$^{3}He(\alpha,\gamma)^{7}Be$ Cross Section Measurement- Project Overview

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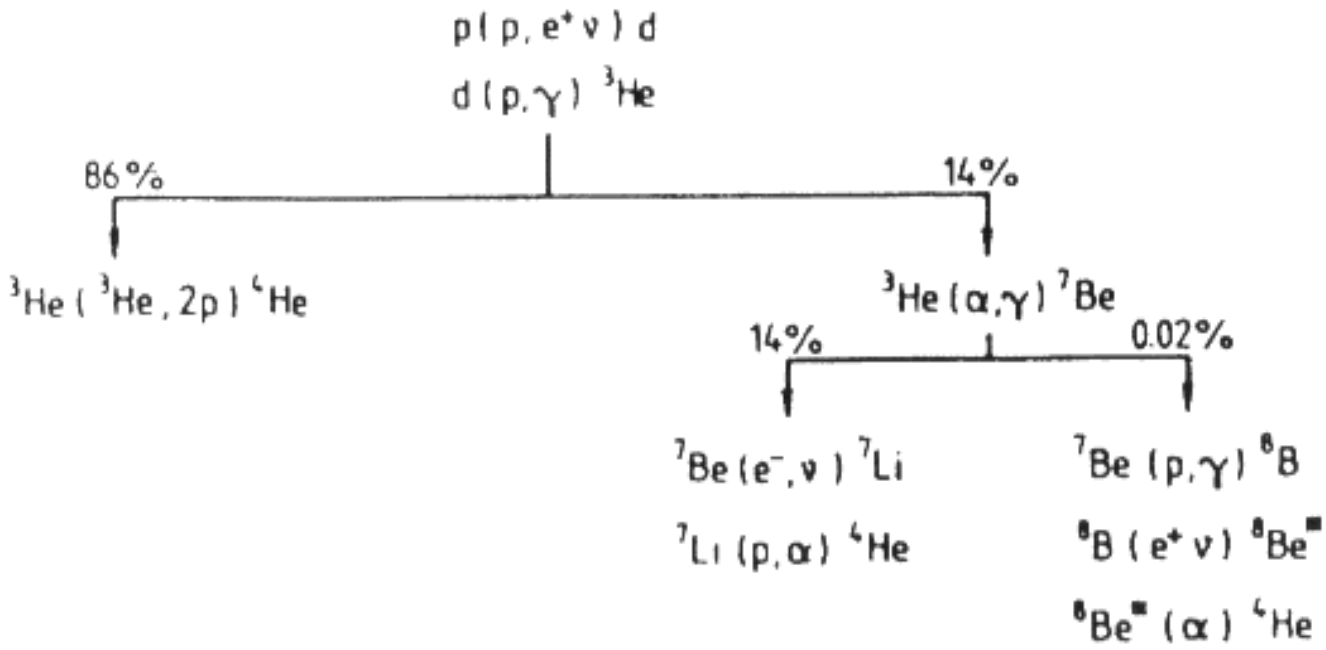


pp I

Q_{eff} = 26.20 MeV

pp II

Q_{eff} = 25.66 MeV

pp III

Q_{eff} = 19.17 MeV

Reaction energy in the Sun

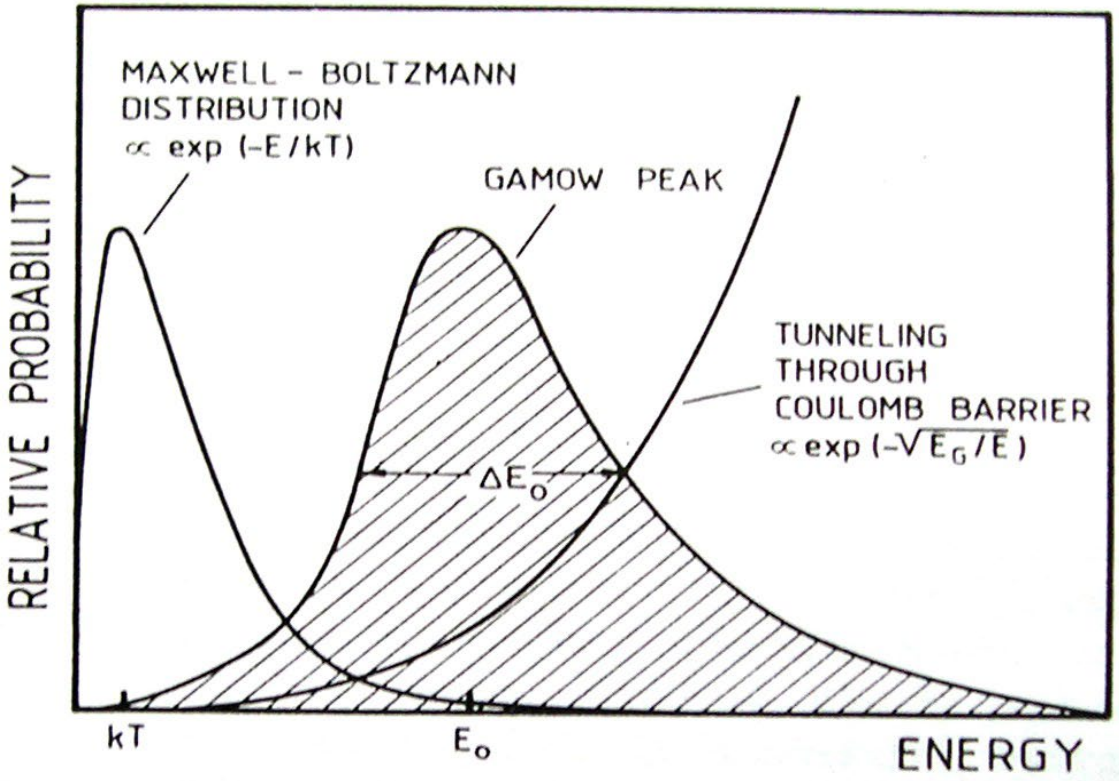
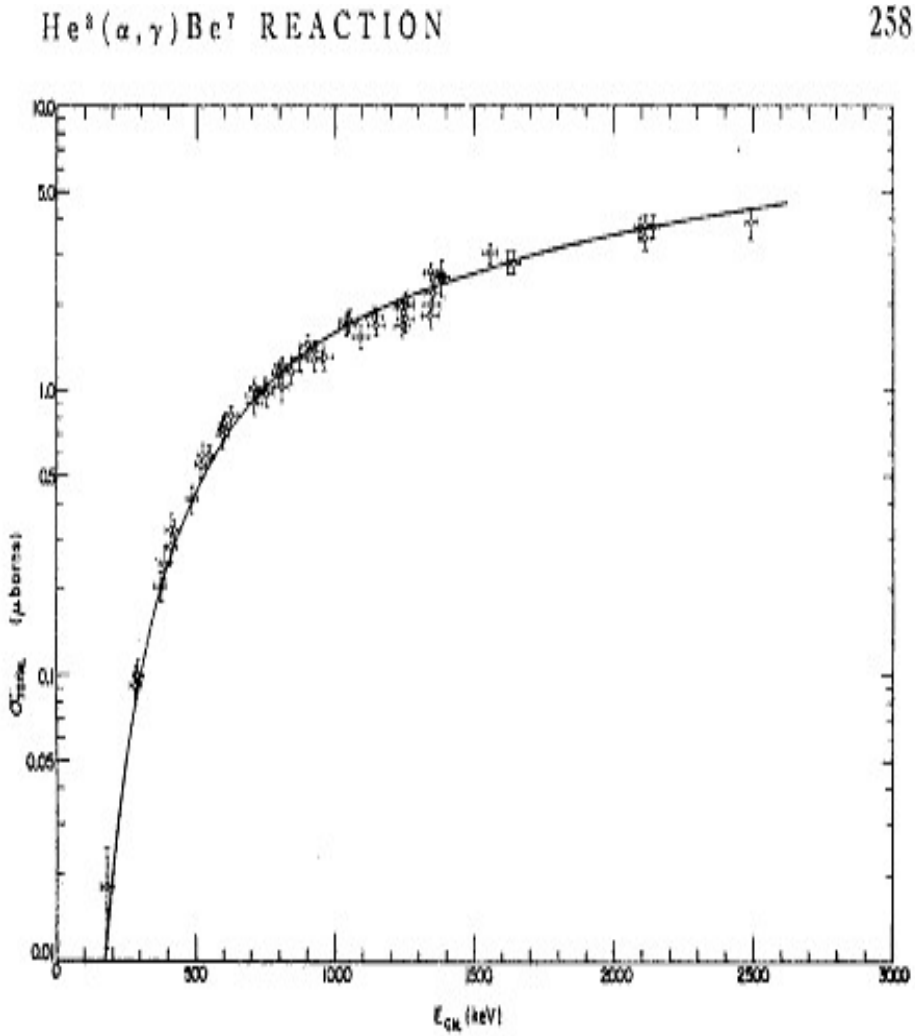


FIGURE 4.6. The dominant energy-dependent functions are shown for nuclear reactions between charged particles. While both the energy distribution function (Maxwell-Boltzmann) and the quantum mechanical tunneling function through the Coulomb barrier are small for the overlap region, the convolution of the two functions results in a peak (the Gamow peak) near the energy E_0, giving a sufficiently high probability to allow a significant number of reactions to occur. The energy of the Gamow peak is generally much larger than kT.

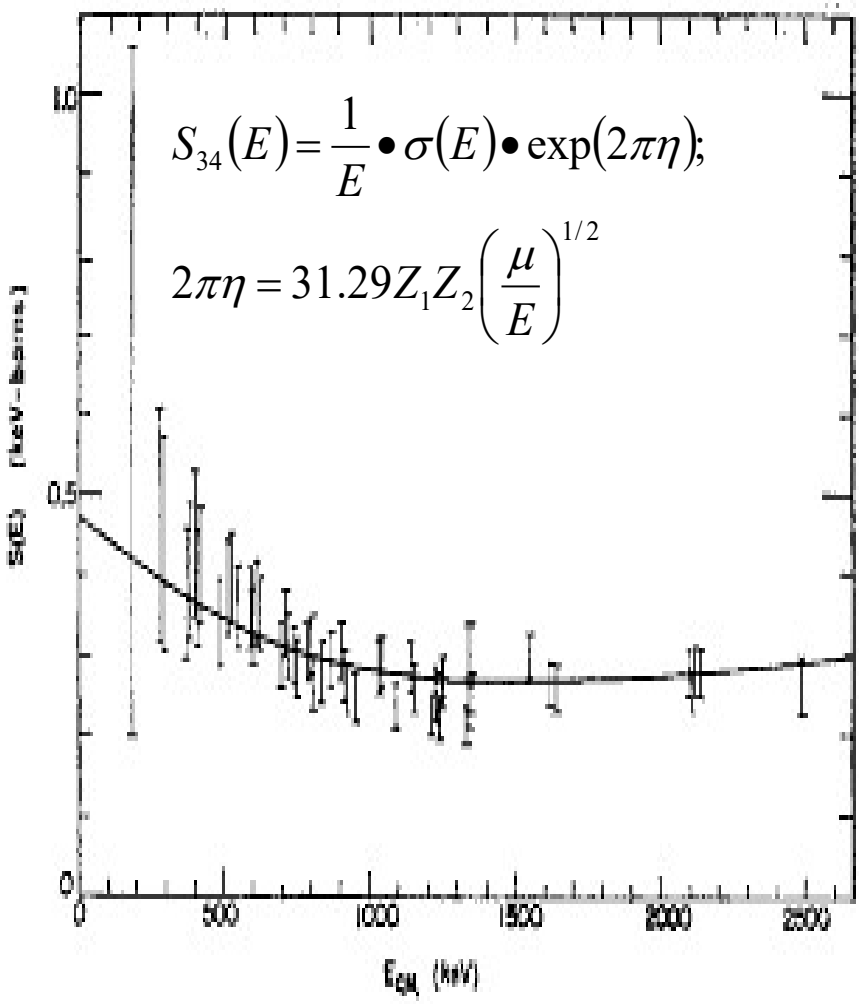
Statement of the Problem

Determine S_{34} (0) with an accuracy <5%



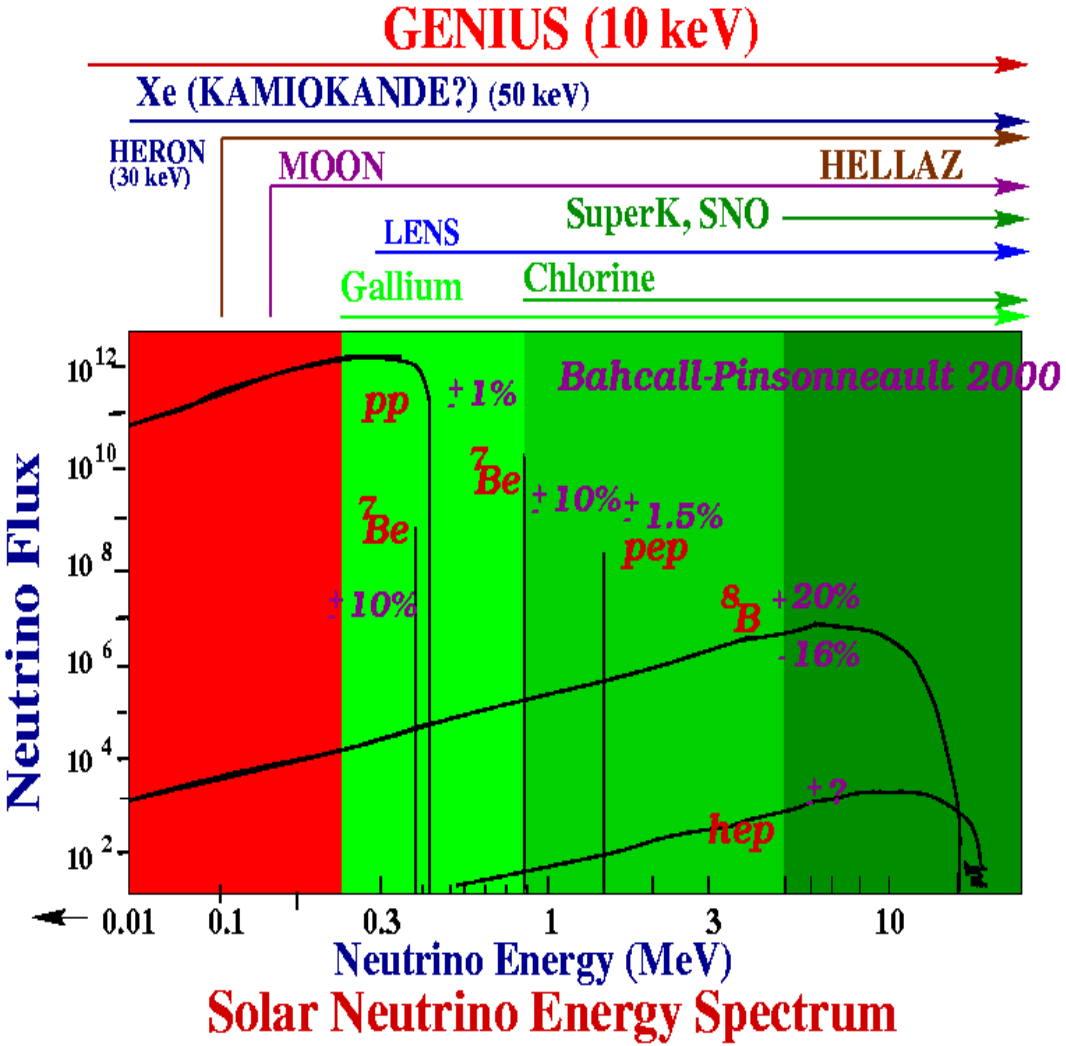
$$S_{34}(E) = \frac{1}{E} \bullet \sigma(E) \bullet \exp(2\pi\eta);$$

$$2\pi\eta = 31.29 Z_1 Z_2 \left(\frac{\mu}{E}\right)^{1/2}$$



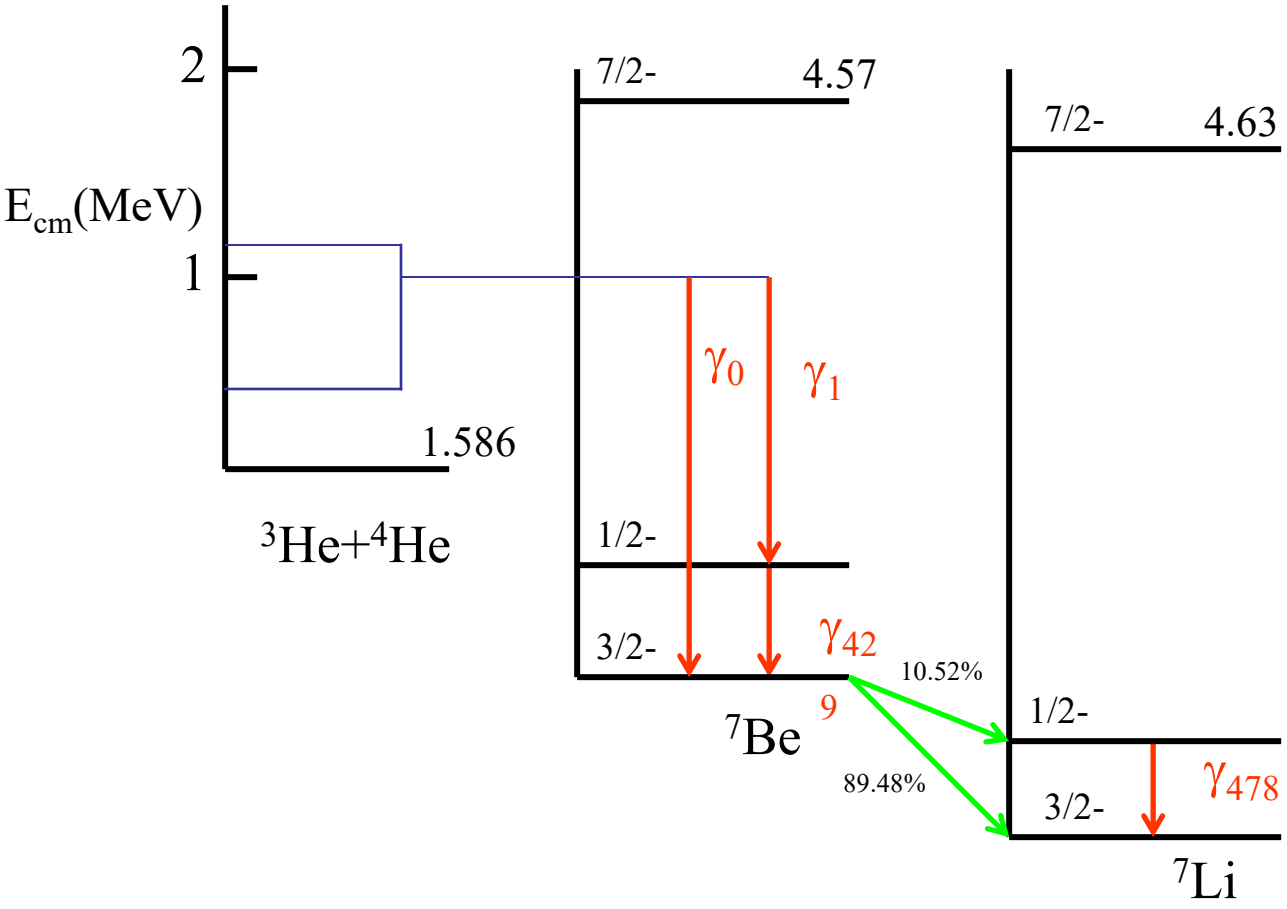
Why measure $S_{34}(0)$?

SSM : $S_{34}(0)=0.53(5)$keVb[1]
SBBN: $S_{34}(0)=0.54(9)$keVb[2]
R matrix: $=0.51(4)$keVb[3]



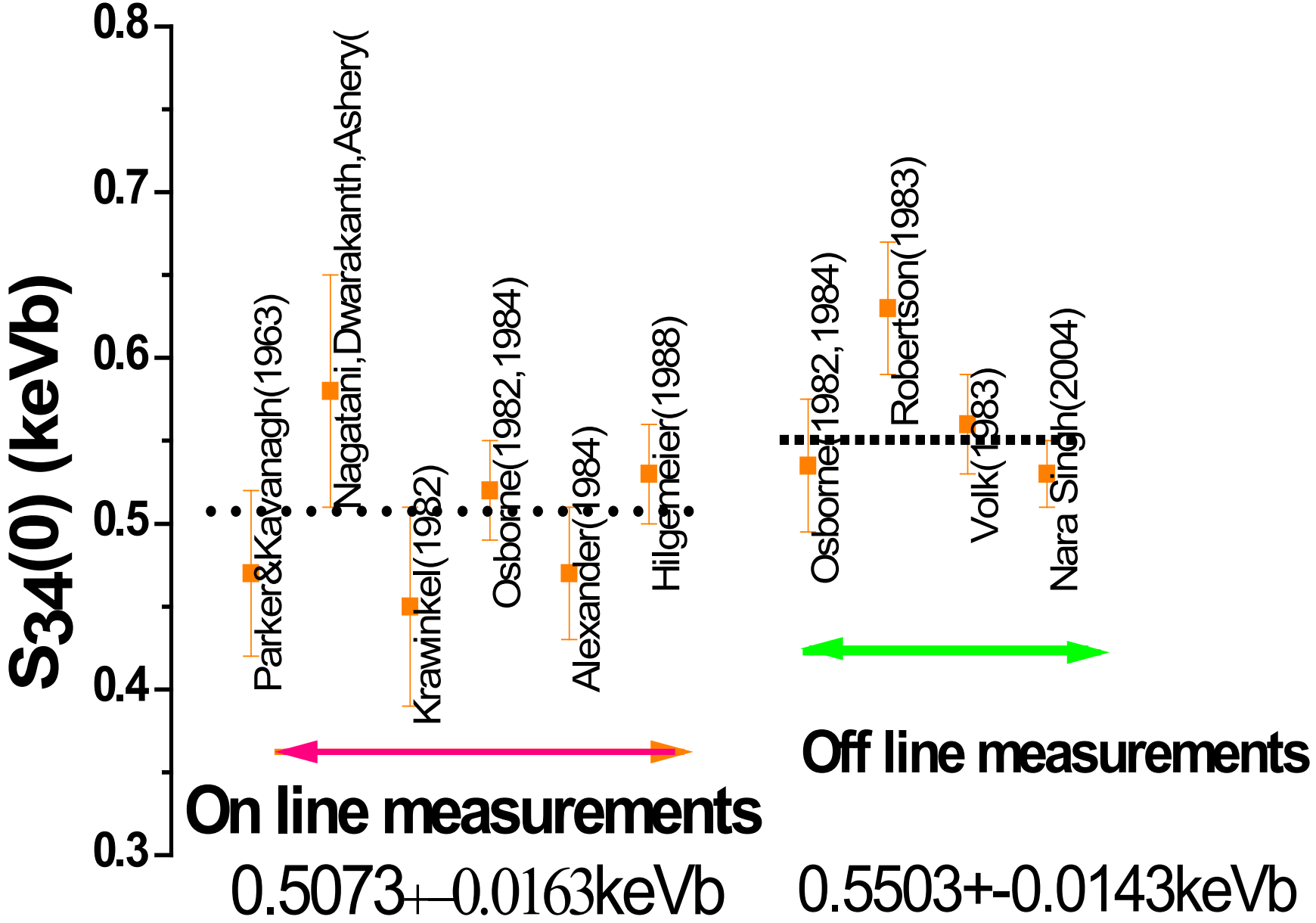
1- E.Adelberger RevModPhys70,1265,1998
2-C.Angulo NPA656,3,1999
3-P.Descouvermont DNDT 88,203,2004

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



Online Measurements:
Capture γ-rays:
$\gamma_0,\gamma_1,\gamma_{429}$

Offline Measurements:
^{7}Be decay: **γ_{478}**


S34(0) (keVb)
0.8
0.7
0.6
0.5
0.4
0.3
Parker&Kavanagh(1963)
Nagatani,Dwarakanth,Ashery(
Krawinkel(1982)
Osborne(1982,1984)
Alexander(1984)
Hilgemeier(1988)
Osborne(1982,1984)
Robertson(1983)
Volk(1983)
Nara Singh(2004)
On line measurements
Off line measurements
0.5073+-0.0163keVb
0.5503+-0.0143keVb

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

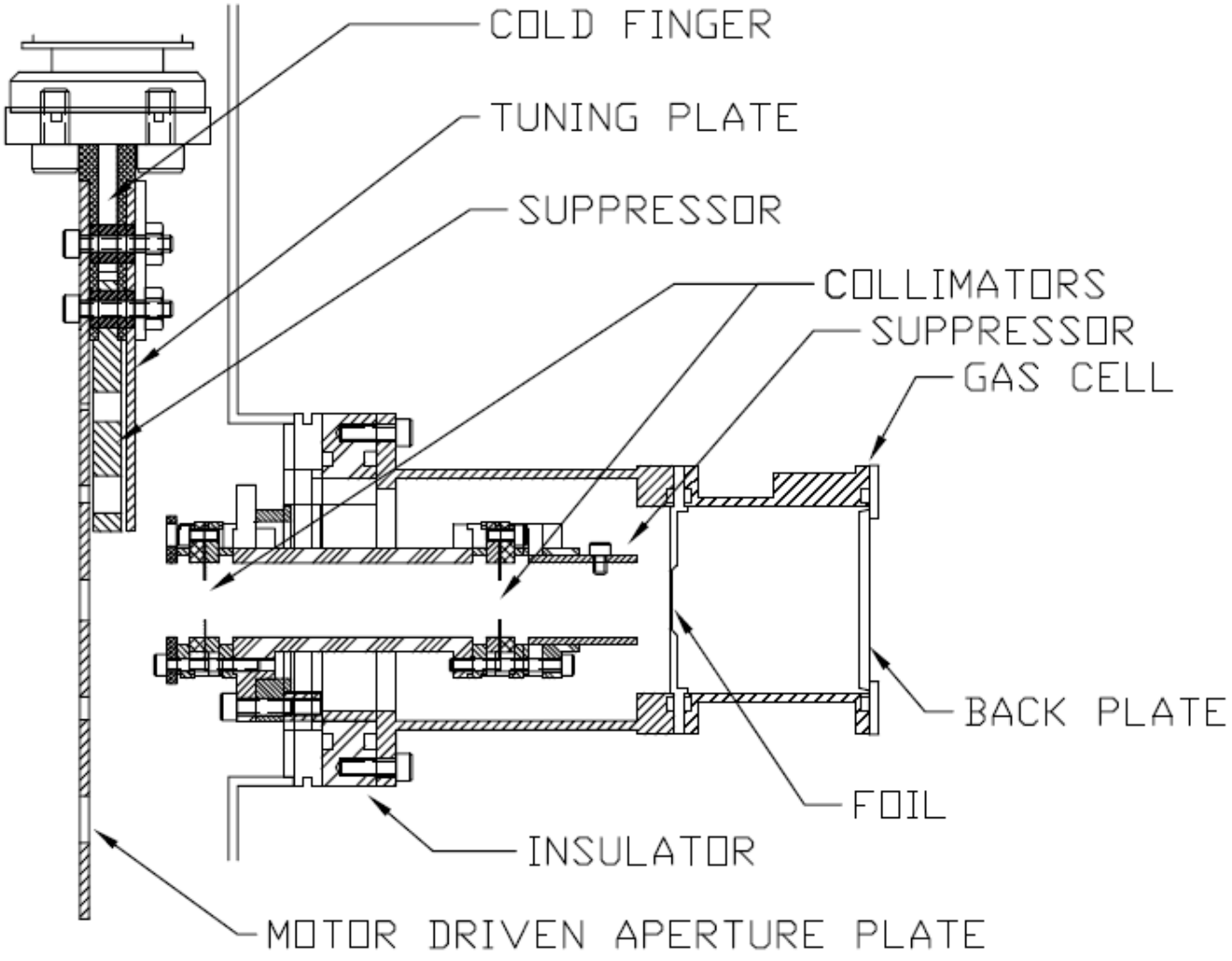
Yield per Incident Ion for $^{3}He(\alpha,\gamma)^{7}Be$ reaction can be calculated:

$$\frac{Yield}{N_i} = N_t \int \sigma(E) dE = N_t \int \frac{\sigma(E) dx}{dE / dx}$$

For 200 Torr, 3cm long gas cell, $E_{\alpha LAB}$=2.9MeV, $\sigma(E_{\alpha CM})$=2.4μb:

$$\frac{Yield}{N_i} = \frac{^{7}Be}{N_\alpha} = 9.6 \times 10^{-11} \frac{atoms}{ion}$$

For I_α=0.5μA, in 1 hour we produce 1*10^{6} ^{7}Be atoms


COLD FINGER
TUNING PLATE
SUPPRESSOR
COLLIMATORS
SUPPRESSOR
GAS CELL
BACK PLATE
FOIL
INSULATOR
MOTOR DRIVEN APERTURE PLATE

Materials

- Gas Cell
  - window : Ni, Ni&Cu, Ni+Au
  - gas : ^{3}He or ^{4}He
  - stopper : Al, Au, Pt, Cu, Nb
  - beam : ^{4}He or ^{3}He

Impurities may affect results !

$^{4}He^{+}$: D_2^{+}, DH_2^{+} from TIS **$^{6}Li(d,n)^{7}Be$** **$^{10}B(p,\alpha)^{7}Be$**

Procedure

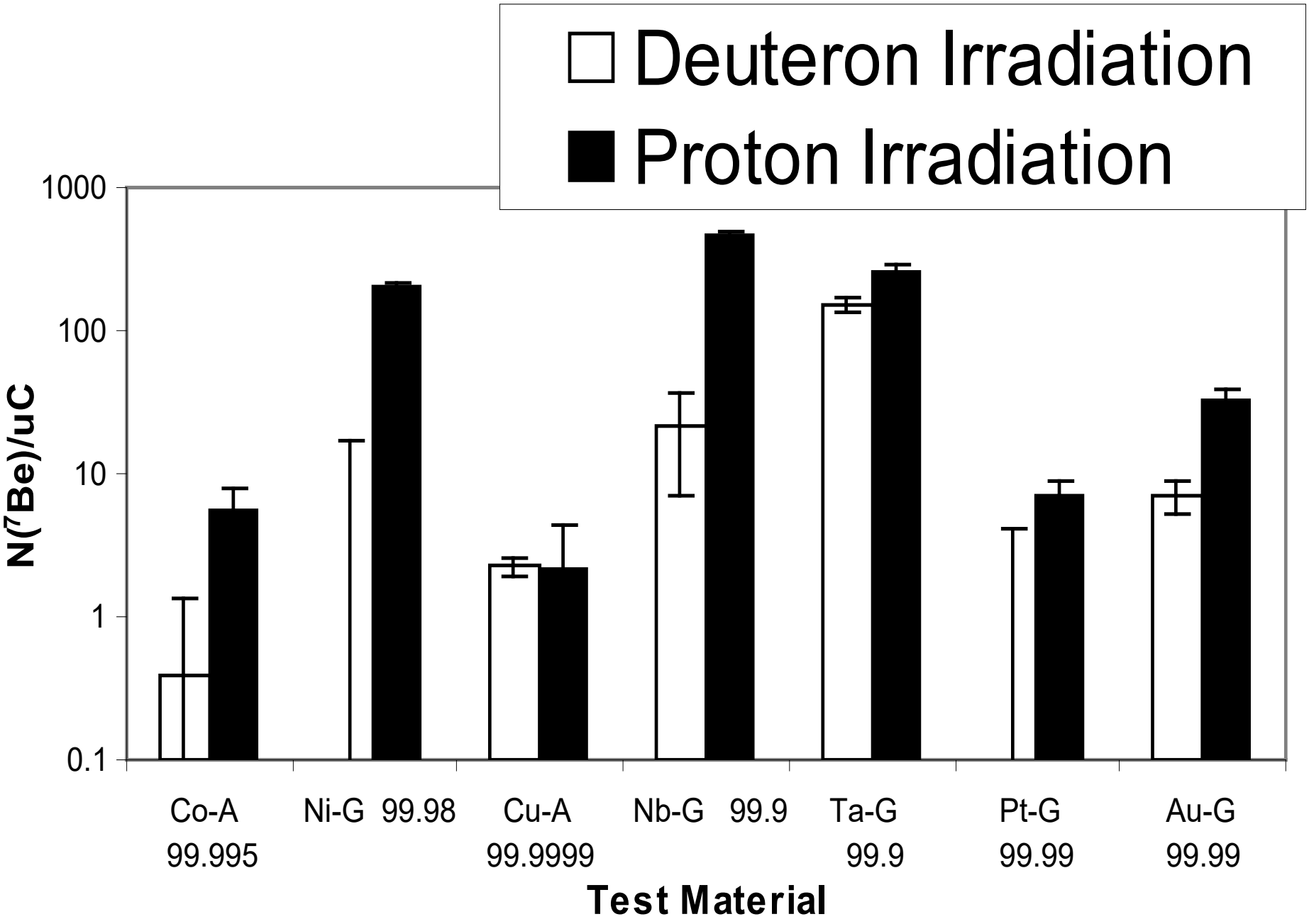
If contaminants in the beam (protons or deuterons), some extra ^{7}Be atoms may be formed, which add to the ^{7}Be atoms created by target bombardment.

Cross sections for the main reactions:

2.2μb $^{3}He(^{4}He,\gamma)^{7}Be$ for E_{α}=3.0MeV

100 mb $^{6}Li(d,n)^{7}Be$ for E_{d}=1.5MeV

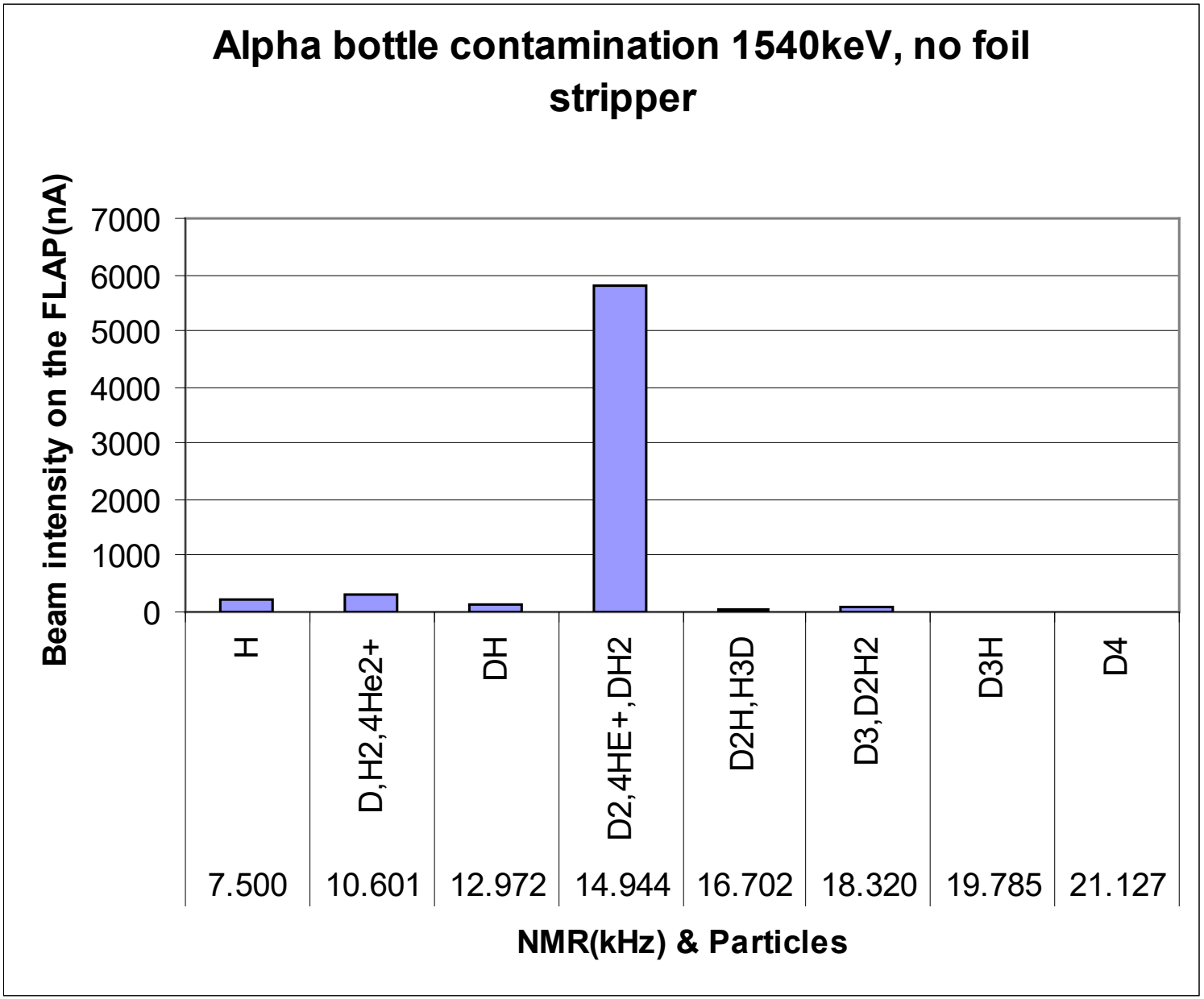
50 mb $^{10}B(p,\alpha)^{7}Be$ for E_{p}=0.75MeV


Deuteron Irradiation
Proton Irradiation
1000
100
10
1
0.1
N(7Be)/uC
Co-A 99.995
Ni-G 99.98
Cu-A 99.9999
Nb-G 99.9
Ta-G 99.9
Pt-G 99.99
Au-G 99.99
Test Material

PPM (mass) Contamination Calculations

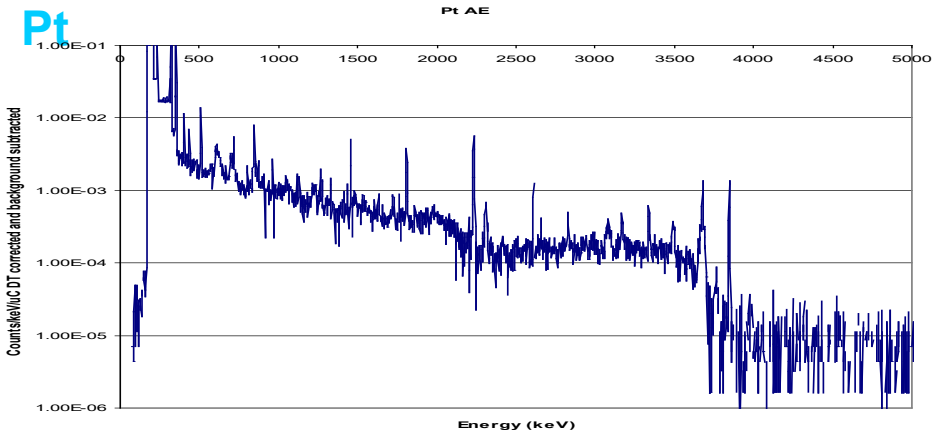
- **^{6}Li contamination from ^{6}Li(p,γ)^{7}Be**
  - **Au: 0.61**
  - **Co: 0.07**
  - **Cu: 0.13**
  - **Nb: 14.53**
  - **Ni: 2.47**
  - **Pt 1.85**
  - **Ta 21.16**
- **^{10}B contamination from ^{10}B(p,α)^{7}Be**
  - **Au 3.14**
  - **Co 0.13**
  - **Cu 0.06**
  - **Nb 16.76**
  - **Ni 6.41**
  - **Pt 0.66**
  - **Ta 10.84**

Beam contamination – no foil stripper

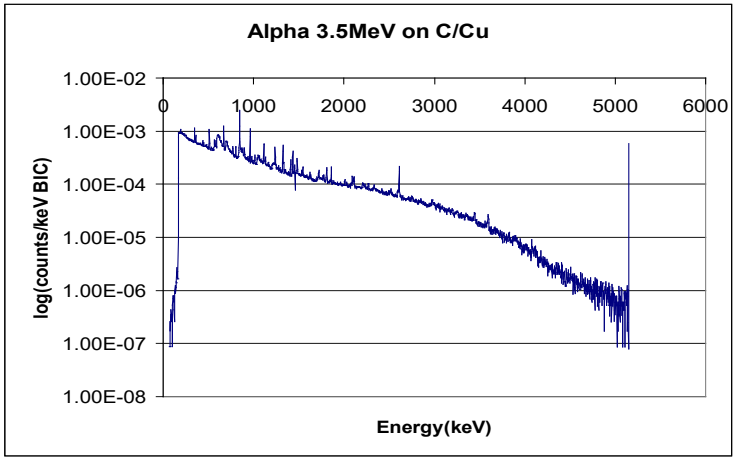


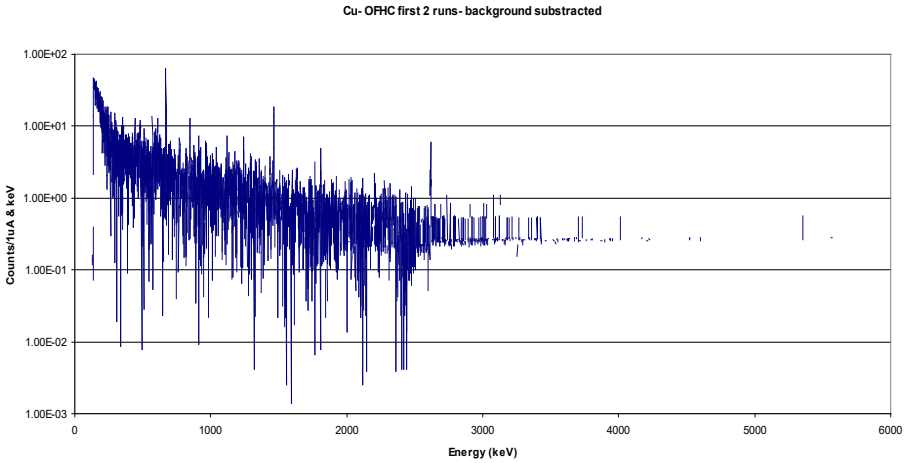
γ-background from α-bombardment of the metal backings (BEAM ON)

Pt



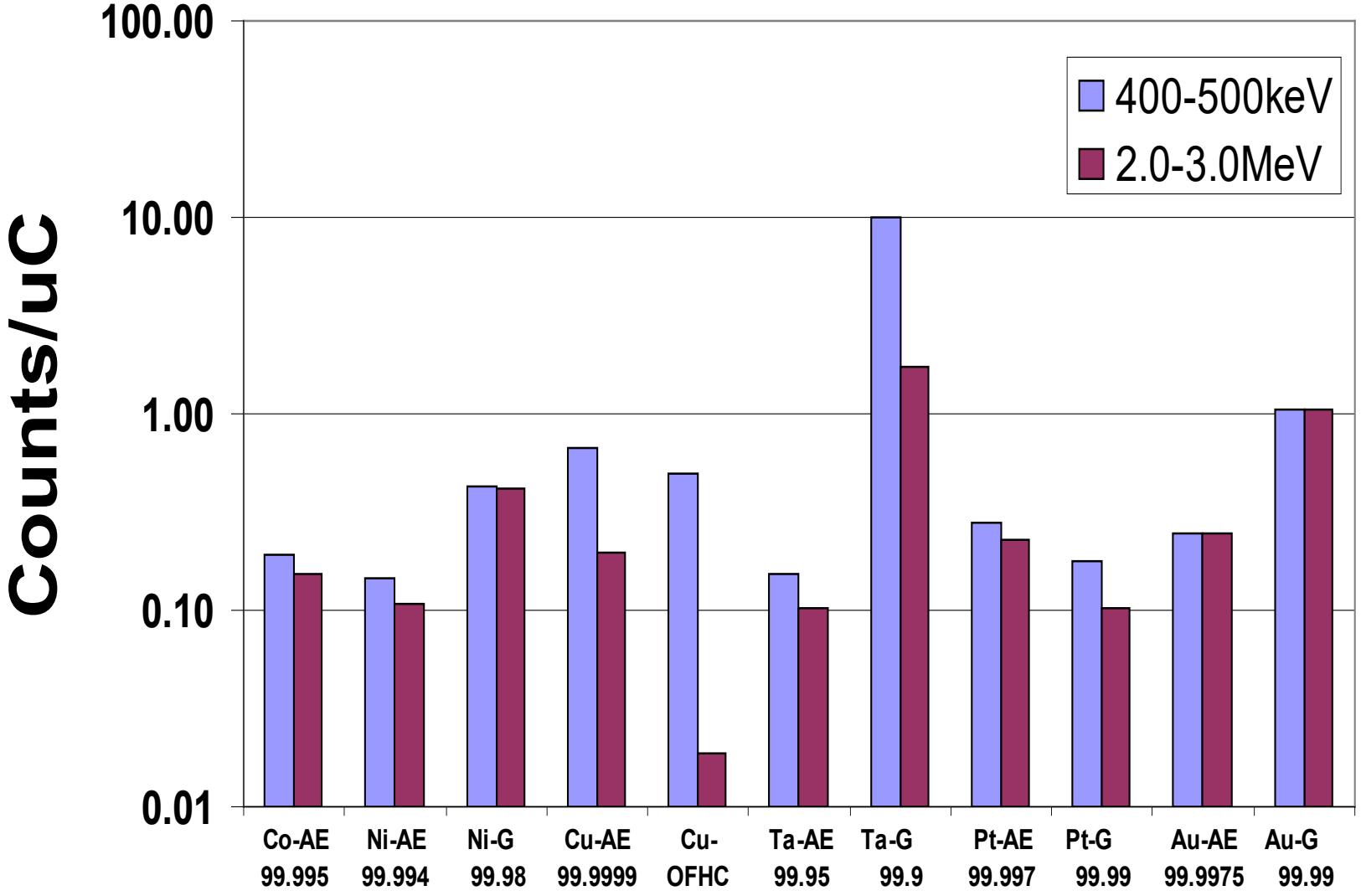
C/Cu





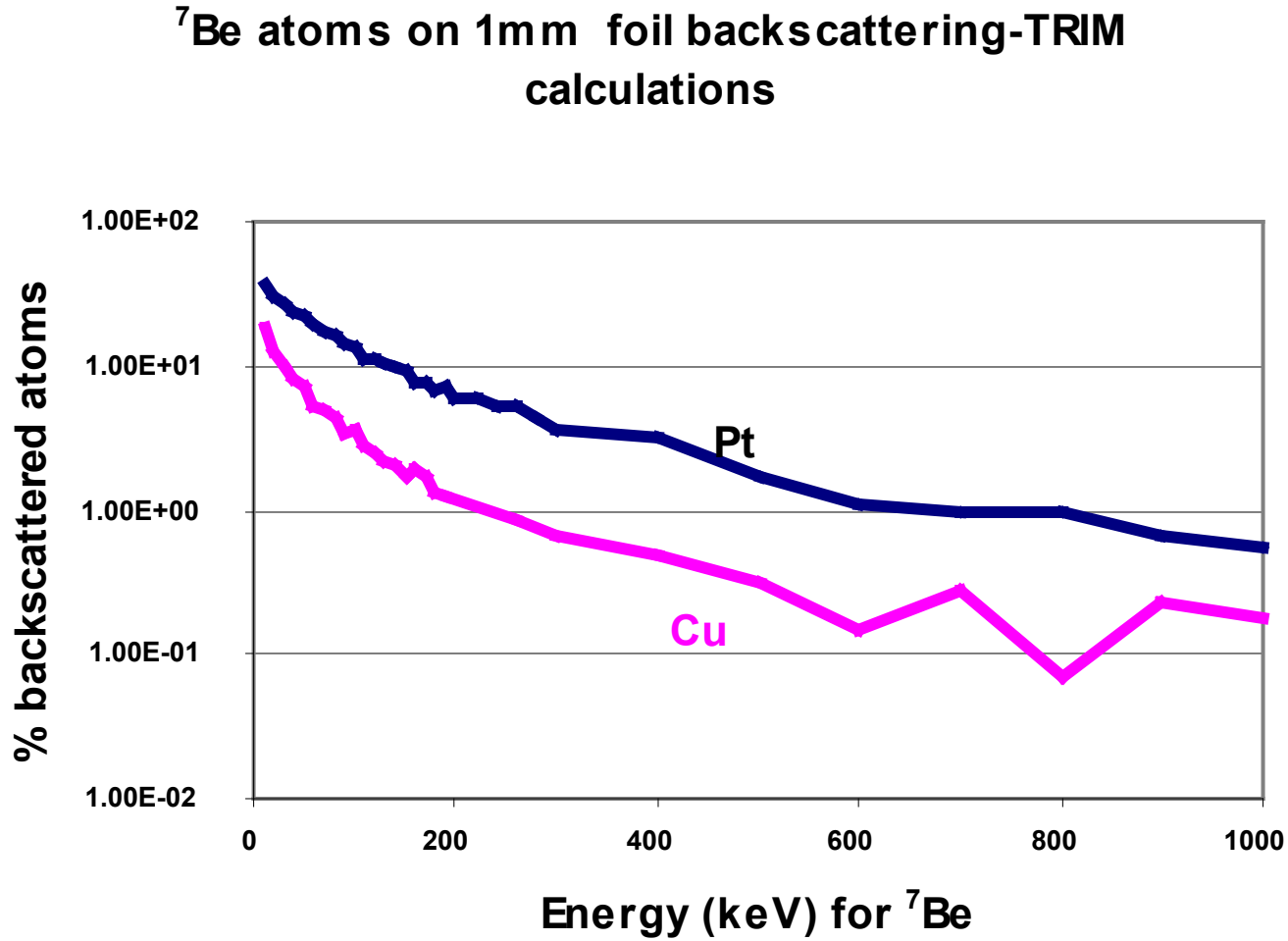
Cu OFHC

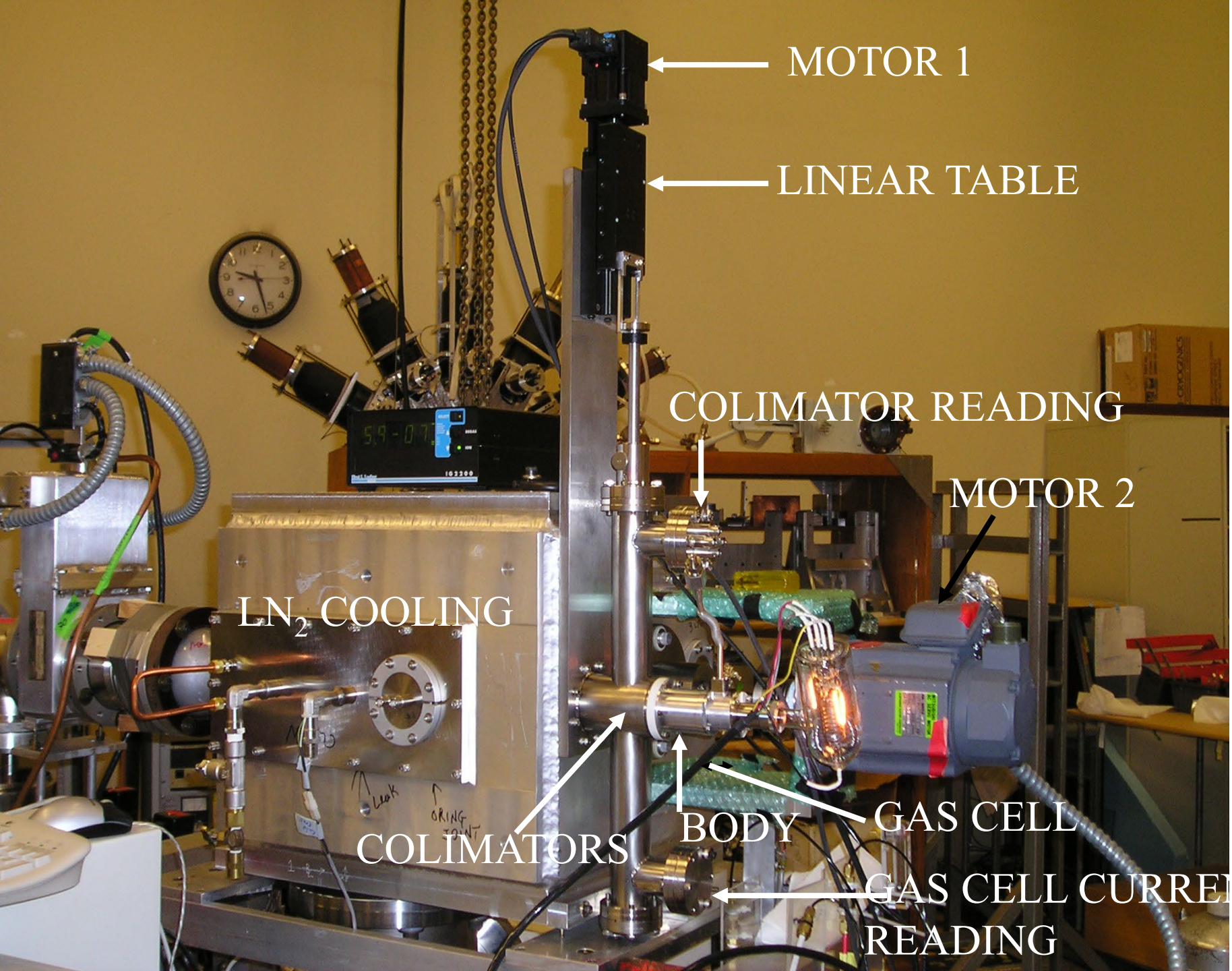
From these measurements, We learned that we have C build-up.


Counts/uC
100.00
10.00
1.00
0.10
0.01
400-500keV
2.0-3.0MeV
Co-AE 99.995
Ni-AE 99.994
Ni-G 99.98
Cu-AE 99.9999
Cu-OFHC
Ta-AE 99.95
Ta-G 99.9
Pt-AE 99.997
Pt-G 99.99
Au-AE 99.9975
Au-G 99.99

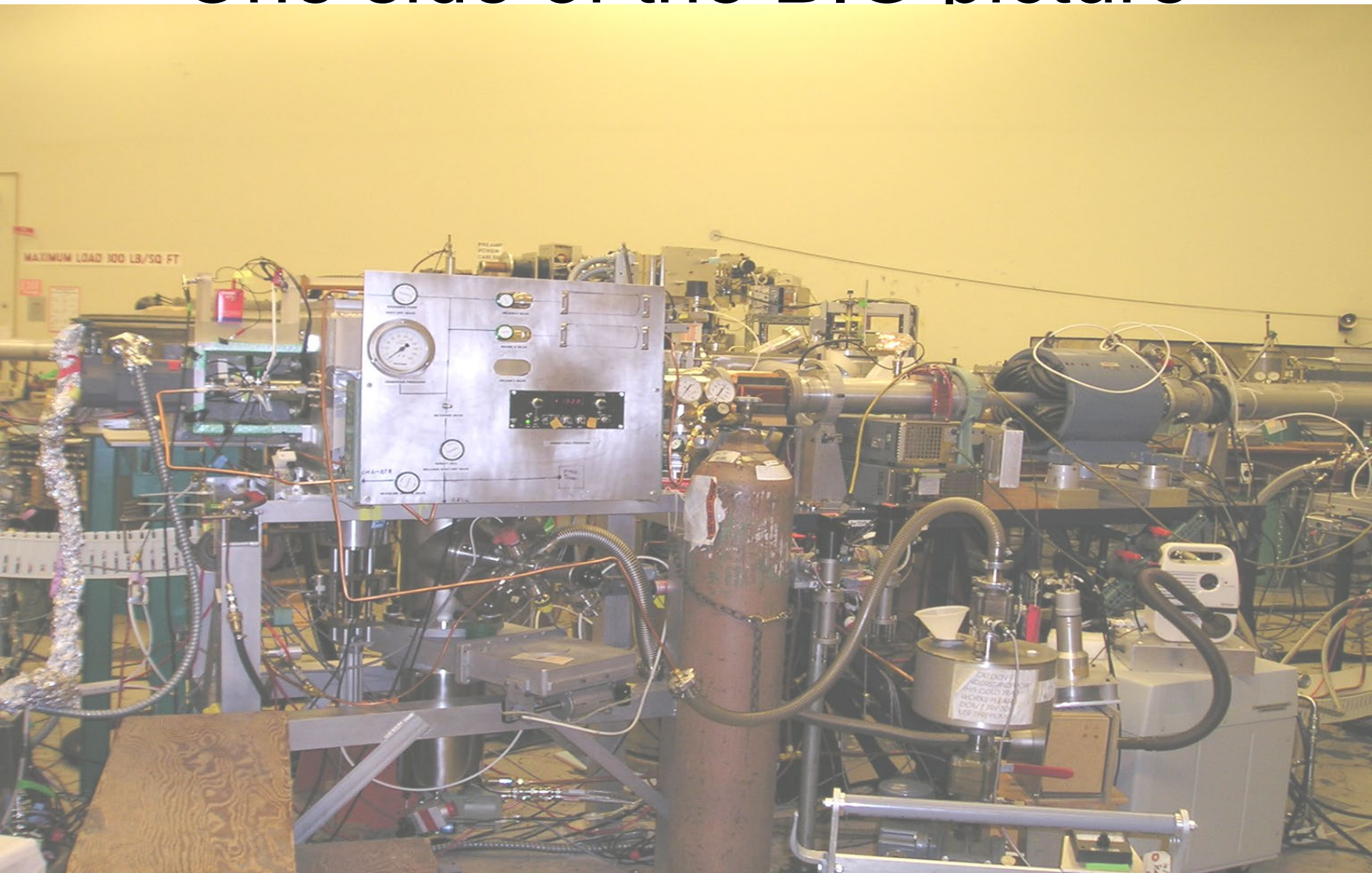
Smallest backscattering

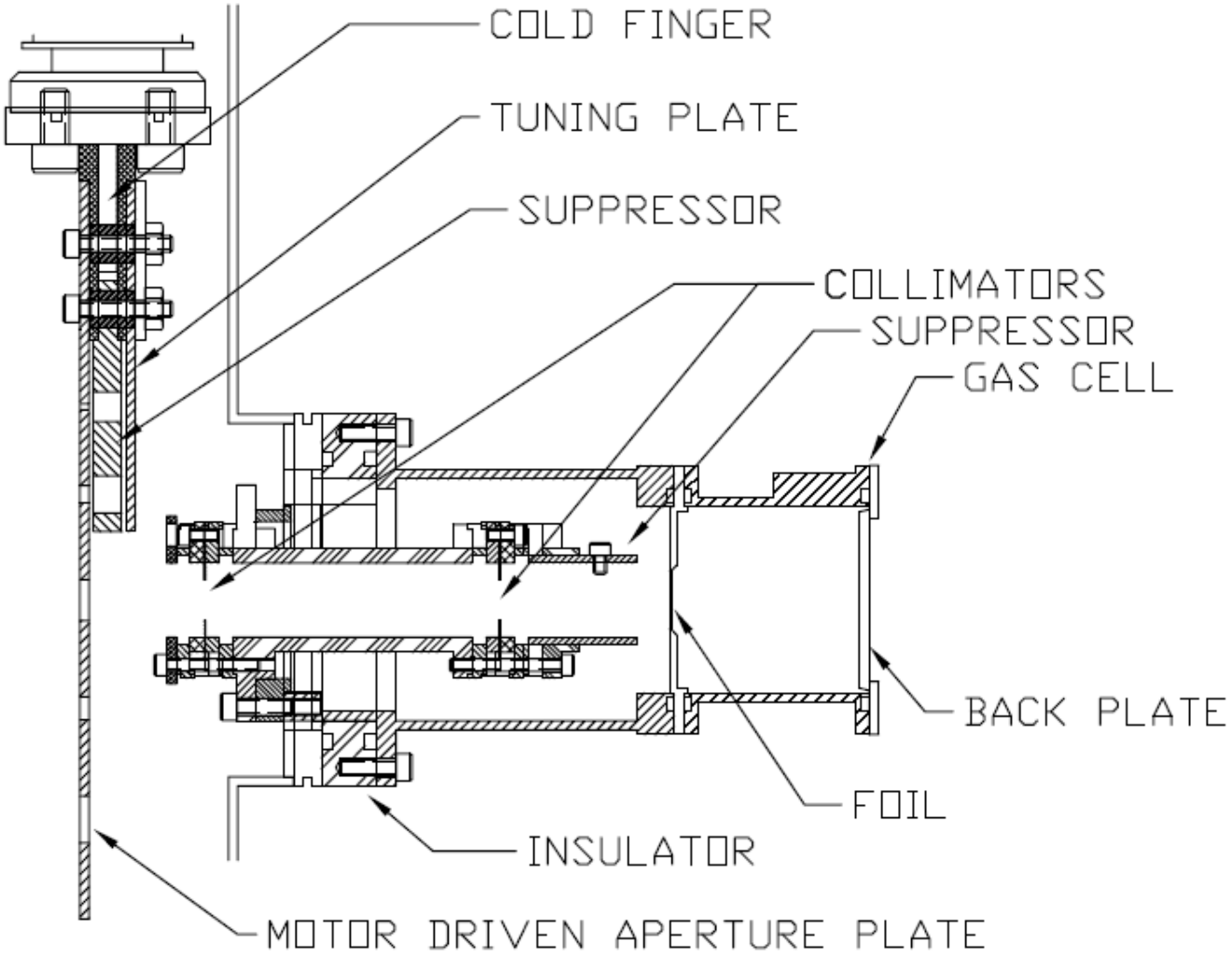
Calculations were done using TRIM




MOTOR 1
LINEAR TABLE
COLIMATOR READING
MOTOR 2
LN2 COOLING
COLIMATORS
BODY
GAS CELL
GAS CELL CURRE
READING

One side of the BIG picture




COLD FINGER
TUNING PLATE
SUPPRESSOR
COLLIMATORS
SUPPRESSOR
GAS CELL
BACK PLATE
FOIL
INSULATOR
MOTOR DRIVEN APERTURE PLATE

Energy transport through the target

- Energy loss & energy straggle through the Ni window for the α beam :SRIM & resonance experiment
- Energy loss & energy straggle through the gas target ^{3}He

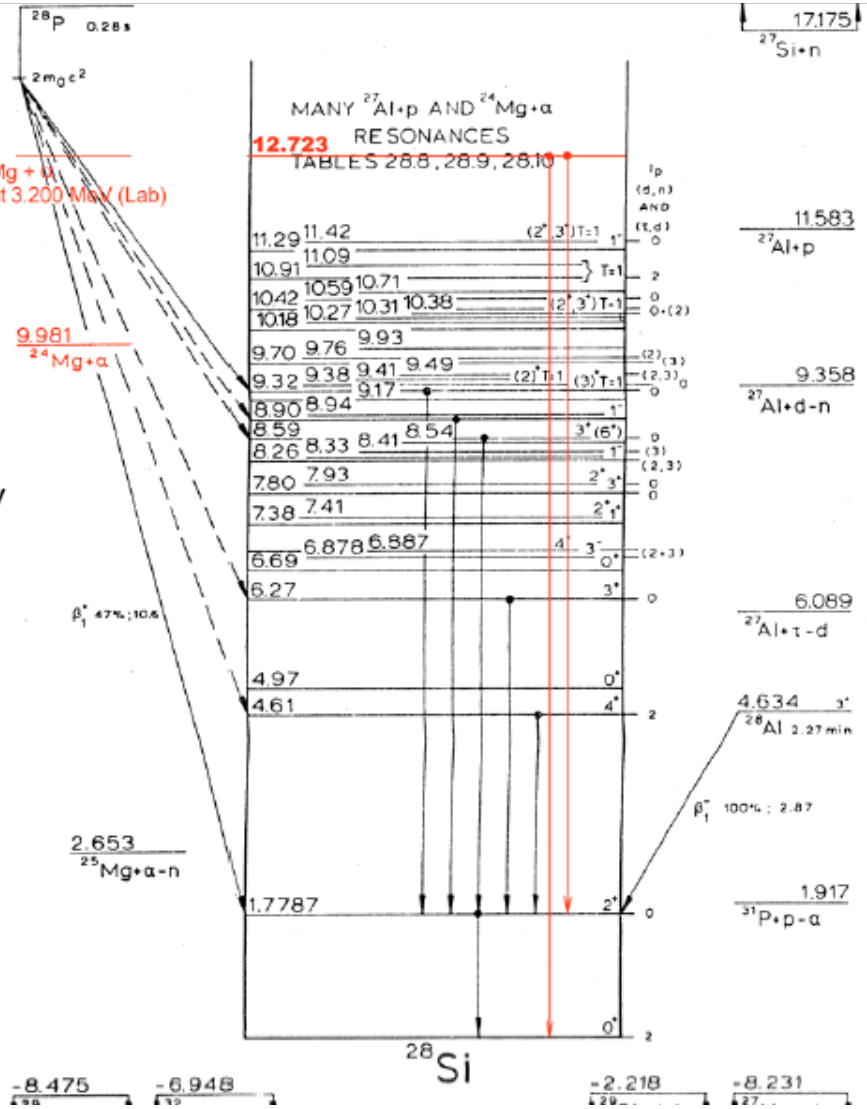
  -for the α beam : SRIM & resonance experiment

and

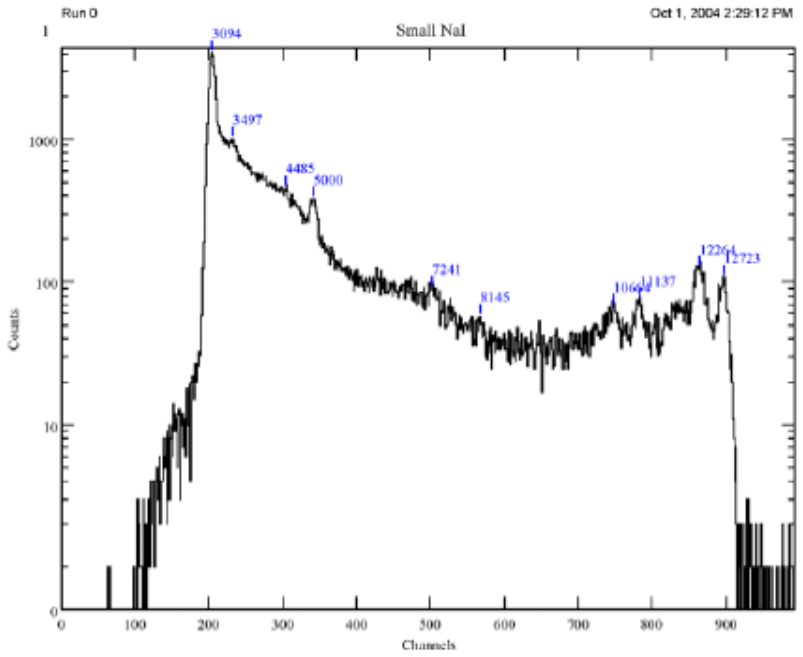
  -for the ^{7}Be atoms created : SRIM

Use 12.723 MeV level of ^{28}Si
In ^{24}Mg(α,γ)

Narrow resonance at 3.200 MeV
Lab energy for α beam

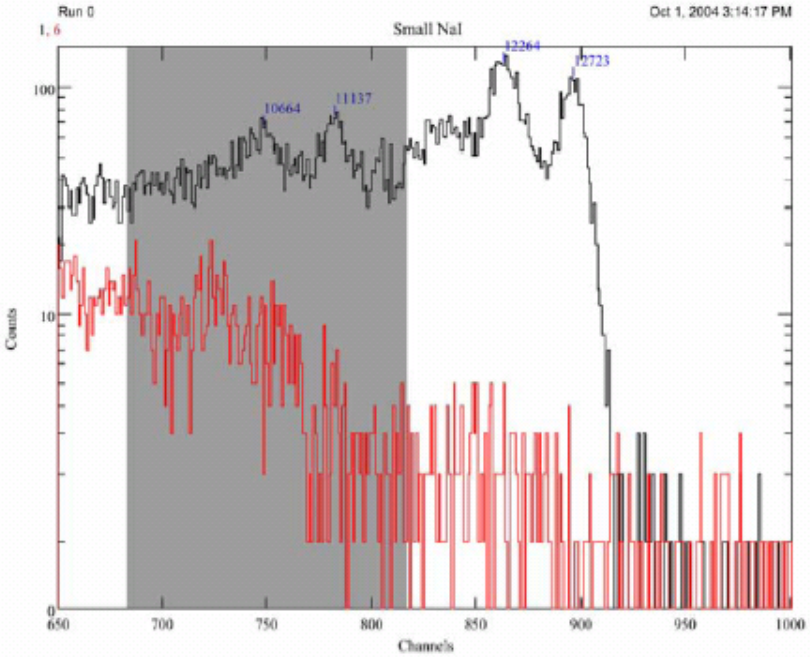


Resonance gamma spectrum



Above resonance

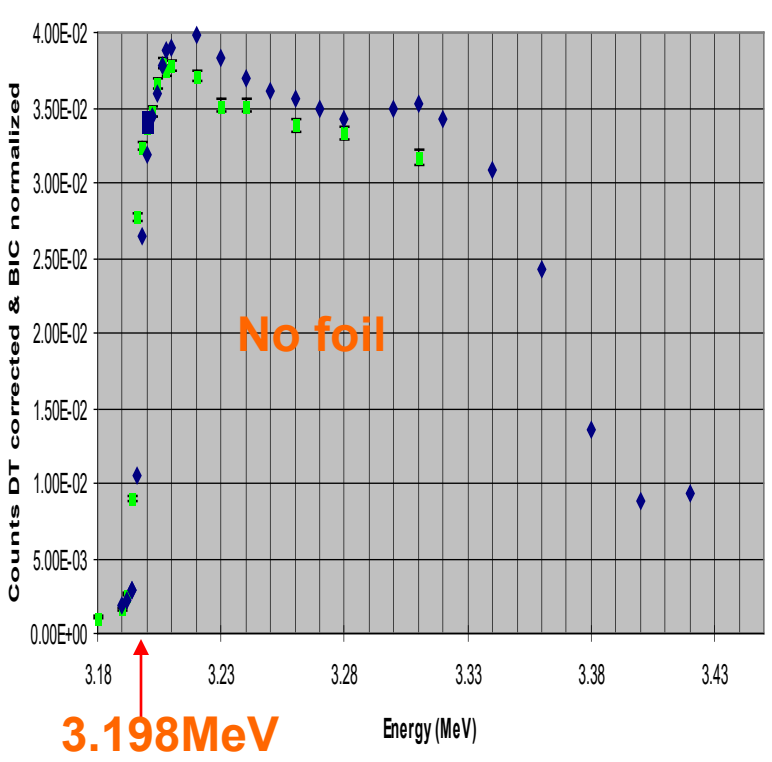
Gate on gamma 1

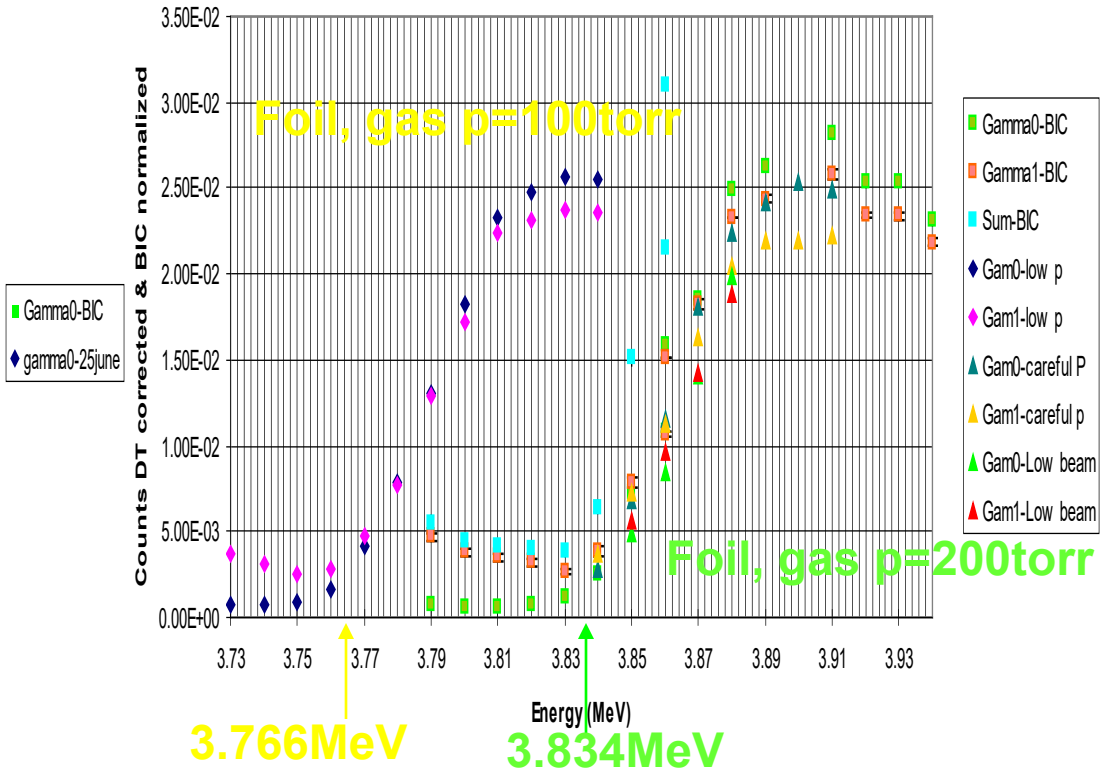


Expanded, above and below resonance

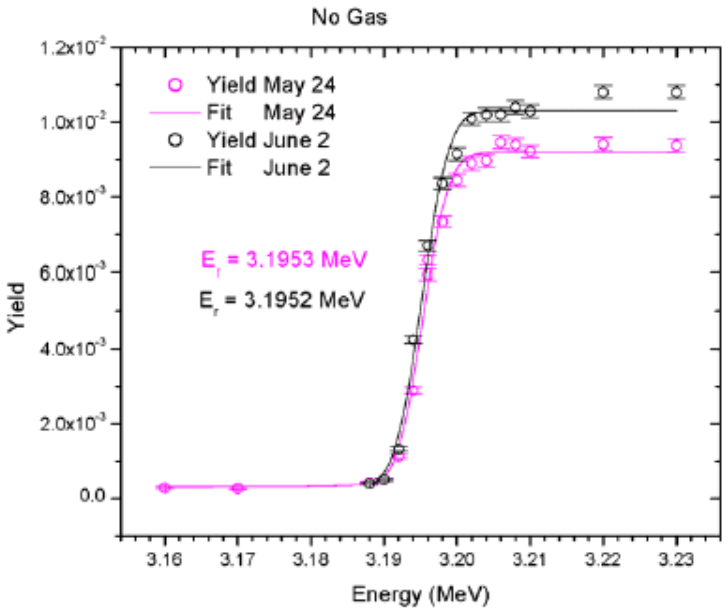
^{3}He atoms density of the gas along the beam path & Ni window thickness (and pin holes)

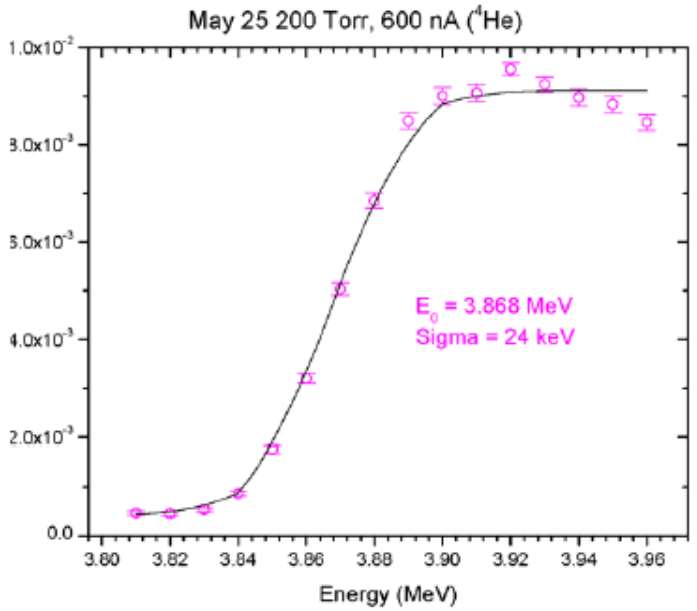
$^{24}Mg+\alpha->^{28}Si+\gamma$





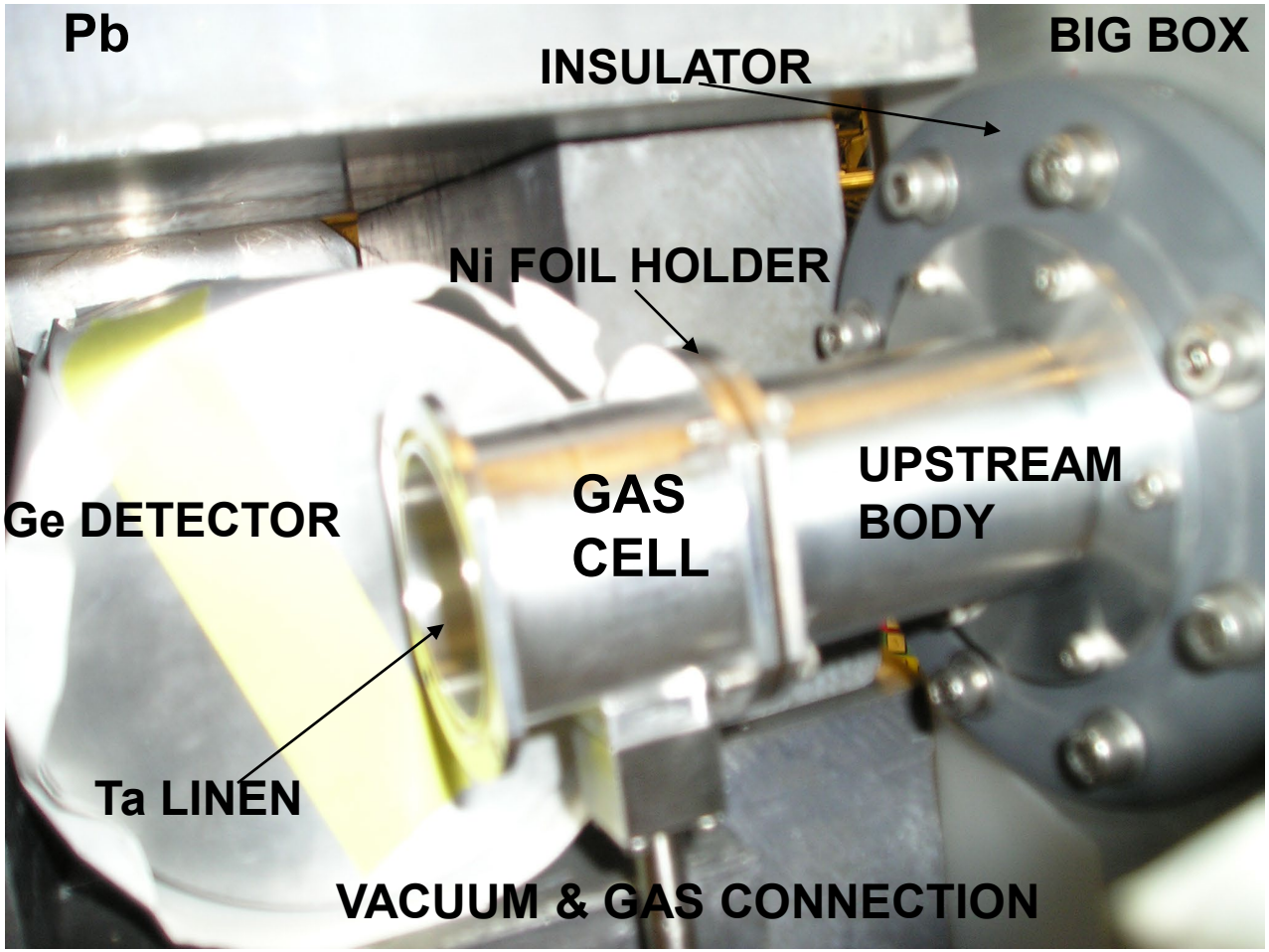
Thick target resonance curves





- Assume Gaussian, integrate over energy range throughout Mg target.
- Add background.
- Central energy is near mid-point of curve.
- Central energy is resonance energy plus energy loss

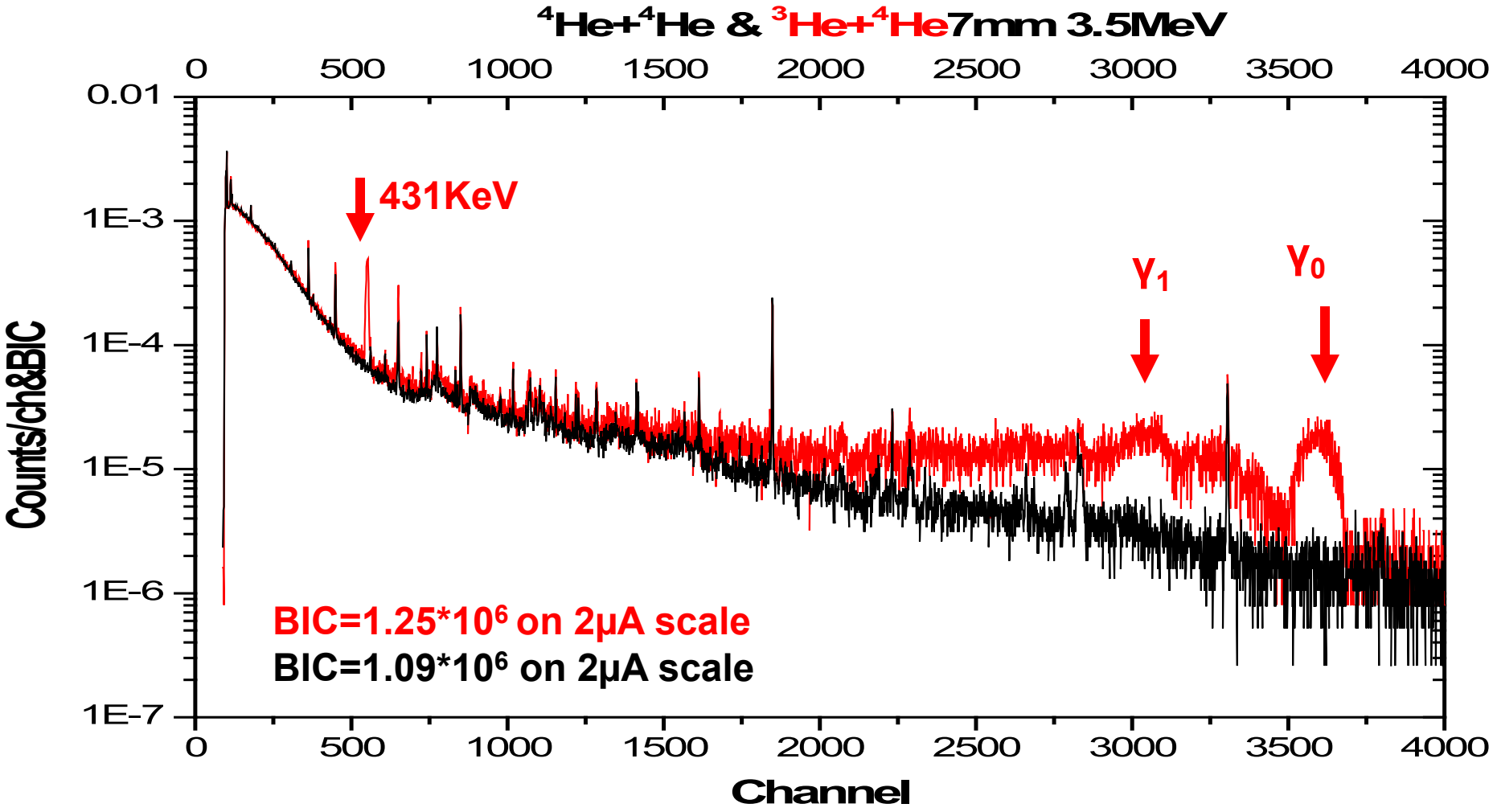
Gas cell


Pb
INSULATOR
BIG BOX
Ni FOIL HOLDER
Ge DETECTOR
GAS
CELL
UPSTREAM
BODY
Ta LINEN
VACUUM & GAS CONNECTION

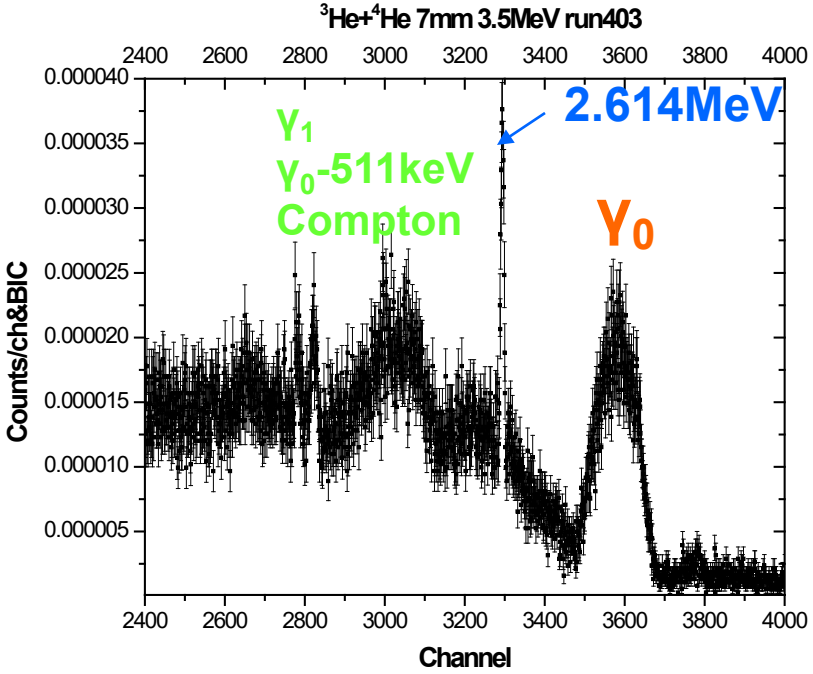
Shape of the peaks

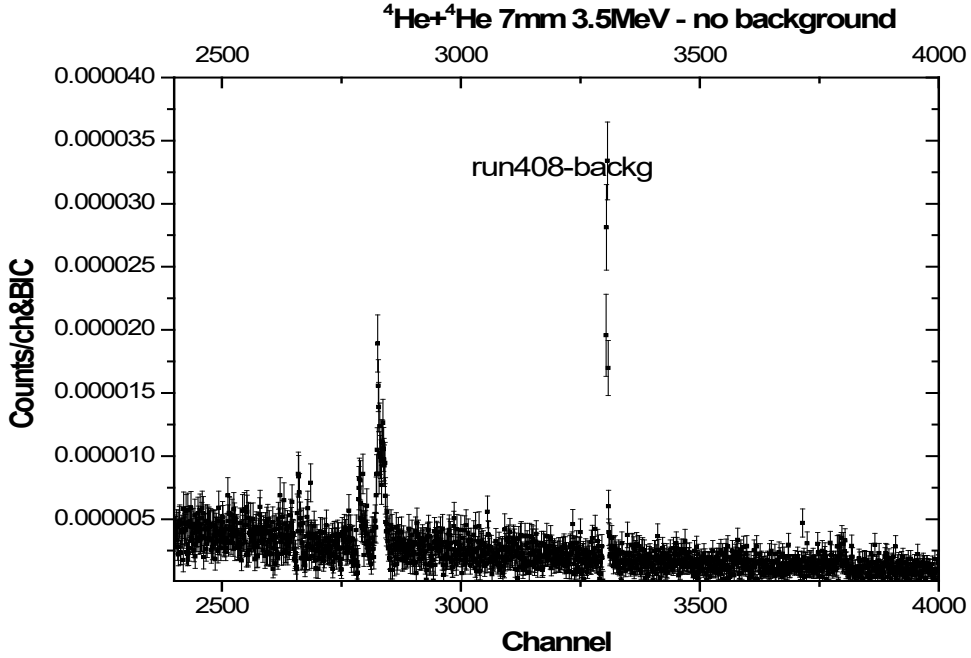
- Doppler broadening
- Doppler shift
- Broadening due to the width of the cell

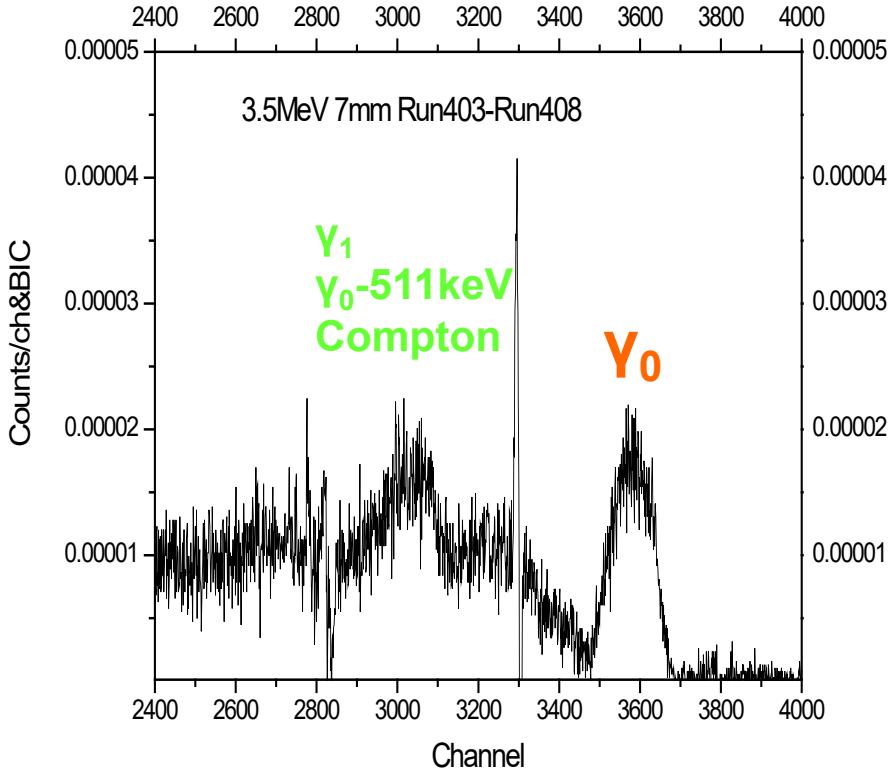
Reaction creates a difference in the peaks of the spectra



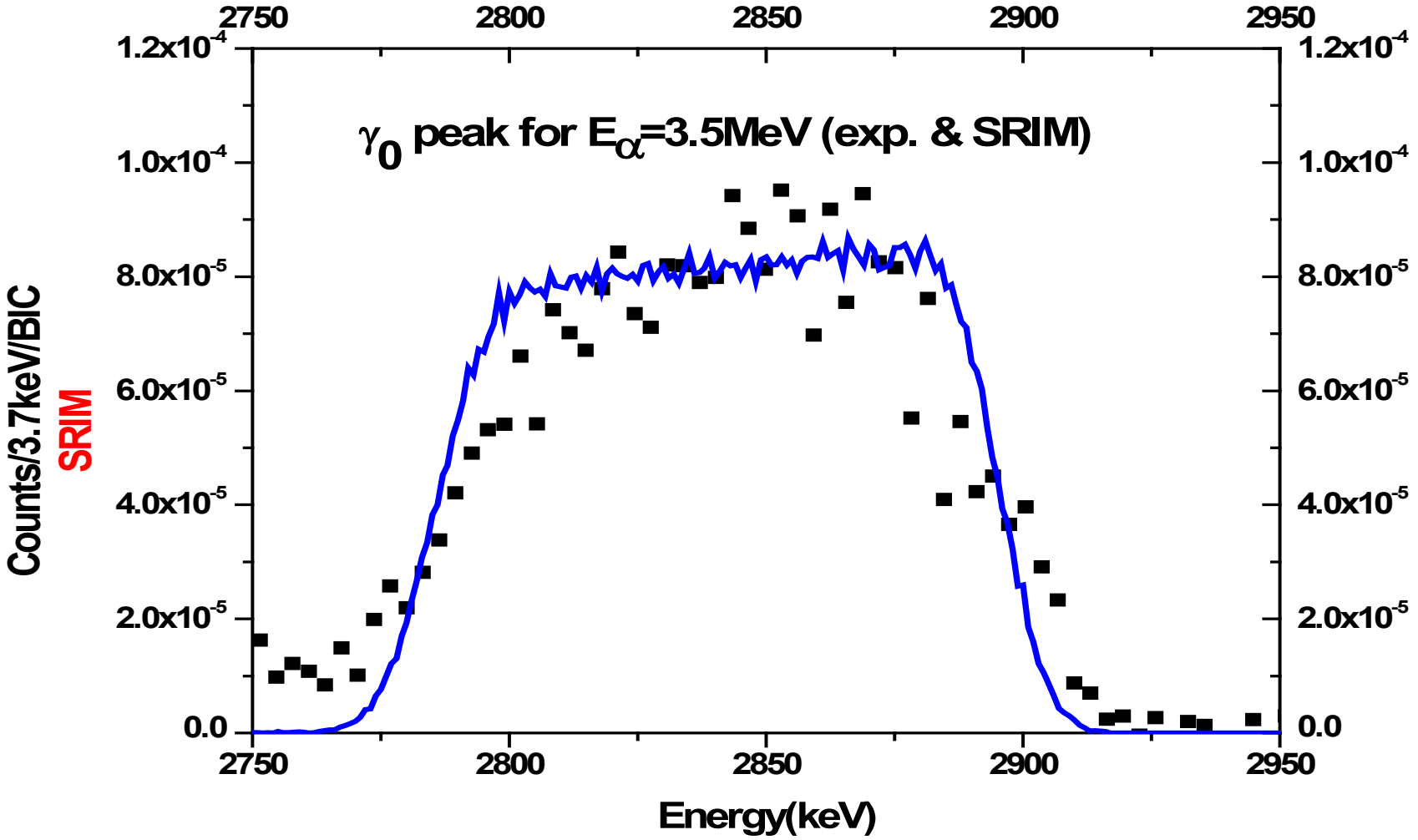
Spectra for E_α=3.5MeV







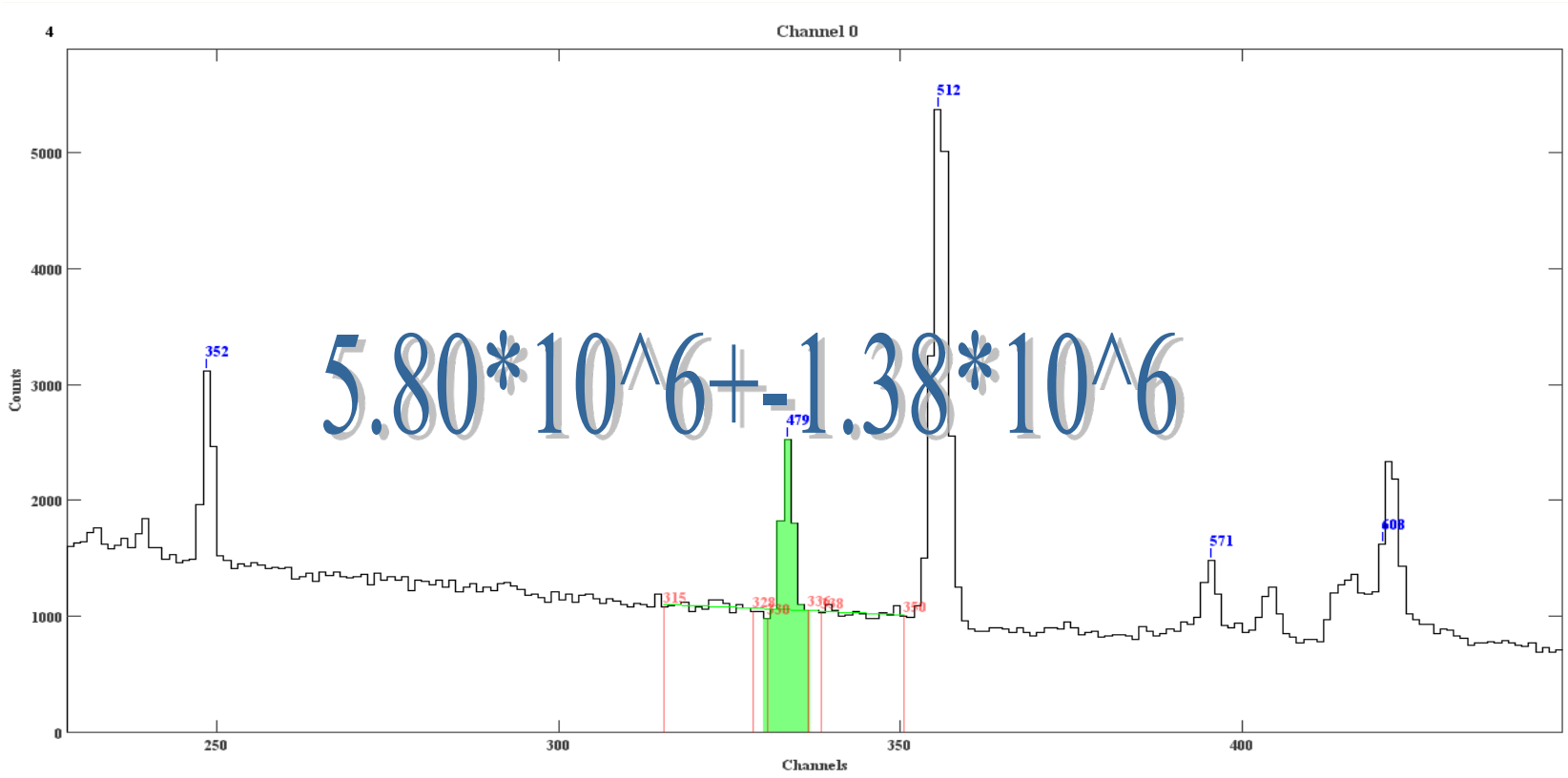
First approximation for γ_0 peak



Rough σ determination

- Net area of the γ_0 peak 7358 cts
- Beam charge evaluation $4.8*10^{16}$ atoms
- Solid angle evaluation & efficiency of the Ge detector 0.0049
- Gas thickness $1.97*10^{19}$ atoms/cm^2
- $\sigma_{\gamma 0}$=1.58μb
- $\sigma_{\gamma 429}$=1.085μb
- σ_t=2.7μb (2.4μb from previous experiment)

^{7}Be decay measurement



Next steps

- Add accuracy in geometrical positioning
- Double check for thicknesses of the Ni window and the gas target
- Check pressure measurement
- Check for Ge detectors efficiency
- Make the experiment for different energies and pressures