大立体角スペクトロメータによる不安定核の研究

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Introduction

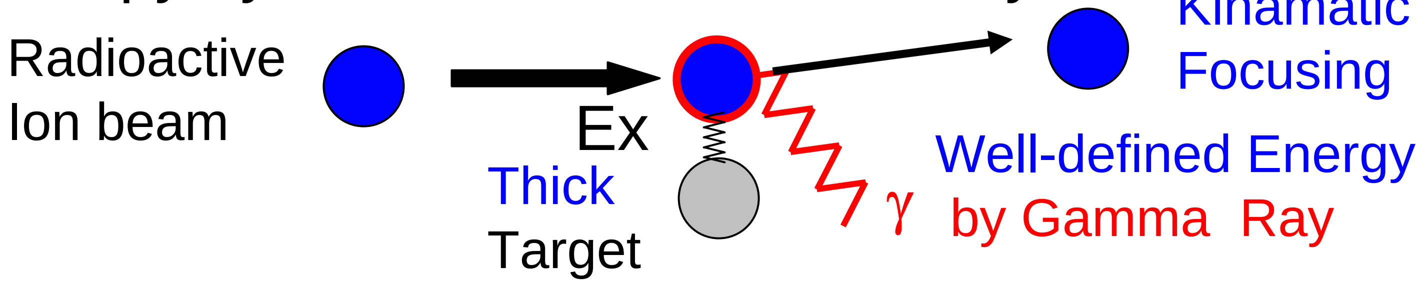
Nuclear Structure @ far from the stability

1) Halo/Skin : Universal?
2) Collective Behavior?
3) Single-Particle Behavior, Shell Model?
4) Structure Beyond Drip Lines?

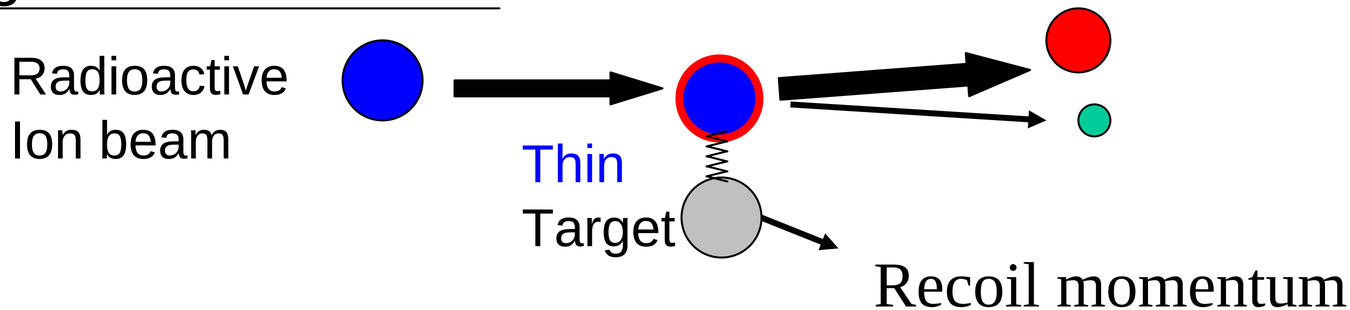
→ Spectroscopic Tool

Reaction Experiment using RIB

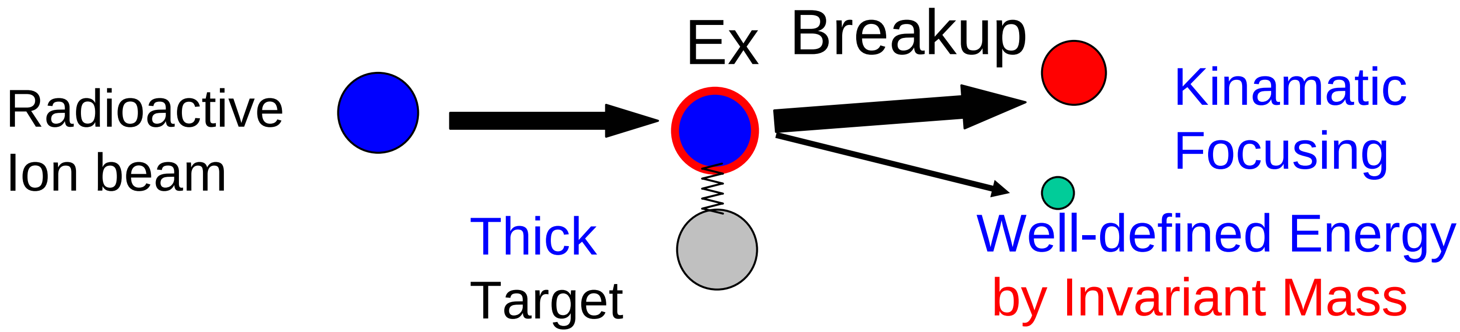
Spectroscopy by Deexcitation Gamma Ray



Missing Mass Method



Invariant Mass Method (不変質量法)



Physics Programs using Invariant Mass Method

- Giant Resonance for nuclei far from the stability

  GDR,GQR,GMR for nuclei with large Tz, neutron-skin/halo

- Low-lying Discrete States of Weakly-Bound Nuclei

  ^{19}B,^{22}C,^{31}Ne etc.

- Coulomb Dissociation as a spectroscopic tool

  ^{31}Ne,^{81}Zn

- Molecular/Cluster States

  ^{12}Be(^{6}He-^{6}He),^{18}C(^{6}He-^{6}He-^{6}He)

- Spectroscopy of Nuclei Beyond Drip Line

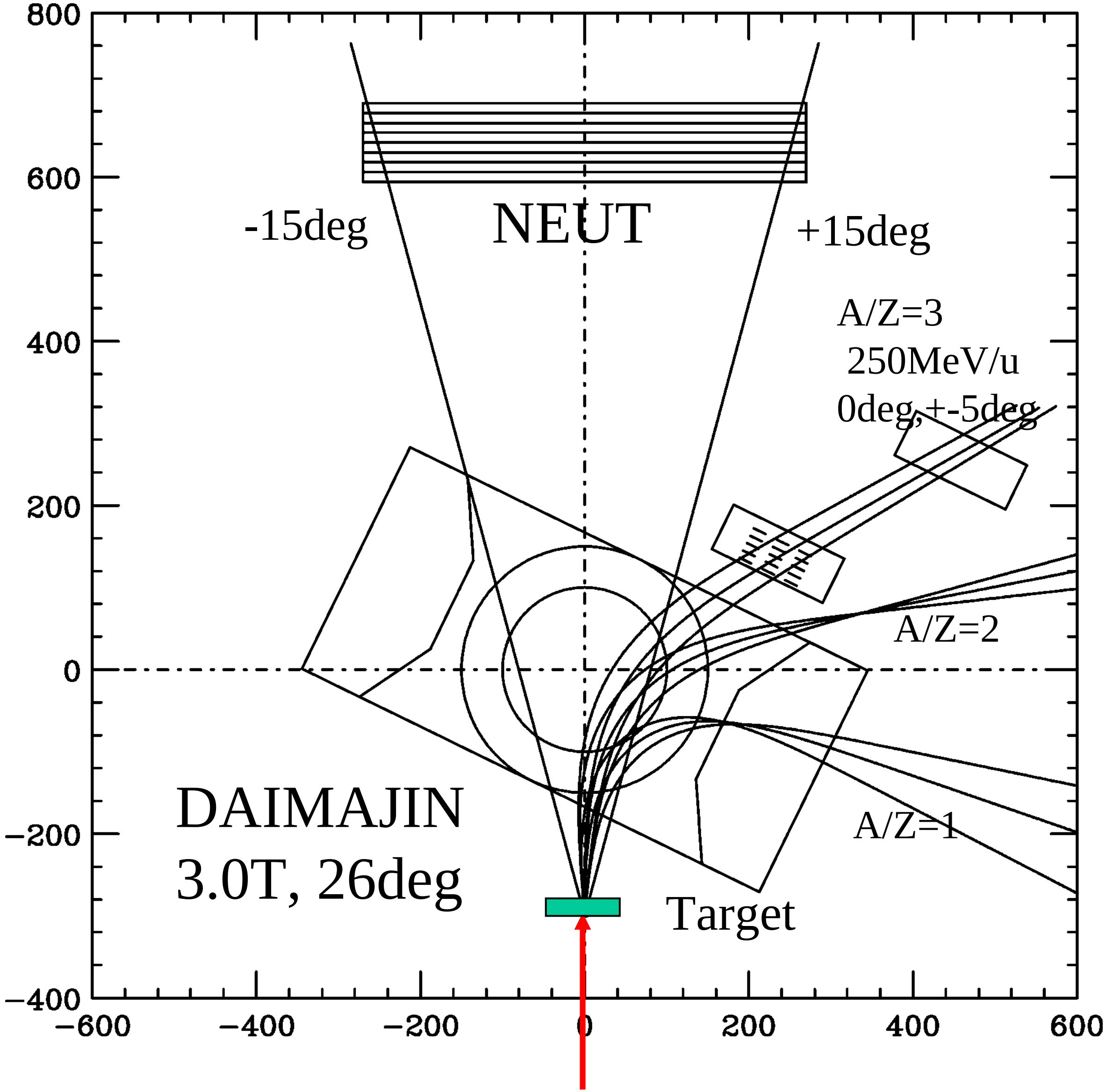
  ^{26,28}O,^{30}F

Other Programs

- Multi-neutron removal cross sections

  Various breakup channels At once σ_{-1n} σ_{-2n} σ_{-3n} ..

実験装置の概略：超伝導磁石(DAIMAJIN)＋中性子検出器



超伝導磁石に対する必要条件

- 中性子に対し大立体角
- ビーム、荷電粒子をスィープする。
- 荷電粒子識別能力
A分解能が高い
A/ΔA~100(4σ分離
- $B\rho_{max}$=7.3Tm
E/A=250MeV
for A/Z=3

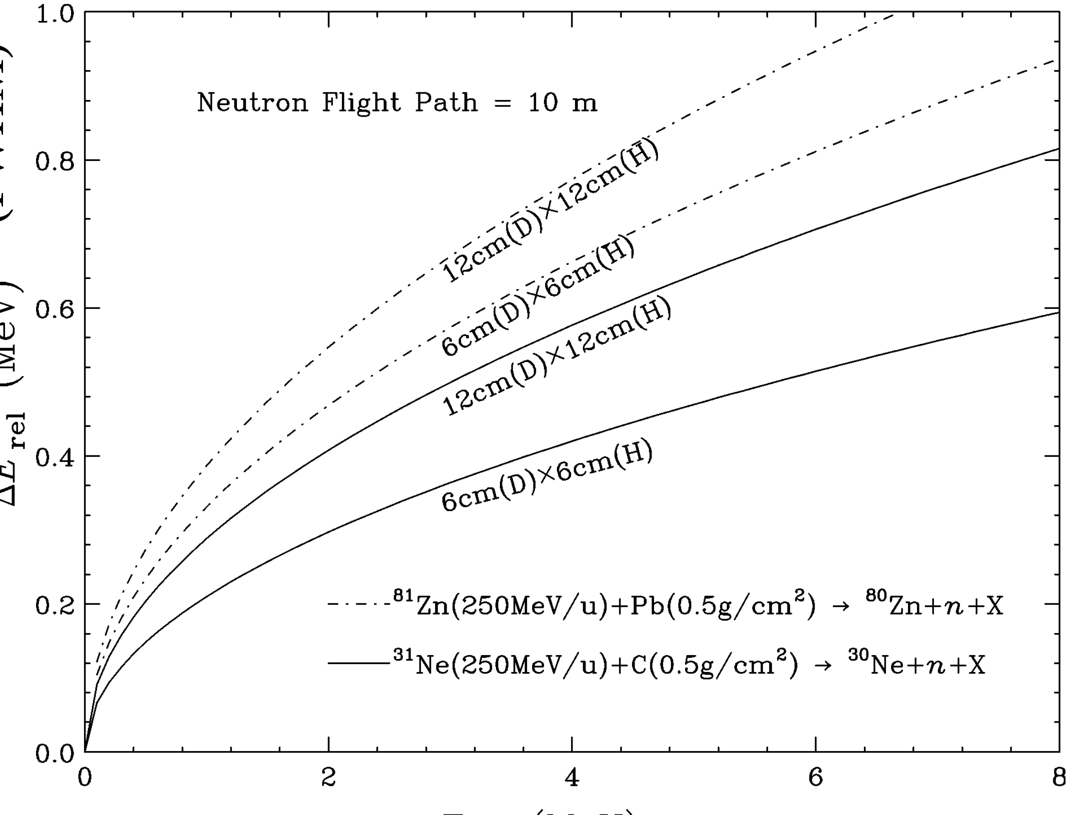
Required Resolution

- PID Resolution: Mass resolution 100 with 4σ separation

$$\frac{\Delta A}{A} = \sqrt{(\gamma \frac{\Delta T}{T})^2 + (\frac{\Delta B\rho}{B\rho})^2} \qquad \frac{\Delta T}{T} \sim \frac{\Delta B\rho}{B\rho} \sim 0.2\%(1\sigma)$$

→ Large Bending Magnet
BL~7Tm

- Relative Energy Resolution



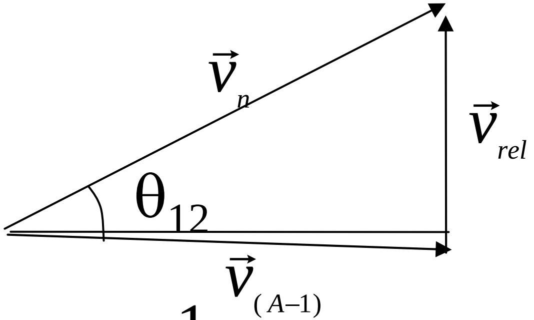
$$\Delta E_{rel} \propto \sqrt{\frac{E}{A} E_{rel}}$$

(better for 250MeV/u than 600MeV/u)

→ Long Flight Path
High Granularity
For neutron detection

$$\Delta E_{rel}(2body) \approx \Delta E_{rel}(3body)$$

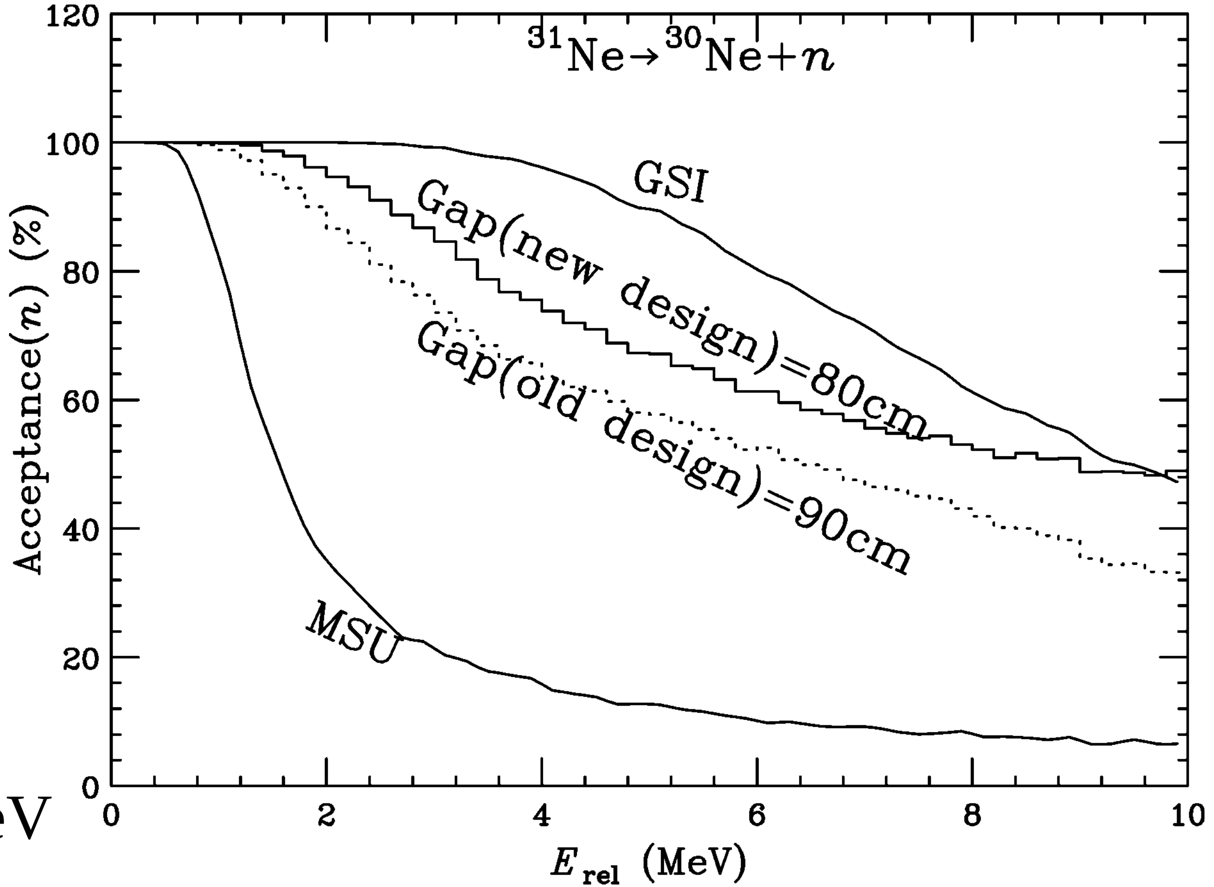
Acceptance



$$E_{rel} = \frac{1}{2}\mu v_{rel}^2$$

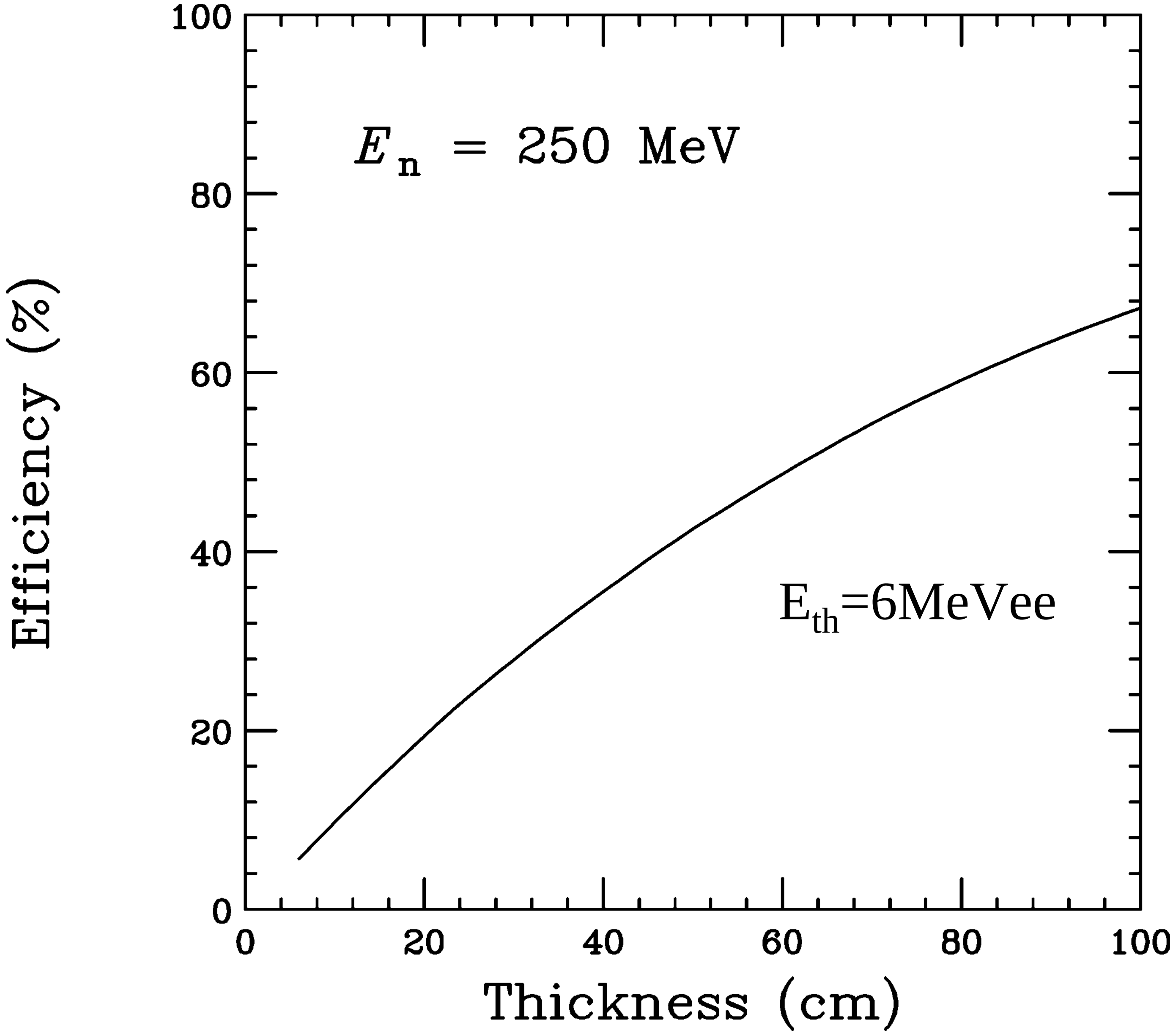
Acceptance
is determined
by neutron!

10deg @Erel=8MeV



	E_n		
Daimajin(new)	250MeV	10deg(V) X 30deg(H) (90msr)	BL=7Tm
Daimajin(old)	250MeV	8.6deg(V) X 19deg(H)	
GSI	600MeV	9.16deg(V) X 9.16deg(H)	BL=5Tm (being designed)
MSU	80MeV	11.4deg(V) X 11.4deg?(V)	BL=2.8Tm

Detector depth vs. Efficiency (Code by Cecil et al.)



70% @ 1m

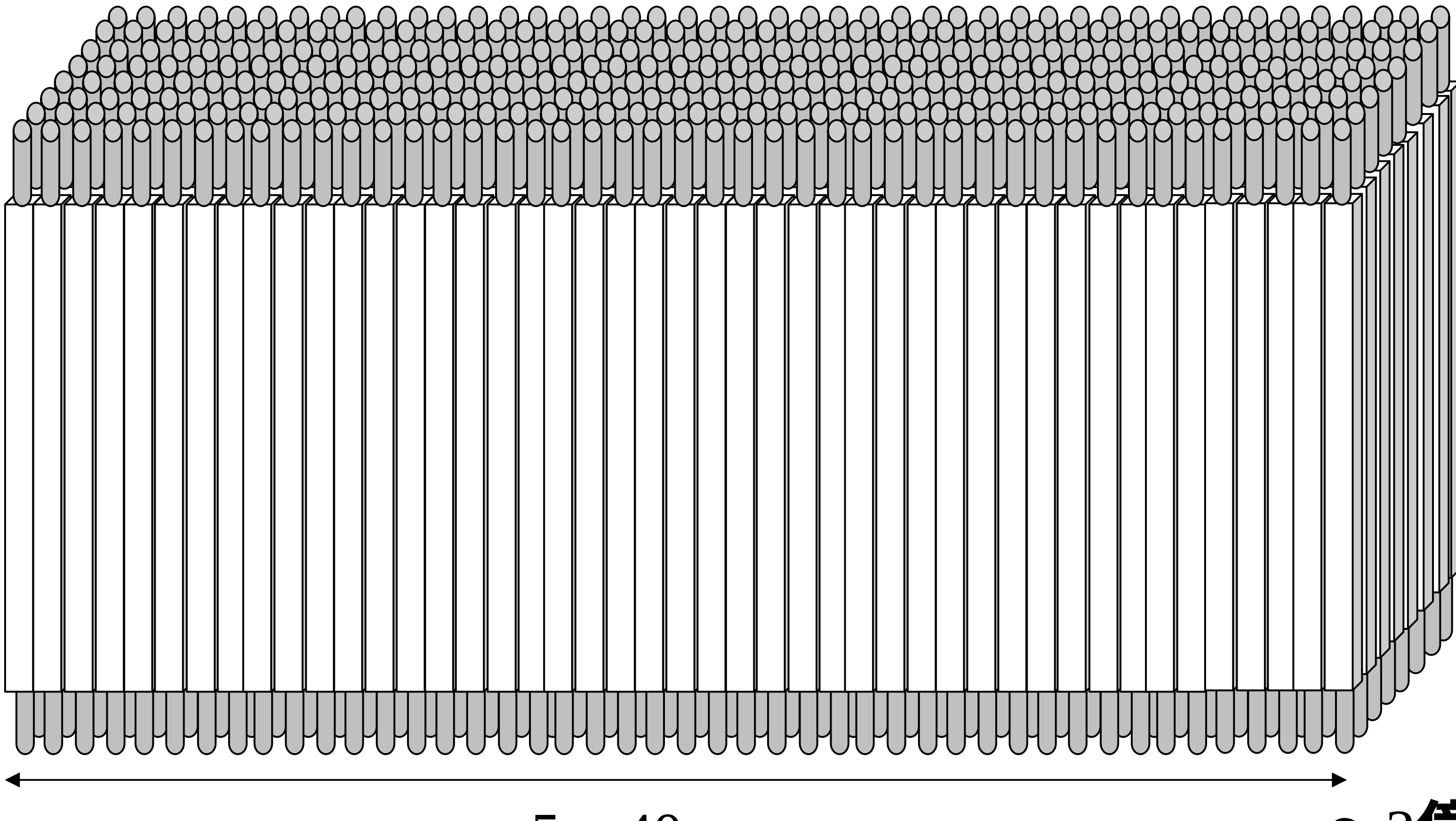
Brute Force で中性子検出器を考えると。。。

12cm X 12cm X 200cm/1本 (45 x 8 layers=320 Modules)

180cm(V) x 540cm(H) X 96cm(D)

後面までの飛行距離10mとして

Acceptance=10.2deg(V) X 30.2deg(H)



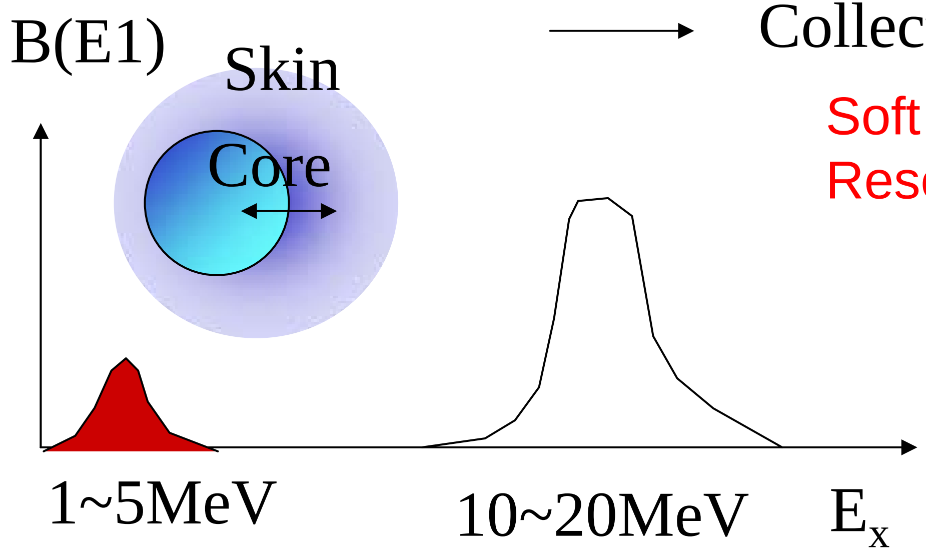
〜2億円

c.f. LAND 2m(V)X2m(H)X1m(D) 200 Modules

Collective Behavior of Neutron-Skin Nuclei

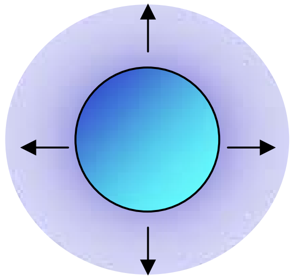
Thick Neutron-Skin : Contain many neutrons

→ Collective Mode



Soft Dipole(E1) Resonance?

Coulomb Breakup



Breathing Mode(E0): Incompressibility

neutron- star

supernova

Soft Dipole Resonance:

RIBF(250MeV/u) vs. GSI(600MeV/u)

^{80}Zn + ^{208}Pb ^{80}Zn Beam: RIBF=100*GSI

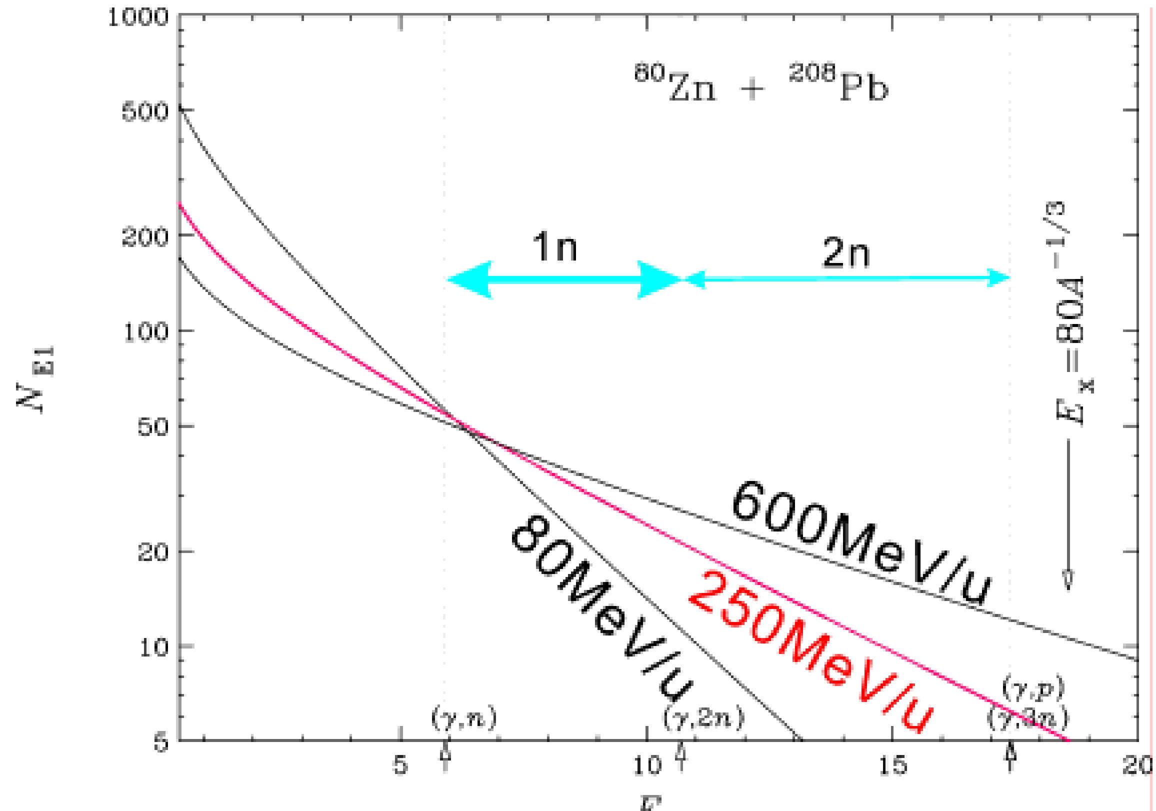
^{80}Zn(~1kcps @RIBF vs. ~10cps@GSI)

Target Thickness : RIBF=0.4*GSI

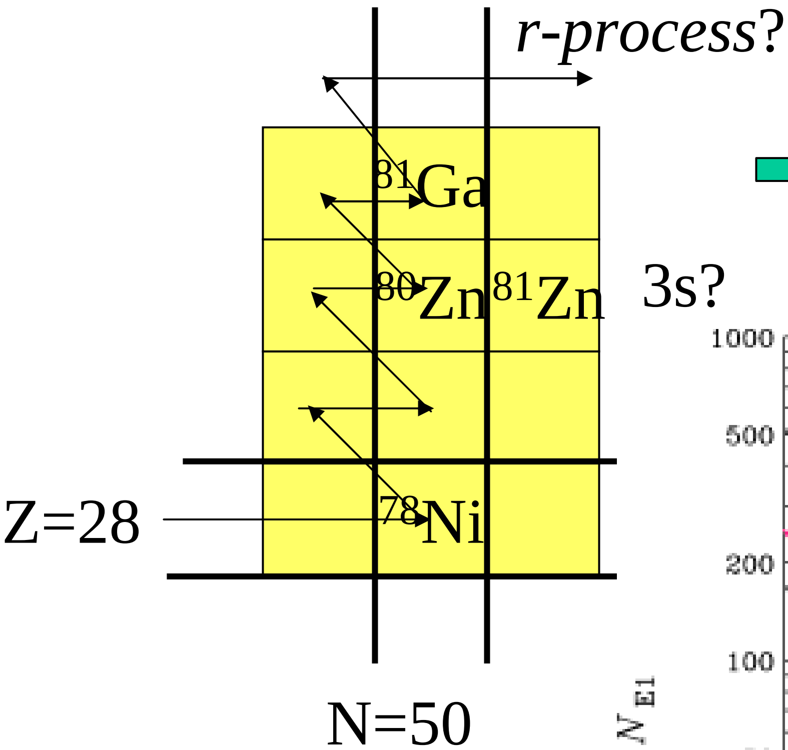
E1 Photon @Ex=10MeV: RIBF=0.8*GSI

Neutron efficiency : RIBF=0.6*GSI

Total Yield : RIBF=~20*GSI



Single Particle State

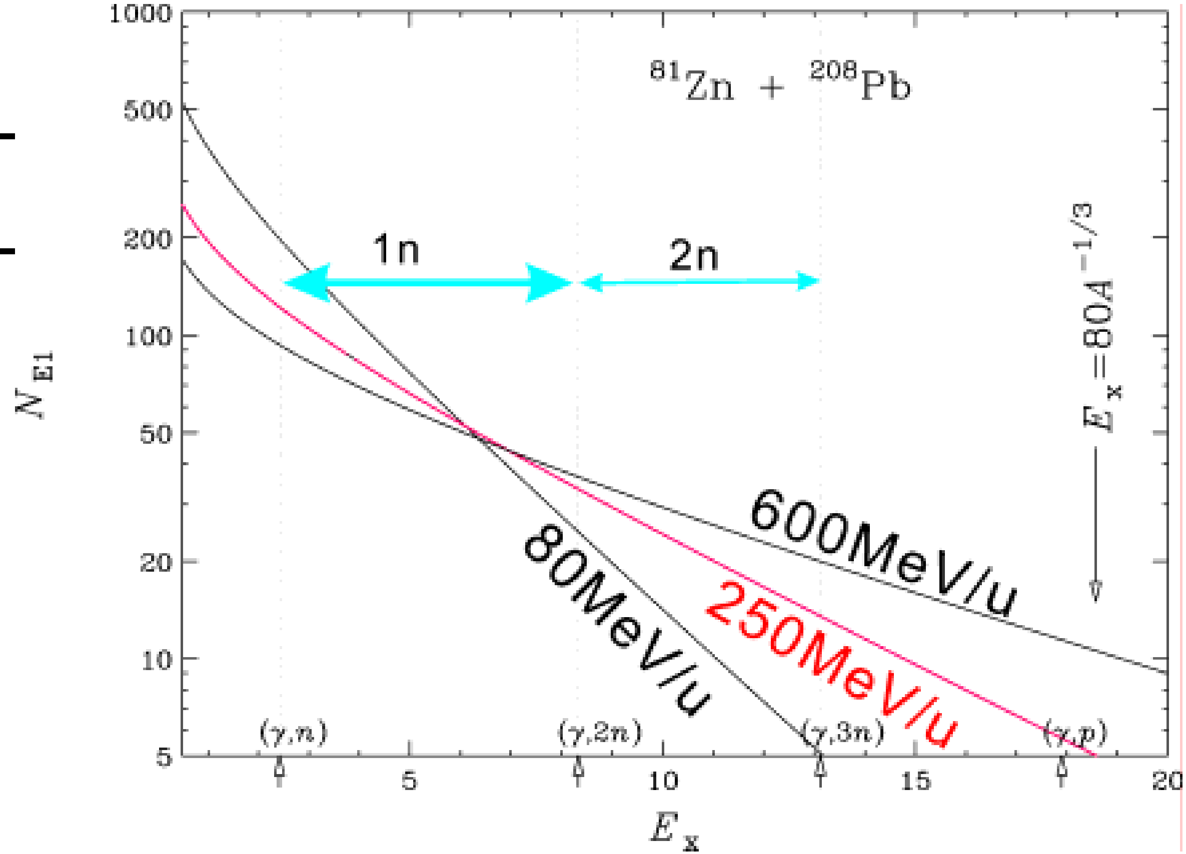


c.f.
Coulomb Dissociation of ^{19}C
T.Nakamura et al., PRL**83**,1112(1999).

Non-resonant Soft Excitation

→ Spin-parity, Spectroscopic factor for g.s.

$^{81}Zn + ^{208}Pb$



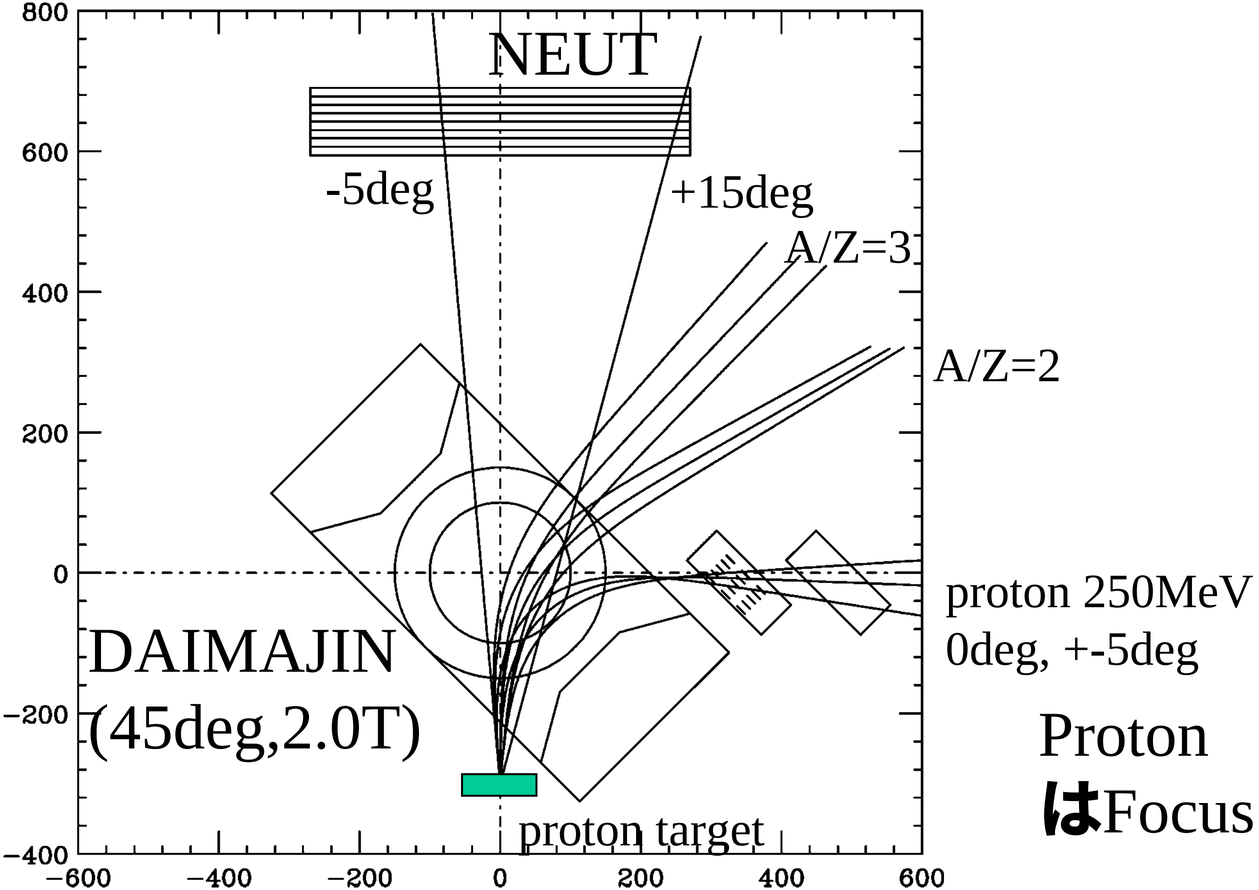
(p,n) type reaction

IAS

$^{11}Li + p \rightarrow {}^{11}Be^* + n$

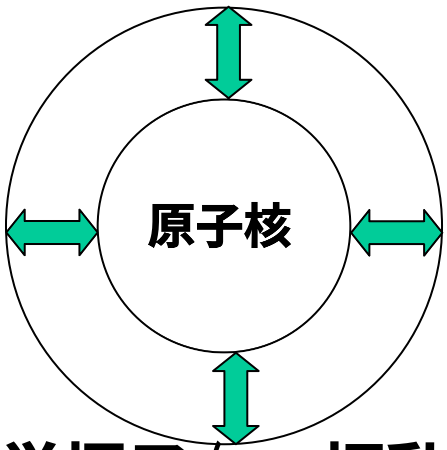
$\quad\quad\quad\quad\quad\quad \rightarrow {}^{9}Li + p + n$

Teranishi et al. PLB**407**(1997) 110-114.
Takeuchi et al. PLB



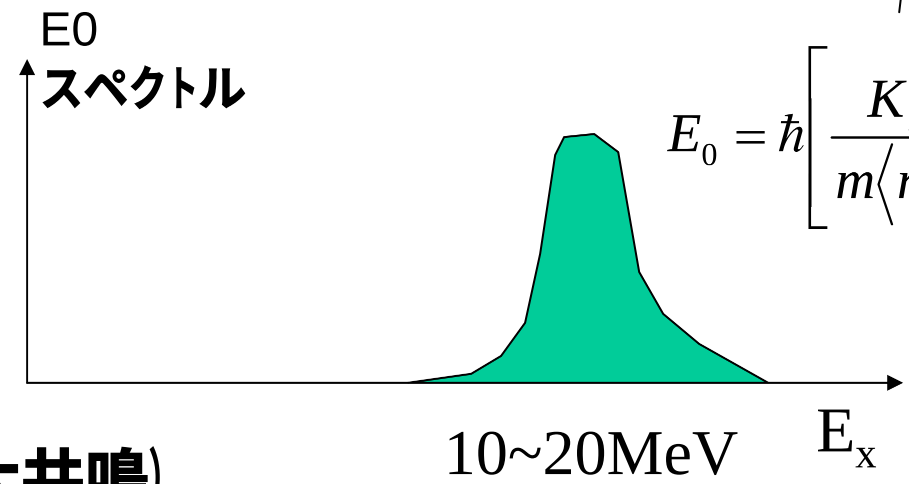
Proton
はFocus

非圧縮率と単極子 (E0)巨大共鳴



単極子 (E0)振動 (巨大共鳴)

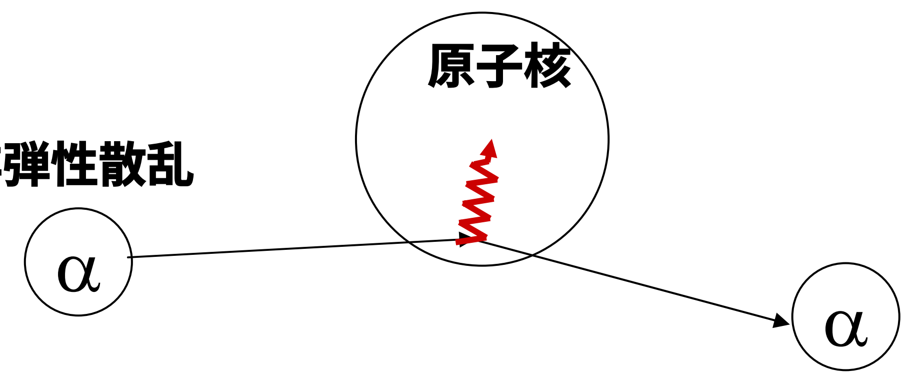
Breathing Mode



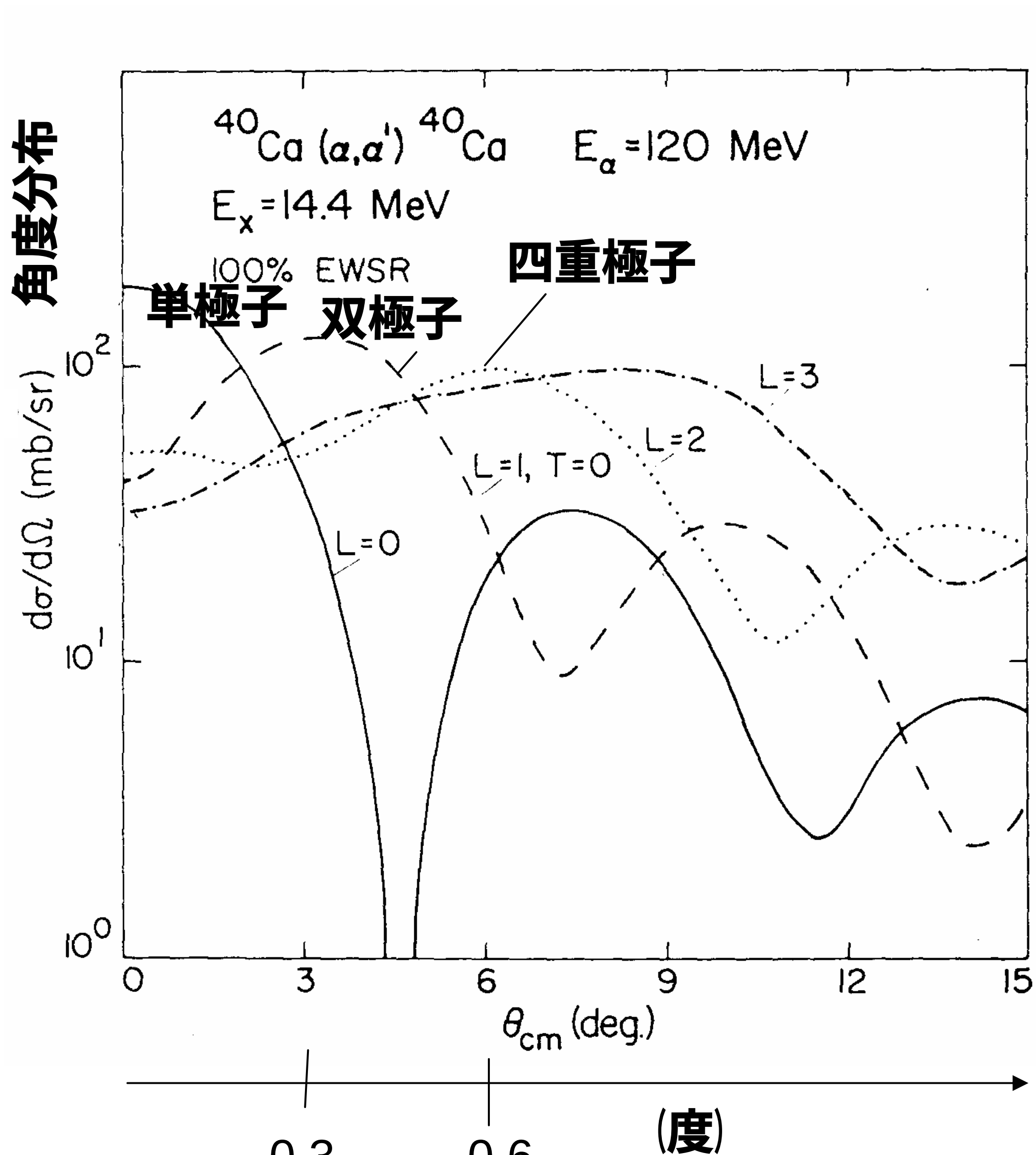
非圧縮率

$$E_0 = \hbar\left[\frac{K_A}{m\langle r^2\rangle}\right]^{1/2}$$

アルファ粒子の非弾性散乱



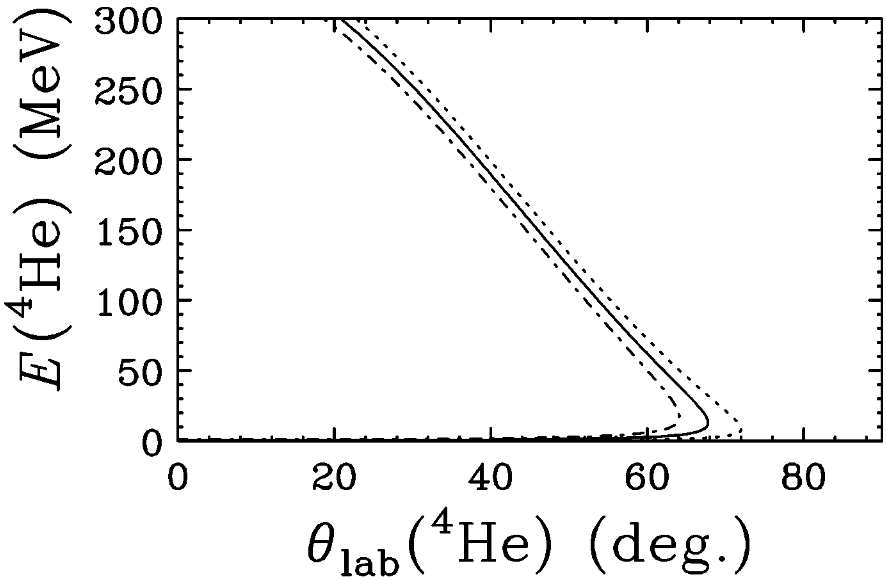
他の励起モードとの分離法　角度分布を使う

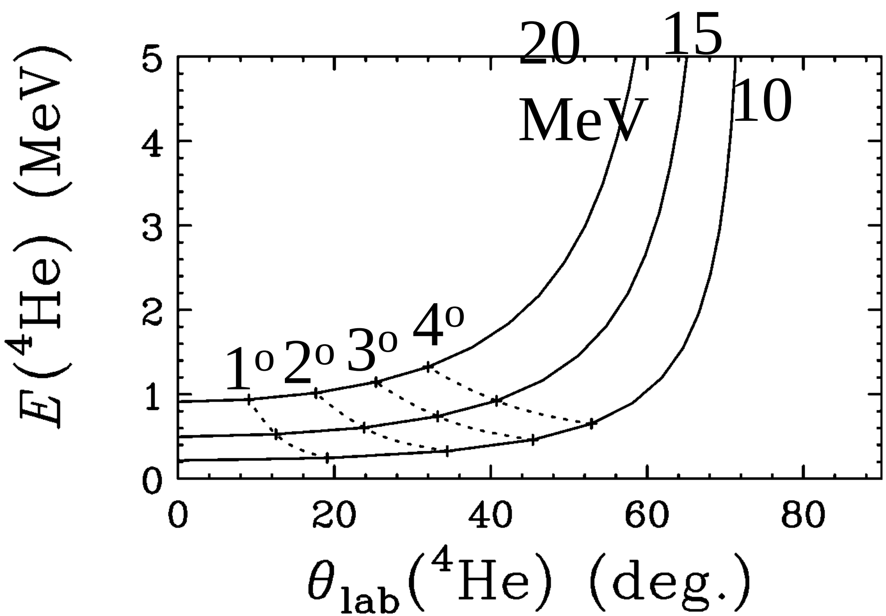


不変質量法：
放出粒子が前方に集中

~0.1度の角度分解能が必要

Recoil法との組み合わせ





^{4}He入り
TPC？
角度だけ測って。
エネルギー
は不変質量法
という方法もあり？

^{4}He(^{30}Ne,^{30}Ne)^{4}He
@30MeV/u

装置

DAIMAJIN ＋中性子検出器

物理の目玉

Soft Mode
Nuclear Incompressibility

Collective Excitation

Lowering of 3s orbital

Single Particle State

Broad-Range PI Machine

Measurement of
σ_{-xn} at once

DAIMAJIN
(**大曲げ角度、大立体角、磁場式ニュークレアスペクトロメータ**)
（**DAIMA**gekakudo-dairittaikaku **JI**ba-shiki **N**uclear spectrometer
和英混合ですが。。。）