Study on Surface Asperities in Bakelite-RPC

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Introduction

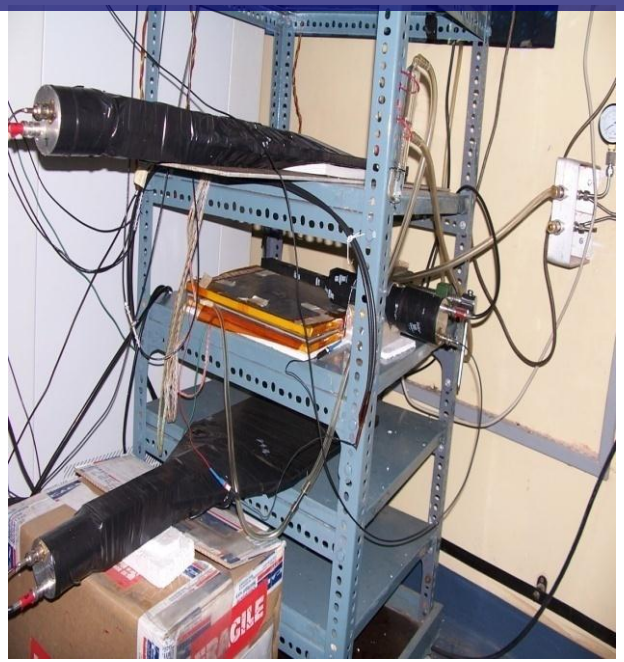
The active detector in India-based Neutrino Observatory (INO) ⇨ RPC

Main goal of the study

To develop large bakelite RPC without linseed oil coating for the experiment in India-based Neutrino Observatory
&
For operation in streamer mode

S. Biswas et al., RPC2010

Cosmic ray test bench



Arrangement of the scintillators and the RPC

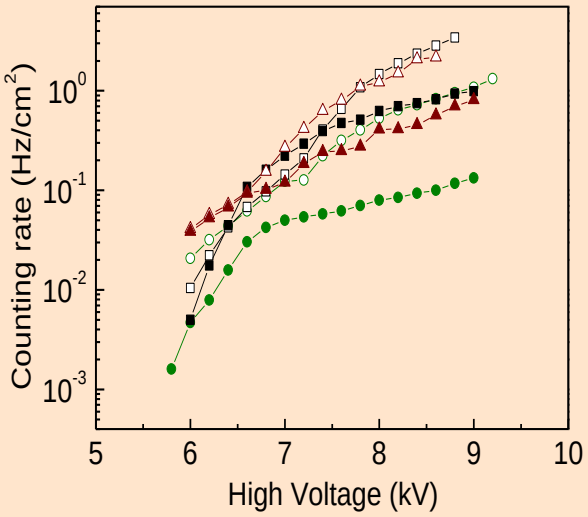
Power supply, front-end electronics and DAQ

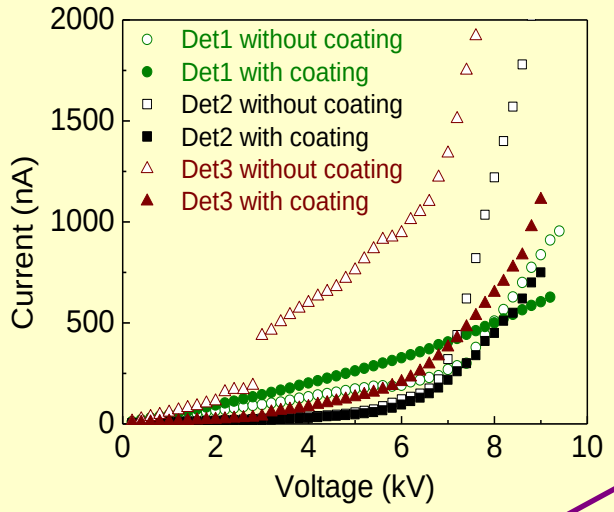
- Flow rate: 0.4 ml/min (3 detector volume/day)

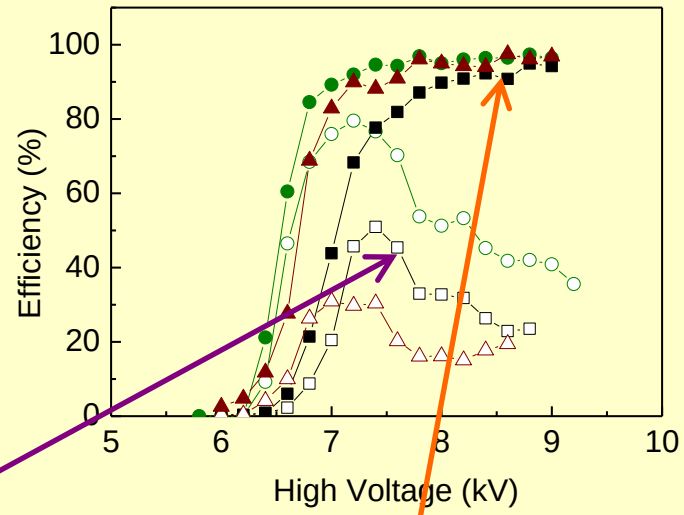
4 gas mixing unit

S. Bose et al., Nucl. Instr. and Meth. A 602 (2009) 839.
S. Biswas et al., RPC2010

Initial results







A few small prototypes have been tested

Without silicone coating

- **Current increases rapidly.**
- **After a certain voltage efficiency decreases in all cases.**

S. Biswas et al., RPC2010

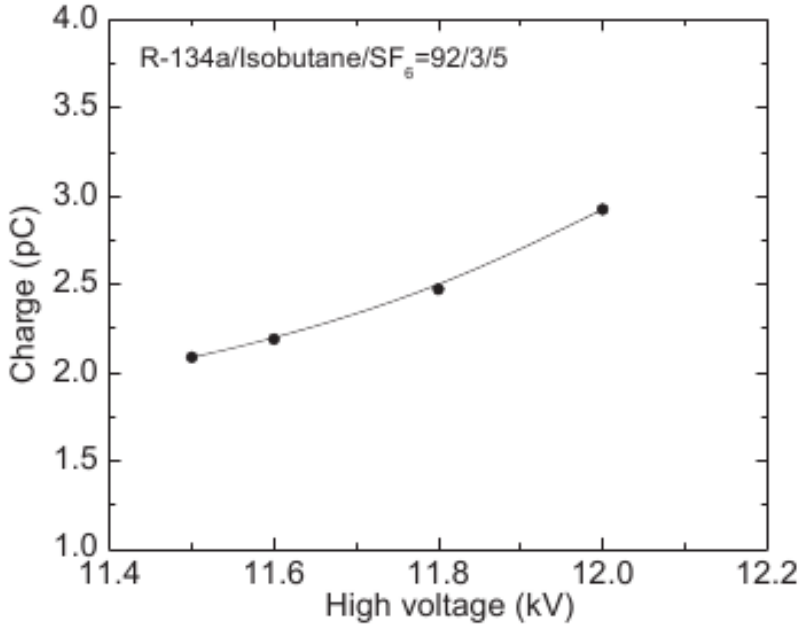
With silicone coating

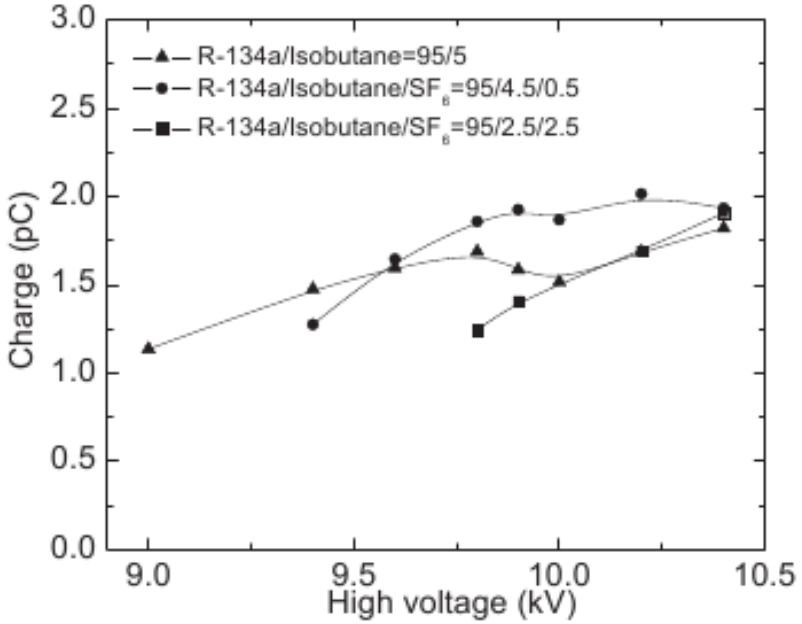
- **Efficiency plateau >90% obtained.**
- **Counting rate decreased.**
- **Current decreased,**

Induced Charge Measurements

Gas Mixtures:

TFE + Isobutane (95:5))
TFE + Isobutane +SF6 (95:4.5:0.5, 95:2.5:2.5, 92:3:5)

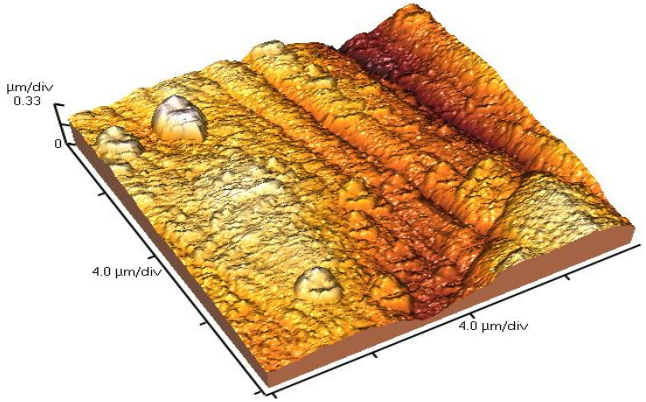




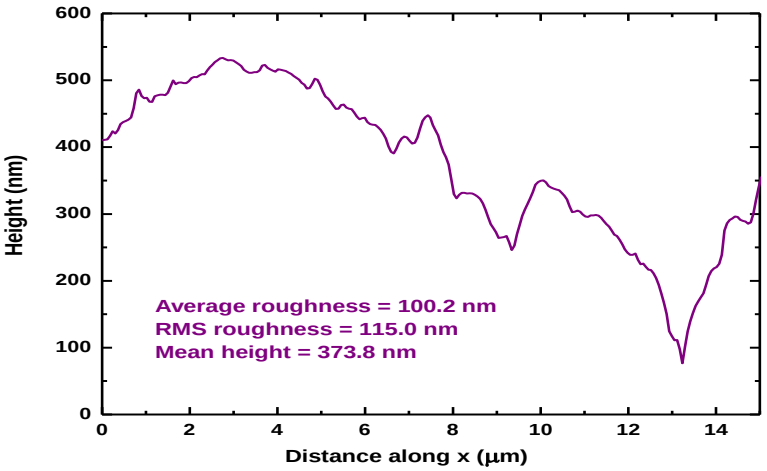
Measured charge in avalanche mode of operation of silicone coated RPC

Ph. D. Thesis, S. Biswas

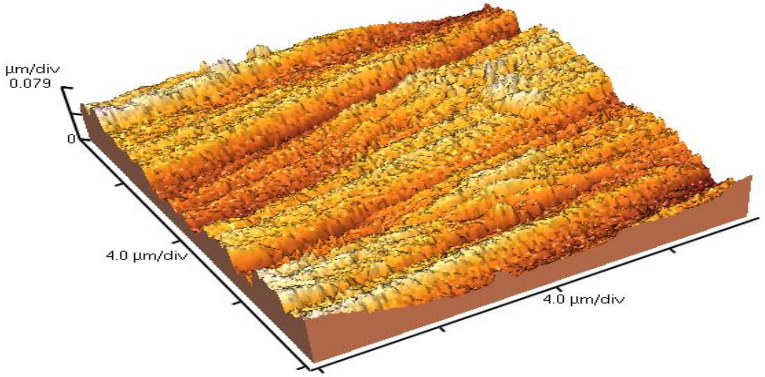
AFM Images and Analysis of Bakelite Surfaces



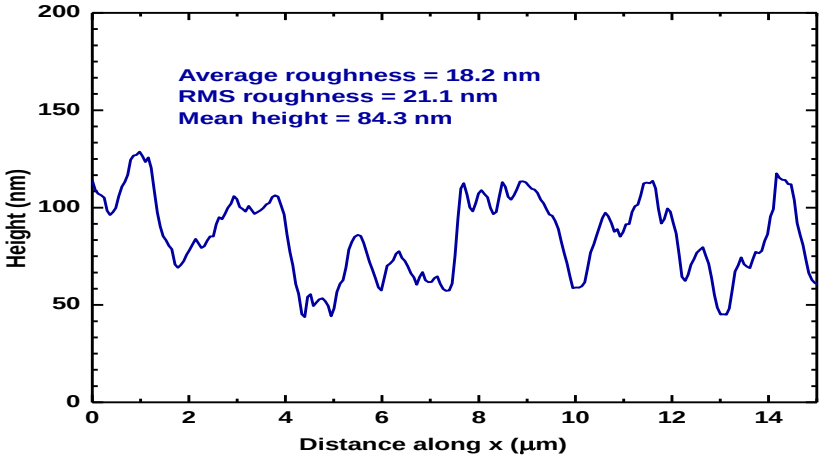
2 mm thick



S. Biswas et al., RPC2010

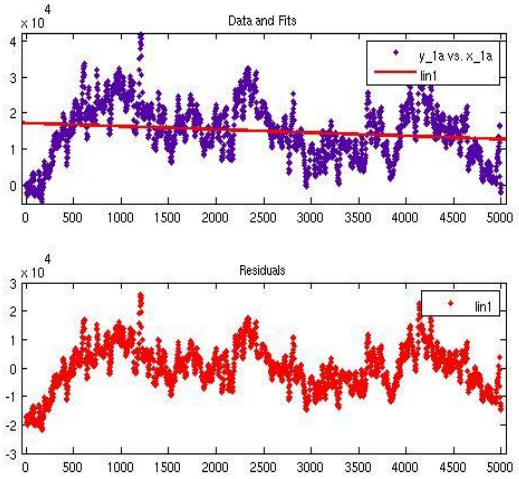


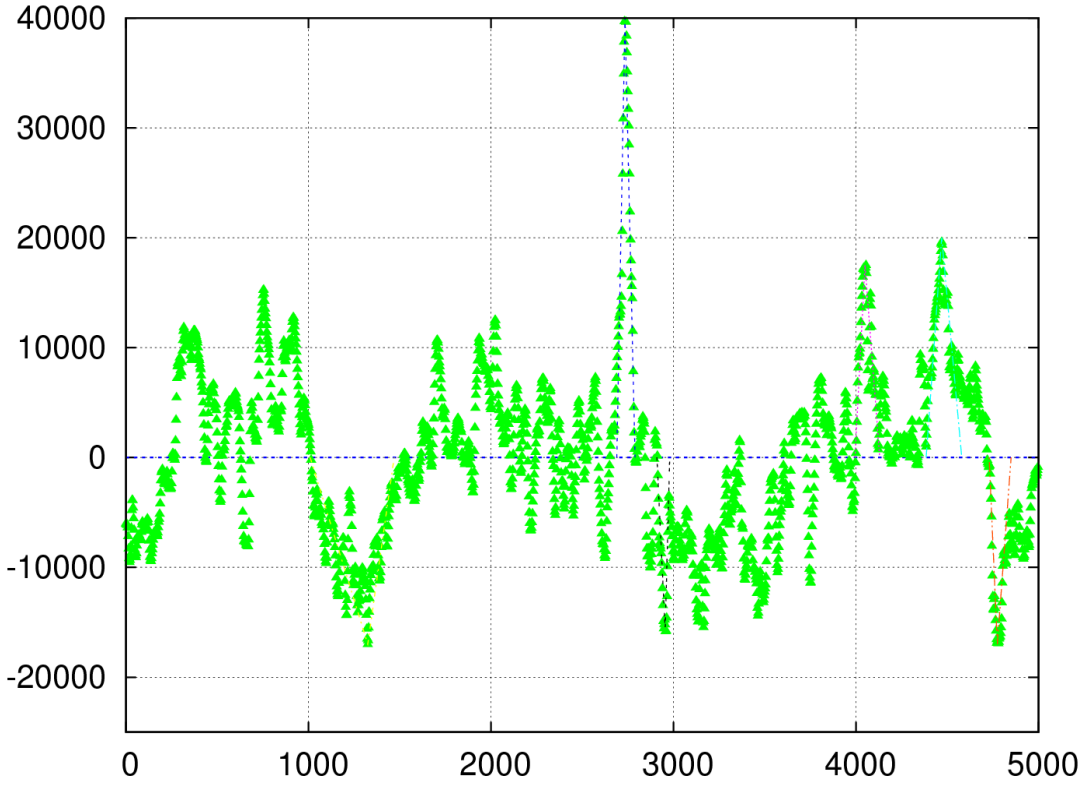
1.6 mm thick (Smoother surface)



This material was selected for most of the RPC fabrication

Estimation of Surface Roughness



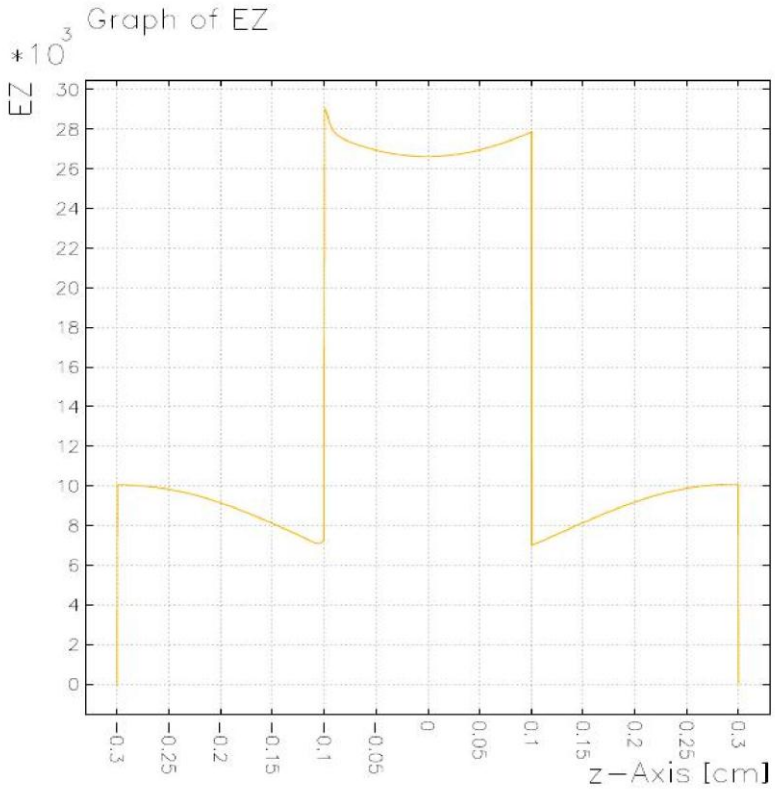


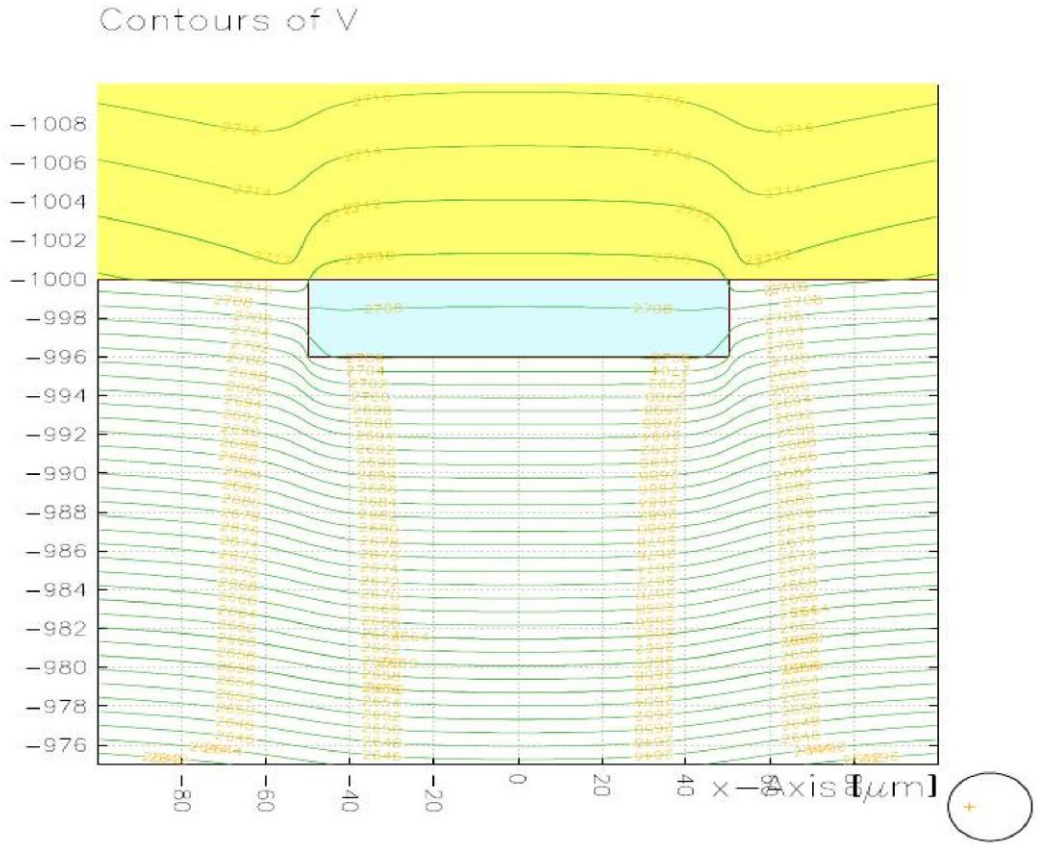
Least square fitting of profilometer data and plot of residuals

S. Biswas et al., RPC2010

Modeling of Surface Asperities

Electric field configuration inside the gas gap and in close proximity to a square pillar of height 4 micron and base 100x100 micron^2

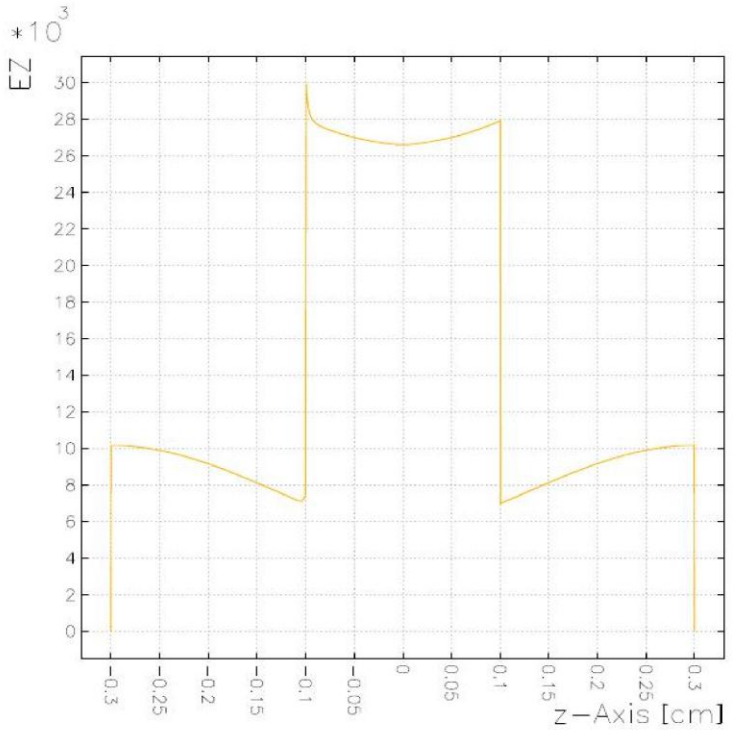


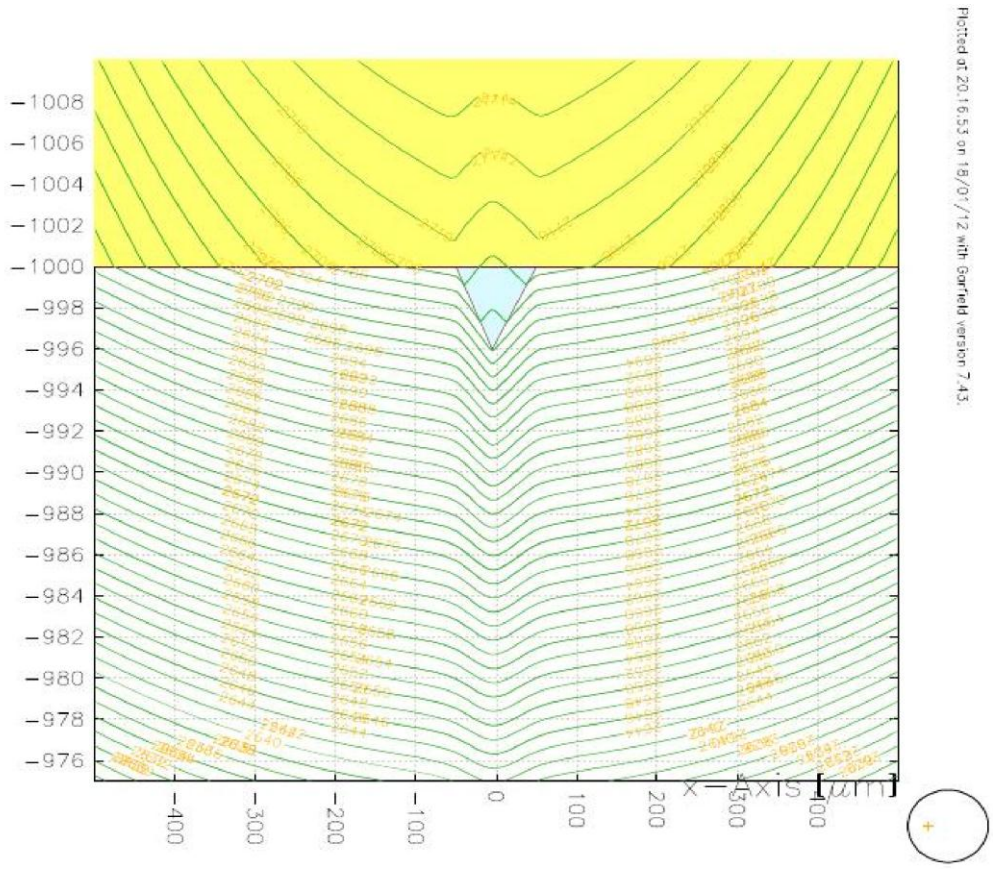


Voltage: 9kV
Analytic field: 29.67 kV/cm

Modeling of Surface Asperities

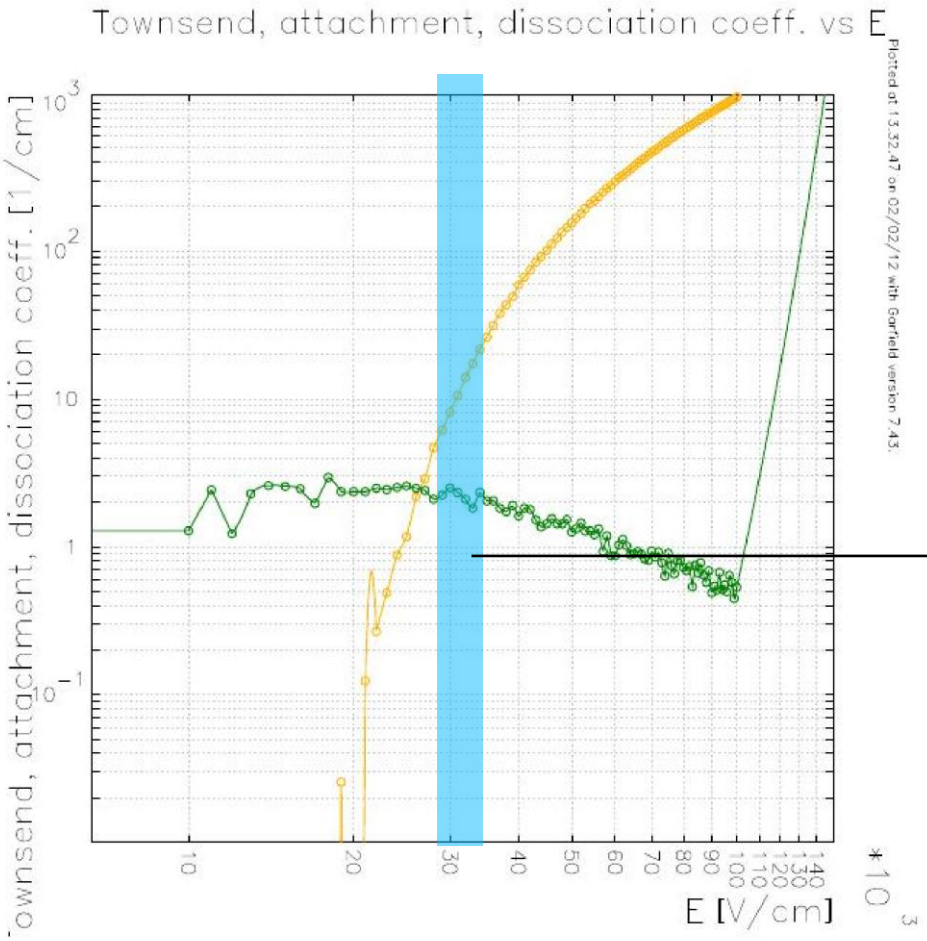
Electric field configuration inside the gas gap and in close proximity to a cone-shaped asperity of height 4 micron and base 100x100 micron^2





Voltage: 9kV
Analytic field: 29.67 kV/cm

Transport Properties

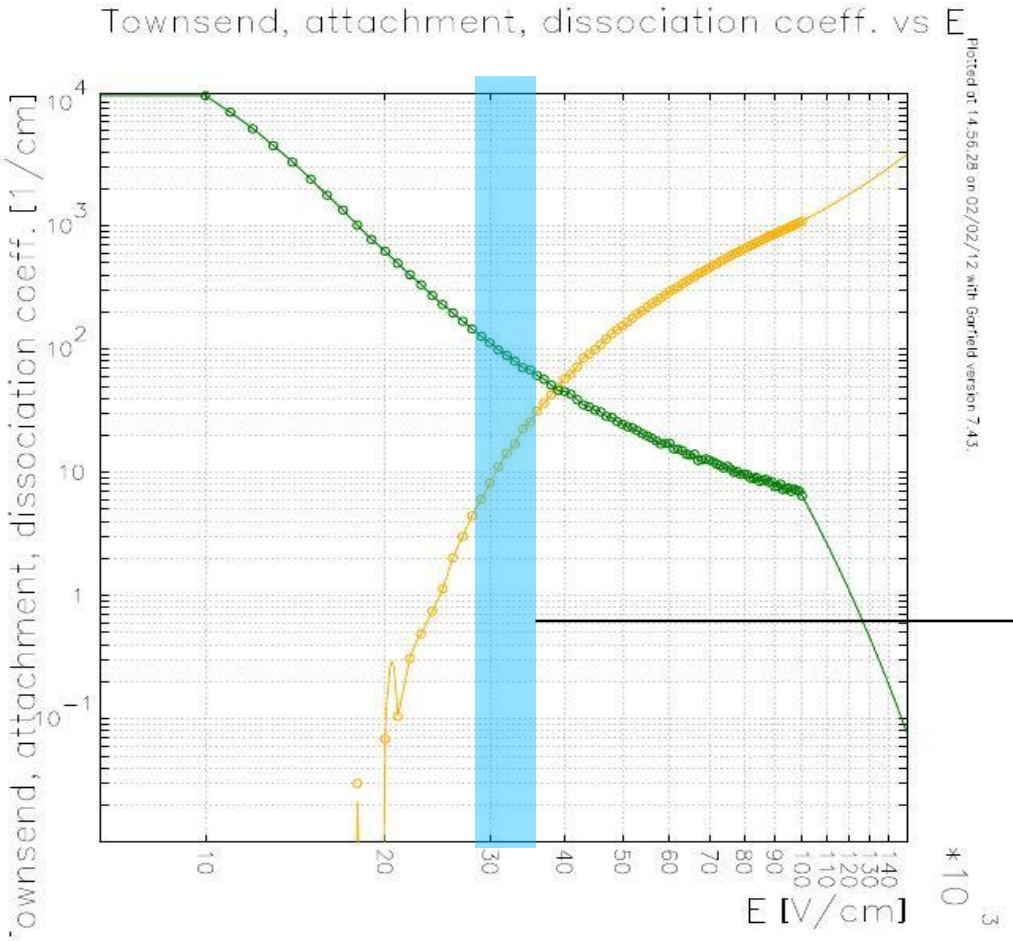


TFE + Isobutane mixture (95:5)
Operating voltage: 8.9 kV – 10.39 kV
Analytic Field: ~ 29.34 – 34.26 kV/cm

Operating region

Amplification by a few tens of electrons accompanied by negligible attachment !!

Transport Properties

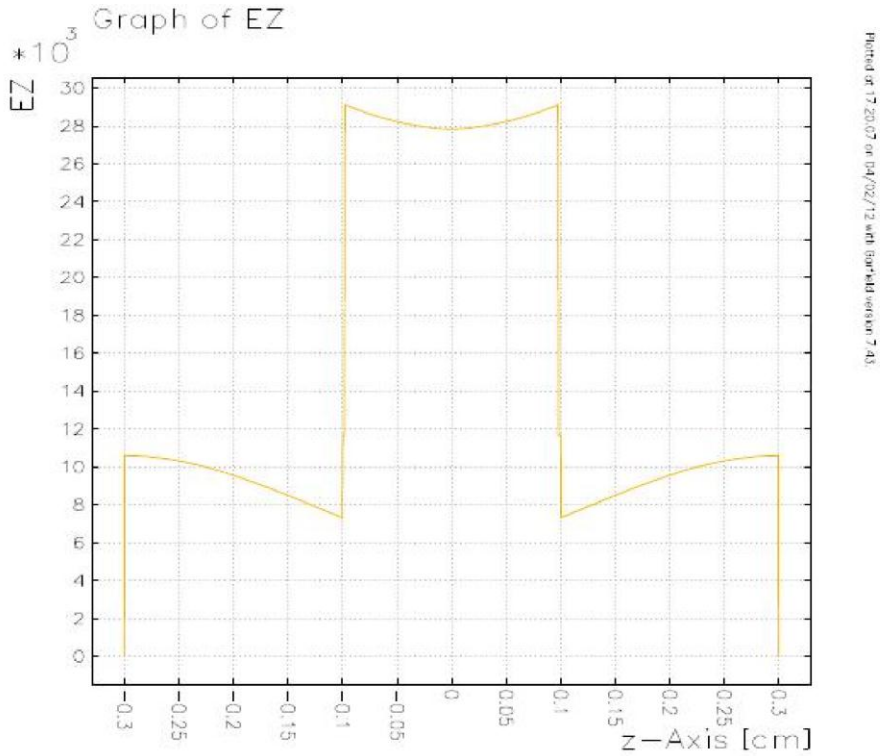


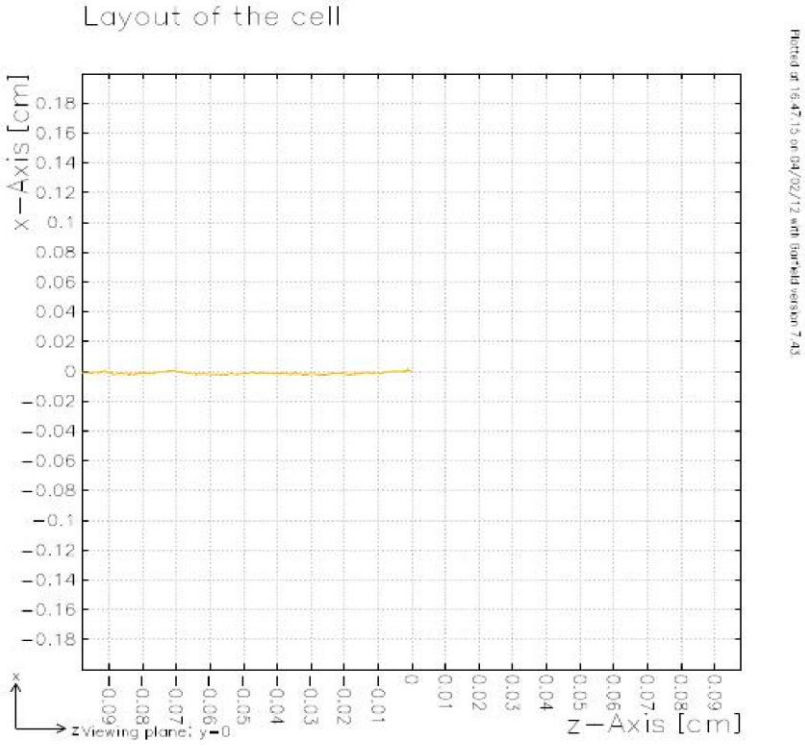
TFE + Isobutane + SF6 (95:4.5:0.5)
Operating voltage: 8.91 – 10.39 kV
Analytic field: 29.37 – 34.56 kV/cm

Operating region

Amplification by a few tens of electrons accompanied by a few hundreds of attachment !!

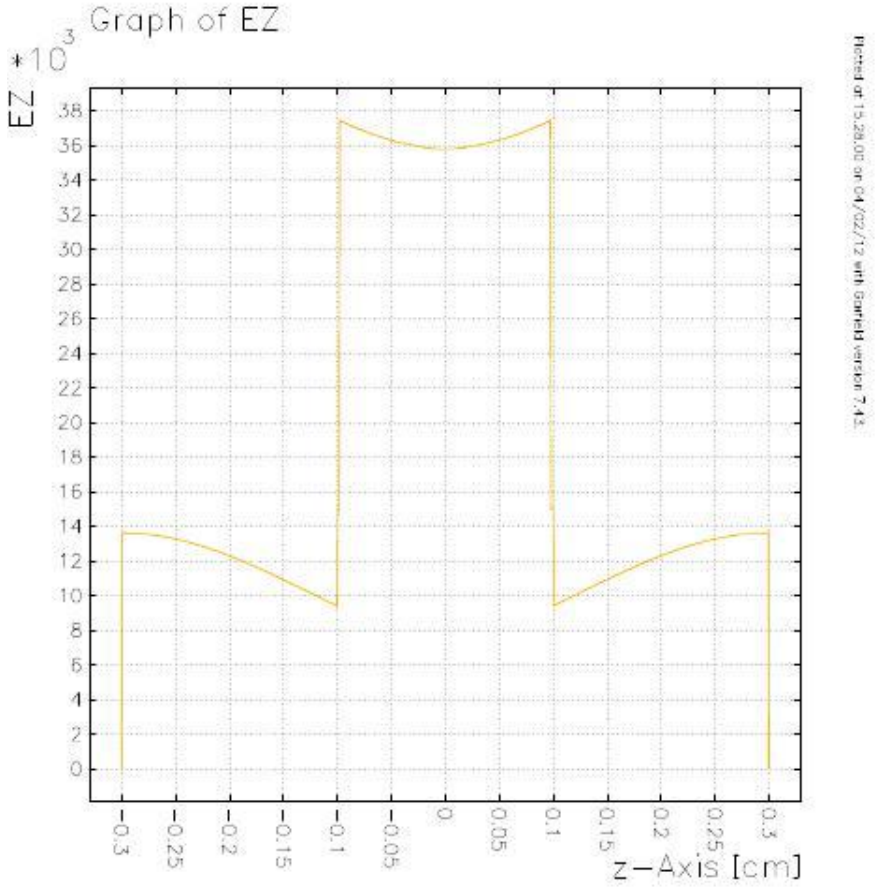
Electron Avalanche

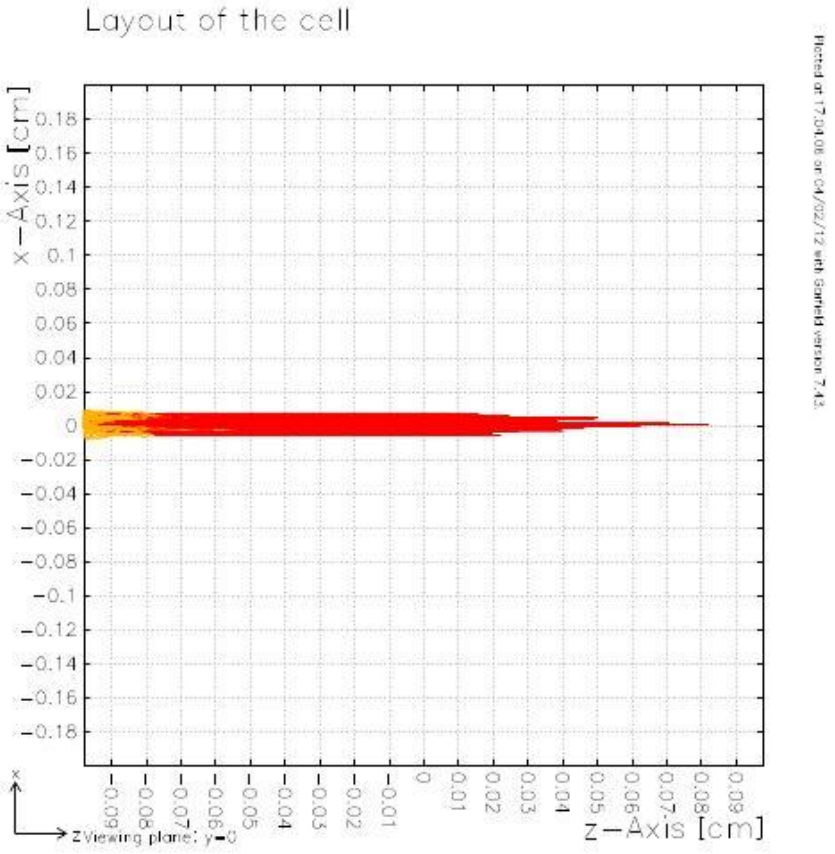




Avalanche of an electron released at the centre
Operating voltage 9.86 kV
Gas: TFE + Isobutane (95:5)

Electron Avalanche

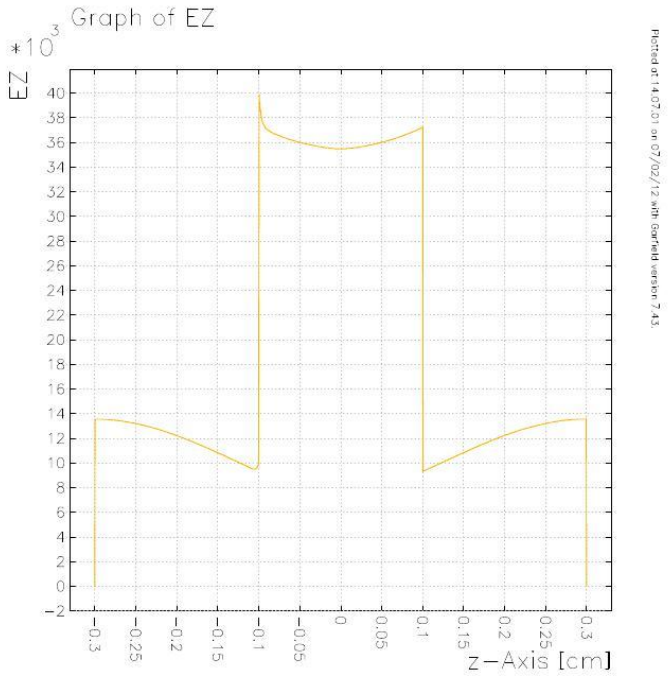




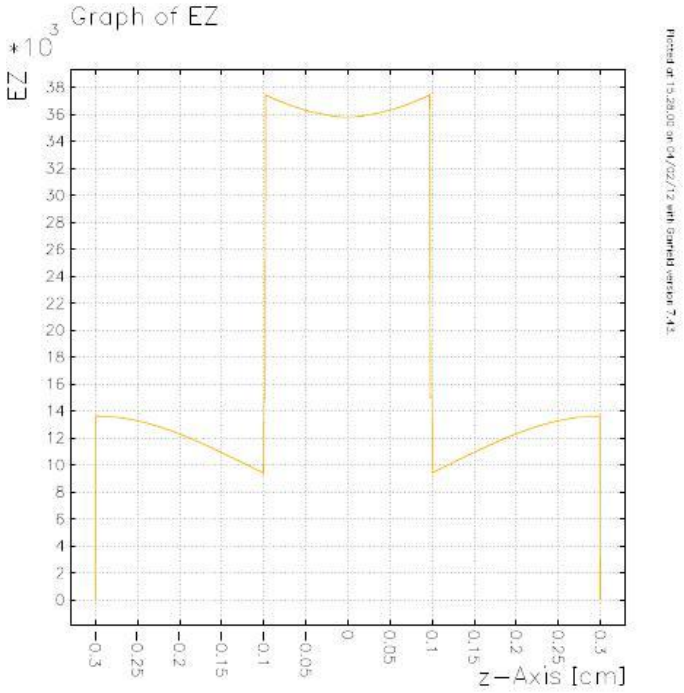
Avalanche of an electron released at the centre
Operating voltage: 12 kV
Gas: TFE + Isobutane (95:5)

Effect of Surface Asperity

Simulated electric field with 12 kV potential applied to the RPC



With a cone shaped asperity on Bakelite

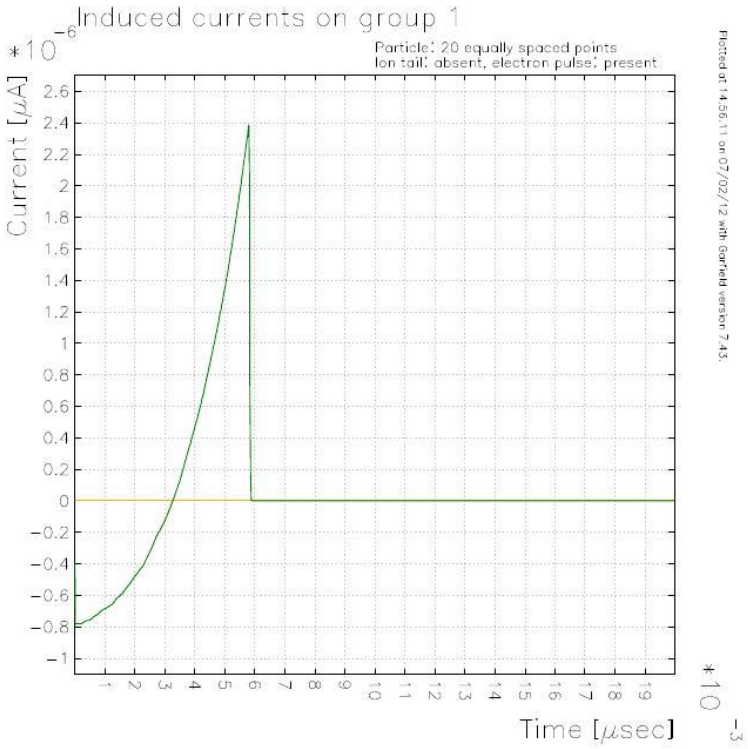


With silicone-treated Bakelite

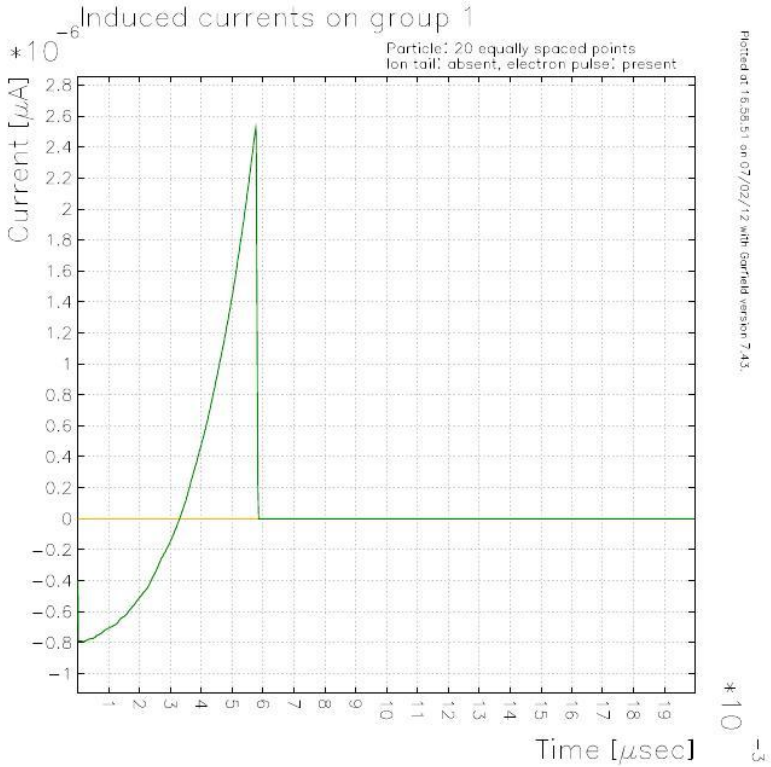
A sharp rise in the field near asperity which can alter the induced charge or signal. Surface treatment removes the spike and the field is larger throughout!!

Effect of Surface Asperity

Simulated induced current with 12 kV potential applied to the RPC



With a cone shaped asperity on Bakelite

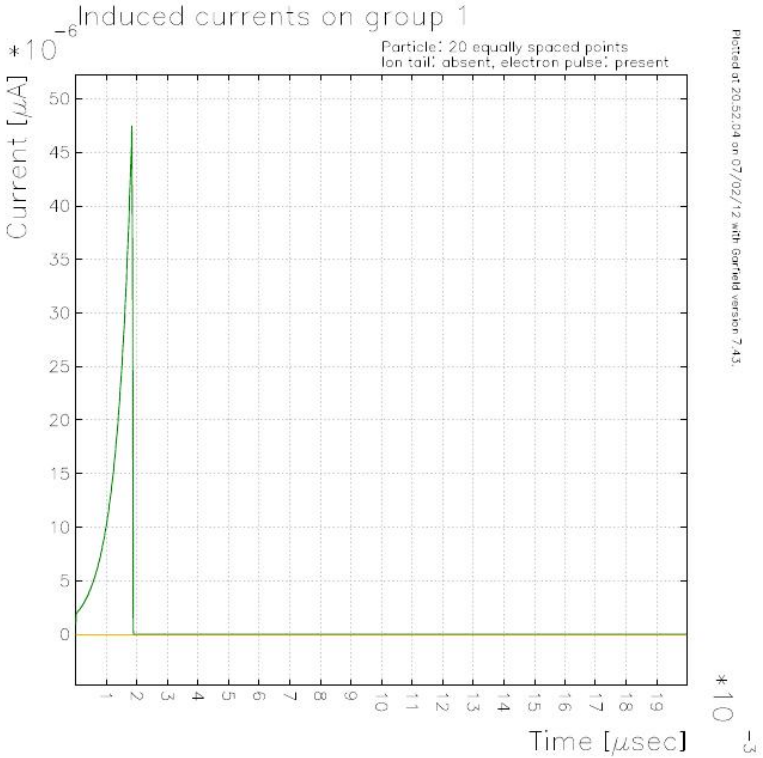


With silicone-treated Bakelite

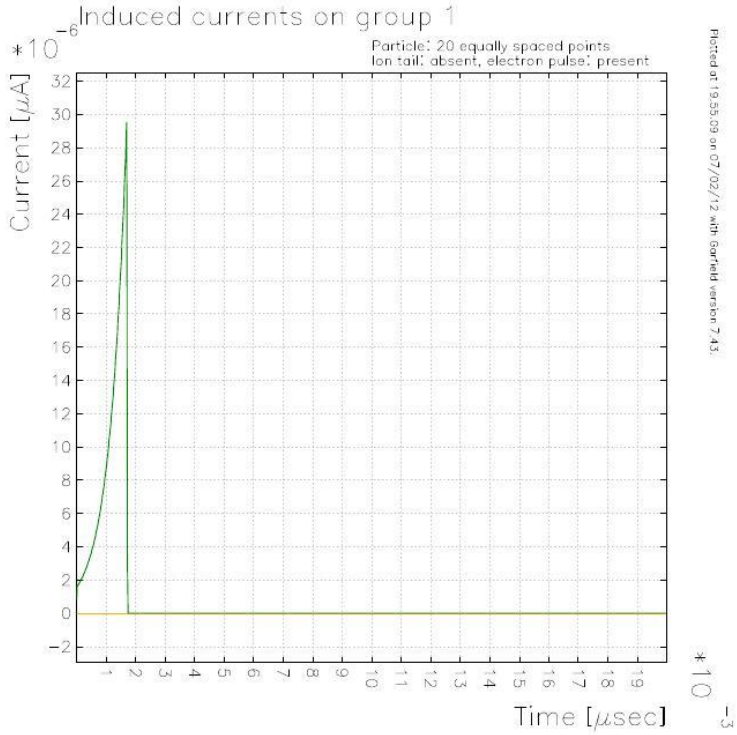
Larger signal is induced in surface treated Bakelite which follows the field configuration.

Effect of Surface Asperity

Simulated induced current with 16 kV potential applied to the RPC



With a cone shaped asperity on Bakelite



With silicone-treated Bakelite

Larger signal is induced in uncoated Bakelite with asperity which conforms the increase in the field near the asperity.

Concluding Remarks

1. ***The present simulation in general seems to under-predict the induced signal in Bakelite RPC in comparison to the measurements.***
2. ***Possible reasons for the disagreement of the simulation with experiment may be:i) improper field simulation ii) underestimated transport properties, iii) experimental uncertainties.***
3. ***Field has been simulated by neBEM V1.8.7 which produced field values in agreement with analytical ones. However, more accurate configuration can be achieved by introducing more precise geometrical and physical parameters.***
4. ***The transport properties of TFE based mixtures may require some attention since Magboltz 8.9.3 indicates very low amplification in the relevant parameter space.***
5. ***Experimentally, there can be uncertainties arising in the geometrical parameters, as well as electrical permittivity of various dielectric media.***

Concluding Remarks

6. ***The presence of surface asperities has been found to significantly distort the otherwise uniform field configuration depending on their shape and amplitude.***
7. ***The distorted field can be responsible for localized large currents following larger amplification.***
8. ***Far from the asperity, present calculation shows slightly larger induced current in surface-treated RPC in comparison to that without surface treatment.***
9. ***Further detailed investigation is underway.***

Thank You!!