Tunability studies for PS2

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Abstract

PS2 is part of a design study for the LHC injector complex upgrade, potentially replacing the existing PS machine at CERN. A normal conducting synchrotron with significantly higher injection and extraction energy is considered. Transition crossing is avoided by a negative momentum compaction (NMC) lattice. In this poster, the design of the linear lattice of a racetrack shaped ring based on NMC arc-cells and two long straight sections is presented. Dispersion suppressors match the optics of the arc to the zero dispersion straight sections. Magnet and space constraints are incorporated in the design. The tunability of this lattice with respect to linear beam optics parameters and chromaticity is investigated.

1. INTRODUCTION

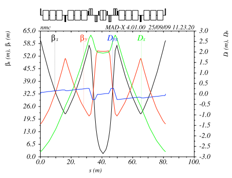
PS2 is a design study of a normal conducting proton (ion) synchrotron. It is considered as a mid term option to replace the existing PS machine in the course of LHC injector complex upgrade. This upgrade should provide significantly higher beam brightness compared to the present machines. Due to aperture limitations at LHC injection energy, this increase in beam brightness can only be reached by increasing the beam intensity.

In order to reduce space charge effects due to higher beam intensities, the injection energy for the PS2 will be 3.5 GeV. Thus, the total beam intensity can be up to four times larger compared to the PS with injection energy of 1.4 Gev. The extraction energy of the PS2 ring is chosen to be 50 GeV (26 GeV for the PS), well above the transition energy of the subsequent SPS synchrotron. Constraints from the desired extraction energy and from the filling of the SPS lead to a circumference of the PS2 of 1346.4m [1].

Transition crossing in the PS2 ring is avoided by a negative momentum compaction (NMC) lattice [2] resulting in imaginary gamma at transition, γ_t (transition energy). The "racetrack" option for the PS2 study presented here consists of two arcs, each formed by 5 basic NMC cells and 2 dispersion suppressors. The two straight sections are used for injection/extraction and collimation/acceleration, respectively. Adjusting the phase advances in the NMC cells and matching the dispersion suppressors allows for tuning the working point of the machine.

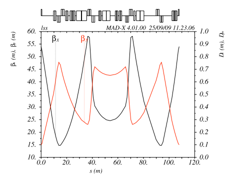
Parameter	Value
Injection kinetic energy [GeV]	4
Extraction kinetic energy [GeV]	~ 50
Circumference [m]	1346.4
Bρ [Tm]	169.8
Transition energy [GeV]	imaginary, adjustable
Maximum bending field [T]	< 1.7
Maximum quadrupole gradient [T/m]	~ 15
Maximum beta functions [m]	< 60
Maximum dispersion function [m]	< 6

2. LATTICE DESIGN



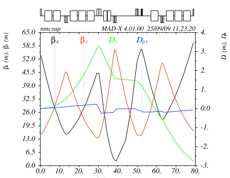
Basic NMC module

- Basic module of a flexible momentum compaction lattice [2]
- Phase advances of 258.5° (horizontal) and 150.1° (vertical) for the nominal working point
- Optics of the basic cell are optimized to low imaginary Gamma at transition, γ_t



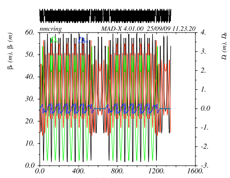
Straight section

- Long zero-dispersion straight section (LSS) composed of two pairs of doublets distributed symmetrically about the center
- Allows for very compact arrangement of the injection/ extraction elements while avoiding intersection of beam lines near the PS2 [3]



Dispersion Suppressor

- Dispersion suppressor needed to match the optics of the straight section to the NMC cell
- Dispersion suppressor has to be matched to the varying beta functions at the end of the NMC cell for tuning the working point of the machine

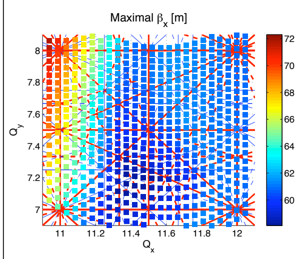


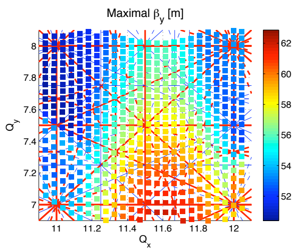
PS2 Ring (nominal working point)

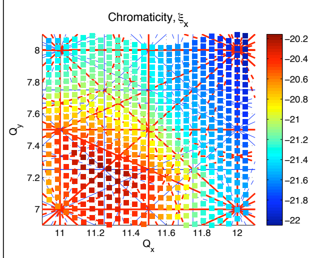
- Nominal working point, tunes of 11.25 in horizontal and 7.25 in vertical plane
- Maximal beta functions, β_x=60.05 m and β_y=56.5 m
- Gamma at transition, γ_t=33i
- Maximal dispersion function, D_x=3.3 m

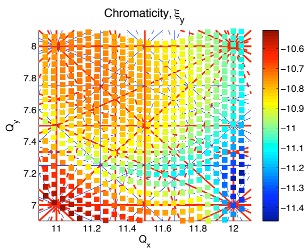
3. TUNABILITY

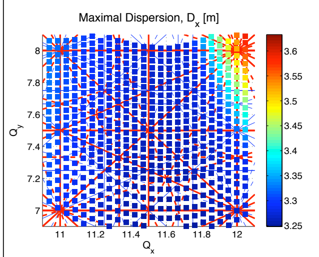
The lattice is tuned to about 700 working points by adjusting the phase advance of the basic NMC cells. Maximal quadrupole gradients are close to the required target value of 15 T/m. Tune diagrams shown below include resonances (systematic and non-systematic) up to fourth order.

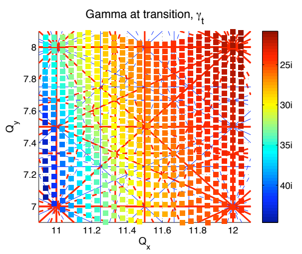


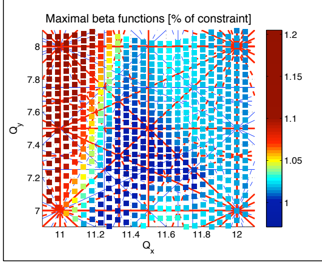












- Beta functions below or slightly above 60 m in most regions of tune diagram
- Chromaticities around -21/-11 in horizontal/vertical plane
- Max. dispersion funct. well below 6 m
- Gamma at transition between 21i-45i
- The results induce good tunability in both planes – tunability limited by maximal beta functions

CONCLUSION

A basic version of the negative momentum compaction lattice for the PS2 synchrotron is presented. The tunability range of the linear lattice (with respect to linear beam dynamics) is studied. The present lattice can be tuned smoothly to a wide range of working points. Further optimization may allow to reduce the maximal horizontal beta function below 60 m for most part of the tune diagram. Working point optimization and non-linear analysis, including resonance driving terms, dynamic aperture, tune shift with amplitude, etc. needs to be done.

REFERENCES

[1] M. Benedikt, PS2 presentation, CERN (May 2008).

[2] S.Y. Lee, K.Y. Ng, D. Trbojevic, Phys. Rev. E, 48, 3040 (1993).

[3] W. Bartmann, PS2 presentation, CERN (July 2009).