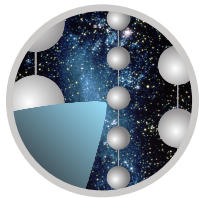
Partikeldagarna 2017

A Search for Magnetic Monopoles with the IceCube Neutrino Observatory



A. Burgman

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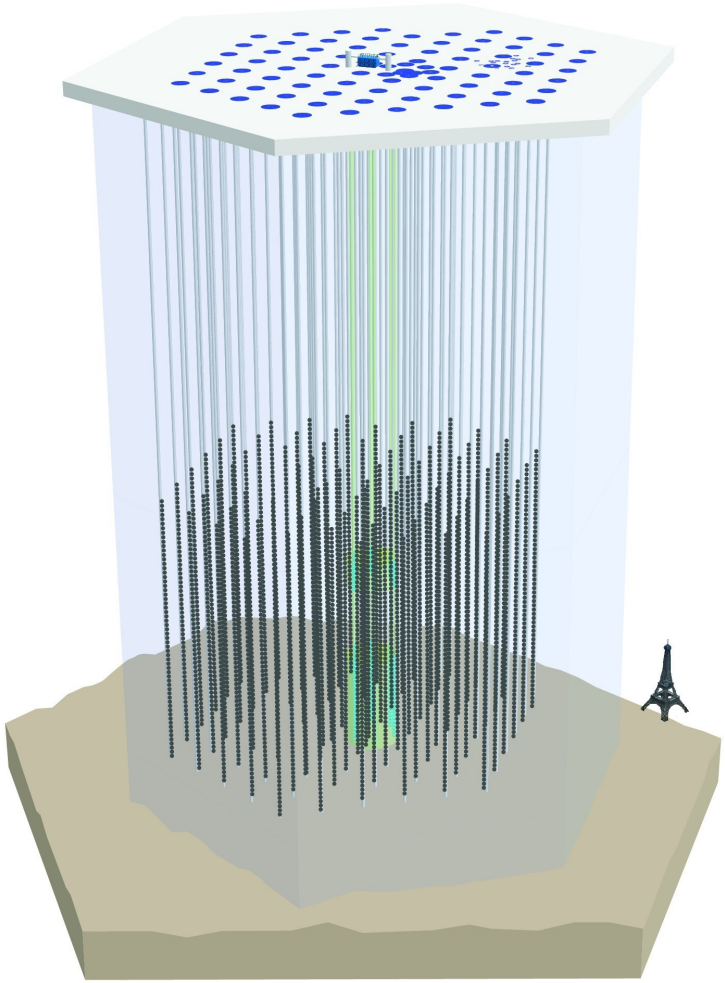
Uppsala University

2017–11–06

IceCube — Reminder



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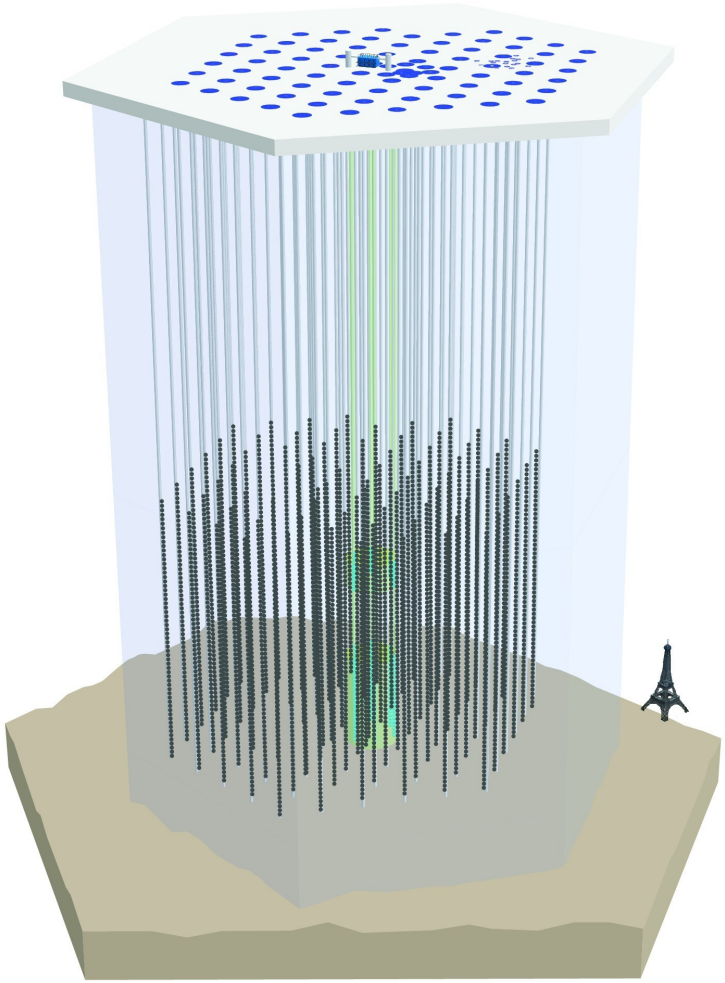

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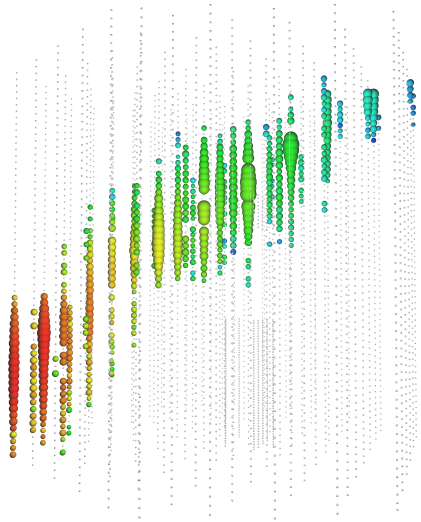
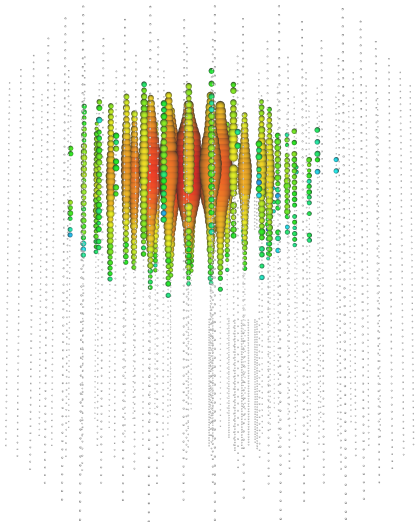


Cascades:



Magnetic Monopoles

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    - Magnetic charge: $g_n = n\frac{1}{2\alpha}e$
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    - Magnetic charge: $g_n = n\frac{1}{2\alpha}e$
    - Dirac charge: $g_D = g_1 \approx 68.5e$
- $m_{MM} \in [10^4\,\text{GeV}; 10^{17}\,\text{GeV}]$
  - Lower mass monopoles $\rightarrow$ collider searches
  - Higher mass monopoles $\rightarrow$ primordial flux searches
    - Primordial population accelerated to $E_{kin} \lesssim 10^{15}\,\text{GeV}$ by extragalactic magnetic fields

Magnetic Monopoles in Ice

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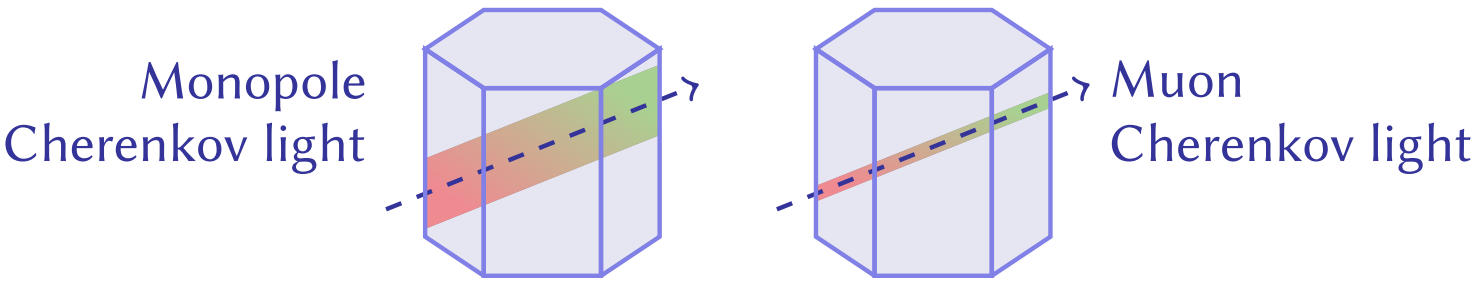
$$\Rightarrow \quad [\textit{light from monopole}] \approx 4700 \times [\textit{light from muon}]$$



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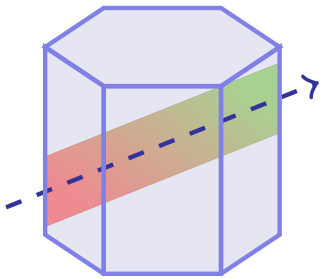
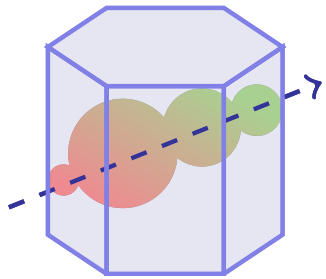
Monopole Cherenkov light





Muon Cherenkov light & stochastic losses

Analysis

Searching for: **Primordial flux of magnetic monopoles**

β Range:	$\beta \in [0.750; 0.995]$
Light Production:	Cherenkov light
Data:	6 years of IceCube data

Magnetic Monopole Event Signatures

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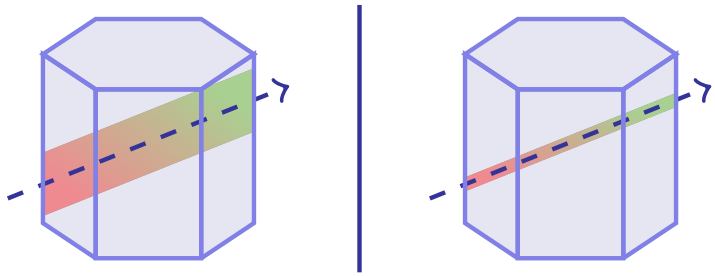
Monopole Event **Non-Monopole Event**

Very Bright:



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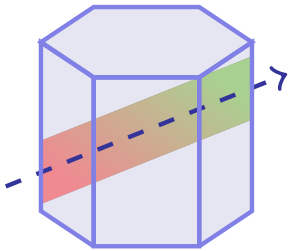
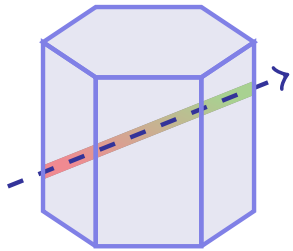
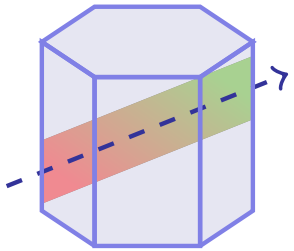
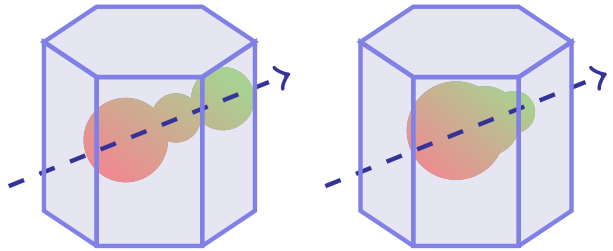
Very Bright:		
Through-Going Track:		

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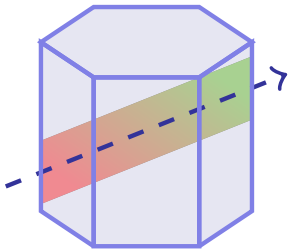
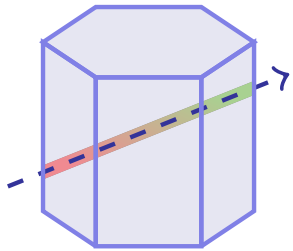
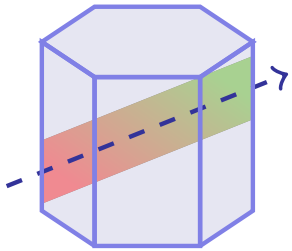
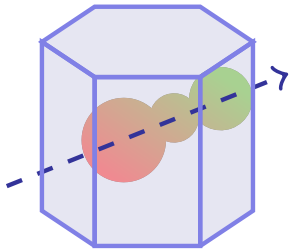
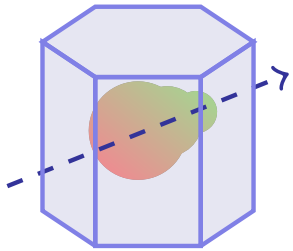
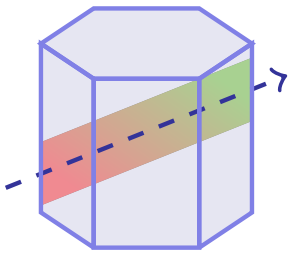
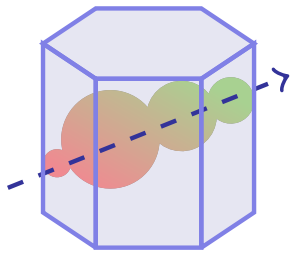
Very Bright:		
Through-Going Track:		 
Smooth Track:		

Analysis — Initial Approach

Simplest approach

Monopole Signature:

- Very bright events

Method:

Reuse cuts from a previous search in IceCube — **the EHE** *(Extremely High Energy)* **Analysis**

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Searches for the extremely high energy neutrinos produced in the GZK process

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Result:

Competitive sensitivity!

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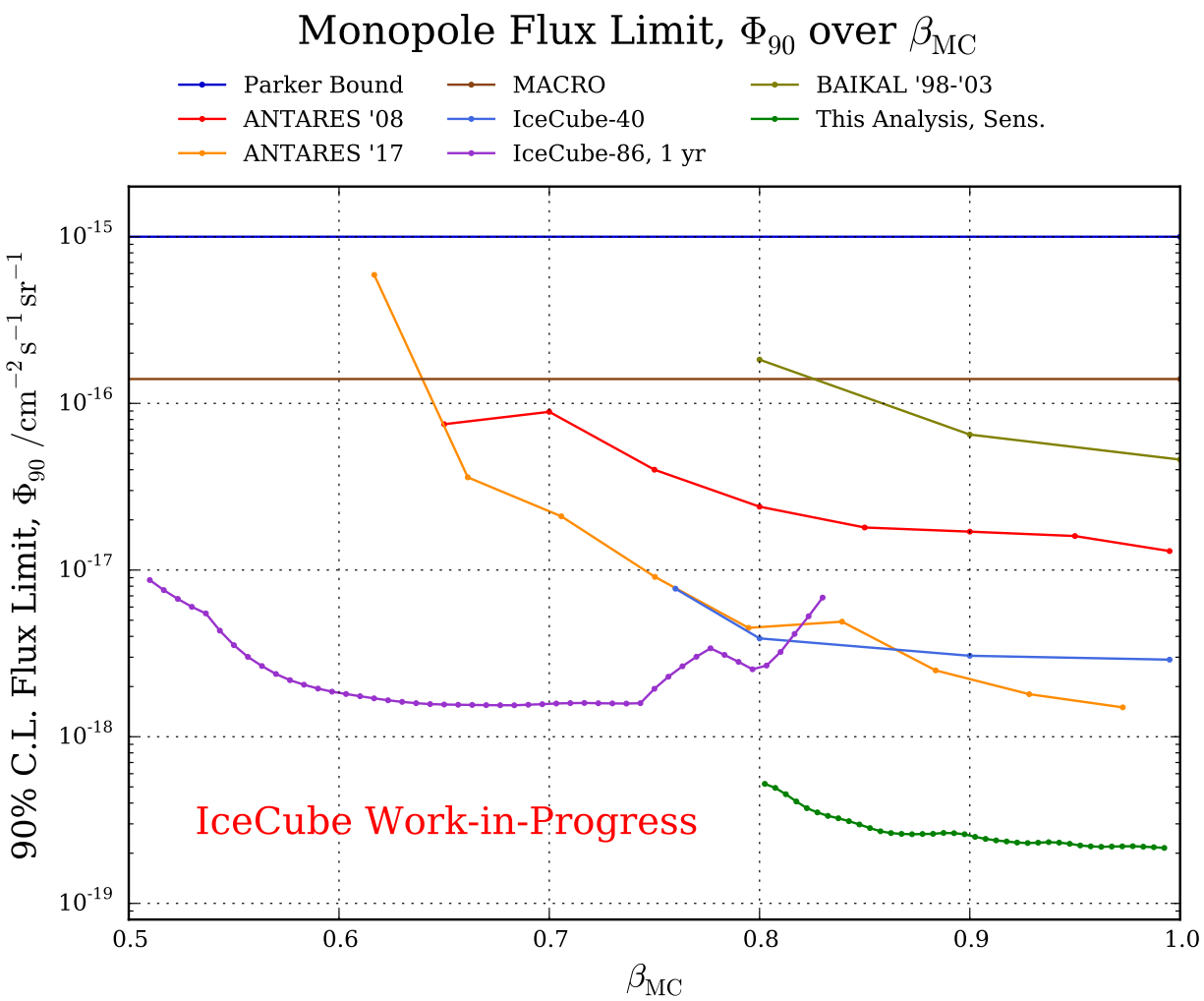

EHE Analysis sensitivity

Analysis — Ongoing Effort

We can do better! (Hopefully)

Motivation: The EHE Analysis keeps bright events, regardless of flavor

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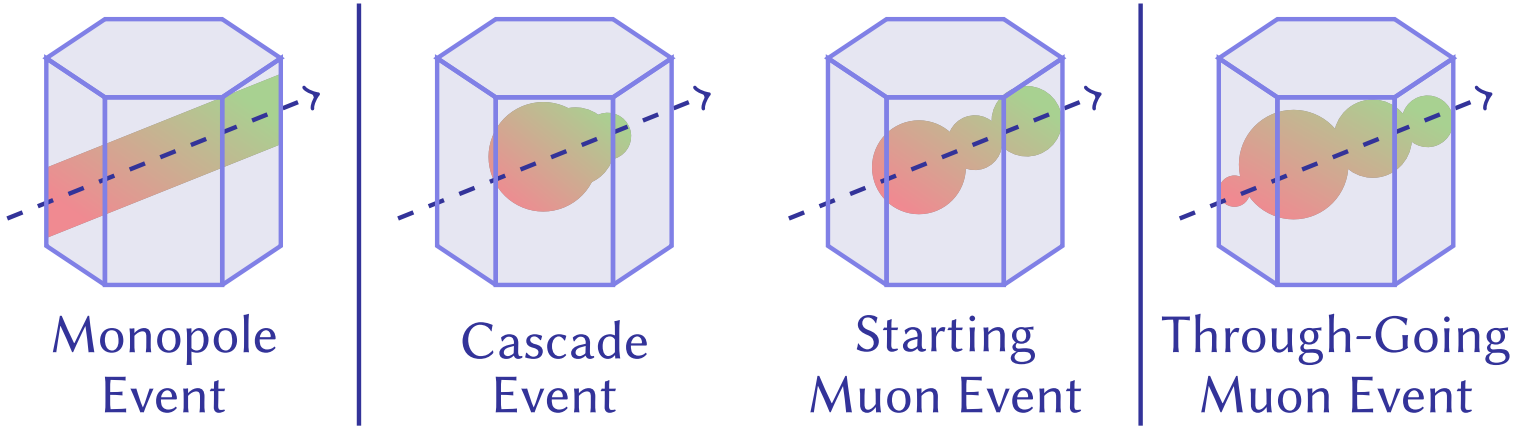
Monopole Signatures:

- Through-going tracks
- Smooth tracks



Through-Going Track

Monopole Signature:

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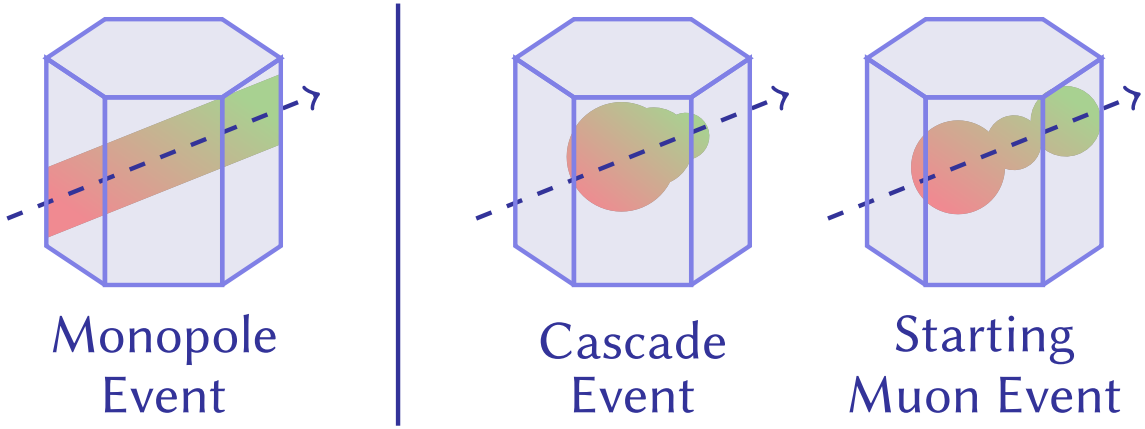
Cut on: Track length



Smooth Track

Monopole Signature:

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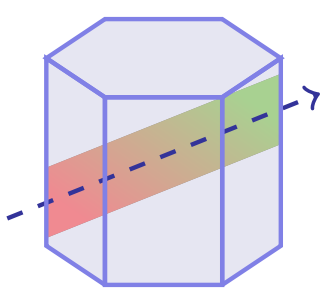
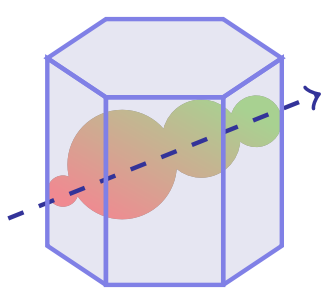
Cut on:

Model track as a series of stochastic losses:

- Variance of stochastic loss sizes
- Size of largest stochastic loss



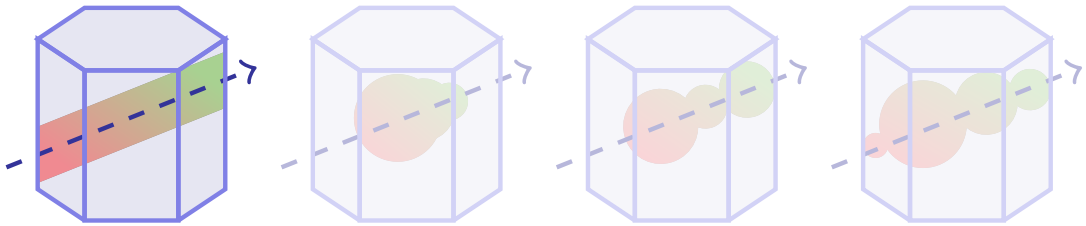
Monopole Event



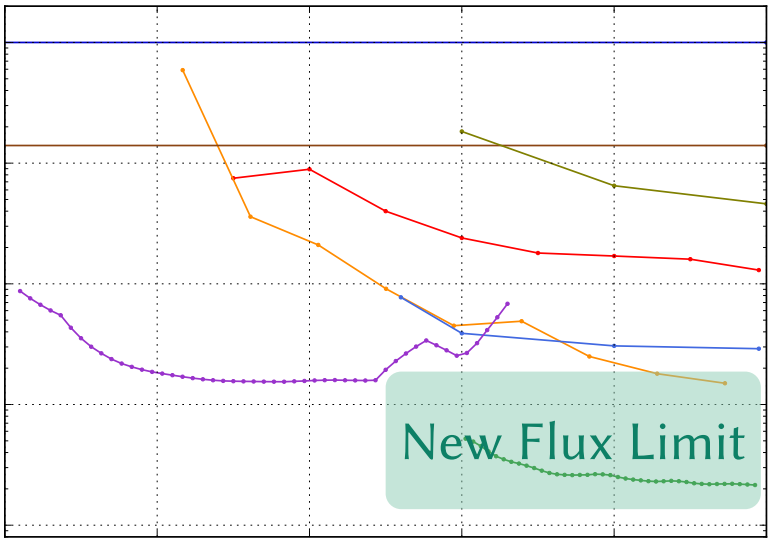
Through-Going Muon Event

Outlook

Finalize Selection Criteria:



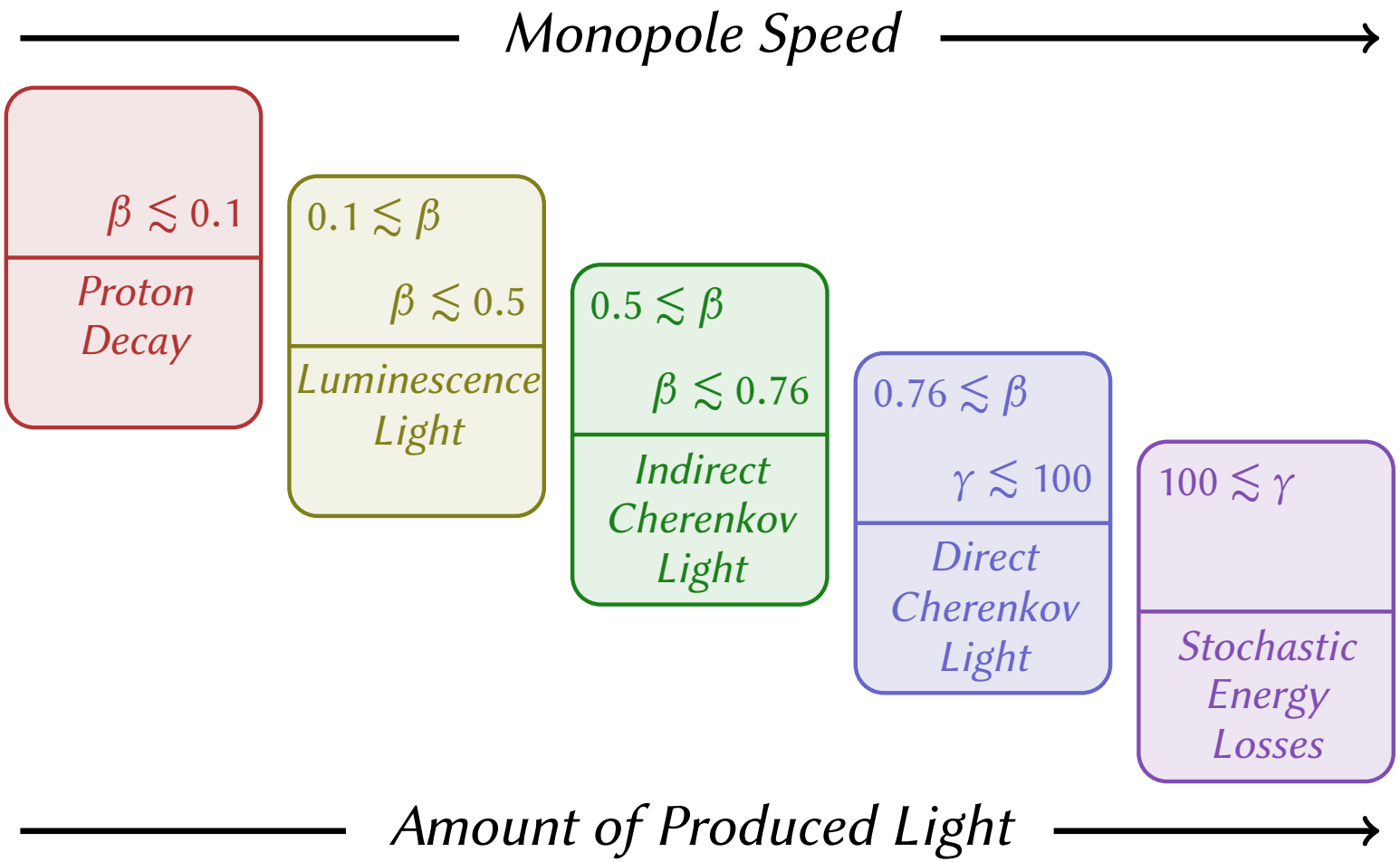
Calculate Flux Limit:



Thank you

Backups

Backup I — Magnetic Monopoles in Ice



Backup II — Monopole Mass Predictions

Model	**Mass** /GeV
$\Lambda_{MM} \sim \Lambda_{EW}$	4.0×10^4
$\mathrm{SU}(15)$	10^8
$\mathrm{SO}(10)$	$10^{10} - 10^{16}$
$\mathrm{SU}(5)$	10^{17}

Backup III

Accelerator	Magnetic Field /μG	Coherence Length /Mpc	Kinetic Energy per passing /GeV
Normal Galaxies	$3 - 10$	10^{-2}	$(0.3 - 1)\times 10^{12}$
Starburst Galaxies	$10 - 50$	10^{-3}	$(1.7 - 8)\times 10^{11}$
AGN jets	~ 100	$10^{-4} - 10^{-2}$	$1.7\times(10^{11} - 10^{13})$
Galaxy Clusters	$5 - 30$	$10^{-4} - 1$	$3 \times 10^{9} - 5 \times 10^{14}$
Extragalactic Sheets	$0.1 - 1$	$1 - 30$	$1.7 \times 10^{13} - 5 \times 10^{14}$

- A monopole interacting only with one accelerator type:
  - Broad energy distribution centered on $E_{kin} \times \sqrt{n}$
  - n is the expected number of passings
- A primordial monopole arriving at Earth today
  - Passed ~ 100 extragalactic sheet domains
  - Energy distribution centered at $\sim 10^{15}$ GeV

Backup IV — EHE Analysis Cuts

Cuts from the EHE Analysis

Level 2 — *Analysis Cut:*	Cuts on n_{pe}, n_{ch} and the χ^2_{red} of the EHE ILF to get extremely bright events
Level 3 — *Atmospheric ν_e Cut:*	Cut on $\log(n_{pe})$ depending on χ^2_{red} to demand more light for more cascade like events than track like events
Level 4 — *Atmospheric μ Cut:*	Cut on $\log(n_{pe})$ depending on zenith direction to demand more light for downgoing events
Level 5 — *IceTop Veto:*	Remove events with one or more IceTop hits within a certain time window