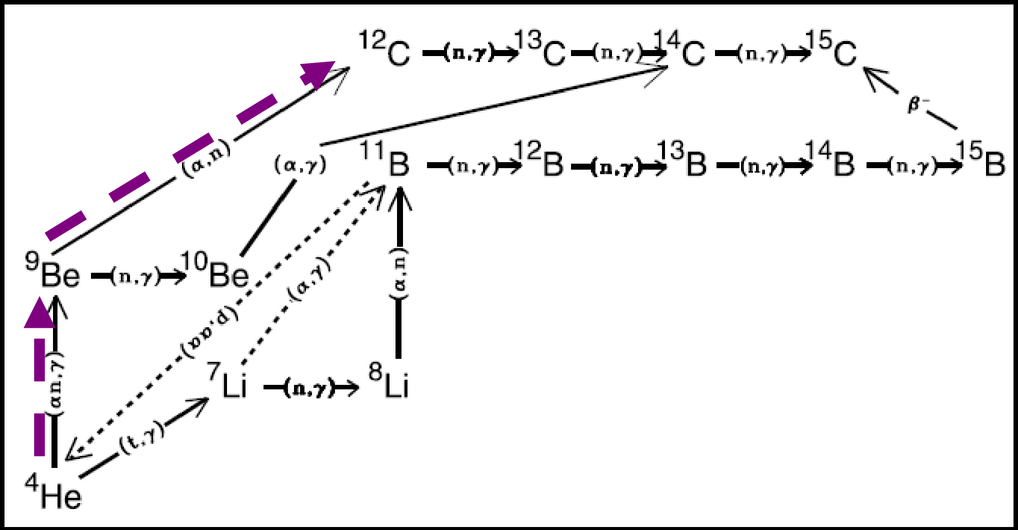
$^{12}B(n,\gamma)^{13}B$ by the (d,p) reaction

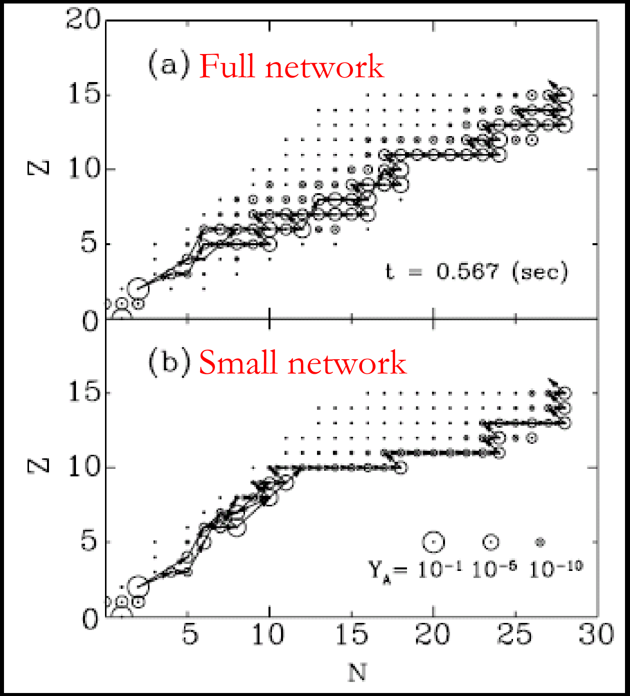
Hye Young Lee

Argonne National Laboratory

Interest in light, neutron-rich nuclei

Terasawa *et al.* (2002) suggested a new nuclear reaction path during r-process in supernovae in light, neutron-rich nuclei





Extended nuclear reaction network (40 more unstable nuclei for Z≲10) was used and this shows new nuclear reaction paths that can change the heavy-element abundance by upto a factor of 10.

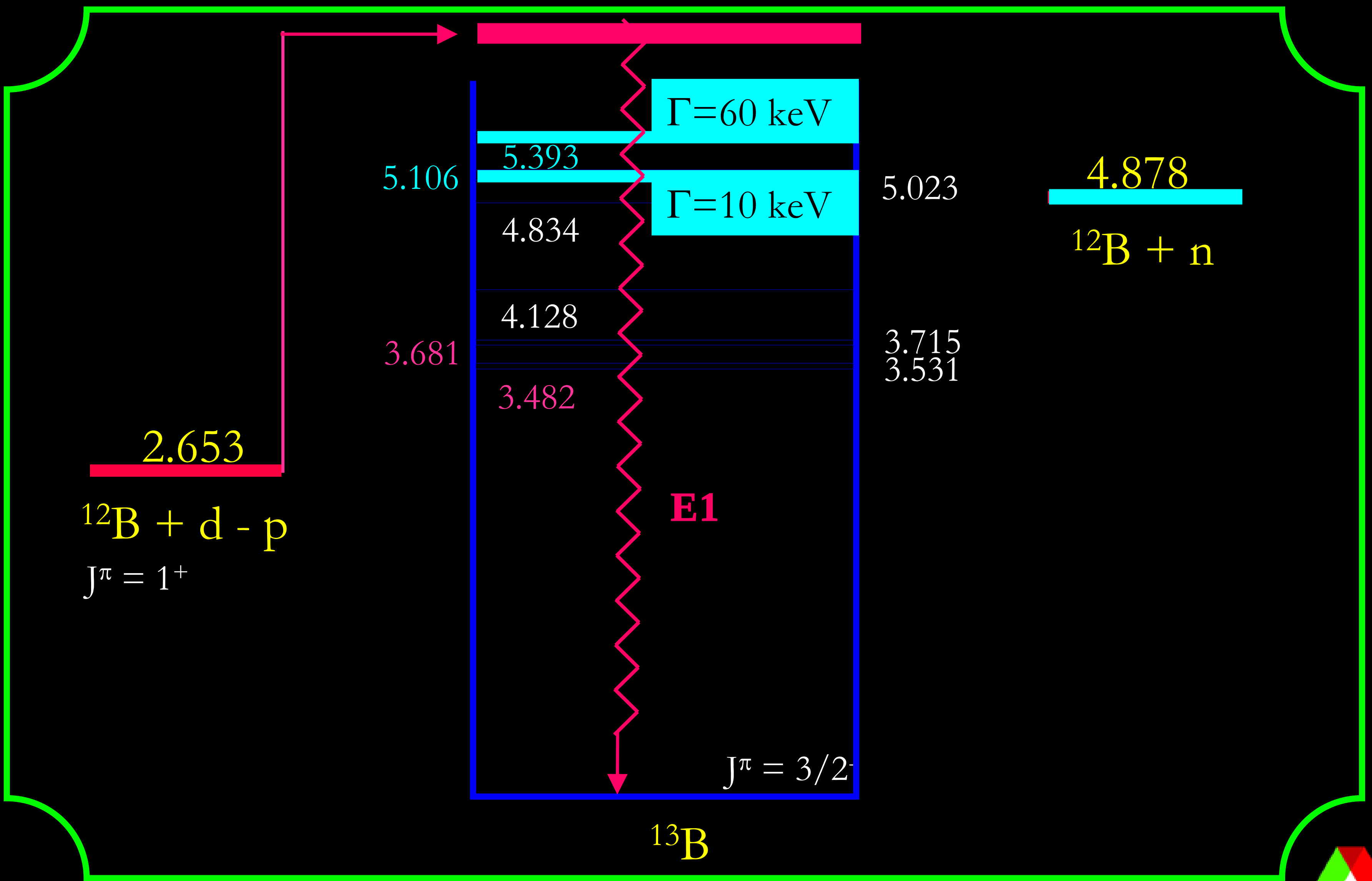
Introduction : $^{12}B(n,\gamma)^{13}B$ reaction

Sasaqui *et al.* (2005) emphasized the importance of accurate experimental data for light element by studying the sensitivity of light-element reactions for r-process nucleosynthesis.

Reaction	$N_A\langle\sigma\upsilon\rangle$	Ref
$^{11}B(n,\gamma)^{12}B$	$7.38\times10^2 + 3.86\times10^3\, T_9^{-3/2}\exp(-0.244/T_9) + 3.34\times10^4\, T_9^{-3/2}\exp(-4.99/T_9)$	[5]
$^{12}B(n,\gamma)^{13}B$	$1.7\times10^3 + 9.548\times10^3\, T_9^{-3/2}\exp(-1.625/T_9)$ $+ 1.562\times10^3\, T_9^{-3/2}\exp(-2.666/T_9) + 1.163\times10^4\, T_9^{-3/2}\exp(-5.919/T_9)$	[5]
$^{13}B(n,\gamma)^{14}B$	$1.02\times10^1 + 4.950\times10^1\, T_9 + 4.940\times10^4\, T_9^{-3/2}\exp(-4.76/T_9)$	[5]
$^{14}B(n,\gamma)^{15}B$	$1.906\times10^3 + 1.142\times10^3\, T_9$	[5]

[5] : Rauscher *et al.* (1994) presented the resonant and non-resonant contributions to the reaction rates of neutron capture on light elements. For non-resonant terms, s-wave direct capture was mostly dominant and the unbound levels for resonant capture were sometimes estimated with a shell model calculation of the unknown resonances.

^{13}B level scheme



Determine Spectroscopic Factors

Cross section for direct captures (E1) :

$$\sigma_{DC} = \frac{2E_\gamma}{\hbar^2 c v_i (2j_p + 1)(2j_t + 1)} \sum_{m_i, m_f} |\langle f, m_f | H_{\text{int}} | i, m_i \rangle|^2$$

$$\sigma_{\text{exp}} = \sum_{l_f} C^2S\,(l_f)\,\sigma\,(l_f)_{\text{calc}}$$

Resonance strength for (n,γ) capture :

$$\omega\gamma = \frac{2J+1}{(2j_p+1)(2j_t+1)} \frac{\Gamma_{\text{in}}\Gamma_{\text{out}}}{\Gamma_{\text{tot}}}$$

$$\Gamma_p = 3\frac{\hbar^2}{\mu R^2} P_\ell C^2 S$$

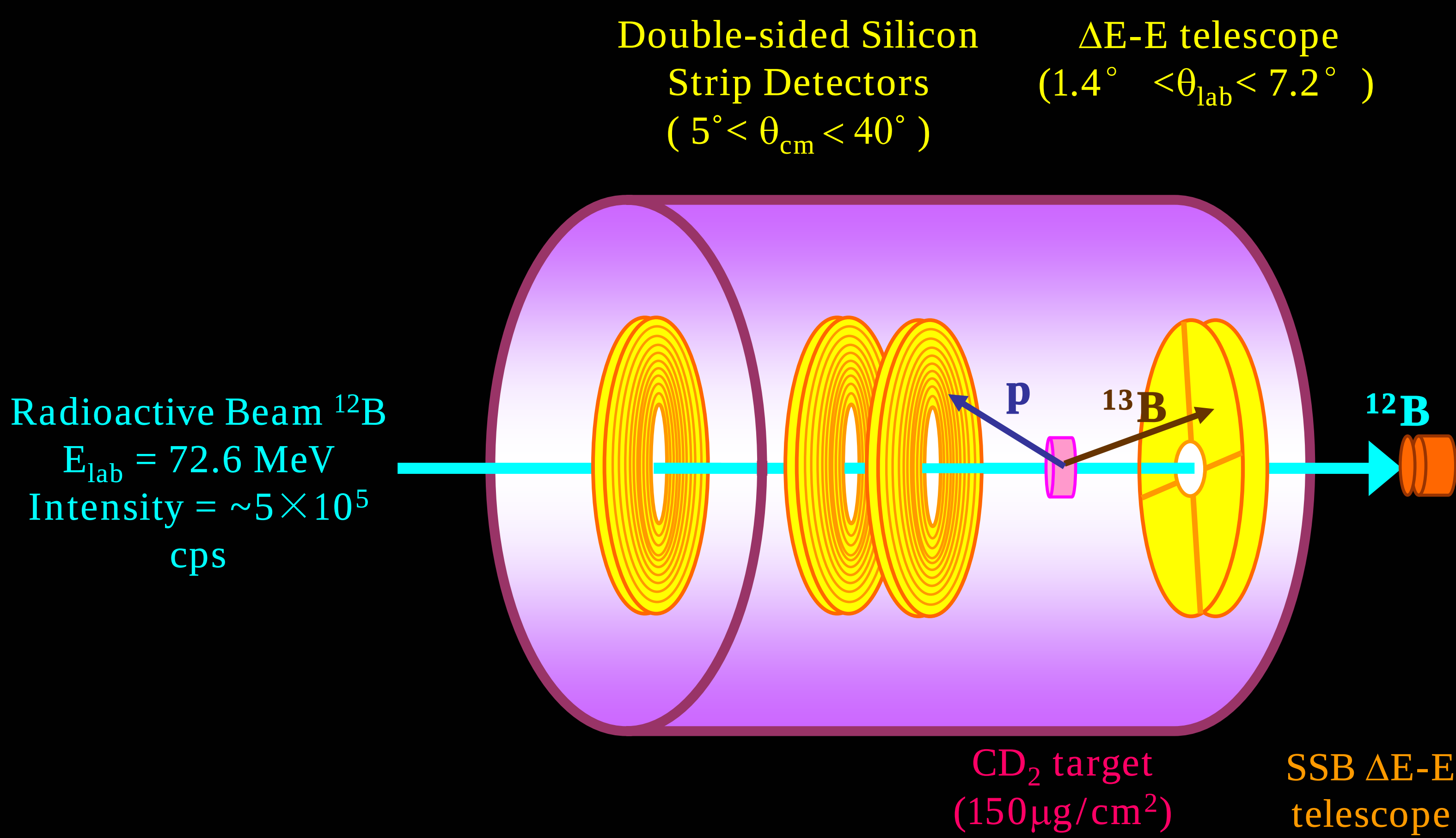
Theoretical prediction for $^{12}B(n,\gamma)^{13}B$:

Ex=5.024 $(5/2^-)$ → Γ_n = 6.0E4, Ex=5.388 $(3/2^-)$ → Γ_n = 1.0E4

C^2S for s-wave direction capture to the ground state $(3/2^-)$= 0.72

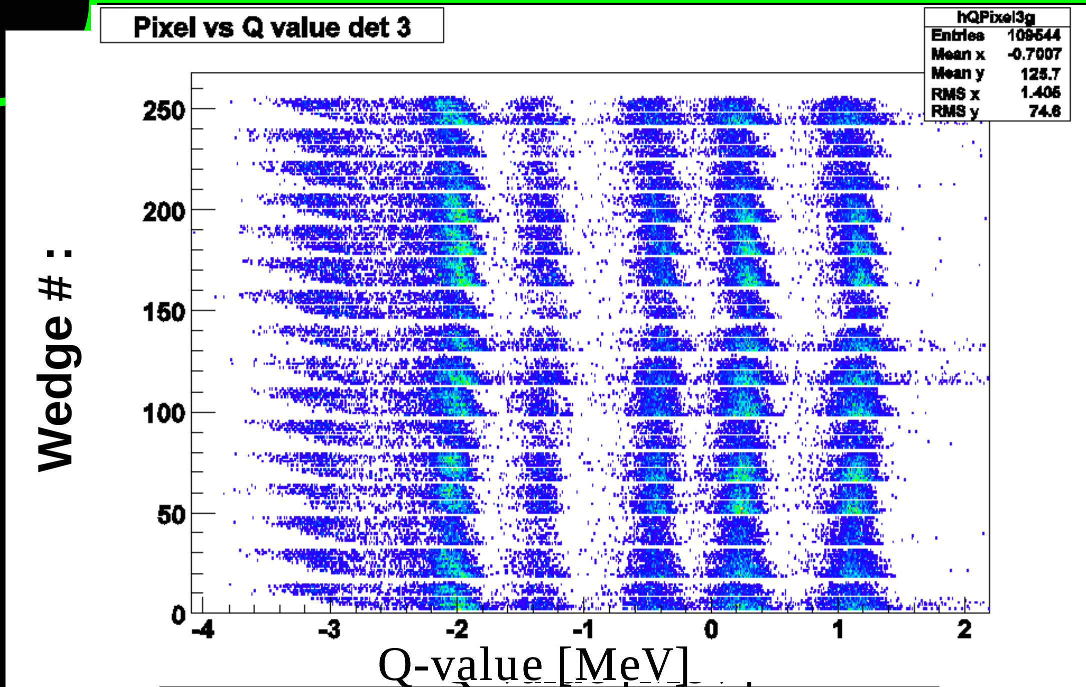
Wiescher *et al.* (1989)

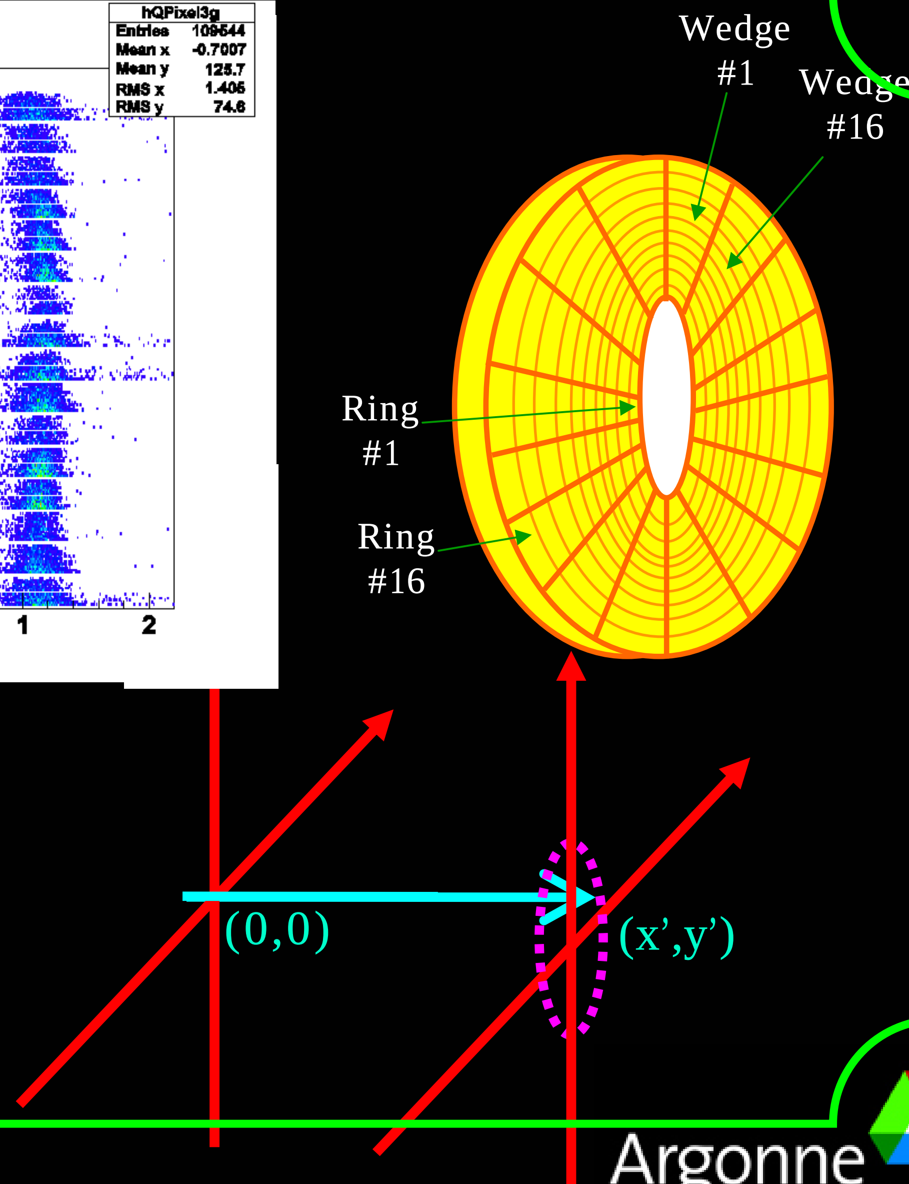
Experimental Setup for $^{2}H(^{12}B,p)^{13}B$



Argonne NATIONAL LABORATORY

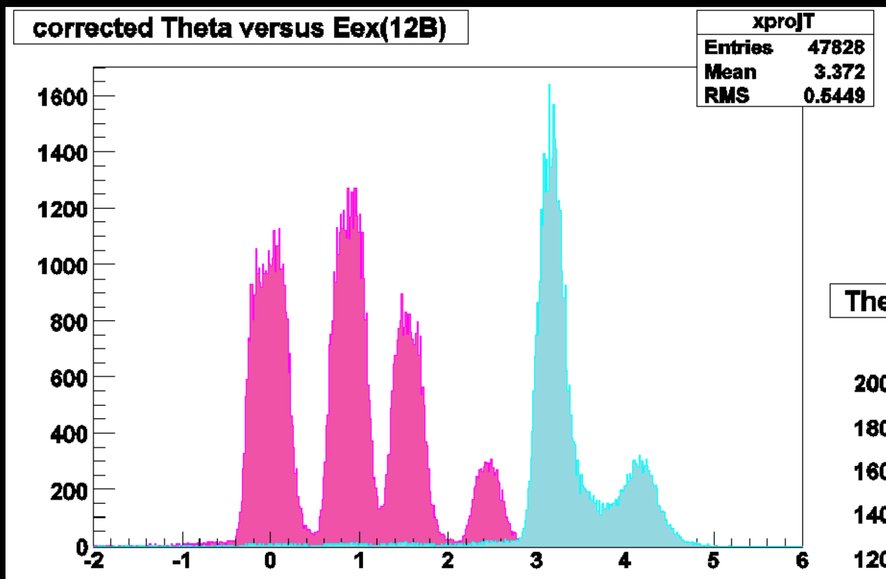
Correction for kinematic shifts with $^{2}H(^{11}B,p)^{12}B$



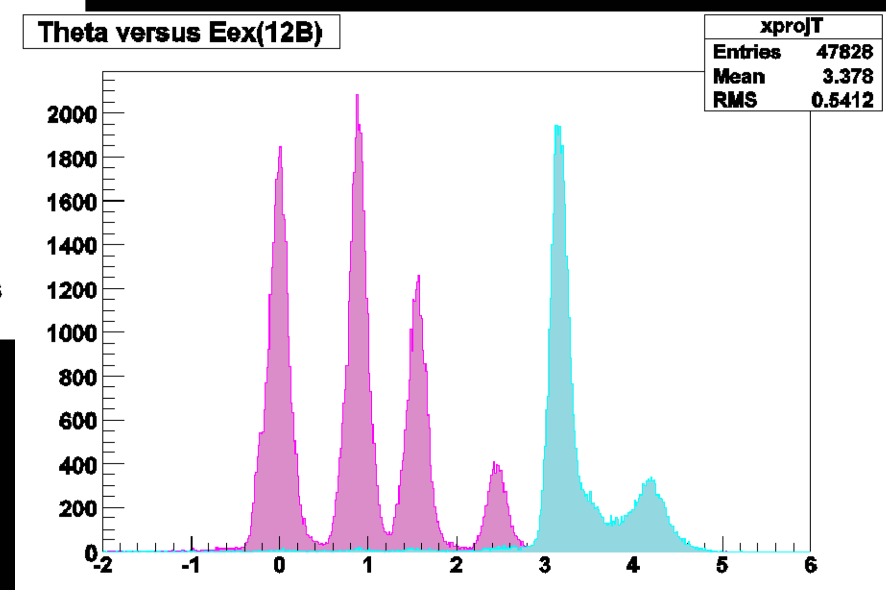


Beam spot offset (x',y')
-> ϕ correction
dead layer on each ring
-> θ correction

Improved Energy Resolution Due to Corrections



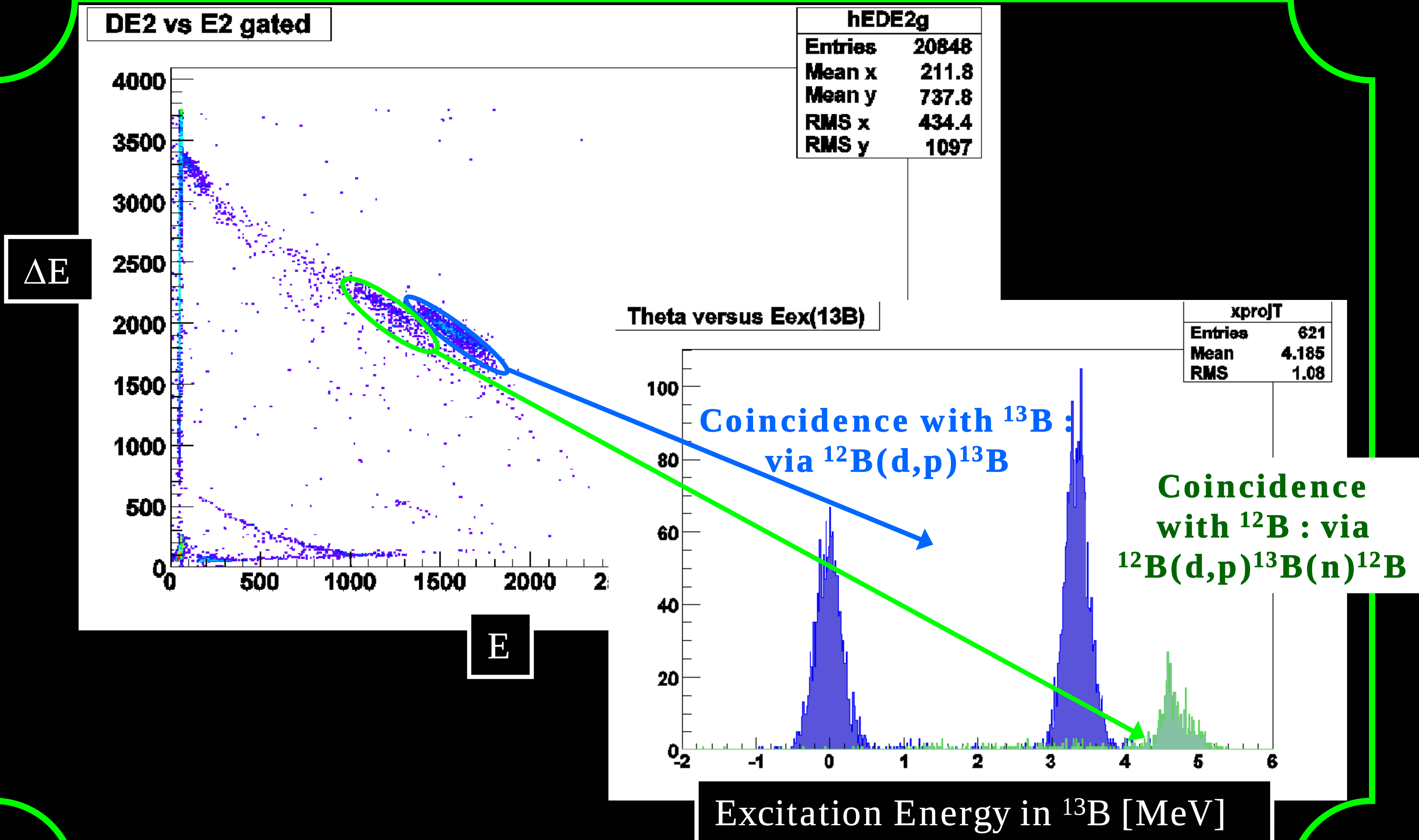
Excitation Energy in ^{12}B [MeV]



Excitation Energy in ^{12}B [MeV]

Argonne
NATIONAL LABORATORY

Preliminary results of $^{12}B(d,p)^{13}B$



Outlook

1. More careful corrections and Monte Carlo simulation are required to improve the energy resolution to separate closely-spaced states.
2. Determine the spectroscopic factors for direct capture to ground state (E1) and resonant captures by comparing with the DWBA calculations.
3. Apply the same method to determine the spectroscopic factors for existing sets of data : d(^{11}B, p)^{12}B and d(^{8}Li,p)^{9}Li.
4. Recalculate the reaction rates using the measured spectroscopic factors and run the network code in order to test the impact of light, neutron-rich nucleosynthesis during r-process.

Collaborators

J.P. Schiffer, K.E. Rehm, B. Back, J.P. Greene, D. Henderson, C.-L. Jiang, M. Notani, R.C. Pardo (Argonne National Laboratory)

A. Wuosmaa, N.J. Goodman, J.C. Lighthall, S.T. Marley (Western Michigan University)

L.J. Jisonna (Northwestern University)

N. Patel (Colorado School of Mines)

X. Tang (University of Notre Dame)

Argonne NATIONAL LABORATORY