E-Cloud Simulation With VORPAL
Goals and Plan

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Introduction: Motivation & Context

- Fermilab Main Injector upgrades includes a significant (3x) increases in the bunch charge, within the same longitudinal emittance budget => Peak current will increase by a factor three. Same (or lower!) beam losses, to avoid activation of the machine. => electron cloud induced (e-Cloud) beam instability could get worse.
- So far, electron propagation in e-Cloud has been simulated with a 2D code. A cursory look at a few electron trajectories can quickly convince the reader that, w/o magnetic, it is probably not good enough ==> VORPAL can address this problem.

Introduction: Grand Plan

- Goal has not changed since we started this 1.5 years ago: *detailed and accurate simulation of the e-cloud and the microwave absorption experiment.*
- Guide the MI e-Cloud experimental program, with, if feasible, data/experiment comparison.
- Field maps (or 4d current density, or potential) needs to be delivered in a suitable form to Synergia.
- PAC09 & SCIDac contributions need to be firmed and published in Journal referee paper.

Goals: (I) E-Cloud Sim itself.

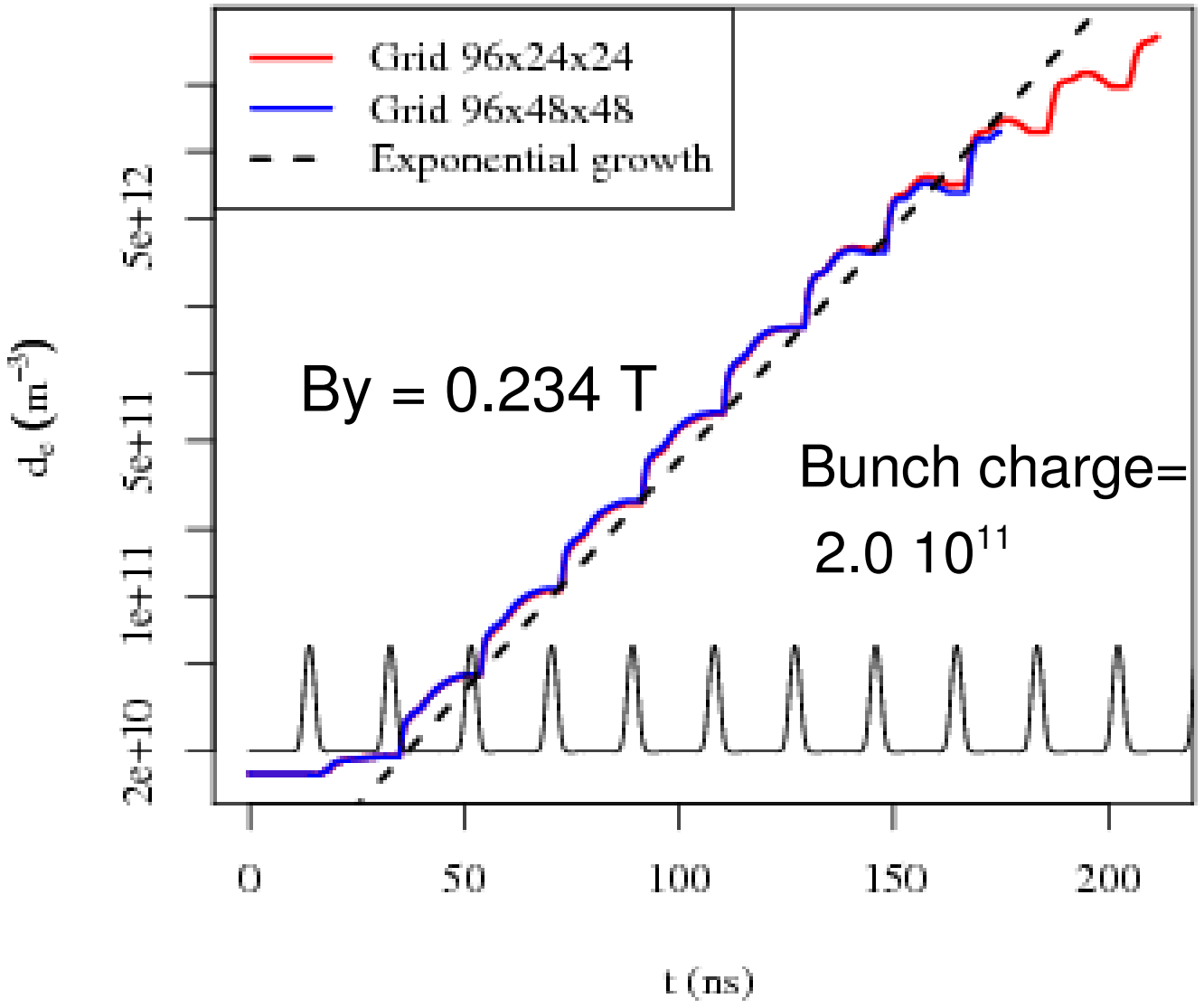
- Study of systematic uncertainty in e-cloud density and induced Electric field at beam location. (example later on in this talk)
  - Varying Usual PIC parameters (grid size, weights,..)
  - Secondary Emission Model parameters.
- Dependency of e-Cloud density on beam current: monotonic or not?
  - Effect of the decrease of the SEY above 300 EeV?
  - Or approximations in the calculation.?

Goals: (II) μ-Wave Experiment

- Amplitude vs frequency modulation: Linear theory predicts no AM. Indirect E-density measurement are difficult to interpret if AM occurs... Up to the experimentalist to show that they don't occur. -> Detailed simulation of the μ-wave signal required.
- Simulation of the 14 m. long “old” (FY09) setup at MI, then, if applicable, the new 2 m. long “short, B=0.” at MI currently in operation... Quadrupoles included (modeling accuracy?)
- Extra-credit: role of ions, hybrid resonances?

Example of systematic uncertainties studies

- What is the e-Cloud induced Electric field at ~3 sigma from the beam, vs grid spacing.. w/o static magnetic field, vs time
- Steps in the calculations:
  - Remove μ-wave, for sake of simplicity
  - Short beam pipe, to speed things up (but not too short, to avoid leakage on the side.)
  - Weighted Monte-Carlo (not yet there..***Must do***)

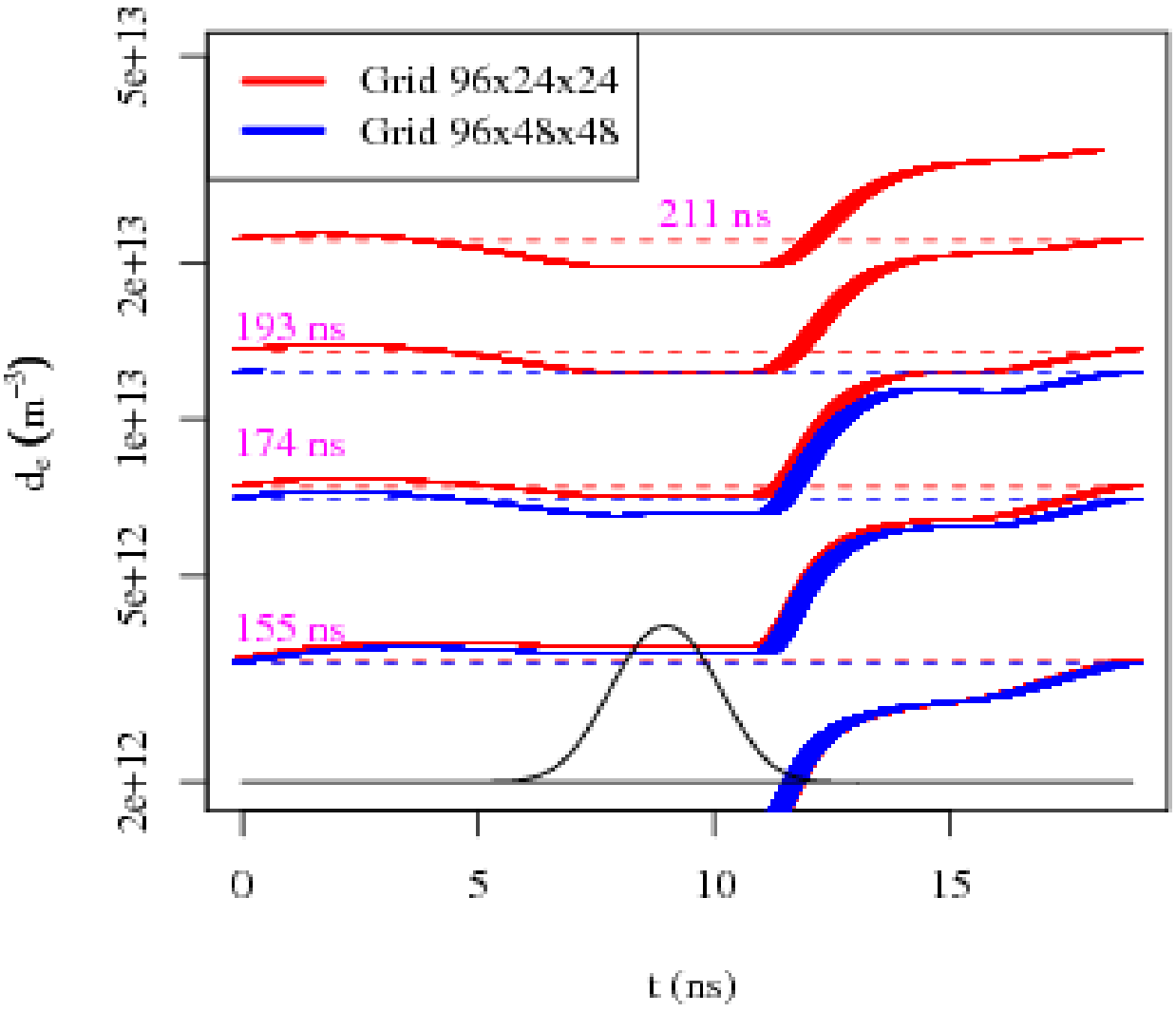


Simulation of the of the e-cloud growth:

- cell size ~ 1 mm
- Length: 25 cm.
- time step: 3 to 5 ps.

Result:

- Clear indication of saturation, without electron culling, or “dark surface”.



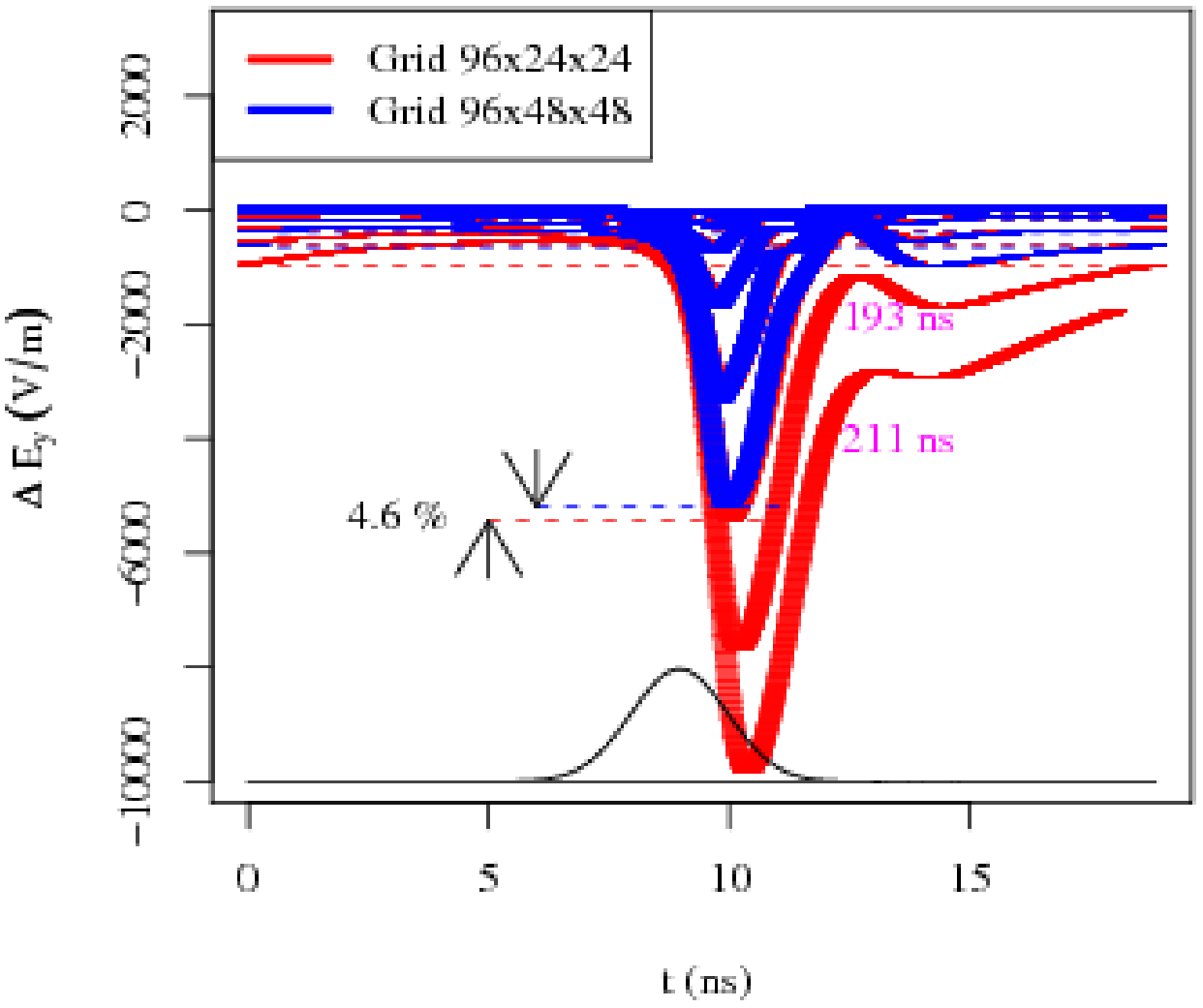
... Modulo beam freq.

Result:

- Clear indication of saturation, without electron culling, or “dark surface”.
- At ~ 5 10^{13} e/m^{-3}, linear density of e-Cloud ~ bunch, after 10 to 15 bunches.

Same data as in previous slide.

(Black curve is Ey due to beam.. (a.u.))



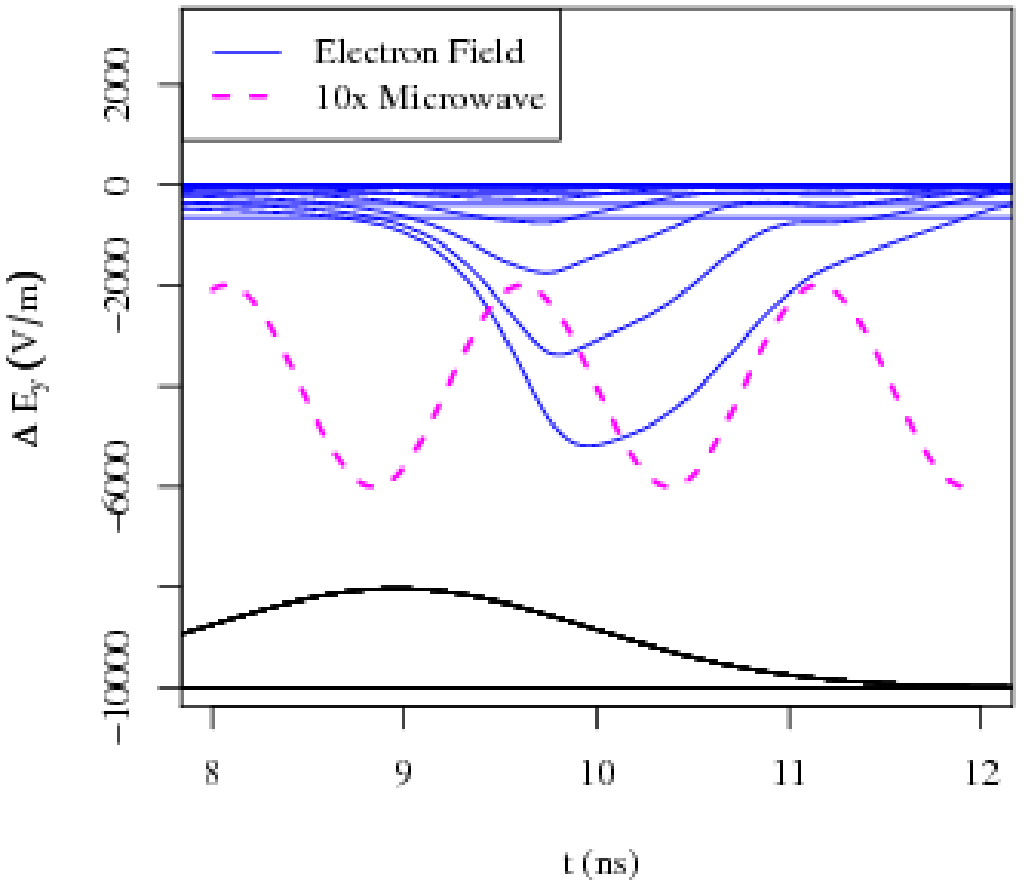
(Black curve is Ey due to beam.. (a.u.))

... What counts for beam physics:

Electric field induced by the e-Cloud Obtained by subtracting w/o seed electrons

At 1 cm above from center of beam (or beam pipe)

μ-Wave: Amplitude Modulation?



Same composite plots as previous,with the 1.5 GHz μ-wave surimposed.

e-could induced field ~10 time higher, same ν range. => AM !

But appears at 53.1 MHz !...

Plans: Physics issues

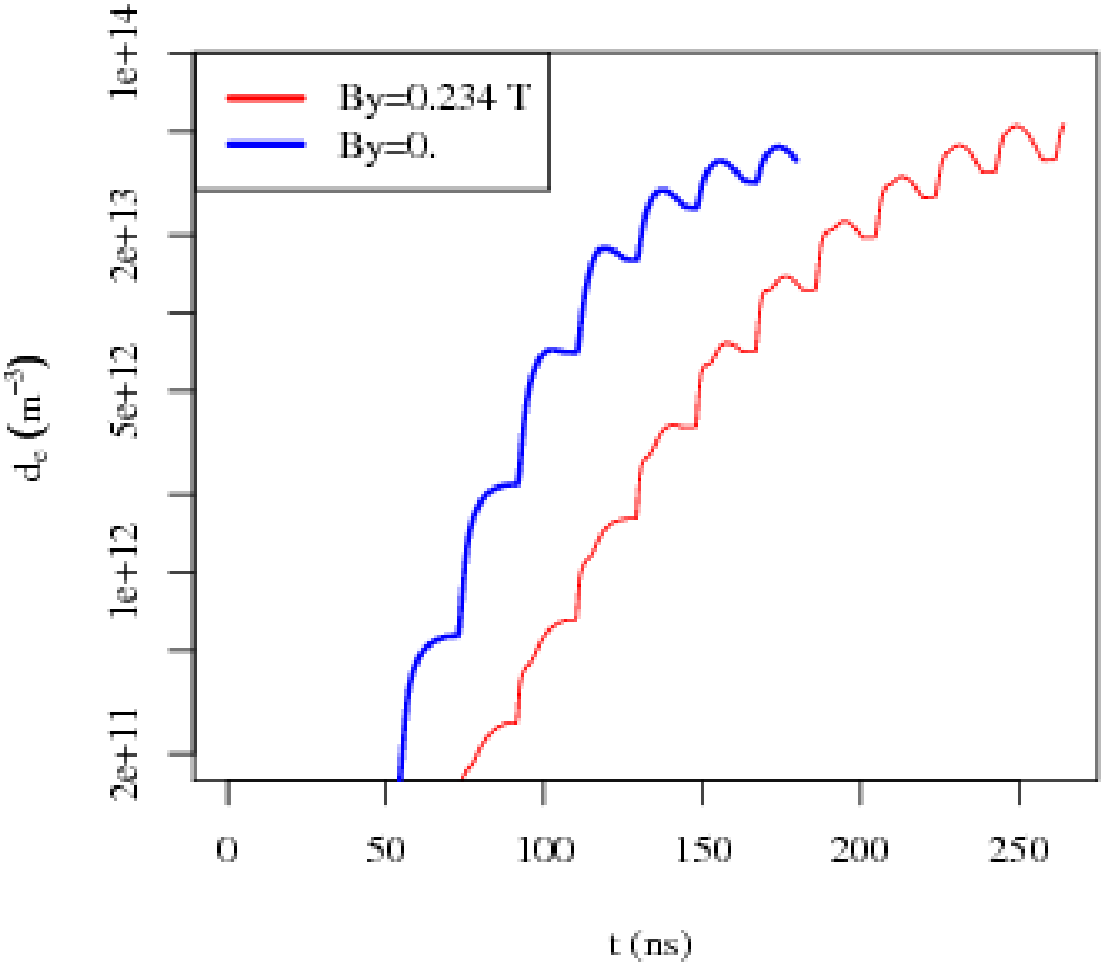
- Many parameters to scan -> tedious..
- Most Critical source of uncertainties comes from Secondary emission model!..
- μ-wave: simulation of cancelation of signals at 53.1 MHz via integration over many bunches, => not feasible right now.. need ~100 times more CPU power... or other idea..

Plans: Required VORPAL upgrades.

- Access to Secondary Emission model parameters
- Ability to cull the electron cloud, to save CPU time... Simple, light CPU load algorithm strongly preferred. (strictly random cull!, to be discussed tomorrow)
- Port to Intrepid. (or, just use multipole for a few month (~ year(s)...)

How can I help???

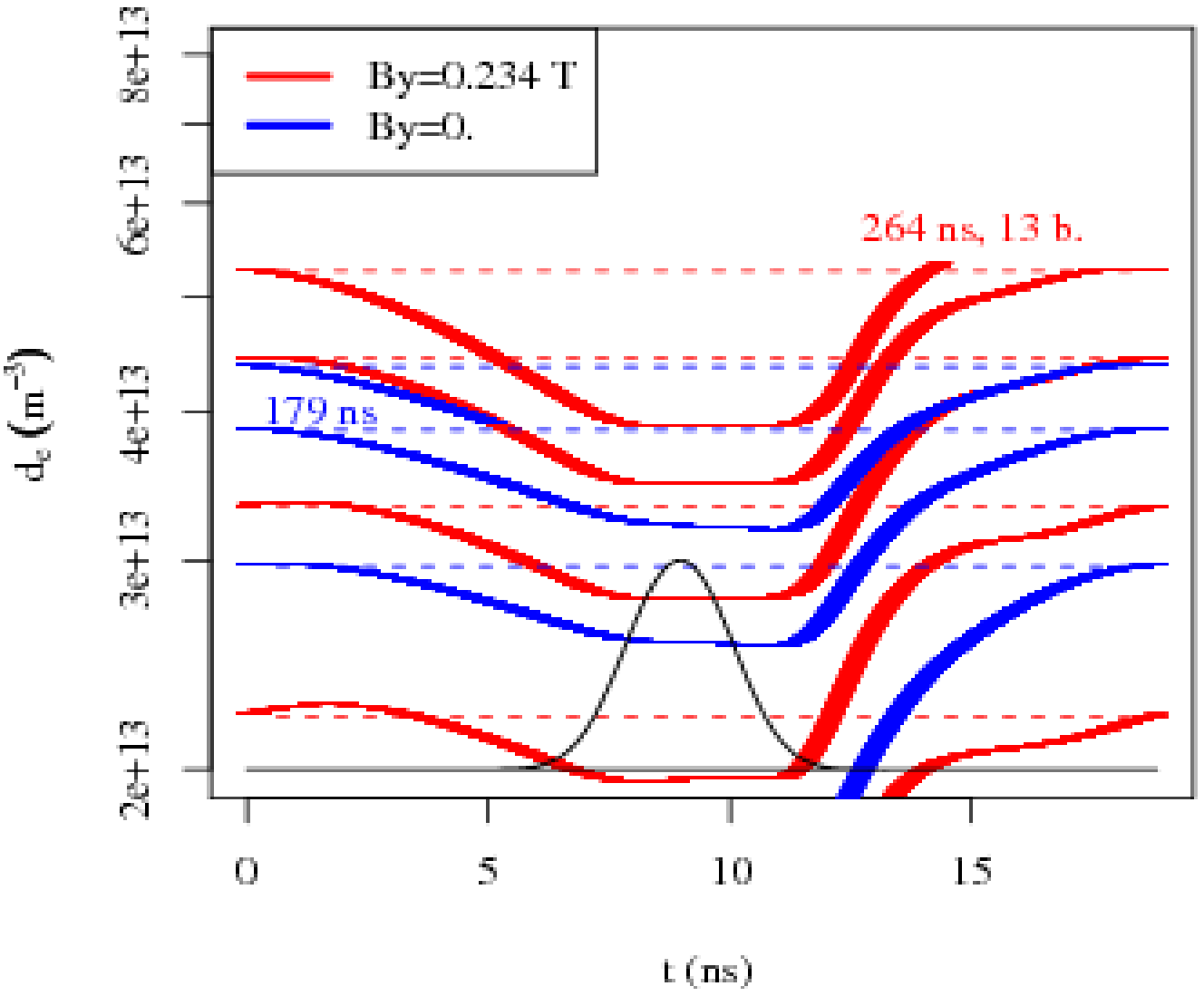
Extra, if time permit...



Running a bit longer..

Saturation clearly seen after ~ 13 bunches...

Slower with a magnetic field (as expected..)

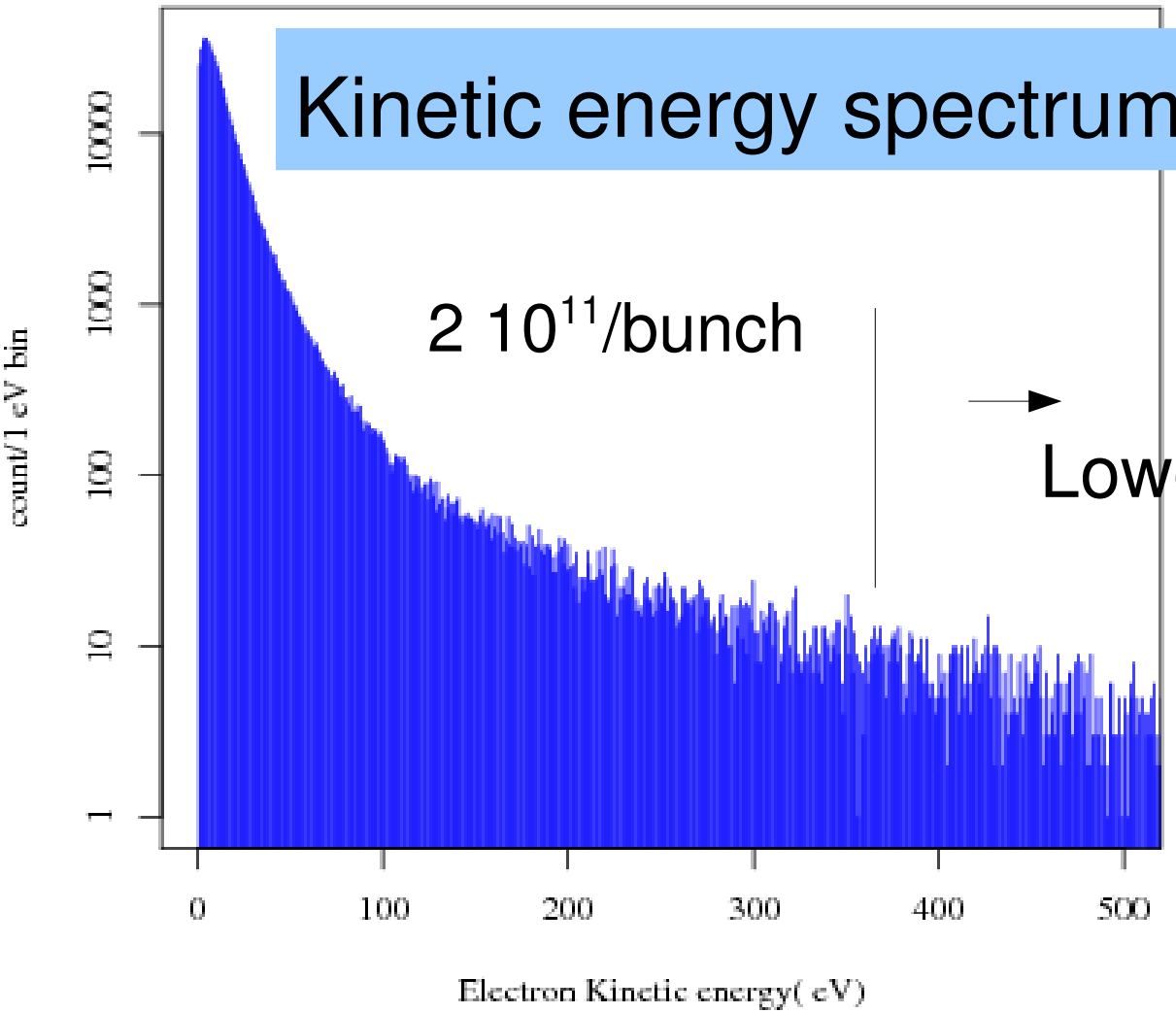


Close to 100% saturation of linear charge density...:

(Beam pipe x-section $4.4\ 10^{-3}\ m^2$

Bunch length : 1 m

Bunch charge: $2.\ 10^{11}$)



Reduced e-Cloud density at high beam current ??

I suspect Not!

Lower SEY..

But so what!.

Despite a peak field of 80 kV/m, plenty of low energy electrons!.

Electron Cloud Experimental Upgrade - 2009

Major upgrade just finished installation, this summer

- 2 New experimental Chambers
  - Identical 1 m SS sections, except that one is coated with TiN
- 4 RFAs (3 Fermilab & 1 Argonne)
- 3 microwave antennas and 2 absorbers
  - Measure ECloud density by phase delay of microwaves

- Primary Goal: validate TiN as a potential solution for Project X
- Secondary Goals:
  - Remeausure threshold and conditioning
  - Further investigate energy-dependence
  - Measure energy spectrum of electrons
  - Test new instrumentation
  - Directly compare RFA and Microwave
  - Measure spatial extinction of ECloud