Stau Search in IceCube

Pursuing a novel idea for SUSY particle searches using neutrino telescopes:
A first sensitivity study with the IceCube Neutrino Observatory from

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ICECUBE SOUTH POLE NEUTRINO OBSERVATORY

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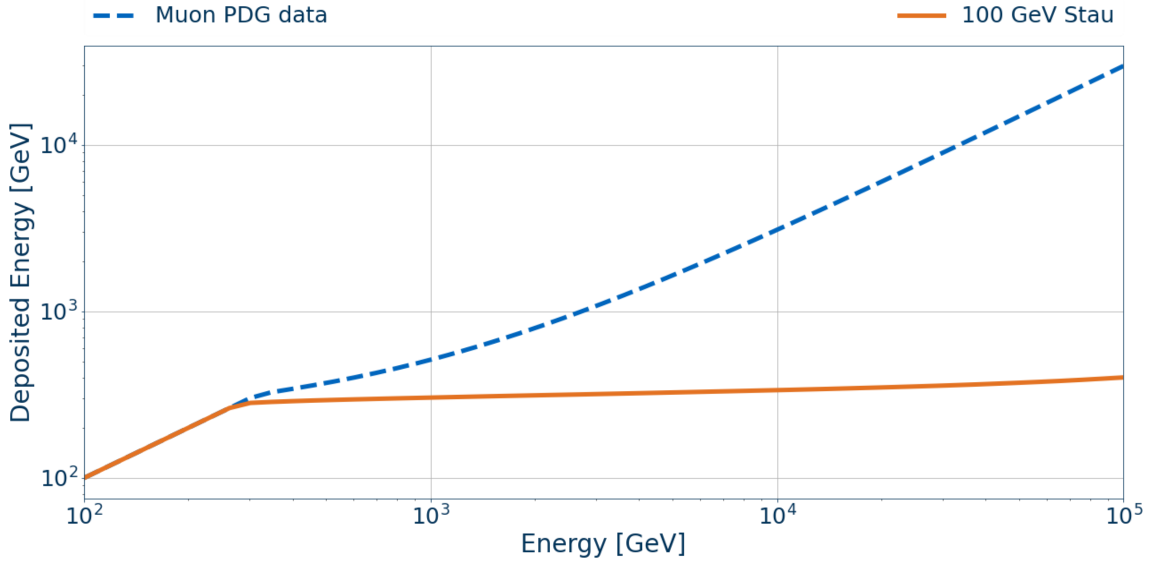
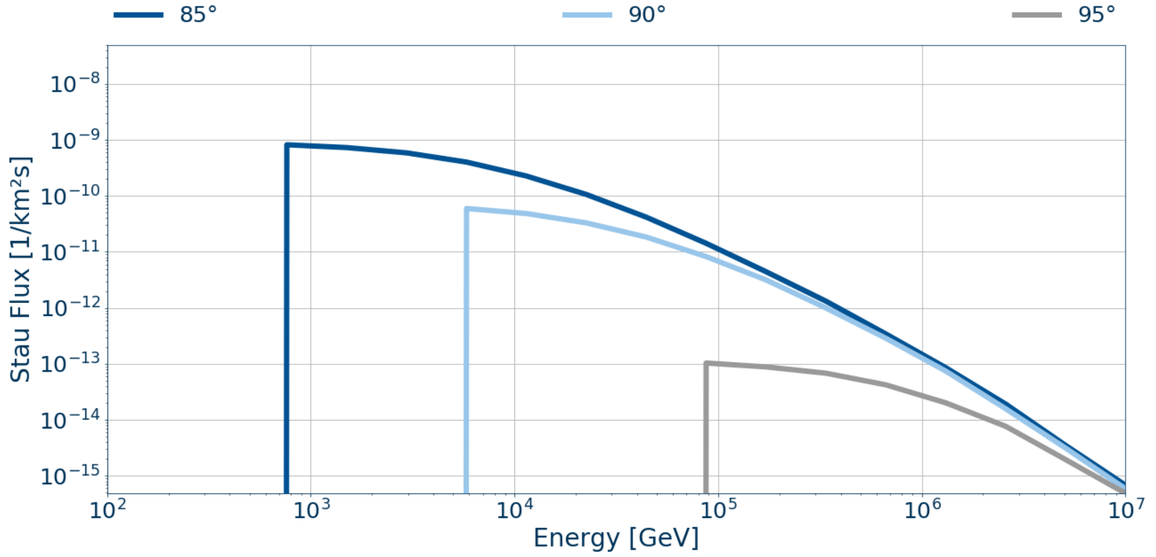
Analysis Fundamentals:

- Stau is supersymmetric partner of tau lepton
- Generation via Drell-Yan processes in cosmic-ray air showers
- Staus are sufficiently long-lived to reach the detector
- Staus appear as minimally ionizing muons, due to the suppression of stochastic losses by their mass [1]
- Search for excess in region with low muon background



Stau Flux at Detector Surface:

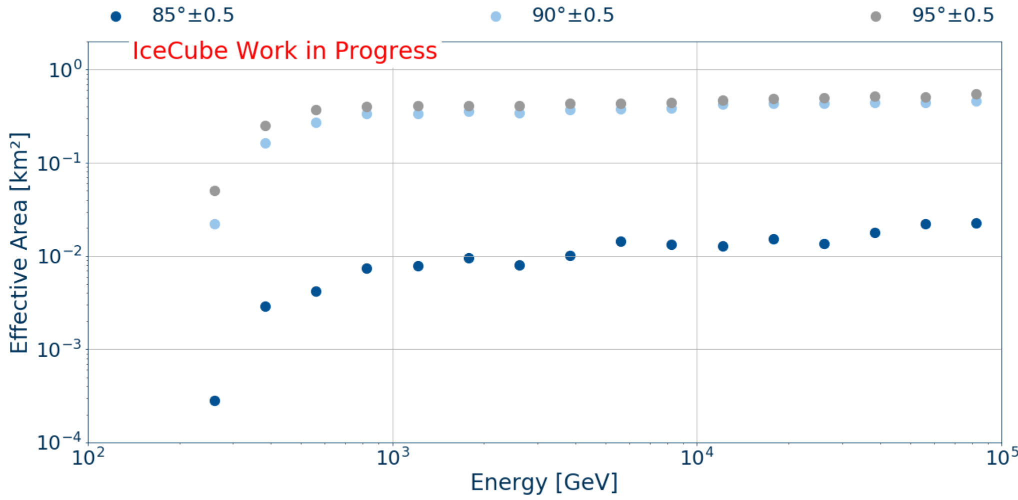
- MadGraph cross sections for stau production [2]
- MCEq air shower simulation [3]
- Propagation through air, ice, rock for different zeniths



-> flux attenuation at higher zeniths due to more material passed
-> Cut-off due to current (software related) restriction to relativistic staus

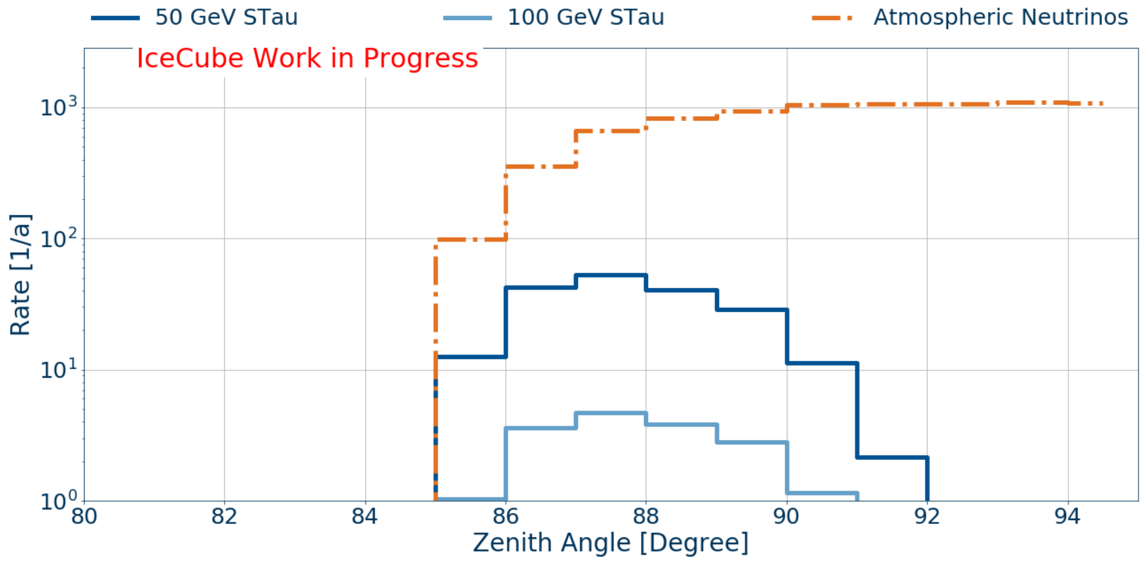
Staus inside IceCube:

- Energy loss during propagation (PROPOSAL) [4]
- Photon propagation (CLSim) [5]
- Event selection for atmospheric neutrinos, zenith > 85° [6]



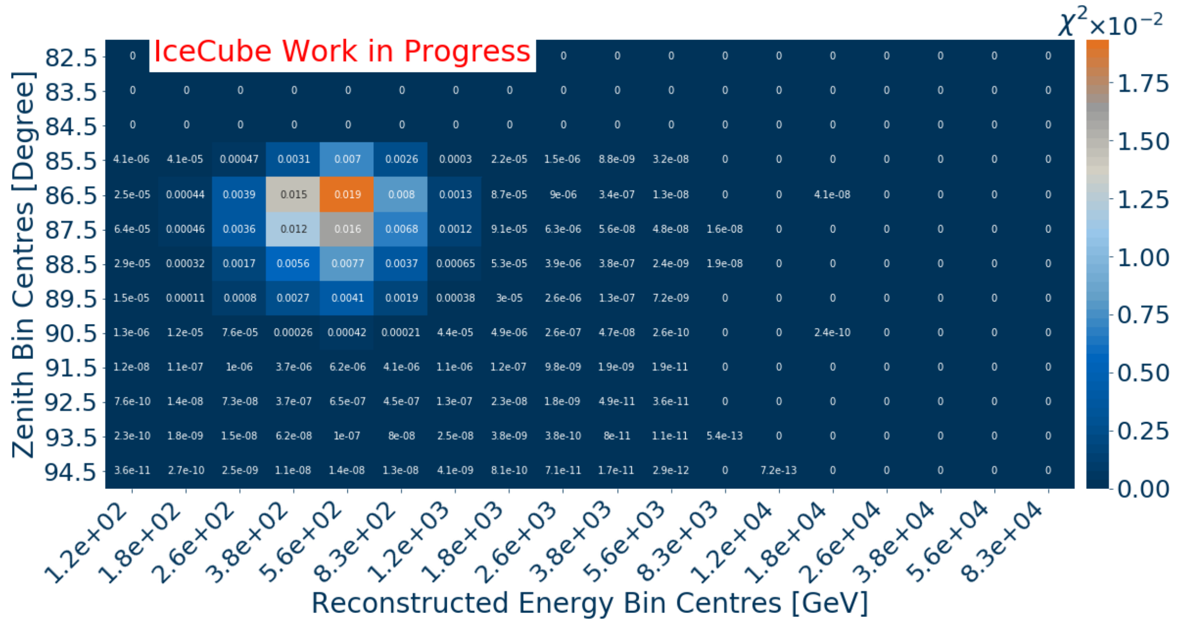
-> Constant energy deposition leads to constant effective area
-> Event selection suppresses bins close to cut-off

- Rates integrated over energy range form 100GeV –1TeV



Findings:

- Chi² calculation (signal rate² /background rate²) for 1 year of data and a stau mass of 100 GeV



Using this event selection and neglecting systematic uncertainties, IceCube would be able to exclude stau masses < 63.2 GeV with 90% confidence level.

Despite an unoptimized event selection, our sensitivity study shows that IceCube is capable of constraining new physics.

Targeted improvements:

- Improved energy estimator for minimally ionizing tracks
- Event selection incorporating the full zenith region of interest (80°- 95°) with background discrimination.

References:

[1] Stephan Meighen-Berger et al. ‘New constraints on supersymmetry using neutrino telescopes’. In: Phys. Lett. B 811 (2020), p. 135929. DOI : 10.1016/j.physletb.2020.135929 .

[2] J. Alwall et al. ‘The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations’. In: Journal of High Energy Physics 2014.7 (July 2014). ISSN : 1029-8479. DOI : 10 . 1007/jhep07(2014)079 .

[3] Anatoli Fedynitch et al. Calculation of conventional and prompt lepton fluxes at very high energy. 2015. arXiv: 1503.00544 [hep-ph] .

[4] J.-H. Koehne et al. ‘PROPOSAL: A tool for propagation of charged leptons’. In: Computer Physics Communications 184.9 (2013), pp. 2070–2090. ISSN : 0010-4655. DOI : https://doi.org/10.1016/j.cpc.2013.04.001

[5] Kopper Claudio. CLSim -Photon Propagation. 2019. URL : https://github.com/claudiok/clsim (visited on 18/06/2020).

[6] Christian Haack. ‘Observation of high-energy neutrinos from the galaxy and beyond’. PhD thesis. RWTH Aachen U., 2020. DOI : 10.18154/RWTH-2020-07059 .

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