

Medición del nivel de humedad del suelo mediante detectores de neutrones de rayos cósmicos

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LA-CoNGA Physics

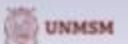
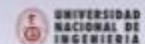
14 de Noviembre de 2022



Latin American alliance for
Capacity building in Advanced physics
LA-CoNGA physics

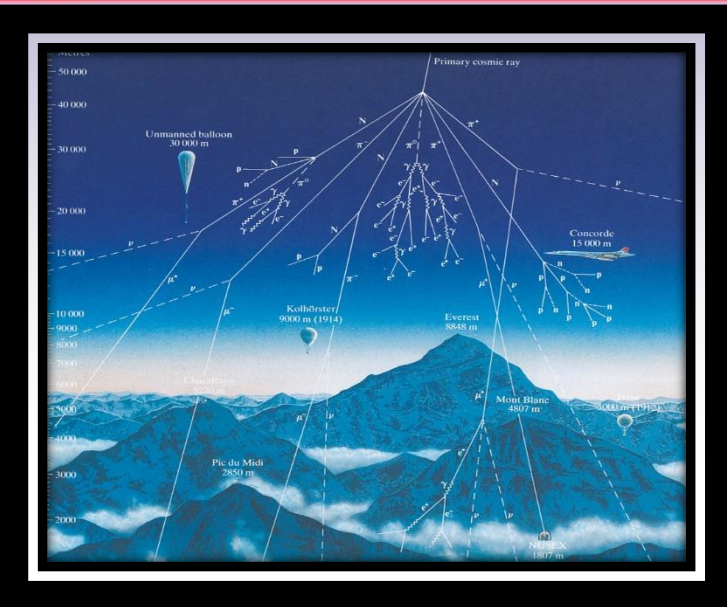


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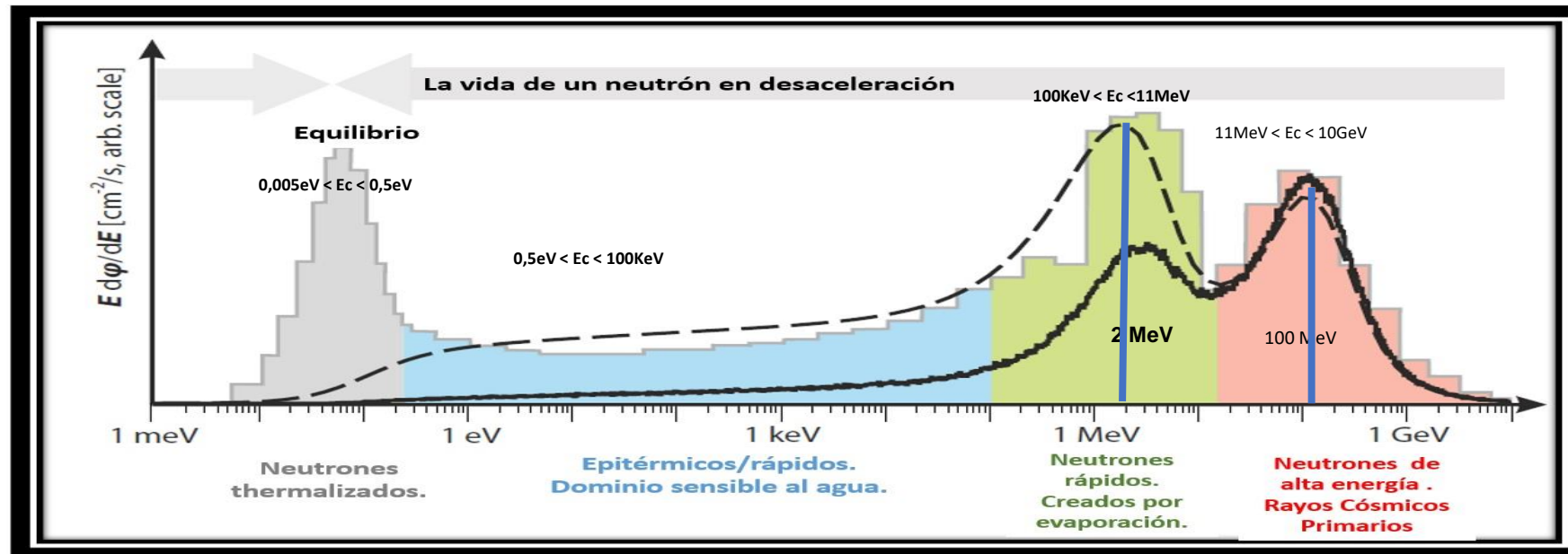


Humedad del suelo y los neutrones atmosféricos



Componente	Porcentaje
Protones	~ 87%
Partículas alfa	~ 10%
Electrones	~ 2%
Elementos Ligeros (Li, Be, B ...)	~ 0.25%
Antimateria	~ 0.01%

Goldhagen, P., J.M. Clem, and J.W. Wilson. (2004). The energy spectrum of cosmic-ray induced neutrons measured on an airplane over a wide range of altitude and latitude. Radiat. Prot. Dosim. 110(1-4): Pages 387–392. doi:10.1093/rpd/nch216.





Humedad del suelo y los neutrones atmosféricos



$$\phi = \frac{I_{fuente}}{E \cdot [N_H \sigma_H \xi_H + \sum_{i=2}^n (N_i \sigma_i \xi_i)]}$$

$$N_H = \frac{\frac{I_{fuente}}{E\phi} - \sum_{i=2}^n (N_i \sigma_i \xi_i)}{\sigma_H \xi_H}$$

$$\theta(N) = \frac{a_0}{\frac{N_{corr}}{N_0} - a_1} - a_2$$

$$N_{pint} = N_{patm} \frac{I_m}{I_0}$$

$$N_{patm} = N_{sensor} e^{\left(\frac{p_0 - p}{L}\right)}$$

$$N_{patm} = N_{sensor} e^{\left(\frac{p_0 - p}{L}\right)}$$

$$N_{corr} = N_{pint} (1 + 0,0054 \Delta \rho_{v0})$$

$$a_0 = 0,0808$$

$$a_1 = 0,372$$

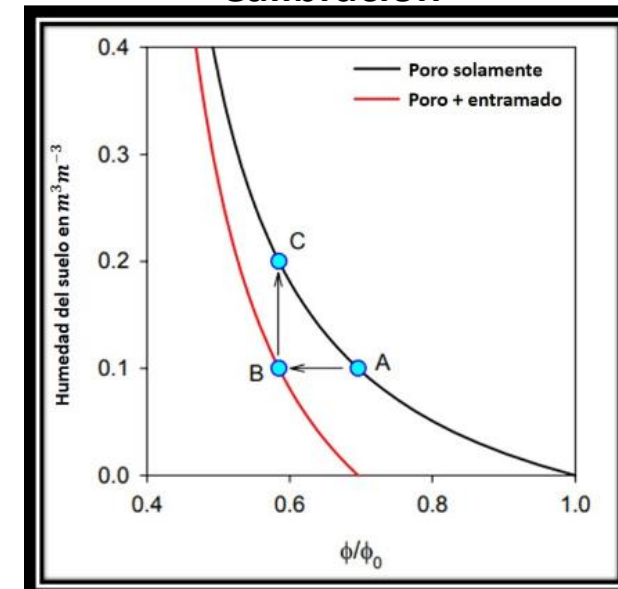
$$a_2 = 0,115$$

$$\theta_v = \theta(N) \rho_{aparente}$$

$$\rho(z) = \rho_{v0} e^{\left[\frac{-(z-z_0)}{H}\right]}$$

Elemento	A	σ_{sc}	NC	ξ	PF	C
H	1.0079	22.02	18	1.000	22.016	--
O	15.9994	4.232	149	0.120	0.508	487875
C	12.011	5.551	113	0.158	0.875	87638
Si	28.08557	2.16	257	0.070	0.151	281367
Na	22.9898	3,28	211	0.085	0.277	23206
Ca	40.078	2.83	364	0.049	0.139	70963
Al	26.9815	1.503	247	0.072	0.109	58015
Fe	55.84	11.62	505	0.035	0.411	28980
Mg	24.305	3.71	223	0.080	0.297	13436
K	39.0983	1.96	355	0.050	0.099	19137

Calibración



Zreda, M., W.J. Shuttleworth, X. Zeng, C. Zweck, D. Desilets, T. Franz R. Rosolema. 2012. COSMOS: The COsmic-ray Soil Moisture Observing System. Hidrol. Sistema de la Tierra Sci. 16:4079–4099. doi:10.5194/hess-16-4079-2012.



Correcciones a la función de humedad del suelo



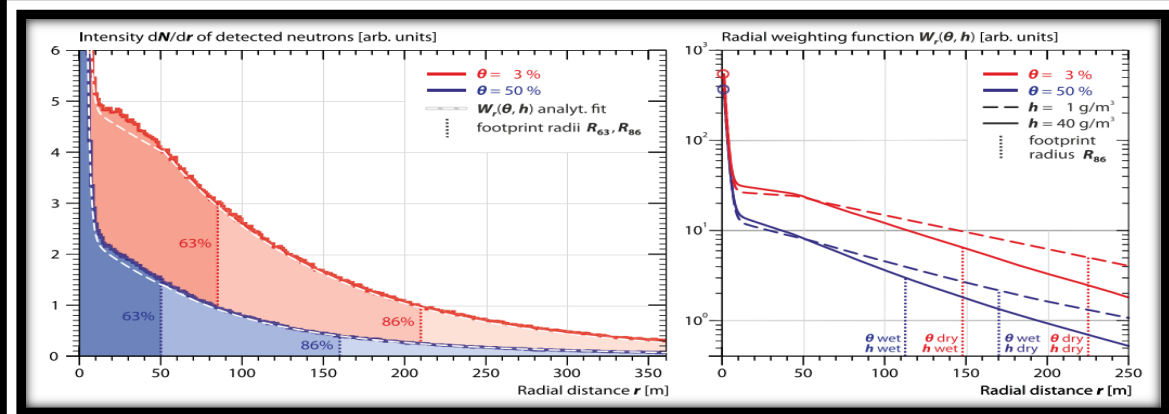
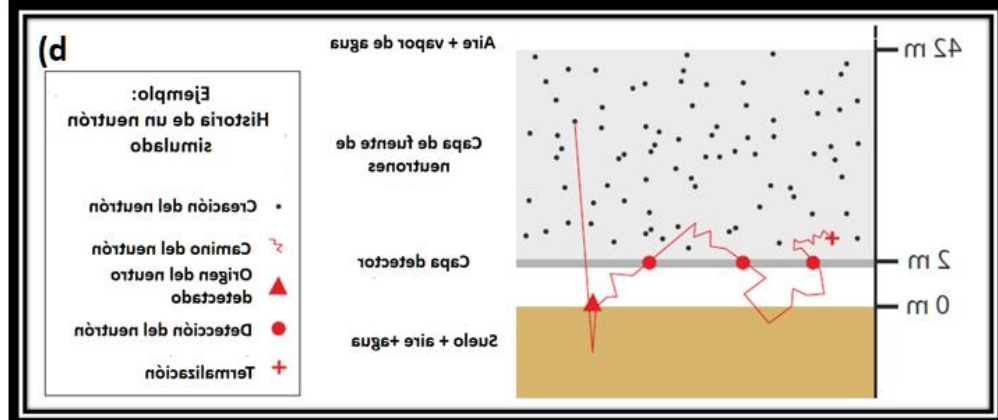
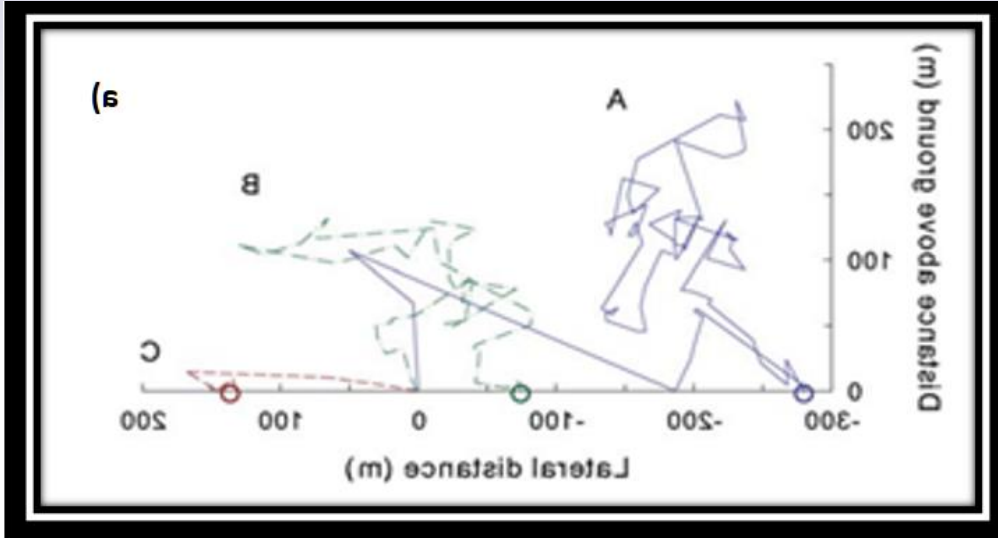
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Huella detector: $E_i = 2 \times 10^6 eV$ hasta $E_f = 10^2 eV$

$$R_{86}(h, \theta, p, veg) = f_p f_{veg}(\theta) R_{86}(h, \theta)$$

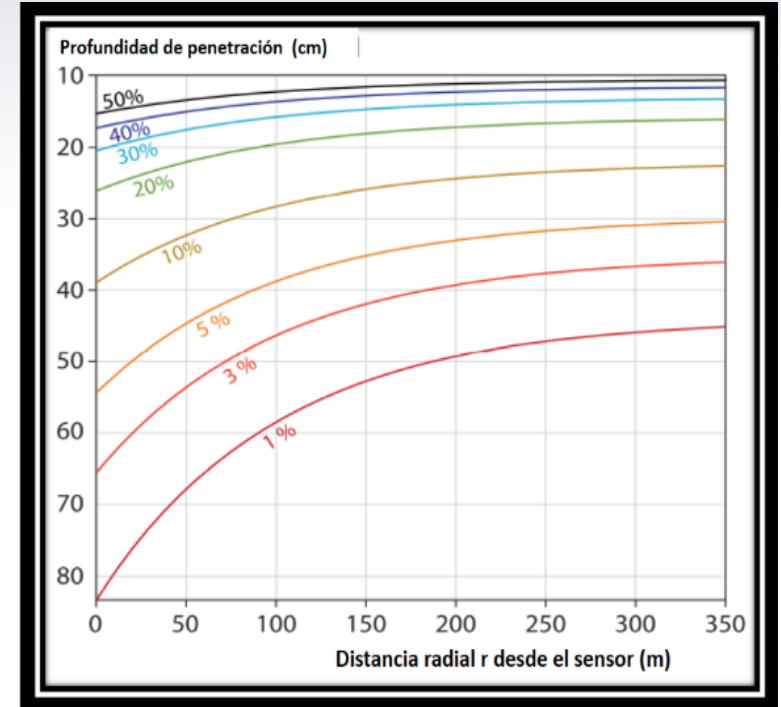
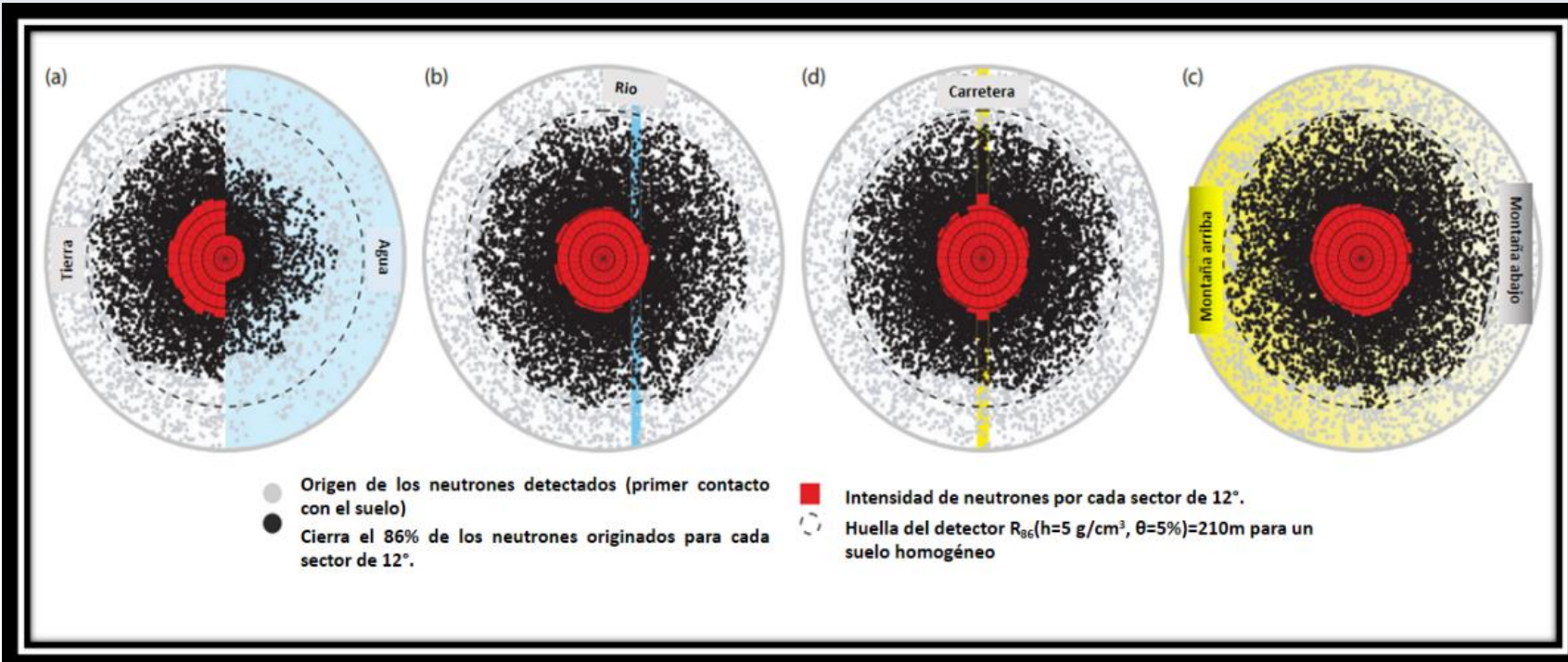
$$f_p = \frac{0,5}{0,86 + e^{-p/p_0}} \approx -p/p_0$$

$$f_{veg}(\theta) = 1 - 0,17(1 - e^{-0,41 H_{veg}})(1 + e^{7\theta})$$



Profundidad de penetración:

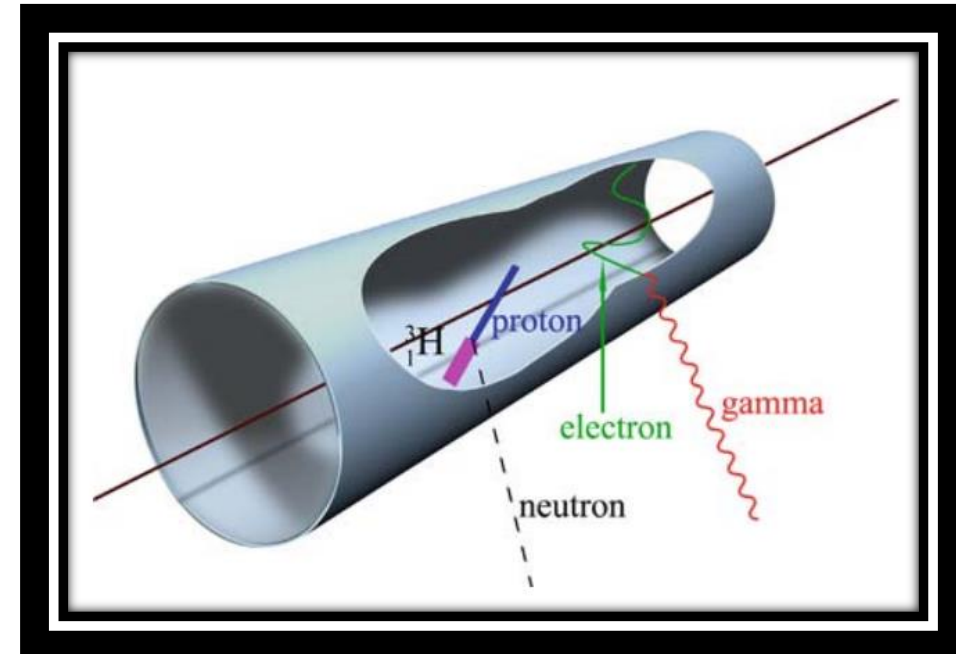
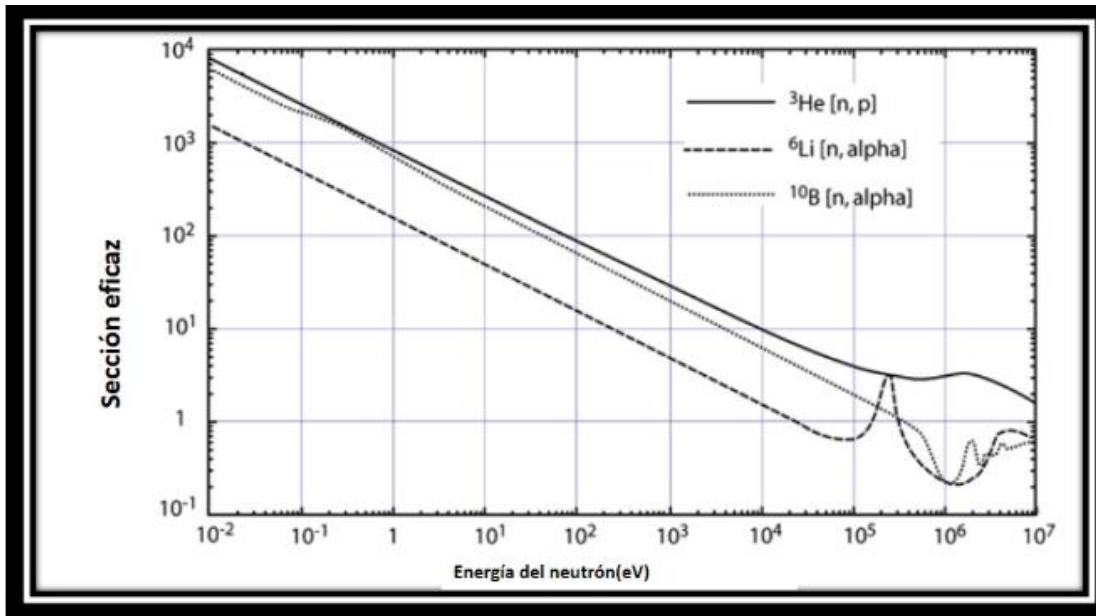
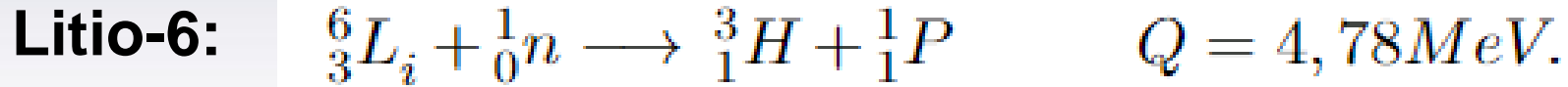
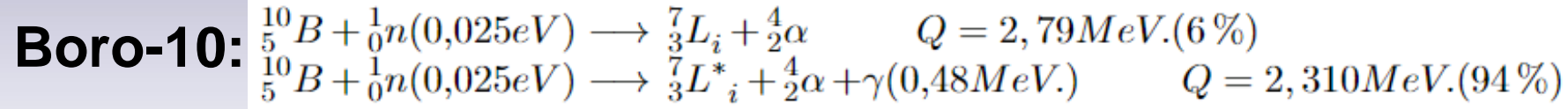
$$LA(cm) = A_{superficie} + A_{celosia} + A_{poro} = A_s + \frac{\rho_{aparente}(z)\tau(z)z}{\rho_a} + \theta(z)z$$



Zreda, M., W.J. Shuttleworth, X. Zeng, C. Zweck, D. Desilets, T. Franz R. Rosolema. 2012. COSMOS: The COsmic-ray Soil Moisture Observing System. Hidrol. Sistema de la Tierra Sci. 16:4079–4099. doi:10.5194/hess-16-4079-2012.



Detectores de neutrones

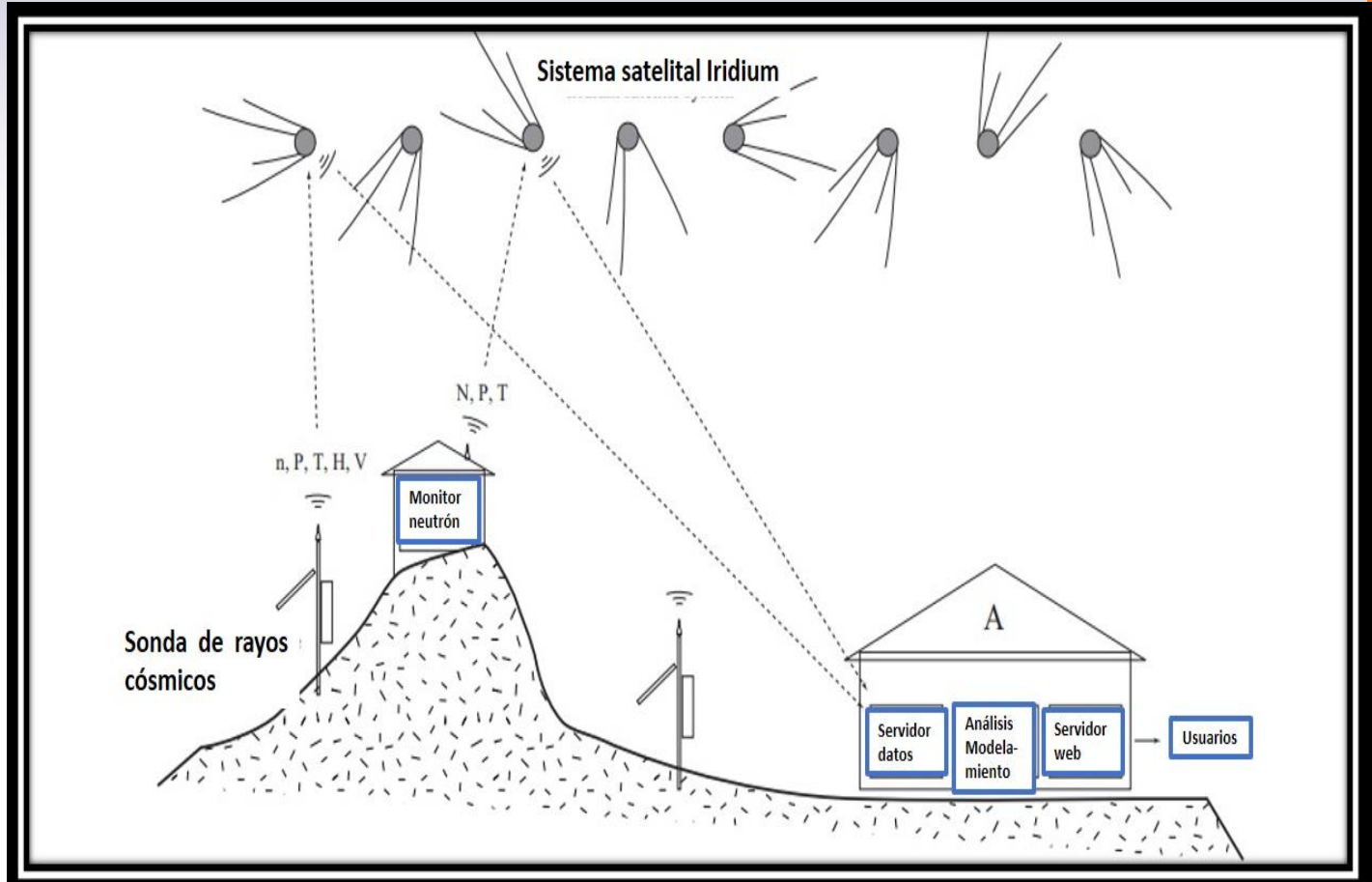
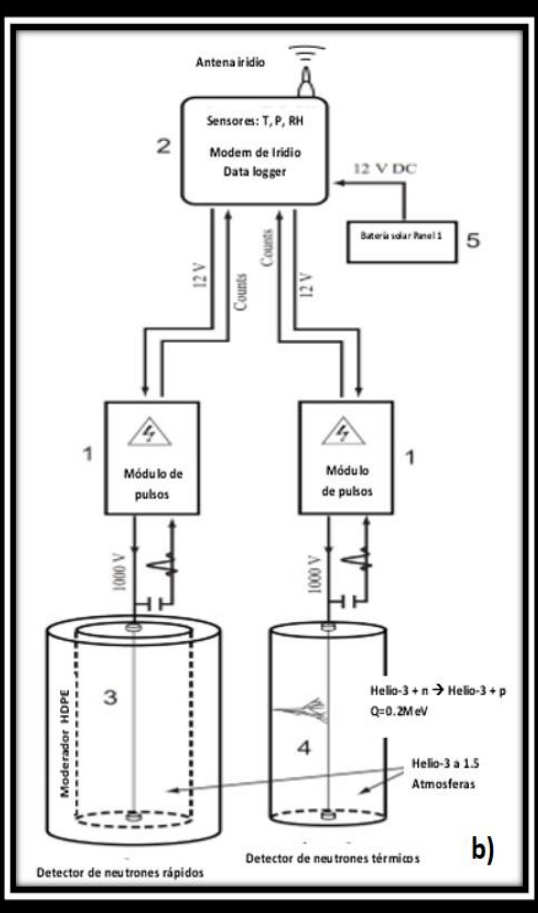
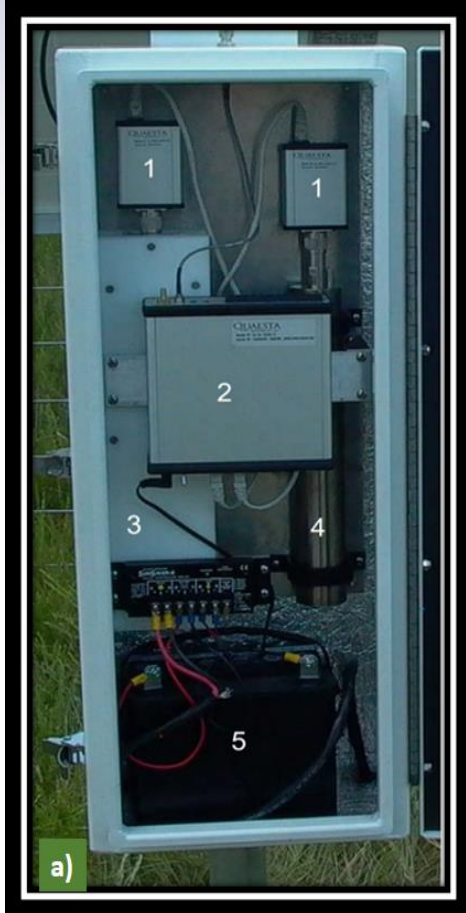


Stefaan T., 2014. Experimental Techniques in Nuclear and Particle Physics. (pp. 209-224). Salmer; 2010 edición

Zreda, M., D. Desilets, T.P.A. Ferré, and R.L. Scott. 2008. Measuring soil moisture content non-invasively at intermediate spatial scale using cosmicray neutrons. Geophys. Res. Lett. 35:L21402. doi:10.1029/2008GL03565



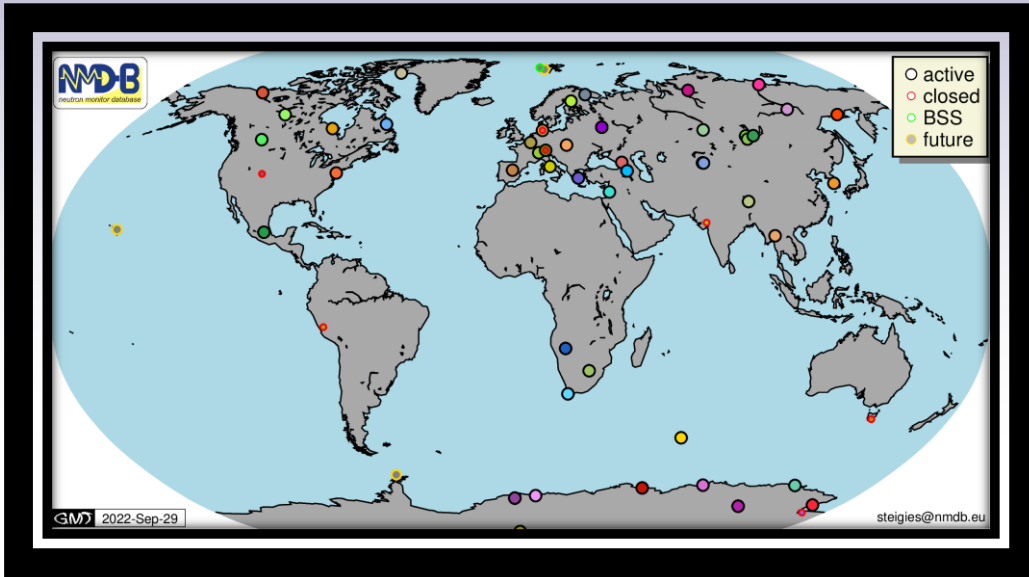
Detectores de neutrones



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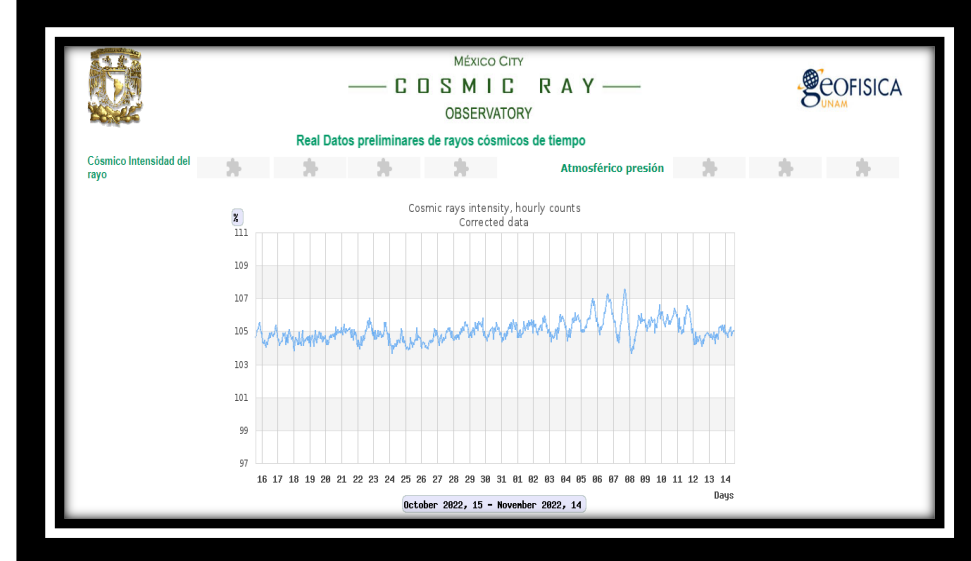


Base de datos de neutrones en tiempo real (NMDB)



Características técnicas

Detector	Monitor de neutrones estándar 6-NM-64
Latitud geográfica	19.33° N
Longitud geográfica	260,82° E
Altitud	2274 metros s.n.m.
Rigidez de corte vertical efectiva	8,2 VD
En funcionamiento continuo desde	1990

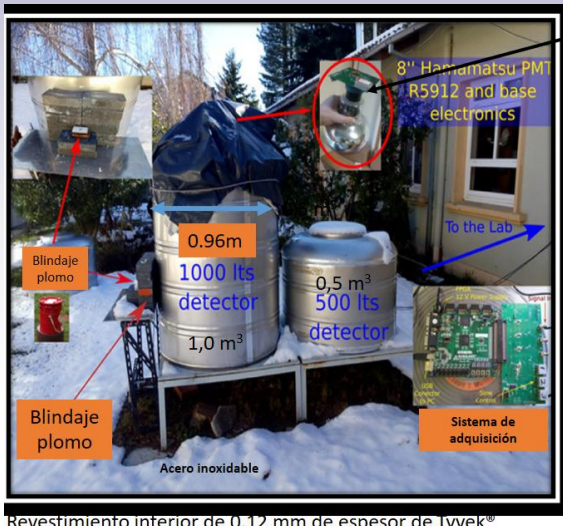
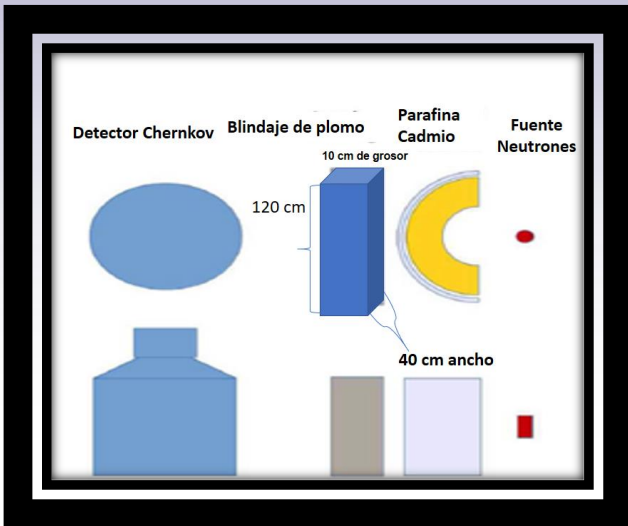


Steigies, C. (2009). "NMDB: towards a global neutron monitor database". *Unión Geofísica Americana, Reunión de otoño. 2009*: SH51B–1280.



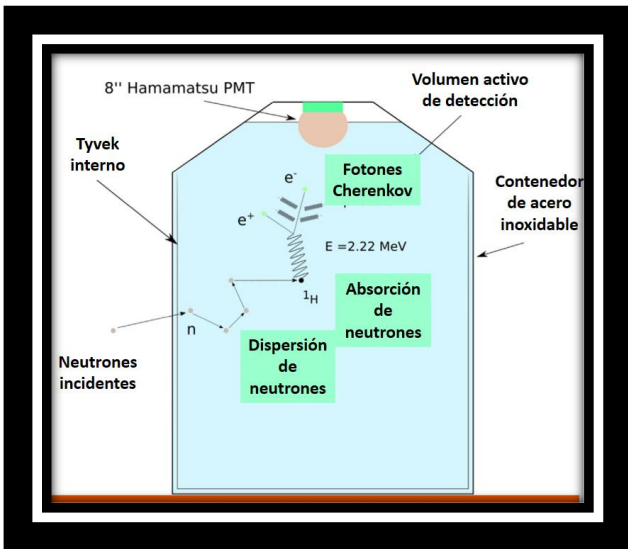


Detección de neutrones con detector Cherenkov



Resultados experimentales de la eficiencia de detección en comparación con las simulaciones

Volumen sensible	Resultados experimentales (%)	Simulación (%)	Total de capturas (%)	
			¹ H (%)	³⁵ Cl (%)
Agua pura	19 ± 12	10.18	10.17	0
Agua + ³⁵ Cl (2.5 %)	44 ± 10	24.19	15.57	7.91



Volumen Sensible	Probabilidad de capturar neutrones (%)	Distancia máxima de absorción (cm)
H ₂ O	25.18	8.4±0.1
H ₂ O + 2.5% NaCl	26.73	8.0±0.1
H ₂ O + 5% NaCl	27.65	7.7±0.1
H ₂ O + 10% NaCl	29.26	7.3±0.1

Sidelnika I., Asorey H., Jerónimo J., Gómez M., Neutron detection using a water Cherenkov detector with pure water and a single PMT. <https://doi.org/10.1016/j.nima.2017.02.048>

Sidelnik, H. Asorey, N. Guarín et al., Neutron detection capabilities of Water Cherenkov Detectors, Nuclear Inst. and Methods in Physics Research, A (2019), <https://doi.org/10.1016/j.nima.2019.03.017>.

Sidelnik I., Asorey H., Guarín N., Suárez M., Gómez M. B., Lipovetzky J., Blostein J., (2020), Simulación de neutrones de 500 MeV mediante el uso del detector Cherenkov de agua dopado con NaCl, Avances en Space Research, volumen 65(9), <https://doi.org/10.1016/j.asr.2020.02.0>

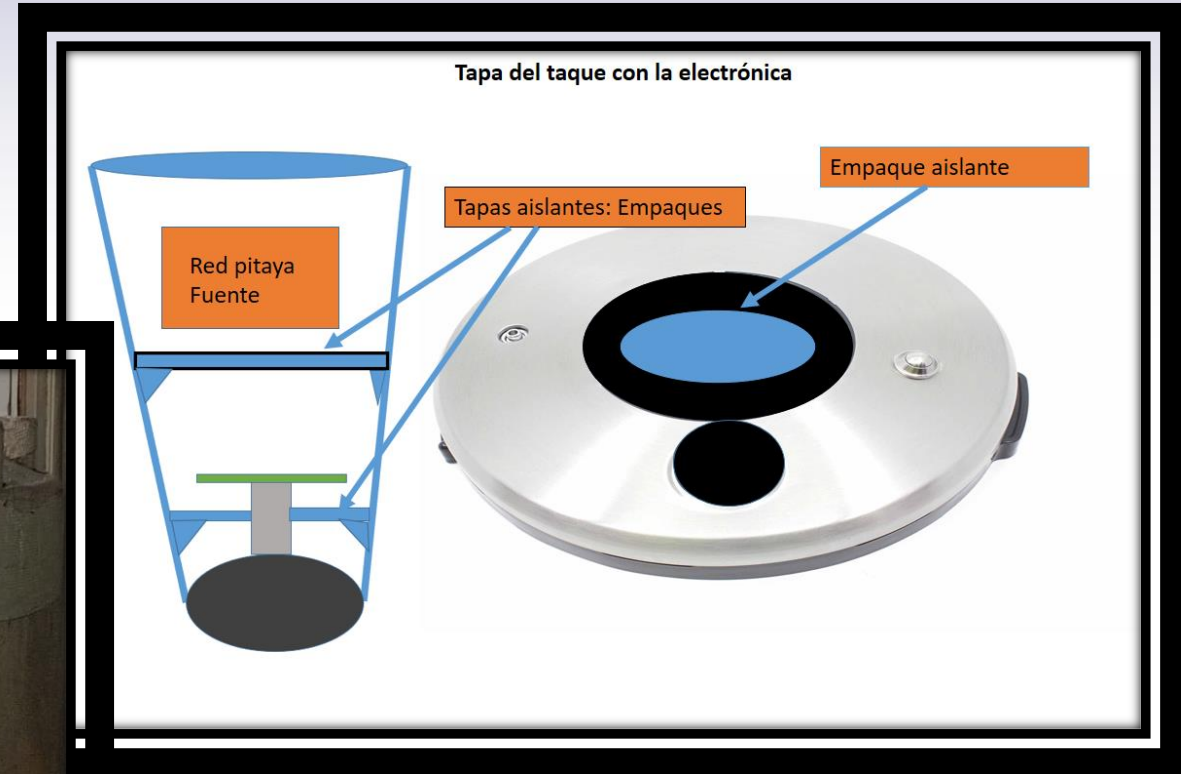
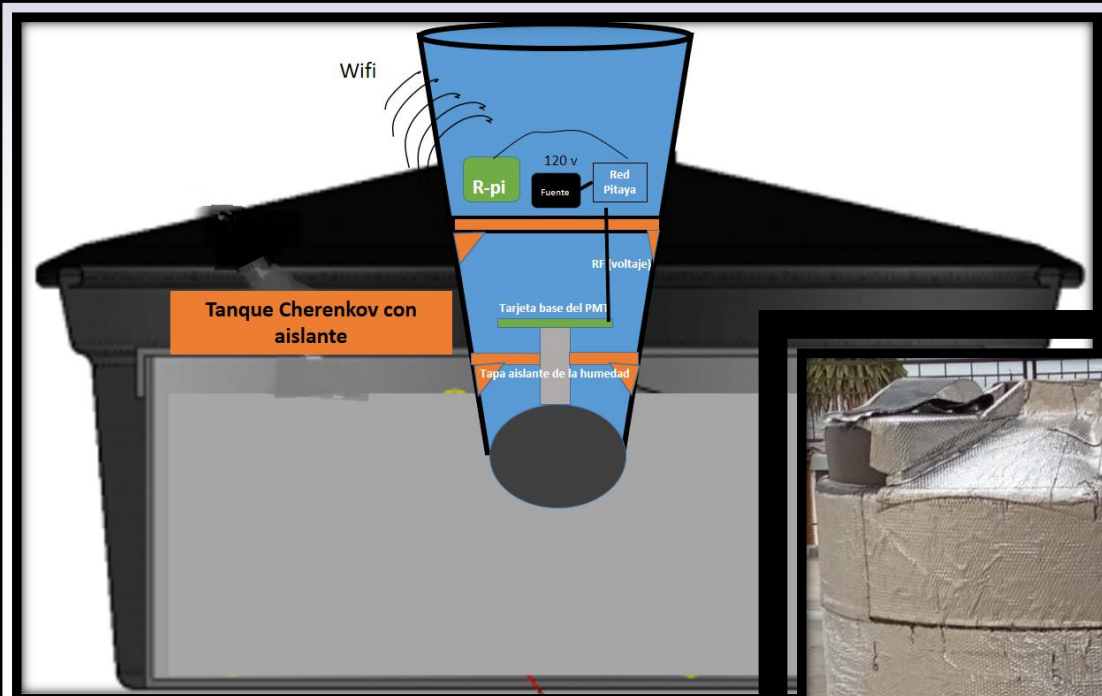




Detección de neutrones con detector Cherenkov



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¡GRACIAS POR LA ATENCIÓN PRESTADA!



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