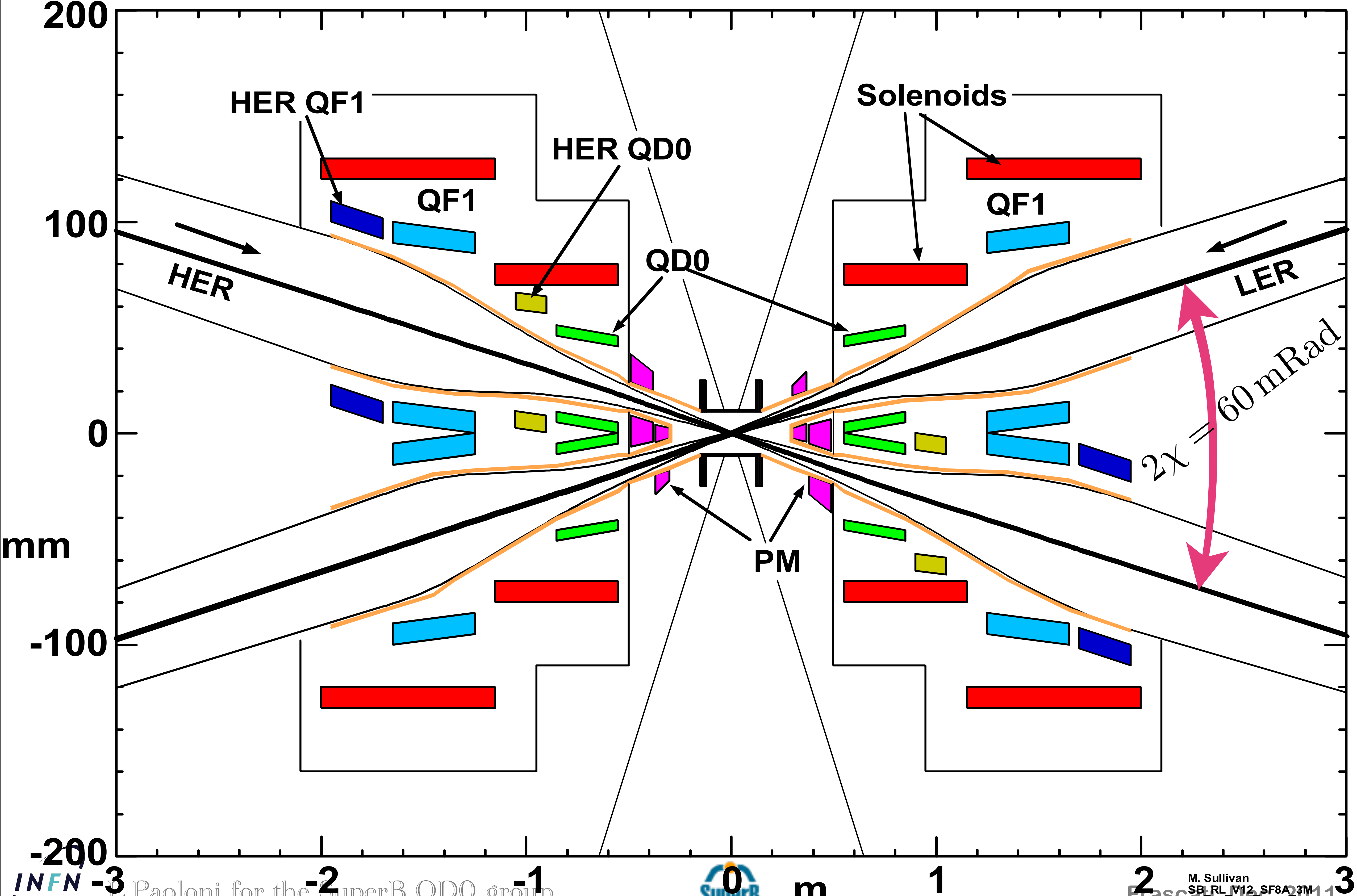
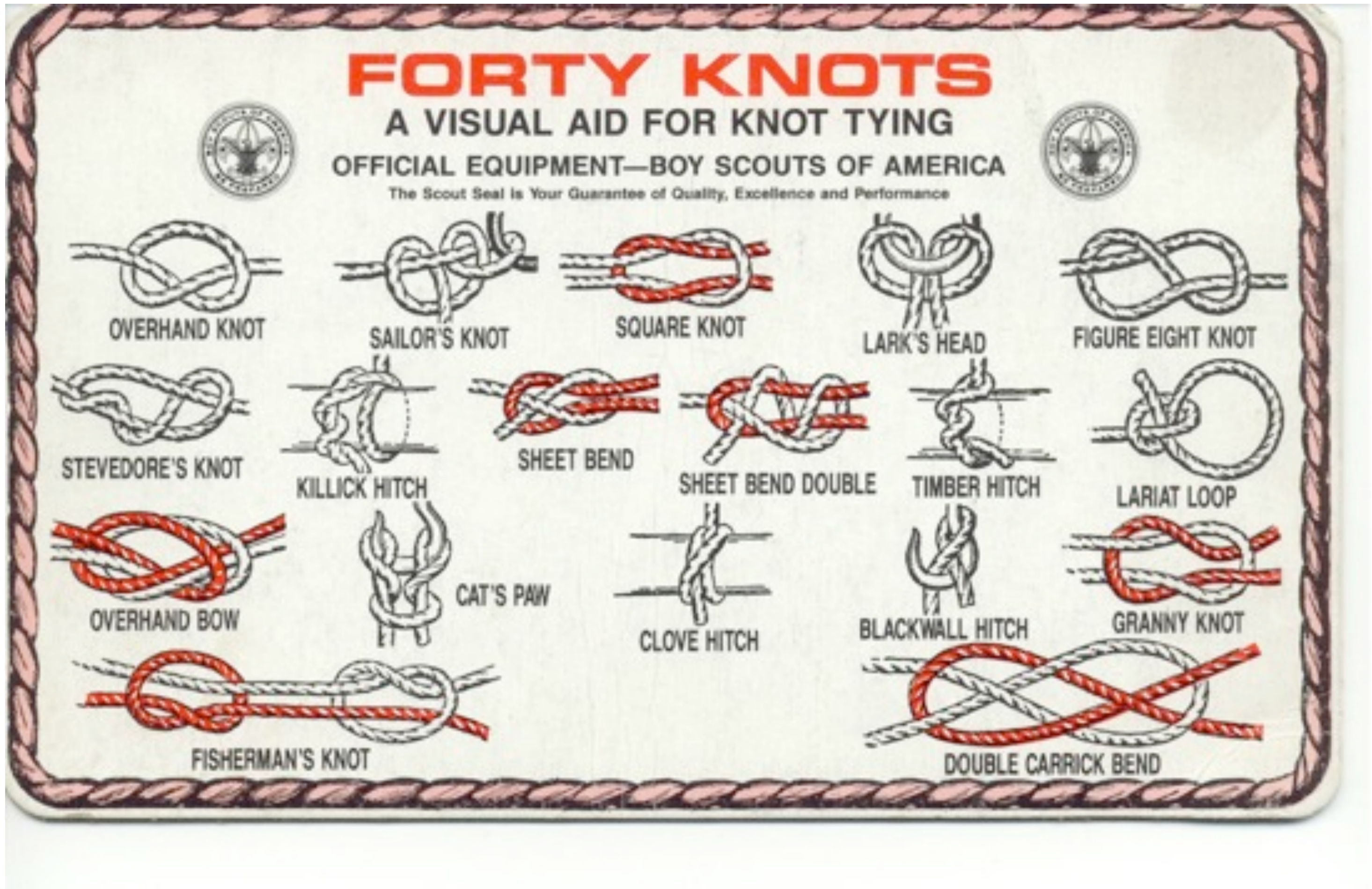
Interaction Region Layout

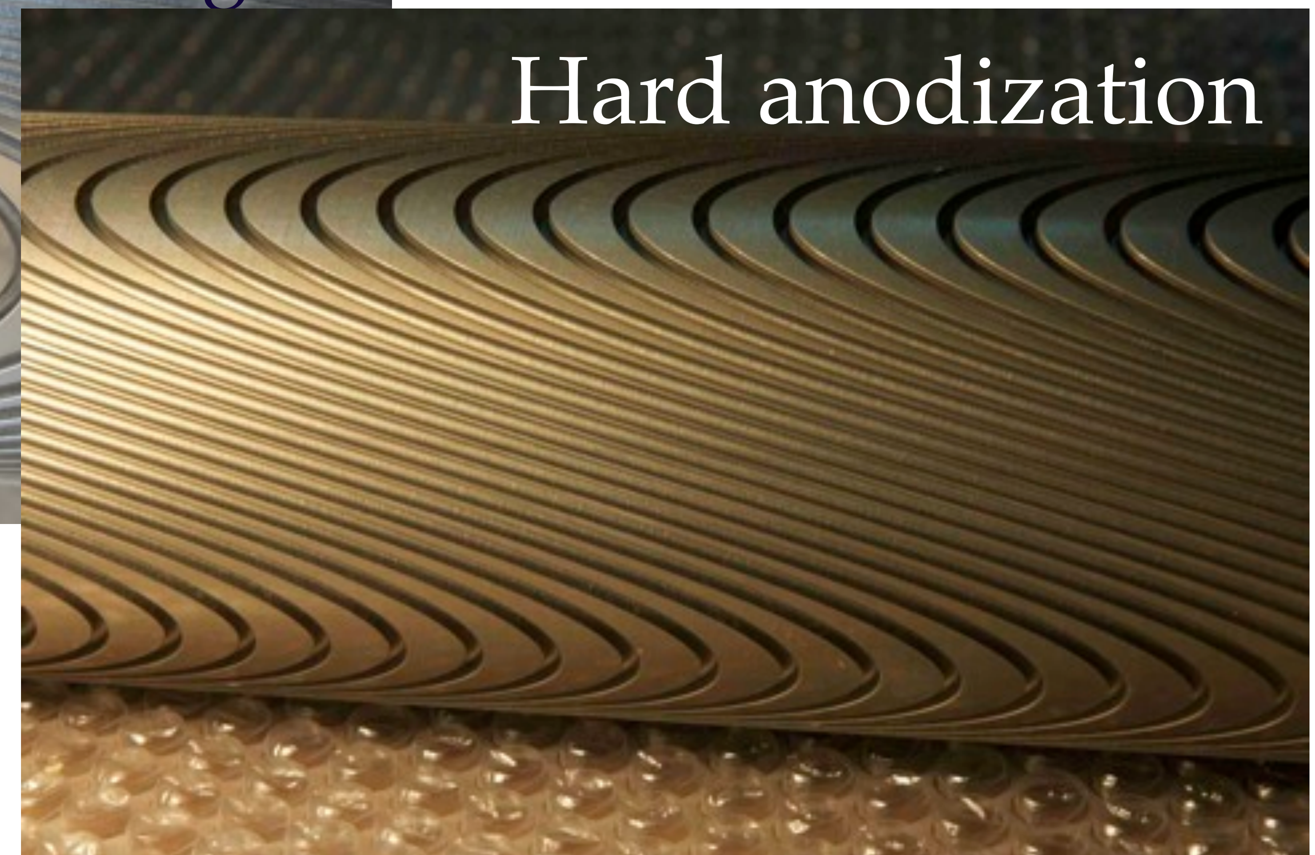


Differences W.R.T. V16 lattice

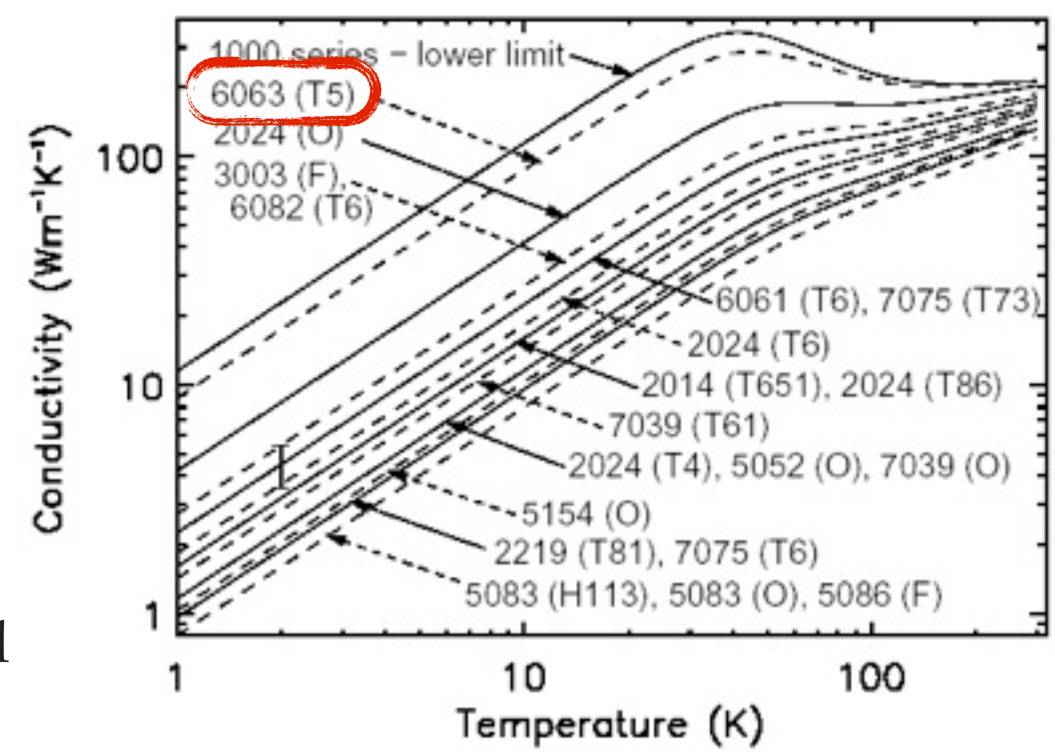
- A single short SC quadrupole for the LER. (Pantaleo requirement)
- A smaller crossing angle (Mike: simulation of Synchrotron radiation effects on the SVT)
- Displaced QD0 (Pasquale: cold mass + helium vessel + thermal insulation are objects in space)
- All the knots come to the comb
- We should try to have a consistent model



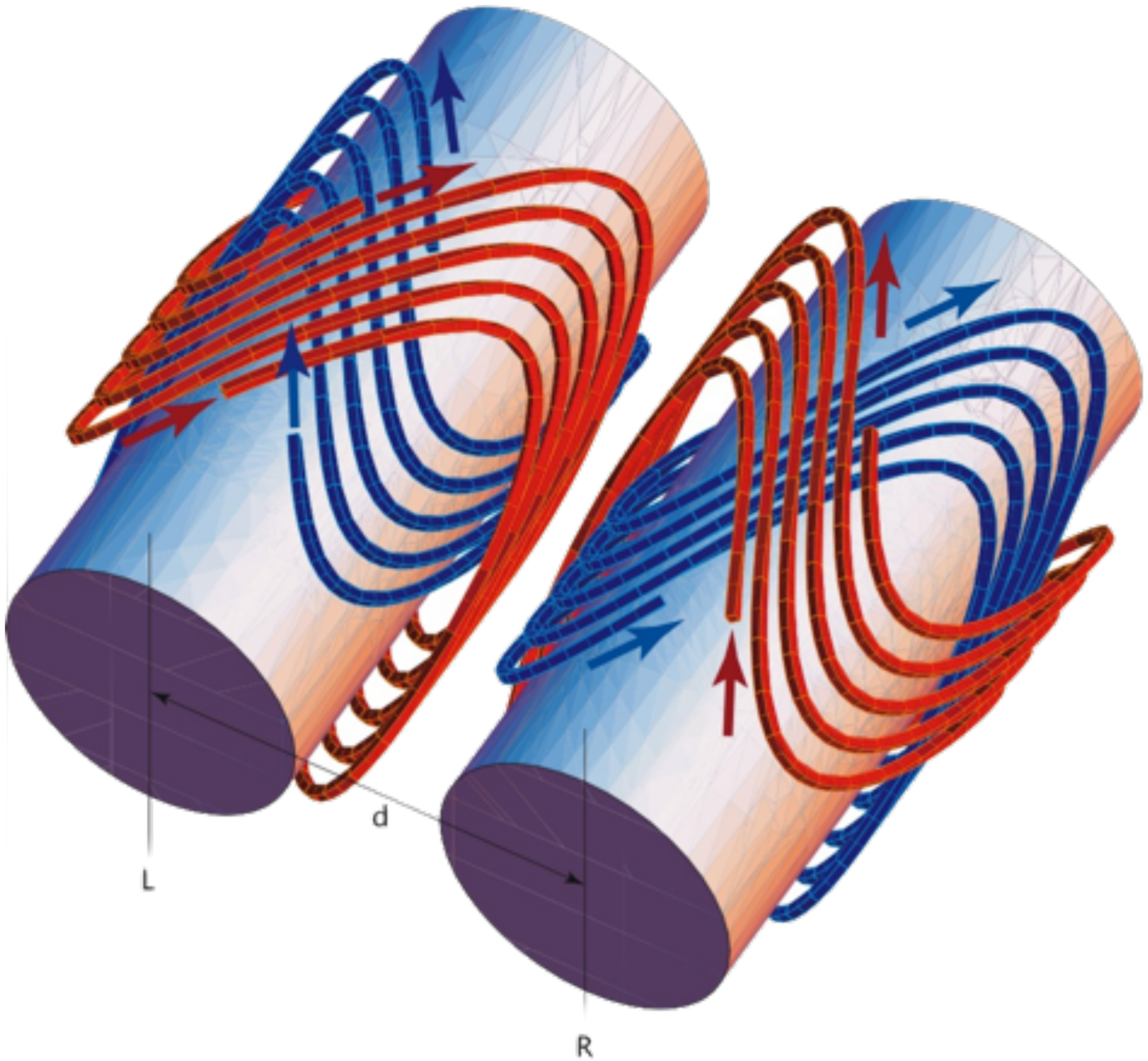
How the Thing is Built

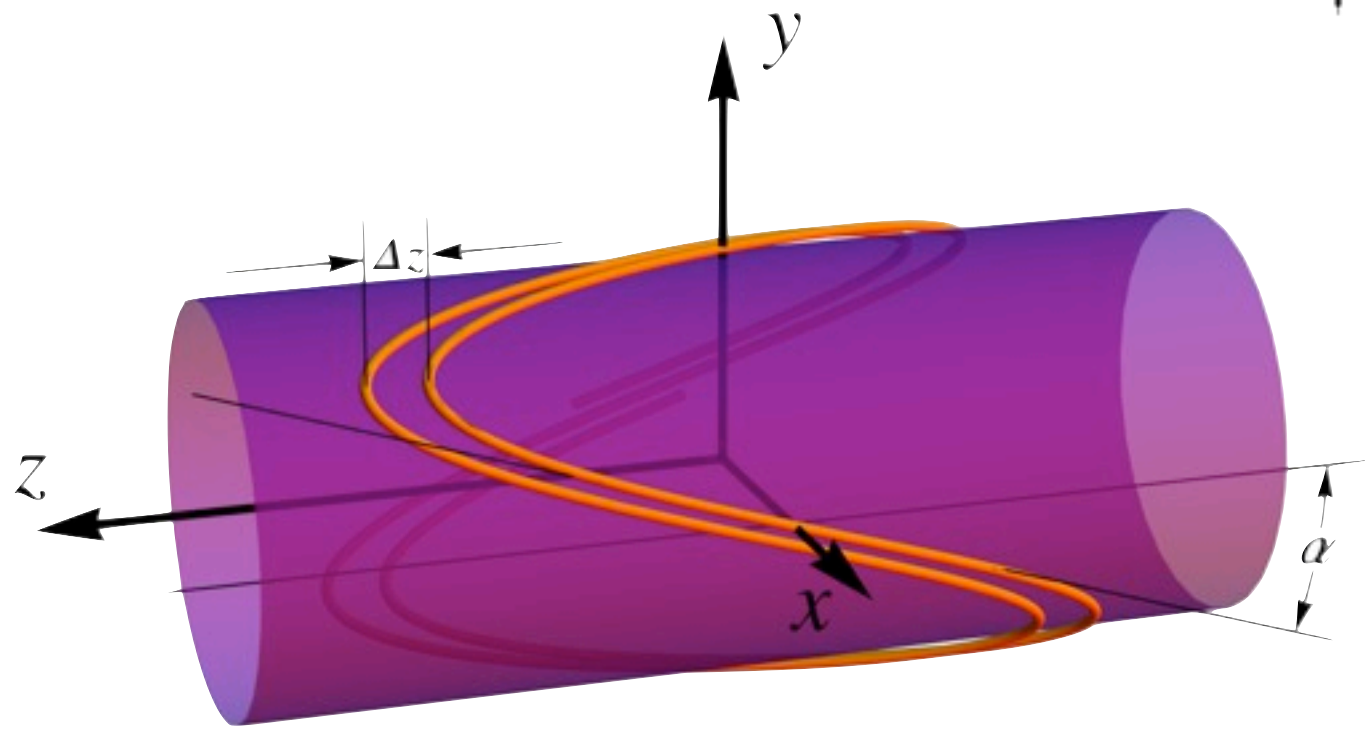


- Anticorodal 6063 had been chosen for its high thermal conductivity at cryogenics temperature
- The grooves on the support cylinders are milled with a 4 axis CNC machine, then electro polished and anodized
- The NbTi wire is insulated with a polyester braid
- The wire is deposited on the groove and kept in place by a layer of glass tape
- The two cylinder are then coupled and epoxy impregnated



Double Helical Coils Main Concept





- Compact and thin cold mass: 2 x wire diameters + few mm
- Excellent field quality over the whole aperture
- Arbitrary multipole combinations can be generated by a proper coil shape

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COMBINED FUNCTION MAGNETS USING DOUBLE-HELIX COILS *

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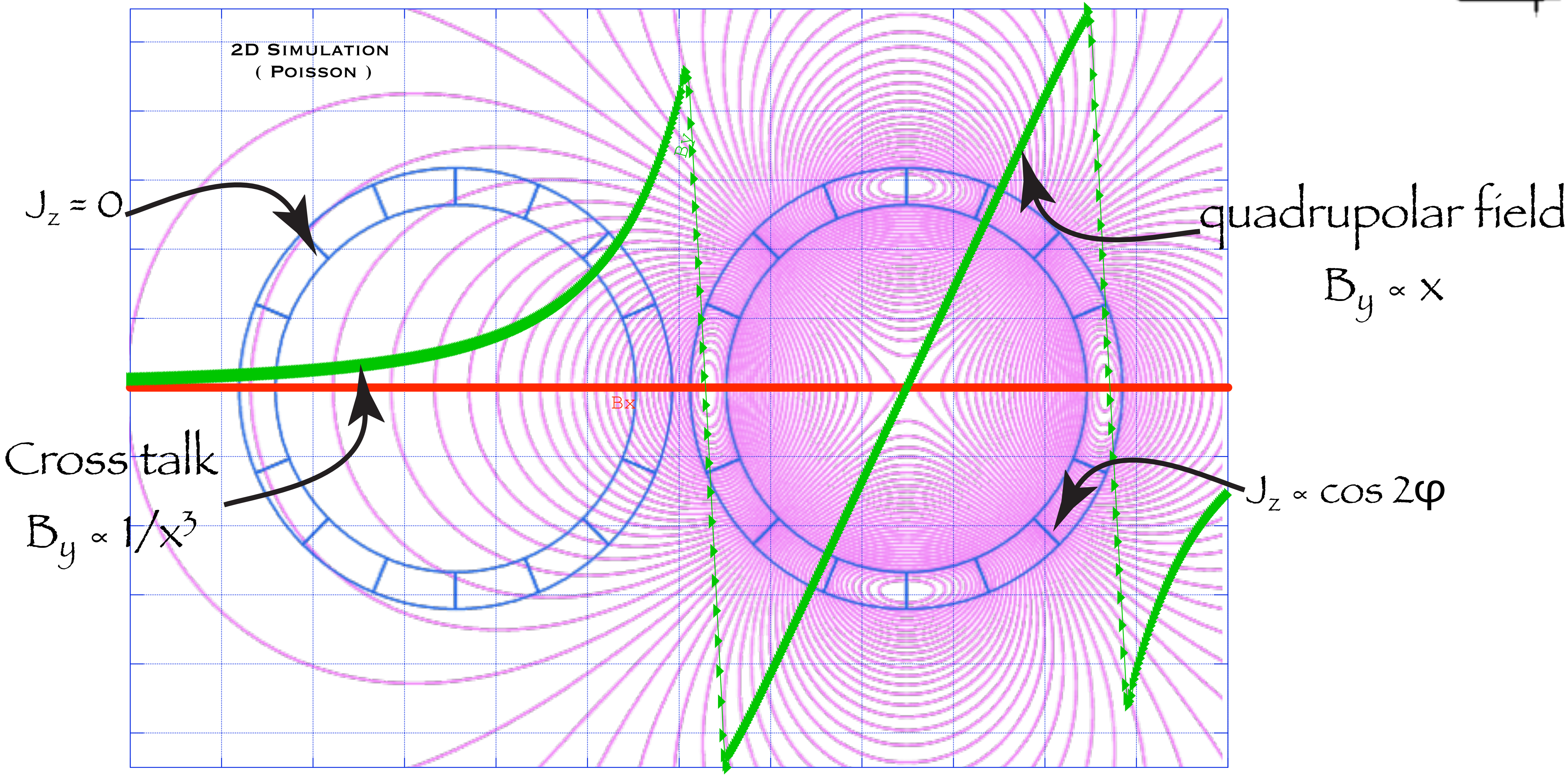
Cross Talk Compensation



- Idea: exploit the superposition principle to design the coil shape in such a way that the integrated beam kick is a linear function of the displacement from the reference orbit

The Algebra Behind The Curtain

Zero-th order approximation: the particle is undeflected (i.e. she travels parallel to the magnet axis)
First order correction: the particle get a transverse kick proportional to the the B field integrated over the zero-th order trajectory, that is:

$$\vec{\mathcal{B}}(x,y,z) \equiv \int_{-\infty}^{+\infty} \vec{\mathbf{B}}(x,y,z+\lambda))\, d\lambda, \qquad \partial_z \vec{\mathcal{B}}(x,y,z) = \vec{0}$$

$\vec{\mathcal{B}}$ is a solution of the magnetostatic equations being a linear superposition of $\vec{B}$ fields in vacuum, it is invariant for translations along the $\hat{z}$ direction hence can be conveniently described by an harmonic function

$$\zeta \equiv x + i\,y \qquad B(\zeta) \equiv \mathcal{B}_y + i\,\mathcal{B}_x$$

$$B(\zeta) = \sum_{n=1}^{\infty} C_n \zeta^{n-1} \qquad C_n = \frac{1}{2\pi\, i} \oint \frac{B(\zeta)}{\zeta^n}\, d\zeta$$

C_n are given by the value of $B(\zeta)$ on a circle $\Rightarrow$ the overall field is determined by its value on a circle

Compensation Scheme

Determine the winding shape (for each winding) so that B(z) is the desired one:

1) Use Biot & Savart (i.e. neglect the wire thickness)

$$\vec{\mathbf{B}}(\vec{\mathbf{r}}) = I\frac{\mu_0}{4\pi}\int \frac{\vec{\mathbf{w}}'(l)\times(\vec{\mathbf{r}}-\vec{\mathbf{w}}(l))}{\left|\vec{\mathbf{r}}-\vec{\mathbf{w}}(l)\right|^3}\,dl$$

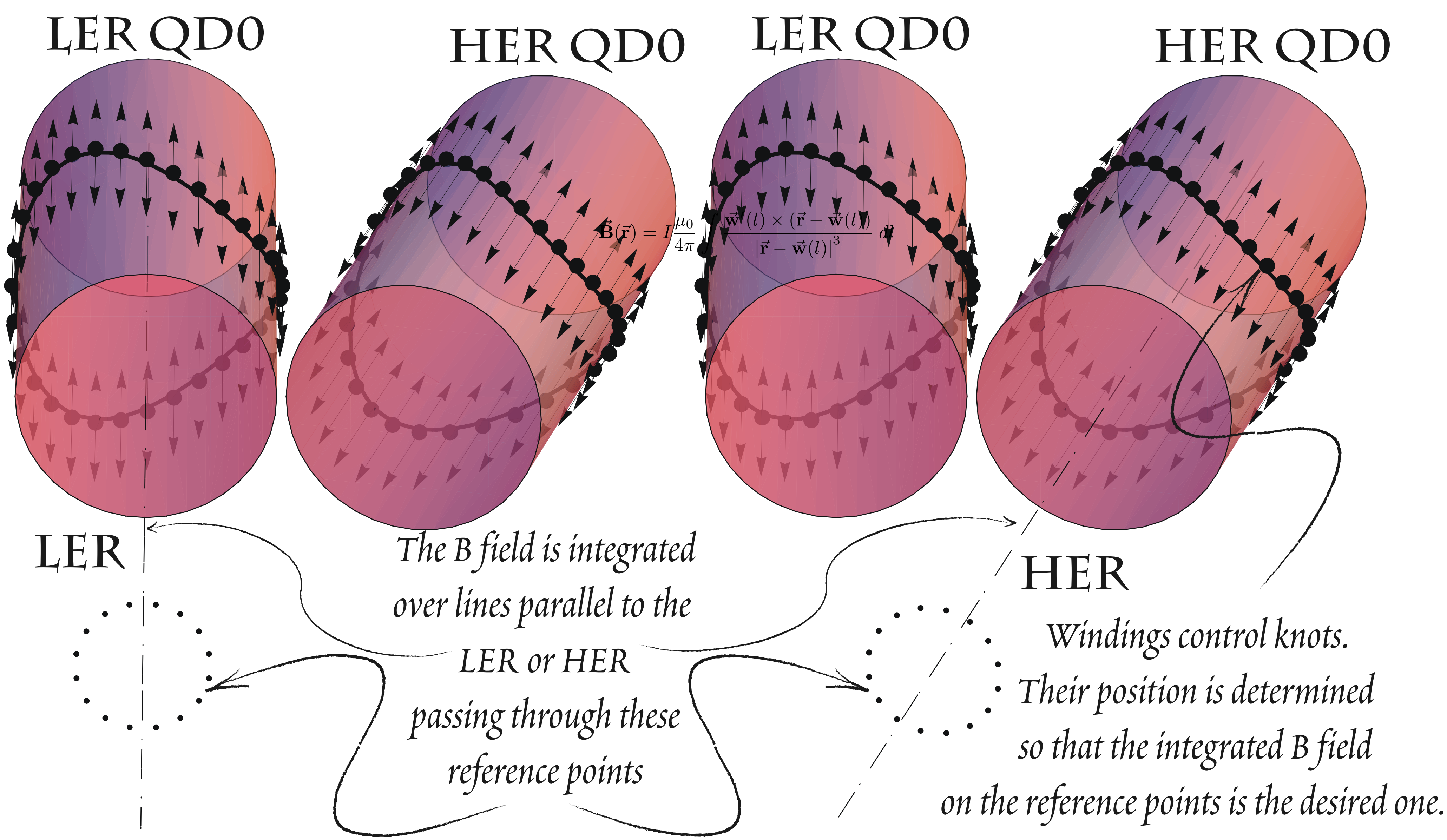
where $\vec{\mathbf{w}}(l)$ gives the position of the center of the SC wires as a function of some continuous parameters l and I is the current flowing in the wire. From this expression one can obtain for $\vec{\mathcal{B}}$:

$$\vec{\mathcal{B}}(\vec{\mathbf{r}}) = \\ = I\frac{\mu_0}{2\pi}\int \frac{\vec{\mathbf{w}}'_{\parallel}(l)\times(\vec{\mathbf{r}}-\vec{\mathbf{w}}(l))+\vec{\mathbf{w}}'_{\perp}(l)\times(\vec{\mathbf{r}}_{\perp}-\vec{\mathbf{w}}_{\perp}(l))}{\left|\vec{\mathbf{r}}_{\perp}-\vec{\mathbf{w}}_{\perp}(l)\right|^2}\,dl \tag{4}$$

Compensation Scheme

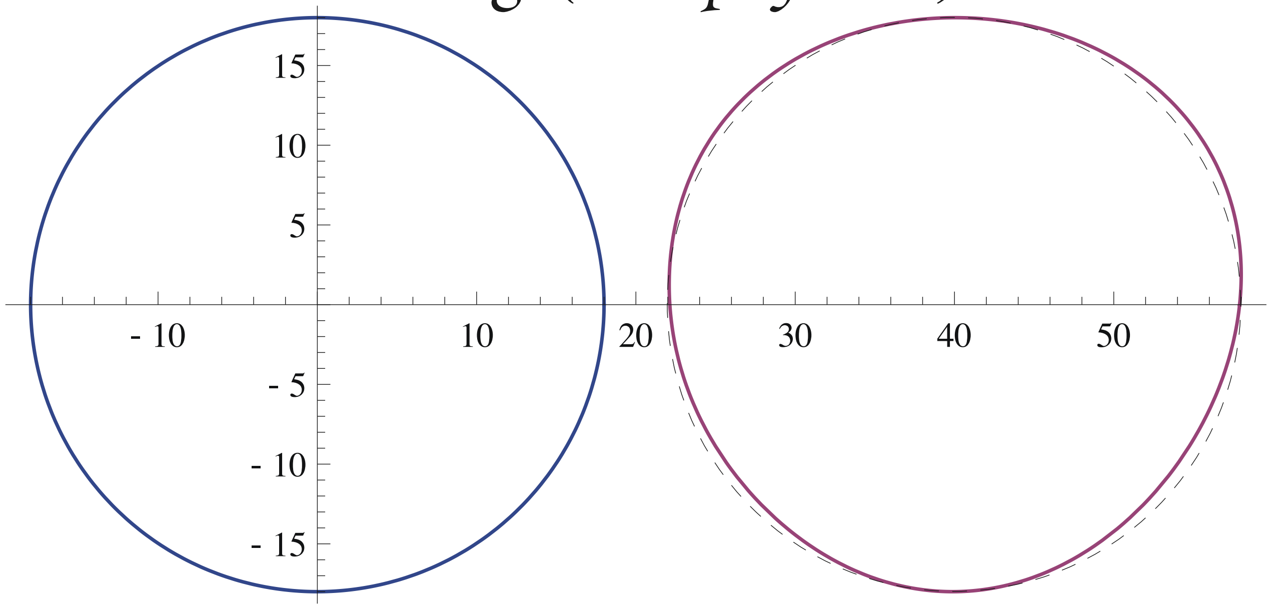
Parametrize $\vec{\mathbf{w}}(l)$ as an interpolating polinomial controlled by N key points sliding along the support cylynder.

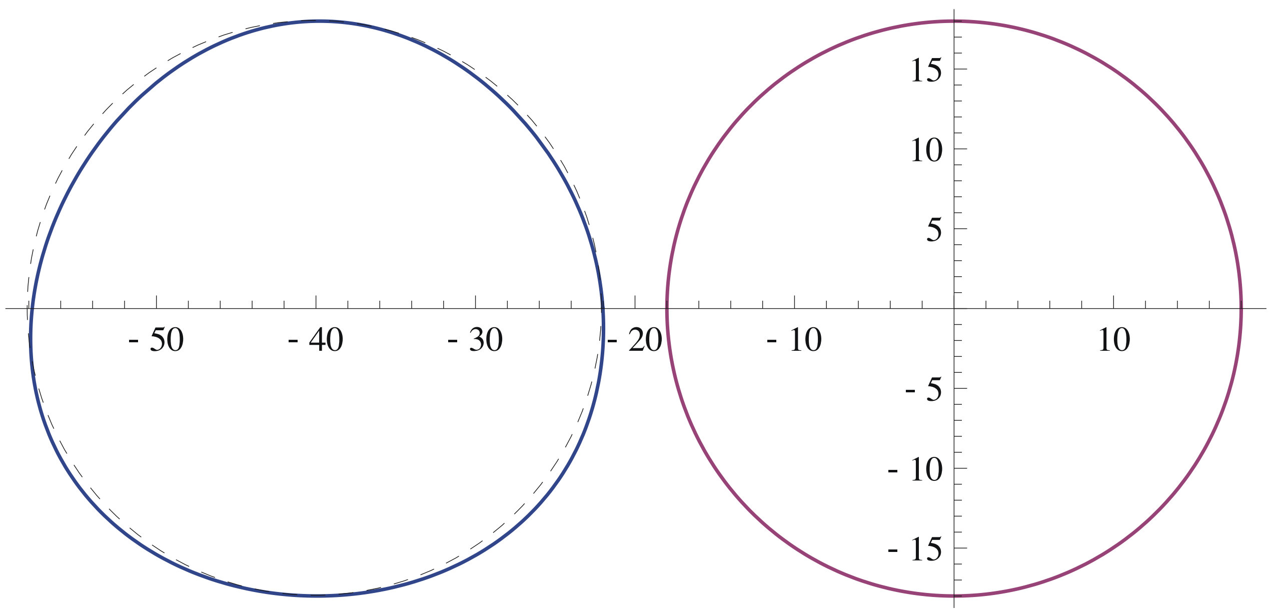
Determine the position of these N point in such a way that $B(z)$ is the desired one on N points over the reference circumference.



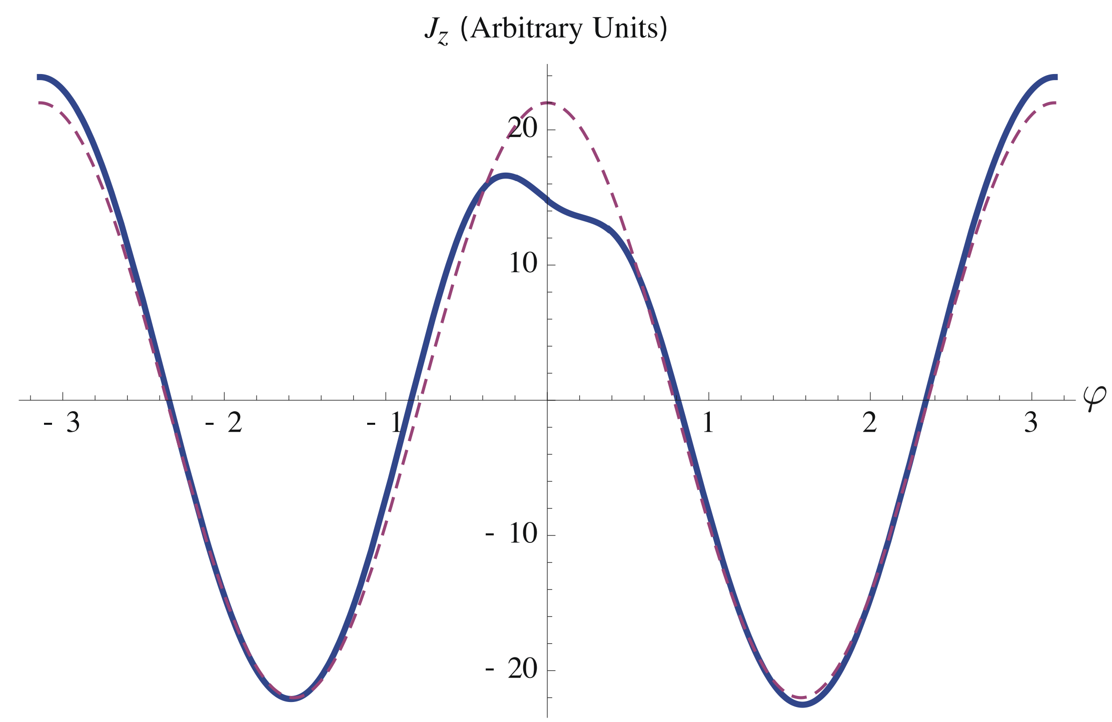
Compensated Winding Shape

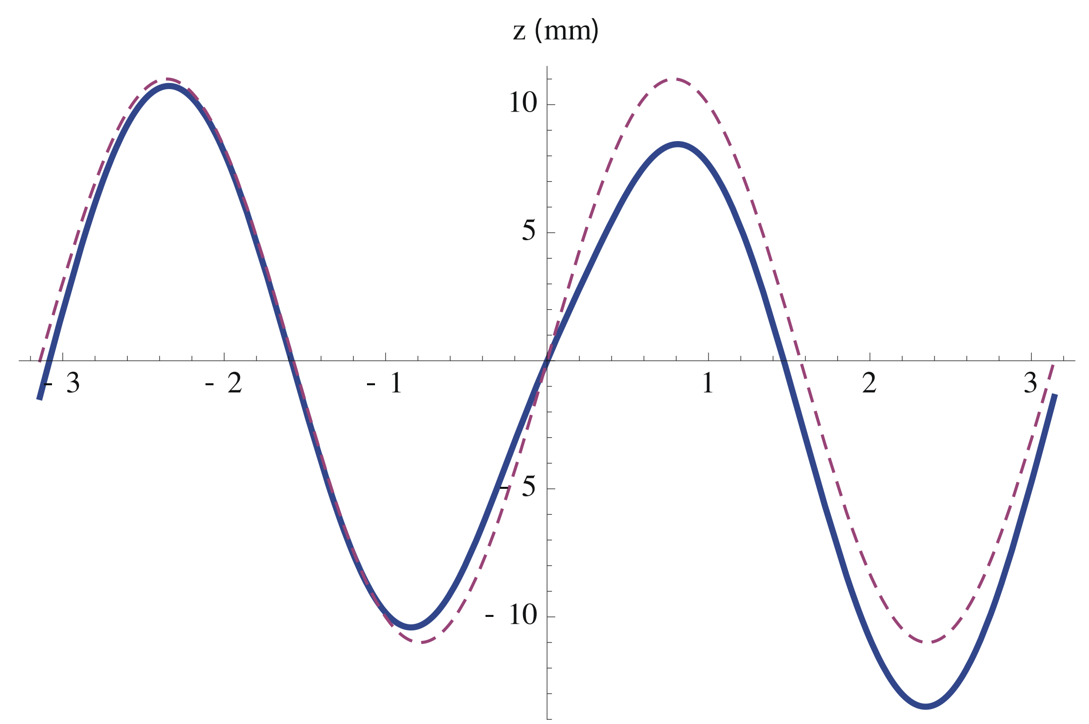
Windings (LER projection)





Windings (HER projection)

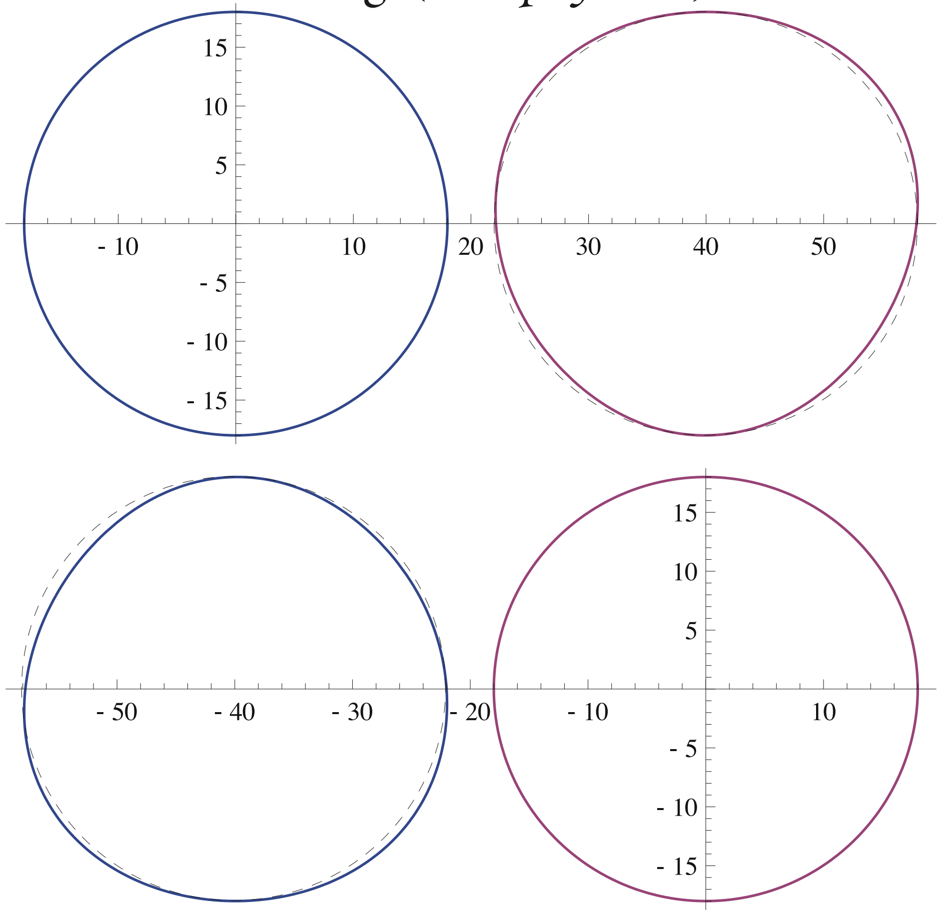




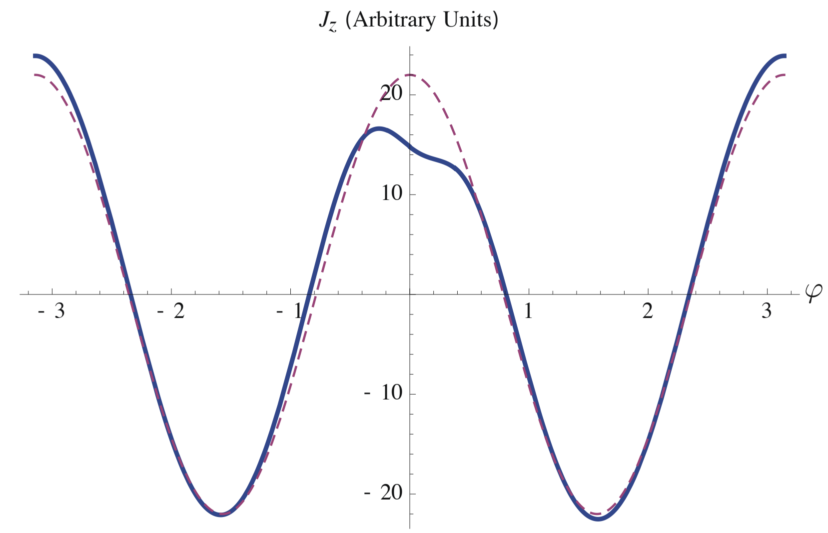
Compensated Winding Shape (prelim.)

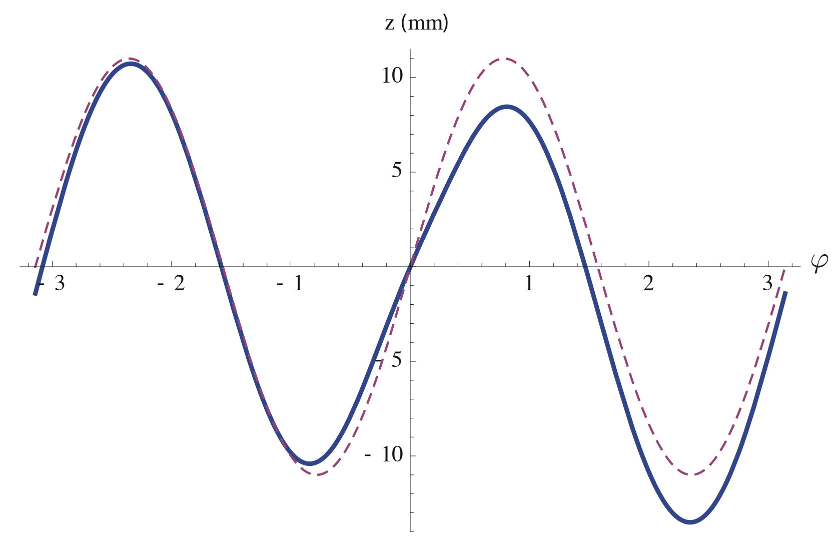
I=3000A
Nturns=110
Gradient = 100 T/m
Magnetic Length=300 mm
R = 18mm
CPU time for a single winding:
1700s (N = 32 points/

Windings (LER projection)

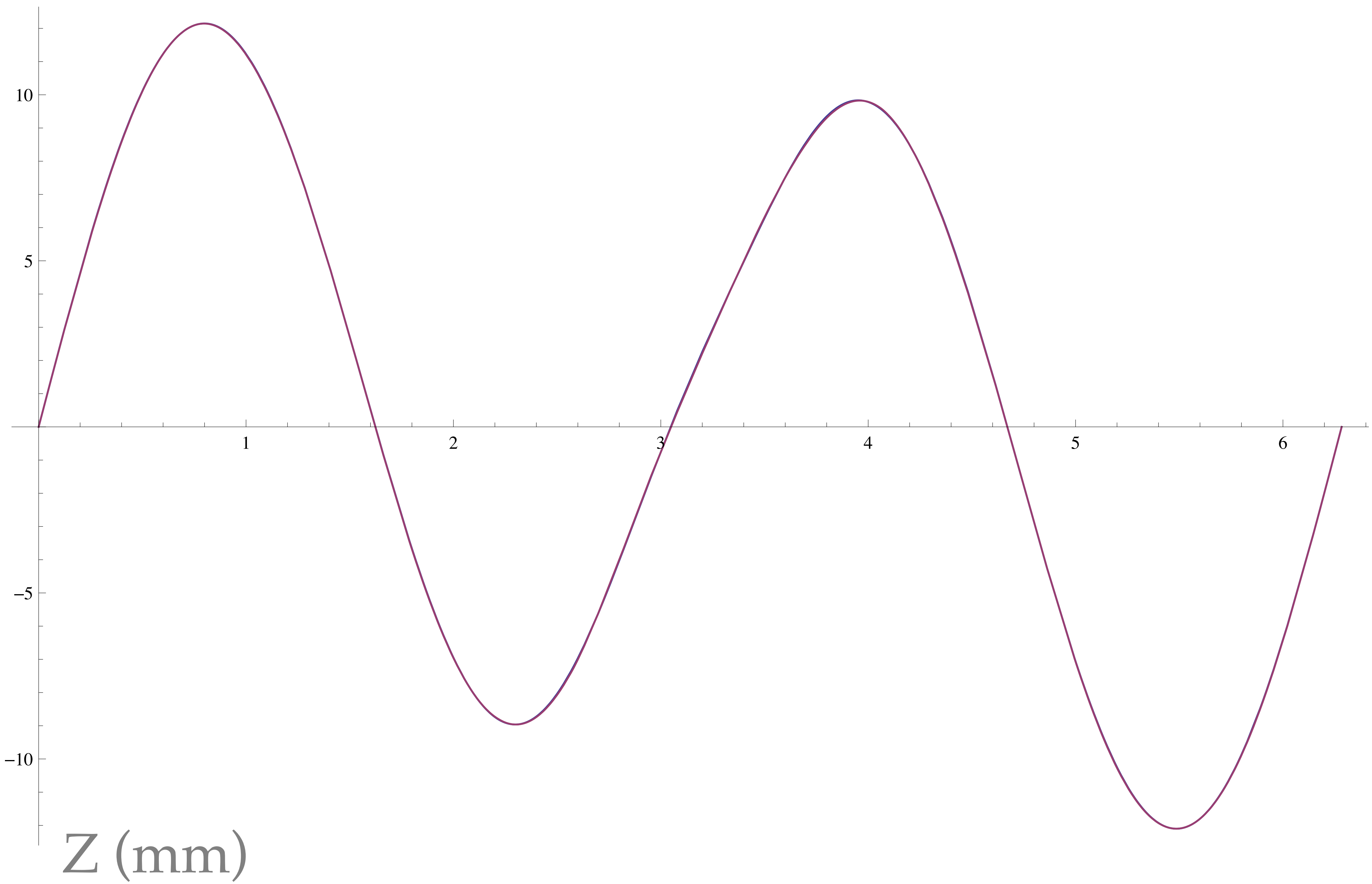


Windings (HER projection)





Convergence Check (N=16 vs N=32)



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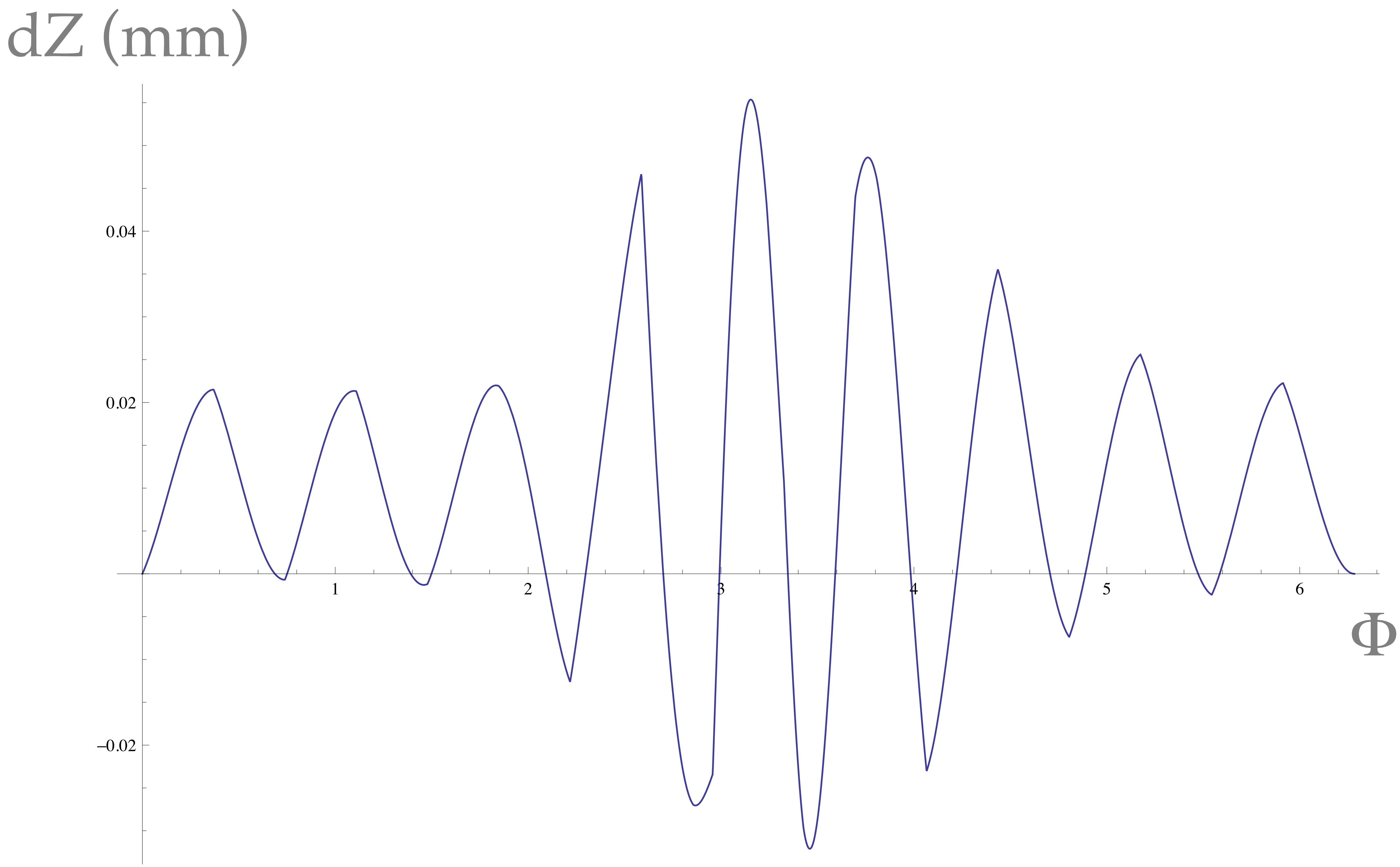

Conclusions

- An algorithm to compensate the cross talk for the twin QD0 with converging mechanical and magnetic axis had been presented
- Limitation:
  - The algorithm converges as long as each magnetic axis is parallel to the mechanical axis of its support cylinder
- Test passed:
  - The algorithm is able to find the single quadrupole solution
  - The algorithm is able to reproduce the twin quadrupoles with parallel axis compensation

Spares