LCLS S-band Structure Coupler

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Outline

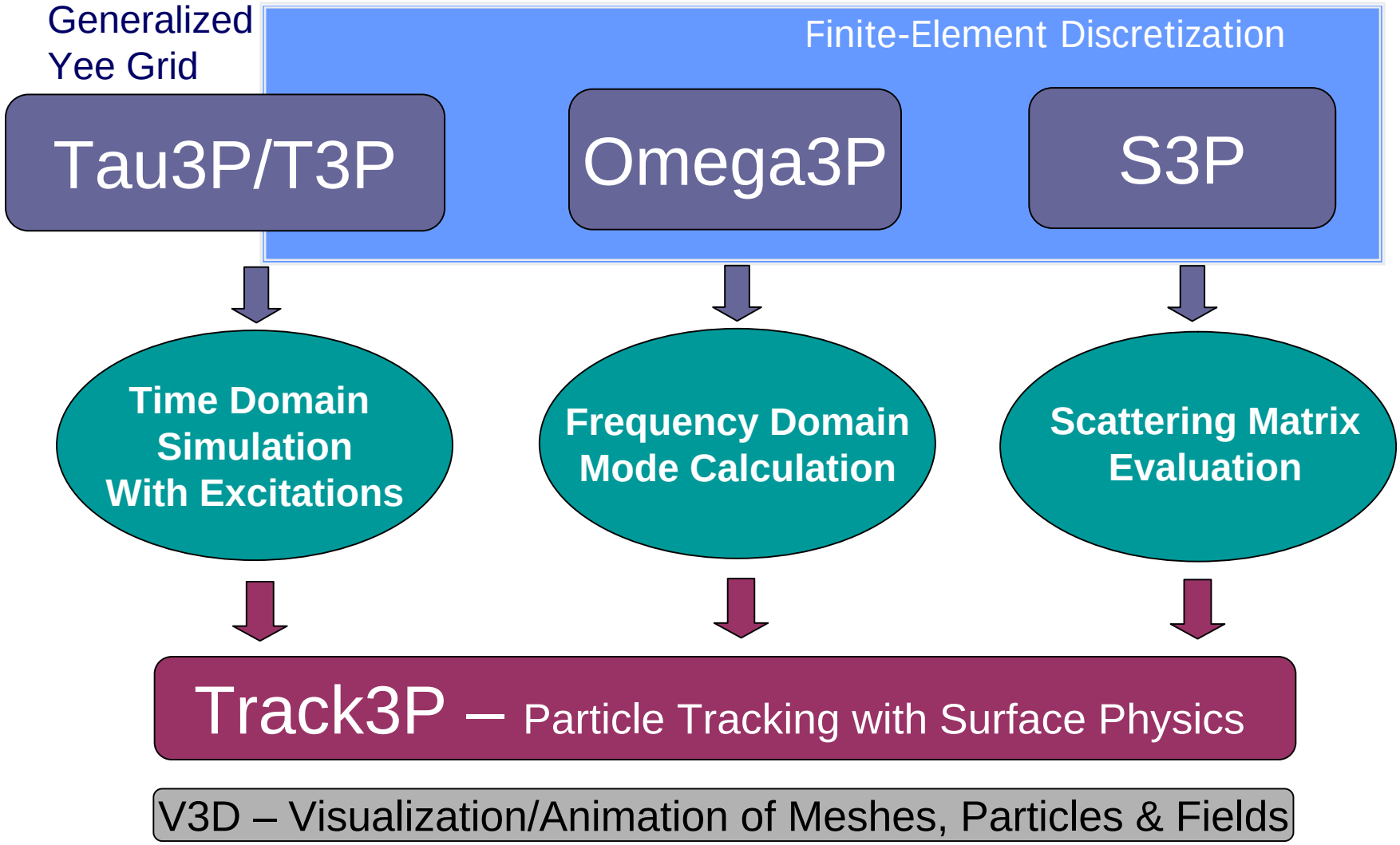
- Motivation
- Modeling tool
- S3P model of S-band coupler
- Field analysis
- Beam analysis

Discussions

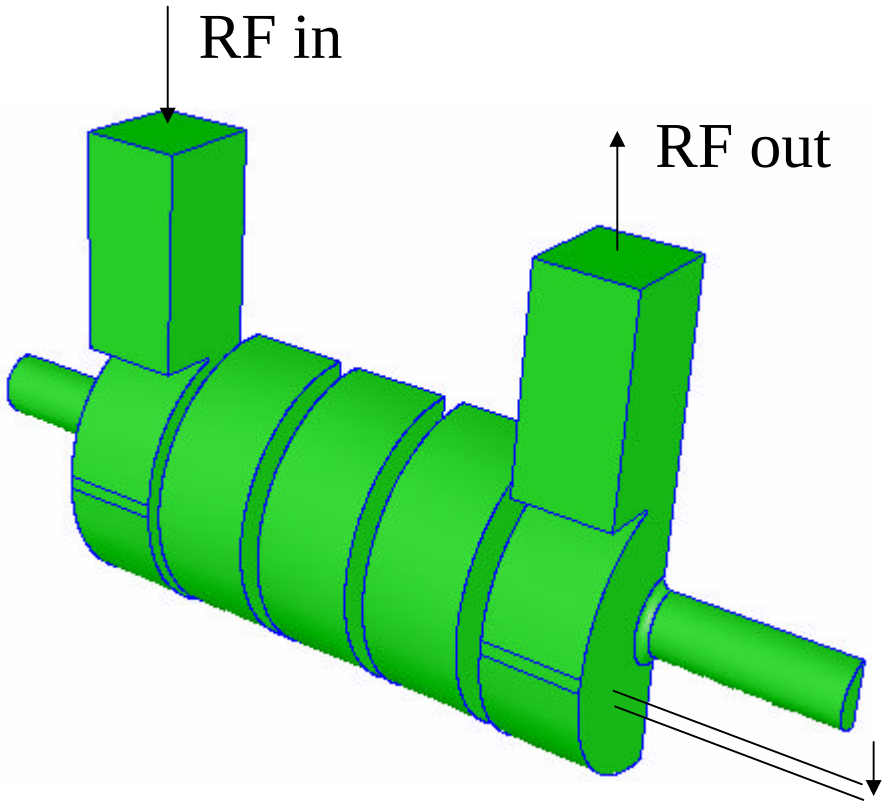
Motivation

- To understand effects of multipole fields on beam dynamics in single-feed coupler
- Work on alternative designs if necessary

Parallel EM Codes On Unstructured Grids



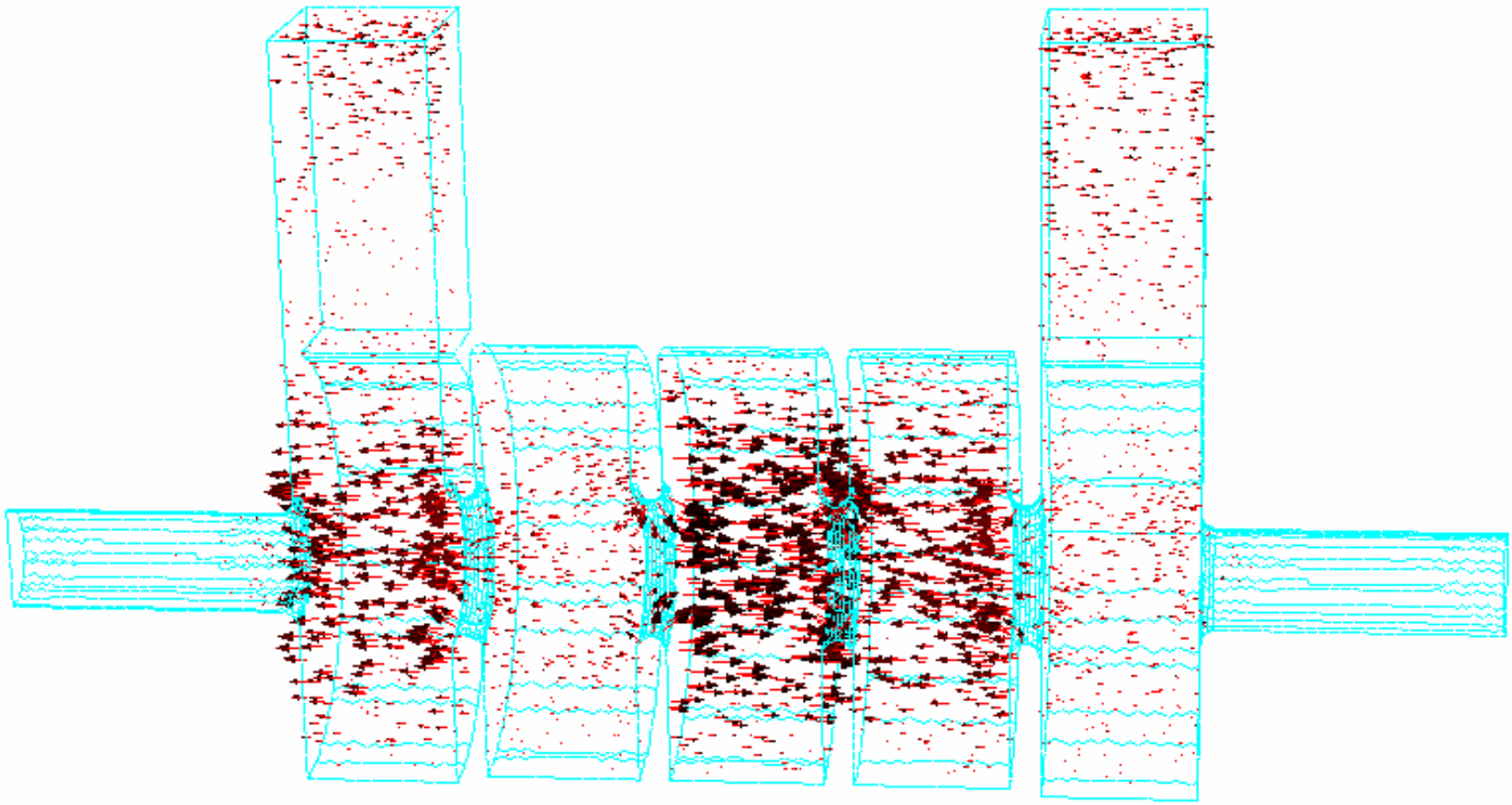
LCLS S-Band Coupler – S3P Model



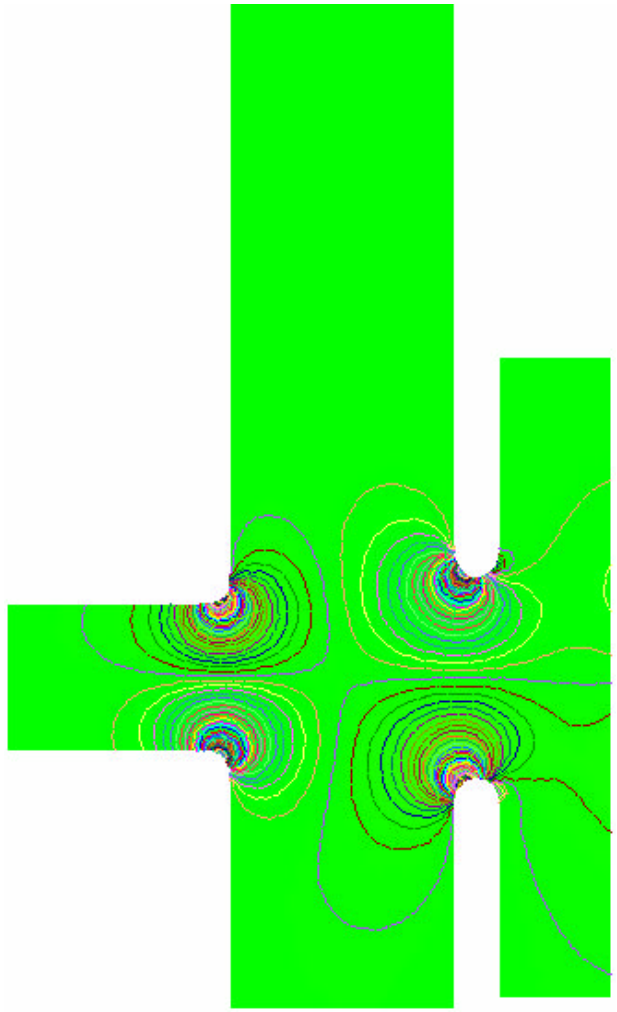
For field symmetry

- Dimensions directly from drawings
- Reflection about 0.05
- Should be ok for this study

Field Snapshot



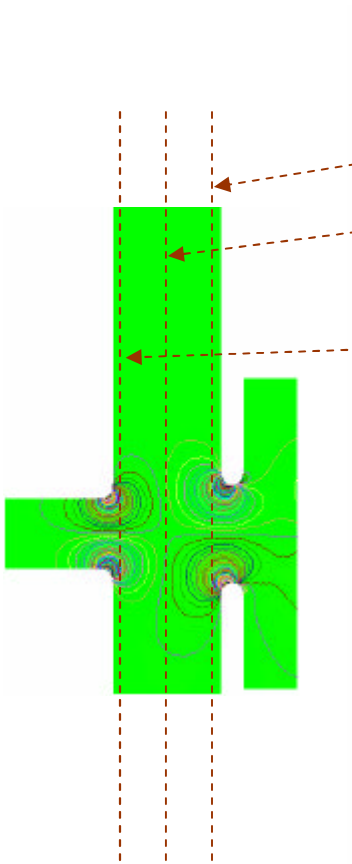
Field Asymmetry In Coupler Cell- Ey

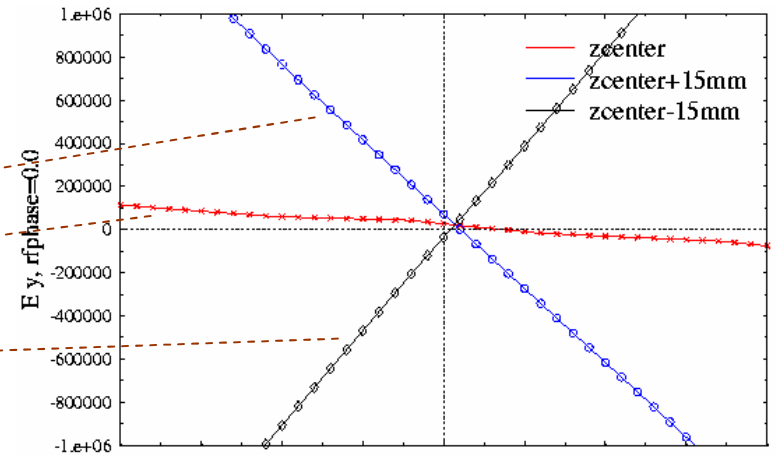


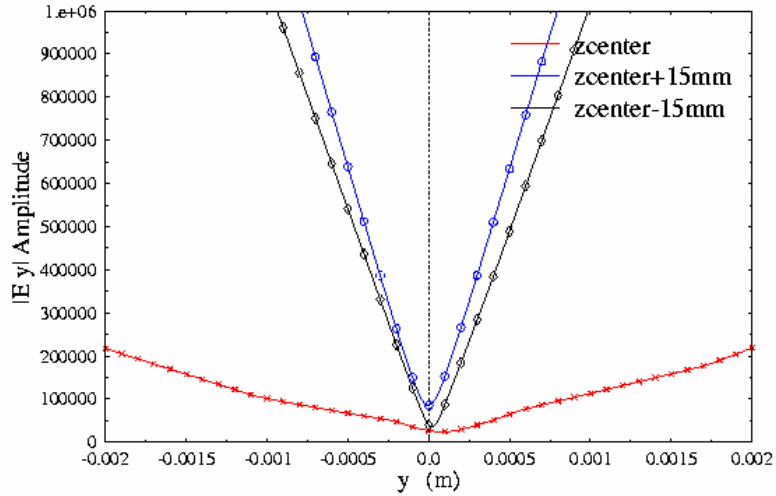
Ey:

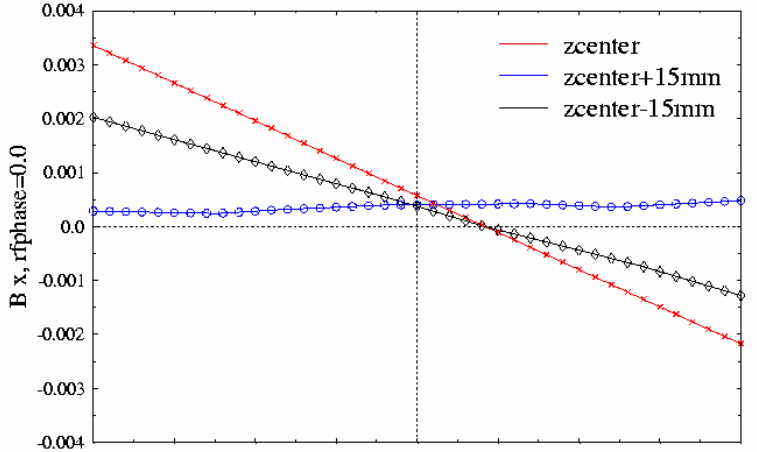
- Snapshot
- Contour plot

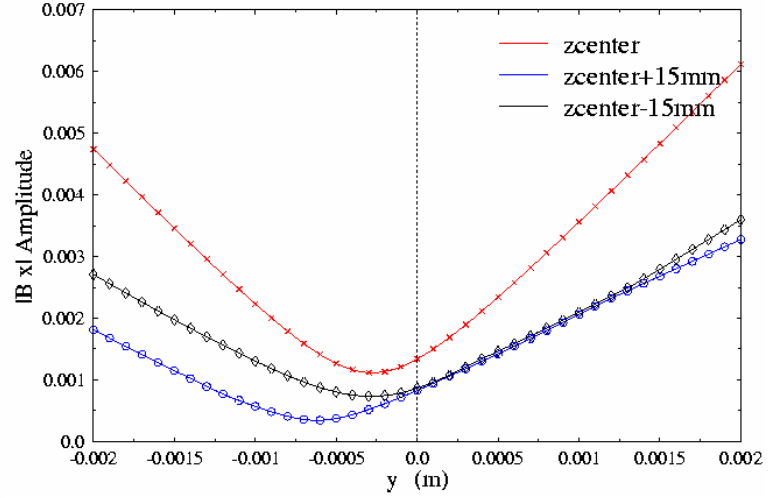
Field Asymmetry



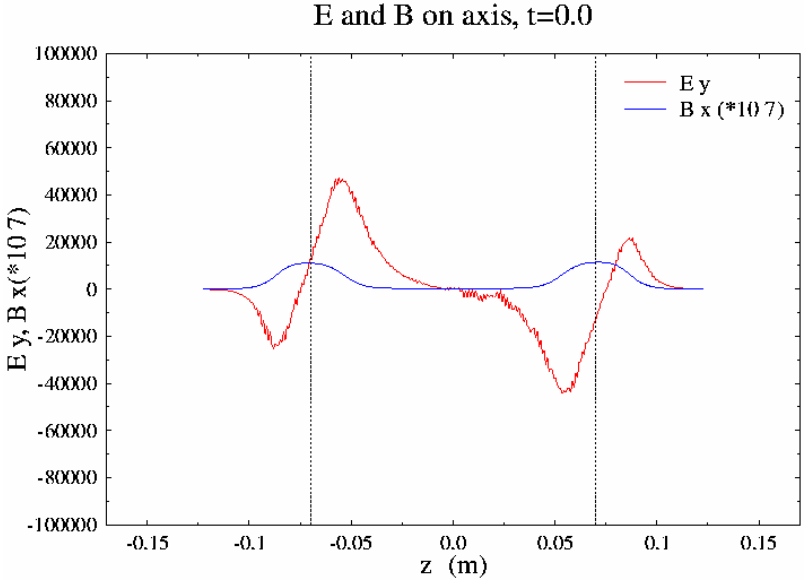


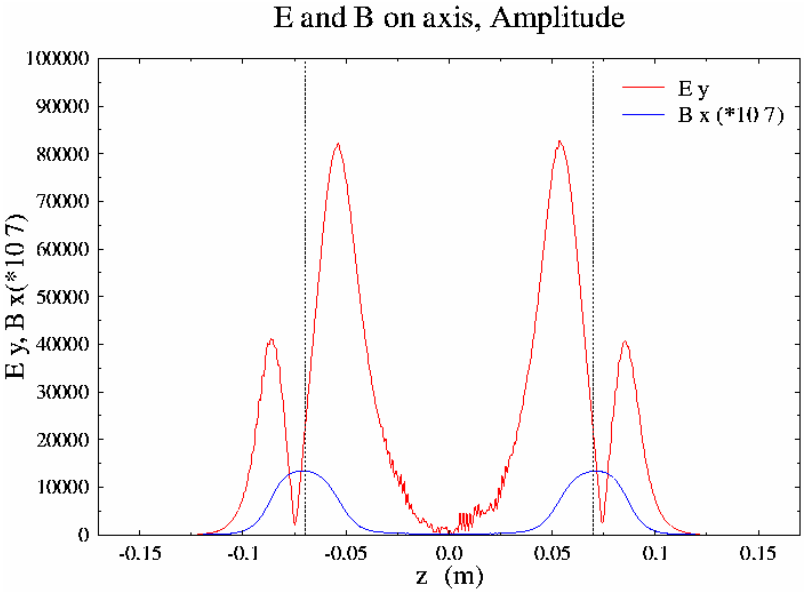






Fields On Axis





On-axis Ey and Bx are non-zero in the coupler region

Beam Dynamics

- Equation of motion: $\frac{d(g\vec{b})}{dt} = \frac{e}{m_0 c}(\vec{E} + c\vec{b} \times \vec{B})$
- Transverse momentum

$$\Delta\vec{P}_{m\perp} = -\frac{je}{w}\nabla_{\perp}\int E_z(r,q,z,m)e^{jwt-jz_z z}dzdz$$

$$E_z(r,q,z,z_z) = \sum_{m=0}^{\infty} A_m J_m(h_r r)\cos(mq)e^{-jz_z z} + \sum_{m=0}^{\infty} B_m J_m(h_r r)\sin(mq)e^{-jz_z z}$$

where $h_r^2 + z_z^2 = \frac{w^2}{c^2}$

- To the first order

$$\Delta\vec{P}_{\perp} = -\frac{je}{w}\left(\underbrace{-\frac{h_r^2 A_0}{2}(x\hat{x}_0 + y\hat{y}_0)}_{\text{focusing}} + \underbrace{\frac{h_r A_1}{2}\hat{x}_0 + \frac{h_r B_1}{2}\hat{y}_0}_{\text{dipole}} + \underbrace{\frac{h_r^2 A_2}{4}(x\hat{x}_0 - y\hat{y}_0)}_{\text{quad}} + \underbrace{\frac{h_r^2 B_2}{4}(y\hat{x}_0 + x\hat{y}_0)}_{\text{skew quad}}\right)$$

γ Dependence Of Momentum Multipoles

- 1/γ dependence for azimuthal focusing (full structure - back-back coupler in our case)

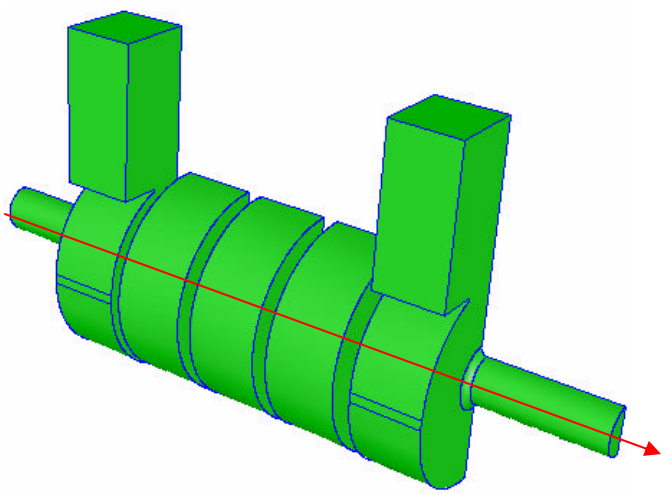
$$g(\infty)b_r(\infty) = \overbrace{g(-\infty)b_r(-\infty)\left(1+\frac{I_{01}}{g}+\frac{I_{02}-I_{03}}{g^2}\right)}^{\text{Adiabatic damping}} - \overbrace{r(a)\left(\frac{I_{11}}{g}+\frac{I_{12}-I_{13}+I_{14}}{g^2}\right)}^{\text{RF focusing}}$$

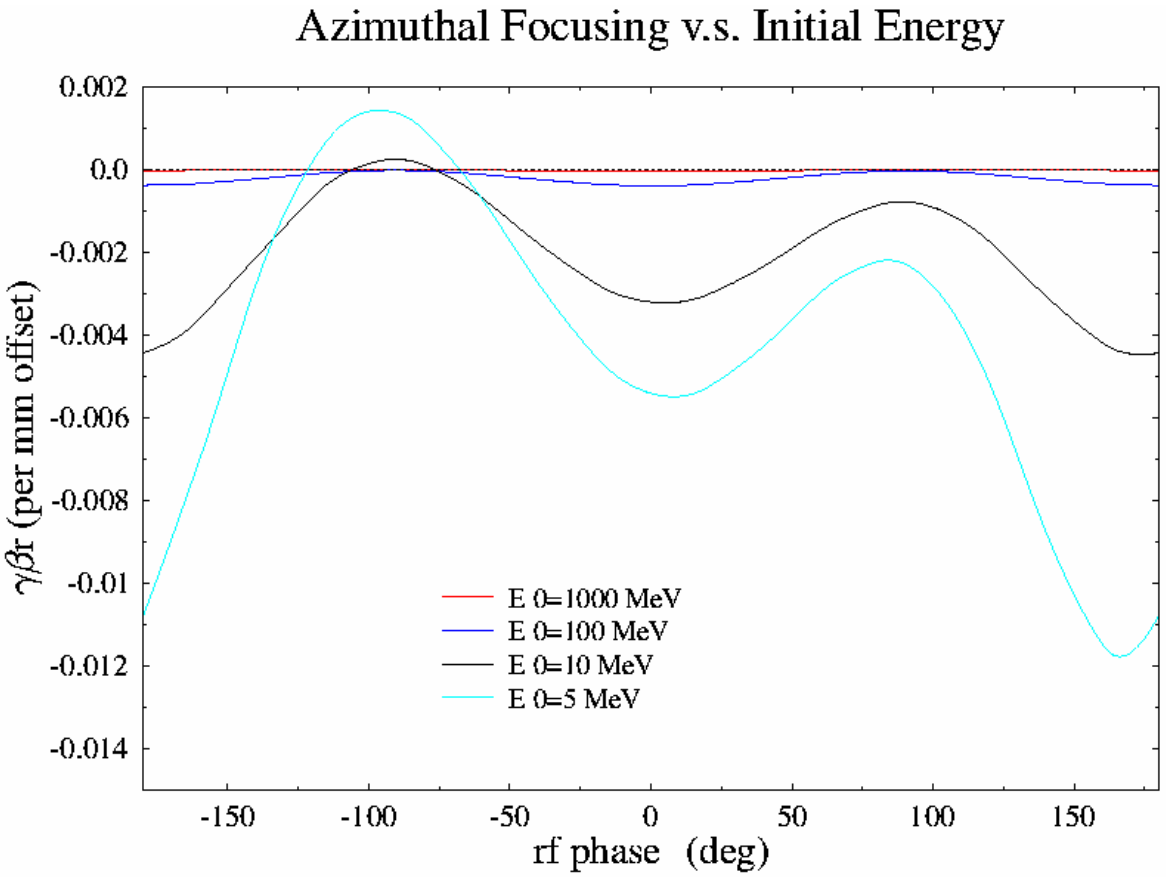
where I_{mn} are integrals of E_z field

- Dipole and quadrupole are γ independent.

Azimuthal Focusing

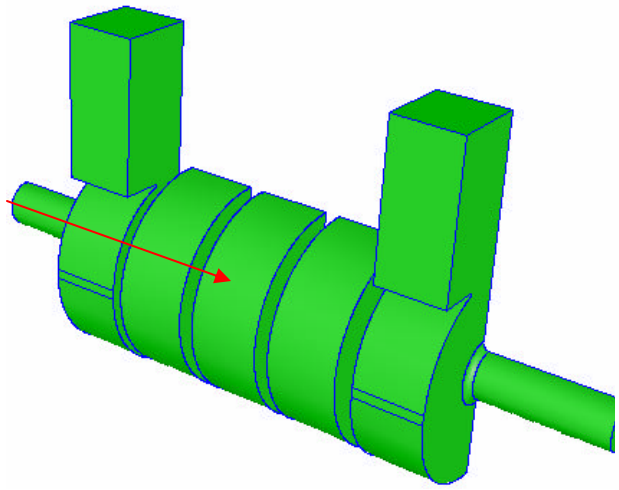
- Full back-back system simulation

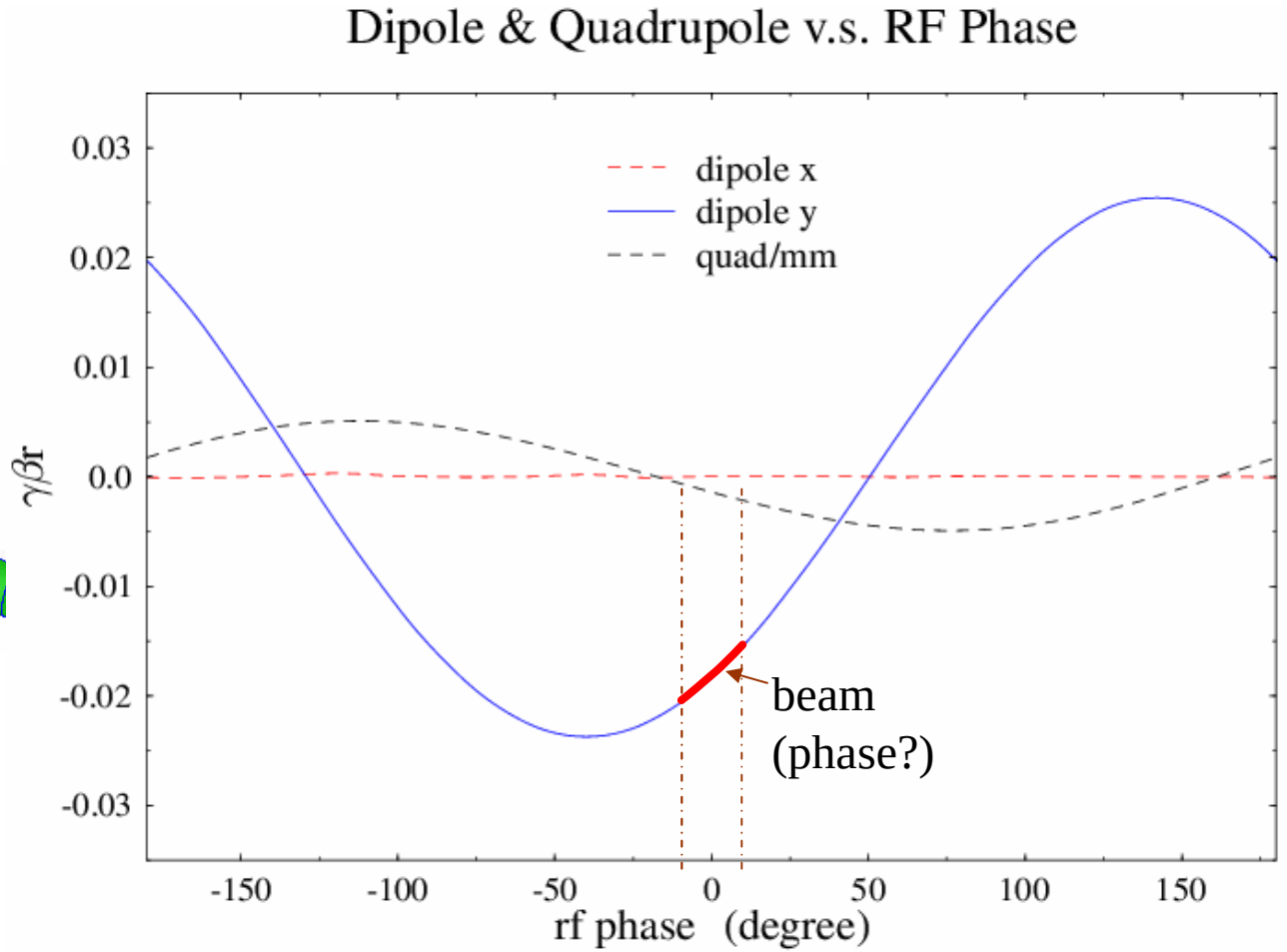




Dipole & Quadrupole

- Effect of input coupler
- Integrate through half of the model





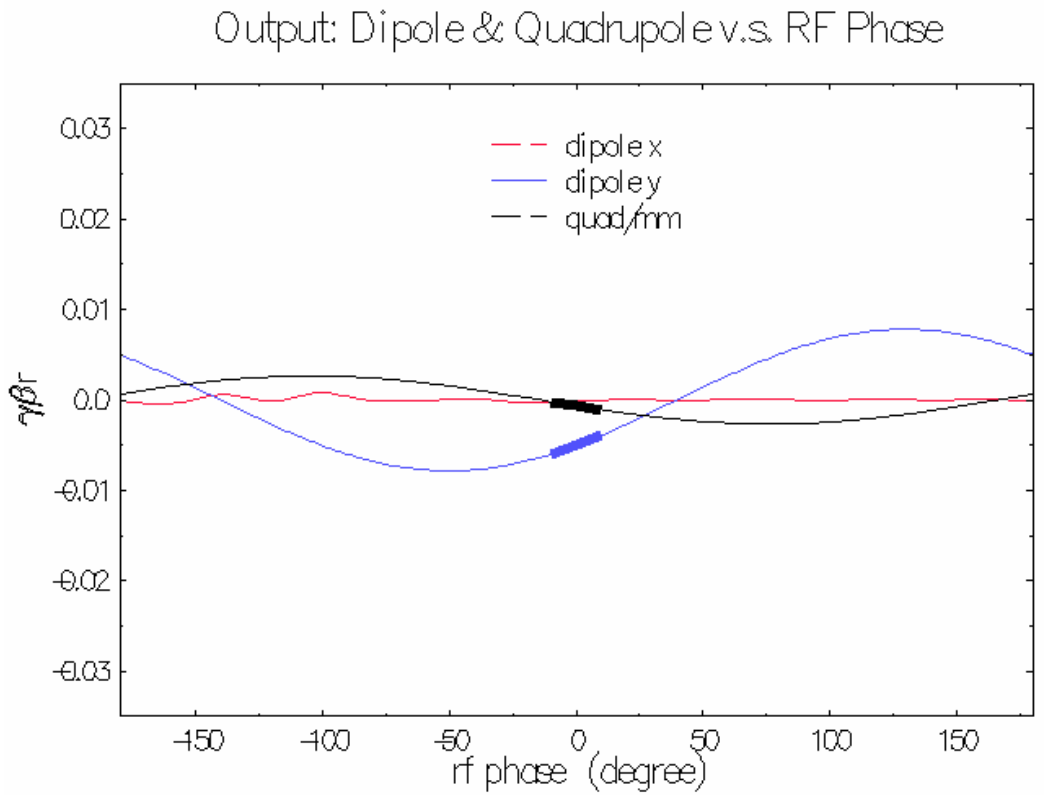
Head-Tail Effect

- "Zero" phase is not accurate since only a few cells are included in the present model – phase slippage and coupler effect significant
- Amplitude of dipole and quadrupole OK
- Bunch spans ±10 degrees in RF phase
- If beam on crest, head to tail $\Delta(\gamma\beta_\perp)$ is
  - Dipole $\Delta(\gamma\beta_\perp)$: 0.005
  - Quadrupole $\Delta(\gamma\beta_\perp)$: 0.0015/mm (focusing)

Output Coupler

Iris dimension adjusted to obtain a good match

- Adjust amount: 0.75mm
- Tuned in real structure



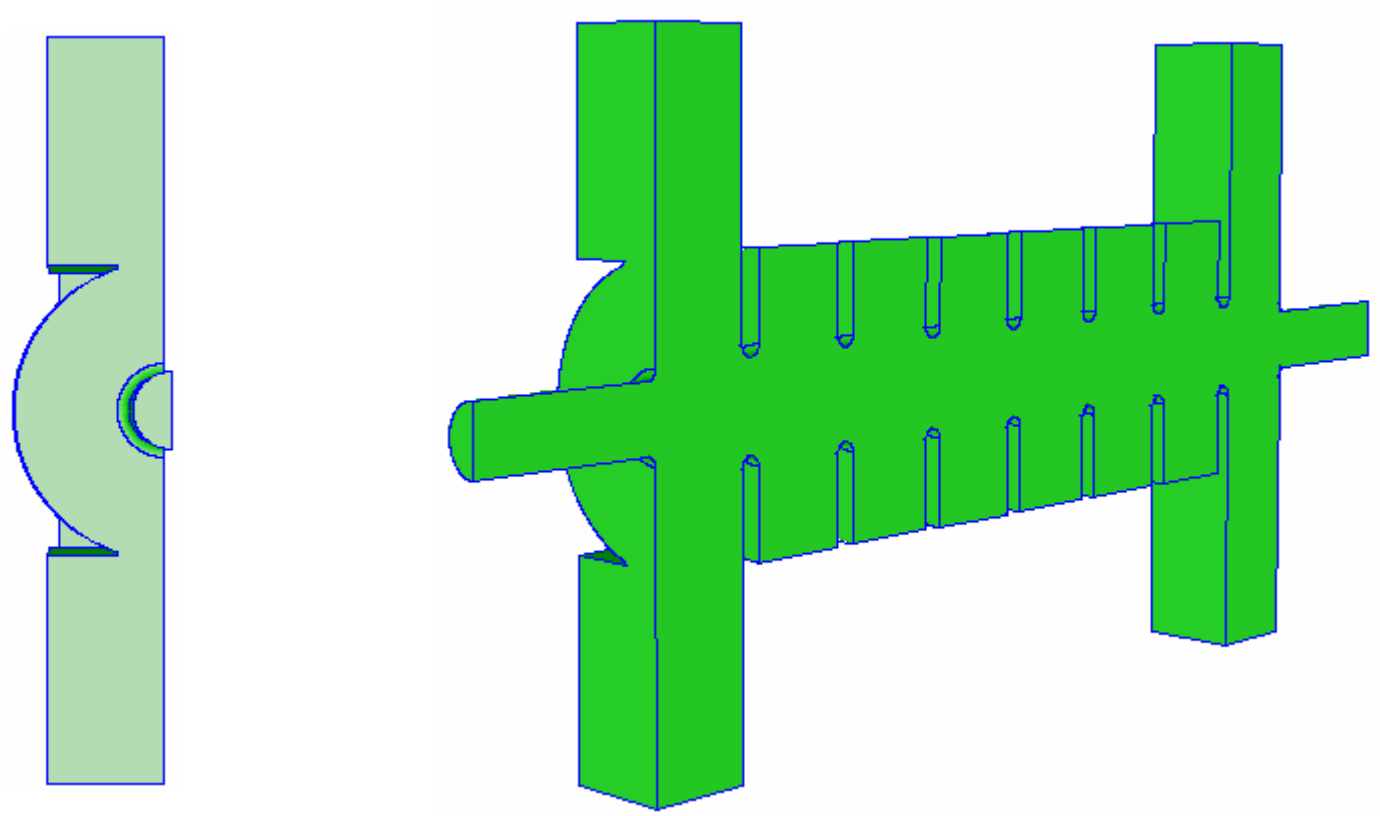
$\gamma \approx 100$

±10 degree bunch length

Dipole $\Delta(\gamma\beta\perp)$: 0.0021

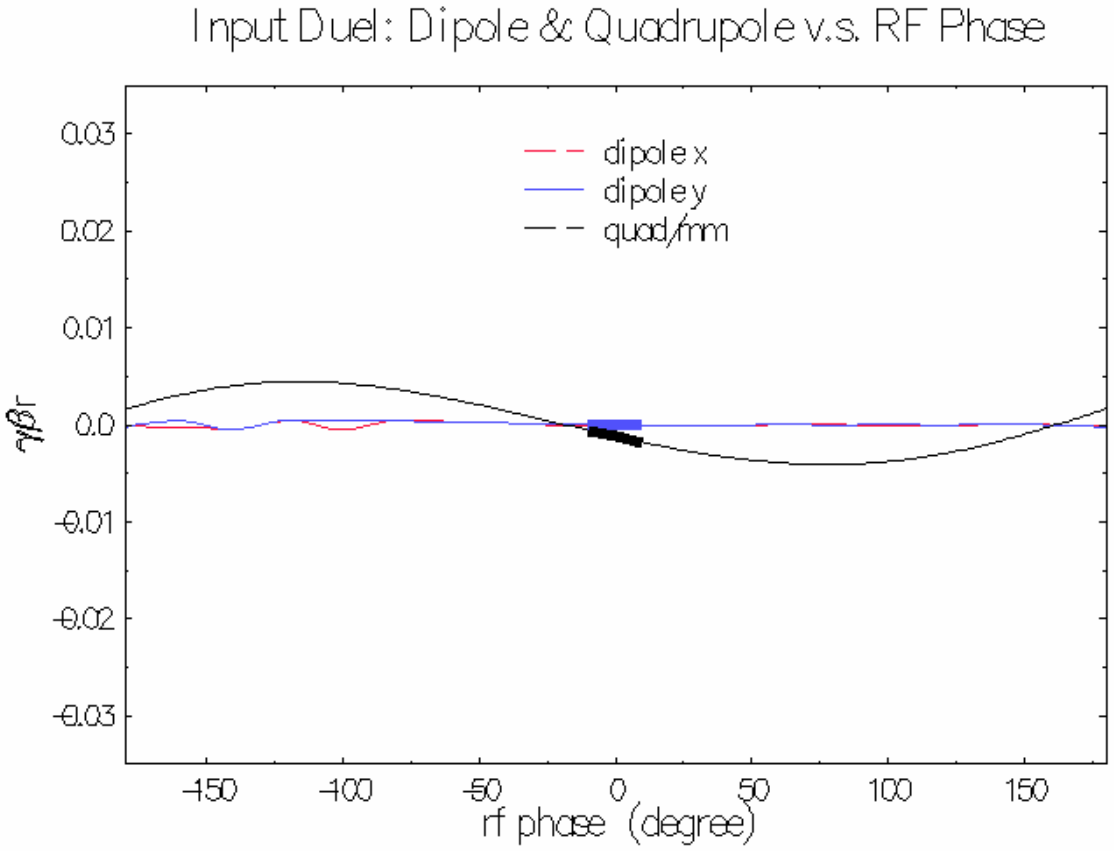
Quadrupole $\Delta(\gamma\beta\perp)$: 0.00088/mm (focusing)

Input Coupler – Duel-feed



Width change: 3.502 mm
Cell radius change: 0.800 mm
Iris thickness unchanged

Input Coupler – Duel-feed

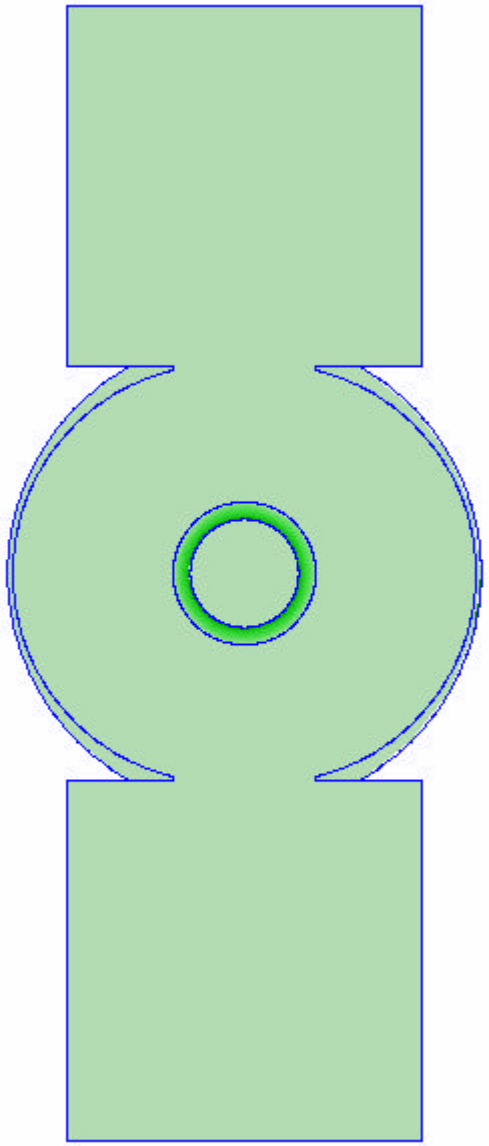


$\gamma \approx 10$

±10 degree bunch length

Quadrupole $\Delta(\gamma\beta\perp)$: 0.00125/mm (focusing)

Input – Racetrack Duel-feed



Need to

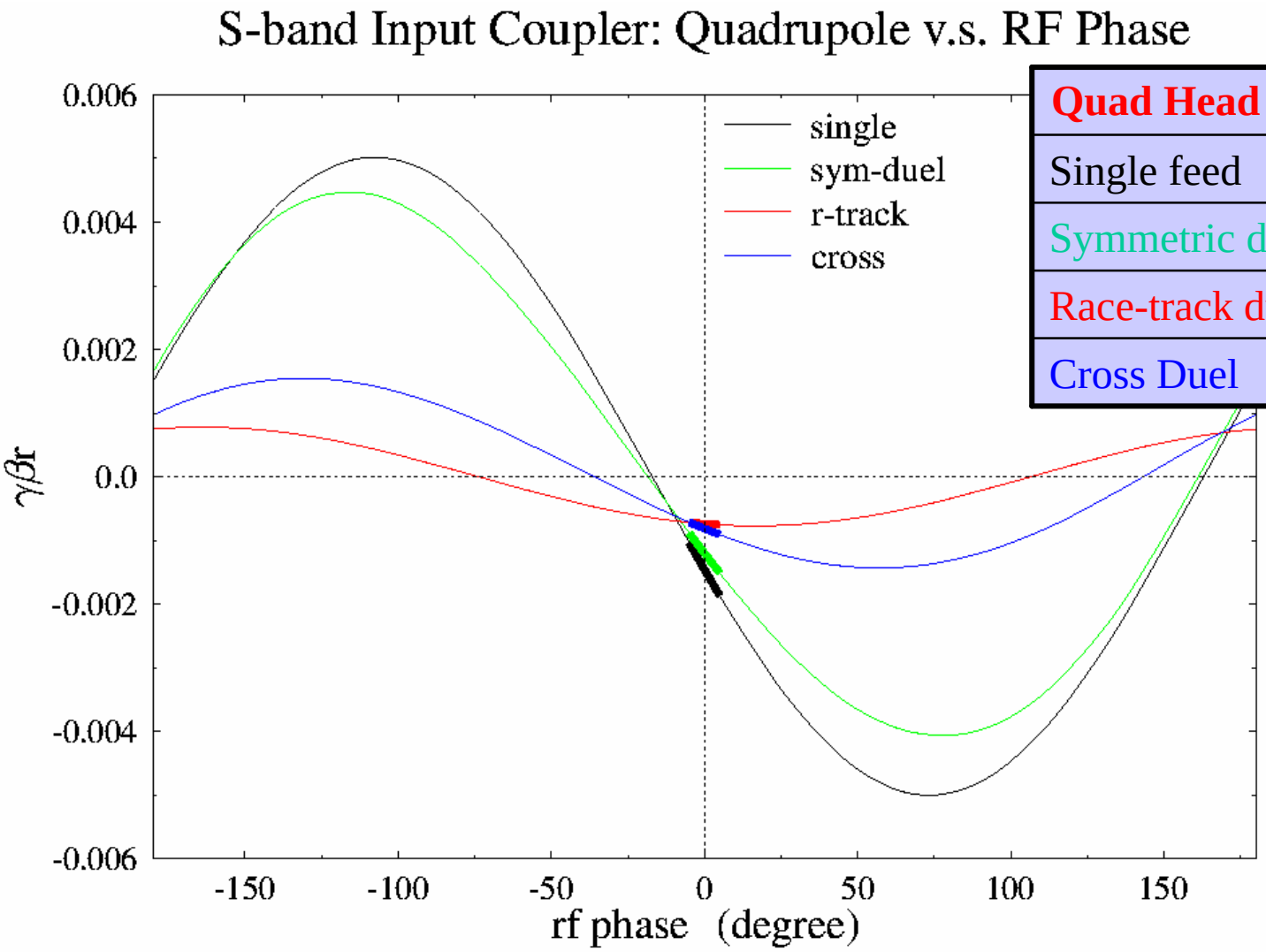
- Match
- Check quad

Cecile's Quad Requirement

- Head-tail angle: 0.075rad/m
- Input duel-feed, cylindrical cell: 0.0625rad/m
- Output single-feed: 0.0044rad/m (OK)

(γ is a factor of 10 large at output)

Coupler Comparison



Quad Head Tail $D(\gamma\beta_{\wedge})$: ±5 Degree	
Single feed	8.3×10^{-4}
Symmetric duel	6.3×10^{-4}
Race-track duel	0.4×10^{-4}
Cross Duel	2.0×10^{-4}

Race-track & Cross Coupler