Design & Simulation: Progress & Plans

Richard Fernow
Brookhaven National Laboratory

MAP Winter Meeting
SLAC
5 March 2012

Design & Simulation

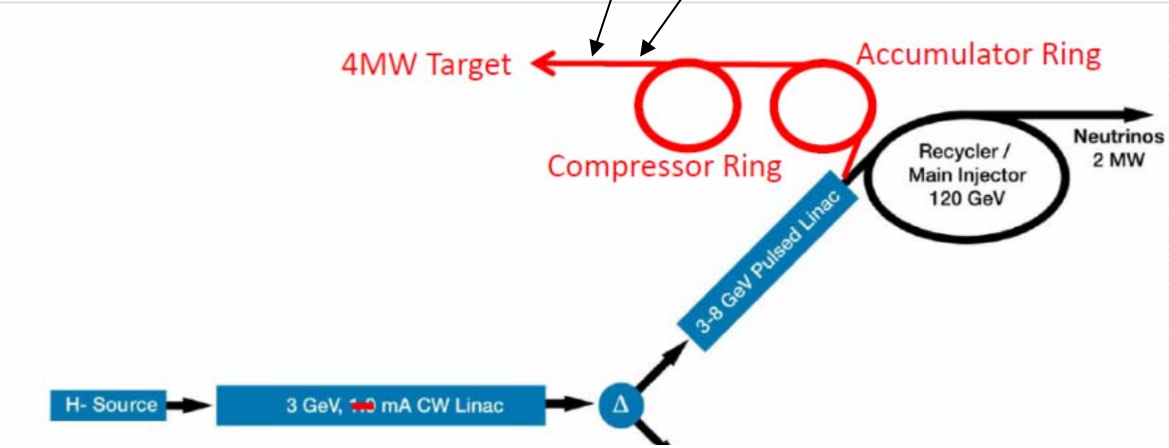
- brief overview of D&S activities, details in subsequent talks
- MAP-paid effort on D&S remains constant ~10 FTEs
- spread over six distinct Level 2 areas
- directing most of our effort at critical design issues in each area
  (as suggested by 2010 DOE review)
- helped prepare Interim Design Report (IDR) for IDS-NF
- prepared more detailed parameter list for MC
  (also suggested by DOE review)

Level 2 areas

Proton driver	Keith Gollwitzer
Front end	Harold Kirk
MC cooling	Tom Roberts
μ acceleration	Scott Berg
Collider ring	Yuri Alexahin
Machine-detector	Nikolai Mokhov

Proton Driver

- Joint MC-PX Task Force is working to ensure that PX design is compatible with requirements for future NF or MC
- studied effects on PX linac running in MC mode (looks OK so far)
- worked on basic lattice design for Accumulator and Compressor rings
- studied bunch compression with space charge
- studied instability thresholds in rings



PD ring simulations

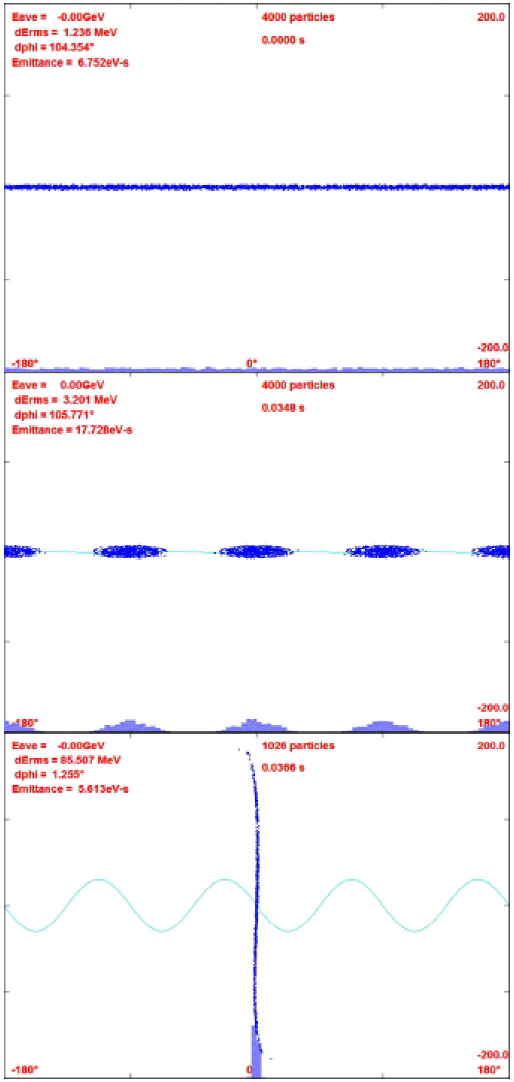


Figure 1. h=4 Simulation of longitudinal motion. In this simulation protons are adiabatically bunched into 4 bunches in the Accumulator. A single bunch is transferred into the Compressor where it is rotated to a short bunch (σ=~3ns). In each of these graphs the x-coordinate is phase around the ring(-180° to +180°), and the y coordinate is the energy offset δE (-200 to +200 MeV).

(D. Neuffer)

Proton Driver plans

- FY12 MAP milestone: complete MC-PX Task Force report
- Some outstanding issues (details in PX session on Wednesday)

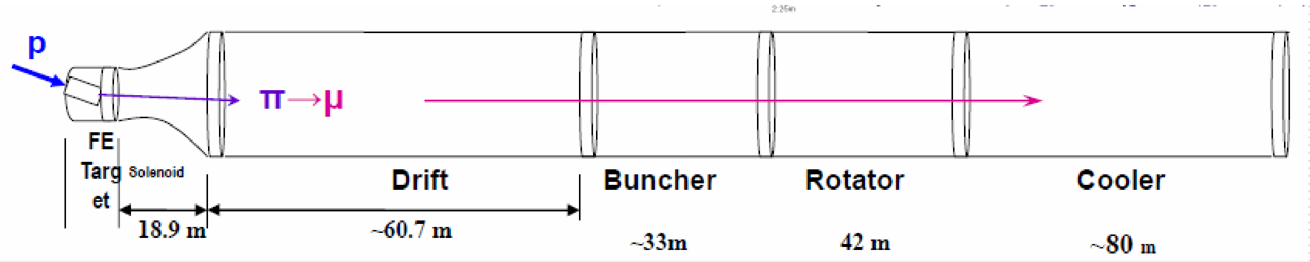
  Accumulator ring
  - design of stripping system
  - simulation of injection painting

  Compressor ring
  - simulation of 6D dynamics with space charge
  - conceptual design of RF system, fast kickers & large aperture magnets

  Design of multiple-beam focusing optics onto the target
  - (close collaboration with Targetry group)

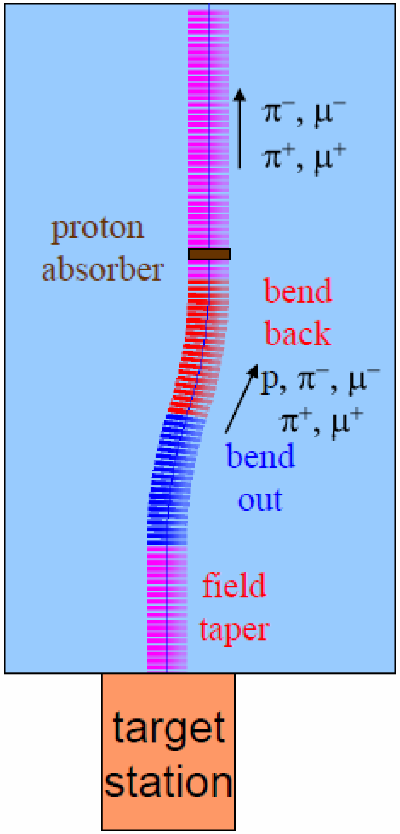
Front end

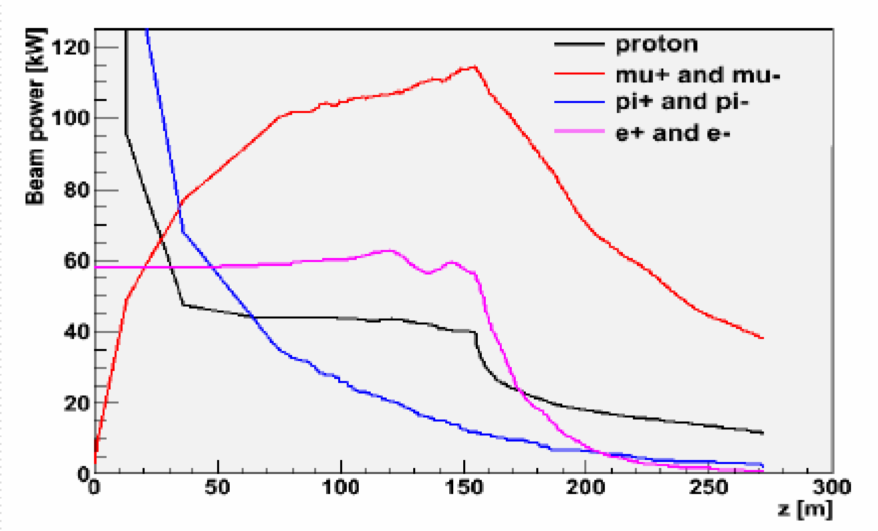
- active group working as part of IDS-NF
- have produced an optimized front end channel design, described in IDR
- initial studies of beam cleaning system to remove unwanted beam downstream from the target
- studying effect of new target & capture configurations on FE performance
- studying effect of using Ga target on FE performance



transverse cooling for NF only

Beam cleaning system





- scheme developed by C. Rogers, D. Neuffer & P. Snopok
- bent solenoid chicane removes high p tail of beam
- Be proton absorber removes low p tail
- simulations look encouraging (details in next session)

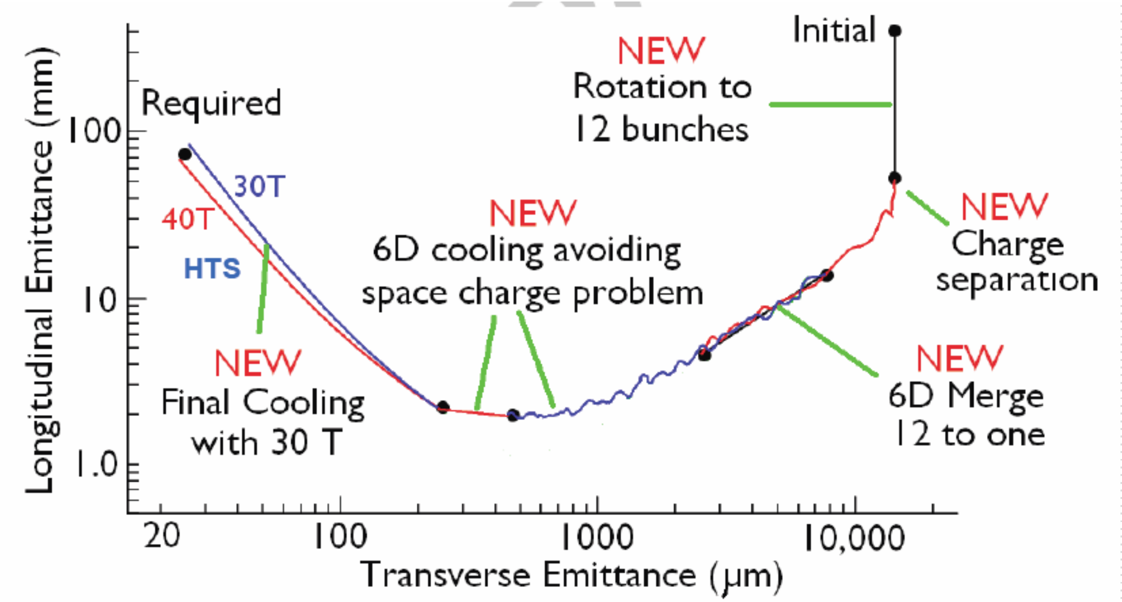
Front end plans

- FY12 MAP milestone: complete an initial design for beam cleaning system

- Some outstanding issues
  - simulate performance using beam from final target configuration
  - incorporate preferred solution RF cavity problem (reduced gradient?)
  - reoptimize the expected μ performance
  - conceptual designs for shielding and solenoids downstream of target

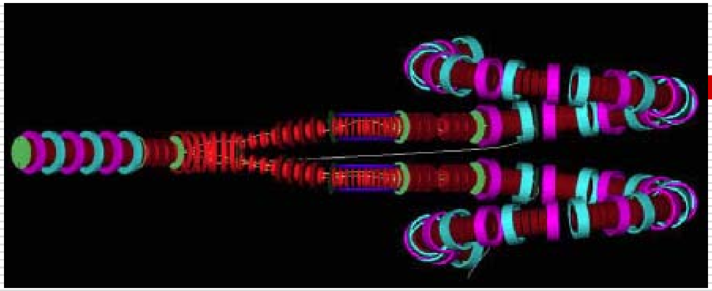
Muon Collider Cooling

- basic scheme for achieving required MC cooling same for last ~5 years
- continued work on improving performance & increasing realism

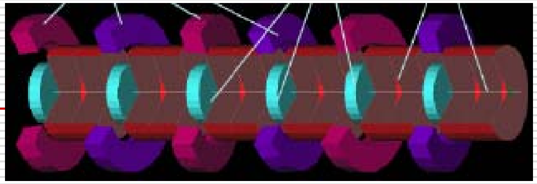


(R. Palmer)

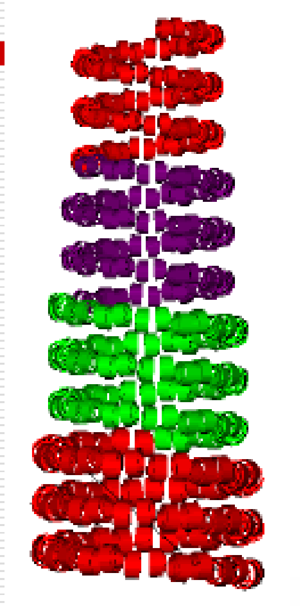
Possible parts of MC cooling channel



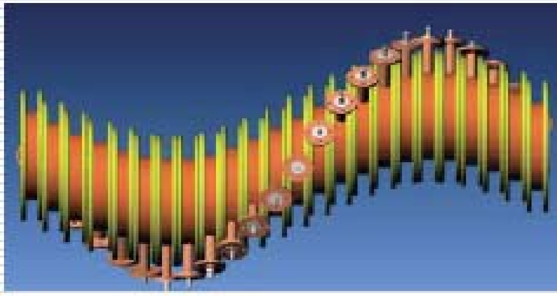
Charge separation



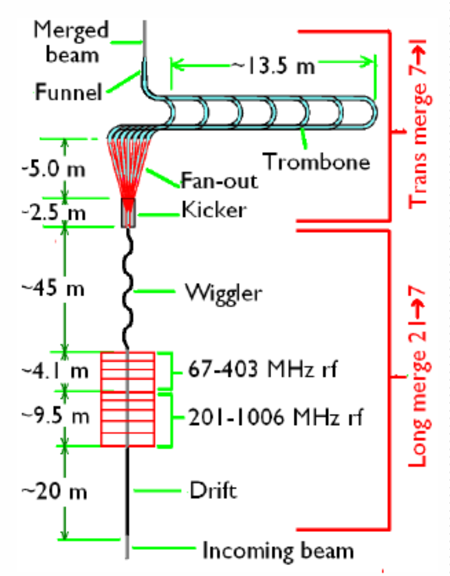
FOFO snake



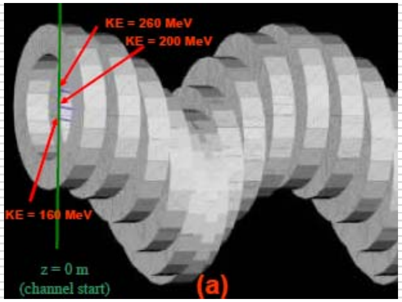
Guggenheim



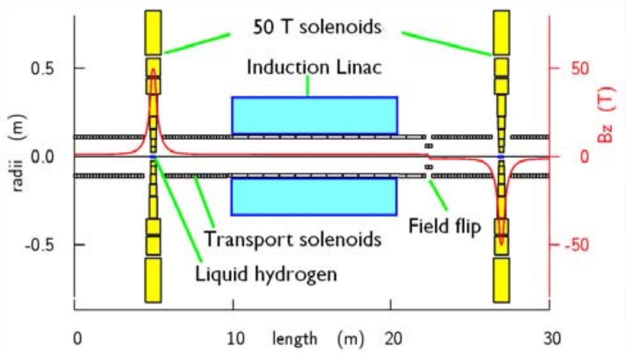
HCC



6D merge



Helical merge



HTS channel

Cooling

- matched FOFO-snake channel with beam from front end (Y. Alexahin talk)
- space charge calculations suggested possible problems (R. Palmer talk)
  modified Guggenheim channel designs
- updated simulations on HCC channel (K. Yonehara talk)
- 6D bunch merging much more efficient than earlier longitudinal design
- new helical bunch merging channel has good performance (C. Yoshikawa talk)
- final cooling with 40 T solenoids can reach MC requirements

Other cooling ideas

- some members of MAP are continuing to study alternate cooling schemes
- mainly funded through SBIRs

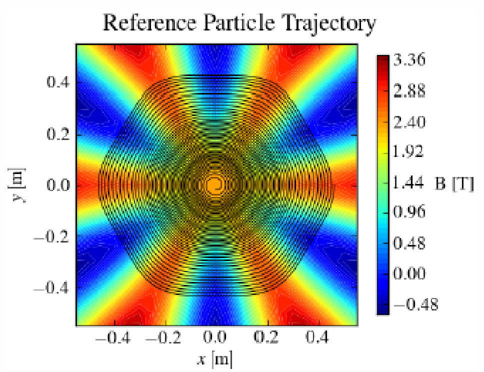
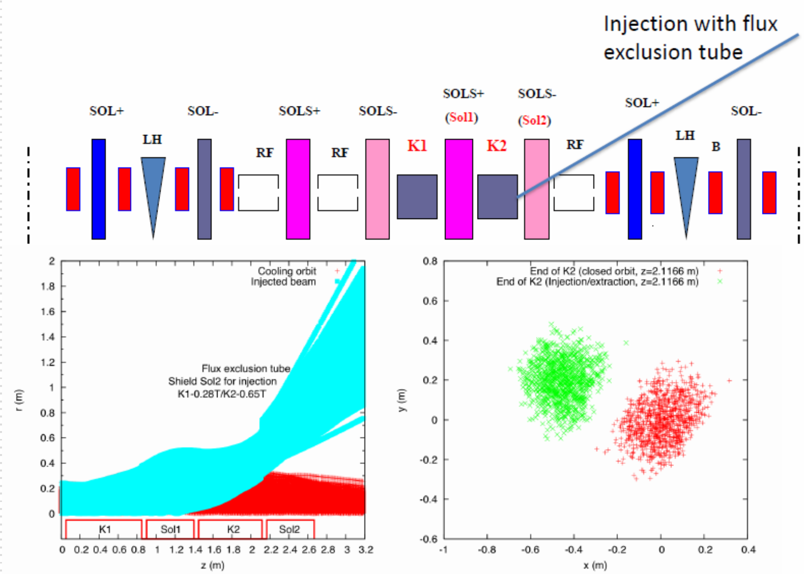


Figure 1: Trajectory of the reference particle with initial momentum of p = 180 MeV/c and initial radius of r = 0.464 m. The color contour behind the trajectory depicts the mid-plane strength of the magnetic field in Tesla.

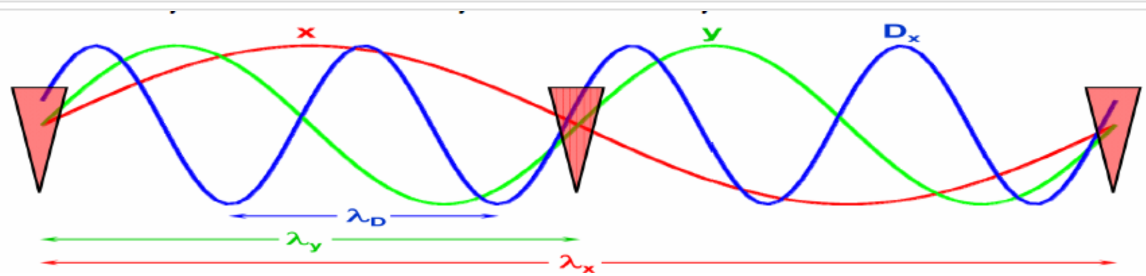
Inverse cyclotron
U. Mississippi,
Tech-X

Injection Scheme of 6D Ring Cooler Using Dipoles/Solenoids



UCLA/PBL/BNL; NIMA 654 (2011) 40-44; MAP-doc-4304 (2011)

Ring
UCLA, PBL, BNL



EPIC
Muons Inc.,
JLAB, Hampton U.

Cooling plans

- FY12 MAP milestones
  - evaluate implications of MTA RF experiments on HCC
  - simulate a new 12-bunch 6D merging system
  - redesign post-merge Guggenheim taking into account space charge calculations
  - make more realistic simulations of post-merge Guggenheim with field maps
  - create algorithm to help design field-flips in final cooling

Additional resources

Muons Inc

- 2012 SBIR on improvements to HCC theory/simulations
- 2011 SBIR on epicyclic parametric ionization cooling (EPIC)

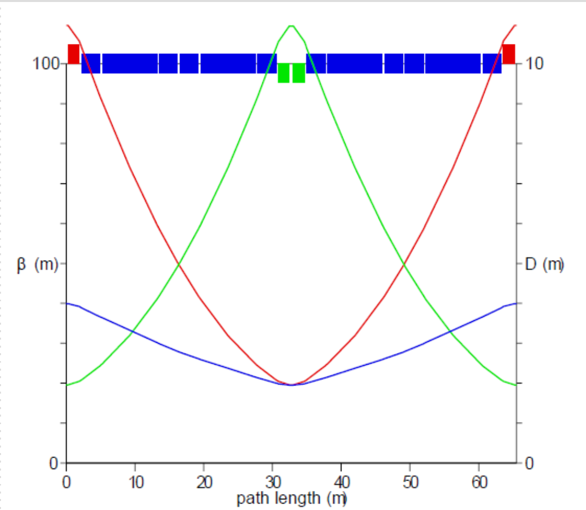
Cooling issues

- Some outstanding issues
  - more realistic space charge simulations for beam near end of the 6D channel
  - conceptual design of ~20 T solenoids used near end of 6D cooling
  - optimize multi-stage parameters for final cooling channel
  - examination of importance of physics effects missing in current simulations

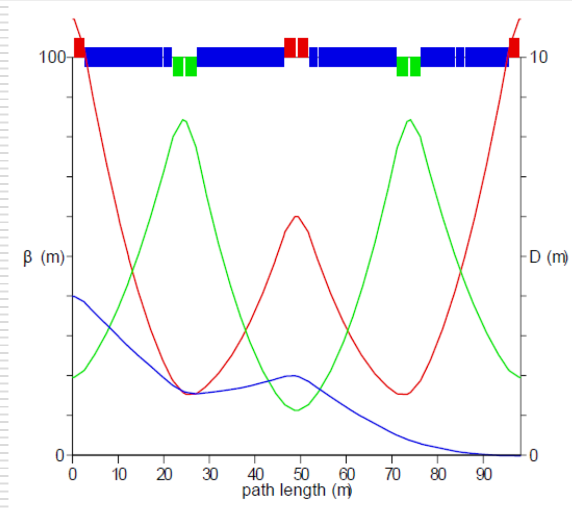
Muon acceleration

- continued refining accelerator designs for NF and MC
  - NF: linac + 2 RLAs + FFAG (A. Bogacz talk)
  - MC: linac + 2 RLAs + 2 RCSs
- studying possible more efficient use of RLAs
  - ramped quads in linac => more passes
  - combined function magnets in arcs => simpler switchyard, fewer arcs
- studying scaled e model of dogbone RLA with multi-pass arcs (A. Bogacz talk)
- analysis of results from EMMA non-scaling FFAG experiment
- did first basic lattice designs for RCS (S. Berg talk)
- started simulating magnet behavior with grain-oriented steel laminations (D. Summers talk)

Muon acceleration



Arc cell lattice functions



Dispersion suppressor

Initial 750 GeV RCS lattice
A. Garren

Muon acceleration

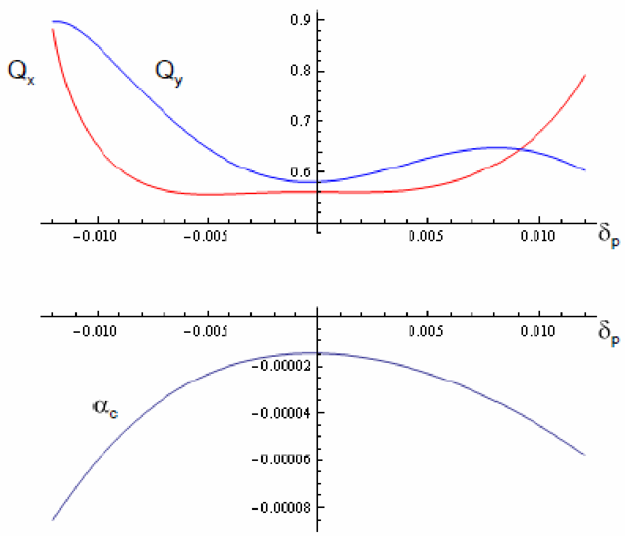
- FY12 MAP milestones
  - complete arc cell lattice design for 750 GeV hybrid RCS
  - examine suitability of existing codes to model grain-oriented steel
- Some outstanding issues
  - controlling time-of-flight variations in hybrid RCS
  - study chromaticity correction on hybrid RCS
  - determine eddy current effects in RCS vacuum chambers
  - study coherent instabilities in hybrid RCS
  - conceptual design of needed injection/extraction systems

Collider ring

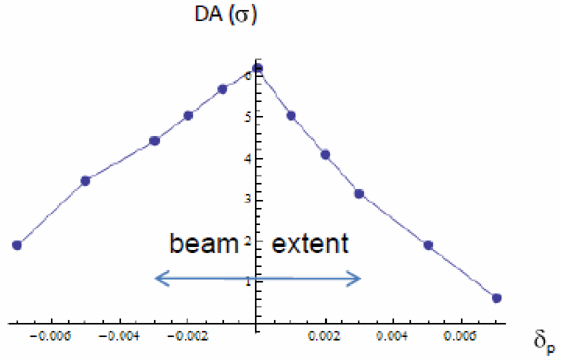
- completed the 1.5 TeV ring design
- studied chromaticity correction for MC optics
- studied correction of fringe field & multipole errors in IR magnets
- simulated effects of beam-beam interactions on beam dynamics
- have a preliminary design for the 3 TeV ring (Y. Alexahin talk)
- designed 3 TeV arc cell based on combined-function magnets

- Additional resources
  Muons Inc
  2011 SBIR on designing achromatic low-β IRs

1.5 TeV ring simulations



Fractional parts of the tunes and momentum compaction factor vs. momentum deviation



"Diagonal" Dynamic Aperture (Ax=Ay) vs. (constant) momentum deviation in the presence of beam-beam effect (ξ = 0.09/IP) for normalised emittance $\varepsilon_{\perp N}$=25 μm

Only muons at bunch center tracked !

Design rms δp/p = 0.1%

(Y. Alexahin, E. Gianfelice et al)

Collider ring

- FY12 MAP milestones
  - complete a 3 TeV ring design
  - update conceptual designs for collider arc dipoles & quadrupoles
- Some outstanding issues
  - design of tuning & collimation sections
  - possible reduction in β^*
  - detailed beam-beam & self-consistent longitudinal simulations
  - study coherent instabilities
  - estimate of collider ring impedance

Machine Detector Interface

- developed detailed MARS model (±200 m from IP) for 1.5 TeV machine
- designed tungsten liners, masks and cone to protect magnets and detector
- extending MARS physics model for EM showers down to 1 keV
- full MARS simulation of 1.5 TeV radiation loads on IR and detector components
- created 1.5 TeV background particle files (BPF) for detector group
- using BPF to adjust ILCroot and lcsim detector models
- started work on 3 TeV MDI model

(N. Mokhov talk)

Machine Detector Interface

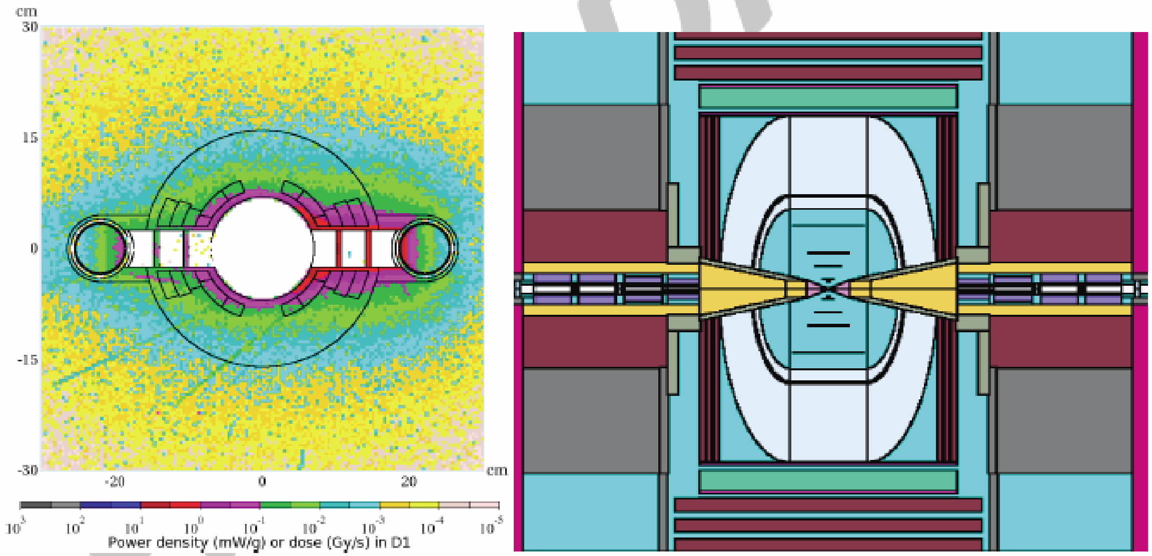


Figure 4.3.2.5.2: Power density (mW/g) in the first IR dipole (left) and MDI MARS model (right).

(N. Mokhov et al)

Machine Detector Interface

- FY12 MAP milestone: continue support of MDI studies
- Some outstanding issues
  - conceptual design of 3 TeV IR magnets
  - detailed MARS model of 3 TeV MDI region
  - MARS 3 TeV production runs for energy deposition & backgrounds
  - update ILCroot and lcsim detector models for 3 TeV
  - conceptual design of collimation system for 0.75 and 1.5 TeV muons

Summary

- we have been trying to address the most critical D&S issues,
  as time and available personnel permit
- work is progressing well towards eventual baseline designs
  for both the neutrino factory and the muon collider