Using cosmogenic neutrinos to determine the fraction of protons in ultra-high-energy cosmic rays

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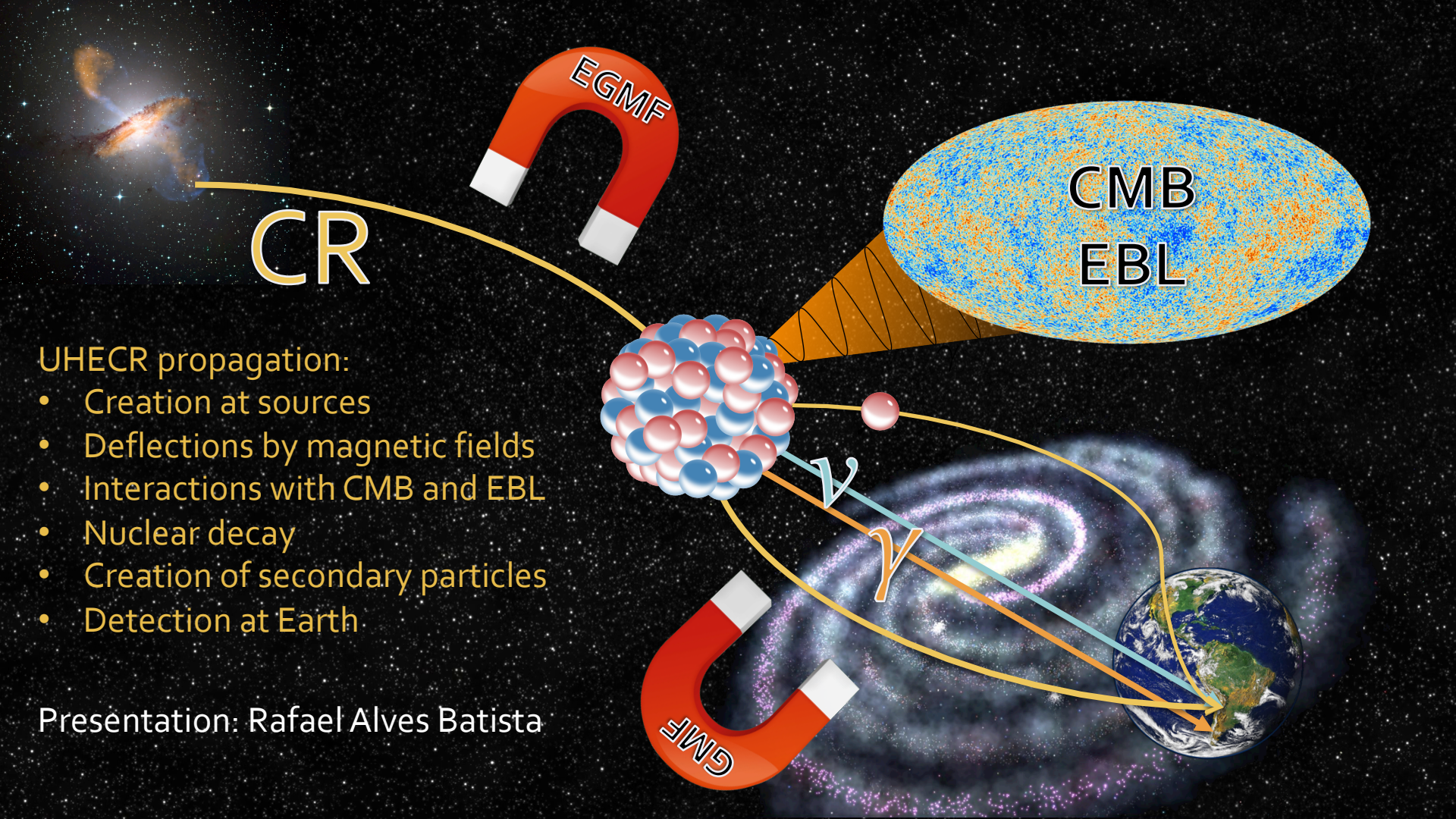
TeVPA

Berlin - 31/08/2018

CRPropa

Radboud University

Image: Pierre Auger Observatory



UHECR propagation:

- Creation at sources
- Deflections by magnetic fields
- Interactions with CMB and EBL
- Nuclear decay
- Creation of secondary particles
- Detection at Earth

Presentation: Rafael Alves Batista

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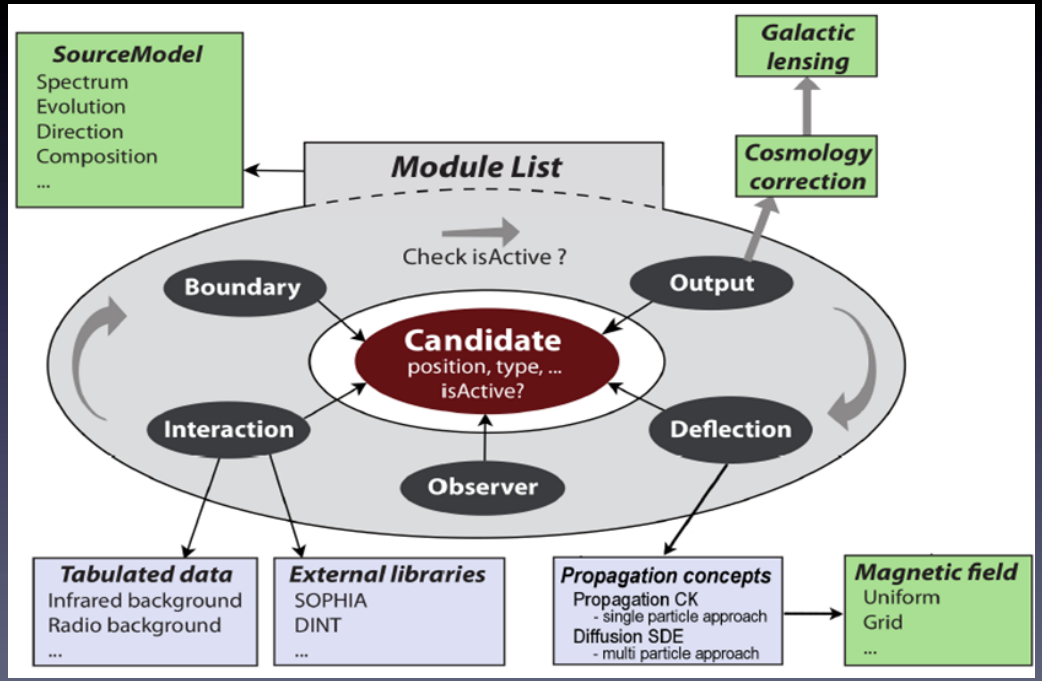
R. Alves Batista, A. Dundovic, M. Erdmann, K.-H. Kampert, D. Kümpel, G. Müller, G. Sigl,
A. van Vliet, D. Walz and T. Winchen, JCAP 1605 (2016) 038

- A public astrophysical simulation framework for propagating extraterrestrial high-energy particles
- Available from

crpropa.desy.de

Presentation: Lukas Merten



Combined Fit

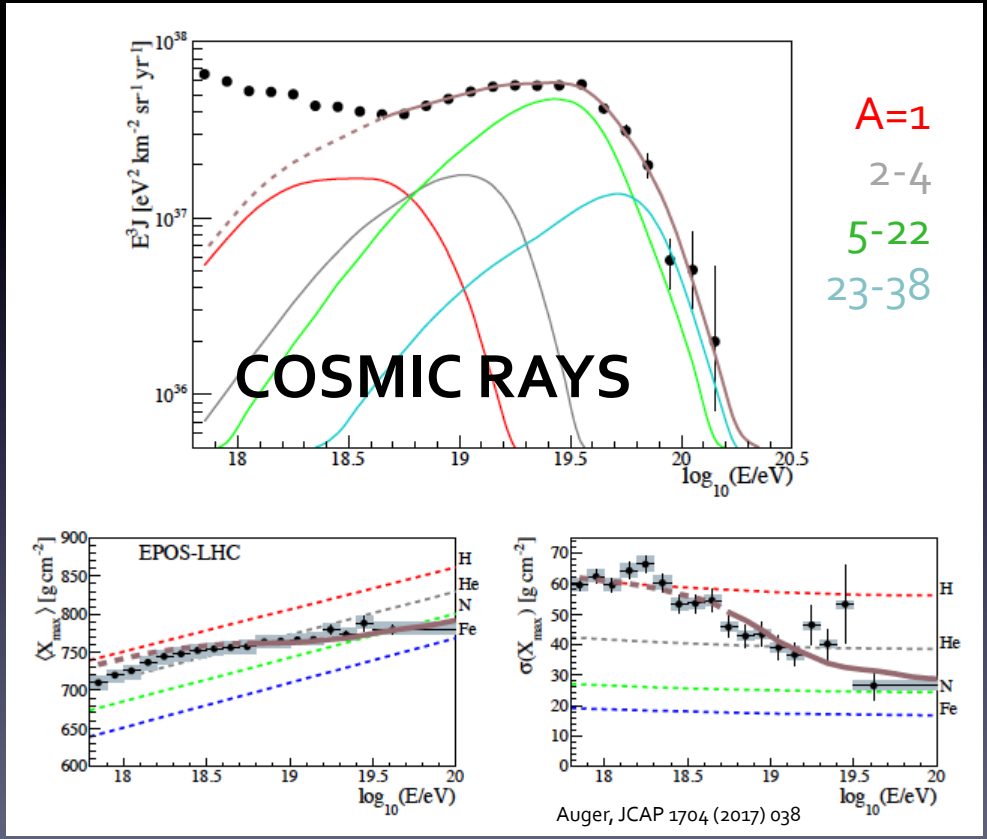
Auger, JCAP 1704 (2017) 038

- Continuous source distribution of identical sources
- Comoving source evolution
- Composition at the sources:

  88% Nitrogen, 12% Silicon
- Spectrum at the sources:

$$\frac{dN}{dE} \propto E^{-\alpha} \exp(-E/ZR_{\text{cut}})$$

- α = 0.87
- R_{cut} = 4.2 EV



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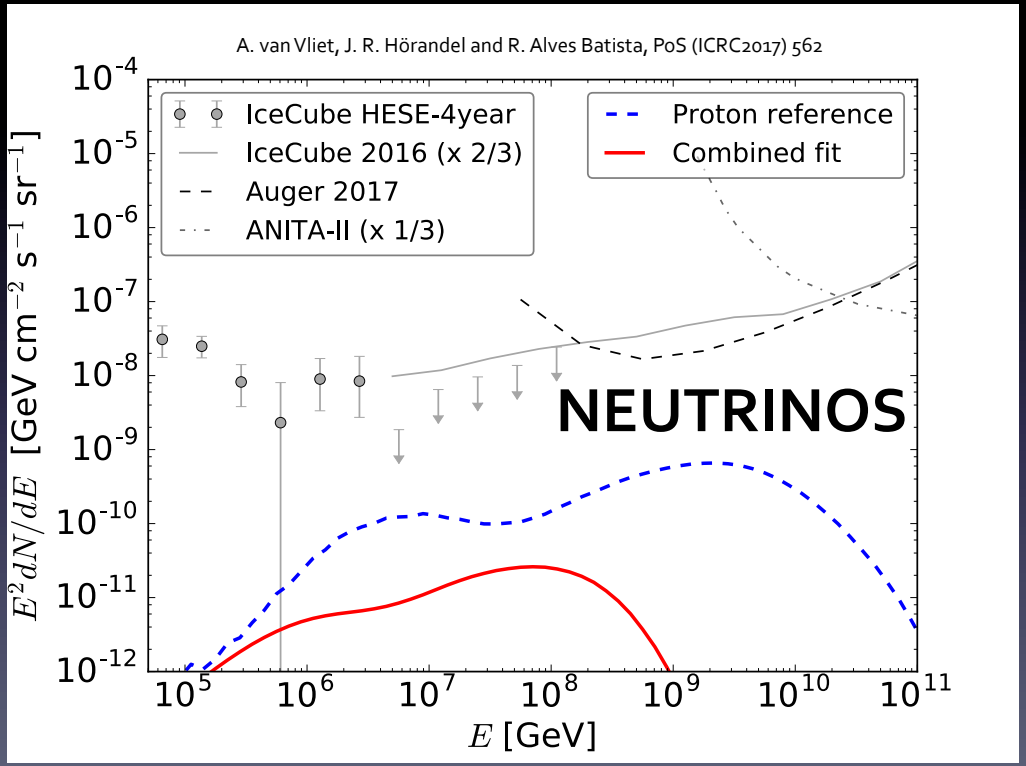

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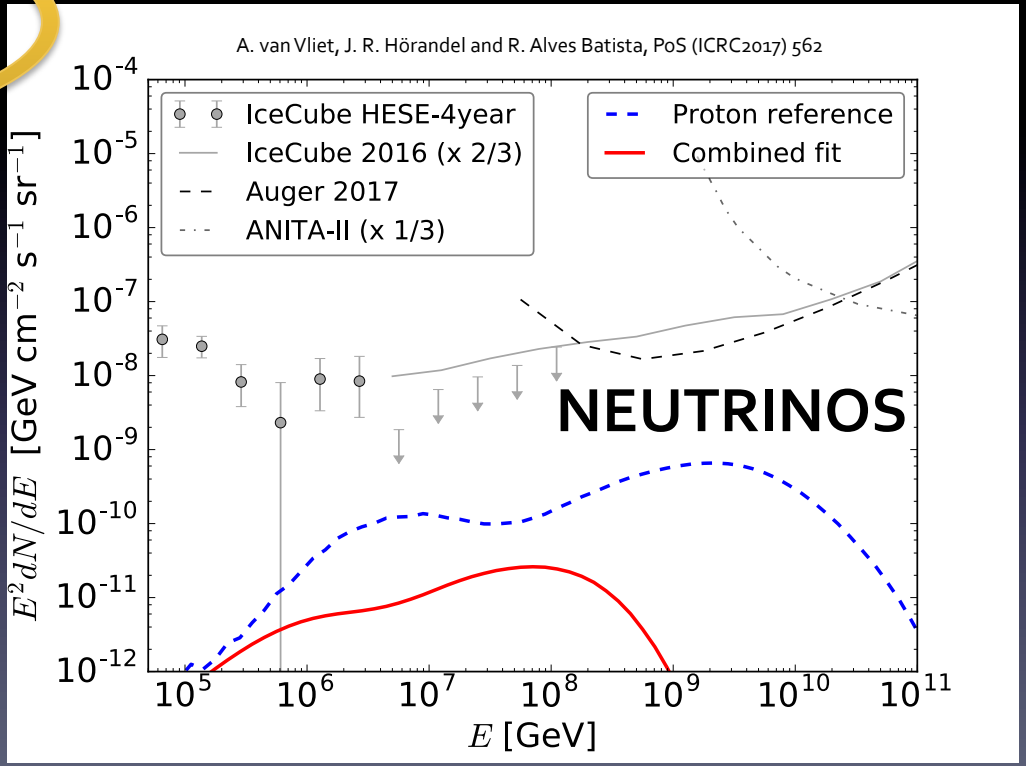
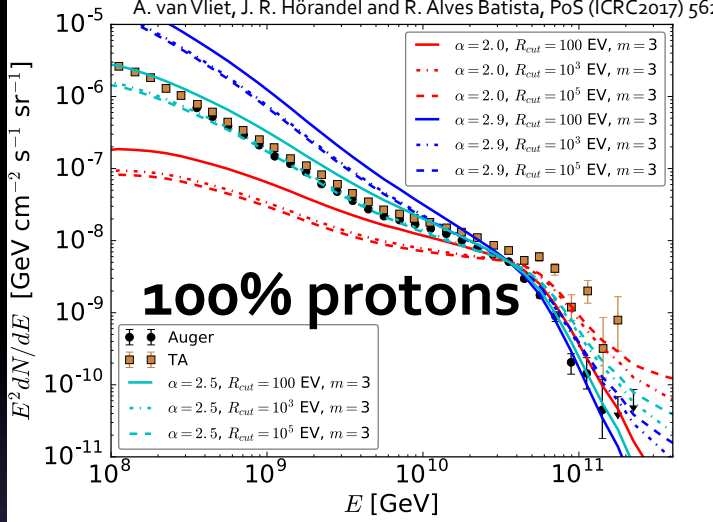


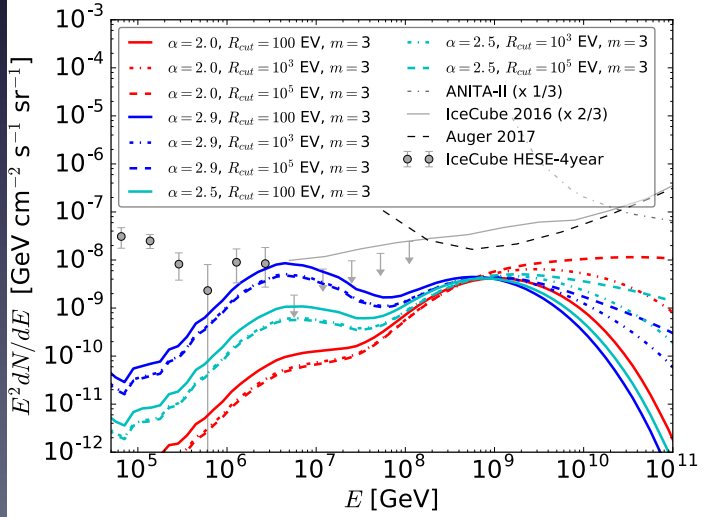
Neutrinos at 1 EeV

- Cosmogenic neutrino flux depends on:
  - Spectral index α
  - Max. rigidity R_{cut}
  - EBL model
  - Composition (proton fraction)
  - Source evolution
- Sweet spot at ~1 EeV, only depends on:
  - Composition (proton fraction)
  - Source evolution (z_{max} = 4)

$$\begin{cases} (1+z)^m \\ 1 \end{cases} \quad \text{if } z > 1.5 \text{ and } m > 0$$

A. van Vliet, J. R. Hörandel and R. Alves Batista, PoS (ICRC2017) 562





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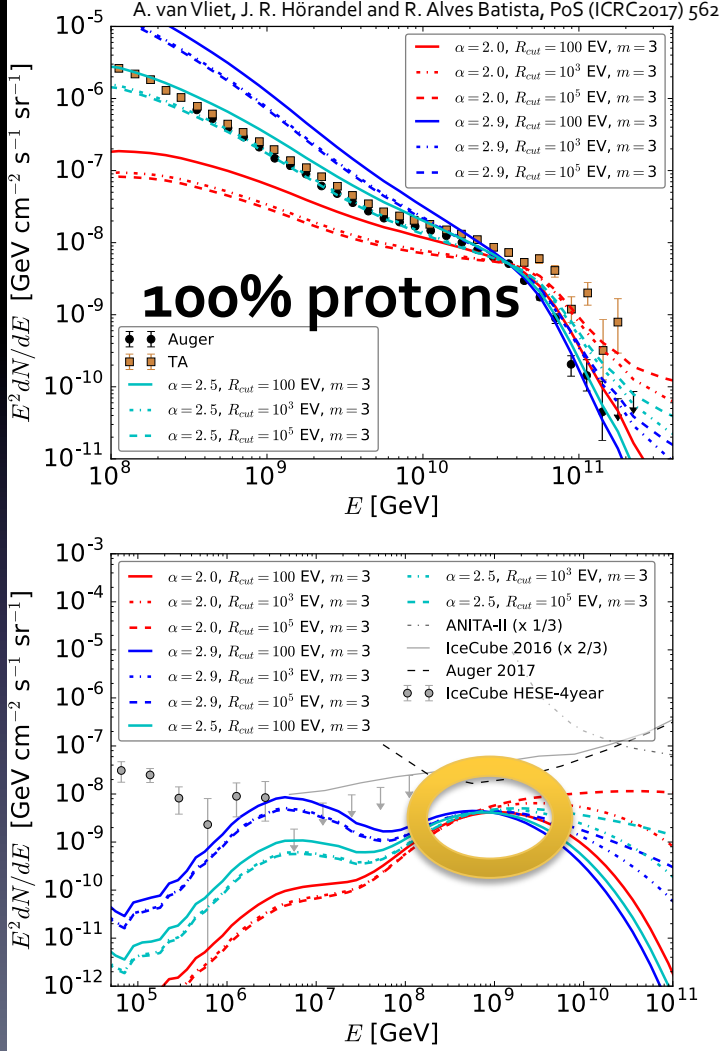
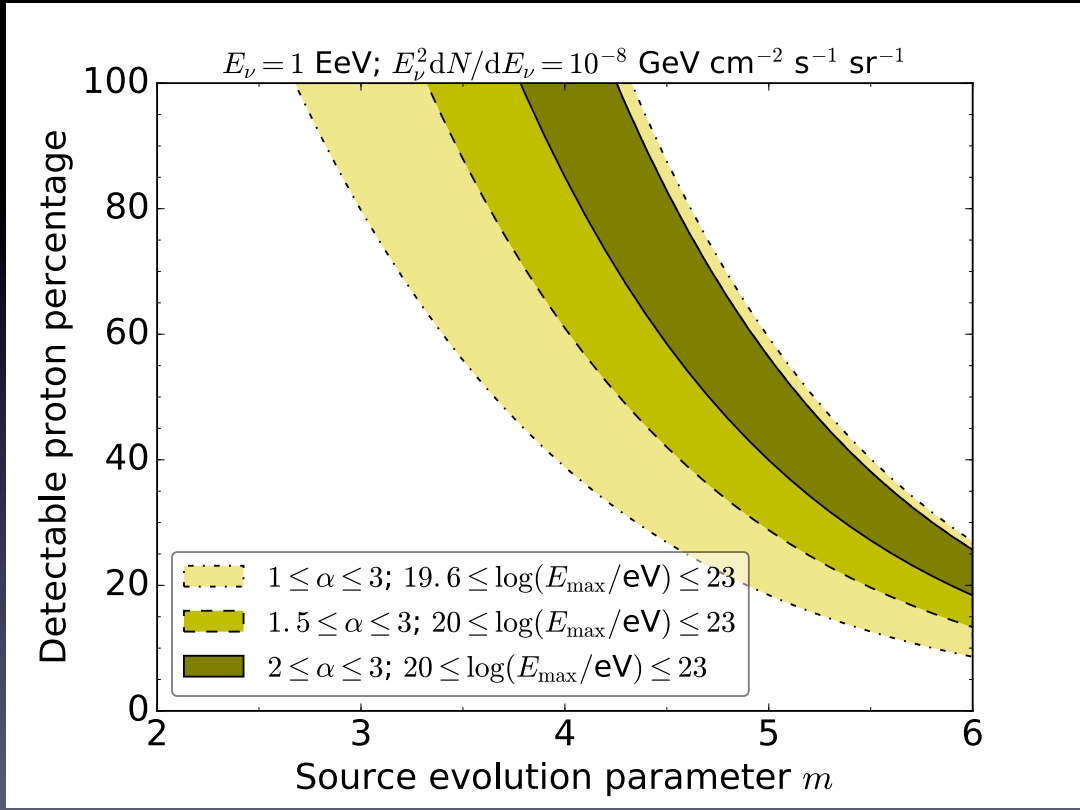


Current Sensitivity

- Single-flavour neutrino flux at ~1 EeV
- Auger and IceCube are both close to

  ~10^{-8} GeV cm^{-2} s^{-1} sr^{-1}
- Large proton fraction and strong source evolution ruled out



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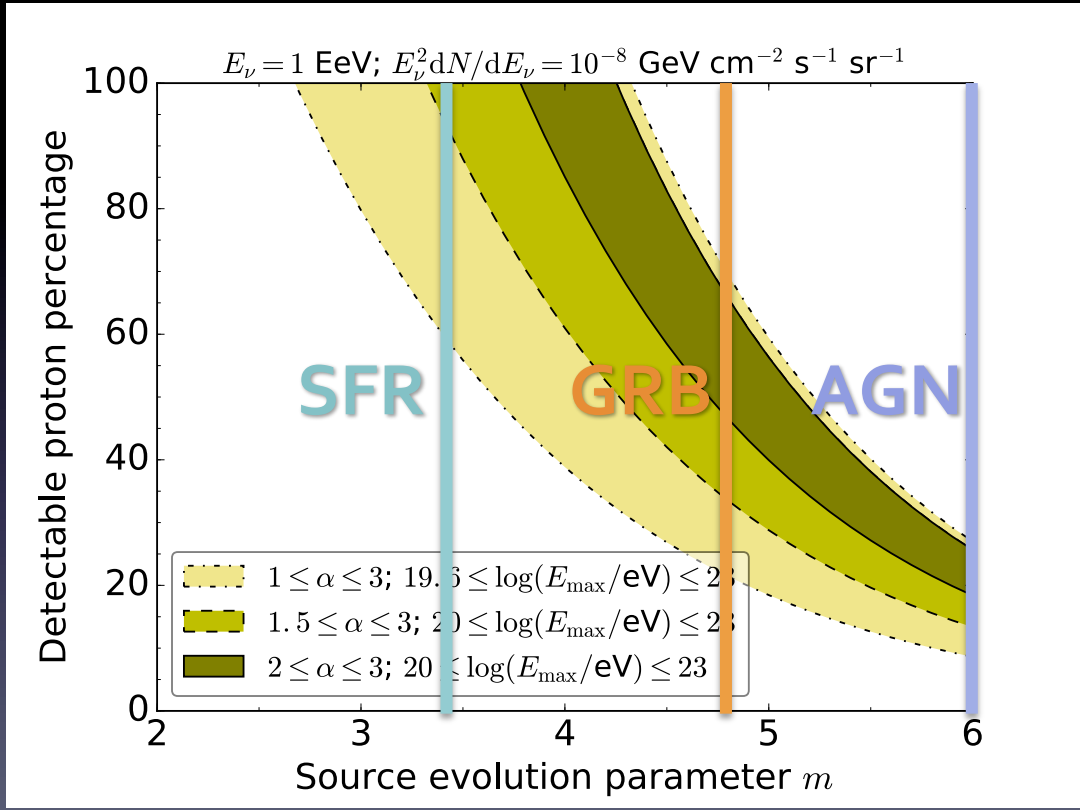
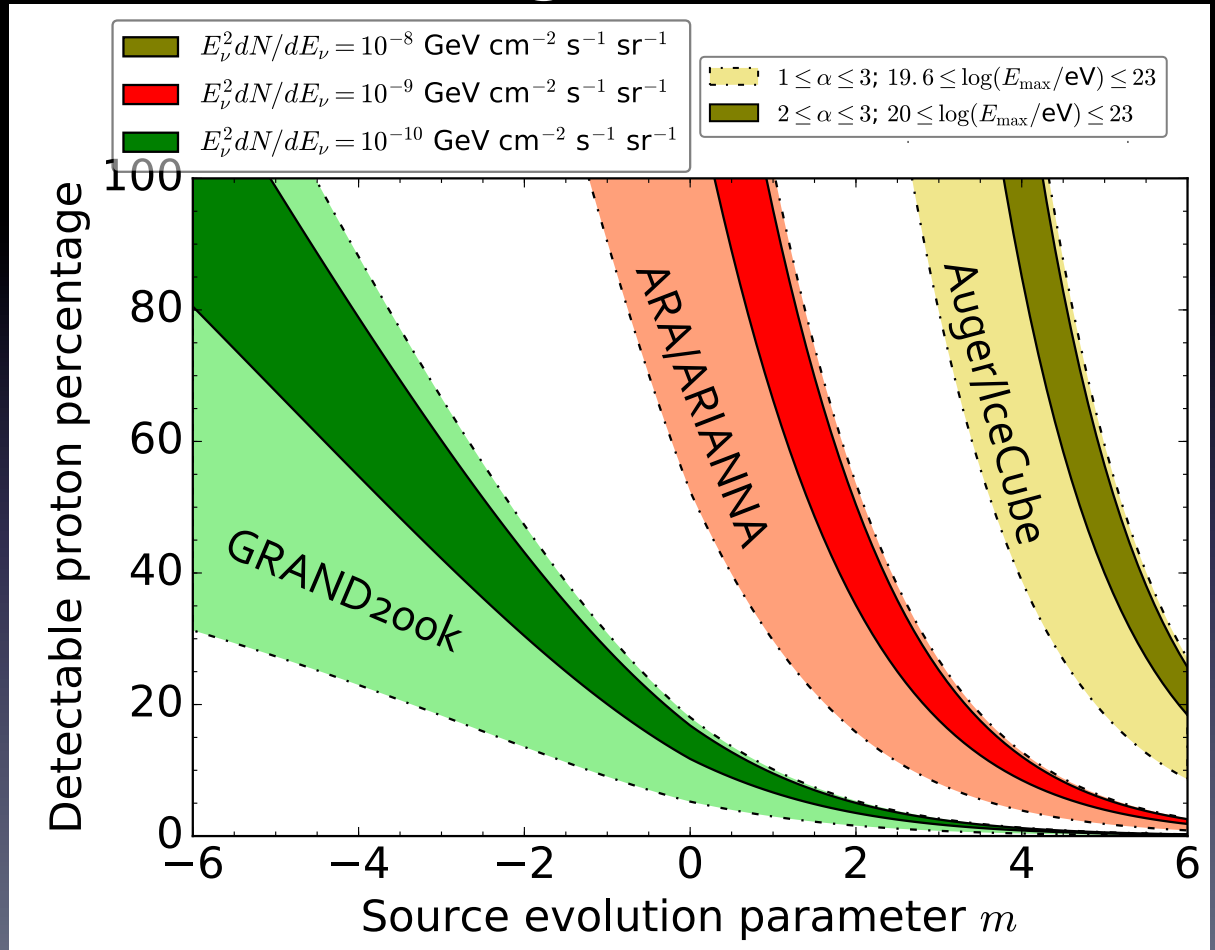


Upcoming Experiments



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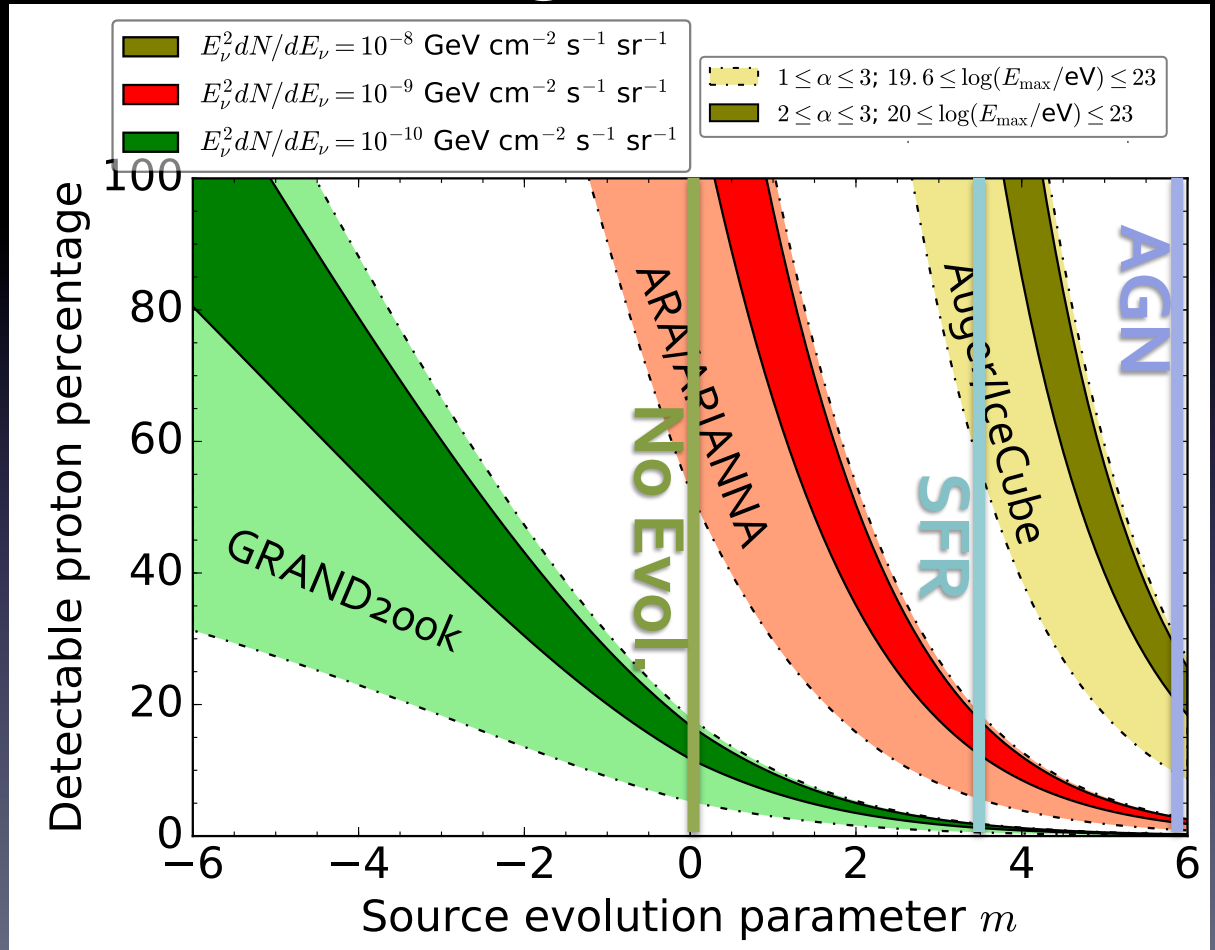

Conclusions

- Neutrino limits at ~1 EeV are able to constrain the proton fraction and source evolution of UHECR sources
- The combination of a large proton fraction and a strong source evolution is already ruled out
- Strong potential for upcoming experiments
- Determine proton fraction in UHECRs independent of hadronic interaction models

BACKUP SLIDES

Proton vs. Iron

- Protons vs. Iron
- R_{cut} = 200 EV
- α = 2.5
- Comoving source evolution
- Neutrino flux strongly reduced in the case of iron primaries