SIMULATION OF THE PICOSEC DETECTOR

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On behalf of
The SINP group

MOTIVATION

Fast detectors are necessary to cope up with high luminosity experiments

High pileup environment expected in near-future experimental scenarios

To disentangle overlapping events in the drift volume, a resolution in the drift direction is necessary.

It depends on the response time, i.e., the time between the arrival of the radiation and the rise of the electronic pulse which leads to a finite temporal resolution

TIME RESOLUTION

Time resolution is influenced by

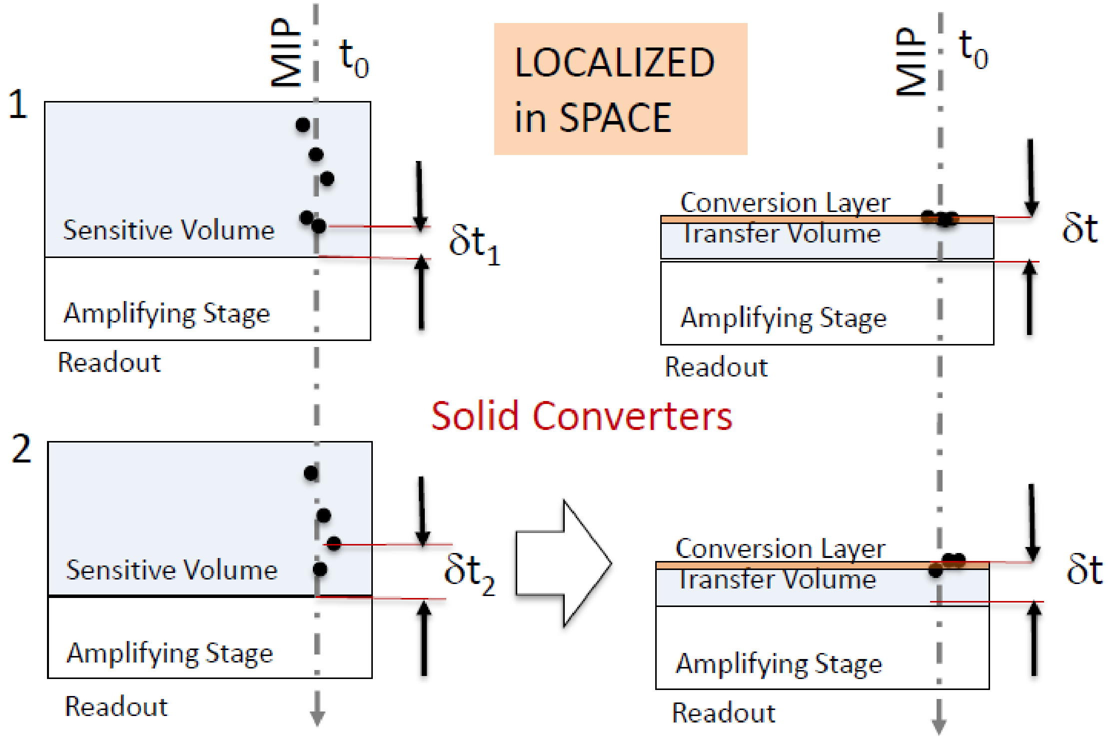
- Fluctuations during primary ionization
- Fluctuations during transport (diffusion)
- Fluctuations during amplification
- Fluctuations during signal acquisition (electronics)

PICOSEC- AN EXPERIMENTAL IMPLEMENTATION

One of the very recent efforts

Reduce primary ionization fluctuations
- make it happen in a small conversion layer

Reduce transport fluctuations
- reduce transfer volume and maintain suitable range of electric field



Sensitive volume (if eventually needed) reduced in order to:
- Avoid direct gas ionization
- Reduce diffusion

Eraldo, Detector Seminar, 29/09/17

NUMERICAL EXPLORATION OF PICOSEC-LIKE DEVICES

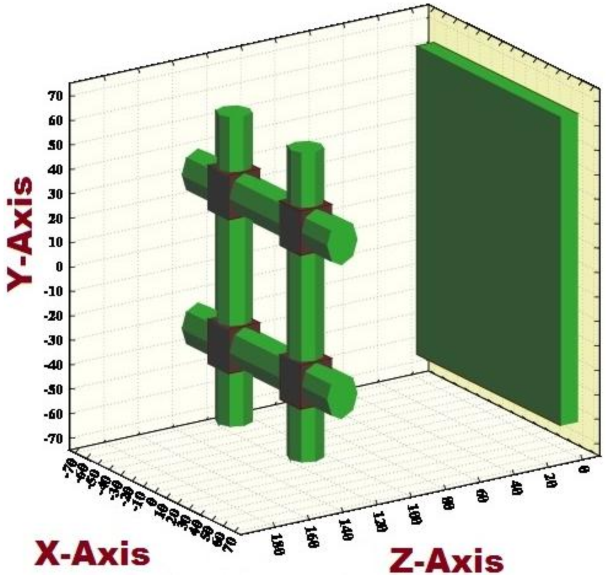
Adopt the PICOSEC geometry

- Assume periodic structure
- Ignore non-uniformities such as spacers

Use a fixed point / line / surface to release electrons

- A point, at present

The results presented here are preliminary in nature

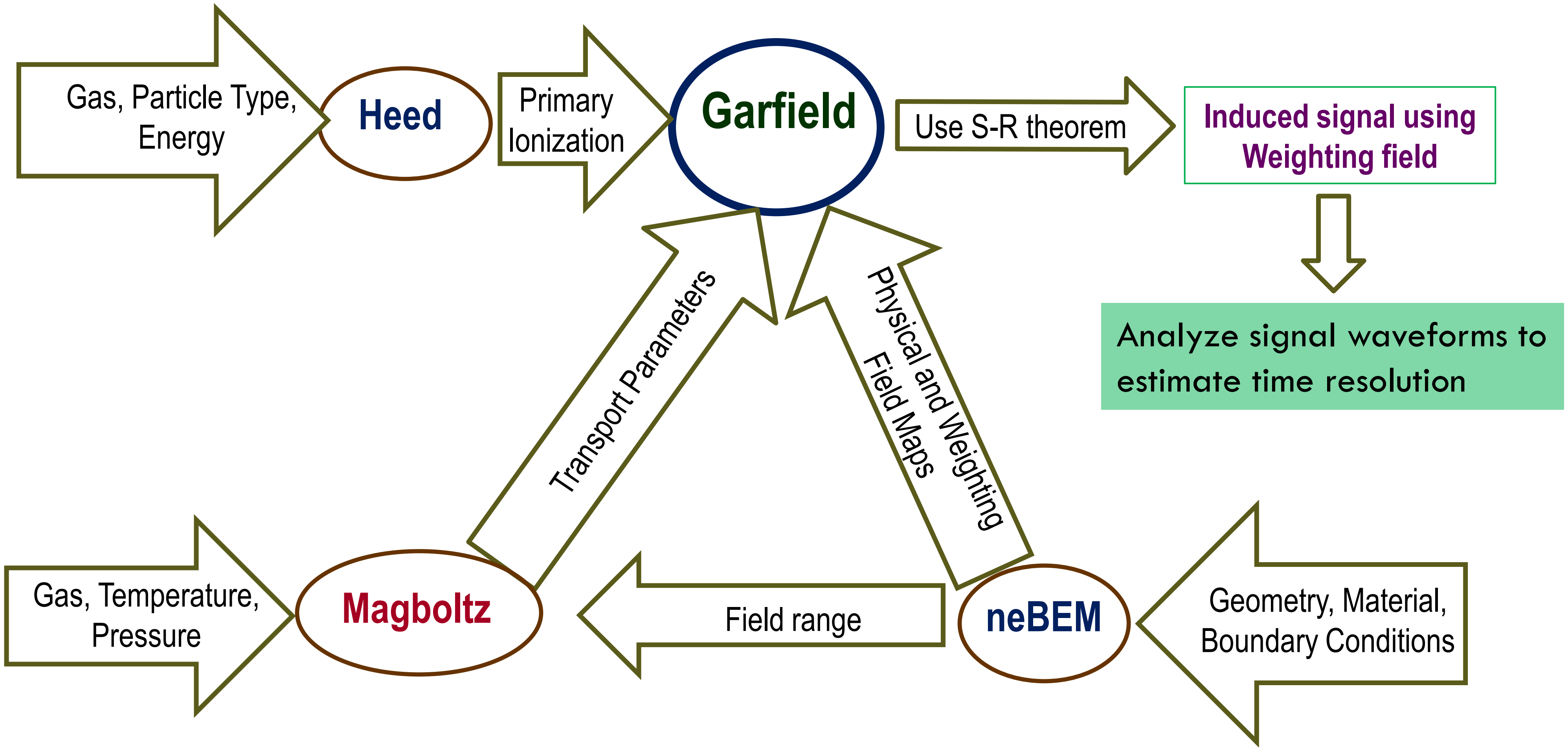


This work is essentially a continuation of our works presented

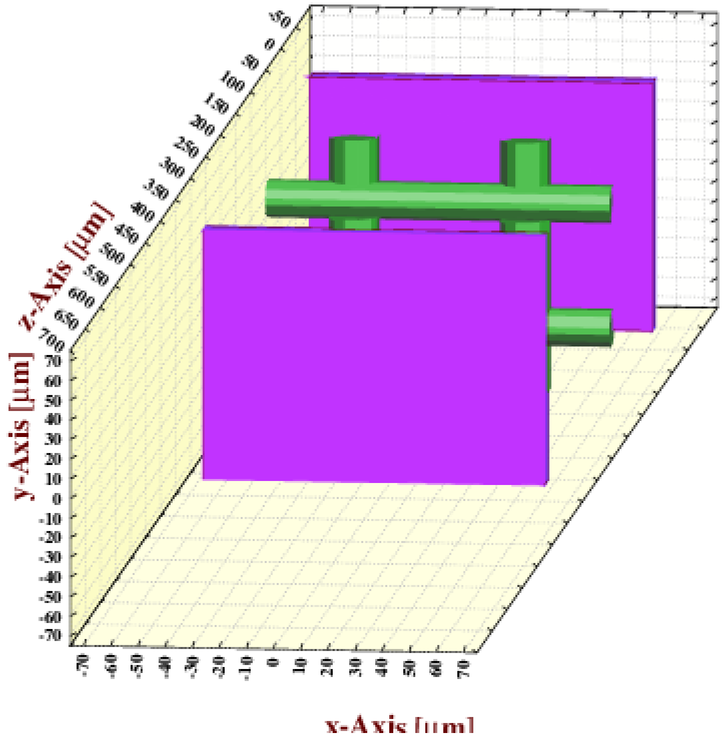
➢At Trieste in MPGD 2015 [*Time Resolution of Micro-Pattern Gaseous Detectors*, **RD51 Note 2016-002, arXiv: 1605.02867**], and

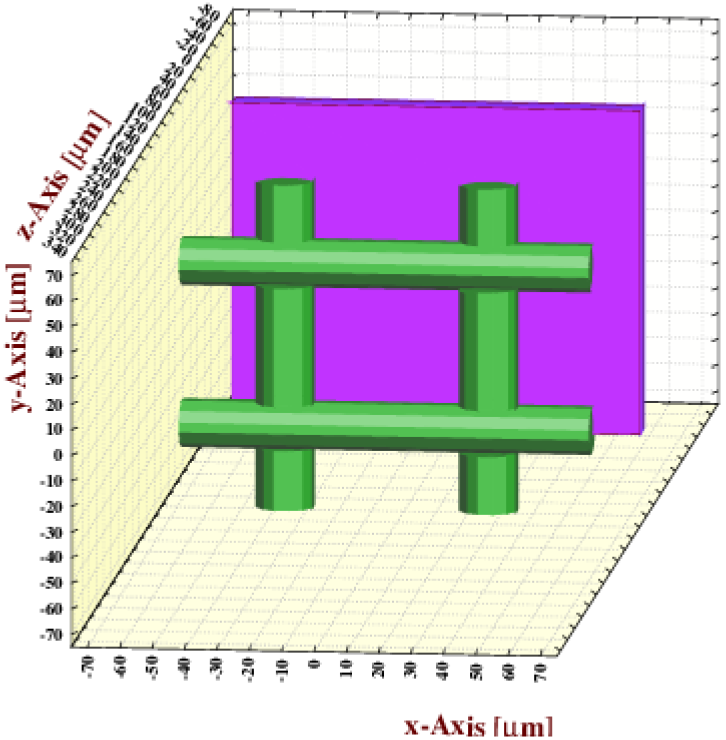
➢At Ghent in RPC2016 [*Numerical study on the effect of design parameters and spacers on RPC signal and timing properties*, **2016 JINST 11 C09014**]

SIMULATION FRAMEWORK



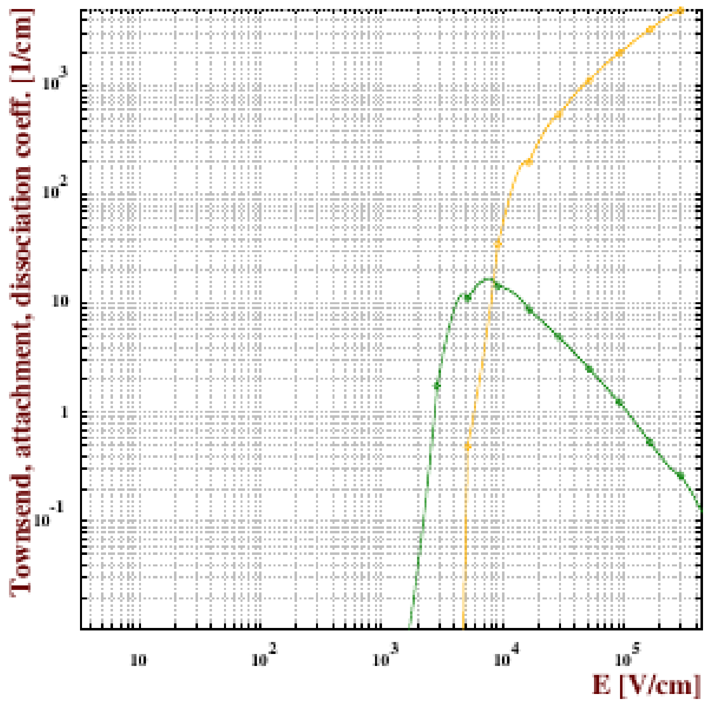
SIMULATION GEOMETRY

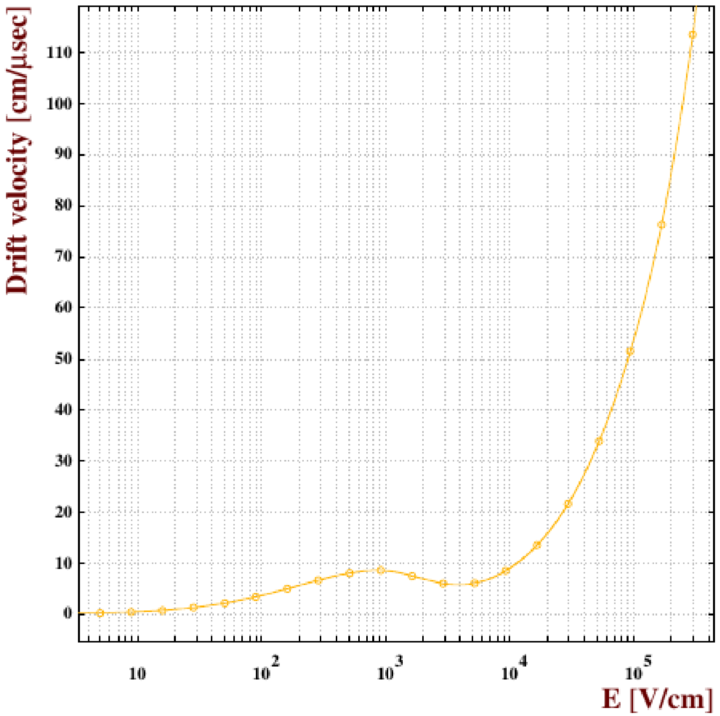


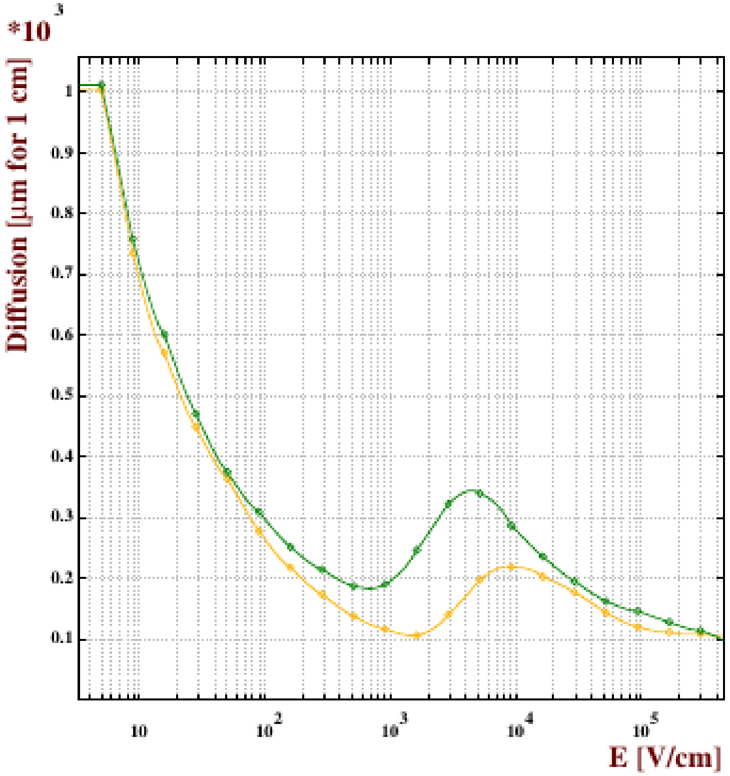


Drift gap: 200 µm
Amplification gap: 128 µm
Wire diameter:18 µm
Wire pitch: 45 µm
Wire cross-section modelled by a cylinder of sides: 16
Target element size: 10 µm

TRANSPORT PROPERTIES FOR NE:C2H6:CF4(80:10:10)

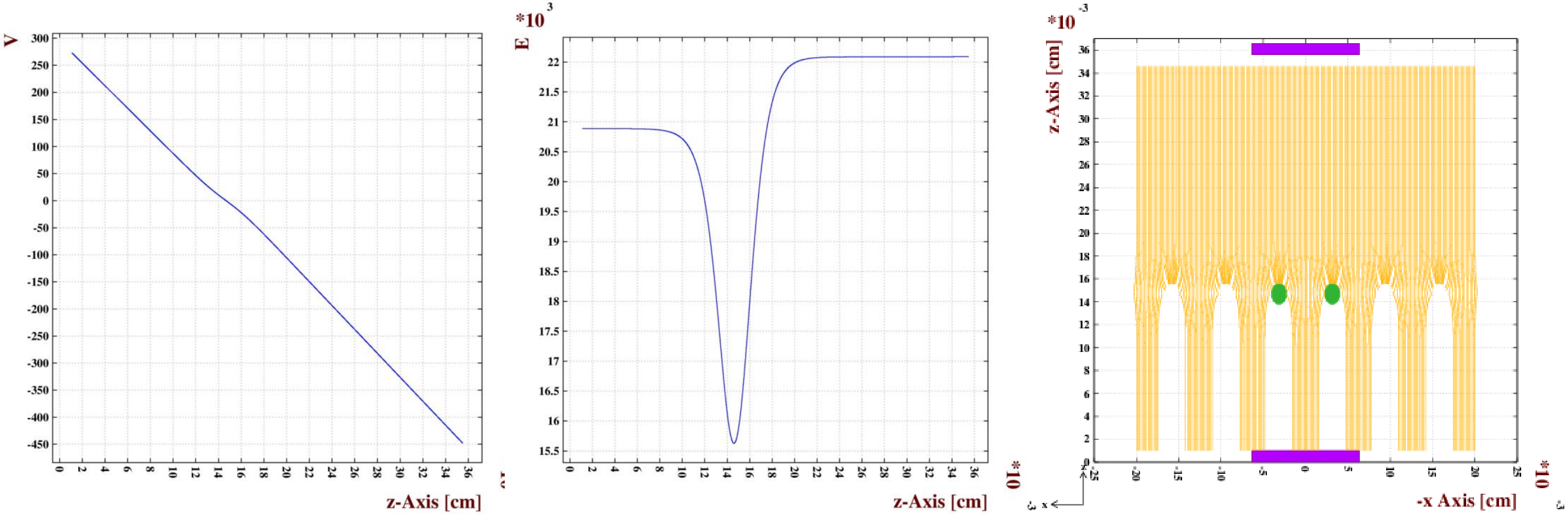






Electric field more than 10kV/cm should be suitable for this gas mixture

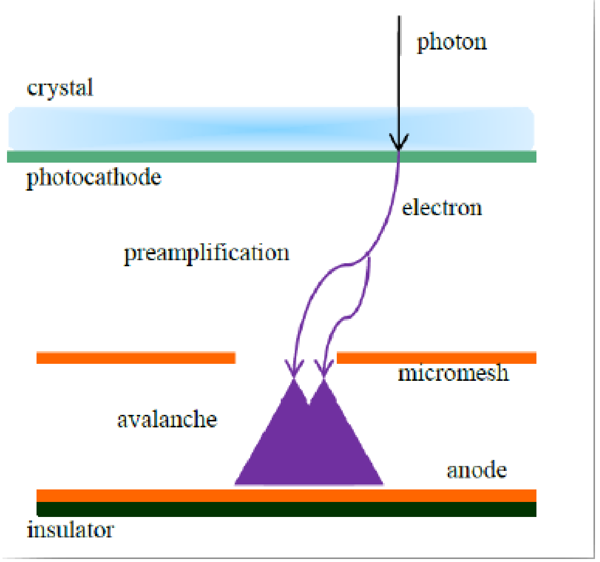
VOLTAGE CONFIGURATION, FIELD AND DRIFT LINES



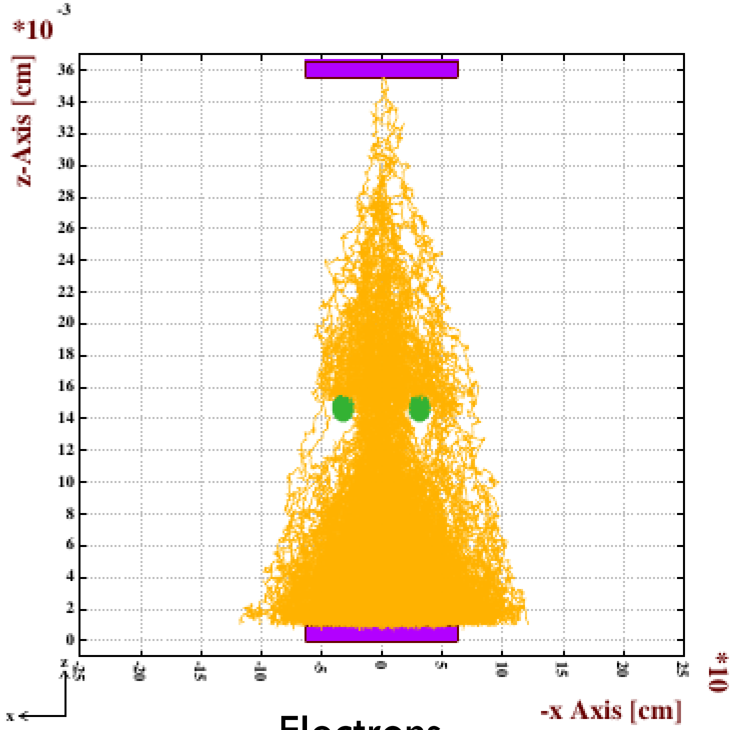
Anode: 275V, Mesh: Grounded, Drift: -450V

This is not an optimum voltage configuration, but one among many “cherry”-s (slide 26 of Eraldo’s talk on 29/09/17)

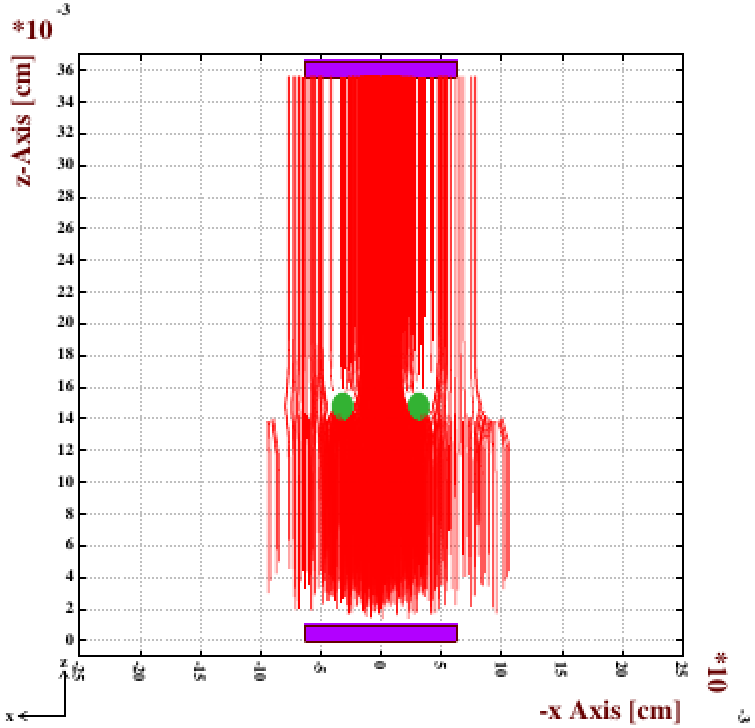
AVALANCHE



Eraldo, Detector Seminar, 29/09/17



Electrons

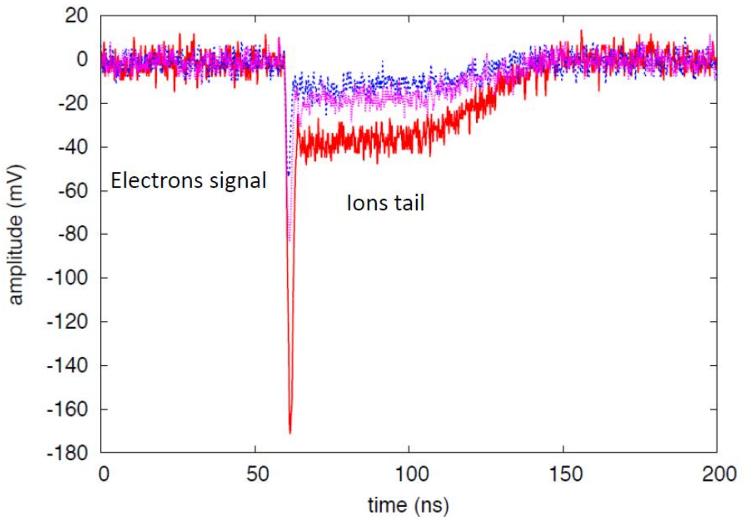


Ions

23.5% of drift volume electrons go into amplification zone: improves for smaller drift and larger amplification field
85% of amplification zone ions get collected by the mesh; 44% of total ions collected at the cathode

SIGNAL

Measurement – MIP(muons)



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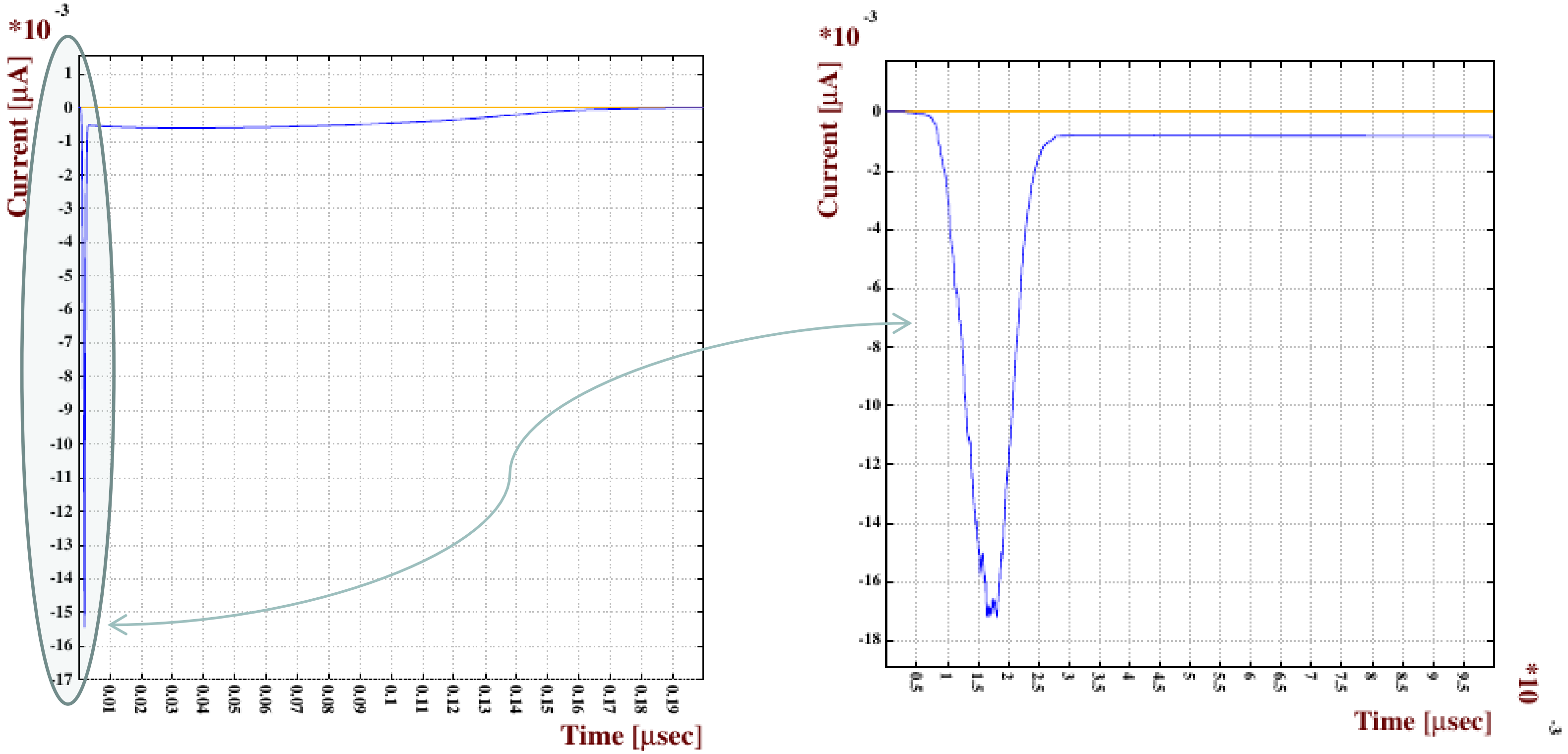


Simulated

Simple assumption of constant ion mobility

RAW SIGNAL TO TIME RESOLUTION

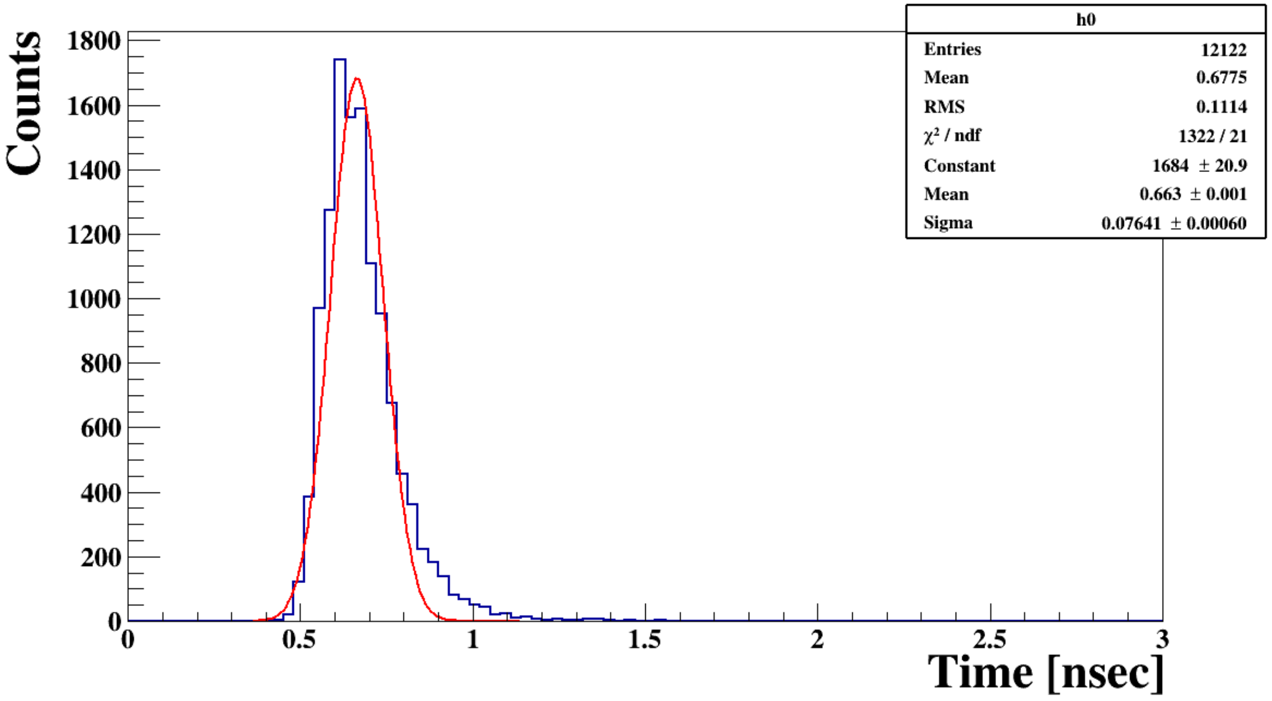
Store individual raw signals per event (amplitude versus time)

- Number of events: 25000
- Neglect signals below threshold: 10 pA

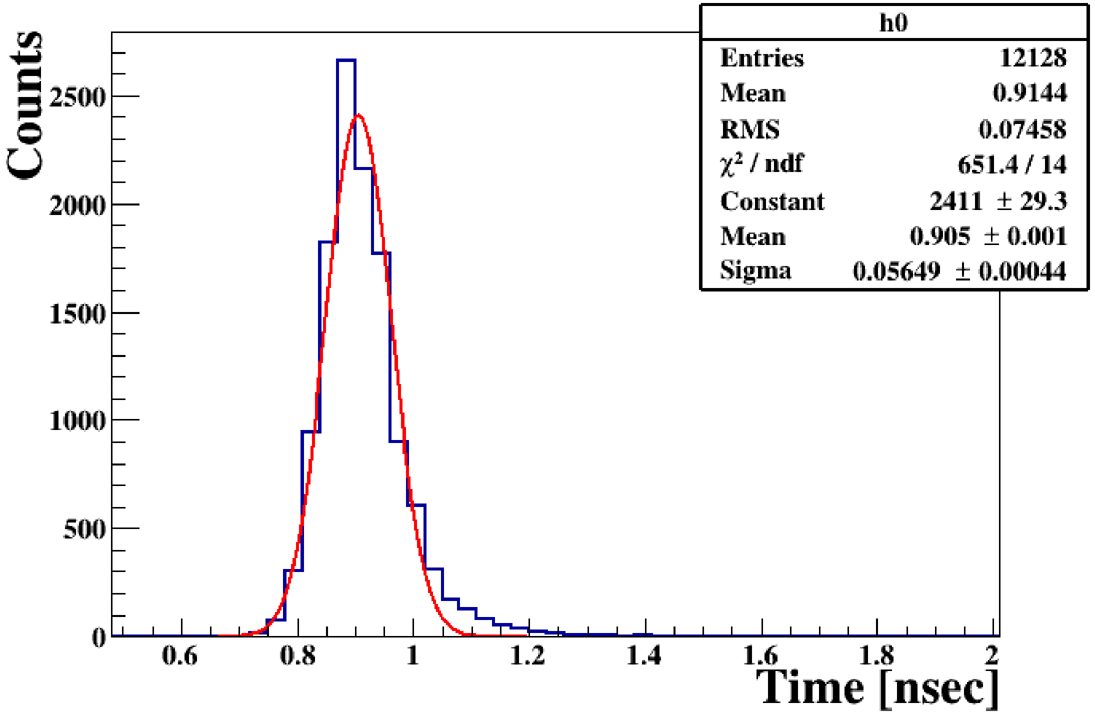
Carry out standard signal analysis as done for experimental data

- Use C / C++ / ROOT
- Leading Edge Threshold: 1 nA
- Constant Fraction Discrimination: 10% of peak

TIME SPECTRA

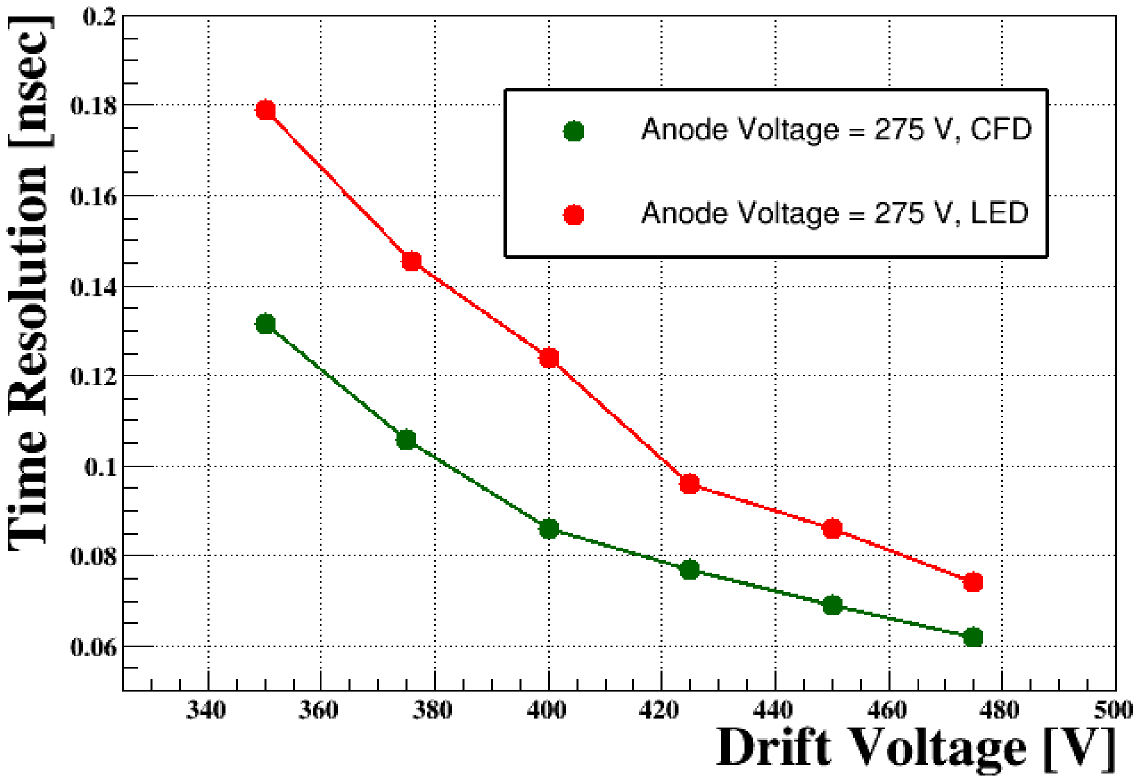


LED spectrum



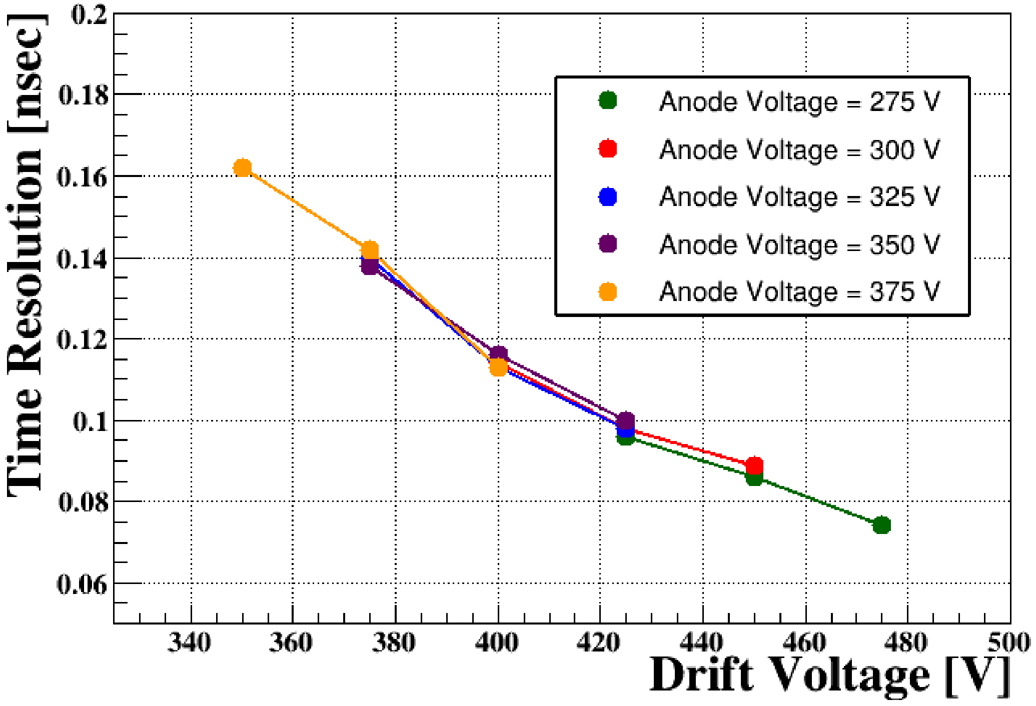
CFD spectrum

EFFECT OF ELECTRONICS

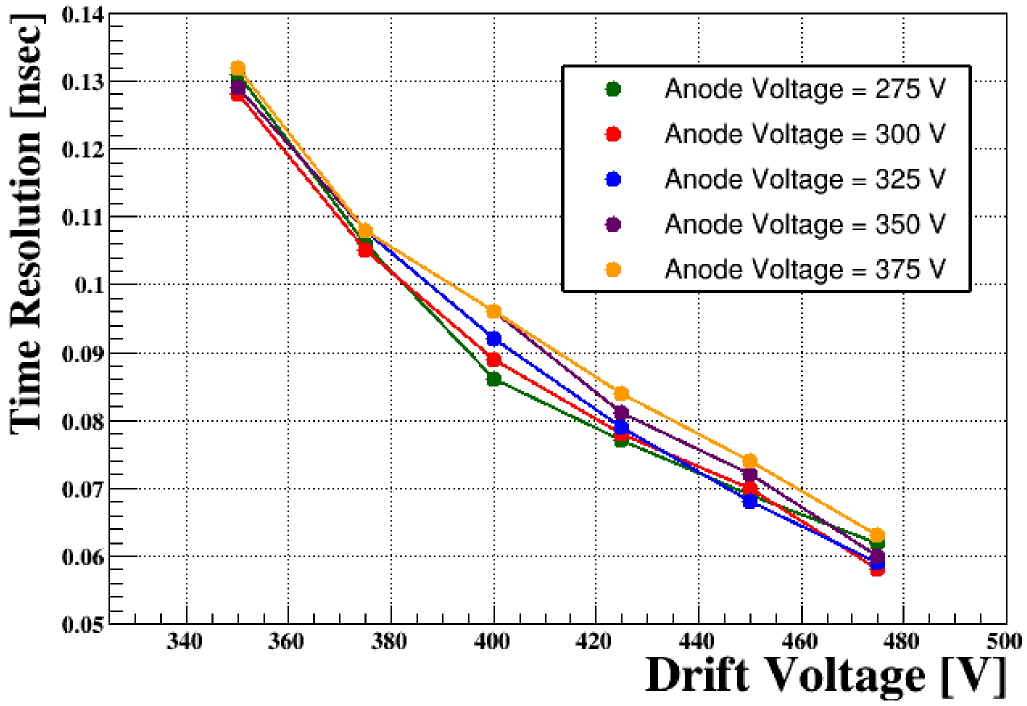


CFD provides a smaller estimate of the time resolution, as expected

EFFECT OF VOLTAGE / FIELD CONFIGURATION

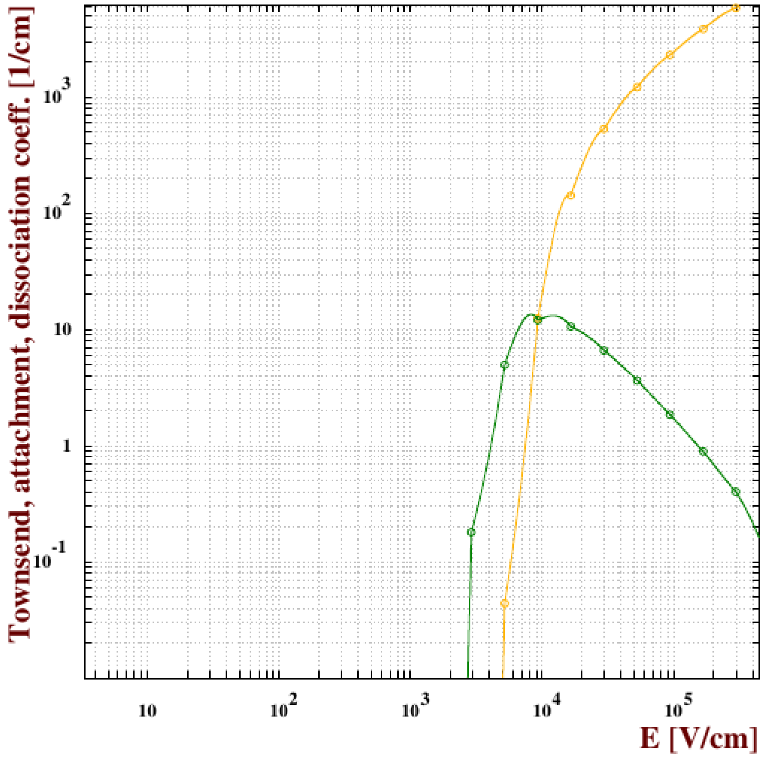


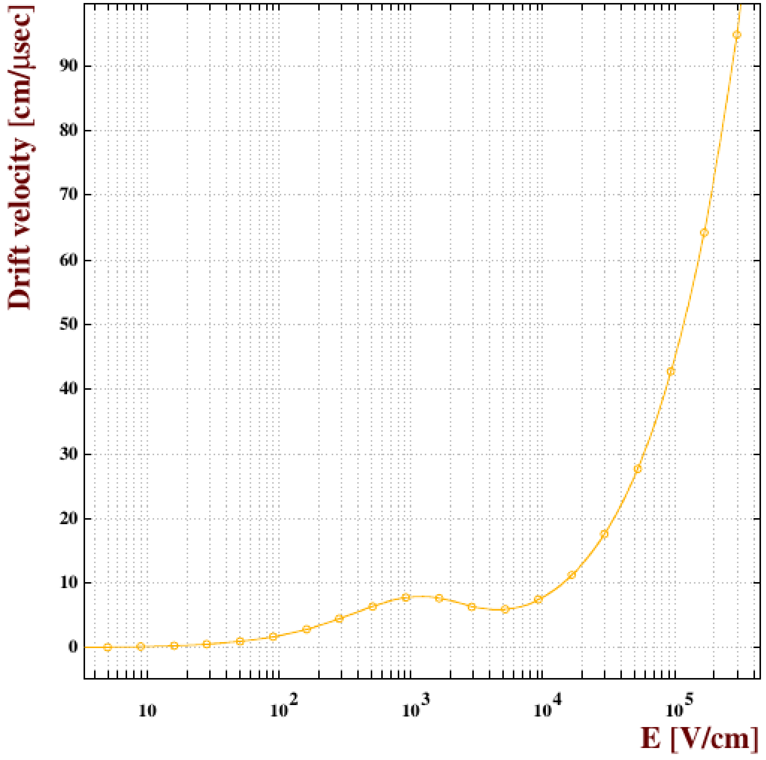
LED Values

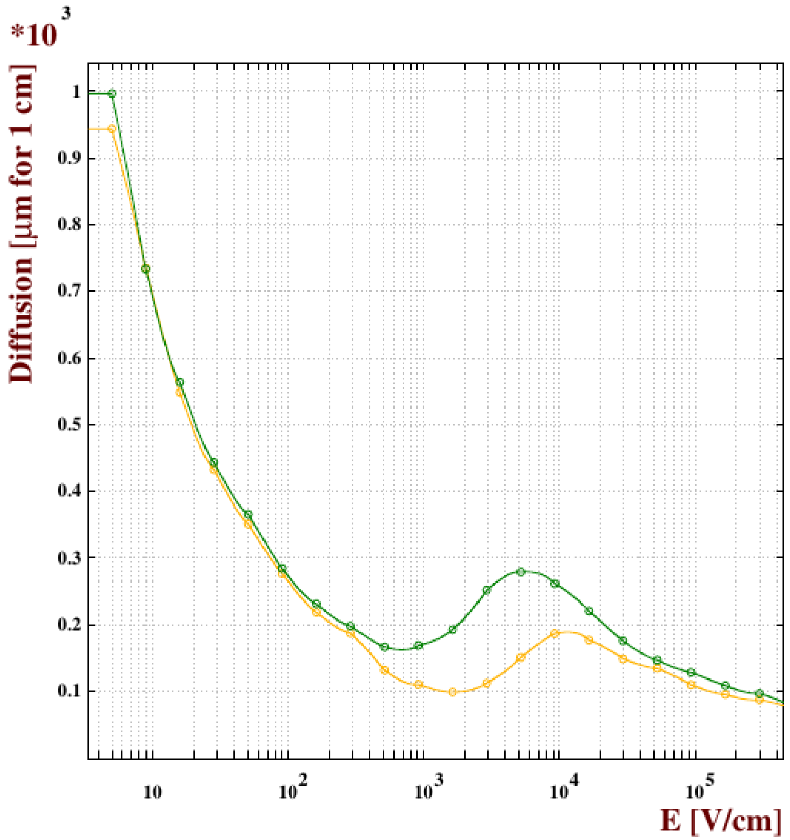


CFD Values

EFFECT OF GAS MIXTURE



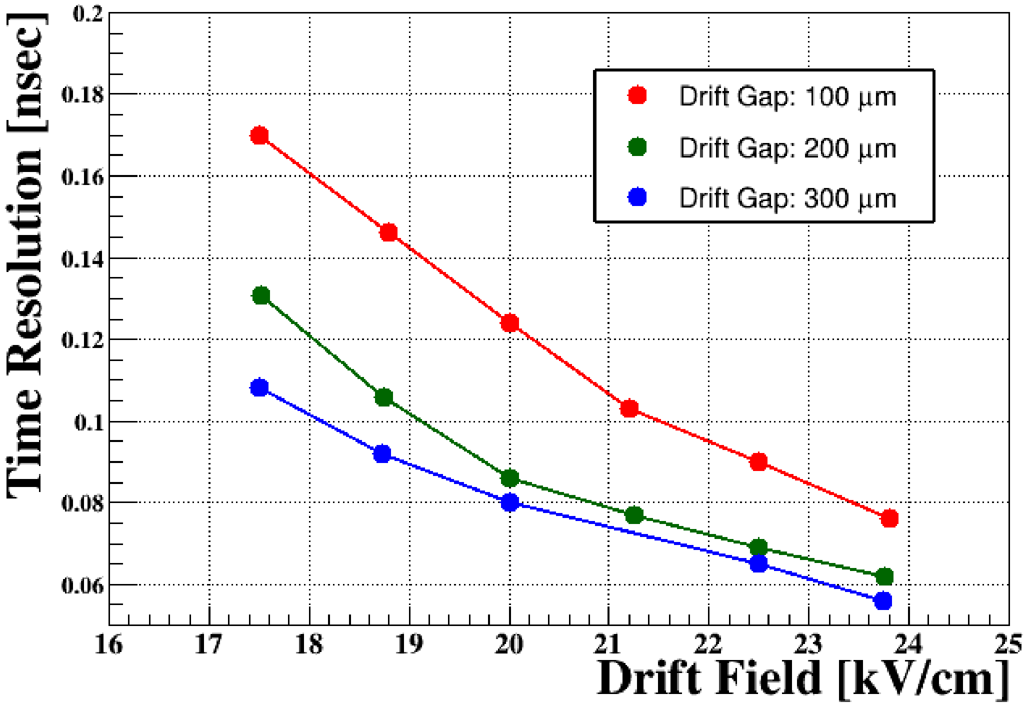




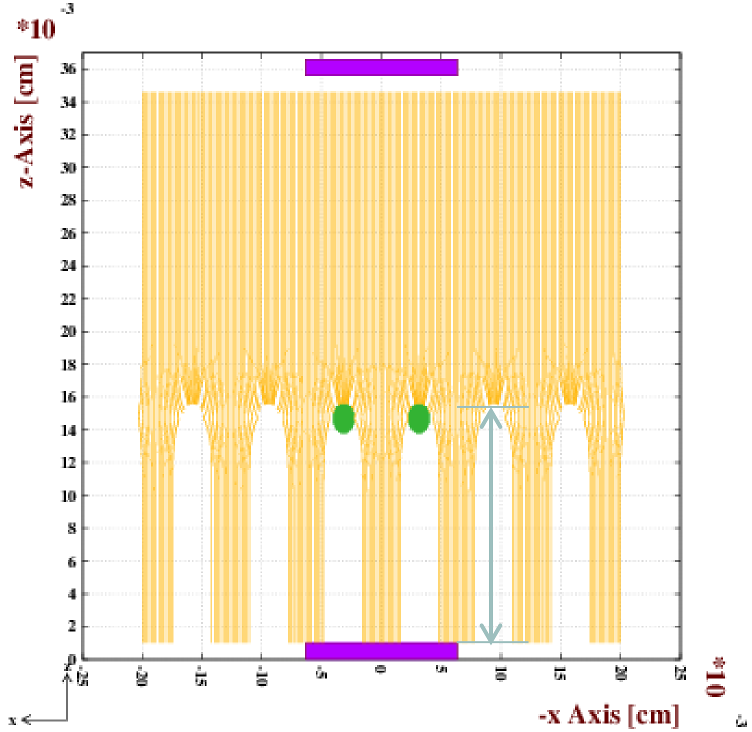
Replace ethane by isobutane: The transport properties are only slightly altered.

Anode 275 V and Drift 450 V: With isobutane the resolution is 78 ps, in comparison to 65 ps with ethane.

EFFECT OF GEOMETRY

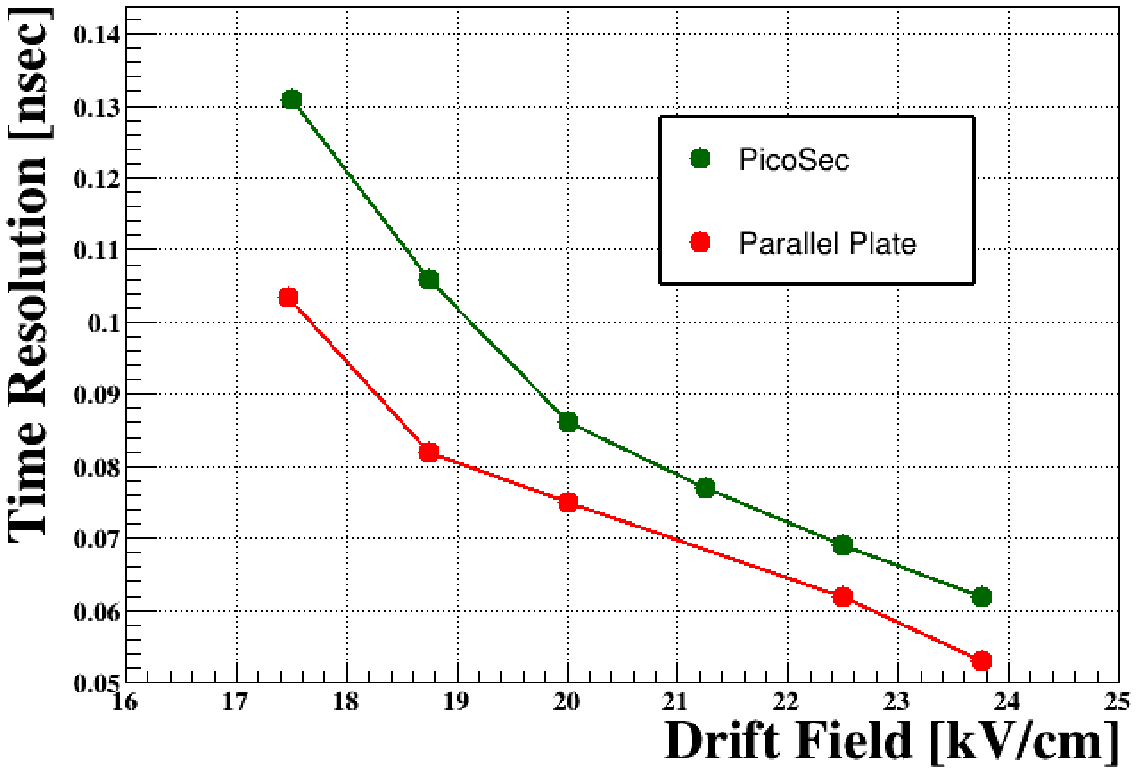


Variation of drift gap



If the amplification gap is considered to be 128μm from the top of the mesh (as shown above), the time resolution is 132 ps in place of 65ps!
Strong influence of the amplification geometry and field.

HOW ABOUT A NO-MESH GEOMETRY?



The PICOSEC has earlier dimensions

•Drift length: 200 μm

•Wire diameter: 18 μm

•Amplification gap: 128 μm

•The no-mesh (parallel-plate) device length of the gas volume: 346μm (200+18+128)

Point to be noted:

•$Picosec_{Gain}$: ~1200

•$Parallel\ Plate_{Gain}$: ~ 500000

Without Penning effects

COMPUTATIONAL RESOURCES USED

Workstation with two XEON E5 2600 processors @ 2.3GHz

Used 8 cores (workstation has 64)

Used 2 GB RAM (workstation has 128GB)

Initial solution: 15 minutes (~2000 elements, 30 repetitions on X and Y, 4mm long device)

Subsequent solutions (same geometry, different voltage configurations): couple of minutes

Production of fast volume: 3 hours (~6000 nodes)

Generation of raw signals: 10 minutes (microscopic tracking)

Post-processing using independent codes (C / C++ / ROOT): few minutes

SUMMARY

Simulation results are reasonably close to the experimental results.

Variations of gas mixture and geometry can be studied easily – two examples have been presented. Both, as expected, have significant influence.

Funnelling does not seem to be very important: a drift field of just below 25 kV/cm and an amplification field of slightly above 25 kV/cm produced nice results.

A geometry without mesh may also work, but it is likely to be prone to sparks at such high fields where transport properties have 'suitable' values. The mesh impedes transport as well as absorbs large number of electrons and ions. On one hand, this leads to worsening of time resolution, on the other, it saves the device from sparks. It is too early to decide, though.

FUTURE PLAN

Refine existing results (easy), compare with the already vast body of experimental data (time consuming)

Geometry

- Microbulk, thin-mesh bulk (easy)
- Effects of pillars and other non-uniformities (easy, but time consuming)
- Effect of mesh (easy, but the understanding may not be)
- Other geometrical variations (easy; include both gaps – is there any optimum value of drift gap around 200 – 300 μm?)

Gas

- Include Penning transfer (easy, but need experimental data for relevant gas mixtures)
- More gas mixtures (easy)
- Effect of primary ionization in the however-small gas volume (easy)

Electronics

- Include ideal electronics (easy); include noise (easy)
- Include formal data analysis (follow experimental approach, also explore alternative approaches)

Explore ways to reduce fluctuations during amplification (interesting but not tried)

Primary ionization physics (interesting but not tried)

ACKNOWLEDGMENTS

The SINP group is not a part of the PICOSEC collaboration, but we have been encouraged to try simulating the experimental results and have been provided with all the necessary details.

We are specially indebted to Leszek, Eraldo, Thomas and Rob.

THANK YOU!