A tool for calculation of $^{7}Li(p,n)^{7}Be$ neutron spectra and the development of RF power measurement technique for low energy charged particle accelerators

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Outline

- Introduction
- RF Power Measurement Technique
  - Motivation
  - Results
- Development of neutron energy spectrum code
  - Database Formalism
  - Results – Validation & Distribution

INTRODUCTION: Nuclear and Hydrogen Energy Research Group (NHERG)

- Measurement of $^{70}Zn(n,g)^{71}Zn^{m}$ cross section at E_p = 2.25, 2.60, 2.80 and 3.50 MeV using $^{7}Li(p,n)^{7}Be$ reaction as neutron source
- Proton beam energy spread is ±20 keV
- Due to continuous proton beam structure, we have to rely on calculated neutron energy spectrum

1. RF Oscillator

- **Application**
  - Particle accelerators
  - NBI systems for fusion devices
  - Bio-medical Sciences, etc…

- **Motivation**
  - RF power stability
  - RF power measurement

Circuit Description

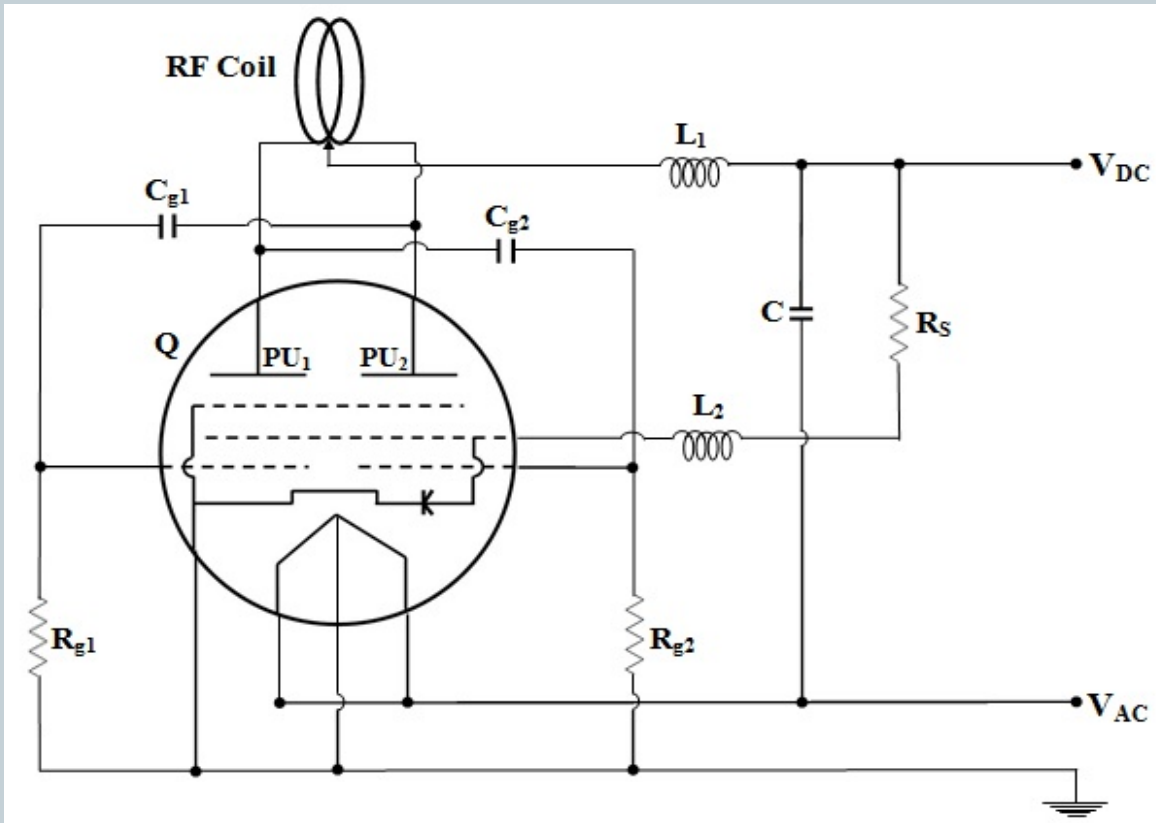


Figure 1: Circuit diagram of RF oscillator. Q = 829B/GI30 twin beam-power tetrode; RF Coil: tube diameter = 0.6 cm, pitch = 1 cm, coil diameter = 7 cm; R_S = 20 kΩ, 20 W; $R_{g1} = R_{g2}$ = 6.8 kΩ, 1 W; $C_{g1} = C_{g2}$ = 1 pF, 1 kV; C = 50 µF, L_1= 586 µH; L_2= 589.5 µH.

C. D. Moak, H. Reese, Jr., and W. M. Good, Nucleonics 9(3), 18 (1951).

Circuit Description

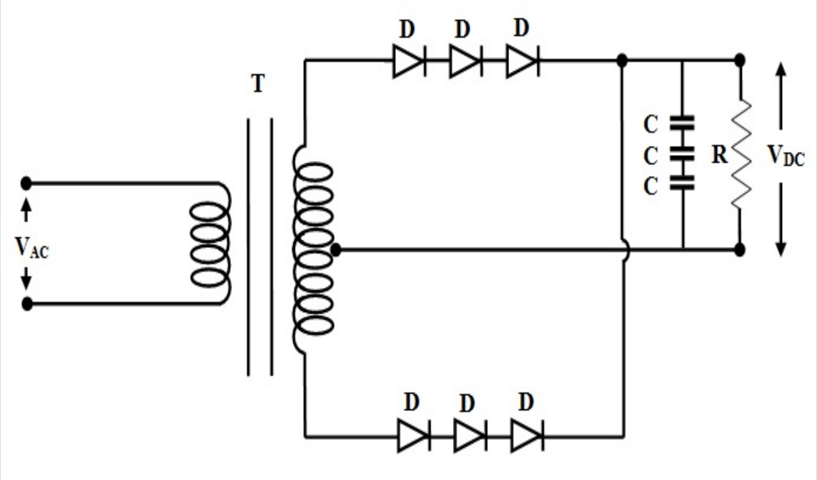


Figure 2: Circuit diagram of **1 kV DC power supply**. T = 100 VA Step-Up Transformer; D = IN 4007, 700 V (PIV); C = 330 μF, 450 V; R = 1.18 MΩ.

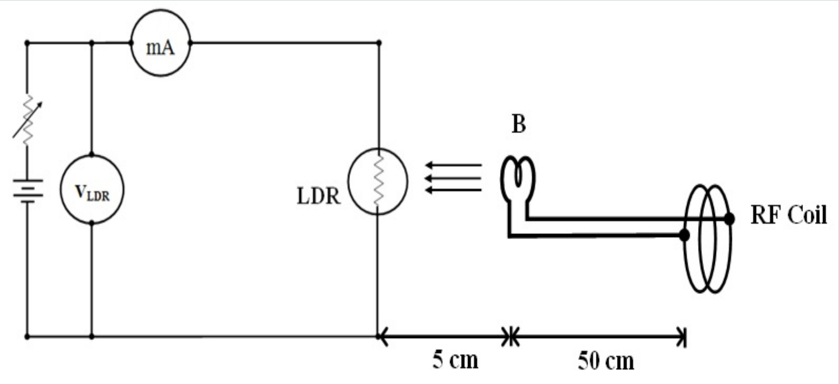
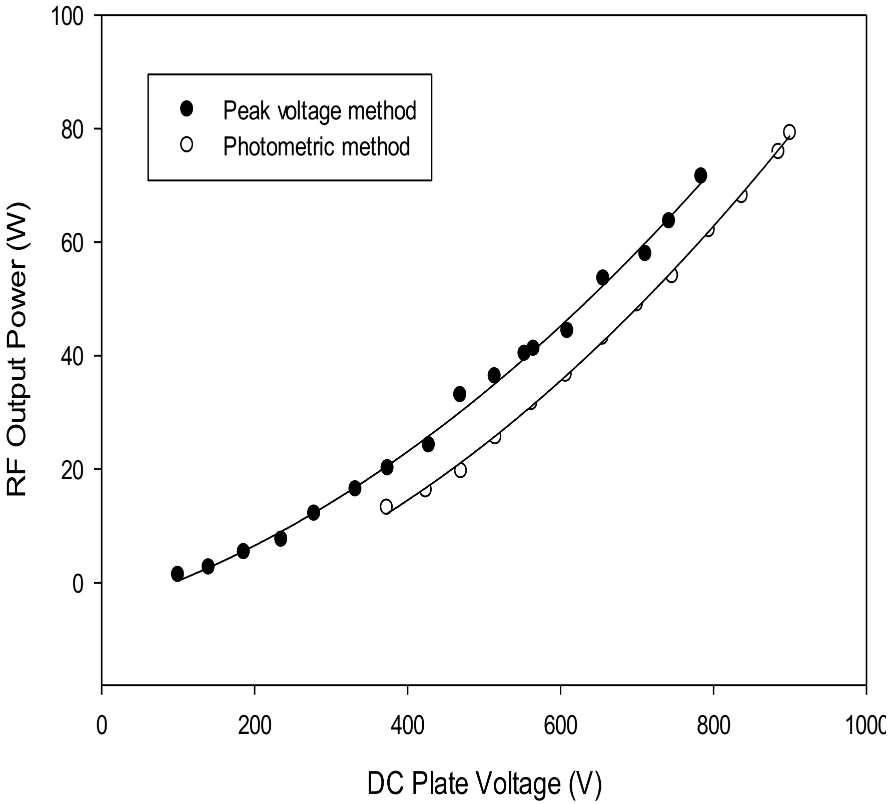


Figure 3: Experimental setup for **RF power measurement.**

Results

- The oscillation frequency
  - $f = 102$ MHz (measured with frequency counter FC 2400)
  - Inter-electrode capacitance of ≈ 4.4 pF reduces frequency from 169 MHz to 102 MHz (Stable).
- Power stability
  - RF output power is found to decrease by about 10% due to tank coil oxidation.



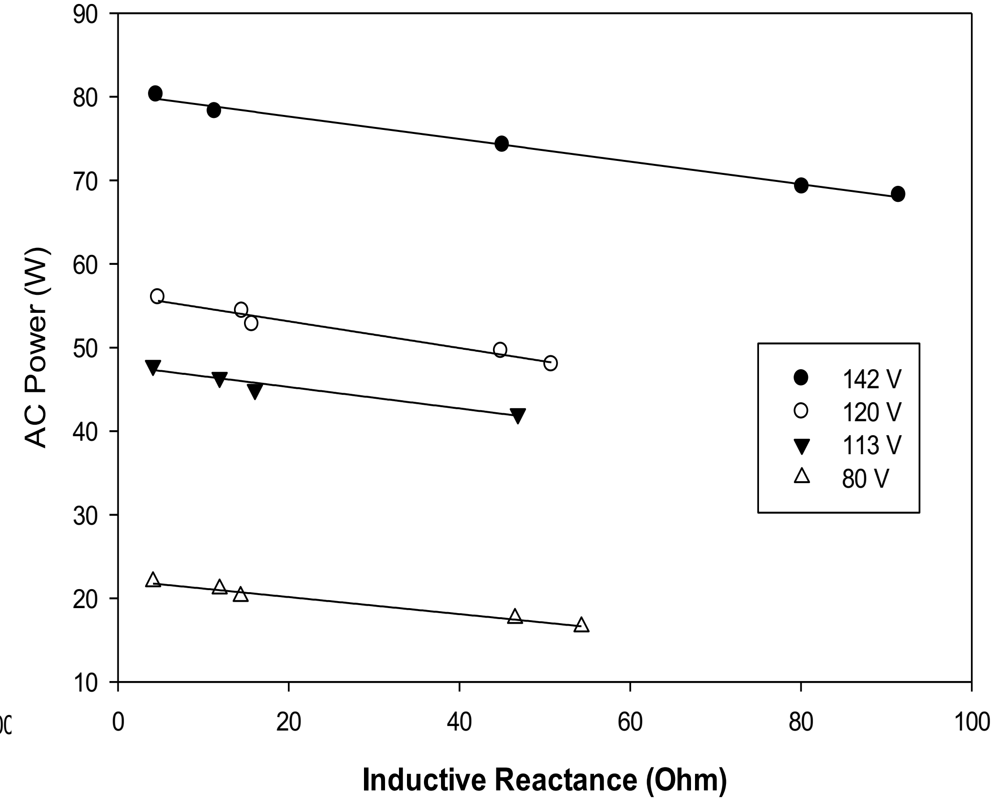
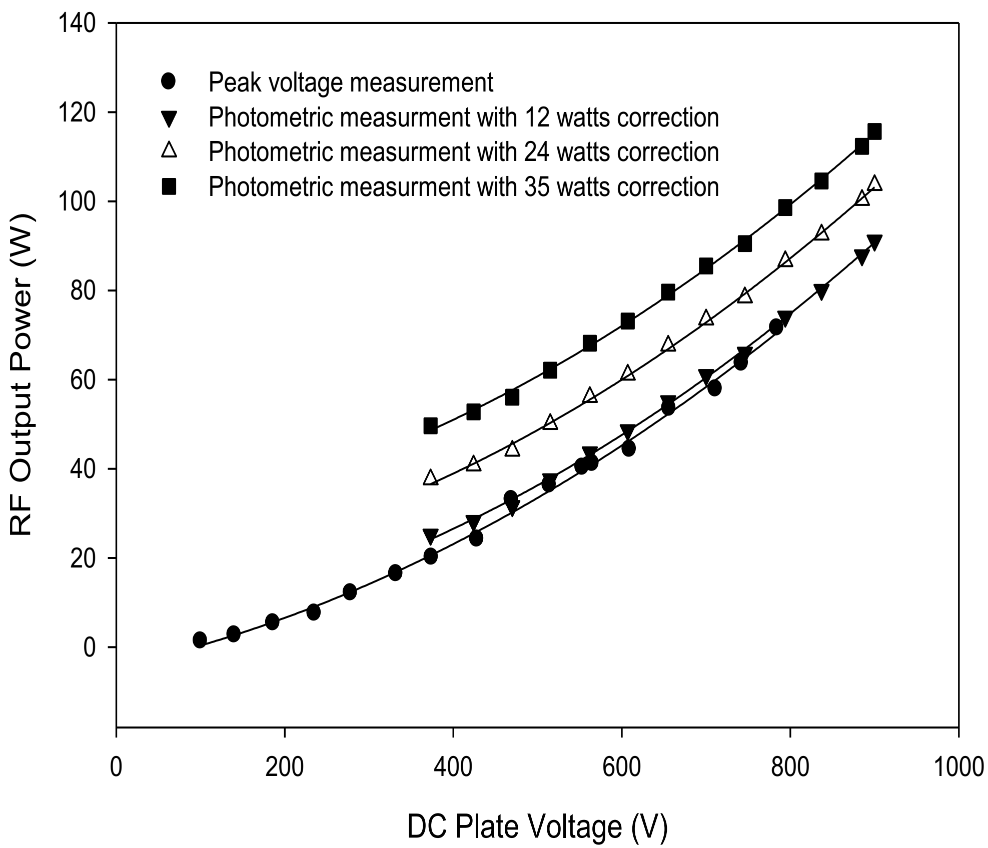


Figure 4: Variation of RF output power with plate voltages (350-900 V) for 829B according to photometric and peak voltage measurements.

Figure 5: Variation of AC power dissipated by 100 watt incandescent lamp at different values of inductive reactance and applied voltages.

- Power correction of 12 watts comes from the **inductive reactance X_L of the bigger coil** alone having inductance **141 nH.**

- With this correction, the total output power of the oscillator **at 900 V** plate voltages becomes **91 watts**.



REVIEW OF SCIENTIFIC INSTRUMENTS **87**, 045101 (2016)

A revisit to self-excited push pull vacuum tube radio frequency oscillator for ion sources and power measurements

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Self-excited push-pull vacuum tube oscillator is one of the most commonly used oscillators in radio frequency (RF)-ion plasma sources for generation of ions using radio frequency. However, in spite of its fundamental role in the process of plasma formation, the working and operational characteristics are the most frequently skip part in the descriptions of RF ion sources in literatures. A more detailed treatment is given in the present work on the RF oscillator alone using twin beam power tetrodes 829B and GI30. The circuit operates at 102 MHz, and the oscillation conditions, stability in frequency, and RF output power are studied and analyzed. A modified form of photometric method and RF peak voltage detection method are employed to study the variation of the oscillator output power with plate voltage. The power curves obtained from these measurements are quadratic in nature and increase with increase in plate voltage. However, the RF output power as measured by photometric methods is always less than the value calculated from peak voltage measurements. This difference is due to the fact that the filament coil of the ordinary light bulb used as load/detector in photometric method is not a perfect inductor. The effect of inductive reactance on power transfer to load was further investigated and a technique is developed to estimate the amount of power correction needed in the photometric measurement result. [http://dx.doi.org/10.1063/1.4944943]

2. Development of neutron energy spectrum code

- $^7Li(p,n)^7Be$ reaction -neutron source.
- Subtraction of (p,n_1) - neutron-induced reaction cross section.

We developed a new deterministic code

EPEN-Energy of **P**roton **E**nergy of **N**eutron

$$\frac{dY(E_n)}{dE_n} = \int d\Omega \frac{d^2Y(\theta, E_n)}{dE_n d\Omega} w_1(\theta) w_2\left(E_p(\theta, E_n)\right)$$

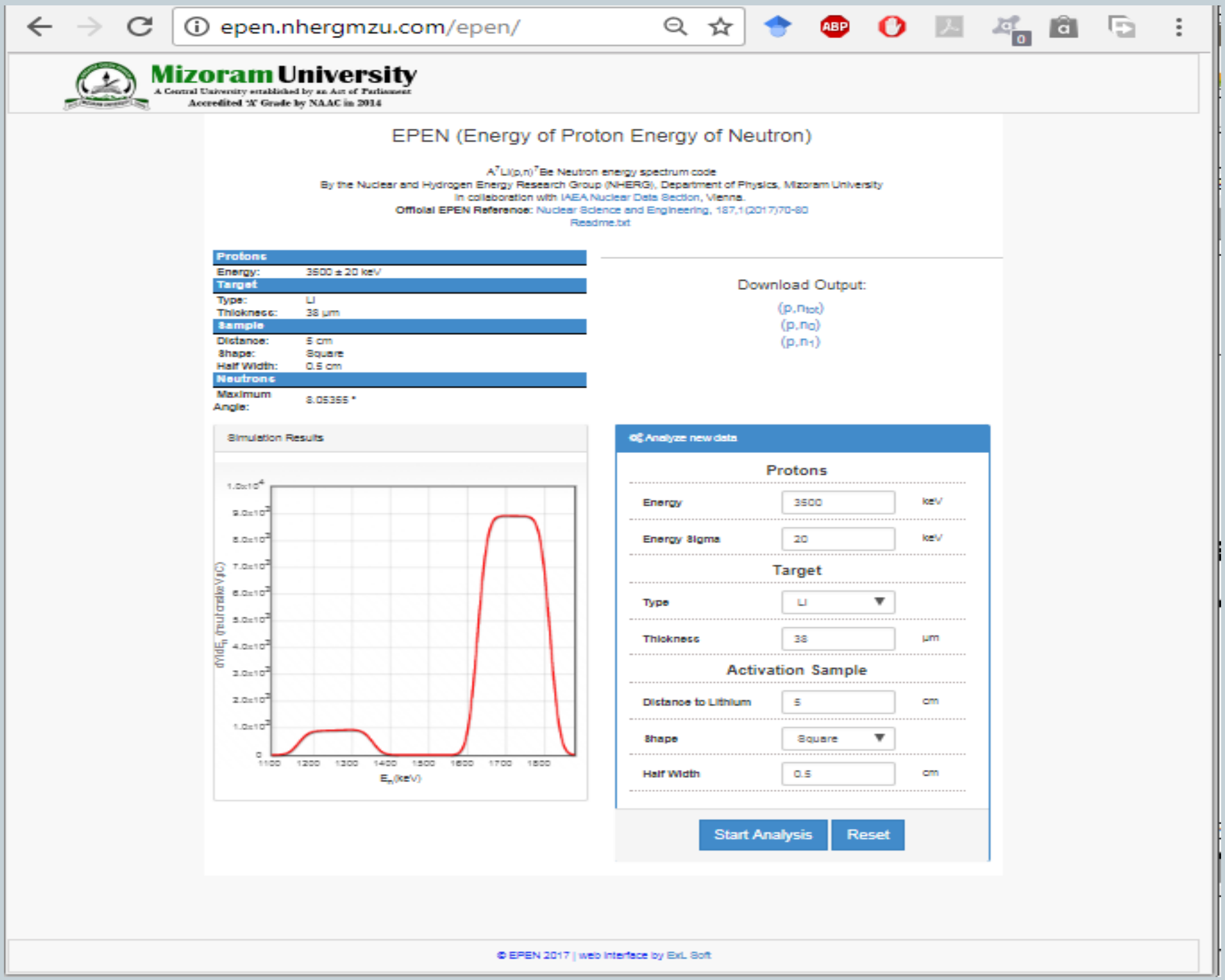
Differential Cross-sections

- **E_p > 1.95 :** Evaluated data - Liskien et. al.
- **E_p near threshold :** Functional form – Macklin & Gibbons
- **1.92 MeV< E_p <1.95 MeV :** Cubic Spline fits

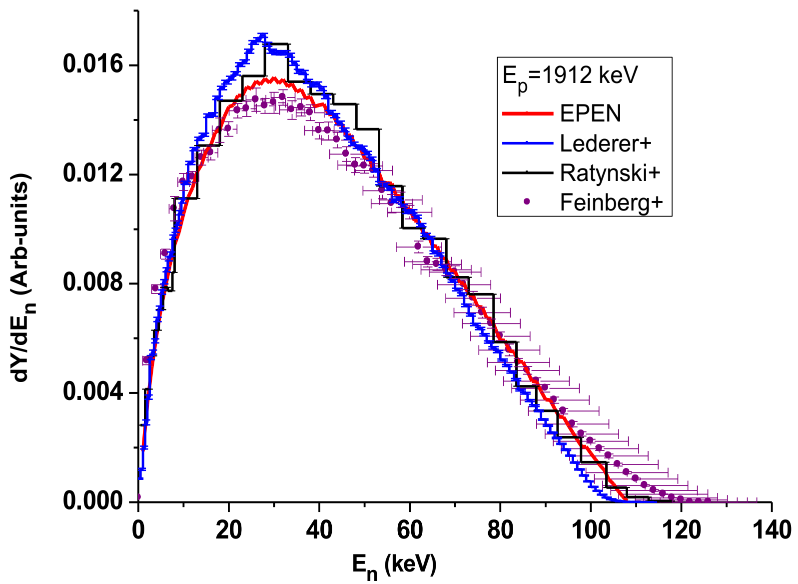
Weighting

- Solid angle covered by sample (w_1)
- Proton energy spread (w_2)

http://epen.nhergmzu.com/epen/#

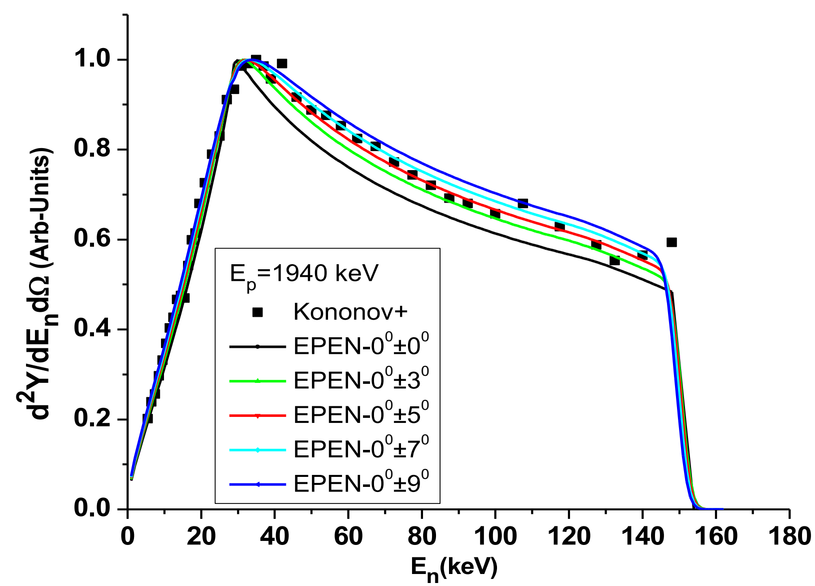


RESULTS

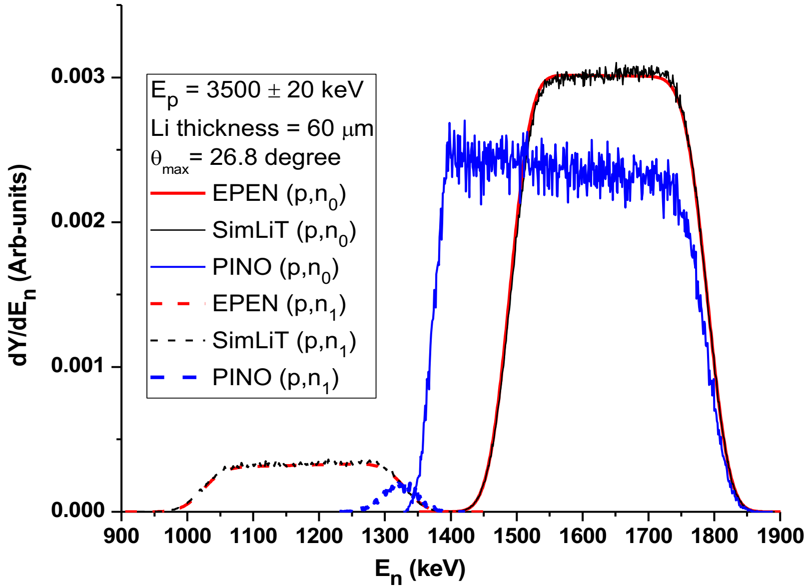


Validation

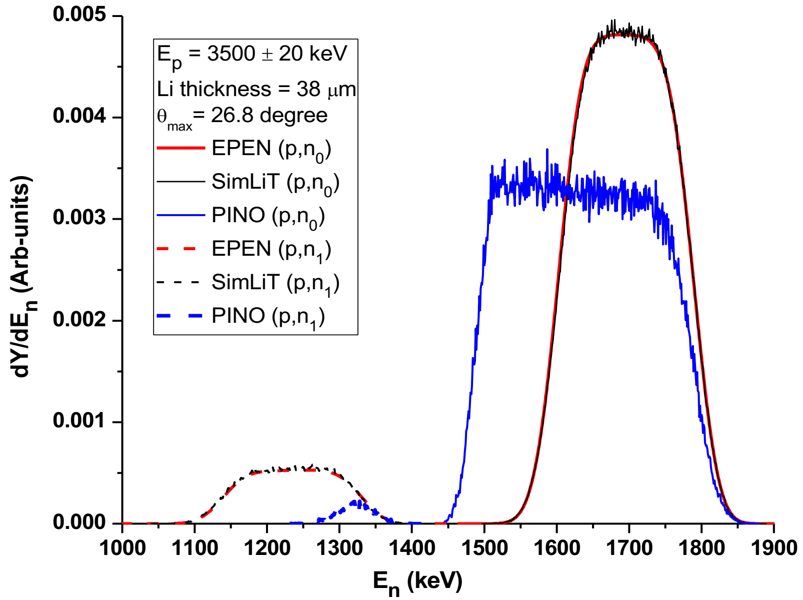
EPEN reproduces experimental spectra well



Comparison of EPEN with Monte Carlo codes



- EPEN always agree with SimLiT perfectly
- PINO – narrow (p,n_1) spectrum centred near the upper boundary of the (p,n_1) energy spectra of EPEN & SimLit



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Technical Papers

Thick and Thin Target ^{7}Li(*p*,*n*)^{7}Be Neutron Spectra Below the Three-Body Breakup Reaction Threshold

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Abstract

Recently, we measured the ^{70}Zn(n,γ)^{71}Zn^{m} activation cross sections using the ^{7}Li(p,n)^{7}Be neutron source for 2.0 MeV < E_p < 3.7 MeV. Since the time-of-flight and multiple foil activation techniques cannot be applied due to the continuous beam structure and weak neutron flux at the facility, we have to rely on calculated neutron energy spectra for data reduction procedure. There are existing Monte Carlo–based codes such as Protons In Neutrons Out (PINO) and SimLiT for calculation of ^{7}Li(p,n)^{7}Be neutron source spectra at these energies. However, these two codes predicted different neutron spectra at these energy regions. We therefore decided to study the thick and thin target ^{7}Li(p,n)^{7}Be neutron spectra from the reaction threshold to the three-body breakup threshold by deterministic calculation. The predicted neutron spectra near threshold were validated by experimental neutron spectra. Our neutron spectra were compared with those predicted by PINO and SimLiT. Our neutron spectra at E_p = 2.8 and 3.5 MeV agree perfectly with those predicted by SimLiT but not with those predicted by PINO.

Keywords: ^{7}Li(p,n)^{7}Be reaction, neutron source, neutron spectra

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