

LARP

PS2 Design Report Update

U. Wienands, SLAC



Post-Chamonix 2010

- CERN decided to not pursue the PS2 upgrade
 - Report to be written summarizing effort so far.
 - to be published as CERN Yellow Report
 - W. Bartmann, editor
 - 17 Chapters. O(10) pages ea. (not a limit)
 - Each chapter has a writer and/or sub-editor.
- **LARP contribution as planned**
 - but adjusted extent and effort to match new time line

Preparation of PS2 CDR

- CERN yellow report as template
- One person responsible per chapter – see list
- Aim to send chapters until 30th September 2010 to Michael and Wolfgang
- Meeting to discuss how detailed the subjects should be described - to be announced

People in charge...

1. **Introduction**
2. **Optics, beam dynamics and operation aspects**
3. Technical Systems
4. Site aspects, buildings and technical infrastructure

Responsible	Chapter
Michael Benedikt	Introduction, basics design choices and general parameters
Yannis Papaphilippou	Ring lattice, linear and non-linear optics & corrections, dynamic aperture
Brennan Goddard	Injection, extraction and transfer lines
Steven Hancock	Longitudinal dynamics
Uli Wienands	Beam stability, collective effects, impedances
Thomas Otto	Beam loss management and radiation protection aspects

People in charge...

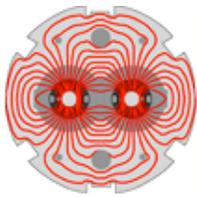
1. Introduction
2. Optics, beam dynamics and operation aspects
3. **Technical Systems**
4. **Site aspects, buildings and technical infrastructure**

Responsible	Chapter
Erk Jensen	RF system
Gijs de Rijk	Magnet systems
Brennan Goddard	Beam transfer systems
Edgar Mahner	Vacuum system
Vasilis Vlachoudis/Yacine Kadi	Collimators and dumps
Rhodri Jones	Beam instrumentation
Hugues Thiesen	Power converters
?	Controls
Michael Poehler	Civil Engineering, site aspects and buildings
?	Electrical infrastructure
?	Cooling and ventilation



The LARP Contribution:

- 24 pages have been written
 - Space-charge (12)
 - e-cloud (5)
 - Impedance (5)
 - Bibliography (2)
- These are $\approx 90\%$ done except for the editing



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LARP Section Pages (first)

PSE Design Report
The PSE Design Team
members: CERN, The LA-EP Collaborators (BNL, FNAL, LBNL and SLAC)

1

Chapter 1
Beam stability and collective effects

2

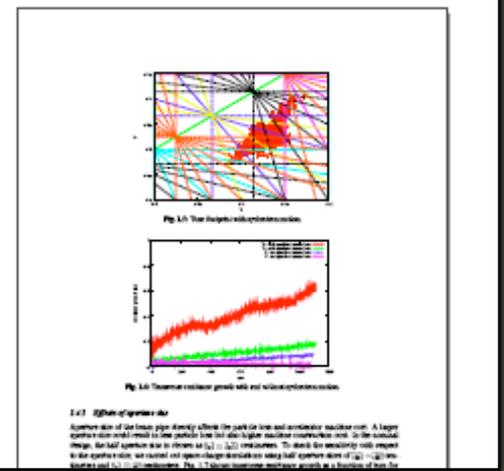
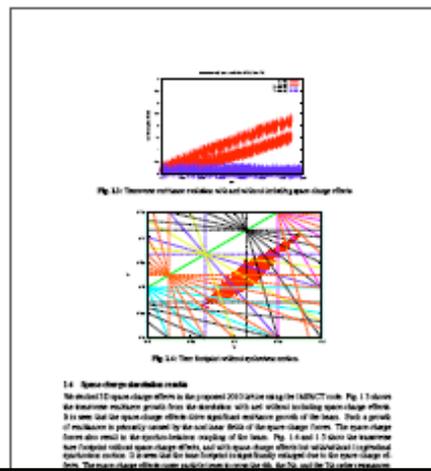
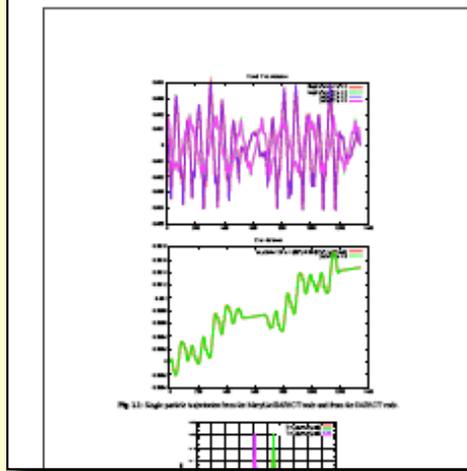
1. Space Charge Effects
1.1 Introduction
Space charge effects have been identified as the most serious stability limitation in the CERN PS and PS Booster [1], since nonlinear space-charge effects in high longitudinal emittance beams cause significant microwave growth and particle losses. These effects are a major goal in the ultimate upgrade for a proposed post-LHC accelerator, FCC-ee, which is expected to require beam rings of 100 km circumference with a 50 GeV hadron energy machine for future neutrino experiments at CERN. Exploiting the space-charge effects through long-term self-consistent particle tracking will help shed light on the nature of microwave growth and particle loss (e.g., space-charge driven resonances and halo growth) associated with these effects through improved lattice design in compensation schemes.

1.2 Compensation Schemes
In the space-charge study of Lawrence Berkeley National Laboratory, we have used the MARSCT code and the newly developed MARSCT++ code for simulation. The MARSCT++ code is a particle particle (p-p) code with the following high-accuracy, high-resolution features: (i) precise, dynamic beam and (ii) stochastic [1]. It consists of two parallel particle-to-particle tracking codes (MARSCT and MARSCT++) that share some longitudinal particles in the longitudinal direction and allow for efficient particle-to-particle interaction as in an RF beam, but take care to be an independent particle and to avoid an unphysical multi-particle with strong space-charge as a perturbation, as if the beam design mode, an average tracking self-consistent mode, and a number of eye and post-processing mode. This special particle tracking mode enables a quasi-deterministic model of the beam (i.e., deterministic self-consistent) in the beam frame, possibly with energy feedback and complete space-charge effects self-consistently at each time step together with the external magnetic and focusing fields. The 1D beam mode is solved in the beam frame at each step of the simulation. The resulting electromagnetic fields are Lorenz transformed back to the laboratory frame to obtain the electric and magnetic fields acting on the beam.

The newly developed MARSCT++ is a hybrid code that combines the beam optics capabilities of MARSCT++ with the parallel 1D space-charge capabilities of MARSCT++ in addition to combining the capabilities of both codes. MARSCT++ has a number of parallel features, including a choice of 32-bit or 64-bit modes, a 3D mode of space-charge, multiple reference particles for tracking, a library of self-consistent modes, a number of input/output options, a number of modes with post-processing fields, and a number of other features. The code allows for easy production, long tracking, particle tracking, and 3D mode tracking. It includes a single, compact, user interface: MARSCT++ has a front end that can be used to run MARSCT++ and MARSCT++ simulations.

1.3 Single-particle beam dynamics
Using the above-mentioned computer codes, we used our simulation studies of the proposed FCC beam. Our initial study was to test the single-particle beam dynamics using a 3D beam design [1]. We adapted the MARSCT++ code for the simulation of the single-particle tracking without space-charge effects because the MARSCT++ code and the MARSCT++ code. Fig. 1.1 shows the beam size and longitudinal coordinates from the beam center. Both codes agree with each other very well even though the underlying tracking methods are quite different. To check the single-particle tracking results against the MARSCT++ output, we also calculate the phase space of the single-particle trajectory of a test macroparticle (initial position and an off-momentum particle using a 2000 km lattice length [2]). The results are shown in Fig. 1.2. Both particles give the same results from within the numerical accuracy. This also means that the two codes accurately simulate the beam loss for MARSCT++ output.

3





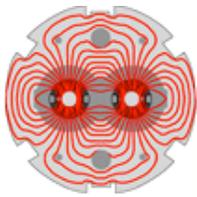
Some Highlight Conclusions

- Space-Charge causes 5...6% emittance growth
 - LHC beam with nominal rf program
 - details of the rf program matter
 - $3\mu\text{m}$ emittance can be met @ 4×10^{11} ppb, but not with overly large margin
- Highest SEY tolerable for 25 ns (LHC nominal) beam ≈ 1.2
 - coatings and/or other mitigation likely necessary (and foreseen)
- Resistive wall will likely need transverse multibunch feedback system
 - but $\approx 10\mu\text{m}$ coating helpful against TMCI
 - unshielded ConFlat gaps unlikely to pose a significant problem



Remaining Scope

- Add Venturini's sec. on e-cloud effect on the beam
 - written, I have the pdf
- We'd like to expand some on the Impedance section
- Some sections still need a summary
- The chapter still needs a summary.
- Integration of whole chapter with the rest.
 - incl. consolidation of bibliography
- Expected effort is consistent with plan
 - but time phasing is slightly later



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Follow-on work

- There is considerable interest in maintaining the collaboration for the space-charge work
 - PSB at 150 MeV injection with Linac 4
 - PS at 2 GeV injection from upgraded PSB
- Qiang (LBL) and Carli (CERN) working on the scope
 - study the emittance growth driven by the space-charge effects
 - study the particle losses and beam halo formation

PSB

An additional topic, we are interested in is a better understanding of the behavior of high brilliance beams experiencing significant direct space charge effects in the PS. The aim is to better understand limitations in the PS, which are a prerequisite to optimising an upgraded LHC injector chain. Furthermore, triggered by a proposal by Roland Garoby, we started discussions on RF gymnastics to increase beam brilliance by batch compression (after acceleration to an appropriate energy). I could well imagine very significant LARP contributions to the simulation and optimization of this process. (C. Carli)



Conclusion

- LARP Contributions to PS2 Design Report are mostly in hand
- Editing of the chapter is in progress
- The whole Report is making progress
 - but final completion may spill into 2011
- 4 Papers on PS2 topics presented at iPAC10.
- There is significant interest in continuing the space-charge work
 - likely with more direct LBL-CERN interaction