Toolkit for simulation of Detector’s Charging Up/Down in MPGDs

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Michael Pitt\textsuperscript{1}, P.M.M. Correia\textsuperscript{2}, S. Bressler\textsuperscript{1}, L. Arazi\textsuperscript{3}, A.E.C Coimbra\textsuperscript{1}, D. Shaked-Renous\textsuperscript{1}, C.D.R Azevedo\textsuperscript{2}, J.F.C.A Veloso\textsuperscript{2} and A. Breskin\textsuperscript{1}

\textsuperscript{1} Weizmann Institute of Science, Israel
\textsuperscript{2} University of Aveiro, Portugal
\textsuperscript{3} Ben-Gurion University of the Negev, Israel
Overview

- Initially developed by Rob Veenhof and Aveiro group ([2014 JINST 9 P07025](#)).
- The aim of the tool is to study the effect of charge accumulation on detector’s insulating surfaces ([2018 JINST 13 P01015](#)).
- Based on the superposition principle (see next slides).
- Applicable for any MPGD geometry.
- It’s a c++ class interfaced with Garfield++ simulation package:

FEM (Ansys® for now)

Electric field maps calculation (see next slides)

Garfield++

ComponentAnsys123

Import Electric field to Garfield++

AvalancheMicroscopic

Avalanche simulation

ChargingUp class

Electric field modification

**Diagram:**

- **FEM (Ansys® for now):** Electric field maps calculation (see next slides).
- **Garfield++:** Import Electric field to Garfield++
- **ComponentAnsys123:** Avalanche simulation
- **AvalancheMicroscopic:** Avalanche simulation
- **ChargingUp class:** Electric field modification
Overview - examples

• Gain variation due to accumulated charges can be simulated using Garfield++ interfaced with the toolkit.
• This allows studies of physics performance of detectors incorporating insulating surfaces
Outline:

- Gain variation due to accumulated charges can be simulated using Garfield++ interfaced with the toolkit.
- This allows the study of physics performance of detectors incorporating insulating surfaces.

**Example**: Study of initial gain stabilization in THGEM with different geometry/conditions.

- Measurements
- Simulation
  - w/o hole-rims
  - with hole-rims

**Graphs**:

- THGEM: Ne/CH4(5%); pen=0.4
  - E_Drift = 0.5 kV/cm, E_PAD = 0.5 kV/cm
  - Rate=100 kHz; E = 5.9 kV/cm
  - G^inf=68.64, G^inf=32.54
  - Fit χ²/n.d.f.=9.97; G=36.10±0.95 [pC]
  - t=0.4:0.01 [min]; step=10 M

**Electrodes**:
- Electrode with an etched hole-rim of 0.1 mm
- Electrode without hole-rim
Overview

• Gain variation due to accumulated charges can be simulated using Garfield++ interfaced with the toolkit.
• This allows studies of physics performance of detectors incorporating insulating surfaces

**Example:** Study of initial gain stabilization in THGEM with different geometry/conditions

**Here:** Implementation of the toolkit will be reviewed
The simulation of charging-up rely on the superposition principle:

1. Electric field calculation due to **applied voltages** on detector’s electrodes
2. Electric field calculation due to **electrical charges** on detector’s surfaces
3. Superposing (1) with (2) to obtain a new field map

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**Diagram:**
- **Uncharged Field Map Calculation (FEM)**
- **Avalanche simulation (Garf++)**
- **Calculate charging-up and Gain (Garf++)**
- **Total Field Map Update (Garf++)**

**Iteration (superposition calculations)**
Superposition principle - example

- Design your detector geometry, calculate field maps when:
  1. Voltage is applied on detector’s electrode
  2. A slice is charged with a single unit charge

Example: THGEM divided into 20 slices

Example files:
- 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_slice2.lis
- PRNSOL_slice3.lis
- PRNSOL_slice4.lis
- PRNSOL_slice5.lis
- PRNSOL_slice6.lis
- PRNSOL_slice7.lis
- PRNSOL_slice8.lis
- PRNSOL_slice9.lis
“ChargingUpAnsys” class allows to manipulate with Ansys field maps:

Feed the class with the list of map files

Calculate the charges to be added to the slices

Update field map

In a new iteration, modified field map will be used
Simulation setup: THGEM case

- In the GitHub entry an example for THGEM is provided.
- In the example, \( n_p \) avalanches simulated, and charge that end-up on the insulating surfaces (\( Q_{up} \)) is stores in `double simulatedCharges[ nSlices];`.
- The actual amount of charge = \( Q_{up} \times step \) (see next slide).
Simulation setup: THGEM case

- Since the total charge accumulated on the slices is small to significantly modify electric field, then one can:
  - Continue to iterating, adding charges (Millions of iteration)
  - Multiply charges by constant value to speed up the process

- Step size is a fixed parameter usually large for high voltages

Gain stabilization as a function of the number of the simulated iterations can be converted to actual time by:

$$ t[sec] = \frac{step}{n_p \times R[Hz]} \times n_{iter} $$

Gives the ability to compare to experimental results
Measurement in pure noble gases showed that after a sable gain is achieved, further changes in irradiation rate are not affecting the detector’s gain (furthermore, the stable gain value is rate independent – see slide 15)

WORK IN PROGRESS

THGEM; $t = 0.8 \text{mm}$; $a = 1 \text{mm}$; $d = 0.5 \text{mm}$

gas: Argon; @30sccm

Drift gap = 5 mm; Ind. gap = 2 mm;

$E_{\text{DRIFT}} = 0.2 \text{kV/cm}$; $E_{\text{IND}} = 0.5 \text{kV/cm}$

$\Delta V = 1420 \text{ V}$; 8 keV x-ray source

* High rate (800 Hz/mm$^2$)
* Low rate (15 Hz/mm$^2$)
+ HV ON; X-ray OFF 2h; LR
- - Stable gain
• With the same operational detector condition, **BUT** different gas mixture – gain stabilization is no longer rate independent.
• This might be attributed to charge evacuation via electronegative gas molecules.

**Measured gain**

**WORK IN PROGRESS**

- THGEM: $t = 0.8\text{mm}; a = 1\text{mm}; d = 0.5\text{mm}$
- gas: Ne/CH$_4$ (65%); @30 sccm
- Drift gap = 5 mm; Ind. gap = 2 mm;
- $E_{\text{DRIFT}} = 0.2\text{kV/cm}; E_{\text{IND}} = 0.5\text{kV/cm}$
- $\Delta V = 2500\text{ V}; 8\text{ keV x-ray source}$
Charge evacuation model

- Introduce down-charging mechanism: \( \Delta Q = Q_{up} - \lambda Q \)
- Charge evacuation rate is currently fixed by a user

```java
//for loop over iterations
// (...) after avalanches calculation and calculation of the
// number of accumulated electrons and ions
file.DownCharge(DownChargeLambda);
file.UpdateFieldMap(simulatedCharges);
file.SaveKaptonChargesFile(iter);
file.printCurrentCharges();

//end of the for loop
```

- In the absence of charging up, \( Q^{THGEM} = Q^{THGEM} \times e^{-\lambda n_{iter}} \)
- Then one can extract the down-charging parameter using gain stabilization time \( \tau_{DN} \), by
  \[
  \lambda = \frac{1}{\tau_{DN}} \times \frac{\text{step}}{n_p \cdot R[Hz][s]} \times 1
  \]
- Work is ongoing to determine evacuation rate for various gas mixtures
Charge evacuation model

- Introduce down-charging mechanism: \( \Delta Q = Q^{up} - \lambda Q \)
- Charge evacuation rate is currently fixed by a user

```cpp
//for loop over iterations
// (...) after avalanches calculation and calculation of the
// number of accumulated electrons and ions
file.DownCharge(DownChargeLambda);
file.UpdateFieldMap(simulatedCharges);
file.SaveKaptonChargesFile(iter);
file.printCurrentCharges();
//end of the for loop
```

**Preliminary**

THWELL; \( t = 0.4; a = 0.96; d = 0.5 \)
Ne/CH4(5%); pen=0.4
\( \Delta V = 450; npe = 100 \lambda = 0.05 \)

- step=100K [avalanches], \( \tau = 15.34 \) [step]

**Simulation**

- \( R = 1.05 \) kHz/mm\(^2\)
- \( R = 15 \) Hz/mm\(^2\)
- \( R = 13.5 \) Hz/mm\(^2\)

**Experiment**

THGEM; \( t = 0.8 \) mm; gas Ne/CH\(_4\) (20%)
\( E_{\text{Drift}} = 0.2 \) kV/cm; \( E_{\text{IND}} = 0.5 \) kV/cm
Drift gap - 5 mm; Induction gap = 2 mm
8 keV x-ray source
• The toolkit is available for the study of charging up/down in detector elements incorporating insulating materials
• Applicable to any MPGD geometry
• The Tool has been used in studies of GEM and THGEMs.
• Permits electric field variations within Garfield++ package.
• Down-charging is currently tested, up to now it is up to the user to fix the rate.
Back up
The simulation of charging-up rely on the superposition principle.
Simulation setup: Limitations

- Step size is a fixed parameter usually large for high voltages, one should scan different steps until the correct range is found.

![Graph 1: Step=500K](image1.png)

![Graph 2: Step=2M](image2.png)

![Graph 3: Step=4M](image3.png)
Simulation setup: Limitations

• Step size is a fixed parameter usually large for high voltages, one should scan different steps until the correct range is found.