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Transition to ecological gas mixtures in EEE MRPC-based muon telescopes

C. Ripoli[p,q,*], M. Abbrescia[a,b], C. Avanzini[c], L. Baldini[c,f], R. Baldini Ferroli[g], G. Batignani[c,f], M. Battaglieri[h,i], S. Boi[j,k], E. Bossini[c,f], F. Carnesecchi[e,m], C. Cicalò[k], L. Cifarelli[e,m], F. Coccetti[d], E. Coccia[n], A Corvaglia[o], D. De Gruttola[p,q], S. De Pasquale[p,q], F. Fabbri[g], A. Fulci[r], L. Galante[s,t], M. Garbini[d,e], G. Gemme[h], I. Gnesi[d,u], S. Grazzi[h,r], D. Hatzifotiadou[e,l], P. La Rocca[v,w], Z. Liu[x], G. Mandaglio[r,w], G. Maron[y], M. N. Mazziotta[b], A. Mulliri[j,k], R. Nania[e], F. Noferini[e], F. Nozzoli[26], F. Palmonari[e,m], M Panareo[o,aa], M. P. Panetta[d,o], R. Paoletti[c,bb], C. Pellegrino[y], O. Pinazza[e], C. Pinto[v,w], S. Pisano[d,g], F. Riggi[v,w], G. Righini[cc], M. Rizzi[b], G. Sartorelli[e,m], E. Scapparone[e], M. Schioppa[u,dd], A. Scribano[bb], M. Selvi[e], G Serri[j,k], S. Squarcia[h,ee], M. Taiuti[h,ee], G. Terreni[c], A. Trifirò[r,w], M. Trimarchi[r,w], A S Triolo[r], C. Vistoli[y], L. Votano[ff], M. Ungaro[i], M. C. S. Williams[e,x], A. Zichichi[e,l,m], R. Zuyeuski[x].

[a] *Dipartimento Interateneo di Fisica, Università di Bari, Bari, Italy*

[b] *INFN Sezione di Bari, Bari, Italy*

[c] *INFN Sezione di Pisa, Pisa, Italy*

[d] *Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", Rome, Italy*

[e] *INFN Sezione di Bologna, Bologna, Italy*

[f] *Dipartimento di Fisica, Università di Pisa, Pisa, Italy*

[g] *INFN Laboratori Nazionali di Frascati, Frascati (Rome), Italy*

[h] *INFN Sezione di Genova, Genoa, Italy*

[i] *Thomas Jefferson National Accelerator Facility, Newport News, VA, USA*

[j] *Dipartimento di Fisica, Università di Cagliari, Cagliari, Italy*

[k] *INFN Sezione di Cagliari, Cagliari, Italy*

[l] *CERN, Geneva, Switzerland*

[m] *Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy*

[n] *Gran Sasso Science Institute, L'Aquila, Italy*

[o] *INFN Sezione di Lecce, Lecce, Italy*

[p] *Dipartimento di Fisica, Università di Salerno, Salerno, Italy*

[q] *INFN Gruppo Collegato di Salerno, Salerno, Italy*

[r] *Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra, Università di Messina, Messina, Italy*

* Speaker

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[s] *Dipartimento di Scienze Applicate e Tecnologia, Politecnico di Torino, Turin, Italy*
[t] *INFN Sezione di Torino, Turin, Italy*
[u] *INFN Gruppo Collegato di Cosenza, Cosenza, Italy*
[v] *Dipartimento di Fisica e Astronomia, Università di Catania, Catania, Italy*
[w] *INFN Sezione di Catania, Catania, Italy*
[x] *ICSC World laboratory, Geneva, Switzerland*
[y] *INFN-CNAF, Bologna, Italy*
[z] *INFN Trento Institute for Fundamental Physics and Applications, Trento, Italy*
[aa] *Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy*
[bb] *Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente, Università di Siena, Siena, Italy*
[cc] *CNR Istituto di Fisica Applicata "Nello Carrara", Sesto Fiorentino (Florence), Italy*
[dd] *Dipartimento di Fisica, Università della Calabria, Rende (Cosenza), Italy*
[ee] *Dipartimento di Fisica, Università di Genova, Genova, Italy*
[ff] *INFN Laboratori Nazionali del Gran Sasso, Assergi (L'Aquila), Italy*
E-mail: cripoli@unisa.it

A muon telescope of the Extreme Energy Events (EEE) Project is made by 3 Multigap Resistive Plate Chambers (MRPC). The MRPCs have been fluxed so far with a standard mixture composed by 98% $C_2H_2F_4$ and 2% SF_6, that are GreenHouse Gases (GHG) phasing out of production. In order to reduce GHG emissions, without affecting MRPC excellent performance, the EEE Collaboration is currently studying alternative mixtures environmentally and economically sustainable. MRPCs performance with new gas mixtures, in terms of resolution (time and space), efficiency, tracking capability and stability, are currently under investigation and will be briefly described in this contribution.

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1. Introduction

The EEE telescopes use the MRPC technology, to detect Extensive Air Showers (EAS) over a large area of the Italian peninsula. The MRPCs are usually operated with a standard gas mixture (98% $C_2H_2F_4$ - 2% SF_6). The EEE Collaboration is currently searching for a gas is focusing on the search of ecological mixtures, that should replace the standard one without affecting the detector behaviour. This request comes from the European Union (EU) regulations that have set a limit on the *Global Warming Potential* (GWP) banning gases with an index greater than 150. The GWP is the index used to quantify the impact of GHG: each gas has a specific GWP (normalized to CO_2 that has a GWP equal to 1) that measures its contribution to greenhouse effect. This limitation is referred to industrial and commercial uses and not to research purpose but the reduced demand for gases, such $C_2H_2F_4$ used in the EEE standard mixture, has also an impact on its price, pushing it out of production.

2. Gas mixtures of EEE telescopes

The EEE detectors are composed of 3 large area (1.58 × 0.82 m^2) MRPCs. Each chamber has six 300 µm gas gaps (250 µm in the new chambers built in the EEE upgrade phase since 2017). The GHG contribution comes from $C_2H_2F_4$ (98%) and SF_6 (2%) used in the MRPCs. This mixture has a GWP of about 1880, since the GWP of of $C_2H_2F_4$ and SF_6 are respectively 1430 and 23900. With its low GWP, only 6, the $C_3H_2F_4$ has been selected as a good candidate to substitute the $C_2H_2F_4$ in the EEE standard mixture.

2.1 Gas emission reduction

The strategy to reduce the EEE gas emissions foresees two different actions: the development of a gas recirculation system and an action to reduce the gas flow used for the experiment. The first action is planning to equip all telescopes with a user friendly and compact gas recirculation system that allows the output gases flow to be recirculated back into the telescope. The results are promising and although the system requires further optimization, at present the prototype can reduce emissions by reusing a fraction of about 60% of the mixture [1]. The gas mixture used in EEE experiment is circulated with a flow of about 2-3 *l*/h; it is possible to reduce the gas flow without affecting the telescopes performance in terms of time and space resolution (σ_t=238 ps, σ_x=1.47 cm, σ_y=0.92 cm), efficiency (93%) and stability [2]. The stability of rate in four EEE telescopes monitored before and after the flow reduction is shown in Figure 1. The rates observed during a test period of about five months in 2019-2020, with a gas flow ≤ 1 *l*/h, are presented on the right panel. A similar data sample taken in 2020 when the flow was ≥ 2 *l*/h, is shown on the left panel. The variation in the track rate is of the order of percent and no significant effects are found. A 65% of EEE detectors currently could work at the moment with a flow about 1 *l*/h, the final goal to run 100% of the array at 1 *l*/h.

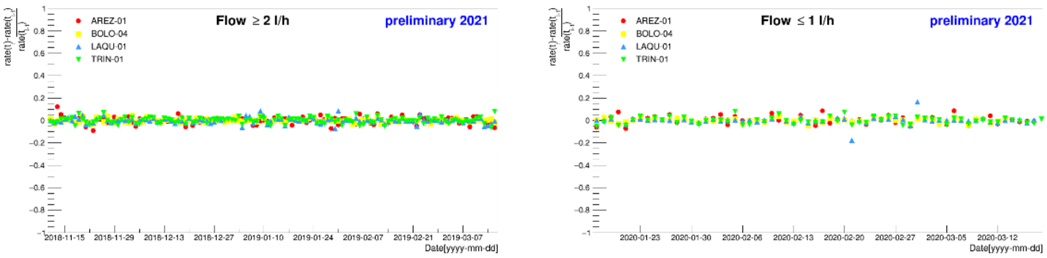

Figure 1. Muon track rates in the monitored telescopes, tested before and after the flow reduction campaign.

2.2 Ecological gas mixtures

Gas mixtures with different percentages of $C_3H_2F_4$ ($C_3H_2F_4$: 90-80-50% + CO_2: 10-20-50% and $C_3H_2F_4$: 95-98-99% + SF_6: 5-2-1%) are under investigation and tests are in progress on different telescopes of the EEE array. The efficiency, the streamer percentage, the current and the cluster size are analyzed under different conditions as a function of the applied high voltage. In the case of pure $C_3H_2F_4$, the streamer component is kept below 5% in the entire HV interval. A stable efficiency plateau is reached when the HV approaches 21 kV. Nevertheless, this condition is too close to the upper limit of operability regime of the EEE MRPCs [3]. Tests on CO_2 mixtures show that it is possible to reach a stable working point inside the limit of the operability regime for the EEE MRPCs. By using these mixtures the efficiency plateau starts at a lower HV value as the CO_2 fraction increases, but produces a high streamer component to be limited by identifying the optimal value of CO_2 percentage. Since $C_3H_2F_4$ and CO_2 GWP are relatively low (respectively 6 and 1), any combination of the two is acceptable.

3. Conclusion

To assess the best compromise in terms of environmental sustainability and efficiency of MRPCs telescopes, the EEE Collaboration implemented a plan consisting of different actions:(1) the development of a recirculation system, (2) the gas flow reduction in the gas detectors and (3) the use of an ecological gas mixture. Measurements are in progress to check that the excellent performance of the EEE MRPCs will still be achieved with the new gas mixture. Very encouraging preliminary results are obtained by using different percentages of $C_3H_2F_4$ and CO_2.

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