

Experimental problems
in low (< 1 MeV) energy
 ν experiments

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ν experiments - real time - < 1 MeV

signal: 0.1 - 0.5 c/d/ton

(organic detecting material)

- background:
- external sources: Rn, n from rocks, etc.
 - cosmogenesis; μ induced activity
 - natural radioactivity

I. primordial ^{40}K , ^{238}U , ^{232}Th ; cosmogenic ^7Be

II. ^{222}Rn , ^{85}Kr

III. ^{14}C

III ●

^{14}C

$\beta \rightarrow$ end point 0.156 MeV

organic liquid $\lambda \sim 5670 \text{ y}$ D

\Rightarrow cannot be removed

\Rightarrow crude oil: residence underground $\sim 10^8 \text{ y}$

tail; pile up

ex: $10^{-18} \text{ } ^{14}\text{C}/^{12}\text{C}$

II ●

^{222}Rn

in air: $\sim 20 \text{ Bq/m}^3$ —

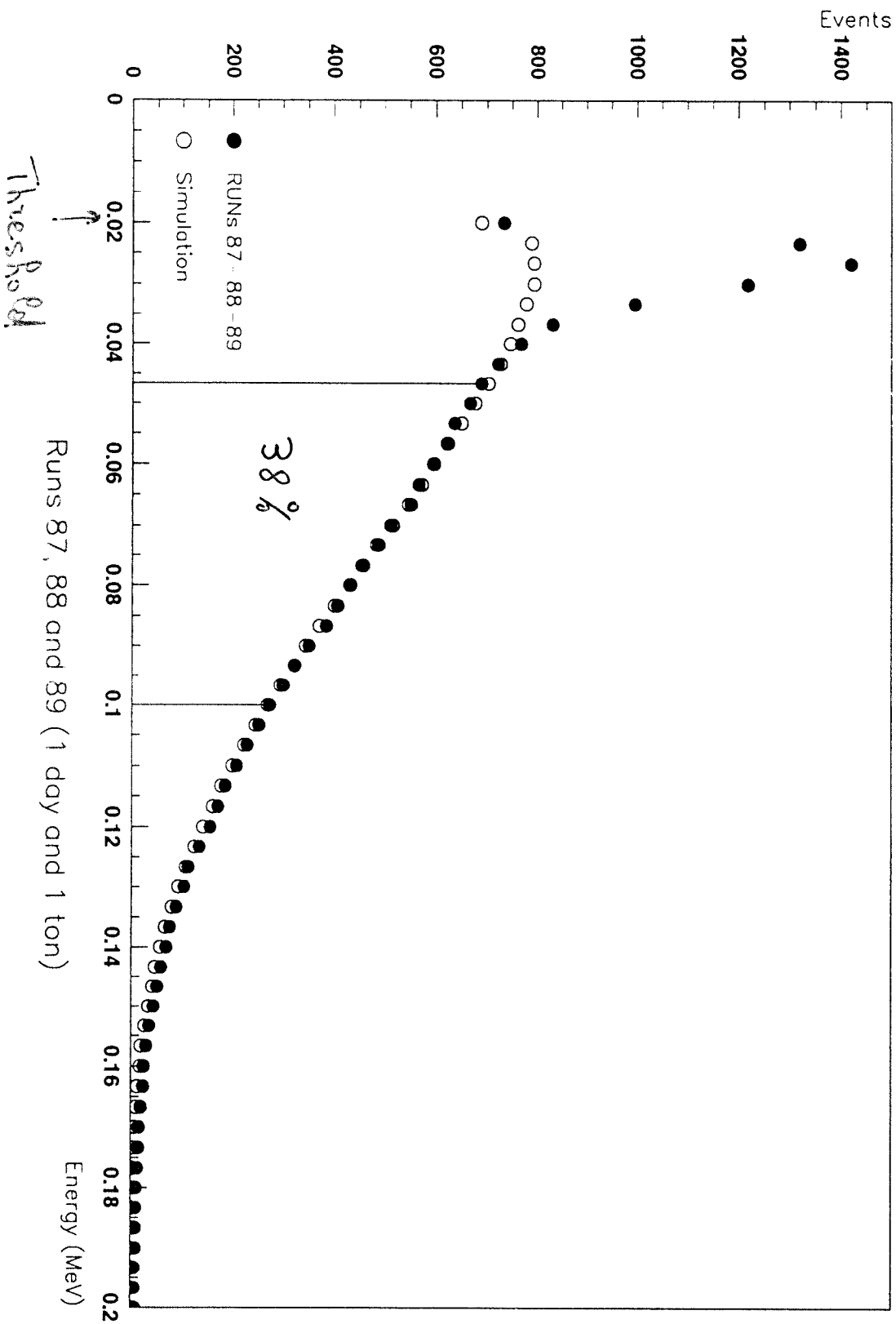
underground: 80 - 100 Bq/m^3

$\Rightarrow \sim$ few $\mu\text{Bq/m}^3$

U

^{222}Rn	α	$5.49 \text{ MeV} \longrightarrow 477 \text{ KeV}$	$\tau=5.48 \text{ d}$
↓			
^{218}Po	α	$6.02 \text{ MeV} \longrightarrow 545 \text{ KeV}$	4.4 min
↓			
^{214}Pb	$\beta+\gamma$	1.03 MeV	38.7 min
↓			
^{214}Bi	$\beta+\gamma$	3.2 MeV	28.4 min
↓			
^{214}Po	α	$7.69 \text{ MeV} \longrightarrow 825 \text{ KeV}$	$236 \mu\text{s}$
↓			
^{210}Pb	$\beta+\gamma$	0.061 MeV	32.17 y
↓			
^{210}Bi	β	1.16 MeV	7.23 d
↓			
^{210}Po	α	$5.305 \text{ MeV} \longrightarrow 440 \text{ KeV}$	200.2 d

^{14}C β -spectrum (simulated and corrected measured spectra)



^{85}Kr $\sim 1 \text{ Bq/m}^3$ $\lambda \sim 11 \text{ y}$

^{39}Ar β end point: 565 keV
 $\lambda \sim 266 \text{ y}$

① ~~→~~ stripping - N_2
↓

N_2 (Rn) free \rightarrow boil-off $\sim 1 \text{ mBq/m}$
? { Kr
 Ar charcoal: liquid N_2
 $\sim 0.5 \mu\text{Bq/m}$

(G.H. tuck)

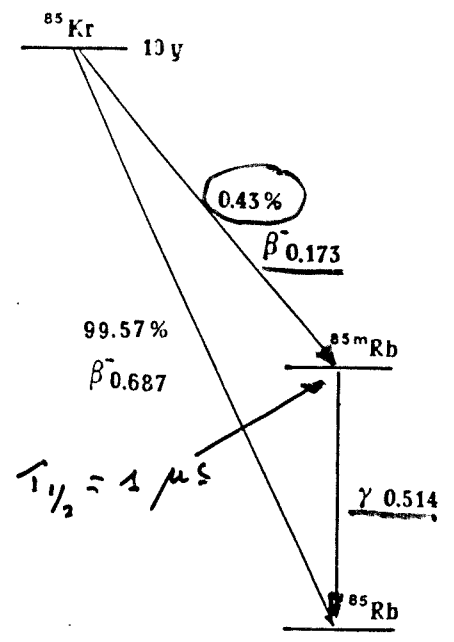
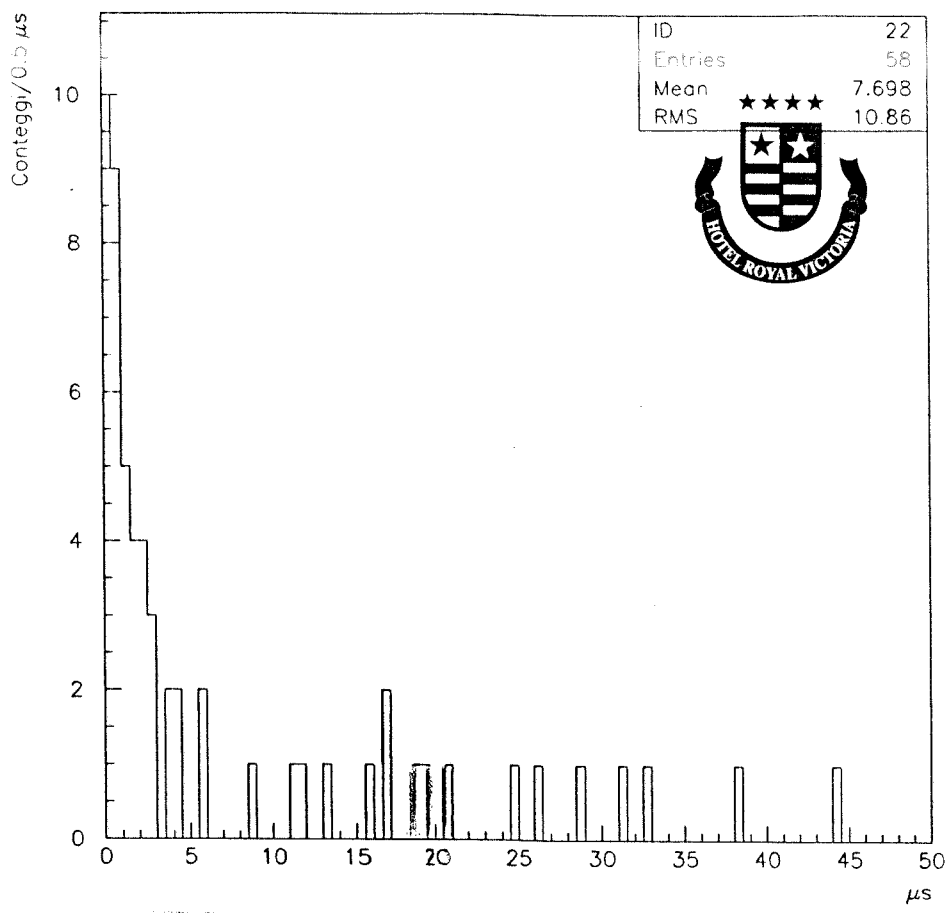
② a ~~→~~ air-tight installations and plants
detector, scintillator handling,
purification systems

Rn, Kr, Ar

tightness single component
 $\rightarrow 10^{-8} \text{ st cm}^3/\text{s}$

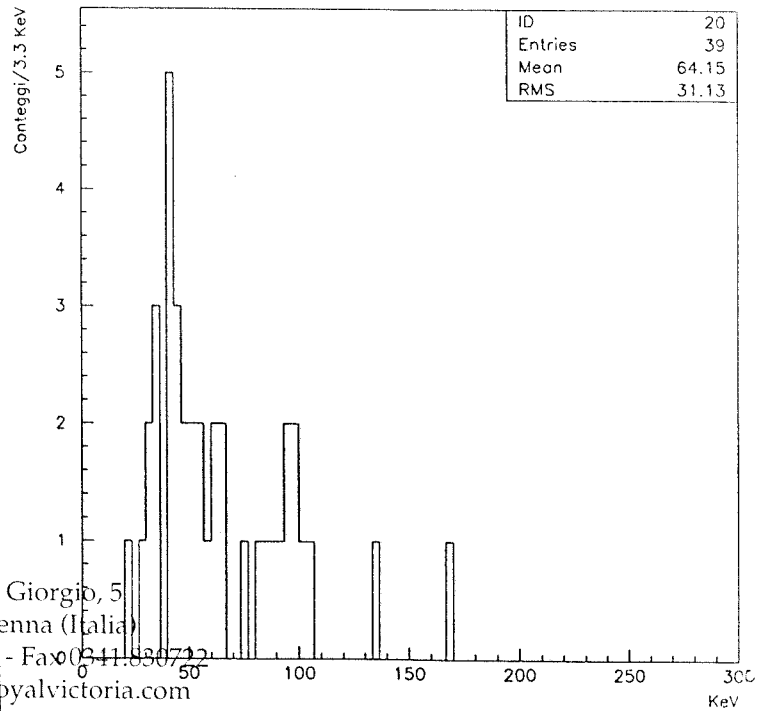
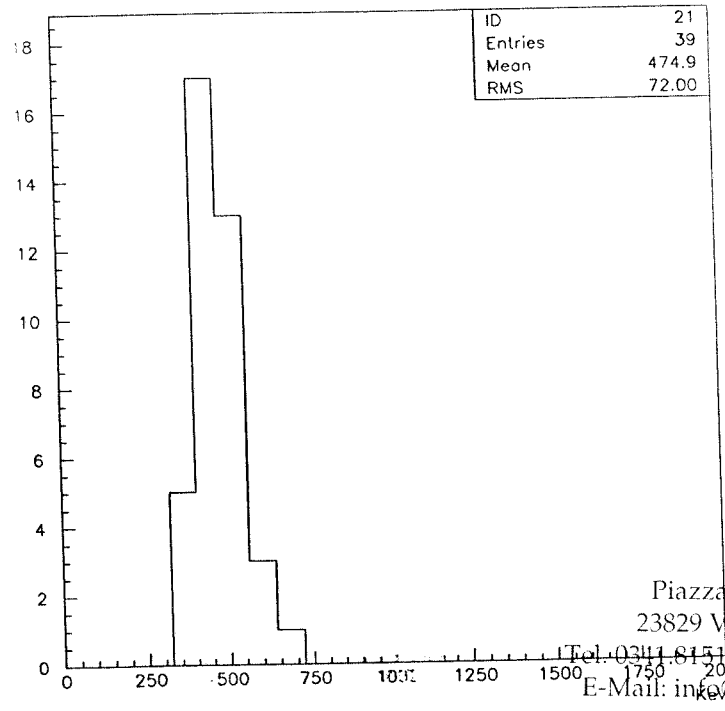
b ~~→~~ emanation: bulk, surface

c ~~→~~ impermeability - thickness of the plastic materials
ex. Nylon dry and wet $\sim 5 \cdot 10^{-12} \text{ cm s}^{-1}$
(2 orders of mag.)



Apr. 21 - May 27: 1.3 ± 0.3 c/d for the coincidence
 $\sim 300 \pm 70$ c/d for ^{85}Kr

Sept. 20 - Oct. 20: 0.2 ± 0.15 c/d for the coincidence
 $\sim 50 \pm 35$ c/d for ^{85}Kr



Ia

● Natural radioactivity

^{40}K ; ^{238}U , ^{232}Th families

● ^{208}Tl $\beta + \gamma$ 50% $\gamma \sim 3.5 \text{ MeV}$
 β : e.p. 1.8 MeV

↳ 23% $\gamma \rightarrow 3.7 \text{ MeV}$
 the real time exp. on solar ν has a threshold $> 5 \text{ MeV}$

I.

high care in the handling of the scintillator components

⊙ dust and particulate

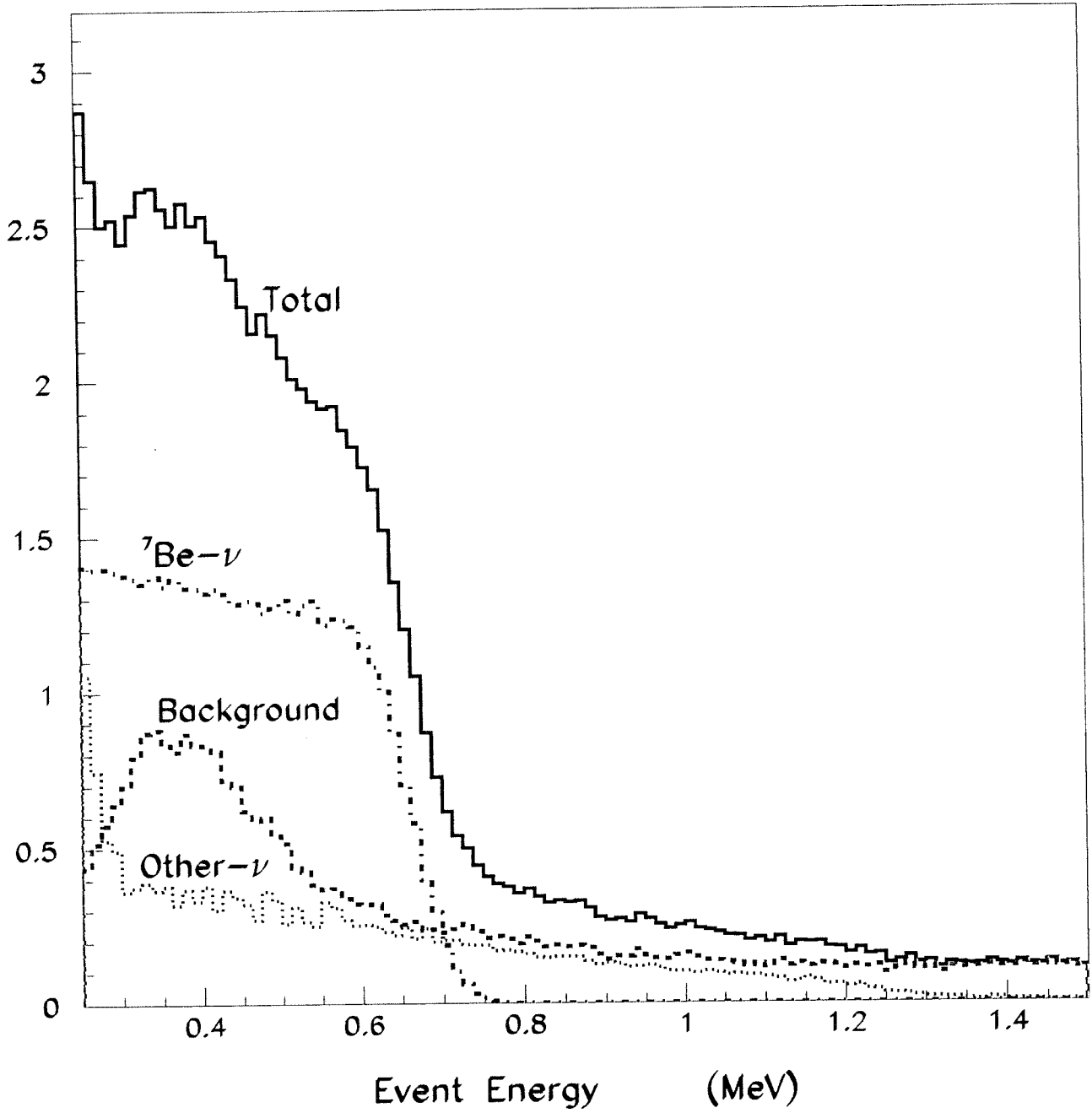
↳ ex. at Gran Sasso 10^{-6} g/g U

⊙ electropolishing pickling and passivation

roughness $\sigma_a < 0.4 \mu\text{m}$

surface: 50 mil. st.

RATE/DAY in FID VOLUME



ν_{Be} "window"

II - Purification

① water extraction + sub-micron filtration
(0.05 μm)

ionizable species such as metals

[~~P. U.~~ : 10^{-14} p/g U, Th; 10^{-10} p/g 4°K]



distillation

vacuum distillation

↳ falling film evaporator/condenser
unit

→ low volatile components (metal and dust particles)



Solid column (SiO_2)

- high affinity of impurities for the column material in dry and wet form

III

- selection of the construction materials
 - selection and purification of the shielding materials
- measur. of bulk activities
- water: reverse osmosis + deionization units + N_2 stripping + ultrafiltration (0.1 μm)
- the whole installation in clean rooms (class 10 - 100)

ex. Gran Sasso

Raw water

10^{-10} g/g U_6, Th

10^{-14}

10^{-7} K_M

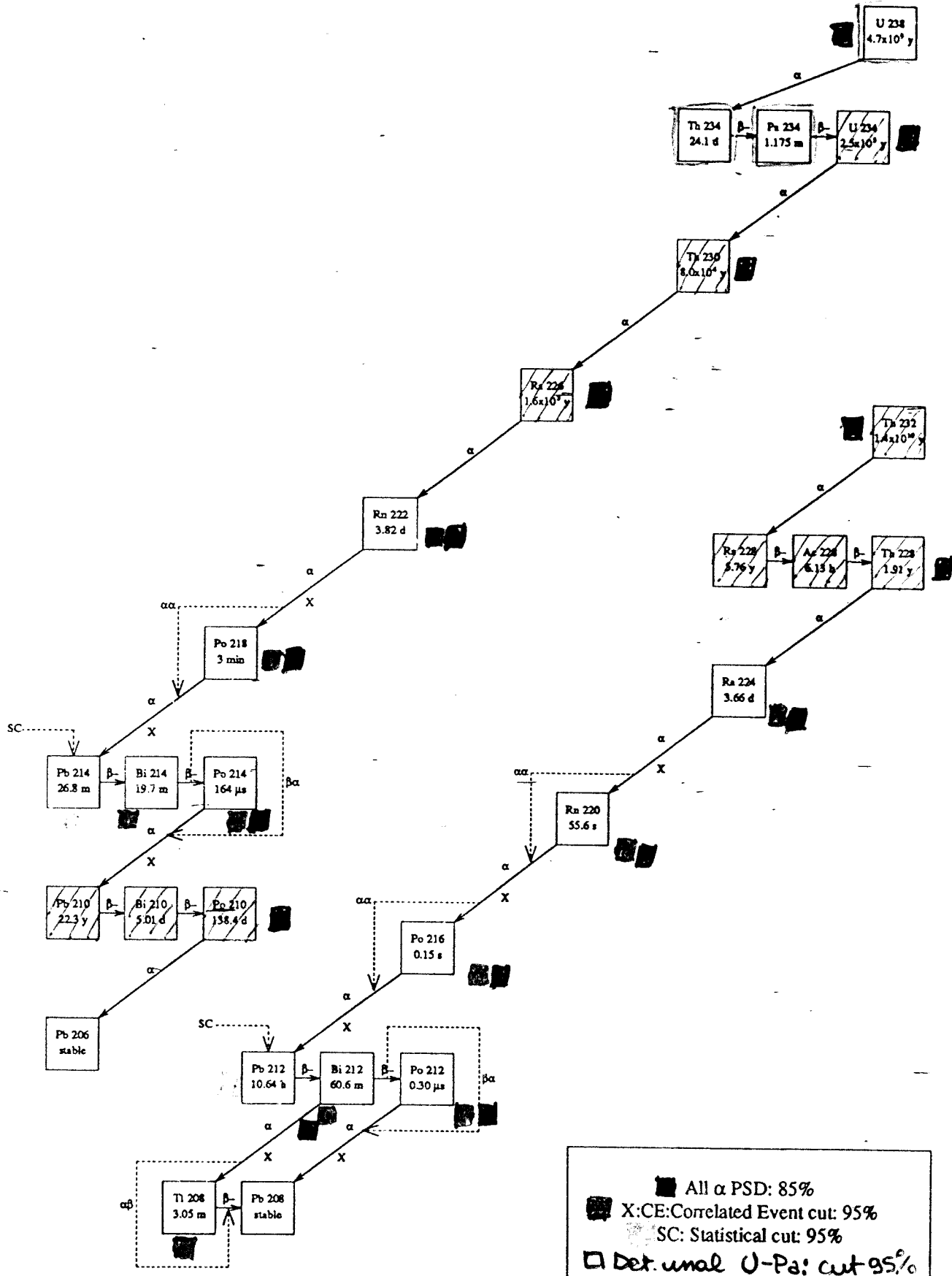
10^{-10}

10^7 mBq/mc R_M/R_a

$2 \cdot 10^2$ R_M

≈ 5 mBq/m³ R_a

ACTIVE background tag



OFF-LINE ANALYSIS: INTERNAL BACKGROUND

~ 90 c/d

1. Correlated events - eff. 99%

Chain	Source	Start event	E MeV	Daughter	Stop event	E MeV	t _{1/2}
²³⁸ U	²²² Rn	α	5.6	²¹⁸ Po	α	6.1	3.05 m
²³⁸ U	²¹⁴ Bi	β ⁻ +γ	0.3-3	²¹⁴ Po	α	7.8	165 μs
²³² Th	²²⁴ Ra	α	5.8	²²⁰ Rn	α	6.4	55 s
²³² Th	²²⁰ Rn	α	6.4	²¹⁶ Po	α	6.9	0.15 s
²³² Th	²¹² Bi	β ⁻ +γ	0.2-2.2	²¹² Po	α	8.9	305 ns
²³² Th	²¹² Bi	α	6.2	²⁰⁸ Tl	β ⁻ +γ	3.2-5.0	3.1 m



direct rejection of the events of these sequences
continuous monitoring of the background

~ 50 c/d

2. α identification - eff. 90%



~ 25 c/d

3. Statistical subtraction

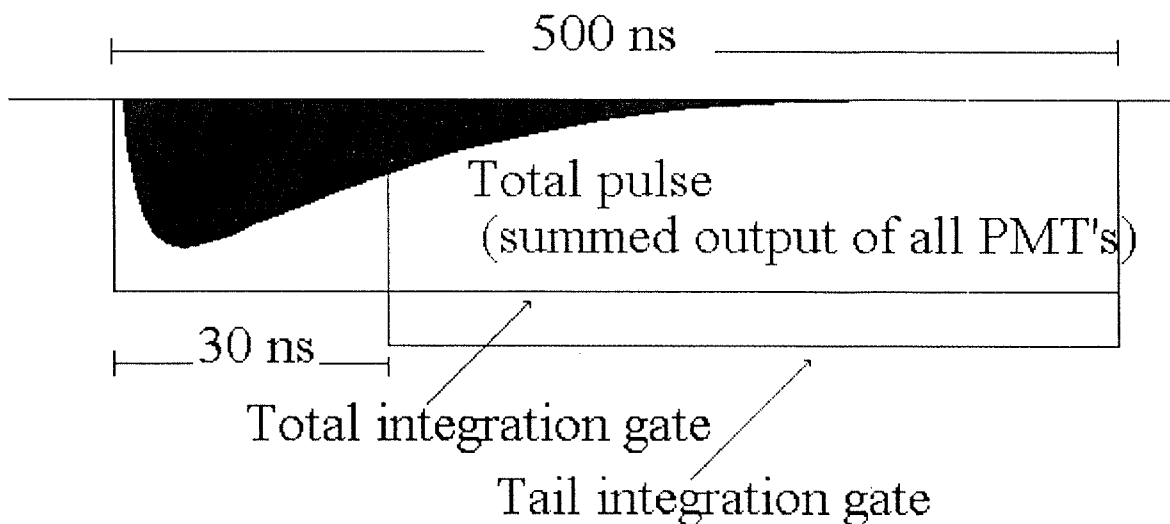
Taggable impurity → concentration of other impurities in the local segment of the decay chain since these adjoining activities are in equilibrium - possible break-up where a long-time decay (>y) is interposed.



11 c/d eff ~ 95%

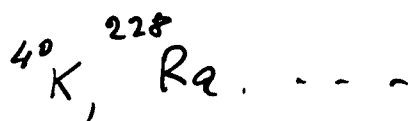
Alpha-Beta discrimination

- Performed by comparing the result of the integration of the whole pulse (summed output of all the PMT's) and of its tail only.
 - Ratio $Q_{\text{tail}}/Q_{\text{total}}$ larger for alpha particle than for electrons
 - Alpha identification efficiency : 99%
 - Beta misidentification probability : 4%
- ⇒ Performance evaluated in CTF by comparing the ^{214}Bi betas and the ^{214}Po alphas



How to measure the low background

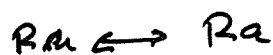
- Ga γ -ray spectrometry
operated underground. ex. G.S. - attenuation of
the μ flux of $\sim 10^6$ (3500 m.v.e.)
shielding with Pb, Cu; continuous N_2 flushing
 \Rightarrow sensitivity $mBq/kg - \sim 10^{-10}$ p/g U, Th



- R_m in gas $\sim \underline{mBq/m^3}$

in liquid $\sim \underline{mBq/m^3}$

G.H. TALK



emanation $\sim 100 \mu Bq/m^3$

- mass spectrometry

• ICPMS - inductive coupled mass spectrometer

• water, other liquids (organic)

• solid (ex. Nylon) via digestion process

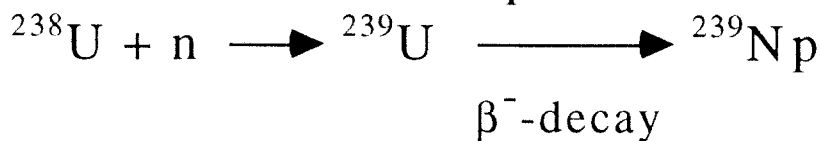
sensitivity - water $\sim 10^{-14}$ p/g

- nylon $\sim 10^{-13}$ p/g

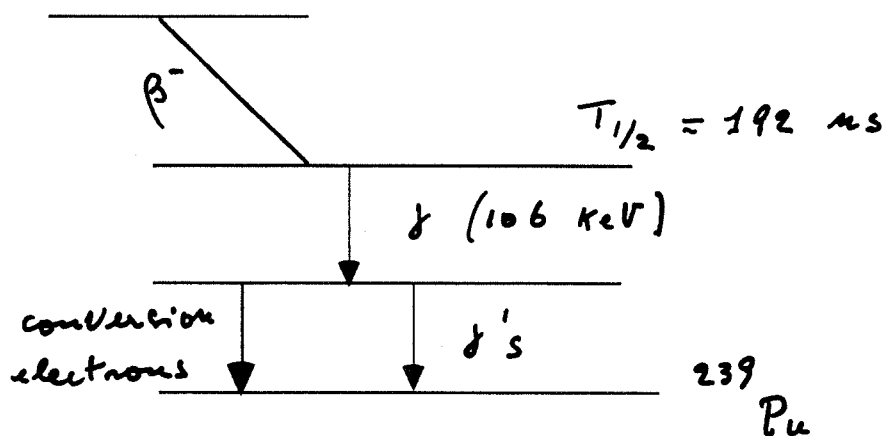
NEUTRON ACTIVATION ANALYSIS

- irradiation;
- irradiated scintillator is extracted with 5% HNO_3 - and then with TBP (tributylphosphate);

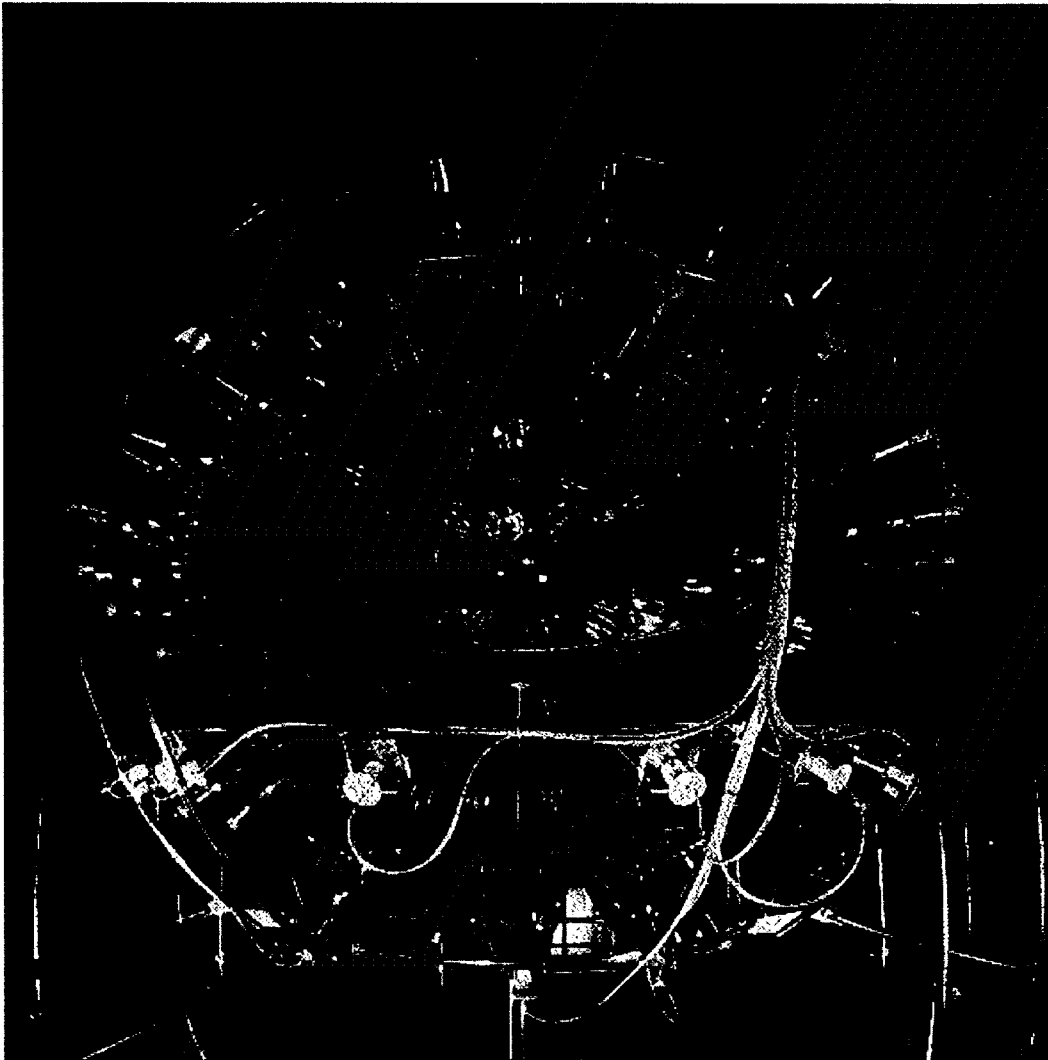
- coincidence technique



${}^{239}\text{Np}$ $T_{1/2} = 2.359 \text{ d}$

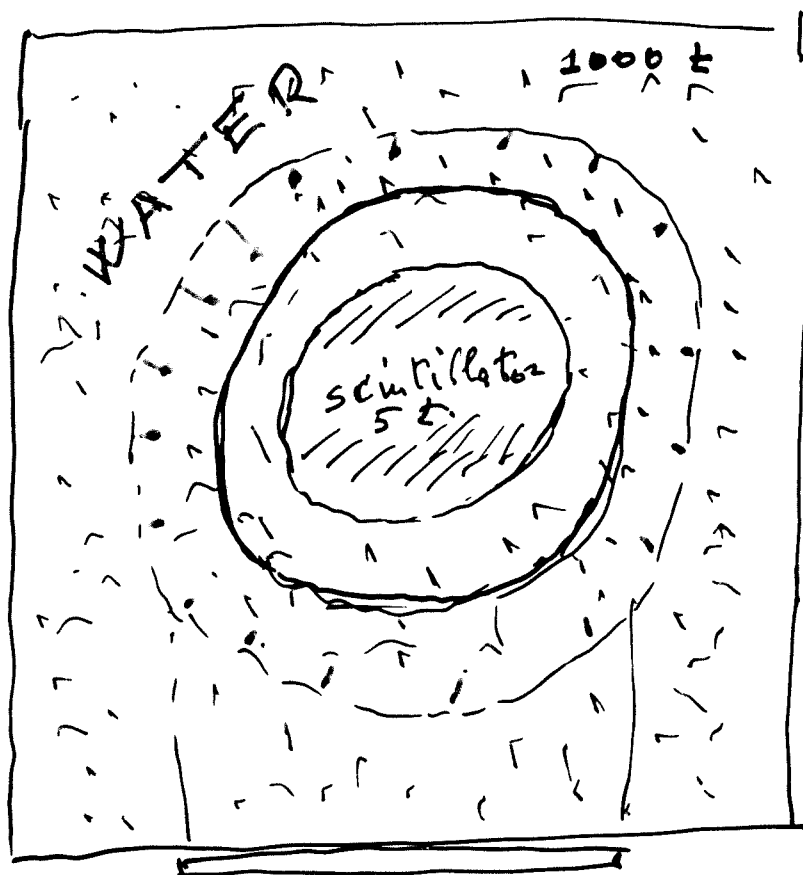


- β^- and conversion electron \longrightarrow PM
- 106 KeV γ \longrightarrow Ge
- reduction of background in f spectrum $\sim 10^4$
 $\longrightarrow 5 \times 10^{-16} \text{ g/g U}$ of sensitivity



Author: Marco G. Giammarchi

Counting Test Facility



- 100 PMT's
- nylon barrier for Rn eman.
- Nylon vessel (300 μm thick)
- ~ 30% of coverage
- ~ 300 e/c/keV

background $\sim 0.1 \text{ c KeV}^{-1} \text{ Kg}^{-1} \text{ y}^{-1}$ 250-2500 KeV
 $\sim 2 \text{ e/d}$ 250-500 KeV
 $\sim 7 \text{ e/d}$ 0-3500 KeV

sensitivity $\sim 10^{-16} \text{ g/g U, Th}$
 $\sim 10^{-19} \text{ }^{12}\text{C}/^{14}\text{C}$

Table 12.1 Radioactive contamination of construction materials

Material	^{238}U (g/g)	^{232}Th (g/g)	K_{nat} (g/g)	^{60}Co (Bq/kg)
Steel Tank	1.5×10^{-8}	2.2×10^{-8}	7×10^{-5}	0.008
Water	$\sim 10^{-13}$	$\sim 10^{-13}$	$\sim 10^{-10}$	
PMT support	6×10^{-9}	8×10^{-9}	1.1×10^{-5}	0.02
PMT's	6.4×10^{-8}	4.7×10^{-8}	2.9×10^{-5}	0.003
Nylon	2×10^{-11}	2×10^{-11}	2×10^{-8}	

Ib

μ

- underground 10^{-6} with respect to the surface
- $2 \mu / m^2 / h$ at Gran Sasso

1. μ or prompt secondaries

- very high pulse in the scintillator
- pattern of the hit PMT's in the shielding lipriods (& light)
- μ veto
- track spot at the entry point

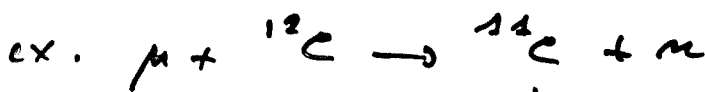
2. γ from cosmogenic n

- path to reach thermal energies ($\approx 1 m$)
- p capture and emission of 2.18 keV γ

3. μ induced radioactivity

β^- emitters : $^8Li, ^9Li, ^{11}Be, ^{12}B$
 $\lambda \approx 0.1 - 10 \text{ sec}$

β^+ emitters : $^8B, ^9C, ^{12}C$

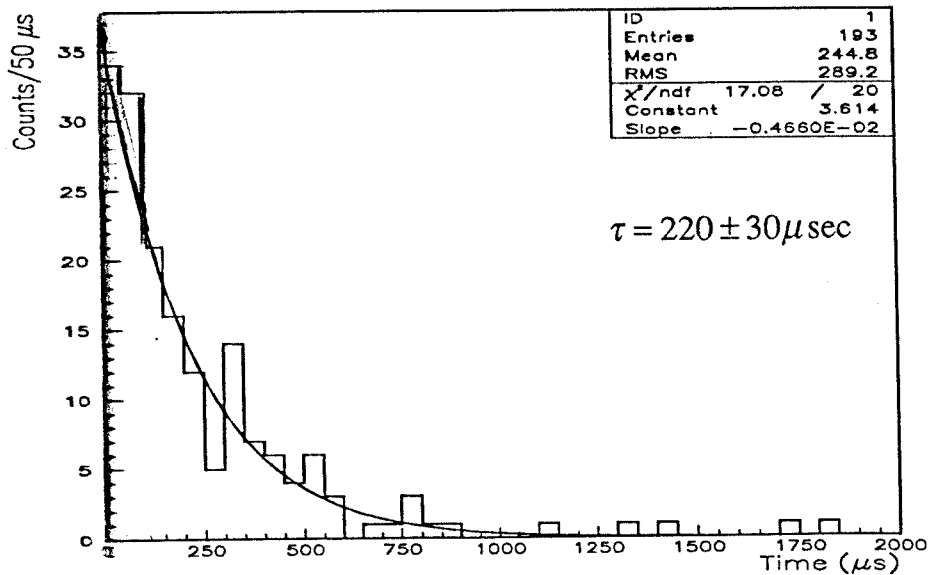
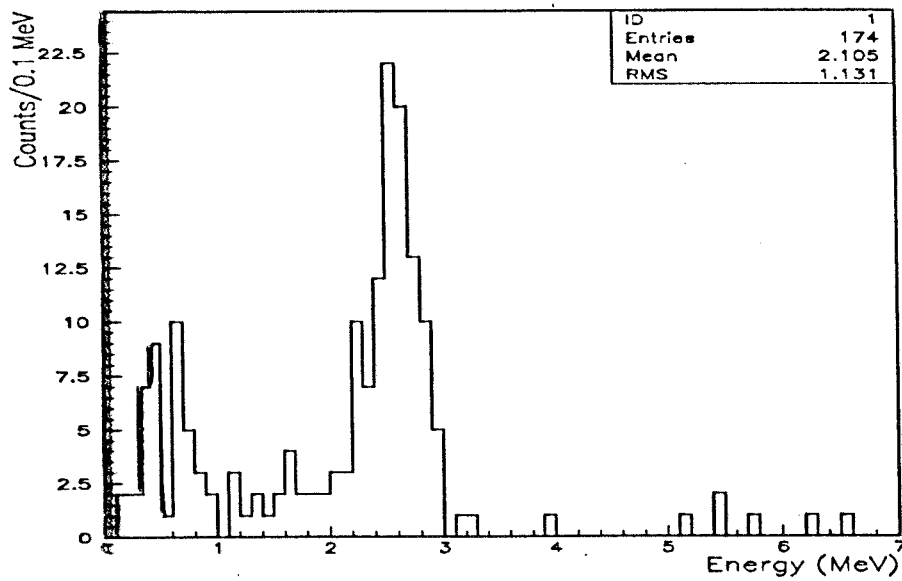
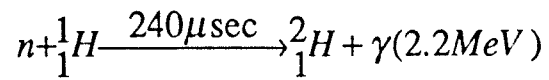


$\downarrow 20 m$

$\beta^+ (\approx 1. \text{keV}) \rightarrow \beta^+ \text{ capture}$

$\rightarrow n$ position - software cut

Neutrons generated by crossing muons



-Measurement done trough 130 days;

-1.2 delayed coincidence detected per day;

-All rejected

Summary

1. A lot of different techniques have to be adopted and developed to work in real time below 1 MeV
2. Real time: energy independent time variations of the ν flux.
3. Low energy solar ν .
4. In this field records have been achieved in low radioactive levels and in measuring them

5. Ahimonti et. al.; Astroparticle Phys., 16(2002) 205
6. Arpesella et. al.; " " July 2002