MHSP, MSGC and GEM

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10th RD51 Collaboration Meeting, 30th September – 5th October, 2012, Stony Brook University, New York

Numerical Simulation of MPGDs

Current Activities

Garfield+neBEM+Magboltz+Heed

- ***Simulation of the performance of MHSP with realistic dimensions***

- ***Investigation of variation of electric field due to change in various physical dimensions of detector***

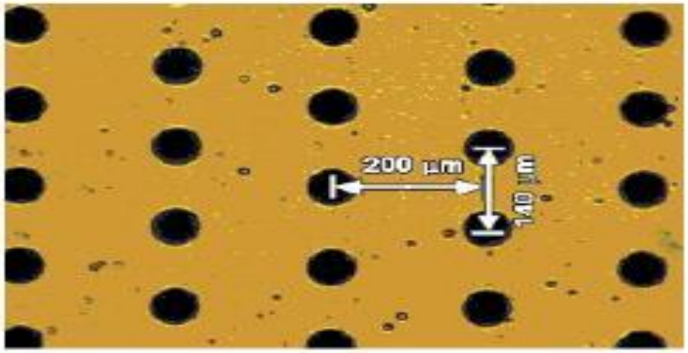
- ***Estimation of different detector characteristics: detector gain, transparency, efficiency etc.***

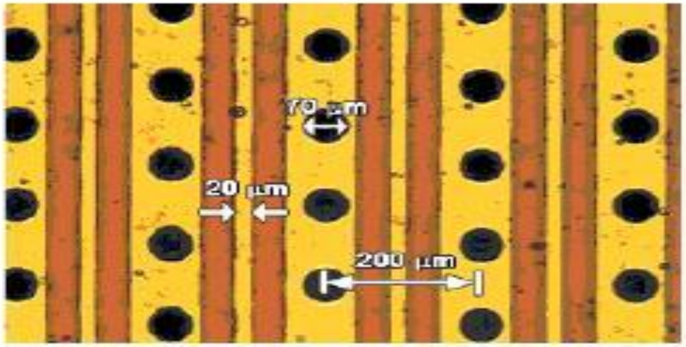
- ***A comprehensive comparison between GEM and MSGC having similar geometrical and material features***

- ***Comparison of present numerical estimates with existing experimental and simulation results***

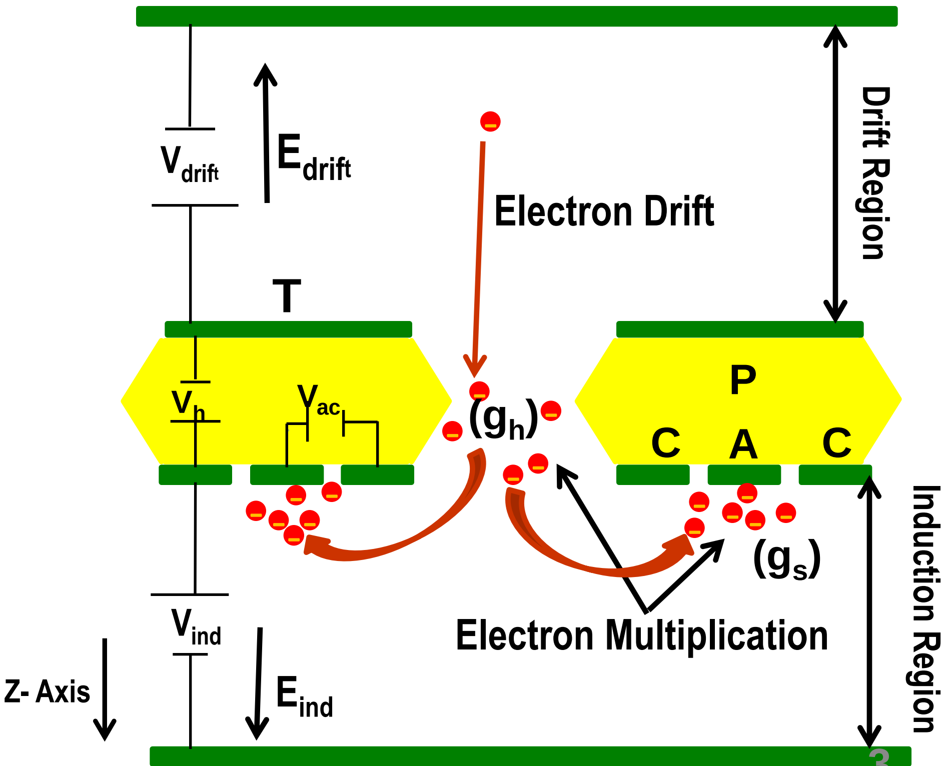
MICRO HOLE STRIP PLATE

- *Merges the Micro Strip Gas Counter (MSGC) and GEM characteristics in single plate*
- *Provides two independent charge amplification stages – slotted hole, operated as GEM and Micro Strip anode*
- *Electric Field inside holes are high – 1st charge amplification*
- *Electrons emerging from holes deflect towards anodes – 2nd amplification*





MHSP electron multiplier – top and back surface



Operating Principle of MHSP

Procedure

Using GARFIELD define a typical cell structure →

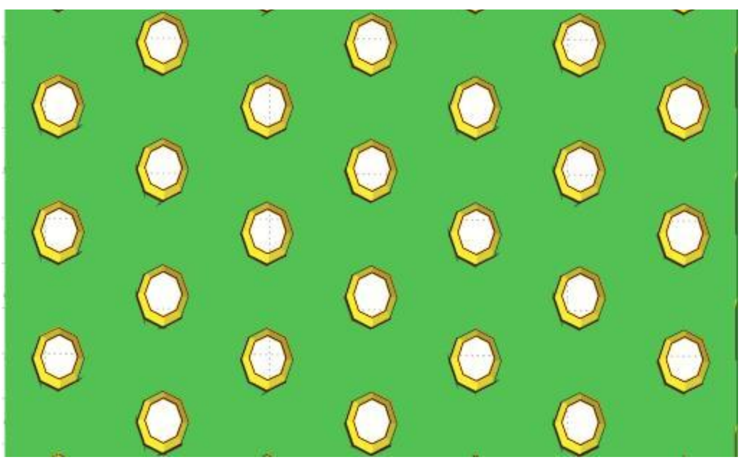
- 50 μm thick Kapton film with 5 μm copper layer on both sides
- Microstrip pattern : 175 μm pitch ;
- Anode widths : 15 μm ; Cathode widths : 100 μm ;
- Anode - cathode gap : 30 μm

- Bi-conical hole of diameter 70 μm (in copper layer) & 50 μm (in Kapton film)

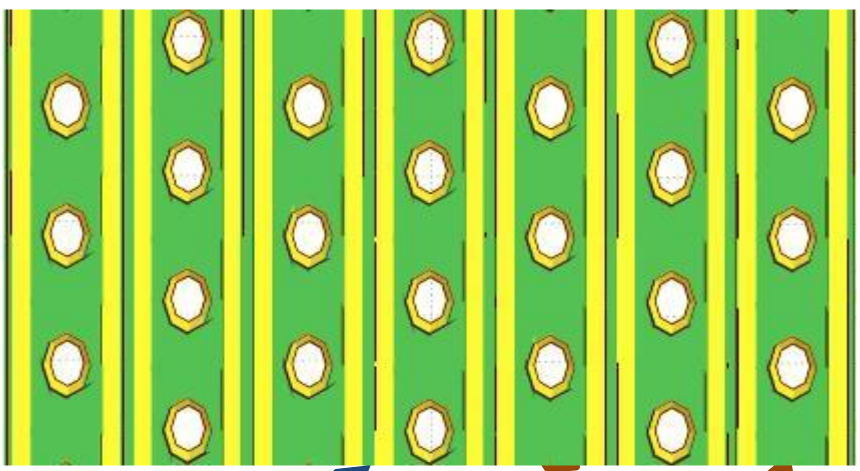
- Drift electrode at a distance of 2.5 mm from front surface of MHSP (not shown in figure).
- Induction plane at a distance of 2 mm from back surface of MHSP (not shown in figure)

- Drift electrode and induction plane – negatively biased w.r.t. MHSP

Front Surface of MHSP



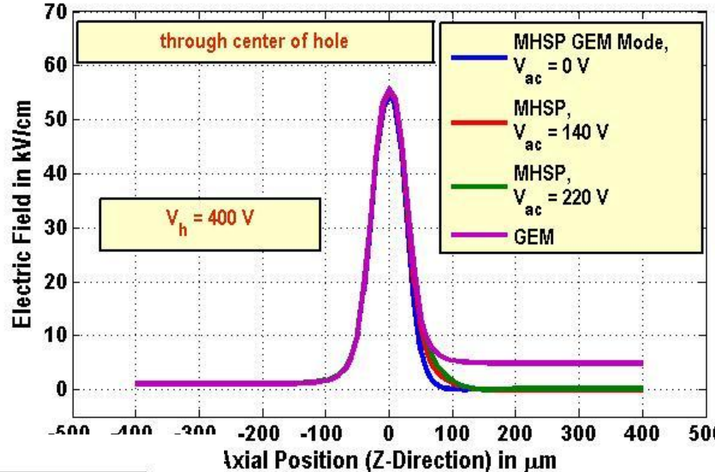
Back Surface of MHSP



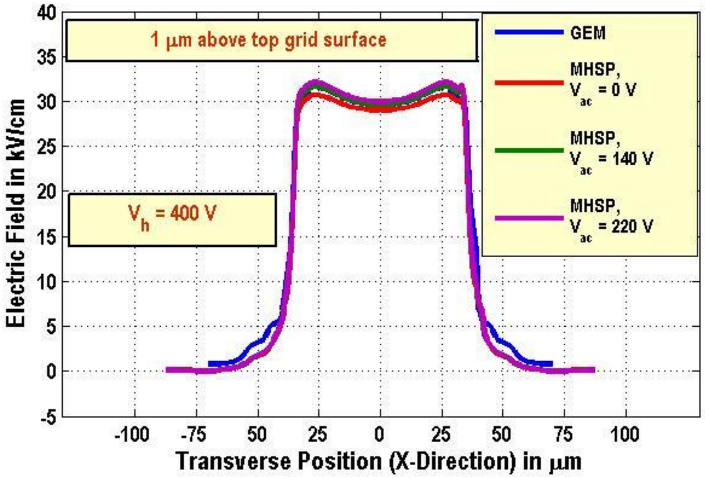
Anode Strips

Cathode Strips

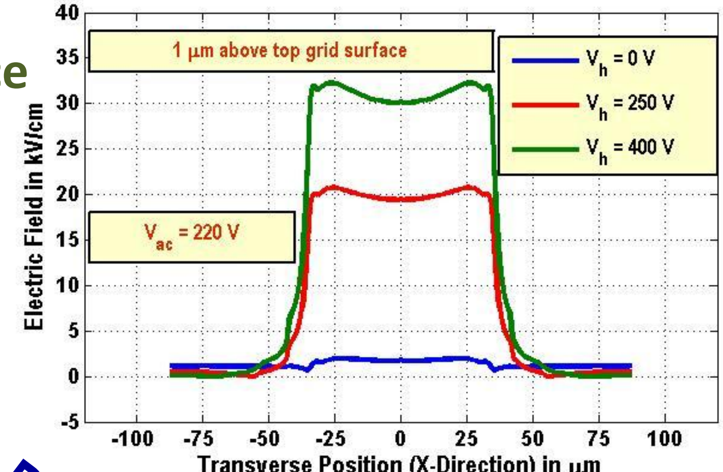
neBEM to calculate Electric Field



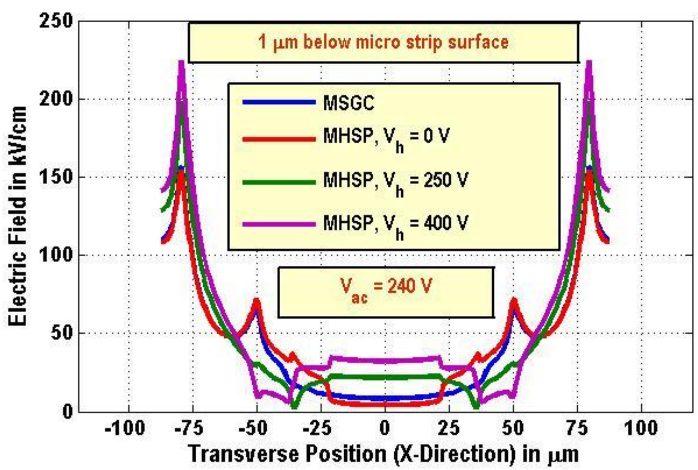
In Axial Direction



Top Grid Surface

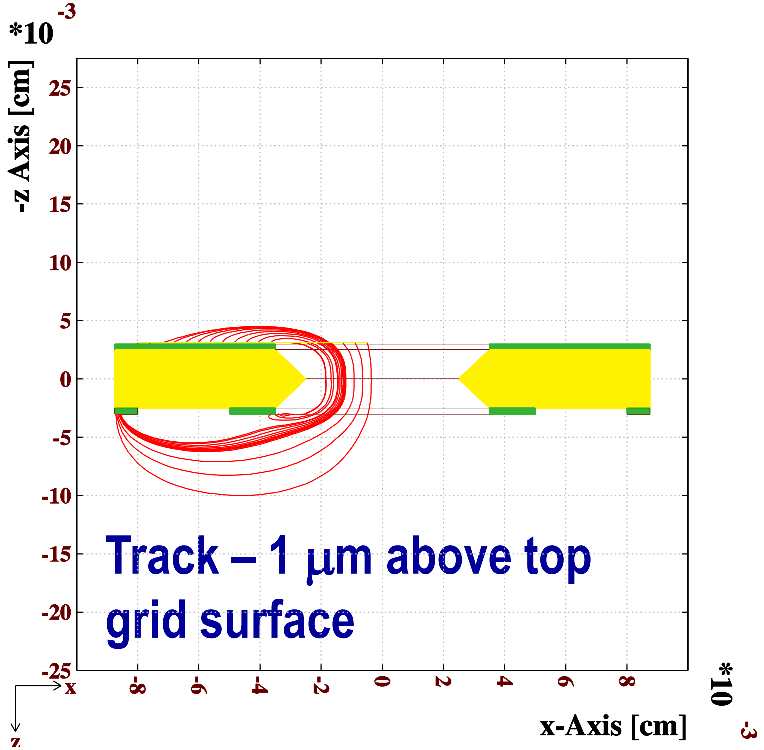


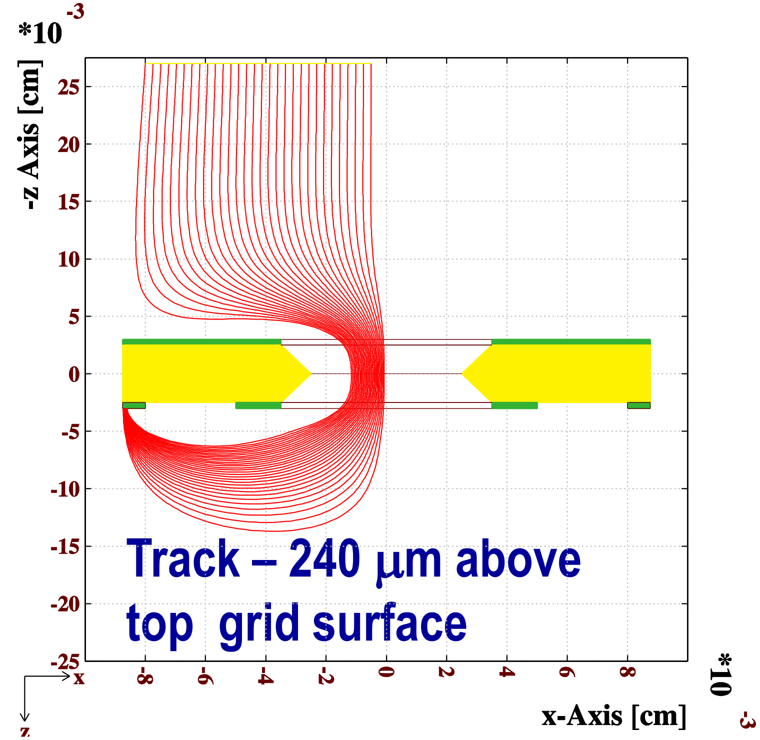
In Transverse Direction



Bottom Micro Strip Surface

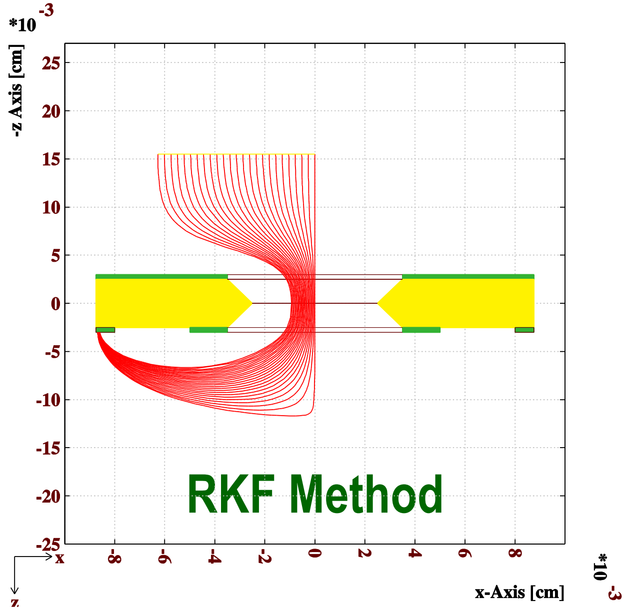
Electron Drift Lines (Gas: Argon70% + CO_2 30%, Temp.: 293 K, Pressure: 1 Atm)

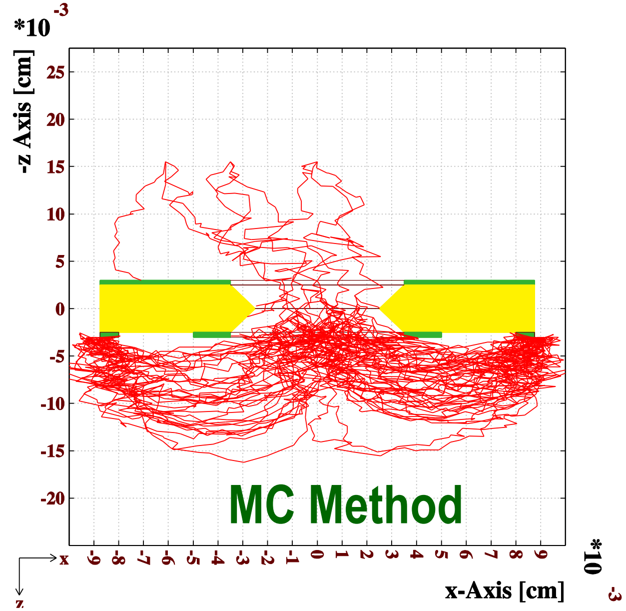




- Electrons near the MHSP top grid surface behave quite differently than electrons of the middle of drift region
- Electron collection efficiency of anode and multiplication factor of these two sets of electrons differ
- Radiation liberates primary electrons in different part of drift region
- For a correct estimation of detector gain, electrons from different drift region should be considered

Electron Drift Lines (Gas : Argon70% + CO_2 30%, Temp.: 293 K, Pressure : 1 Atm)





- **RKF Method: Diffusion is ignored and electrons follow the lines of electric field flux**
- **MC Method: Diffusion is considered**
- **Due to diffusion, loss of electrons on different electrodes increases**

Calculation of Gain: ε_{prim} x g_{mult} x ε_{sec} , where

ε_{prim} - *primary electron collection efficiency*

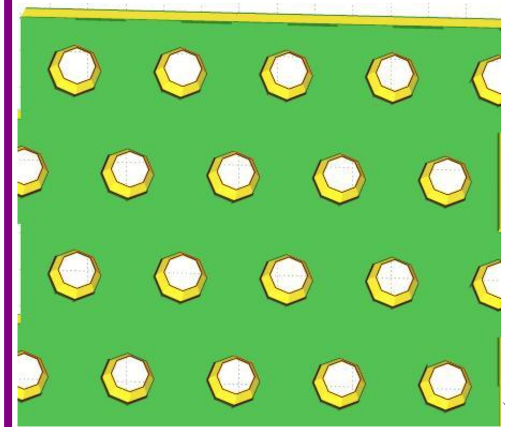
g_{mult} – *multiplication factor of the electrons throughout their trajectories*

ε_{sec} - *secondary electron collection efficiency*

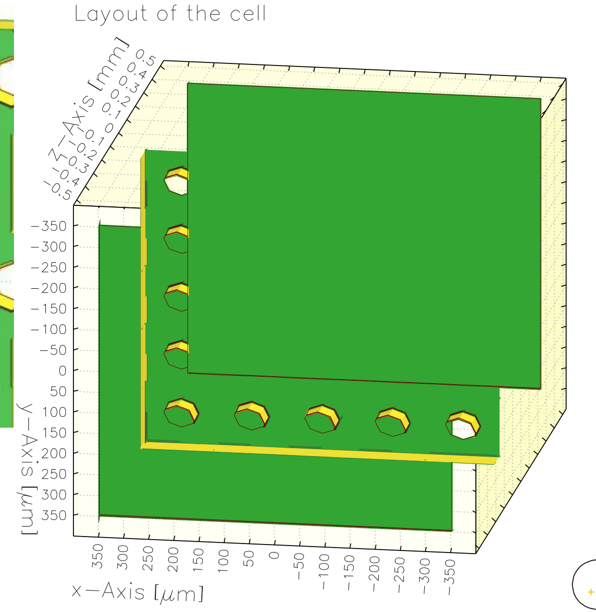
Gas Electron Multiplier (GEM)

Model using GARFIELD

- *50 μm kapton foil, double sided copper coated (5 μm thickness)*
- *Bi-conical holes (70 μm in copper layer, 50 μm in kapton layer)*
- *A drift plane and a readout electrode*



Cell Structure

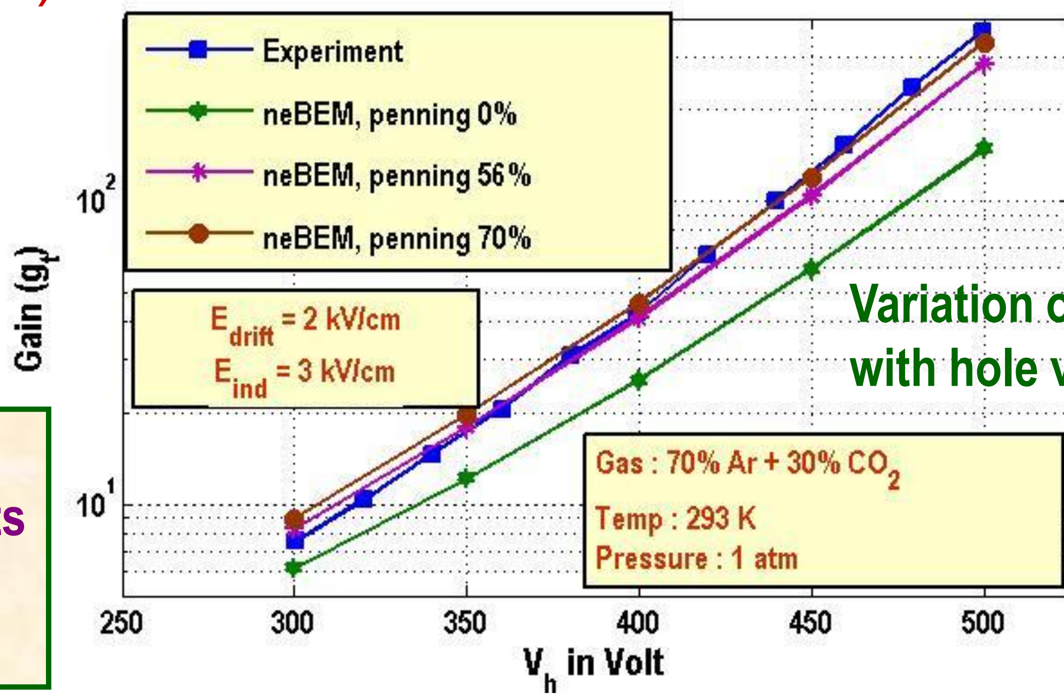


(Expt. Ref. Ph.D Thesis of G. Croci)

Penning 56% - Extrapolated value from Ref. JINST 5 P05002

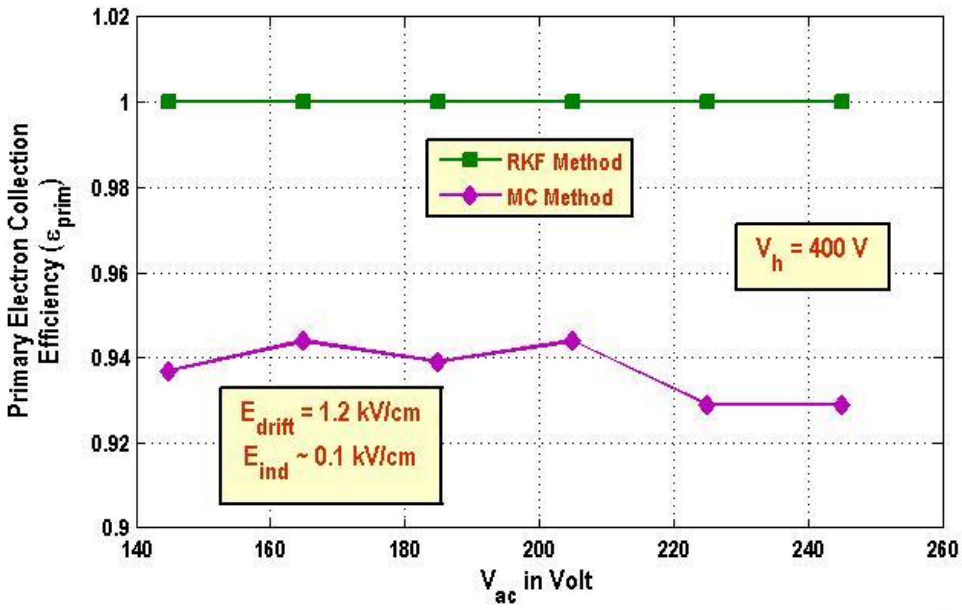
Penning 70% - Guess work

With higher values of Penning transfer rate, simulation results agree quite well with experimental data.

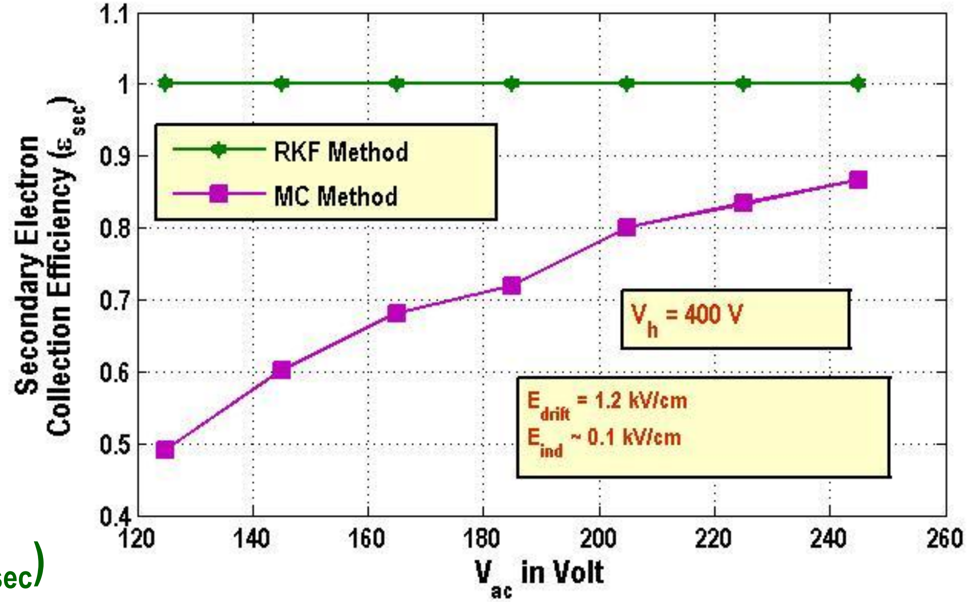


Variation of gain with hole voltage

Variation with anode to cathode strip voltage



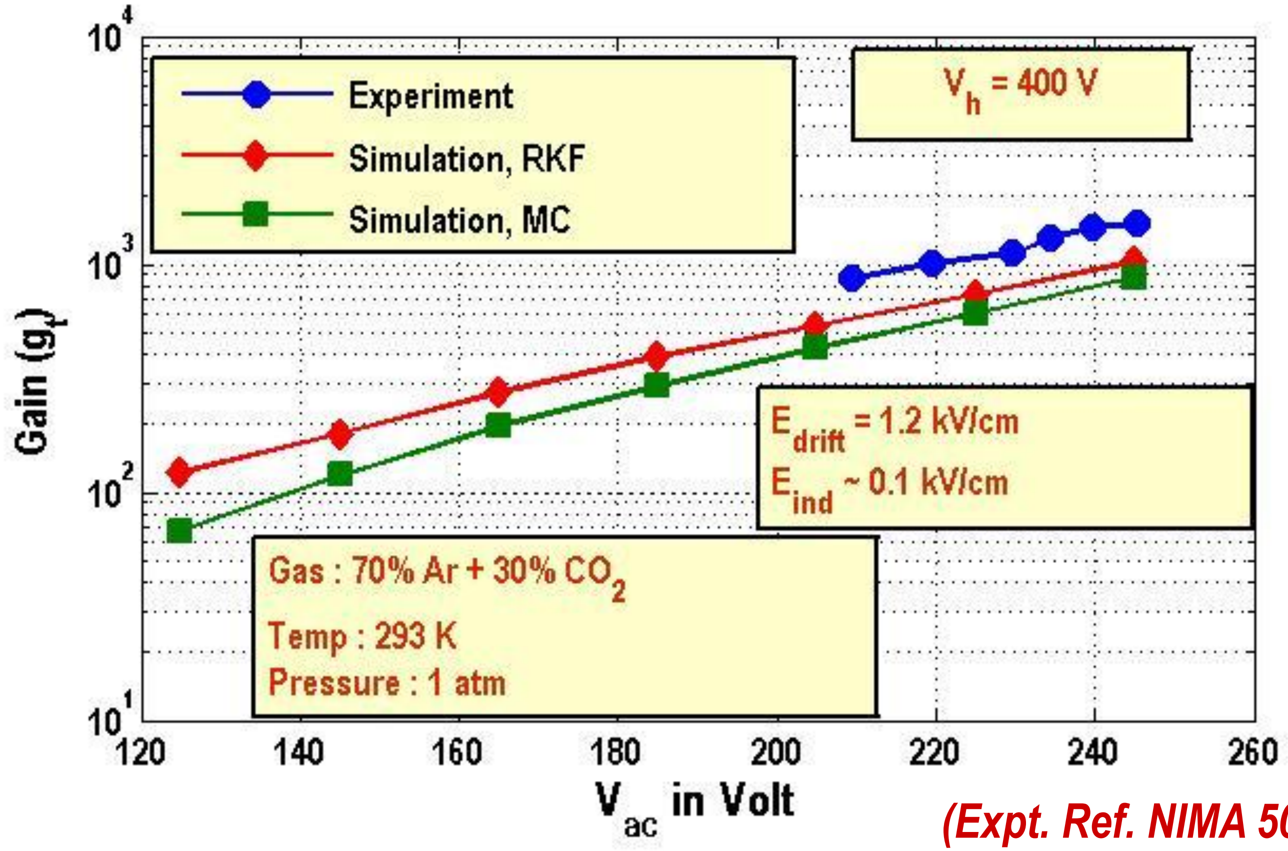
Primary Electron Collection Efficiency (ε_{prim})



Secondary Electron Collection Efficiency (ε_{sec})

MC method yields a smaller efficiency than RKF

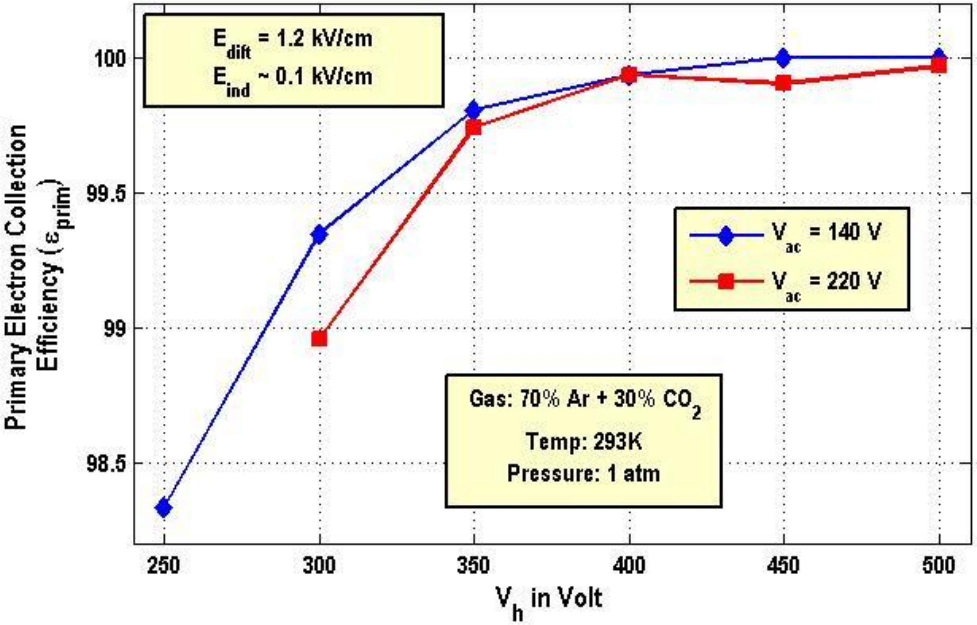
Variation with anode to cathode voltage



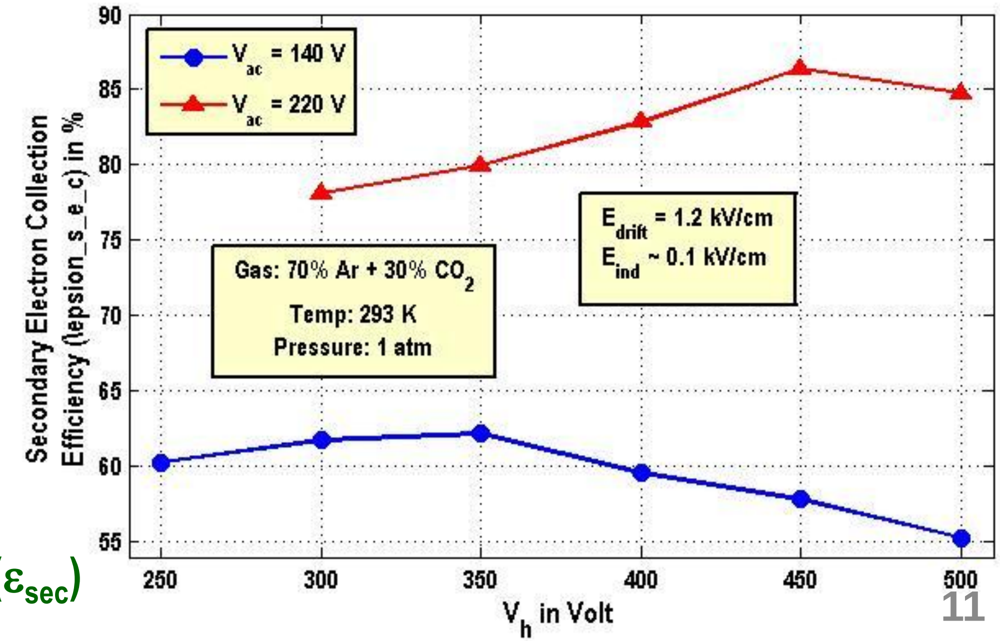
(Expt. Ref. NIMA 504 (2003), 364)

- Consider only the collected charge at anode strips
- Charge induction effects of moving electrons have not been considered
- Inclusion of these effects - MC estimates much closer to measured value

Variation with hole voltage

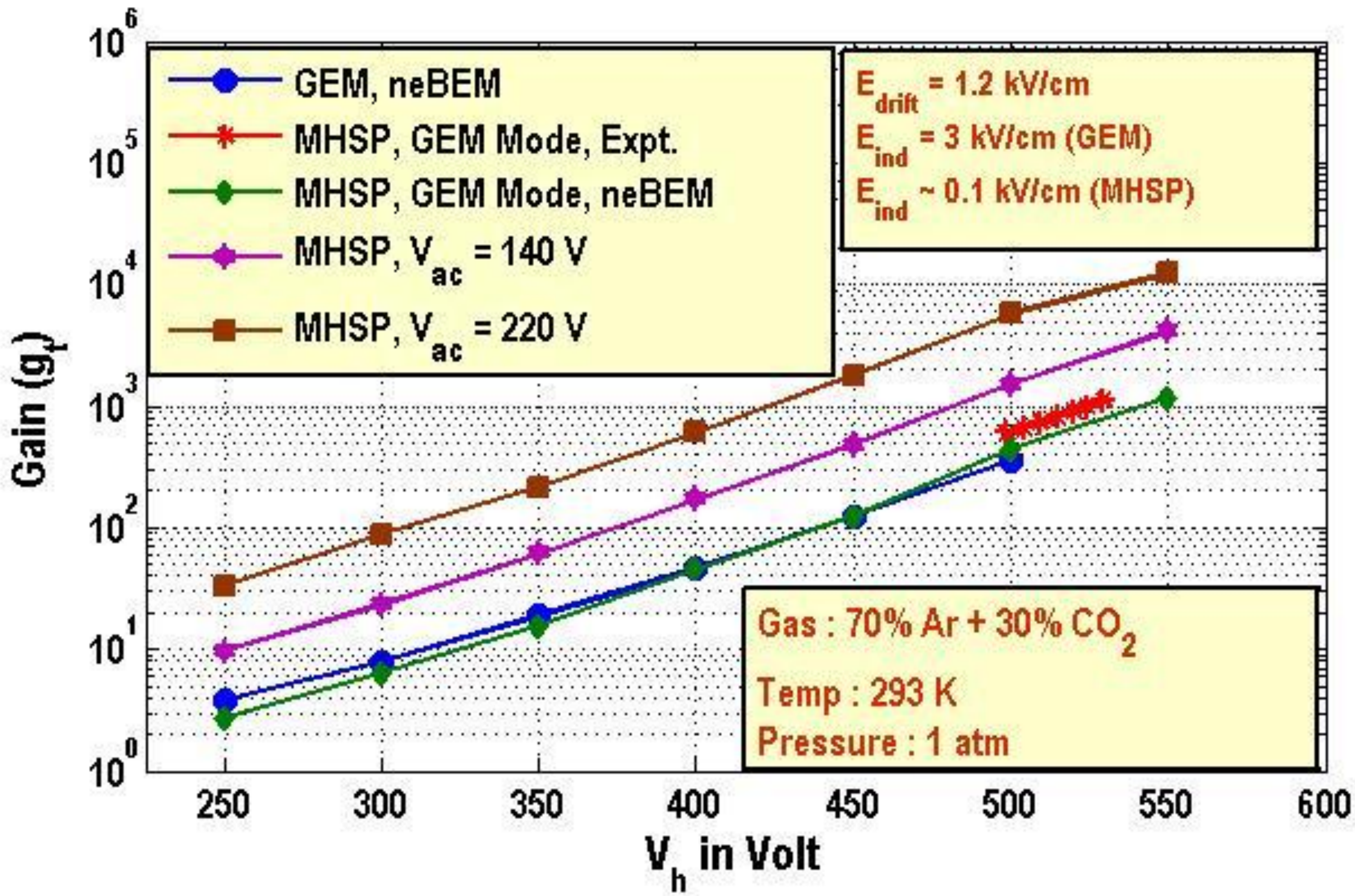


Primary Electron Collection Efficiency (ε_{prim})



Secondary Electron Collection Efficiency (ε_{sec})

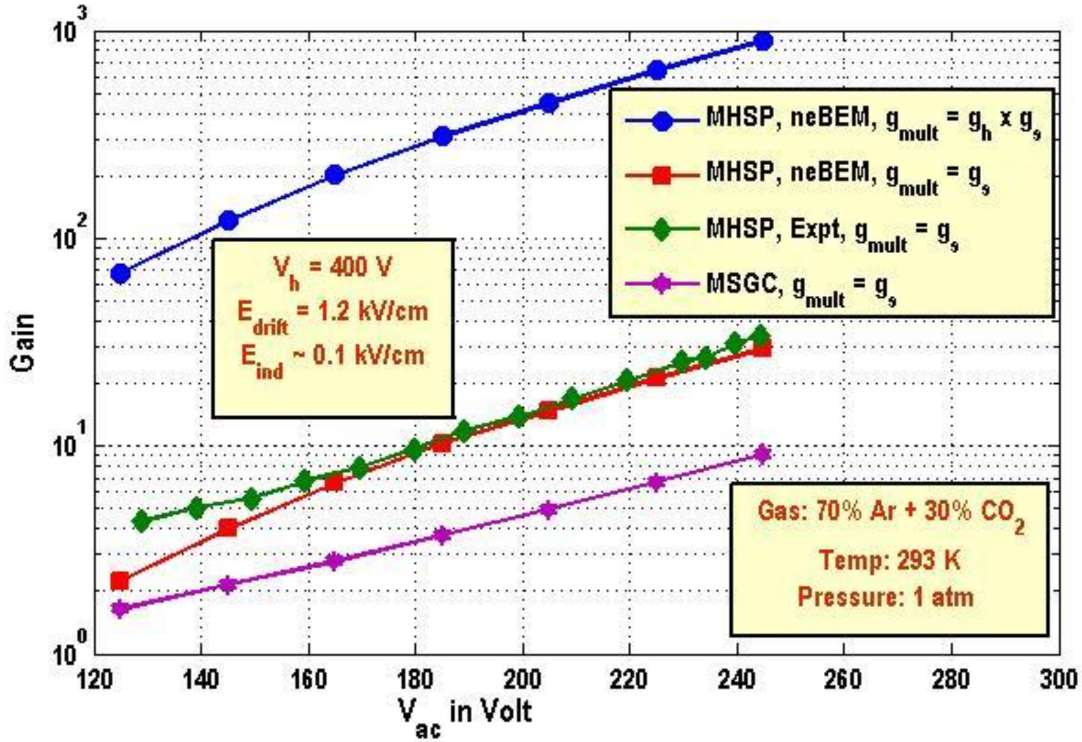
Variation with hole voltage



- **Simulated results agree quite well with experimental trend**
- **With proper optimization of two sets of voltages (hole voltage & anode to cathode voltage) total gas gain for MHSP can be higher than that for a single GEM**

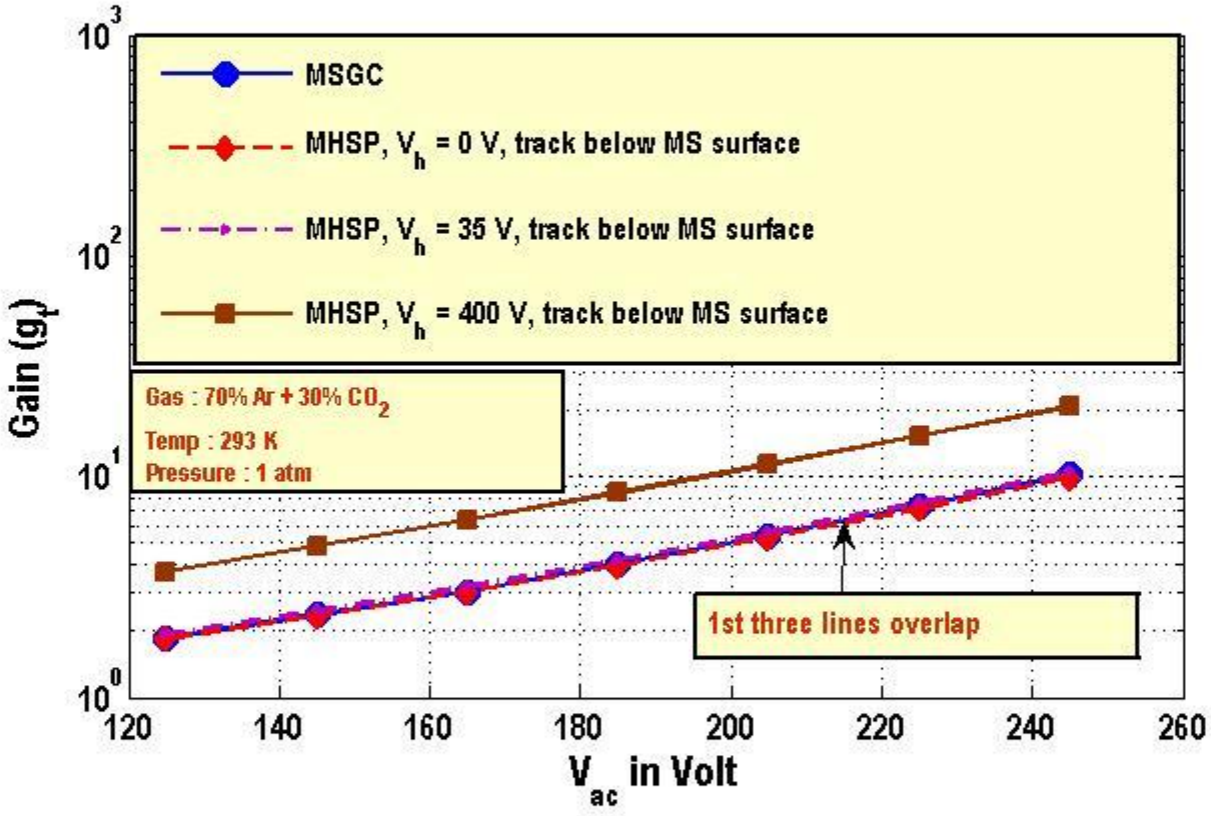
Comparison with MSGC

- MHSP operated in GEM mode, the multiplication factor for fixed V_h can be estimated from this procedure
- Estimation of multiplication factor in 2nd stages only



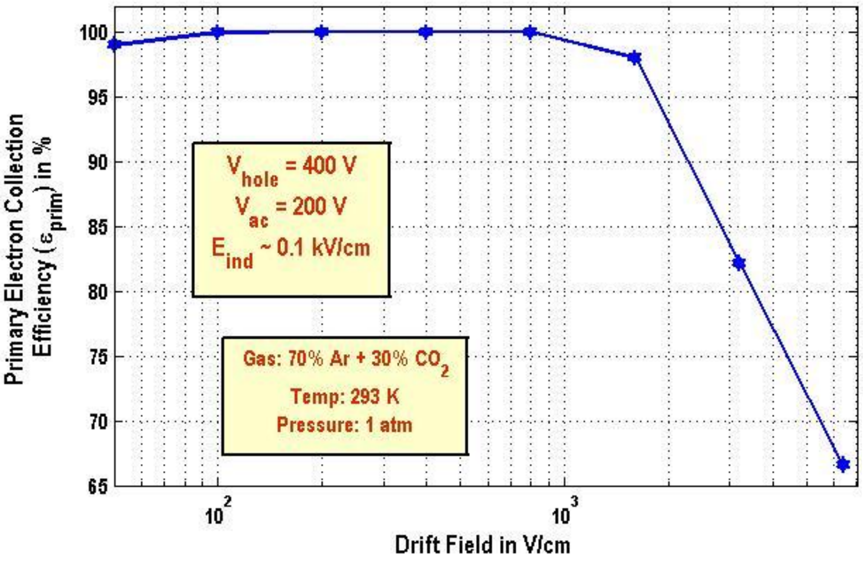
The multiplication factor in 2nd stage of MHSP is higher than that of MSGC

- **Consider electron track below the micro strip surface of MHSP**
- **Set different hole voltage**

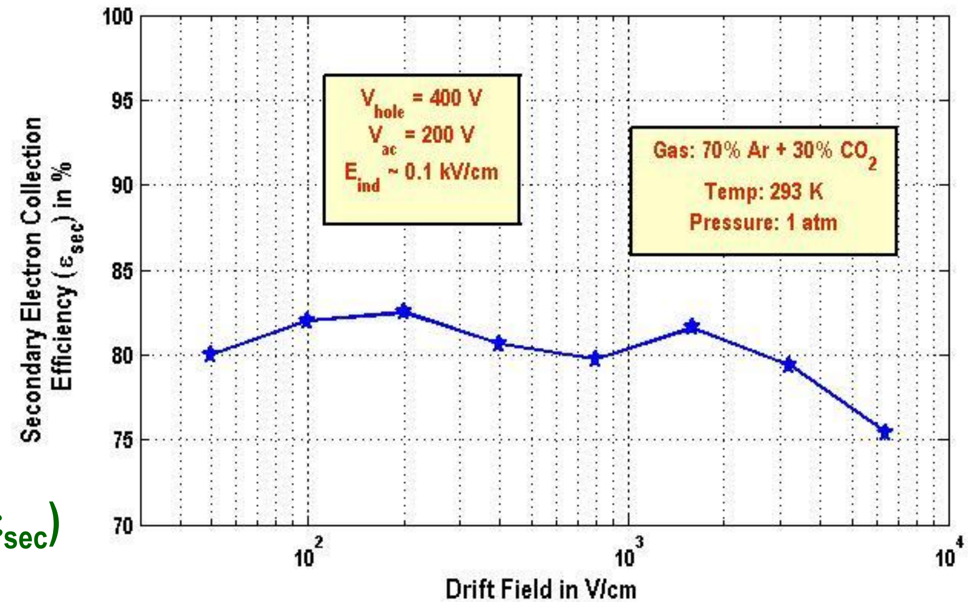


The multiplication factor in 2nd stage depends not only on anode to cathode strip voltage, but also on hole voltage

Effect of Drift Field



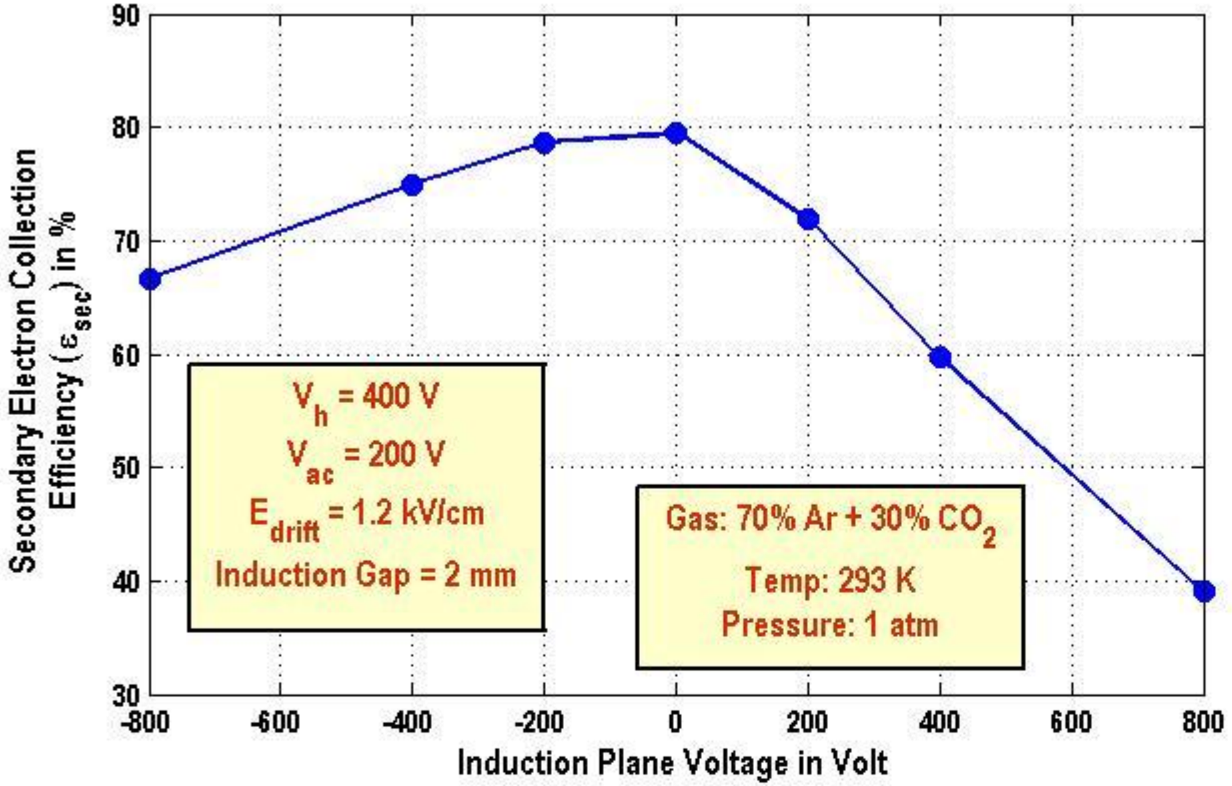
Primary Electron Collection Efficiency (ε_{prim})



Secondary Electron Collection Efficiency (ε_{sec})

- The focusing of electrons towards hole i.e Primary electron collection efficiency depends on it
- No significant effect on secondary electron collection efficiency except at the high drift field
- Variation may be due to less number of statistics

Effect of Induction Field on Secondary Electron Collection Efficiency (ε_{sec})



- Induction field is changed by making the voltage on induction plate negative or positive w.r.t lower cathode strips
- Too much negative or positive voltage affect the secondary efficiency

Concluding Remarks on Numerical Results

1) Garfield+neBEM+Magboltz+Heed combination is flexible enough to model crucial features of MPGDs such as large length scale variation, intricate 3D geometrical features etc.

2) Explored so far: Nature of electric field with different detector parameters, qualitative and quantitative estimation of detector gain, transparency, efficiency and their dependence on different detector parameters. Encouraging agreement has been observed when compared with available experimental data.

On going work:

1) Increase of statistics for MC calculation

2) Optimization of different electron efficiencies and detector gain with drift field and induction field

3) Simulation of ion backflow fraction

Future Work:

1) Consider manufacturing tolerances and defects in the simulation

2) Estimate induced component of the signal, space charge and charging up effects

Experimental Activity at SINP

With a lot of help from the RD51 community and, specially, CEA/IRFU, Saclay

A test bench for the characterisation of micro-pattern gas detectors

***Present Status*:**

Gas flow system, controllers and purification system

Residual Gas Analyser: SRS RGA Model 200

Digital Microscope: OLYMPUS MX 51

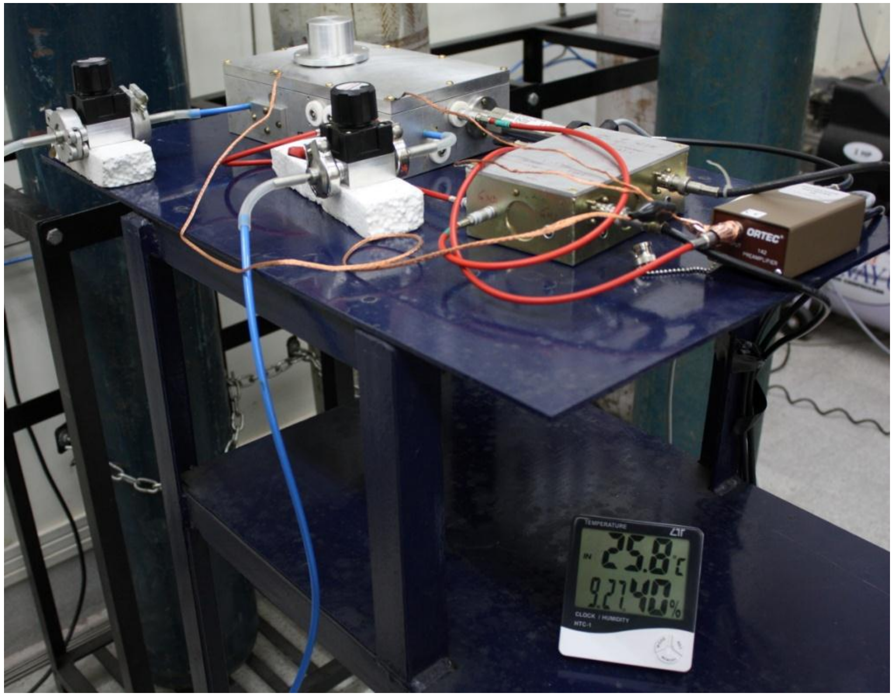
Radiation source: ^{55}**Fe** (IEC 122) 185 MBq with dimension Φ 12.5 mm x 3 mm,

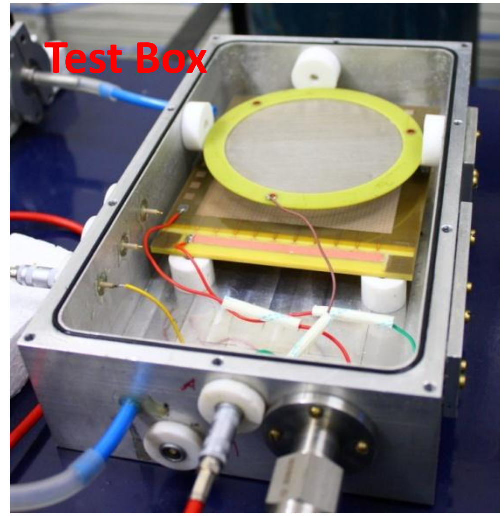
Bulk Micromegas, Drift Mesh etc: Obtained from our collaborators

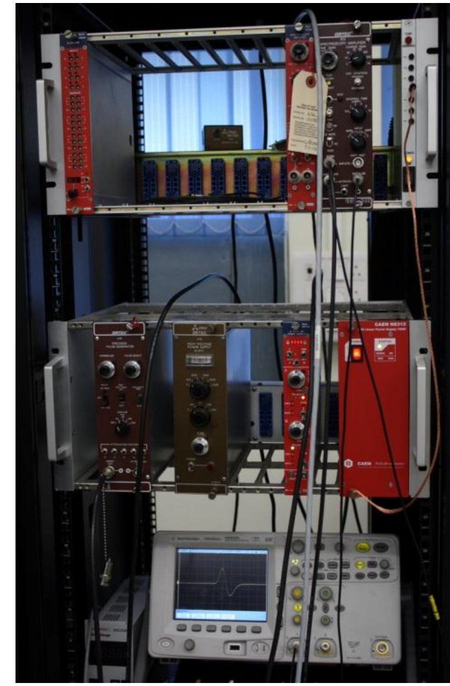
Test Box: Designed and fabricated in the workshop at SINP

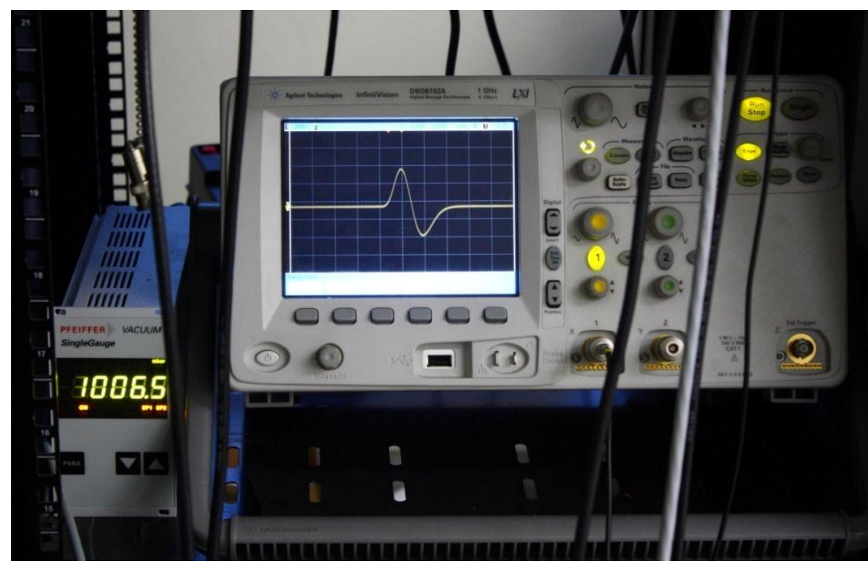
Electronics: N471A Power Supply (CAEN) / ORTEC 456 Power Supply/ 142IH Pre-amplifier (ORTEC)/ ORTEC 672 Amplifier/ AMTEK MCA 8000A/ Precision Pulse Generator ORTEC 419

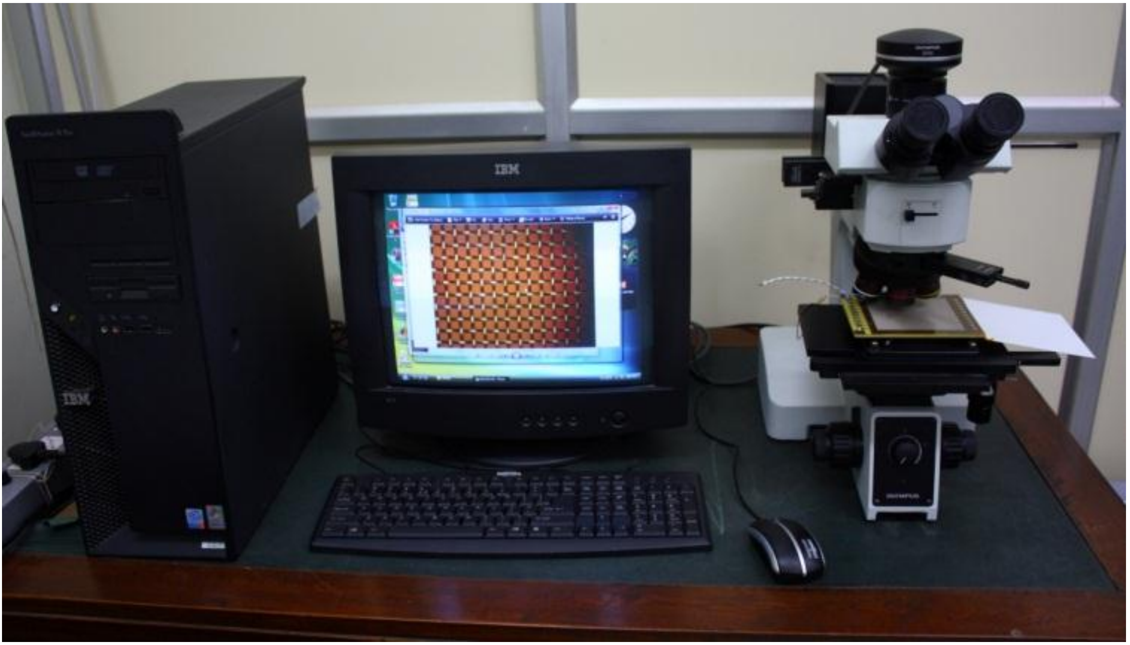
Micro-Pattern Gas Detector Laboratory





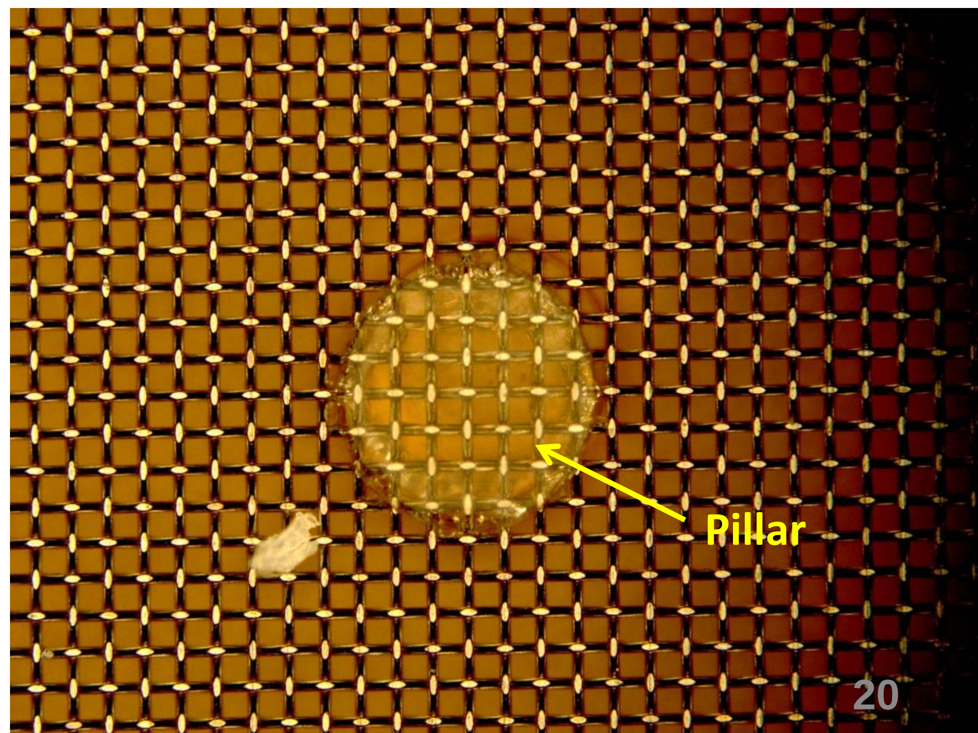


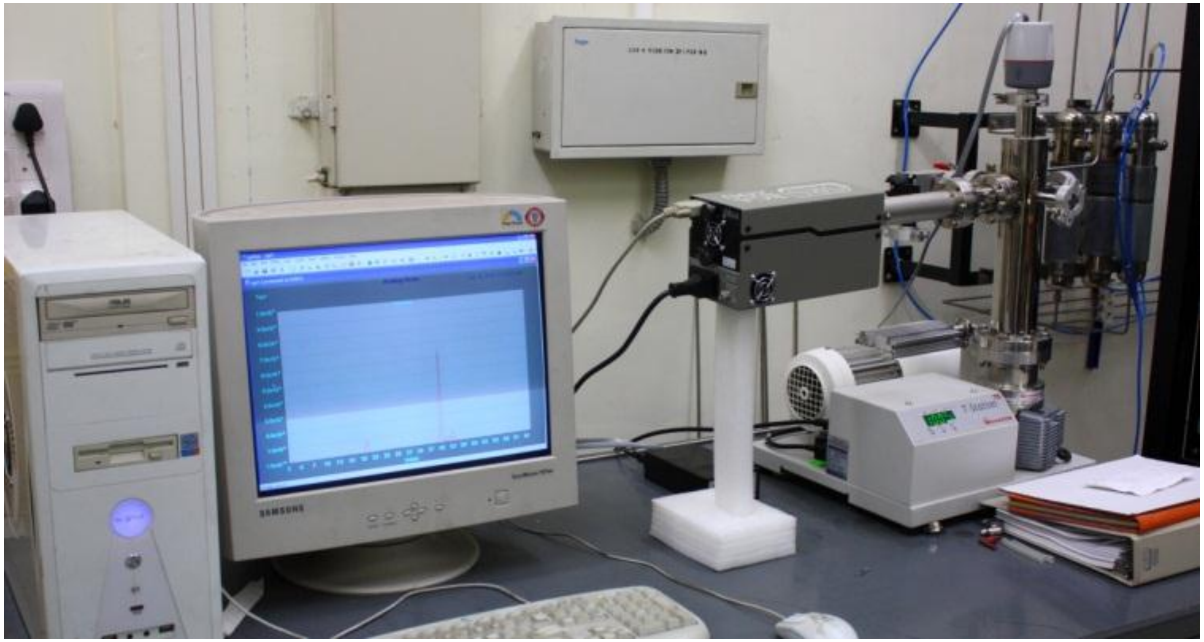




Digital Microscope

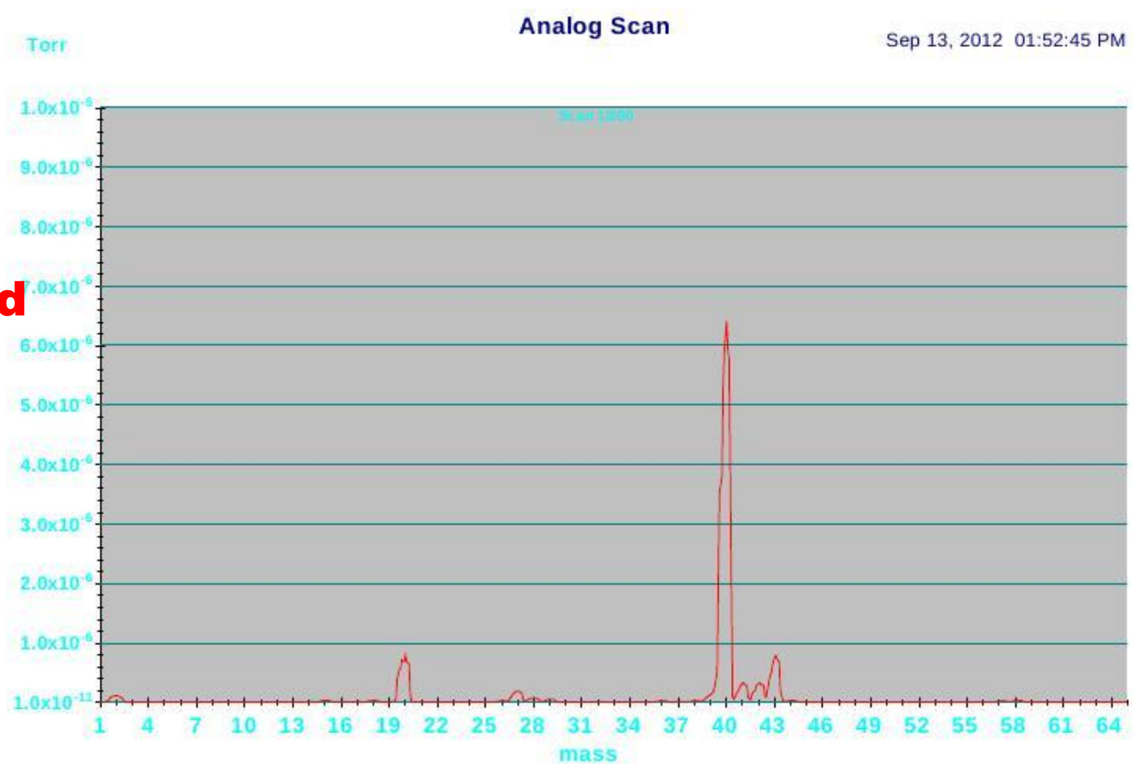
Microscopic Picture of BULK Micromegas





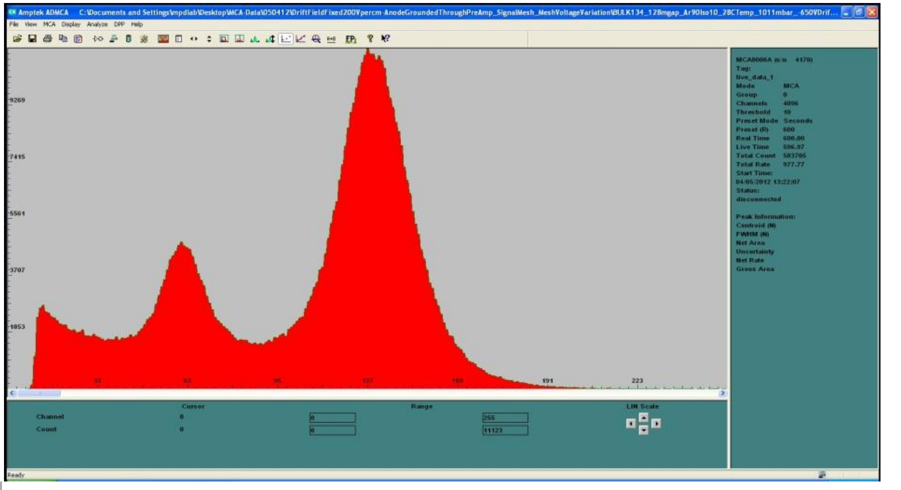
Residual Gas Analyzer

RGA Spectrum for fixed Argon – Isobutane Gas Mixture



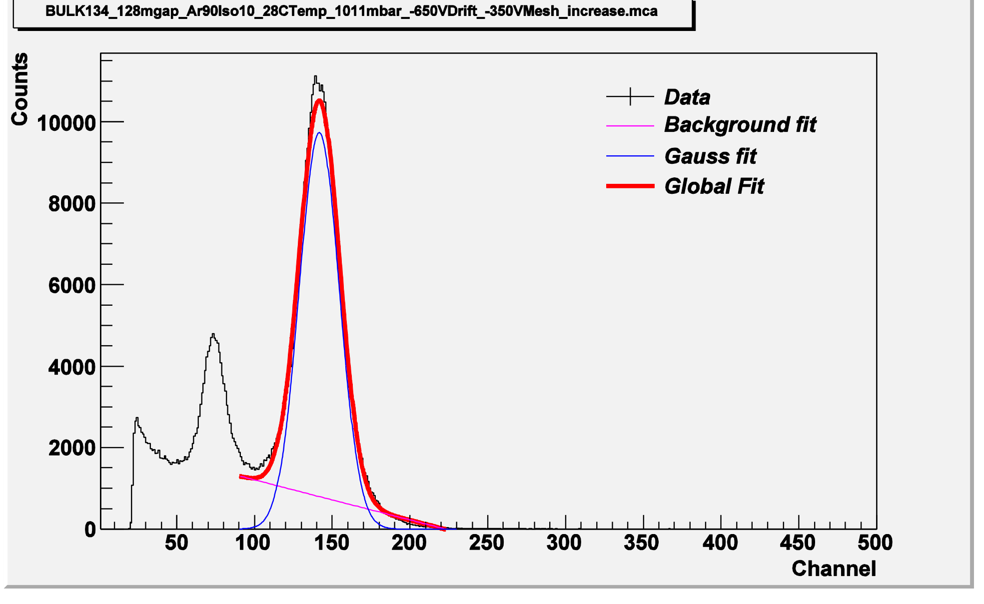
Details of BULK Micromegas :

1) 10x10 cm² active area
2) 128 μm amplification gap
3) Nickel mesh, 18 μm mesh wire diameter, 45 μm hole diameter, 63 μm pitch
4) Dielectric spacer, diameter 400 μm, pitch 2 mm



Details of typical RUN :

- 200V/cm Drift Field
- -350V Mesh Voltage, 27 kV/cm amplification field
- Gas mixture of Argon and Isobutane (90:10)



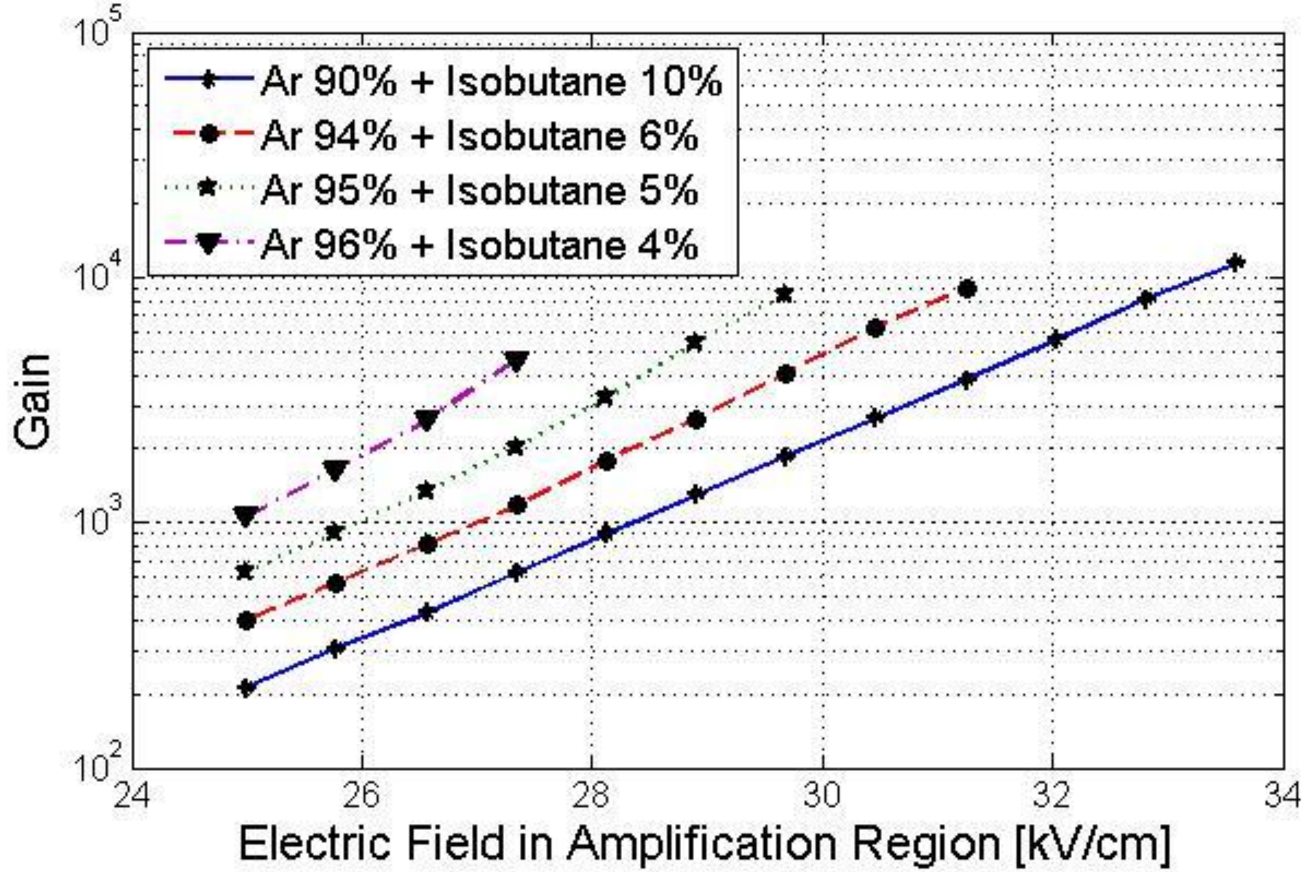
Typical MCA Spectrum of ^{55}Fe

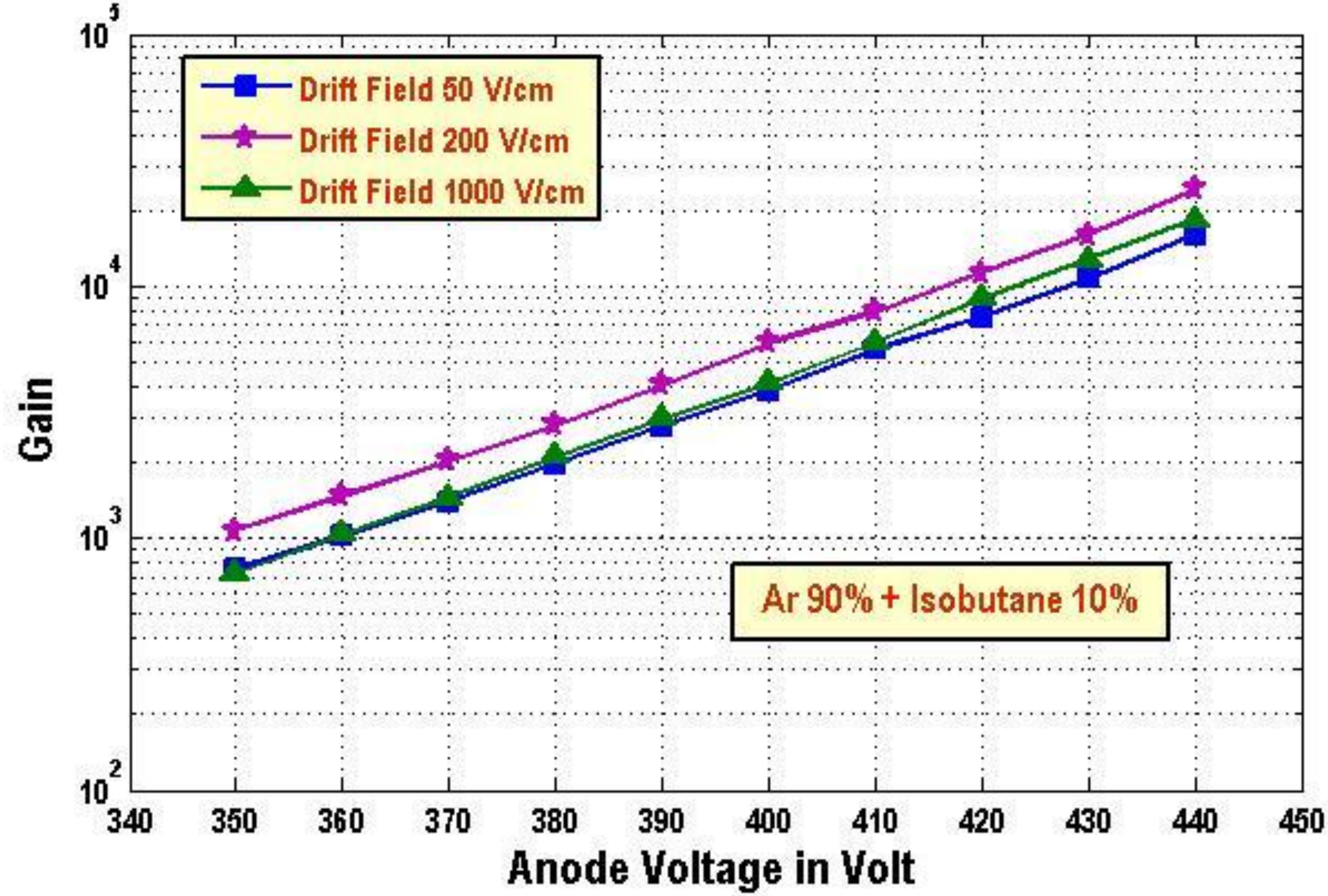
Photo-peak is fitted. In this RUN, gain is 470 and energy resolution (σ_p/ P) is around 9%

Gain : $G = N_t / N_p = kP/ N_p$, where

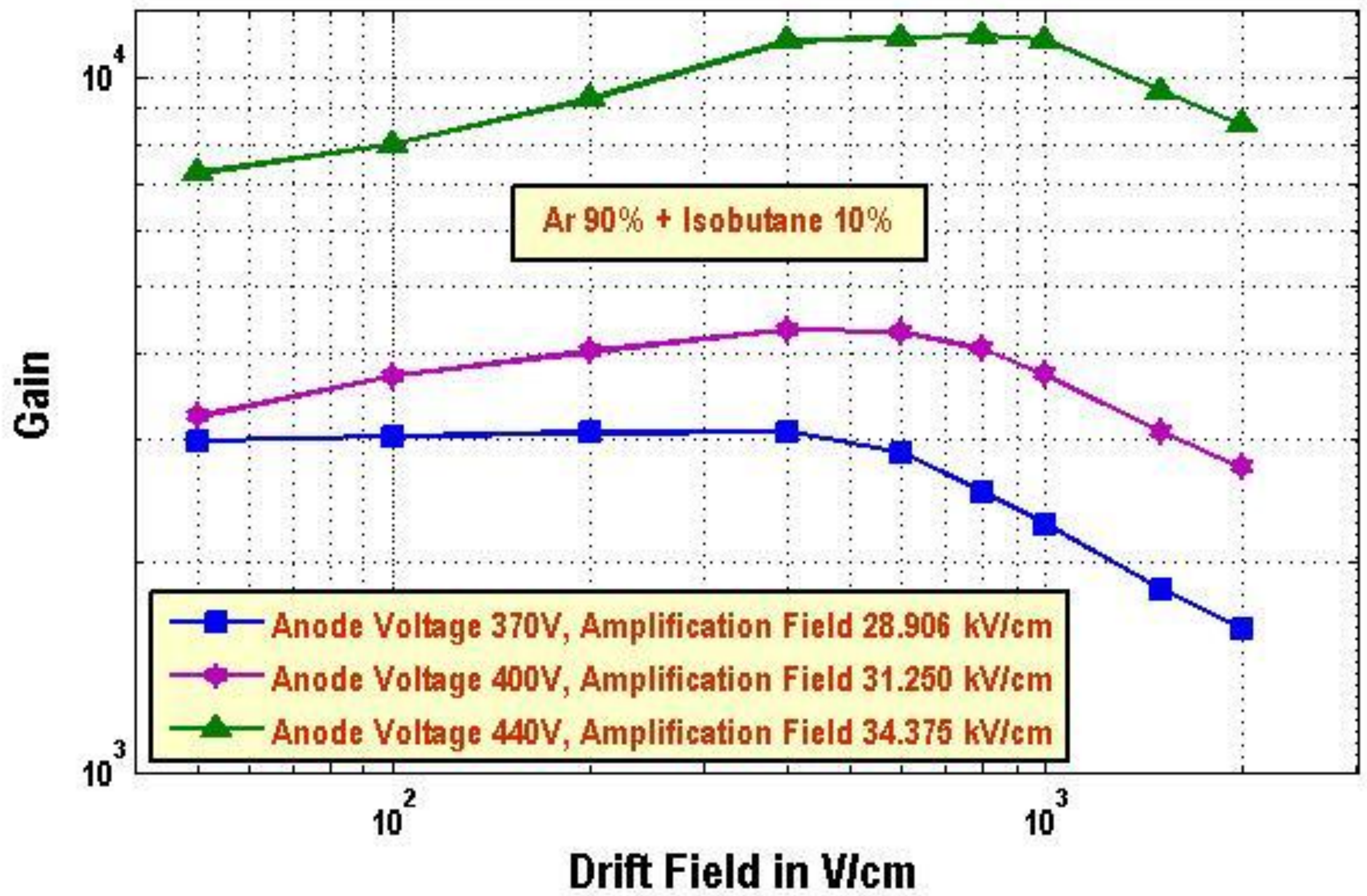
- N_t → Total number of electrons
- N_p → Primary electrons
- k → Constant, depends on Preamplifier, Amplifier, MCA specification
- P → Peak Position

Variation of gain with amplification field in different argon-based gas mixture (drift field 200 V/cm)





Variation of gain with amplification field for different drift field



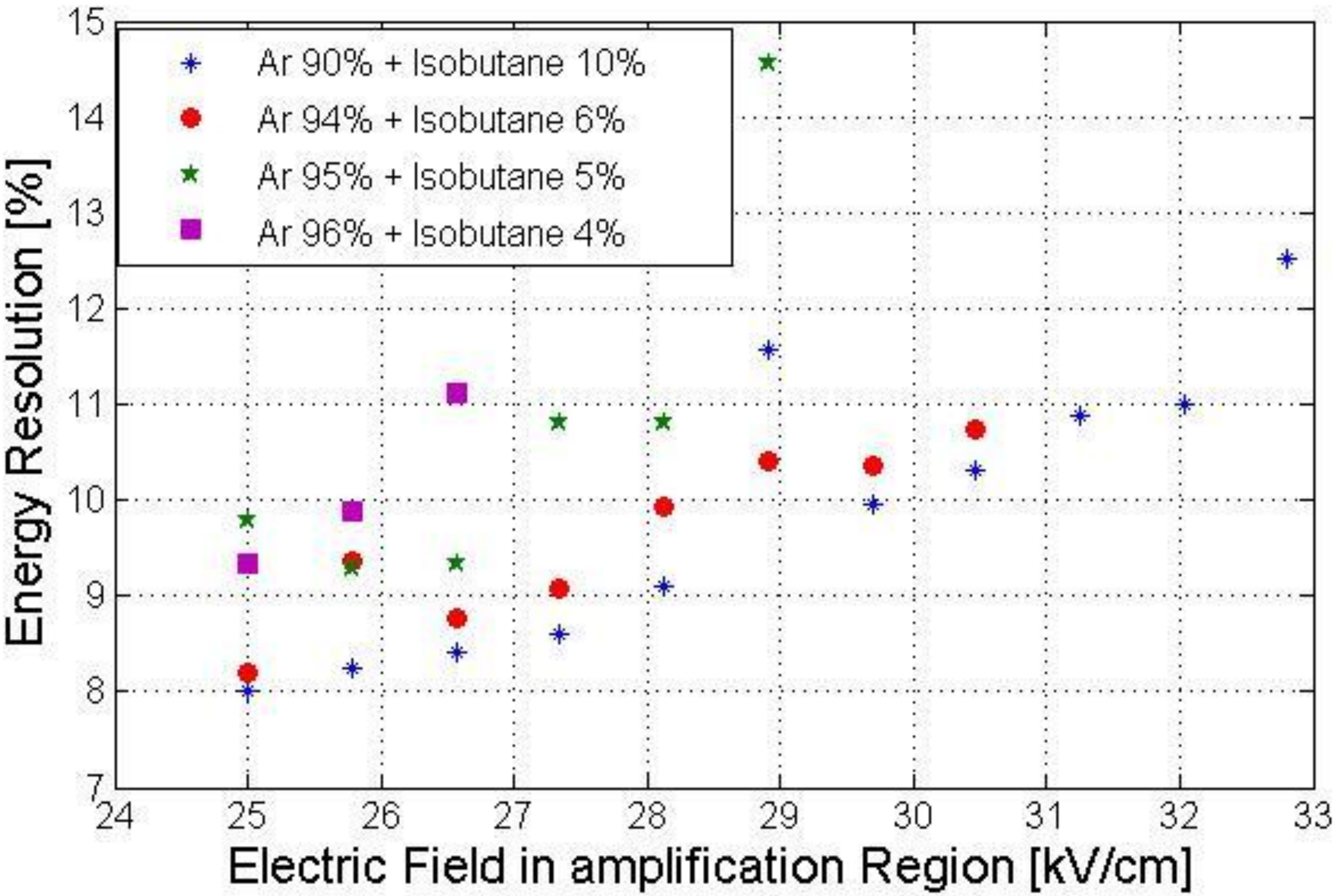
Variation of gain with drift field for different amplification field

Energy Resolution : $R = \sigma_P/P$, where

$\sigma_p \rightarrow$ r.m.s. of the pulse height distribution

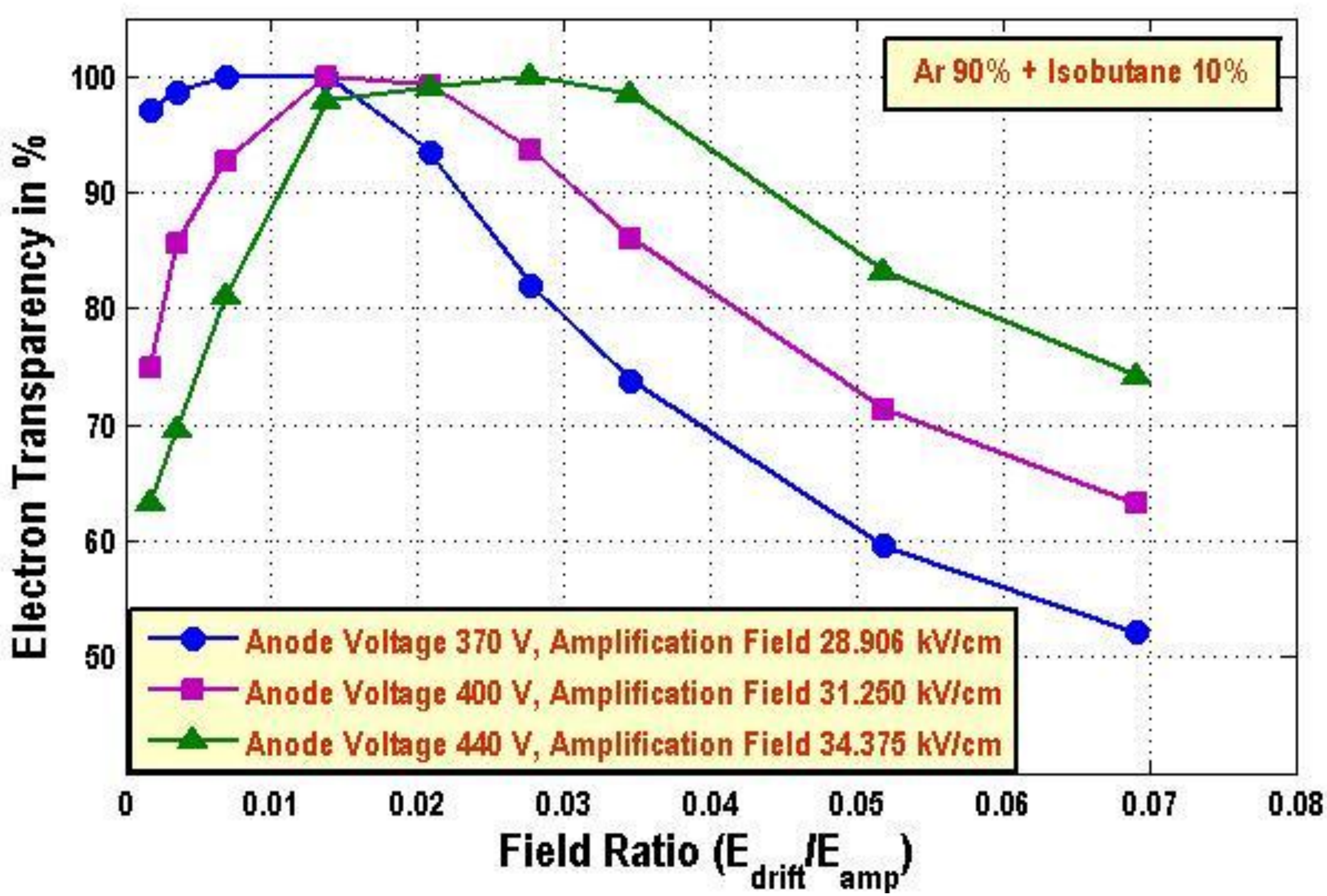
$P \rightarrow$ peak position

Variation of energy resolution at 5.9 keV with amplification field in different argon-based gas mixture (drift field 200 V/cm)



Electron Transparency : Fraction of electrons arriving in amplification region

Variation of drift field



Outlook

- Preliminary data are quite promising, need further investigation.
- Variation of gain, energy resolution, transparency with other detector parameters will be performed for different gas mixture.
- Necessary set up will be done for measurement of other detector features.
- Parallel effort will be given to the numerical simulation of Micromegas detector.
- Extend the set up for some basic experiments with GEM, MHSP etc.

Acknowledgment

- Satyajit Saha (SINP)
- Sandip Sarkar (SINP)
- Rob Veenhof (CERN)
- Paul Colas (Saclay)
- David Attie (Saclay)
- Maxim Titov (CERN)
- Ioannis Giomataris (Saclay)

- RD51 community

- Technical support teams at CERN, Saclay and SINP

THANK YOU

Backup slides

Simulation tools

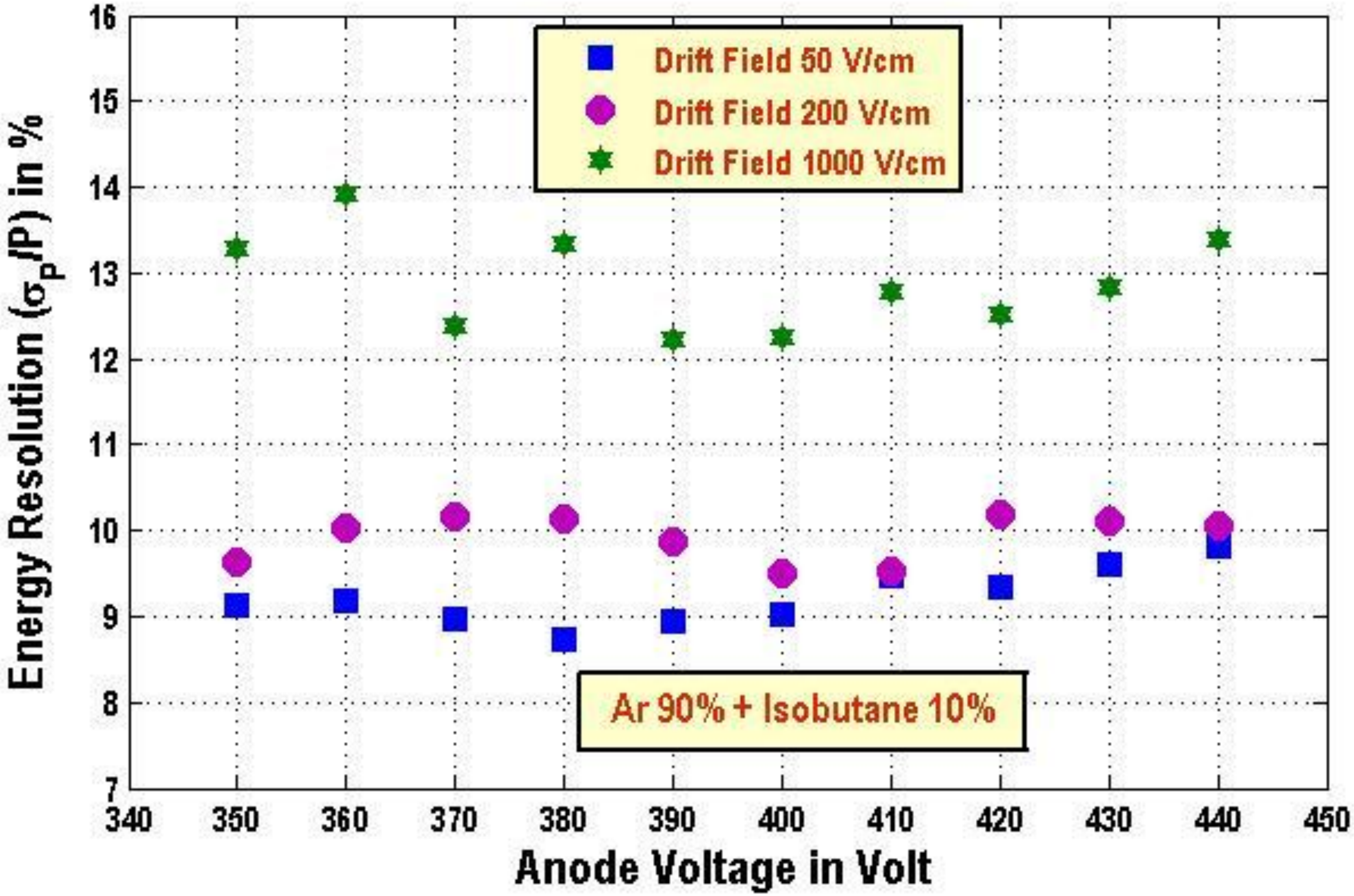
Garfield framework

- ***Ionization:*** ***energy loss through ionization of a particle crossing the gas and production of clusters – HEED***

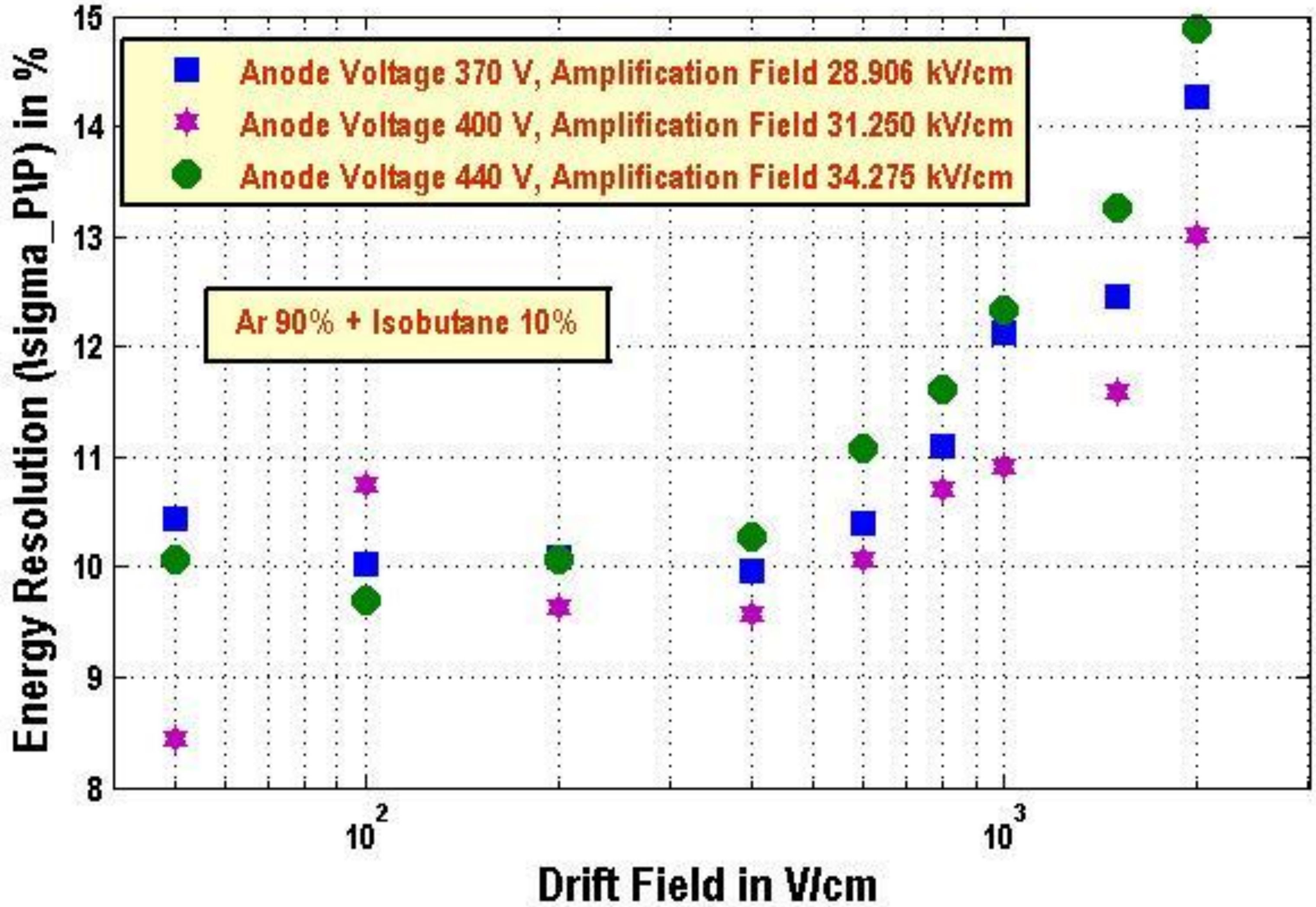
- ***Drift and Diffusion:*** ***electron drift velocity and the longitudinal and transverse diffusion coefficients – MAGBOLTZ***

- ***Amplification:*** ***Townsend and Attachment Coefficient – MAGBOLTZ***

- ***Field Solver:*** neBEM (nearly exact Boundary Element Method) - ***A formulation based on green's function that allows the use of exact close-form analytic expressions while solving 3D problems governed by Poisson's equation. It is very precise even in critical near-field regions and microscopic length scale***



Variation of energy resolution with amplification field for different drift field



Variation of energy resolution with drift field for different amplification field