Search for Ultra-Relativistic Magnetic Monopoles

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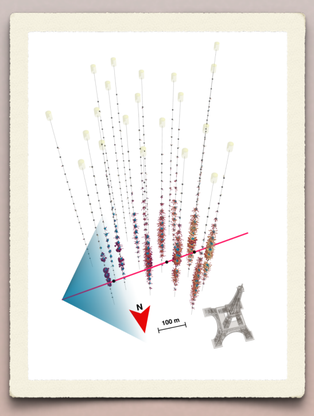
INTRODUCTION

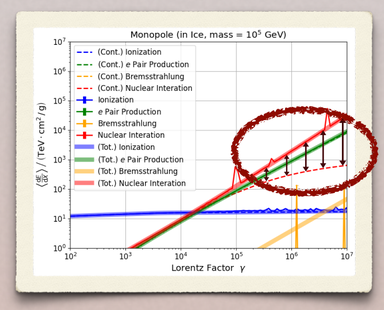
KM3NeT KM3-230213A event



On 13 February 2023, a muon with an energy of about 120 PeV was detected by the KM3NeT neutrino telescope, which is a deep-sea telescope from the abyss of the Mediterranean Sea. This implies that the primary neutrino that generated the muon had an even higher energy, estimated at the level of 220 PeV, significantly higher than any neutrino ever detected before.

Another possibility → Magnetic Monopole?

Magnetic Monopole



- Magnetic monopoles: Hypothetical particles that carry a single magnetic charge (unlike ordinary magnets, which always have both poles).
  - Previous Icecube searches for magnetic monopoles: Up to gamma ~ 10
    - Figure: Magnetic monopoles start to lose energy stochastically from gamma ~ 10^4.
      - Our research: Investigation on the probability of KM3-230213A being interpreted as an ultra-relativistic (gamma ~ 10^4 ~ 10^7) magnetic monopoles through Monte Carlo simulations.

Monopole Generation & Propagation

- Using PROPOSAL (particle propagator)
- Monopole mass: 10^8 MeV
- Magnetic charge: g_D or $4*g_D$
  (g_D: Dirac charge, the minimum magnetic charge a monopole can have)
- Gamma: 10^4 or 10^5
- Energy loss ΔE along the trajectory

Photon Propagation

- Using PPC (Photon Propagation Code)
- Direct Cherenkov light emission

$$\frac{d}{dx}N_\gamma^{DirCherenkov} = a\left(1 - \frac{1}{b\beta^2}\right)$$

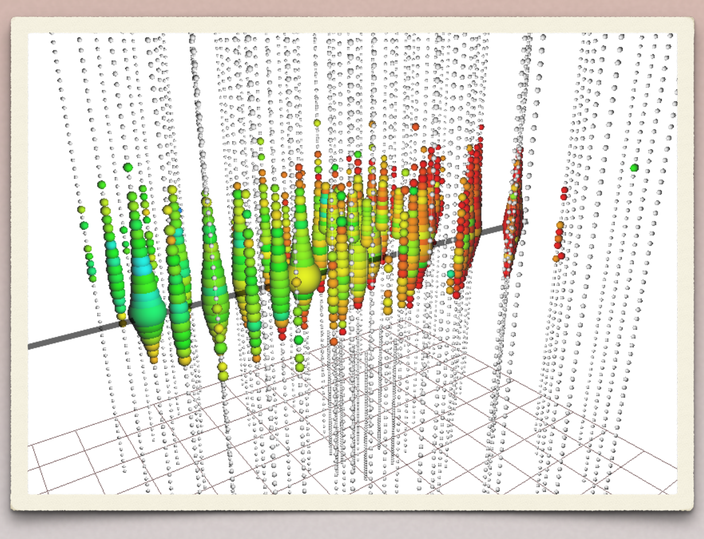
- Light emission from cascades

$$\frac{d}{dx}N_\gamma^{\Delta E} = Y \cdot \Delta E$$

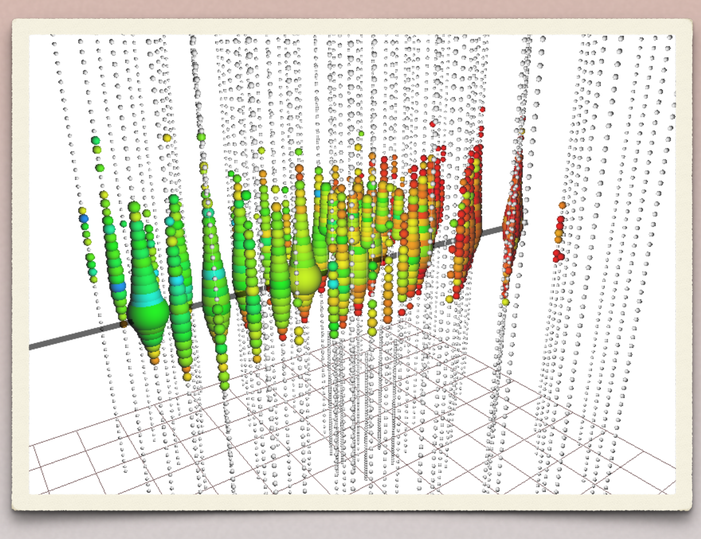
Detector Simulation

- Hits and waveforms simulation
- Noise injection
- Background simulation
- .....

SIMULATION



$\gamma = 10^4$
$Q = g_D$

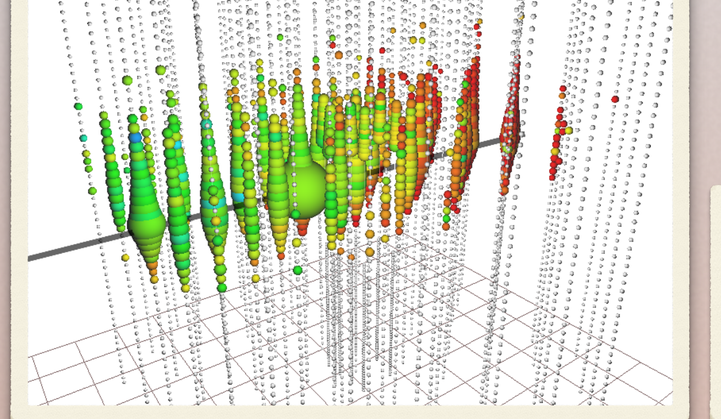


$\gamma = 10^4$
$Q = 4g_D$

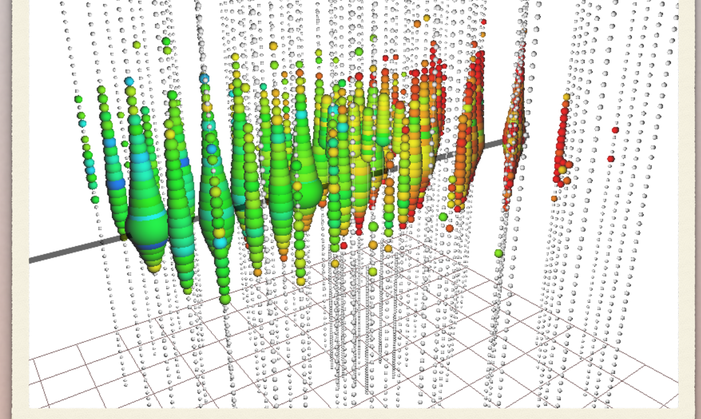
SIMULATION

SCAN ME

SIMULATION



$\gamma = 10^5$
$Q = g_D$



$\gamma = 10^5$
$Q = 4g_D$

SIMULATION

REFERENCES

1. KM3NeT Collaboration. Observation of an ultra-high-energy cosmic neutrino with KM3NeT. Nature 638, 376–382 (2025). DOI: 10.1038/s41586-024-08543-1.
2. J.H. Koehne et al. Comput.Phys.Commun. 184 (2013) 2070-2090 DOI: 10.1016/j.cpc.2013.04.001
3. PPC (Photon Propagation Code), IceCube Collaboration, private communication

FUTURE WORK

- Detector simulation
- Event selection
- IceCube effective area evaluation
- .....