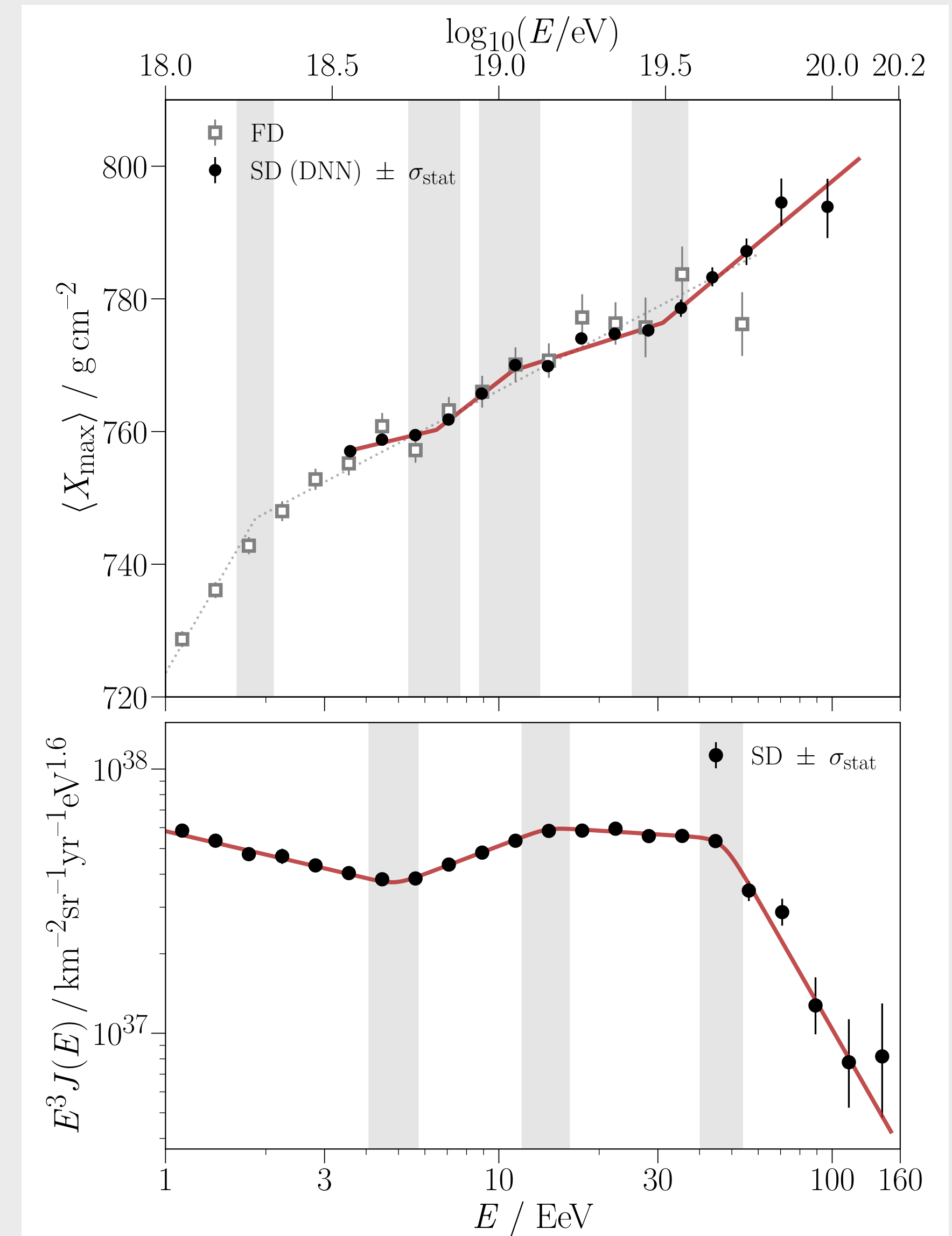
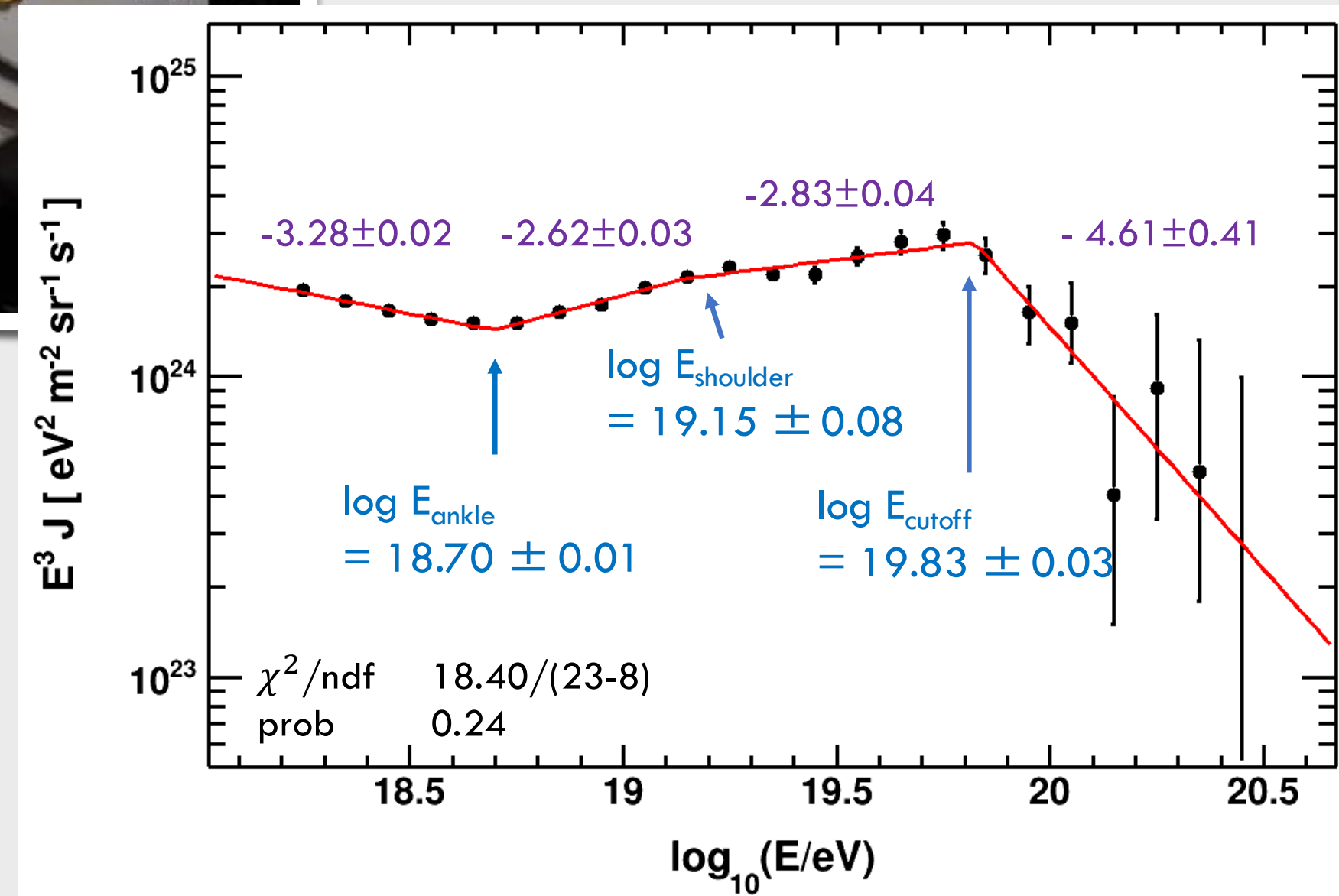


UHECR Symposium 2024 – Wrap-up

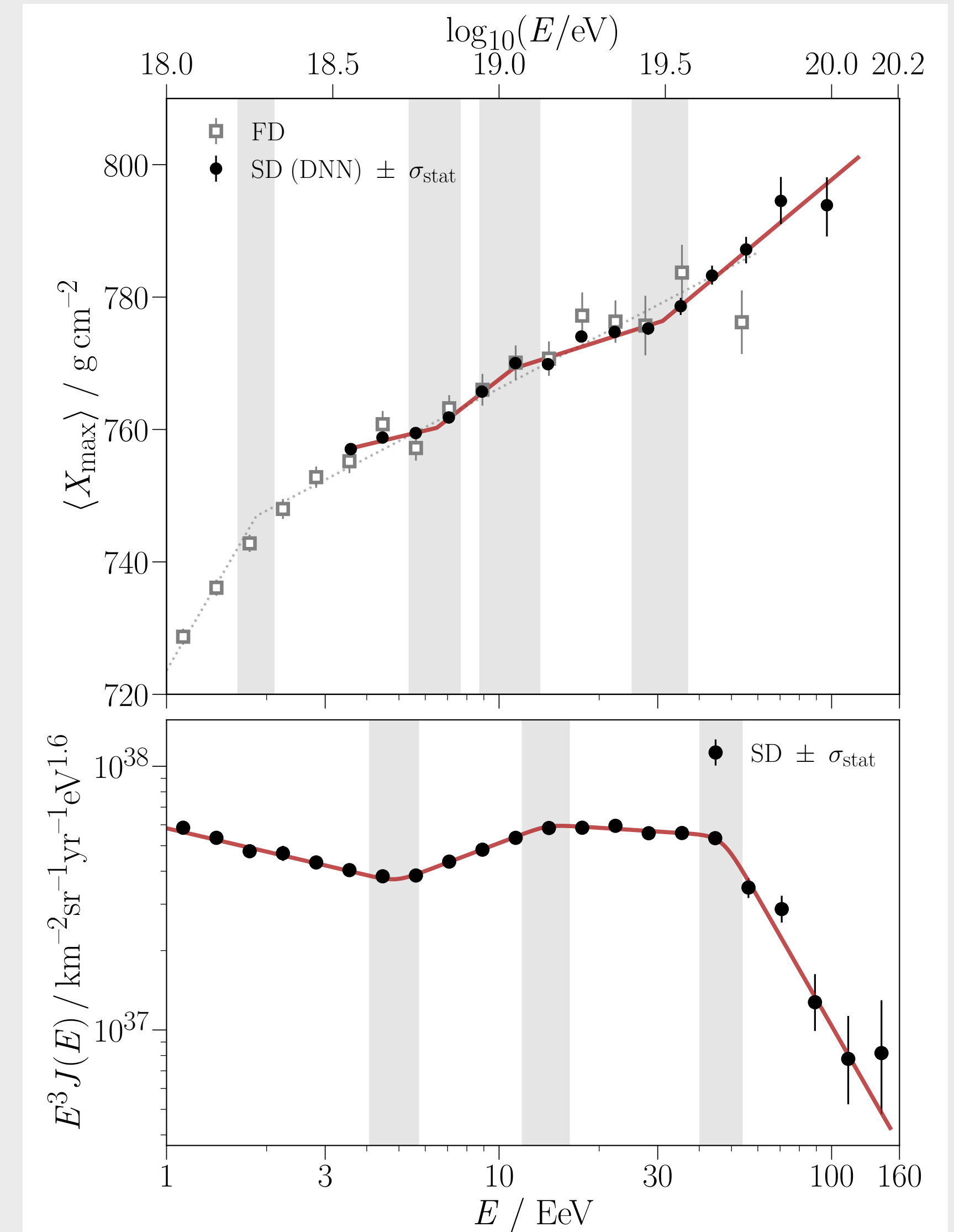
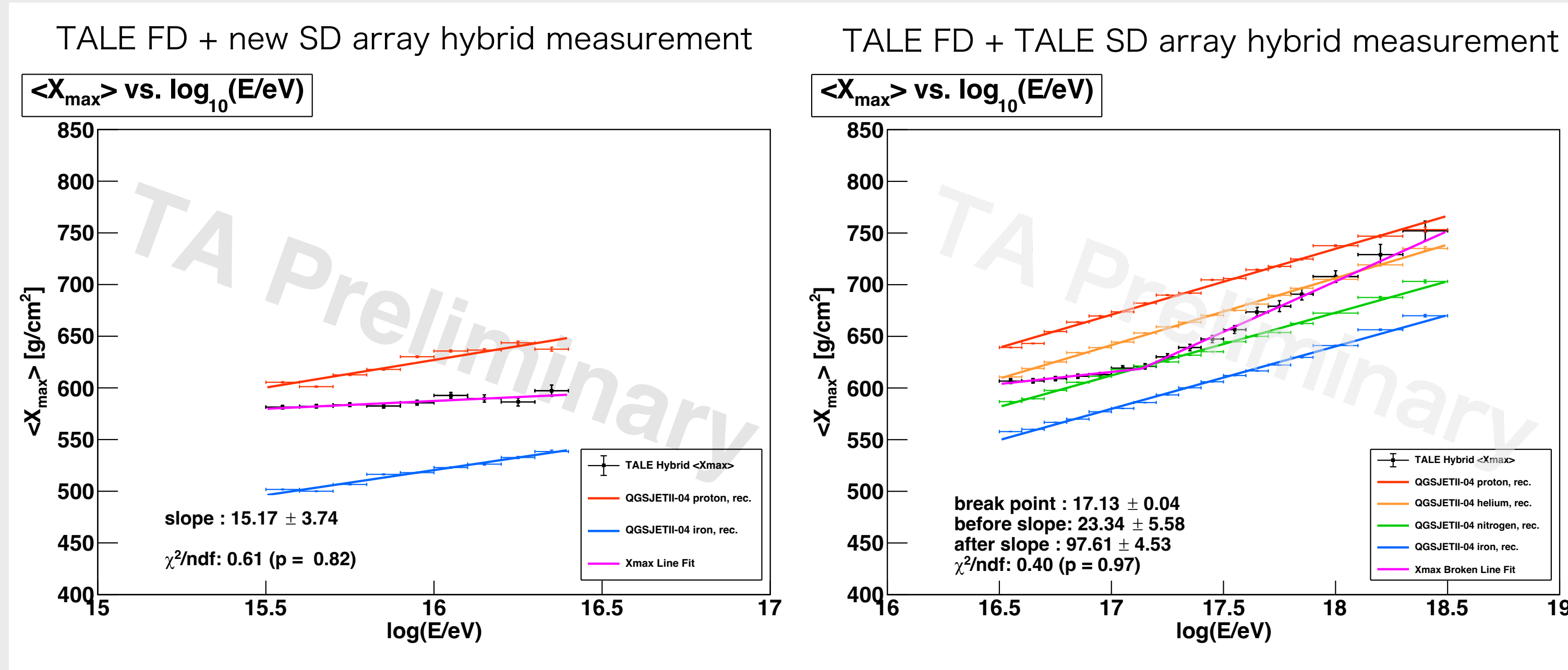
Ralph Engel (KIT)

Some thoughts – energy spectrum



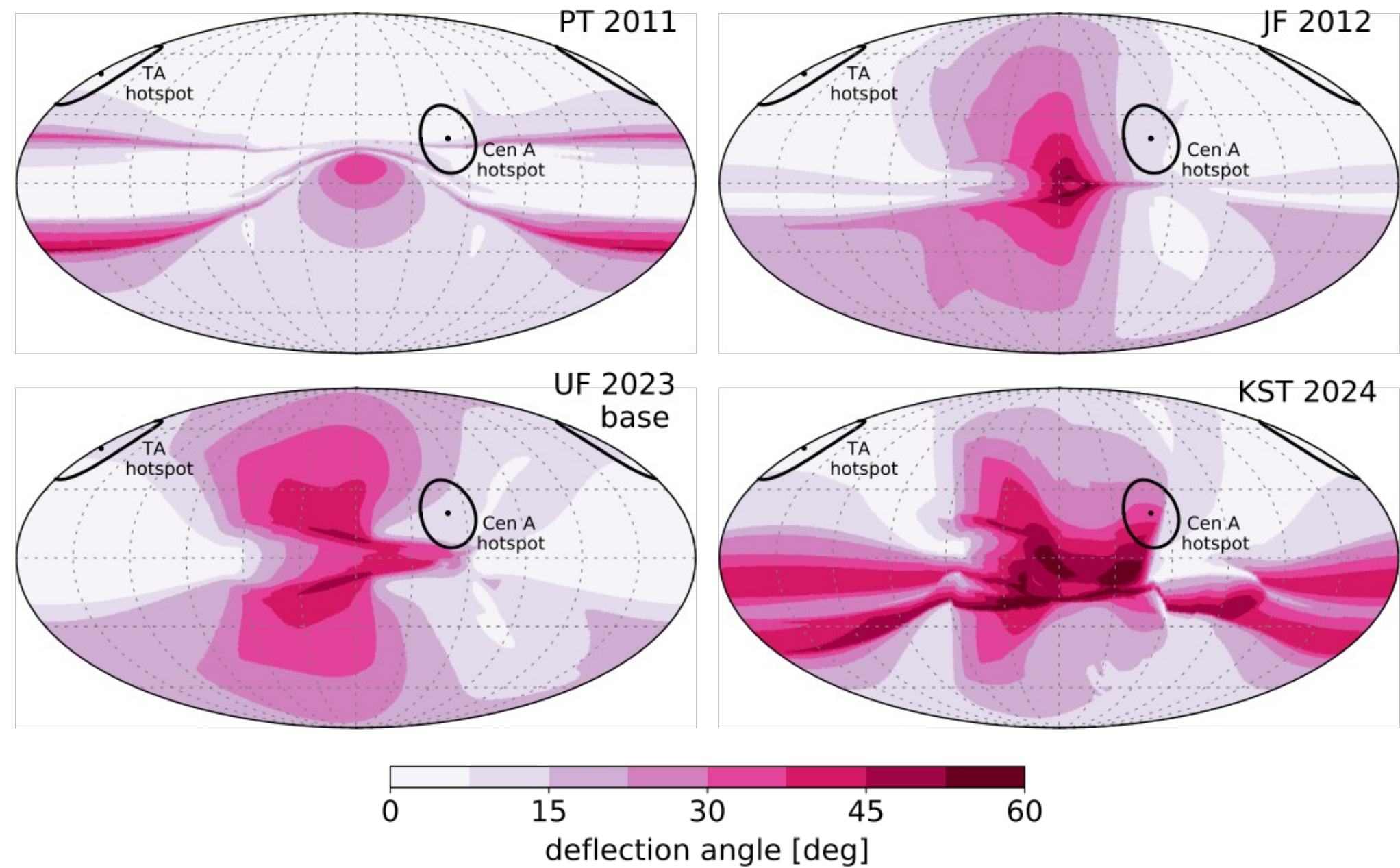
Consistency of data in overlap region of declination
 Sharpness of transition between different segments
 Interplay of spectrum and anisotropy (energy ranges)

Some thoughts – mass composition

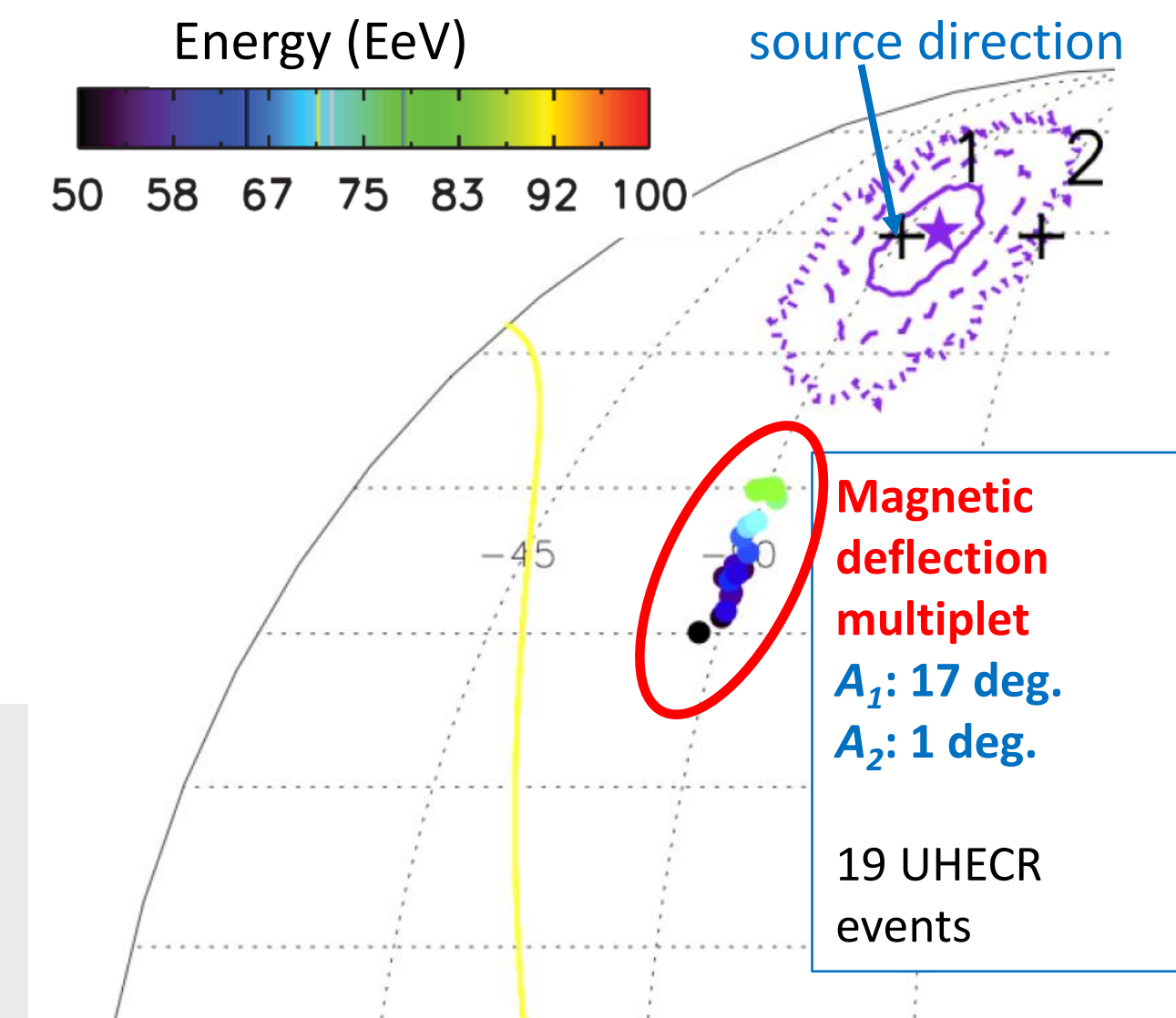
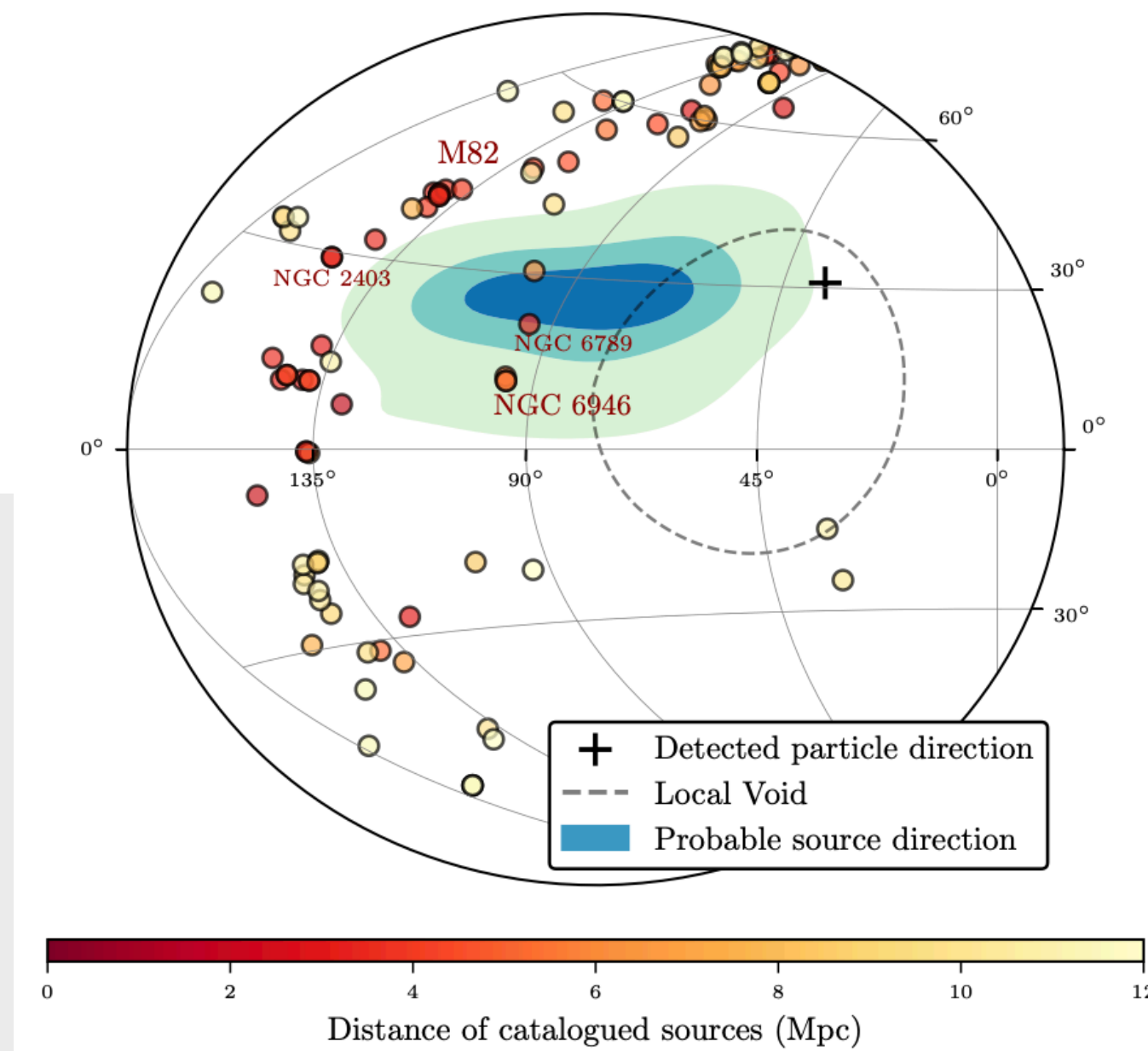
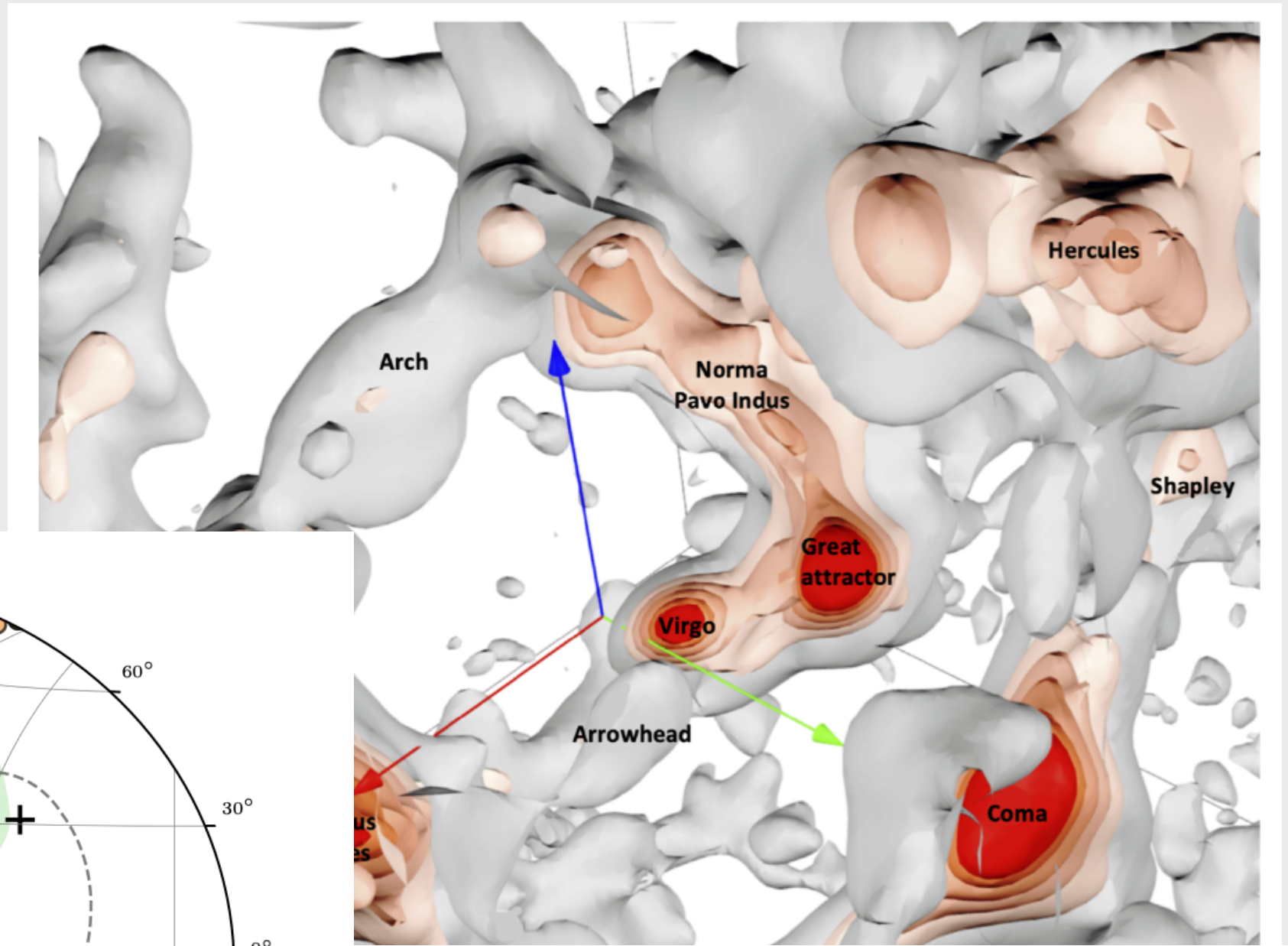


- Consistency of data in energy range with expected isotropy
- Sharpness of transition between different regions
- Tension between mean Xmax and fluctuations
- Model uncertainty for mass composition interpretation
- Muon discrepancy (low/high energy, muon energy spectrum)

Some thoughts – anisotropy

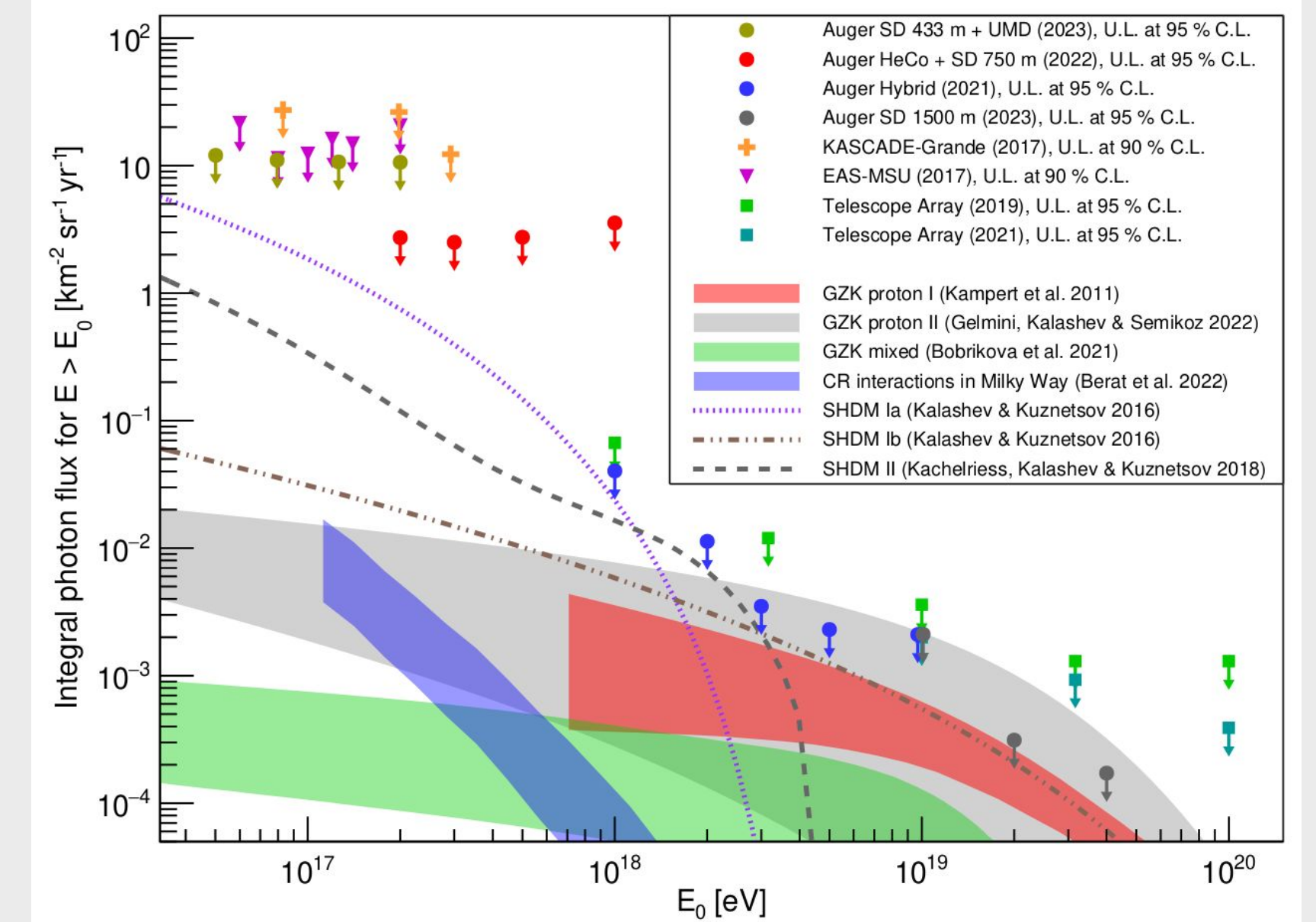
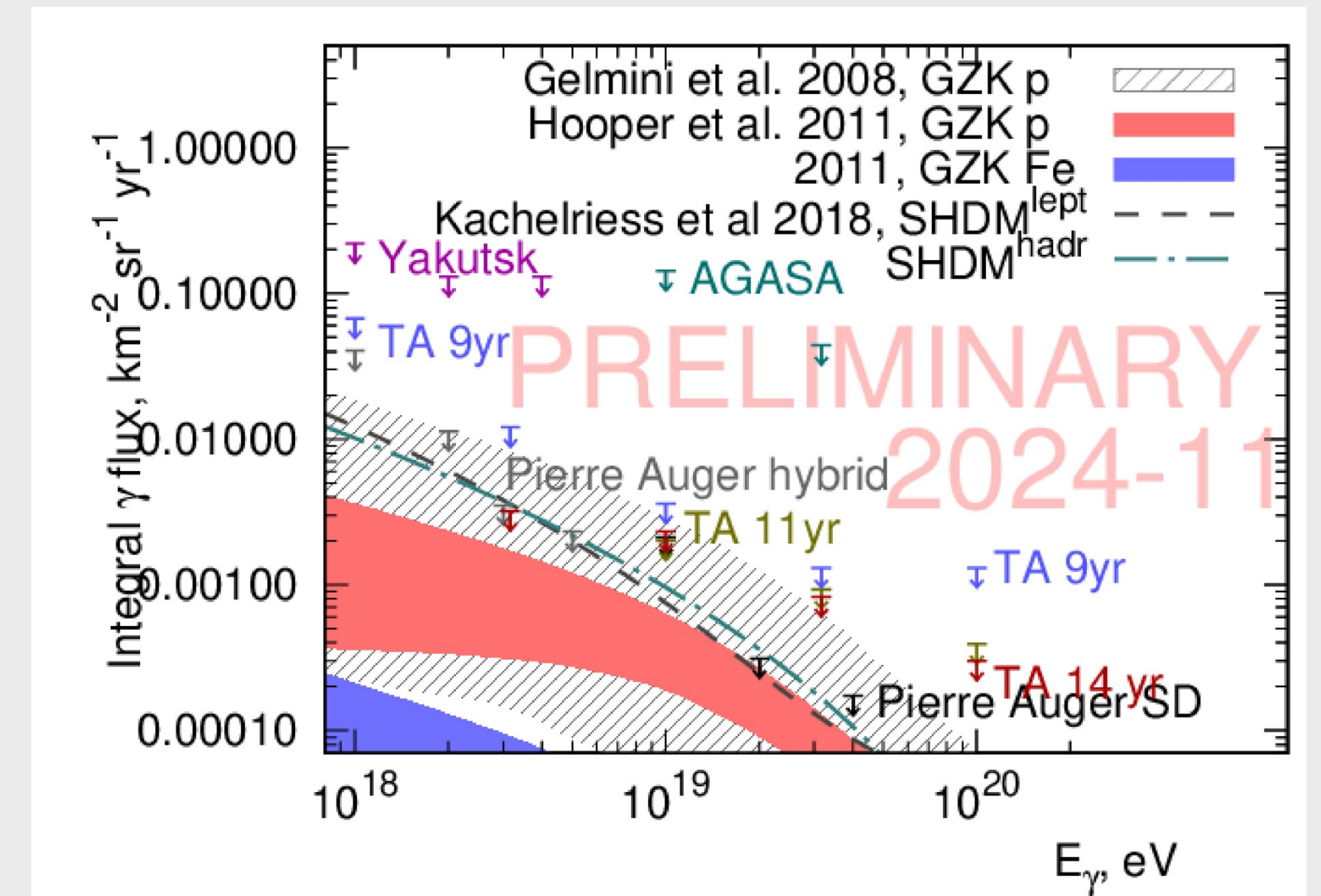
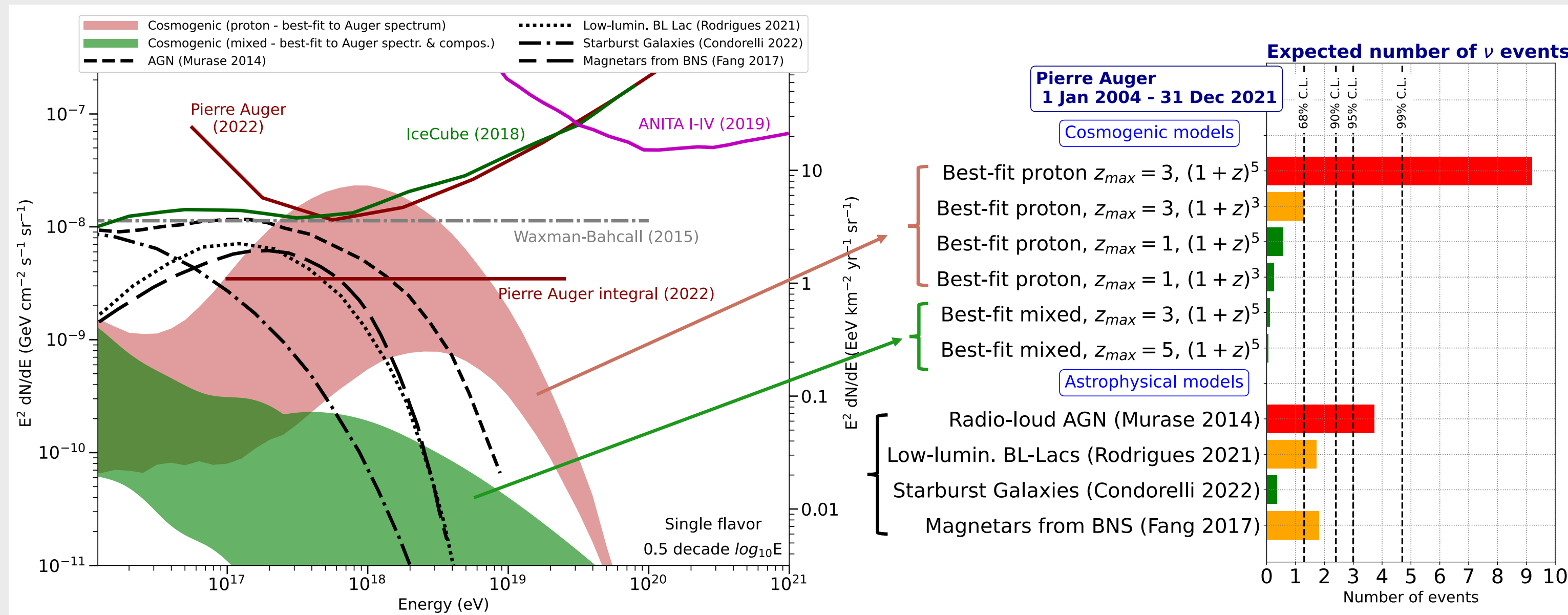


$R = 20 \text{ EV}$



- Consistency of data in common regions of sky
- Interpretation of dipole anisotropy
- Information from highest energy events
- Feasibility of single source scenario (source diversity)

Some thoughts – multi-messenger observations

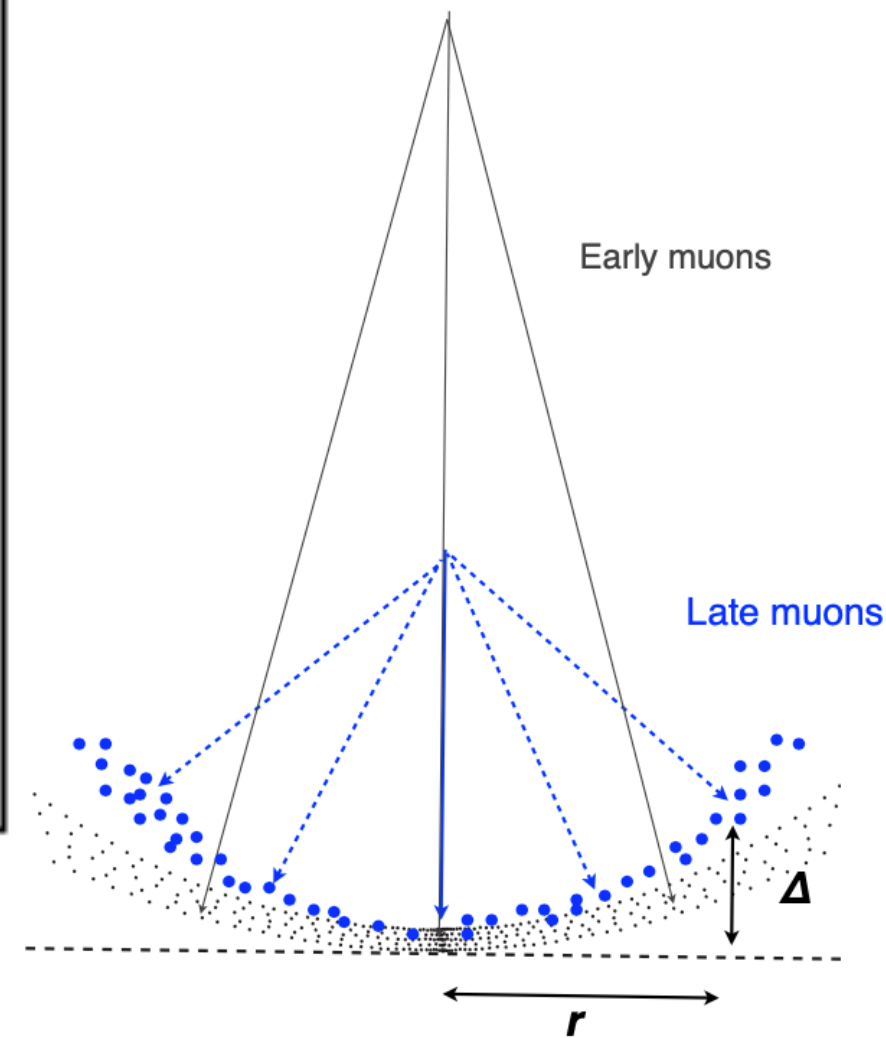
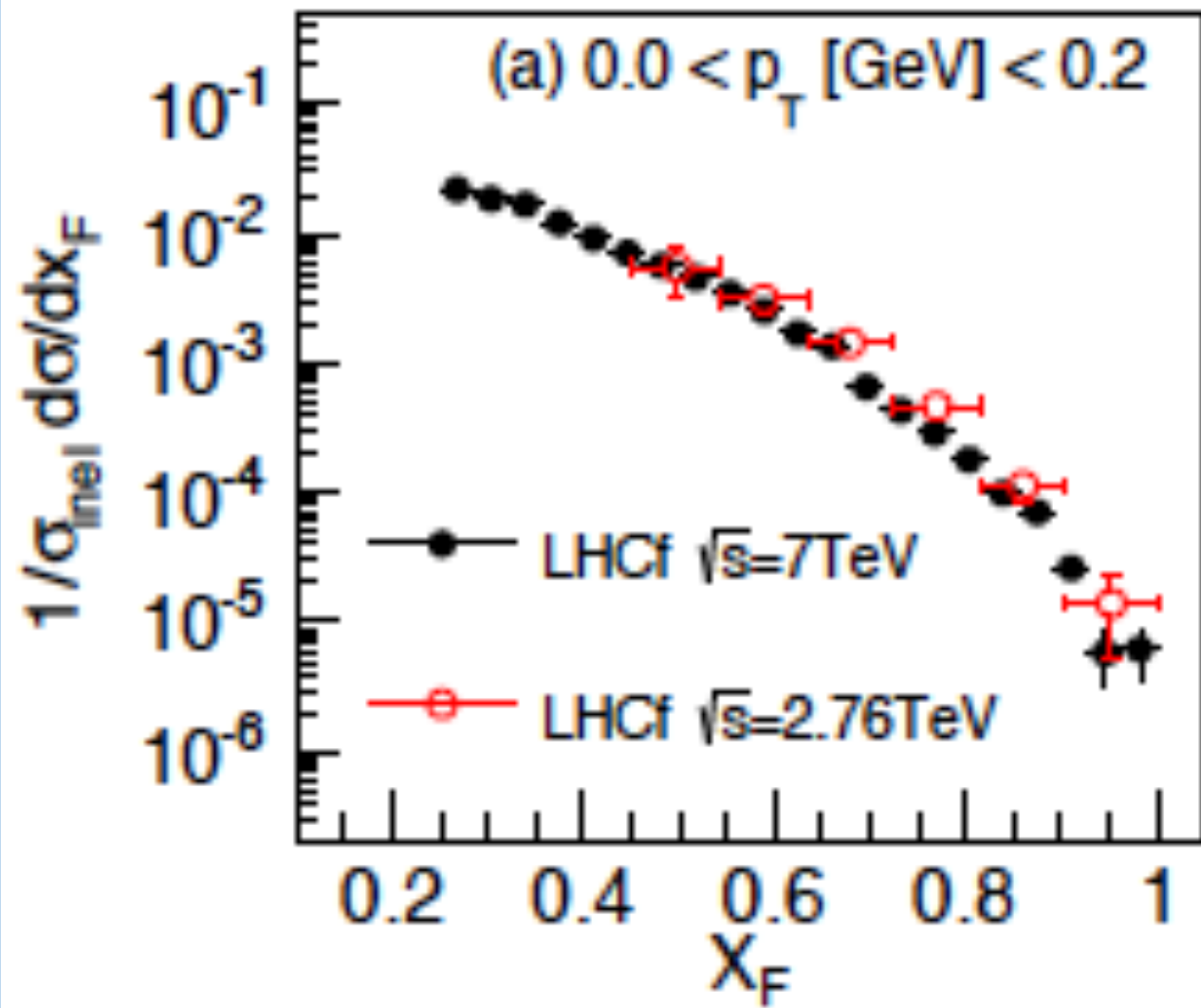


- Increasingly important – aim at discovery
- Lowering of low-energy threshold
- Development of new detection channels or instruments
- Might be only possibility to break compositions uncertainty
- Predictions based on openly available codes

Some thoughts – hadronic physics & searches

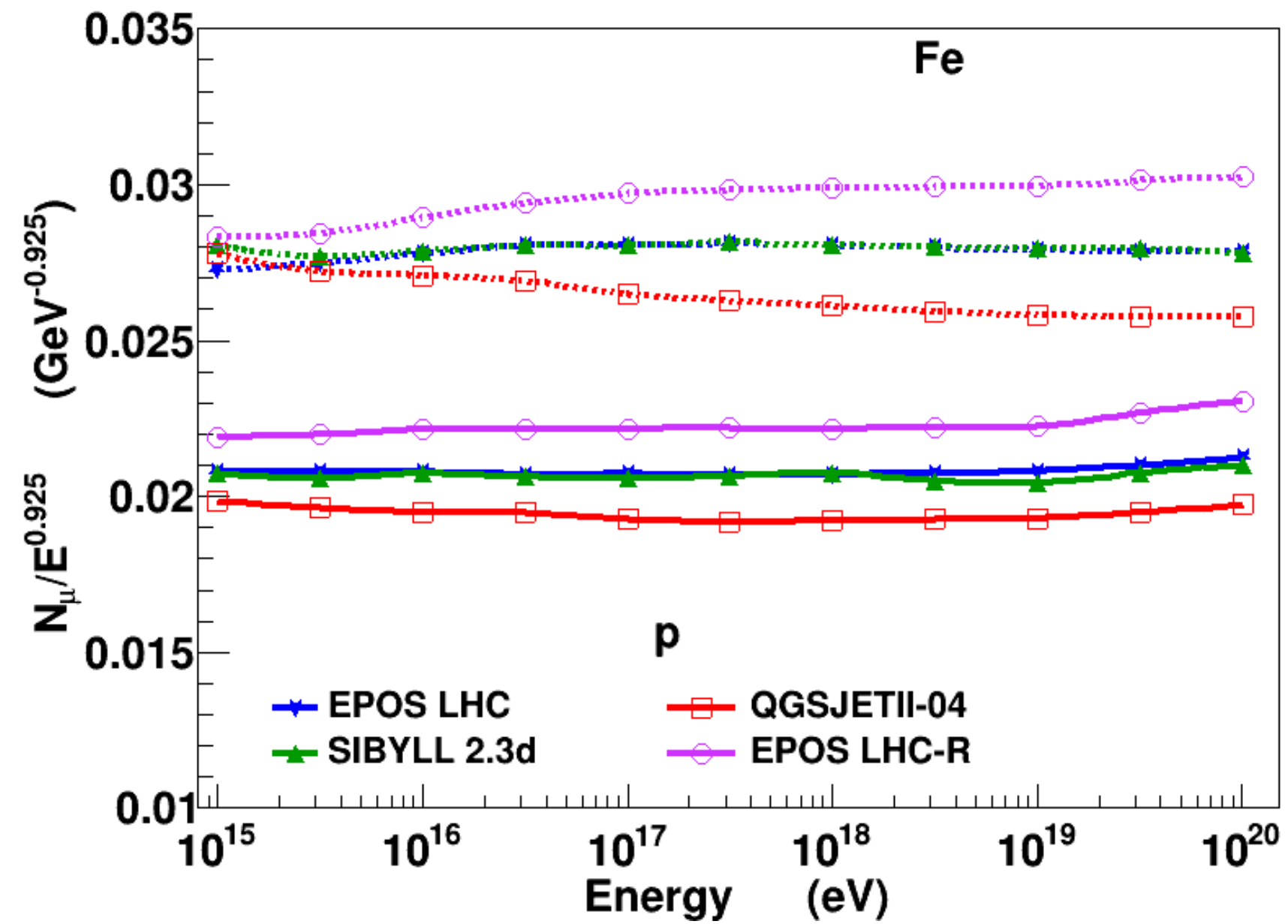
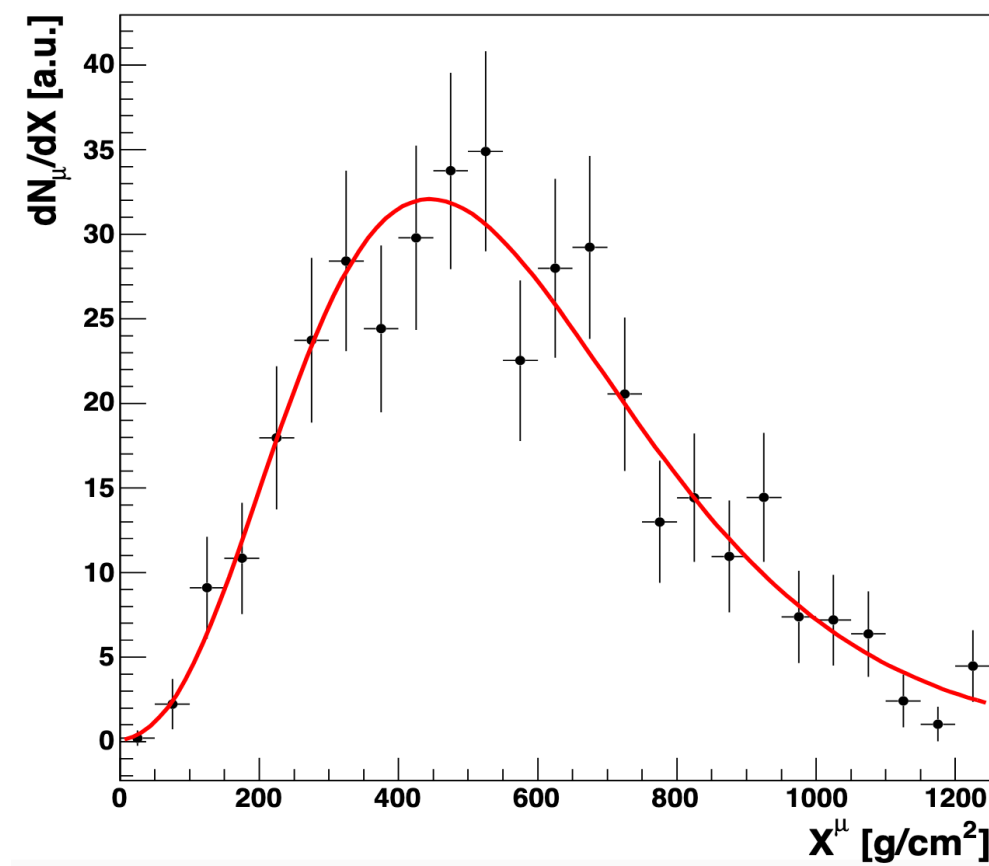
Forward π^0

Cazon et al. Astropart. Phys. 23, 2005



$$z \simeq \frac{1}{2} \left(\frac{r^2}{c(t - \langle t_\varepsilon \rangle)} - c(t - \langle t_\varepsilon \rangle) \right) + \Delta - \langle z_\pi \rangle$$

Pierre Auger Coll., Phys.Rev.D 90 (2014) 1, 012012



Re-consider uncertainties of model predictions

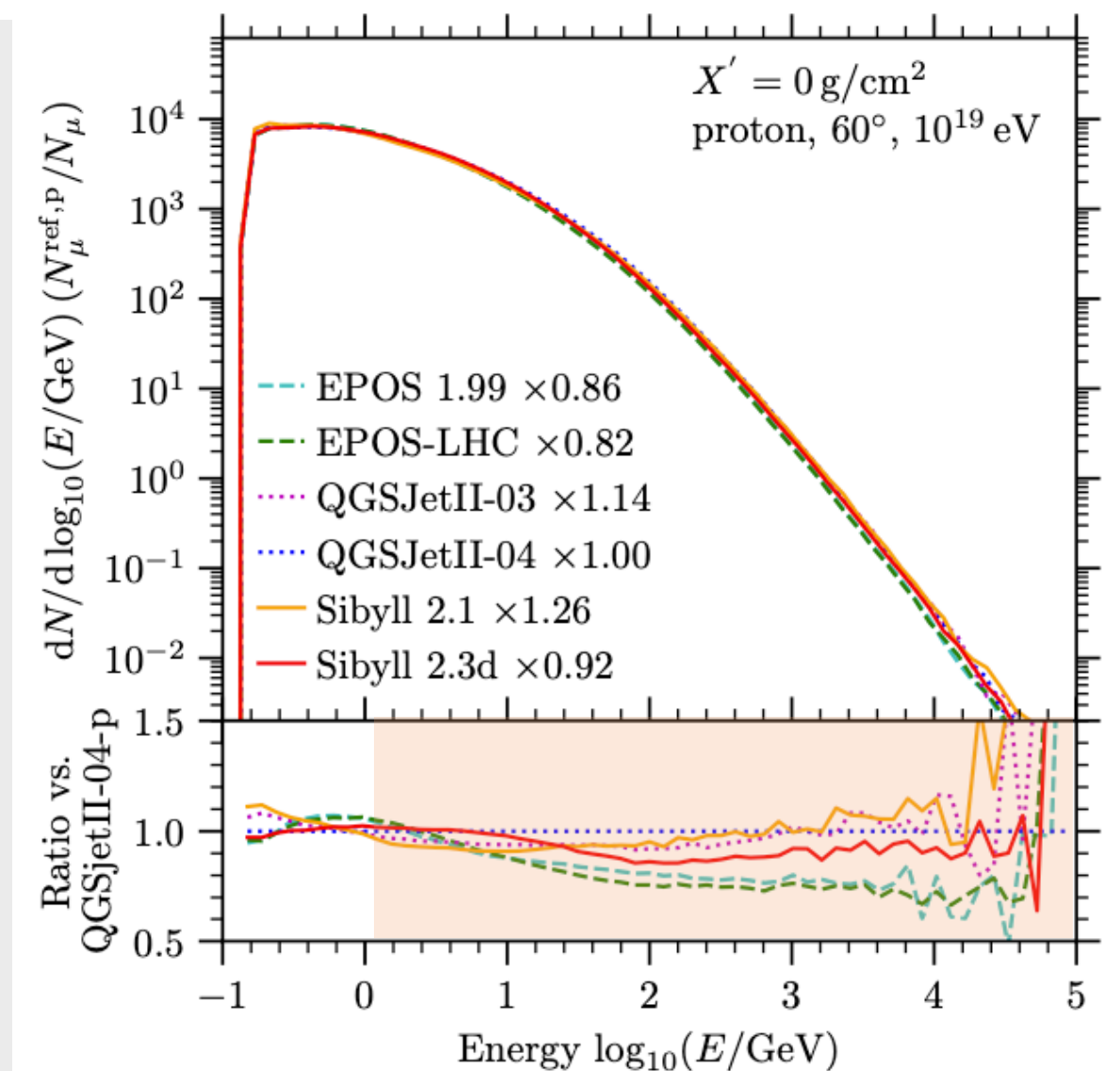
Use of accelerator data for tuning, proton-oxygen run of LHC

Connection of air shower observables with interaction characteristics

Combined cross section and composition analysis

Dedicated muon studies (theory and observation/experiment)









Consideration of more exotic scenarios (LIV, BSM, etc)

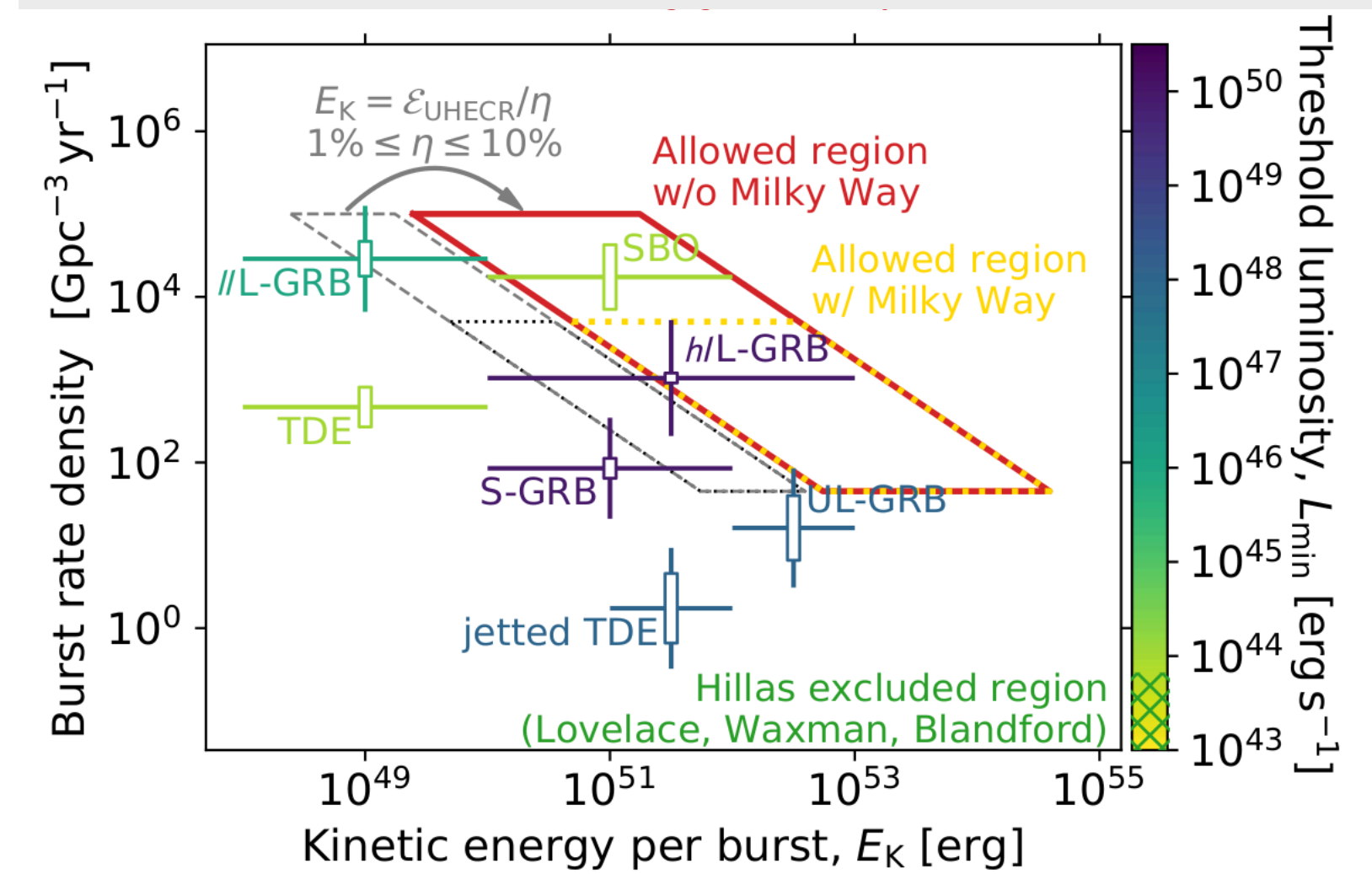
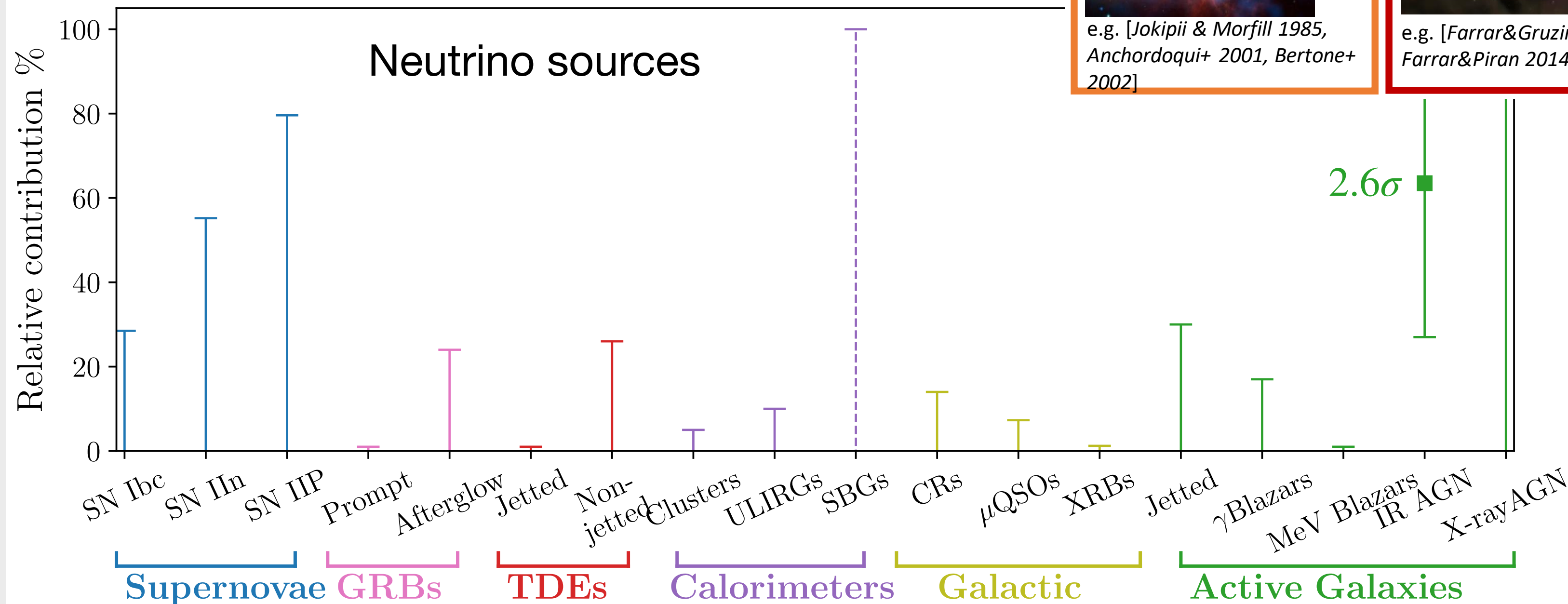


Some thoughts – source model building

- Model development of central importance
- Multitude of constraints available
- More critical consideration of models
- Single / many source classes contributing
- Open-source tools for predictions

$$L_{\text{bol,min}} > \frac{1}{2} \Gamma^2 c \beta \left(\frac{E}{Ze\beta} \right)^2 \sim 10^{45} \text{ erg s}^{-1} \Gamma^2 \beta^{-1} \left(\frac{E}{Z10^{20} \text{ eV}} \right)^2 \quad [\text{LoveLace 1966; Waxmann 1995; Blandford 2000}]$$

 <p>Magnetar/Pulsar</p> <p>e.g. [Blasi+ 2000, Arons 2003, Murase+ 2009, Fang+ 2012]</p>	Energetic transients in star-forming galaxies $L_{\gamma\text{iso}} \sim 10^{52} \text{ erg s}^{-1}$		
 <p>Transrelativistic SN/Hypernova</p> <p>e.g. [Murase+ 2006 2008, Wang+ 2007, Chakraborty 2009]</p>	 <p>Long GRB Short GRB</p> <p>e.g. [Waxman 1995, Vietri 1995, BTZ+ 2024]</p>	 <p>BNS (Kilonova)</p> <p>e.g. [Takami+ 2013, Kimura+ 2018, Rodrigues+ 2019]</p>	
 <p>Starburst galaxy superwinds</p> <p>e.g. [Jokipii & Morfill 1985, Anchordoqui+ 2001, Bertone+ 2002]</p>	Supermassive black holes		Merger shocks
 <p>TDE</p> <p>e.g. [Farrar&Gruzinov 2009; Farrar&Piran 2014; BTZ+ 2017]</p>	 <p>AGN/Blazar/Radio galaxy</p> <p>e.g. [Ginzburg & Syrovatskii 1964, Takahara 1990, Rachen & Biermann 1993, Murase+ 2012]</p>	 <p>Galaxy cluster</p> <p>e.g. [Norman+ 1995, Kang+ 1996; Inoue+ 2007, Murase+ 2008]</p>	



UHECR 2024, Malargüe, Argentina



153 participants
20 countries
Argentina
Belgium
Brazil
China
Czechia
France
Germany
Italy
Japan
Mexico
Netherlands
Norway
Peru
Poland
Portugal
Russia
Slovenia
Spain
Taiwan
United States

8 review talks, 53 contributed talks, 59 poster contributions, 2 poster prizes

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