Racetrack Ring Design for Positron Production and Luminous Annihilation with Electrons

S. Alex Bogacz♦

Center for Advanced Studies of Accelerators
Thomas Jefferson National Accelerator Facility
12000 Jefferson Avenue,
Newport News, VA 23606

Abstract

A functional description of a Racetrack Collider ring is shown in Figure 1. It consists of two 180^{O} arcs and a pair of straight sections containing: (1) A Positron Production Target straight with a low beta insert and (2) a Luminous straight for co-moving electron/positron annihilation that would also accommodate RF and injection. The ring would operate in a range of momenta - between 2 and 20 MeV/c in a mode that avoids transition crossing. Here we consider pros and cons of two lattice options: (1) a low transition gamma lattice (γ_t = 1.5) and (2) an imaginary transition gamma optics. Finally, a complete linear optics for the racetrack ring with the imaginary transition gamma is summarized.

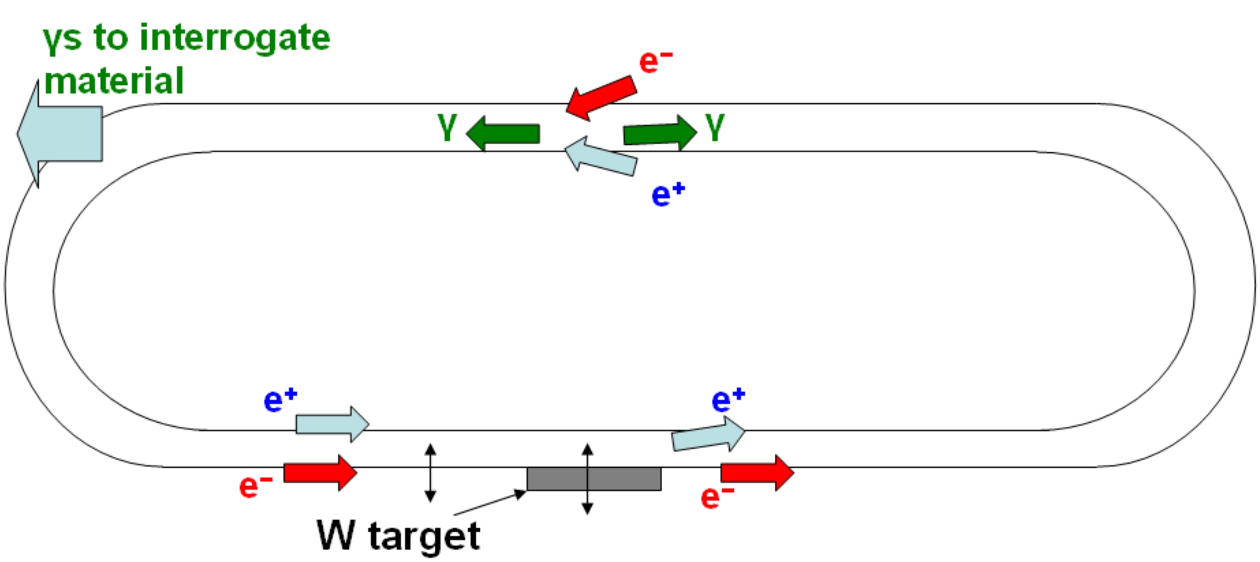

Figure 1: Conceptual layout of the racetrack collider ring. At the bottom of the figure is the production of positrons from beam of electrons impinging on a W target. Either the electron beam, W target, or both may move to provide collisions.

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♦bogacz@jlab.org

180^0 Arc – Flexible Momentum Compaction (FMC) Lattice

The FMC lattice offers vast flexibility in shaping the dispersion while preserving well balanced beta functions and tunes. A FMC cell consists of alternating triplets and singlets interleaved between bends. Such a lattice tuned to get large positive dispersion is illustrated in Figure 2.

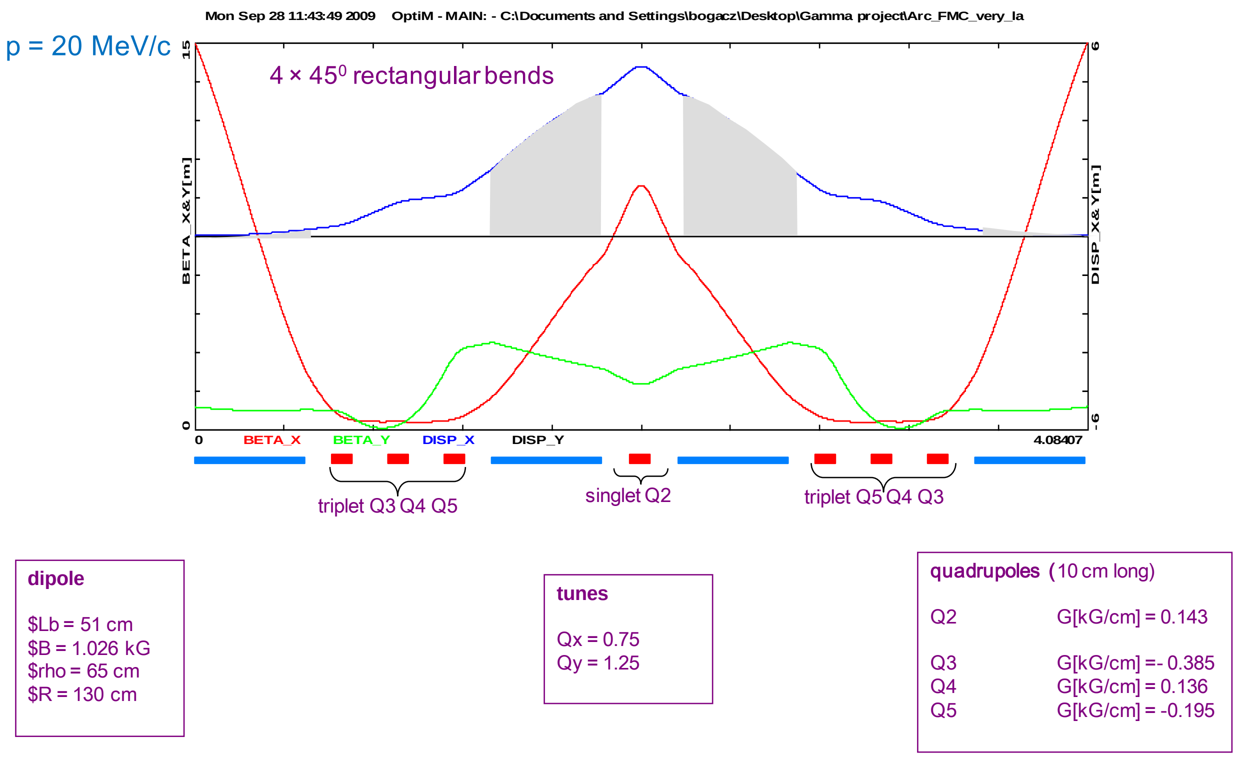

Figure 2: 180^0 Arc - Low transition gamma lattice based on a single FMC cell.

The arc features a large value of momentum compaction, α =0.444, expressed by the following formula:

$$\alpha = -M_{56} / L \tag{1}$$

with

$$M_{56} = -\int \frac{D_x}{\rho} ds = -\frac{1}{\rho} \int_{dip} D_x ds \tag{2}$$

The lattice was designed to achieve very low γ_t of 1.5 for the entire racetrack ring according to the parameters listed below:

$$\alpha = \frac{1}{\gamma_t^2} = 0.444 \quad , \quad M_{56} = 533\,cm, \;\; L = 12\,m \tag{3}$$

A drawback of this lattice is a very large value of the dispersion (5.2 m) at the middle of the arc. An alternative design of the FMC cell to achieve a negative value of momentum compaction by driving the dispersion function to negative values (α = -0.019) according to Eq. (1) is illustrated in Figure 3.

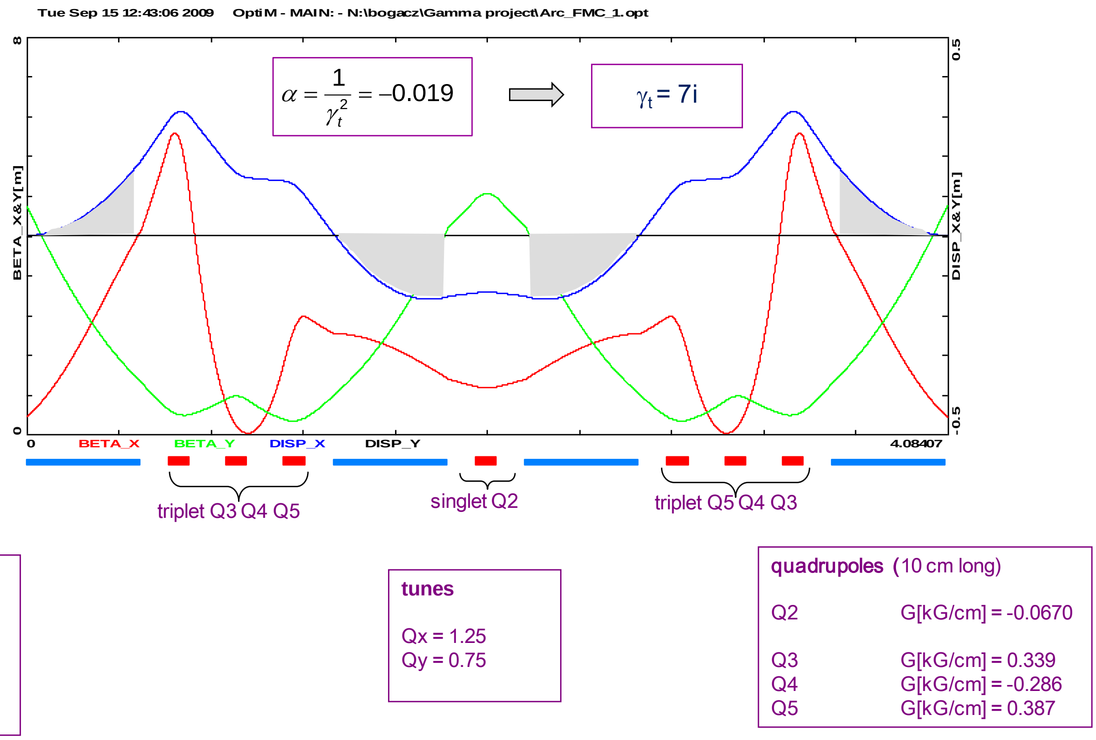

Figure 3: 180^0 Arc - imaginary transition gamma lattice based on a single FMC cell.

The resulting lattice is well balanced in terms of beta functions and tunes, and features very small dispersion (30 cm), which is very desirable for transporting beams with large momentum spread. Comparing basic features of both arc optics design choices illustrated in Figures 2 and 3 one can immediately see that the imaginary transition gamma lattice is more appropriate for the collider ring design.

Target Straight – Low beta Insert

To accommodate small electron beam spot size on the positron production target one needs to design a small beta insert similar to an interaction region in the case of a collider. The low beta insert can be implemented by two symmetricly placed triplets with focal lengths equal to their distance from the target. Such a lattice with 10 cm betas in both planes is illustrated in Figure 4. The remaining mirror symmetric triplets and singlets in the outer region of the straight create the underlying FMC optics, which is 'by design' matched to the TWISS functions of the arc.

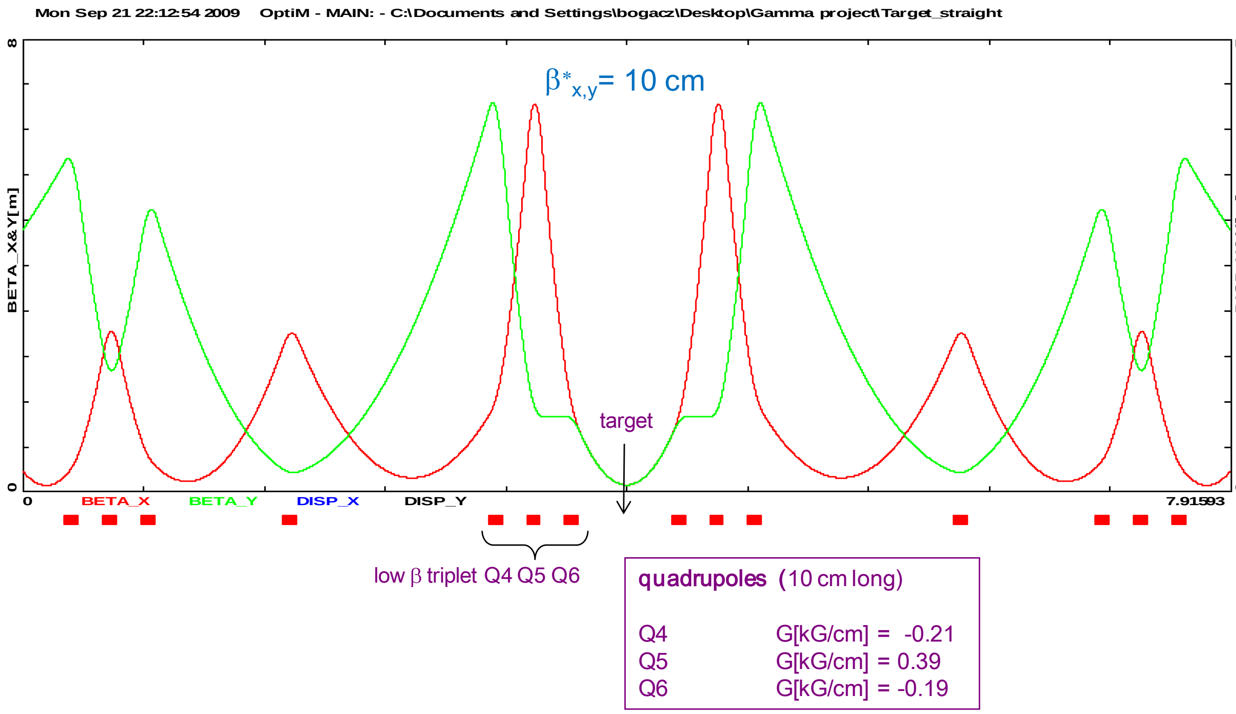

Figure 4: Target straight with small beta insert – Optics based on FMC lattice.

Luminous Straight

A luminous region, where both co-propagating electron and positron beams annihilate, can be facilitated by a long straight featuring a relatively low, slowly varying beta function. Such a lattice with 2 meter betas extended over a large distance is illustrated in Figure 5. The remaining outer quads form a 120^{O} FODO structure suitable for the RF and matched to the TWISS functions of the arc.

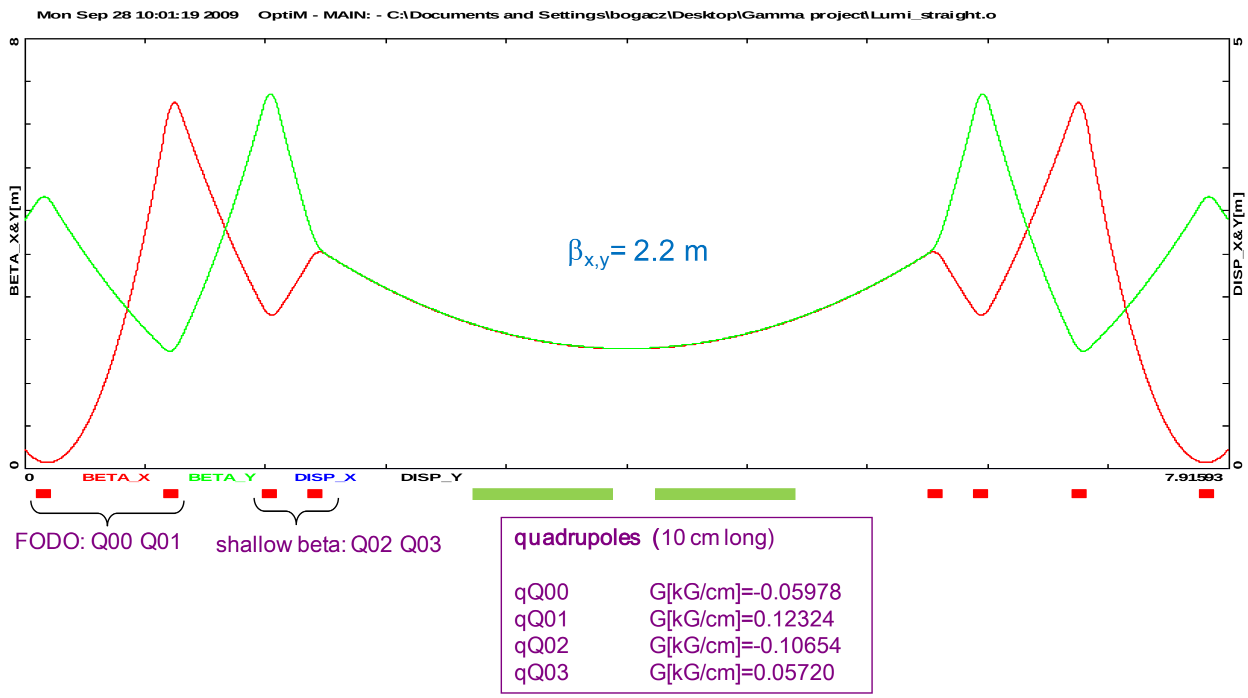

Figure 5: Luminous straight with 'shallow' beta insert. Optics are based on 120^{O} FODO lattice.

To further decrease the values of beta in the lminous region one can think of two counter wound solenoids, or helical quadrupoles, placed symmetrically around the center of the straight (green boxes). This would produce a decoupled low beta insert if needed.

Ring Lattice – Tunes

To summarize, a compact 24 meter long racetrack ring was proposed. The linear lattice is based on FMC optics with an imaginary transition gamma. The overall optics is illustrated in Figure 6.

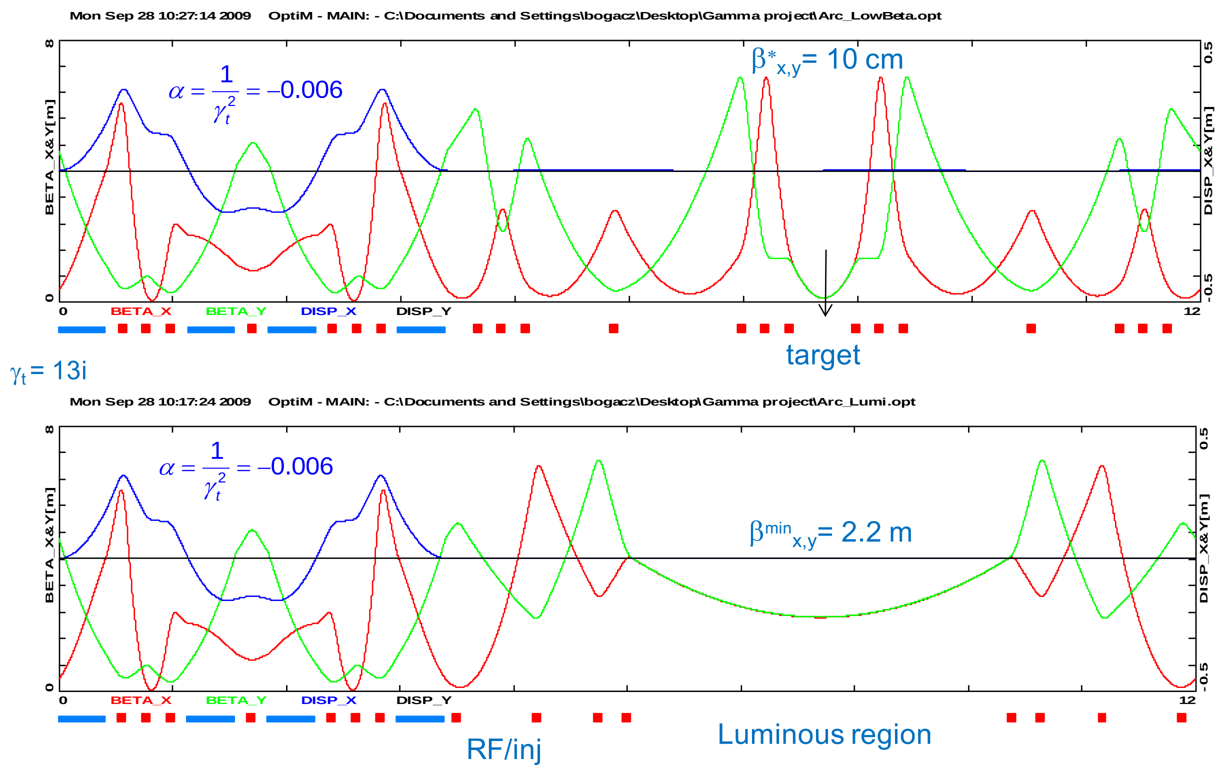

Figure 6: Complete linear lattice for the ring: Arc–Target Straight (top) and Arc-Luminous Straight (bottom).

The ring optics exhibits high degree of tunability through a set of functionally orthogonal ‘knobs’ (quads) in the outer regions of both straights (matching quads). The ring is tuned away from resonances as illustrated in Figure 7.

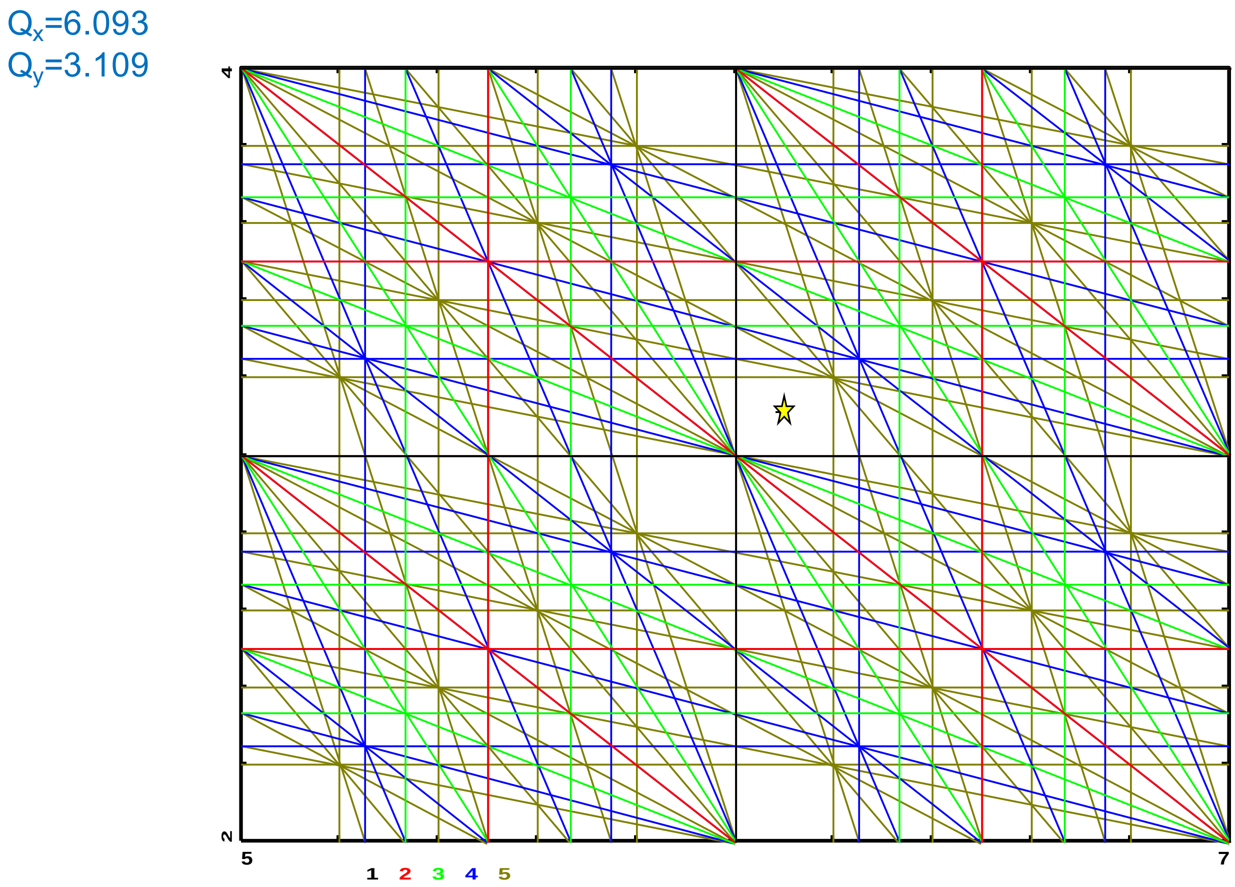

Figure 7: Tune diagram with the sum and difference resonances up to the 5-th order. The ‘star’ marks the operational tune of the ring.