Summary ECLOUD'02

Session V: Specific Comparisons and Plasma Approaches

T. Katsouleas and R. Assmann

Talks covering a wide range of topics:

Electron cloud
Beam-beam
Plasma wakefields
Synchrotron radiation
Theory of holes in particle beams
Vlasov-Poisson equations

Results for …
PS, SPS, BEPC, BEPCII, SLAC plasma exp., Heavy Ion Fusion

It shows: *Modeling and understanding of e-cloud is an area with a very large scope of issues and interests!*
Session brought together wide range of diverse expertise!

Session V: Wednesday morning, 17.04.2002

Specific Comparisons and Plasma Approaches

Session Chair: Tom Katsouleas, USC

Scientific Secretary: Ralph Assmann, CERN

9:00 Electron cloud build up and instability: comparison between observations and numerical simulations for the CERN PS

R. Cappi, M. Giovannozzi, E. Metral, G. Metral, G. Rumolo, F. Zimmermann, CERN

Experimental observations on the electron cloud have been collected at the CERN PS throughout the last two years. At the same time, an intense campaign of simulations has been carried out. Simulations of electron cloud build up in different regions of the PS ring and single bunch instabilities occurring above a threshold of about 3×10^{10} *protons/bunch have satisfactorily reproduced and explained the observed data. All simulation results are here presented and discussed in detail.*

9:20 Complex phenomena of Beam-Beam and Beam-Electron Cloud Effects in Circular e^+e^- Colliders

Kazuhito Ohmi, KEK

The electron cloud causes various effects in high intensity positron storage rings. We here discuss interactions between a positron bunch and electron cloud. The positron bunch and electron cloud can be considered a typical two stream system with a plasma frequency. Beam-beam effect is also important effect for high luminosity circular colliders. Colliding two beam also can be also considered as a two-beam system with another plasma frequency. We have to care the two-stream nature for the beam-beam system, because the beam-beam disruption parameter, which is phase advance of plasma oscillation of the two beams, is of the order of 1 in recent colliders. We study complex phenomena of the beam-electron cloud and beam-beam effects from a viewpoint of two complex "two stream effects" with two plasma frequencies.

9:40 The simulation study on ECI for BEPC and its upgrade plan BEPCII

Jun Xing, IHEP

The Beijing Electron Positron Collider (BEPC) will be upgraded to enhance the luminosity in the energy of 1.55 GeV. The machine will become a double ring (BEPCII) from a single ring. The multi-bunch electron and positron beams will circle in each ring respectively. The electron cloud instability is suspected to occur in the positron ring, and it may influence the performance of the collider on the luminosity. A simulation code has been developed based on similar programs, which have been used to study ECI in other laboratories. The physics model of the instability, the simulation results comparing to the observation in the BEPC experiments and simulation results on the BEPCII design study will be discussed in this paper. (Co-authors: J. Xing, Z.Y. Guo, Q. Qin and J.Q. Wang, IHEP, Beijing China)

10:00 Plasma Modeling of Collective Wakefields in Electron Clouds

Tom Katsouleas, USC

To estimate the importance of collective fields of an electron cloud interacting with a positively charged particle beam, we apply two particle-in-cell codes from plasma physics – OSIRIS and QuickPIC. These codes have been used extensively to model the wakefields excited by positron bunches in a neutral plasma in the scheme known as the plasma wakefield accelerator (PWFA). The collective wakefields excited in the electron cloud plasma are similar. Analytic estimates and numerical solutions for the wakefields are obtained and their importance assessed. The basic approach as well as special features of the codes such as moving windows and quasi-static wakefield approximations are described.

Co authors: A. Ghalam, W.B. Mori‡, C. Huang‡ Institutions: *University of Southern California, ‡Univ. of Calif. at Los Angeles*

Work supported by USDoE

10:30 Coffee Break

11:00 On the Transparency of the Electron Cloud to Synchrotron Radiation

Dobrin Kaltchev, TRIUMF

We study the interaction of the synchrotron radiation, produced by a relativistic particle in a bending magnet, with the electron cloud present in the same magnet. The cloud is described as a collisionless magnetized plasma of very low, but *finite temperature. Expressions are derived for the spectral intensity of synchrotron radiation far from the particle, which in absence of a cloud, reduce to the Schott spectrum of radiation in vacuum. For typical cloud parameters – a rarefied plasma, we fully neglect the refraction and only take into account the damping of the extraordinary and ordinary plasma waves at frequencies near the first electron cyclotron resonance (wave lengths of the order of mm) via interaction with resonance electrons. This effect would be the strongest in case of an electron beam and electron cloud, but is expected to be weaker in the realistic case of positively charged beam particle (proton, positron). In the later case, by taking Maxwellian velocity distribution of the electrons (r.m.s. velocity $v_e = \beta_e c$) and fully neglecting the ordinary wave (factor β_e), we have estimated that the dominant effect is the coupling between (decay of) the π- mode of the spontaneous radiation and the extraordinary plasma wave.*

11:20 Kinetic Theory of Periodic Holes in Debunched Particle Beams

Hans Schamel, Universitaet Bayreuth

A self-consistent theory of periodic hole structures in coasting beams in storage rings and synchrotrons is presented [1]. The analysis reveals new intrinsic nonlinear modes which owe their existence to a deficiency of particles trapped in the self-sustained potential well,showing up as notches in the thermal range of the distribution function. It is hence the full set of Vlasov-Poisson equations which is invoked;linearized treatments as well as their nonlinear extensions fundamentally fail to cope with this strongly nonthermodynamic phenomenon.Qualitative agreement with the periodic holes found recently at the CERN Proton Synchrotron Booster is shown.The effect of an electron cloud on these structures will also be discussed briefly .

[1] J.-M.Griessmeier,H.Schamel,and R.Fedele,Phys.Rev.ST Accel.Beams (to be published in 2002)

11:40 Electron cloud effects in intense, ion beam linacs & theory and experimental planning for HIF*

Molvik, A.W., Cohen, R.H. (LLNL); Bieniosek, F.M., Lee, E.P., Prost, L.R., Seidl, P.A., Vay, Jean-Luc (LBNL) Heavy-Ion Fusion Virtual National Laboratory

Heavy-ion accelerators for heavy-ion inertial fusion energy (HIF) will operate at high aperture-fill factors with high beam current and long durations. (Injected currents of order 1 A and 20 s at a few MeV for each of 100 beams, will be compressed to the order of 100 A and 0.2 s, reaching GeV energies in a power plant driver.) This will lead to beam ions impacting walls, liberating gas molecules and secondary electrons. Without special preparation, the 10% electron population predicted in the High-Current Experiment (HCX), currently being commissioned, will affect beam transport; but wall conditioning and other mitigation techniques should result in substantial reduction. Theory and particle-in-cell simulations suggest that electrons, from ionization of residual and desorbed gas and secondary electrons from vacuum walls, will be radially trapped in the 4 kV ion beam potential. Trapped electrons can modify the beam space charge, vacuum pressure, ion transport dynamics, and halo generation, and can potentially cause ion-electron instabilities. Within quadrupole (and dipole) magnets, the longitudinal electron velocity is limited to drift velocities (E x B and grad-B) and the electron density can vary azimuthally, radially, and longitudinally. These variations can cause centroid misalignment, emittance growth and halo growth. Diagnostics are being developed to measure the energy and flux of electrons and gas evolved from walls, and the net charge and gas density within magnetic quadrupoles. We will also measure the depth of trapping of electrons, their axial and radial transport, and the effects of electrons on the ion beam.

**Work performed for the USDOE by UC-LLNL under Contract W-7405-ENG-48, and by UC-LBNL under Contract DE-AC03-76F00098.*

12:00 Discussion

13:00 Lunch Break

ECLOUD'02 (17.04.2002)

G. Rumolo and F. Zimmermann, CERN, SL/AP
R. Cappi, M. Giovannozzi and E. Metral, CERN, PS/AE

Electron Cloud Build Up and Instability: Comparison between Observations and Simulations for PS.

- Electron cloud build up in CERN PS with an LHC bunch train.: dependence on type of region, bunch intensity and bunch length

- Wake fields caused by the electron cloud in the PS.

- Instability study: dependence on bunch intensity, chromaticity, bunch length.

- The horizontal instability ?? Preliminary study of the influence of combined functions. magnets.

Electron cloud at the CERN PS: observations

- Since 2000 the electron cloud has been detected by pick-up electrodes for LHC-type bunch trains after bunch compression (16 ns → 4 ns)

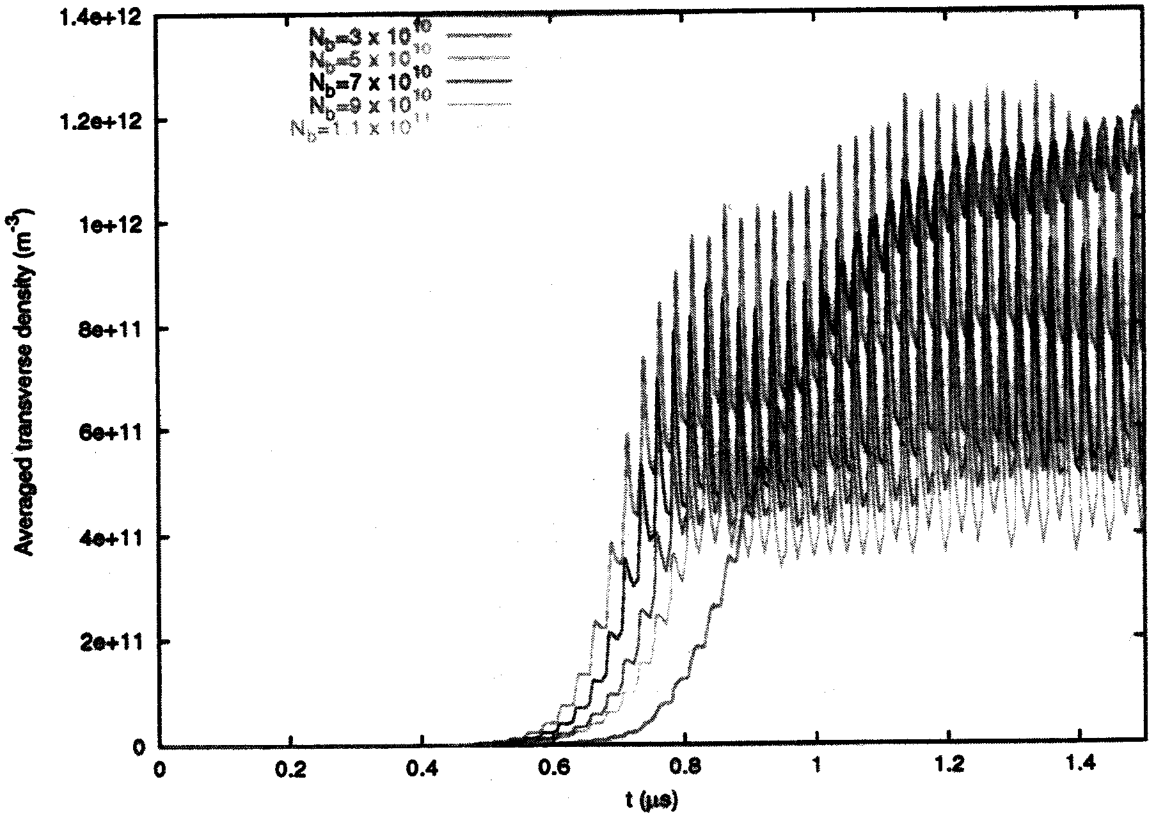
- If an LHC-type bunch train with 10-ns long bunches is stored, a fast instability develops.

  (1) The instability is a single-bunch phenomenon which sets in above a threshold of about 4×10^{10} protons/bunch.

  (2) It is especially evident in the horizontal plane.

  (3) It develops with a rise time of a few ms.

  (4) It can cause an emittance growth as large as a factor 10–20.



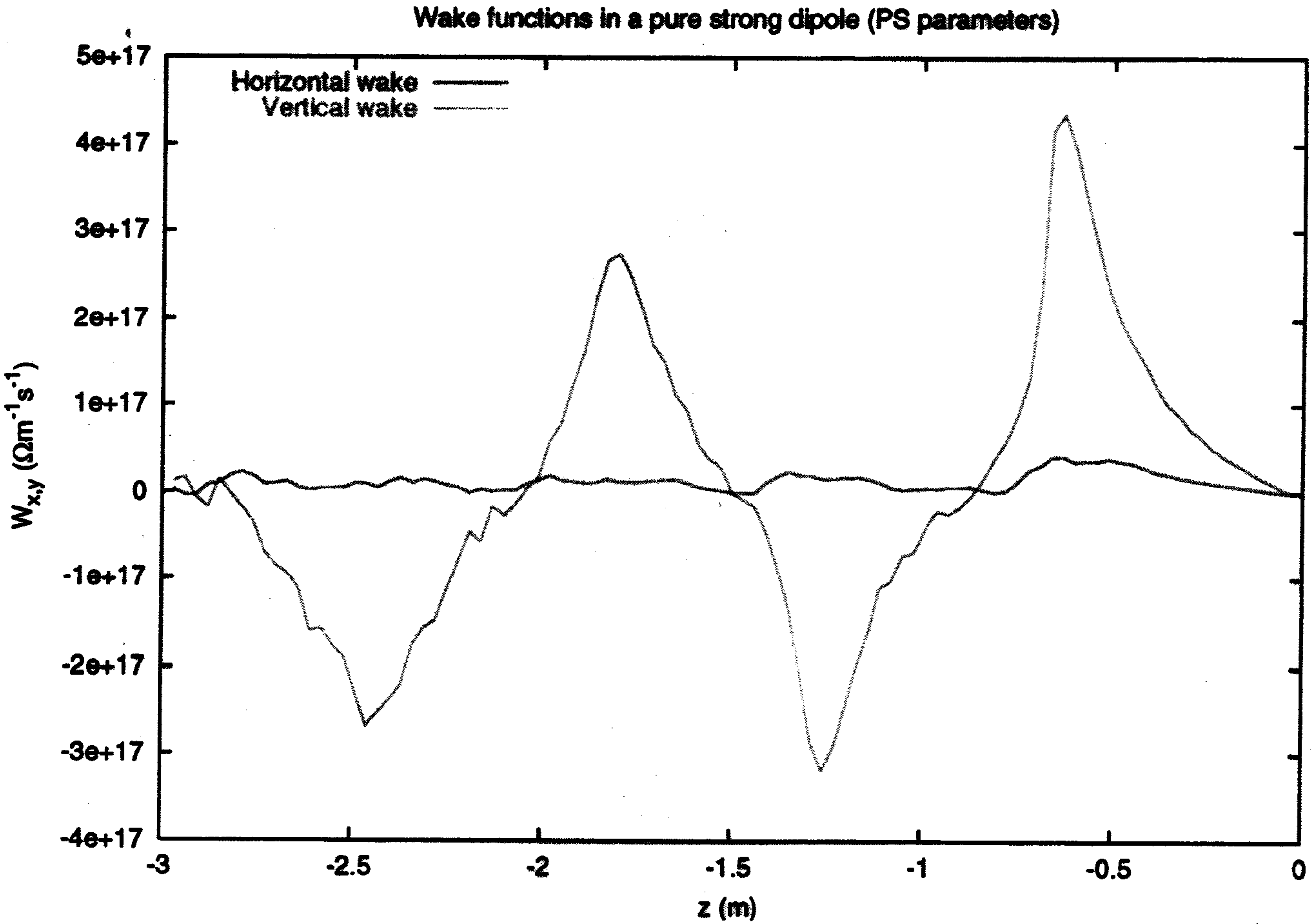
Electron cloud build up in a PS dipole for different bunch intensities. The electron cloud reaches saturation after the passage of about 40 bunches. While the rise time does not seem to be much affected by this parameter, the saturation value tends to decrease with increasing current.

Can the magnetic field configuration cause the instability to be mostly horizontal ?

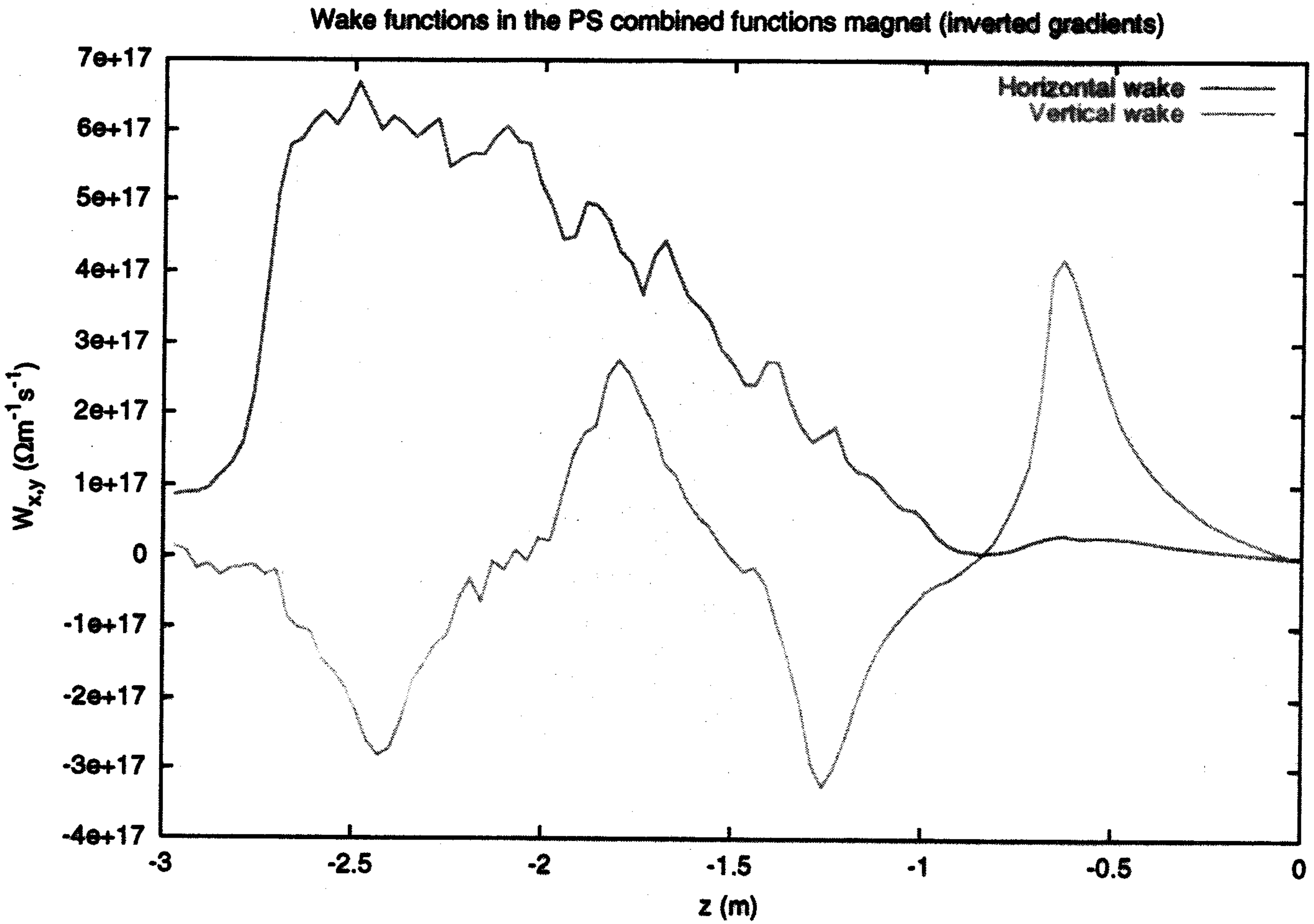
PS has combined functions magnets over 90% of its length:

$$B_x(x,y) = \pm G y$$
$$B_y(x,y) = B_{y0} \mp G x$$

($B_{y0} = 1.26$ T and $G = 5.2$ T/m - further nonlinear multipole components neglected). If we approximate with a pure strong dipole, no effect will be visible in the horizontal plane.



The absence of pinching in the horizontal direction due to the electrons moving around the field lines causes the horizontal wake to be negligible with respect to the vertical wake.



A magnetic field gradient ($|\partial B_y/\partial x| = 5.2$ T/m) seems to generate a strong horizontal wake. Its sign does not depend on which the focusing plane is. Its frequency is much lower than that of the vertical wake.

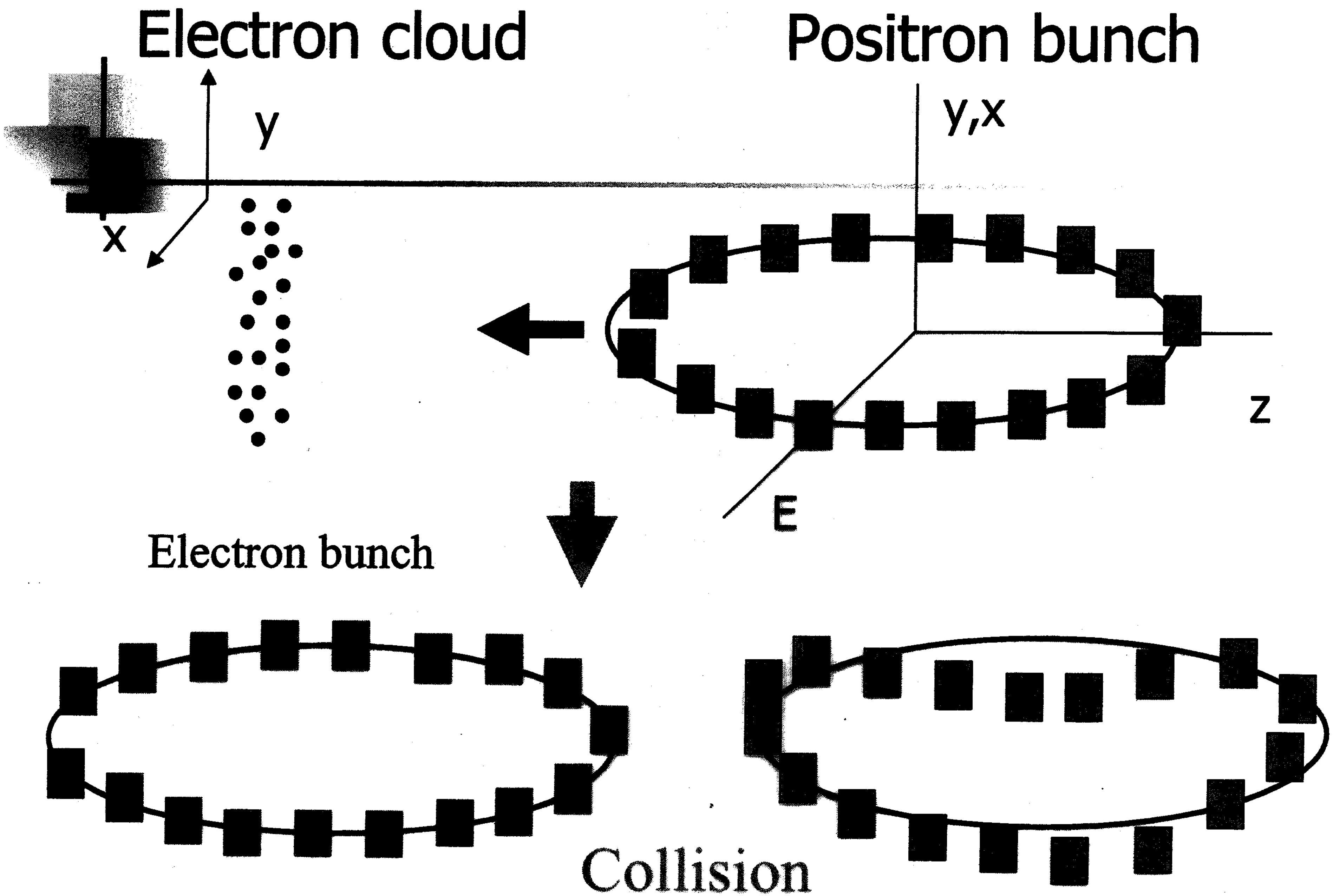
Summary

- The electron cloud build up in the PS has been simulated with the ECLOUD code, and the dependence on bunch length reproduced.
- Using the HEADTAIL code we have shown that in the range of parameters involved an e-cloud instability is likely to occur:
  * Bunch unstable above a threshold at around 3×10^{10} protons/bunch.
  * Shorter bunch, higher $Q_s \Rightarrow$ bunch more stable.
  * Chromaticity helps to suppress the instability.
  * Emittance rise times are in the order of some ms.
  * Emittance blow up can amount up to factors 10–20.
- The combined functions magnets, which cover 90% of the PS circumference, seem to play an important role in making the instability more violent in the horizontal plane.

Combined phenomenon of the beam-beam and the beam-electron cloud effects

K.Ohmi (KEK)
E.Perevedentsev, A.Valishev, A.Chao

ECLOUD2002 , 15-19 Apr. 2002


Electron cloud
Positron bunch
y
x
y,x
z
E
Electron bunch
Collision

Summary

- Combined phenomena of beam-beam and beam-electron cloud were studied by using a linear theory and a simulation with Gaussian approximation.
- Below the each threshold of beam-beam and beam-cloud, an instability occurs due to their combined effect in linear theory and Gaussian model.
- The complex phenomena should exist.

Strong-strong simulation using soft Gaussian model shows unexpected results

- Vertical instability is smeared by nonlinear beam-beam force, while horizontal instability is enhanced.
- When linear force is applied to the beam-beam interaction, the simulation shows instability as is predicted.
- Growth for linear force is much faster. Strong Landau damping due to beam-beam affects the results.
- We need mode studies.

Simulation Study on ECI for BEPC and its Upgrade Plan BEPCII

J. Xing, Z.Y. Guo, Q. Qin , J.Q. Wang, IHEP

Abstract

The Beijing Electron Positron Collidor (BEPC) will be upgraded to enhance the luminosity in the energy of 1.55 GeV. The machine will become a double ring (BEPCII) from a single ring. The multi-bunch electron and positron beams will circle in each ring respectively. The electron cloud instability is suspected to occur in the positron ring, and it may influence the performance of the collidor on the luminosity. A simulation code has been developed based on similar programs, which have been used to study ECI in other laboratories. The physics model of the instability, the simulation results comparing to the observation in the BEPC experiments and simulation results on the BEPCII design study will be discussed in this paper.

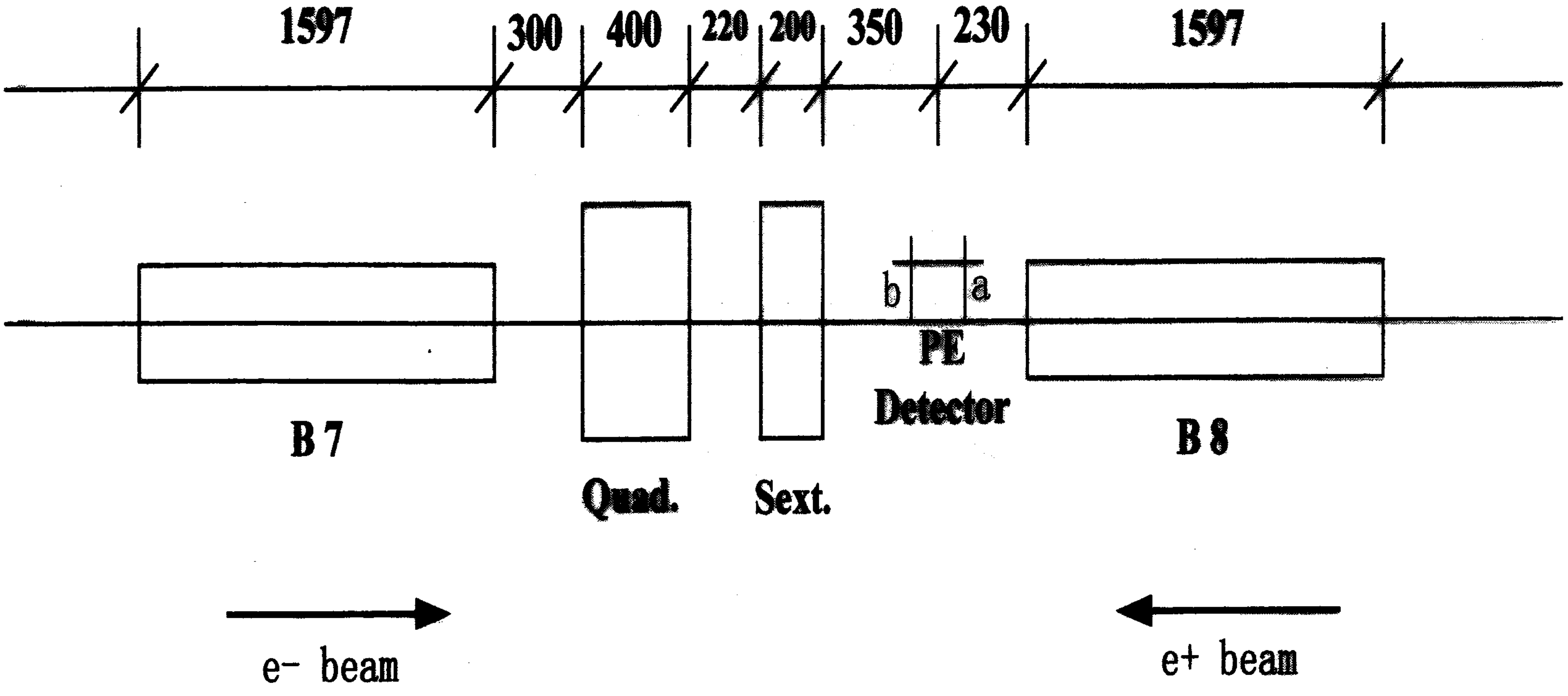


Figure 1: Position of the PE detector at the BEPC storage ring (seen from inside of the ring).

The collected electron current I_c as a function of beam current I_b is measured in the cases of single bunch and multi-bunch. Normalized by I_b, I_c is almost the same in different bunch spacing. It reads about 25nA/mA at the bunch current of 2 mA, Fig. 5. No any saturation effect, in which electron generation and loss equilibrate, is found with a long bunch train and a weak bunch current, even 40 bunches are used with the bunch current of 1 or 2 mA (I_b is 40 or 80 mA).

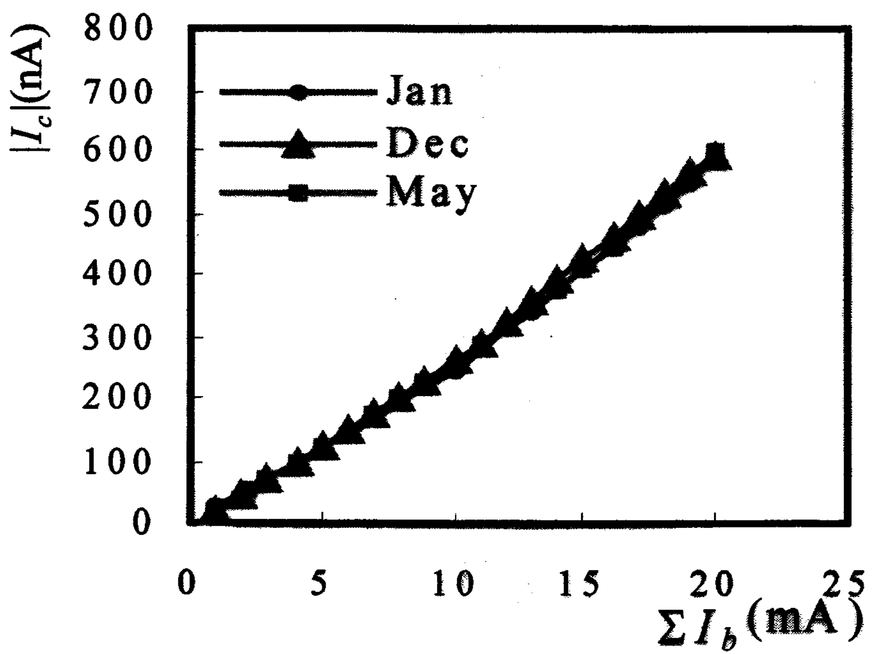


Figure 5: Collected electron current I_c as a function of beam current I_b

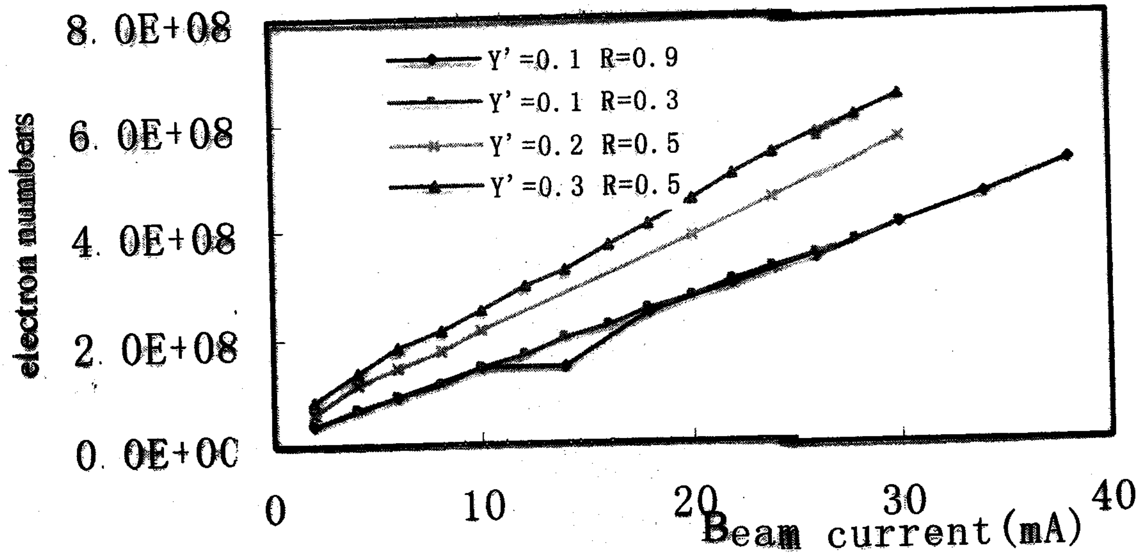


Figure 8: PE creation for different yield and reflectivity.

Table 3: Parameters of a few storage rings

	BEPCII	KEKB	PEPII
Beam energy(GeV)	1.89	3.5	3.1
Bunch population $N_b(10^{10})$	4.84	3.3	9
Bunch spacing L_{sep}(m)	2.4	2.4	2.5
Rms bunch length σ_z(m)	0.015	0.004	0.013
Rms bunch sizes $\sigma_{x,y}$(mm)	1.18,0.15	0.42,0.06	1.4,0.2
Chamber half dimensions $h_{x,y}$(mm)	60,27	47	25
Slippage factor η (10^{-3})	22	0.18	1.3
Synchrotron tune Q_s	0.033	0.015	0.03
Circumference C(km)	0.24	3.0	2.2
Average beta function(m)	10	15	18
Parameter n_{min}	9.24	10	1
e^- oscillation/bunch $n_{osc} \equiv \omega_e \sigma_z/(\pi c)$	0.42	1.0	0.9
Density enhancement H_e	15	13	12
Adiabaticity A	17.4	9	8
TMCI threshold $\rho_e[10^{12}m^{-3}]$	22.7	0.5	1
Density ratio $\rho_{e,sat}/\rho_{e,threshold}$	0.19	4	4

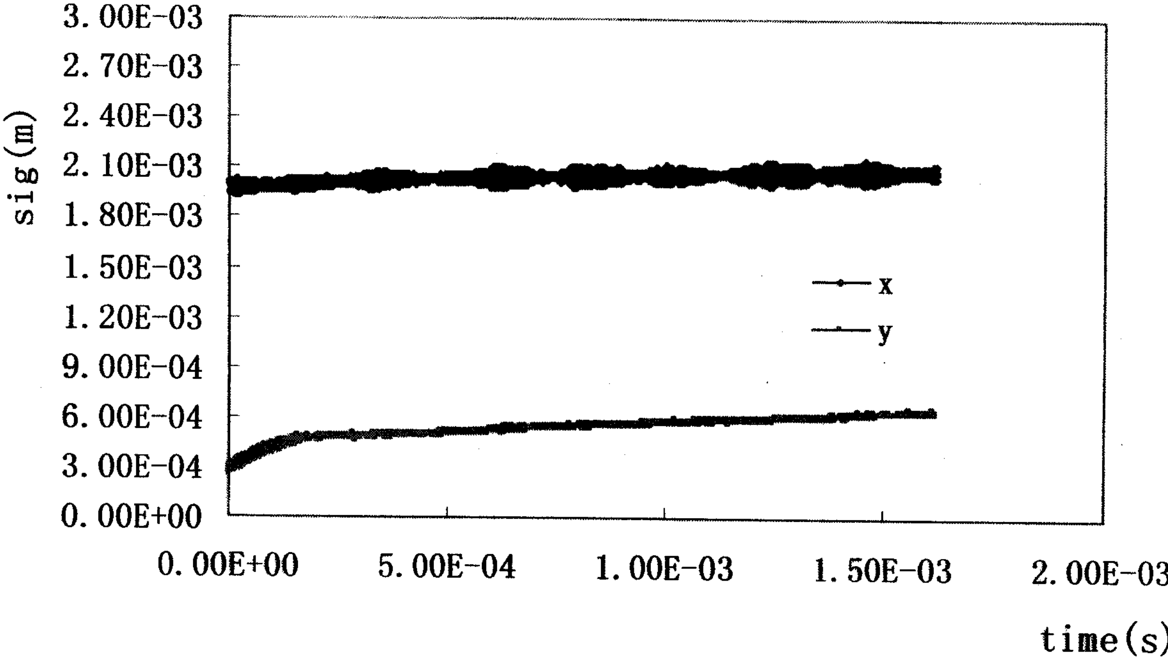


Figure :Sqrt(beam size) growth as a function of time,assume the elcetron density is $2.0\times10^{12}/m^3$ and x,yoffset = 1mm at the beginning.

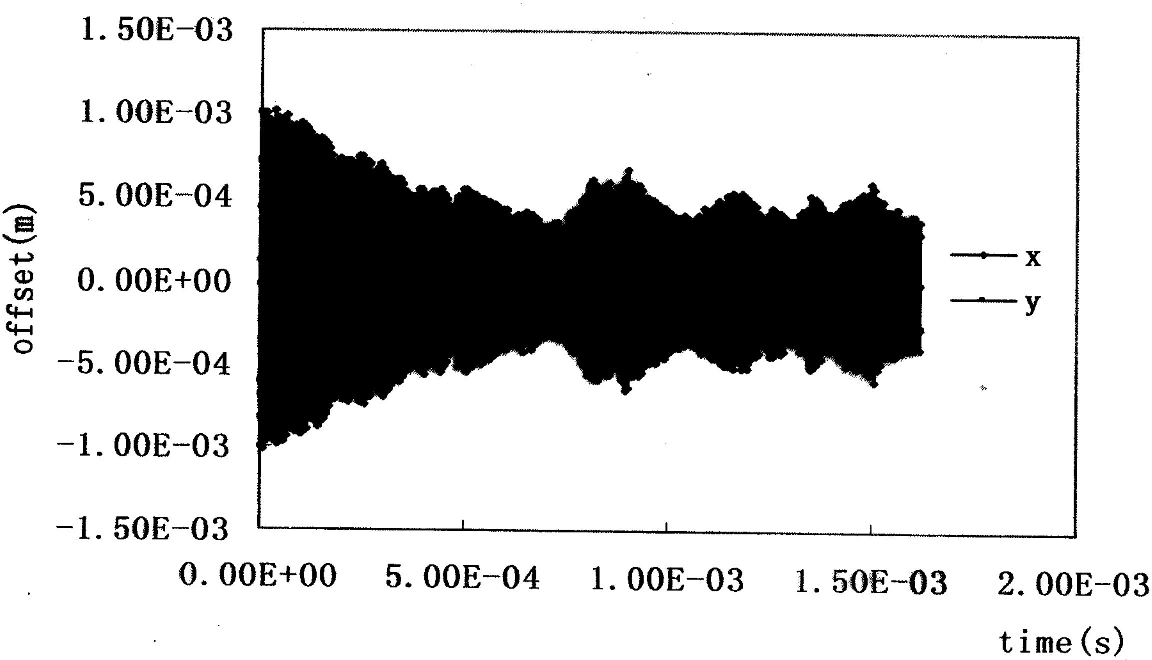


Figure : Beam centroidmotin as a function of time ,assume the elcetron density is $2.0\times10^{12}/m^3$.

3. summary

From the simulation result,the instabilities caused by the electron cloud seems not so seriously as expected even use the the maximum ecloud density in the field free region and think all the ring is the field free region.

One possible explaination is that the BEPCII will work under the TMCI threshold of eletron cloud volumedensity.And the other benefit is nearly half of the positron ring is the strong dipole magnet which will strongly suppress the electron cloud volume density.Also we consider the effect of the solenoid and the clearing electrode that had been successfully used to deal with the ecloud instabilities.

More study will be down on different conditions to make sure that the instabilities caused by the electron cloud will not influence the designed performance of the collider so much.

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Plasma Modeling of Wakefields in Electron Clouds:

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With special thanks to Frank Zimmerman for inviting me in to this problem