Analyzing Sources of Uncertainty in a Precision Measurement of $^3He(\alpha,\gamma)^7Be$

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Outline

- Introduction
- Experimental Setup
- Background Radiation
- Beam Heating
- Detector Efficiency
- Conclusion

Introduction

- High precision measurement of the $^{3}He(\alpha,\gamma)^{7}Be$ reaction
- Determine the astrophysical S-factor, $S_{34}(0)$, to ±5% or better in order to compare with Standard Solar Model (SSM) calculations
- Measure and minimize important sources of systematic errors

Solar proton-proton chain

- Uncertainty in this reaction rate is currently the largest nuclear physics uncertainty in solar model calculations of the neutrino flux from the decay of both ^{7}Be and ^{8}B in the sun
- Cross section of reaction can be used to determine neutrino flux
- Cannot measure cross section at the low energies in the sun
- S-factor calculated, used to extrapolate cross section at lower energies
  - σ(E) = [S(E)/E]*exp(-2*pi*η(E))

$$4\ ^1H \rightarrow\ ^4He + 2\ e^+ + 2\ \nu_e$$

$$^1H + e^- +\ ^1H \rightarrow\ ^2D + \nu_e$$

$$^1H +\ ^1H \rightarrow\ ^2D + e^+ + \nu_e$$

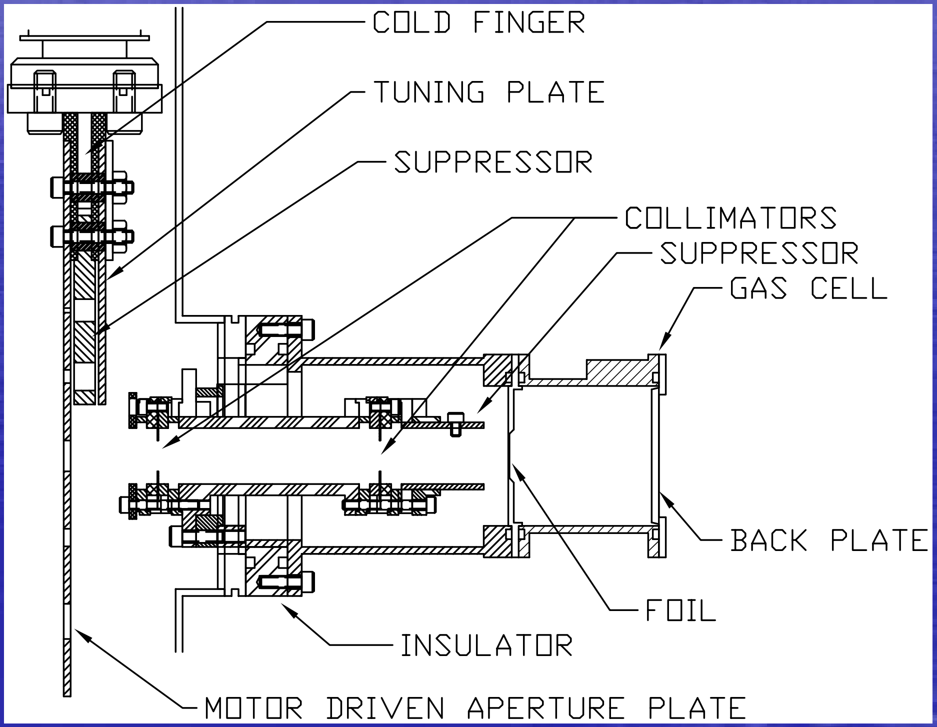
$$^2D +\ ^1H \rightarrow\ ^3He + \gamma$$

pp–I	(a)	$^3He +\ ^3He \rightarrow\ ^4He + 2p$
	(b)	$^3He +\ ^4He \rightarrow\ ^7Be + \gamma$
pp–II	(b1)	$^7Be + e^- \rightarrow\ ^7Li + \nu_e$
		$^7Li + p \rightarrow 2\ ^4He$
pp–III	(b2)	$^7Be +\ ^1H \rightarrow\ ^8B + \gamma$
		$^8B \rightarrow\ ^8Be + e^+ + \nu_e$
		$^8Be \rightarrow 2\ ^4He$

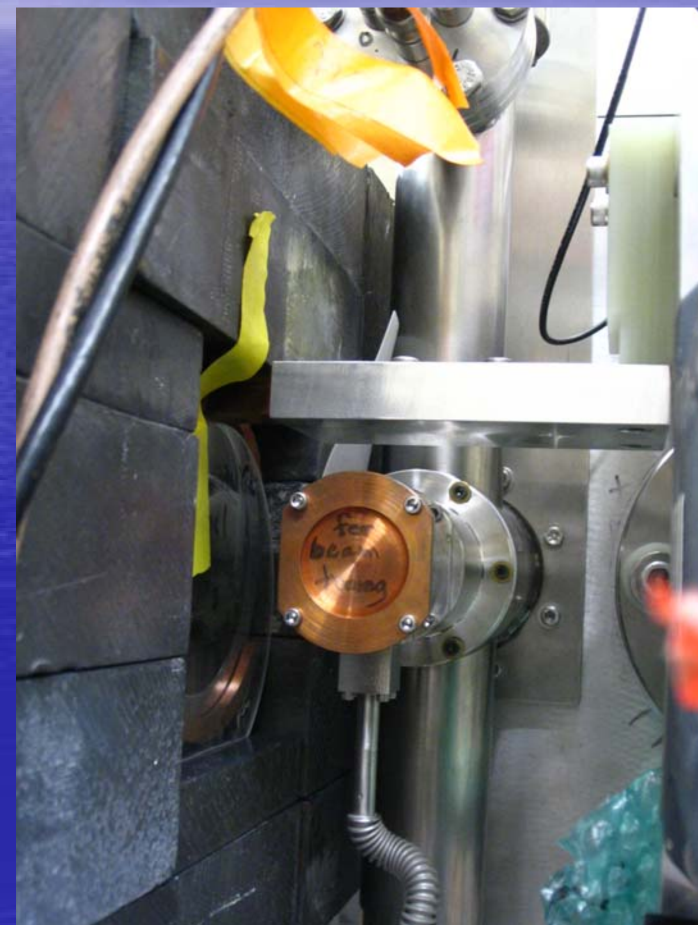
W.C. Haxton, P.D. Parker, C.E. Rolfs, nucl-th/0501020, 10 Jan 2005

Experimental setup

- Alpha beam is accelerated through the Tandem van de Graaff accelerator at alpha energies of 2.1, 2.35, 2.6, and 3.5 MeV
- Focused through a sliding aperture plate, then passed through collimators
- Beam passes through a Nickel foil (some energy loss)
- Reacts with ^{3}He or ^{4}He gas (more energy loss)
- ^{7}Be nuclei collected in Cu back plate and tantalum liner, and measured at a later time

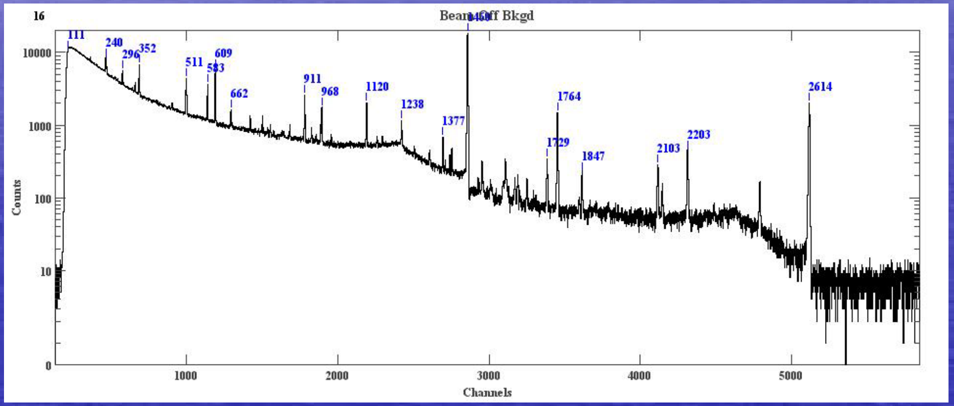


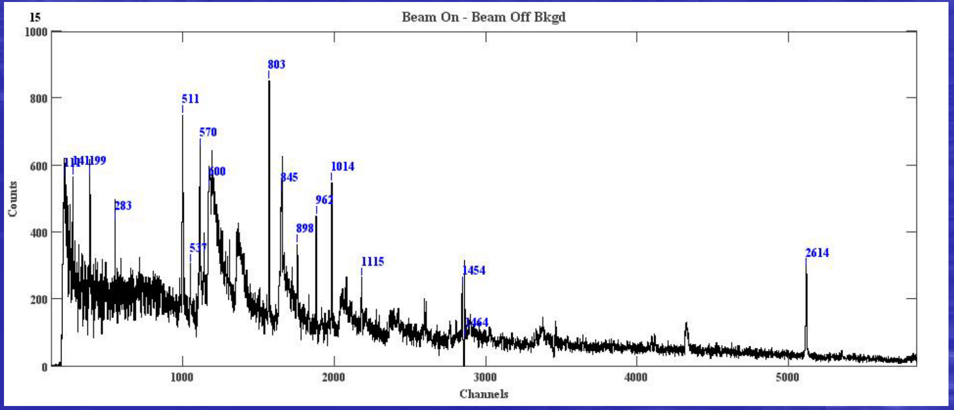
Experimental setup



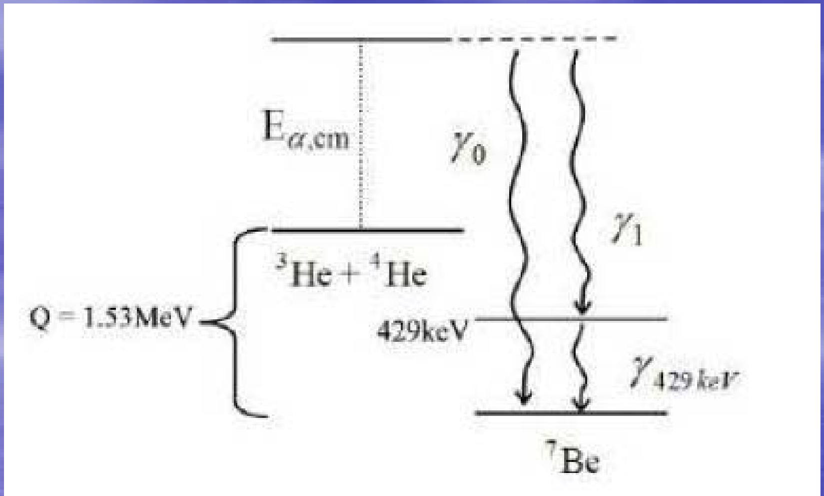
Background radiation

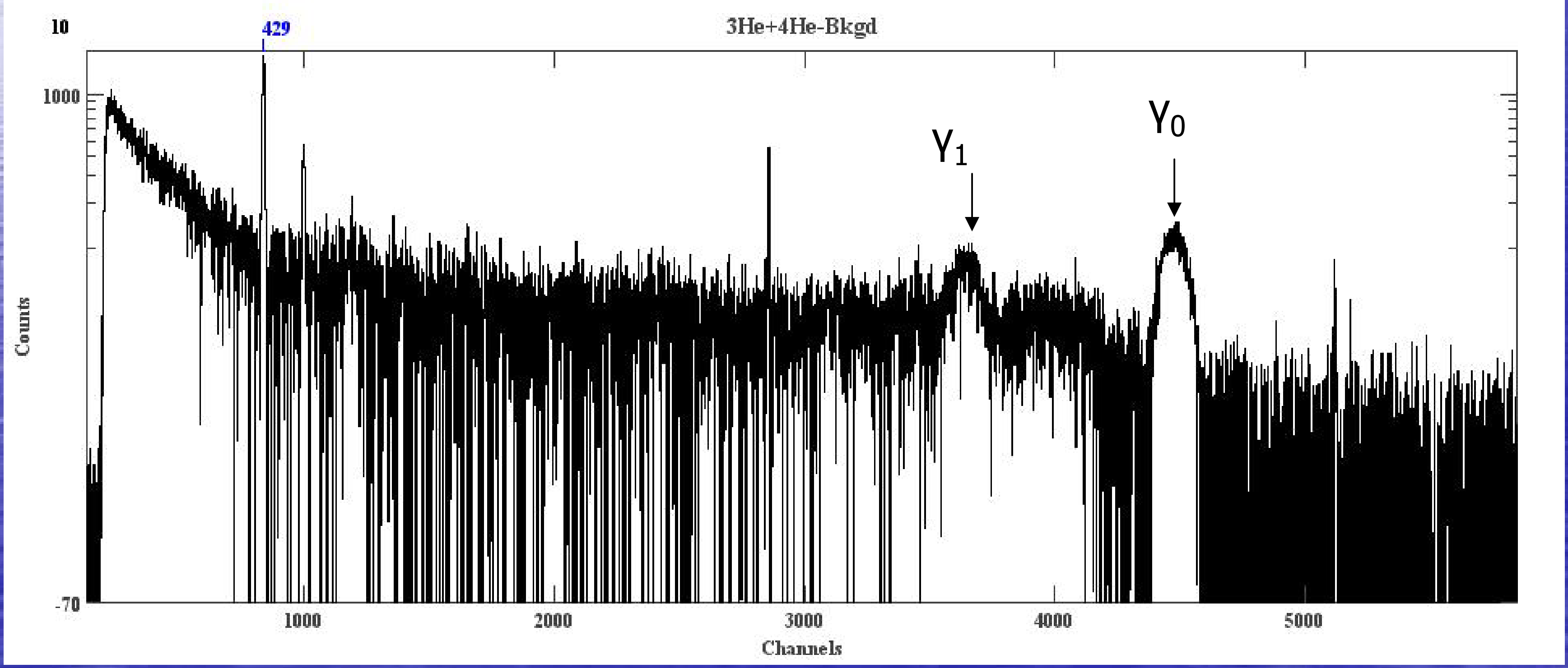
- Run to measure beam-off radiation
- $^4He(\alpha,\gamma)$ runs to measure beam-on radiation, assuming that $^4He+^4He$ produces same background as $^3He+^4He$
- Search through NNDC databases[1] and Table of Isotopes to find candidates for sources of particular gamma rays[2]
- Found various gamma rays from ^{63}Cu and ^{65}Cu in the online background spectrum



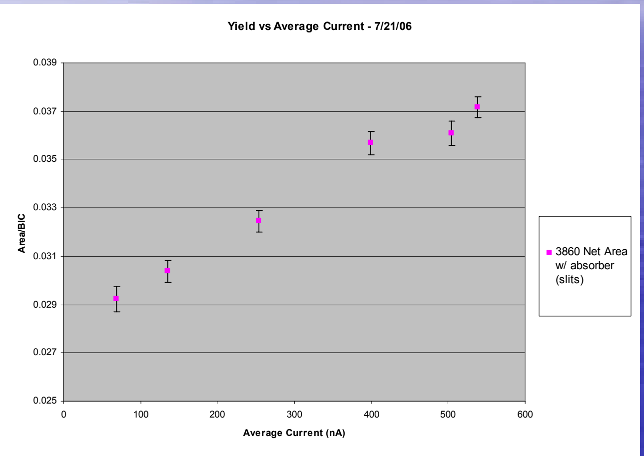


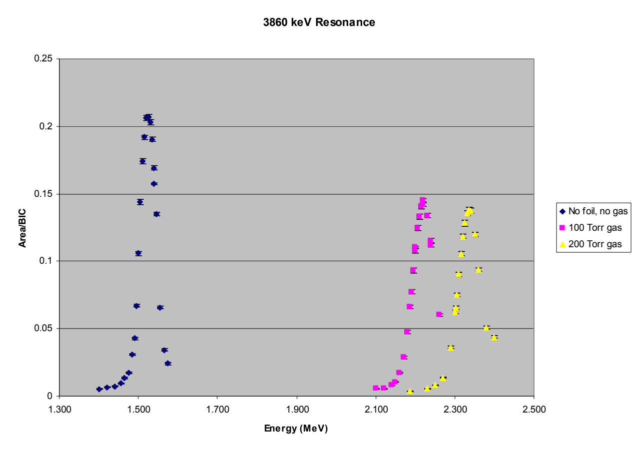
[1]www.nndc.bnl.gov/nudat2/ [2]Thanks Wes!


$E_{\alpha,cm}$
γ_0
γ_1
$^3He + {}^4He$
Q = 1.53MeV
429keV
$\gamma_{429\,keV}$
^7Be


3He+4He-Bkgd
10
429
1000
-70
Counts
1000
2000
3000
4000
5000
Channels
γ_1
γ_0

Beam heating





- Beam heats up gas in target cell, can't measure temp in direct line of beam
- Causes a change in gas density (target thickness)
  - $\sigma = R_b/I_aN$
  - R_b=rate of outgoing particles, I_a=current of incident particles per unit time, N=target nuclei per unit area
- Without beam heating correction, N is too high because the temperature is too low
- $(d\rho/dI)/\rho_0$ at 100 Torr = $.089\pm.015\mu A^{-1}$
- $(d\rho/dI)/\rho_0$ at 200 Torr = $.130\pm.020\ \mu A^{-1}$
- $\rho(I) = \rho_0[1-(1/\rho_0)(d\rho/dI)*I]$

Detector efficiency

- Can change if detector is moved
- Periodically place various sources in the center of the target chamber
  - ^{60}Co, ^{137}Cs, ^{203}Hg, ^{54}Mn, ^{113}Sn, ^{88}Y
- Measure ratio of yields for chosen gamma rays
- Between May and July, efficiency changed by ~1%
  - Upon inspection, detector was moved small distance from gas cell

Conclusion

- Helped with measuring the $^3He(\alpha,\gamma)^7Be$ and $^4He(\alpha,\gamma)$ reactions
- Identified sources of background radiation
- Determined effects of beam heating on the target gas
- Measured changes in the detector efficiency
- Experiment will continue at lower energies in order to extrapolate a value for $S_{34}(0)$

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