Direct measurements of the nuclear reaction $^{7}Be(p, gamma)\ ^{8}B$

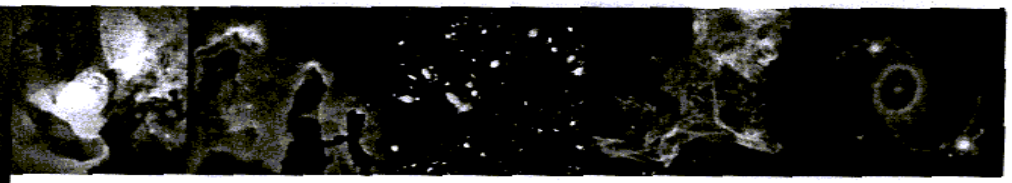
U. Greife

Nukleare Astrophysik

L. Gialanella U. Greife D. Rogalla C. Rolfs F. Schümann F. Strieder S. Thiels H.-P. Trautvetter

Physik mit Ionenstrahlen

Applied Nuclear Physics



Nuclear Astrophysics

-measurement of nuclear reactions at the 180 kV CSM accelerator

-nuclear reactions with radioactive ion beams (ORNL, TRIUMF, GSI)

Nuclear Fusion

-detector development for fusion reactors

Surface Analysis with Ion Beams

- time-of-flight Rutherford backscattering analysis (RBS)

-nuclear reaction analysis

Theoretical Nuclear Physics

-nuclear reaction theory

-renormalisation group theory

-chiral nuclear models

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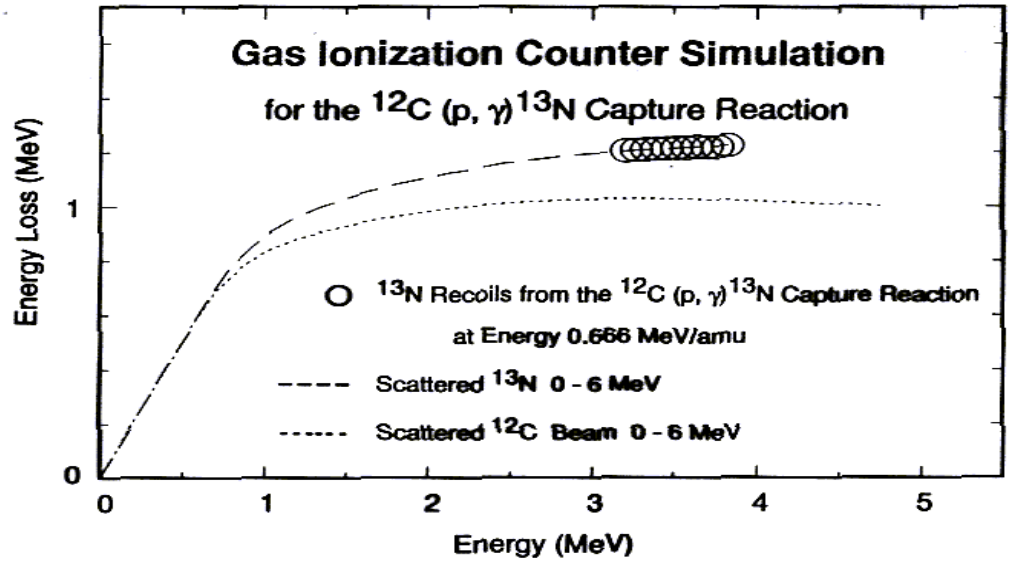
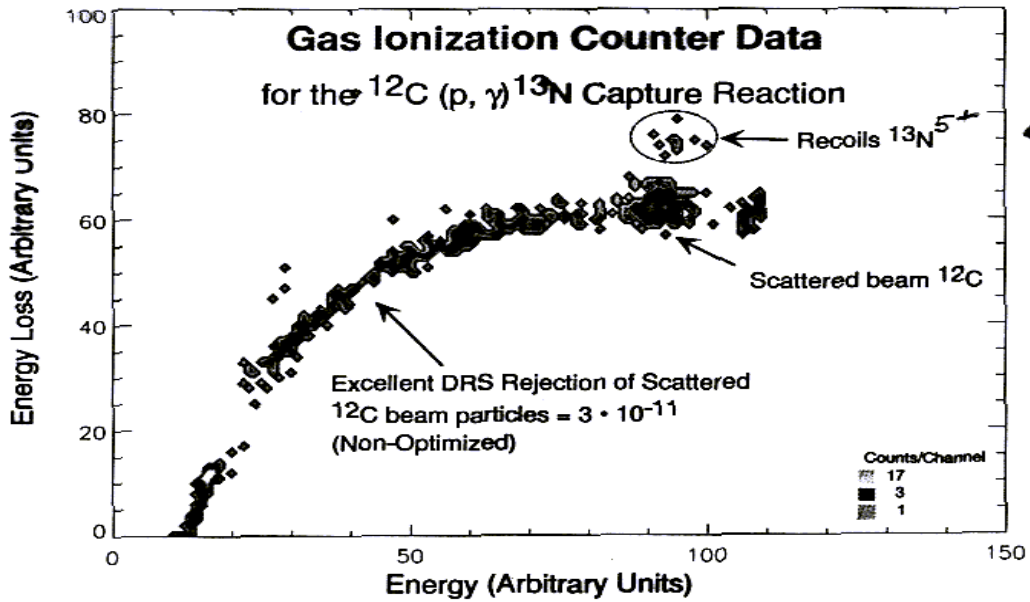
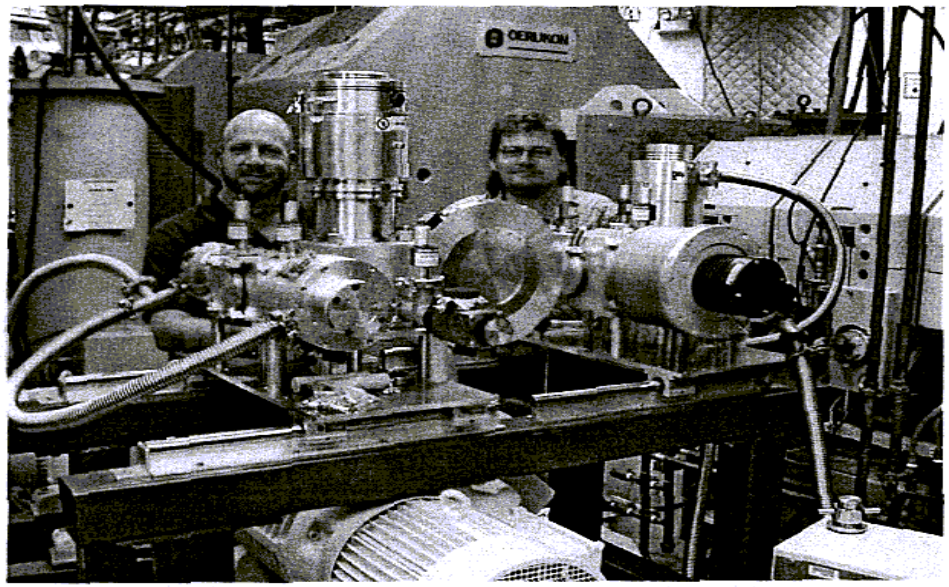
ORNL HRIBF Daresbury Recoil Separator

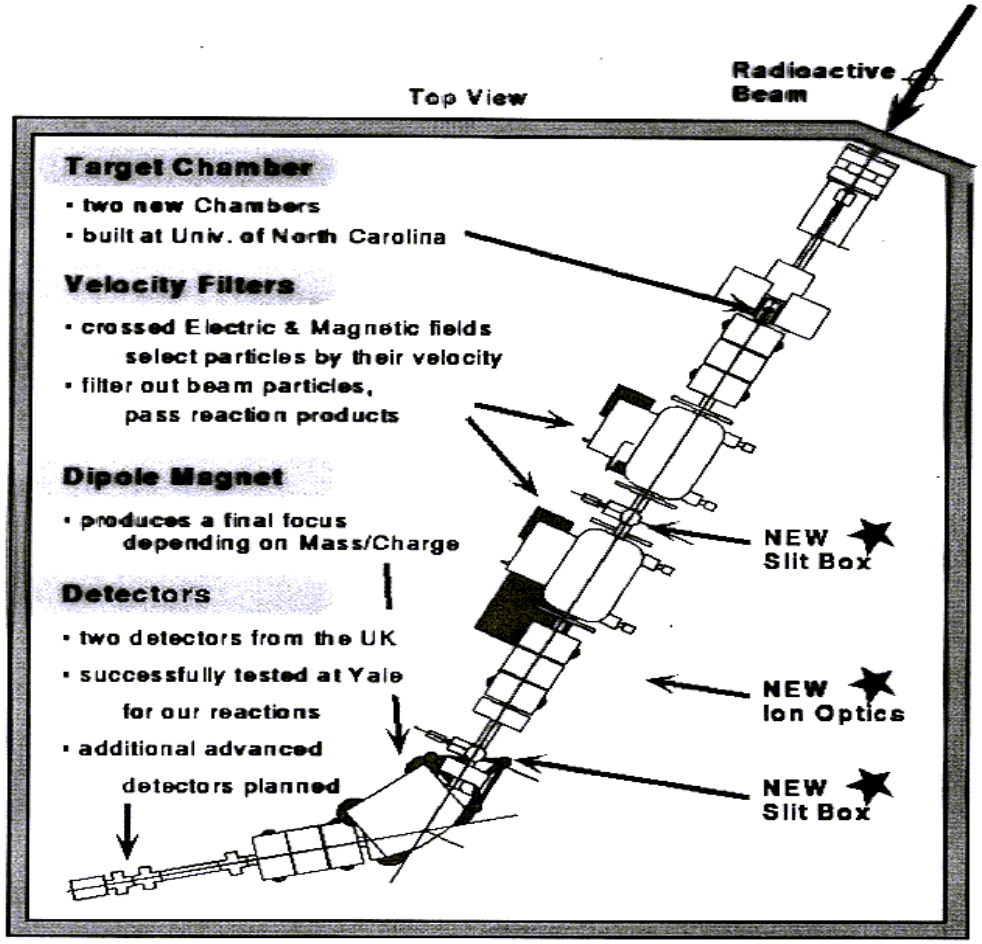




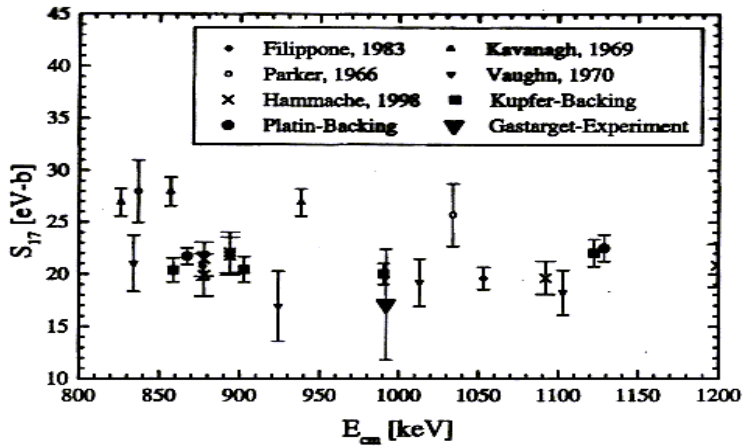

OERLIKON

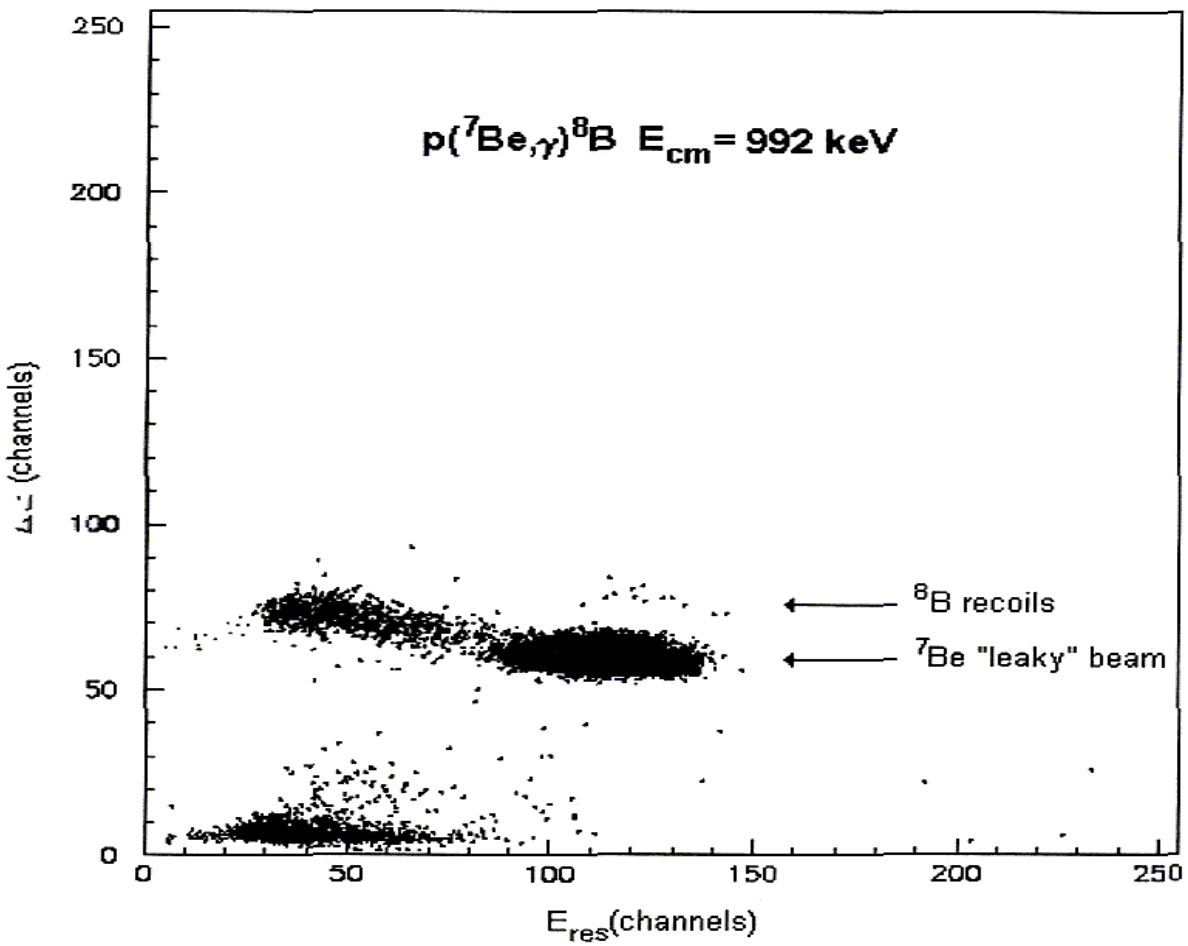
http://www.phy.ornl.gov/astrophysics/rib/drs.gif

Daresbury Recoil Separator Floor Plan

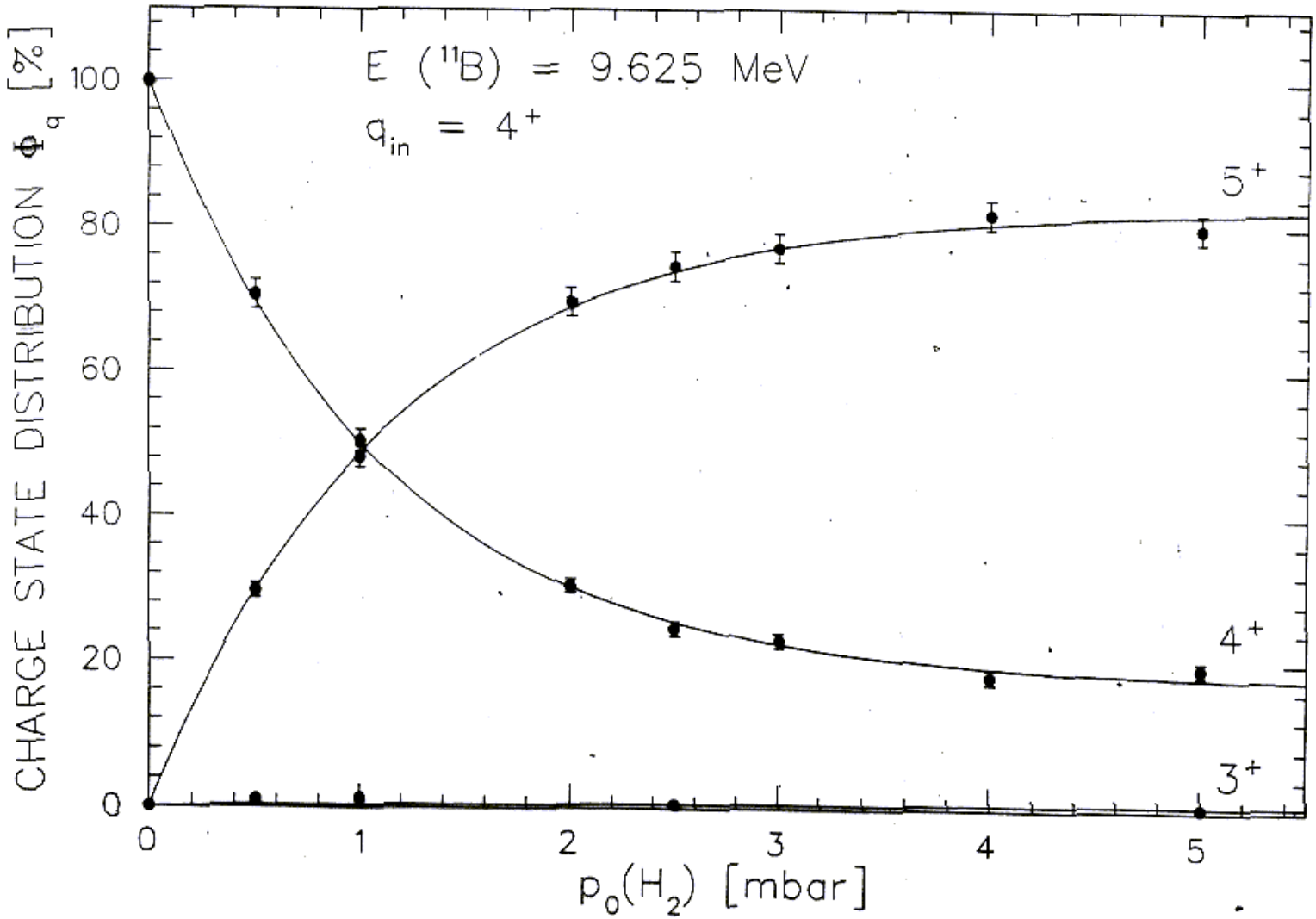


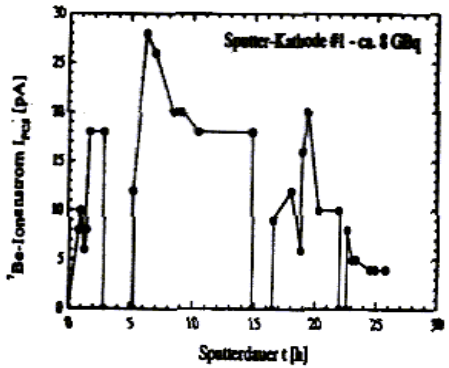
$\ell_{eff}\Omega = 11.3 \pm 0.4$ mm·msr
$\sigma_{cm,s}(\theta, E_{eff}) = 84.9 \pm 0.6$ mb/sr
$\Omega_{cm}/\Omega_{lab} = 2.833 \pm 0.003$
$\ell_{effB} = z_{MW} = 376 \pm 8$ mm
$q_{in} = 4^+$
$\Phi_S^* = 65 \pm 2\%$
$Y_{*B} = 13 \pm 4$ Ereignisse
$Y_s(\theta_{lab} = \pm 45°) = 345 \pm 15$ Ereignisse
$Y_{*B}/Y_s = (3.77 \pm 1.17) \times 10^{-2}$
$\sigma(E_{eff}) = 0.42 \pm 0.13\ \mu b$
// $S(E_{eff}) = 17.1 \pm 5.3$ eV·b //

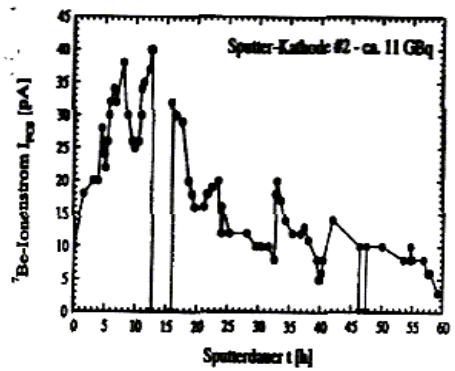


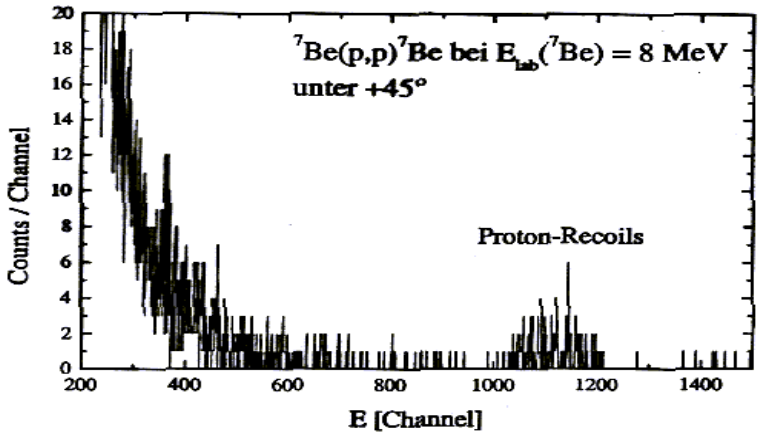

p(7Be,γ)8B Ecm= 992 keV
8B recoils
7Be "leaky" beam
Eres(channels)
(channels)
0
50
100
150
200
250

real gas target conditions




Sputter-Kathode #1 - ca. 8 GBq
Sputterdauer t [h]


Sputter-Kathode #2 - ca. 11 GBq
Sputterdauer t [h]


^{7}Be(p,p)^{7}Be bei E_{lab}(^{7}Be) = 8 MeV
unter +45°
Proton-Recoils
Counts / Channel
E [Channel]

Transmission and charge state probabilities !

Ion source efficiency ≈ 2-3%

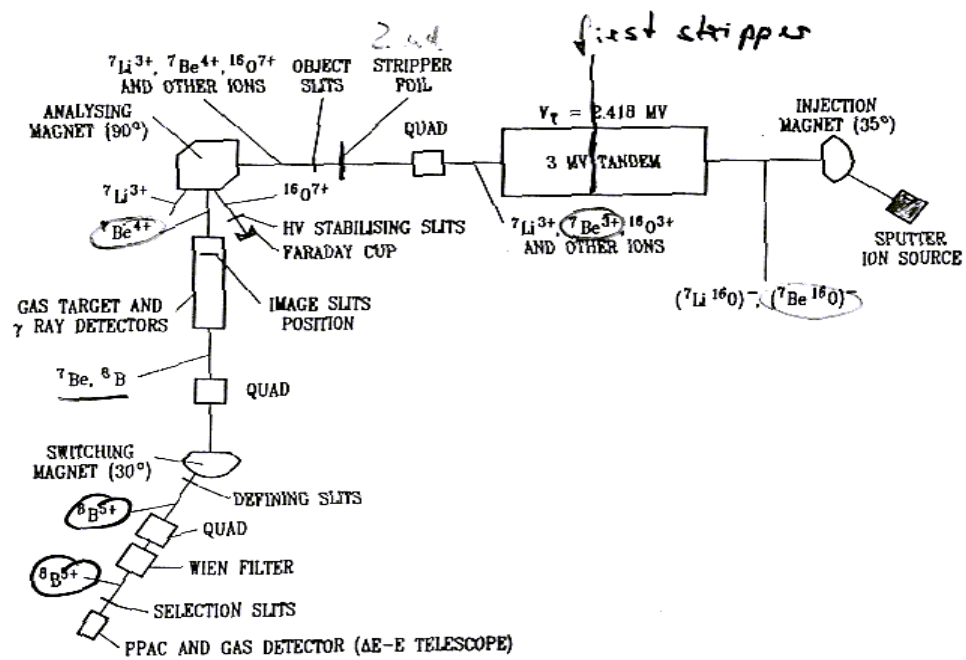
Φ_{3+} (first stripper) ≈ 12% ←

Φ_{Tandem} ≈ 30% ←

Φ_{4+} (post stripper) ≈ 67%

$\Phi_{Gas\ target}$ ≈ 50% ←

$\Phi_{B^{5+}}$ ≈ 65%



File: Uwe/3MV

YABO 17

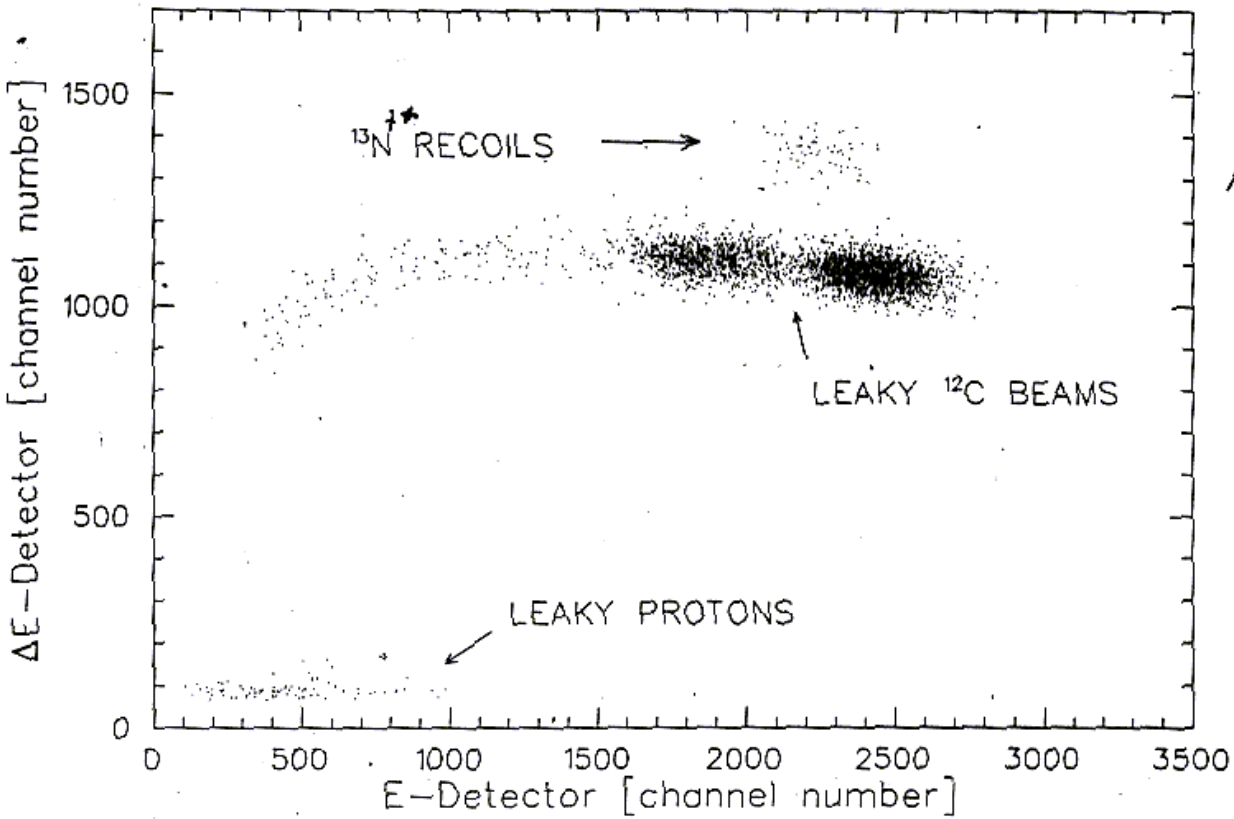


Fig. 9

$$N_{Rec}(^{13}N) / N_{Inc}(^{12}C) = 3.6 \cdot 10^{-13}$$

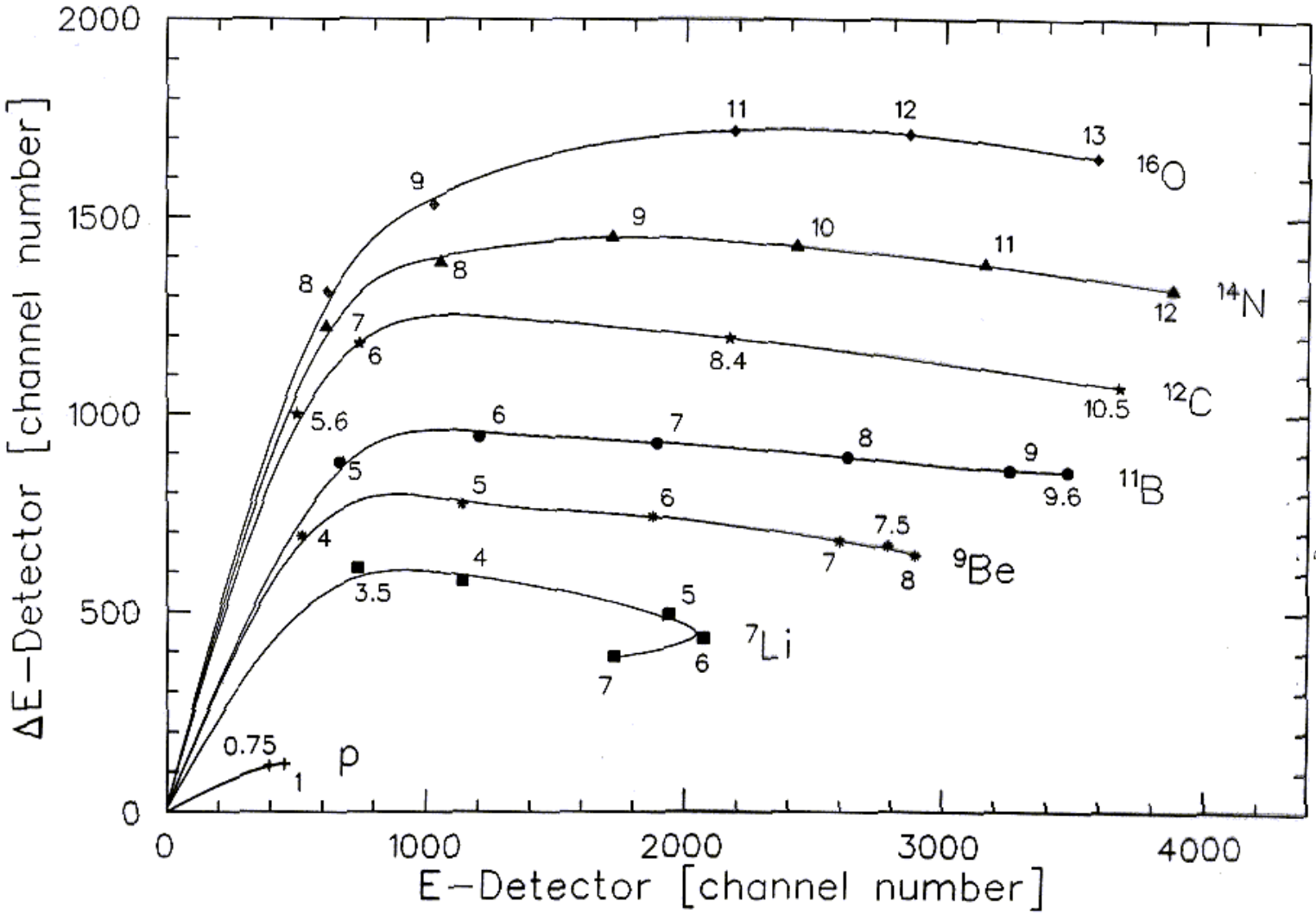
≙ Suppression factor

$$N_{Rec}(^{8}B) / N_{Inc}(^{7}Be) \approx 5.6 \cdot 10^{-12}$$

$^{12}C(p,\gamma)^{13}N$

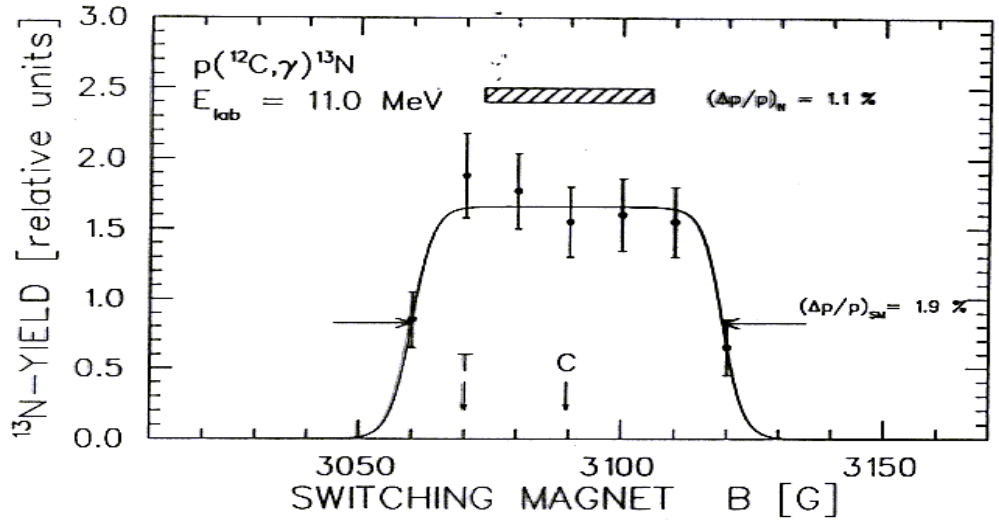
$\sigma_{meas.} = 0.37 \pm 0.02\ \mu b$

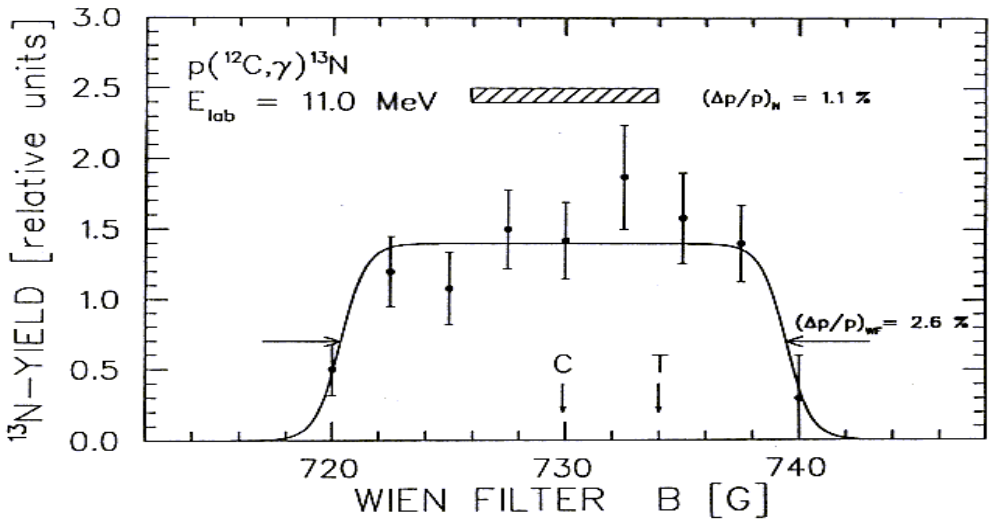
$\sigma_{Lit.} = 0.38 \pm 0.04\ \mu b$

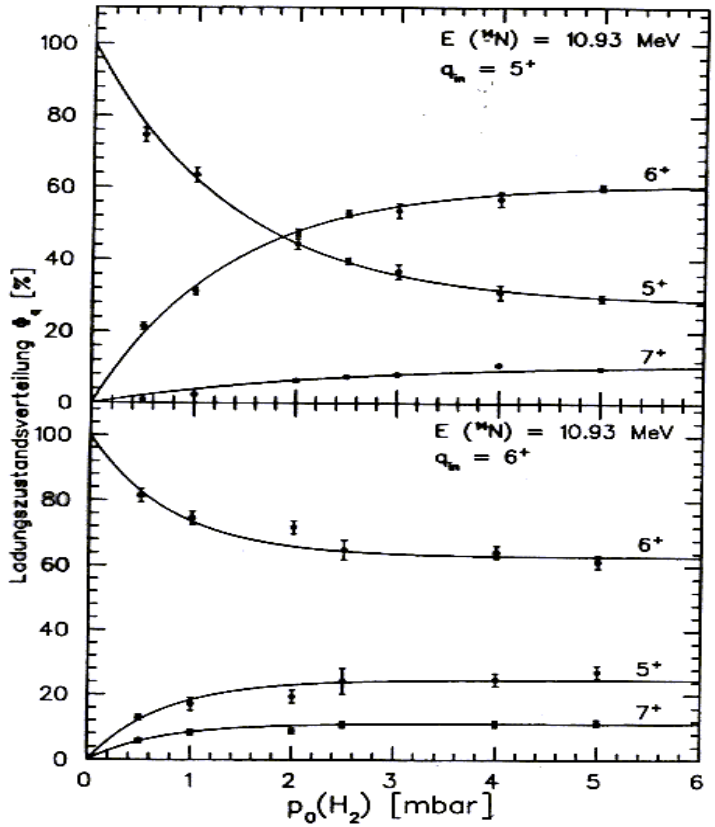


alternative: monolithic silicon detector telescope

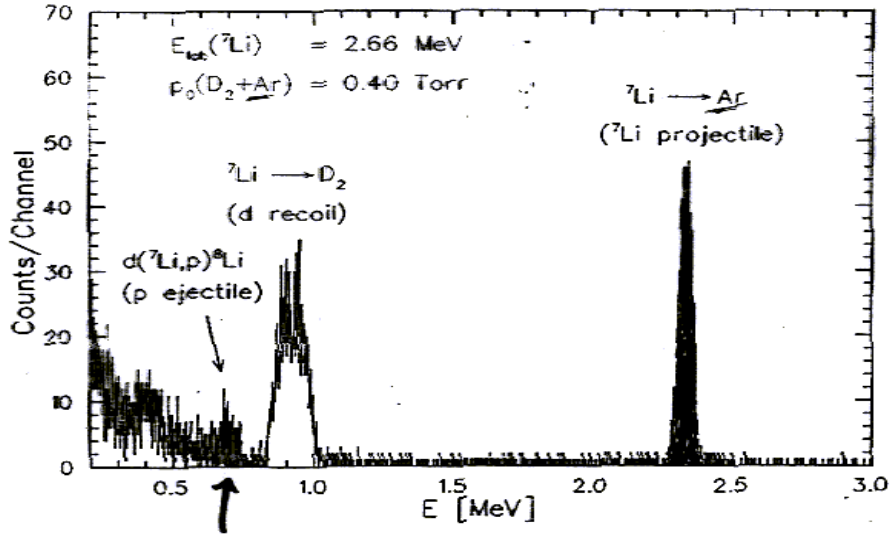
Acceptance ?


p(12C,γ)13N
Elab = 11.0 MeV
(Δp/p)N = 1.1 %
(Δp/p)SM = 1.9 %
T
C
13N–YIELD [relative units]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3050
3100
3150
SWITCHING MAGNET B [G]

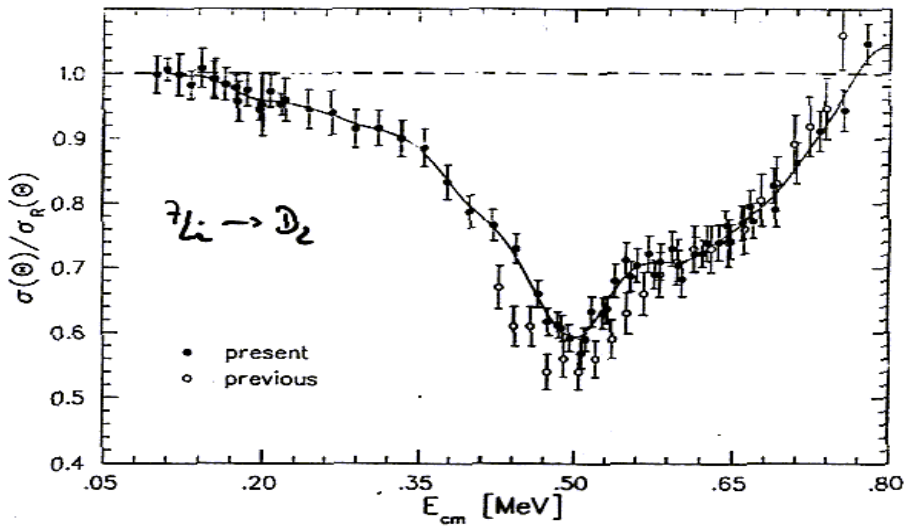

p(12C,γ)13N
Elab = 11.0 MeV
(Δp/p)N = 1.1 %
(Δp/p)WF = 2.6 %
C
T
13N–YIELD [relative units]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
720
730
740
WIEN FILTER B [G]


E (¹⁴N) = 10.93 MeV
q_in = 5+
6+
5+
7+
E (¹⁴N) = 10.93 MeV
q_in = 6+
6+
5+
7+
Ladungszustandsverteilung Φ_q [%]
p_0(H_2) [mbar]
0
20
40
60
80
100
0
1
2
3
4
5
6

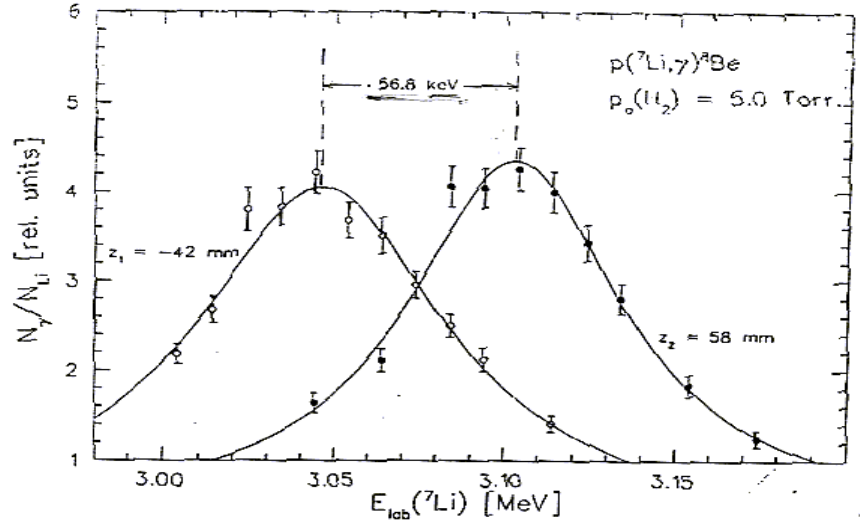
• RUTHERFORD SCATTERING ?



CHECK
$d(^7Li,p)^8Li$ cross section

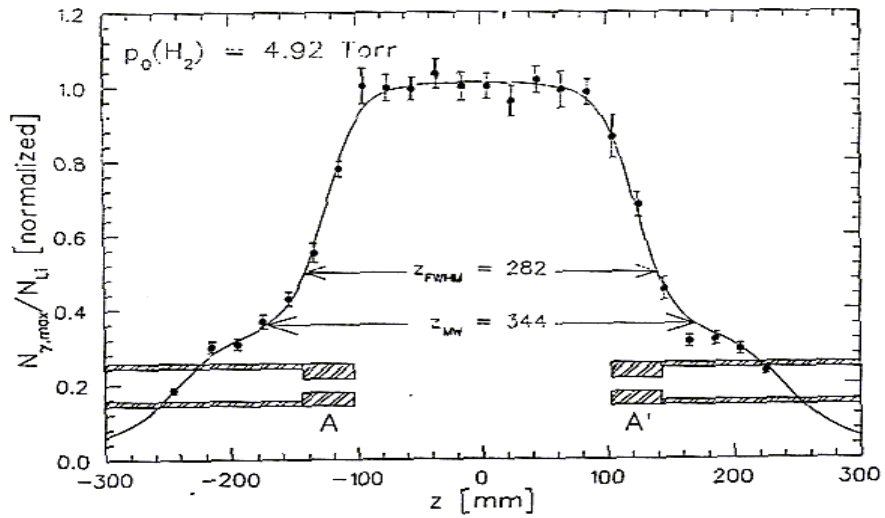


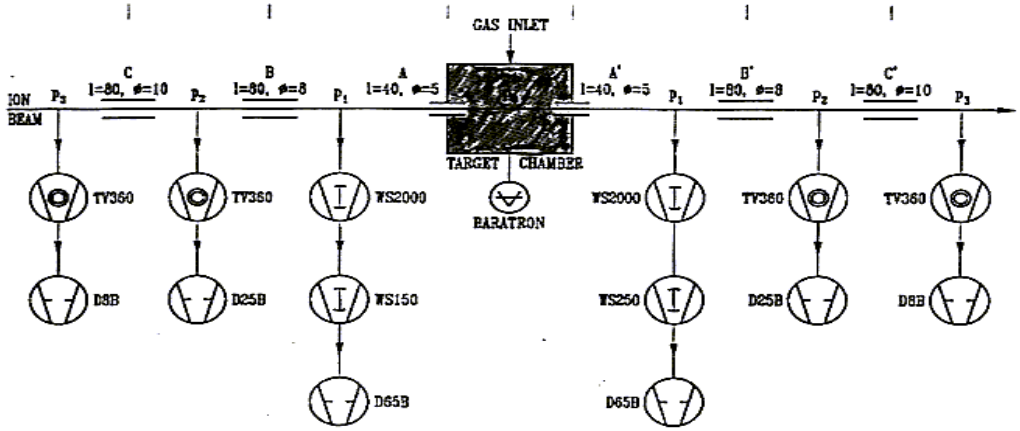
• BGO MEASUREMENTS



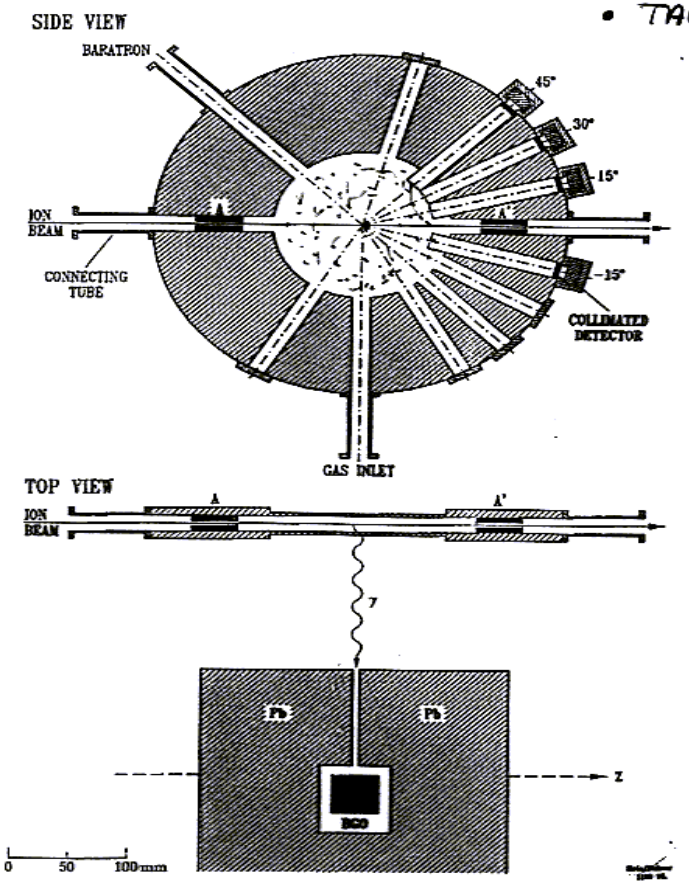
ENERGY LOSS

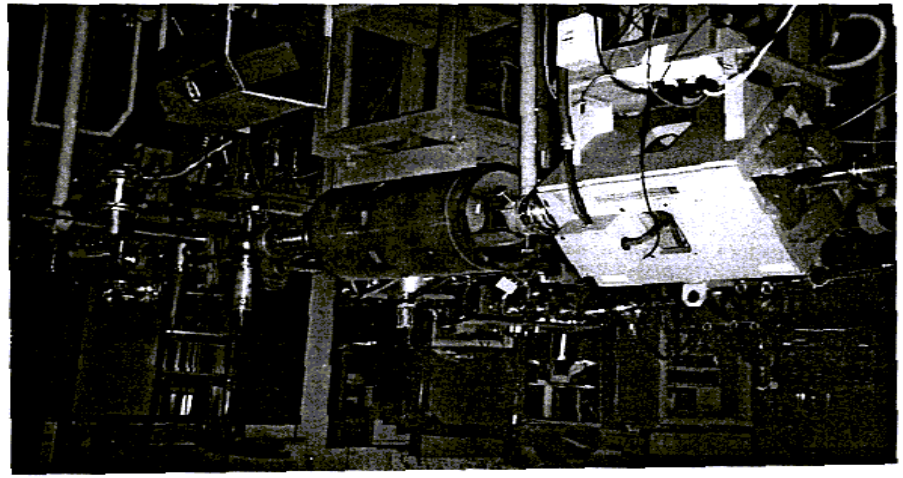
→ PRESSURE DISTRIBUTION

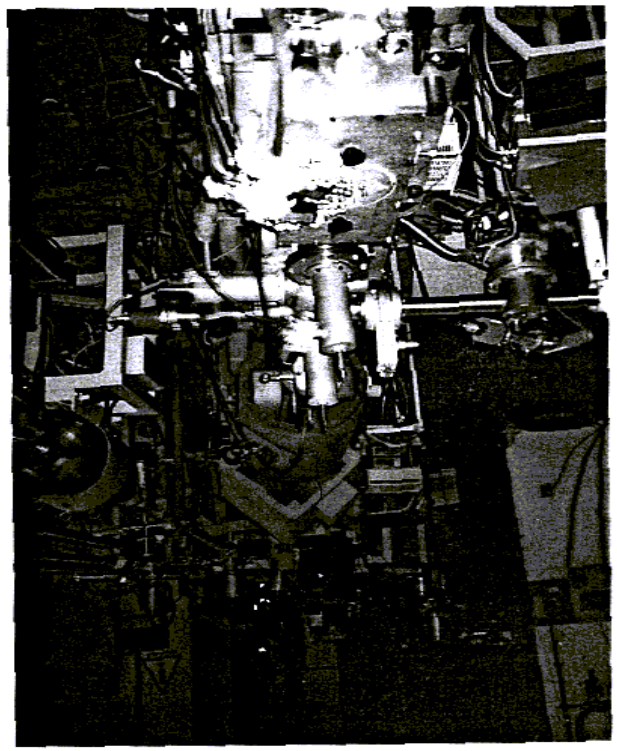


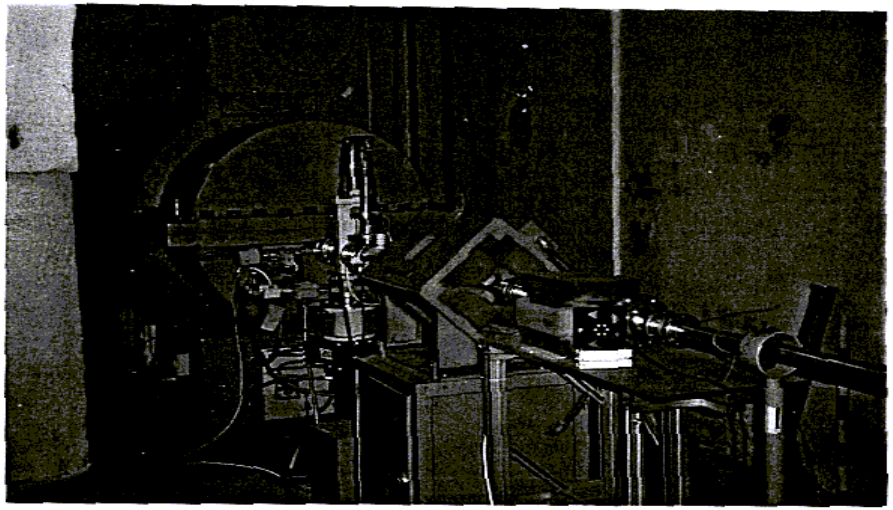


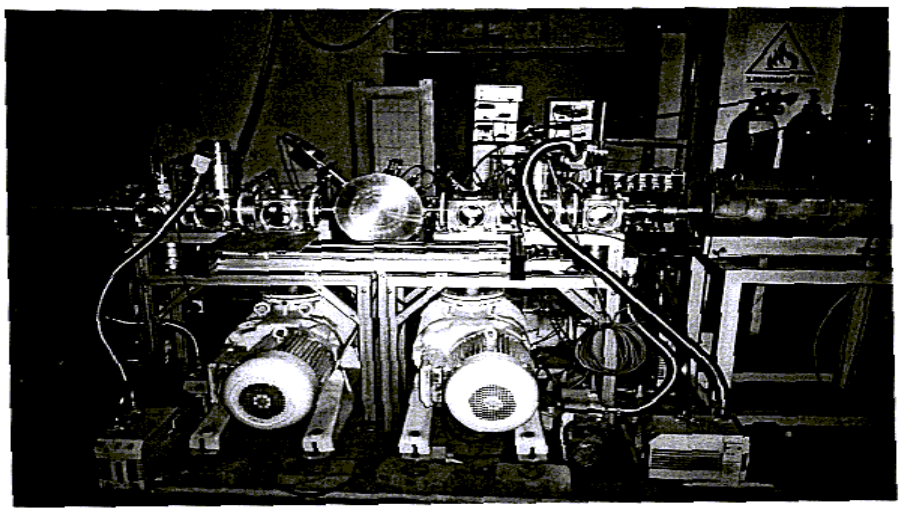
• TARGETCHAMBER



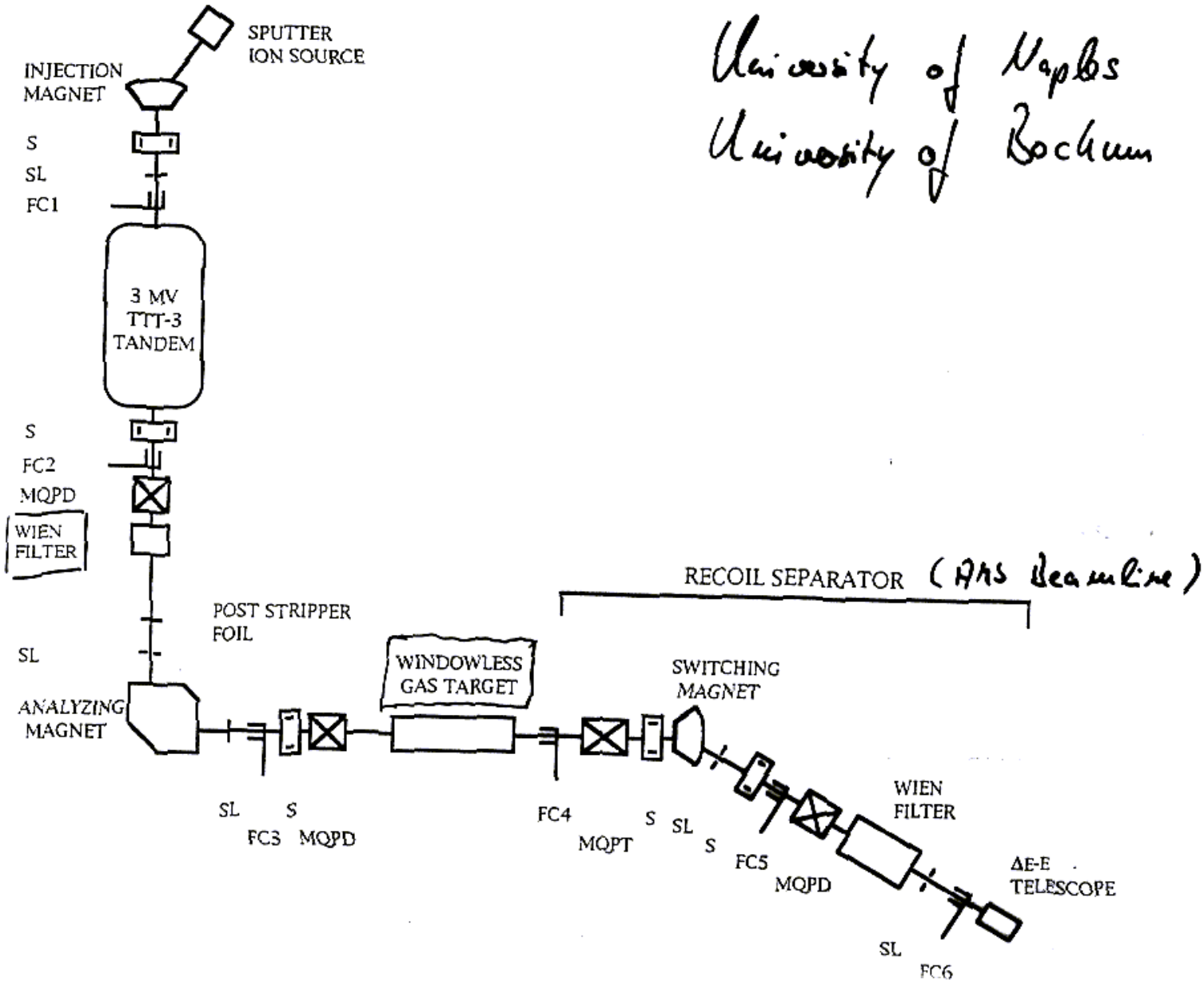








University of Naples
University of Bochum



Problems: - target stochiometry

- radioactive targets

- cosmic background

Solution:

Inverse kinematics

Exchange of target and projectile i.e.:

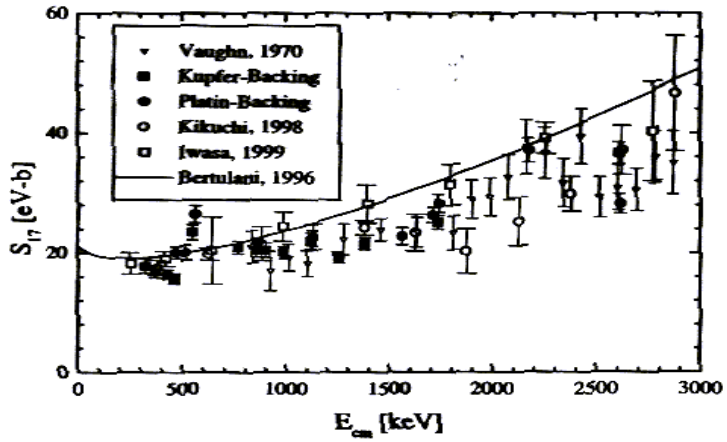
^{7}Be beam $\longrightarrow$ H_2 gas target

Advantage: the reaction recoil ^{8}B carries a lot of energy in the laboratory system

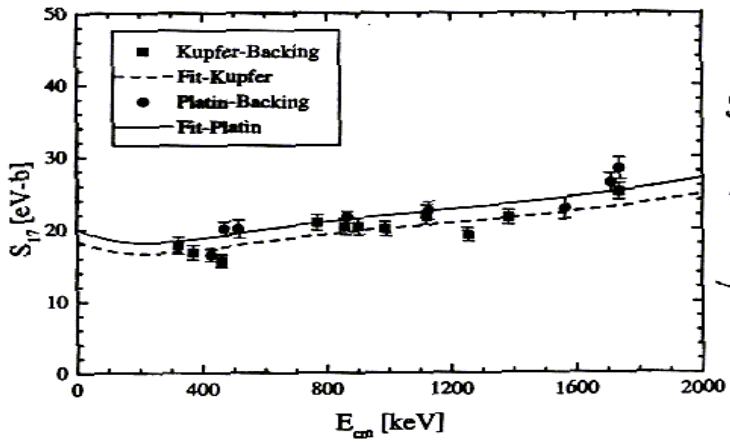
allows for a different detection system

Direct Capture Component

including Coulomb Breakup



Our Results



Cu - backing

$S_{17}(0) = 18.4 \pm 1.4$ eV·b

Pt - backing

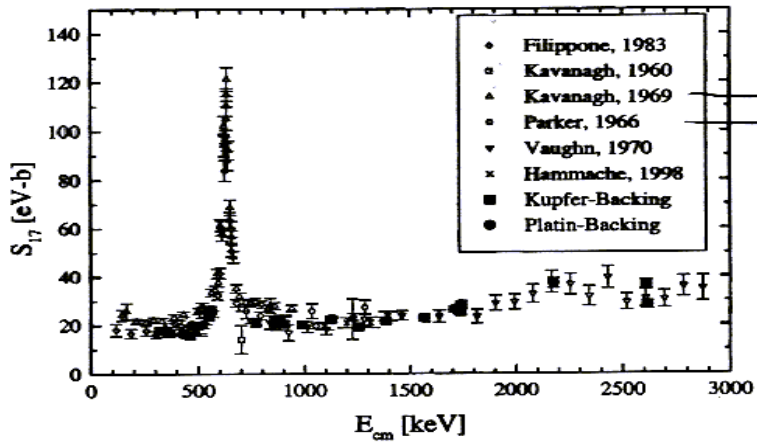
$S_{17}(0) = 20.1 \pm 1.7$ eV·b

↓

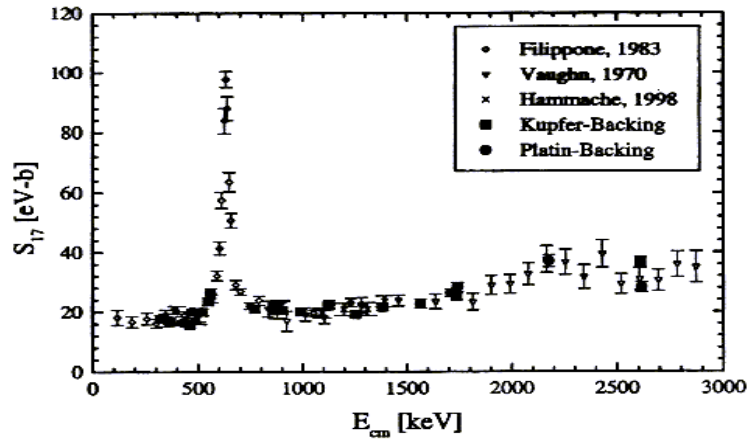
systematically higher

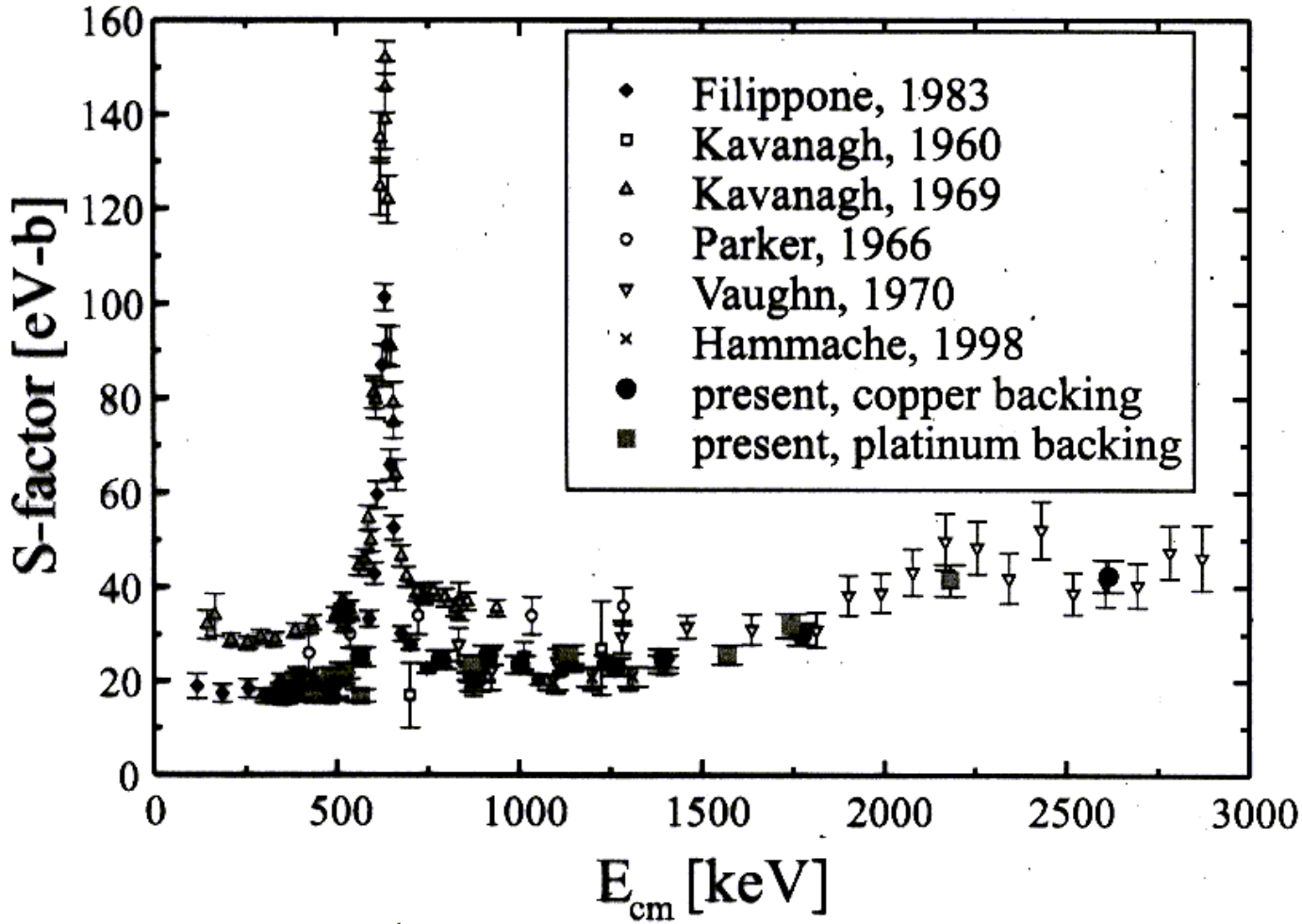
→ Recoil loss effect?

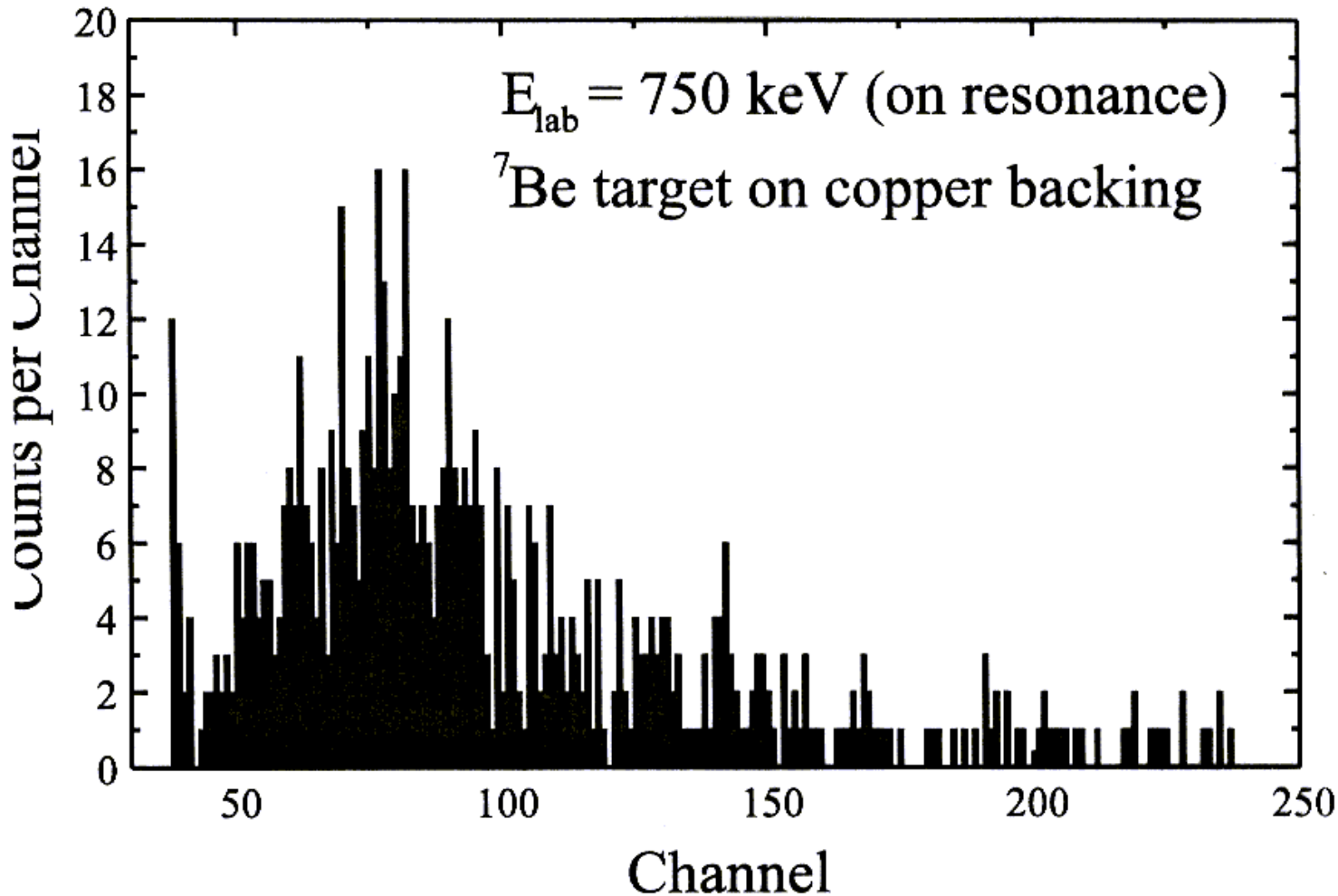
Direct Measurements

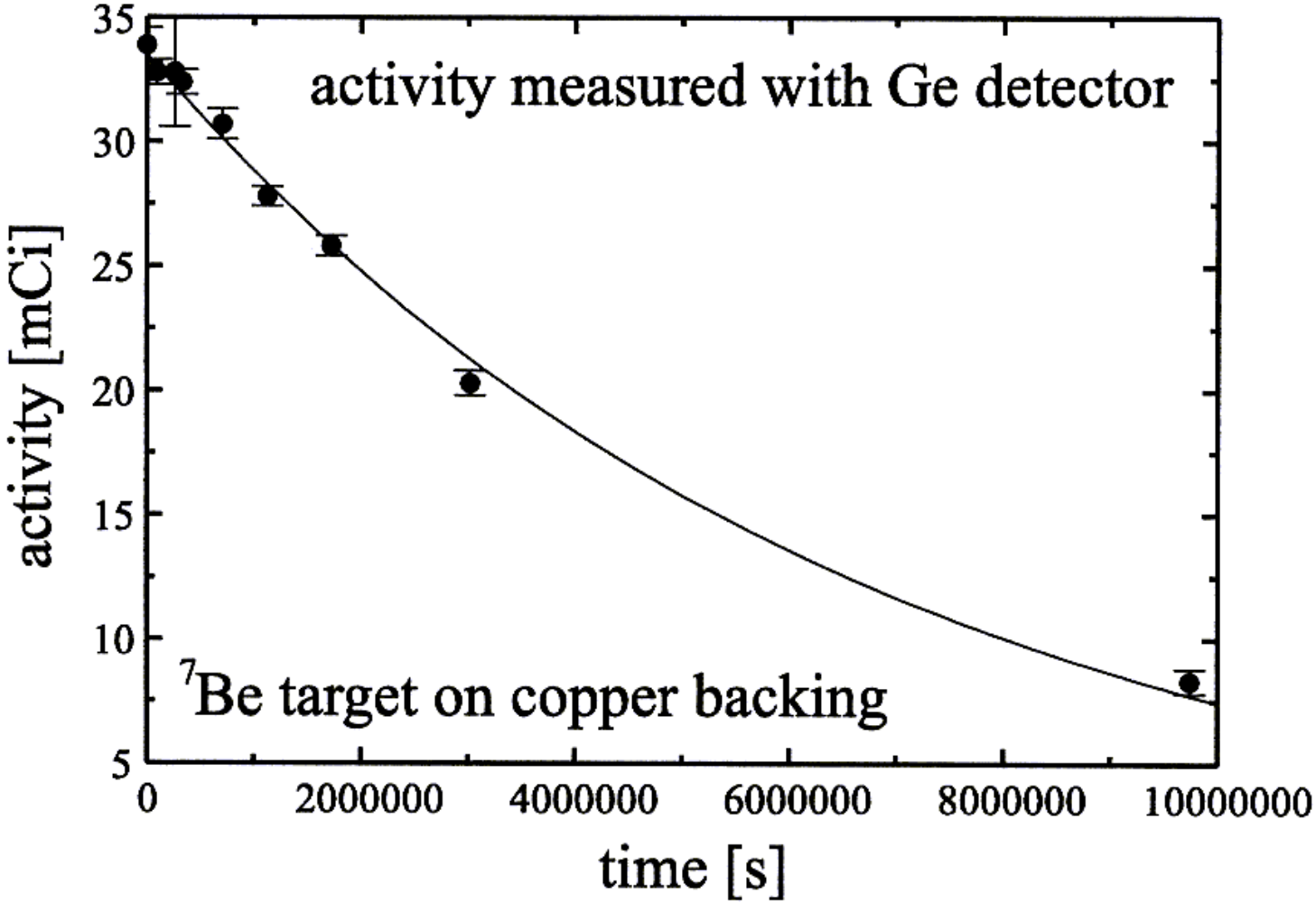


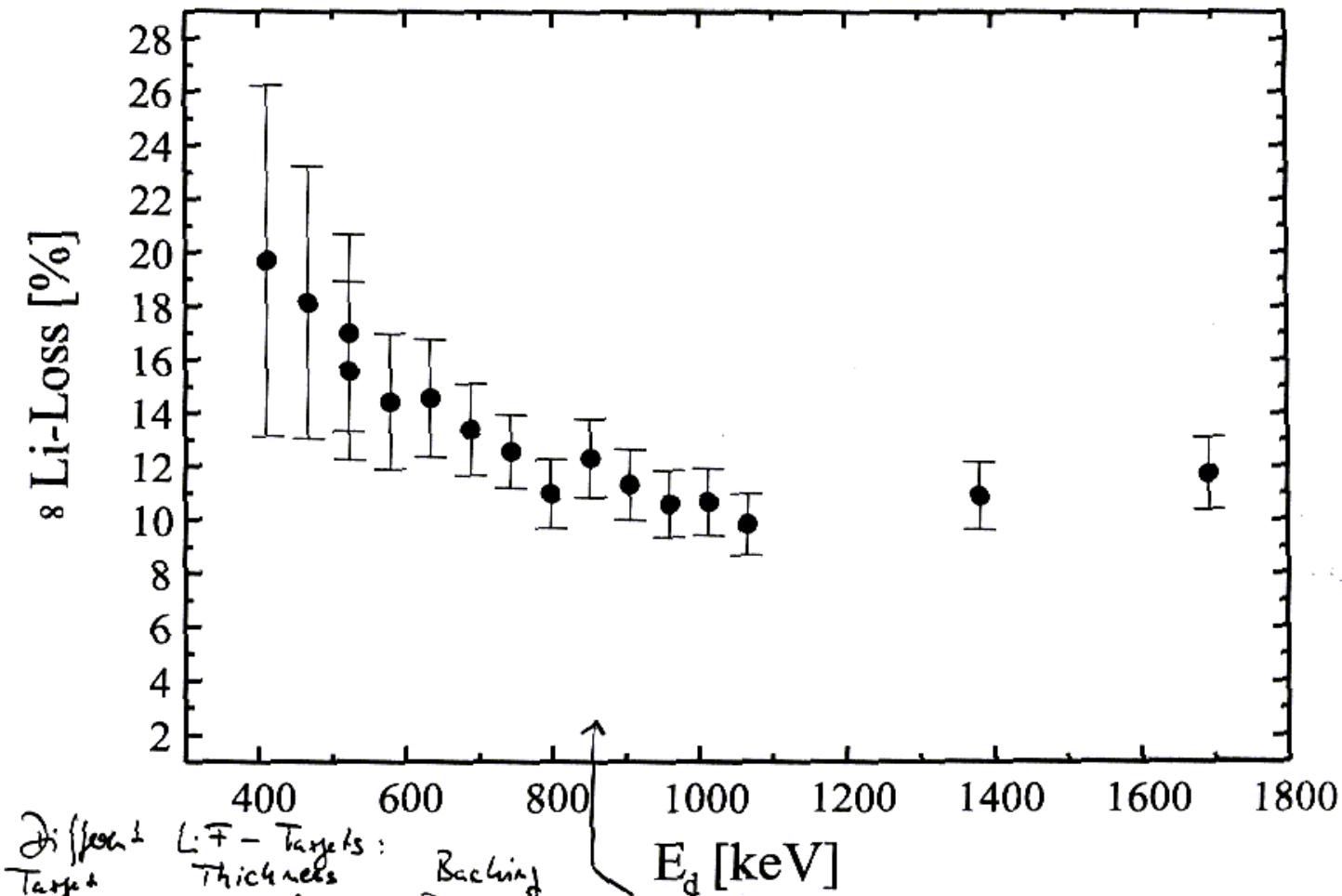
measured only relative to $^7Li(d,p)^8Li$




Filippone, 1983
Kavanagh, 1960
Kavanagh, 1969
Parker, 1966
Vaughn, 1970
Hammache, 1998
present, copper backing
present, platinum backing
S-factor [eV-b]
E_cm [keV]
0
20
40
60
80
100
120
140
160
0
500
1000
1500
2000
2500
3000


E_{lab} = 750 keV (on resonance)
^{7}Be target on copper backing
Counts per Channel
Channel
0
2
4
6
8
10
12
14
16
18
20
50
100
150
200
250


activity measured with Ge detector
^{7}Be target on copper backing
activity [mCi]
time [s]
35
30
25
20
15
10
5
0
2000000
4000000
6000000
8000000
10000000

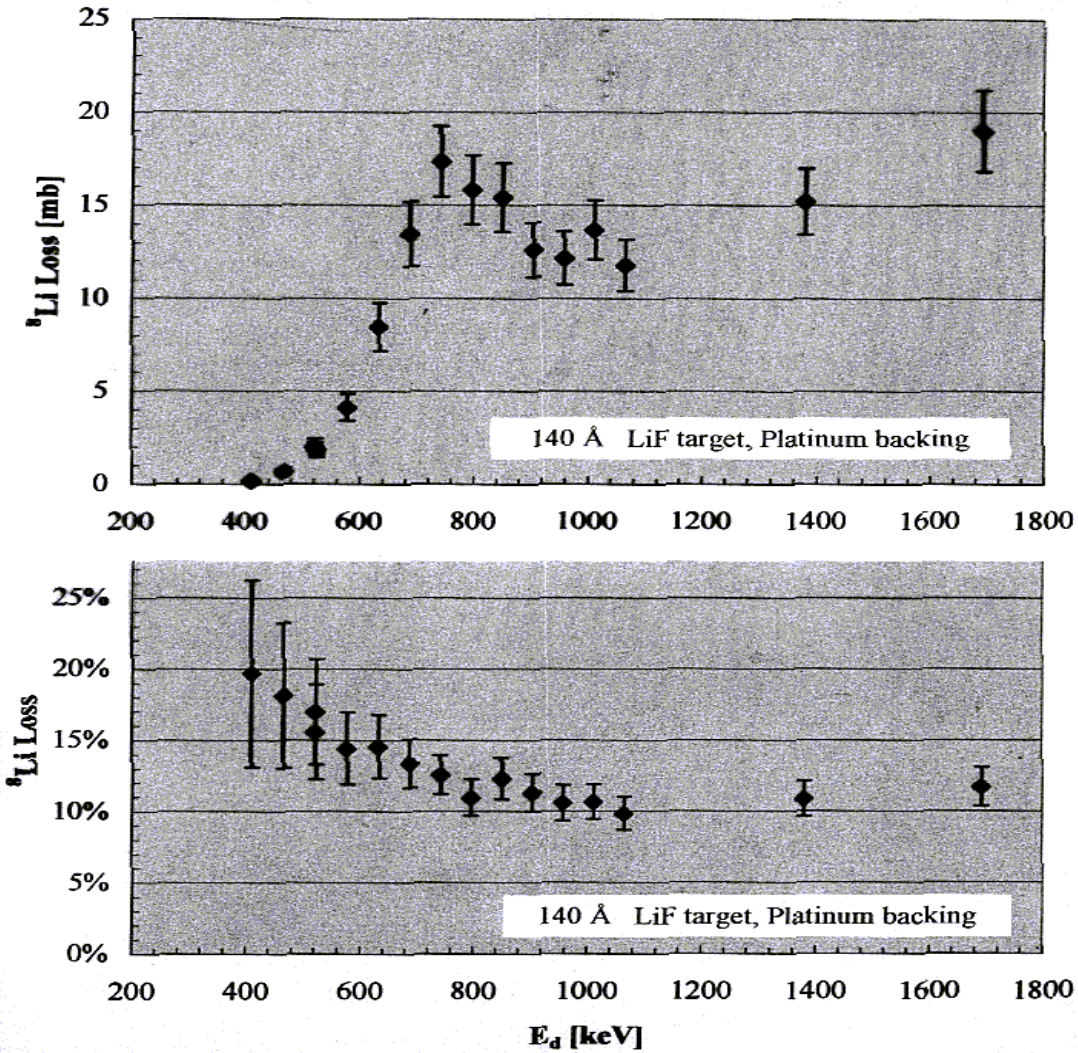


Different LiF – Targets:

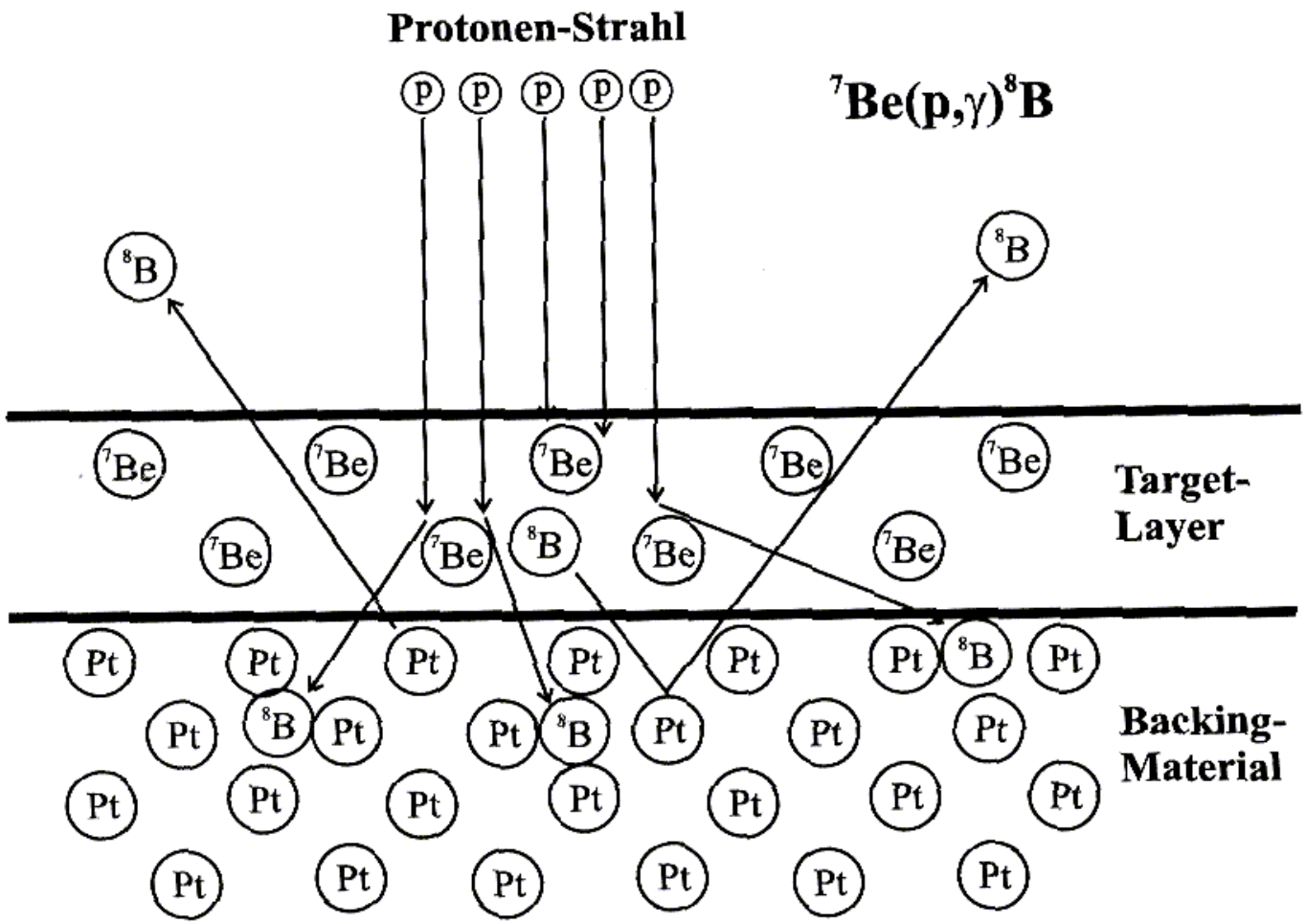
Target	Thickness	Backing	
#1	12000 Å	Platinum	0.9 %
#2	3150 Å	Copper	1.4 %
#3	140 Å	Platinum	12.5 %
#4	140 Å	Copper	1.1 %
#5	140 Å	Aluminum	0.2 %

^{8}Li – Recoil loss

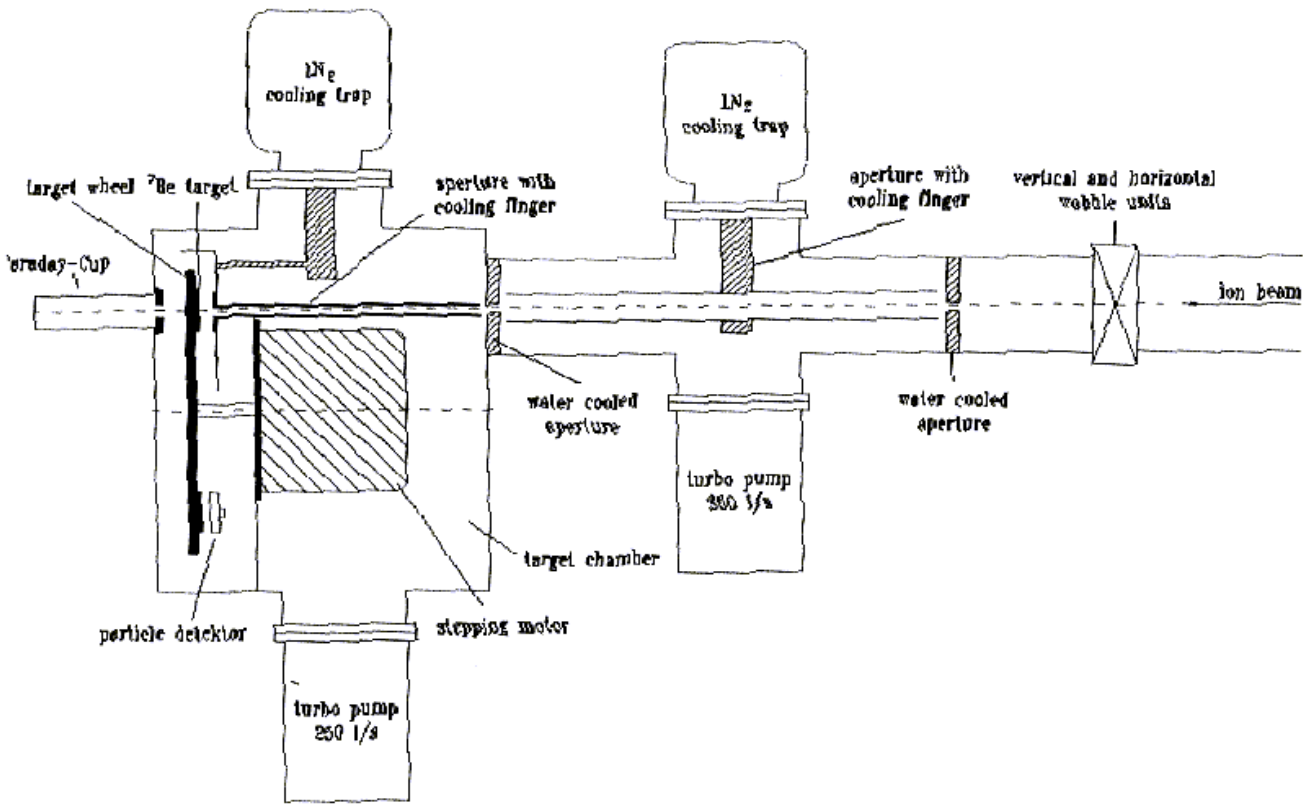
↳ what about ^{8}B – loss



^{8}LI RECOIL LOSS - RESULTS


Protonen-Strahl
p p p p p
$^7Be(p,\gamma)^8B$
^8B
^8B
^7Be
Target-Layer
Pt
Backing-Material

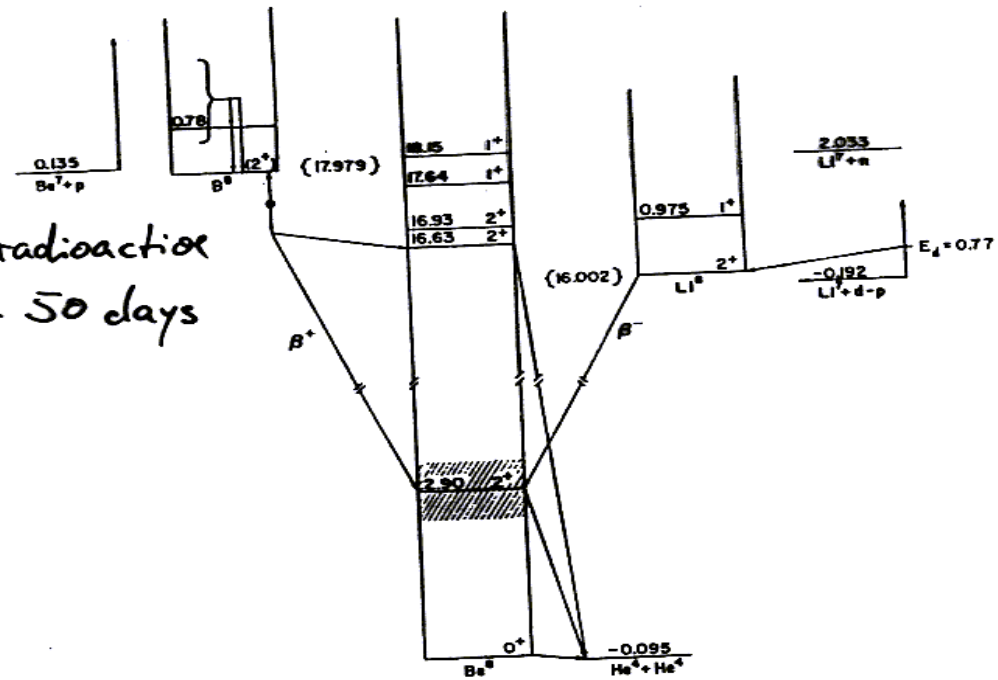
Sideview Target Chamber



$^7Be(p,\gamma)^8B$ $\qquad$ $^7Li(d,p)^8Li$

^7Be radioactive

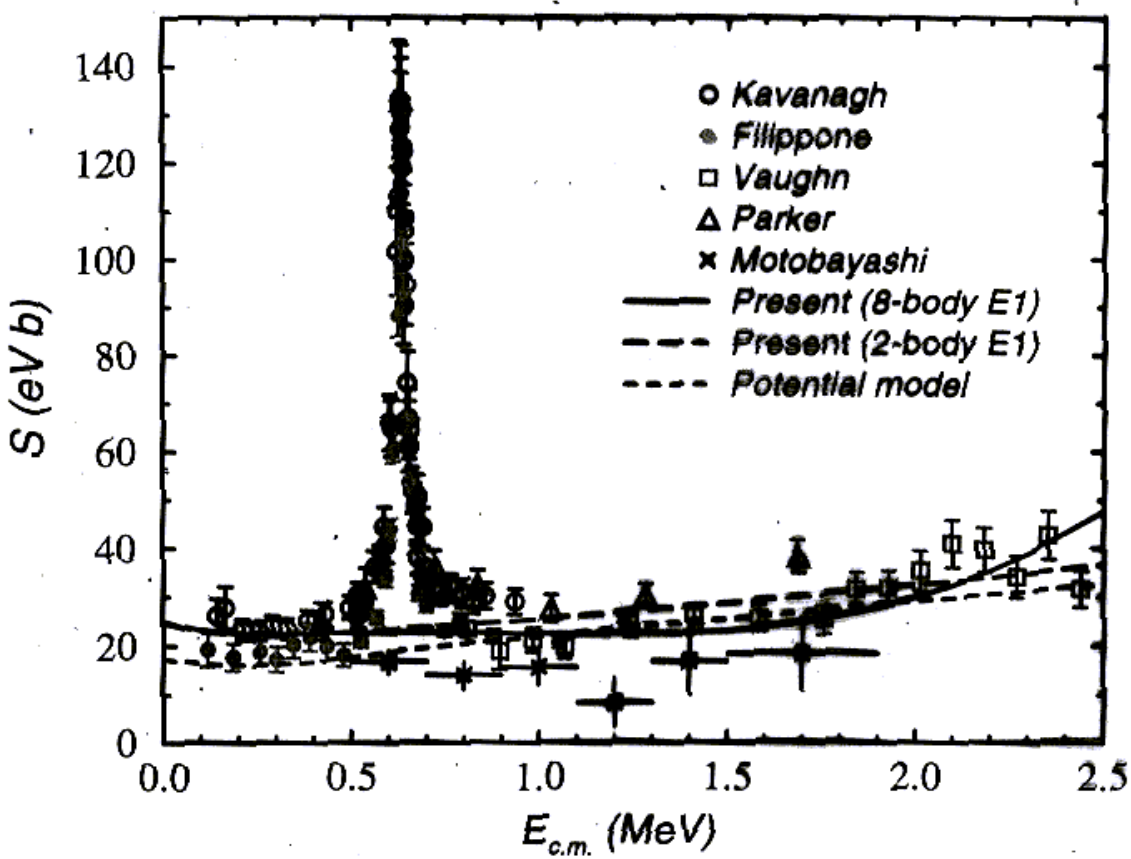
$T_{1/2} \sim 50$ days



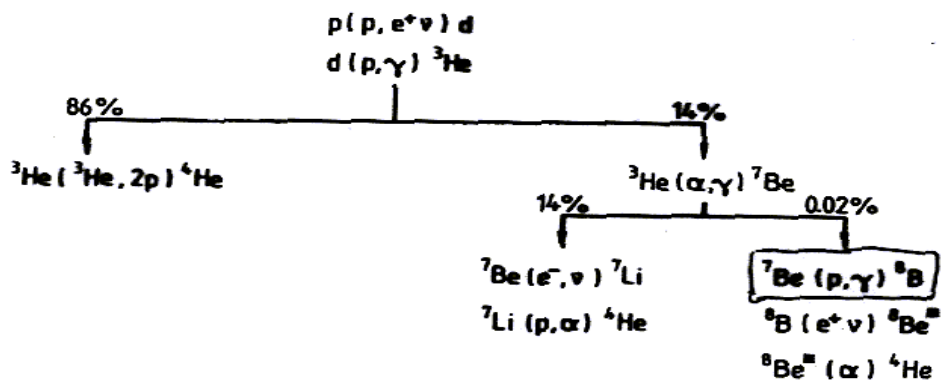
$$^8B \xrightarrow{+\beta} {}^8Be \rightarrow 2\alpha \leftarrow {}^8Be \xleftarrow{\beta^-} {}^8Li$$

Off-shell effects in $^7Be(p,\gamma)^8B$

by A. Csoto



THE REACTIONS OF THE P-P CHAIN



CHAIN I	CHAIN II	CHAIN III
Q_{eff} = 26.20 MeV	Q_{eff} = 25.66 MeV	Q_{eff} = 19.17 MeV
(2.0% loss)	(4.0% loss)	(28.3% loss)

NET - RESULT : $4p \longrightarrow {}^4He + 2e^+ + 2\nu + Q_{eff}$