RPC 2020
ROME

XV Workshop on
Resistive Plate Chambers
and Related Detectors

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Partner von DRESDEN concept

Precise investigations of gas parameters in timing RPC with laser test facility

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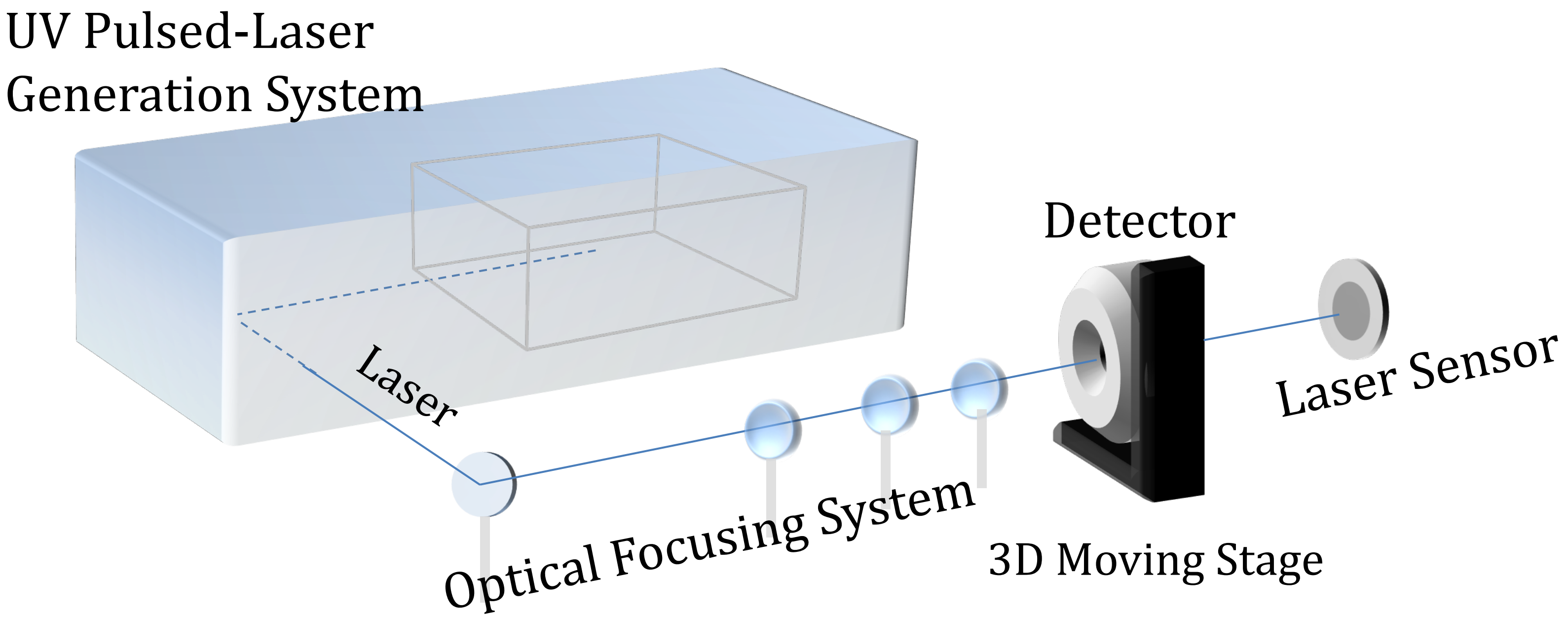
Outline

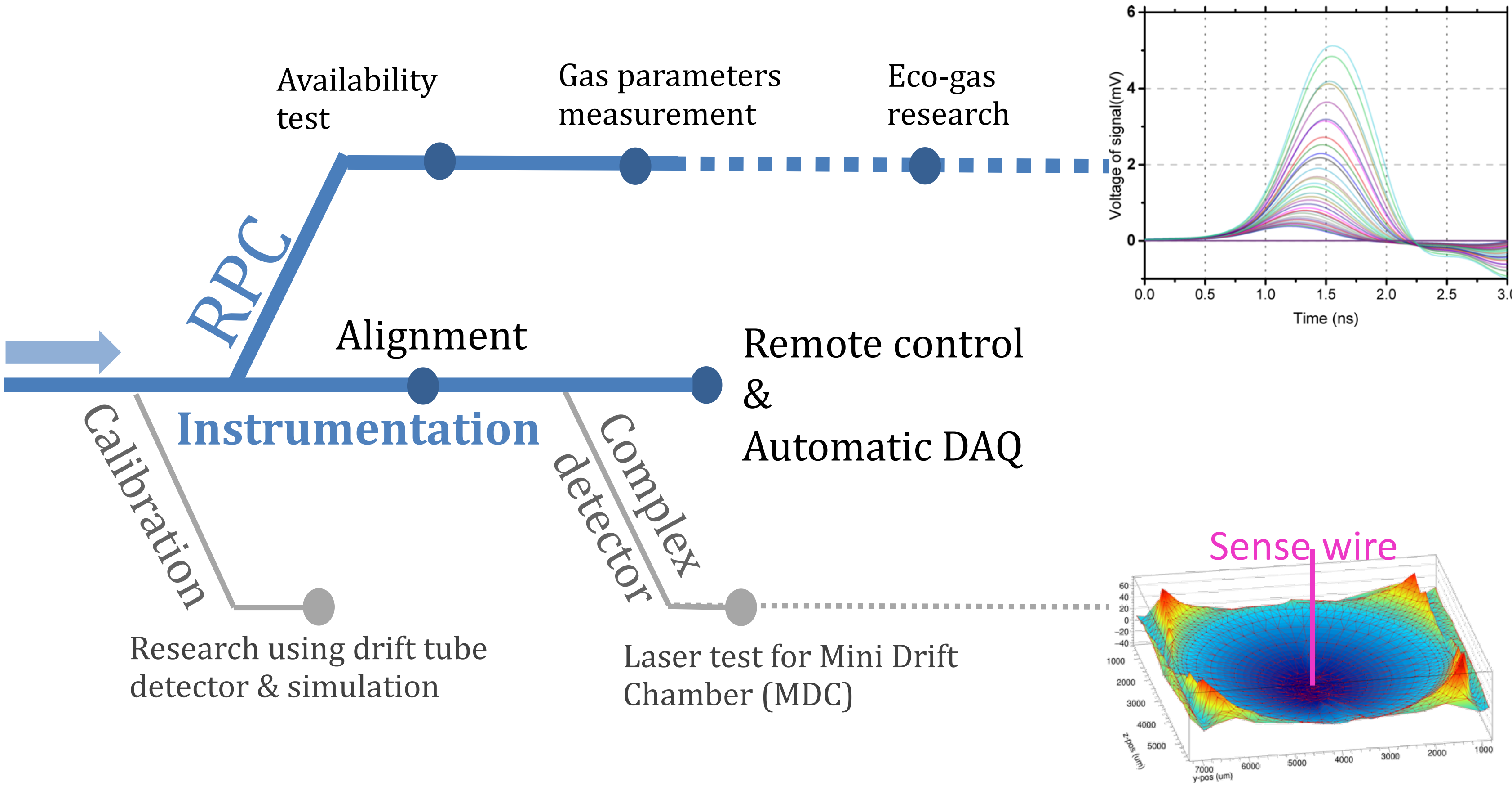
- Introduction
- HZDR laser test facility
- Experiment on RPC detectors
- Summary

HZDR Laser Test Facility

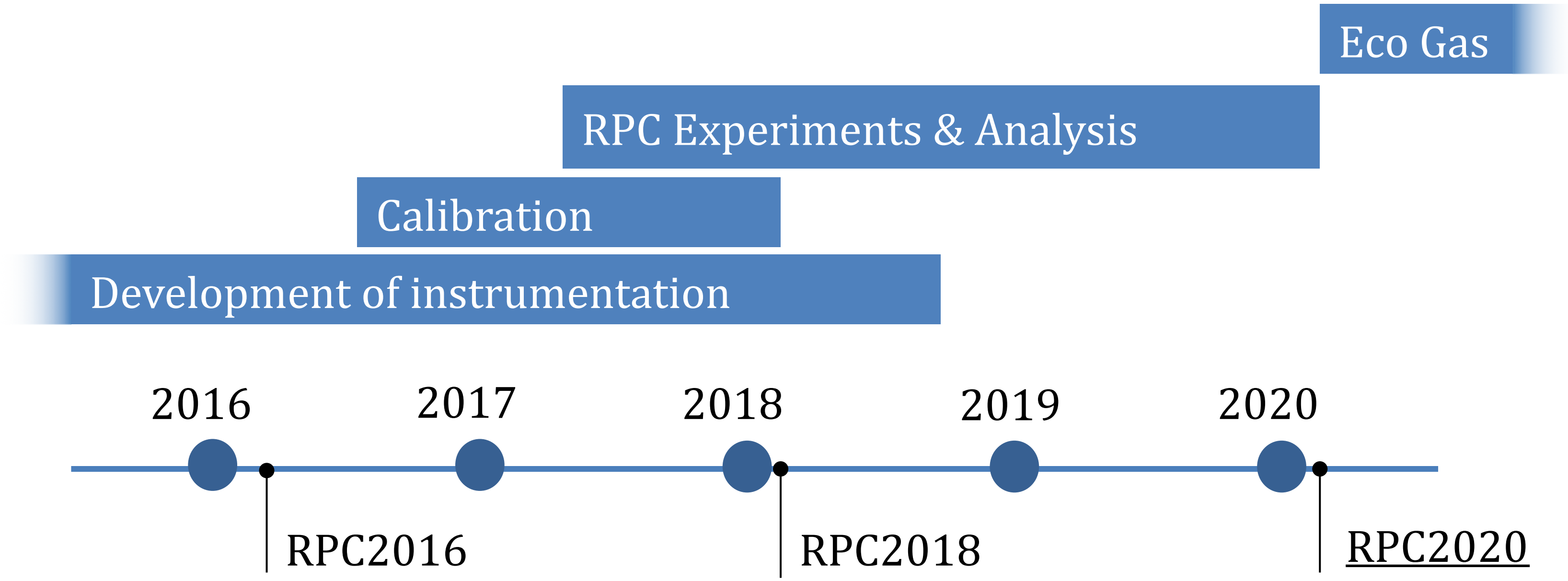


- Table-size, multi-purpose test facility;
- Focused UV laser to ignite primary electrons;
- High precision moving system, remote automatic DAQ system.

Main activities

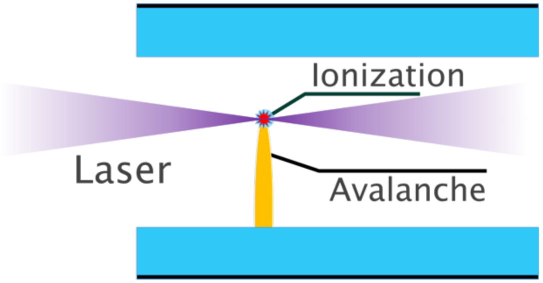


R&D milestones

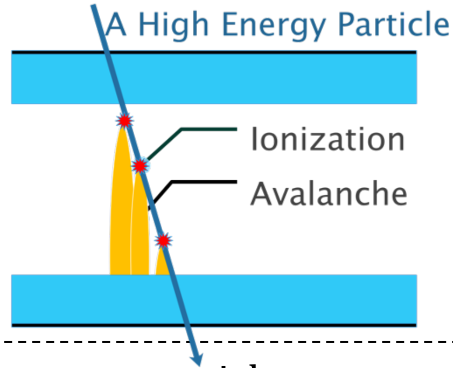


- Development since 2013;
- Reported in three RPC workshops;
- R&D procedure finished, eco-gas test on the way.

Concepts & Motivation



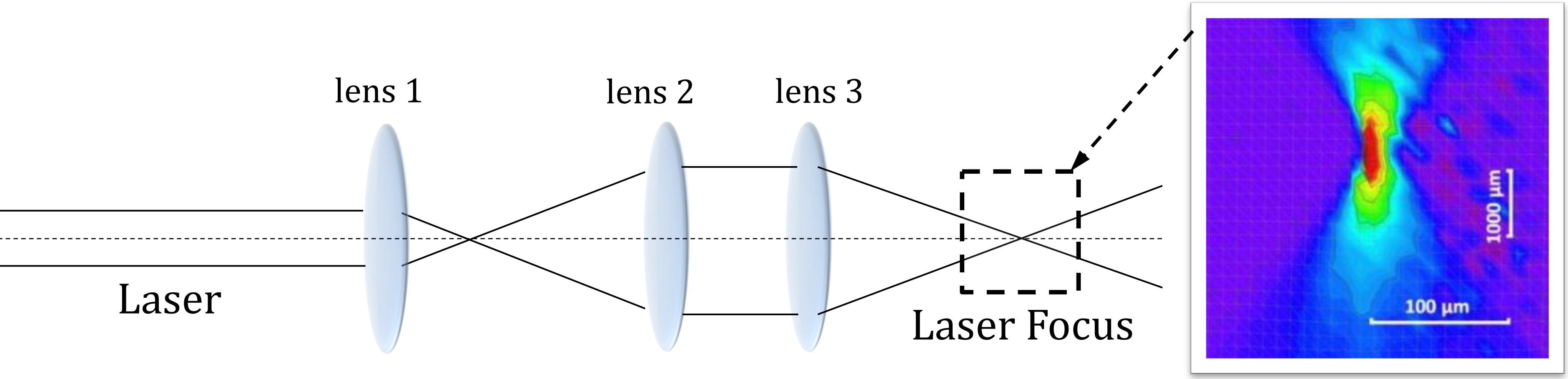
Focused UV laser:
controlled N_e , fixed position



High energy particle:
random N_e , random positions

- Concepts:
  - Laser ionizations have fixed positions;
  - MPI (Multi-Photon Ionization) effect produces very tiny ionization volume;
  - Gas parameters can be measured.
- Motivations:
  - Direct measurement of gas parameters in **timing RPC** (i.e. MRPC);
  - Investigations of RPC performance;
  - Research for **new eco-gases**.

Laser ionization



Laser intensity distribution

- **Controlled UV laser pulses:**

  257 nm wavelength, short pulse duration (2 ps), adjustable laser intensities and repetition rates.

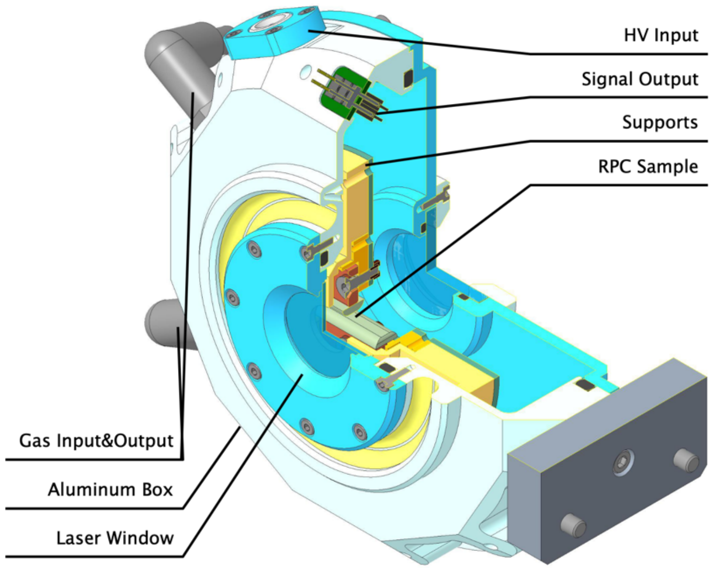
- **Tiny laser focus**:

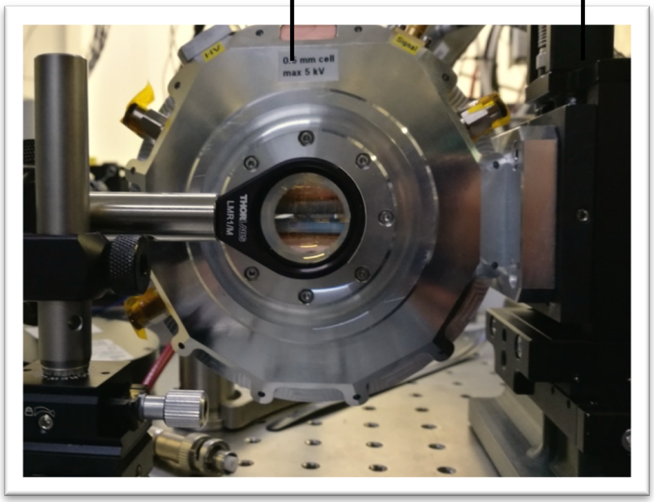
  radius: ~5 µm, length: ~500 µm (FWHM)

- **Tiny ionization volume:**

  ionization volume is within laser focus.

Realistic RPC prototype





- **RPC prototype**:

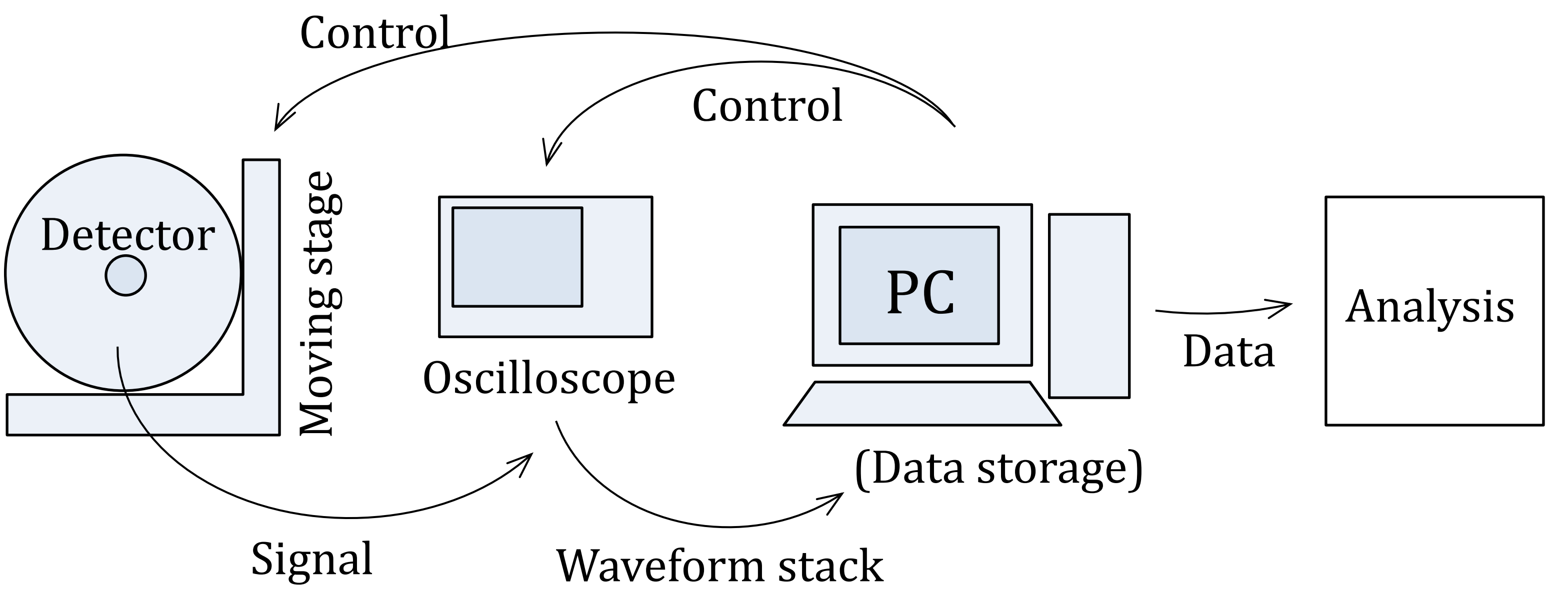
  Gas gap width: 500 µm in experiments; 300, 500 and 1000 µm possible.

  Materials of electrodes: Low resistivity ceramic or float glass.

- **Precise position stage:**

  3 dimensions, accuracy on the order of 1 µm.

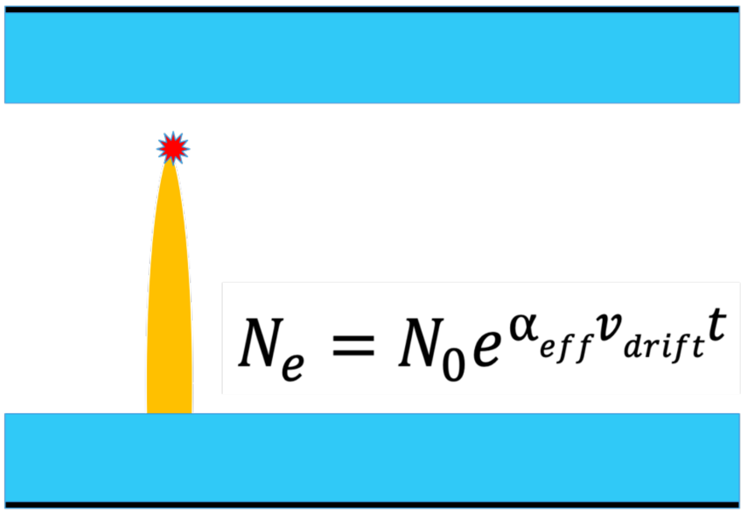
Automatic DAQ & Analysis



- Automatic programmed experiments:
  - Remote control;
  - Pre-program & Execute;
  - Off-line data analysis.

RPC gas parameters

- The gas parameters for avalanche developments:



$$N_e = N_0 e^{\alpha_{eff} v_{drift} t}$$

α_{eff}: Effective Townsend coefficient

v_{drift}: Electron drift velocity

N_e: Number of electrons

N_0: Number of primary electrons

- The ‘puzzle’ of α_{eff} at the region of strong field:
  - Simulated α_{eff} is taken from low pressure & reduced electric field[1].

    $$\alpha_{eff}/p = A\, e^{-B/(E/p)}$$
  - Simulated α_{eff} is **much larger** compared to real RPC at timing RPC electric field[2,3].

[1]G. Brunner. NIM, 154(1):159–163, 1978
[2]W. Riegler and C. Lippmann, NIMA, 518(1-2):86–90, 2004.
[3]L. Naumann, M. Siebold, M. Kaspar, et al. JINST, 9(10):C10009, 2014.

An overview of RPC experiments

RPC set-ups:	**Trigger RPC**	**Beyond trigger RPC**	**Timing RPC**
Field strengths:	~50 kV/cm	50-90 kV/cm	~100 kV/cm
Gas mixtures:	94.7% Freon 5% iso-Butane 0.3% SF6	Both gas mixtures ↔	85% Freon 5% iso-Butane 10% SF6

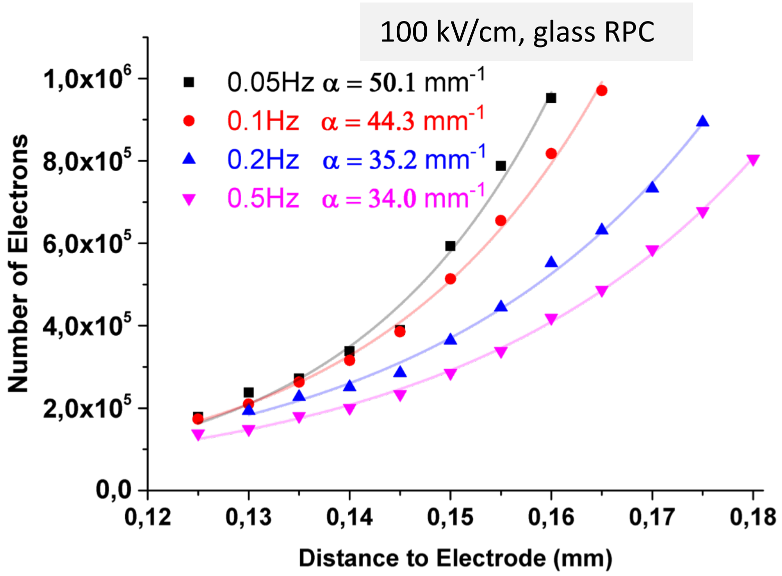
Description:

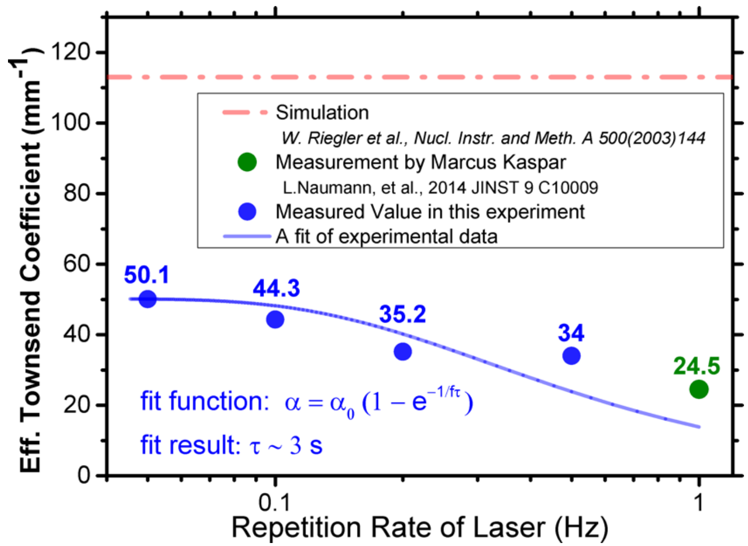
Trigger RPC
- Start with the values that are well-known and well-measured to verify the overall availability of the system.

Beyond trigger RPC
- To explore RPC performance at higher electric fields.
- R&D to prepare for experiments for timing RPC.
- Using both gases.

Timing RPC
- Work in realistic timing RPC conditions to measure the gas parameters.
- First measurement of gas parameters at atmospheric pressure at this region.

Field reduction measurements





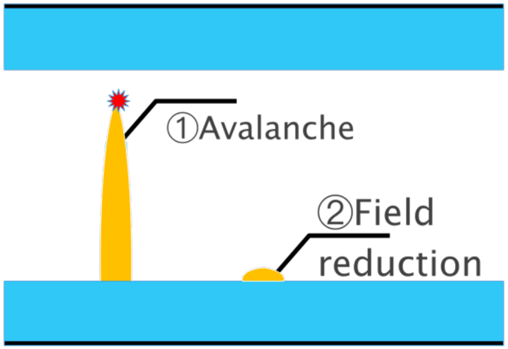
Significant field reduction due to laser repetition rate.

Assume an factor τ related to the time constant, $\tau \sim 3$s obtained.

- Dependence of laser repetition rate on the measured α_{eff} observed for glass electrodes.
- Explains the field reduction and recovery.

Field reduction due to avalanches

- The first direct observation of the tiny size of avalanches:



RPC with glass electrodes:

·Time constant : $\tau \sim \rho_0 \varepsilon_0 \varepsilon_r \sim$ some seconds

·Typical rate capability: ~1 kHz/cm^2

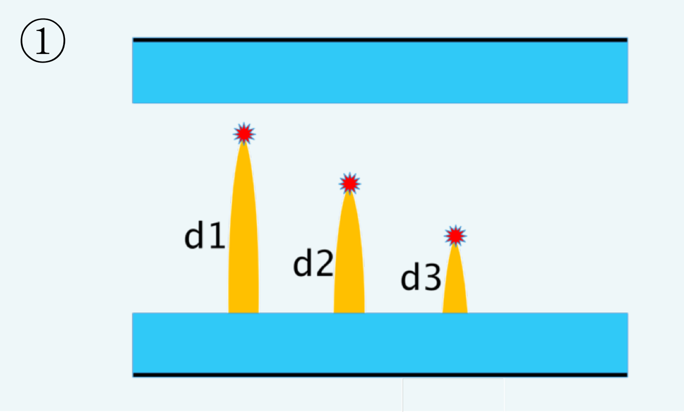
$\Longrightarrow$**Estimated area in the order of several μm^2.**

- Comparison to low resistivity electrodes:

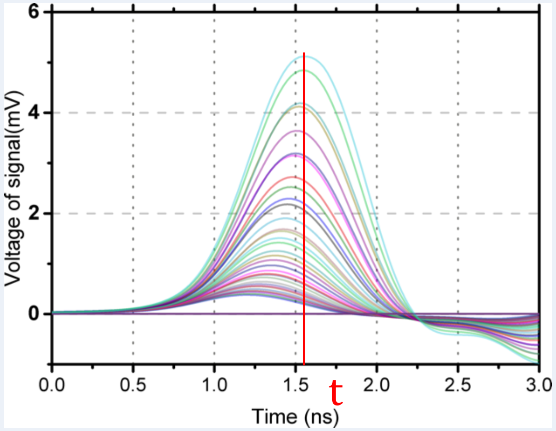
Material	Bulk resistivity	Rate capability in RPC	Time constant	Experimental rate capability
Glass	~10^{12} Ω·cm	~kHz/cm^2	~ s	3 s
Ceramic	~10^{9} Ω·cm	hundreds kHz/cm^2	~ ms	<< 0.1 s

Measurement of v_{drift}

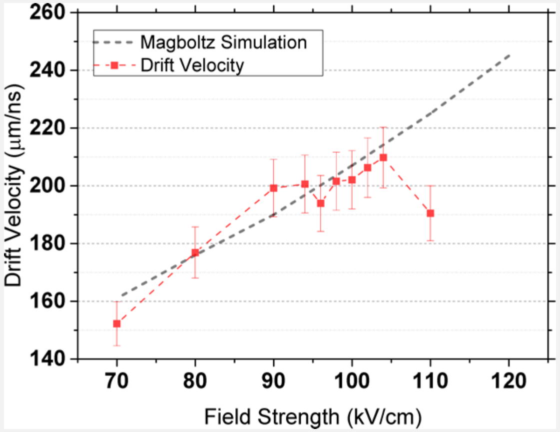
①



②



- Obtain average waveforms with different d.
- Obtain the arrival time t at max. Voltage.
- Make a $t-d$ linear fit to obtain v_{drift}.

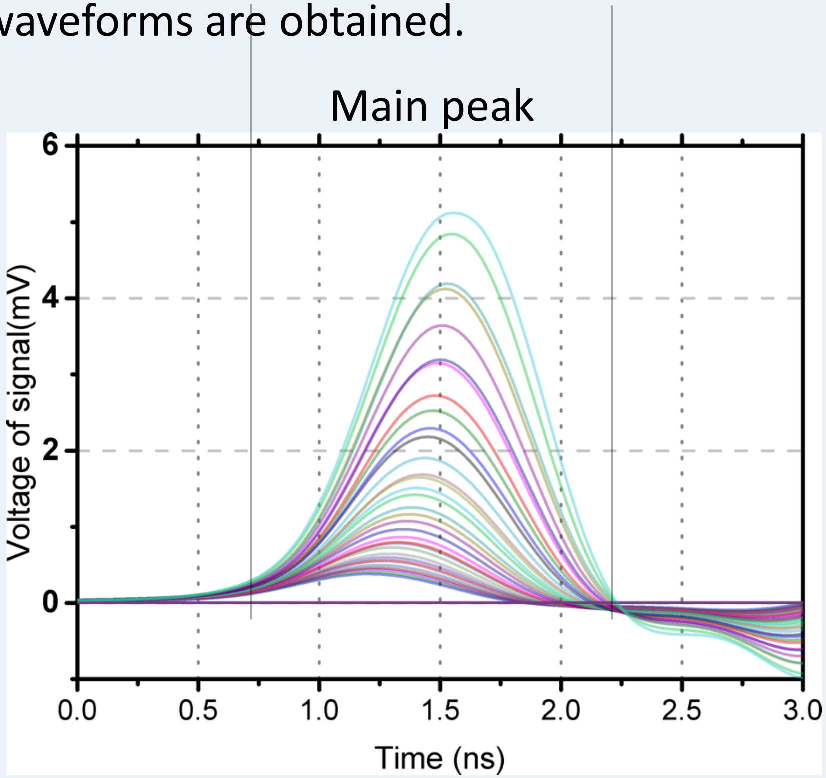


③Results compared to simulation:

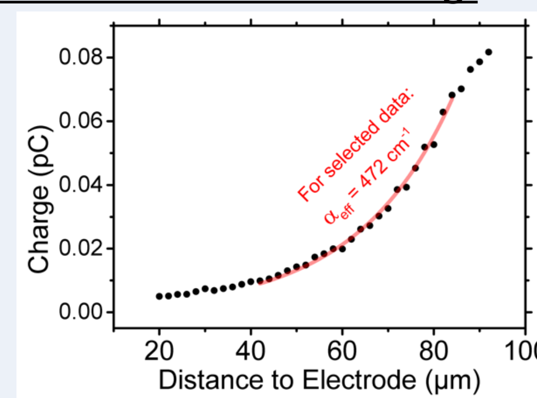
- Agreement in a wide range, up to ~105 kV/cm
- Above ~105 kV/cm measurement failed, due to streamers.

Measurement of α_{eff}

① Charges of main peak Q of the waveforms are obtained.

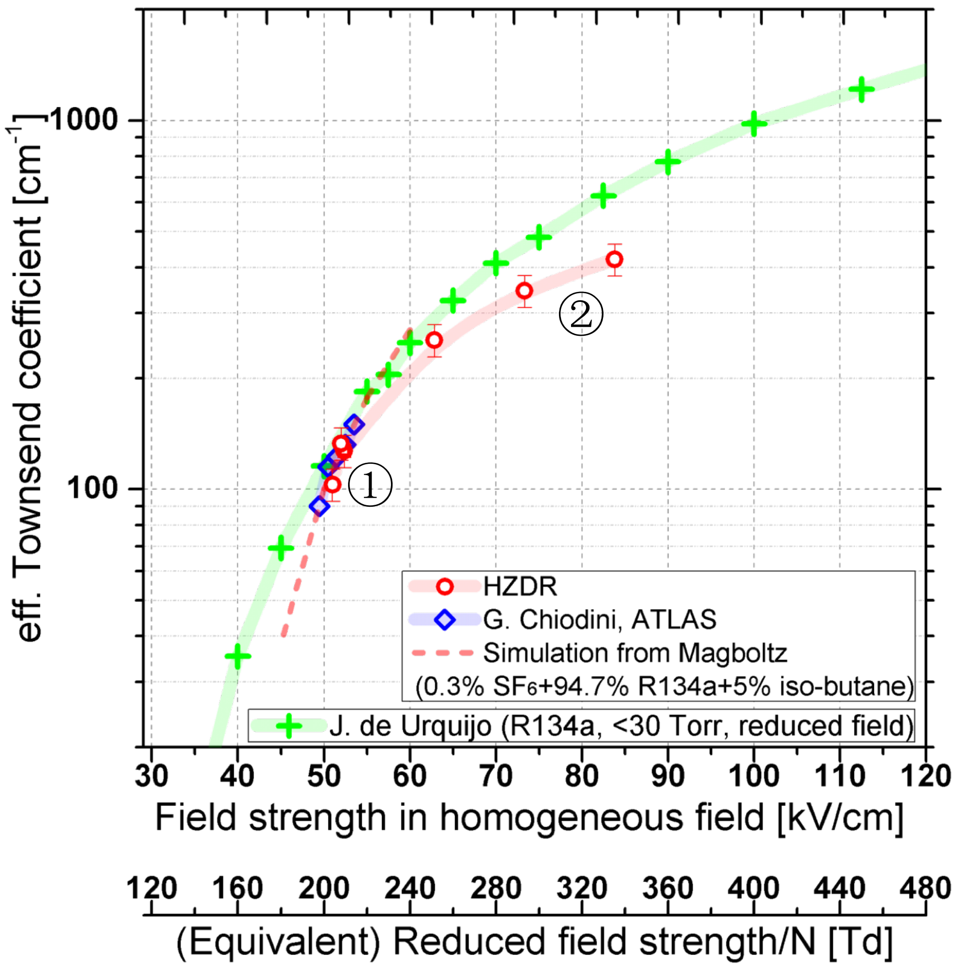


② eff. Townsend coefficient is accumulated from fitting.



- First measurement of α_{eff} above 60 kV/cm, up to timing RPC region.

Measurement of α_{eff}



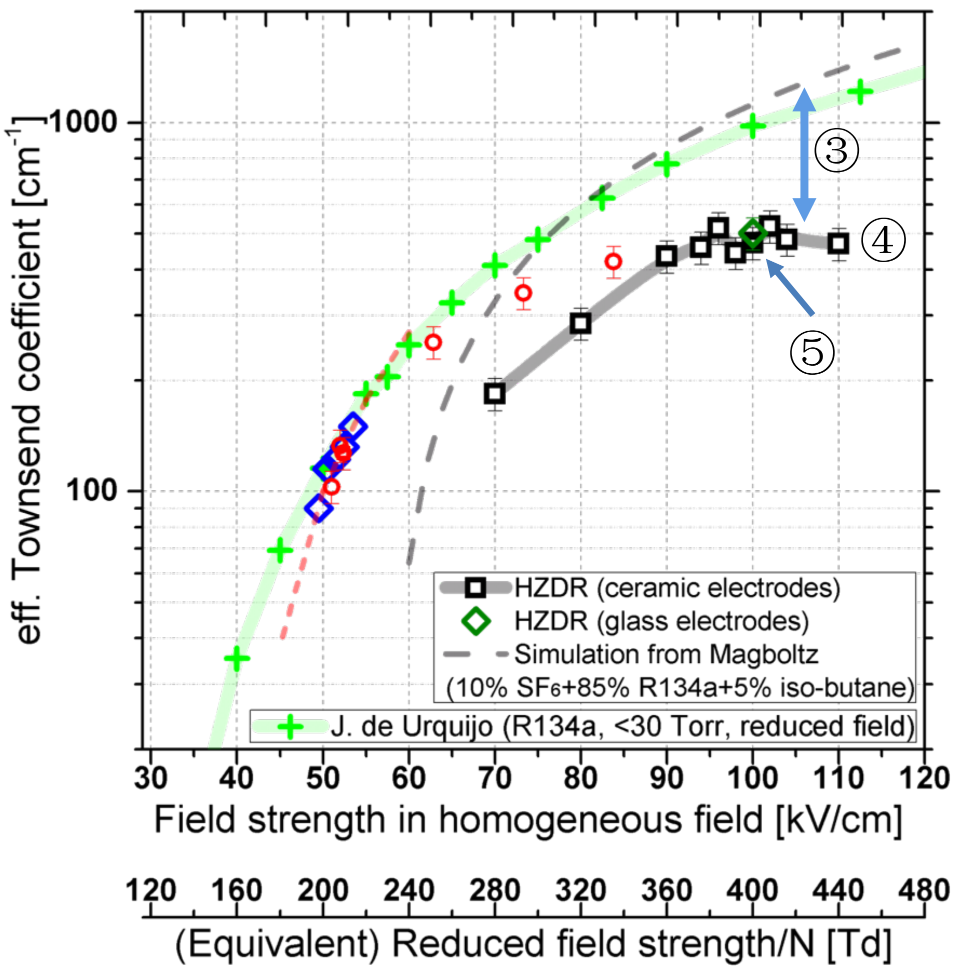
Compared to measurement results from:

- [1] W. Riegler, et al., NIMA. A 500 (2003) 144.
- [2] G. Chiodini et al., NIMA. 602 (2009) 757.
- [3] J. de Urquijo et al., Eur. Phys. J. D 51 (2009) 241.

① α_{eff} in agreement with both experiment and simulation, at the field strength of around 50 kV/cm.

② α_{eff} begins to separate with simulation, when the field is increased above 60 kV/cm.

Measurement of α_{eff}



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③ α_{eff} measured for timing RPC field (around 100 kV/cm) is ~2 times less than prediction from reduced pressure.

④ α_{eff} seem to reach a plateau for timing RPC field (around 100 kV/cm).

⑤ α_{eff} is not affected by electrode material.

Conclusions & Outlook

- Laser Test Facility
  - Characteristics
  - Methods

- Direct measurements of RPC gas parameters:
  - Field reduction range. (Proved the RPC principle.)
  - Electron drift velocity. (Agreement with simulation.)
  - Eff. Townsend coefficient. (Agreement & differences with simulation.)

- Outlook:
  - Investigations for gaseous detectors with complicated geometry;
  - Investigations for new gases: **HFO mixture.**

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Thank you!

End of Presentation