Lattices for Secondary Beam Collection and Cooling – a Pre-conceptual Design

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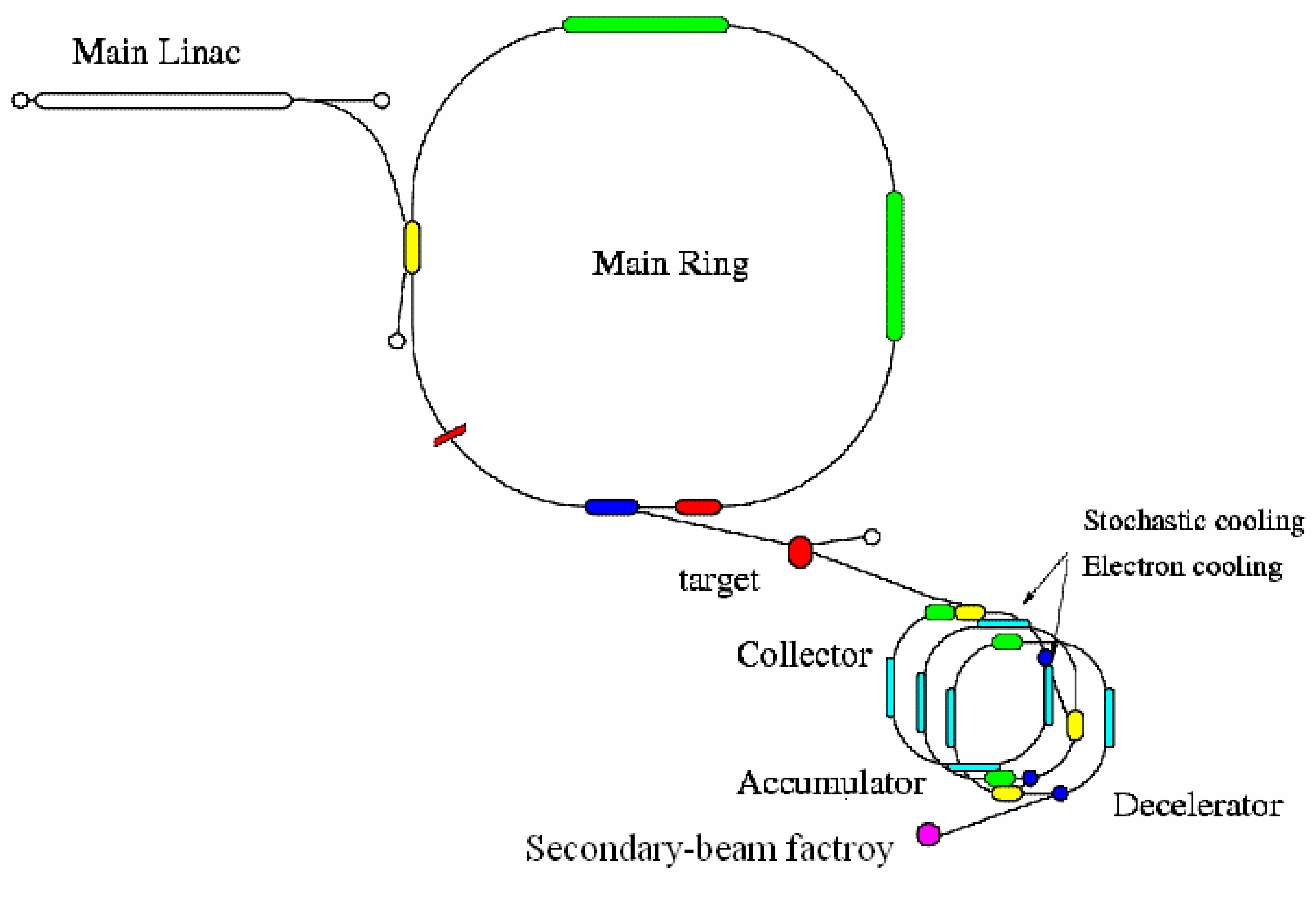
Outline

- Introduction
- Split-function ring lattice
- Summary

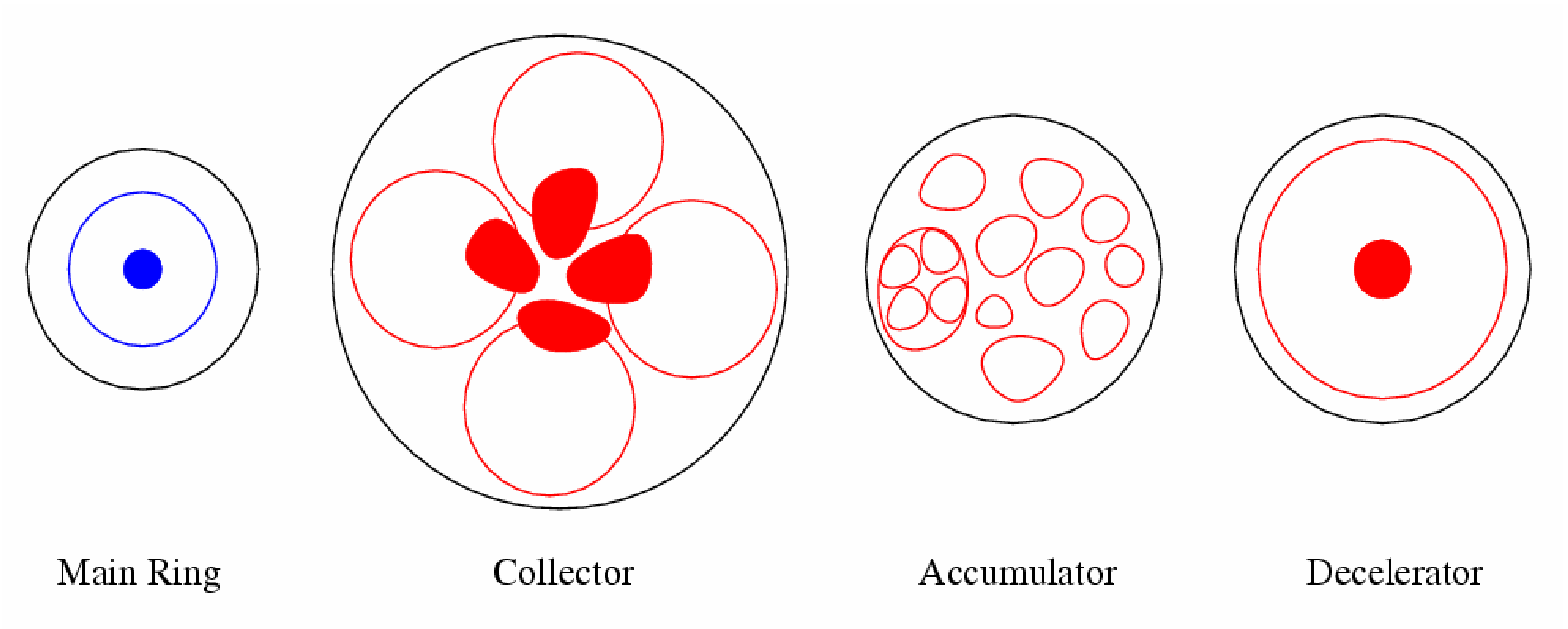
Acknowledgements: S. Peggs …

Introduction

- Secondary beam generation, accumulation deceleration

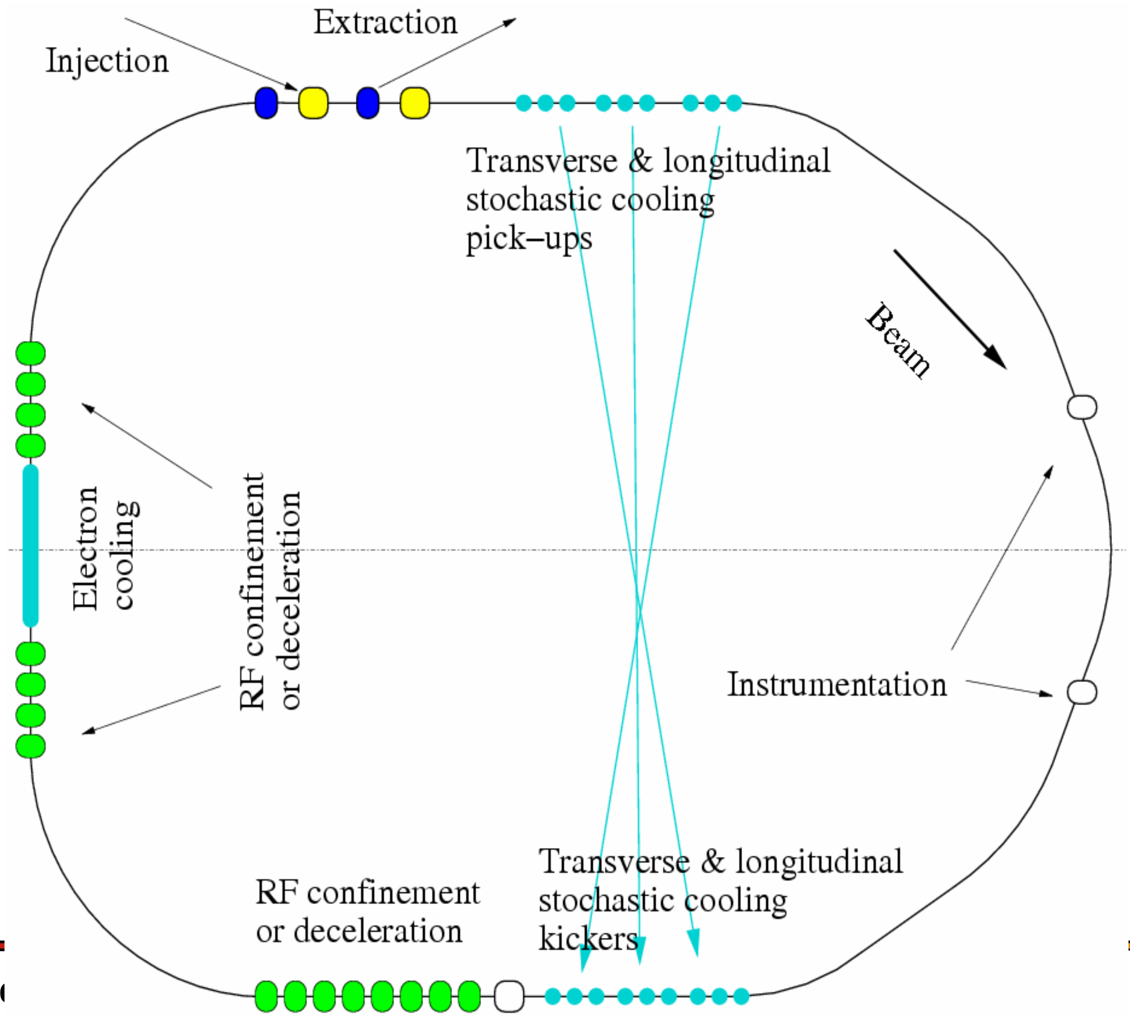


Ring typical cross-sections



Layout of split-function rings

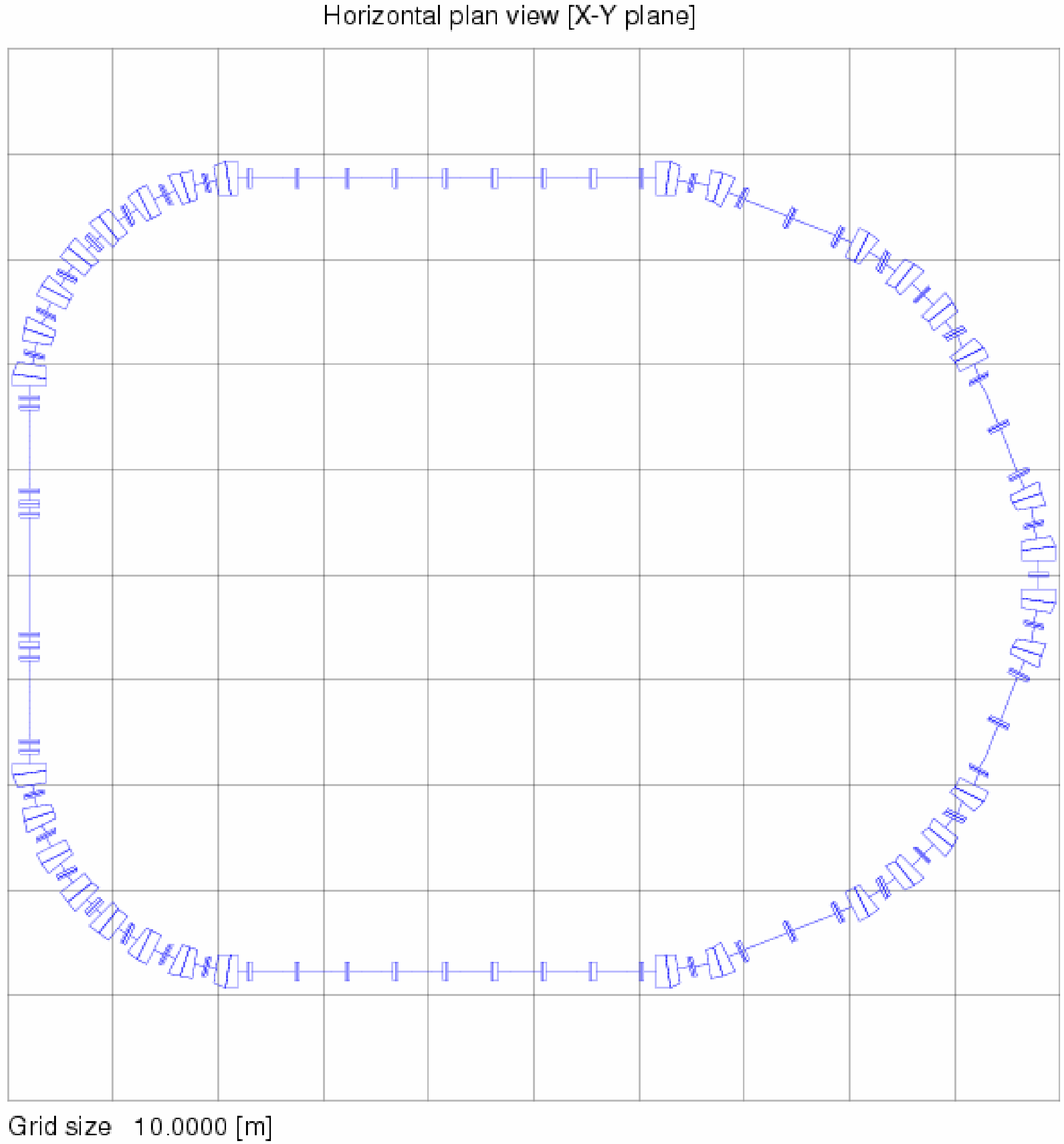
- Circumference: 291.55 m, beam energy: max. 3 GeV
- Half-ring: zero momentum compaction; half-ring: regular



Design philosophy

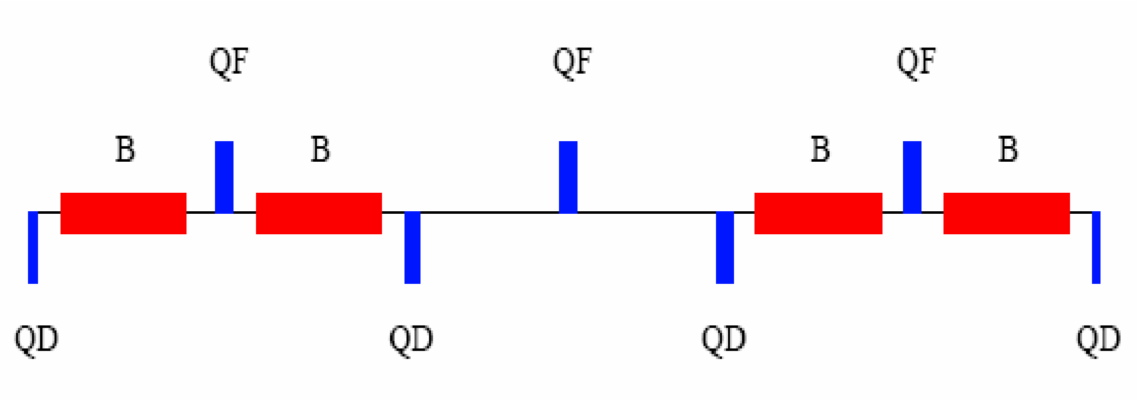
- Split-ring lattice to facilitate efficient stochastic cooling
  - Minimize “bad mixing”: Near-zero phase slip between cooling pick-ups and kickers
  - Normal phase slip between kickers and next-turn pick-ups
- Avoid transition crossing
- Three rings can reside in the same tunnel
- Dispersion-free injection and extraction
- Adequate space to place RF cavities for bunch rotation, deceleration, confinement
- Long uninterrupted drift space of zero dispersion for electron cooling

Collector/Accumulator/Decelerator magnet layout



Flexible momentum compaction module

- A FMC lattice module consisting of three FODO cells with missing dipole in the middle cell.
- The horizontal phase advance of about 90^{o} per cell excites dispersion oscillation so that high dispersion occurs at locations of missing dipole.



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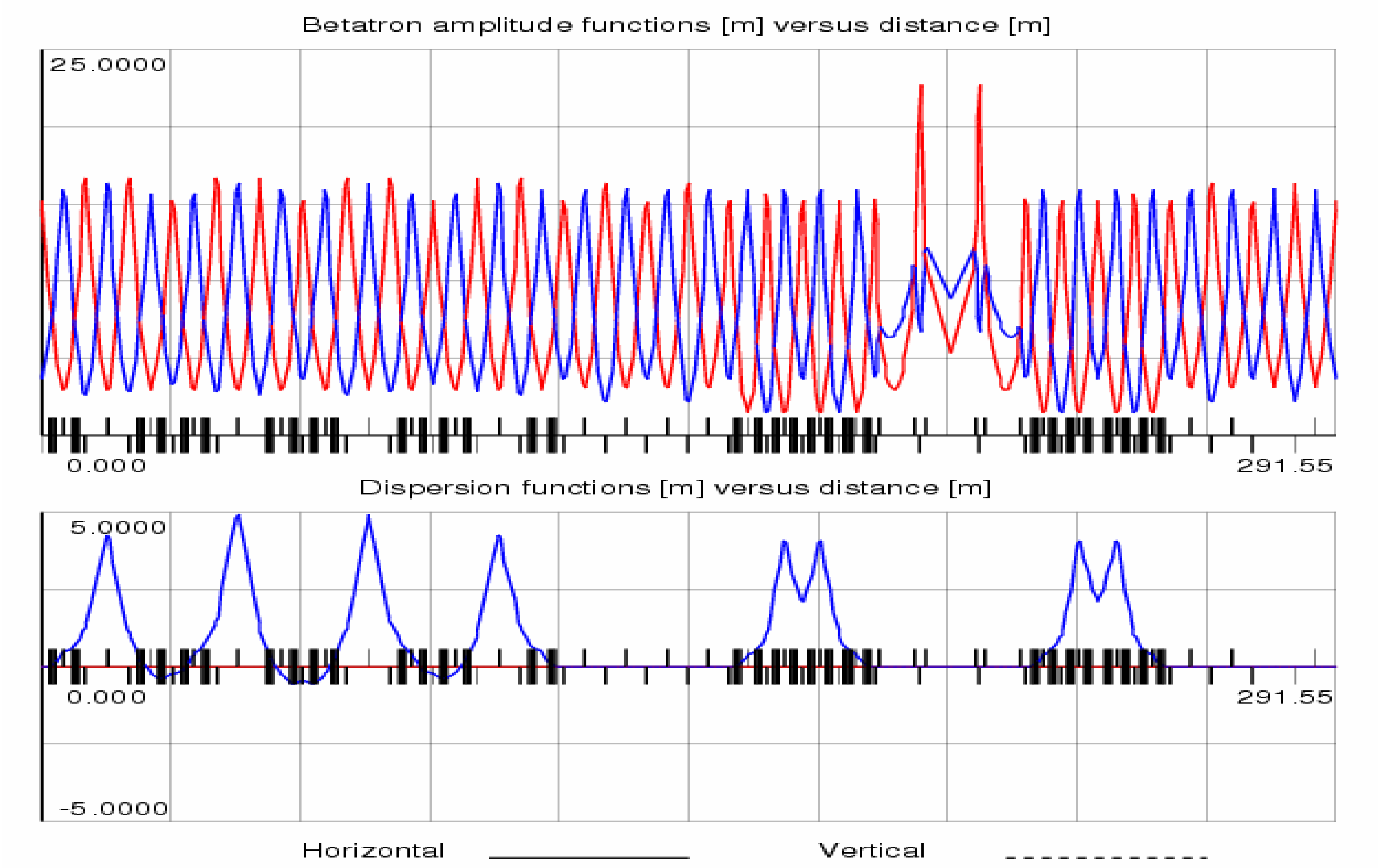
Split-ring lattice functions



Lattice features

- The horizontal phase advance in the arc FODO cell is near but not necessarily equal to 90^o.
- The horizontal phase advance is exactly 6π across the near-zero momentum compaction arc, and is exactly 2π across each of the two normal arcs.
- Between two arcs of normal FODO cells, there is a long dispersion-free straight section
- The Focusing structure in the straight section is triplet, providing long drift space with small beam envelope to accommodate electron cooling devices, and allowing for circumference matching.
- The two straight sections between the arc with normal and FMC modules are used to house stochastic-cooling pickups and kickers, and to accommodate injection, extraction, and RF systems.
- Transition energy is high ($\gamma_T = 7.7$)

Collector

- Four-turn injection from the antiproton target
- Large acceptance to accept "hot" antiprotons from the target
  - Momentum spread ~ +/- 3%
  - Acceptance ~ 1200 mm mr
  - Vacuum chamber diameter: 280 mm ~ 580 mm
- No ramping; 3 GeV kinetic energy
- Large bore, DC magnets
- Large amount of RF voltage for bunch rotation
- Lattice optimized for fast stochastic cooling

Accumulator

- Accumulates 10 pulses from the collector (0.5 Hz)
- Lattice optimized for fast stochastic cooling (split ring) and electron cooling (low beta)
  - Assuming 2 (last pulse) to 10 (first pulse) e-folding time
- Ramps down from 3 GeV to 20 MeV kinetic energy
  - Magnetic rigidity ratio of 20
  - Adiabatic blow-up of emittance
  - Acceptance: 500 mm mr
  - Vacuum chamber diameter: ~ 200 mm

Decelerator

- 0.5 Hz repetition rate
- Lattice optimized for fast stochastic cooling (split ring) and electron cooling (low beta)
  - Assuming 6 e-folding time
- Ramps down from 20 MeV to 50 keV kinetic energy
  - Magnetic rigidity ratio of 20
  - Adiabatic blow-up of emittance
  - Acceptance: 500 mm mr
  - Vacuum chamber diameter: ~ 200 mm
- Reaching space-charge limit in the ring (tune shift ~ 0.5)
- Output emittance
  - Normalized rms emittance: 0.06 mm mr
  - Un-normalized rms emittance: 5.9 mm mr

References

[1] J. Wei, Rev. Mod. Phys. 75 (2003) 1383

[2] J-PARC Accelerator Technical Design Report, JAERI/KEK (2002)

[3] B. Autin et al, CERN/PS/AA78-3 (1978) ; E.J. Wilson et al, CERN 83-10 (1983)

[4] M.D. Church, J. Marriner, Ann. Rev. Nucl. Part. Sci. 43 (1993) 253; Fermilab Design Report, Tevatron I Project (1984)

[5] W.F. Henning, EPAC04 (2004) 50; http://www-aix.gsi.de/GSI-Future/cdr/

[6] R.C. Gupta et al, IEEE Tran. Nucl. Sci. **NS-32** (1985) 2308 ; D. Trbojevic et al, EPAC90 (1990) 1536 ; E.D. Courant et al PAC91 (1991) 2829

[7] S. Wang, J. Wei, et al, EPAC (2006) 2074