IceCube

http://icecube.wisc.edu
http://www.etap.physik.uni-mainz.de/icecube

Recent Improvements in the Detection of Supernovae with the IceCube Observatory

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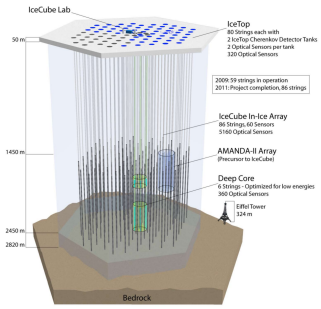
The IceCube neutrino observatory



- World's largest ν-detector monitoring $1\,\mathrm{km}^3$ of Antarctic Ice
- 86 strings with 60 DOMs each
- Primary goal: Extraterrestrial neutrino point sources
- Supernova searches: Detect $\bar{\nu}_e$s with $\mathcal{O}(10\,\mathrm{MeV})$ energies by collective increase in dark rate
- Most precise detector for analyzing core collapse SN in our Galaxy

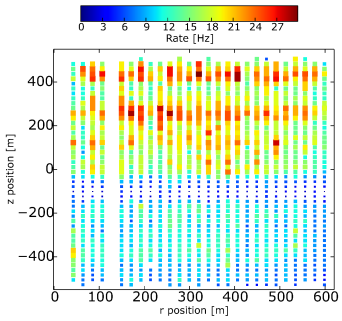
Atmospheric muon hit subtraction

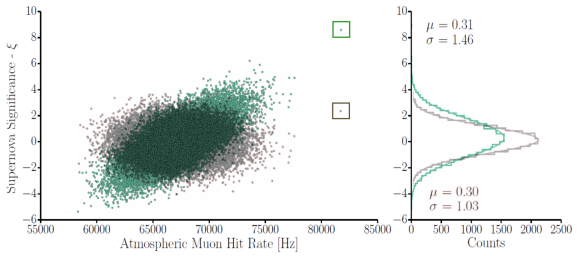
- μ_{atm} with $E_\mu \approx 400\,\mathrm{GeV}$ reach detector and trigger if $E \approx 550\,\mathrm{GeV}$ $\rightarrow$ induced hits main background
- Correction method fits correlation between R_μ^{hit} & ξ linearly (offset a, slope b)

$$\rightarrow \xi' = \xi - b \cdot R_\mu^{\mathrm{hit}} - a$$

- Sample alert below:

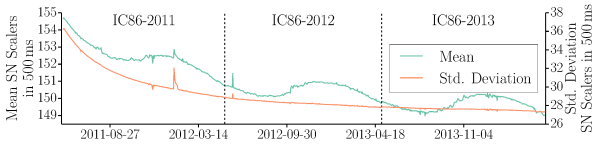
$$\xi = 8.59 \rightarrow \xi' = 2.44$$





Long term behavior of DOM dark rates

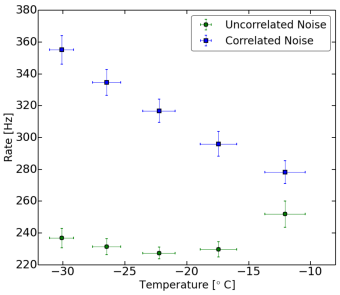
- Surprising observation: Average dark noise rate decrease by 3.5%
- 2% increased sensitivity to atm. µs $\rightarrow$ 50% more false positive alerts



- Triboluminescence (due to hole-ice freezing) suspected to emit the light

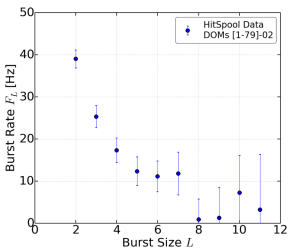
Non-Poissonian noise characteristics from HS data

- HitSpooling (HS): Buffers all PMT hits after external request
- Complete detector information available for SN candidates

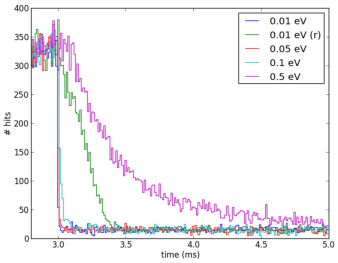


Non-Poissonian correlated and Poissonian uncorrelated components of dark noise rate

- HS data to investigate correlated dark noise at low temperatures
- Burst structure confirmed:
  (as mentioned by H.O. Meyer, *EPL* **89** (2010) 58001.)

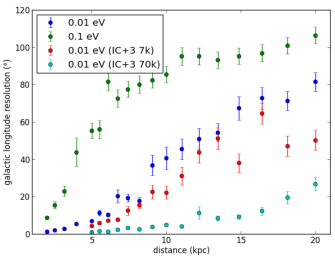


Estimation of supernova direction



- No individual SN-ν interactions detectable due to $\mathcal{O}(10\,\mathrm{MeV})$ energies
- e^+-direction uncorrelated to ν-direction in inverse beta decay
- $\rightarrow$ determine direction from temporal hit pattern when neutrino wavefront abruptly change its intensity

  $\rightarrow$ Black Hole forming SN model



- Unbinned likelihood analysis using an optimised minimizer
- Reasonable directional resolution achievable only for close-by supernovae and low neutrino masses
- Potential improvement by deploying additional distant strings

Future developments

- Assessment of sensitivity to the absolute neutrino mass
- Improvement of the energy determination
- Investigation of shorter bursts
- Extension of hitspooling to other use cases, e.g. the estimation of hadronic energy in highly energetic events from the delayed neutron capture signal