Ecloud simulation

2007 ILC Damping Rings Mini-Workshop

18-20 December, 2007

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Content

- Update of the ecloud in wiggler
- Update of Grooved Chamber
- Electrode effect
- Simulation of the ecloud experiment in PEPII
- Head-tail instability
- Summary

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Ecloud in wiggler

(L. Wang, F. Zimmermann, PAC07, TUPAS067)

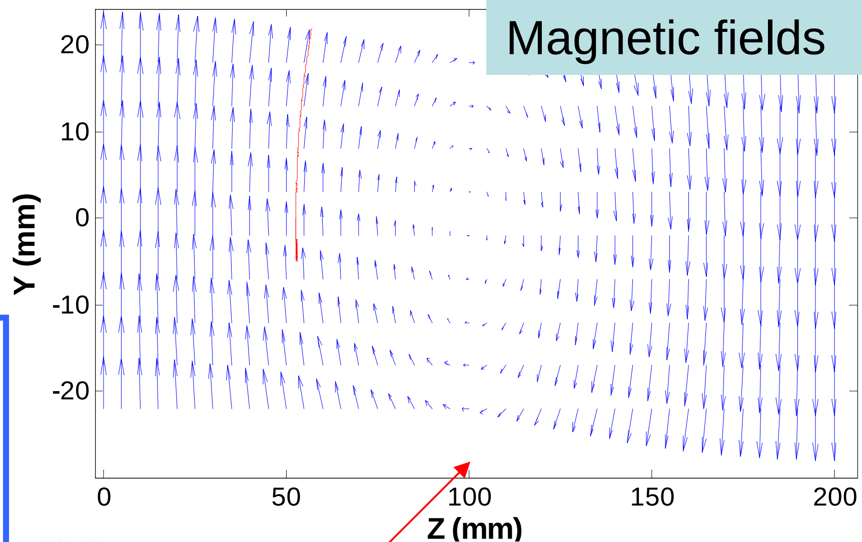
Wiggler fields

$$B_x = \frac{k_x}{k_y} B_0 \sinh(k_x x)\sinh(k_y y)\cos(kz)$$

$$B_y = B_0 \cosh(k_x x)\cosh(k_y y)\cos(kz),$$

$$B_z = -\frac{k}{k_y} B_0 \cosh(k_x x)\sin(k_y y)\sin(kz)$$

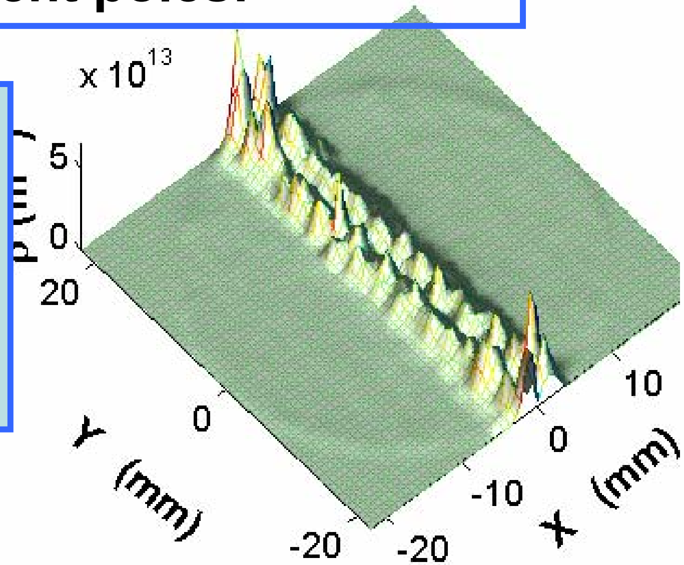
SEY=1.2

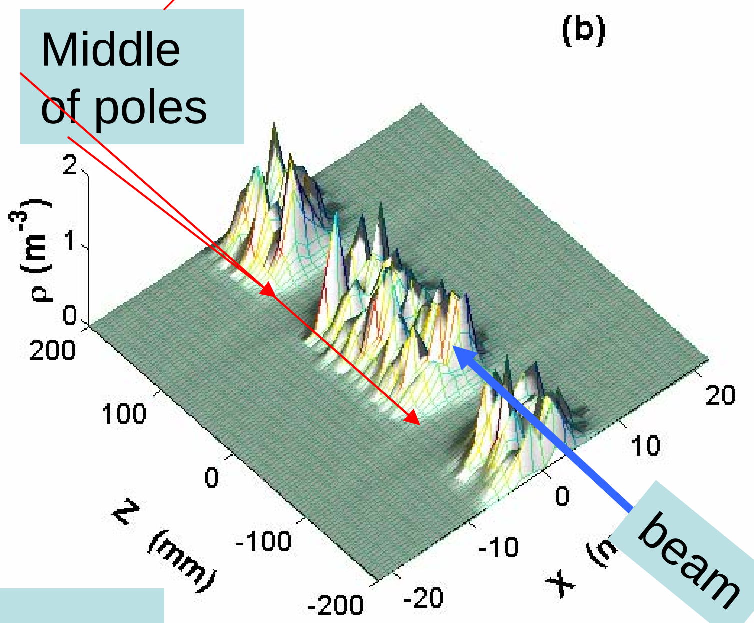


3D distributions shows:

There is very low e-cloud density in the middle of the two adjacent poles!

Grooved Chamber and clearing electrode should work in wiggler (similar as in dipole magnet!)



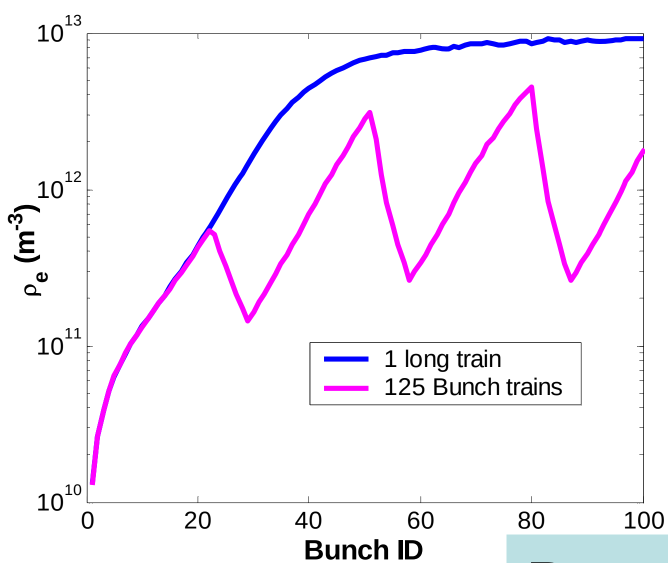


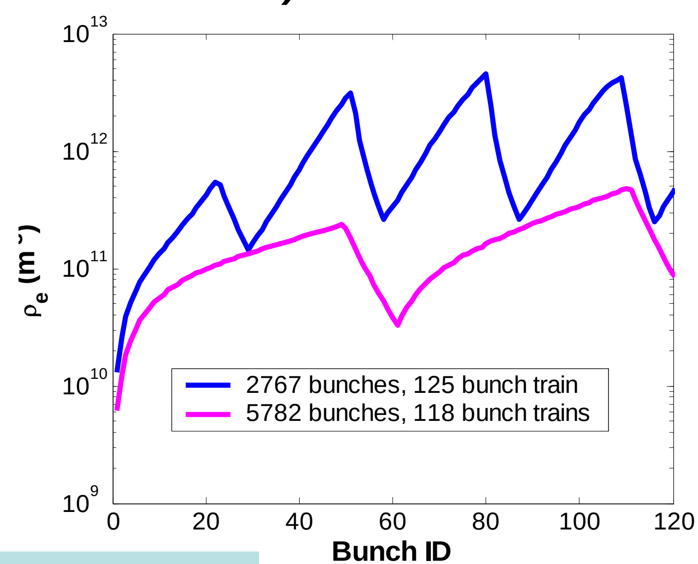
Ecloud in wiggler magnet

Ecloud build-up in wiggler

- A long bunch train with low bunch current (Low Q) can significantly reduce the electron density

- The short period of the wiggler magnetic field can slightly reduce the electron density (**a field with a period of 0.2m reduces the electron cloud density 30% comparing it with a period of 0.4m**.)



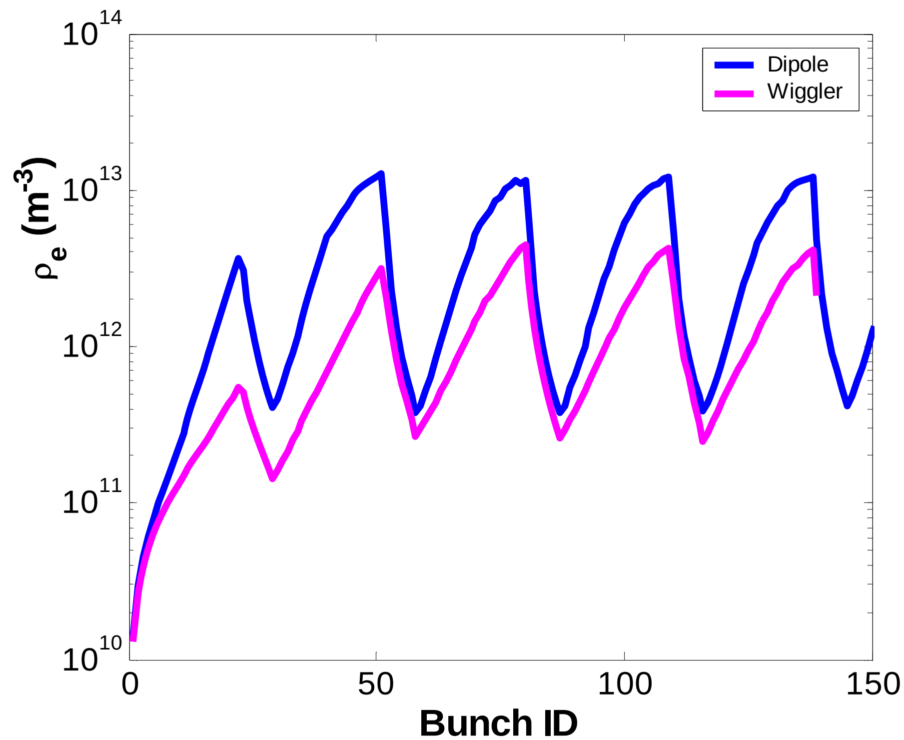


Beam filling pattern effect

Comparison with dipole magnet

There is a lower ecloud density in wiggler!

The peak electron density in the dipole magnet is larger than that in a wiggler by a factor of 2.7 due to the variation of the field with longitudinal position and the absence of multipacting in the region between successive wiggler poles



Electron build up in a dipole and in a wiggler, for a beam of 2767 bunches and 125 bunch trains.

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- **Update of Triangular Grooved Chamber**
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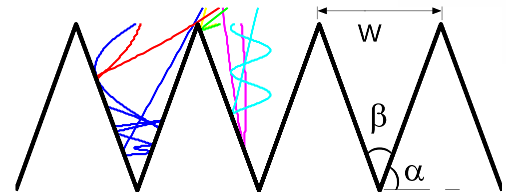
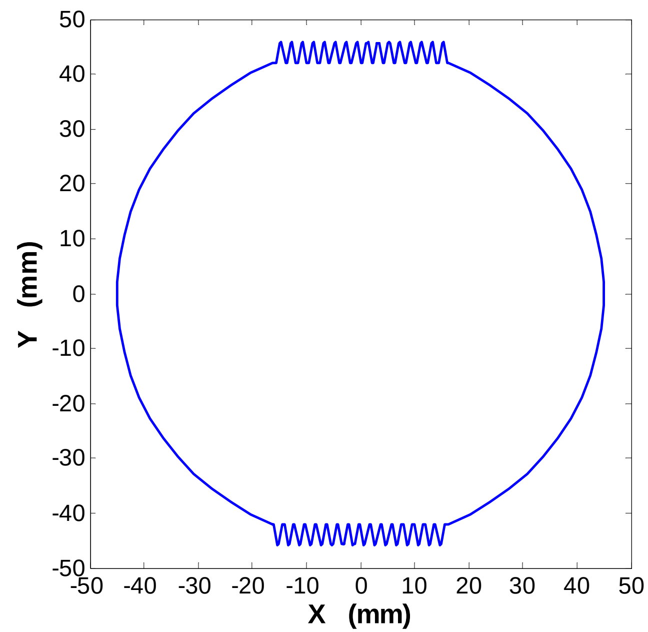
Impedance enhancement of grooved chamber

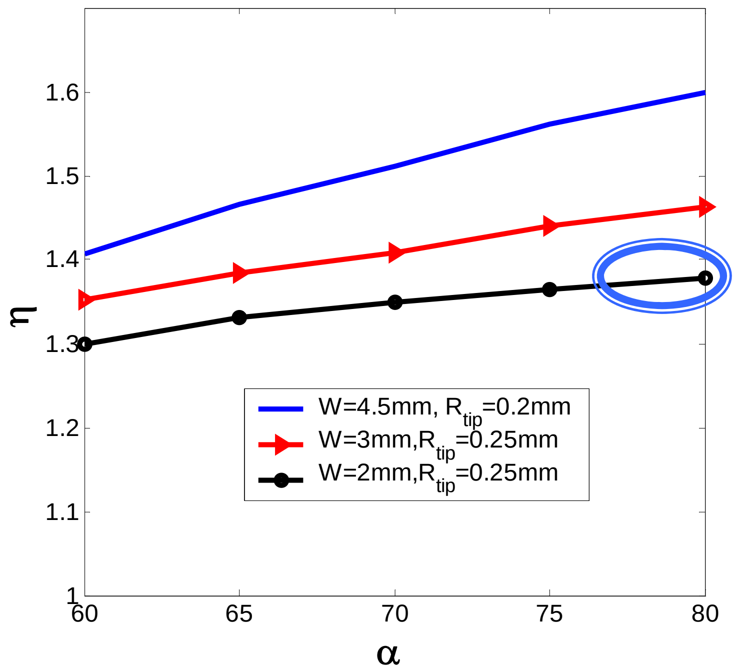
The impedance enhancement factor increases linearly with angle α in the region we are interested in and it is smaller than 2.0. The required grooved surface is only 15% of the total surface. Therefore, the overall impedance enhancement due to the grooved surface is small.



(L. WANG, et. al. NIMA, 571 (2007) 588)



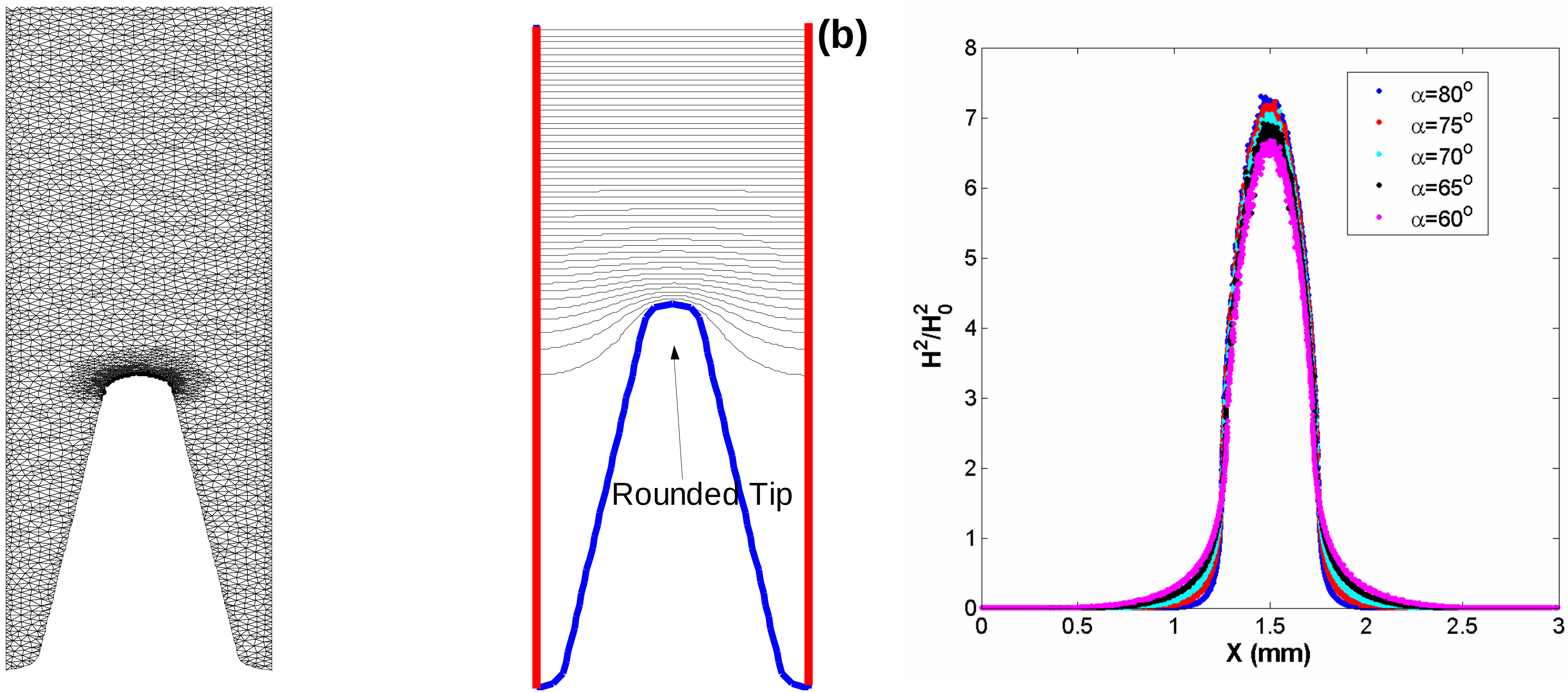
Model of the beam pipe with grooved surface in a dipole magnet in CLOULAND



Impedance enhancement factor of the triangular grooved surface with round tips

Adaptive IMEPDANCE ANALYSIS of Grooved Surface

(Thanks Karl Bane for very helpful discussions)

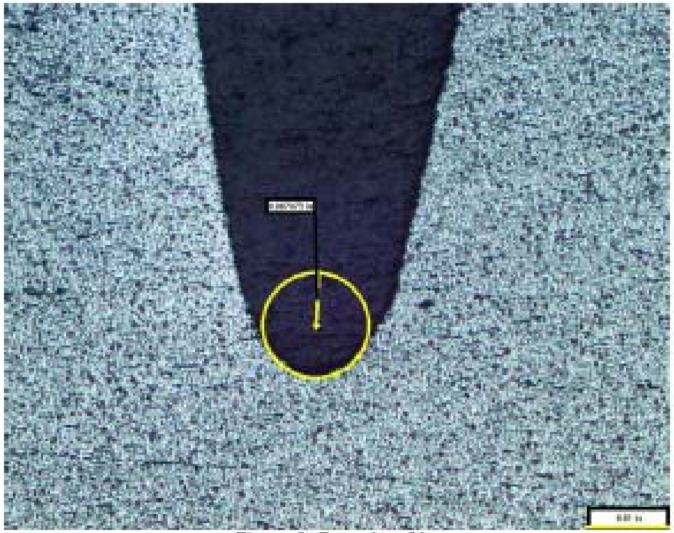


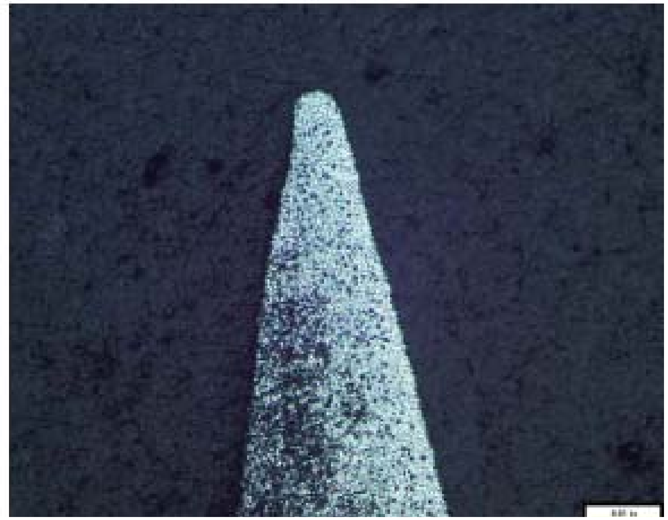
Mesh and field near the grooved surface

(L. Wang, PAC07, THPAS067)

Roots and Tips of the grooved surface(sample)

(Courtesy Frank Cooper, SLAC)





Surface and Materials Science Department
Metallography Report

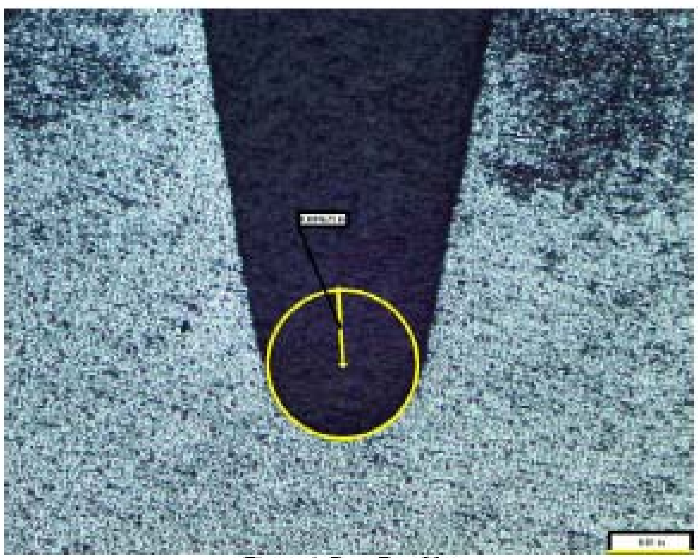


Figure 4: Root B at 31x

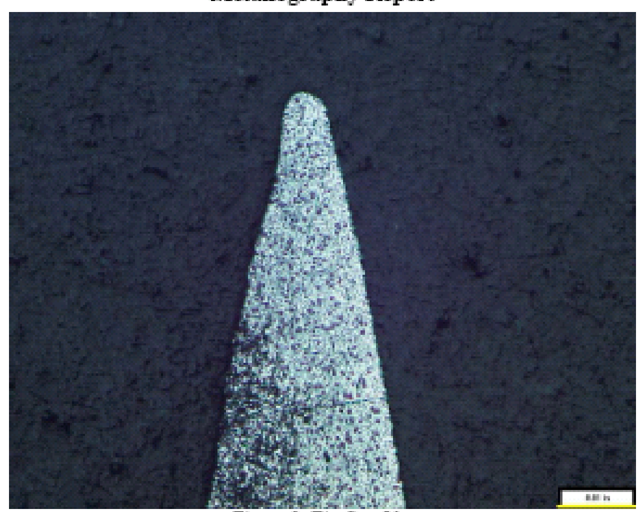


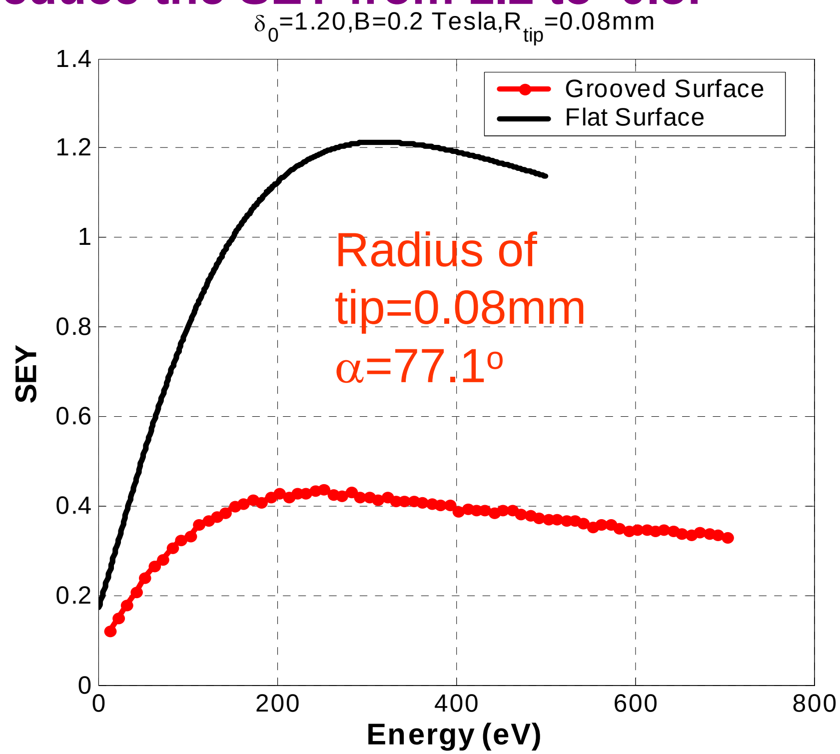
Figure 9: Tip C at 31x

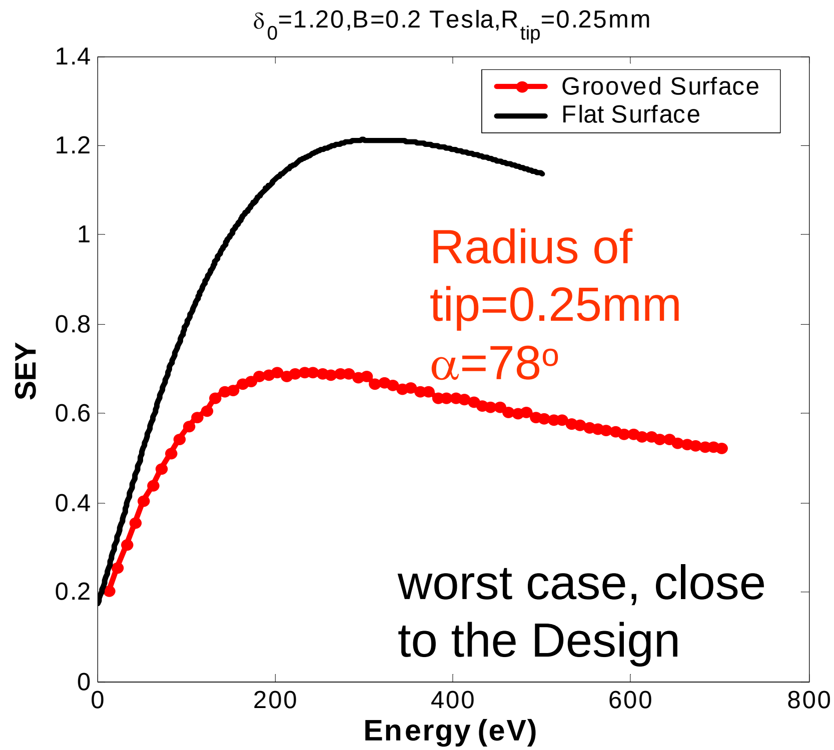
Estimation of SEY of the grooved chamber in PEPII Dipole magnet

Simulation Parameters

Peak SEY δ_0=1.2, Width =2mm, Dipole field=0.2Tesla

The radius of the tips from manufacture is smaller than we expected! It can reduce the SEY from 1.2 to 0.5!





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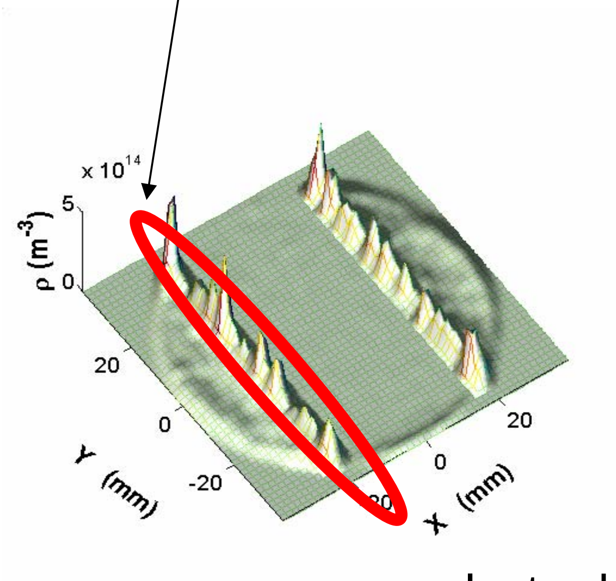
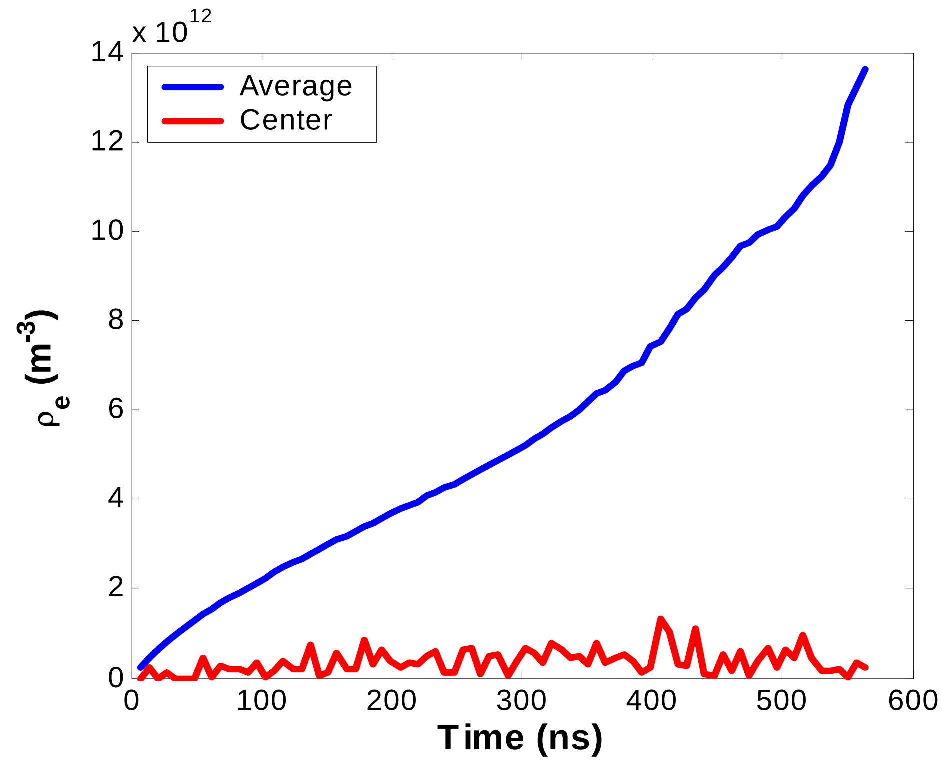
Accumulation of ecloud around electrode

In most cases, Electron density near the beam is low, but more electrons can accumulate outside the electrode



electrode

One electrode at the bottom



Sey=1.4 v=300Volts

Effects of the rectangular grooved chamber in PEPII

- Reduction of the premaries
- Reduction of the secondaries

Estimation of the reduction of primary electrons

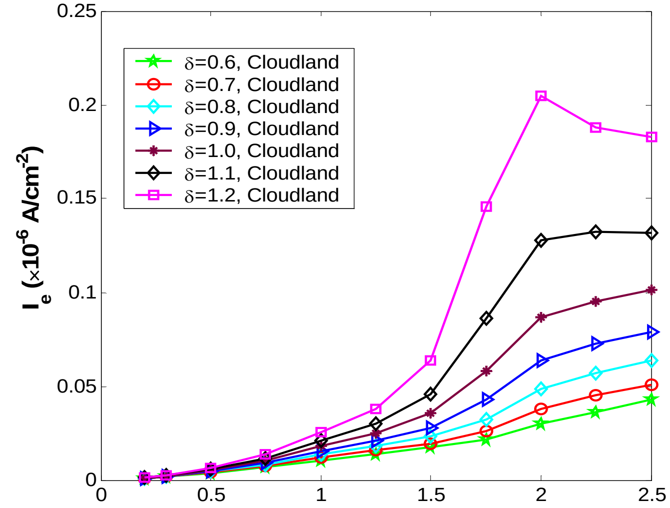
The rectangular grooved chambers reduced the photon electrons by a factor of 13~18! (like a mini-ante-chamber)

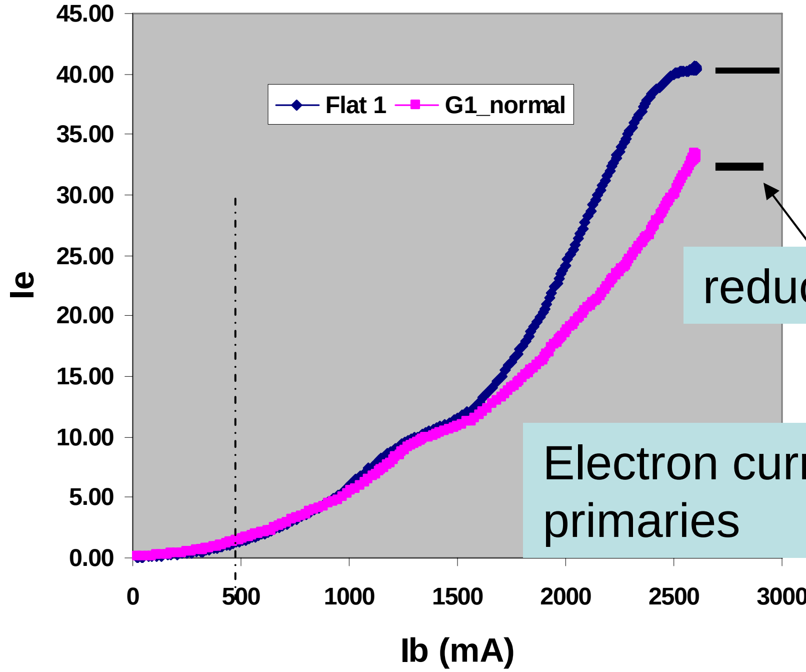
Results (relative Photon electron number for the same amount of photons):

1. Flat 1 : 1.0
2. Flat 2: 0.8
3. Groove 1: 0.04 (1/14)
4. Groove 2: 0.041 (1/13)

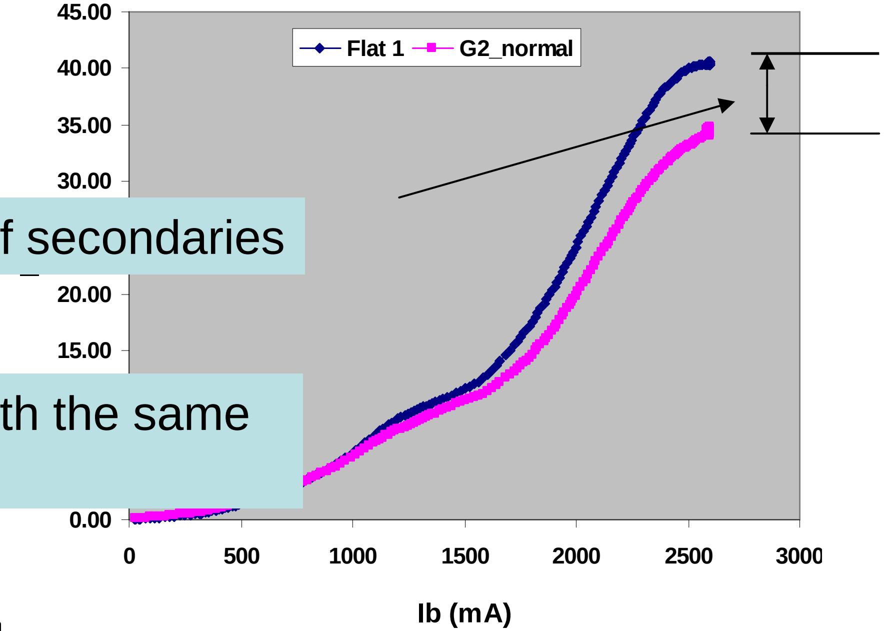
Suppression of the secondaries

- **Due to the coating (SEY<1), there are no much secondaries, further reduction of the SEY by grooved chamber doesn't reduce the electron current much although the SEY is LOWER!**





reduction of secondaries



Electron current with the same primaries

Comments

- In the test of clearing electrode and grooved surface, our goal is to reduce the secondaries. Therefore, it would be better to let the multipacting happen (generate more secondaries), and then suppress them, make the effects more clear and easier in analysis

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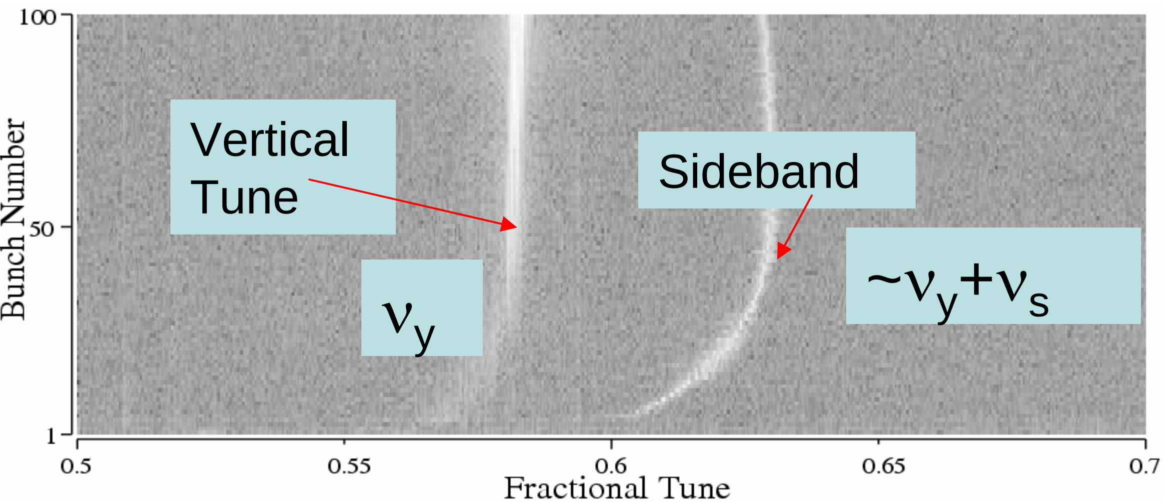
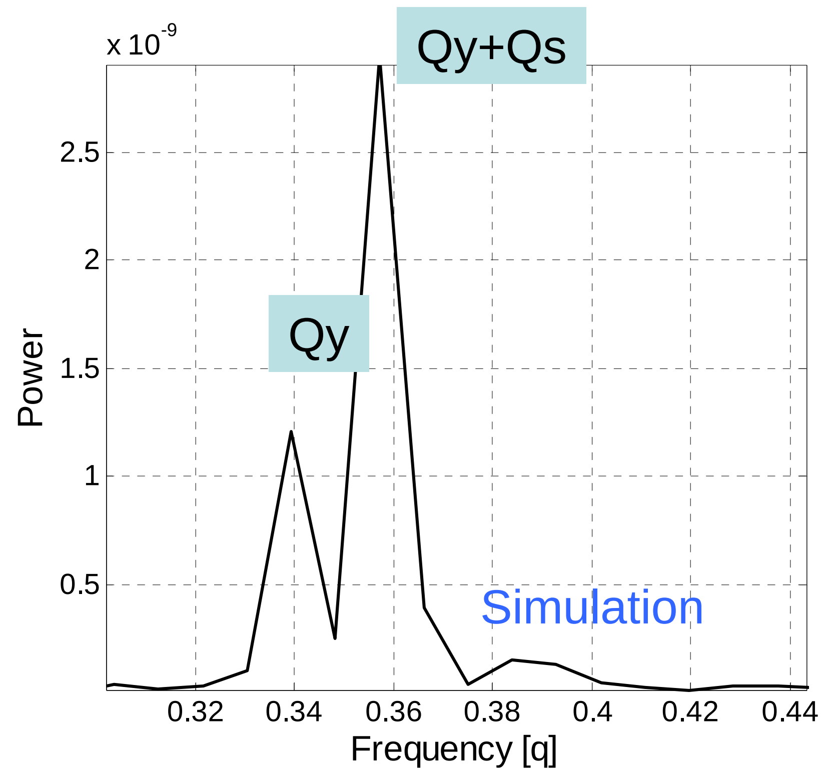
Electron-Beam instability (single bunch)

Beam size blow-up
Synchro-beta sideband

- ➢two-streams instability PIC code is developed
- ➢Sideband is reproduced



Measurements KEKB

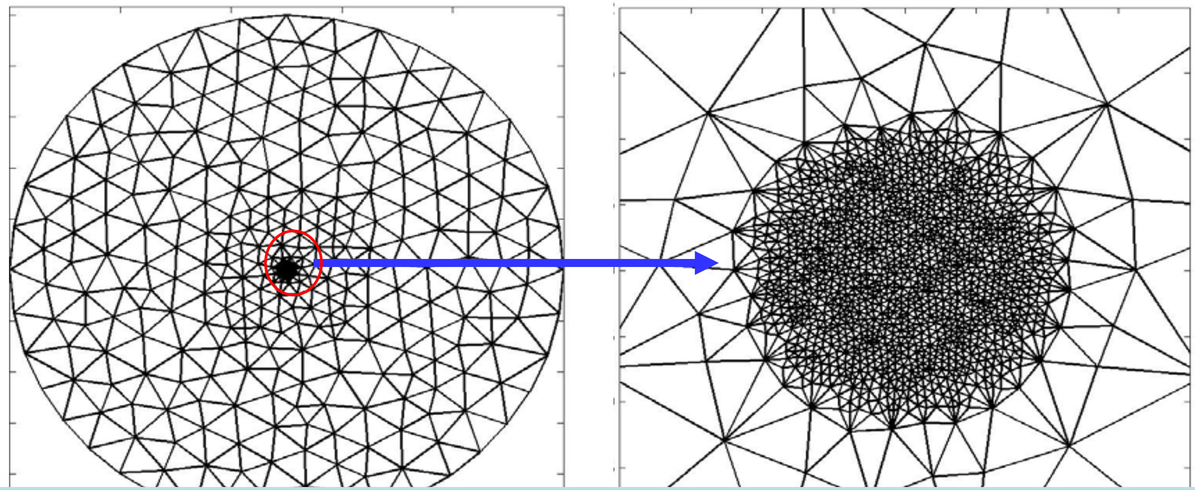


J.W. Flanagan, K. Ohmi, et. al., Phys.Rev.Lett.94:054801, 2005.

Adaptive simulation of Head-tail

- Challenge in such kind of simulation: Very large ecloud vs. very small beam spot (a few μm) , The pinch factor in ILC is very larger (60)(15for B-factory)

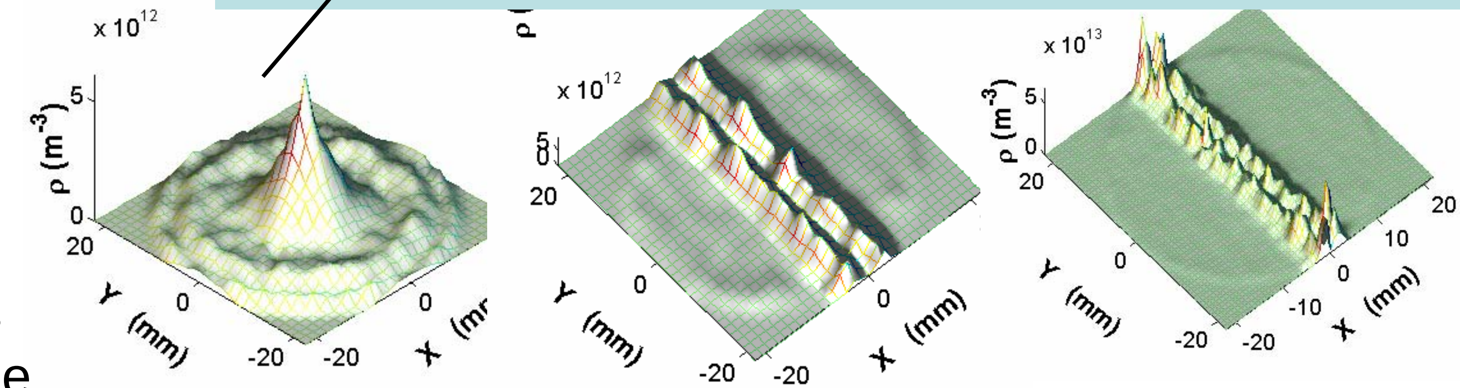
- adaptive method will be applied, the ecloud from the build-up can be loaded to the instability simulation



Sample: Mesh of chamber & beam in field free region

Advantages

- High accuracy
- Fast
- Very Easy to use
- Arbitrary boundaries
- Arbitrary beam shape and ecloud shape



Drift region dipole wiggler

Summary

- We simulated the ecloud in various conditions with 3D program CLOUDLAND
- Electron cloud in wiggler is understood:

There is a minimum ecloud density at the middle the magnet poles

A low Q beam has low electron density

A small period of the wiggler can low the ecloud density

The ecloud in wiggler is lower than in dipole

- The radius of the round tip of the triangular grooved chamber is smaller than we expected and the grooved surface can significantly reduce SEY. A build-up simulation with the design geometry is under the way.
- The rectangular grooved chamber can reduce both primaries and secondaries. However, it is extremely difficult to distinguish them precisely due to the coating effect.
- There is a strong pinch effect in ILC, we use a adaptive code to simulate of single bunch Instability, which can model the realistic distributions of the ecloud (Very large) and Beam (VERY small)

Beam-Ion instability in PEPII HER

(Courtesy S. Heifets, et.al.)

1730 bunches with 2 RF bucket spacing (total ring can fill 1746 bunches)

Beam current
Number of bunches increase

HER Beam
Dipole oscillation + beam size blow-up

(LER beam size drop)

Luminosity drop

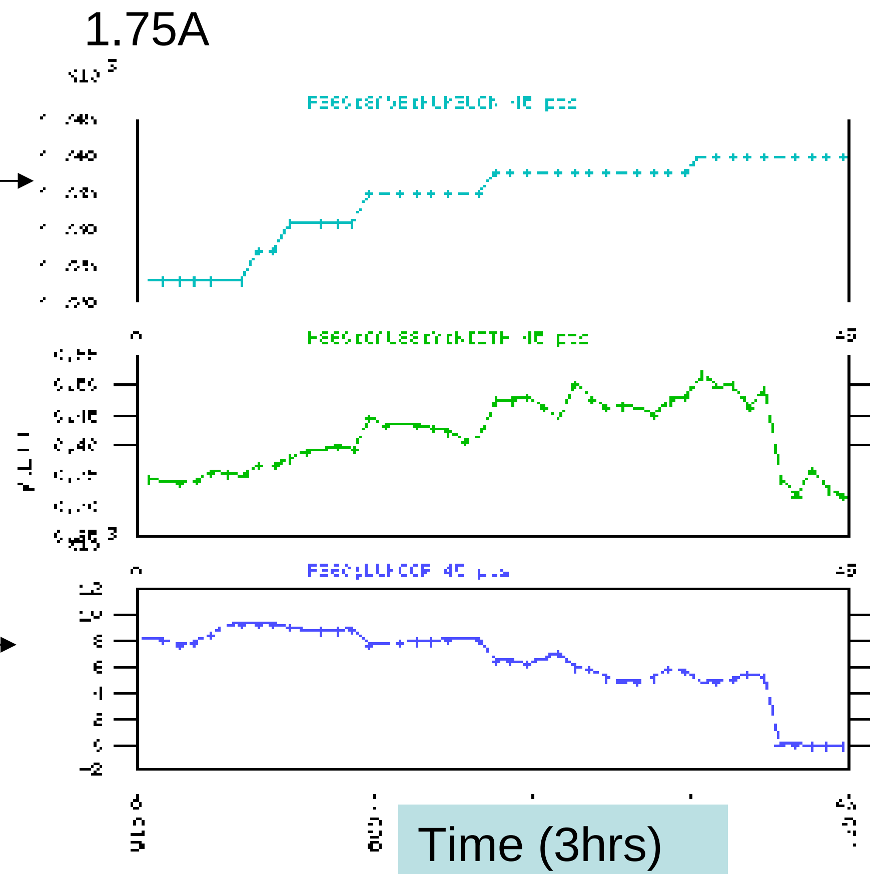


Figure 6: Gap instability. Variation of the number of bunches (top pane), the vertical rms σ_y of the electron beam, and the luminosity (bottom pane) with time. The total time span about 3 hours.

ION-MAD has been used to simulate ATF, However,

Challenge of the Strong-strong simulation for ILC

Minimum requirements:

- Number of Bunches: >1000
- Number of elements along the ring (ion-stations) ~500
- Macro Number particle per bunch: 10000
- Macro number particle per element 10000
- Number of turns > 1000

1000CPU?

Total macro particles of beam: 10E7

Total macro particles of ions: 5E7

A. Kabel, Cho-Kuen NG from SLAC (Advanced Computation Department) are going to help.

Beam study (ATF, ALS, PEPII)

Thank you all!

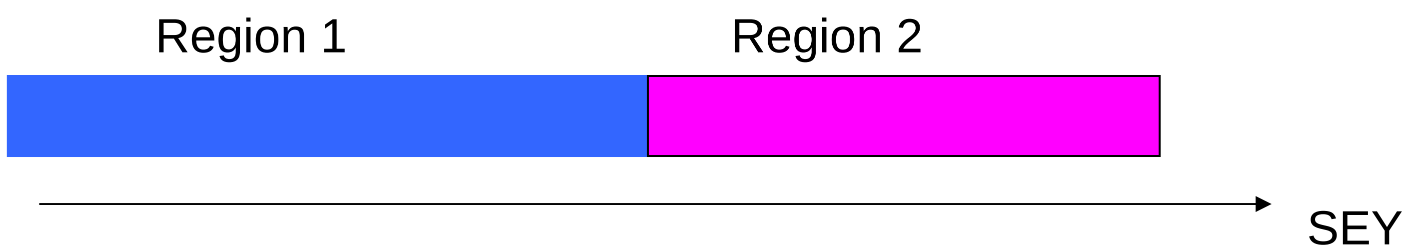
Merry Christmas!

&

Happy New Year!!

Backups

Application of the ecloud Mitigations

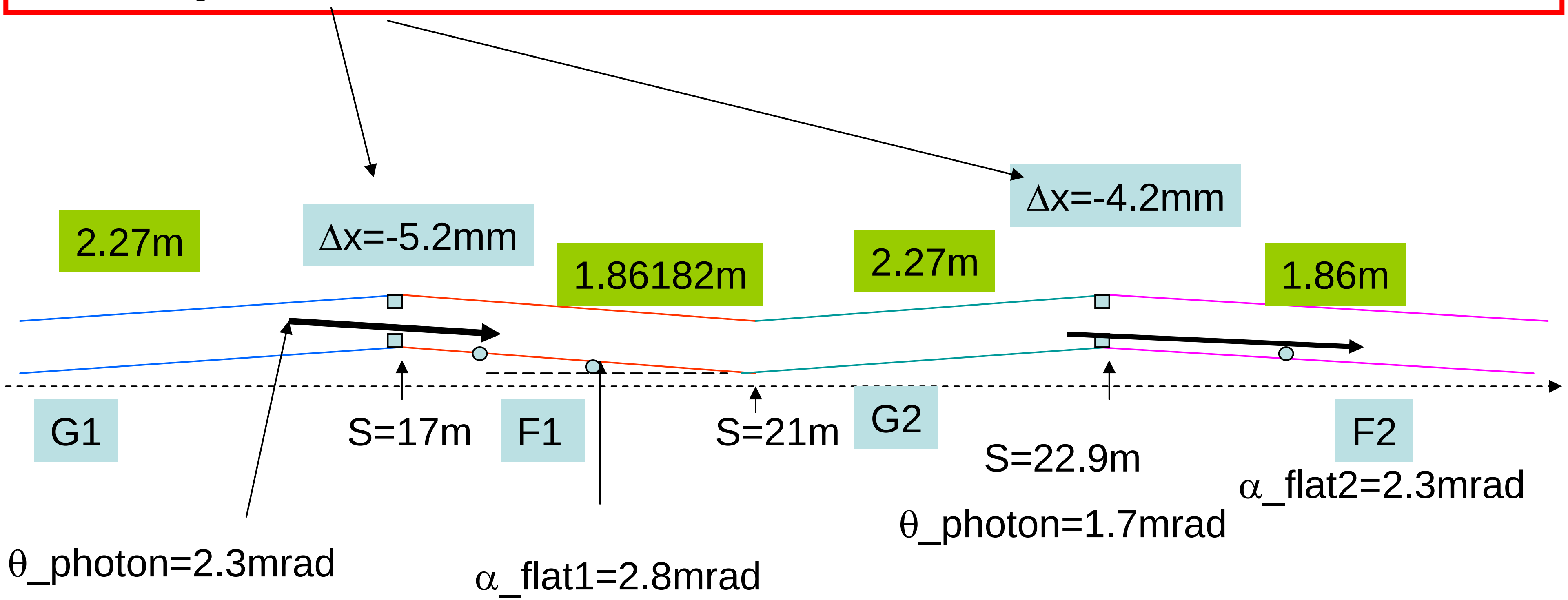


Ante_chamber

- Coating
- Grooved chamber
- electrode

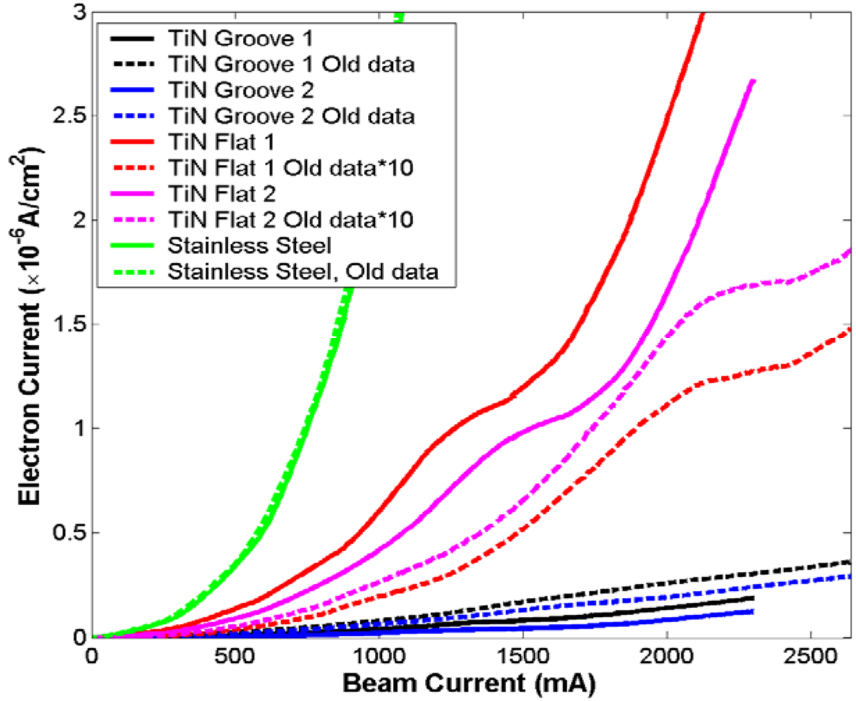
Photon flux before alignment

The large horizontal offset shadows the two Flat chambers!



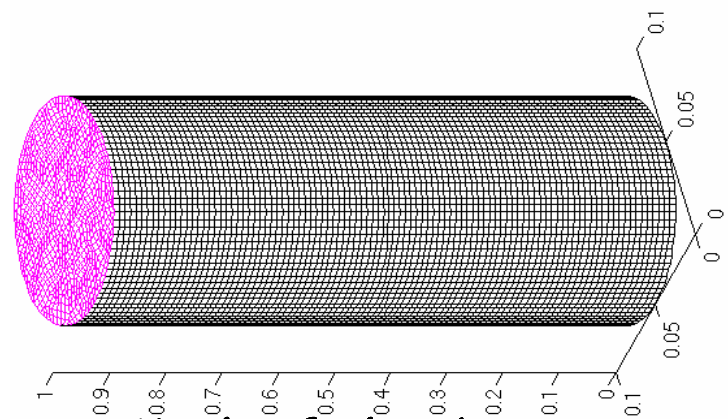
Electron current change after the beam pipe alignment

- E-current in the flat chambers increases by a factor >20/10; the shape also changed!
- E-current in Grooved chamber reduced by a factor 2
- E-current of the stainless steel chamber remain the same.

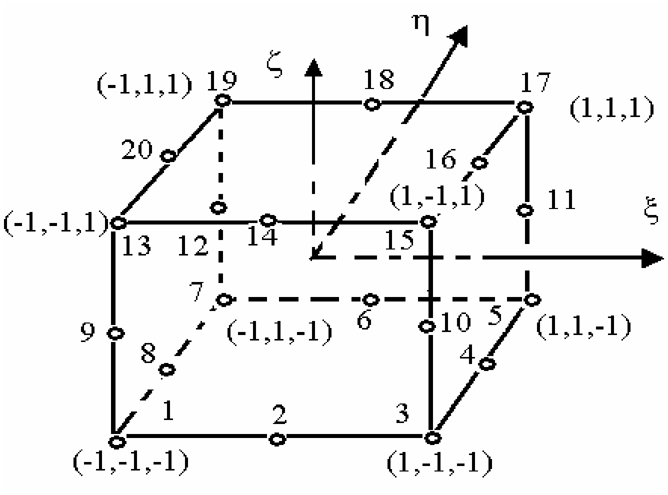


Particle Mesh In CLOUDLAND

- Three dimensional irregular mesh to better represent the general chamber geometry
- handle accuracy with high order elements.



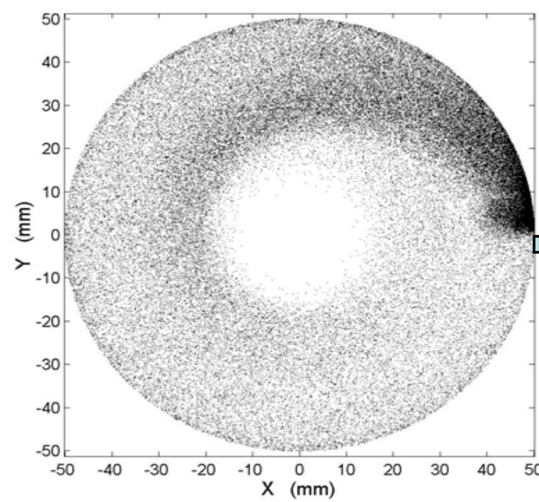
Mesh of chamber



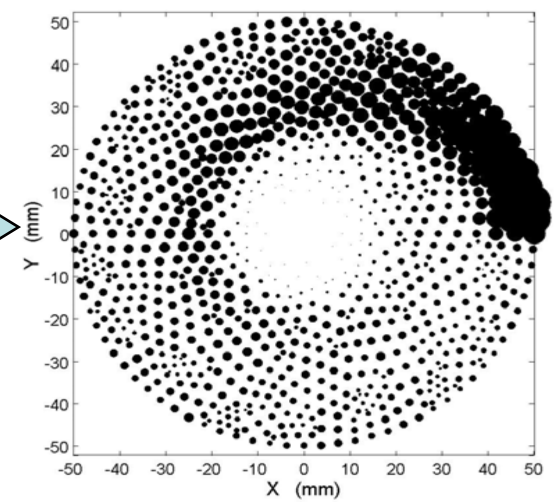
20 node element

Charge assignment

$$Q_i = N_i Q_0 \quad \sum_i N_i = 1$$



Real charge distribution



Meshed Charge distribution