^{3}He(α,γ)^{7}Be with DRAGON

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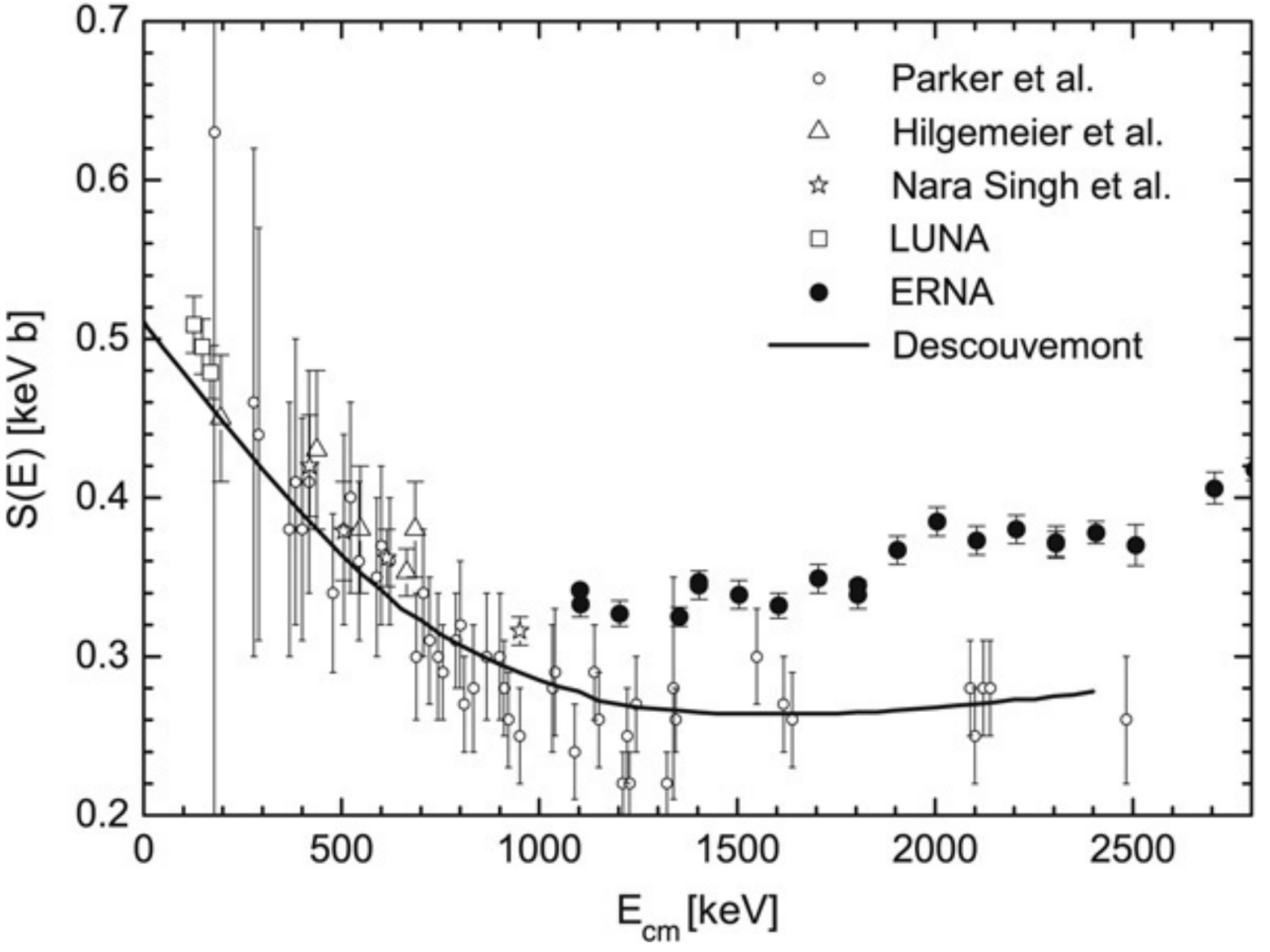
Background Interest

- SOLAR NEUTRINOS: $\phi_\nu(^7\text{Be}) \propto S_{34}^{0.86}$,$\phi_\nu(^8\text{B}) \propto S_{34}^{0.81}$
  $\sigma(E) = \dfrac{S(E)}{E} e^{-2\pi\eta}$
- BIG BANG NUCLEOSYNTHESIS: $^3\text{He}(\alpha,\gamma)^7\text{Be}$
  $^7\text{Be} \rightarrow {}^7\text{Li} + \beta^+ + \nu_e$ ($\tau_{1/2} \approx$53 days)

The predictions of BBN are robust because essentially all input microphysics is well determined: The relevant energies, 0.1 to 1 MeV, are well explored in nuclear physics laboratories, and with the possible exception of ^{7}Li, the experimental uncertainties have minimal impact. (Schramm and Turner, Reviews of Modern Physics **70**, 303 (1998).

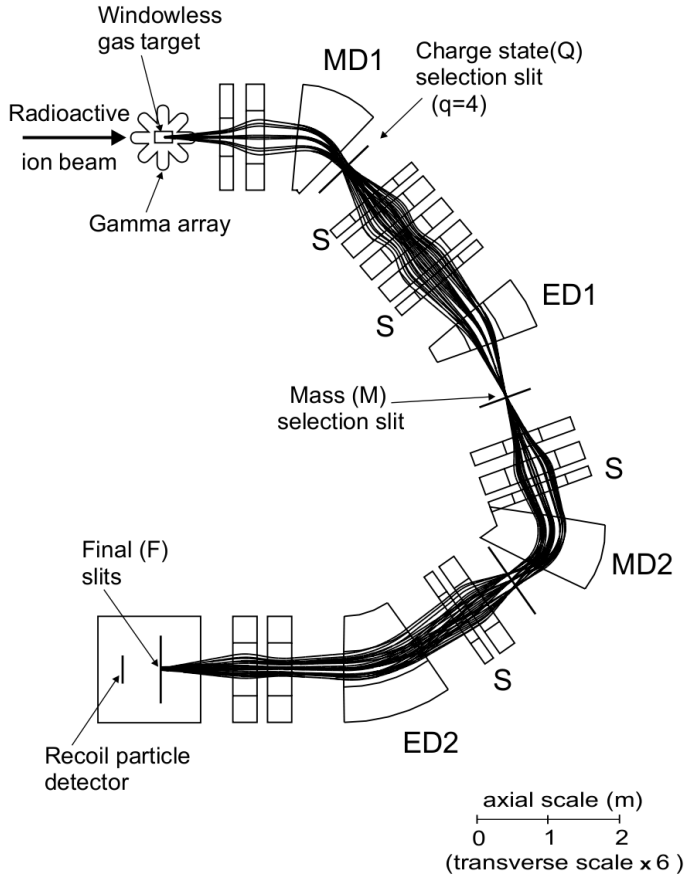
Experimental Interest



Parker and Kavanaugh, Physical Review **131** (1963).

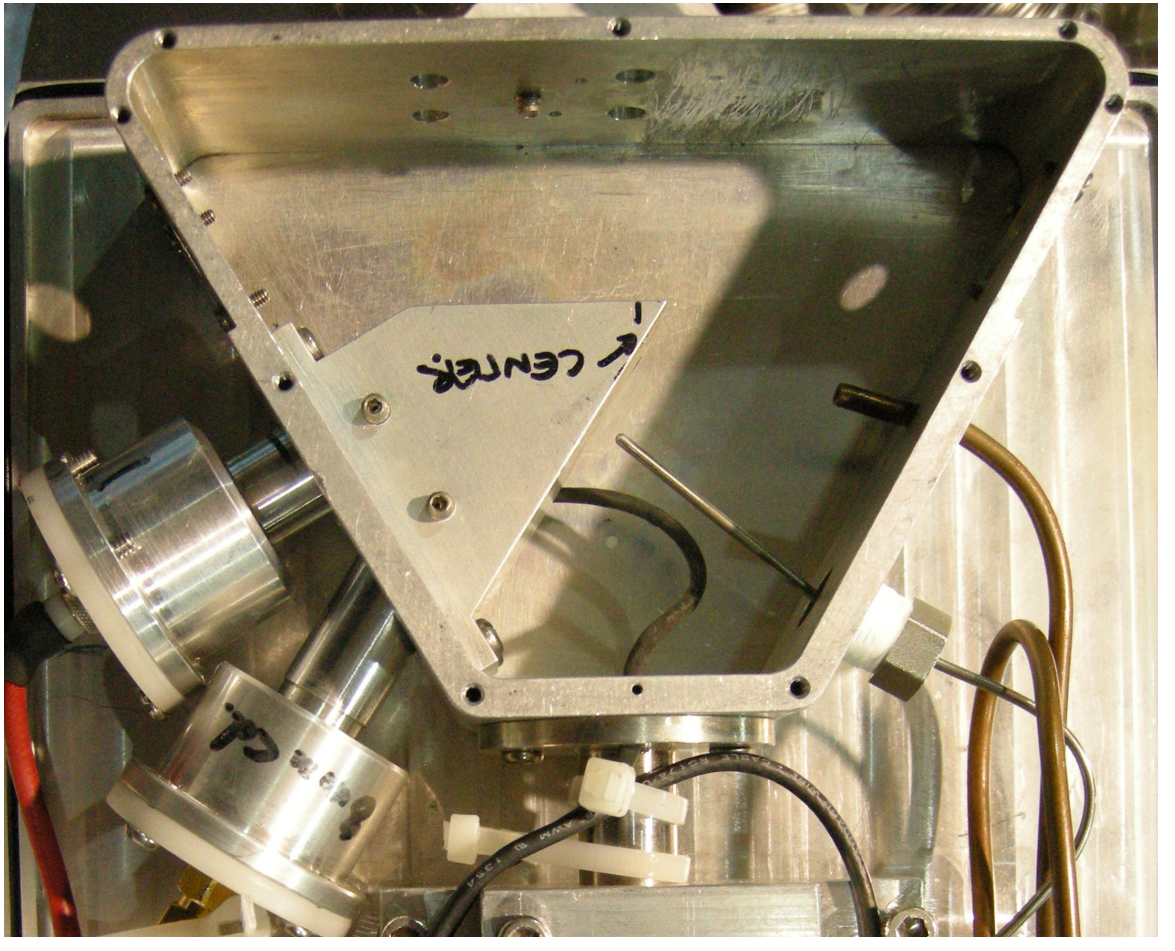
A. di Leva *et al*, Nuclear Instruments and Methods in Physics **59**, 562 (2008).

DRAGON Separator



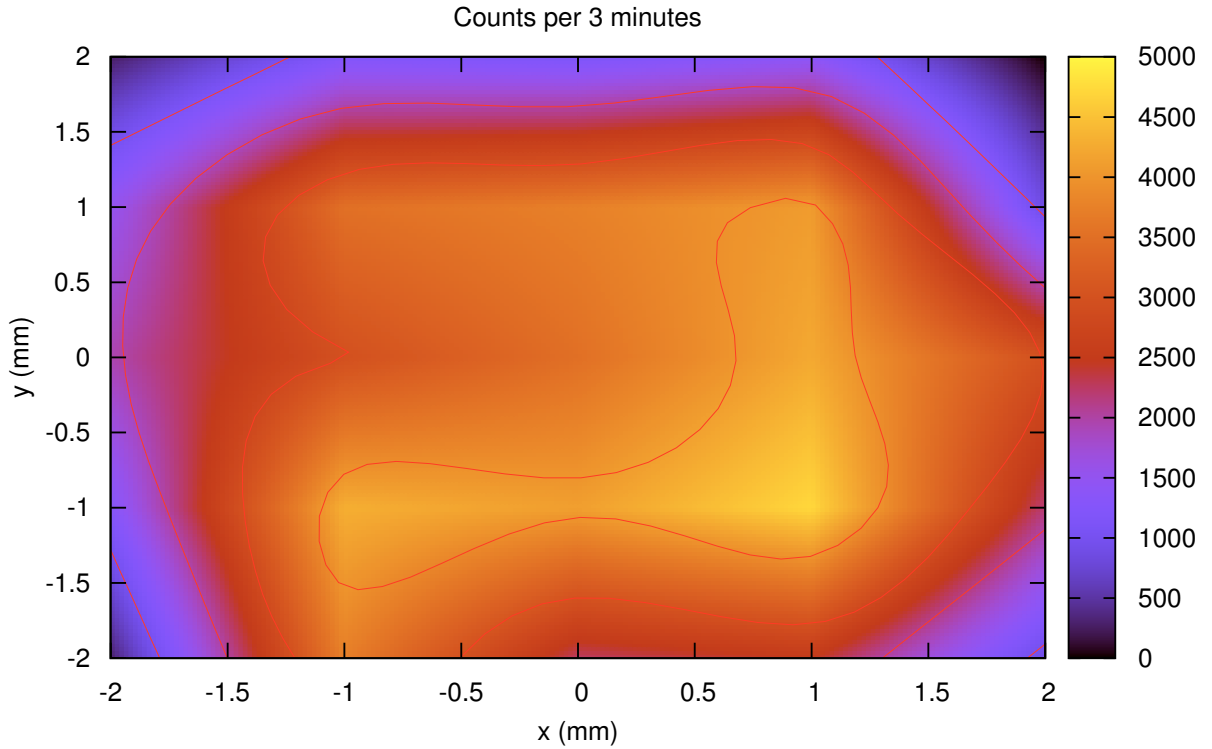
Beam suppression is $\mathcal{O}(10^{10})$ or better

Windowless Gas Target



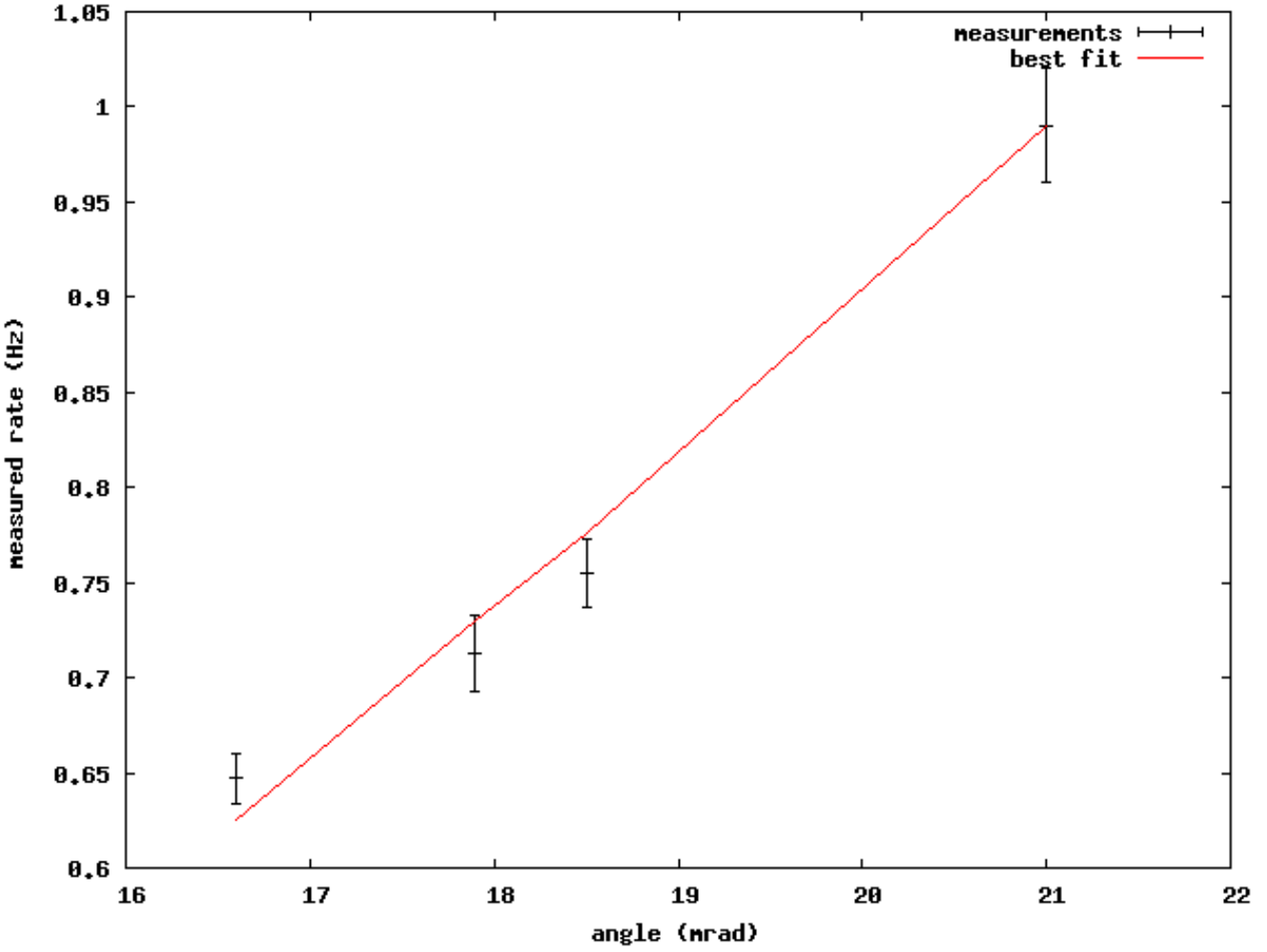
For a resonant capture, reactions will generally be localized.
For nonresonant capture, reactions will not be localized.

First Acceptance Measurement



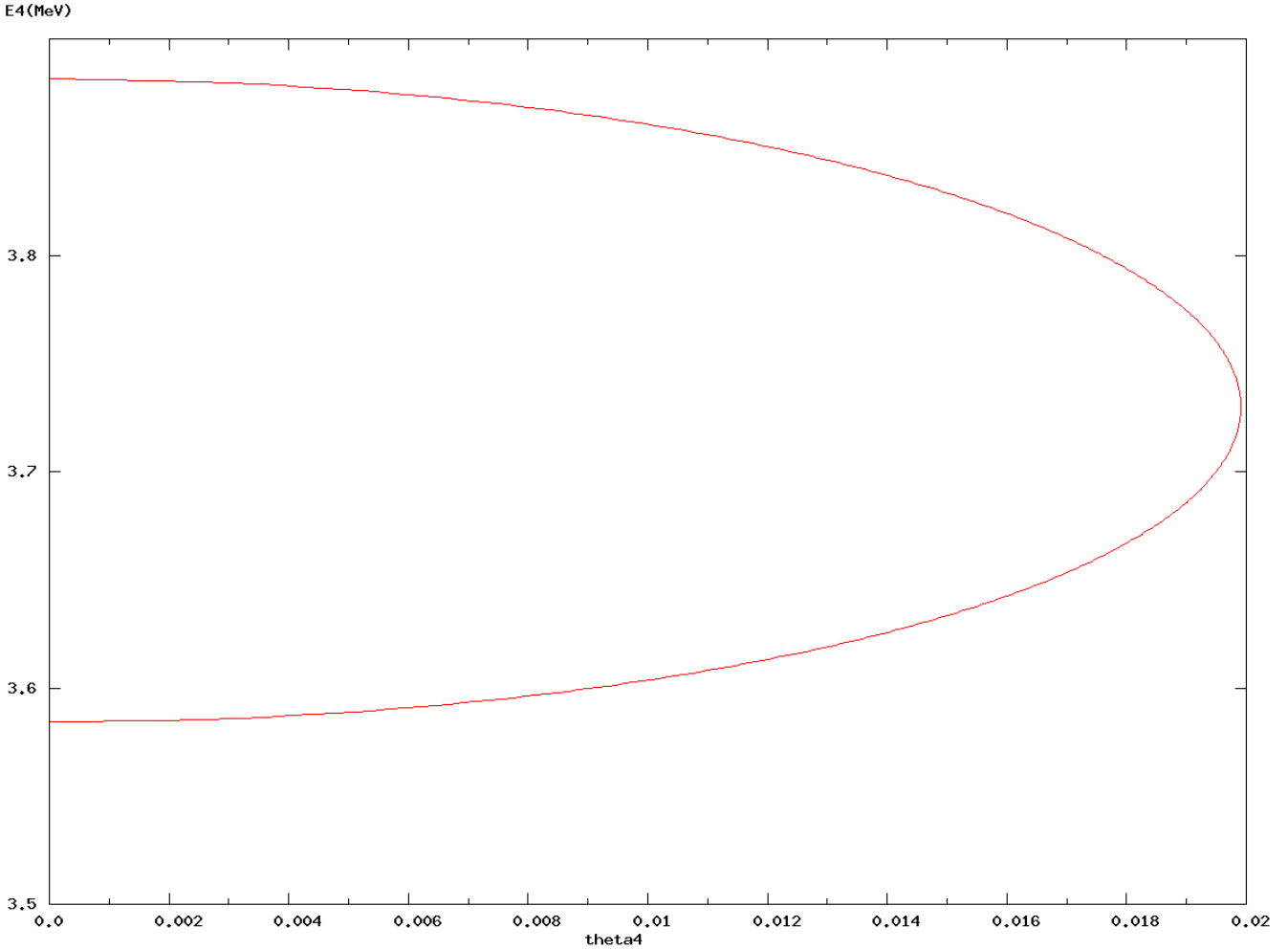
Gd α source made at TRIUMF

First Acceptance Measurement



1 mm aperture on hot spot of Gd α source at center of gas target

^{7}Be Recoil Cone

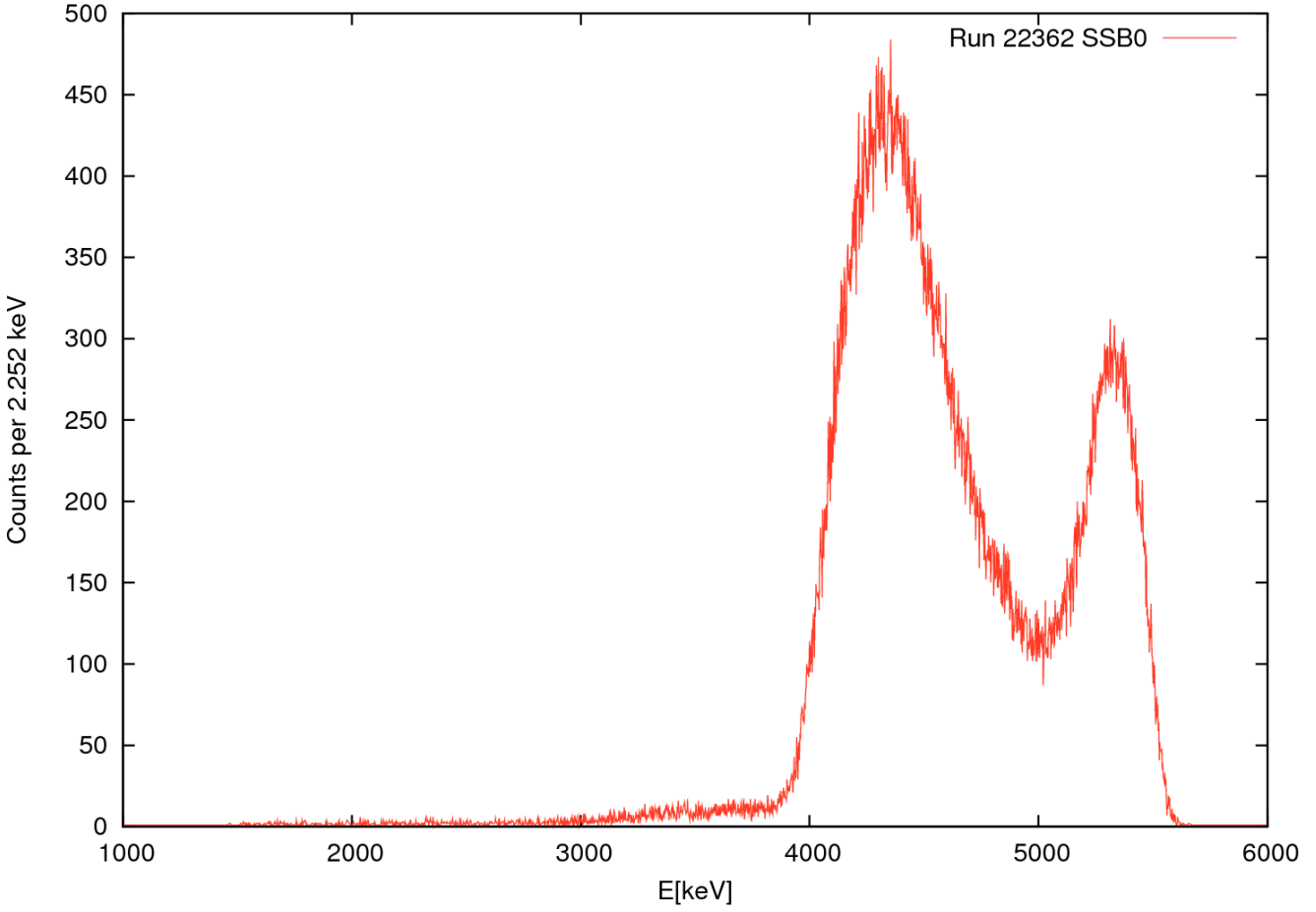


The ^{7}Be recoils push the limits of DRAGON's acceptance

Source Mount

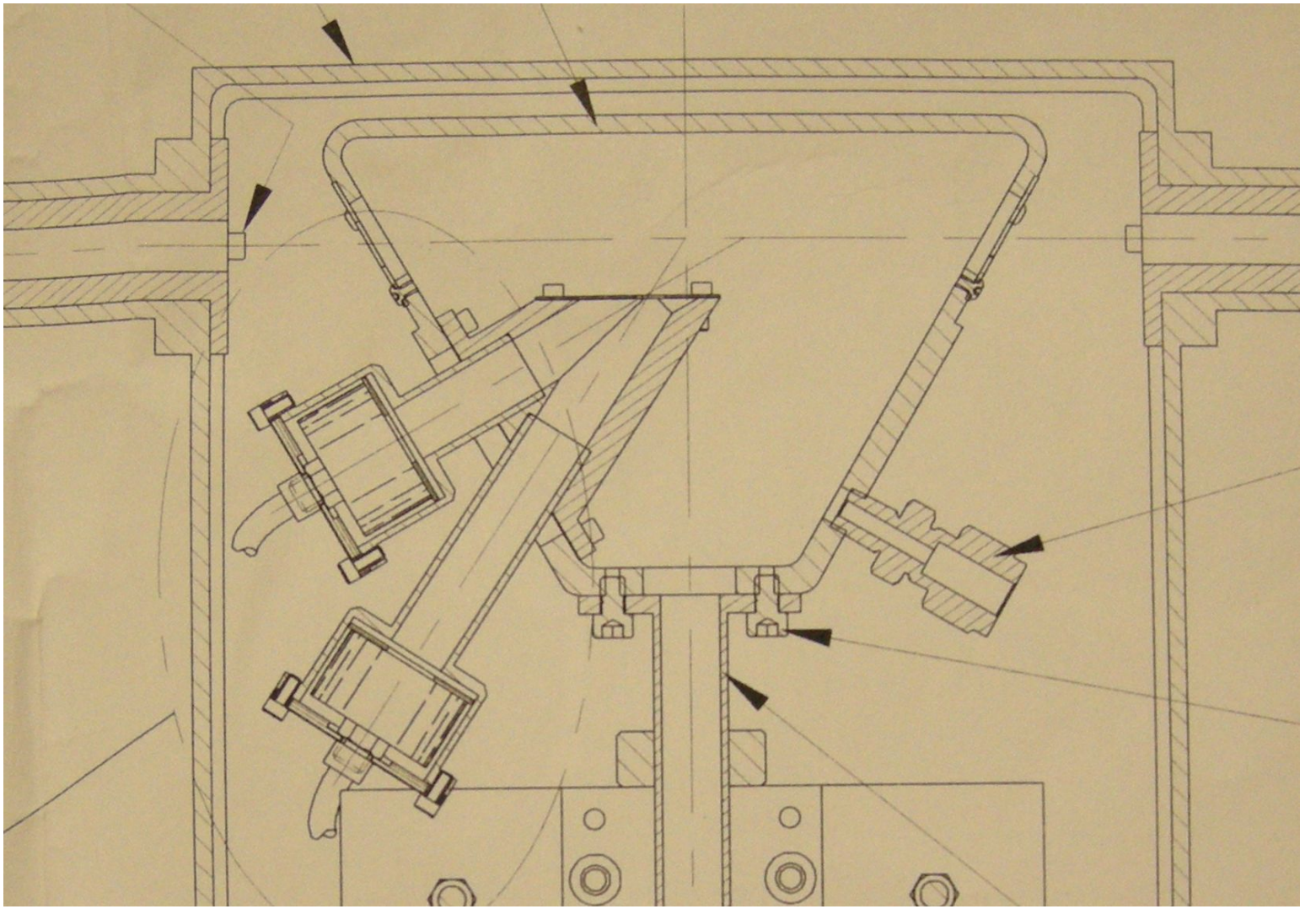
We will measure acceptance as a function of x, y and z in the target!

Confusing Data

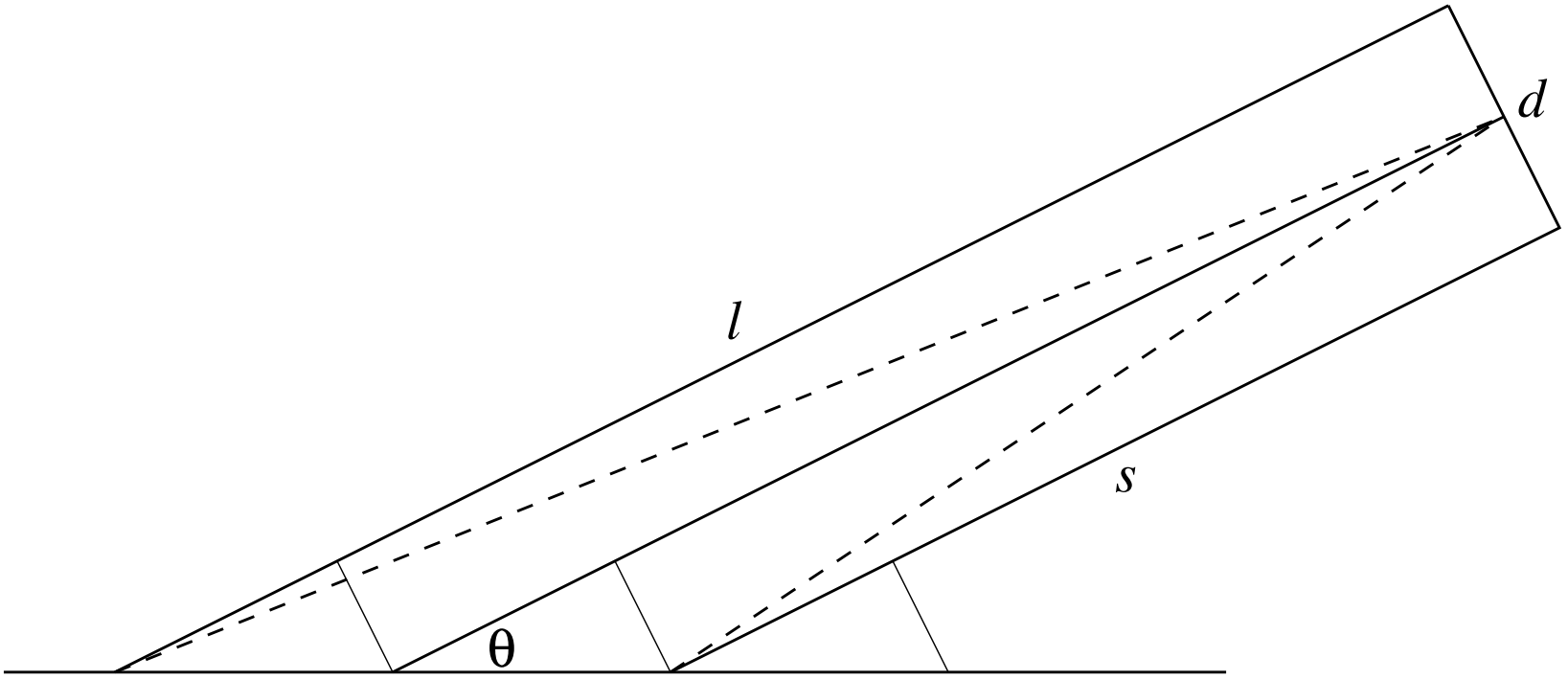


Spectrum from a “30°” SSB detector in the gas cell during the run

Geometry



Trigonometry

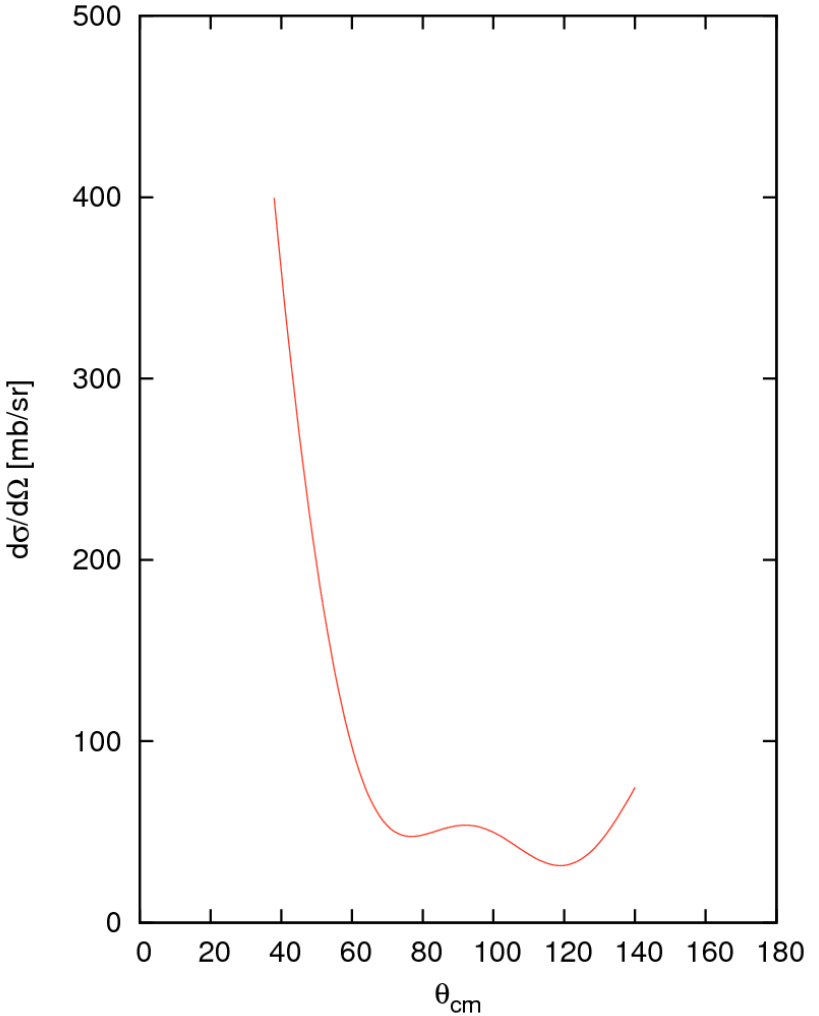


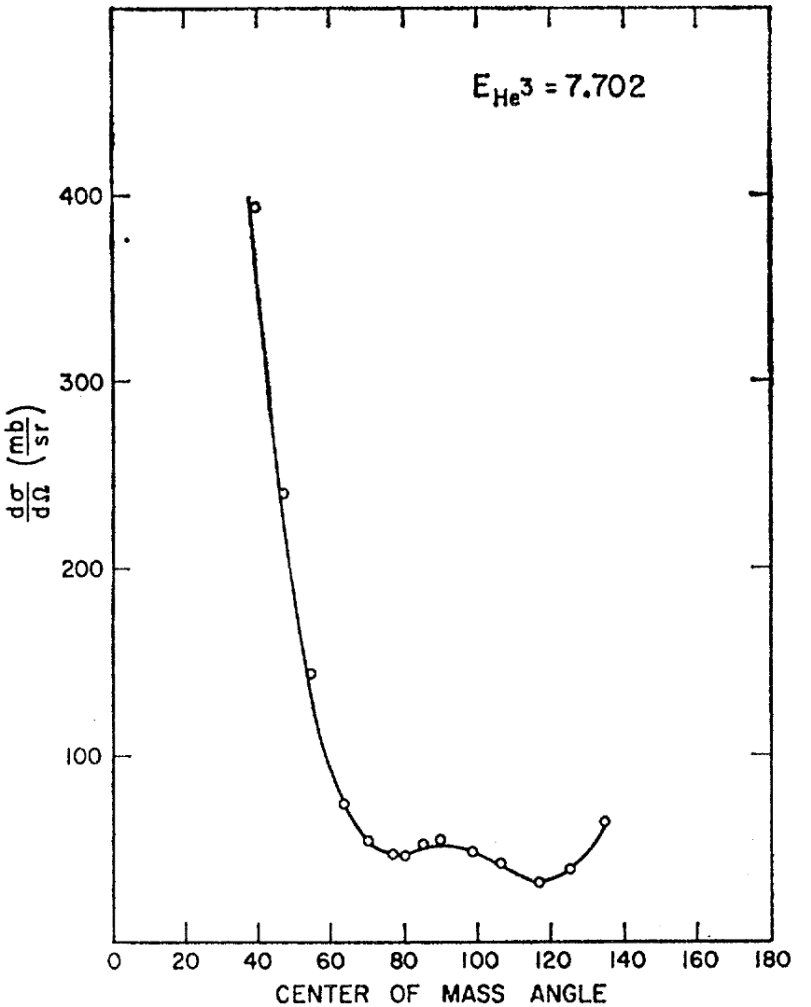
$$\theta_{min} = 30^\circ - \arctan\frac{d}{2l}$$

$$\theta_{max} = 30^\circ + \arctan\frac{d}{2s}$$

A crucial aperture was missing from the SSB detector setup so a large range of angles could reach the detector.

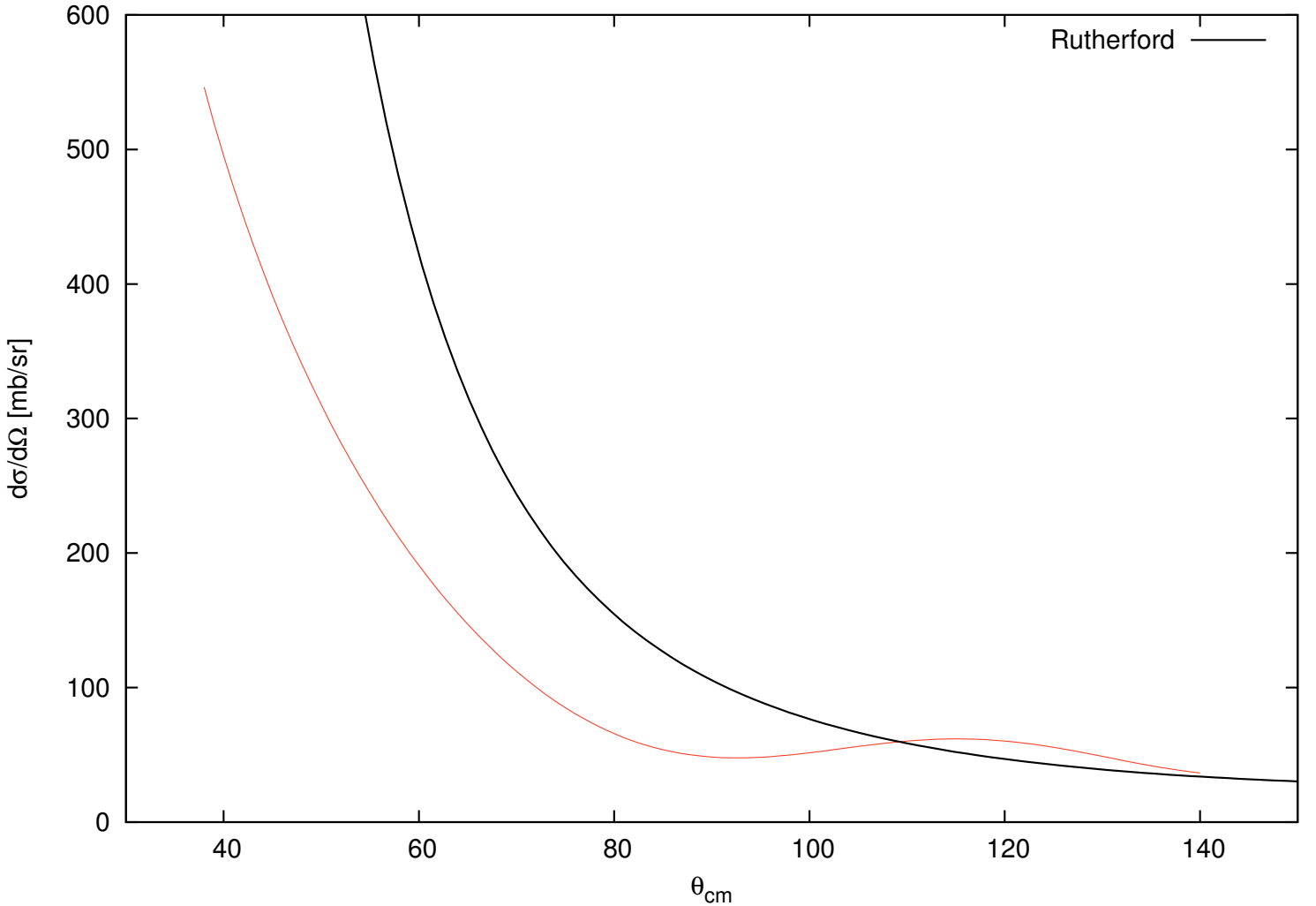
^{3}He(α,α)^{3}He cross sections





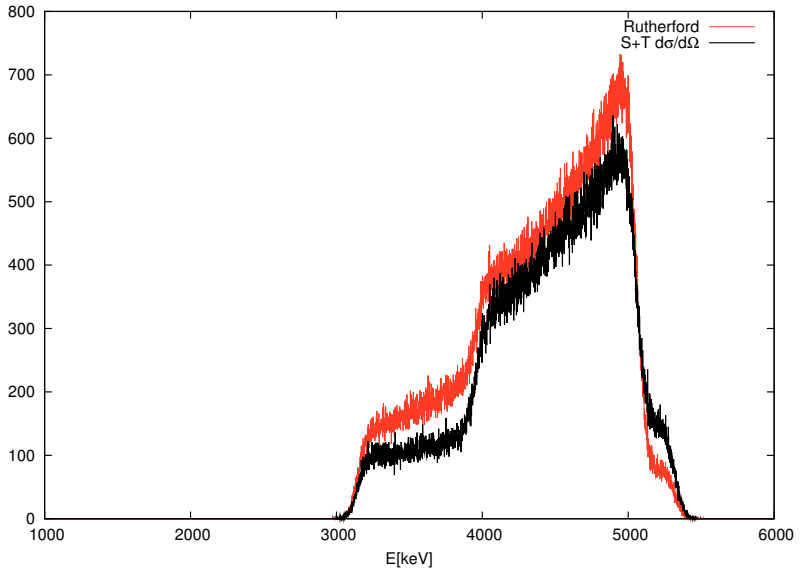
From Spiger and Tombrello, Physical Review **164**, 964 (1967). NB: $\delta_{l\pm}$ vs δ_{J^π} and $\sum_{l=1}^{\infty}$ vs $\sum_{l=0}^{\infty}$!

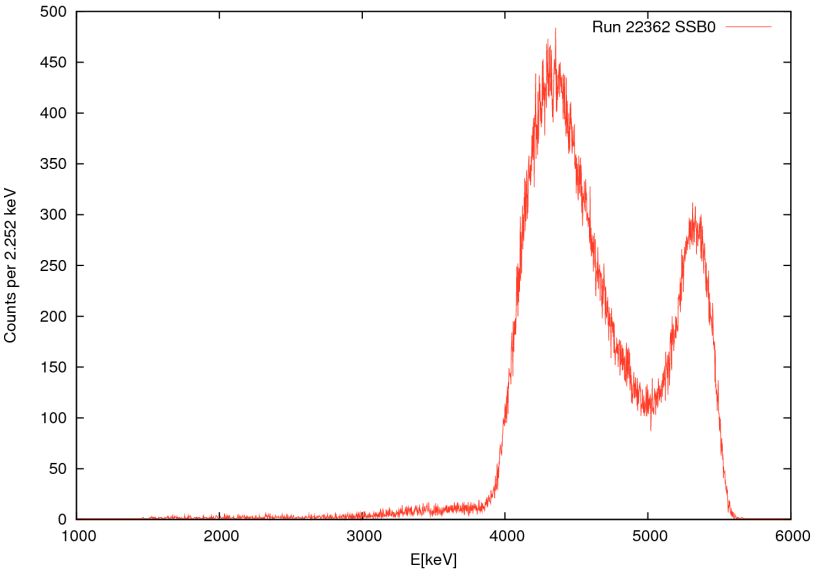
^{3}He(α,α)^{3}He cross sections



at $E_{^3He} = 4.9$ MeV or $E_\alpha = 6.55$ MeV or $E_{rel} = 2.8$ MeV

30° SSB simulation vs data

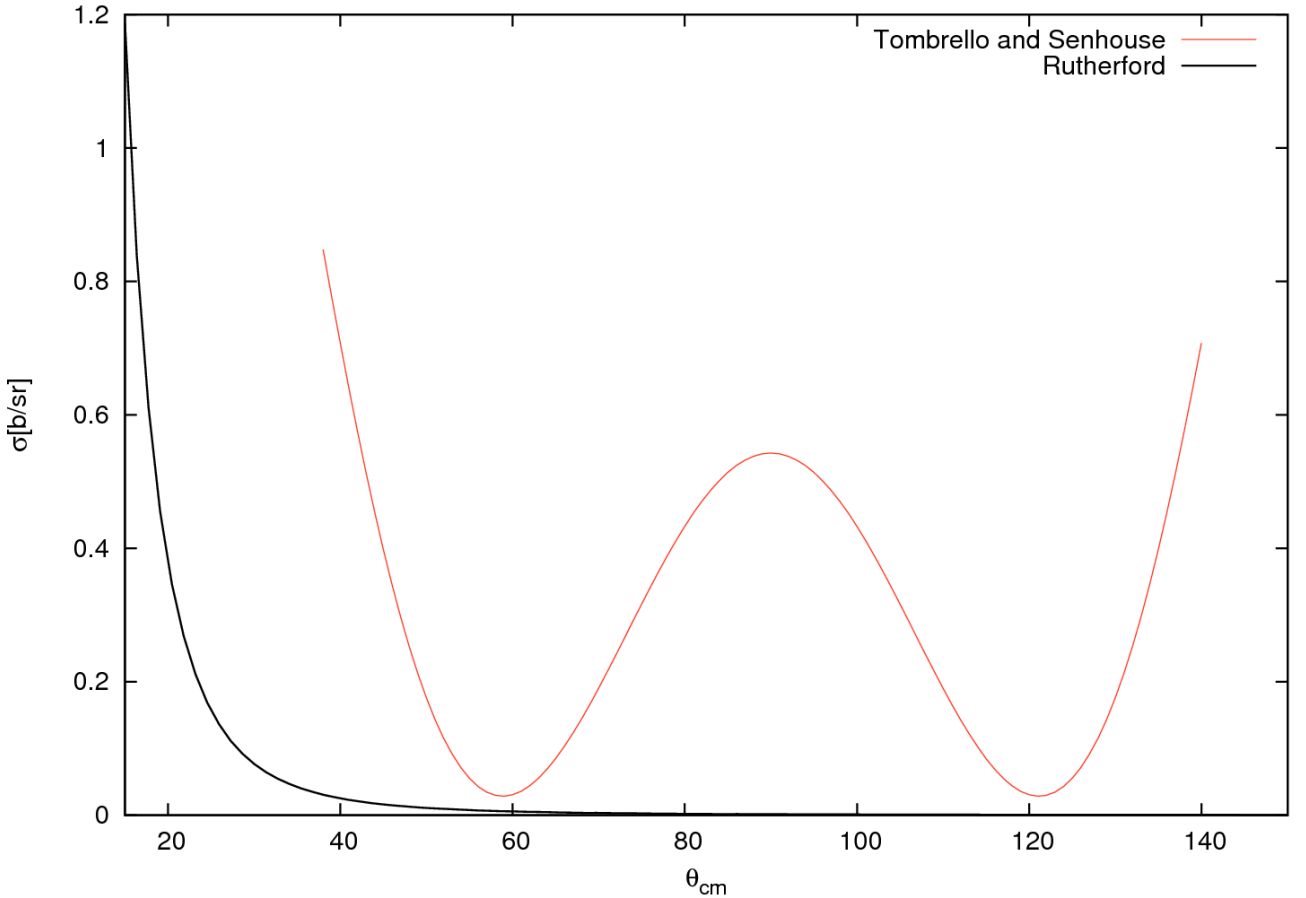




And the data win by a lineshape!

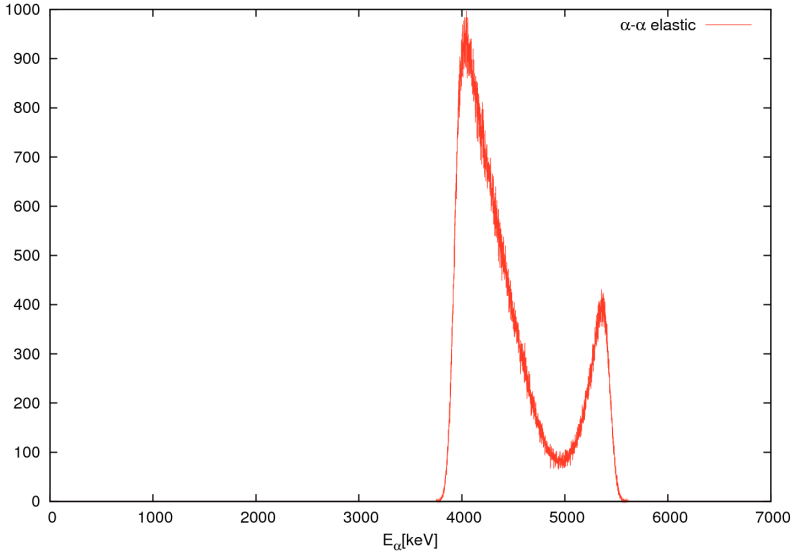
But what if our gas also had ^{4}He in it?

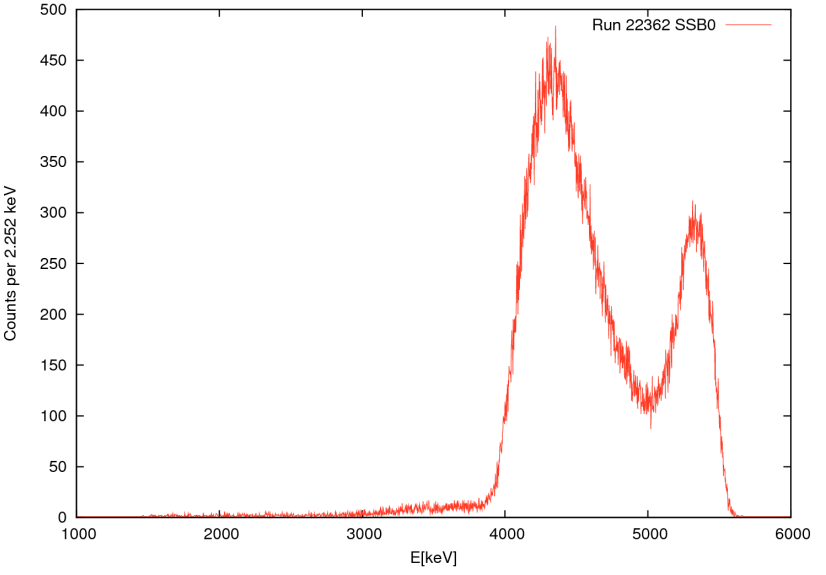
^{4}He(α,α)^{4}He cross sections



at $E_\alpha = 6.47$ MeV or $E_{rel} = 3.24$ MeV from Physical Review **129**, 2252 (1963). Strictly speaking, my figure is faulty and the $\theta_{\rm cm}$ should only go to 90° because they are identical particles.

The Smoking Gun?

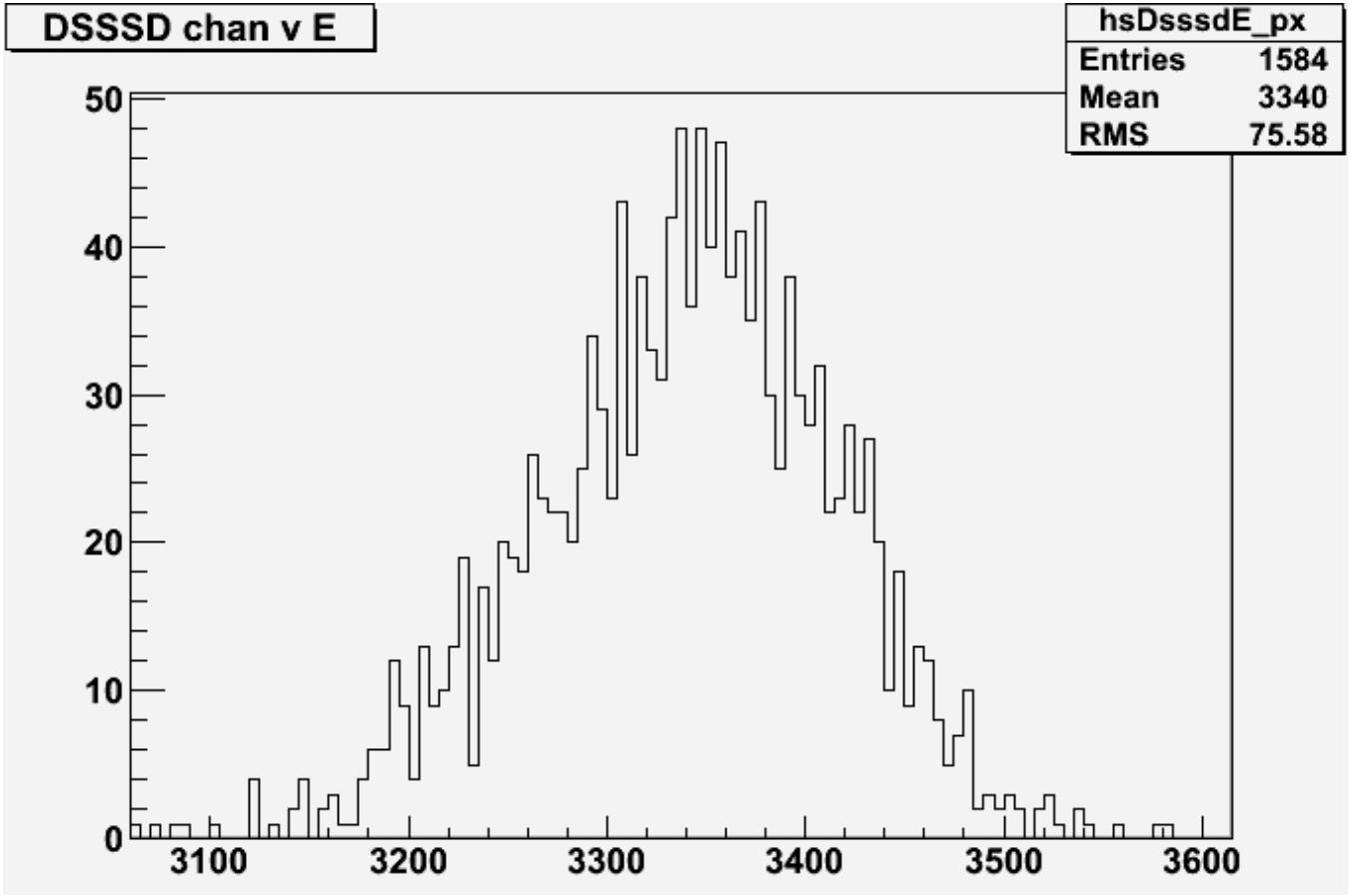




The rough simulation of $\alpha - {}^4$He scattering looks an awful lot like the data. An added fraction of ^{3}He lineshape (shown two slides ago) reproduces the overall lineshape quite well.

Pure ^{3}He has been ordered.

Real Recoil Data



These are ^{7}Be recoils from one run (about 2 hrs?) so current limitations are not statistical!

Next Run

- Measure gas density profile using ^{3}He(^{12}C,p)^{14}N
- Resonance at 1.0 MeV/u decays by 6.44 MeV γ rays. We will detect them with the BGO detectors and measure the target's gas density profile.