Damping Ring R&D updates SLAC

Mauro Pivi SLAC

Allison Fero SLAC, Theo Demma INFN, Kiran Sonnad KIT and Yusuke Suetsugu KEK

Linear Collider Workshop of the Americas

Sept 29 – Oct 4, 2009

CMAD code

CMAD single-bunch instability code developed at SLAC (M.P.)

Motivations:

- **Simulation in a real lattice**
- **Parallel simulations to deal with several ring elements (> 10000) and many turns (>1000)**
- **Electron cloud build-up and instability in the same code (build-up is not in yet)**
- **Study incoherent emittance long-term growth below threshold: "real or numerical?"**

Simulation code features

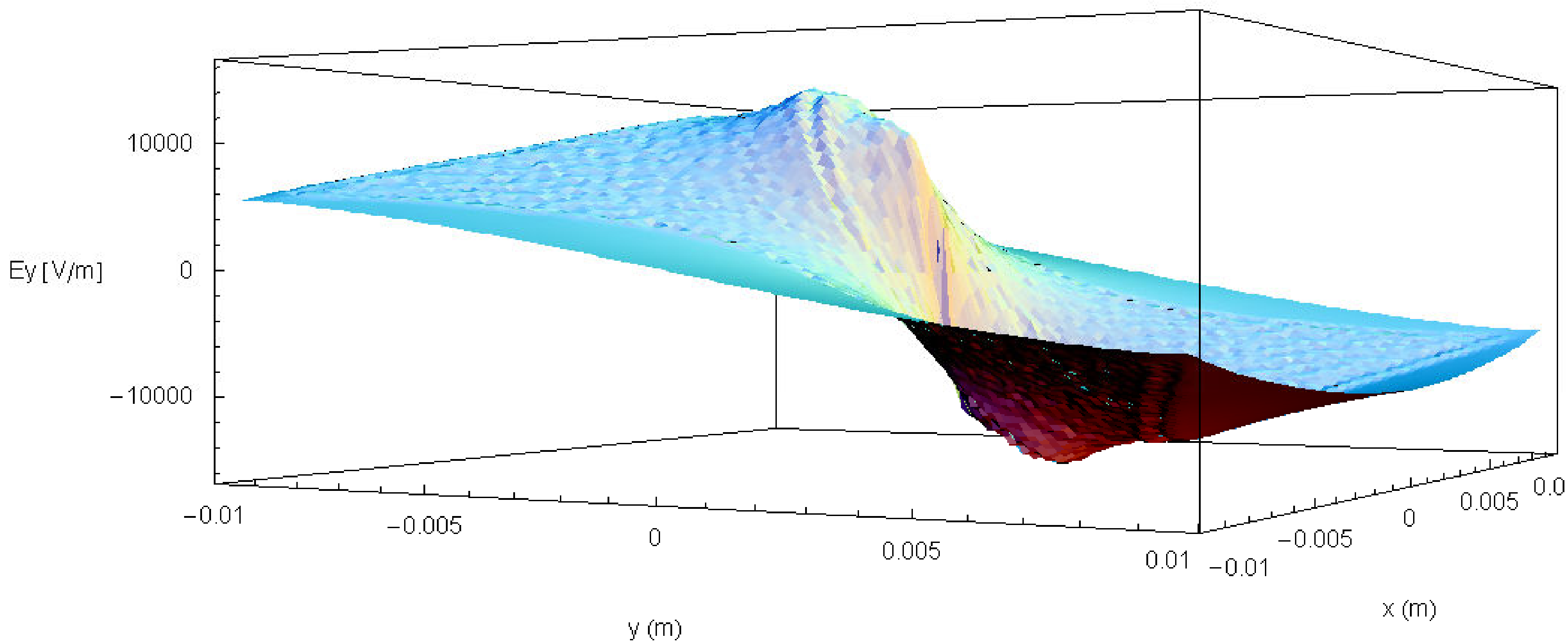
- CMAD is taking as input MAD-8 or MAD-X “optics” files, thus a real lattice.
- 6D (x,x’,y,y’,z,δ) tracking the beam with high-order transport maps in the MAD lattice
- Beta functions, dispersion, phase advance, chromaticity … are included
- Interaction between the bunch and the cloud occurs continuously at each ring element
- Multi-processor parallel simulations (highly needed!)
- Variation of the initial e- cloud density along the ring

Simulation code features

- Particle in Cell PIC code
- Beam and e- cloud represented by macroparticles: “Strong-Strong” model
- 3D electron cloud dynamics
- Magnetic fields are included in cloud dynamics
- Beam and electron cloud forces are 2D

CMAD being used at Frascati, Cornell, Karlshrue

Electron cloud forces: Electric field

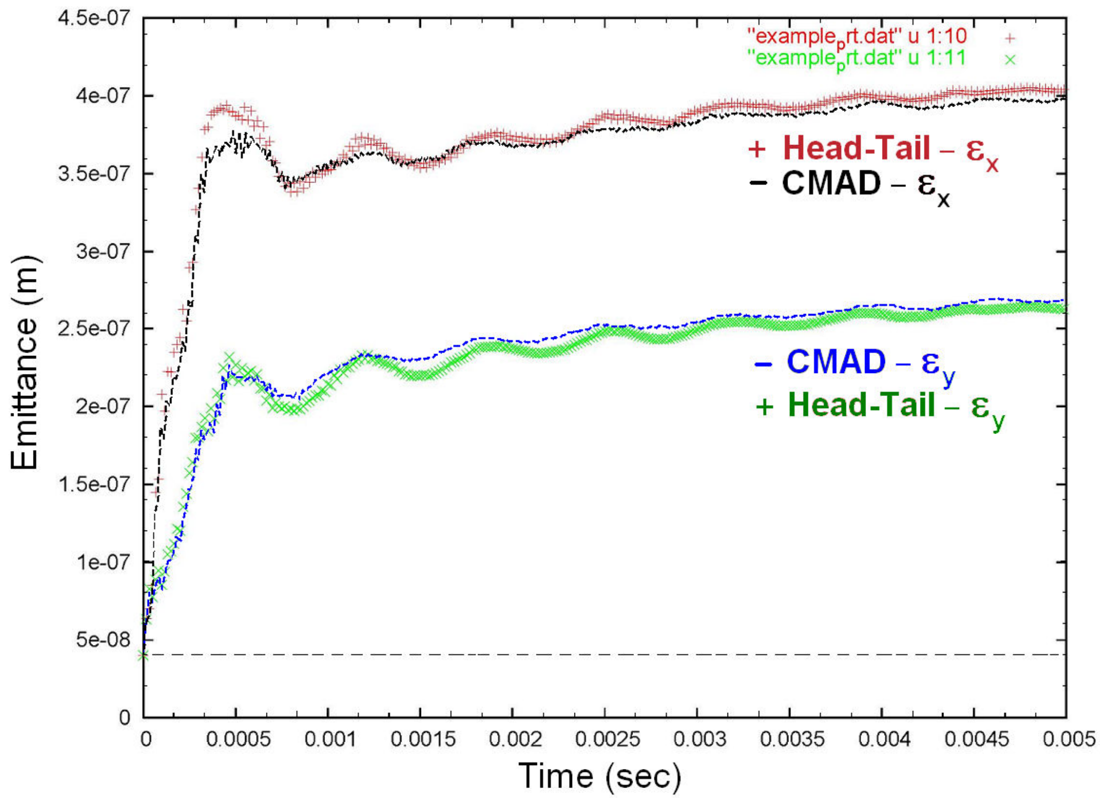


Open space: e- Cloud Vertical Electric field using 100000 macroelectrons (middle of LHC beam)

Recent codes benchmarking (1/3)

- Compare with Head-Tail (CERN) and WARP (LBNL)
  http://conf-ecloud02.web.cern.ch/conf-ecloud02/CodeComparison/modelinst.htm

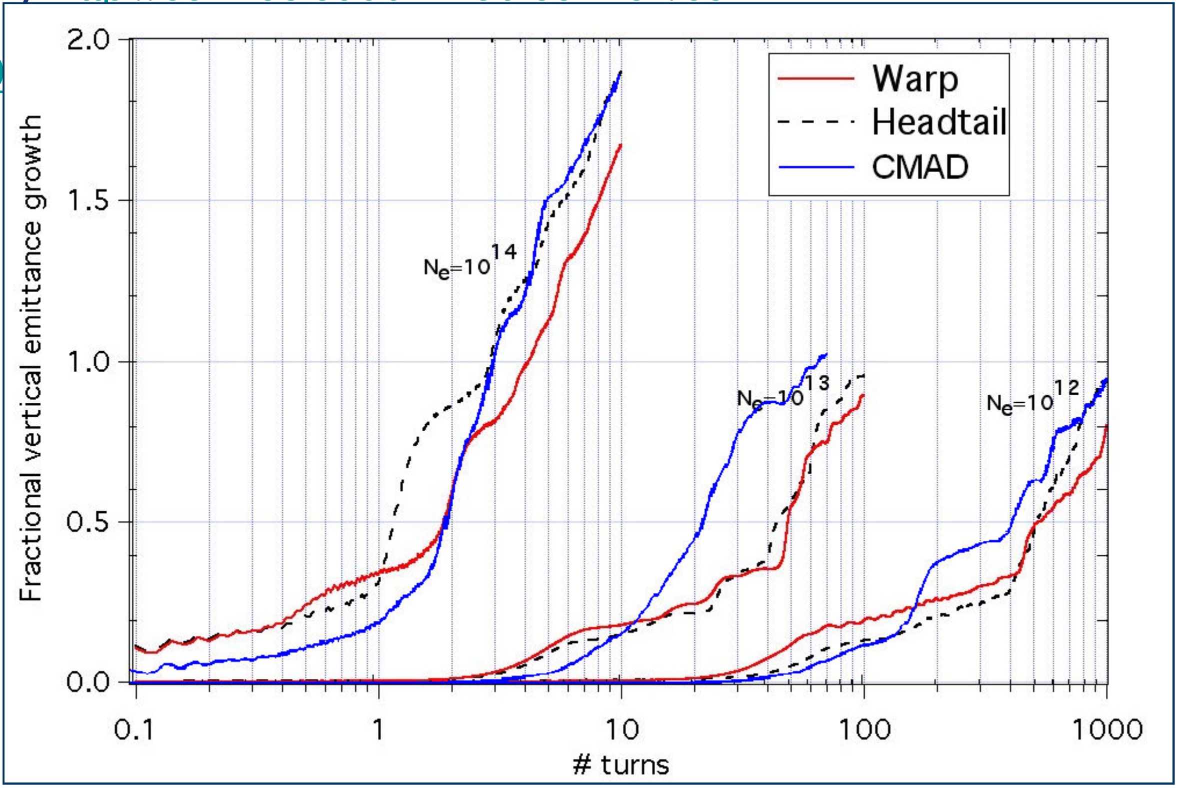
  (CERN page)
- Hea
  ben S (Ohmi,
  KEI



1 beam-cloud IP/turn, SPS with cloud density 1e12m^3. "New 2006 simulations results"

Recent codes benchmarking (2/3)

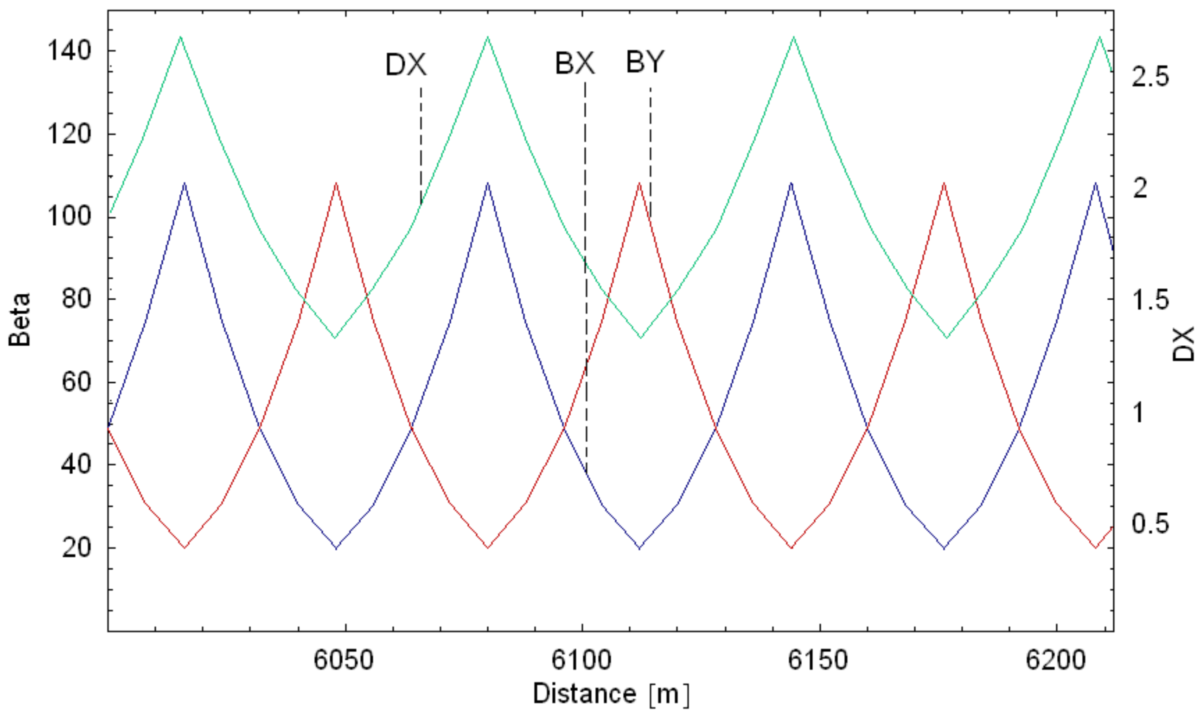
- Compared with Head-Tail (G. Rumolo, R. Thomas CERN) and WARP (J-L Vay and Kiran Sonnad LBNL) http://conf-ecloud02.web.cern.ch/conf-ecloud0



100 beam-cloud IP/turn. LHC with cloud density 1e12 to 1e14m^-3. 2008 simulations results. Constant beta function. Magnetic free region.

Recent codes benchmarking (3/3)

SPS/CERN lattice simplified from MADX with 250 beam-cloud interactions IP/turn.

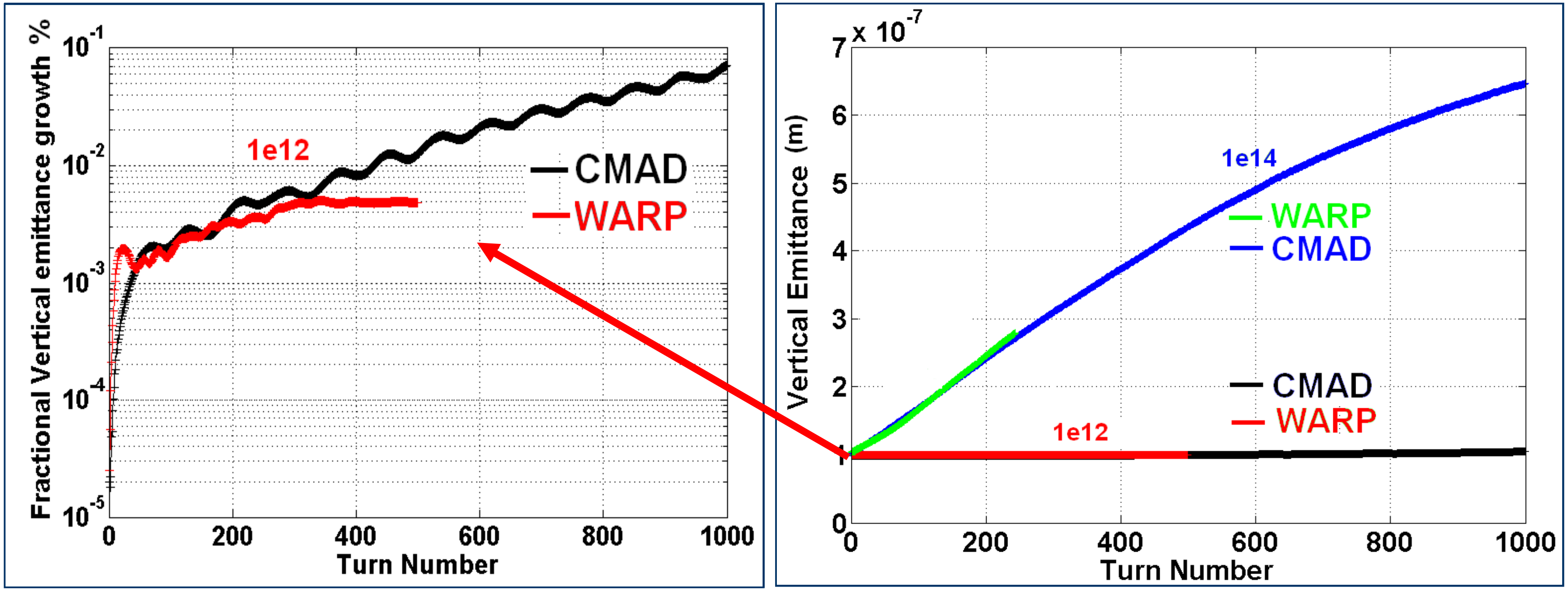


Energy (GeV)	26
Bunch population	1.15e11
Synchrotron tune	0.00592
Emittance (m)	1e-7
σz	0.24
dp	0.003887
α	1.63539
Qx’, Qy’	0

Benchmarking proposed by F. Zimmermann; Simplified lattice by R. Thomas.

Recent codes benchmarking (3/3)

SPS/CERN lattice simplified from MADX with 250 beam-cloud interactions IP/turn.

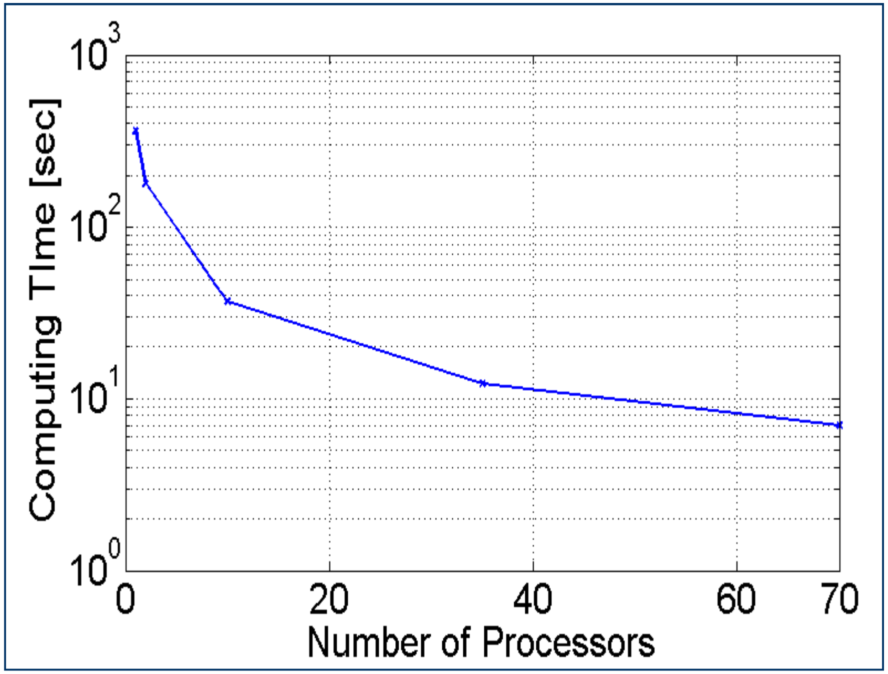


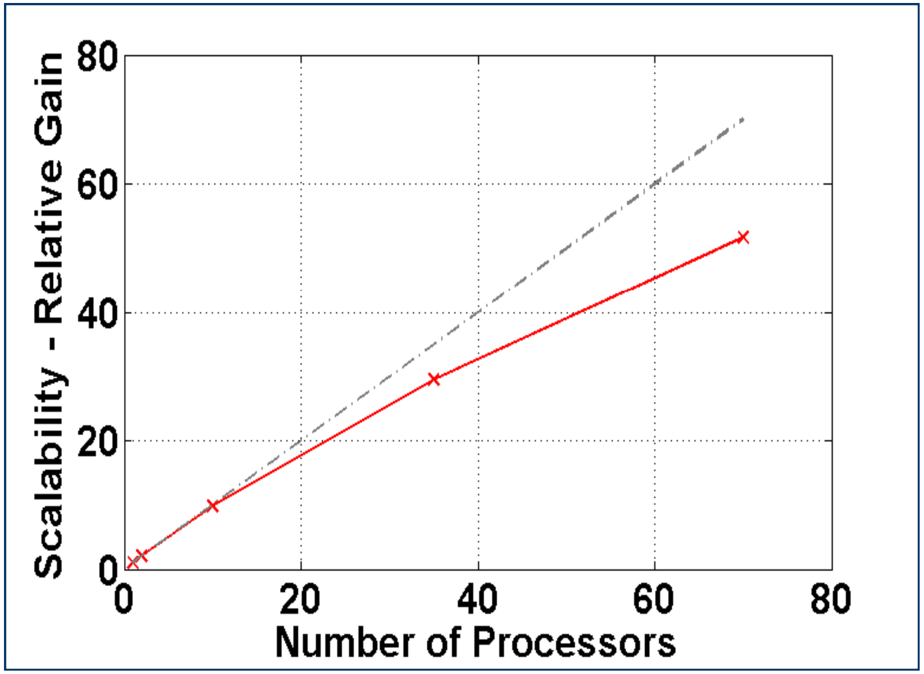
[CMAD run 3.5 hours at rate 13 sec/turn on Franklin/NERSC machine with 64 processors]

Benchmarking in collaboration with Kiran Sonnad and J-L Vay

Scalability of parallel computation

- Typically ~70-100 computer processors used
- Example: gain factor 53 in speed with 70 processors





Computing time (using NERSC computers) vs number of processors; example: LHC with 100 interactions / turn

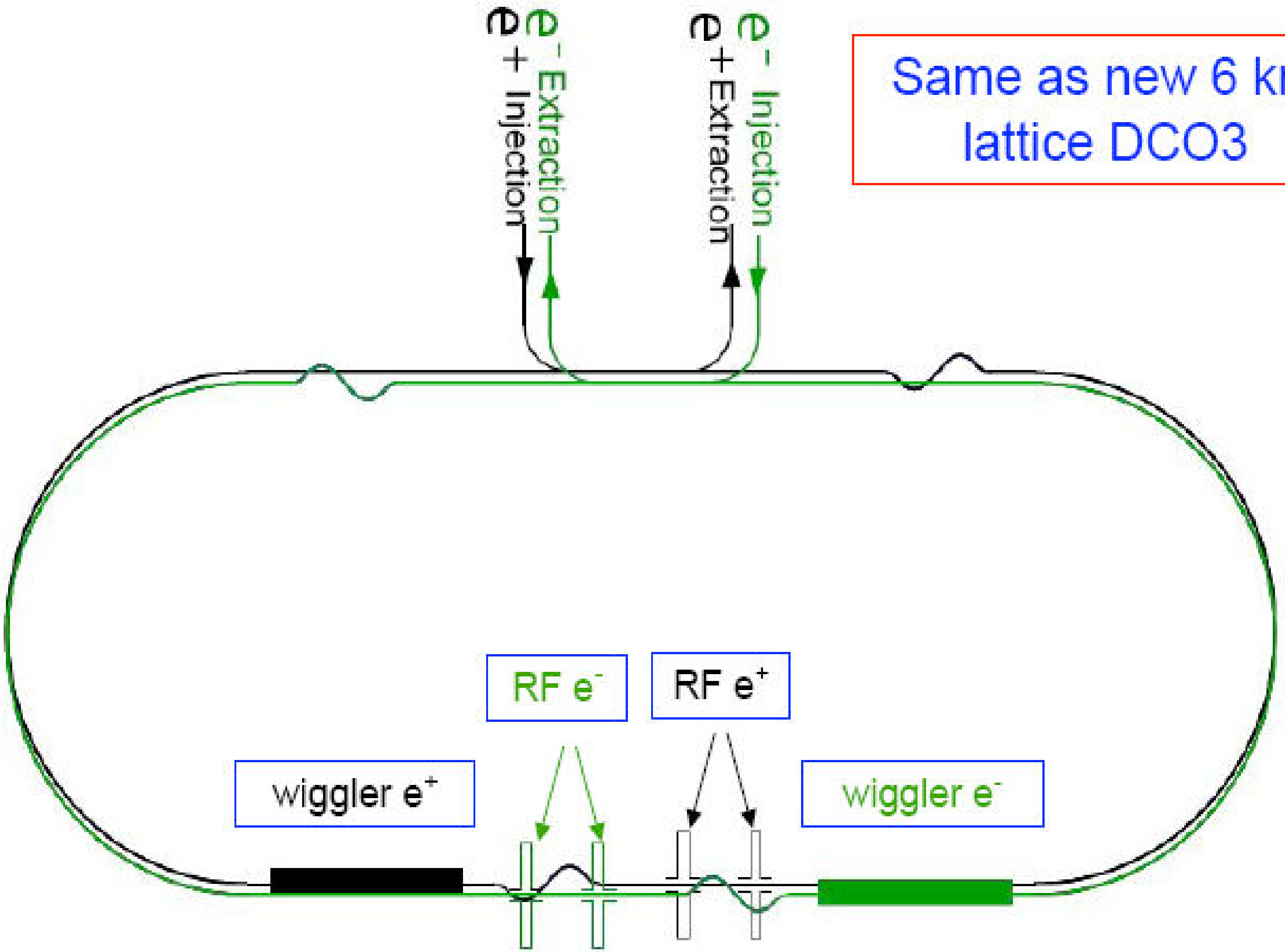
ILC DR

- ILC DR “DSB3” 3km version from Guiducci, Biagini INFN

	DSB3	DC02
Circumference (m)	3238	6476
Energy (GeV)	5	5
Bunch population	2e10	2e10
Synchrotron tune	0.01663	0.038
Emittance H (m)	3.5e-10	8e-10
Emittance V (m)	2e-12	2e-12
σz (cm)	6	6
dp	1.45e-3	1.28e-3
α	0.133E-03	0.17E-03
Qx, Qy	57.505, 32.954	75.20, 71.40
Qx’, Qy’	0	0

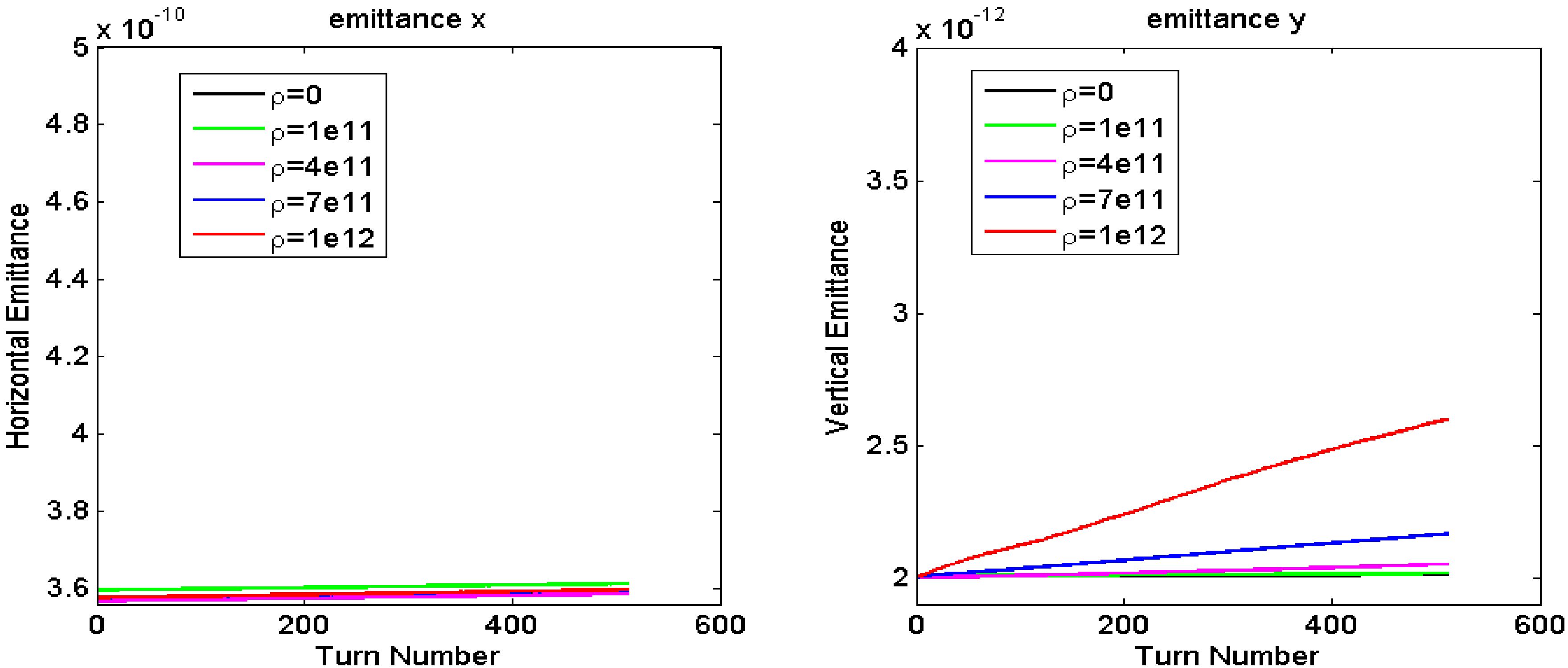
e^+/e^- Layout

Same as new 6 km lattice DCO3



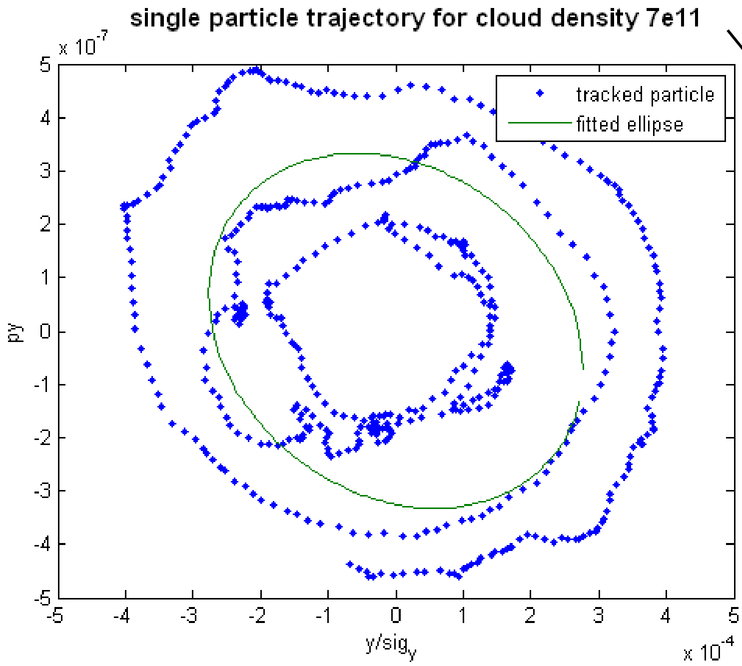
Susanna Guiducci, Jul 2009

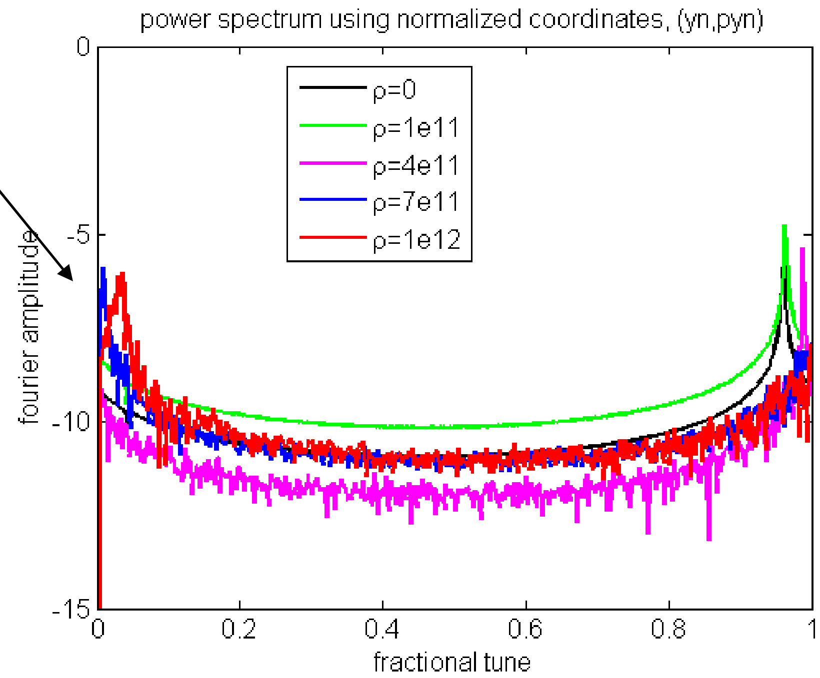
Emittance growth



CMAD simulations

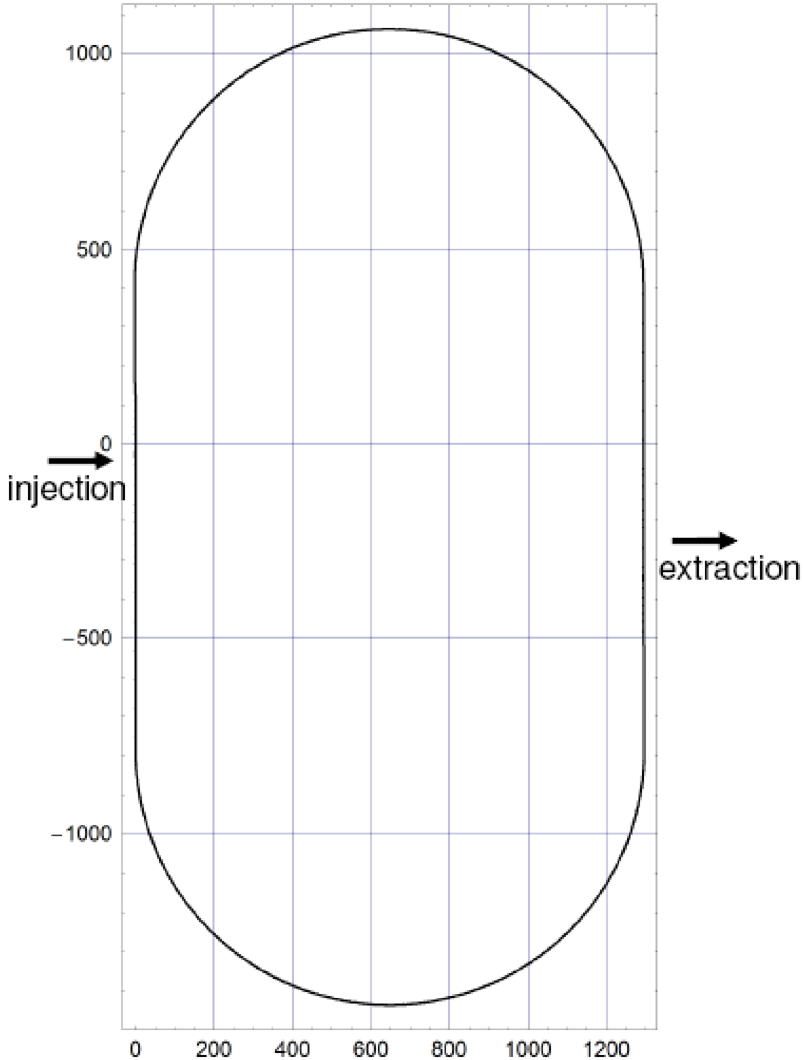
Fourier Spectrum of trajectories





CMAD simulations

ILC DR 6km layout



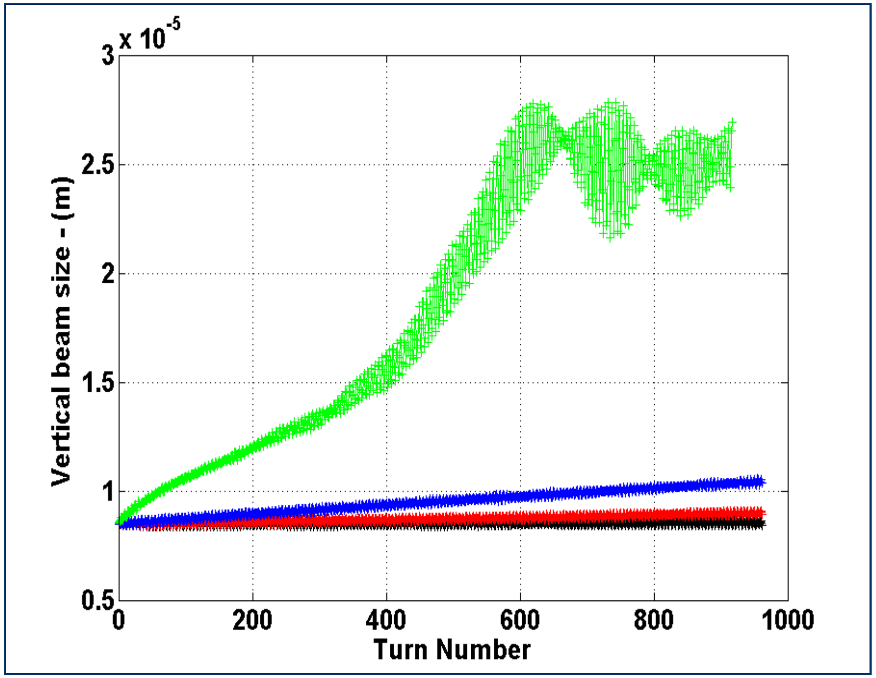
- Arcs consist of a total of 192 FODO cells
- Flexibility in tuning momentum compaction factor, given by phase advance per arc cell:
  - **72° phase advance: α_p=2.8×10^{-4}**
  - **90° phase advance: α_p=1.7×10^{-4}**
  - **100° phase advance: α_p=1.3×10^{-4}**
- No changes in dipole strengths needed for different working points.
- Racetrack structure has two similar straights containing:
  - **injection and extraction in opposite straights**
  - **phase trombones**
  - **circumference chicanes**
  - **rf cavities**
  - **"doglegs" to separate wiggler from rf and other systems**
  - **wiggler**

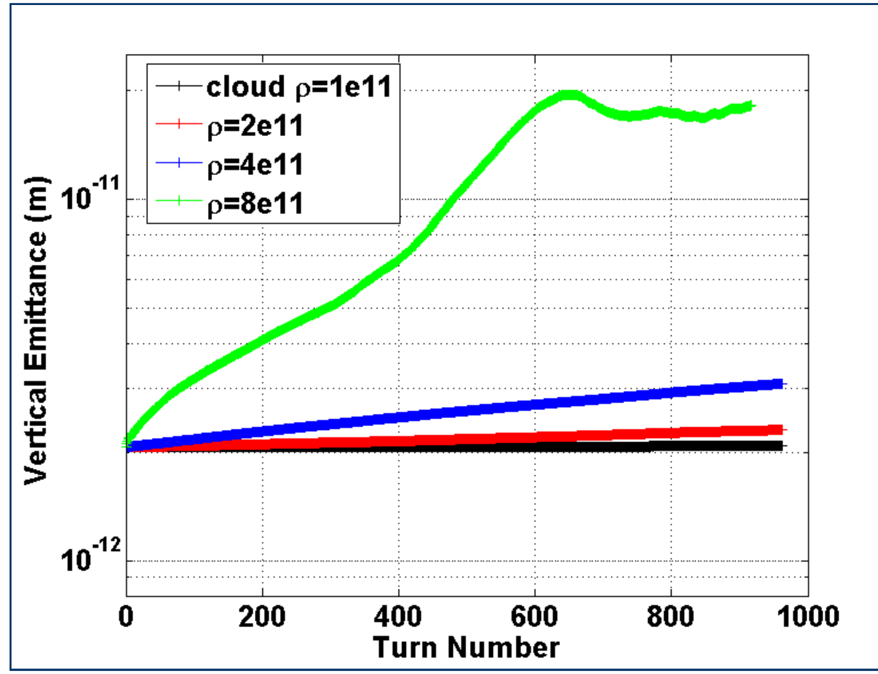
Major Parameter

Beam energy	5 GeV
Circumference	6476.440 m
RF frequency	650 MHz
Harmonic number	14042
Transverse damping time	21.0 ms
Natural rms bunch length	6.00 mm
Natural rms energy spread	1.27×10^{-3}

Phase advance per arc cell (approximate)	72°	90°	100°
Momentum compaction factor	2.80×10^{-4}	1.73×10^{-4}	1.29×10^{-4}
Normalised natural emittance	6.53 μm	4.70 μm	4.27 μm
RF voltage	31.6 MV	21.1 MV	17.2 MV
RF acceptance	2.35%	1.99%	1.72%
Synchrotron tune	0.061	0.038	0.028
Horizontal tune	64.750	75.200	80.450
Natural horizontal chromaticity	-76.5	-95.1	-106.9
Vertical tune	61.400	71.400	75.900
Natural vertical chromaticity	-75.6	-93.4	-103.5

DC02 6km ring

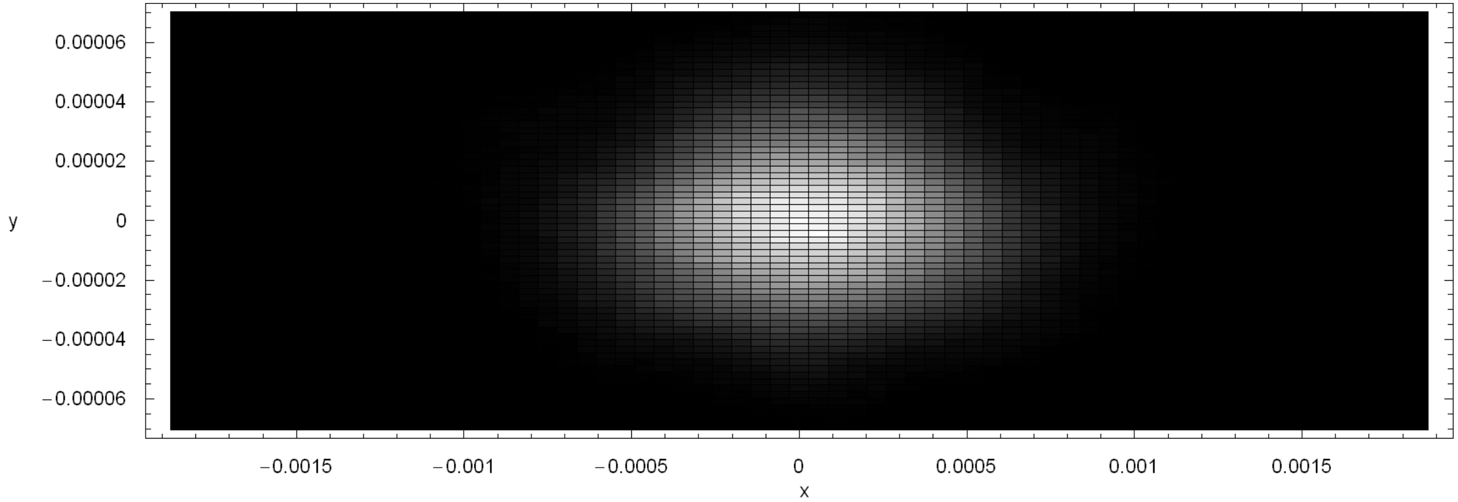




CMAD simulations

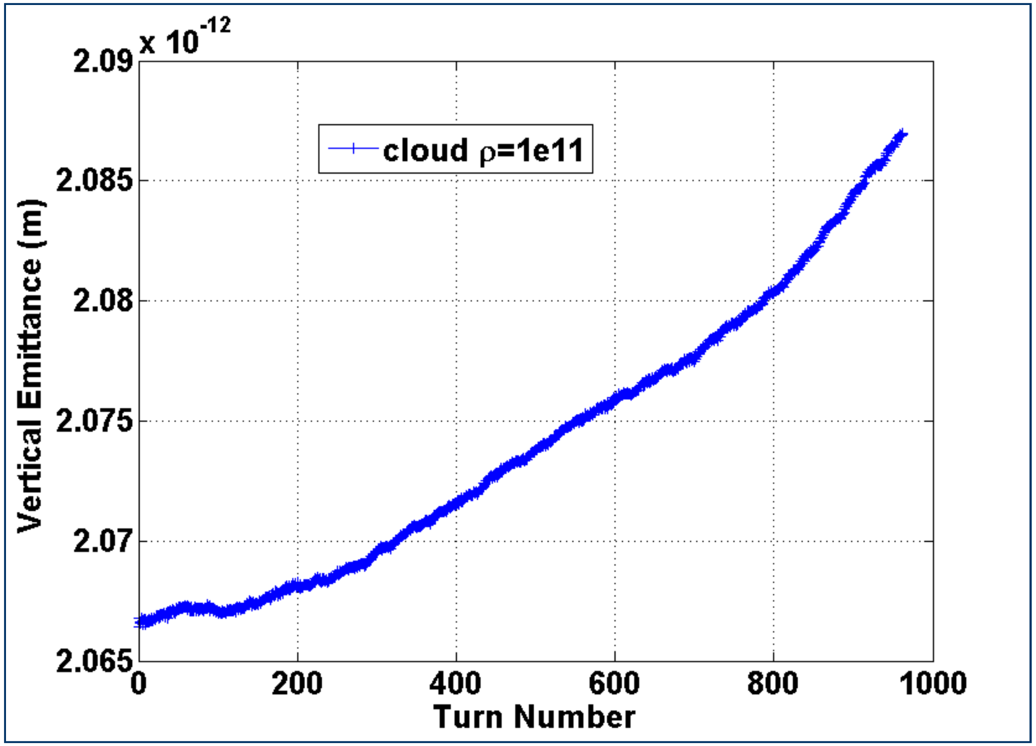
- Horizontal emittance small increase
- Threshold ~8e11 e/m^3
- In the 8e11 case, also beam losses of 40%

Beam-size monitor



End of run 8e11 e/m^3

6km DR Simulations



CMAD simulations

Incoherent emittance growth <u>below</u> instability threshold:

Next: include radiation damping and quantum excitations

…

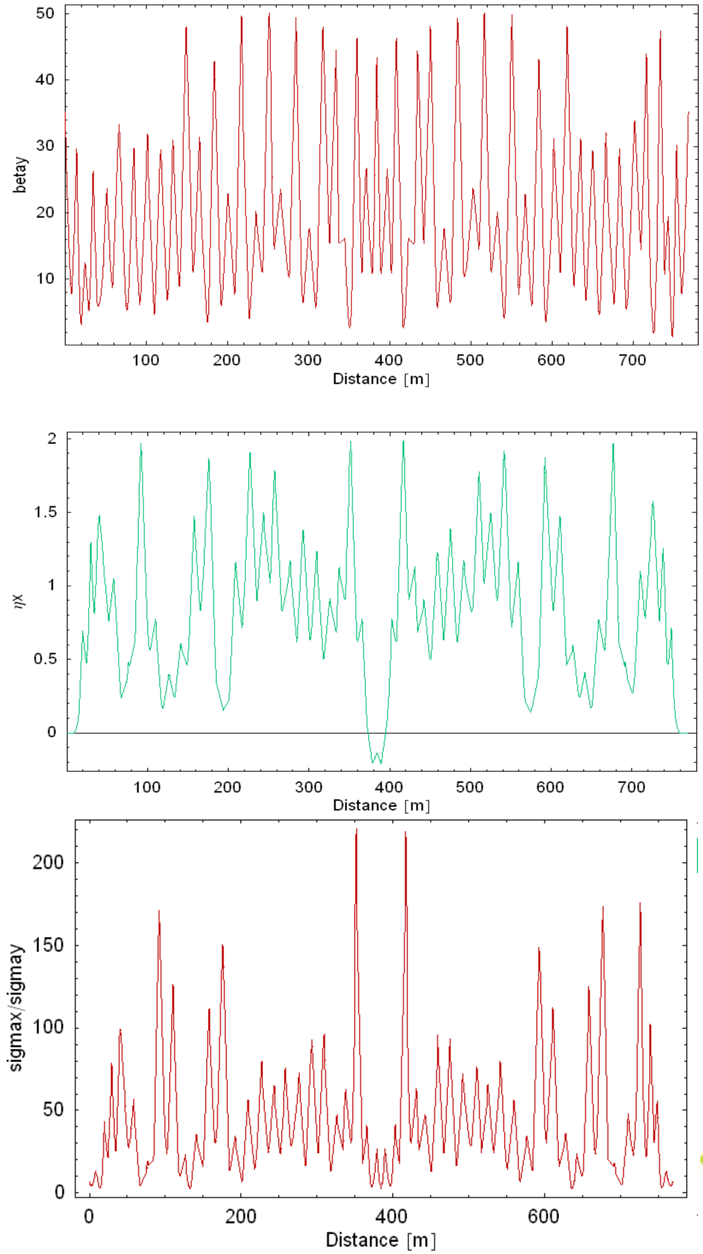
CesrTA simulations

- CesrTA simualtios using CMAD (M. Pivi, Kiran Sonnad and Theo Demma) possibly benchmarking with PEHTS and/or WARP.
- Showing results for the MAD lattice: cta_4000mev_20090814.mad8
  - **cloud density threshold for emittance blow-up**
  - **Tune shifts and tune footprint**
  - **Features of instability**
- In parallel with CesrTA operations (FY09-FY10)
  - **Experimentally determine electron cloud density threshold for single-bunch instability at CesrTA**
- Purpose is to tune simulation codes on CesrTA for ILC DR simulations

CesrTA simulations

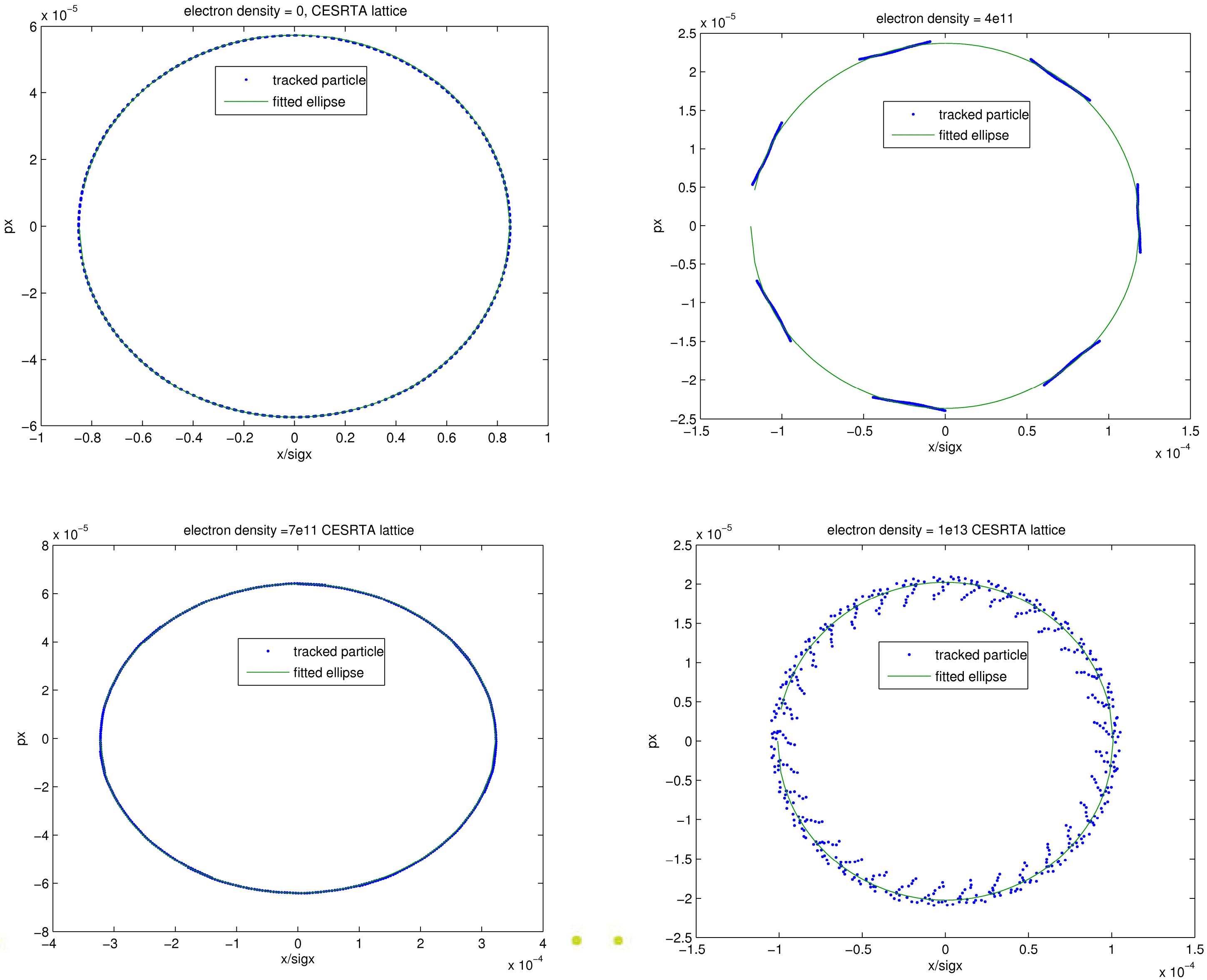
- To compare with other codes: we run the model with 40 beam-cloud interaction points along the ring and constant beta functions (not showed here) instead of a complete real CesrTA lattice

CesrTA 4GeV lattice simulations



	CesrTA
Circumference (m)	768
Energy (GeV)	4
Bunch population	2e10
Synchrotron tune	0.00510
Emittance (m)	1e-7
Emittance (m)	1e-7
σz (cm)	13.5
dp	8.9e-4
α	0.63e-2
Qx', Qy'	0

Single Particle Trajectory in x

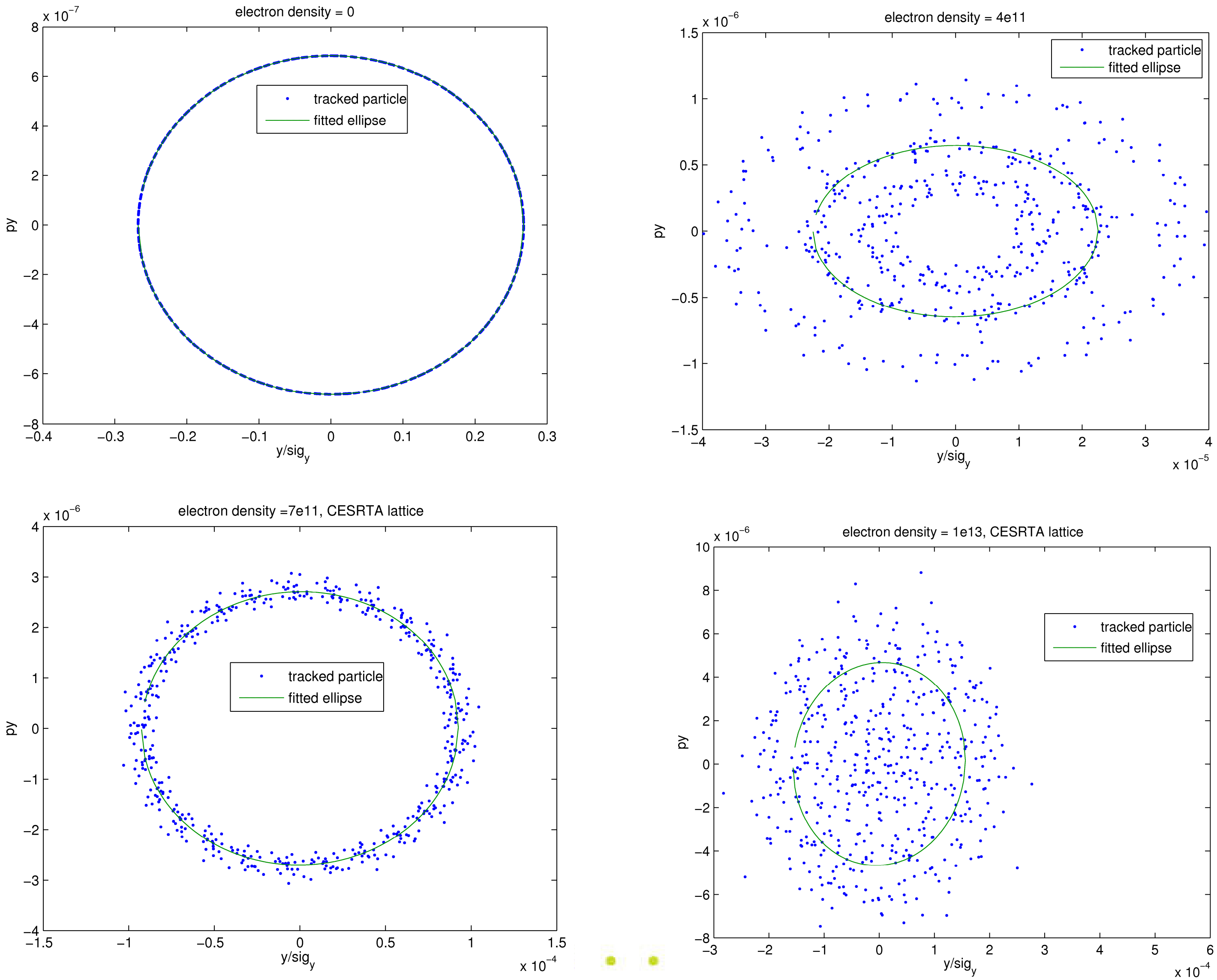


Simulation runs 27-28 Sep 2009

CMAD

Kiran Sonnad KIT, M. Pivi SLAC, T. Demma INFN

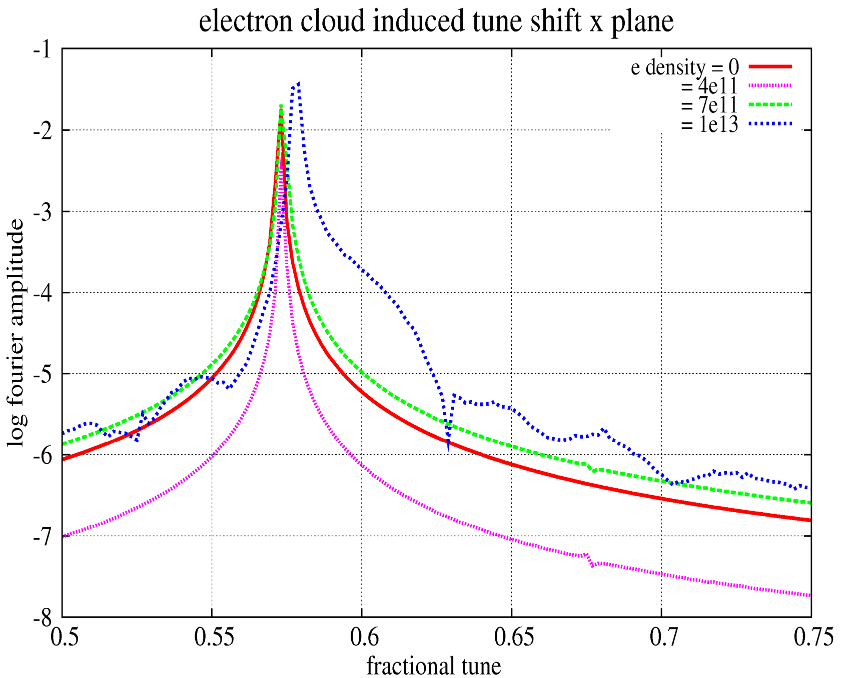
Single Particle Trajectory in y

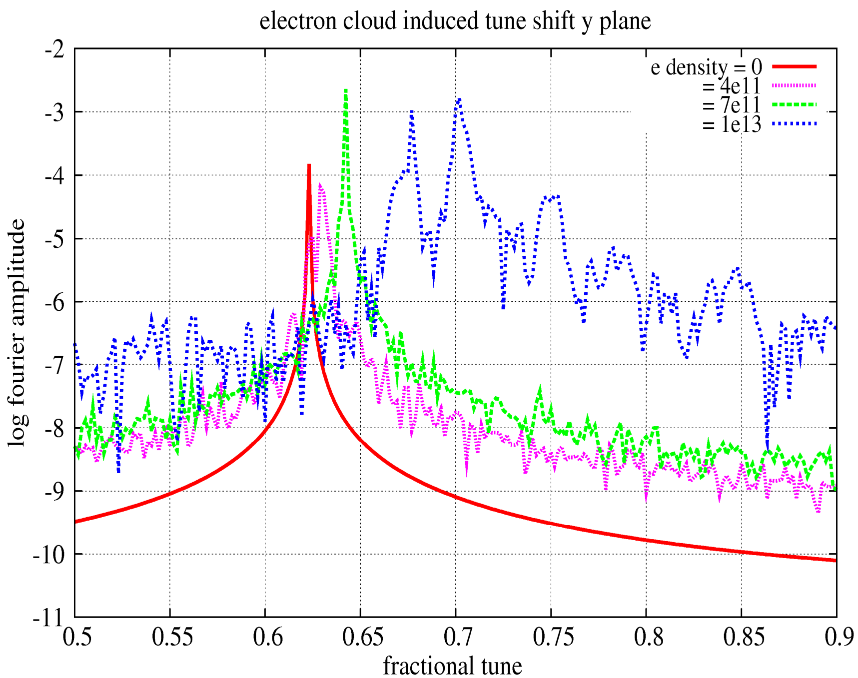


CMAD simulations

Kiran Sonnad KIT, M. Pivi SLAC, T. Demma INFN

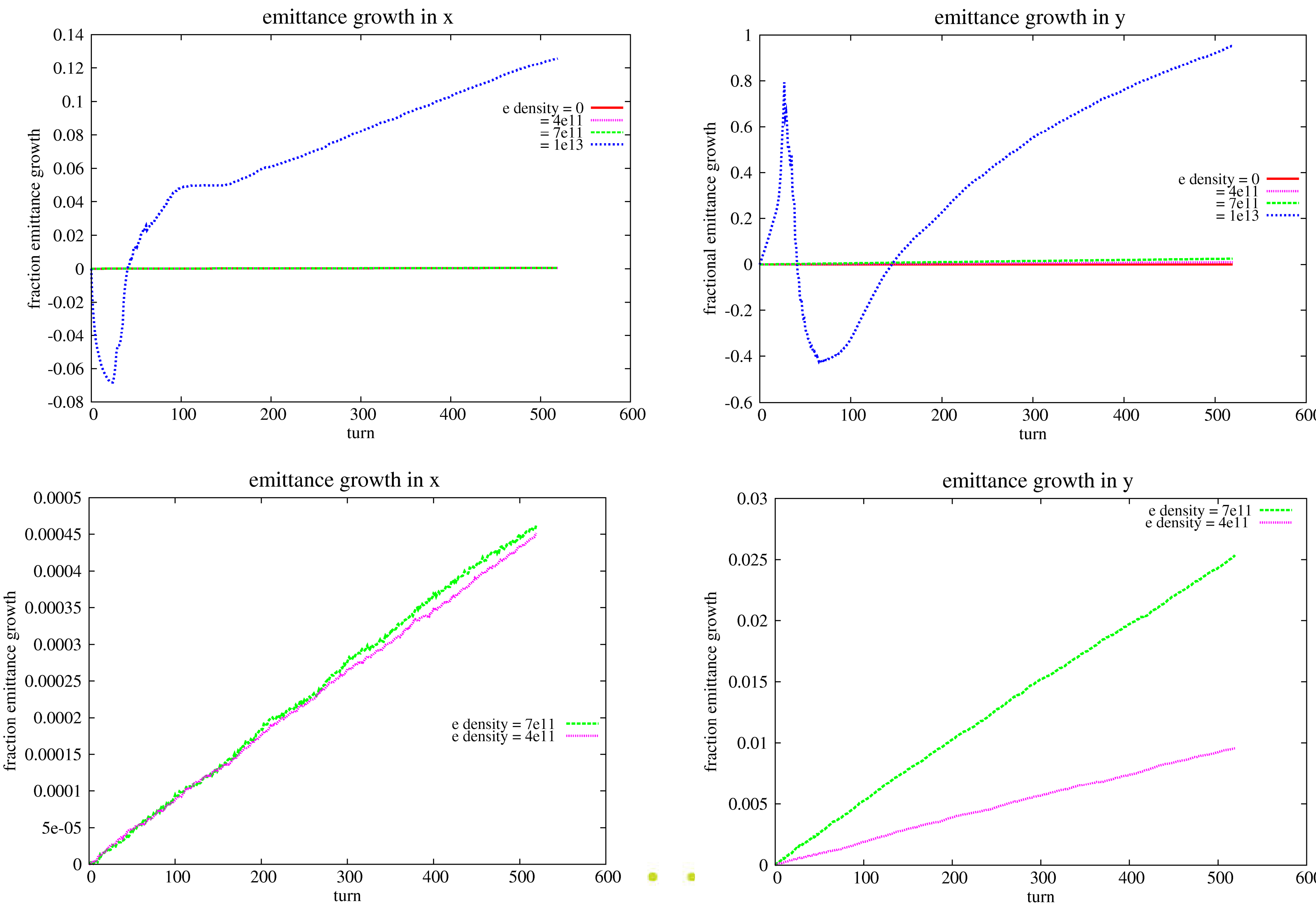
Fourier Spectrum of trajectories





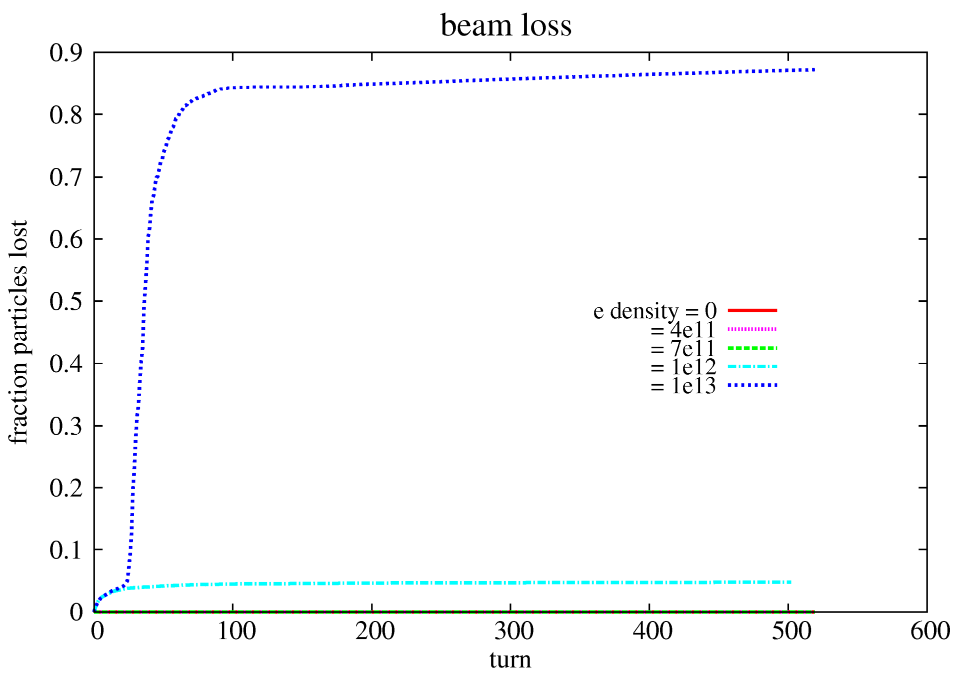
CMAD simulations by Kiran Sonnad KIT, M. Pivi SLAC, T. Demma INFN

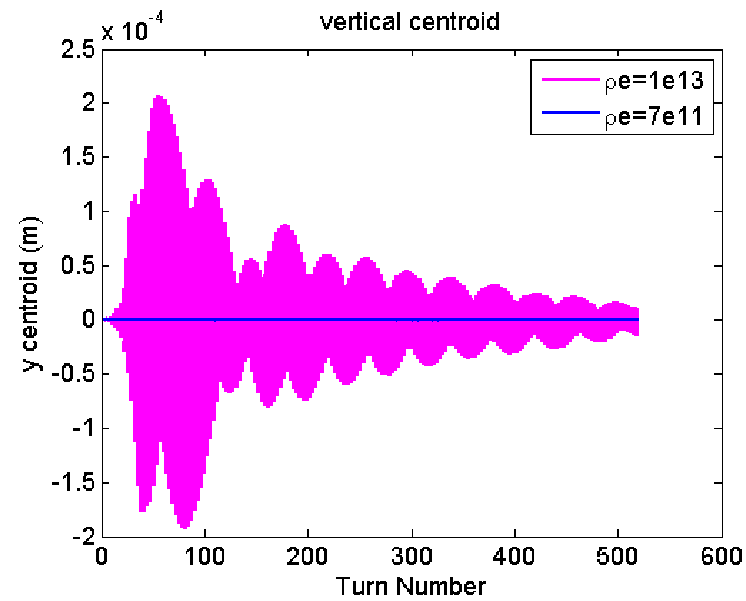
Emittance growth



CMAD simulations by Kiran Sonnad KIT, M. Pivi SLAC, T. Demma INFN

Beam losses





- Need transverse feedback in realistic simulations?!

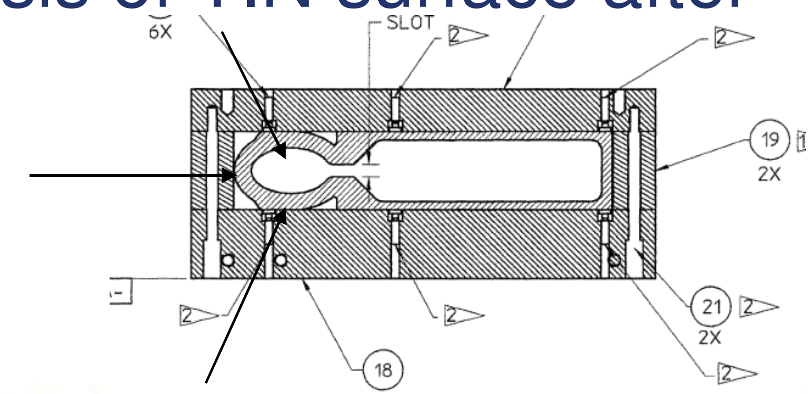
Single-bunch instability in CesrTA

Possible Studies:

- Possibly run with large number of bunches (>100) to reach an equilibrium cloud density after build-up.
- Measure X-ray monitor beam sizes blow-up as a function of bunch position in the train
- Dependence of instability/tune shift on beam energy
- In case of suspected head-tail, vary chromaticity to verify its dependence
- Verify the long-term incoherent emittance growth below threshold by varying positron bunch current
- Transverse feedback on / off
- Test different working points in tune space
- (possible?!) measure equivalent of tune spread footprint of a single bunch

TiN coating PEP-II chambers

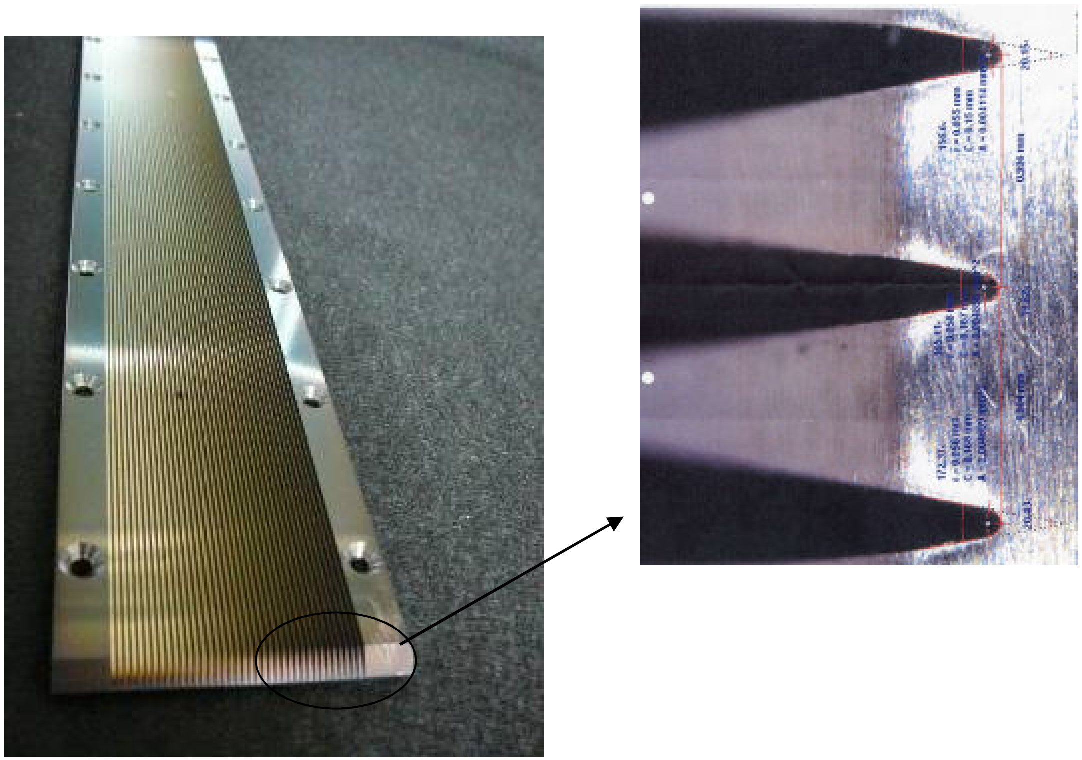
- PEP-II chamber analysis of TIN surface after 10 years operation



SECTION A–A

Groove tests in KEKB

5mm groove tests in KEKB: successfull reduction up to one order of magnitude less cloud current



Y. Suetsugu, H. Fukuma KEK, M. Pivi, L. Wang SLAC

New 2mm groove manufactured at KEK. SLAC-KEK design.

Summary

Code Benchmarking

of single-bunch instability codes is very good

Simulation results

- At first analysis, instability threshold for ILC DR DSB3 3km lattice is higher then DC02 90deg 6km lattice

- CesrTA results for 4GeV lattice

- More simulation confirmation of the incoherent emittance growth below threshold

  - **(Need to include radiation damping and quantum excitations)**

Next

CesrTA simulations at different energies

complete ILC DR simulations for 6km and 3km rings

CesrTA: 40 IPs instead of real lattice

- Model: use 40 interaction points beam-cloud along the ring and with constant beta function instead of real lattice to compare with other codes