Precise Measurement of Gas Parameters in RPC Probes with Laser Induced Electrons

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Introduction

- Application of UV laser beams for calibration and surveying of gas filled wire chambers since 1979

  [M. Anderhub et al. NIM 166 (1979); RPC: E. Gorini et al. NIMA 425 (1999)]

- RPC operating in strong and homogeneous electric fields at atmospheric pressure

  Trigger RPC ~ 50 kV/cm gap size ≥ 1mm

  Timing RPC ~ 100 kV/cm gap size ≤ 0.5 mm

- Micro-plasma creation and positioning inside a sub-millimeter narrow gas gap for RPC research since 2009

  [50kV/cm: G. Chiodini et al. NIMA 602 (2009); P. Fonte et al. NIMA 613 (2010);
  100kV/cm : L. Naumann et al. JINST 9 (2014) C10009]

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Introduction

Transport parameter measurements in narrow gap samples

Gas	P [Torr]	Gap [mm]	E_{max} [kV/cm]	v_d	α, η	Ref.
IB, N_2	760	1.5	50	-	m, s	Lima et al., NIMA 670 (2012)
IB	7	3.0	2.1	-	m	Nakhostin et al., NIMA 615 (2010)
IB, N_2	760	0.5	50	m, s	m, s	Fonte et al., NIMA 613 (2010)
RPC_{mix1}	760	2.0	54	m, s	m, s	Chiodini et al., NIMA 602 (2009)
IB, methane	10 – 30	1.6	6.25	-	m	Tsumaki, Jap. J. AP V. 27 N.3 (1988)
RPC_{mix2}	760	0.3	100	m	m	Naumann et al., JINST 9 (2014) C10009

IB - isobutane
RPC_{mix} - freon, IB, SF_6

m - measurement
s - simulation

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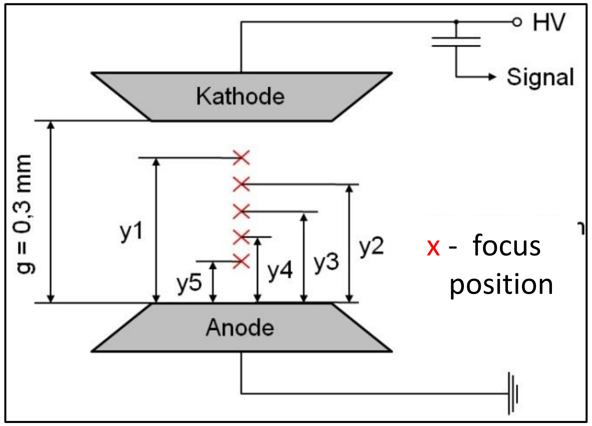
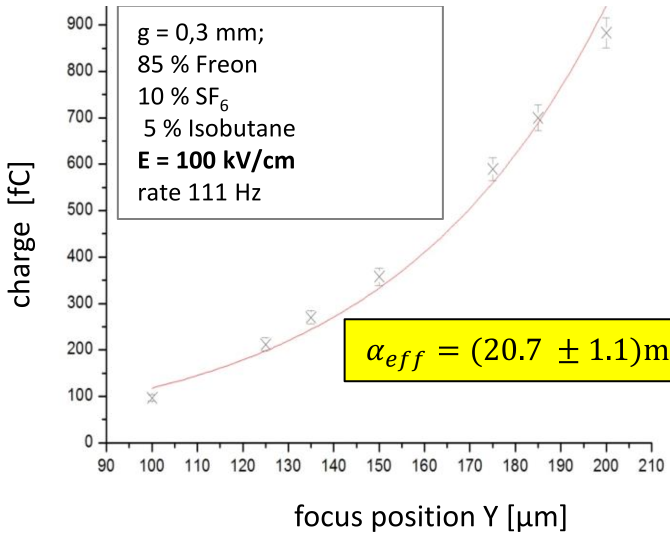
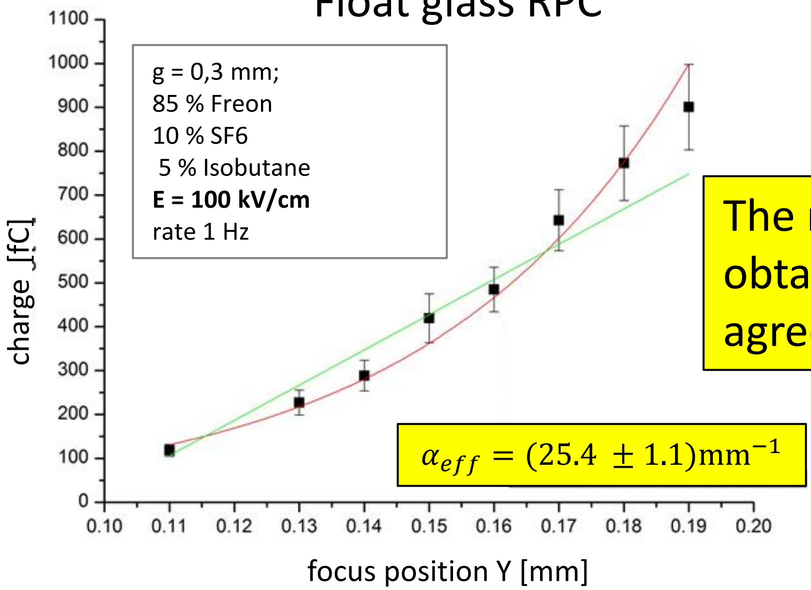
Effective Townsend coefficient



charge vs. drift path – Ceramics RPC



charge vs. drift path – Float glass RPC



The results of the effective Townsend coefficient, obtained under different conditions, are in a good agreement to each other

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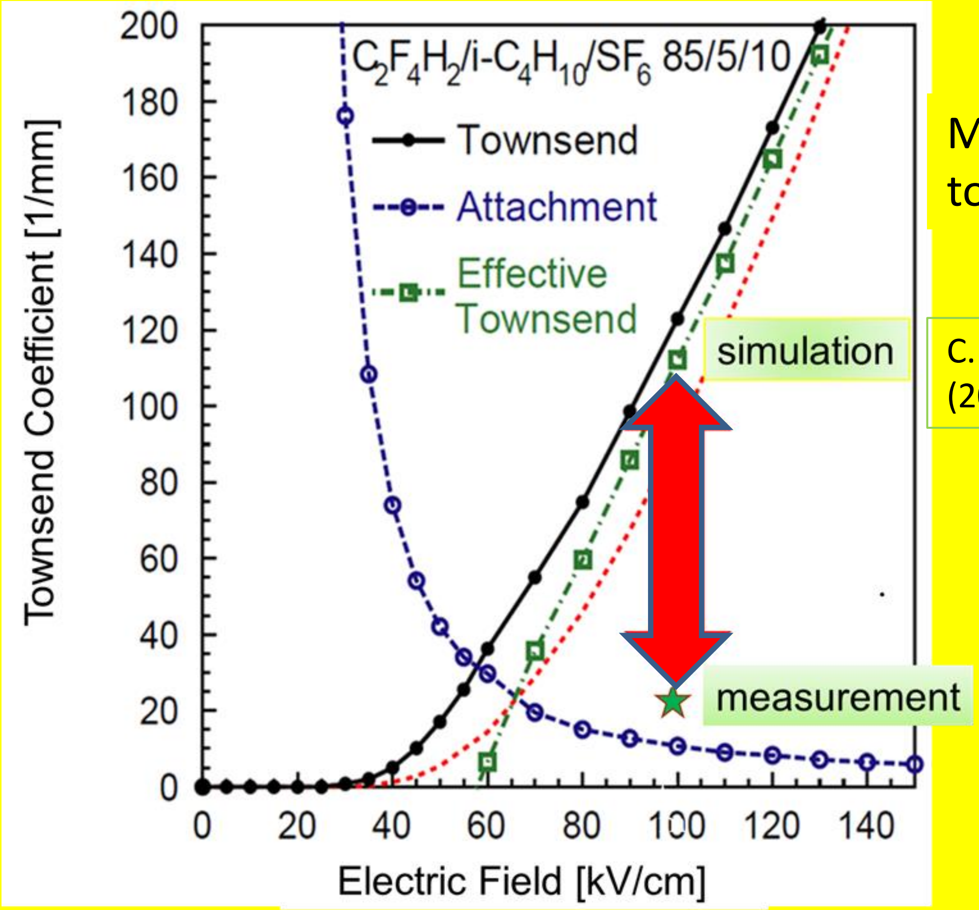
The Townsend Puzzle

First measurement for strong fields of 100 kV/cm in 300 µm gaps at atm. pressure

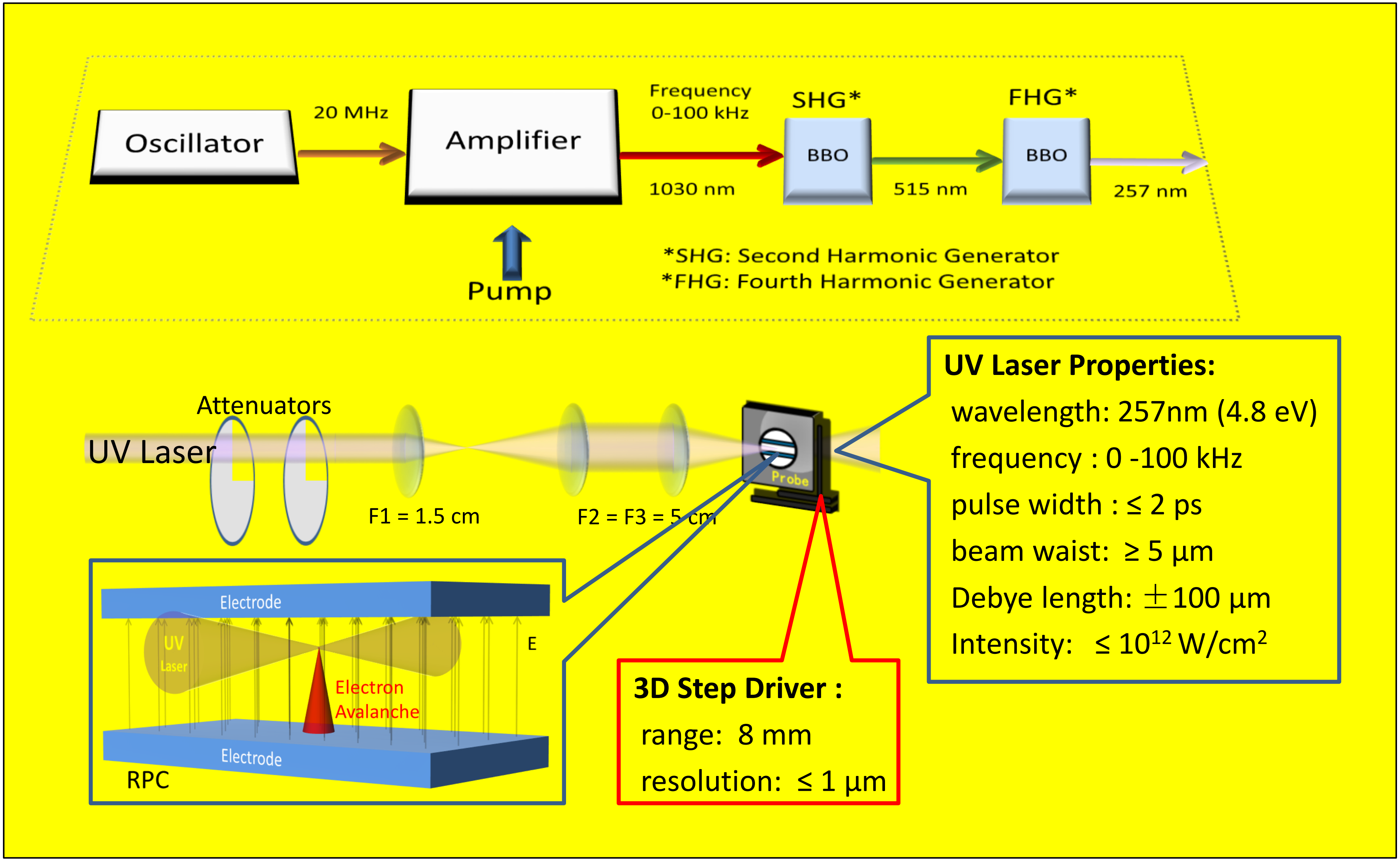


Magboltz simulation in disagreement to our measurements!

C. Lippmann et al., Nucl. Instr. and Meth. A 518 (2004) 86

L. Naumann et al. JINST 9 (2014) C10009

HZDR Laser Facility



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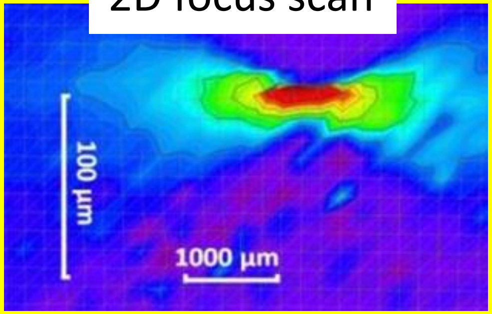
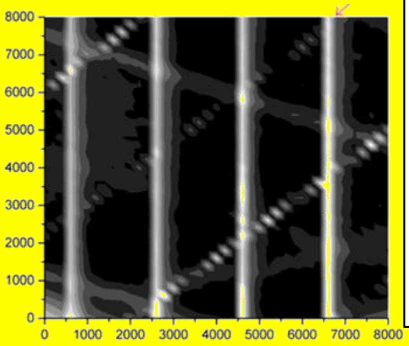
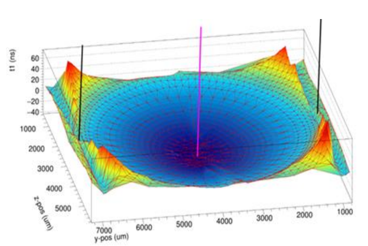
2D focus scan

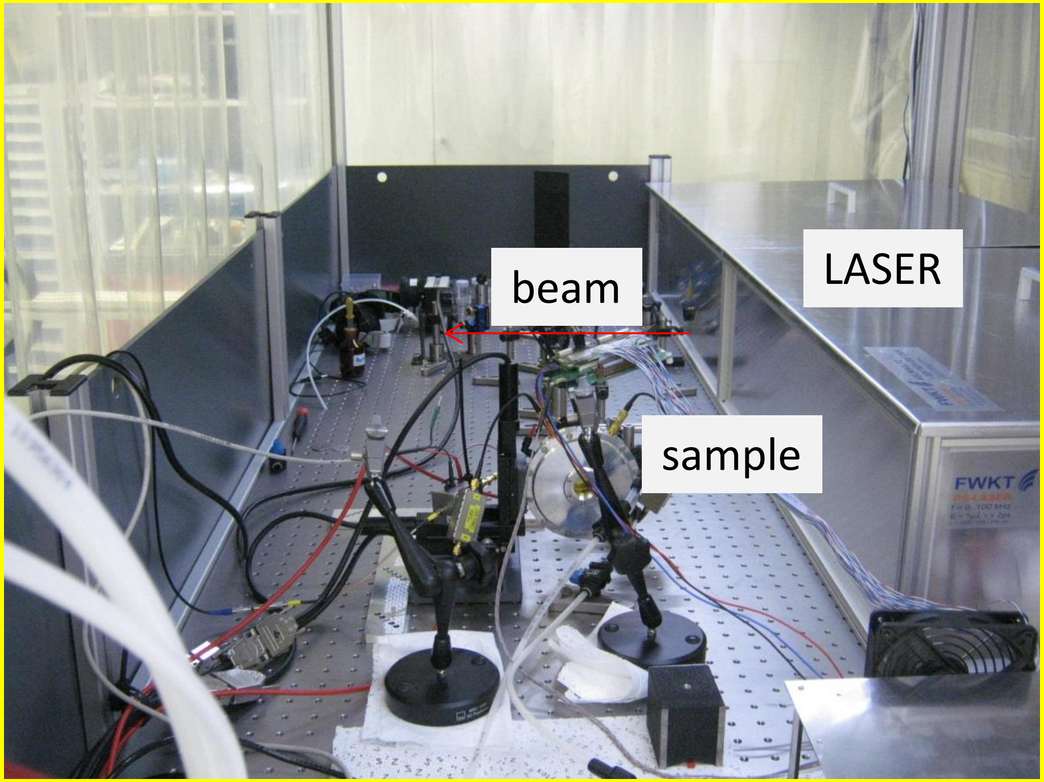


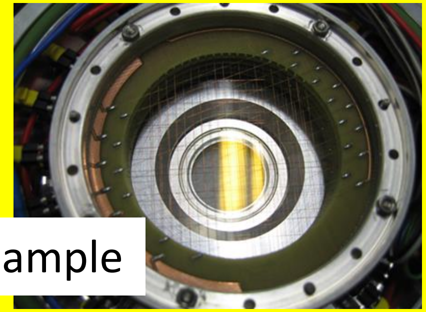
MDC tomography



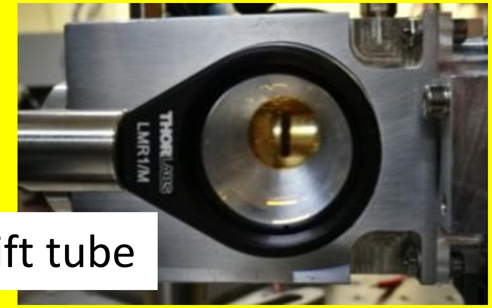


Drift time distribution
1290 data points
8000 ev. /point

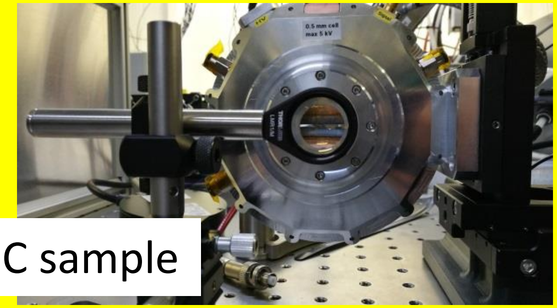




MDC sample



Drift tube



RPC sample

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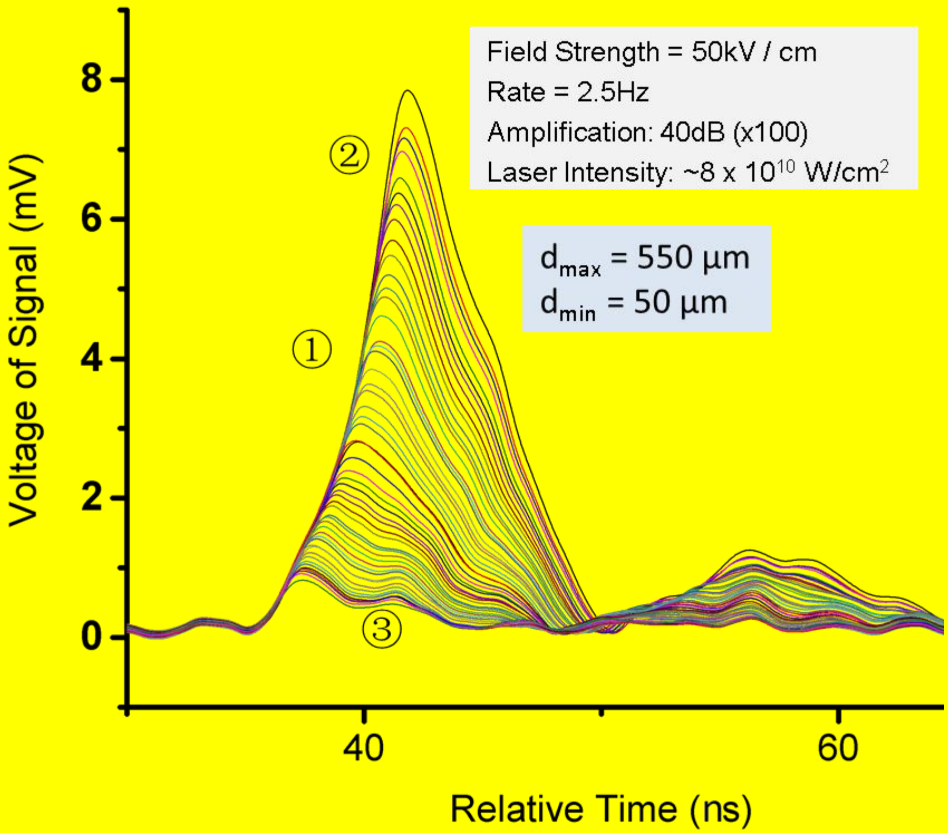
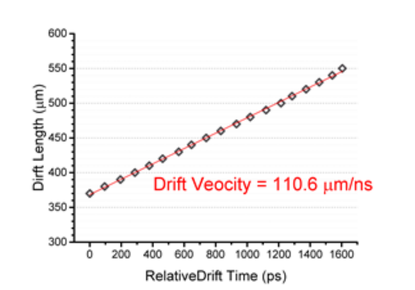
HZDR Laser Facility

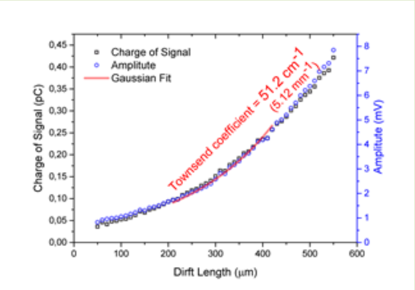


①Rising edge of the signal is overlapped, no matter where the avalanche is started.

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

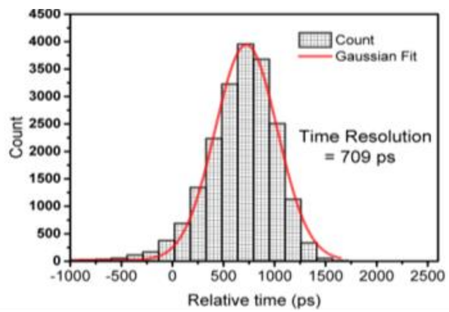


③ The area represents the charge of signal, <u>amplification (eff. Townsend coefficient)</u> can be measured:

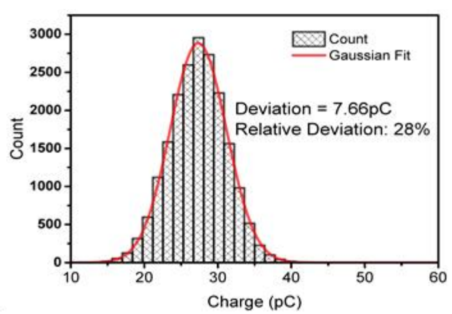


Trigger-RPC: 50 kV/cm; 1.0 mm

time



charge

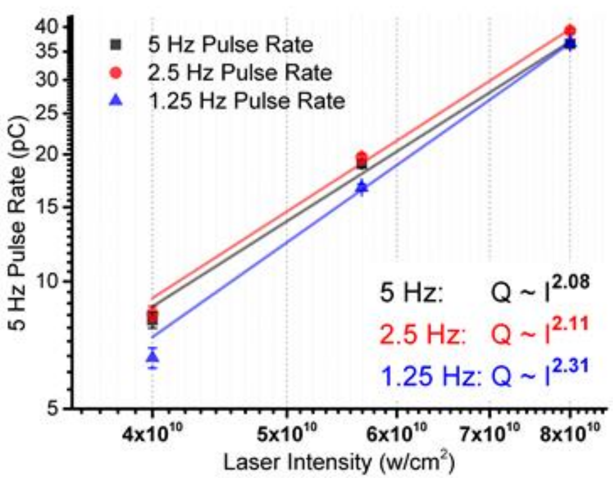


Efficiency: 100%

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) :

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

$$x \geq 2$$

$\rightarrow$ **double-photon-ionization**

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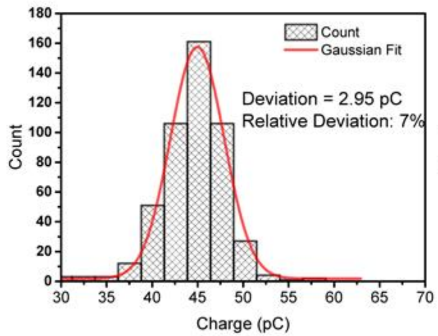
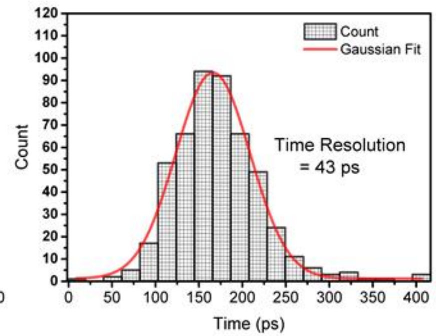
Timing-RPC: 100 kV/cm; 0.3 mm

charge



time

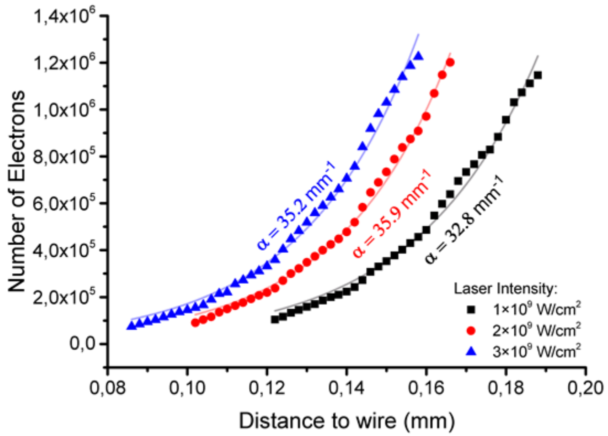


Efficiency: 100%

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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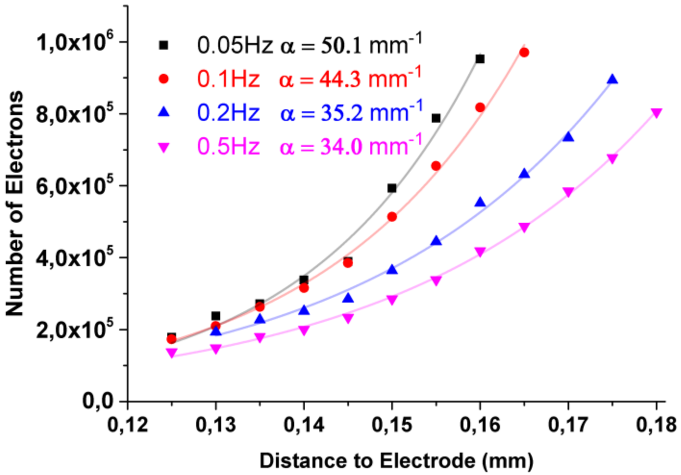
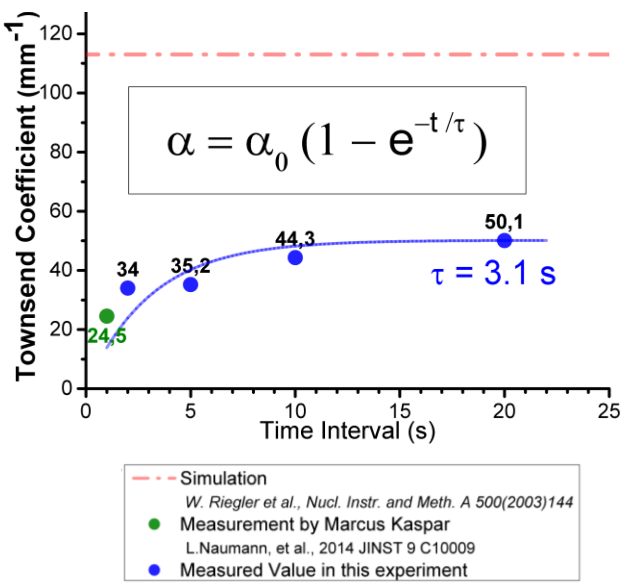
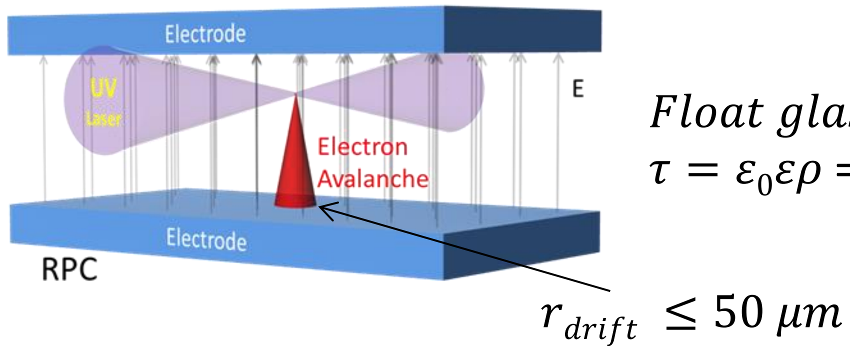
α_{eff} Timing-RPC: 100 kV/cm; 0.3 mm







Float glass sample

$\tau = \varepsilon_0 \varepsilon \rho$ = (3±0.5)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 ≤ 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/cm²

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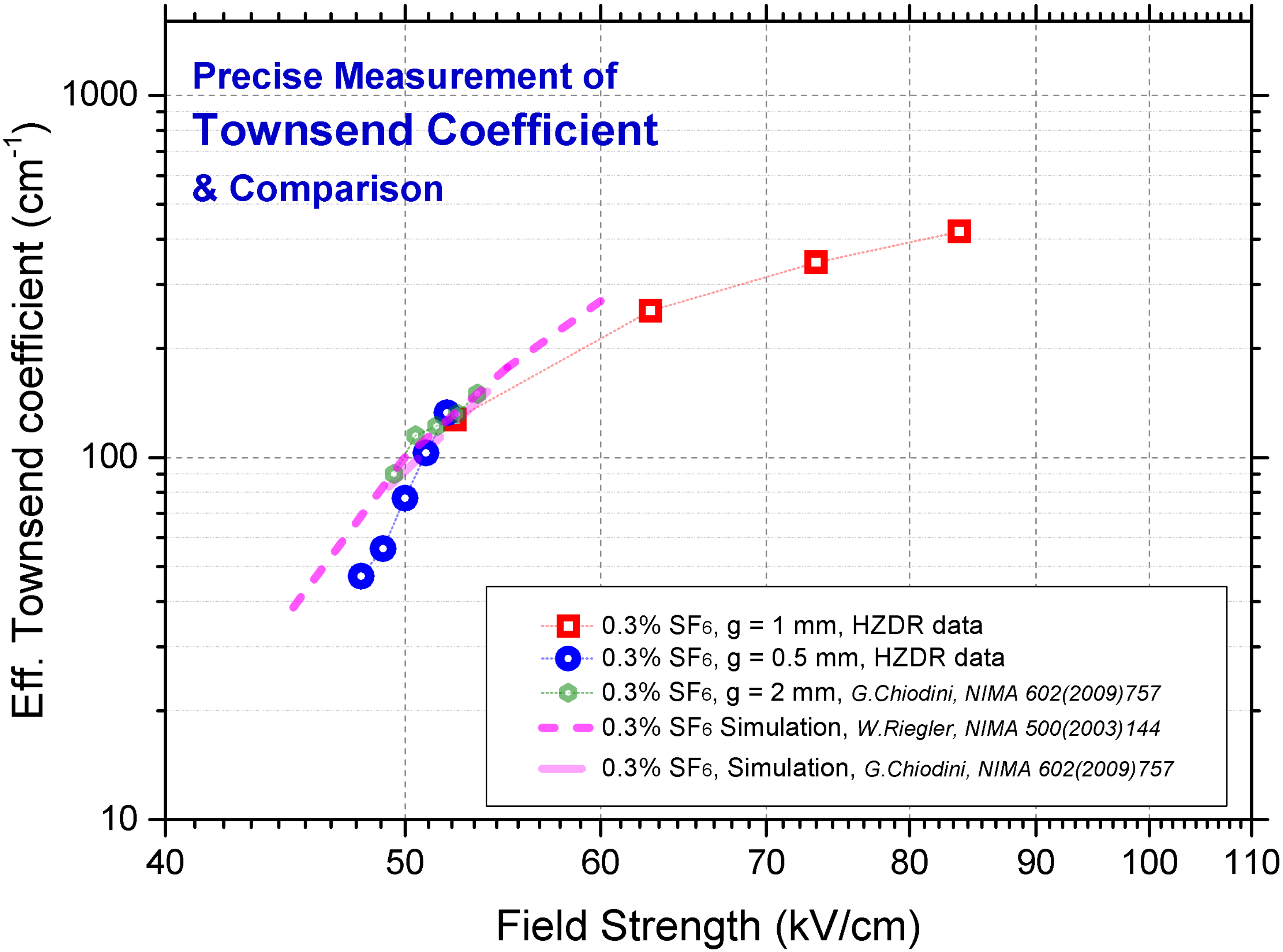
Effective Townsend coefficient (1)



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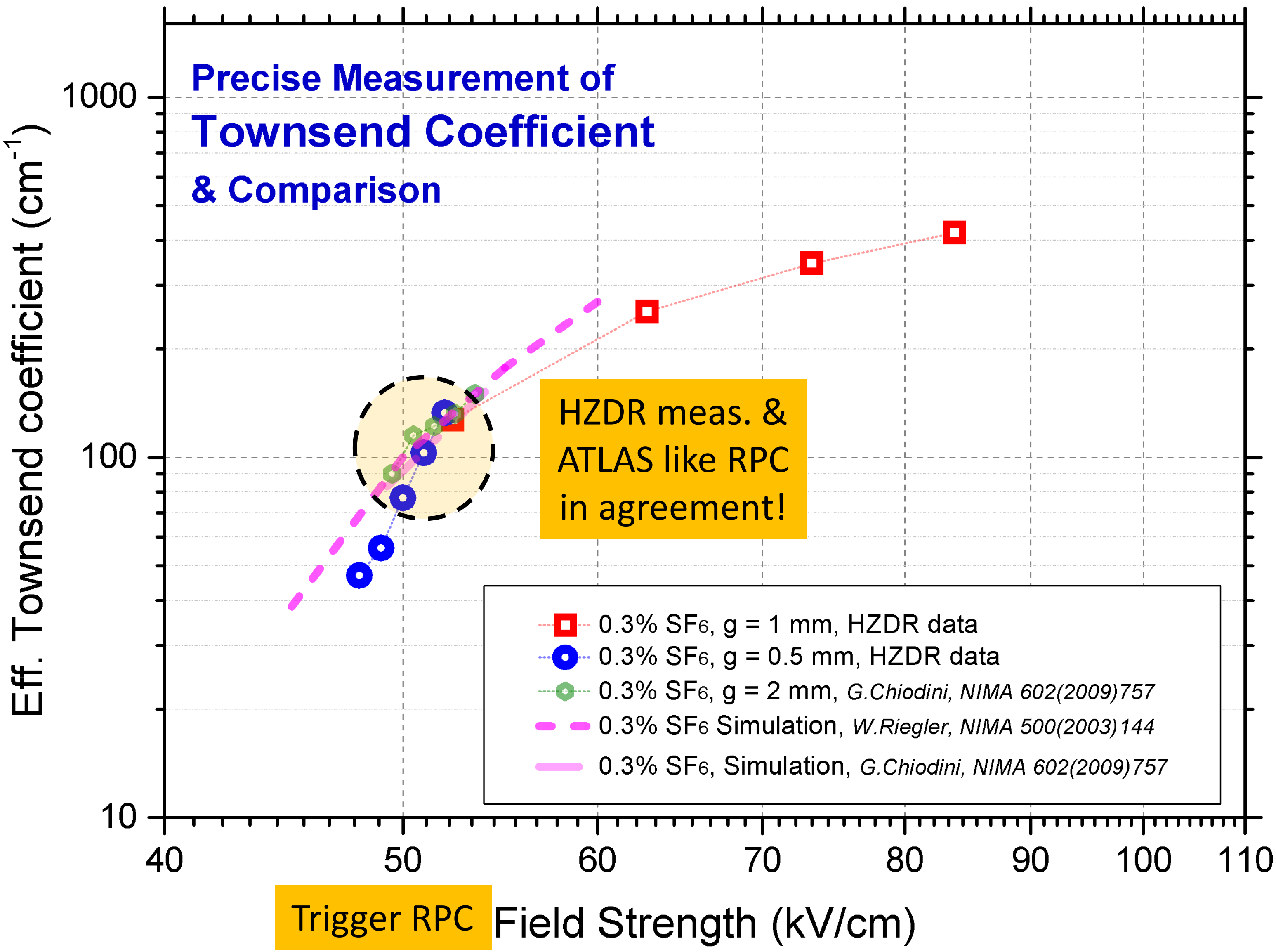
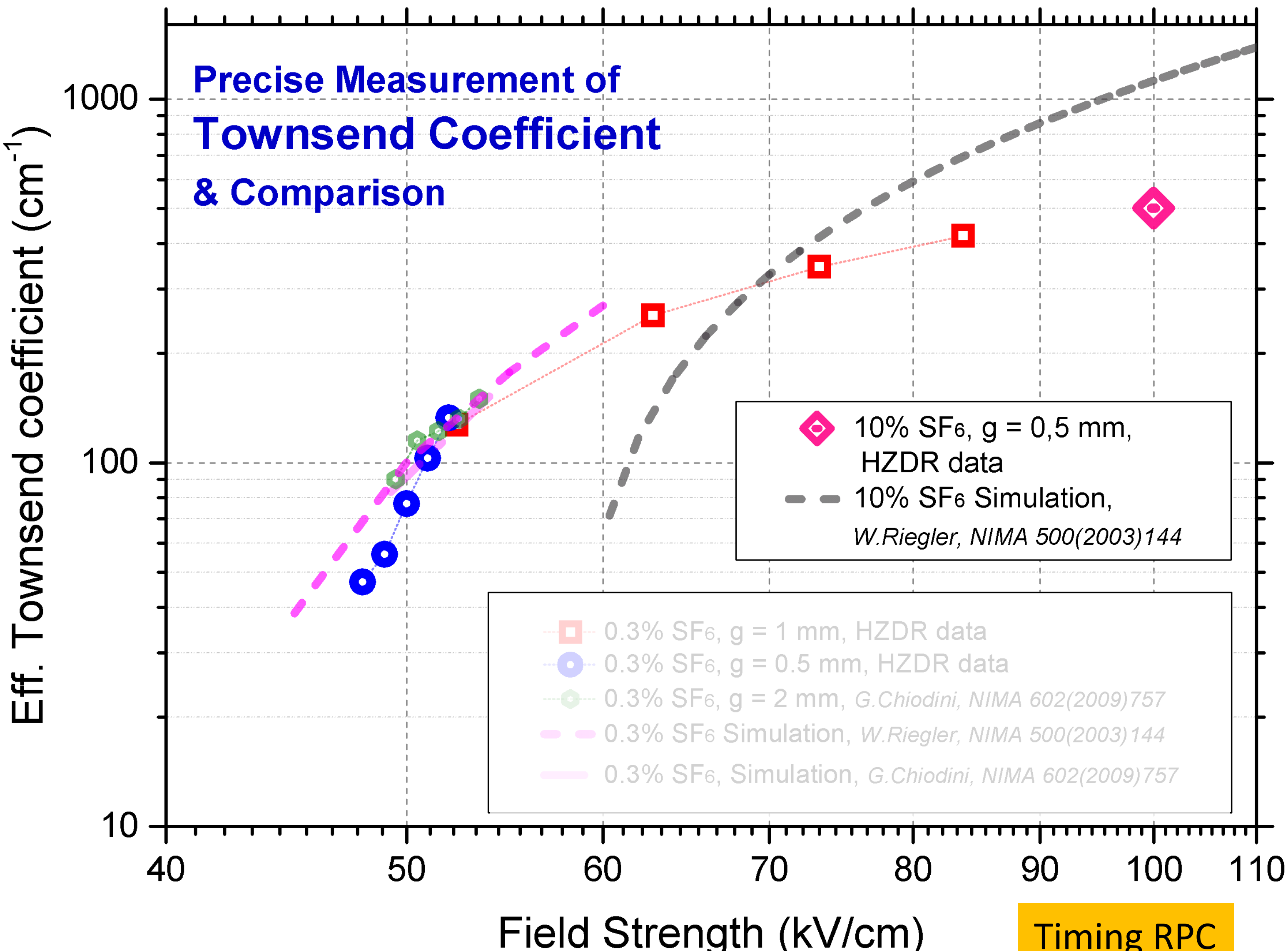
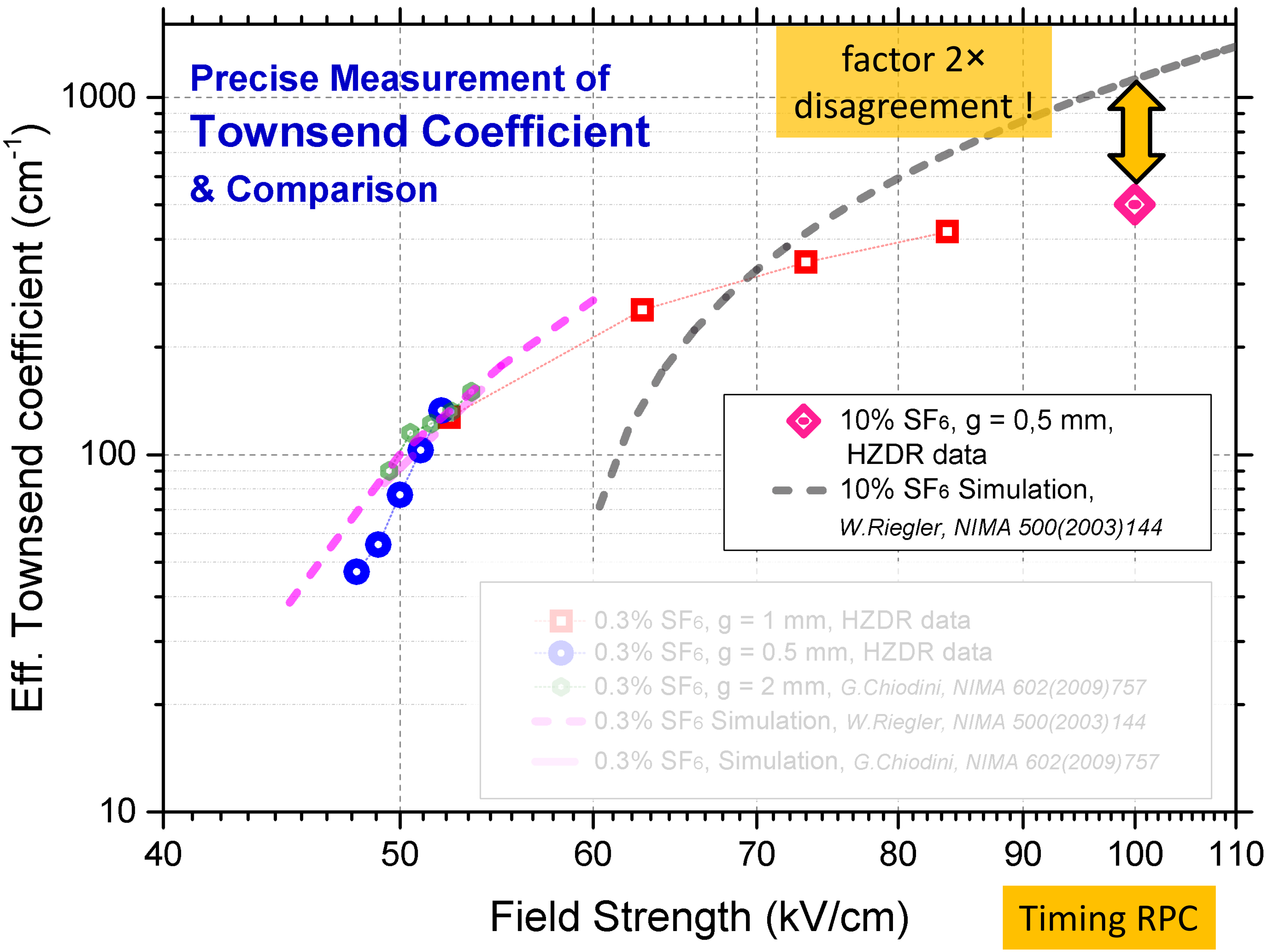


Effective Townsend coefficient (2)



Timing RPC

Effective Townsend coefficient (2)



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Summary

Overview of transport parameter measurements

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IB, methane	10 – 30	1.6	6.25	-	m	Tsumaki, Jap. J. AP V. 27 N.3 (1988)
$RPC_{mix1;2}$	760	.3, .5, 1.0	45 - 100	m	m	X. Fan, PHD thesis in prep.

IB - isobutane
RPC_{mix} - freon, IB, SF_6

m - measurement
s - simulation

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Summary

- **Upgrade of the laser driven facility** for

  detector tests under atmospheric pressure and highest homogenious electric fields of up to 100 kV/cm

- **Comparision of the eff. Townsend coefficient** for Freon(94.7%)+IB(5%)+SF_6(0.3%) at 50 kV/cm, at the highest available field up to now shows an agreement for ALICE and HZDR experiments and MAGBOLTZ simulations

- **Solution of the Townsend puzzle** for Freon(85%)+IB(5%)+SF_6(10%) at 100 kV/cm MAGBOLTZ overestimates the eff. Townsend coefficient by factor of 2

Outlook

- 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

DRESDEN concept

HZDR