

17th Workshop of the

FCPPN/L

France-China Particle Physics Network and Laboratory

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Diffuse Gamma-ray Emission from Milky Way

Zhanfeng Zhu

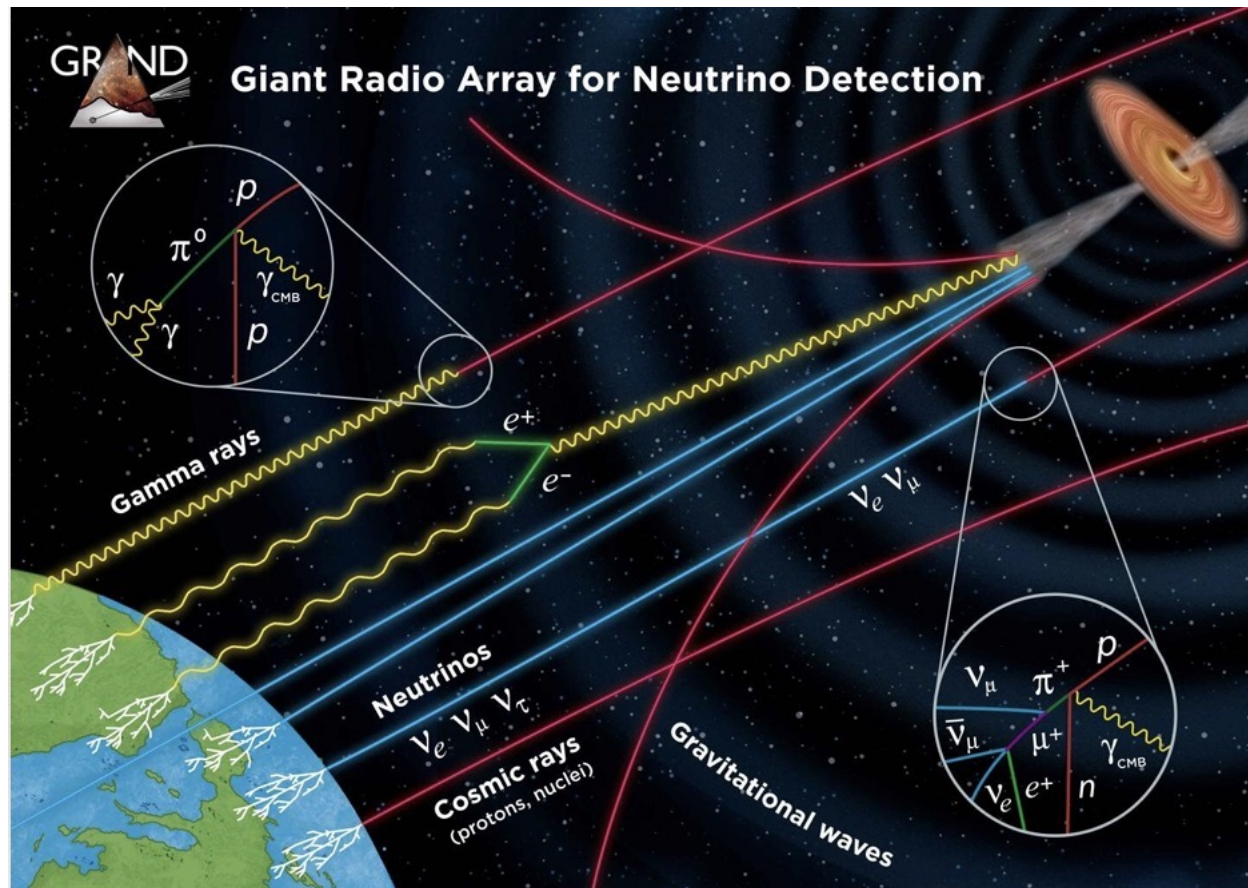
Astroparticule et Cosmologie, CNRS, Université de Paris Cité, F-75013 Paris, France



Outline

- Local cosmic ray measurement and modelling
- Production of diffuse emission and measurement
- Modelling of the diffuse gamma-ray and neutrino flux
- Conclusion

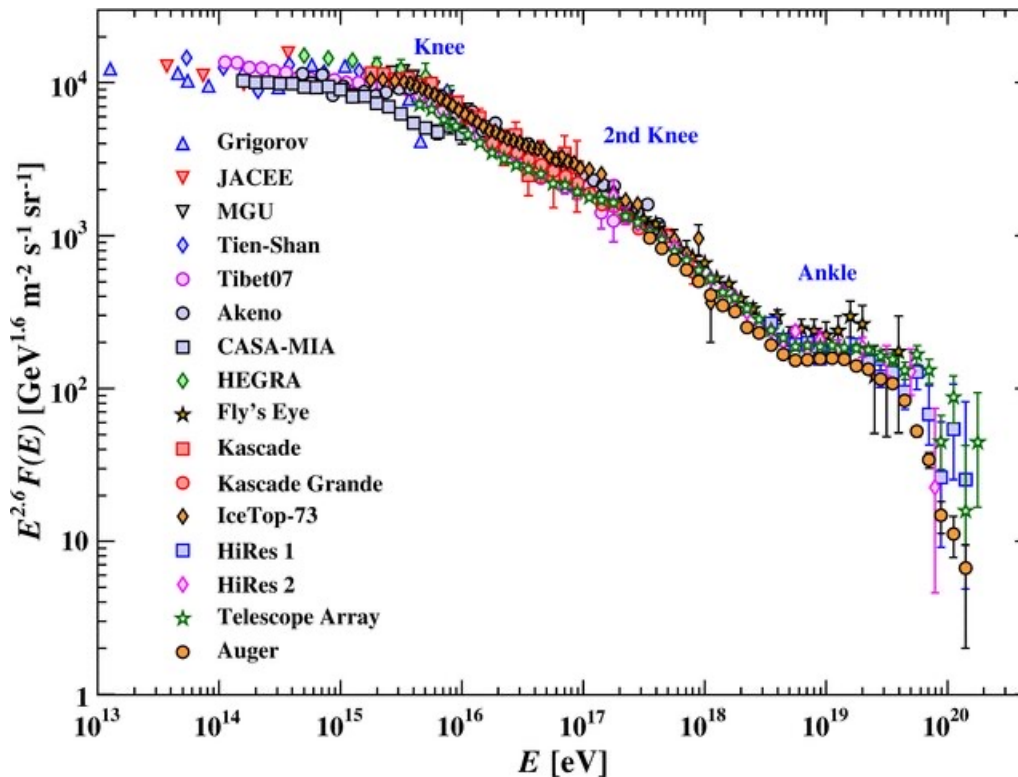
Multi-messenger signals



Credit: ©Science China Press.

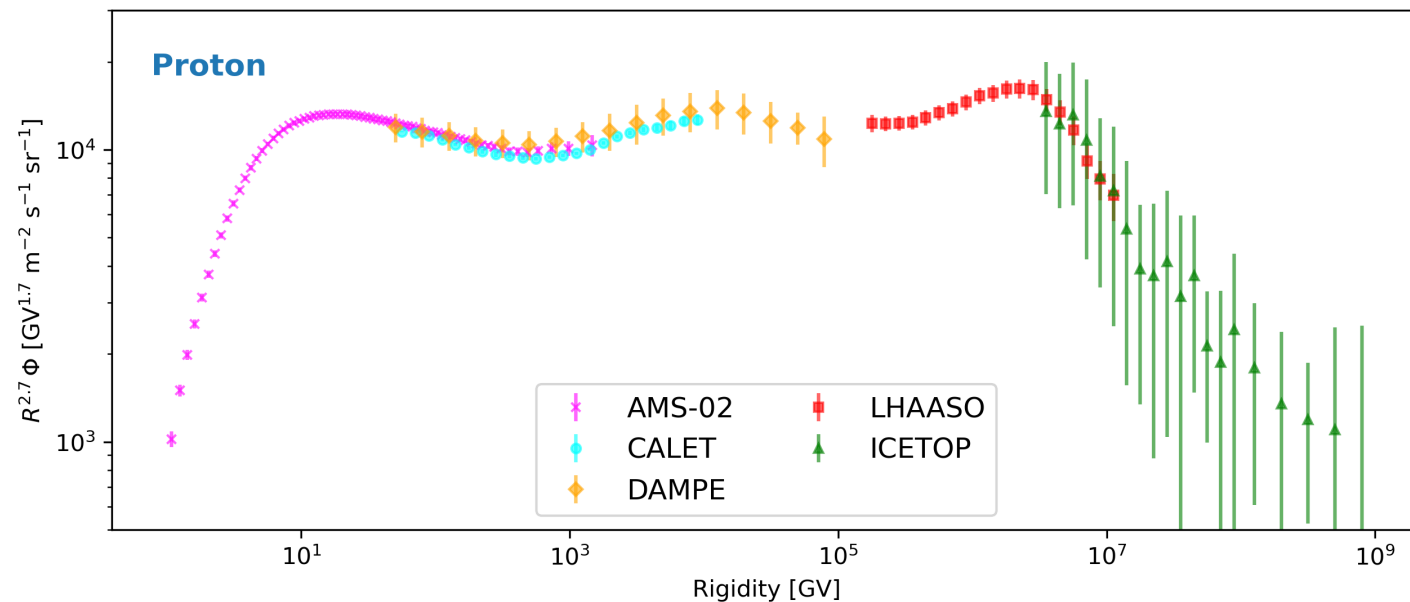
Cosmic Rays

- Cosmic rays (CR) are high energy particles (mostly protons + heavier nuclei). The spectrum of CR covers a wide range of energies, from GeV and up to 10^{20} eV.

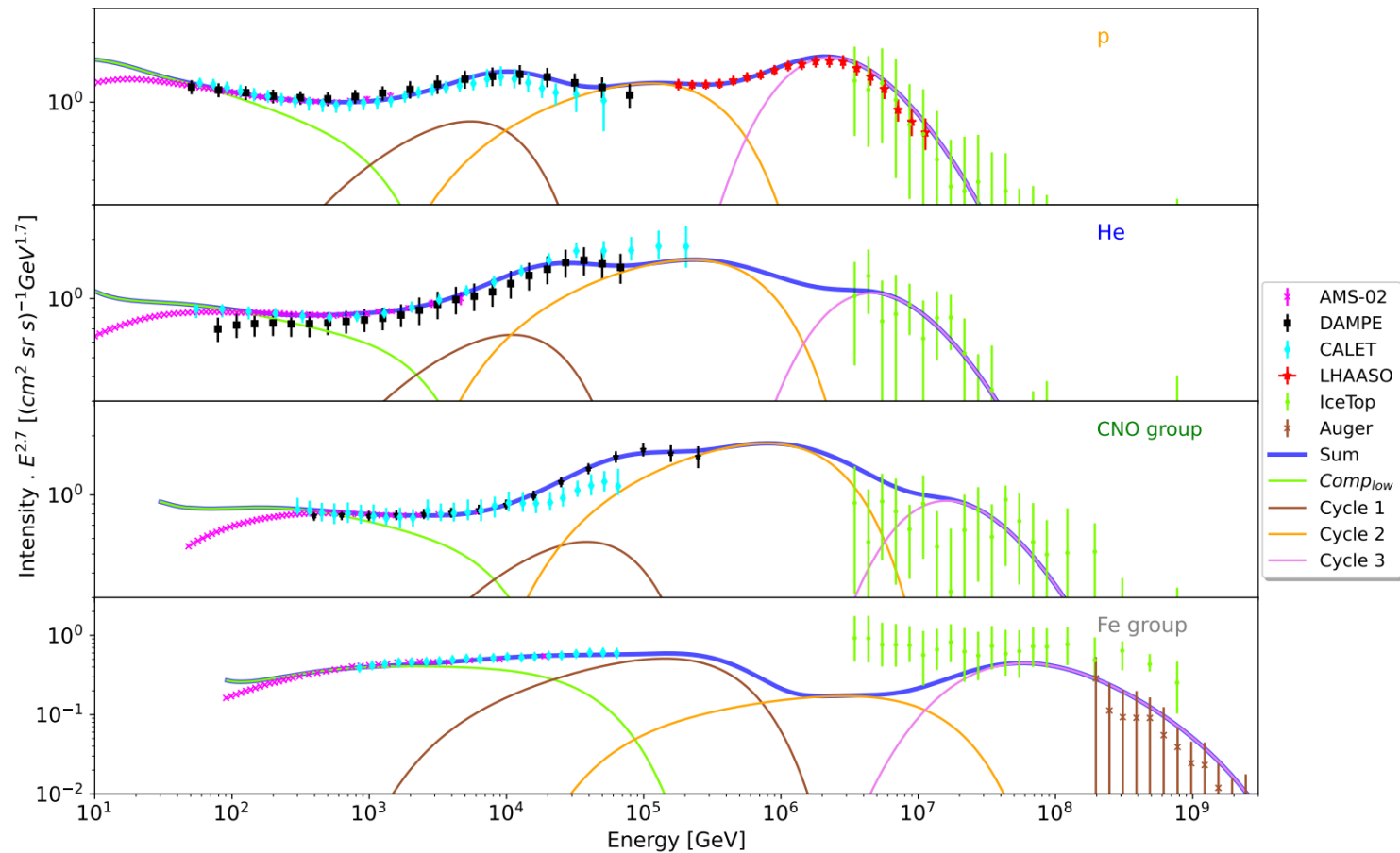


anabashi M et al.
(Particle Data Group)
2018

- The local cosmic ray can be modelled as different source populations (SNR, AGN, PWN...)
- The spectra in rigidity ($\mathcal{R} = \frac{pc}{Ze}$) of different elemental groups only differs in the relative normalization



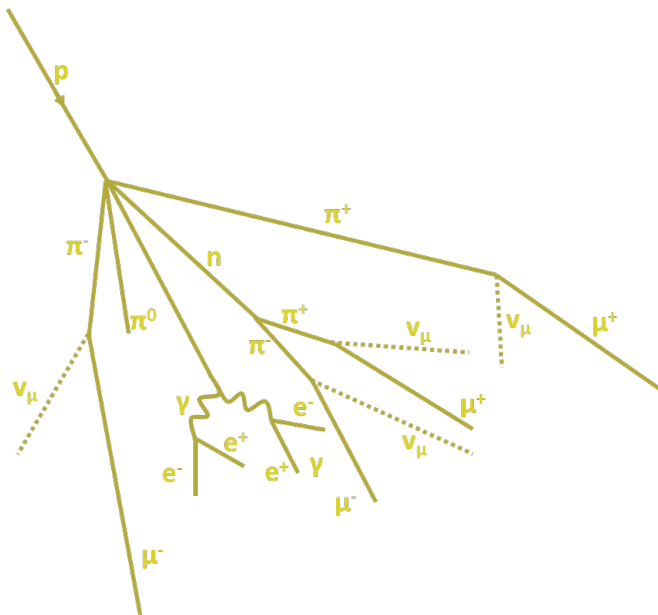
Modelling of the local CR



The production of diffuse emissions

- As CR travel through the space, it will interact with interstellar medium and produce gamma rays and neutrinos

- Hadronic



$$I_{\gamma}(E, l, b) = \sum_{A, A'} \int_0^{\infty} ds n_{\text{gas}}^A(\rho, z) e^{-\tau(s, E)} \int_E^{\infty} dE' \frac{d\sigma^{A' A \rightarrow X\gamma}(E', E)}{dE} I_{A'}(E', \rho, z),$$

- Leptonic

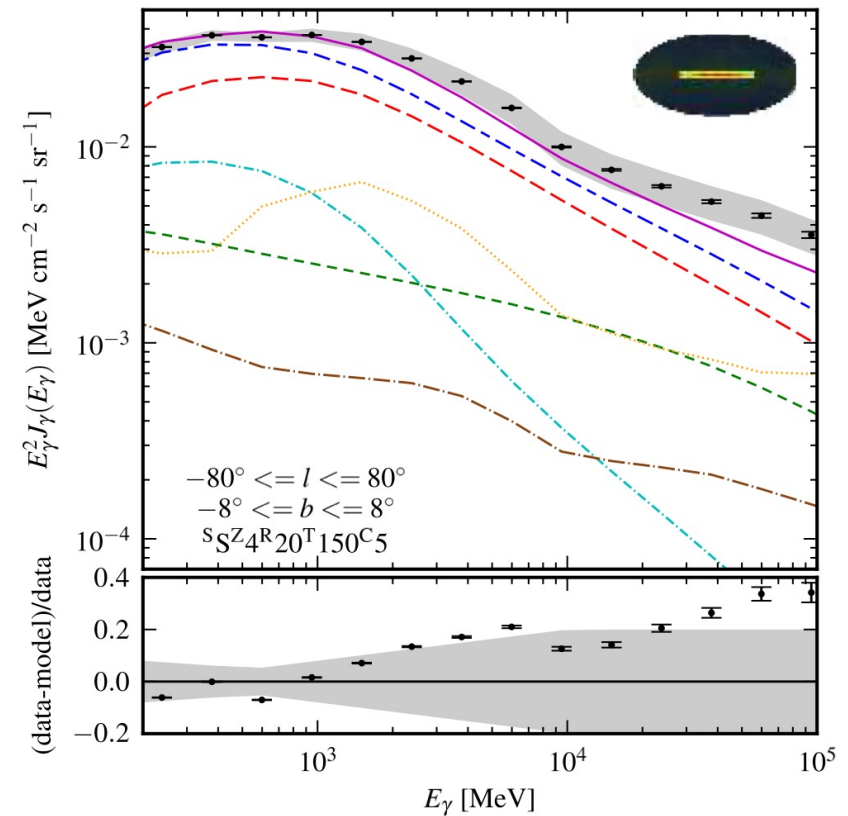
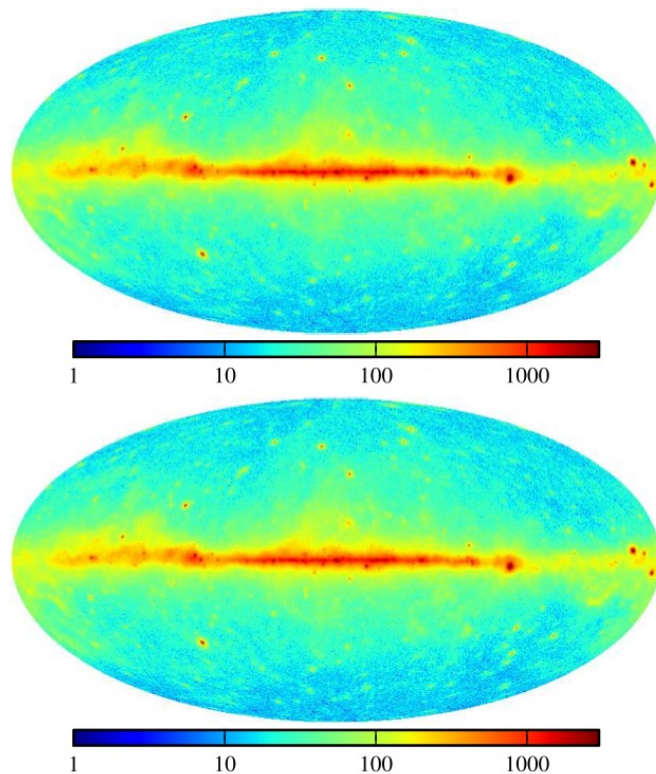
Inverse Compton:

Energetic CR electrons scatter low-energy background photons.

Bremsstrahlung:

Energetic CR electrons emit gamma rays when deflected by interstellar gas nuclei.

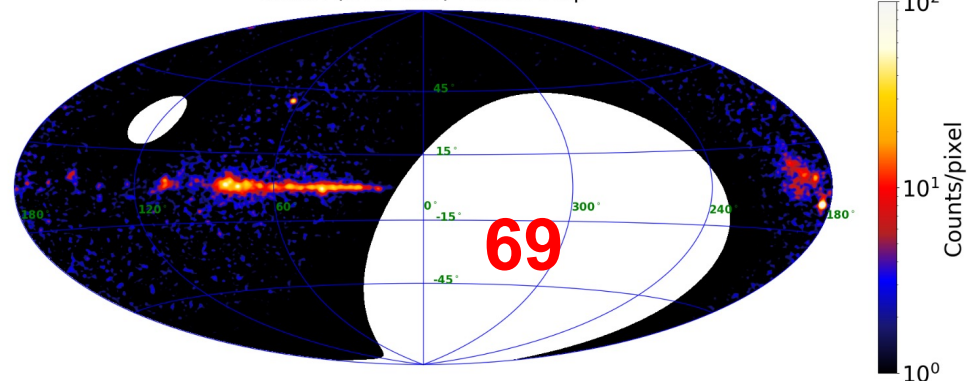
Diffuse gamma from Galaxy



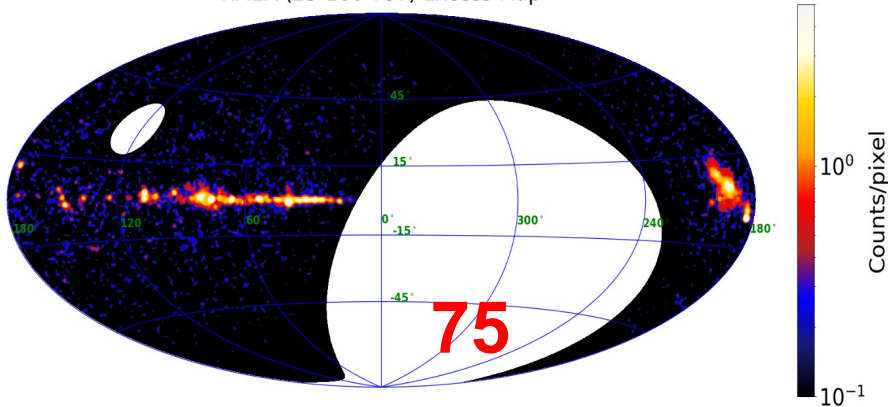
1 LHAASO catalog

- **90** in 1st LHAASO sources.
- **32** new discoveries
- **43** UHE

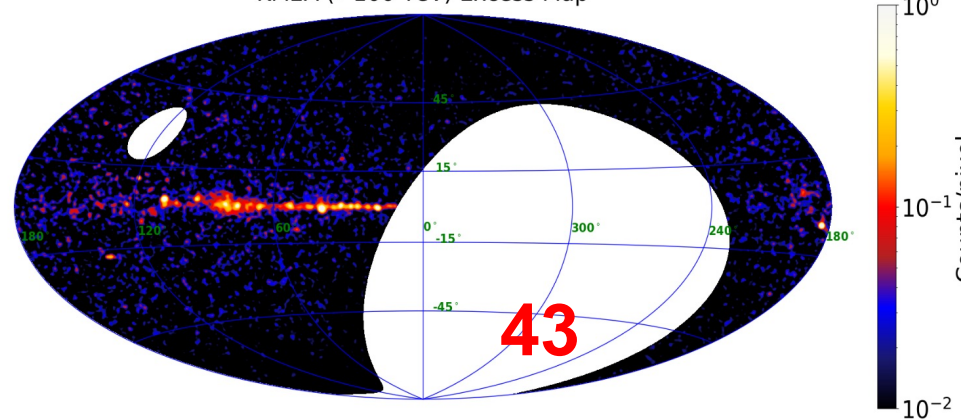
WCDA (1-25 TeV) Excess Map



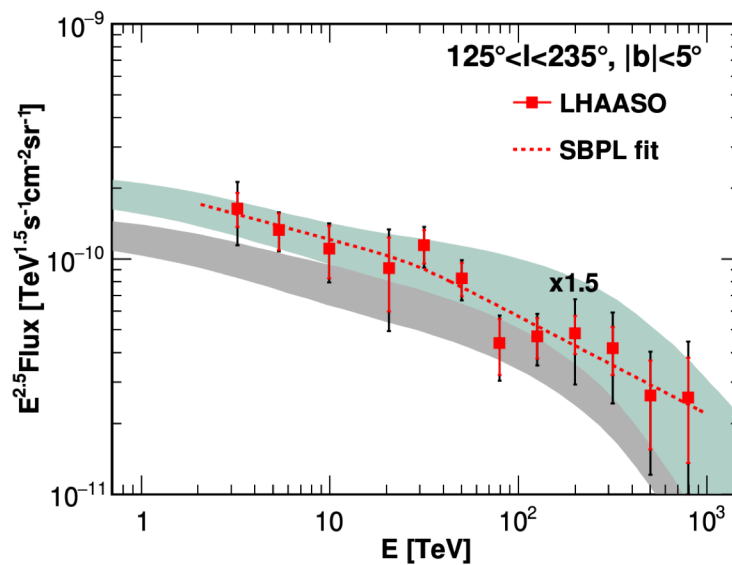
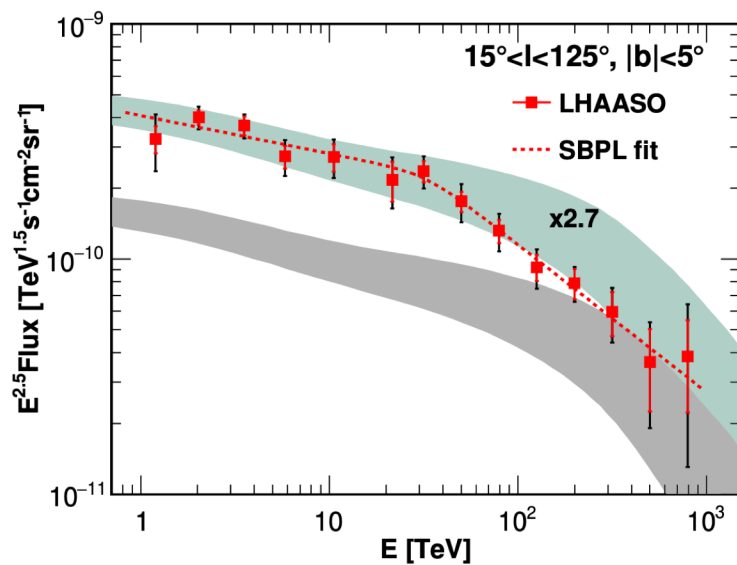
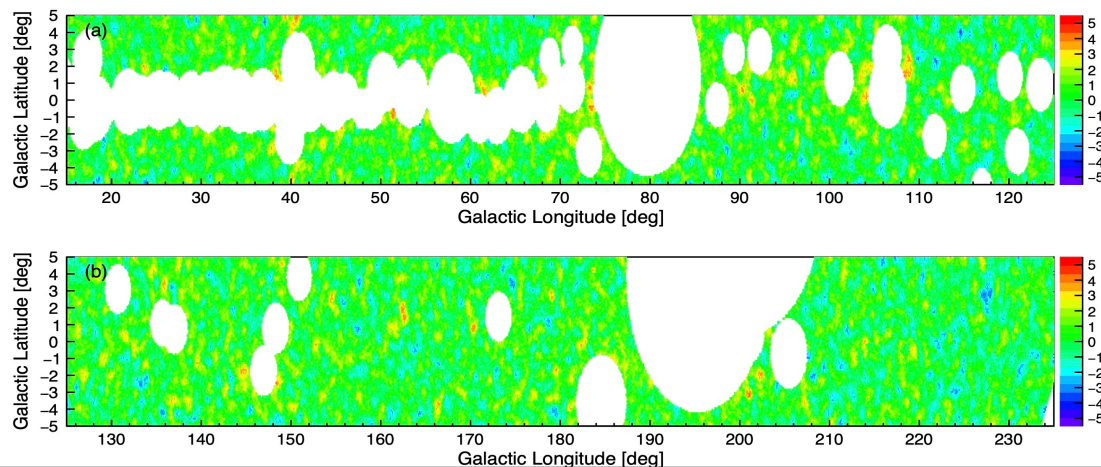
KM2A (25-100 TeV) Excess Map



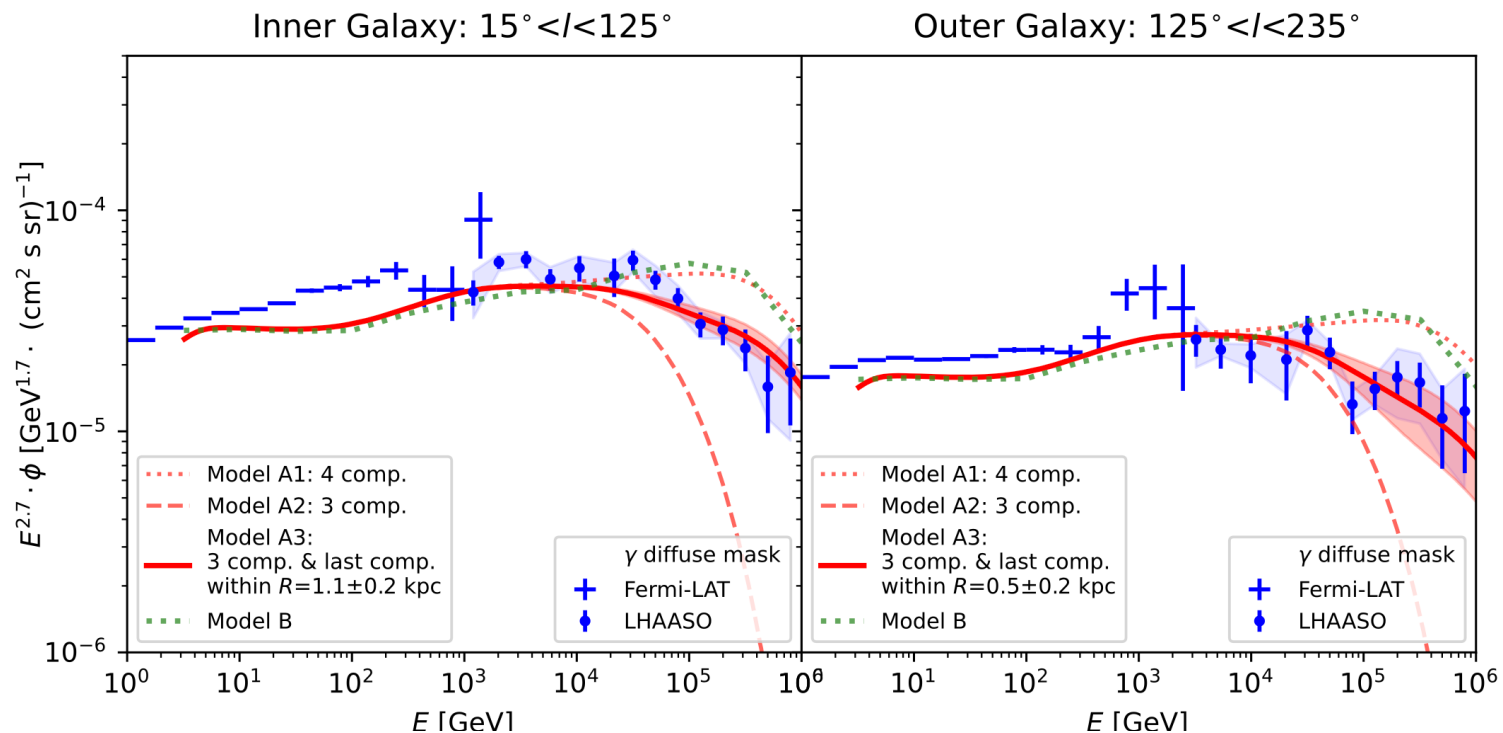
KM2A (>100 TeV) Excess Map



LHAASO masked diffuse



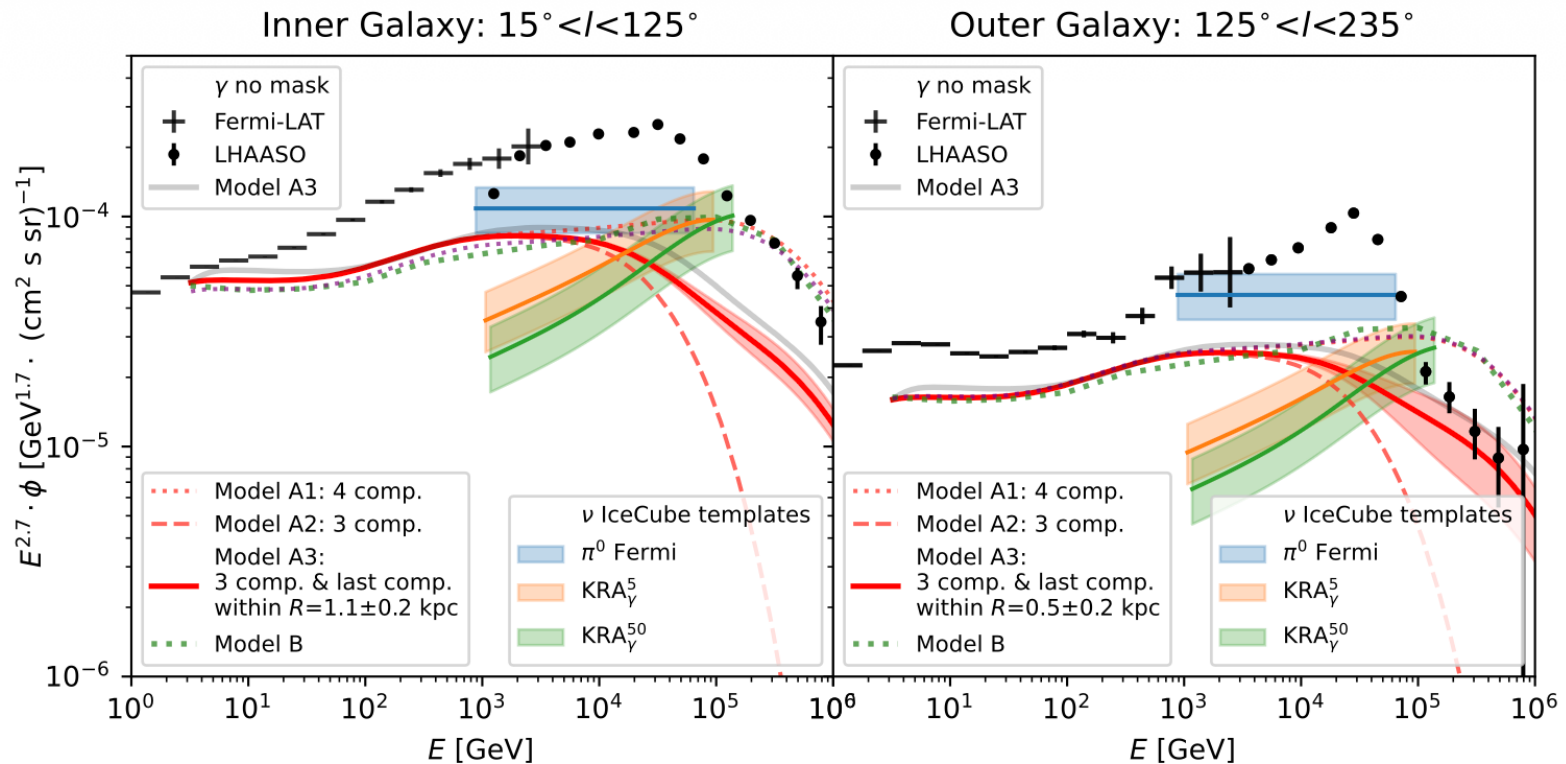
Modelling of the gamma-ray spectrum



Local PeV source?

- The hadronic model based on the locally measured CR spectrum agrees with Fermi-LAT and LHAASO diffuse gamma-ray data up to 30 TeV
- Above 100 TeV, the model significantly overpredicts the LHAASO diffuse gamma-ray flux. This could be an indication that the knee may be a local feature caused by some rare and local sources
- A toy model with a local PeV CR bubble of size 1.1 kpc in inner galaxy and 0.5 kpc in outer galaxy, could reproduce the LHAASO data

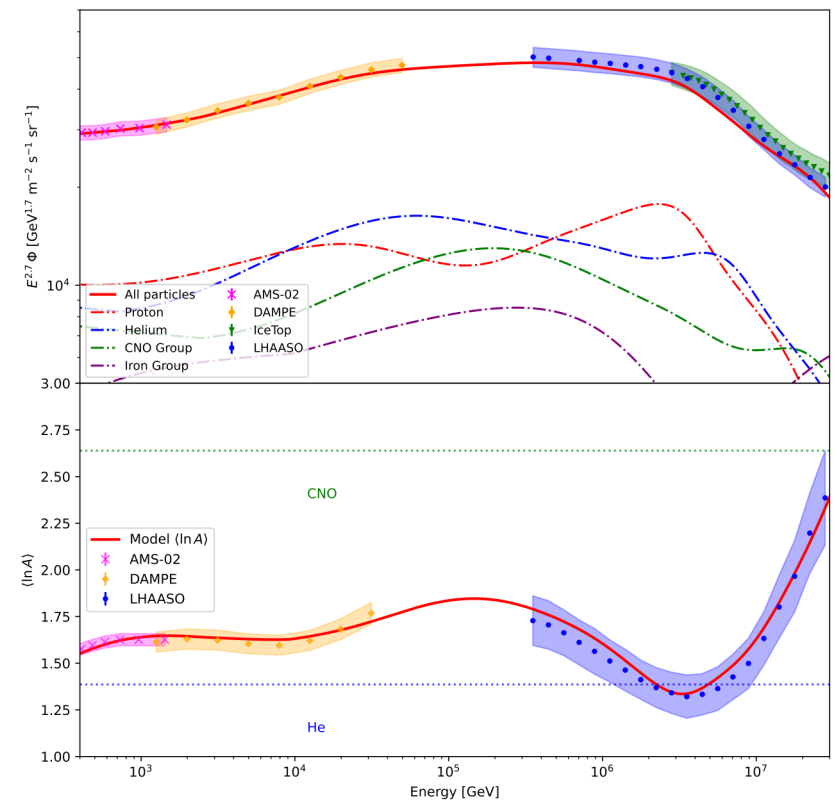
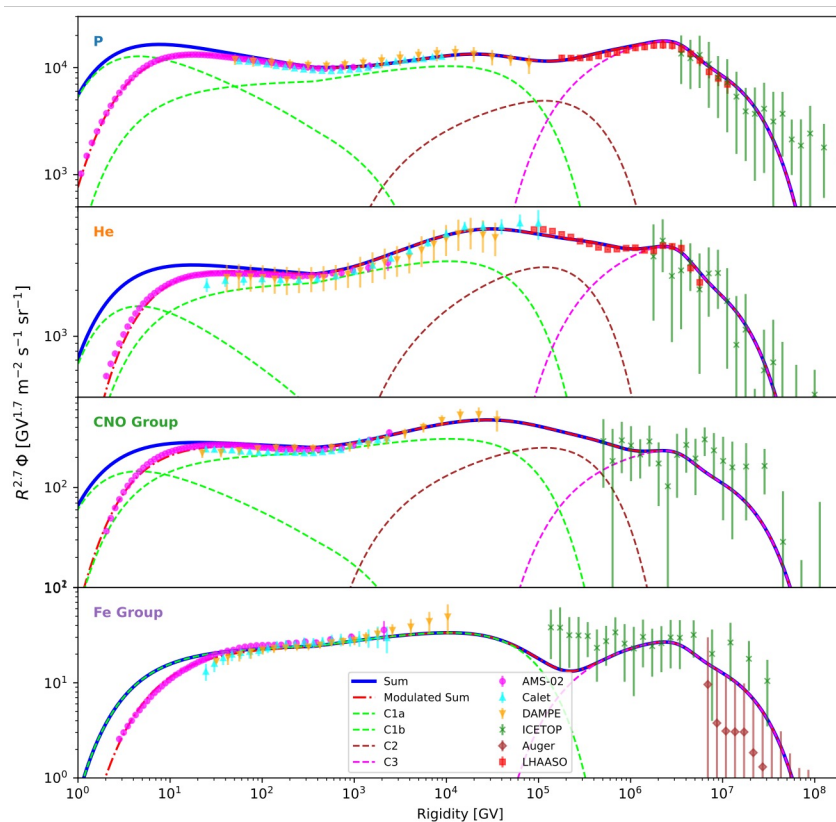
Neutrino spectrum



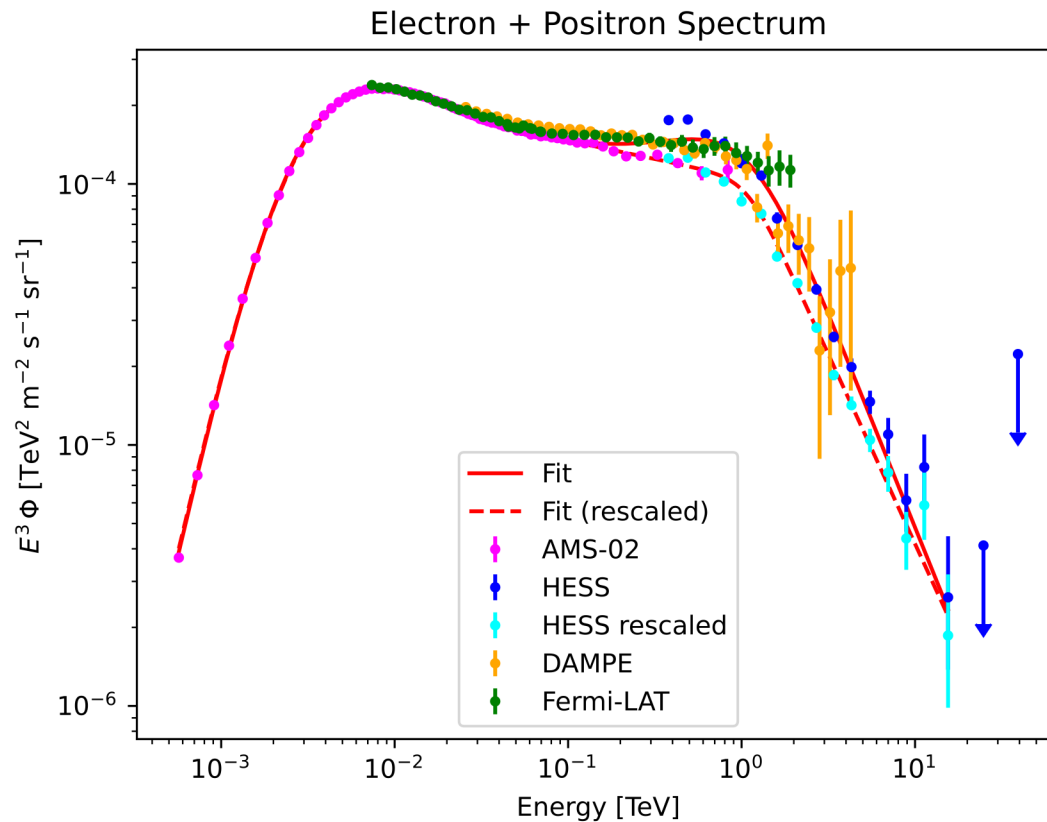
Update of the model

With new helium data from LHAASO above 0.1 PeV, we updated the fit of the model

We also add the first break as a propagation effect according to AMS-02 data



Leptonic contribution



Conclusion

- Local cosmic-ray measurements provide the input for modelling Galactic diffuse gamma-ray and neutrino emission.
- The last population with a limited size of 1.1 kpc can reproduce the LHAASO data, could be an implication of local source contributed to the knee
- We are updating the model with new LHAASO helium data and adding leptonic gamma-ray components. We also test different gradients for different source populations.