Interface between Collider Ring Design and Magnets (Field quality and other parameters)

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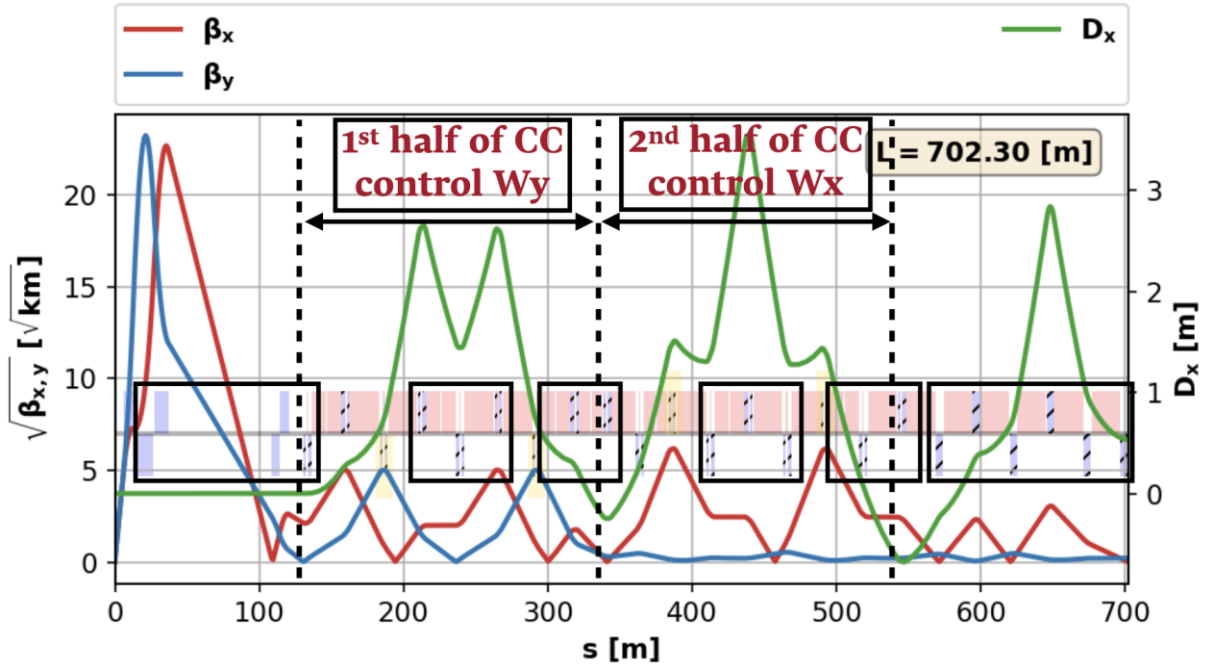
Muon Collider annual meeting, 20th June 2023

- Consequences on Collider Lattice Design
- Neutrino Radiation Issue
- Open questions between WPs Magnets and Collider Design

Collider Lattice Design

10TeV Muon Collider - Extended Final Focusing Schemes

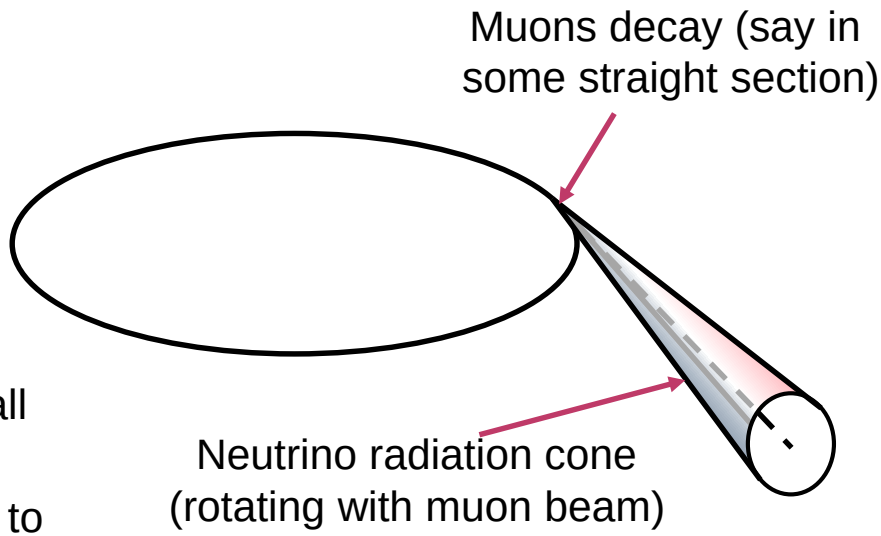
Slide and work from K. Skoufaris



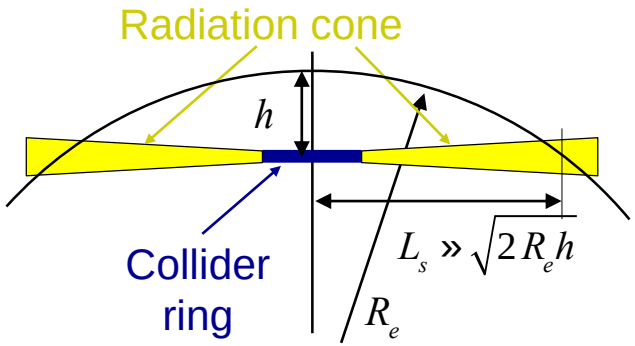
- Strong quadrupoles at locations with large Twiss betas and large momentum spread
  - Strong chromatic aberrations from IP to be corrected by local compensation
  - Sensitivity to unwanted mutipolar components and
    - Short beam life-time helps for slow diffusion driven by high orders
  - Sections with large beam sizes and, thus, apertures
- Note: lattice design still done with (too) optimistic assumptions (maximum fields, apertures ..)

Neutrino Radiation Issue

- Radiation due to neutrino beam reaching the earth surface
  - Narrow radiation “cone” for a short piece of the machine
  - Very small interaction cross sections
    - Earth does not act as shielding (very small cross sections)
    - Showers from neutrinos interacting close to earth surface generate dose seen at surface



- Strong increase of maximum dose with muon energy
  - Cross sections about proportional to energy
  - Typical energy per interaction of neutrino with matter proportional to muon energy
  - Opening of radiation cone inversely proportional to muon energy

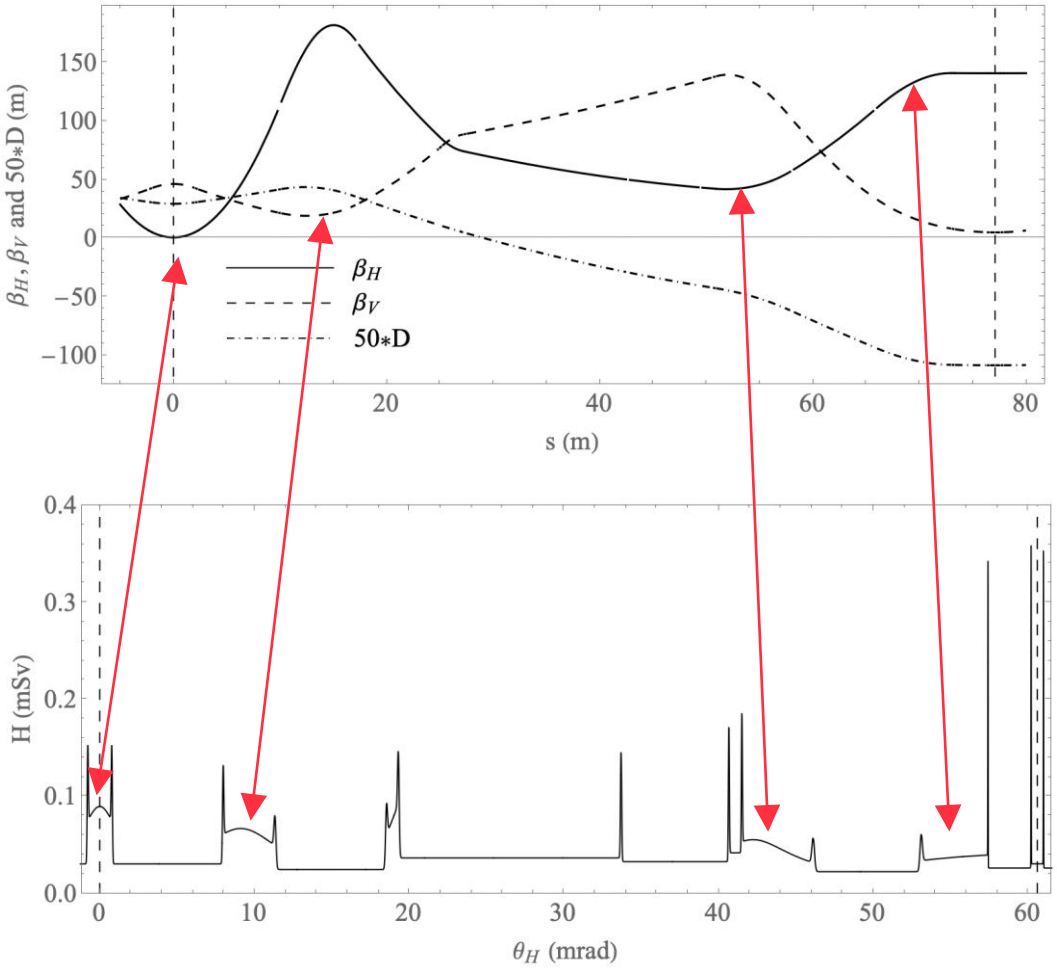


Neutrino Radiation Issue

- Integrals evaluated for present (work in progress by K. Skoufaris) 10 TeV collider arc half cell
  - In collider mid-plane as function of J_H (i.e., $J_V = 0$) for one year (5000 h operation)

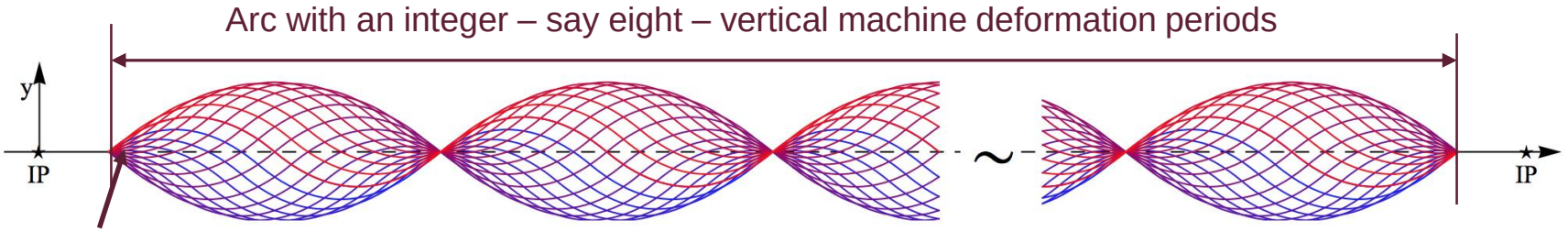
Peaks from 30 cm straight sections
=> Some lower due to beam divergence (D' or betatron motion)
Longer regions with higher radiation from quadrupoles and X-poles
=> Lower dipolar magnetic field

30 cm short straights with hard edge transitions probably unrealistic?
=> Get realistic bending field versus position profile and reevaluate



Neutrino Radiation Issue
Mitigation by "Wobbling"

- Wobbling of machine in vertical direction – part of MAP proposal
  - High precision movement system for time-dependent mechanical deformation of ring around arc (including chromatic compensation, matching section and FMC arc cells
  - Vertical slope modulation within ± 1 mrad reduce peak dose by factor ~100
- For 10 TeV com collider with 10 km circumference and say 3.6 km arcs



Vertical bend ±16.7 Tm

  - Combination of pieces of parabola – two pieces with opposite curvature one period
- Initial proposal
  - Say 8 periods ~600 m long periods leading to vertical position excursions ±150 mm
  - Horizontal magnetic field (average) of ±0.11 T needed for vertical deflections (in addition and independent from main bending and multipolar fields!!)
- Proposal for reduced vertical position excursions
  - More periods about 100 m long leading to vertical position excursions ±25 mm
  - Horizontal magnetic field (average) of ±0.67 T needed for vertical deflections

Some open questions between WPs Magnets and Muon Collider Design

- Field quality (main topic of session)
  - Round apertures and harmonics of unwanted fields (standard for other synchrotron projects) are fine
  - Conflicting requirements(?)
    - Message from magnet working group that field quality with HTS expected to lower than with Nb_3Sn
      - Large ratio, due to W absorbers, between cold bore and reference radius to define multipolar components – should help, i.e., reduce multipolar components related to reference radius
    - Strong focusing (and bending) with large betatron functions unavoidable with $\beta^* = 1.5\ \mathrm{mm}$ and beam energy of 5 TeV. In turn, stringent requirements on tolerances (power converters and magnets)
      - Quantitative evaluations not yet available with the collider design work in progress
- Maximum dipolar fields and (wanted) higher order multipoles (quad, X-poles …) as function of aperture
  - Needed as input for the final lattice design
  - Profit from modern stress management schemes to allow higher fields, gradients … ?
- Magnetic field profile (B_y versus longitudinal position s)
  - Required as input for the “neutrino induced radiation to public” study
- Involving other Working Groups
  - Exact composition of “W” absorber, cooling fluids, choice of superconductors and temperatures, apertures .. .