Precision measurements of ^{17}S with radioactive beams

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Precision Measurements of $^{7}Be(p,\gamma)^{8}B$ With Radioactive Beams and the ^{8}B Solar neutrinos Flux

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The Astrophysical Cross Section Factor - $S_{17}(20)$ of the $^{7}Be(p,\gamma)^{8}B$ Reaction

The Coulomb Dissociation of ^{8}B
1. RIKEN Data
2. GSI Data

A Direct Measurement With ^{7}Be Beams
1. LLN Experiment (PH120)
2. Yale Data, $^{7}Li(d,p)^{8}Li$

III. SCREENING (PLASMA)

$^7Be(p,\gamma)^8B$

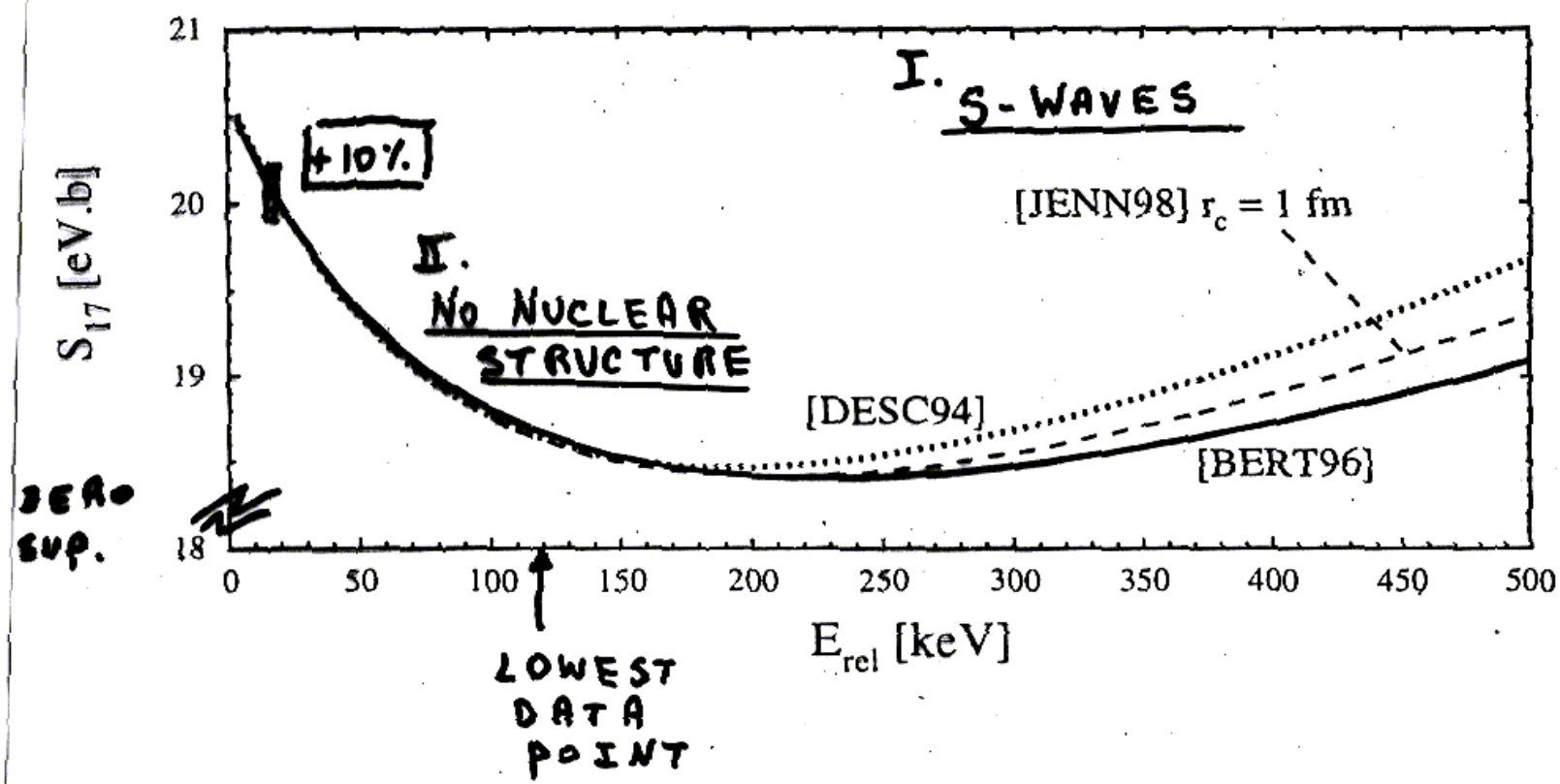


Figure 7-8 : Comparison between $S_{17,El}$-factors from [JENN98] parametrisation normalised at E_{rel} = 20 keV to the same $S_{17}(20)$.

 BARNES et al. - 1987

E0, M1, E1 ≈ 0

E2

⟹ D waves

... AND S waves!!

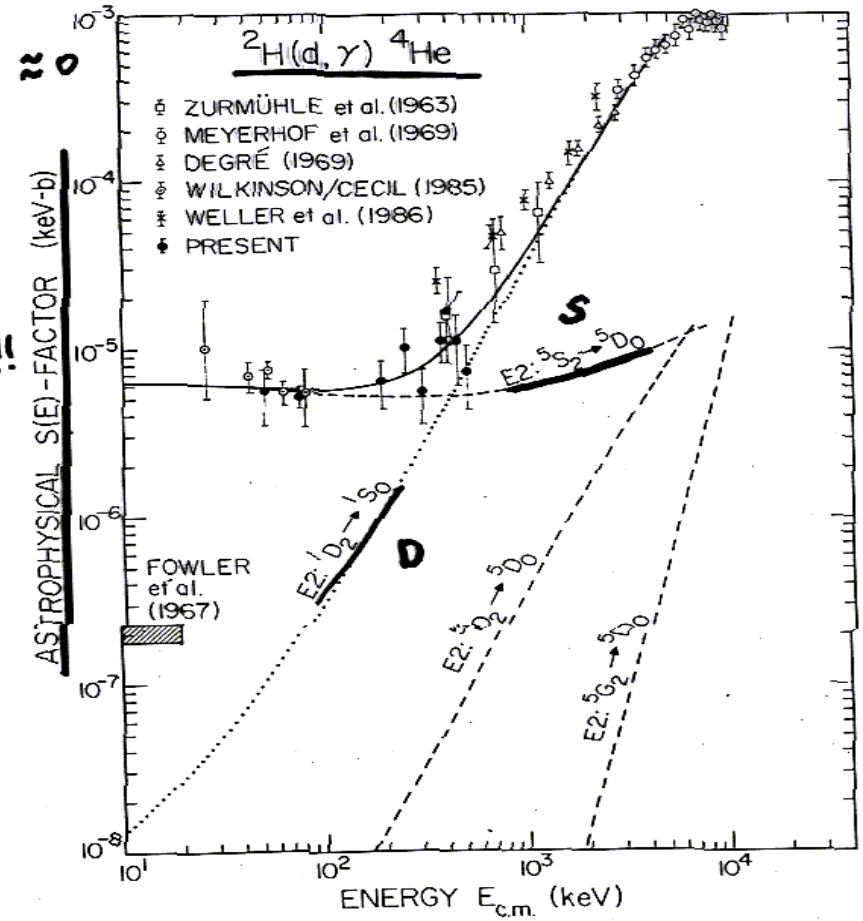
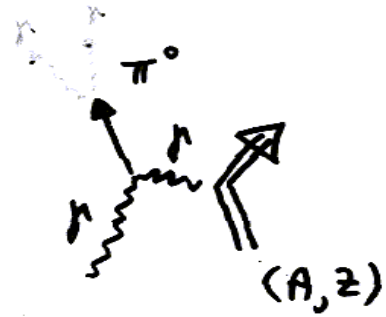
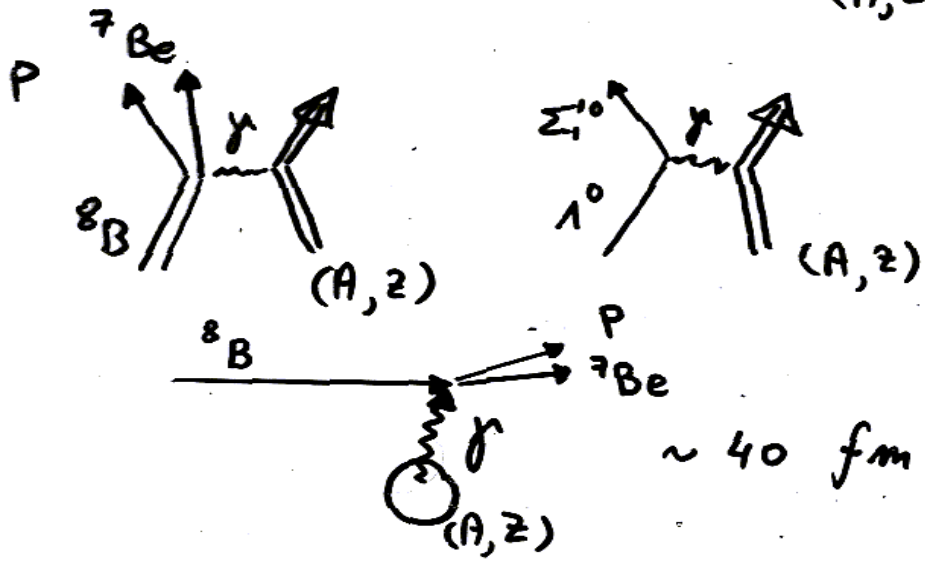


Fig. 1. Excitation function for $^2H(d,\gamma)^4He$ from the present and previous work [3–8]. The data from 1–4 MeV are described well by an E2 direct capture process, $^1D_2 \to {}^1S_0$ (dotted curve). The high cross sections at low energies are attributed to E2 radiation from an initial S-state of relative motion of the deuterons. The calculated $^5D_2 \to {}^5D_0$ and $^5G_2 \to {}^5D_0$ yields are negligible. Also shown is the previously recommended astrophysical $S(0)$ value, 2×10^{-7} keV b [9].

CAPTURE REACTION: $^7Be + p \rightleftarrows {}^8B + \gamma$

PRIMAKOFF (1951):





~ 40 fm !!

ENHANCEMENT: (I) $\pi/k^2 \lesssim 1{,}000$

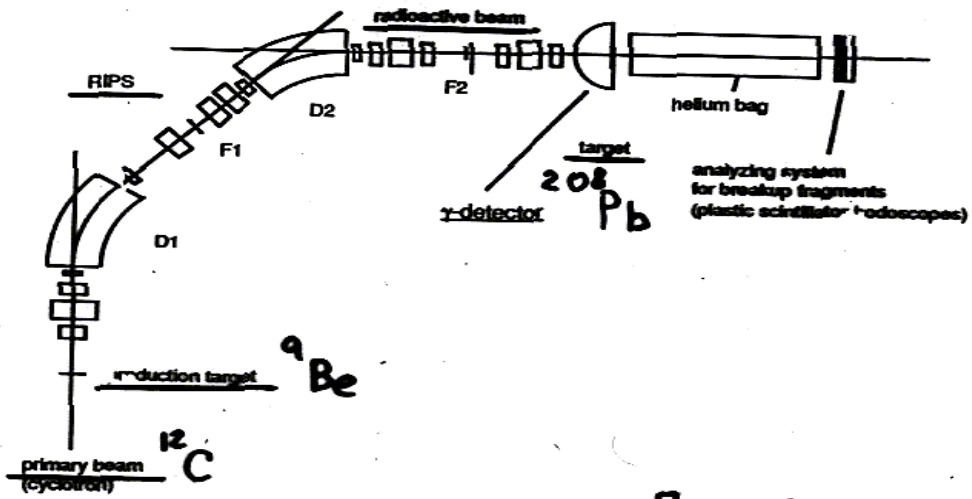
(II) $n_\gamma(E1) \lesssim 1000$

BAUR, BERTULANI, REBEL - 1986

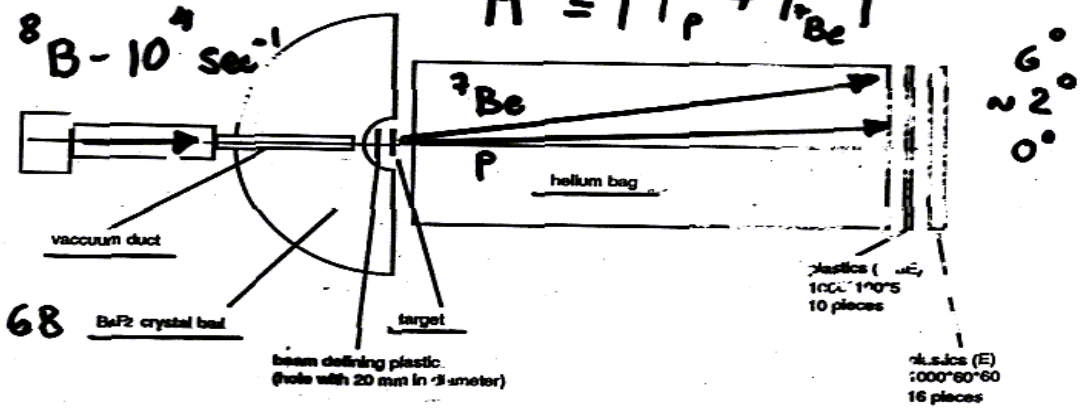
^{8}B Breakup 実験覚え書き

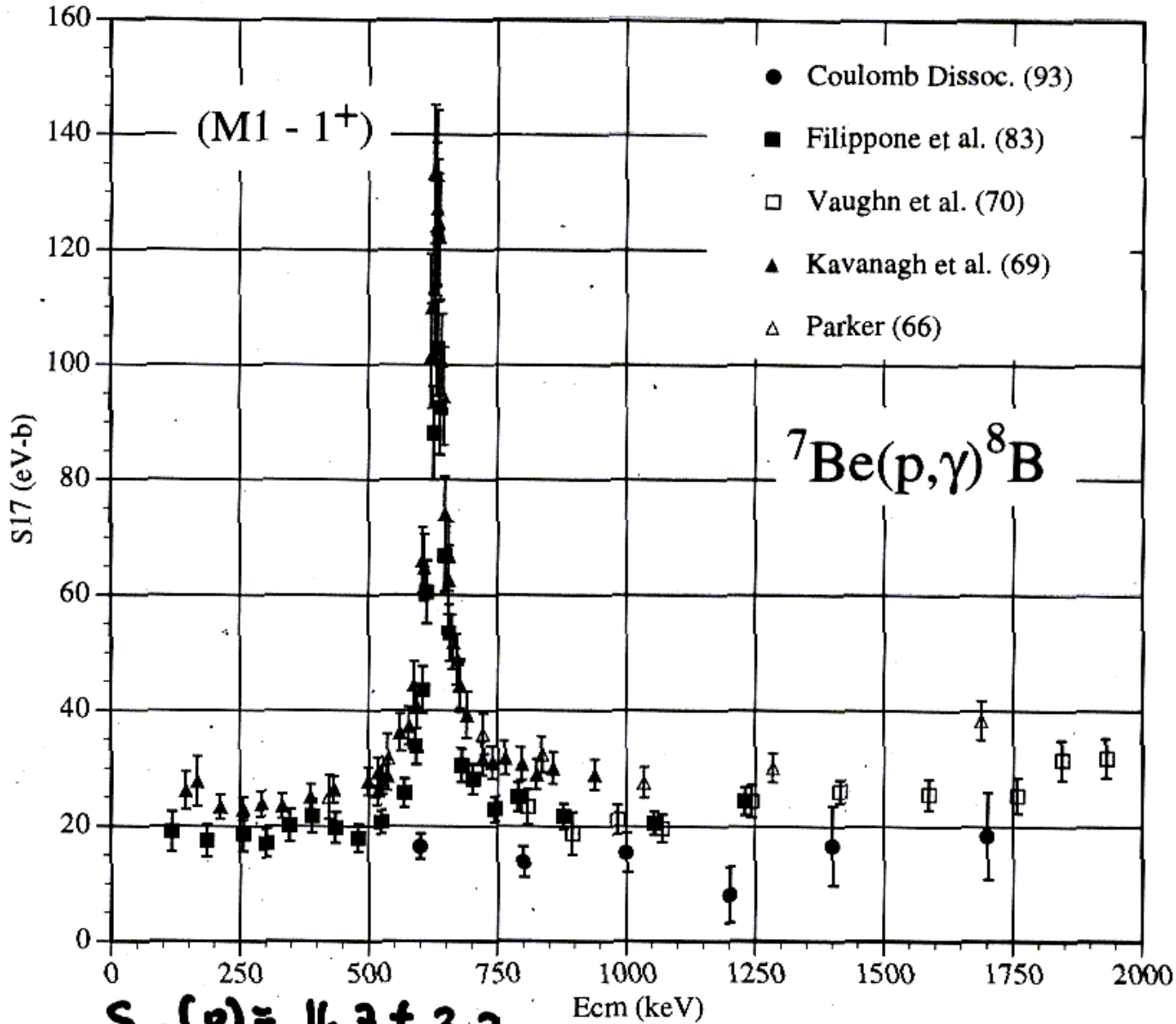
20 Mar. 1992 本林

setup



$$M^2 = |\vec{P}_p + \vec{P}_{Be}|^2$$





$S_{17}(0) = 16.7 \pm 3.2$ eV-b

When a Dog Speaks it Does not Matter What it Says...

Igal Talmi

BERTULANI, GAI - 1997

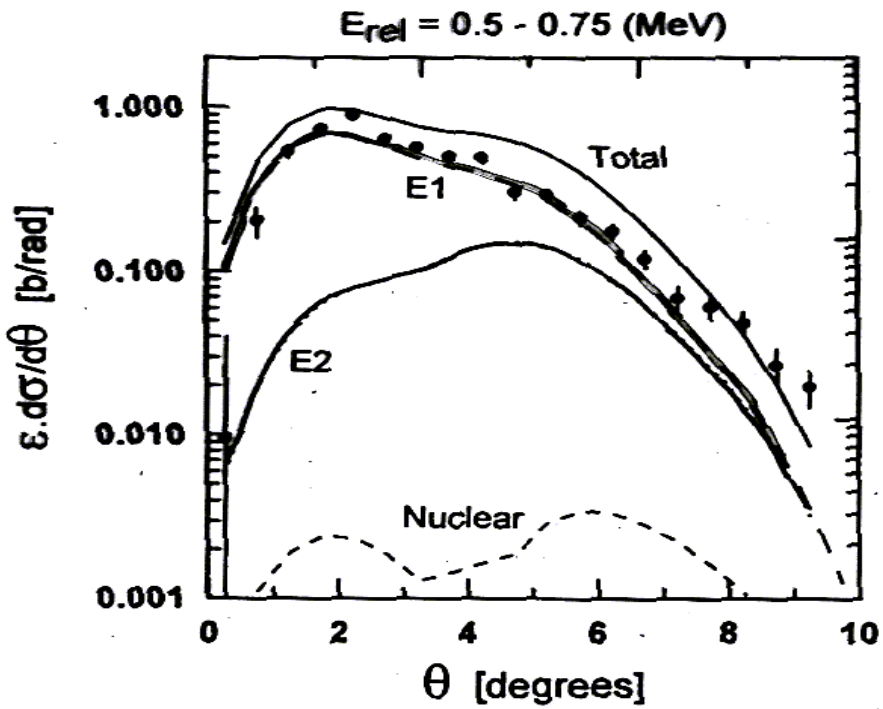
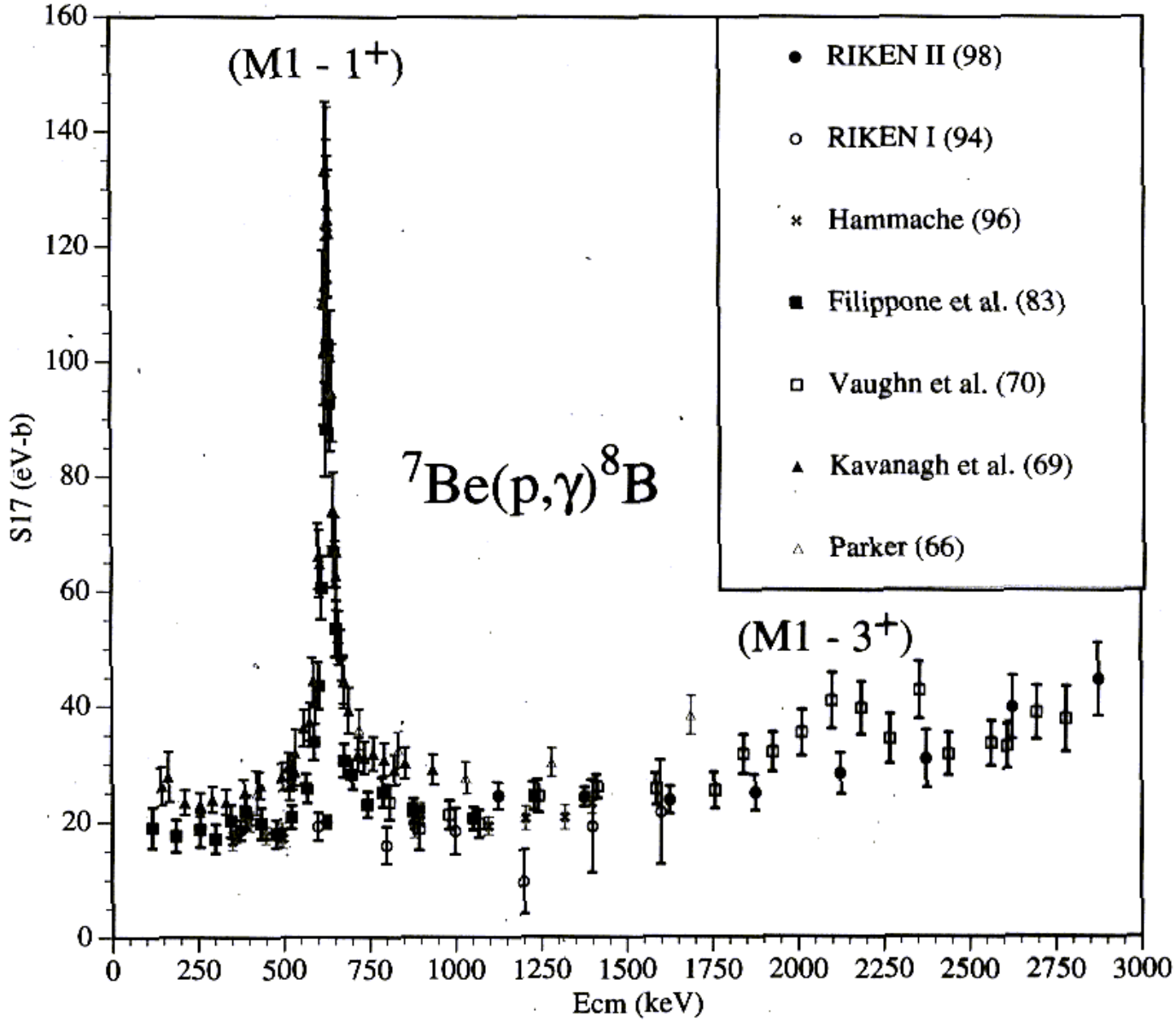


Fig. 13


(M1 - 1+)
(M1 - 3+)
7Be(p,γ)8B
RIKEN II (98)
RIKEN I (94)
Hammache (96)
Filippone et al. (83)
Vaughn et al. (70)
Kavanagh et al. (69)
Parker (66)
S17 (eV-b)
Ecm (keV)
0
20
40
60
80
100
120
140
160
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000

PHYS. REV. LETT. - 1999

A Measurement of the Coulomb Dissociation of ^{8}B at 254 MeV/nucleon and the ^{8}B Solar Neutrino Flux

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[10] *Universidade Federal do Rio de Janeiro, Brazil.*

(Version: June 15, 1999)

We have measured the Coulomb dissociation of ^{8}B into ^{7}Be and proton at 254 MeV/nucleon using a large-acceptance focusing spectrometer. This process allows the extraction of the cross section for fusion of ^{7}Be + p to ^{8}B and thus the astrophysical S_{17} factor for the ^{7}Be(p,γ)^{8}B reaction at $E_{c.m.} = 0.25 - 2.78$ MeV is deduced. Using a theoretical prescription to extrapolate to zero energy, we obtain $S_{17}(0) = 20.6 \pm 1.2$ (exp.) $\pm$ 1.0 (theo.) eV-b. This result agrees with the presently adopted zero-energy S_{17} factor obtained in the direct-reaction measurements and with the results of other Coulomb Dissociation studies performed at 46.5 and 51.2 MeV/nucleon.

PACs: 25.40.Lw, 25.60.-t, 25.70.De, 26.65.+t

The precise knowledge of the solar thermonuclear fusion of ^{8}B (from ^{7}Be plus proton) is crucial for estimating the ^{8}B solar neutrino flux and the predicted neutrino rates in terrestrial neutrino measurements. This rate is dependent on the cross section of the reaction ^{7}Be + p $\rightarrow$ ^{8}B + γ, and is parameterized in term of the astrophysical cross section factor-$S_{17}(0)$, where $S_{17}(E) = \sigma(E)E\exp\{2\pi\eta(E)\}$ and $\eta = Z_1Z_2e^2/\hbar v$. The flux of ^{8}B solar neutrinos is particularly important for the results of the Homestake, Kamiokande, Super Kamiokande and the SNO experiments [1] which measure high-energy solar neutrinos mainly or solely from the ^{8}B decay.

Unfortunately, this cross section has not been known with sufficient accuracy for a long time, despite the fact that several comprehensive direct measurements were reported for the ^{7}Be(p,γ)^{8}B reaction [2 –6]. The main difficulty in such experiments is the determination of the effective target thickness of the radioactive ^{7}Be target. This difficulty is reflected in the fact that the results of these measurements can be grouped into two distinct data sets which agree in their energy dependence but disagree in their absolute normalization by about 30%. In view of this discrepancy, experimental studies with different methods are highly desirable.

As an alternative approach one can measure the inverse process, the Coulomb dissociation (CD) of ^{8}B into ^{7}Be and proton [7]. The CD yields are enhanced because thicker targets can be used and a larger phase space is available for CD. This method uses stable targets and thus is free from the difficulty of determining the effective target thickness. Moreover, the detection efficiency is high because it involves measuring high-energy charged-particles. On the other hand, direct (p,γ) and Coulomb dissociation measurements have different sensitivities to the multipole composition of the photon fields. The E2 amplitude is enhanced in CD due to the large flux of E2 virtual photons, whereas it can be neglected in the (p,γ) reaction. Information on the M1 and E2 admixtures to the dominant E1 component is helpful for a precise extraction of the ^{7}Be(p,γ)^{8}B cross section from the CD data.

Recently, Motobayashi *et al.* have performed a CD experiment at $E(^8\text{B}) = 46.5$ MeV/nucleon, yielding values for S_{17} in the energy range 0.6–1.7 MeV [8]. The extracted (p,γ) cross section is consistent with the results from the lower group of direct-reaction data points [4 –6]. Another measurement at 51.9 MeV/nucleon by the same group with improved accuracy led essentially to the same conclusion [9].

In this article, we report on an experiment of the CD of ^{8}B at a higher energy of 254 MeV/nucleon performed at the SIS facility at GSI, Darmstadt, Germany. The present incident energy has several advantages compared to the one used in Refs. [8 ,9]: (i) due to the strong forward focusing of the reaction

$$M^2 = |\vec{P}_p + \vec{P}_{^7Be}|^2$$

GSI - KAOS

254 MeV/u

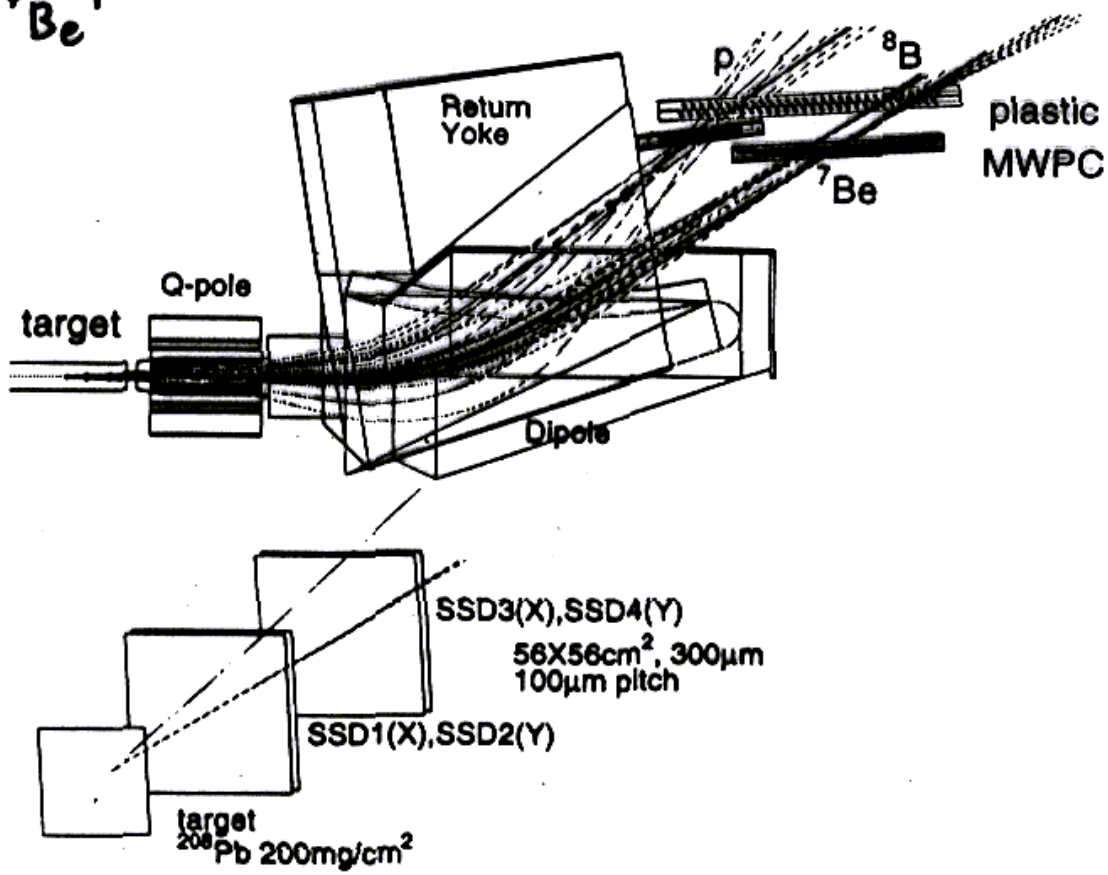
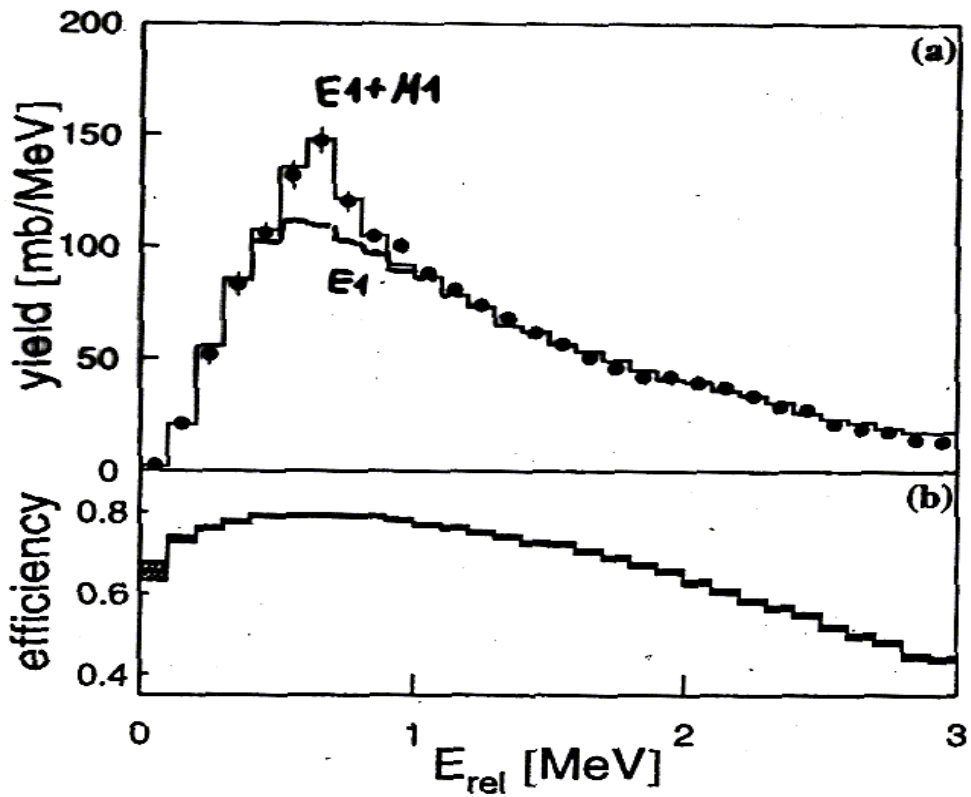
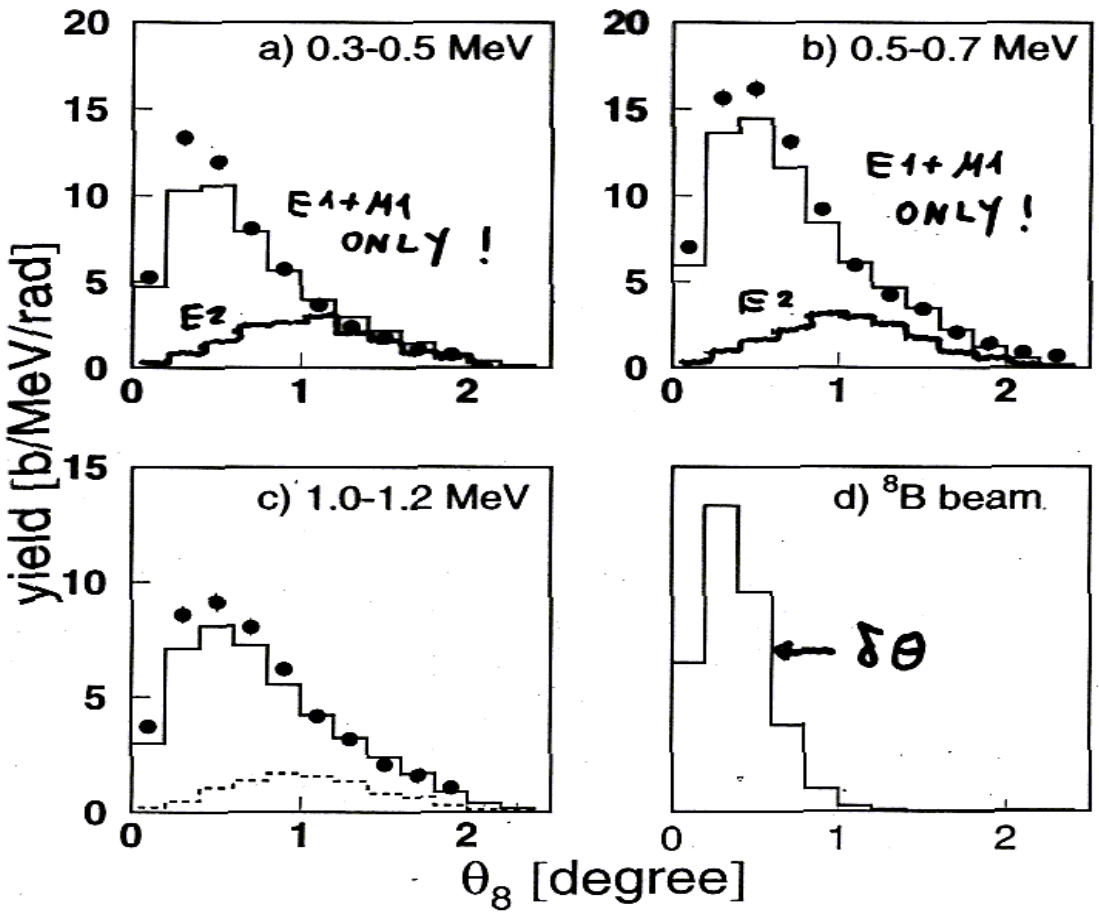
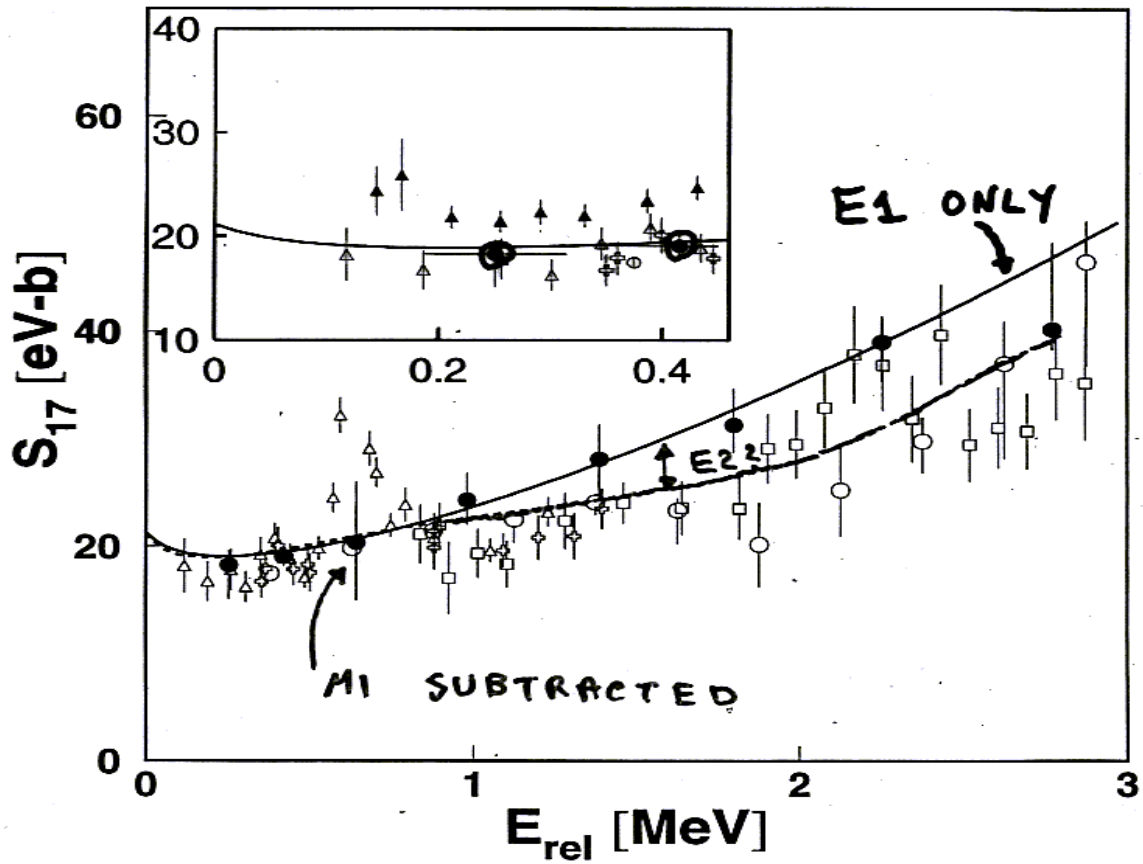


FIGURE 1. Schematic view of the experimental setup.


200
150
100
50
0
yield [mb/MeV]
(a)
E1+M1
E1
0.8
0.6
0.4
efficiency
(b)
0
1
2
3
E_rel [MeV]

$$\frac{S_{E2}}{S_{E1}} < 3 \times 10^{-5} \quad 0.5 - 0.7 \text{ MeV}$$



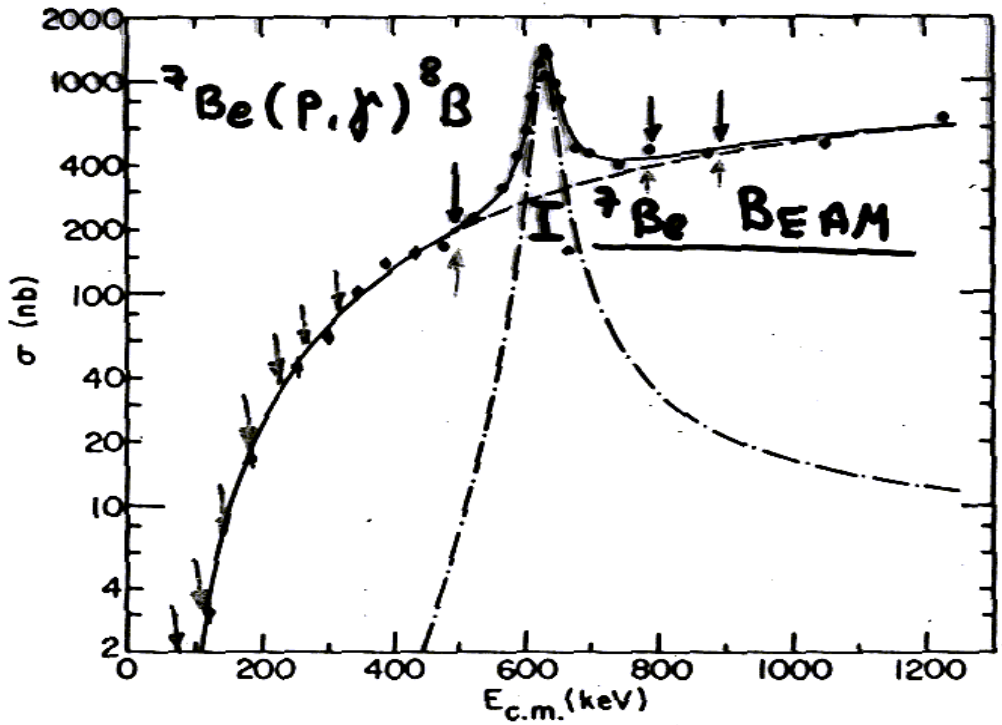

E1 ONLY
E2
M1 SUBTRACTED
S_{17} [eV-b]
E_{rel} [MeV]
0
20
40
60
0
1
2
3
10
20
30
40
0
0.2
0.4

	S_{E1} (eV-b)	S_{E2}/S_{E1} (0.6 MeV)
RIKEN I:	16.9 ± 3.2	$< 7 \times 10^{-4}$
RIKEN II:	18.9 ± 1.8	$< 4 \times 10^{-5}$
GSI I:	$20.8 \pm 1.2 \pm 1.0$	$< 3 \times 10^{-5}$
MSU:		$6.7^{+2.8}_{-1.9} \times 10^{-4}$

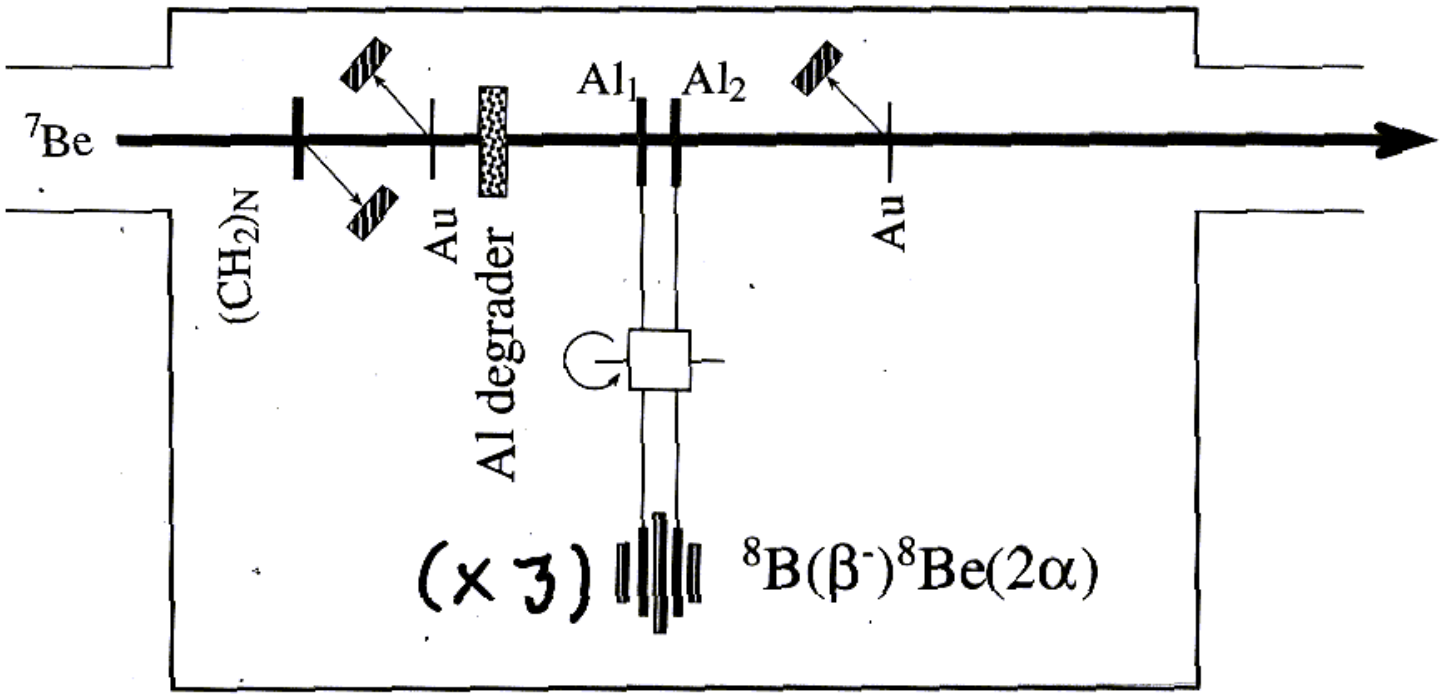
$\downarrow$

WEIGHTED: $\boxed{19.5 \pm 1.8 \text{ eV-b}}$

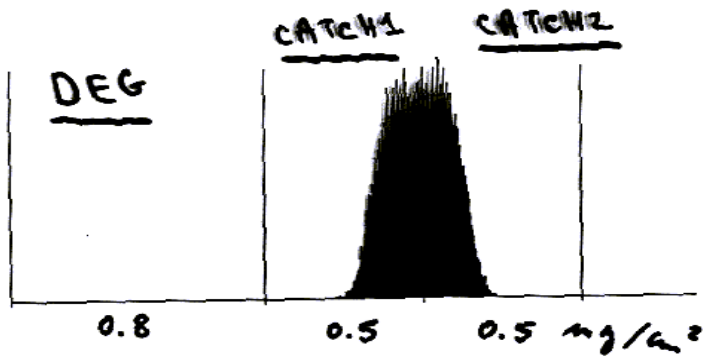
APPROVED : LLN - UCONN PH-120

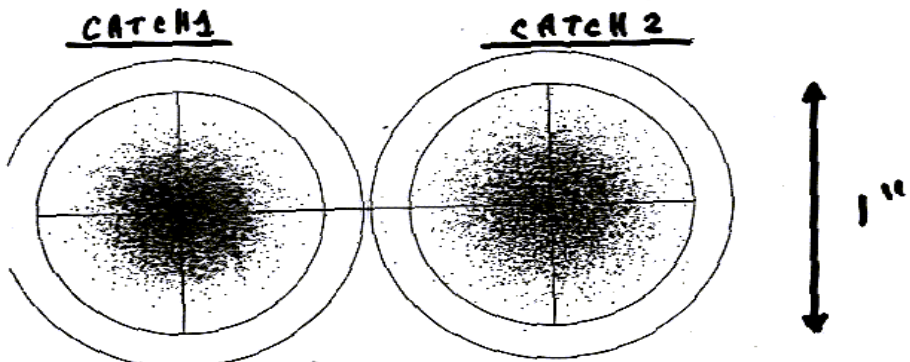


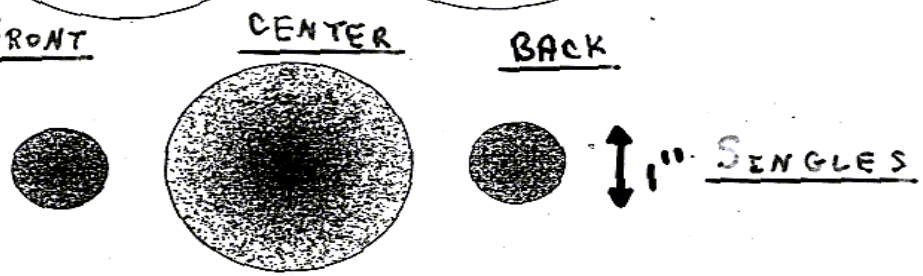
II. ^{7}Be IMPLANTED TARGET

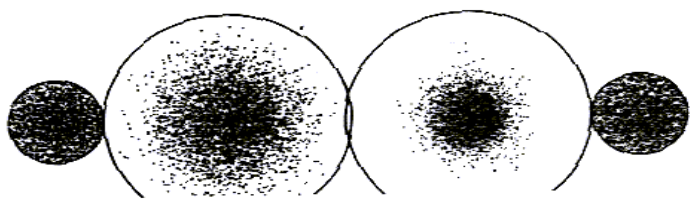

^{7}Be
$(CH_2)_N$
Au
Al degrader
Al_1
Al_2
Au
(×3)
$^8B(\beta^-)^8Be(2\alpha)$

$^{7}Be(p,p)^{8}B$ $E_{^{7}Be} = 7$ MeV









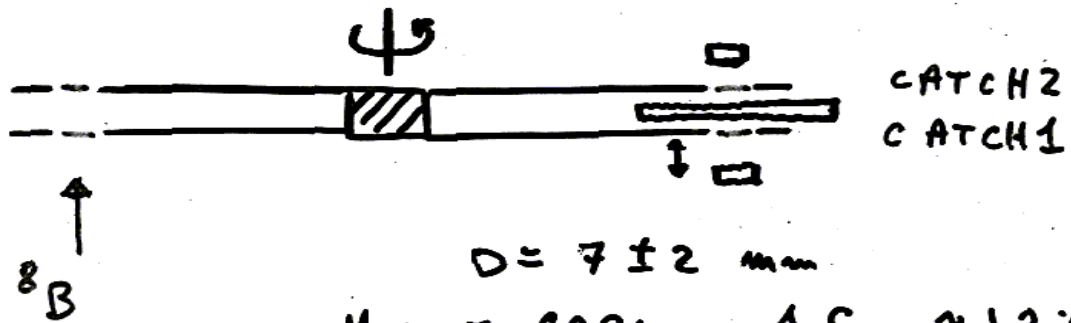
CLOSED GEOMERY

$\Delta\varepsilon_{SYSTEMATICS} = ?$

$D = 7 \pm 0.5$ mm

$\Delta\varepsilon_{SYST} \approx 15\%$

$\Delta\varepsilon_{SYST} \approx 0\%$

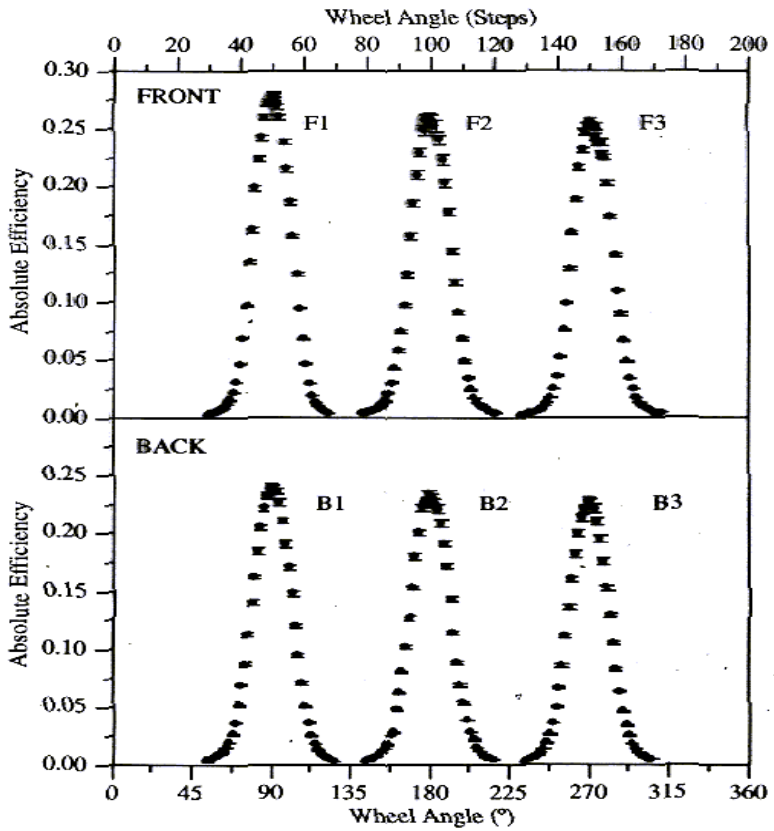


$D = 7 \pm 2$ mm

MONTE CARLO $\Delta\varepsilon_{SYS} \approx 1.2\%$

I. PARALLEL

II. EQUAL DIST. ^8B


Wheel Angle (Steps)
0
20
40
60
80
100
120
140
160
180
200
FRONT
F1
F2
F3
Absolute Efficiency
0.30
0.25
0.20
0.15
0.10
0.05
0.00
BACK
B1
B2
B3
Absolute Efficiency
0.25
0.20
0.15
0.10
0.05
0.00
0
45
90
135
180
225
270
315
360
Wheel Angle (°)

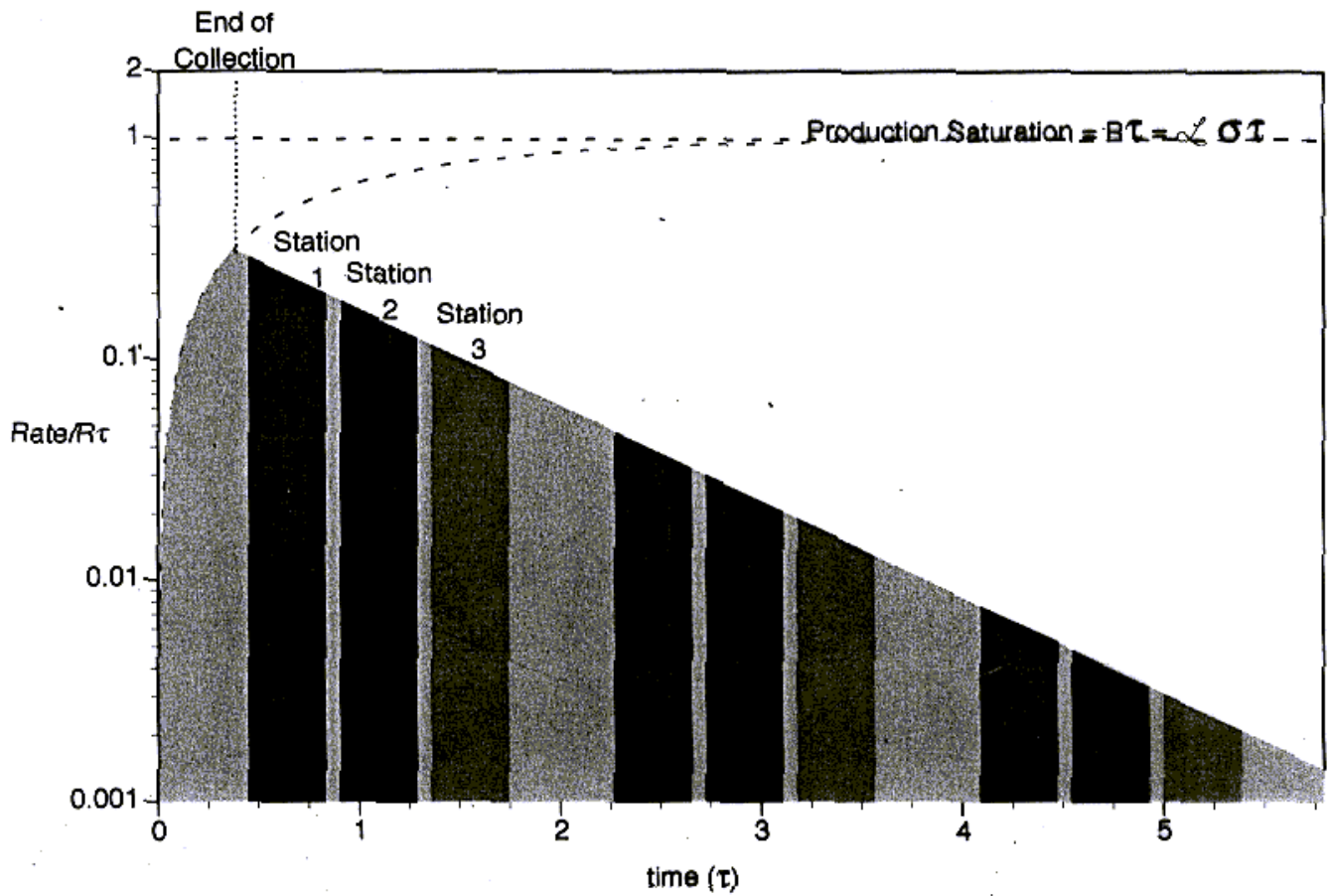
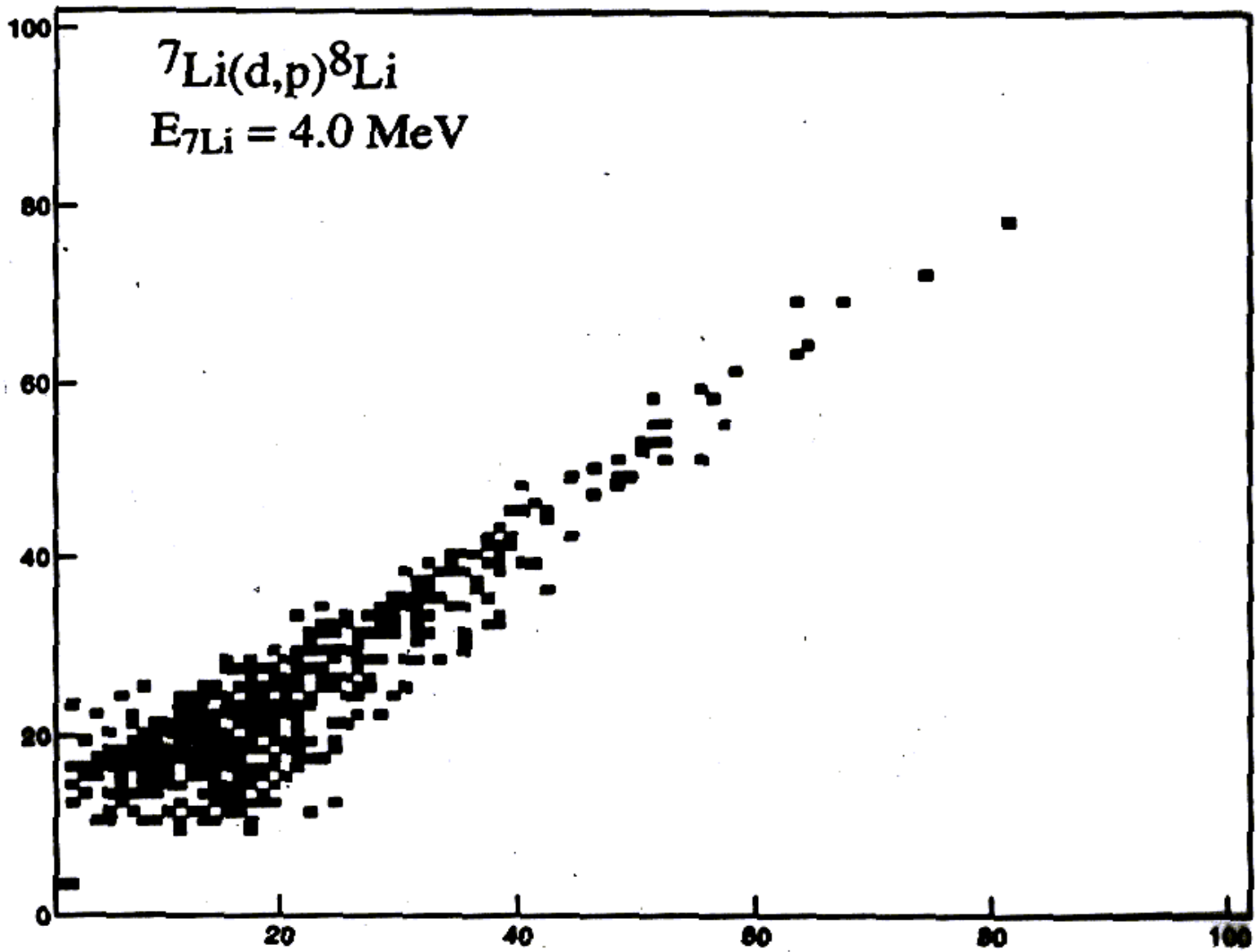
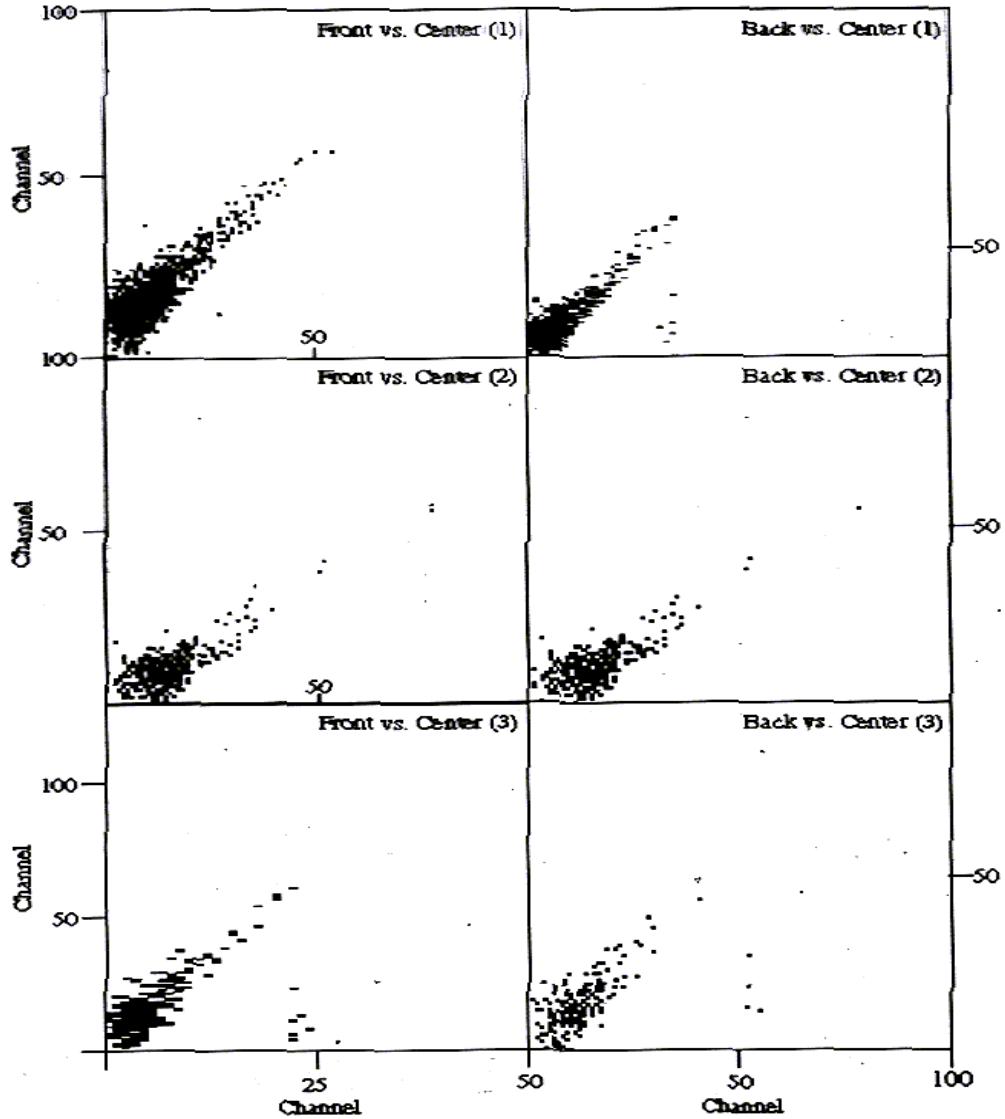


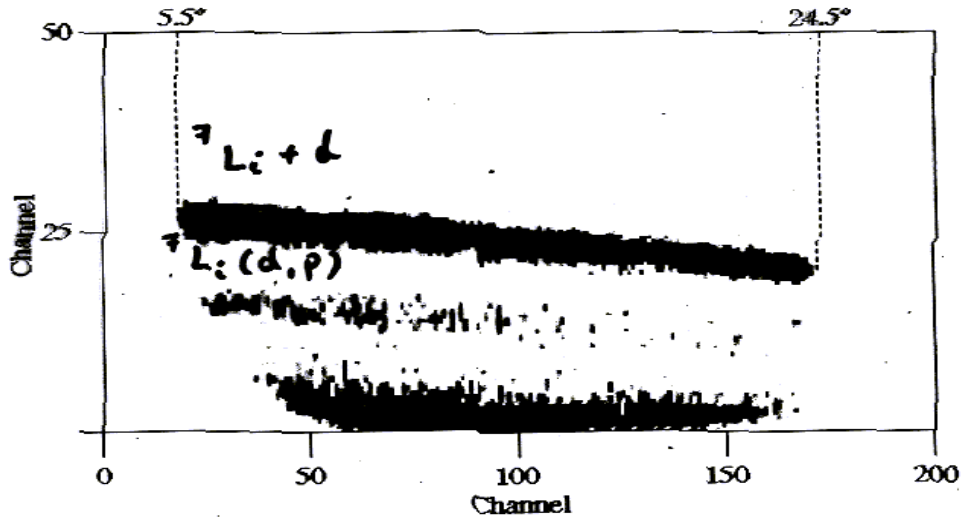
Figure 4.1: The collection and decay curve of ^{8}Li based on the timeline used in the present experiment. *The shaded areas represent the activity detected at each counting station due to one collection period.*


^{7}Li(d,p)^{8}Li
$E_{^7Li}$ = 4.0 MeV
100
80
60
40
20
0
20
40
60
80
100

4.5 ^{7}Li
YALE 1/00



Data taken at Yale, January 2000. Beam at 4.0 Mev, 5 pA



Right position senstive detector, Run#2014 using CD_2 Target

4.5 MeV

10^8 /sec

YALE 3/00

FILIPPONE - 1982

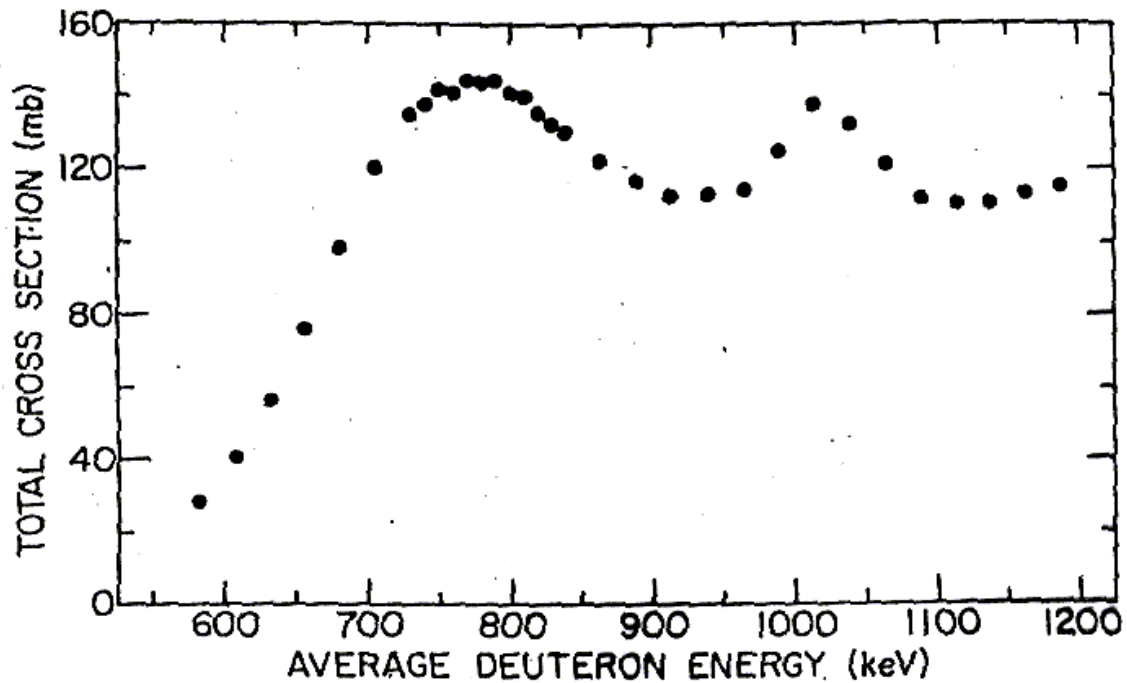


FIG. 5. $^7Li(d,p)^8Li$ excitation function for a 69 $\mu g/cm^2$ LiF target. The relative uncertainties are approximately the size of the points.

Conclusions:

The Coulomb Dissociation of ^{8}B --A viable Method (but should be used with Sechel !!)

$S_{E2}/S_{E1} < 10^{-4}$ [CD(E2) < 3-5%]

The Astrophysical Cross Section Factor:
S17(20) ~~19 ± 2~~ eV-b (Filippone et al.)
19.5 ± 1.8
Experiments with ^{7}Be Beams ±5%