The Electron Cloud Problem and Potential Remedies

R. Cimino

LNF-INFN Frascati (Roma) Italy.

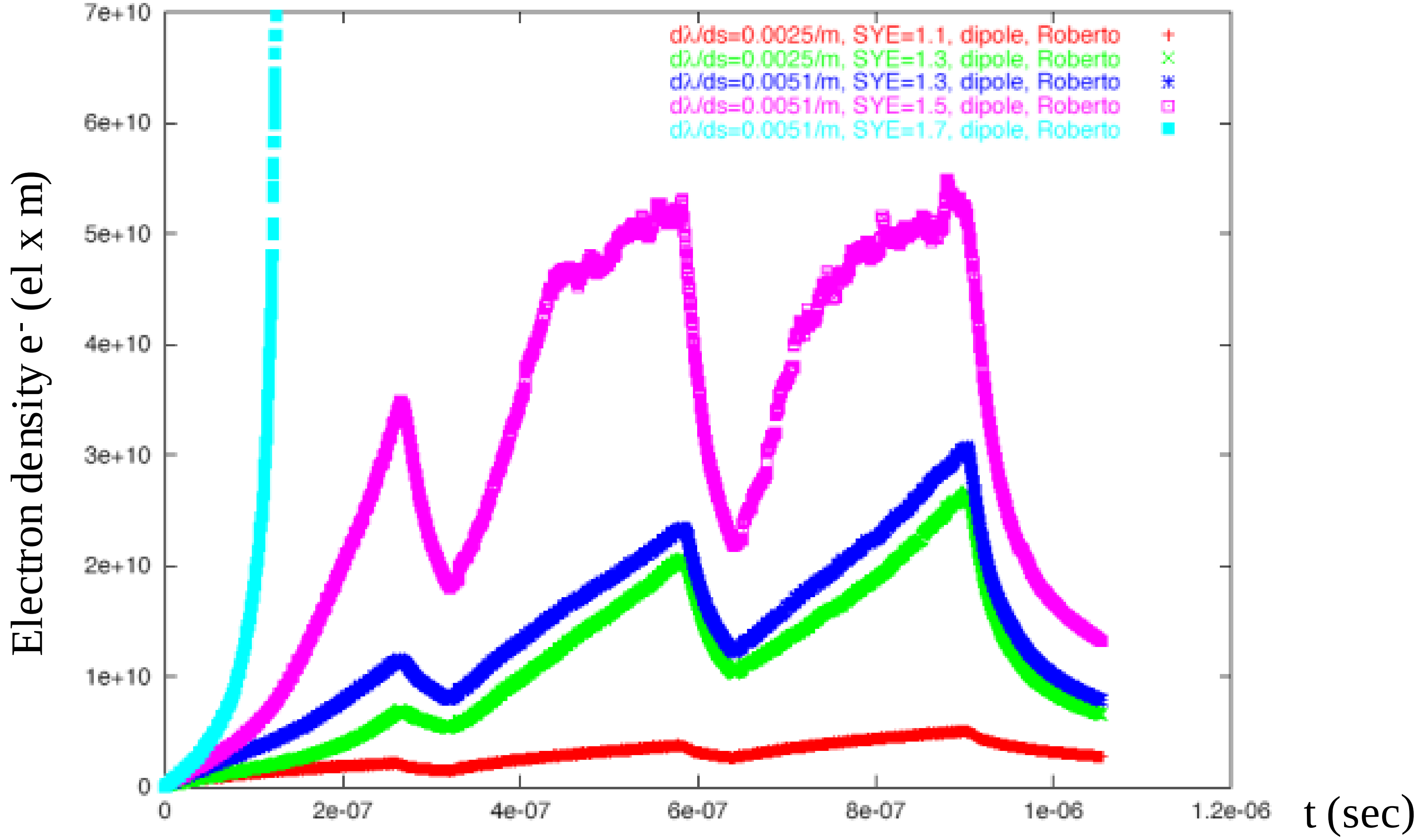
- Introduction: DaΦne and the "e-cloud"
- The e- cloud problem: The LHC case
- Surface science techniques to provide input parameters.
- Some selected results
- Future work and implications to DaΦne-2 project.

DaΦne and the "e-cloud"

- In 1997, the first e-cloud simulations on positive beam accelerators have predicted the presence of unwanted "e-cloud" effects on DaΦne (see Advanced ICFA Workshop on Beam Dynamics Issues for e+e- Factories 20-25 October 1997 Frascati (Rome) - Italy)

- Since than, "e-cloud" effects has been seen and/or predicted in different accelerators like SPS, KEK, PEP, LANL-PSR…….

Also recent simulations suggest multipacting at DaΦne :



From: G. Rumolo, F. Zimmermann, C. Vaccarezza, and R.C.

DaΦne and the "e-cloud"

DaΦne runs with more than 1 to 1.3 A e^+ without observing detrimental phenomena induced by the "e-cloud" contrary to more recent simulations…..

This clearly indicates that either the geometry of the vacuum chamber, or the material properties or other important parameter or assumptions or…. are not correct!

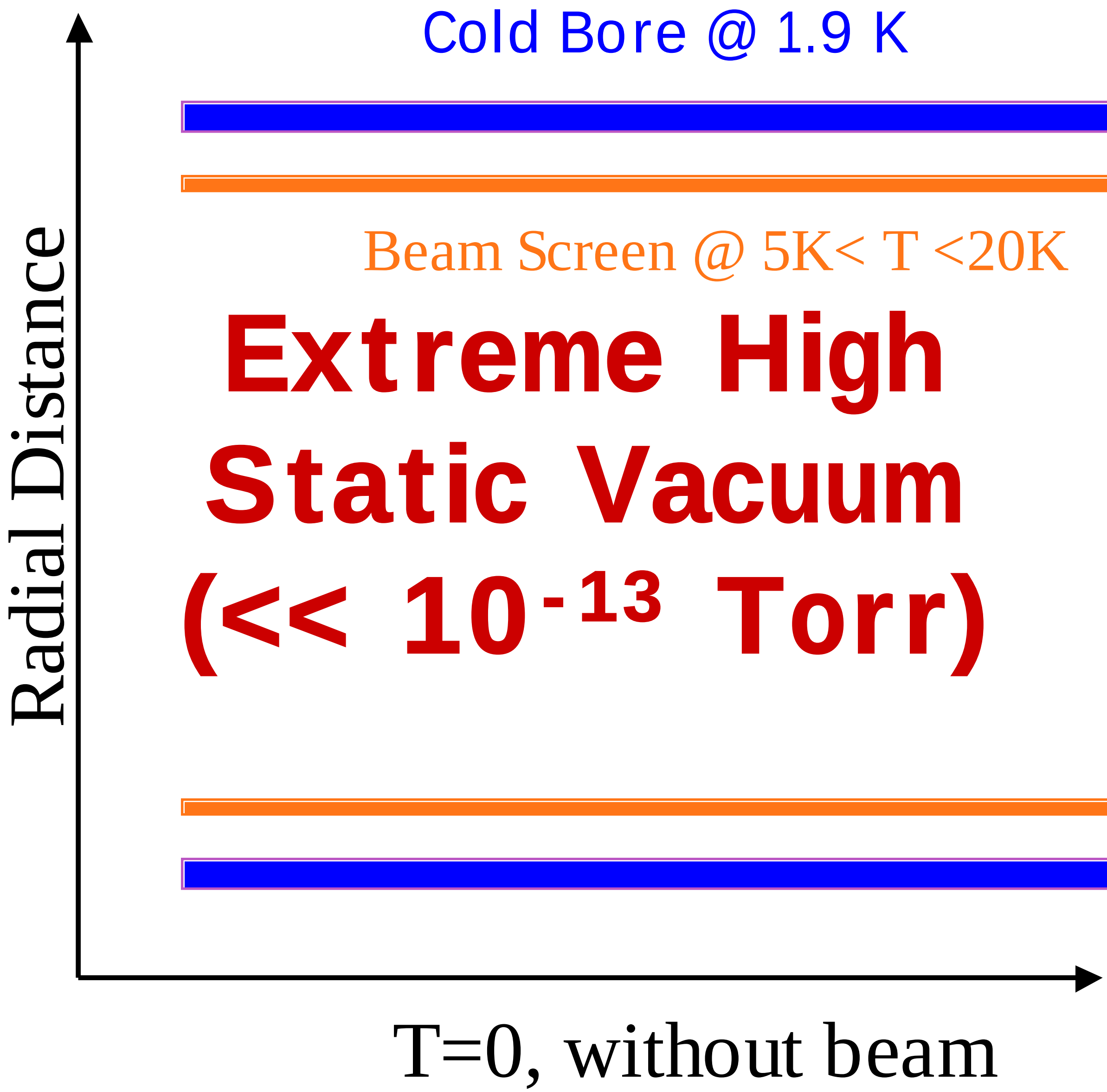
- **Indicates as well that DaΦne is an ideal machine to benchmark the codes…**

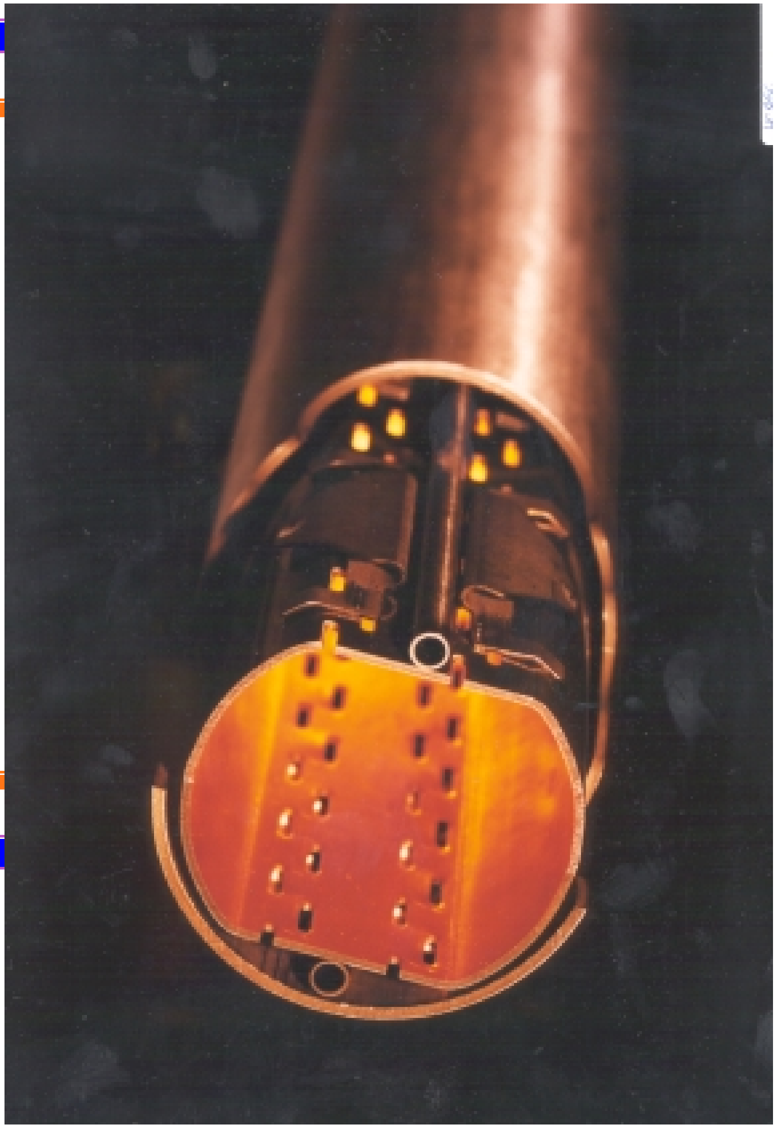
e^--cloud

Will DaΦne-2 be as “lucky” as DaΦne ?????
What parameters and assumptions need to be studied and crosschecked?

Let us see what is causing the occurrence of an e-cloud build-up, and consequently, beam, and/or pressure instabilities , by describing the case of the L.H.C. arcs

Static


Cold Bore @ 1.9 K
Beam Screen @ 5K< T <20K
Extreme High Static Vacuum (<< 10^{-13} Torr)
Radial Distance
T=0, without beam



Static

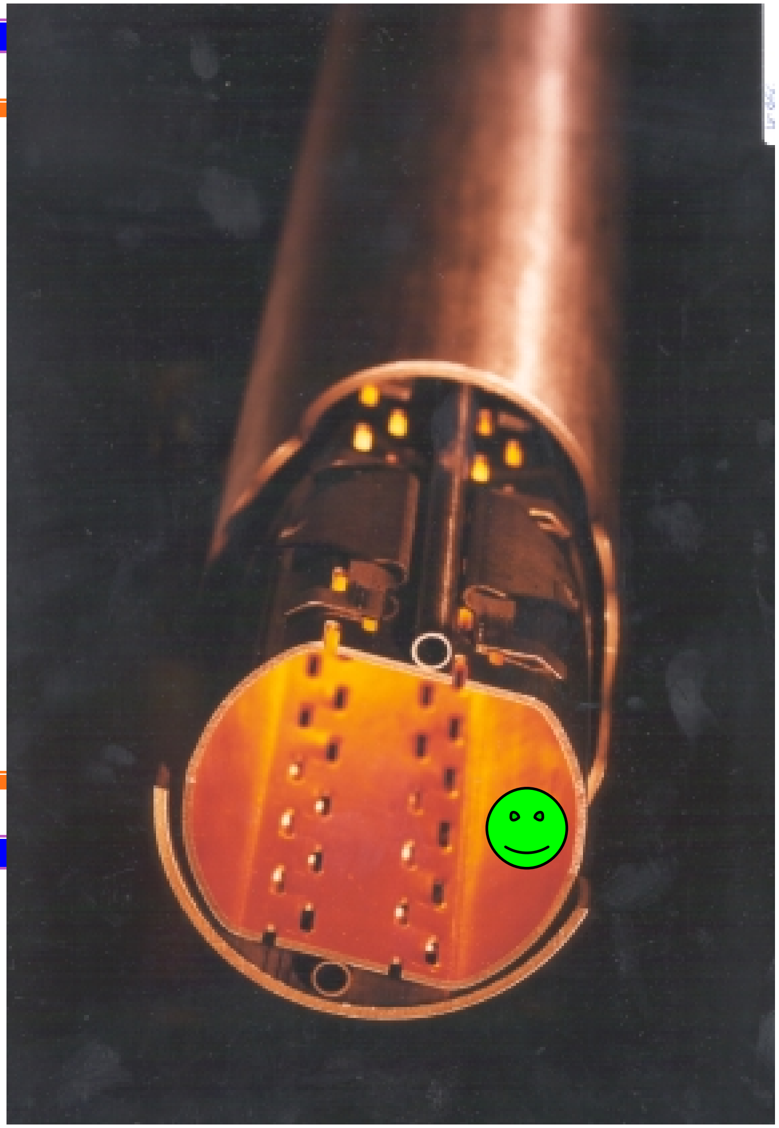
Cold Bore @ 1.9 K

Beam Screen @ 5K< T <20K

Extreme High Static Vacuum ($\ll 10^{-13}$ Torr)

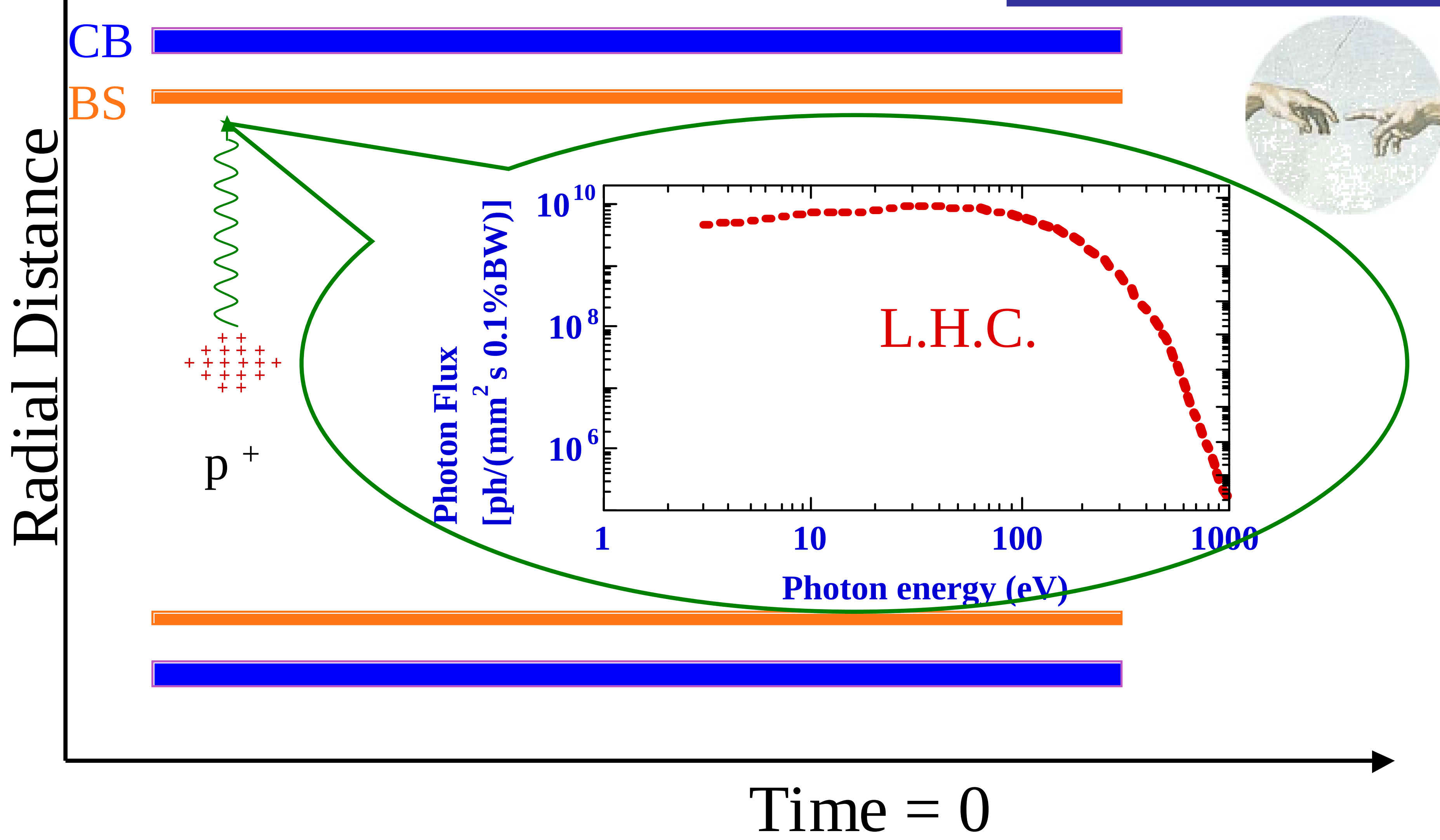
Radial Distance

T=0, without beam



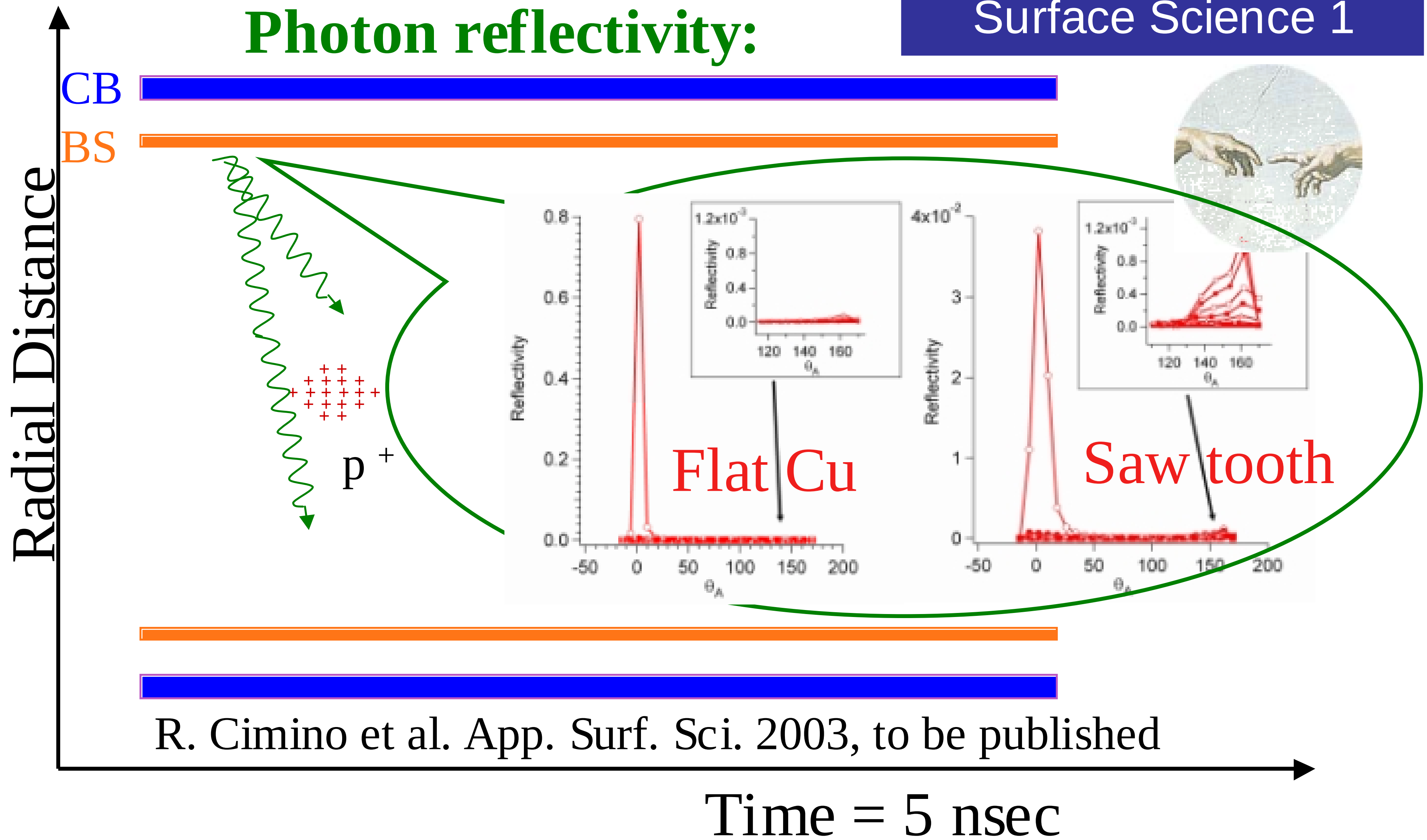
Synchrotron Radiation: Ec = 44 e V @ LHC

calculation



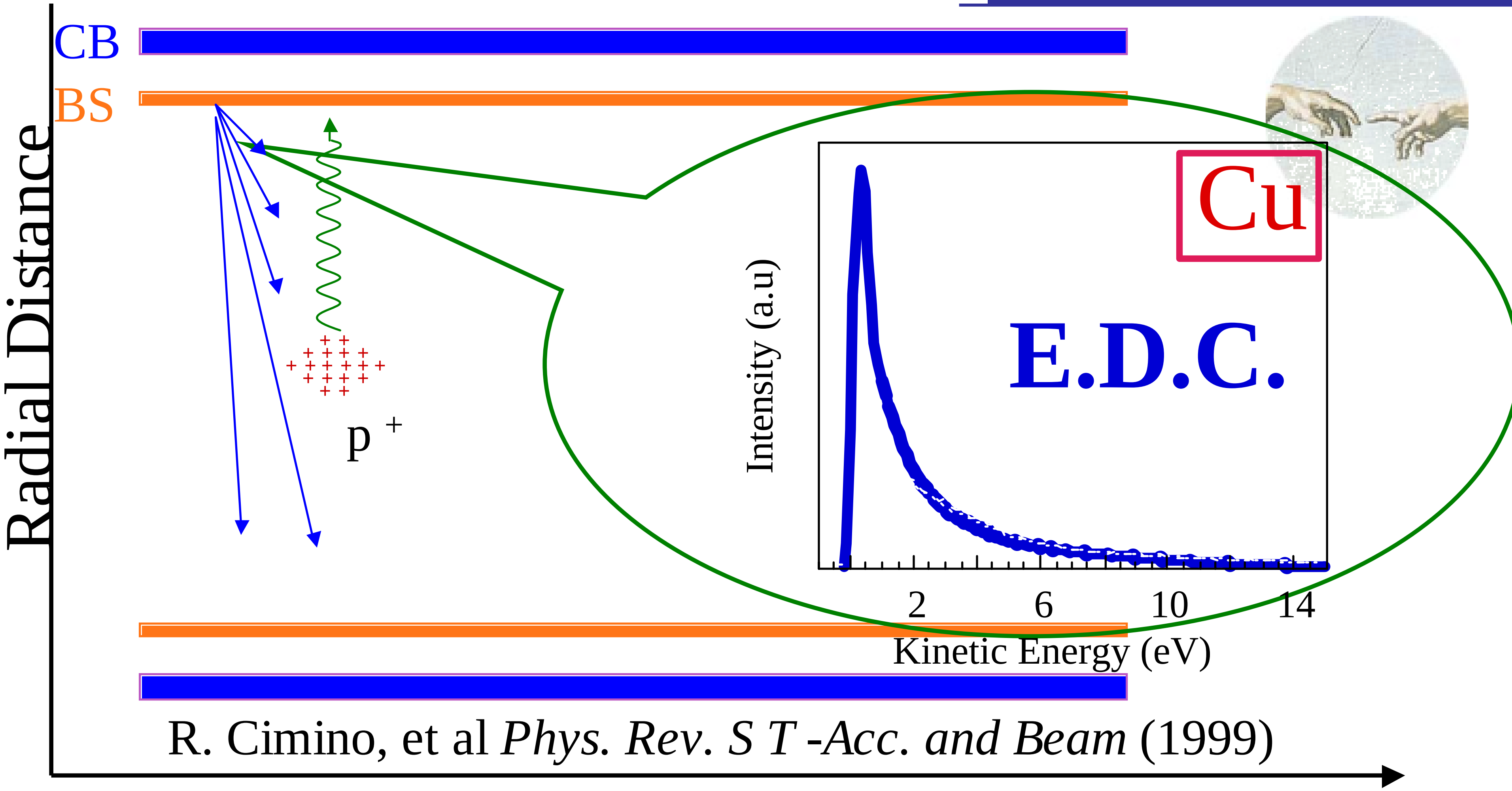
Photon reflectivity:

Surface Science 1



R. Cimino et al. App. Surf. Sci. 2003, to be published

Photoemission:(vs. hν, Θ, E,T, B)



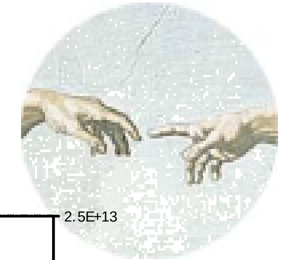
R. Cimino, et al *Phys. Rev. S T -Acc. and Beam* (1999)

Time = 5 nsec

observation

Even in absence of SR:

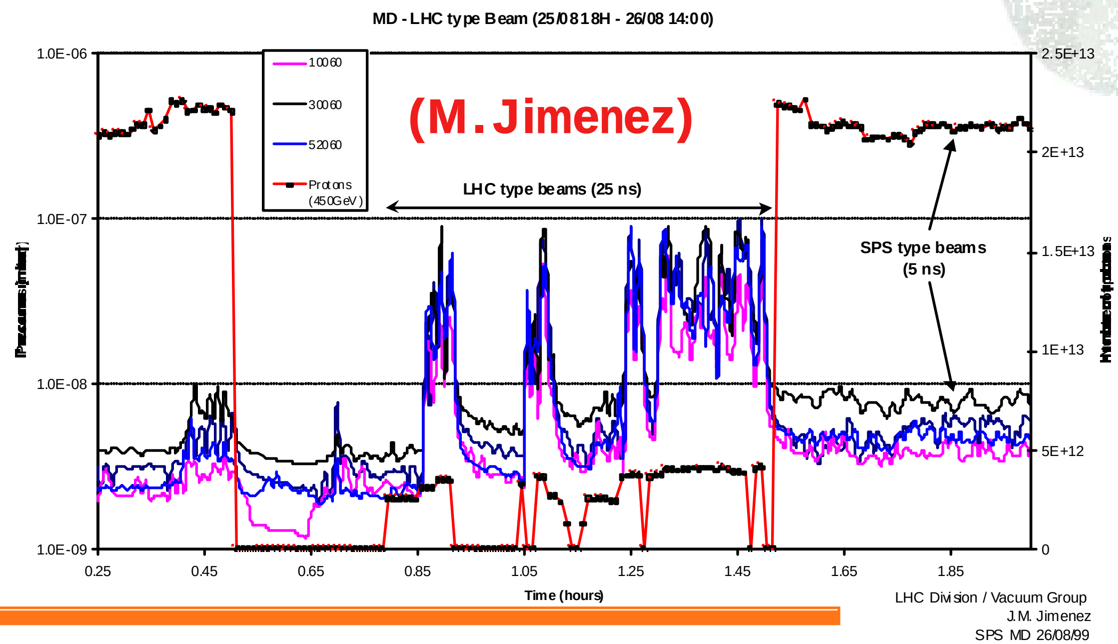
e⁻ from ionization of residual gas… etc



SPS

e⁻

p +



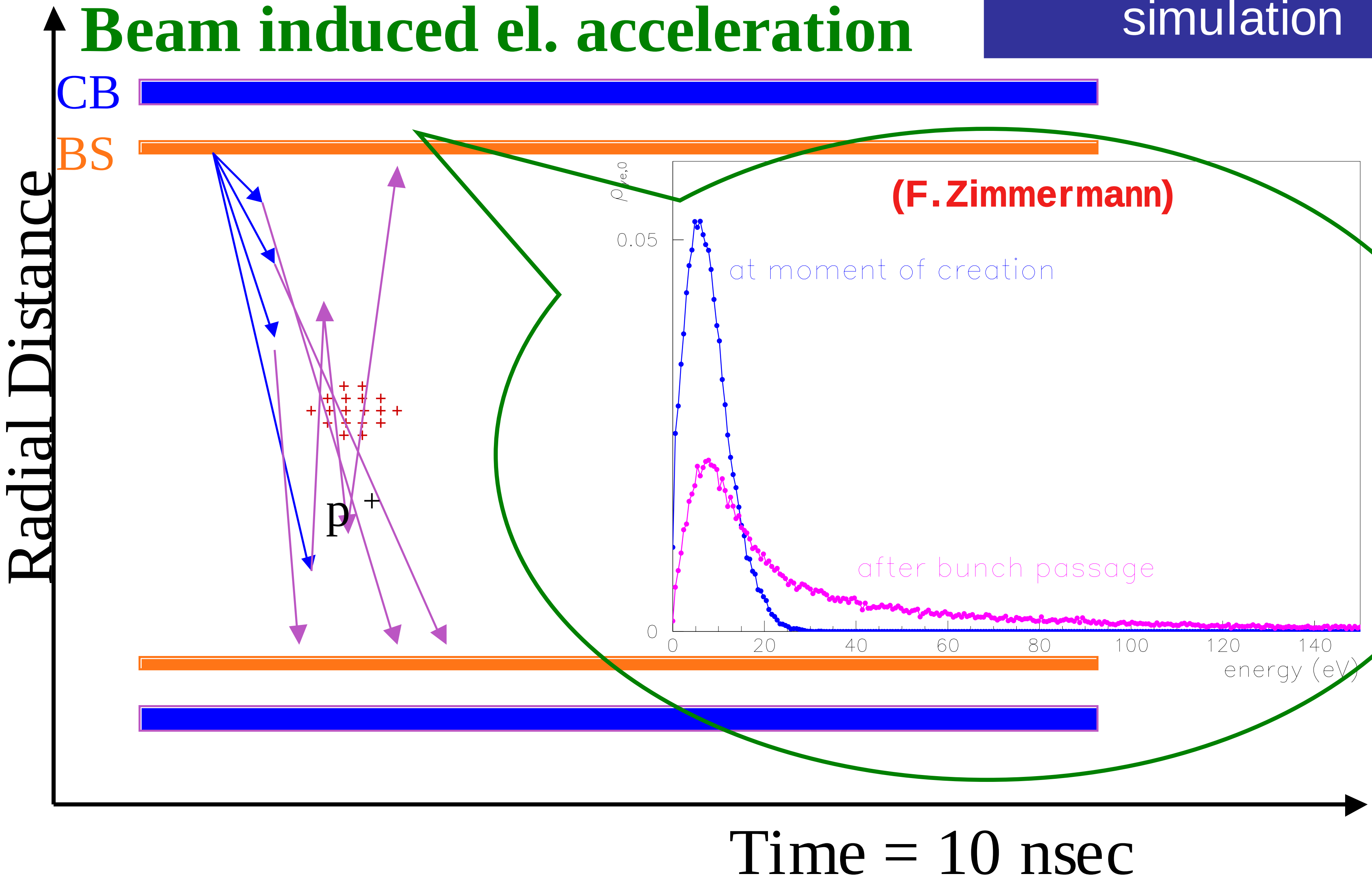
Beam induced multipacting is observed in SPS, with LHC type beam, where no e⁻ are photoemitted.

Radial Distance

Time = 5 nsec

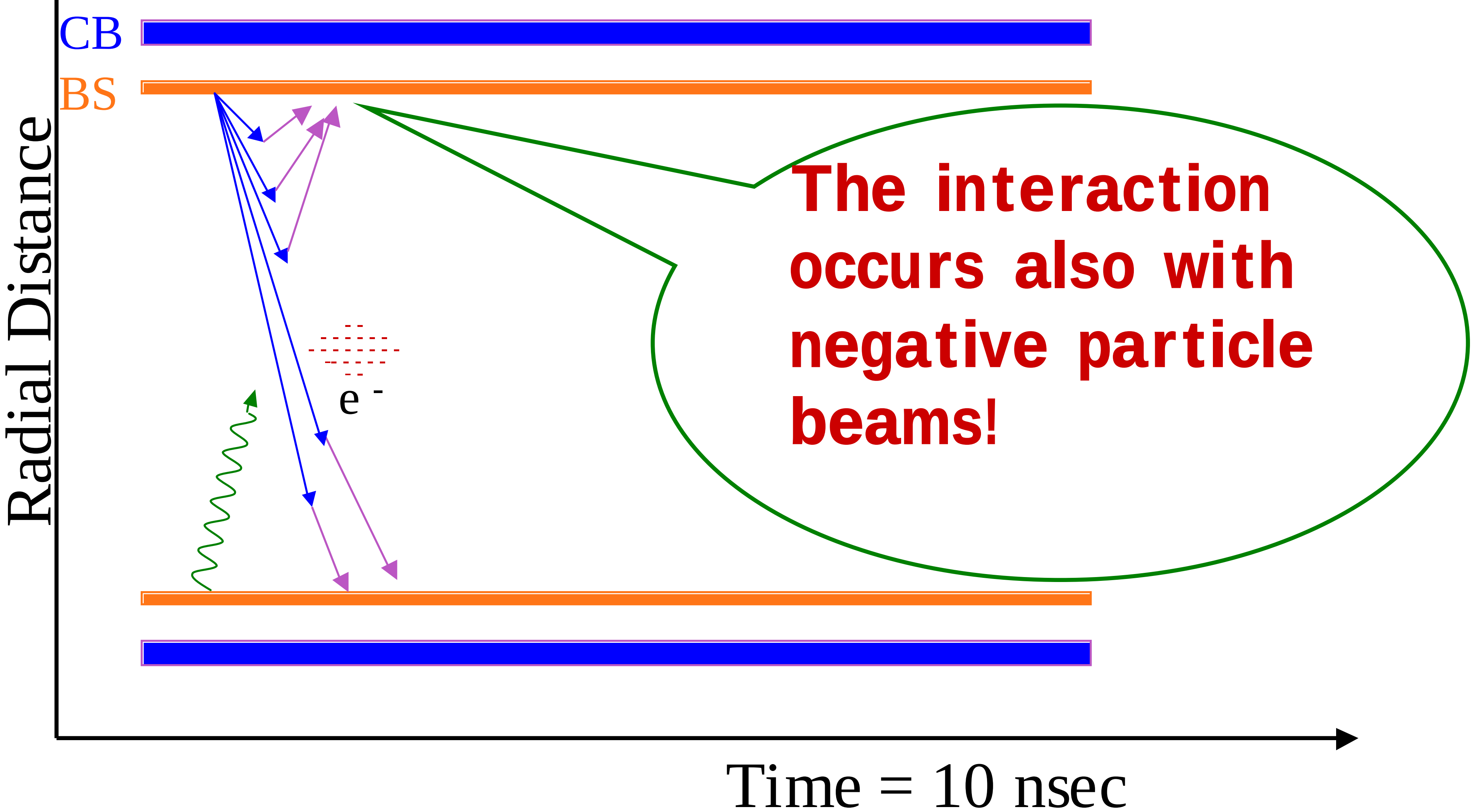
Beam induced el. acceleration

simulation

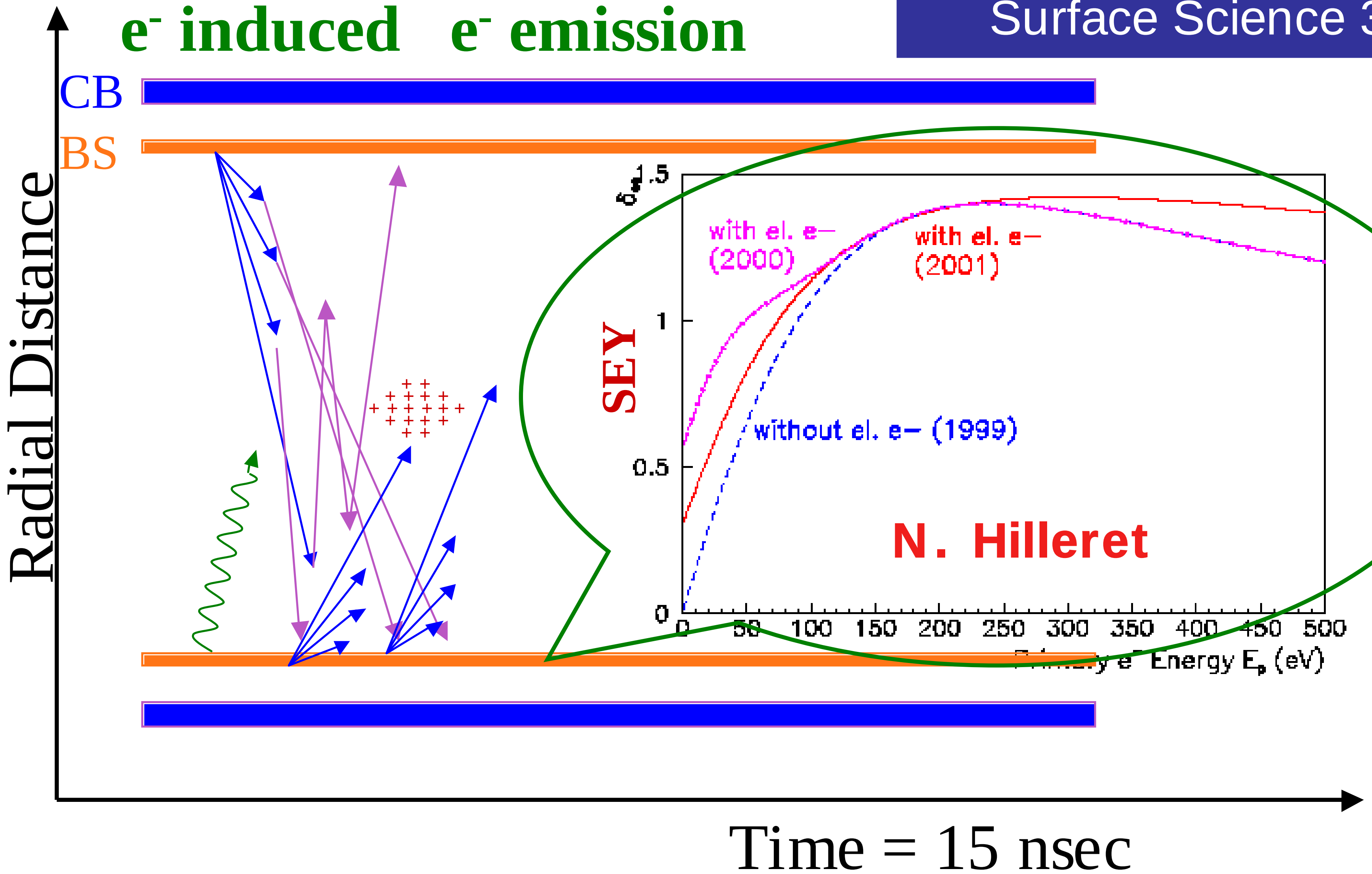


e^- cloud - Beam interaction

simulation

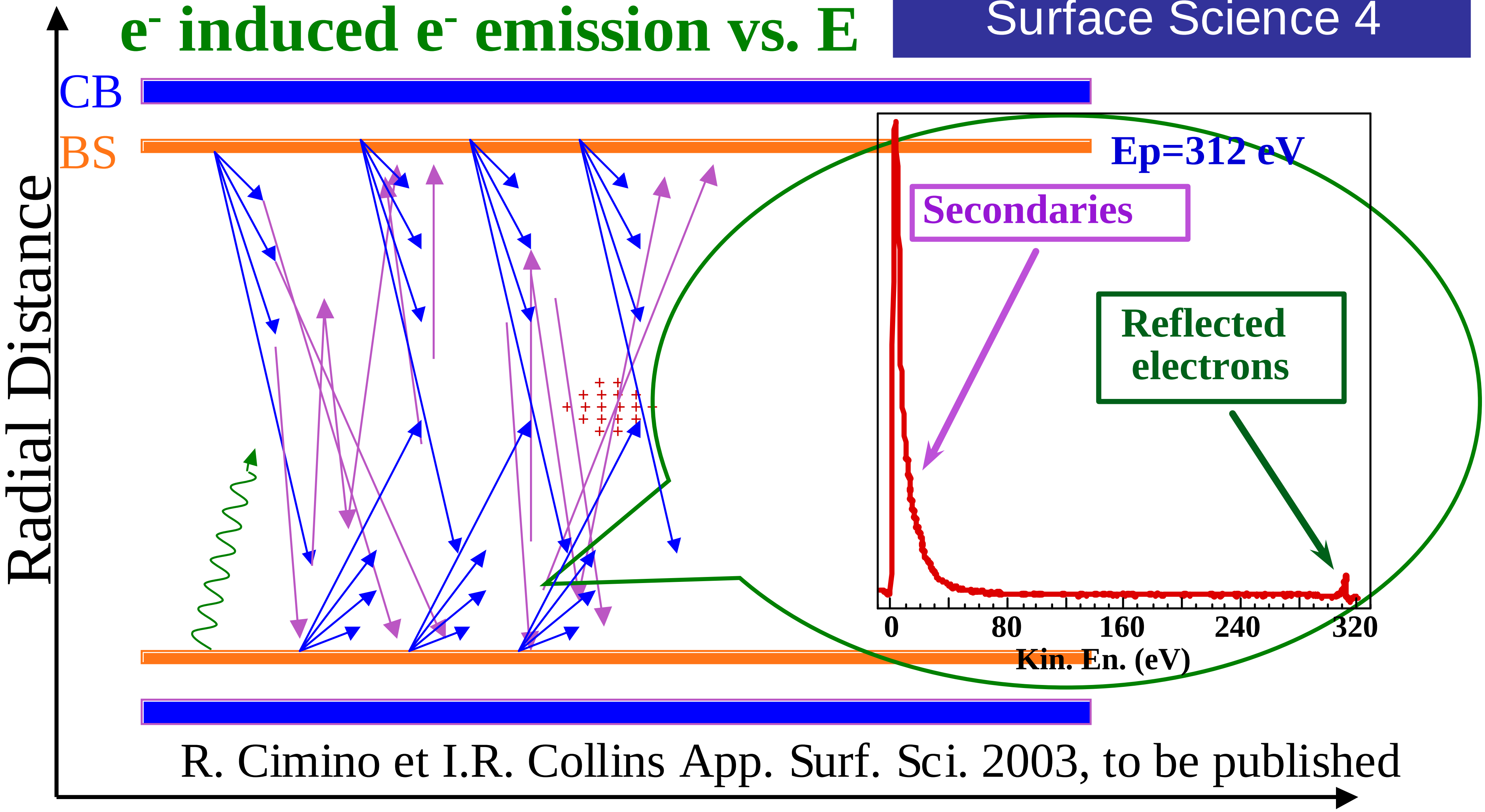


e^- induced e^- emission



e^- induced e^- emission vs. E

Surface Science 4

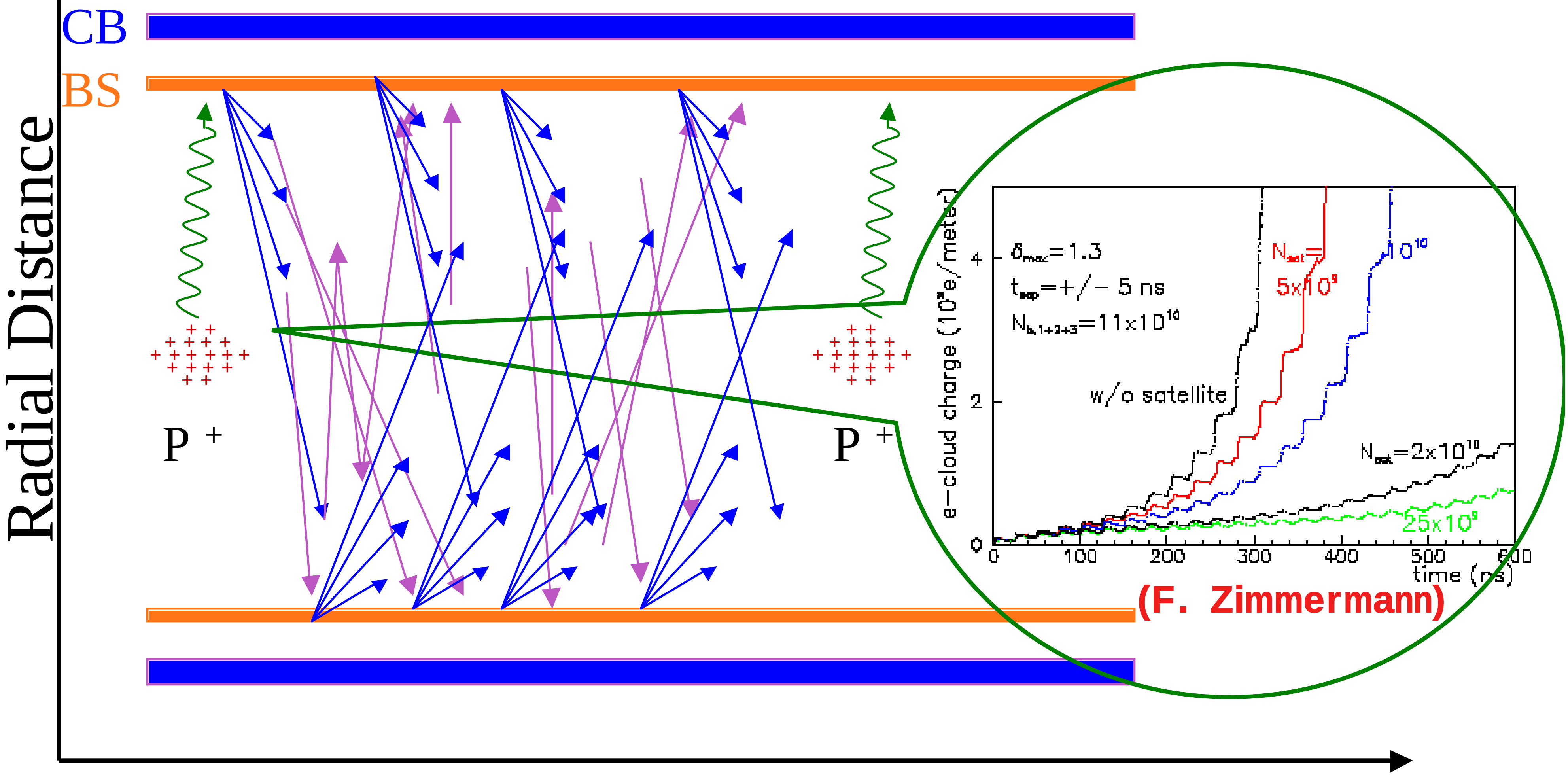


R. Cimino et I.R. Collins App. Surf. Sci. 2003, to be published

Time = 20 ns

e$^-$ cloud Build-up

simulation

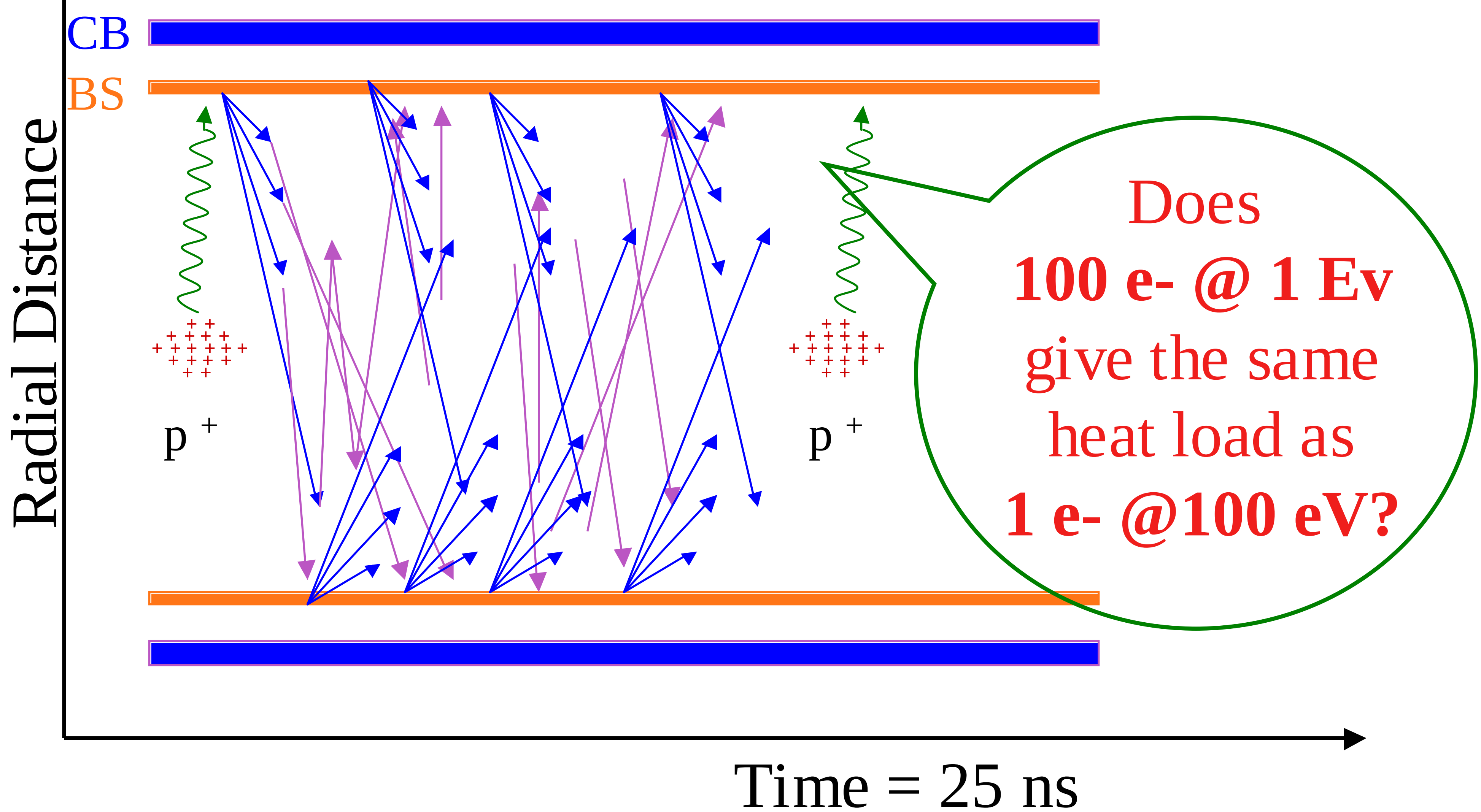


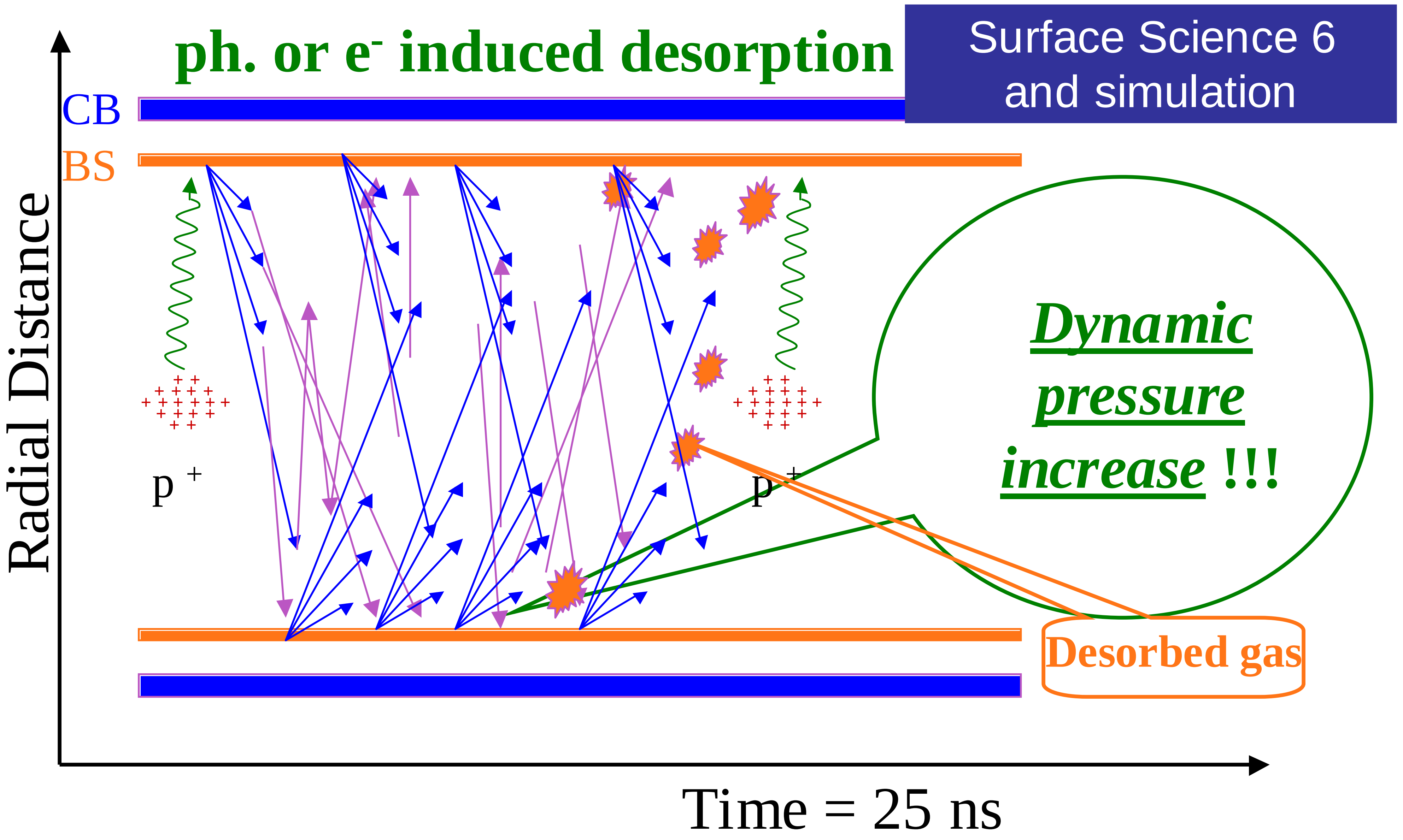
Time = 25 ns

Time structure vs Simulations.

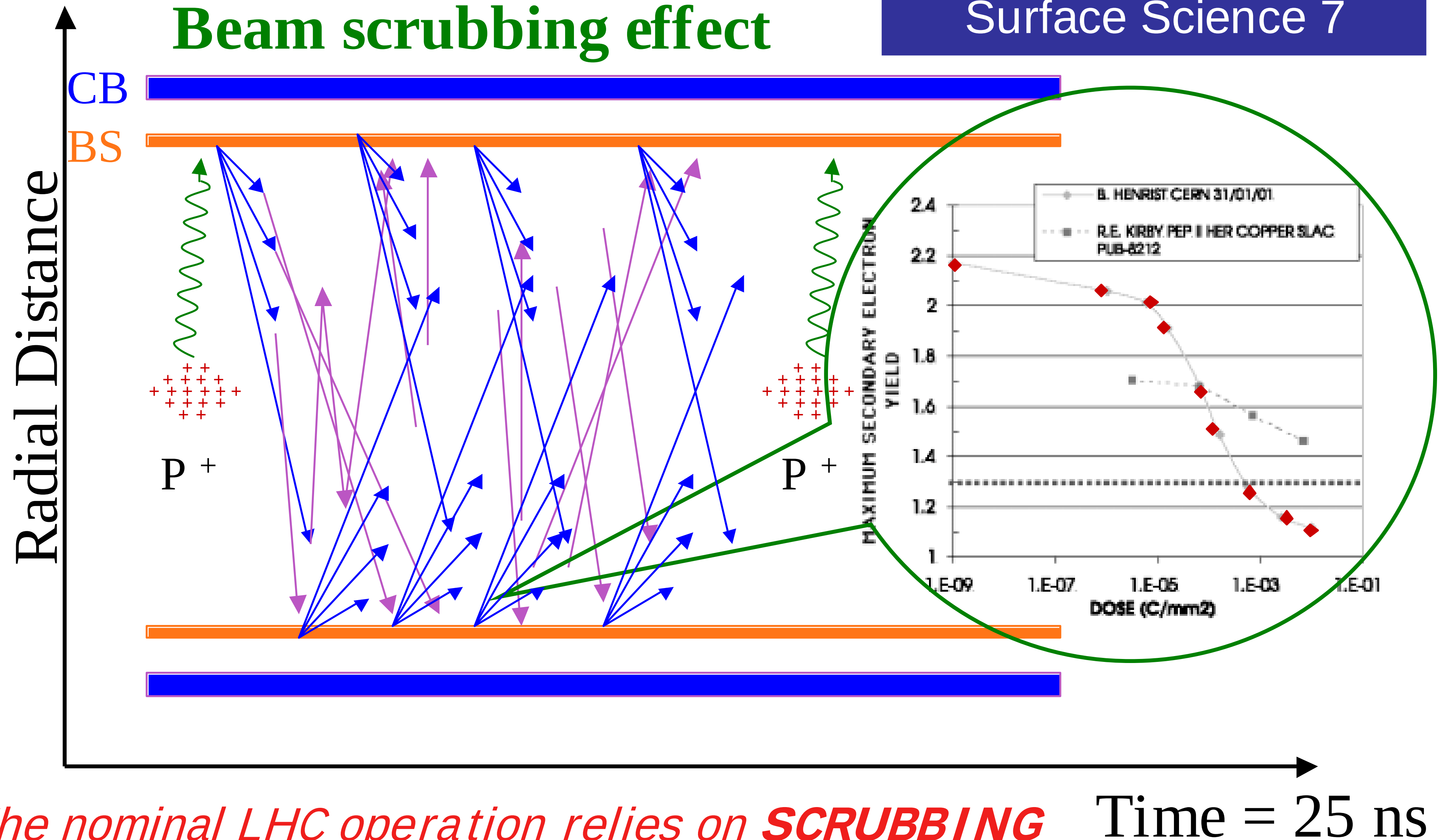
e^- induced heat load

Simulation




ph. or e- induced desorption
Surface Science 6 and simulation
CB
BS
Radial Distance
p +
p +
Dynamic pressure increase !!!
Desorbed gas
Time = 25 ns

Beam scrubbing effect



The nominal LHC operation relies on ***SCRUBBING***

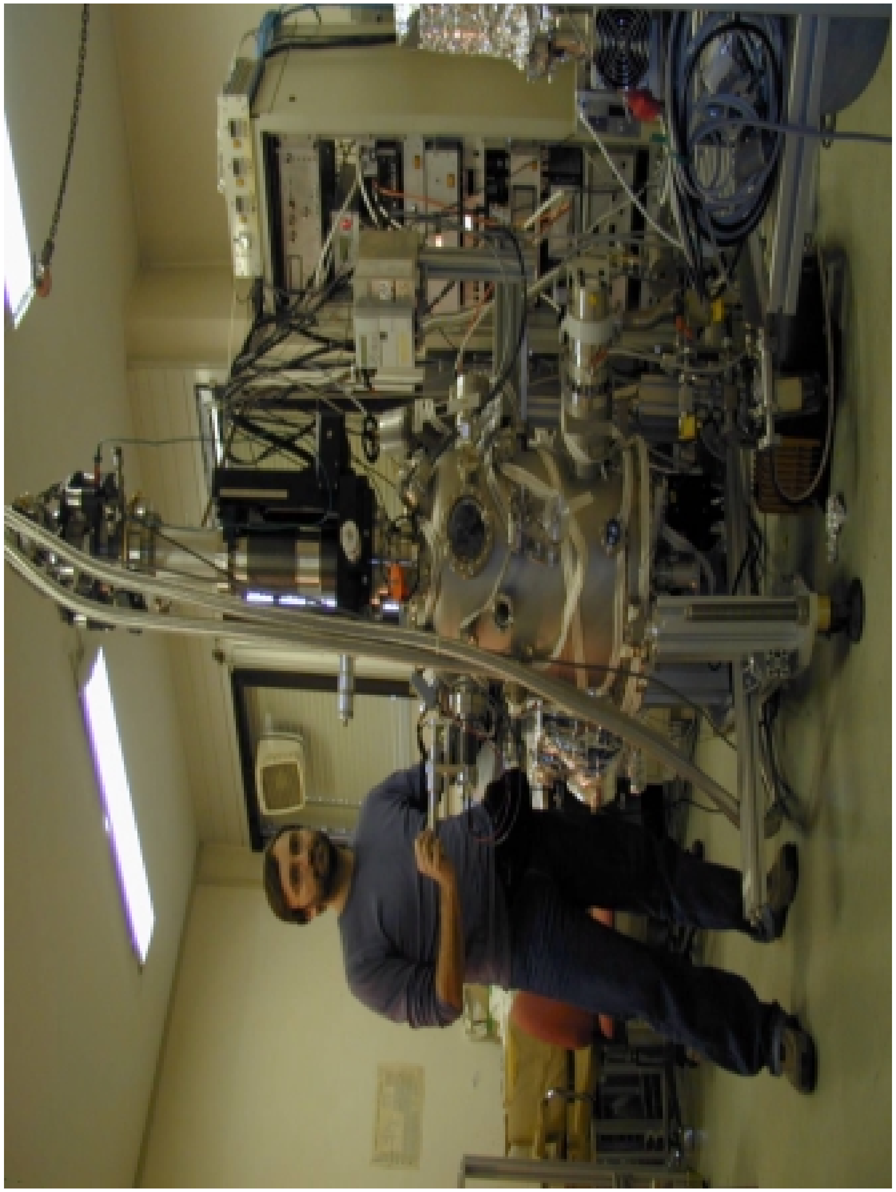
To predict the effect of the “e-cloud“ on DAΦNE- 2:

Surface Science Imputs: Constructive candidate materials (Al, Cu NEGs, etc etc) needs to be studied to give accurate:

- **Secondary electron yield,**
- **Photoemission,**
- **photon reflectivity**
- **electron and photon induced electron emission**
- **electron and photon induced desorbtion,**
- **Surface chemistry during operation**
- **etc etc.**

A surface science lab.

- μ-metal chamber;
- En. & angle res. analyser;
- Low T manipulator;
- LEED - Auger RFA;
- Faraday cup.
- Low energy electron gun
- Mass spectrometer
- Sample preparation

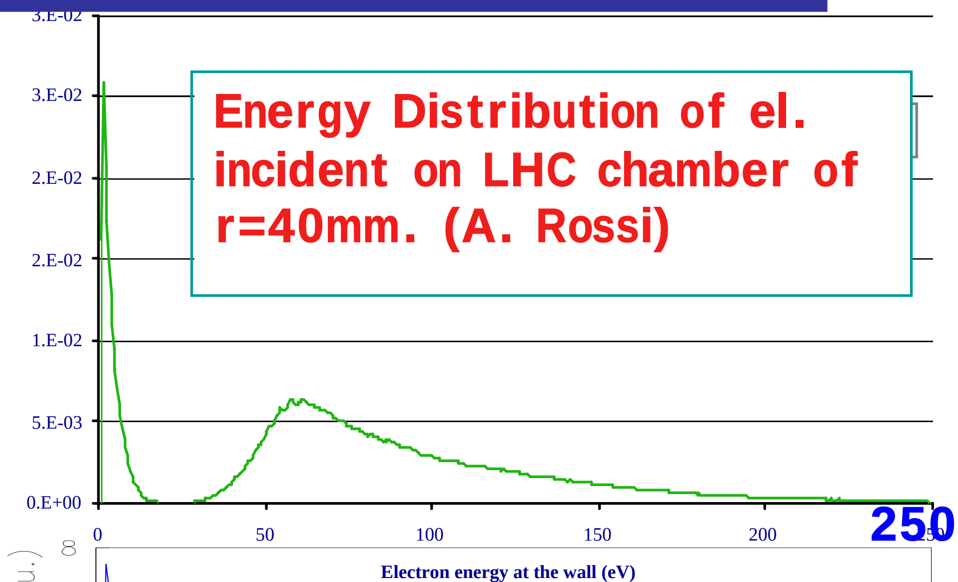


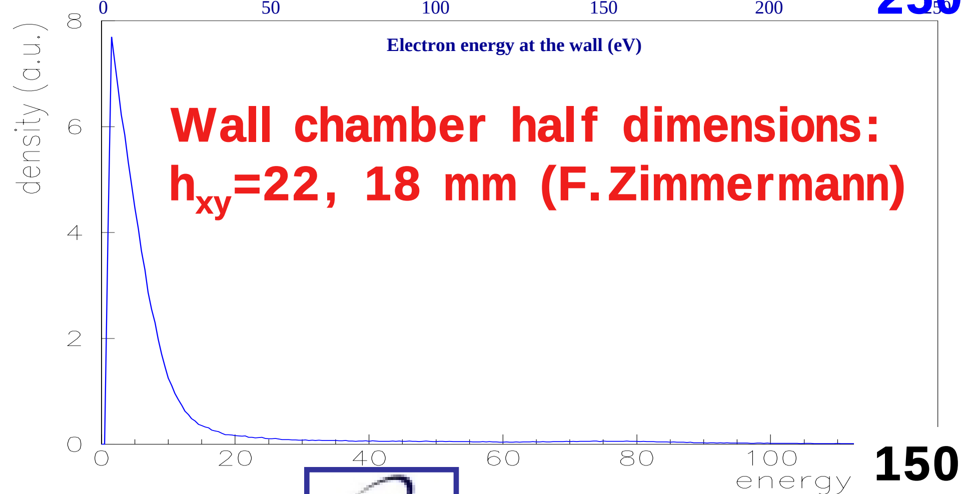
Given the importance to study the very low energy electrons:

- By applying a bias to the sample:

Ep = Egun + E bias

- It is possible to measure **from ZERO** primary energy in a region where the gun is stable (Egun >50 eV).

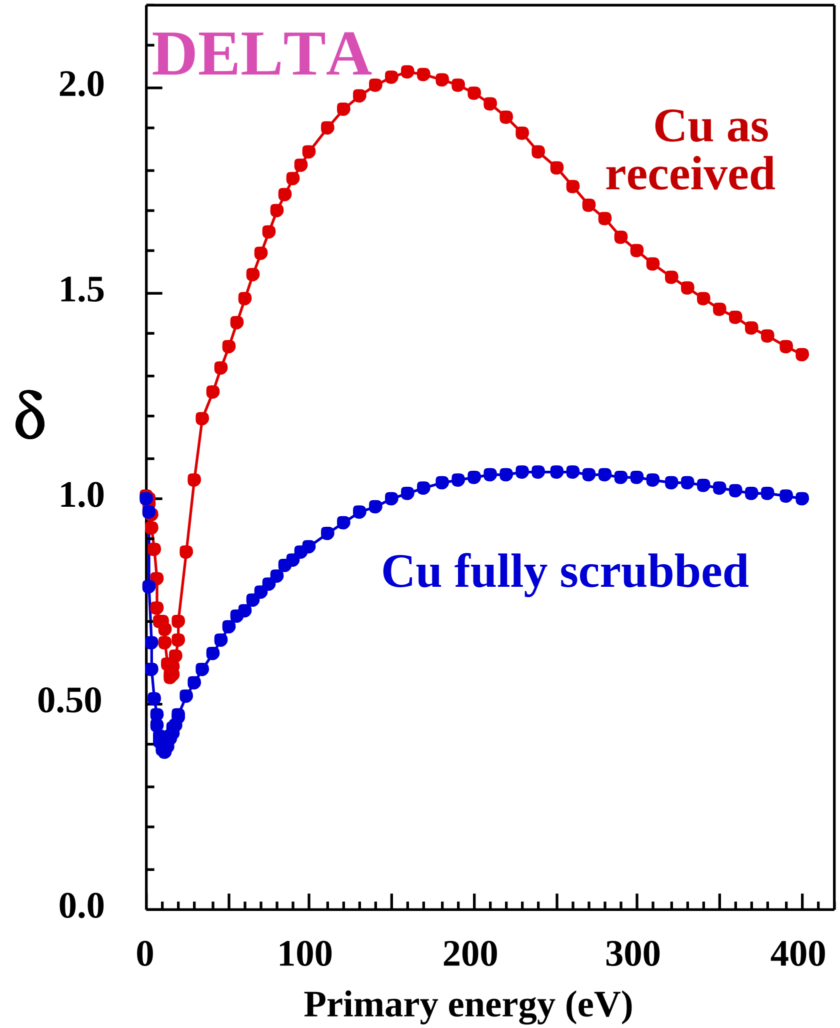




Measure of Secondary e$^-$ YIELD @LT

- At each Primary energy we can measure **Igun** **(with the Faraday cup)** and **Isample.**

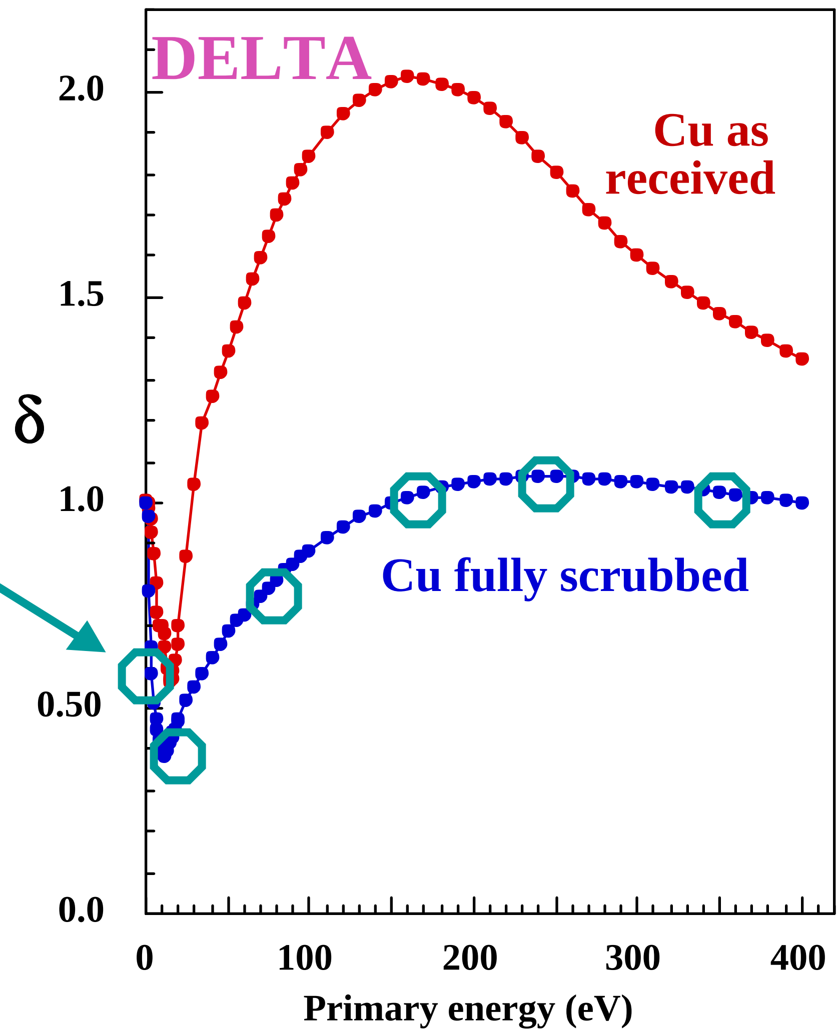
$$\delta = \frac{I_{gun} - I_{sample}}{I_{gun}}$$



Measure of Secondary e$^-$ YIELD @LT

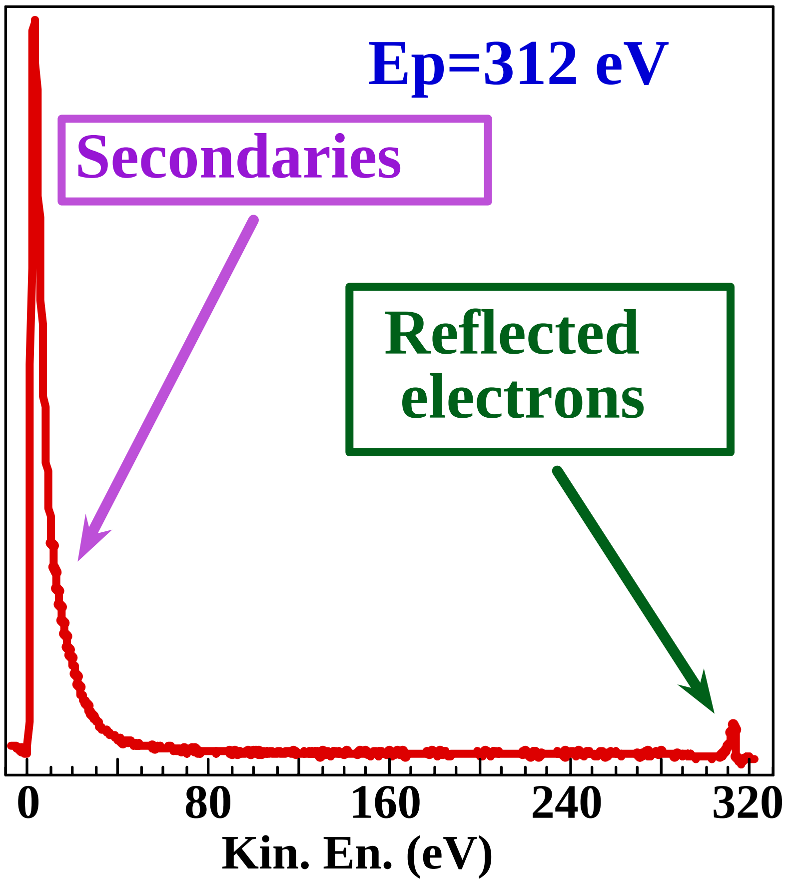
- Each single point in a DELTA plot gives the total number of electrons emitted at a give primary energy.

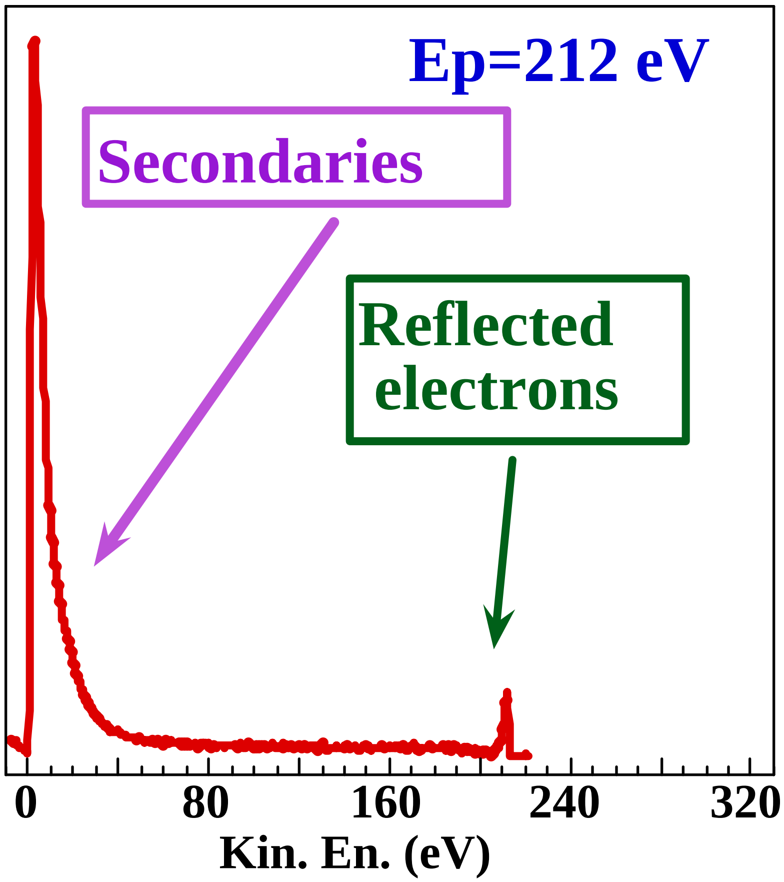
The energy distribution of such emitted electrons is important for the simulations.



What has been measured on f.s. Cu

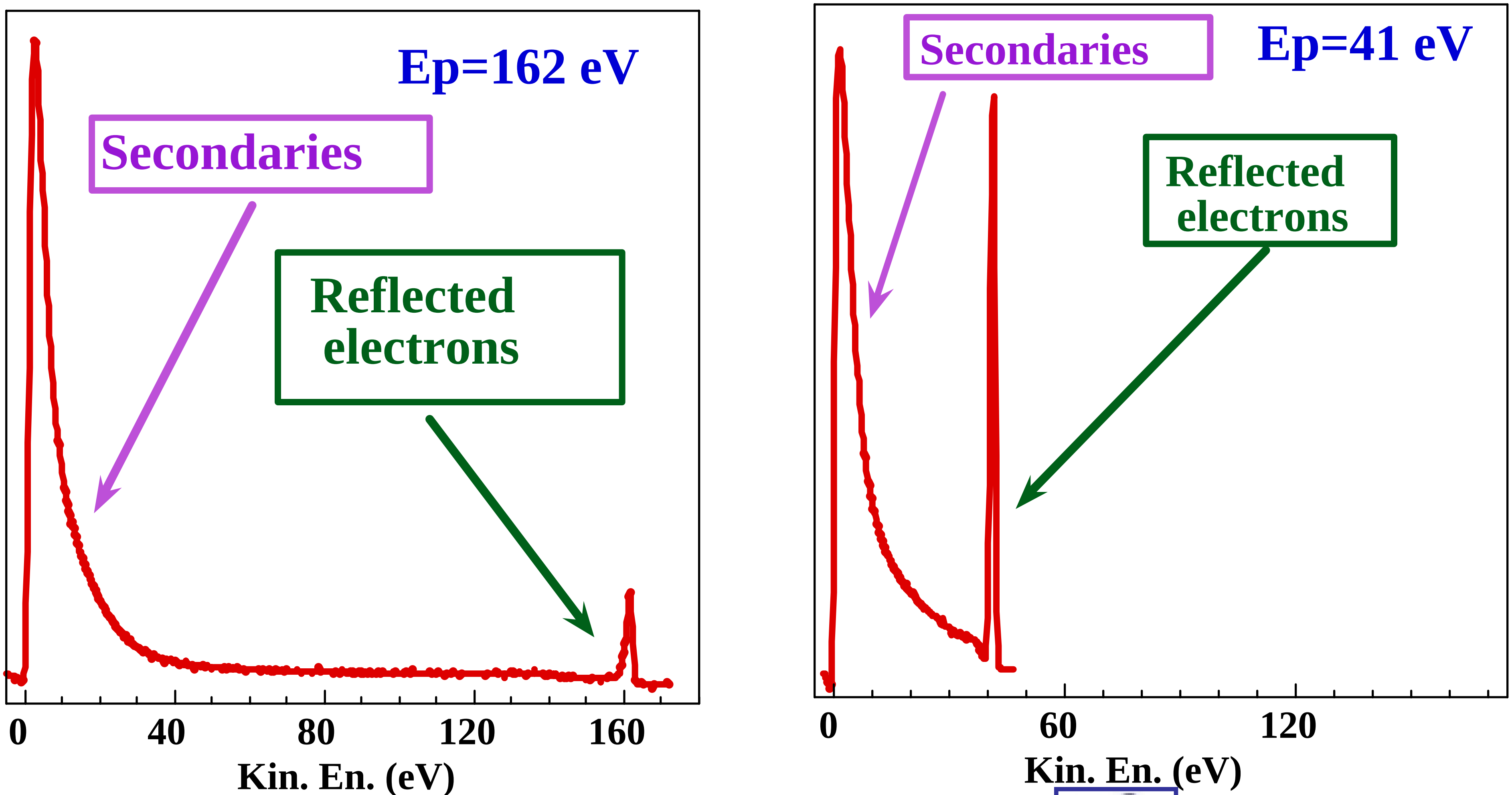
- Energy Distribution Curves as function of Ep @LT





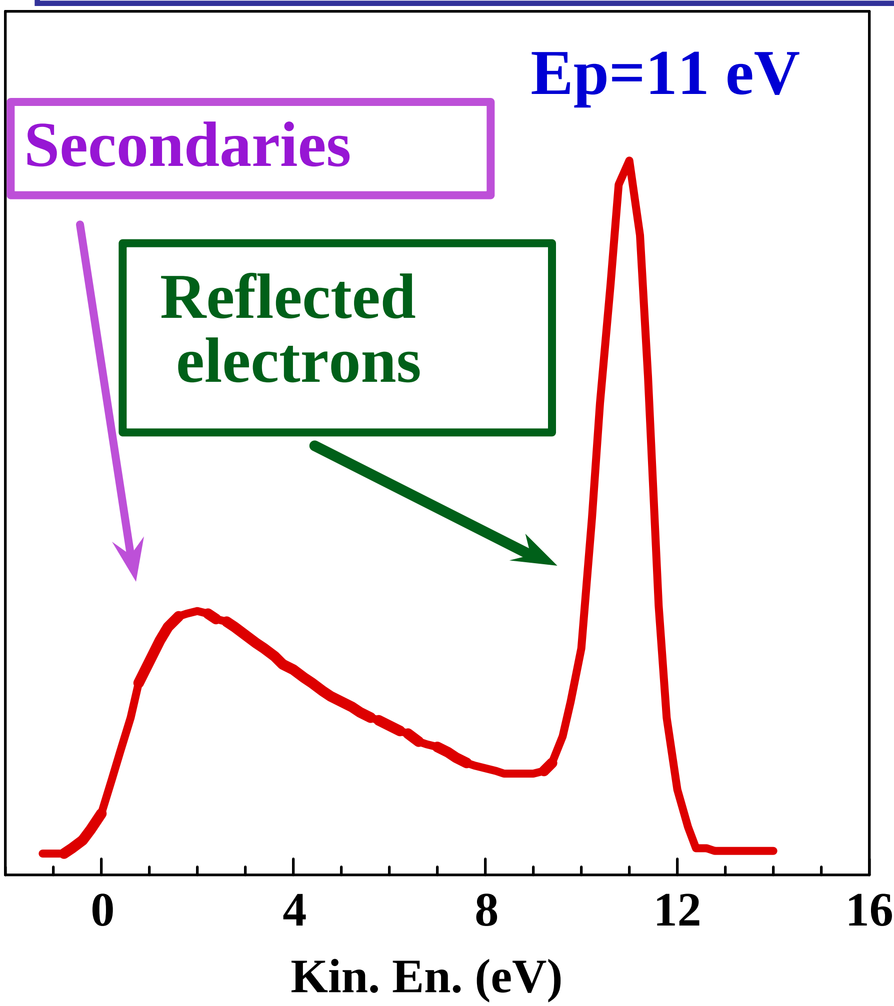
What has been measured on f.s. Cu

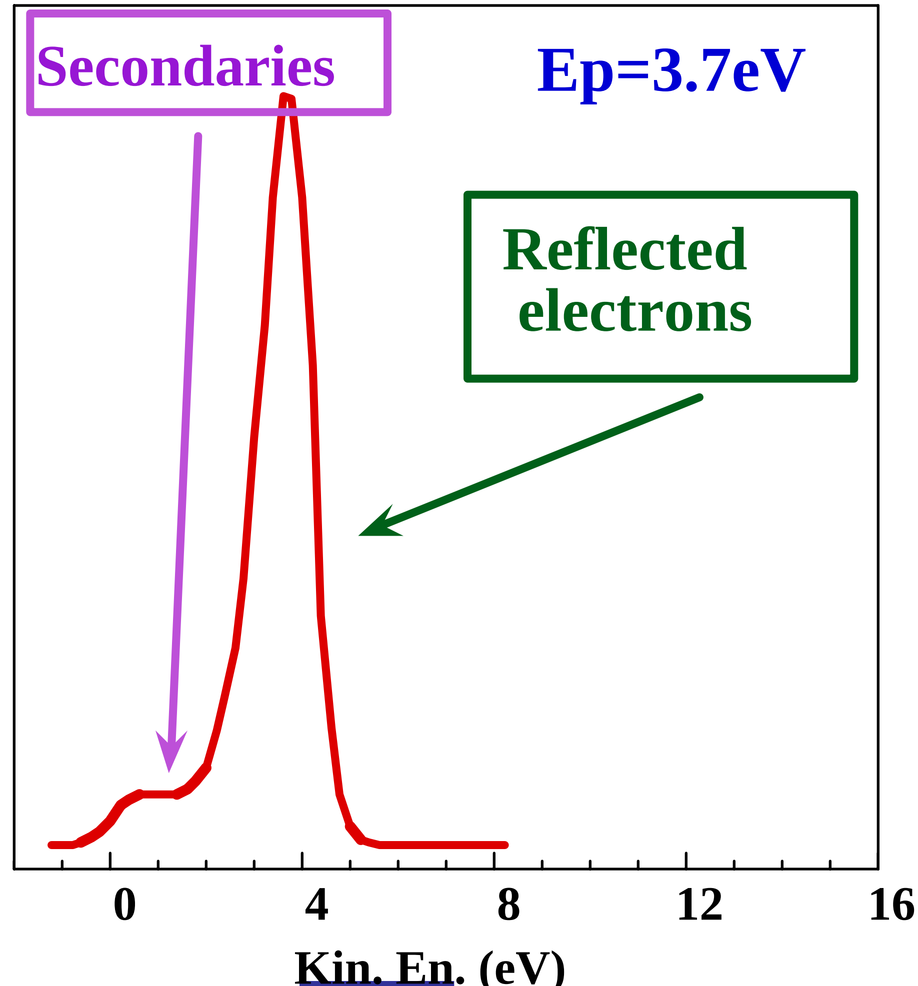
- Energy Distribution Curves as function of Ep @LT



What has been measured on f.s. Cu

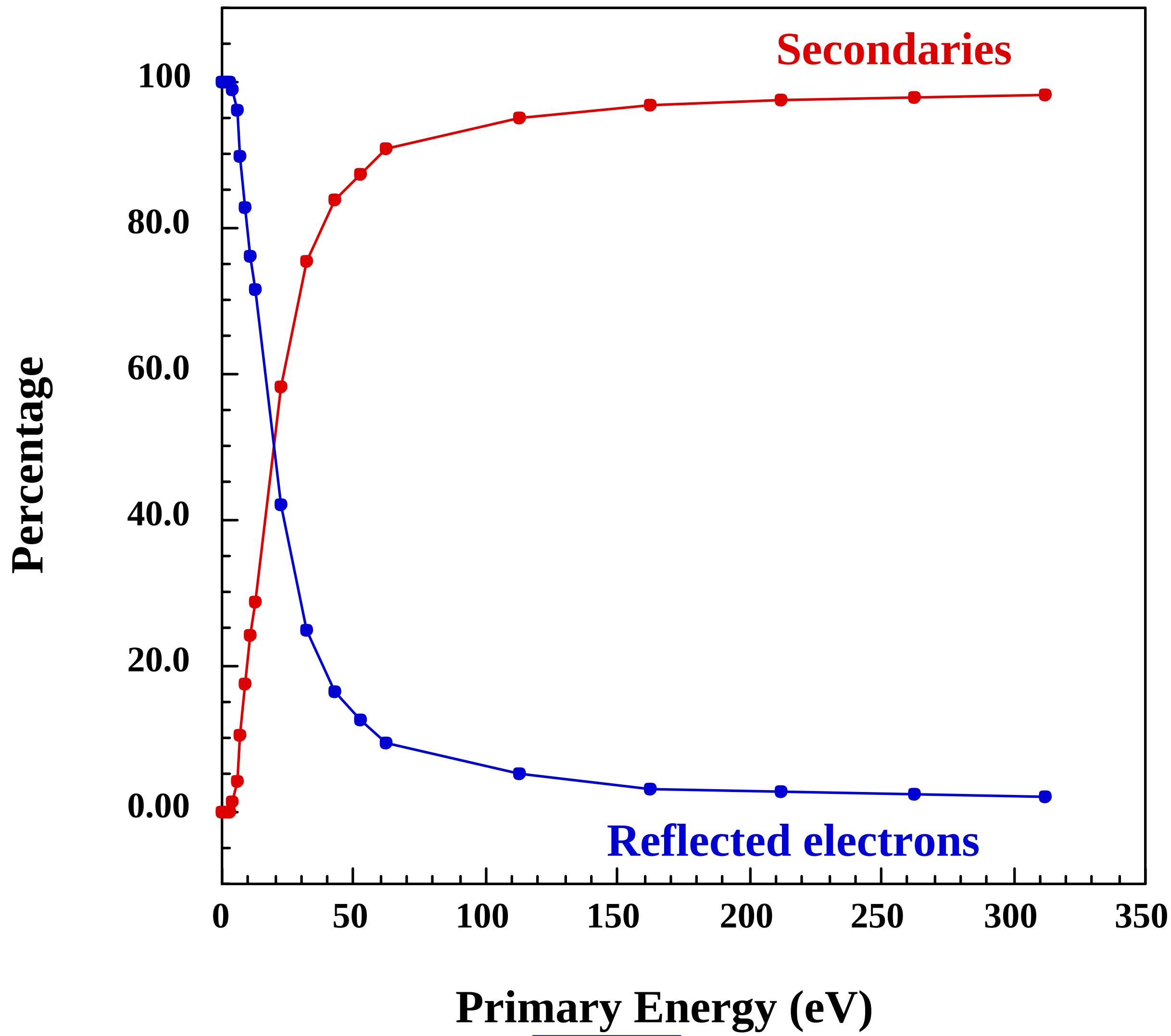
- Energy Distribution Curves as function of Ep @ LT





What has been measured on f.s. Cu

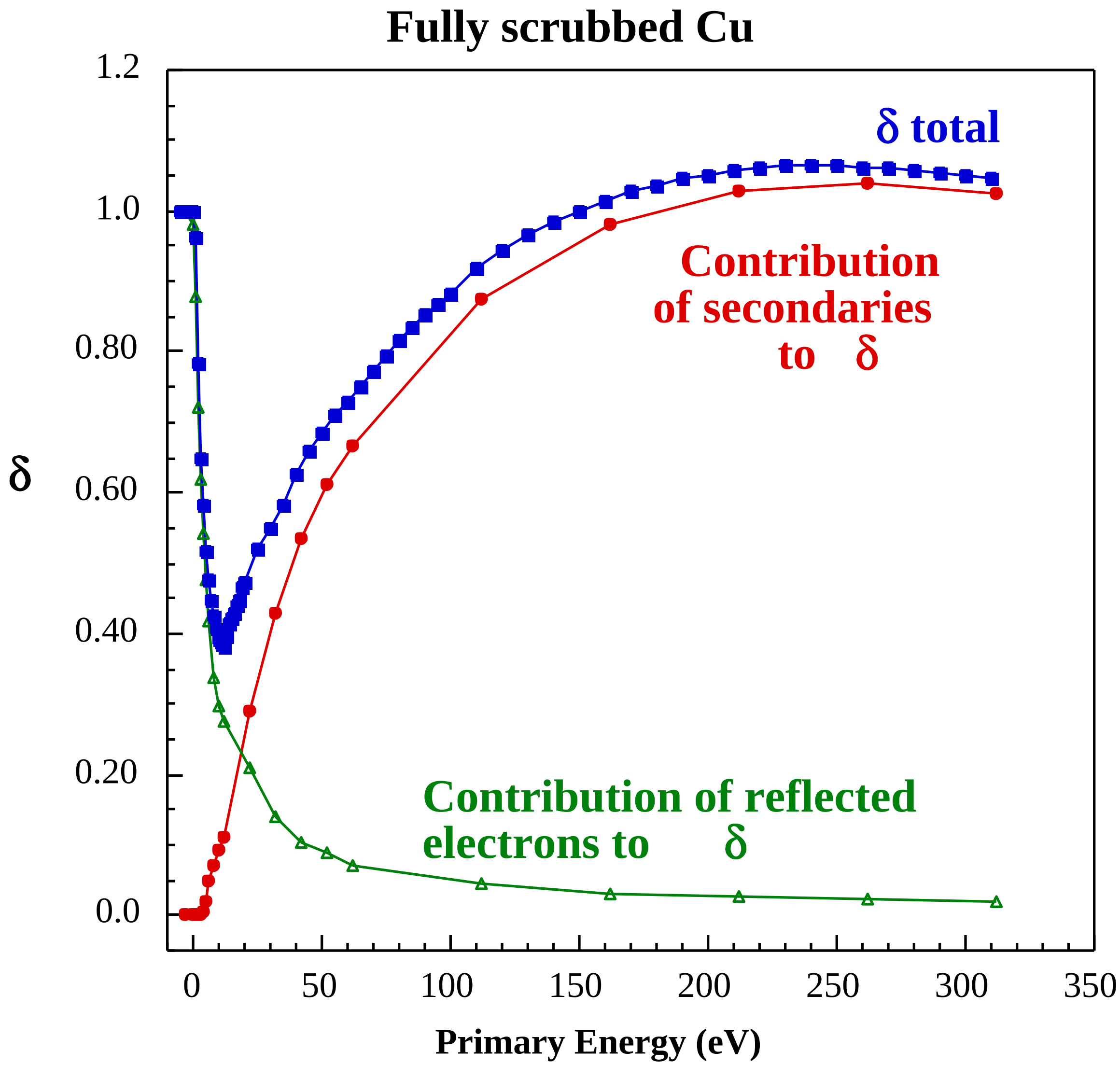
Secondaries
and
Reflected
Electron
VERSUS
Primary
Energy



What has been measured on f.s. Cu

• **we can single out the contribution to δ of the secondaries and the reflected electrons versus primary energy.**

$$\delta = \frac{I_{gun} - I_{sample}}{I_{gun}}$$

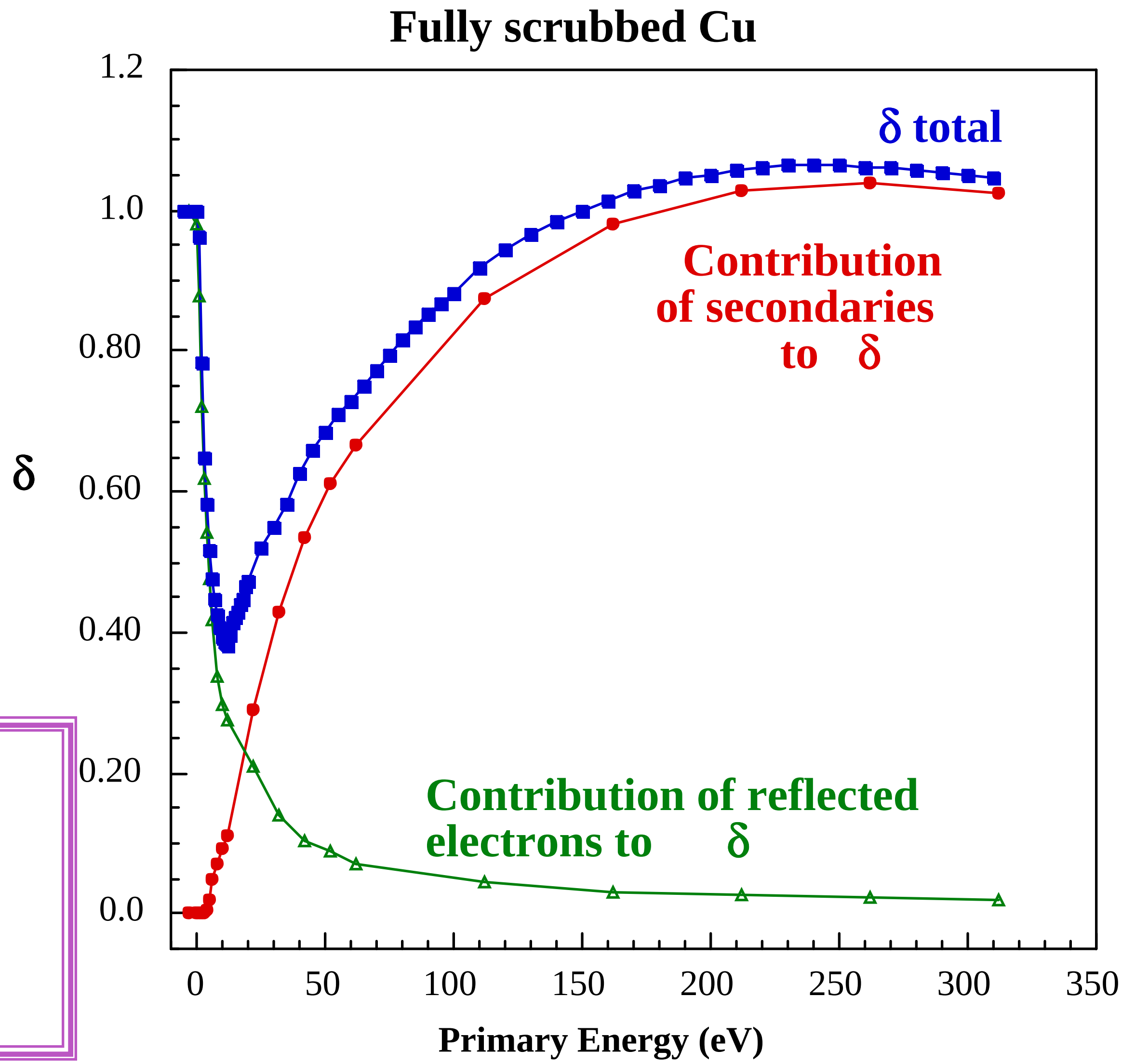


What has been measured on f.s. Cu

The value for the minimum, its energy and width vary with sample, sample spot, scrubbing and T.

A systematic study is necessary to give values.

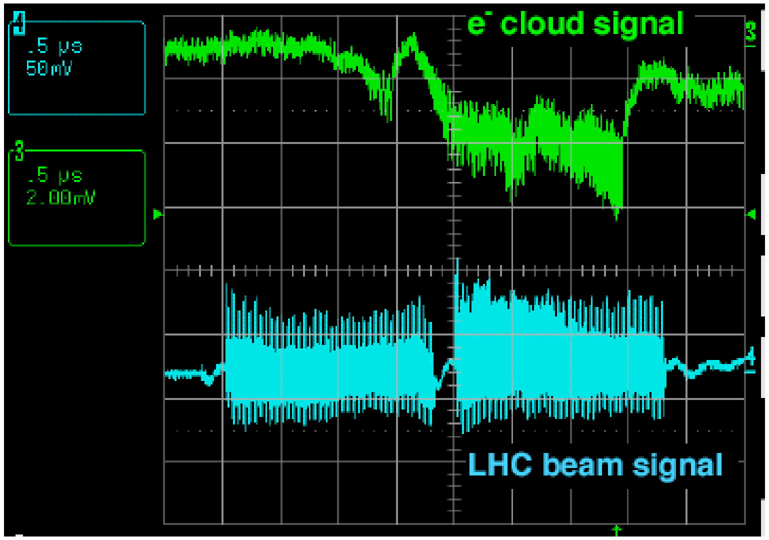
It is clear that the reflected component plays a major role in δ at low energy.

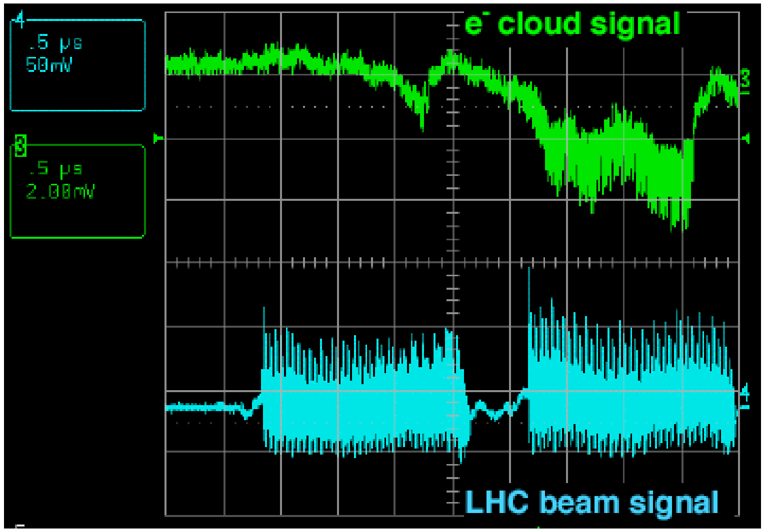


Implication

- Low energy electrons have a long survival time. Explains observations atKEK, SPS, PSR, LANL....

Observed Memory Between Bunch Trains: SPS 2002 (Electron Flux)





SPS pick-up signals for 225-ns and 550-ns spacing between two 72-bunch trains. Memory!

Implication

- Low energy electrons have a long survival time. Explains observations at KEK, SPS, PSR, LANL....
- In FELs a low repetition rate is supposed to ensure no e^- cloud problems. BIEM has to be considered.
- BIEM simulations need to be updated for the LHC and other machines.

- **Reflected el. are NOT absorbed and do not directly contribute to heat load !!!**
- **However they will be accelerated by the following bunches, gaining energy to be deposited on the BS.**

Secondary electron yield (SEY) model
(courtesy M.Pivi)

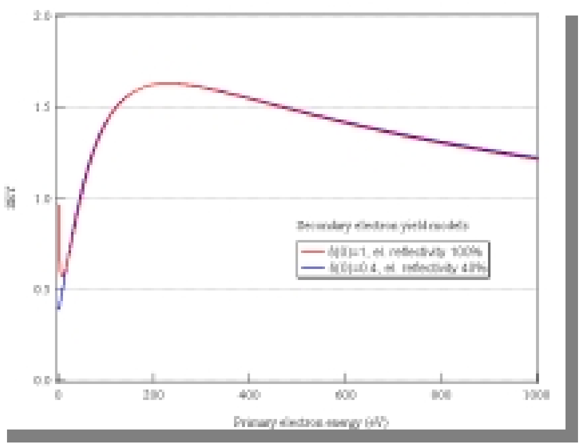


Fig. 1 Secondary electron yield model as described in [1]

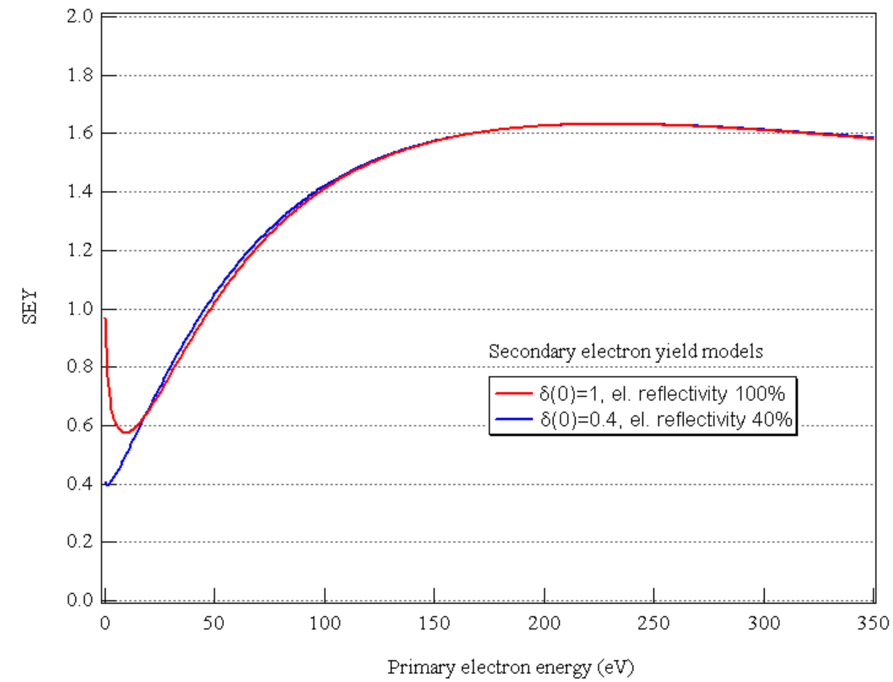


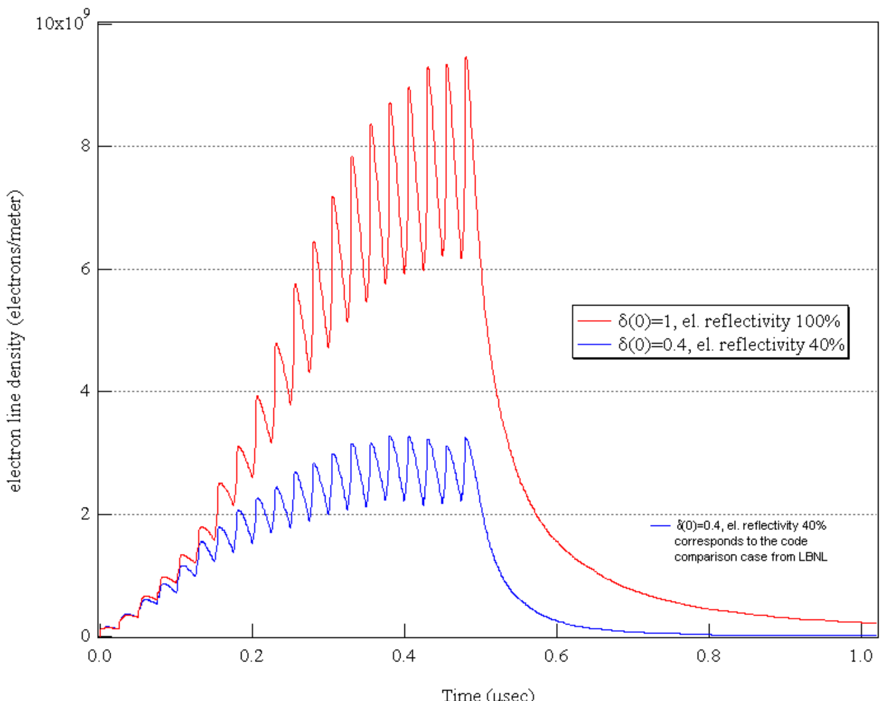
Fig. 1_zoom. Details of the simulated SEY at low incident electron energy

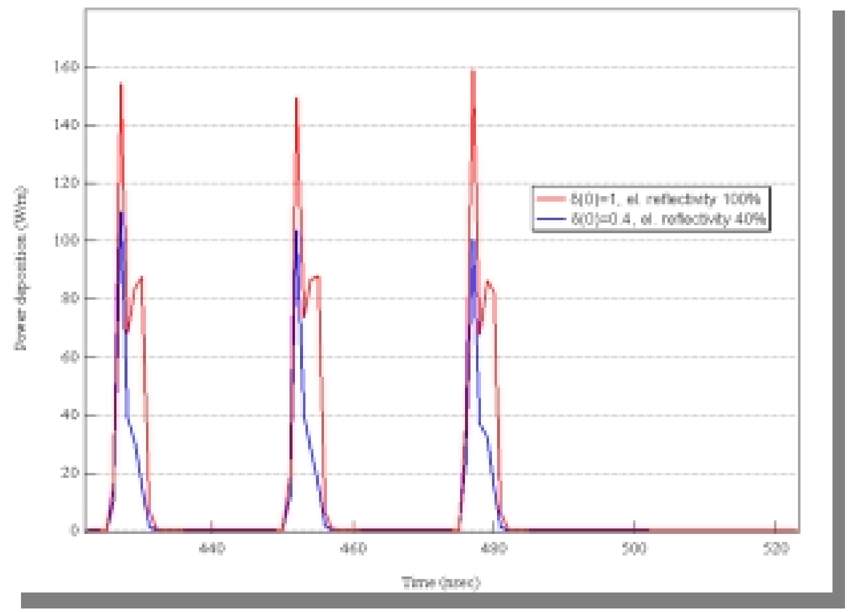
The model for the LHC Build Up Simulations is described in the CERN code comparison web page:

[1] http://wwwslap.cern.ch/collective/ecloud02/ecsim/modelbu.html

Note: CERN measurements by R. Cimino and I. Collins show 100% reflectivity at zero energy, with a SEY closed to the curve shown in red.

LHC e^- line charge and power deposition for different electron reflectivity models





LHC field free region. Electron line density in electrons/meter and power deposition in W/m for three different reflectivity behavior at low incident electron energy. Note: CERN measurements by R. Cimino and I. Collins show 100% reflectivity at zero energy.

To understand the implications of the “e-cloud problem“on DAΦNE- 2:

- **Significant R&D work is required in terms of:**
- **Vacuum Science ……**
- **Accelerators theory (simulations and chamber geometry)…...**
- **Material and Surface Science… (Al chamber)**
- **Synchrotron Radiation Spectroscopy**
- **…….**

Conclusion:

Simulation codes needs to be upgraded: In particular to simulate the boundary condition specific to the DAΦNE and DAΦNE- 2 machines.

An experimental campaign not only in the lab. but on DAΦNE machine itself (measuring e- activity,etc)could be launched to benchmark the codes vs. experiments.