Comments on Induced Signals in Charge Readout

Josh Renner
UC Berkeley / LBNL
RD51 Mini-Week, WG4
April 25, 2013

Background:

- Garfield and Garfield++ support simulations of electron/ion drift in finite-element fields and corresponding calculation of induced signals

- Purpose of these comments:
  - describe components of a charge readout signal
  - demonstrate in detail the time development of an induced signal

- Will make use of Garfield++, Gmsh [1] and Elmer [2]

[1] Gmsh: http://geuz.org/gmsh
[2] Elmer: http://www.csc.fi/english/pages/elmer

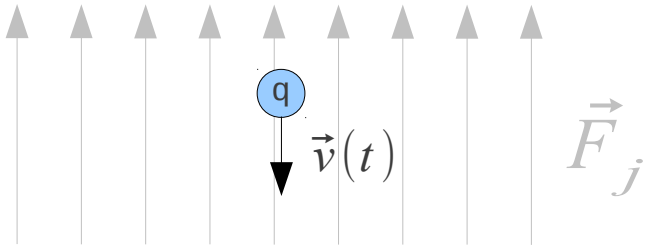
Signal readout: weighting fields

From RD51 Mini-Week WG4, 01/30/13

- Induced signals

  - A charge moving toward an electrode induces a current; product of [1]:

    → the charge q
    → the velocity of the moving charge v(t)
    → the **weighting field** F = -∇V,
    for V = 1 on electrode, V = 0 all other conductors



$$i_j(t) = -q\,\vec{v}(t)\cdot\vec{F}_j$$

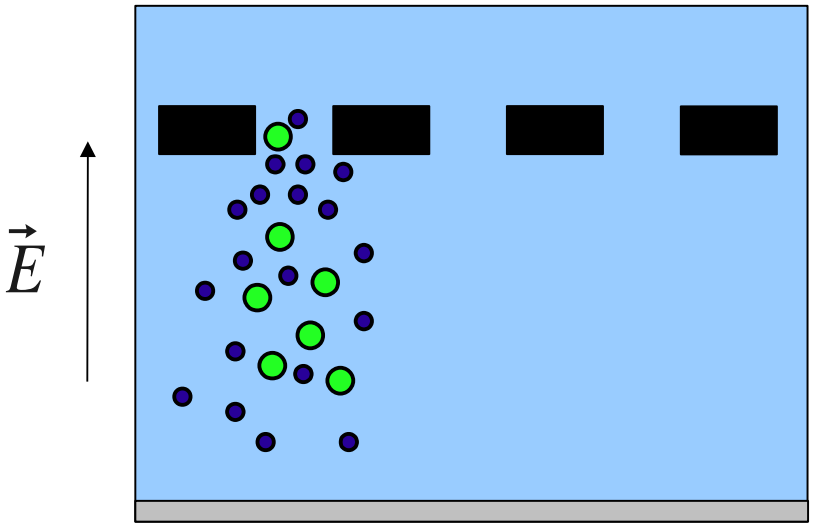
V = 1 electrode j

[1] H. Spieler, “Radiation Detectors and Signal Processing,” VII. Heidelberger Graduate Lectures in Physics, 2001. http://www-physics.lbl.gov/ spieler/Heidelberg Notes 2001/index.html

Example: LEM readout + attachment

Modified from RD51 Mini-Week WG4, 01/30/13

- LEM-based readout process



→ single-electron avalanche
→ e- drift towards readout electrode
→ some e- attach along the way and drift as negative ions
→ meanwhile positive ions (not shown) drift back through the LEM

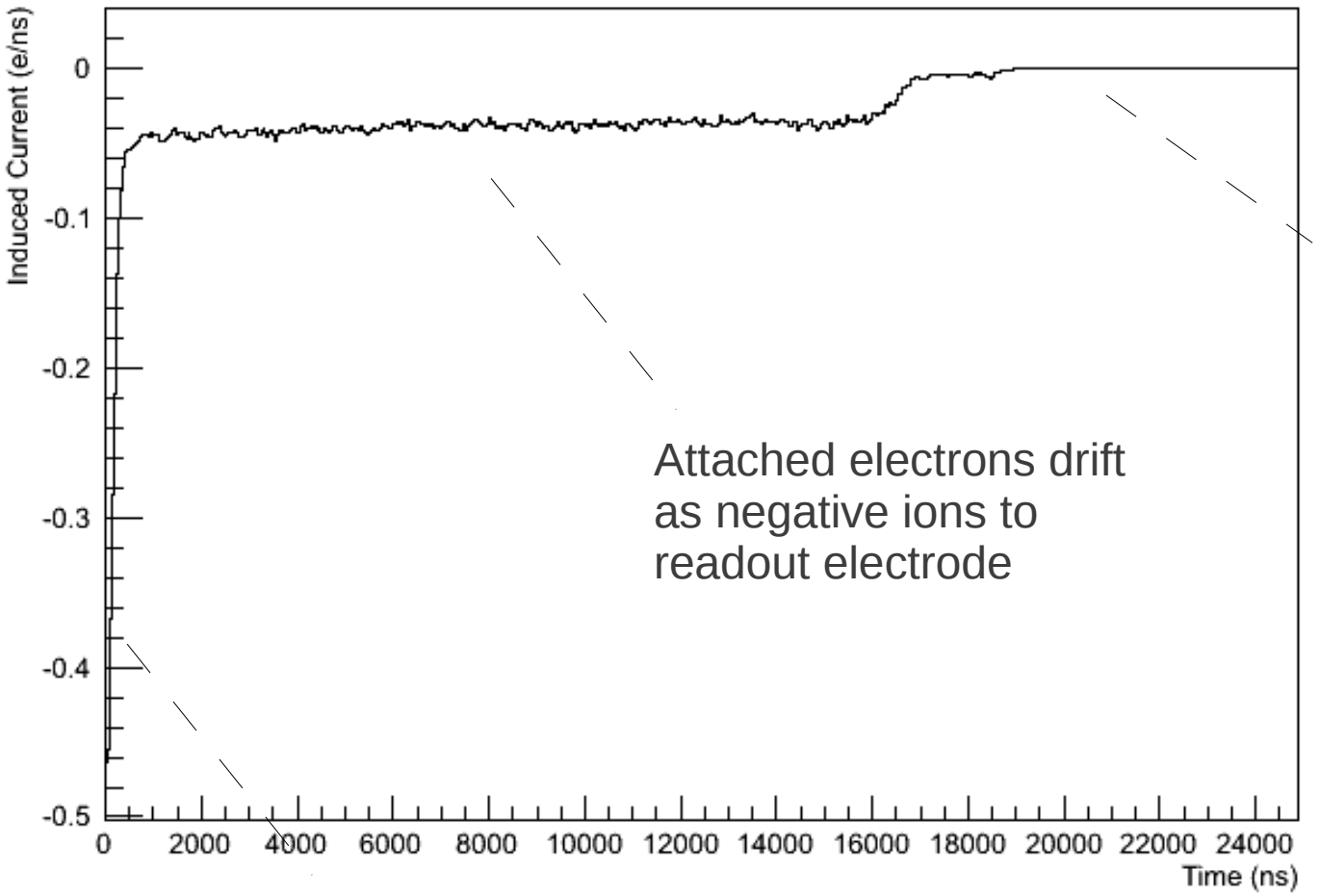
- Simulate in Garfield++:
  - Ar (30%) CO_2 (26%) O_2 (4%)
  - single e- incident on LEM produces an avalanche
  - drift a positive ion from each point of ionization
  - drift a negative ion from each point of e- attachment

Collaborators: Mike Heffner and Melinda Sweany (LLNL)

Example: LEM readout with attachment

From RD51 Mini-Week WG4, 01/30/13

- Ion component (+ and -) of induced signal



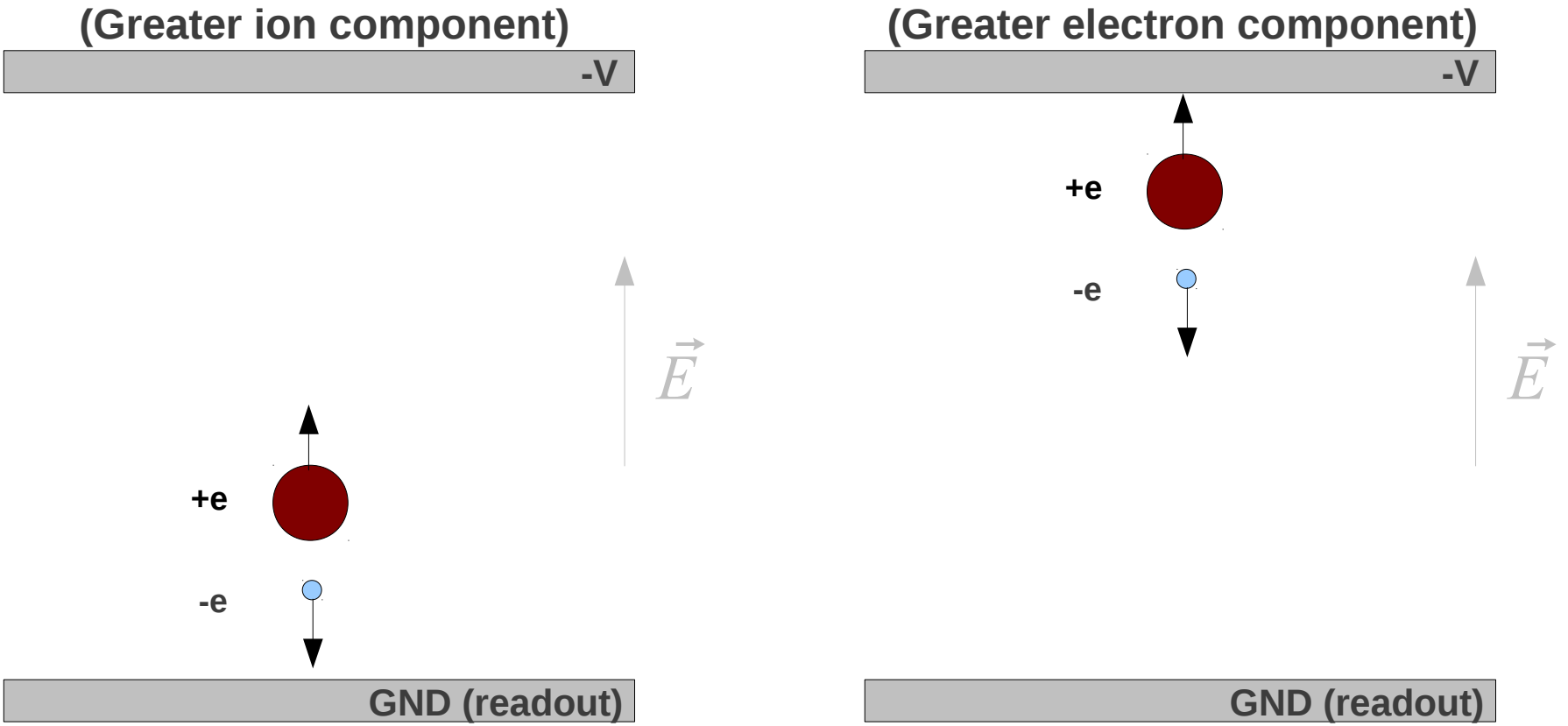
Positive ions continue to drift away from the LEM

Attached electrons drift as negative ions to readout electrode

Positive ions from avalanche move quickly out of the LEM

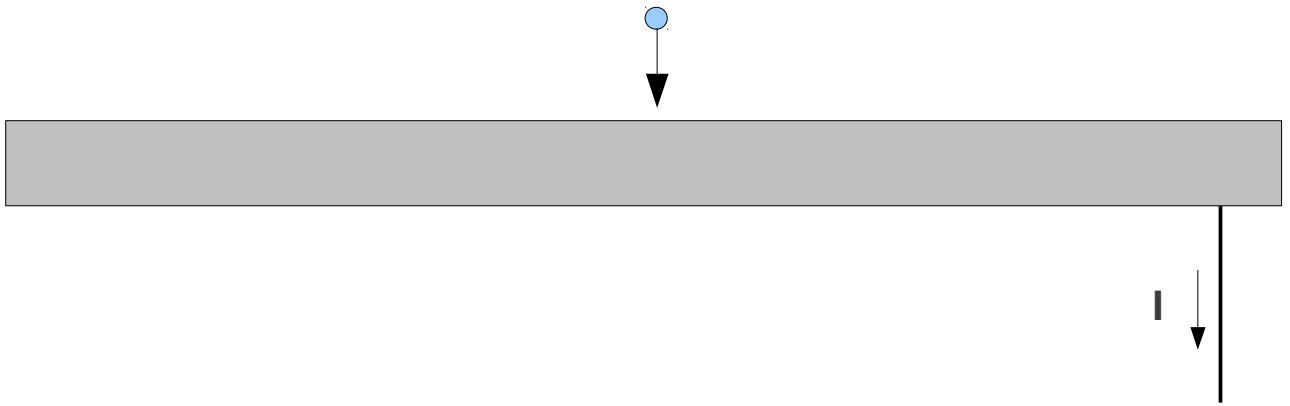
Comments on induced signals

- Induced signals: signal components
  - Ionization commonly read out as an induced signal
  - Depending on proximity of ionization to the electrode, the drifting ion may contribute ≥ the electron itself



Comments on induced signals

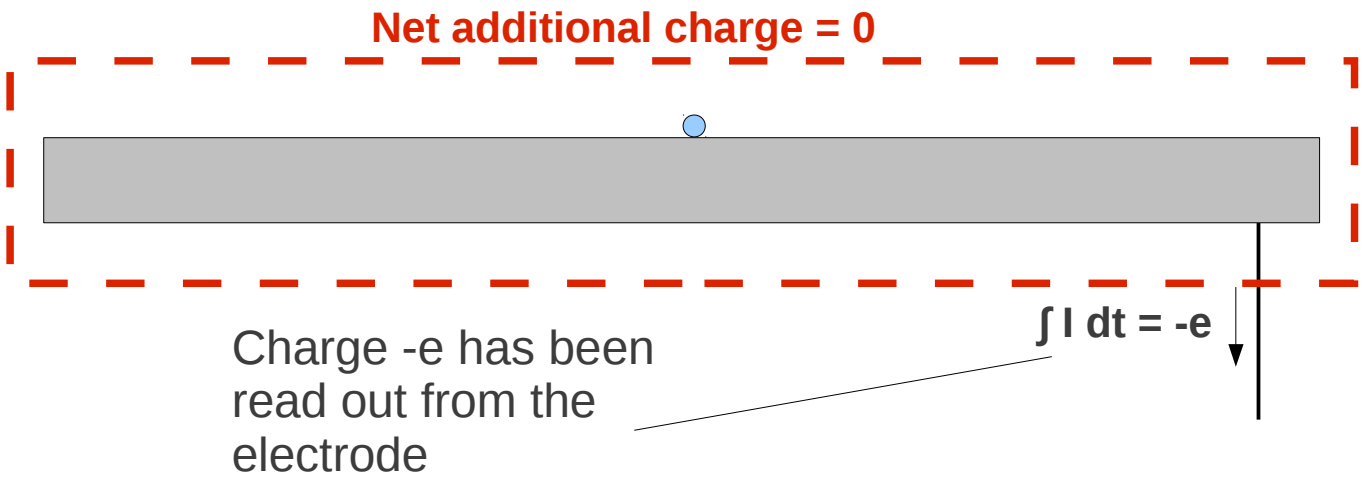
- Induced signals: charge neutralization
  - No “spike” of current is produced on contact with the electrodes
  - A net charge of -1 has already been observed through the induction process



Comments on induced signals

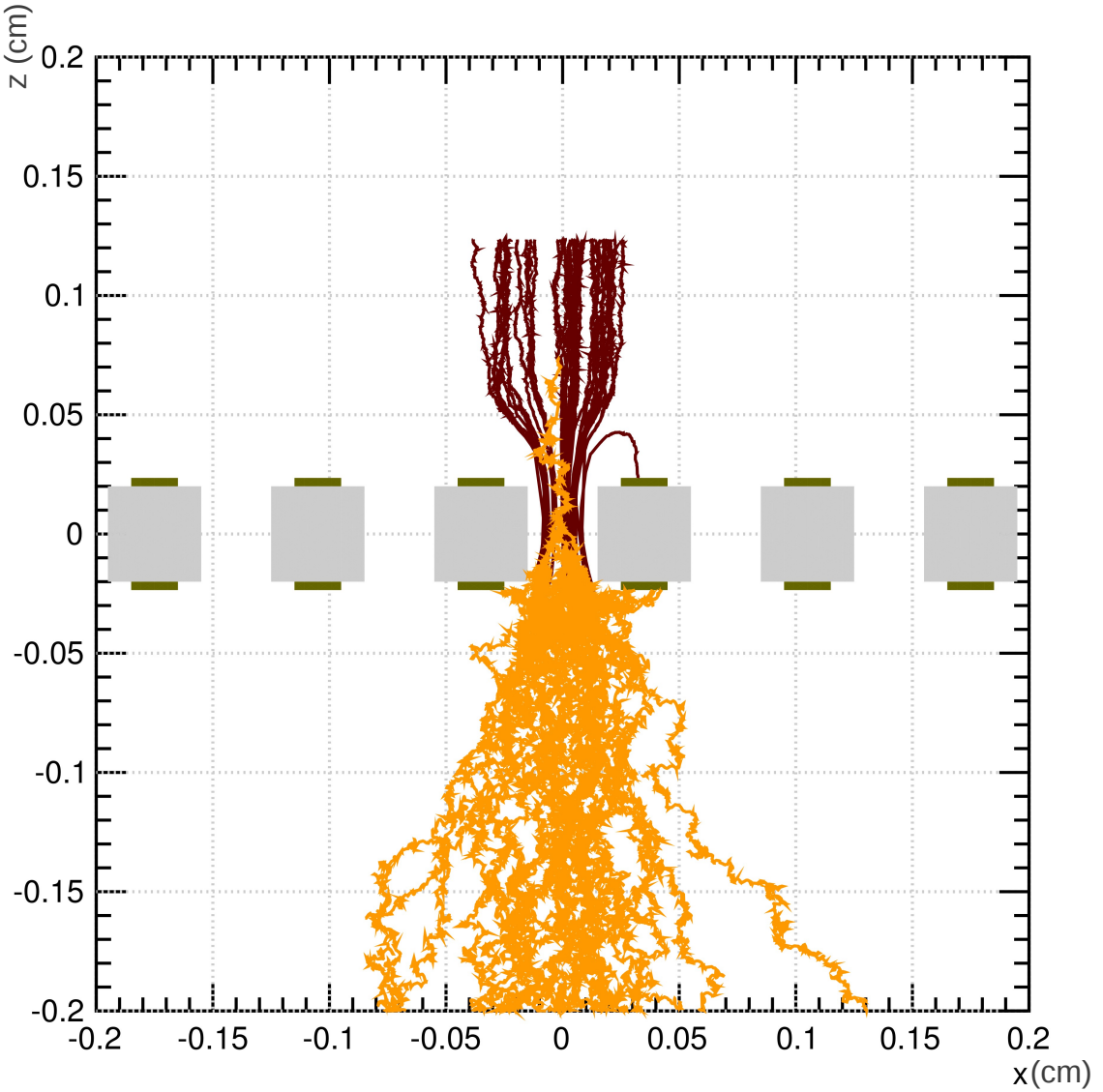
- Induced signals: charge neutralization
  - No “spike” of current is produced on contact with the electrodes
  - A net charge of -1 has already been observed through the induction process

Assuming ionization occurred far away from the electrode:



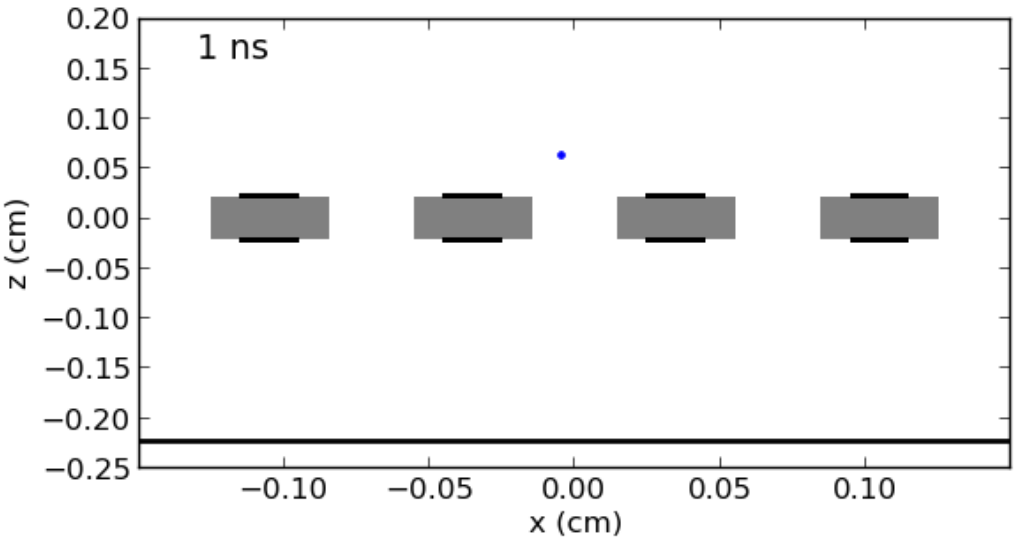
Detailed example: electron and ion signals

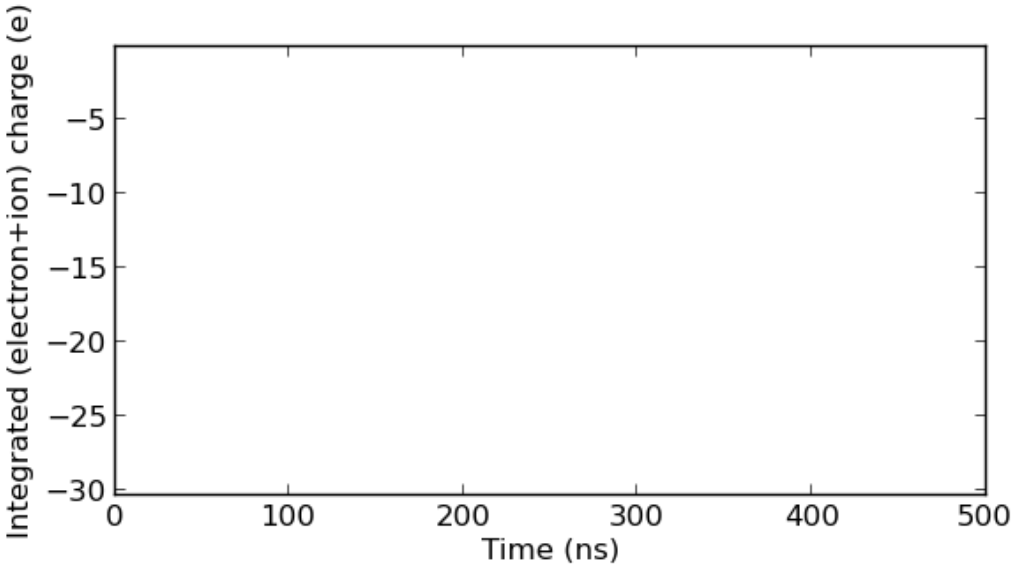
- LEM geometry (THGEM #9 of [1])
- 190 torr Ar/CO_2 (70/30)
- Single electron dropped above LEM and drifted through LEM hole to produce an avalanche
- Example shown: 25 electrons from the avalanche reached the readout plane (note: only considering electron and positive ion signals – 4 attached electrons are not drifted as negative ions)

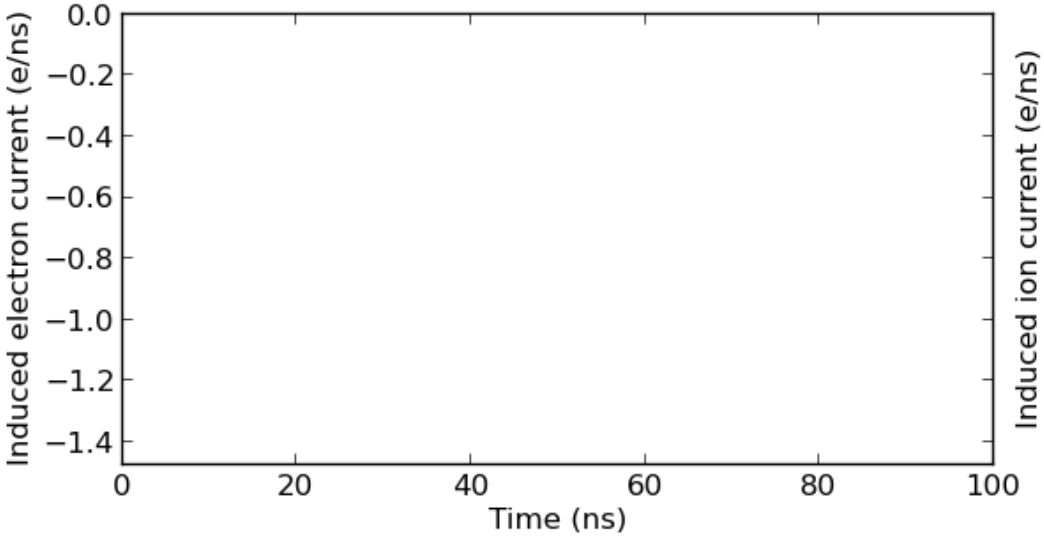


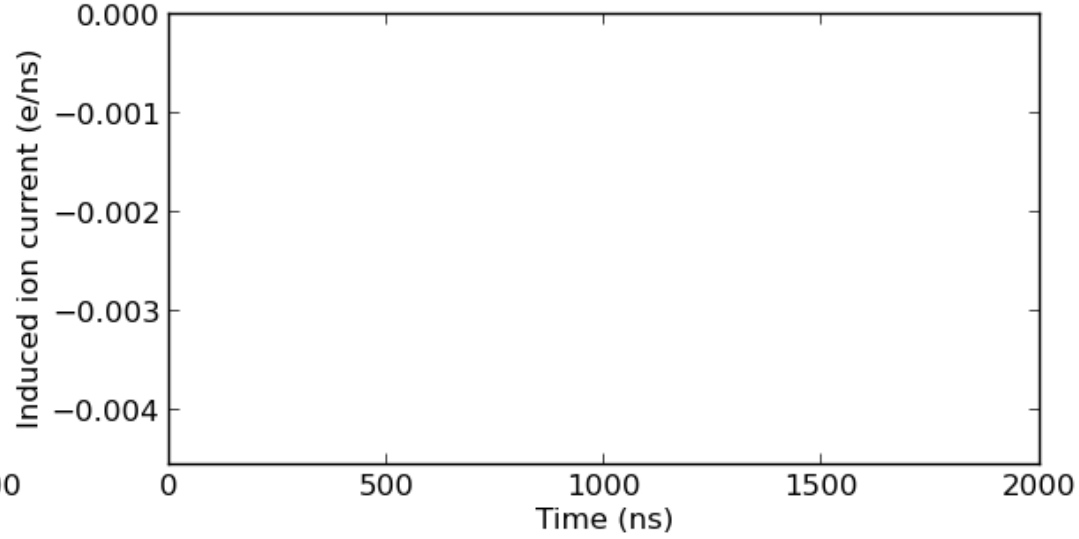
[1] C. Shalem *et. al.* NIMA 558, 475 (2006).

Detailed example: electron and ion signals

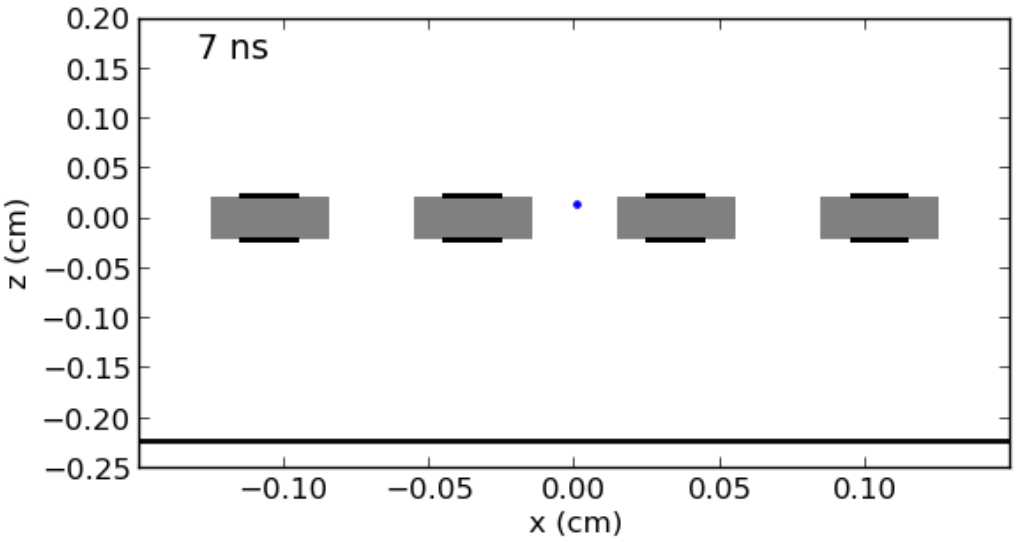


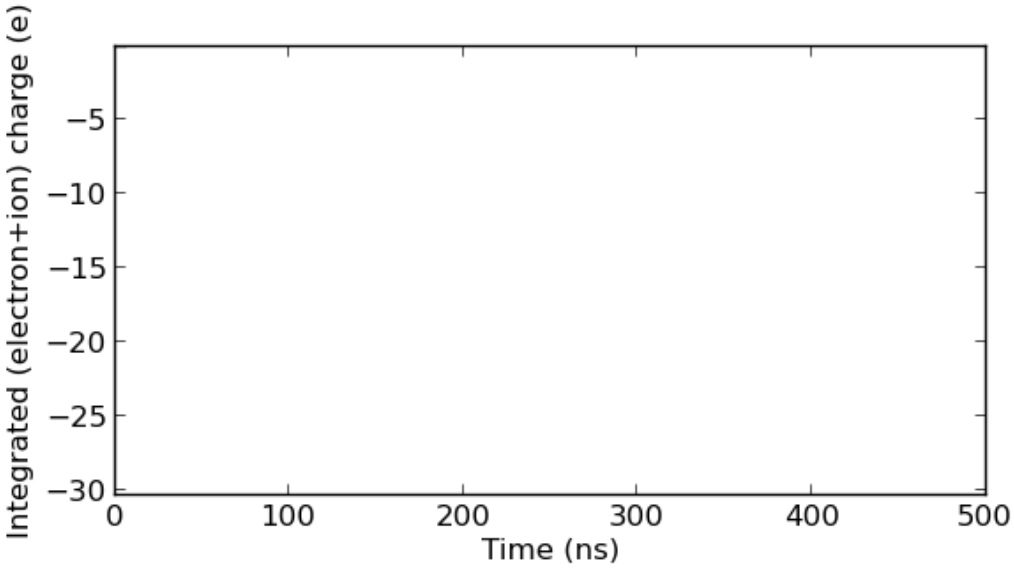


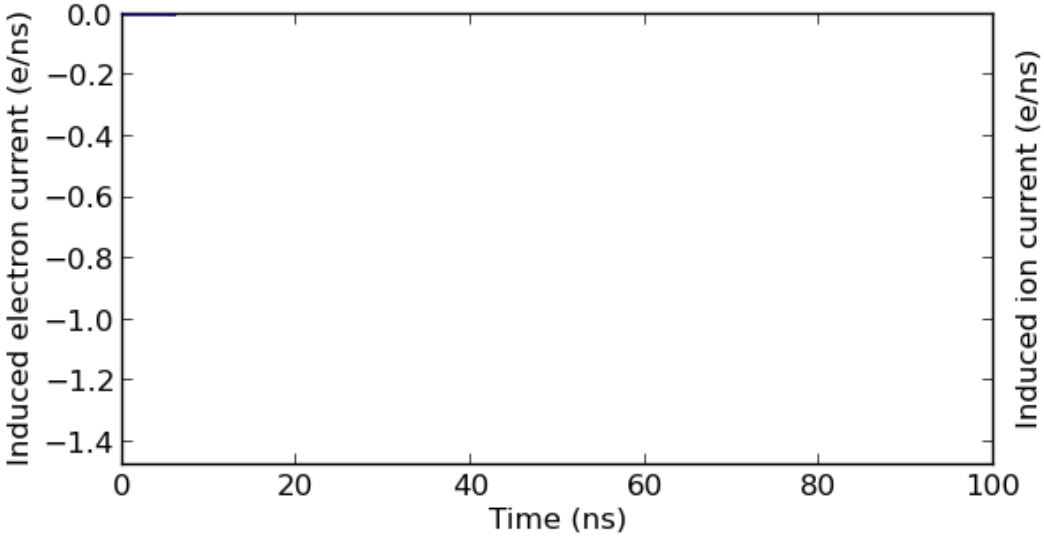


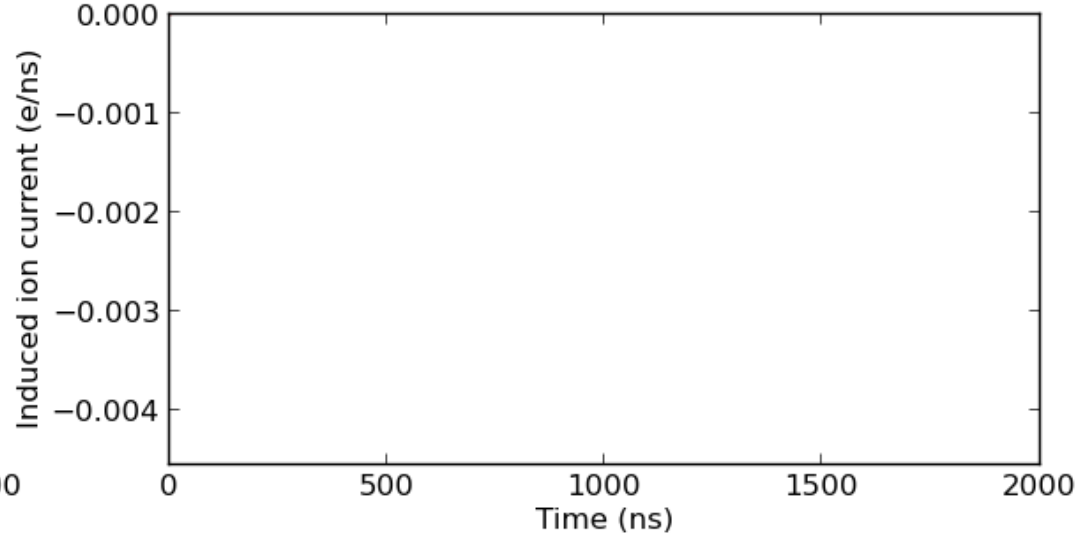


Detailed example: electron and ion signals

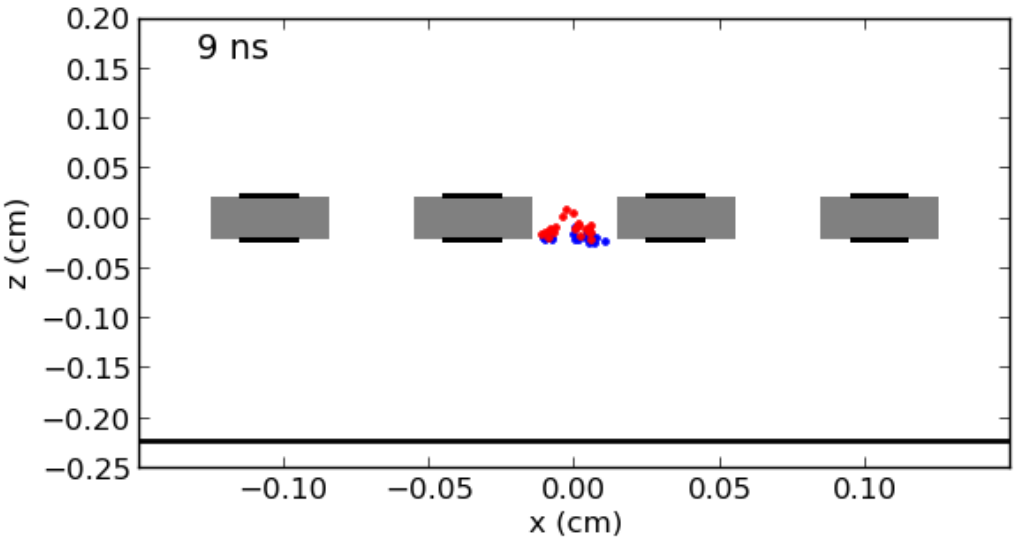


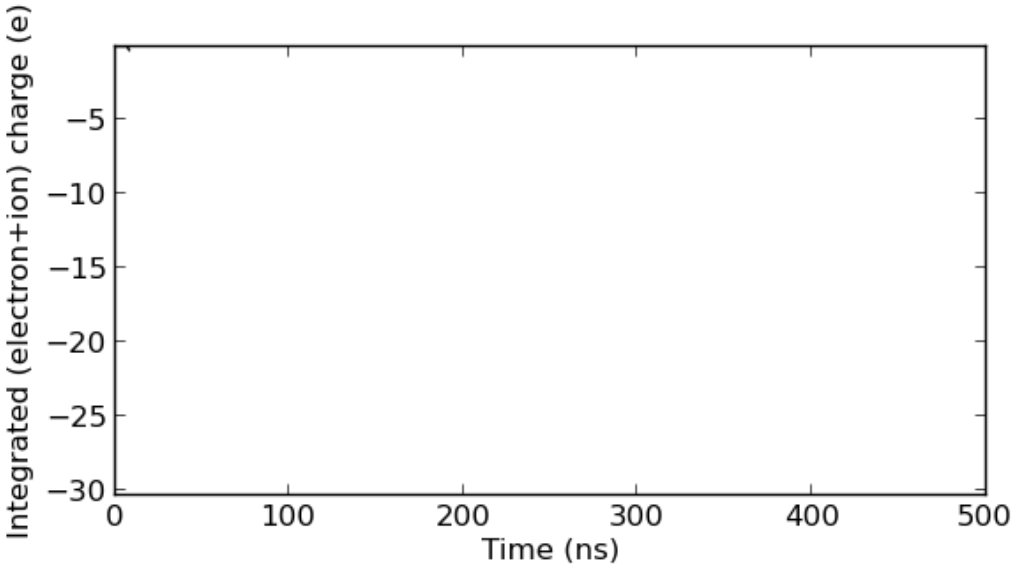


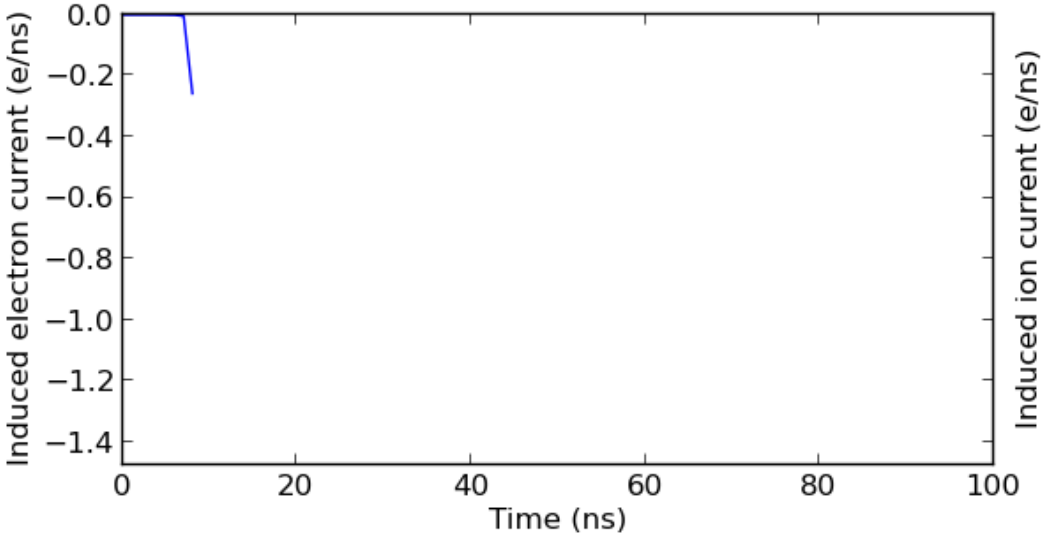


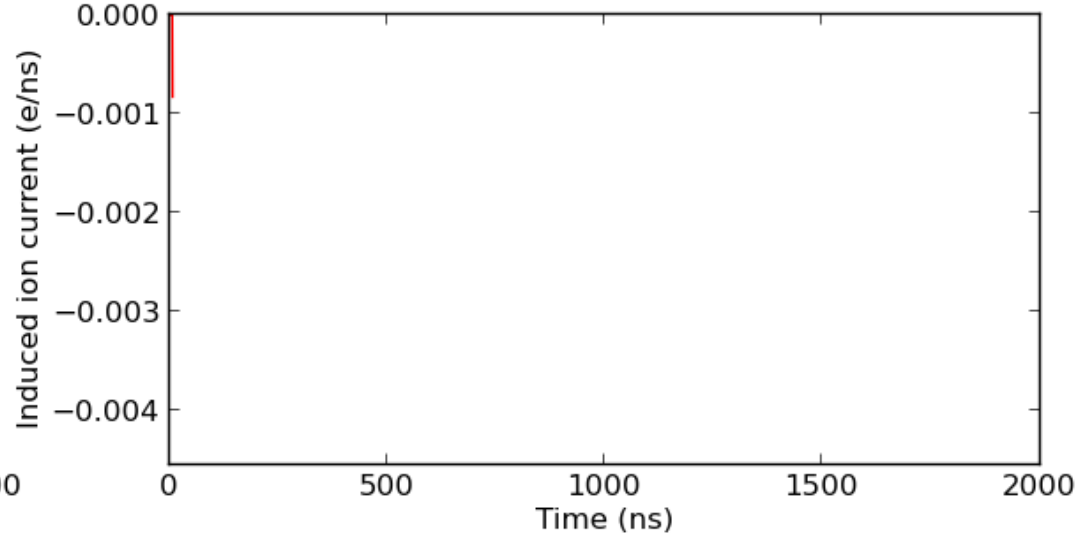


Detailed example: electron and ion signals

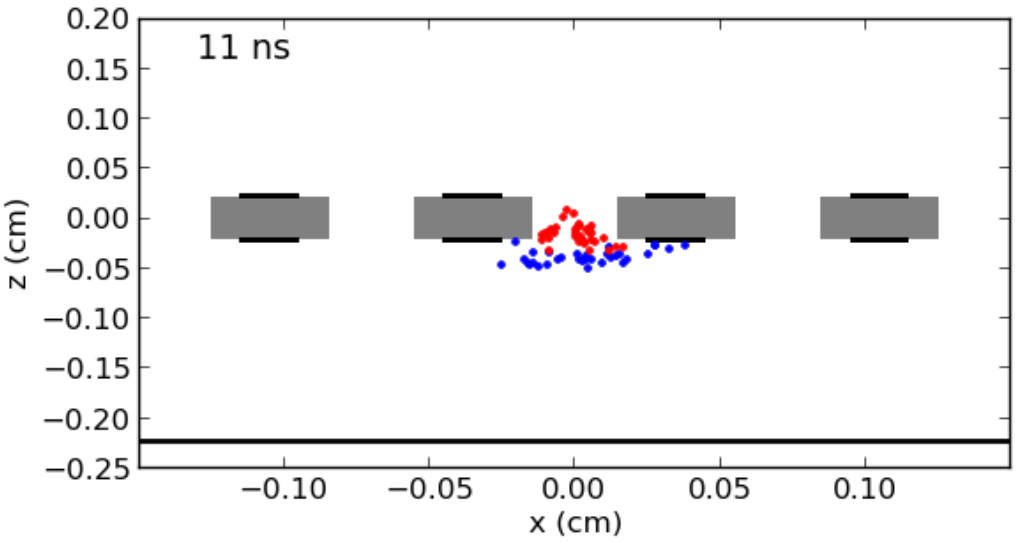


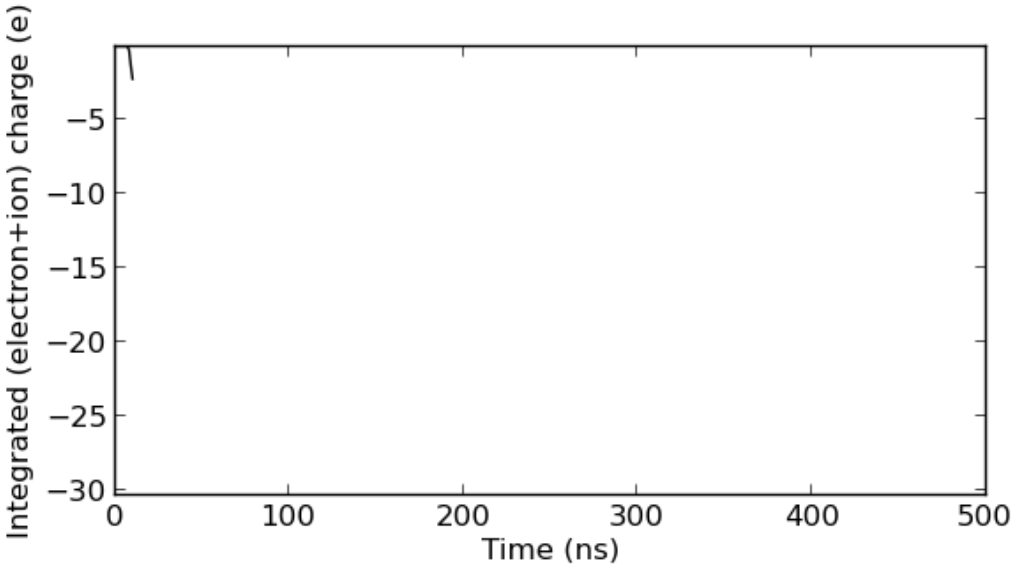


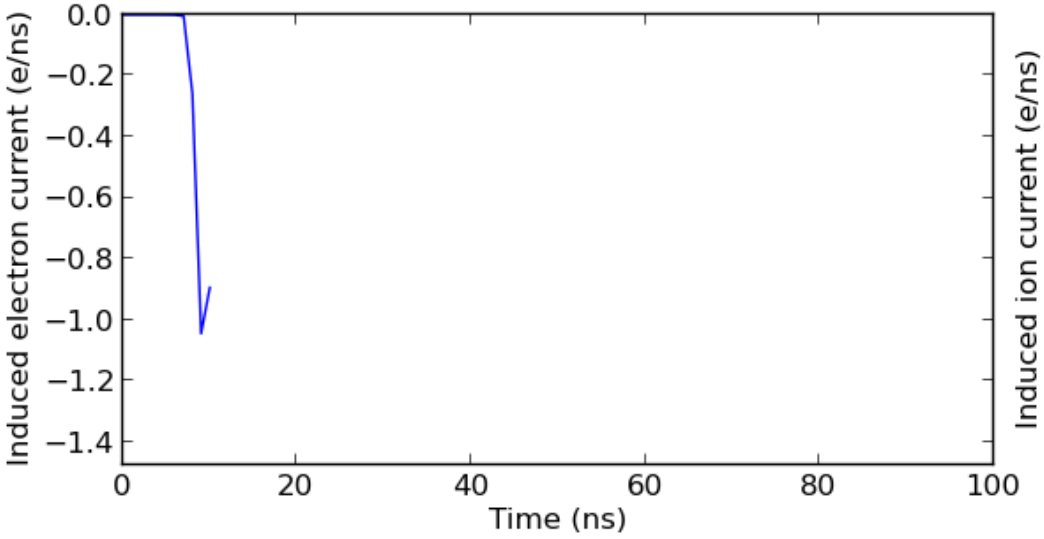


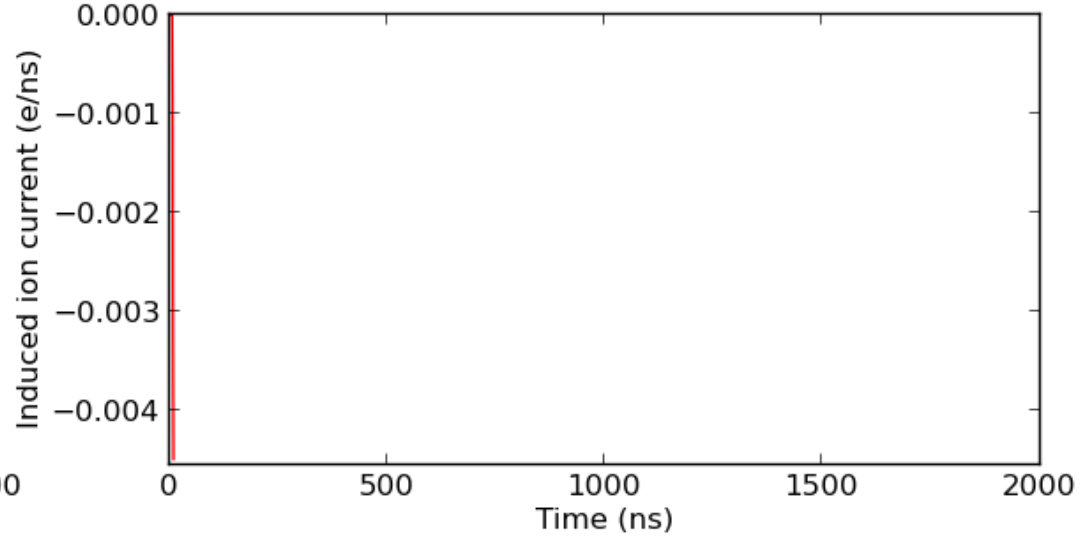


Detailed example: electron and ion signals

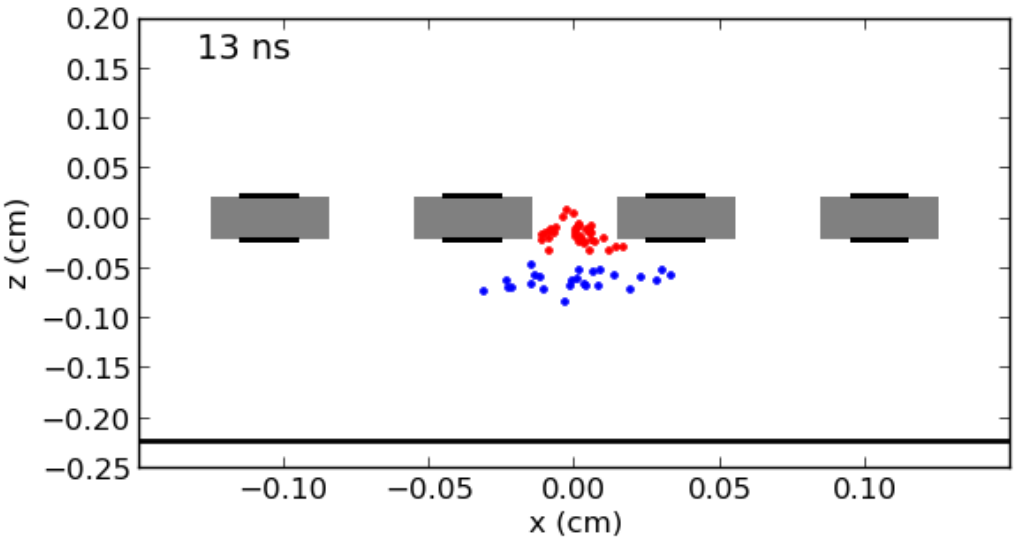


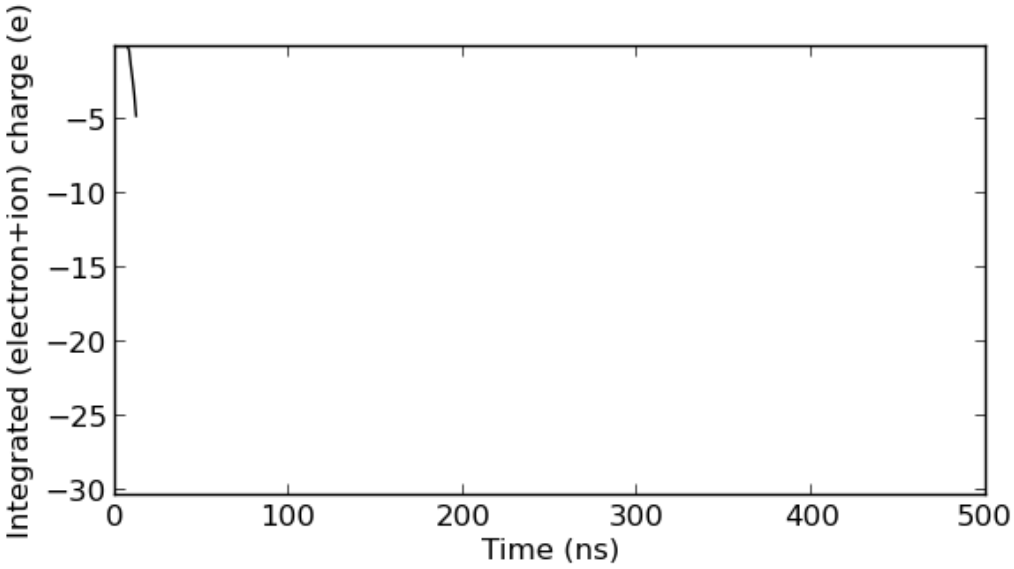


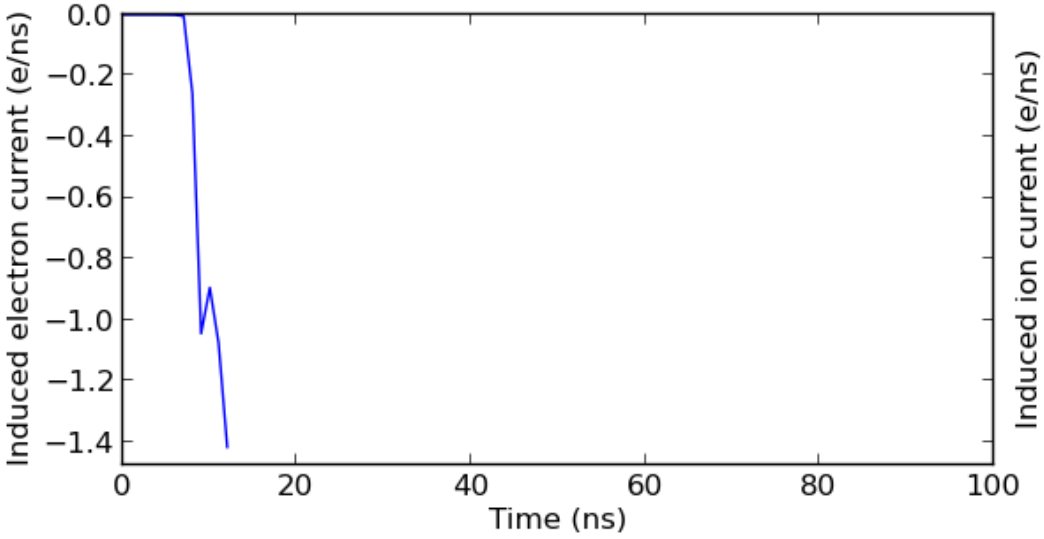


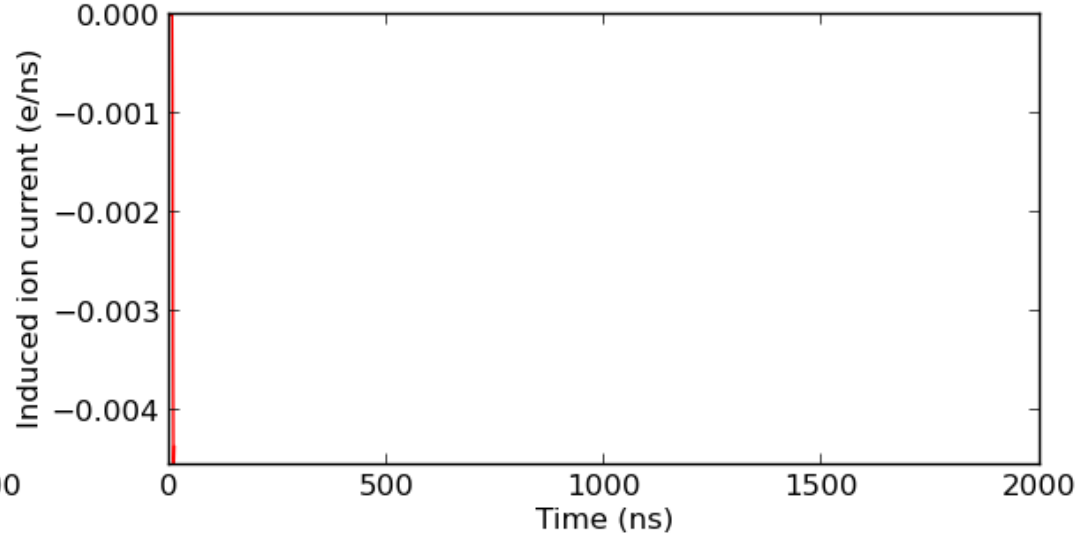


Detailed example: electron and ion signals

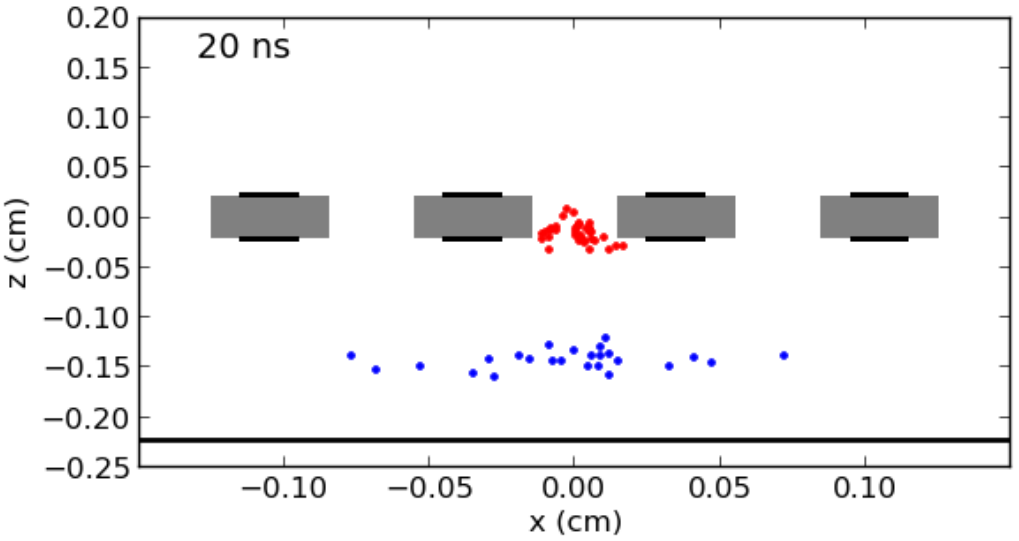


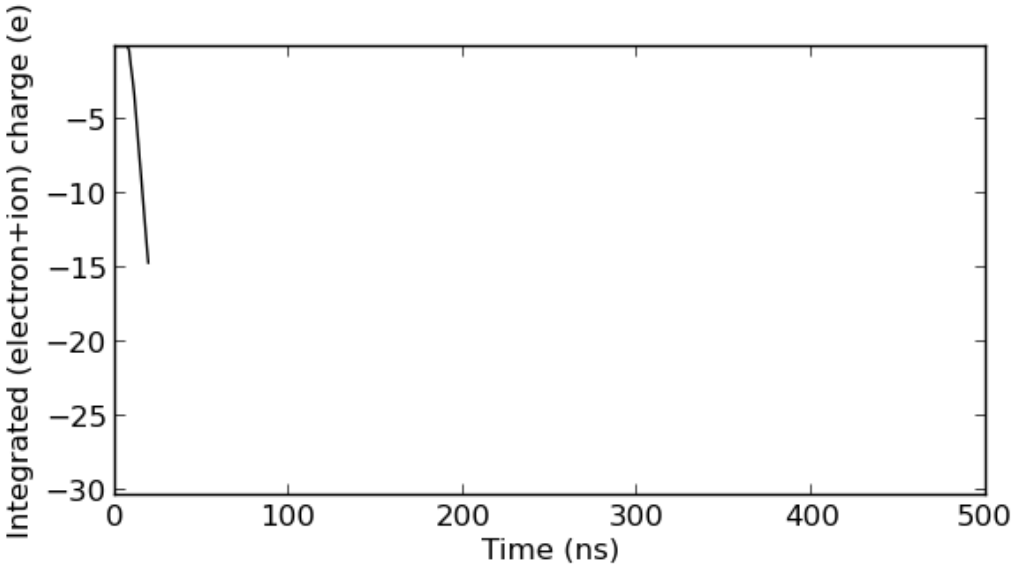


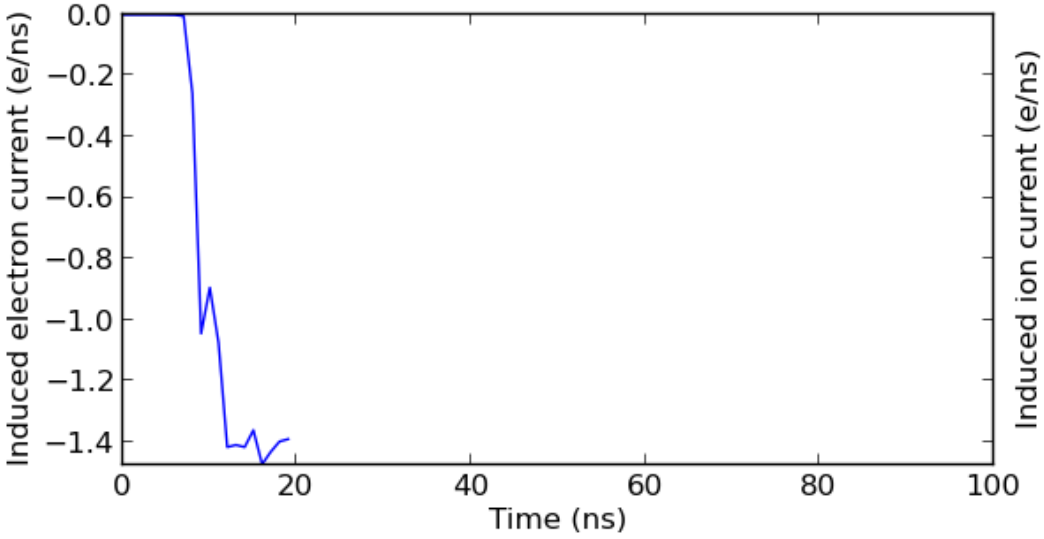


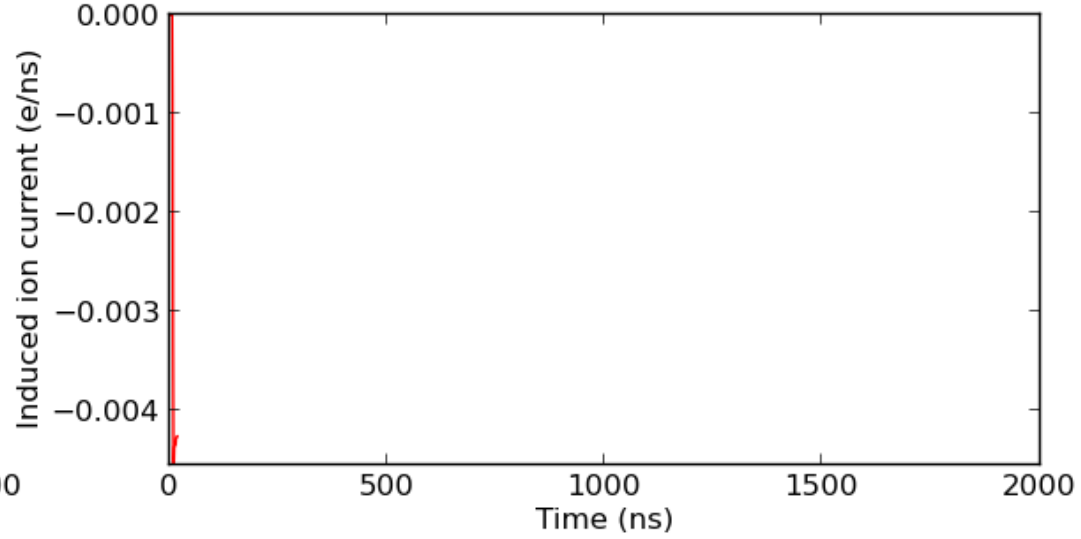


Detailed example: electron and ion signals

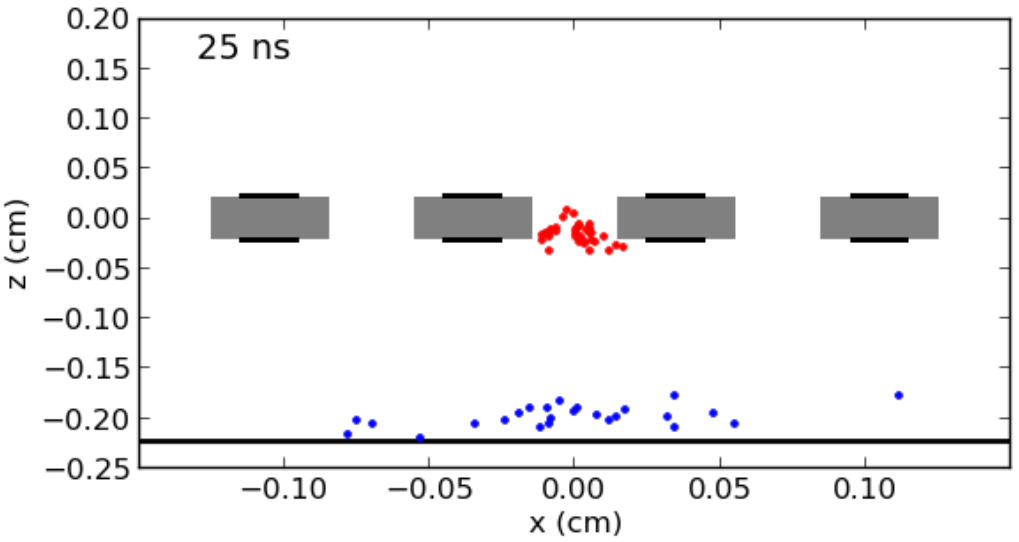


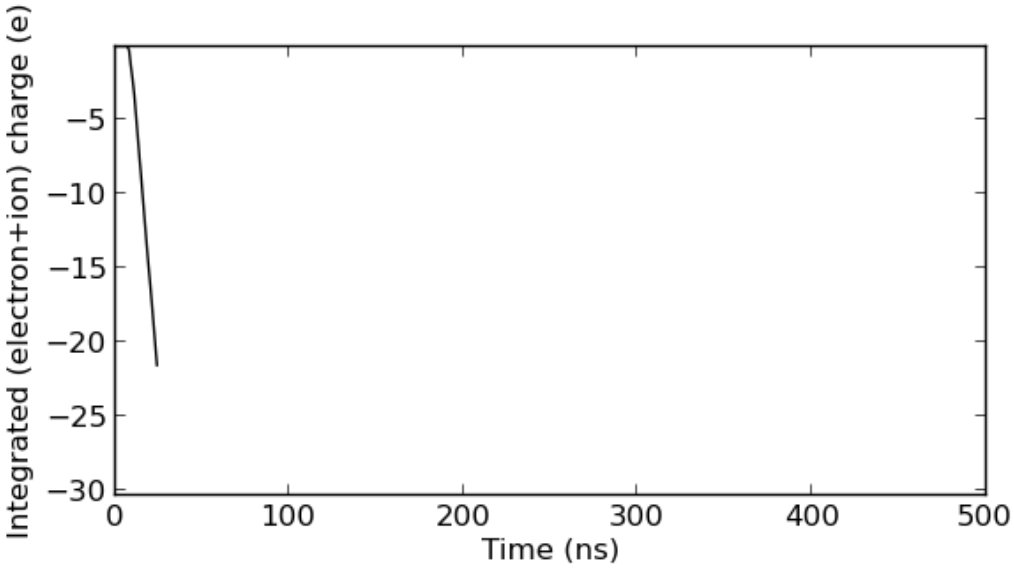


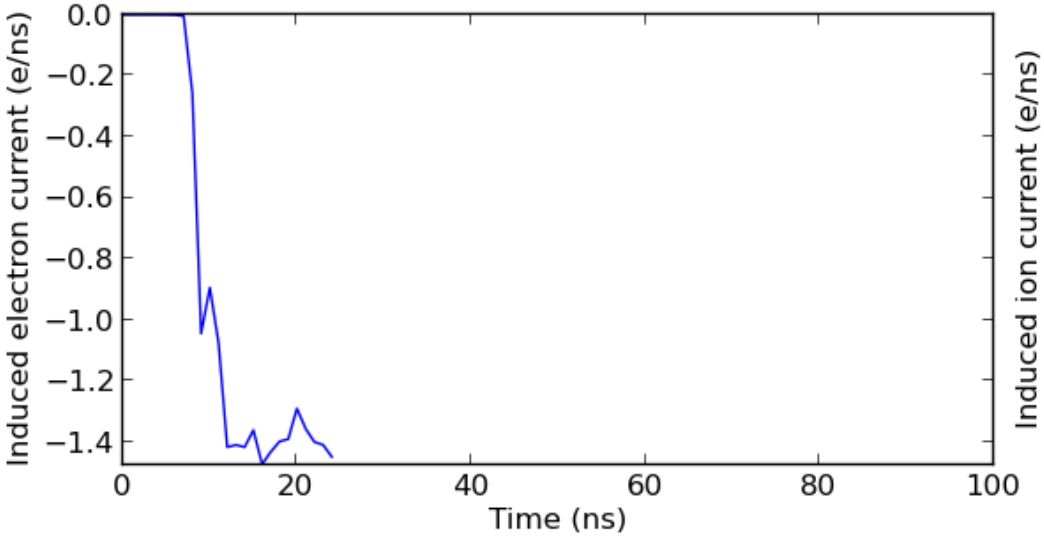


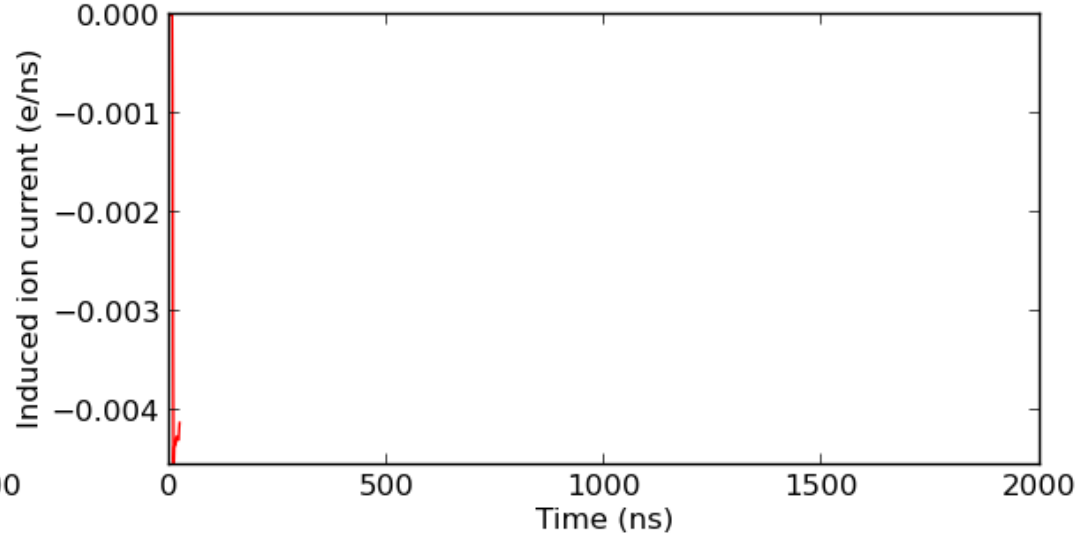


Detailed example: electron and ion signals

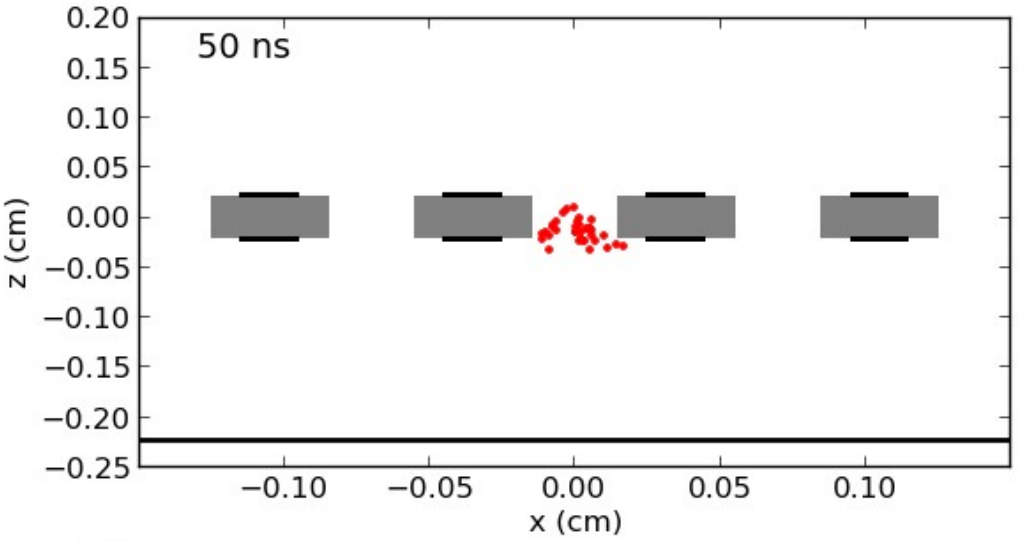


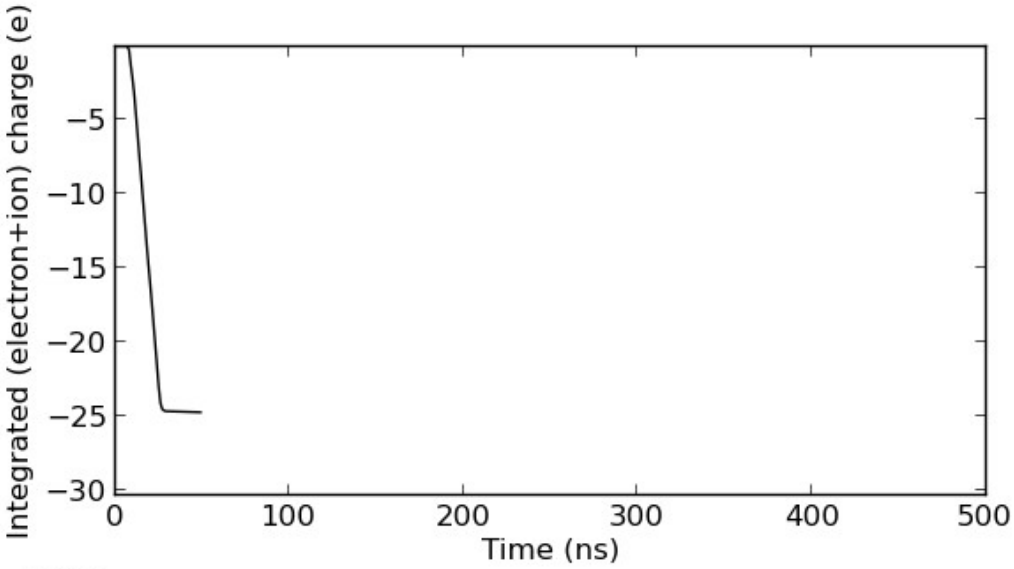


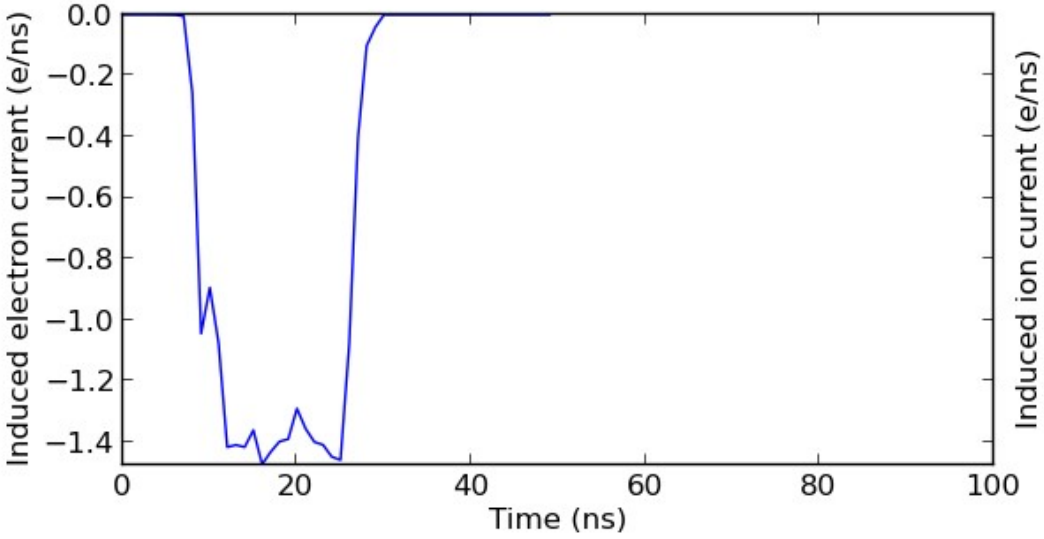


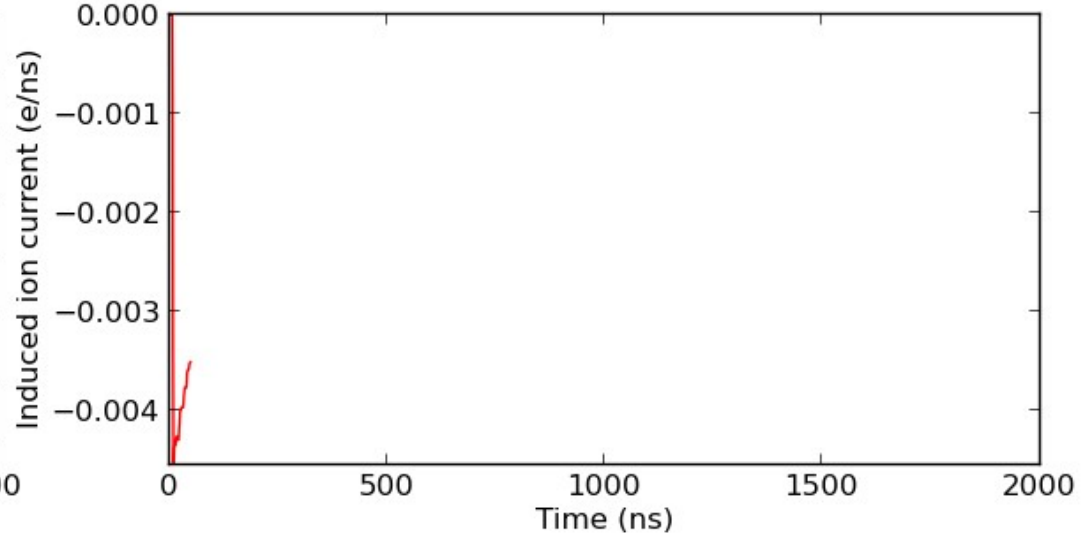


Detailed example: electron and ion signals

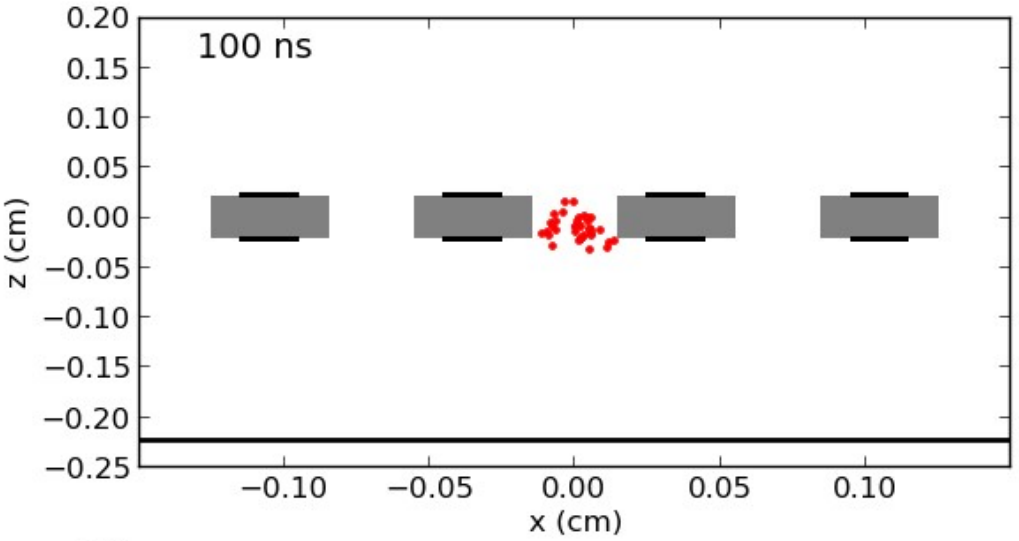


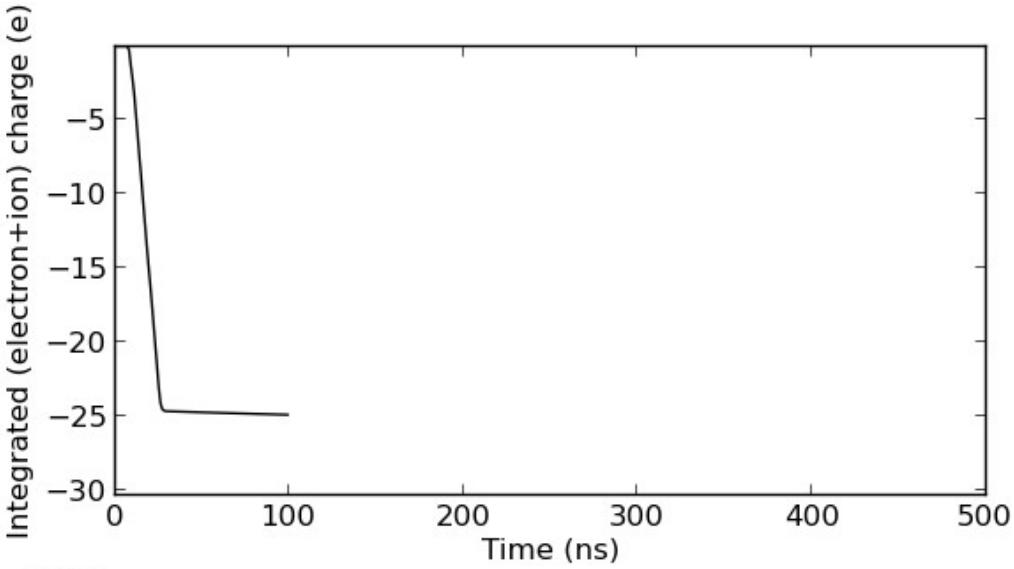


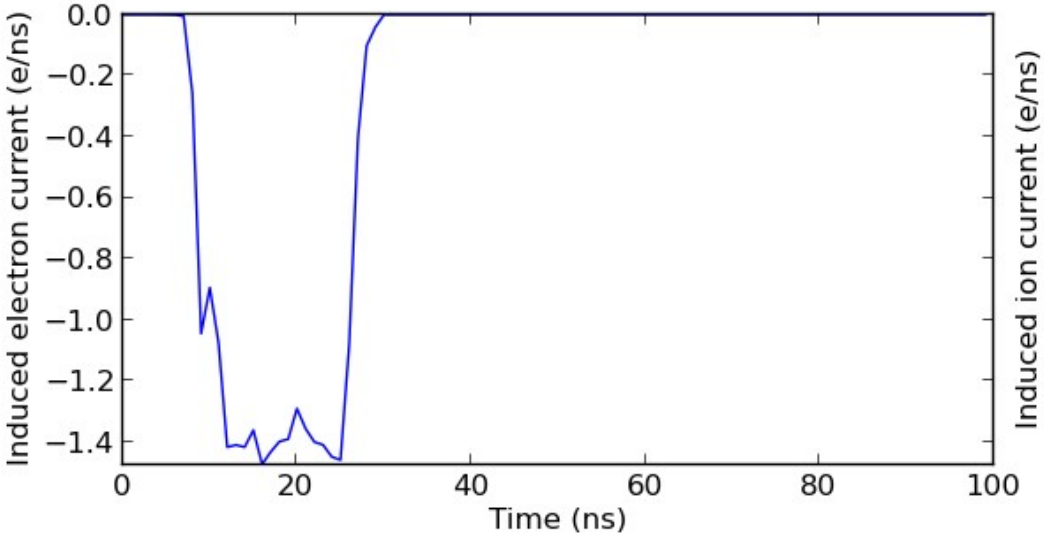


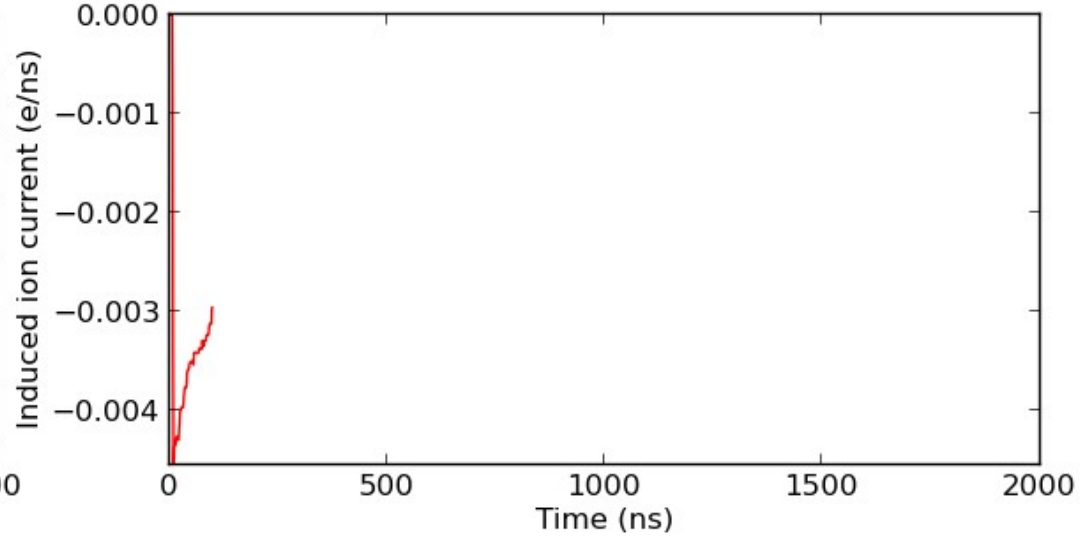


Detailed example: electron and ion signals

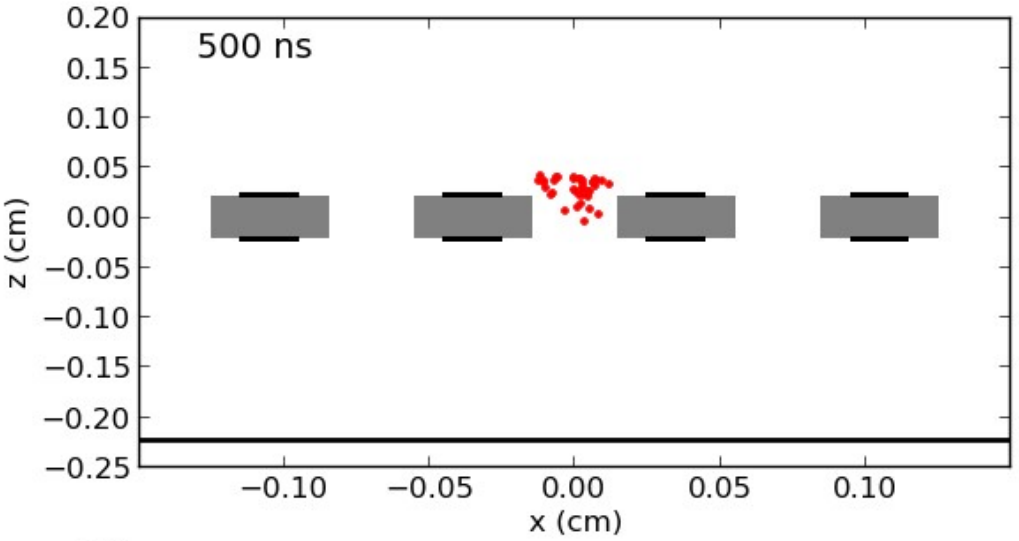


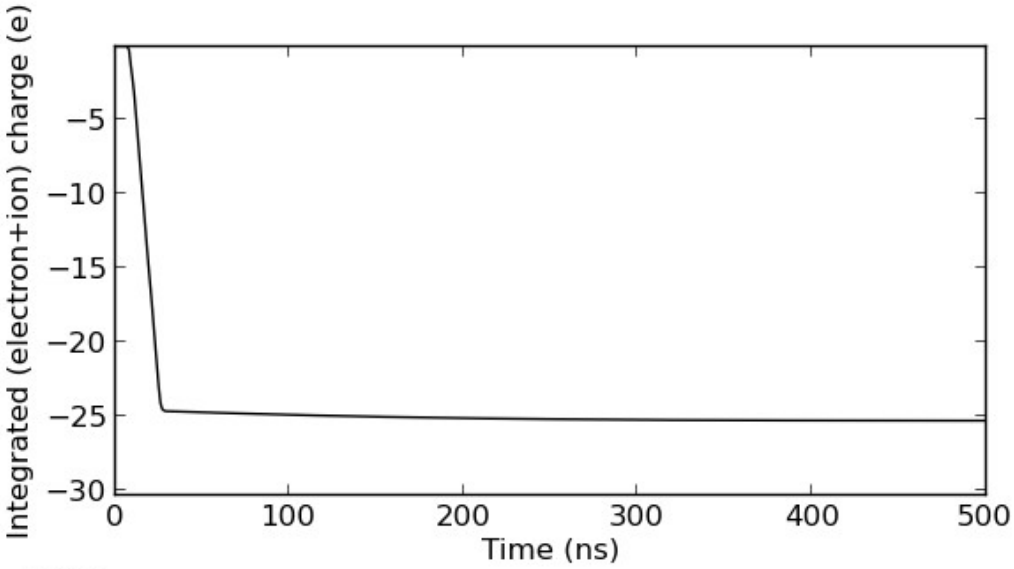


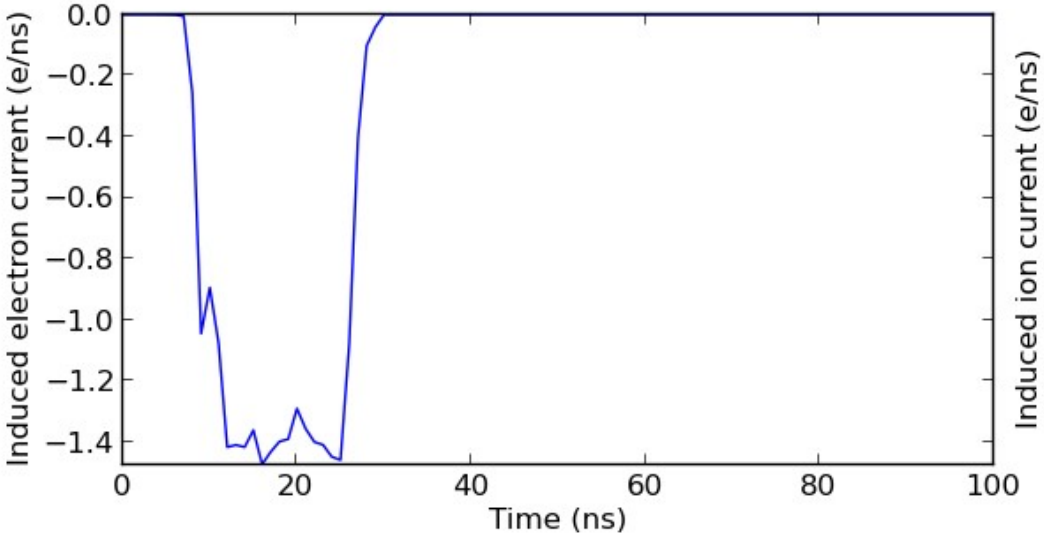


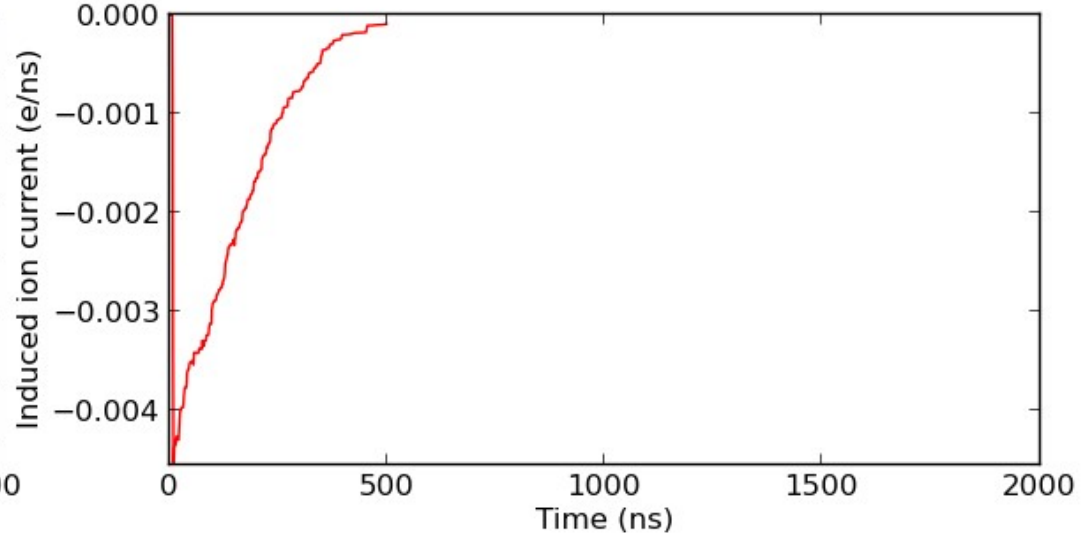


Detailed example: electron and ion signals

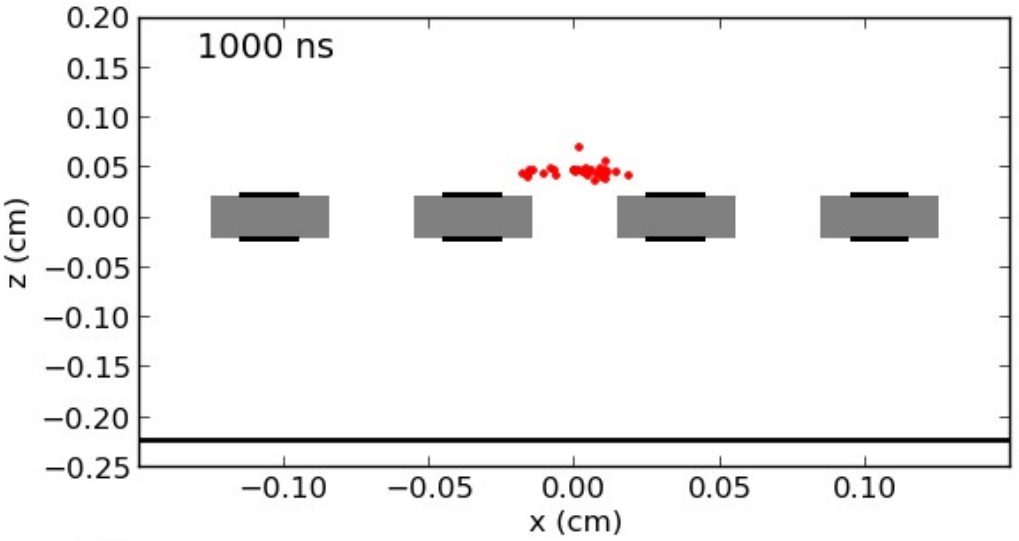


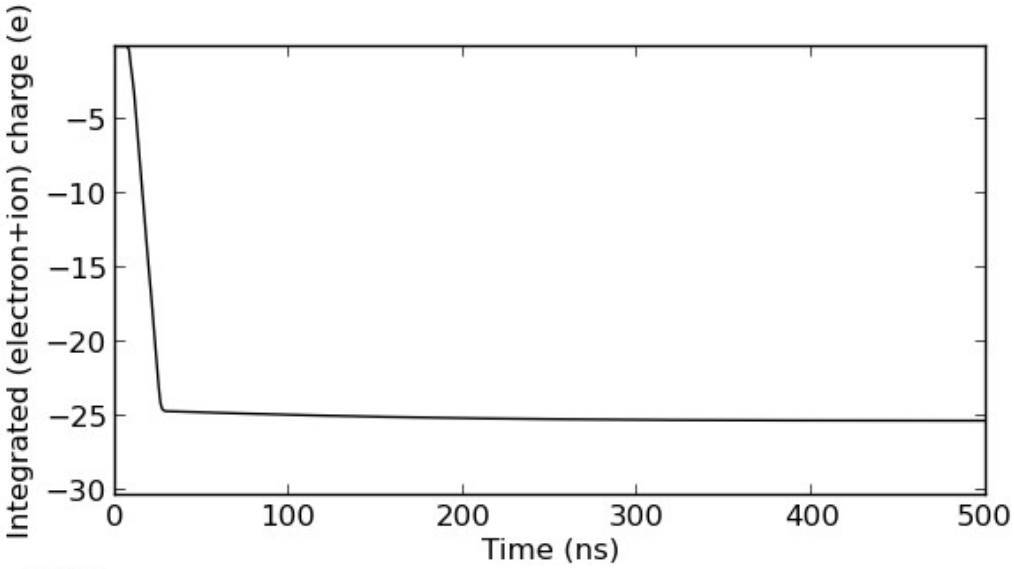


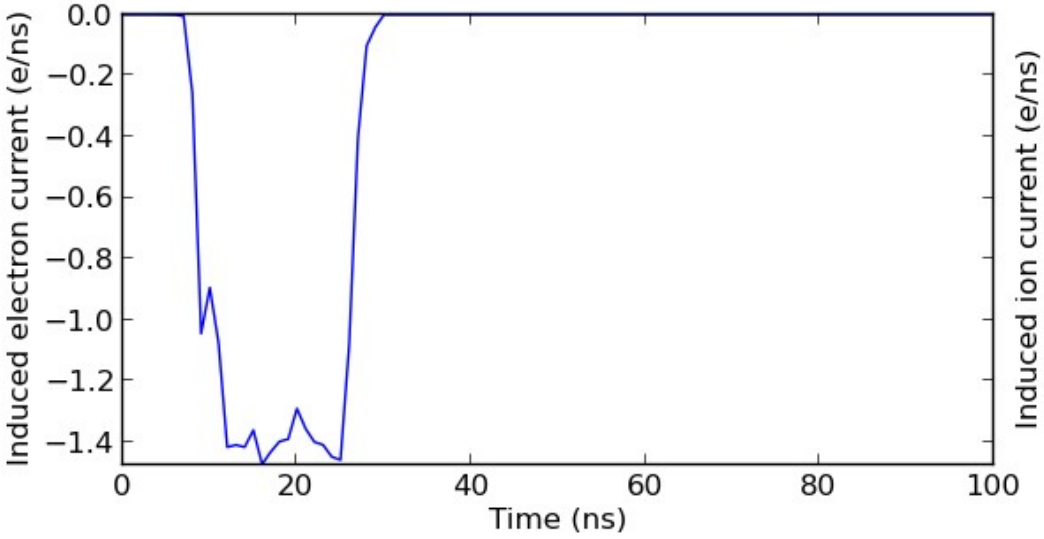


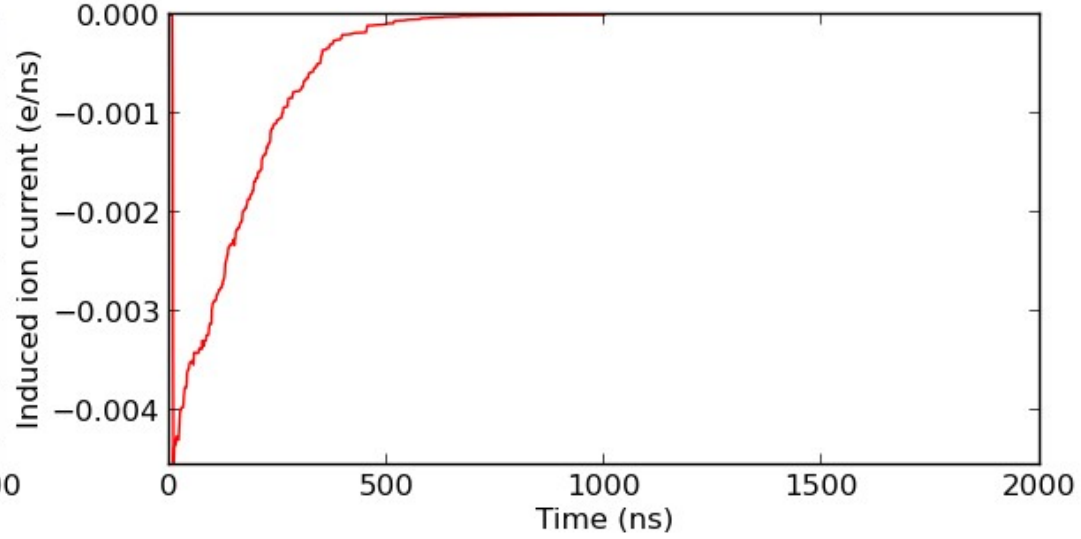


Detailed example: electron and ion signals

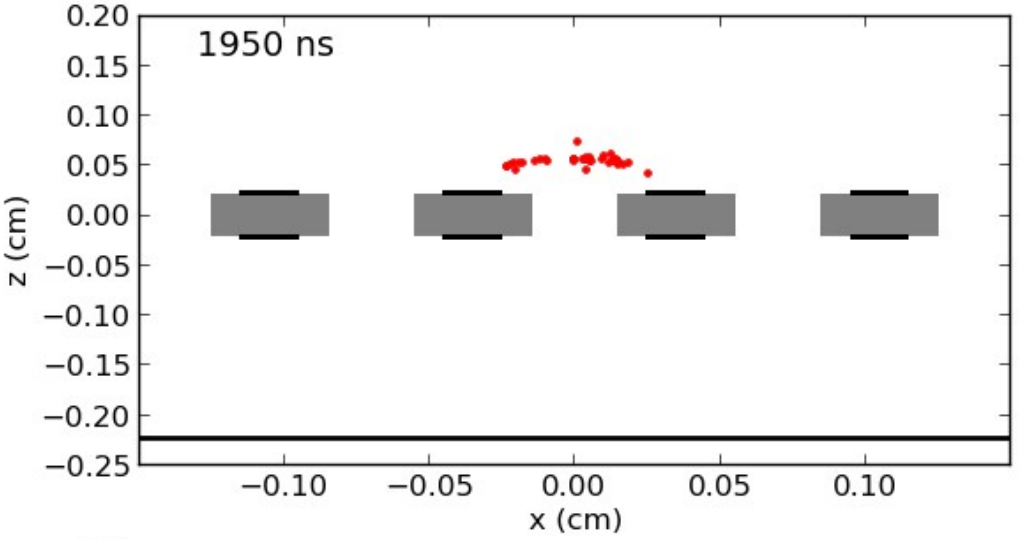


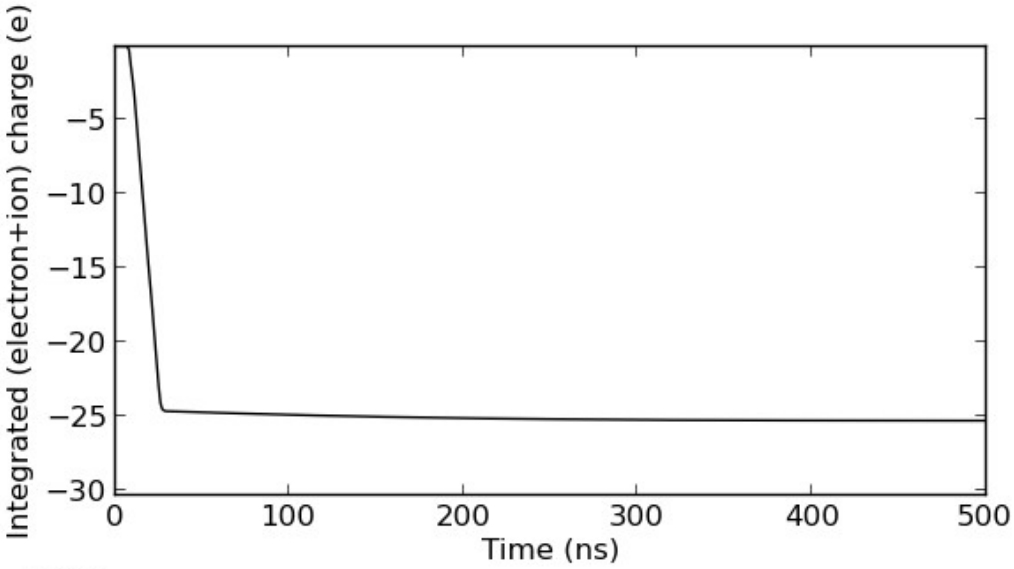


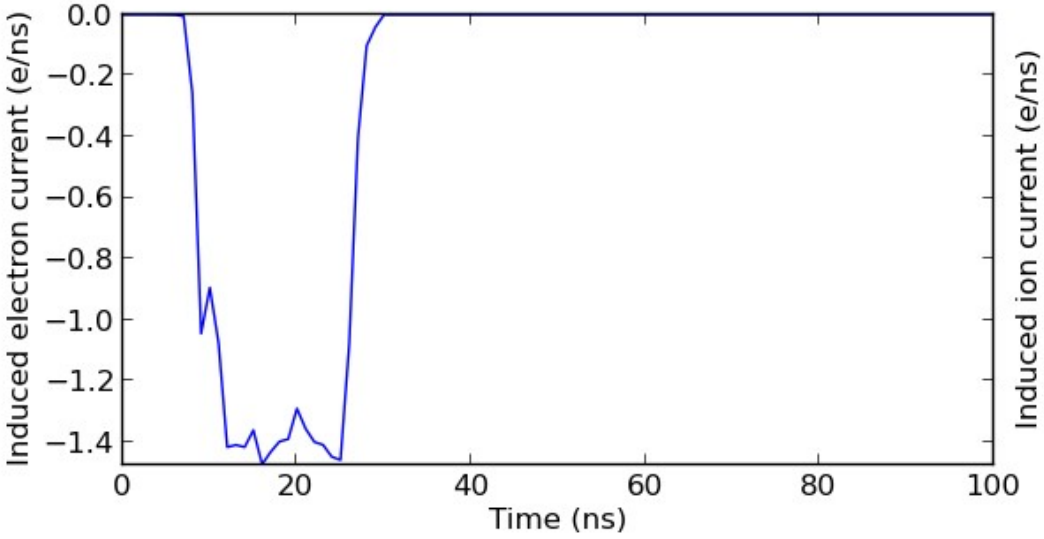


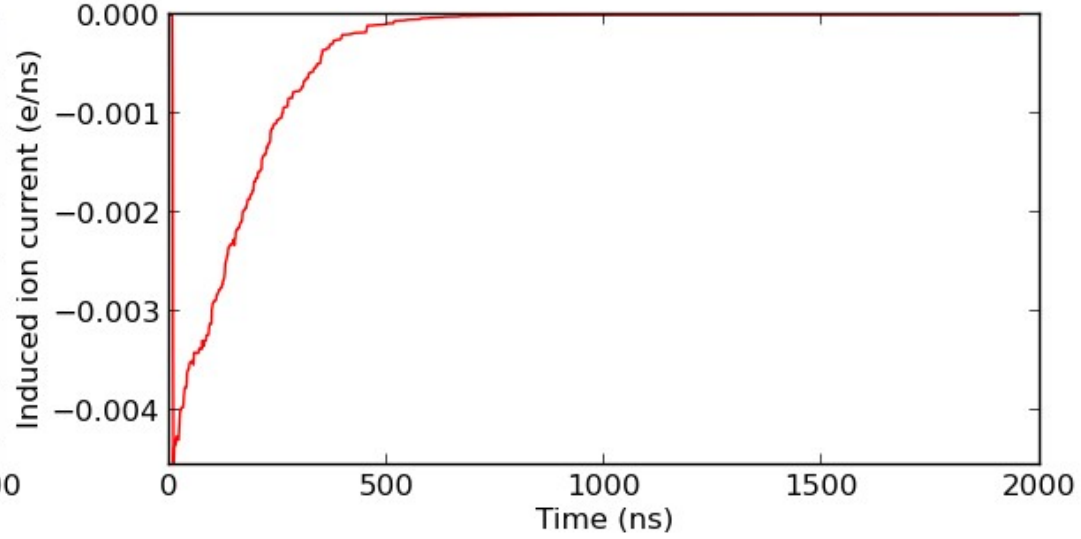


Detailed example: electron and ion signals









Conclusions:

- Ionization is read out by signals induced on electrodes, not as pulses produced suddenly upon neutralization of electrons
- Depending on the location of the ionization, the signal induced by the drifting ion may be larger than that induced by the electron being collected
- This process can be simulated in detail using finite element weighting field maps

Acknowledgements

- LLNL Negative Ion TPC Group
- Garfield++ team; especially Heinrich Schindler and Rob Veenhof
- LBNL Xenon Group and NEXT Collaboration; especially Azriel Goldschmidt and Carlos Oliveira
- DOE NNSA Stewardship Science Graduate Fellowship