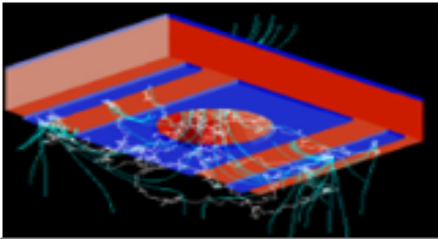
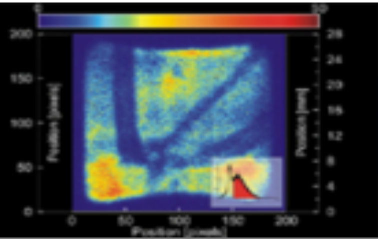
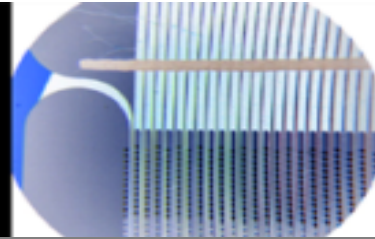
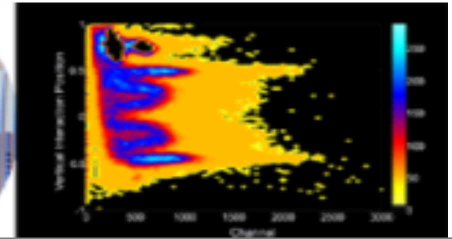

How charging up affects THGEM detectors gain

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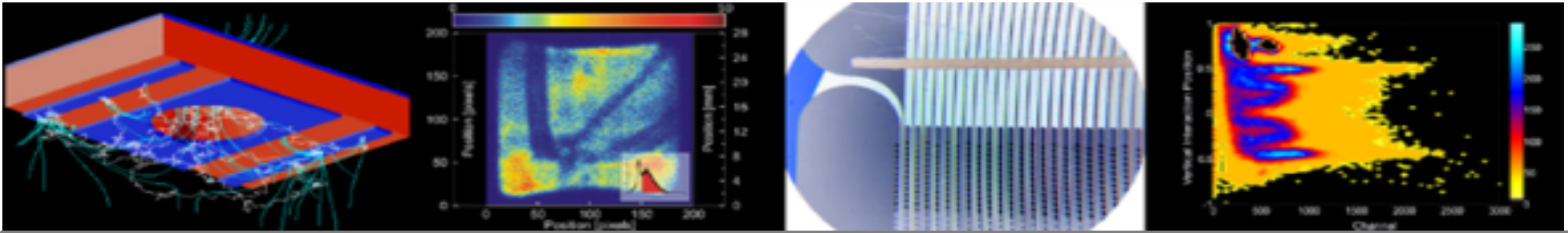
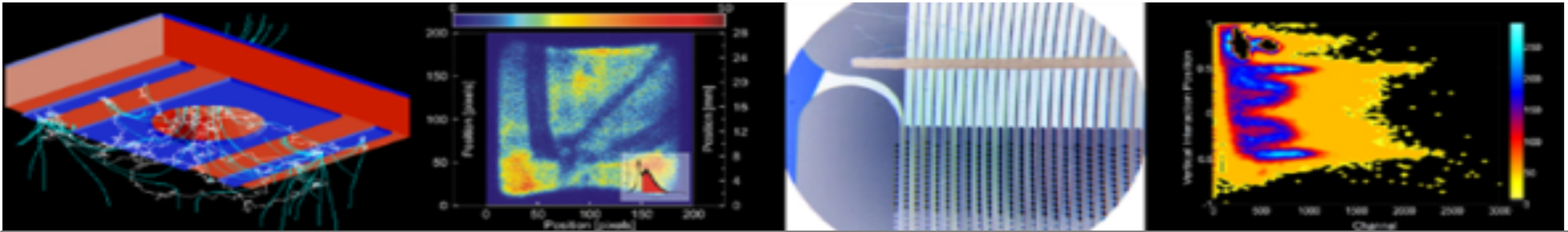


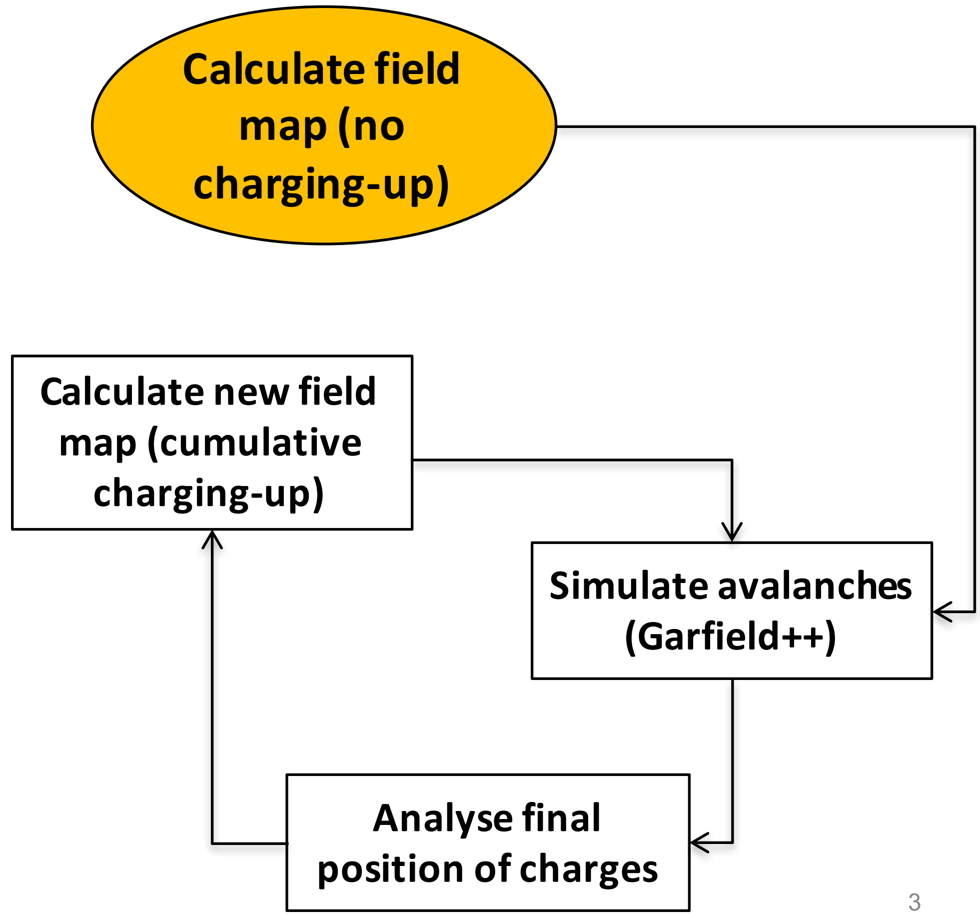
Outline

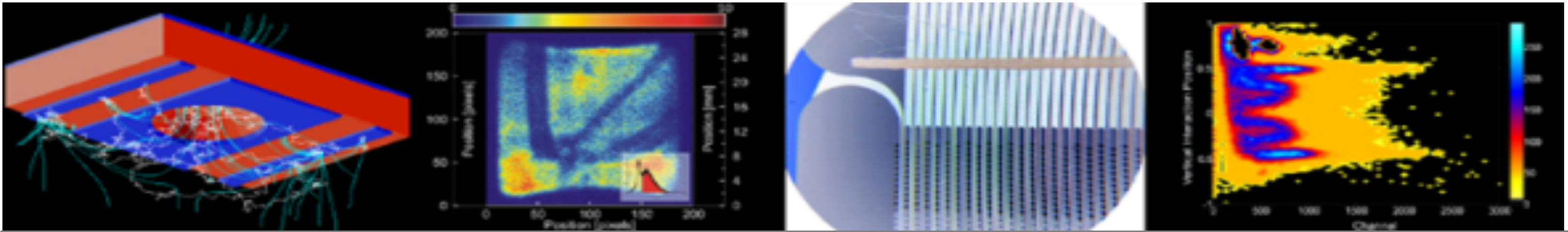
- Charging-up calculations
  - Recent developments
  - Discussion of a possible Garfield++ new class
  - Application to the Thick-GEM:
    - Gain evolution over time
    - RIM influnce
    - Discharge
- Conclusions



Charging-up calculation

- Iterative-based calculation
- Calculation of field maps require several FEM calls
- Previous calculation studies were made:
  - M. Alfonsi et al, NIMA 671 (2012) 6–9
  - P M M Correia et al, 2014 JINST 9 P07025
- Only static method will be discussed for simplicity

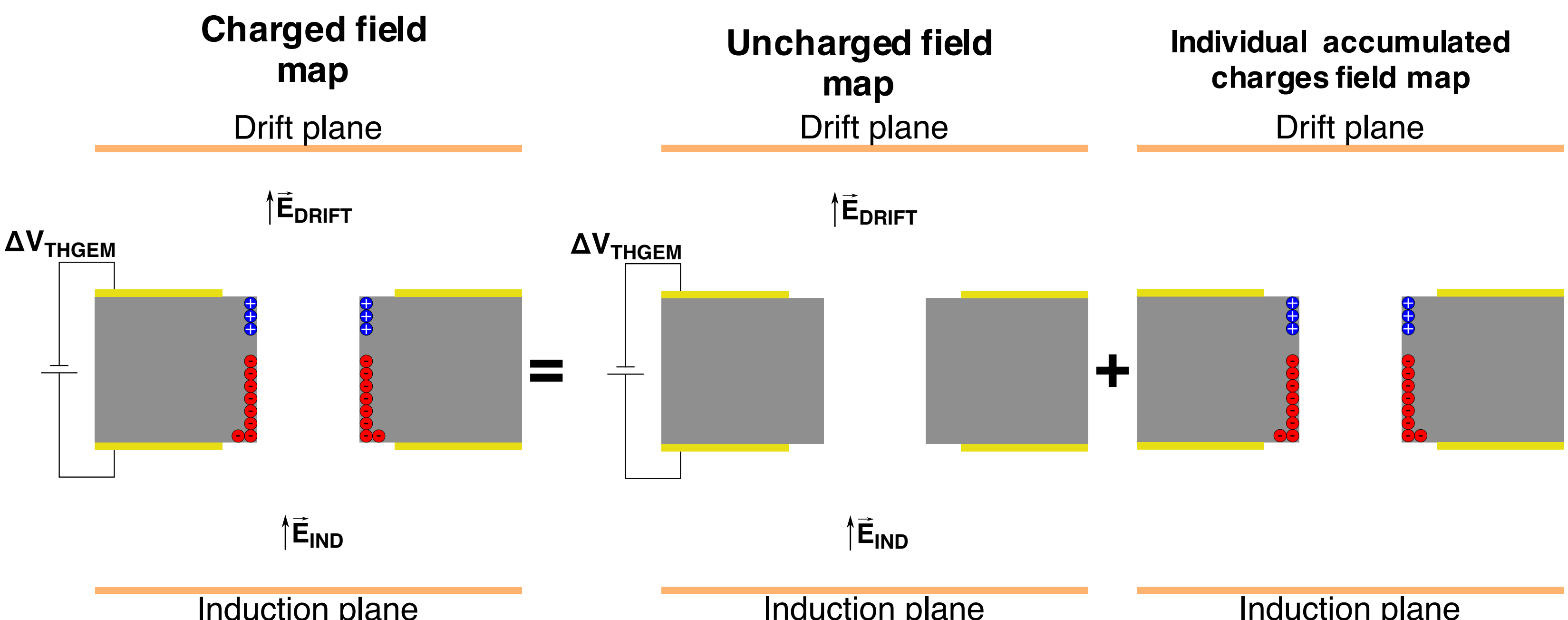


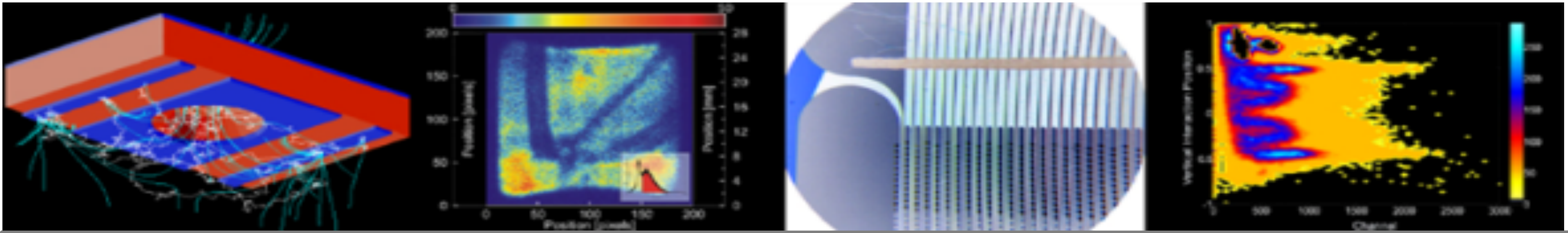


Principle of superposition

- The need of several executions of FEM is tedious
- Solution: Calculate **Potential field map** + **Charged field maps** at the beginning of the simulation
- Garfield++ reads potentials as a list of **nodes** and **E. Potential**
- For each node, the new **E. Potential** for each iterations is calculated inside Garfield++!

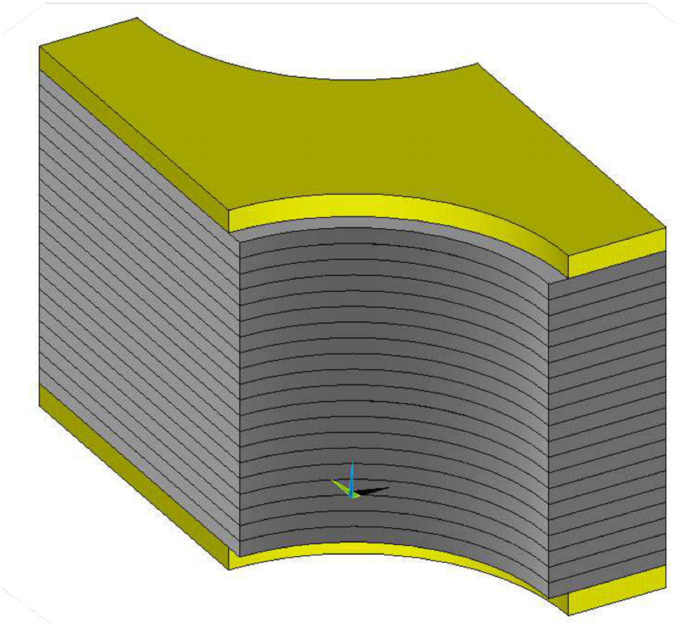
$$V(charged, i) = V(uncharged, i) \pm N \times V(accum.\,charges)$$



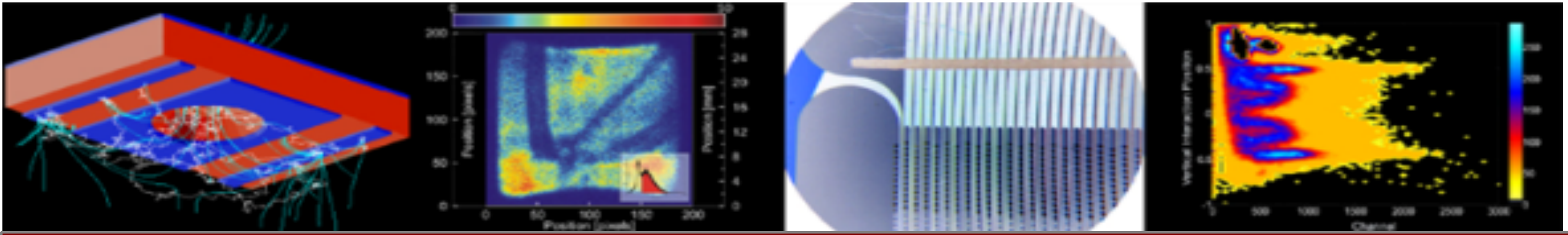


Principle of superposition

- Ex: Thick-GEM, insulator with 20 slices
- For each voltage between electrodes, field map is calculated as usually (without charging-up)
- For each slice, the field map correspondent to 1 electron accumulated on the correspondent slice surface is calculated
- 22 field maps due to charges + 1 (at least) potential field map are needed for full simulation



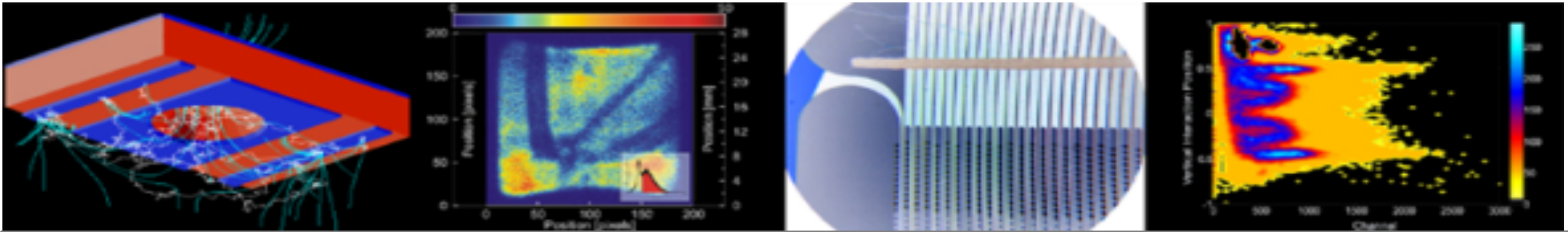
```
PRNSOL_700V.lis
PRNSOL_750V.lis
PRNSOL_800V.lis
PRNSOL_900V.lis
PRNSOL_slice10.lis
PRNSOL_slice11.lis
PRNSOL_slice12.lis
PRNSOL_slice13.lis
PRNSOL_slice14.lis
PRNSOL_slice15.lis
PRNSOL_slice16.lis
PRNSOL_slice17.lis
PRNSOL_slice18.lis
PRNSOL_slice19.lis
PRNSOL_slice1.lis
PRNSOL_slice20.lis
PRNSOL_slice2.lis
PRNSOL_slice3.lis
PRNSOL_slice4.lis
PRNSOL_slice5.lis
PRNSOL_slice6.lis
PRNSOL_slice7.lis
PRNSOL_slice8.lis
PRNSOL_slice9.lis
PRNSOL_sliceRimBottom.lis
PRNSOL_sliceRimTop.lis
```



Garfield++ Method

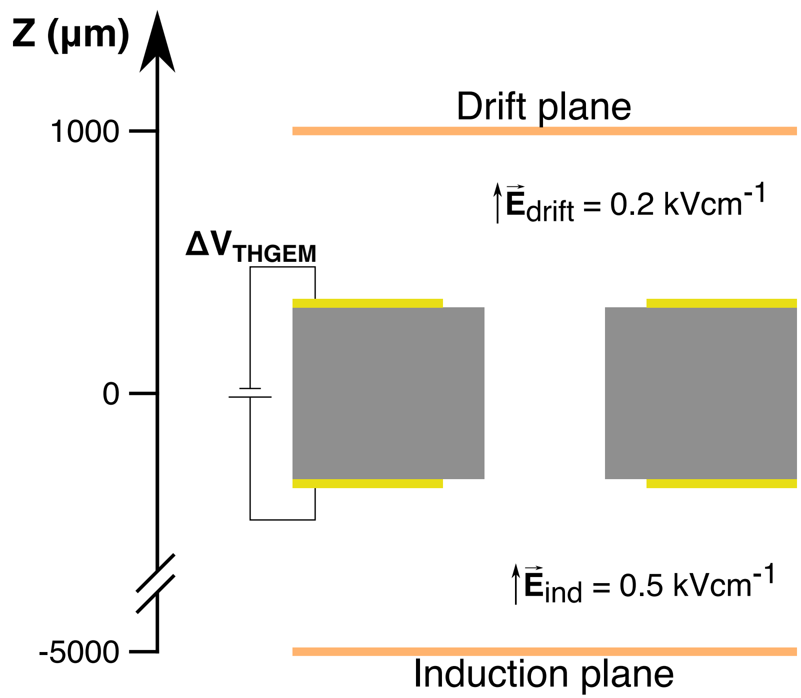
- A new Garfield++ class has been developed (~500 lines of code, up to now).
- Responsible to find the field maps (only **ANSYS** at the moment)
- Writes a temporary field map depending on the number of accumulated charges for each iteration
- It allows restart simulation at a specific iteration if previous field maps are stored
- (code for demonstration only)

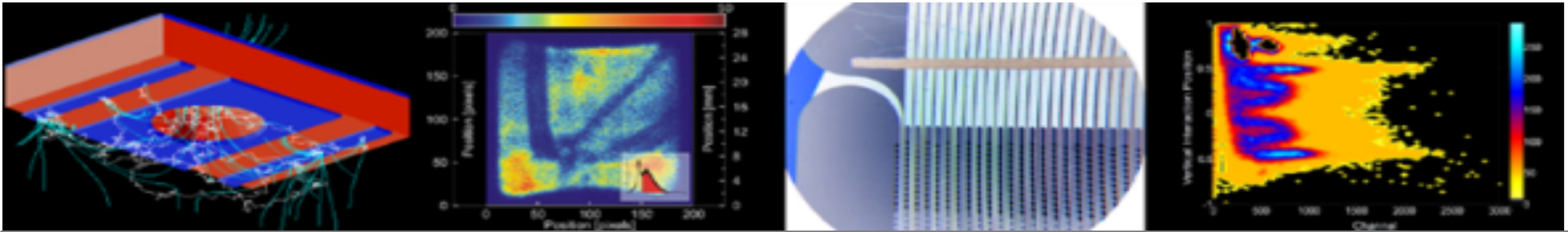
```
#include "ChargingUpAnsys.hh"

using namespace std;
using namespace Garfield;
int main(int argc, char * argv[]) {
    double ChargesVector[ nSlices ];

    //(...);

    ChargingUpAnsys file(mapfilesdir, nSlices, ChargesVector, gasstr, vgem, npe);
    if (!file.checkSlicesFieldMaps()){
        std::cout<<"Error 1, files does not exist"<<endl;
        exit(0);
    }
    file.loadSlicesFieldMaps();


    double simulatedCharges[ nSlices ];

    //for loop over iterations
    // (...) after avalanches calculation and calculation of the
    // number of accumulated electrons+ions

    file.UpdateFieldMap(simulatedCharges);
    file.SaveKaptonChargesFile(iter);
    file.printCurrentCharges();
    //end of the for loop

}
```



Simulation setup

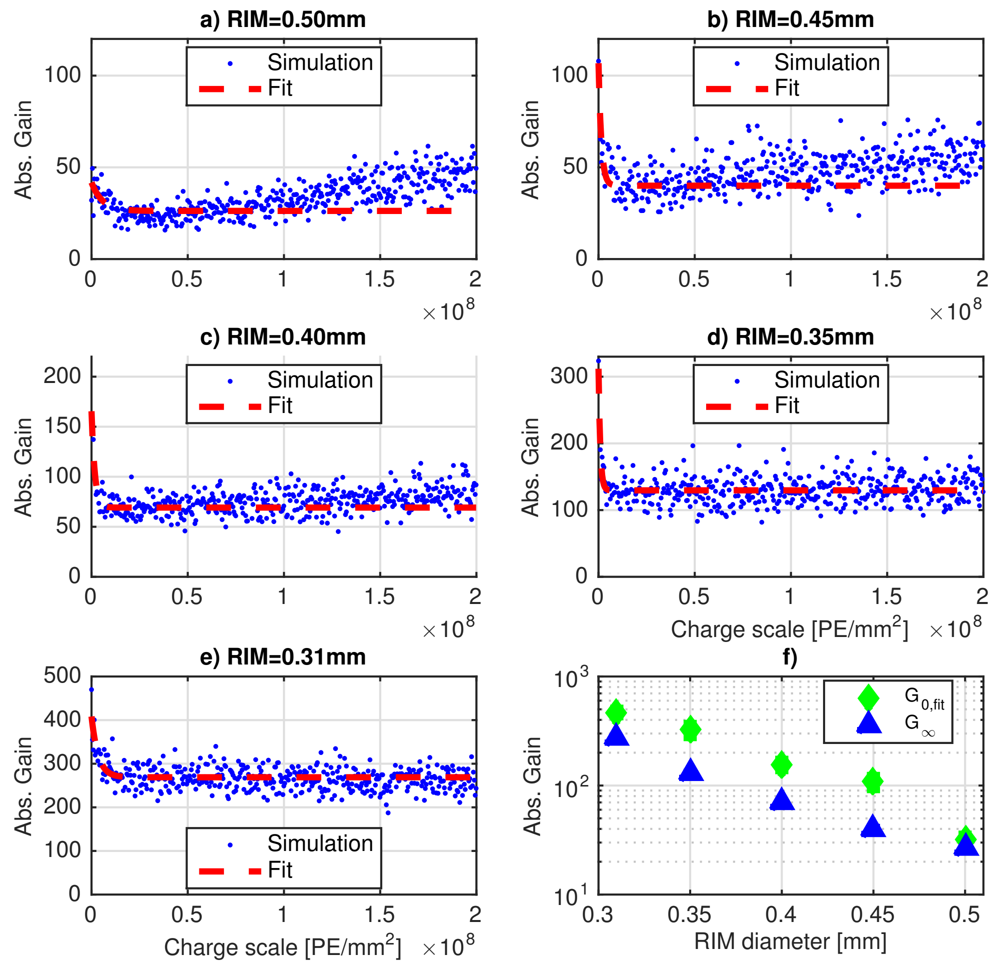
- Pitch 0.7 mm, thick 0.4 mm, hole diam 0.3 mm
- Variable RIM width -> 0.01 mm to 0.1 mm
- Drift field 0.5 kV/cm
- Induction field 2.0 kV/cm
- V_{THGEM} 500 V
- Ne/CH4(5%), penning factor of 0.4
- Standard room conditions for temperature (293 K) and pressure (760 Torr)
- Primary electrons start drifting at the drift plane
- Two different iteration steps were used to mimic different irradiation reates: **1x10⁵ (small step)** and **5x10⁵ (large step)** e.p. per primary cell per iteration.

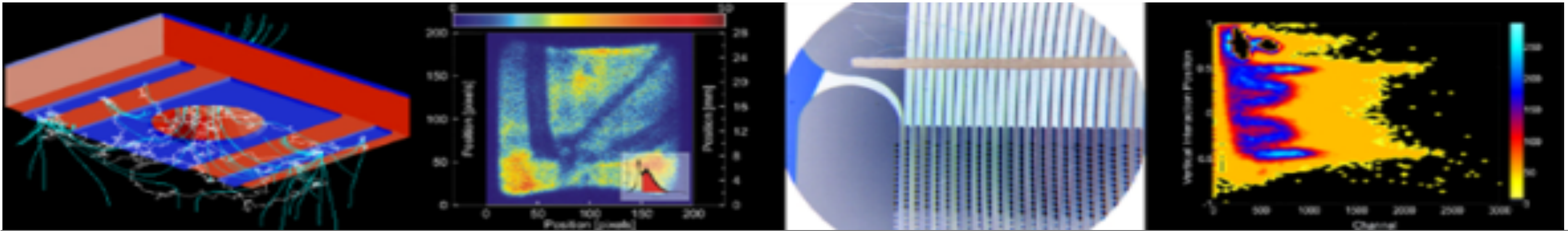




Small step

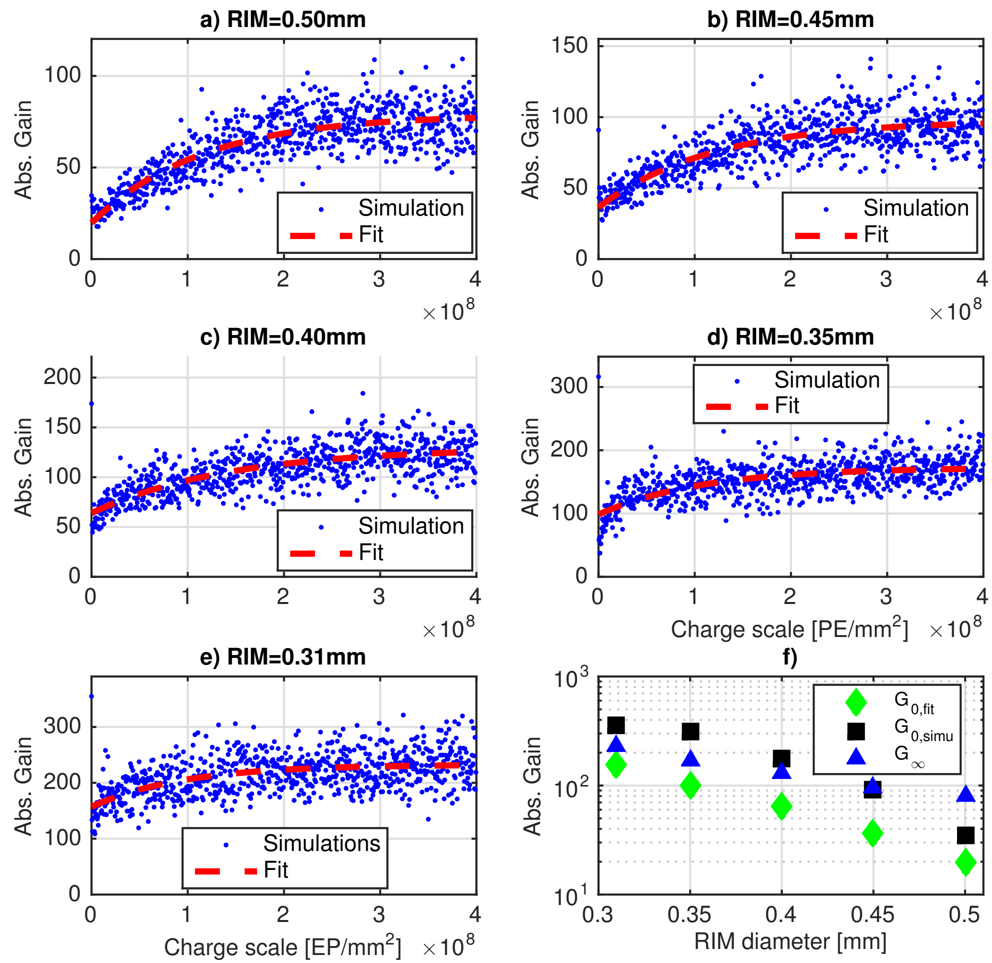
- Small step: **1x10^5** primary avalanches/mm^2 was used to mimic lower irradiation rate
- Fast decrease followed by a plateau or a slow increase
- Gain after stabilization is (almost) always lower than initial gain
- RIM size determines the gain decrease

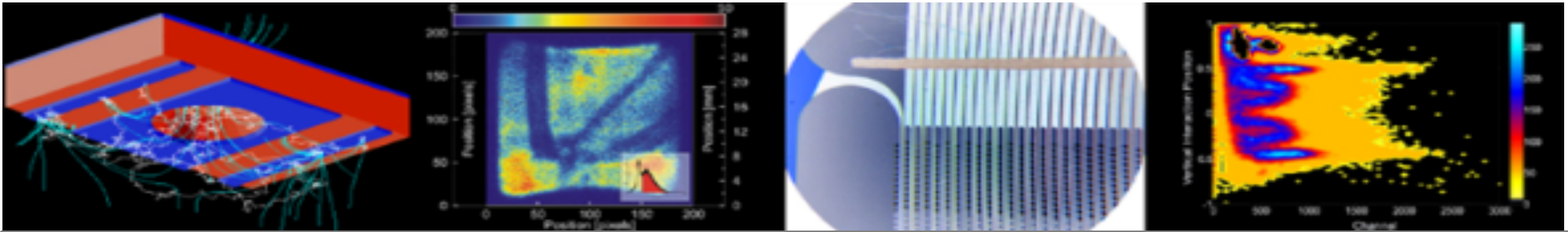




Large step

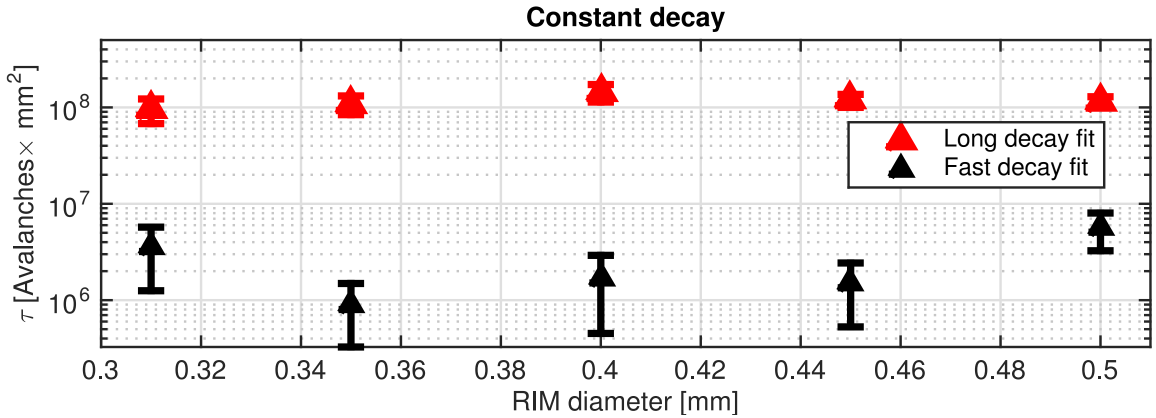
- Large step: **5x10^5** primary avalanches/mm^2 to mimic higher irradiation rate
- **Very fast decrease** (almost impossible to notice) followed by an exponential-like increase
- Depending on the **RIM** the gain after stabilization can be higher or lower than the first simulated point – **but is always higher than the initial gain if the exponential fit neglets the first point**
- Different exponential constants are found for small and large steps

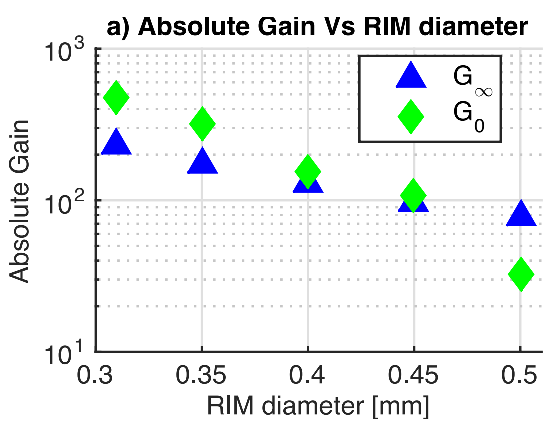


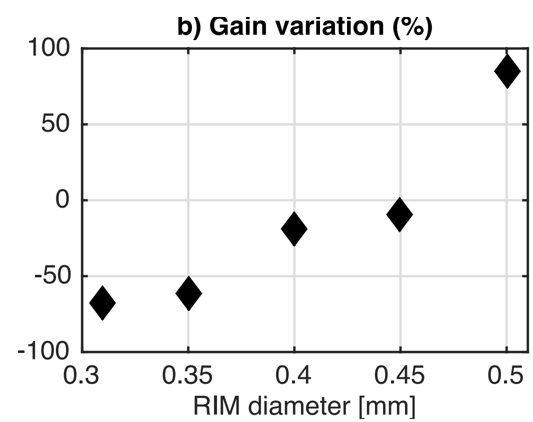


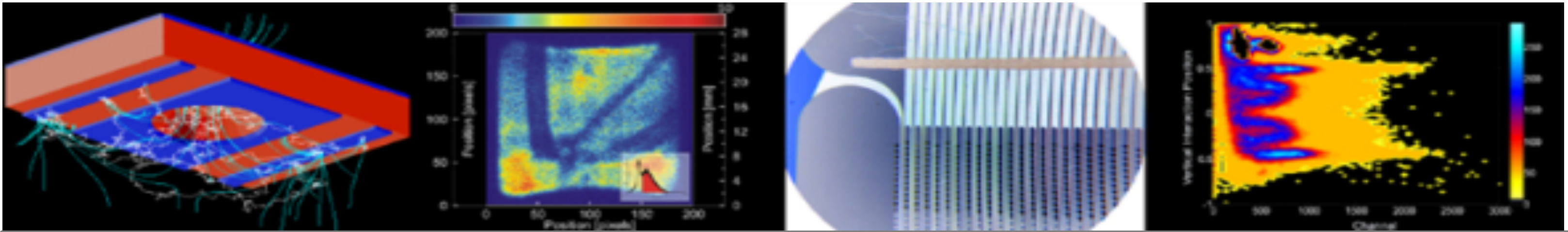
Constant decays

- Two different exponential constants were found
- **RIM** seems to not affect these exponential constants
- However, depending on **RIM** the gain after stabilization can be higher or lower than the initial value



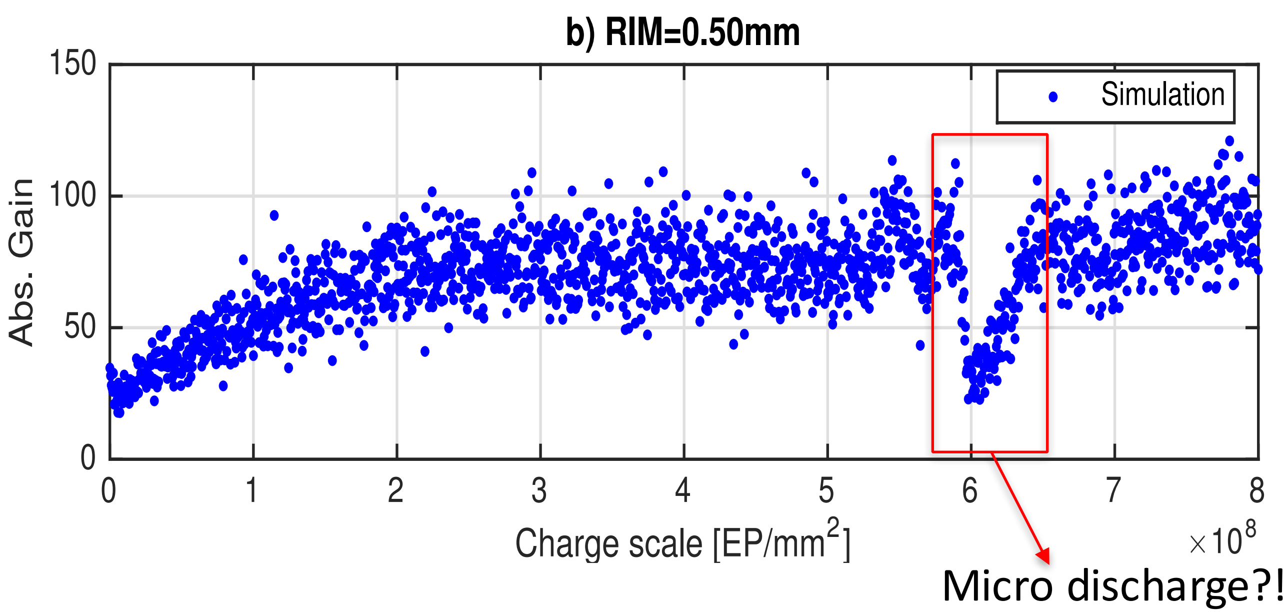


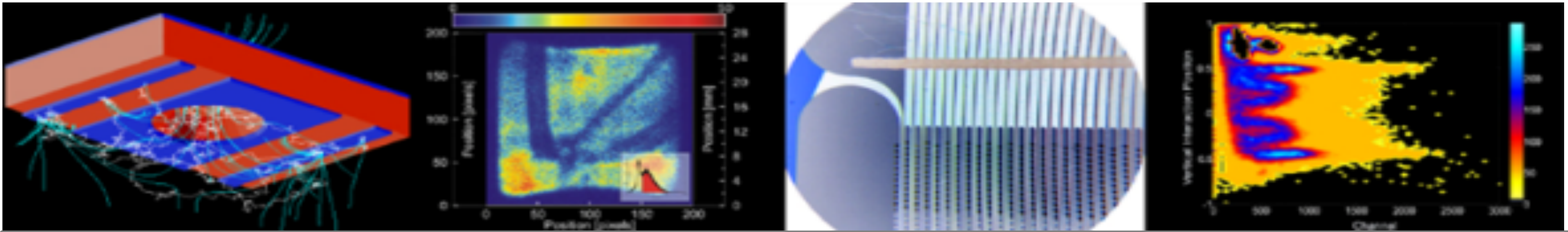




Discharge simulation

- During simulations, discharge-like events appears at random
- It happens when an unusual large amount of charges accumulates in the insulator regions of the hole
- Can charging-up explain these micro-discharges?





Conclusions

- Charging-up gain calculations are now performed completely inside Garfield++:
  - A **new class** has been written, only needs the **initial field maps** corresponding of each insulator slice
  - No need to call FEM software after each iteration -> **time and memory saving**
  - Results coherent with previous simulations. Short-time gain evolution as described by experimental work.

- Application to THGEM:
  - Two different regimes were found in the simulations
  - RIM size determines whether the gain after stabilization is lower or higher than initial gain
  - Micro discharges appears during simulations, **charging-up** might explain these