Electron Cloud Simulations for ANKA

U. Iriso
CELLS, Barcelona, Spain

in collaboration with S. Casalbuoni[1], U. Iriso[2], G. Rumolo[3], F.Zimmermann[3]

[1]Researh Center Karlsruhe, Germany
[2]CELLS, Barcelona, Spain
[3]CERN, Geneva, Switzerland

Electron Cloud Mitigation Workshop 2008
Nov. 20-21st, 2008

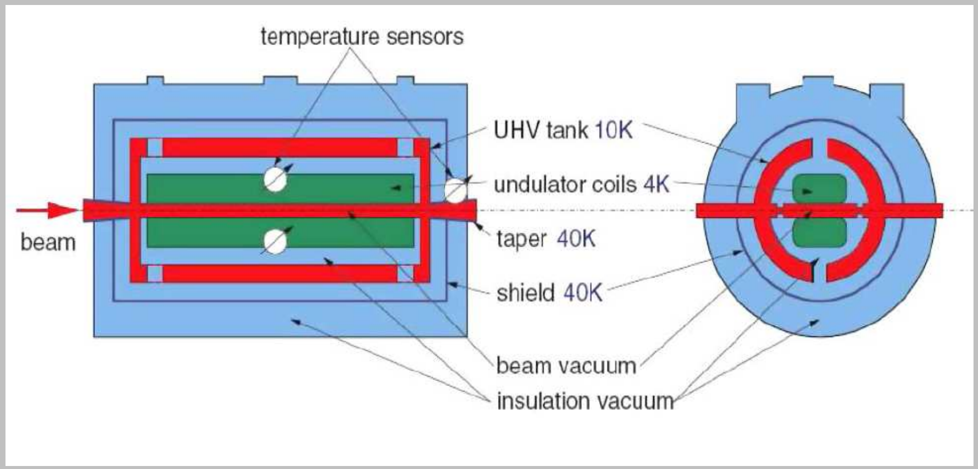
Contents

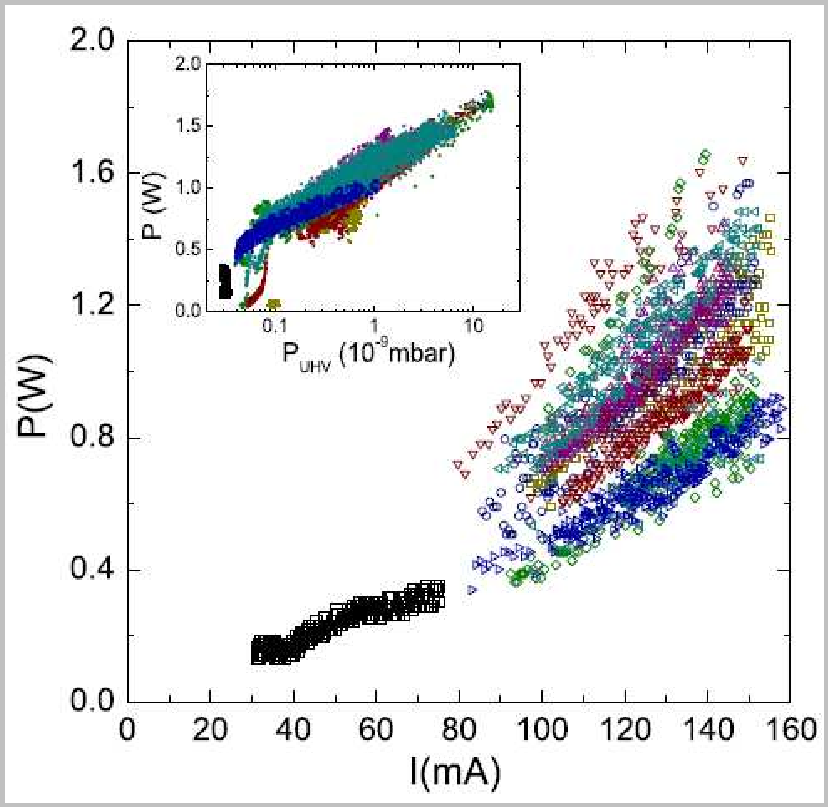
Contents

Introduction

2005 & 2006:
Heat load and vacuum pressure rise observed at ANKA Superconducting Undulator

(See S. Casalbuoni's presentation)





Measured heat load

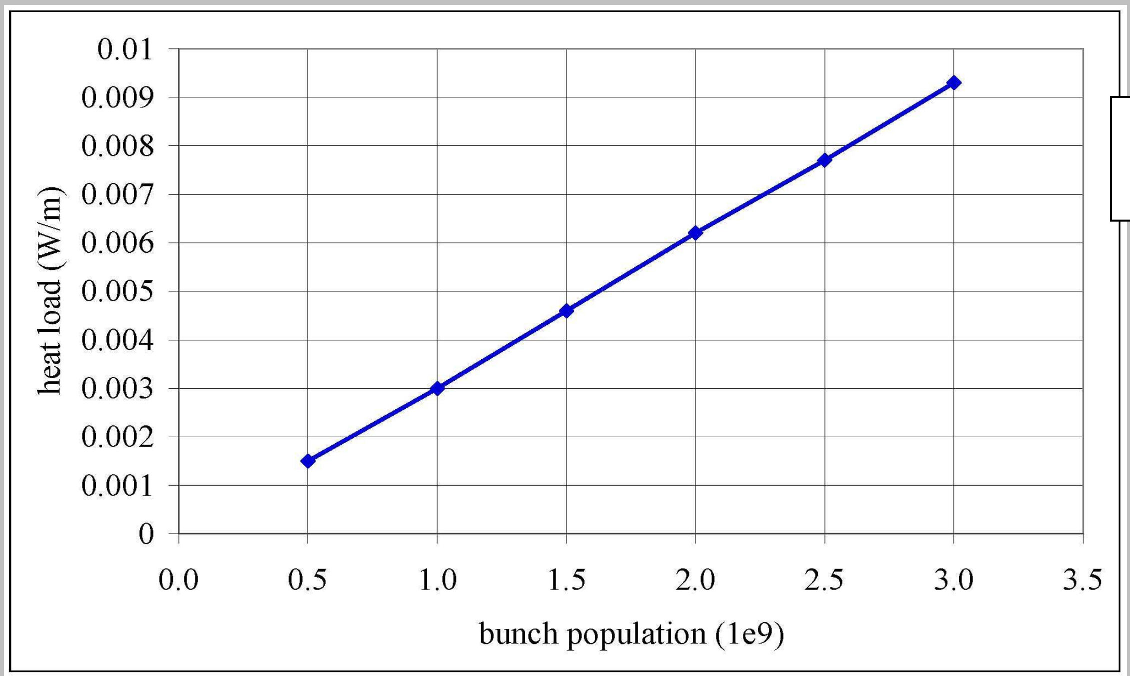
- not consistent with synchrotron radiation
- not consistent with resistive wall effects
- but, consistent with electron bombardment model*

→ What is the nature of this electron bombardment?

*S.Casalbuoni et al, PRST-AB 10, 093202 (2007)

Introduction

2007 & 2008:
Simulations using ECLOUD are performed in order to crosscheck if the electron bombardment is due to an electron cloud build-up.



F. Zimmermann, Heat load at ANKA, 2007 (unpublished).

First results scanning SEY=1.5, 1.7, 1.9 show a discrepancy about a factor of [20 – 100].

In this ppt:
- → Scan of different ECLOUD parameters
- → Compare results with observations at the clearing electrode (used as electron detector)

1. Introduction
2. **ECLOUD build-up simulations**
3. Comparison results
4. Summary

ECLOUD simulations

wrt ECLOUD code:

Electron cloud build-up with electron beams can be simulated with **ECLOUD***
Be careful: **ECLOUD** uses NAG libraries in many subroutines
NAG libraries are not always available at other labs than CERN

wrt cryomodule:

Uncertainty in the usual key ingredients related with surface physics parameters (δ_0, δ_{max}, E_{max}, ...) is amplified at 4 K.

For instance:
1. Ype = # e- / # photons
Determines the number of primary electrons created by bunch passage.
Important for e- (and e+) machines

2. SEY @ cryomodule?

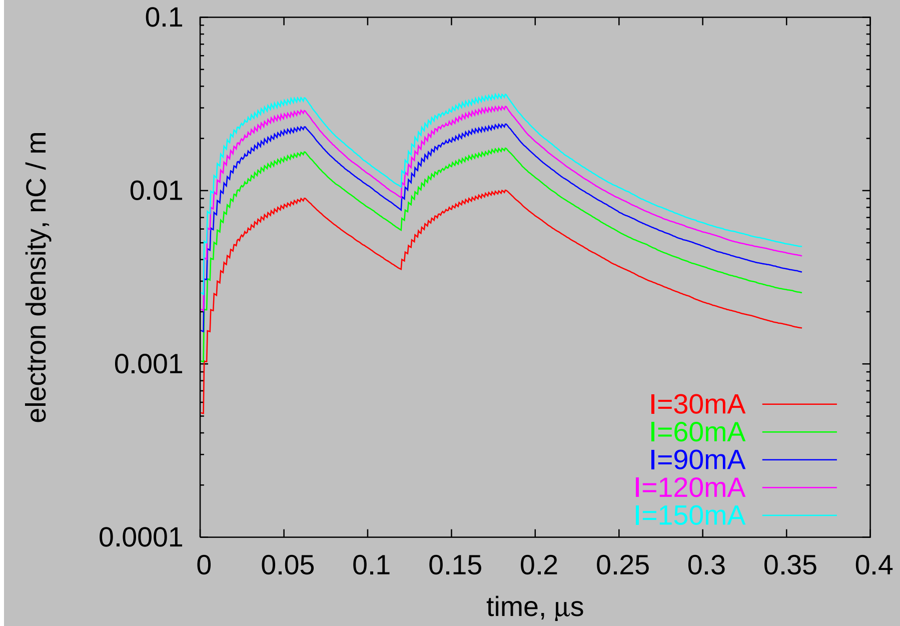
***ECLOUD CODE:** http://wwwslap.cern.ch/collective/electron-cloud/Programs/Ecloud/ecloud.html

Input parameters

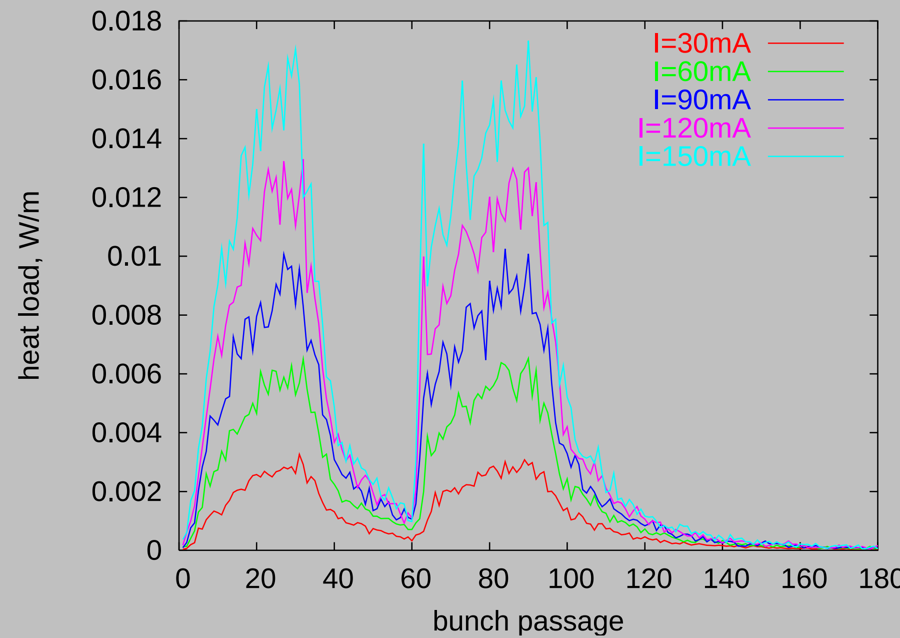
Parameter	Unit	Ref. Value	Scan Range
Beam intensity	mA	**100**	30 – 150
Bunches / train	…	**32**	…
Bunch trains	…	**2**	1 – 3
Bunch Charge	e-/bunch	**3.5e9**	Depend on intensity and # bunch trains
Bunch spacing	ns	**2**	…
Energy	GeV	**2.5**	
Rev. Period	ns	**360**	…
hor / ver beam size	mm	**0.840 / 0.063**	…
Long. beam size (rms)	mm	**12**	…
hor aperture (rms)	mm	**80**	…
ver aperture (rms)	mm	**30**	8 – 40
SEY max, δ_{max}	…	**2.0**	1.5 – 5
Energy for max. SEY	eV	**290**	…
SEY at zero energy, δ_0	…	**0.5**	0.5 – 0.9
Ype	%	**10%**	2 – 20

Ref. Case – Beam intensity scan

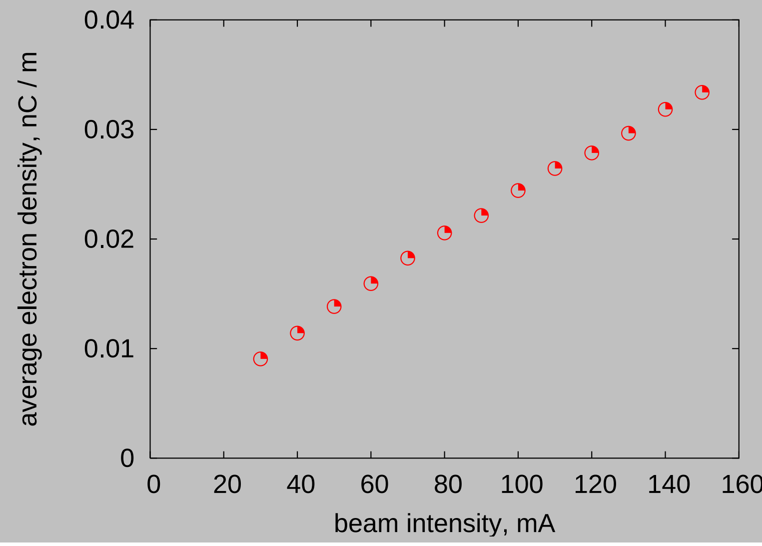
Linear electron density in one revolution



Heat loat in one revolution

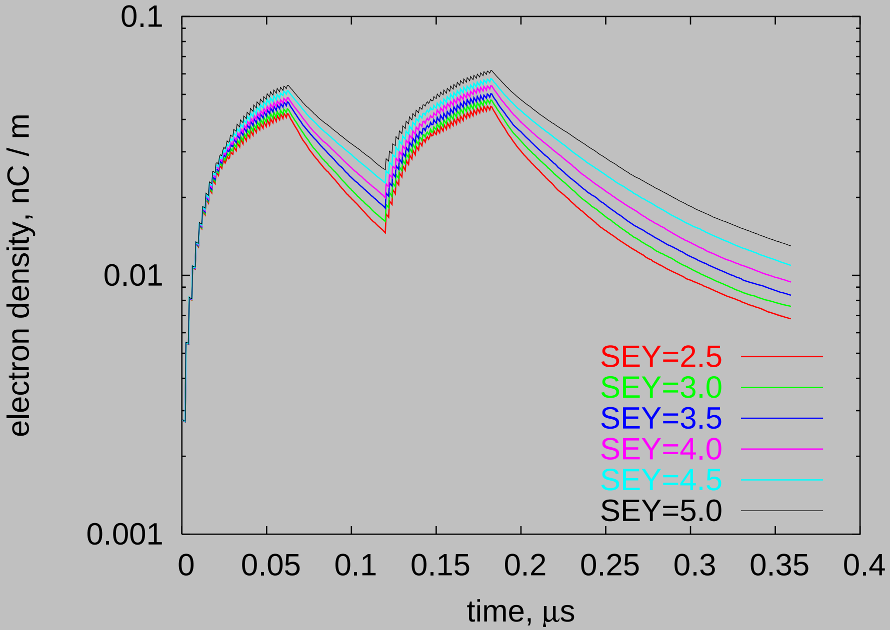


- Big first jump due to photo-electrons created by synchrotron radiation.
- Simulated heat load is about a factor of 50 lower than measured
- Average electron density shows a quite linear dependence on beam intensity

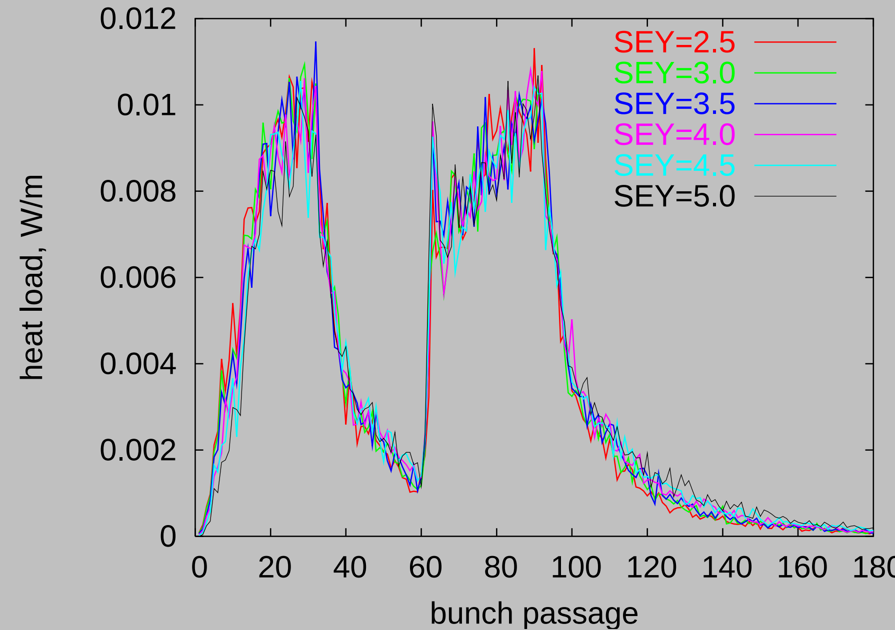


Ref. Case – δ_{max} scan

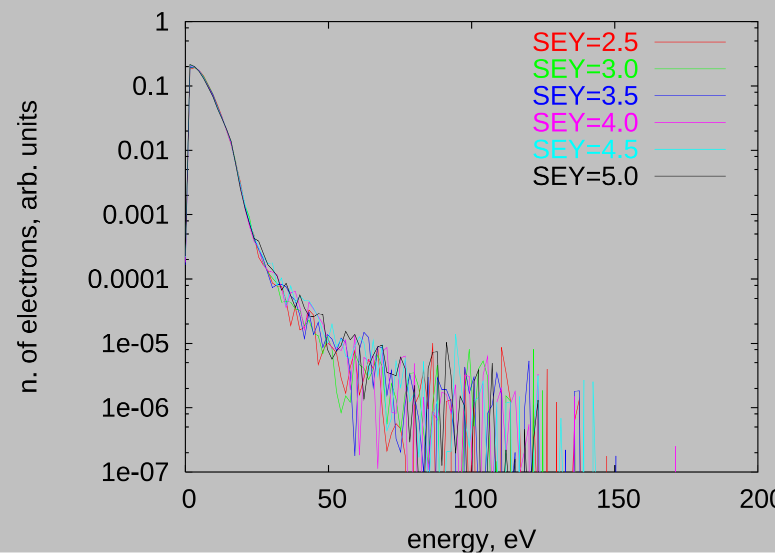
Linear electron density in one revolution



Heat loat in one revolution

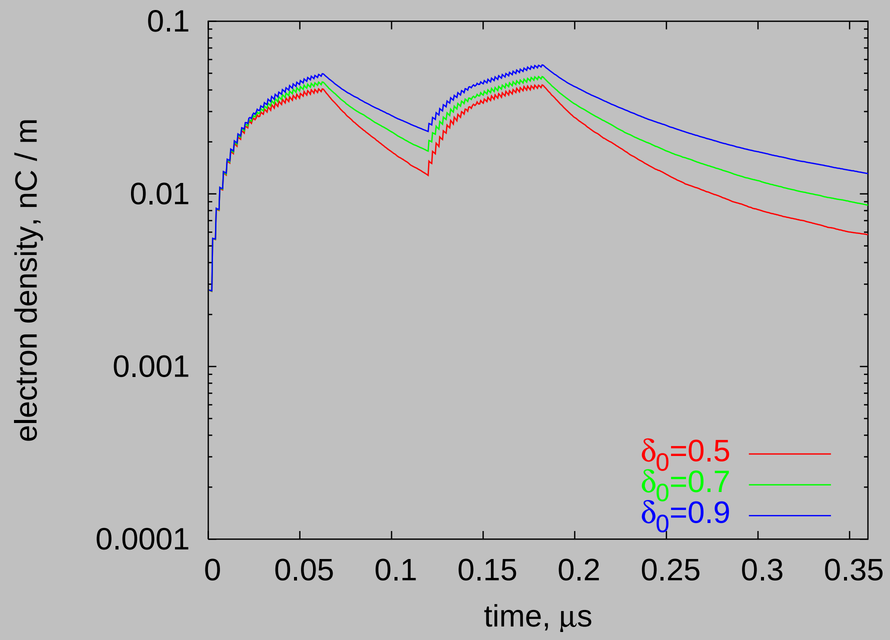


- Cryopumped gases coming from outside the SCU may largely increase the SEY
- Even for δ_{max} = 5, simulated heat load is about a factor 50 lower than measured
- Energy spectrum doesn't change much for the different SEY

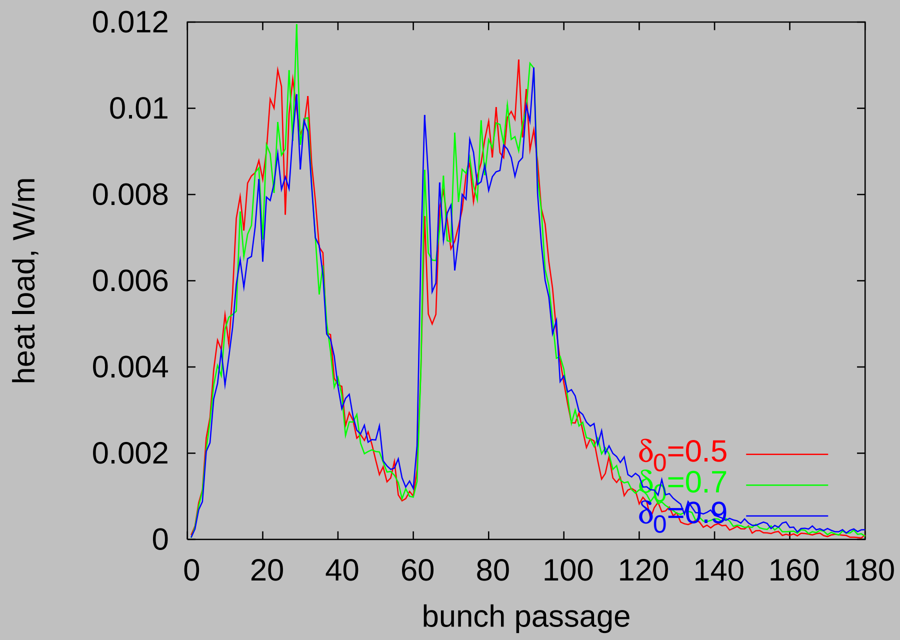


Ref. Case – δ_0 scan

Linear electron density in one revolution



Heat loat in one revolution

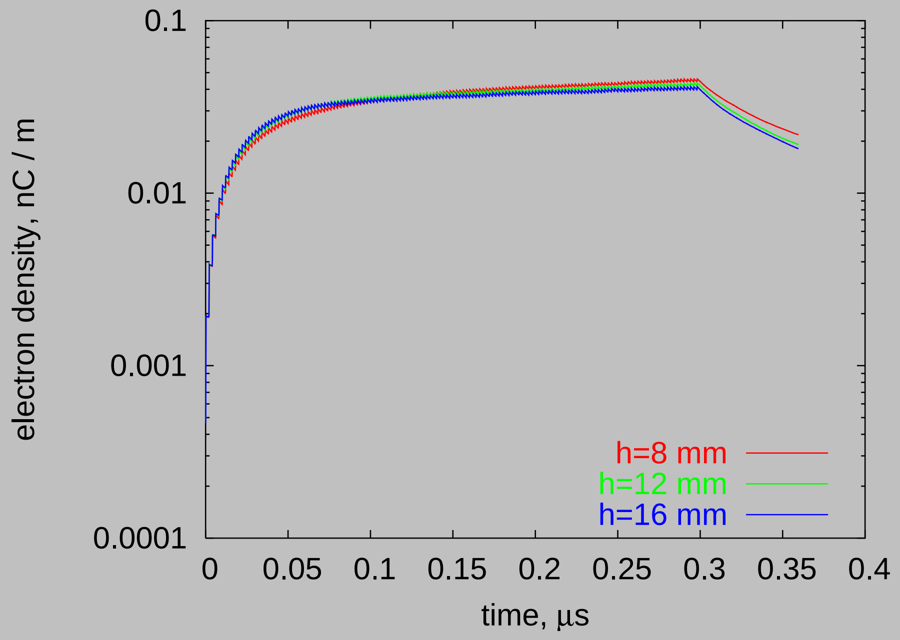


- The electron line density slightly increases with δ_0
- Negligible consequences on the heat load

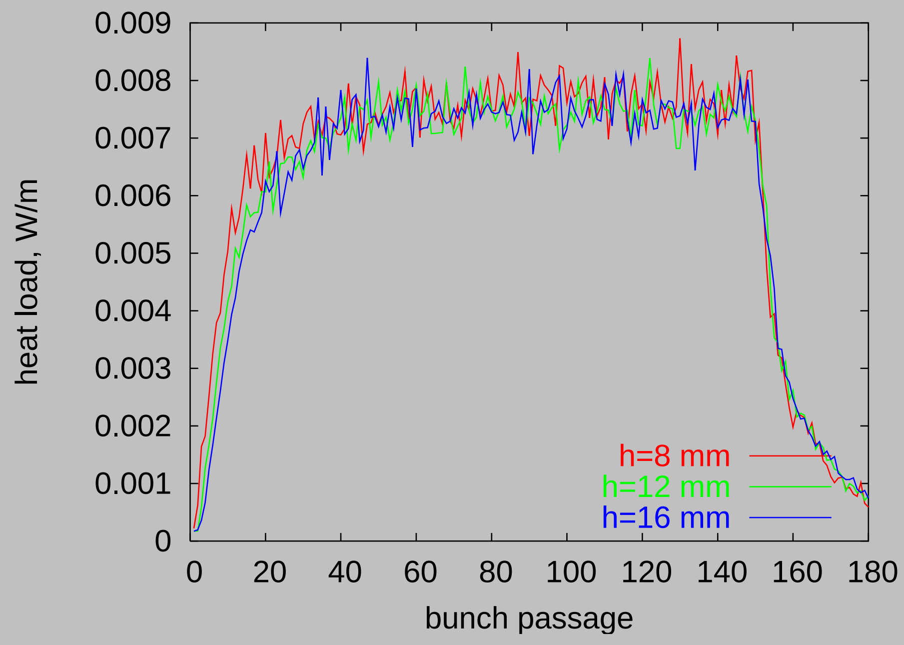
Vertical Aperture Scan

In this case, beam parameters slightly changed:
→ Simulated a continuous bunch train of 150 bchs + 30 empty bchs.
→ Used a beam of 2.45e9 e-/bunch (corresponding to 160mA in 3 trains)

Linear electron density in one revolution



Heat loat in one revolution



Ref. Case – Ype Scan (1)

As seen in previous plots, the big jump is due to primary electrons created after collisions of synchrotron radiation with vac. chamber.

- Photon flux: $\frac{d\phi}{d\theta_x} = \frac{5}{2\sqrt{3}}\alpha\gamma$ ph/rad/part.beam
- Ph-elect. Yield: Ype = # e- / # photons ; (Assumed = 10%*)

In the **ECLOUD** code, this is controlled by the input parameter *peeff,*

$$peeff = (d\phi / d\theta_x) * \Delta\Theta_x * Y_{pe} \quad \sim 0.005 \text{ e-/part. beam/mrad}$$

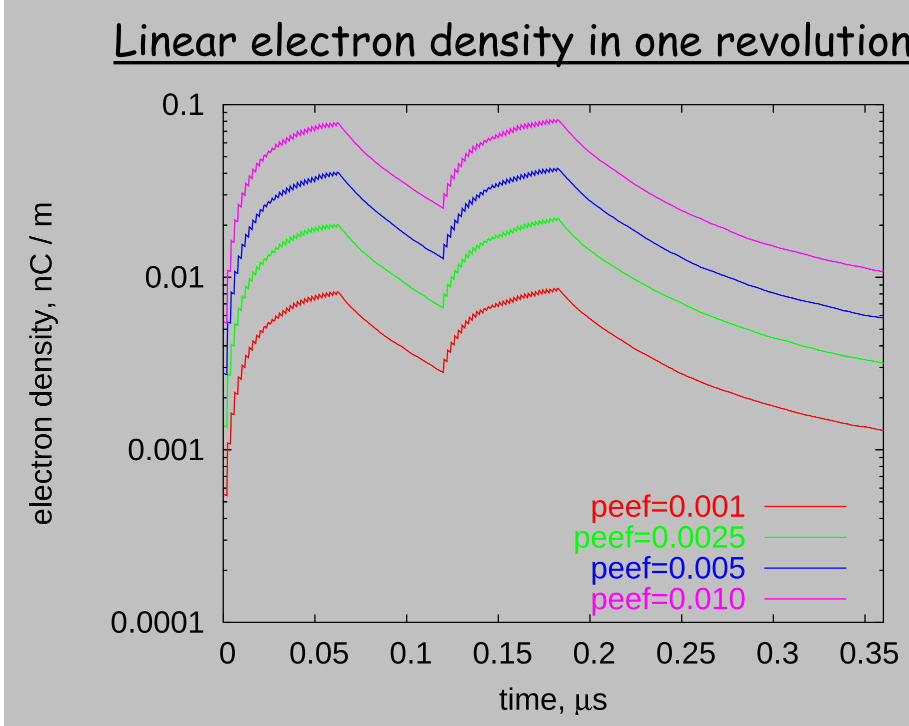
Ype	Peeff
20%	0.010
10%	0.005
5%	0.0025
2%	0.001

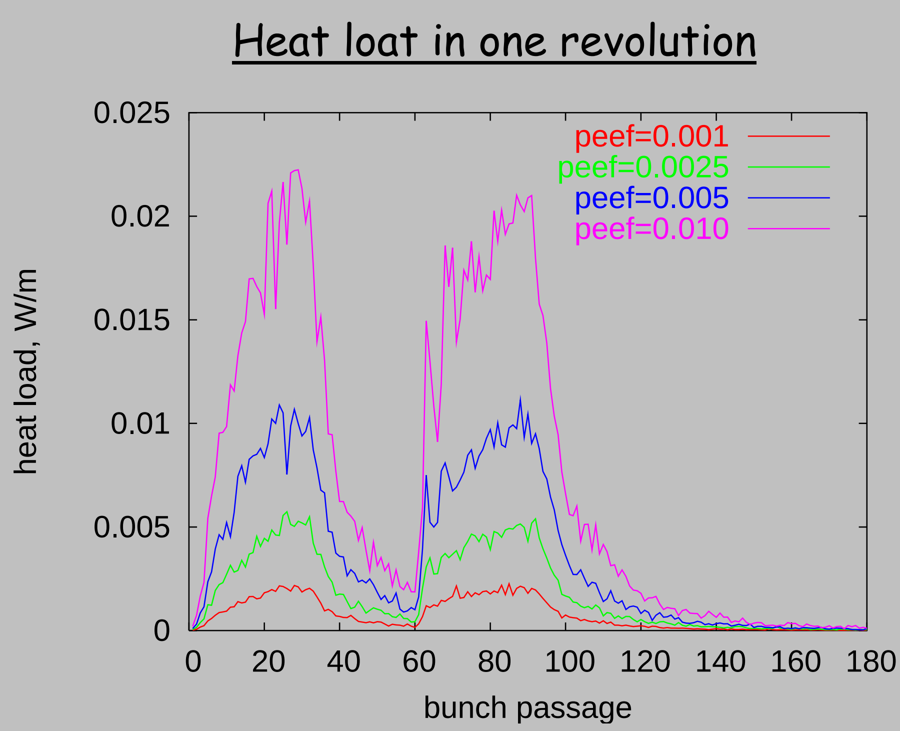
*value found at e-cloud simulatiosn in B-factories:

1%: H. Fukuma, L. Wang, Simulation study of e-cloud instability at SuperKEKb, PAC'05.

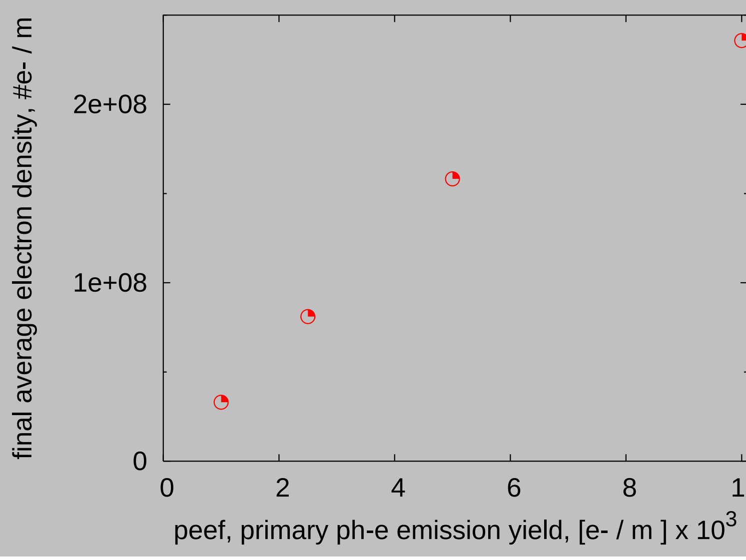
10%: F.Zimmermann, Electron Cloud studies for KEKb and ATF, ATF Int. Report, 03-03, 2003

Ref. Case – Ype Scan (2)





- heat load still factor ~50 lower wrt measured values
- quite linear dependence of average e-density with peeff



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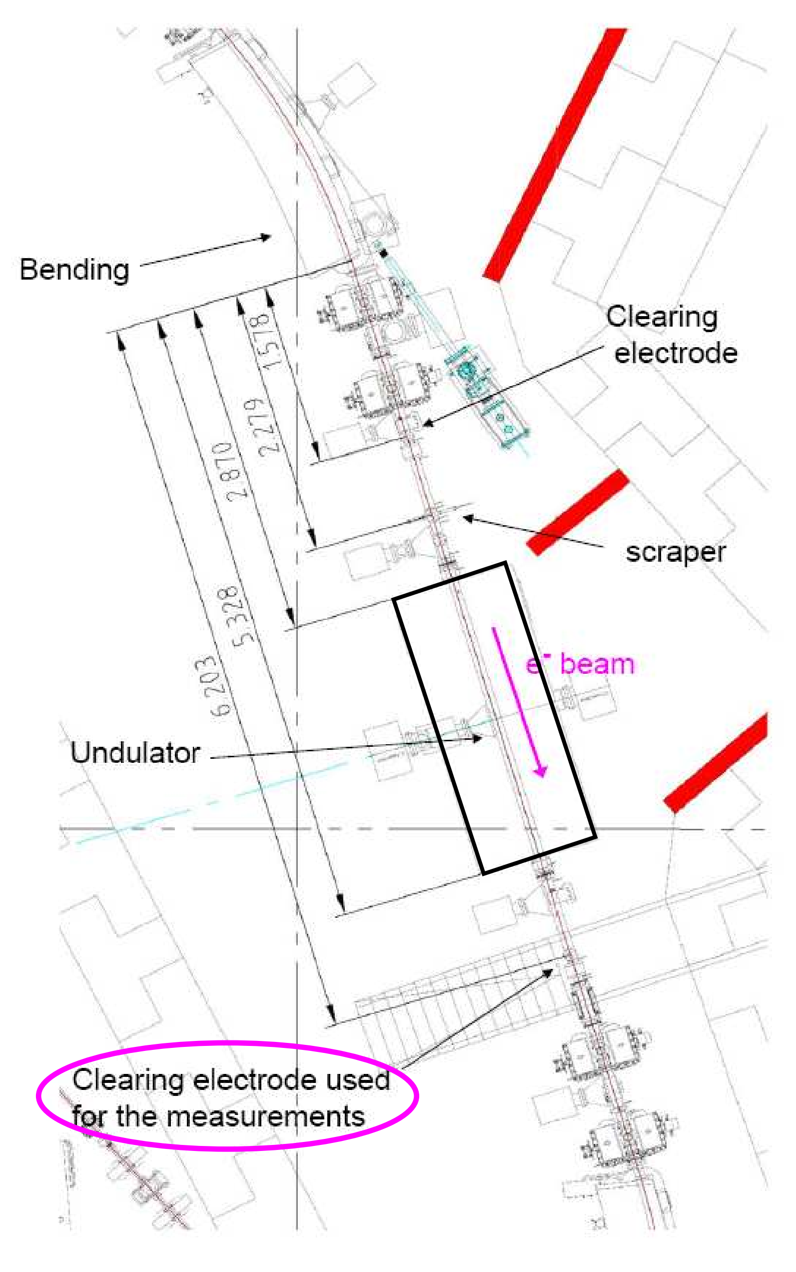
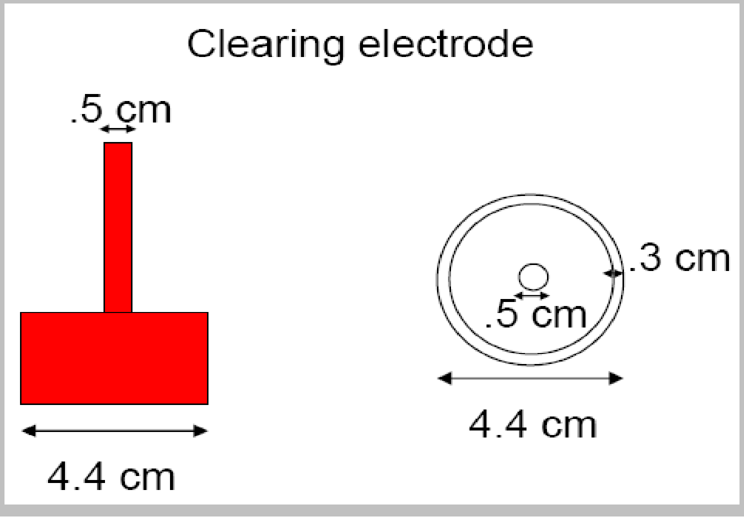
4. Summary

Comparison with e-detector results



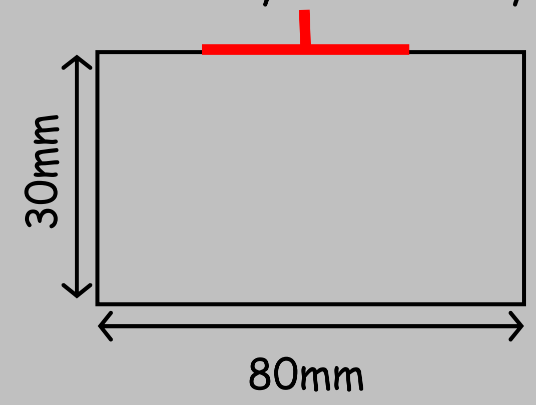
2007:
Electron detector (clearing electrode) installed downstream the SC vac. chamber.



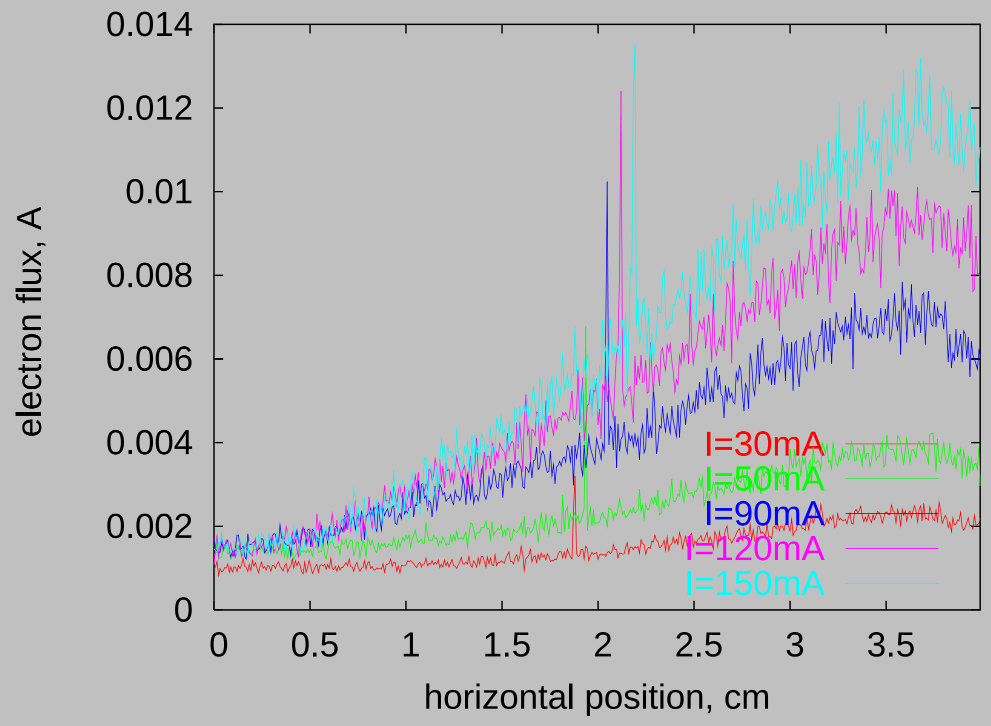
Comparison with e-detector results

• Since e-beams repel from center the cloud electrons, important to obtain e-flux at clearing electrode location.

Geometry under study:



Example: ref. case – scan in beam intensities



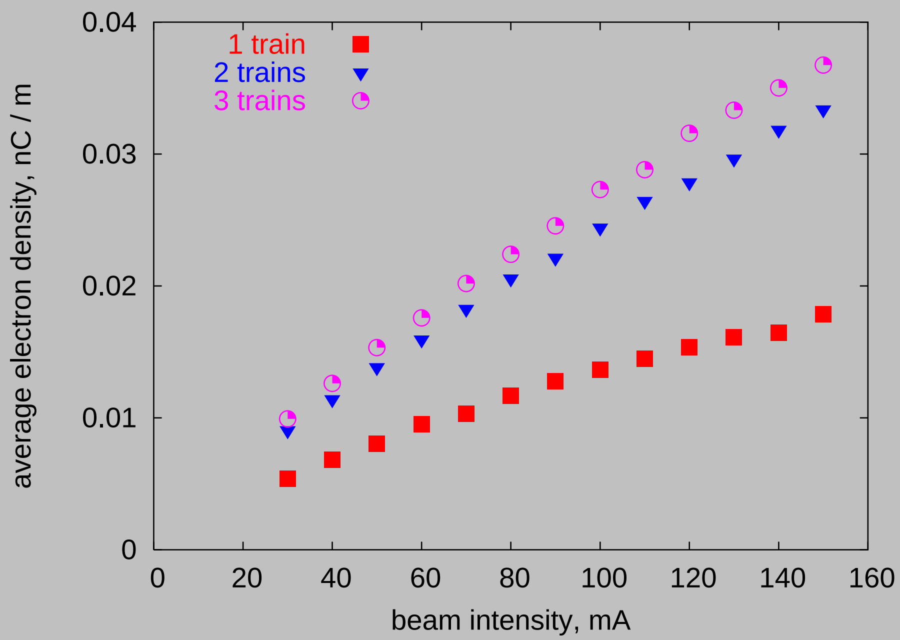
Average flux vs hor. position at vac. chamber

flux at center is ~5 times larger than flux at edges

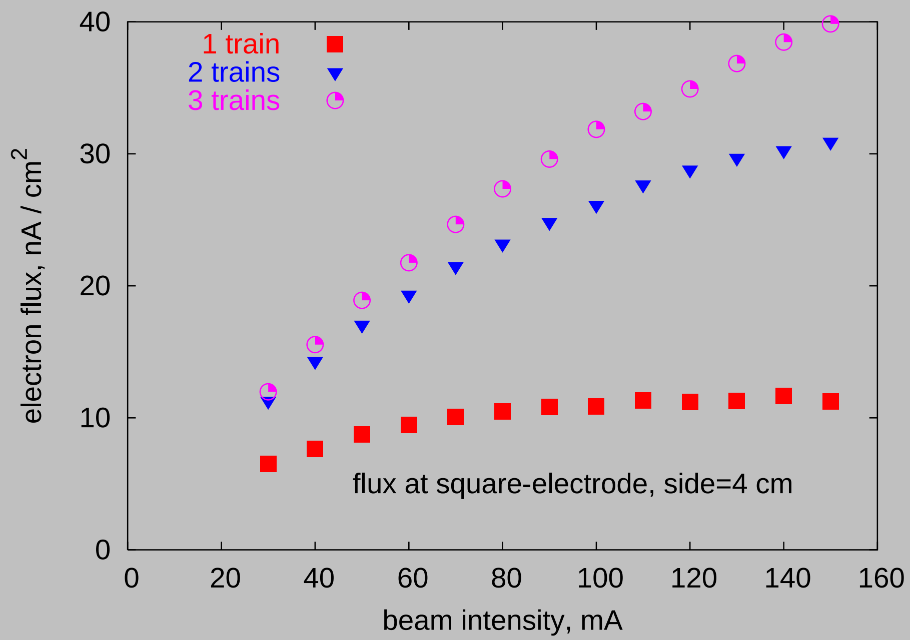
Comparison with e-detector

- Simulation of different bunch patterns: 1, 2, 3 bunch trains

Linear electron density:



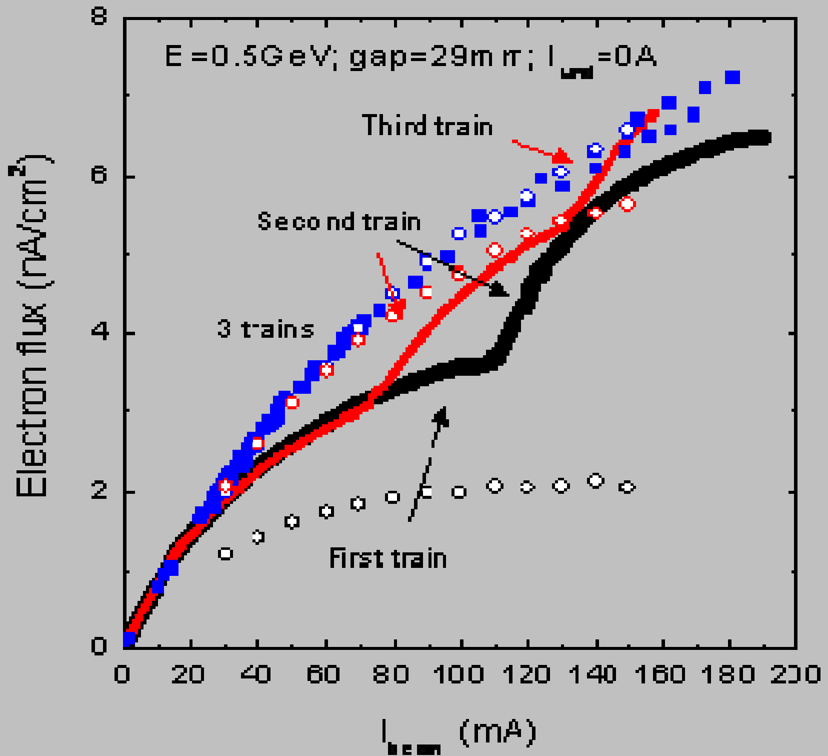
Electron flux at clearing electrode:



The electron density increases linearly in all cases, almost identical for 2 and 3 trains

Electron flux at center of beam pipe shows a stronger saturation for 1-train

Comparison with e-detector



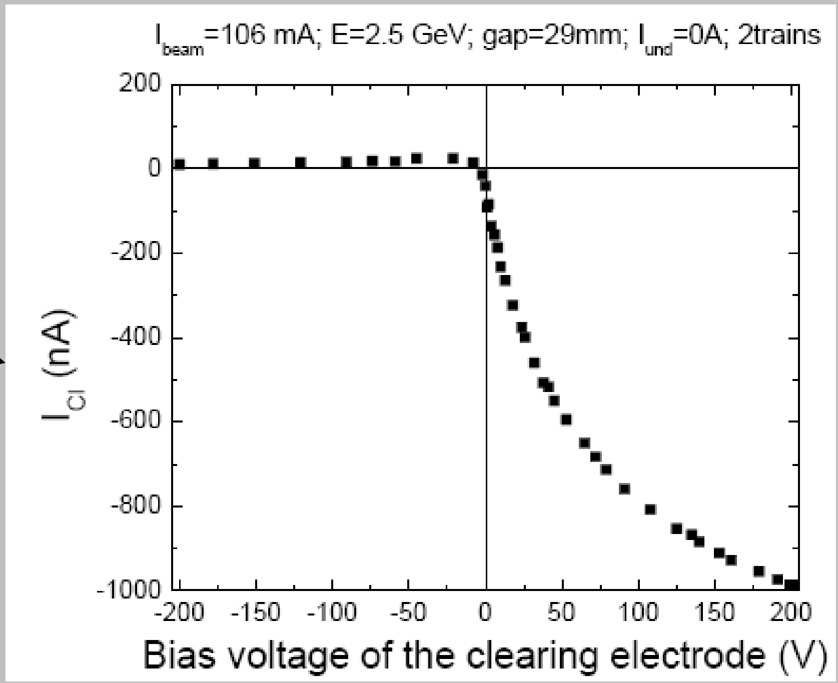
Simulated values re-scaled to fit inside measured plot.

Filled points → observed data

Hollow points → simulated data

Electron flux behavior compares relatively well for 2 and 3 trains, shows a larger discrepancy for 1-train case.

Absolute value in simulations larger than measured with clearing electrode (which strongly depends on bias voltage)



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SUMMARY

1. Different scans have been performed using the ECLOUD code to simulate conditions at the ANKA SC Undulator.

2. The heat load inferred from the simulations in all scans is still about a factor 50 smaller than measurements (~10mW vs ~0.5W).

3. In general, we found a linear dependence of e-density with rest of input parameters (beam intensity, peeff).

4. Absence of any onset suggesting an electron avalanche effect indicates that no multiplication takes place around the e-detector, but rather an electron accumulation due to synchrotron radiation.

5. The ECLOUD code is used to study the electron flux behaviour at the clearing electrode location, where the results for the bunch pattern with 1-train are not well understood.

Acknoledgements

• F.Zimmermann (CERN) substantially helped with all compilation problems of **ECLOUD** and useful comments.

• R. Weigel, A-S. Müller, E. Mashkina, A. Grau (ANKA) for their help collecting data with the clearing electrode