

# Investigation of Gaseous Detectors with Laser Induced Electrons

Lothar Naumann



**hzdr**

**HELMHOLTZ**  
ZENTRUM DRESDEN  
ROSSENDORF

# Introduction

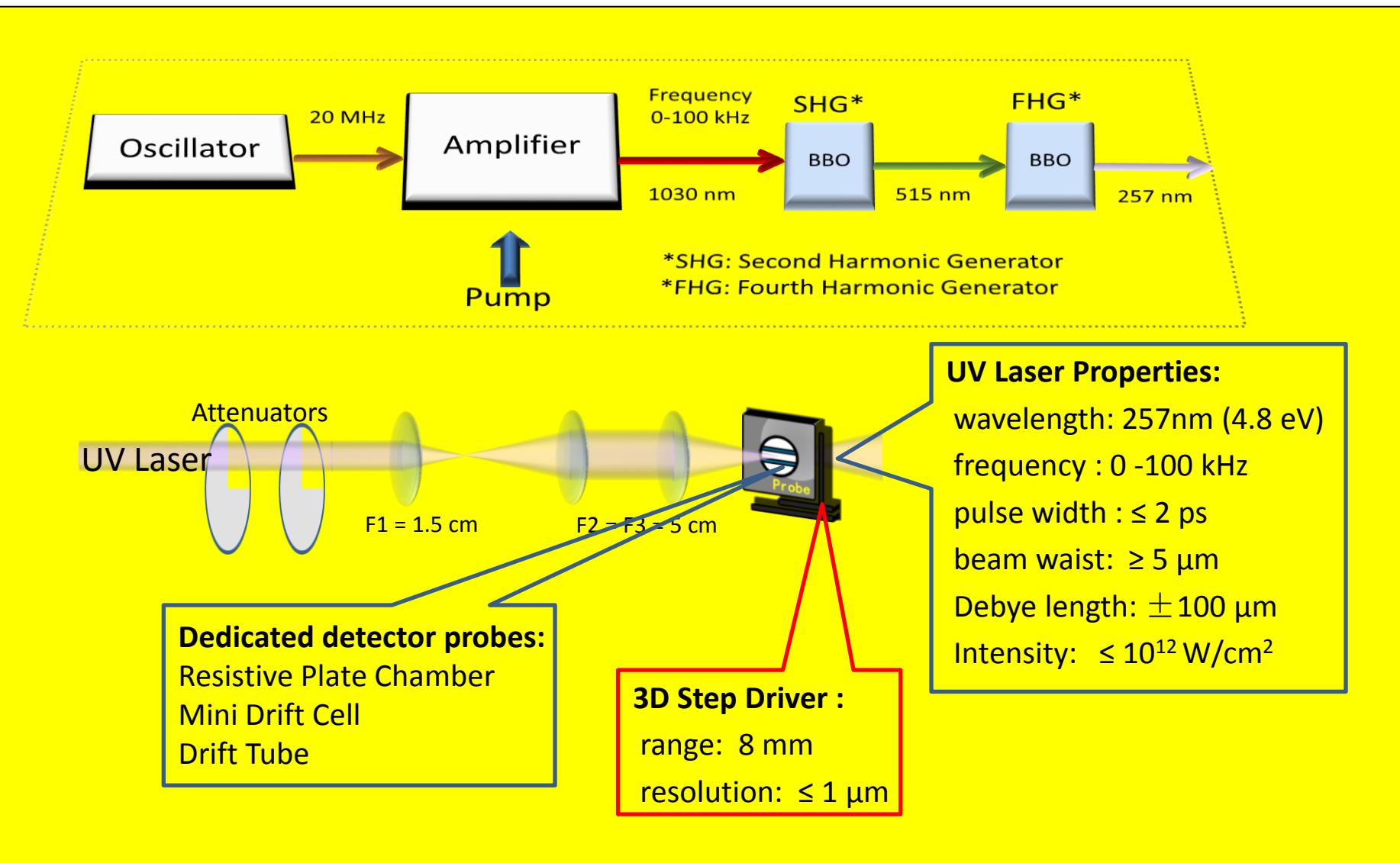
- Application of UV laser beams for calibration and surveying of Wire Chambers since 40 years  
Resistive Plate Chambers since 30 years
  - [*M. Anderhub et al.; NIM 166 (1979)*]
  - [*E. Gorini et al.; NIMA 425 (1999)*]
- RPC operating in strong and homogeneous electric fields at atmospheric pressure → 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

# Introduction

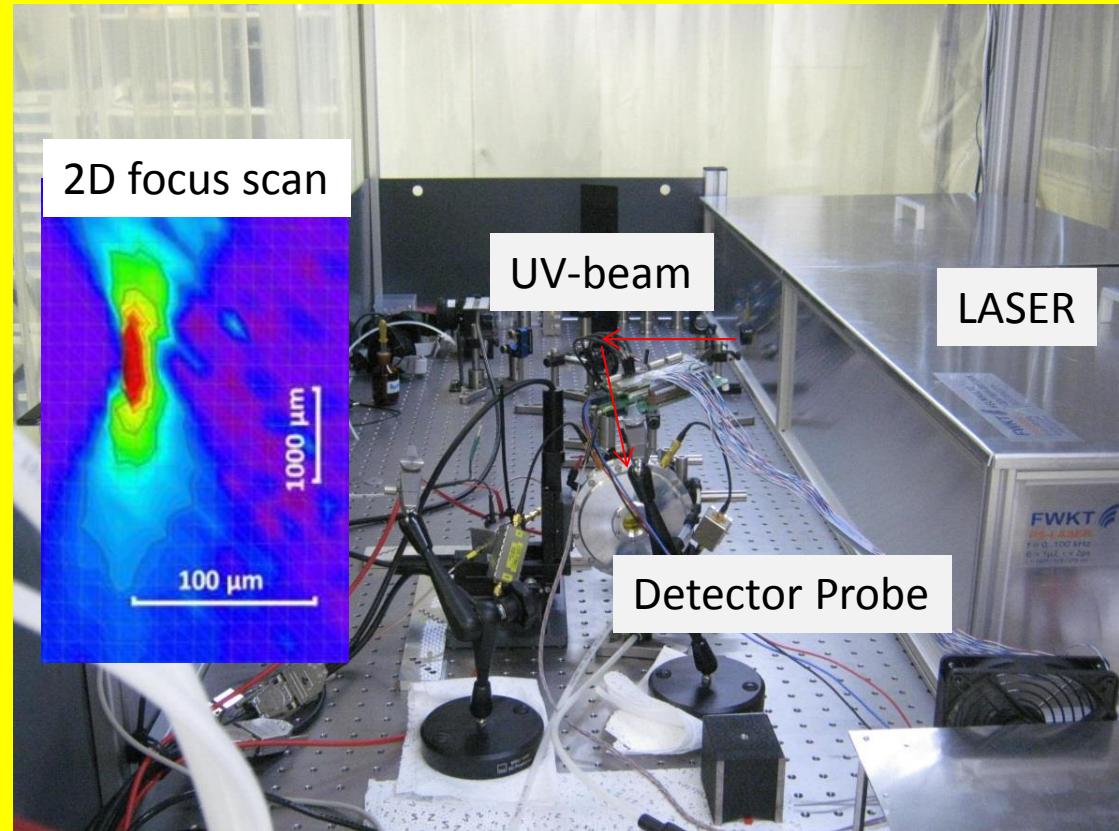
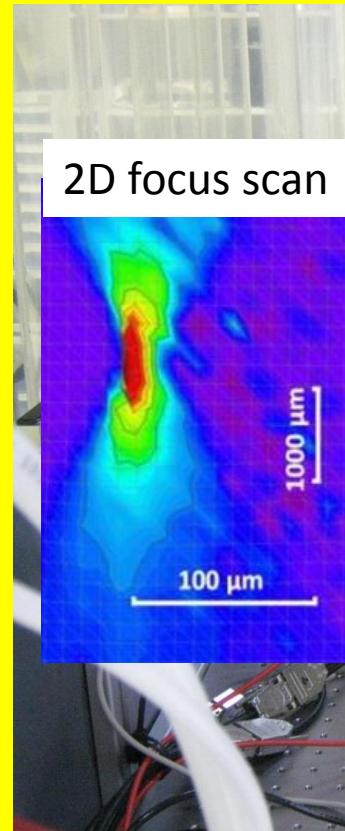
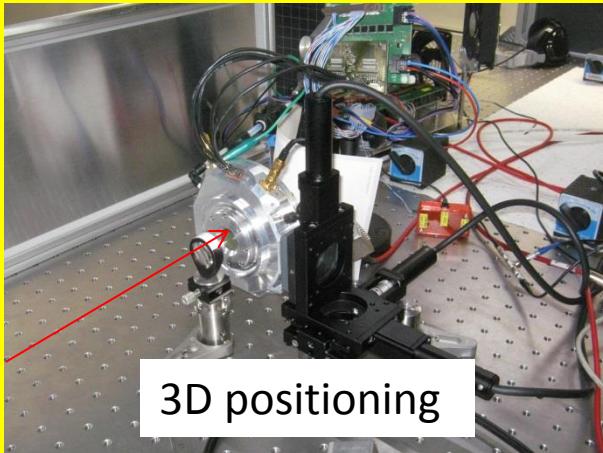
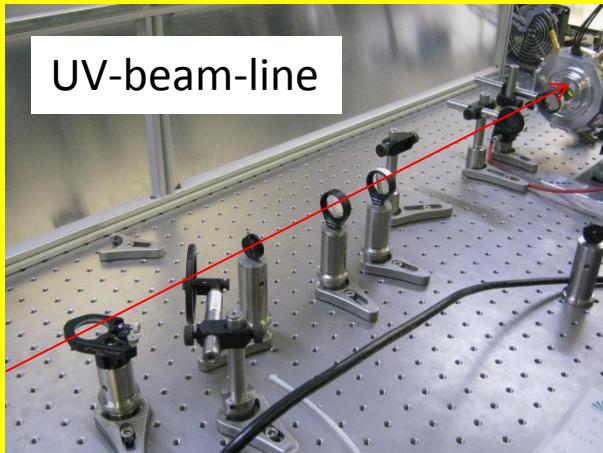
**Micro-plasma** creation and precise **micro-positioning** inside the active volume of gaseous detectors allows to improve the detector tests:

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

# HZDR Laser Facility



# HZDR Laser Facility

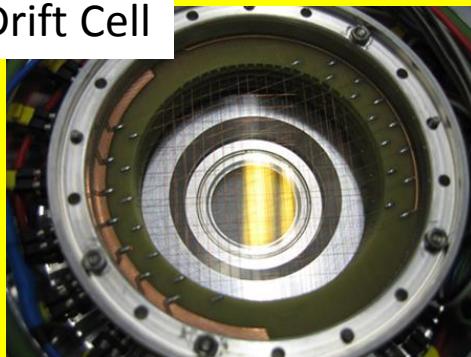


# HZDR Laser Facility

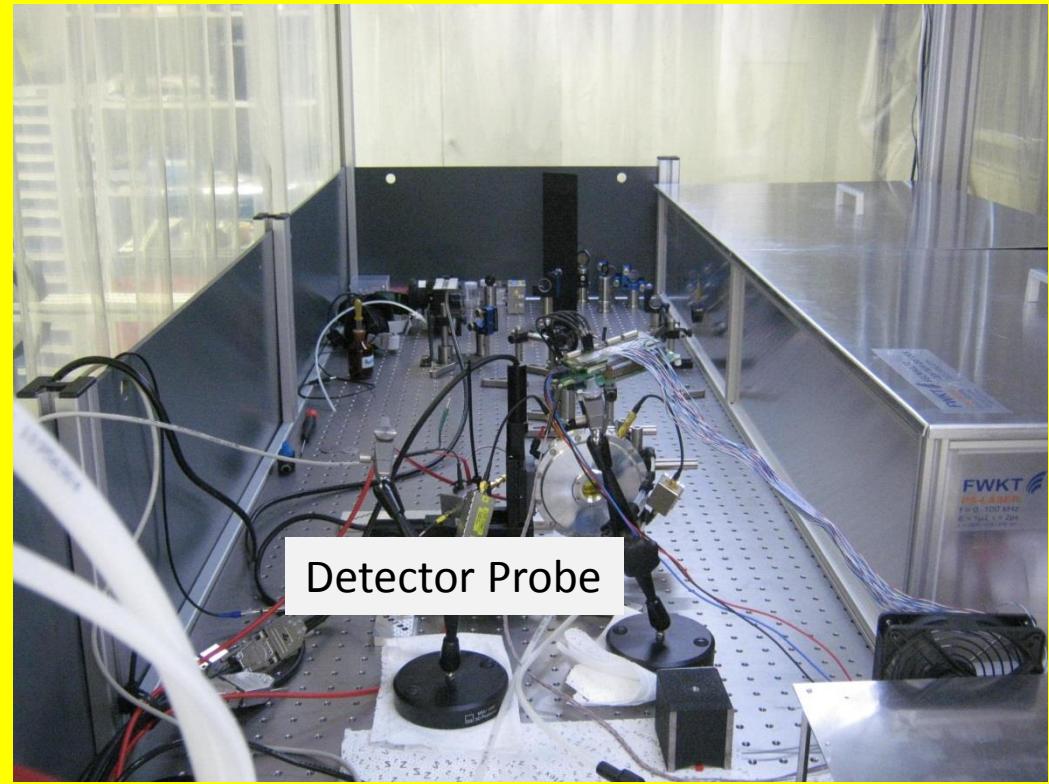
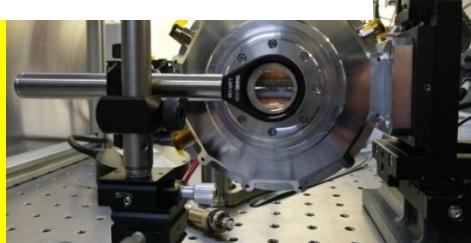
Drift Tube



Mini Drift Cell



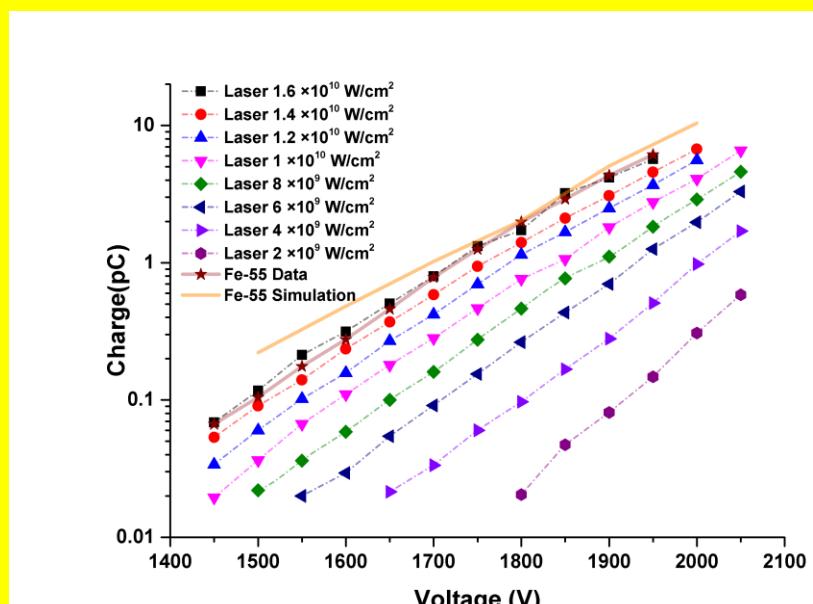
Resistive Plate Chamber



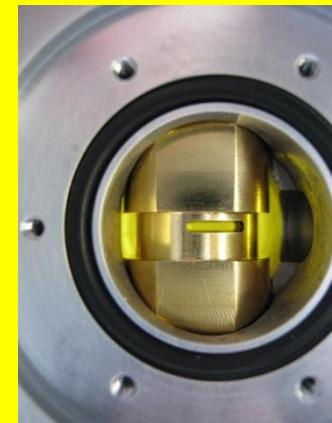
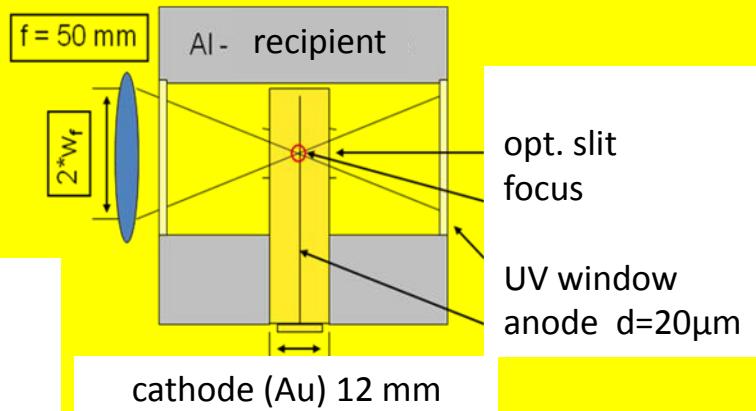
Detector Probe

# Drift Tube

$\lambda = 257 \text{ nm} \rightarrow \text{photon energy } 4.8 \text{ eV}$   
 $\rightarrow \text{multi-photon ionization } \geq 2$

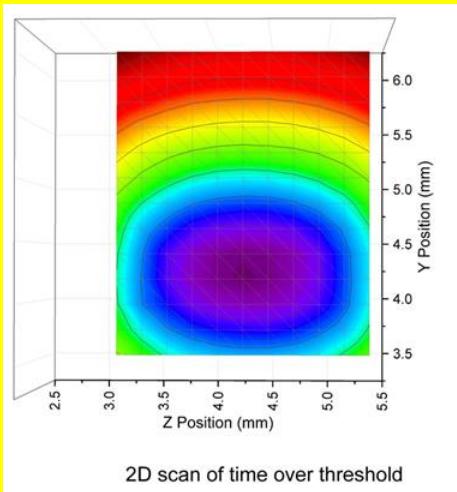


drift tube detector

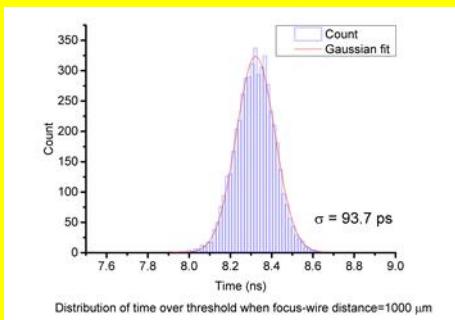


# Drift Tube

$\lambda = 257 \text{ nm} \rightarrow \text{photon energy } 4,8 \text{ eV}$   
 $\rightarrow \text{multi-photon ionization } \geq 2$

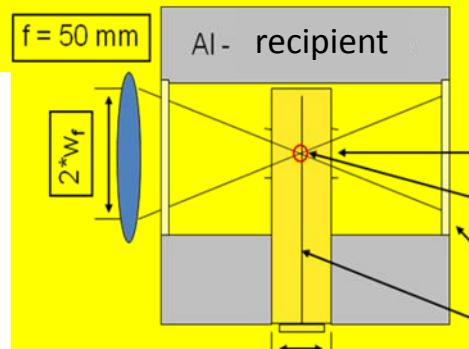


2D scan of time over threshold



Distribution of time over threshold when focus-wire distance=1000  $\mu\text{m}$

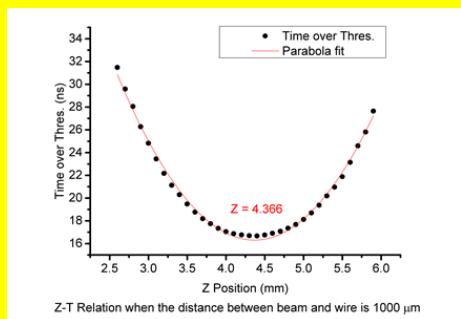
drift tube detector



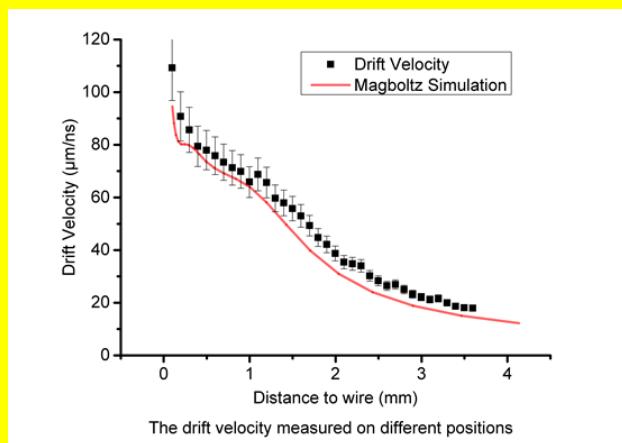
opt. slit  
focus

UV window  
anode  $d=20 \mu\text{m}$

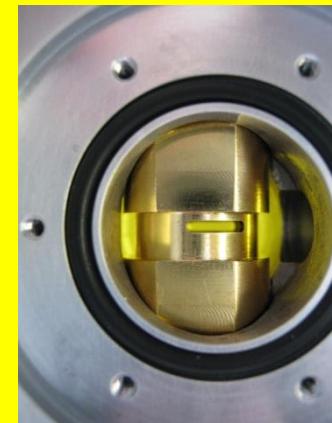
cathode (Au) 12 mm



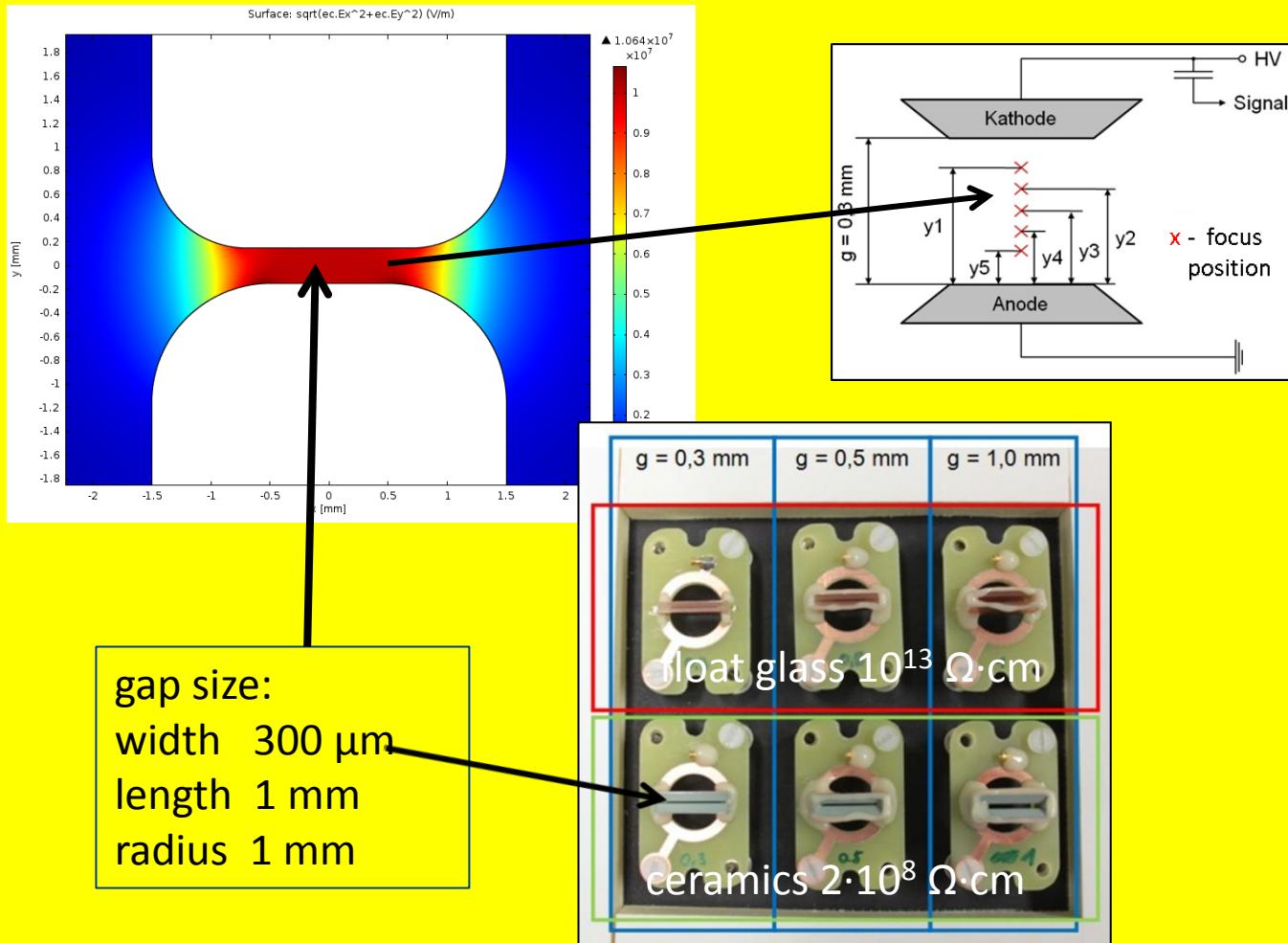
Z-T Relation when the distance between beam and wire is 1000  $\mu\text{m}$



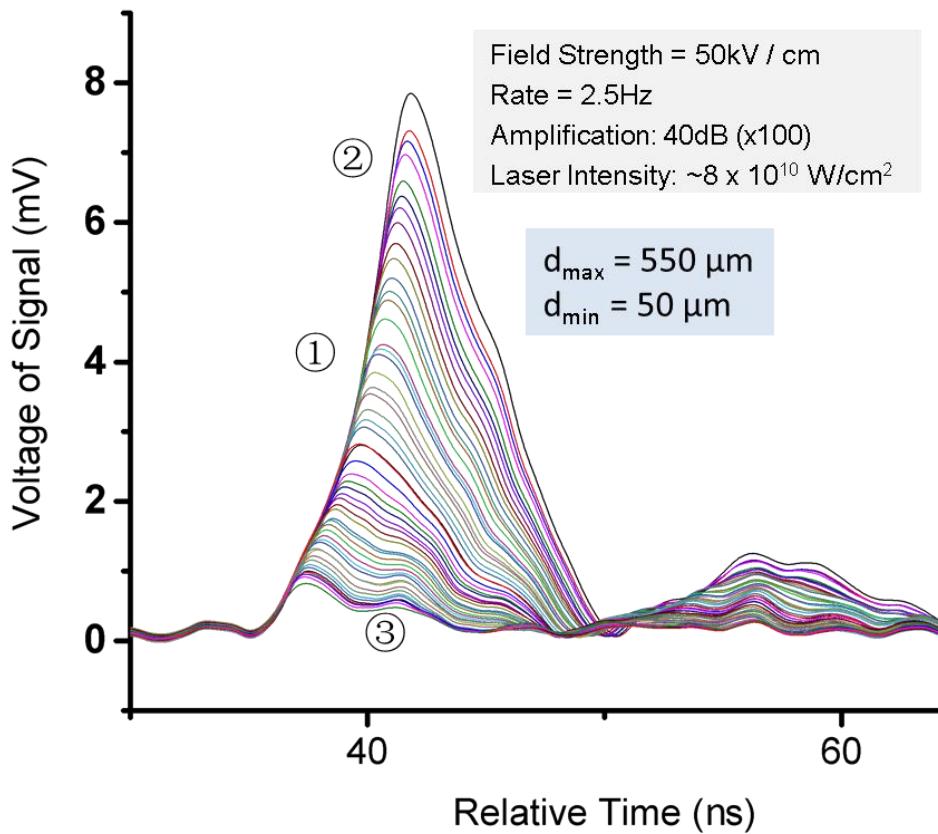
The drift velocity measured on different positions



# RPC probe

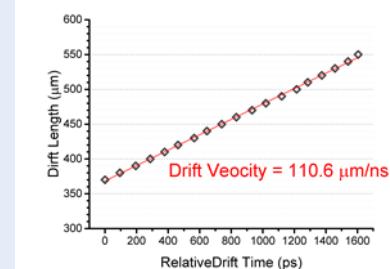


# Trigger-RPC: 50 kV/cm; 1.0 mm

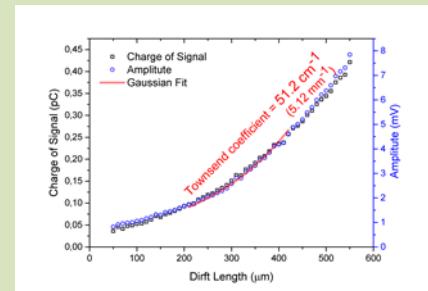


① Rising edge of the signal is overlapped, no matter where the avalanche is started.

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

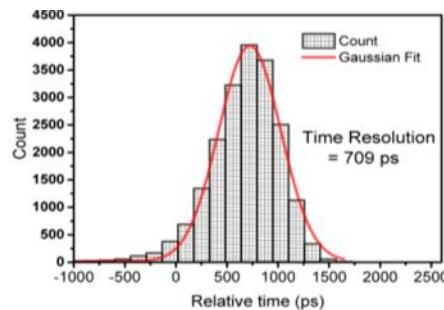


③ The area represents the charge of signal, amplification (eff.), Townsend coefficient can be measured:

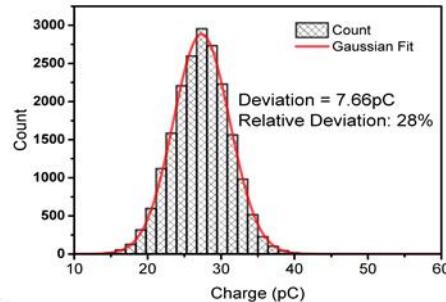


# Trigger-RPC: 50 kV/cm; 1.0 mm

time



charge

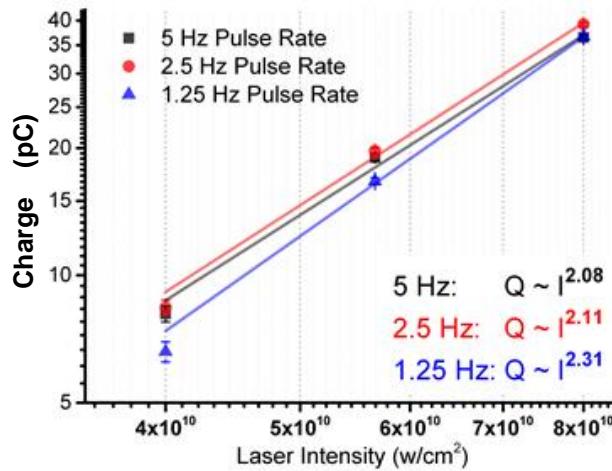


Efficiency: 100%

Time resolution: 700 ps

rel. charge deviation: 28%

charge vs. laser intensity



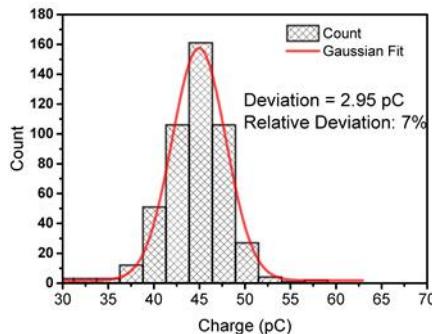
Proportionality of charge( $Q$ ), number of primary electrons( $N_e$ ) and intensity( $I^x$ ):

$$Q \sim N_e \sim I^x$$
$$x \geq 2$$

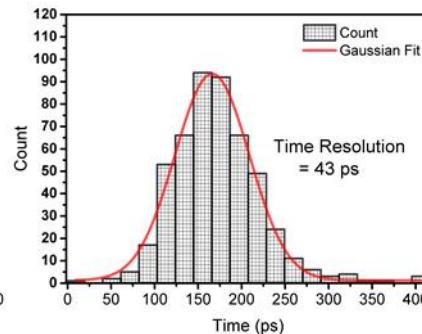
→ double-photon-ionization

# Timing-RPC: 100 kV/cm; 0.5 mm

charge



time

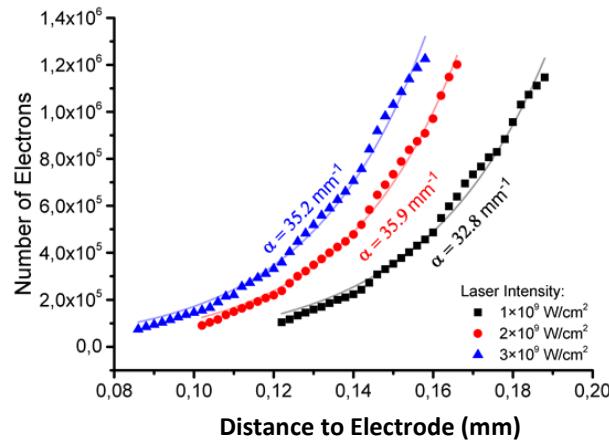


Efficiency: 100%

Time resolution: < 50 ps

rel. charge deviation: 7%

eff. Townsend coefficient



Rate = 0.5Hz

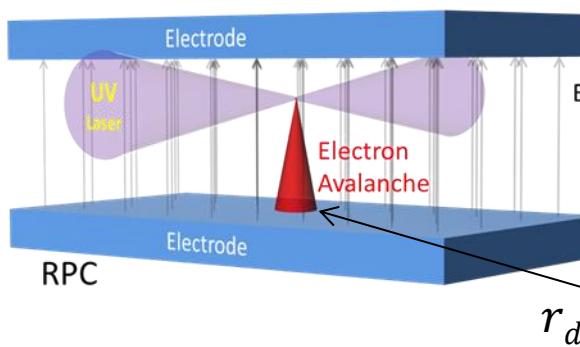
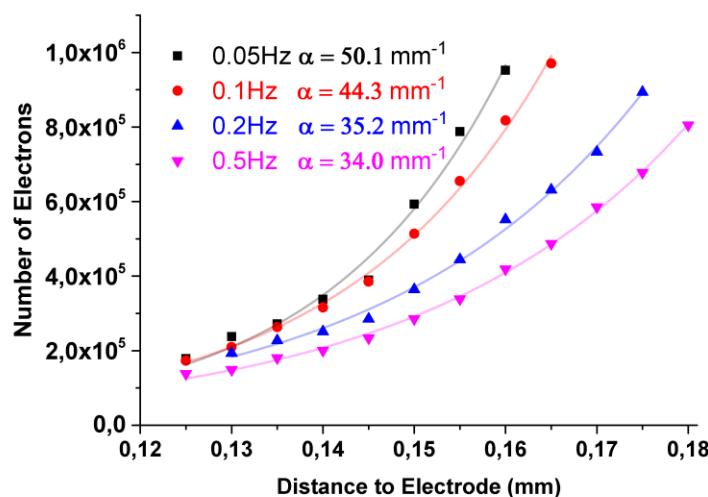
Increment : 2  $\mu\text{m}$

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

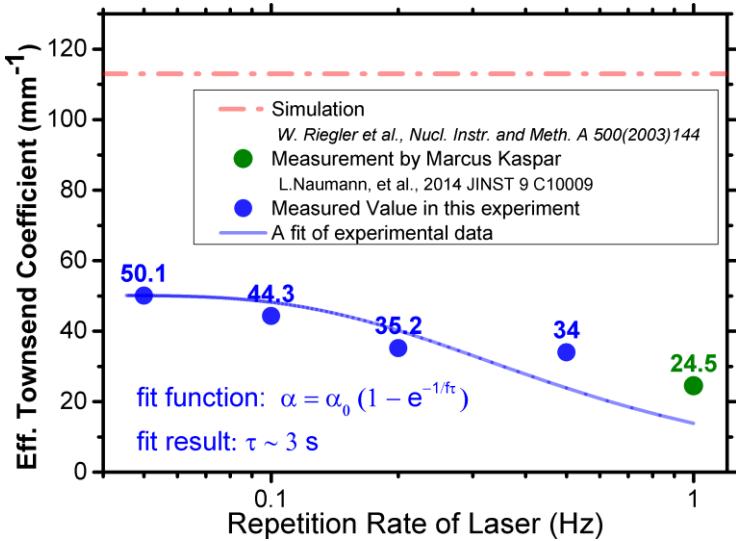
$$\alpha_{eff} = \text{const.} \quad \text{for} \quad Q \sim N_e \sim I^2$$

→ no space-charge effect

# $\alpha_{\text{eff}}$ Timing-RPC: 100 kV/cm; 0.5 mm

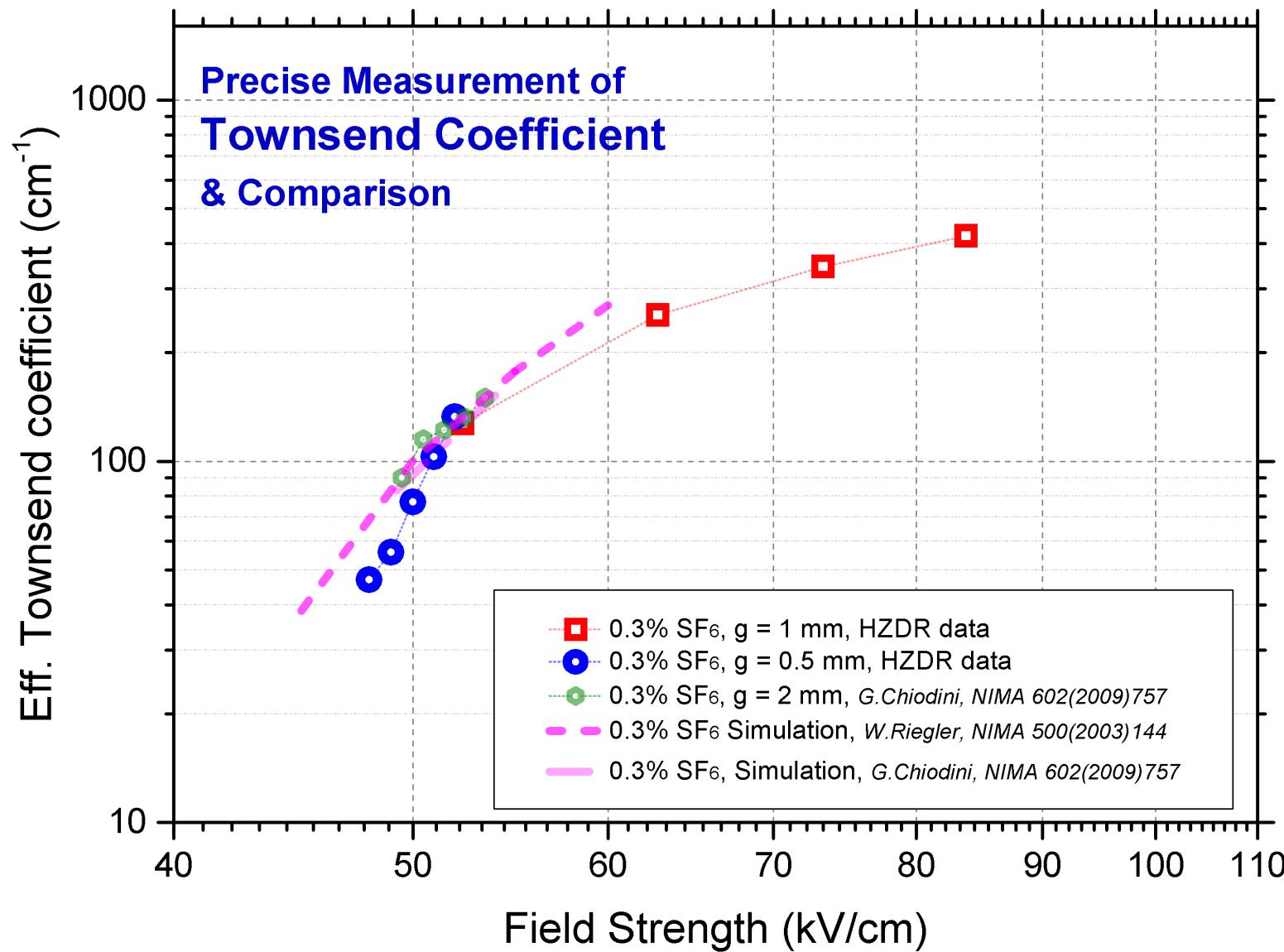


Float glass sample  
 $\tau = \varepsilon_0 \varepsilon \rho = (3 \pm 0.5) \text{ s}$

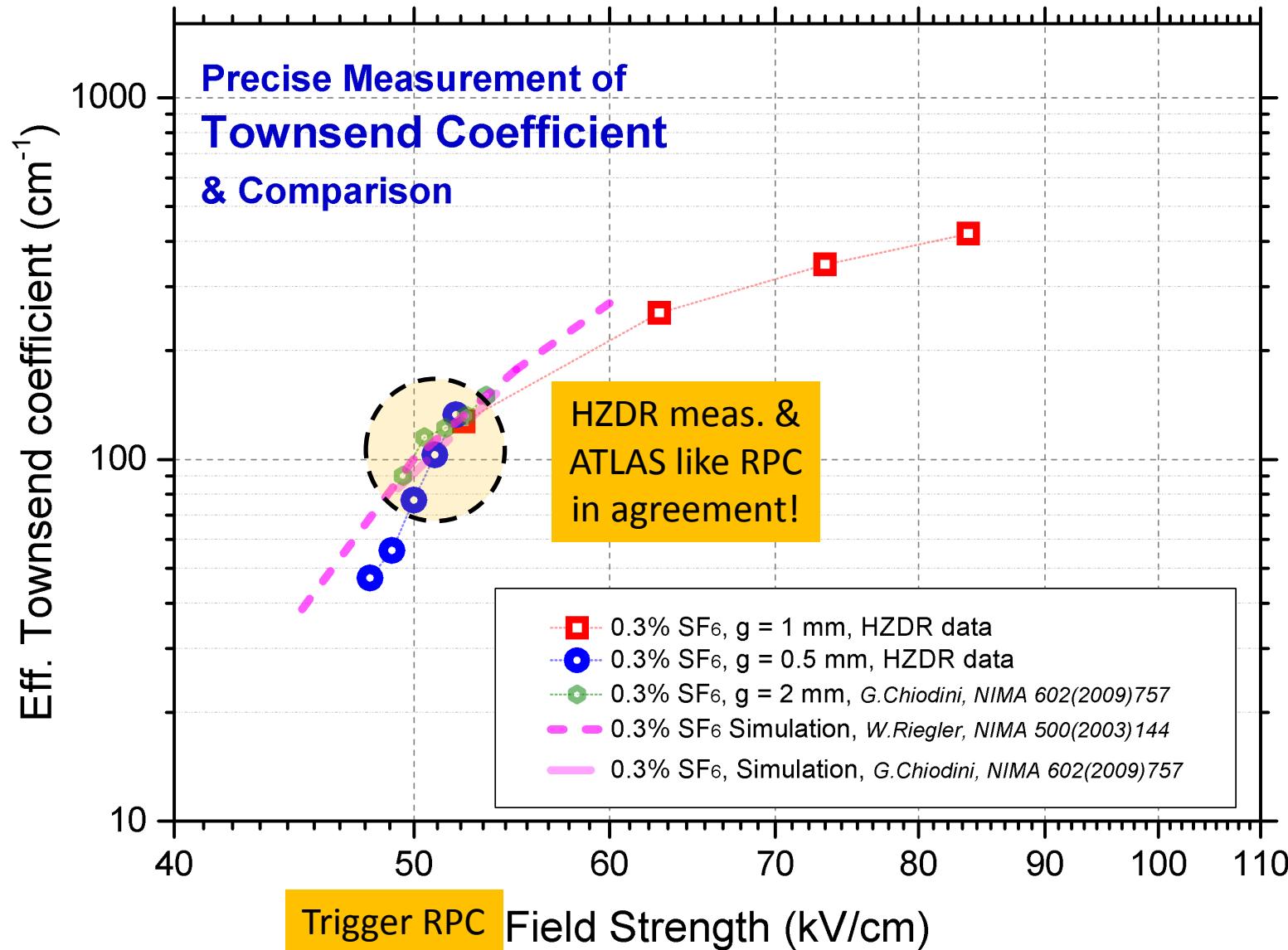


- The eff. Townsend coefficient depends on the laser repetition rate.
- The Time constant of the float glass sample is in agreement with the data.
- Data reach the horizontal asymptote at  $\leq 0.1 \text{ Hz}$ .
- The ionisation occurs always at the same micro-volume and the charges are accumulated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

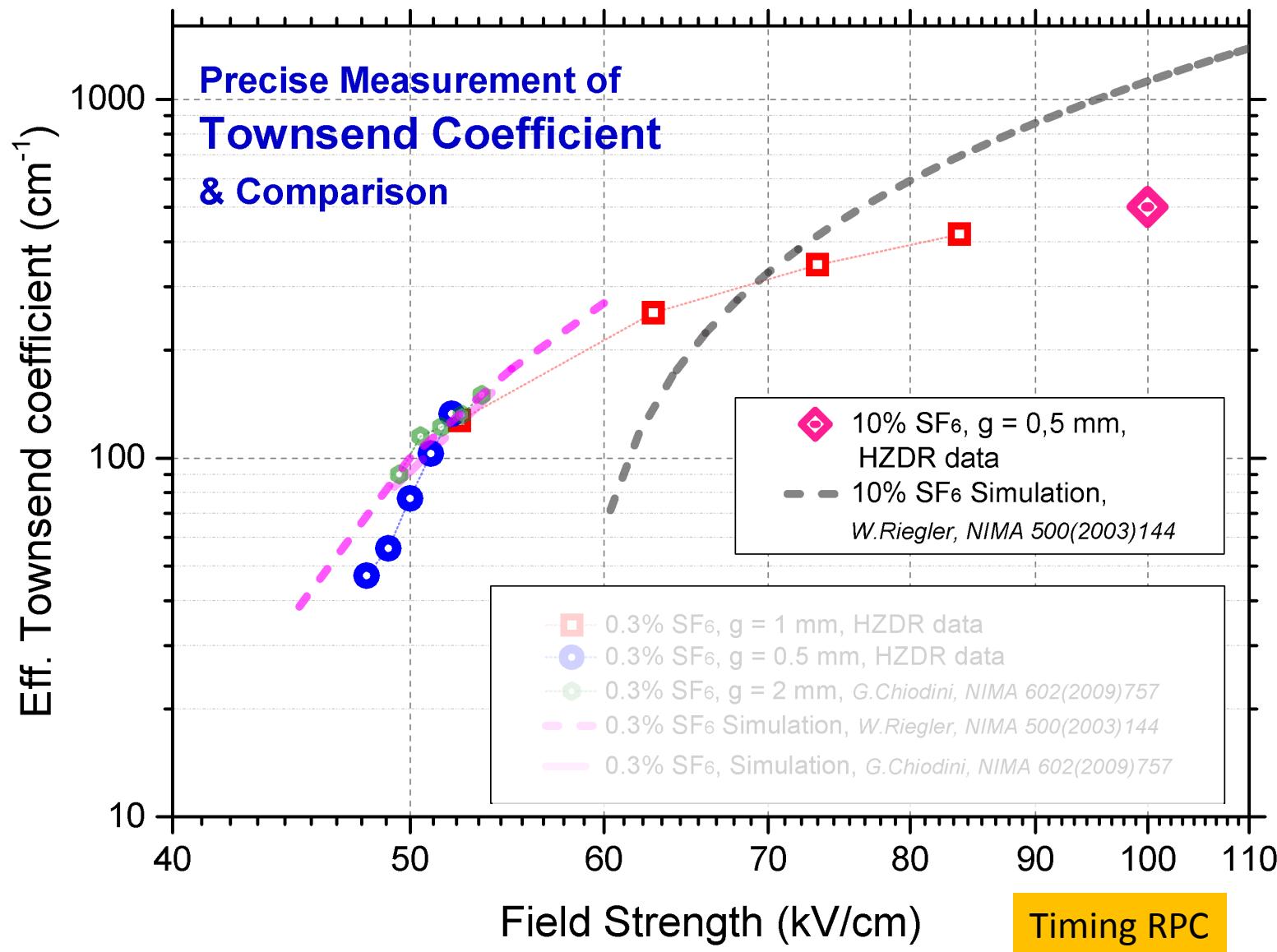
# Effective Townsend coefficient (1)



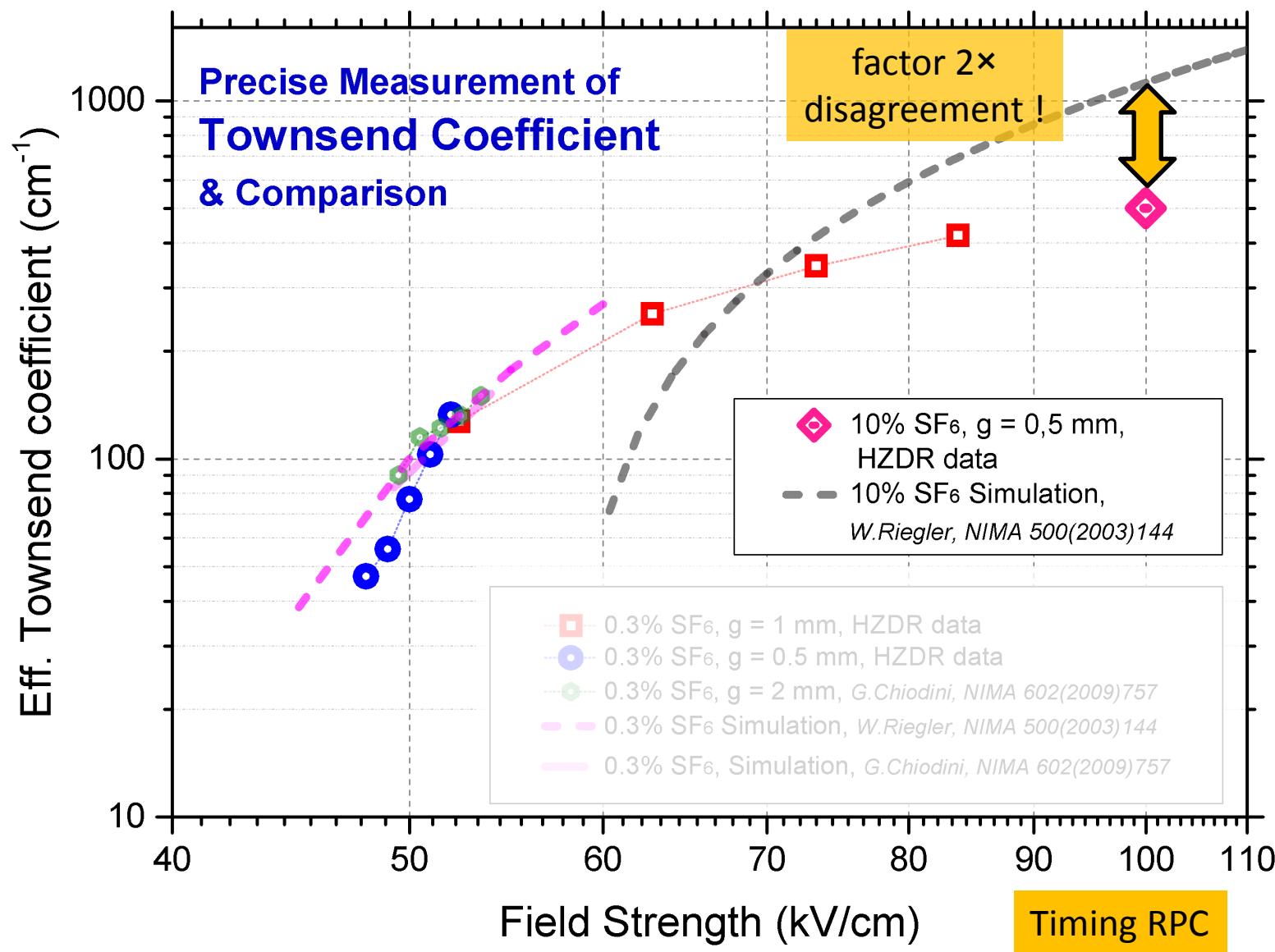
# Effective Townsend coefficient (1)



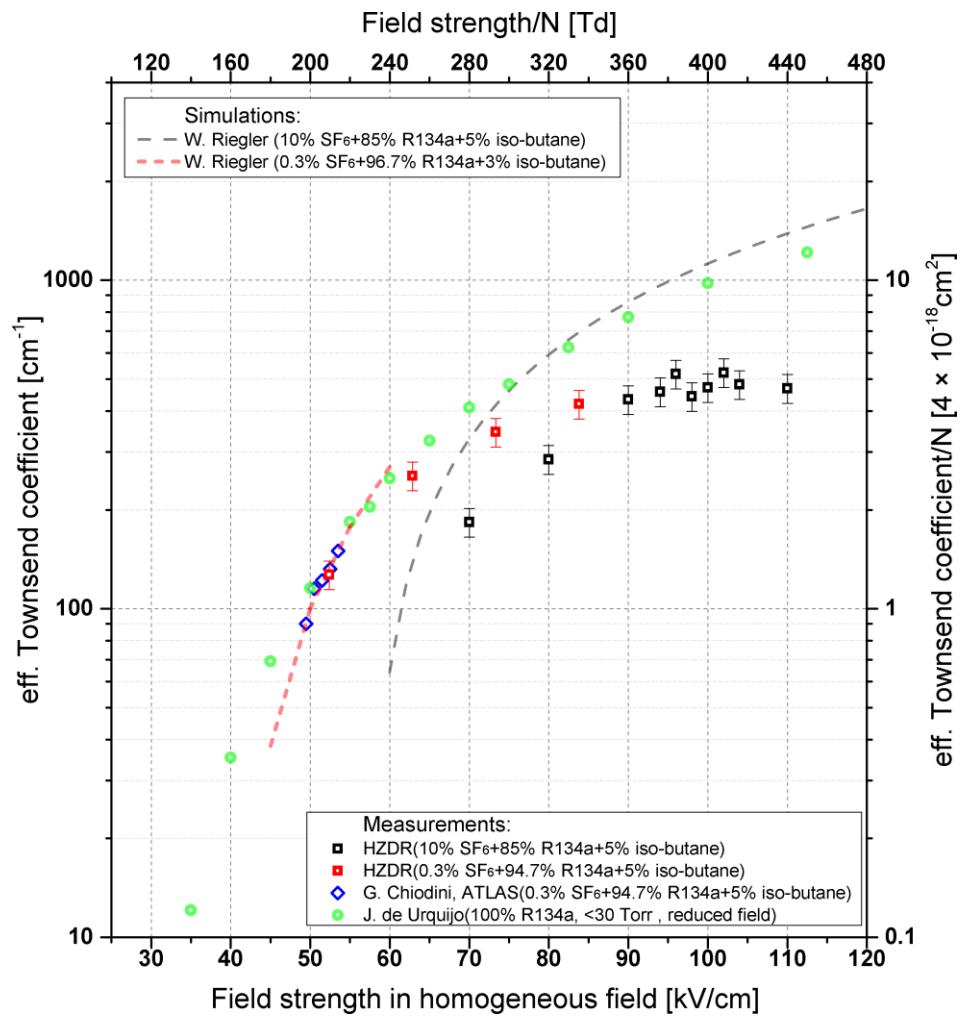
# Effective Townsend coefficient (2)



# Effective Townsend coefficient (2)

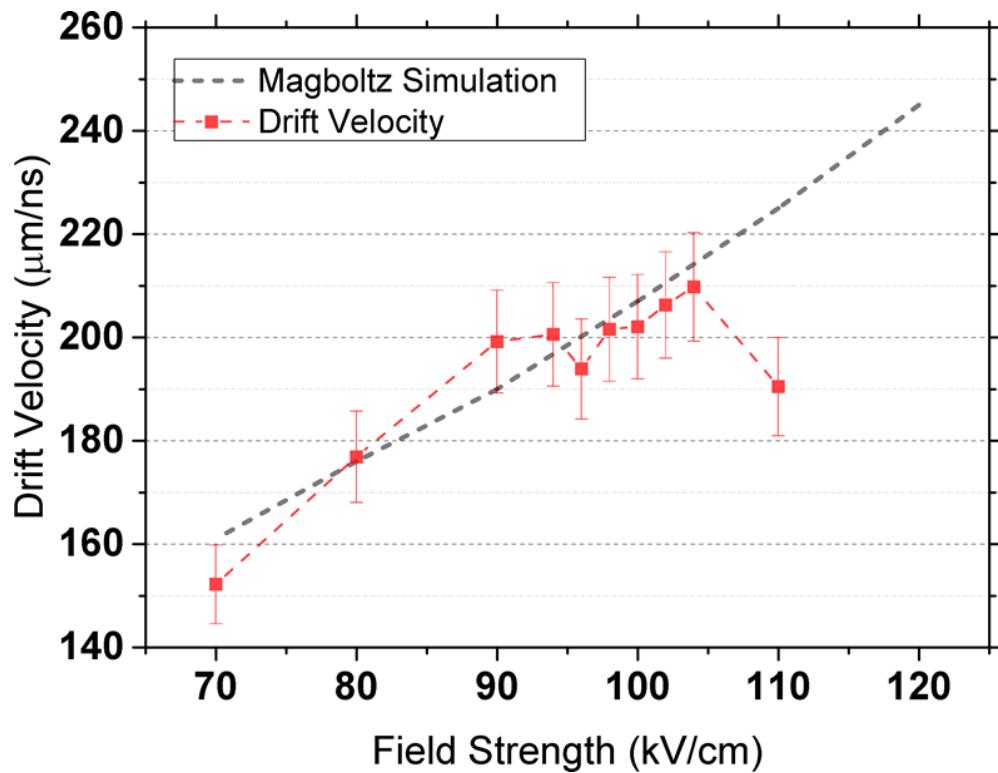


# Effective Townsend coefficient (3)



- 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

# Mini Drift Cell (HADES-like)

**HADES MDC**

The diagram illustrates the HADES Mini Drift Cell (MDC) with six layers labeled 1 through 6. The layers are oriented at various angles relative to the horizontal (0.0 degrees). The layers are color-coded: 1 (+40 deg), 2 (-20 deg), 3 (+20 deg), 4 (-0 deg), 5 (+20 deg), and 6 (-40 deg). The coordinate system shows X and Z axes, with the origin at 0.0 degrees. Labels indicate 'left', 'right', 'up', and 'down' directions.

A photograph of the anode/field plane of the Mini Drift Cell. It shows a circular copper frame with numerous small electrodes or wires attached to it.

A photograph of the full Mini Drift Cell assembly, showing the central cylindrical structure and the surrounding field coils.

anode/field plane

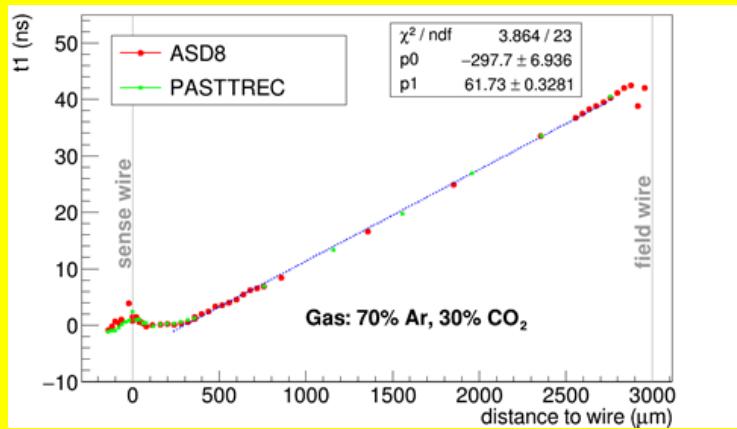
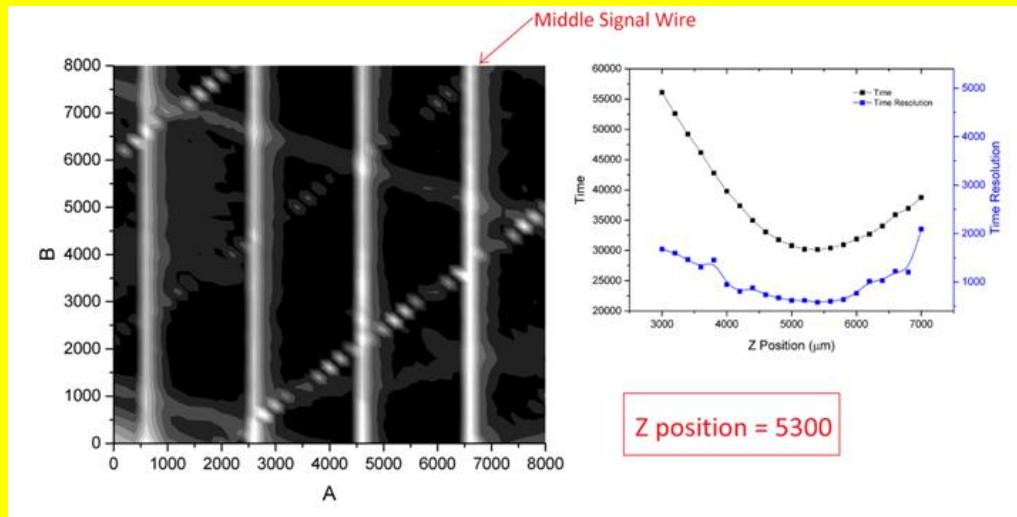
HADES MDC2 geometry

The schematic diagram shows the experimental setup. A pulsed UV-LASER beam passes through an Attenuator and a lens, then hits a Model MDC on an XYZ gantry. The gantry is positioned along the Z-axis. The signal from the MDC is processed by an Analog Front-End (ASD8 / PASTTREC) and sent to a TDC on a TRB3 board, which then connects to a DAQ PC. A trigger / reference time signal is also sent from the TDC to the DAQ PC.

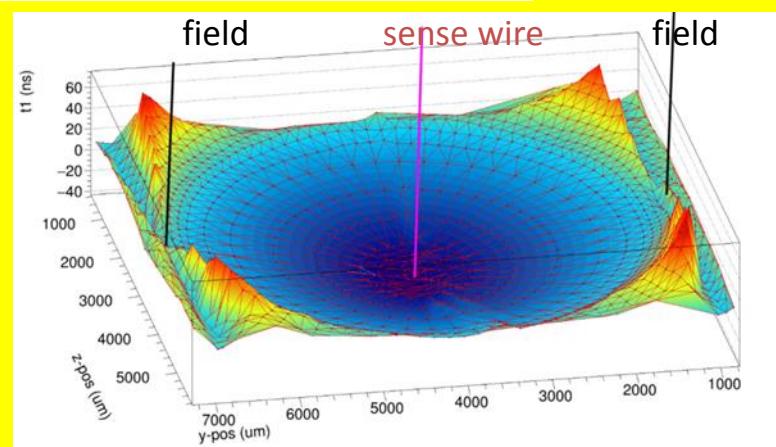
This diagram shows a cross-section of the MDC2 geometry. It features two parallel vertical planes of cathode wires (labeled +HV) separated by a distance of 2.5 mm. Between these cathodes are several horizontal field wires, also labeled +HV. Red lines represent sense wires, which are positioned between the cathodes and the field wires. The diagram is noted to be "not to scale". A text box states: "corresponds to geometry of MDC plane 2".

# Mini Drift Cell

## MDC tomography



Electron drift velocity  $v_e = 62 \mu\text{m}/\text{ns}$   
Spatial resolution  $\leq 60 \mu\text{m}$



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

# 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

# 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<sub>6</sub>(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<sub>6</sub>(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.

# 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

HZDR: **X. Fan, B. Kämpfer, M. Siebold, M. Sobiella, D. Stach**

GSI: **C. Wendisch, M. Wiebusch**



**hzdr**

**HELMHOLTZ**  
**ZENTRUM DRESDEN**  
**ROSSENDORF**