

# Study of the Time Dependence of Radioactivity

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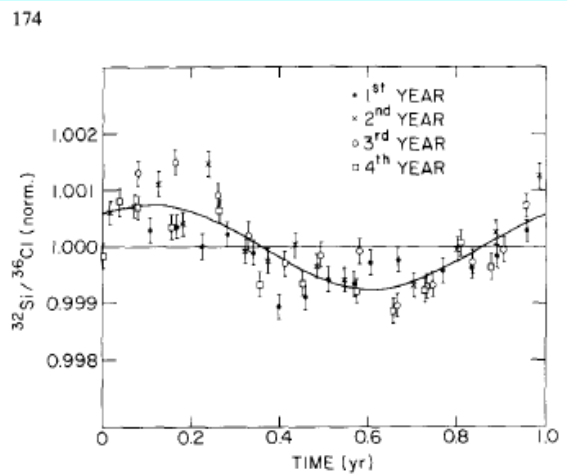
$$\text{☀} \quad N(t) = N(0) e^{-t/\tau}$$



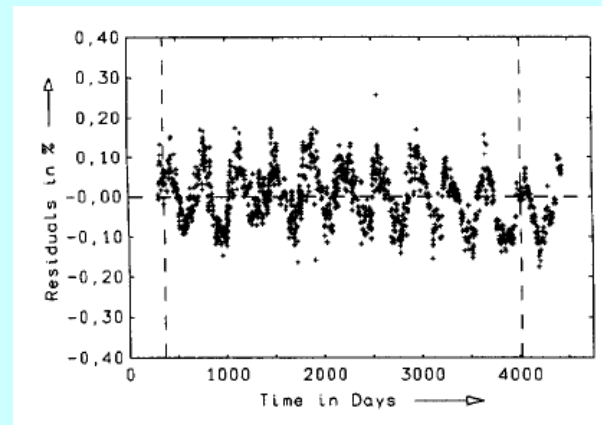
Carlo Broggini, INFN-Padova

Evidence of correlations between nuclear decay rates and Sun-Earth distance  
By Jenkins, Fischbach et al., AstroPP 32(2009)42

BNL-1986



PTB-1998



<sup>226</sup>Ra

Moscow U. -2010 <sup>60</sup>Co, <sup>90</sup>Sr-<sup>90</sup>Y

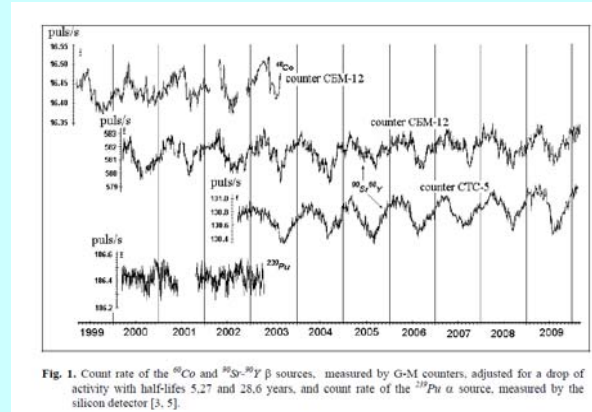
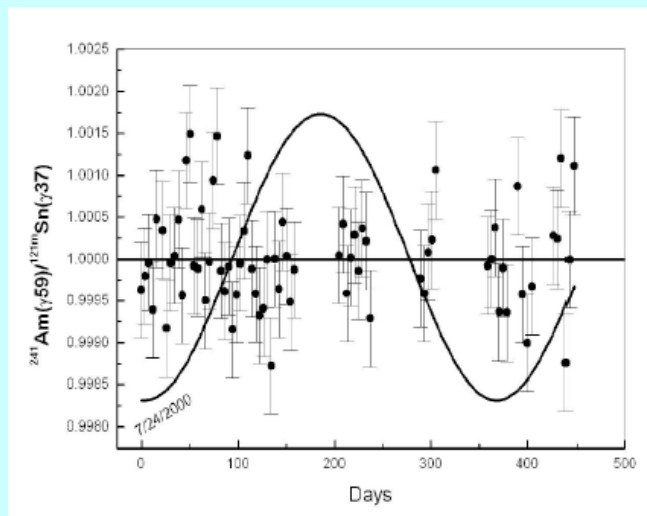
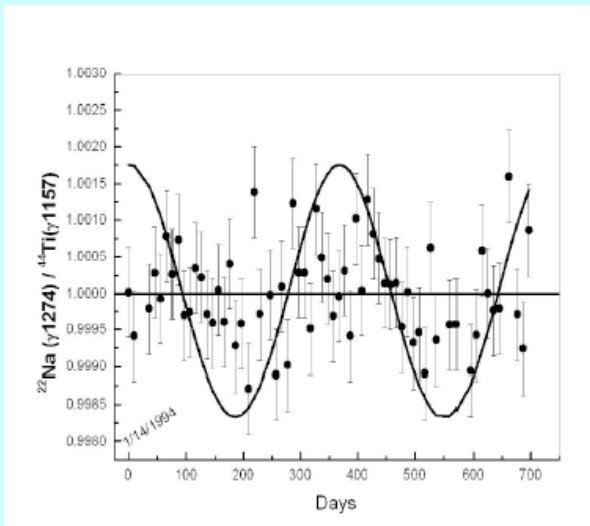


Fig. 1. Count rate of the <sup>60</sup>Co and <sup>90</sup>Sr-<sup>90</sup>Y β sources, measured by G-M counters, adjusted for a drop of activity with half-lives 5.27 and 28.6 years, and count rate of the <sup>239</sup>Pu α source, measured by the silicon detector [3, 5].

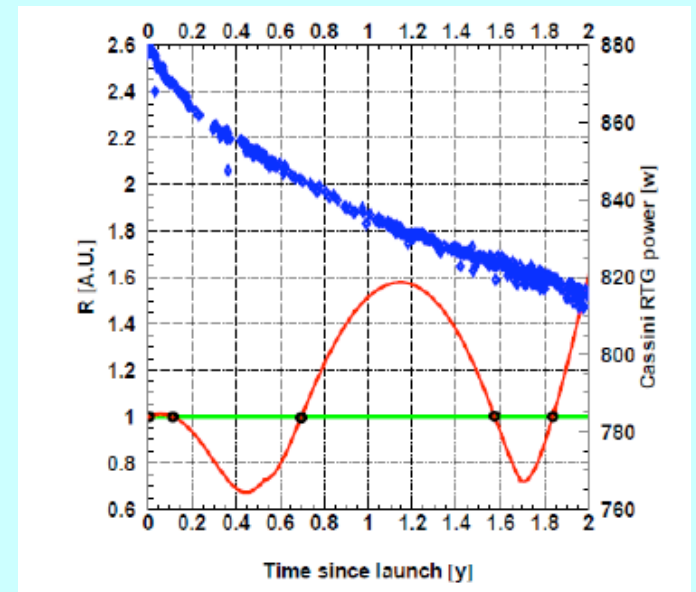
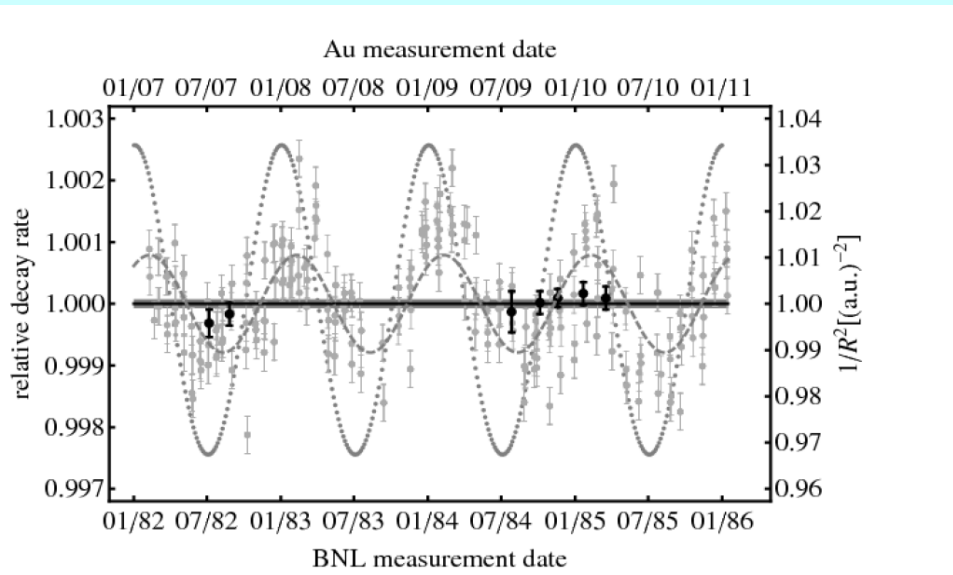
Effect: ±0.1-0.2 %,  
Max. February, Min. August

+ <sup>54</sup>Mn, <sup>56</sup>Mn, <sup>133</sup>Ba, <sup>152</sup>Eu, <sup>154</sup>Eu.....  
Beta and EC decay

Evidence against correlations between nuclear decay rates and Sun-Earth distance  
 Norman et al., *AstroPP* 31(2009)135 (assuming different amplitude for the isotopes)



Measurement of a short life-time in different period of the year, Hardy et al, arXiv: 1108.5326 (2011)135,  $^{198}\text{Au}$  ( $t_{1/2}$ : 2.7d)



Cassini  $^{238}\text{Pu}$  ( $t_{1/2}$ : 87.7d) power generator. No effect on alpha-decay  
 Due to Sun-source distance

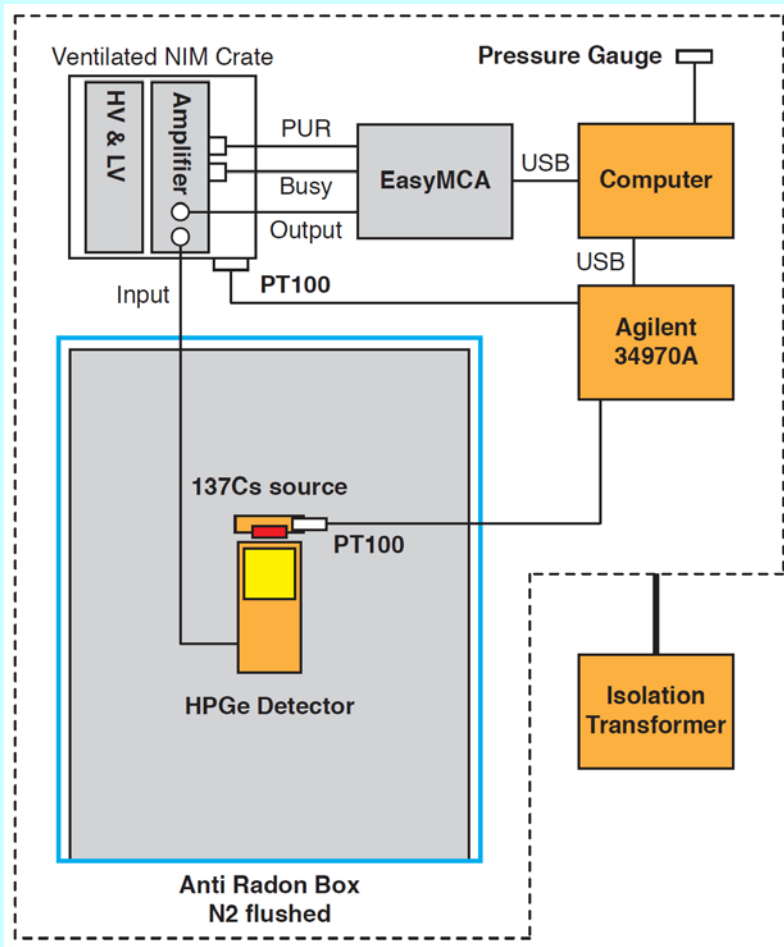
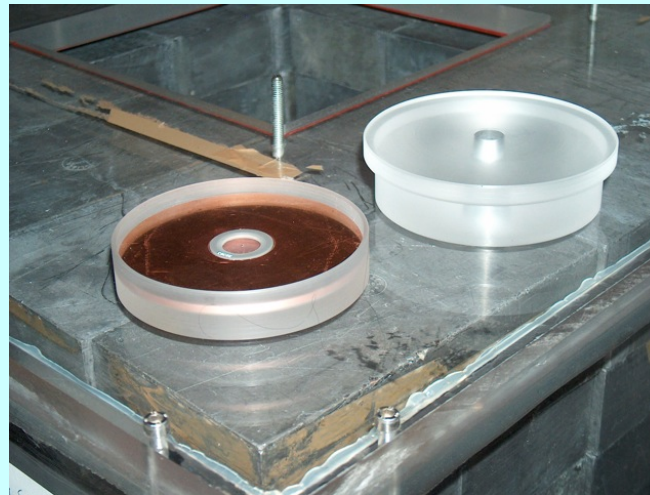
Mechanism responsible (if not some systematic effect):

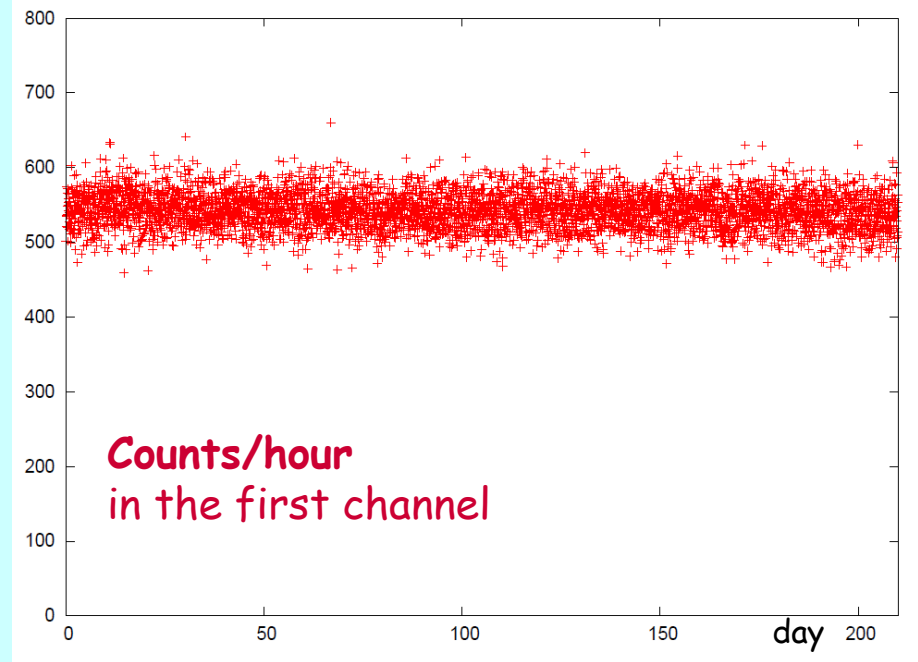
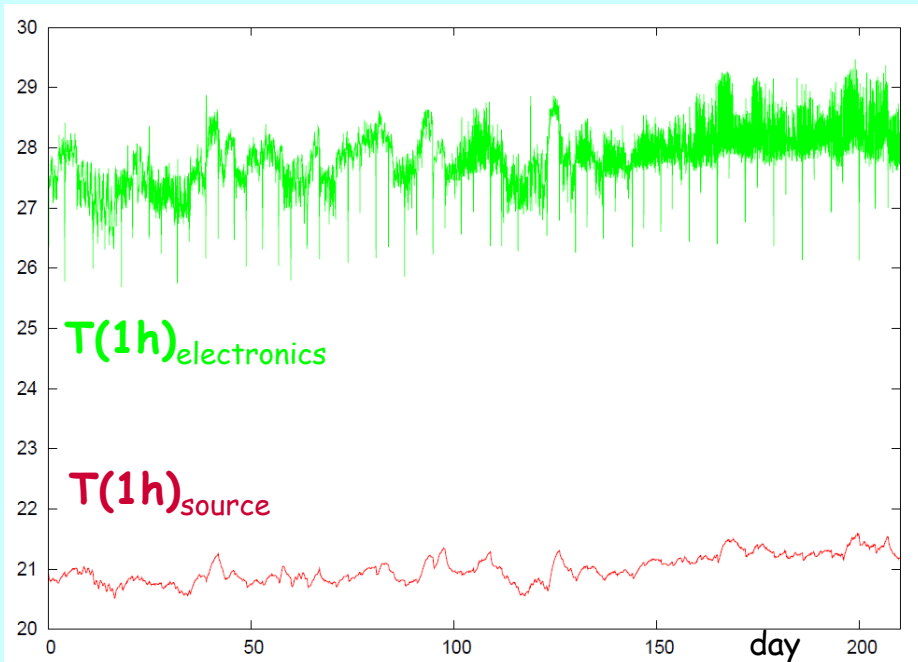
- $\pm 3\%$  annual variation in the flux of solar neutrinos, but  $\sigma?$  de Meijer et al. (2011) no effect larger than  $\sim 10^{-4}$  on the decay of  $^{22}\text{Na}$ ,  $^{54}\text{Mn}$ ,  $^{137}\text{Cs}$  and  $^{152}\text{Eu}$  at 8m from the core of a 2 MWth reactor
- scalar field from the Sun coupled to matter density (Chameleon fields?)
- ??

Dedicated experiment @Gran Sasso with a  $^{137}\text{Cs}$  source and a Ge detector

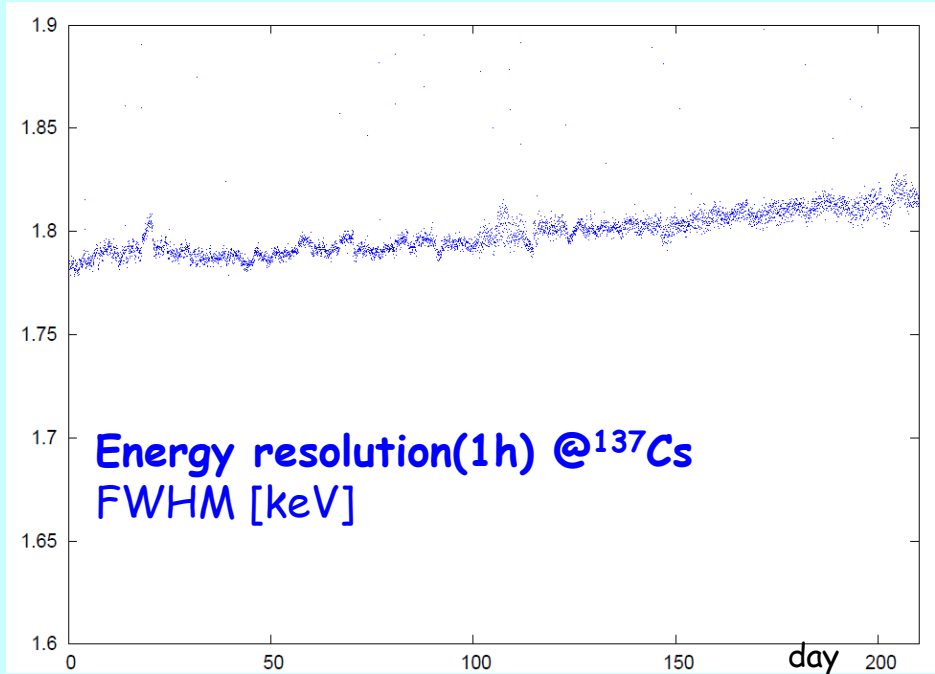
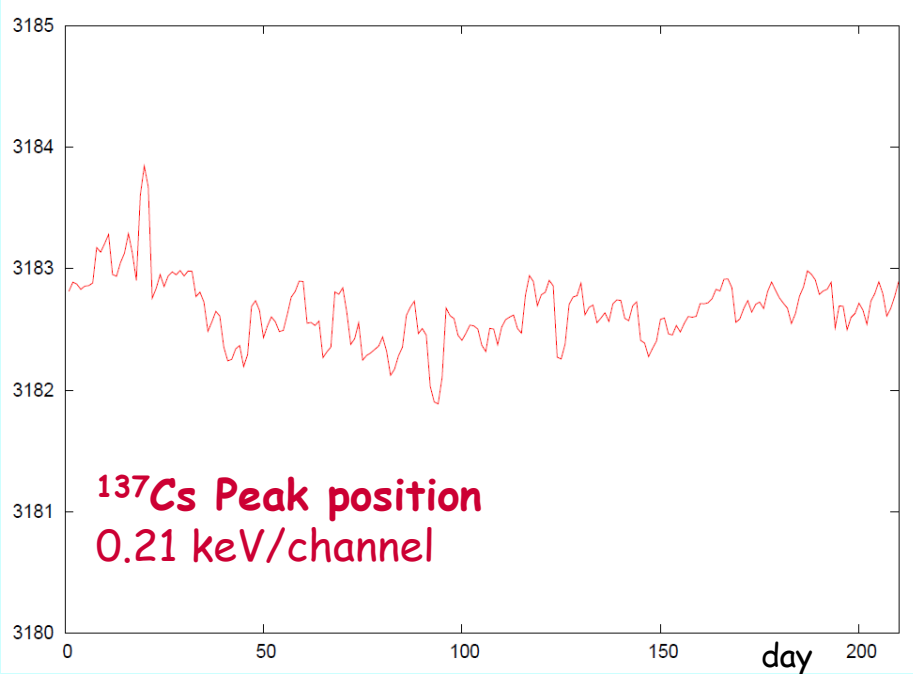
0.2% effect seen by Baurov with 24-hour and 27-day period in a 4 month experiment (1998-99)

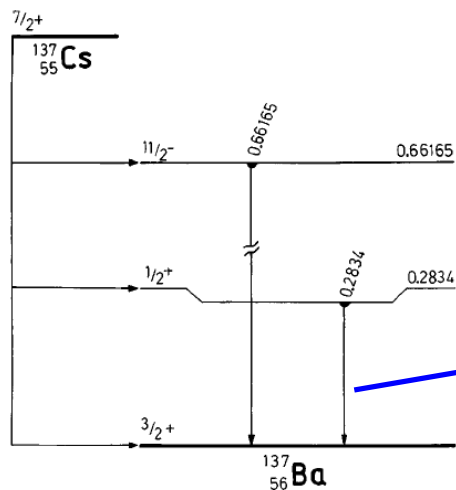
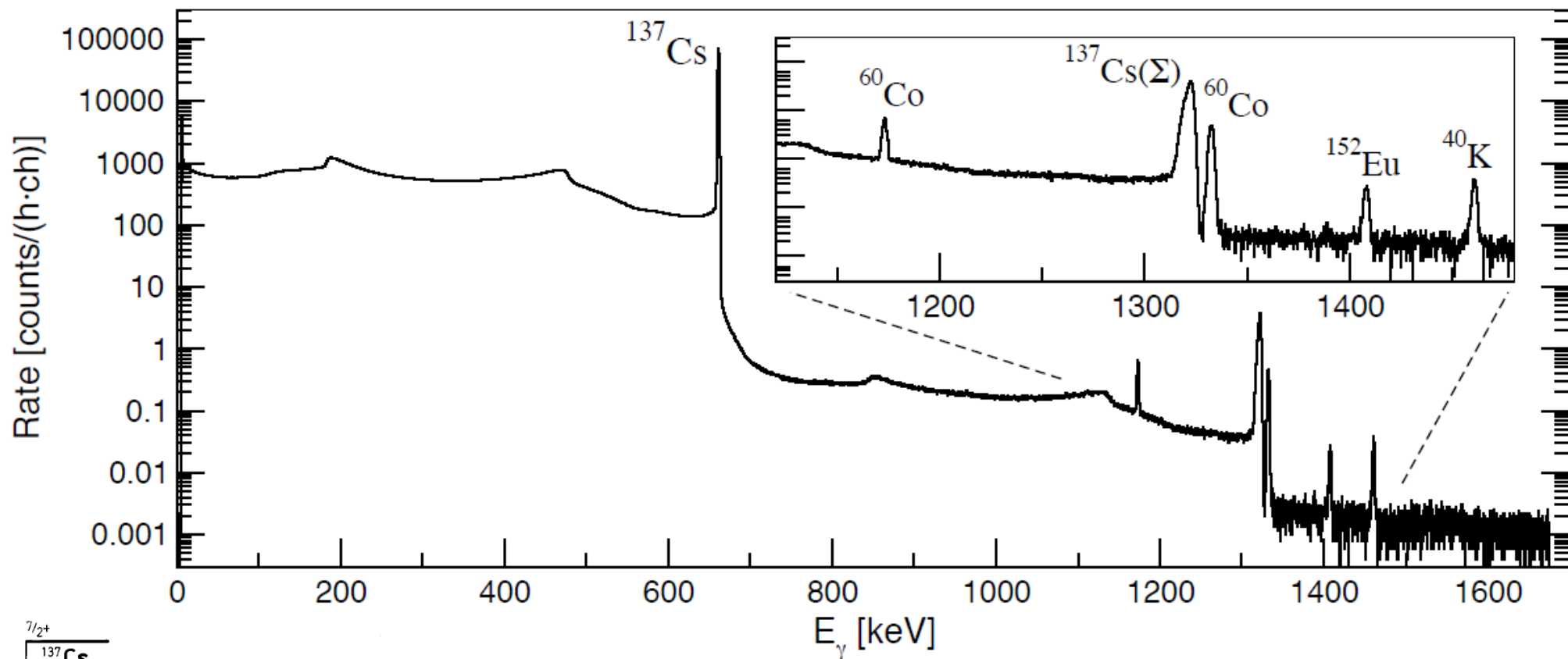
- 3.0 kBq activity
- 96% p-type High Purity Ge
- source fixed at the copper end-cap ( $1\mu\text{m} \rightarrow 5 \cdot 10^{-5}$  efficiency change)
- 5cm Cu + 25cm Pb + anti-Rn



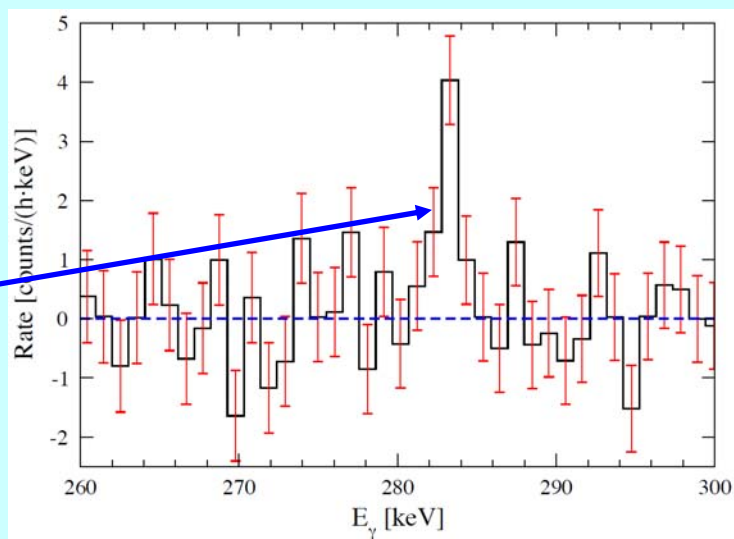


Data acquisition starting on June 6th 2011

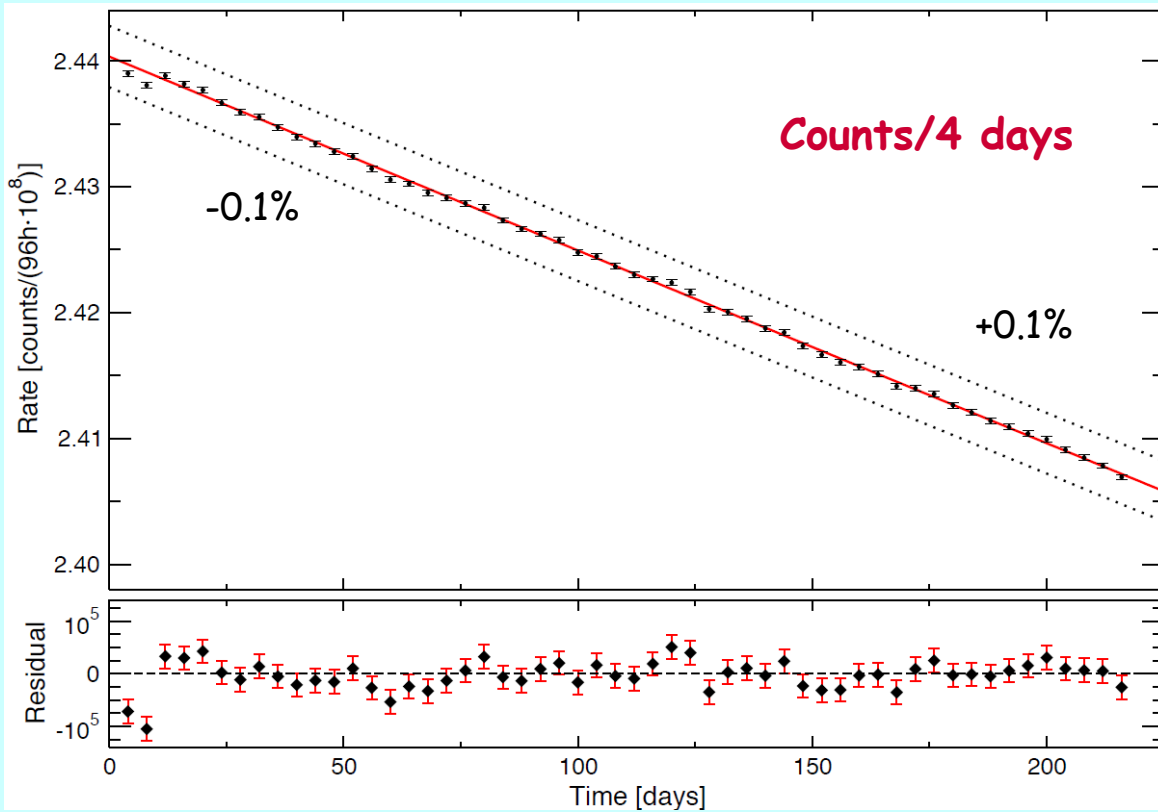
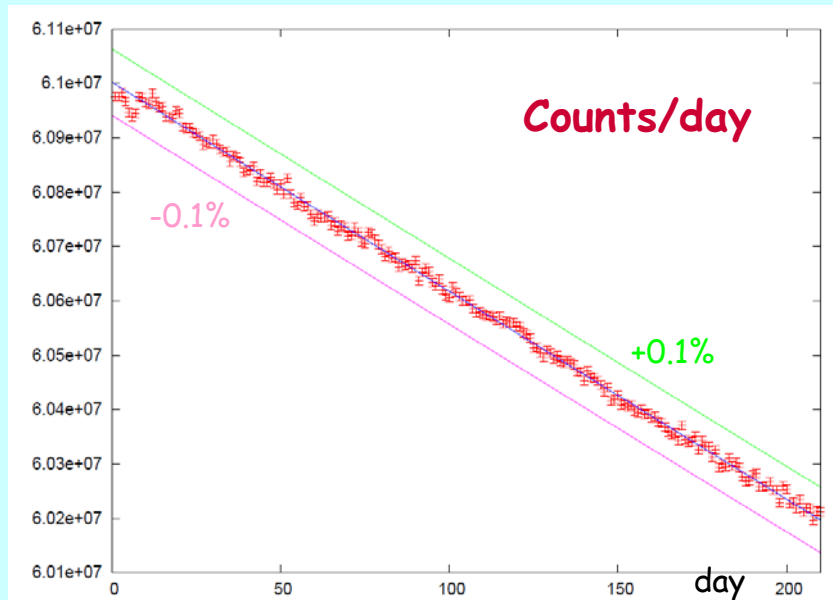
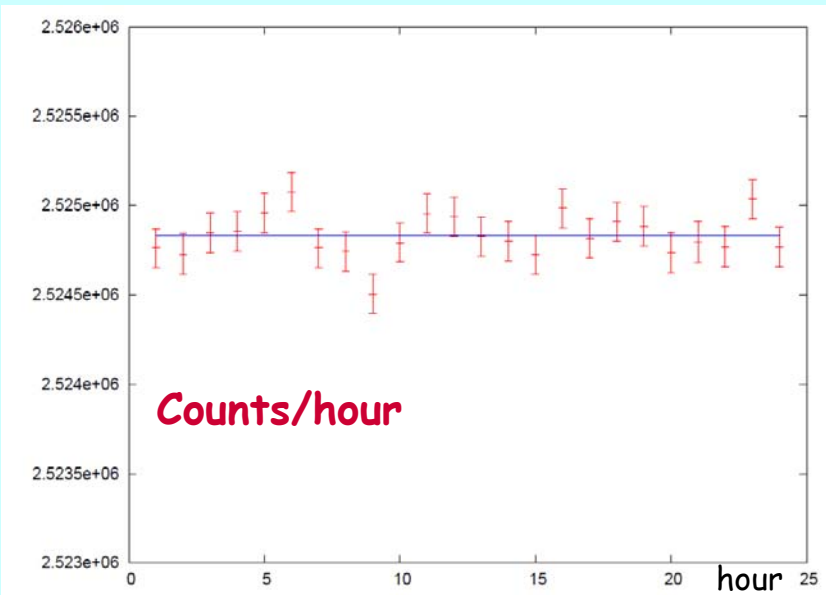




Intensity of the 283.4 keV transition:  $5.3(14) \cdot 10^{-6}$



- \* Rate above from 7 keV to 1.7 MeV:  $\sim 700$  Hz
- \*  $^{60}\text{Co}$ :  $1.7 \cdot 10^{-2}$  Hz
- \*  $^{40}\text{K}$  and  $^{152}\text{Eu}$ :  $2.7 \cdot 10^{-3}$  Hz
- \* No source:  $\sim 0.01$  Hz
- \* Dead time: 5.10% ↓



- \*  $t_{\frac{1}{2}} = 29.96 \pm 0.08 \text{ y}$   $\chi^2/\text{d.o.f.} = 1.02$   
(world mean  $30.05 \pm 0.08 \text{ y}$ )
- \* Modulation with amplitude larger  $9.6 \cdot 10^{-5}$  (95% C.L.) excluded  
(6 hours - 400 days)
- \* Annual modulation with amplitude larger than  $8.5 \cdot 10^{-5}$  excluded (95%)

☀ Annual oscillations observed in the radioactive decay of different nuclei (beta and EC) with 0.1-0.2% amplitude

☀ The size of the effect depends on the given nucleus

☀ Unknown mechanism responsible for the effect

☀ Dedicated experiment made @LNGS with a  $^{137}\text{Cs}$  and a low background Germanium detector (PLB 710 (2012) 114)

☀ No modulation with amplitude larger than  $9.6 \cdot 10^{-5}$  (95% C.L.) with period 6 hours-400 days

☀ Future: few more months with  $^{137}\text{Cs}$  then a source with a 'strong' annual modulation