The Coulomb Dissociation of ^{8}B: The Triumph of Good Science

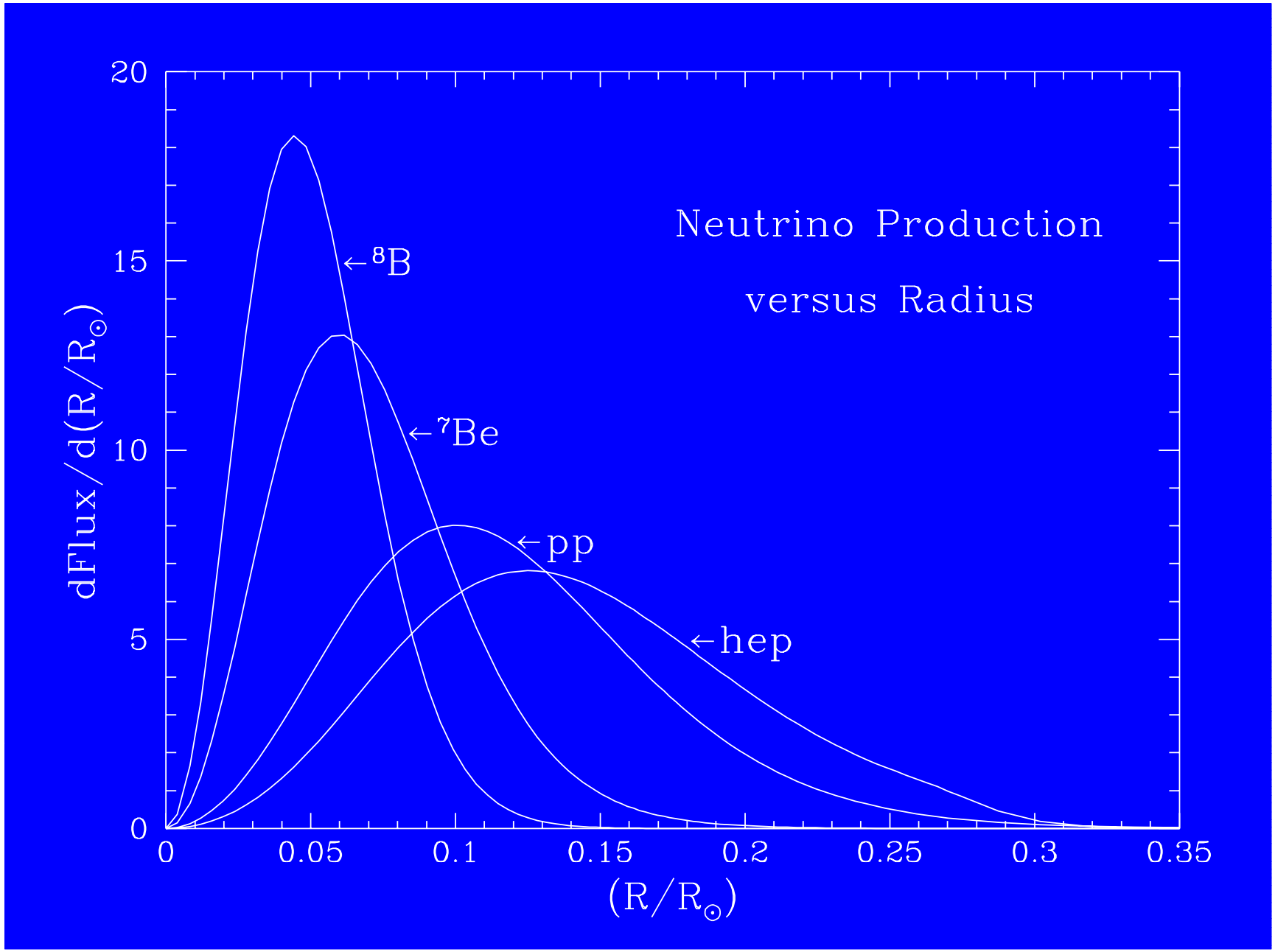
Moshe Gai
Laboratory for Nuclear Science at Avery Point

1. **The Method of CD.**
2. **The Caltech 94 Saga.**
3. **The Seattle 05 Saga.**
4. **What Have We Learned?**
   (Standard Solar Model)

San Diego, March 18, 2006

The Laboratory for Nuclear Science
At Avery Point


Laboratory for
Astrophysics
1084 Shennecossett


Neutrino Production
versus Radius
←8B
←7Be
←pp
←hep
dFlux/d(R/R⊙)
(R/R⊙)
0
5
10
15
20
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

SNO Salt Phase Result:

$$\Phi_\nu \;=\; 4.94 \pm 0.21\ (\text{stat})\ {}^{+0.38}_{-0.34}(syst)\ \times 10^6\ cm^{-2}sec^{-1} \qquad [1]$$

$$\frac{\Phi_{SSM}}{\Phi_\nu} = 1.17 \qquad [2]$$

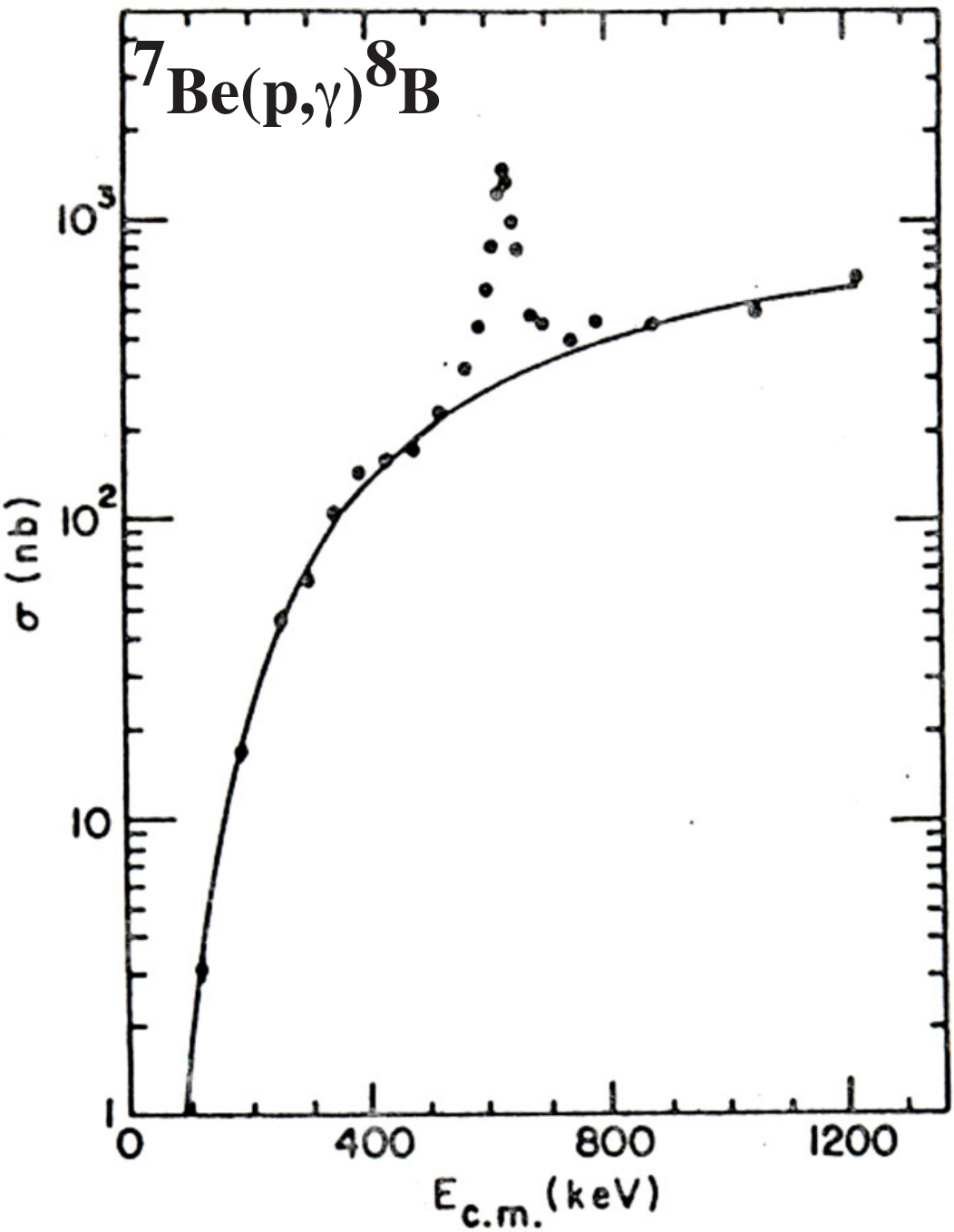
[1] B. Aharmin *et al.*; nucl-ex/0502021.

[2] J.N. Bahcall and M.H. Pinsonneault; Phys. Rev. Lett. **92**(2004)121301.

$$\sigma_{17} = S_{17}/E \times e^{-2\pi\eta}$$

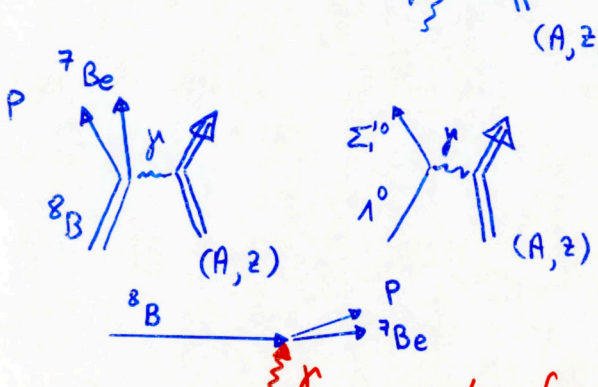
$(\eta = Z_1 Z_2 \alpha/\beta)$ $\quad E_{cm} = 18$ keV

Fillipone(1983)



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

PRIMAKOFF (1951):



ENHANCEMENT: (I) $\pi/k^2 \approx 1,000$

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

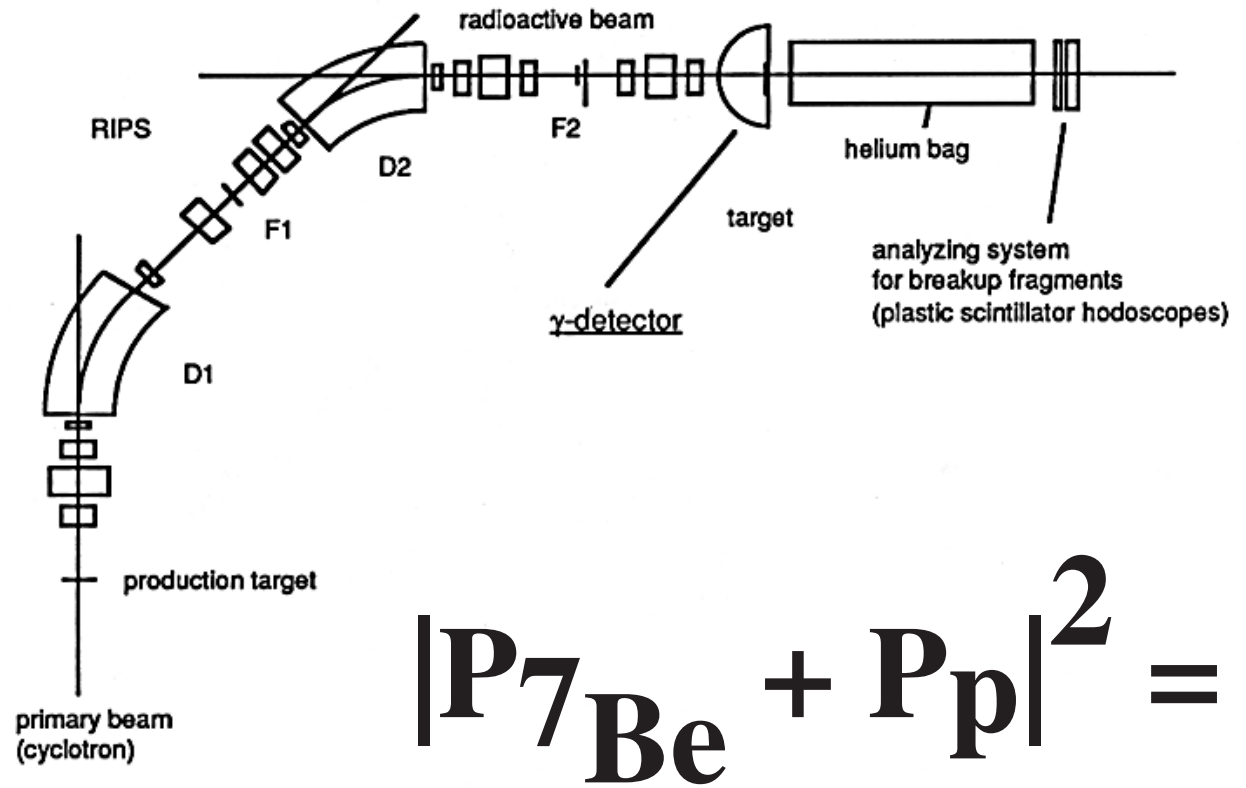
BAUR, BERTULANI, REBEL - 1986

^{8}B Breakup 実験覚え書き

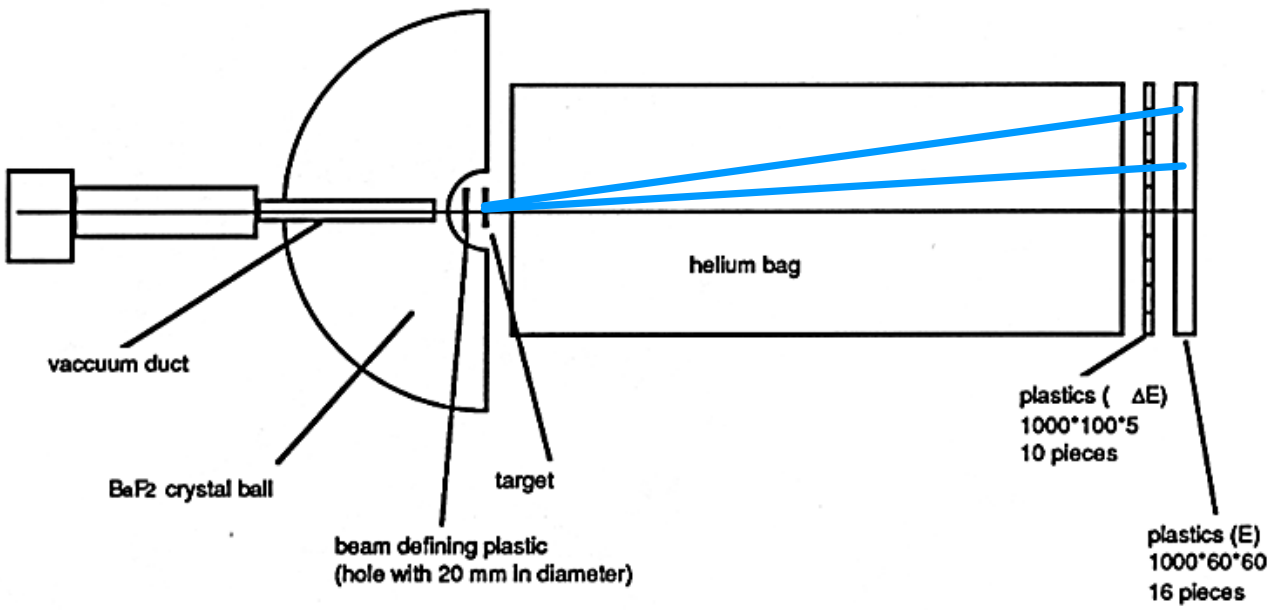
RIKEN - RIPS

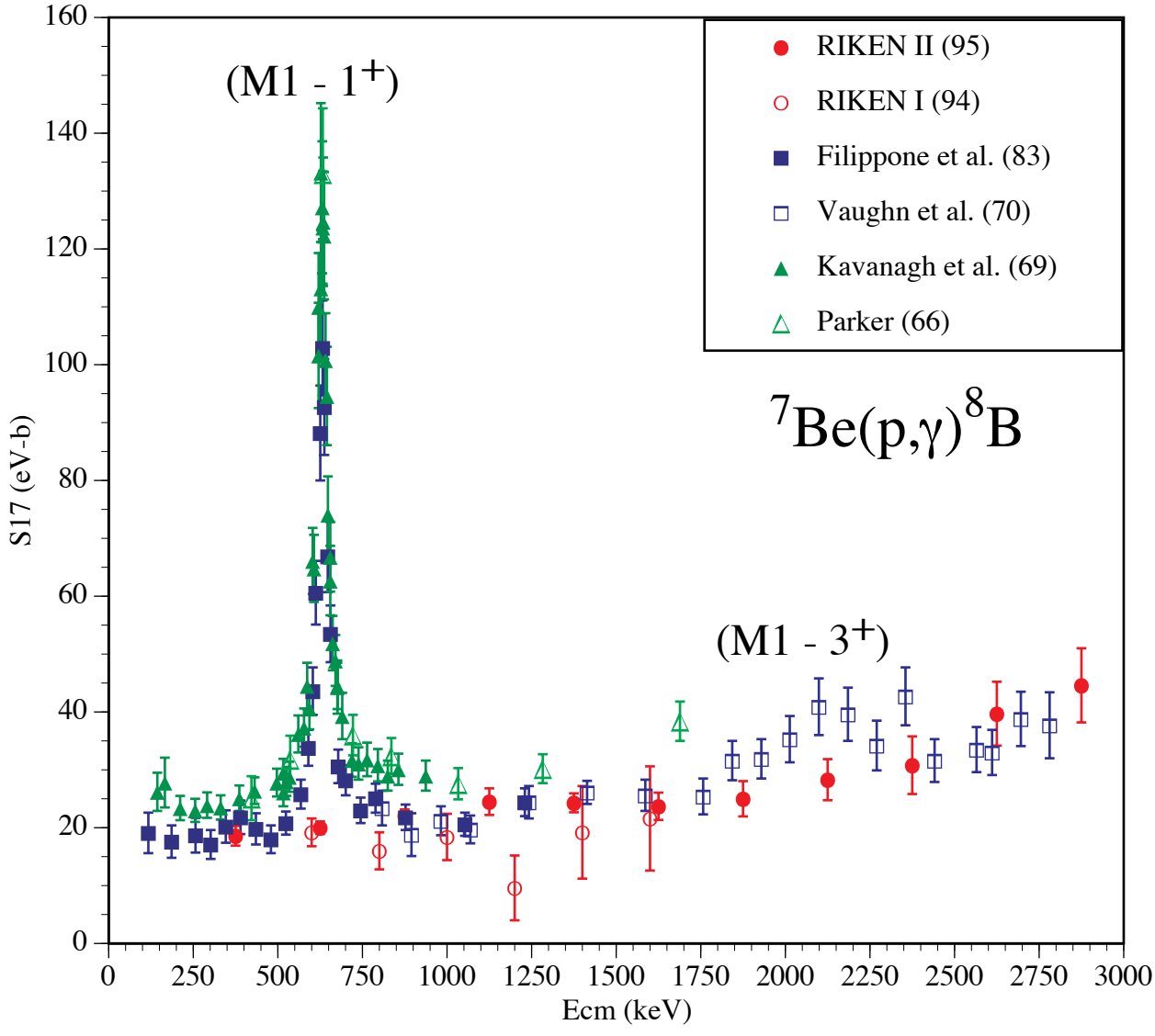
20 Mar. 1992 本林

setup



$$|P_{^7Be} + Pp|^2 = M^2$$




RIKEN II (95)
RIKEN I (94)
Filippone et al. (83)
Vaughn et al. (70)
Kavanagh et al. (69)
Parker (66)
(M1 - 1+)
(M1 - 3+)
7Be(p,γ)8B
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

Coulomb Dissociation of ^{8}B and the ^{7}Be$(p,\gamma)^8$B Reaction at Low Energies

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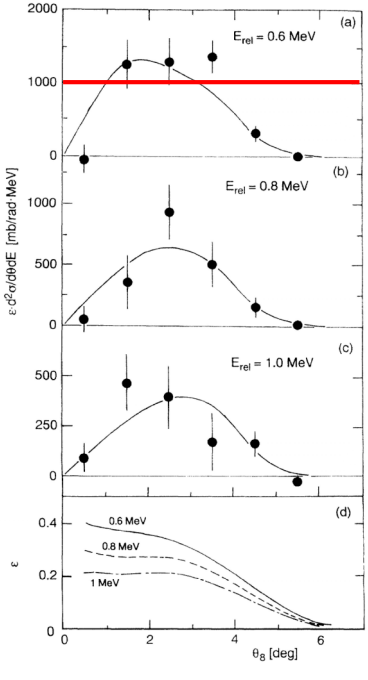
(Received 4 January 1994; revised manuscript received 13 July 1994)



RAPID COMMUNICATIONS

PHYSICAL REVIEW C VOLUME 49, NUMBER 4 APRIL 1994

$E2$ contribution to the $^8B \rightarrow p + {}^7Be$ Coulomb dissociation cross section

K. Langanke and T. D. Shoppa

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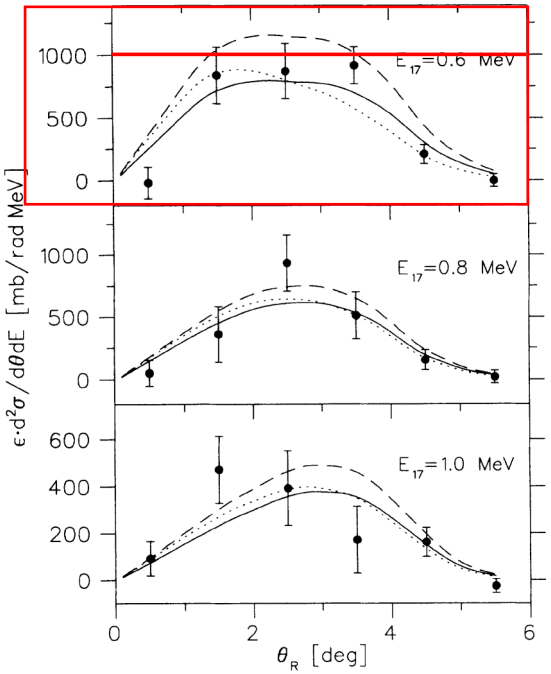
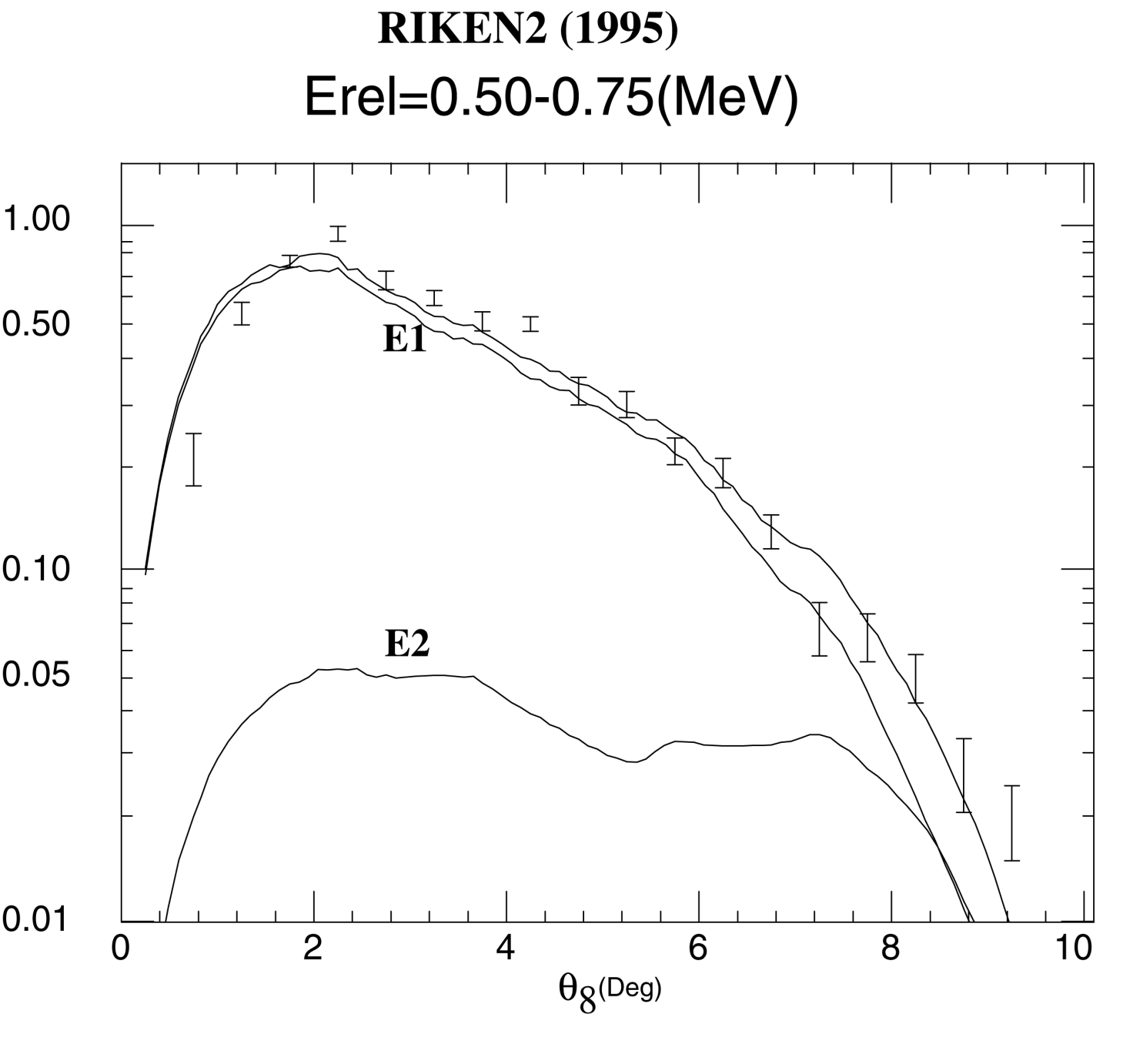
(Received 1 February 1994)

We have calculated the $E1$ and $E2$ contributions to the low-energy $^8B + {}^{208}Pb \rightarrow p + {}^7Be + {}^{208}Pb$ Coulomb dissociation cross sections using the kinematics of a recent experiment at RIKEN. Using a potential model description of the $^7Be(p,\gamma)^8B$ reaction, we find that the $E2$ contributions cannot *a priori* be ignored in the analysis of the data. Its inclusion reduces the extracted $^7Be(p,\gamma)^8B$ S-factor at solar energies by about 25%.

PACS number(s): 25.70.De, 25.70.Jj, 25.40.Lw



The S factor extracted here from the $^8B + {}^{208}Pb \rightarrow p + {}^7Be + {}^{208}Pb$ data is noticeably smaller and incompatible (within 2 standard deviations) with the one recently derived from the various direct measurements of the $^7Be(p,\gamma)^8B$ reaction [2]. As it is important to resolve this apparent difference between the two methods, a precise direct capture experiment at one energy to pin down the overall normalization of the direct capture results is highly desirable. A confirmation of the Coulomb dissociation data and a verification of its assumed relation to the capture cross section is also desirable.


RIKEN2 (1995)
Erel=0.50-0.75(MeV)
1.00
0.50
0.10
0.05
0.01
E1
E2
0
2
4
6
8
10
θ8(Deg)

COMMENTS

Comments are short papers which criticize or correct papers of other authors previously published in the **Physical Review.** *Each Comment should state clearly to which paper it refers and must be accompanied by a brief abstract. The same publication schedule as for regular articles is followed, and page proofs are sent to authors.*

Comment on "$E2$ contribution to the $^8B \rightarrow p + ^7Be$ Coulomb dissociation cross section"

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and Gesselschaft für Schwerionenforschung Darmstadt m.b.H., KPII, Planckstrasse 1, D-64291 Darmstadt, Germany
(Received 25 May 1994)

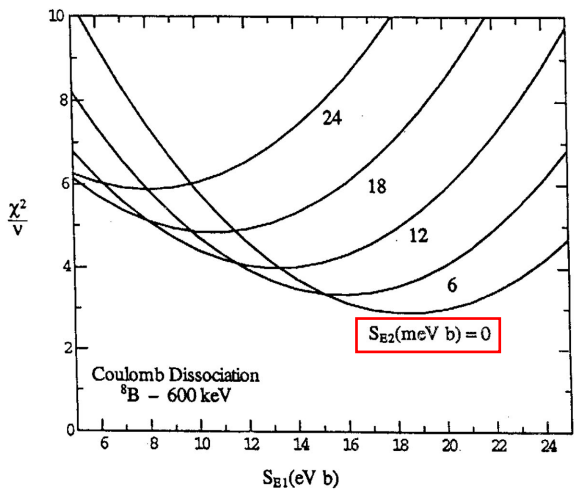


FIG. 1. The reduced χ^2 obtained from fitting the 600 keV angular distribution of the RIKEN data [3] with $\sigma_{CD}(E1) + \sigma_{CD}(E2)$, as discussed in the text.

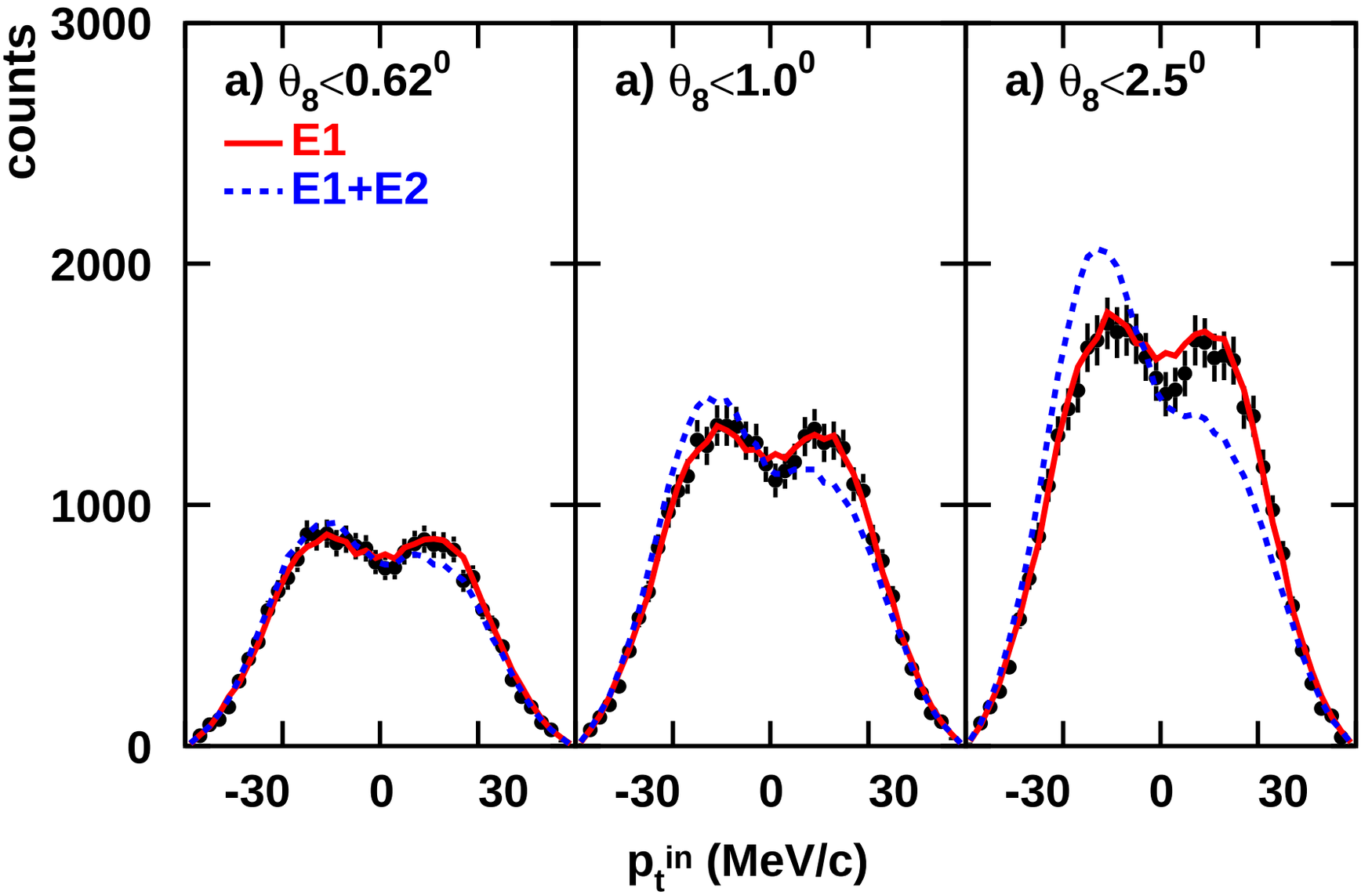
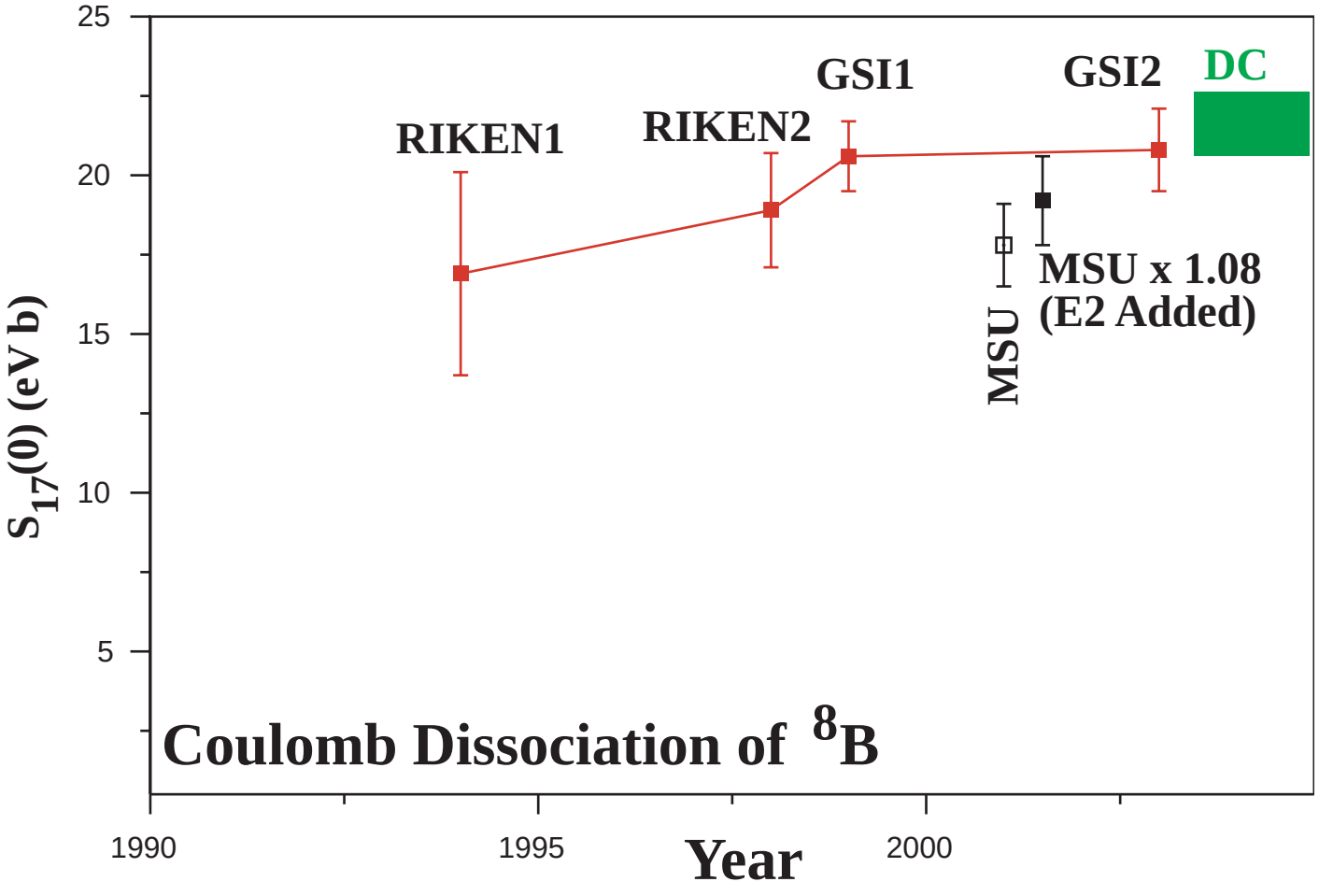
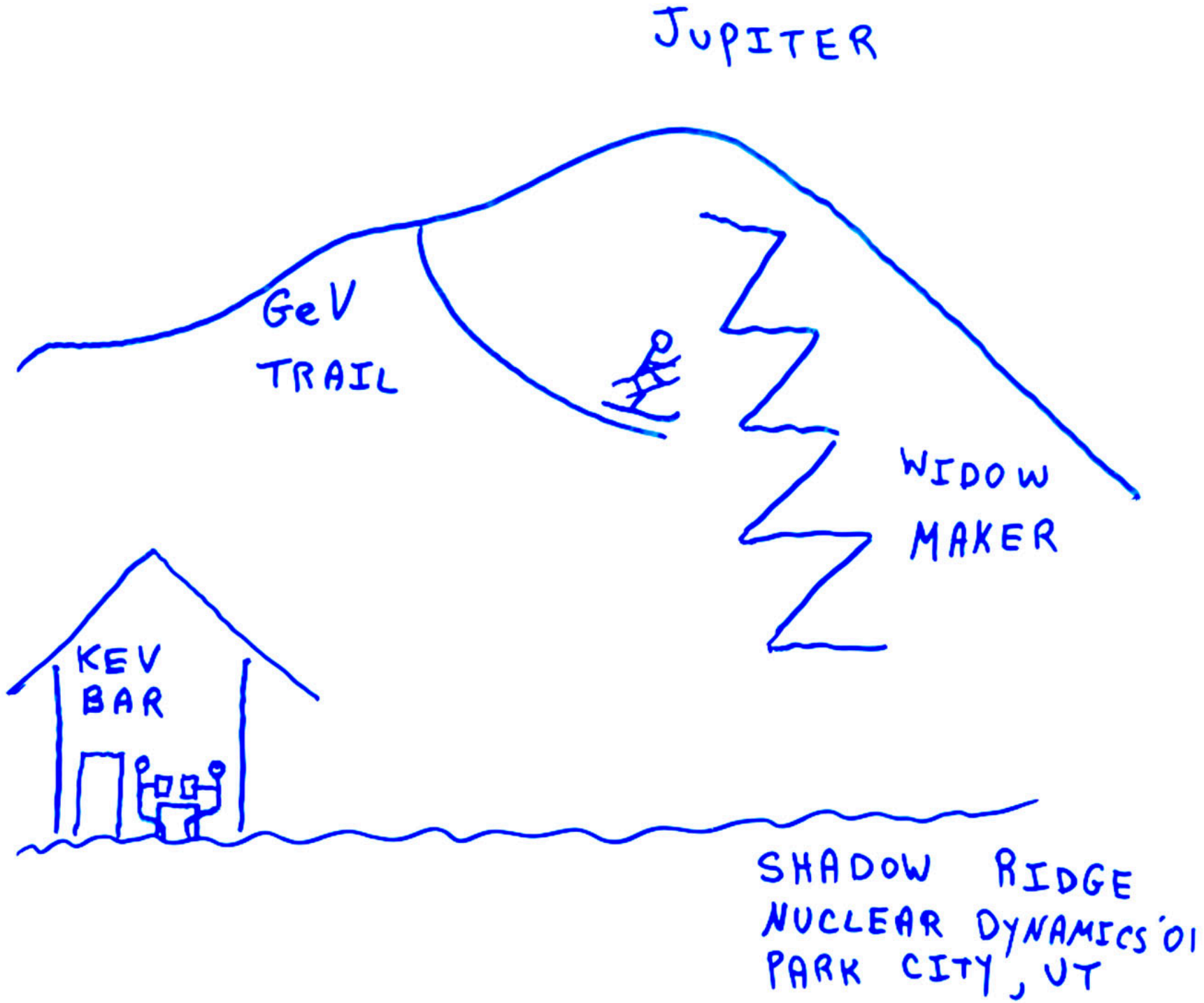


FIG. 12: (Color online) In-plane transverse momenta, p_t^{in}, of the breakup protons for three different cuts in θ_8. The theoretical curves (full red lines: E1 multipolarity, dashed blue lines: E1+E2 multipolarity) have been calculated in first-order perturbation theory. They were normalized individually to the data sets in each frame.


25
20
15
10
5
$S_{17}(0)$ (eV b)
RIKEN1
RIKEN2
GSI1
GSI2
DC
MSU
MSU x 1.08
(E2 Added)
Coulomb Dissociation of ^{8}B
1990
1995
2000
Year

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

Igal Talmi


JUPITER
GeV
TRAIL
WIDOW
MAKER
KEV
BAR
SHADOW RIDGE
NUCLEAR DYNAMICS '01
PARK CITY, UT

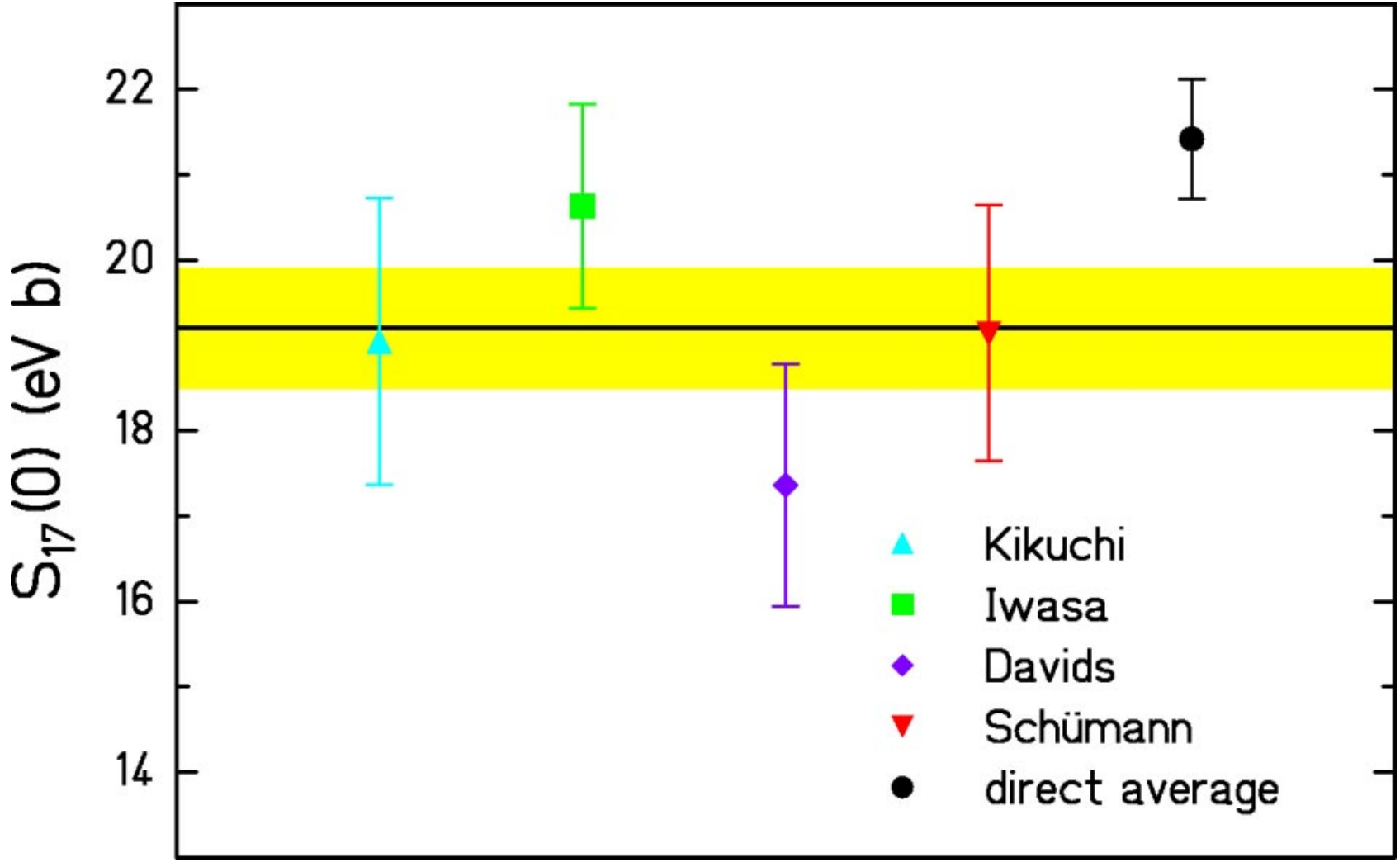


FIG. 20. (Color online) CD $S_{17}(0)$ values from DB fits to $S_{17}(\overline{E}_{\text{c.m.}})$ values below 425 keV, compared to the direct mean. The total uncertainties are shown. The horizontal solid and dashed lines indicate the CD mean value $S_{17}(0)=19.2\pm0.7$ eV b.

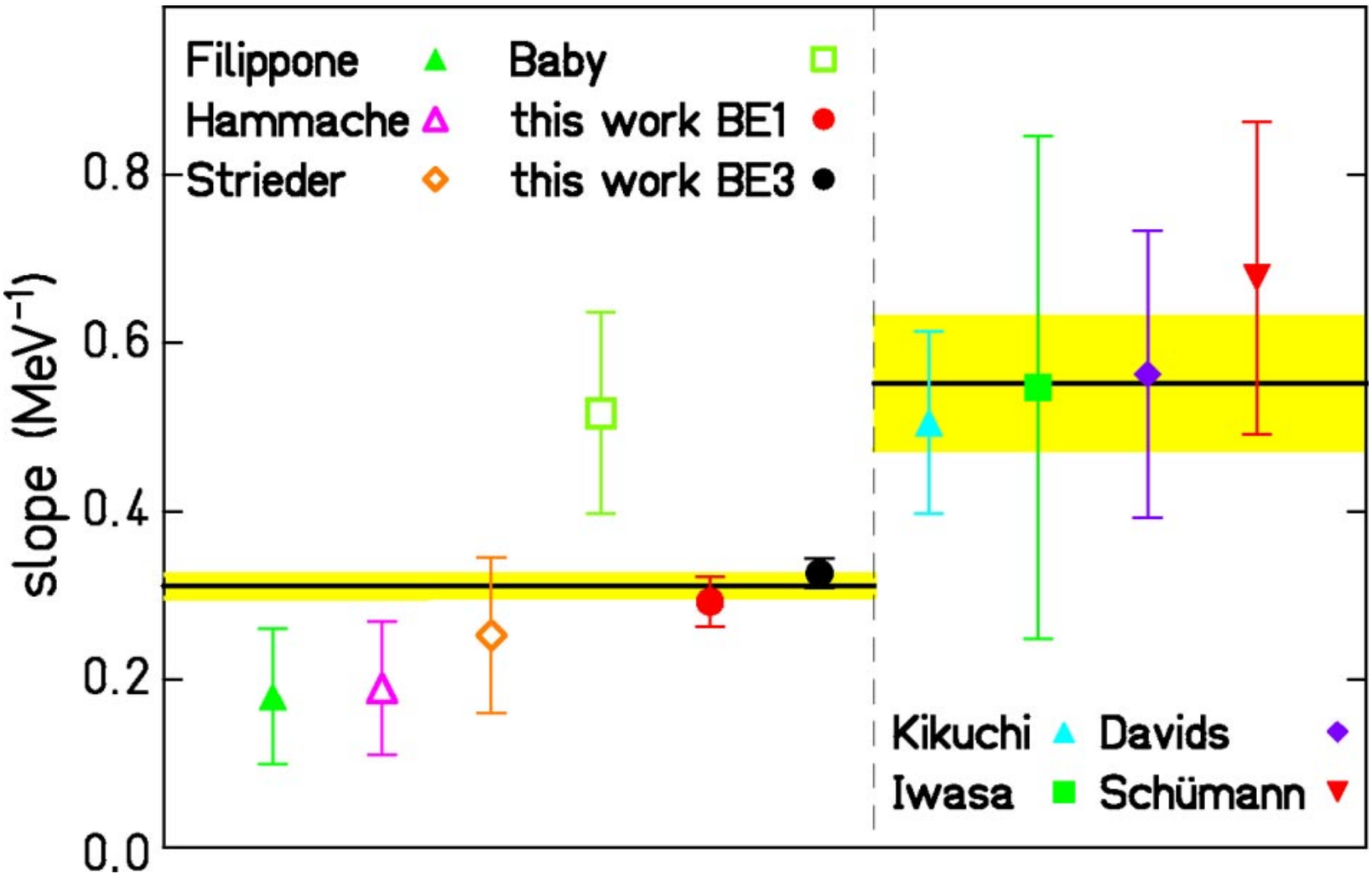


FIG. 19. (Color online) $S_{17}(\overline{E}_{\mathrm{c.m.}})$ slopes determined from straight-line fits to direct $S_{17}(\overline{E}_{\mathrm{c.m.}})$ data (corrected for the 1^+ resonance tail) (left panel) and to $S_{17}(\overline{E}_{\mathrm{c.m.}})$ values inferred from CD experiments (right panel). The horizontal lines and shaded regions correspond to the mean values and uncertainties determined from the direct data and from the CD data, respectively.

Reconciling Coulomb Dissociation and Radiative Capture Measurements

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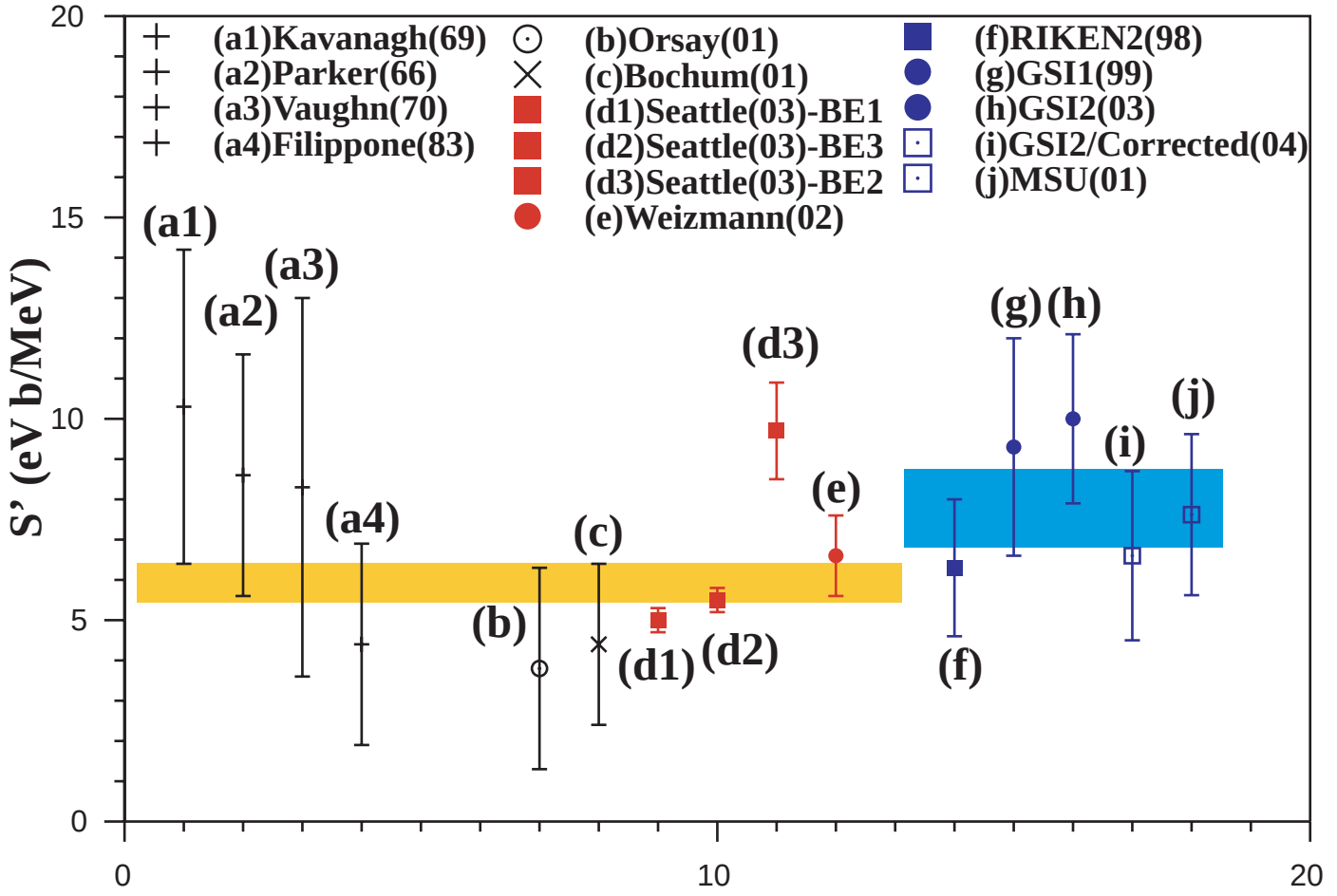
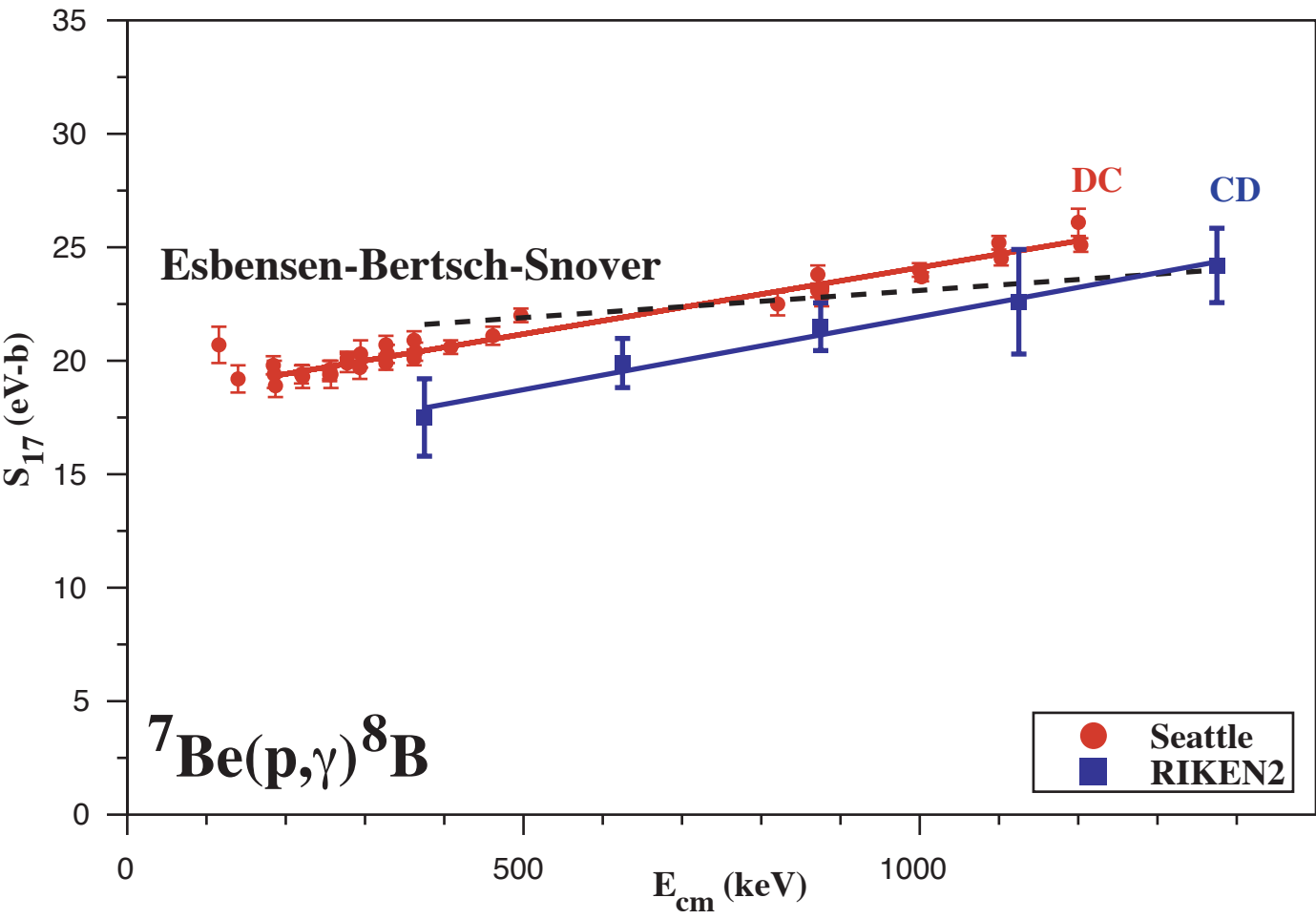
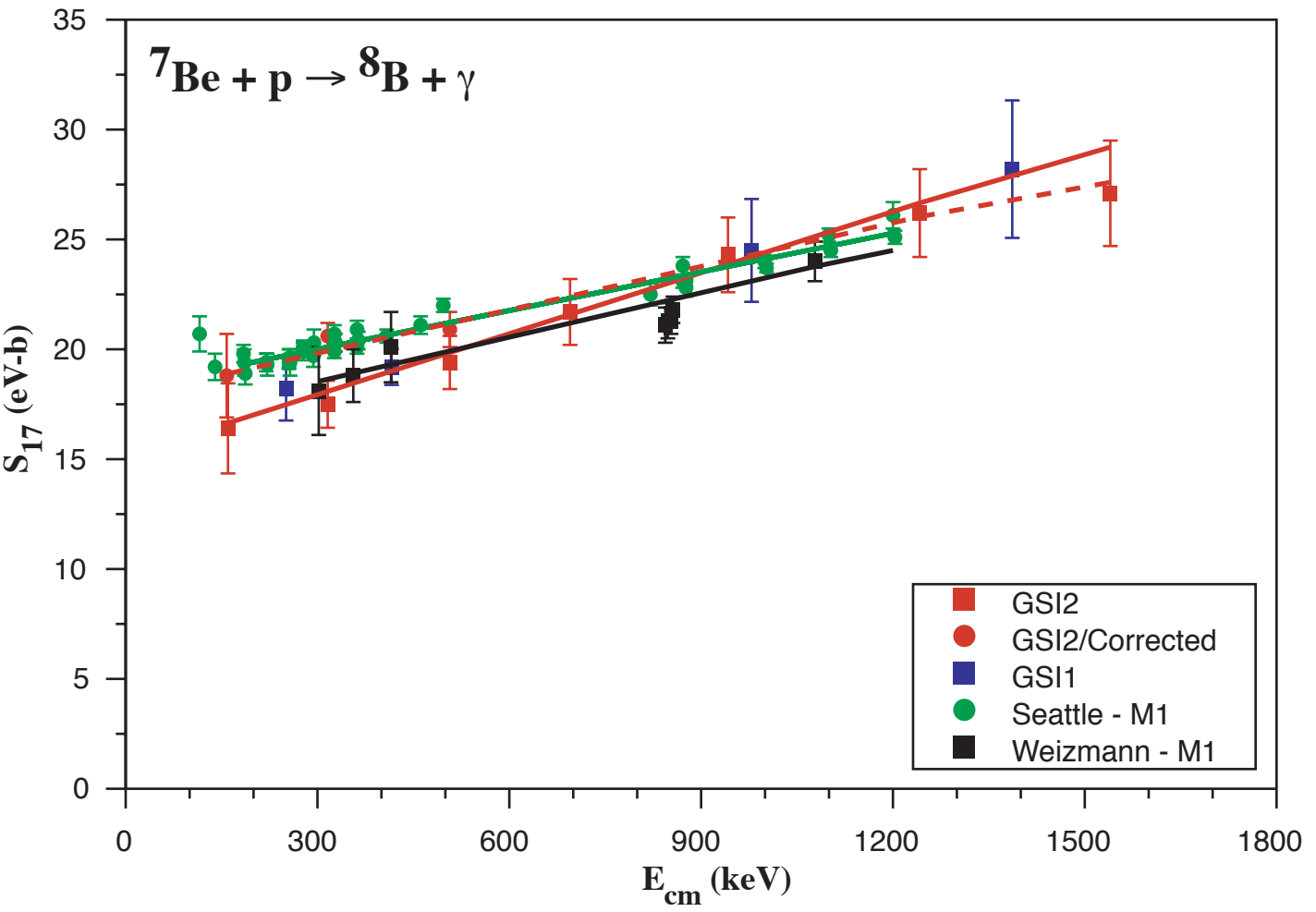
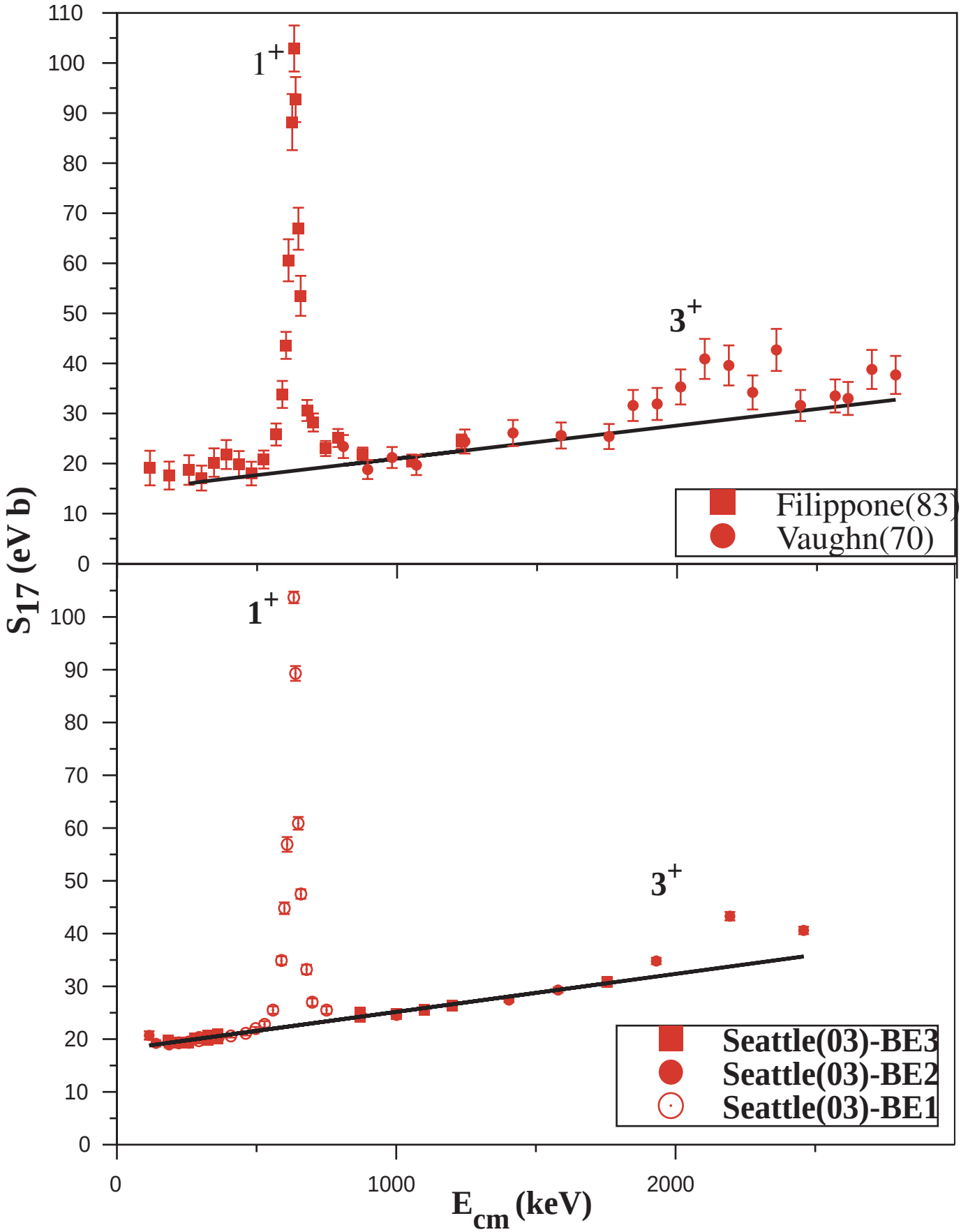
(Received 6 October 2004; published 31 January 2005)

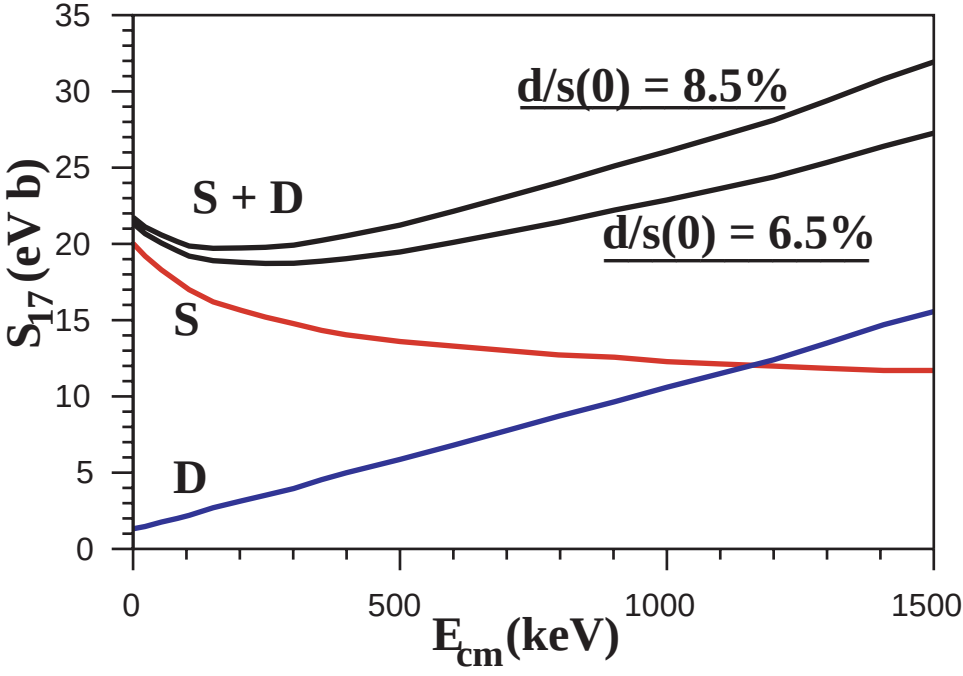
Two major differences between CD and direct determinations of the ^{7}Be$(p,\gamma)^8$B S factor (here labeled S_{17}) were identified in [1]. First, the zero-energy extrapolated $S_{17}(0)$ values inferred from CD measurements [2–7] are, on average, about 10% lower than the mean of modern direct measurements (see [1,8] for the most recent measurements). Second, the S_{17} values extracted from CD data have a significantly steeper slope as a function of $E_{\rm rel}$, the relative energy of the proton and the ^{7}Be fragment, than the direct results. We show that these differences are due in part to the manner in which the CD experiments were analyzed and can be reduced considerably by using more precise Coulomb breakup theory.


(a1)Kavanagh(69)
(a2)Parker(66)
(a3)Vaughn(70)
(a4)Filippone(83)
(b)Orsay(01)
(c)Bochum(01)
(d1)Seattle(03)-BE1
(d2)Seattle(03)-BE3
(d3)Seattle(03)-BE2
(e)Weizmann(02)
(f)RIKEN2(98)
(g)GSI1(99)
(h)GSI2(03)
(i)GSI2/Corrected(04)
(j)MSU(01)
S' (eV b/MeV)
0
5
10
15
20
0
10
20


Esbensen-Bertsch-Snover
DC
CD
^{7}Be(p,γ)^{8}B
Seattle
RIKEN2
S_{17} (eV-b)
E_{cm} (keV)
0
5
10
15
20
25
30
35
0
500
1000


$^7Be + p \rightarrow {}^8B + \gamma$
S_{17} (eV-b)
E_{cm} (keV)
0
5
10
15
20
25
30
35
0
300
600
900
1200
1500
1800
GSI2
GSI2/Corrected
GSI1
Seattle - M1
Weizmann - M1


S_{17} (eV b)
E_{cm} (keV)
1^+
3^+
Filippone(83)
Vaughn(70)
Seattle(03)-BE3
Seattle(03)-BE2
Seattle(03)-BE1


35
30
25
20
15
10
5
0
0
500
1000
1500
S_{17}(eV b)
E_{cm}(keV)
d/s(0) = 8.5%
d/s(0) = 6.5%
S + D
S
D

Seattle Result on $^7Be + \mathrm{p} \rightarrow {}^8B + \gamma$:

$$S_{17}(0) = 21.4 \pm 0.5 \text{ (expt)} \pm 0.6 \text{ (theory) eV-b} \quad [1]$$

Previous Compilation:

$$S_{17}(0) = 19 \ {}^{+4}_{-2} \text{ eV-b} \quad [2]$$

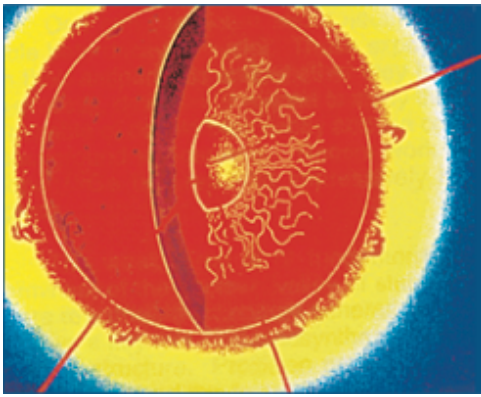
Reasonable Conservative Estimate:

$$S_{17}(0) = 21.4 \pm 0.8 \text{ (expt)} \ {}^{+0.0}_{-3.0} \text{ (extrap) eV-b} \quad [3]$$

[1] A.R. Junghans *et al.*; Phys. Rev. **C68**(2003)065803.

[2] E.G. Adelberger *et al.*; rev. Mod. Phys. **70**(1998)1265.

[3] M. Gai; nucl-ex/0312003.



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at Avery Point

1. **The Coulomb Dissociation Method**
   Viable Method
   (^{8}B testing Ground of Method)

2. **The Slope of Cross Section Factor (S_{17})**
   NOT KNOWN With High Accuracy

3. **Uncertainty of Formation of Solar ^{8}B**
   (Must Be Resolved by a Measurement)

San Diego, 18 March, 2006