Nuclear recoil quenching factor measurement for HPGe detector

Xichao Ruan

China Institute of Atomic Energy, Beijing

CDEX-TEXONO collaboration

Outline

1 Introduction

2 Neutron beam facility at CIAE

3 Quenching factor measurement for Ge crystal at CIAE neutron beam facility

Introduction

$$Q(E_R) = E_{ee}/E_R$$

Eee: electron-equivalent energy (energy loss due to ionization)

ER: nuclear recoil energy

The ratio of electron-equivalent energy and nuclear recoil energy with the same magnitude of output signal as a function of ER

Introduction

Quenching factor measurement is important for dark matter detection, especially for the WIMPs detection by detecting the signature of nuclear recoils due to WIMP-nuclei elastic scatterings.

HPGe detector : has long been proposed and used for dark matter detection and neutrino coherent scattering.

To do this, the QF must be well known from some tens of keV down to sub-keV region

Introduction

One of the most dramatic way to produce the nuclear recoils with known energy is neutron scattering.

In this talk, the quenching factor measurement for HPGe detector using CIAE neutron beam facility are shown.

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Neutron beam facility at CIAE

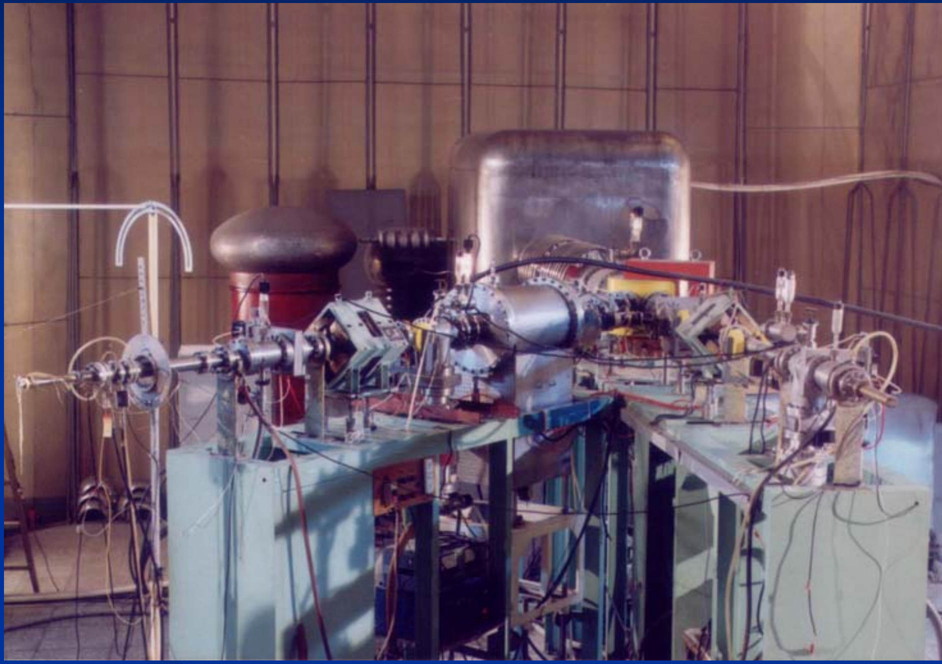
HI-13 Tandem 2×13 MV

5 40 MeV neutrons by p-T, d-T and d-D reactions. Pulsed and continuous

< 5 MeV neutrons by H (^{7}Li,n) and ^{15}N(p,n) reactions. Pulsed and continuous

White neutron source by d-Be reaction. Pulsed and continuous

Neutron beam facility at CIAE



Neutron generator

2.5 and 14 MeV neutrons with high intensity. Pulsed and continuous

Small tandem 2 × 1.7 MV

< 5 MeV neutrons. Continuous beam, pulsed beam under development

Reactor : high flux thermal neutron

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Commonly used methods

1. Neutron inelastic scattering

   $Et = Eee(ER) + E\gamma$

   quite a few measurements (sub-keV to MeV)

2. Neutron elastic scattering

   directly measure the ER in coincidence with the elastic scattered neutrons

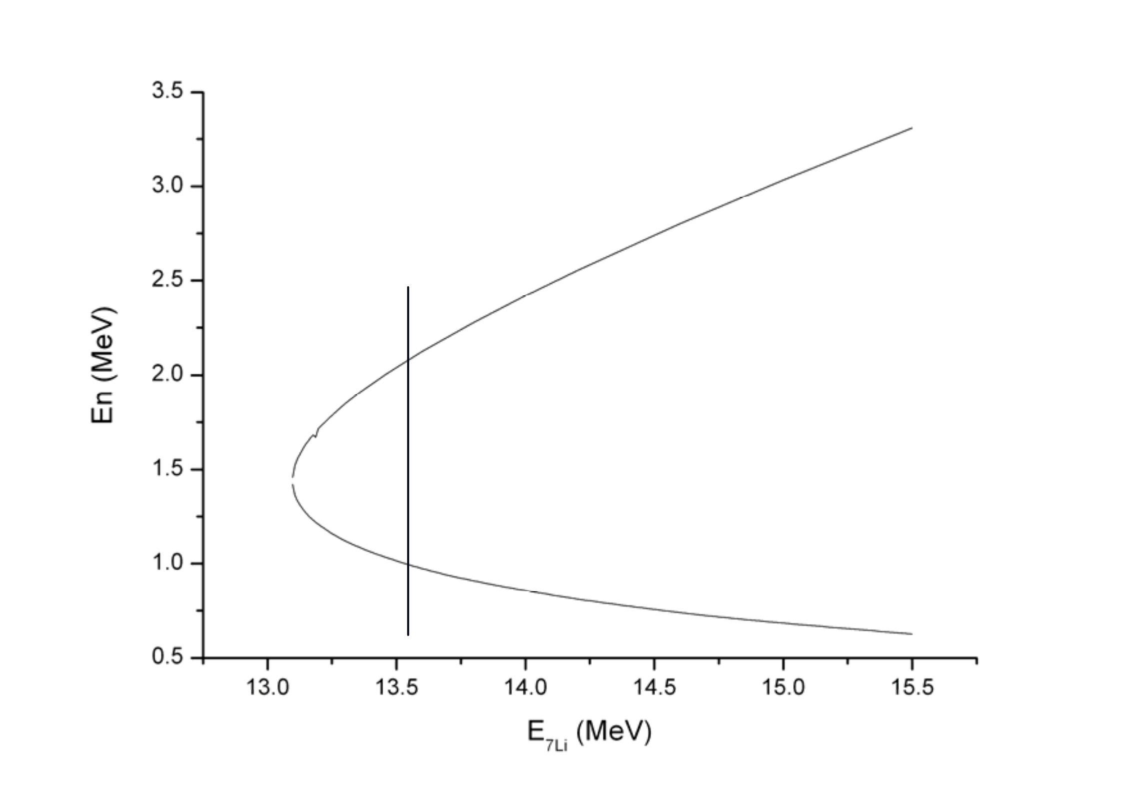
   few measurements were reported

Our aim : use elastic scattering method to measure the QF, the ER down to sub-keV region

Experiment

- HI-13 Tandem
- H(7Li,n) reaction neutron source
- 53 and 10 grams HPGe detector
  noise : ~ 1keV, ~180 eV
  resolution : ~550 eV and ~200 eV for 55-Fe source

The $^{1}H(^{7}Li,n)$ reaction was chosen to produce low energy mono-energetic neutrons on HI-13 Tandem Accelerator.



Kinematics of $^{1}H(^{7}Li,n)^{7}Be$ reaction

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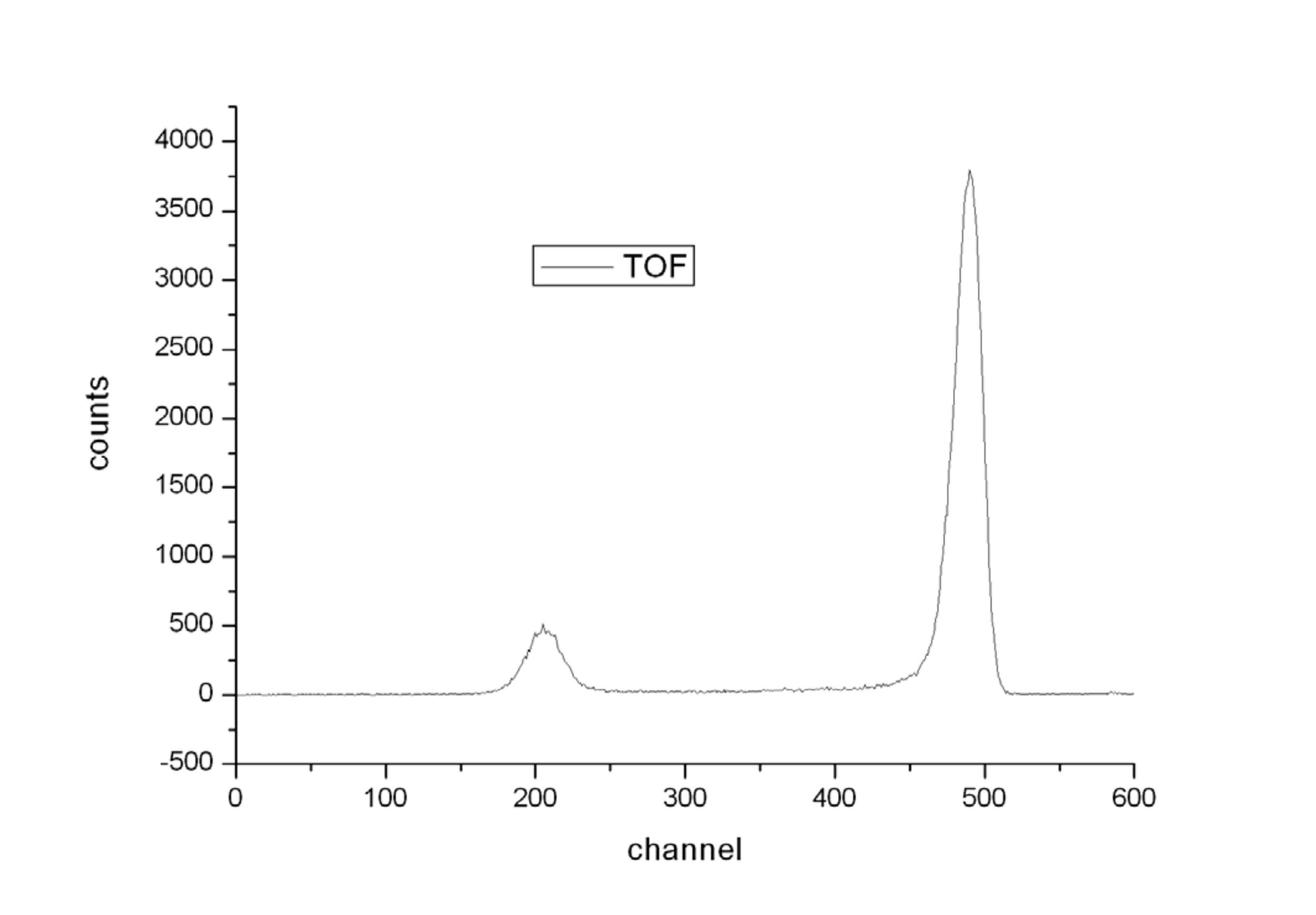
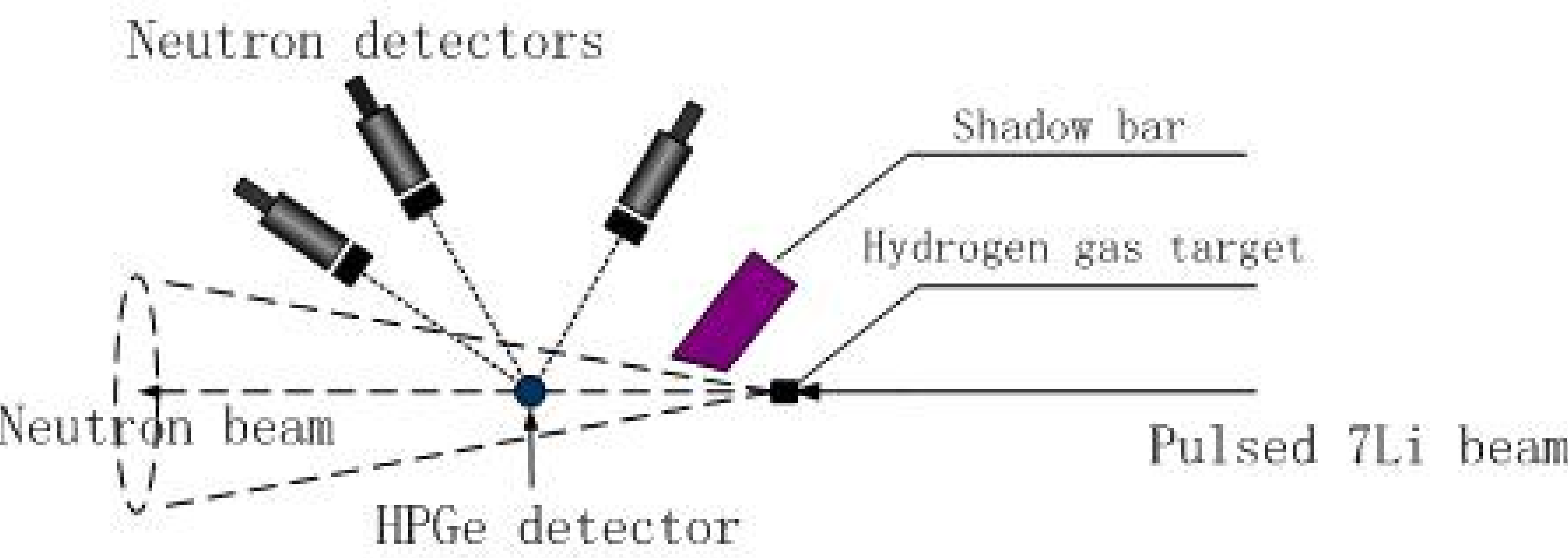


TOF spectra measured at 0 deg.
(E_{7Li} = 16.5 MeV, E_{n1} = 2.35 MeV, E_{n2} = 0.86 MeV)



Experimental setup

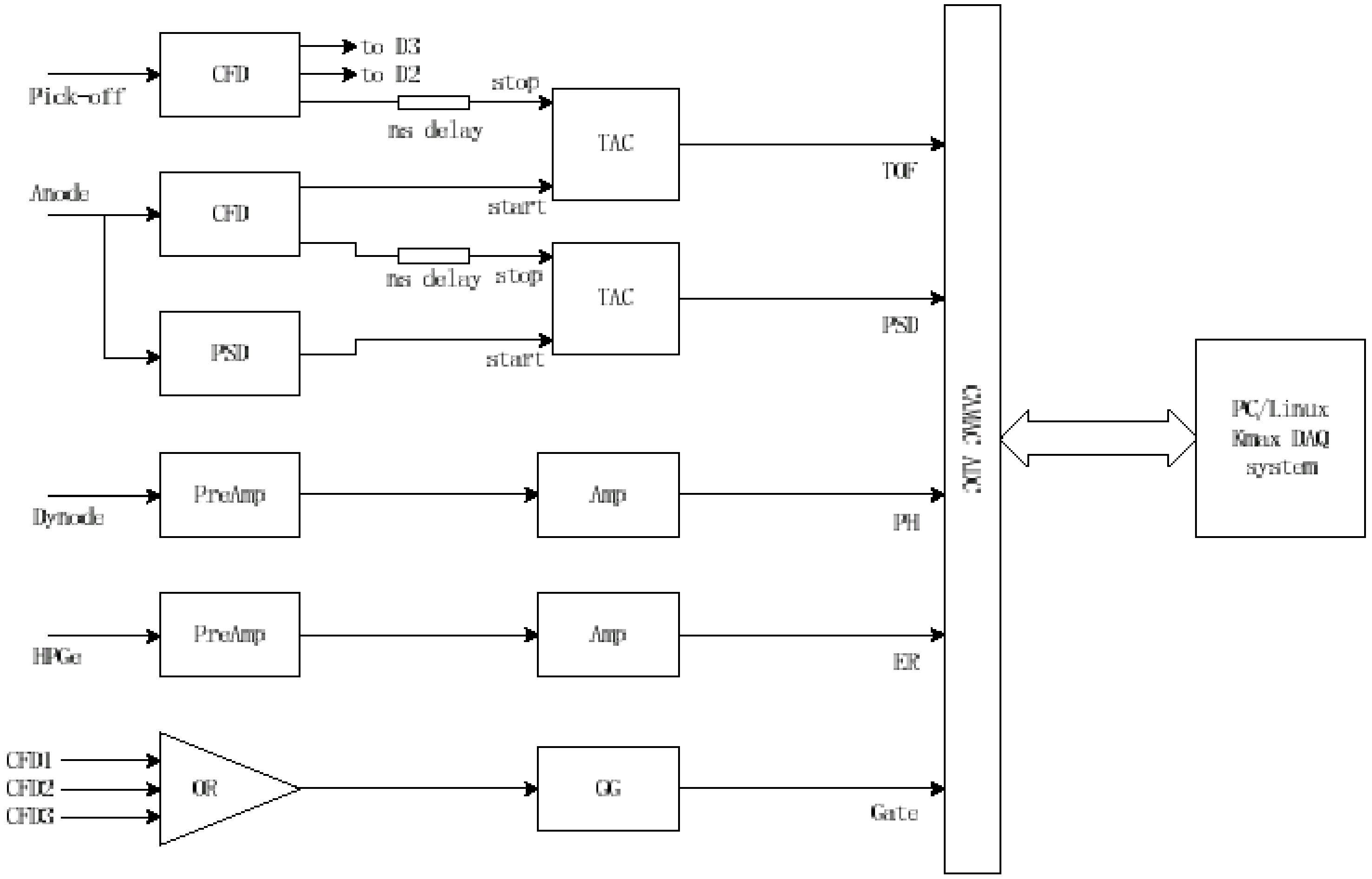
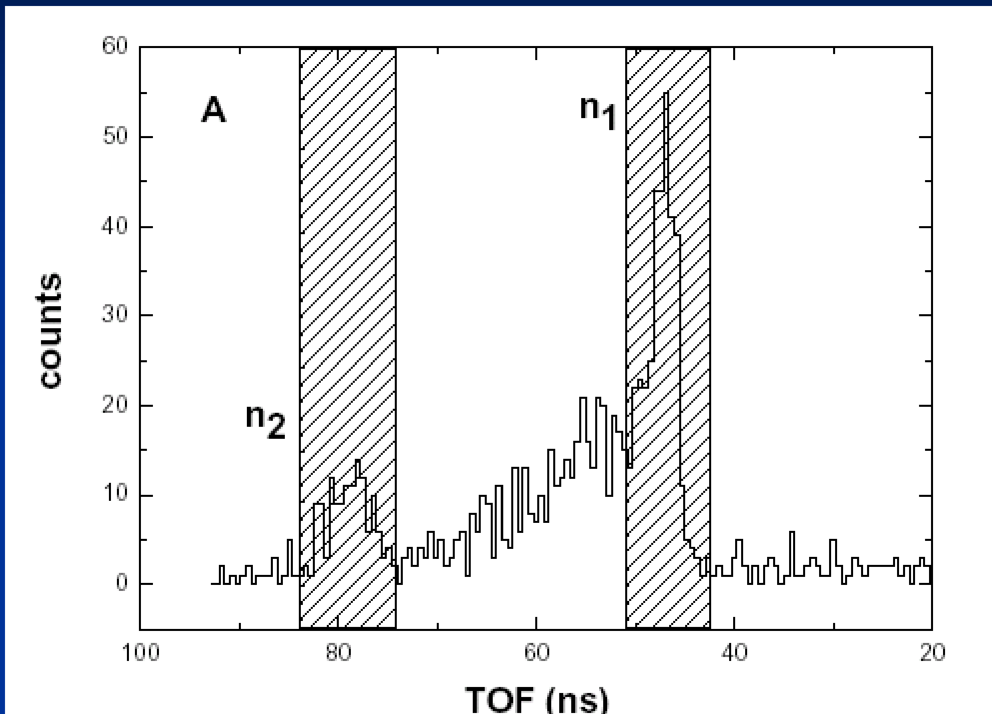
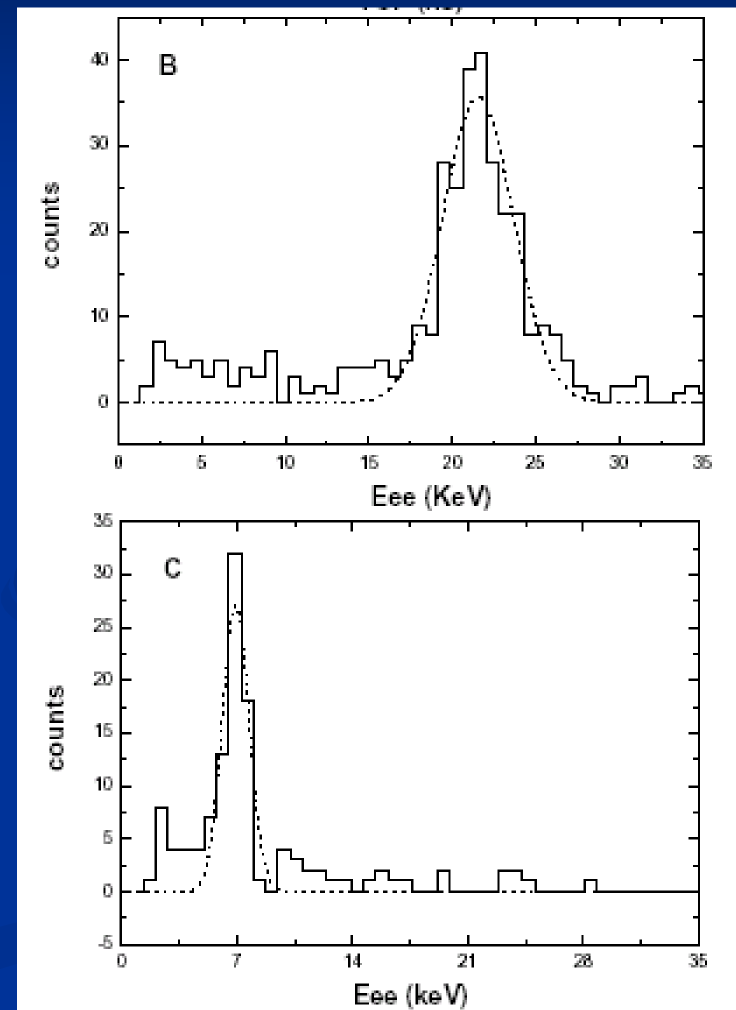
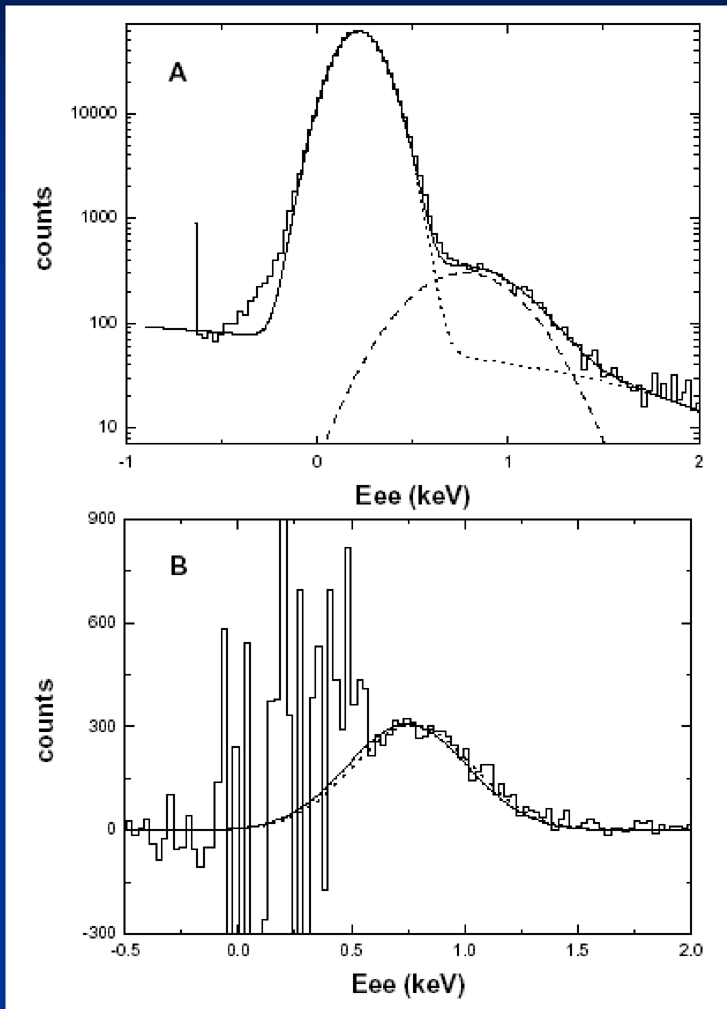


FIG. 4: Block diagram of the electronics and DAQ setup.

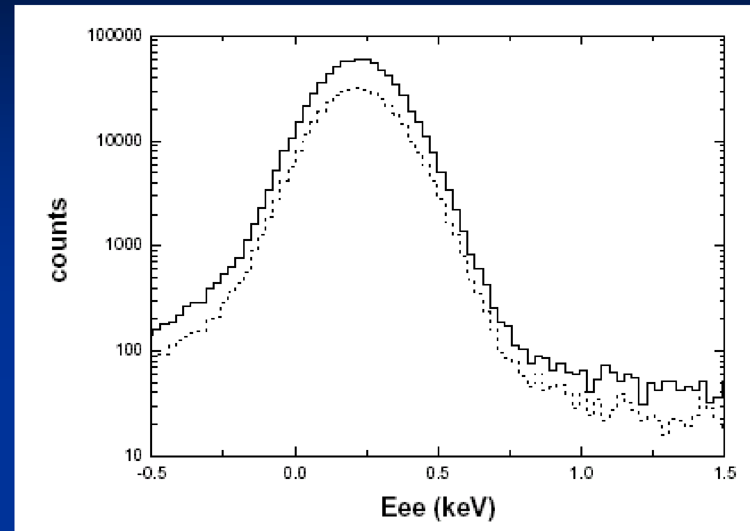


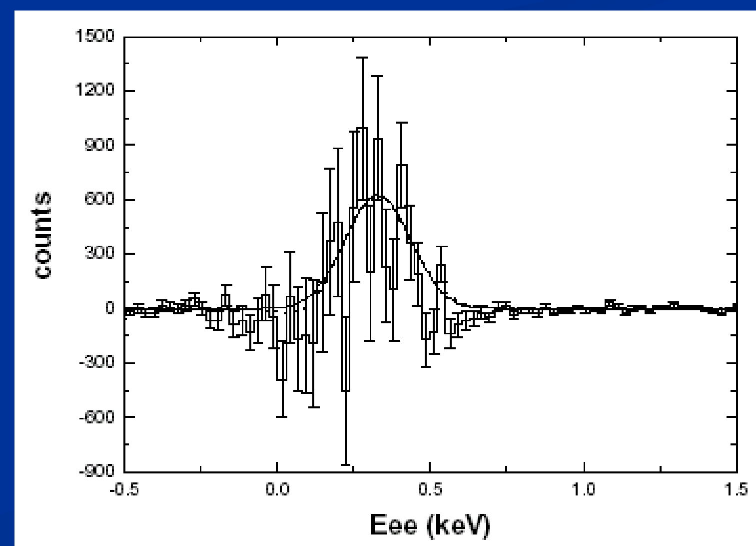


TOF spectrum for scattered neutrons from Ge and corresponding measured ER spectra

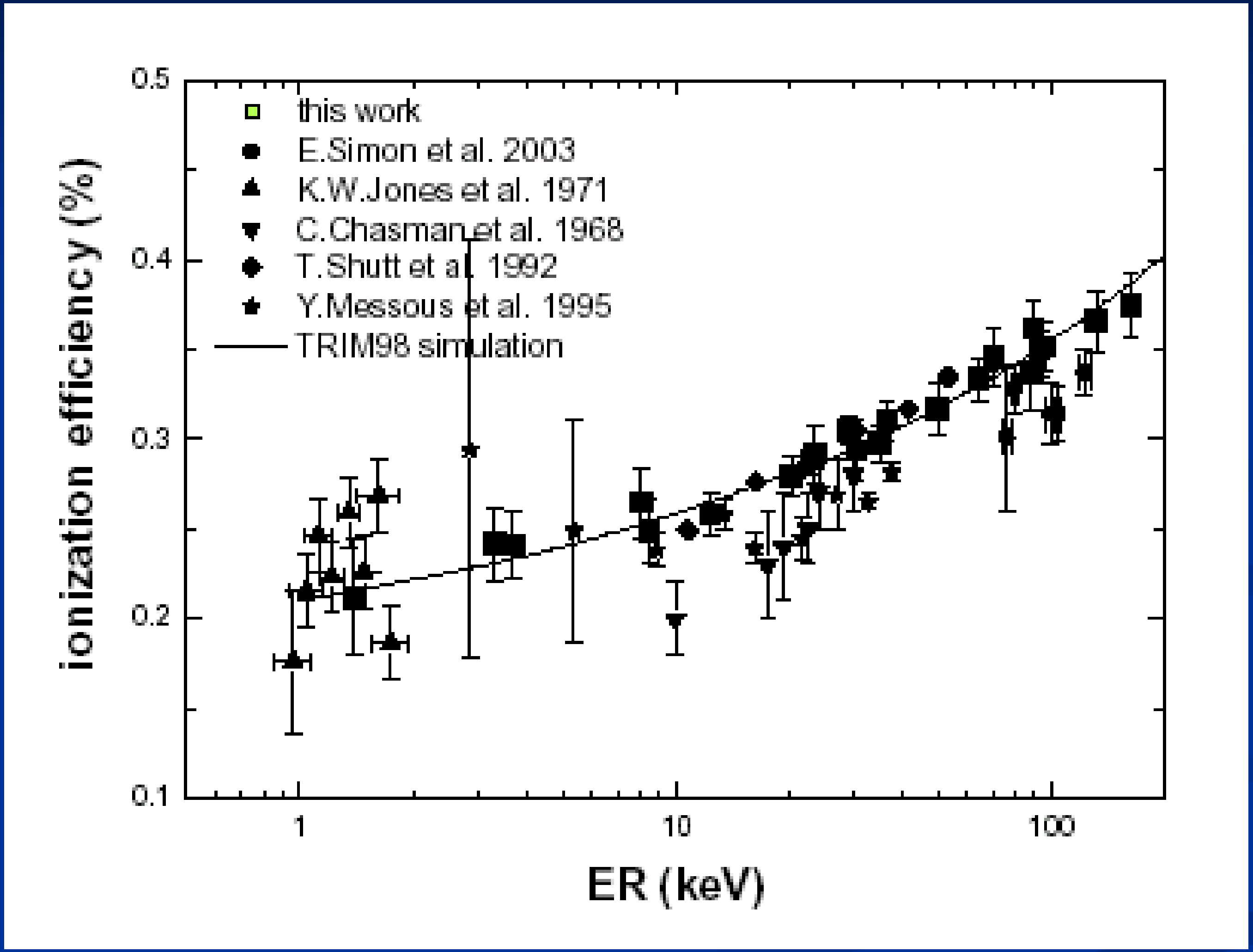


ER = 3.3 keV





ER = 1.4 keV



Measured result (1.4 --- 160 keV)

Future plan

@ Try to observe the recoil signal at sub-keV region by

1. Using ULE-HPGe detector
2. PSD technique to distinguish the true signal from noise (to see the possibility)

A new measurement is planed !

Future plan

- Channeling effect

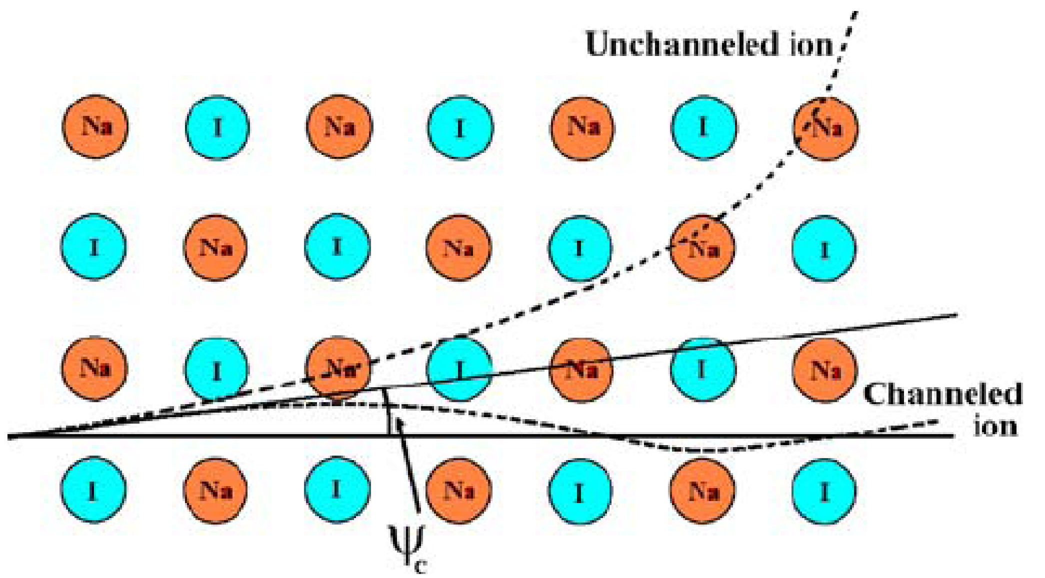


Fig. 1. Simplified schema of the channeling effect in the NaI(Tl) lattice. The axial channeling occurs when the angle of the motion direction of an ion with the respect to the crystallographic axis is less than a characteristic angle, Ψ_c, depicted there (see for details Sect. 2). Two examples for channeled and unchanneled ions are also shown (*dashed lines*)

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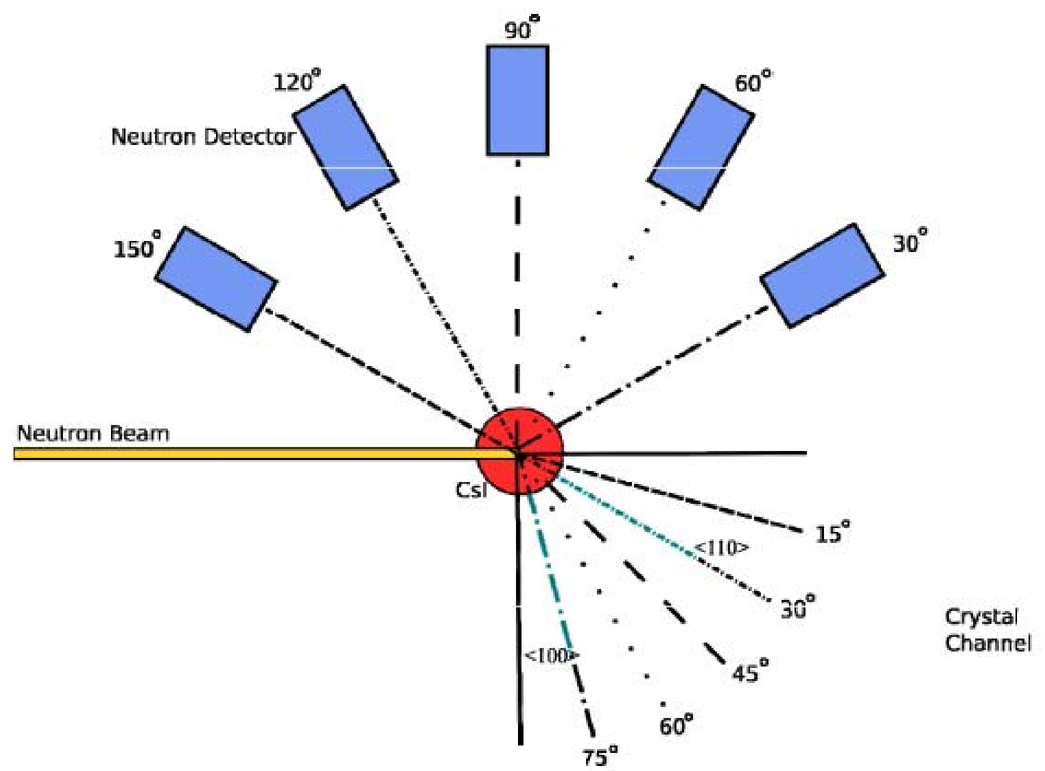
To observe it experimentally

1. Find QF enhancement at some special crystal plane
2. Change the plane by rotating the crystal
3. Angle resolution < 1 deg.
4. Neutron beam energy: ~ 1 MeV



Start with CsI crystal !

Thanks