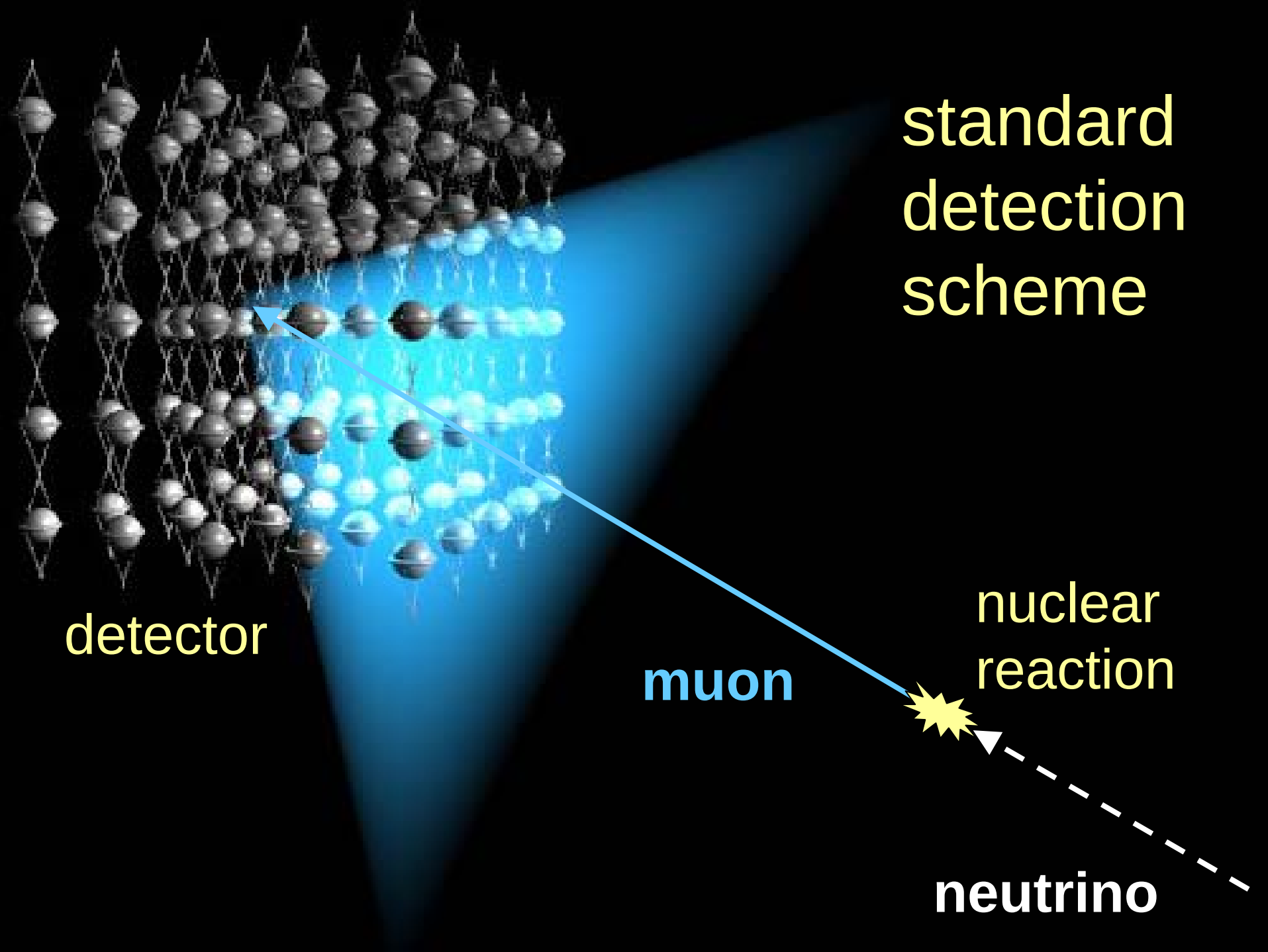
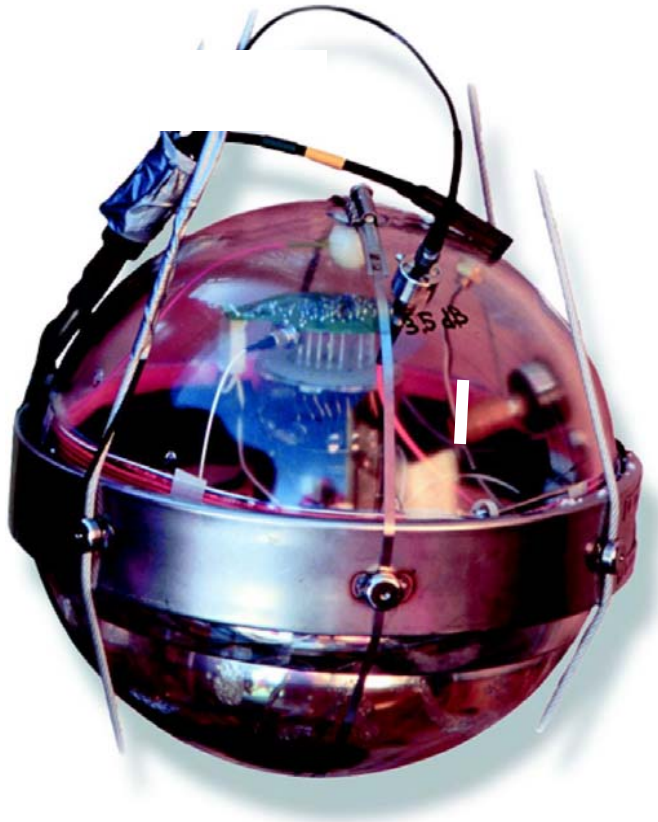
Search for very heavy exotic particles with IceCube

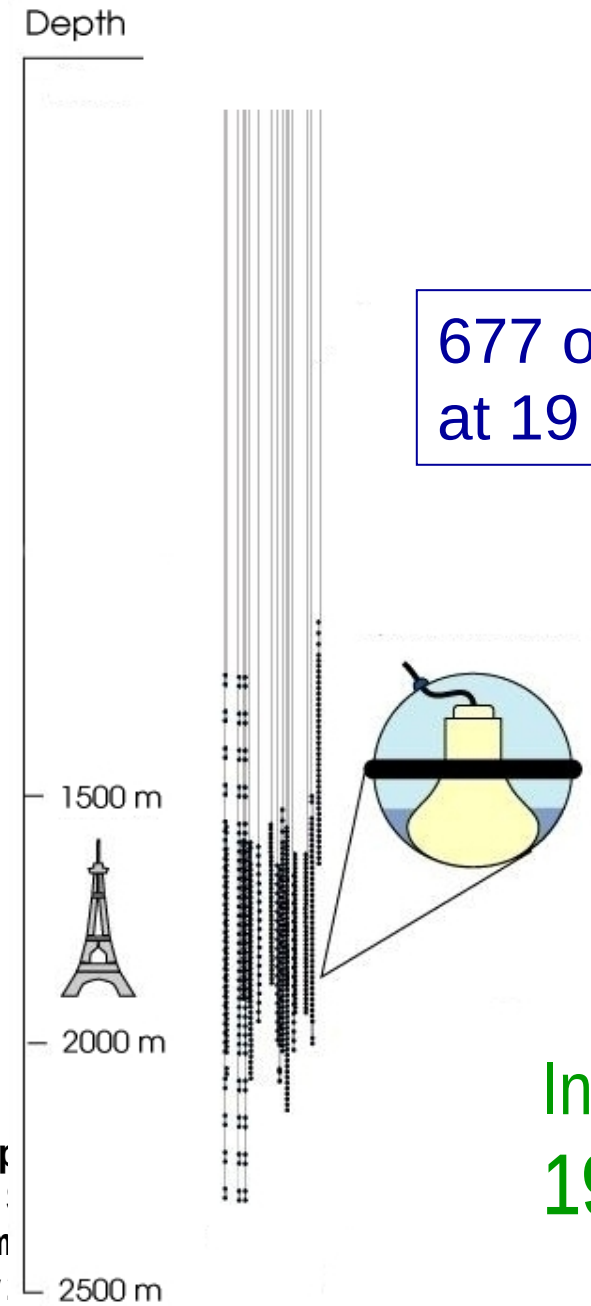
Christian Spiering, SFB 676


standard
detection
scheme
detector
muon
nuclear
reaction
neutrino

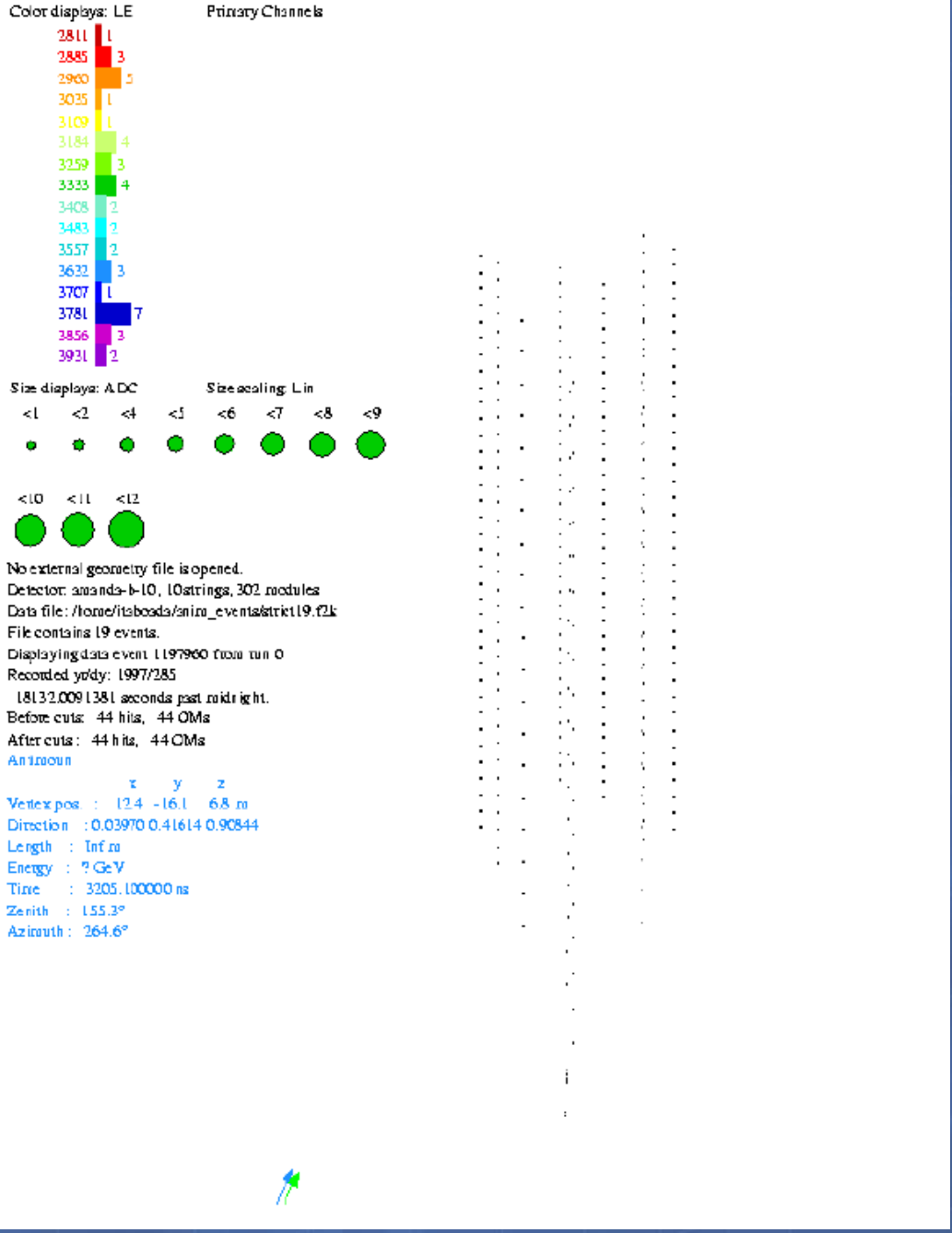
AMANDA-II

677 optical modules
at 19 strings





Installation
1996-2000



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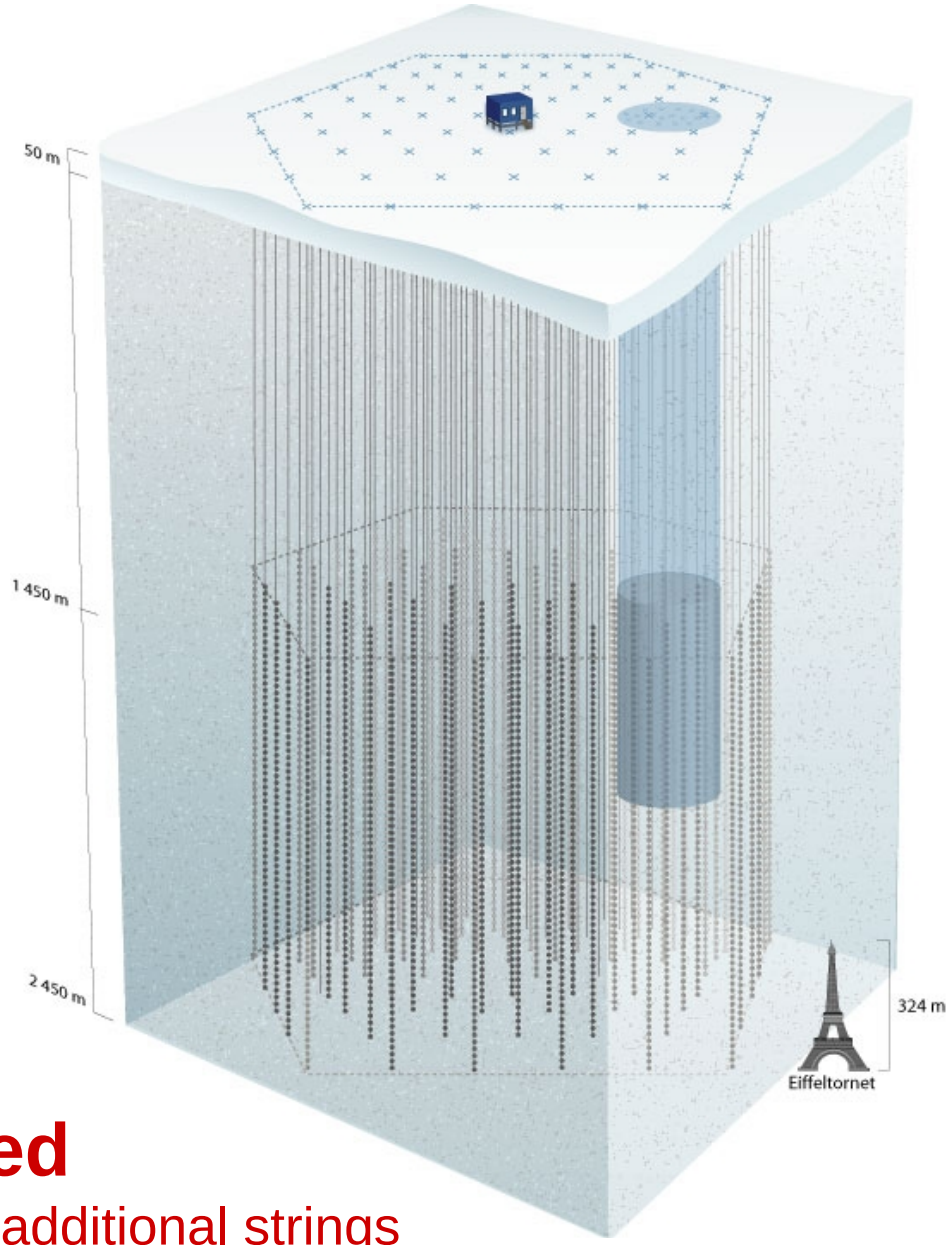
IceCube

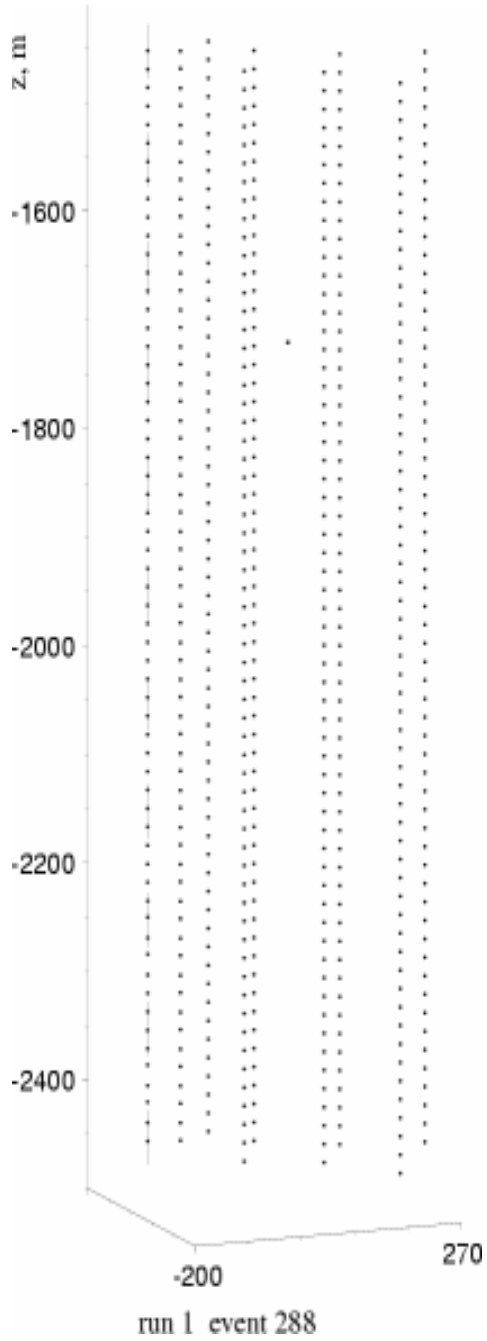


- 80 Strings
- 4800 PMTs
- Instrumented Volume: 1 km^3
- Installation: 2005-2011

9 strings installed

plan for this season: 12 additional strings

One of the first Neutrino candidates seen with the nine deployed IceCube strings



WIMPs

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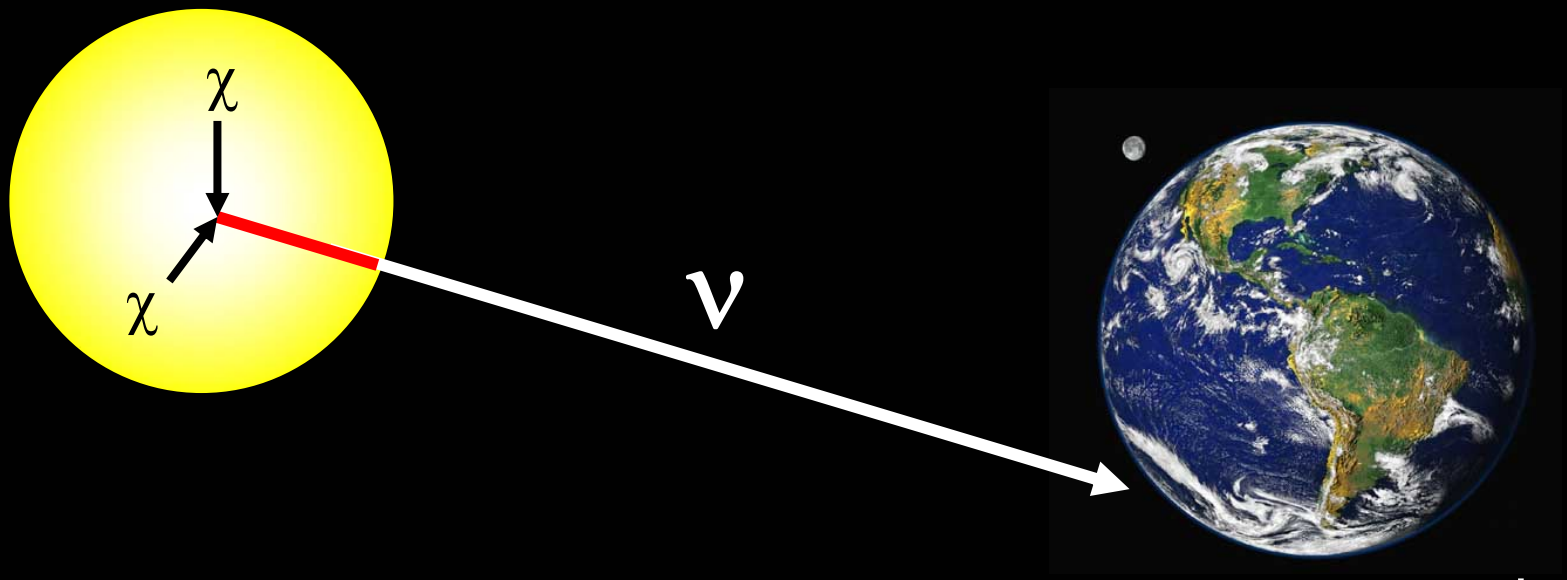
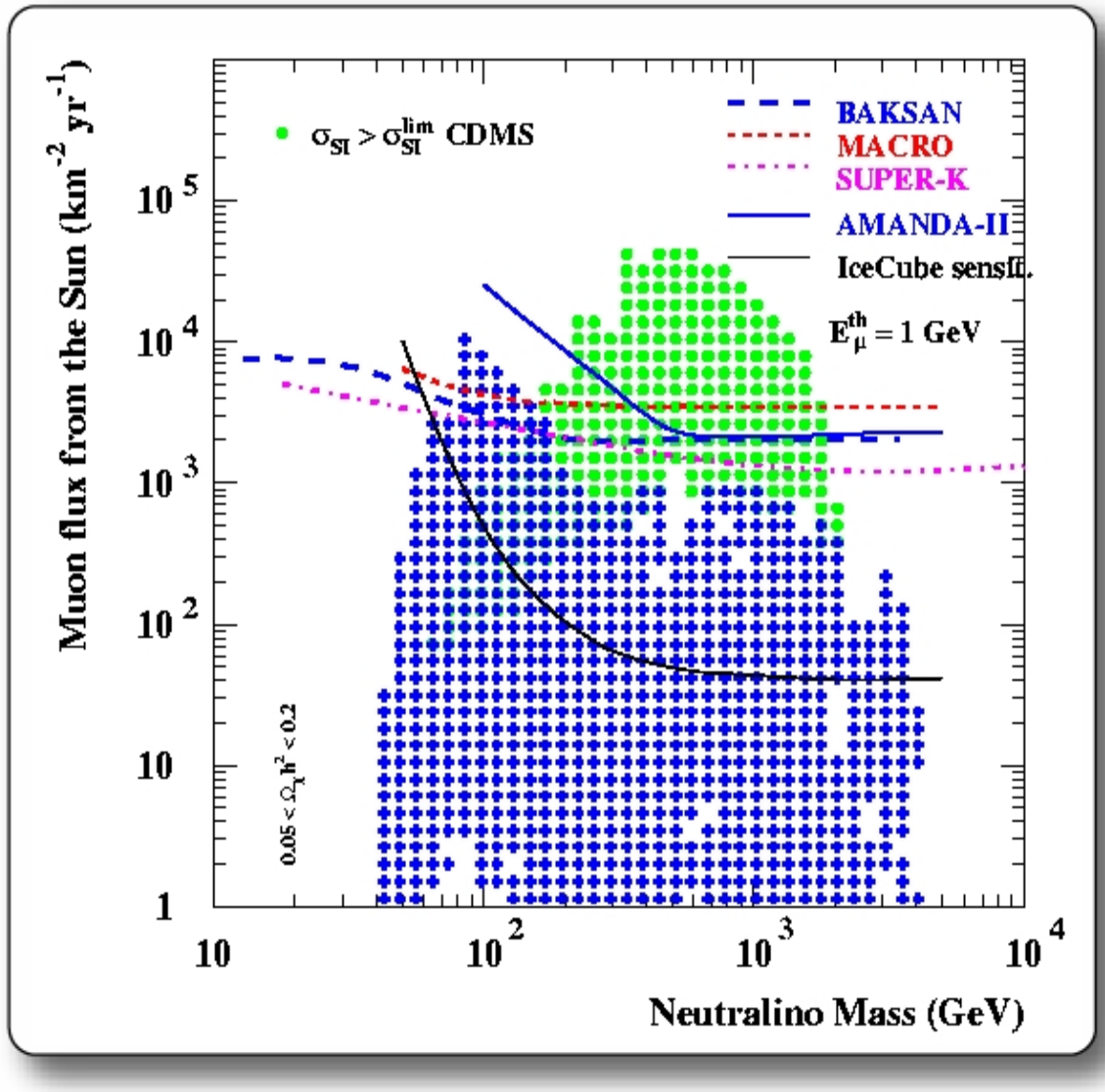
Indirect Search for WIMPs

Neutrinos from the Sun



Present upper limits and expected IceCube sensitivity on muon flux from neutralino annihilations in center of Sun



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Magnetic Monopoles

Nuclearites

Q-Balls

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Magnetic Monopoles

- Dirac 1931
- Typical signature when crossing a s.c. coil (Cabrera)
- Strong Ionization:
  ~ $(g/e)^2$ with g/e = 137/2
- Astrophysical Parker Bound:
  ~ 10^{-15} cm^{-2} s^{-1} sr^{-1}
- GUT Monopoles may catalyze proton decay
- MACRO at Gran Sasso:
  most prominent monopole detector
  (closed in 2000, ionization &ToF)

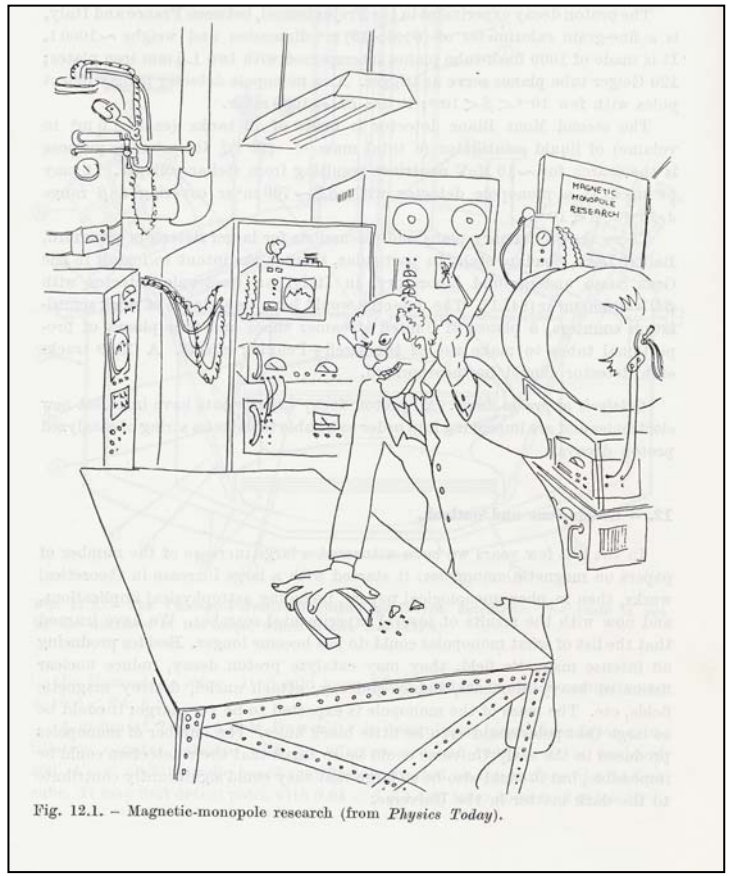
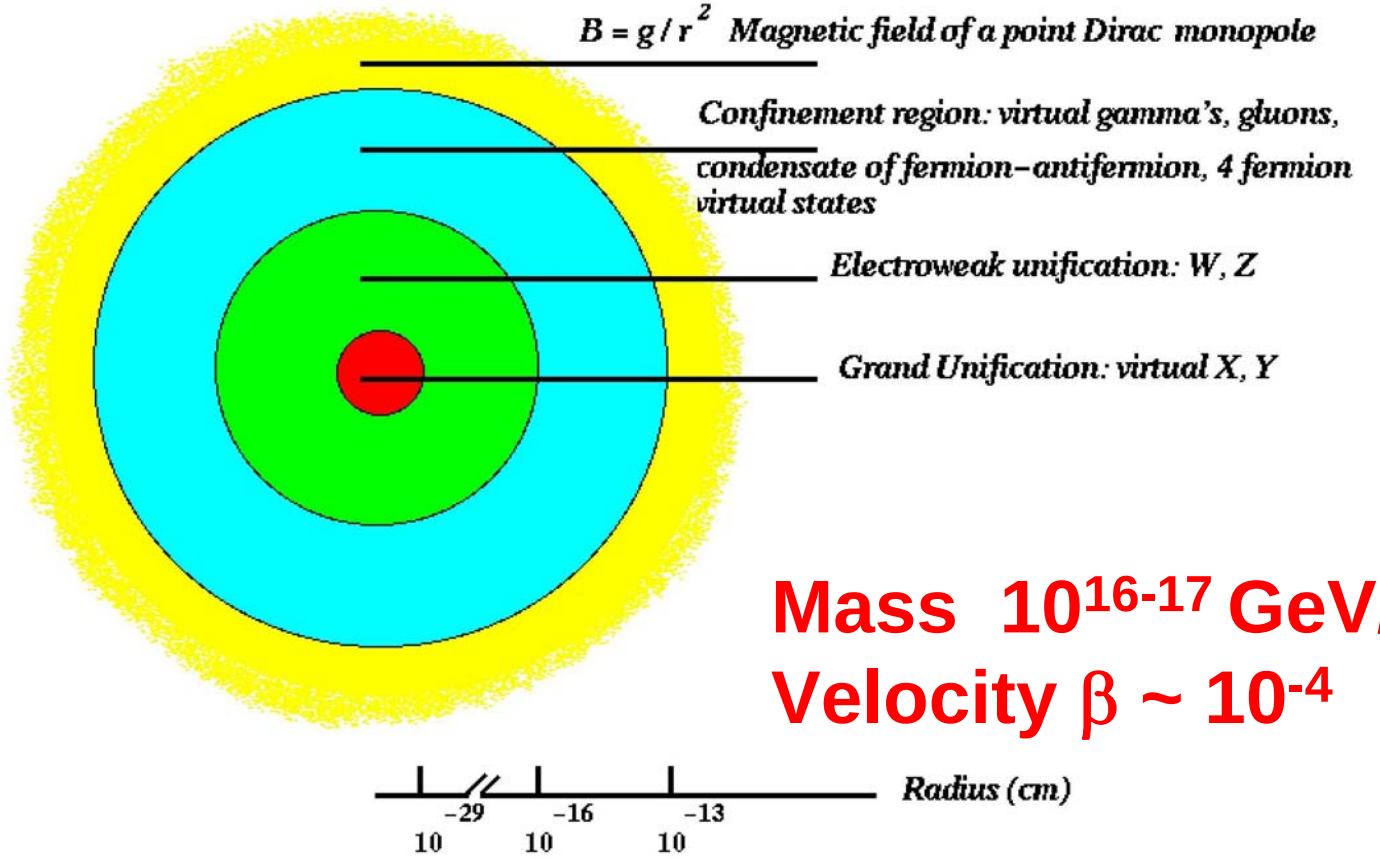


Fig. 12.1. – Magnetic-monopole research (from *Physics Today*).

GUT Monopoles

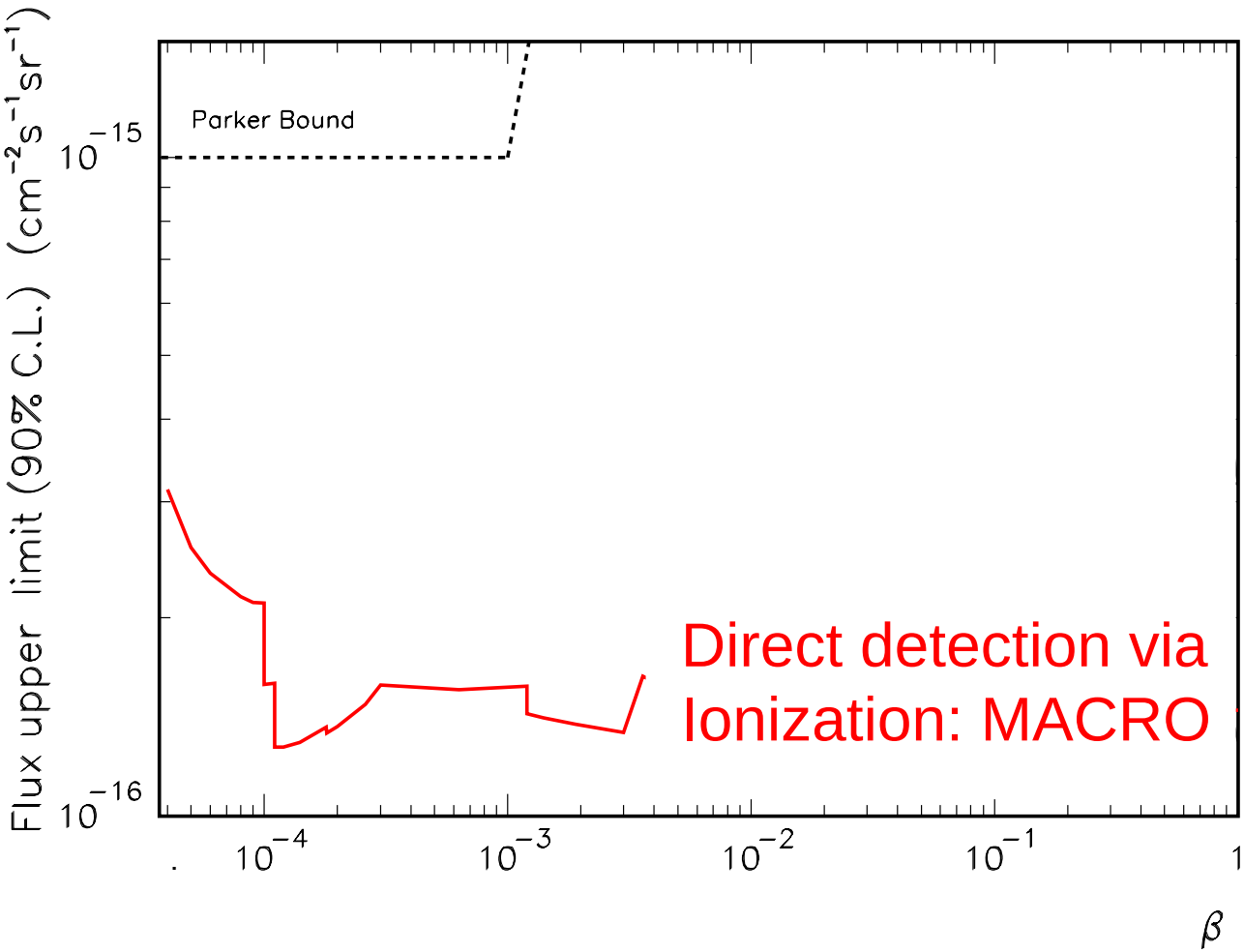


Mass $10^{16\text{-}17}$ GeV/c²
Velocity $\beta \sim 10^{-4}$

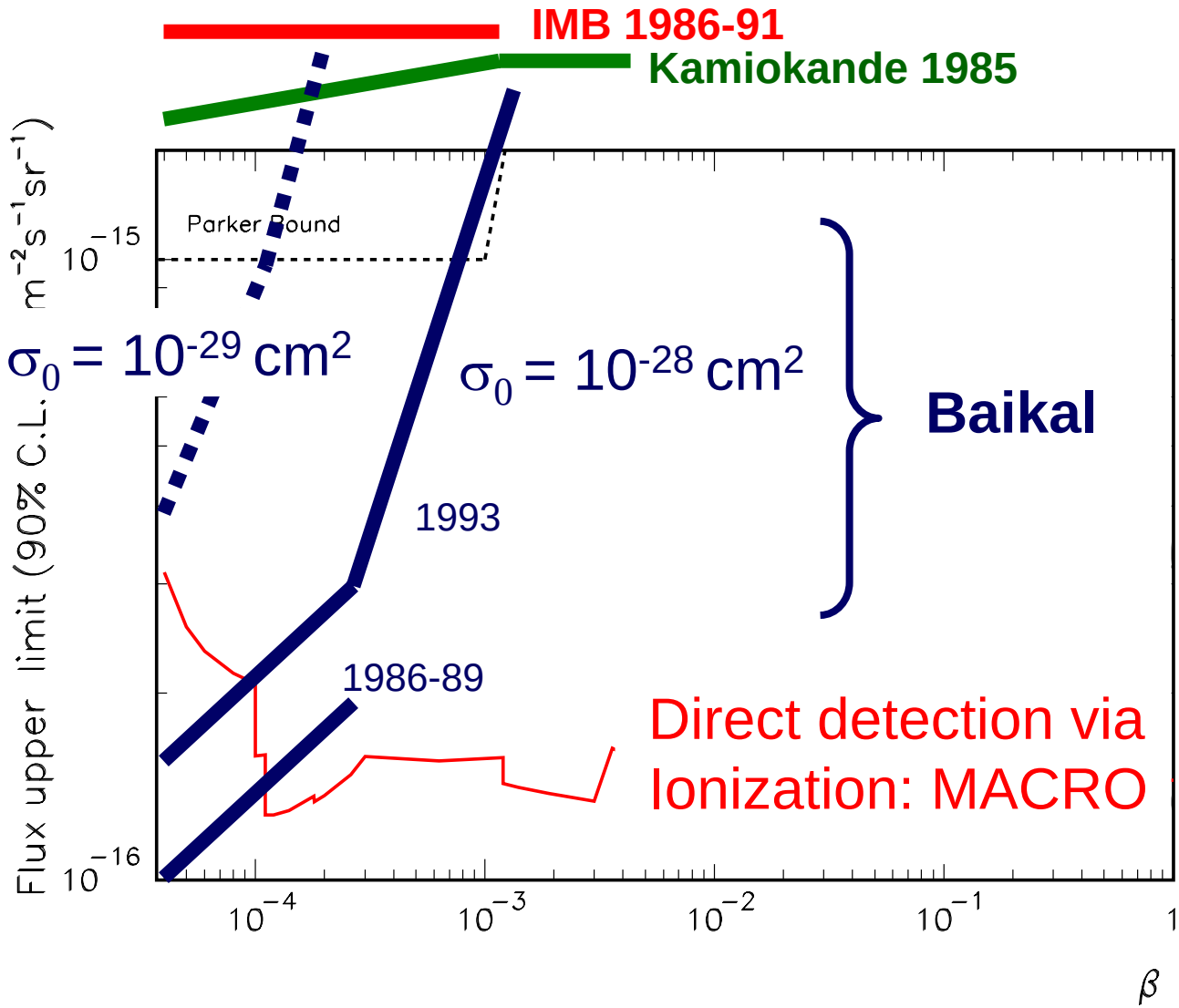
$M + p \rightarrow M + e^+ + \pi^0$

May catalyze proton decay with $\sigma \approx \sigma_0 / \beta^2$
→ bright track from Cherenkov radiation from proton decay products in water detectors

Flux upper limits for GUT Magnetic Monopoles



Flux upper limits for GUT Magnetic Monopoles



… including limits from p-decay catalysis assumption

Intermediate mass Magnetic Monopoles

Mass 10^5 - 10^{12} GeV

→ Produced in the Early Universe in later phase transitions

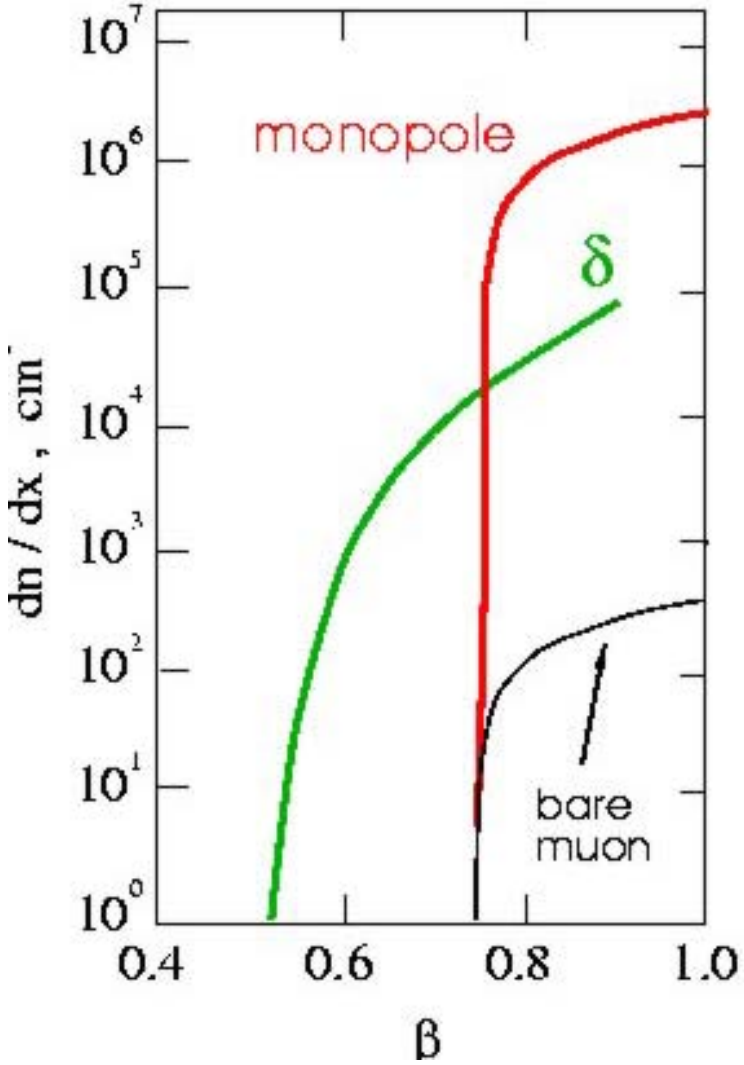
→ Can be accelerated in the galactic B field to relativistic velocities

W = g_D B L ~ 6 x 10^{19} eV (B/3x10^{-6} G) (L/300pc)

Galaxy	W ~ 6 × 10^{19} eV
Neutron stars	W ~ 10^{20} - 10^{24} eV
AGN	W ~ 10^{23} - 10^{24} eV

Connection to highest energy cosmic ray showers @ E > 10^{20} eV ?

Detection via Cherenkov light



Cherenkov Light $\propto$ $n^2 \cdot (g/e)^2$

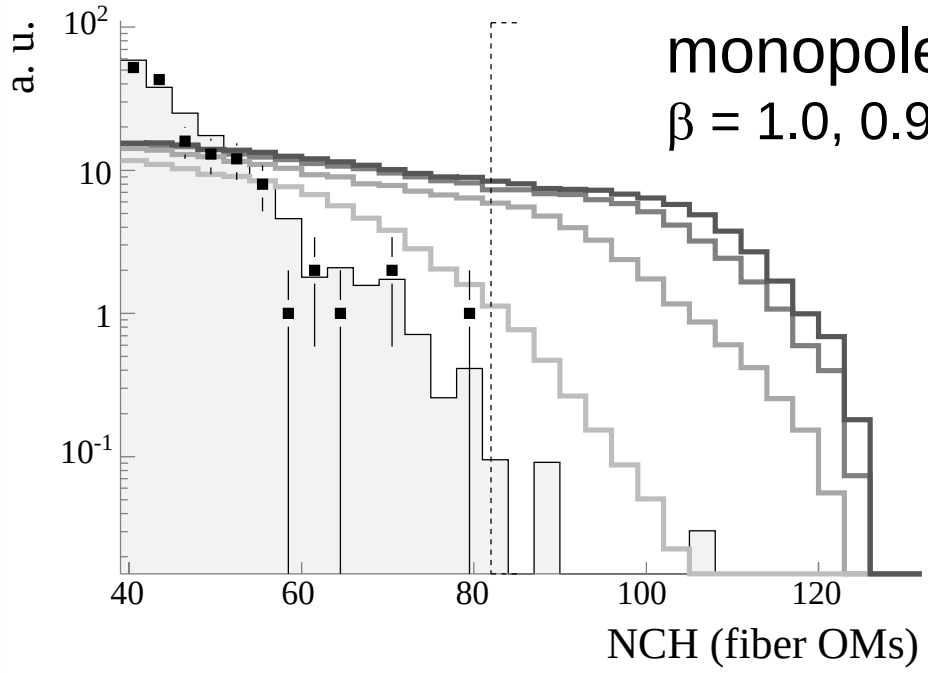
n = 1.33

(g/e) = $^{137}/_{2}$

$\approx$ 8300

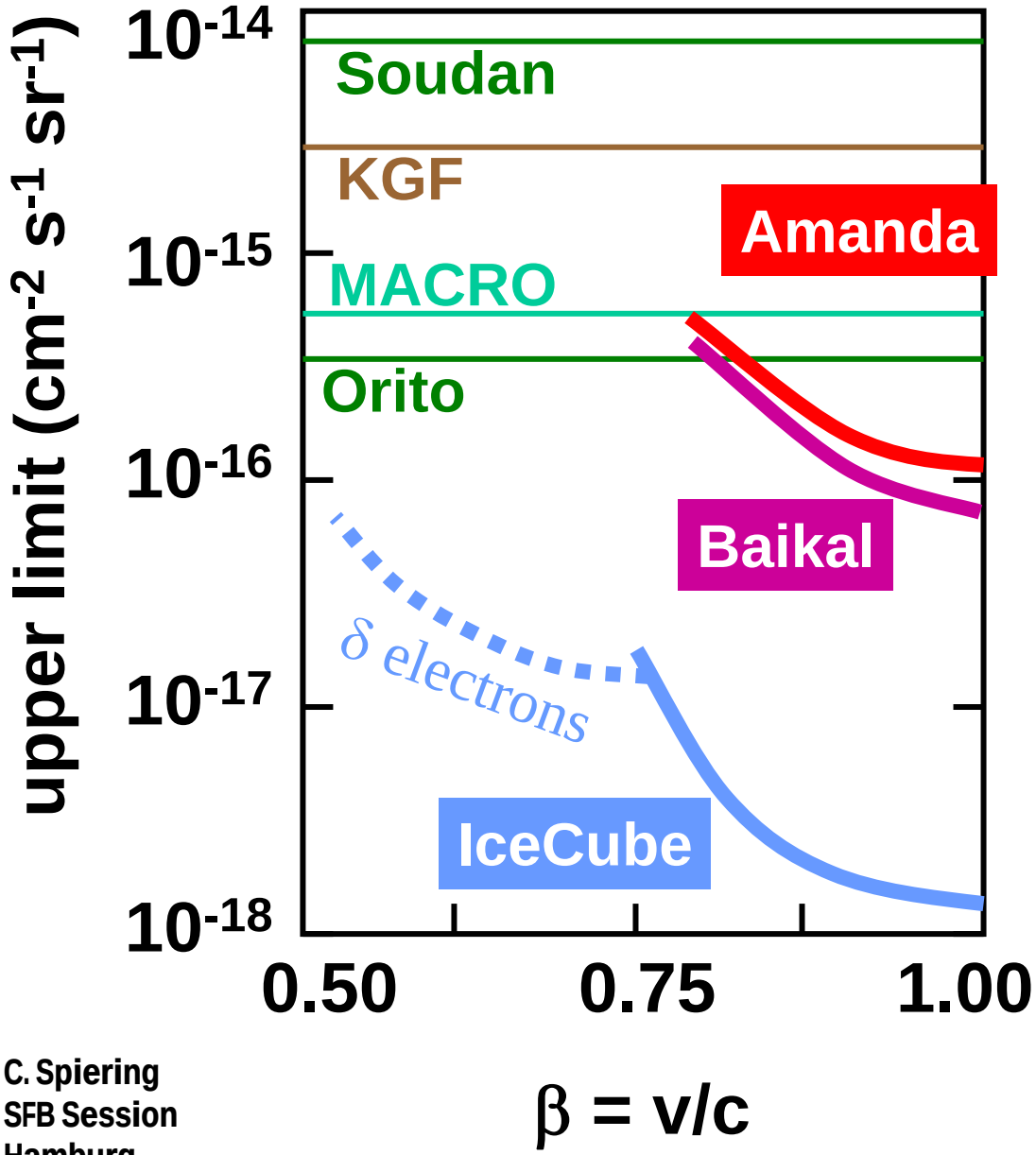
Amanda 2000

blue: background MC
dots: exp. data



monopole with
β = 1.0, 0.9, 0.8, 0.76

Relativistic Magnetic Monopoles



Cherenkov-Light $\propto$

$n^2 \cdot (g/e)^2$

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$(g/e) = 137/2$

≈ 8300

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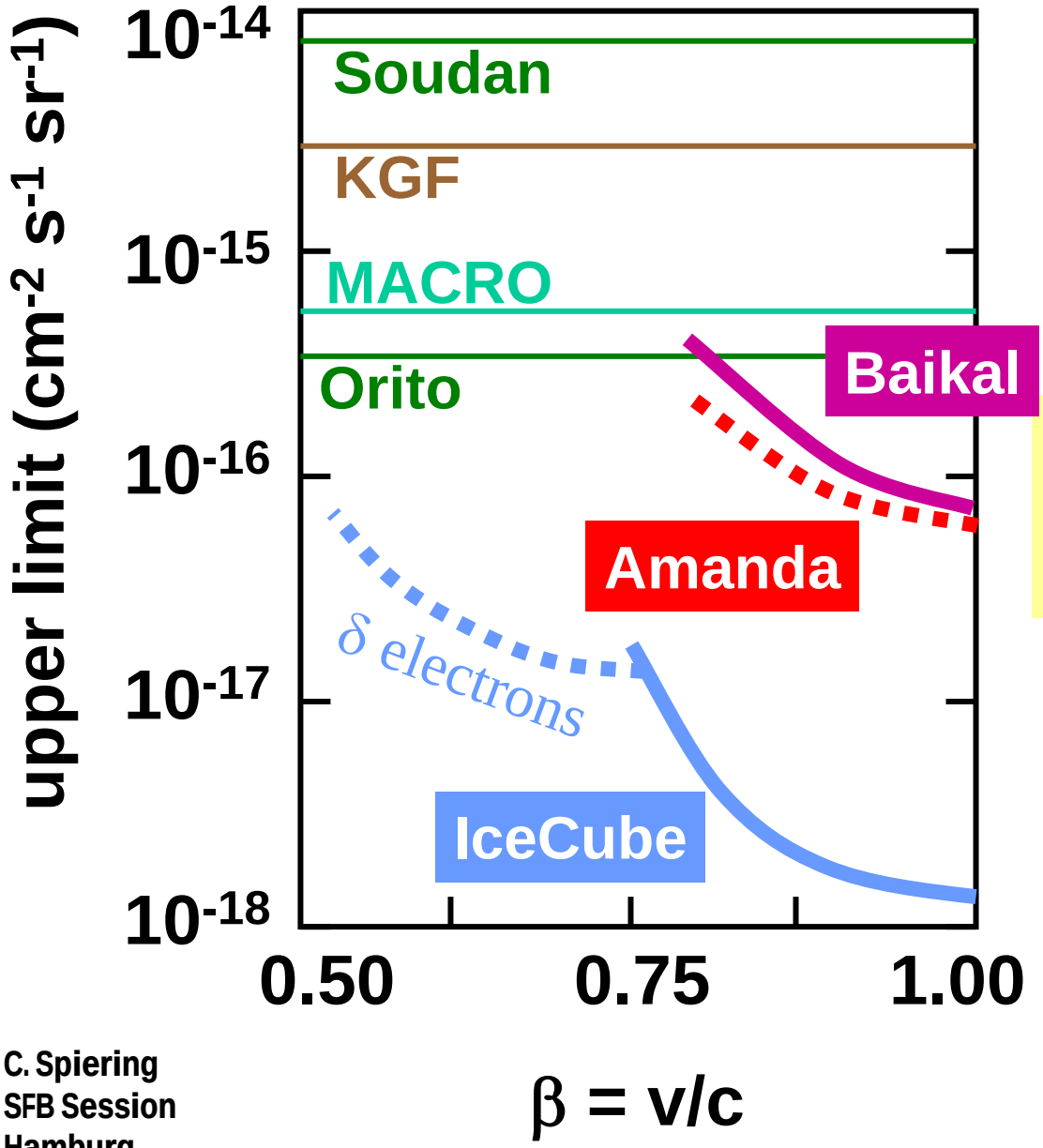
Relativistic Magnetic Monopoles



Cherenkov-Light $\propto$

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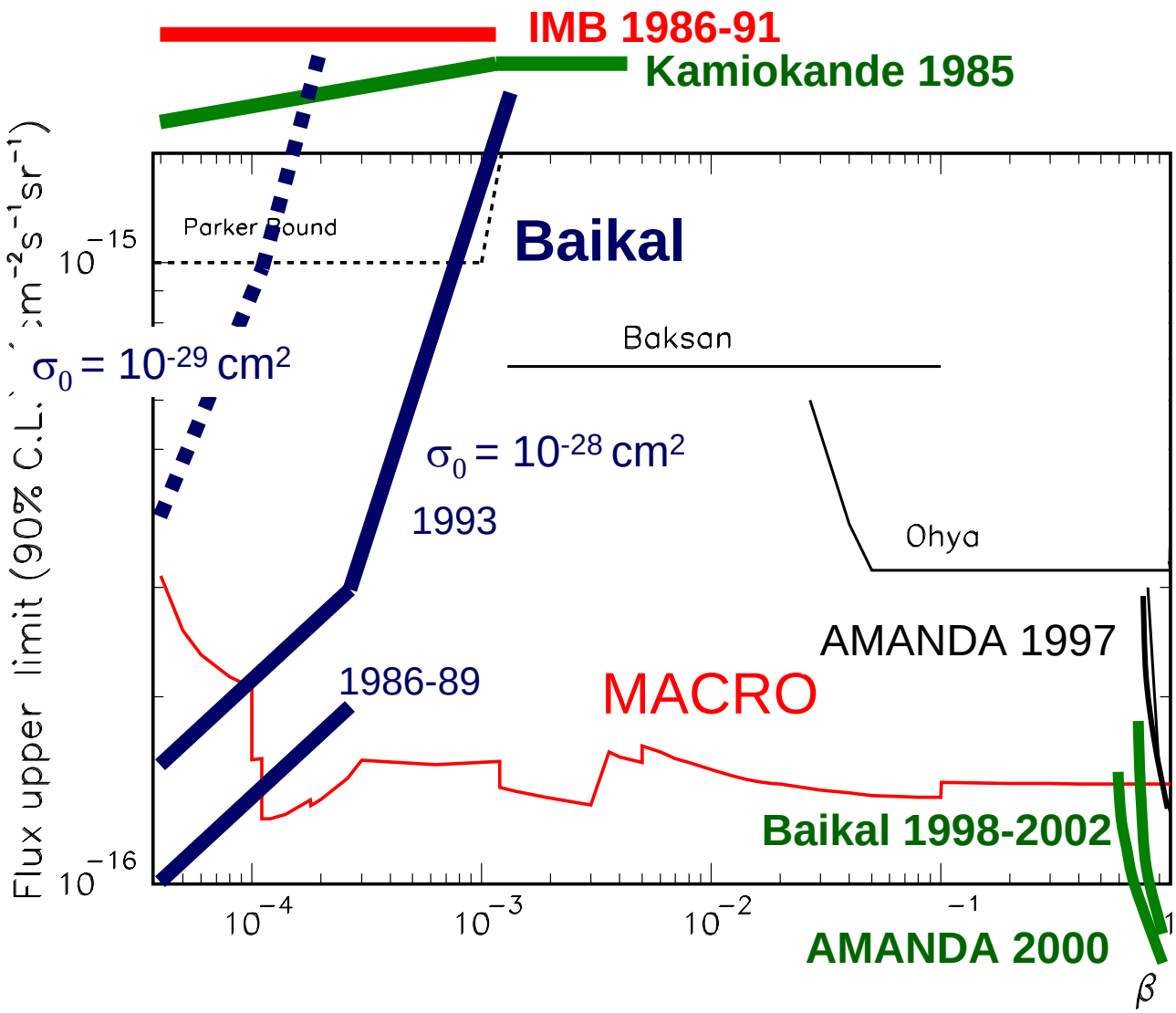
Flux upper limits for Magnetic Monopoles



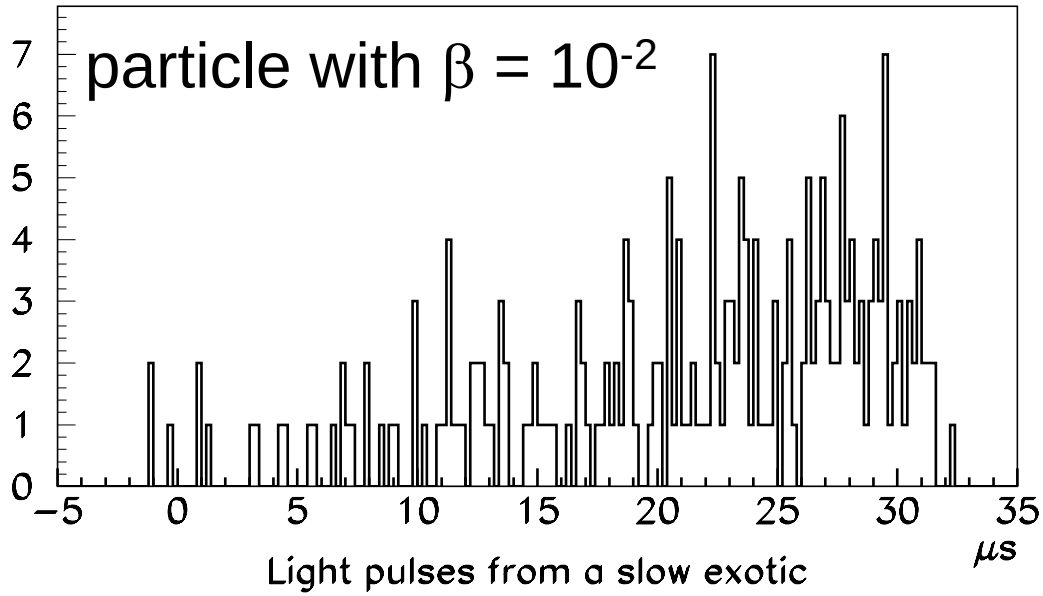
NUCLEARITES (Strange Quark Matter+electrons)

- Aggregates of u, d, s quarks + electrons
- Stable for baryon number $\sim 300 < A < 10^{57}$
- $\rho_N \sim 3.5 \times 10^{14}$ g cm^{-3} ($\rho_{nuclei} \sim 10^{14}$ g cm^{-3})
- Produced in Early Universe, candidates for sub-dominant dark matter
- May be produced also in neutron stars
- Light generation via Planck radiation
- Virial velocities

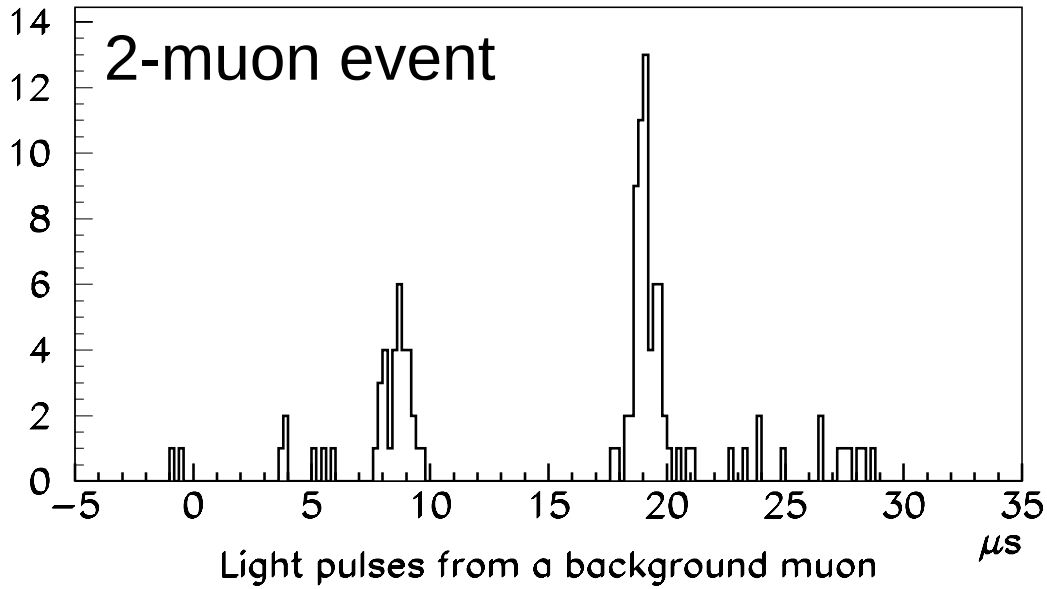
Supersymmetric Q-balls

- Coherent states of squarks, sleptons and Higgs fields
- $10^8 < M_Q\ 10^{25}$ GeV
- Produced in Early Universe, candidates for sub-dominant dark matter
- Light generation via ionization or catalysis of proton decay
- Virial velocities

Slow Particles in AMANDA / IceCube



$\beta \geq 5\times10^{-3}$: elongated events



Slow Particles in AMANDA / IceCube

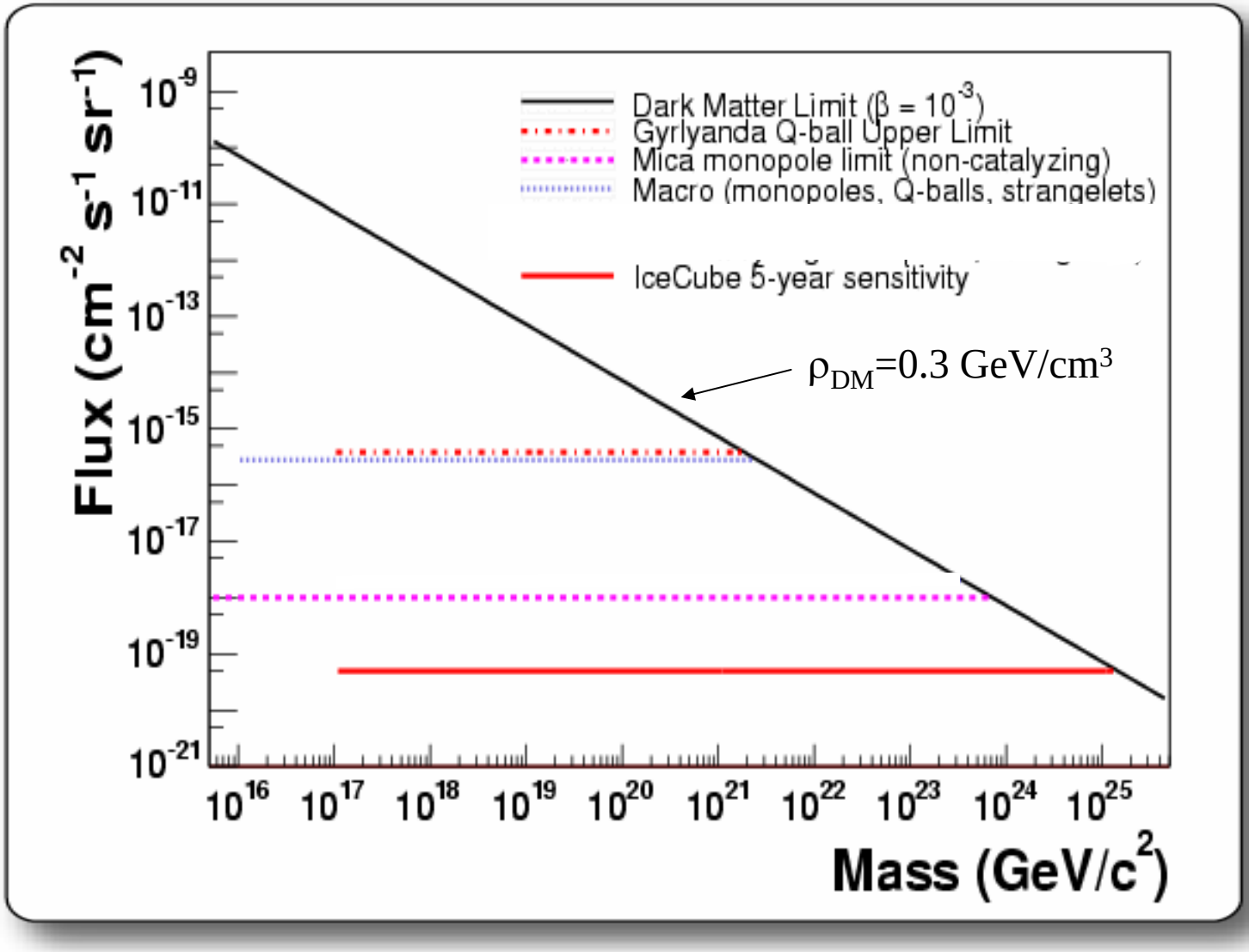
$\beta \sim 10^{-5} - 10^{-4}$

- increased counting rates of individual PMs (msec windows, “Supernova Trigger”)

  or

- several sequential events aligned along a straight path

Upper limits on Q-Balls and Nuclearites



Plans

- Expect postdoc in January
- Only IceCube, not AMANDA
- Decision slow vs. relativistic
- If slow, decision which method:
  - Elongated events
  - Supernova trigger
  - Sequential events
- Start analysis with 21-string IceCube