Update on Garfield++ Simulations with Open-Source Finite Element Electrostatics

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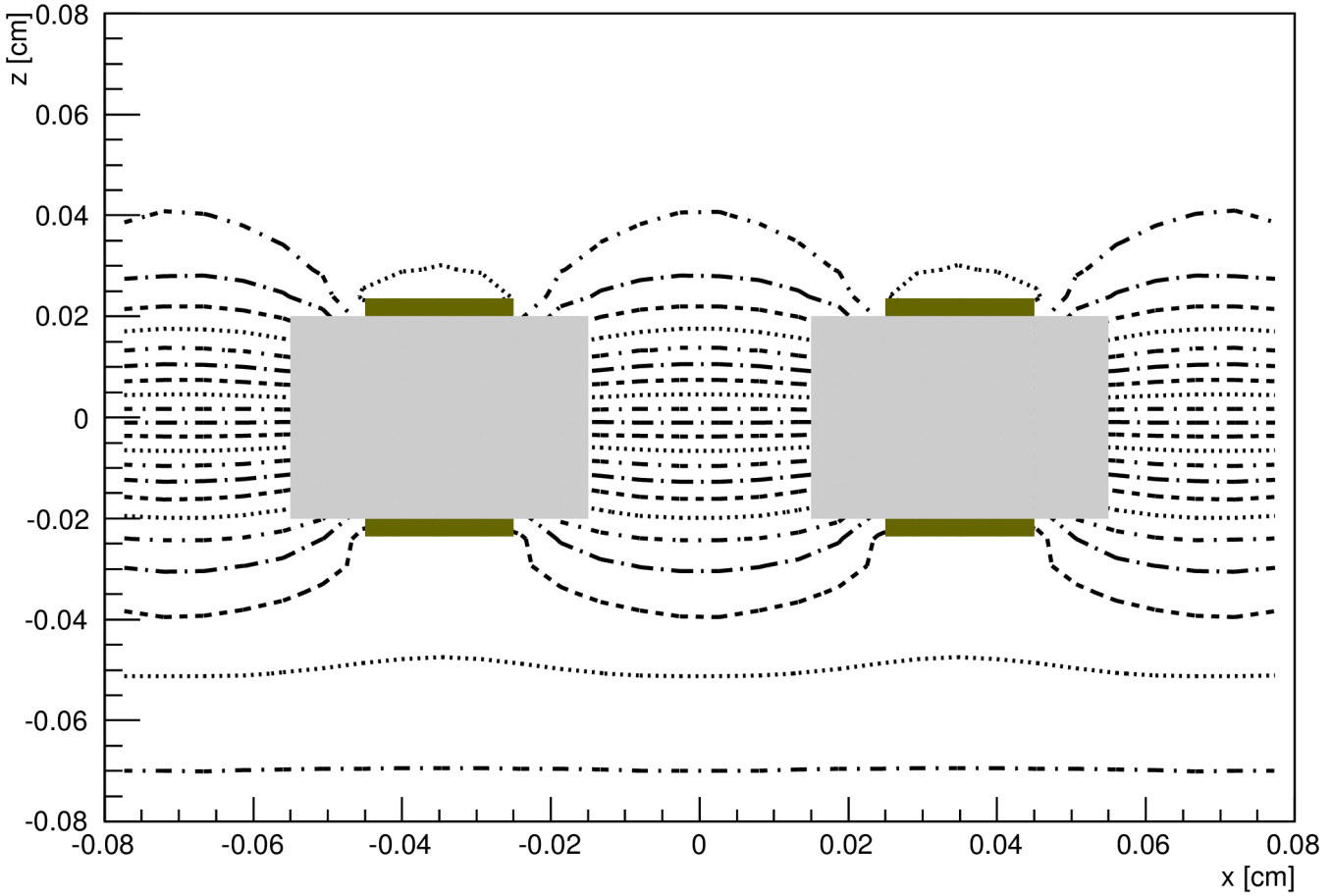
Background:

- Garfield and Garfield++ support simulations of electron/ion drift in finite-element fields
- Open-source tools Gmsh [1] and Elmer [2] can be used to create finite-element electrostatic maps
- Support now included for import of weighting field maps and use with Garfield++ signal readout methods
- See accompanying writeup and code: http://garfieldpp.web.cern.ch/garfieldpp/examples/elmer/

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

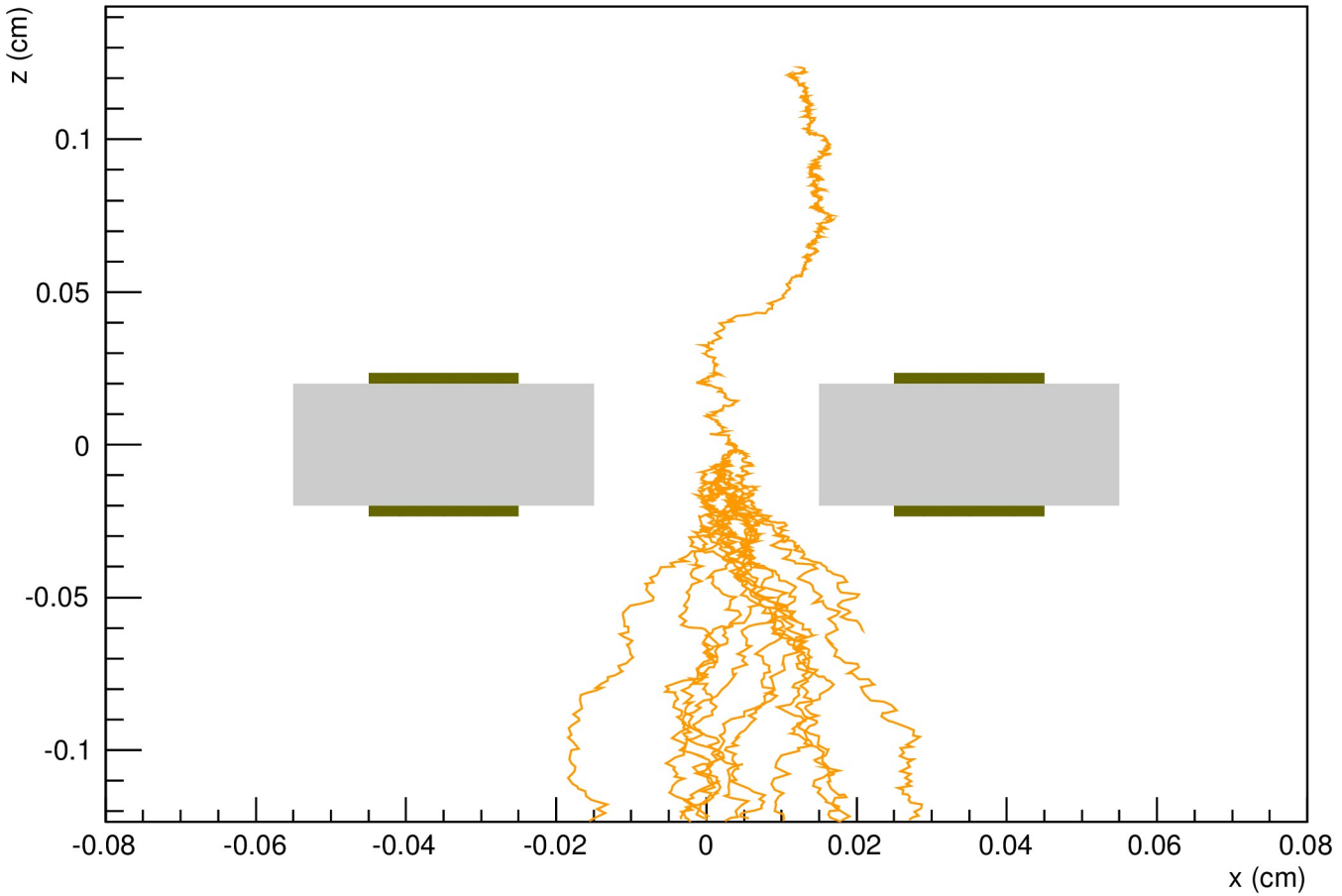
Background:

- Gmsh/Elmer + ViewFEMesh + ViewField: contours for a LEM



Background:

- AvalancheMicroscopic + ViewFEMesh + ViewDrift: avalanche in a LEM

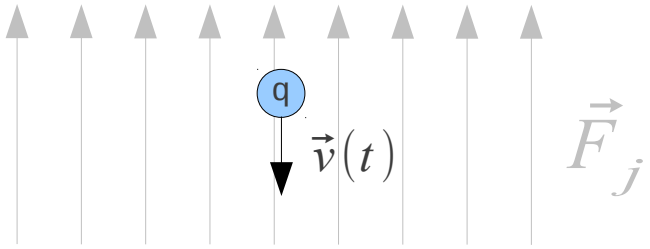


Signal readout: weighting fields

- 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



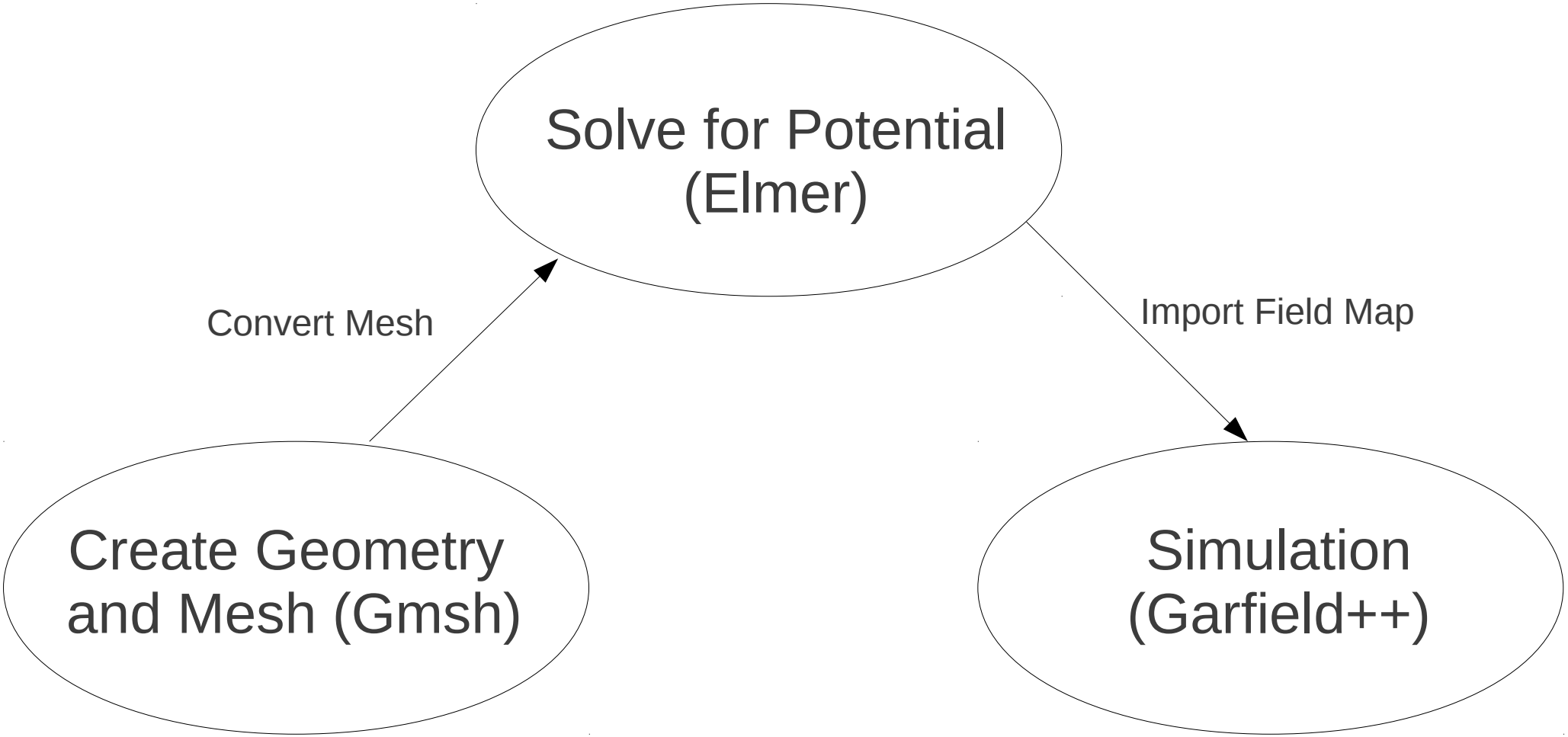
$$i_j(t) = -q\,\vec{v}(t)\cdot\vec{F}_j$$

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

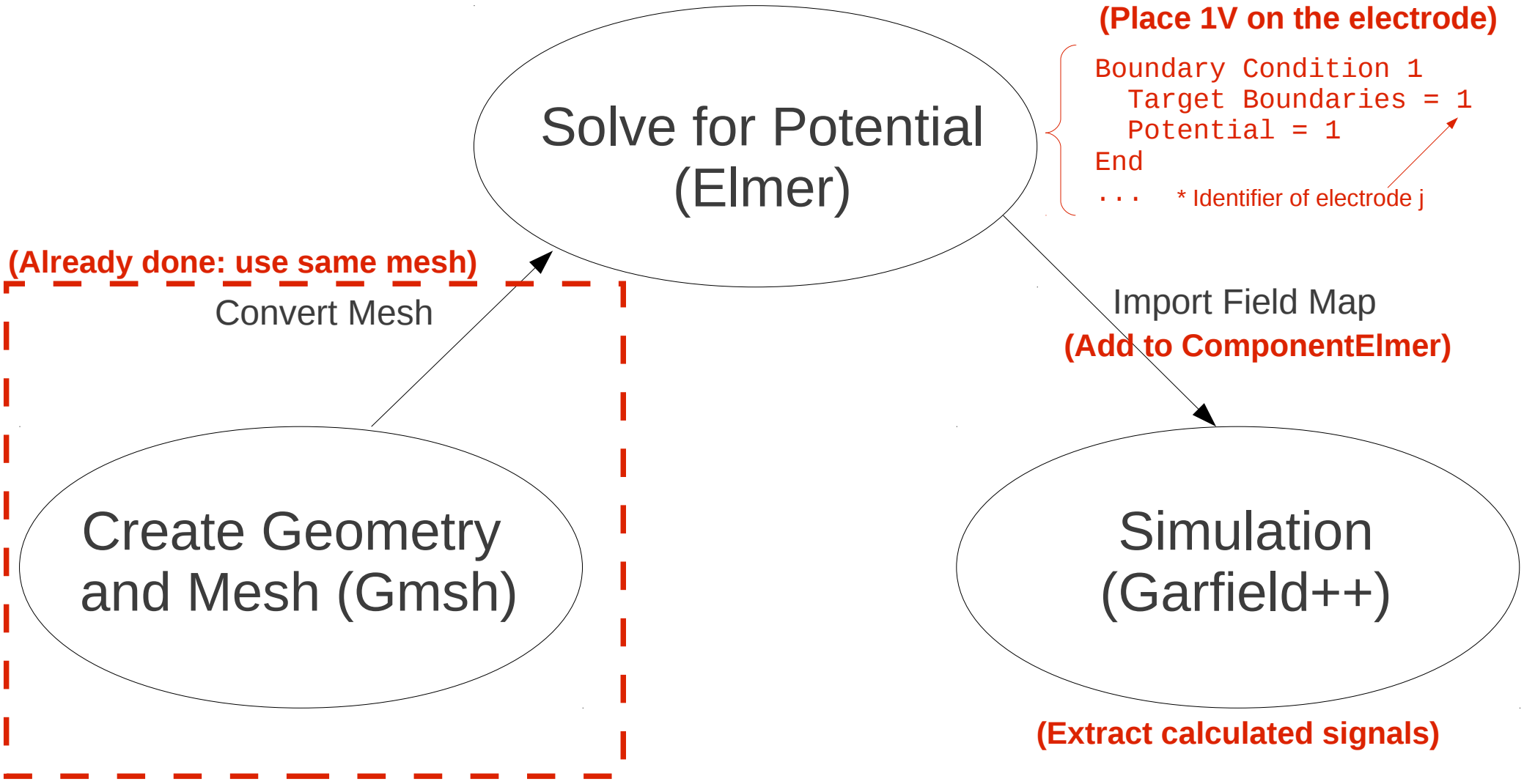
Signal readout: weighting fields

- General finite-element drift calculation



Signal readout: weighting fields

- Addition of a weighting field



Signal readout: weighting fields

- Induced signals in Garfield++:

```
ComponentElmer * elm = new ComponentElmer(...);
...
elm->SetWeightingField(".result file","wtlel");
```

Set up component; add weighting field

```
Sensor* sensor = new Sensor();
...
sensor->AddElectrode(elm,"wtlel");
sensor->SetTimeWindow(tStart,binWidth,nsBins);
```

Set up sensor to calculate signals using weighting field

```
AvalancheMicroscopic* aval
 = new AvalancheMicroscopic();
...
aval->EnableSignalCalculation();

// (perform avalanche)
```

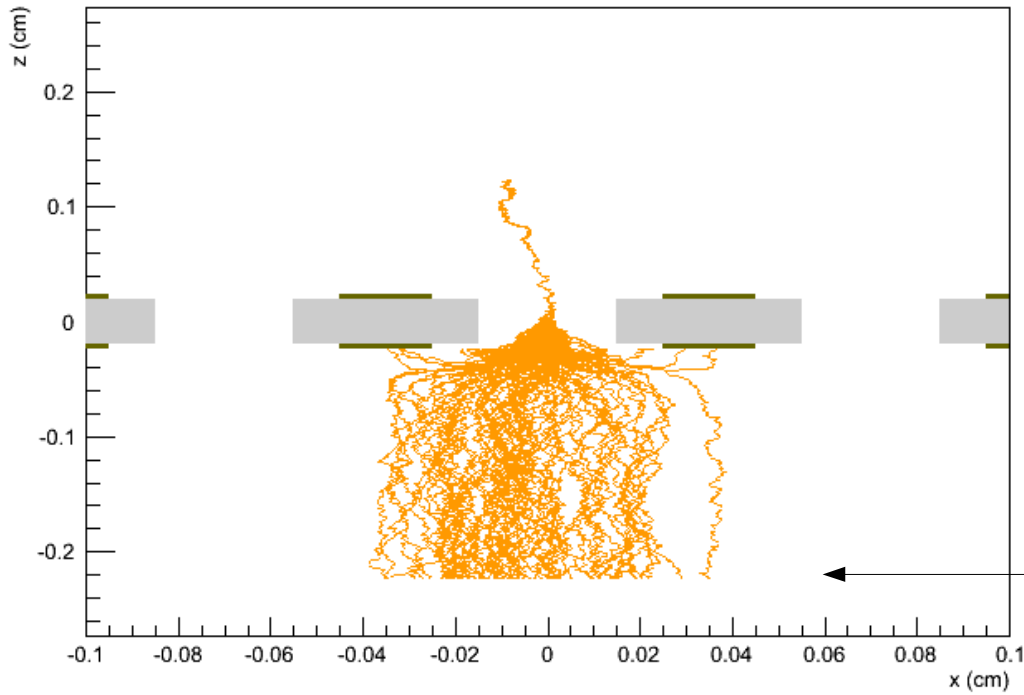
Set up avalanche to enable calculation of signals

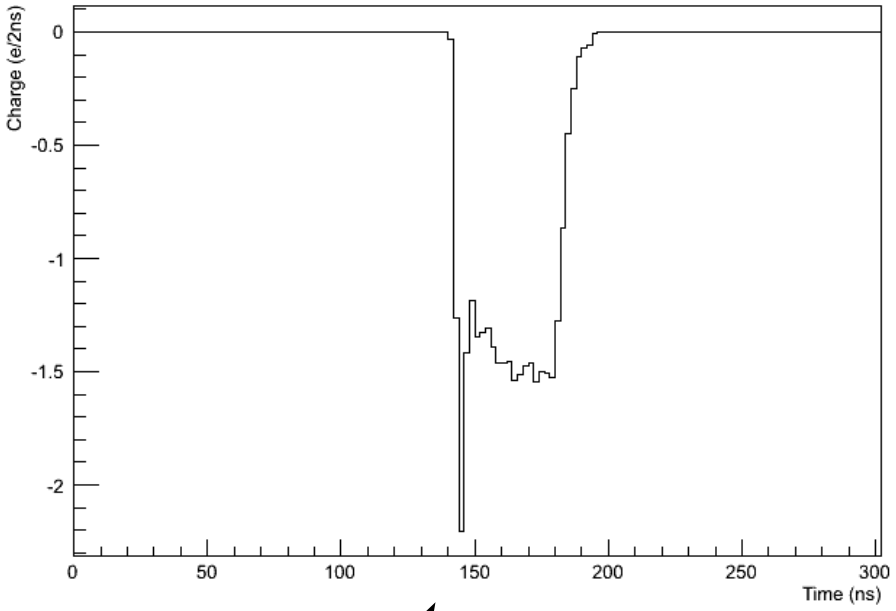
```
for(int i = 0; i < nsBins; i++) {
  double s = sensor->GetSignal("wtlel",i);
  // …
}
```

Extract the signals

Example: Signal readout in a LEM

- Drift a single electron through a LEM with AvalancheMicroscopic; record induced signal



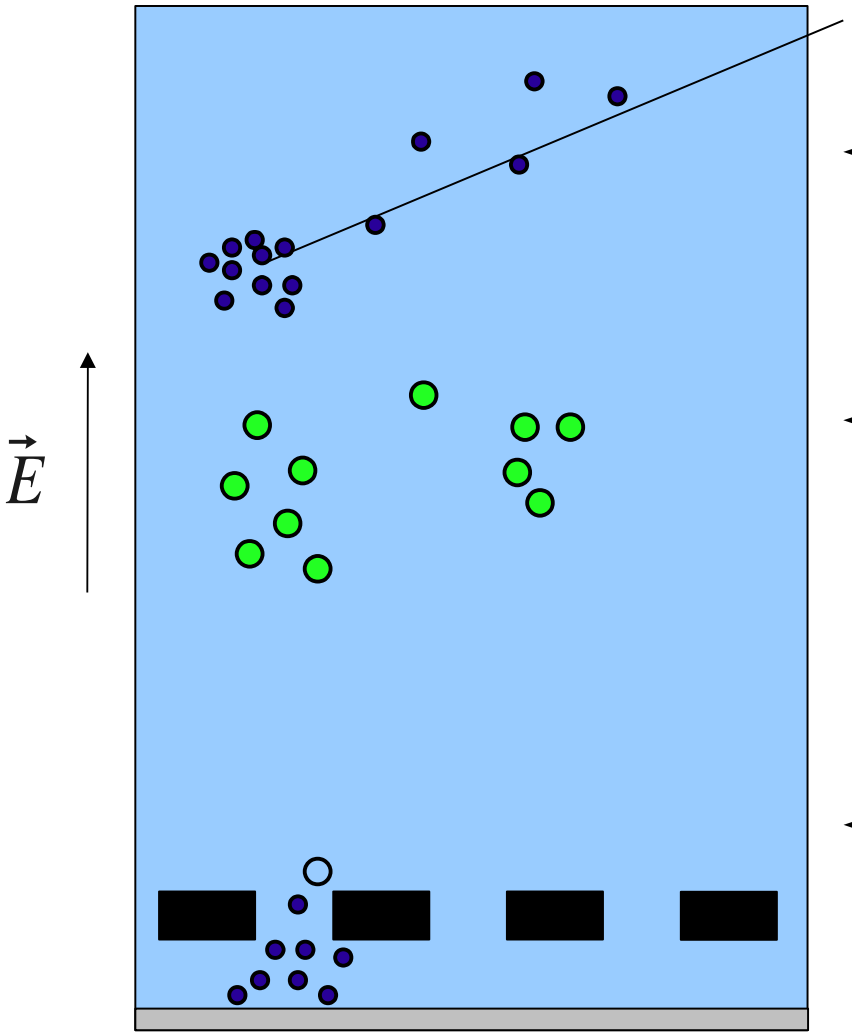


Electrode: signal induced (e- only)

- This will be made available as an example

Example: LEM readout with attachment

- Negative ion drift*: ionization is transported as ions



Incident particle deposits energy through ionization

e- drifted until they attach to impurities to form negative ions which continue drifting

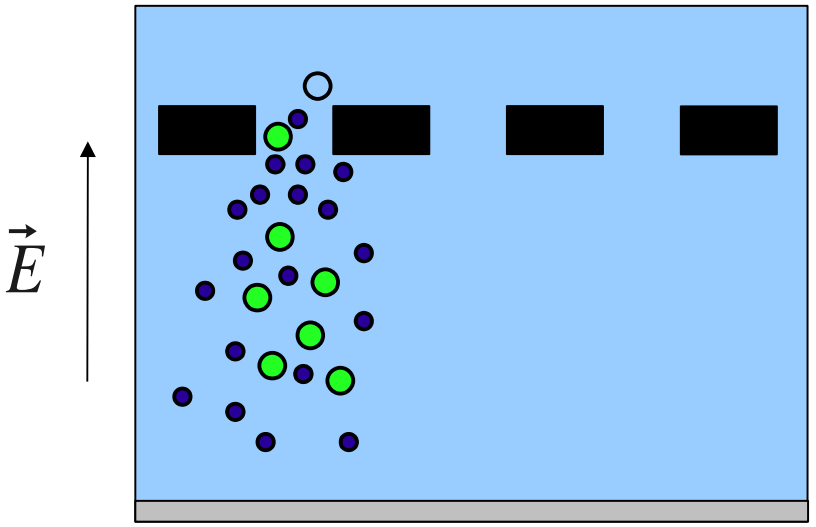
e- removed from ion and multiplies in the high LEM field yielding one detectable signal for each ion

*** References:**

- P. Sorensen et. al. NIMA 686, 106 (2012). arXiv:1205.6427v1. (http://dx.doi.org/10.1016/j.nima.2012.05.078)
- C. J. Martoff *et. al.* NIMA 440, 355 (2000).
- D. Nygren. J. Phys. Conf. Series 65 (2007) 012003.

Example: LEM readout with attachment

- LEM-based readout process



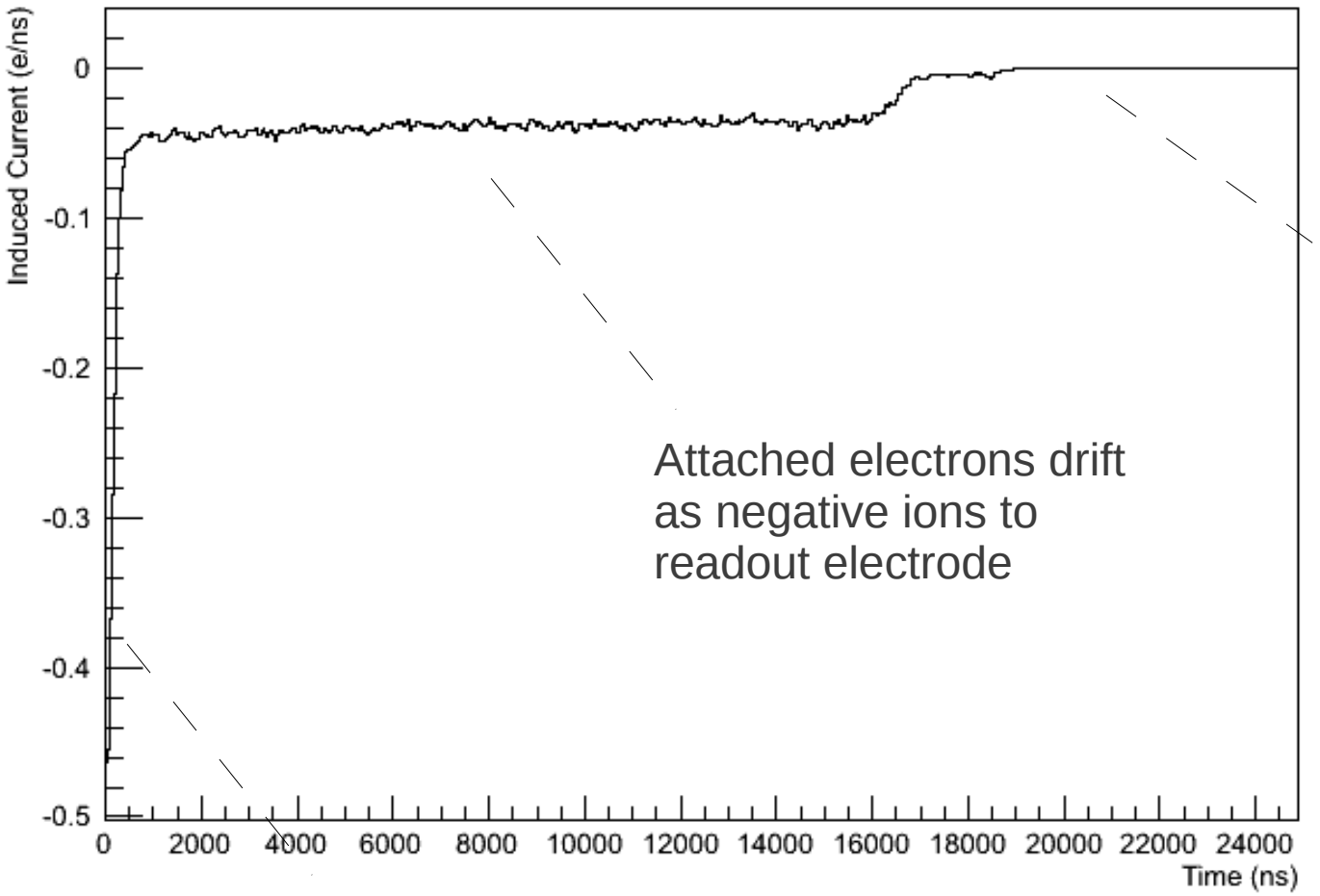
→ e- detaches from negative ion
→ avalanche produced
→ e- drift towards readout electrode
→ some e- attach along the way and drift as negative ions
→ meanwhile positive ions (not shown) drift back through the LEM

- 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

- 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

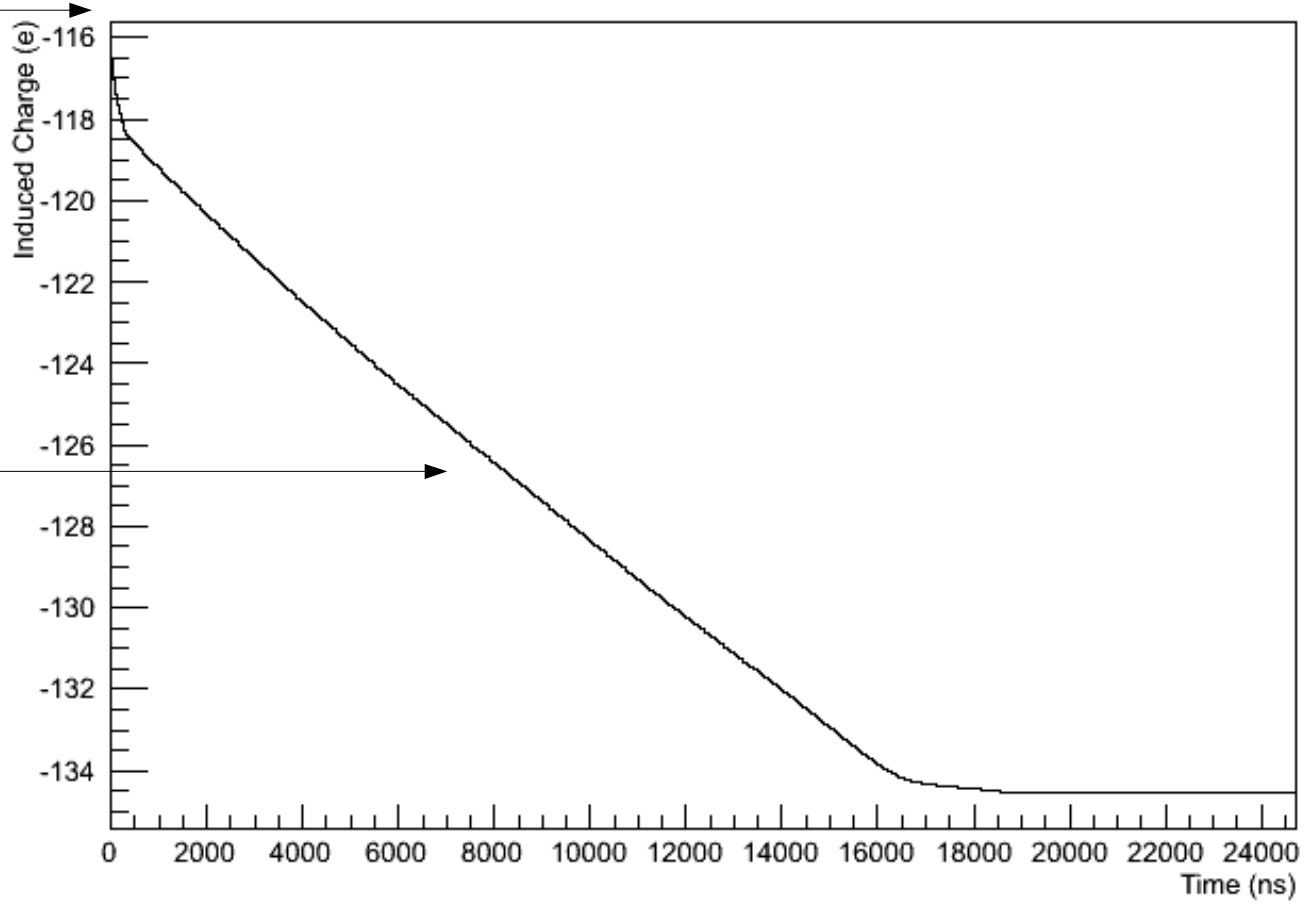
Example: LEM readout with attachment

- Integrated signal (all components)

Fast electron signal
(immediate rise)

Slow ion signal

Arrived at readout plane:
- 115 electrons
- 20 negative ions



- Slow (ion) component is a greater fraction of the total signal with attachment between the LEM and readout plane

Summary

- Finite element tools
  - Open-source tools: Geometry (Gmsh), Electrostatics (Elmer), Simulation/visualization (Garfield++)
  - Calculation of weighting fields allows simulation of induced signals on electrodes
  - Updated code available now, avalanche readout example and updated LEM script for weighting field calculation to be made available
- Requests?
  - Feel free to request improvements/additions to the open-source finite element capabilities

Acknowledgements

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