How A “Surface” Array At DUSEL Can Help

1. in the dark matter detection

~~2. in neutrino experiments~~

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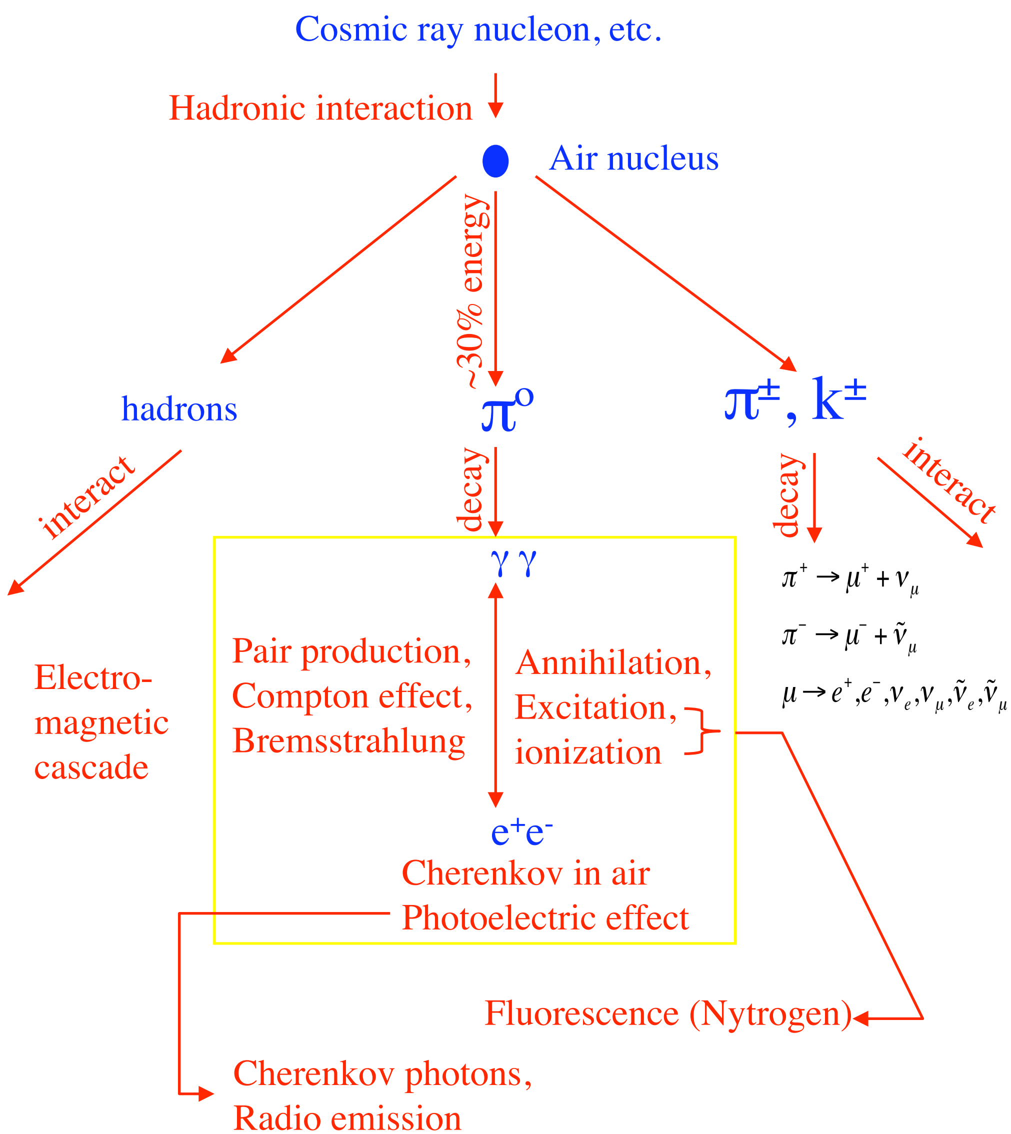
Contents

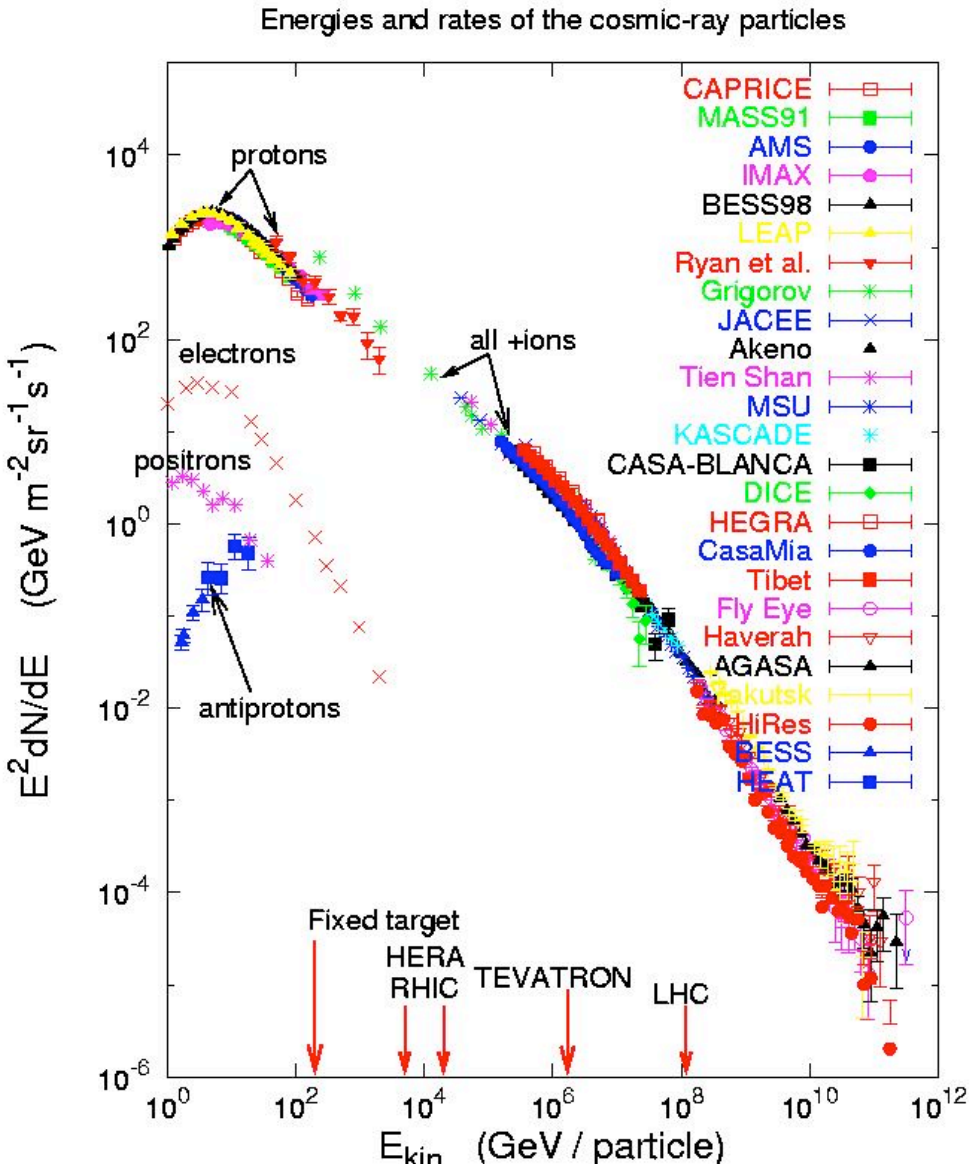
- **Cosmic rays: what we know and what we don't**
- **Uncertainties associated with CRs:**
  - **Interactions (underground background estimation and "control")**
  - **Neutrinos**
  - **Long term modulations**
  - **Non-isotropy in cosmic ray arrival directions (dark matter distribution, the position and moving direction of the Earth)**
- **One easy solution – EAS array on the surface**

Cosmic Rays, EAS & EAS Array



1. CRs were discovered ~100 years ago
2. Many discoveries were made in CR experiments

CRs: Knowns & Unknowns & TBC

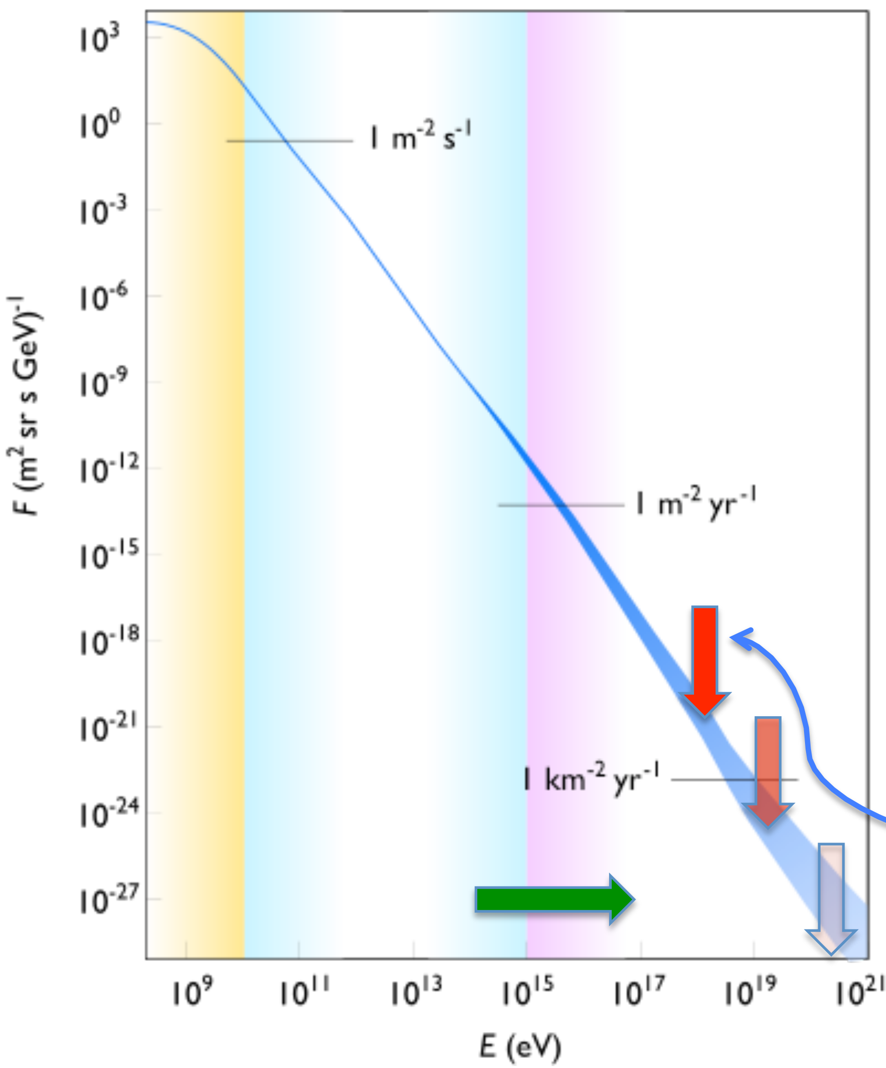


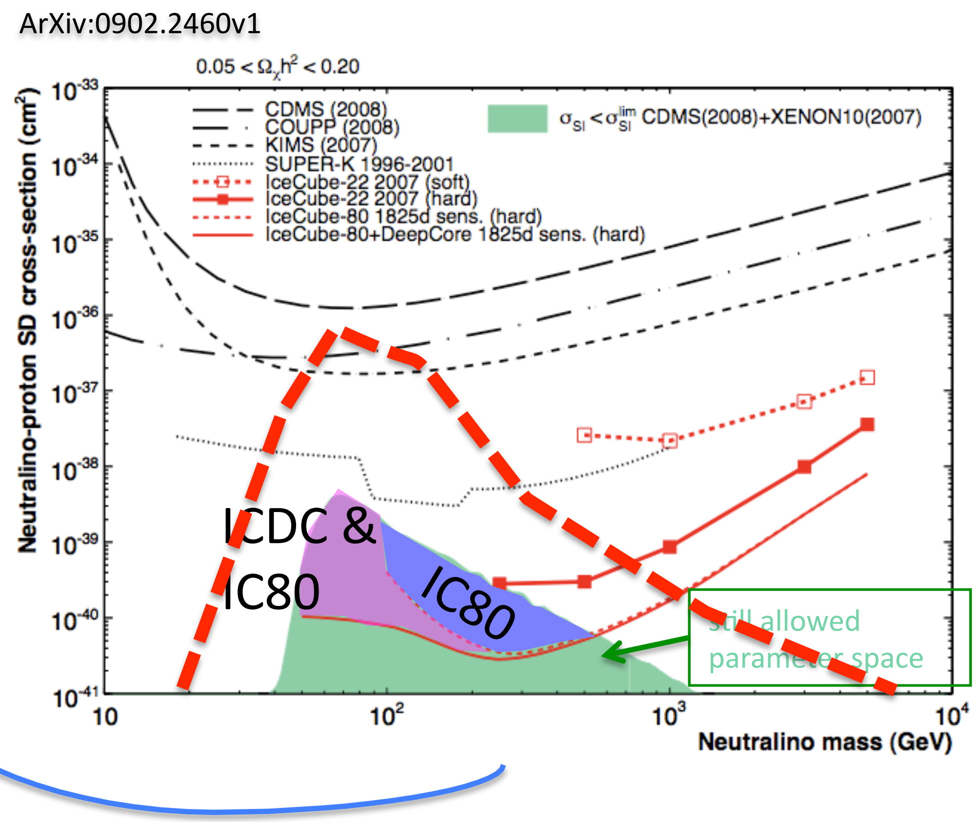
1. HE CRs are NOT DM (mainly ions)
2. Covers huge energy range
3. Power law spectrum
4. Knee
5. Ankle

- Compositions at high energies
- The source for high energy CRs
- Long term correlation with astrophysical phenomena
- Interactions at high energies
- Cut-off at the end?

CR μ contamination in dark mater detection

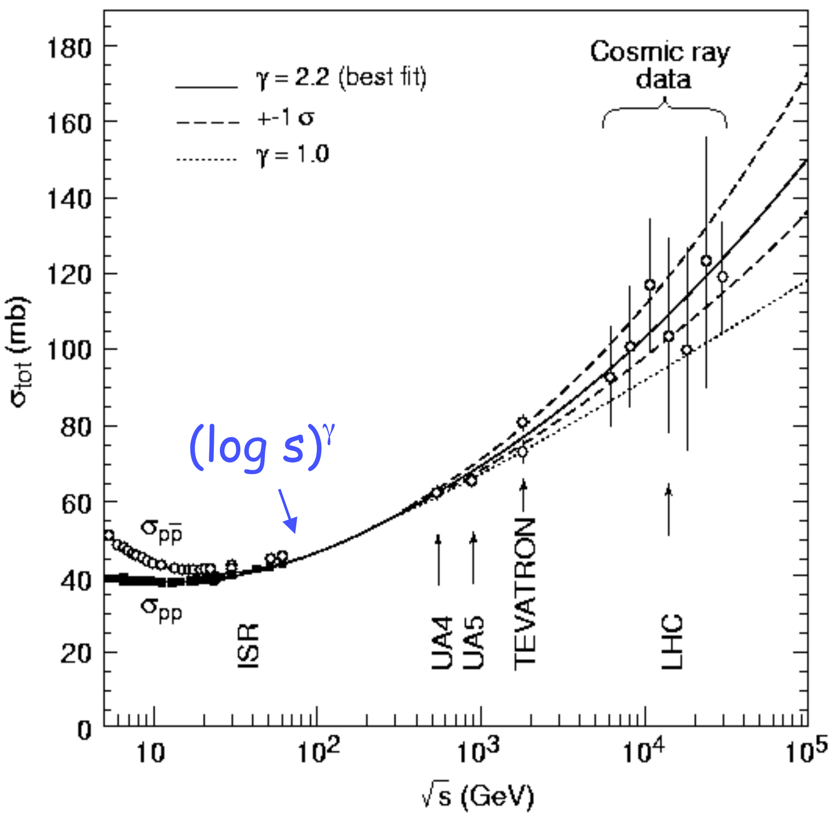
CR Rates & dark matter signals



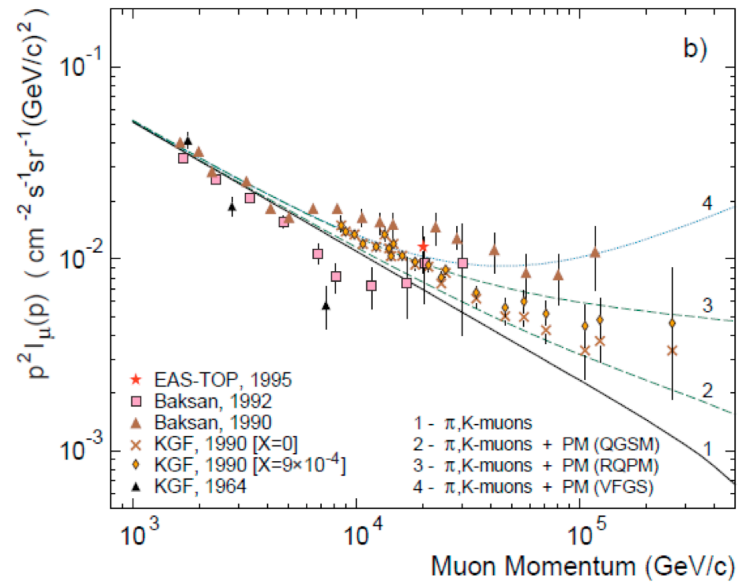


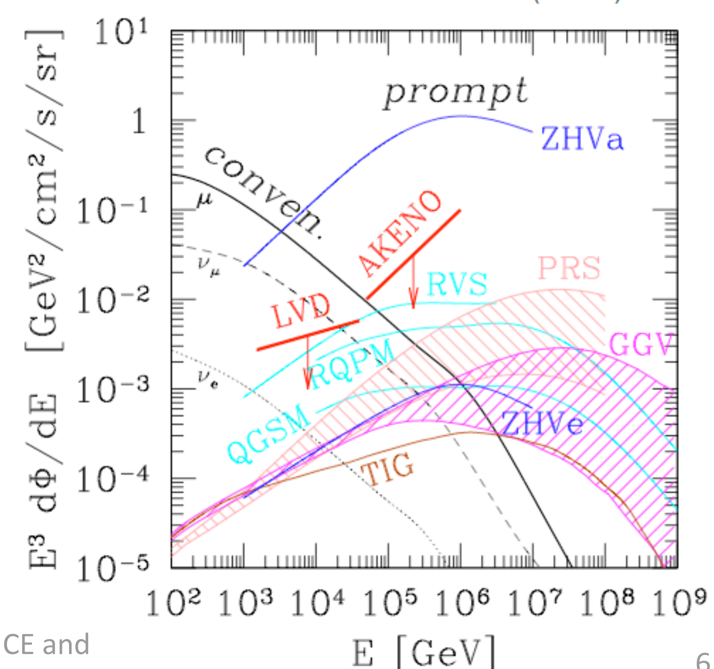
Uncertainties: CR Interactions, HE μ production

The p-p total cross-section



James L. Pinfold, IVECHRI 2006, 14





Uncertainties: μ interactions (propagation)

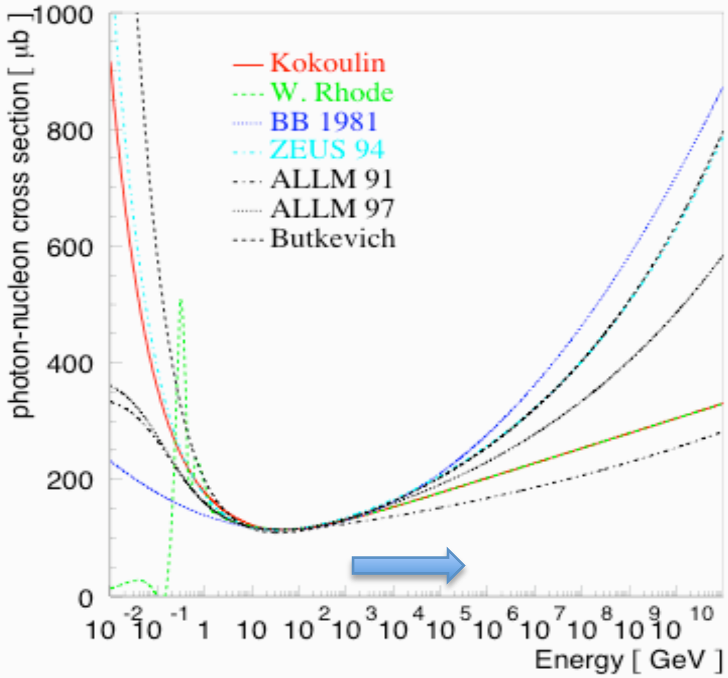


Fig. 37. Photon-nucleon cross sections, as described in the text: Kokoulin [43], W. Rhode [44], BB 1981 [45], ZEUS 94 [46], ALLM 91 and 97 [47], Butkevich [48]. Curves 5-7 are calculated according to $\sigma_{\gamma N} = \lim_{Q^2 \to 0} \frac{4\pi^2 \alpha F_2^N}{Q^2}$

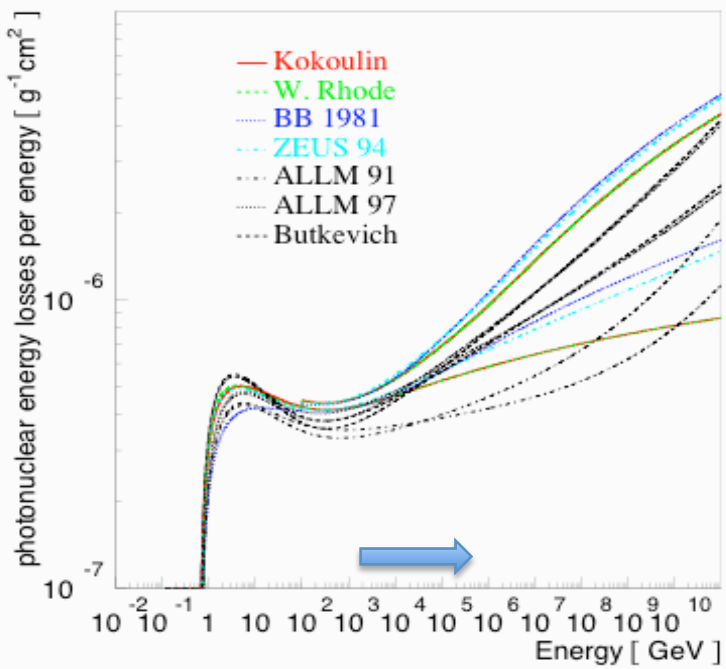
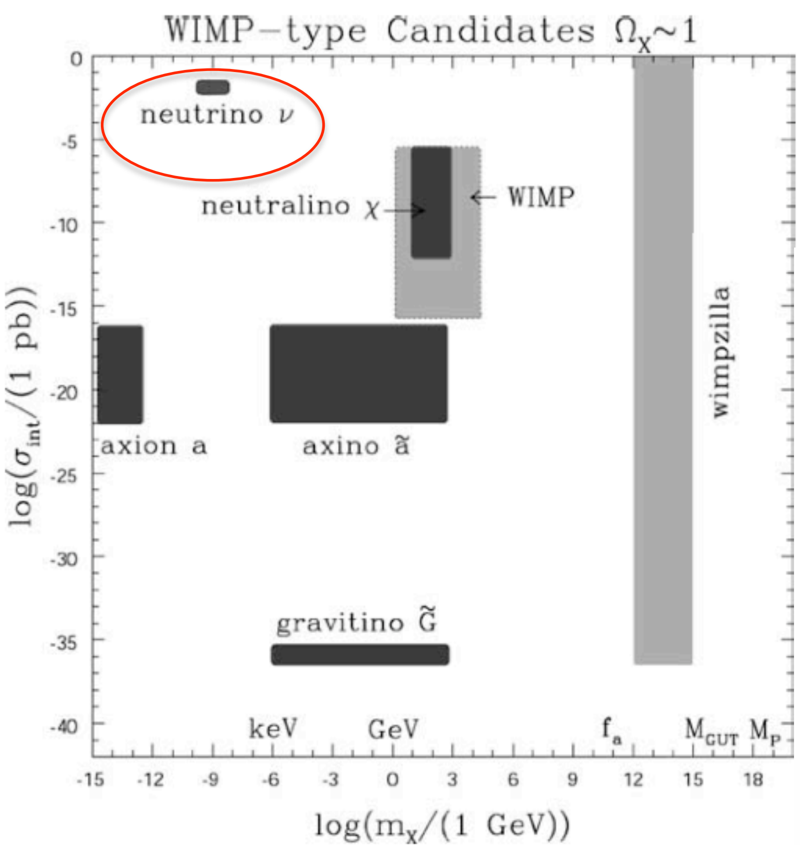


Fig. 38. Photonuclear energy losses (divided by energy), according to formulae from Section 9.3. Higher lines for the parameterizations 1-4 include the hard component [49], higher lines for 5-7 calculate shadowing effects as in Section 9.3.3, lower as in Section 9.3.2

Uncertainties: neutrinos (1)

15~20% primary energy

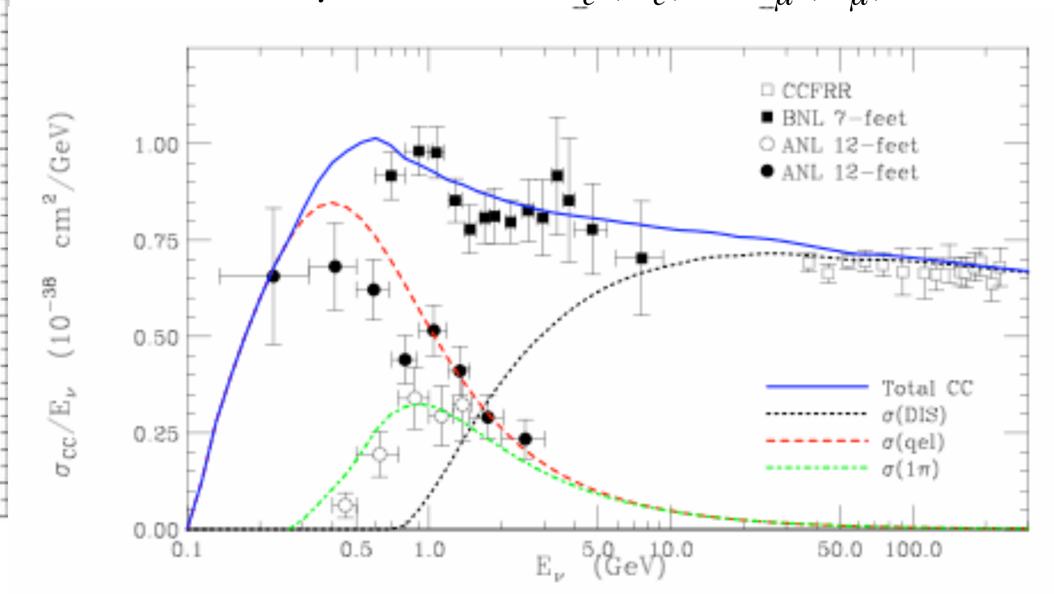


$$\pi^{\pm} \rightarrow \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu}), (\sim 100\%)$$

$$K^{\pm} \rightarrow \mu^{\pm} + \nu_{\mu}(\bar{\nu}_{\mu}), (\sim 63.5\%)$$

$$K_L \rightarrow \pi^{\pm} + e^{\pm} + \nu_e(\bar{\nu}_e), (\sim 38.7\%)$$

$$\mu^{\pm} \rightarrow e^{\pm} + \nu_e(\bar{\nu}_e) + \nu_{\mu}(\bar{\nu}_{\mu})$$



The DM density in the neighborhood of our solar system is expected to be ρ_{DM} ~ 0.3 GeV cm^{-3}.

Charged current neutrino cross section as a function of energy (in GeV):

quasi-elastic ---------

Single pion ---------

Deep inelastic ---------

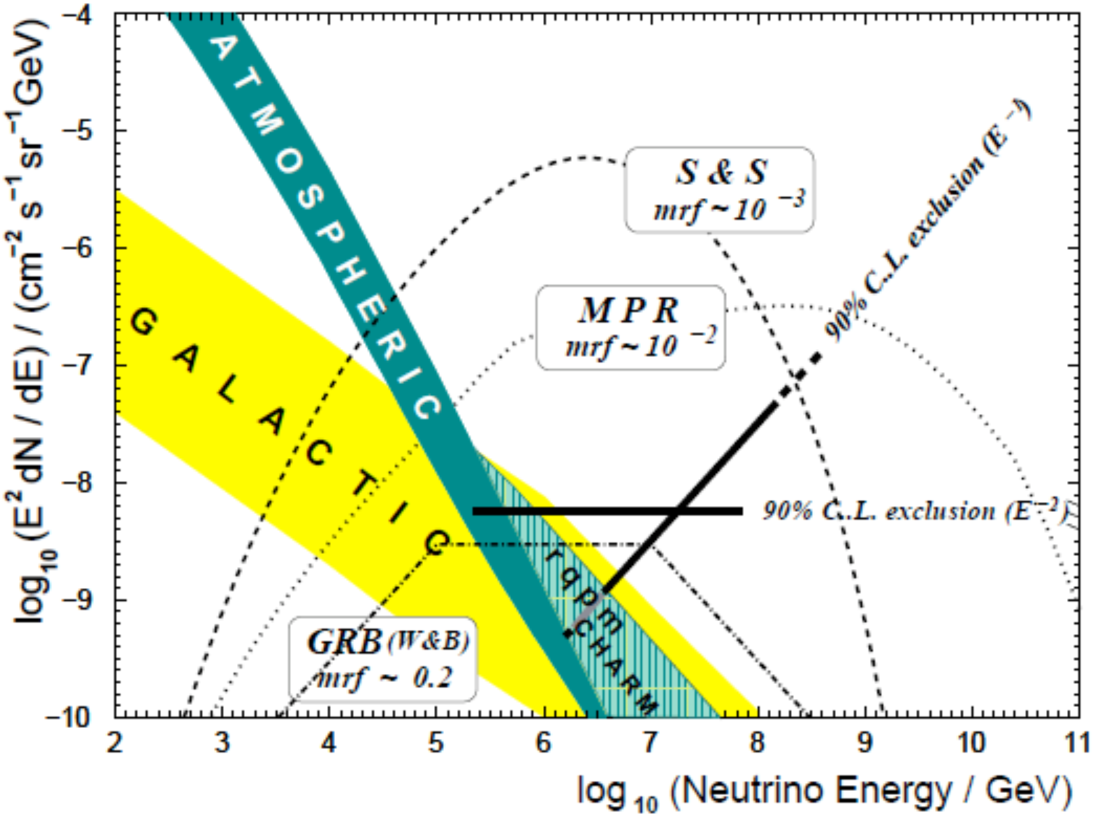
1 b = 10^{-28} m^2

1 pb = 10^{-40} m^2

Uncertainties: neutrinos (2)

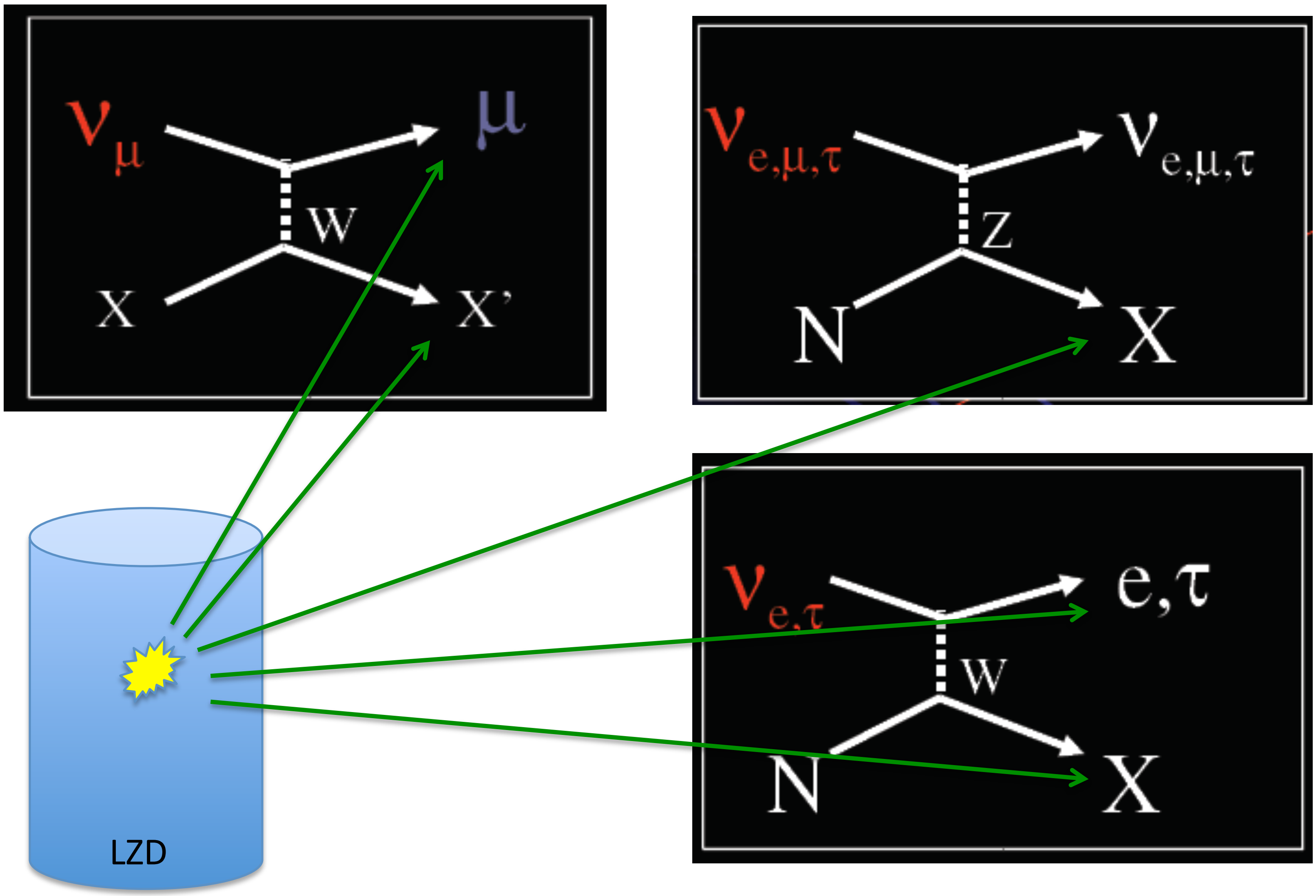
$$\frac{d^2\Phi_{\nu\mu}}{d\Omega\, dE_\nu} \simeq 0.0286 E_\nu^{-2.7}\left(\frac{1}{1+\frac{6E_\nu\cos(\theta)}{115\ \mathrm{GeV}}}+\frac{0.213}{1+\frac{1.44E_\nu\cos(\theta)}{850\ \mathrm{GeV}}}\right)(\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}\,\mathrm{GeV}^{-1}),$$

1. Fold it with the neutrino cross section → interaction rate is ~1 events/ton/year (on ^{16}O)
2. *Mainly by quasi-elastic nuclear scattering.*
3. *There is no good way to reject this background.*

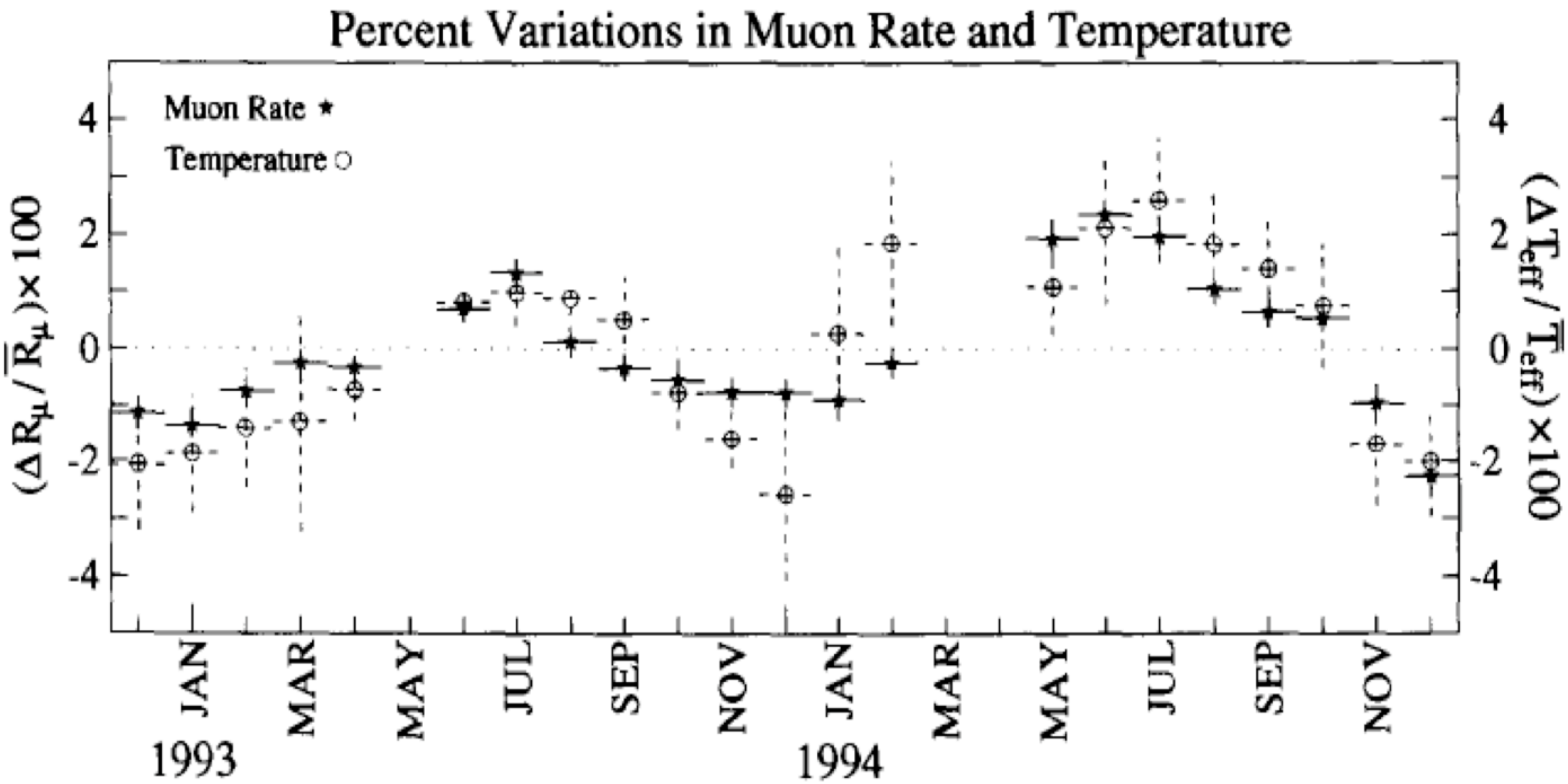


Uncertainties: neutrinos (3)

- CC-ν_μ interactions
- NC-ν and CC-ν_e/ν_τ interactions



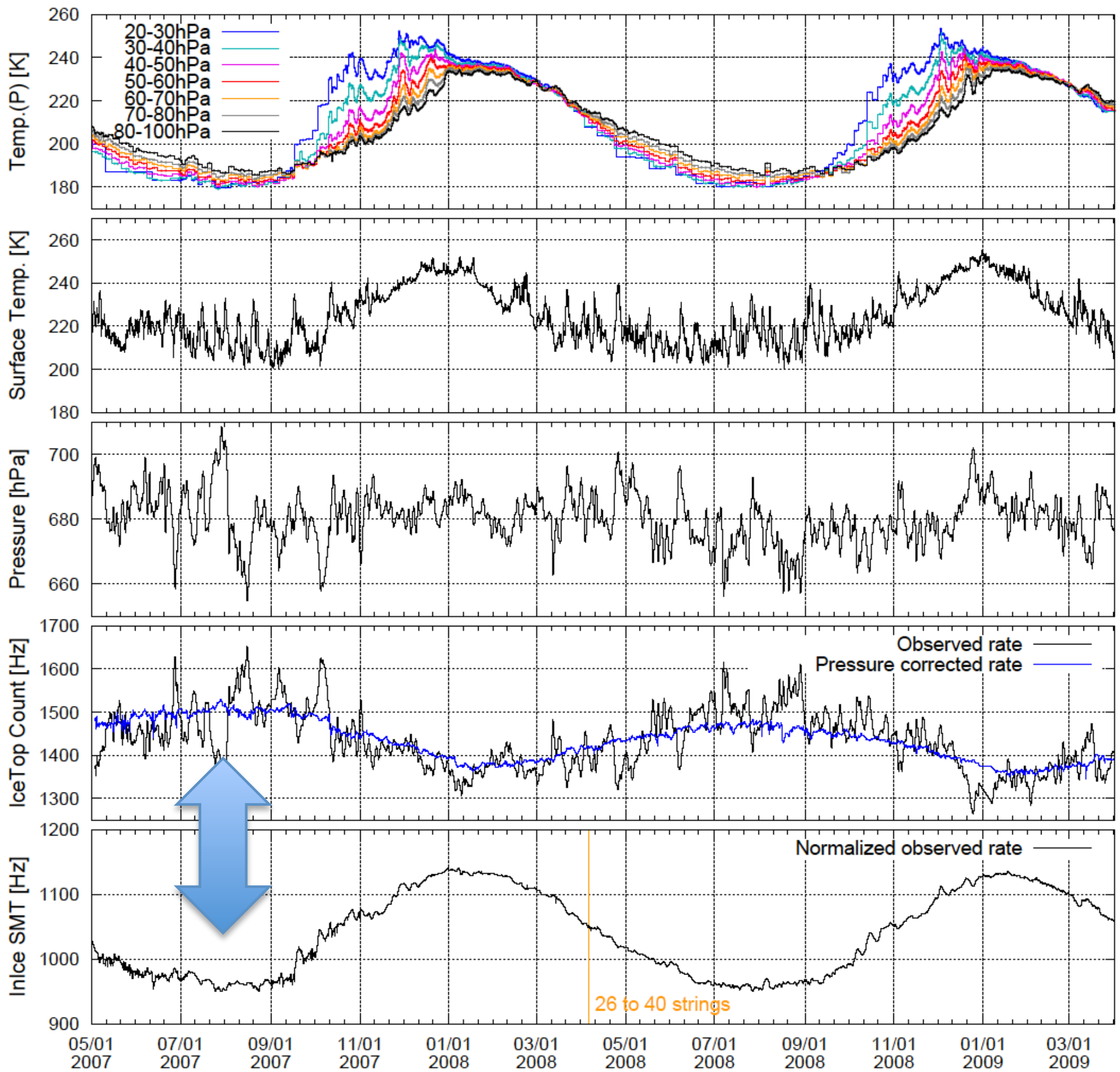
Long term behavior(1): Seasonal modulation in MACRO



$$T_{eff} = \frac{\int T(X)[\exp(-X/\Lambda_\pi) - \exp(-X/\Lambda_N)]dX/X}{\int [\exp(-X/\Lambda_\pi) - \exp(-X/\Lambda_N)]dX/X} \approx \frac{\sum_i [T(X_i)/X_i][\exp(-X_i/\Lambda_\pi) - \exp(-X_i/\Lambda_N)]}{\sum_i [1/X_i][\exp(-X_i/\Lambda_\pi) - \exp(-X_i/\Lambda_N)]}$$

atmosphere attenuation lengths for pions and nucleons

Long term behavior(2): Seasonal modulation in IceCube



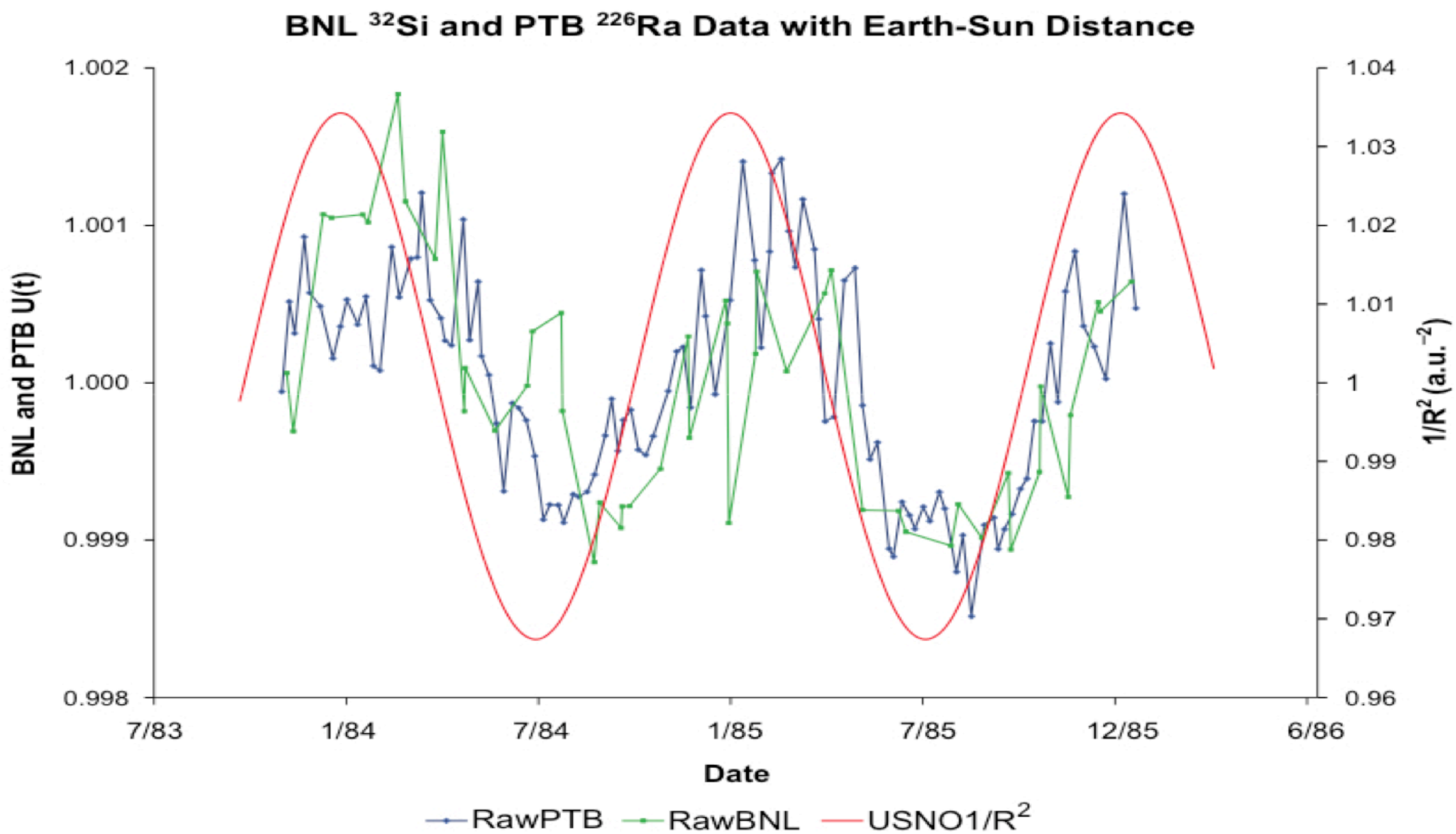
- Upper atmospheric temperature from balloon observation at different pressure level from 20hPa(~25,000m) to100hPa(~15,000m)
- Surface temperature (-75~-25°C)
- Surface pressure (average value is P_0=680hPa)
- IceTop count rate at DOM 74-63 pressure uncorrected, corrected

$$I^{corr} = I^{obs} \exp(-\beta(P - P_0))$$

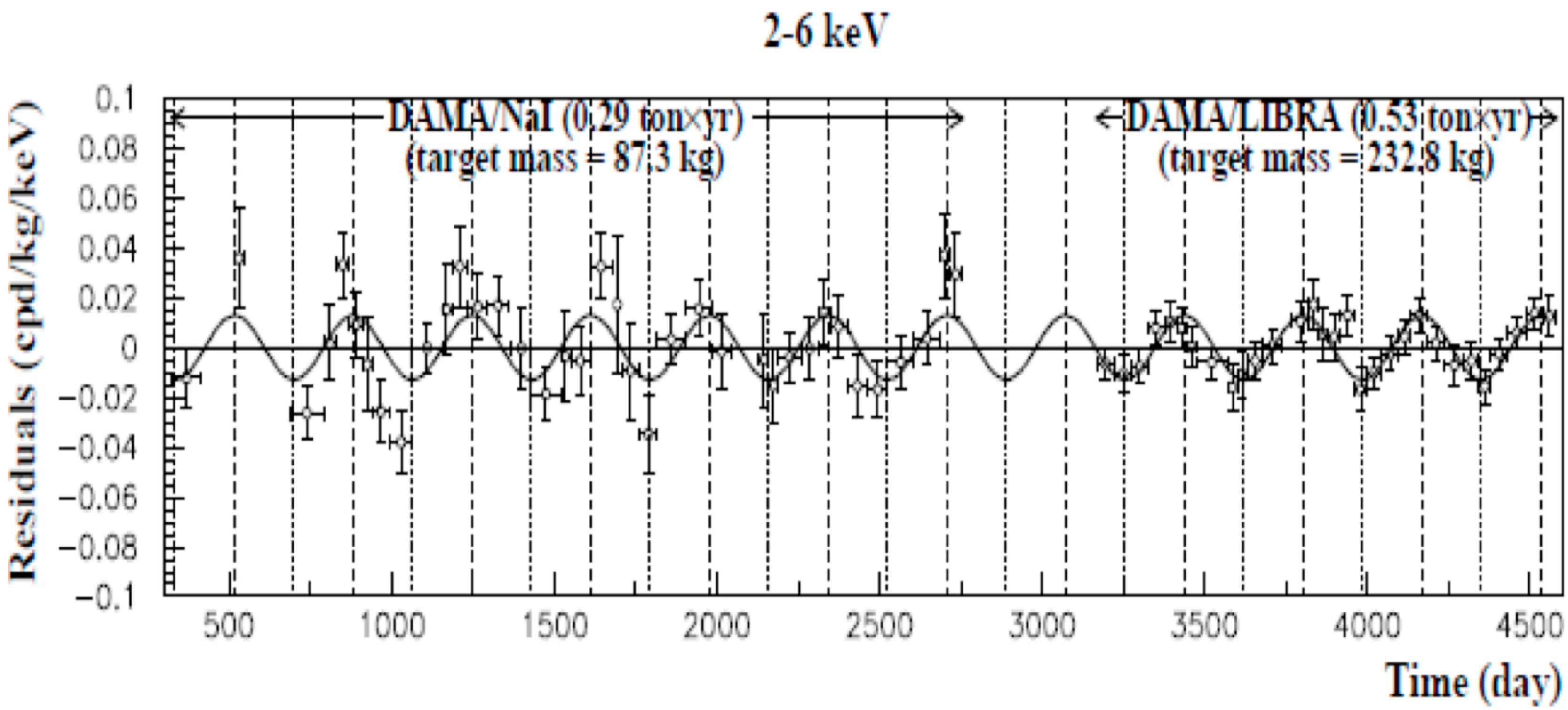
$$\beta = -0.42[\%/\text{hPa}]$$

- InIce SMT rate data during IC-26 is normalized to IC-40 level

Long term behavior(3): Nuclear decay rates



Long term behavior(4): Seasonal modulation in DAMA



No comments

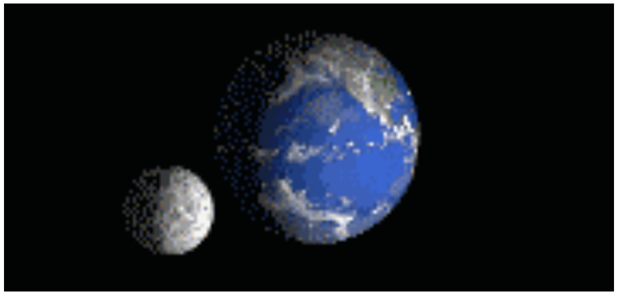
average 1400 m rock coverage

Uncertainties: CR Large scale anisotropy

Some Possible Causes (~~Dark Matter~~):

- ***Uneven distribution of CR sources***
- ***Discreteness of SNRs and stellar winds***
- ***Magnetic field structures***
- ***CR transport parameters***
- ***Compton-Getting (CG) effect***
- ***Heliospheric magnetotail: tail-in enhancement***

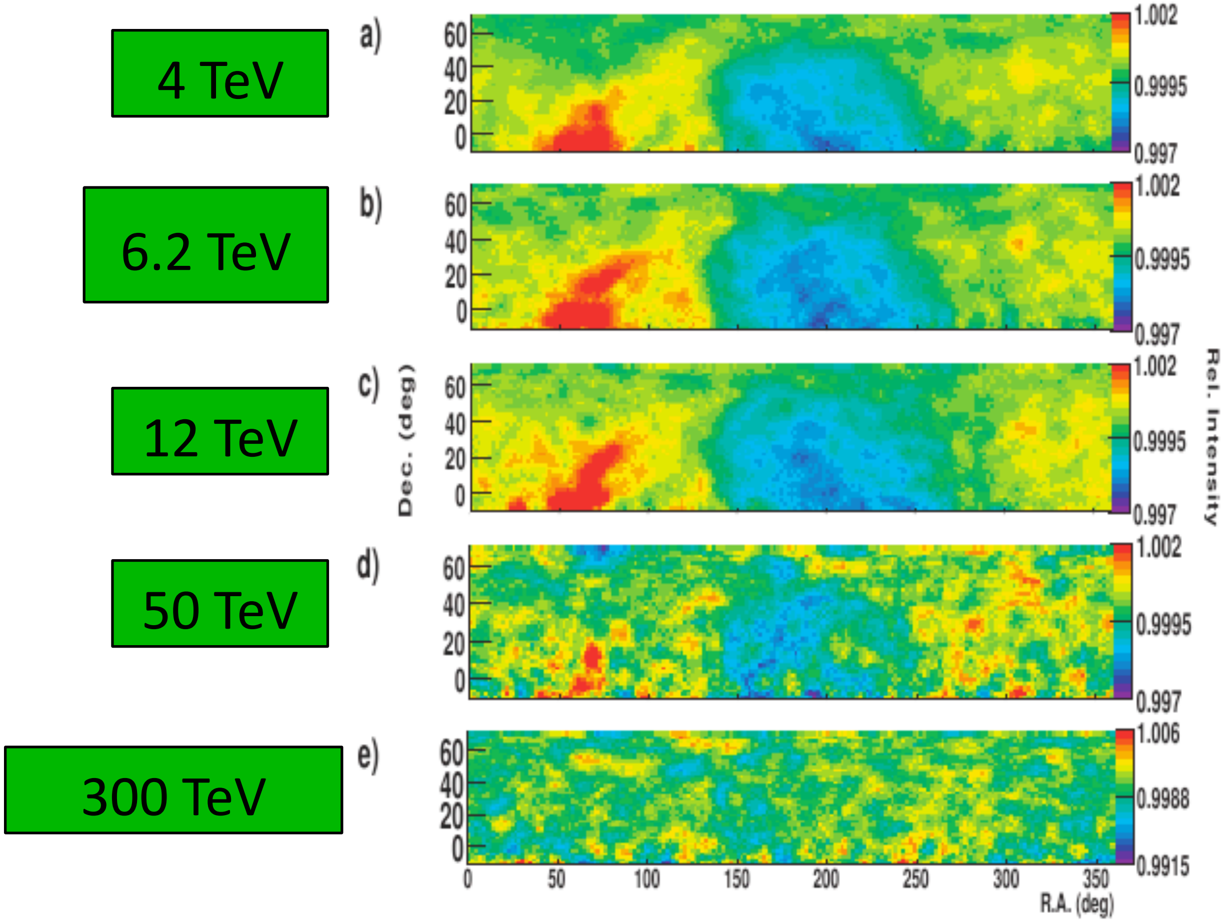
- ***Related to Dark Matter ????***



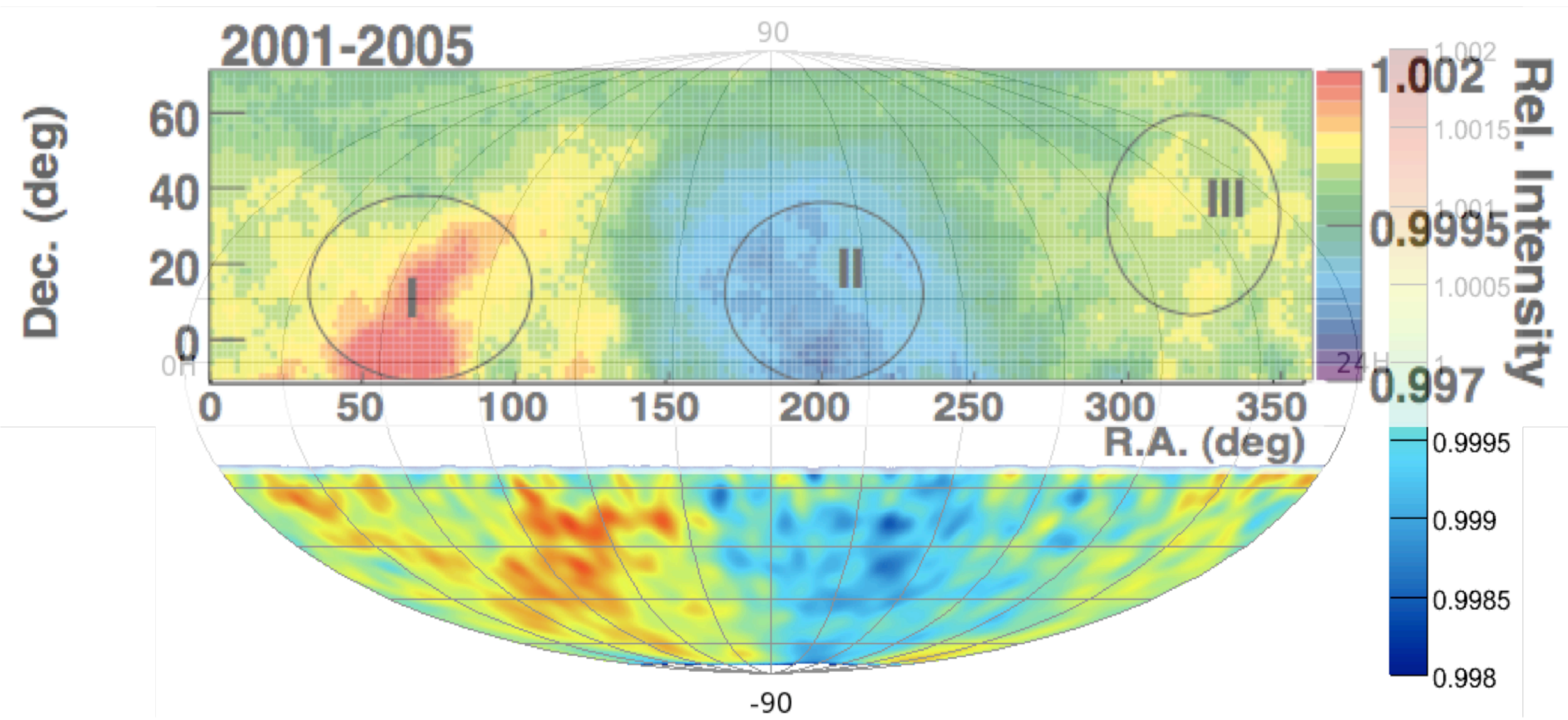
Uncertainties: Large scale anisotropy

by Tibet Array (surface array)

Science Vol. 314. no. 5798, pp. 439 - 443



More from IceCube (high energy muons)



IceCube &
Tibet Array

Ozone hole can also trick …

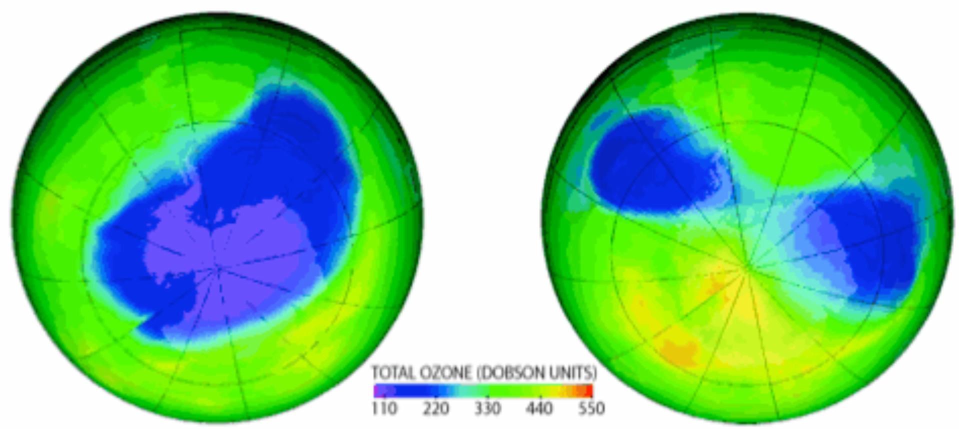
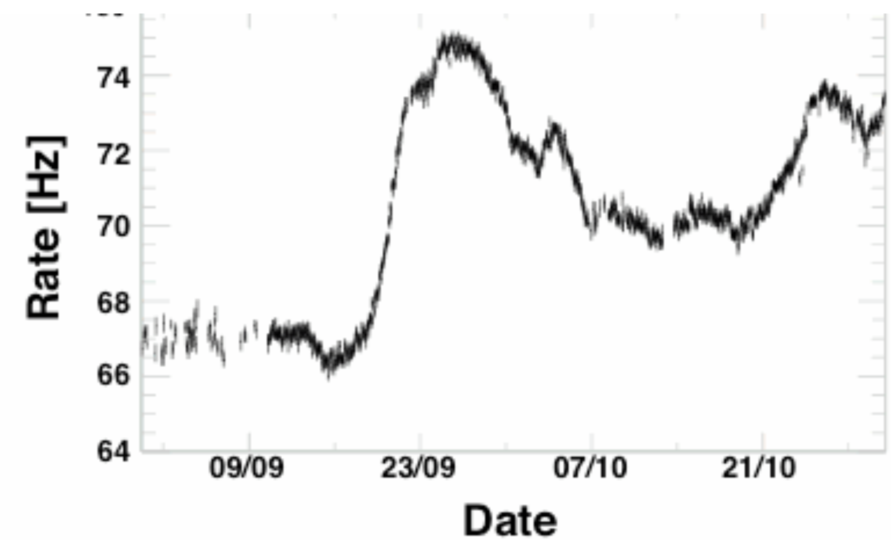
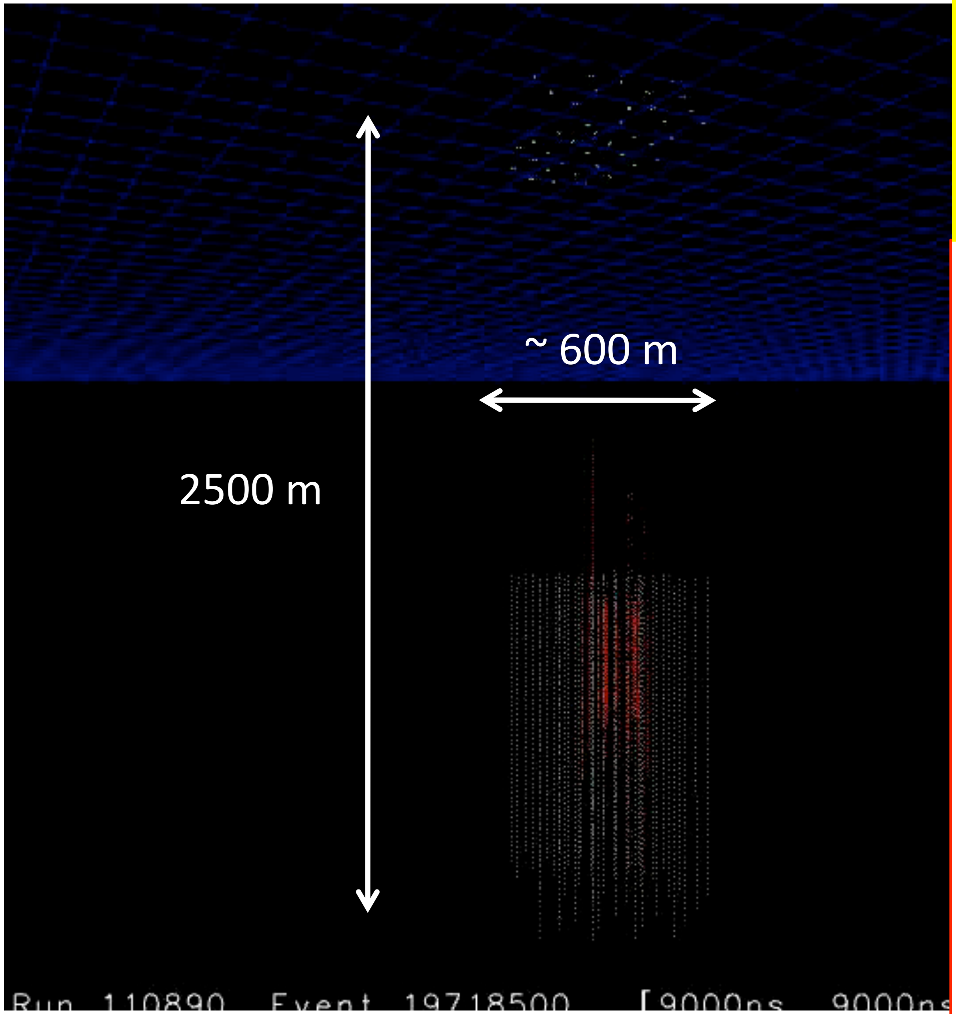


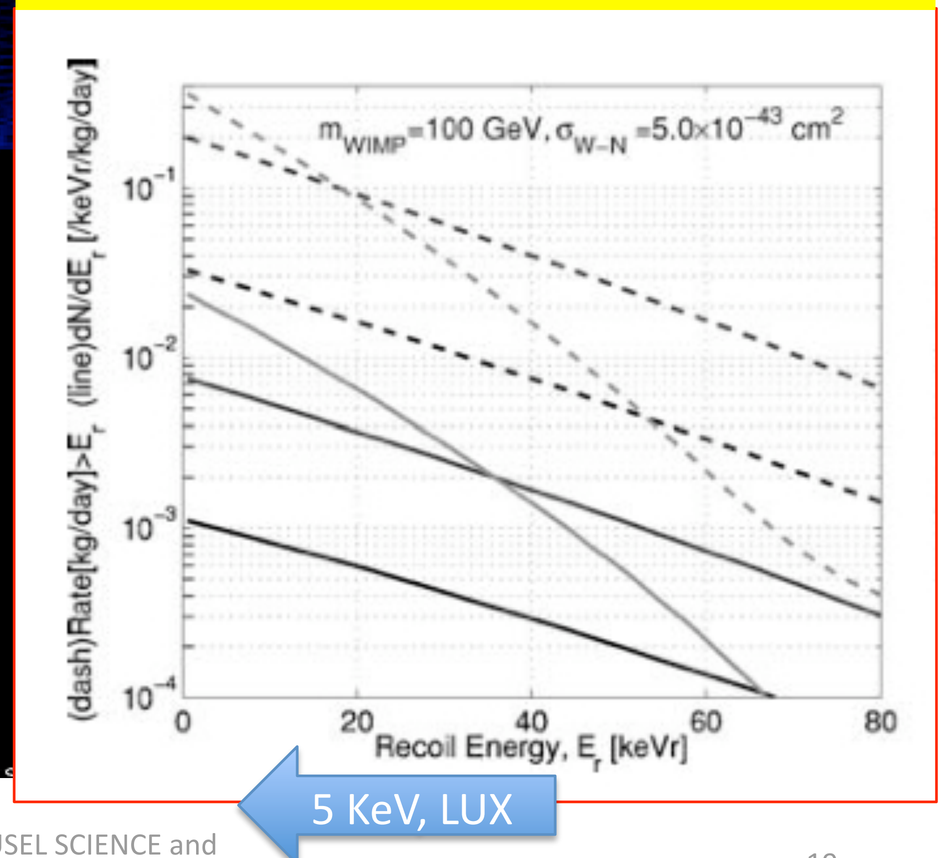
Fig. 3. Ozone concentration over the southern hemisphere on September 20th 2002 (left) and September 25th 2002 (right) [10].



How big the effect might be

Calculated differential spectrum (lines)
Integrated event rate (dashed lines)
For Xe, Ge, and S targets
100 GeV WIMP
SI cross section σ = 5 × 10− 43 cm^2 was used

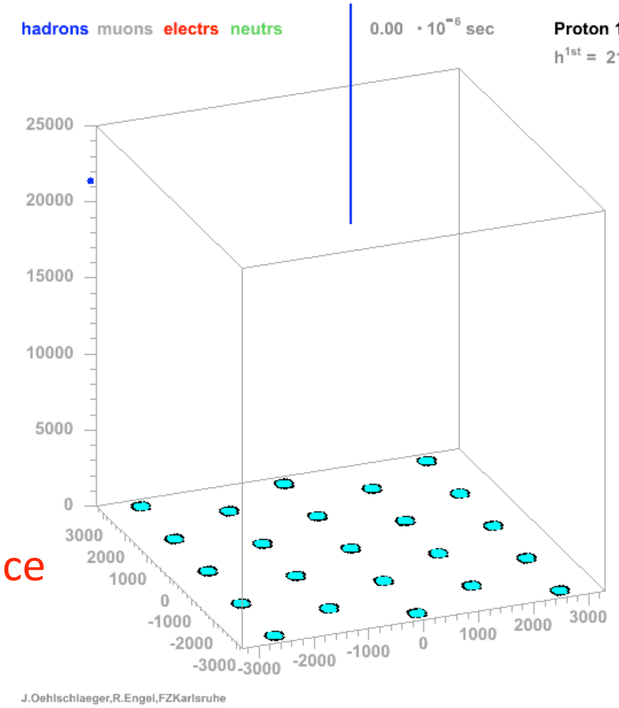




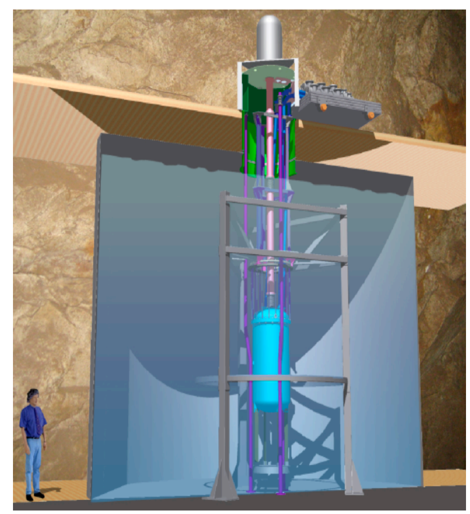
Hard DM scientists' life made easier

&

~100% trigger efficiency at the surface

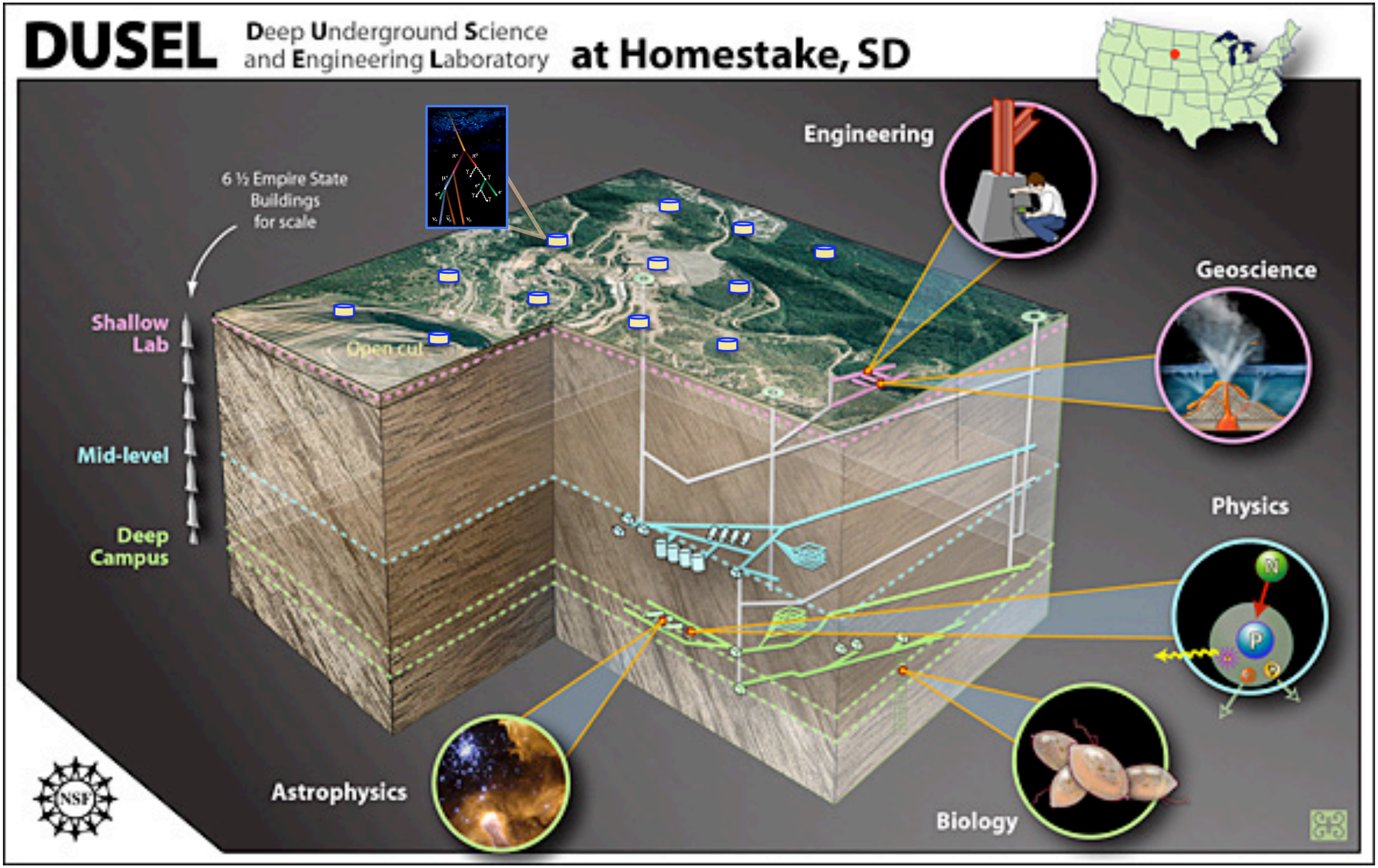


Study the CR related signals in deep underground



Available techniques

To be better …



DUSEL
Deep Underground Science and Engineering Laboratory
at Homestake, SD
6 ½ Empire State Buildings for scale
Shallow Lab
Mid-level
Deep Campus
Open cut
Engineering
Geoscience
Physics
Astrophysics
Biology
NSF