Searches for Exotic particles with the IceCube detector

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Introduction

- Dirac introduced the magnetic monopole in order to explain the quantization of the electric charge
  - ❖ Elementary magnetic charge *g* and electric charge *e* are related by:

    $g_D = 68.5e$

- GUT: Masses of magnetic monopoles ~ masses of X,Y GUT boson:

  $m_M \sim 10^{16}$ GeV → cannot be accelerated to relativistic velocities

- MMs are produced during phase transitions in the early universe

- Intermediate-Mass Monopoles (IMM) with $m_M = 10^5$-10^{15} GeV may have been produced in later GU phase transitions

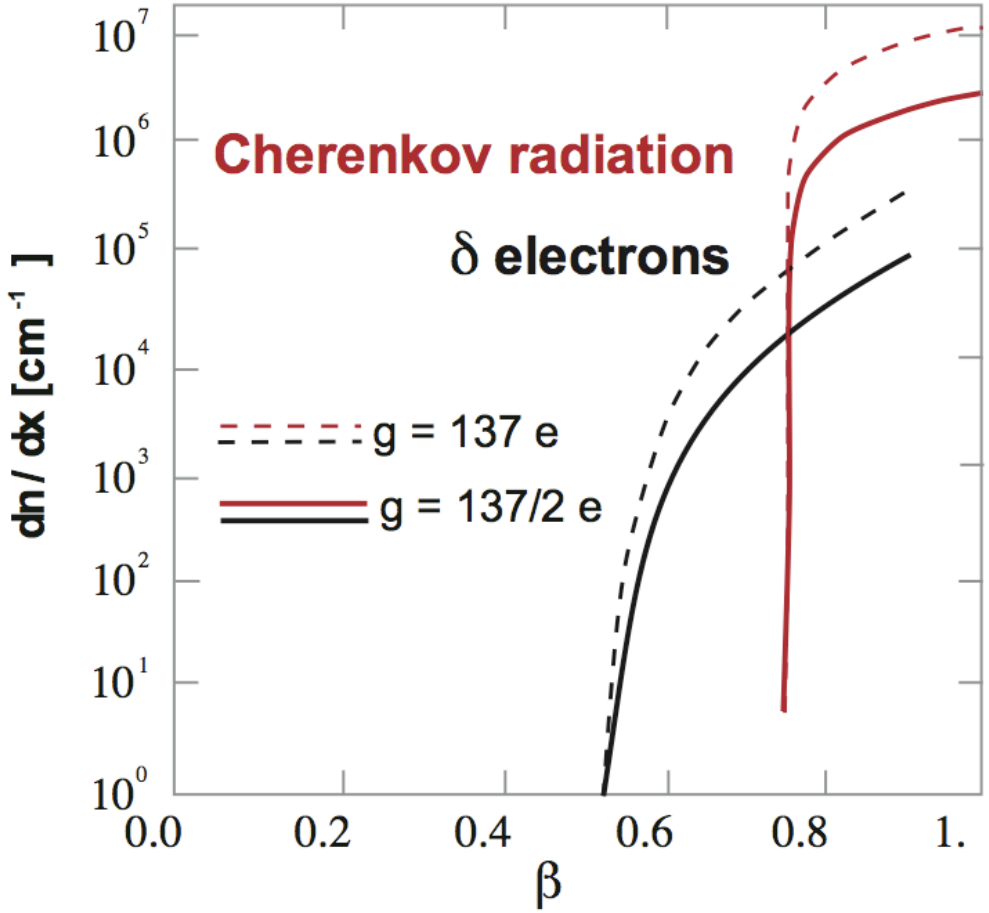
→ IMM can be accelerated to relativistic velocities by the galactic magnetic field

Search methods: Relativistic Monopoles

In Neutrino Telescopes (water or ice) IMM with β>0.75 produce Cherenkov light

$$\frac{d^2N}{d\lambda dx} = \frac{2\pi\alpha}{\lambda^2}\left(\frac{gn}{e}\right)^2\left(1-\frac{1}{\beta^2 n^2}\right)$$

Monopoles with β>0.52 can produce
δ -electrons which can emit Cherenkov light



Cherenkov emission ~8400 times more than a bare muon

Searches for relativistic monopoles with IC22

B. Christy & J. Posselt

Data set

- Signal:
  Monopoles with
  - β = 0.76,0.8,0.9 & 0.995
  - isotropic flux
- Background:
  - Corsika
  - Neutrino: NuE and NuMu
  - Burn sample

Data processing

- Used variables are based on Saturated Hits in the fADC

→ Bright events, hits close to the track

- Level0: Online filter, selects events with N_OMs>80

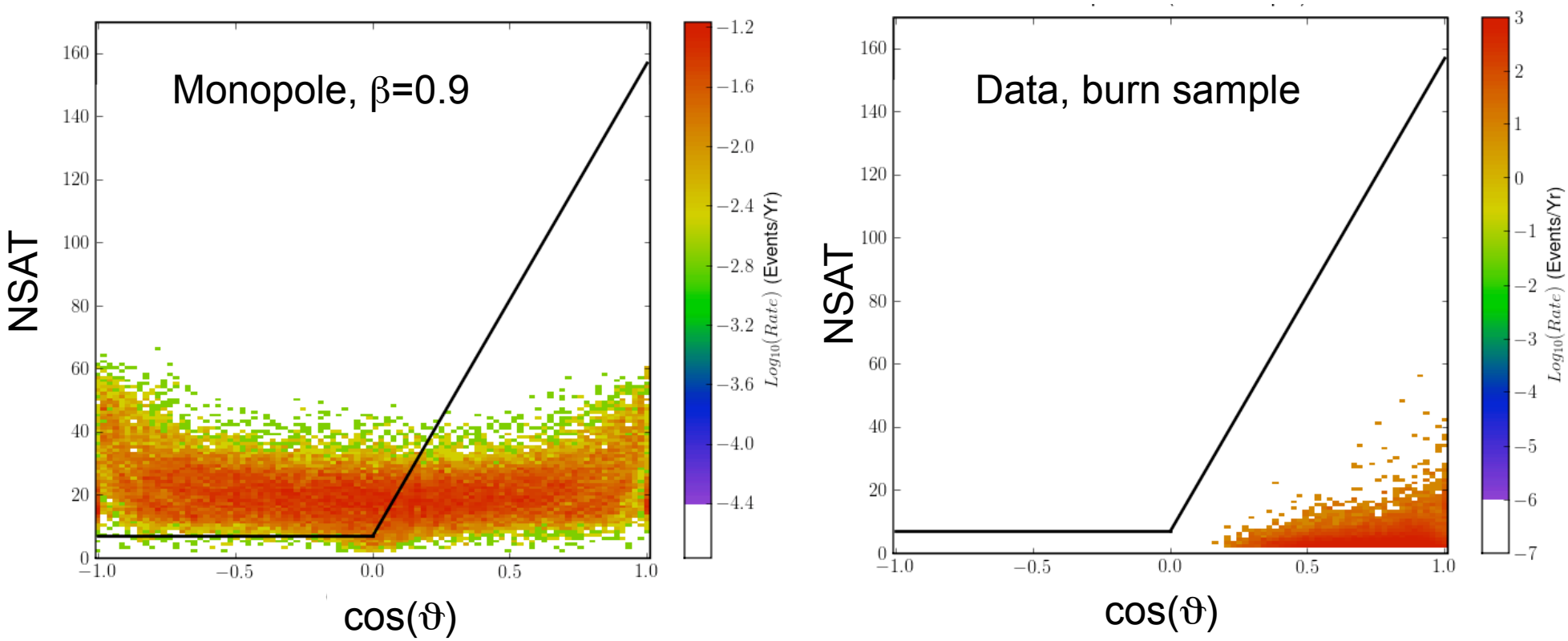
- Level1: data reduction filter, keep events with N_Saturated_Hits >1

- Level2: Hit cleaning based on times of Saturated Hits

- Level3: remove poorly reconstructed events

Optimazation and final cut

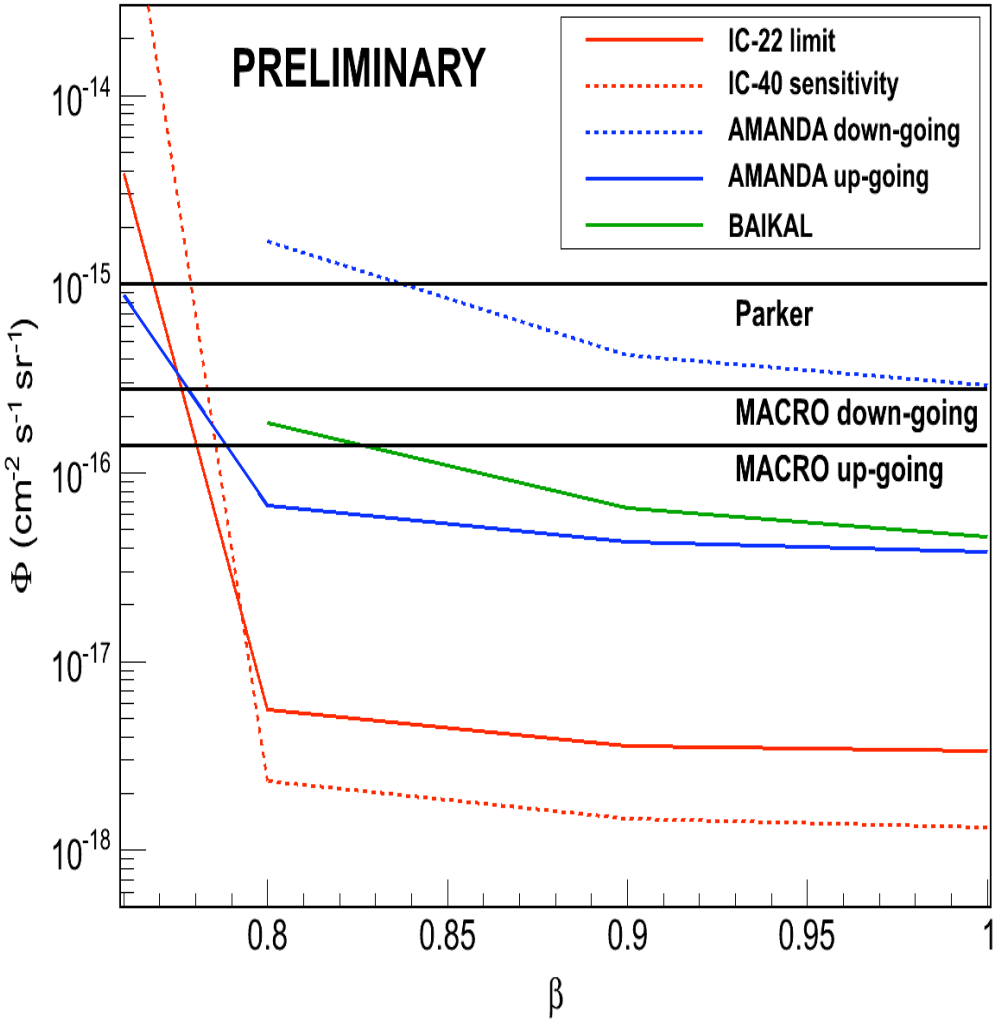
- The final cut is, linear cut on the number of bright (saturated) hits, NSAT, and the zenith angle, reconstructed from LineFit



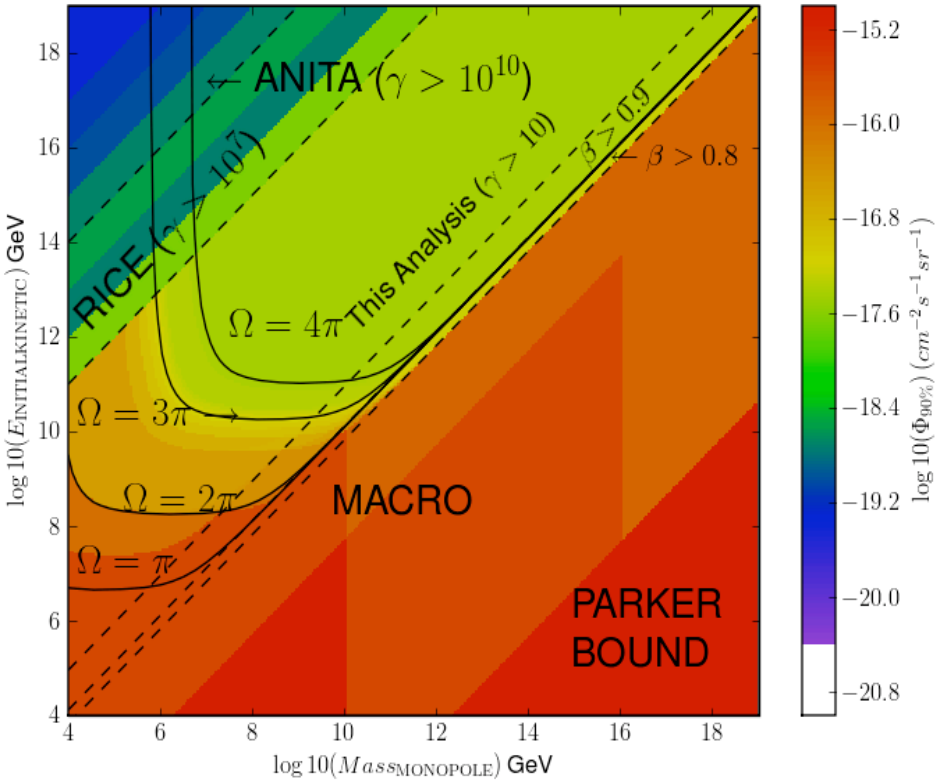
Cuts:

- In the upgoing region, the cut is flat in NSAT
- In the downgoin region, NSAT cut increases linearly with cos(ϑ)
- Final cut is set using the *Model Rejection Factor*

Sensitivities



Sensitivities at earth surface over mass/energy parameters for IC22



Best flux limit are obtained for $\beta \leq 0.995$ ($\gamma \leq 10$):

$\Phi < 1 \times 10^{-18} cm^{-2} s^{-1} sr^{-1}$ (IC40)

Slowly moving particles(SLOPs)

SLOPs: GUT Monopoles, Q-Balls and Nuclearites

- **GUT Monopoles**
  - Predicted by GUT theories
  - $M_M \geq m_x/\alpha_{GUT} \sim 10^{16}$-$10^{17}$ GeV
- **Q-balls**
  - Heaviest Dark Matter Candidates of SUSY theories
  - Aggregates of squarks, sleptons and Higgs field.
  - 10^5 GeV < M_Q < 10^{22} GeV
- **Nuclearites (Strange Quark Matter)**
  - Almost equal proportion of u, d and s quarks
  - Should be stable for baryon number $300 < A < 10^{57}$

Phase space parameters

The catalysis cross section is given by:

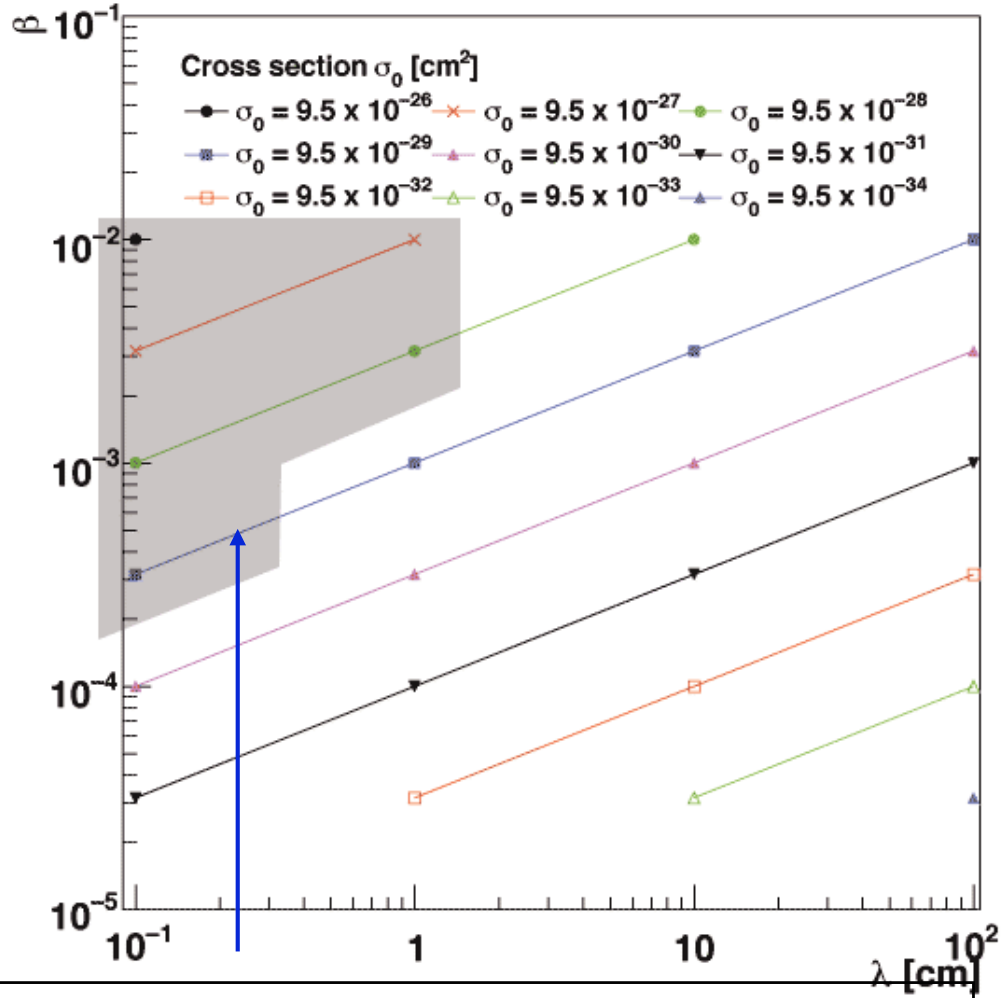
$$\sigma_0 = \frac{\beta^2}{0.0175 \cdot N_A \cdot \lambda}$$

λ is the distance between two catalysis

Depending on β:

- Monopoles with high σ_0 ($\sigma_0 > 10^{-28}$) tend to fire triggers continuously

- Monopoles with low σ_0 ($\sigma_0 < 10^{-28}$) split up in several subsequent events

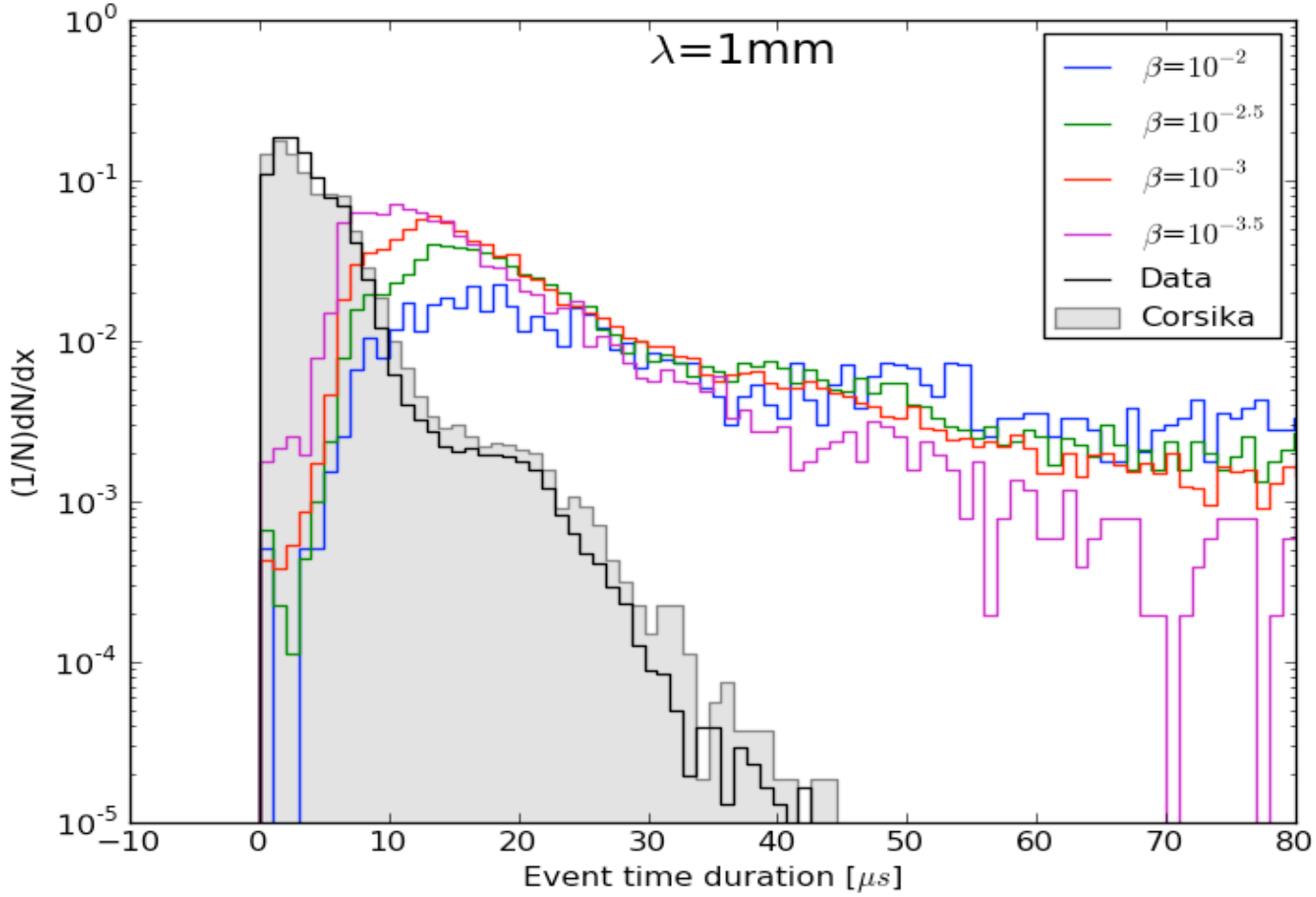


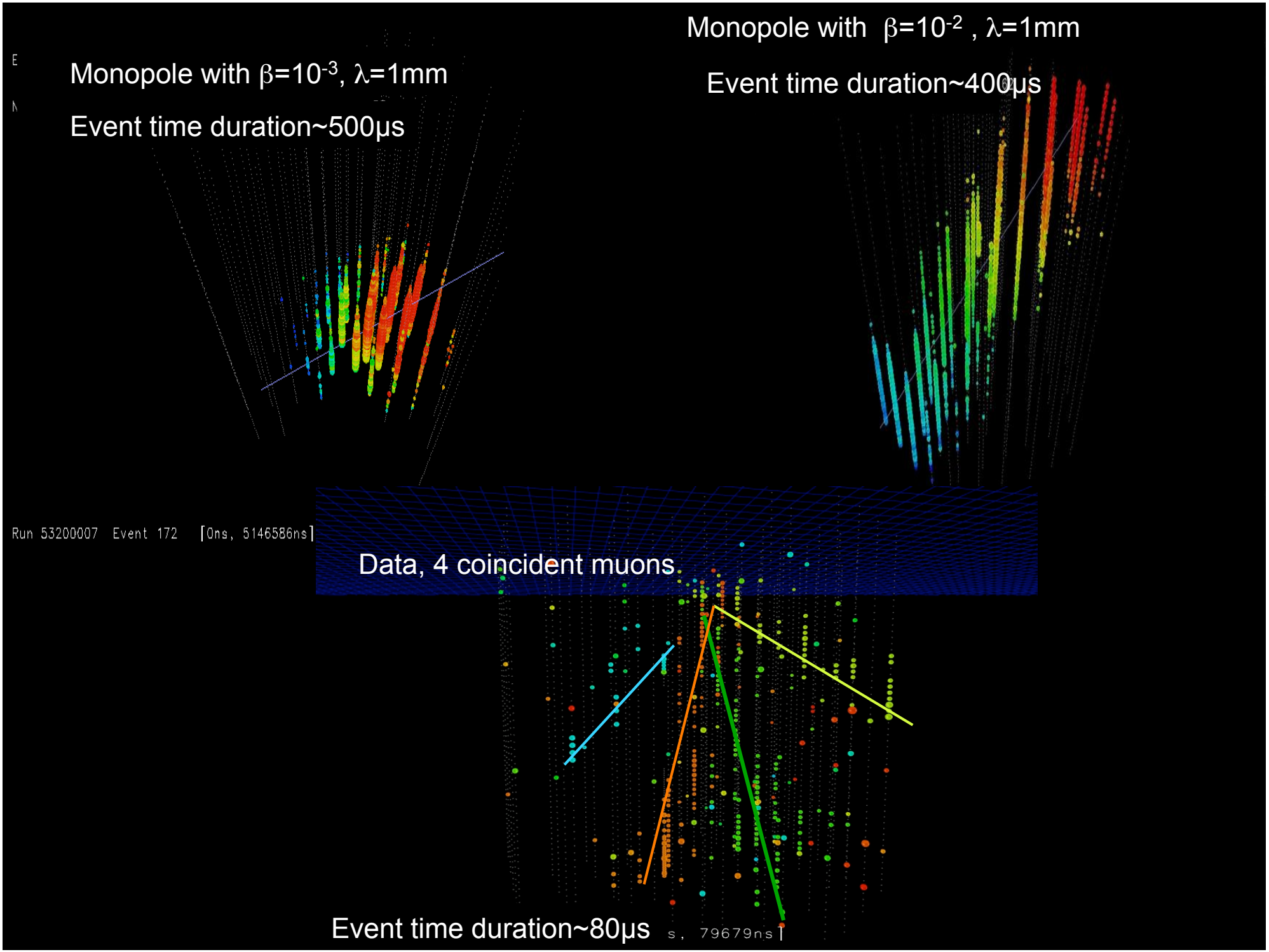
IC59 analysis focuses on :
(β, λ) = 10^{-2}(1mm,1cm),$10^{-2.5}$(1mm,1cm),10^{-3}(1mm), $10^{-3.5}$(1mm)

Variables used for this analysis

- During the 2009 season no dedicated filter was deployed for SLOPs,
  → use events originating from all available filters

- Look for events with long event time duration



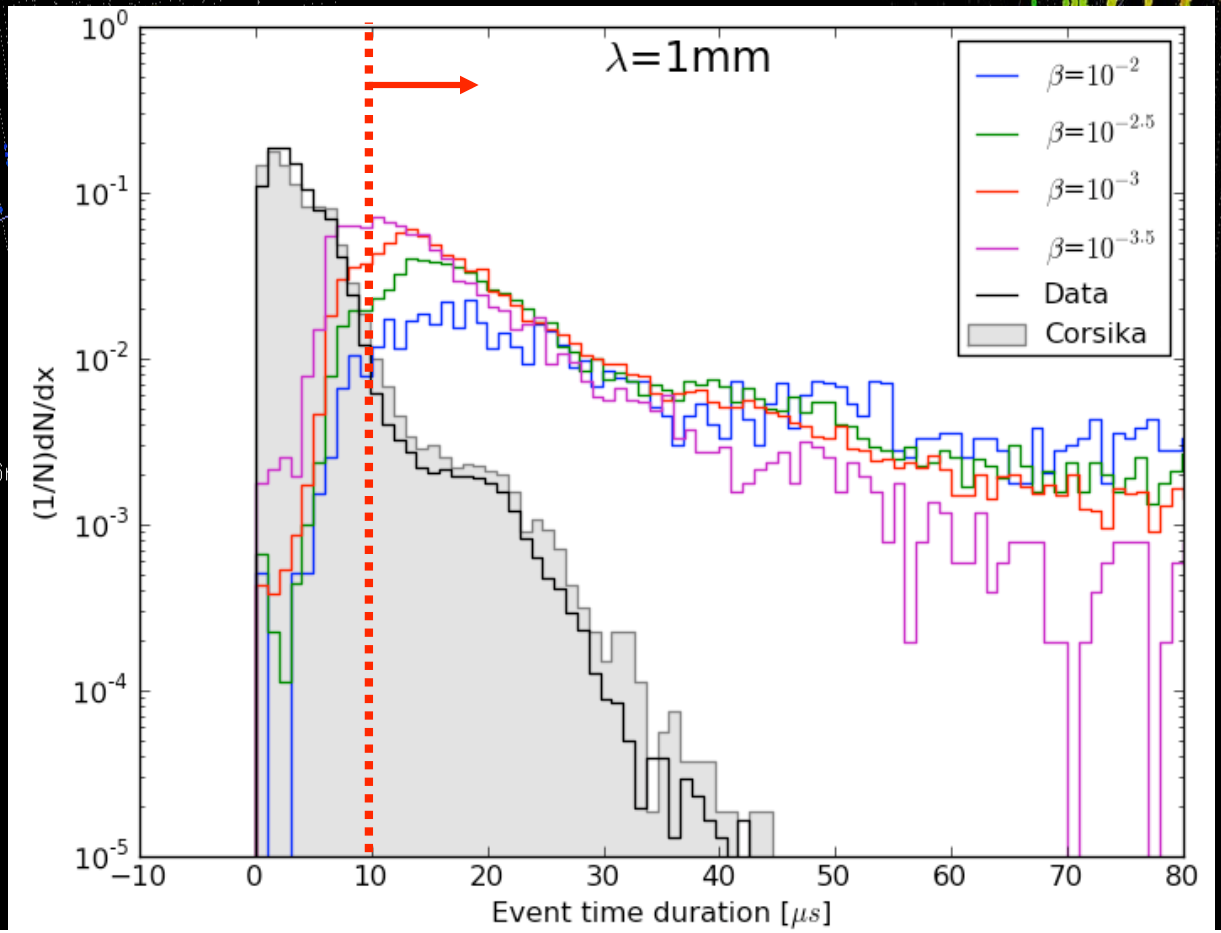

Monopole with $\beta=10^{-3}$, λ=1mm
Event time duration~500μs
Monopole with $\beta=10^{-2}$, λ=1mm
Event time duration~400μs
Run 53200007 Event 172 [0ns, 5146586ns]
Data, 4 coincident muons
Event time duration~80μs
s, 79679ns]

Monopole with $\beta=10^{-3}$, λ=1mm

Event time duration~500μs

Monopole with $\beta=10^{-2}$, λ=1mm

Event time duration~400μs

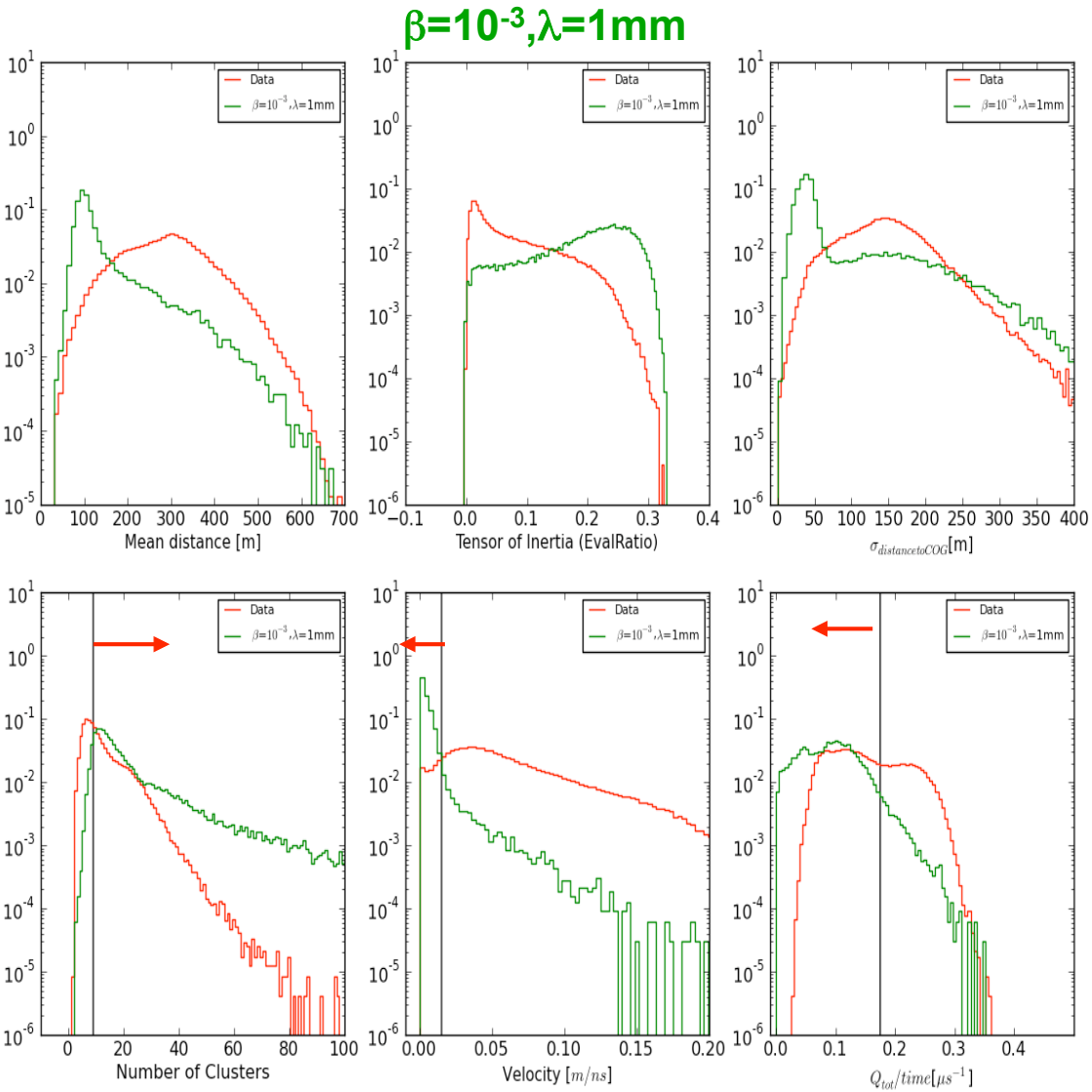


A cut at 10μs is applied to the data (λ=1mm) before starting a MultiVariate Analysis

Event time duration~80μs

Variables used for MVA

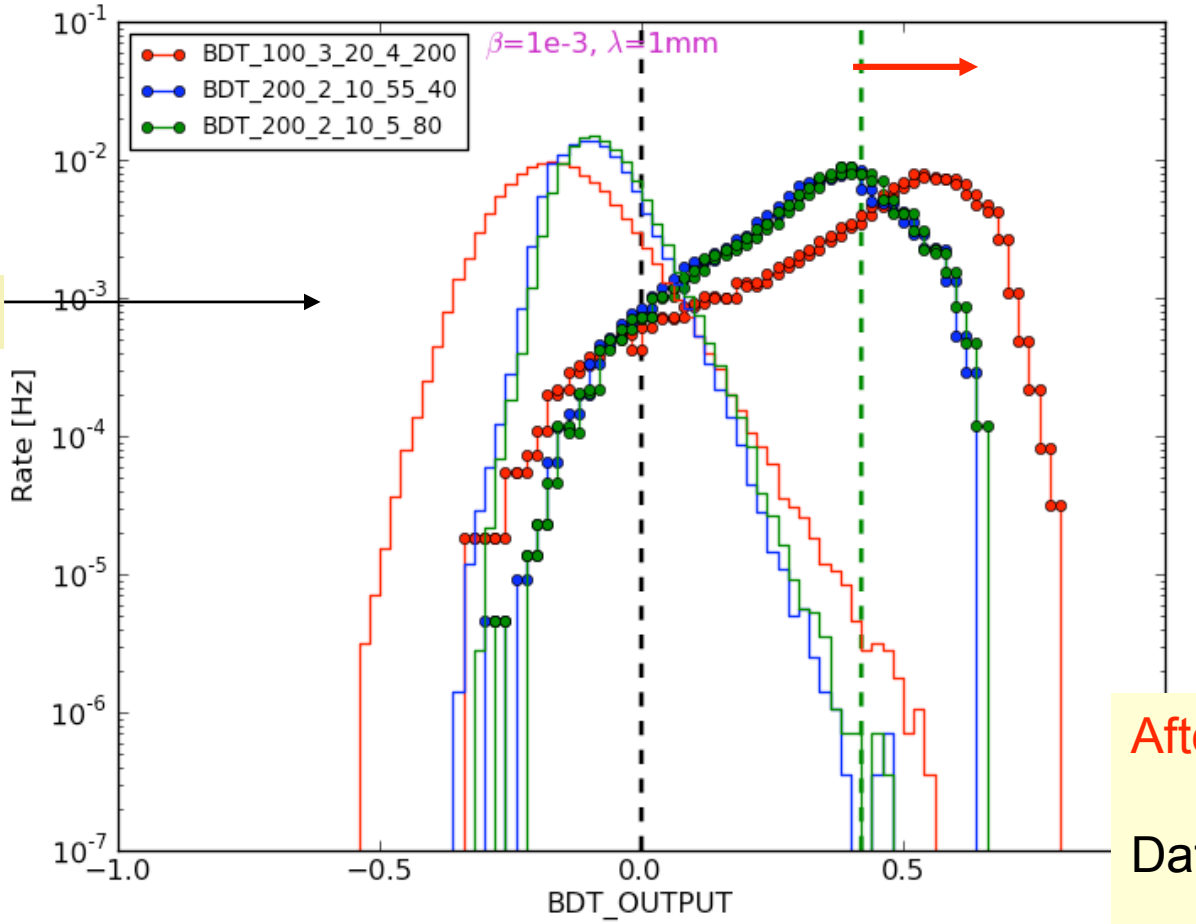
- Mean distance of Hit-position from COG
- σ(distance of Hits to COG)
- LineFit velocity
- Nclusters: is the number of hits within a causal distance of 225m
- Combine event time duratrion and NPE or mean distance from COG



Applying BDT scores to the Burn sample

- The burn sample has 31.7 days, about 10% of the whole year
- At Level4 the data rate is ~ 0.1 Hz

Background-like



Signal-like

After BDT cut>0.42:

Data:10^{-6} Hz

Signal:44%

Searches for SLOPs with IC79

E. Jacobi

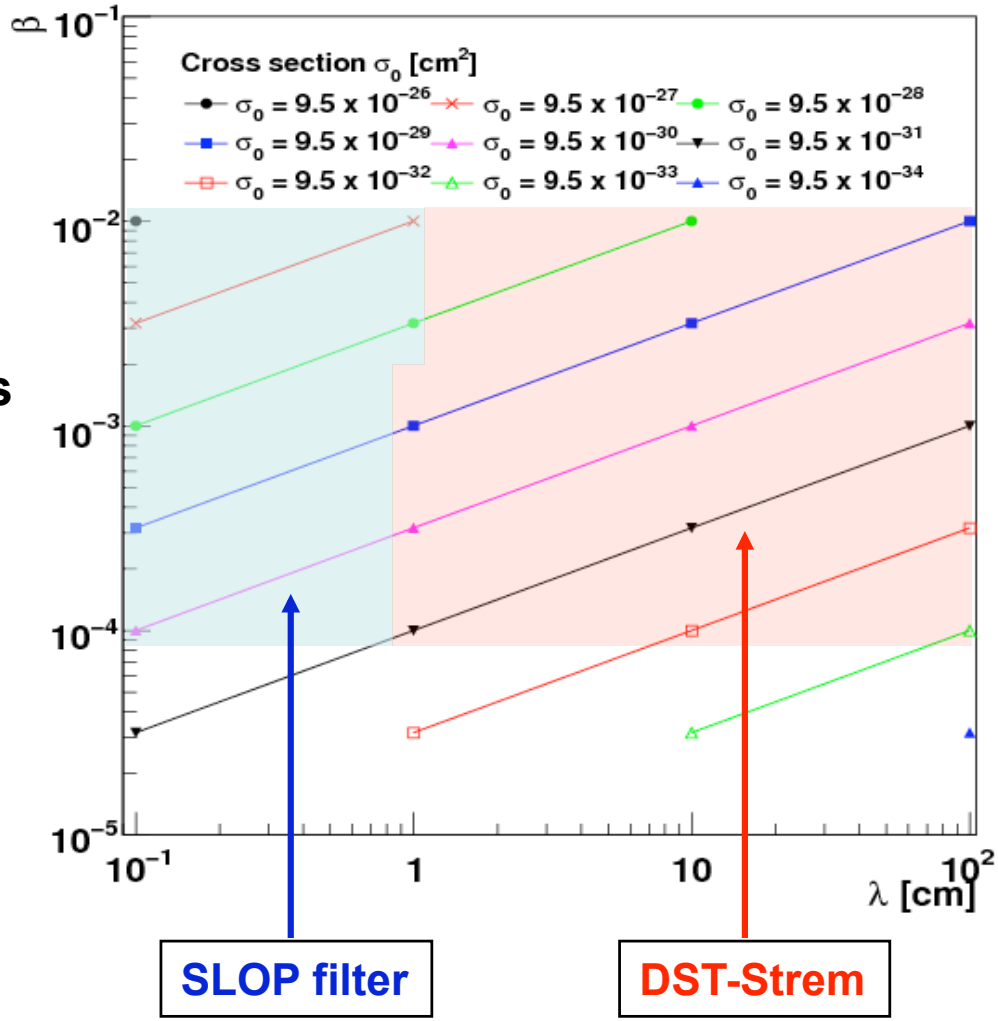
- During 2010/2011 season two filters instaled at South Pole

  – SLOP filter:

  - selects events with duration > **33μs**
  - covers $\sigma_0 > 10^{-28} cm^2$

  – DST stream:

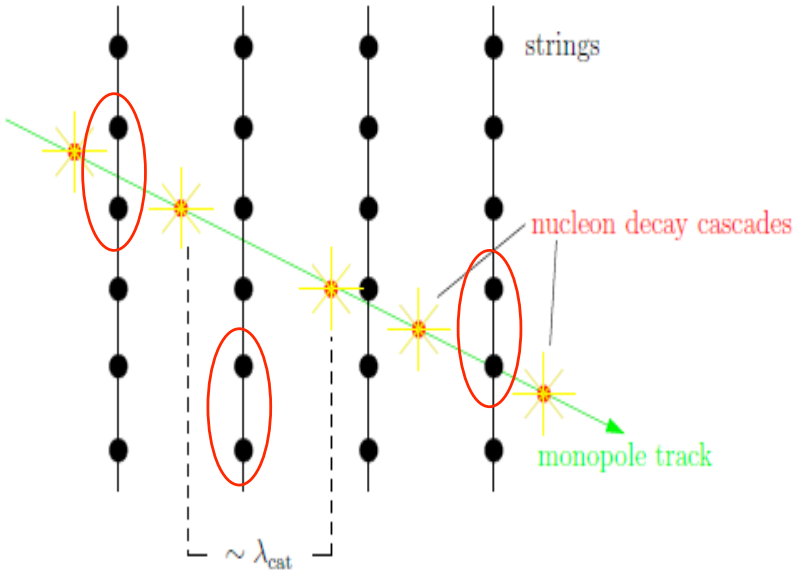
  - takes every triggered events
  - sensitive to $\sigma_0 < 10^{-28} cm^2$

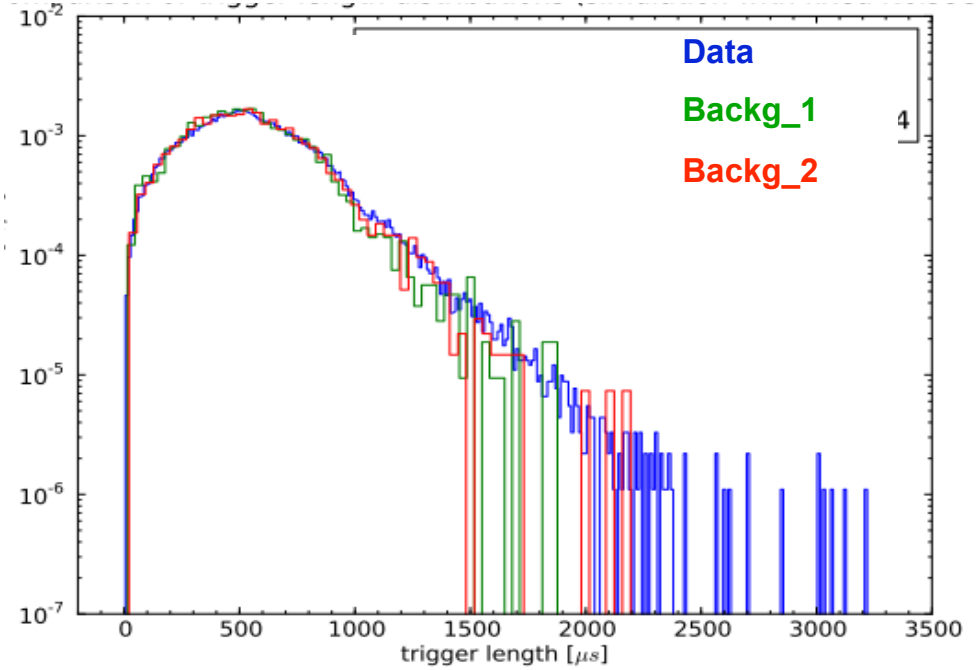


Trigger for SLOPs

T. Glüsenkamp, E.Jcobi & C.Wiebusch

- Implemented already at Pole
- Uses HLC pairs as input
  - Clean early HLC (from μ's)
  - Find correlation in space and time between HLCs pairs in an open time window [0, 0.5ms]
- It is running for DeepCore with 1Hz rate
- A trigger proposal for full IceCube will be submited to the TFT board





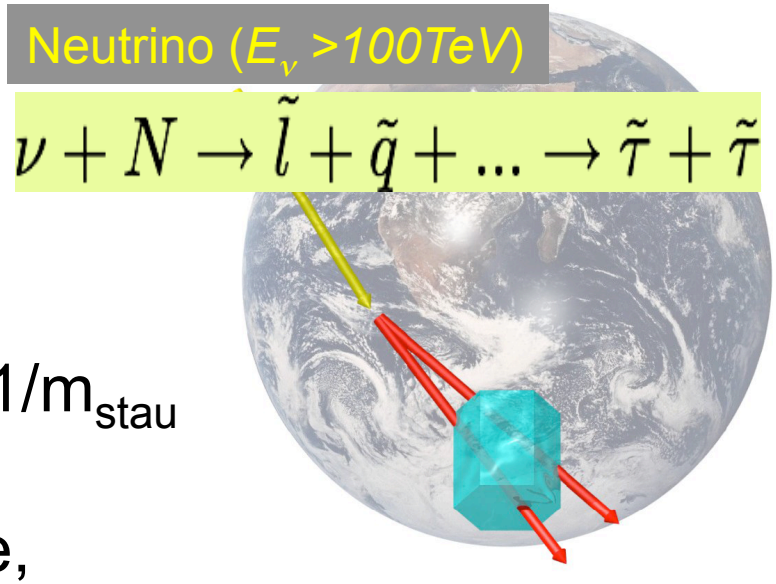
Direct SUSY searches with IceCube

S. kopper

- Certain SUSY models predict existance of metastable NLSP

- Stau energy loss is suppressed by $1/m_{stau}$

- Depending on SUSY breaking scale, Staus can have long range ~10-10^5 km
  → Large effective volume



Signal: pair of parallel charged tracks

- Due to high boost factor:
  - Tracks appear in IceCube as parallel traks
  - Tracks are separted by d>100m

Summary

- Best limit for Reltivistic Monopoles ($0.8<\beta<0.999$) obtained with IC22 $\Phi < 3.3 \cdot 10^{-18} cm^{-2} s^{-1} sr^{-1}$
- SLOPs (GUT monopoles & Q-Balls) searches with IC59 will be unblined soon
- Searches for SLOPs with IC79 ($\sigma_0 < 10^{-28} cm^2$) is ongoing. For $\sigma_0 > 10^{-28} cm^2$, analysis will start by the end of this year
- SLOPs trigger is installed at Pole for DeepCore and taking data (for IC86)
- Extension of the SLOP trigger for the whole detector next season
- Direct SUSY searches are ongoing