Spin Resonance Free electron ring injector

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Spin Resonance Review

T-BMT Equation:

$$\frac{d\vec{S}}{dt} = \frac{q}{\gamma m}\vec{S} \times \left((1+G\gamma)\vec{B}_\perp + (1+G)\vec{B}_\parallel\right)$$

T-BMT in Spinor form:

$$\frac{d\Psi}{d\theta} = -\frac{i}{2}\begin{pmatrix} f_3 & -\xi \\ \xi^* & -f_3 \end{pmatrix}\Psi.$$

Driving Terms:

$$\xi(\theta) = F_1 - iF_2 = \sum_K \varepsilon_K e^{-iK\theta}.$$

Spin Resonances Amplitudes:

$$\varepsilon_K = -\frac{1}{2\pi}\oint \left[(1+G\gamma)(\rho z'' + iz') - i\rho(1+G)(\frac{z}{\rho})'\right] e^{iK\theta} d\theta$$

Review Continued:

Froissart-Stora formula

$$\frac{P_f}{P_i} = 2e^{-(\pi|\varepsilon_K|^2/2\alpha)} - 1$$

$$\alpha \approx d(G\gamma)/d\theta$$

Spin Resonances come from vertical motion mostly. The z'' term dominates

$$z = z_\beta + z_{co}$$

Intrinsics Resonance (z_β)

$$K = N \pm Q_z$$

Imperfection Resonance (z_{co})

$$G\gamma = K = N$$

$$\zeta_P(\frac{K \pm Q_z}{P})$$

$$\zeta_P(x) = \frac{\sin(P\pi x)}{\sin(\pi x)}.$$

Tell when they are significant

Concept OverView

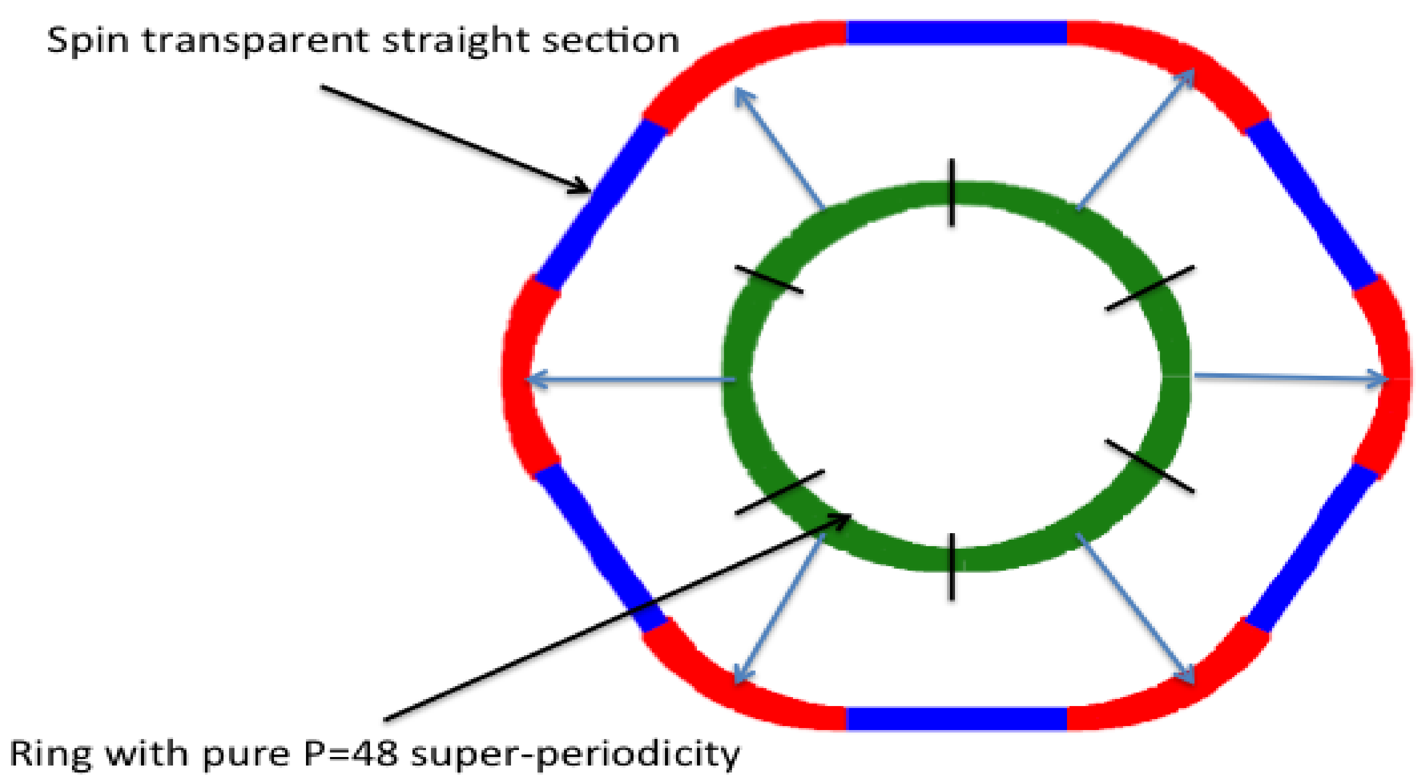
A spin resonance free electron ring injector for an electron ion collider. Such an accelerator will provide spin polarized electrons for energies up to 20 GeV. The proposed device will fit in the existing RHIC tunnel, employ standard technology

- This can be accomplished due to the fact that both the strong intrinsic and imperfection resonances occur at:
  - K = nP +/- Qy
  - K = nP +/- [Qy] (integer part of tune)
- To accelerate from 200 MeV to 20 GeV requires the spin tune ramping from:
  - 0.24 < Ggamma < 45.5.
- If we use a periodicity of P> 48 and a tune with an integer value also greater than 48 then our first two intrinsic resonances will occur outside of the range of our spin tunes
  - K1 = 48 – 48.nuy = nuy (nuy is the factional part of the tune)
  - K2 = 2*48 – 48.nuy = 48.nuy
- Also our Imperfection will follow suit:
  - K1 = 48 – 48 = 0
  - K2 = 2*48 – 48 = 48

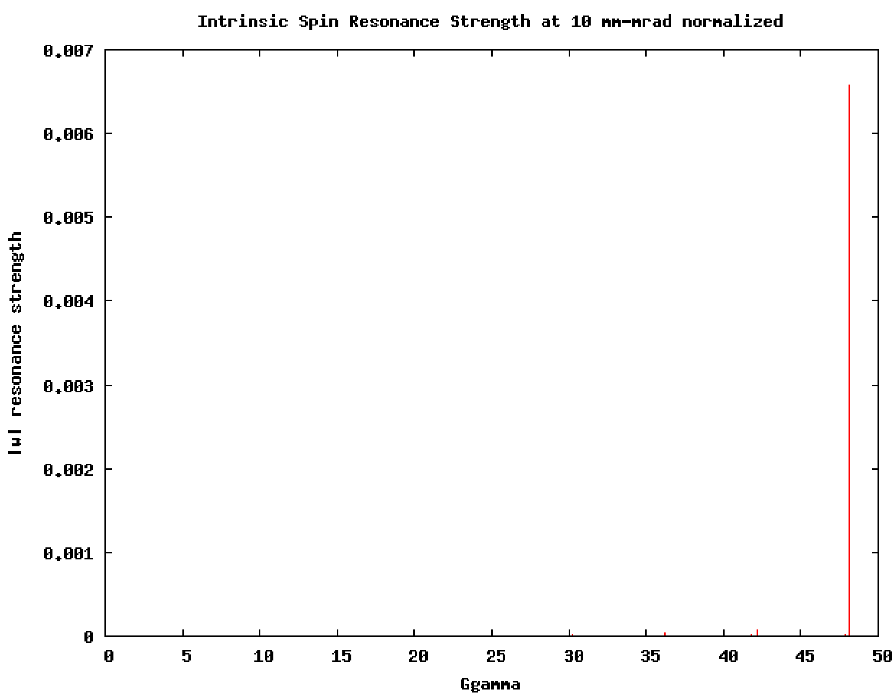
How to make this work in the RHIC tunnel?

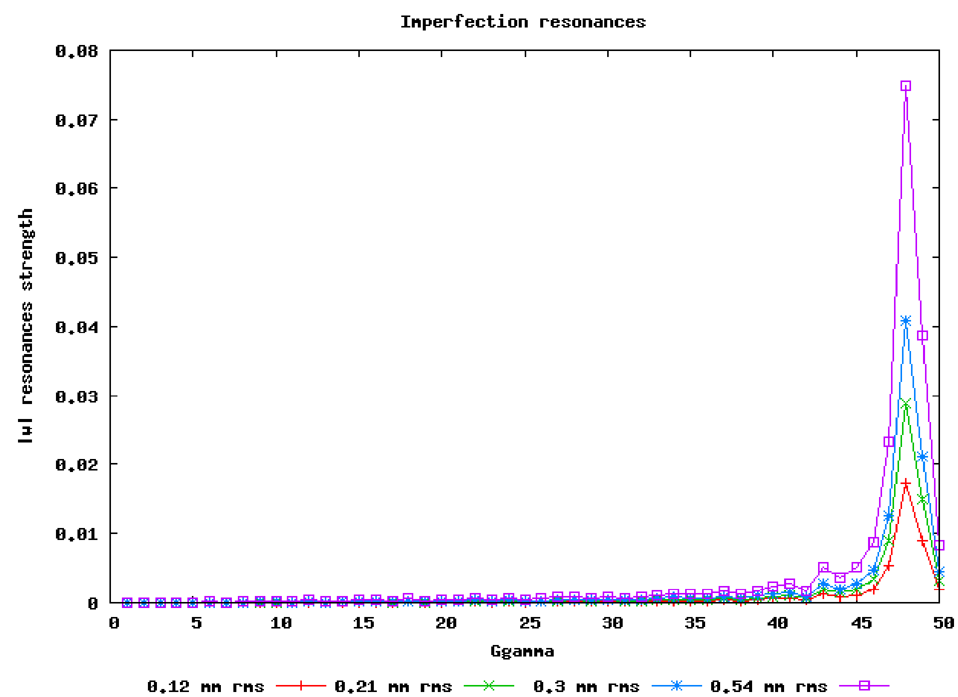
- It is easy to accomplish this with a perfectly circular ring. Just construct a series of FODO cells with bending magnets so that we have total periodicity of 48.
- The problem is that the RHIC tunnel is not circular and has an inherent six fold symmetry.
- The Solution make the spin resonances integrals over the straight sections equal to zero.
- We actually ended up doing this using 2*48 = 96 Super periodicity. So our first resonance is at:
  - K1 = 96 – 48.nuy=48.nuy

Project onto the RHIC tunnel

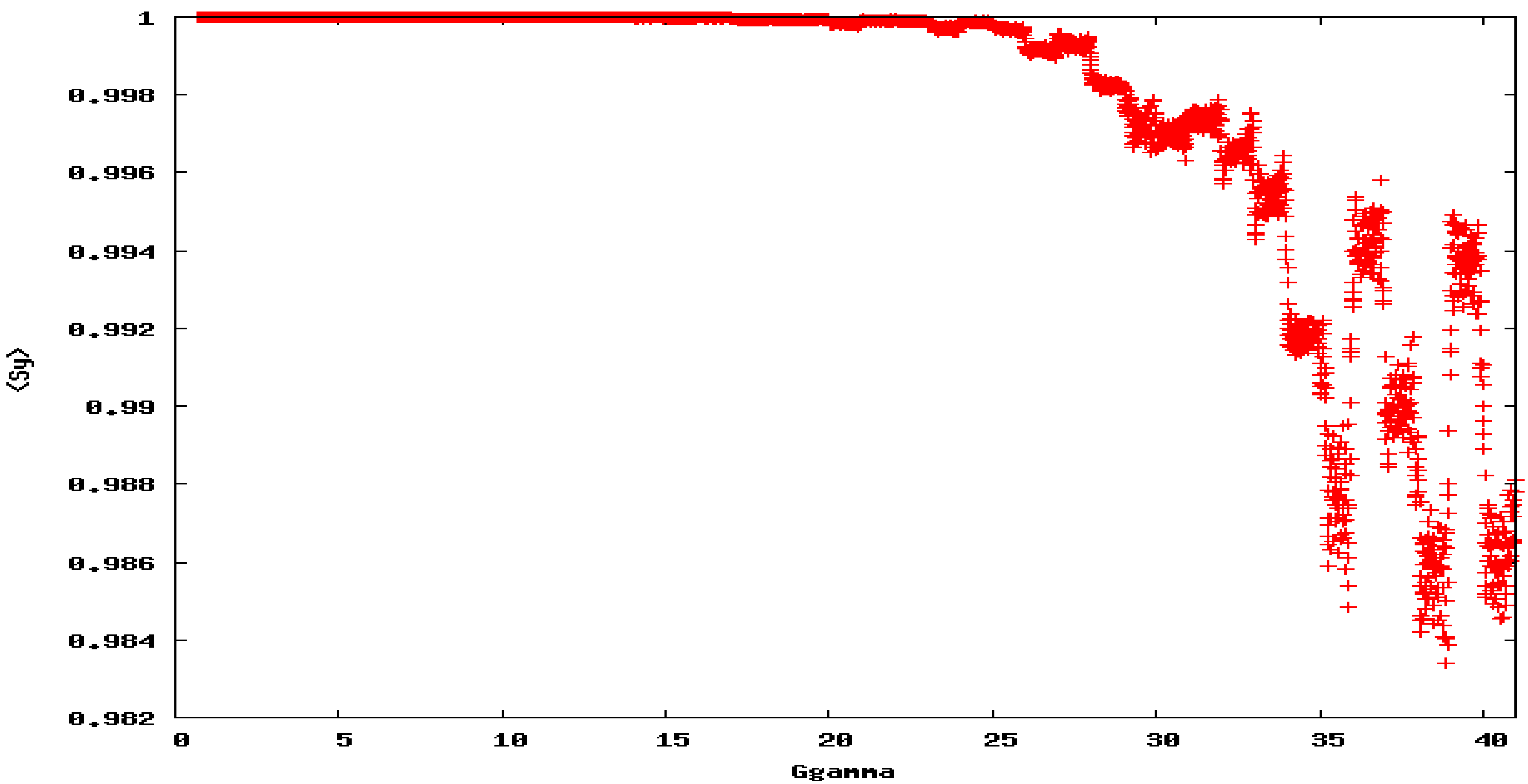


Checking the Spin Resonances with DEPOL





Ramp 50 msec with 1 mm rms orbit errors plus 1% k1 errors in quads with Emittance=1000mm-mrad

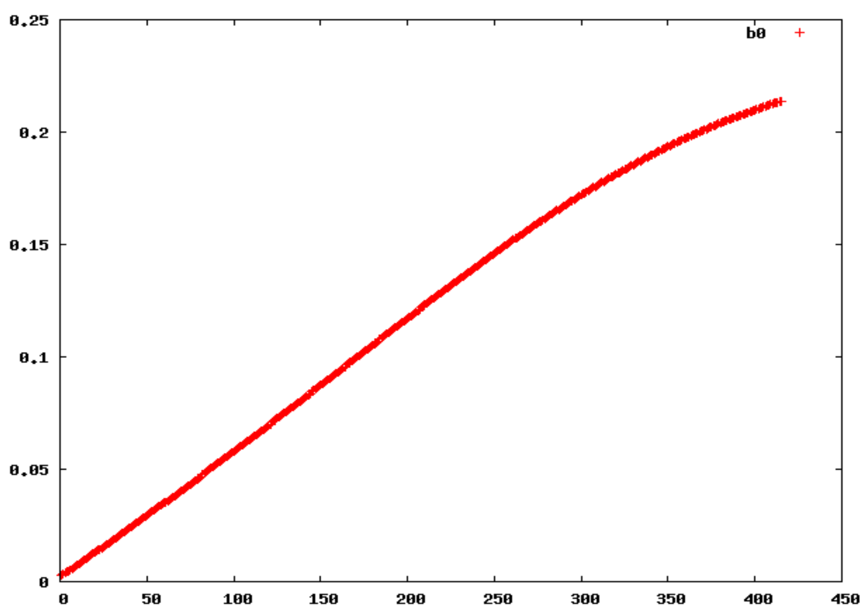


Can we ramp this fast?

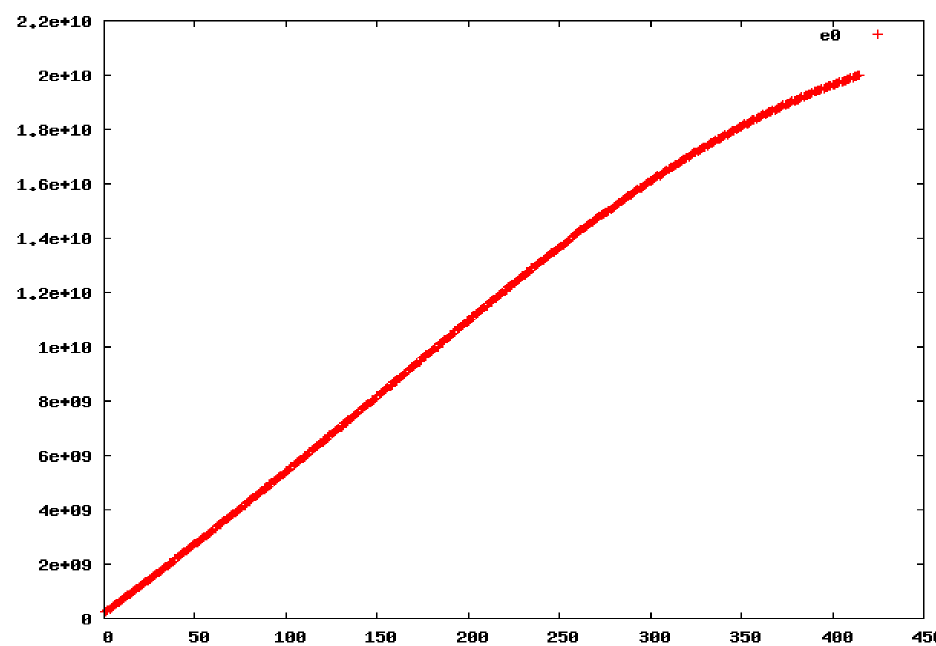
Can we build a cost and risk effective system to take us from 200 MeV to 18 GeV over 50 msecs?

- From just the point of view of ramping the dipoles it shouldn't be a problem
  - Dipoles for this lattice are L=4.64 m, angle = 0.016363 rad.
  - At 20 GeV reach peak field of 0.22 Tesla. We should at least be able to cycle in 50 msec (20Hz) (for example ISIS ring at Rutherford Lab does 0.7 Tesla in 50 Hz)

Dipole Field Ramping



Beam Energy



Quad and Sextupole Magnet Specs

- We have One family of focusing and defocusing quads in our arcs:
  - $L=0.3m$, $|K1| < 0.37\ m^{-2}$
- We have 6 more families of focusing and defocusing quads in the straight sections
  - $L=0.3m$, $|K1| < 0.32\ m^{-2}$
- We also have 7 families of sextupoles
  - $L=0.5m$, $|K2| < 4.5\ m^{-3}$
- Our beam pipe will be 4 cm in Diameter.

Magnet Layout

- // -------- The FODO cell beam line ------------------------
- ACELL : LINE=(HQD, ODSX, SX1, ODSX, D, ODIF, HQF, HQF, ODSX, SX2, ODSX, D, ODIF, HQD);
- BCELL : LINE=(HQD, ODSX, SX3, ODSX, D, ODIF, HQF, HQF, ODSX, SX4, ODSX,D, ODIF, HQD);
- ARC : LINE=(16*(ACELL, BCELL));
- // A ring.
- RING : LINE=(IP6, -TM, ARC, TM, IP8, -TM, ARC, TM, IP10, -TM, ARC, TM, IP12, -TM, ARC, TM, IP2, -TM, ARC, TM, IP4, -TM, ARC, TM, IP6);