

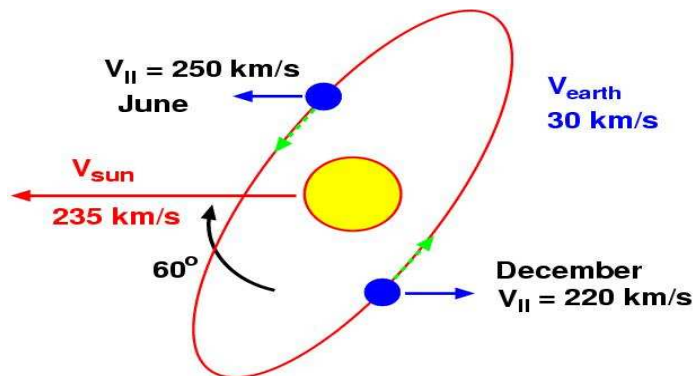
DAMA vs. the annually modulated muon background

arXiv:1110.0857v1

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Modulation annuelle

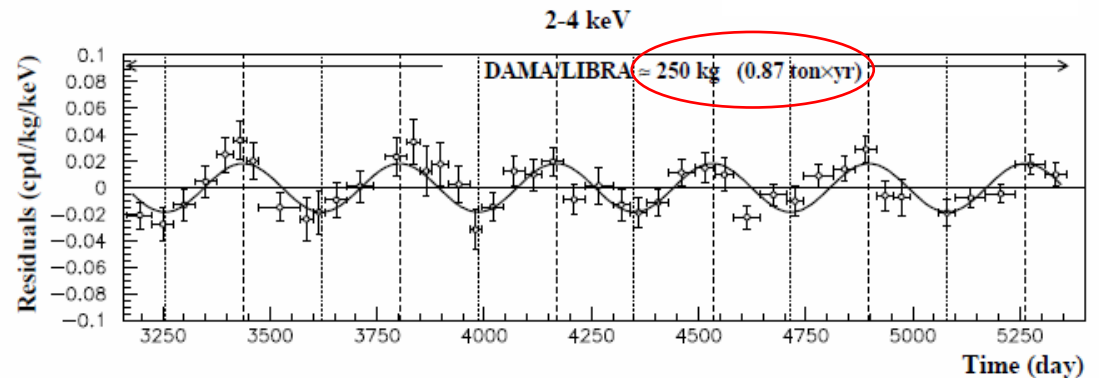


Drukier, Freese & Spergel *et al.* PRD 1986

$$R = \sigma \times \left(\frac{\rho_0}{m_\chi} \right) \times \langle v \rangle \times \frac{1}{m_N}$$

Résultat DAMA/LIBRA

arXiv:1002.1028



- 8.9 σ CL
- période = 0,999 +- 0,002 an
- phase = 146 +-7 jour (26 mai)

Zone DAMA ?

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Annual variations in the muon flux underground have been measured by many experiments [9, 10, 11, 12, 13]. Modulation was also reported for neutrons [14] which are produced, among other

MACRO → 10, 11, 12, 13
MINOS → 11, 12, 13
IceCube → 12, 13
ICARUS → 14
LVD → 14

mechanisms, through muon interactions with rock. In the northern hemisphere the muon rate peaks around June-July, close to the DAMA phase. The coincidence of the modulation in phase and amplitude motivated Refs. [6, 7] to consider underground muons and/or neutrons as a possible explanation to the DAMA signal.

DAMA vs. the annually modulated muon background

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K. Blum, arXiv:1110.0857

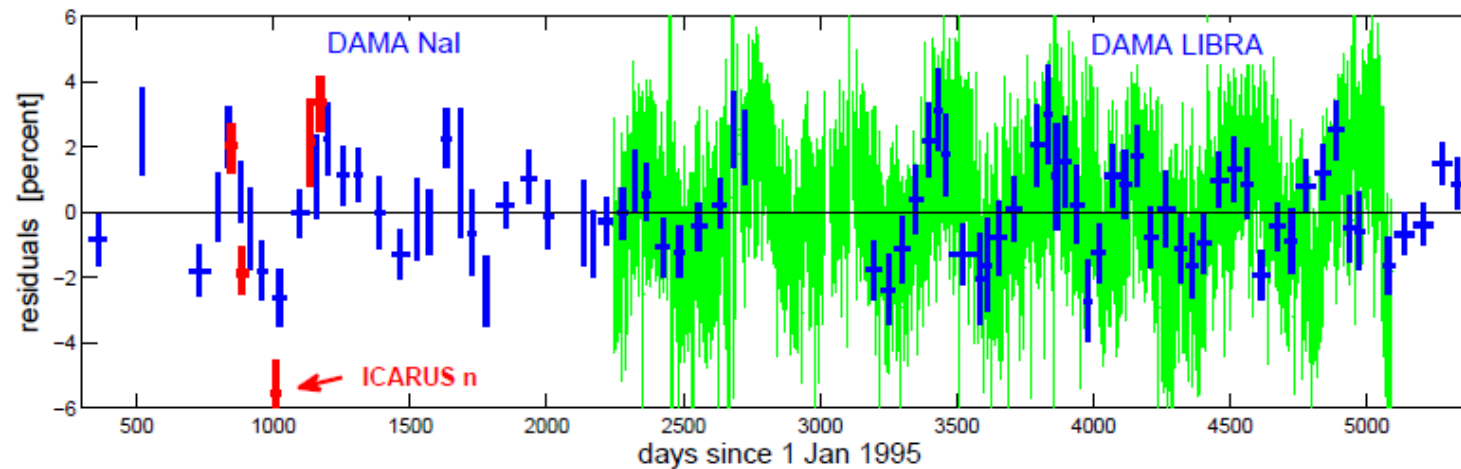
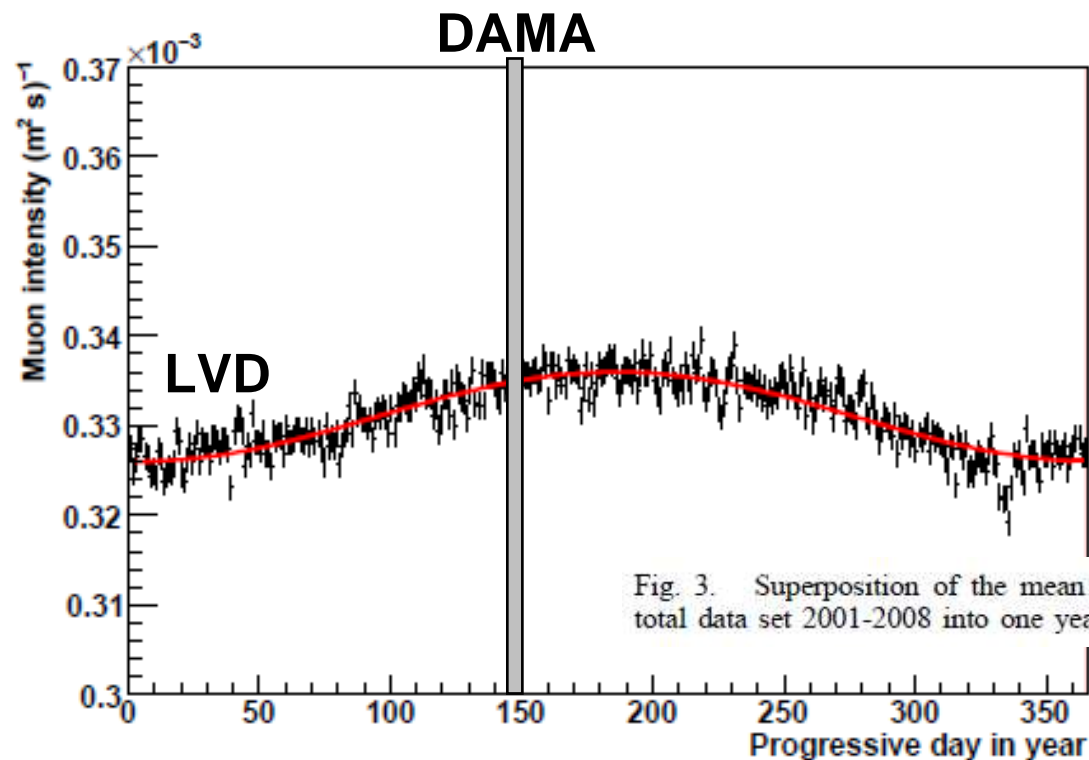


Figure 1: DAMA residuals (blue [2, 3]) and LVD muon intensity residuals (green [9]) in percent from the respective baselines. ICARUS neutron measurements during 1997-1998 are added (red [14]).

À Gran Sasso...

Phase

Analysis of the seasonal modulation of the cosmic muon flux in the LVD detector during 2001-2008. – ICRC 2009.



In quoting a $> 5\sigma$ discrepancy, DAMA ignored the reported error on the LVD muon fit. In fact, the reported LVD phase is July 5 ± 15 days. The combined DAMA/LIBRA and DAMA/NaI phase, May 26 ± 7 , is thus less than 3σ away from the muon phase.

Pourquoi une modulation pour les muons ?

P.H. Barrett et al., Rev. Mod. Phys. 24 (1952) 133.

- muons atmosphériques proviennent des pions/kaons (15 km)

$\tau(\pi^{\pm})=26$ ns

→ Désintégration π versus Interaction π (pas de muon...)

→ si T ↗ la densité locale ↘

la proba d'interaction des π ↘ le flux de muons ↗

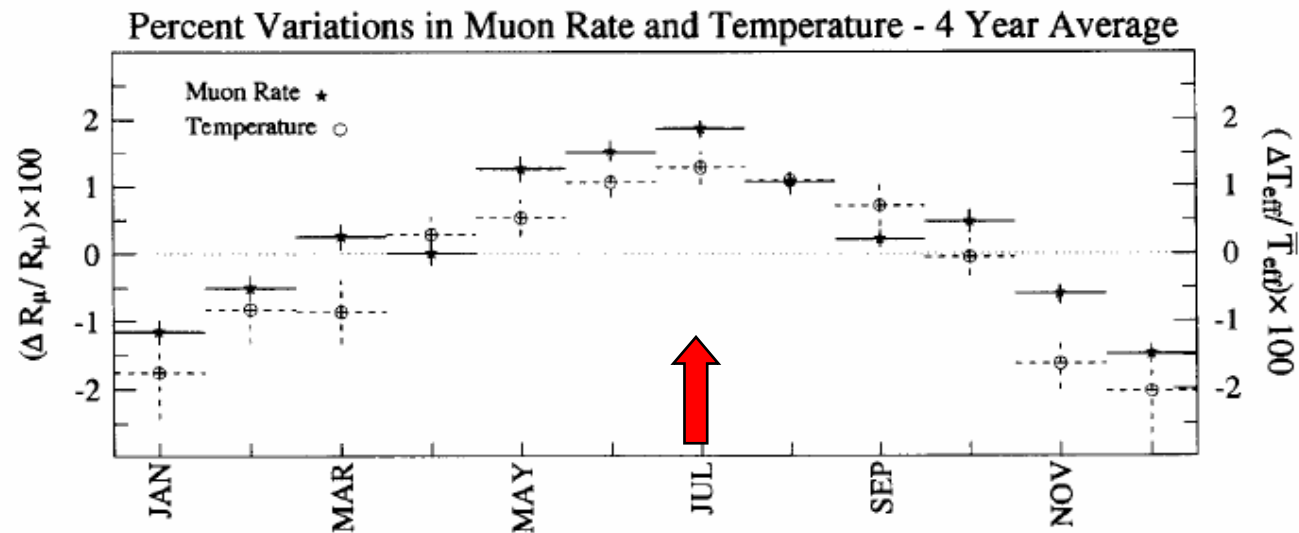
→ Dans l'hémisphère nord : maximum en été, minimum en hiver...

→ Très forte corrélation avec la température de l'atmosphère à cette altitude

$$\frac{\Delta R_{\mu}}{R_{\mu}} = \alpha_T \frac{\Delta T_{eff}}{T_{eff}},$$

Température vs muons

MACRO Collaboration/Astroparticle Physics 7 (1997) 109-124



Computation of T_{eff} . The effective temperature T_{eff} corresponds to an average of the temperature at different layers in the atmosphere, weighted by the probability for the observed muons to be formed at each layer. A useful approximate relation is given by [10]

$$T_{eff} = \frac{\int \frac{dX}{X} T(X) (e^{-X/\Lambda_\pi} - e^{-X/\Lambda_N})}{\int \frac{dX}{X} (e^{-X/\Lambda_\pi} - e^{-X/\Lambda_N})}, \quad (16)$$

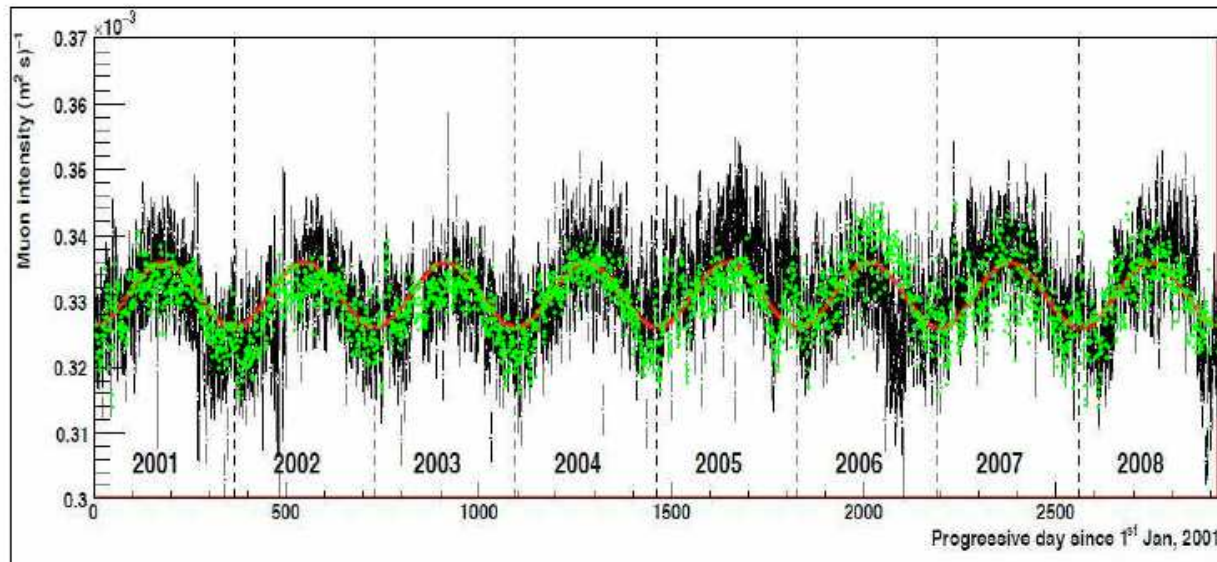
where $\Lambda_\pi = 160 \text{ gcm}^{-2}$, $\Lambda_N = 120 \text{ gcm}^{-2}$ and the integration is over the slant depth X (in units of gcm^{-2}), for which we use an approximate isothermal expression [21]

$$X(h) \approx X_0 e^{-h/h_0}, \quad X_0 = 1030 \text{ gcm}^{-2}, \quad h_0 = 6.4 \text{ km} \quad (17)$$

with h the geophysical height in km.

K. Blum, arXiv:1110.0857

Température vs muons



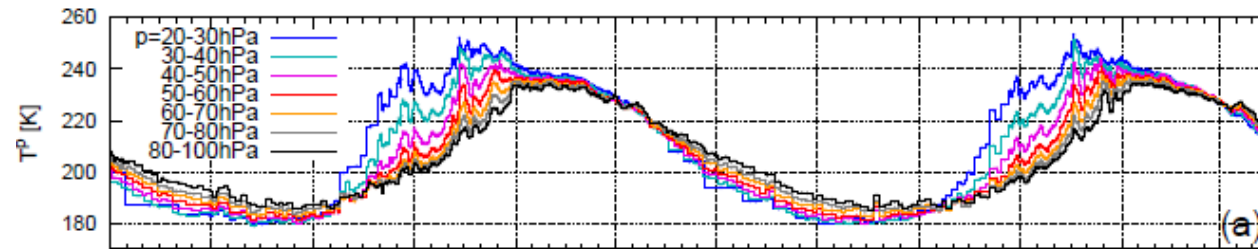
LVD

Température

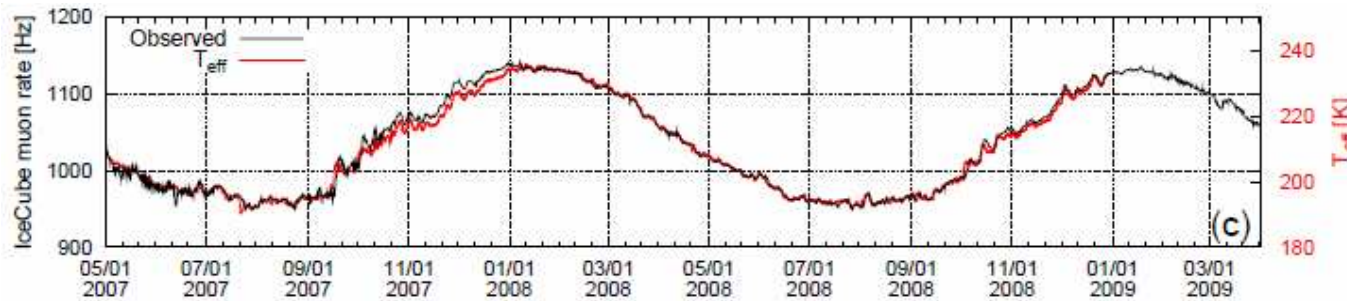
K. Blum, arXiv:1110.0857

Et dans l'hémisphère sud ?

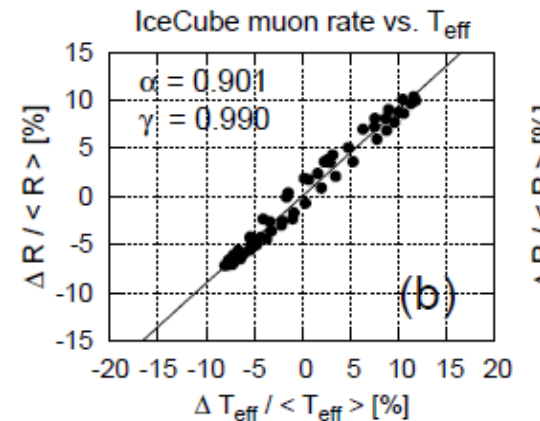
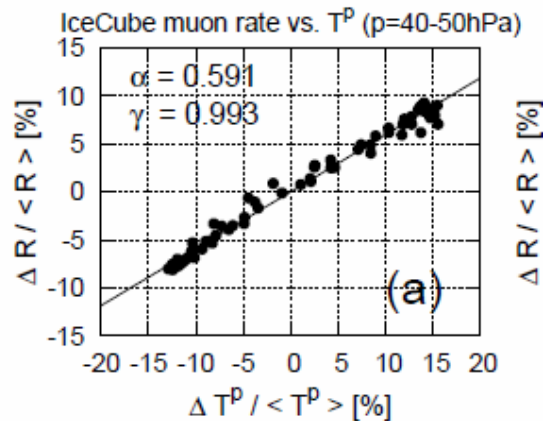
arXiv:1001.0776v2



Température

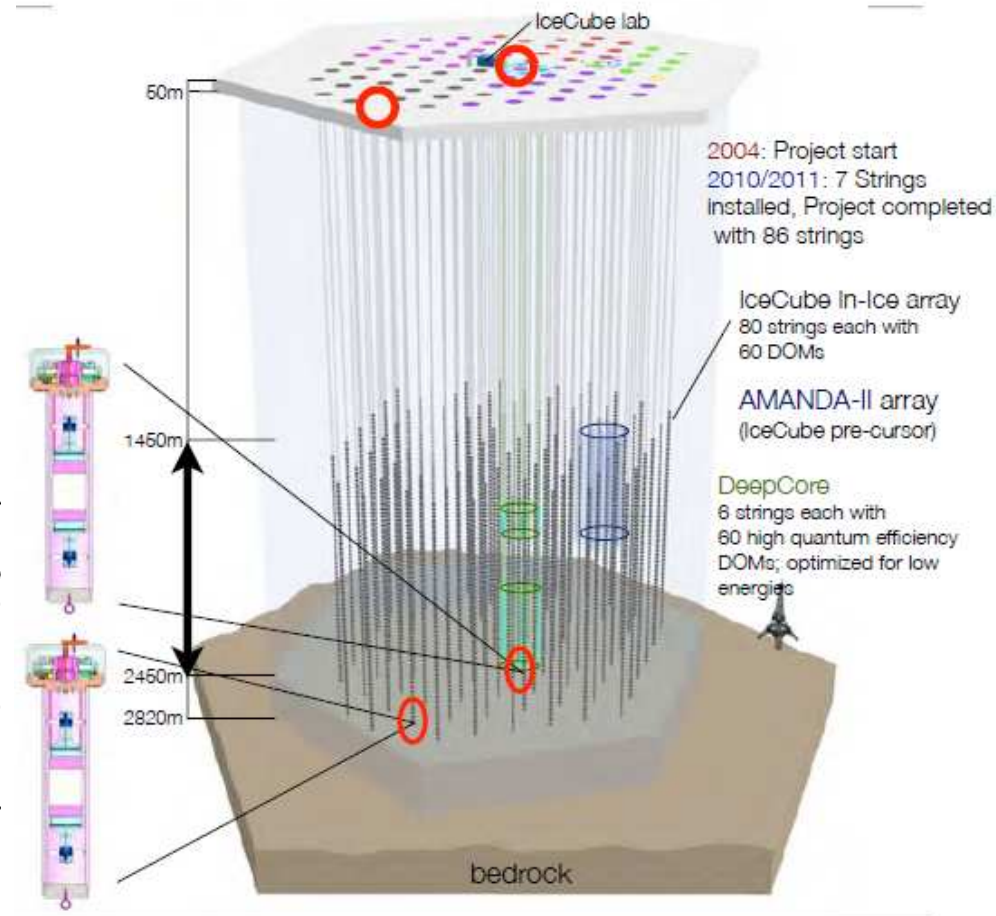
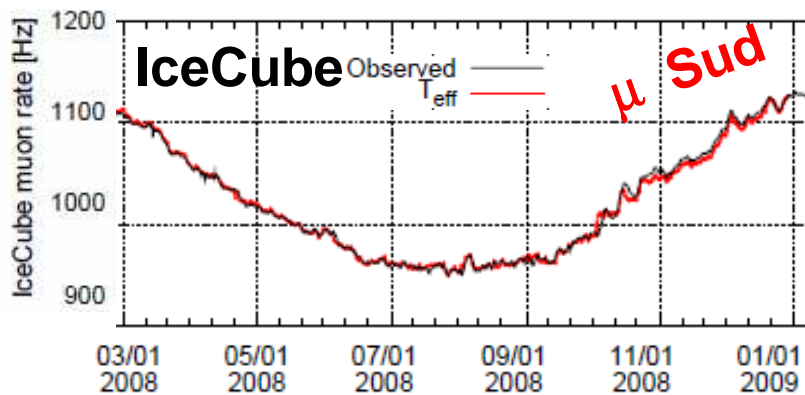
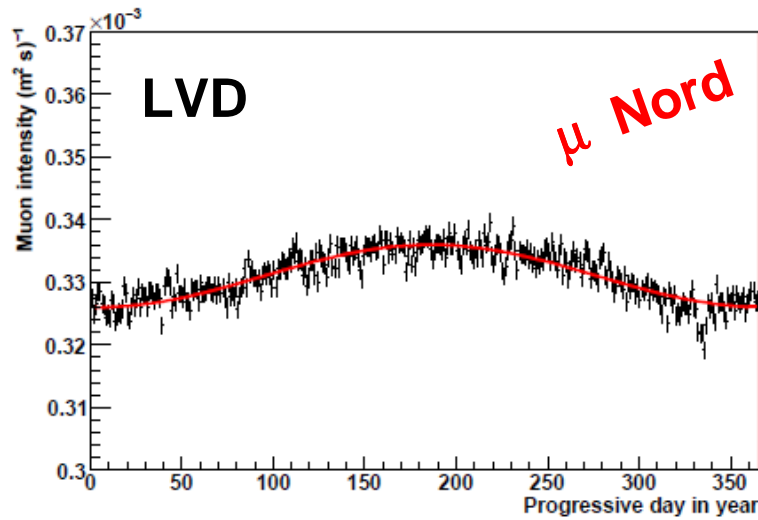


Flux de muons
(IceCube)



DM-Ice

- 17 kg NaI



→ Muons déphasés (π) / WIMP inchangés

R. Maruyama (TAUP 2011)

2.3 The usefulness of annual baseline data

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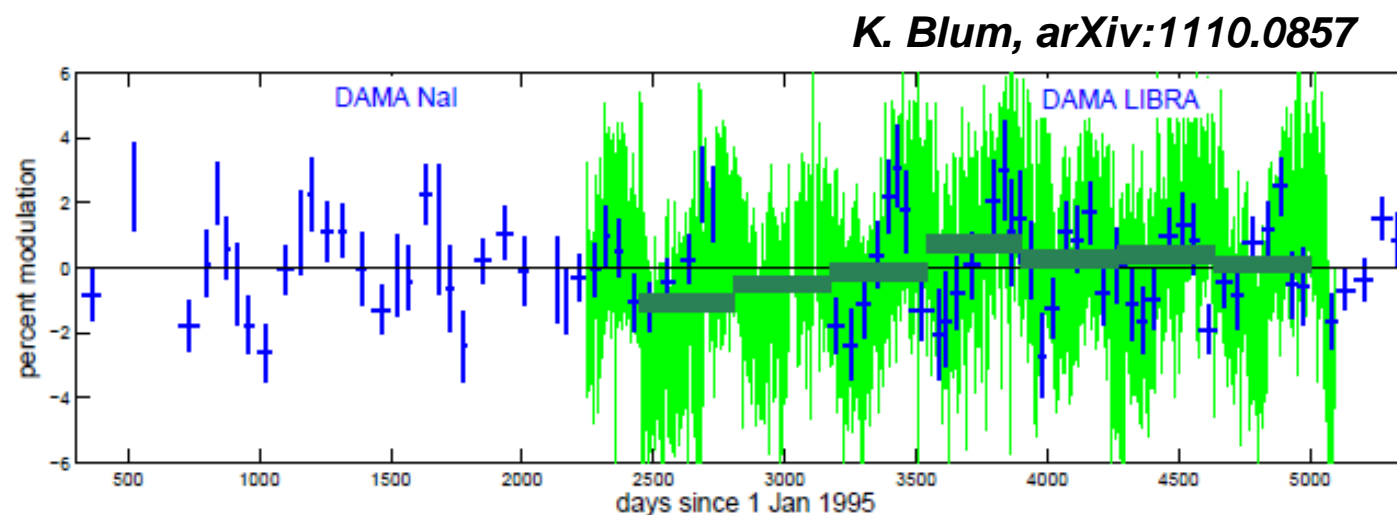


Figure 4: Long term modulation in the annually-averaged muon rate (thick dark green) with respect to the seven year average in the period Sep 9 2001 until Sep 9 2008. The thickness of the horizontal bars is $\pm 0.25\%$, representing the expected DAMA resolution for the energy range 2-4 KeV. Here, in contrast to Fig. 1, the short term muon intensity residuals (green) were defined with respect to the seven year baseline rather than to the different annual baselines.