New Flux Limits in the Low Relativistic Regime for Magnetic Monopoles at IceCube

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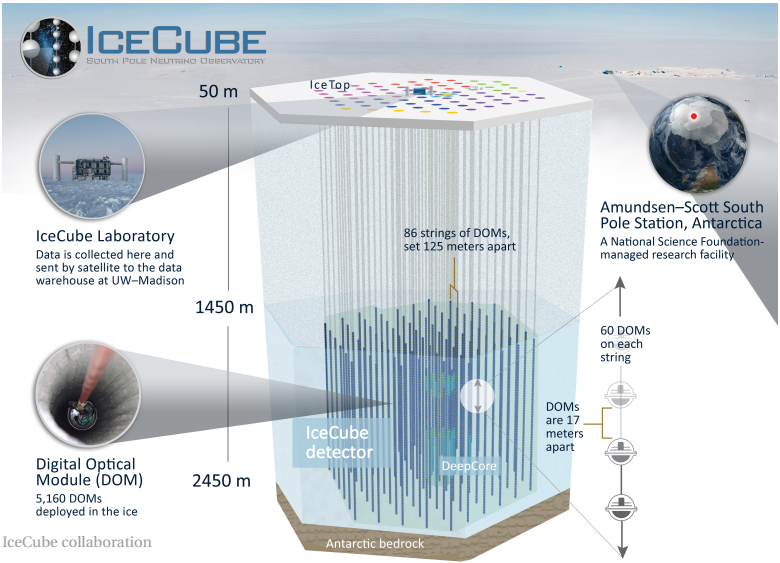
IceCube

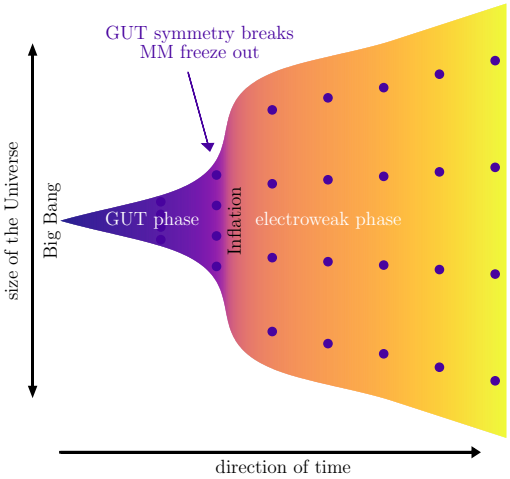

IceCube
South Pole Neutrino Observatory
50 m
IceTop
IceCube Laboratory
Data is collected here and sent by satellite to the data warehouse at UW–Madison
1450 m
86 strings of DOMs, set 125 meters apart
Amundsen–Scott South Pole Station, Antarctica
A National Science Foundation-managed research facility
60 DOMs on each string
DOMs are 17 meters apart
IceCube detector
DeepCore
Digital Optical Module (DOM)
5,160 DOMs deployed in the ice
2450 m
Antarctic bedrock
IceCube collaboration

Relic Monopoles

- hypothesized particles
- at least one magnetic charge
- wide mass range

  $10^{10}\,\mathrm{GeV\,c^{-2}} \leq M_{\mathrm{GUT}} \leq 10^{17}\,\mathrm{GeV\,c^{-2}}$
- charge

$$g = k\frac{e}{2\alpha} \approx 68 \cdot e$$

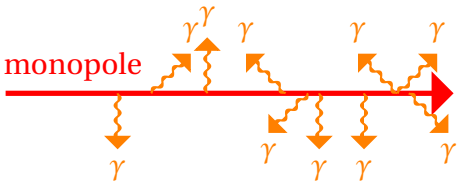


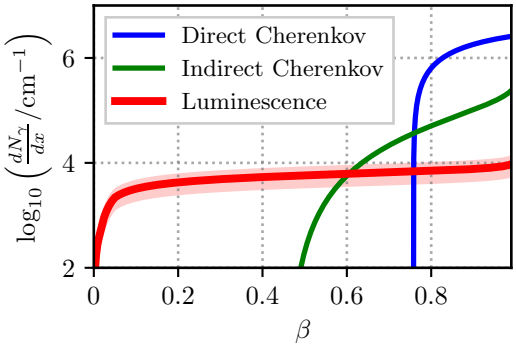
Luminescence Light

- excitation of medium
- delayed light emission
- isotropic
- wide range of light yield

  $\frac{1\gamma}{\text{MeV}}$ expected at IceCube

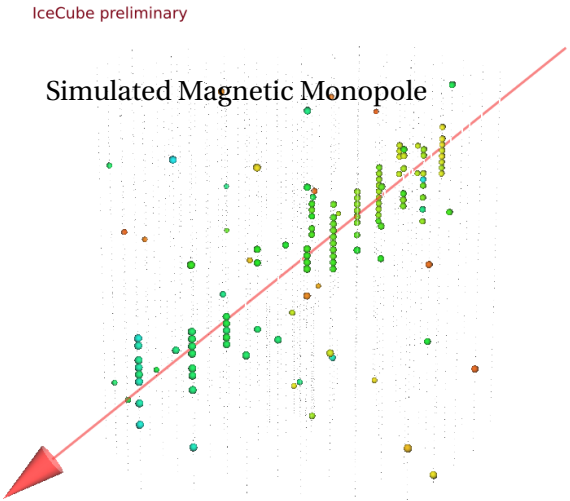
  (see PoS(ICRC2021)1093)
- light yield $\propto dE/dx \propto \frac{q_{\text{MM}}}{q_{\mu}} \propto 68^2$





Analysis target

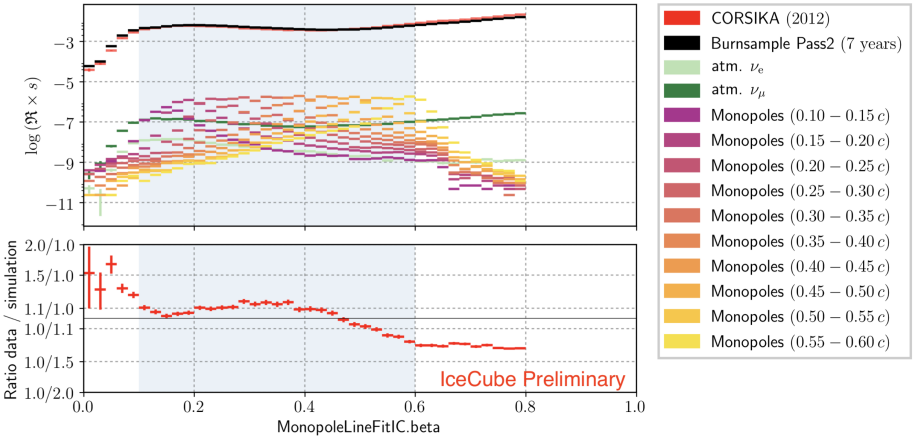
- search for magnetic monopoles
- low relativistic $0.1\ c \leq v \leq 0.55\ c$
- only produce luminescence light
- only downgoing events, Earth opaque for higher charges
- track like
- designed based on simulation
- cut & count analysis



Analysis overview: Part1

Begin with straight cuts:

- smoothness of hits on track
- number of hit DOMs
- multiple velocity reconstructions
- length of track in fiducial volume

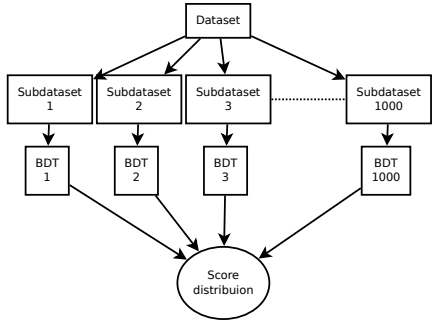


Analysis overview: Part 2

last step, machine learning based approach based on BDTs

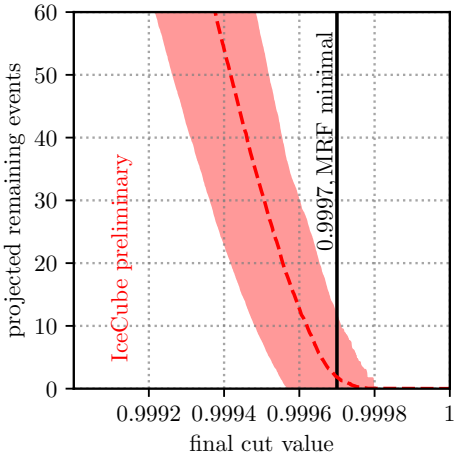
challenge: low statistic in simulation

- chose bootstrapping approach based on set of BDTs
- to select events: cut on mean of predictions
- to project distributions past the cut: interpret predictions as probability density



Final Cut, projected number of remaining events

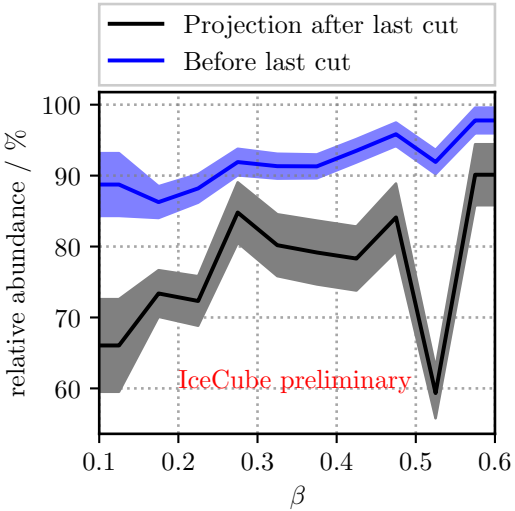
- project number of remaining background and signal events
- calculate and minimize model rejection factor
- minimal at BDT score of 0.9997
- projected remaining background:
  at most 10, on average 2 events



Systematic effects

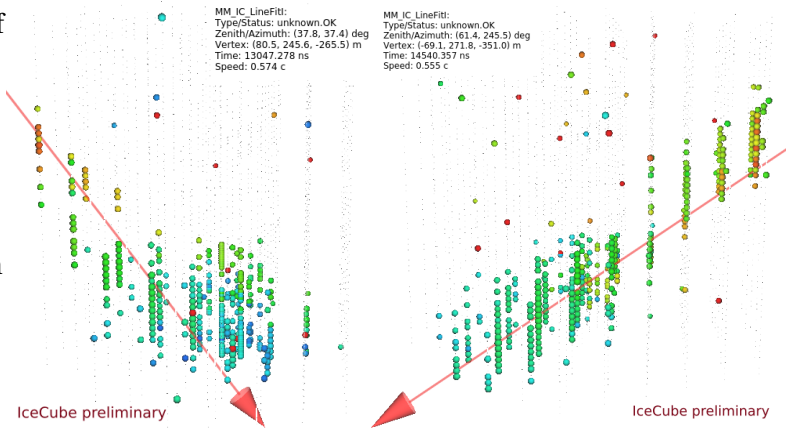
Systematic variation simulation

- DOM Efficiency
- bulk ice scattering
- bulk ice absorption
- luminescence light yield
- hole ice effects



Results

- applied to 2524.6 days of data
- 2 events remain
- consistent with global background estimate
- KDE based investigation indicates same origin but not monopoles
- most likely coincident muons



Summary

- first luminescence analysis at IceCube
- no magnetic monopoles detected
- approx. 2 orders of magnitude better than previous best limits down to $9.6 \cdot 10^{-19}$ /cm^{-2}/s/sr^{2}