WG4 summary

- Presentations by:
  - Carlos Bastos
  - Özkan Şahin
  - Gabriele Croci
  - Kostas Nikolopoulos
  - Alain Bellerive
  - Wilco Koppert

Simulation tool for electroluminescence assessment in gaseous avalanche detectors

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14/06/09

Propose of the work

- Study of the physical processes of light emittion in avalanche detectors
- This information can be usefull for:
  - Dark Matter research
  - $\beta\beta - 0\nu$
  - other TPCs

Scintillation in Noble gases

Xenon excimers / Simulation model

- Eximer formation (3 body collision)

  $R^* + 2R \rightarrow R_2^{**} + R$

- Direct radiative decay

  $(p > 400 mbar)$

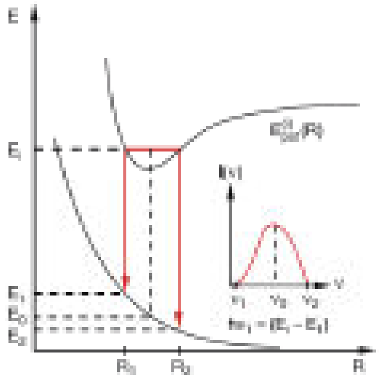
  $R_2^{**} \rightarrow 2R + h\nu$

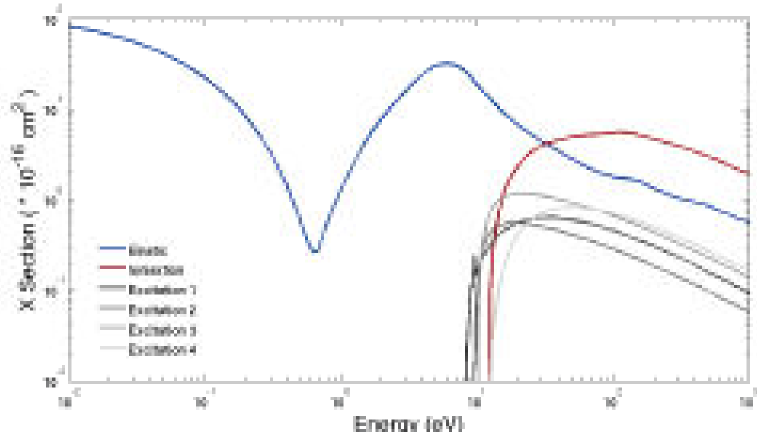
- 3 body collision + radiative decay

  $(p < 400 mbar)$

  $R_2^{**} + R \rightarrow R_2^{*} + R$

  $R_2^{*} \rightarrow 2R + h\nu$



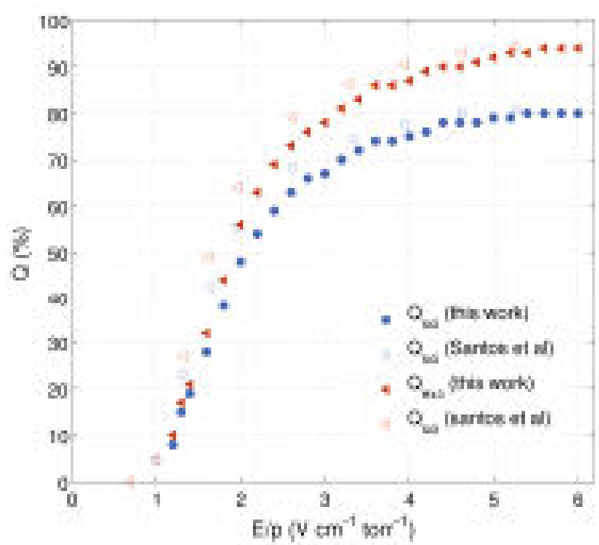


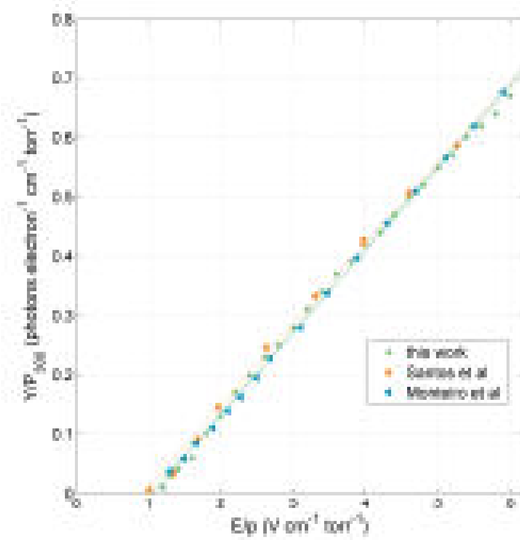
- 1 excited state -> 1 VUV photon of $\varepsilon_{sci} = 7.2eV$
- X sections from Magboltz
- Microscopic technique of Garfield

Validation

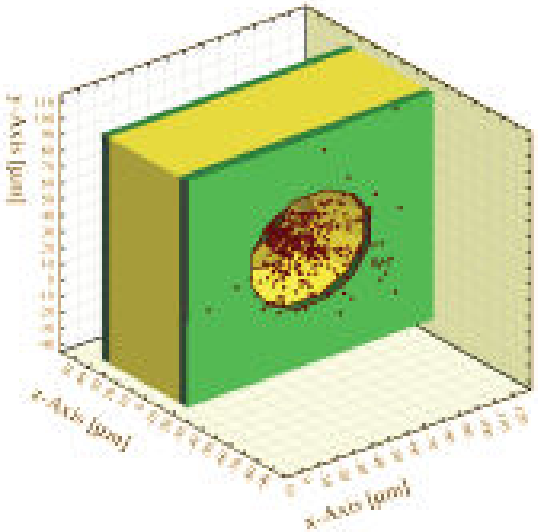
Uniform field

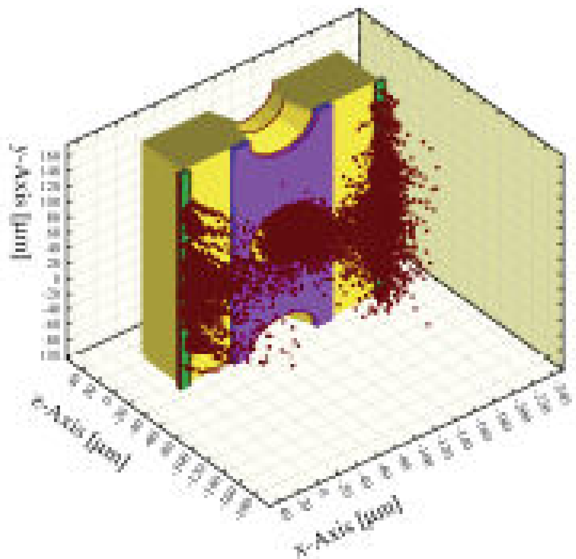
- $1 < \left(\frac{E}{p}\right) < 6Vcm^{-1}torr^{-1}$ (only elastic and excitation collisions)
- $Q_{exc}, Q_{sci}, \frac{Y}{p}$
- good agreement with former simulation work and experimental data (F. P. Santos et al, JPhysD-27(1994)42 & Monteiro et al, JInst-2(2007)5001)





Model apllied to MPGD's
GEM & MHSP

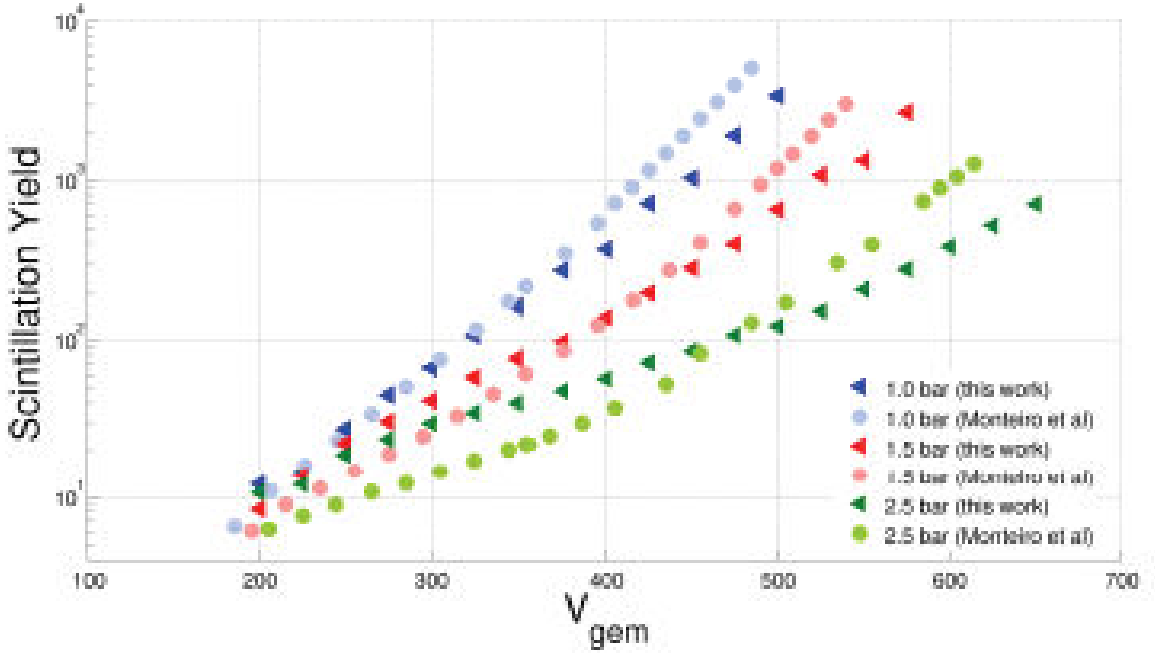




- field maps from Ansys
- random (x, y)
- $N_e = f(V, p)$
- $N_{exc} = f(V, p)$

Results

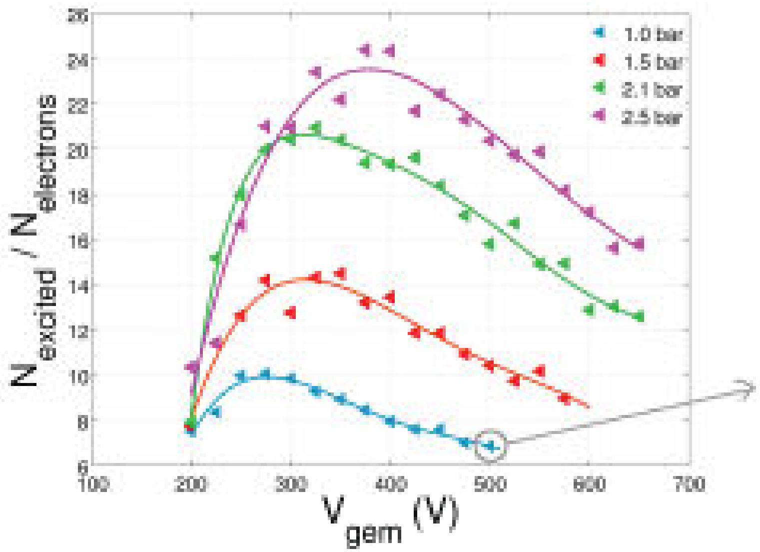
GEM - Scintillation Yield

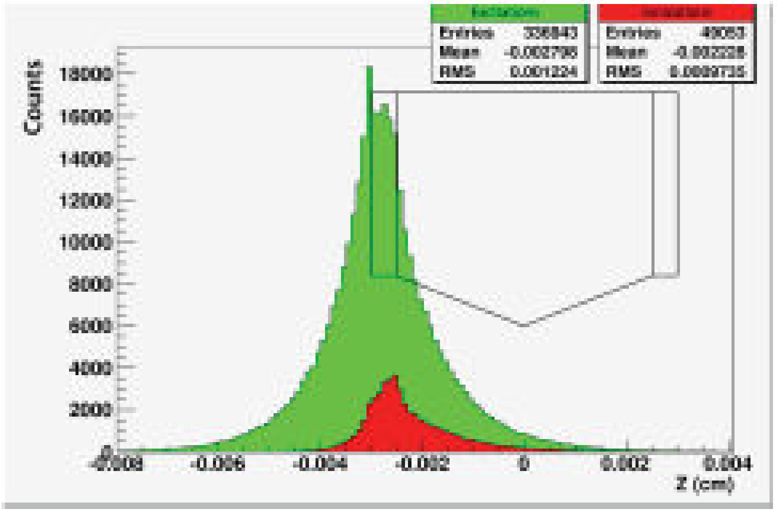


- Similar behaviour as experimental data (Monteiro et al, PLB)
- Little differences are being studied

Results

GEM - Racio between light and charge





- $N_{exc} >> N_e$
- $\frac{N_{exc}}{N_e}$ increases with p (λ decreases -> less $\varepsilon_{electron}$ -> P_{ion} decreases)
- Possible usefull addicional information

Penning transfers:

survey of available data, life-time of excited states, pressure dependence

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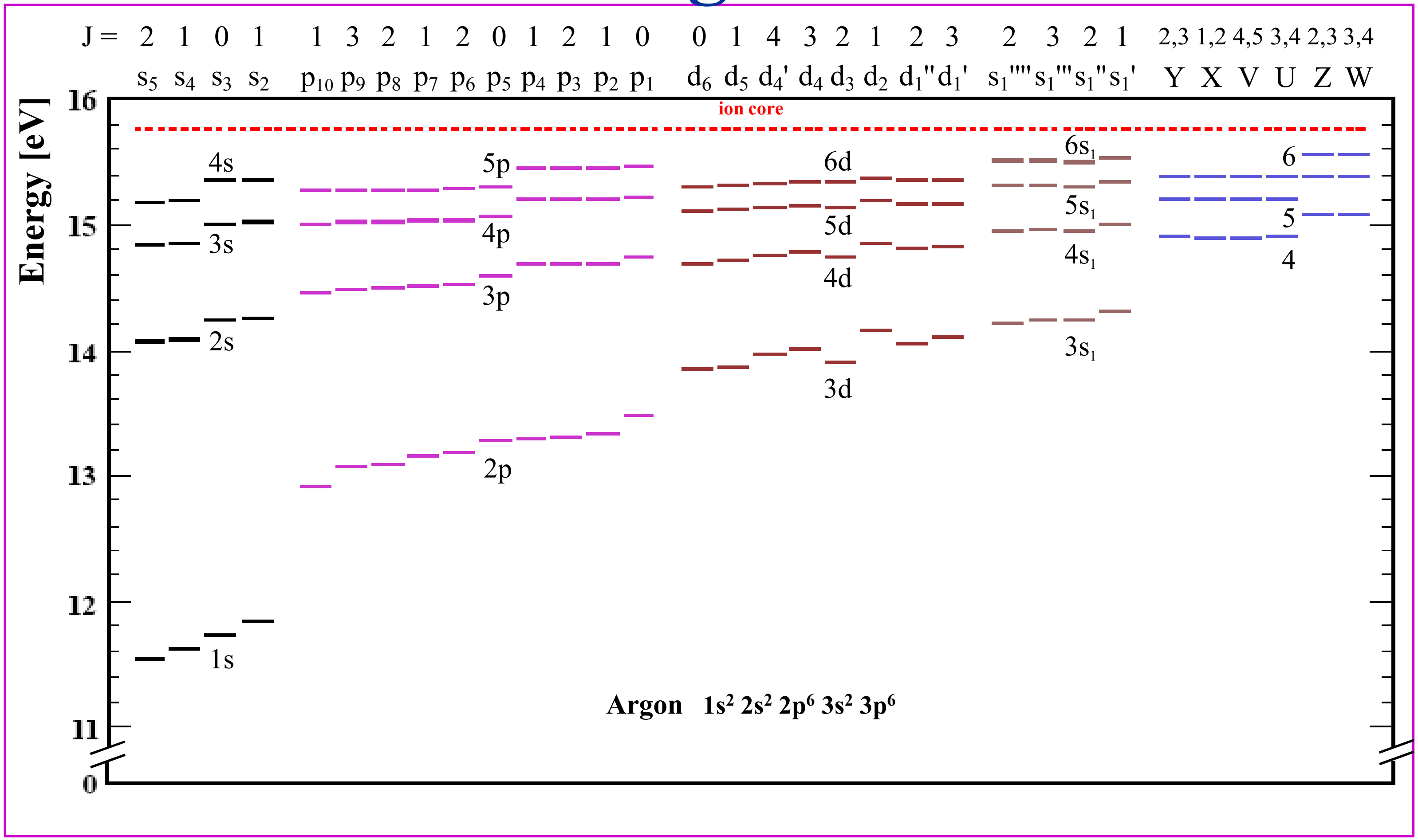
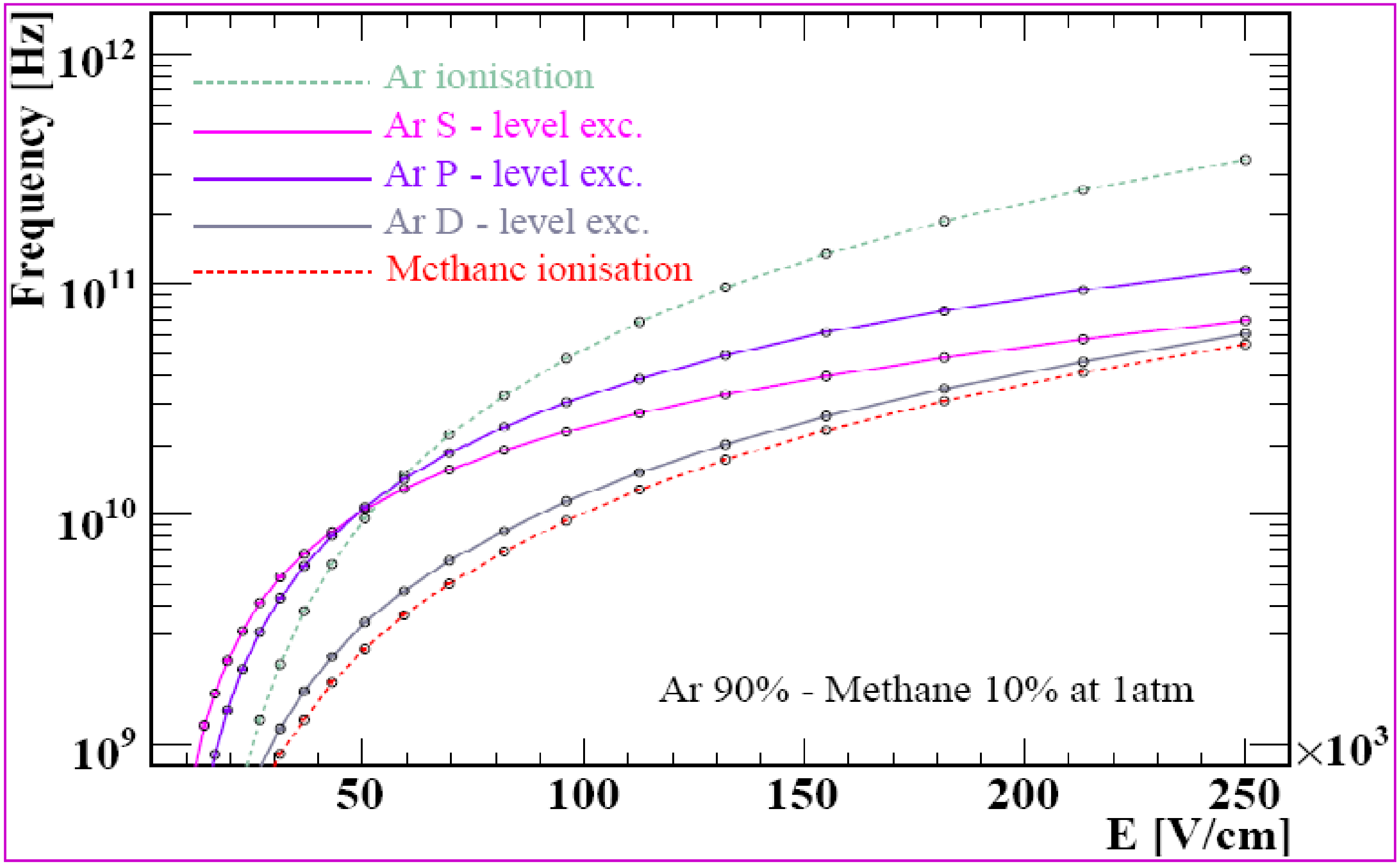
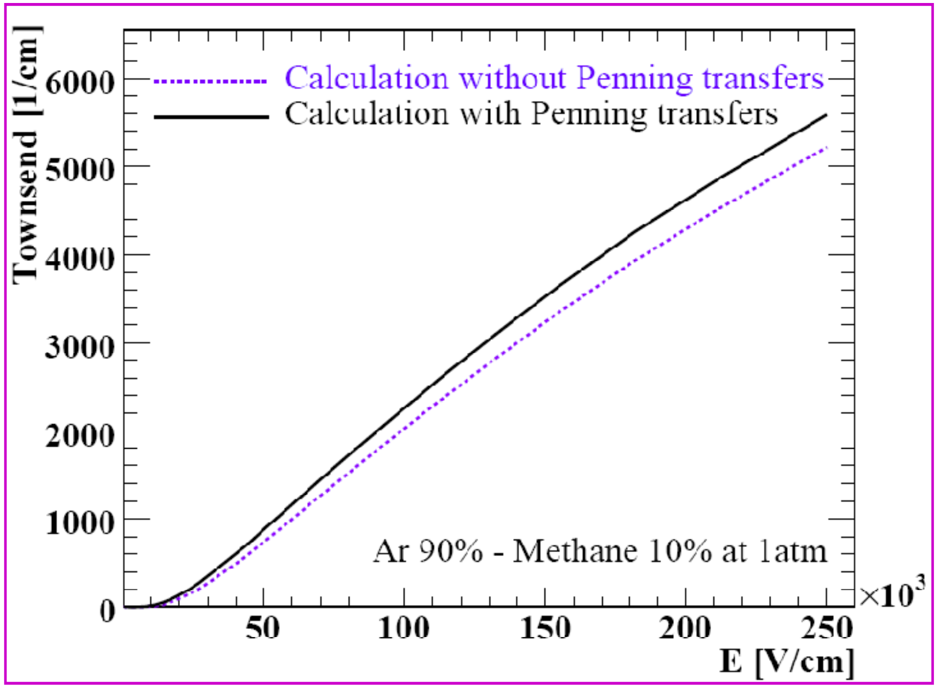
Schematic view of the energy levels for argon

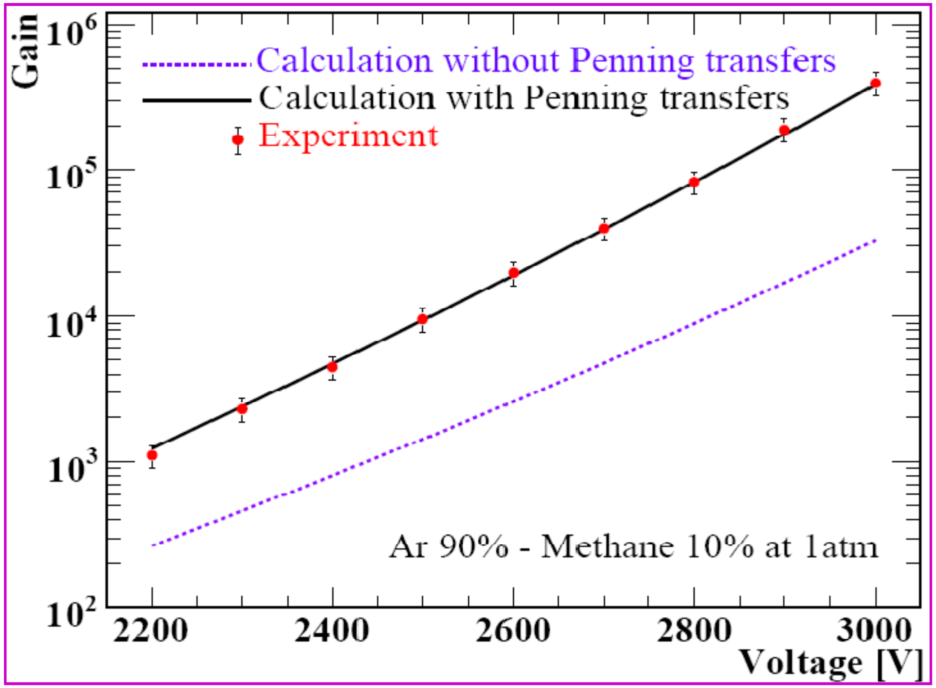


Variations of excitations and ionisations frequencies with electric field



Calculations





The Townsend coefficients with and without Penning transfers (left).

Measured and calculated gain curves with and without Penning transfers (right).

Investigated gas mixtures

1- **Argon – Ethane**

2- **Argon – Isobutane**

3- **Argon – Propane**

4- **Argon – Methane**

5- **Argon – Acetylene**

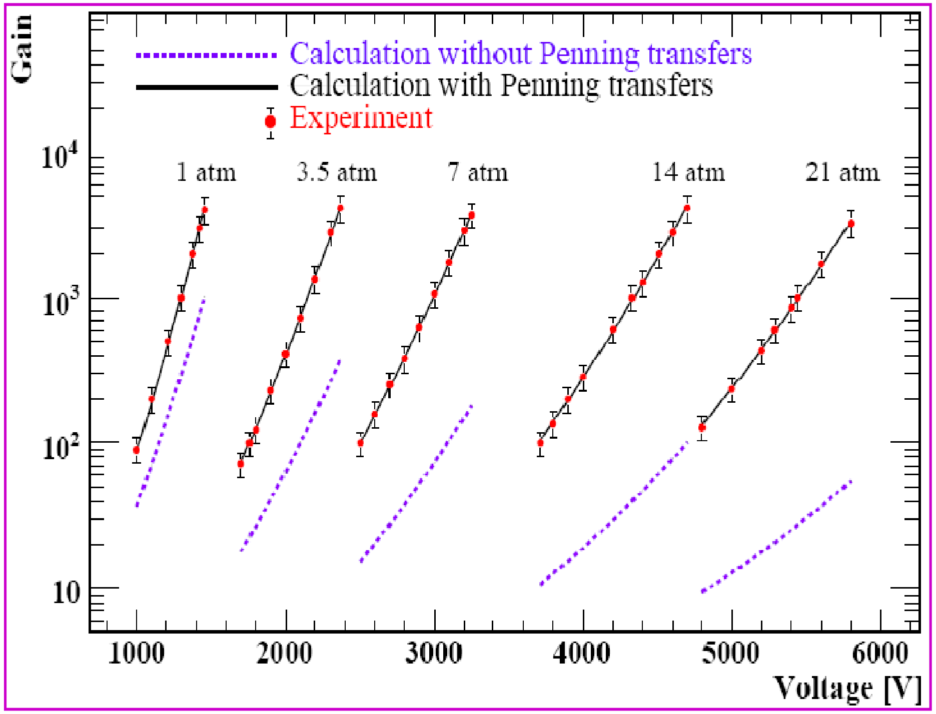
6- **Argon – CO_2**

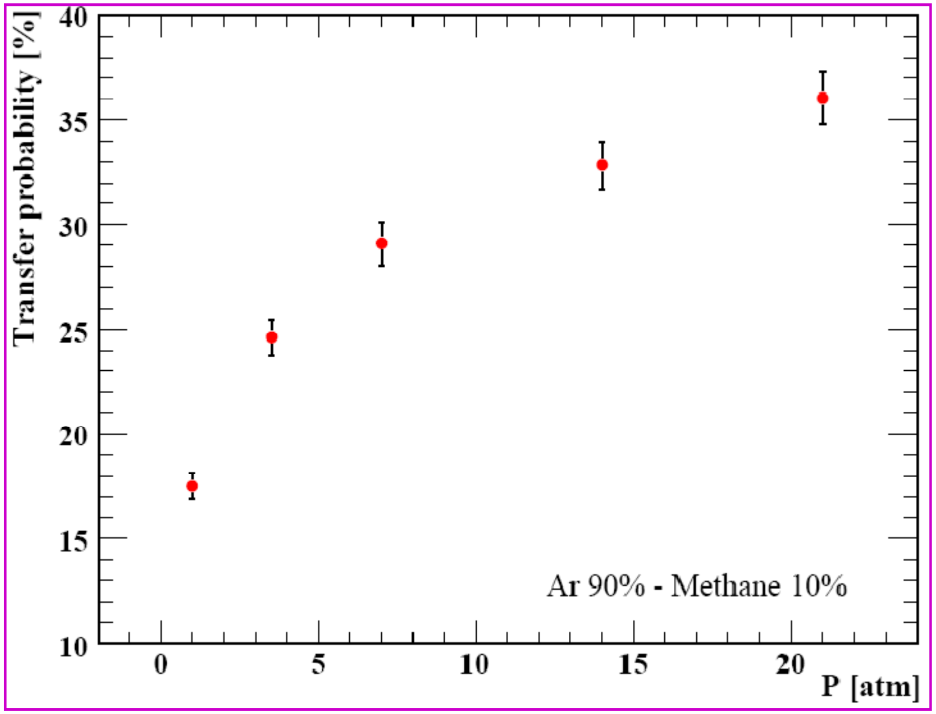
7- **Argon – Xenon**

Radiative lifetimes of Ar I excited levels

Levels jK	Levels Paschen	Energy [eV]	Lifetimes [ns] Experimental	Lifetimes [ns] Theoretical
$4s\,(3/2)_1$	$1s_4$	11.624	8.44[a]	8.60[a]
$4s'\,(1/2)_1$	$1s_2$	11.828	2.14[a]	2.15[a]
$4p\,(1/2)_1$	$2p_{10}$	12.907	32.4[b]	32.2[c]
$4p\,(5/2)_3$	$2p_9$	13.076	25.3[b]	25.2[c]
$4p\,(5/2)_2$	$2p_8$	13.095	26.8[b]	27.0[c]
$4p\,(3/2)_1$	$2p_7$	13.153	24.8[b]	25.8[c]
$4p\,(3/2)_2$	$2p_6$	13.172	24.4[b]	25.3[c]
$4p\,(1/2)_0$	$2p_5$	13.273	21.6[b]	22.0[c]
$4p'\,(3/2)_1$	$2p_4$	13.283	26.4[b]	26.0[c]
$4p'\,(3/2)_2$	$2p_3$	13.302	25.0[b]	25.5[c]
$4p'\,(1/2)_1$	$2p_2$	13.328	24.2[b]	24.8[c]
$4p'\,(1/2)_0$	$2p_1$	13.480	19.5[b]	18.5[c]
$3d\,(1/2)_0$	$3d_6$	13.845	------	54.2[a]
$3d\,(1/2)_1$	$3d_5$	13.864	94.0[a]	40.8[a]
$3d\,(7/2)_4$	$3d_4'$	13.979	72.0[d]	52.0[a]
$3d\,(7/2)_3$	$3d_4$	14.013	55.0[d]	50.8[a]
$3d\,(3/2)_2$	$3d_3$	13.903	3.48[a]	57.6[a]
$3d\,(3/2)_1$	$3d_2$	14.153	40.0[d]	9.0[a]
$3d\,(5/2)_2$	$3d_1''$	14.063	68.0[d]	49.9[a]
$3d\,(5/2)_3$	$3d_1'$	14.099	54.0[d]	49.0[a]
$3d'\,(5/2)_2$	$3s_1''''$	14.214	51.9[e]	49.9[a]
$3d'\,(5/2)_3$	$3s_1'''$	14.236	------	49.7[a]
$3d'\,(3/2)_2$	$3s_1''$	14.234	49.9[e]	48.3[a]
$3d'\,(3/2)_1$	$3s_1'$	14.304	53.3[e]	3.36[a]
$5s\,(3/2)_2$	$2s_5$	14.068	------	42.1[a]
$5s\,(3/2)_1$	$2s_4$	14.090	17.5[a]	4.74[a]
$5s'\,(1/2)_0$	$2s_3$	14.241	61.0[d]	43.9[a]
$5s'\,(1/2)_1$	$2s_2$	14.255	10.1[a]	3.2[a]
$5p\,(1/2)_1$	$3p_{10}$	14.464	170.0[f]	166.0[f]
$5p\,(5/2)_3$	$3p_9$	14.499	150.0[f]	122.0[f]
$5p\,(5/2)_2$	$3p_8$	14.506	165.0[f]	129.0[f]
$5p\,(3/2)_1$	$3p_7$	14.525	170.0[f]	109.0[f]
$5p\,(3/2)_2$	$3p_6$	14.529	175.0[f]	192.0[f]
$5p\,(1/2)_0$	$3p_5$	14.588	95.0[f]	73.0[f]
$5p'\,(3/2)_1$	$3p_4$	14.681	180.0[f]	127.0[f]
$5p'\,(3/2)_2$	$3p_3$	14.688	175.0[f]	123.0[f]
$5p'\,(1/2)_1$	$3p_2$	14.687	170.0[f]	123.0[f]
$5p'\,(1/2)_0$	$3p_1$	14.738	80.0[f]	83.0[f]
$4d\,(1/2)_0$	$4d_6$	14.694	120.0[g]	124.0[g]
$4d\,(1/2)_1$	$4d_5$	14.711	74.0[a]	113.0[a]
$4d\,(7/2)_4$	$4d_4'$	14.757	226.0[g]	230.0[g]
$4d\,(7/2)_3$	$4d_4$	14.781	285.0[g]	297.0[g]
$4d\,(3/2)_2$	$4d_3$	14.743	147.0[g]	384.0[g]
$4d\,(3/2)_1$	$4d_2$	14.859	200.0[f]	234.0[f]
$4d\,(5/2)_2$	$4d_1''$	14.809	360.0[f]	348.0[f]
$4d\,(5/2)_3$	$4d_1'$	14.834	350.0[f]	335.0[f]
$4d'\,(5/2)_2$	$4s_1''''$	14.955	295.0[f]	275.0[f]
$4d'\,(5/2)_3$	$4s_1'''$	14.972	310.0[g]	317.0[g]
$4d'\,(3/2)_2$	$4s_1''$	14.953	223.0[g]	259.0[g]
$4d'\,(3/2)_1$	$4s_1'$	15.004	71.9[h]	3.78[a]

Pressure dependence





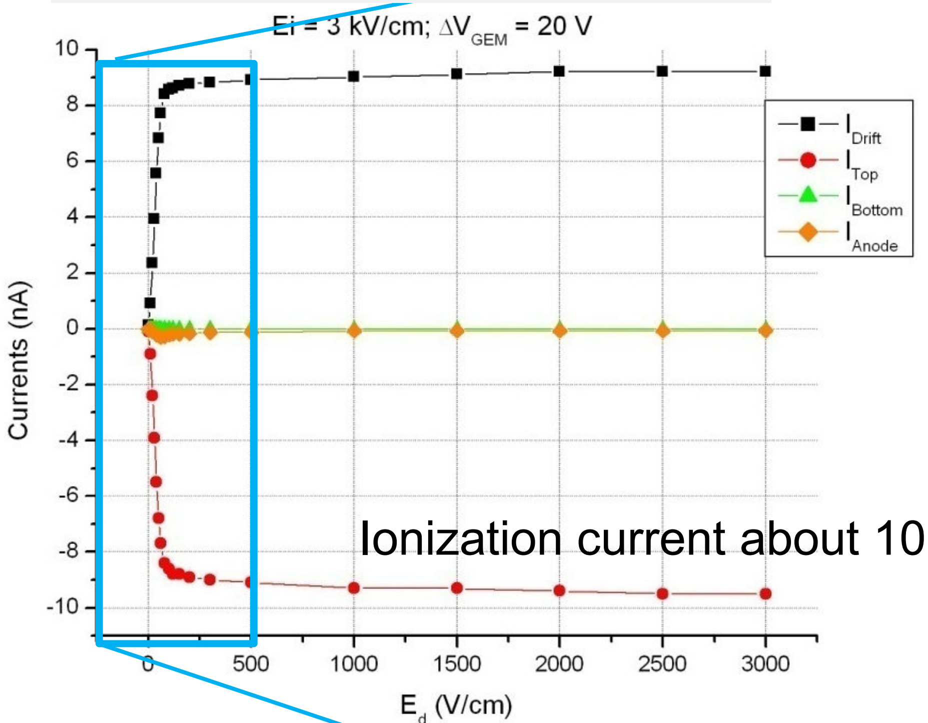
Measured and calculated gain curves for P-10 gas at different pressures (left).
Calculated Penning transfer probabilities with their error bars for P-10 gas at different pressures (right).

Standard GEM
Charging Up Simulation

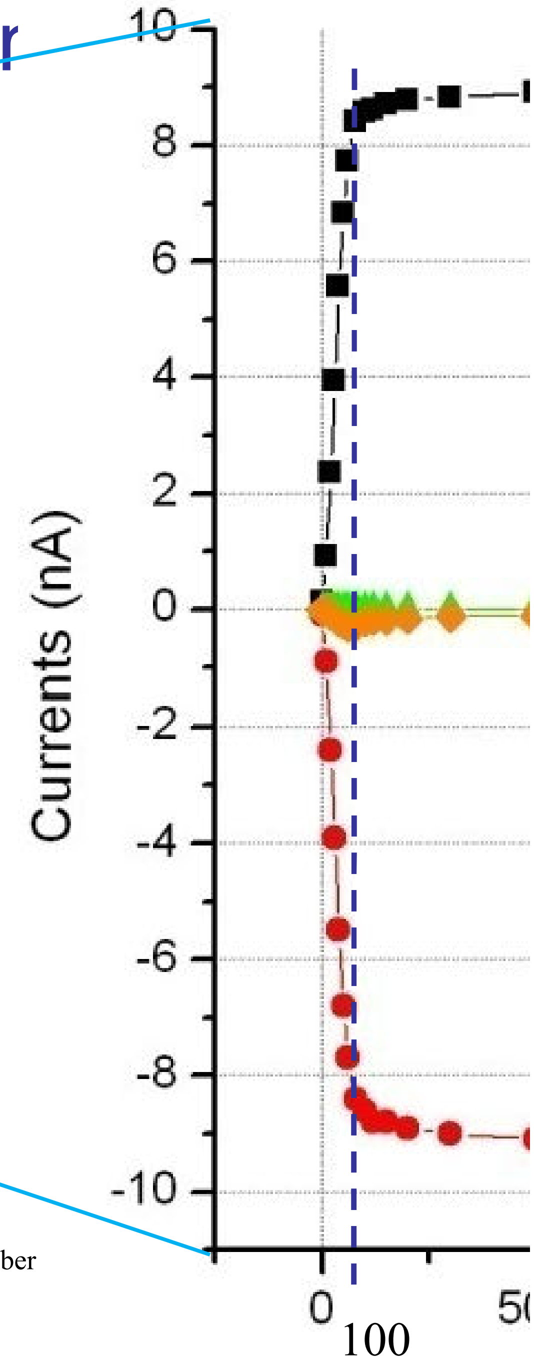
Gabriele Croci, *Matteo Alfonsi, Serge Duarte Pinto, Leszek Ropelewski, Rob Veenhof, Marco Villa (CERN), Elena Rocco (INFN-To & Univ. Eastern Piedmont)*

ΔV_{GEM}= 20 V: The measuremer

Drift Scan (current vs drift field)



Ionization current about 10nA



8.9 keV X-Rays collimated beam shot from the side
to be sure to have conversion only in the drift gap

Drift Current

X-Rays

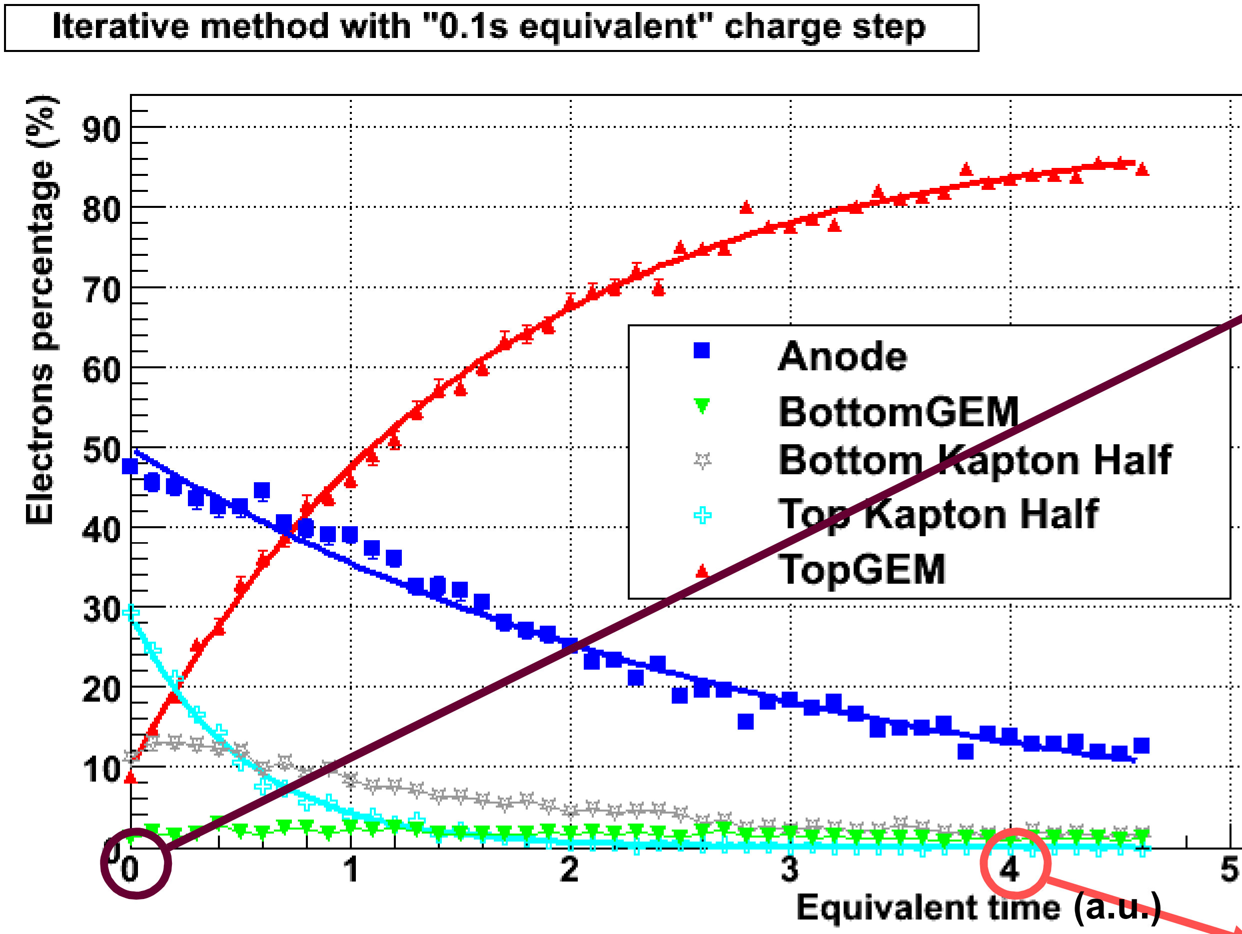
Top GEM Current

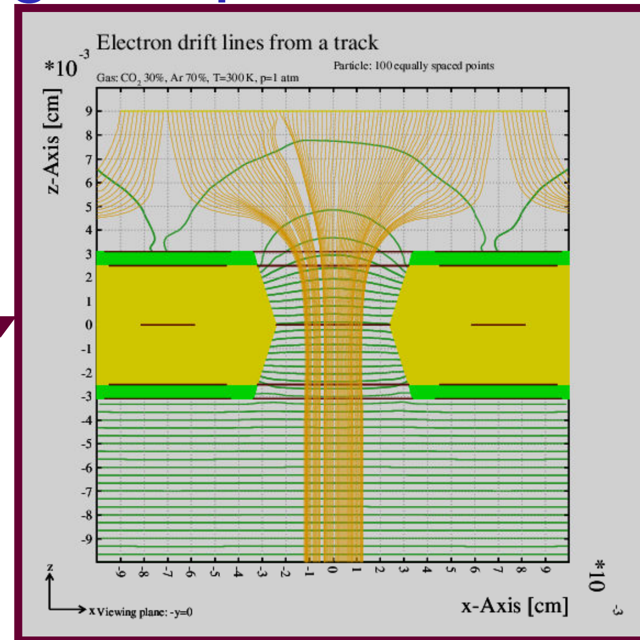
Bottom GEM Current

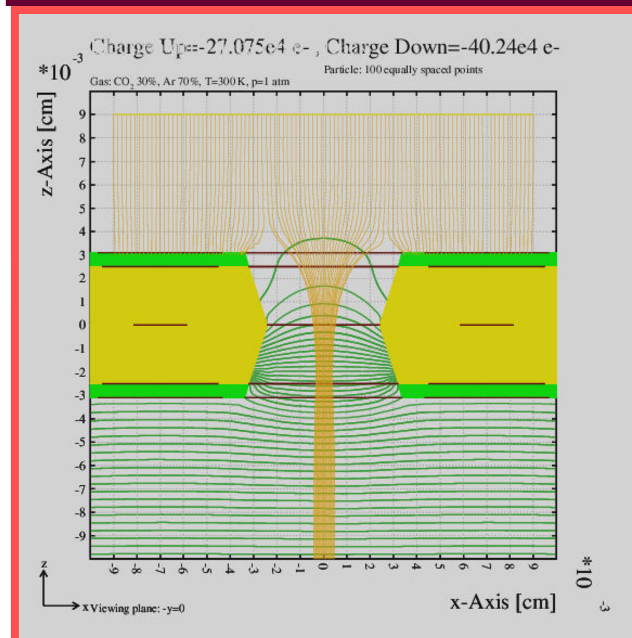
Anode Current

G. Croci et al: GEM Transparency Studies: electrons and ions measurements, 2nd RD51 Collaboration Meeting Paris 13-15 October

First "manual" iterative method simulation with "0.1s equivalent" charge step







Recent developments

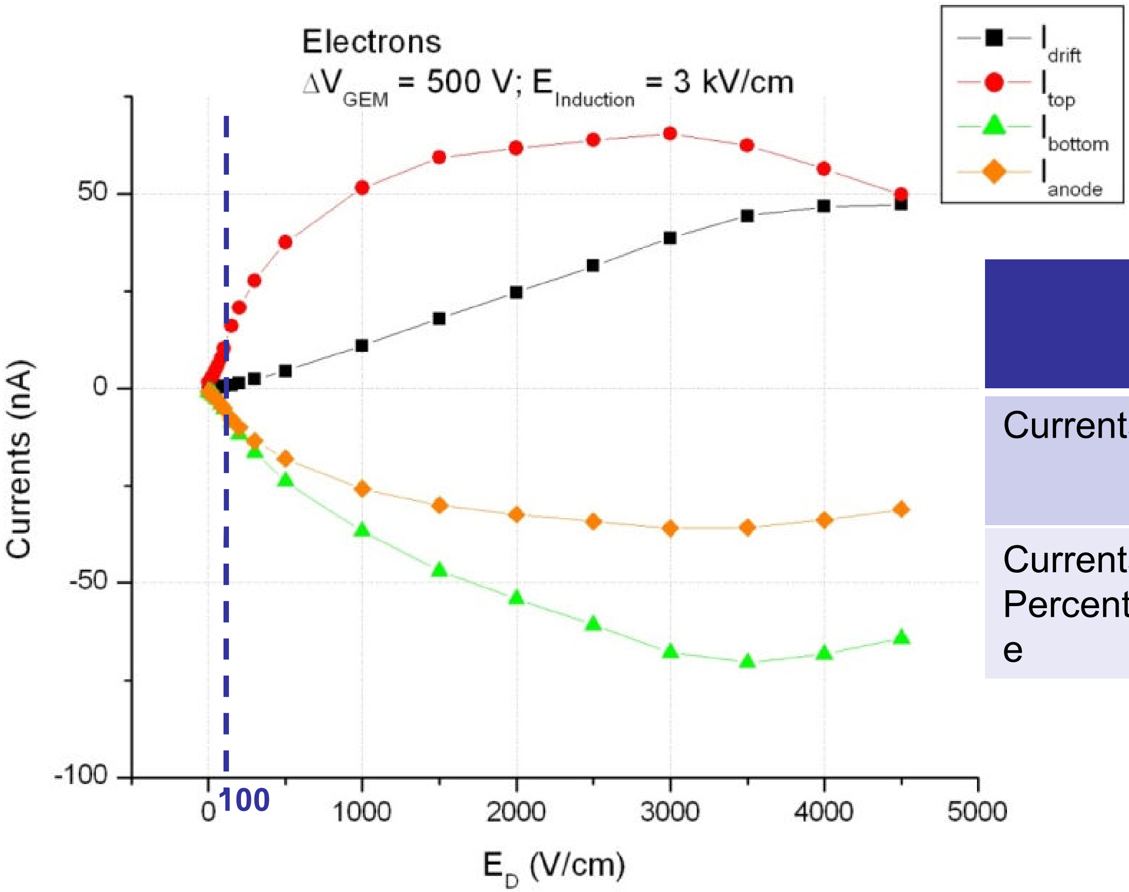
The simulation took about 2 weeks!!!!!!!

→ We managed to write a shell script that automatizes all the required steps and is submitted to lxbatch.cern.ch:

- Creates a map with no charges (Ansys) and converts it to Garfield
- Launches a Garfield script that starts 2000 e- 290 μm before the top GEM, executes the *microavalanche* procedure and writes an output file with x-end, y-end, z-end and t-end for each electron and ion in the simulation. To use multi-processor capability many Garfield sessions are started at the same time
- Starts a ROOT macro that analyzes the output file and computes the electrons/ions ending place percentage, the real gain and the effective gain (if any)
- Creates another Ansys macro applying to the kapton wall charges proportional to estimated percentages
- Reconverts the Ansys solution to Garfield map, starts another simulation of 2000 e- and continue

ΔV_{GEM}= 500 V: The measurements

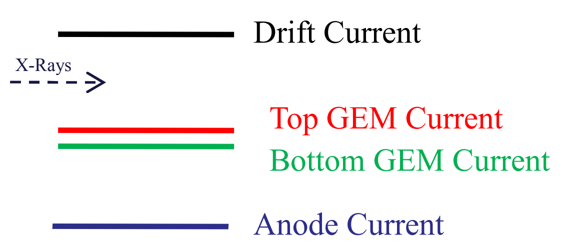
Drift Scan (current vs drift field)



Currents values @ Ed = 0.1 kV/cm

	I_{drift}	I_{top}	I_{bottom}	I_{anode}
Currents	0.7nA	10.4nA	-5.5nA	-5.5nA
Currents Percentage	I^+ 6.3%	I^+ 93.7%	e^- 50%	e^- 50%

G. Croci et al: GEM Transparency Studies: electrons and ions measurements,
2nd RD51 Collaboration Meeting Paris 13-15 October

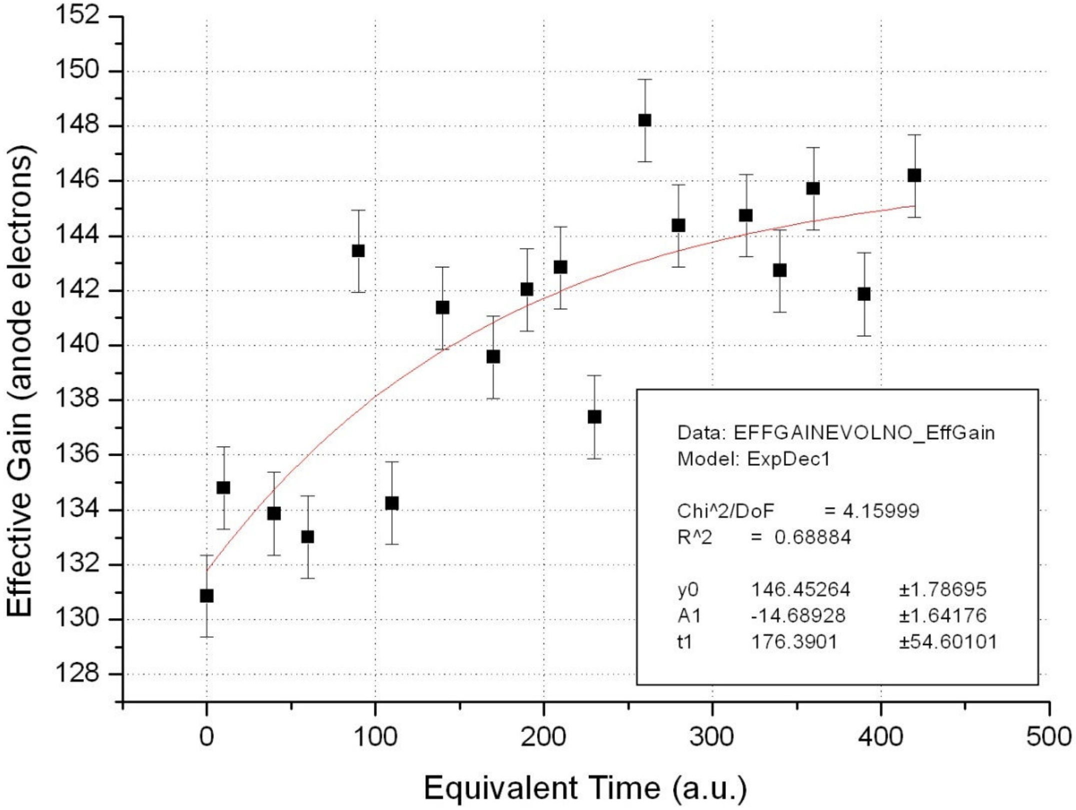


8.9 keV X-Rays collimated beam shot from the side to be sure to have conversion only in the drift gap

Gain Setup: Simulation Started

Preliminary Results on simulation of gain setup:

- The currents distribution seems to be correct
- The gain is still too low even if it seems to increase



SUMMARY

Simulation of Micromegas and Micromegas Mesh Transparency

K. Nikolopoulos[1,2], V. Chernyatin[2],
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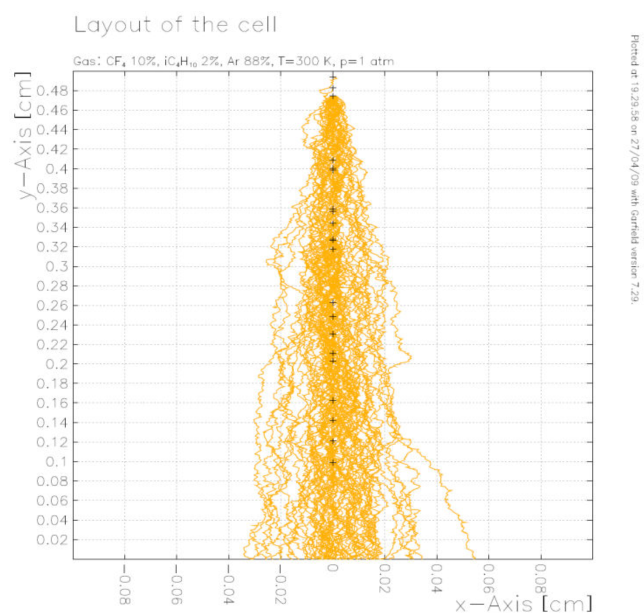
[1]University of Athens
[2]Brookhaven National Laboratory

RD51 meeting - WG4 Simulation
16th June 2009



Micromegas Simulation

Parameter	Value
Gas	Ar 88% CF_4 10% C_4H_{10} 2%
Drift Gap	5 mm
E_{Drift}	220 V/cm
Gain	$5 \cdot 10^3$
t_{ion}	200 ns
$\sigma_{Amplitude}$	$2 \cdot 10^3$ e
Strip-to-Strip Cross-Talk	2%
Shaper t_{peak}	200 ns

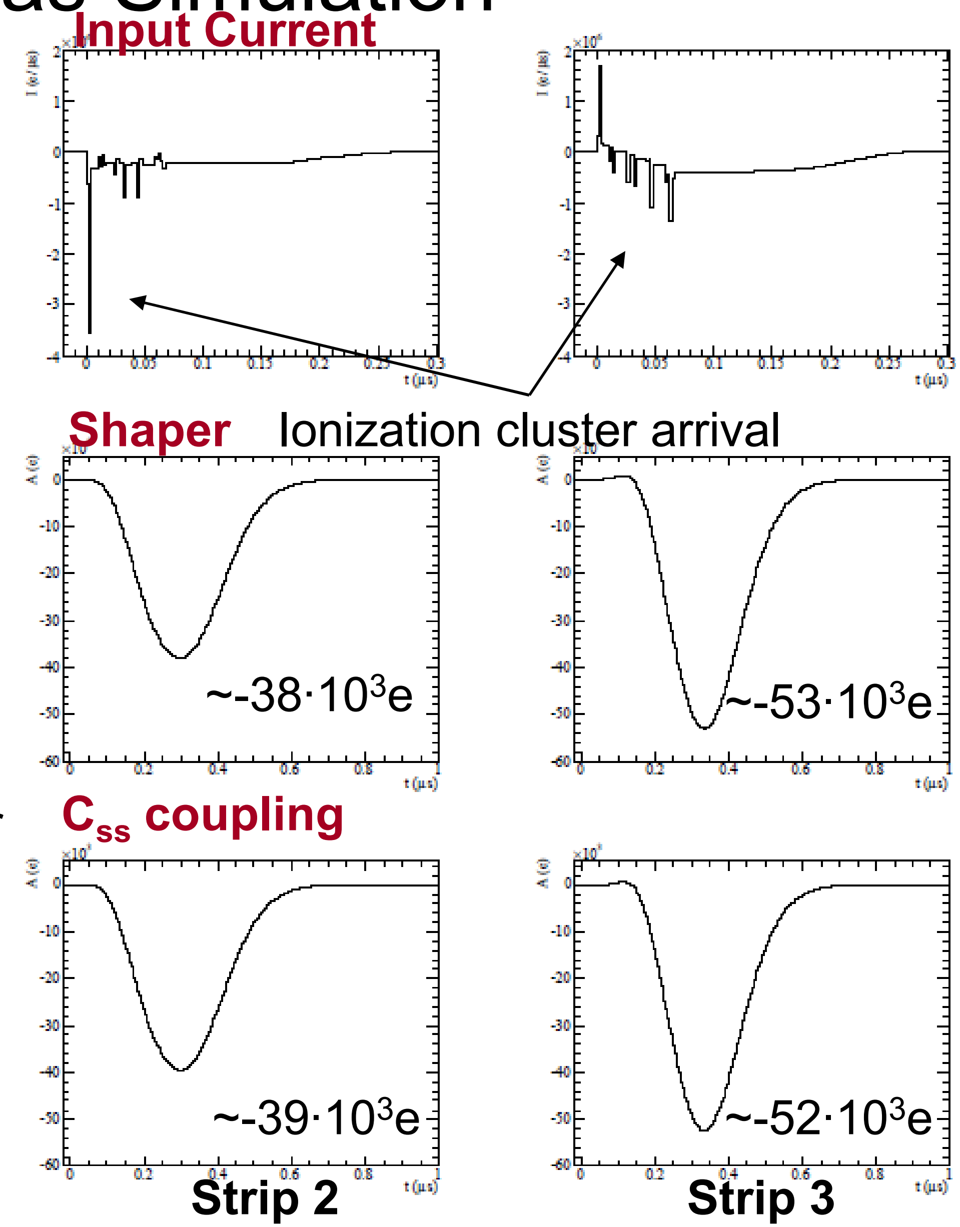
GARFIELD/HEED/MAGBOLTZ

for electron production/drift.

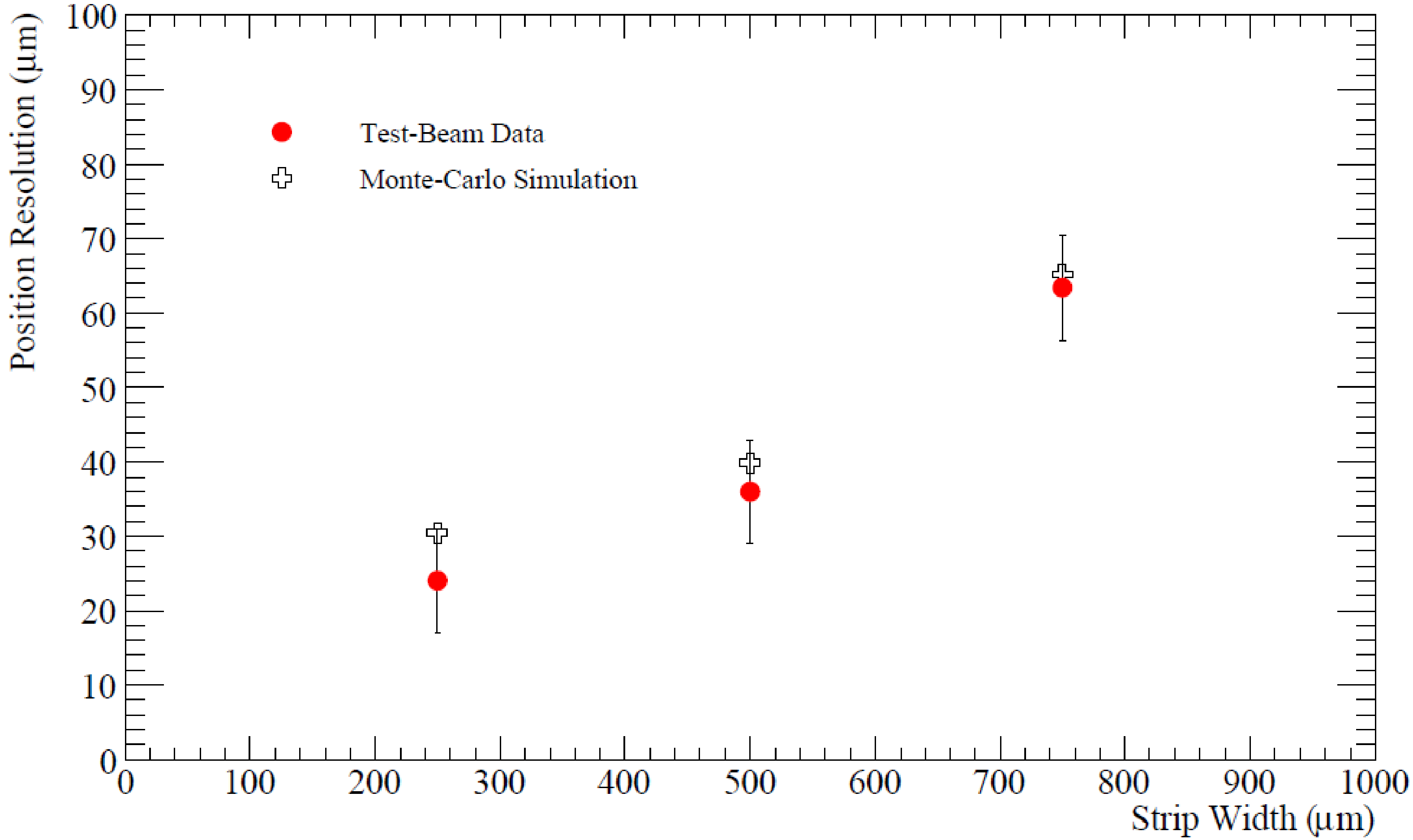
Mathieson's semi-analytical approach for

ion induced charge / include shaper /

electronic noise e.t.c

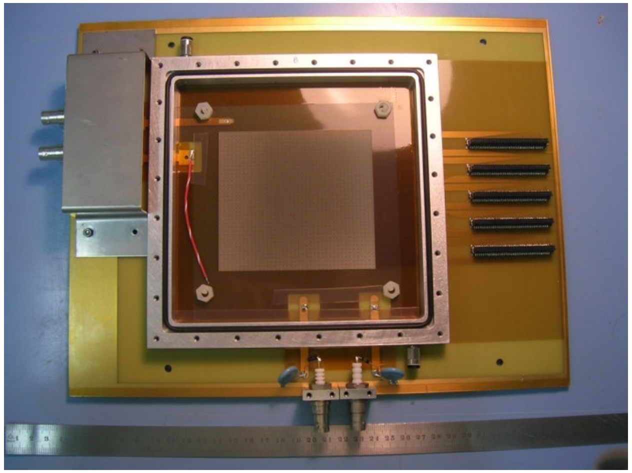


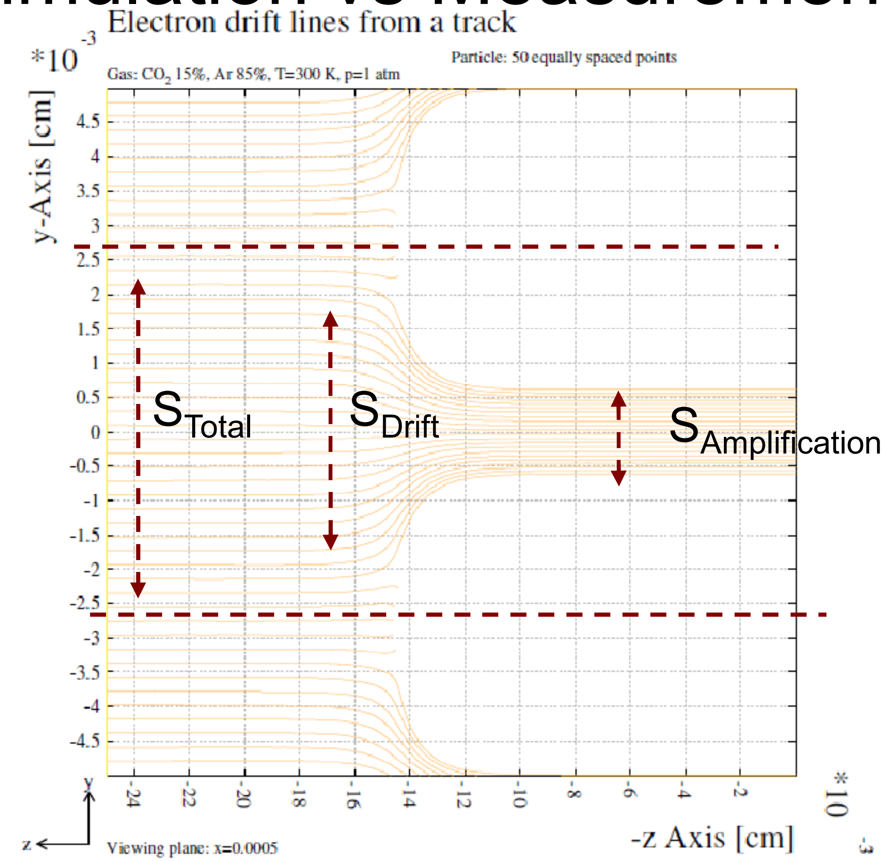
Simulation Comparison with Test-Beam Data



Comparison of **Test-Beam data** resolution with **simulation** for three different strip sizes → agreement observed

Electron Transparency : Simulation vs Measurements





Basic chamber characteristics:

- "T2K" mesh

450 line/inch = 56.4 µm pitch (calendered)

18 µm wire diameter

128 µm amplification gap

Segmented mesh

- Drift distance = 4.5 mm
- Ar 85% CO_2 15%

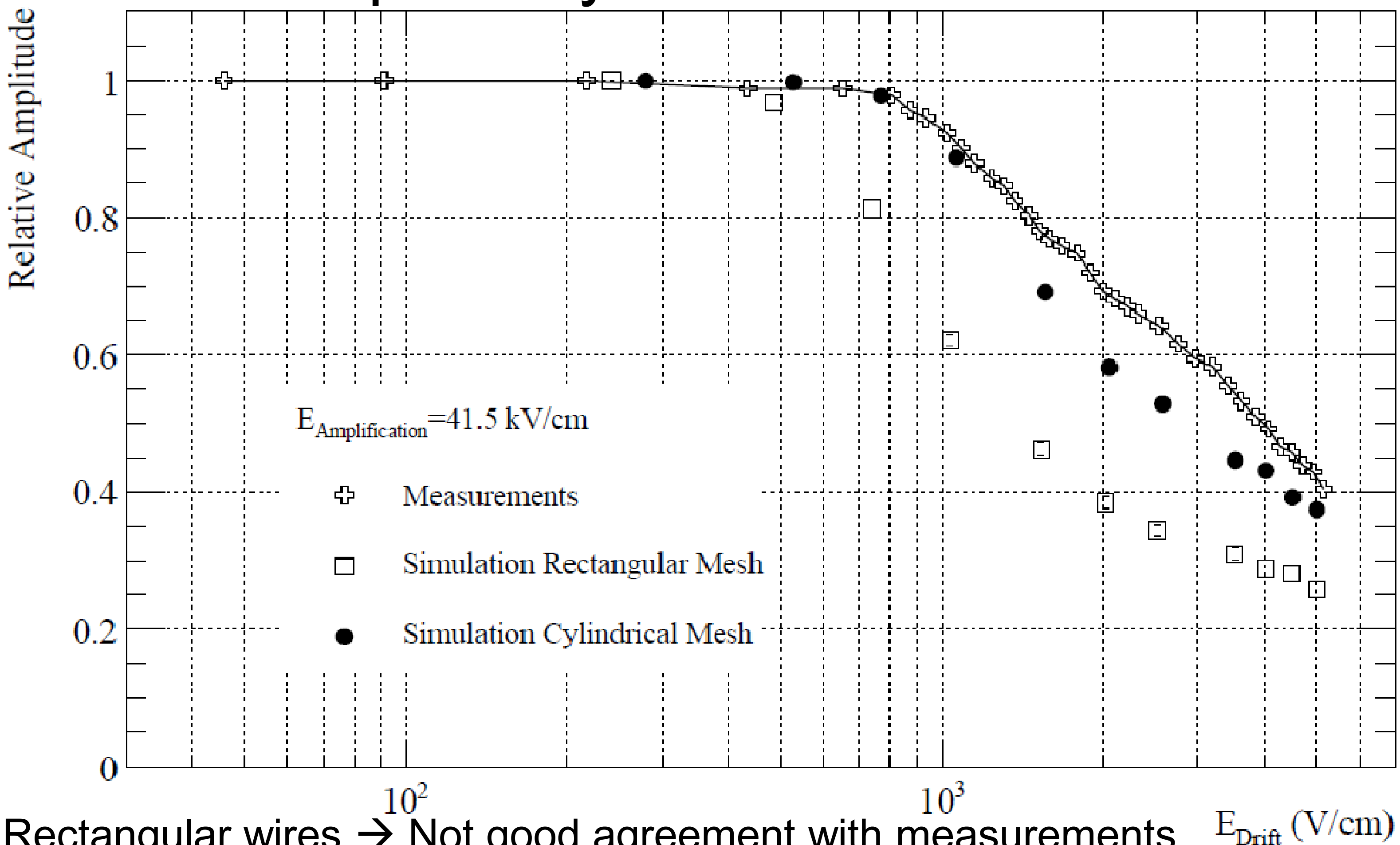
$$P(\text{e-collection}) = S_{Drift} / S_{Total}$$

$$= S_{Amplification} \times \text{Field-Ratio} / S_{Total}$$

$\sim$ (hole diameter)^2 $\sim$ (wires pitch)^2

Ignores diffusion/attachment/details of mesh geometry

Electron Transparency : Simulation vs Measurements

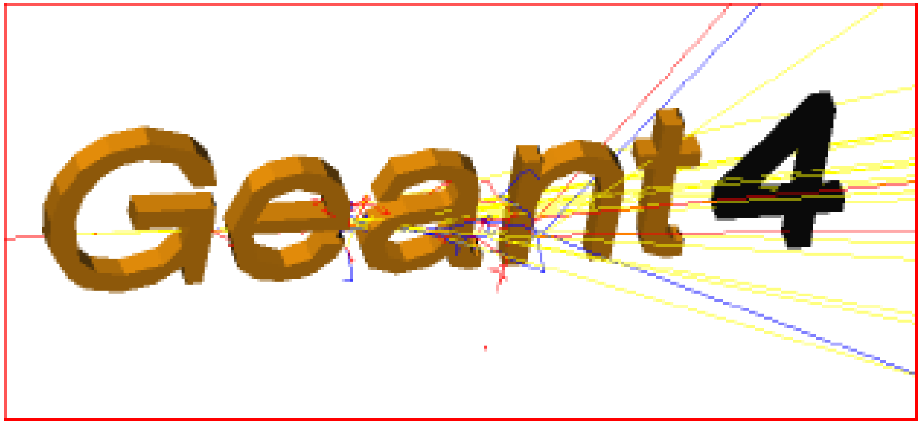


Rectangular wires → Not good agreement with measurements

Cylindrical wires → Much better agreement.

- Efficiency decrease starts at same drift field with the data (E_a/E_d ~ 55)
- Predicted efficiency in the falling slope within 10% from the measurement

What is Geant4?



"**Geant4** is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science." – *Geant4 website*

Strengths:

- Detector Construction/Geometry
- Visualization
- Accessibility
- Lots of built in features

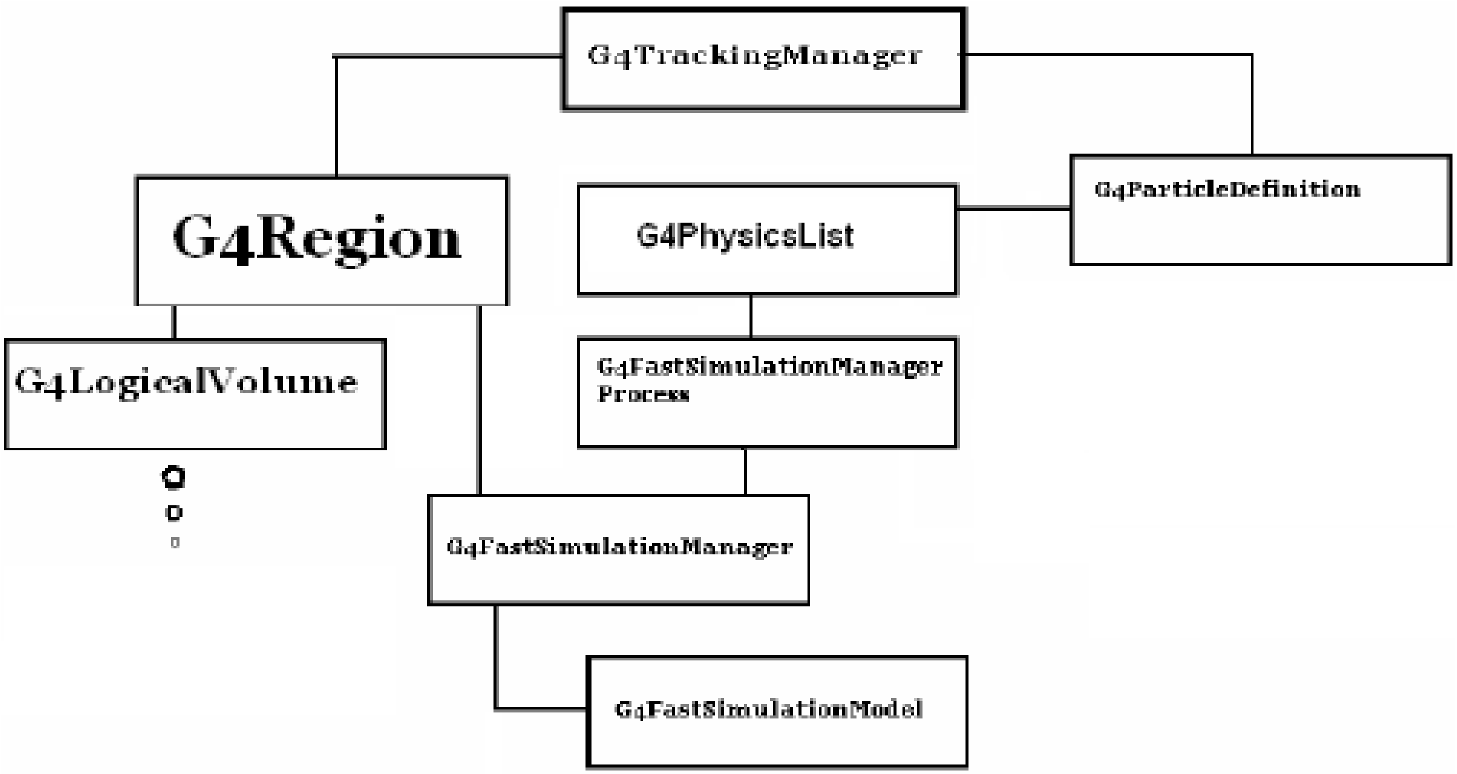
Weaknesses:

- Transport through Gases
  - Accuracy
  - Speed
- Limited support for EM fields
  - Only uniform fields or user entered field maps

Weaknesses severely limit simulations of gas detectors!

Geant4 Parameterization Framework

"The Geant4 parameterization facilities allow you to shortcut the detailed tracking in a given volume and for given particle types in order for you to provide your own implementation of the physics and of the detector response." – *Geant4 Application Developers Guide*



Geant4 Parameterization Framework

- To implement parameterization need to define concrete instance of abstract class G4VFastSimulationModel:
- Define 3 pure virtual functions:
  - void DoIt(G4FastTrack&, G4FastStep&)
  - bool isApplicable(const G4ParticleDefinition&)
  - bool ModelTrigger(const G4FastTrack&)

G4FastSimulationModel: GarfieldModel

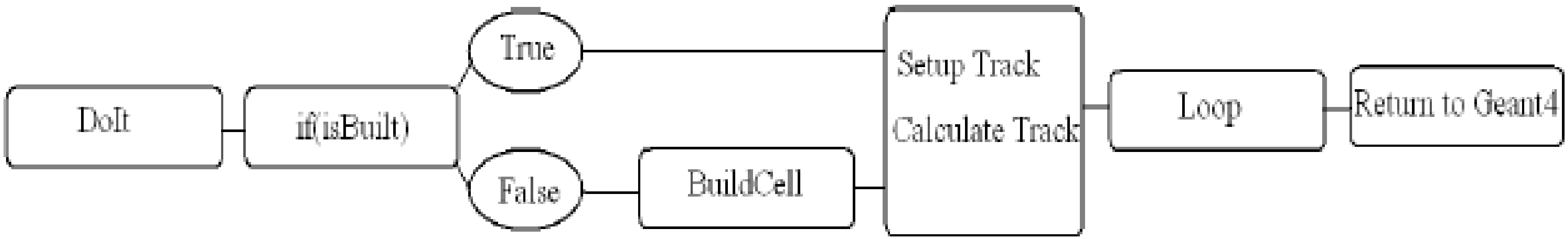
GarfieldModel Class Definition:

- Declares Members:
  - *Cell * cell*
  - *DriftLine * dl*
  - *Gas * gas*
  - *Track * track*
  - *G4PolyLine* electronPaths*

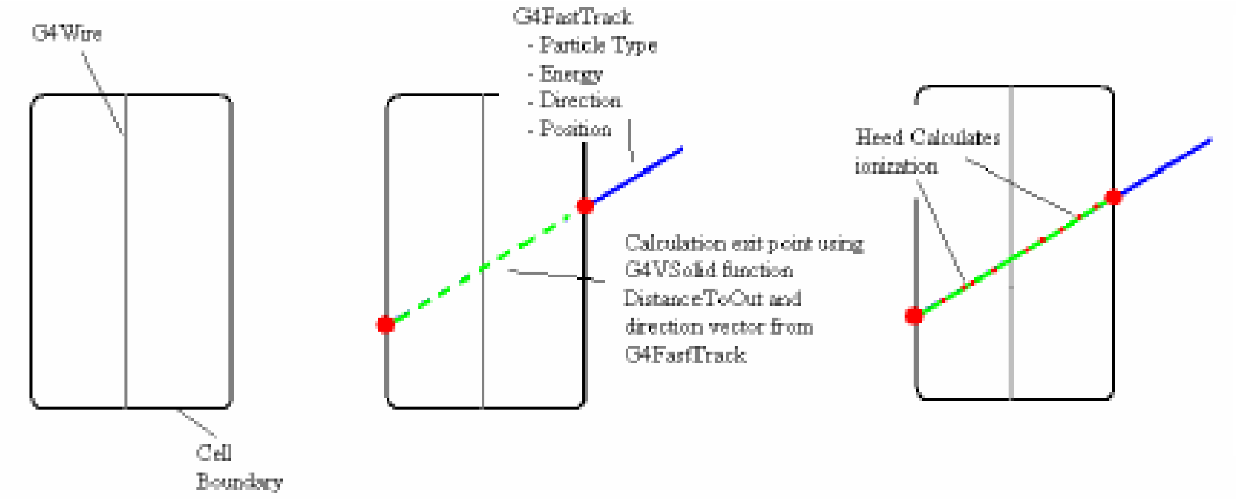
- Member Functions:
  - Constructors
  - *void BuildCell()*
  - Get methods
  - Virtual Functions
    - *bool isApplicable*
    - *bool ModelTrigger*
    - *void DoIt*

G4FastSimulationModel: GarfieldModel

The DoIt Member Function Flow Chart:

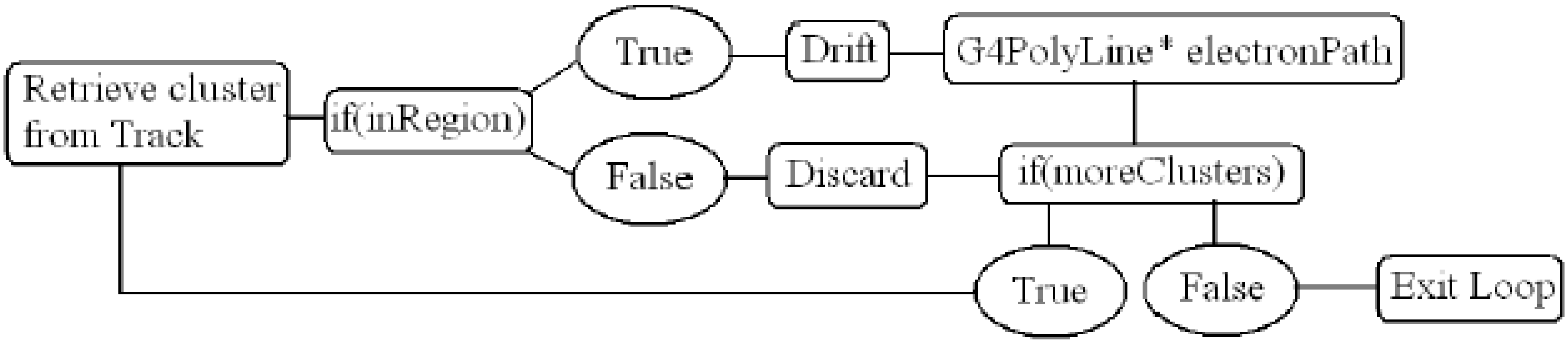


The DoIt Member Function Pictorial Representation:

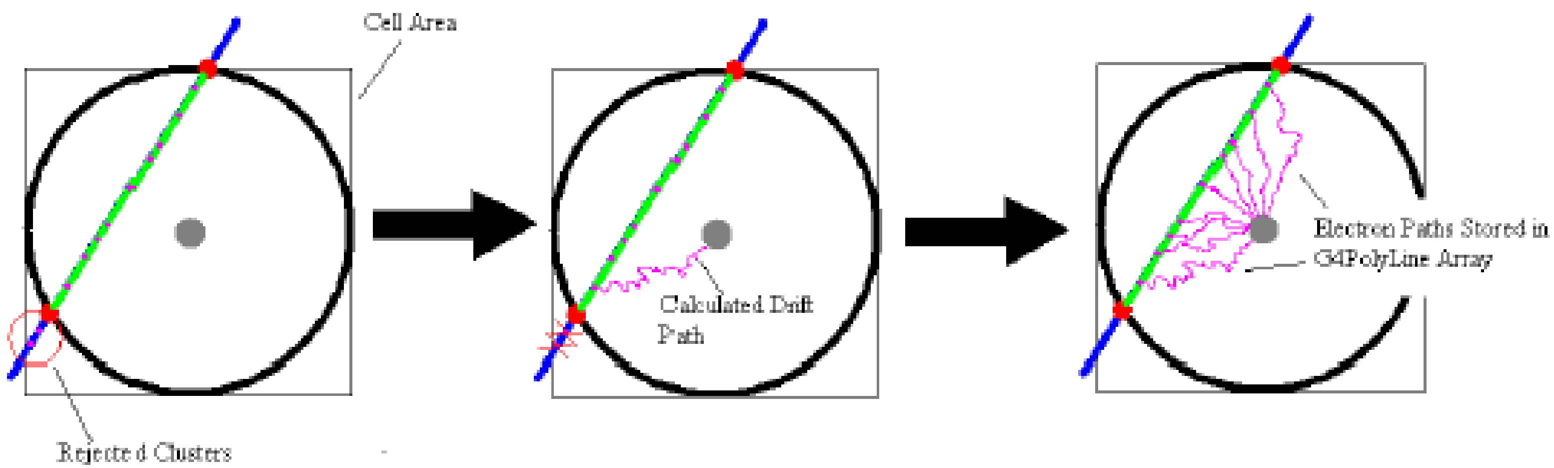


G4FastSimulationModel: GarfieldModel

The DoIt Member Function Loop:



The DoIt Member Function Loop Pictorial Representation:



Conclusion and Future Work:

- Interface between Geant4 and Garfield Successful
  - Can run Garfield Simulation in Geant4 and exchange information
- Basic interface complete however Garfield has many more features
  - More ionization models
  - FEA field maps
  - Magnetic fields
  - Signal Calculations

neBEM Status

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3rd RD 51 Collaboration meeting
June 16-17, 2009
OAC, Kolympari, Crete, Greece

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neBEM as a toolkit

It is now easier to use, interface and integrate neBEM

Stand-alone
A driver routine
An interface routine
Post-processing, if necessary

Garfield
Garfield prompt
Garfield script

ROOT
ROOT prompt
ROOT script
py-ROOT script

Charge density at all the interfaces

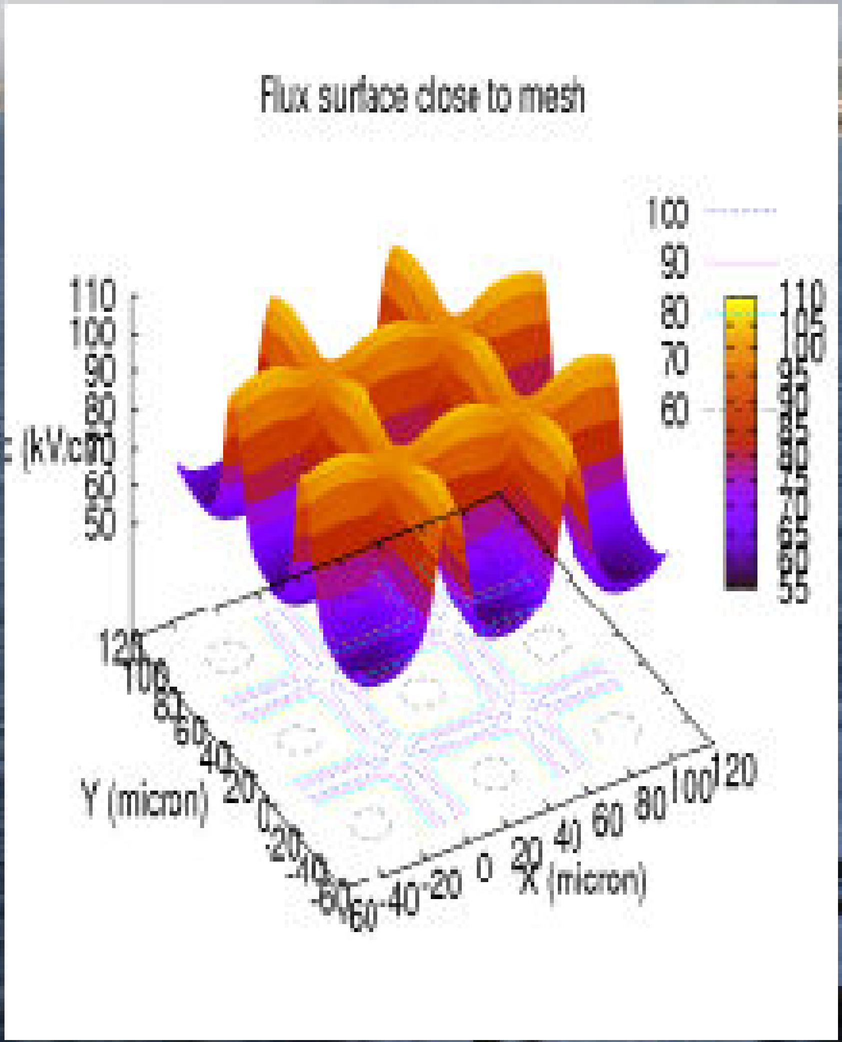
Potential at any arbitrary point

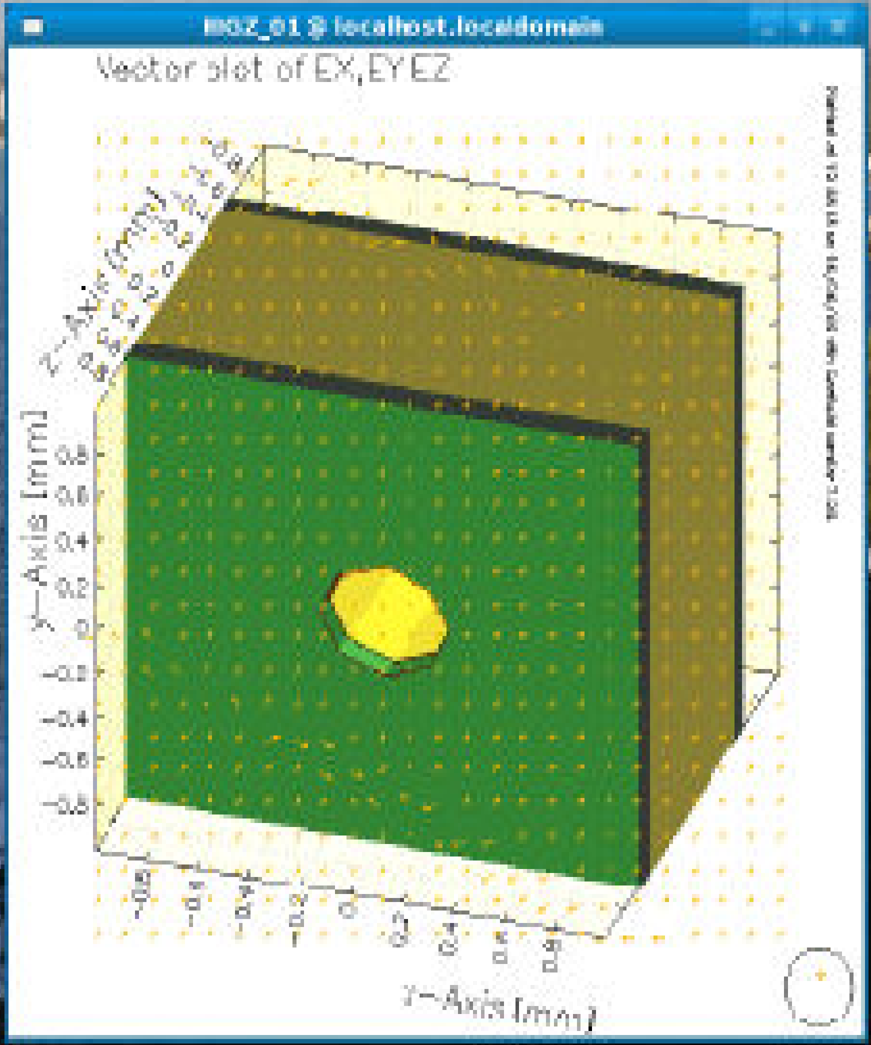
Flux at any arbitrary point

Capacitance, forces on device components properties can be obtained by post-processing

Other interfaces can also be developed easily – specially exciting could be experimental and CAD interfaces

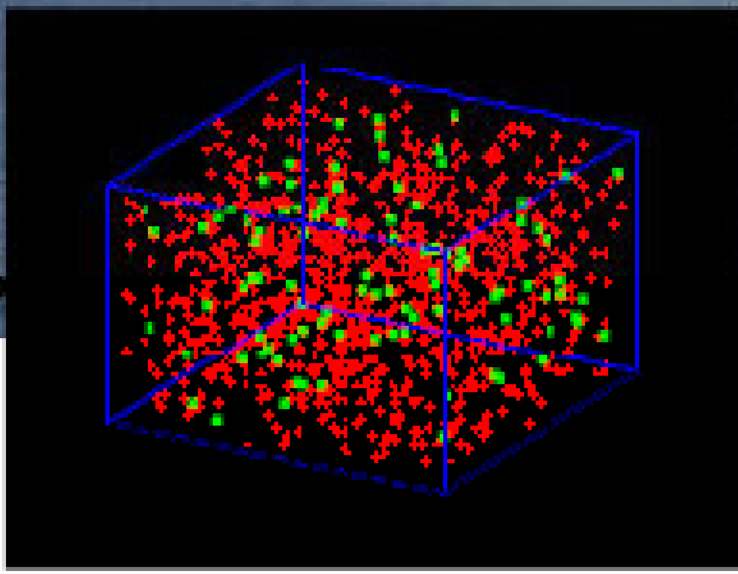
neBEM as a toolkit – stand alone and with Garfield



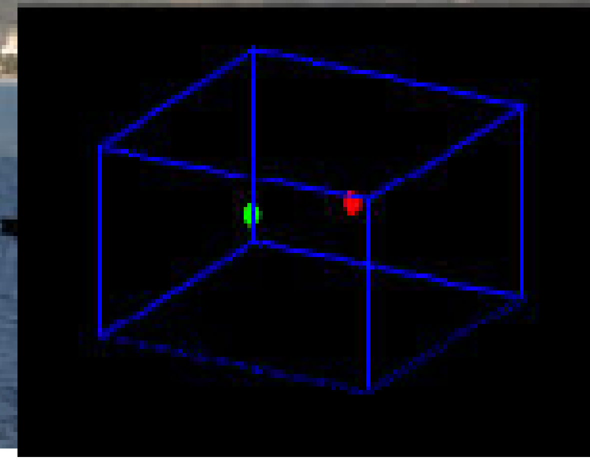


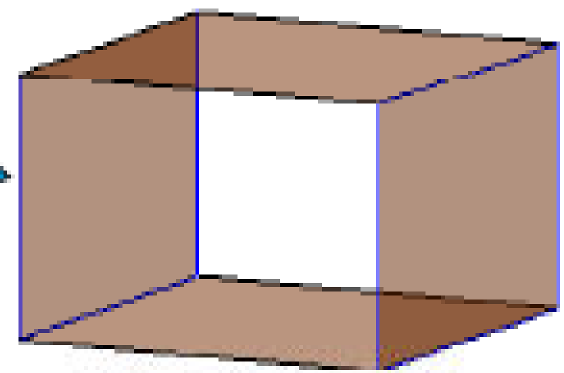
Particles on Surface (ParSue)

An improved model to represent space charge



PIC





Possible through the use of neBEM formalism

Charging dynamics, magnetostatics

These are some of the other areas that could prove useful and need attention

Charging dynamics can be modeled using a quasi-static approach

Magnetostatics should be an easy extension of the existing formulation

We hope to report some advancement in the next collaboration meeting, especially on the former

Conclusions and future plans

- neBEM is expected to provide us with one of the important missing pieces in the projected simulation framework
- Written in a toolkit fashion, it is available for users to be used in a stand-alone fashion, or interfaced / integrated with other codes
- Periodicity has been included – other efficiency issues need to be resolved
- Dynamics charging is an issue that can be tackled using the same formulation in a quasi-static fashion - needs lot of work though
- Space charge can be modeled in a more accurate fashion using ParSue – proof-of-concept seems to be successful. Needs implementation
- Magnetostatics is another aspect that should be easily tackled using a similar formulation
- Documentation is in a very bad shape – we plan to put good effort into this within the coming couple of weeks
- User feed-backs will be essential in further improvements

Development of a General Framework for MCs of MPGD

Purpose: Development one complete framework containing all ingredients for simulations of MPGDs

Why?

- All pieces are put together in one piece → makes things clear, makes it easy to use.
- Should used in general, everybody knows the contents and the setup → saves discussions about contents of personal MCs and double work, results can be compared more easily.
- Better to understand for outsiders, should be compatible with current and future MCs for CERN experiments

Framework Contents

-A charged particle travelling through a gas all (user defined) processes included, output: (x,y,z,px,py,pz) electrons+photons

-Drifting of electrons + (new) E-field calculation + proper treatment of insulators + charge up effect + impurities insulator

-Avalanche statistics

-Signal development (kind of ions + signal dist. at readout pads)

-Special studies: Discharge, electron emission foil, charge up, Rate effects, TwinGrids, effects hot electrons (up to 100 eV) in materials

-In ROOT?, need for supervision?

Some of the current activities

- Photon from excitations via excimers
- Penning transfer measurement
- GEM transparency with charge-up
- Micromegas pad response and transparency
- Gas simulation in Geant 4
- Nearly exact boundary element method
- Framework