

Exploring Fundamental Physics with Atmospheric Collider



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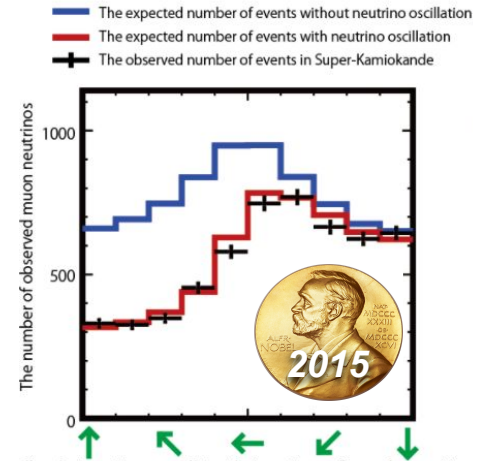
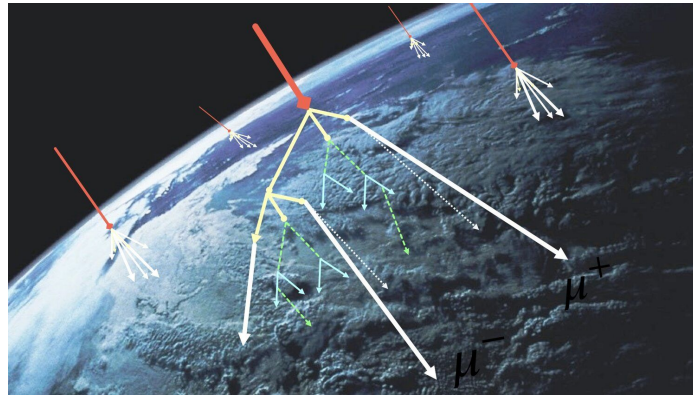
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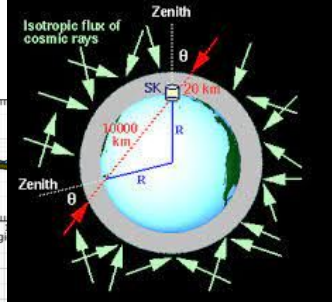
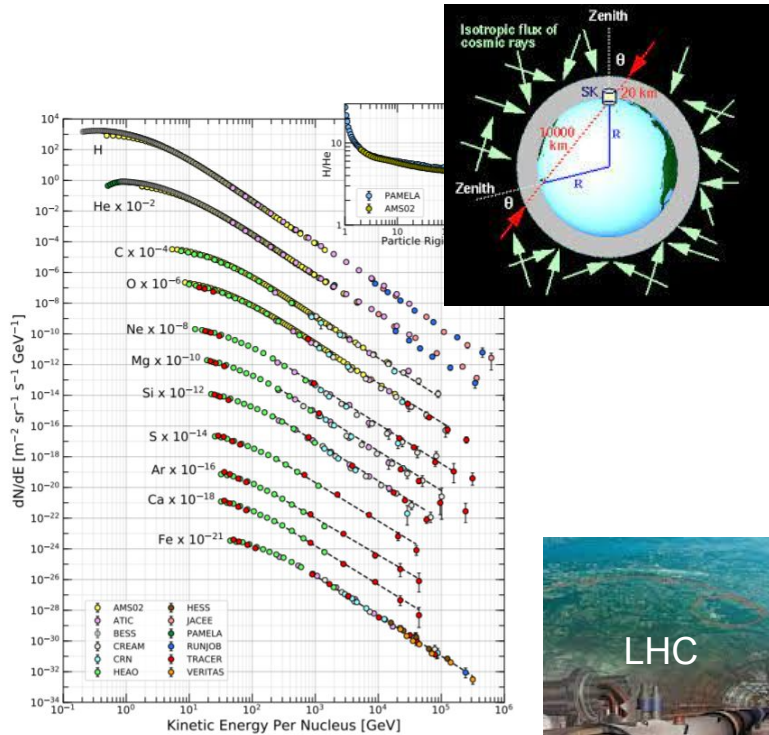


Atmospheric Neutrinos, Briefly

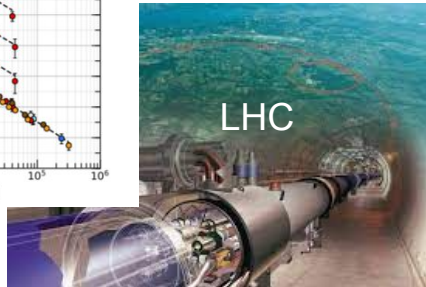
- Super-Kamiokande (~50 kton water Cherenkov) multipurpose experiment originally built to search for nucleon decay (e.g. [VT+ (SK), *PRL*, 1409.1947; *PRL* 1508.05530], review [VT, 1605.03235])
- Cosmic rays bombarding atmosphere lead to copious mesons decaying to neutrinos
→ **discovery of neutrino oscillations** [Fukuda+ (SK), *PRL*, 1998]



Collider in the Sky



- Unique natural source of (\sim pp) collisions
- “Collider” always ON
- Robust flux for ALL terrestrial experiments
- Broad energy spectrum

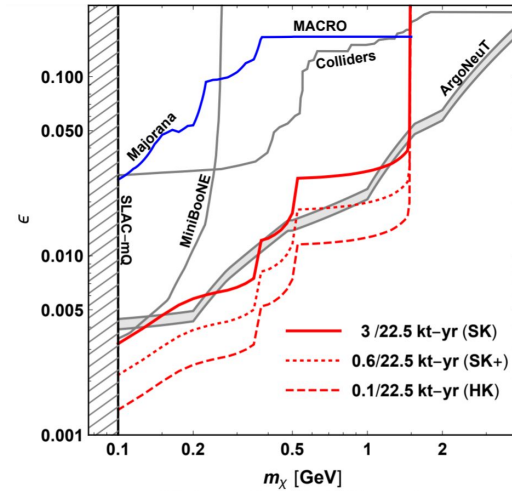
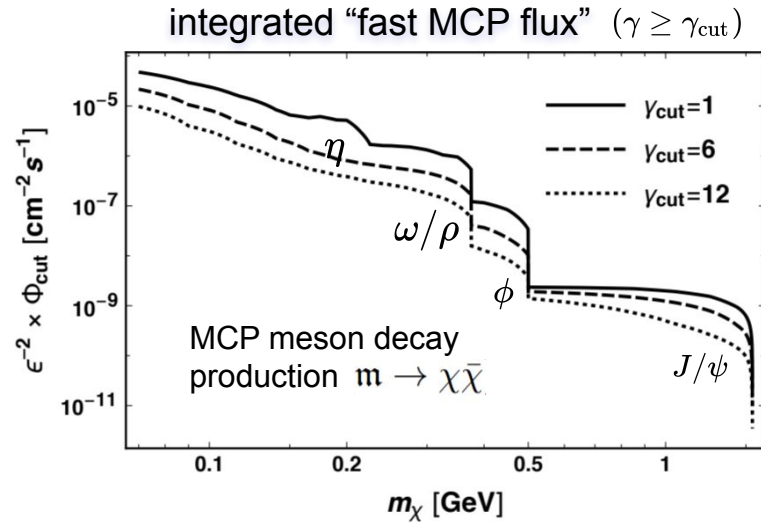


→ **unprecedented opportunity for exploration of new physics !**

Millicharge Particles

- Is familiar electric charge *actually* quantized? How small can it be?
- In Standard Model anomaly cancellation restricts hypercharge $U(1)$ assignment
→ but for 3 generations some freedom (e.g. [Foot+, 1992])
- Quantization motivates broader ideas: Grand Unification...
- Quantum gravity link? [Shiu+, *PRL*, 2013]
- Related with dark sector / dark matter
- Connections with astronomy (e.g. EDGES anomaly [Barkana, *Nature*, 2018;...])

Millicharge Particles



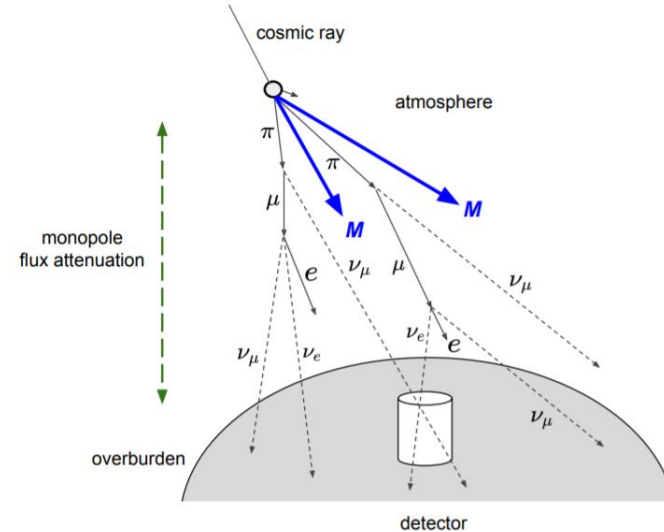
[Plested, VT, Tsai, Bringmann, Kusenko, Pospelov, *PRD*, 2002.11732]

- Idea with decades of history, first comprehensive study - *allows comparing historic searches*
 - revisited with detailed simulations [Argüelles, Kelly, Munoz, 2021]
 - other interesting searches with mesons [Coloma, Hernandez, Munoz, Shoemaker, 2019] (HNLs), [Argüelles, Coloma, Hernandez, Munoz, 2020] (LLP), [Alvey, Campos, Fairbairn, You, 2019] (light DM)

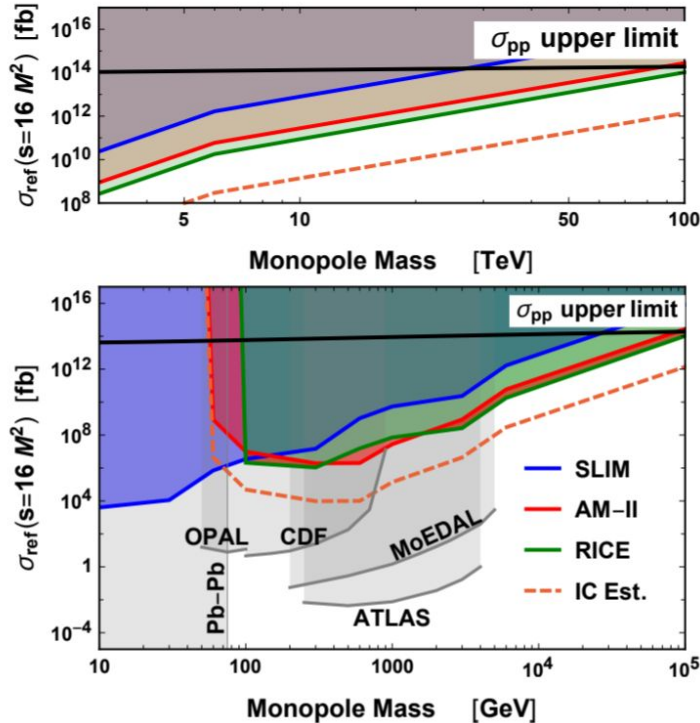
Monopoles

[Iguro, Plestid, VT, 2111.12091]

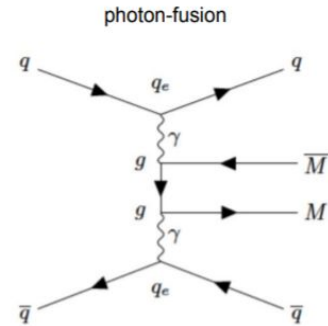
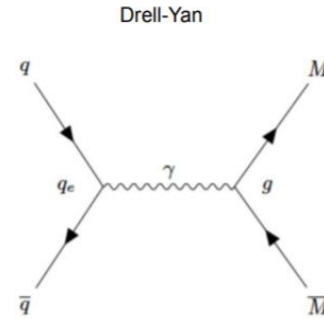
- Decades of history
- Symmetrize Maxwell equations, charge quantization [Dirac, 1931]
- Naturally appear in Unification models [t'Hooft, 1974; Polyakov, 1974]
- Cosmology predictions highly uncertain [Kibble, 1976; Zurek, 1985]
- Reinvigorated recent interest with models of EW-scale monopoles (e.g. [Ellis+, 2017])
- Many searches look for “ambient” unknown monopole flux



Monopoles



perform collider simulations, as LHC



- atmospheric collider establishes robust universal source, connects many historic searches
- set leading bounds, new analysis strategies

[Iguro, Plestid, VT, 2111.12091]

Summary

- Atmospheric collider has proven to be an invaluable tool for exploring particle physics
- Collider always ON
- Robust universal flux allows to overcome historic challenges of many experiments searching for unknown “ambient” flux of new physics constituents (or associated with highly uncertain cosmological predictions)

→ ***novel opportunities for discovering BSM & fundamental physics !***