Minimal Model for Cosmic Rays and Neutrinos

Michael Kachelrieß

NTNU, Trondheim

(No) Poster: Cosmic Ray Signatures of a Local Source

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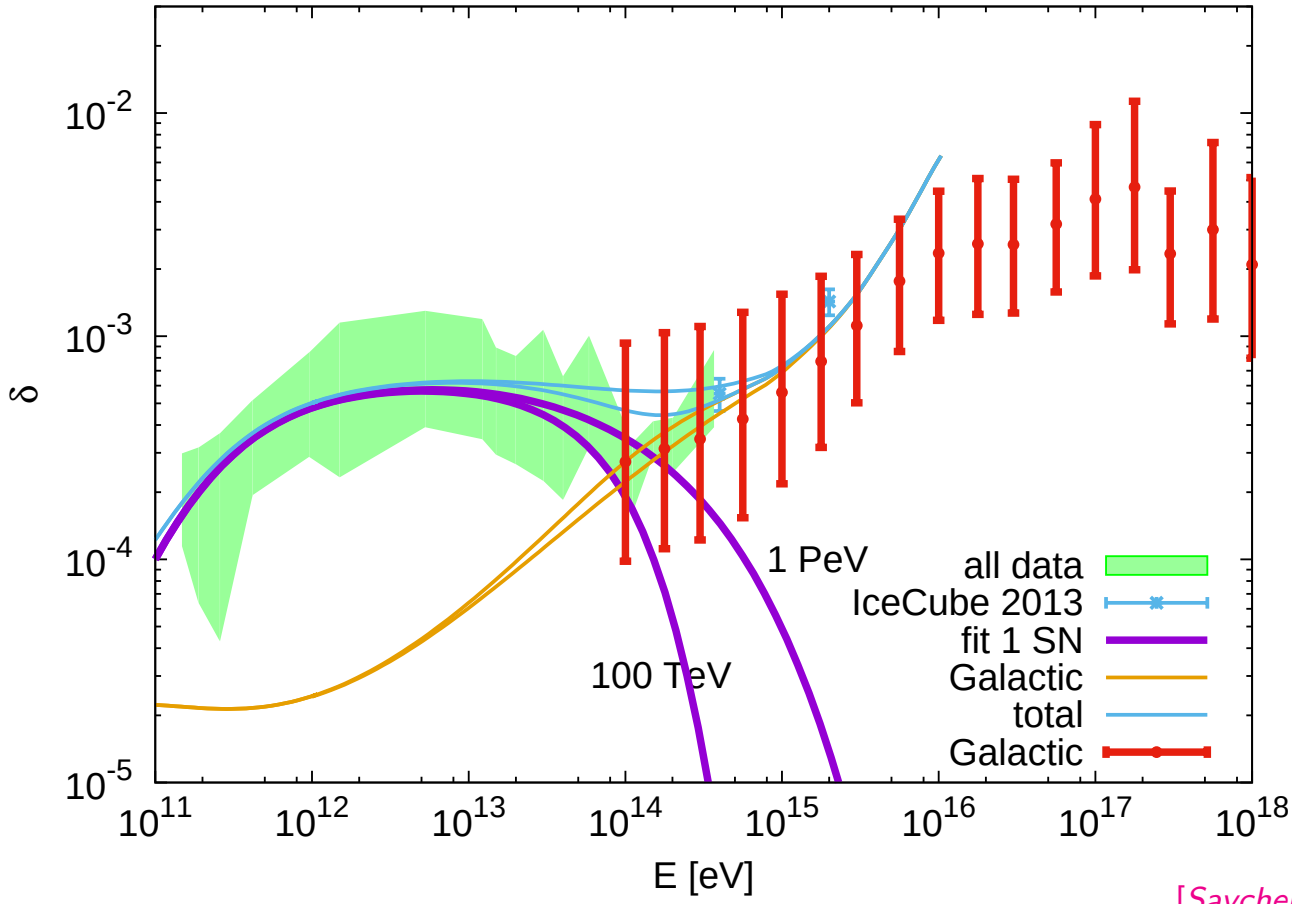
   - amplitude dipole anisotropy $\delta \sim \text{const.}$ at 1–30 TV: $\delta = 3R/T$



[*Savchenko, MK, Semikoz '15*]

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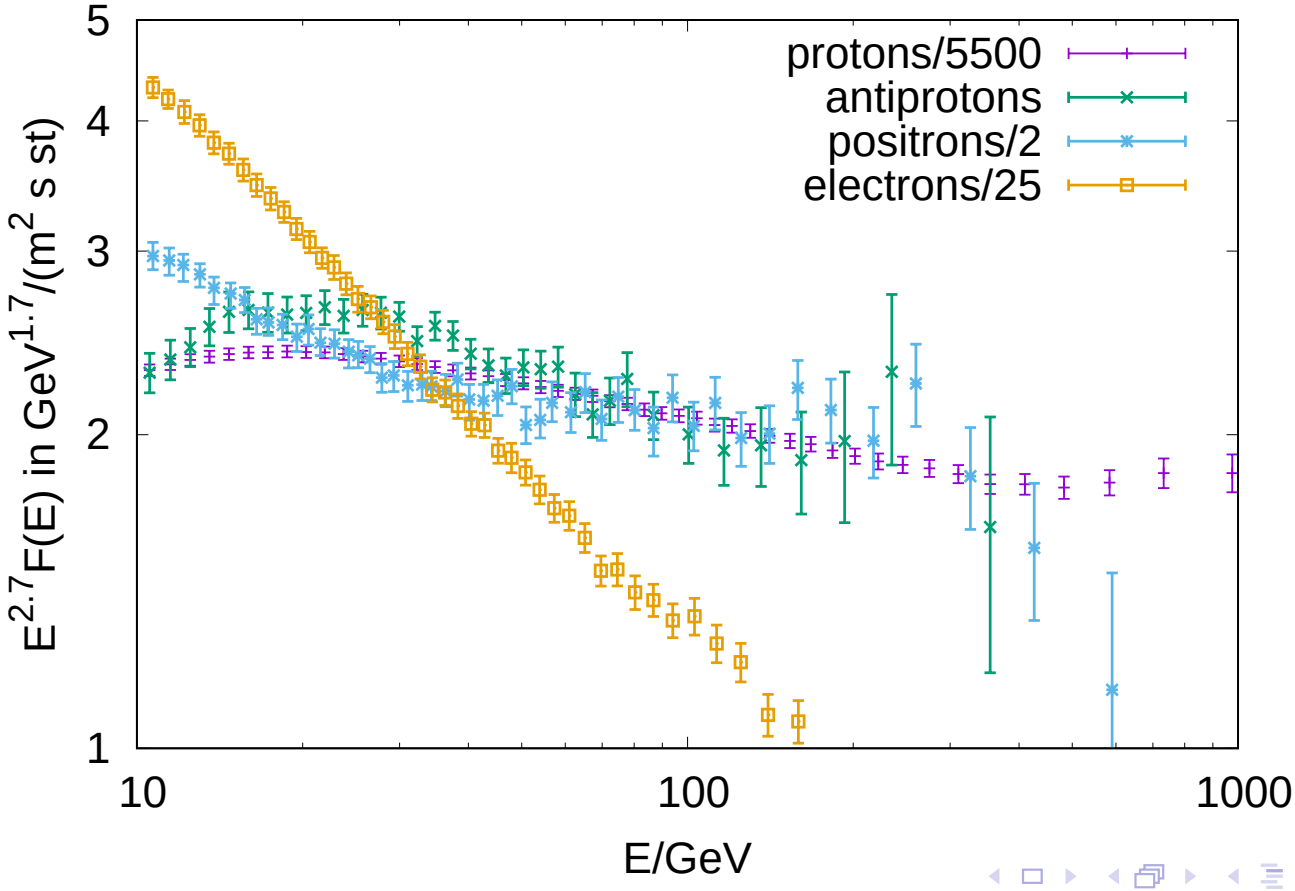

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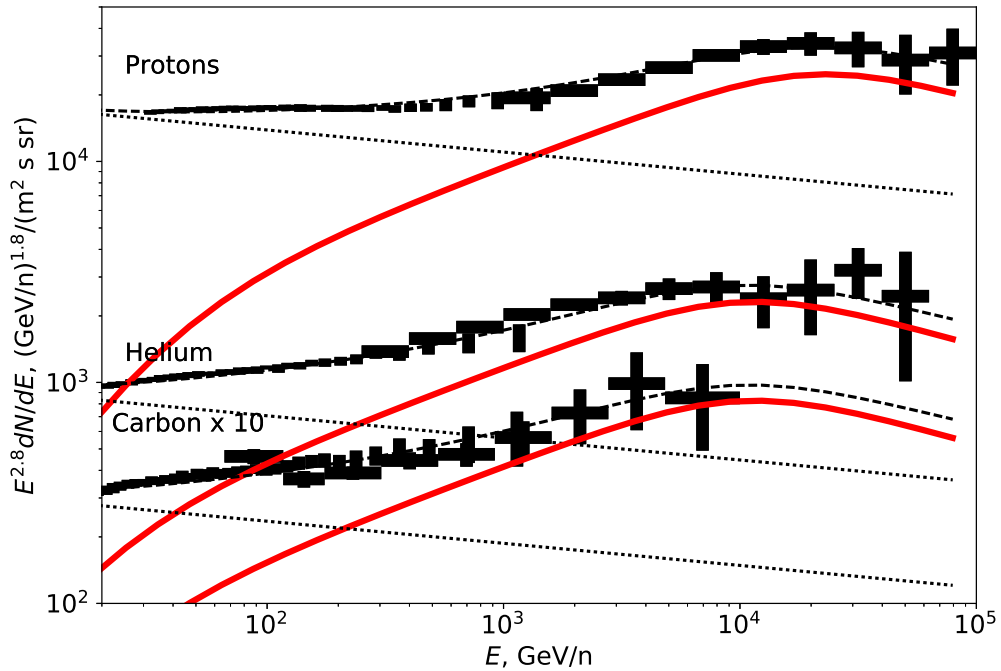

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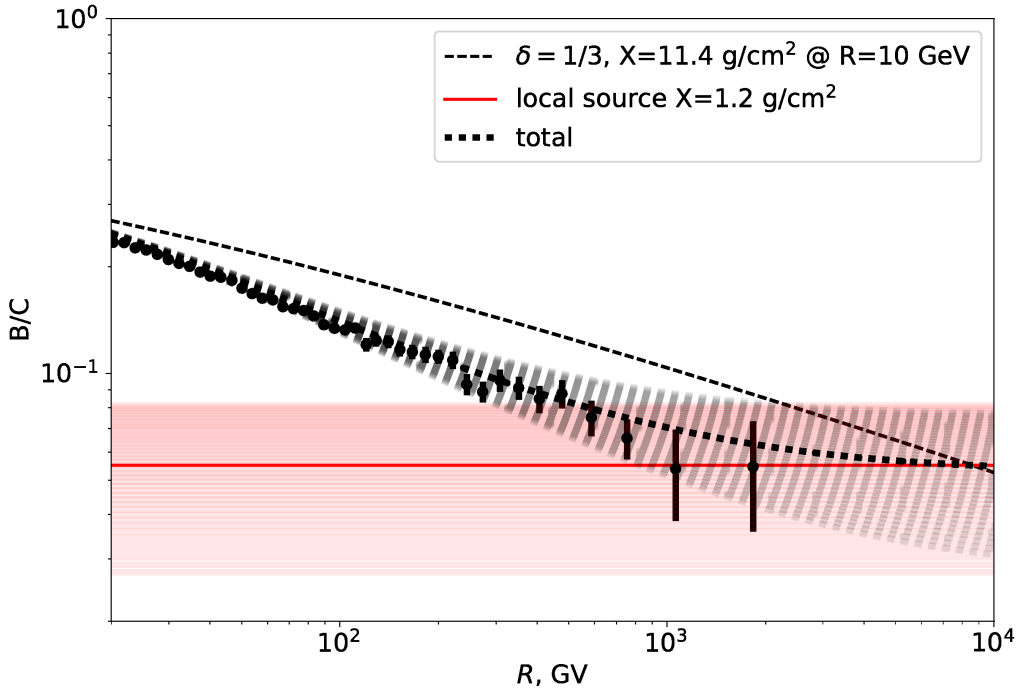

[MK, A.Neronov, D.Semikoz, '15 and arXiv:1710.02321]

Outline of the talk

1. Introduction
   - CR–γ–ν connection
   - elmag. cascades
   - CR composition
   - constraints & wishes
2. Escape model for Galactic CRs
   - main properties
   - neutrinos from starburst galaxies
3. Minimal model for UHECRs and neutrinos

Our aim:

- ⋆ is a single source class responsible for extragalactic CRs, neutrinos and photons?

4. Conclusion

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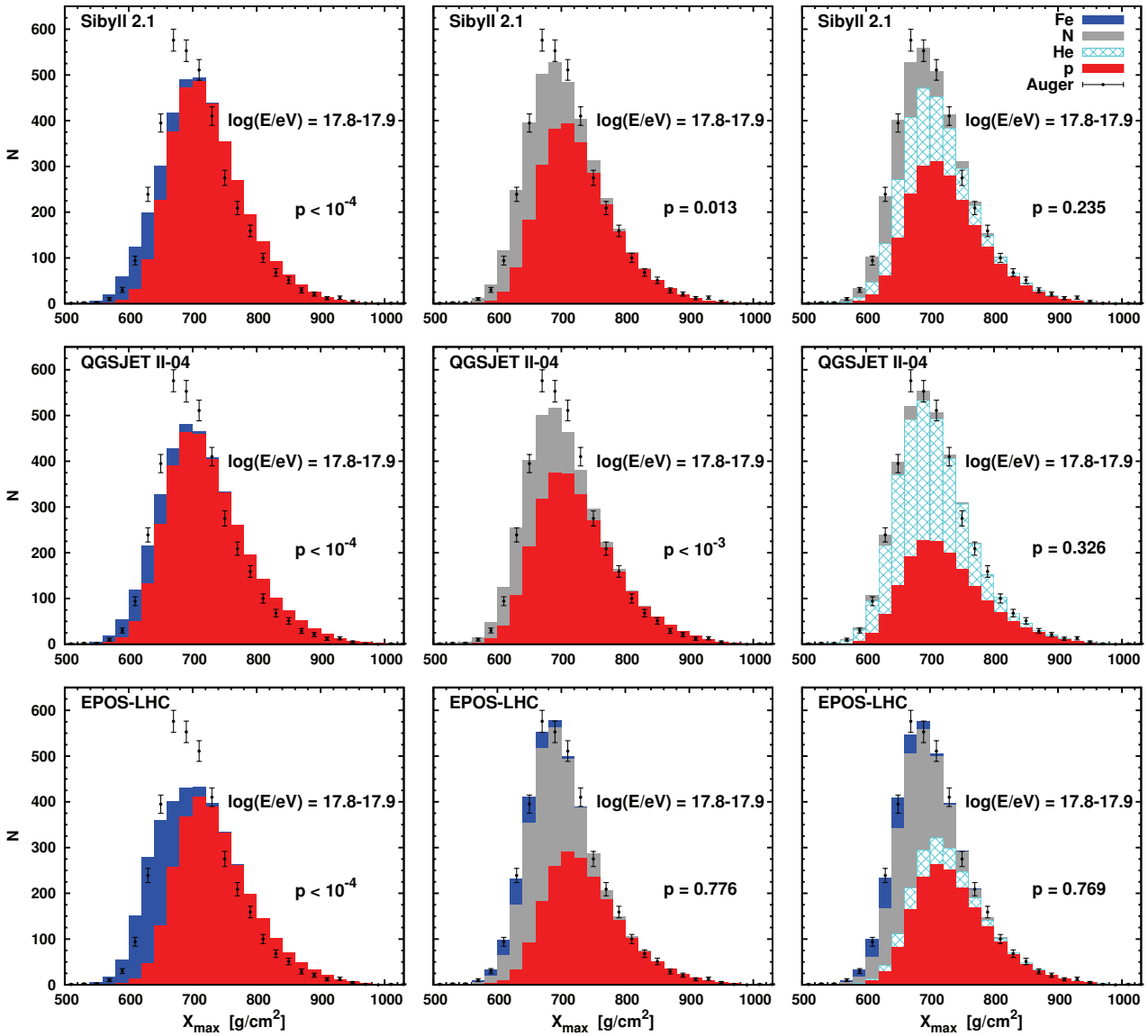
Composition of CRs: Auger

[arXiv:1409.5083]



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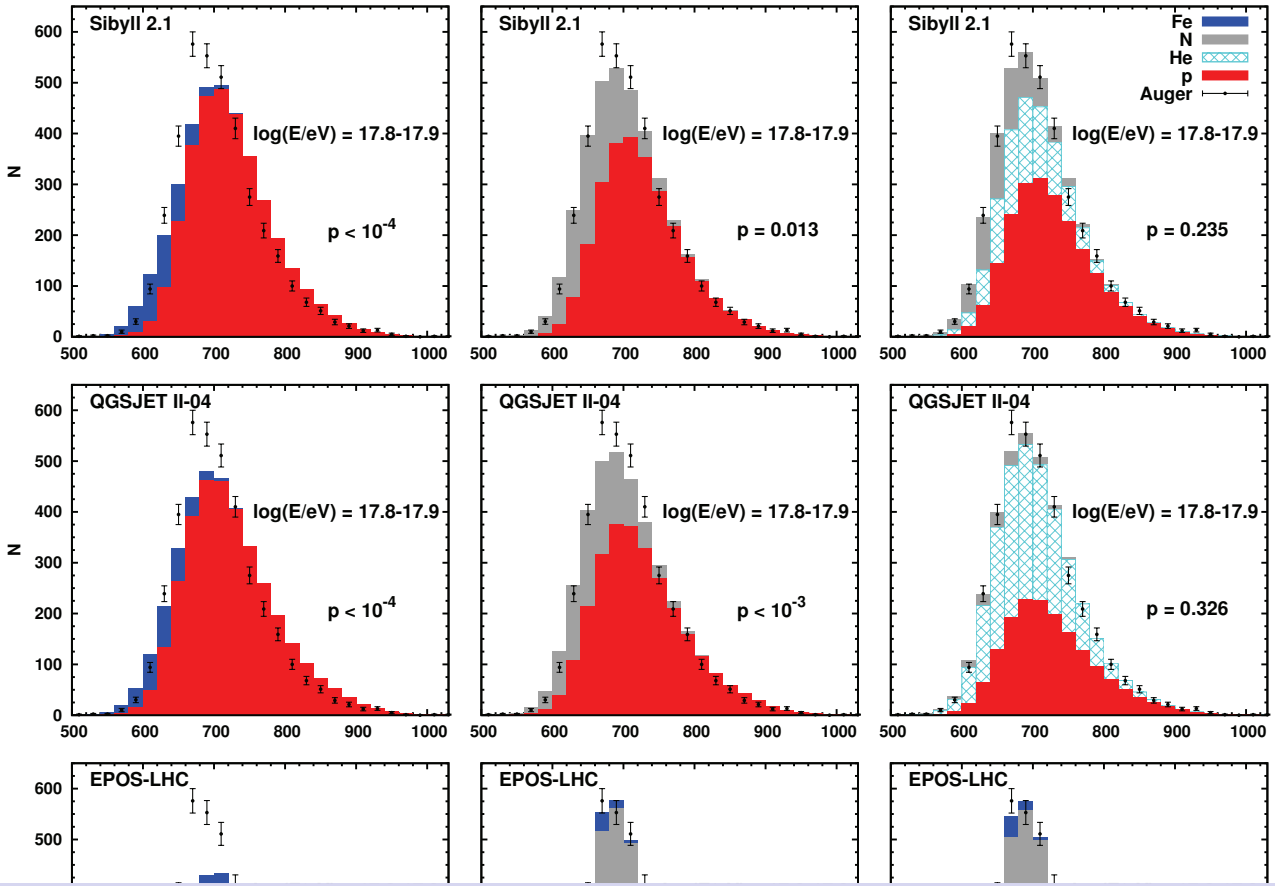

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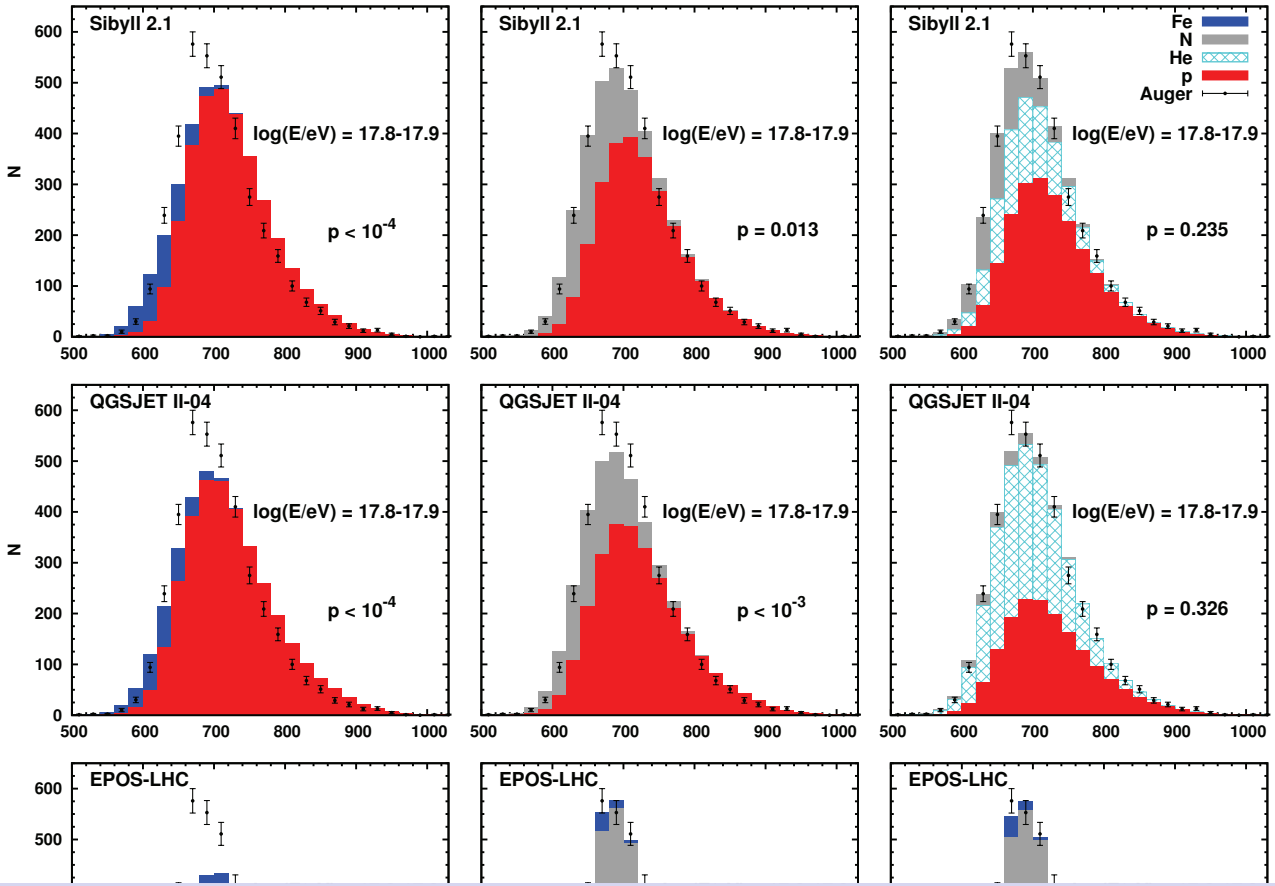

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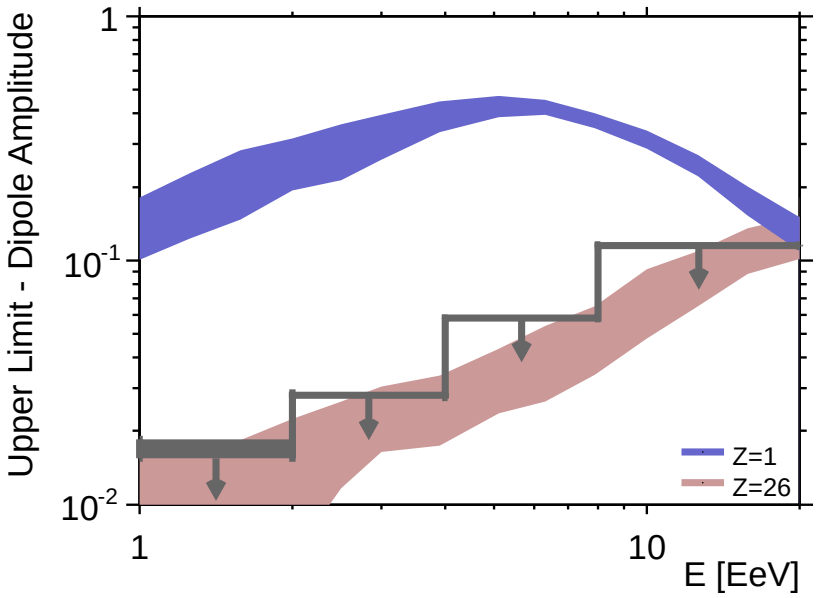
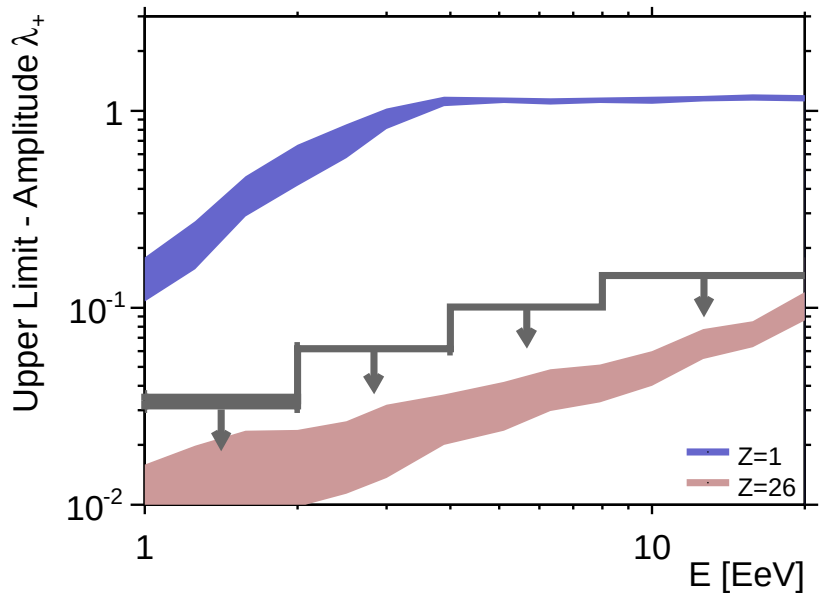
- early transition from Galactic to extragalactic CRs

Transition to extragalactic CRs – anisotropy limits

dipole



quadrupole



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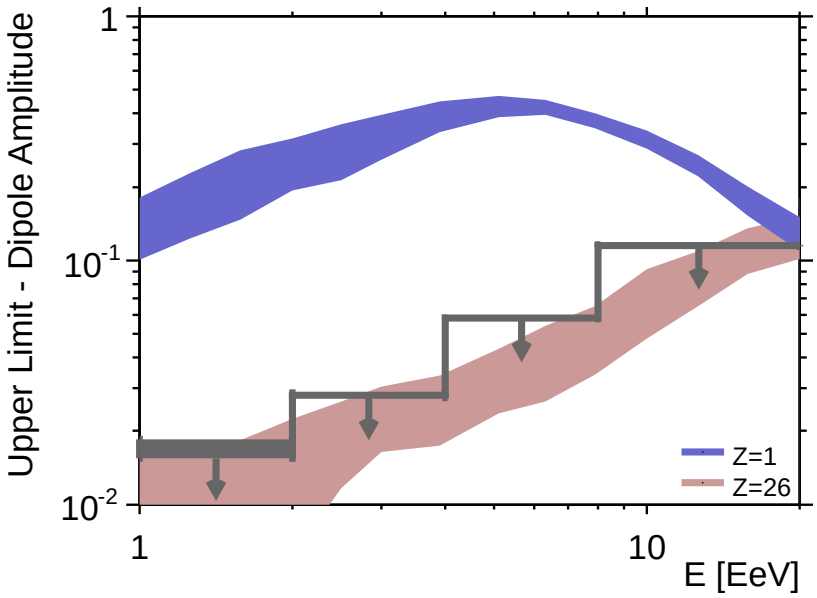

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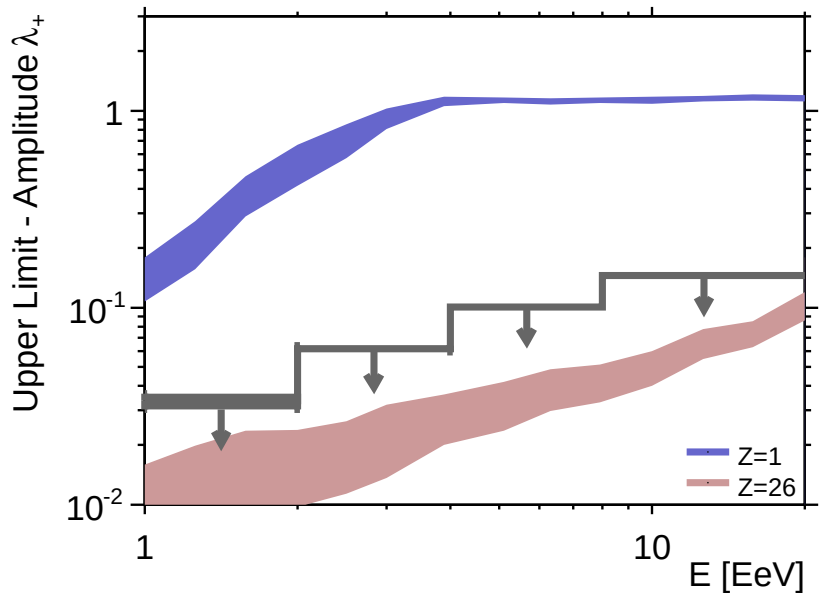

dominant light Galactic composition around $E = 10^{18}$ eV excluded

[Giacinti, MK, Semikoz, Sigl ('12), PAO '13]

Effect of heavier nuclei

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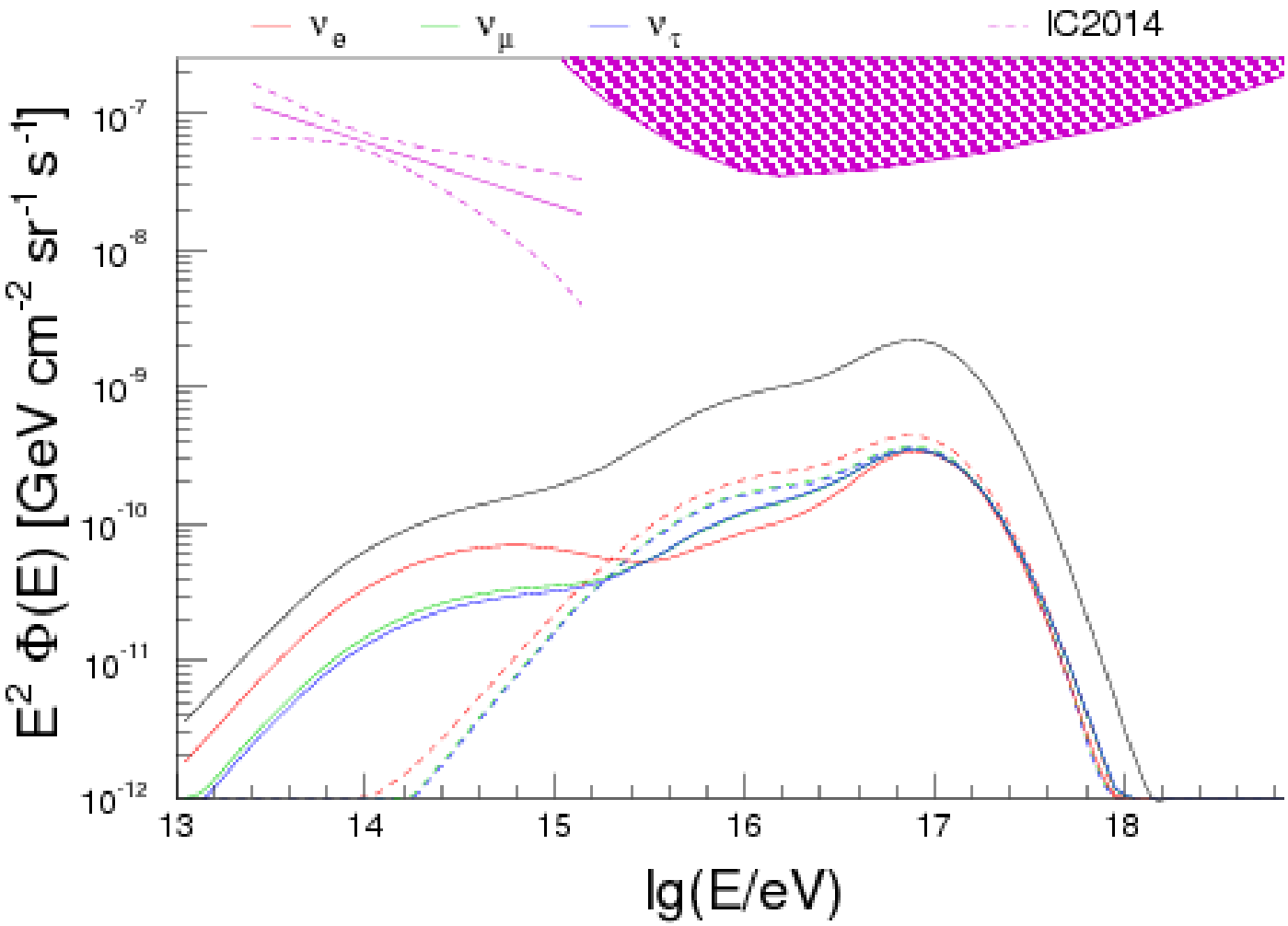
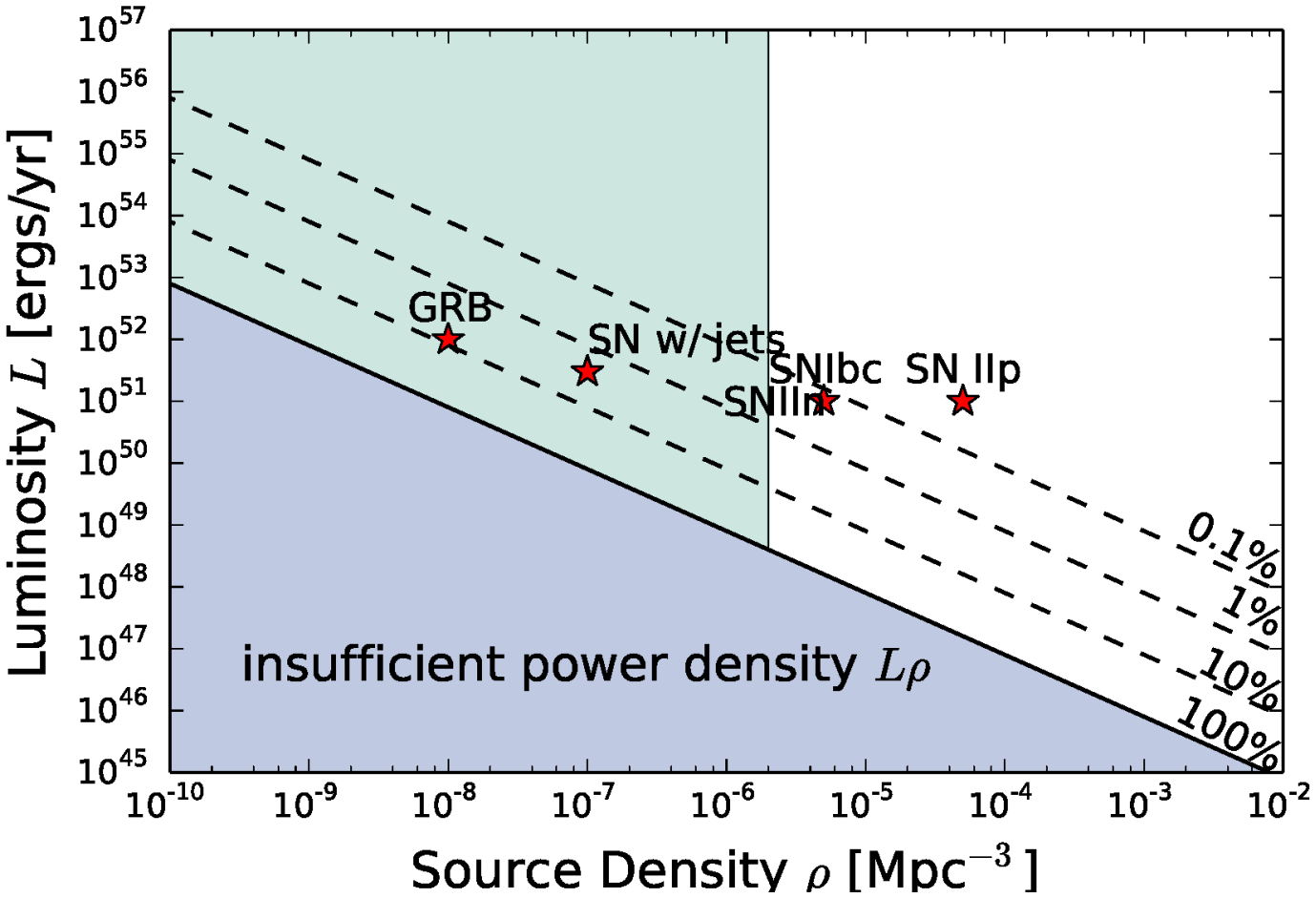
$\Rightarrow$ ν flux is too small, at too high E

ν and mixed composition

[e.g. Unger, Farrar, Anchordoqui '15]



IceCube searches for sources: transient sources



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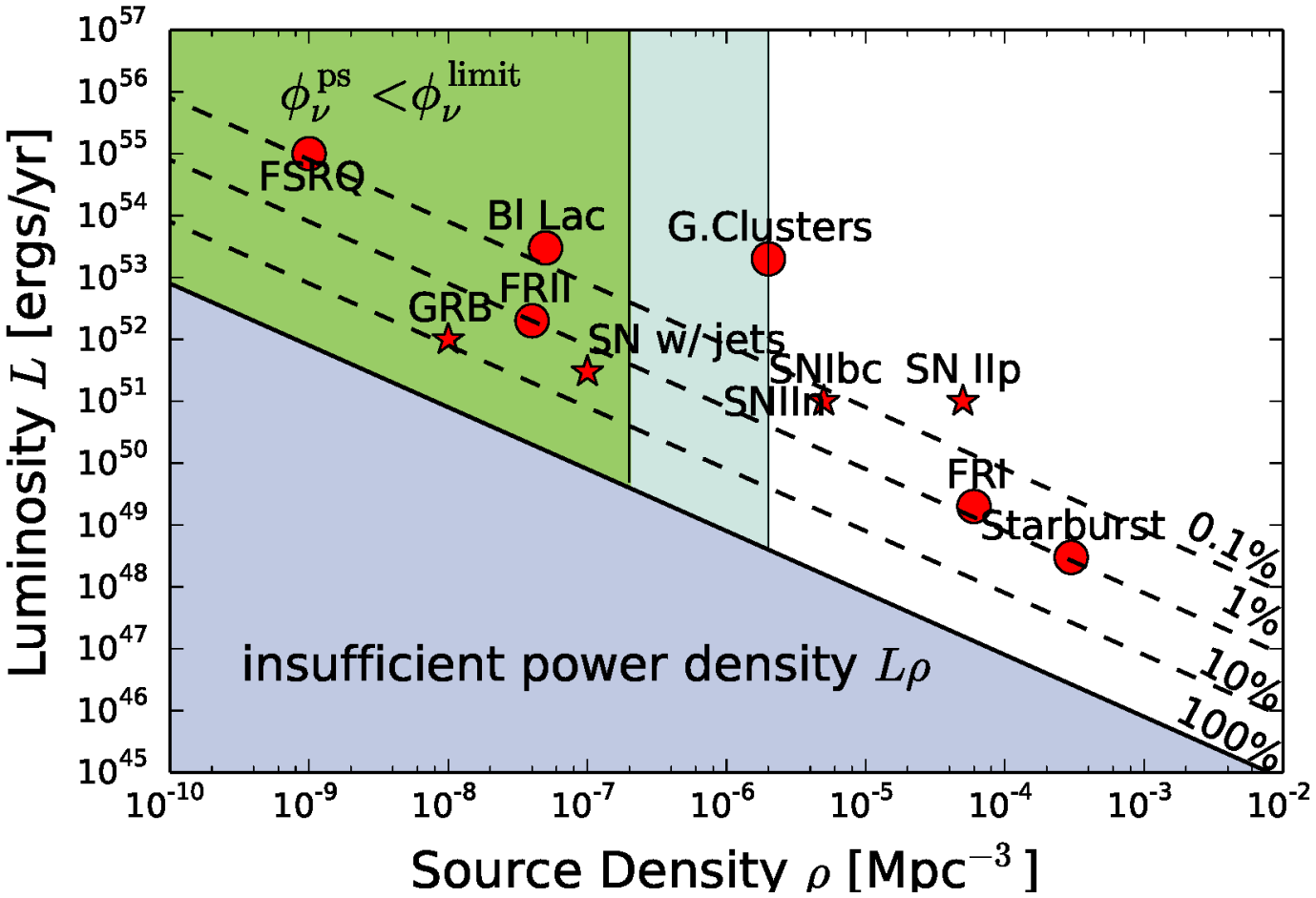
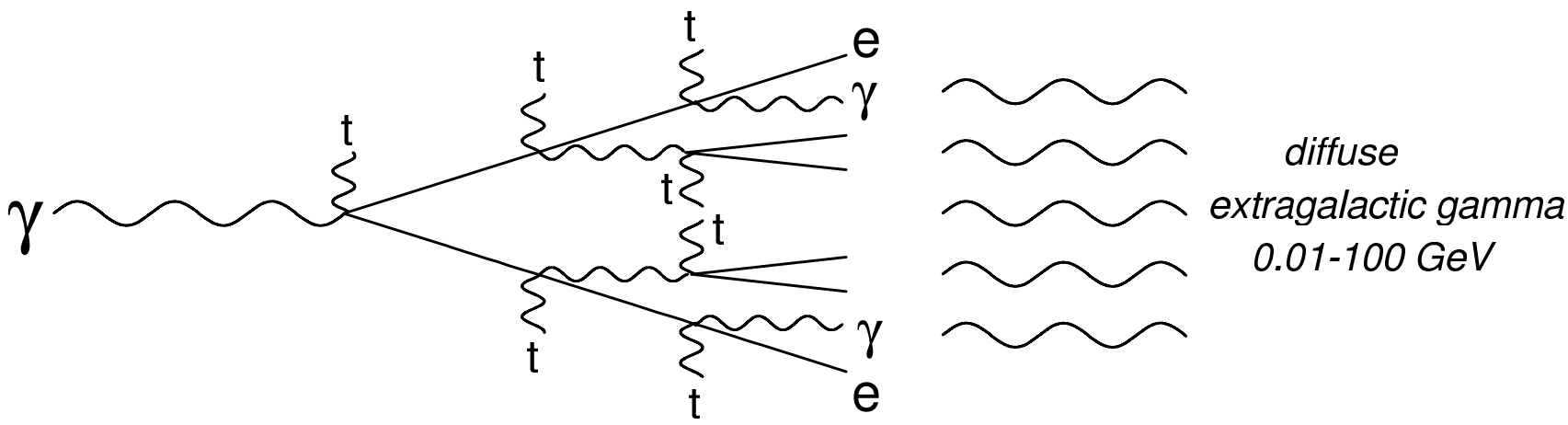
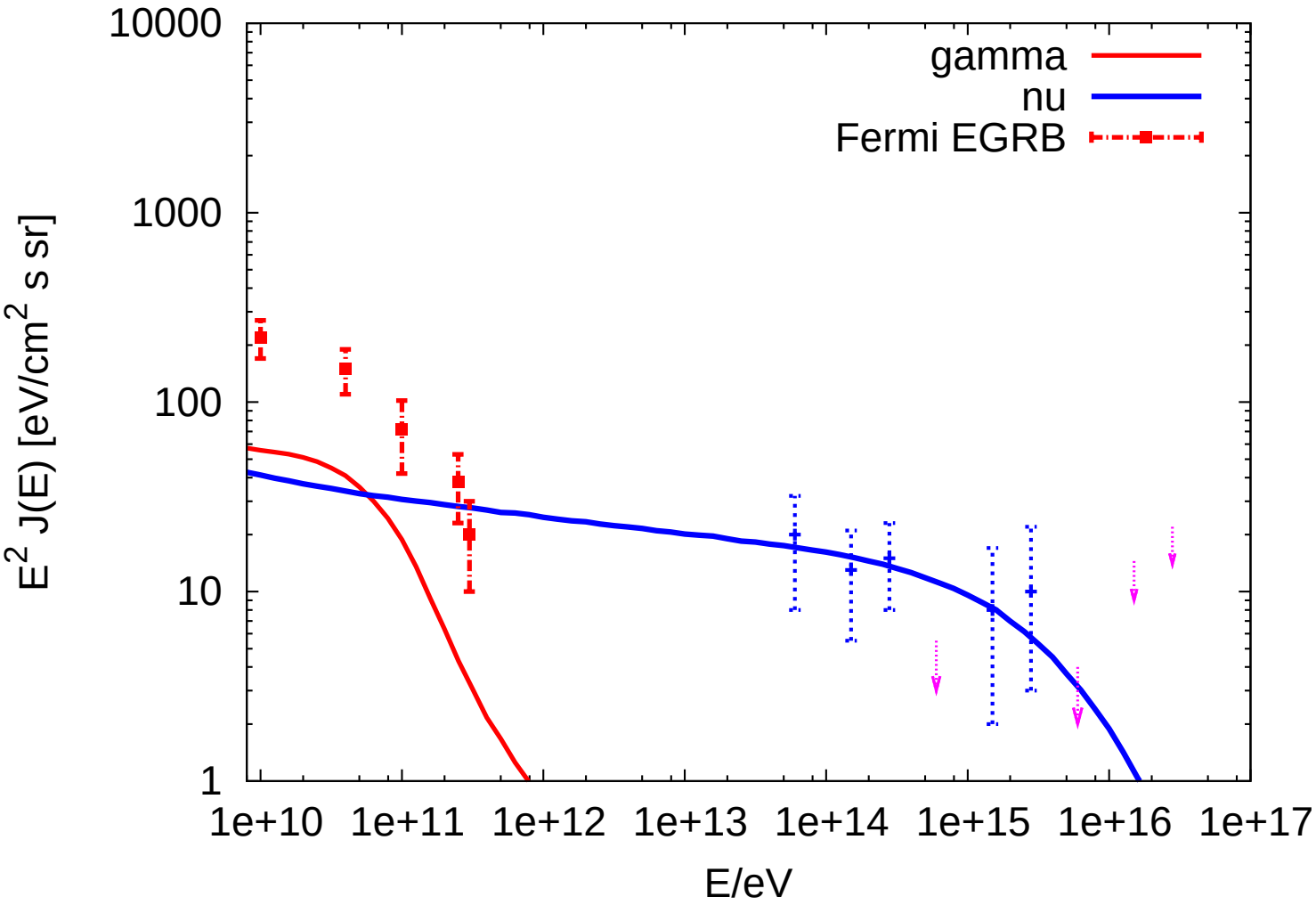


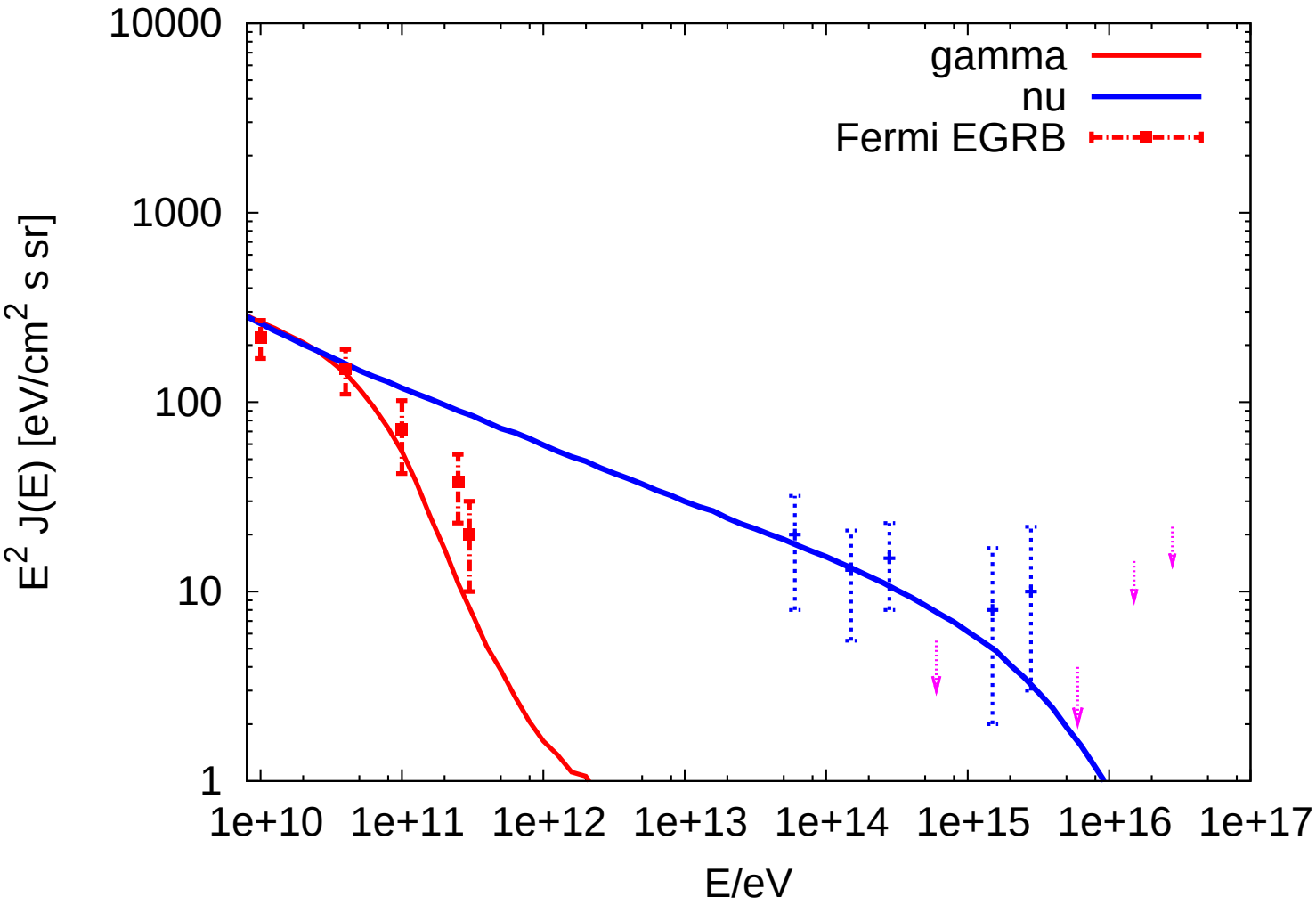
Development of the elmag. cascade:



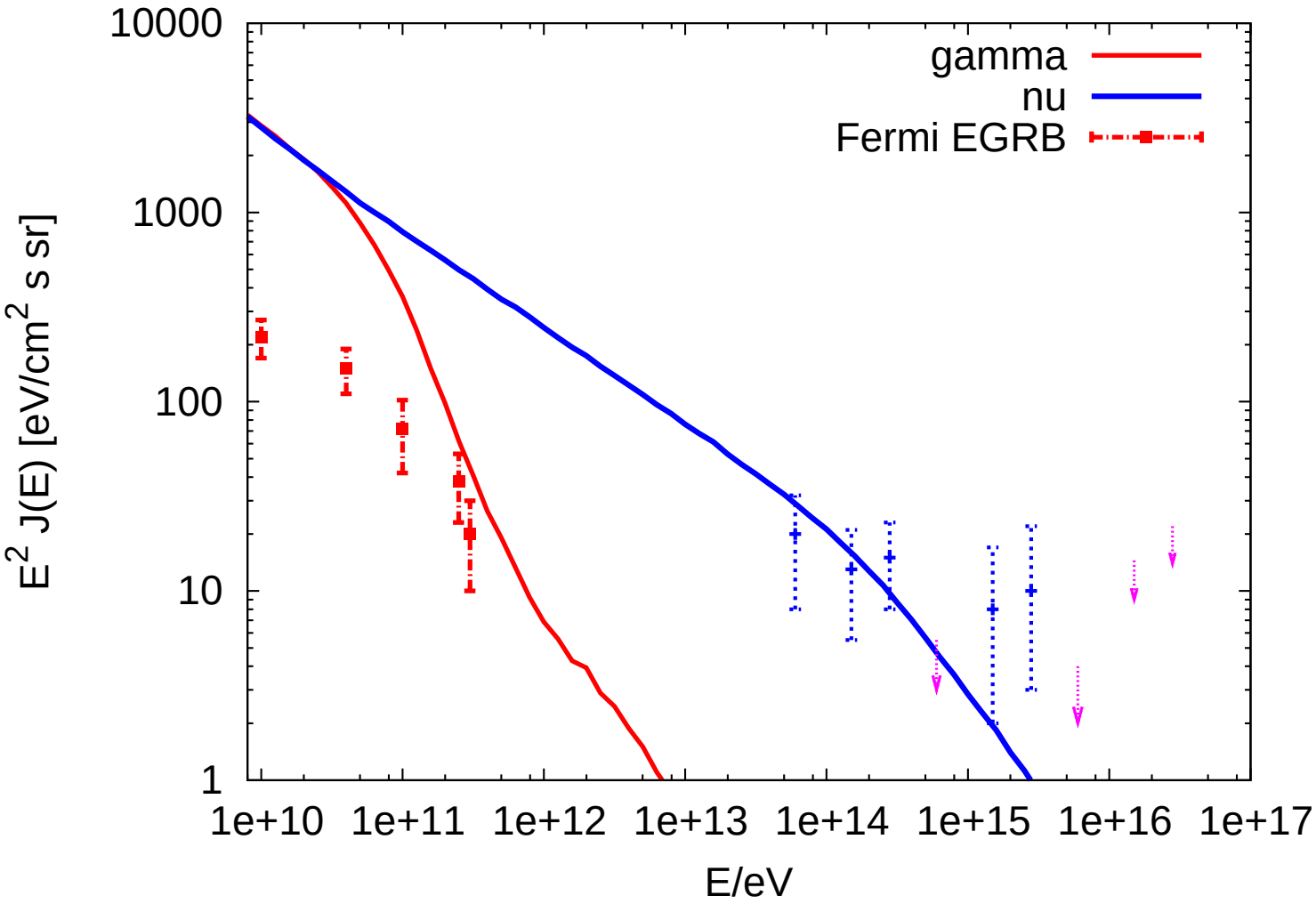
Cascade limit: $\alpha = 2.1$



Cascade limit: $\alpha = 2.3$



Cascade limit: $\alpha = 2.5$



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- leptonic blazar models favored to explain EGRB
- neutrino sources should give sub-dominant contribution to EGRB

Constraints on a minimal model:

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- fits the extragalactic UHECR flux and composition
- fits the (extragalactic) neutrino flux
- gives subdominant contribution to EGRB
- consistent with early Galactic to extragalactic transition

$\Rightarrow$ ankle has to be a feature of source spectrum

Escape model for Galactic cosmic rays

[Giacinti, MK, Semikoz '14+]

- reproduces fluxes of individual CR groups
- explains dipole anisotropy
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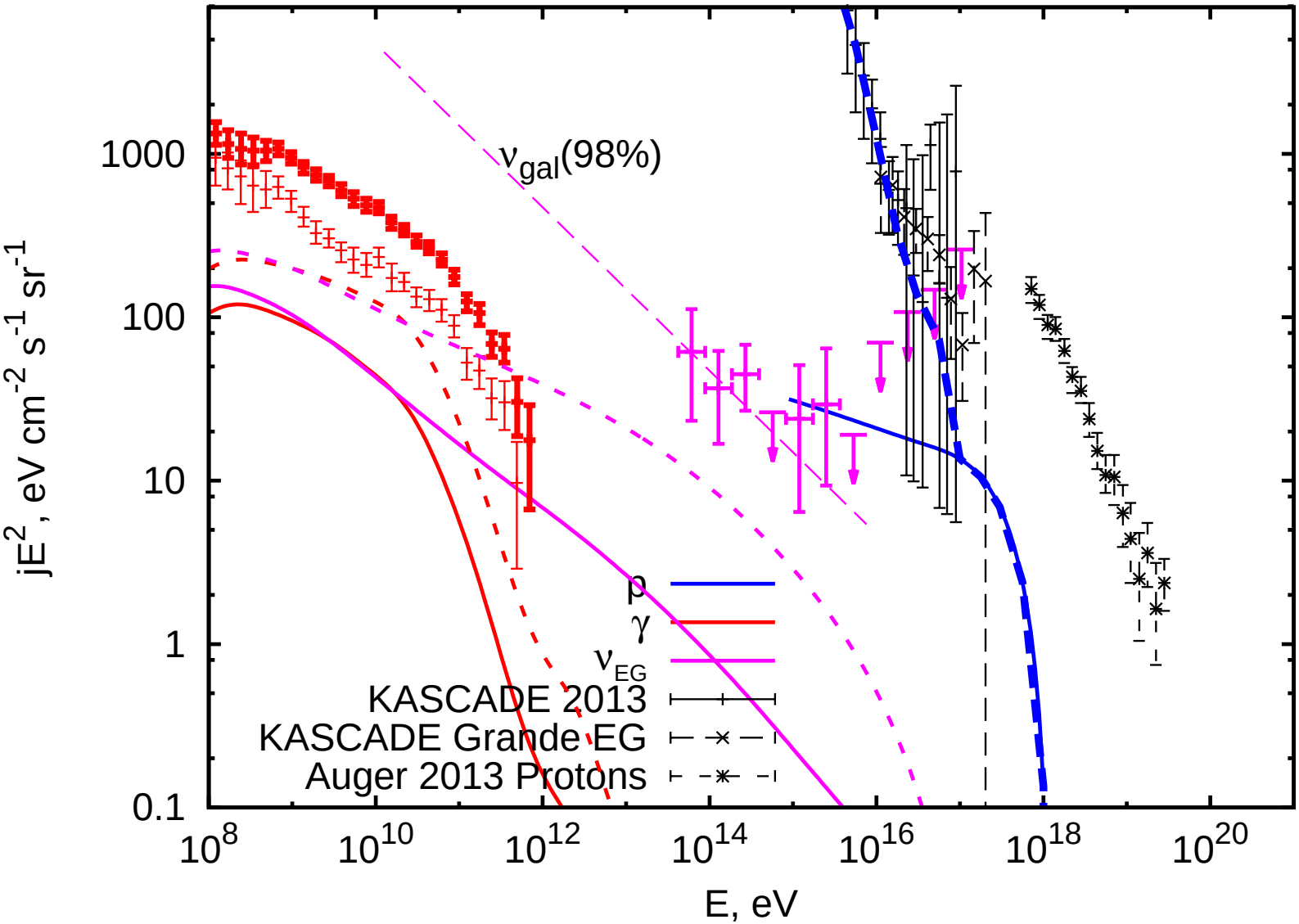
    - ★ source: $E_{\rm max} \sim B_{\rm CR}$, neutrino knee at few $\times 10^{14}$ eV

Normal and starburst galaxies:

- assume $E^{-2.2}$ source spectrum
- normalisation from escape model
- starburst: $B \sim 100 B_{MW} \Rightarrow$ rescale grammage and $E_{\rm max}$
- fix Q_{CR} via SN/star formation rate
- vary gas density

Normal and starburst galaxies:

[*Giacinti, MK, Kalashev, Neronov, Semikoz '15*]



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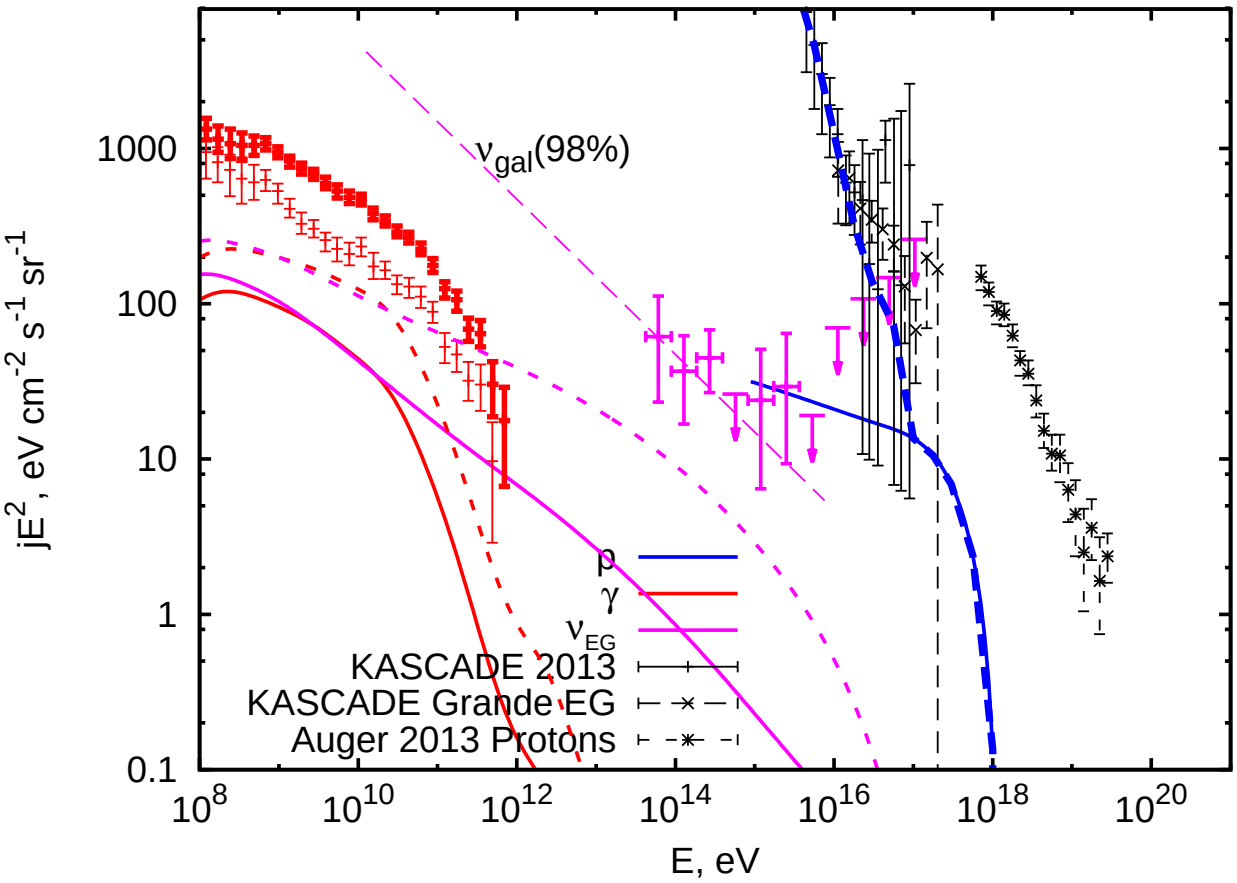

- can not explain exgal. protons
- sources can not be dominant sources of both EGRB and neutrinos

Source model:

- 3 zones
  - core: rigidity dependent acceleration $dN/dR \propto R^{-\alpha} \exp(-R/R_{\rm max})$
  - inner zone: $A\gamma$ interactions
  - outer zone: Ap interactions
- diffusion: increase of effective $\tau_{\rm int}$
- source evolution
  - BL Lac $\simeq$ peaked at late times
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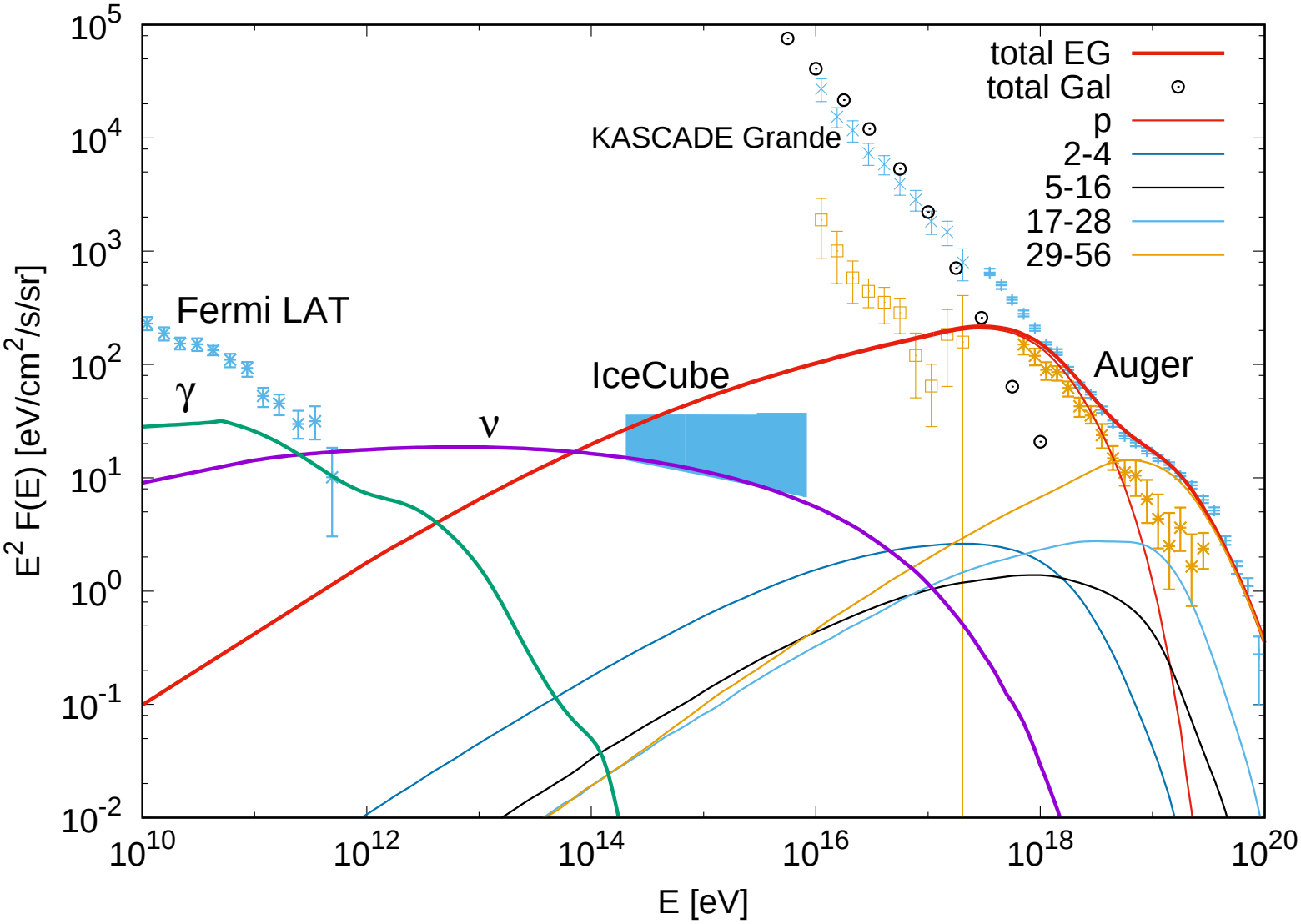

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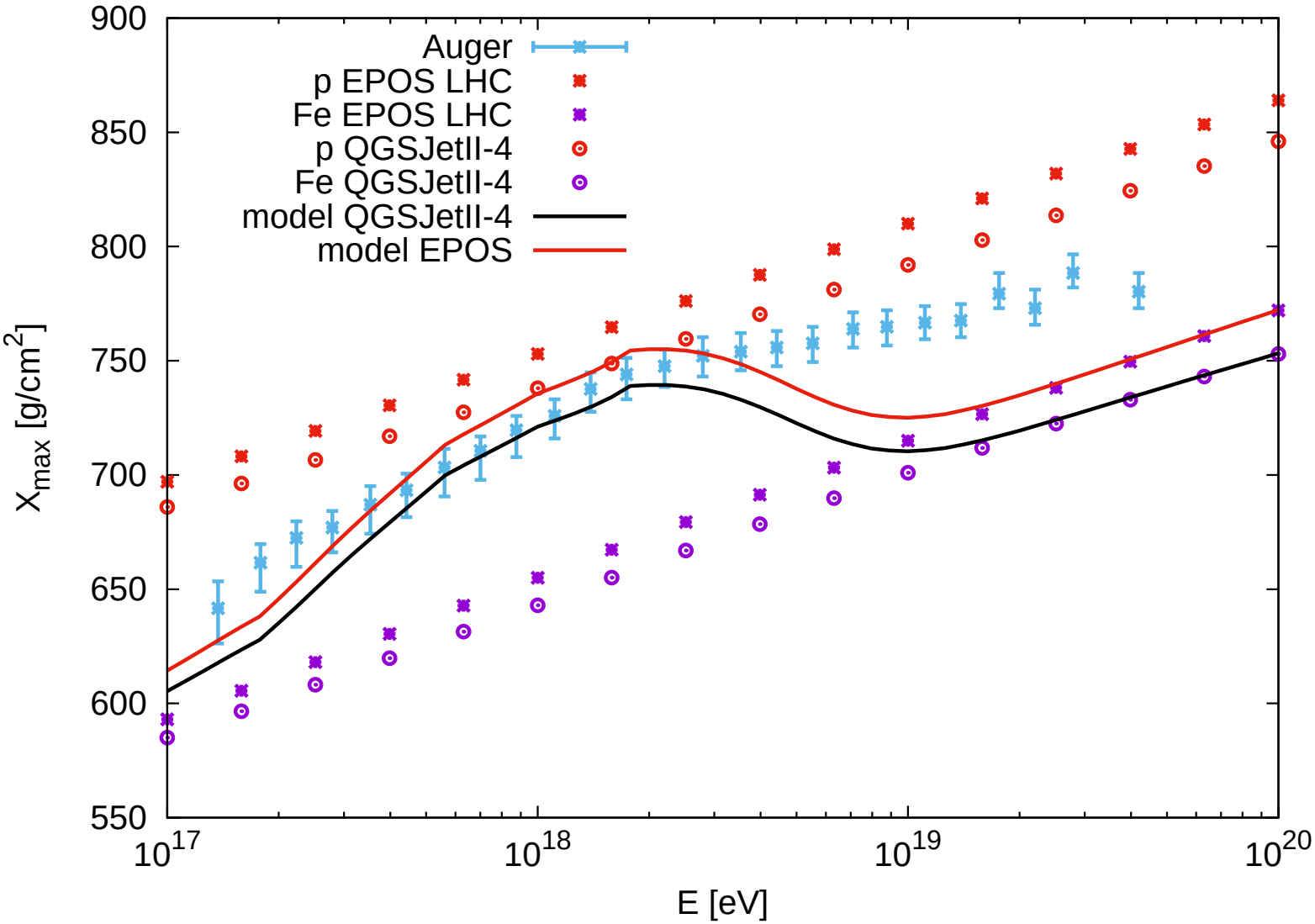

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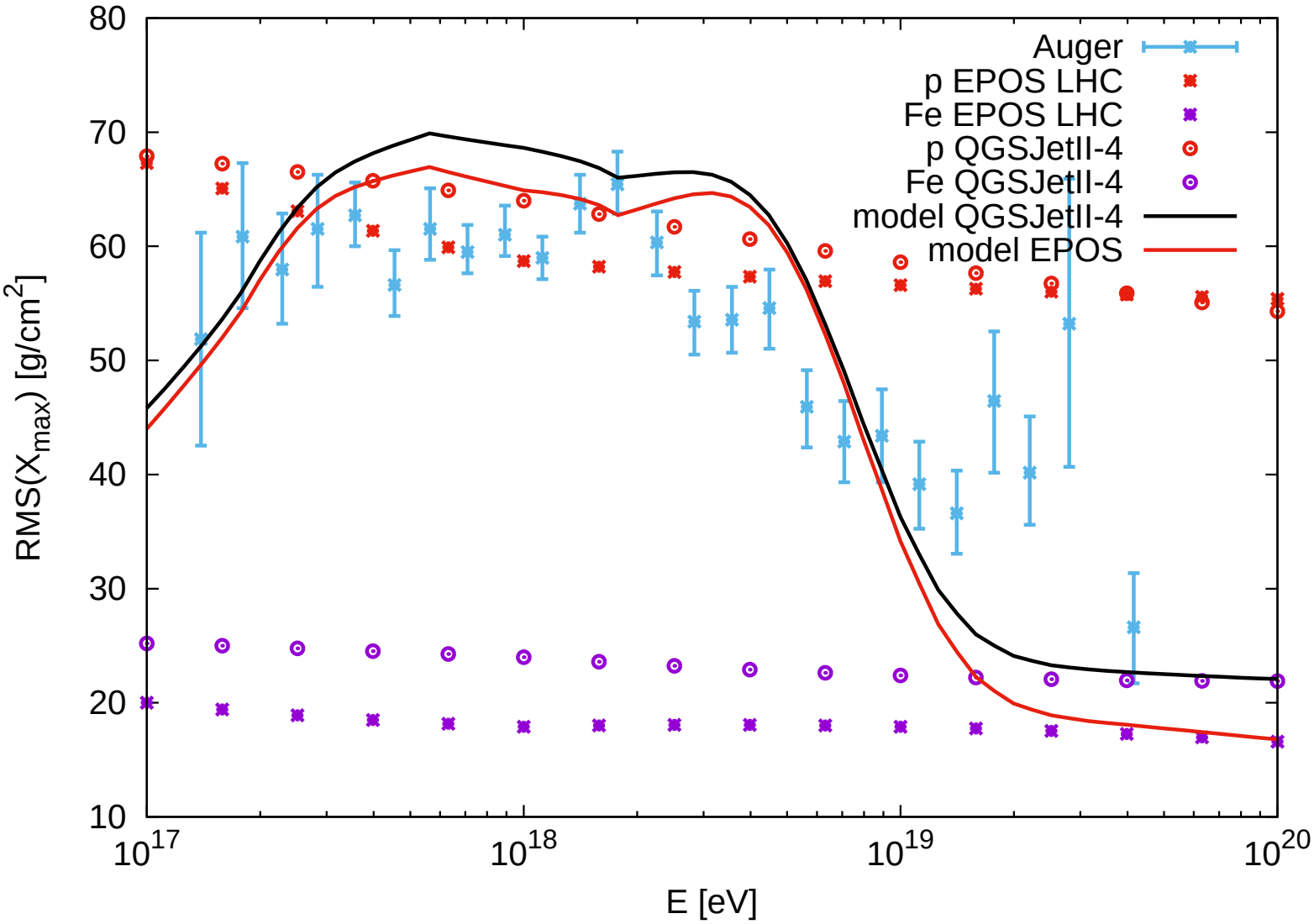

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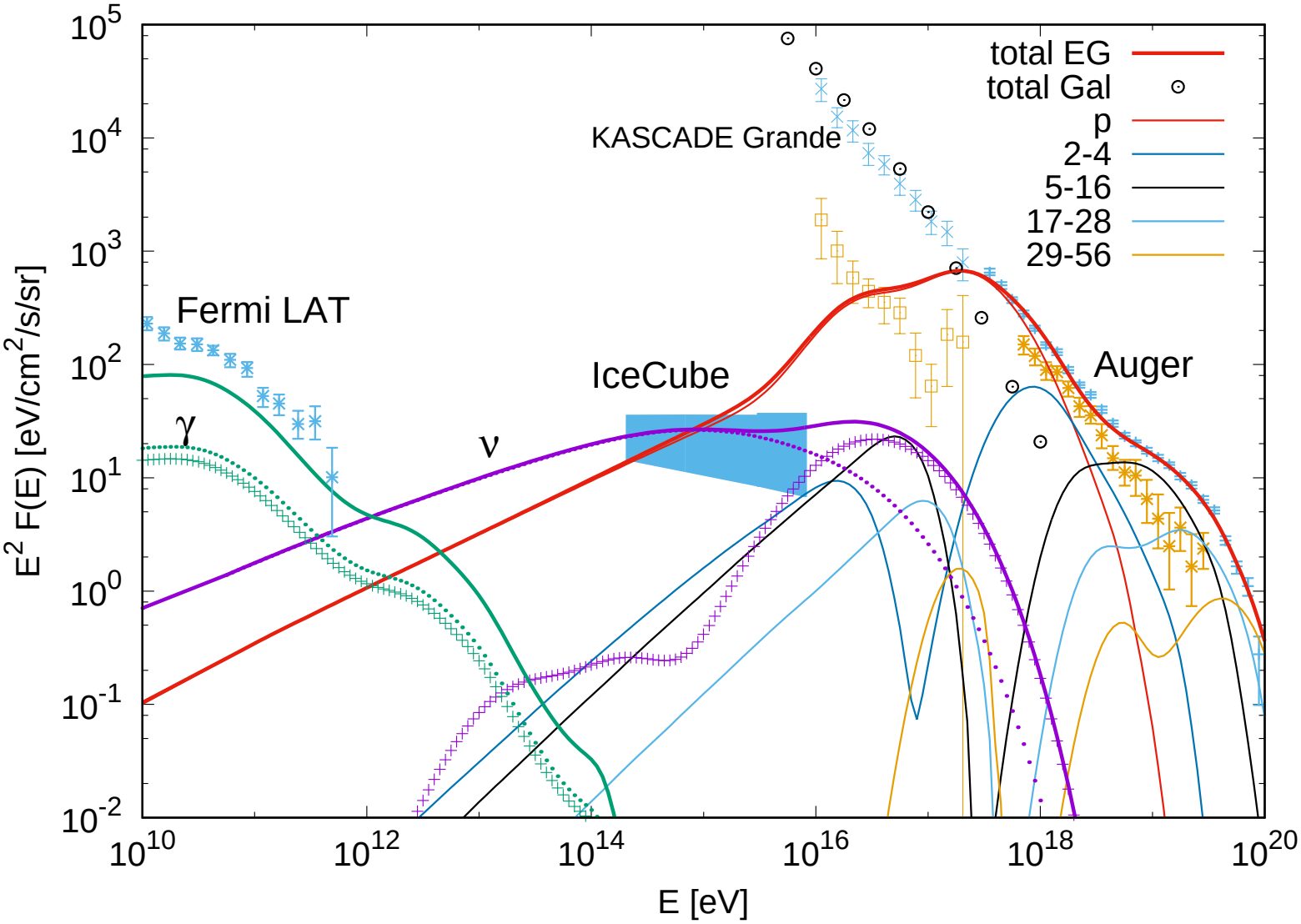

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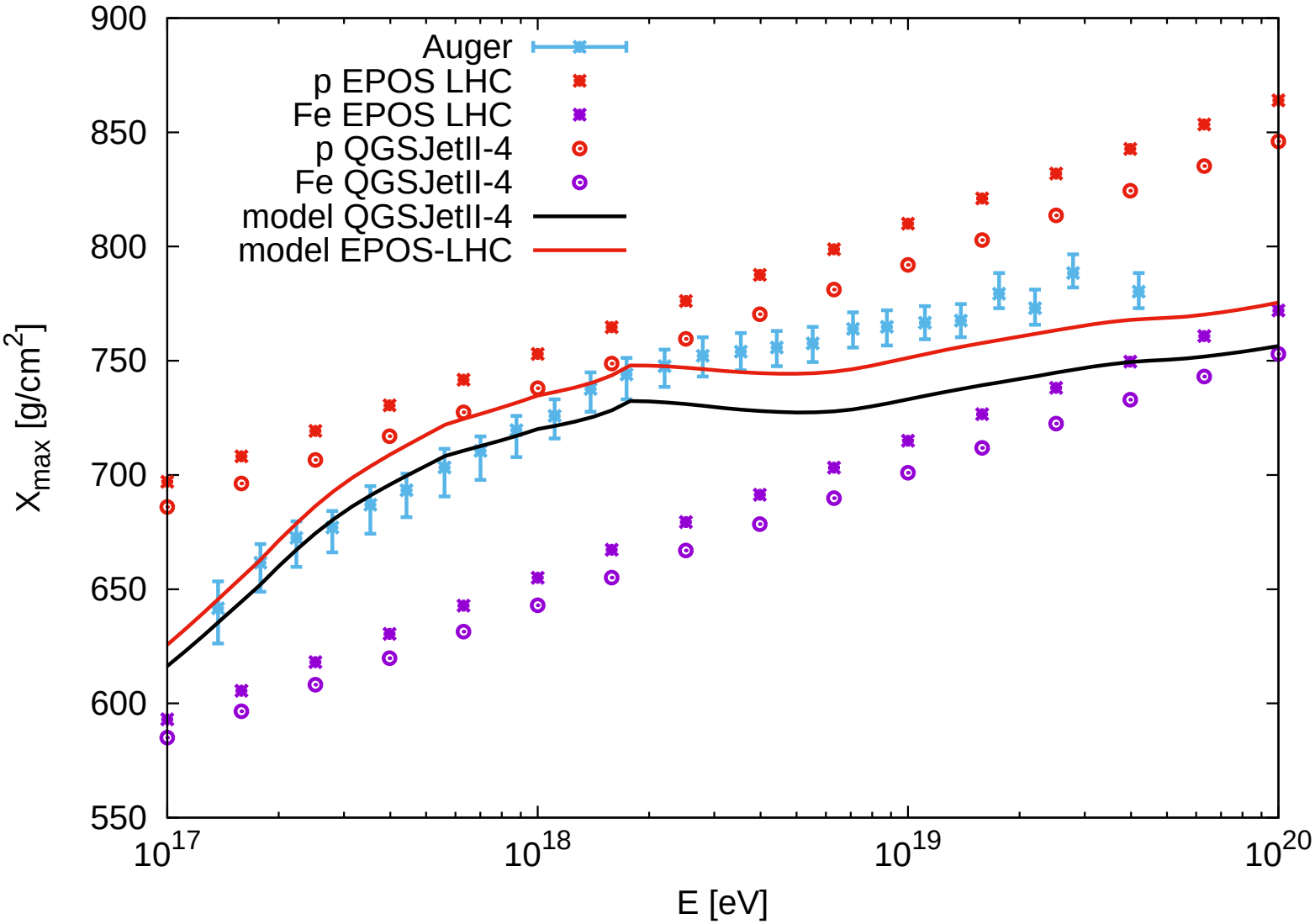

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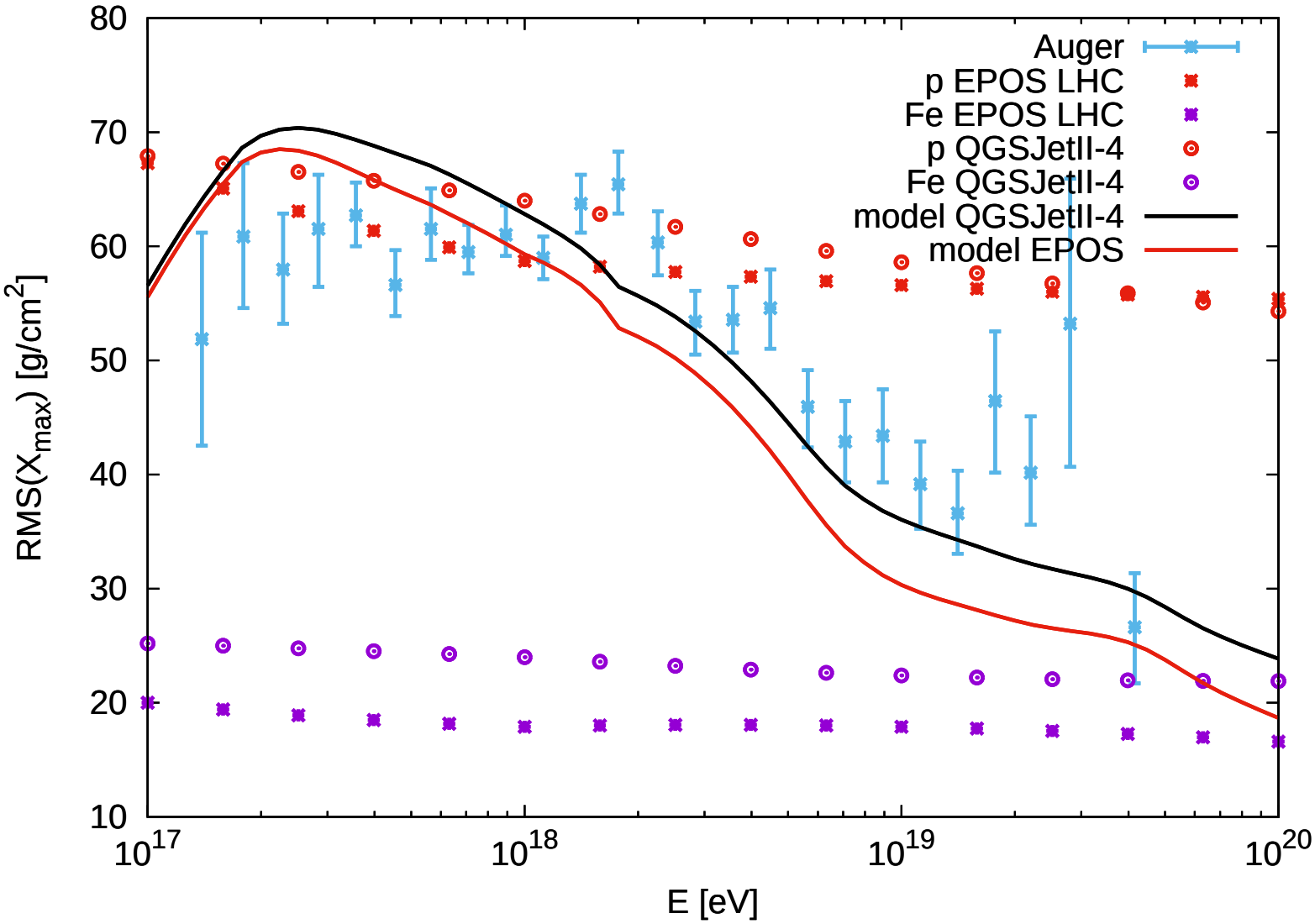

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Summary

1. EGRB constrains stronly neutrino sources:
   - slope of extragal. neutrino $\alpha \lesssim 2.3$
   - neutrino sources are not main source class of EGRB
2. neutrino signal in IceCube:
   - isotropy favours dominant extragalactic origin above 10–100 TeV
   - steeper additional contribution dominating at low energies (?)
3. common source class for UHECRs and neutrinos?
   - several candidates as GRBs are already disfavoured
   - (subclasses of) AGNs remain attractive option
   - large neutrino flux at "low" energies requires Ap interactions
   - UHECR composition favours nuclei with $A\gamma$
   - sources with both Ap and $A\gamma$ interactions needed