combined analysis of the spectrum and anisotropies of UHECRs

Daniel De Marco

Bartol Research Institute
University of Delaware

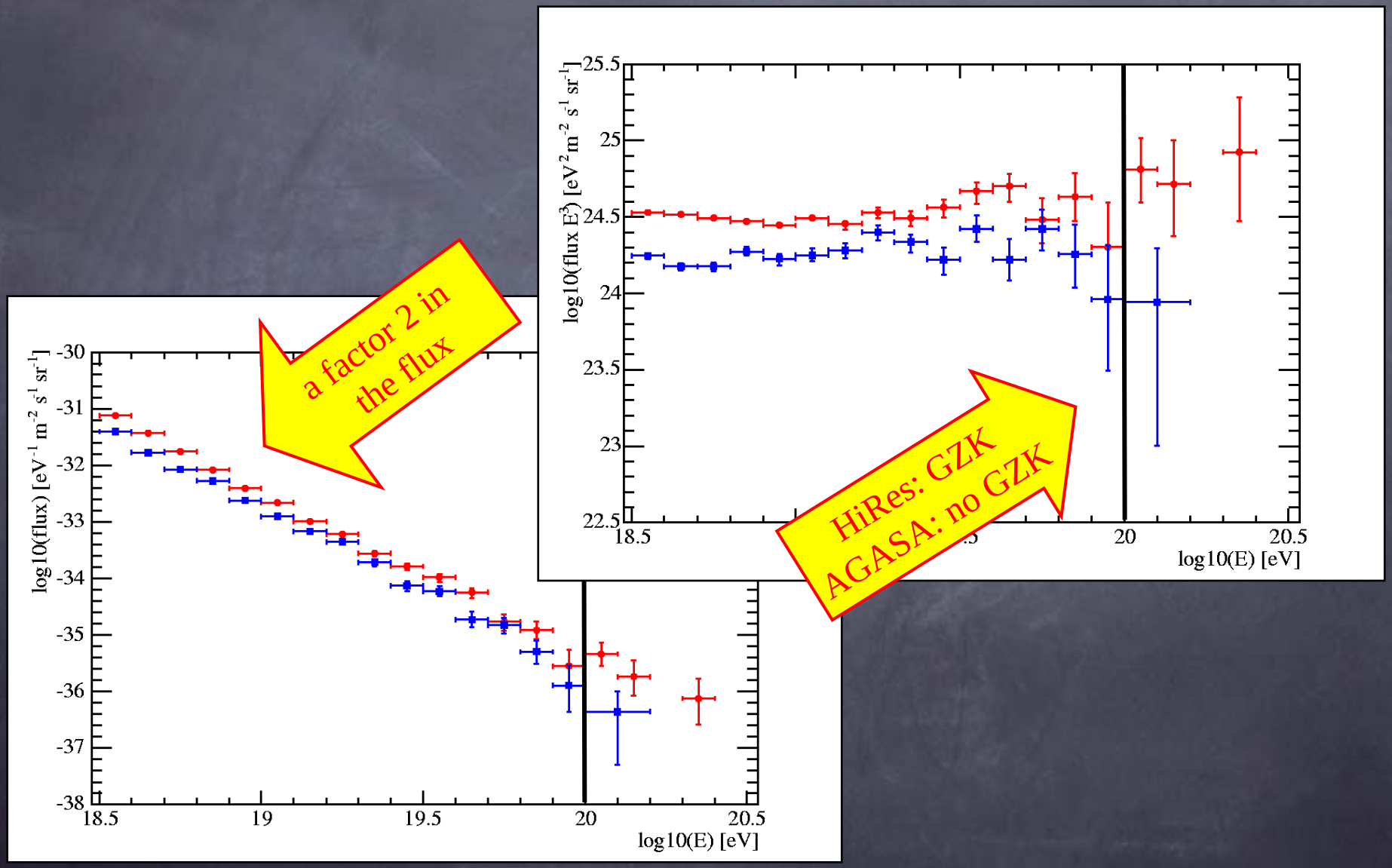
plan

AGASA vs HiRes

AGASA: spectrum vs ssa

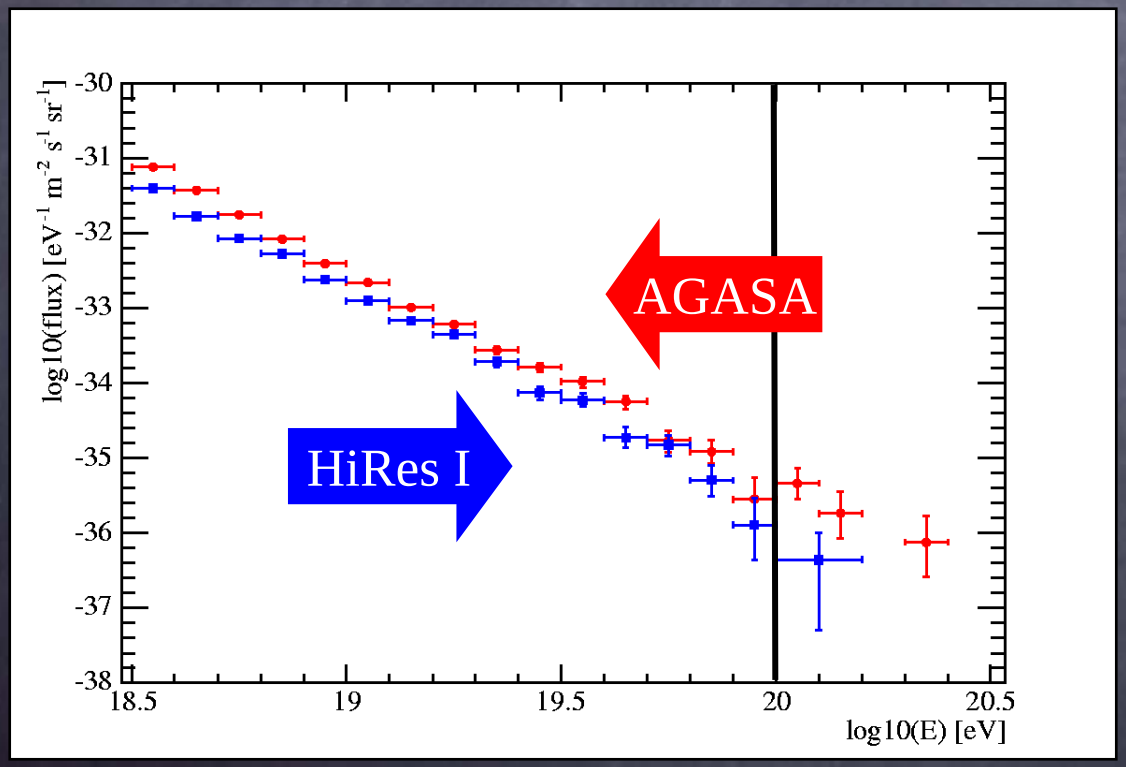
expectations for Auger

AGASA & HiRes


log10(flux E^3) [eV^2 m^-2 s^-1 sr^-1]
25.5
25
24.5
24
23.5
23
22.5
18.5
20
20.5
log10(E) [eV]
HiRes: GZK
AGASA: no GZK
log10(flux) [eV^-1 m^-2 s^-1 sr^-1]
-30
-31
-32
-33
-34
-35
-36
-37
-38
18.5
19
19.5
20
20.5
log10(E) [eV]
a factor 2 in the flux

systematic errors (?)

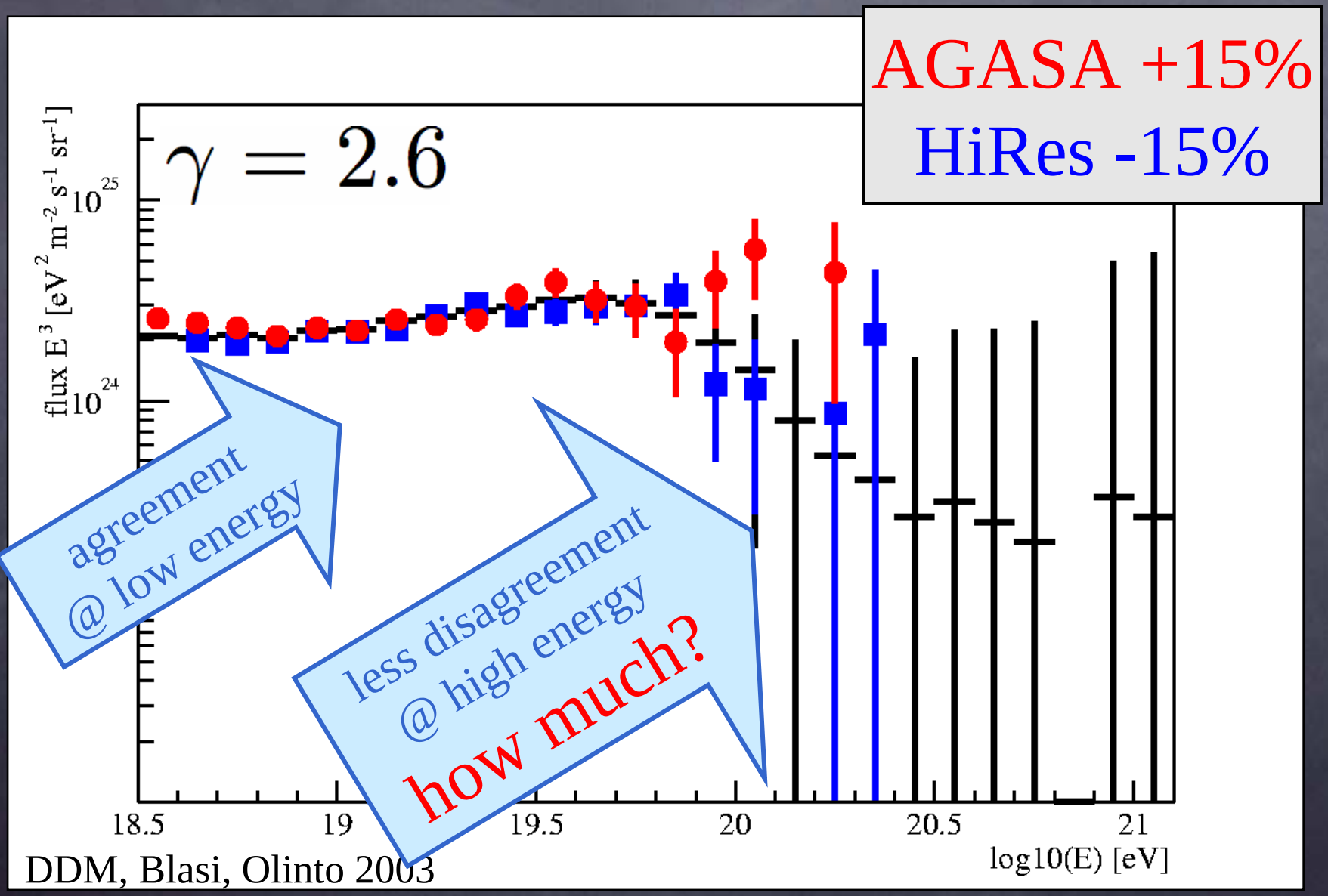
systematic errors may be the explanation (at low energy)



a factor 2 in the flux can be accounted for with a systematic error in the energy determination of about 30%

15% within limits allowed by both collaborations

systematic errors (?)



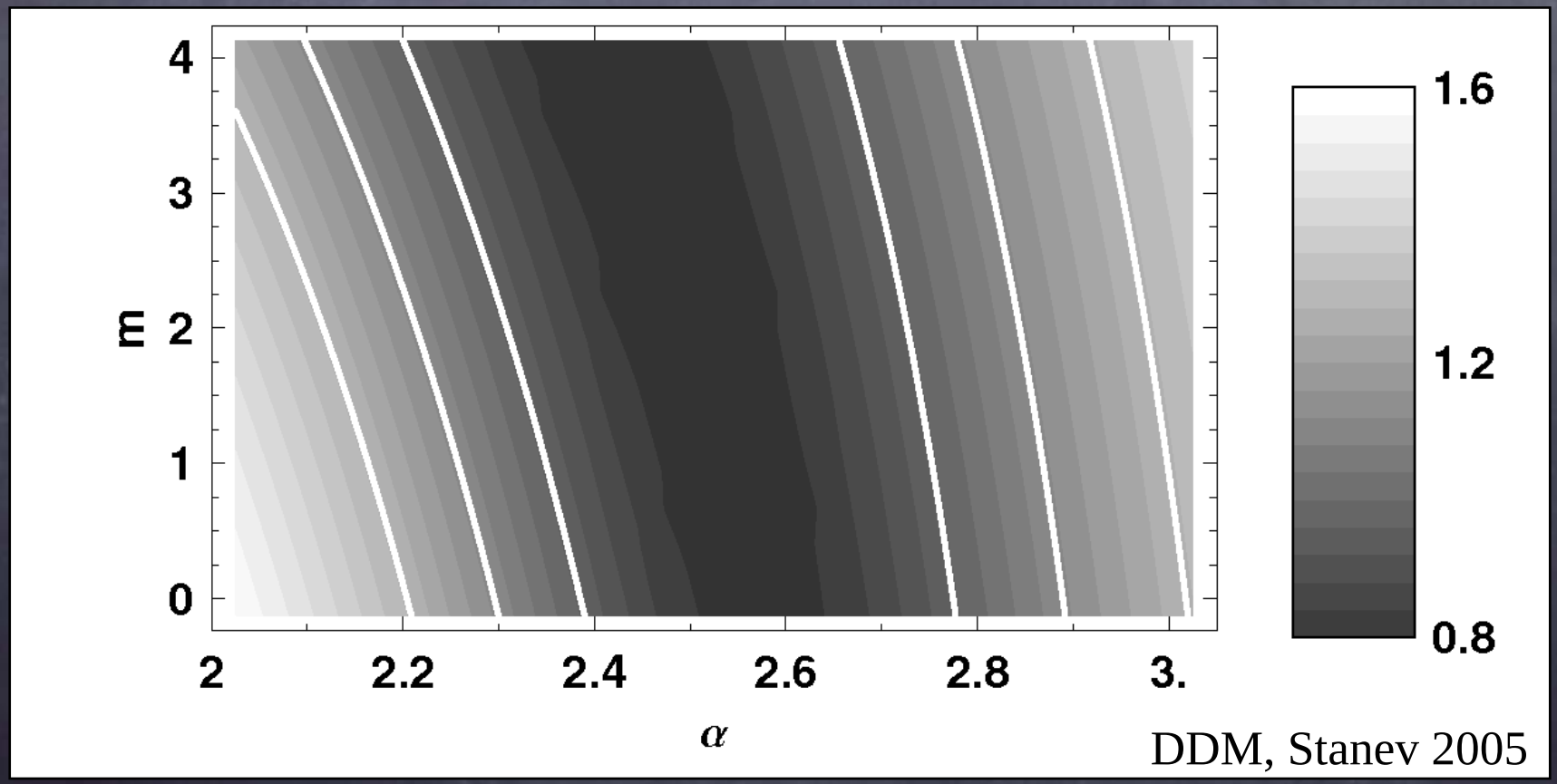
DDM, Blasi, Olinto 2003

fit uncertainties

fit to shifted data in the range 10^{19} eV to 10^{20} eV

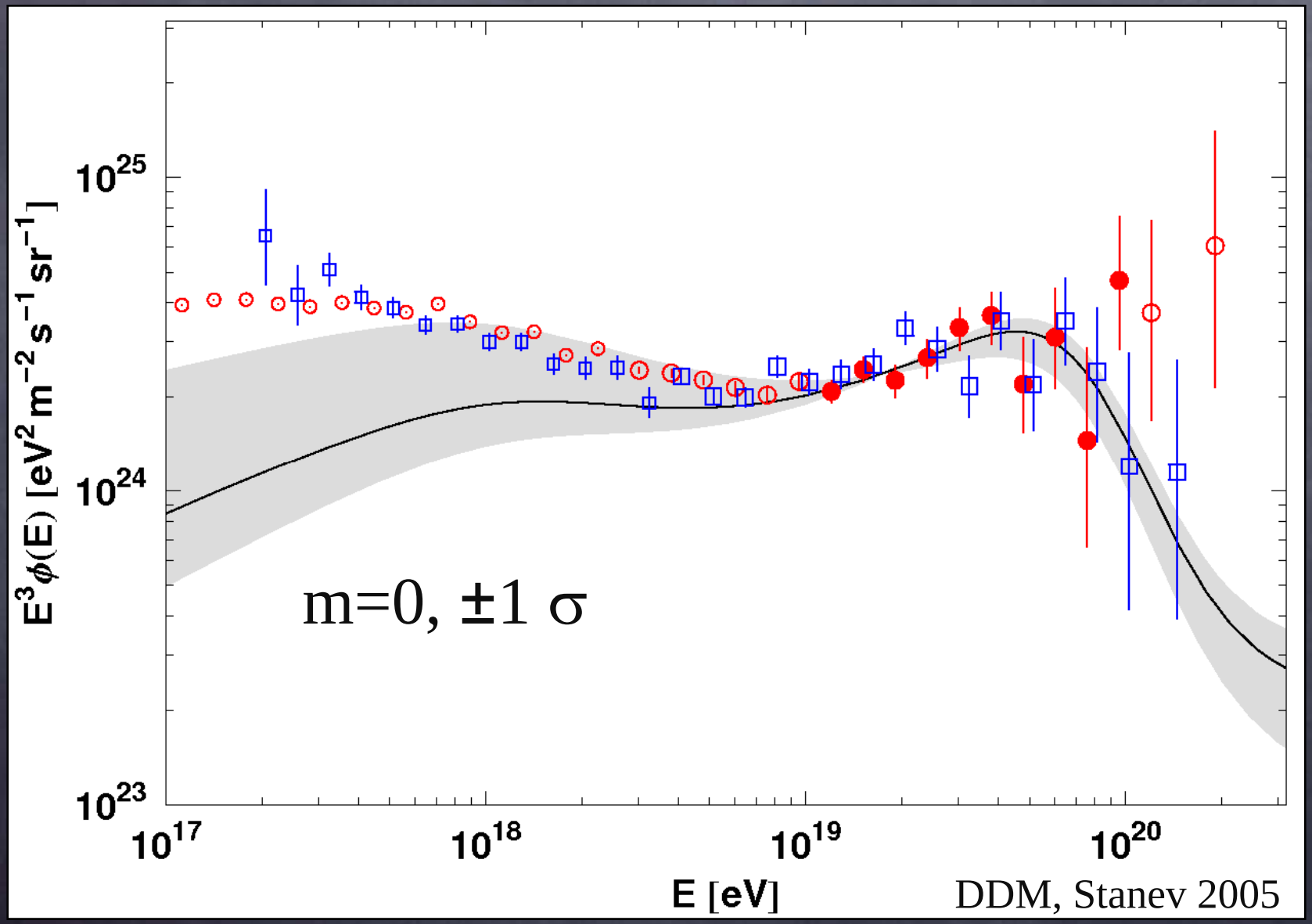
proton propagation

$\log_{10}\chi^2$

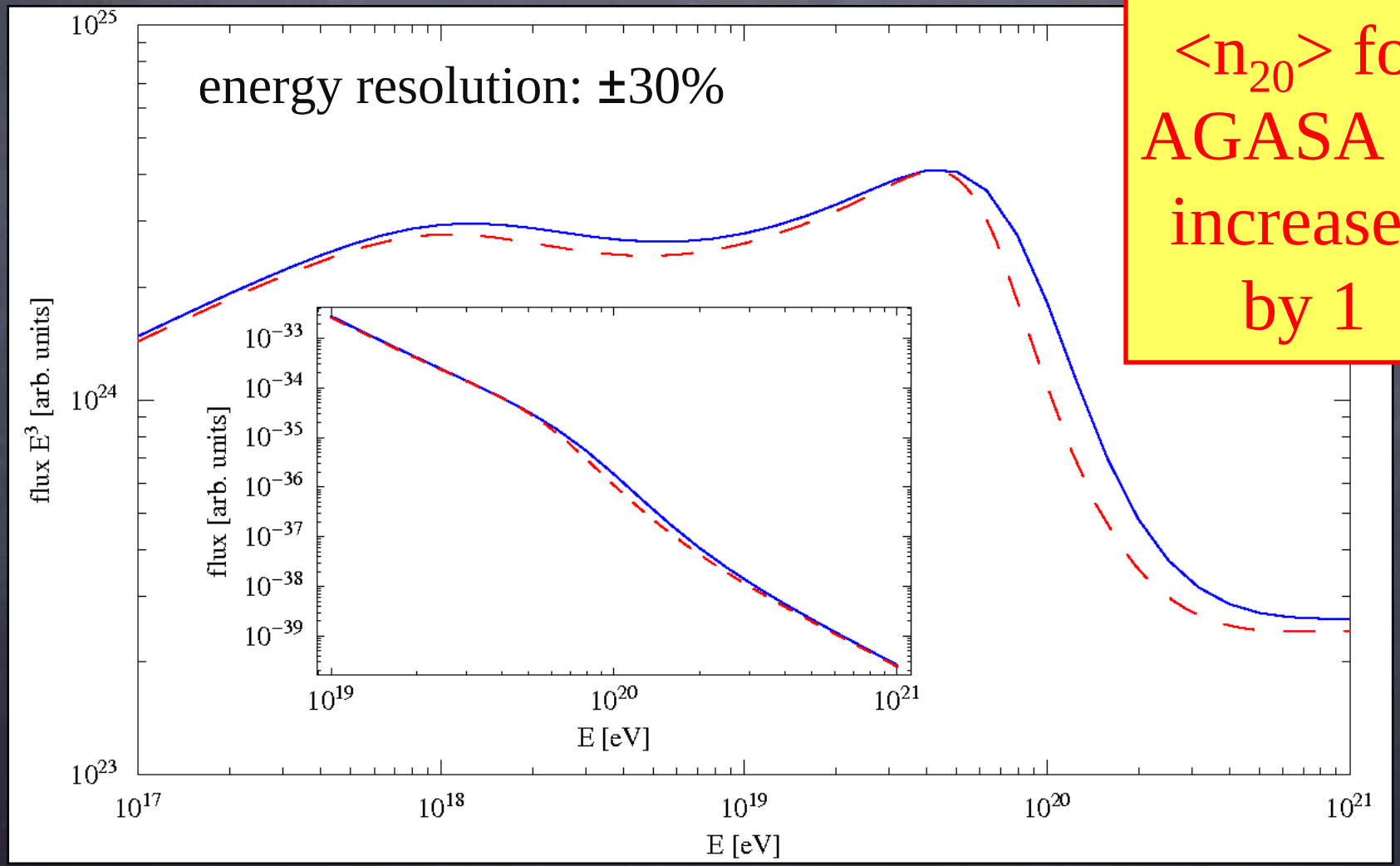


DDM, Stanev 2005

fit uncertainties



statistical error in the energy reconstruction



$\langle n_{20} \rangle$ for AGASA is increased by 1

high energy: AGASA

we simulated 30000 realizations of the AGASA statistics above $4 \cdot 10^{19}$ eV (72 events) and we counted the number of events with energy above 10^{20} eV.

18 realizations produced 11 or more events above 10^{20} eV

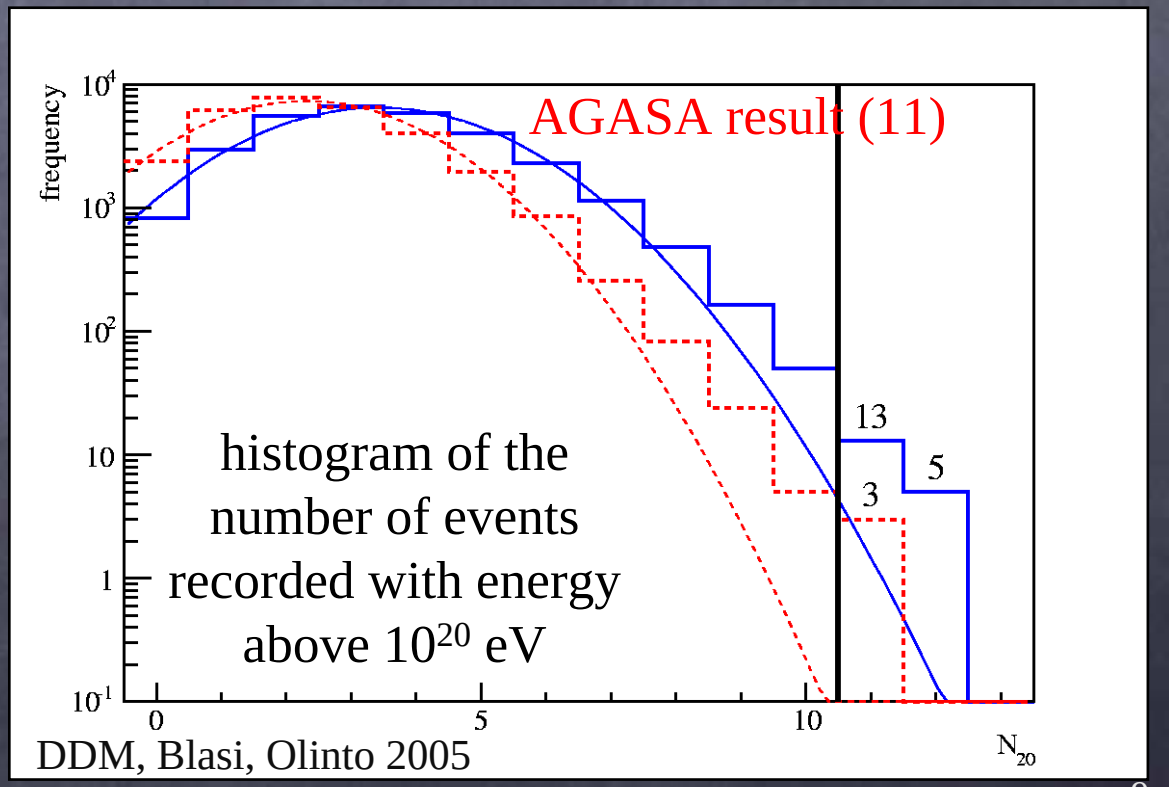
probab.: **$6 \cdot 10^{-4}$ — 3.2 σ**

the same procedure applied to the AGASA-15% statistics resulted in a probability of

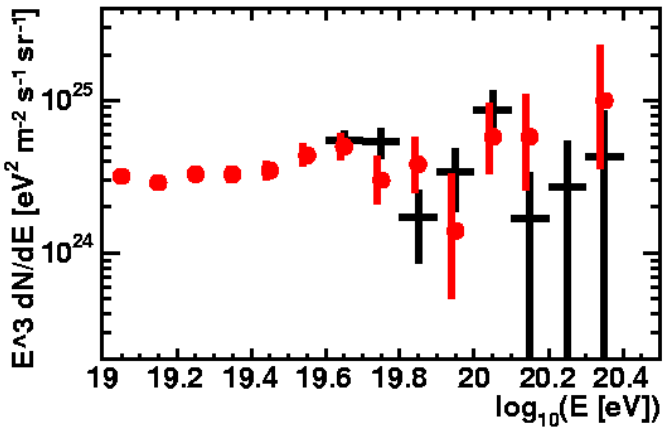
about **1% — 2.3 σ**

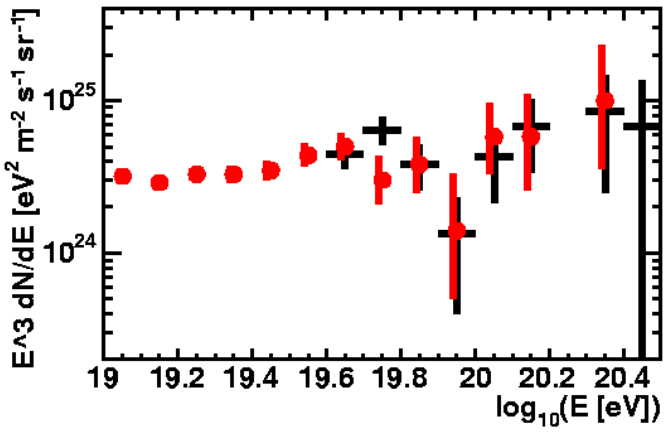
accounting for the sys. errors, the AGASA result doesn't have a high statistical significance

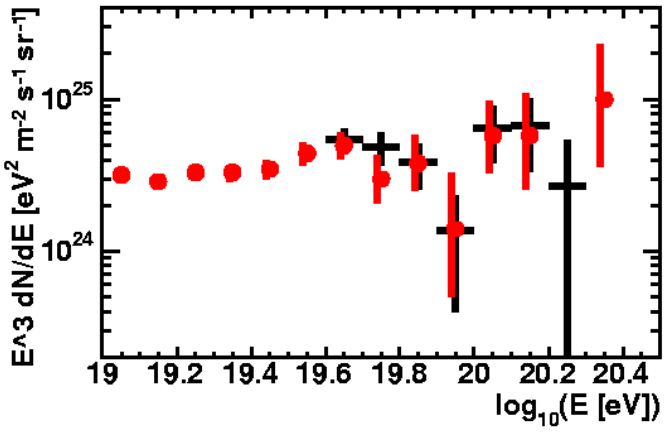
propagation simulation (γ=2.6)
GZK suppression

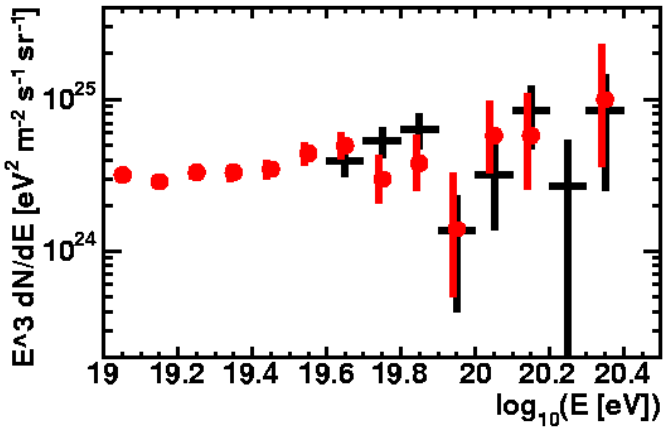


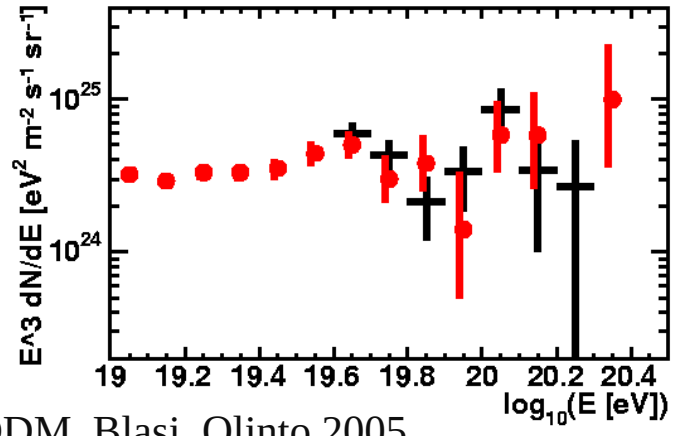
some AGASA spectra

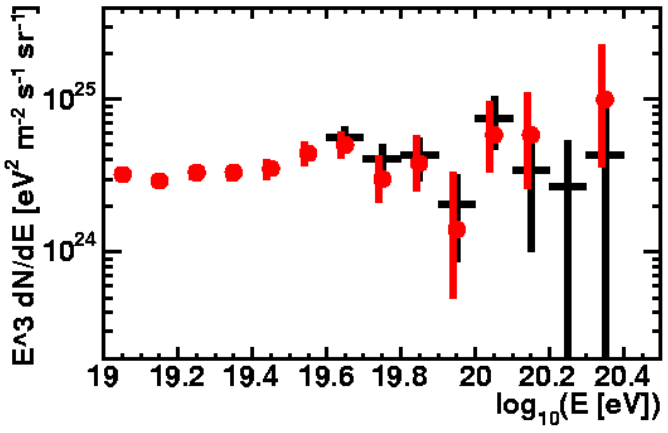












DDM, Blasi, Olinto 2005

high energy: HiRes

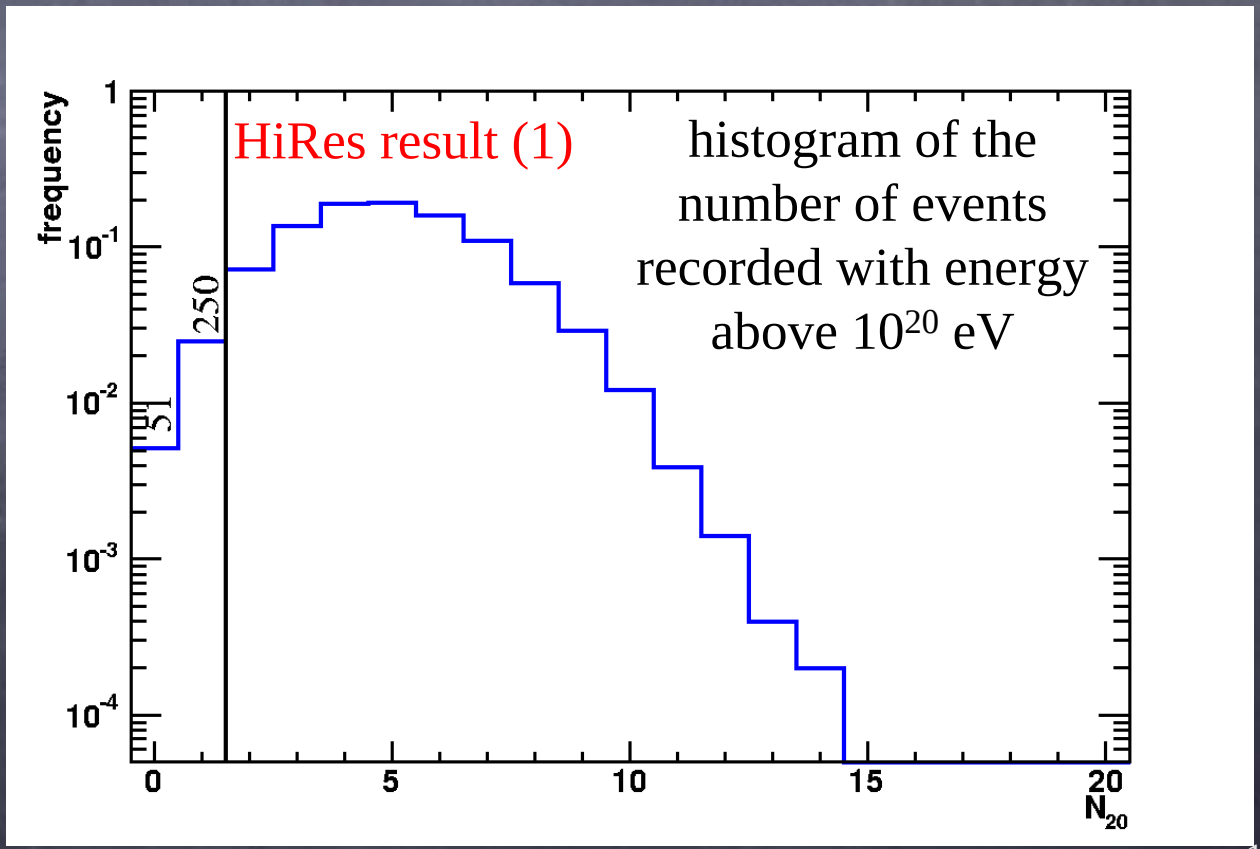
we simulated 10000 realizations of the HiRes statistics above $4 \cdot 10^{19}$ eV (27 events) and we counted the number of events with energy above 10^{20} eV.

no propagation, we used as template the AGASA measured spectrum, but for the HiRes statistics

301 realizations produced 1 or less events above 10^{20} eV

prob.: 3% — 2 σ

the HiRes result as well does not have a high statistical significance



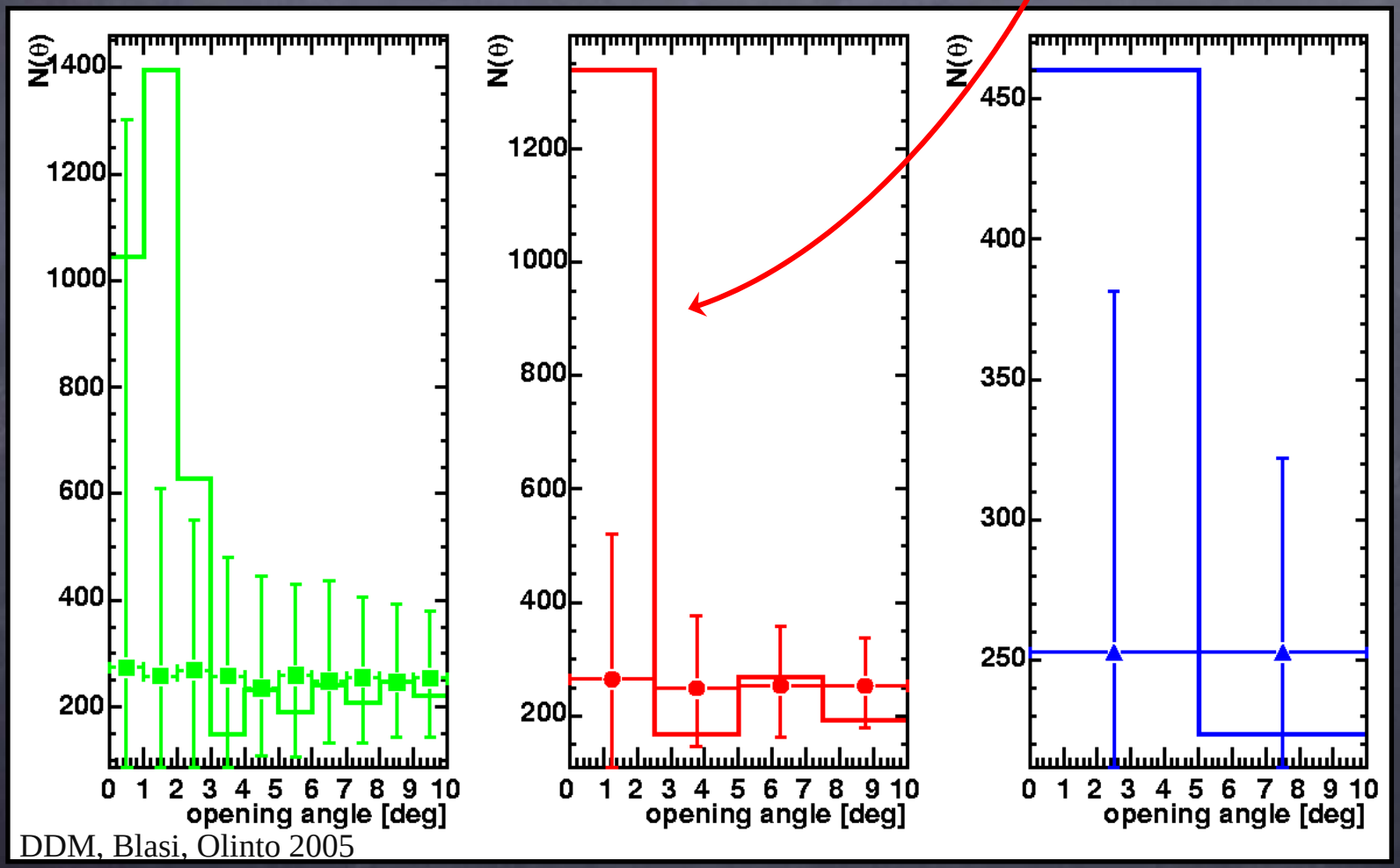
no strong discrepancy between AGASA and HiRes spectra

Small Scale Anisotropies: what can they tell us?

simulation of the propagation from astrophysical point sources

AGASA 2pcf

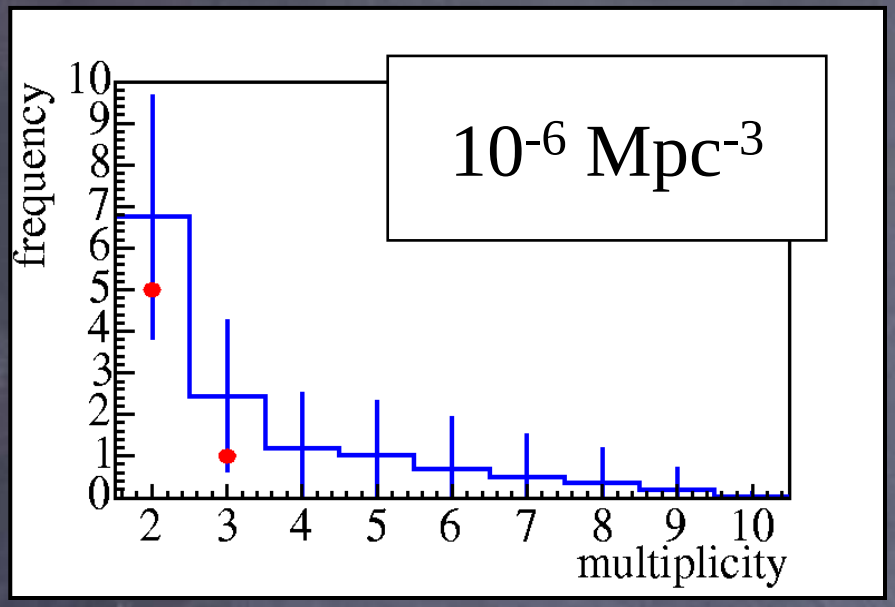
point sources (?)



DDM, Blasi, Olinto 2005

see also Finley and Westerhoff 2003

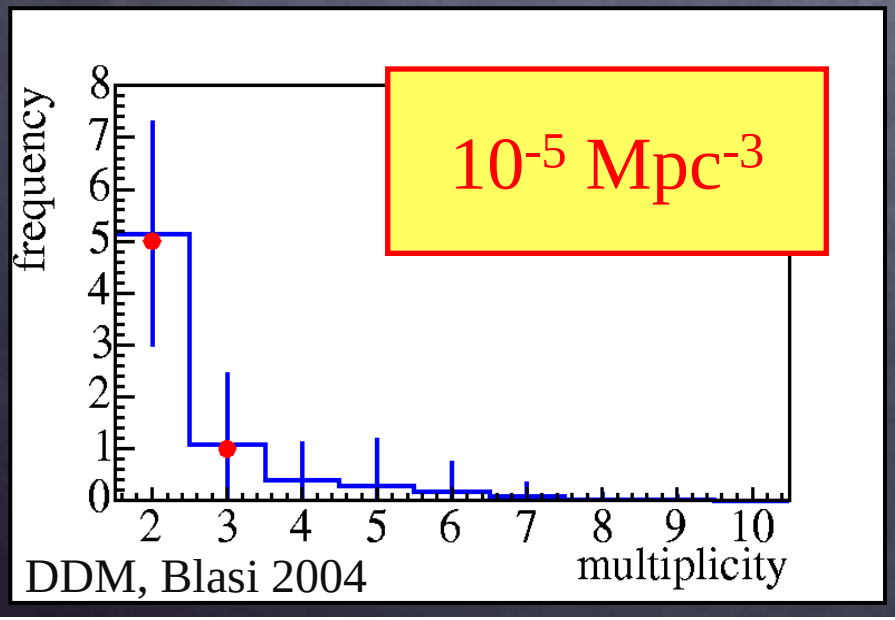
AGASA multiplets

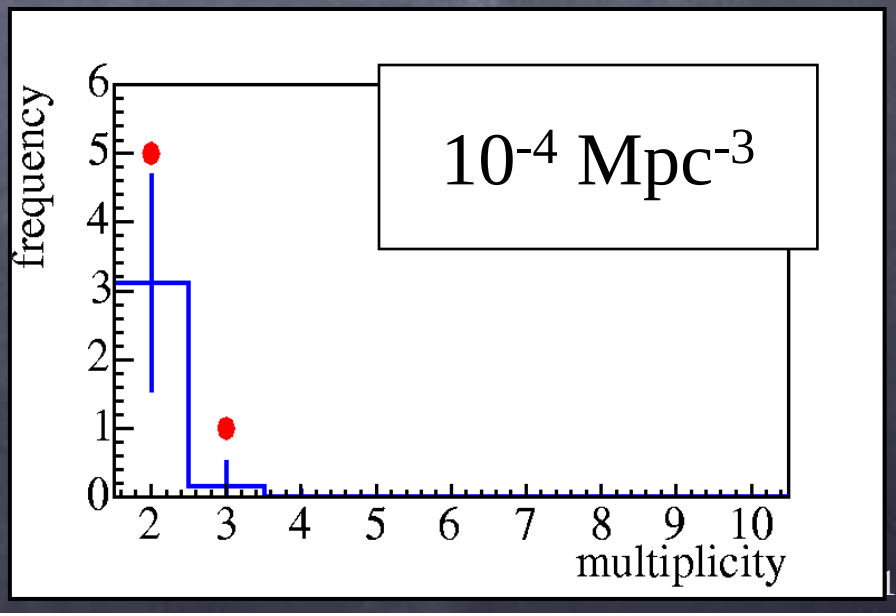


B~<10^{-10} G resol.=2.5°

γ=2.6 m=0

E > 4 10^{19} eV - 57 events





sources characteristics

- $L_{CR} = 6\ 10^{44}$ erg/yr/Mpc^3 ($E>10^{19}$ eV - from spectrum fits)

$n_0 = 10^{-5}$ Mpc^{-3} (from ssa)

$L_{src} = 2\ 10^{42}$ erg/s ($E>10^{19}$ eV)

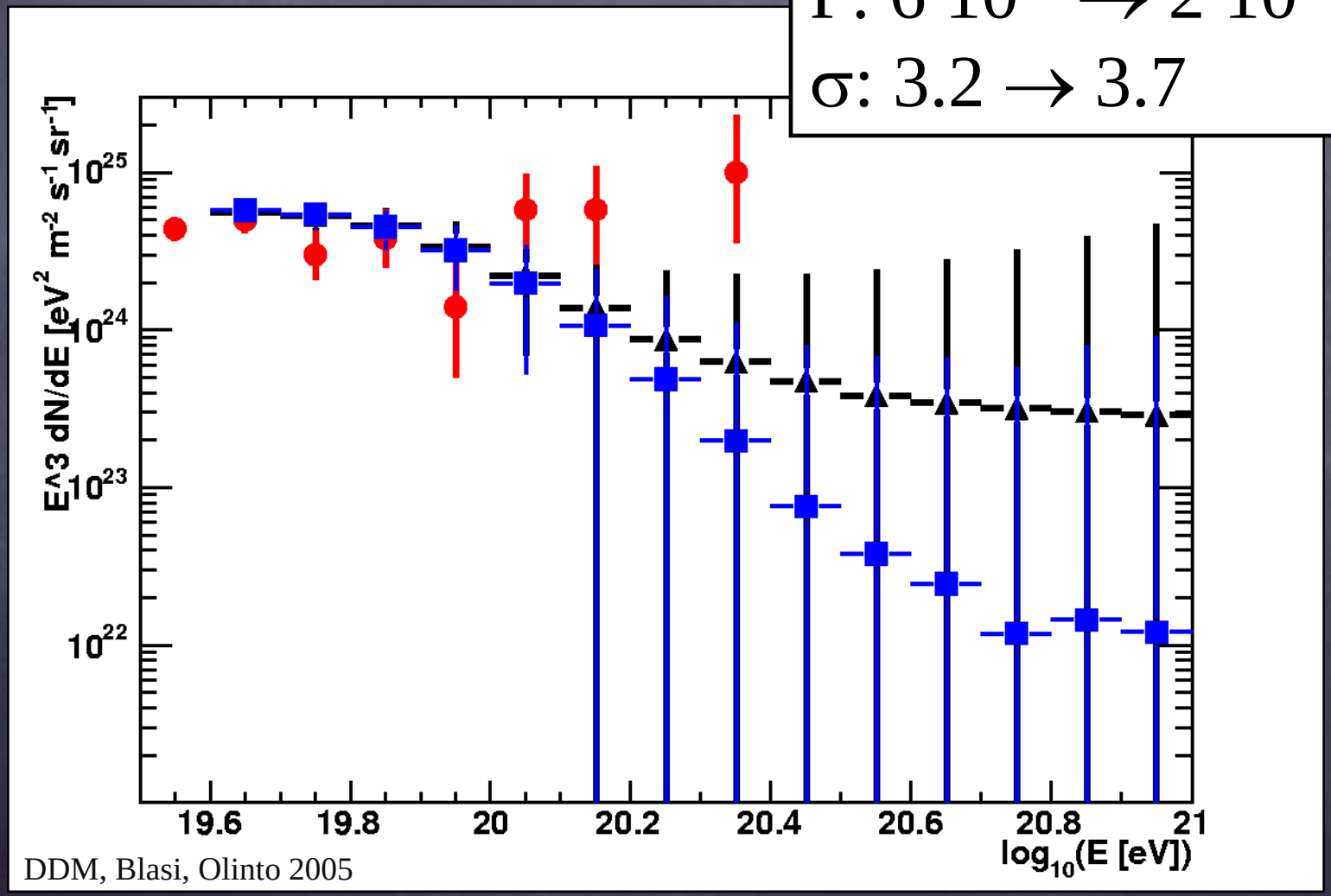
are these ssa for real?

- the significance of the AGASA result is not clear
- HiRes doesn't see them
- some internal inconsistency

AGASA spectrum discrete sources

P: $6\ 10^{-4} \rightarrow 2\ 10^{-4}$

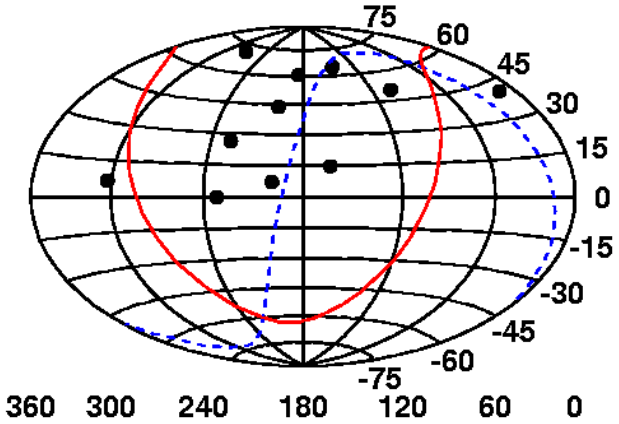
σ: $3.2 \rightarrow 3.7$

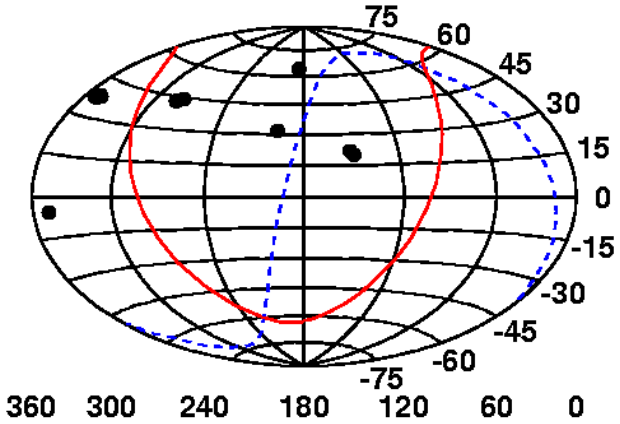


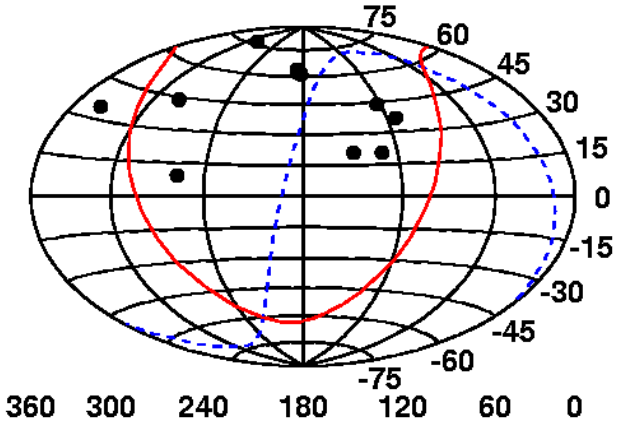
DDM, Blasi, Olinto 2005

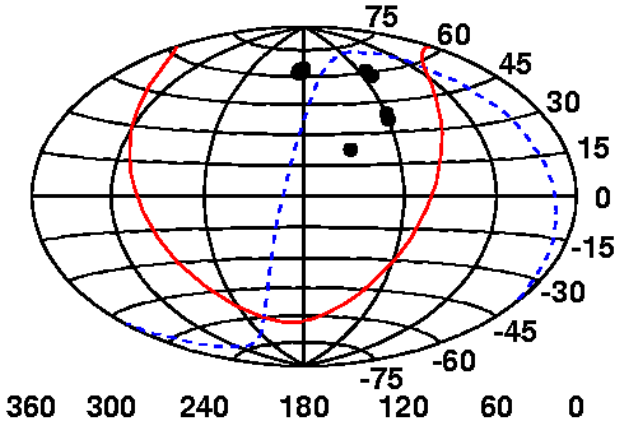
arrival directions

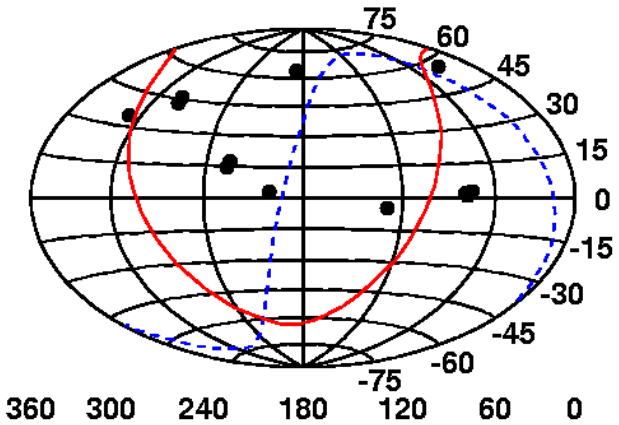
$P \sim 2\ 10^{-5}$

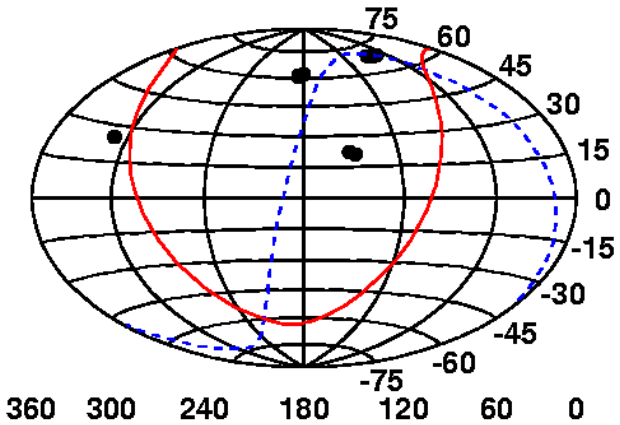












DDM, Blasi, Olinto 2005

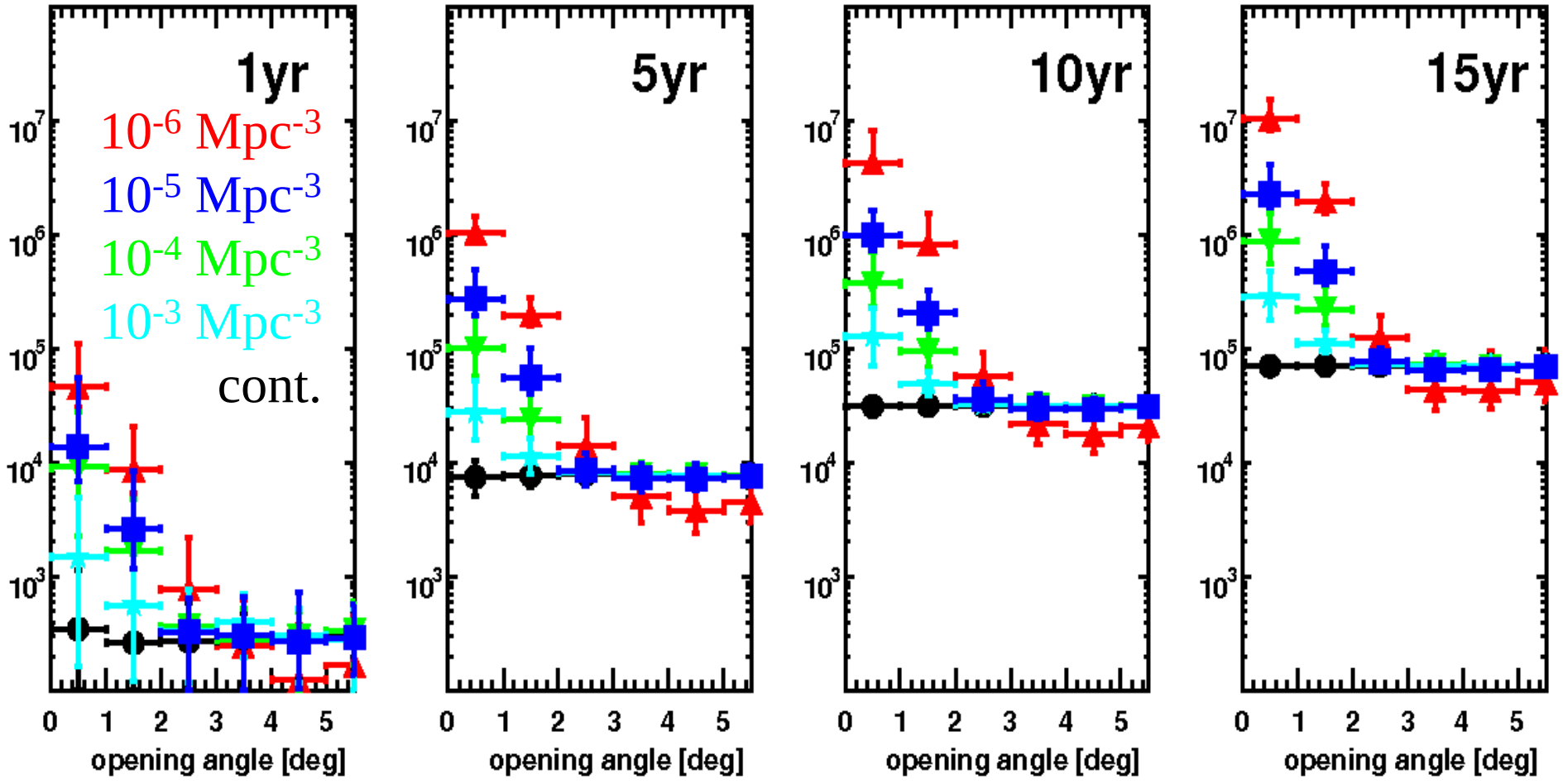
both the ssa and the spectrum measurement need more statistics to be conclusive and reliable

Auger 2pcf

E>4 10^{19} eV

$$d_{\min} = (2\sqrt[3]{\rho})^{-1}$$

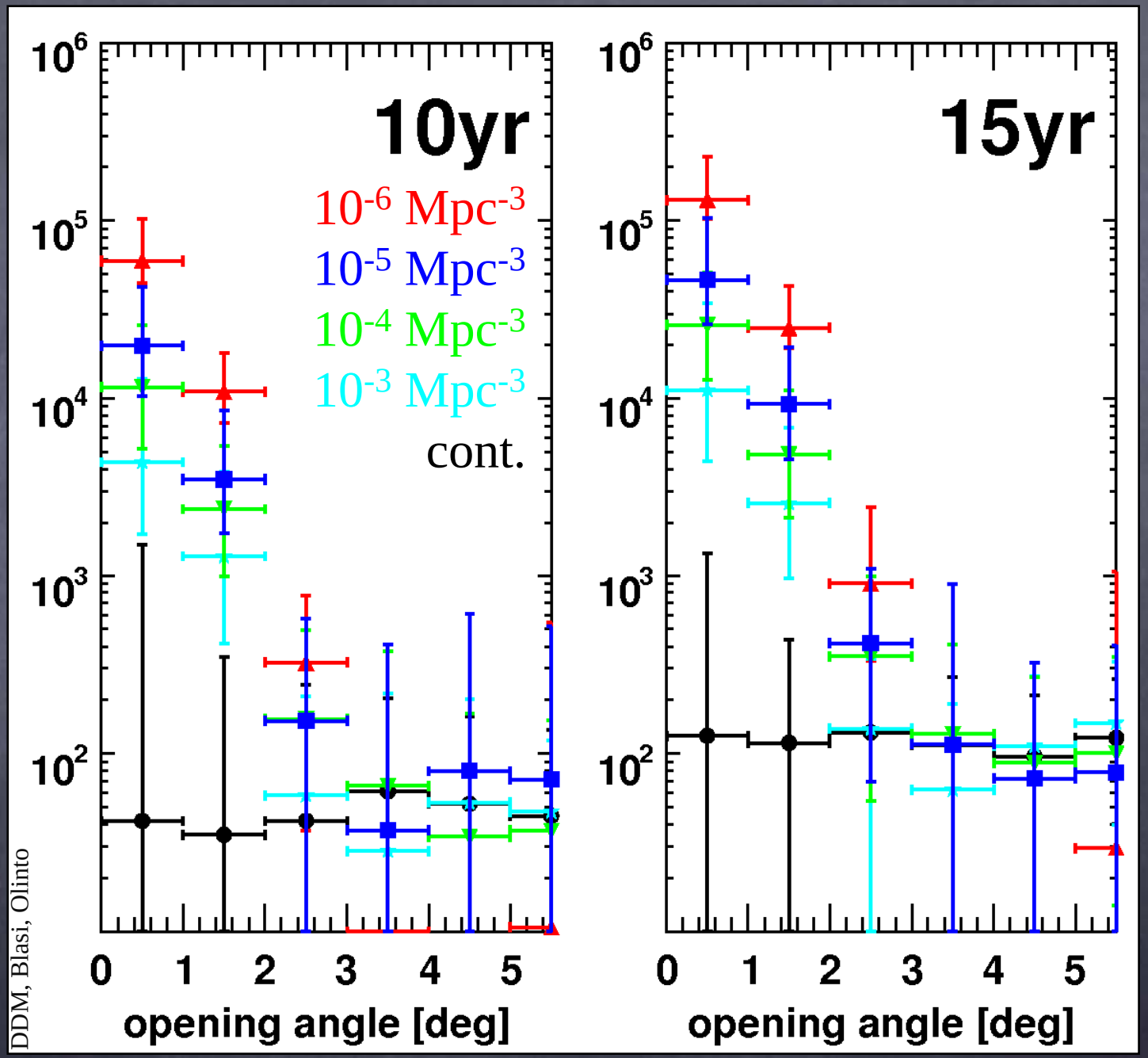
DDM, Blasi, Olinto



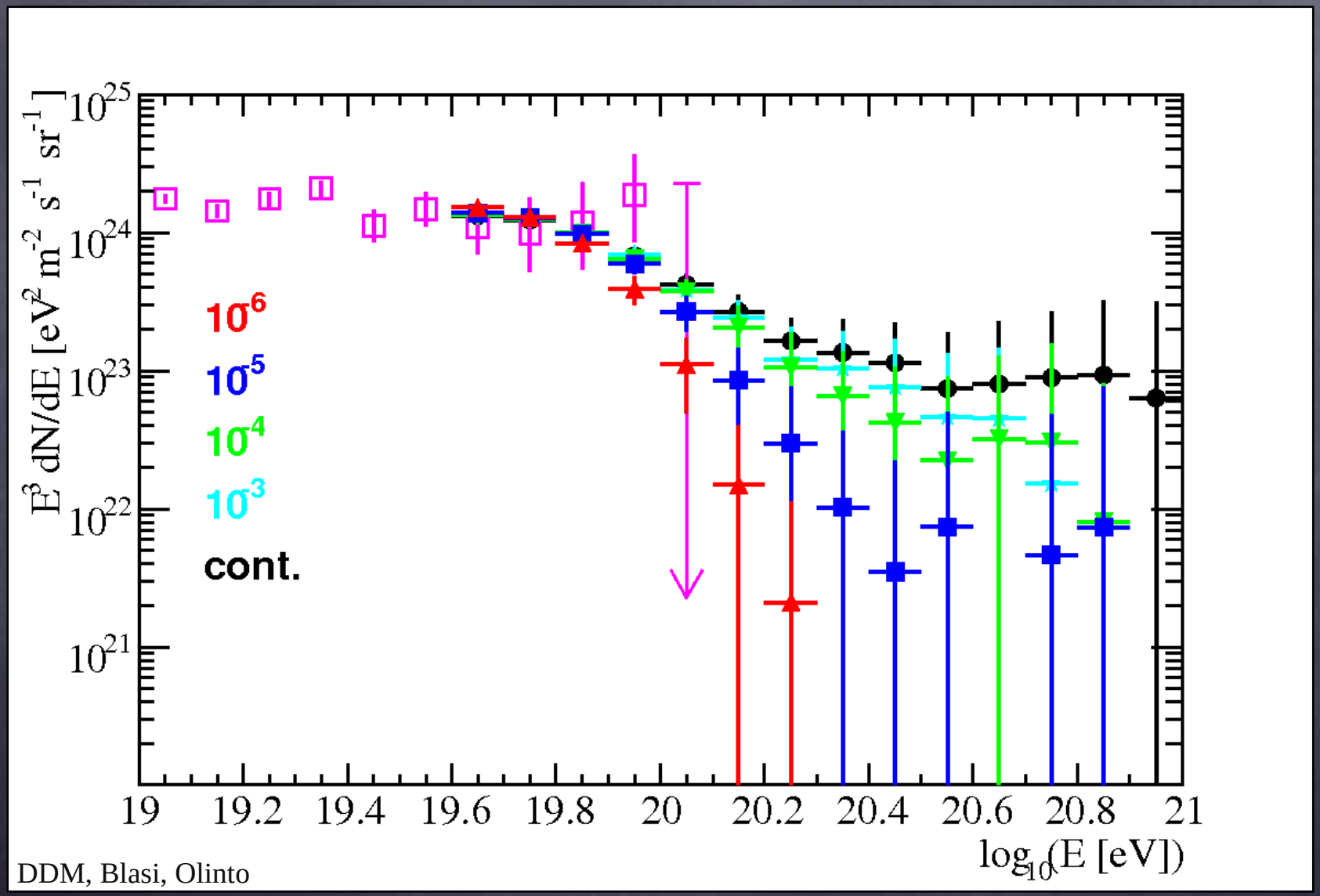
Auger 2pcf

$E > 10^{20}$ eV

$$d_{min} = (2\sqrt{p})^{-1}$$

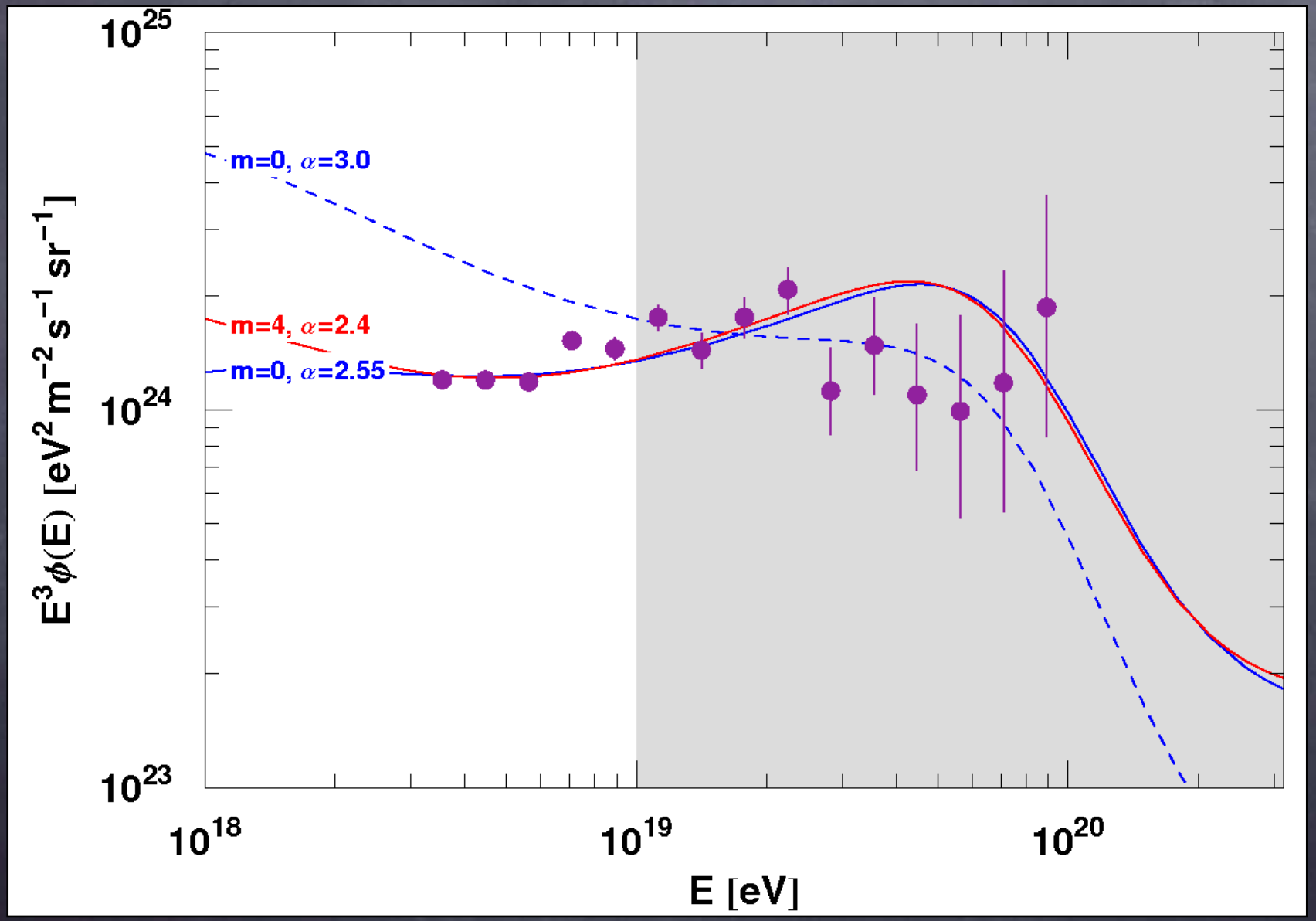


Auger spectrum $d_{\min} = (2\sqrt[3]{\rho})^{-1}$



DDM, Blasi, Olinto

conclusions

- AGASA & HiRes: statistics too low to reach conclusions on spectrum & ssa
- m & γ degeneracy: we need good composition measurements or other method to determine where the galcatic CRs end (ex: anisotropy)
- Auger should be able to shed light on some of these issues

Auger ICRC spectrum