WP3 - Damping Ring

S. Guiducci

EUROTeV Workshop

Orsay 15-17 May 2006

International Context

- The EUROTeV study will form part of the European contribution to the design of the ILC
- The WP3 plans are well integrated into the Global Design Effort (GDE).
- WP3 participants where actively involved in the choice of Damping Rings layout and circumference
- This process started at the 2nd ILC Workshop, Snowmass August 05, and was finalized at CERN DR meeting, 9-11 November with a recommendation for the **ILC Baseline Configuration**

WP3 - ECLOUD Task
Status & Progress
May 2006

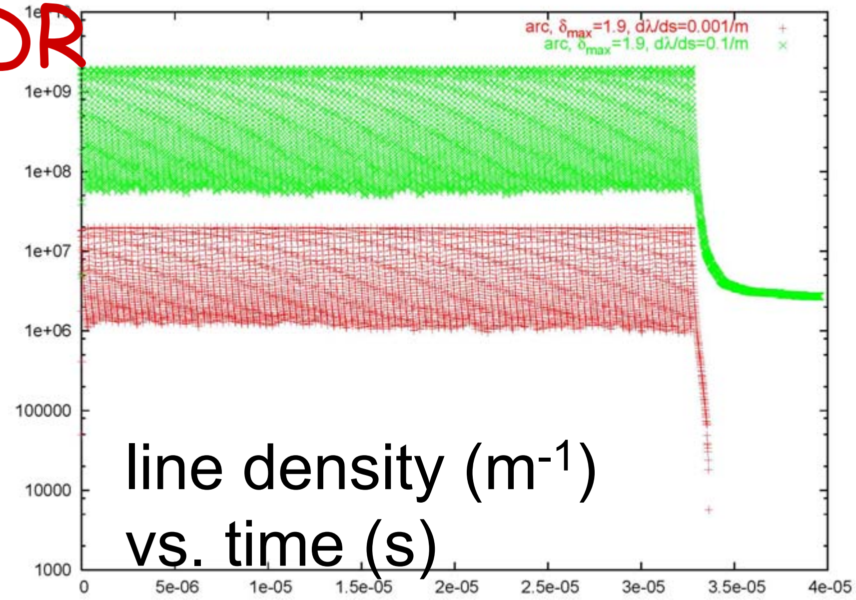
Task reporter
F. Zimmermann, CERN
contacts:
R. Wanzenberg, DESY
C. Vaccarezza, LNF
R. Cimino, LNF
O. Malyshev, CCLRC
R. Reid, CCLRC

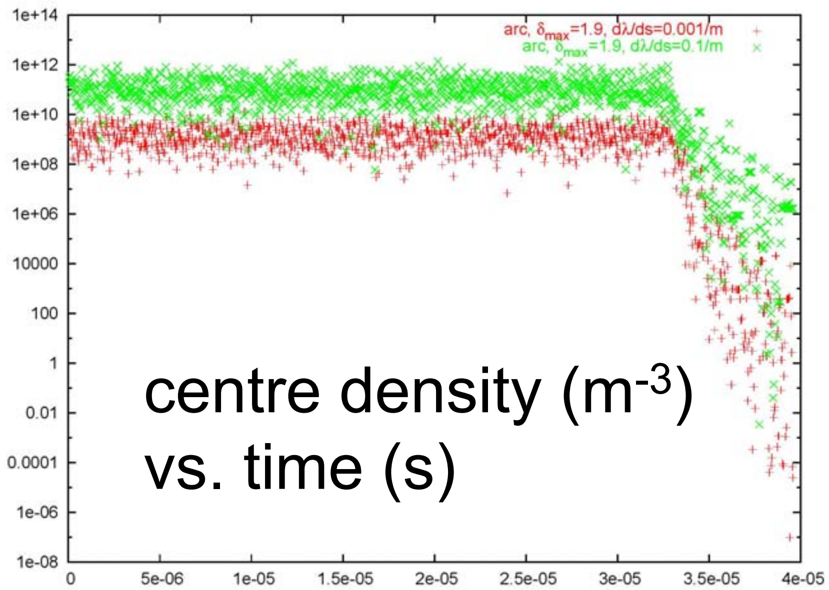
recent ECLOUD highlights

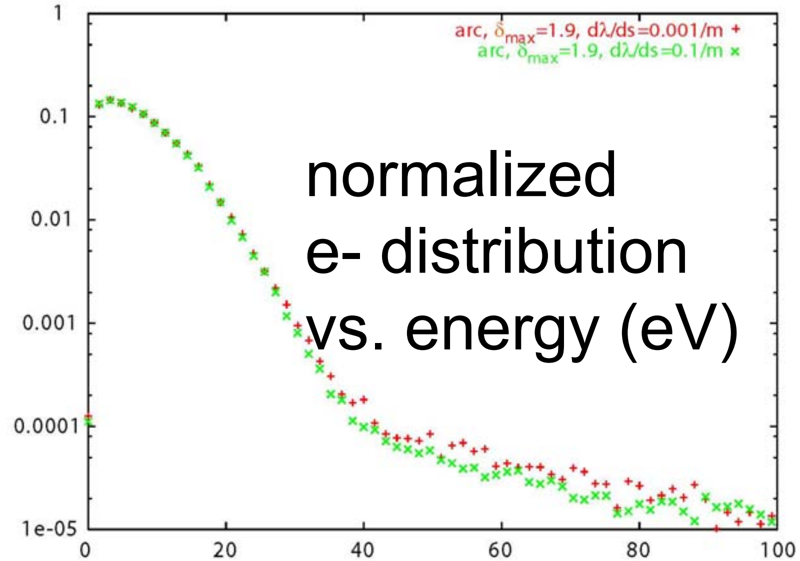
- ***complete study of e-cloud in wigglers for ILC, CLIC & DAFNE*** (photon flux, e- build up, instabilities)
  → *EUROTeV-Report-2006-002*
- development of a ***new electron cloud code***, which can simulate arbitrary boundary shapes, electron build up, cloud-beam interaction, & ions by Warner Bruns at CERN. The code is parallelized and runs on a cluster. It will be able to simulate 3D problems. Wigglers are important example.
- ***mechanisms of incoherent e-effects*** identified (periodic crossing of resonances or of region with linear instability)
- ***impedance of e- clearing electrodes*** computed
- ***e-cloud simulations for 2x6-km ring*** (next slides) confirm that, as expected, ***e-cloud is no problem for the present ILC DR baseline***
- discussions with Oleg Malyshev at CERN on 21/02 and 01/03, 2006 provided ***input needed for vacuum design***

e- build-up for 2x6 km DR

max. sec. yield: δ_{max}=1.9,
primary photo-electron rate:
$d\lambda/ds$= 0.1 m^{-1} or 0.001 m^{-1},
bunch train with gap,arc, log scale







Completely dominated by photons not absorbed by antechamber;no evidence for beam-induced multipacting; negligible e- heat load and low electron impact energies

where do we stand?

fully accomplished
in progress

Task2 ECLOUD								
Financial Year	Jan 05				Jan 06			
Quarter	1	2	3	4	1	2	3	4
New RAs		**1.1**	**1.2** **1.3**					
Benchmarking of build-up simulations		**2.1**	**2.2**	**2.3**		**2.4**	**2.5**	
Benchmarking of instability simulations				**3.1**	**3.2** **3.3**			
Improvement of simulation codes		**4.1**	**4.2** **4.3** **4.4**		**4.5**	**4.6**	**4.7**	
Predict effect in the damping rings				**5.1** **5.2** **5.3**		**5.4**		**5.5**
Experimental determination of surface parameters		**6.1**			**6.2**	**6.3**		**6.4**
Vacuum design of damping rings		**7.1**		**7.2** **7.3**				**7.4** **7.5**

outstanding tasks from 04/05

2.3 December 05 (or June 06): Perform electron-cloud build up simulations for the DAFNE wiggler and perform qualitative comparison with measurements (pressure rise, beam instability, possibly designated electron detectors).

→ ***simulations run at CERN using field maps from LNF***

5.3 October 05: Simulate instability thresholds with HEADTAIL for a 3-km, 6-km and 17-km damping ring and compare them with predicted electron densities.

→ ***simulations were run at CERN and DESY*** in collaboration with M. Pivi (SLAC) and K. Ohmi (KEK); ***since 2x6-km configuration was selected, we have stopped simulations of the previous three rings***

tasks of 01/06

3.2 February 06: Compare experimental lifetimes at the SPS with HEADTAIL simulations of emittance growth below the fast instability threshold.

→ ***completed at CERN by E. Benedetto (see next slide)***

3.3 March 06: Compare measured instability growth rates in DAFNE with single-bunch growth rates simulated by the HEADTAIL code and with multi-bunch growth rates estimated from the ECLOUD build-up simulations

→ ***completed by CERN-DESY-INFN collaboration in 2005***

4.5 February 06: Implement an antechamber geometry, and, if foreseen by the ILC design, also synchrotron radiation photon stops and/or clearing electrodes, in ECLOUD code.

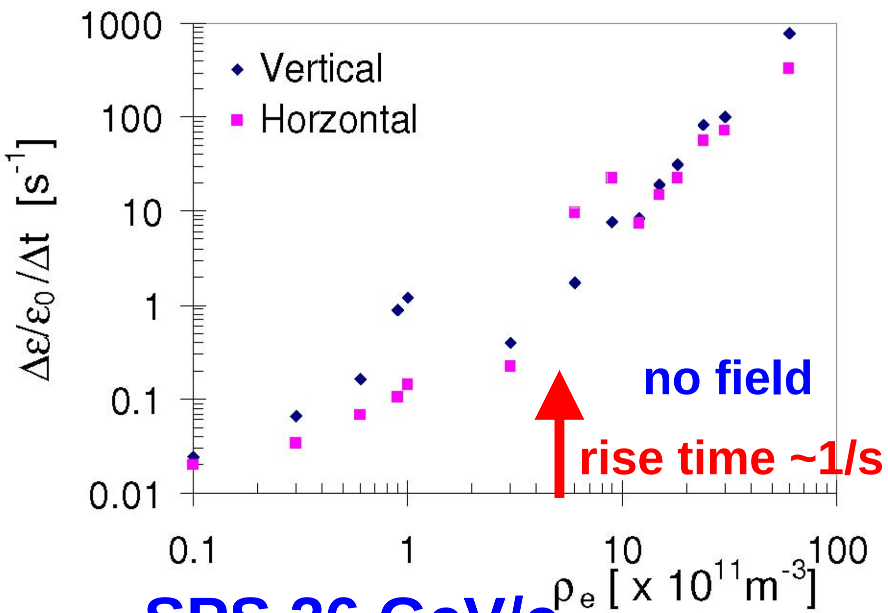
→ ***will be implemented in new e-cloud code at CERN***

6.2 Define sec. electron yield & electron reflectivity for the real Al-chamber DAFNE constructing material, and its relevance on the simulations based on more realistic input parameters.

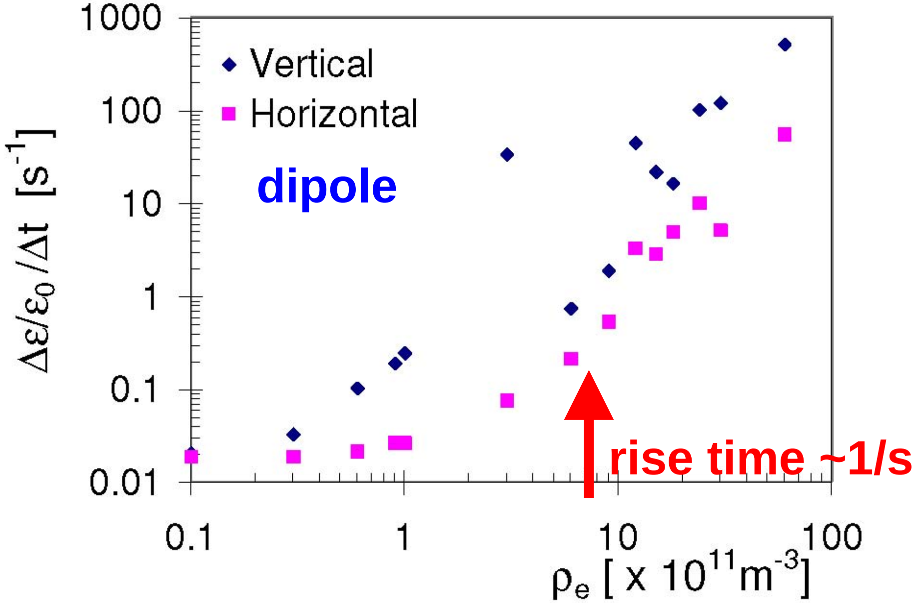
→ **DAFNE chamber characterized, LNF&CERN simulations**

emittance growth vs. electron density for SPS

HEADTAIL simulations E. Benedetto
→ consistent with experimental observations within measurement uncertainties

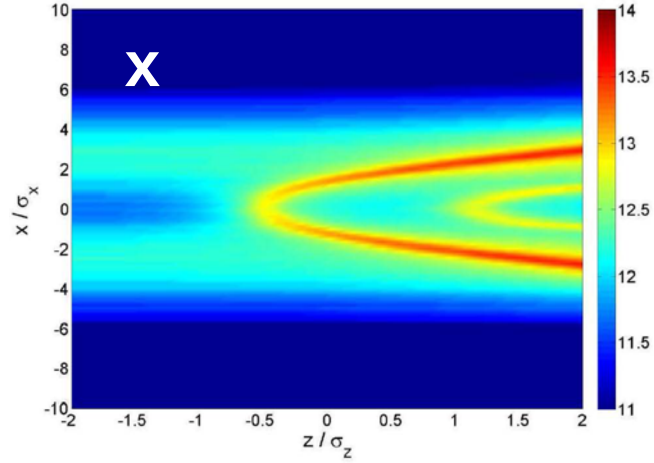


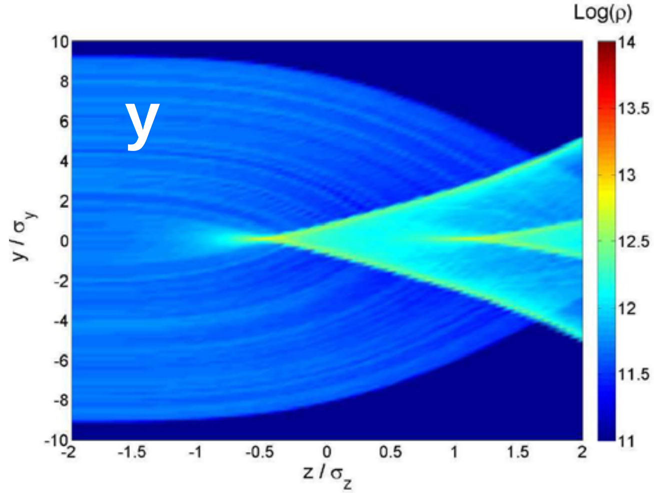
SPS 26 GeV/c



e- density evolution during bunch passage in a dipole field

SPS





tasks for 02/06

2.4 June 06: Study efficiency of various proposed countermeasures in simulations.

→ ***impedance of e- clearing electrodes was computed by GdfidL at CERN***

4.6 May 06: Update ECLOUD model parameters based on the results of code benchmarking.

→ ***updated elastically reflected electron component based on SPS benchmarking at CERN***; ***importance of re-diffused electrons is under scrutiny***

5.4 June 06: Estimate the importance of incoherent emittance growth due to electron cloud for the different damping-ring designs.

→ ***for 2x6-km ring in progress at CERN***

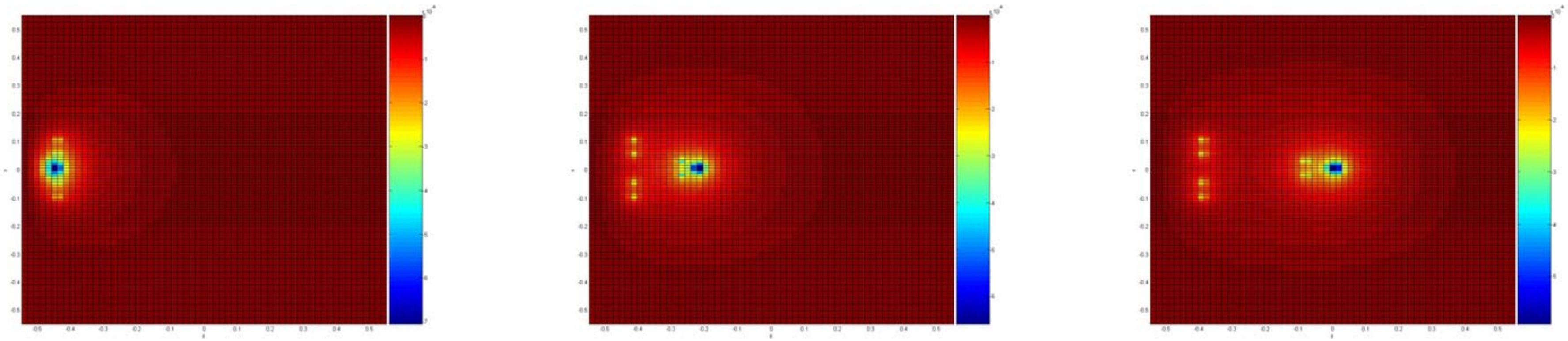
6.3 June 06: Study the dependence on electron and photon doses of the experimentally determined values of SEY and its relevance on the simulations based on more realistic input parameters.

→ ***in progress at LNF***

Current Ecloud Activities:
Collaboration between the University of Rostock and DESY

Aleksandar Markovik, University of Rostock, Germany :
Particle Tracking Program - MOEVE

First version of the tracking routine
- Based on the Poisson solver for space charge fields in a beam pipe of elliptical shape
- Time integration of the particle equations with relativistic generalization of the equations



R. Wanzenberg

Current Ecloud Activities:
Collaboration between the University of Rostock and DESY

Current work:

- Improve the solver
- Implementation of external fields (longitudinal ***E***-, transversal ***B***-fields)
- Verification and comparison of the tracking routine with existing programs
- Parallelization of the code
- Definition of the initial particle distribution – possible use of available bunch generation programs

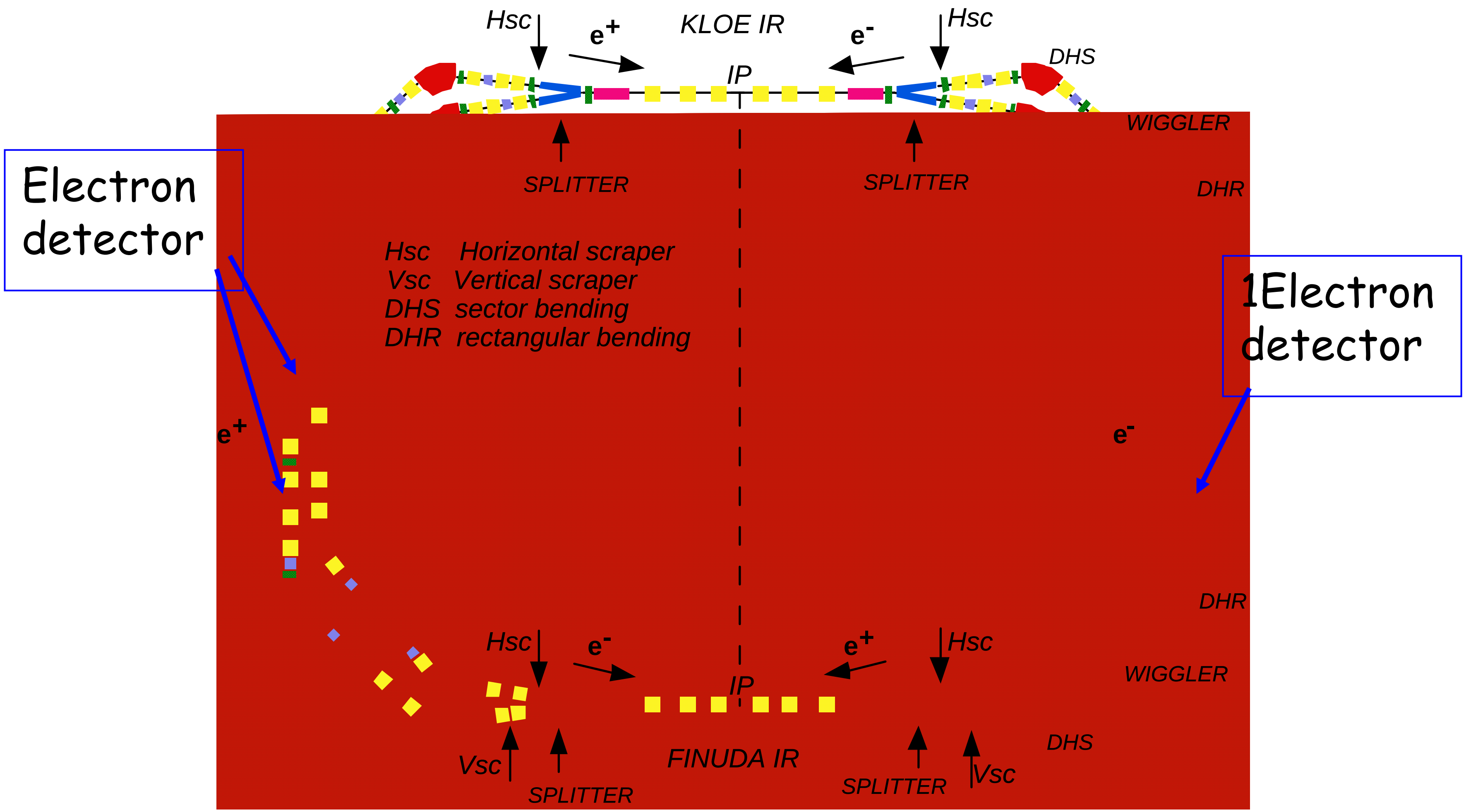
aleksandar.markovik@uni-rostock.de

future e-cloud plans at CERN

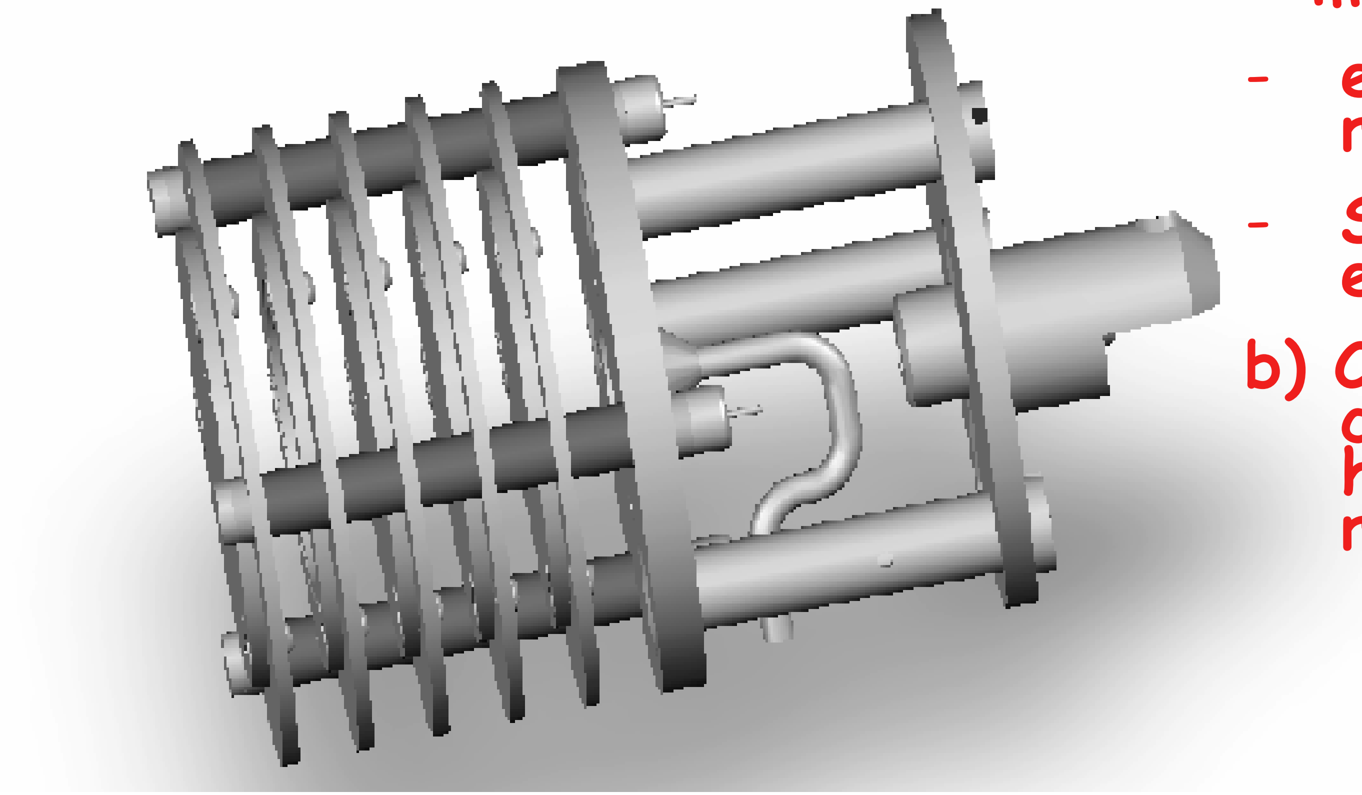
- ***continue benchmarking new e-cloud code*** against existing programmes, ***extend code to fully 3D***; explore ***role of ions***
- implement ***antechamber & possibly clearing electrodes*** in the simulation
- complete ***study of e-cloud driven instabilities for 2x6 km ring***
- study ***e-cloud in damping-ring quadrupoles***
- ***repeat*** e-cloud build up and instability ***simulations*** for the ***chamber material properties and vacuum chamber layout that will be proposed for the ILC damping ring***

Future e-cloud plans at LNF

Installation of electron detectors at DAΦNE



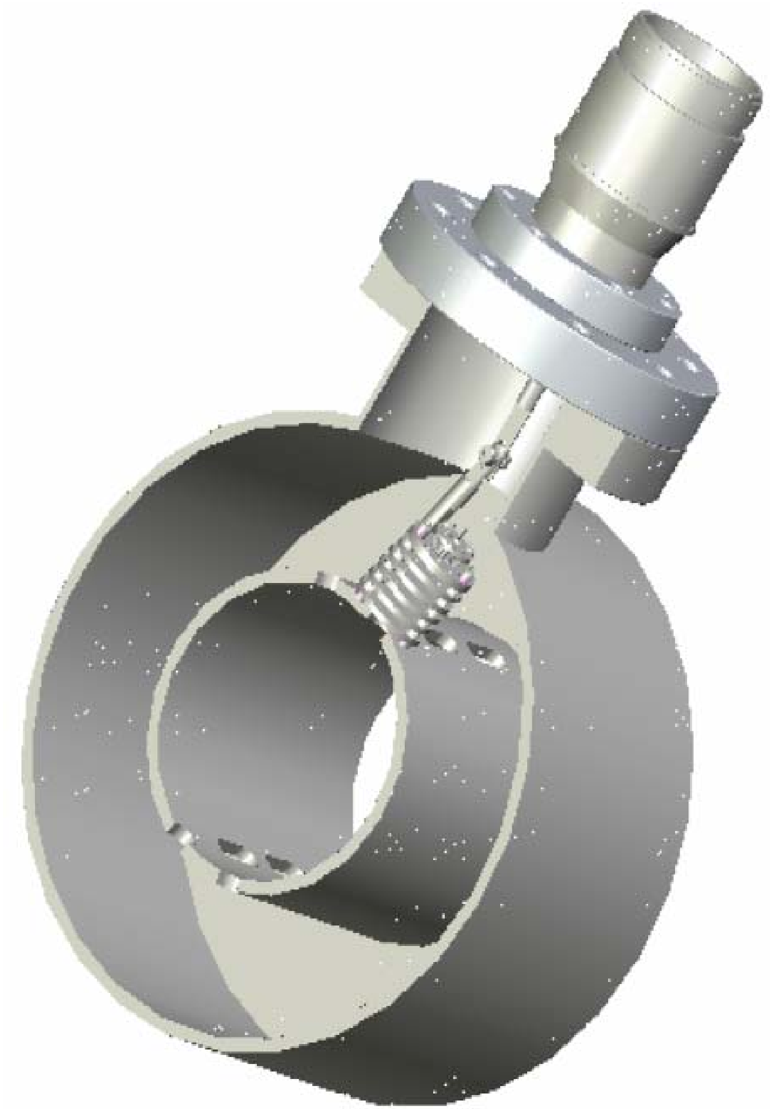
Energy-resolved El. detectors on DaΦne



a) 5 grids for:
- mass screening
- energy resolution
- Sensitivty to low energy electrons

b) Channeltron / channelplate for high counting rate

Energy-resolved El. detectors on DaΦne



To be inserted in 3 positions looking trough the existing slots at the beam:

- electron-ring (for reference)
- Positron ring (Uncoated chamber)
- Positron ring (TiN coated chamber)

Main results of the modelling

- NEG coating of vacuum chamber along both the arcs and the wigglers as well as a few tens meters downstream of both looks to be the only possible solution to fulfil vacuum requirement for the ILC dumping ring
- Considering thermal and photon stimulation desorption only the most of the straights can be made of stainless steel tube with 30 l/s pumps located every 20-30 m
- **Beam induced electron Multipacting** (BIEM) looks to make **negligible impact** in to vacuum model, it is essential double check it as it may change the pumping philosophy.
- **Power dissipation from SR** (and BIEM if there is any) have to be considered:
  - vacuum chamber **water cooling is required in wigglers, arcs** and a few tenth meters downstream of both.
  - **end power absorber** for SR from the **wiggler** (at first dipole downstream a wiggler)
- NEG coated power absorber for wiggler vacuum chamber needs to be studied experimentally.

O. Malyshev

Ideal vacuum chamber for ILC DR

- Round or elliptical tube
  - Cheapest from technological point of view
- No antechamber (if not needed to reduce e-cloud)
  - Beam conditioning is most efficient
- NEG coated
  - Less pumps with less pumping speed
  - 180°C for NEG activation instead of 250-300°C bakeout
  - Choice of vacuum chamber material (stainless steel, copper and aluminium) does not affect vacuum in this case
- There are experience results that NEG coated elliptical vacuum chamber might be re-activated even without baking to 180°C, just by SR.
  - Accurate experimental study is needed

Data collecting

- The NEG coating is in a focus of studies for the DR vacuum system.
- There is a confidence that NEG coating works well in accelerators (6-year experience of NEG coated ID vessel at the ESRF and CERN, Elettra, RHIC, KEK, ASTeC, etc.)
- There is a **lack of data** for the modelling for the NEG coating behaviour as a function of **very large photon doses** (yeas of DR operation) and at **very large power** (important for vacuum chamber inside and down stream the wigglers).
- The 45th IUVSTA workshop NEG coating for accelerators was organised by O. Malyshev (with active support from ASTeC and AIV) on 4-8 April 2006 in Catania (no EUROTeV money used). The results of the workshop are very useful for ILC DR vacuum design: experimental data, data from working accelerators, operational experience.
- Some other studies of the NEG coating are needed on SR beamline:
  - Lower activation temperature or SR activating of the coating, large dose measurements, etc.
  - ASTeC has no access to SR beamline: any suggestions are welcome.

Milestones

7.1 June 2005: pressure profiles for TESLA Damping Ring – done.

7.2 December 2005: pressure profiles for TESLA Damping Ring with use of NEG coatings – done and reported in ILC-DR Workshop at CERN in November 2005.

7.3 December 2005: Report on collated results…

- *Results are collated and used for modelling*
- *Report is under writing*

7.4 December 2006: Pressure profiles due to electron multipacting – ongoing

- *if there is no electron multipacting expected, this time will be spent for more detailed study of the ion induced pressure instability in positron DR.*

What is needed from accelerator scientists:

- *DR conditioning scenario: How long the beam will be used for conditioning before DR use, i.e. required pressures at Arcs, Straights and wigglers after ?? A*hrs.*
- *What vacuum chamber needed made of: Stainless still, aluminium or copper? (impedance, other issues)*
- *Is 1-mkm NEG coating OK? (impedance)*

Activity on Fast Ion Instability at DESY

Guoxing xia

Ion Effects Overviews

- Collision ionization of residual gas in the vacuum chamber is the main source of ions production
- Ion effects will arise when ions are trapped in the potential well of the beam
- Ions accumulate until stabilized by neutralization, second ionization, etc
- In high current storage rings or linacs with long bunch trains, the ions accumulate during the passage of a single bunch train
- This leads to fast beam-ion instability, which is noticeable in the damping rings for ILC

EUROTeV-Report-2006-004

Fast beam ion instability (FBII)

- FBII is due to residual gas ionization
- Beam **bunches' motion** couple the **ions' motion**
- FBII is a single pass instability like BBU, unlike the classical trapped-ion instability
- FBII can arise due to ionized ions in an electron beam or electrons in a positron (proton) beam

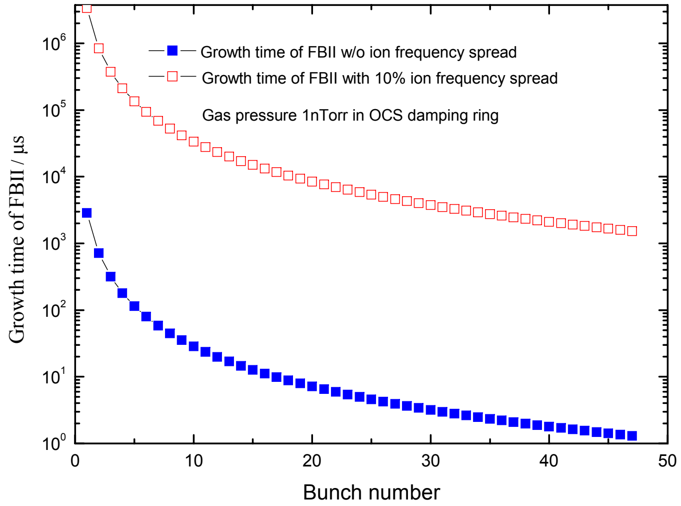
Potential cures:

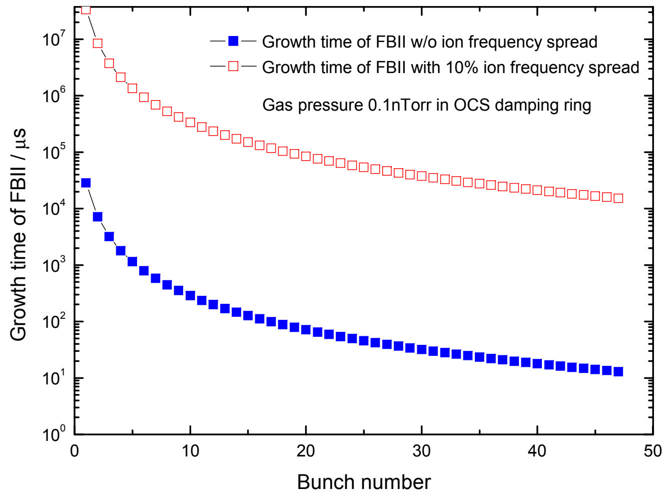
- Upgrade the vacuum condition
- Increase the ion frequencies spread using an optical lattice, so that the ion frequencies varies significantly with the time, and no coherent oscillation can therefore develop
- Introduce the gaps in the bunch trains in order to clear the ions or make ions unstable
- Bunch by bunch feedback system to realign the trailing bunch

Analytically estimation of growth time of FBII

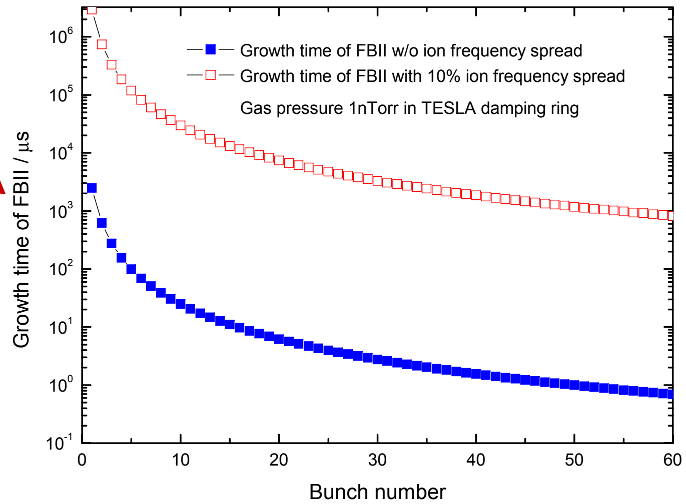
- The growth time of FBII in straight sections. It can be foreseen at the bunch train end, the growth time is very fast.

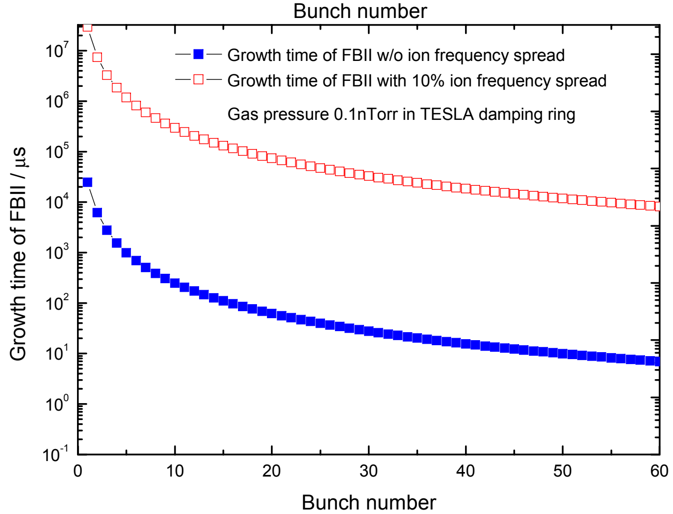
OCS





TESLA





EUROTeV-Report-2006-003

Simulation model of FBII

- A weak-strong model is used.
- We assume beam is rigid Gaussian distribution while the ions are regarded as marco-particles
- The equations of motion of two stream read

$$\frac{d^2\bar{\mathbf{x}}_e}{ds^2} + K(s)\bar{\mathbf{x}}_e = \frac{2r_e}{\gamma}\sum_{j=1}^{N_i}\mathbf{F}(\bar{\mathbf{x}}_e - \mathbf{x}_{i,j})$$

$$\frac{d^2\mathbf{x}_{i,j}}{dt^2} = \frac{2N_e r_p c^2}{A}\mathbf{F}(\mathbf{x}_{i,j} - \bar{\mathbf{x}}_e)$$

Here, N_i is the number of ions, and

$$F(x,y) = -\frac{\sqrt{\pi}}{\sqrt{2(\sigma_x^2-\sigma_y^2)}}\left[w\left(\frac{x+iy}{\sqrt{2(\sigma_x{}^2-\sigma_y{}^2)}}\right) - \exp\left(-\frac{x^2}{2\sigma_x{}^2}-\frac{y^2}{2\sigma_y{}^2}\right)w\left(\frac{\frac{x\sigma_y}{\sigma_x}+i\frac{y\sigma_x}{\sigma_y}}{\sqrt{2(\sigma_x{}^2-\sigma_y{}^2)}}\right)\right]$$

Simulation model of FBII (cont'd)

characteristics of this code

- It can be used in any lattice
- Several ion production points are used
- Several marco-ions created by a bunch
- Various filling modes
- Clearing macro-ions every turn

The first results will be presented at EPAC06:

"Preliminary Studies of Ion Effects in ILC Damping Rings" Guoxing Xia, Eckhard Elsen (DESY, Hamburg)

Damping Ring - LETS Task
Low Emittance Tuning Studies Update

James Jones

ASTeC, Daresbury Laboratory

Progress

- Coupling correction studies have been integrated into simulation framework
  - Includes correction of closed orbit by quadrupole movers *or* dipole steerers
  - Vertical dispersion correction included in orbit correction *or* with skew quadrupoles along with coupling correction
  - Coupling correction is minimisation of cross-plane response matrix using skew-quadrupole response matrix inverted via SVD
- Analysis was performed for some of the initial 7 damping ring designs and presented at Snowmass, August 2005.
- Analysis has begun for new reference lattice, RDR1
  - Tolerences have been studied
  - Analysis of diagnostic requirements underway

Work Force & Plans

- There are still < 2 people working on this task
  - 1 Post-Doc & 1 Staff Member @ DESY (0.5SY – 1.0SY)
  - 1 Staff Member @ CCLRC (0.3SY Total)
- PhD student @ Daresbury still not in post

- Due to the lack of effort it is likely that the milestones for the coming year will slip, at least to some extent.

RFSEP Task
task reporter: F. Marcellini

Main Results form 2005

- The activity on RF deflectors has been postponed according to the priority assigned by the Baseline Configuration recommendation:

  "The damping ring kickers should be based on "conventional" strip-line kickers driven by fast pulsers"

Special stripline geometry has been studied in order to optimize efficiency and field uniformity and to minimize the beam coupling impedance

The electromagnetic design of the stripline has been completed and presented at the ILCDR meeting at CERN (Nov.05)

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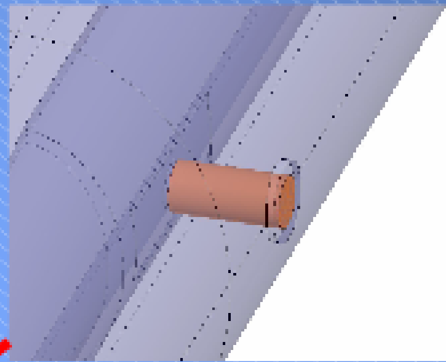
3) DAΦNE stripline kickers design: 3D electromagnetic model (1/3)

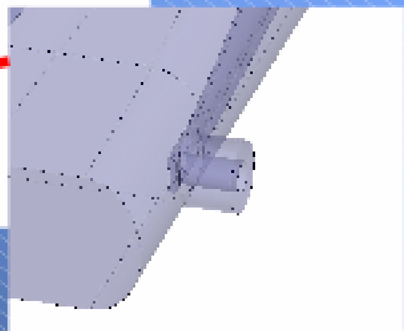
a) Ceramic stand-off effects

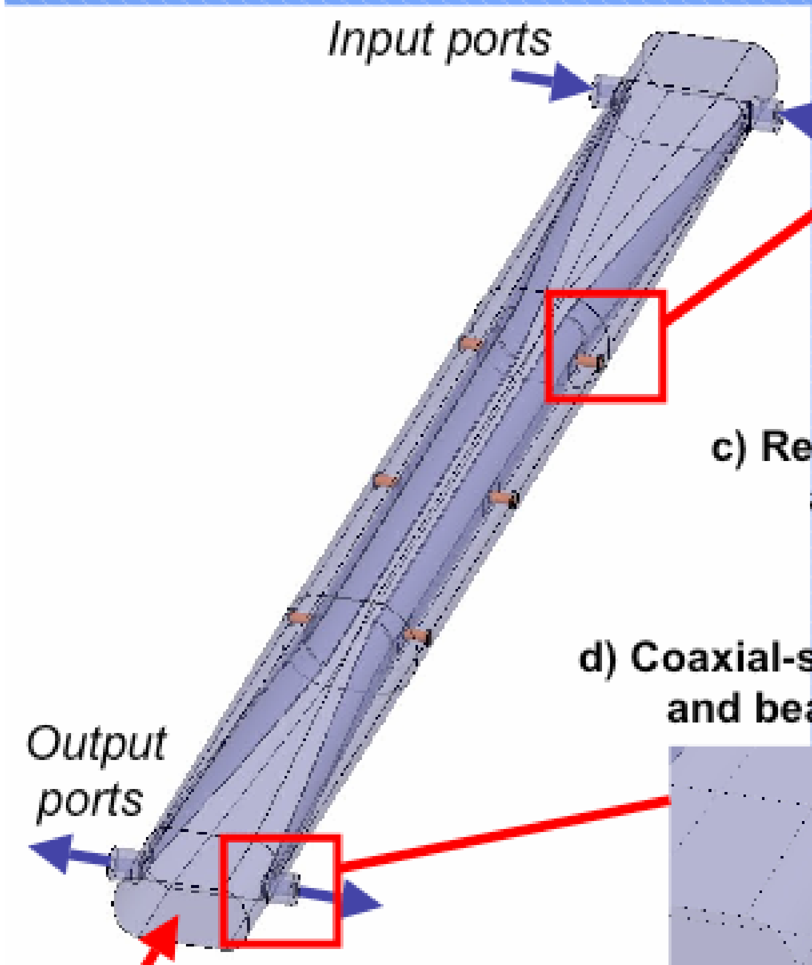


b) HOM studies

c) Real deflecting field calculation and frequency response

d) Coaxial-strip transition optimization and beam transfer impedance



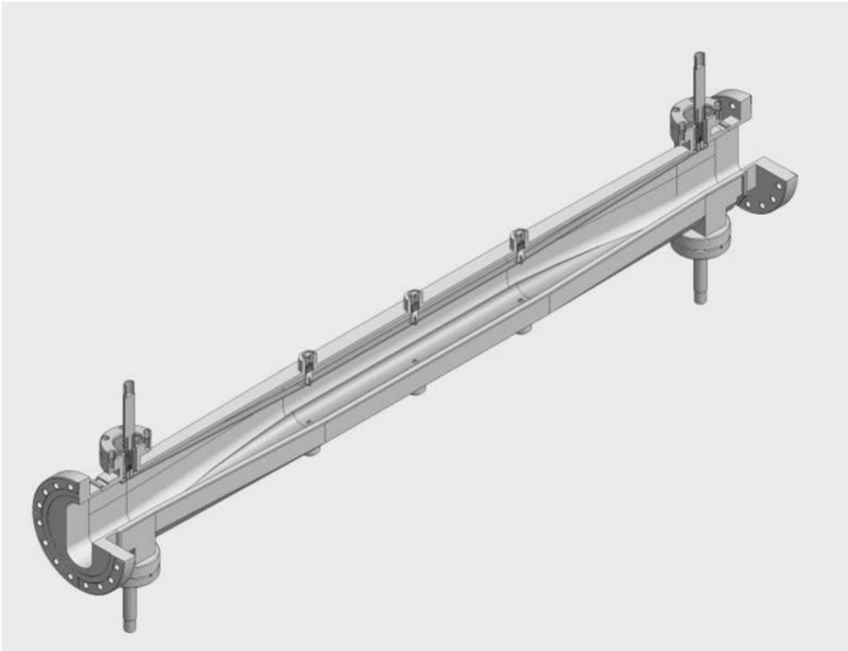


Optimization of the whole structure

Design completed

Fast stripline kicker

- The same kind of structure studied and simulated as kicker for the ILC electron damping ring, has been designed for the upgrade of the DAΦNE injection system
- The mechanical drawings have been completed and we are ready to order a prototype of the kicker
- Pulser specifications have been also defined and a first pulser has been already ordered. It will be at LNF within this month for high power and reliability tests

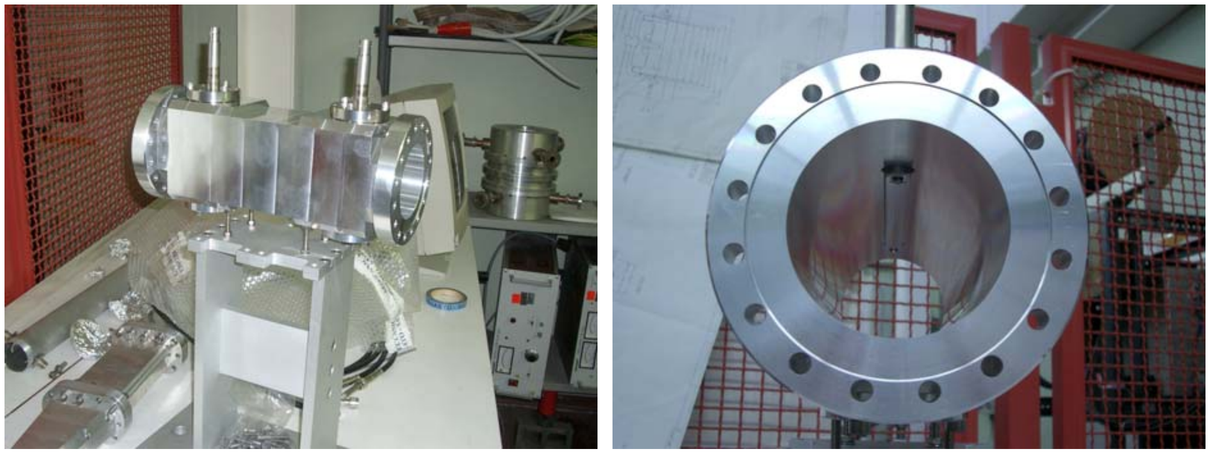


The injection kicker designed for DAFNE

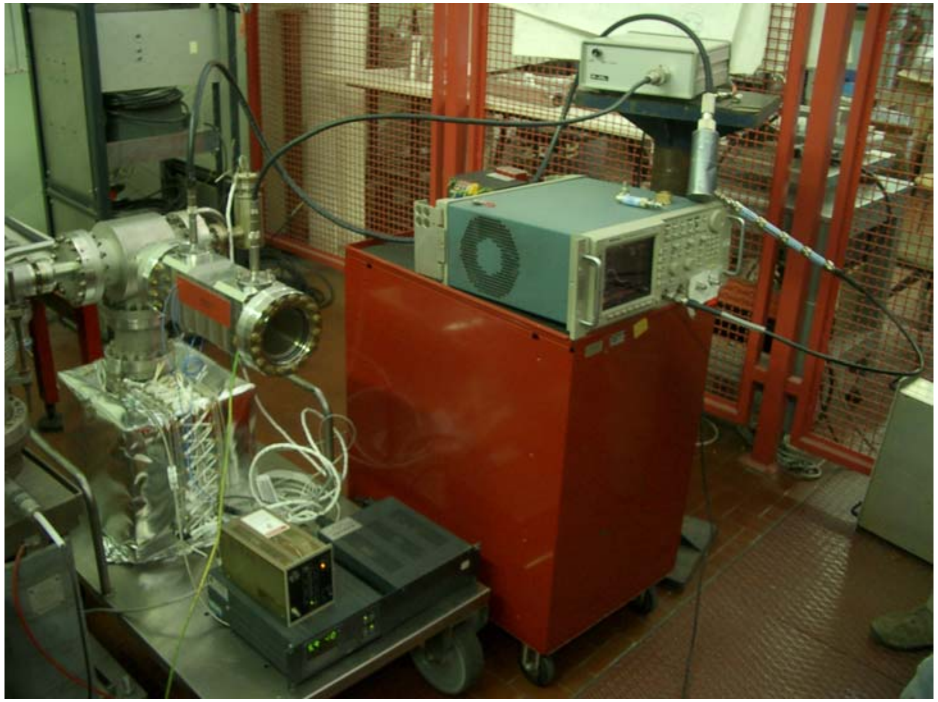
The main characteristics of this kicker are the low beam impedance, the wide region of field unifomity and the very short pulse (few ns).
A prototipe of this kicker and a pulser (FID technology – pulse amplitude 50kV, pulse length 5ns) have been ordered.

In the meanwhile we have done some tests using a pulser borrowed from FID, with same pulse length and half pulse amplitude, and a short constant section stripline.

test stripline



FID pulser



The High Voltage measurement set up

We have measured with a network analyzer the frequency response of the test stripline with the feedthroughs connected and we have verified that they do not introduce reflections of the signal.

Using the pulser we have been able to test both the feedthrough and the stripline at HV operation. The section of the short stripline is the same of the end-section of the kicker electrodes where the electrode itself is closer to the vacuum tube and the possibility of discharges is higher.

We did not observe any discharges in the device under test.

More details on the tests will be presented at EPAC06:

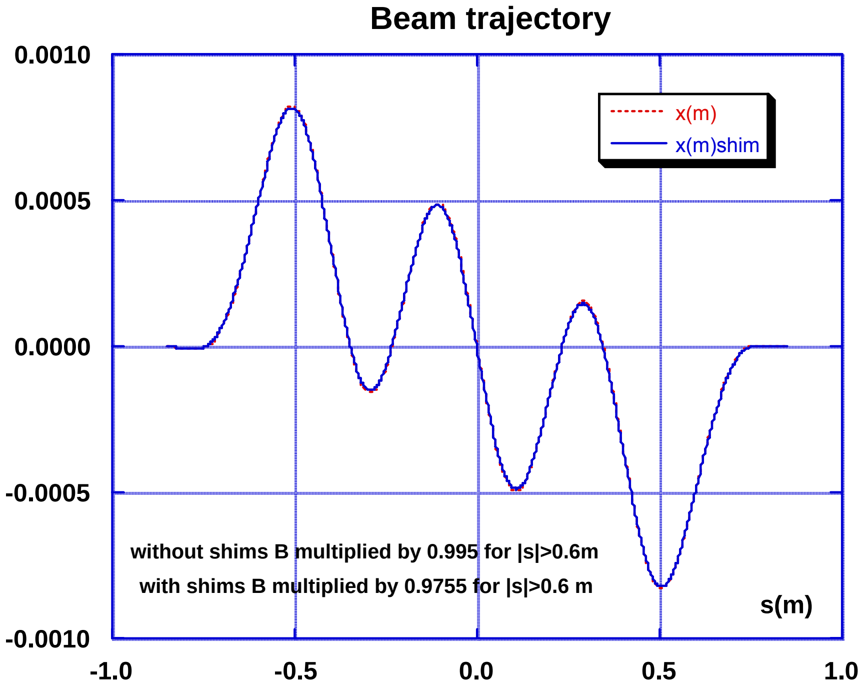
“Design and Tests of New Fast Kickers for the DAFNE Collider and the ILC Damping Rings” D. Alesini, S. Guiducci, F. Marcellini, P. Raimondi (INFN/LNF)

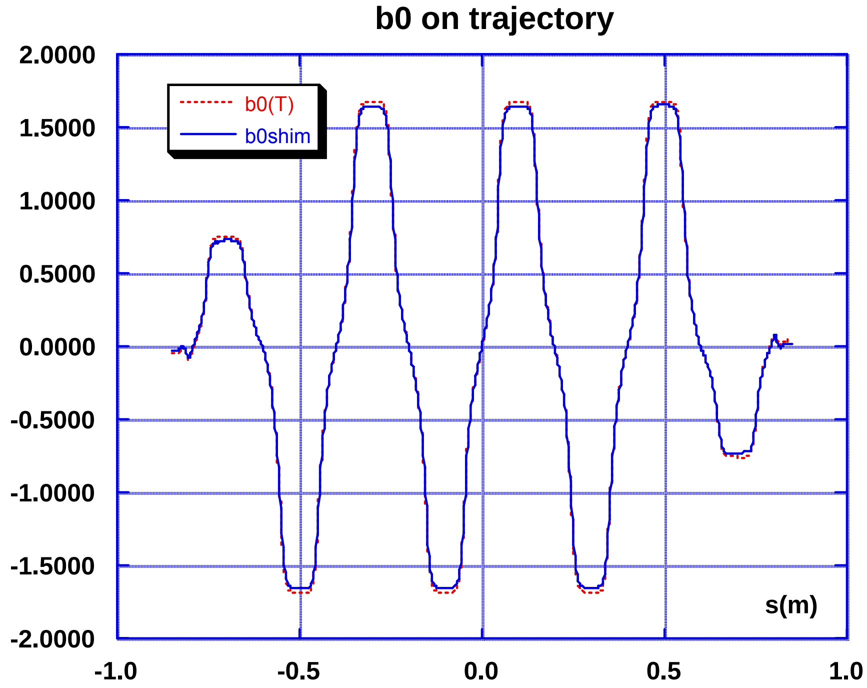
WGLRDYN Task
task reporter: M. Biagini

- Prof. A. Babayan from Yerevan Physics Institute is collaborating on wiggler field optimization for the Damping Ring of the ILC
- He will provide the wiggler field map in order to calculate the trajectory and the nonlinear terms that affect the beam dynamics
- The objective is to minimize the influence of the wiggler on the ILC Damping Ring dynamic aperture
- In particular in 2006 the collaboration will be dedicated to study the possibility of realizing a good field quality even with a magnet gap larger than the present value, as required in the Baseline Configuration Document (BCD) by the GDE.

Wiggler field map with and without shims

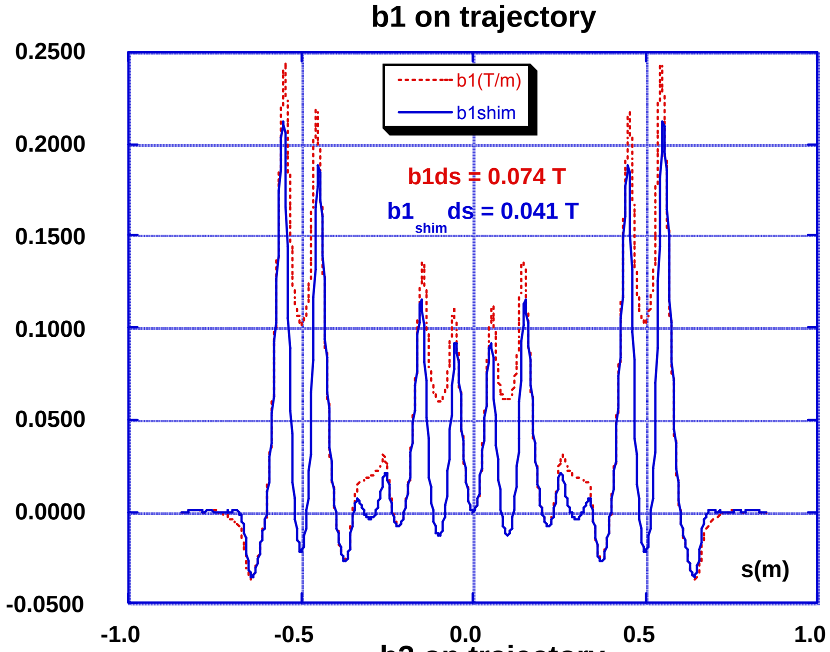
Gap = 25mm

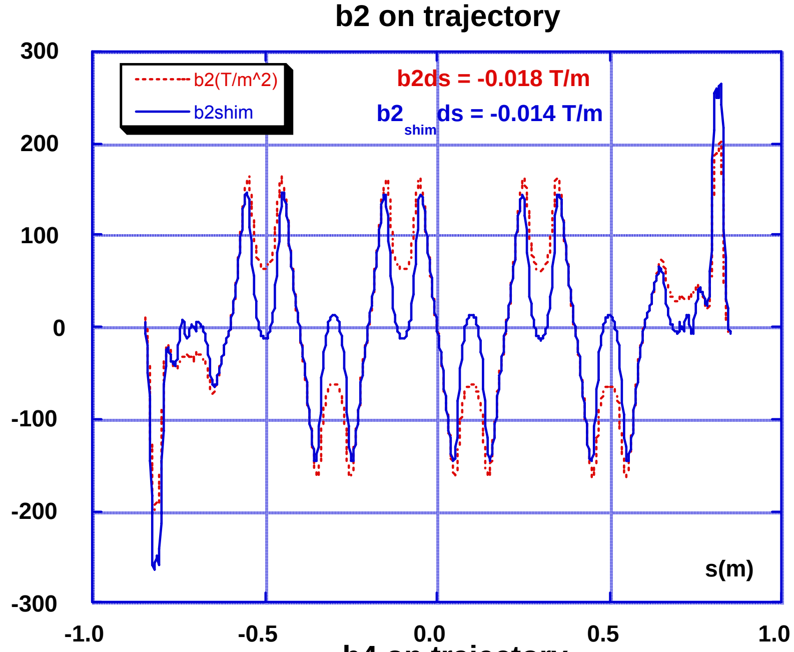


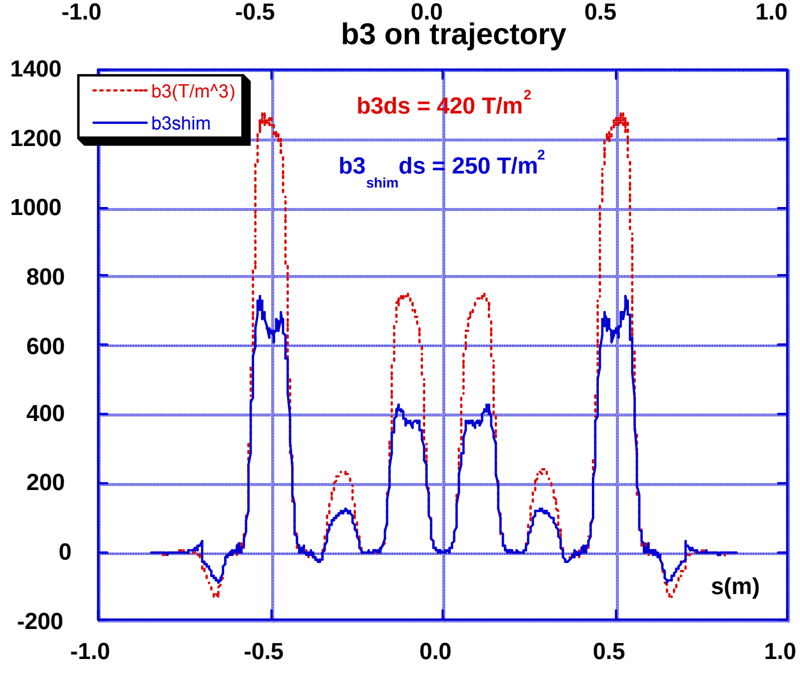


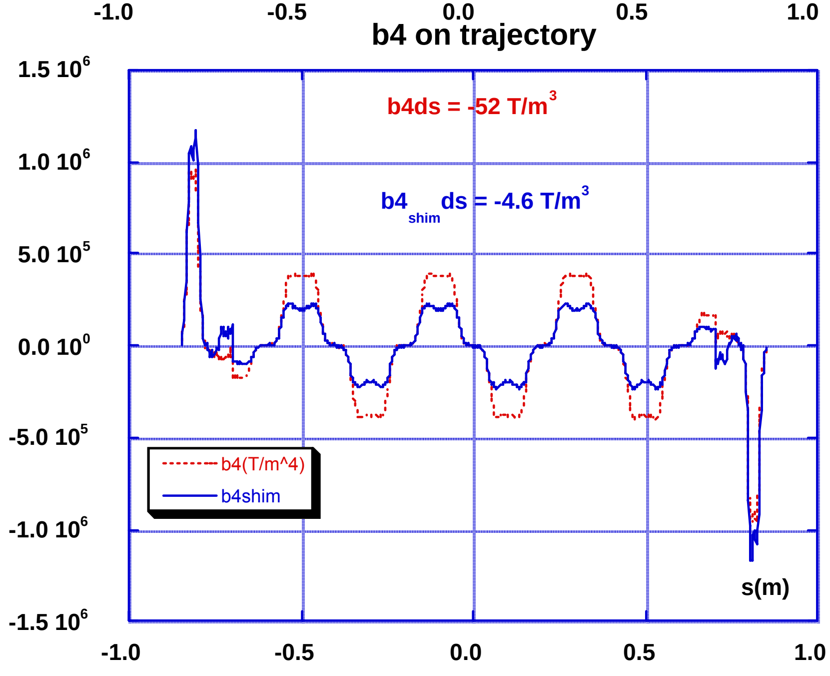
Wiggler field optimization is described in *EUROTeV-Report-2006-011*

Multipole components of the field on the trajectory









Future plans

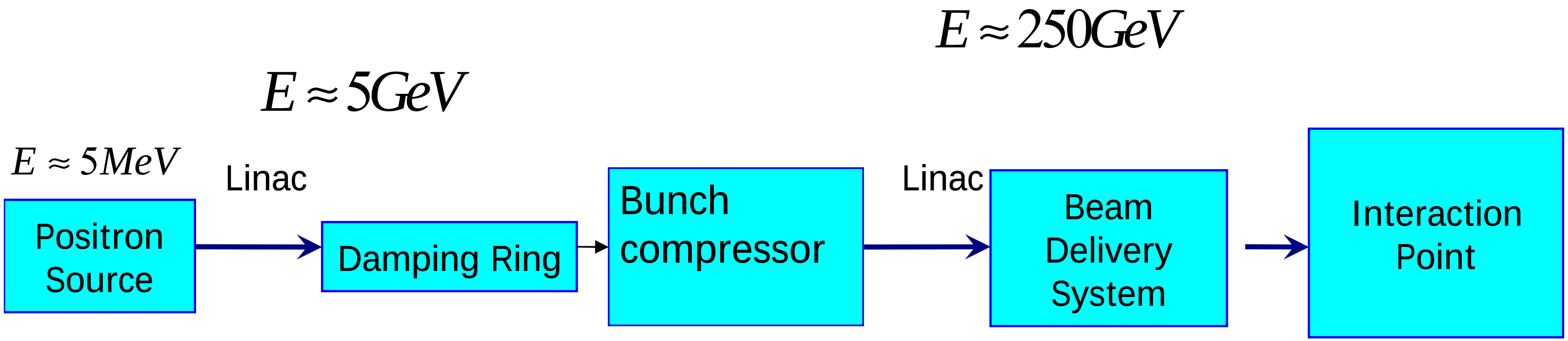
- Optimize the field map and calculate multipole terms for a larger gap
- Complete Benchmarking of dynamic aperture simulation code with measurements at DAFNE.
- Estimate the effect of this wiggler field on dynamic aperture and injection efficiency for ILC Damping Ring

- The last two items have been delayed due to lack of manpower
- Now a postdoc, funded by EUROTeV, has been hired at LNF starting from June and will be dedicated to this activity

Depolarisation in the ILC damping rings

Cockcroft Institute
D P Barber, I R Bailey, J A Clarke,
L I Malysheva, G A Moortgat-Pick,
D J Scott

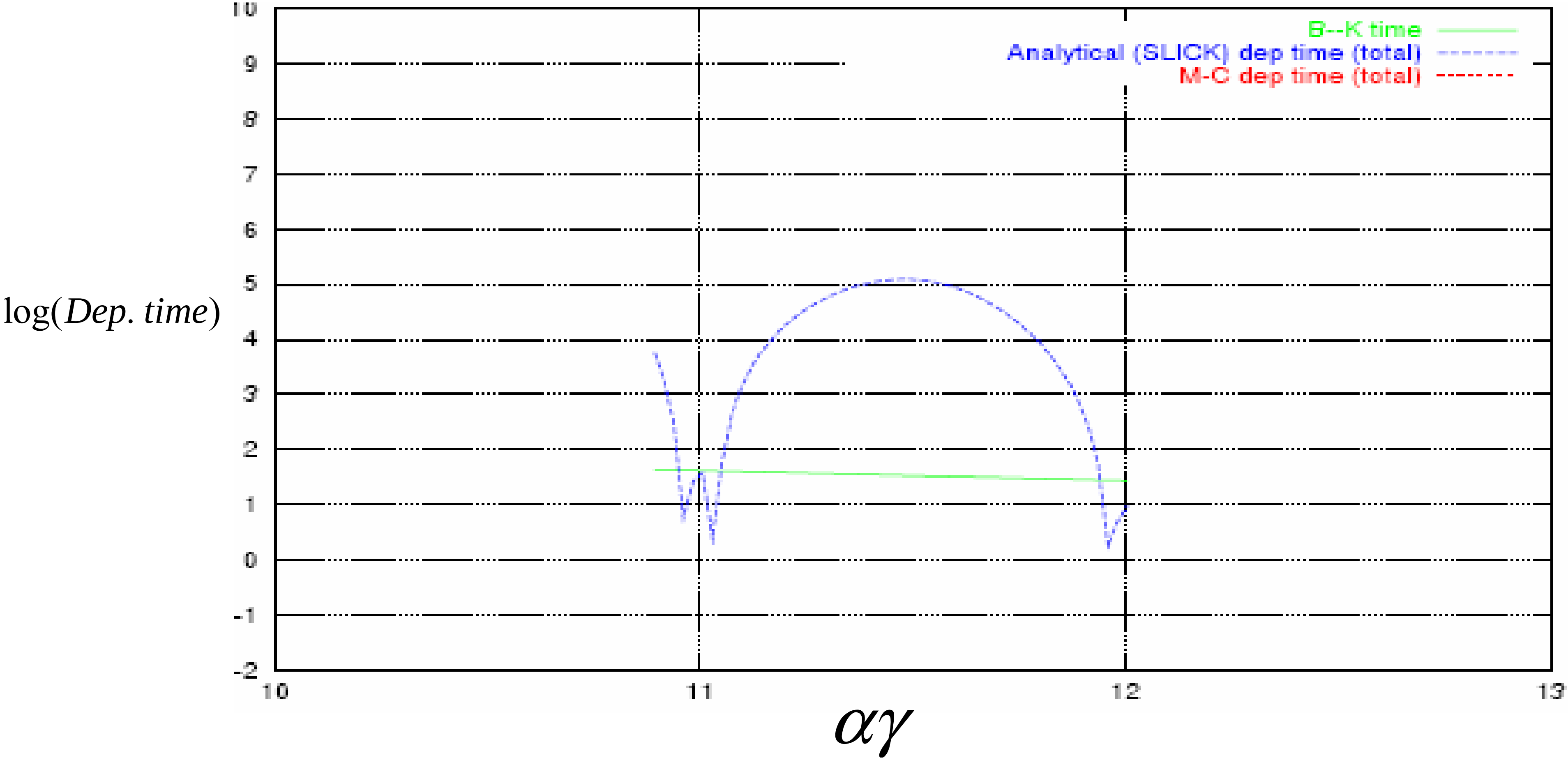
Spin Transport at the ILC



intense polarised e+ beam $\rightarrow$ Depolarisation? $\rightarrow$ Depolarisation??

Misalignments, Synchrotron radiation, Spin precession,
Resonances,
bunch- bunch effects ...

OCS ring depolarisation time with misalignments



Damping rings for the ILC

- In ideal Damping Ring depolarising effects are expected to be negligible
- Enhancement of synchrotron radiation (wigglers) might lead to the depolarisation effects
- The results of polarisation study for the OCS and TESLA lattices

DAMPING RING

- damping time (msec)
- S –T effect negligible
- No equilibrium polarisation
(evolution of spin distribution over a few damping times)
- MERLIN

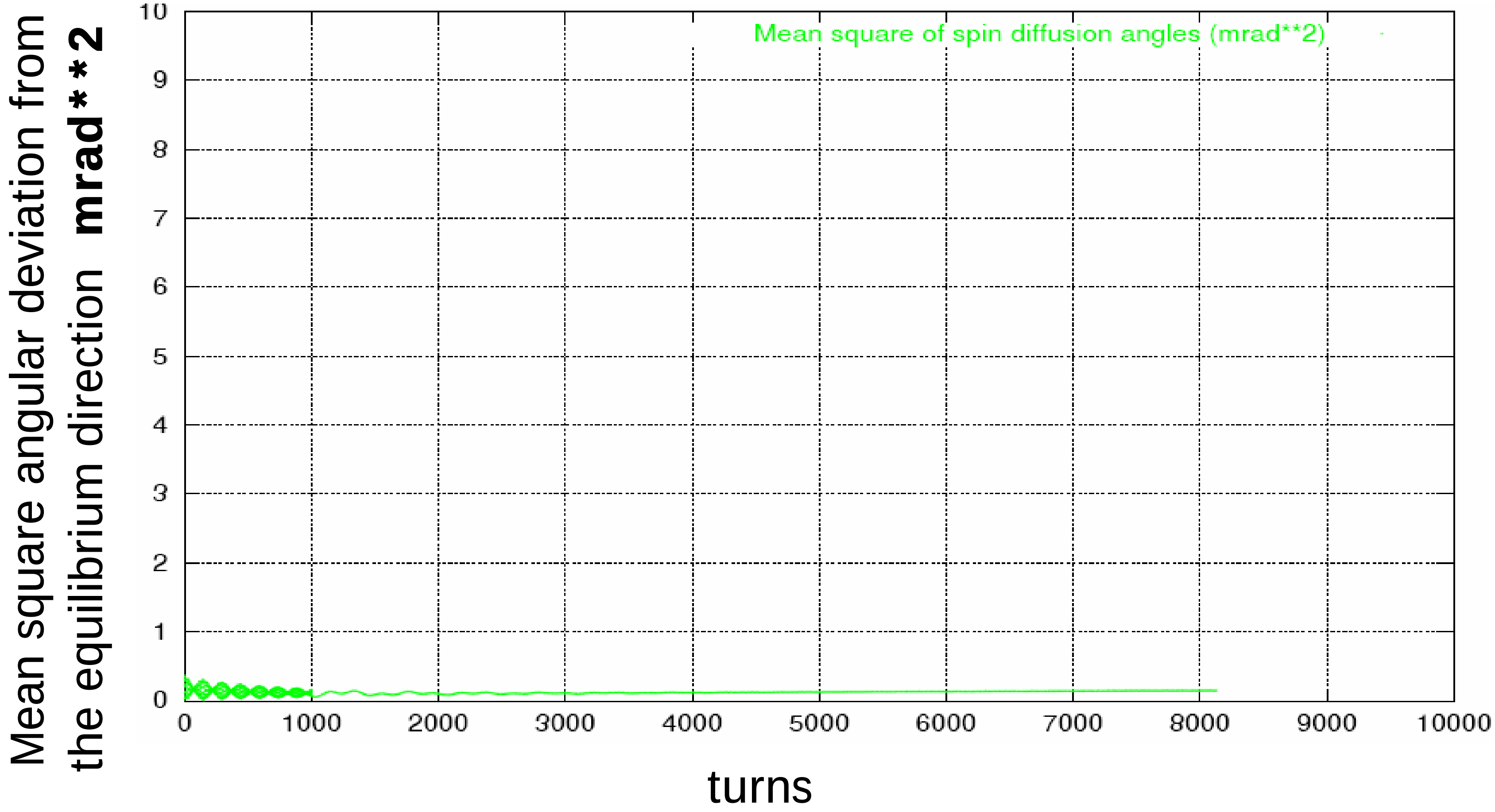
STORAGE RING

- storage time (hours)
- S –T effect significant
- Equilibrium polarisation (depolarisation rate can be "measured")
- More then 10 different codes available (Handbook)

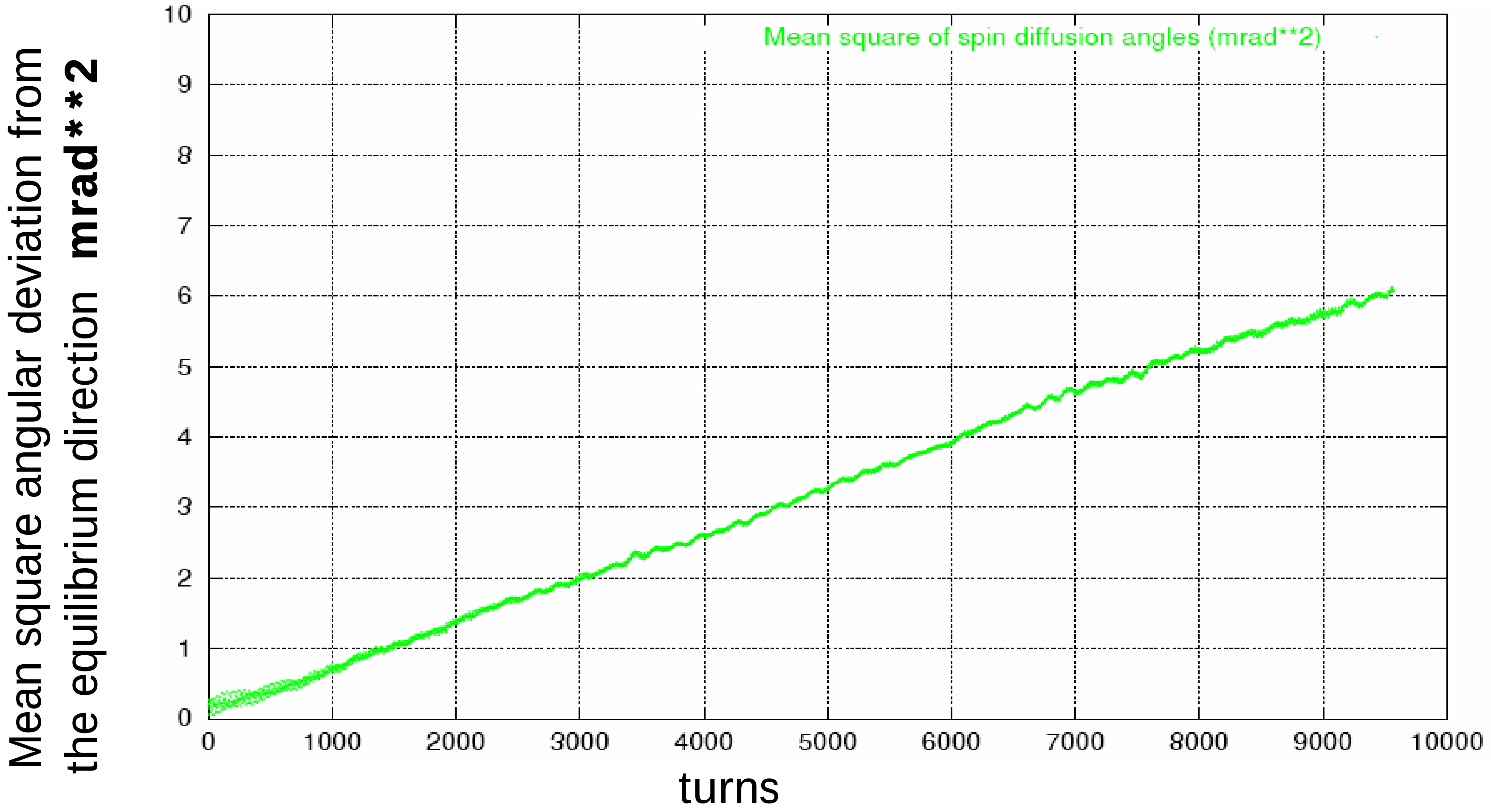
Computer Simulation

- Misalignments are introduced
- Slick : linearised orbital and spin motion. Reference point as well as energy scan
- Slicktrack: Monte-Carlo simulation of the effects of synchrotron radiation: evolution of the spin distribution over a few damping times including full 3-D spin motion

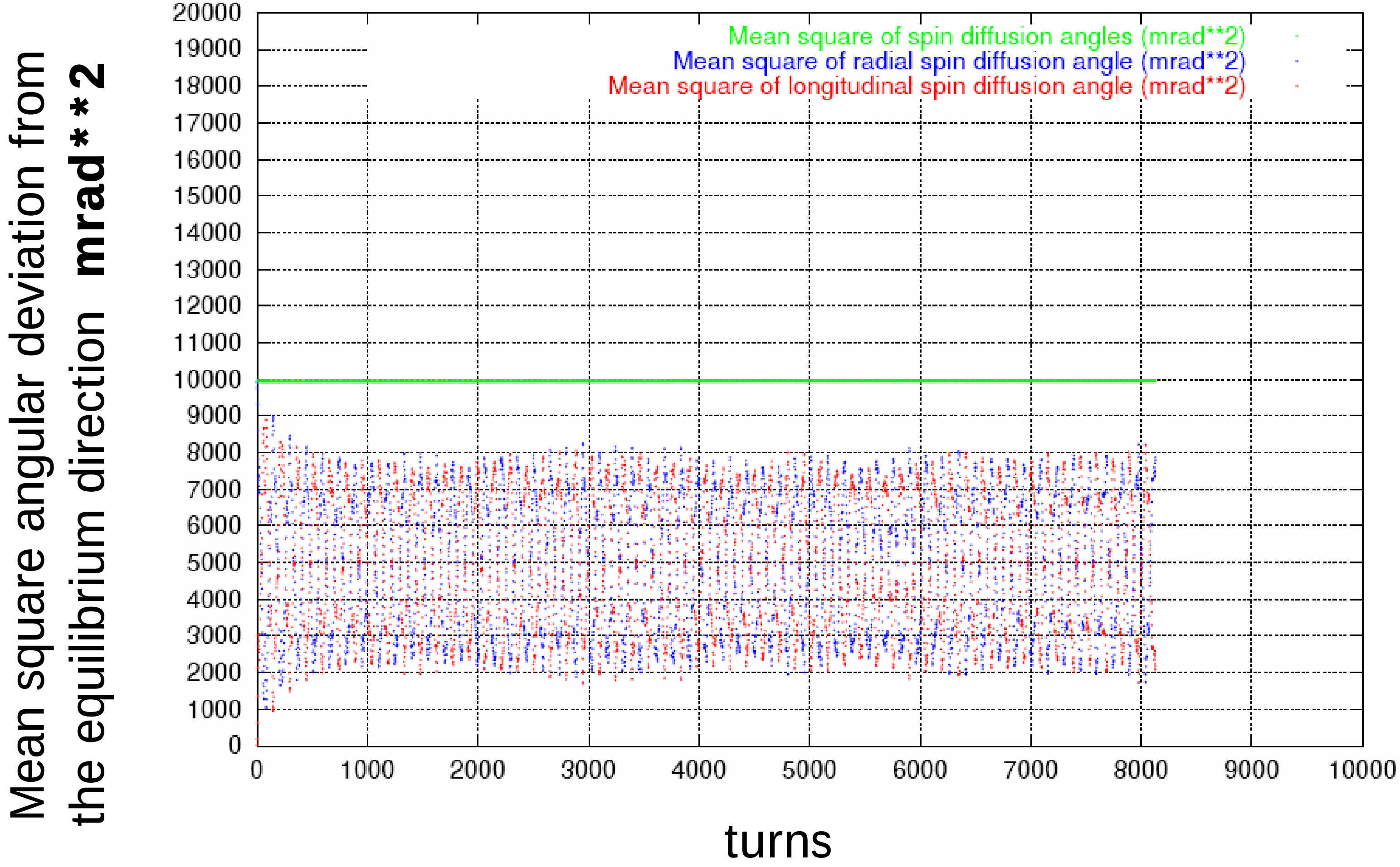
OCS Spin Diffusion at 5.006 GeV



OCS Spin Diffusion at 4.8 GeV



OCS Spin Diffusion at 5.066GeV for spins initially at 100 mrad from $\hat{n}_0$



Conclusions

- Two possible layouts have been studied
- Energy scan for both designs was performed
- Evolution of spin distribution over a few damping times was obtained for both TESLA and OCS ring
- NO significant depolarising effects have been detected confirming the earlier works
- But we will maintain a rolling study to include extra effects as necessary
- Modelling of depolarisation in the BDS

Plans for FP7

Damping Ring topics that will need further study in 2008 and beyond:

In general Beam dynamics studies will be always needed in order to be fully confident on the DR performance and to reduce costs and improve performance:

- Studies on "low emittance tuning" are still interesting.
- Collective effects are very important and need further studies and R&D, in particular:
  - e-cloud instabilities (Including R&D on vacuum design)
  - fast ion instabilities

R&D on technical systems

- Fast kickers: stripline and pulser design
- Feedback systems
- Design of 650 MHz RF cavity
- Evaluation of impedance vacuum chamber and design of low impedance chamber
- Diagnostics (emittance measurements, bpms for ultra low vertical emittance,..)
- Wiggler Design

- Discussion on DR test facilities (HERA, CESR,..)