Stability of SD energy reconstructions under NKG and Power Law lateral distribution functions

Update since Lisbon 2013

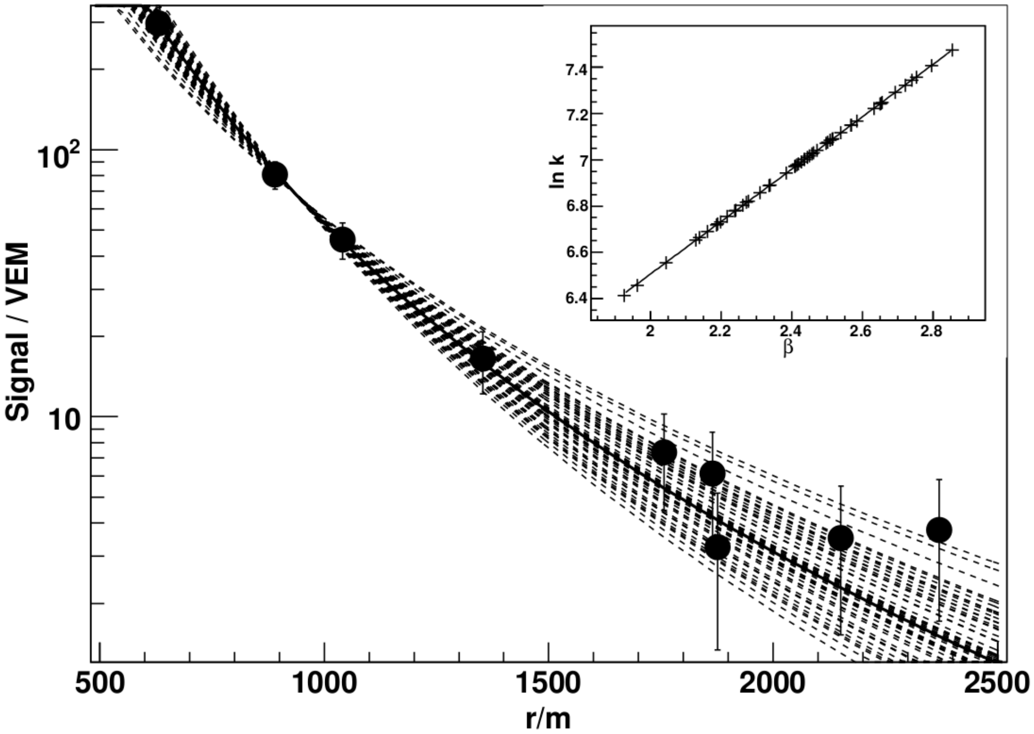
David Schmidt, Eric Mayotte, Fred Sarazin
Colorado School of Mines

Should surface detector energy reconstructions depend on the lateral distribution function (LDF)?

IDEALLY, NO
By design, S1000 is least sensitive to different parameterizations of the LDF.
(Newton, Knapp, Watson 2006)

REALISTICALLY, SOME

- CIC(θ) is LDF dependent.
  (Schmidt, Maris, Roth 2006)
- Core reconstruction is LDF dependent.
- Functions differ in their fitting behaviors.



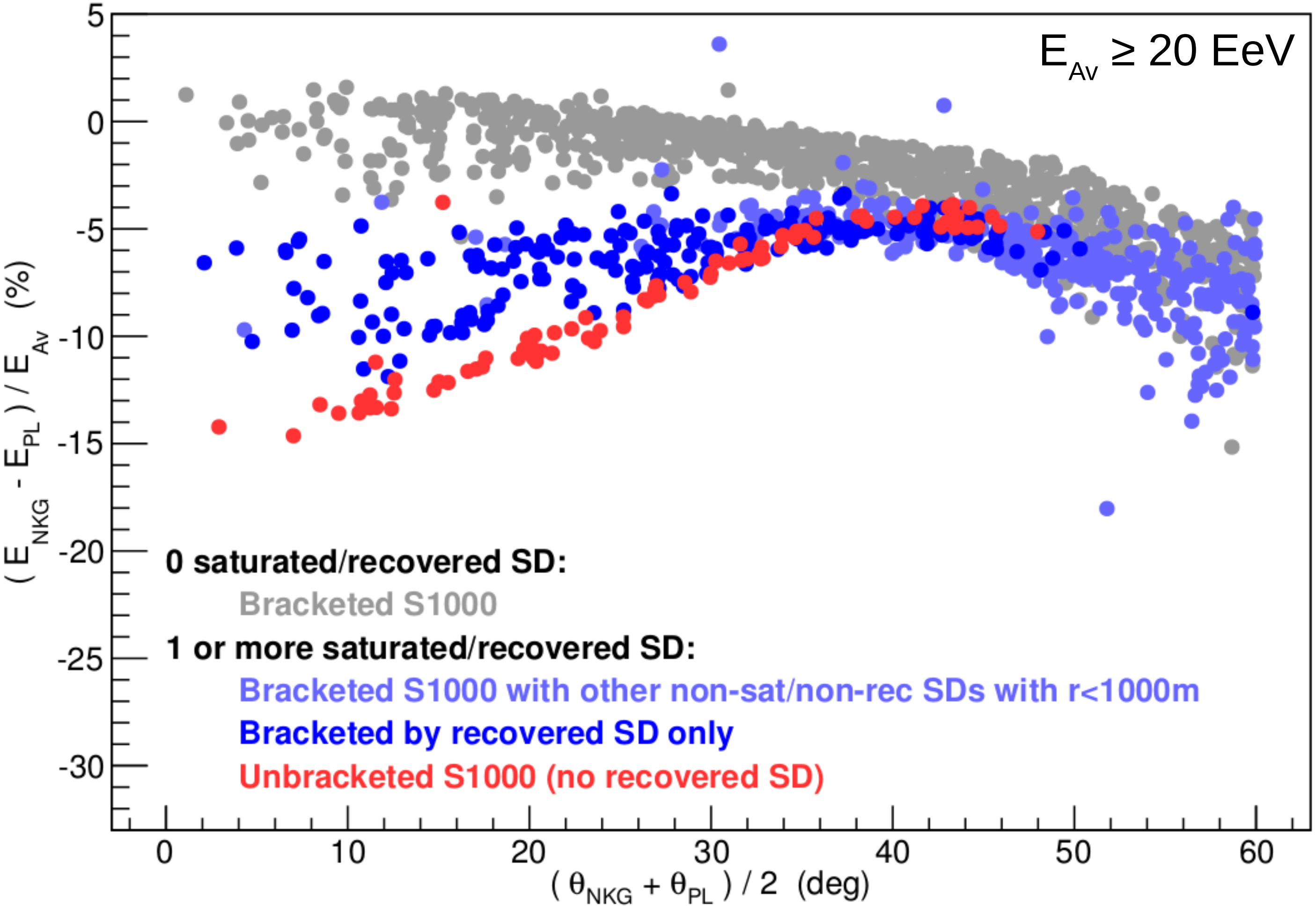
TAKEAWAY
Appropriate, well-fitting, LDFs should yield similar values for S1000, and in turn energy, as long as S1000 is well constrained. Small differences, however, are expected.

Previously Reported Results

DATA SET: 01.2004 – 08.2012
OFFLINE VERSION: 2.7.8
PHYSICAL TRIGGER: 6T5

LDFS: NKG and Power Law

Both functions have been substantiated and fit the distance vs. signal data well.



RESULTS:

- Significant differences in energy reconstructions at low zenith angles due to poor bracketing of S1000.
- Dominance of such significantly different events at high energies.

PROPOSED MODIFICATIONS:

- Derive independent CIC(θ) curves for NKG and Power Law.
- Perform independent energy calibrations for NKG and Power Law.

Updated Study Parameters

LDFS: NKG and Power Law

Both functions have been substantiated and fit the distance vs. signal data well.

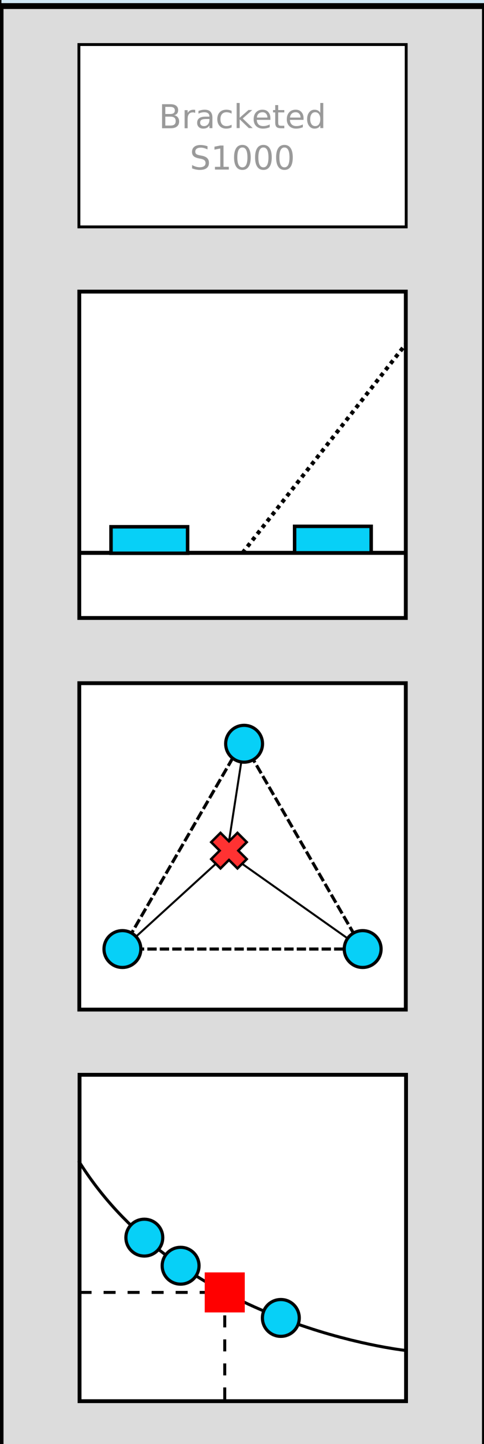
DATA SET: 2004 – 2012

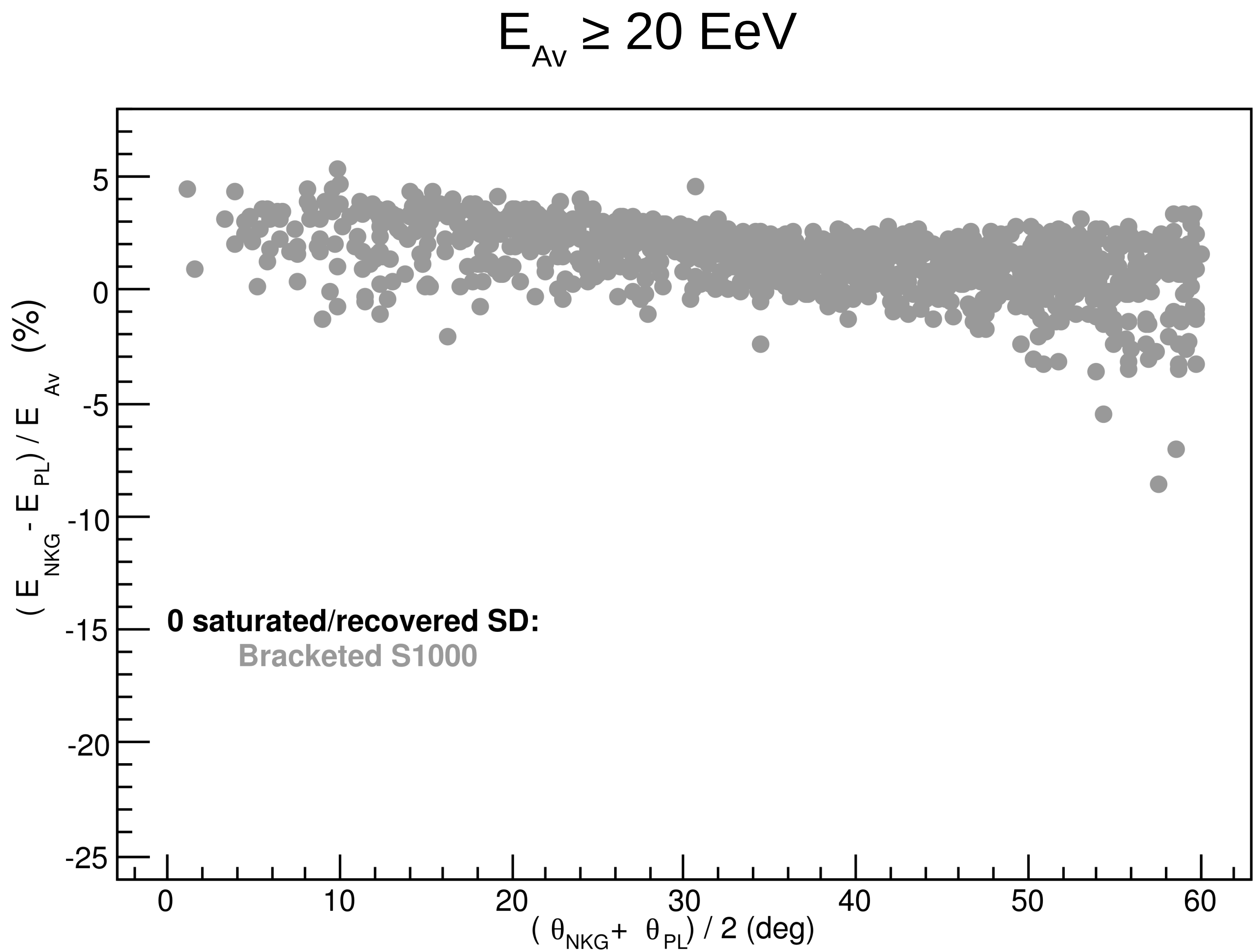
OFFLINE VERSION: 2.9.1 (including ICRC2013 updates)

PHYSICAL TRIGGER: 6T5

- Separate CIC(θ) derived for NKG and Power Law (see backup slides)
- Separate Energy Calibrations performed for NKG and Power Law (see backup slides)

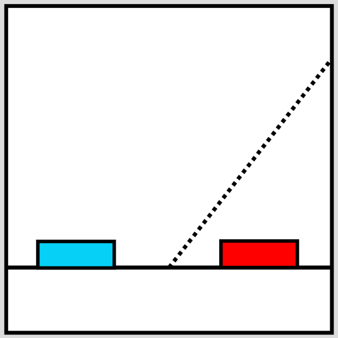
Bracketing Distinctions

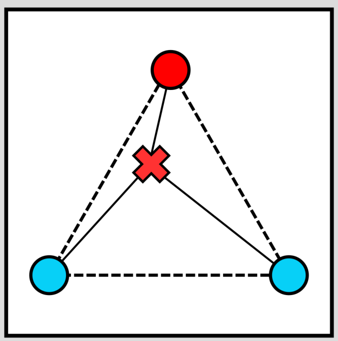


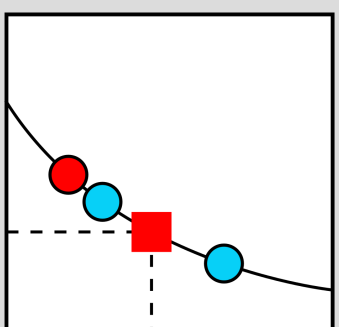


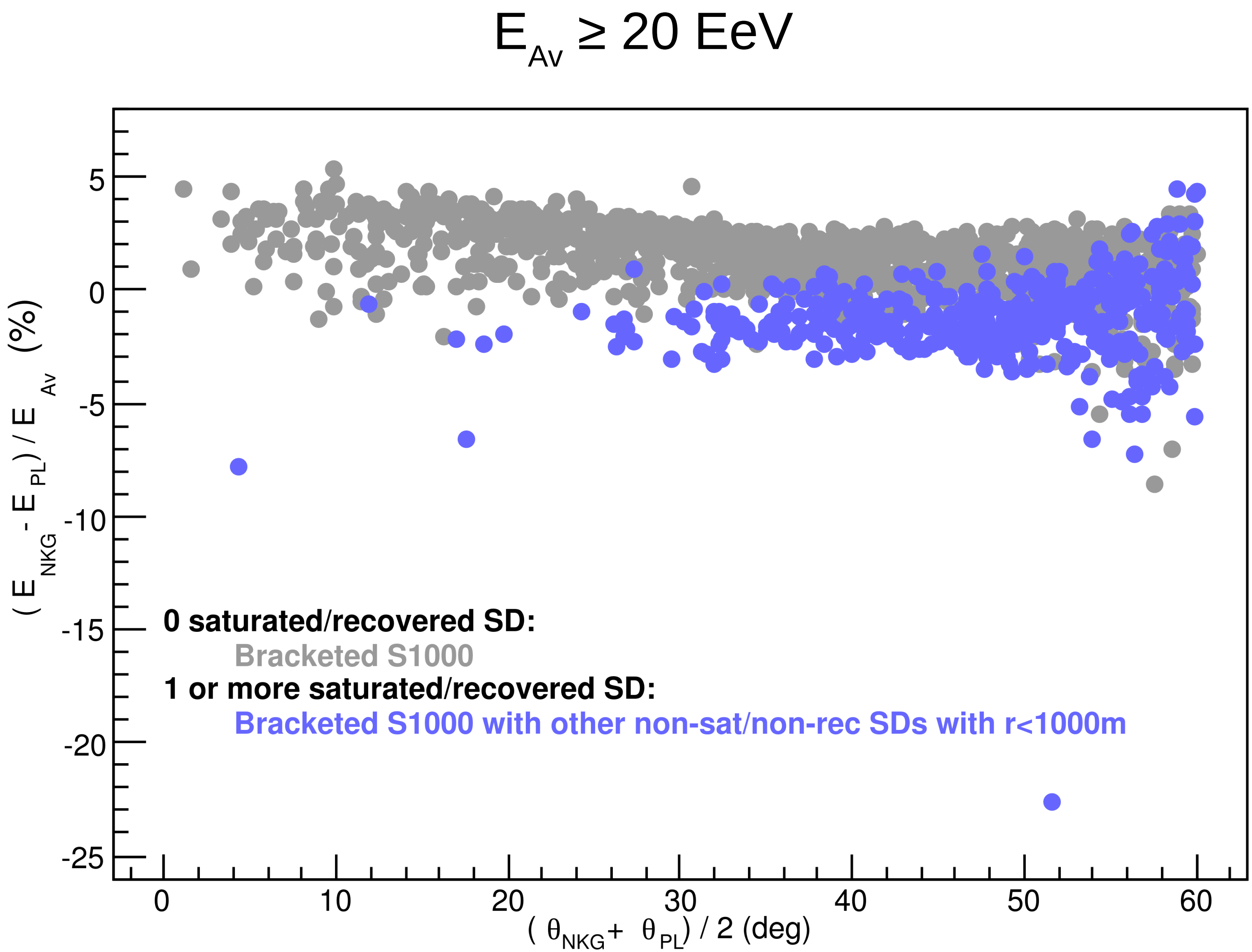
Bracketing Distinctions

Bracketed S1000 with other non-sat/non-rec SDs with r<1000m



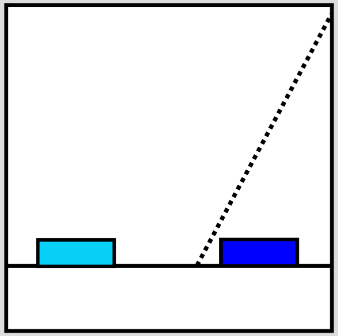


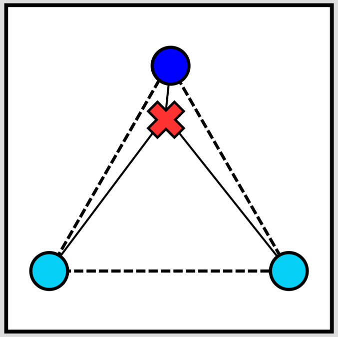


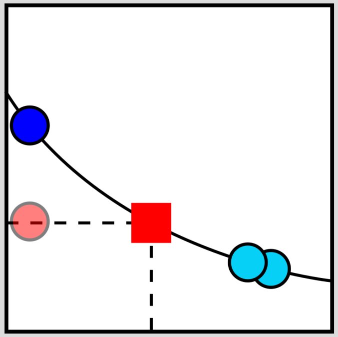


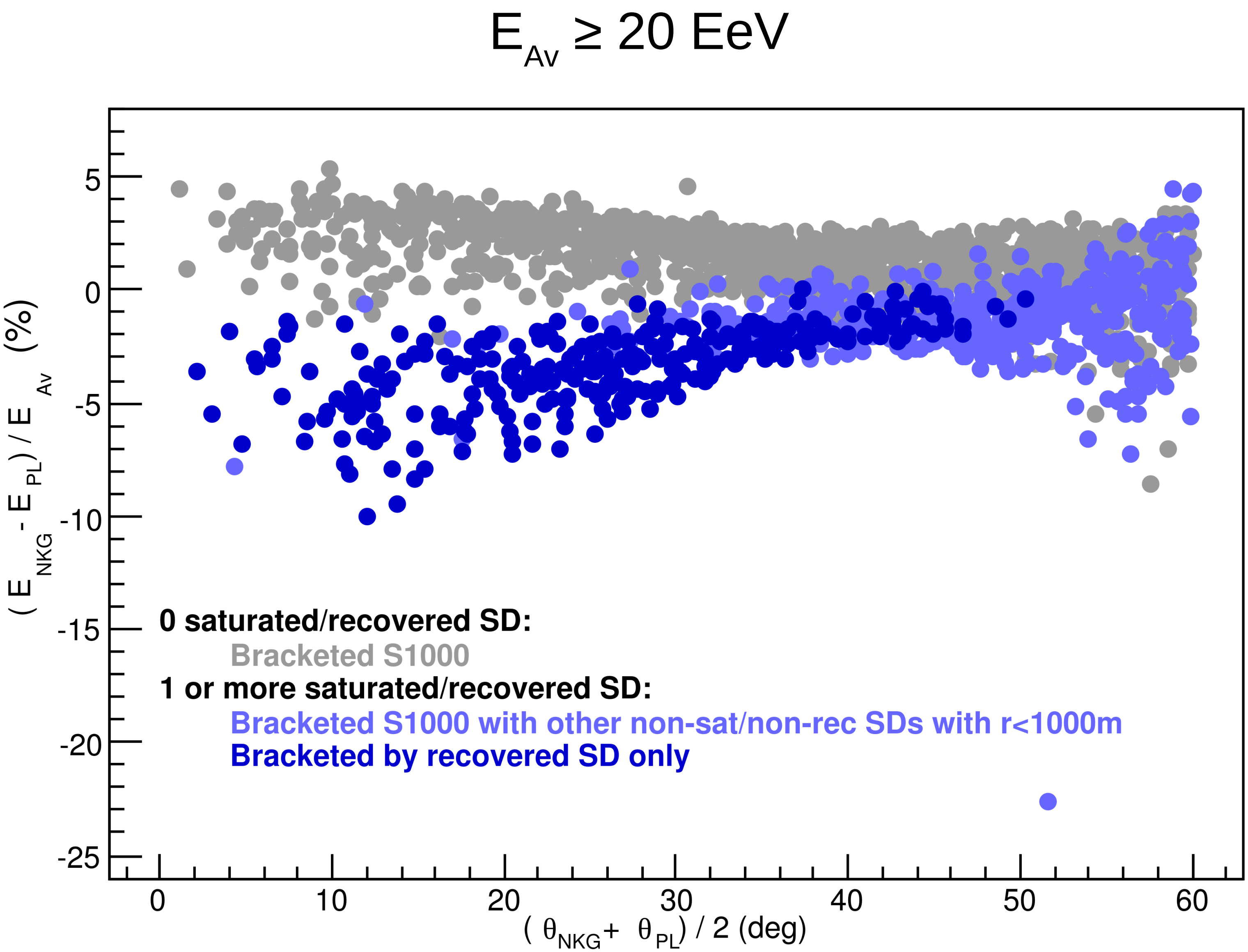
Bracketing Distinctions

Bracketed by recovered SD only



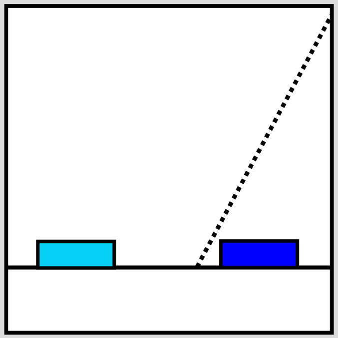


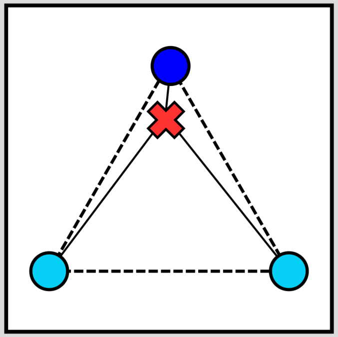


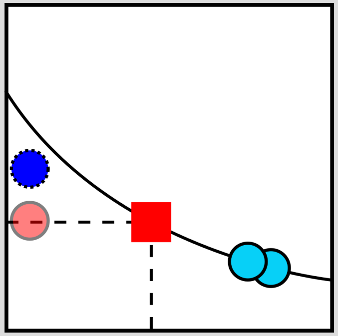


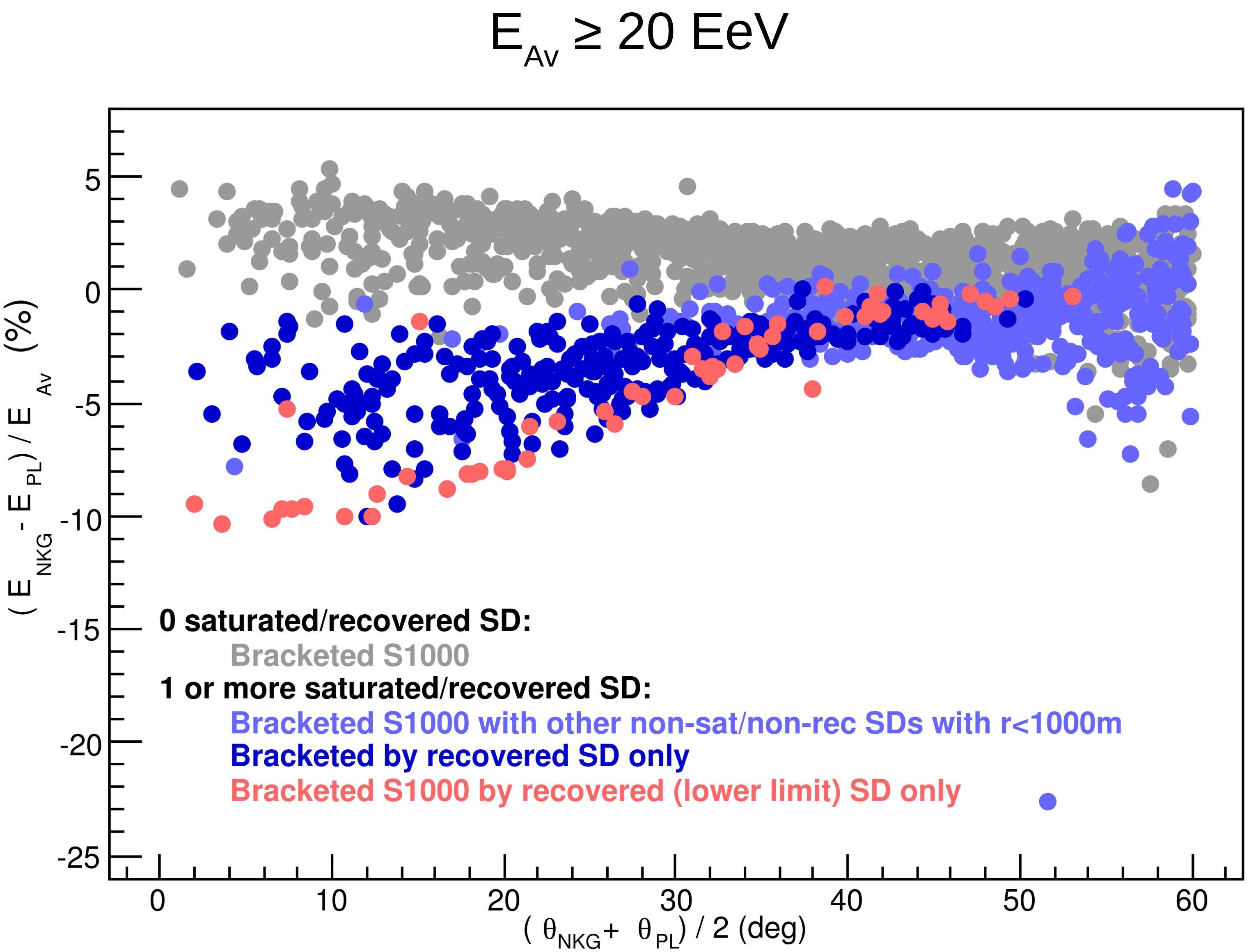
Bracketing Distinctions

Bracketed S1000 by recovered (lower limit) SD only



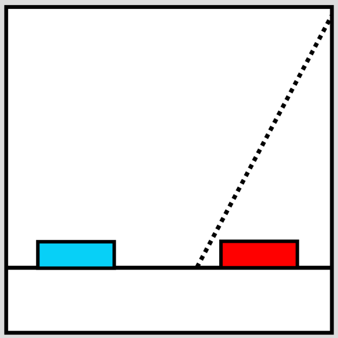


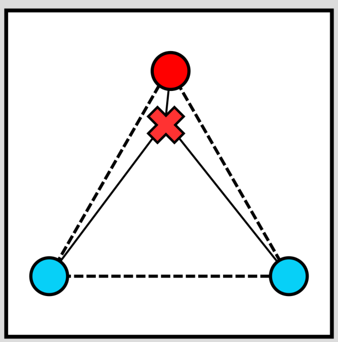


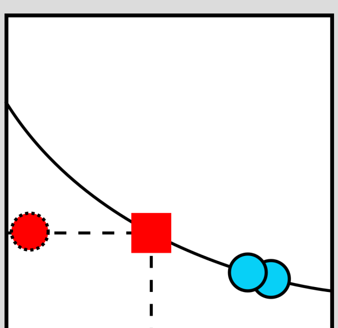


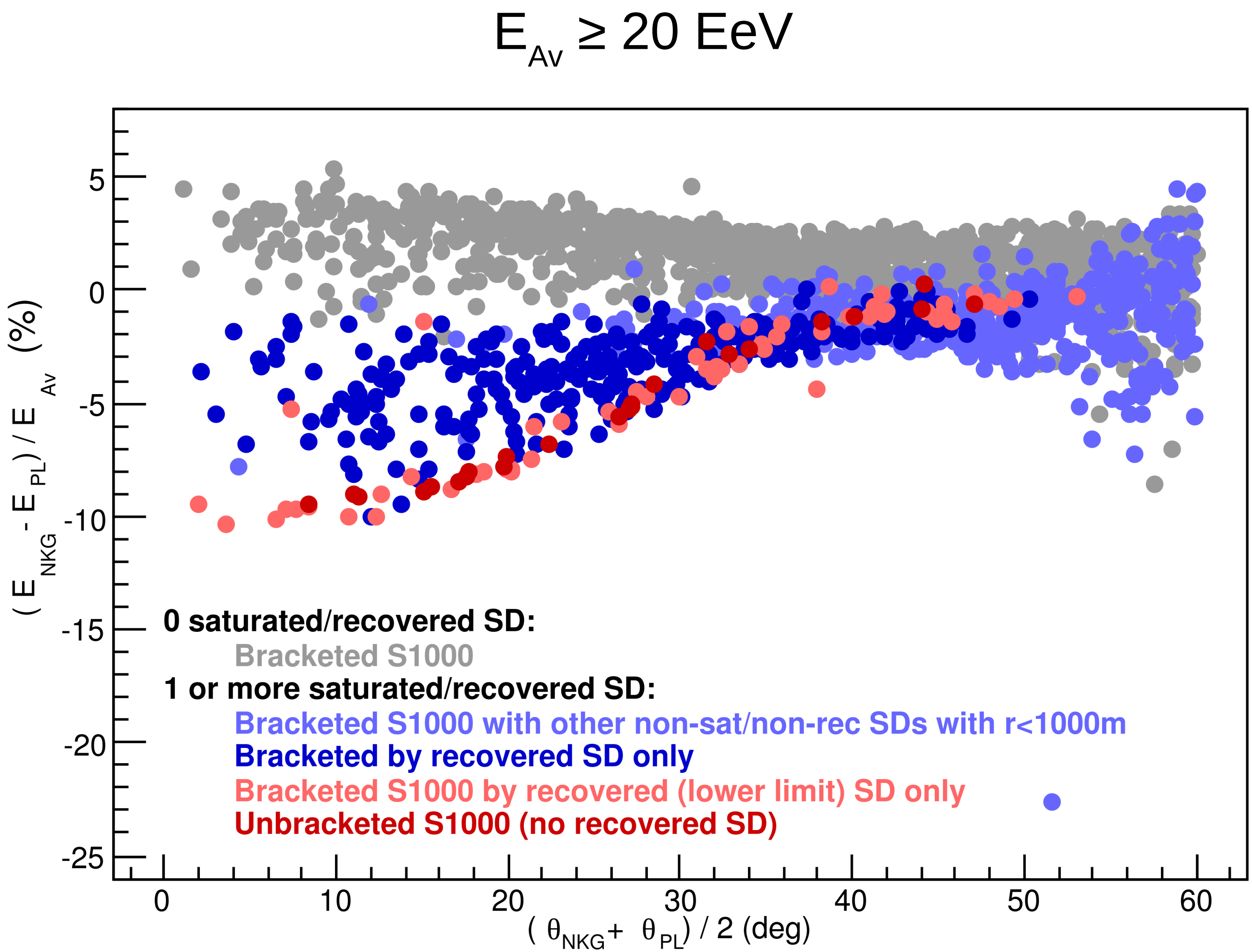
Bracketing Distinctions

Unbracketed S1000 (no recovered SD)



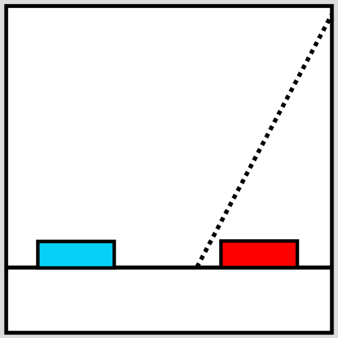


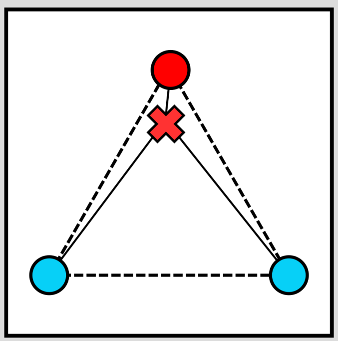


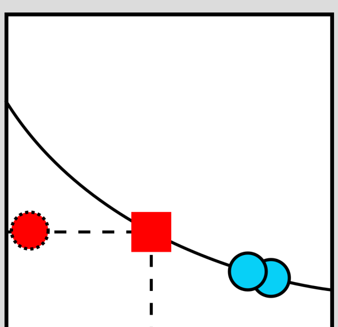


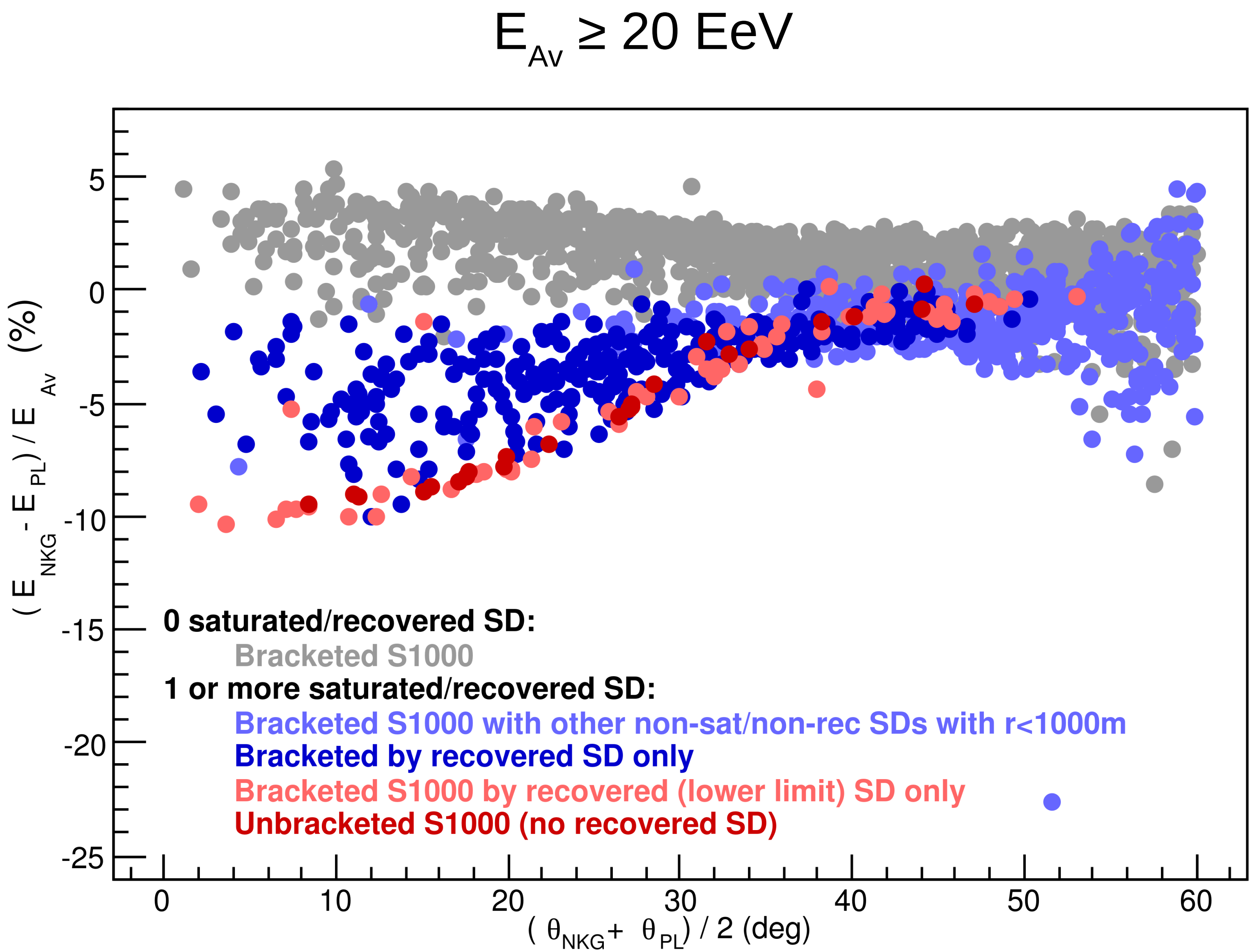
Bracketing Distinctions

Unbracketed
S1000
(no recovered SD)



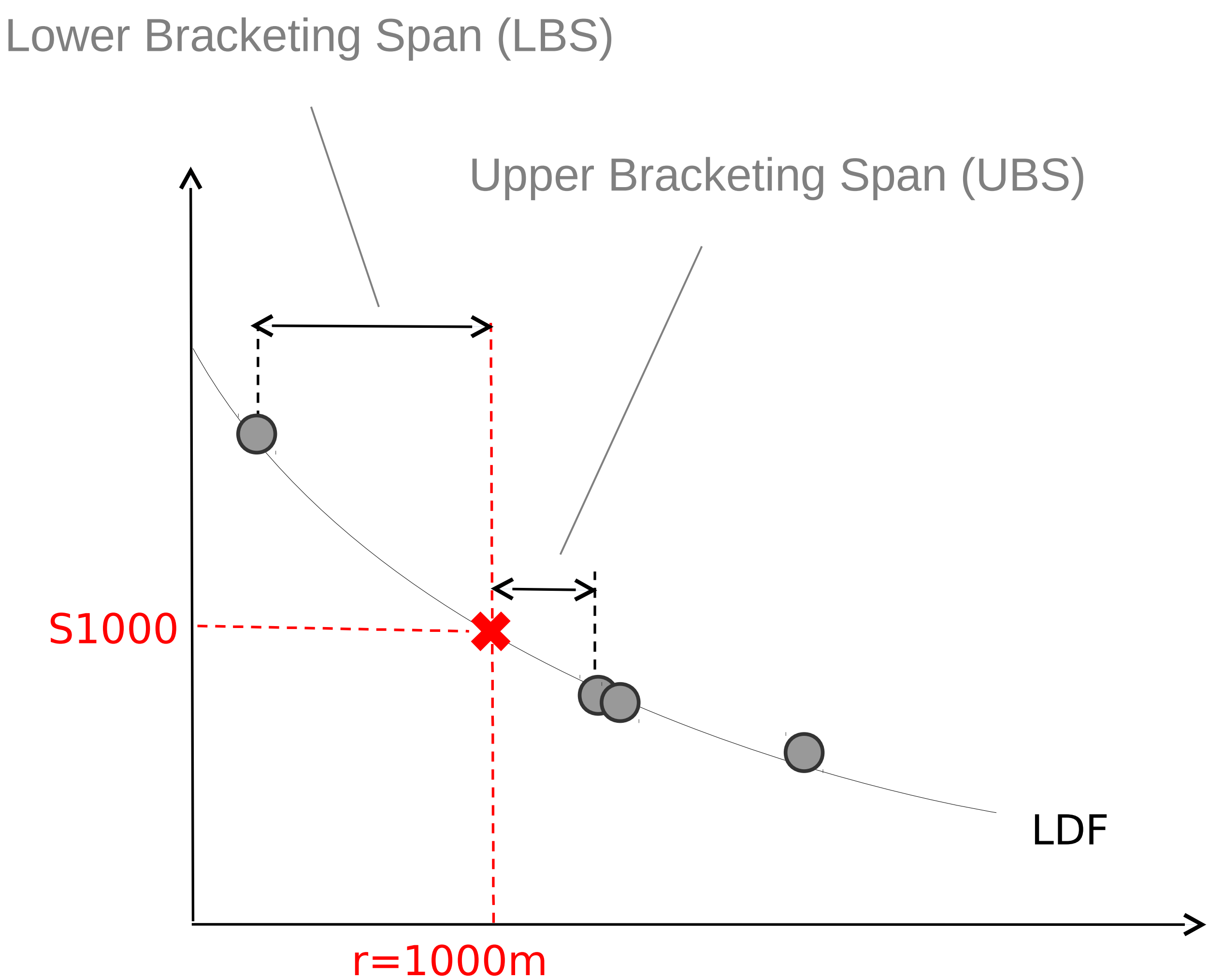






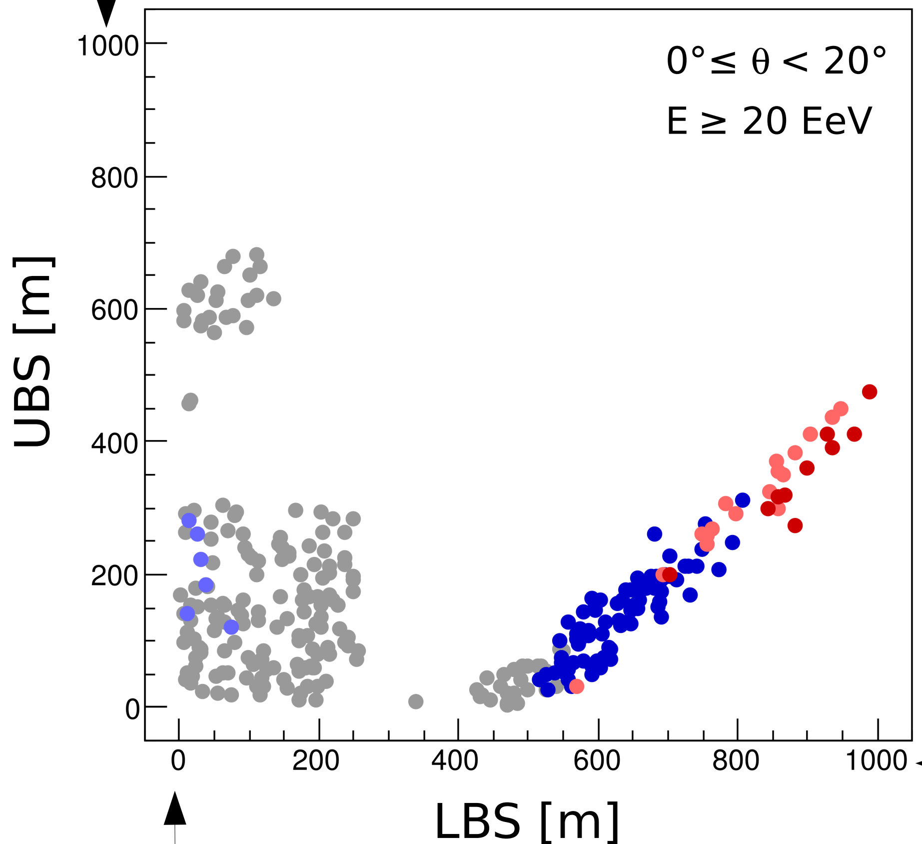
GEOMETRIC EFFECT

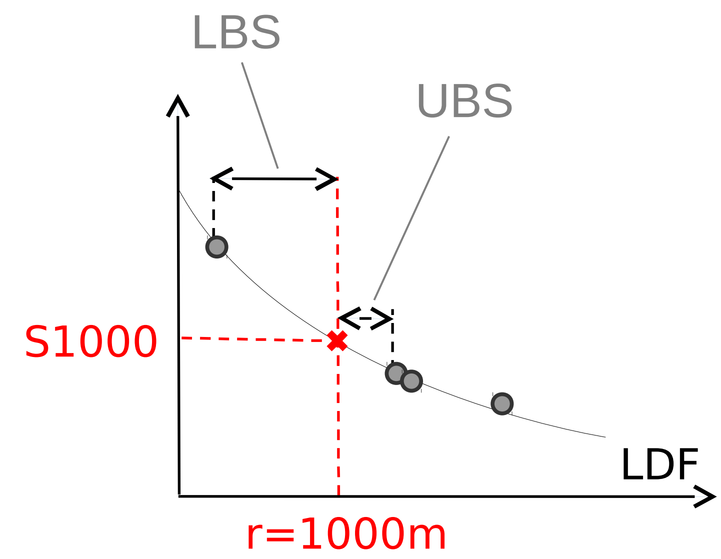
Bracketing Span



Bracketing Span

A UBS of 1000 m equates to a tank at 2000 m from the core, with no tanks between 1000 and 2000 m from the core.



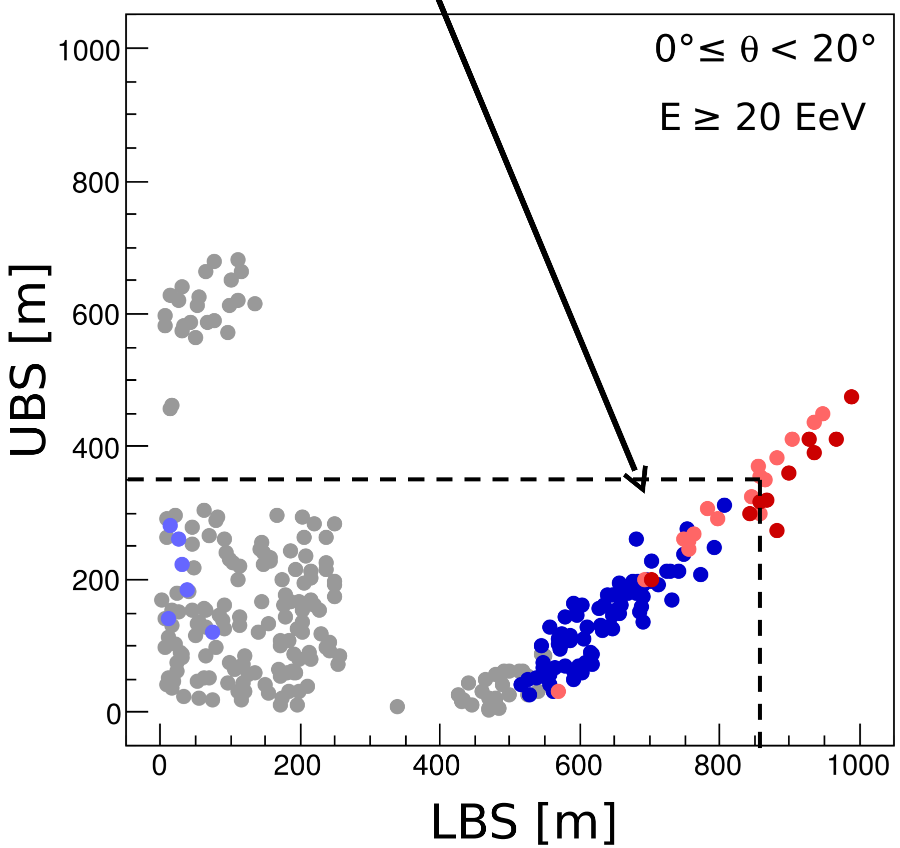


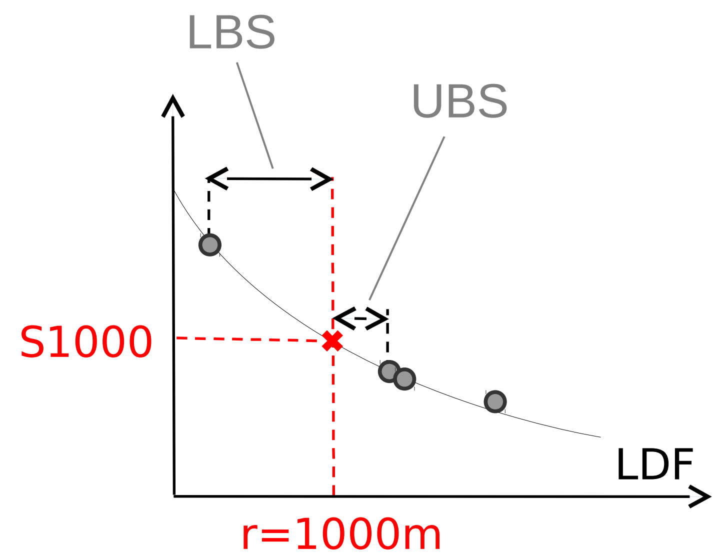
A LBS of 1000 m equates to the shower core landing directly on the hot tank with no other tanks between the hot tank and 1000 m from the core.

An LBS or UBS of 0 equate to tanks directly at 1000 m from the core.

Bracketing Span

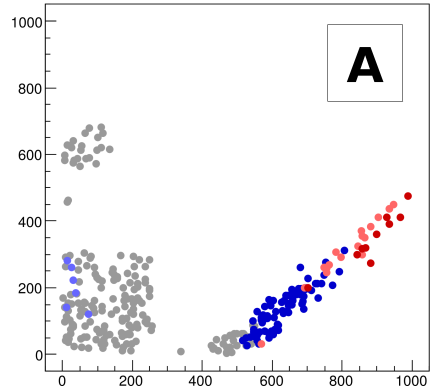
If, for a shower with a low zenith angle, a tank saturates within 200 m of the core and is not recovered, the first station usable in the LDF fit is ~1400 m from the core.



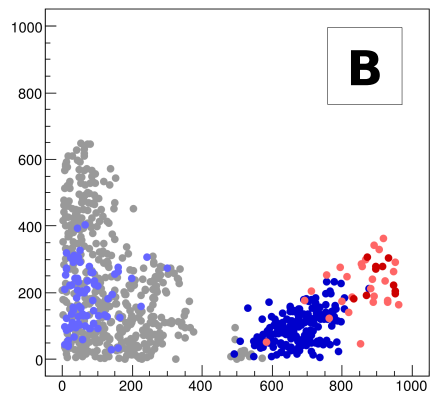


Bracketing Span & Percent Energy Difference

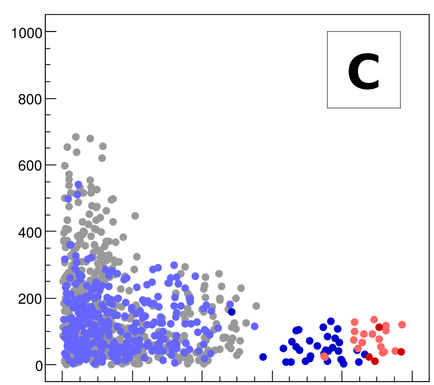
$0° \leq \theta < 20°$



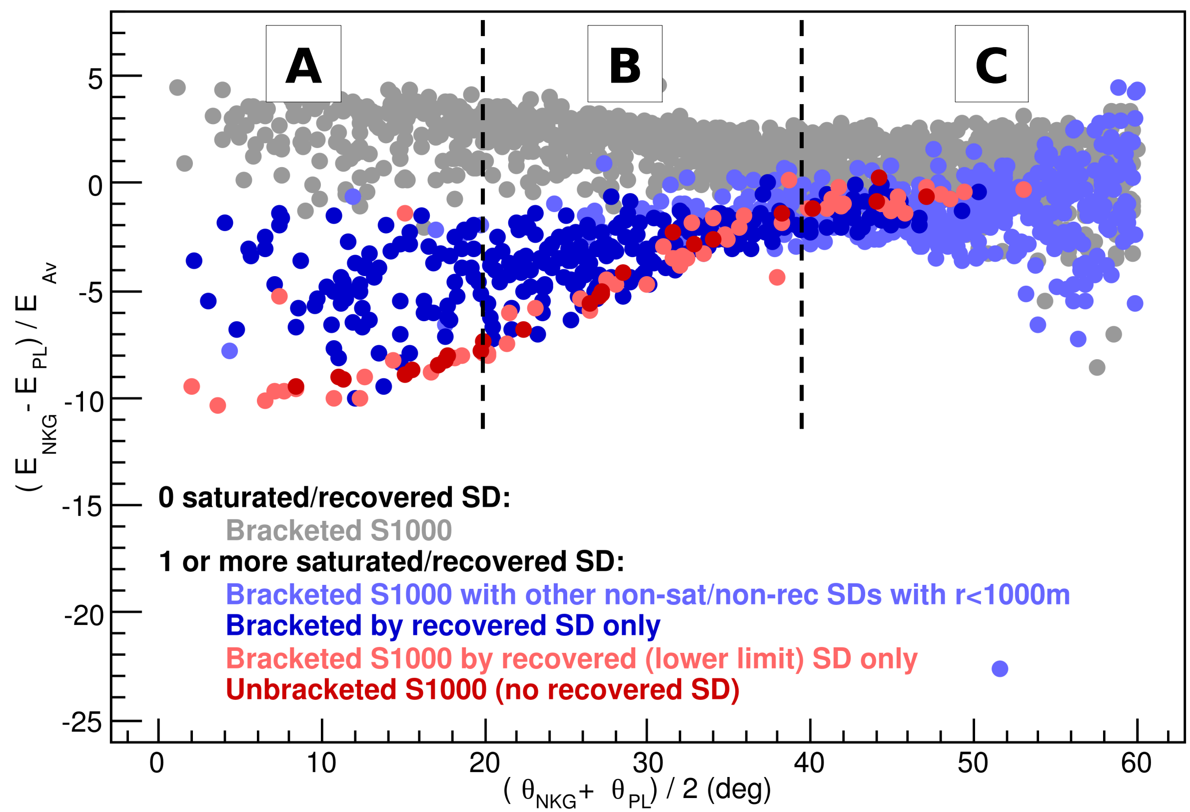
$20° \leq \theta < 40°$



$40° \leq \theta < 60°$

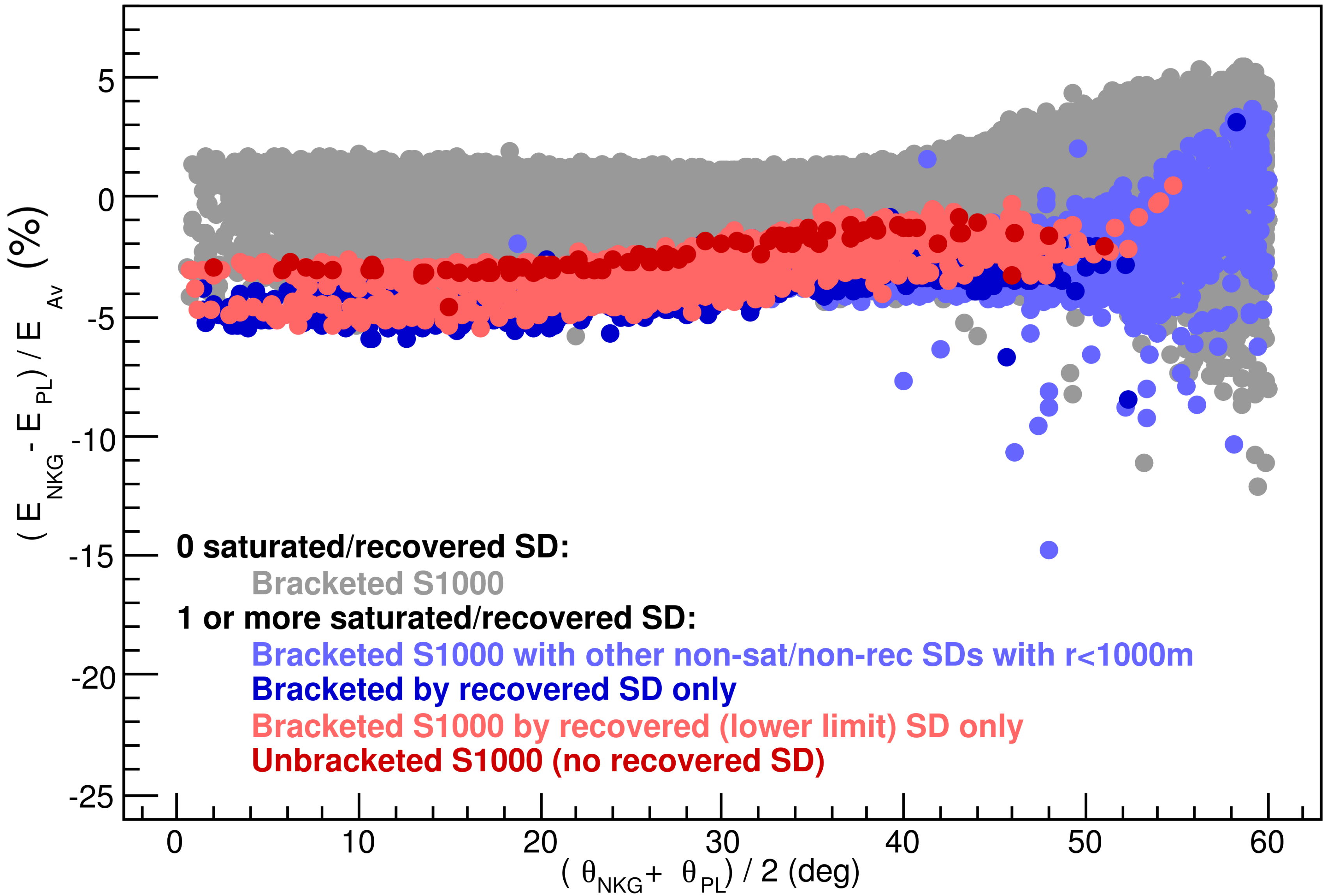


$E_{Av} \geq 20$ EeV



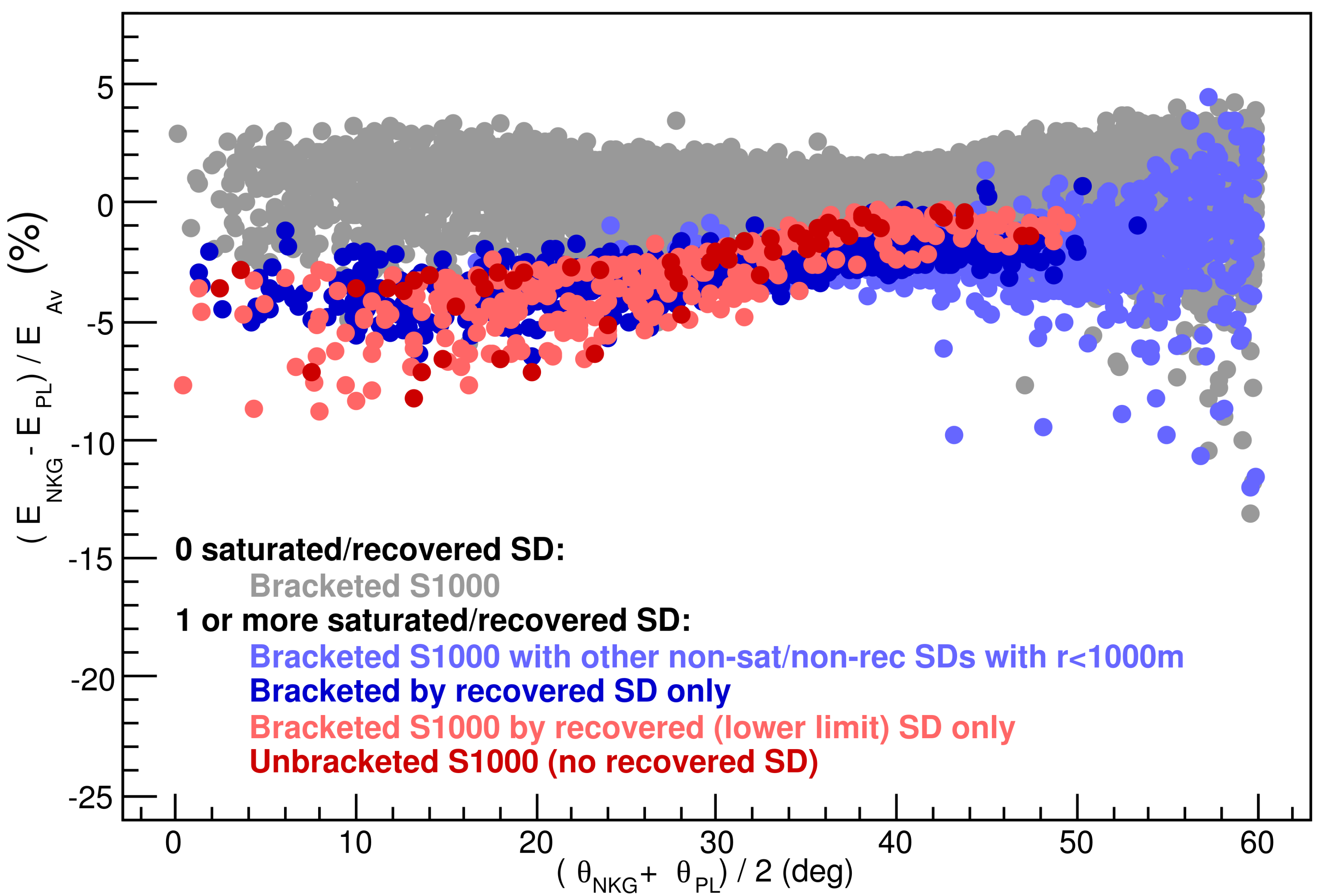
Energy Regions

5 EeV ≤ E_{Av} < 10 EeV

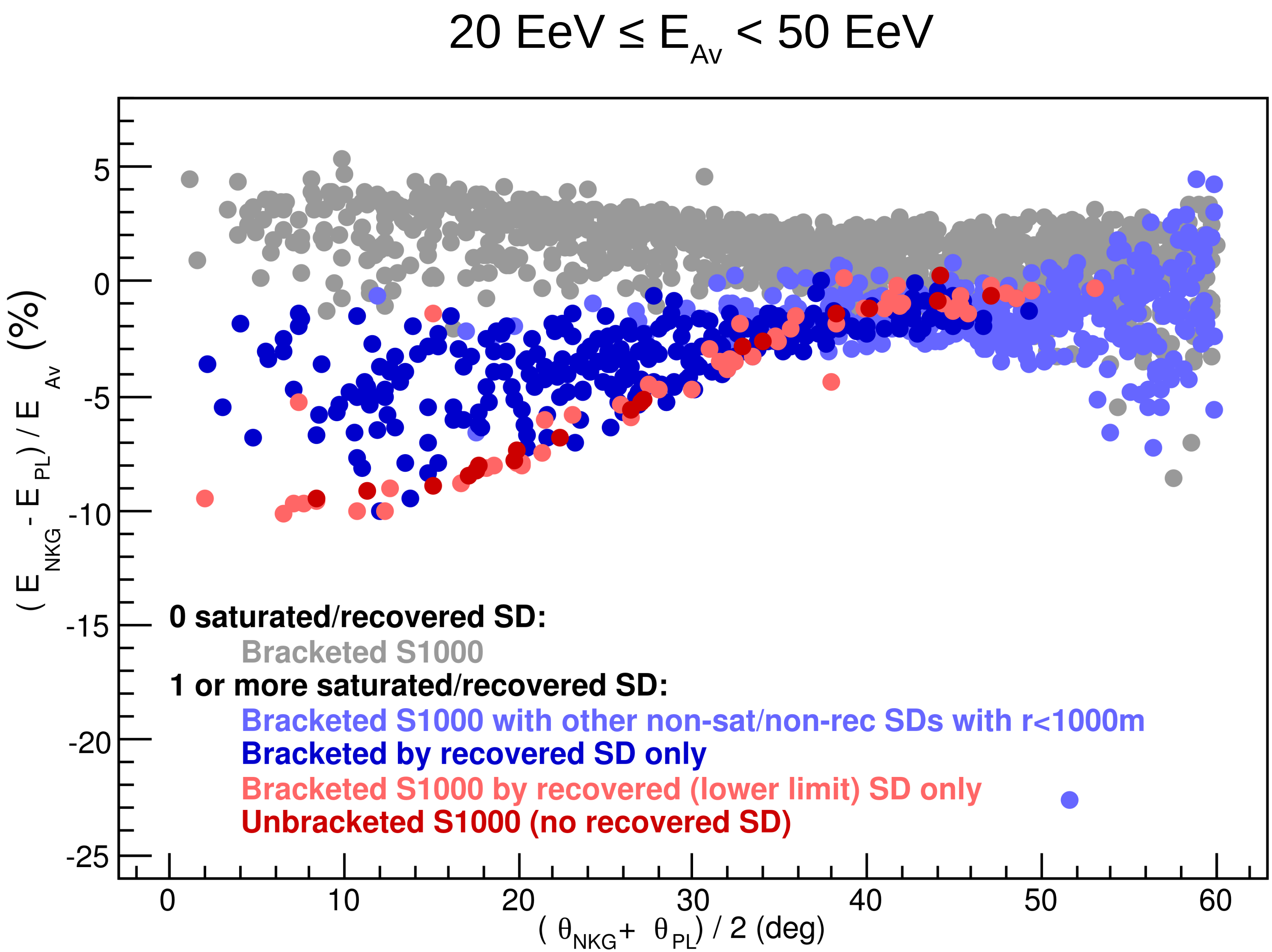


Energy Regions

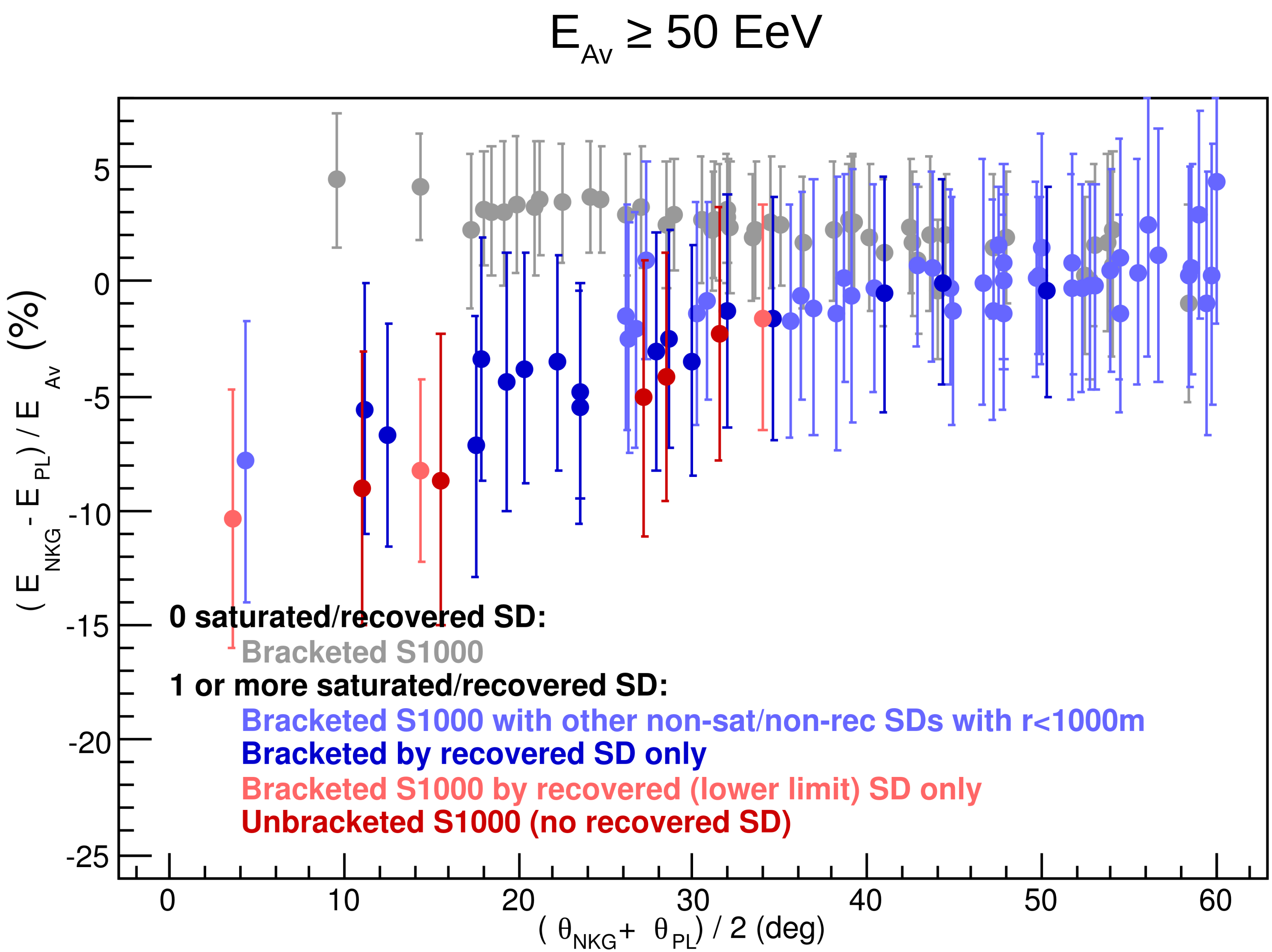
10 EeV ≤ E_{Av} < 20 EeV



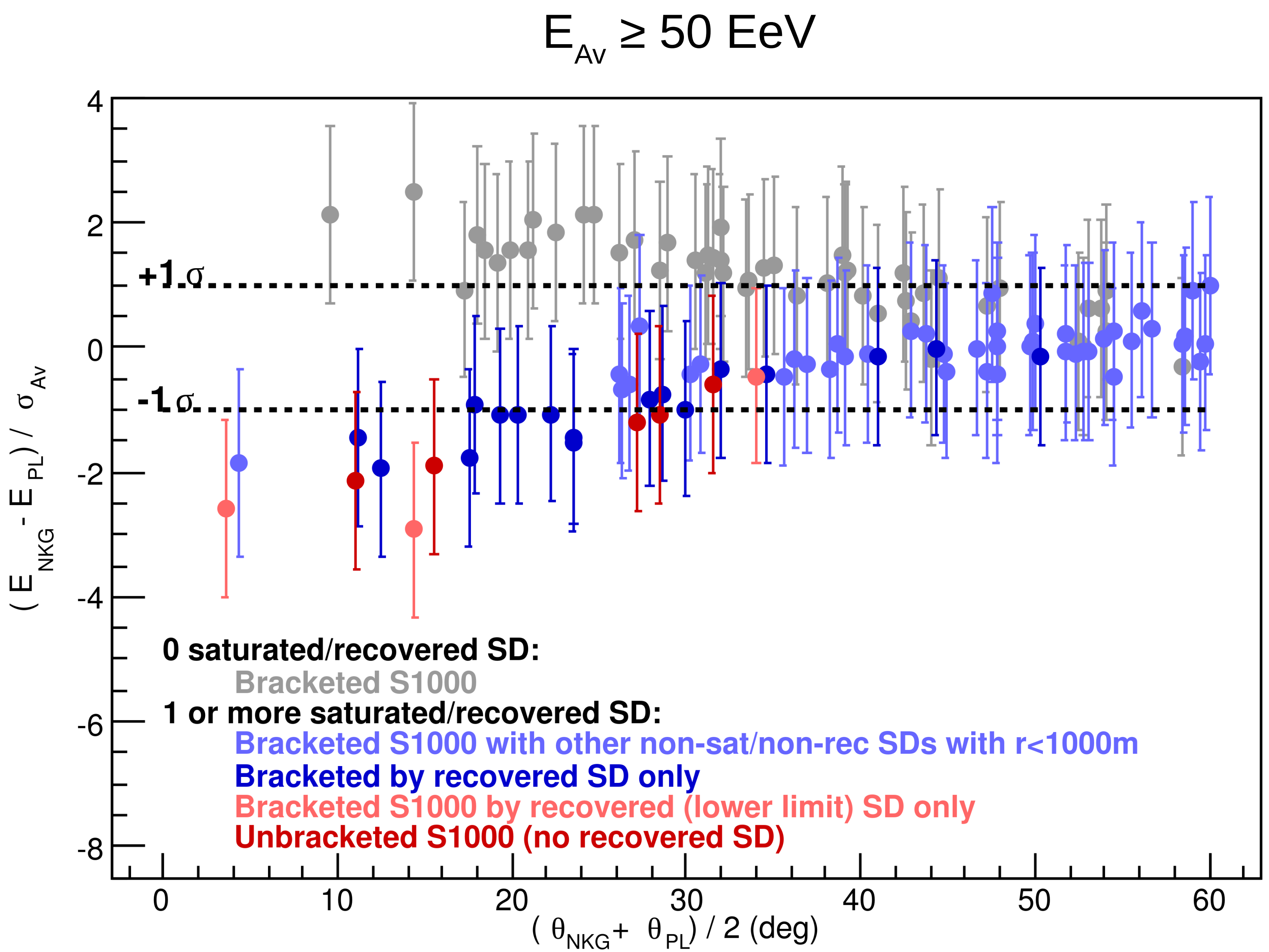
Energy Regions



Energy Regions



Comparison with Observer SD Energy Uncertainties



Summary

CONCLUSIONS

- Geometry of the array coupled with shower geometries can result in poor or good bracketing of S1000.
- E_{SD} deviates significantly between reconstructions using valid, yet different LDFs
- E_{SD} differences are most prevalent for low zenith angle showers in which one or more tanks saturate.

IMPLICATIONS

- Larger uncertainty in energy.
- Possible biasing of energy calibration by events with saturated tanks.
- Possible biasing of energy spectrum, anisotropy, etc.

POSSIBLE SOLUTIONS

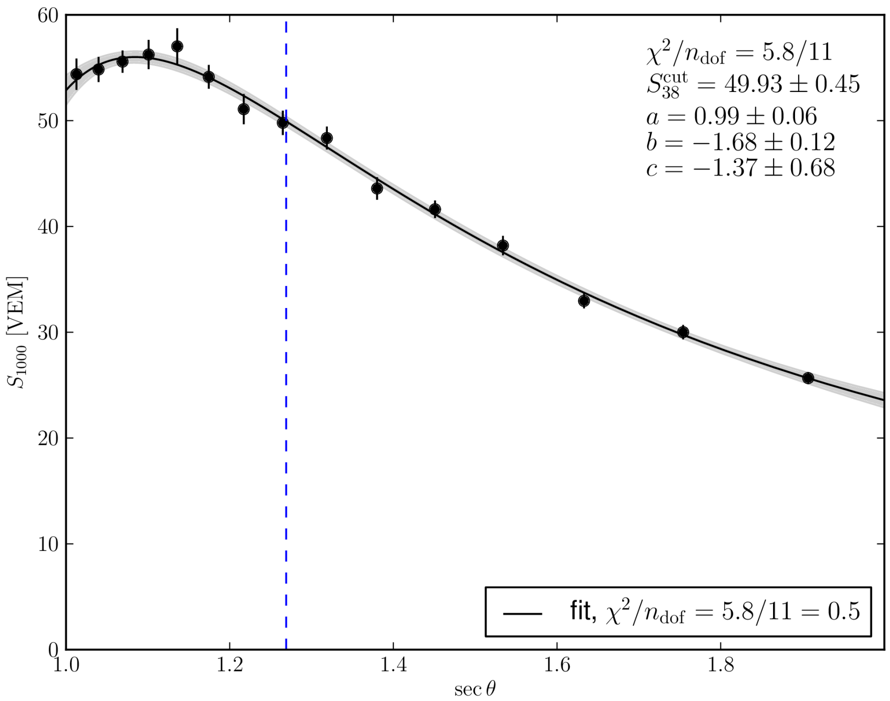
- Better fitting LDF which is not systematically biased for larger bracketing spans.
  - Possibility: Adelaide LDF (Alexander Herve) - GAP-2013-076
- Use of S1500 for events where S1000 is typically poorly bracketed (e.g. low zenith angle, 1+ tanks saturate)

END

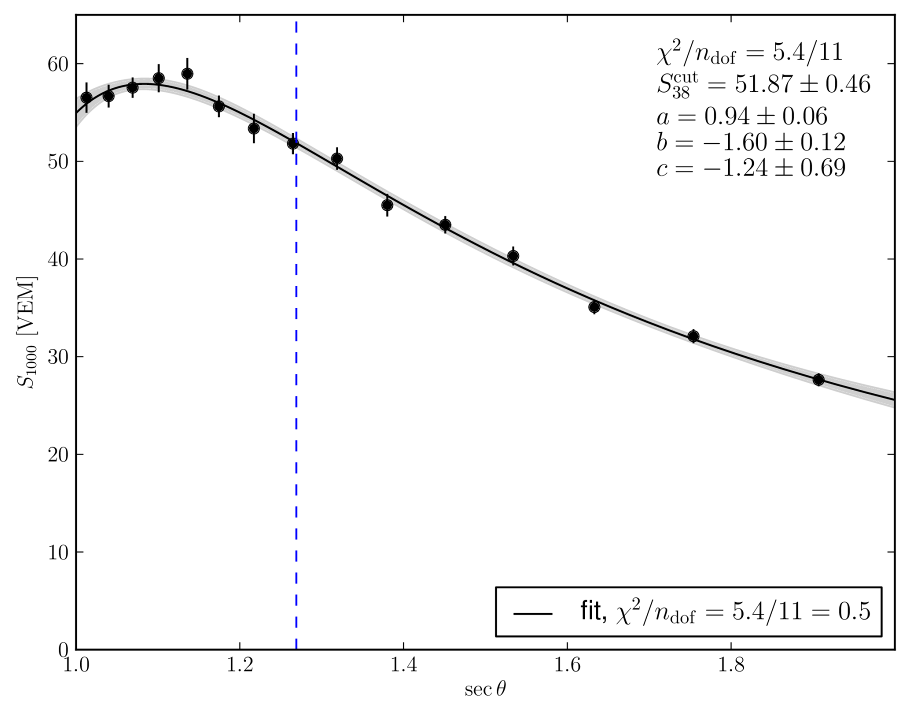
ADDITIONAL SLIDES

CIC(θ) Derivations

NKG

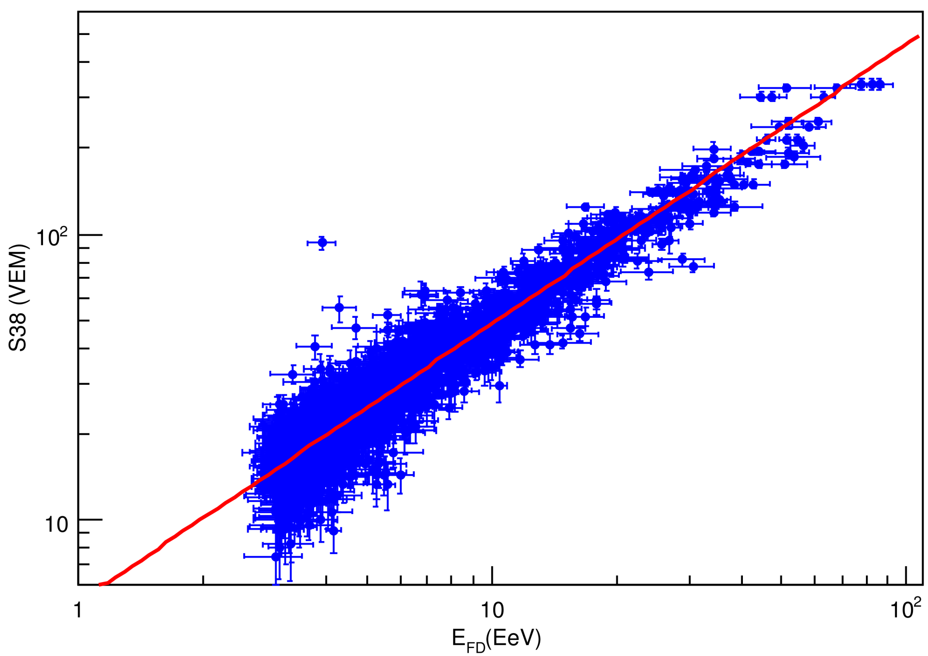


Power Law



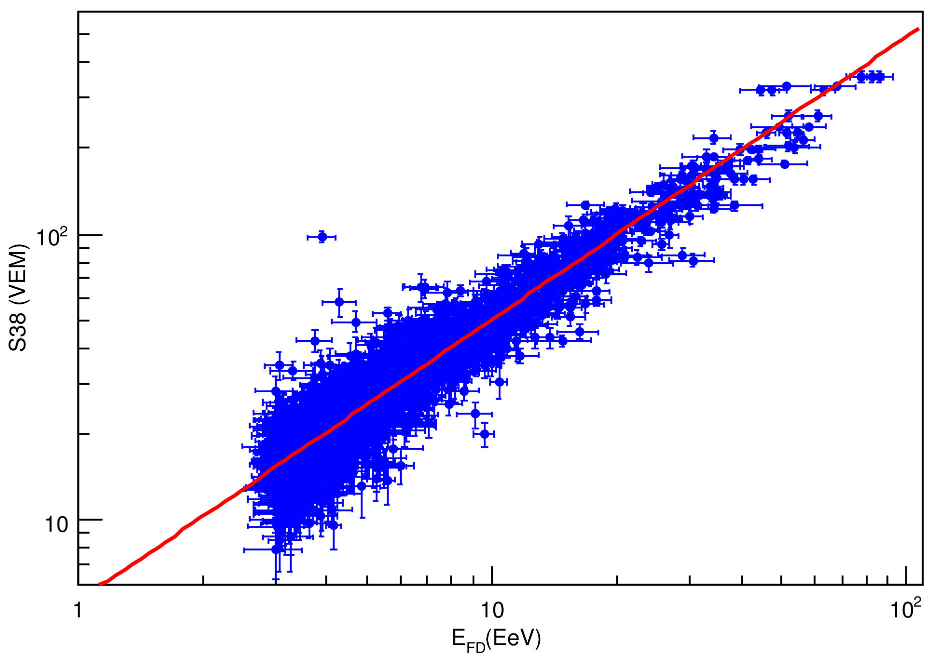
Energy Calibrations

NKG



A = 0.185 +/- 0.003
B = 1.025 +/- 0.004

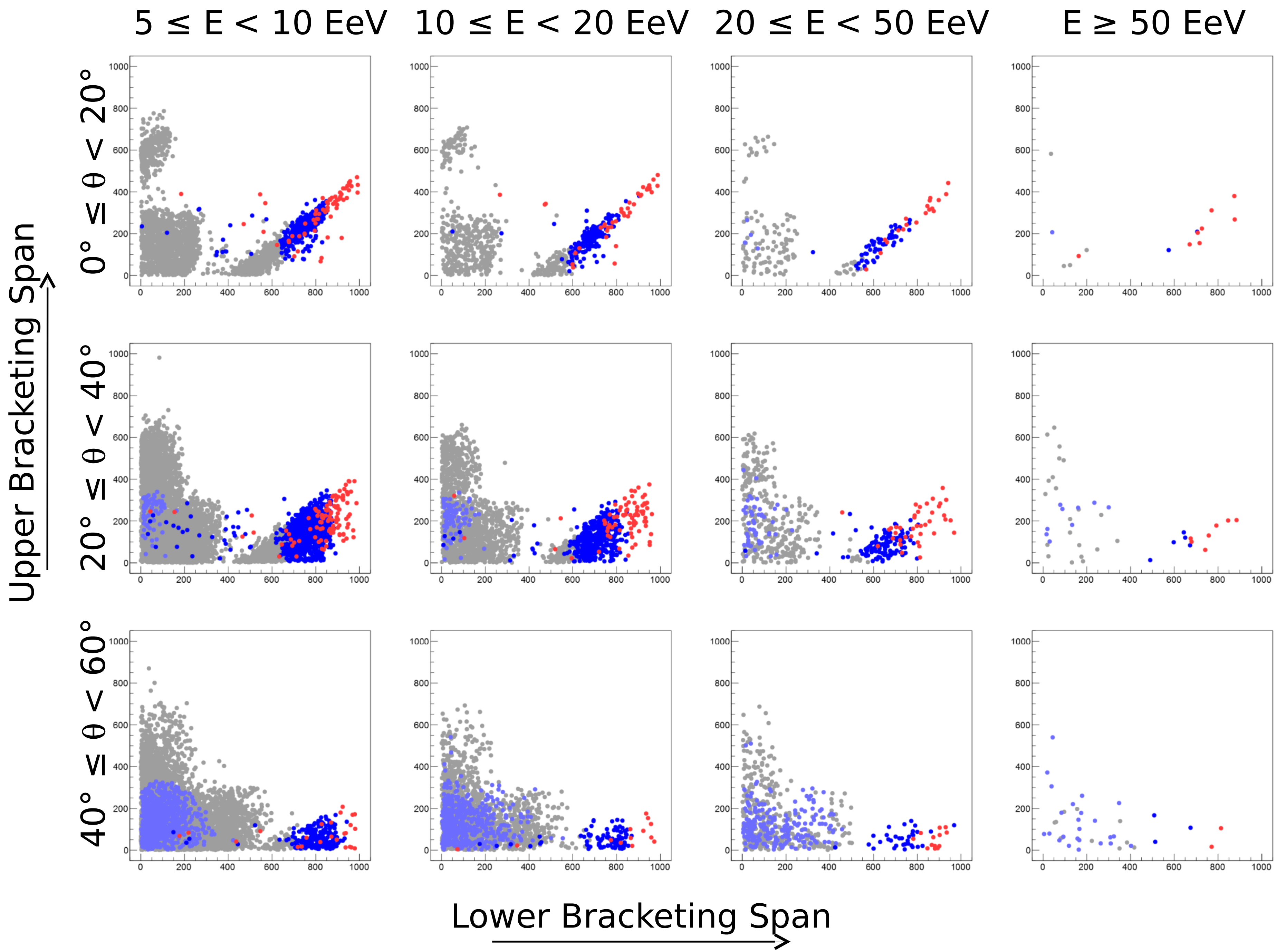
Power Law



A = 0.187 +/- 0.002
B = 1.014 +/- 0.004

ICRC 2013 (NKG)
A = 0.190 +/- 0.005
B = 1.025 +/- 0.007

Note:
- 2 FD cuts failed (minBackgroundRMS & profileChi2Sigma
- Chi squared minimization used vs. max likelihood
- Resolution in progress



5 ≤ E < 10 EeV
10 ≤ E < 20 EeV
20 ≤ E < 50 EeV
E ≥ 50 EeV
0° ≤ θ < 20°
20° ≤ θ < 40°
40° ≤ θ < 60°
Upper Bracketing Span
Lower Bracketing Span