



## Can KM3-230213A be compatible with a cosmogenic origin?

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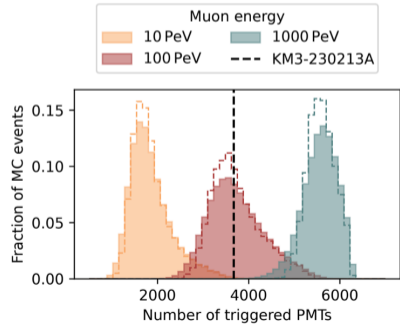
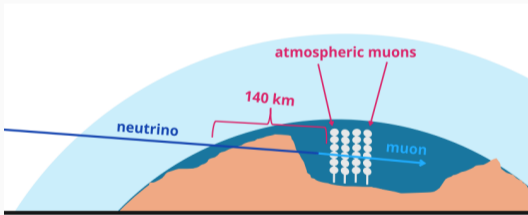
Antonio Condorelli – Université Paris Cité, CNRS, Astroparticule et Cosmologie,

Antonio Marinelli – Università' Federico II, INFN sezione di Napoli,

On behalf of the KM3NeT collaboration, based on O. Adriani et al 2025 *ApJL* **984** L41

July 21, 2025

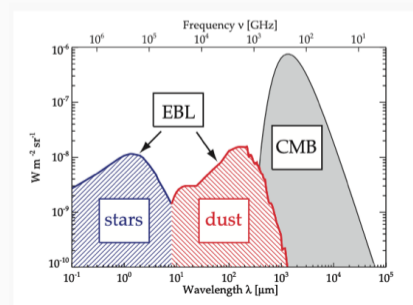
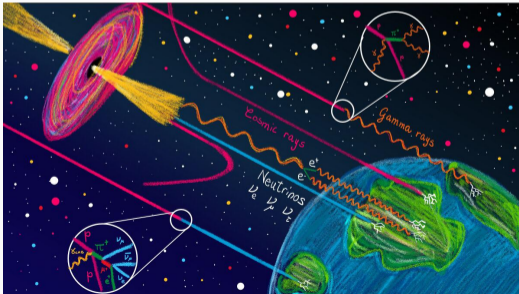
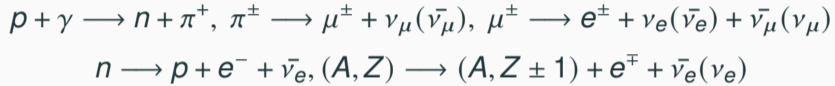
- Exciting result published in Nature, 638, 376–382 (2025).
- Initial muon energy estimate in the hundreds of PeVs.
- Horizontal event ( $1^\circ$  above horizon) as expected since Earth opaque to neutrinos at PeV scale.



<sup>1</sup>M. Lamoreaux, This conference, 17/07, Room A

# Cosmogenic origin

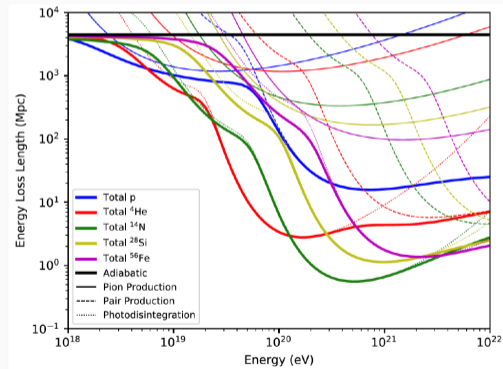
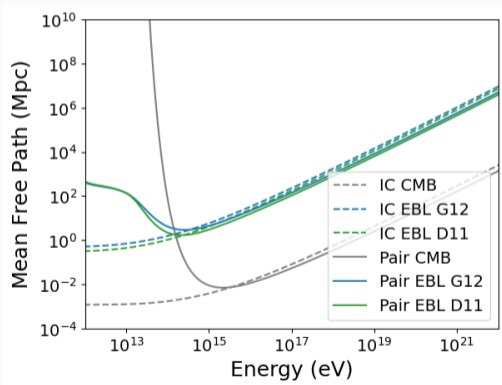
We investigated the probability that KM3-230213A has a cosmogenic origin, i.e. it has been produced due to CR interaction with extra-galactic photons.



# Main question

With other messengers  $\rightarrow$  high-energy Universe is opaque above  $z = 1$ .

**Main question:** Is the observed neutrino compatible with the other messengers in the nearby Universe?



# Cosmological Framework for Neutrino Fluxes

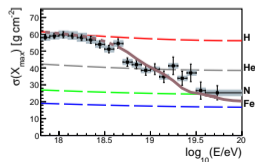
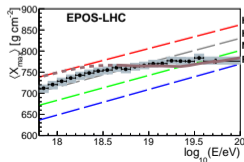
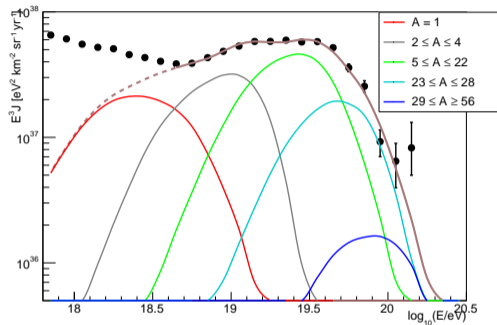
- ☛ Minimal approach: cosmological framework to compute neutrino fluxes produced in Extra-Galactic propagation;
- ☛ Assume that each source is identical and distributed with a given evolution  $m$ ;
- ☛ Fit to UHECR data above the ankle ( $10^{18.7}$  eV)  $\rightarrow$  normalization to neutrino flux;
- ☛ Important parameters to fix:  $m$  and  $z$ . All the **others** are fitted to describe UHECR data.

$$\frac{dN}{dE} \propto f_A \left( \frac{E}{10^{18} \text{ eV}} \right)^{-\gamma} \times f_{\text{cut}}(E, Z, R_{\text{cut}}) \times S(z, m)$$

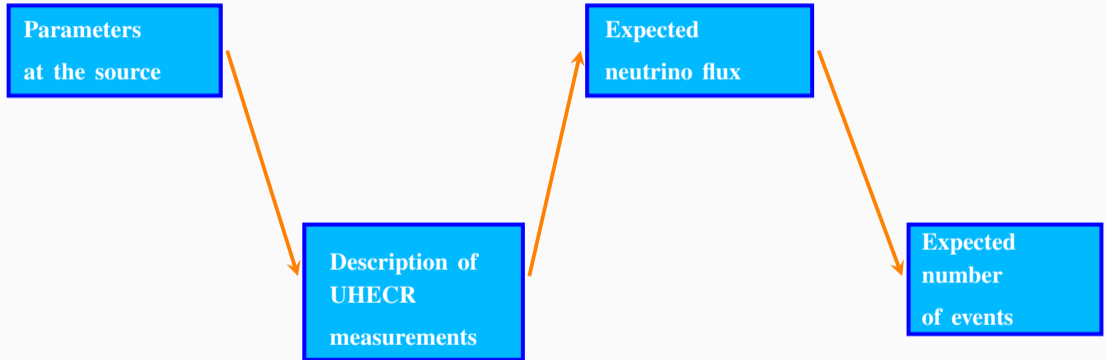
$$S(z, m) \propto (1+z)^m, \quad z_{\text{max}} = 1, 6, \quad m \in [-5, 5]$$

# Fitted spectrum and composition

- ☛ Nuclei at the highest energies;
- ☛ Hard injection spectrum and low rigidity cutoff;
- ☛ Very few protons injected  $\rightarrow$  mostly produced in EG propagation;
- ☛ Normalization of the expected CR spectrum  $\rightarrow$  normalization of the neutrino flux.

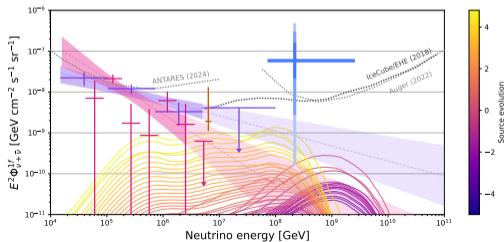
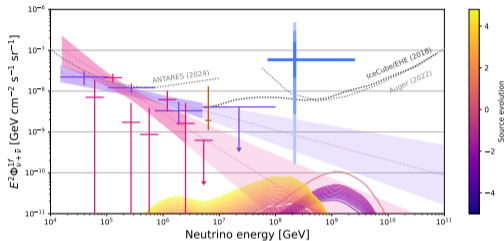


# Parameter Flow Diagram



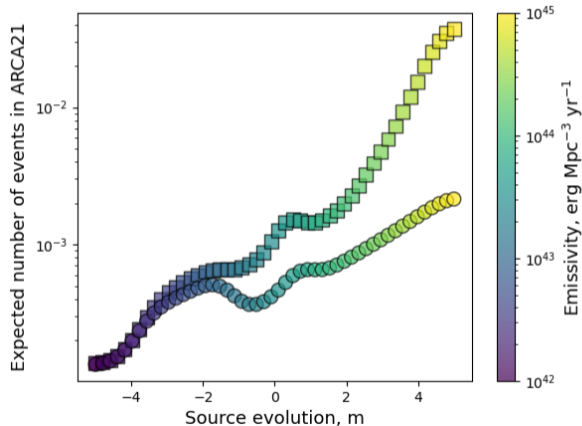
# Minimal scenario

- ☛ The neutrino flux associated to UHECR ( $z = 1$ ) is very low for any  $m$ ; Significant contribution from far away sources ( $z = 6$ ).
- ☛ Different shape (from yellow to violet) due to proton-poor configurations.
- ☛ Neutrino spectrum not-fully saturated  $\rightarrow$  in agreement with neutrino produced in astrophysical sources.



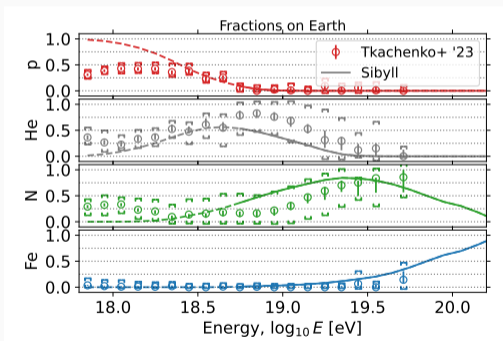
## Expected number of events

- ☛ Negative evolutions  
→ two scenarios not distinguishable.
- ☛ Positive evolution → preferred, less tension with respect to our observation → constrain on source emissivity required!

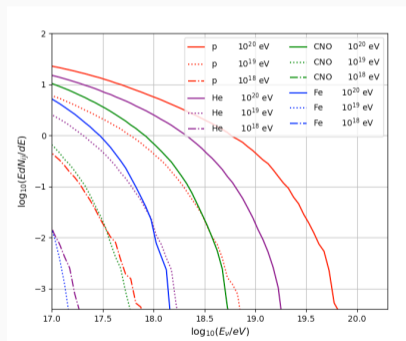


## Extended scenario

- ☛ In the minimal scenario  $\rightarrow$  no protons above the ankle.
- ☛ Investigation of a second component of protons at the highest energies  $\rightarrow$  subdominant, do not spoil the UHECR data but it has a great effect on neutrino fluxes!

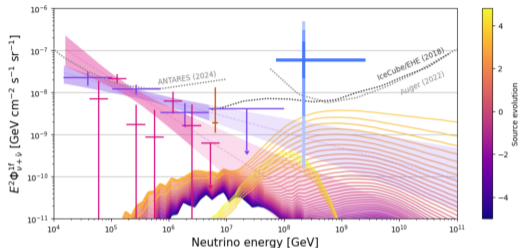
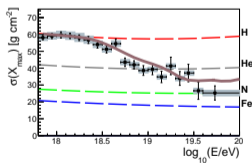
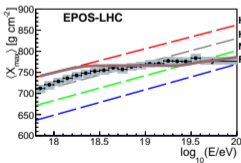
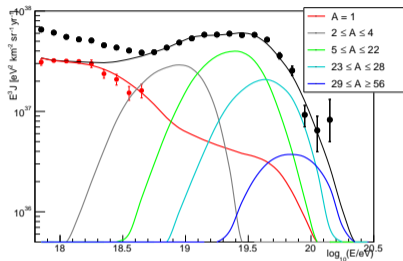


S. Marafico et al 2024 *ApJL* 972 1,4



C. Berat et al 2024 *ApJL* 966 186

# Extended scenario

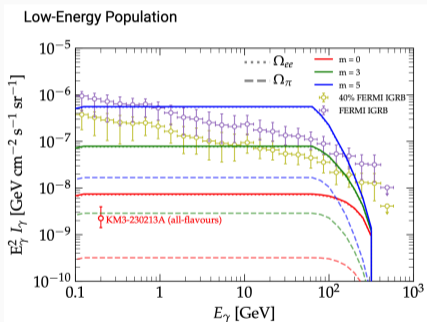


☛ Proton flux compatible with protons at lower energies  $\rightarrow$  enhanced neutrino flux.

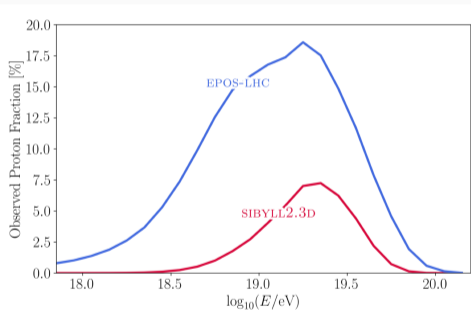
O. Adriani et al 2025 *ApJL* 984 L41

## Other works

☛ Including photon propagation  $\rightarrow$  stronger constrain on the source evolution.



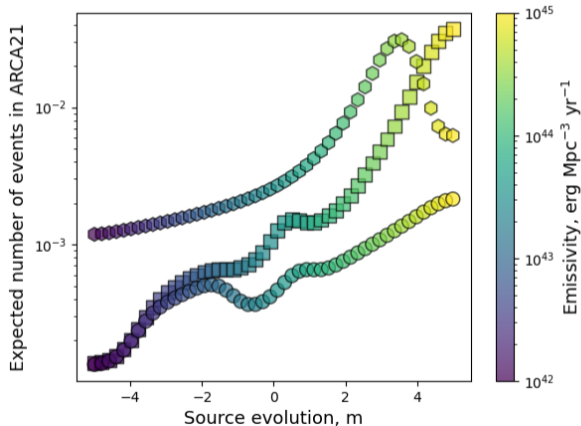
Alessandro Cermenati, this conference, 21/07



Abdulrahman Alhebsi, this conference, 21/07

# Conclusion

- Study to investigate the possible cosmogenic nature of the VHE event;
- Minimal scenario tends to exclude a cosmogenic origin;
- Combination of source evolution and proton fraction at the highest energies can reconcile the tension;
- Results fully compatible if we consider the combined effective area (see [J. Mauro, this conference](#));
- Robust result independent from the systematic uncertainties;



Thanks for your attention!