Composition of CR obtained with KASCADE-Grande

And how it depends on the hadronic interaction model

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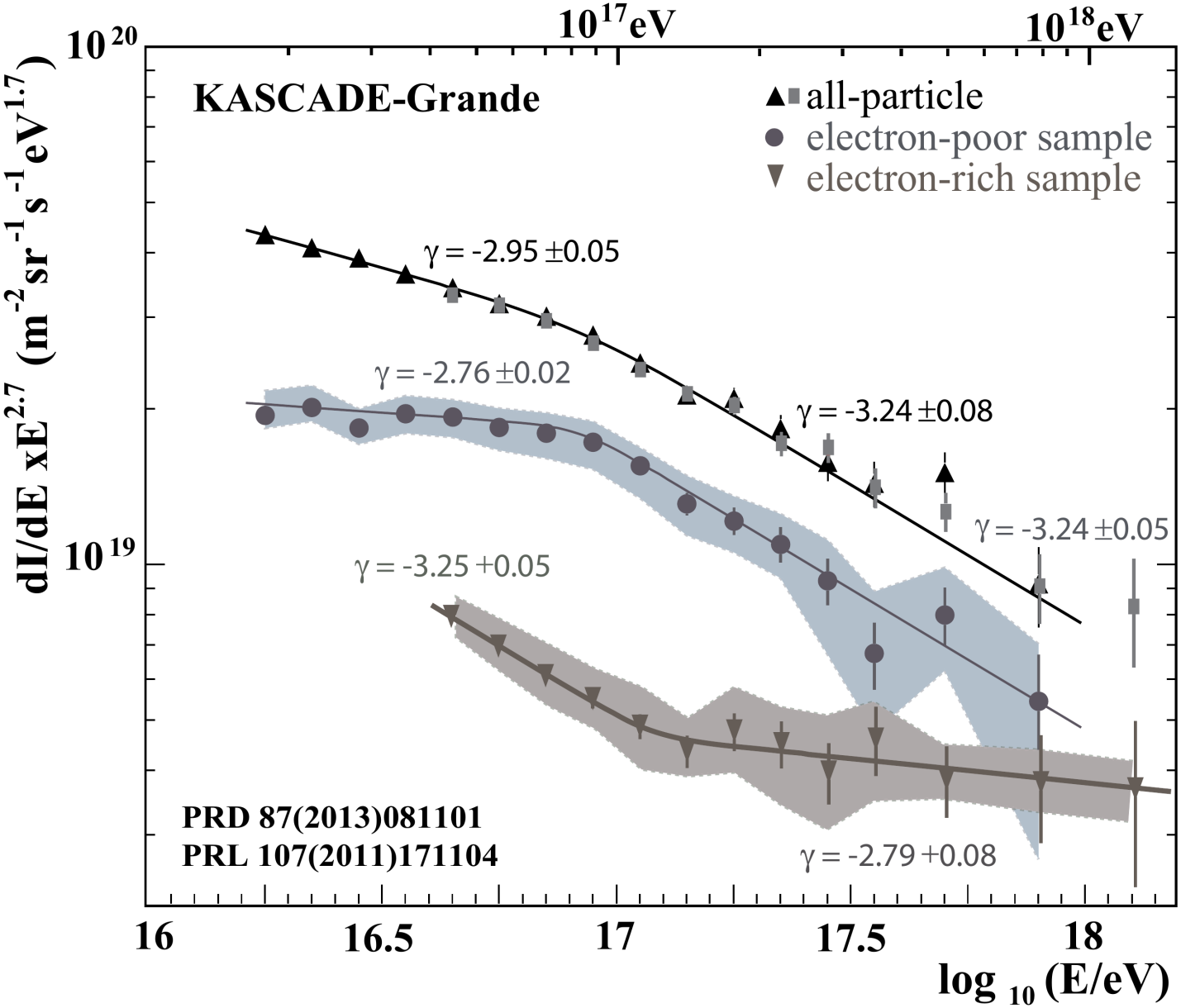
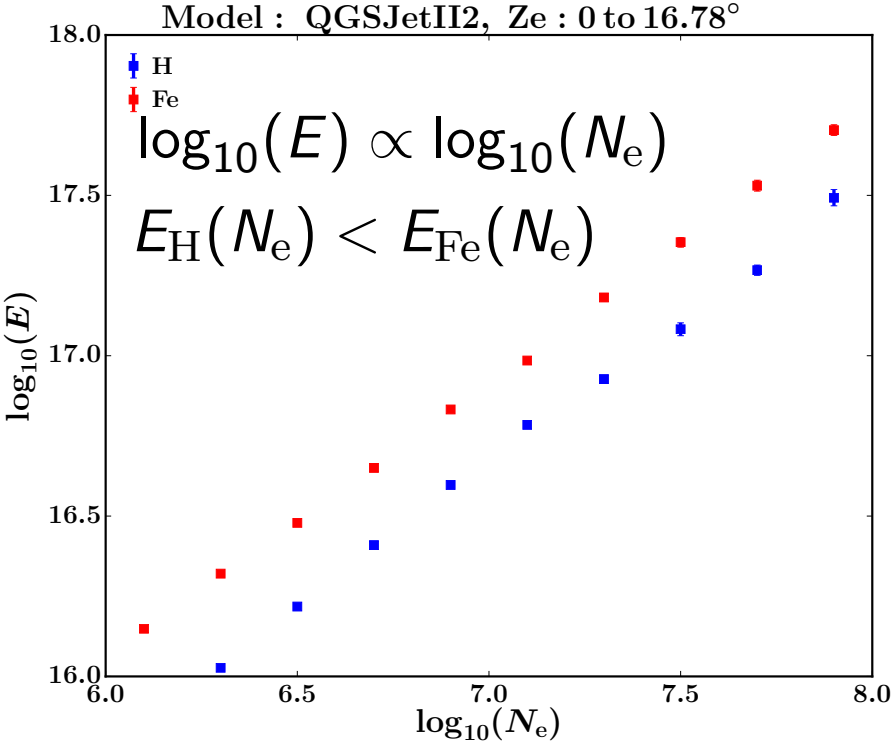
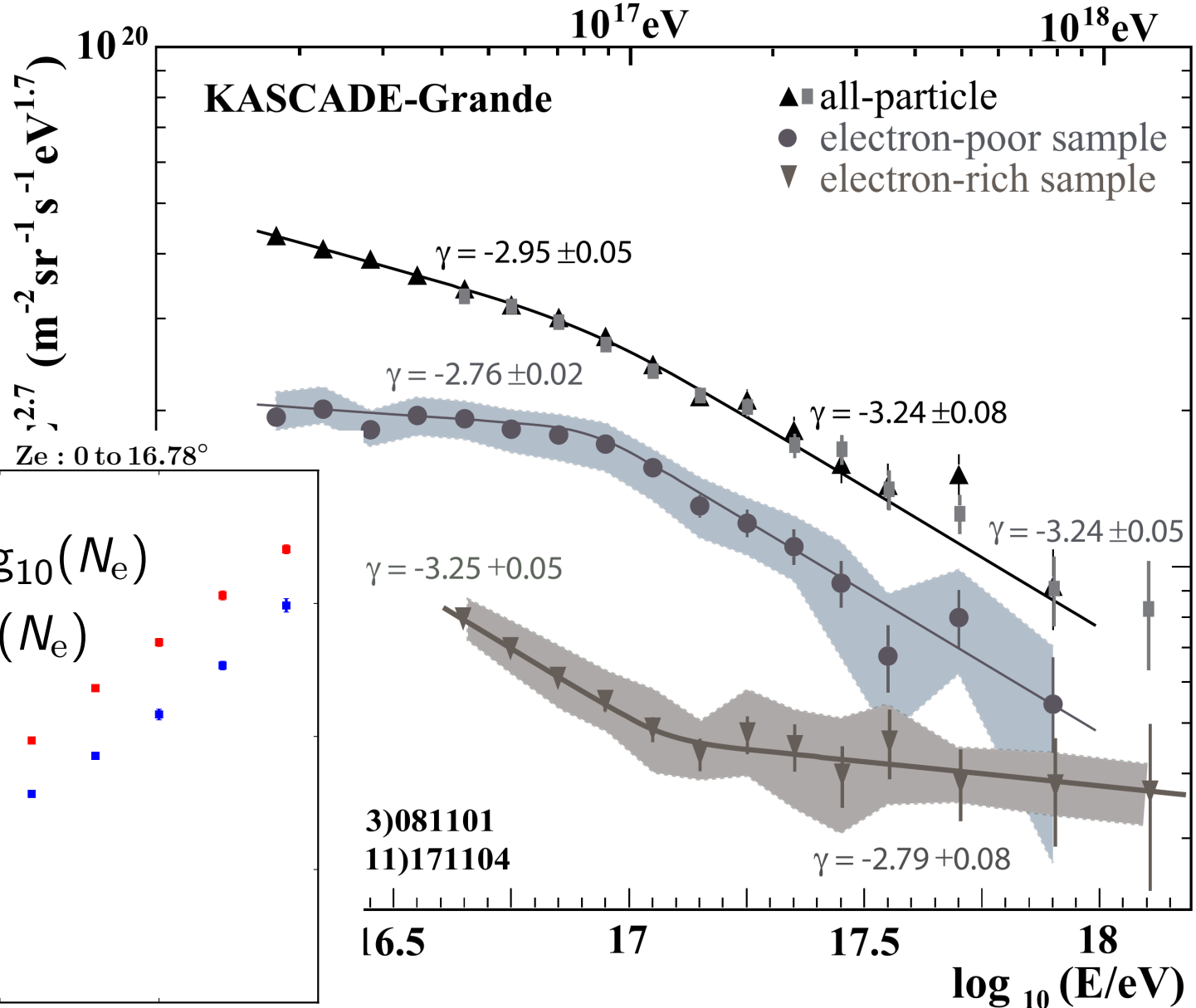
Energy reconstruction

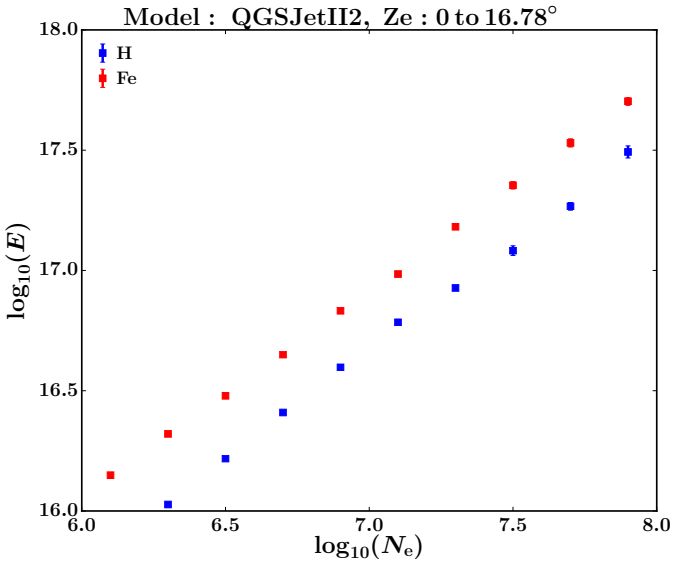


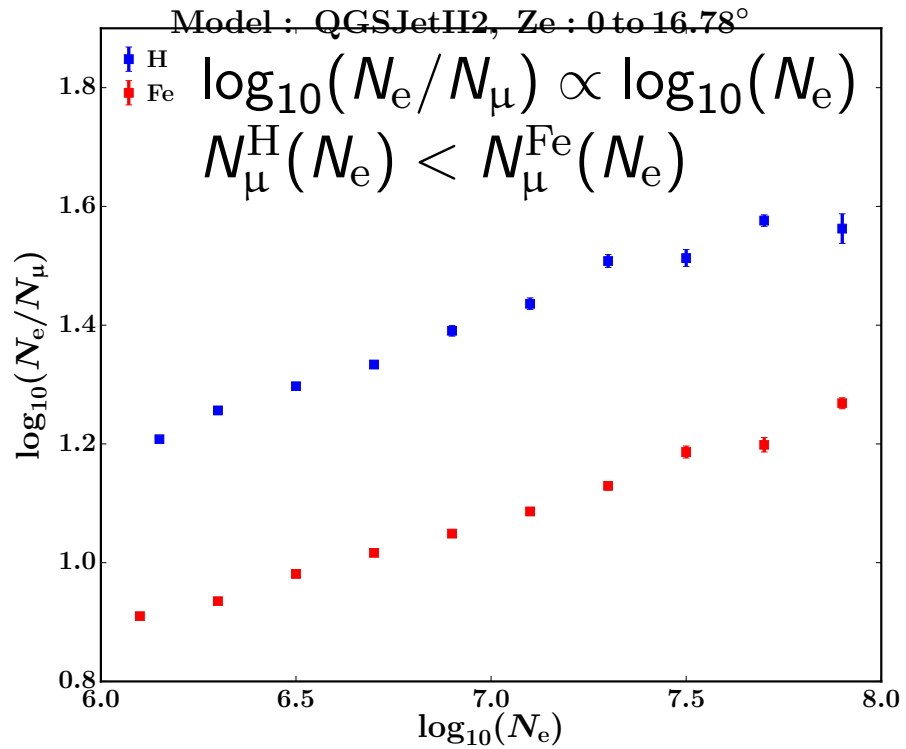
Energy reconstruction

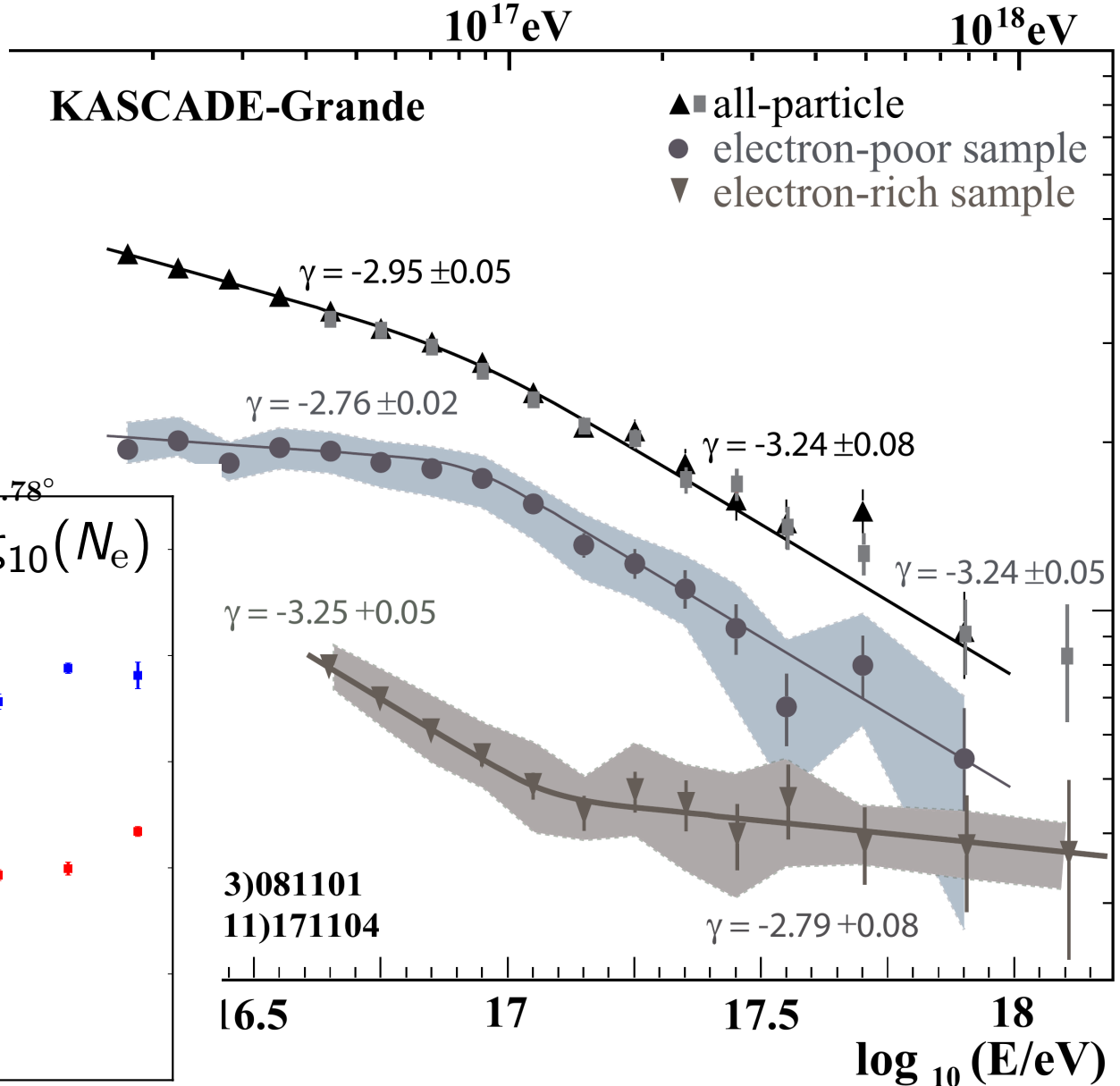




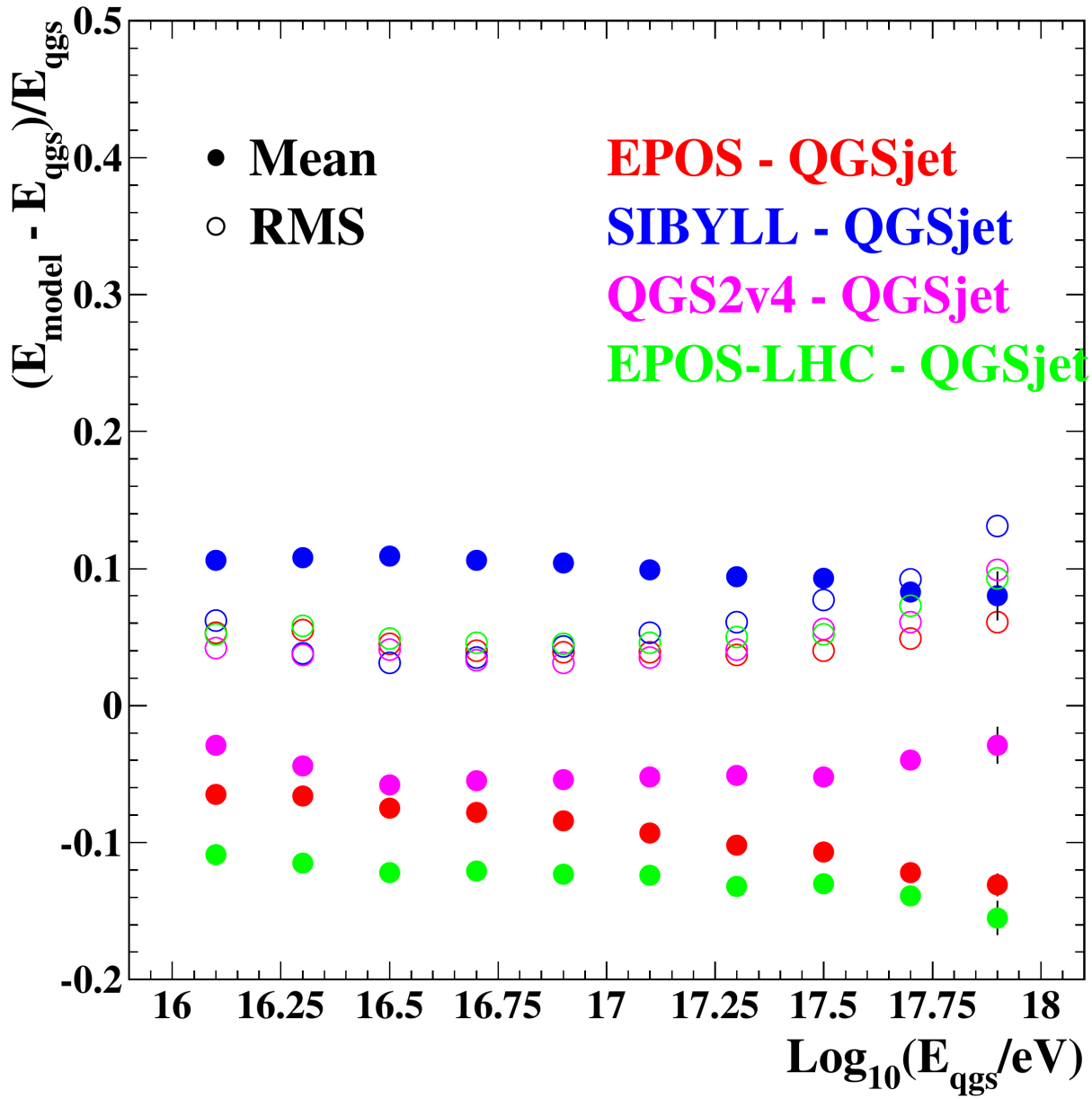
Energy reconstruction



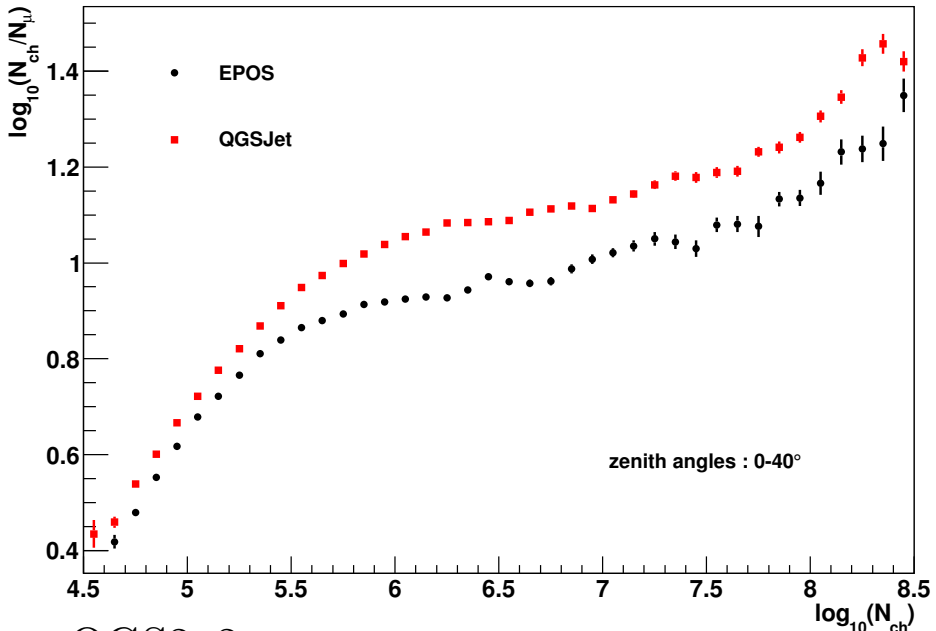




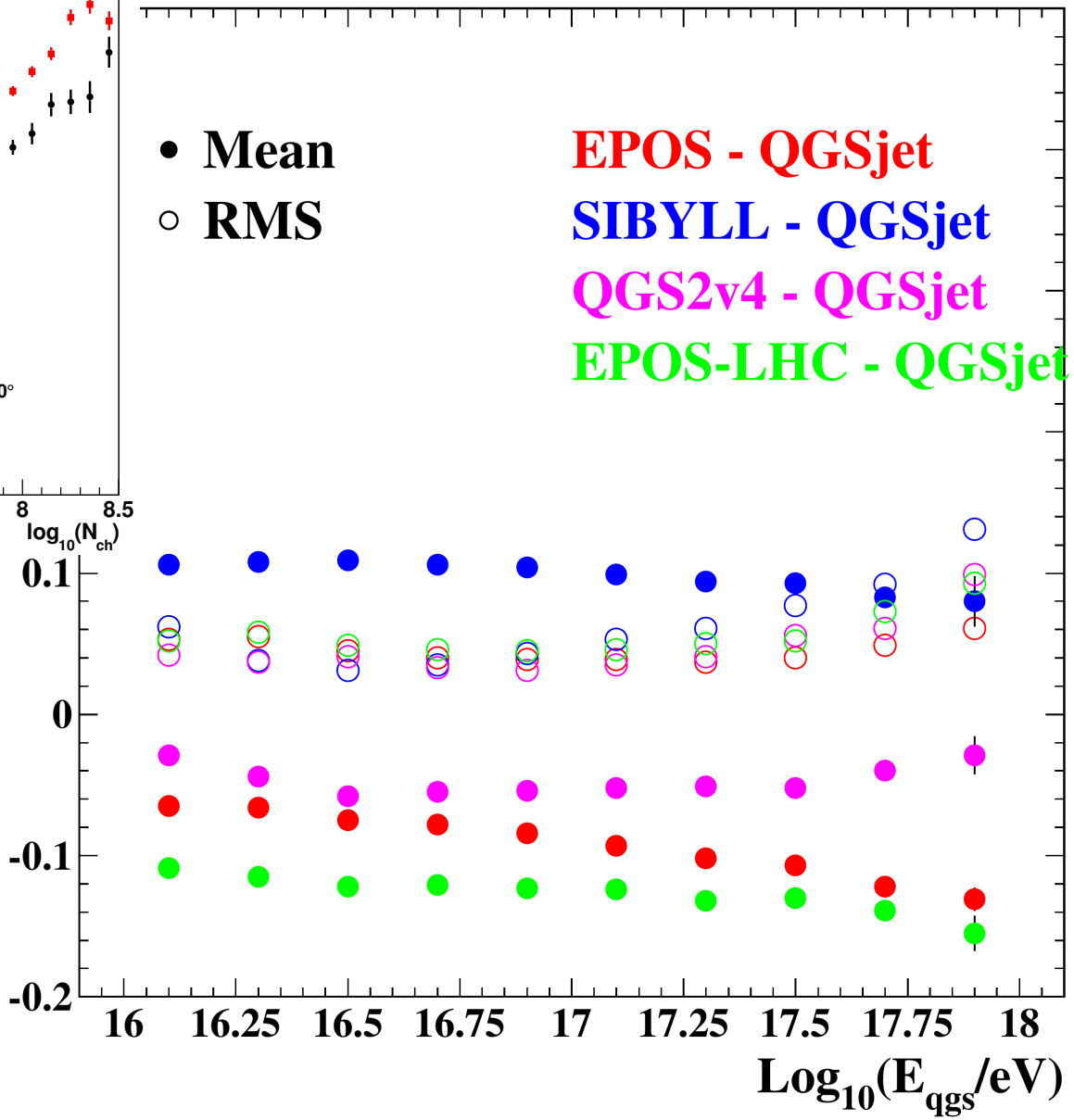
Energy reconstruction - Model dependence



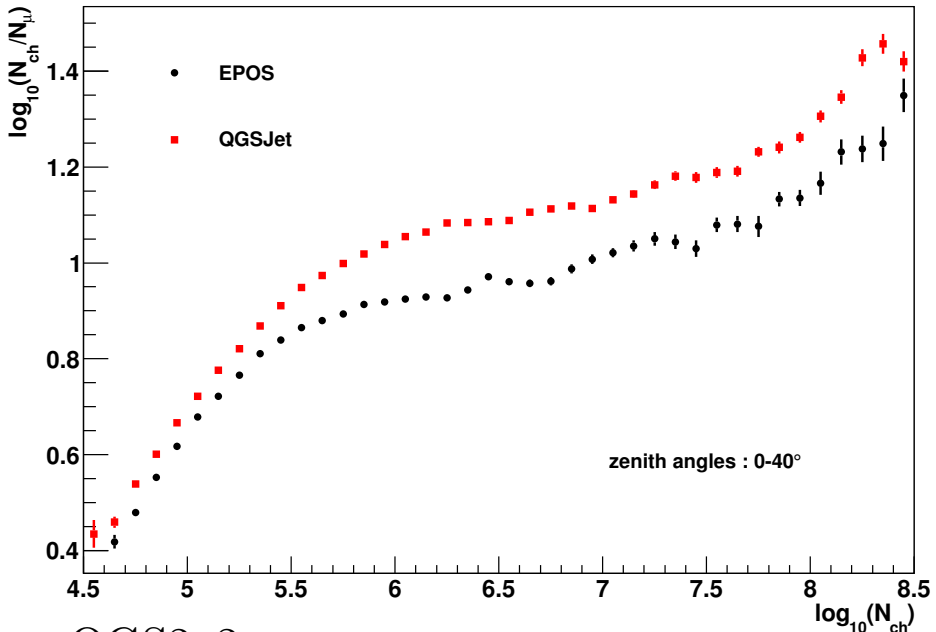
Energy reconstruction - Model dependence



$$N_\mu^{\mathrm{QGS2v2}}(N_e) < N_\mu^{\mathrm{EPOS}}(N_e)$$



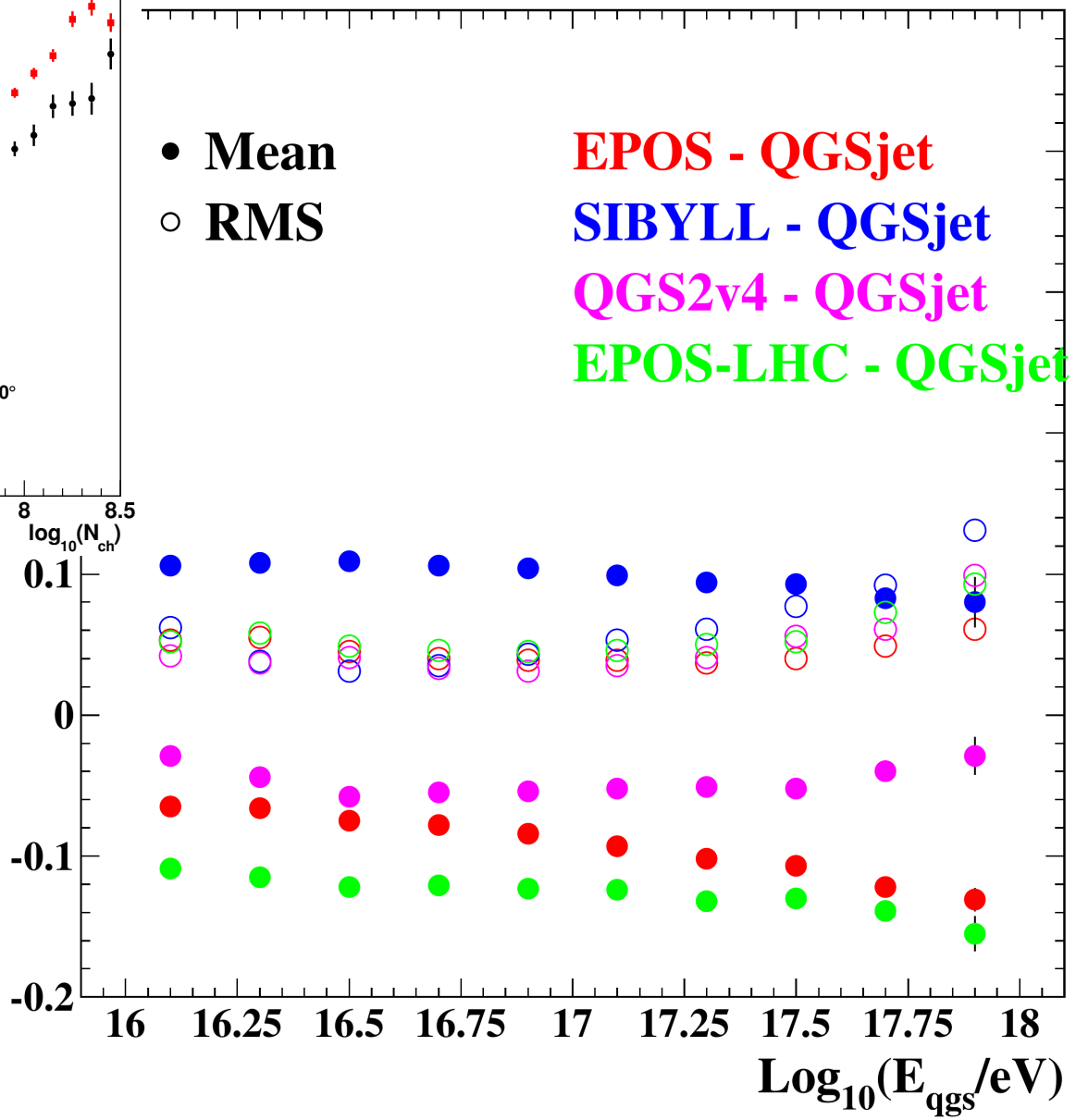
Energy reconstruction - Model dependence



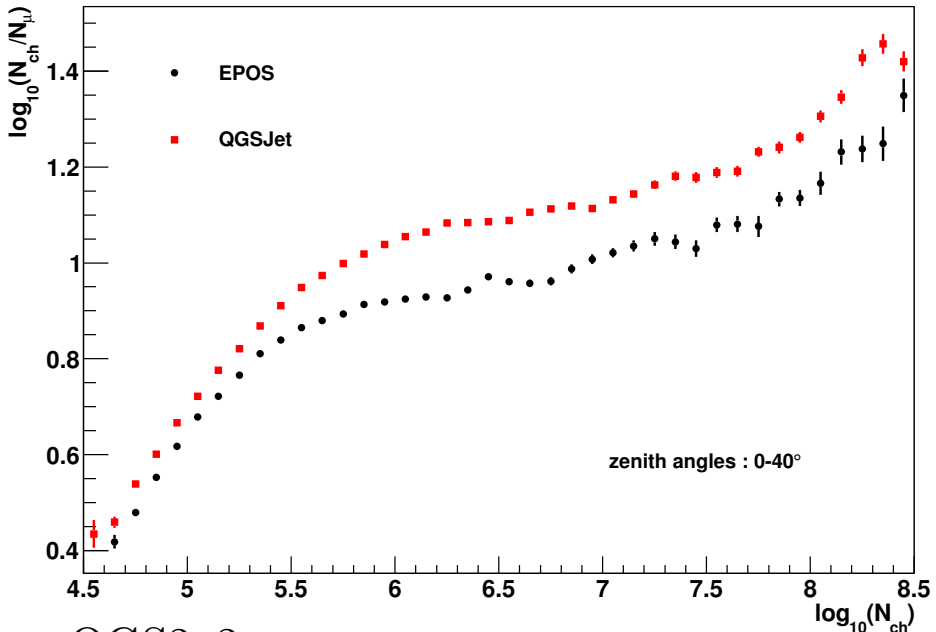
$$N_\mu^{\mathrm{QGS2v2}}(N_e) < N_\mu^{\mathrm{EPOS}}(N_e)$$

$\rightarrow$ lighter composition

$$E_H(N_e) < E_{Fe}(N_e)$$

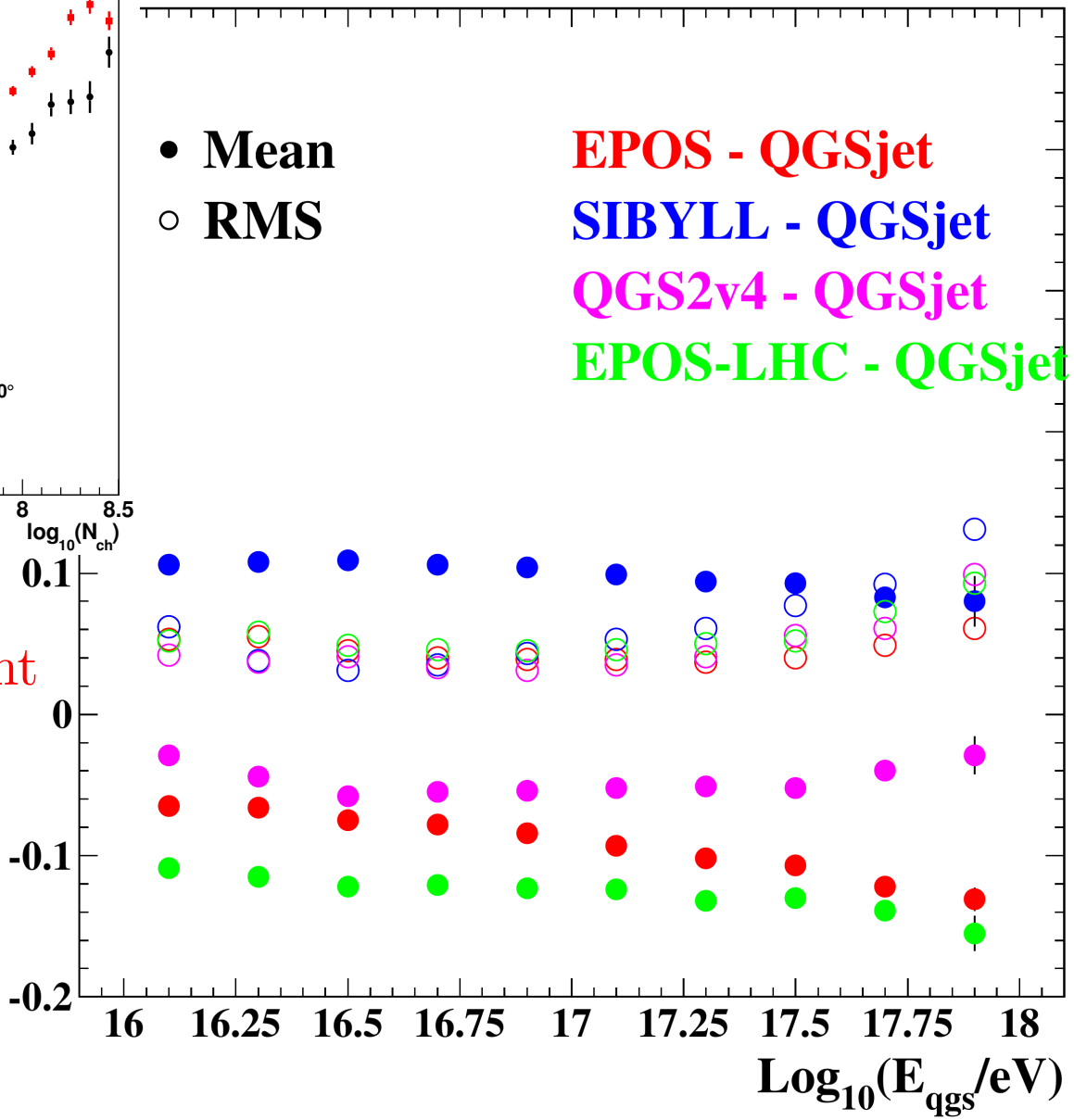


Energy reconstruction - Model dependence

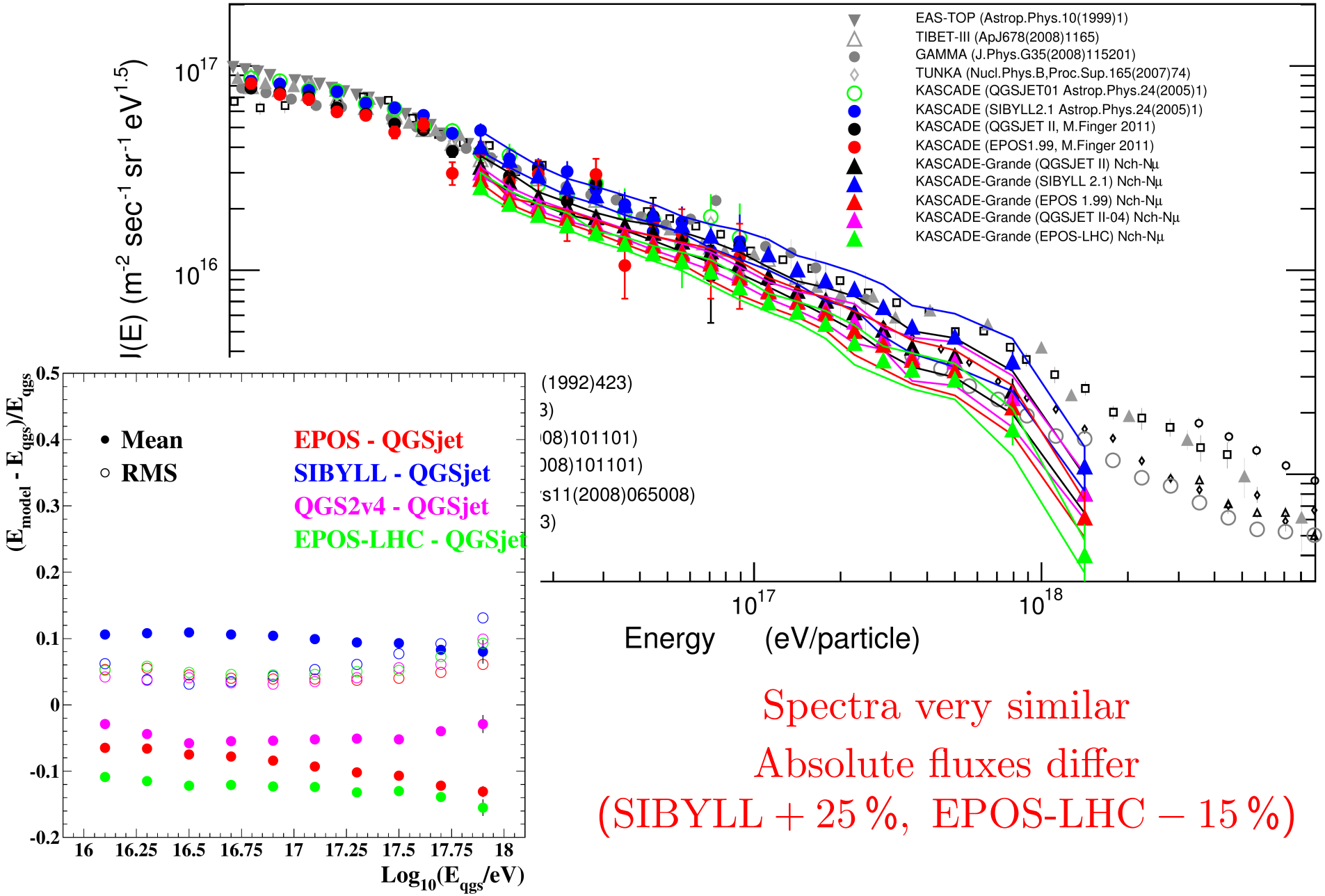


$$N_\mu^{\mathrm{QGS2v2}}(N_e) < N_\mu^{\mathrm{EPOS}}(N_e)$$

QGS2v2 based light component too heavy if EPOS is correct (contains H not H + He)



Energy spectra - Model dependence

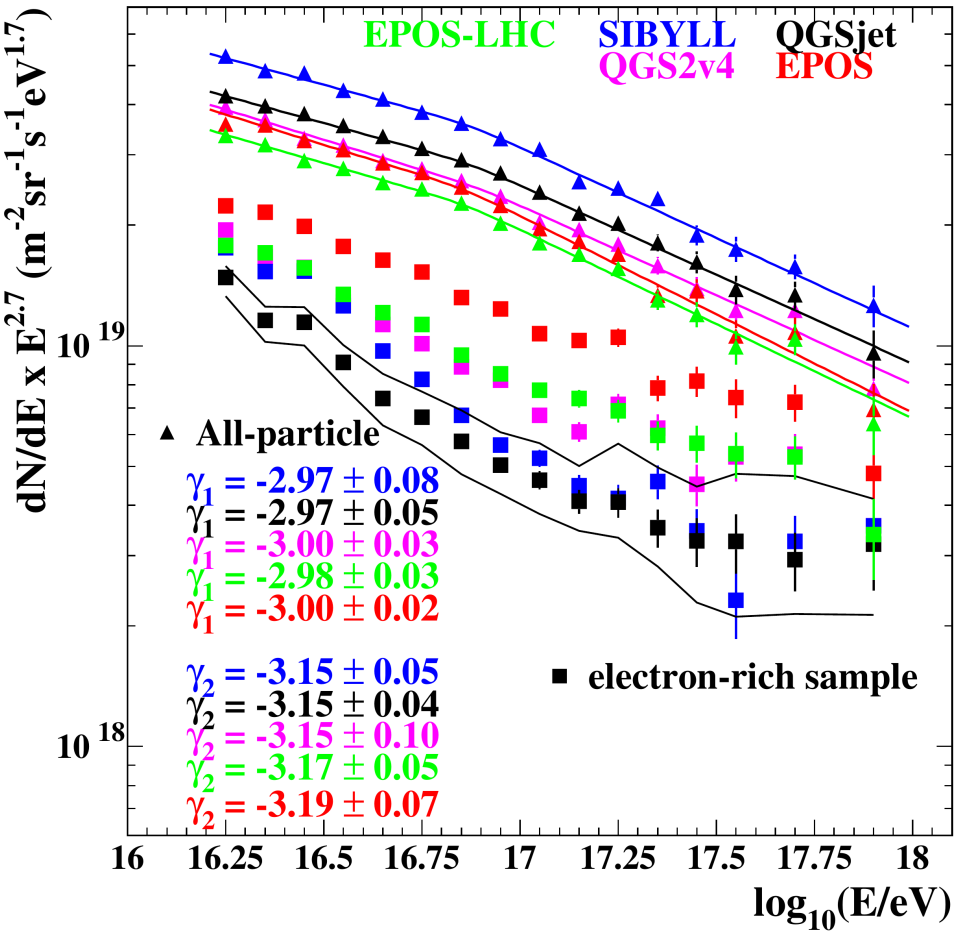


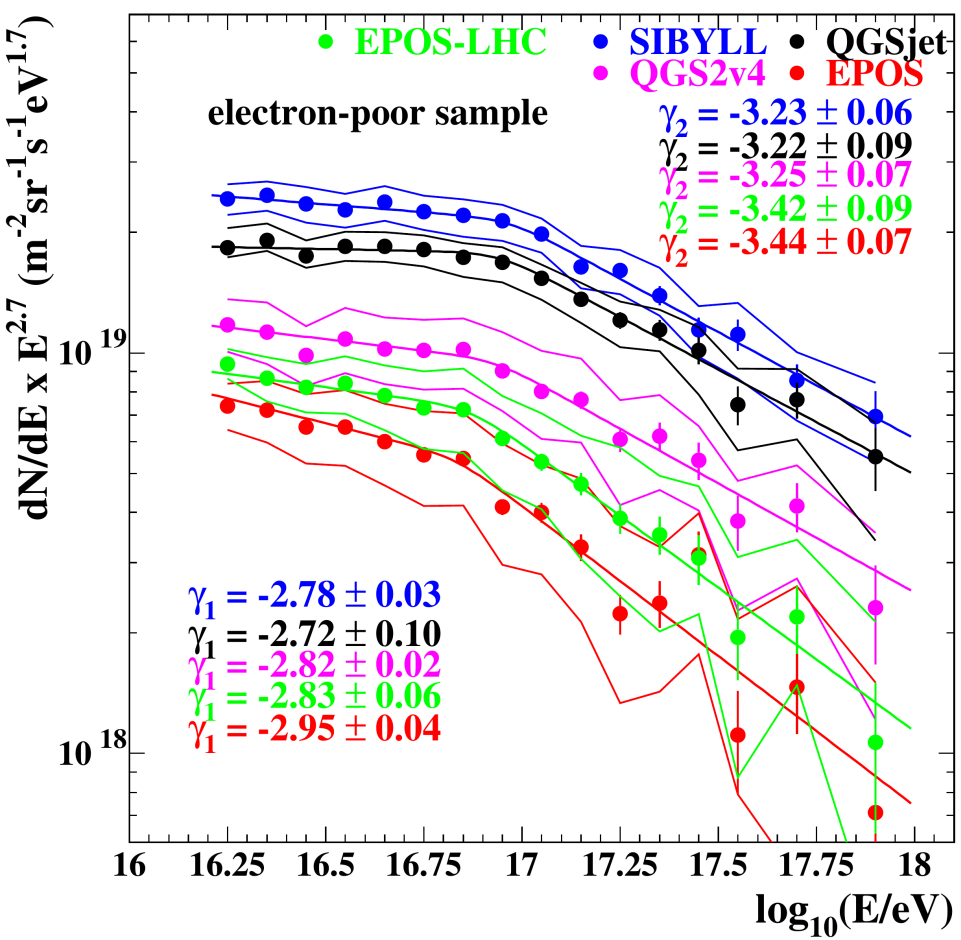
Spectra very similar

Absolute fluxes differ

(SIBYLL + 25 %, EPOS-LHC − 15 %)

Composition - Model dependence

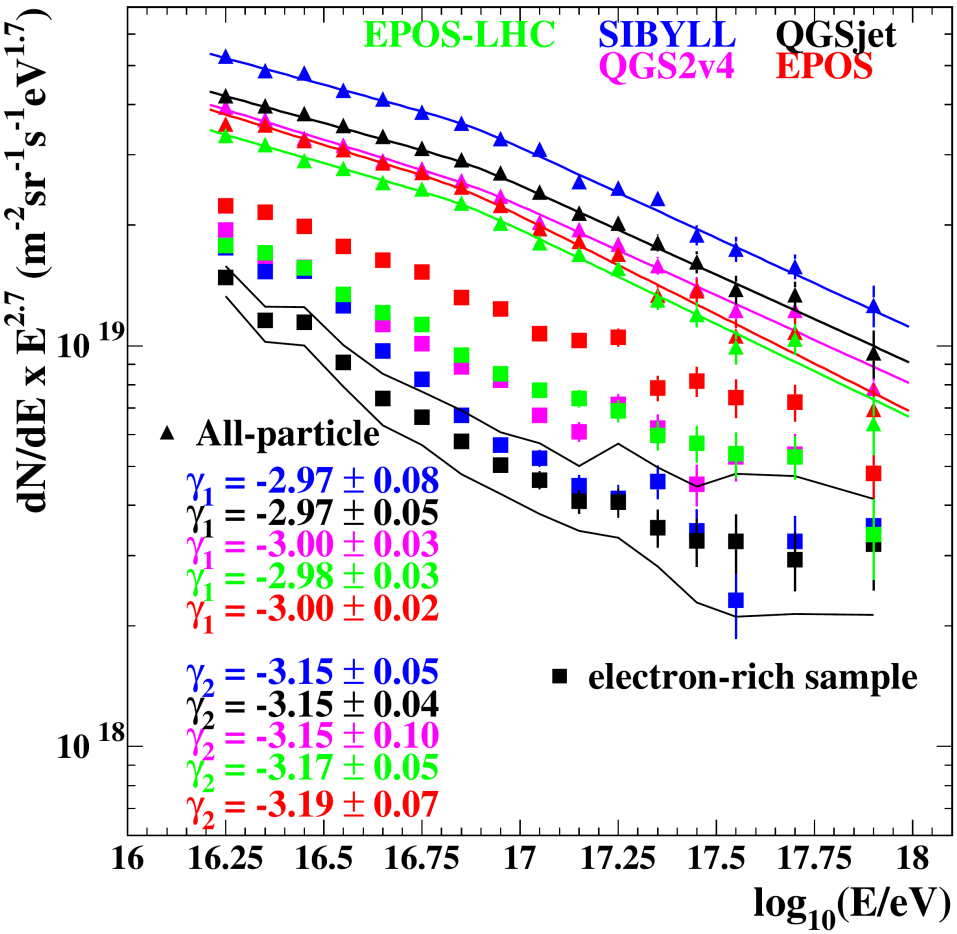


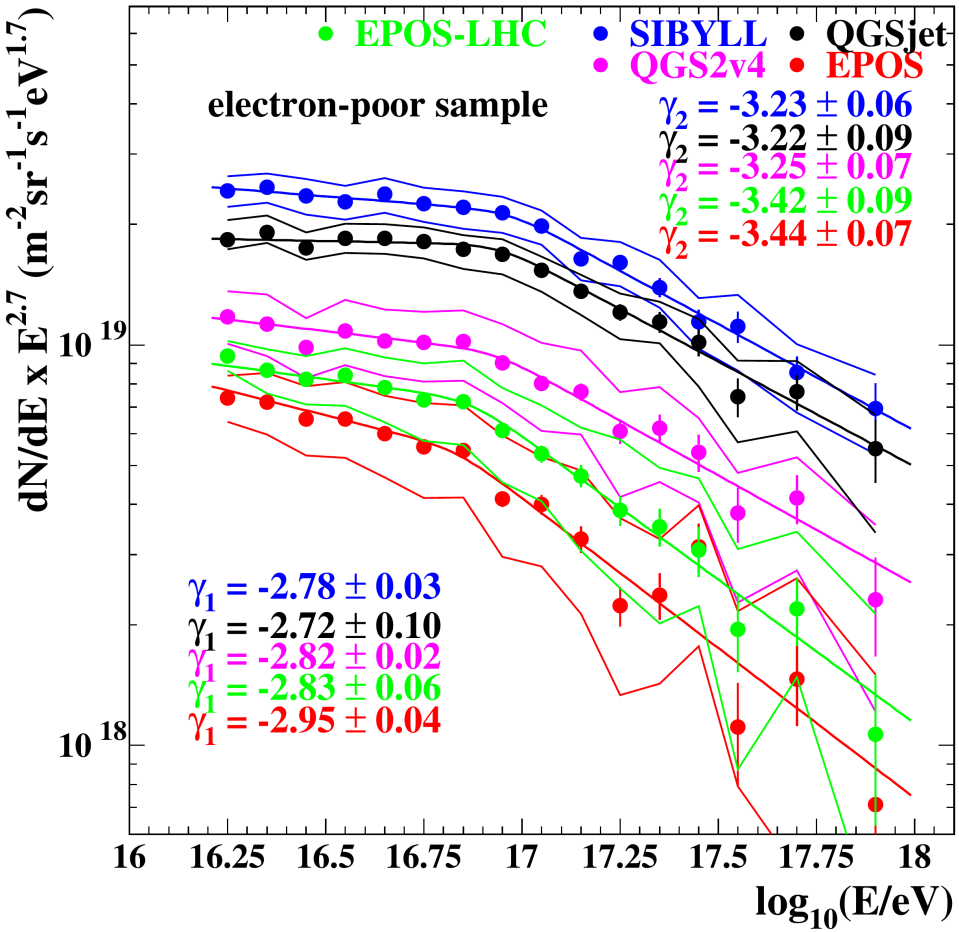


Exact location of feature is slightly model-dependent

Features visible for all models

Composition - Model dependence





Exact location of feature is slightly model-dependent

Features visible for all models

Interplay of N_e and N_μ is important

Higher energy for SIBYLL ! = simply fewer muons predicted

Numbers

Source of uncertainty	10^{16} eV (%)	10^{17} eV (%)	10^{18} eV (%)
Intensity in different angular bins (attenuation)	−0/+6.5	10.9	21.3
Energy calibration and composition	10.3	5.8	13.4
Slope of the primary spectrum	4.0	2.0	1.9
Reconstruction (core and shower sizes)	0.1	1.4	6.5
Total	−11.1/+12.8	12.6	26.1
Artificial spectrum structures (extreme cases)		<10	
Hadronic interaction model (EPOS-QGSJet)	−5.3	−16.9	−14.6
Statistical error	0.6	2.7	17.0
Energy resolution (mixed composition)	24.7	18.6	13.6

Apel et al., Astroparticle Physics 36 (2012) 183

Model	EPOS	EPOS-LHC	QGS2v4	QGSjet	SIBYLL
All-particle					
γ_1	-3.00 ± 0.02	-2.98 ± 0.03	-3.00 ± 0.03	-2.97 ± 0.05	-2.97 ± 0.08
γ_2	-3.19 ± 0.07	-3.17 ± 0.05	-3.15 ± 0.10	-3.15 ± 0.05	-3.15 ± 0.05
$\log(E/eV)$	16.86 ± 0.10	16.87 ± 0.12	16.91 ± 0.24	16.88 ± 0.16	16.87 ± 0.16
signif. (σ)	4.4	3.0	2.8	7.4	2.7
Heavy component					
γ_1	-2.95 ± 0.04	-2.83 ± 0.06	-2.82 ± 0.02	-2.72 ± 0.10	-2.78 ± 0.03
γ_2	-3.44 ± 0.07	-3.42 ± 0.09	-3.25 ± 0.07	-3.22 ± 0.09	-3.23 ± 0.06
$\log(E/eV)$	16.83 ± 0.05	16.87 ± 0.09	16.93 ± 0.06	16.94 ± 0.09	16.97 ± 0.05
signif. (σ)	3.0	11.0	3.7	9.7	11.6

Mario Bertaina, ICRC 2015

Combined Analysis

N_e :

KASCADE : gray, red detectors

Grande : blue detectors

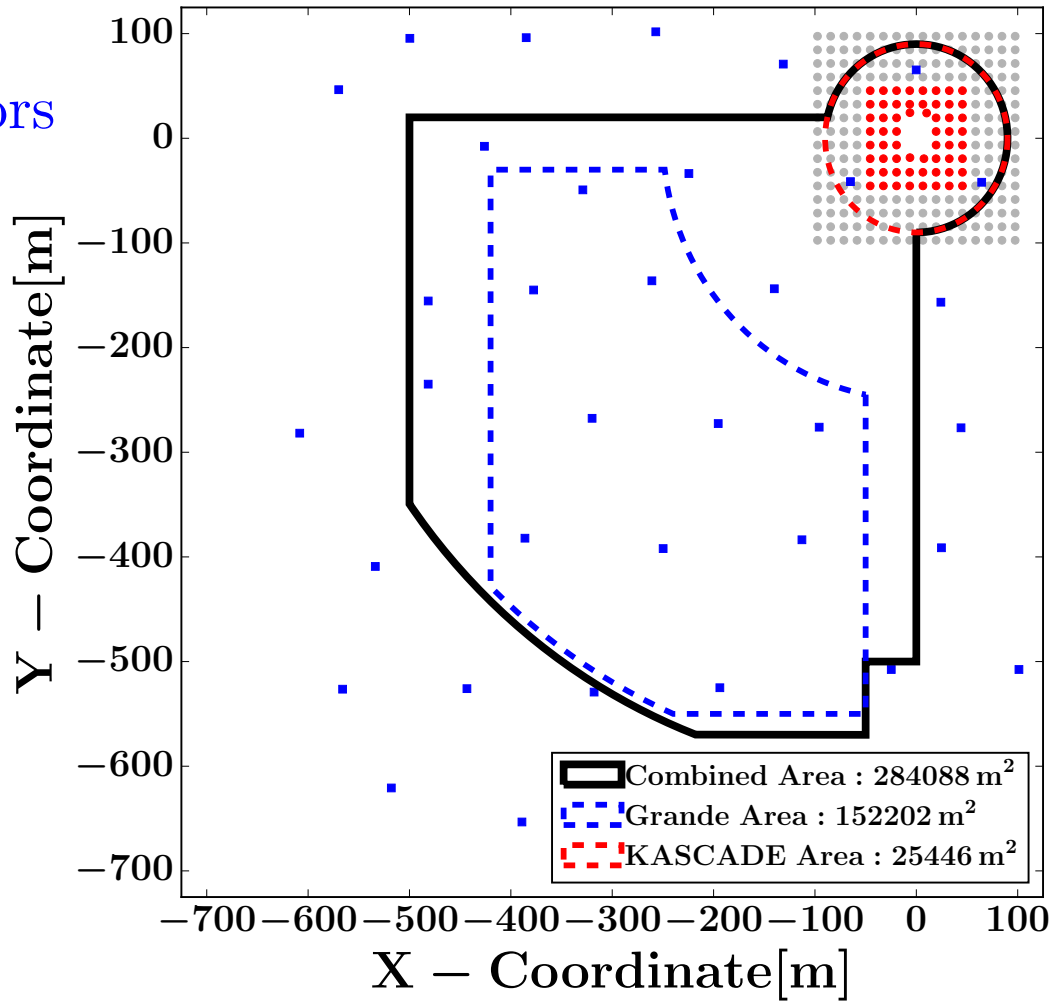
Comined : both

N_μ :

KASCADE : red detectors

Grande : red detectors

Comined : red detectors



Combined Analysis

No corrections applied yet

Mass separation kept very simple

New models

are consistent with Grande

agree below 10^{16} eV

result in a lower flux

Same features as before