MRPC with eco-friendly gas

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Outline

- Motivation
- Used MRPC
- High rate beam test at T10
- MRPC performance with eco gas mixture
  - Efficiency, Rate capability, Streamer rate, Time-slewing correction, Time resolution, Position resolution

- Summary
Motivation

- RPC-type detectors
  - Excellent timing performance and low noise
  - Reasonable cost for a large coverage
  - Gas: HFC-based gas mixtures
    - Mainly, $\text{C}_2\text{F}_4\text{H}_2$ (GWP=1430) and $\text{SF}_6$ (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 × 20cm
  - PCB-based 24 pickup strips
    - 0.7cm × 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): $\sigma \sim 47\text{ps}$
- Trigger scintillators (P1-P4)
  - $1 \times 1\text{cm}^2$ (P1-P2) and $2 \times 2\text{cm}^2$ (P3-P4)

Beam position on chamber

Multiplicity

- Cluster size $\sim 2.5$
Efficiency

- Data taken at \( \sim 1.3\text{kHz/cm}^2 \) 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+CO\(_2\): eff. \( \sim 87\% \) @18-20kV, unstable plateaux
- eco+SF\(_6\): Similar efficiency and plateau to the STD one
- Dark current: Most gas mixtures are below 0.15\(\mu\)A, relatively low for eco+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 ~ 47ps
Time resolution

- Time resolution @knee voltage
  - STD: \(\sim 87\) ps @15 kV
  - pure eco: \(\sim 110\) ps @20 kV
  - eco+CO\(_2\): \(\sim 125\) ps @18.5 kV
  - eco+SF\(_6\): \(\sim 83\) ps @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.
- $\sigma_{\text{position}}$: 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 CF$_3$I(Trifluoroiodomethane) instead of SF$_6$
  - CF$_3$I $\sim$ 700$/kg$, GWP < 5
- 3 component gas mixtures