Investigation of Gaseous Detectors with Laser Induced Electrons

Lothar Naumann

DTS

Partner von DRESDEN concept exzellenz-dresden.de

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Introduction

- Application of UV laser beams for calibration and surveying of
  Wire Chambers since 40 years *[M. Anderhub et al.; NIM 166 (1979)]*
  Resistive Plate Chambers since 30 years *[E. Gorini et al.; NIMA 425 (1999)]*

- RPC operating in strong and homogeneous electric fields at atmospheric pressure → relevant gas parameters obtained in reduced electric field

- Drift Detectors operating in inhomogeneous electric field-topologies → relevant gas parameters obtained in simplified electric field topologies

Dr. Lothar Naumann I L.Naumann@hzdr.de I Institut of Radiation Physics I www.hzdr.de

Introduction

Micro-plasma creation and precise **micro-positioning** inside the active volume of gaseous detectors allows to improve the detector tests:

- **Resistive Plate Chambers:** timing and trigger RPC samples
- **Mini Drift Cells:** HADES-like MDC topology
- **Drift Tube:** for laser facility calibration purposes

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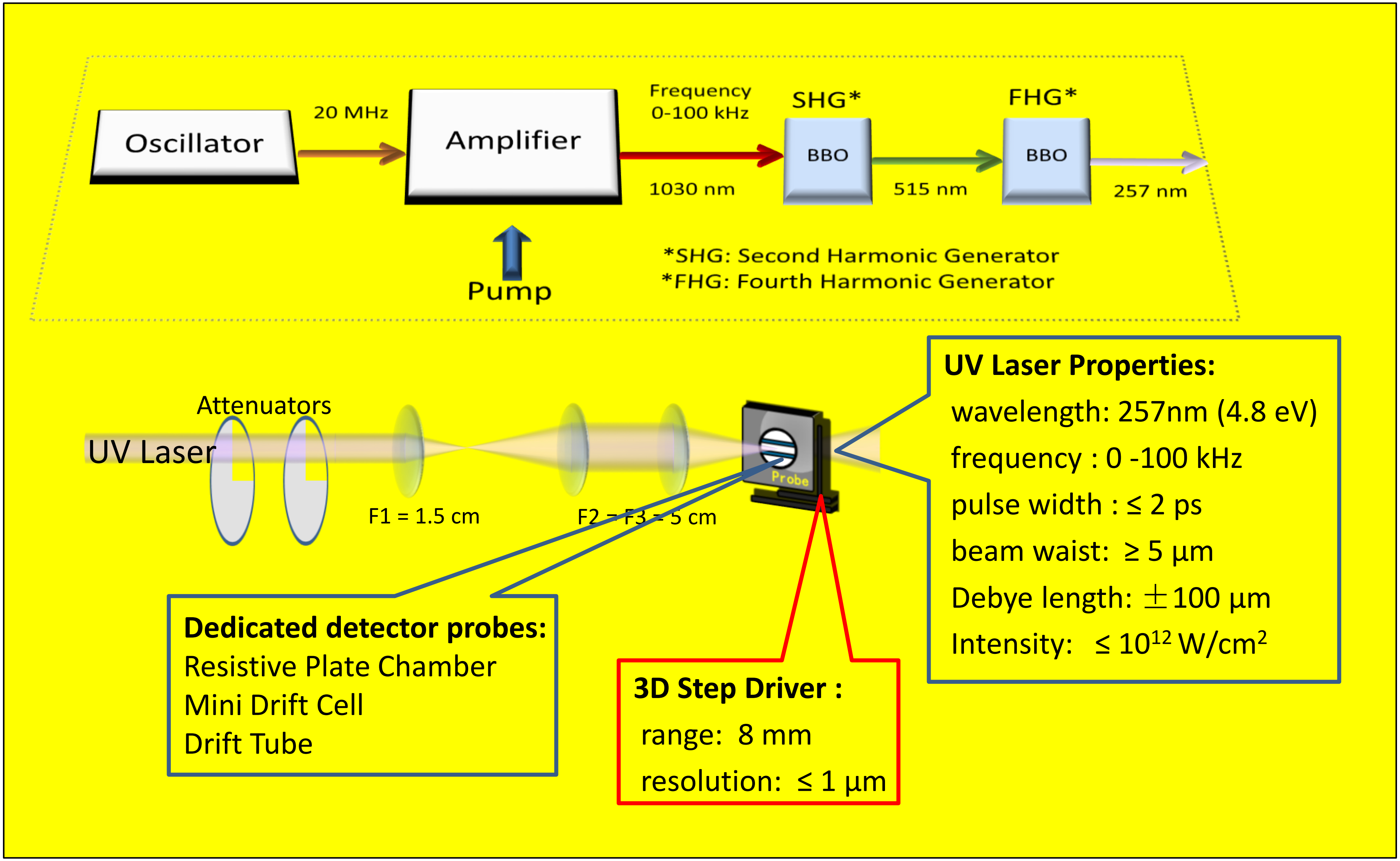
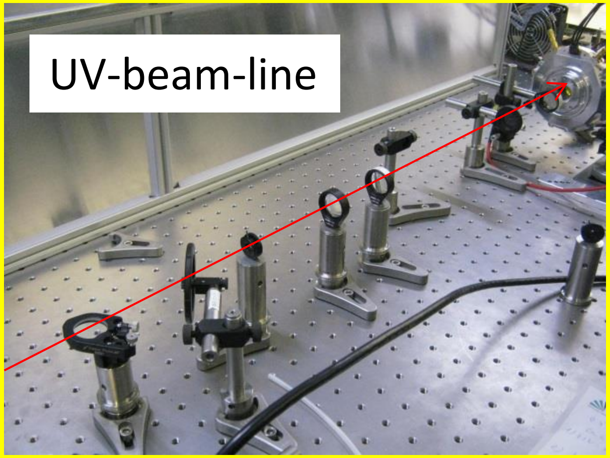
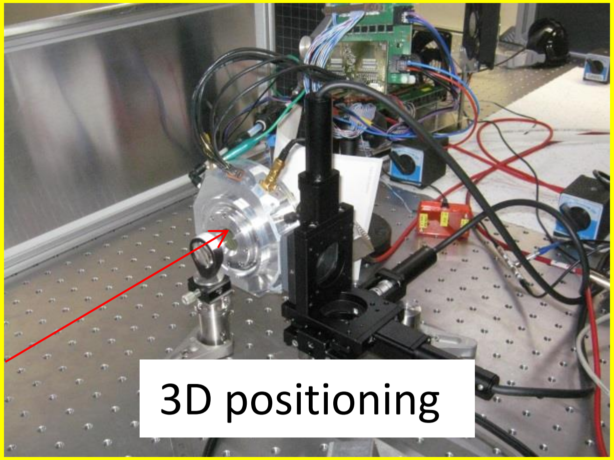
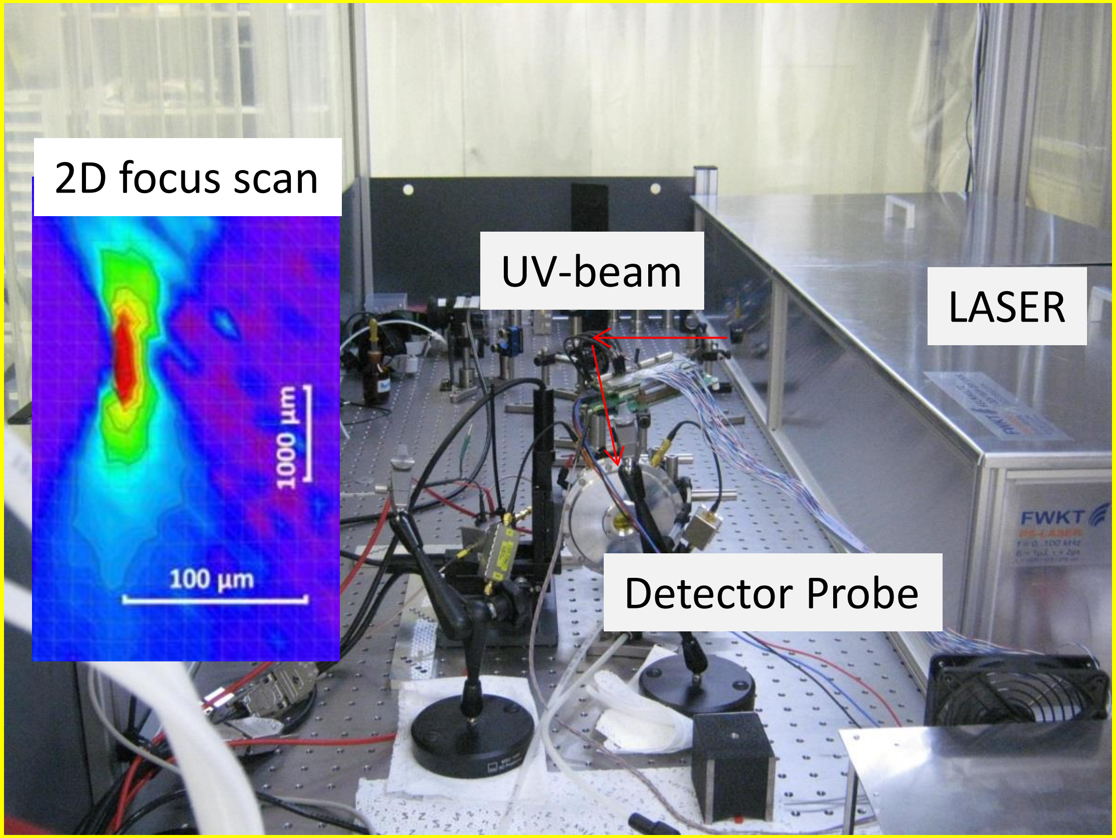
HZDR Laser Facility



HZDR Laser Facility







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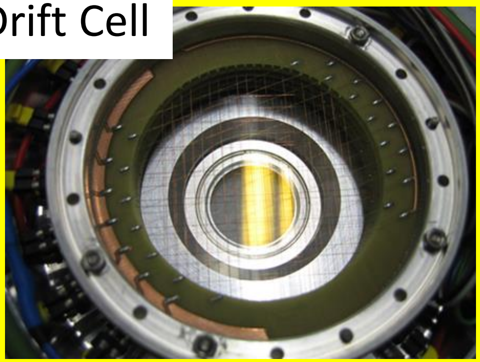
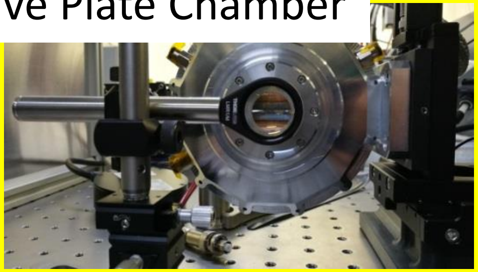
HZDR Laser Facility

Drift Tube

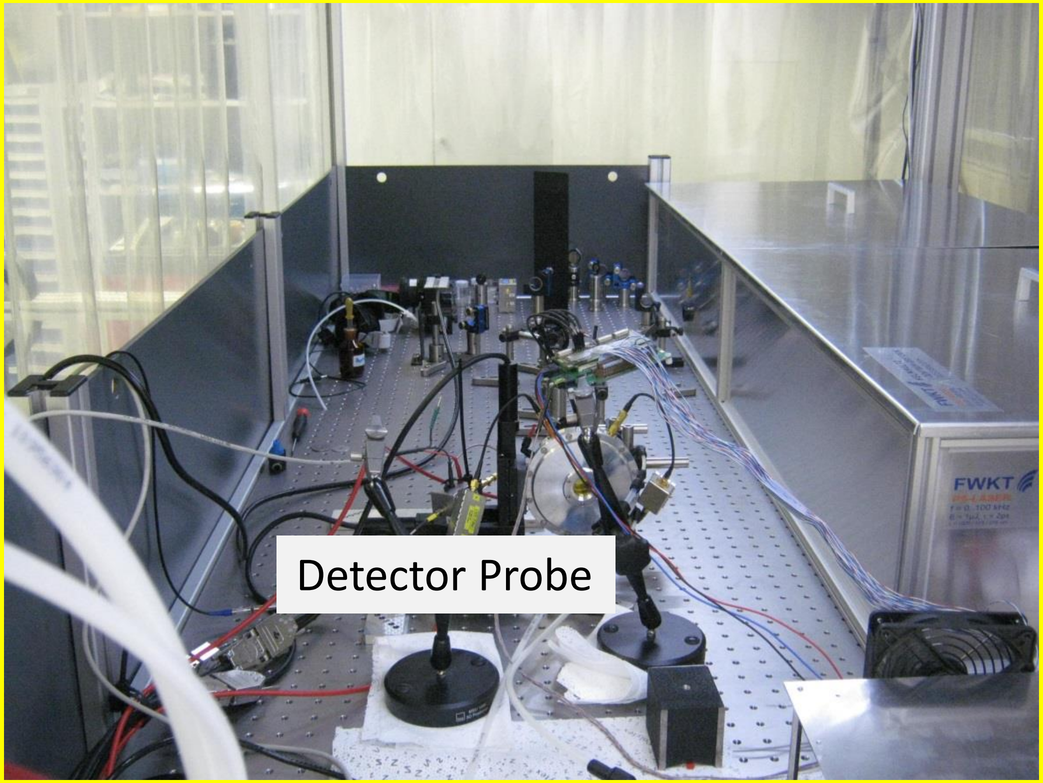
Mini Drift Cell



Resistive Plate Chamber



Detector Probe



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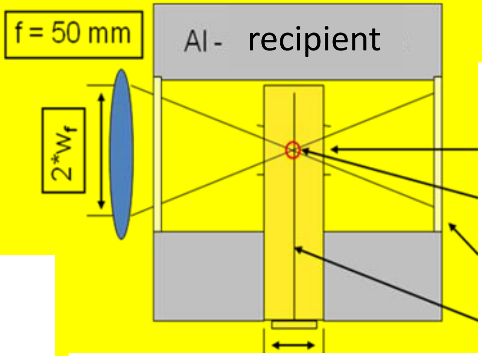
Drift Tube

λ = 257 nm -> photon energy 4,8 eV

→ multi-photon ionization ≥ 2

drift tube detector

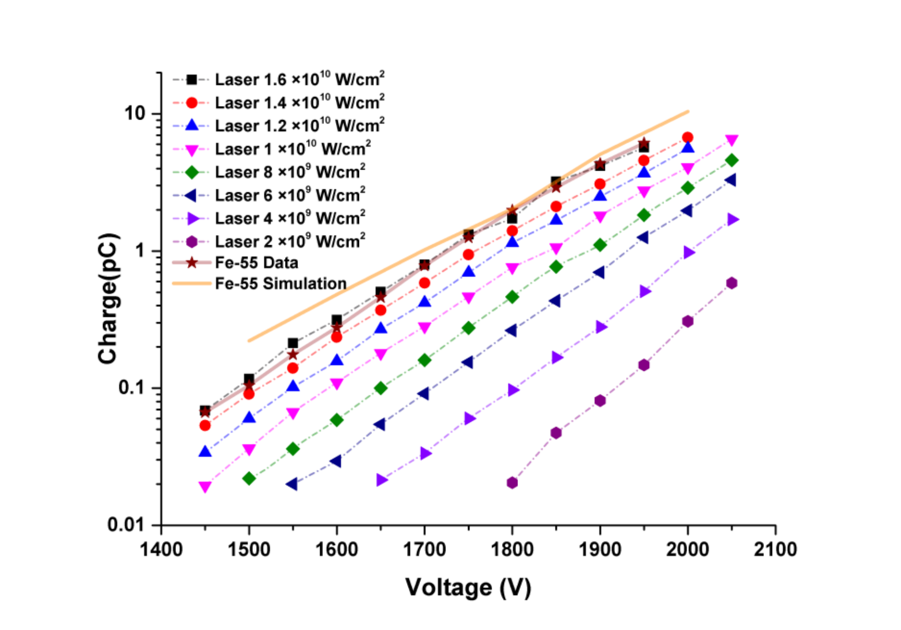


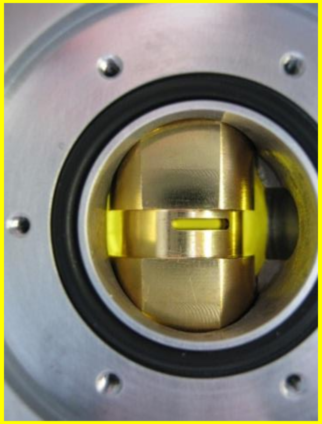
opt. slit focus

UV window

anode d=20µm

cathode (Au) 12 mm

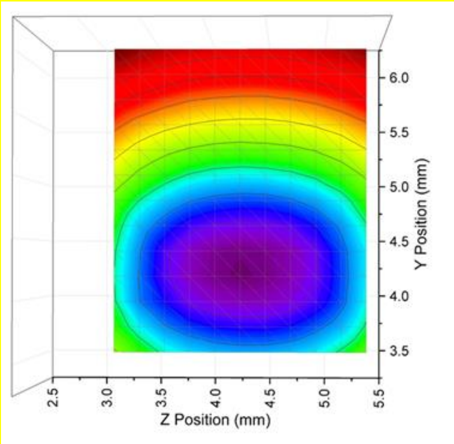




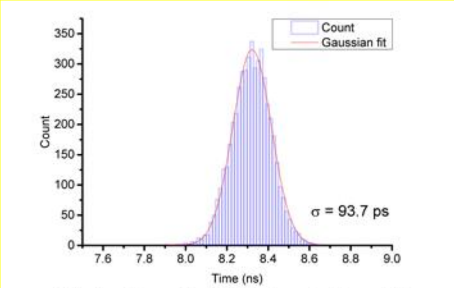
Drift Tube

λ = 257 nm -> photon energy 4,8 eV

→ multi-photon ionization $\geq$ 2

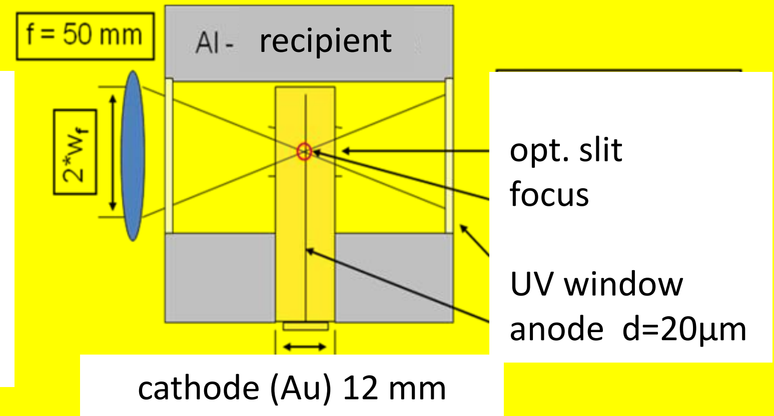


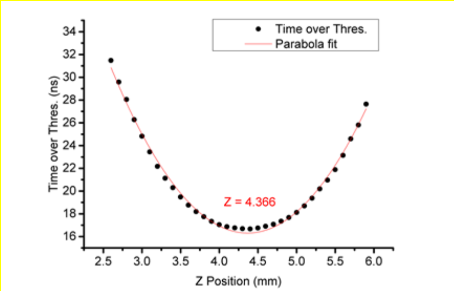
2D scan of time over threshold



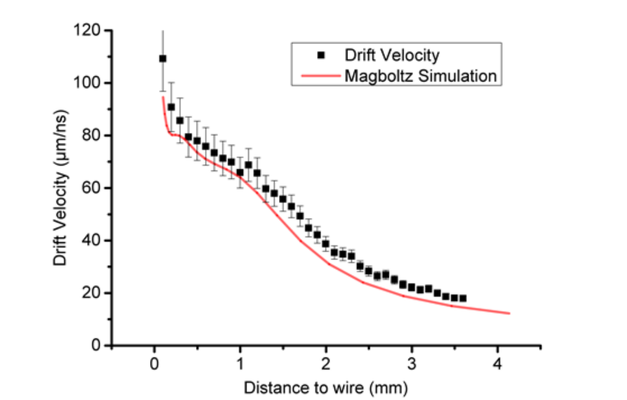
Distribution of time over threshold when focus-wire distance=1000 µm

drift tube detector

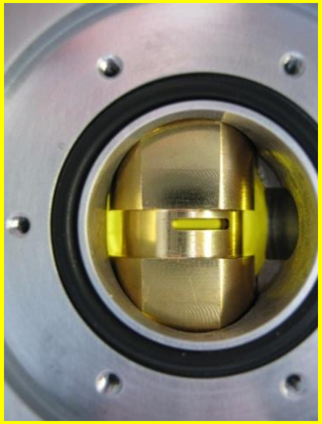




Z-T Relation when the distance between beam and wire is 1000 µm



The drift velocity measured on different positions



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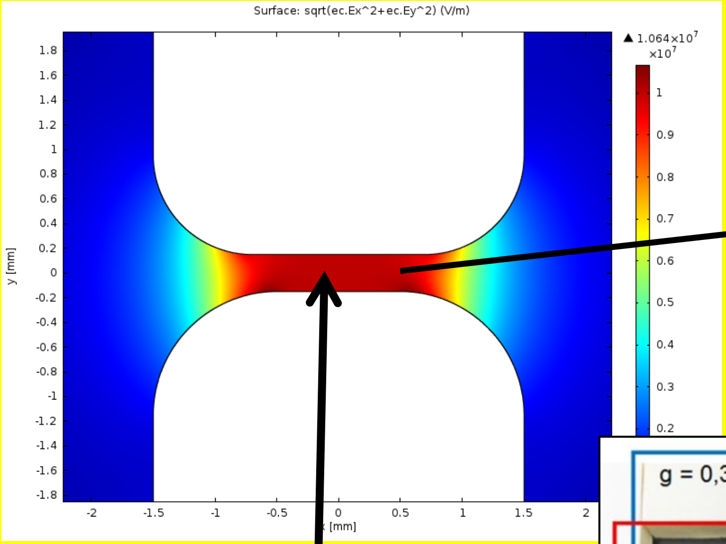
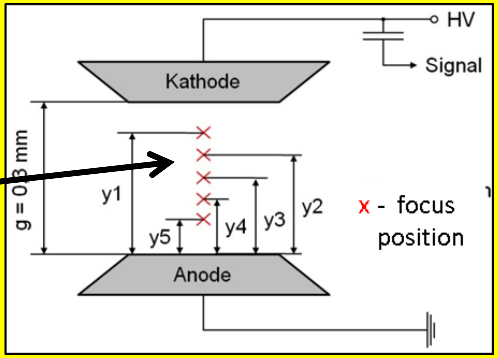
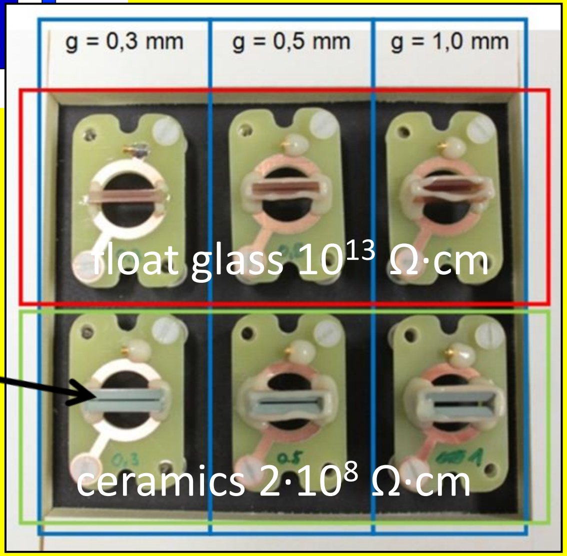
RPC probe





gap size:
width 300 µm
length 1 mm
radius 1 mm



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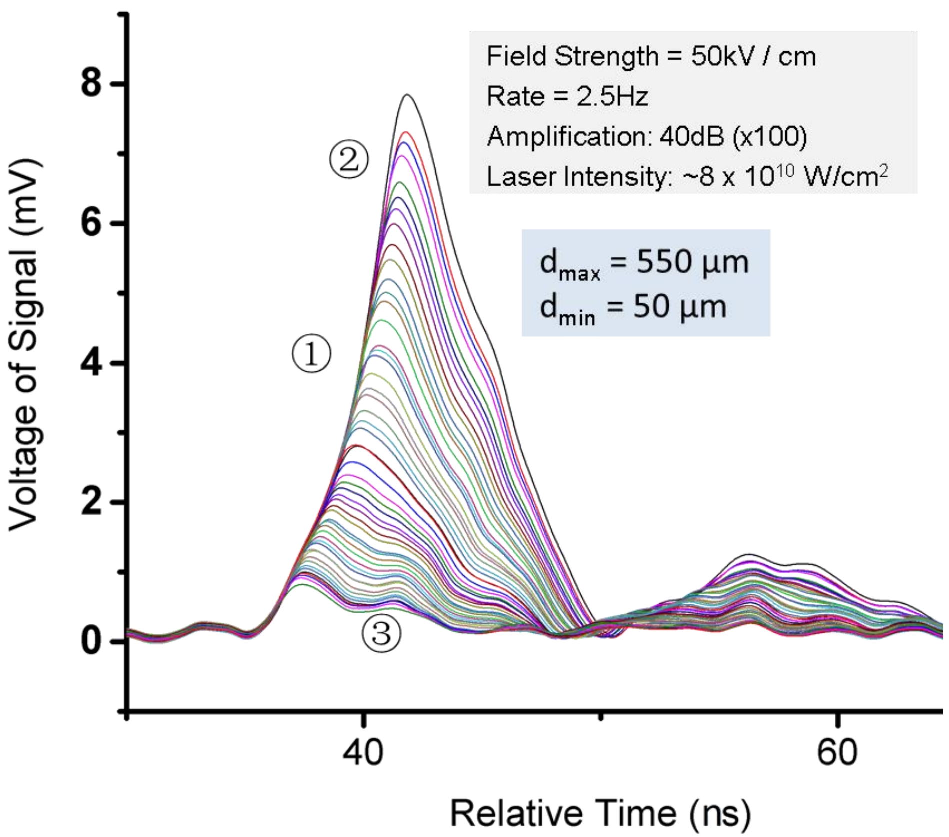
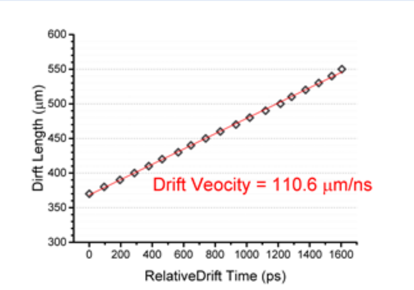
Trigger-RPC: 50 kV/cm; 1.0 mm

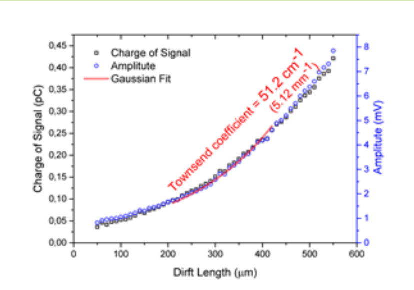


①Rising edge of the signal is overlapped, no matter where the avalanche is started.

② By setting a relative threshold on the waveform, we can measure the <u>drift velocity</u>:



③ The area represents the charge of signal, <u>amplification (eff. Townsend coefficient)</u> can be measured:



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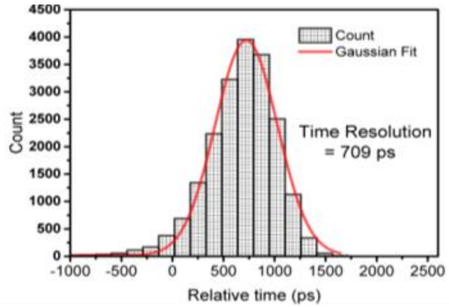
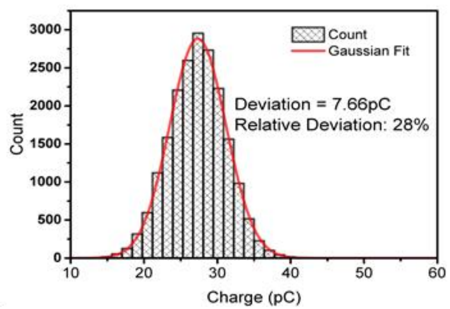
Trigger-RPC: 50 kV/cm; 1.0 mm

time

charge



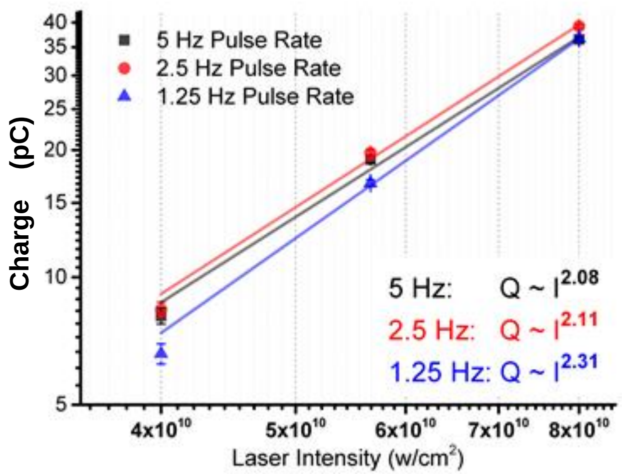


Efficiency: 100%

Time resolution: 700 ps

rel. charge deviation: 28%

charge vs. laser intensity



Proportionality of charge(Q), number of primary electrons(N_e) and intensity(I^x) :

$$Q \sim N_e \sim I^x$$

$$x \geq 2$$

→ **double-photon-ionization**

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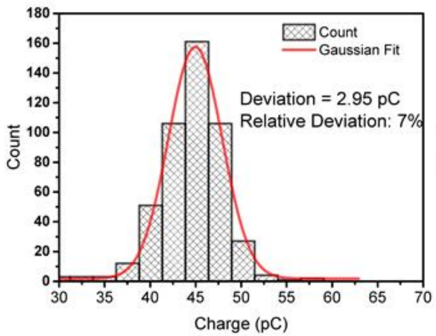
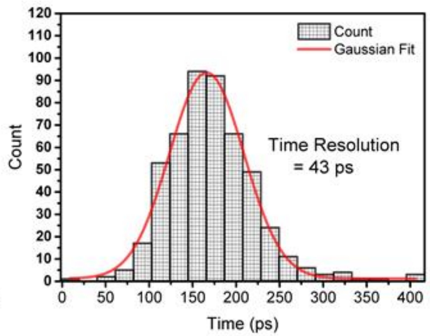
Timing-RPC: 100 kV/cm; 0.5 mm

charge



time

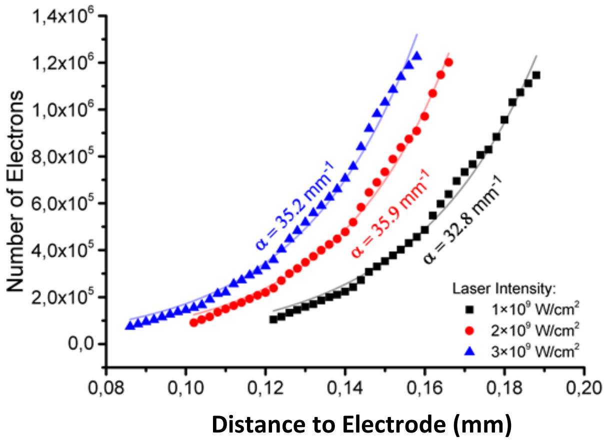


Efficiency: 100%

Time resolution: < 50 ps

rel. charge deviation: 7%

eff. Townsend coefficient



Rate = 0.5Hz

Increment : 2 µm

The effective Townsend coefficient is independent on the number of primary electrons (N_e)

$$\alpha_{eff} = const. \quad for \quad Q \sim N_e \sim I^2$$

→ **no space-charge effect**

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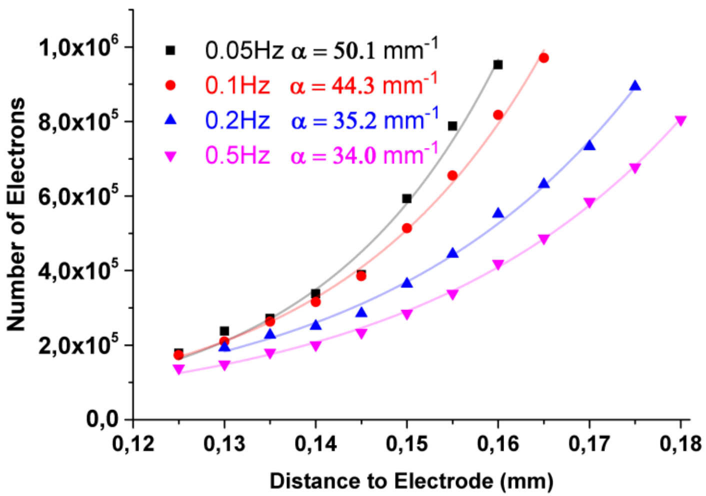
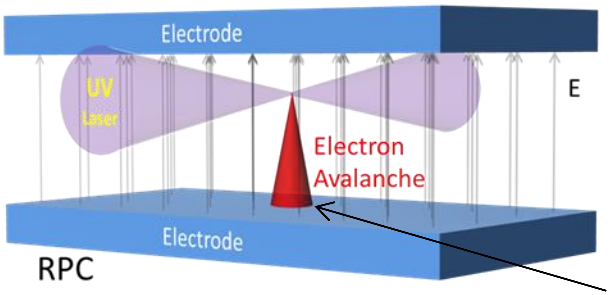
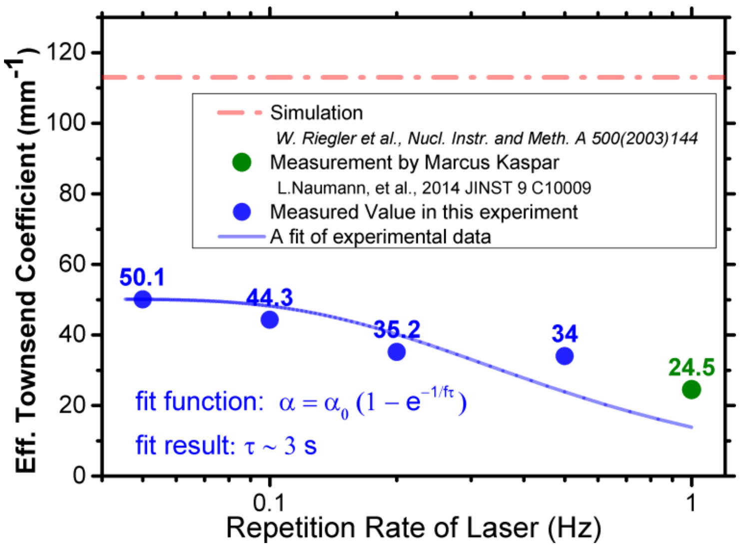
α_{eff} Timing-RPC: 100 kV/cm; 0.5 mm





Float glass sample
$\tau = \varepsilon_0 \varepsilon \rho$ = (3±0.5)s

$r_{drift} \leq 50\ \mu m$



- **The eff. Townsend coefficient depends on the laser repetition rate.**
- The Time constant of the float glass sample is in agreement with the data.
- Data reach the horizontal asymptote at ≤ 0.1 Hz.
- The ionisation occurs always at the same micro-volume and the charges are accumulated on the same area of the electrode surfaces ⟶
  0.1 Hz/(aval. area) is comparable to ≥ 1kHz/cm^2

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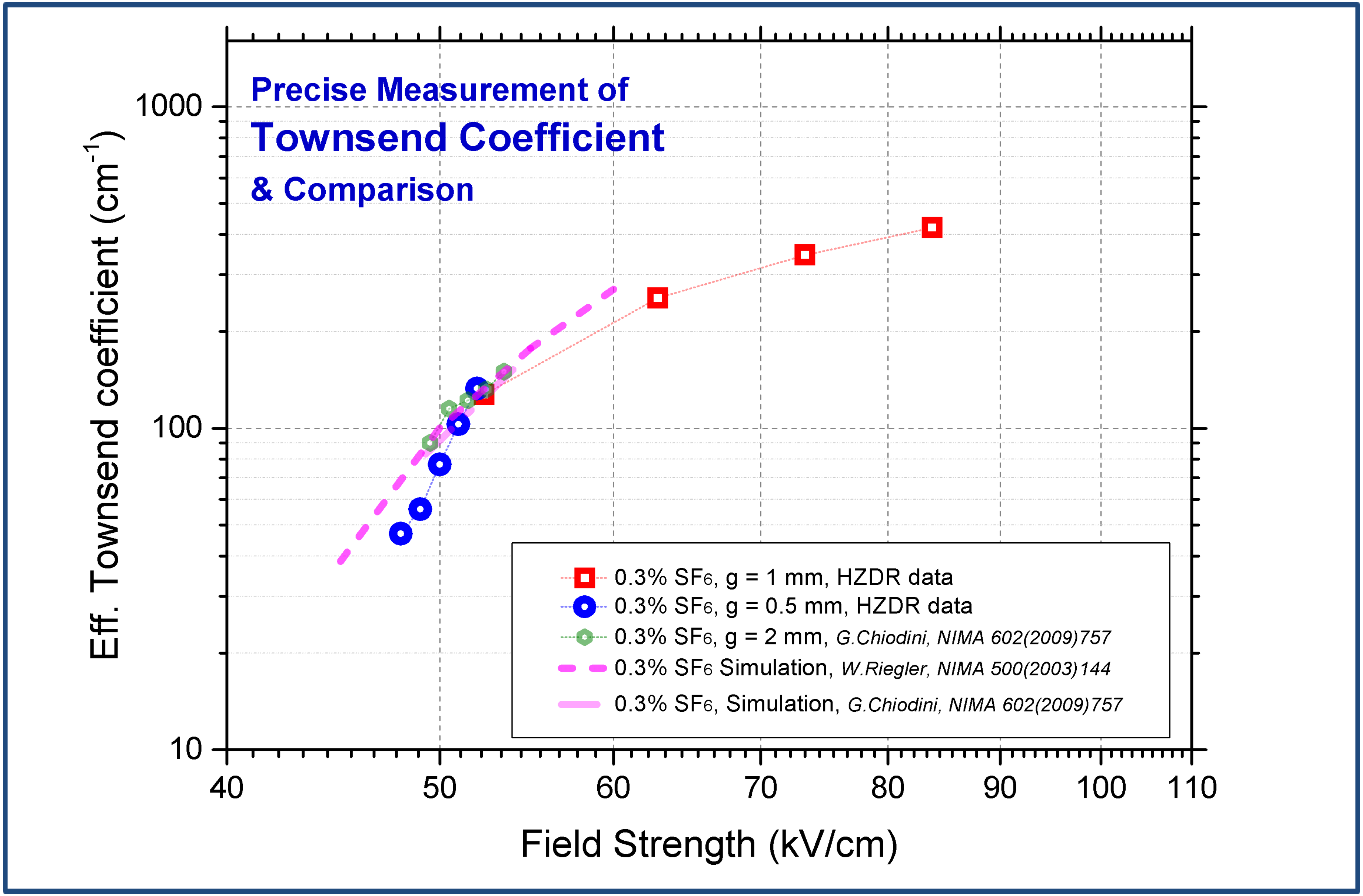
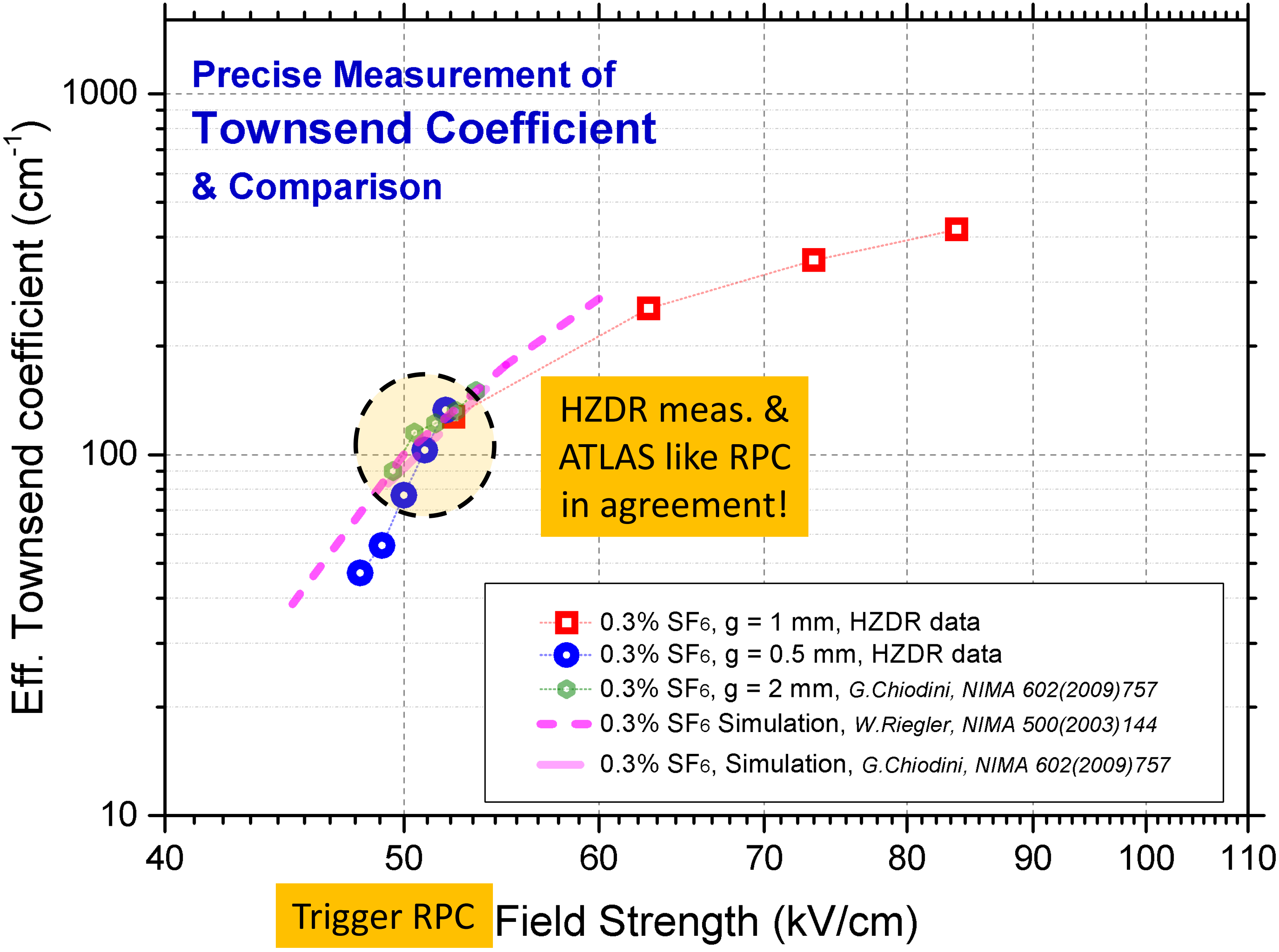
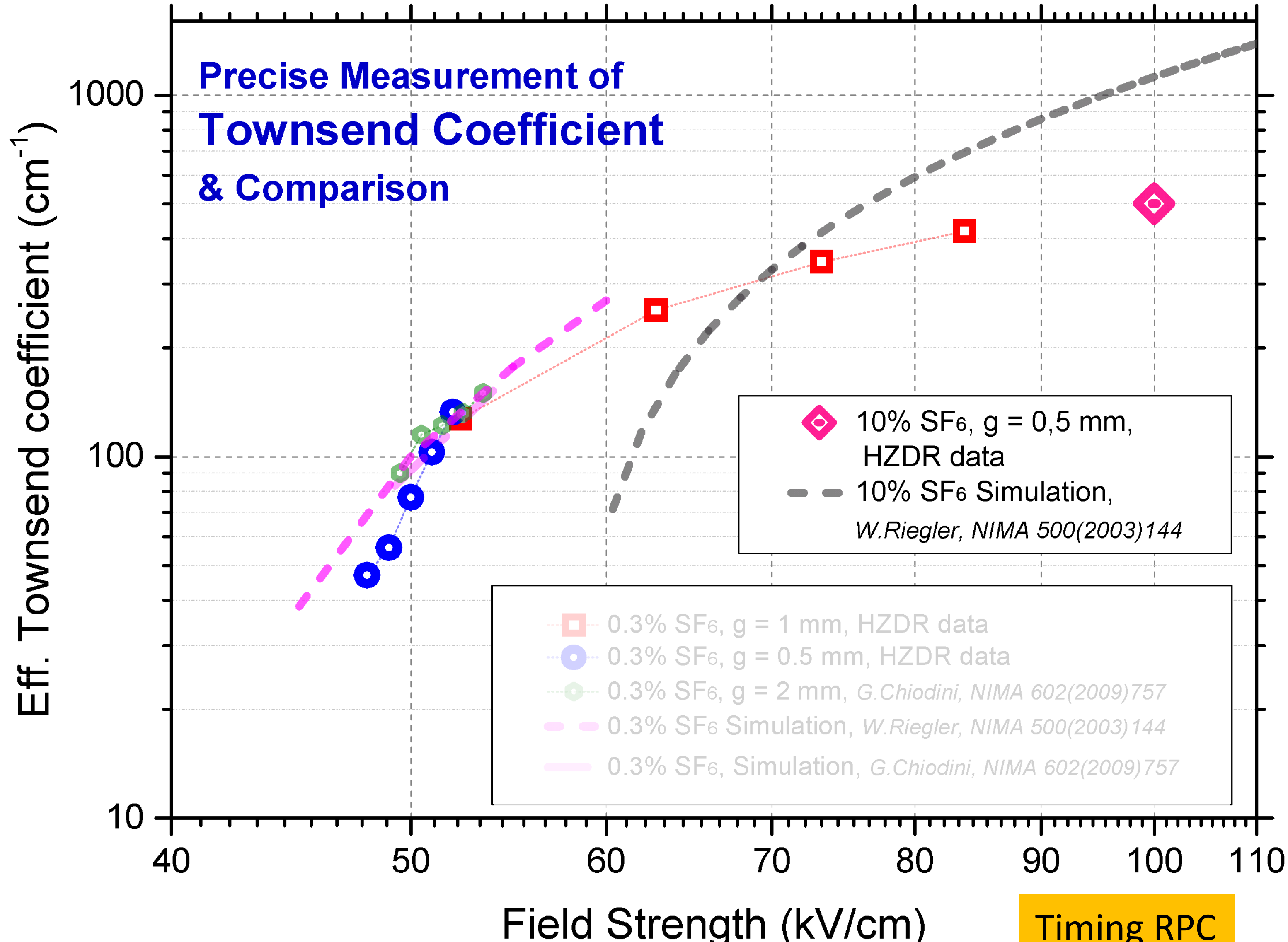
Effective Townsend coefficient (1)



Effective Townsend coefficient (1)

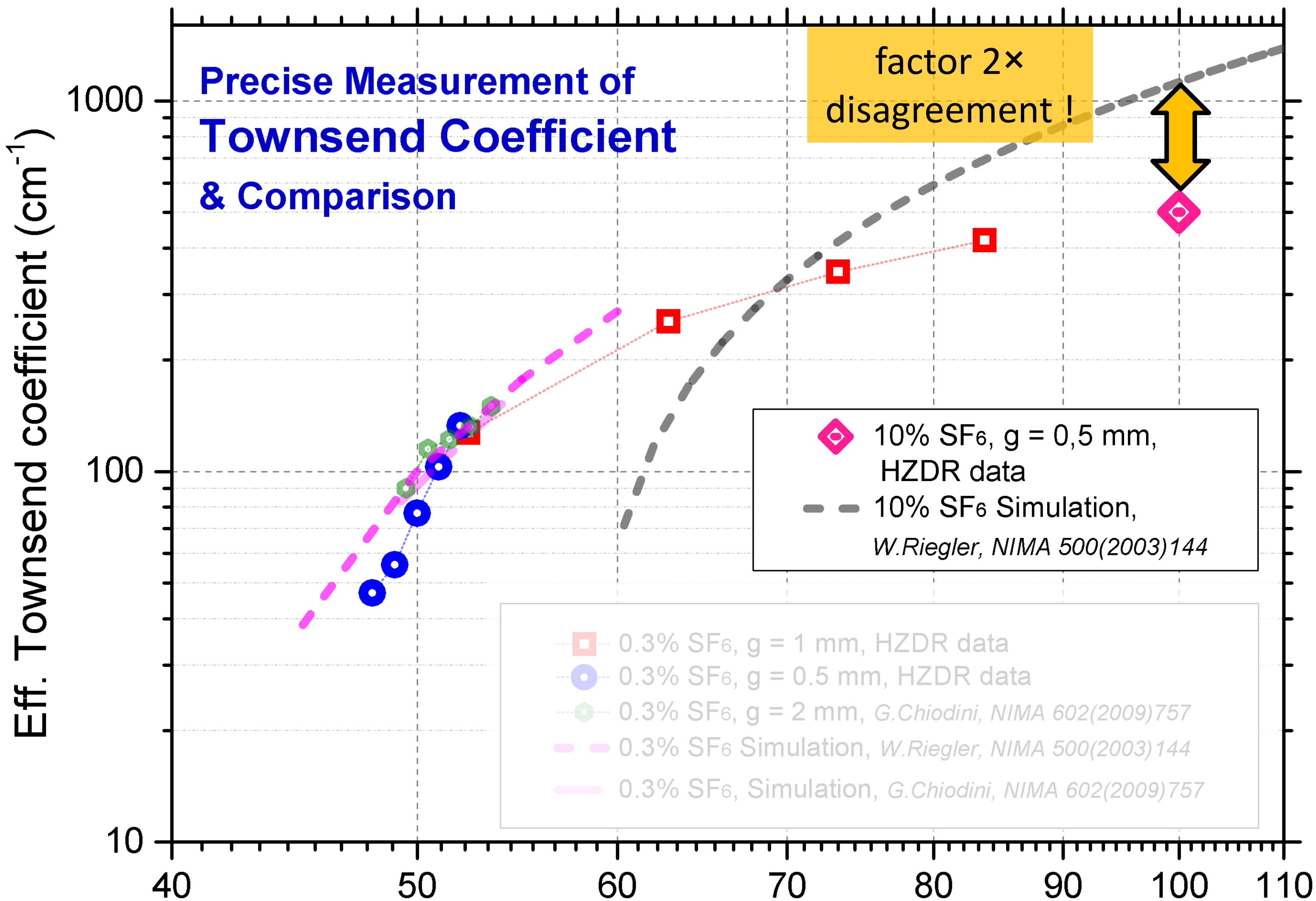


Effective Townsend coefficient (2)



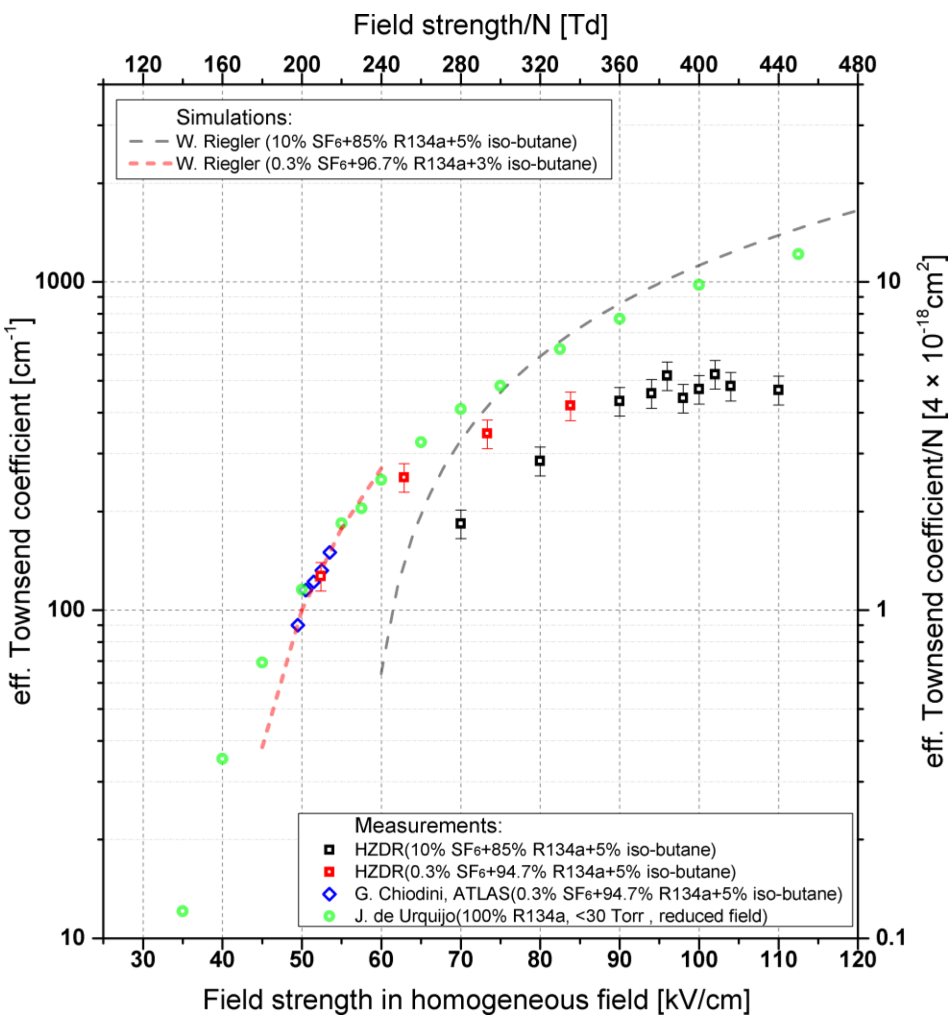
Timing RPC

Effective Townsend coefficient (2)



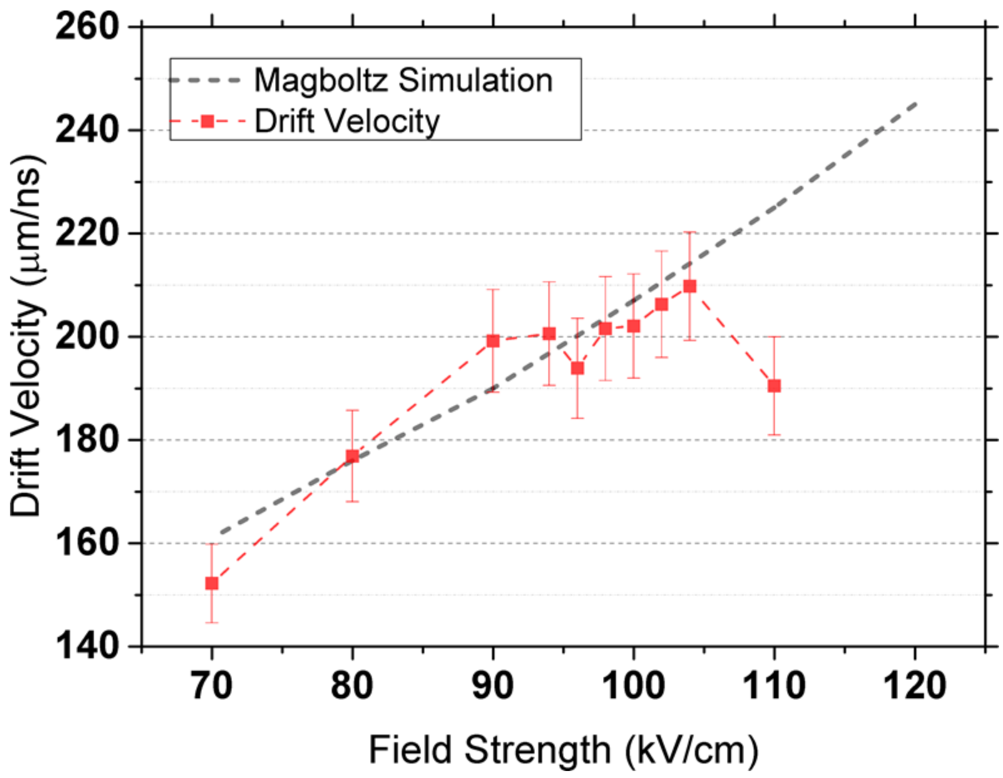
Timing RPC

Effective Townsend coefficient (3)



- reduced field data are in agreement with Magboltz simulation
- HZDR data shows a saturation above 90 kV/cm

Electron drift velocity



- data are in agreement with Magboltz simulation

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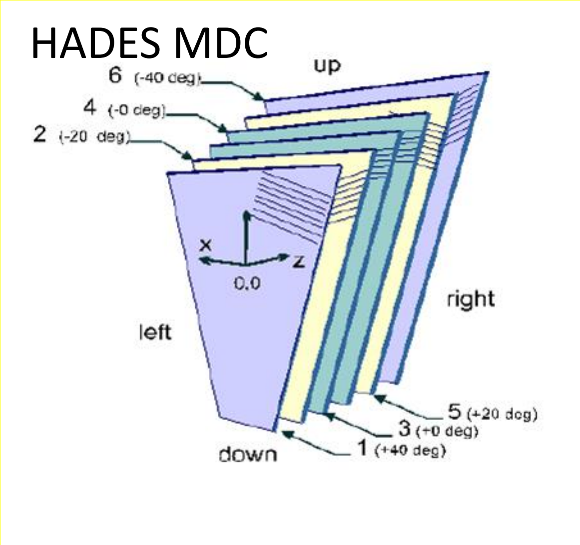
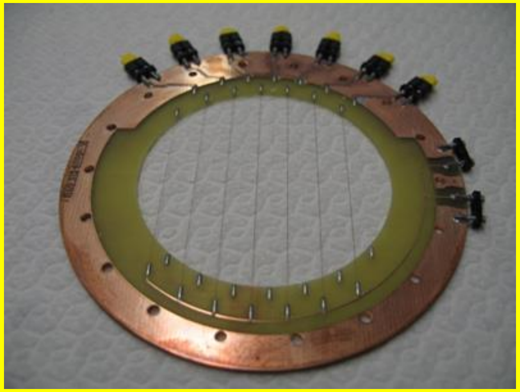
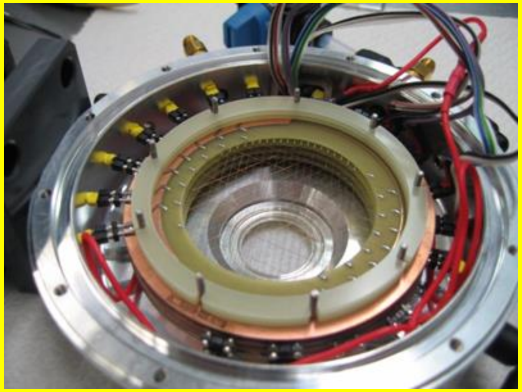
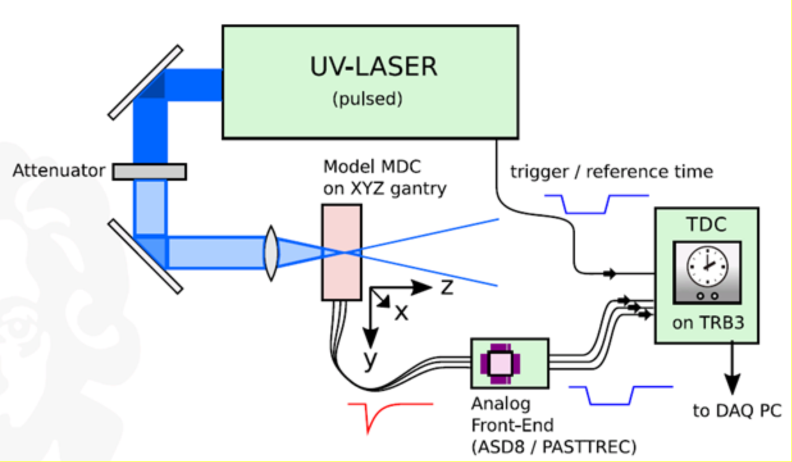
Mini Drift Cell (HADES-like)



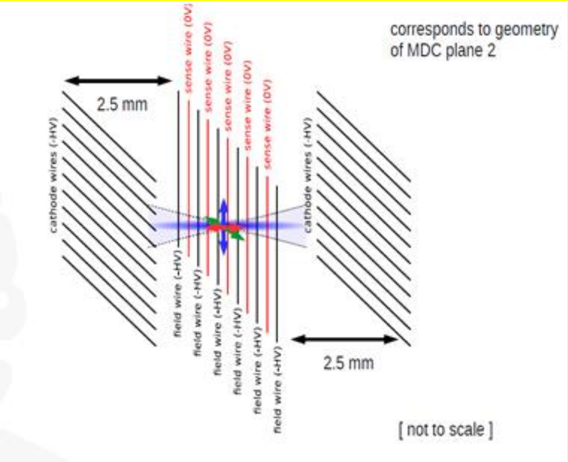




anode/field plane



HADES MDC2 geometry



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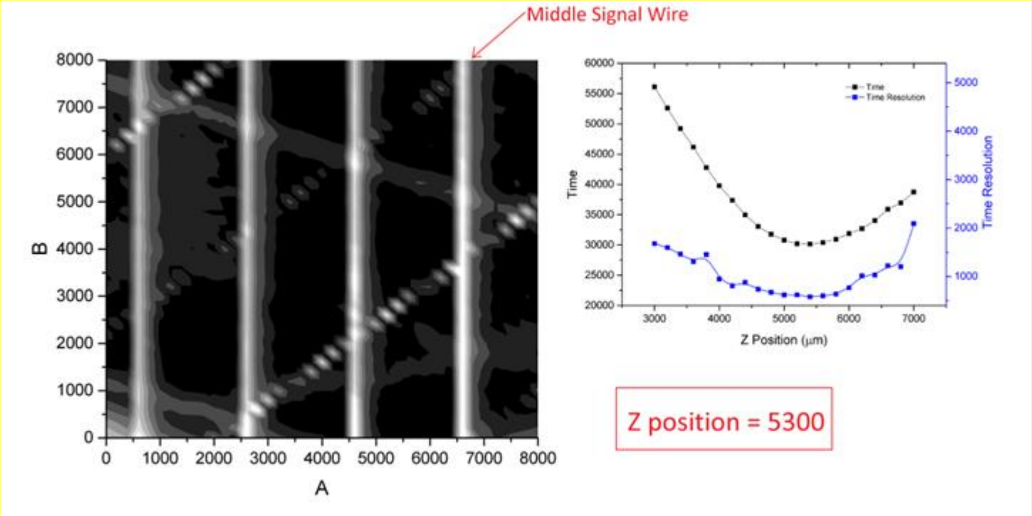
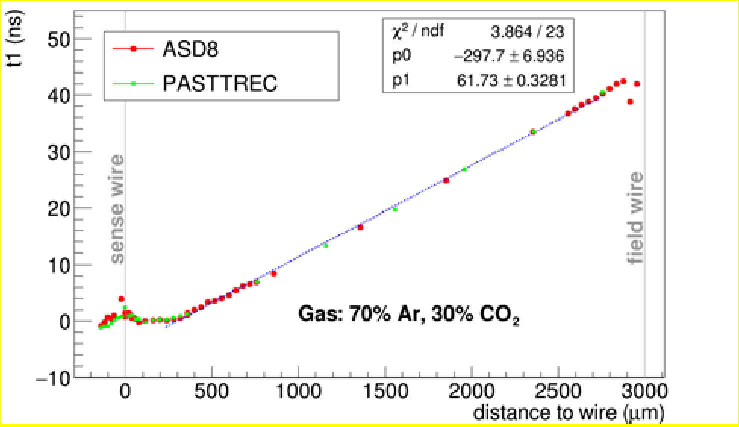
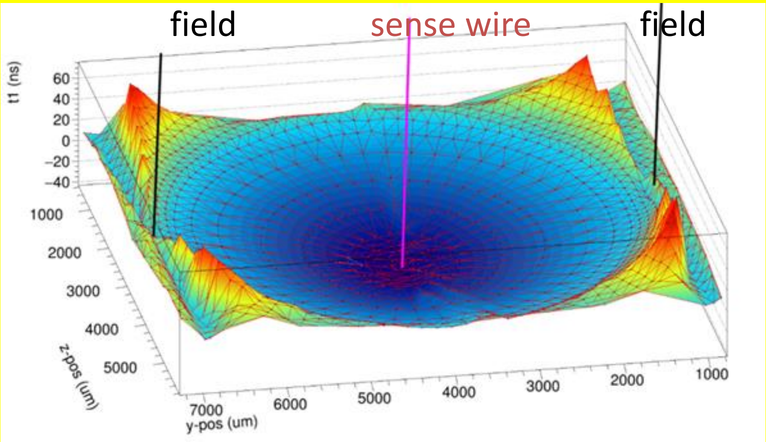
Mini Drift Cell

MDC tomography







Electron drift velocity v_e = 62 μm/ns
Spatial resolution ≤ 60 μm

Drift time distribution: 1290 data points with 8000 ev. /point

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Summary

The UV-Laser driven test facility for gaseous detectors at HZDR is works very stable in an automatically regime to provide detector tests with micro-positioning of the generated micro-plasma

For HADES-like Mini Drift Cells operating in inhomogeneous electric fields has been obtained:

- a deeper understanding of the field topology
- spatial resolution better than 60 µm

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Summary

For RPC operating in strong and homogeneous electric fields at atmospheric pressure has been shown:

- **Agreement** of the eff. Townsend coefficient for Freon(94.7%)+IB(5%)+SF_6(0.3%) **at 50 kV/cm** for ATLAS-like and HZDR RPC prototype measurements and MAGBOLTZ simulation.
- **Disagreement (factor 2)** of the eff. Townsend coefficient measurement for Freon(85%)+IB(5%)+SF_6(10%) **at 100 kV/cm** and the MAGBOLTZ simulation.
- **Agreement** of the drift velocity with simulation.
- **Agreement** of RPC parameter measurements of rate capability, time and energy resolution with model predictions.

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Next Tests

- Investigation of RPC rate capability test with low resistive RPC
- Investigation of RPC double hit behavior
- Evaluation of environmentally friendly gas mixtures for RPC application
- Investigation of the Townsend puzzle

Acknowledgement

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