Neutrino Source Accelerator Diagnostic Problems

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Content

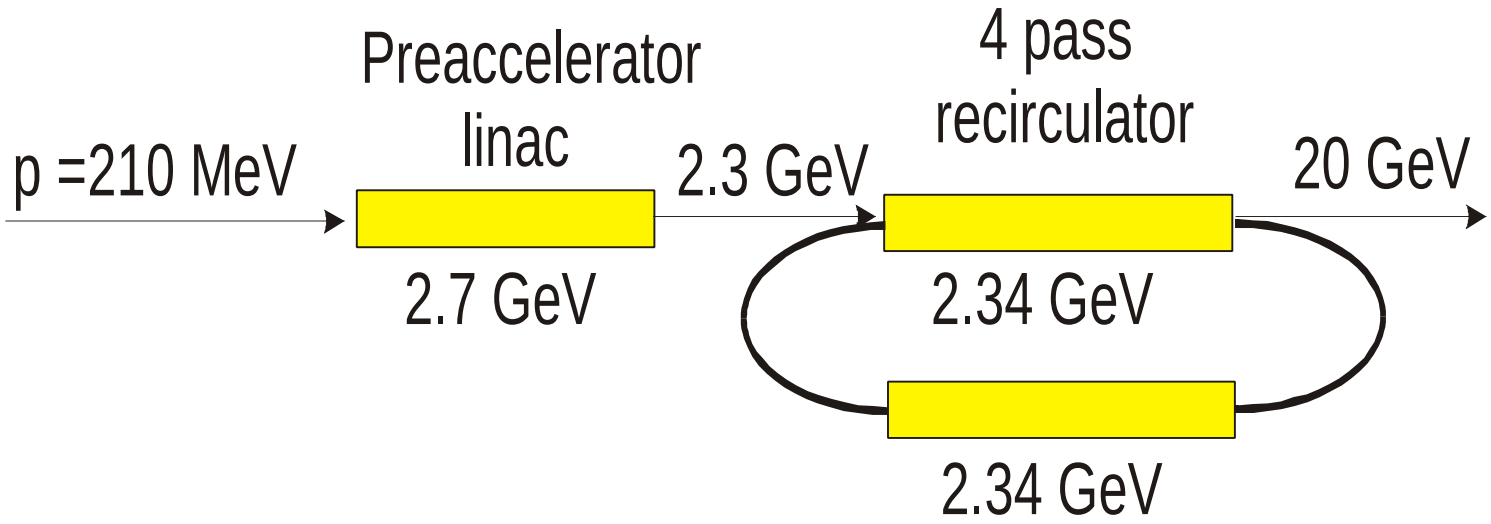
1. Machine layout and main parameters
2. Basic measurements
3. Required diagnostics

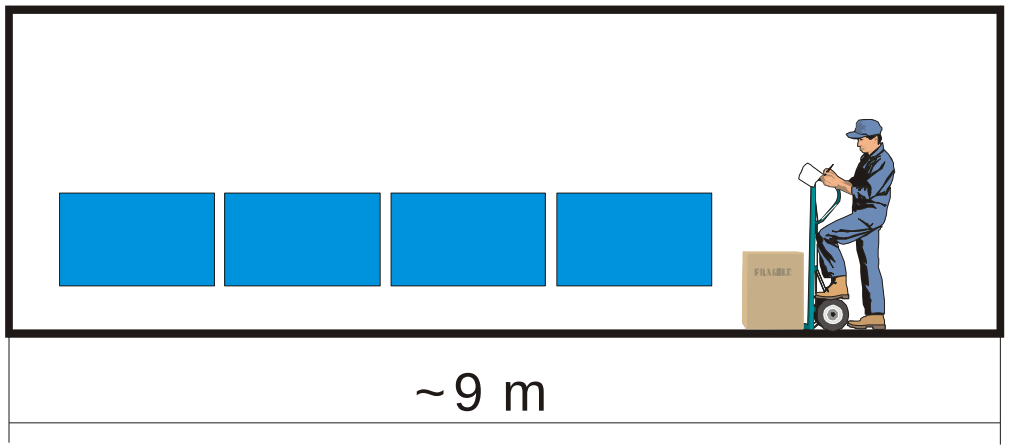
Machine layout and main parameters

Basic MAD Parameters

Injection momentum/Kinetic energy	210/130 MeV
Final energy	20 GeV
Initial normalized acceptance	9.3 -> 15 mm·rad
Initial longitudinal acceptance, $\Delta p L_b/m_\mu$ L_b $\Delta p/p$	150 mm ±290 mm ±0.26
Number of bunches per pulse	67
Number of particles per bunch/per pulse	$4.4\cdot10^{10}$ / $3\cdot10^{12}$
Bunch frequency/Accelerating frequency	201.25/201.25 MHz
Average repetition rate	15 Hz
Pulse structure	6 bunches at 50 Hz with 2.5 Hz rep.rate
Beam Power	144 kW

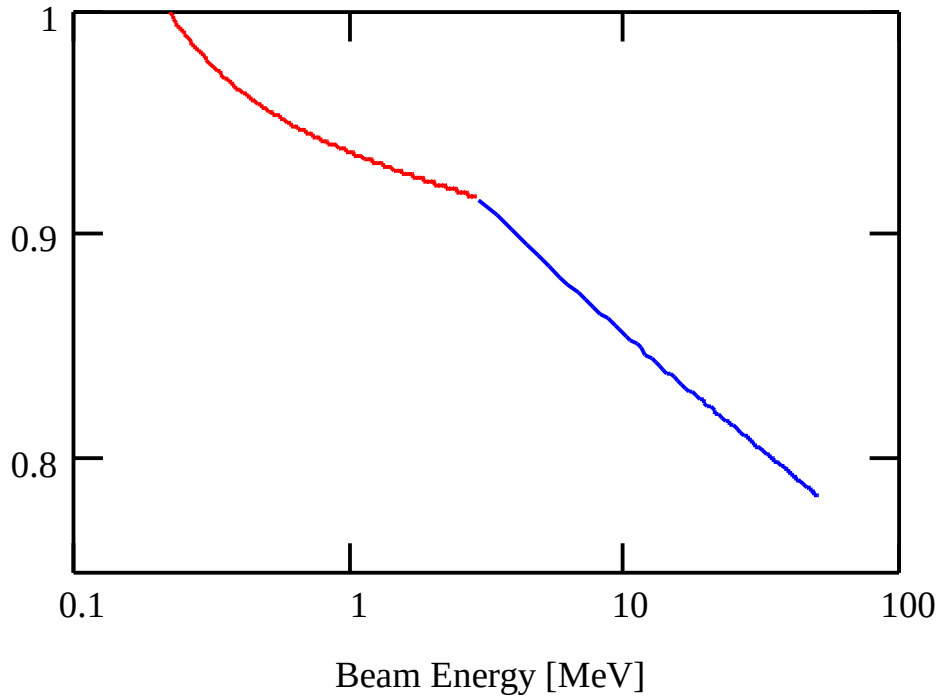
MAD layout


p =210 MeV
Preaccelerator
linac
2.7 GeV
2.3 GeV
4 pass
recirculator
2.34 GeV
2.34 GeV
20 GeV


~9 m

Muon Decay

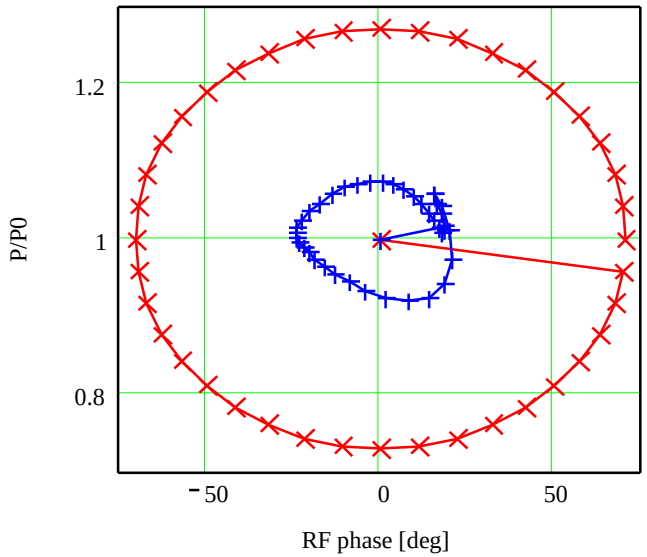
- Muon decay time - 2.2 μs
- Accelerating gradient of 15 MV/m
  - Real estate accelerating gradient in linac – 8.2 MV/m
  - Real estate accelerating gradient in recirculators – 3 MV/m



Red line – decay in linear accelerating part

Blue line – decay in recirculators

- Decay losses depend approximately linearly on the accelerating gradient

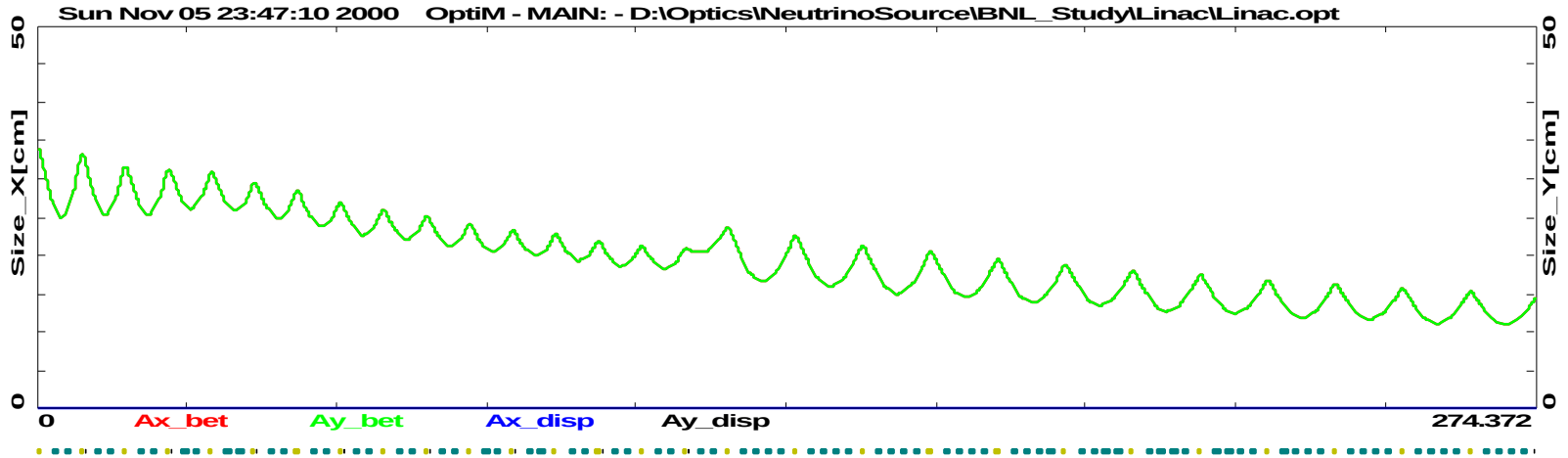


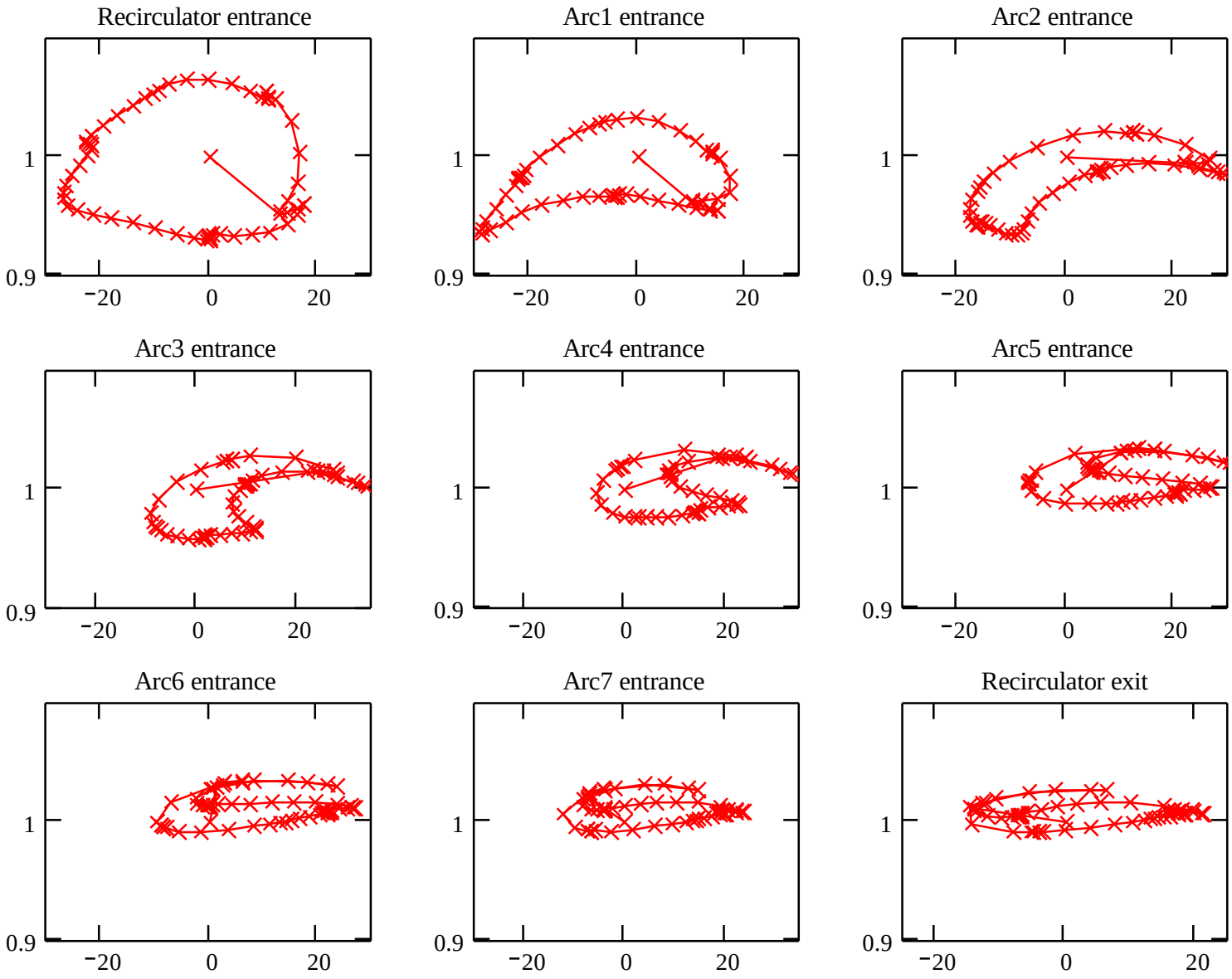
Longitudinal acceptance at the beginning and at the end of the linac

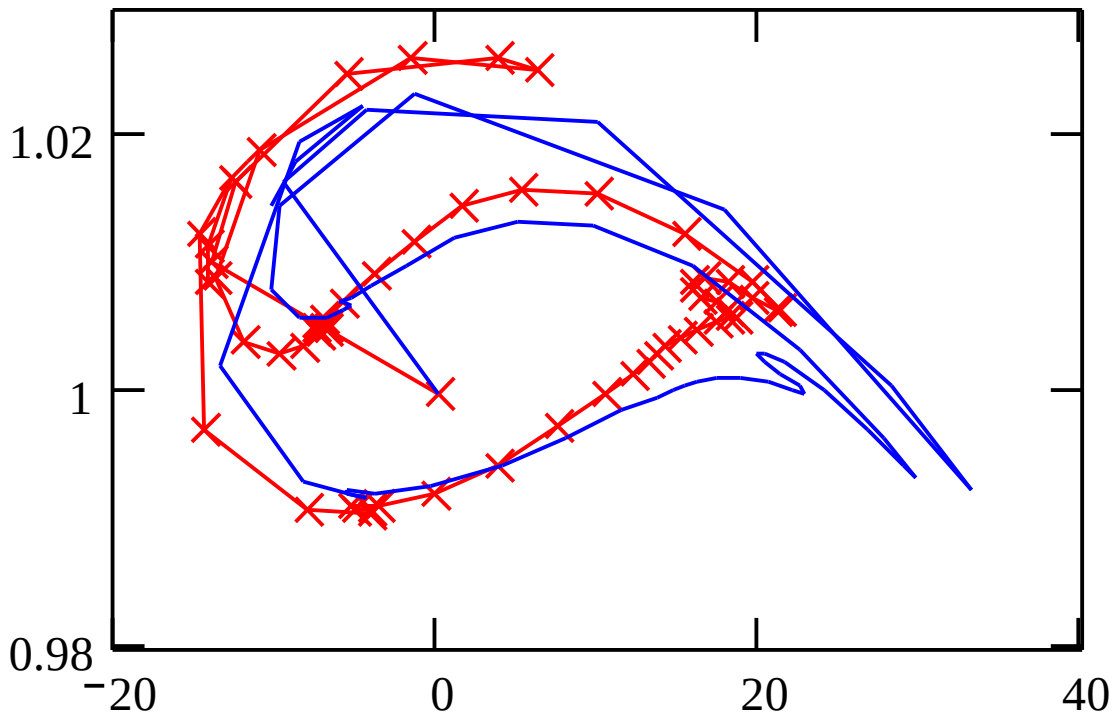
Beam size for the acceptance of 15 mm at the linac front-end

Maximum beam size in cavities $2a$ = 28*2 cm

in solenoids $2a$ = 34*2 cm



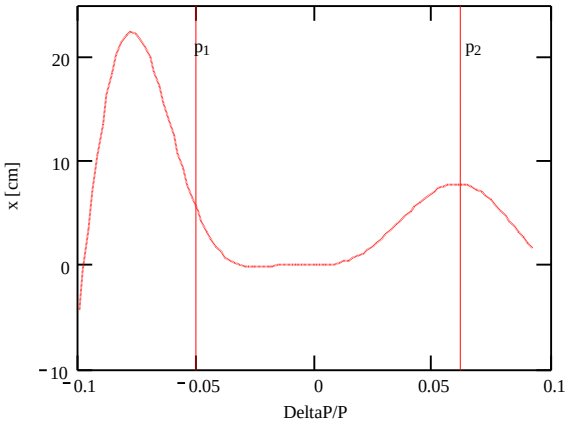

Recirculator entrance
Arc1 entrance
Arc2 entrance
Arc3 entrance
Arc4 entrance
Arc5 entrance
Arc6 entrance
Arc7 entrance
Recirculator exit
1
0.9
−20
0
20

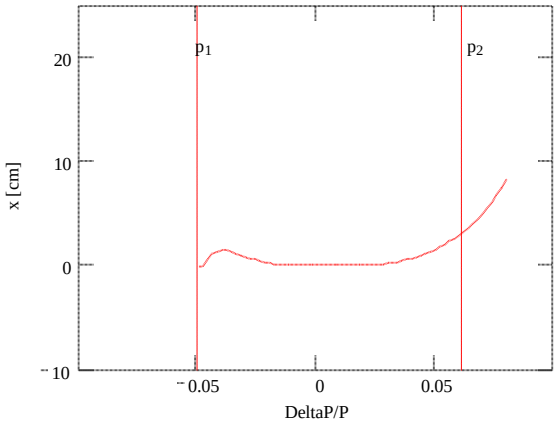


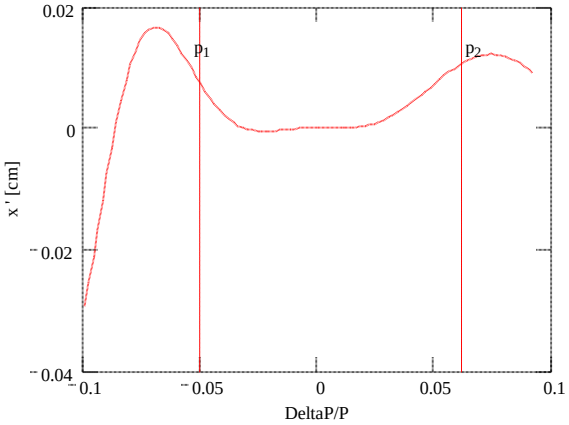
Effect of beam loading

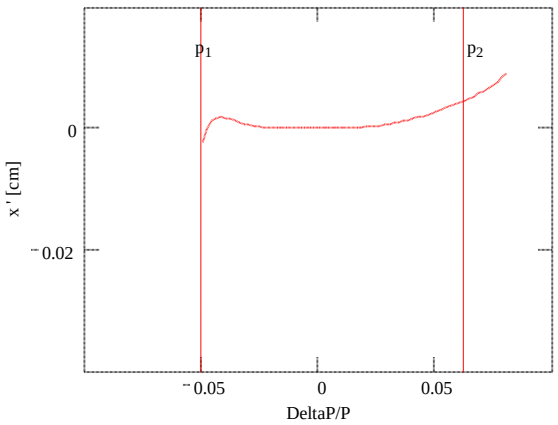
$\Delta E/E=6\cdot10^{-3}$, $N_{\mu}=6\cdot10^{12}$

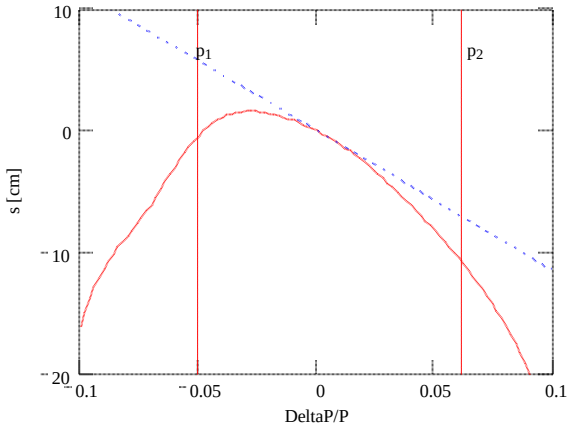
Blue line at the last slide shows longitudinal phase space for the last bunch of 6 10^{12} particle train. The difference in comparison with the first bunch is related to the voltage droop (0.6% per pass for 200 MHz) in RF voltage due to beam loading.

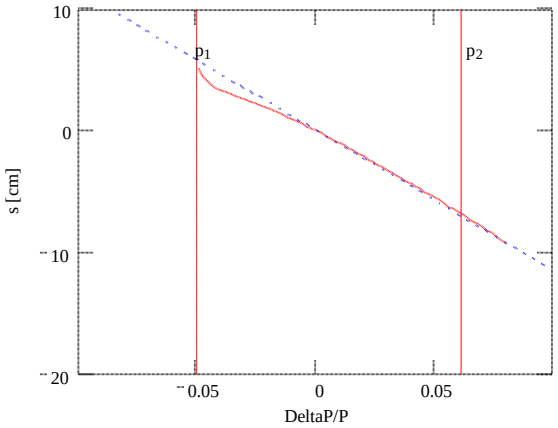












Chromaticity correction for Arc 1

Non-linearity for

- Dispersion
- Dispersion-prime
- M_{56}

For the cases of

- no sextupole corrections
- 3 sextupole families

What do we need to measure and correct?

- Beam current
- Total beam current loss and loss distribution along the machine
- Beam coordinates
  - Beam orbit
  - Path length
  - Phases of RF cavities and the gang phase relative to the beam
- Linear transfer functions
  - Betatron transfer functions
  - Coupling
  - Dispersion
  - M56 (momentum compaction)
  - Phase advances of betatron motion
  - Energy and SC cavities voltage droop due to beam loading

What do we need to measure and correct (continue)?

- Beam sizes
  - Beam envelopes and emittances
  - Bunch length
  - Energy spread
- Non-linearity of the transfer functions
  - Emittance growth
  - Dispersion
  - M56
- Hardware diagnostics
  - Magnets off the hysteresis loop
  - Finding non-stable cavities

Additional requirements for achieving high machine reliability

- On-line optics modeling
  - To take into account non-uniform distribution of the accelerating gradient
  - To bypass fast improperly functioning cavities
- Possibility of machine tuning at full power in the course of beam delivery
- Immunity to high radiation

Intensity

- Average beam current - 7.2 μA
- Beam current in macropulse - 1.4 A
- Peak beam current (in the bunch) - 8 A

Beam position monitors

- To measure
  - Beam orbits
  - Differential beam orbits
  - Beam current and beam loss
- Modes of operation (full and limited intensity)
  - Absolute
  - Relative
  - Differential
- Required accuracy (rms)
  - Absolute: 2-5% of aperture (10 cm yields 2-5 mm)
  - Relative and differential: 0.1-0.5% of aperture (10 cm yields 100-500 μm)
- Quantity and locations (at every triplet)
  - ~50 - in linac
  - ~50·2=100 - in recirculating linacs (multipass)
  - ~50·7=350 - in arcs
- Hardware or implementation choice
  - Any of standard choises is expected to be good
  - Effect of secondary emission due to beam loss needs to be studied

Longitudinal BPM or cavity

- To measure
  - Longitudinal relative pass-to-pass bunch position in recirculating linacs
  - Differential measurements (M_{56})
  - High accuracy beam current and pass-to-pass beam loss
- Modes of operation (full and limited intensity)
  - Absolute
  - Relative
  - Differential
- Required accuracy (rms)
  - Relative and differential: 0.1 deg (10% M_{56} measurements for $\Delta p/p=5\cdot10^{-3}$)
- Quantity and locations
  - 2 - 1 in each recirculating linac
- Hardware or implementation choice
  - Second or third harmonic cavity with mixing of the signal to the second harmonic of the master oscilator

Profile monitors

- To measure
  - Betatron match
  - Emittance and emittance growth
  - Tails in particle distribution
- Modes of operation (full and limited intensity)
  - Profile per bunch
  - Profile per train
  - Averaged profile
- Required accuracy
  - Dynamic range ~100-1000
  - Resolution 10-20% of σ
- Quantity and locations
  - ~5·7=35 - in each of 7 arcs
- Hardware or implementation choices (current density ~1 nA/mm^2)
  - Multiwire monitor
  - OTR monitor
  - Viewer

Bunch length measurements

- To measure
  - Longitudinal bunch length and particle distribution
- Modes of operation
  - full and limited intensity
- Required accuracy (rms)
  - 10% of bunch length ~1 cm ~
- Quantity and locations
  - 2 - 1 (multipass) in each recirculating linac
- Hardware or implementation choice
  - Radiation from OTR

Energy spread measurements

- Beam profile at dispersive locations
  - Can we find something additional to that

Additional instrumentation for RF cavities

- Cavity cresting
- Reliable registration of cavity misbehavior

Non-linearity measurements

- Scraping major fraction of the beam (both transverse and momentum) with concequetive differential measurements at large amplitude
  - Can we find something additional to that