Gas Parameters in Micro-meter Gap at High Electric Field

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Outline

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  - Motivation
  - Laser facility
- Experimental Measurements
  - Drift chamber probe
  - RPC probe
- Comparison of test results and simulation
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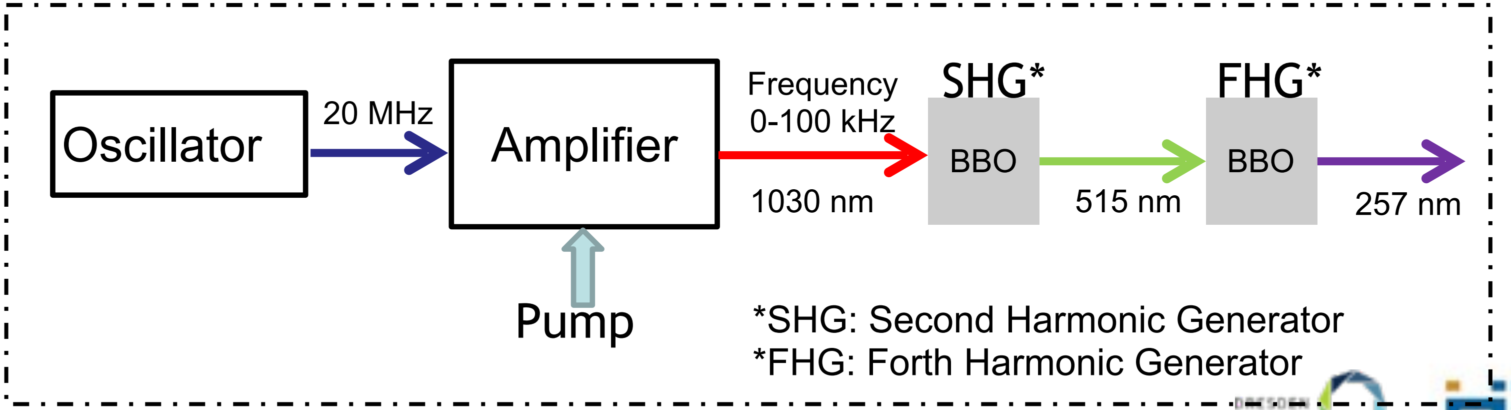
Introduction

- Motivation:
  - Precision measurements of gas parameters of effective Townsend coefficient and drift velocity under atmospheric pressure and strong electric field (~100 kV/cm)
  - Further analysis of avalanche process in RPC
  - Searching for new gas
- Laser test facility:
  - Laser: focused UV laser (257 nm, 0 - 100 kHz)
  - Detector probes: special designed for laser input
  - Position: precise controlled by step driver (1 µm)
  - DAQ: for measurement of time and charge.

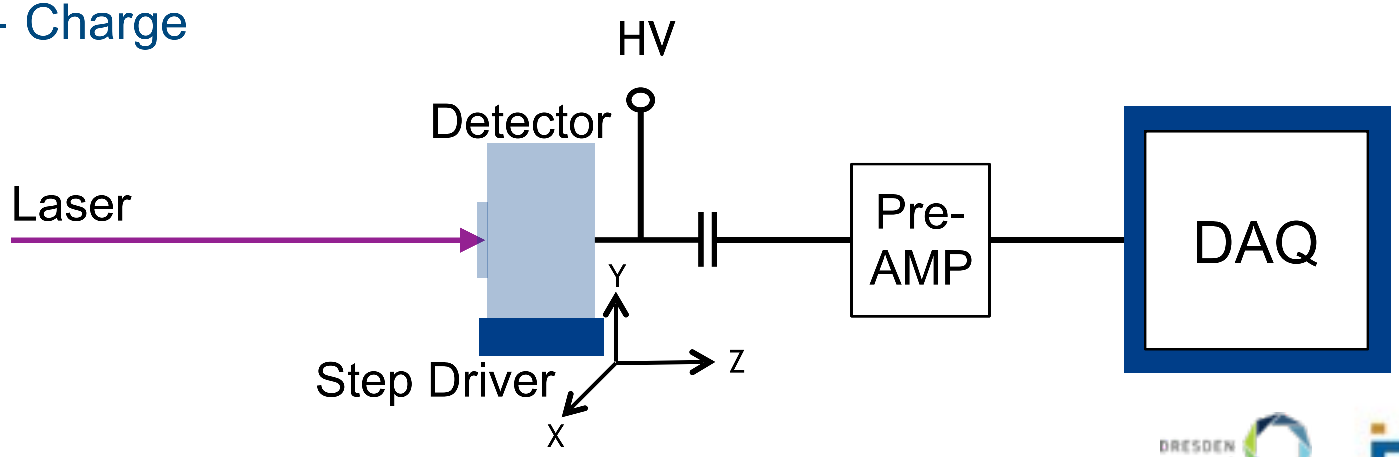
Laser Generation

- Laser Parameters
  - Wavelength : 257 nm (UV laser)
  - Frequency of Pulses : 500 Hz
    - (Possible range of 0-100 kHz)
  - Size of Focus : ~10 µm
  - Intensity: 0-700 nJ



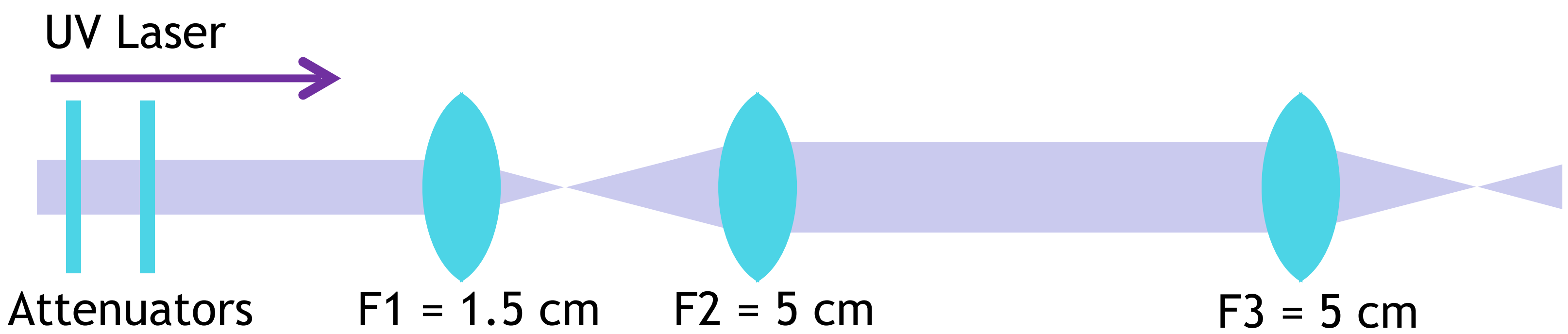
Step-driver and DAQ System

- Step-driver :
  - Detector (gas box) is mounted on the step-driver controlled by PC
  - Range: 8000 μm for 3 dimensions.
  - Accuracy: ~1 μm
- DAQ system:
  - DAQ system is connected to PC via oscilloscope.
- Measuring :
  - Time (Triggered by laser)
  - Charge



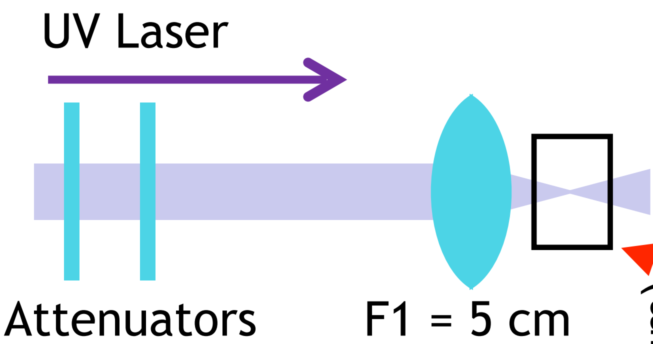
Optics and focus

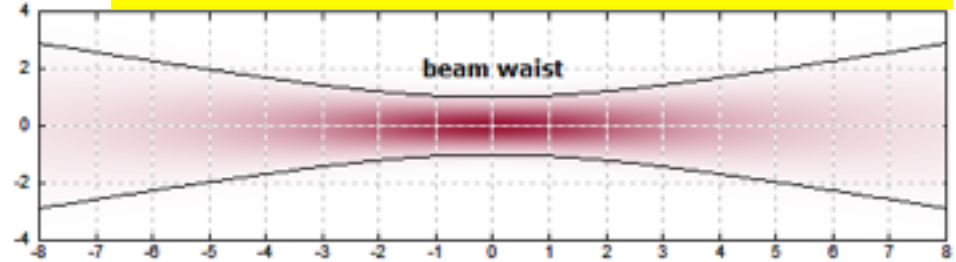
- Parameters:
  - Width of Focus : ~10 µm
  - Length of Focus : ~1 mm

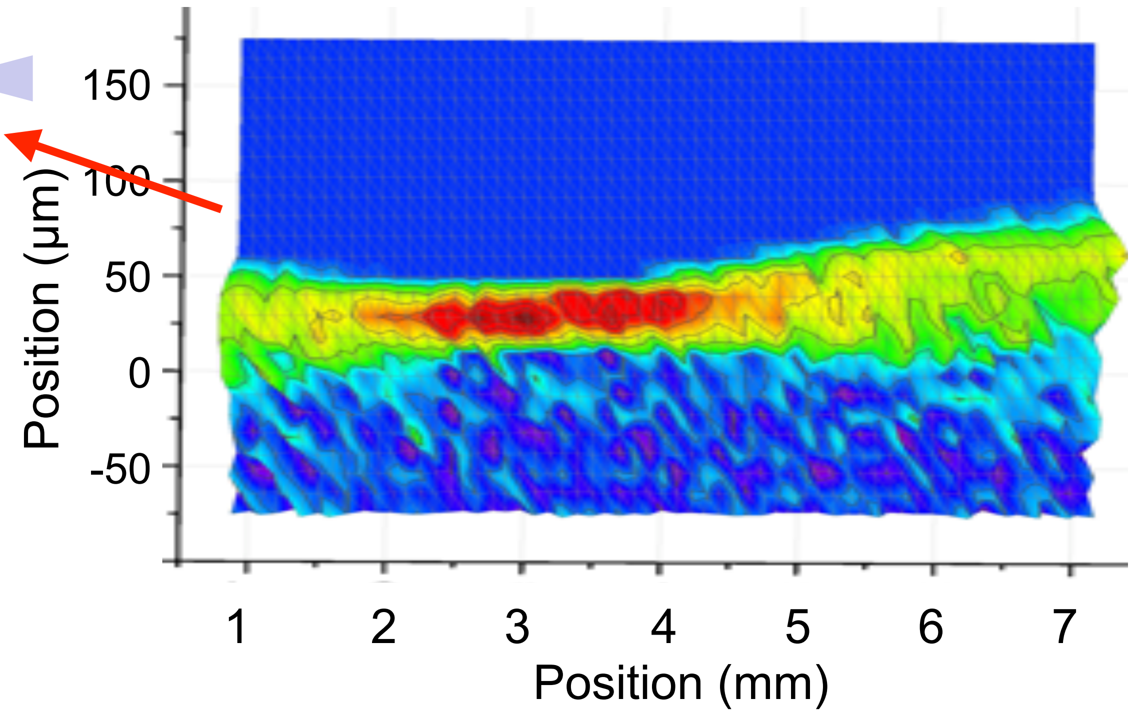


- https://www.rp-photonics.com/gaussian_beams.html

Focus



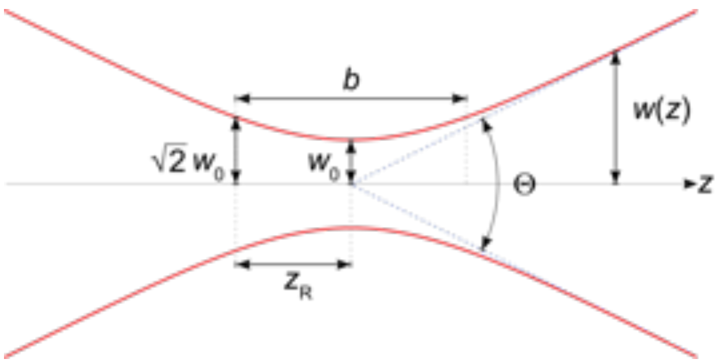




Set up:
Only one lens with f = 5 cm is mounted for simplify the situation
Scan of focus:
An edge is mounted on the step driver (Page.5). Along programmed path, the edge is positioned along many sections. The difference of intensity of 2 positions on a section is the laser intensity in this position.

– Width of focus : < 40μm
– Waist size ~ 20 μm

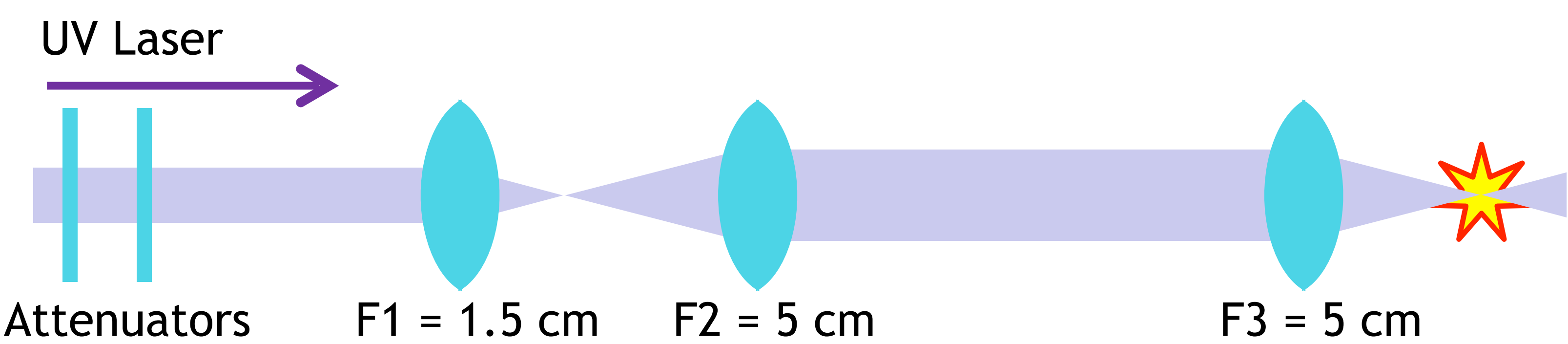
Measurement of focus



$$w_0 = \frac{2\lambda}{\pi\Theta} = \frac{\lambda}{\pi\theta} = \frac{\lambda f}{\pi w_f} \sim f$$

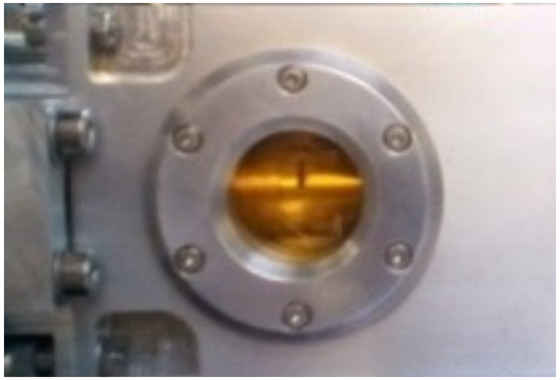
$$z_R = \frac{\pi w_0^2}{\lambda},$$

- focus size of following tests:
  - Waist size ~ 6 µm
  - Rayleigh length ~ 0.44 mm

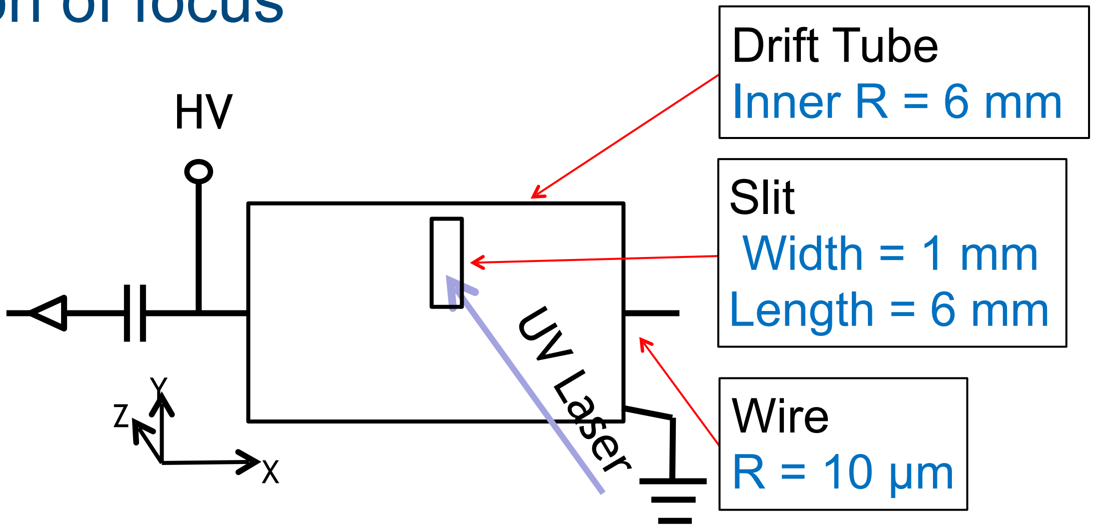


Drift tube probe

- Test the accuracy, reliability… of the facility with well-known detector (drift tube) and gas mixture
- Calibrating primary ionizations – laser intensity
- Calibrating position of focus

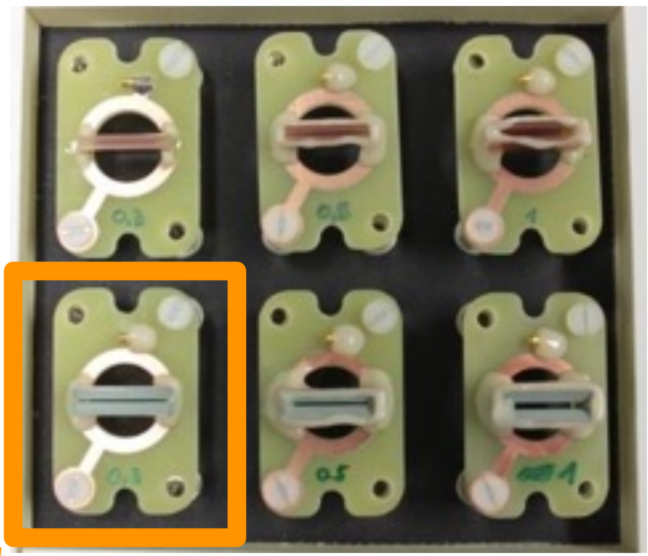


Laser window of gas box
& slit on the drift tube



RPC probes

– Six different kinds of RPC probes are designed

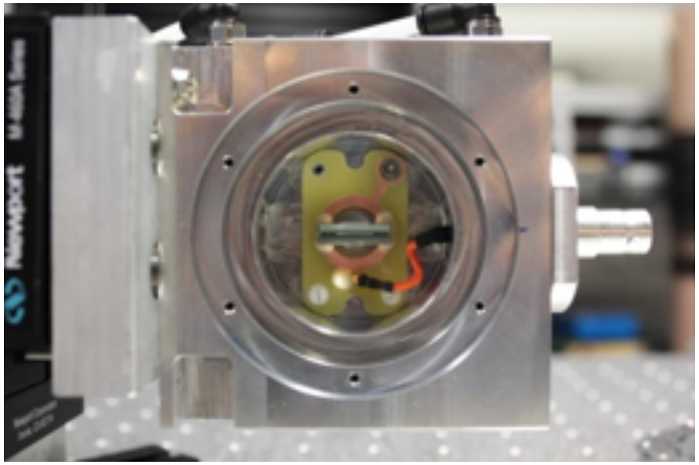


Float glass 0.3 mm	Float glass 0.5 mm	Float glass 1 mm
Ceramic 0.3 mm	Ceramic 0.5 mm	Ceramic 1 mm

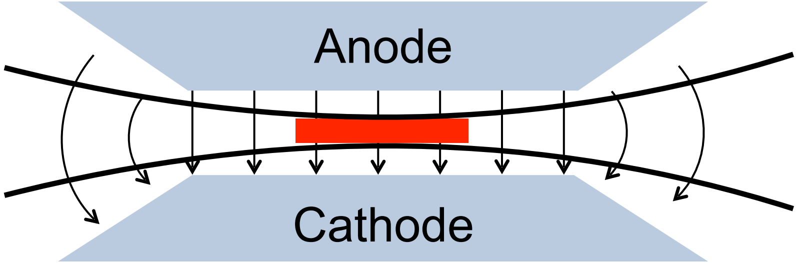
Gas gap width: 300 µm
Size of electrodes: 2.4 mm × 15 mm

RPC probes

- Analyzing the avalanche process in homogeneous electric field
- Measurements of drift velocity and effective Townsend coefficient

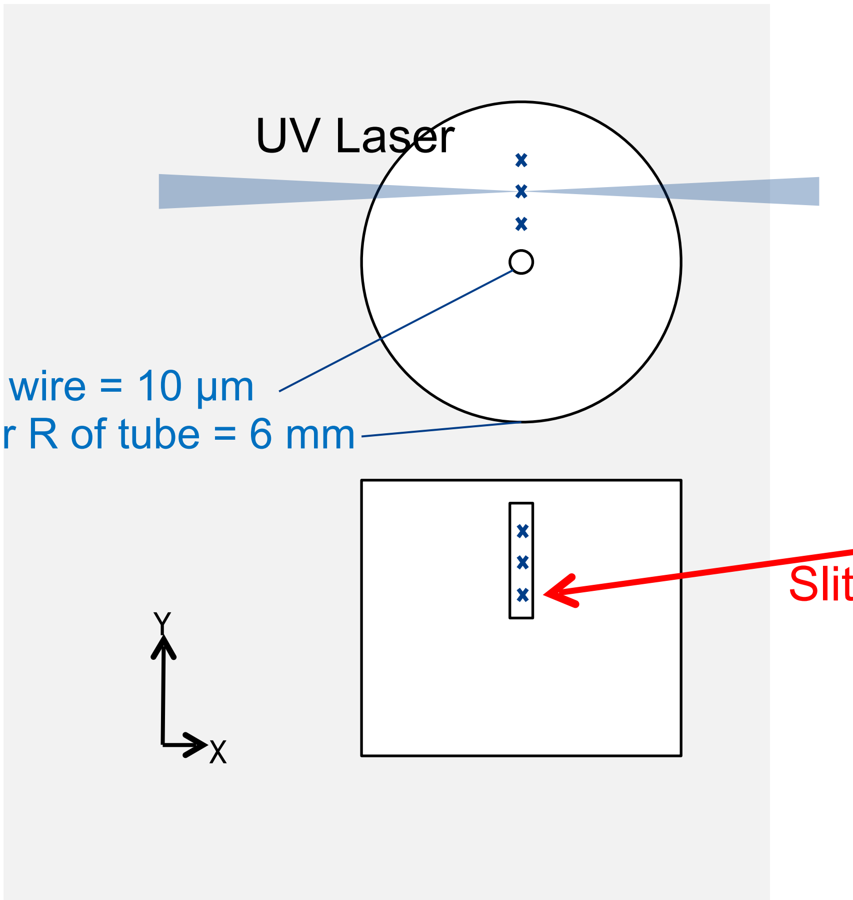


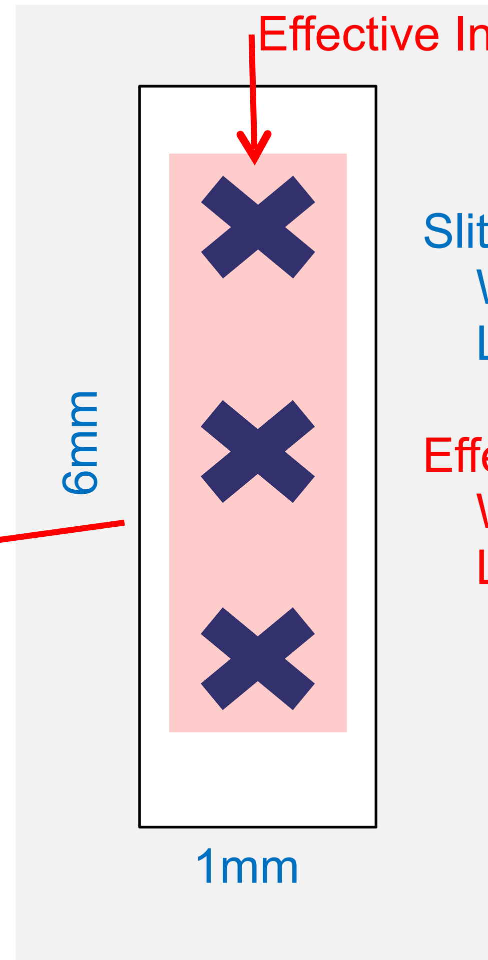
RPC probe under installation



Gas gap width: 300 µm
Size of electrodes: 2.4 mm × 15 mm

Electron drift velocity and time resolution of drift tube



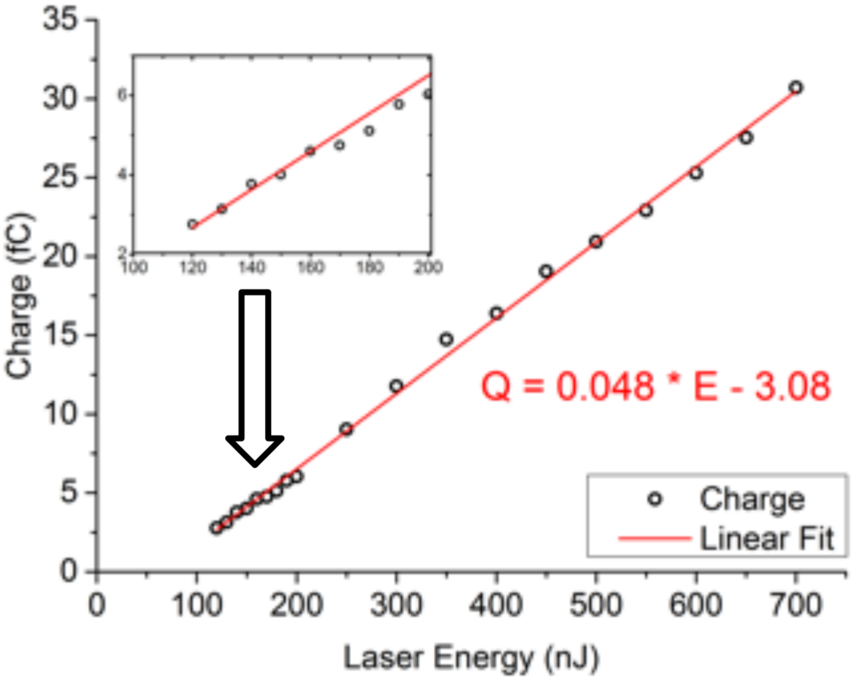


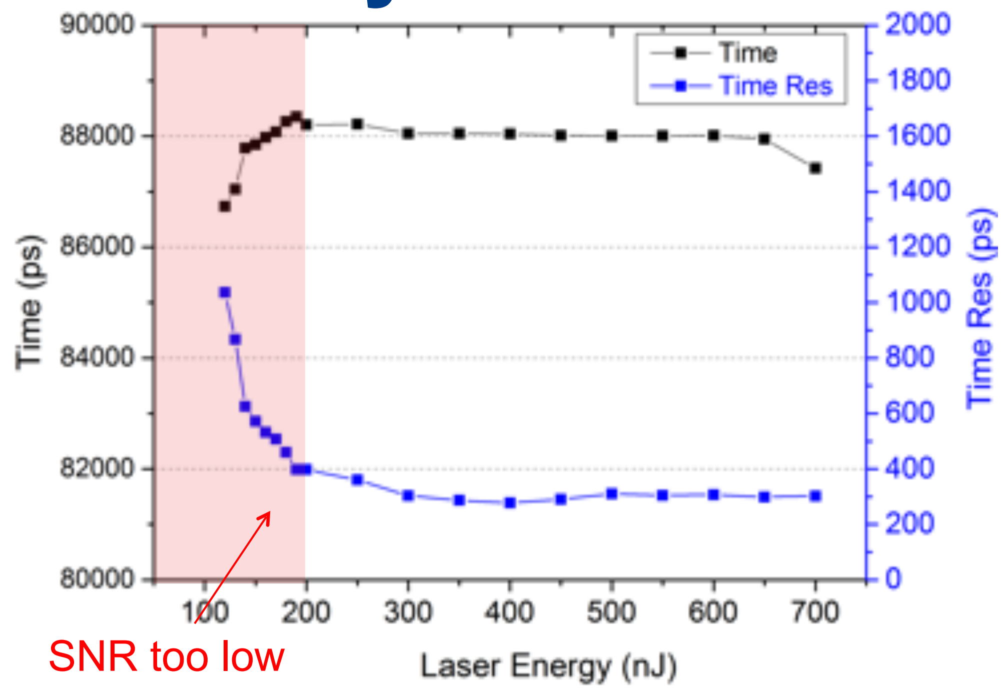
Slit on the tube:
Width = 1 mm
Length = 6 mm

Effective area:
Width = 800 µm
Length = 4 mm

Gas: Ar (70%) + CO_2 (30%)

Influence of laser intensity

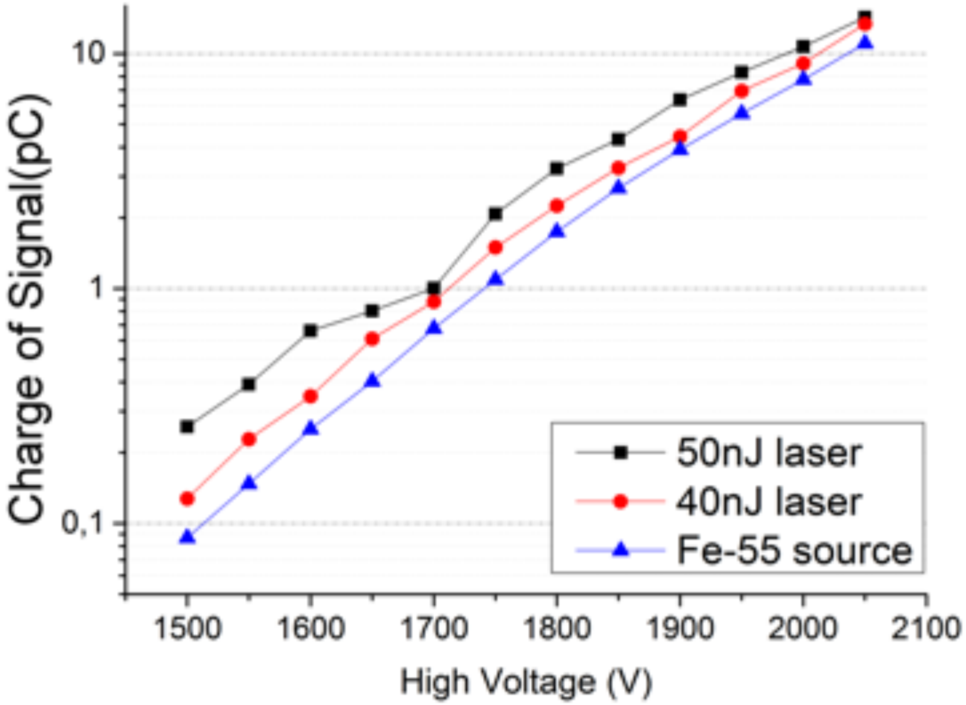




Charge - intensity
(Gas: Ar/CO_2 (70%/30%), HV = 1350 V, Distance to wire = 2.5 mm)
With the laser energy of 0-700nJ, the relation of signal charge-laser intensity is tested. A linear fit is plotted on the figure.

Time resolution and drift time along with laser intensity
(Gas: Ar/CO_2 (70%/30%), HV = 1350 V, Distance to wire = 2.5 mm)
As the intensity changes, the drift time and time resolution is stable.

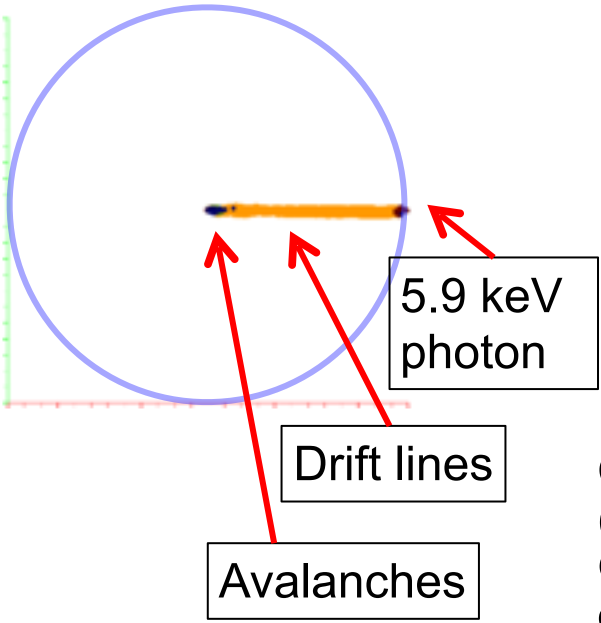
Influence of electric field



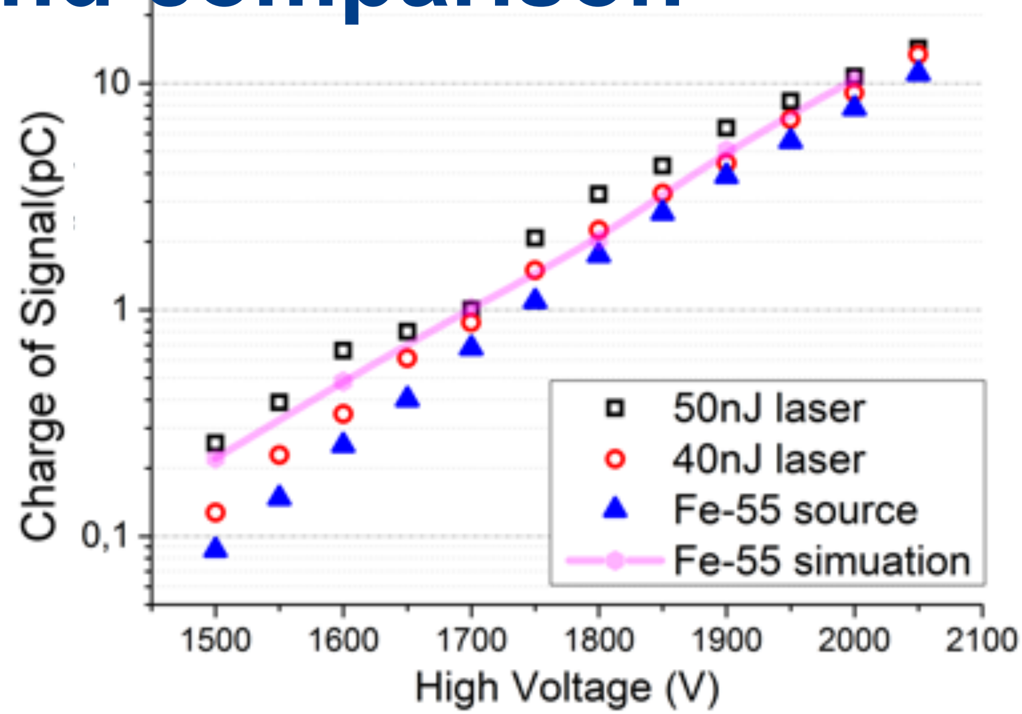
The charge – electric field relation is tested with both laser and an Fe-55 source (Gas: Ar/CO_2 (70%/30%), Distance to wire = 2.5 mm)
The curves of the 3 different ionization sources shows a exponential relation between charge and voltage. This test also helps to calibrate the number of ionization, aiming at minimum ionization in the future.

Simulation and comparison

R of wire = 10 µm
Inner R of tube = 6 mm
Gas: Ar (70%) + CO_2 (30%)



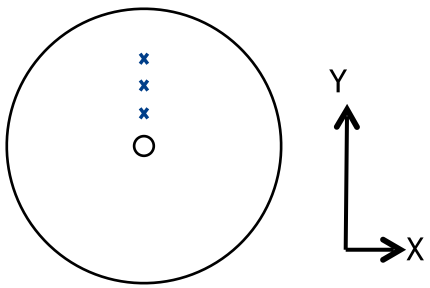
Simulation of avalanches by photons of Fe-55

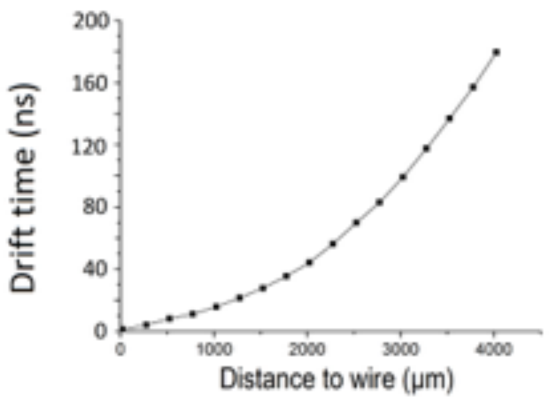


Compare with simulation of avalanches by Magboltz (Magboltz is used for simulation of drift and avalanches, Garfield++ is used for definition of geometry, gas and electric field based on the probe.)

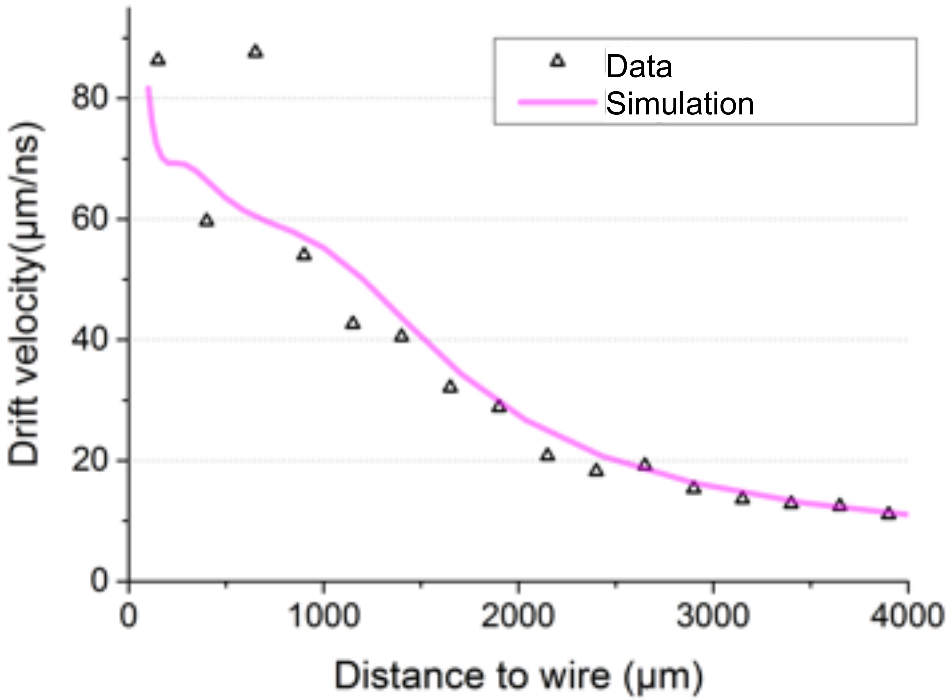
Despite the difference of simulated value and measured value varies from 1.2 to 2.5 times in different voltage, the trend of values is comparable.

Electron drift velocity measured vs. Magboltz simulated



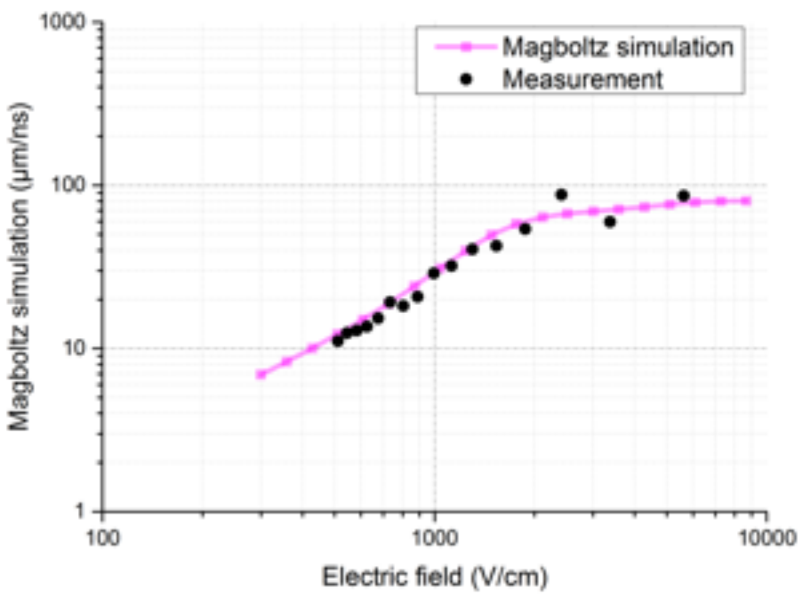


Time-Position test (1350 V)
Laser energy is set to 200 nJ
With drift time measured, it is possible to calculate the drift velocity. Bin width ΔL= 250 μm.

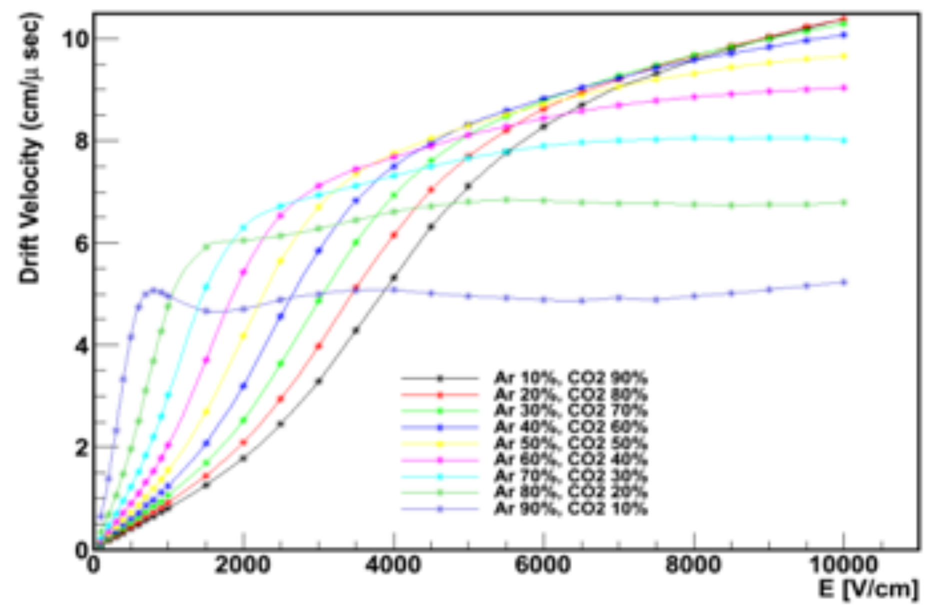


Comparison of measurement and Magboltz simulation (Ar/CO_2 (70%/30%))
Drift velocity V = ΔL/Δt
The Magboltz value is in good agreement with measured value.

Comparing with other results



Comparison of measurement and Magboltz simulation (vs. electric field)
Ar/CO_2 (70%/30%)



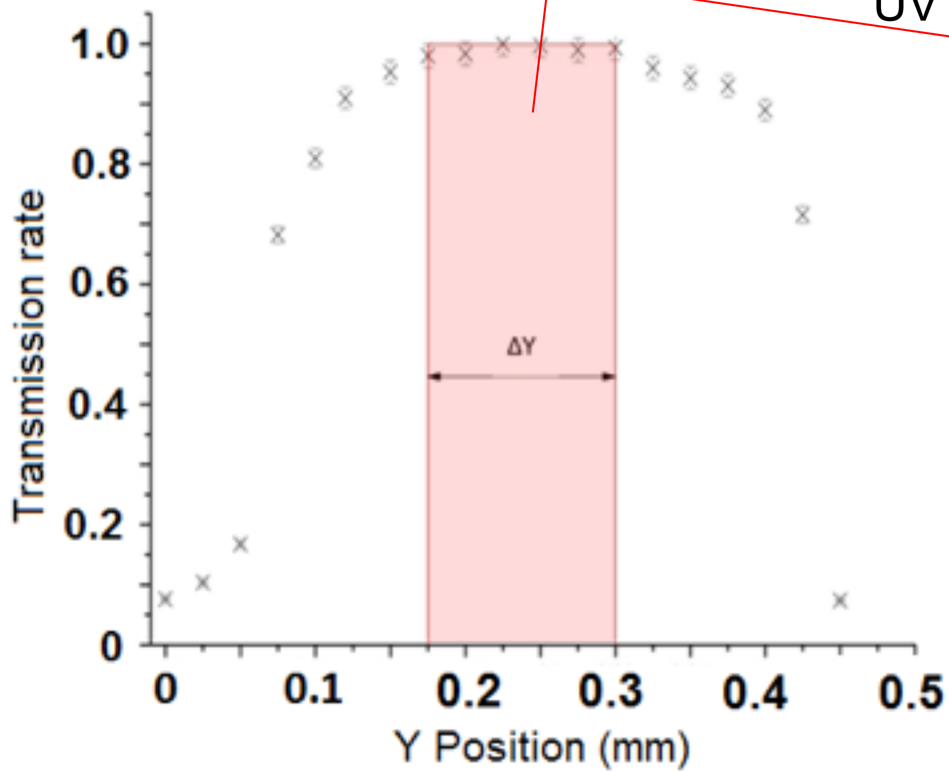
- Y. Assran, "Transport properties of operational gas mixtures used at LHC", 2011. arXiv:1110.6761

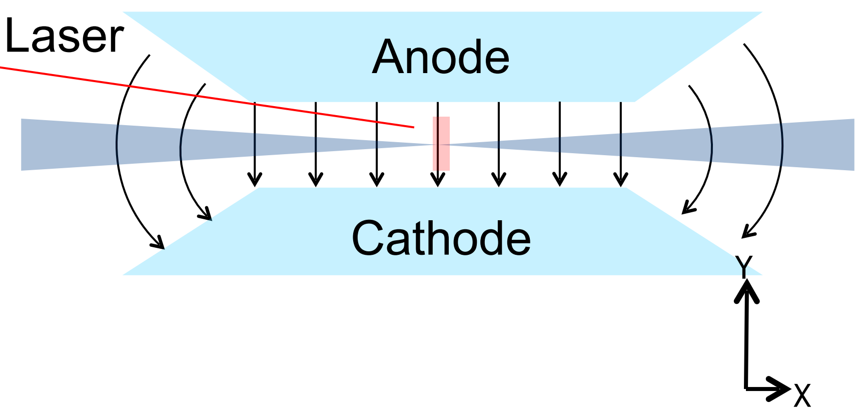
In good agreement!

Calibration of RPC probe

*L.Naumann, *et al.*, 2014 *JINST* **9** C10009,
Precision measurement of timing RPC gas mixtures with laser-beam induced electrons

Effective Y Range =125 µm

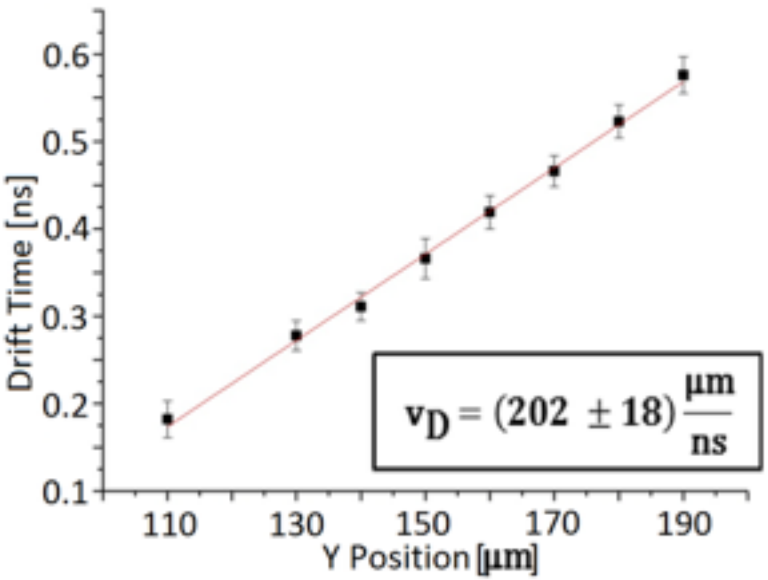




Relative beam energy transmission test

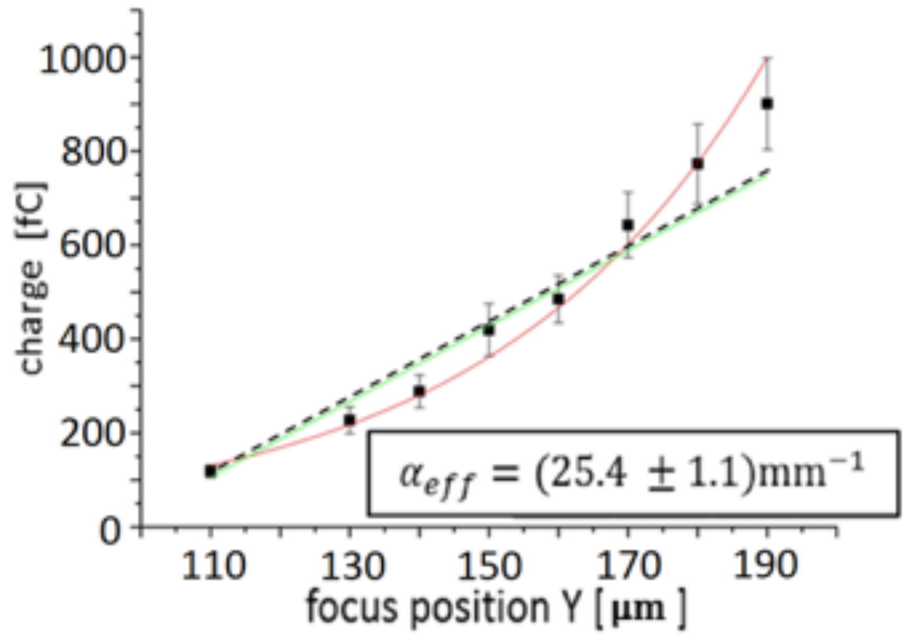
For the 300 µm gap, transmission Energy is tested along Y axis. From the figure we can conclude the effective Y position has a range of about 125 µm.

Drift velocity and Townsend coefficient



Drift velocity test

Drift Velocity = 202 ± 18 µm/ns



Effective Townsend coeffecient test

eff. Townsend coefficient = 25.4 ± 1.1 mm^{-1}

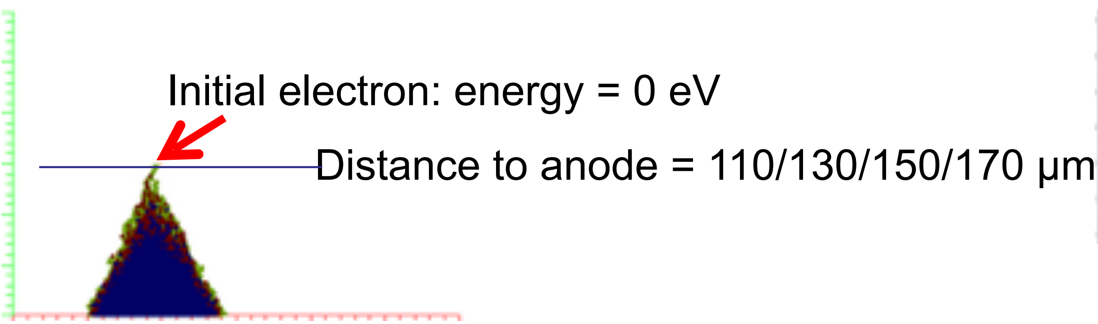
Gas: $C_2F_4H_2/SF_6/i\text{-}C_4H_{10}$ (85%/5%/10%)

Rate: 1 Hz

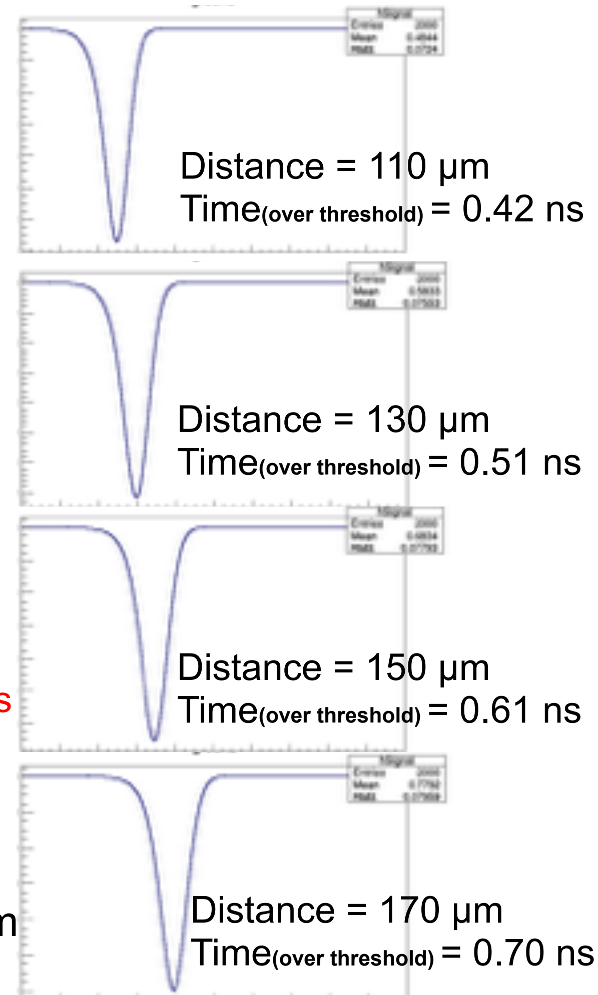
Electric Field: 100 kV/cm

Magboltz simulation of avalanches

- Input of Magboltz :
  - 0.3 mm gap
  - 100 kV/cm homogeneous electric field.
  - $C_2F_4H_2/SF_6$/i-C_4H_{10} (85%/5%/10%)
- Gas parameters from Magboltz:
  - Drift velocity : 187 µm/ns
  - Effective Townsend coefficient : 87.2 mm^{-1}
- Simulation of avalanches:
  - Initial electrons are started from the experimental position to simulate the signal waveforms.
  - The drift velocity calculated from time over threshold is 214 µm/ns



Threshold = 1/2 Maximum



DRESDEN concept HZDR

Comparison

	Drift Velocity (µm/ns)	eff. Townsend coefficient (mm^{-1})
Measurement	202 ± 18	25.4 ± 1.1
Magboltz Value (Avalanche)	214	87.2

Note:
The simulation of avalanche in RPC requires too much CPU, effective Townsend coefficient is not calculated with avalanches at present. For future improvement.

Upgrades and plans

- Minimum ionization: to achieve minimum ionization (´single´ electron).
- Test methods: Improve the test method of RPC for precise measurements of Townsend coefficient and drift velocity.
- Full test: full test of gas parameters for different electric field, different gas ratio of mixtures.
- Simulation: better simulate the avalanches to estimate charge - position relation.
- New probes: RPC with pressure attenuation.
- New gas: Search for substitution of climate harmless gases (Freon, SF6)

DRESDEN concept

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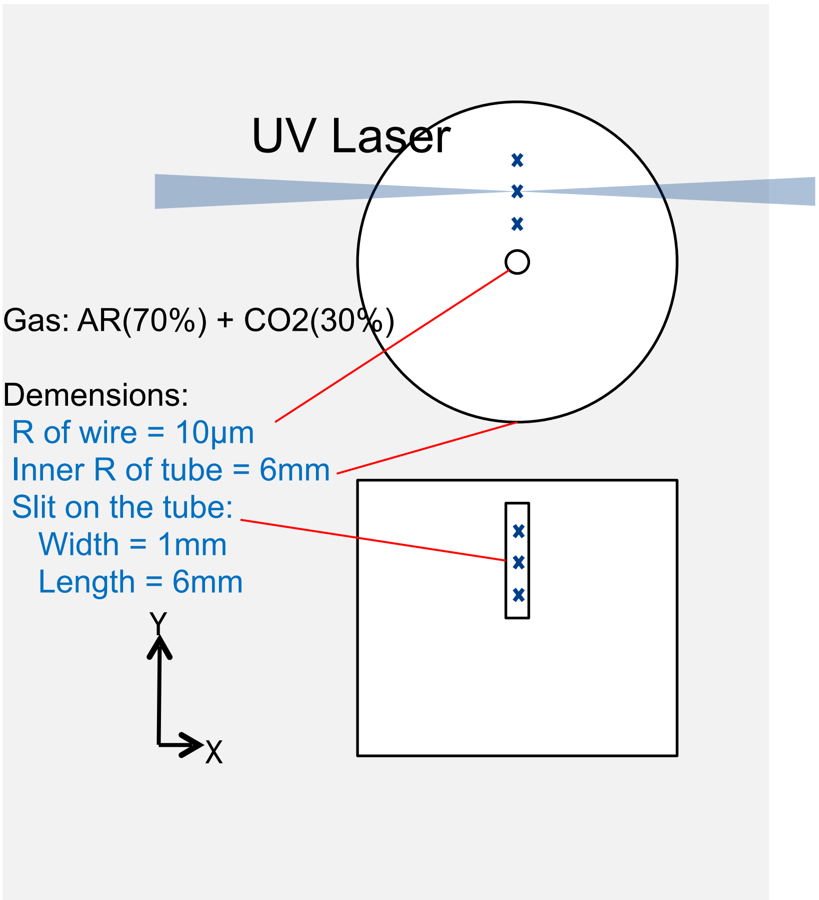
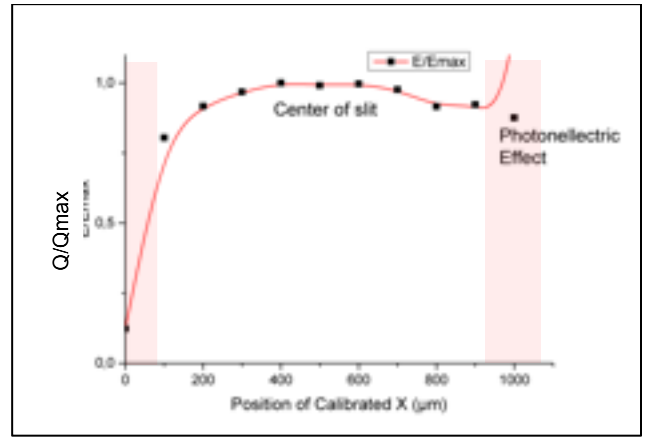
Conclusions:

- First steps has been made to combine different techniques for measurements on laser test facility.
- Calibration for laser intensity and position is done with well known detector and gas and with Fe-55 source.
- Simulations for the same geometry, gas and electric fields as experiments by Magboltz/ Garfield++ are performed.
- First measurements of gas parameters are operated.

Thank you!

Drift velocity and time resolution of drift tube





X axis scan

Charge of signal is measured along x axis to calibrate the effective range and center. The charges are divided by the maximum charge in the accepted range.

Y axis range

The effective Y range is about 4mm due to the edge effect.

Simulation & measurement comparison along Electric field