Study of the Ecological Gas for MRPCs

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Overview

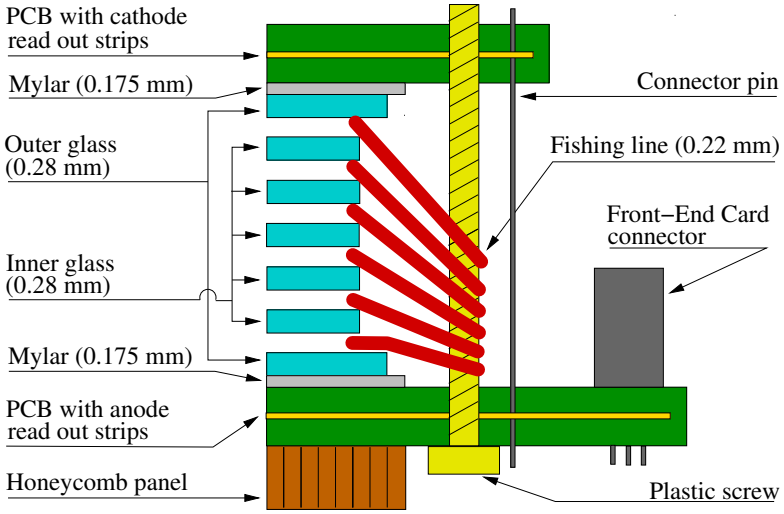
- Motivation
- MRPC, T10 setup
- Efficiency, Time-slewing correction, Time resolution, Position resolution, Streamer probability
- Conclusion

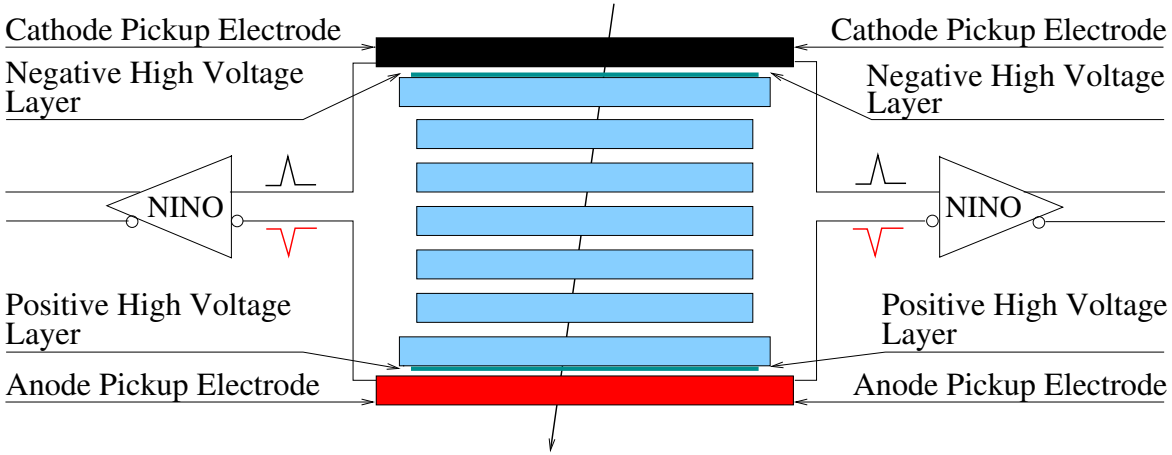
Motivation

- Commonly used gas mixtures for RPC-type gas detectors
  - ✓ $C_2H_2F_4$(TetraFluoroethane): Ionization gas by incident particle, > 95% of mixture gas, GWP=1300
  - ✓ SF_6(Sulfur hexafluoride): Electronegative gas, reduce streamer by absorbing electrons, GWP=23800
  - ✓ i-C_4H_{10}: Quenching gas, reduce streamer by absorbing soft X-ray, flammable gas, GWP<5
  - $C_2H_2F_4$ & SF_6 are being phased out by EU restrictions, prices increased.
- Tested ecological gases
  - ✓ $C_3H_2F_4$ (TetraFluoropropene): ecological Freon, GWP < 7
  - ✓ CF_3I (TriFluoroiodomethane): GWP < 1
  - ✓ CO_2: (Carbon dioxide): GWP=1

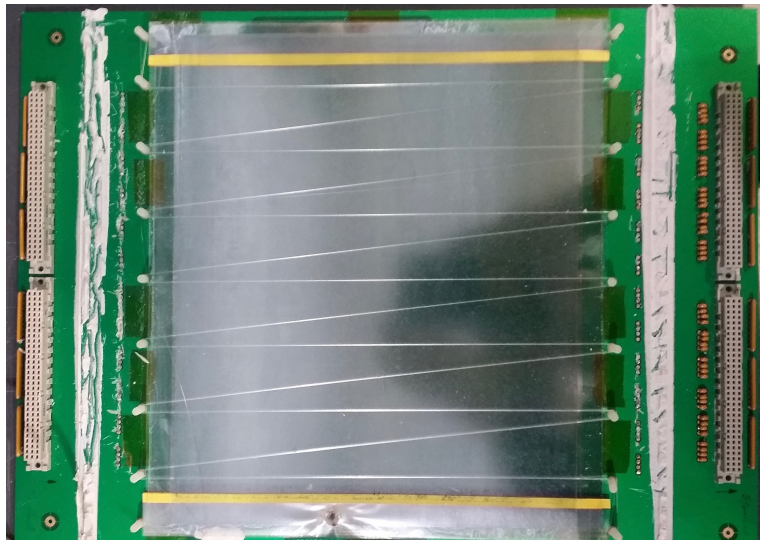
- GWP(Global Warming Potential): a relative measure of how much heat a greenhouse gas traps in the atmosphere, which is caused by the same mass of CO_2.

MRPC



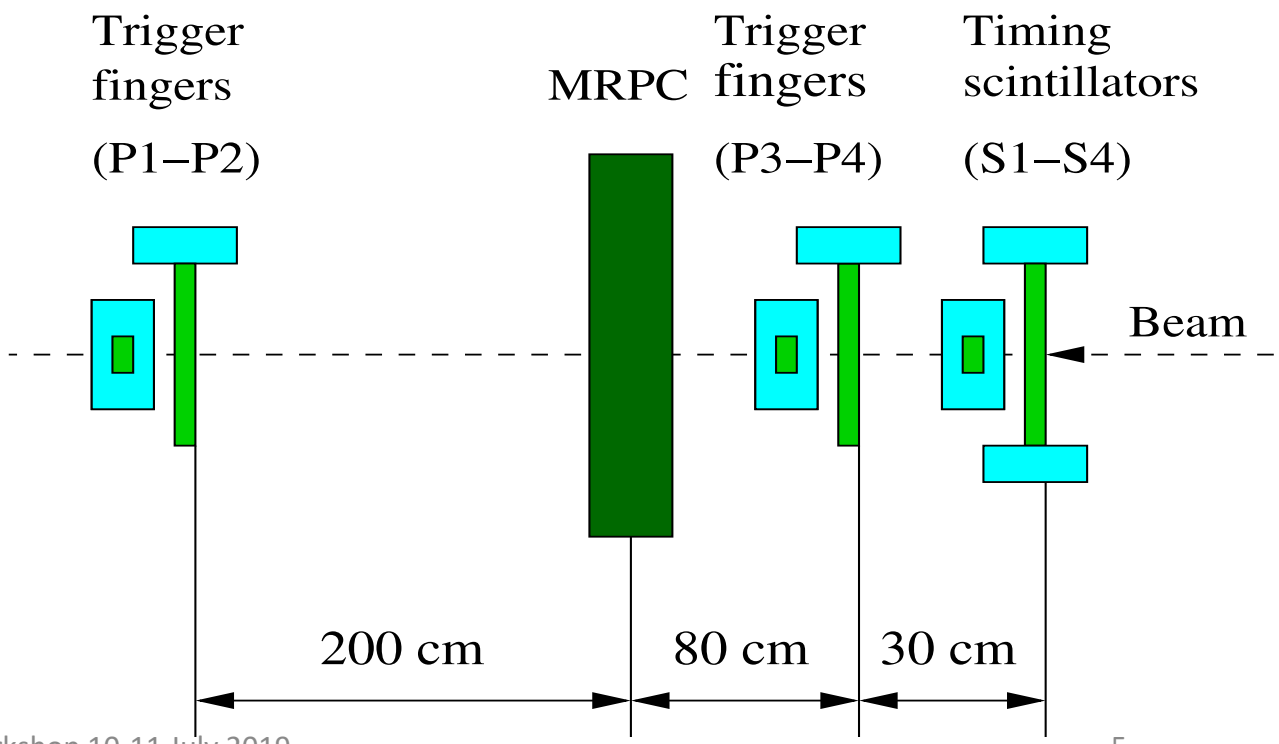


- A small active area of 20 x 20 cm^2
- PCB-based 24 pickup strips
- 6 gaps with 220µm
- Glass thickness: 280µm
- Readout: NINO card at both ends

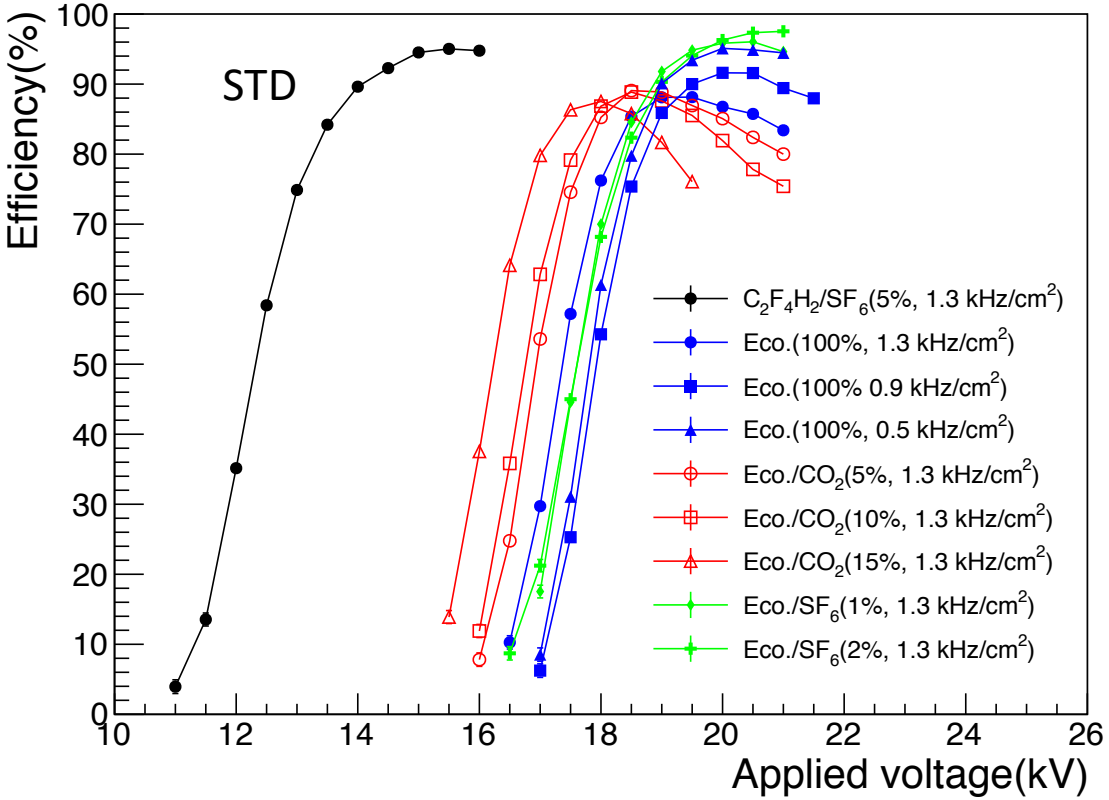


T10 setup

- Pion beam with 6 GeV/c
- Trigger scintillators: P1-P2(1 x 1 cm^2), P3-P4(2 x 2 cm^2)
- Timing scintillators: S1-S4(2 x 2 x 10 cm^3)
  - ✓Time reference = (S1+S2+S3+S4)/4
  - ✓σ = ((S1+S2)/2 - (S3+S4)/2)/2
    = 35 ~ 45ps

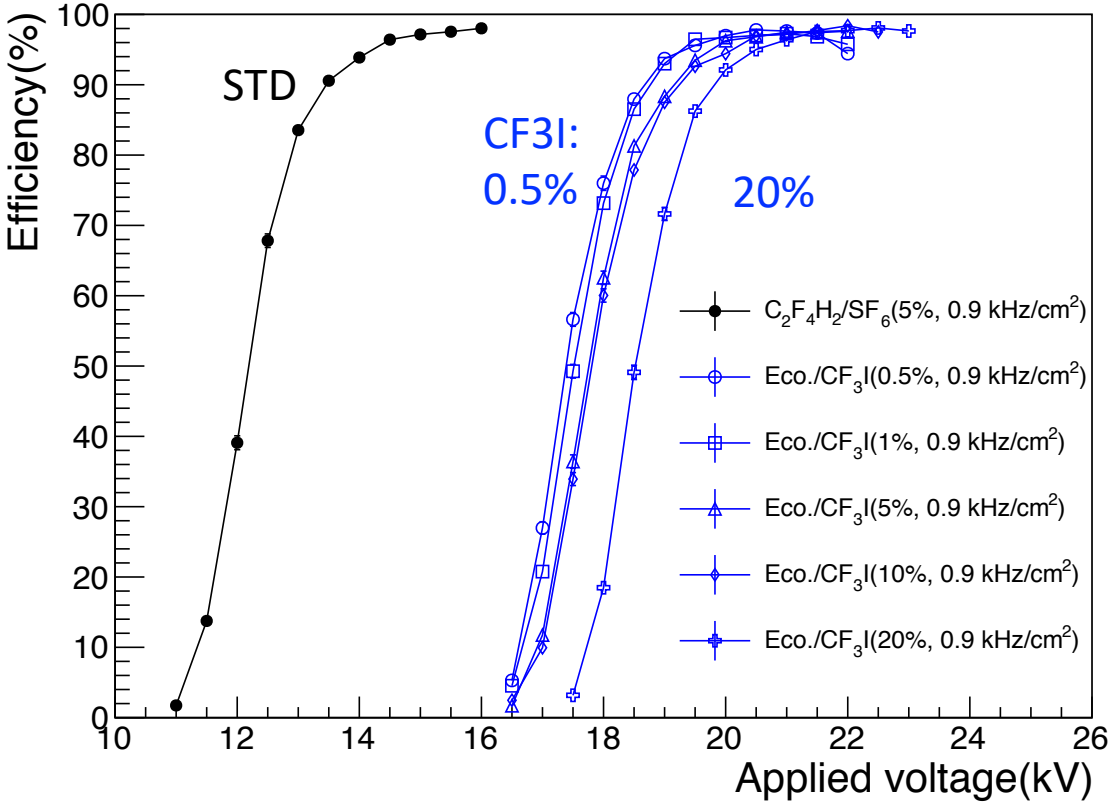


Efficiency



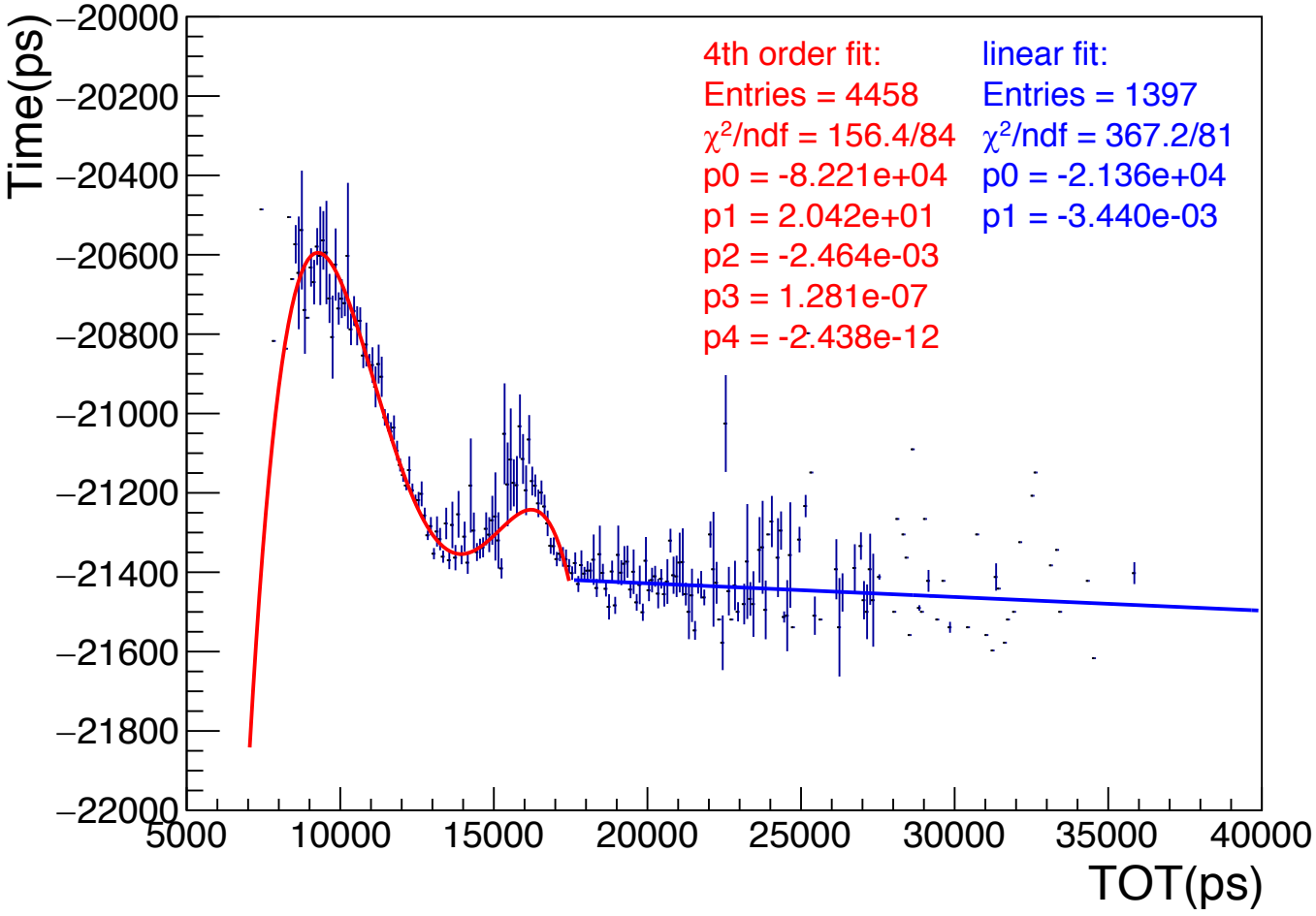
- Beam intensity: 1.3 kHz/cm^2
- STD(5% SF_6): eff. ~ 95%@15kV
- Pure Eco Rate: 0.5, 0.9 and 1.3 kHz/cm^2
  - 4.5kV higher operating voltage
  - Eff. of Eco @0.5 kHz/cm^2 ~ Eff. of STD
- Eco/CO_2 (5, 10 & 15%)
  - Reduce operating voltage, but plateau worsens
- Eco/SF_6 (1 & 2%)
  - 2%: better & stable plateau

Efficiency

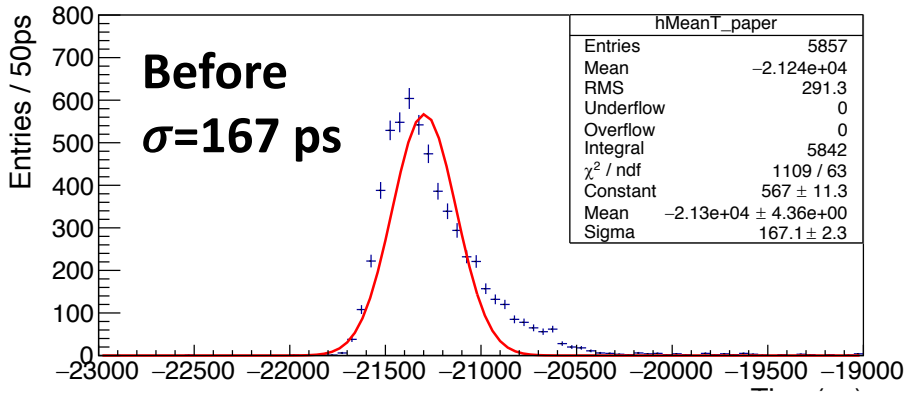


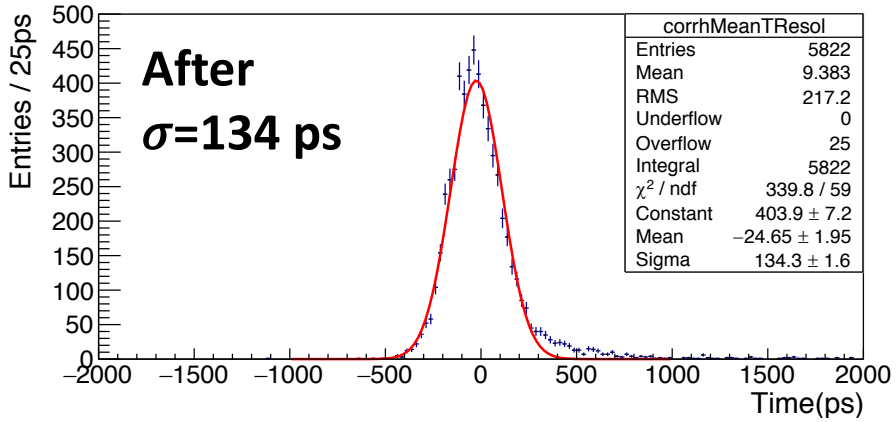
- Beam intensity: 0.9 kHz/cm^2
- Eco/CF_3I (0.5, 1, 5, 10 & 20%) @0.9 kHz/cm^2
  - 4-6 kV higher operating voltage
  - Eff. of Eco(0.5) ~ Eff. of STD
  - Stable plateau by increasing CF_3I ratio

Time-slewing correction

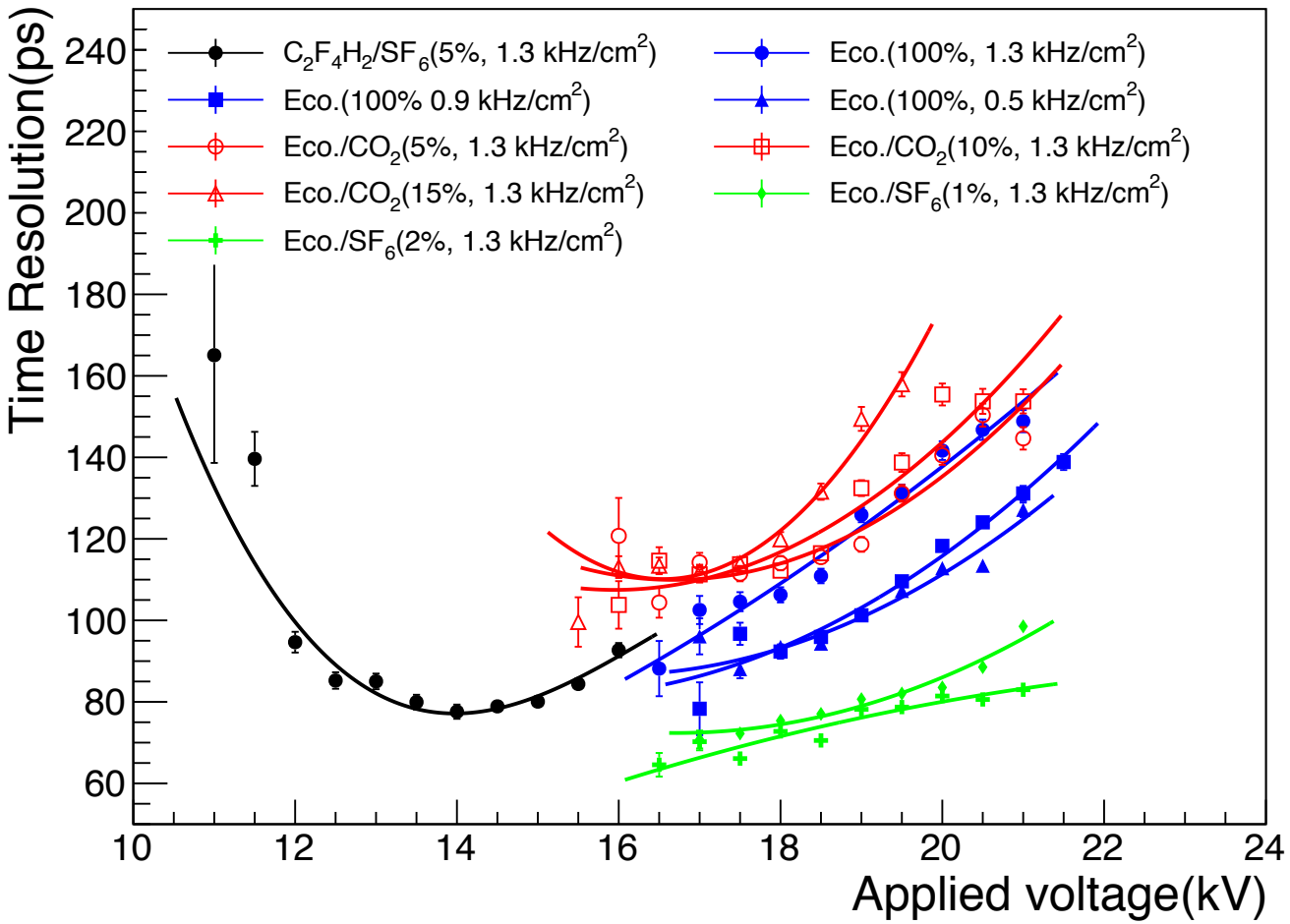


- Fitting on T-A profile: 4th order polynomial and linear fit functions



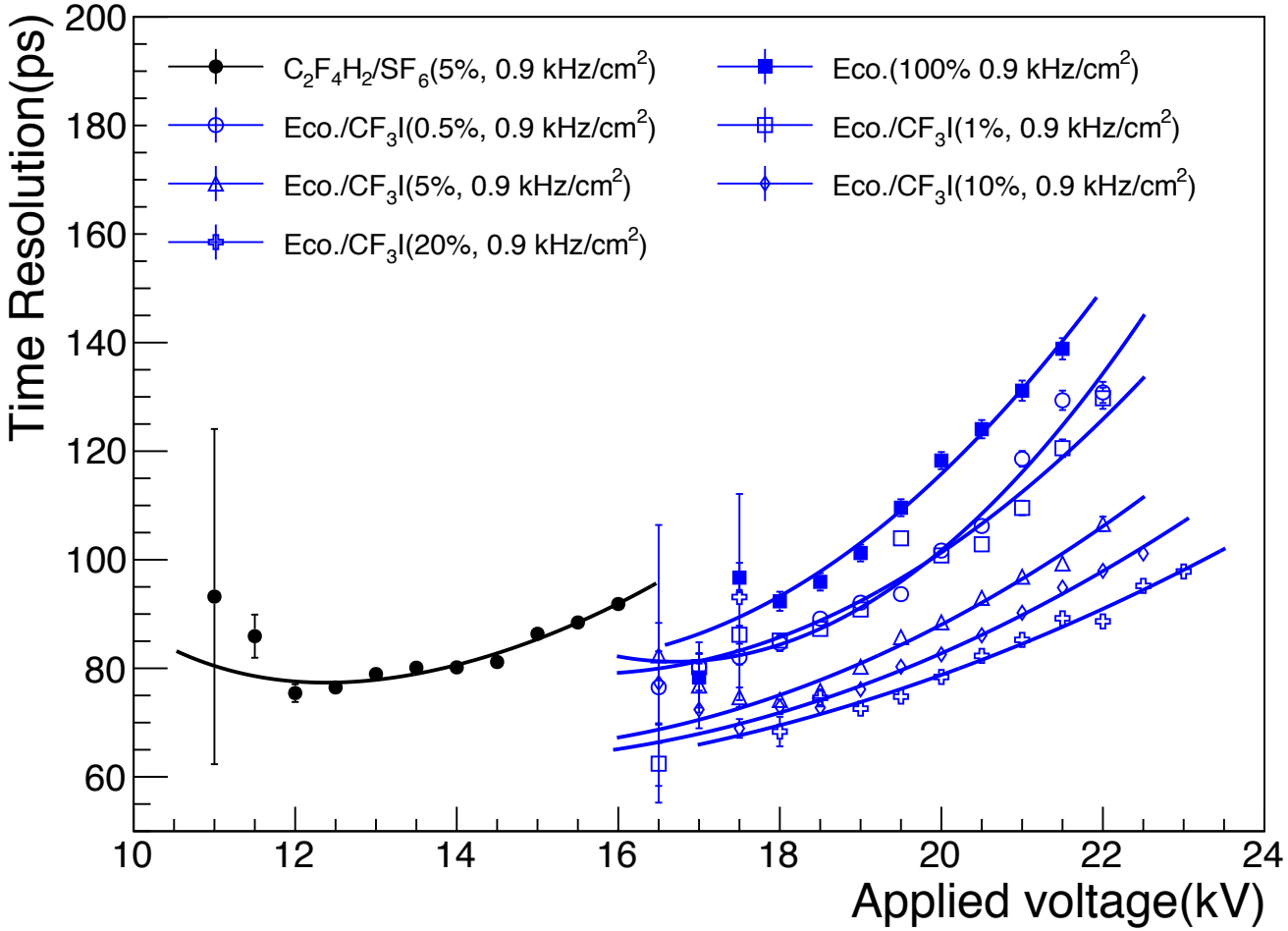


Time resolution



- σ(STD) = 80 ps@15 kV
- σ(Eco./CO_2) = 110 ~ 140 ps @18~19 kV
  - ✓ Increasing CO_2 ratio, eff. drops.
- σ(Eco.) = 100 ~ 130 ps @19~20 kV
  - ✓ better at low beam intensity
- σ(Eco./SF_6) = 80 ~ 100 ps @20~21 kV
  - ✓ Good result with a small amount of SF_6.

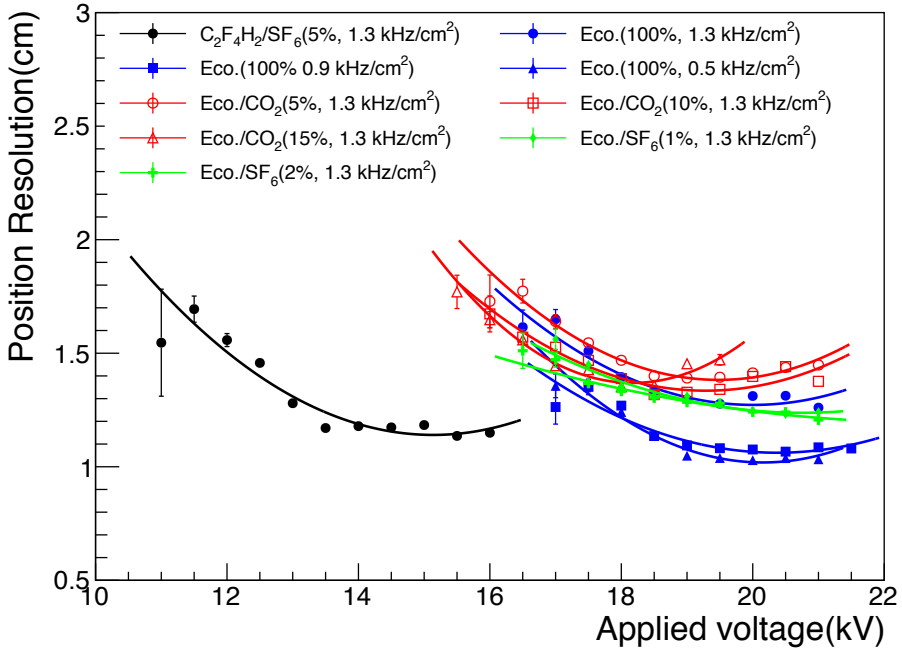
Time resolution

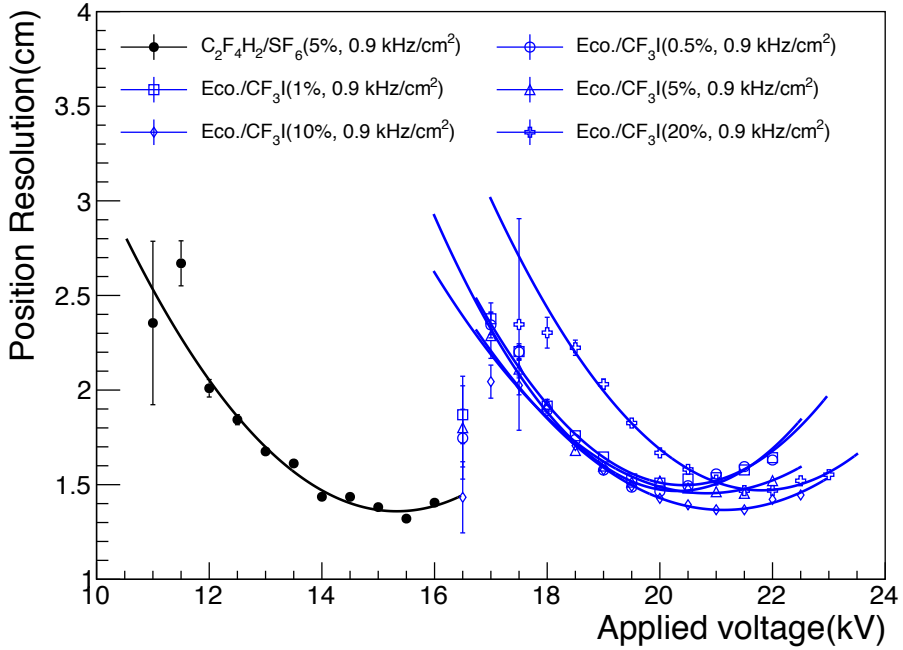


- σ(STD) = 85 ps@15 kV
- σ(Eco./CF_3I) = 85 ~ 115 ps @20~22 kV
  - ✓Adding CF3I increases the operating voltage slightly.
  - ✓Increased depending on CF_3I ratio.

Position resolution

- Convert: 2/3 of the speed of light
- Resolution: 1.1 ~ 1.5cm

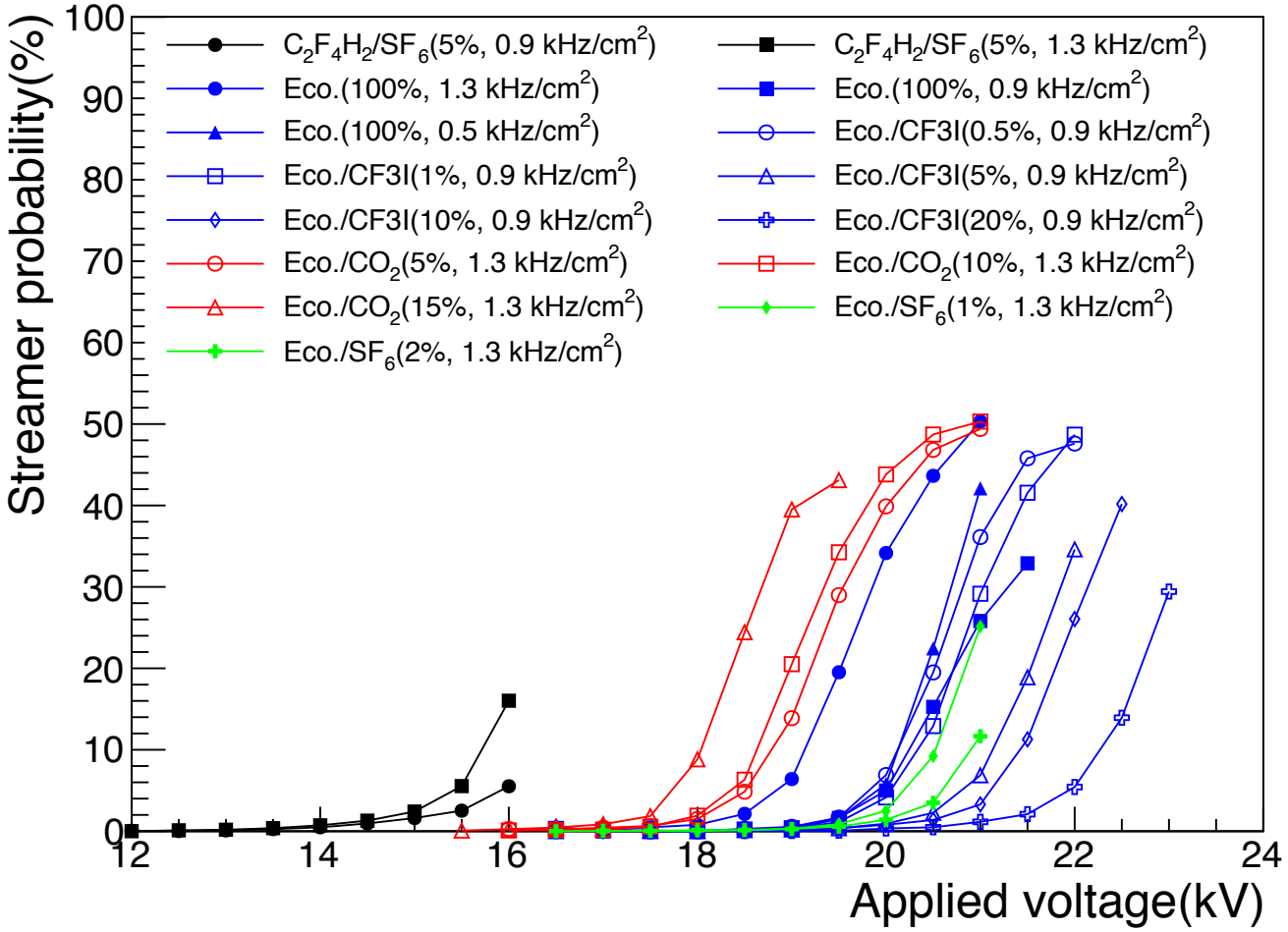




- STD: 1.2cm, Eco./CO2: 1.4cm
- Eco/SF_6: 1.3cm, Eco.: 1.1cm

- STD: 1.4cm
- Eco.: 1.4~1.5cm

Streamer probability



- Streamer event: hit more than 5 neighboring strips
- STD: <2% @15kV
- Eco.: ~6% @ 19~20kV
- Eco./CO_2: 10~20%@18~19kV
- Eco./CF_3I: <7% @20~22kV
- Eco./SF_6: <5% @20kV

Conclusion

- Checked feasibility of using the ecological gases, $C_3H_2F_4$(HFO-1234ze, GWP < 7) and CF_3I (GWP < 1), to substitute for greenhouse gases
- Performance of MRPC with the $C_3H_2F_4$-based ecological gas mixtures
  - ✓Basically, it needs 25% higher operating voltages
  - ✓Adding SF_6, almost same result except for the operating voltage
  - ✓Adding CF_3I, efficiency plateau becomes better depending on the amount, operating voltage slightly increases
- Overall performance of $C_3H_2H_4/CF_3I$(80/20%) mixture
  - ✓Very similar performance as the one of $C_2H_2F_4/SF_6$
  - ✓However, CF3I is currently very expensive

- Publication
  - Nucl.Instrum.Meth. A927 (2019) 366-370(2019-05-21)