Electron Cloud Update

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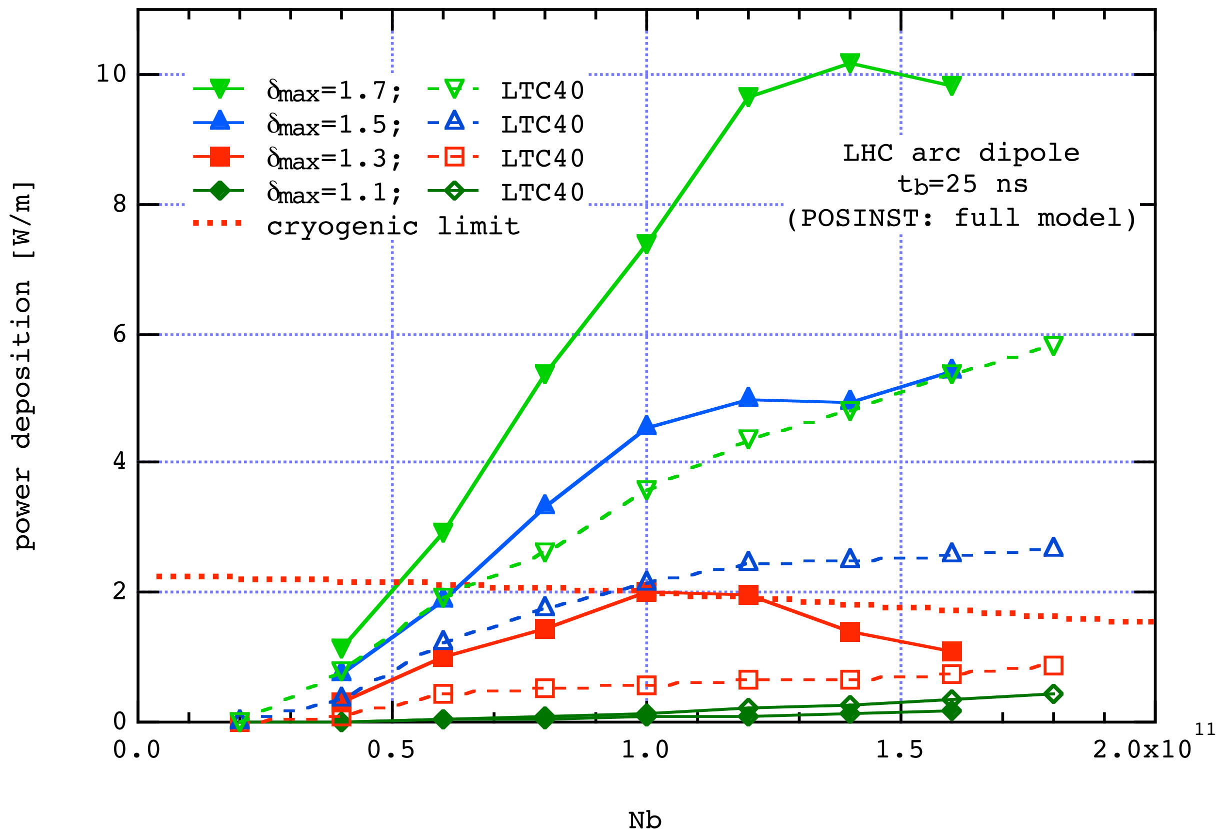
LARP Collaboration Mtg.
Pheasant Run (Illinois) Oct. 5-6 2005

Recent activities

- BNL
  - CERN e^- detectors for IP12 (not LARP funded, but important)
    - Two dipole magnets, B≤0.2 T, room temperature (one detector/dipole)
    - J. Miguel Jiménez to come this month to BNL for installation
    - Testing and calibration during 2006 run (A. Drees)
  - Ping He now working on ecloud
- LBNL
  - Summer student (V. Chaplin, July 2005)
    - Updated simulations of ecloud power deposition for LHC arc dipoles (next viewgraph)
  - Renewed RHIC simulations; goal: map out parameter space
    - Calibrate against measurements
    - Explain phase transitions
  - Augmented diagnostic capability of POSINST code
    - Quantify effects from various components of the electron-emission spectrum
  - 3D self-consistent code (WARP/POSINST)
    - Not LARP-funded in FY05
    - Initial results for one LHC arc FODO cell in early 2005 (LARP mtg, Apr. 05)
    - Will take up in FY06 (Jean-Luc Vay)

Simulated LHC arc dipole power deposition bunch spacing: t_b=25 ns

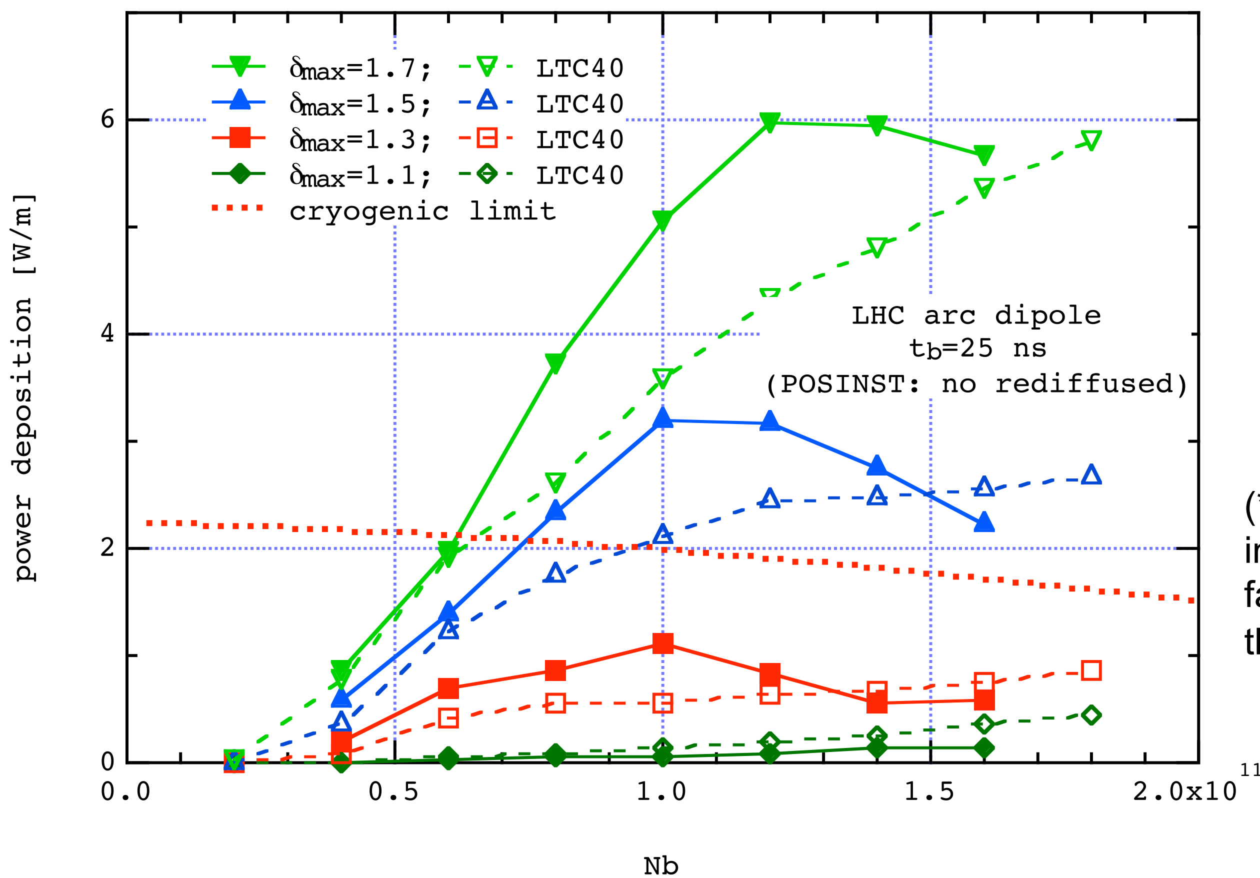
Aver. power deposition vs. bunch intensity
for a given peak value of the SEY
(POSINST and ECLOUD codes)



* “LTC40”: LHC Tech. Committee. Mtg #40, April 2005 (CERN simulations, presented by F. Zimmermann)

Same as previous (t_b=25 ns) but no rediffused electrons(*)

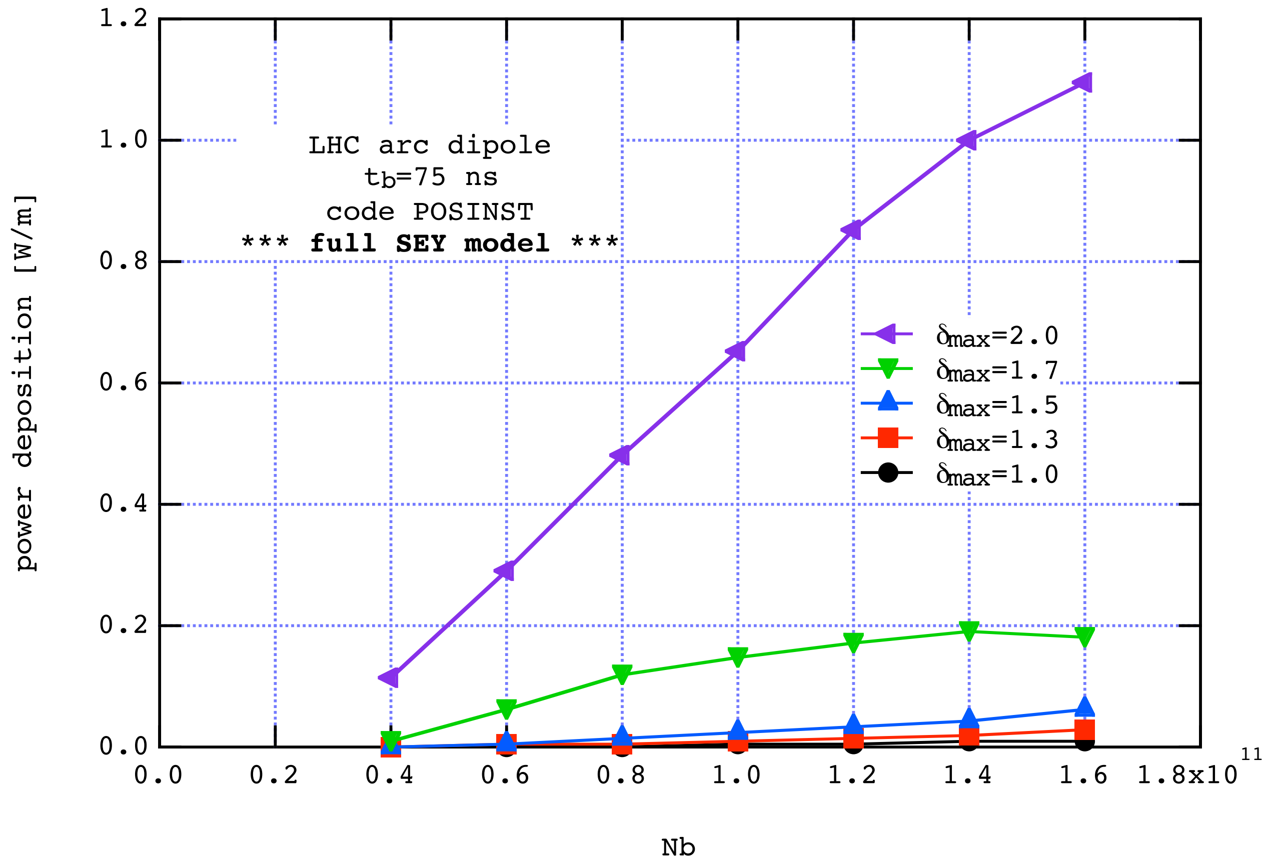
Motivation: POSINST model w/o rediffused ≈ ECLOUD model



(*) We set δ_r=0 and simultaneously increased δ_e and δ_{ts} by a common factor such that δ_{tot} remained the same

This is “good agreement” by the standards of the trade (IMHO)

Bunch spacing: t_b=75 ns (POSINST code)



Updated LHC dipole simulations: conclusions

- No problem for t_b=75 ns, even up to $N_b=1.6\times10^{11}$ and $\delta_{max}=2$
  - In qualitative agreement with CERN results
- If rediffused electrons ignored, good agreement with CERN simulations
  - As expected (similarity of models)
  - No problem up to $\delta_{max}\approx1.4$ (for $N_b=1\times10^{11}$)
- But rediffused electrons are there
  - Our model is based on bench measurements of emission spectrum for Cu
  - Maximum acceptable $\delta_{max}\approx1.3$ (for $N_b=1\times10^{11}$)

- Caveats:
  - Power depos. estimates above are based on 1 batch (=72 bunches + gap)
    - Steady-state estimates are higher by ~30-40%
  - $\delta(0)$ varies in 0.3-0.5 depending on δ_{max}; we have not assessed sensitivity to $\delta(0)$ separately from δ_{max}

Goals for FY05-06 (list from LARP mtg. April 05)

- LHC heat-load estimate: POSINST-ECLOUD benchmarking (*) essentially done
- 3D beam-ecloud self-consistent simulations (*) ongoing
  - Electrons, gas, ions, …
  - Main goal: understand effects from ecloud on beam
- Analyze June 2004 SPS data (*) ongoing
  - Especially e^- energy spectrum
  - Constrain SEY model for better predictions for LHC
  - Benchmark CERN calculations
  - σ_z dependence
- Help define optimal LHC conditioning scenario (*) not started
  - Define optimal fill pattern during first two (?) years of LHC beam
- Apply Iriso-Peggs maps to LHC (*) not started
  - Understand physics of map simulation technique
  - Understand global e-cloud parameter space, phase transitions
- Simulate e-cloud for RHIC detectors (**) just begun
  - Calibrate code
  - Then predict BBB tune shift
- Simulate e-cloud for LHC IR4 "pilot diagnostic bench" not started
  - What to expect when high-N, low-s_b beam turns on

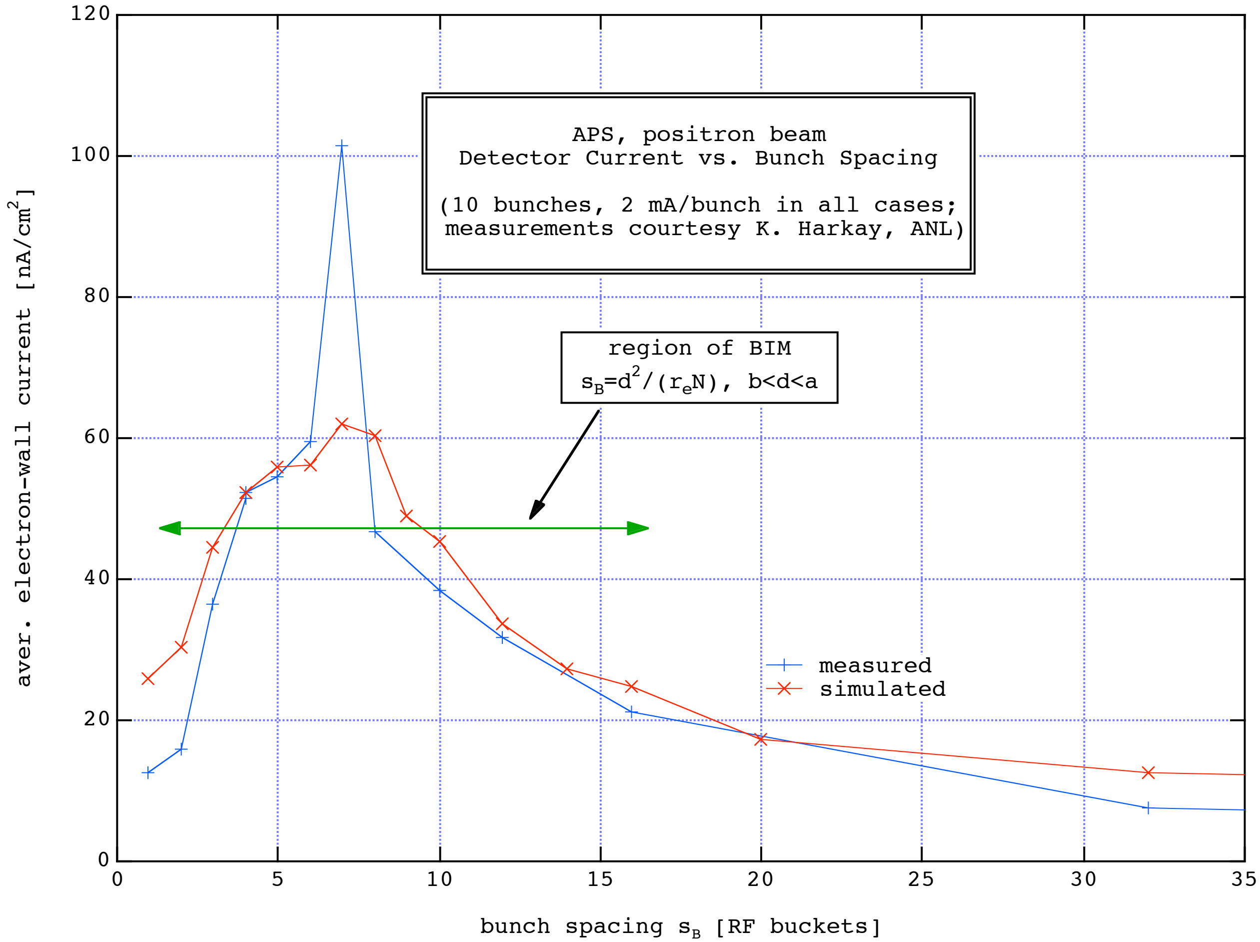
(*) endorsed by CERN AP group

(**) endorsed by CERN vacuum group

Additional material

Calibration of POSINST at APS (e^+ beam)

time-averaged e^- flux at wall vs. bunch spacing

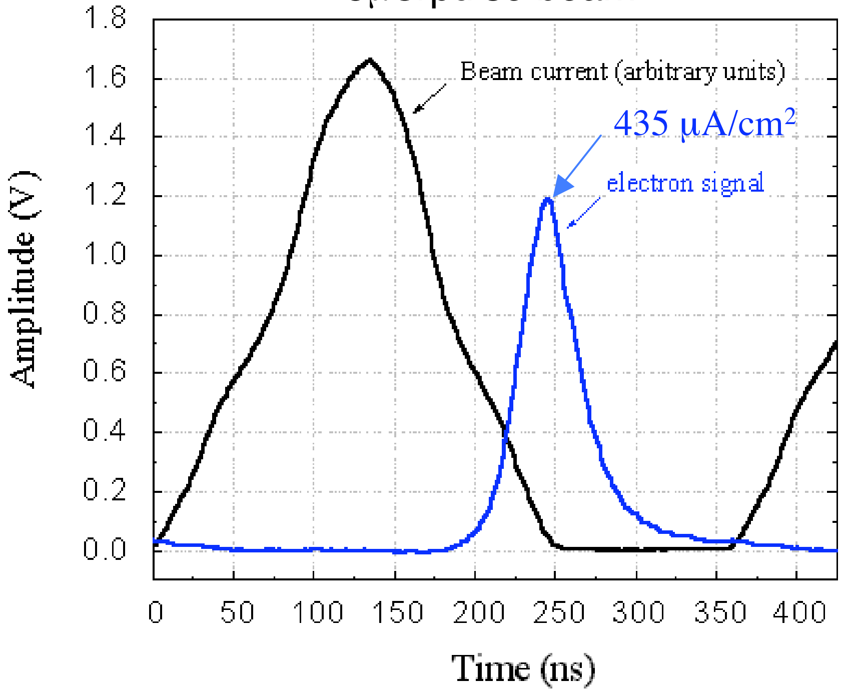


(Furman, Pivi, Harkay, Rosenberg, PAC01)

Calibrating POSINST at PSR

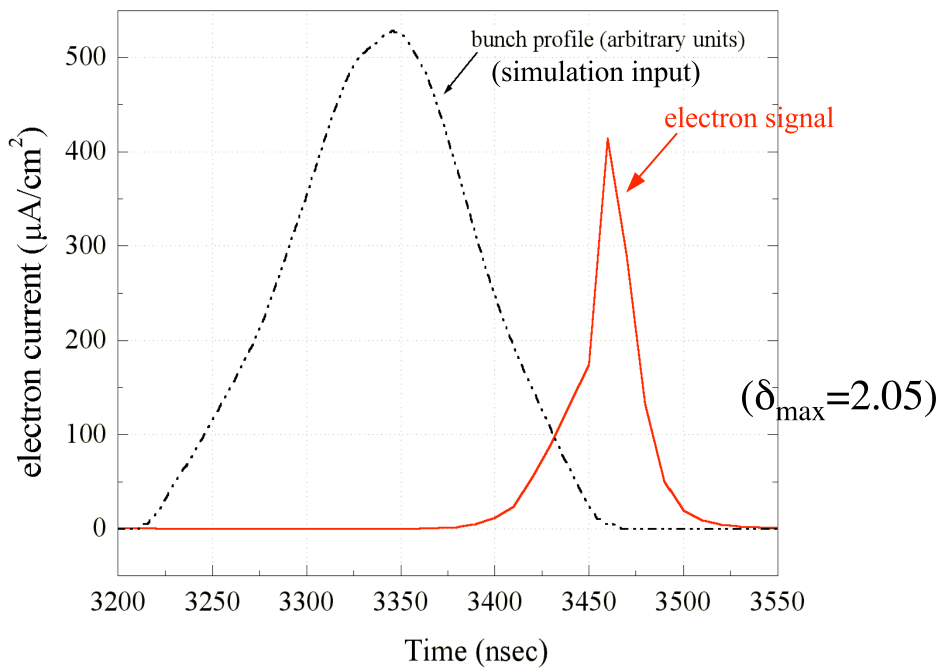
- bunch length ~60 m
  - a portion the EC phase space is in resonance with the "bounce frequency"
  - "trailing edge multipacting" (Macek; Blaskiewicz, Danilov, Alexandrov,…)

ED42Y electron detector signal
8μC/pulse beam



measured (R. Macek)

(ROAB003; RPPB035)



simulated (M. Pivi)

Three components of secondary emission:

sample spectrum at E_0=300 eV

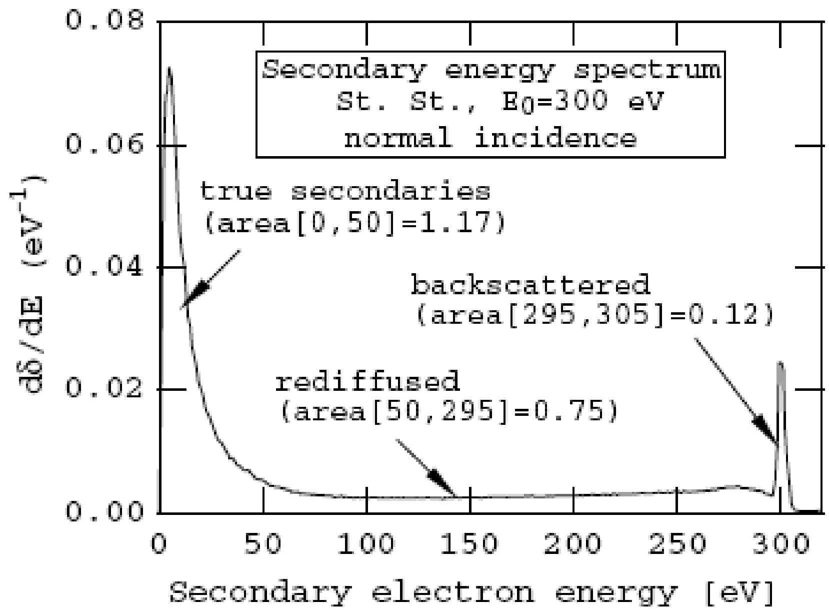


FIG. 2. A sample of the measured energy spectrum $d\delta/dE$ for an unconditioned sample of stainless steel at $E_0 = 300$ eV, normal incidence. The three components of the secondary yield are given by the values of "area $[E_1, E_2]$," each of which represents the integrated spectrum between E_1 and E_2. Thus for this case, $\delta_{ts} = 1.17$, $\delta_r = 0.75$, and $\delta_e = 0.12$, for a total SEY $\delta = 2.04$. The upper energy cutoff for the true secondaries is somewhat arbitrarily, but conventionally, chosen to be 50 eV. Data courtesy of R. Kirby.

from M. F. and M. Pivi, PRST-AB 5, 124404 (2002)

Electron-wall collision energy

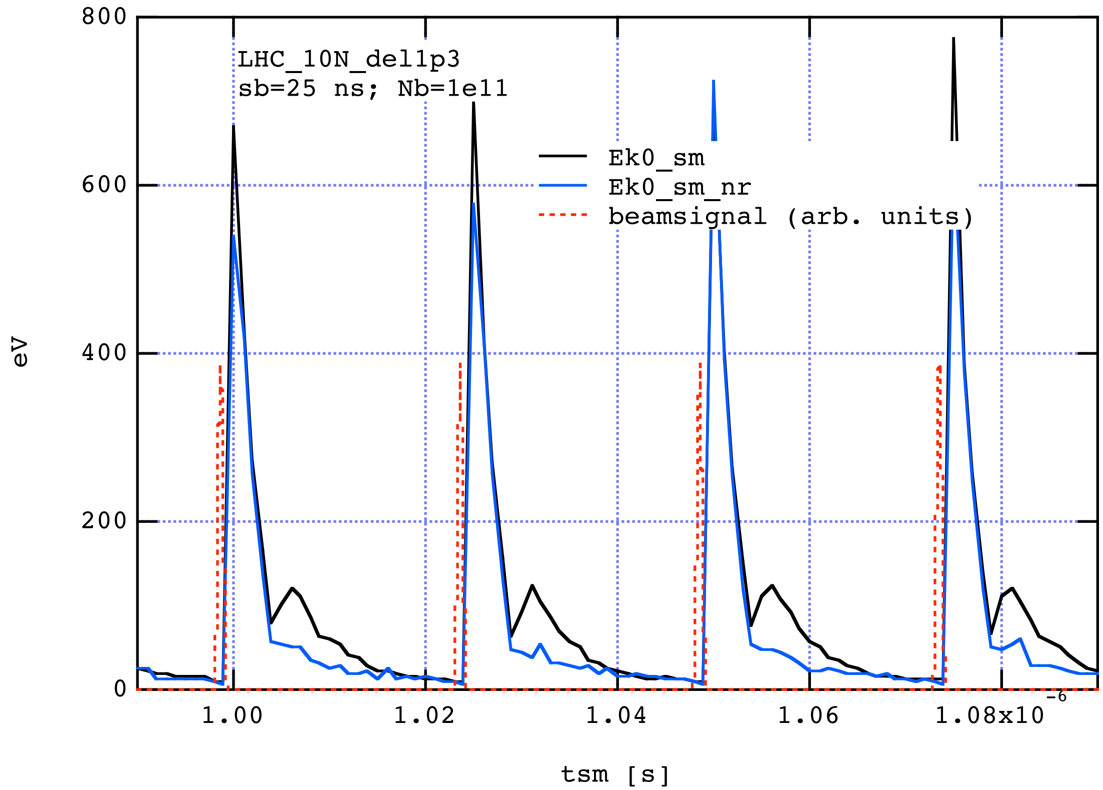
comparison w/wo rediffused electrons

~5 ns after bunch passage: 1st wave of electrons hits the wall (were kicked by the beam)

~5 ns later: second wave of electrons hits the wall; these were mostly rediffused electrons created when the 1st wave hit the wall

NB: the 2nd wave is absent in the “NR” case (“no rediffused”)

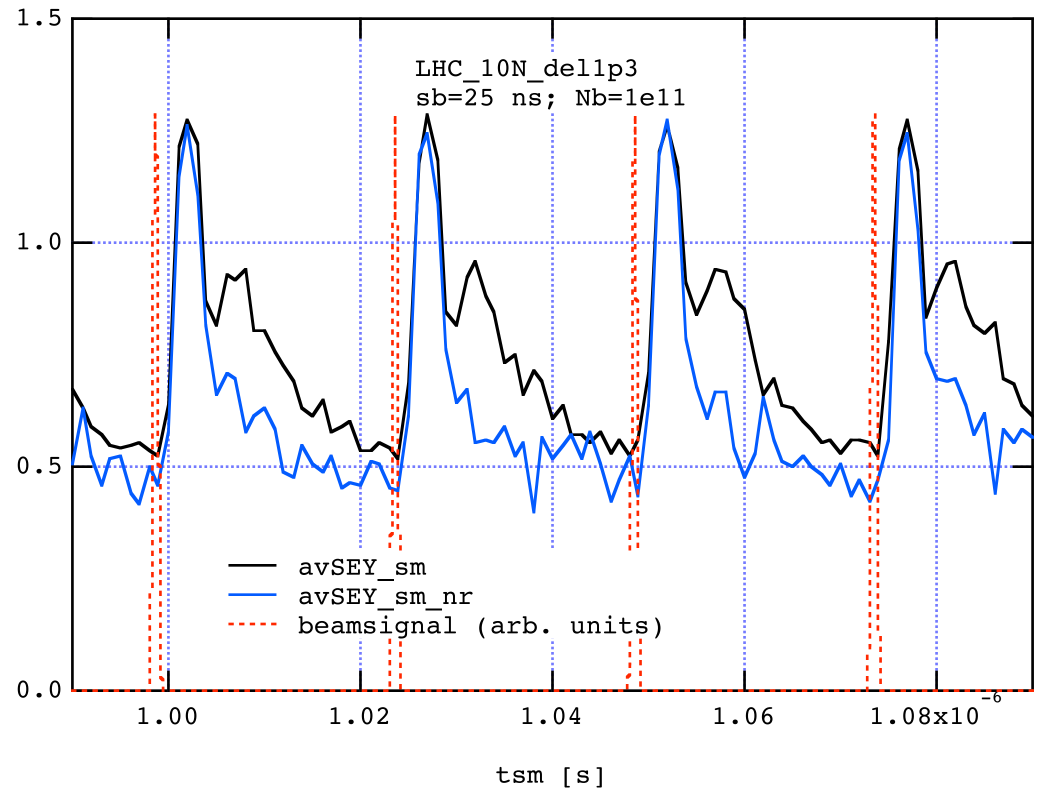
Four successive bunches in a 25-ns batch



Effective SEY

comparison w/wo rediffused electrons

The 2nd wave leads to a higher effective SEY (δ_{eff}) than in the "NR" case…

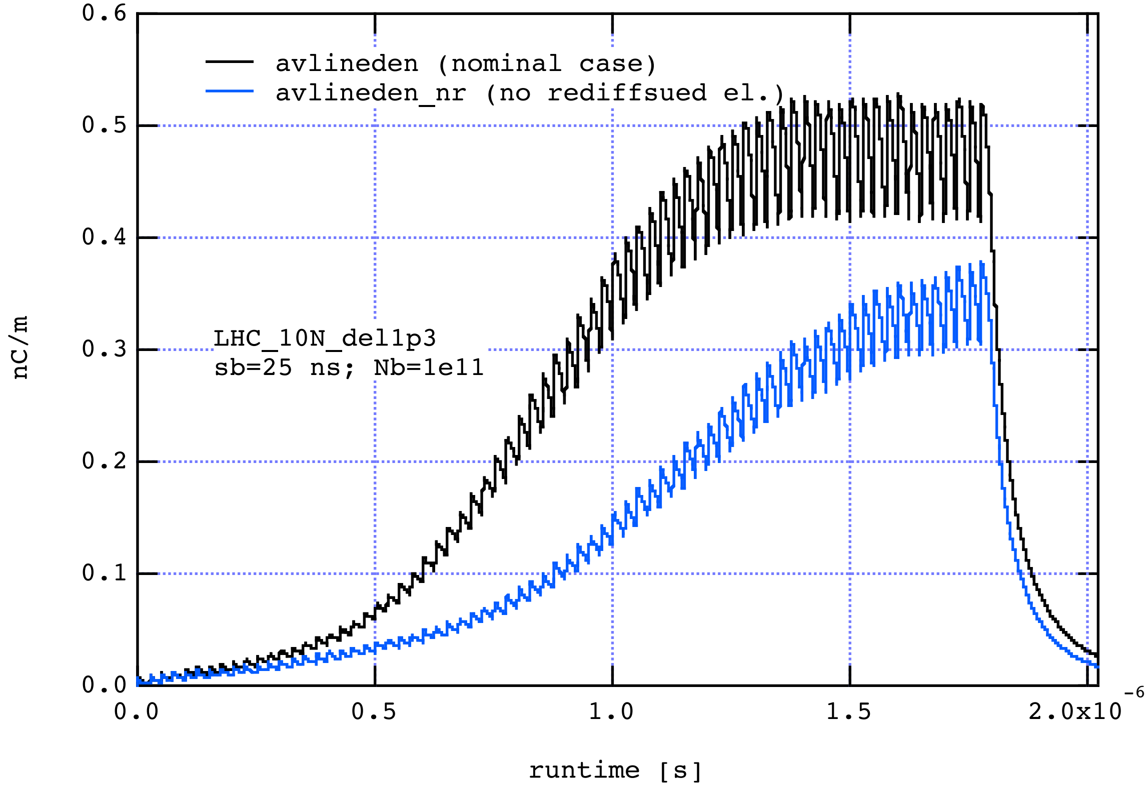


[definition: δ_{eff}= (no. of emitted electrons)/(no. of incident electrons) averaged over all electron-wall collisions anywhere on the chamber wall, over any given time interval]

Average electron line density

comparison w/wo rediffused electrons

…which leads to ~twice the number of electrons…



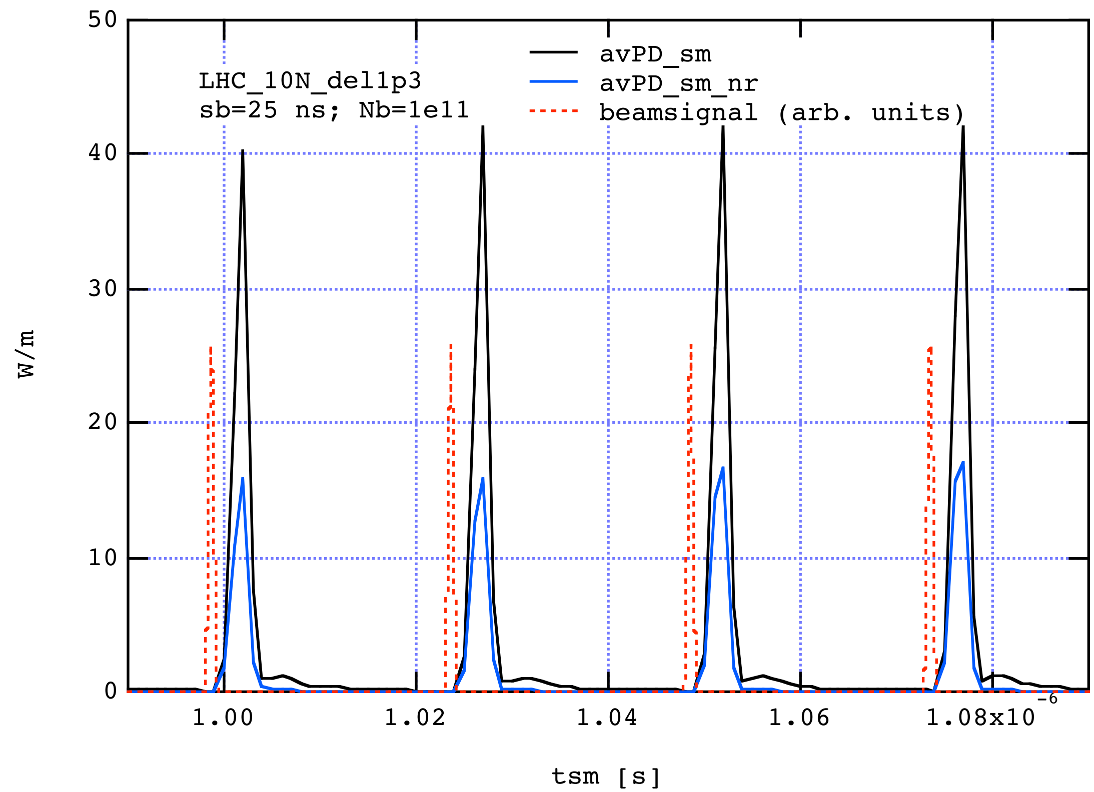
Average power deposition

comparison w/wo rediffused electrons

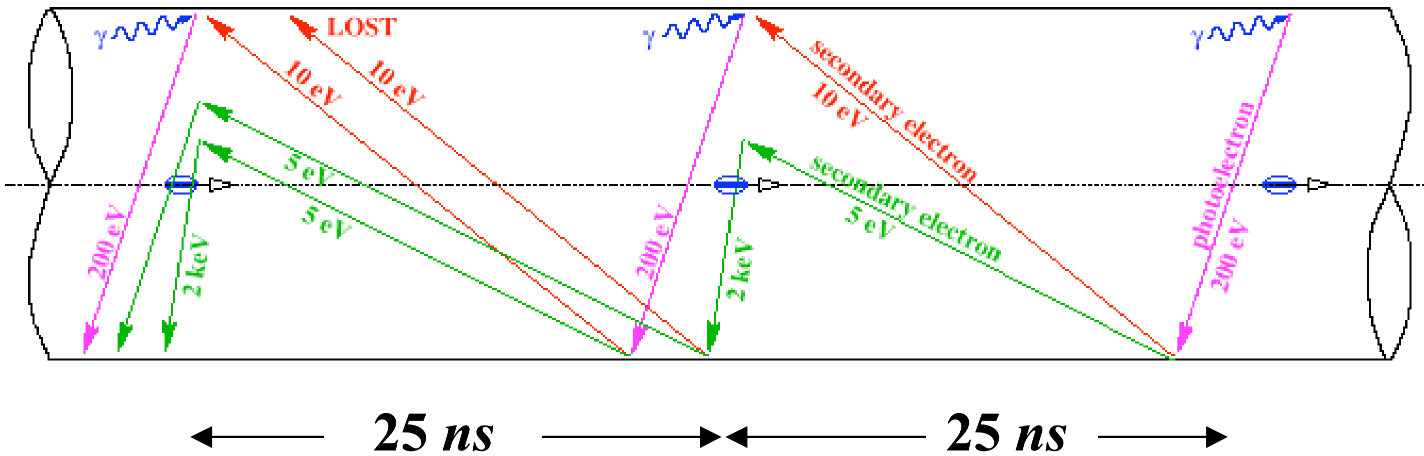
…which, in turn, leads to ~twice the power deposition.

Most of the power deposition comes from the 1st-wave electrons. The factor ~2 is mostly because there are ~twice the number of electrons.

The 2nd wave contributes an additional ~5-10% of "direct" power deposition (small bump ~10 ns after the bunch passage)



The electron-cloud effect in LHC



- Beam synchrotron radiation is important
  - provides source of photo-electrons
- Secondary emission yield (SEY) $\delta(E)$ is important
  - characterized by peak value δ_{max}
  - determines overall e^- density
- e^- reflectivity $\delta(0)$ is important
  - determines survival time of e^-
- Bunch intensity N_b and beam fill pattern are important
- Main concern: power deposition by electrons