Cross-correlation studies with UHECRs

Federico Urban

CEICO

Institute of Physics
Czech Academy of Sciences
Prague

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Operational Programme Research,
Development and Education

MINISTRY OF EDUCATION,
YOUTH AND SPORTS

:: take home message ::

:: take home message ::

We look for UHECR anisotropies

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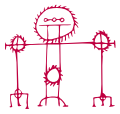

Harmonic space: global properties

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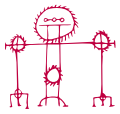

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Auto-correlation: large scales

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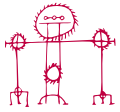

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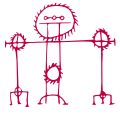

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Cross-correlation with galaxies: small scales

A&A 2021, JCAP 2022, +ongoing x3

with D. Alonso, M. Bustamante, S. Camera, K. Tanidis


some theory

:: harmonic ::

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© Tinyakov & FU, 2014

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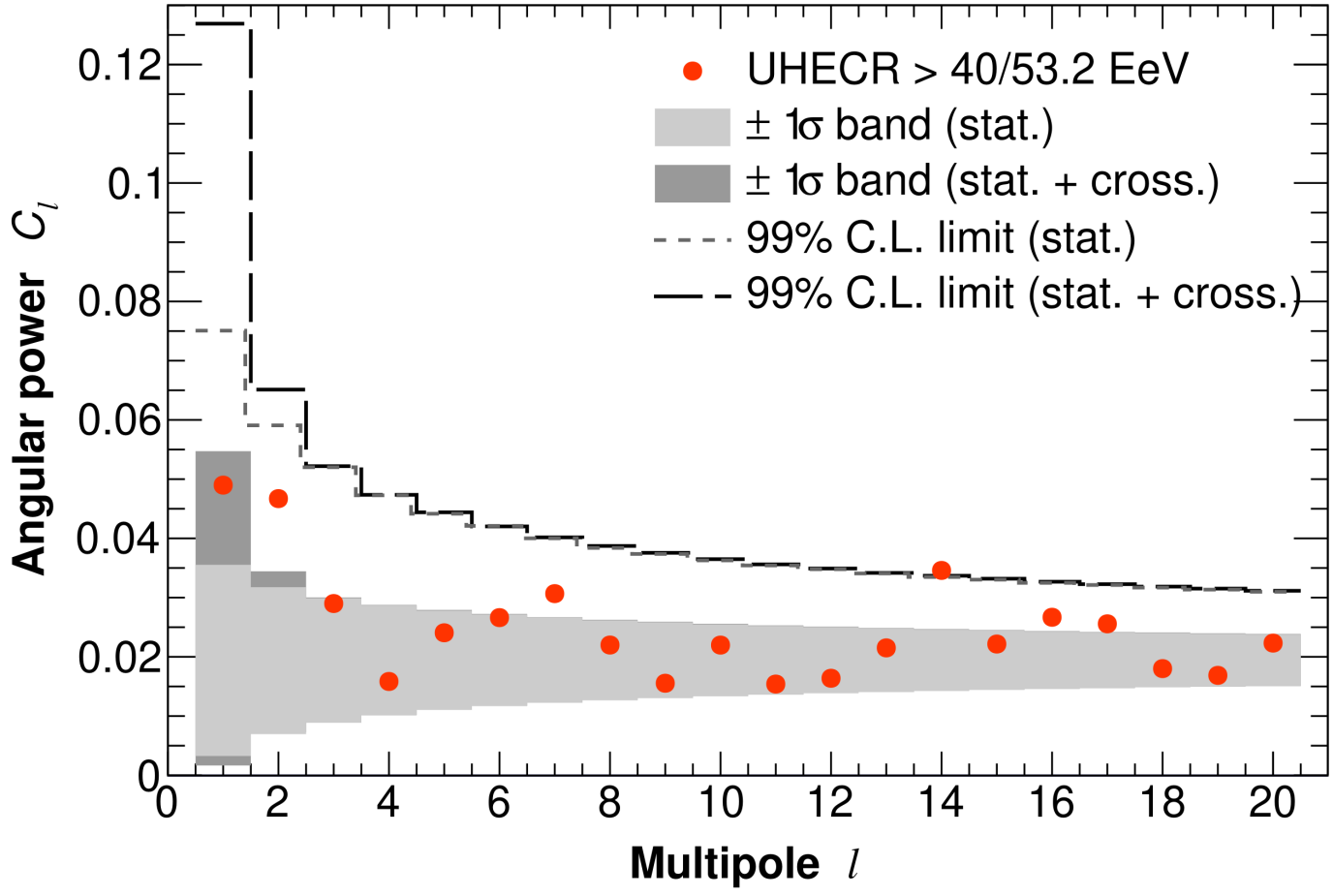
we find the autocorrelation AC

$$C_\ell = \frac{1}{2\ell + 1} \sum_m |a^*_{\ell m} a_{\ell m}|$$

:: observations ::



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:: cross correlation ::

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i. The measured UHECR flux anisotropy expands as

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Noise

$$\mathrm{AC}\ \frac{1}{N_{\rm CR}} \gg \frac{1}{N_{\rm gal}}\ \mathrm{XC}$$

:: kernels ::

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The 'observed' UHECR flux anisotropy is given by

$$\Delta_{\rm CR}(\hat{\rm n}, E_{\rm cut}) = \int {\rm d}\chi\, \phi_{\rm CR}(\chi)\, \delta_{\rm s}(z, \chi\hat{\rm n})$$

where the radial kernel $\phi_{\rm CR}(\chi) \sim \alpha(z, E_{\rm cut}; \gamma, Z)$

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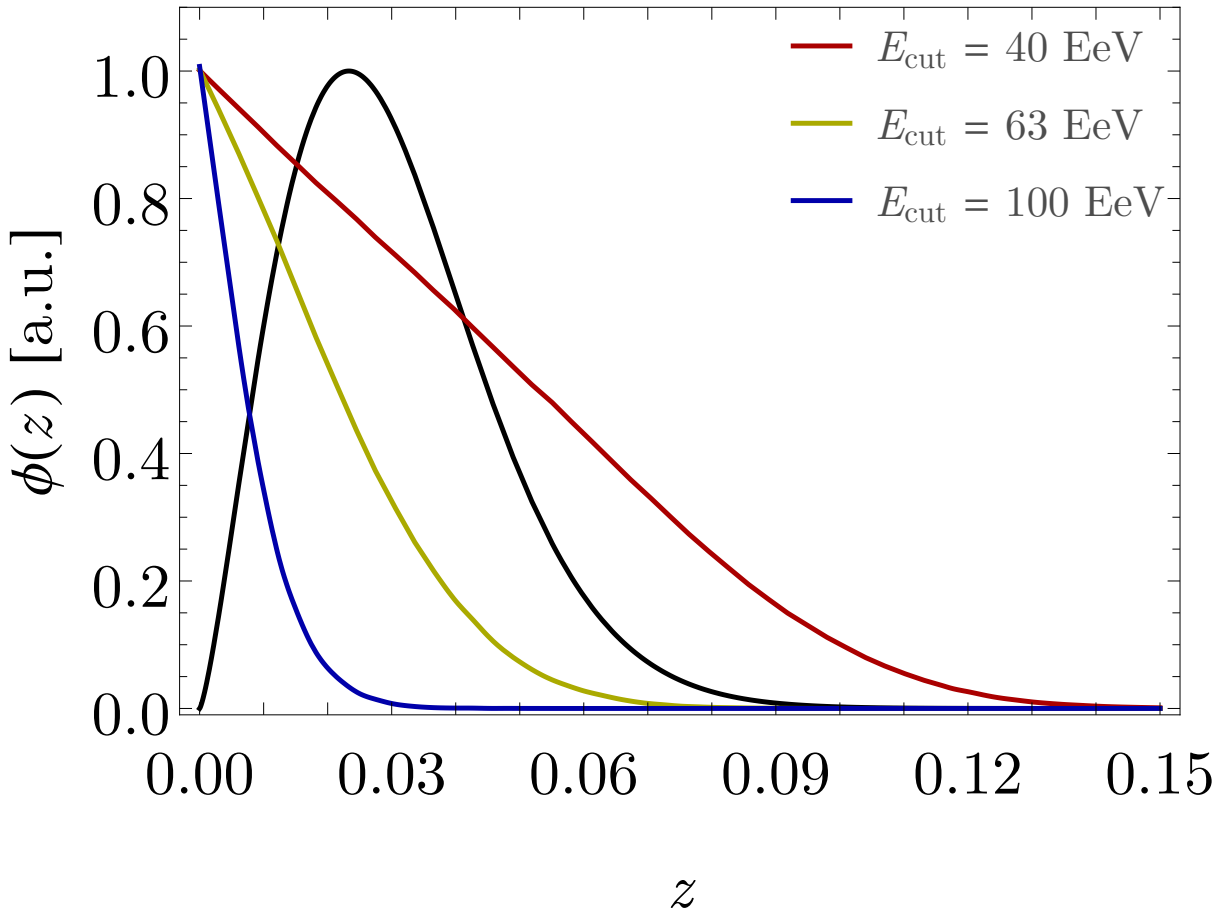
The (optional) weights $w(\chi)$ account for

the probability that a galaxy at distance χ
is the origin of an UHECR above $E_{\rm cut}$

:: kernels ::



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:: modelling uhecrs ::

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- UHECR Sources

  $E_{\rm cut} = 40, 63, 100$ EeV with 1000, 200, 30 events

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UHECR Sources

$E_{\rm cut} = 40, 63, 100$ EeV with 1000, 200, 30 events

Primaries, three examples: H1, O16, Si28

Injection: $\gamma = 2.60$, $\gamma = 2.10$, $\gamma = 1.50$

$\rightarrow$ for Si28 we cut at $E_{\rm max} = 280$ EeV

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UHECR Kernel

Attenuation $\alpha(z, E_{\rm cut}; \gamma, Z)$ calculated with SimProp

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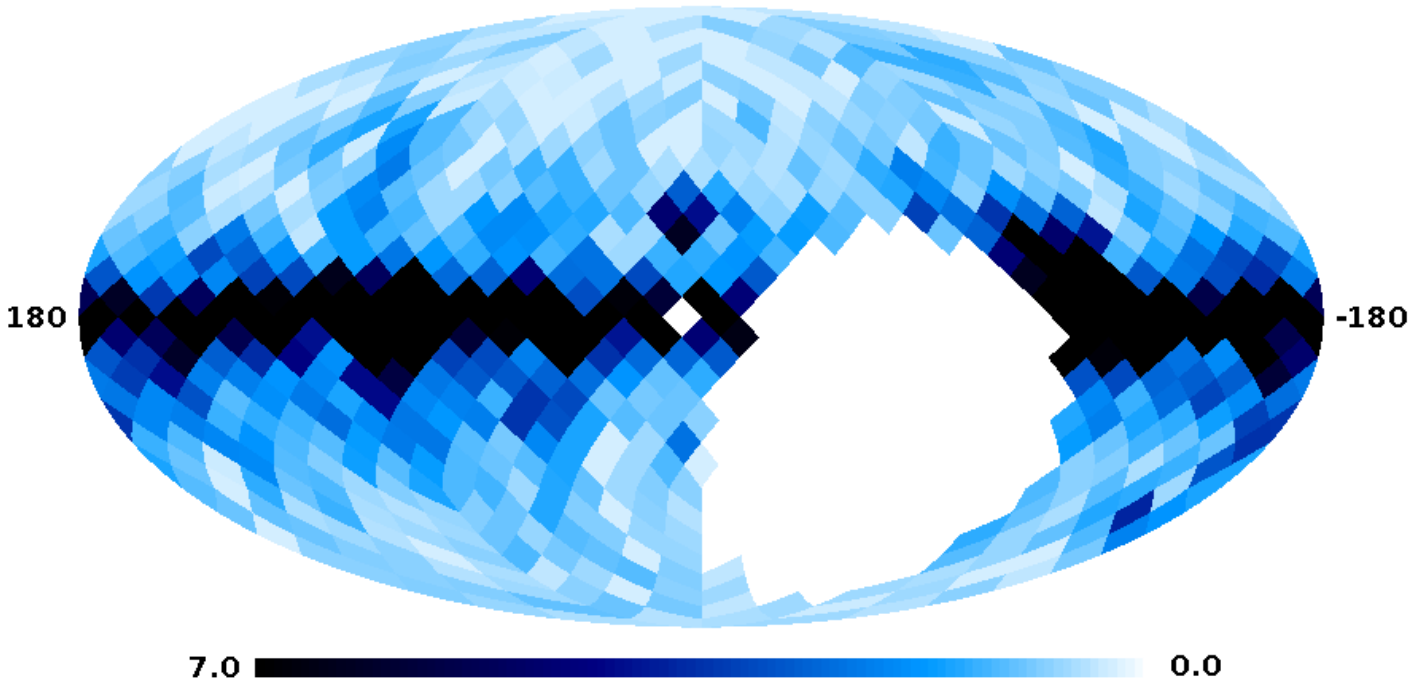
Magnetic beam

Smearing with $\sigma \sim 1\text{deg}\,(40Z/E)/(\sin^2 b + 0.15)$ © Pshirkov, Tinyakov & FU, 2013

$\rightarrow$ we smear with the max angle within a given sky patch

:: rotation measures ::



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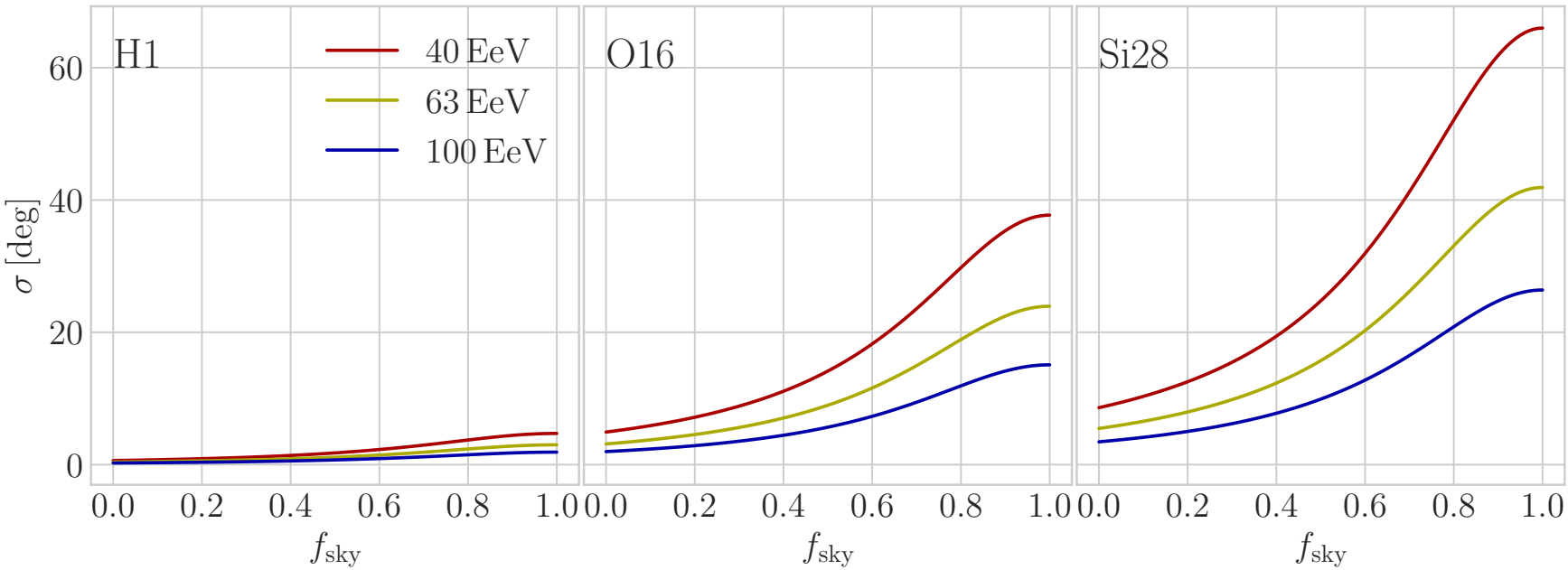
:: smearing ::



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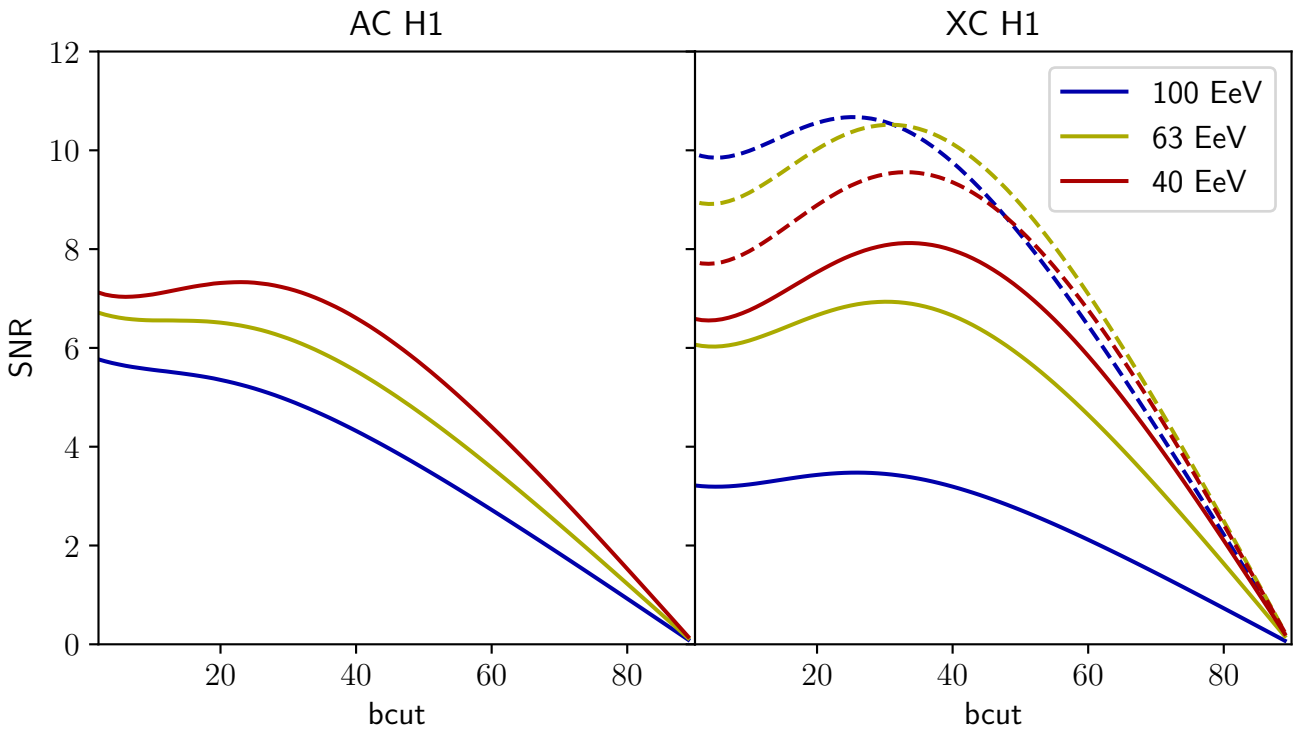
results

:: hydrogen ::



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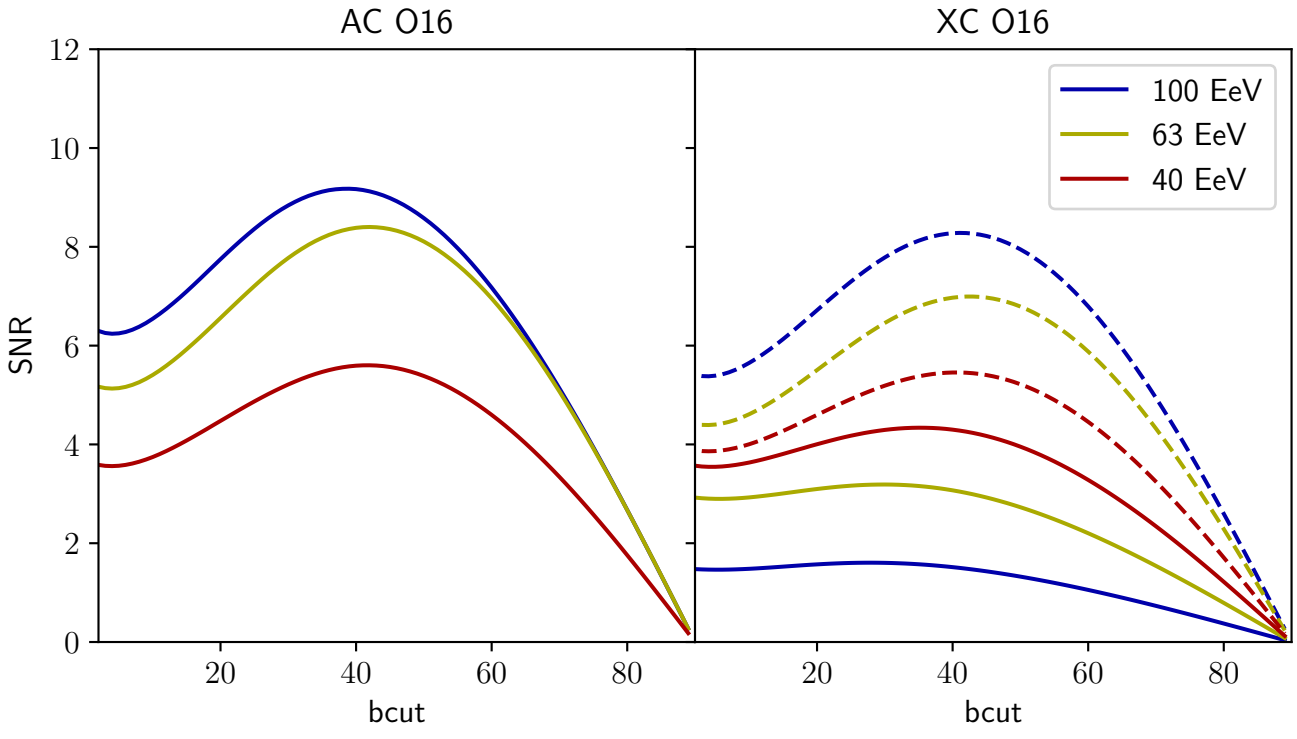
:: oxygen 16 ::



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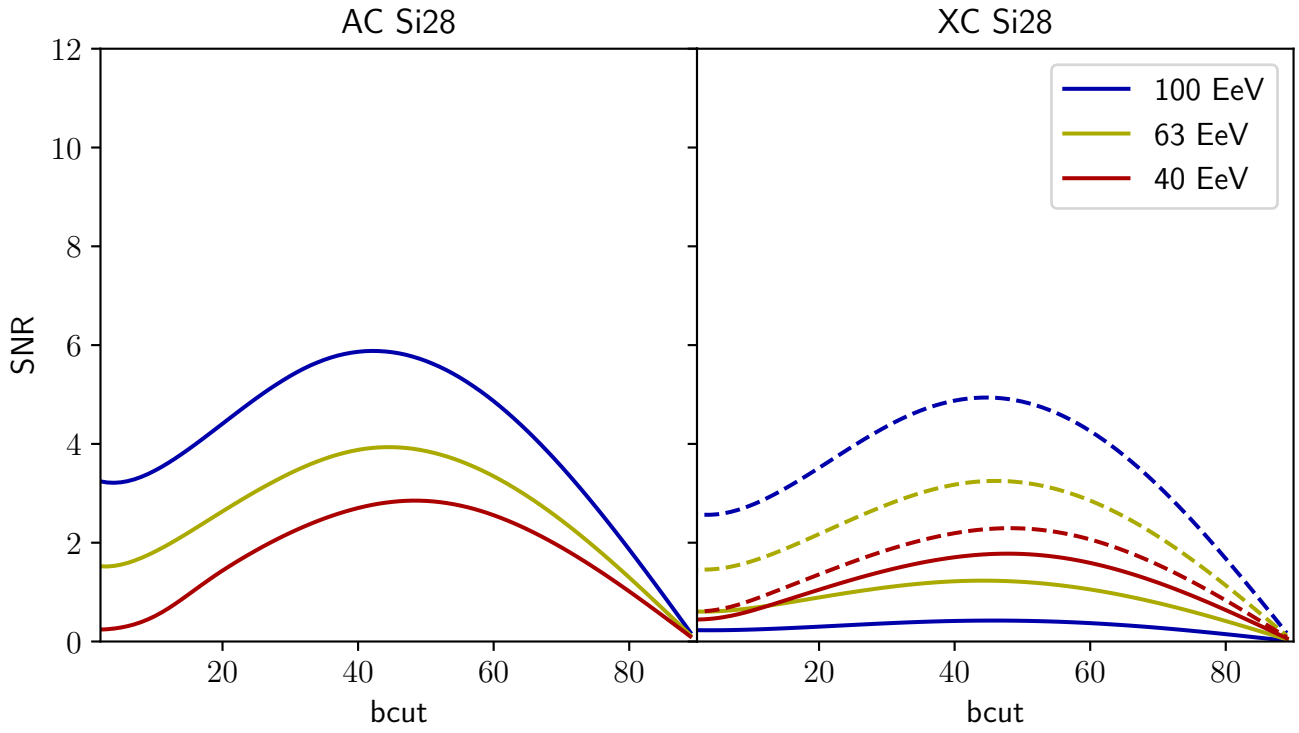
:: silicium28 ::



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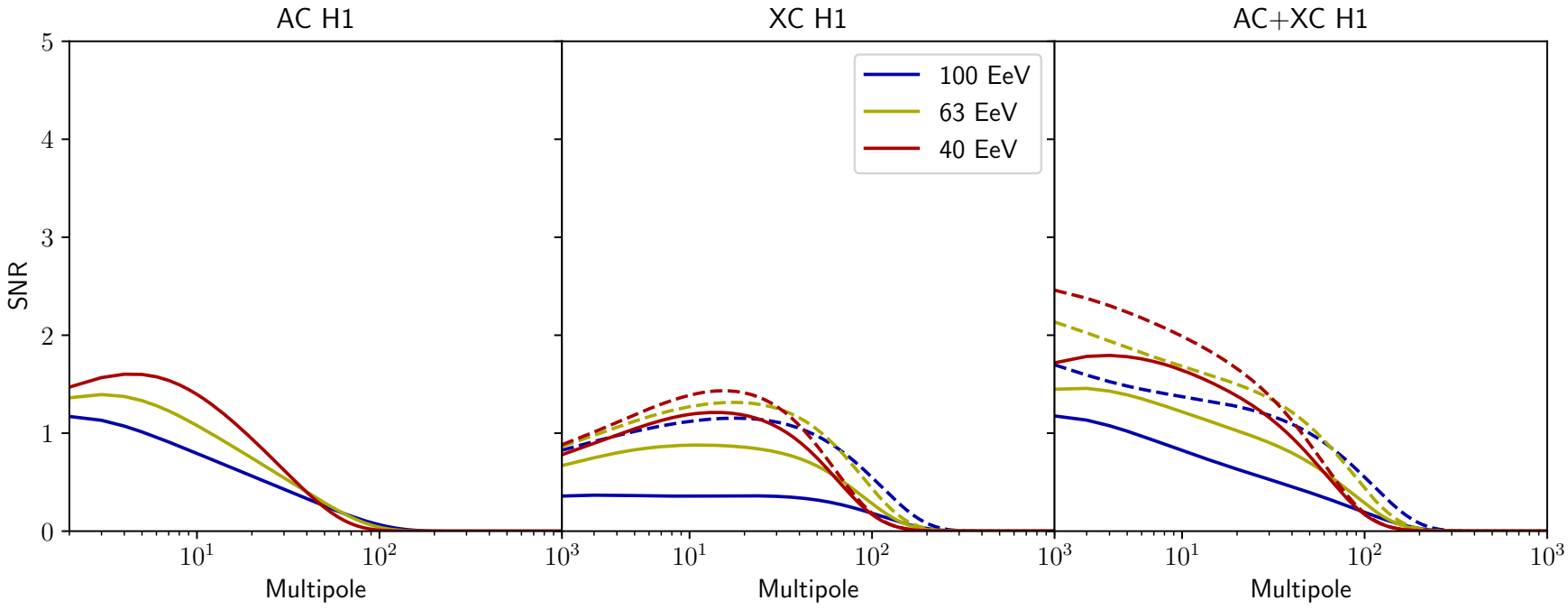

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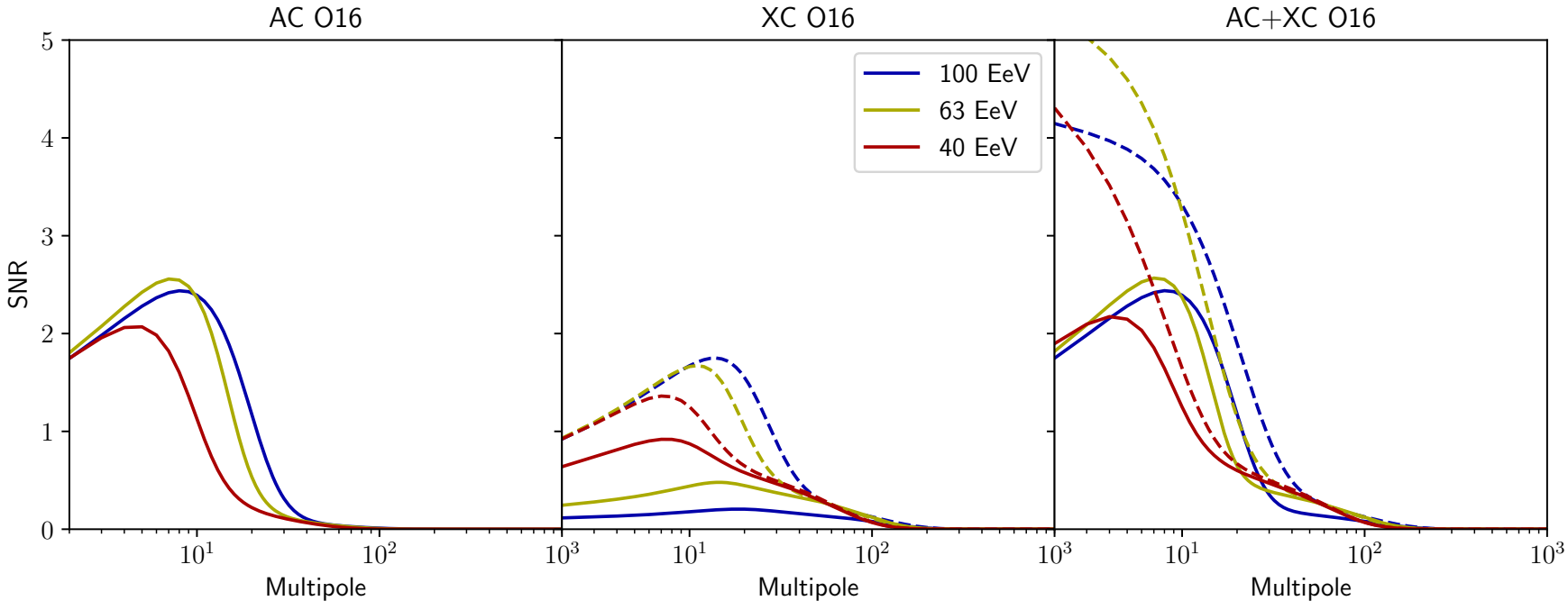

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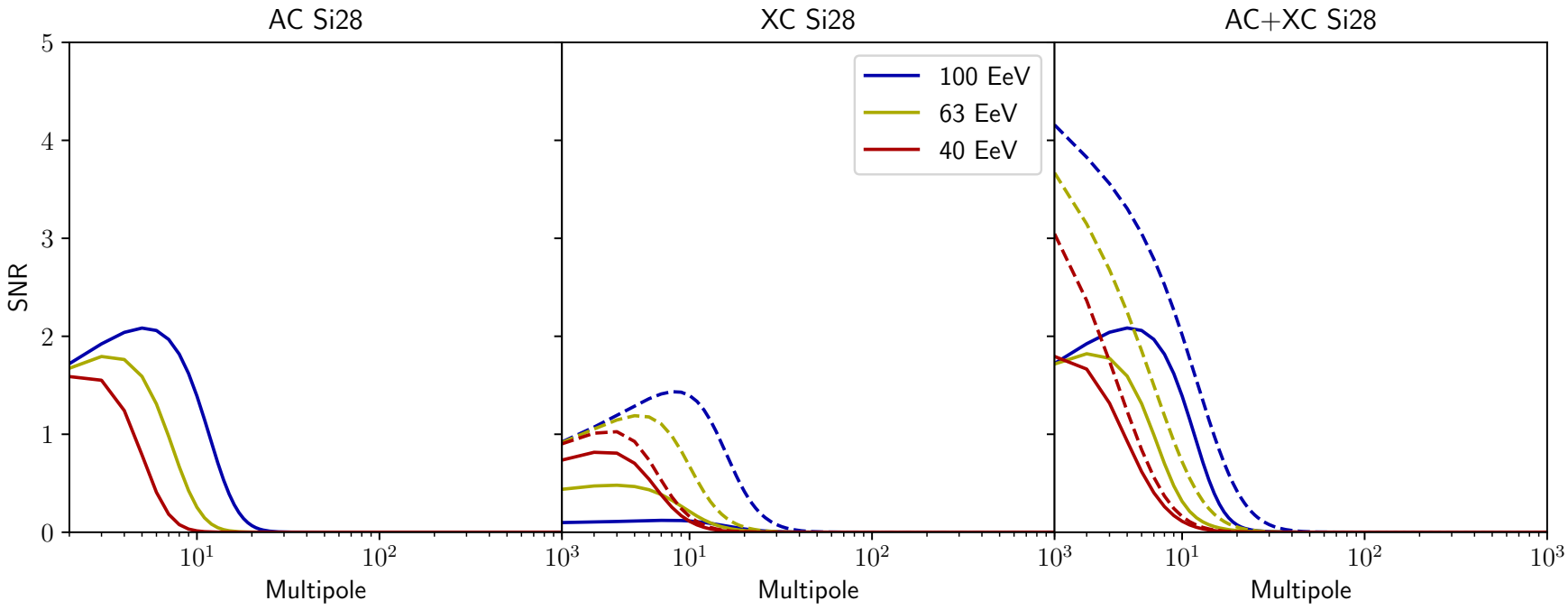

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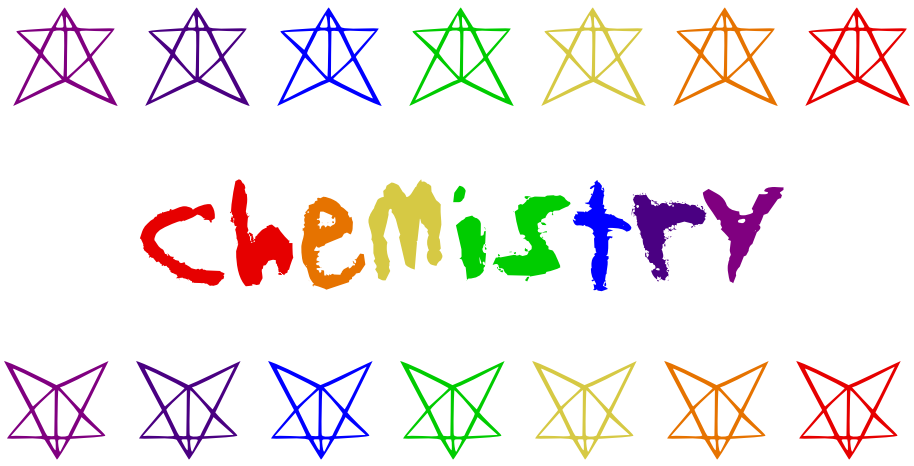
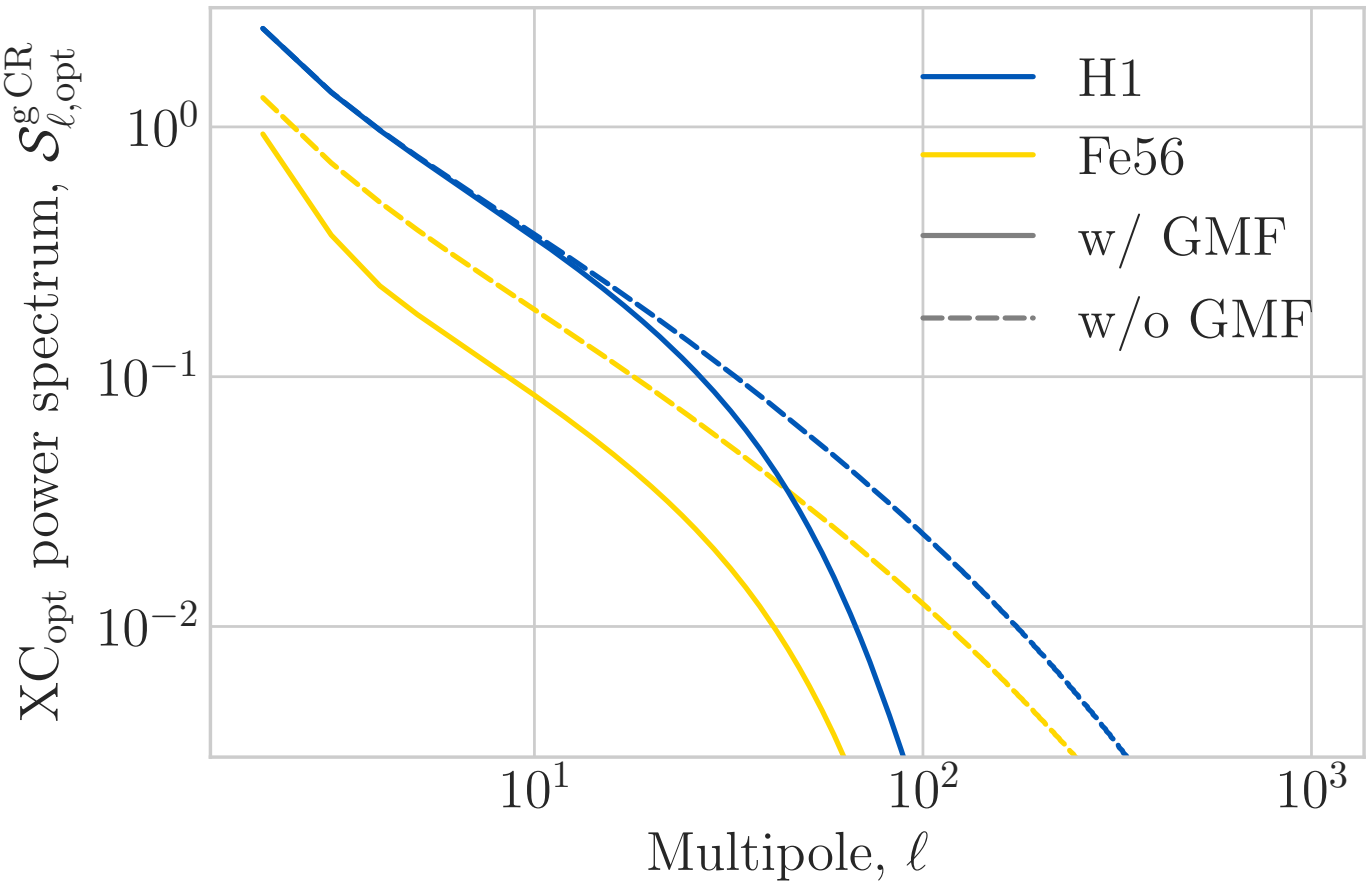

chemistry

:: hydrogen or iron ::



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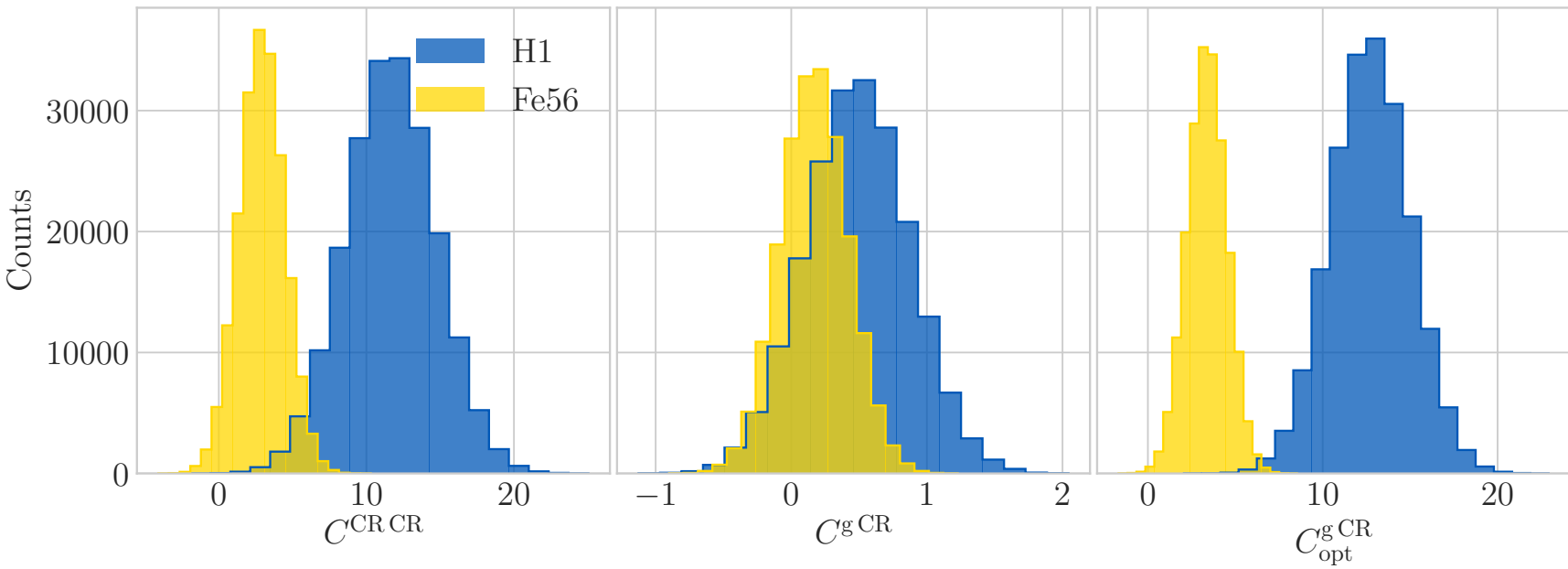
:: total power ::



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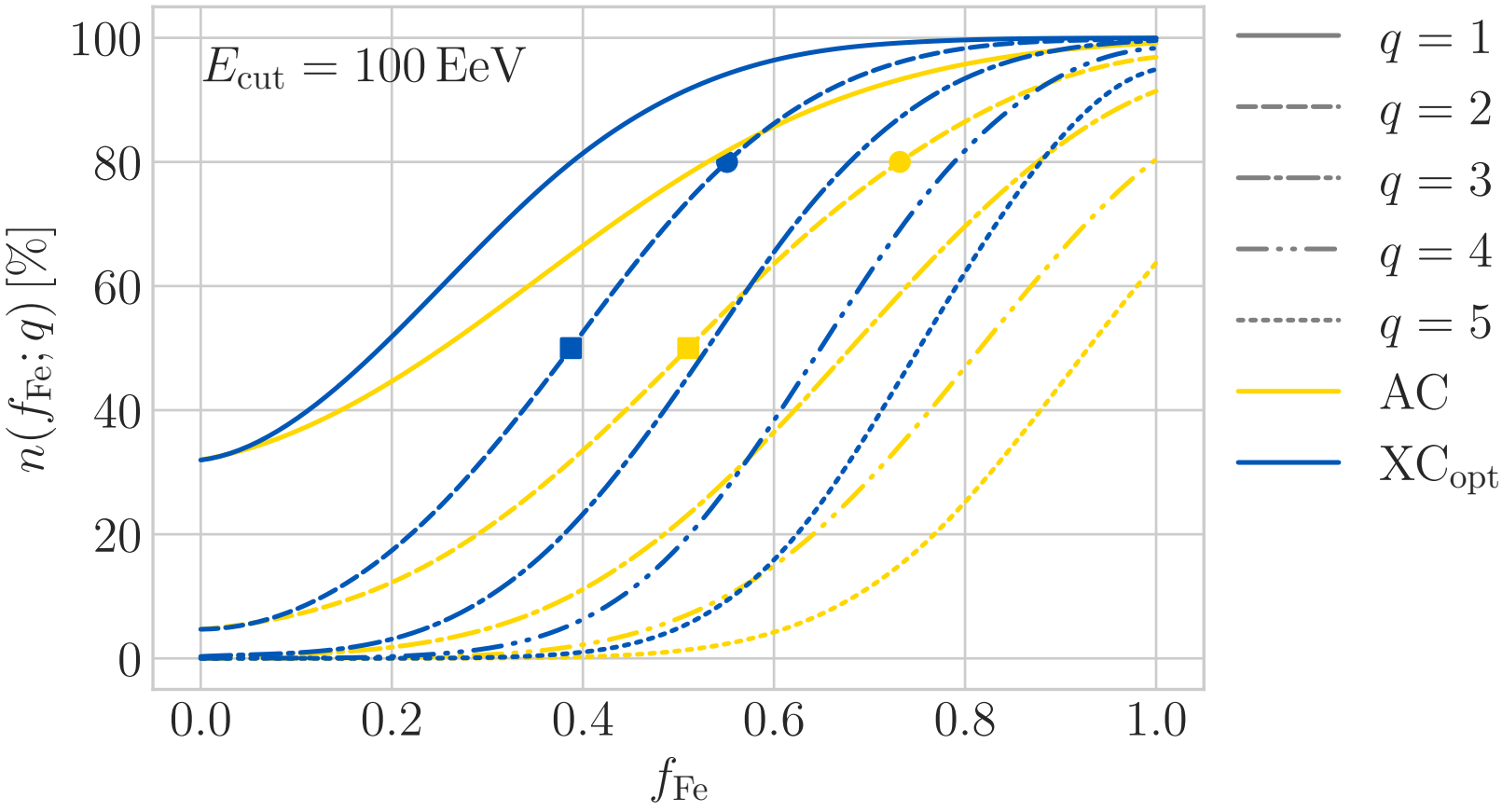
:: how much iron ::



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...and work in progress...