The cosmogenic neutrino flux determines the fraction of protons in UHECRs

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UHECR
Paris – 10/10/2018

Radboud University

Image: Pierre Auger Observatory

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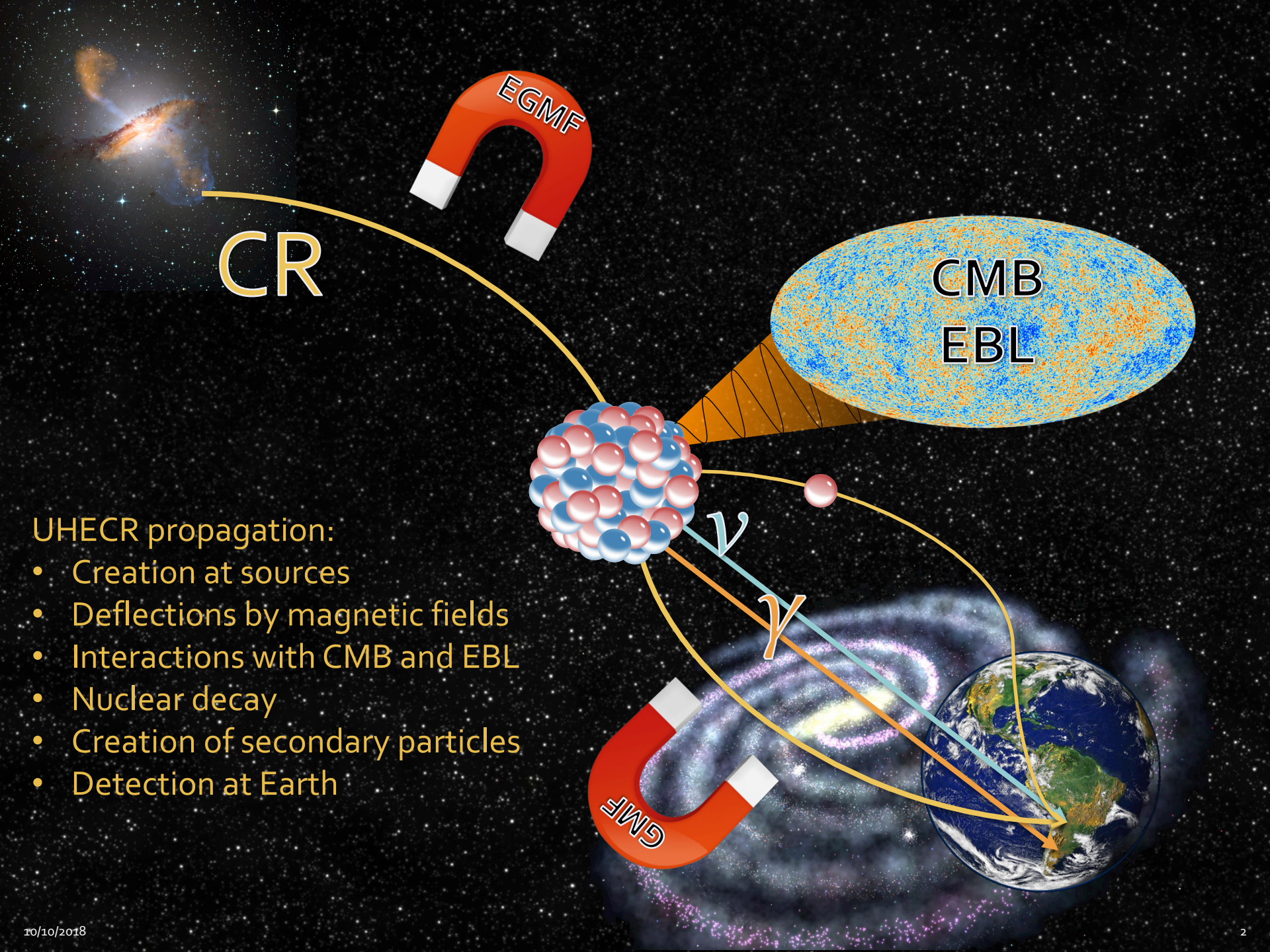


UHECR propagation:

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

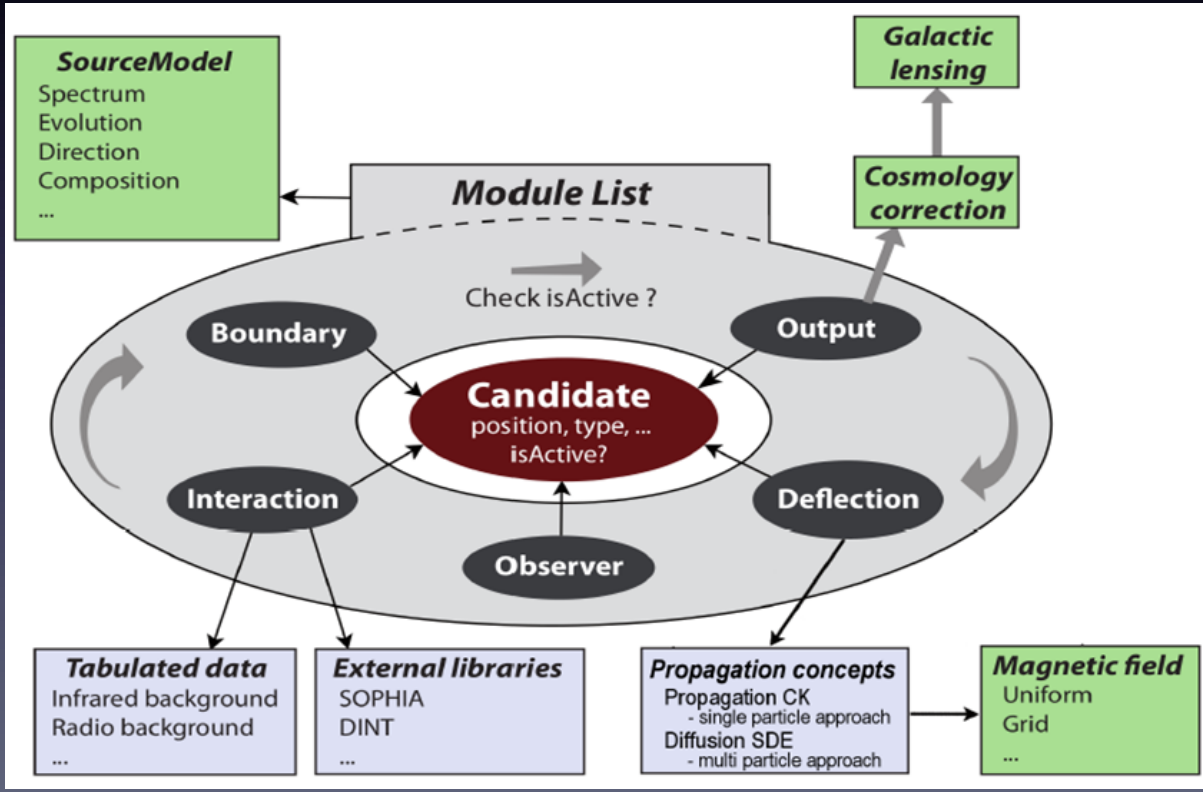
CRPropa 3

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

- Open-source astroparticle simulation framework from TeV to ZeV energies
- Available from

crpropa.desy.de

Poster: A. van Vliet
CRPropa 3.2



Combined Fit

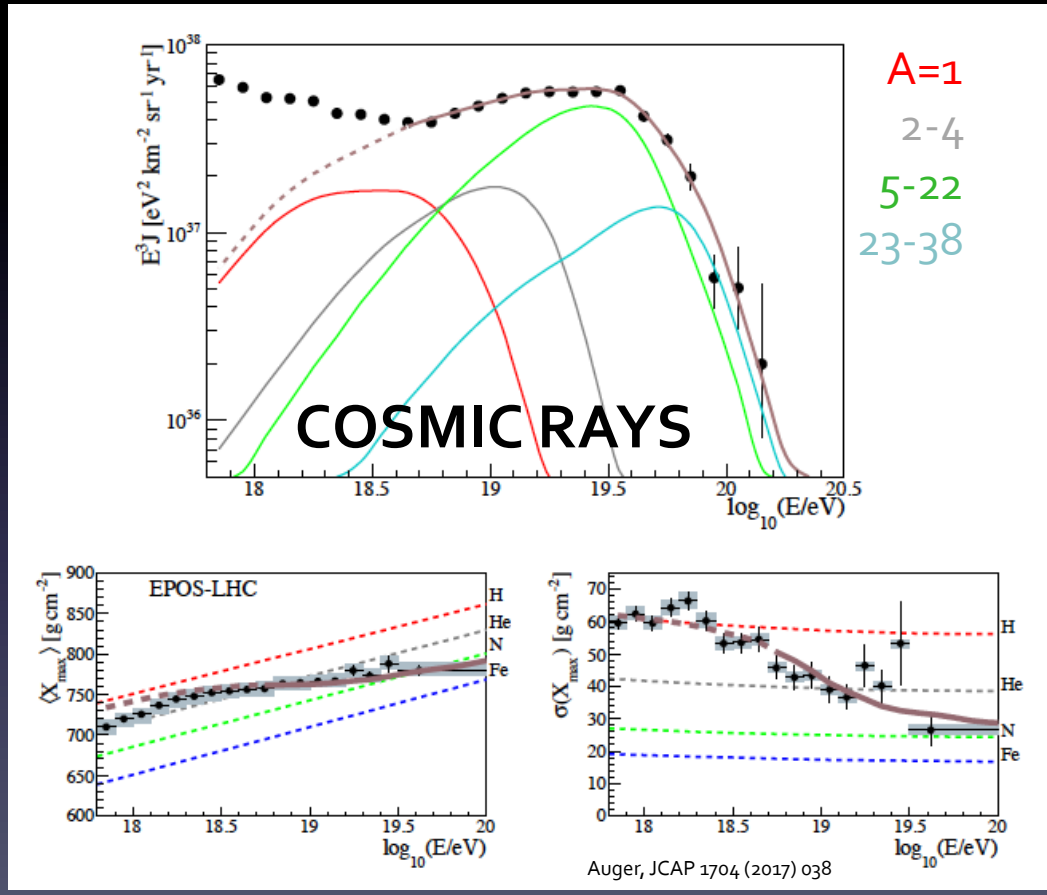
Auger, JCAP 1704 (2017) 038

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

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

$$\frac{\mathrm{d}N}{\mathrm{d}E} \propto E^{-\alpha} \exp\left(-E/ZR_{\max}\right)$$

- $\alpha = 0.87$
- $R_{\max} = E_{\max}/Z = 4.2$ EV



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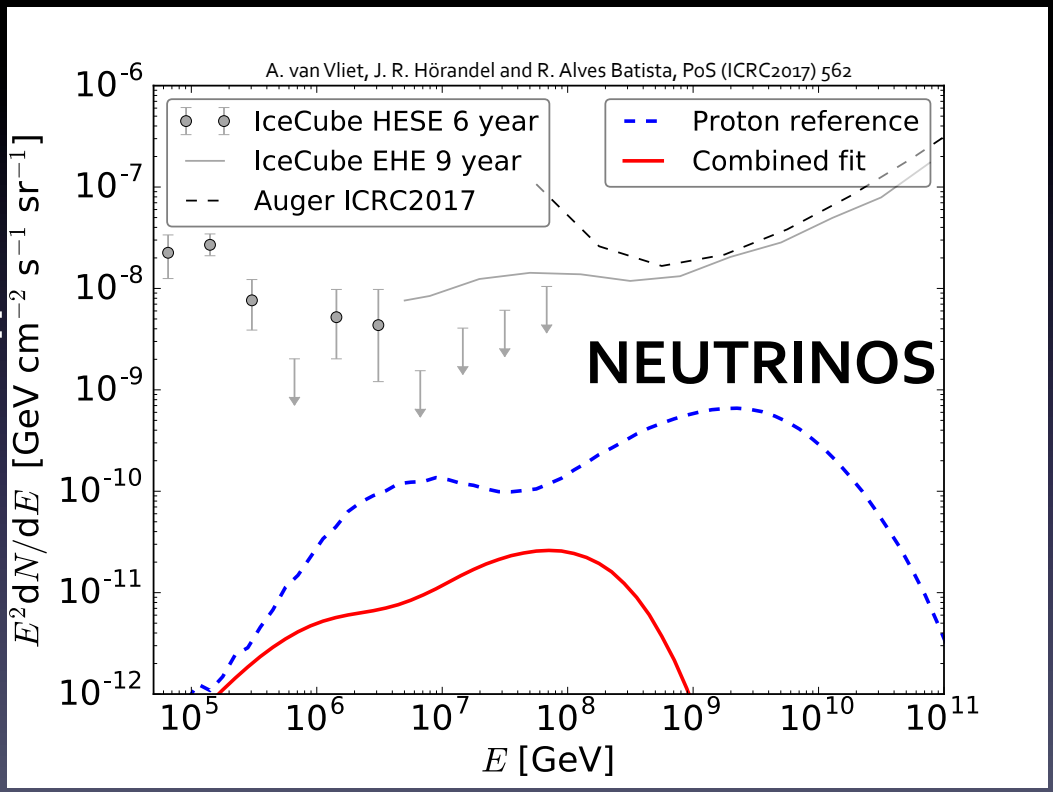

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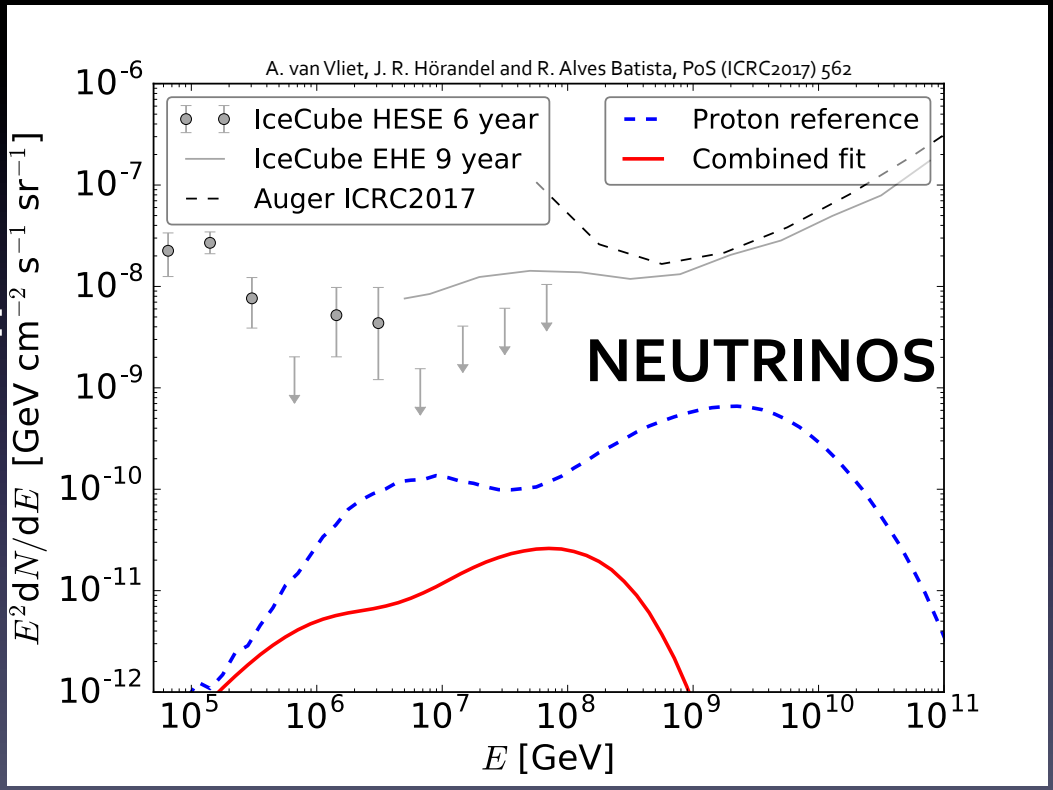
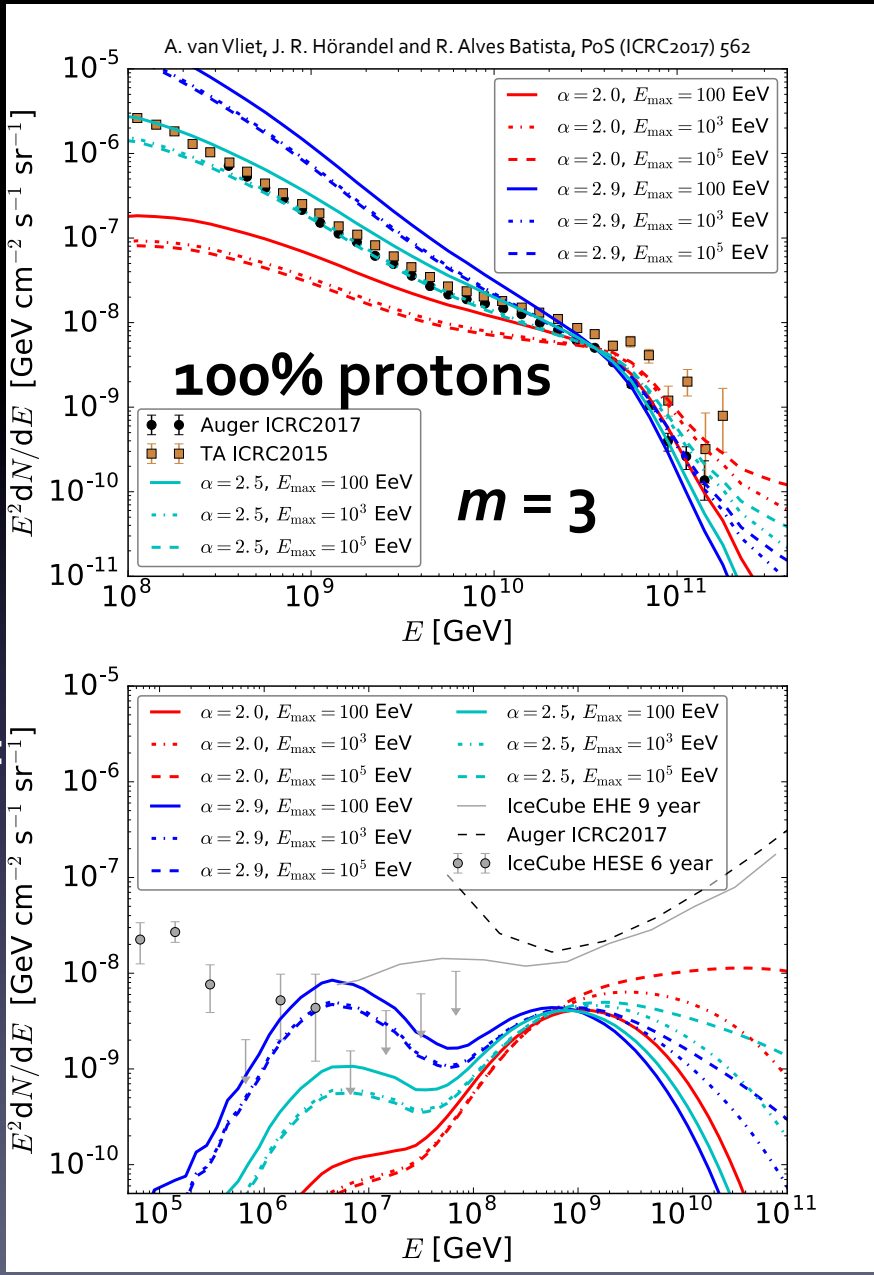


Neutrinos at 1 EeV

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

$$\mathrm{SE} = \begin{cases} (1+z)^m & \text{for } m \le 0 \\ (1+z)^m & \text{for } m > 0 \text{ and } z < 1.5 \\ 2.5^m & \text{for } m > 0 \text{ and } z \ge 1.5 \end{cases}$$



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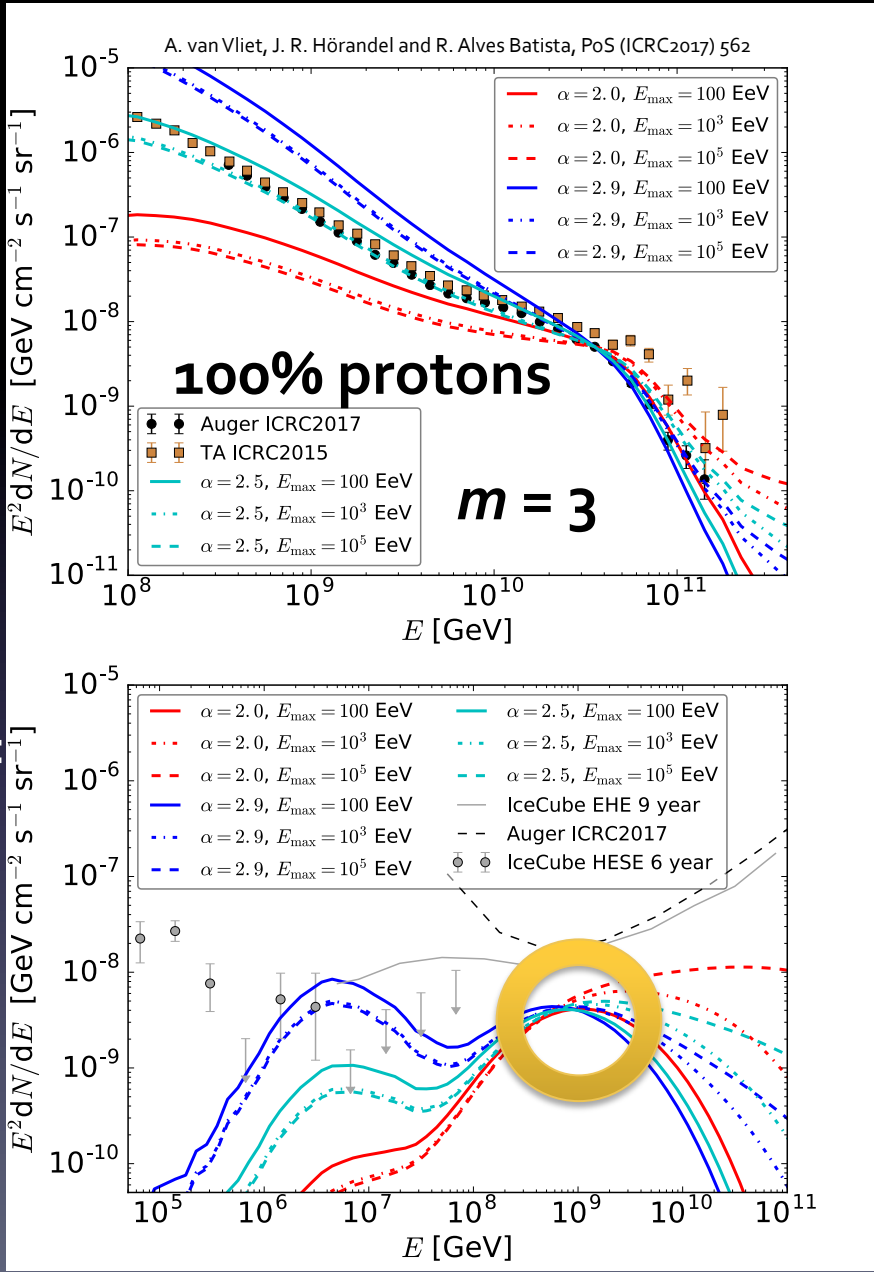
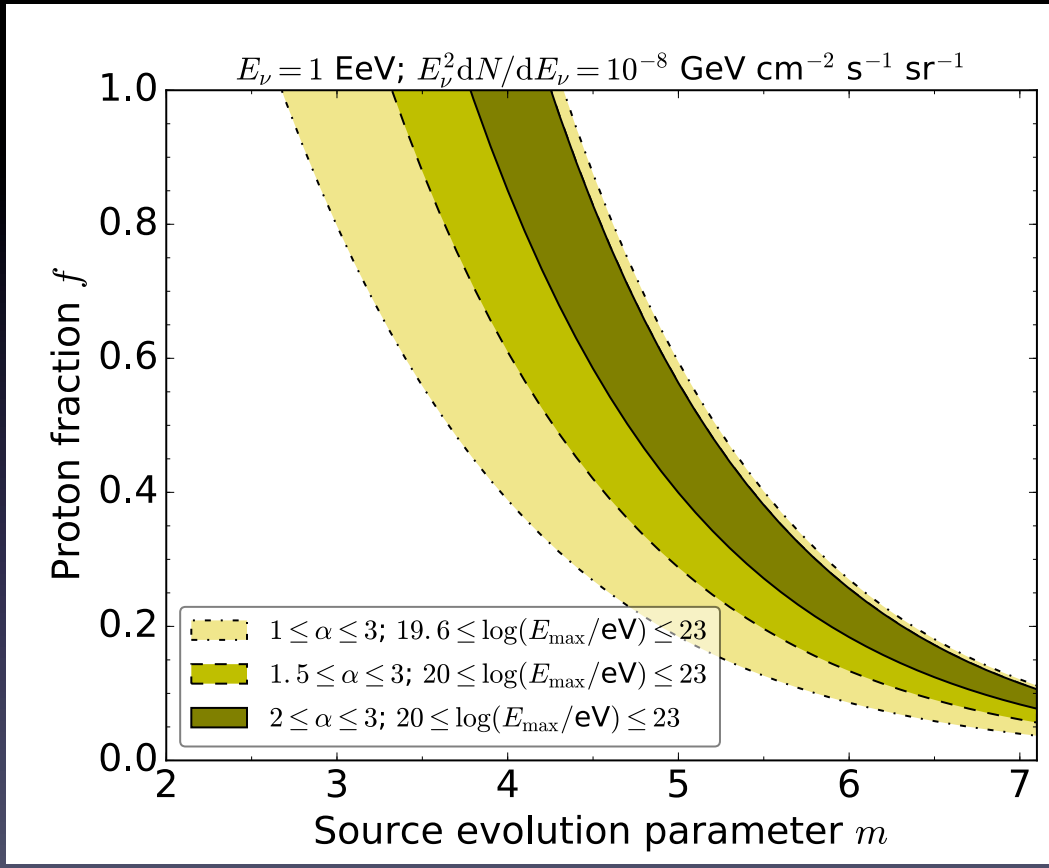


Current Sensitivity

- 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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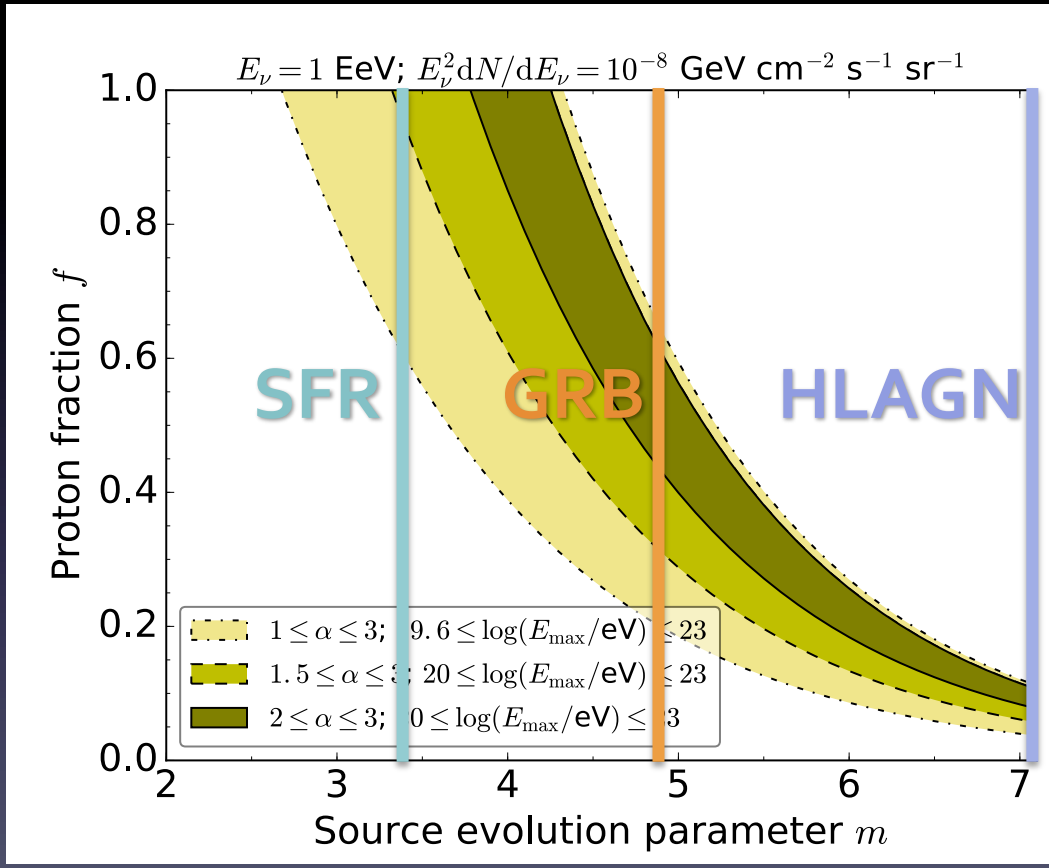
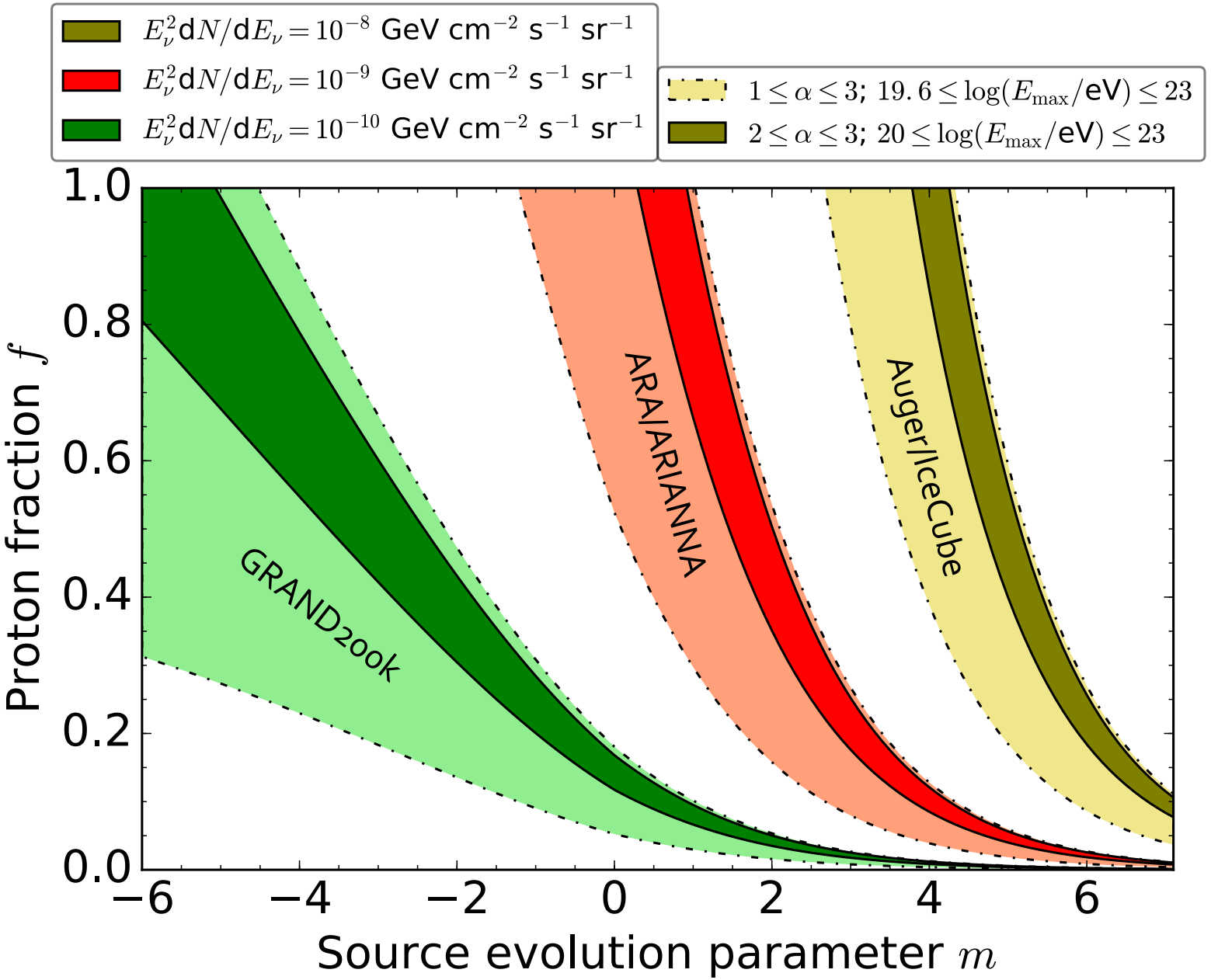


Upcoming Experiments



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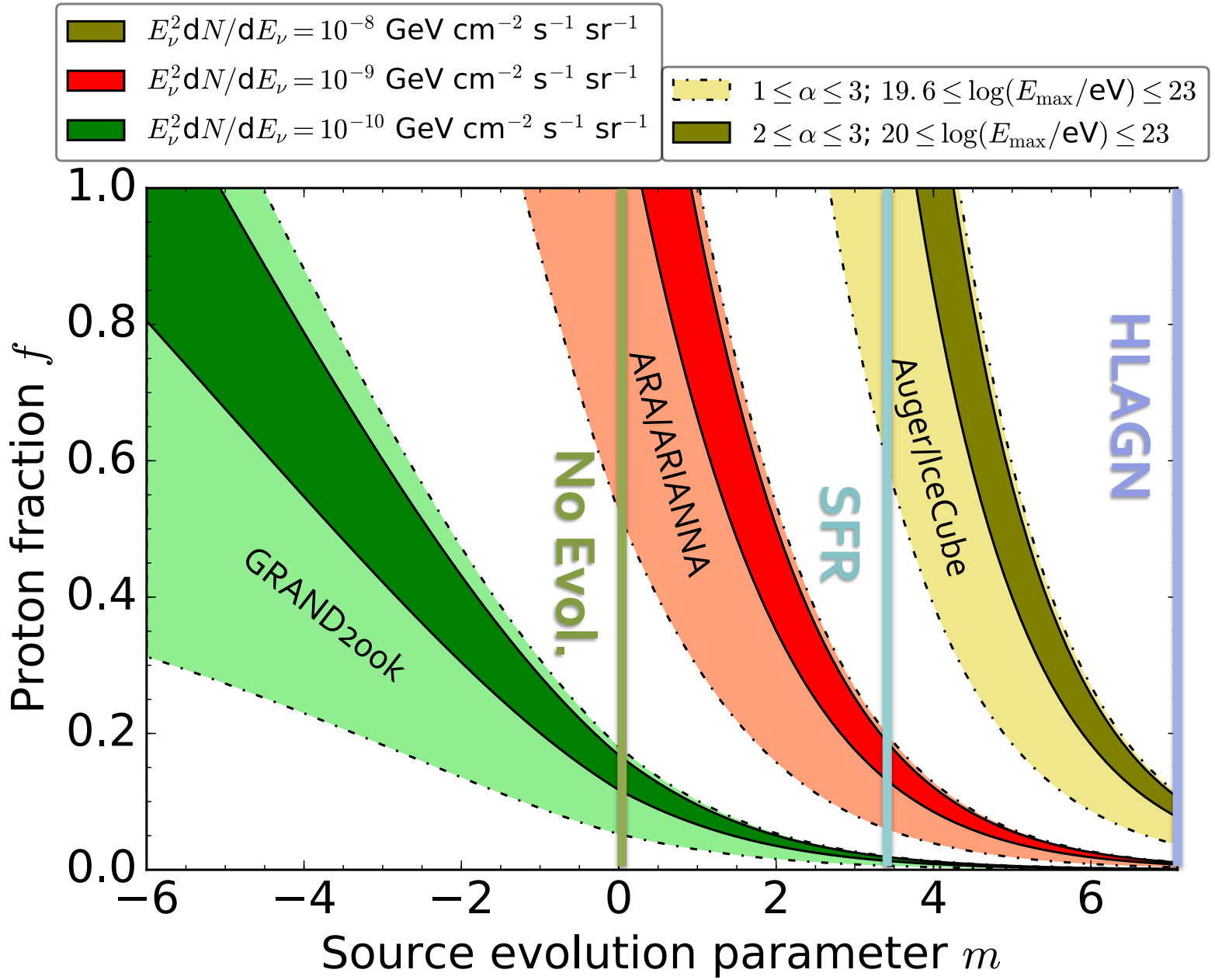

Conclusions

- 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 to measure a cosmogenic neutrino flux at ~1 EeV
- Determine proton fraction in UHECRs independent of hadronic interaction models

BACKUP SLIDES

Proton vs. Iron

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