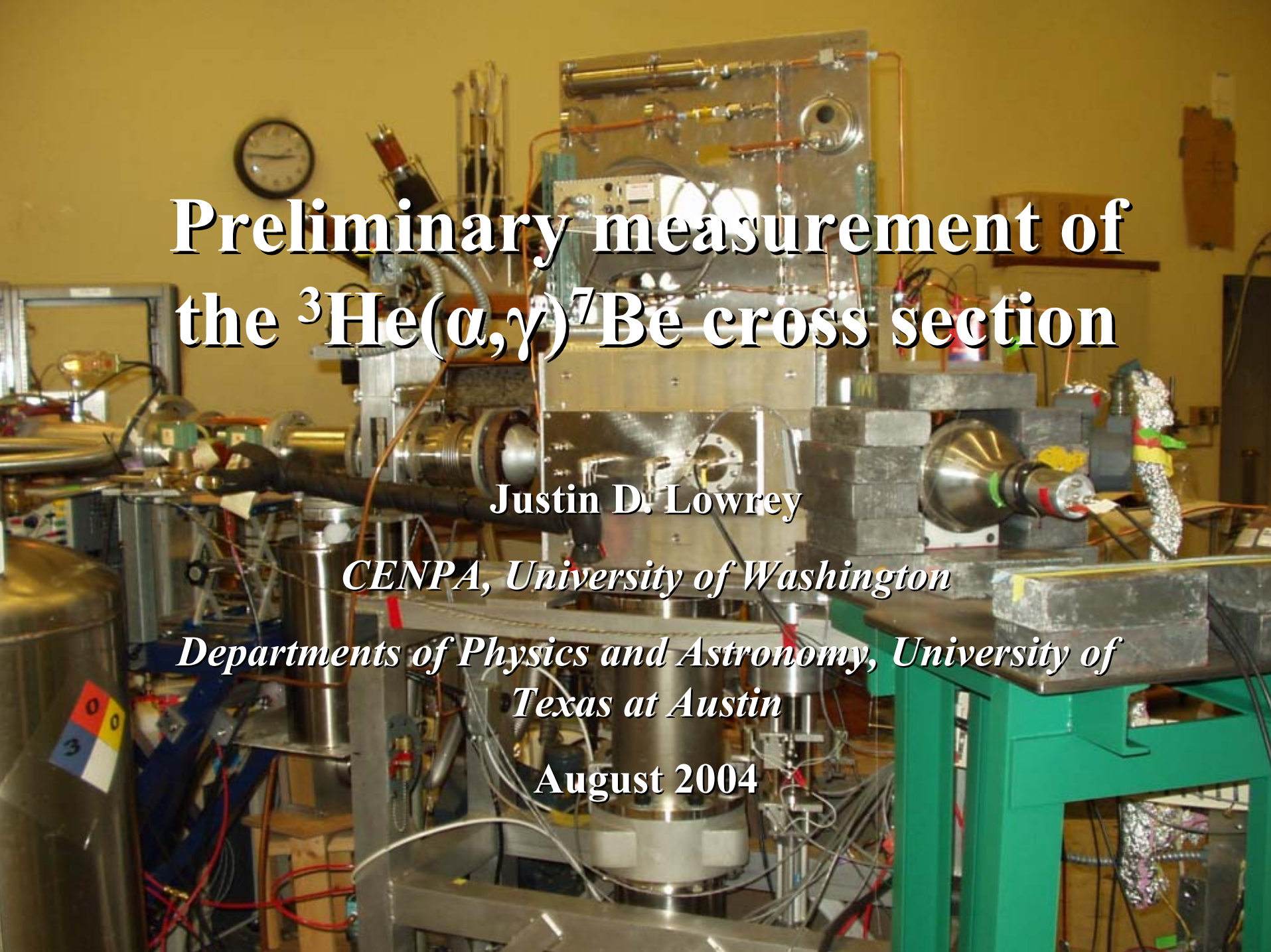

Preliminary measurement of the $^{3}He(\alpha,\gamma)^{7}Be$ cross section

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What I did this summer…

- Assisted in preparation for a high-precision measurement of the $^{3}He(\alpha,\gamma)^{7}Be$ cross section
- Several small subsidiary projects
- Culminated in a test run of $^{3}He(\alpha,\gamma)^{7}Be$

Who cares about this measurement?

- This reaction is a critical part of the proton-proton chain of stellar burning cycle
- The cross section is essentially a measure of the fusion reaction rate
- Major application is to the study of determining the solar neutrino production

Proton-Proton Chain

$$^{3}\mathrm{He} + {}^{3}\mathrm{He} \rightarrow {}^{4}\mathrm{He} + 2\,{}^{1}\mathrm{H}$$

$$^{1}\mathrm{H} + {}^{1}\mathrm{H} \rightarrow {}^{2}\mathrm{D} + e^{+} + \nu$$

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

$$\mathbf{^{3}He + {}^{4}He \rightarrow {}^{7}Be + \gamma}$$

$$^{7}\mathrm{Be} + e^{-} \rightarrow {}^{7}\mathrm{Li} + \nu$$

$$^{7}\mathrm{Li} + {}^{1}\mathrm{H} \rightarrow {}^{4}\mathrm{He} + {}^{4}\mathrm{He}$$

PPII

$$^{7}\mathrm{Be} + {}^{1}\mathrm{H} \rightarrow {}^{8}B + \gamma$$

$$^{8}B \rightarrow {}^{8}\mathrm{Be} + e^{+} + \nu$$

$$^{8}\mathrm{Be} \rightarrow {}^{4}\mathrm{He} + {}^{4}\mathrm{He}$$

PPIII

Current Data

- Two ways to measure the cross section
- First is by measuring prompt γ-rays from $^{3}\mathrm{He} + {}^{4}\mathrm{He} \rightarrow {}^{7}\mathrm{Be} + \gamma$
- Second is by measuring ^{7}Be decay: ${}^{7}\mathrm{Be} + e^{-} \rightarrow {}^{7}\mathrm{Li} + \nu$

- measurements for two methods consistently disagree
- the idea now is to do both simultaneously

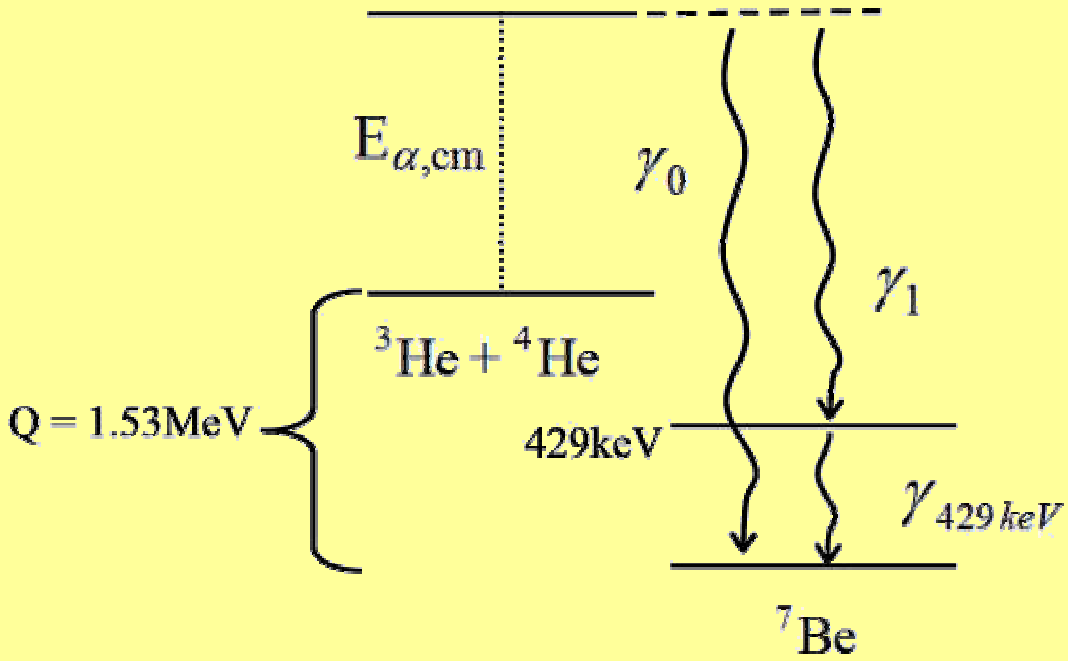
$S_{34}(0)$ (keV b)	Reference
by prompt γ-rays:	
0.47±0.05	*Parker and Kavanagh (1963)*
0.58±0.07	*Nagatani et al. (1969)*
0.45±0.06	*Kräwinkel et al. (1982)*
0.52±0.03	*Osborne et al. (1982, 1984)*
0.47±0.04	*Alexander et al. (1984)*
0.53±0.03	*Hilgemeier et al. (1988)*
Weighted Mean=	0.507±0.016
by ^{7}Be activity:	
0.535±0.04	*Osborne et al. (1982, 1984)*
0.63±0.04	*Robertson et al. (1983)*
0.56±0.03	*Volk et al. (1983)*
Weighted Mean=	0.572±0.026

Method 1: Prompt γ-rays

- count γ-rays coming from $^{3}He(\alpha,\gamma)^{7}Be$ reaction
- you will see three γ-rays: γ_{429}, γ_0, and γ_1

$$E_{\gamma 0} = Q + E_{\alpha,\mathrm{cm}}$$

$$E_{\gamma 1} = E_{\gamma 0} - 429\mathrm{keV}$$



Method 2: ^{7}Be decay

- count γ-rays coming from subsequent ^{7}Be decay
- any produced ^{7}Be will decay with $t_{1/2}$=53.12d
- ~10% decay to excited state of ^{7}Li

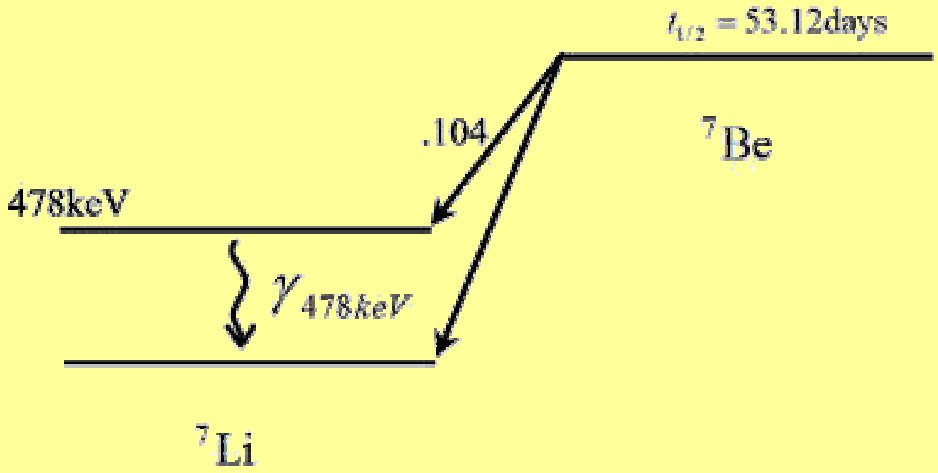
$$^{7}\mathrm{Be} + e^{-} \rightarrow {}^{7}\mathrm{Li} + \nu$$

$$\square$$

$$^{7}\mathrm{Li}^{*}(478\mathrm{keV}) + \nu$$

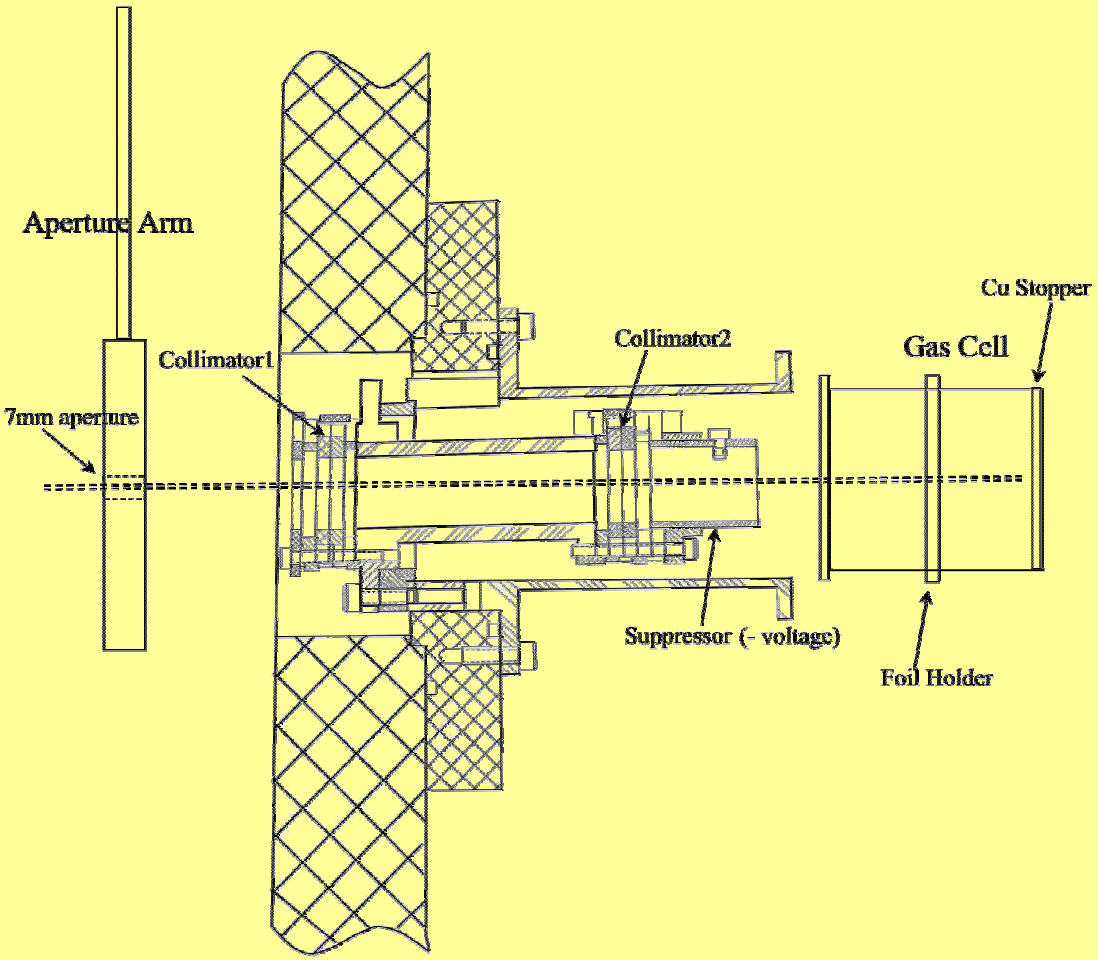
$$\downarrow$$

$$^{7}\mathrm{Li} + \gamma_{478}$$



Experimental Setup

- Using 3.5MeV α beam from VG accelerator
- size of beam controlled by aperture arm
- collimators focus beam and read current
- suppressor keeps e^- from reaching collimators
- Ni foil holds in ^3He gas
- target backing catches the created ^7Be

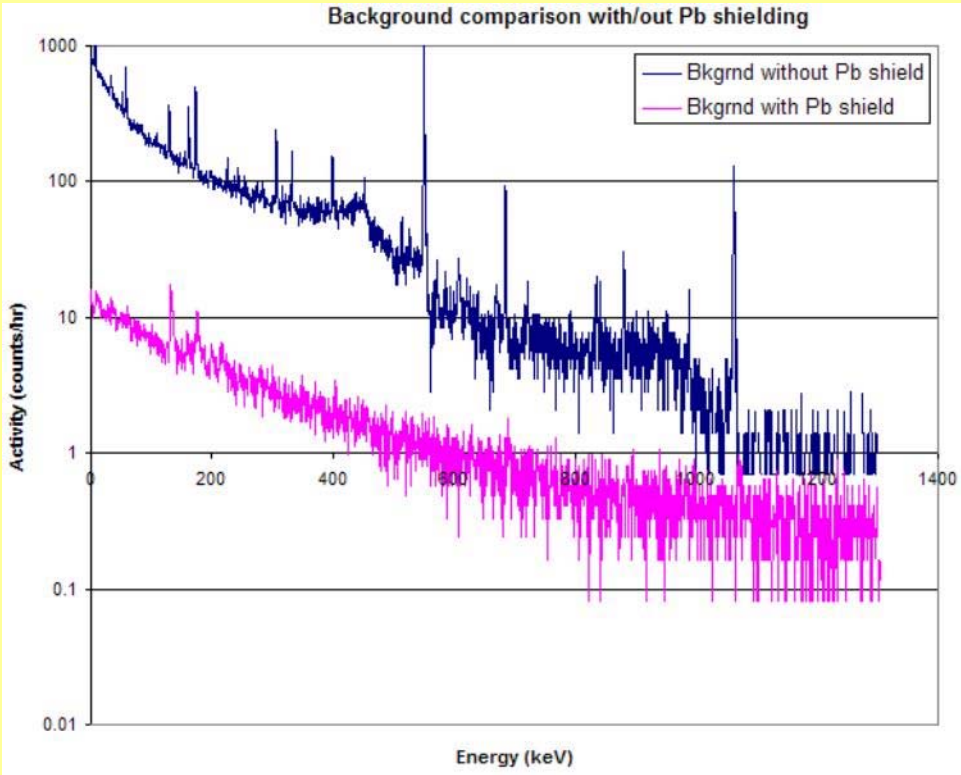


Pb shielding

Pb bricks were used to shield detector

- had a separate low-background room for counting delayed gammas

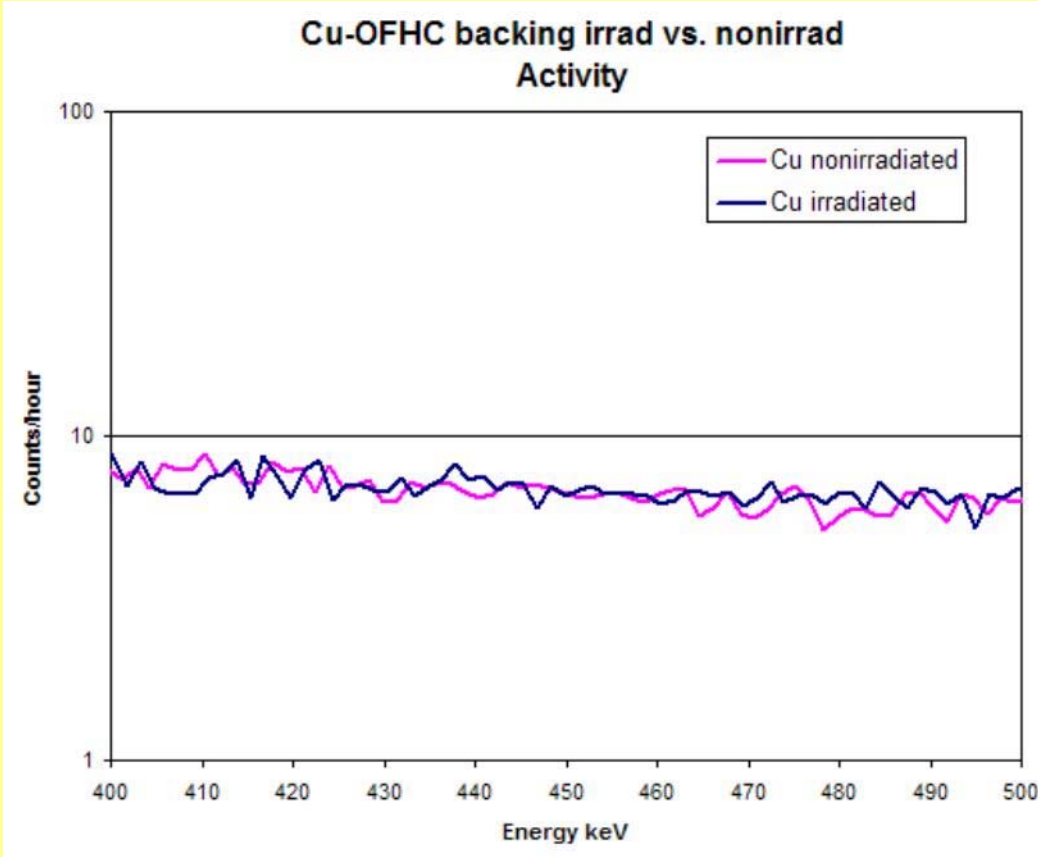
- the shielding that this room reduced bckgrnd by a factor of 13



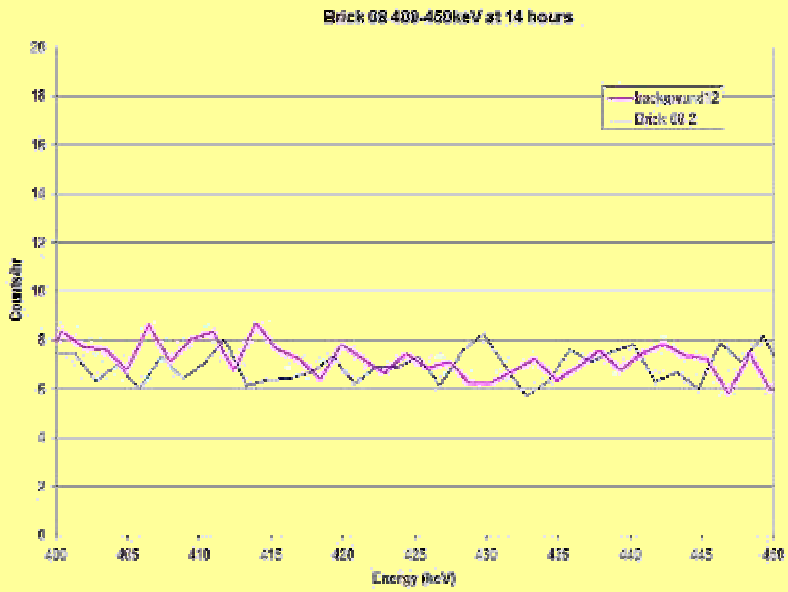
Question 1: Target backing material

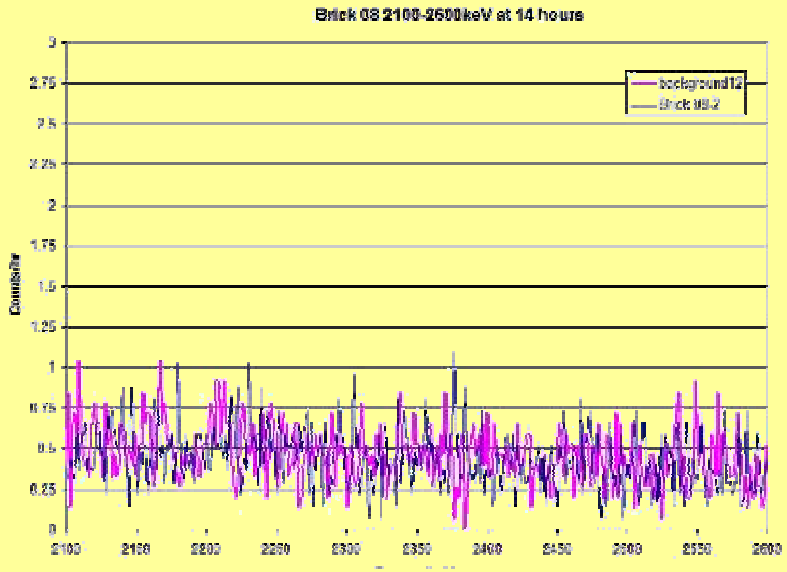
- the target backing catches the produced ^{7}Be, so we need to be able to see the 478keV line

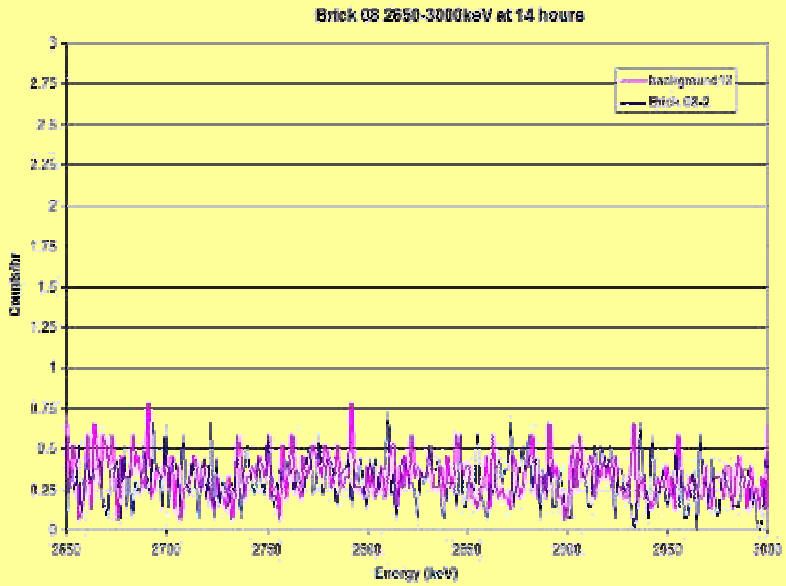
- high Z: less interactive
- low Z: less backscattering
- irradiated Cu-OFHC, Co, and Ni with alpha beam
- compared activity in 478keV region for before/after
- Cu-OFHC showed the cleanest activity; only 2% increase in before/after



Question 2: Brick contamination?





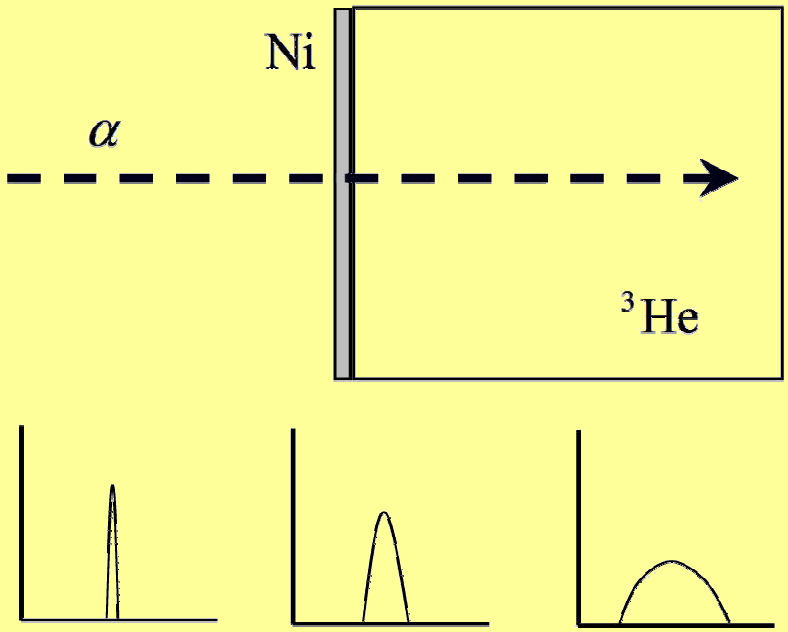


- bricks surround detector on beamline: will brick activity affect prompt γ-ray peaks?
- measured activity of sample of bricks
- no significant activity in the 3 regions of prompt γ-rays

Thickness of the Ni foil and gas

- alpha particles lose energy as they pass through foil and gas
- as they react with ^{3}He in different places, the high-E prompt γ-ray peaks broaden
- γ_{429} is not affected (excited state)
- γ_0, and γ_1 are affected, since the depend on alpha energy
- recall: $E_{\gamma 0} = Q + E_{\alpha,\mathrm{cm}}$

  $E_{\gamma 1} = E_{\gamma 0} - 429\mathrm{keV}$



$$E_{\alpha,lab} = E_{beam} - \Delta E_{foil} - \Delta E_{gas}(x)$$

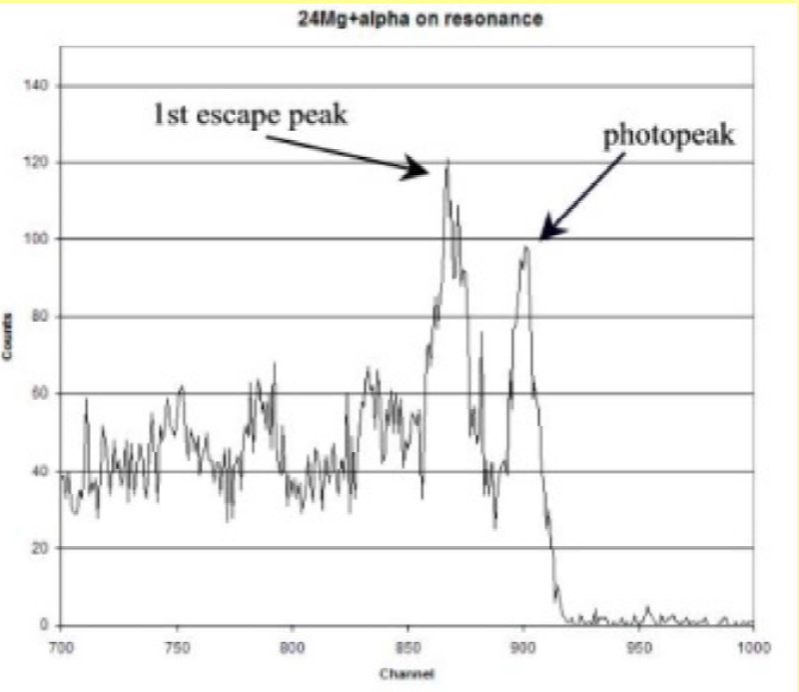
Thickness of the Ni foil and gas(cont.)

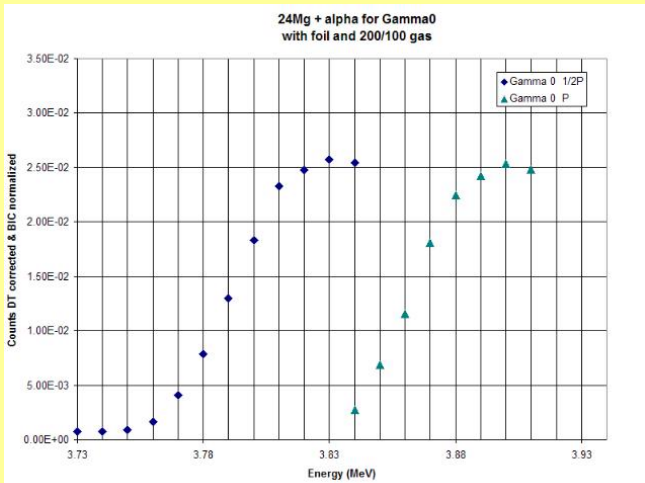
- use resonance of $^{24}Mg(\alpha,\gamma)^{28}Si$
- hit Mg target with alpha beam, vary the beam E and plot location of the photopeak
- if we vary the pressure of gas, and remove foil, the beam energy of the resonance shifts

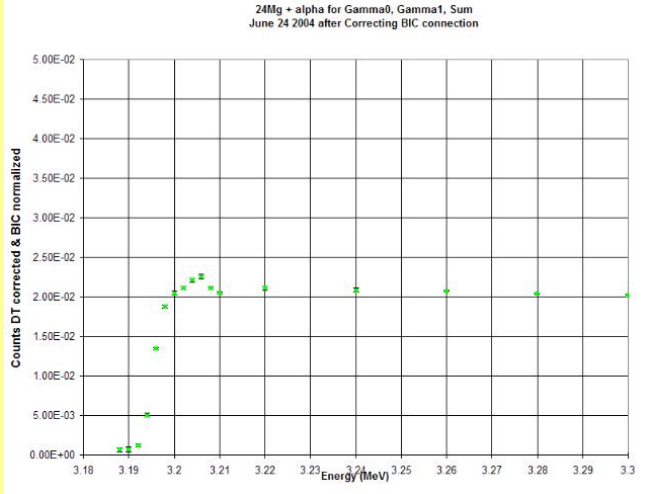
noP : 3.196MeV
P/2+foil: 3.79MeV
P+foil : 3.86MeV

$$> \Delta E_1 = \Delta E_{foil} + 1/2\Delta E_{gas} = .594\text{MeV}$$
$$> \Delta E_2 = -1/2\Delta E_{gas} = 0.07\text{MeV}$$

Find:
ΔE_{foil}=492keV and
ΔE_{gas}=188.16keV

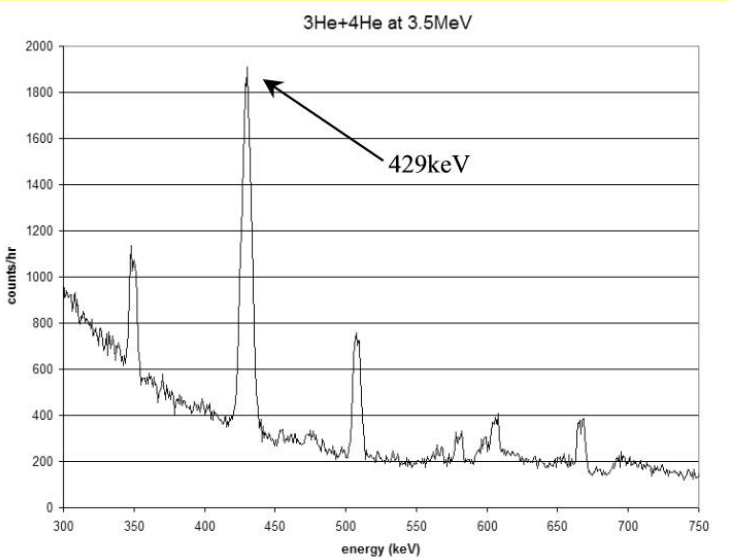


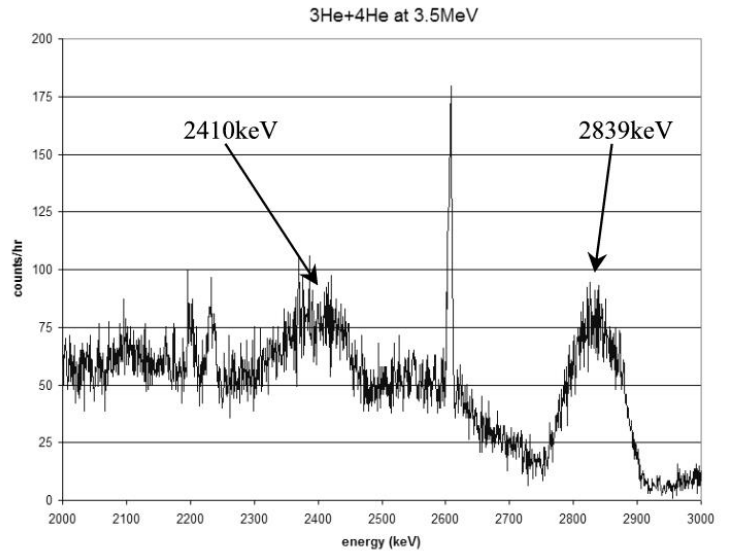




$^{3}He(\alpha,\gamma)^{7}Be$ Experiment

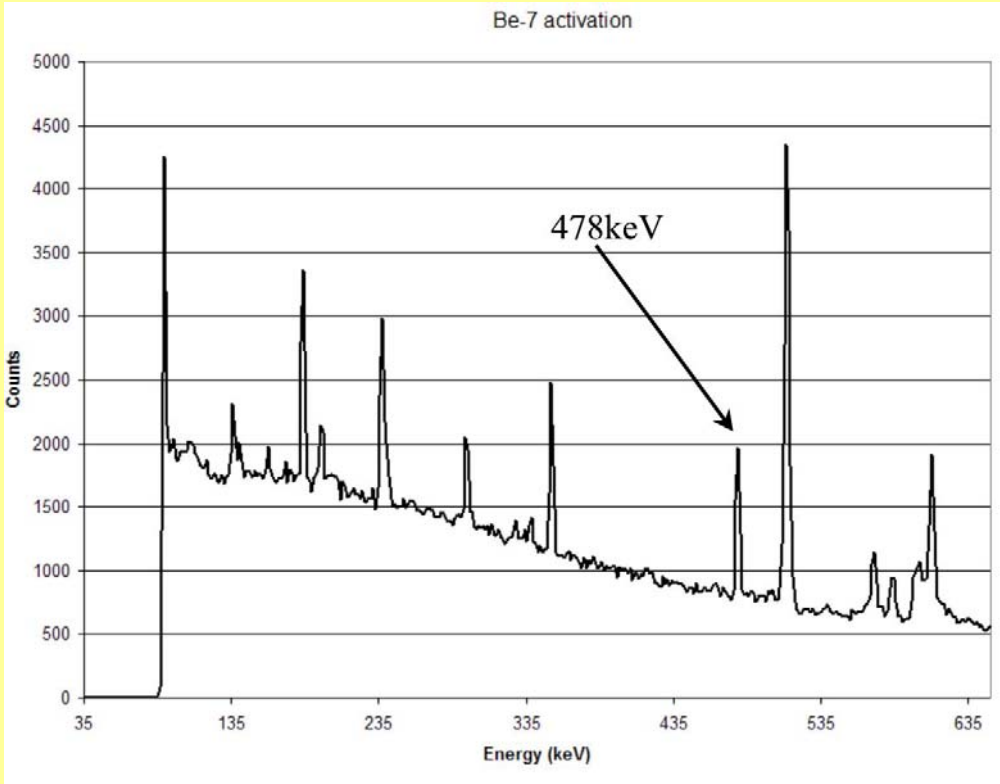
- did a test run, very imprecise; ran the experiment for 7 hours
- we did see the the three prompt gammas where they should be
- placed the target backing with the produced ^{7}Be in the lead house to count decays





^{7}Be counting

- we got the 478keV peak, which means we did produce enough ^{7}Be measure
- take the area of the peak to get the yield, Y
- the number of ^{7}Be atoms produced is calculated by using the simple exponential decay formula:



$$N_{Be} = \frac{Y_{478}}{0.104\varepsilon\left(1 - e^{-\lambda \Delta t_c}\right)} \approx 5.5 \times 10^{6} \ {}^{7}\text{Be atoms}$$

Final Thoughts

- a lot was accomplished this summer to make a test run possible (I can't possibly describe it all in this presentation)
- unfortunately we were not able to make an estimate of the cross section
- BUT…we showed that the experiment does work,
- and of course many improvements must be made before a cross section measurement can be attempted

Thanks are in order for…

- my mentors: Kurt Snover and Derek Storm
- Cristina Bordeanu, whom I worked directly with the whole summer
- Kamil Michniki, Doug Will and Greg Harper, if for nothing else, then for their senses of humor