New Cross Section Data for the $^{10}B(d,n_0)^{11}C$ Reaction Below 160 keV

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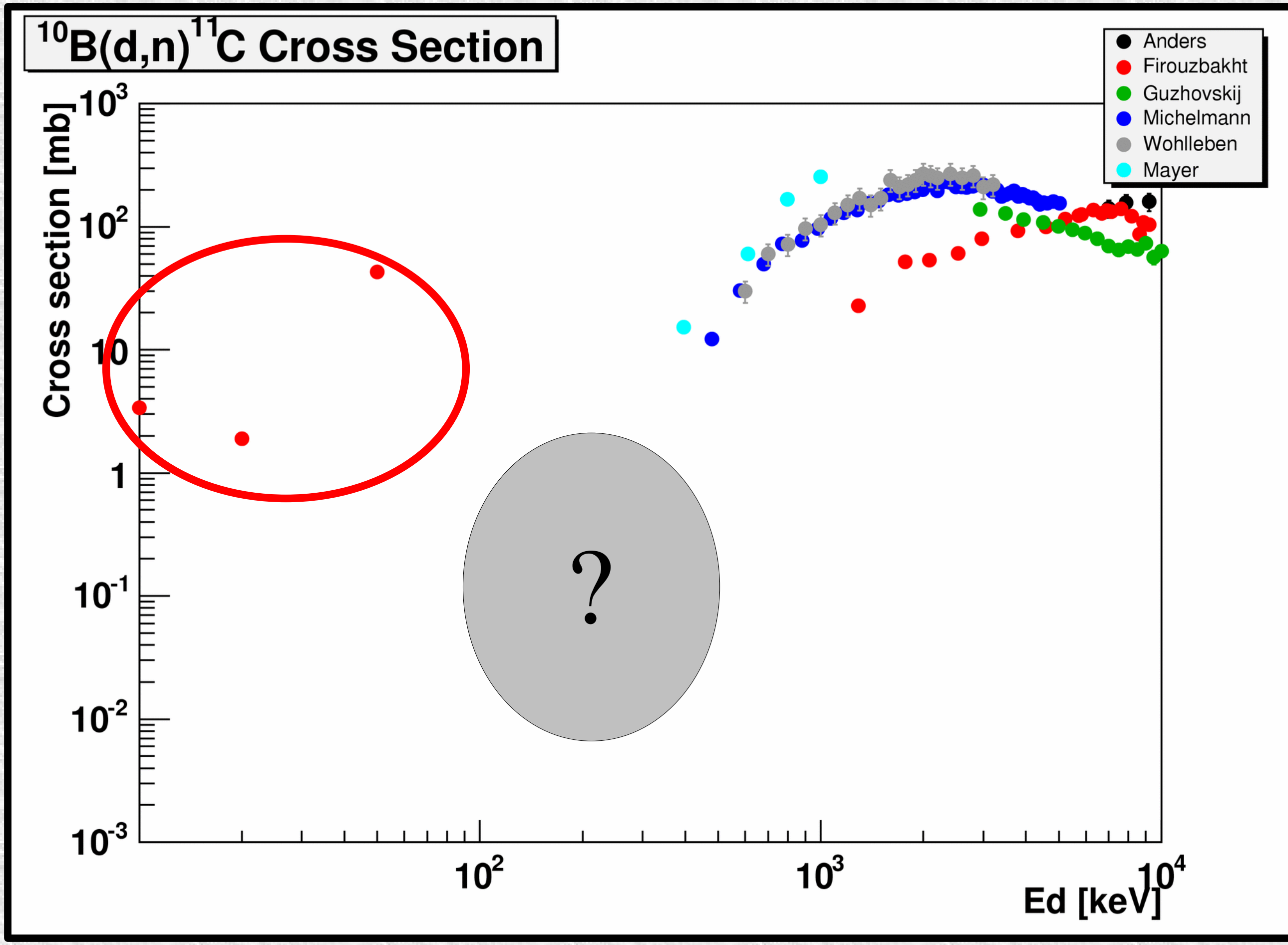
Motivation

- $d(160\ keV) + {}^{10}B \rightarrow n_0(6.3\ MeV) + {}^{11}C$
- Reaction studied to see plausibility of using as a source of 6.3 MeV neutrons
- Older experiment indicated a large cross section (>1 mb) at low energies



Experimental Method

- Deuterons of 160, 140, and 120 keV incident on 3.1 μm ^{10}B target
  (Rate close to background at 120 keV)
- All deuterons stopped in target and total beam current was integrated during the runs
- The neutrons were detected by liquid scintillator neutron detectors at 8 angles between 0 and 150 degrees
- Pulse shape discrimination was used to select neutrons and reject the gamma ray background
- Blank target runs were used to subtract d(d,n) background

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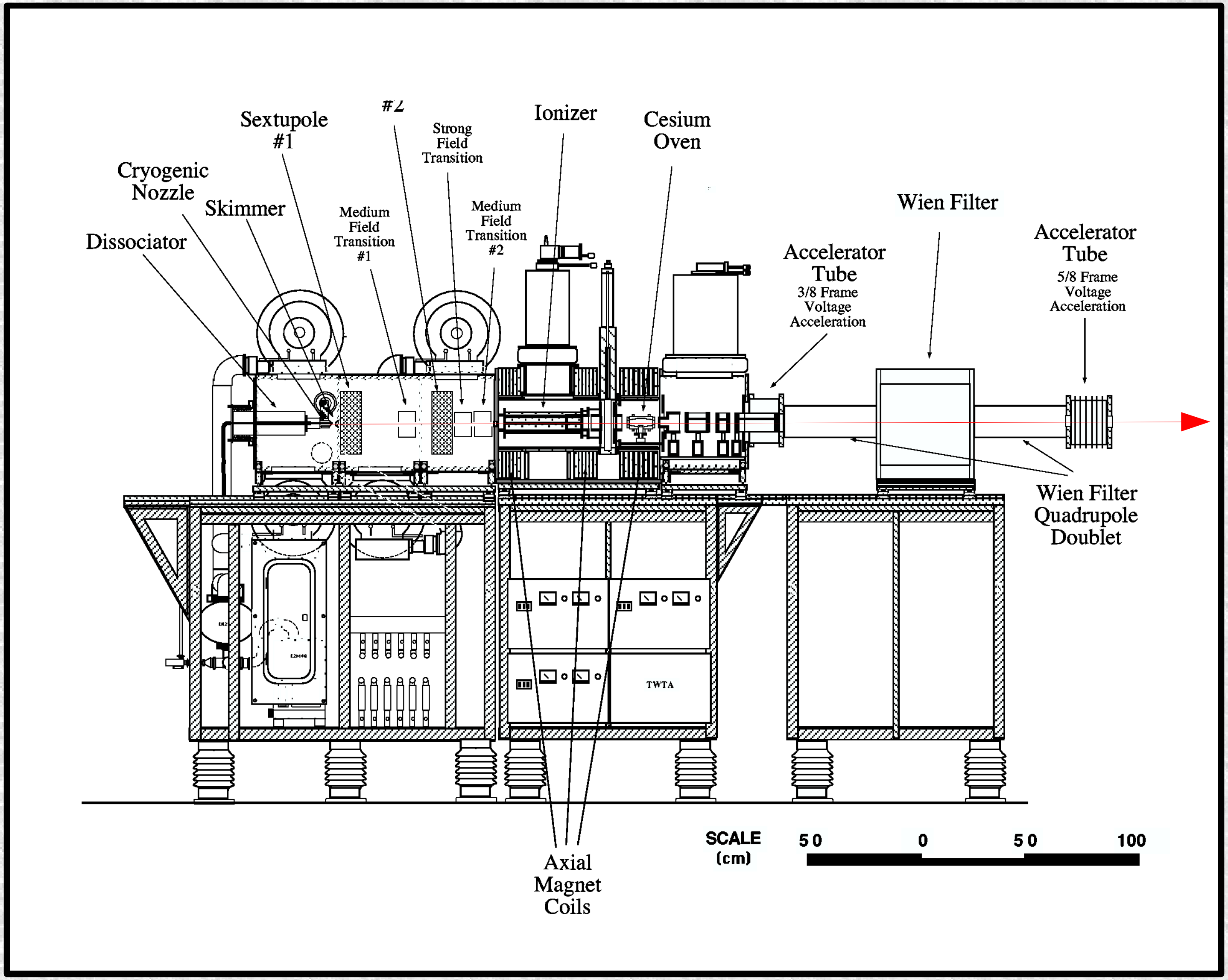
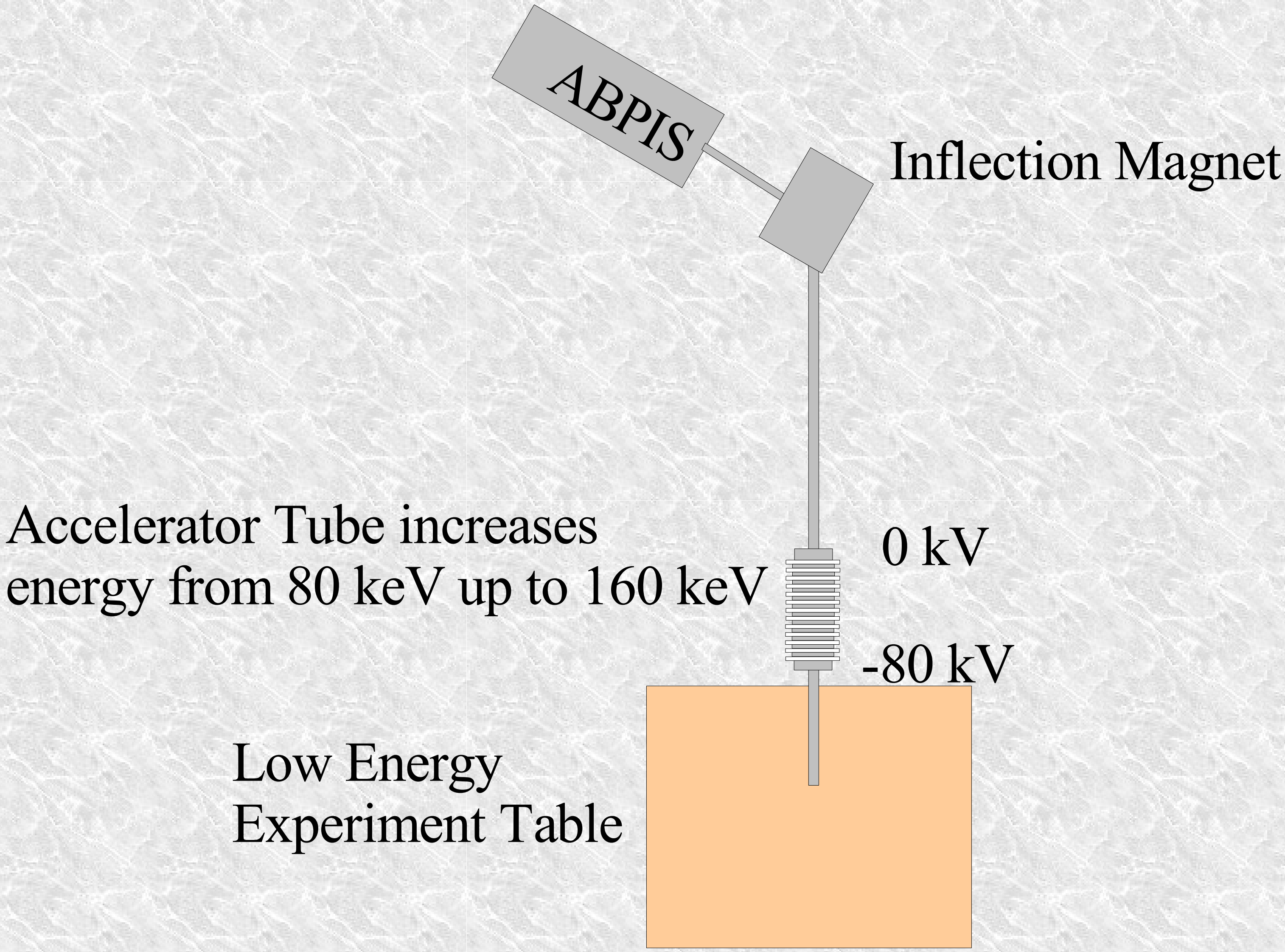
Atomic Beam Polarized Ion Source

- Provides polarized or unpolarized ions up to 80 keV
- Used 80 keV unpolarized d at 20 μA

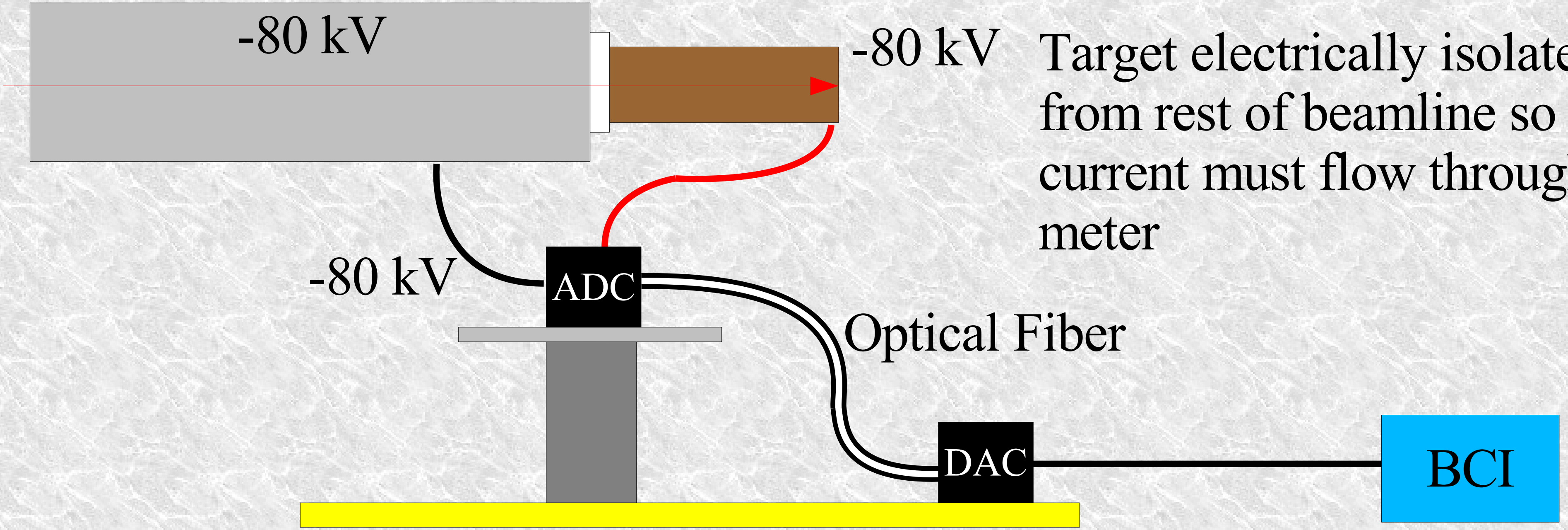


Low Energy Beamline



Optical Readout of Beam Current

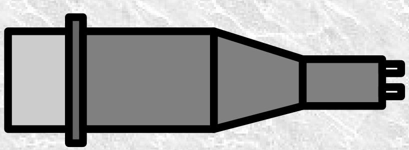
- Direct connection to current integrator difficult due to high voltage nearby (creates path to ground for HV supply)
- Problem solved by using optical readout device to measure current and transmit over optical fiber
- Calibrated using several known input currents



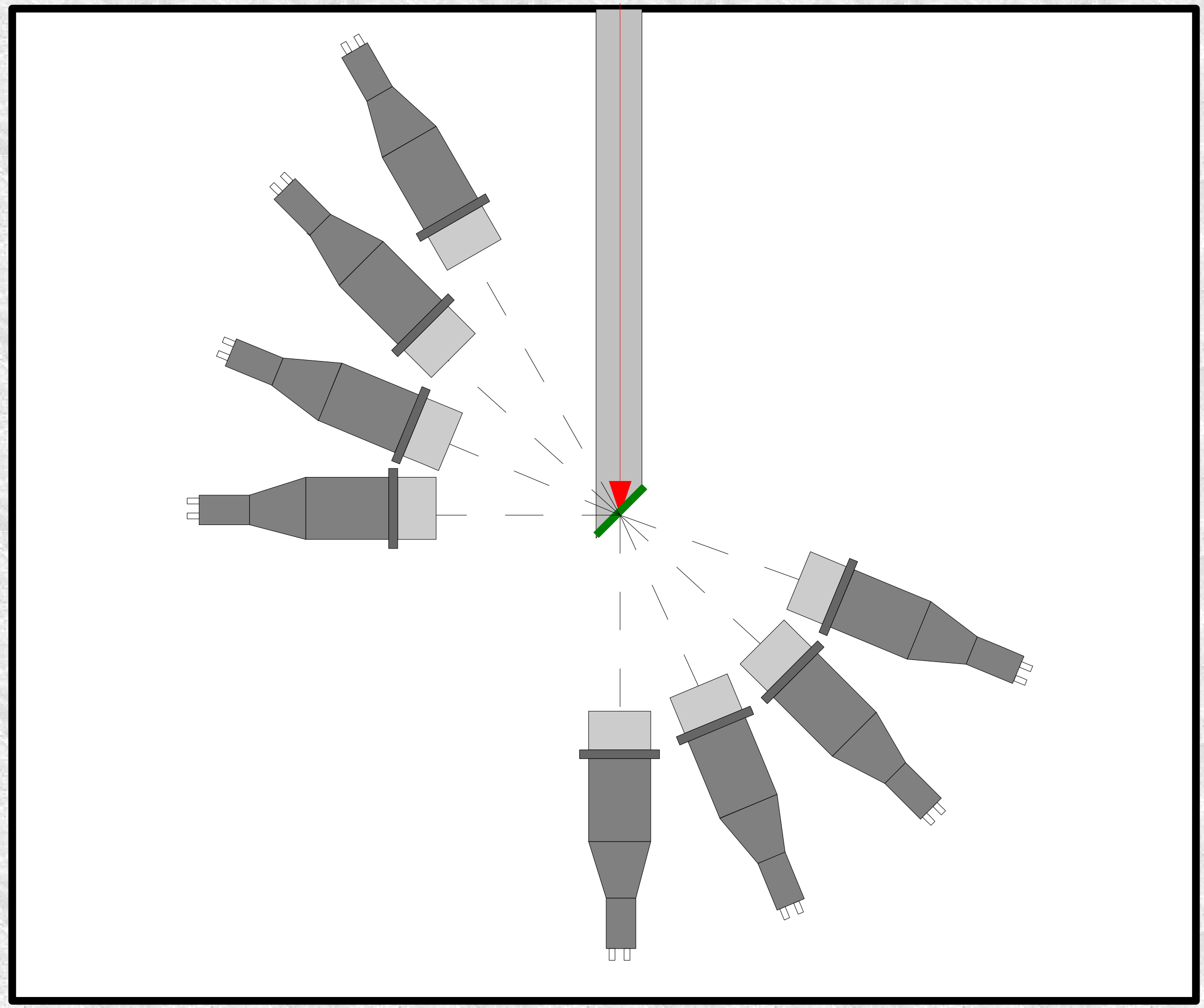
Target electrically isolated from rest of beamline so current must flow through meter

Experimental Setup

Angle (deg)	Solid angle (msr)	Efficiency
0.0	63.8	0.26
22.5	65.2	0.25
45.0	77.4	0.24
67.5	78.9	0.25
90.0	68.5	0.24
112.5	56.0	0.23
135.0	35.8	0.24
150.0	20.8	0.24



Bicron Neutron Detector filled with BC-501A liquid scintillator

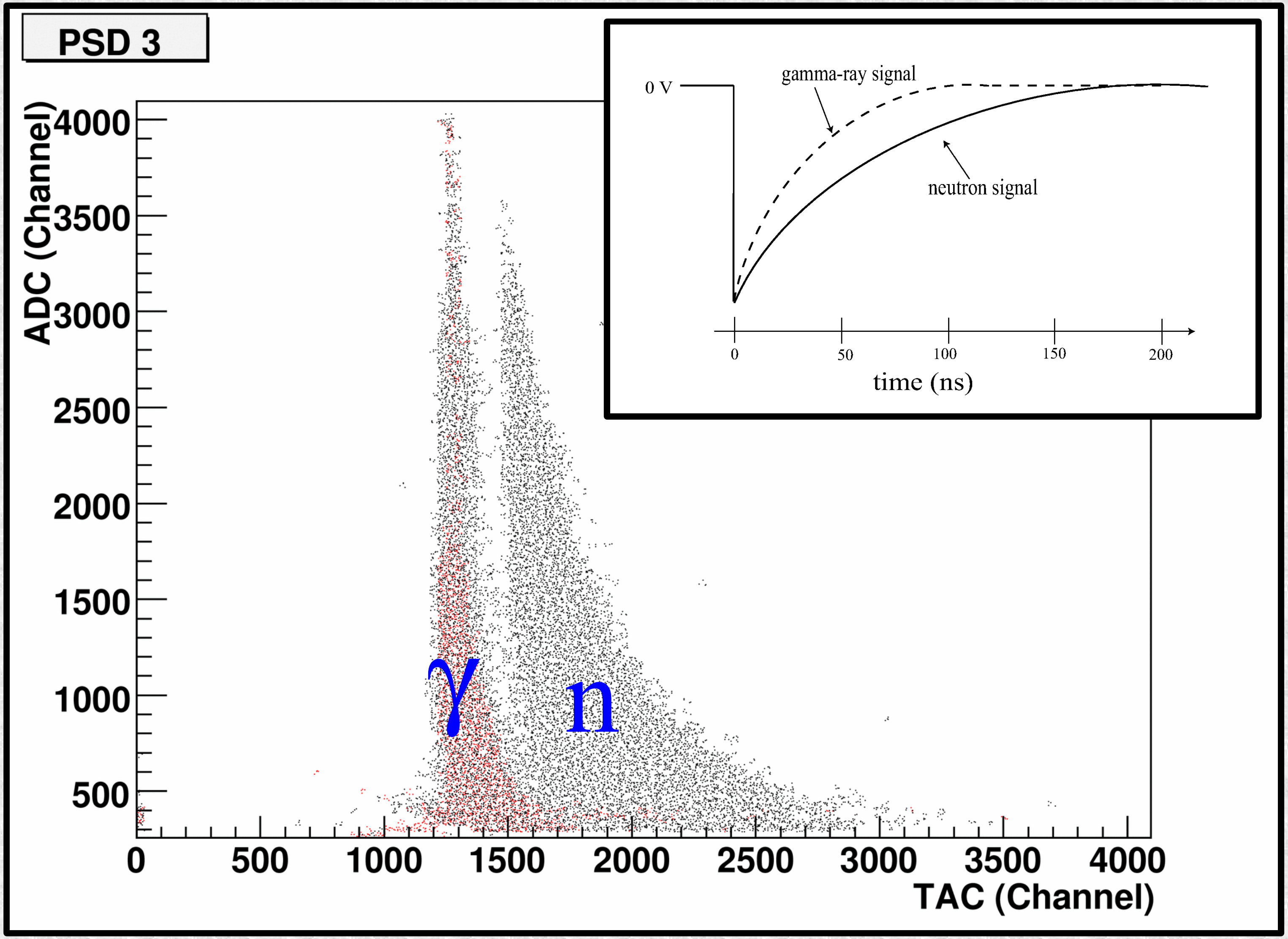


Analysis Method

- Detector response functions were fit to the data to determine the n_0 neutron yield for each detector
- Solid angle and efficiency corrections were applied to arrive at a final neutron count per accumulated charge for each angle
- The angular distributions were fit with a Legendre polynomial expansion which allowed a calculation of the total angle integrated cross section
- The total cross section as a function of the three incident deuteron energies was fit using a constant astrophysical S-factor while correcting for thick target effects

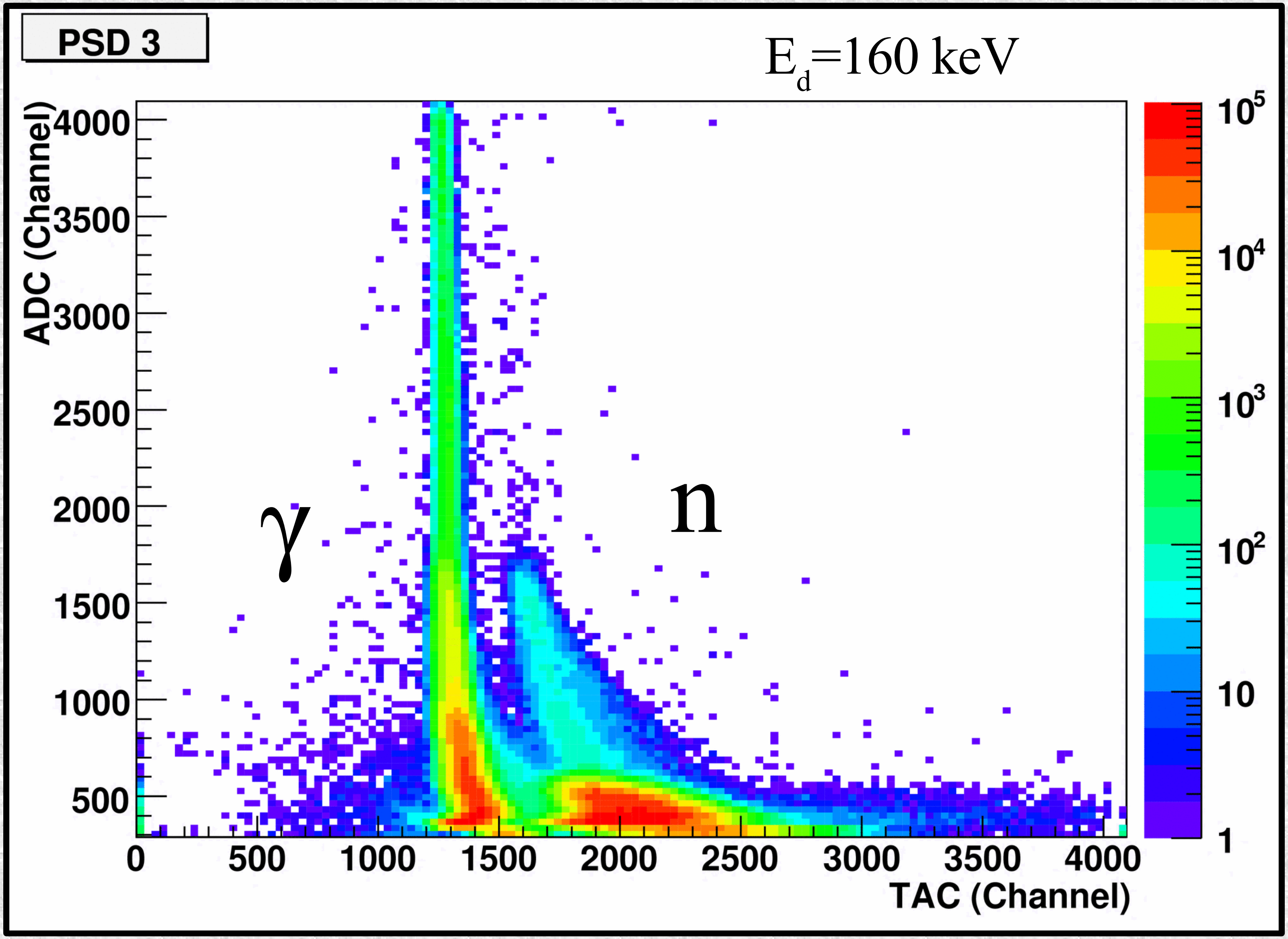
Pulse Shape Discrimination: Sources

- ^{137}Cs (γ)
- $^{241}AmBe$ (γ+n)



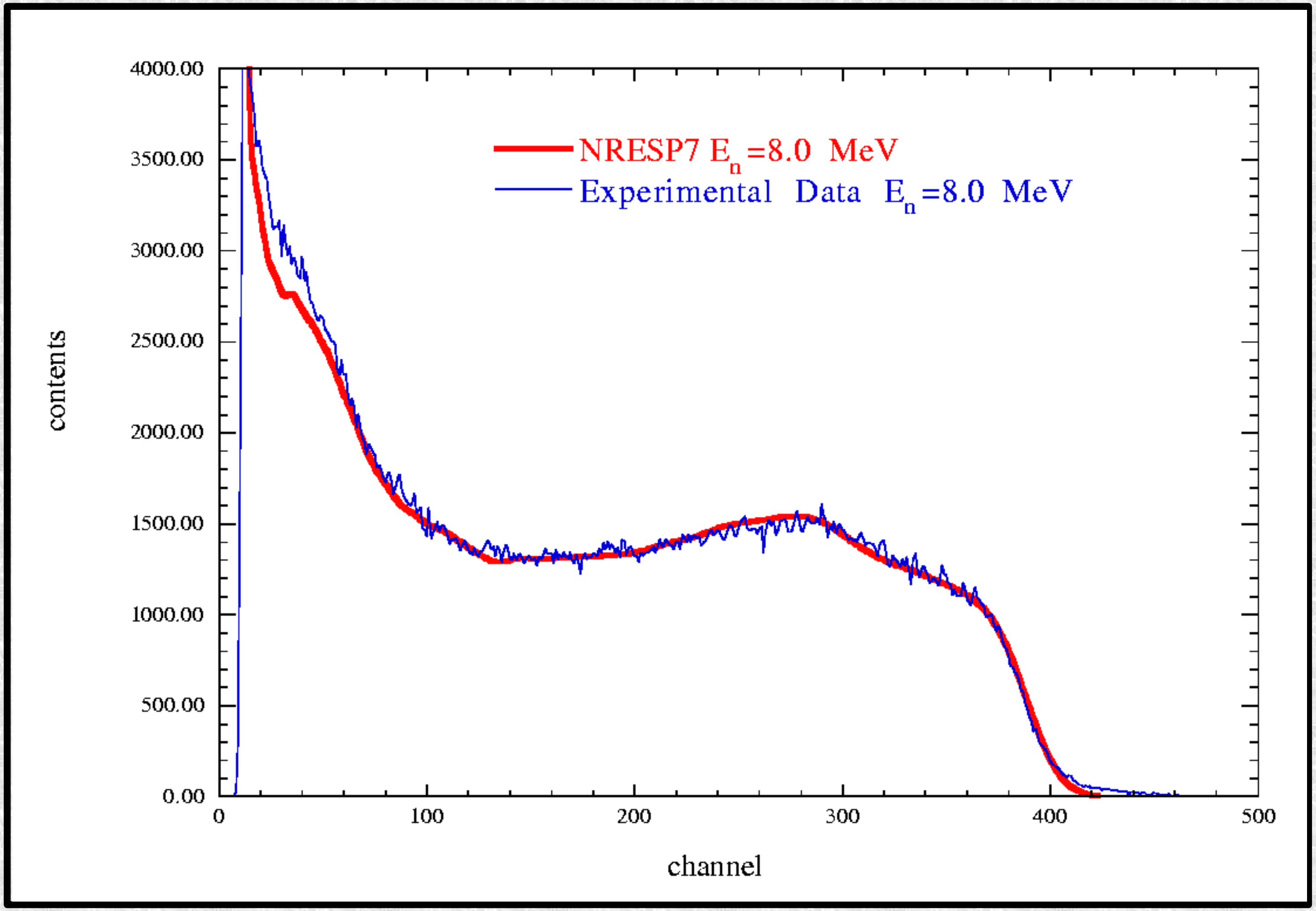
Using Mesytec MPD-4

Pulse Shape Discrimination: Data on ^{10}B



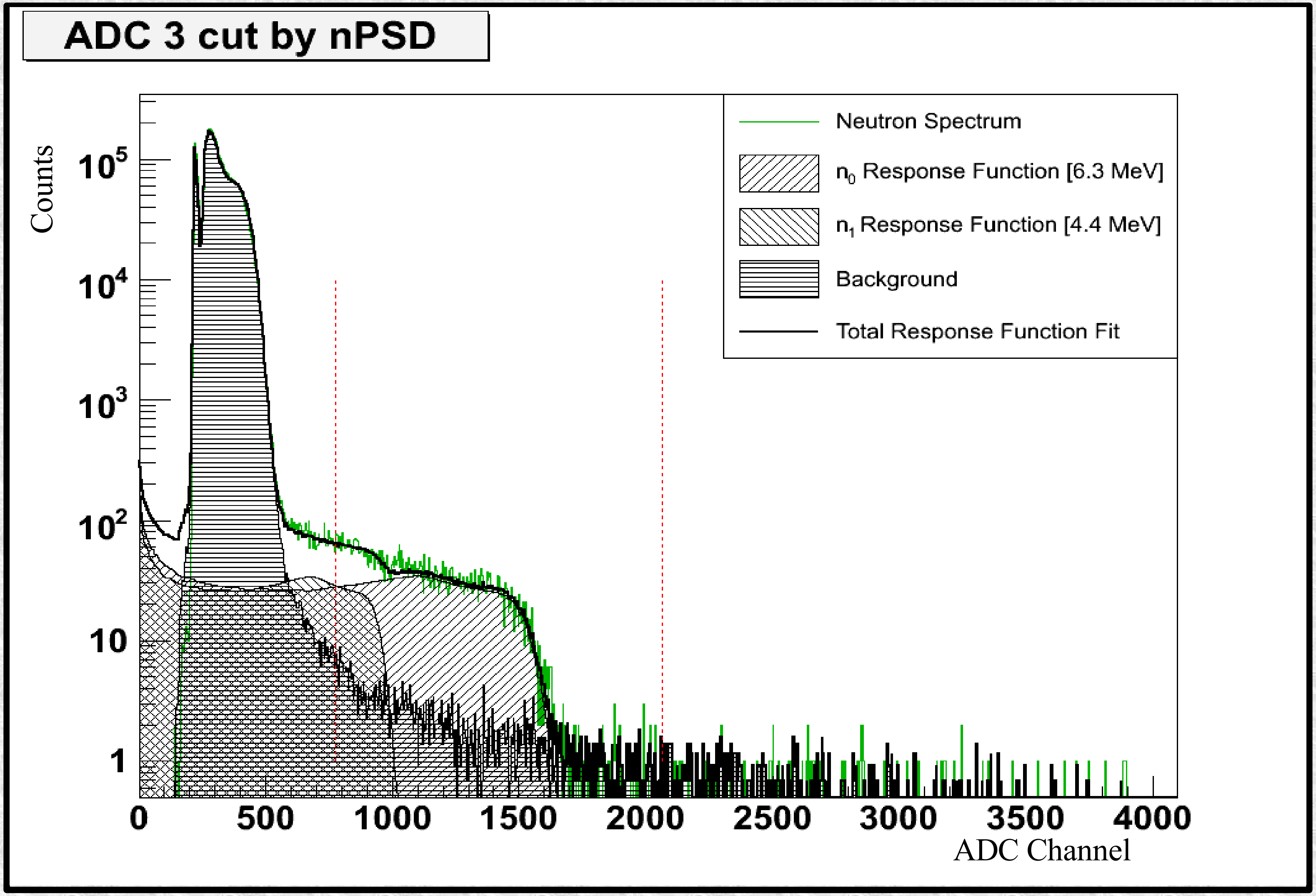
Detector Response Functions

- Responses measured at PTB using monoenergetic neutron beams from $d(d,n)^3He$
- PTB MC code developed to simulate responses
- Generate responses at our energies using the MC code



Fitting the Neutron Shapes

- Simulated response function
- Used BG from blank target run
- $\chi^2/dof=1.14$



Astrophysical S-factor

- Cross section can be written in terms of the astrophysical S-factor:

$$\sigma\left(E_{cm}\right)=\frac{S\left(E_{cm}\right)}{E_{cm}}\mathrm{e}^{-2\pi\eta}$$

  where $2\pi\eta=31.29Z_1Z_2(\mu/E_{cm})^{1/2}$, E_{cm} is the center of mass energy in keV, Z_1 and Z_2 are the projectile and target charges, and μ is the reduced mass in amu.
- Tends to be linear at low energies

Thick Target Integration

- Problem: Deuterons lose energy in target and cross section is a very strong function of energy
- The measured neutron yield is related to the cross section as:

$$Y\left(E_d\right)=C\int_{E_d}^{0}\frac{\sigma\left(E\right)f}{STP\left(E\right)}dE$$

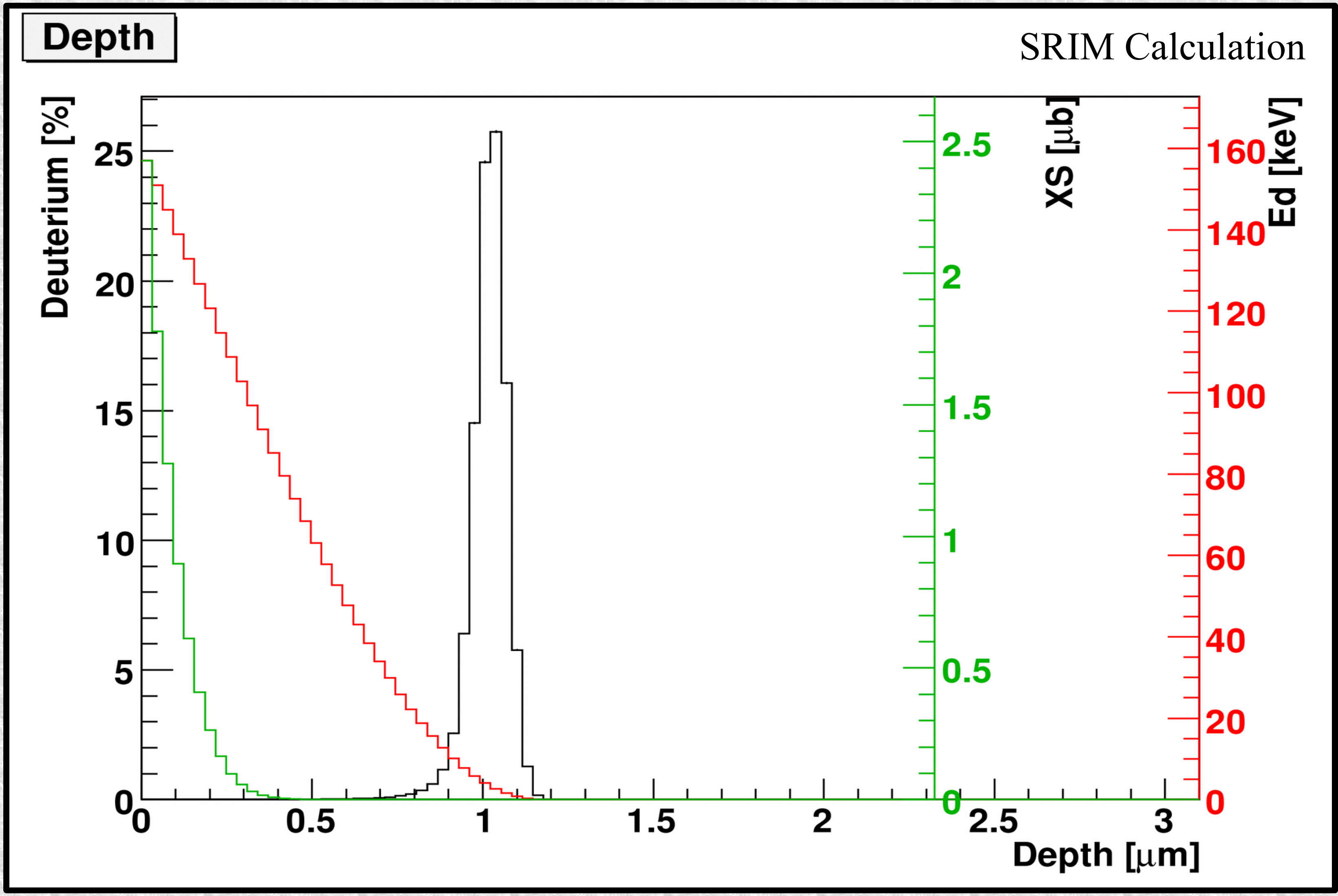
$\sigma(E)$: Energy dependent cross section
f: atomic fraction of the target
STP(E): stopping power of the target for deuterons
C: total number of incident deuterons times the detector solid angle and efficiency

Deuterons vs. Depth

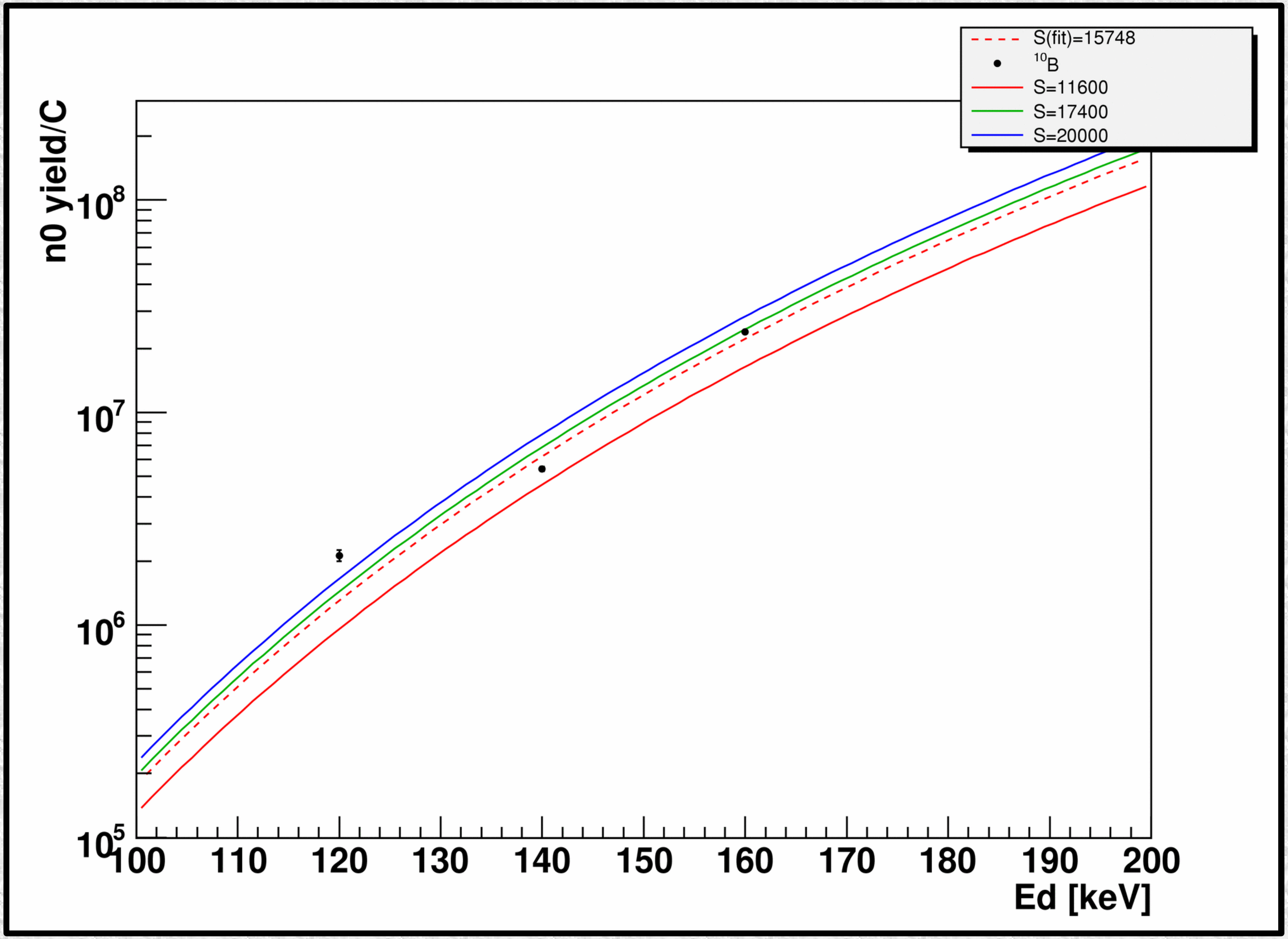
Deuteron %

Deuteron Energy

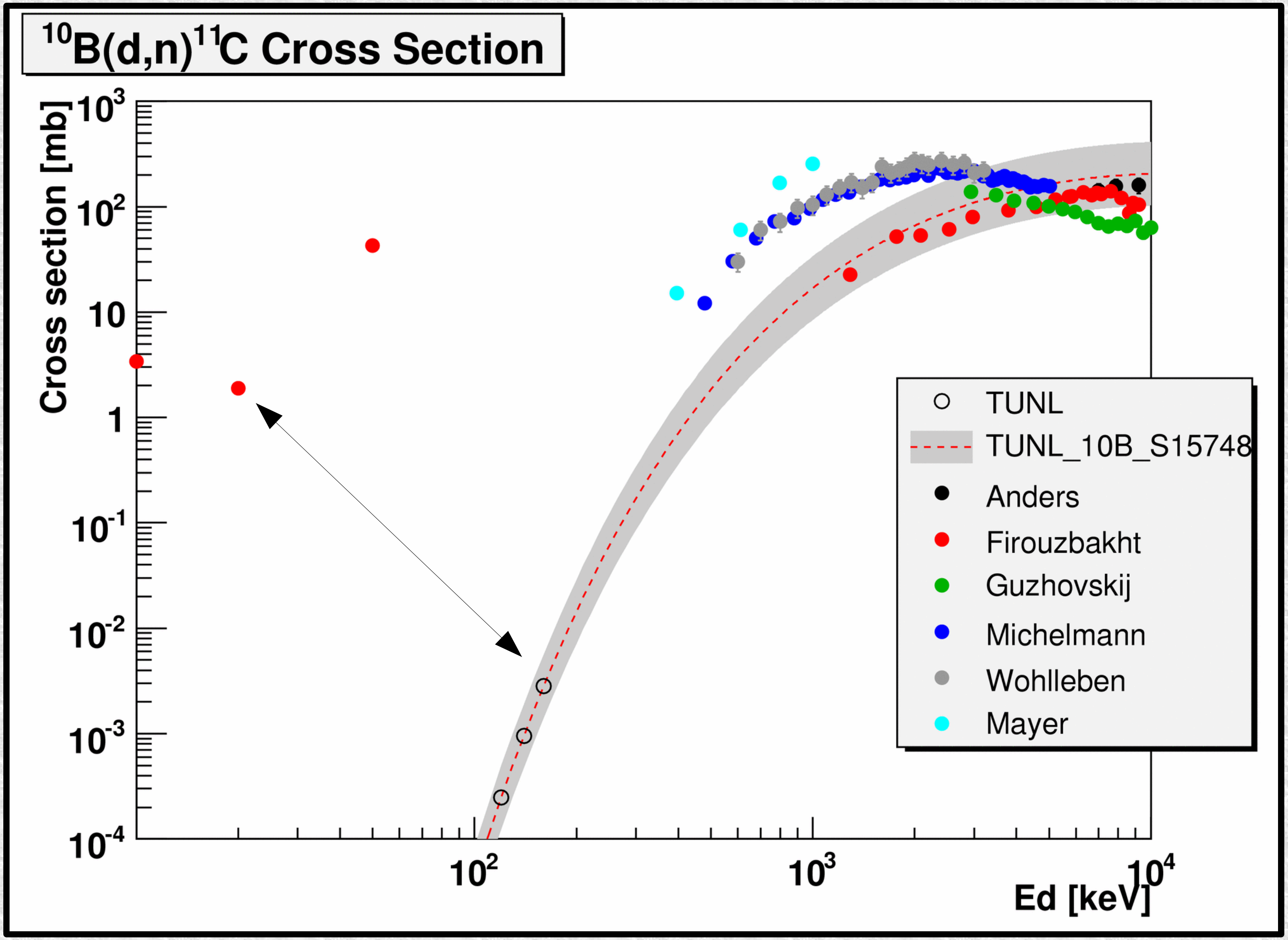
$^{10}B(d,n)^{11}C$ Cross Section



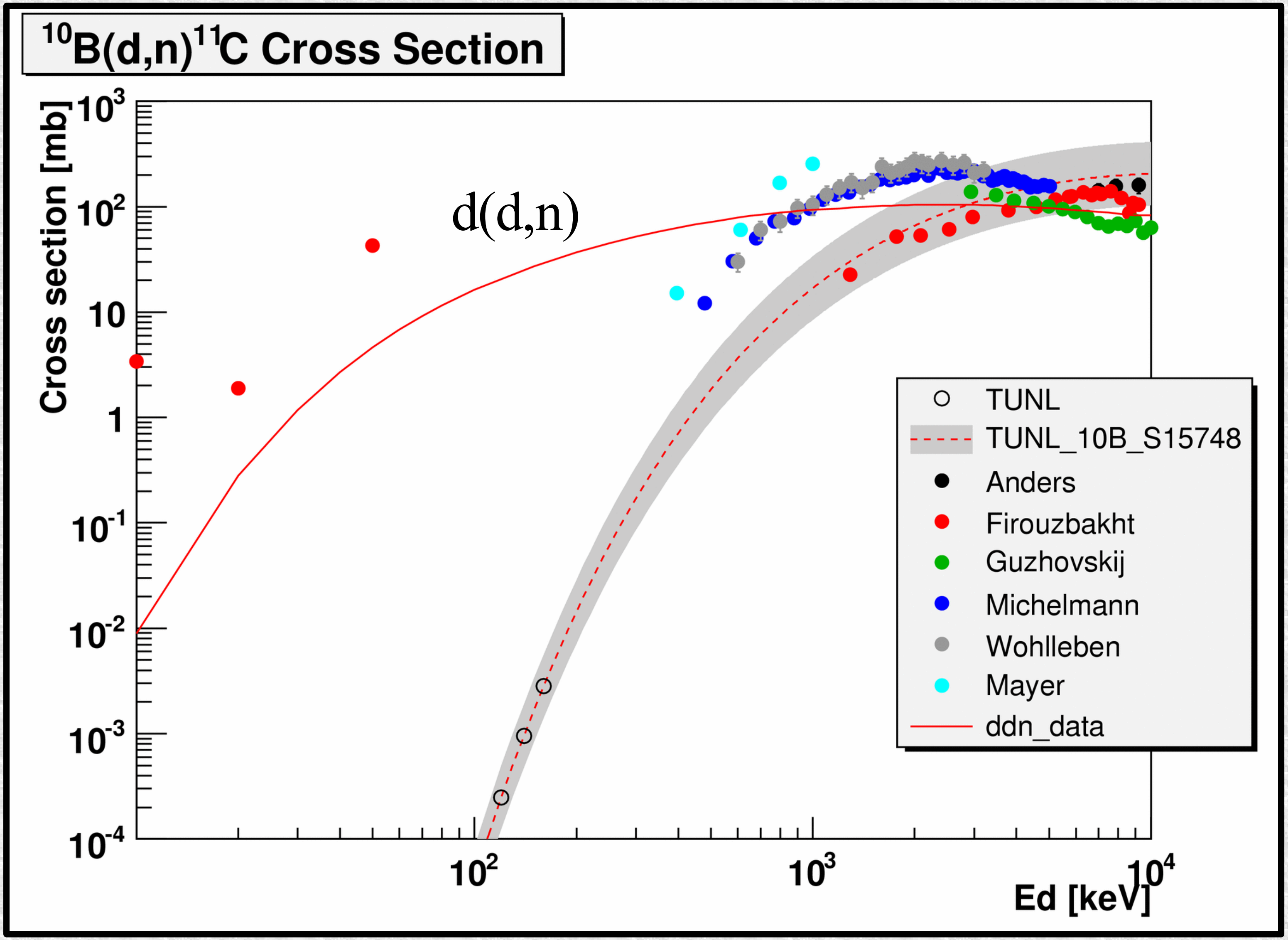
Preliminary Neutron Yield Versus Energy



Preliminary New Results



Preliminary New Results



Conclusions

- Measured $^{10}B(d,n_0)^{11}C$ cross section between 120 keV and 160 keV for the first time
- Preliminary analysis indicates a cross section more than 3 orders of magnitude smaller than lower energy results indicate
- 6.3 MeV neutron cross section too low to be of practical use
- Follow-up experiment to run in May with improved vacuum conditions, current integration, target backings, beamline alignment and detectors
- Will reduce systematic errors and allow for a more precise cross section measurement

Acknowledgements

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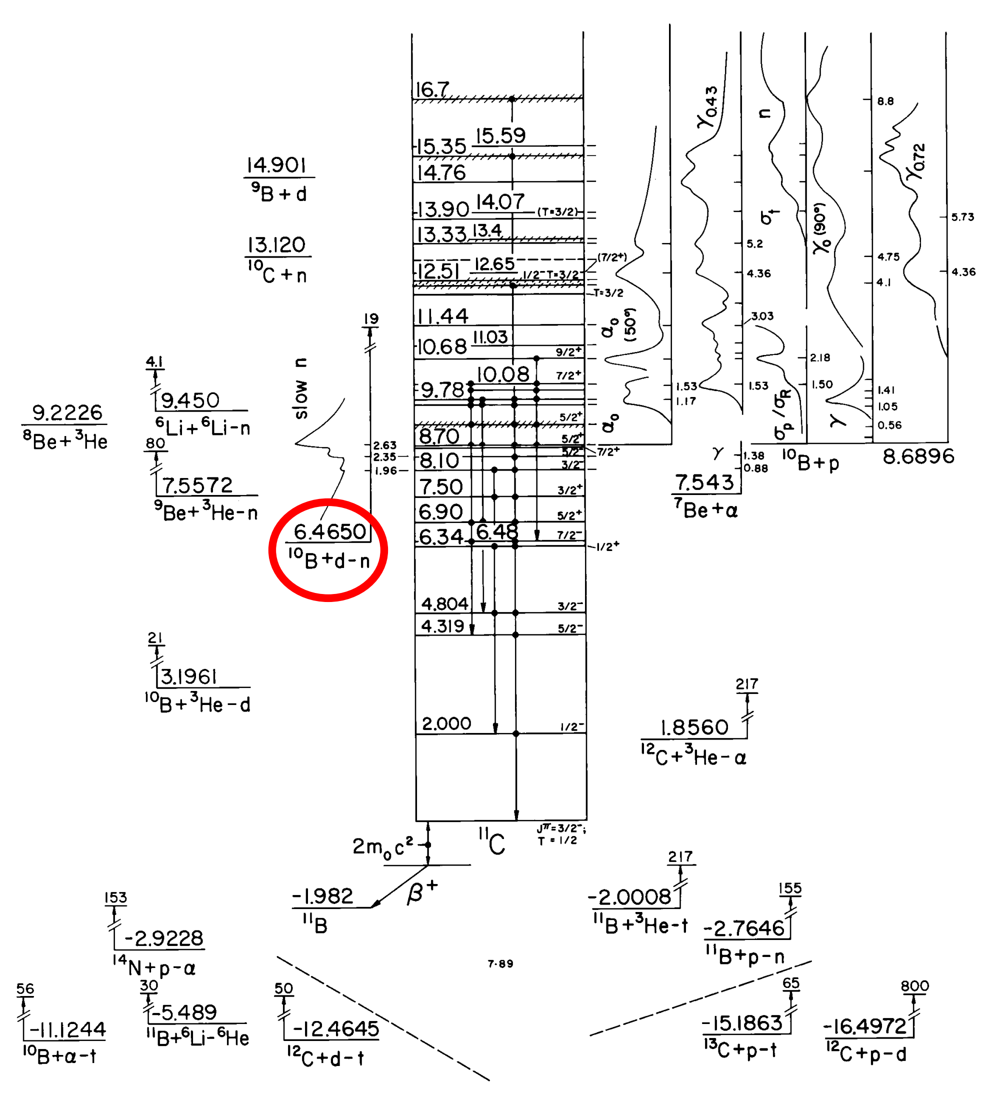
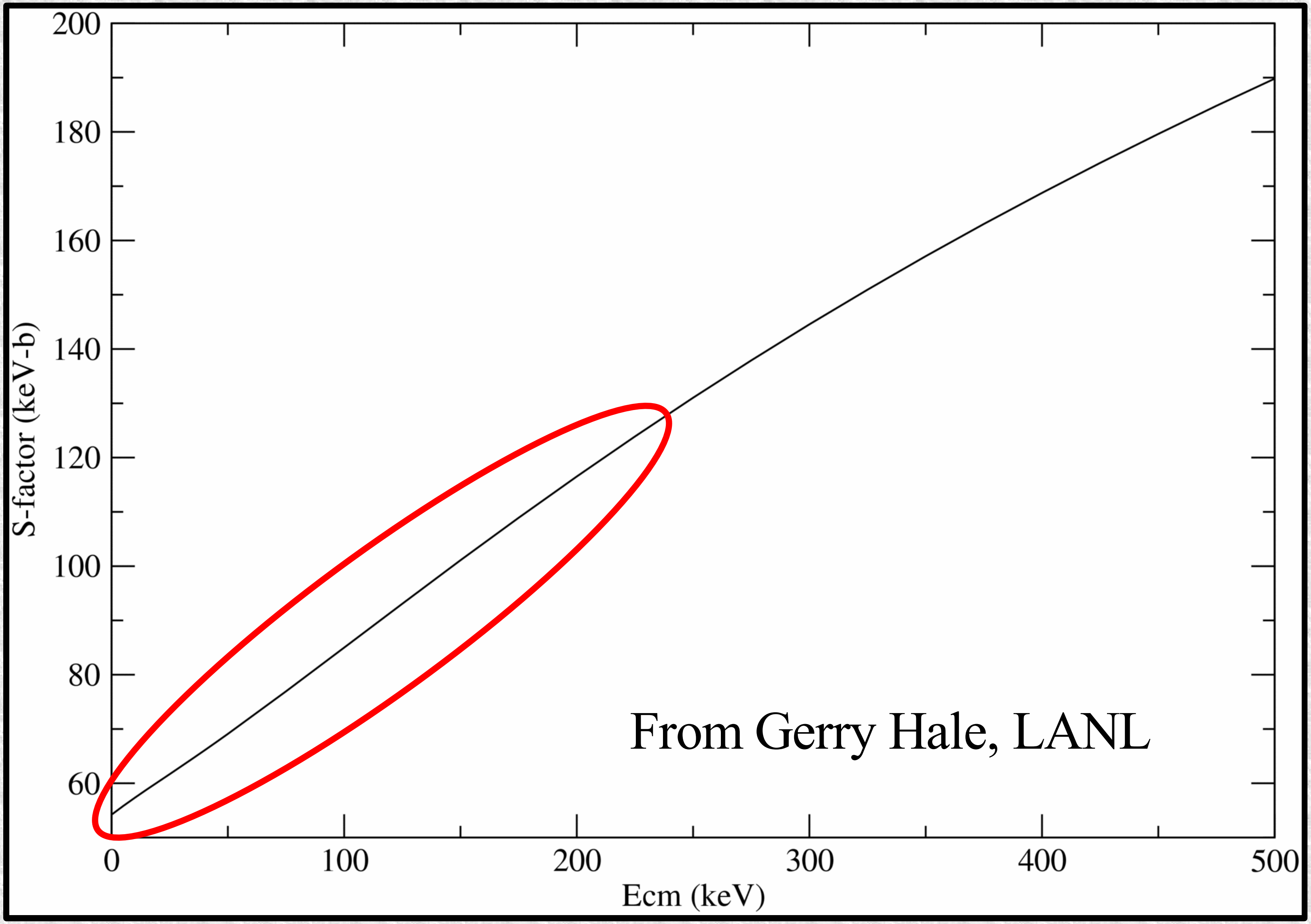
Extra Slides



16.7
15.35
15.59
14.901
^{9}B + d
14.76
13.90
14.07
13.120
^{10}C + n
13.33
13.4
12.51
12.65
11.44
10.68
11.03
10.08
9.78
8.70
8.10
7.50
6.90
6.34
6.48
4.804
4.319
2.000
9.2226
^{8}Be + ^{3}He
9.450
^{6}Li + ^{6}Li - n
7.5572
^{9}Be + ^{3}He - n
6.4650
^{10}B + d - n
slow n
3.1961
^{10}B + ^{3}He - d
7.543
^{7}Be + α
^{10}B + p
8.6896
1.8560
^{12}C + ^{3}He - α
2m$_0$c^2
^{11}C
β$^+$
-1.982
^{11}B
-2.0008
^{11}B + ^{3}He - t
-2.7646
^{11}B + p - n
-2.9228
^{14}N + p - α
-5.489
^{11}B + ^{6}Li - ^{6}He
-11.1244
^{10}B + α - t
-12.4645
^{12}C + d - t
-15.1863
^{13}C + p - t
-16.4972
^{12}C + p - d

S-factor Example: $d(d,n)^3He$



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