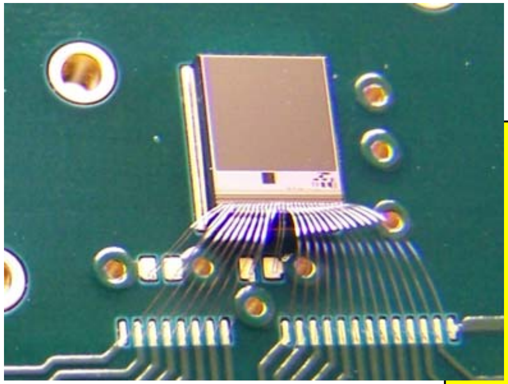


Caractérisation et Qualification d’un Dosimètre Personnel Électronique Neutrons

Encadrement: D.Husson*, S.Higueret (A.Nachab, A.Sellam)

Contexte: dosimétrie opérationnelle N

L'existant (IPHC): chips AlphaRad2 et 3

Ce qui reste à faire:

a) système complet

b) tests en sources + simulations

→ Qualification

International norm IEC 1323, 1995

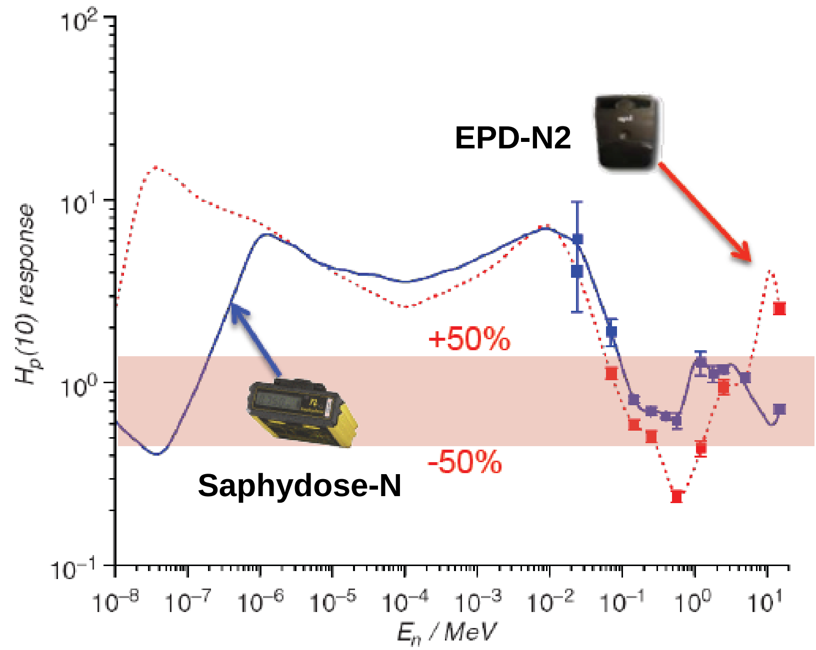
→ Neutron electronic dosemeters mandatory

EVIDOS (Eval. of Individual DOSimetry) EU survey: 2001-2005

==> 2 neutron dosemeters:

Saphymo-IRSN: Saphydose-N (ISO)

APVL Siemens: EPD-N2



[1] M. Reginatto et al, Rad. Prot. Dos. 125 (2007) 285-288

Electronic Personal Dosimetry

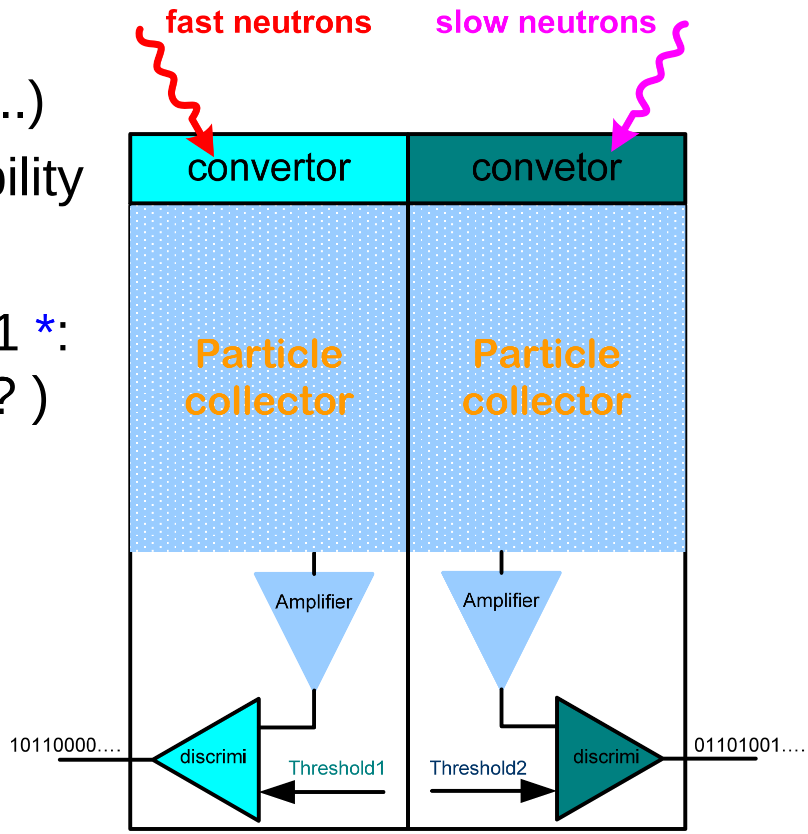
Requirements:

- Real-time + high sensitivity
  (→ alarm @ 20 mSv..)
- Low P consumption → 24h portability
- Cheap (→ 65000 workers in UE)
- Smartness (n/γ discrim. OK @ 1/1 *: what about 1/10 or 1/100..?)
- Growing demand:

a) UE recommandations

b) **dismantling** is just starting..

c) cyclotrons everywhere !



** Thèse Ying Zhang (19/09/2012)*

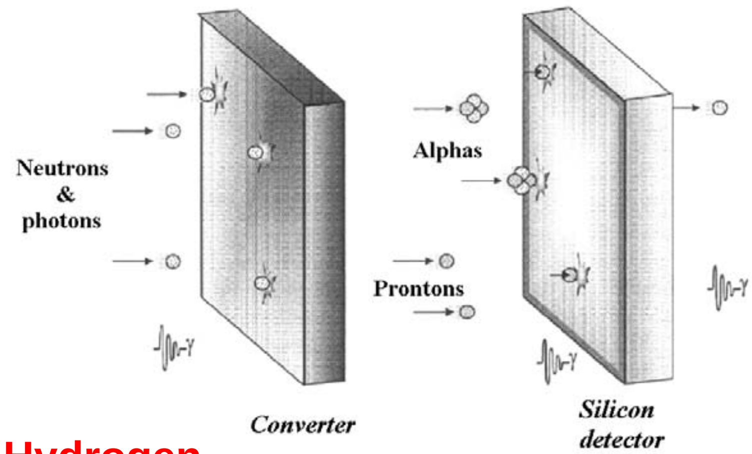
Detection of <u>charged</u> particles → neutron converters needed !

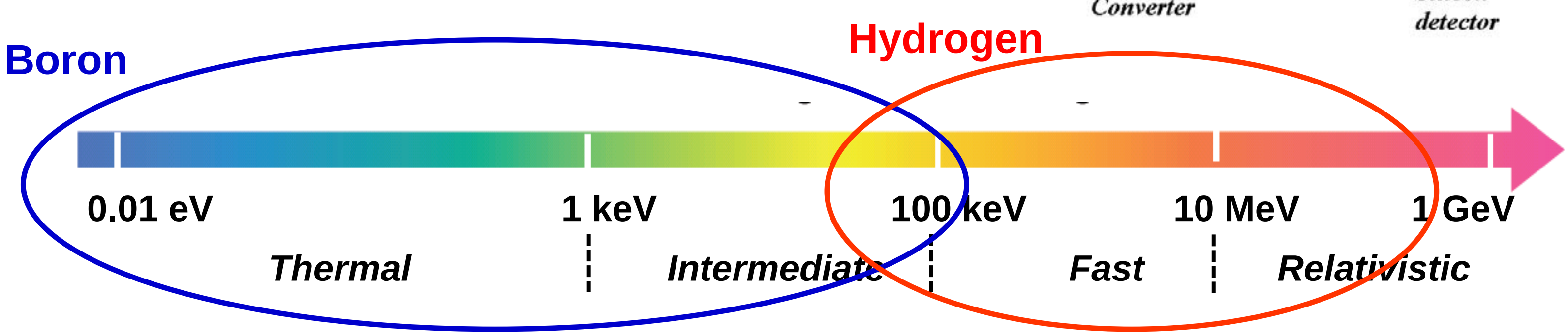
Thermal neutrons: n+ ^{10}B → ^{7}Li + α

Boron converter

Fast neutrons: n + H → n + **p**

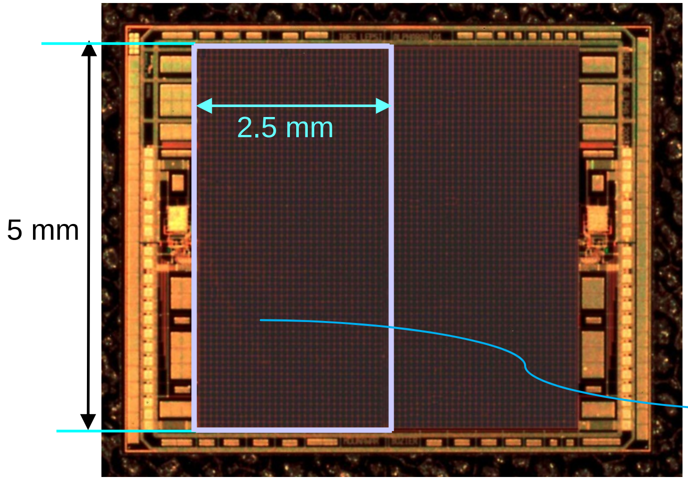
$(CH_2)_n$ converter

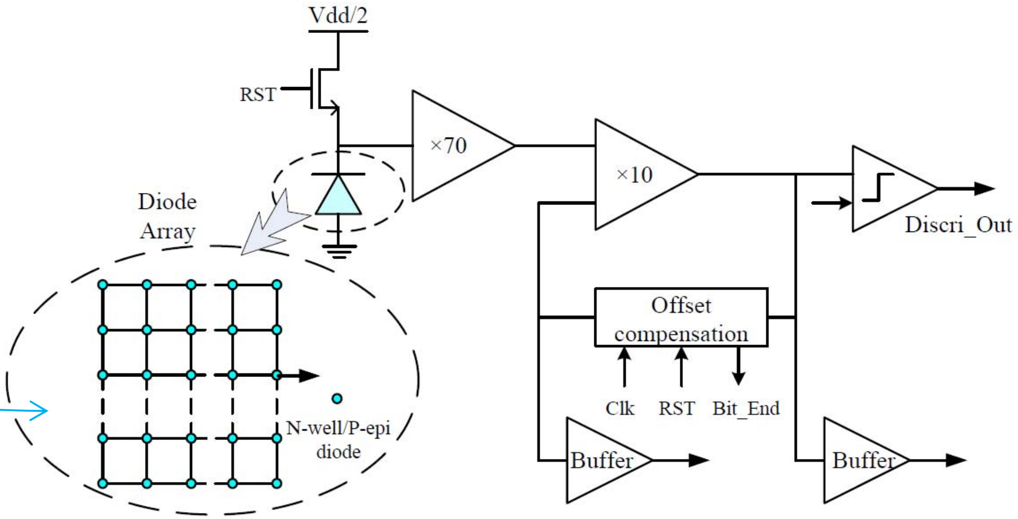




Wide energy range → two converters of different nature

AlphaRad1: dedicated chip for direct α detection (2006)





32 × 64 diodes in parallel

with a single output

High detection efficiency for

5 MeV alpha particles (~100%)

→ → Fast counting on a large area

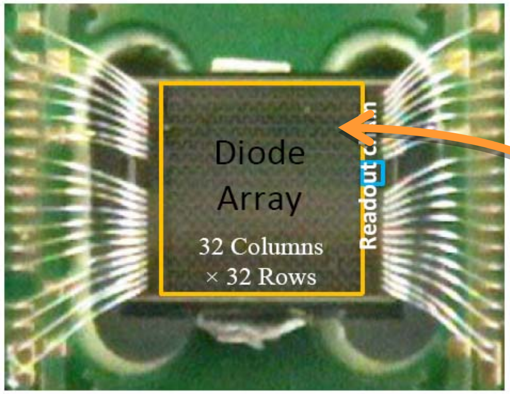
achieved <u>without</u> pixellization

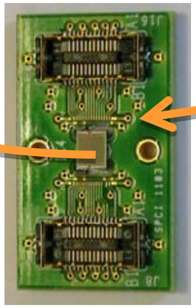
Drawbacks

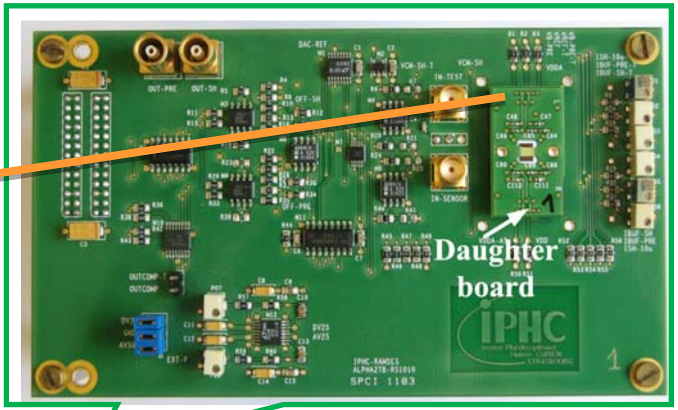
- Equivalent noise charge (ENC) ~14 000 e^-
  - → too high for fast neutrons (threshold 50 000 e^-)
- Power consumption ~10 mW
  - → needs to be reduced !!

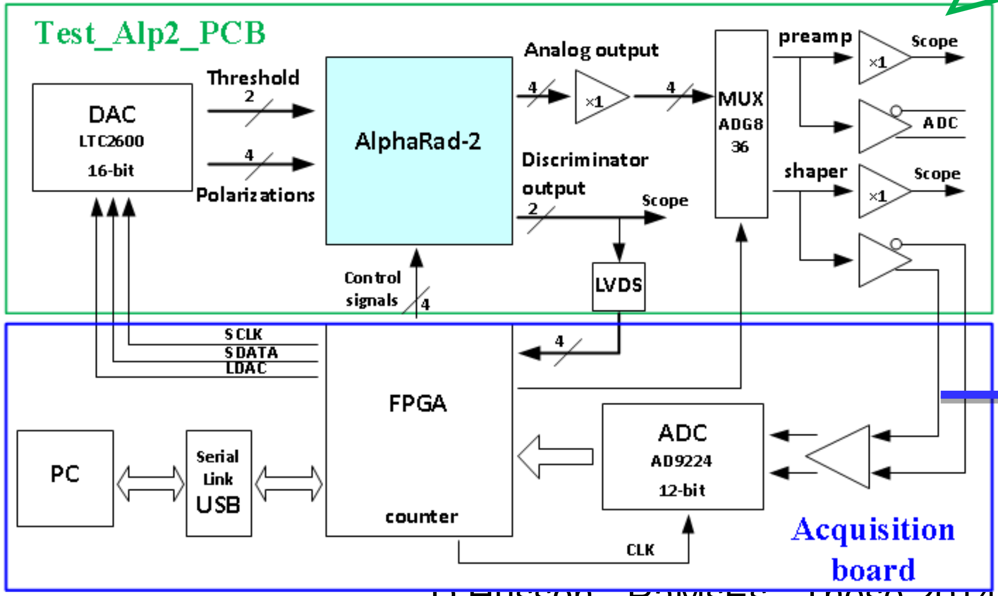
New chip dedicated to a neutron dosemeter

AlphaRad2 (2012)



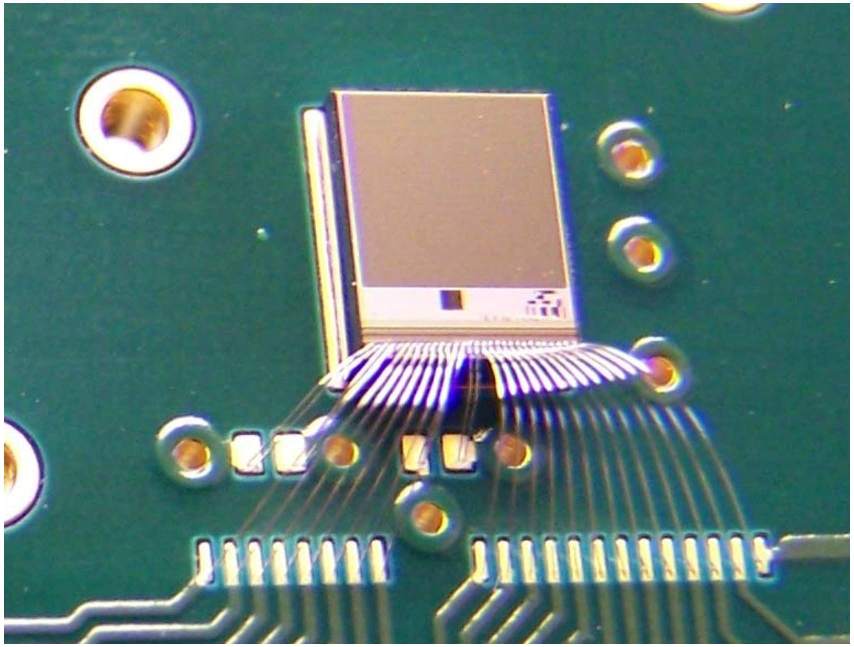




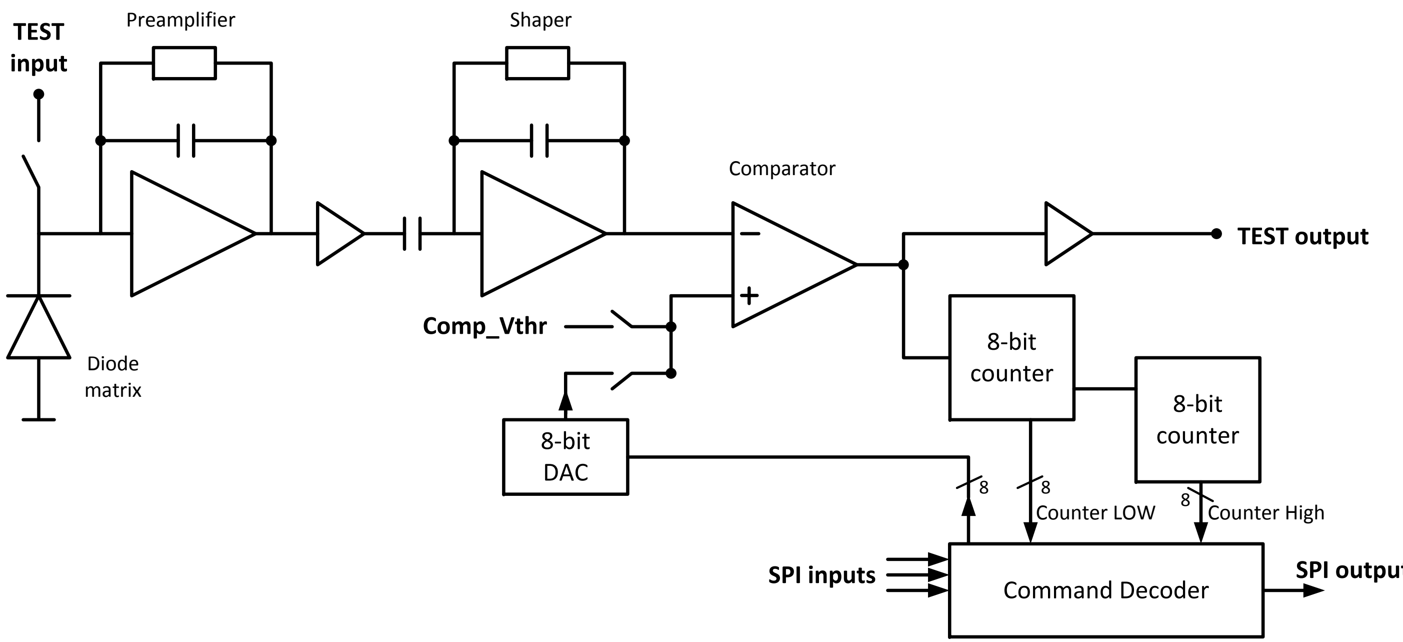


Test options:
–Oscilloscope
–ADC outputs

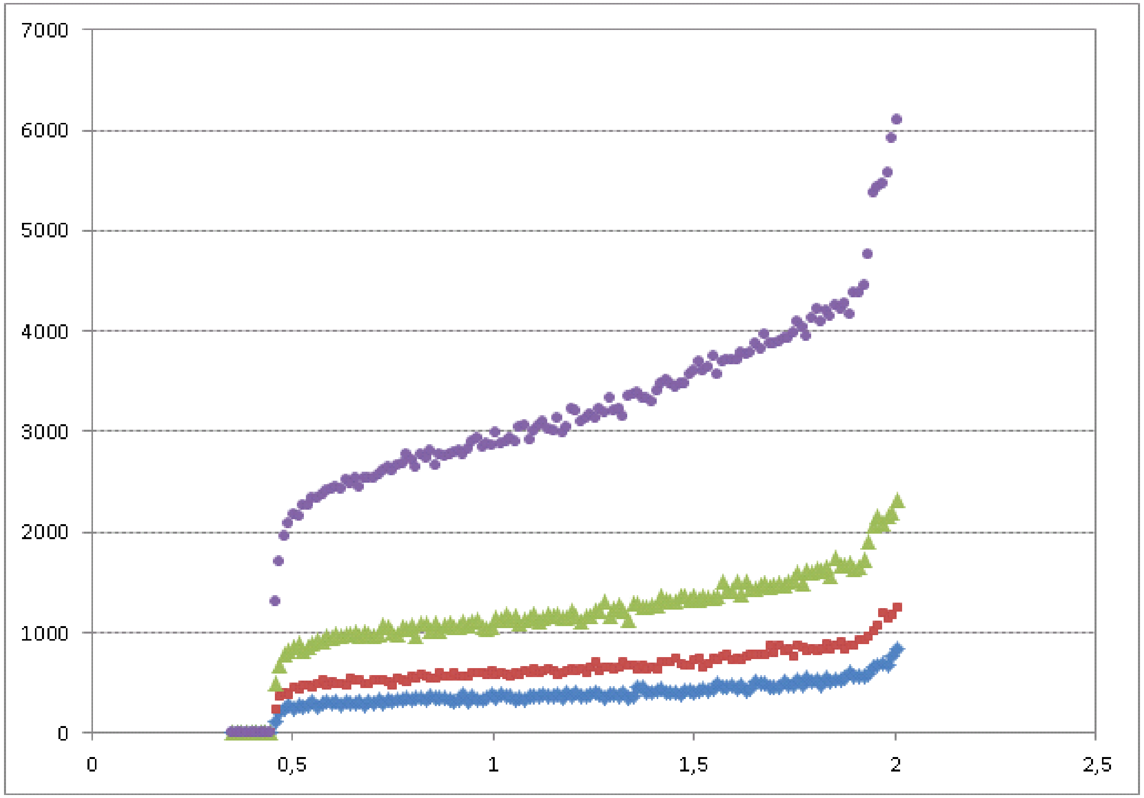
Digitalize analog signals
(output of CSA/shaper)

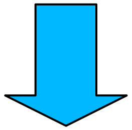


Chip AlphaRad3 (XFAB 0.35 μm)



Measurements with Am alpha source at different distances





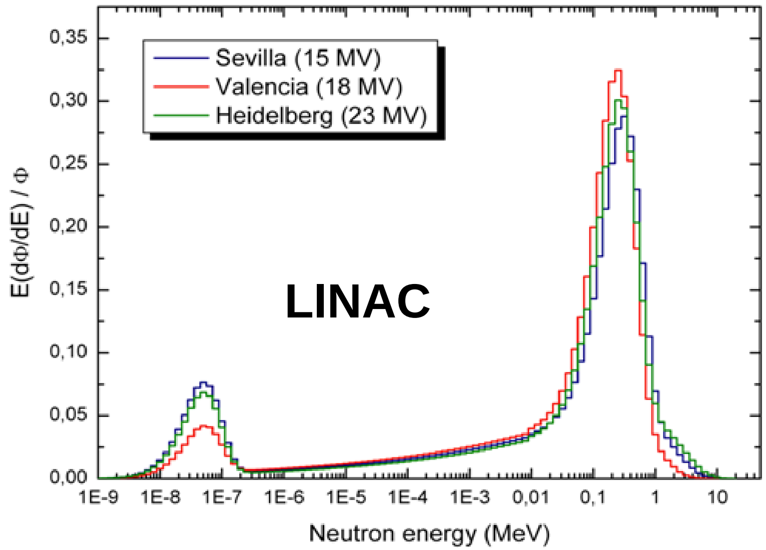
50% < effic < 100% (..?)

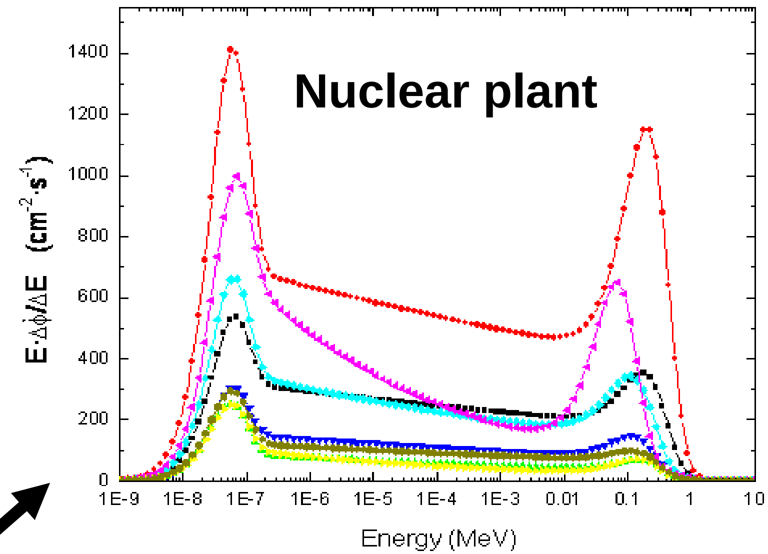
X axis – Comparator threshold voltage
Y axis – Counter value

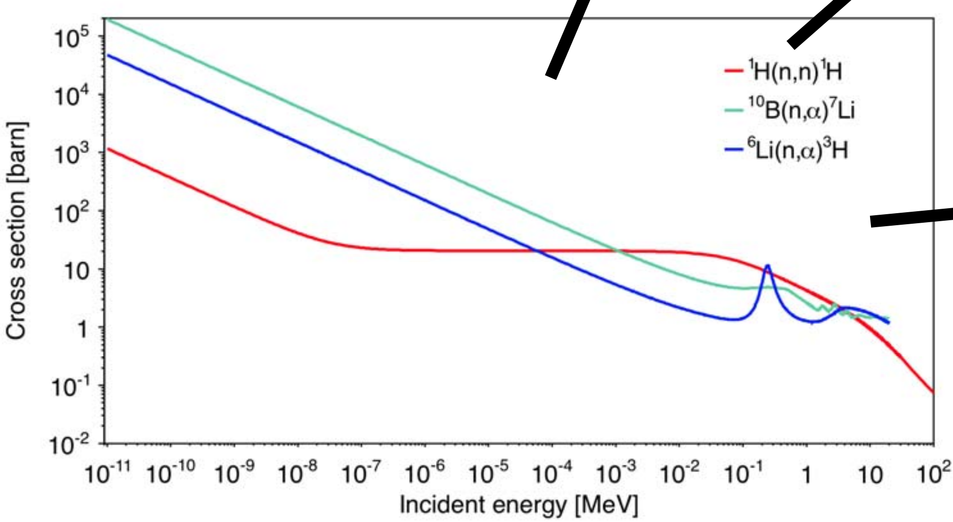
Experimental tests (LMDN Cadarache)

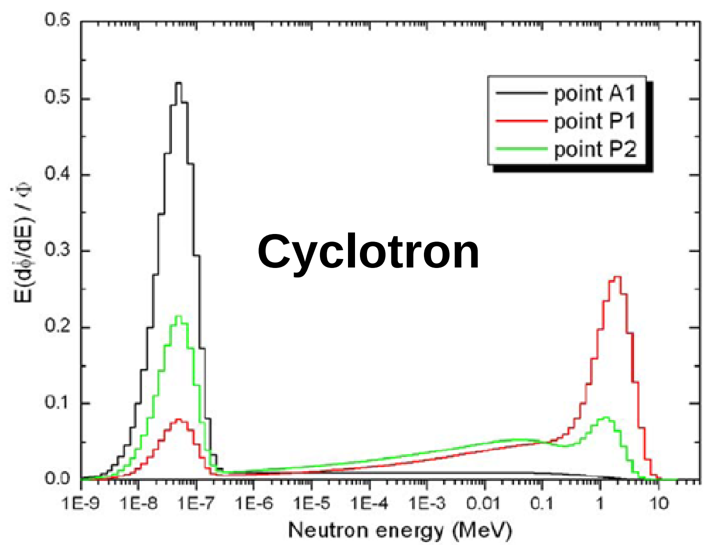
Van Gogh: AmBe source (370 GBq), ^{252}Cf
Fast n + γ 4.438 MeV
fluences well defined(4%)

AMANDE facility : mono-E neutrons
(3 keV-20 MeV)

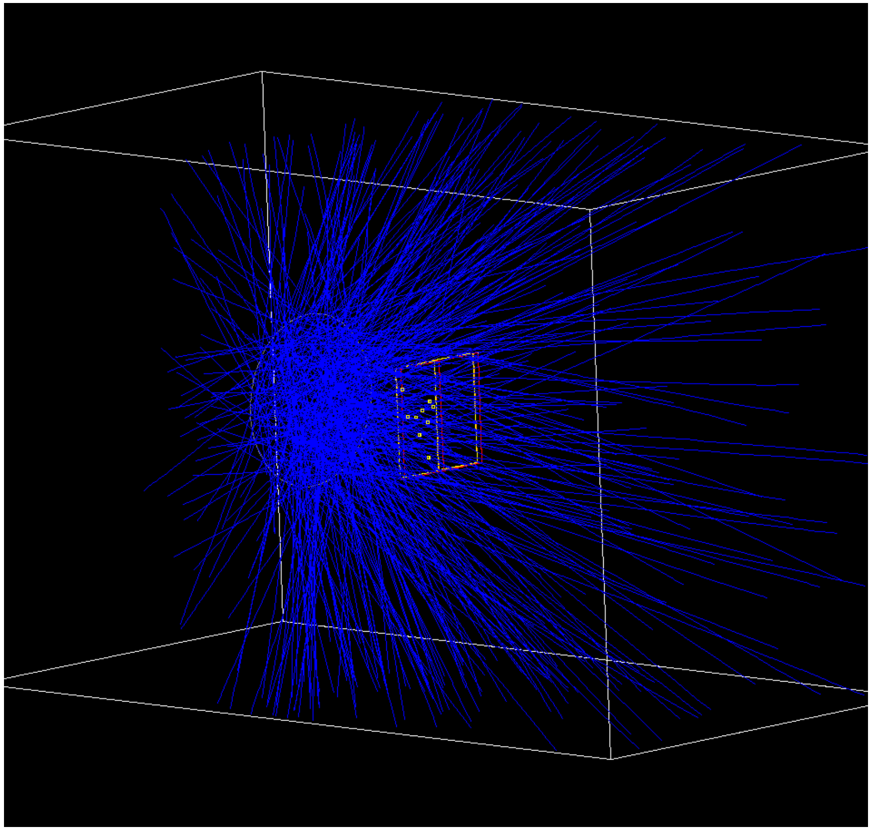

LINAC
Sevilla (15 MV)
Valencia (18 MV)
Heidelberg (23 MV)
E(dΦ/dE) / Φ
0,00
0,05
0,10
0,15
0,20
0,25
0,30
0,35
1E-9 1E-8 1E-7 1E-6 1E-5 1E-4 1E-3 0,01 0,1 1 10
Neutron energy (MeV)


Nuclear plant
E·Δφ̇/ΔE (cm⁻²·s⁻¹)
0
200
400
600
800
1000
1200
1400
1E-9 1E-8 1E-7 1E-6 1E-5 1E-4 1E-3 0.01 0.1 1 10
Energy (MeV)


¹H(n,n)¹H
¹⁰B(n,α)⁷Li
⁶Li(n,α)³H
Cross section [barn]
10⁵
10⁴
10³
10²
10
1
10⁻¹
10⁻²
10⁻¹¹ 10⁻¹⁰ 10⁻⁹ 10⁻⁸ 10⁻⁷ 10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 1 10 10²
Incident energy [MeV]


Cyclotron
point A1
point P1
point P2
E(dφ̇/dE) / φ̇
0.0
0.1
0.2
0.3
0.4
0.5
0.6
1E-9 1E-8 1E-7 1E-6 1E-5 1E-4 1E-3 0.01 0.1 1 10
Neutron energy (MeV)

Simulation

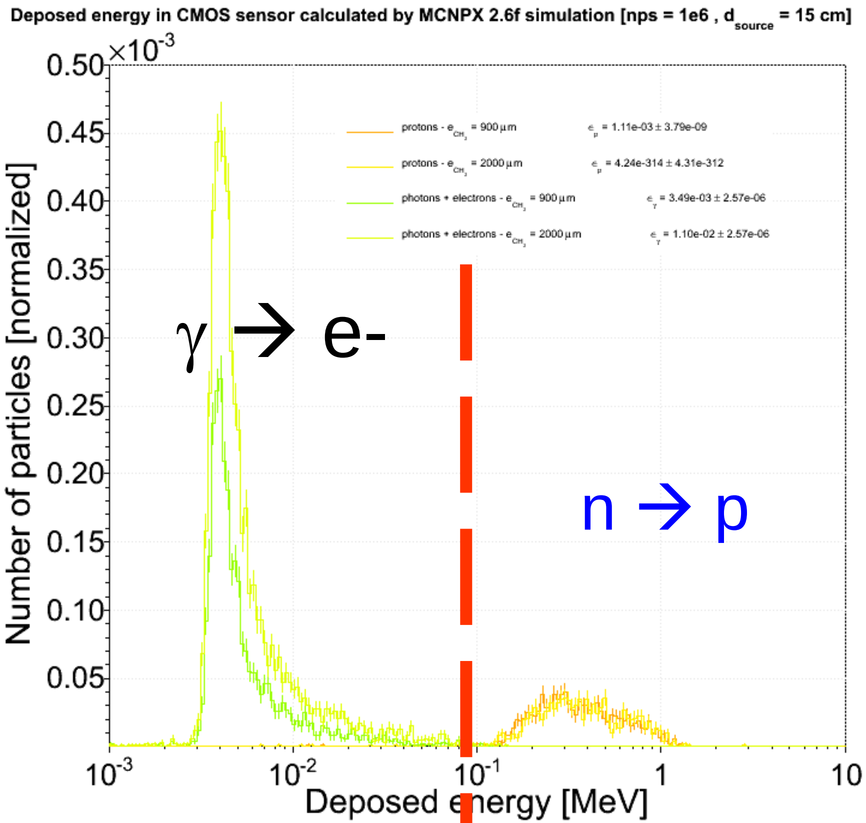


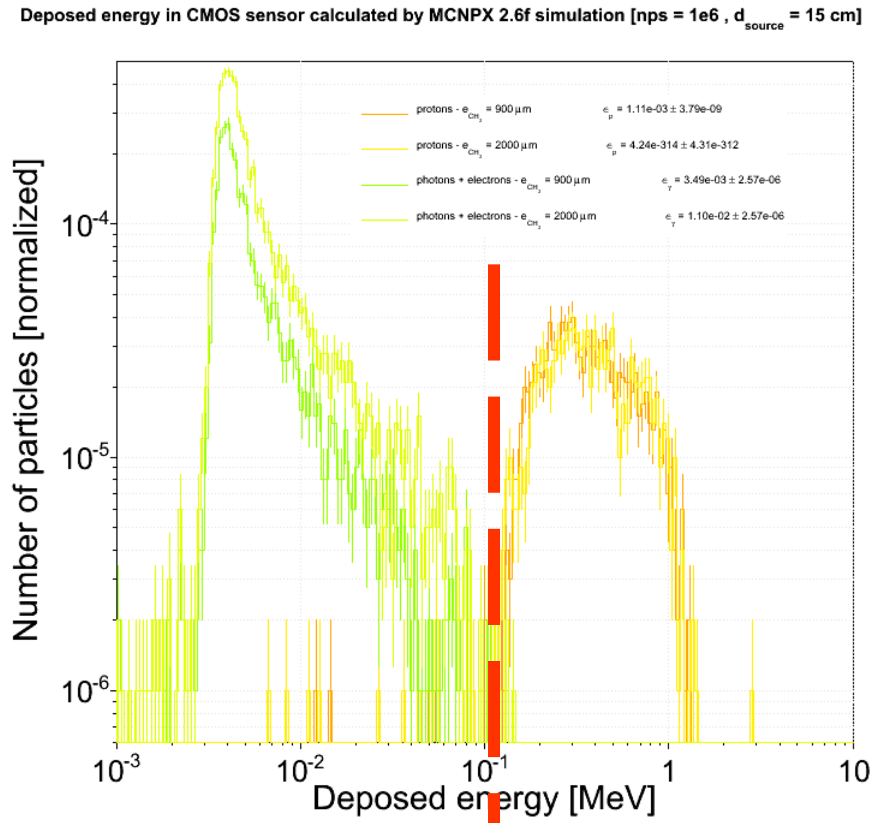
- GEANT IV

-MCNPX

-(+ comparaisons!!)

Discrim n/γ : Simulations (Thèse M.Vanstalle)





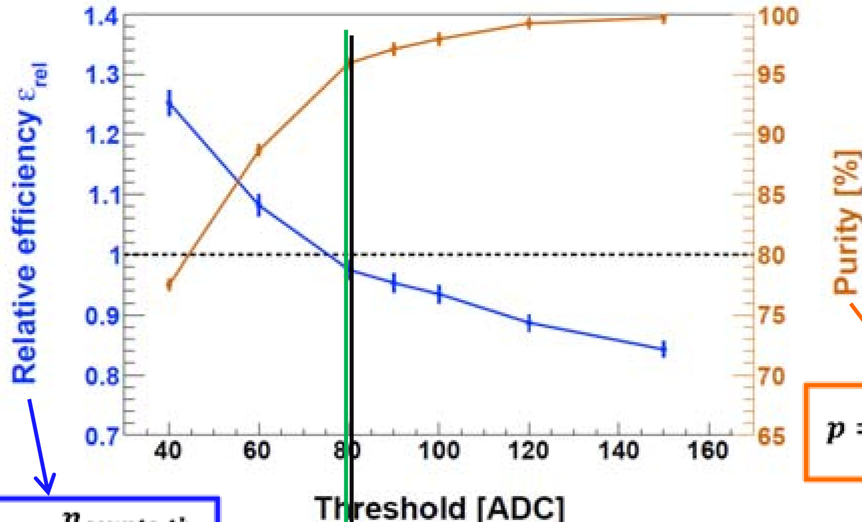
…and real life !

AmBe source, d = 20 cm

310-min exposure

500 µm-thick $(CH_2)_n$ converter

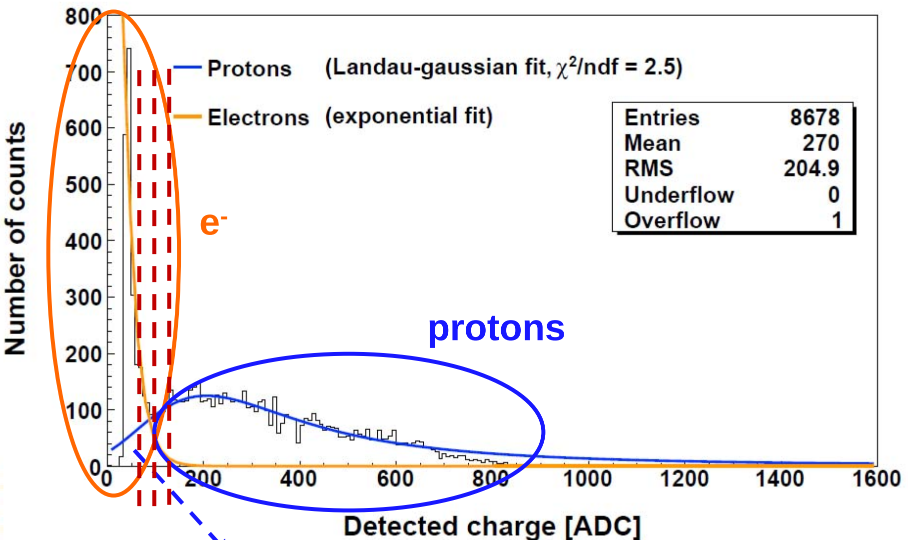
→ **Threshold for n/γ discrimination**



$$\varepsilon_{rel} = \frac{n_{counts\_th}}{n_{protons}}$$

$$p = 1 - \frac{n_{electrons}}{n_{counts\_th}}$$

Q > 80 ADC ➡ High eff. + good purity



Extrapolation of protons in γ-peak

80 ADC

$$\varepsilon_{int} = \frac{n_{det.protons}}{n_{neutrons}}$$

$$\varepsilon_{int} = (7.24 \pm 0.32^{*}) \times 10^{-4}$$

*statistical & source uncertainties

Déjà réalisé:

- Design optimisé de l'électronique intégrée: chip *AlphaRad2* (thèse Ying Zhang).
- Simulations+mesure n rapides+lents +transparence γ , MimoV (thèse Marie Vanstalle)
- Sensibilité: ~10 μSv (!)
- Design *AlphaRad3*, techno XFAB + ouvertures SiO_2 face avant (Maciej Kachel)
- Système complet et autonome (PCB multi-chip) +ACQ mars 2013: M.K.+ S.Higueret
- Réponse α et AmBe: juill13 (stge M2 A.Torres).

Finalisation du projet (thèse)…

Simu!!

- *Réponse n mono-E, fast+slow*
  et sur spectres étendus
- *Influence n lents diffusés*
- *Réponse angulaire*
- *Discri n / γ dans combinaisons artificielles de sources mixtes (1/10, 1/100, 1/1000)*
- *Influence T°; radhardness; blindage EM, …*

→ *Fantômes anthropom.*