Mini-Workshop on gas transport parameters for present and future generation of experiments

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Measurement of effective Townsend coefficient and drift velocity in RPC gas mixtures with UV Laser

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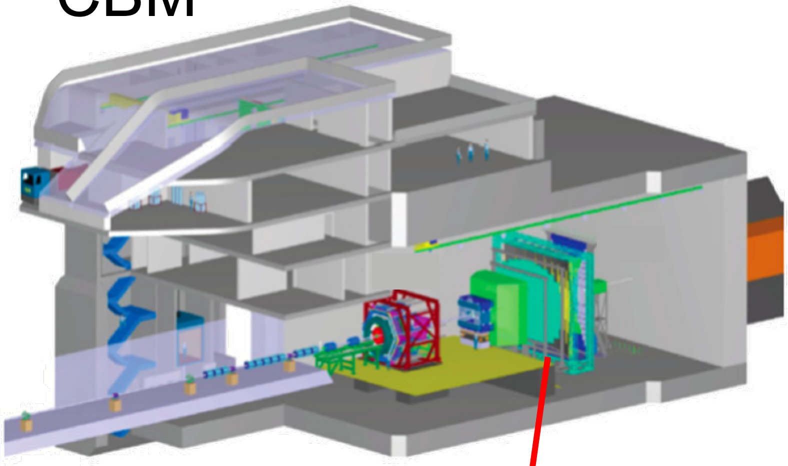
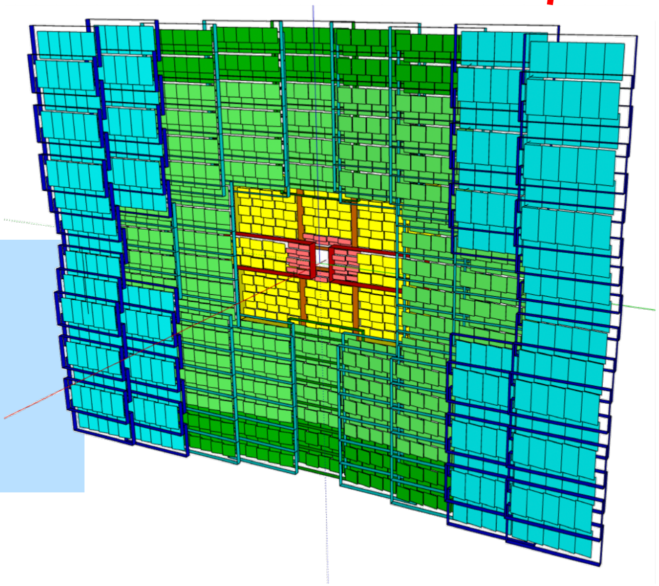
Background: RPC detectors in CBM

Facility of Antiproton and Ion Research (FAIR)

CBM

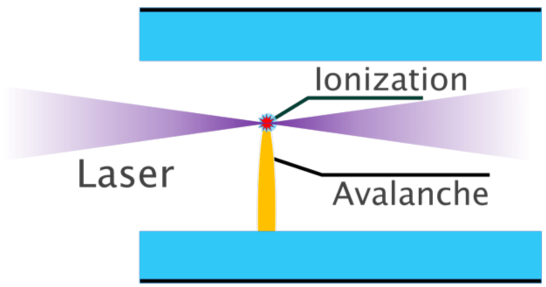




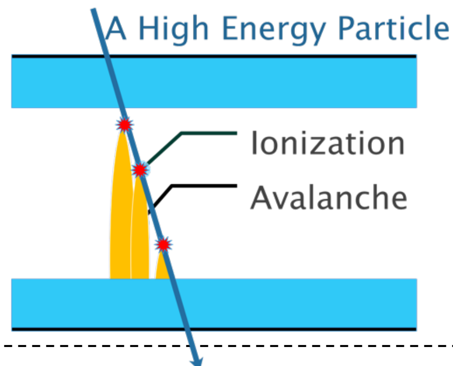
CBM Time-of-Flight (TOF) :

80 ps σ-time resolution for large area and high rate

Concepts & Motivation



Focused UV laser:
controlled N_e , fixed position

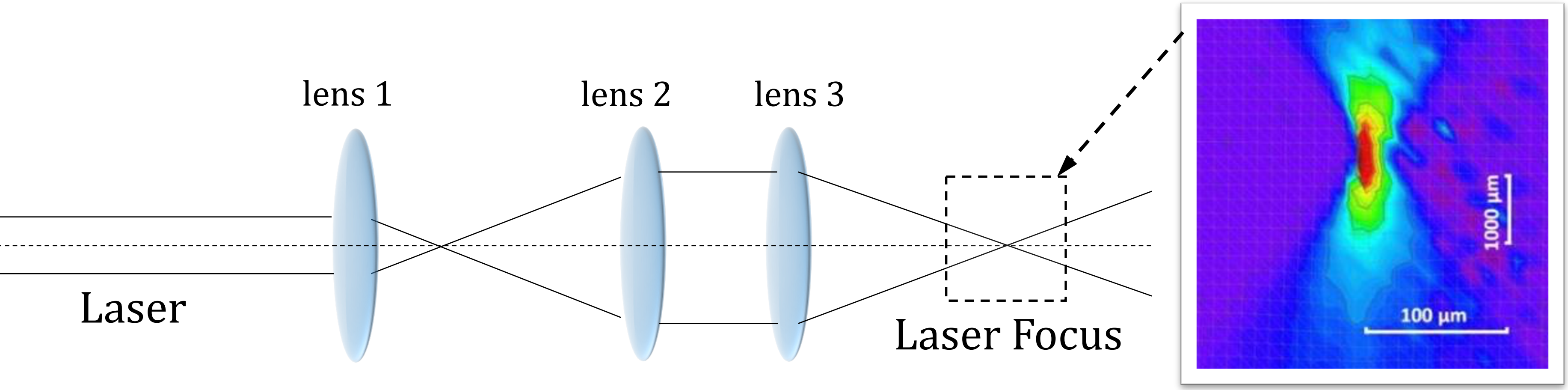


High energy particle:
random N_e , random positions

- 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);**
  - **Research for new eco-gases.**

※ Atmospheric Pressure

Laser ionization



Laser intensity distribution

- **Controlled UV laser pulses:**

  Master Oscillator Power Amplifier (MOPA)*; 257 nm wavelength UV laser; short pulse duration (2 ps); adjustable laser intensities and repetition rates.

- **Tiny laser focus**:

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

- **Tiny ionization volume:**

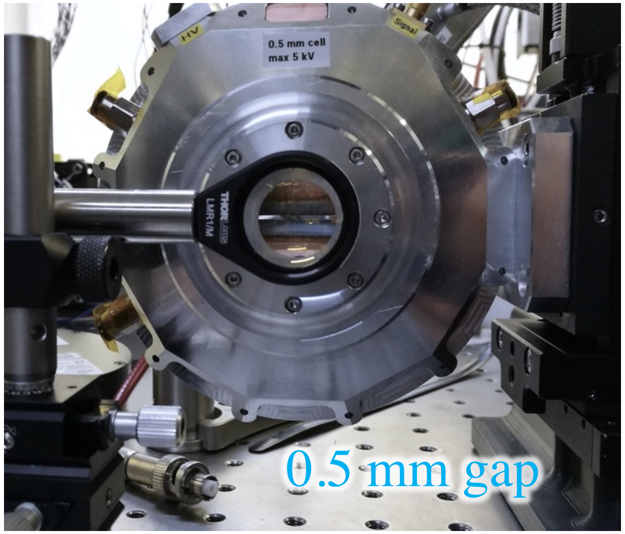
  ionization volume is within laser focus.

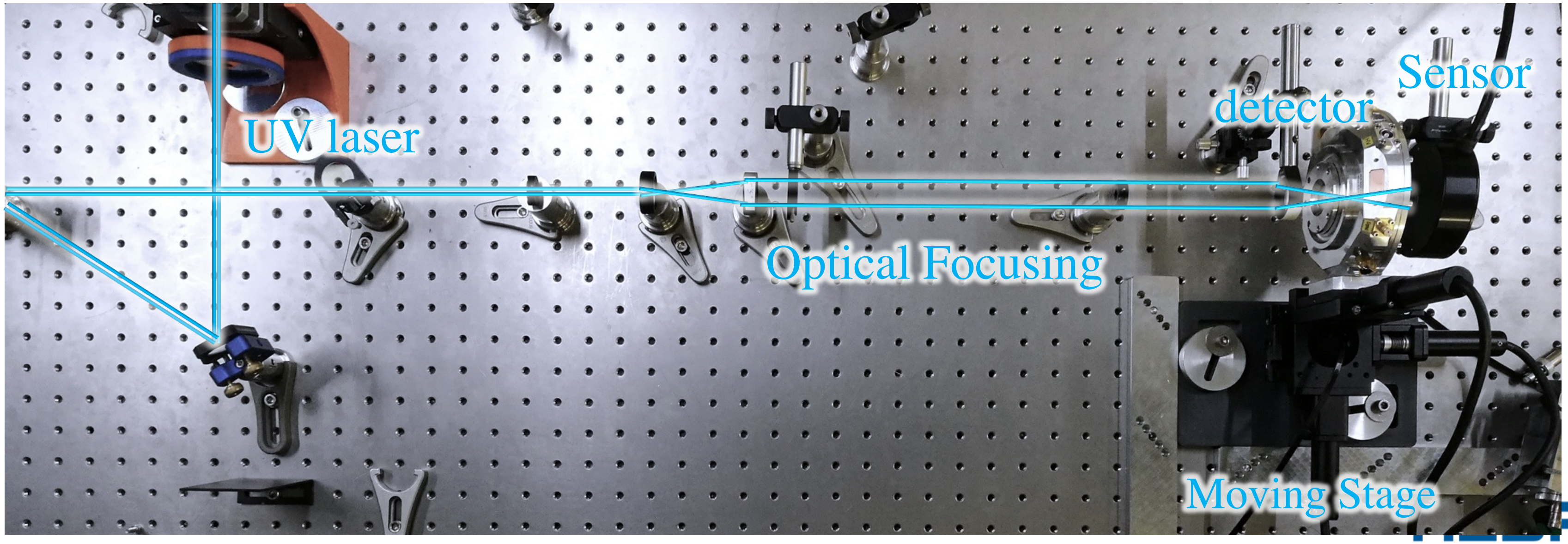
*M. Loeser, M. Siebold, et al., Advanced Solid-State Photonics, AM4A-16

The eff. Townsend coefficient measured from RPC

RPC prototype:

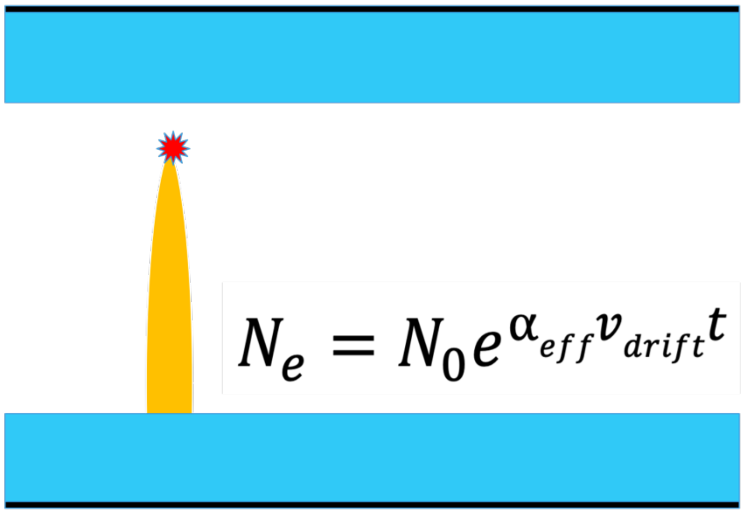
- Low resistivity electrodes with $\rho \sim 10^9\ \Omega \cdot cm$;
- 0.5 mm gas gap;
- position accuracy ~ 1 μm.





The eff. Townsend coefficient

- The gas parameters for avalanche developments:



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

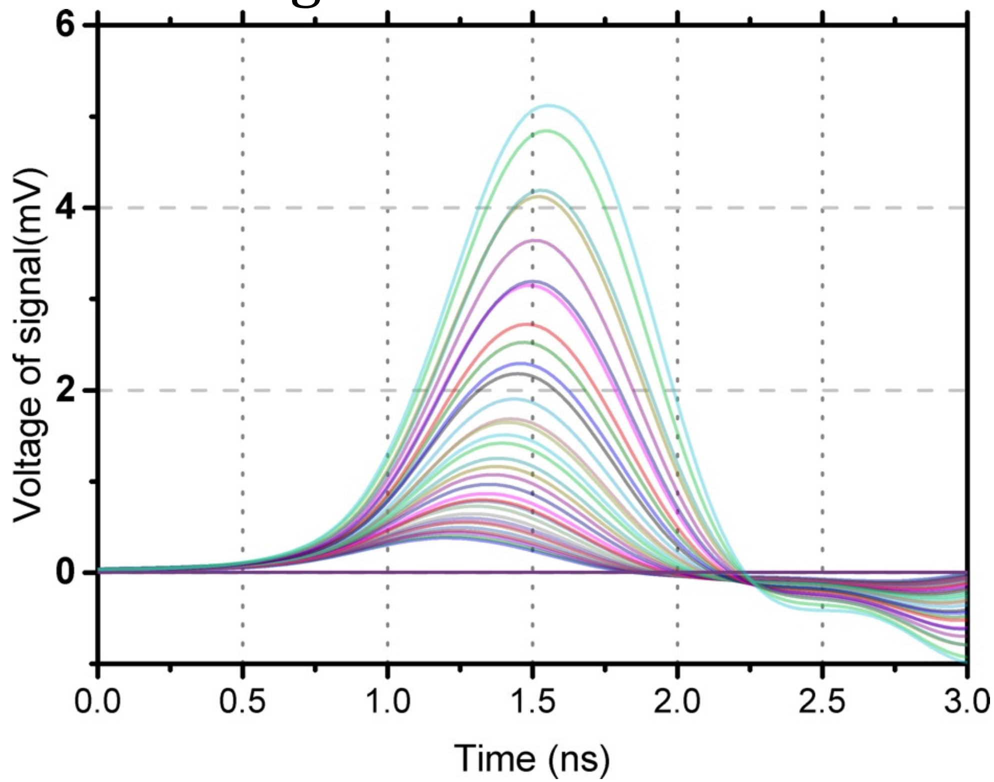
α_{eff}: Effective Townsend coefficient

v_{drift}: Electron drift velocity

N_e: Number of electrons

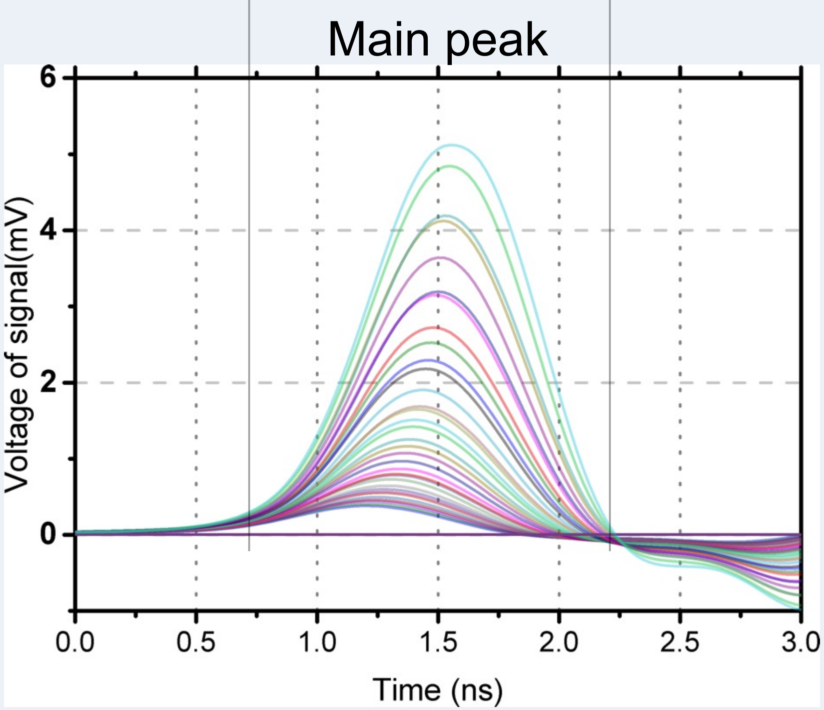
N_0: Number of primary electrons

- Obtain the gas parameters, acquire waveforms at different drift lengths:

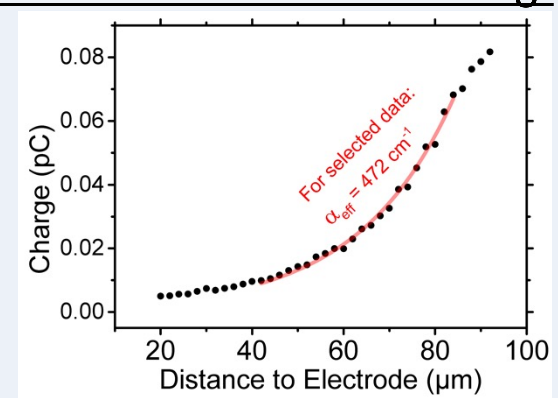


Measurement of αeff

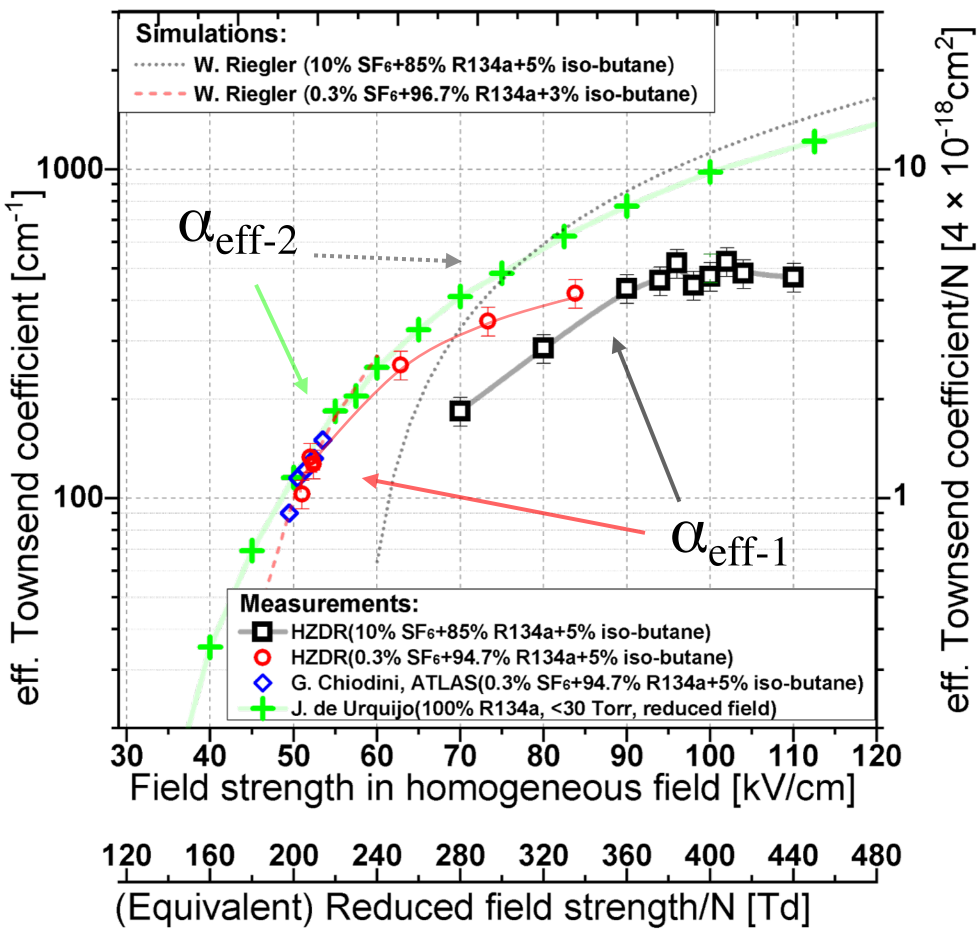
① Charges of main peak Q of the waveforms are obtained.



② eff. Townsend coefficient is accumulated from fitting.



The eff. Townsend coefficient of R134a mixtures



*X.Fan et al., NIMA (reviewing)

The value measured at atmospheric pressure ($\alpha_{eff\text{-}1}$) is compared to the value measured at equivalent reduced pressure($\alpha_{eff\text{-}2}$):

① At ~50 kV/cm, $\alpha_{eff\text{-}1}$ is in agreement with $\alpha_{eff\text{-}2}$.

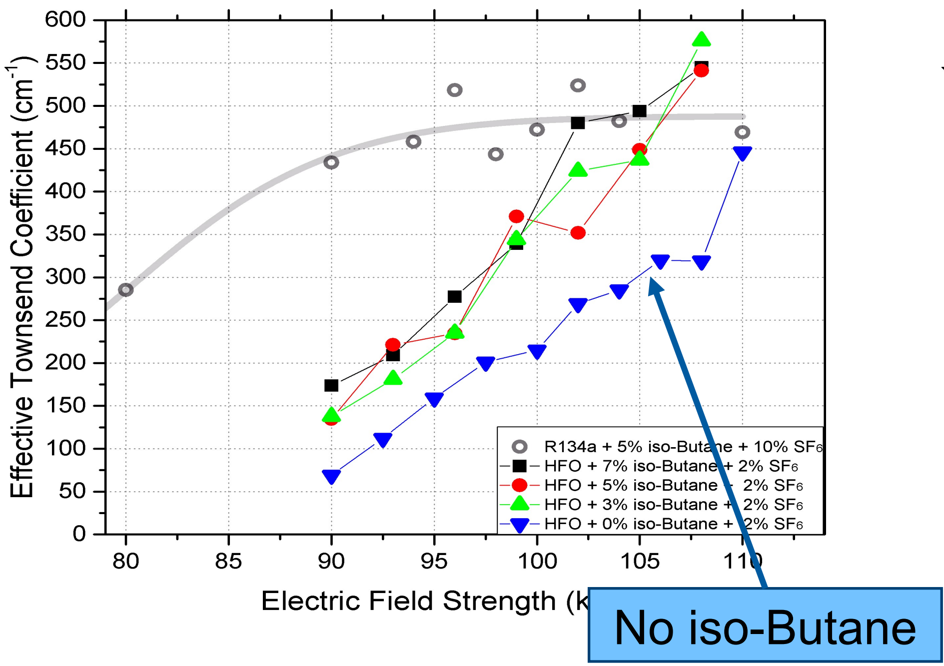
② Between 50 to 90 kV/cm, the values begin to separate.

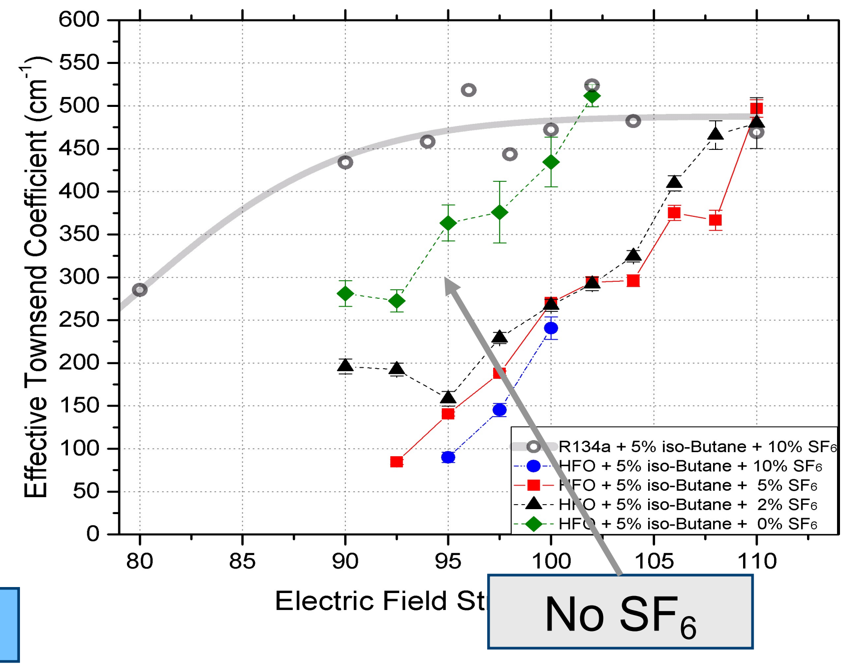
③ Beyond 90 kV/cm, $\alpha_{eff\text{-}1}$ is around half of $\alpha_{eff\text{-}2}$.

④ $\alpha_{eff\text{-}1}$ seems to saturate beyond 90 kV/cm.

The eff. Townsend coefficient of HFO mixtures

Compared to the value of R134a gases:





- Sensitive to the presence of SF_6 and iso-Butane, but not sensitive to their percentage.
- The gas parameter could be similar to Freon-gas, but without a plateau.

The effective Townsend coefficient

The dependence of pressure *p* on α_{eff} (or α_{eff}/p)?

$$\alpha_{\text{eff}}/p = A\, e^{-B/(E/p)}$$

Several similar observations in different works:

[1]- in a **pulsed-Townsend device**, *p* from 3 kPa to 45 kPa:

The effective ionization rate coefficient keff in pure HFO1234ze clearly decreases with increasing gas pressure…. typically due to the occurrence of three-body electron attachment

[2]- in **low-pressure proportional counters**, *p* from 2 kPa to 50 kPa:

α/p is not a univocal function of S_a(reduced electric field strength on anode surface). It depends on filling gas pressure in the range of measured pressures.

[3]- in **RPC prototype**, atmospheric pressure when *p* = 101 kPa:

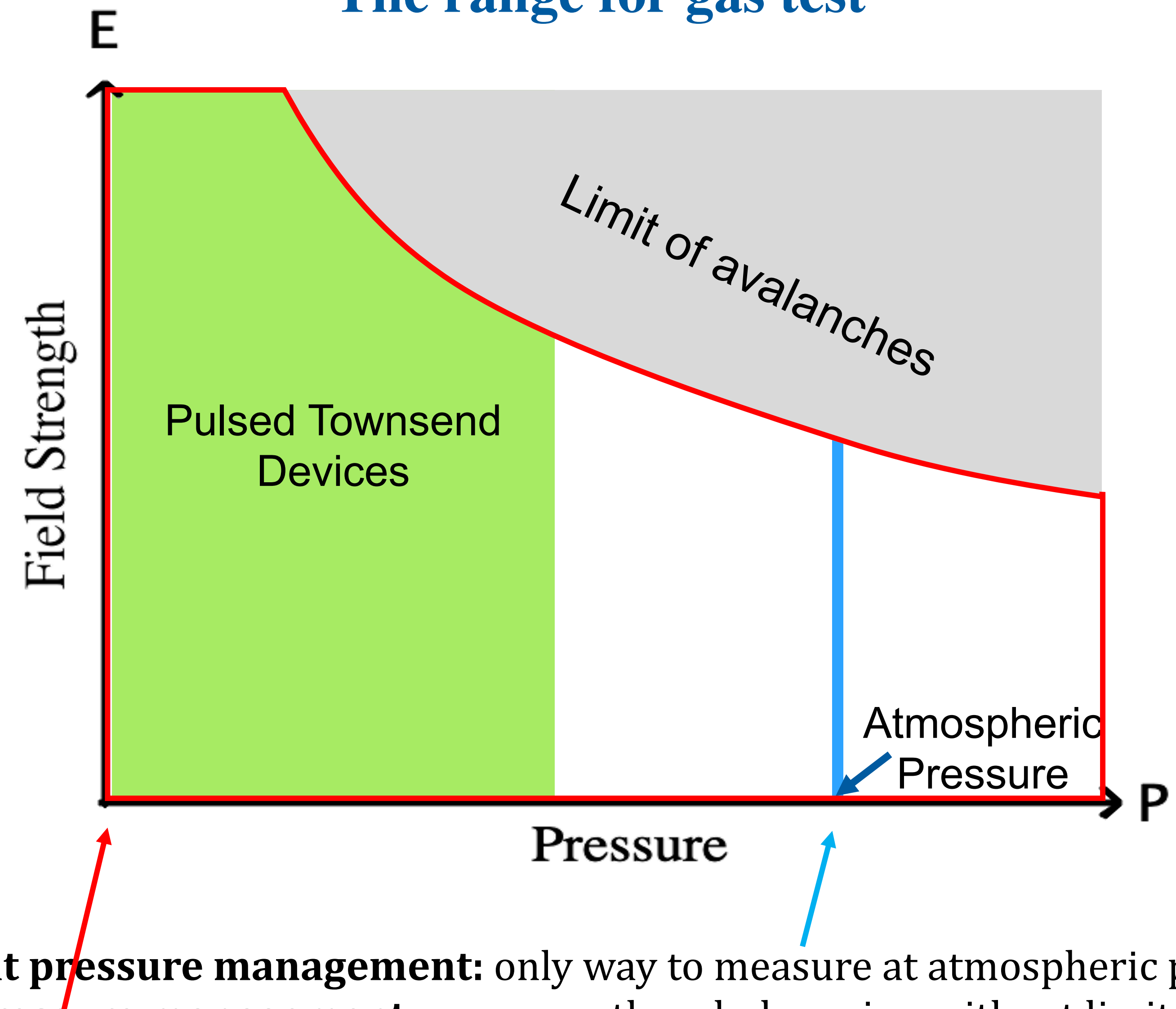
For Freon(R134a)-based gases, α_{eff} is about half of the value obtained from reduced pressure and field.

[1] A. Chachereau et al., Electron swarm parameters of the hydrofluoroolefine HFO1234ze, PLASMA SOURCES SCI T, 25(4):045005, 2016

[2]Kowalski, T. Z. Gas gain limitation in low pressure proportional counters filled with TEG mixtures. JINST 9.12 (2014): C12007.

[3]X. Fan et al., Precise measurement of gas parameters in a realistic RPC configuration: the currently used Freon gas and a potential alternative eco-gas, NIMA (Reviewing)

The range for gas test



- **Without pressure management:** only way to measure at atmospheric pressure.
- **With pressure management:** can cover the whole region without limitation, can investigate the pressure dependence.

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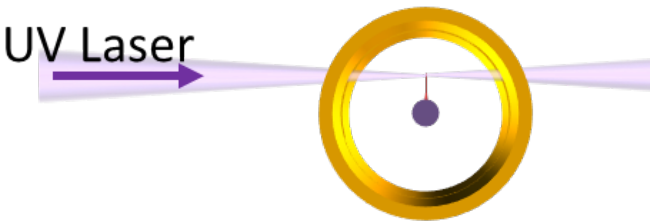
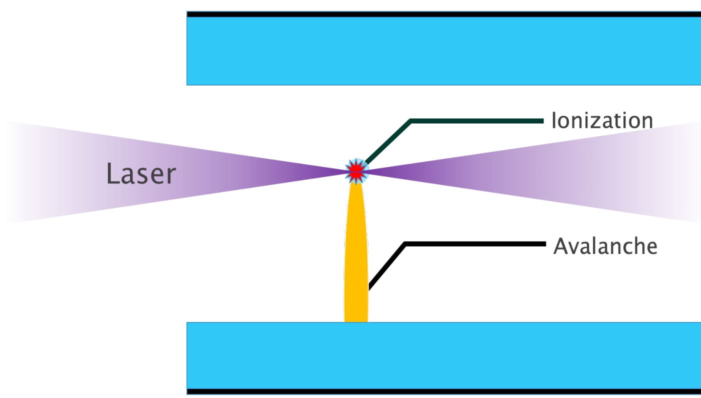
Technique of the laser test method

- Laser:
  - Use MOPA laser to generate picosecond laser pulse.
  - Multi-Photon effect (MPI) to make the focus really small.



↑ Drift tube

- Test:
  - An automatic positioning system and DAQ is necessary.
  - Multiple ways for alignment. Three levels of accuracy: ①able to test drift tube. ②RPC~50kV/cm. ③RPC~100kV.)
  - Need low resistivity material for electrodes.

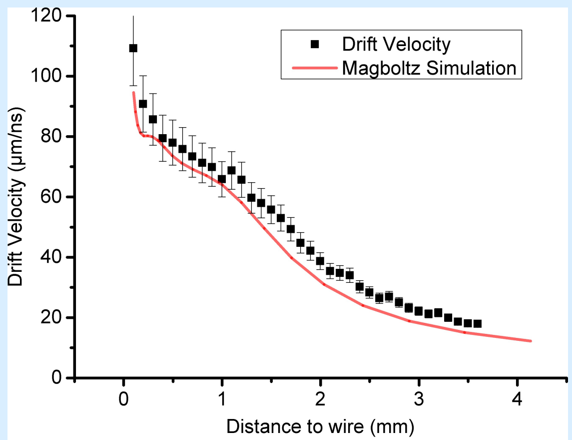


↑ RPC

- Additions:
  - Can work with a detector with volume control.
  - Can be used in any kind of gaseous detector.
  - Can make ageing test.

Directions

①Measure gas parameters with drift tube

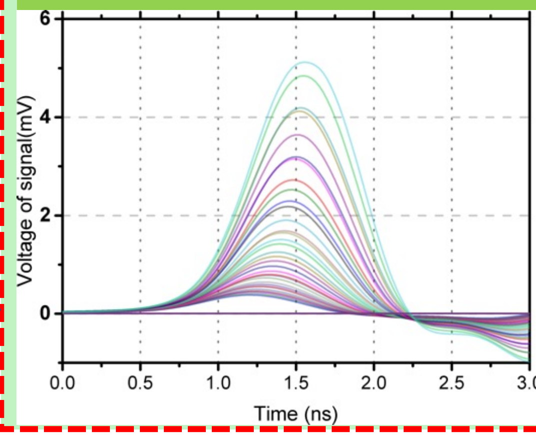


The drift velocity measured on different positions

- As the calibration process for the whole system
- Can measure the drift velocity at the field strength around **1 to 30 kV/cm**.

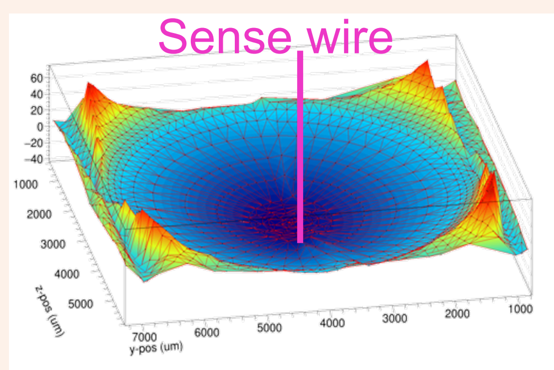
X.Fan et al., NIMA 988 (2021): 164929.

②Measure gas parameters with RPC



- Measure the effective Townsend coefficient and drift velocity from around **50 to 110 kV/cm**.
- Measure the gas parameters of Freon-gases and eco gas (HFO)

③3-D drift distribution with complex detector

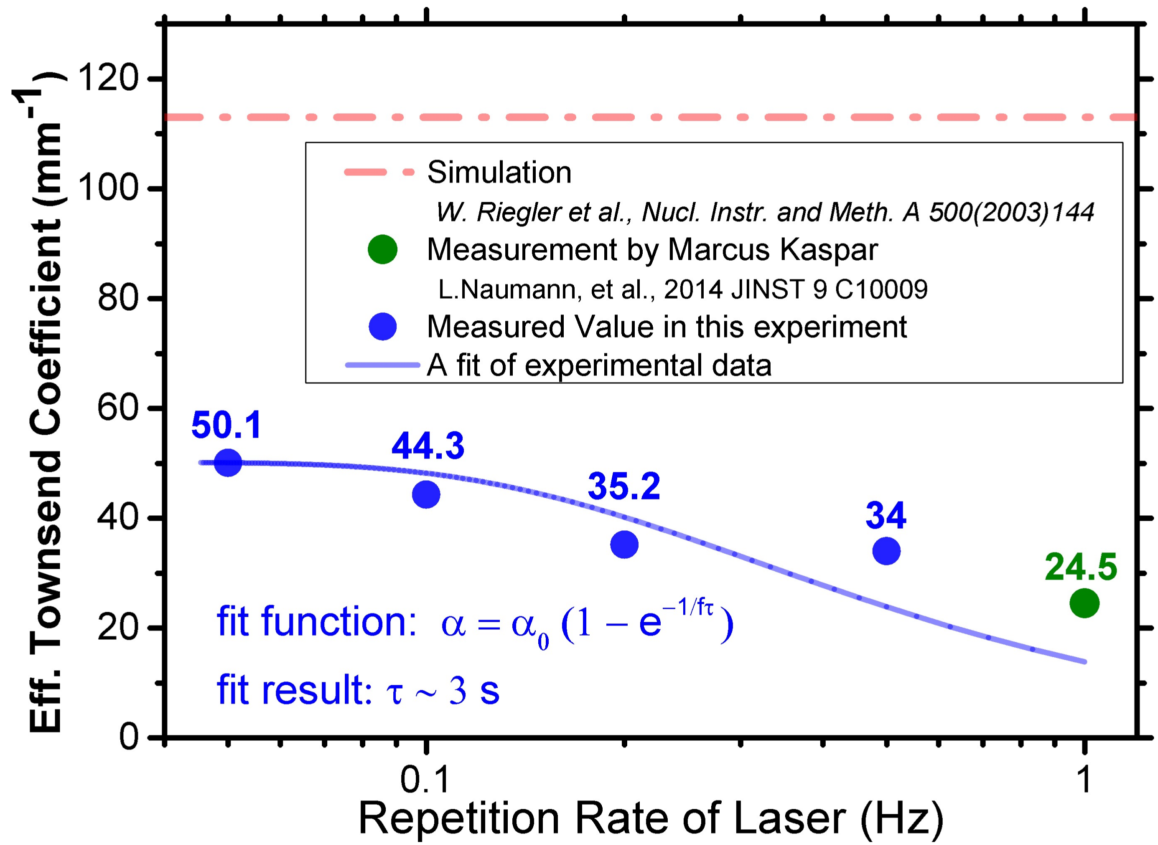


- Measure the drift distribution for mini drift chambers in 3 dimensions

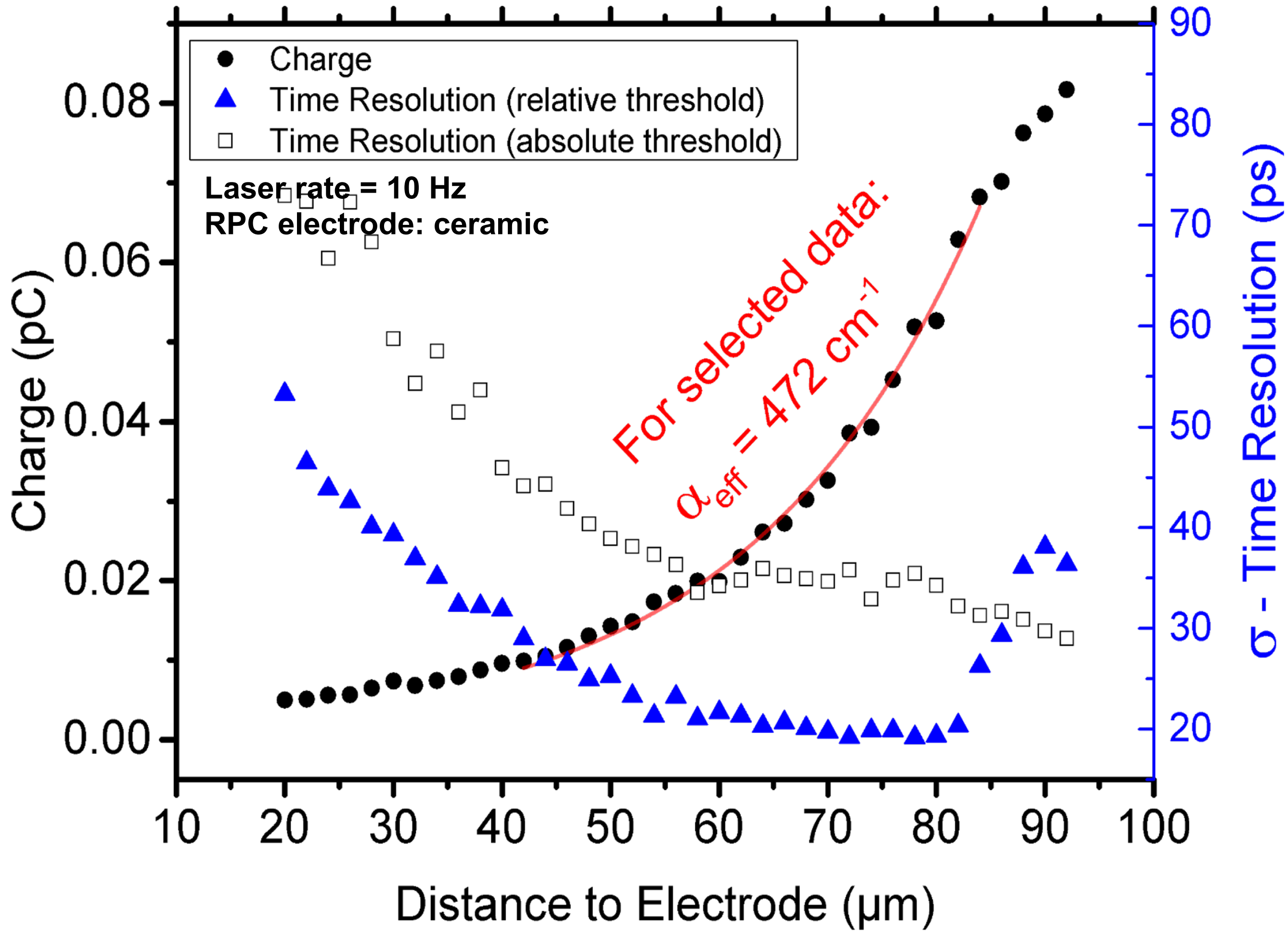
Colloboration with HADES

④ ⑤ ..More in the future?

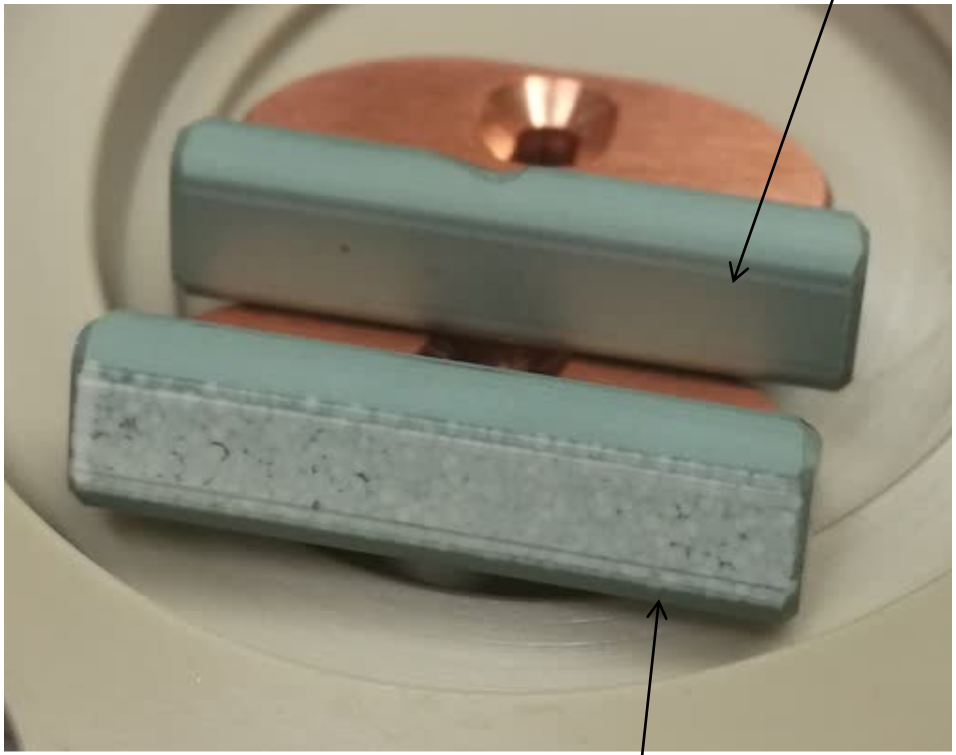
Thank you for attention!



Eff. Townsend Coefficient (mm-1)
120
100
80
60
40
20
0
0.1
1
Repetition Rate of Laser (Hz)
Simulation
W. Riegler et al., Nucl. Instr. and Meth. A 500(2003)144
Measurement by Marcus Kaspar
L.Naumann, et al., 2014 JINST 9 C10009
Measured Value in this experiment
A fit of experimental data
50.1
44.3
35.2
34
24.5
fit function: α = α0 (1 – e−1/fτ)
fit result: τ ~ 3 s



Charge
Time Resolution (relative threshold)
Time Resolution (absolute threshold)
Laser rate = 10 Hz
RPC electrode: ceramic
For selected data:
α_{eff} = 472 cm^{-1}
Charge (pC)
0.00
0.02
0.04
0.06
0.08
σ - Time Resolution (ps)
20
30
40
50
60
70
80
90
Distance to Electrode (μm)
10
20
30
40
50
60
70
80
90
100


1.80% F
7.05% F