Development of glass based RPC and performance study with cosmic ray muons

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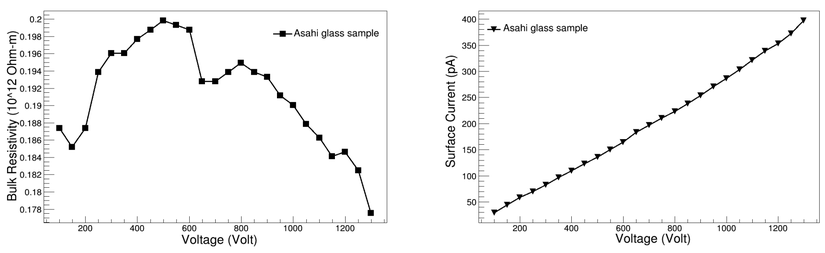
Abstract

The Resistive Plate Chamber (RPC) is an ionization (created due to the passage of charged particles) based gaseous detector made up of two highly resistive electrode plates like glass. The high bulk resistivity of glass helps in limiting the discharge to a limited area in the vicinity of primary avalanche site. RPCs are developed in 1981 by R. Santonico and R. Cardarelli. RPC detector has diverse applications in various fields requiring imaging, scanning and including particles detection due to excellent time and spatial resolutions, simplicity in fabrication & operation etc. In STAR experiment at RHIC and ALICE at LHC, RPCs are a part of time of flight (TOF) system. In Belle experiment, RPCs are used for muon identification and in CMS, ATLAS at LHC are used for triggering purpose. RPCs are also proposed to use in some future experiments like INO etc. In an RPC like detector, quality of electrode material plays a leading role in achieving consistent & good detector performance. In present studies, bulk resistivity measurements, elemental analysis studies are done for the selected electrodes (used for the RPC fabrication). The RPCs of dimensions 1 m X 1 m are developed using locally available Asahi glass plates as electrodes. Performance study of the fabricated RPCs i.e. leakage current measurements, efficiency and noise rate measurements is done with cosmic ray muons using standard gaseous mixtures.

Bulk resistivity & surface current measurements



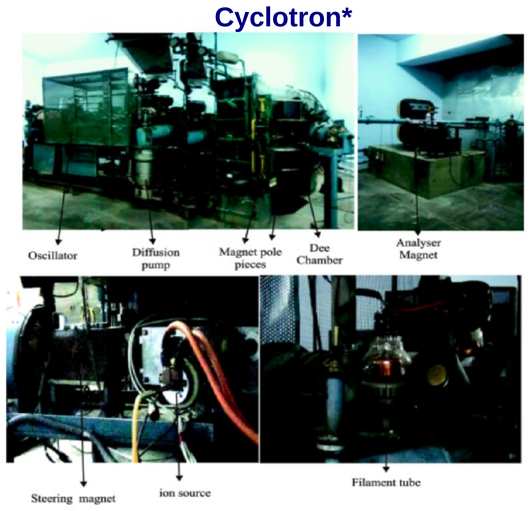
Bulk resistivity vs. voltage characteristics (left), surface current vs. voltage characteristics (right) of Asahi glass sample.

Results
- Bulk resistivity is ~ 10^{12} Ω-m.
- Surface current is ~ 400 pA.

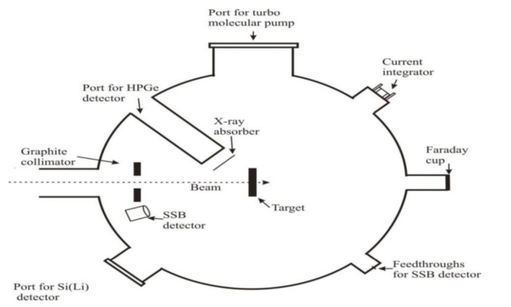
Elemental analysis by WDXRF & PIXE measurements

S8 Tiger Spectrometer*

Cyclotron*



PIXE Chamber*



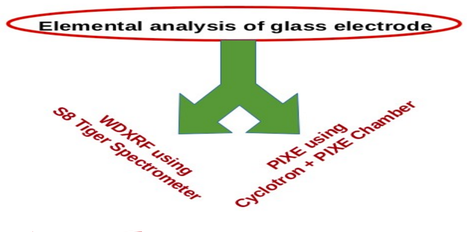


Table 1 : Concentration of constituent elements predicted on the basis of WDXRF, PIXE spectrum analysis.

Element	WDXRF (PPM)	PIXE (PPM)
Na	105000	-
Mg	23400	-
Al	4100	-
Si	335000	449221
S	640	985
K	1600	1292.7
Ca	66600	51499
Sc	-	228.2
Ti	180	121.4
Mn	51.12	37.7
Fe	840	976.3
Ni	22	3.8
Sr	21.15	25.3
Rb	8.22	-
Zr	29	-

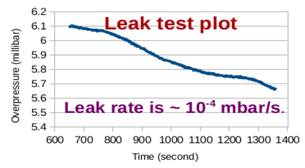
Results
- Concentration of elements predicted from PIXE, WDXRF measurements does not match as experimental setup, limit of detection and principle of technique used in both the cases are different [1, 2].

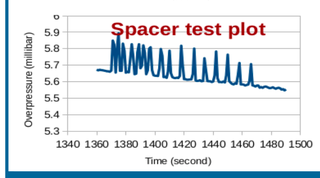
*Cyclotron, PIXE Chamber and S8 Tiger Spectrometer are available at Panjab University.

Fabrication of the glass RPC

- Pictures of fabrication steps of glass RPC (shown above) are taken during fabrication of single gap glass RPC at RPC Lab, Department of Physics, Panjab University. For more details refer to [3, 4].
- Performance study of fabricated RPCs is reported here. For more details refer to [3].

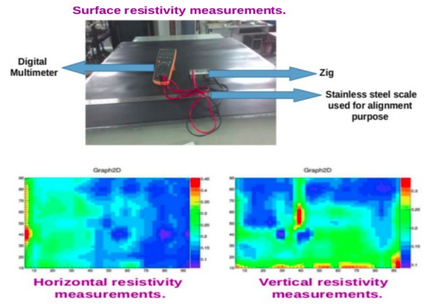
Physical testing





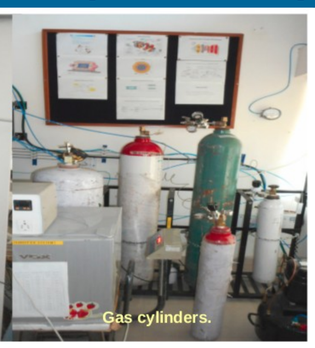
- Leak test & spacer test are performed just after fabrication of RPC gap before assembly.
- For more details, refer to [3, 4].

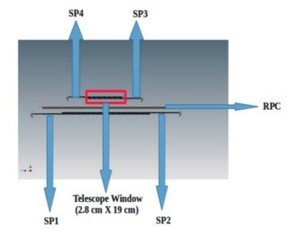
Surface resistivity measurements



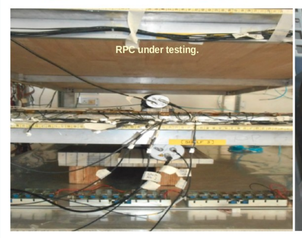
- Measured resistivity values are in the range 0.1-0.45 MΩ (as per requirement for detector operation).
- For more details, refer to [3, 4, 5].

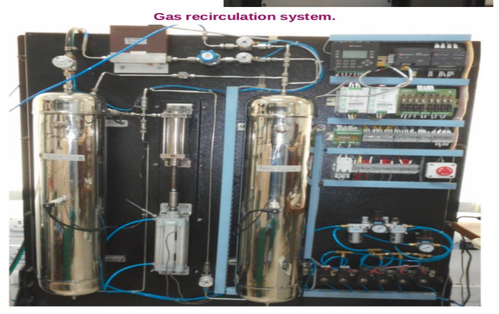
Setup used for performance study





Cosmic ray telescope layout (SP1, SP2, SP3, SP4 are scintillators).





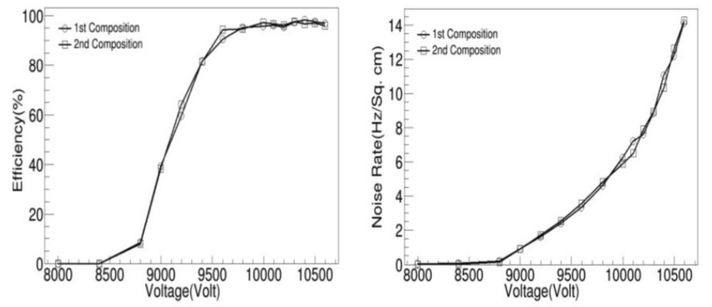
- Pictures of RPC test setup & lab at Department of Physics, Panjab University.

Results

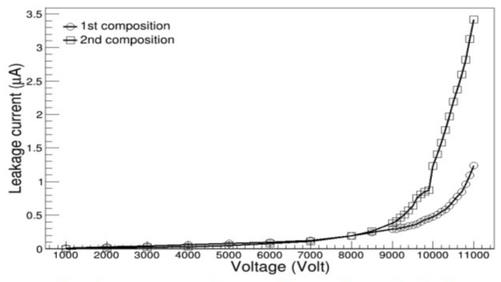
Table 2 : Standard gas mixtures used for performance study of the RPC (Avalanche Mode) [6, 7].

Sr. No.	Freon (R134A)	Isobutane	SF_6
1st composition	95.2 %	4.5 %	0.3 %
2nd composition	95.5 %	4.5 %	-

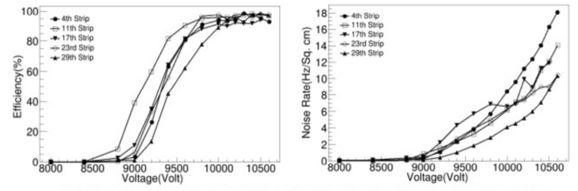
Threshold used: 10 mV for RPC
30 mV for scintillators*



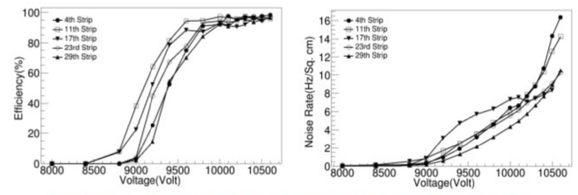
Efficiency vs. voltage characteristics (left), noise rate vs. voltage characteristics (right).



Leakage current vs. voltage characteristics.



Uniformity studies (on the basis of efficiency & noise rate characteristics) for 1st gas composition [3].



Uniformity studies (on the basis of efficiency & noise rate characteristics) for 2nd gas composition [3].

- Performance study shown here is from the RPC test lab at Panjab University.

*BICRON 404 plastic scintillators used for performance study of the RPC are fabricated, assembled and tested at RPC lab, Panjab University.

Summary

- The reported studies establish operating parameters for the single gap glass RPC detector.
- Measured bulk resistivity of the selected electrode for RPC fabrication confirms the choice of good electrode.
- Elemental analysis of glass electrode using PIXE technique is not reported in literature so far, this analysis is done to check any kind of discrepancy at elemental level as the glass electrodes are procured from local market.
- Major constituent elements of glass electrode are Na, Mg, Si, Ca and minor elements are Zr, Rb, Ni, Fe, Ti, K, Al, S etc. predicted from PIXE & WDXRF measurements.
- Performing leakage current studies, it is concluded that the glass RPC can be safely operated for both the above mentioned gas compositions.
- The efficiency of fabricated RPC is ~ 96-97 %, noise rate is in the range of 9-18 Hz/cm^2.
- Uniformity studies confirm consistent behaviour of the RPC for the above mentioned threshold parameters, gas compositions.

References

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4. Manisha et al., Journal of Integrated Science and Technology, 2016, 4(1), 21-24.

5. S.D. Kalmani, et al., Development of glass resistive plate chambers for ino experiment, NIMA 602 (2009) 744–748.

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7. A. Mengucci, et al., NIMA 583 (2007).