e-cloud studies at LNF

T. Demma INFN-LNF

Plan of talk

- Introduction
- New feedback system to suppress horizontal coupled-bunch instability.
- Preliminary analysis of the instabilities
  - Coupled bunch
  - Single bunch
- Clearing electrodes for dipoles and wigglers
- Summary

Electron cloud at DAFNE

- e^+ current limited to 1.2 A by strong horizontal instability
- Large positive tune shift with current in e^+ ring, not seen in e^- ring
- Instability depends on bunch current
- Instability strongly increases along the train
- Anomalous vacuum pressure rise has been oserved in e^+ ring
- Instability sensitive to orbit in wiggler and bending magnets
- Main change for the 2003 was wiggler field modification

New DAFNE e+ Transverse feedback

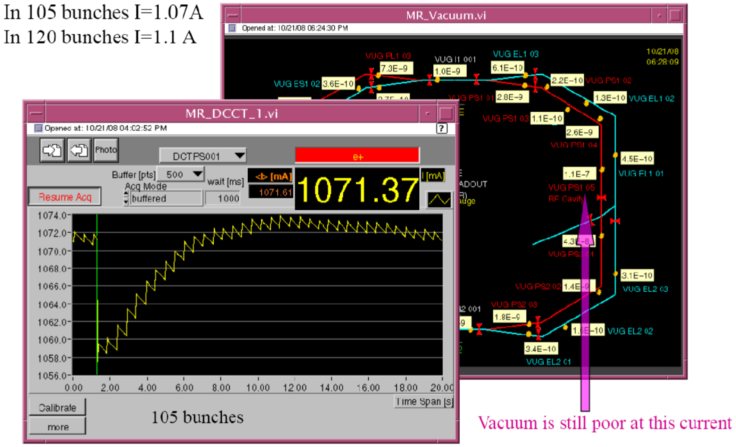
- Observing the linearity of the horizontal instability, growing > 70 (1/ms) for Ibeam>800mA

- We decide to double the feedback power from 500W to 1kW.

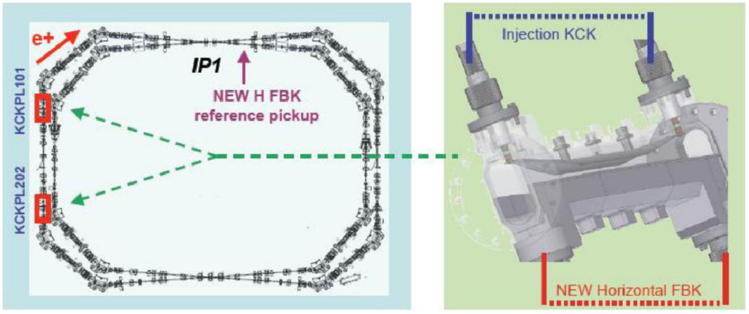
- We decide to test another pickup (to see if less noisy) and to use the spare striplines of the injection kickers.

The current limit has been exceed

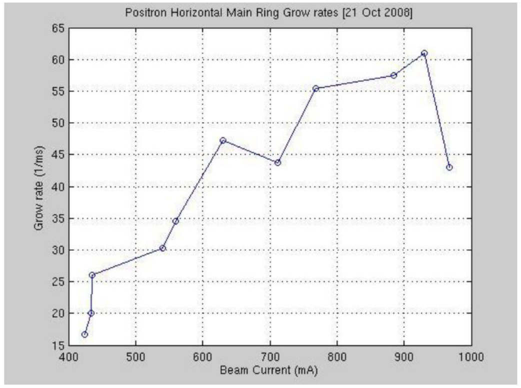
In 105 bunches I=1.07A
In 120 bunches I=1.1 A



- **<u>New e+ Transverse Horizontal Feedback</u>**
- The damping times of the two feedbacks add up linearly
- Damping time measured:
- ~100 ms-1 (1 FBKs) ➔ fb damps in 30 revolution periods (~10 us)
- ~200 ms-1 (2 FBKs) ➔ fb damps in 15 revolution periods (~ 5 us)
- The power of the H FBK has been doubled

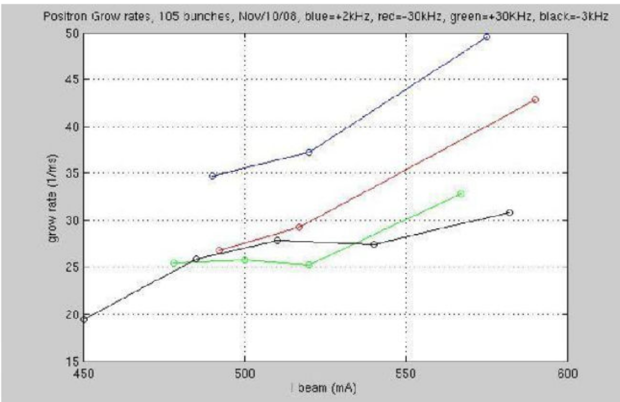


Grow rates at higher e+ current controlling instability by 2 feedback



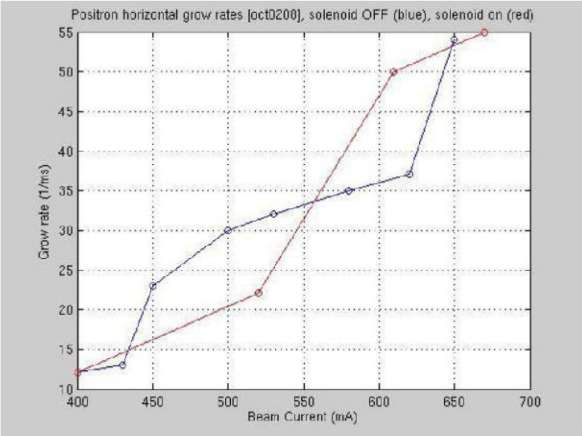
Characterization of the Horizontal Instability

e+ instability grow rates versus orbit in the main ring dipoles



The orbit variation is performed changing the RF frequency and then compensating the beam energy

e+ instability behavior switching solenoids off (blue) & on (red)

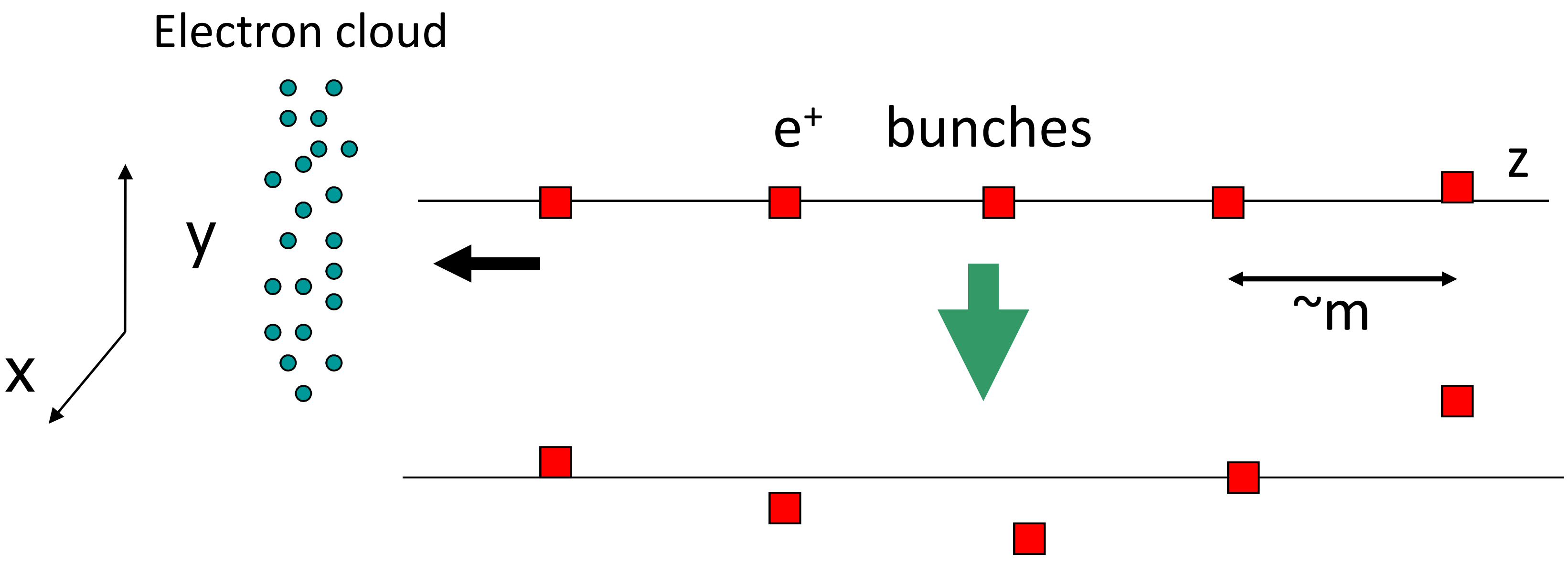


- Switching off the solenoids installed in the positron ring the grow rates of the e+ instability does not change

- Solenoids installed in free field regions strongly reduce pressure but have no effect on the instability
- Instability sensitive to orbit in wiggler and bending magnets
- Most unstable mode -1

PEI-M Tracking simulation

K.Ohmi, PRE55,7550 (1997),K.Ohmi, PAC97, pp1667.



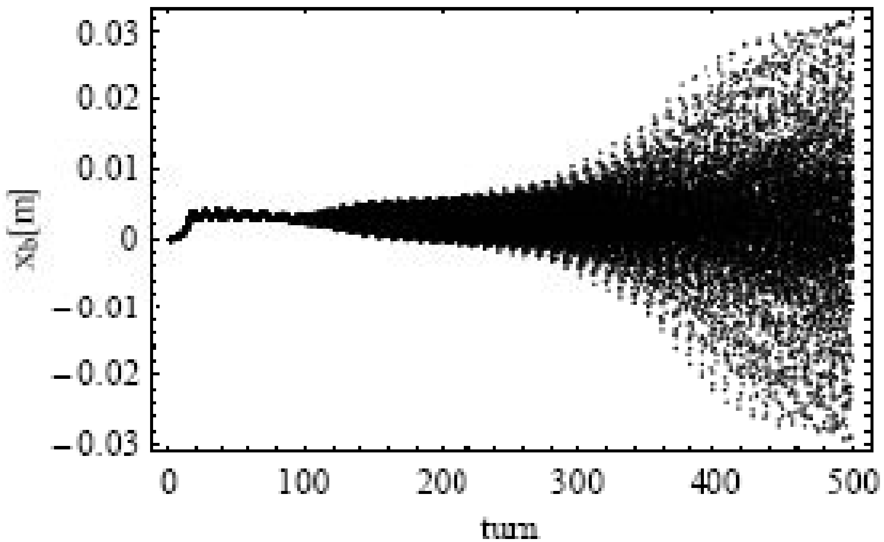
•Solve both equations of beam and electrons simultaneously, giving the transverse amplitude of each bunch as a function of time.

•Fourier transformation of the amplitudes gives a spectrum of the unstable mode, identified by peaks of the betatron sidebands.

Input parameters for DAFNE simulations

Bunch population	N_b	2.1; (4.2 x10^{10})
Number of bunches	n_b	120; (60)
Missing bunches	N_{gap}	0
Bunch spacing	L_{sep}[m]	0.8;(1.6)
Bunch length	σ_z [mm]	18
Bunch horizontal size	σ_x [mm]	1.4
Bunch vertical size	σ_y [mm]	0.05
Chamber Radius	R [mm]	40
Hor./vert. beta function	β_x[m]/β_y[m]	4.1/1.1
Hor./vert. betatron tune	ν_x/ν_y	5.1/5.2
Primary electron rate	$d\lambda/ds$	0.0088
Photon Reflectivity	R	100% (uniform)
Max. Secondary Emission Yeld	Δ_{max}	1.9
Energy at Max. SEY	E_m [eV]	250
Vert. magnetic field	B_z [T]	1.7

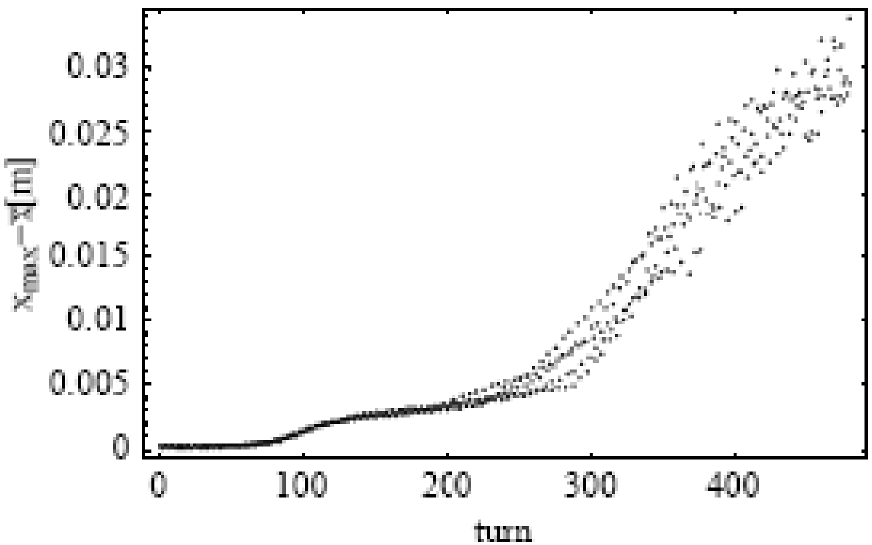
Mode spectrum and growth rate



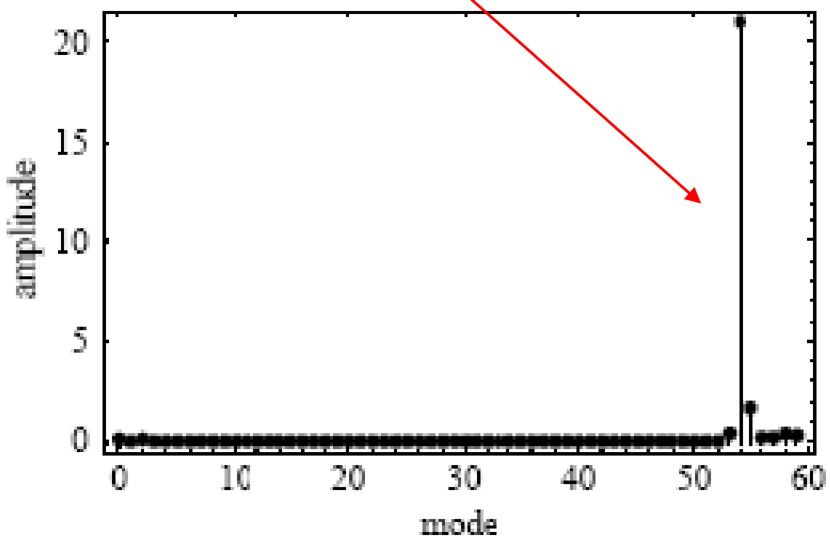
60 equispaced bunches

Beam current 1.2 A

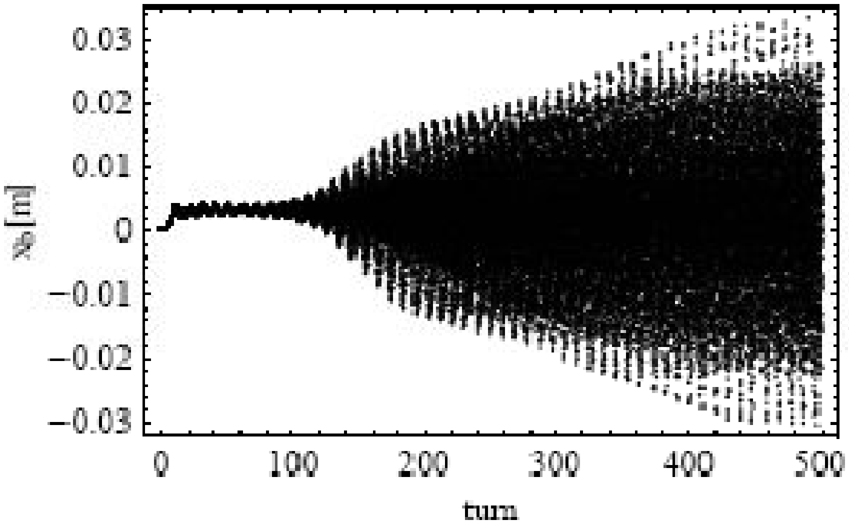
Growth time ~ 100 turn



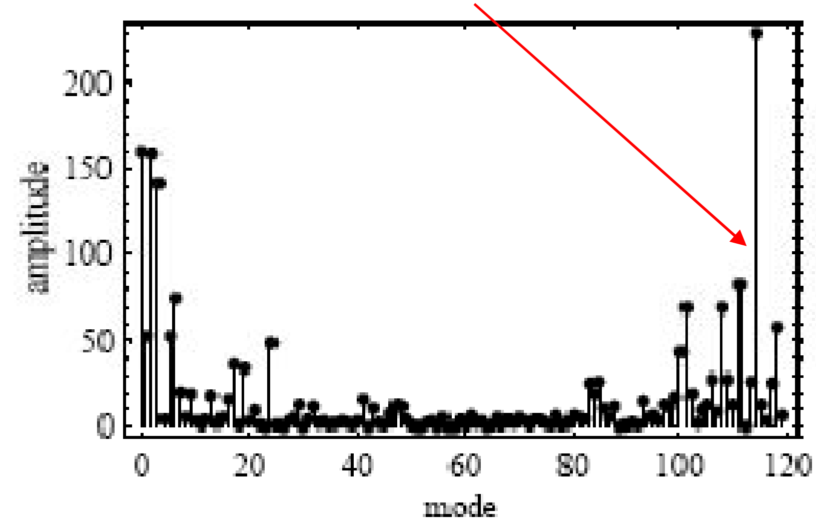
-1 mode (60-5-1=54)

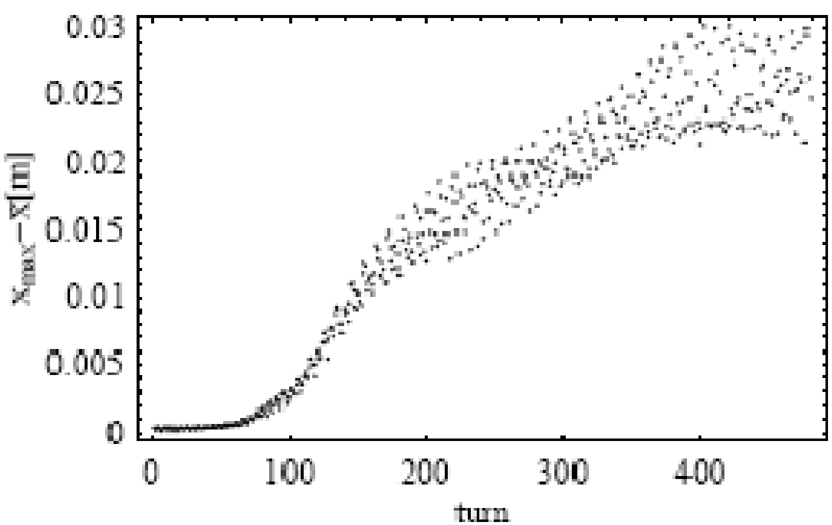


Mode spectrum and growth rate



-1 mode (120-5-1=154)





Measurment		Simulation	
I[A]/nb	τ/T_0	I[A]/nb	τ/T_0
1/105	**73**	**1.2/120**	**100**
0.75/105	56	900/120	95
0.5/105	100	600/120	130

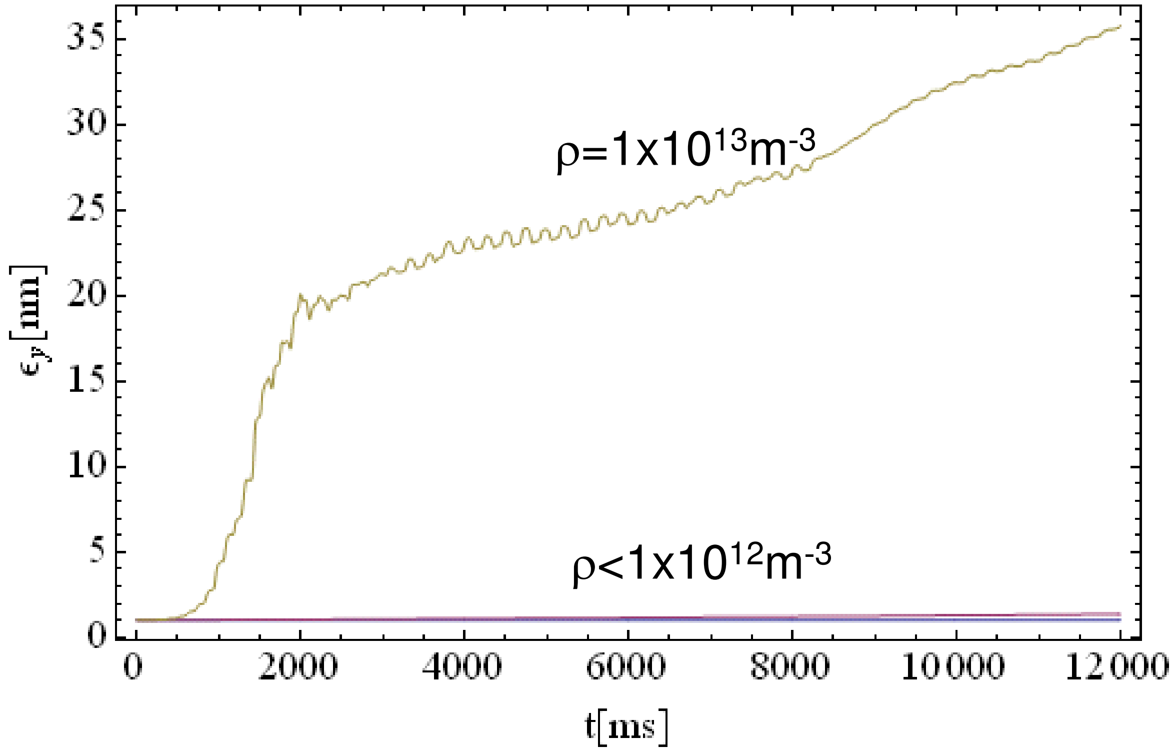
Simulation of single-bunch instability

- Simulations were performed using CMAD (M.Pivi):
  - Tracking the beam (x,x',y,y',z,δ) in a MAD lattice by 1st order and 2nd (2nd order switch on/off) transport maps
  - MAD8 or X "sectormap" and "optics" files as input
  - Apply beam-cloud interaction point (IP) at each ring element
  - Parallel bunch-slices based decomposition to achieve perfect load balance
  - Beam and cloud represented by macroparticles
  - Particle in cell PIC code 9-point charge deposition scheme
  - Define at input a cloud density level [0<r<1] for each magnetic element type

Input parameters for **CMAD**

Beam energy E[GeV]	0.51
circumference L[m]	97.588
bunch population N_b	2.1×10^{10}
bunch length σ_z [mm]	12
horizontal emittance ε_x[um]	0.56
vertical emittance ε_y [um]	0.035
hor./vert. betatron tune Q_x/Q_y	5.1/5.2
synchrotron tune Q_z	0.012
hor./vert. av. beta function	6/5
momentum compaction α	0.019

Emittance growth due to fast head-tail instability

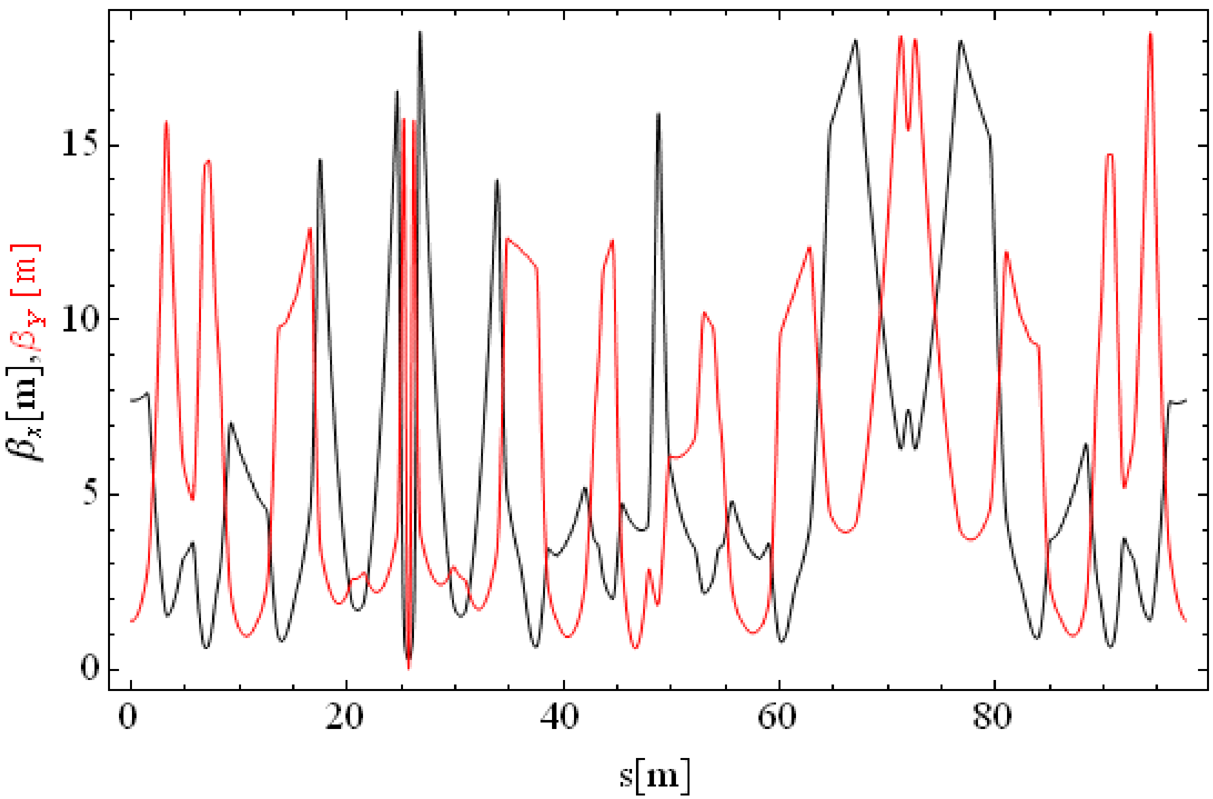


The interaction between the beam and the cloud is evaluated at 40 different positions around the DAFNE e+ ring for different values of the electoron cloud density.

The threshold density is determined by the density at which the growth starts:

$$\rho_{e,th} = 2\times10^{13}\ m^{-3}$$

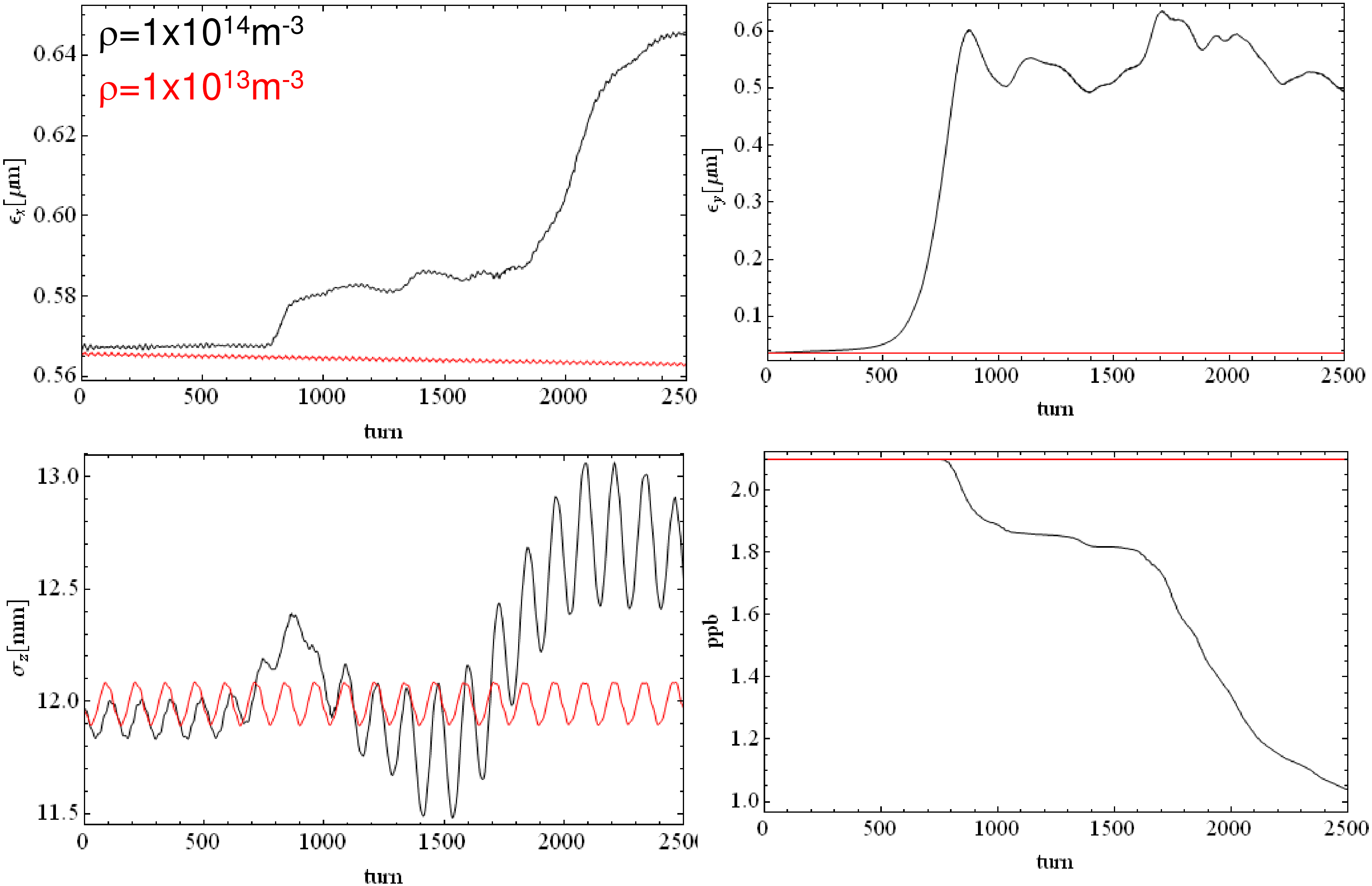
Tracking through the DAFNE ring optics



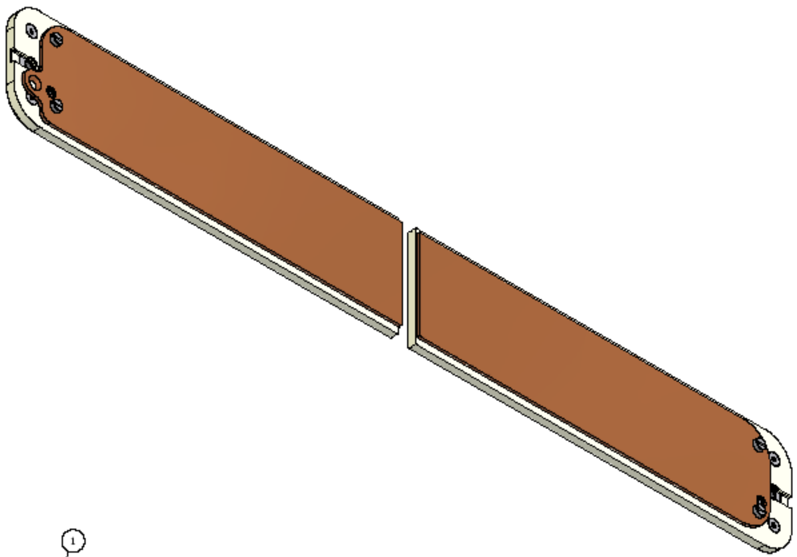
DAFNE MADX model matches quite well beam measurements (C.Milardi)

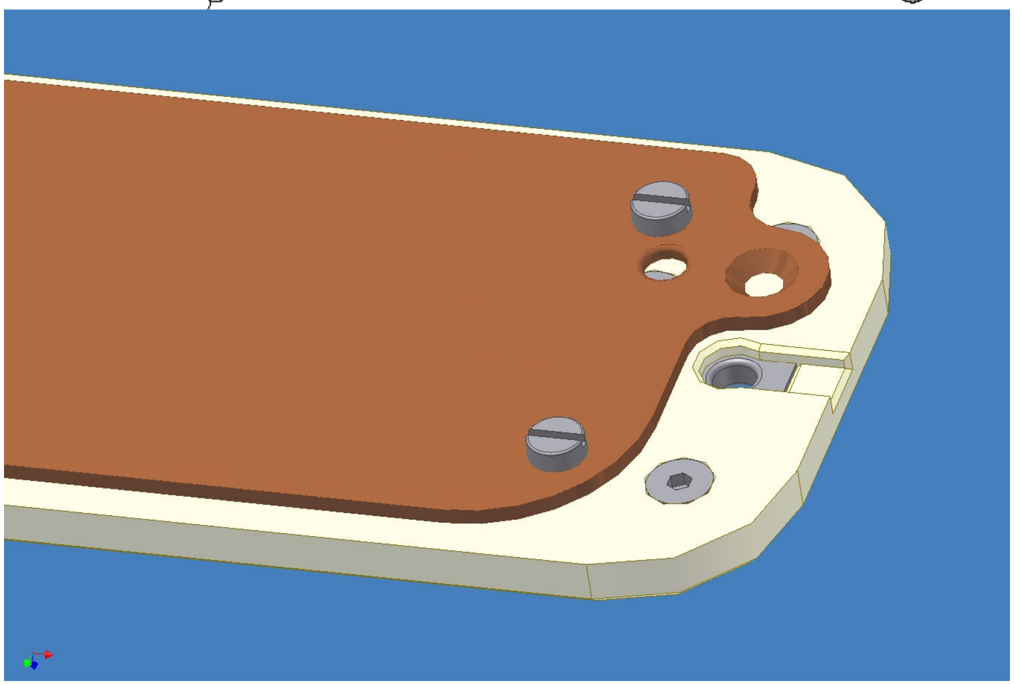
•Tracking the beam (x,x',y,y',z,d) in the DAFNE MADX lattice by 2nd order transport maps.
•Applying beam-cloud kicks in dipoles and wigglers only: assume e-cloud in field free Drift regions is mitigated by solenoids.

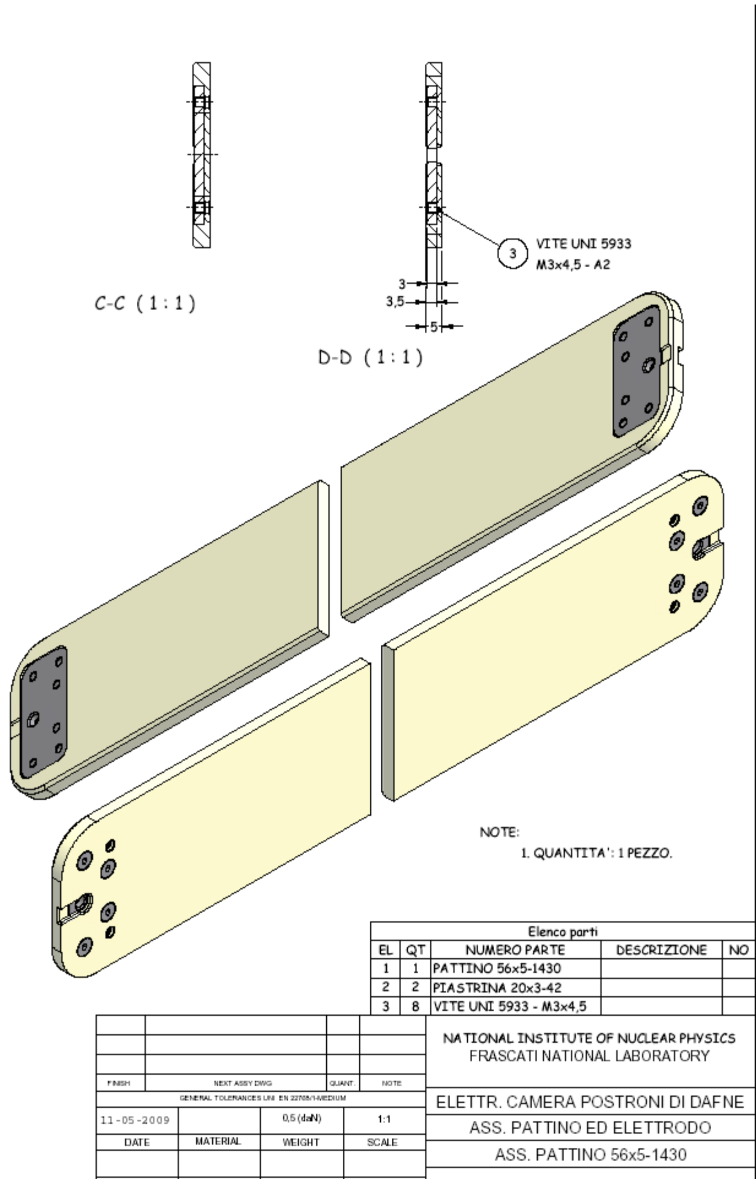
Emittance growth: solenoids on



Clearing Electrodes for DAFNE

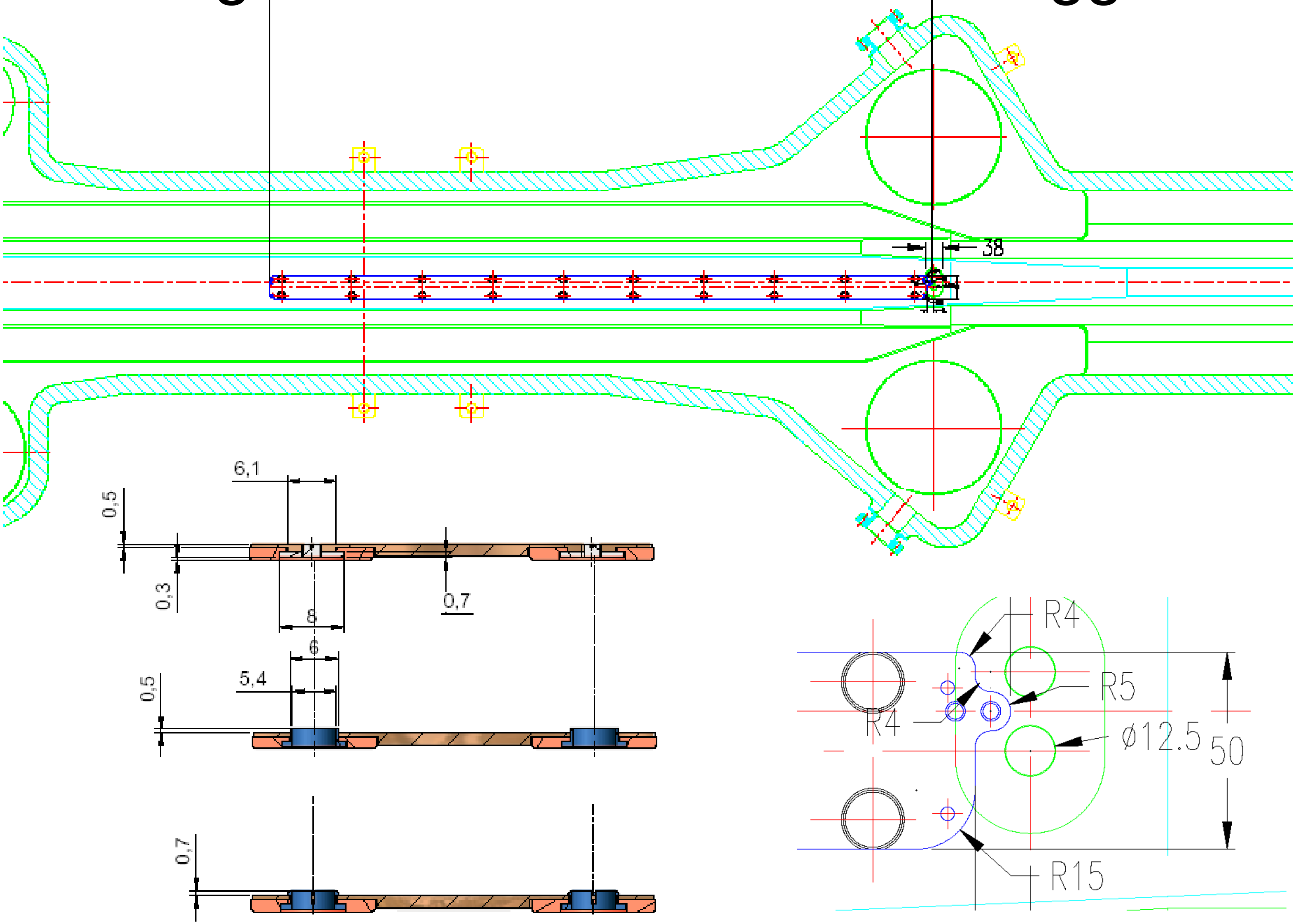






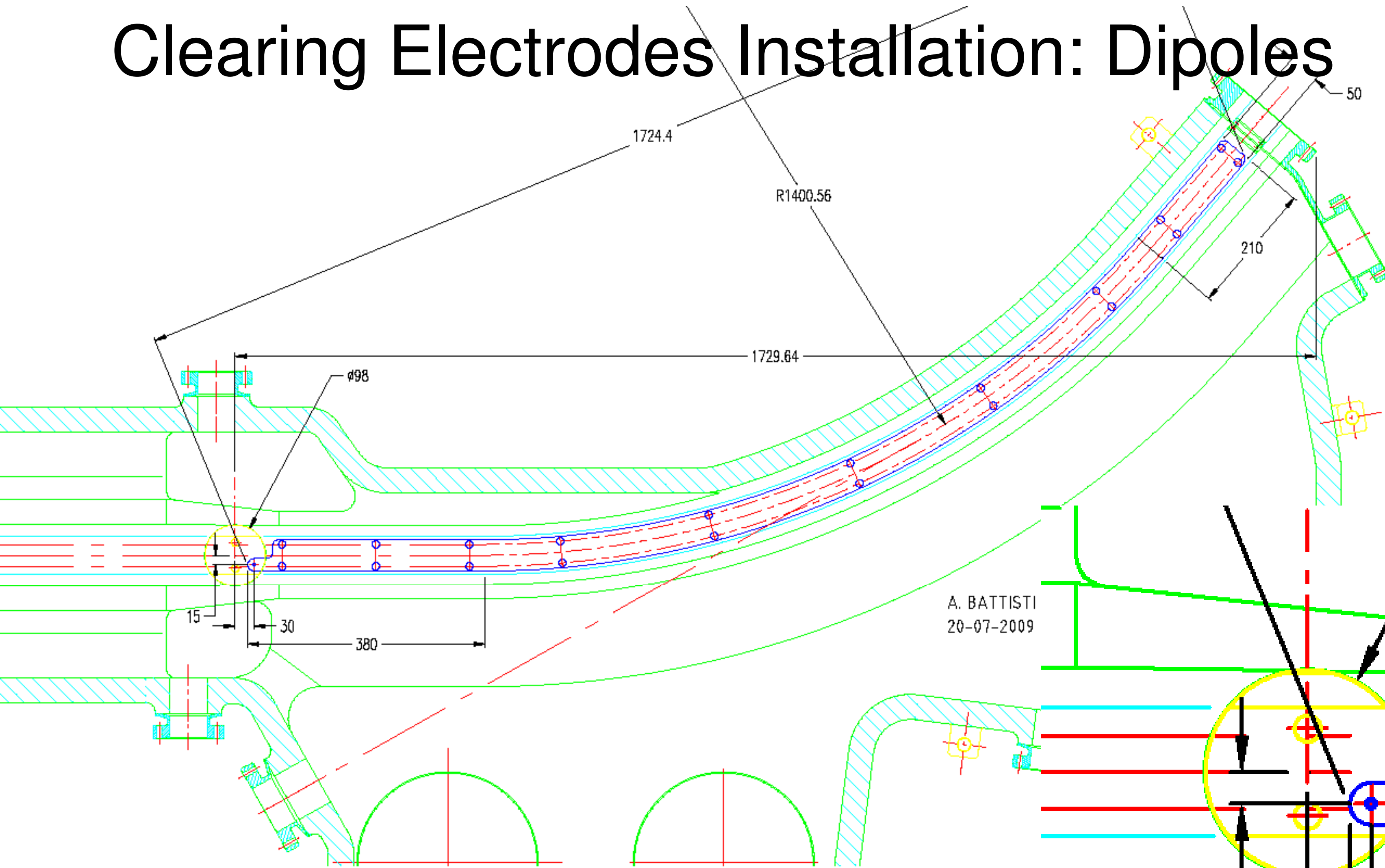
Mechanical design: A.Battisti, R. Sorchetti, V. Lollo (LNF)

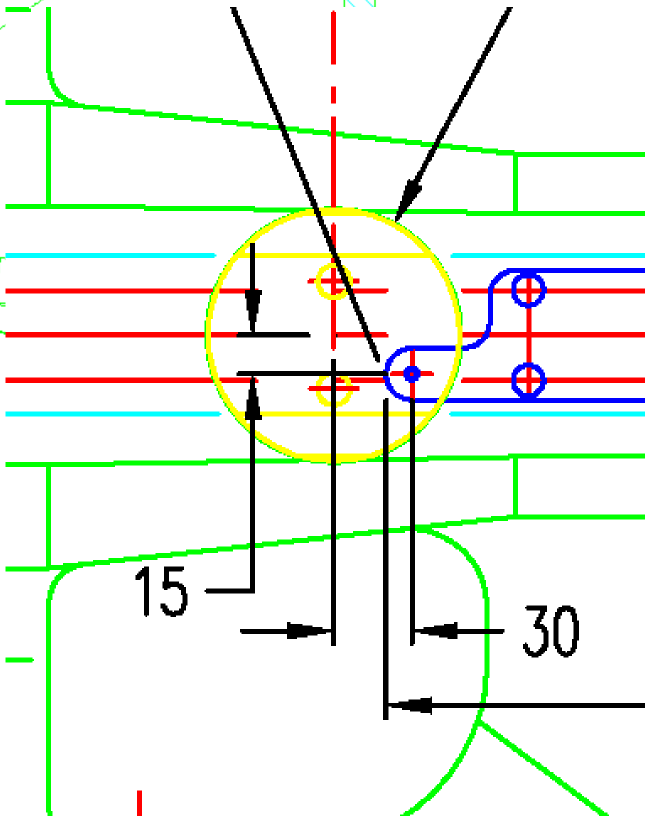
Clearing Electrodes Installation: Wigglers



Mechanical design: A.Battisti, R. Sorchetti, V. Lollo (LNF)

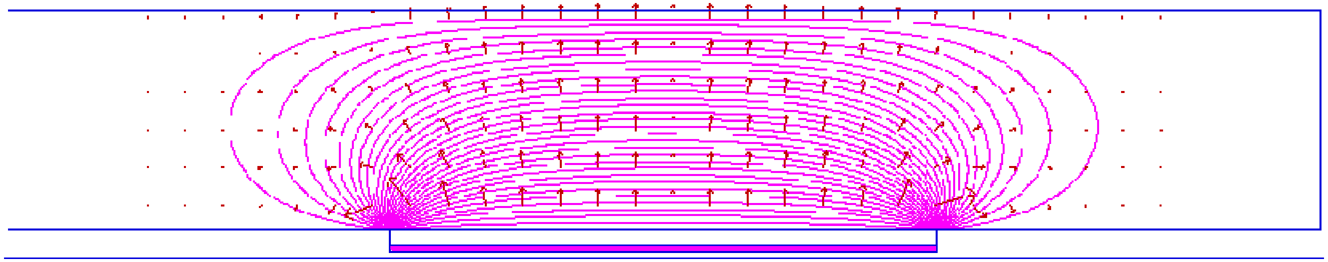
Clearing Electrodes Installation: Dipoles

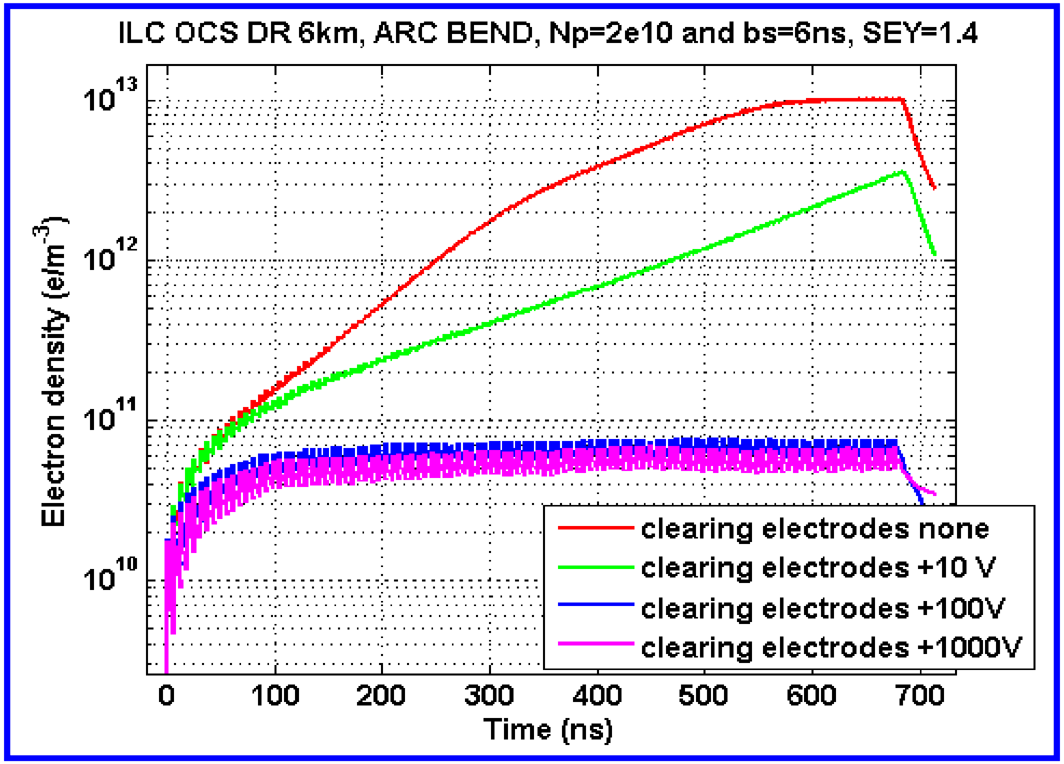




Mechanical design: A.Battisti, R. Sorchetti, V. Lollo (LNF)

Electrodes Field and e-Cloud build-up





Simulation unsing POSINST code of electron cloud build-up and suppression with clearing electrodes. ILC DR positron: assuming one single 6 km ring.

Summary

- Two separate feedback systems for the same oscillation plane work in perfect collaboration doubling the damping time, keeping I+ MAX as higher as possible
- Coupled-bunch instability has been simulated using PEI-M for the DAFNE parameters. Preliminary results are in qualitative agreement with grow-damp measurements.
- Single-bunch instability has been simulated with CMAD tracking the beam through a realistic ring optics model. Preliminary results indicate a threshold well above the current estimated e-cloud density for DAFNE (more detailed study is needed)
- The mechanical drawings of clearing electrodes for DAFNE is complete. Installation is foreseen for the next machine stop (end of 2009). Work is in progress to estimate the impedance budget.
- More work is needed to simulate a more realistic model of beam chembers in the coupled bunch instability code (taking into account also the effect of clearing electrodes)