Juhee Lee
KIMS collaboration
For SCINT2011 @ Giessen University

MEASUREMENT OF QUENCHING AND CHANNELING IN CSI(TL)

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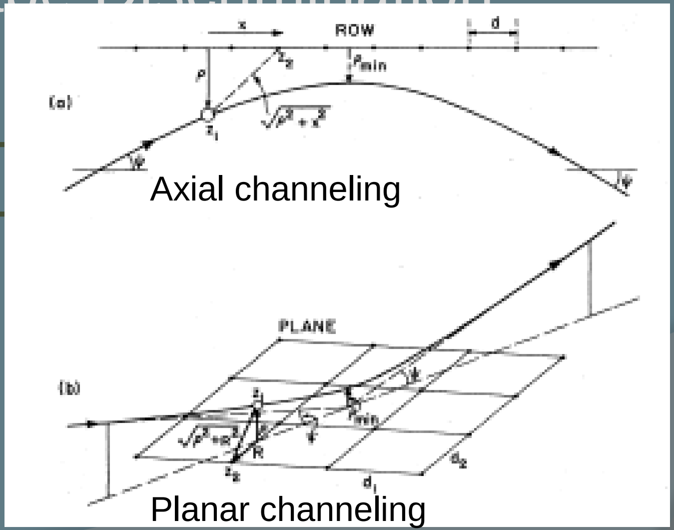
INTRODUCTION

- Motivation
  - A dark matter search group(DAMA) claims[1]
    - Enhanced light output due to Channeling effect
    - Weakness of Pulse Shape Discrimination method
- The Channeling effect[
  - Above ψ_c, ion feels $\phi(\rho)$ as continuum.
  - W/O hard scatterings, ion's penetration is increasing



INTRODUCTION

- Measurements of the Channeling effect

Light yields of ions with different incident angles[3]

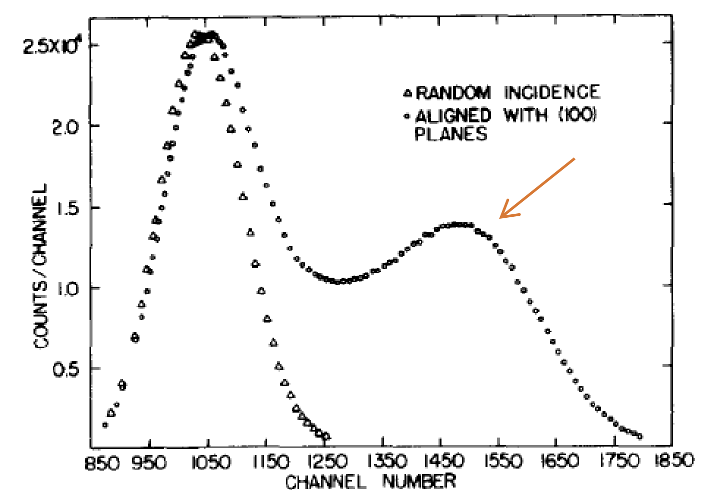


Fig. 2. Response of NaI(Tl) to 10 MeV ^{16}O ions.

Ranges of ions with different incident angles[4]

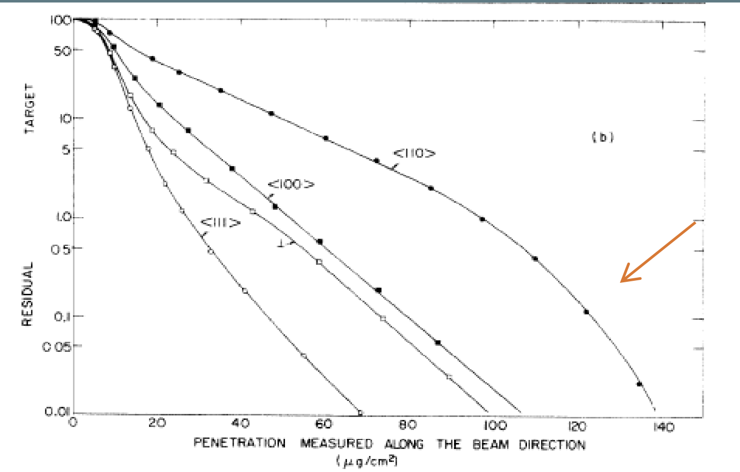


FIG. 1. Experimental range curves showing the residual target activity (percentage of ions not yet stopped) plotted against the penetration distance.

INTRODUCTION

- Measurements of the Channeling effect

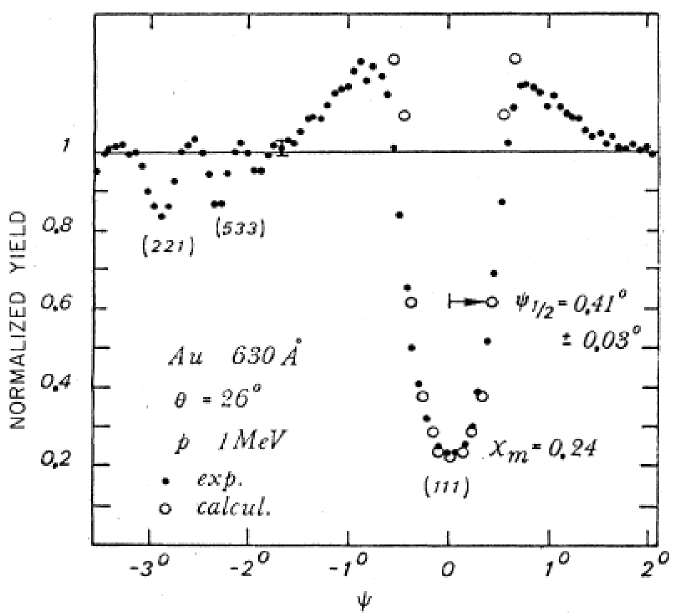


FIG. 43. Planar channeling dip for 1-MeV protons incident in the (111) direction in Au [Po72b]. The crystal thickness was 630 Å and the scattering angle 26°. The solid dots are the experimental points, and the open circles are the results of a calculation which includes multiple-scattering effects [see Sec. 2.4d2, Eq. (2.80), and Fig. 22].

Scattering yields of ions with different incident angles [2]

Calculation[1][2] **axial $\psi_{1/2}$:**

$$\psi_1 = \sqrt{\frac{2z_1z_2e^2}{Ed}}(rad.)$$

$$\psi_2 = \sqrt{\frac{Ca_{TF}}{d\sqrt{2}}\psi_1}$$

$$\psi_{\frac{1}{2}} = 0.8F_{RS}(1.2u_1/a)\psi_2$$

planar $\psi_{1/2}$:

$$\psi_{a2} \approx a_{TF}\sqrt{Nd_p}\left(\frac{2z_1z_2e^2c}{Ea_{TF}}\right)^{1/2}(rad.)$$

$$\psi_{\frac{1}{2}} = 0.72F_{ps}(1.6u1/a_{TF}, d_p/a_{TF})\psi_{a2}(\text{deg.})$$

- All was done with ions from outside target materials

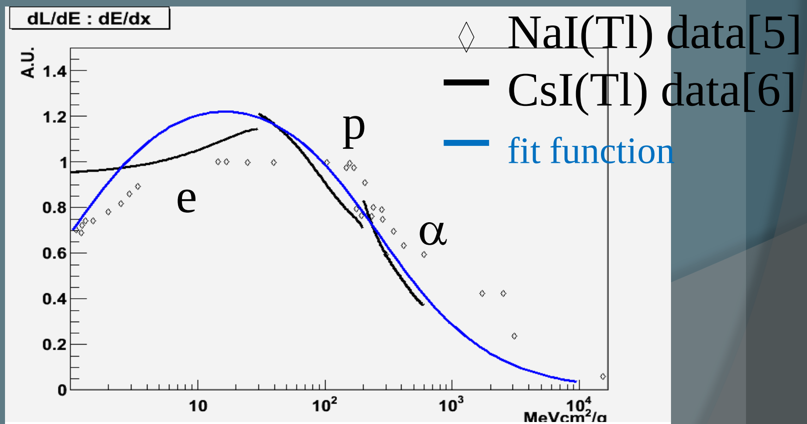
INTRODUCTION

- WIMP(Weakly Interacting Massive Particle) search
  - Channeling effect may contribute to the higher detection sensitivity for low mass WIMPs

- Purpose of this work
  - How many events are subjected to this effect
  - How this effect is shown up in the light yield spectrum
    - Simulations : Reproduction of the light yield spectrum
      Estimation of channeling contributions
    - Experiments : Directional measurements of light yield

Scintillation efficiency

- Scintillation efficiency S(dE/dx)
  - Applicable to the particle without concerning their species
  - Measurable in the L(E) and R(E)
  - Murray and Meyer model
  - Birks model[10]
  - Fitting function to the data



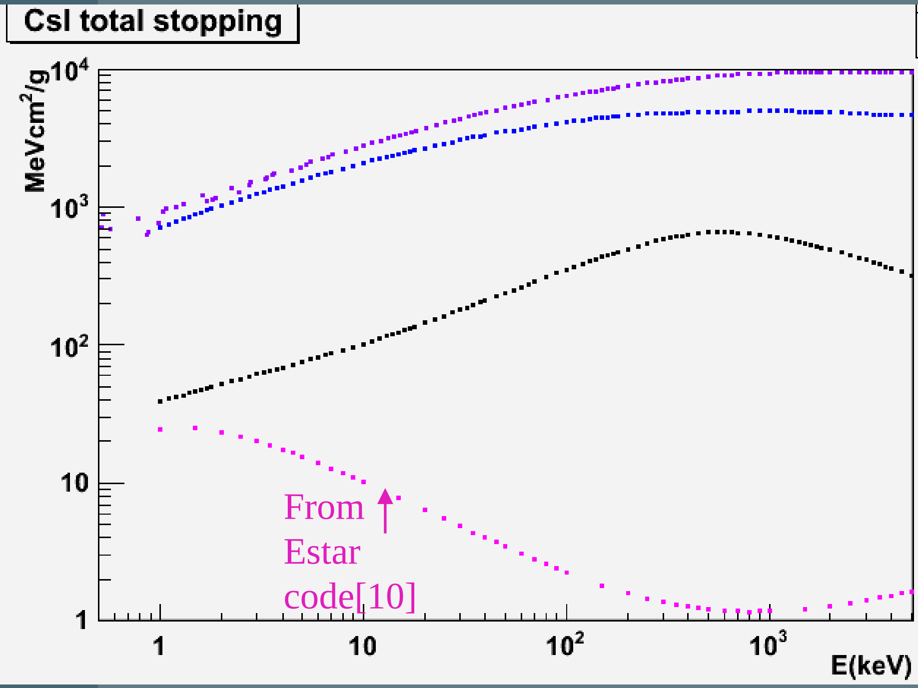
$$S\left(\frac{dE_e}{dx}\right) = 1.375 \frac{\left(\frac{dE_e}{dx}\right)}{\left(1+\frac{dE_e}{dx}\right)} \frac{1}{\left(1+0.0038\frac{dE_e}{dx}\right)}$$

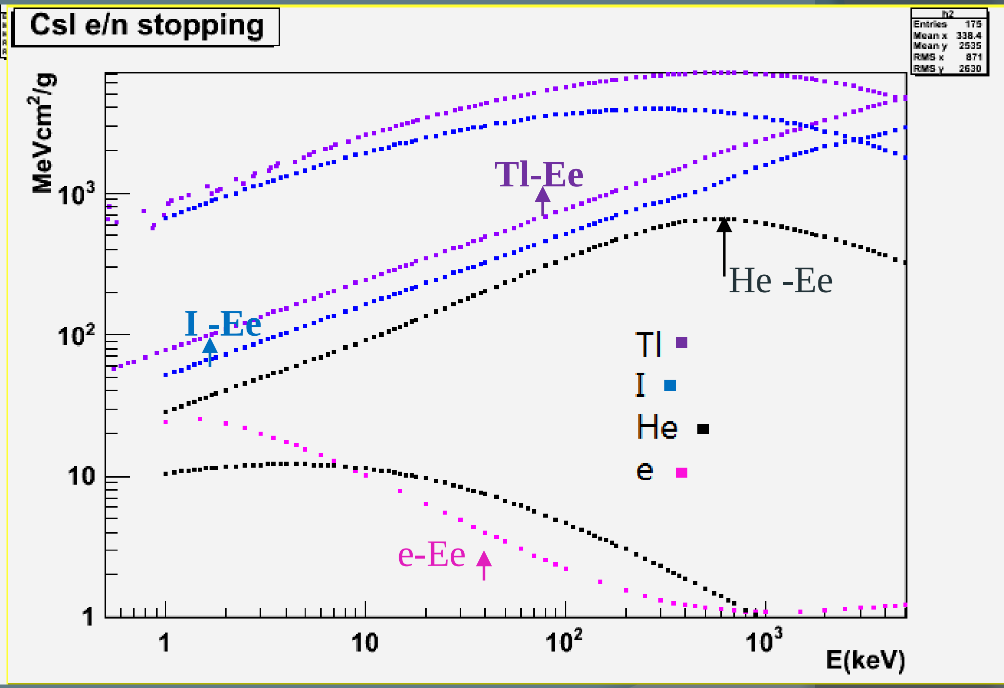
R. Gwin and R. B. Murray[5] data

with CsI(Tl) Tl 0.046mole% ,

7us DAQ time window and 662keV γ calib.

Stopping Power for CsI from SRIM





En : Nuclear Stopping power
phonon energy

Ee : Electronic Stopping power
ionization energy

Quenching Factor

- $E_{measured} / E_{recoil} = L_{ight}/E_{recoil} * [E_0/L_0]_\gamma$
- Calibration factor for WIMP-nuclear elastic scattering
- Many exp. data are reported .

SIMULATION – Quenching Factor

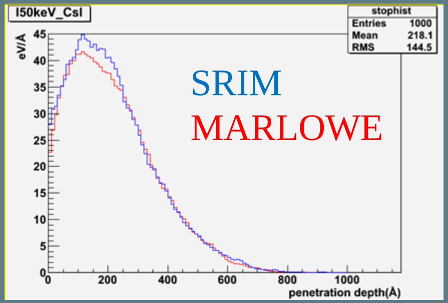
SRIM Quenching factor

1 step : SRIM simulation for 1000events

→ the mean electronic energy loss for each depth bin

2 step : Applying the mean electronic stopping power of each depth bin in unit of MeVcm^2/g to the dL/dx curve (*S(dE/dx) function*)

→ the mean light output for each depth bin



3 step : Summation all light outputs and applying the normalization factor for the energy calibration

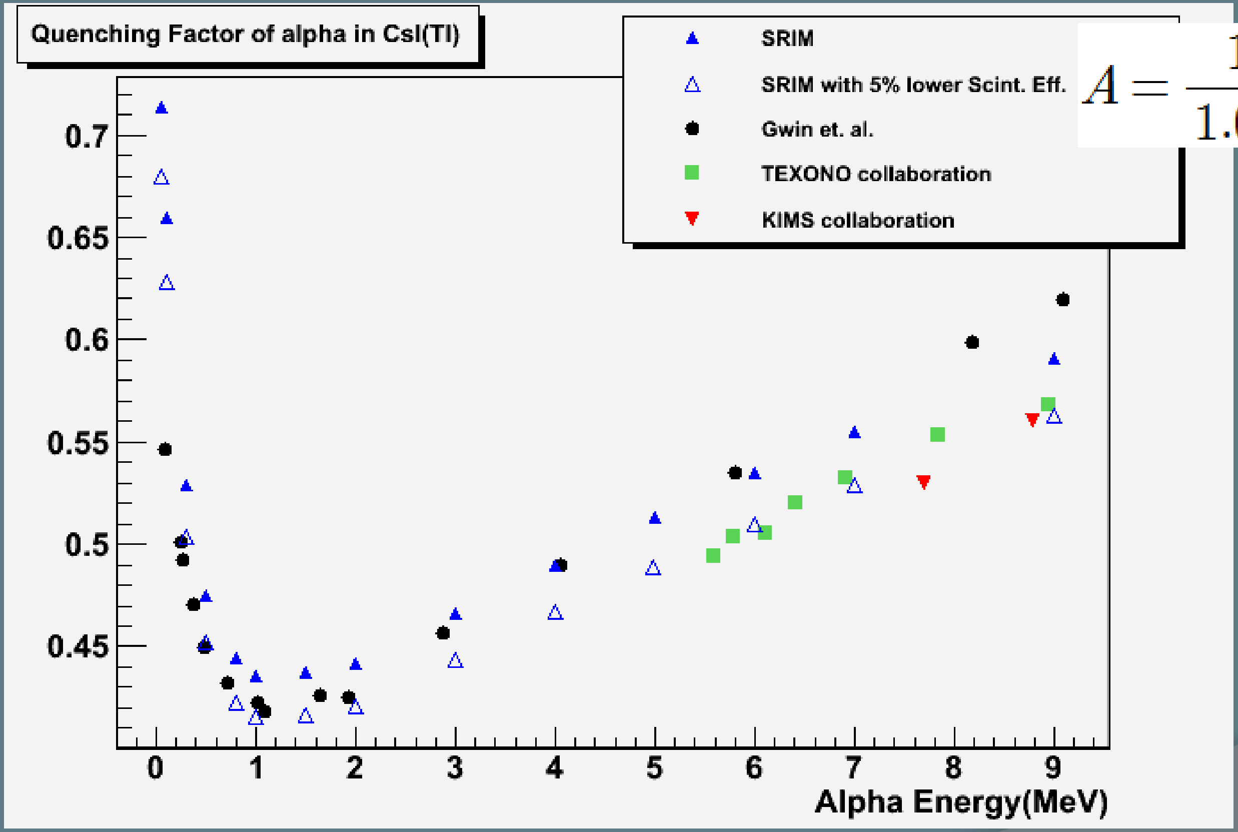
→ the measured energy

by dividing it to the recoil energy, we get the quenching factor

$$Q.F = \frac{A}{E_{recoil}} \sum_{i=1}^{\max \cdot depth\, bin} \Delta E_{e,i} \bullet S(\frac{dE_e}{dx_i})$$

SIMULATION – Quenching Factor

SRIM Quenching factor

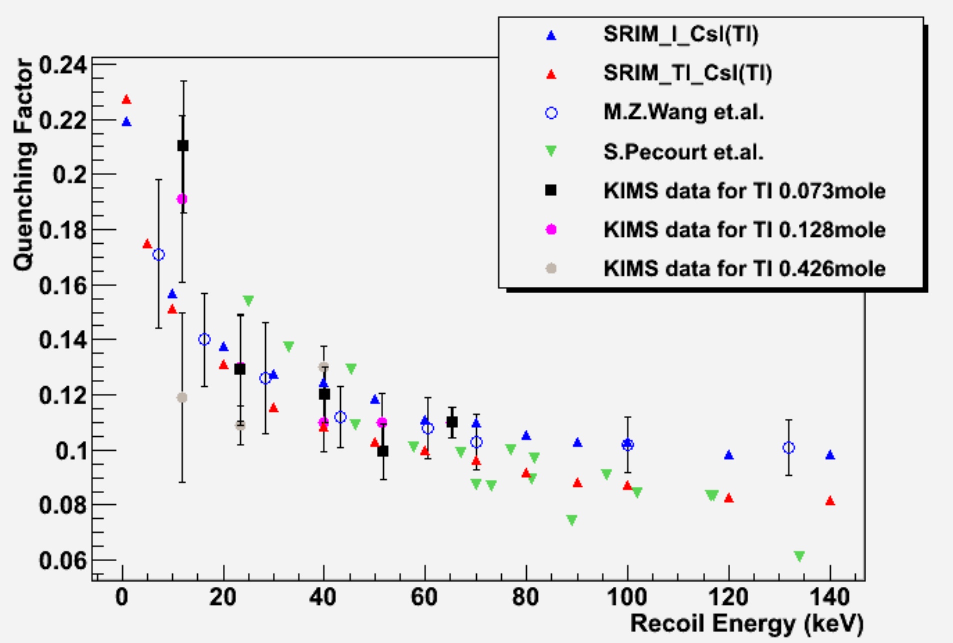


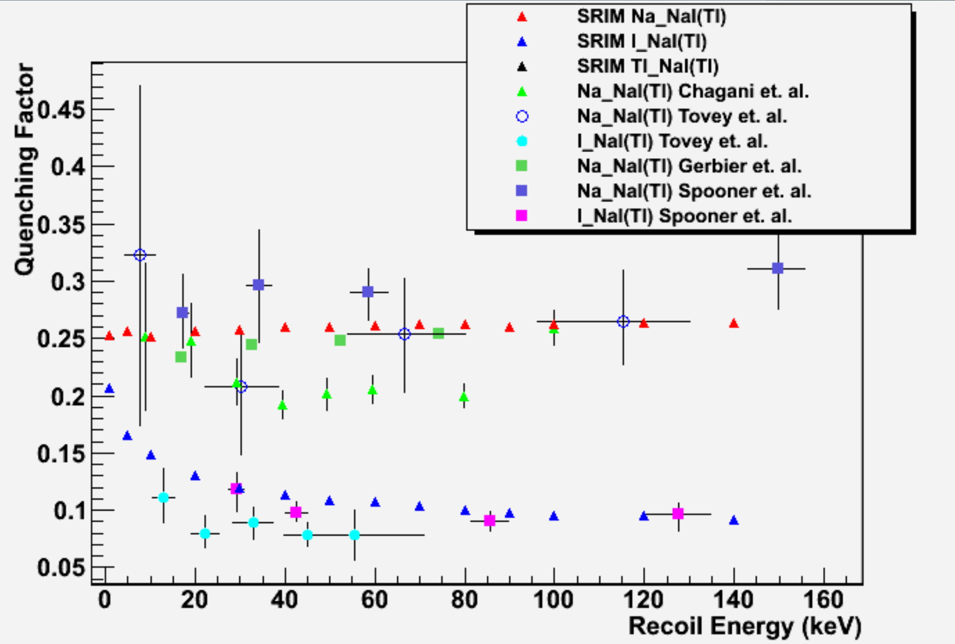
$$A = \frac{1}{1.05}$$

SIMULATION – Quenching Factor

SRIM Quenching factor

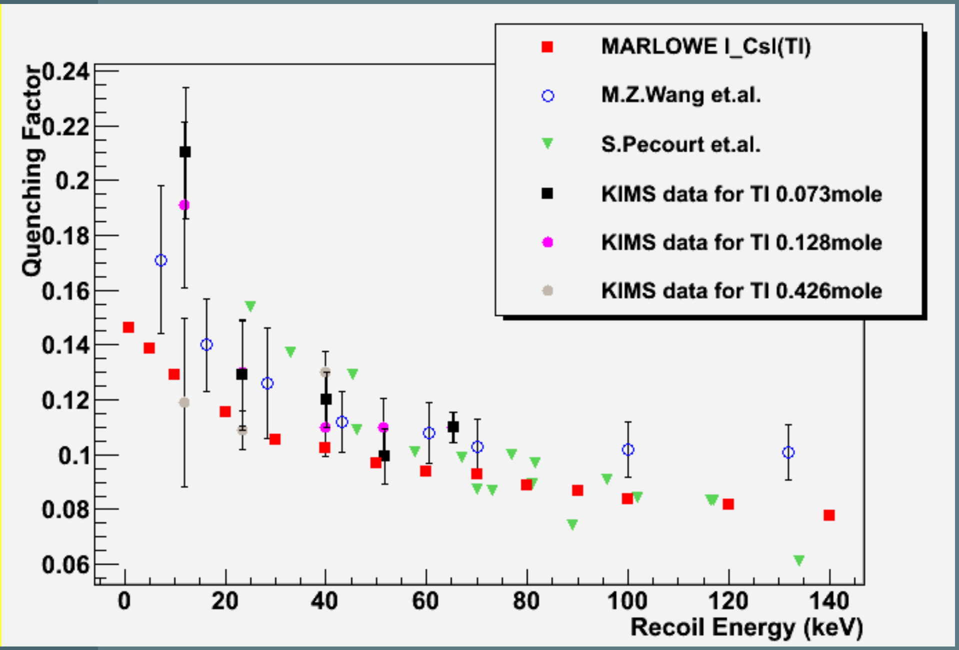
$$A = \frac{1}{1.05}$$

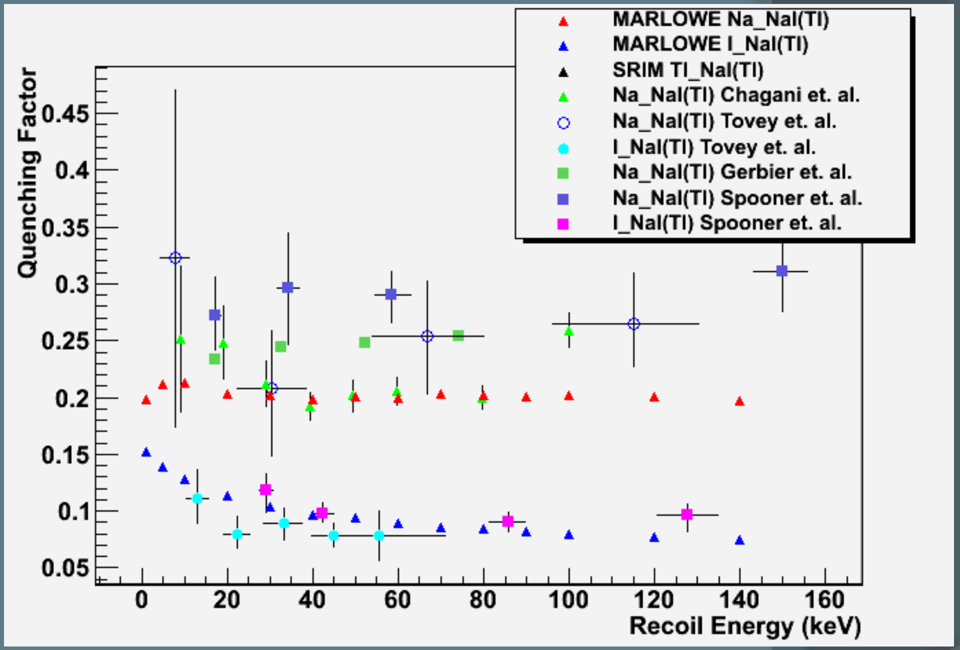




SIMULATION – Quenching Factor

MARLOWE Quenching factor

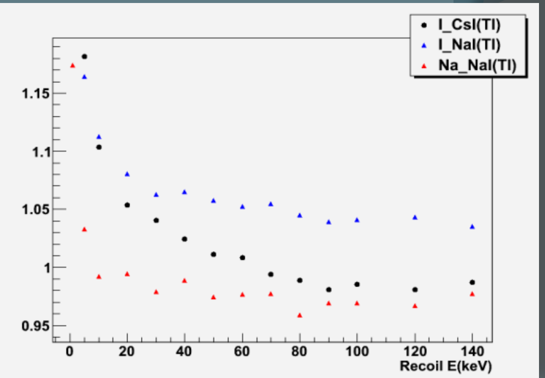




Why the mean values obtained from SRIM and MARLOWE are different?

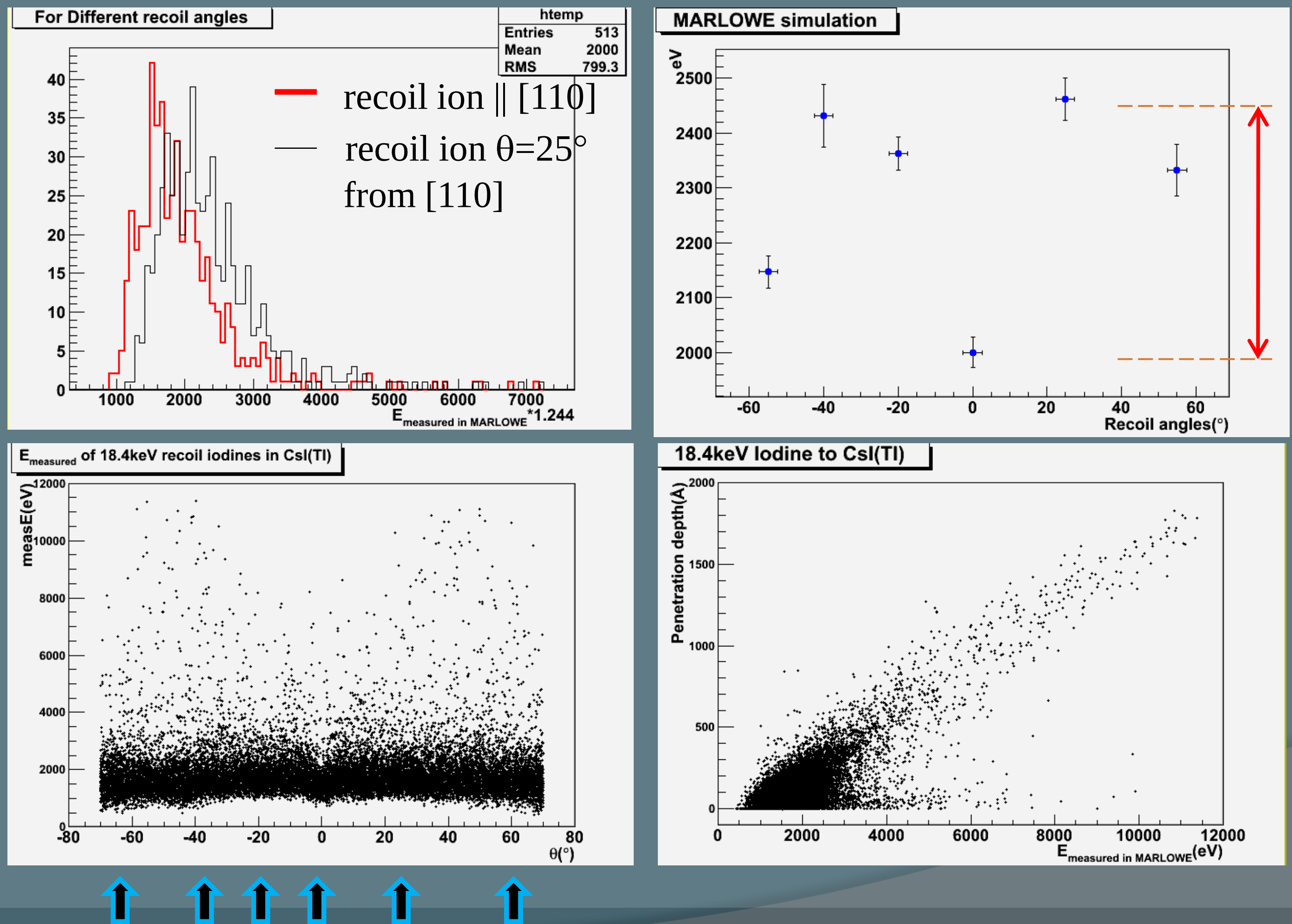
1. Wrong tail of the scintillation efficiency curve?
2. Wrong Method for the reproduction of $E_{measured}$?
3. Total ionization energy loss are different by ±5%.

$$Ratio = \frac{[TRIM]\, E_{e,tot}}{[MALOWE]\, E_{e,tot}}$$



SIMULATION – Channeling effect in the Light yield spectrum

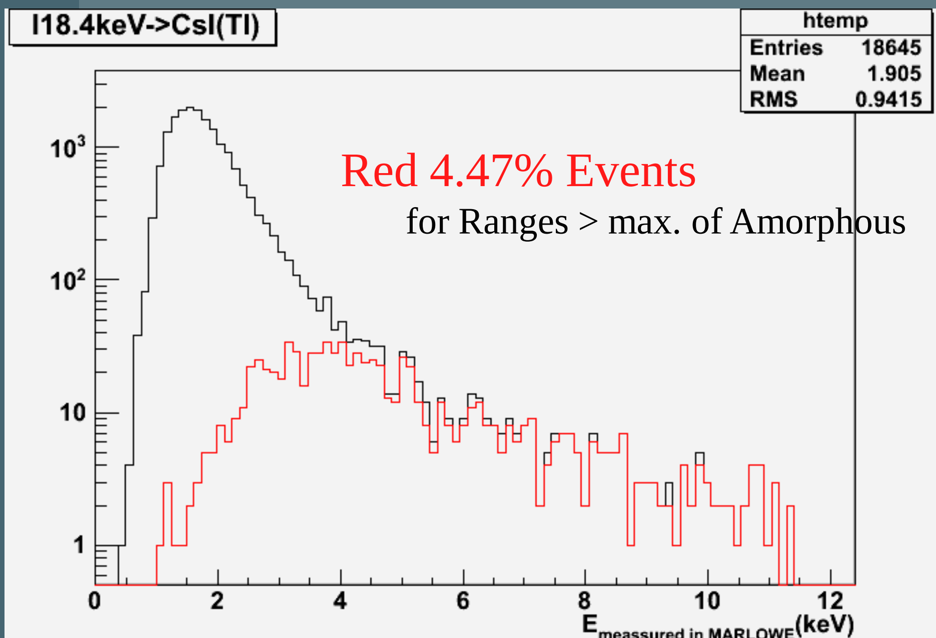
MARLOWE

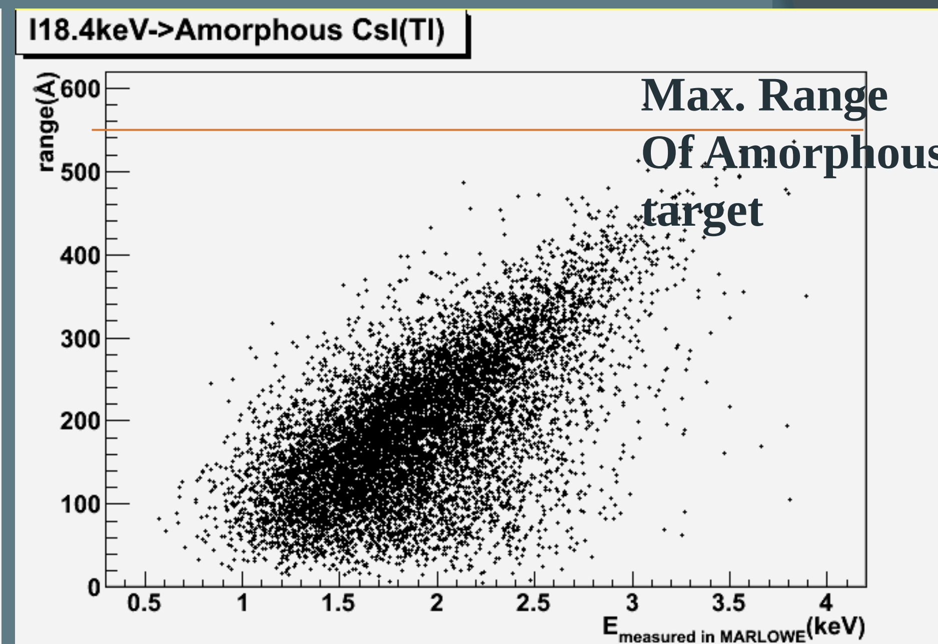


Due to the Different axes, Histogram Mean Values are Different by ~20% In the same crystal

SIMULATION – Channeling Effect in Light Yield Spectrum

MARLOWE

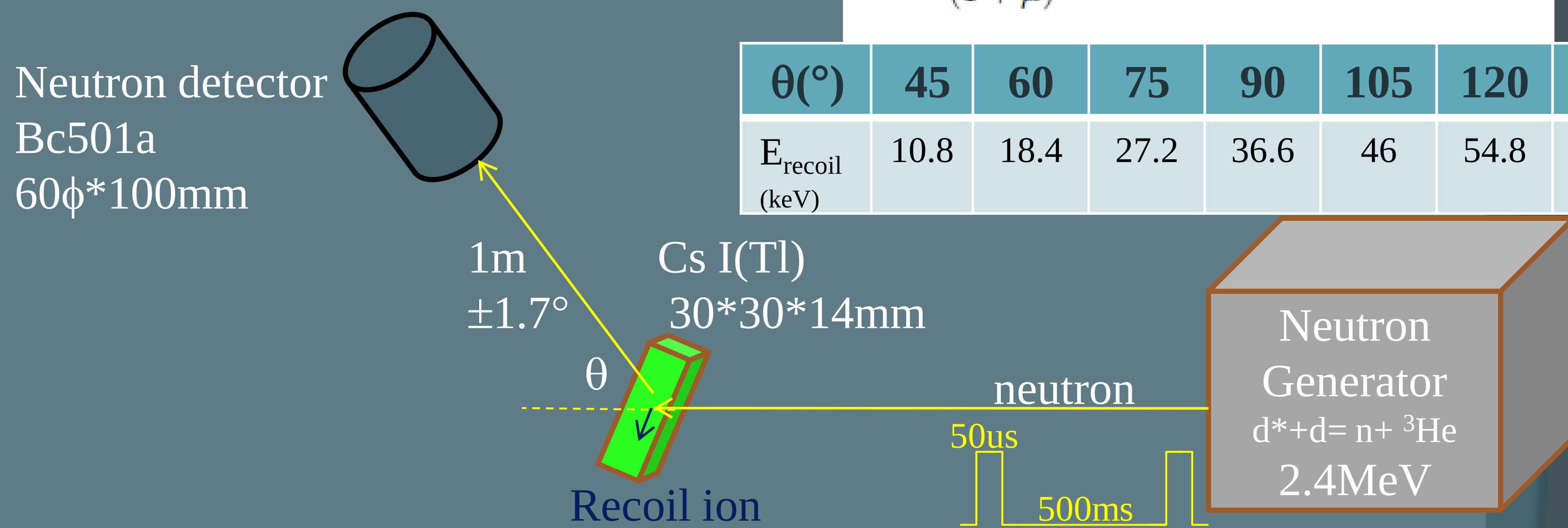


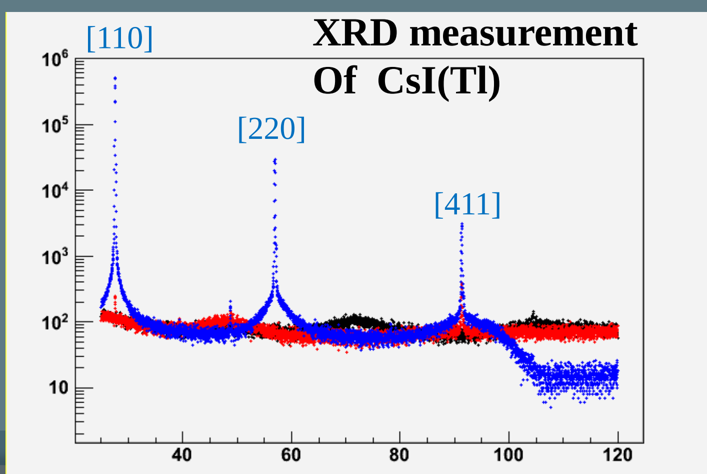


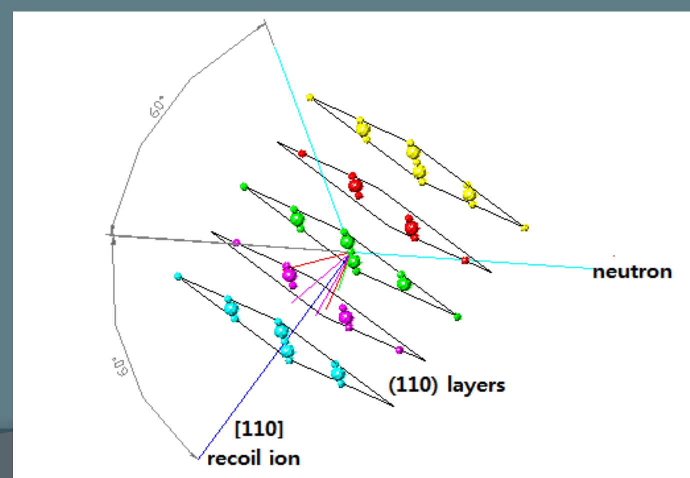
Experiment- Setup

$$E_r = \frac{2E_n}{(1+\mu)^2}\left(\mu + \sin^2\theta - \cos\theta\sqrt{\mu^2 - \sin^2\theta}\right)$$

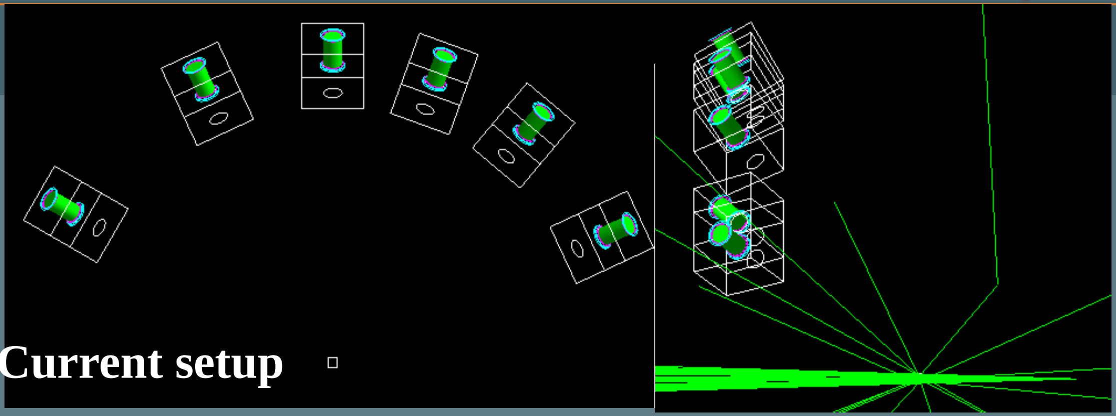
θ(°)	45	60	75	90	105	120	135
E_{recoil} (keV)	10.8	18.4	27.2	36.6	46	54.8	62.2

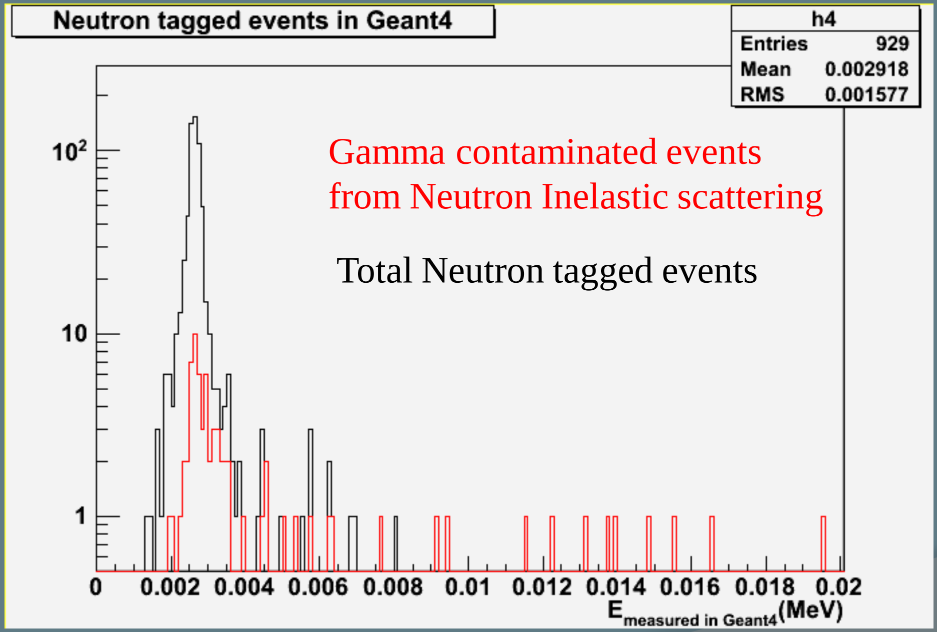






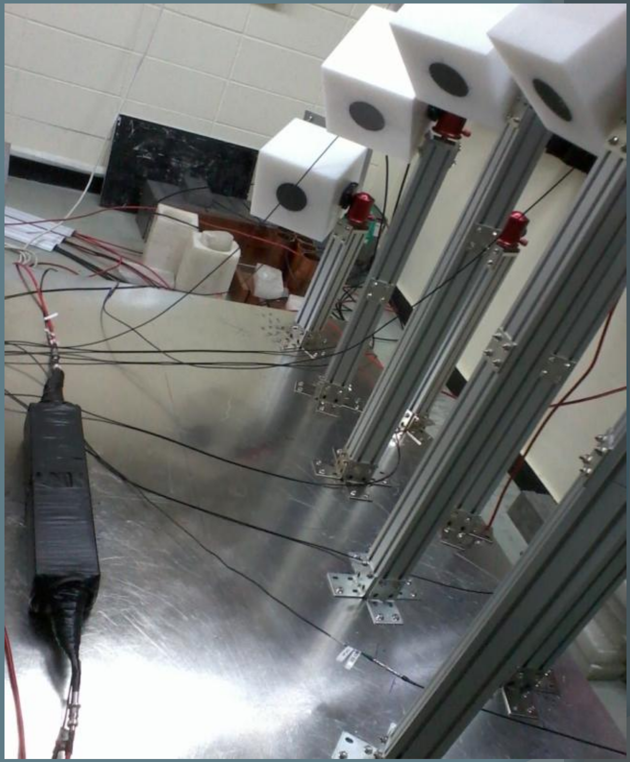
Experiment- G4Simulation for setup





The tail events (E_{meas}>4keV) from inelastic scattering are 3.2%

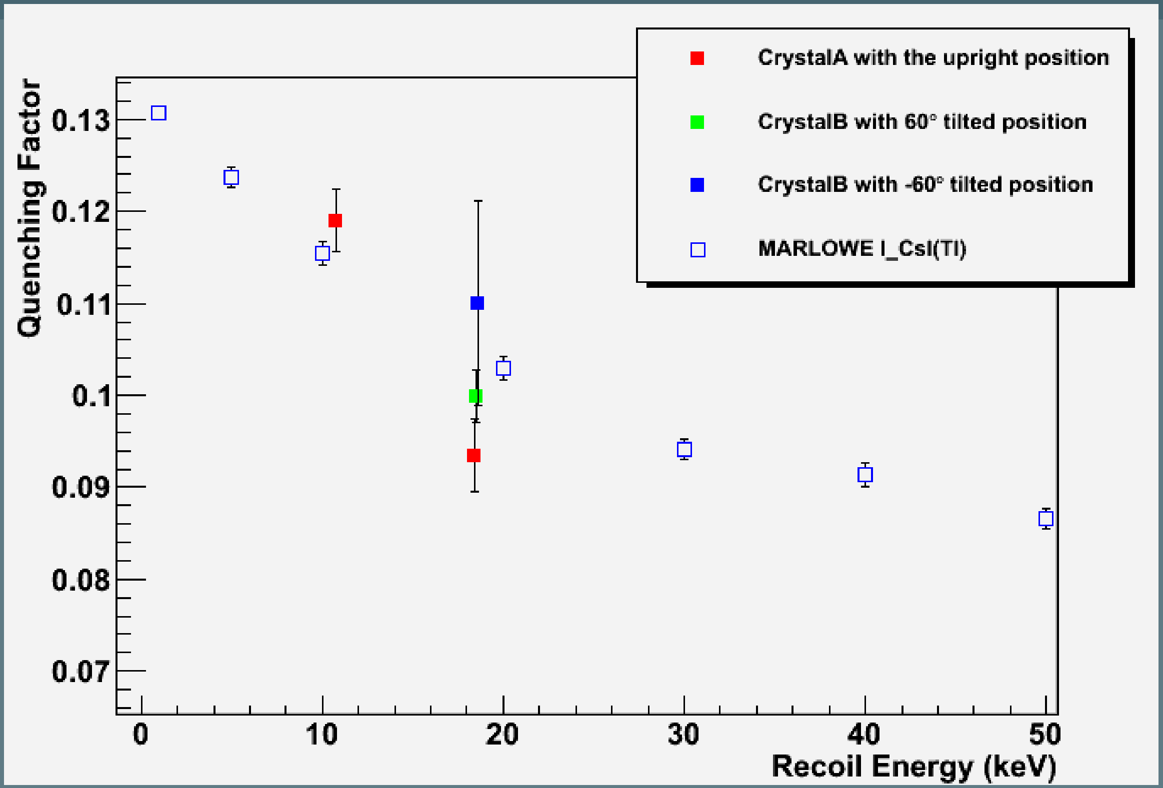
Experiment- Setup



DAQ : 3 Coincidence trigger of Neutron generator, Neutron Detector and Cs I(Tl)

Event Cut : Pulse Shape Discrimination for Neutron detector data
Exponential decay time fit quality cut for CsI(Tl) data

Quenching Factor measurement

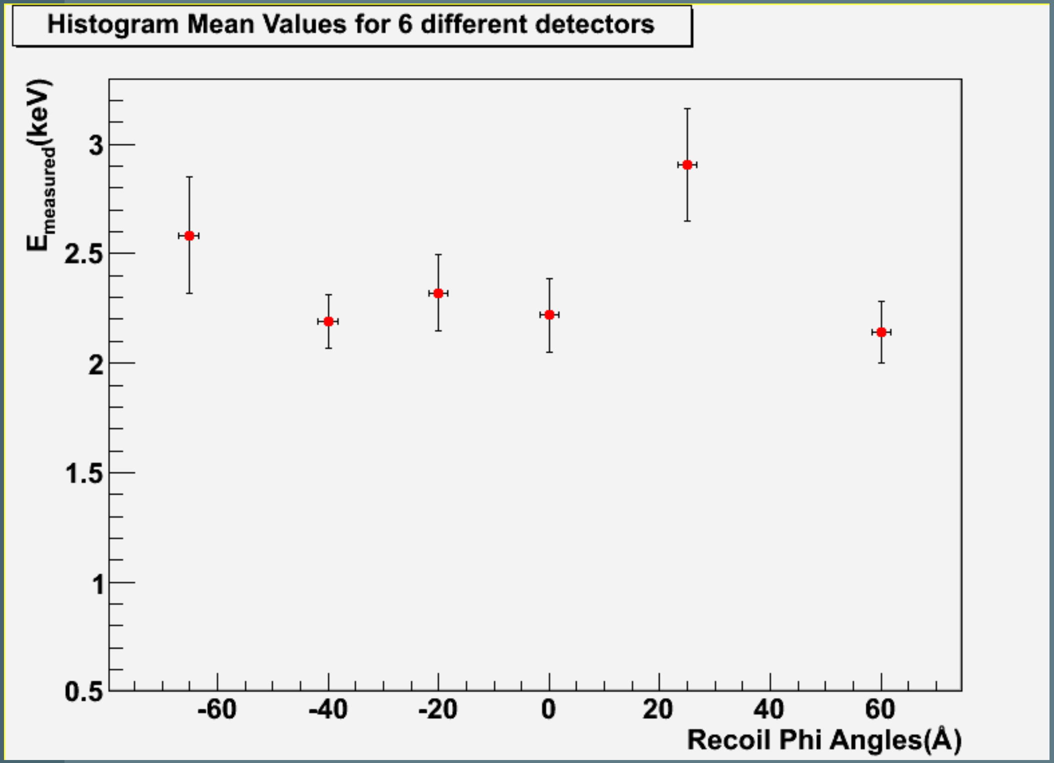


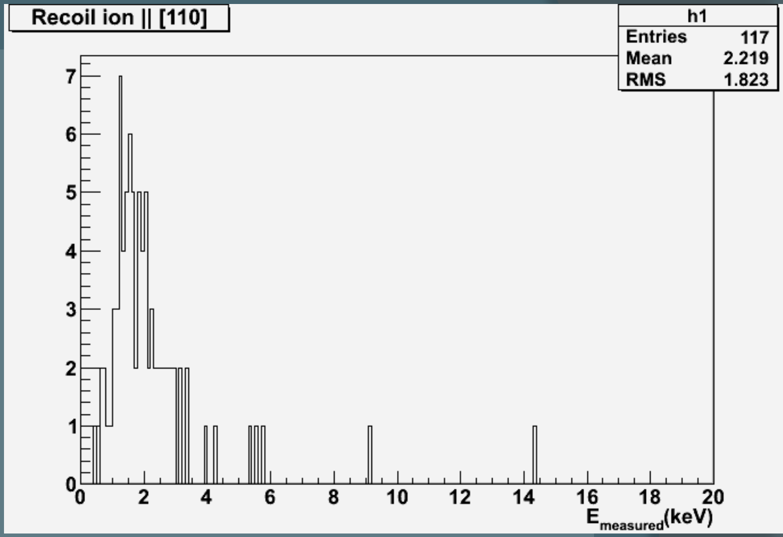
Exp : ^{241}Am γ 59.54keV Calibration

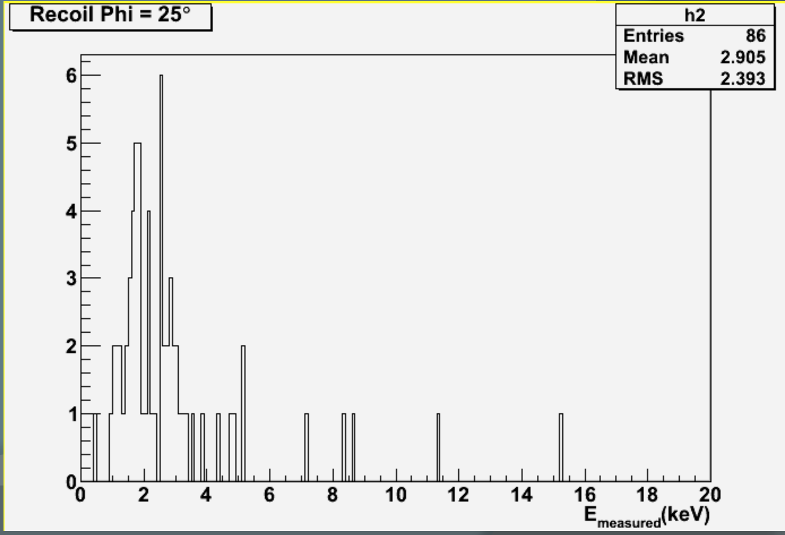
MARLOWE QF/1.12 (Nonlinear factor[5] , $\frac{L_{\gamma,59.54keV}}{L_{\gamma,662keV}}$)

Channeling measurement

The effect of tail events to the Measured energy spectrum







SUMMARY

- We reproduce quenching factors which fit well with experiments by using SRIM and a scintillation efficiency curve.
- We reproduce $E_{measured}$ distribution for the crystalline target with MARLOWE which is similar to TRIM in the case of amorphous target.
- In $E_{measured}$ distribution in the simulation, we see the tails from the channeling effect.
- In the directional measurement setup and CsI(Tl) which is well grown along [110] , we see the differences for the amount of tail events.

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