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MRPC with eco-friendly gas

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Outline

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- High rate beam test at T10
- MRPC performance with eco gas mixture
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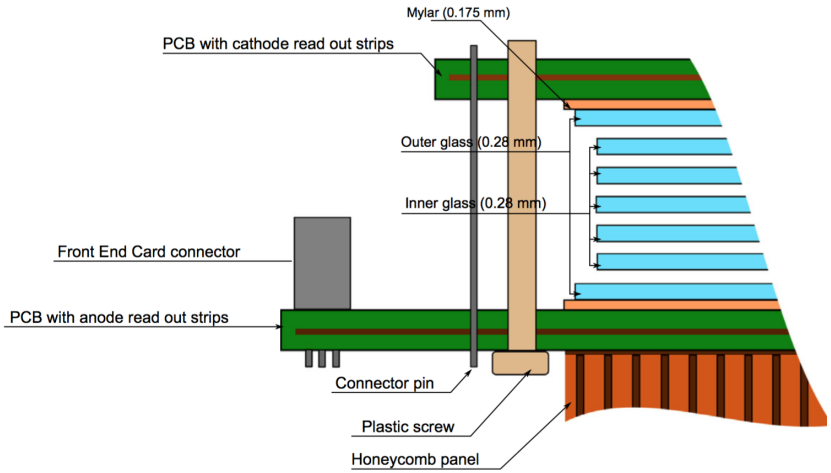
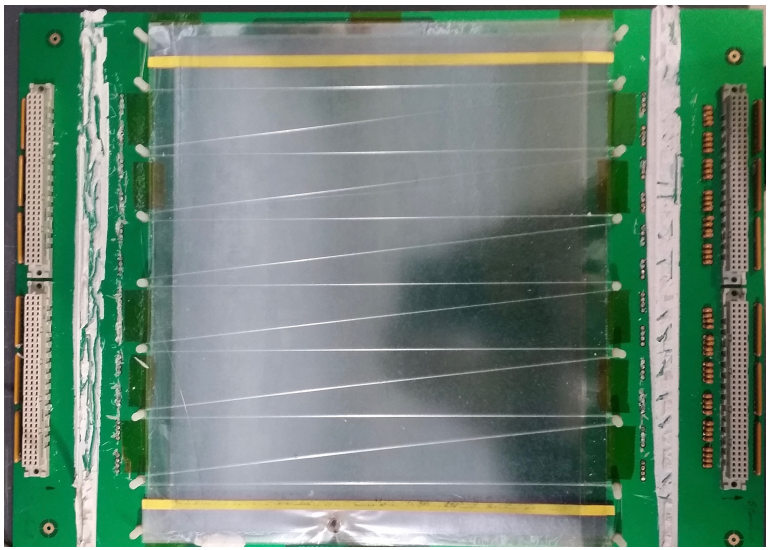
- Summary

Motivation

- RPC-type detectors
  - Excellent timing performance and low noise
  - Reasonable cost for a large coverage
  - Gas: HFC-based gas mixtures
    - Mainly, $C_2F_4H_2$(GWP=1430) and SF_6(GWP=23900)
- Searching for a new eco-gas mixture requires
  - Low GWP and a reasonable cost
  - Comparable performance
- Possible candidate: HFO-1234ze (tetrafluoropropene), GWP < 1
  - Test at low rate: EEE chamber (**Silvia Pisano's talk**)
  - Test at high rate: an extension to general purpose.

Used MRPC

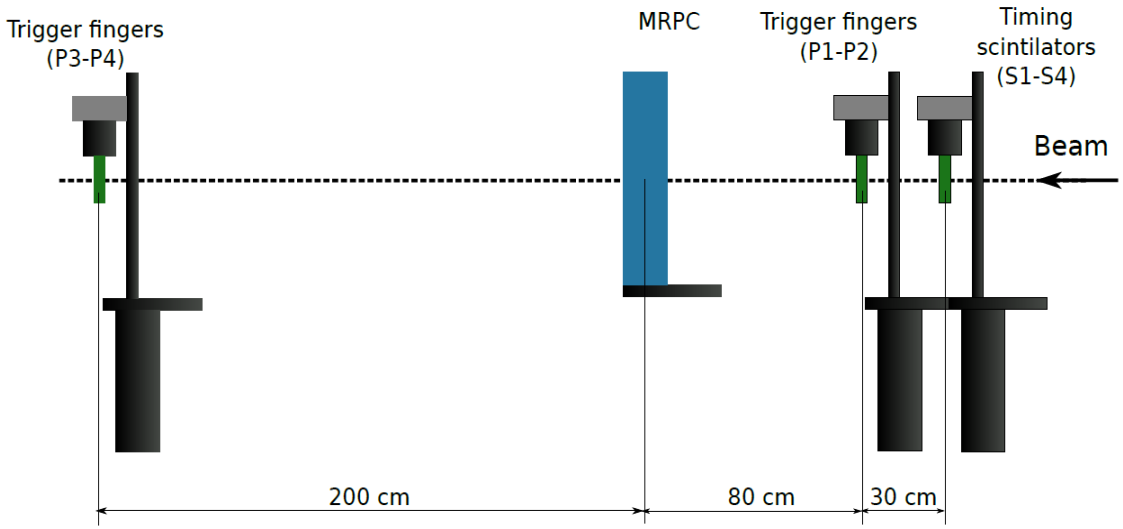




- MRPC
  - Small active area of 20cm $\times$ 20cm
  - PCB-based 24 pickup strips
    - 0.7cm x 20.5cm and 1mm of separation
  - 6 gaps with 220μm
  - Glass thickness of 280μm
- Readout
  - Differential readout by NINO card at both ends
    - Time-Over-Threshold(TOT) technique

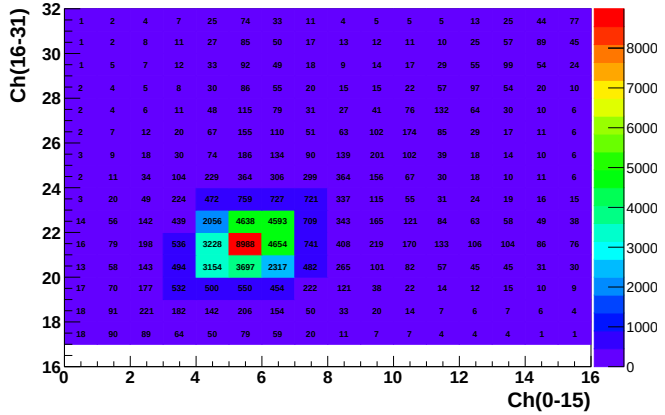
High rate test at T10

Setup at T10

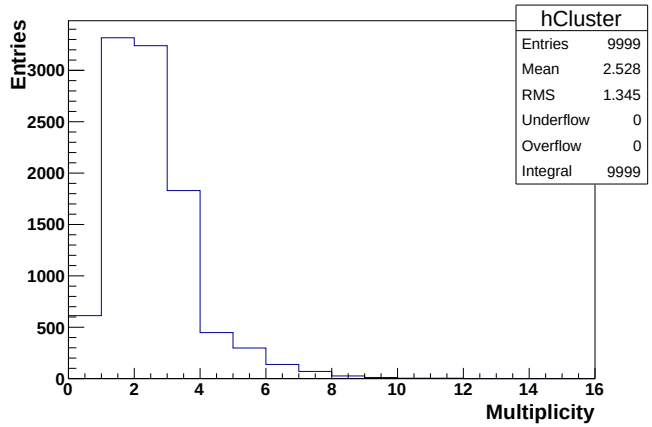


- Beam of 6 Gev/c negative pions
- Timing scintillators(S1-S4): $\sigma \sim 47$ps
- Trigger scintillators(P1-P4)
  - $1 \times 1\mathrm{cm}^2$ (P1-P2) and $2 \times 2\mathrm{cm}^2$ (P3-P4)

Beam position on chamber

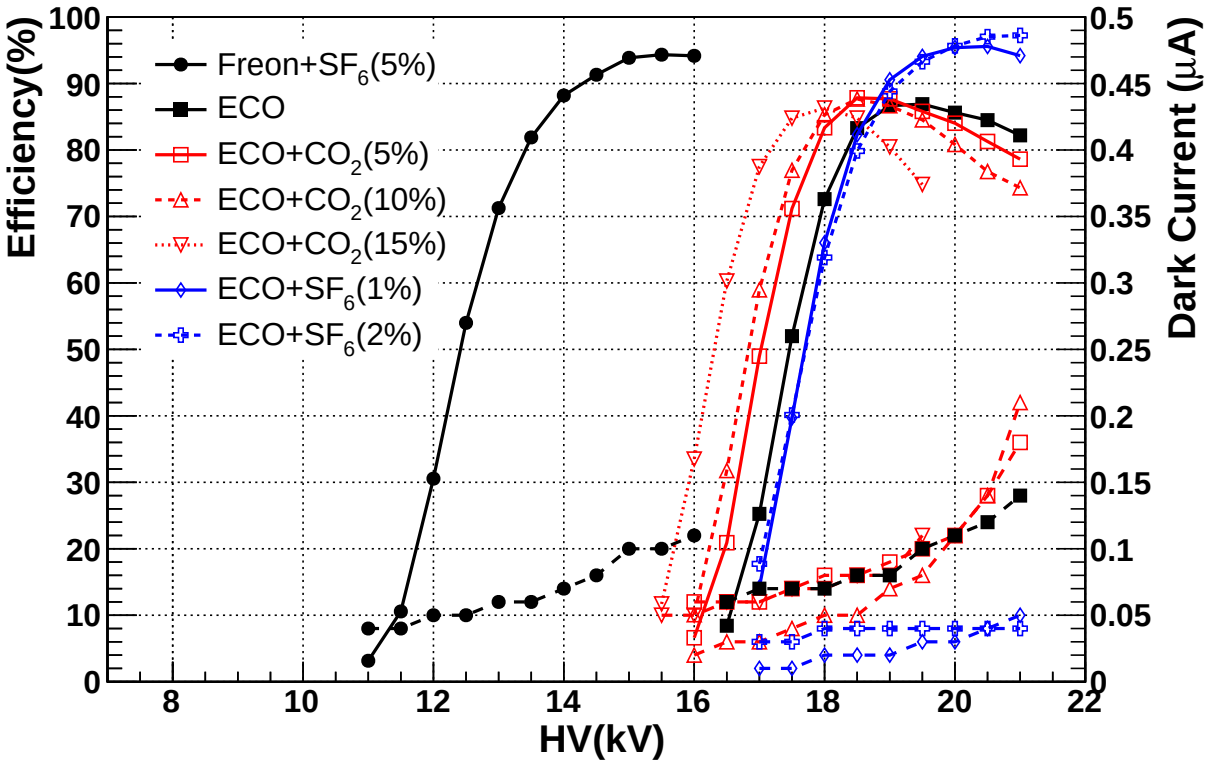


Multiplicity



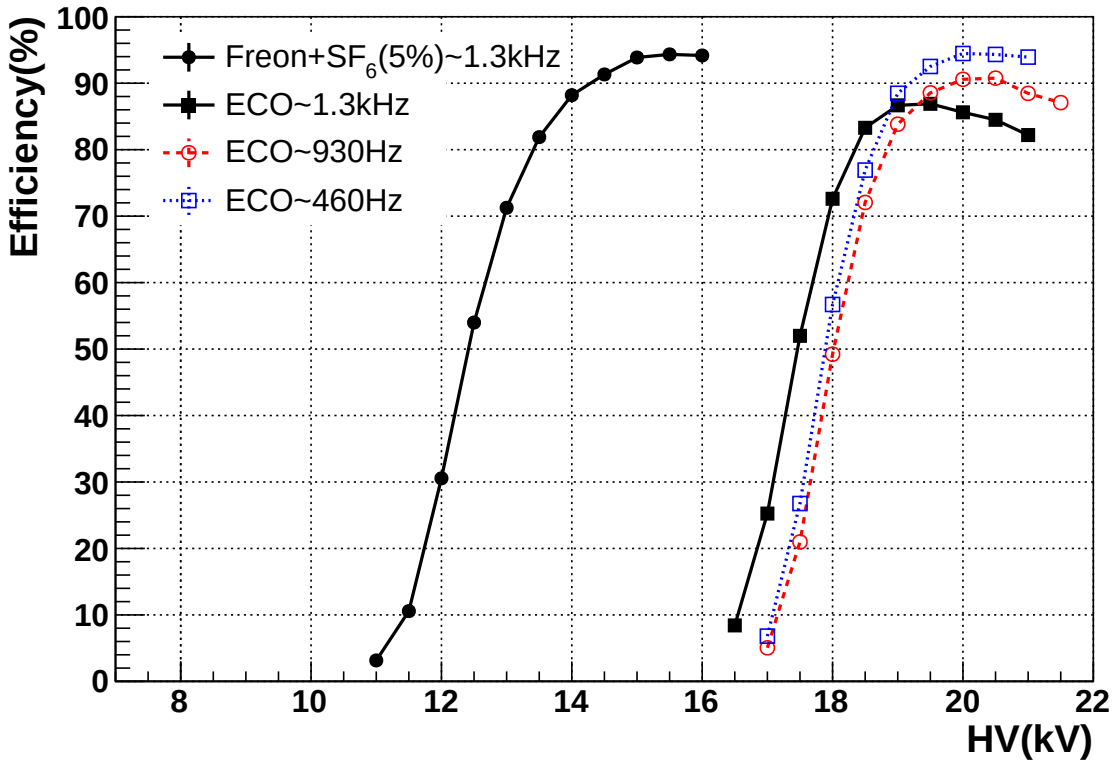
- Cluster size ~ 2.5

Efficiency



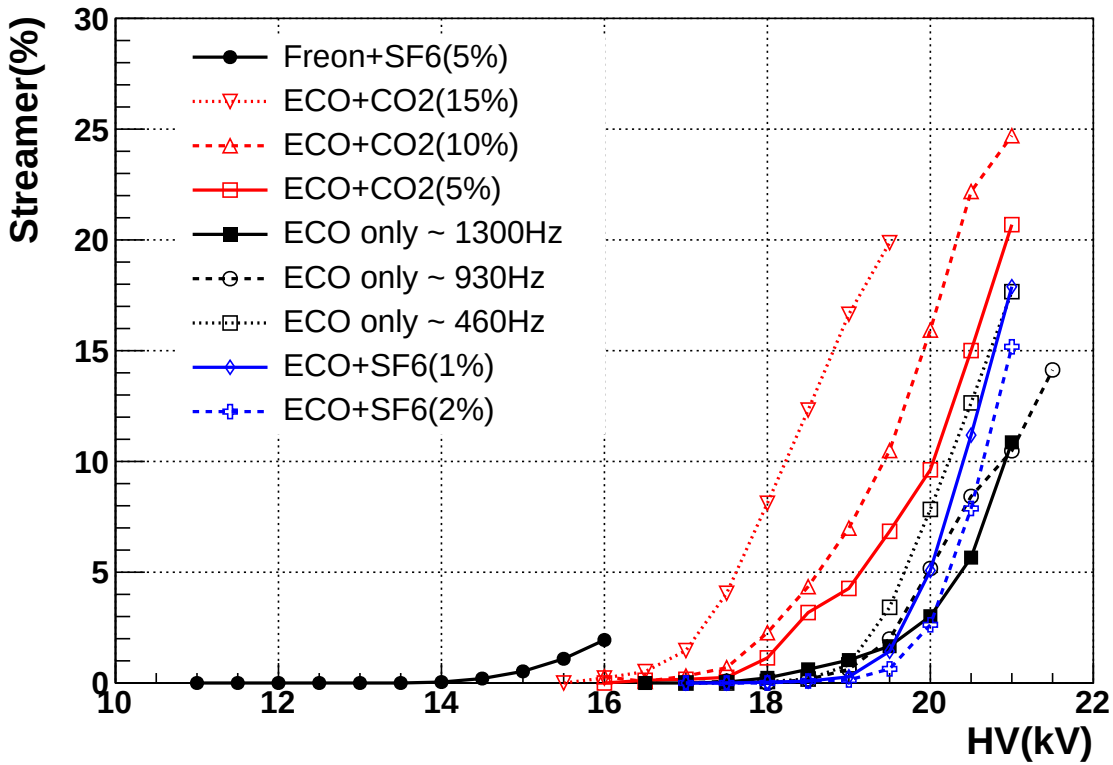
- Data taken at $\sim 1.3\mathrm{kHz/cm^2}$ of instantaneous beam intensity
- About 4 kV higher operation voltage than STD one needs to reach the plateau
- STD gas mixture: eff. $\sim$ 94% @15kV
- Pure eco & eco+$\mathrm{CO_2}$: eff. $\sim$ 87% @18-20kV, unstable plateaux
- eco+$\mathrm{SF_6}$: Similar efficiency and plateau to the STD one
- Dark current: Most gas mixtures are below 0.15μA, relatively low for eco+$\mathrm{SF_6}$

Rate capability



- 1.3kHz: 94%@15kV_STD, 87% @19kV_pure ECO
- 930(460)Hz: 91(95)% @20kV_pure ECO
- Similar performance as STD gas mixture at 460 Hz, but instable plateau.

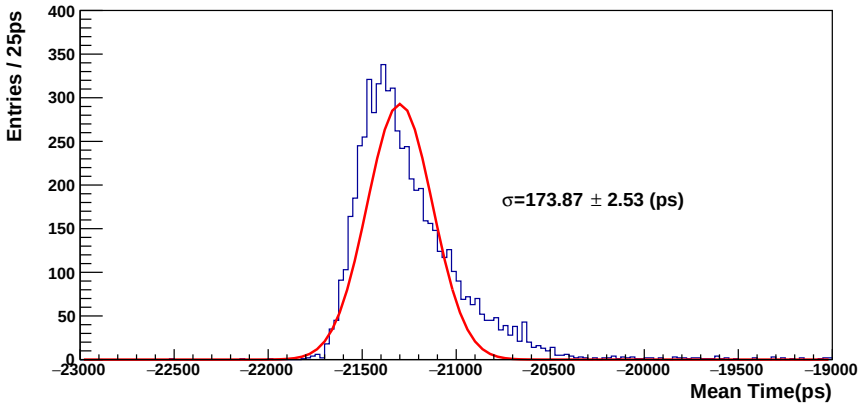
Streamer rate



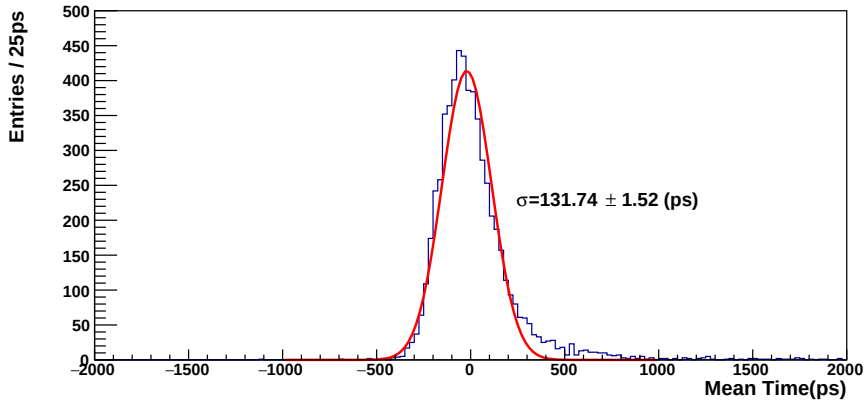
- Streamer: Pulse width(TOT from NINO) $>$ 18ns
  - STD gas: Few streamer rate
  - eco gas mixtures: same level @knee voltages

Time-slewing correction (mean time)

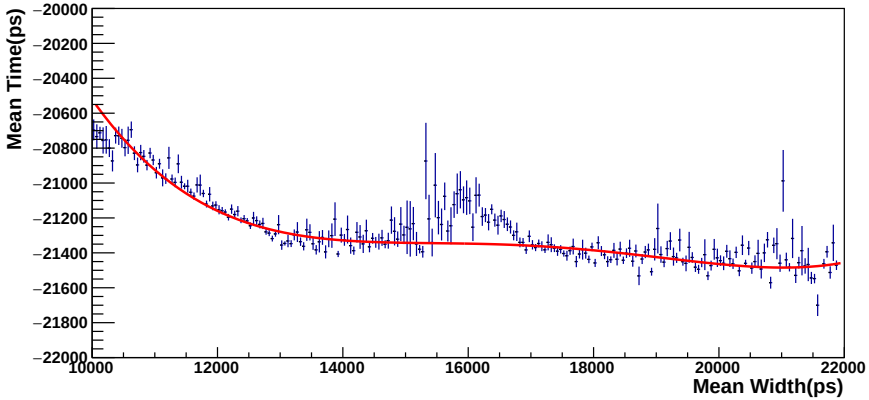
- $T_{MRPC} - T_{ref.}$



- **Corrected ($T_{MRPC} - T_{ref.}$)**

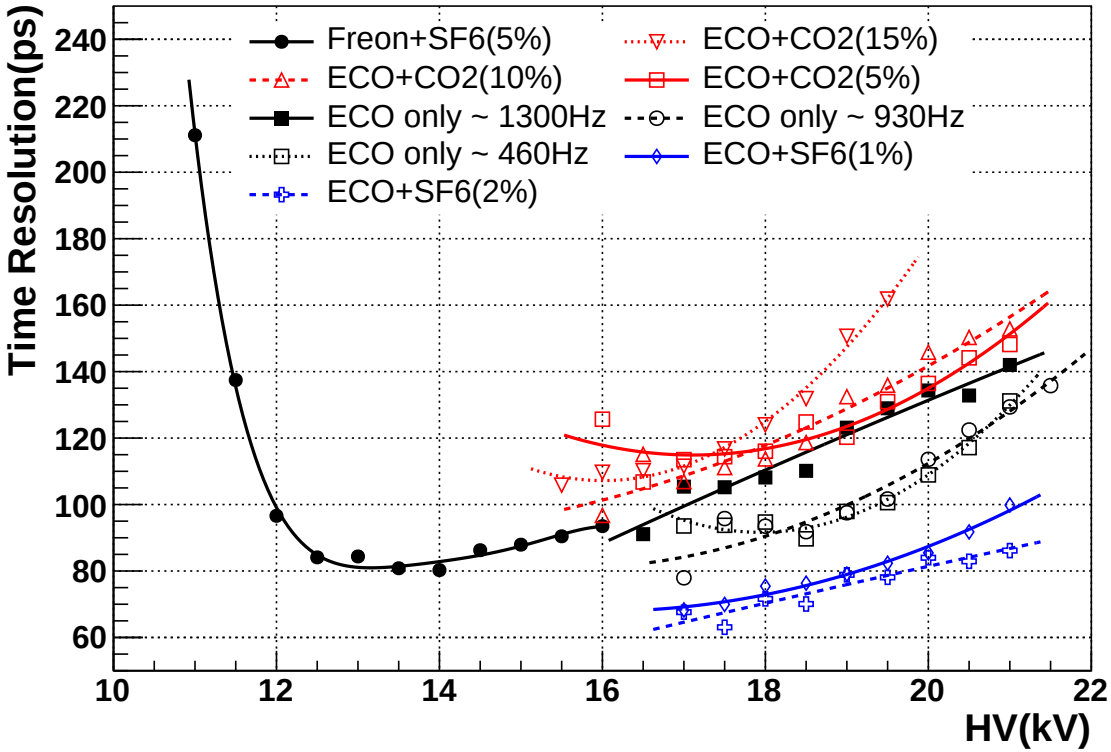


- **Fitting T-A profile**



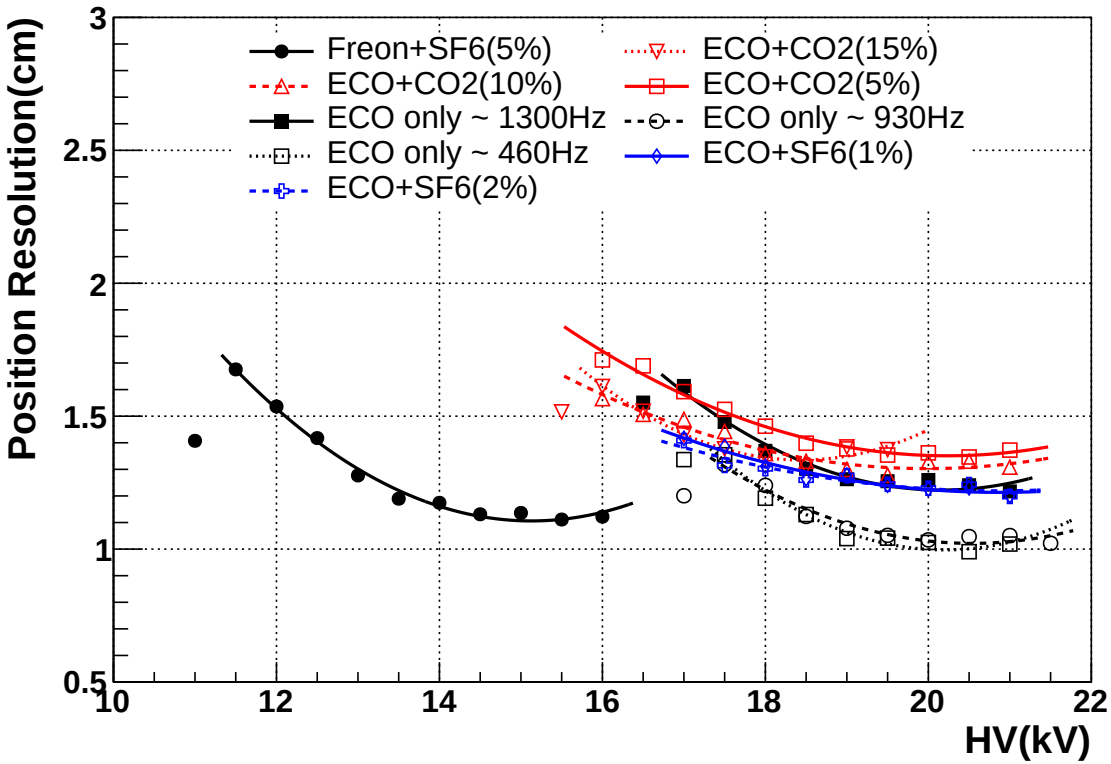
- Time slewing < 0.7ns
- Profile(T-A) fit with 4th order polynomial function
- Time jitter for timing scintillators $\sim$ 47ps

Time resolution



- Time resolution @knee voltage
  - STD: ∼87ps @15 kV
  - pure eco: ∼110ps @20 kV
  - eco+CO_2: ∼125ps @18.5 kV
  - eco+SF_6: ∼83ps @20 kV
- Adding SF_6 gives similar results as obtained from STD gas mixture.

Position resolution



- Position resolution can be calculated from the distribution of time difference at both ends of a strip.
- $\sigma_{position}$: better than 1.3 cm for all gas mixtures @knee voltages.

Summary

- Eco gas mixtures have been tested in high rate of beam condition using a small MRPC and the performance is compared to that of STD gas mixture.
- Performance with eco gas mixtures:
  - Basically, need higher operating voltages.
  - Overall performance is not so far from that of STD gas mixture.
- Conclusion
  - The eco gas mixture shows feasibility that it can substitutes for the STD gas mixture.
  - But, need a quenching gas to get a stable plateau
- Plan
  - Try $\mathrm{CF_3I}$(Trifluoroiodomethane) instead of $\mathrm{SF_6}$
    - $\mathrm{CF_3I} \sim$ 700\$/kg, GWP < 5
  - 3 component gas mixtures