Pulse Discrimination between Recoil Protons and Secondary Electrons for a Silicon Diode Based Neutron Spectrometer

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Outline

- Motivation
- Recoil-proton spectrometer for neutrons
- Silicon diode based neutron detector
- Discrimination of the γ-field
- Conclusions

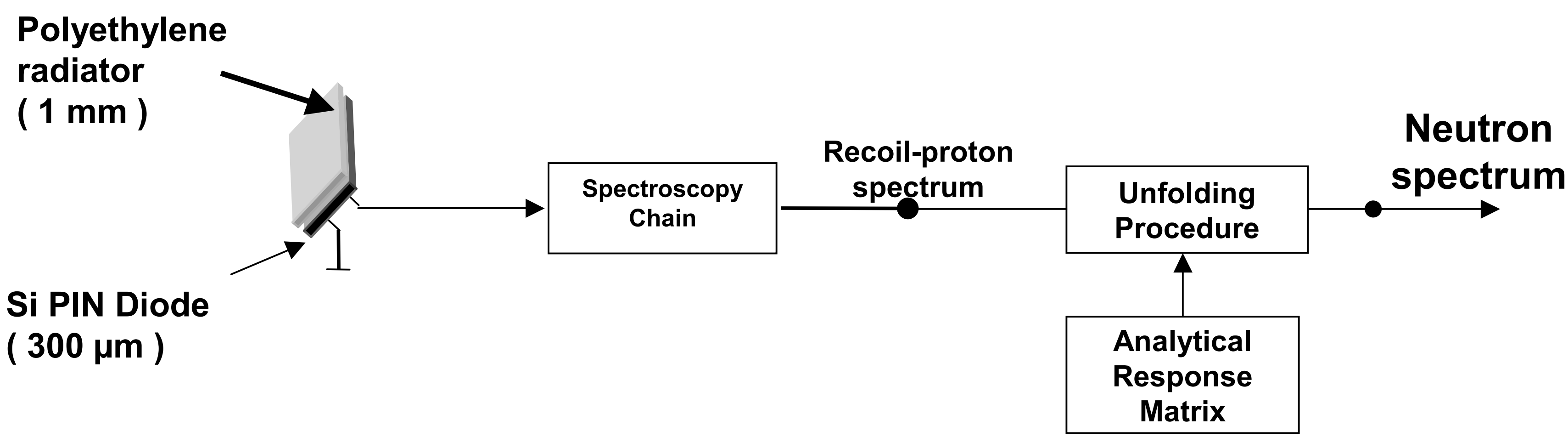
Motivation

Characterization of the low-energy (few MeV) neutron fields generated by low-energy ion-accelerators:

- Biological cultures irradiations
- Electronic circuit radiation damage studies
- Shielding calculation for radiation protection

Offer an alternative to organic scintillator / PMT spectrometers, based on silicon diodes with comparable spatial and energy resolution

Recoil proton spectrometer for neutrons



Distribution of the recoil proton energy p(Ep)

The collision between n and p in the center of mass reference system is isotrope and elastic in the MeV energy renge

In the laboratory system θ is the angle between the incoming n and the recoil p:

$Vp = Vin \cos\theta$, $Ep = Ein \cos^2\theta$ and differenciating $dEp = -\ Ein\ 2 \cos\theta \sin\theta\ d\theta$.

Integrating the differencial cross section (Lab) in the solid angle between θ and $\theta+d\theta$

$p(\theta)\ d\theta = 2 \cos\theta \sin\theta\ d\theta$ maximum for $\theta = \pi/4$

$p(Ep)\ dEp = p(\theta)\ d\theta$

Substituting there is a cancellation and

$p(Ep) = 1/En$ with $0 < Ep < En$ CONSTANT

Distribution of the deposited energy by the recoil protons in the silicon p(Ed)

Model equations:

$p(E_p) = 1/ E_n$ in the interval $(0 – E_n)$

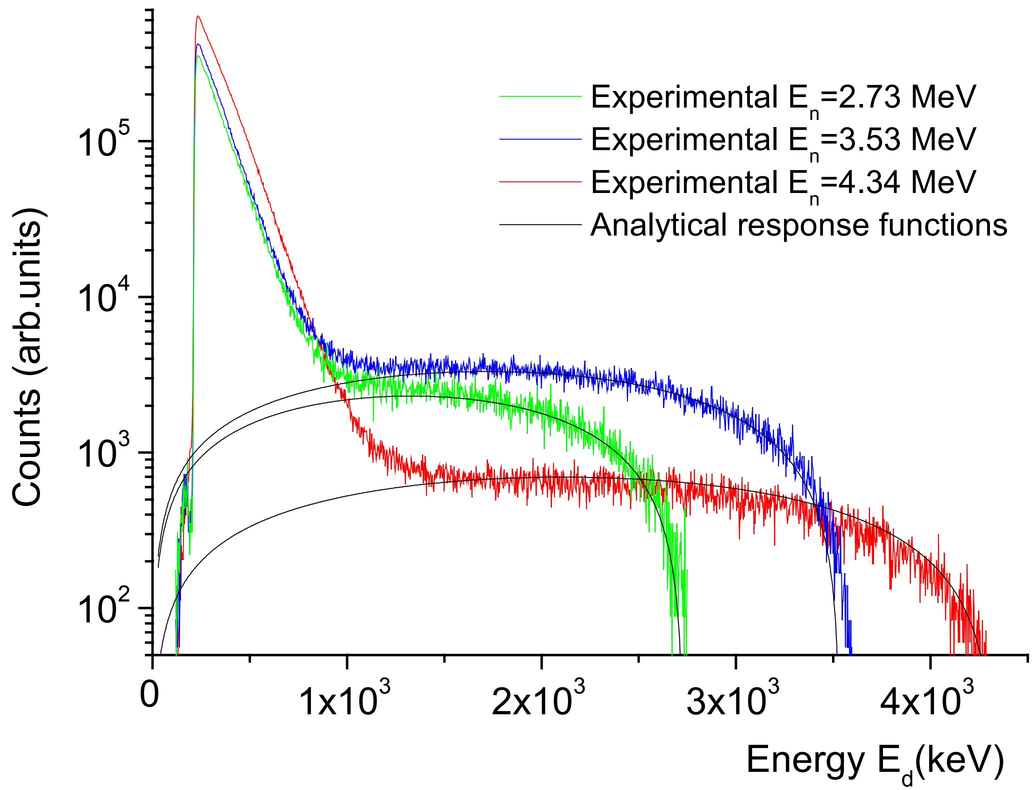
$R_p = R_0 \cdot E_p^{ß}$ range-energy power law

$R_{total} = R_{radiator} + R_{detector}$

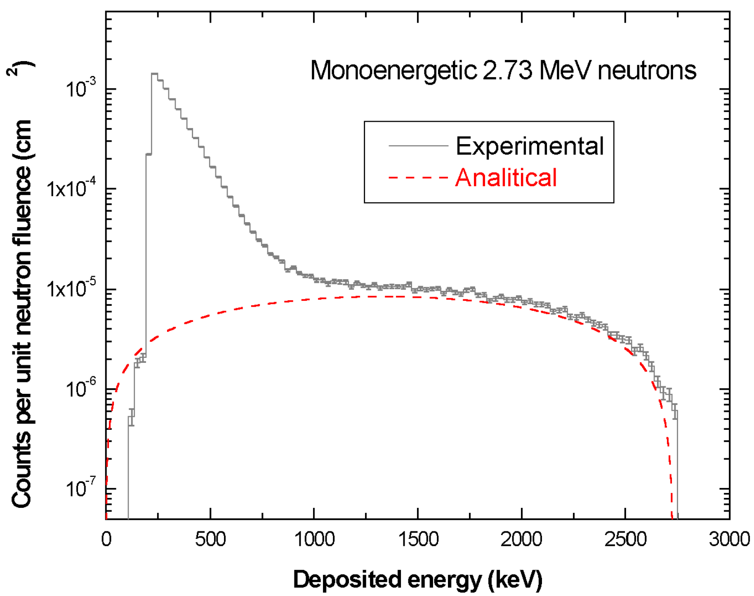
$E_d = [(E_n \cdot \cos^2\theta)^{\beta} - h/(R_0 \cdot \cos\theta)]^{1/\beta}$

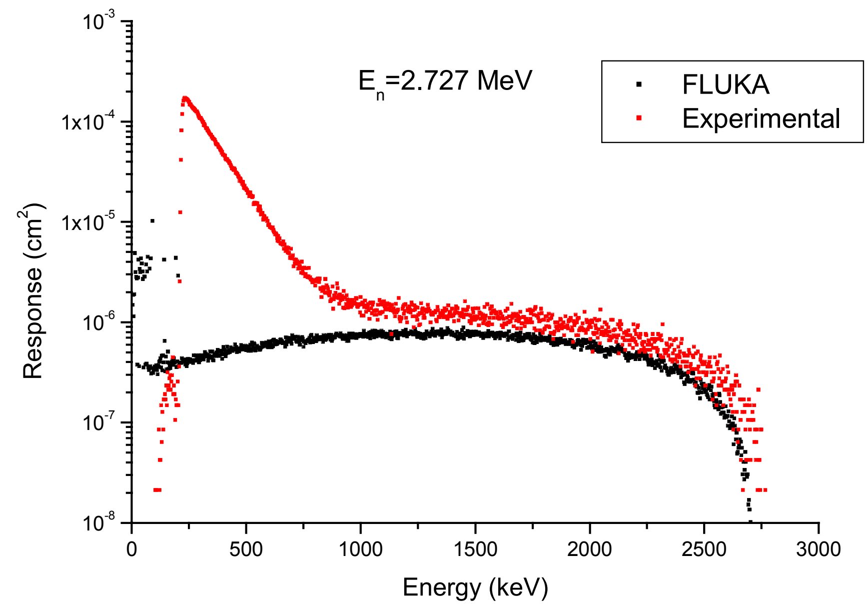
$p(E_d) = 2/3 \cdot ß \cdot (E_d/ E_n)^{ß-1}/E_n \cdot [1 – (E_d/ E_n)^{3/2}]$

Experimental and analytical response functions

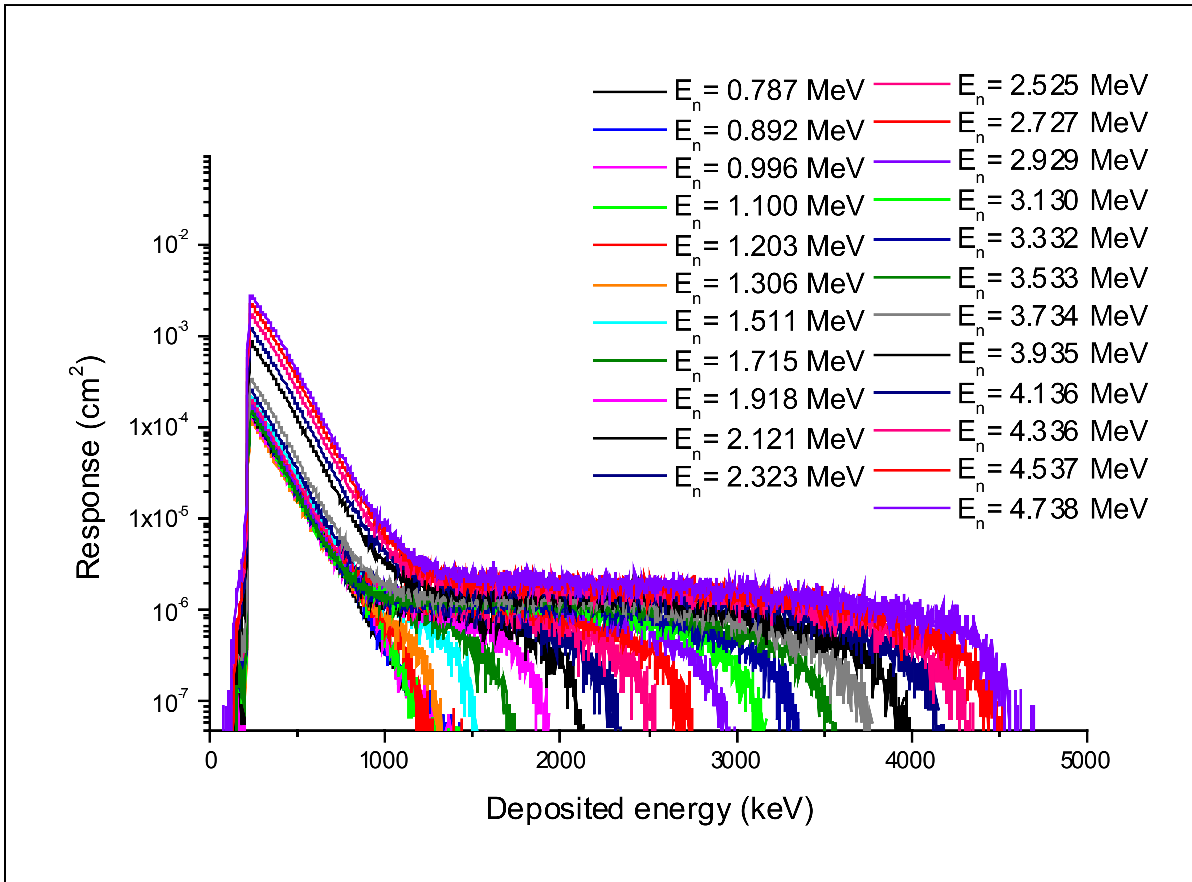


Analytical, simulated and experimental spectrum





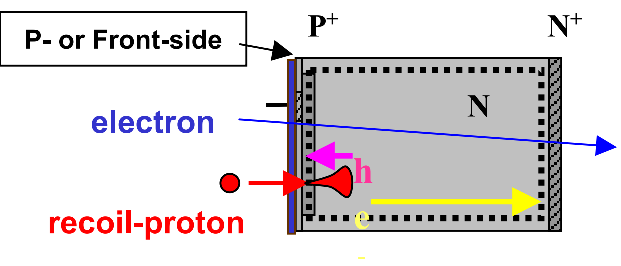
Spectra for monoenergetic neutrons (0.8–4.7 MeV)

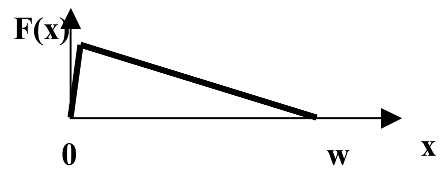


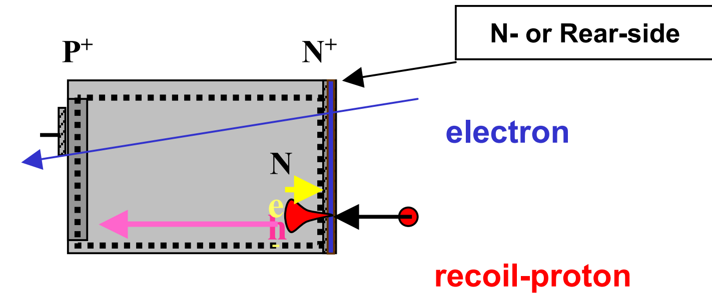
P-i-N diode simulation ….

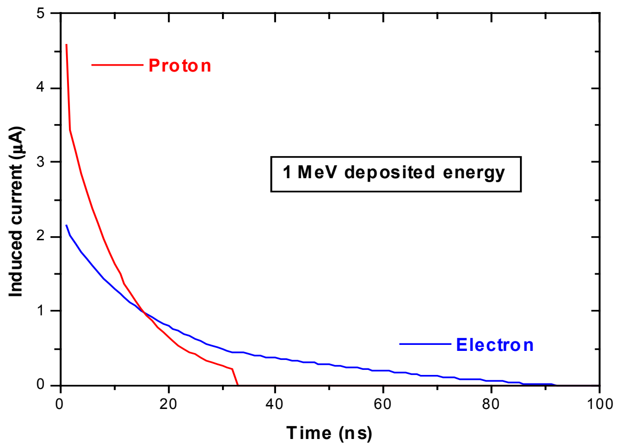
"Front-side injection"

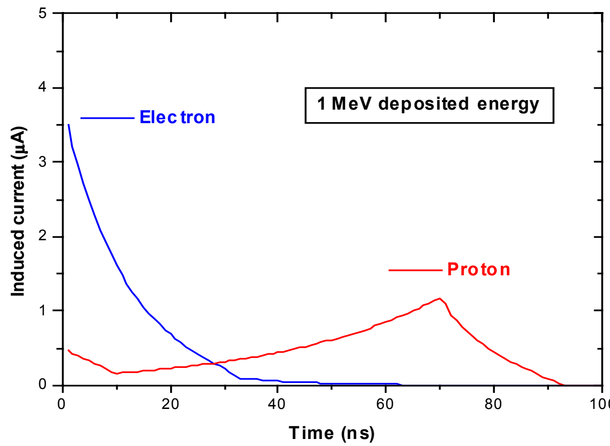
"Rear-side injection"



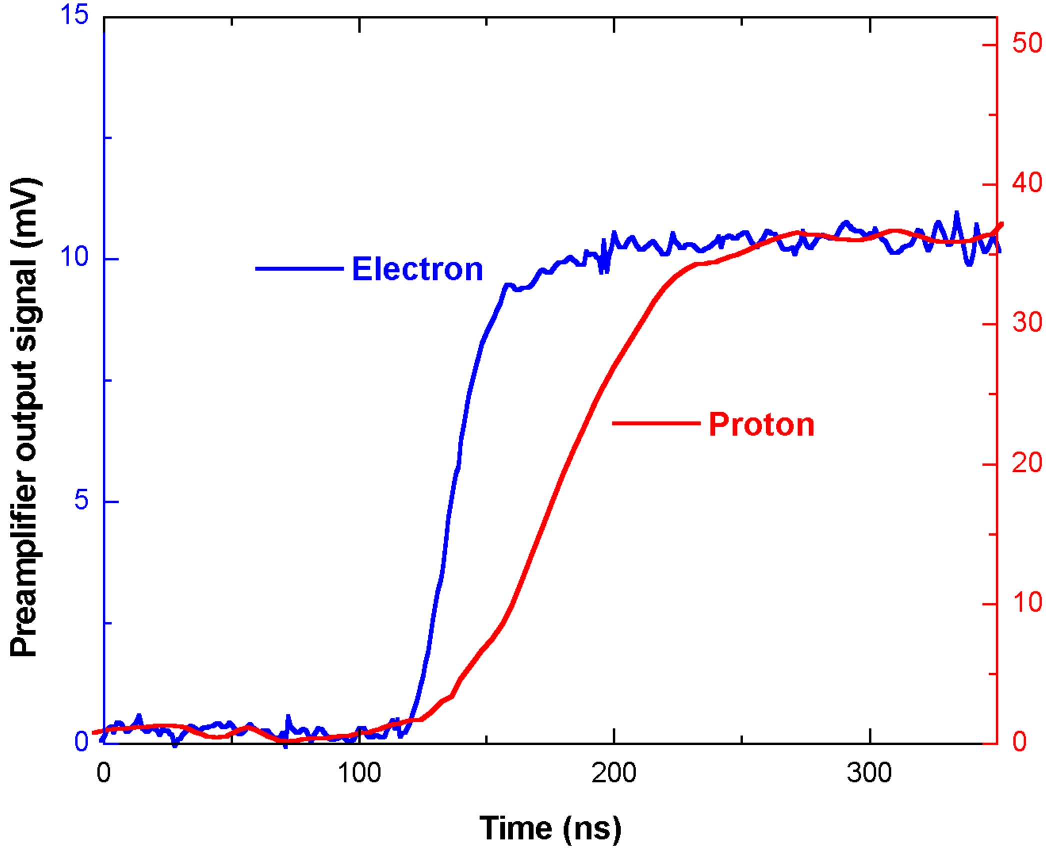




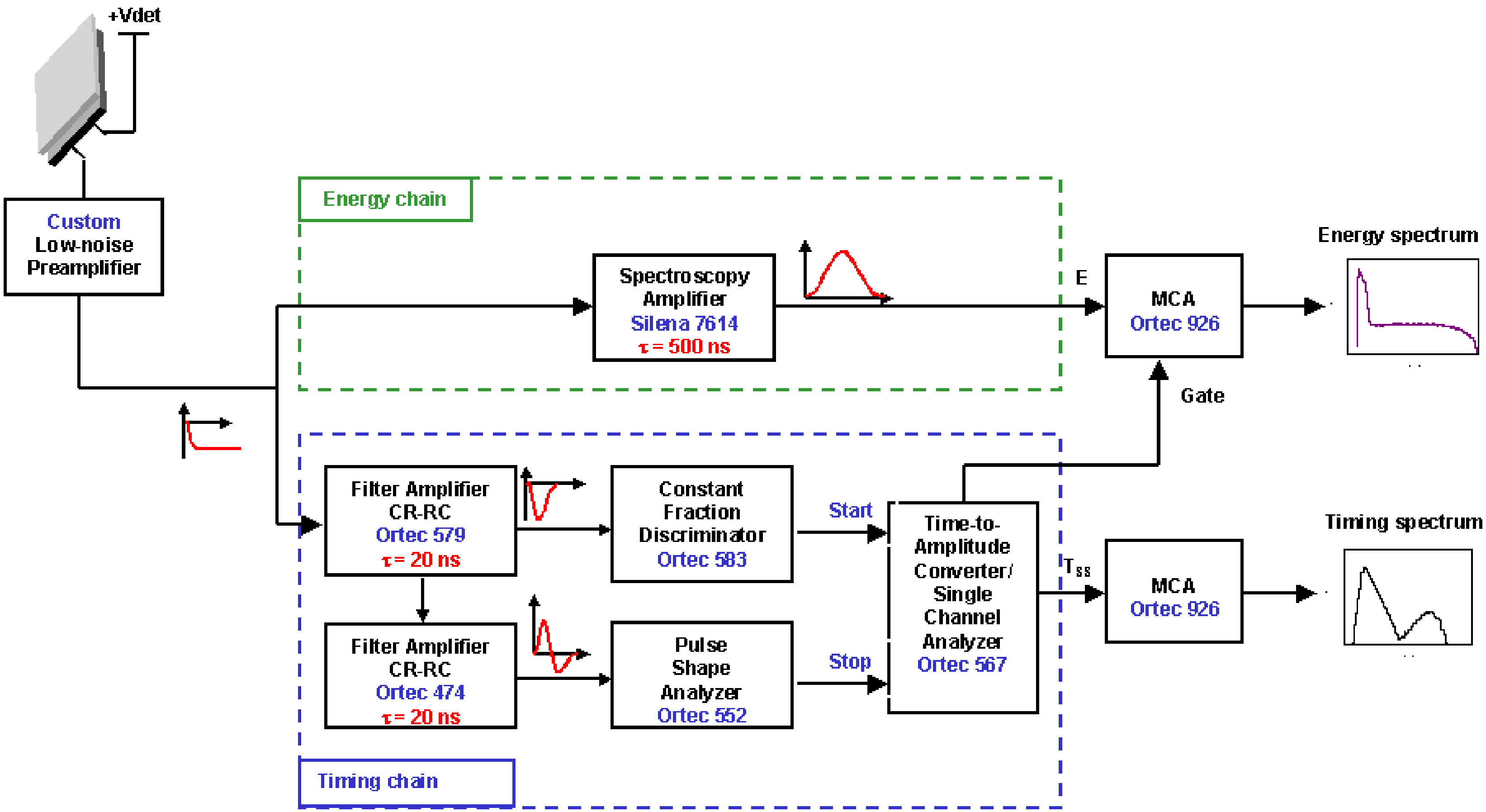




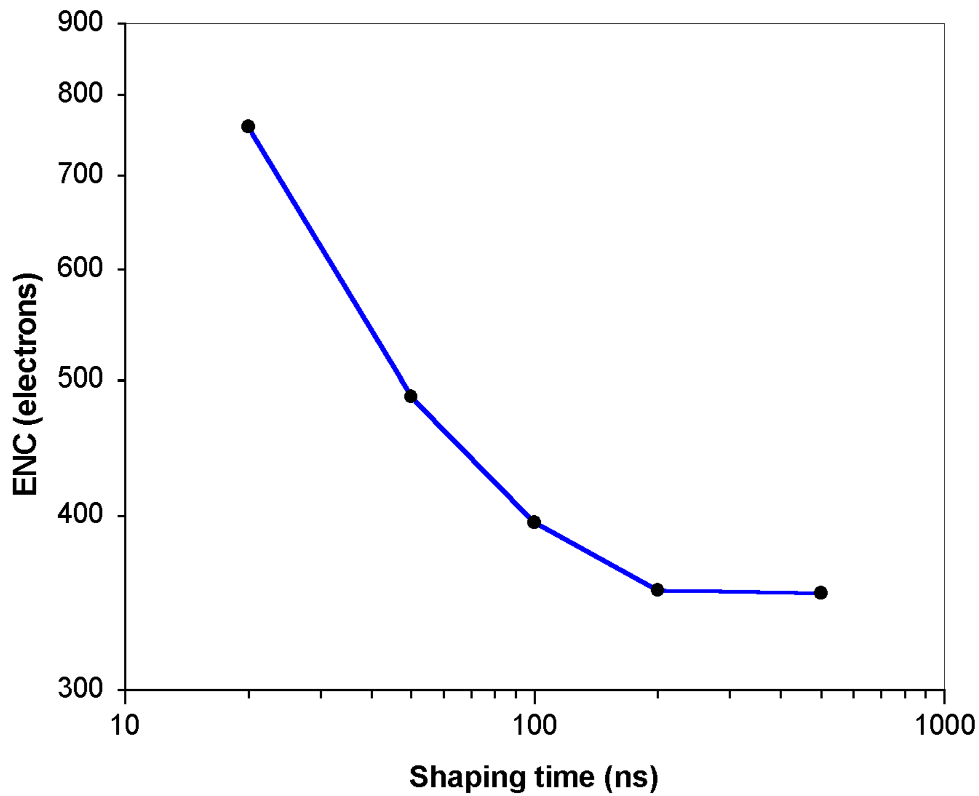
… and measurements



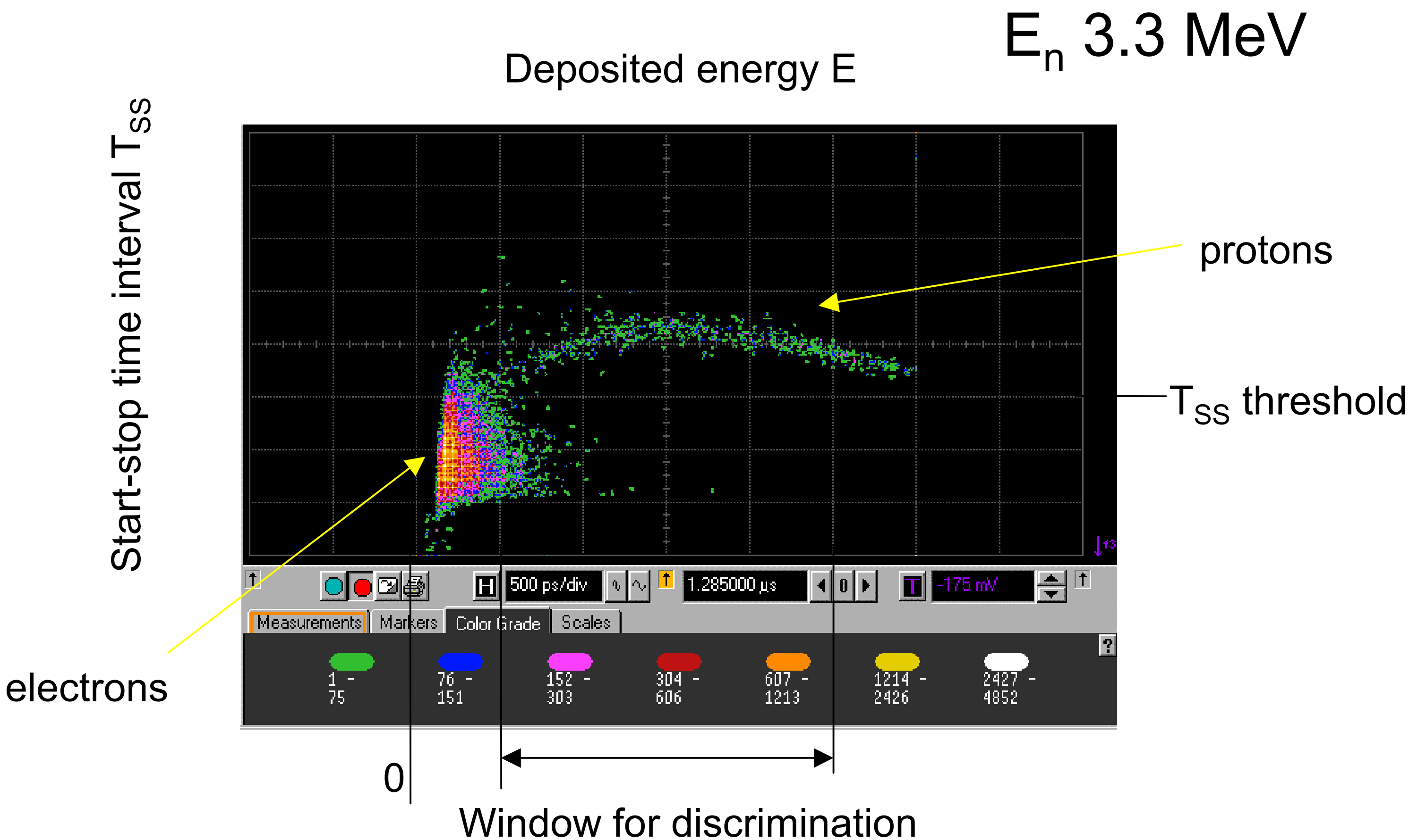
Electronics for pulse shape analysis



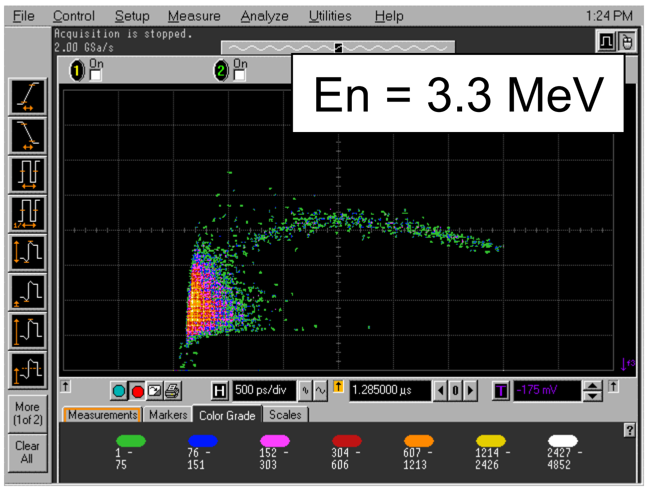
Custom low noise preamplifier

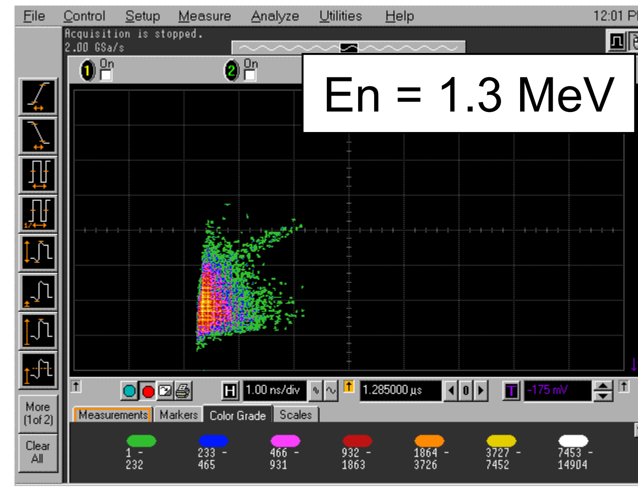


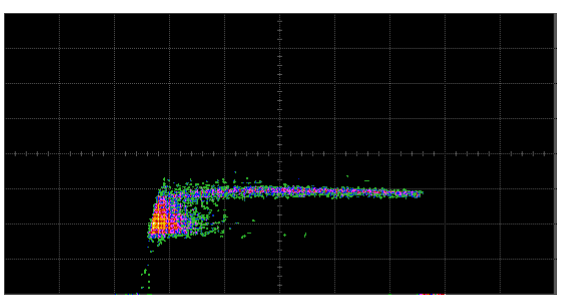
Energy-time scatter plot for monoenergetic neutrons



Pulse width vs. energy scatter plots

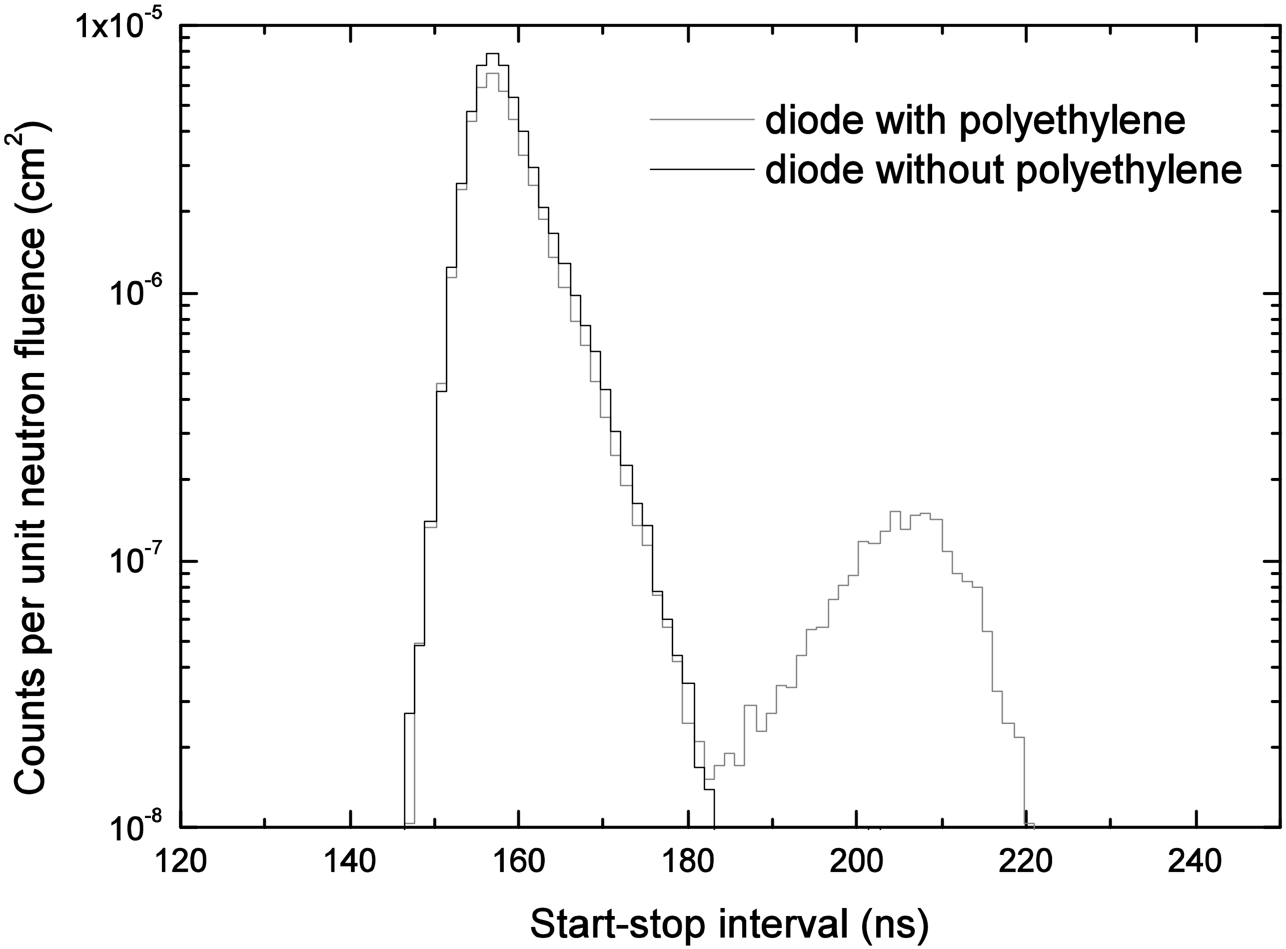




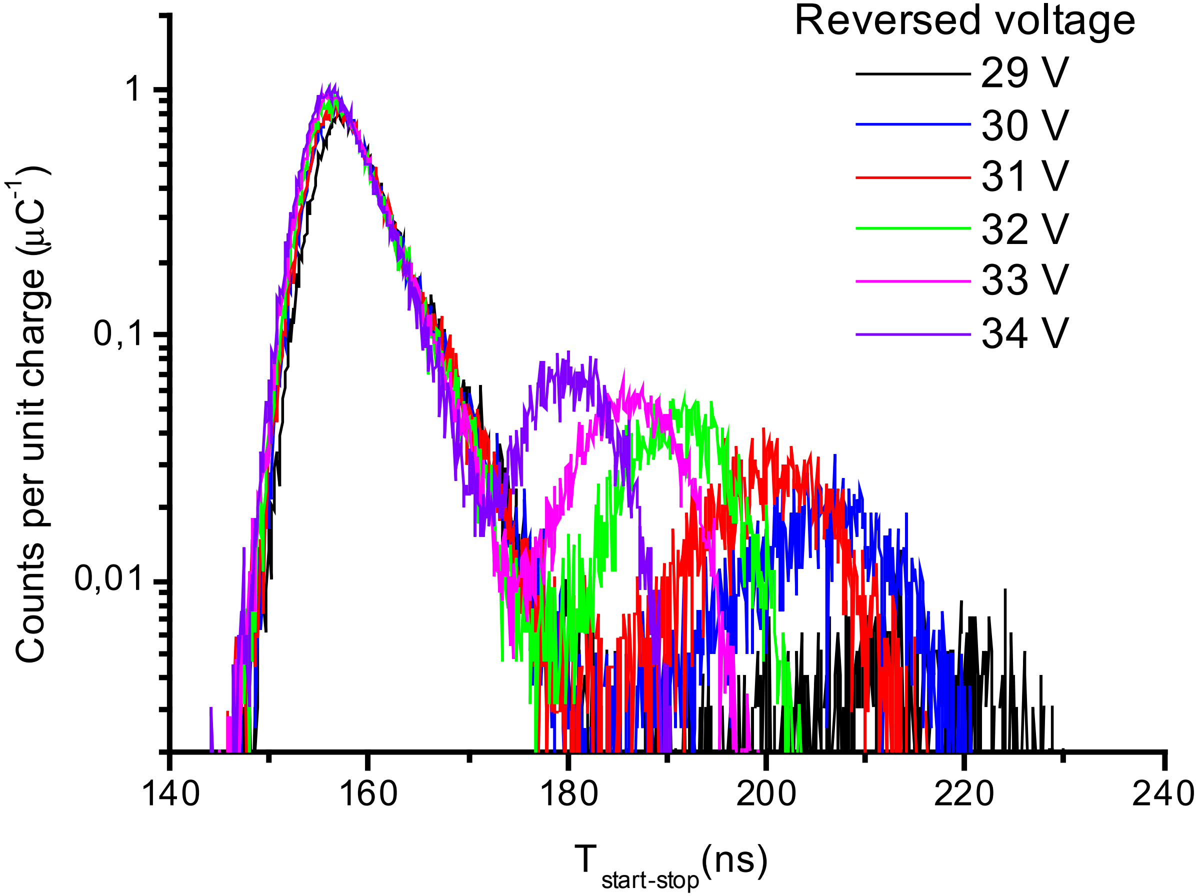


$V_{BIAS} = V_{dep} + 10\ V$

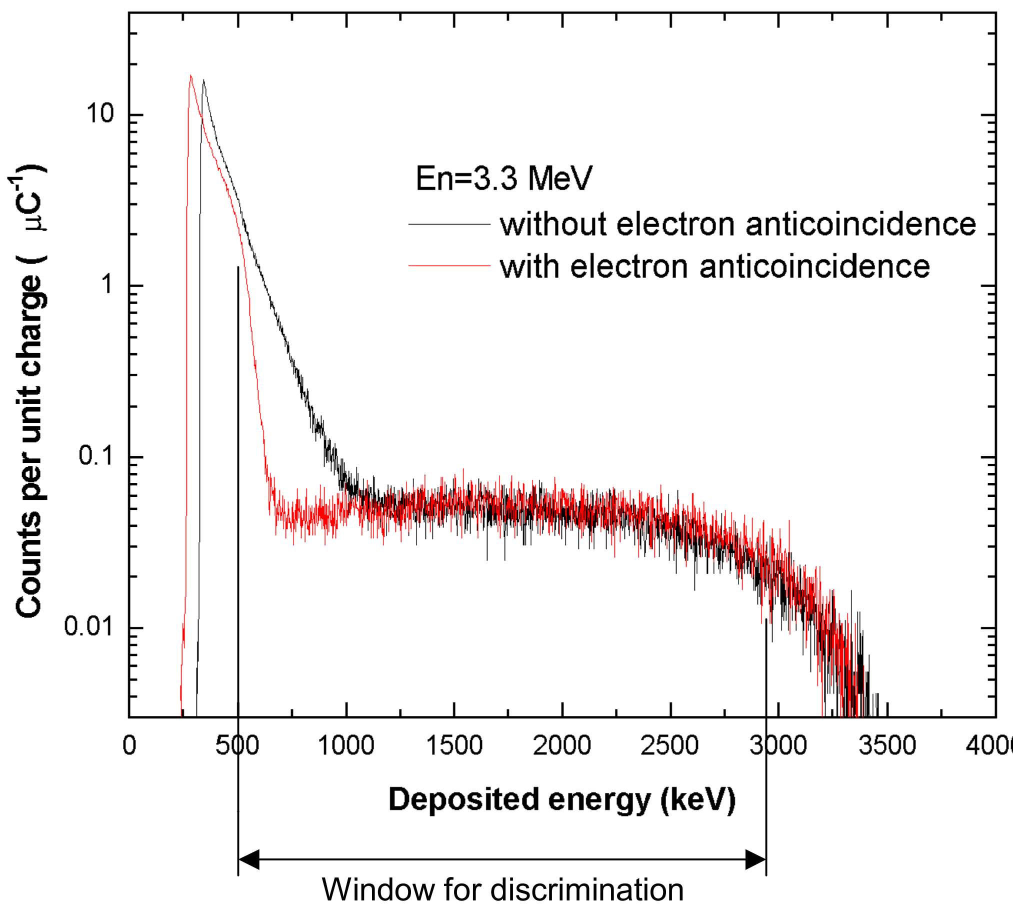
n-γ discrimination on timing spectrum



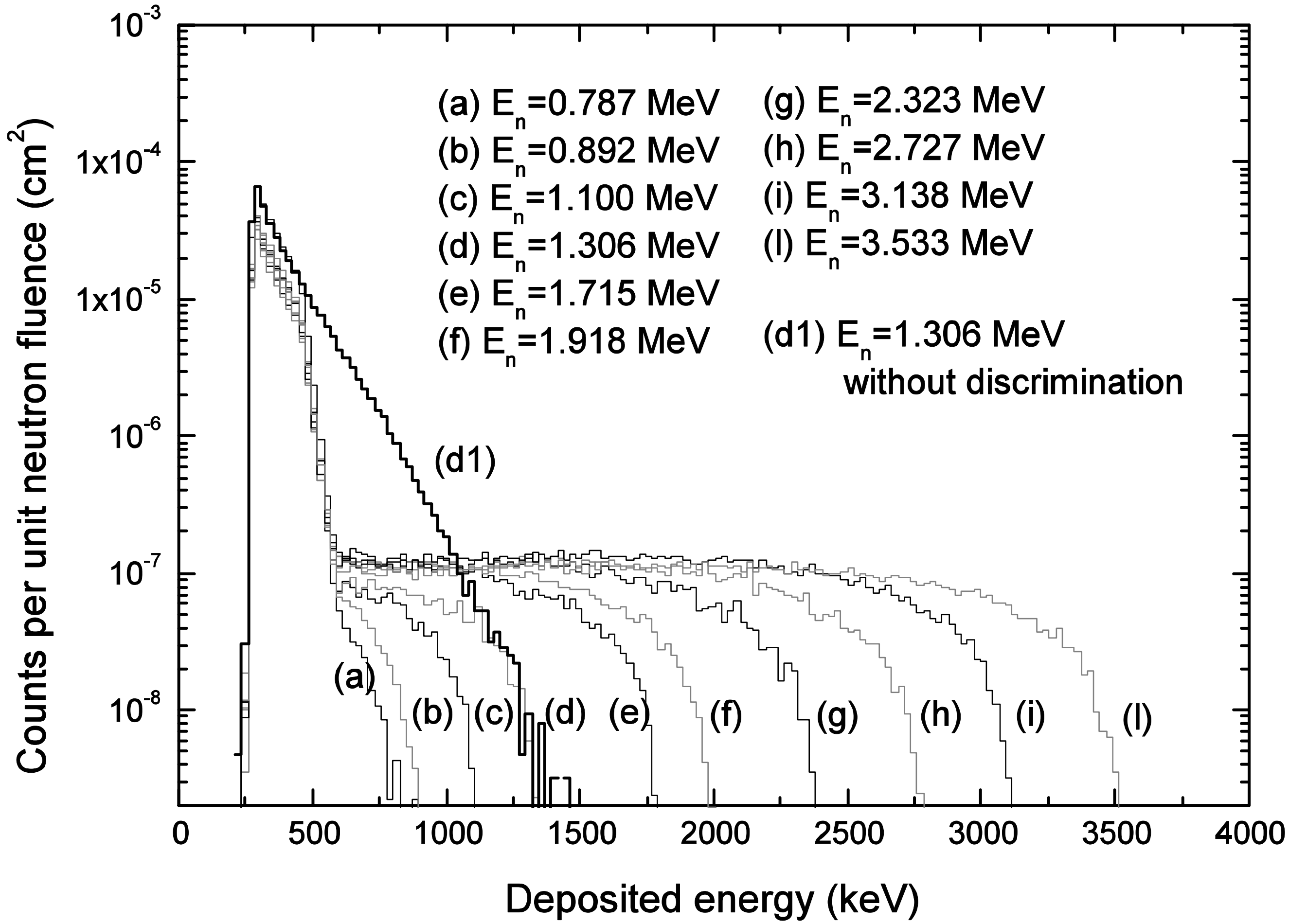
Timing spectra vs. diode bias voltage   En =1.3 MeV



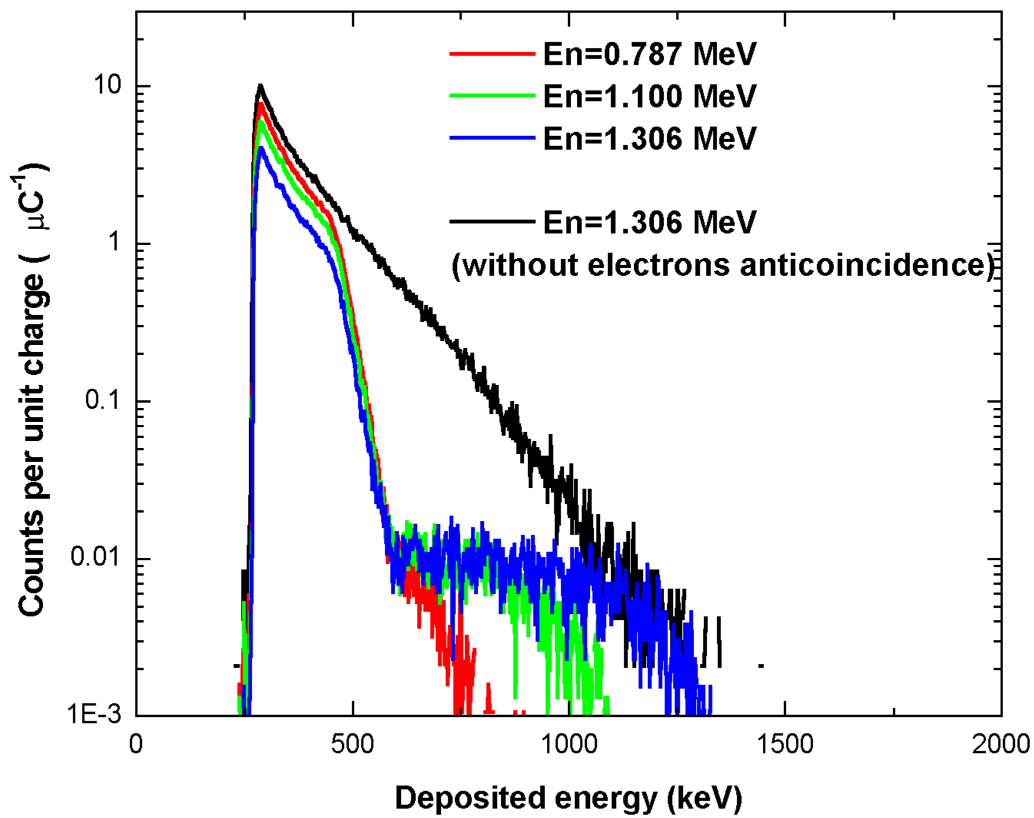
Energy spectrum with electron (γ) anticoincidence



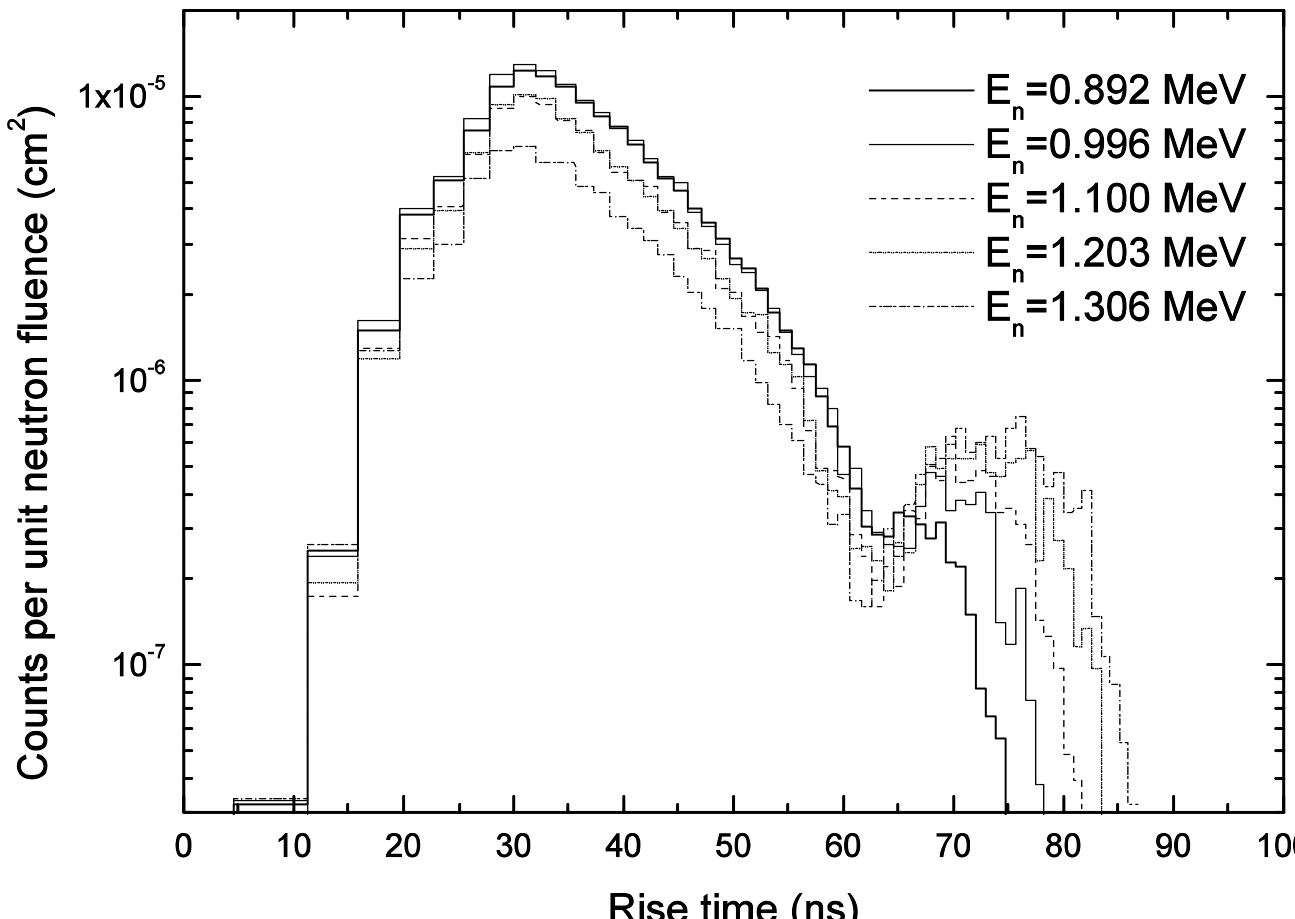
Energy spectra with discrimination (0.8 - 3.5 MeV)



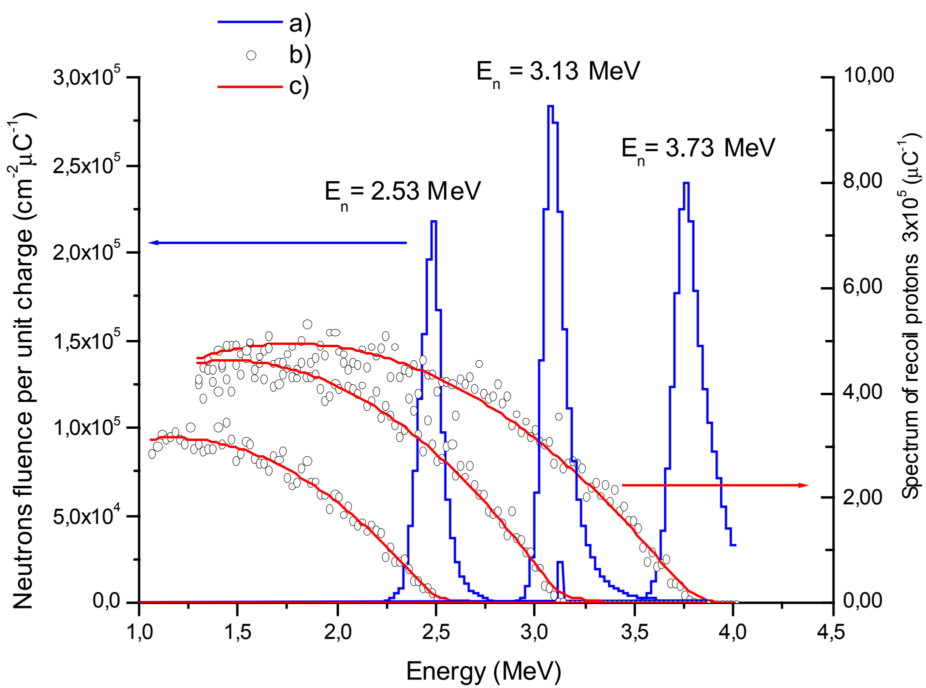
Energy spectra for low-energy neutrons



Timing spectra for low-energy neutrons

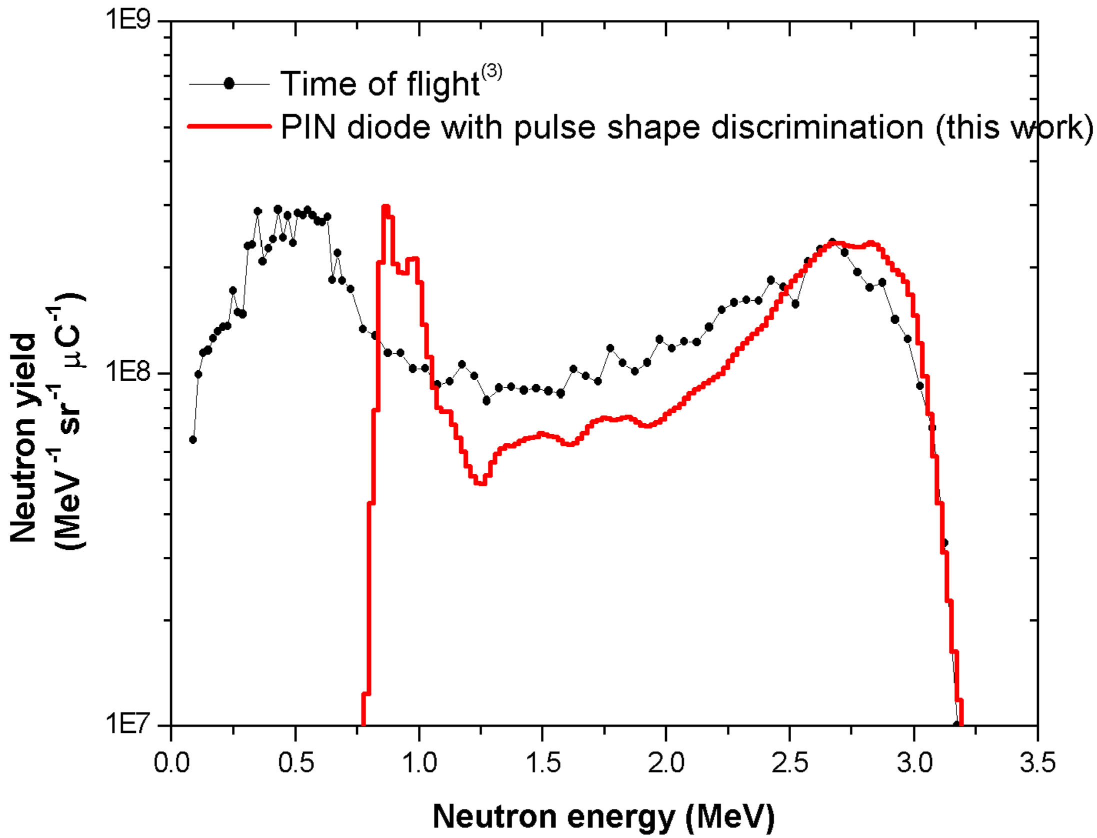


Unfolding check on monoenergetic neutrons



Neutron continuous spectrum

0° by 5 MeV protons striking a thick beryllium target



(3)W.B. Howard, S.M. Grimes, T.N. Massey, S.I. Al-Quraishi, D.K. Jacobs, C.E. Brient, J.C. Yanch, *Measurement of the Thick-Target 9Be(p,n) Neutron Energy Spectra*, Nucl. Sci. Engineering 138(2) (2001) 145-160.

Conclusions and perspectives

•A recoil-proton spectrometer for neutrons based on silicon diode operating in the 1-6 MeV range has been realized and tested

•n-γ discrimination is feasible and effective to lower the detection limit. Partial failure below 1.2 MeV will be investigated

•A thicker diode will increase the upper detection limit to 10 MeV

•A thinner dead-layer will decrease the lower limit

•An intercomparison with other types of n-spectrometer is planned

• Simpler and better (digital?) discrimination will be investigated

References: Proc. 2003 IEEE NSS (Portland), N26-75

S. Agosteo et al.,"Neutron spectrometry with a recoil radiator-solicon detector device," NIM, in press