

# 中間エネルギーにおける 入射核破断片の偏向

高知工科大学

百田 佐多生



九州国際重粒子線がん治療センター 金澤 光隆

放射線医学総合研究所 北川 敦志, 佐藤 真二

# 散乱における核ポテンシャル

- 散乱粒子の角度分布

反応メカニズム・核構造  
光学ポテンシャルによる散乱

- 光学ポテンシャル

クーロン+核 (real + imaginary)

@ $E < 100$  MeV/u

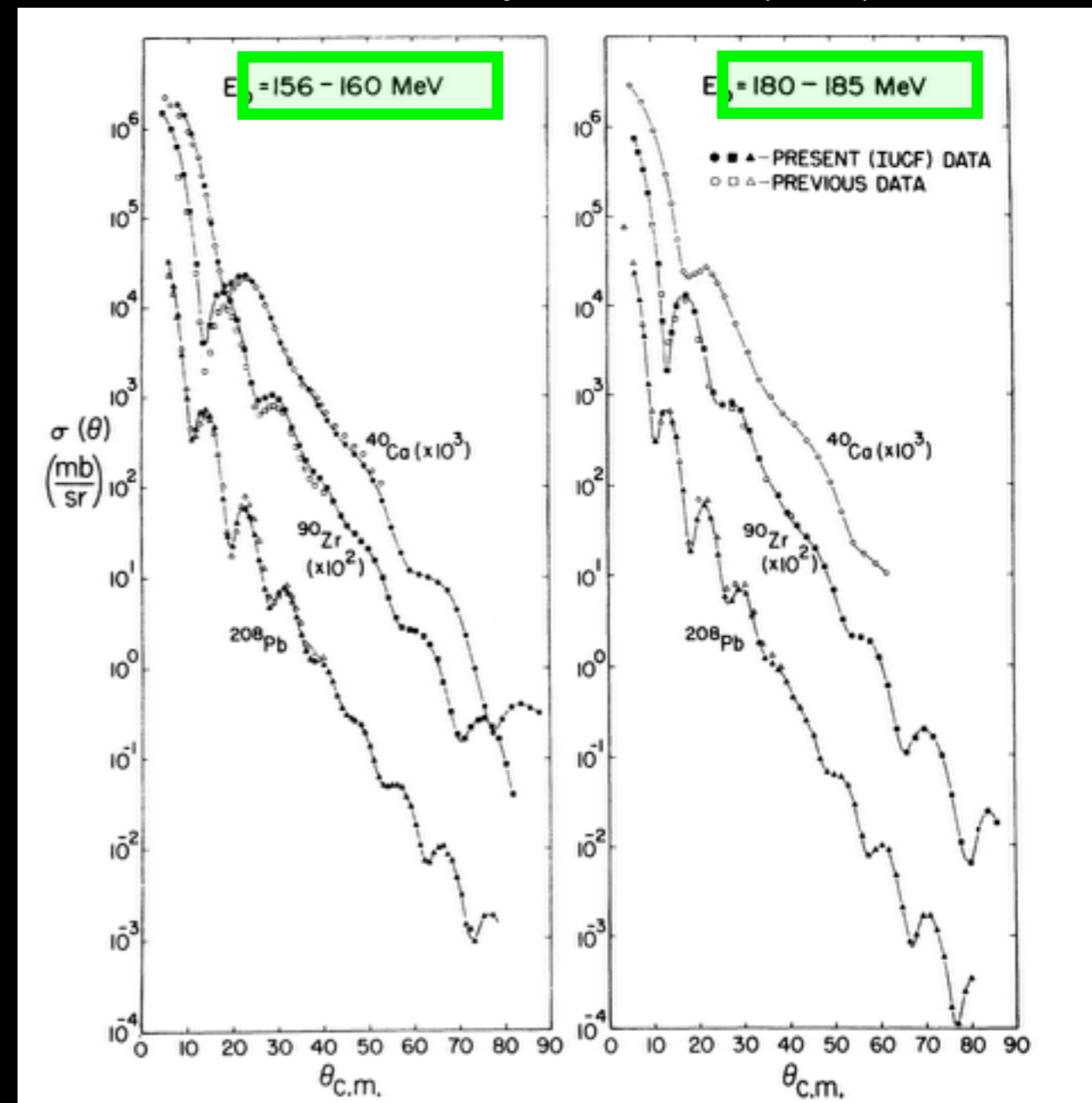
核 = attractive real part  
+ absorptive imaginary part

入射エネルギー依存性

偏向現象に関与

## Elastic scattering of p on $^{40}\text{Ca}$

A. Nadasen et al., Phys. Rev. C 23 (1981), 1023-



# 引力から斥力へ

- 核子の弾性散乱で多くの測定

- 引力→斥力 @200 ~ 300 MeV/u

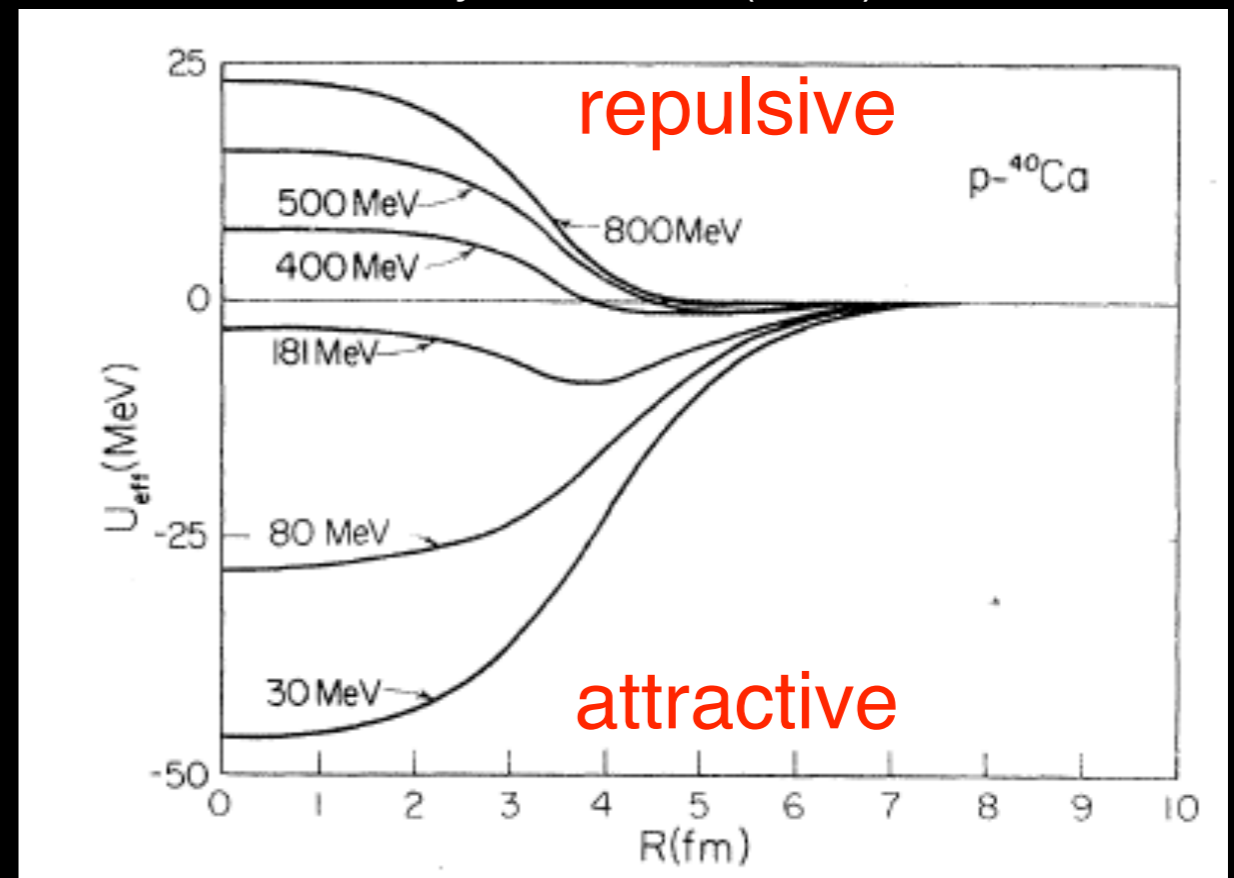
Ex. p + 40Ca By L.G. Arnold et al.,

- HI - HIの理論的研究

Complex G-matrix interaction and the double-folding model

T. Fukumoto et al., Phys. Rev. C 82,(2010) 044612.

Real part of nuclear potential : p+<sup>40</sup>Ca  
L.G. Arnold et al., Phys. Rev. C 25(1982) 936-

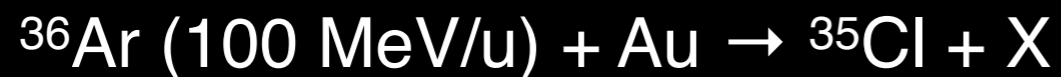
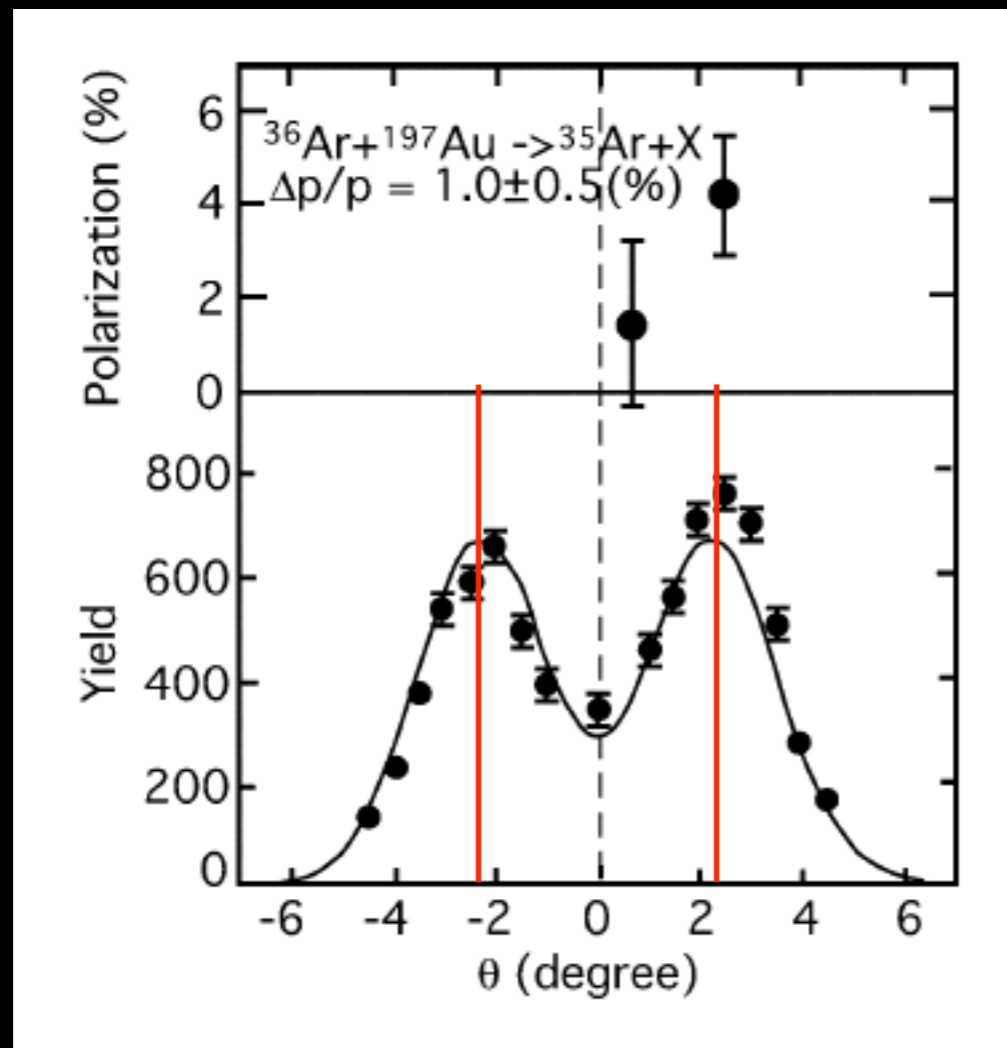


しかし、HI - HIの測定が少ない

# 表面反応における偏向現象

## 100 MeV/uにおける表面反応

偏向現象を利用した核偏極生成

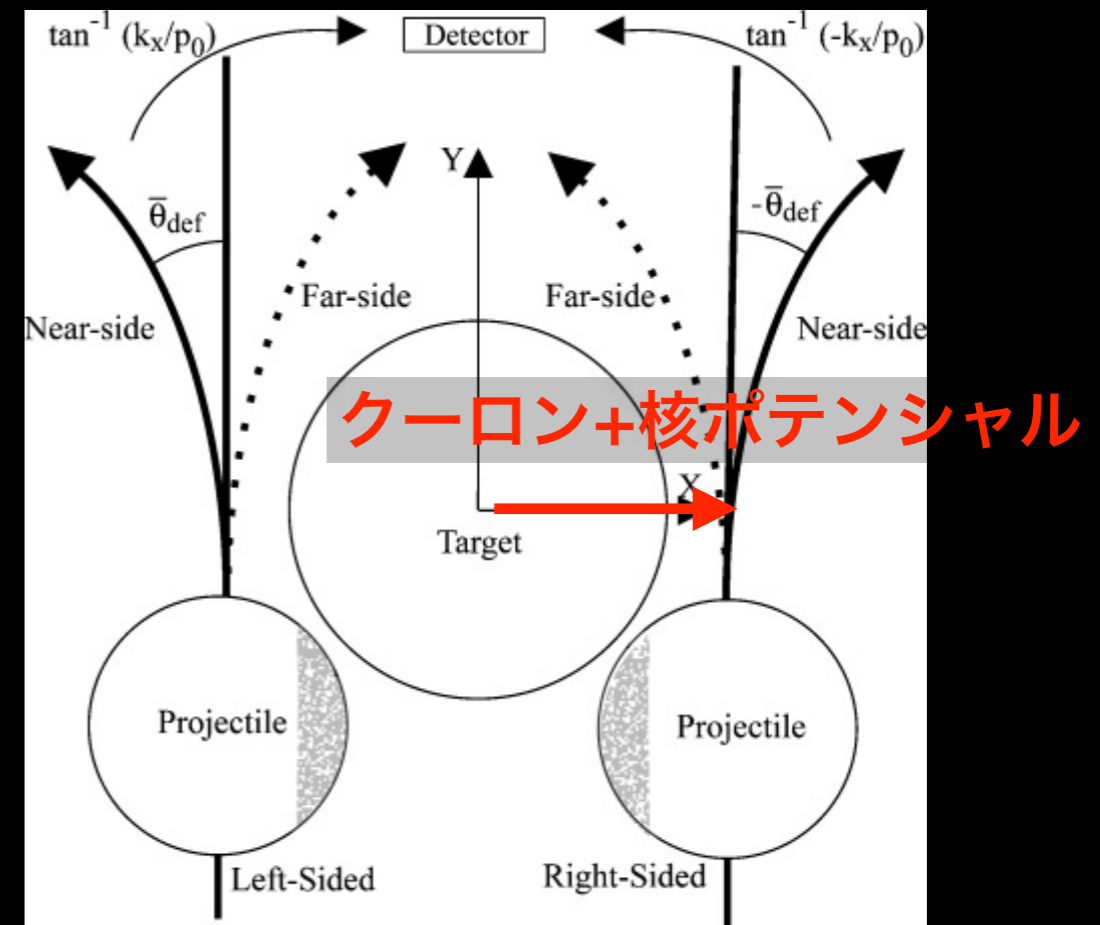
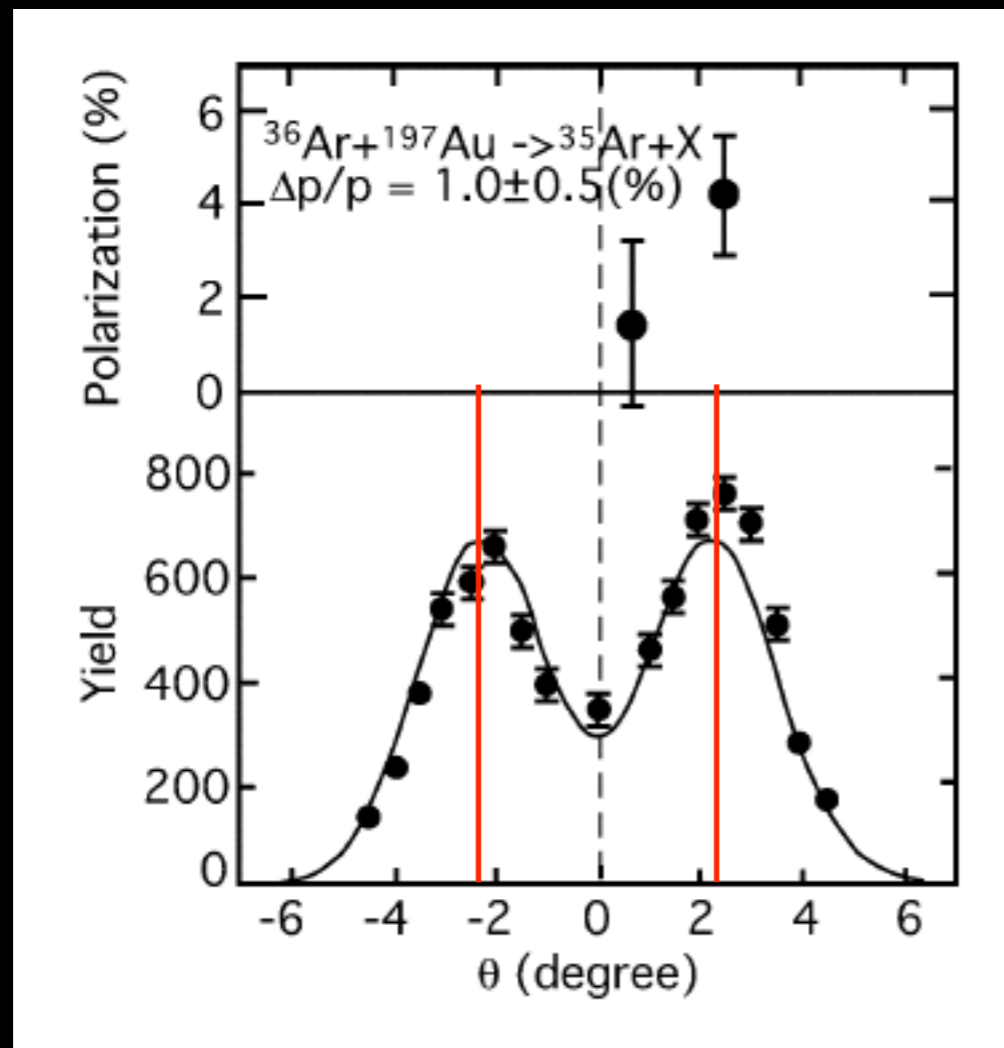


K. Matsuta et al., Nucl. Phys. A 25, 383c (2002).

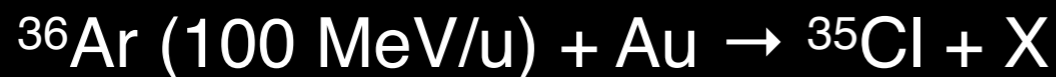
# 表面反応における偏向現象

## 100 MeV/uにおける表面反応

偏向現象を利用した核偏極生成



D.E. Groh et al., Phys. Rev. C76, 054608 (2007).



K. Matsuta et al., Nucl. Phys. A 25, 383c (2002).

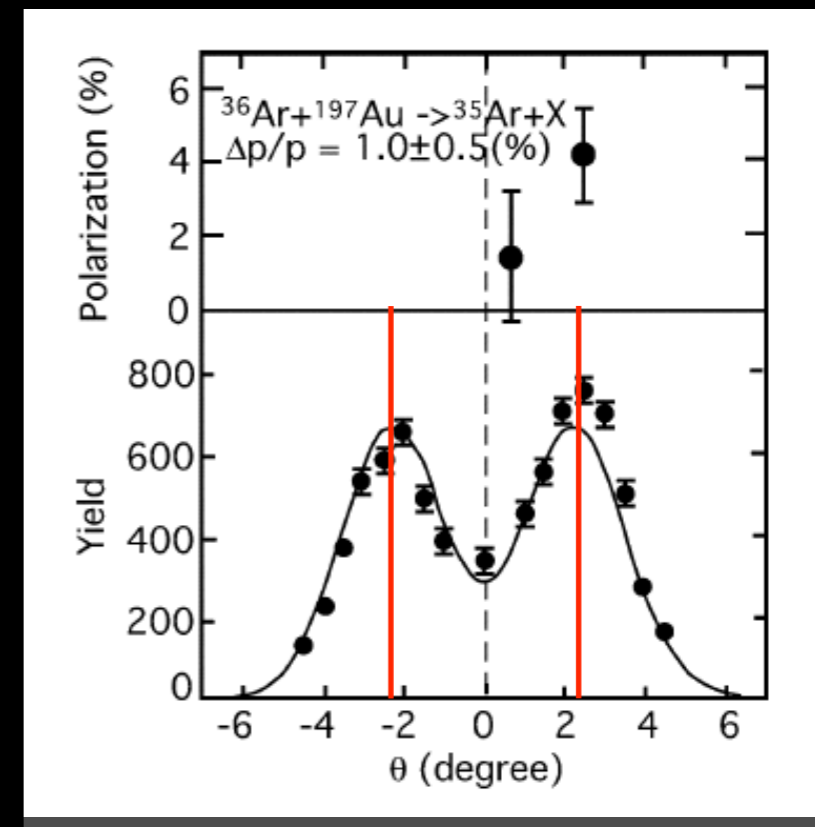
# 研究の目的

$E = 290 \text{ MeV/u}$ の表面反応で測定された  
角度分布

→ 偏向角度

核ポテンシャルの斥力性

エネルギー依存性を持ち重イオン  
に適用できる核ポテンシャルで解析

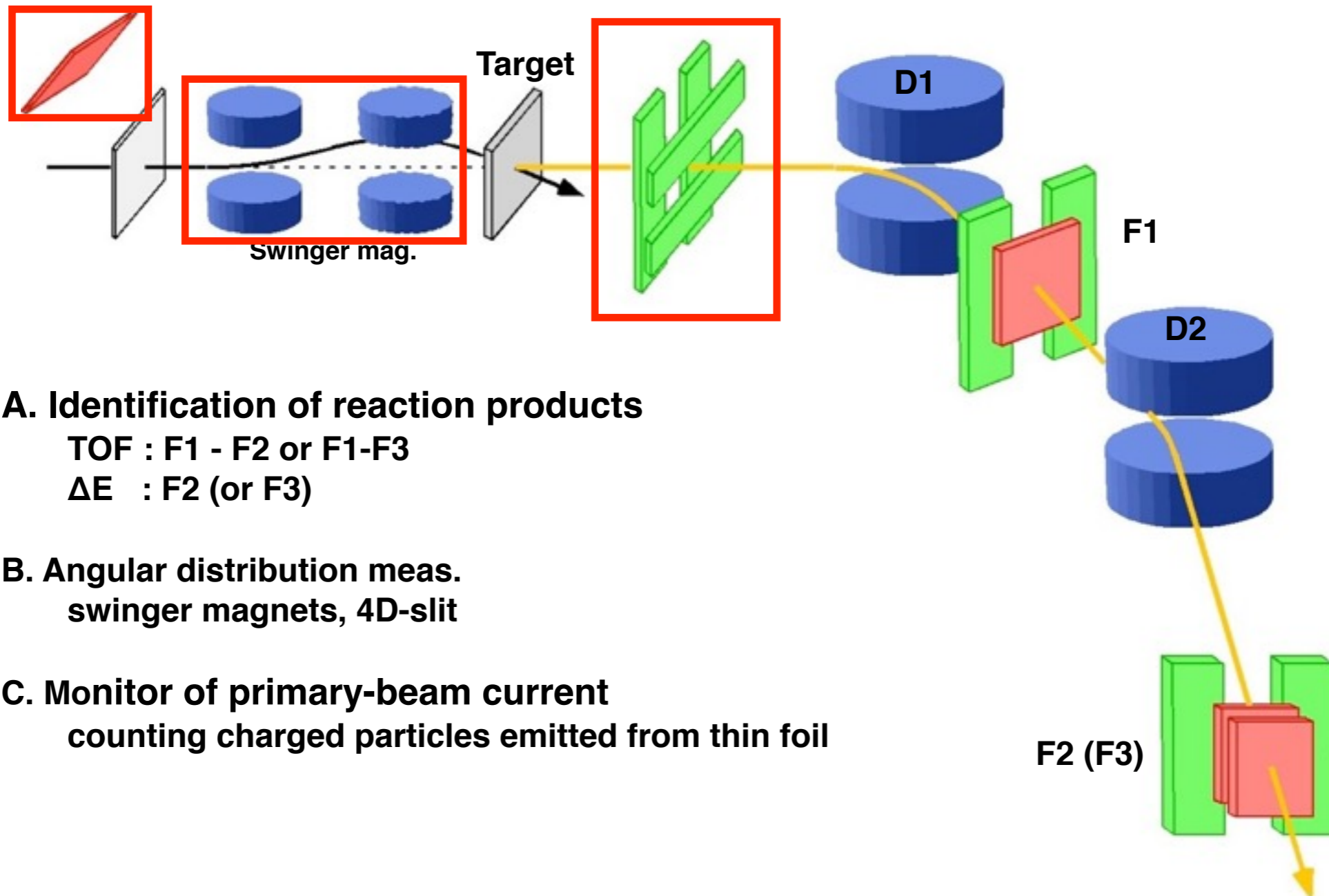


How about  $E = 200 \sim 300$  ?

# HIMAC 加速器施設での測定

## HIMAC加速器+ SB2分離器

Current monitor



### A. Identification of reaction products

TOF : F1 - F2 or F1-F3

$\Delta E$  : F2 (or F3)

### B. Angular distribution meas. swinger magnets, 4D-slit

### C. Monitor of primary-beam current counting charged particles emitted from thin foil

# 反応系・アクセプタンス

1核子はぎ取り or 交換反応



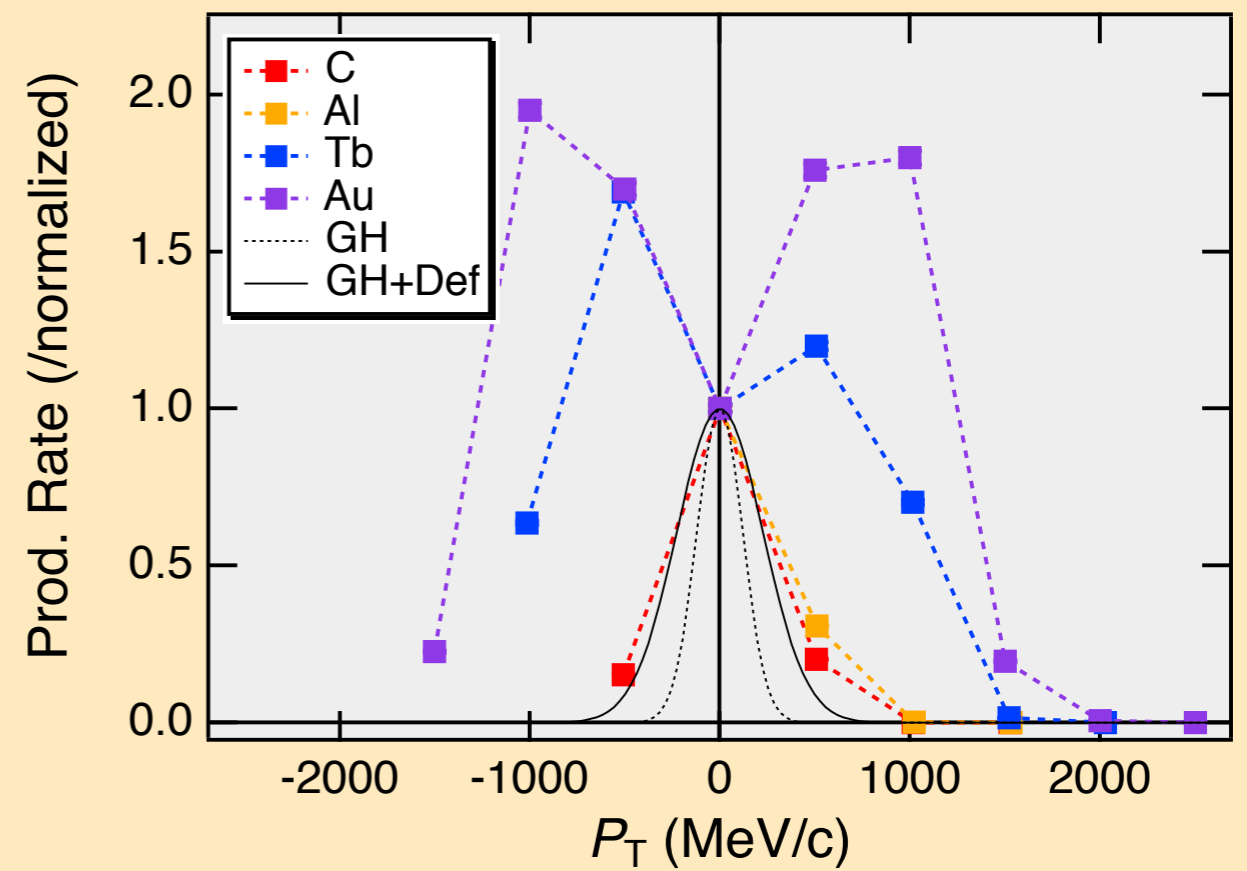
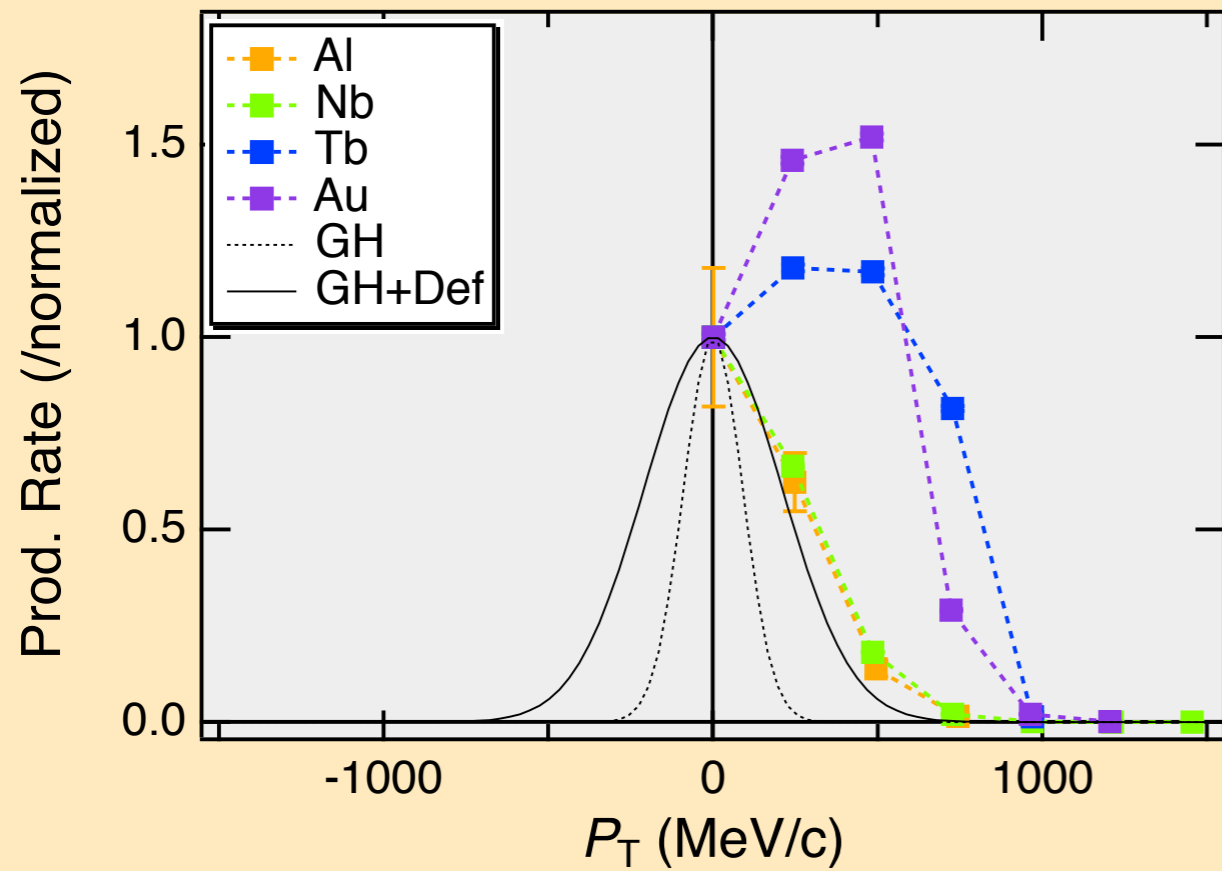
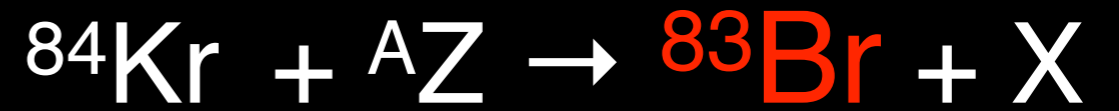
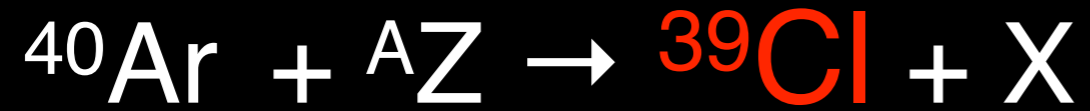
標的： $^{12}\text{C}, {}^{27}\text{Al}, {}^{93}\text{Nb}, {}^{159}\text{Tb}, {}^{197}\text{Au}$   
1.0    0.8    0.5    0.5    0.333 mm

アクセプタンス

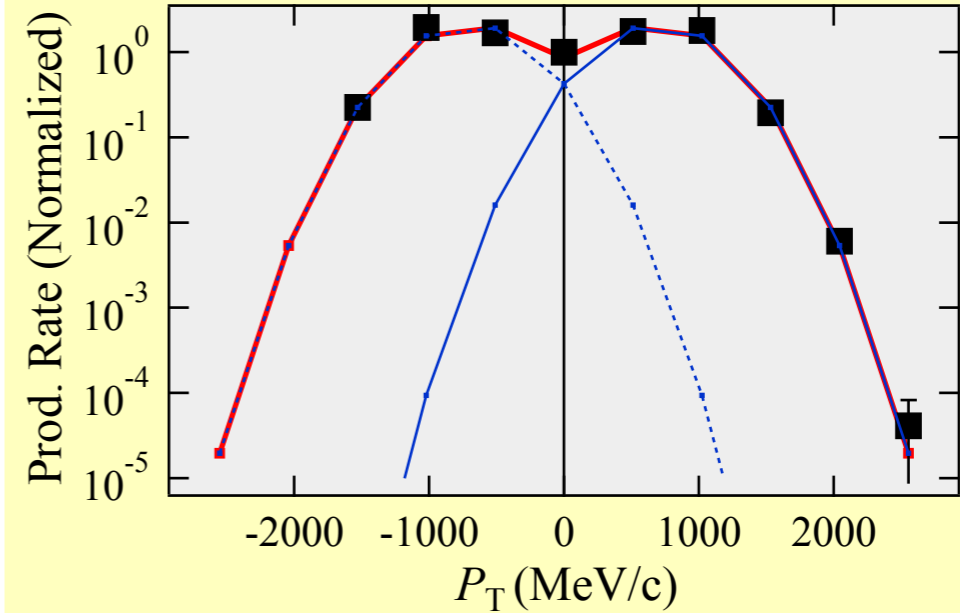
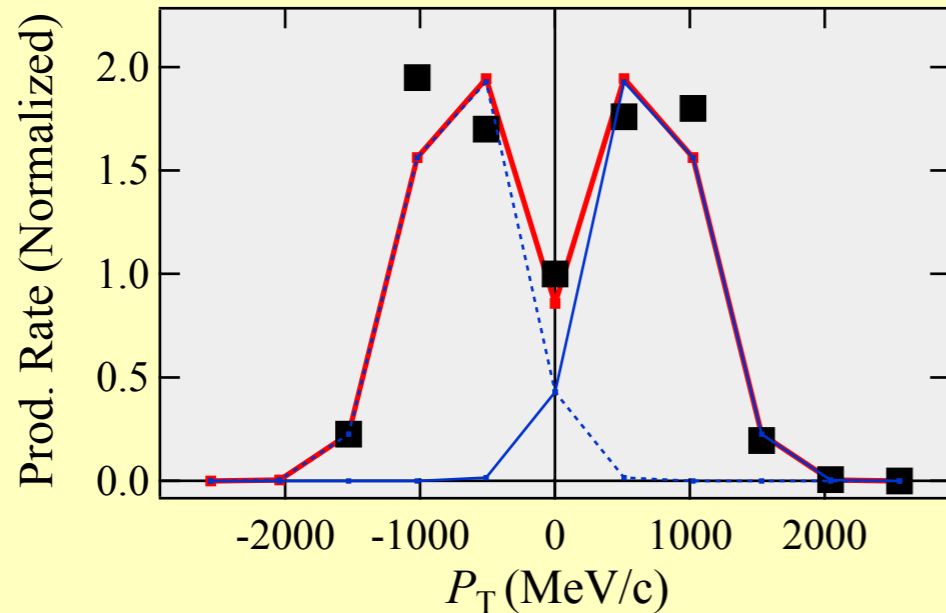
	$^{40}\text{Ar}$	$^{84}\text{Kr}$
$\Delta P/P_0$ (%)	1.0	0.5
$\Delta \theta_x$ (mrad)	16	8



# 角度分布



# 角度分布の解析

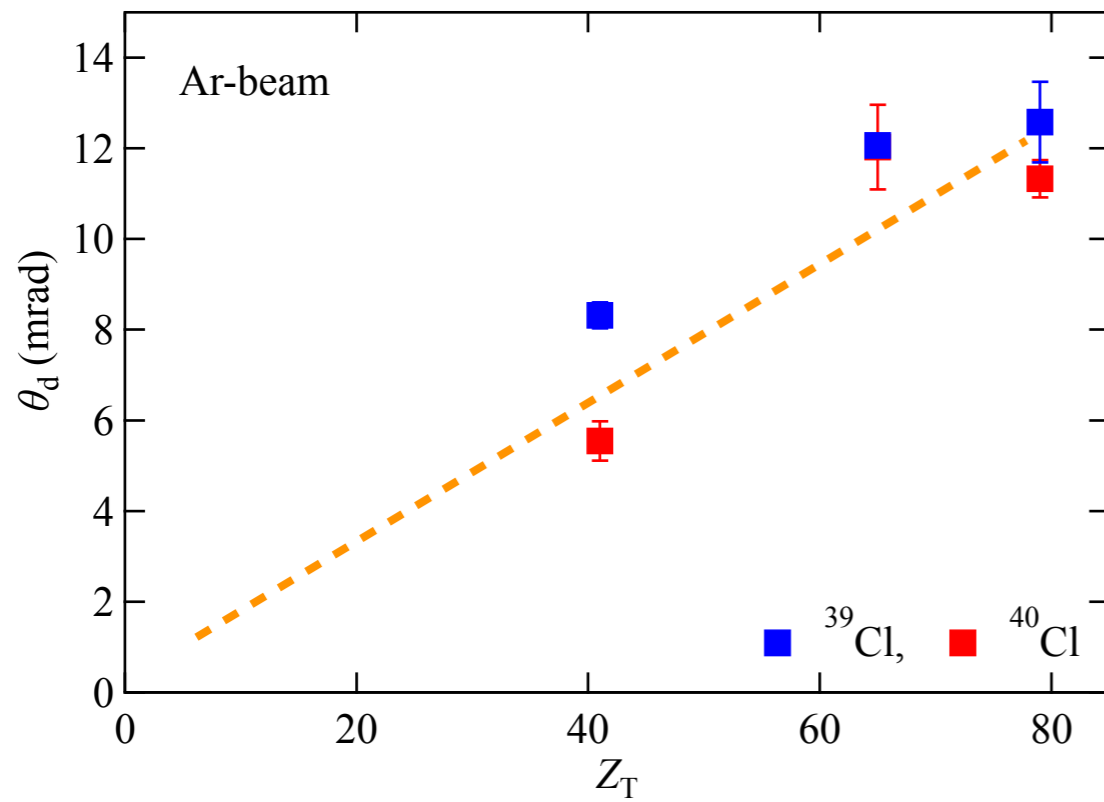


解析関数：偏向 + フェルミ運動量による広がり

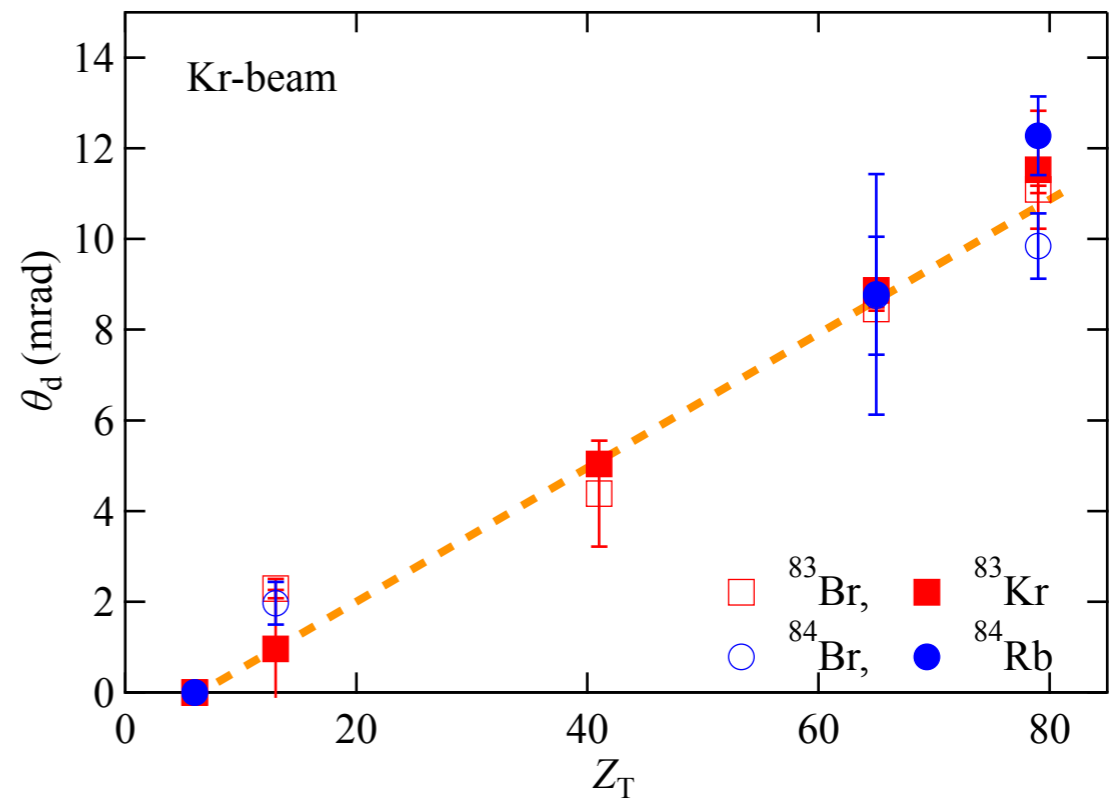
$$f(P_T) = k \left\{ \exp\left(-\frac{(P_T - \Delta P_T)^2}{2\sigma_T^2}\right) + \exp\left(-\frac{(P_T + \Delta P_T)^2}{2\sigma_T^2}\right) \right\}$$

# 解析結果：偏向角度

## Arビーム



## Krビーム



$A_T$ とともに偏向角度が増加

# 核ポテンシャル：Arビーム

## 核ポテンシャルの実部

重イオンビームに適用可能

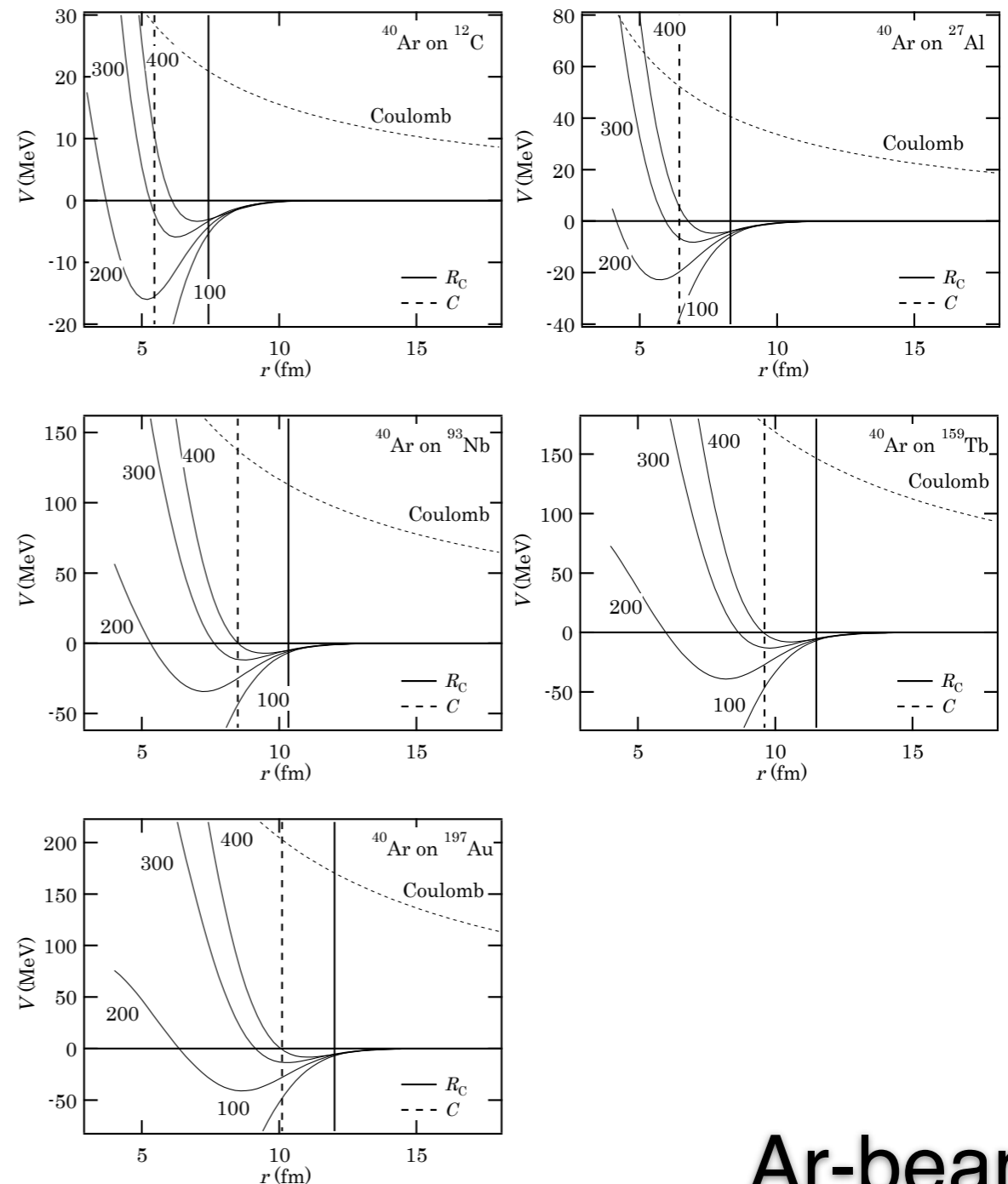
Nucleus-nucleus proximity pot.

W.D. Myers et al., Phys. Rev. C 62 (2000),  
044610

エネルギー依存性

Global opt. pot. derived from the  
microscopic folding model

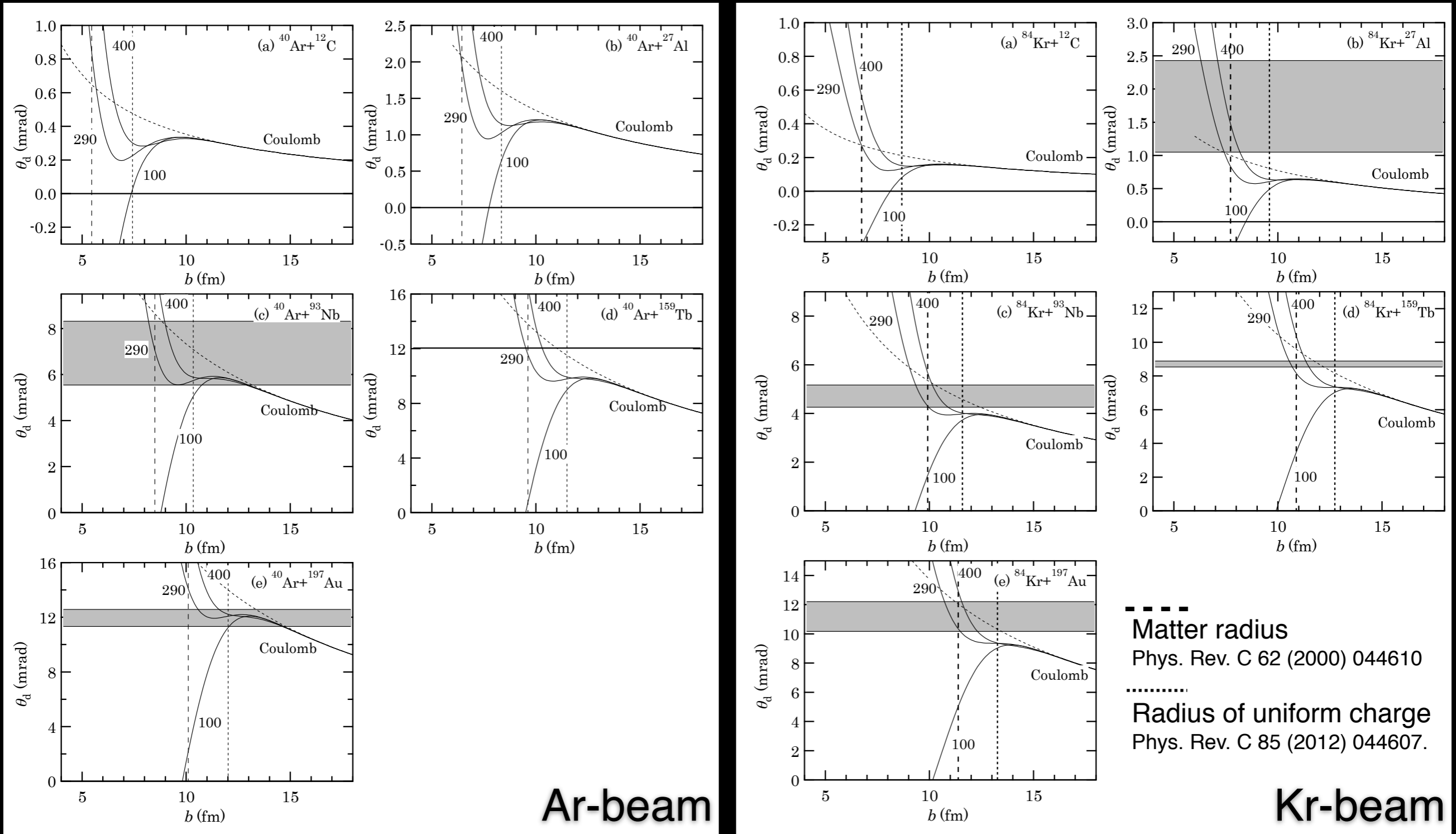
T. Fukumoto et al., Phys. Rev. C 85, 044607  
(2012)



Ar-beam

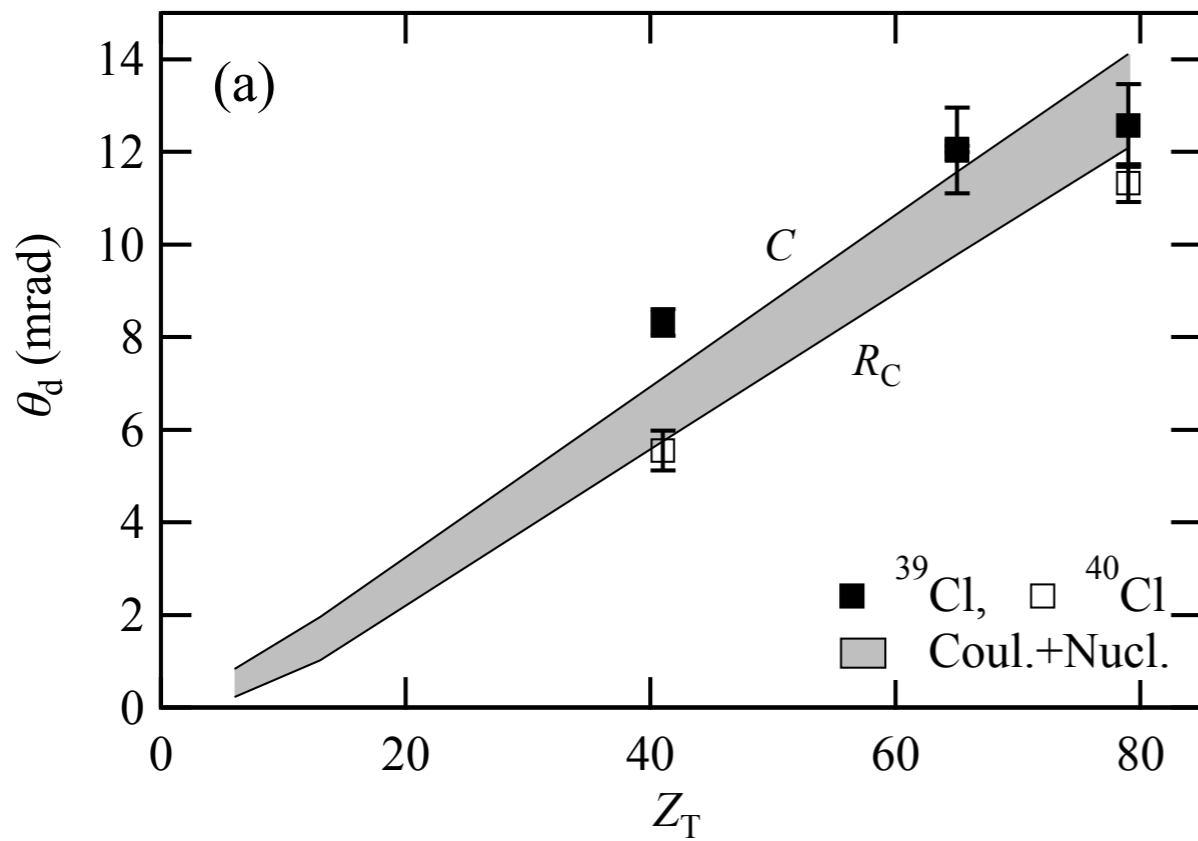
# 偏向角度：ポテンシャルから導出

Coulomb. pot. + Nucl. pot.による入射核の偏向  
 S. Momota et al., Nucl. Phys. A 958, 219–233, (2017).

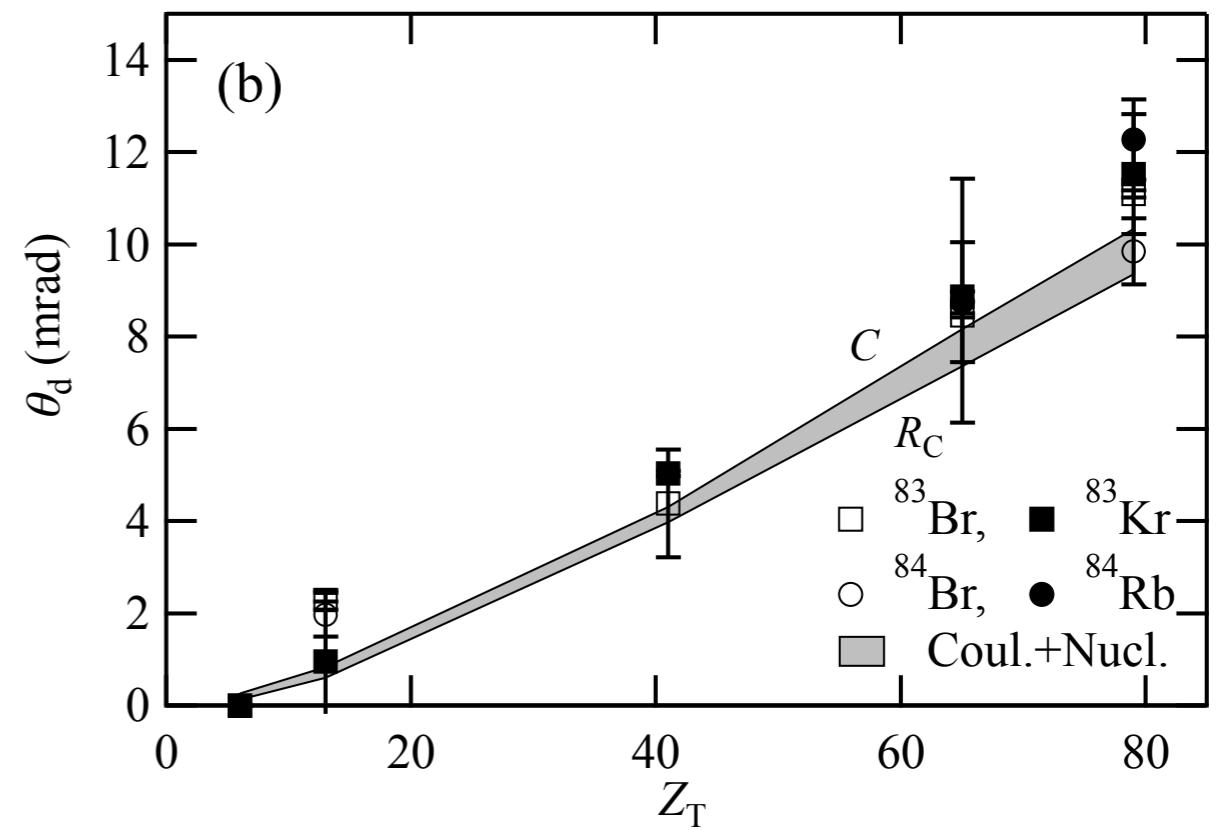


# 偏向角度：実測値との比較

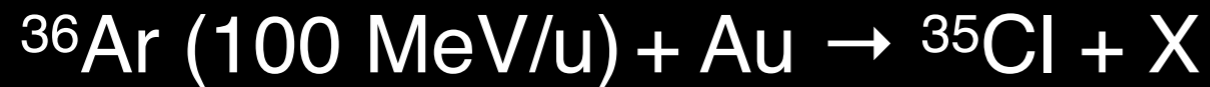
## Arビーム



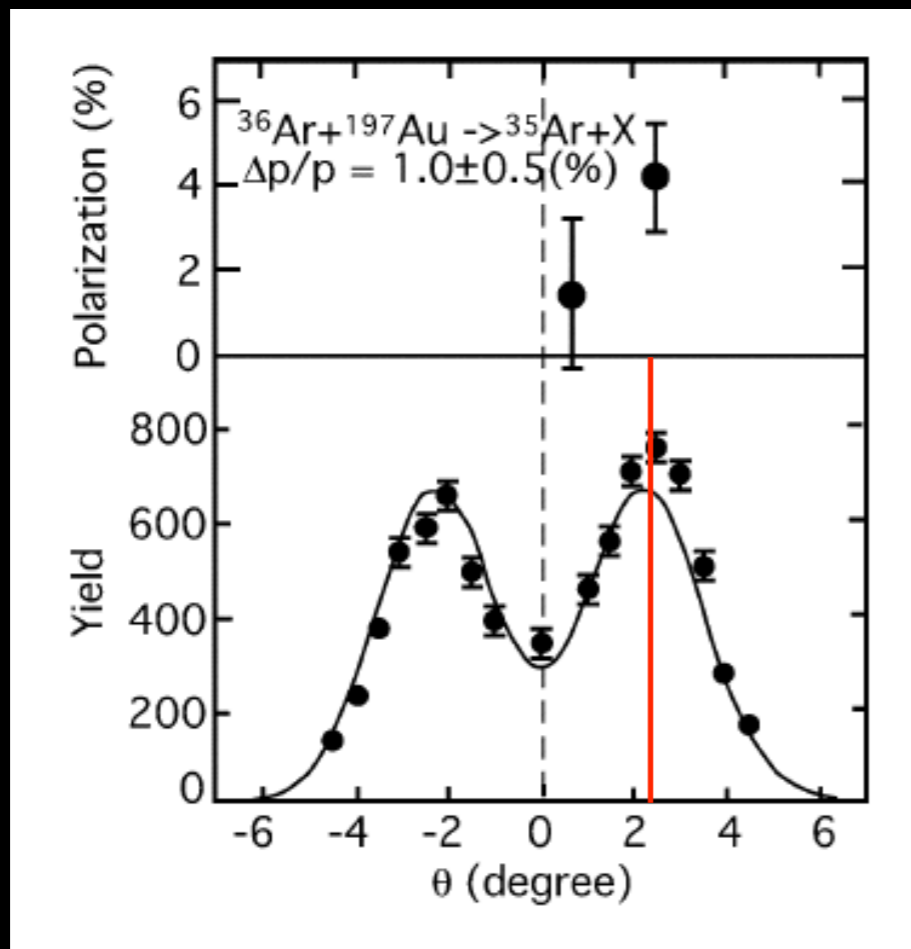
## Krビーム



# 偏向現象： $E \sim 100 \text{ MeV/u}$



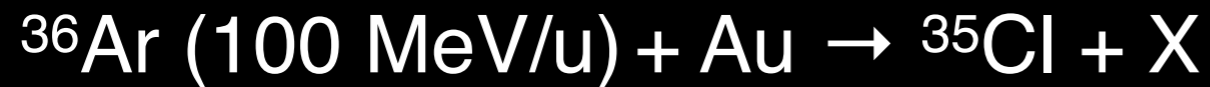
K. Matsuta et al., Nucl. Phys. A 25(2002) 383c-



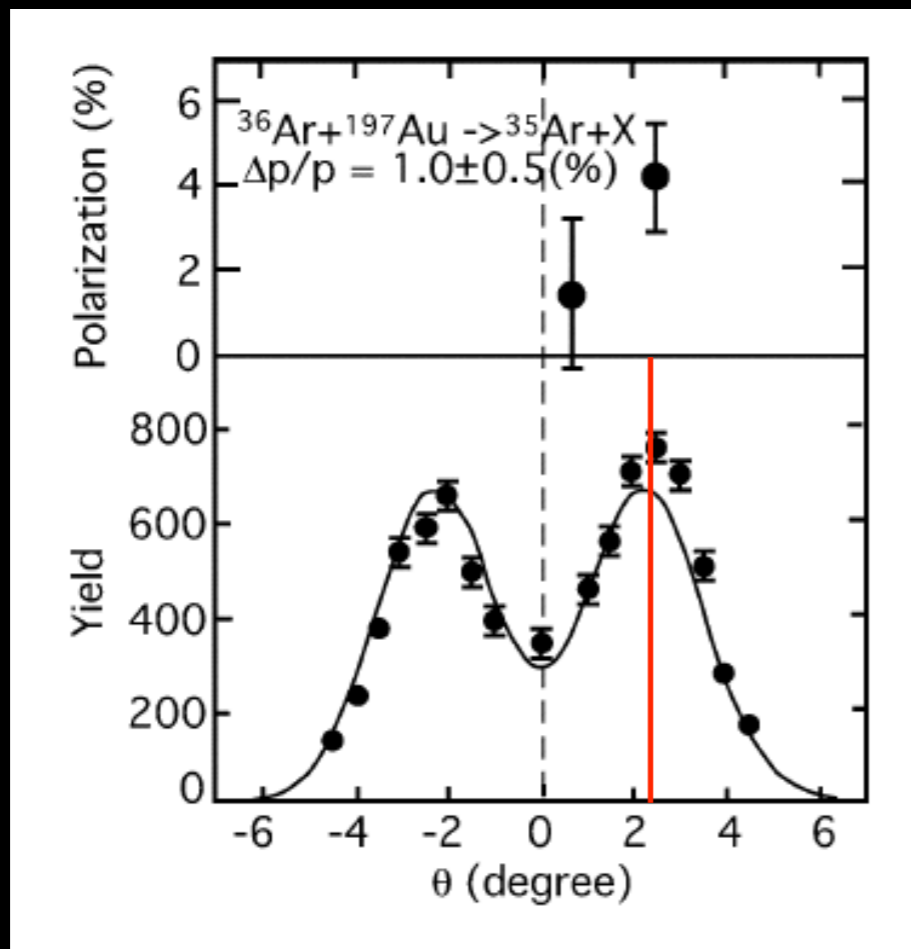
Deflection angle

2.3 deg.  $\sim$  40 mrad

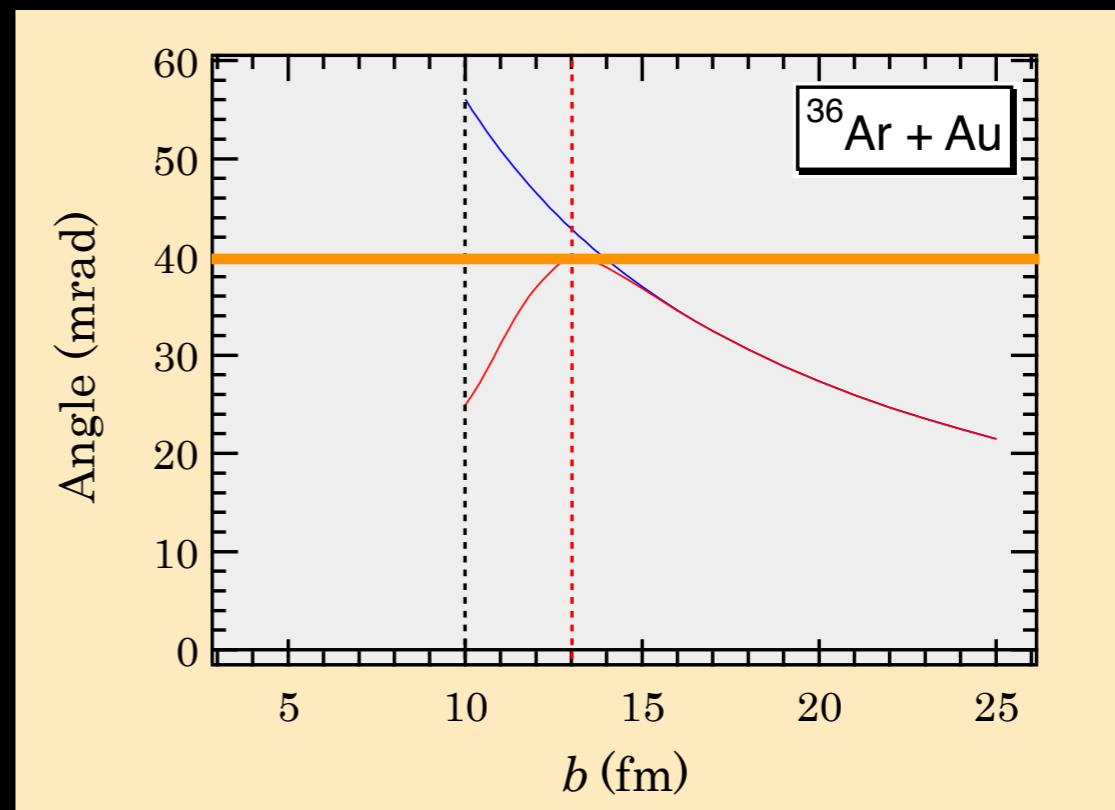
# 偏向現象： $E \sim 100 \text{ MeV/u}$



K. Matsuta et al., Nucl. Phys. A 25(2002) 383c-



Deflection angle  
2.3 deg.  $\sim$  40 mrad



Obs. deflection angle agrees with that consists both of Coulomb and nuclear potentials.



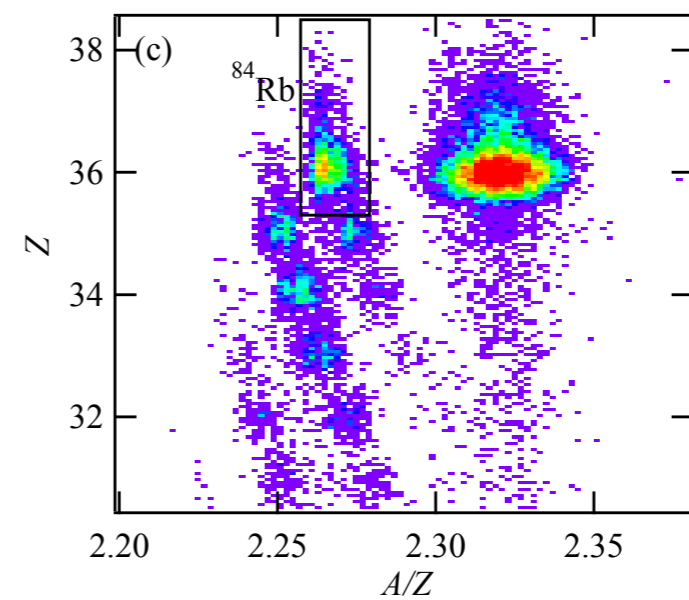
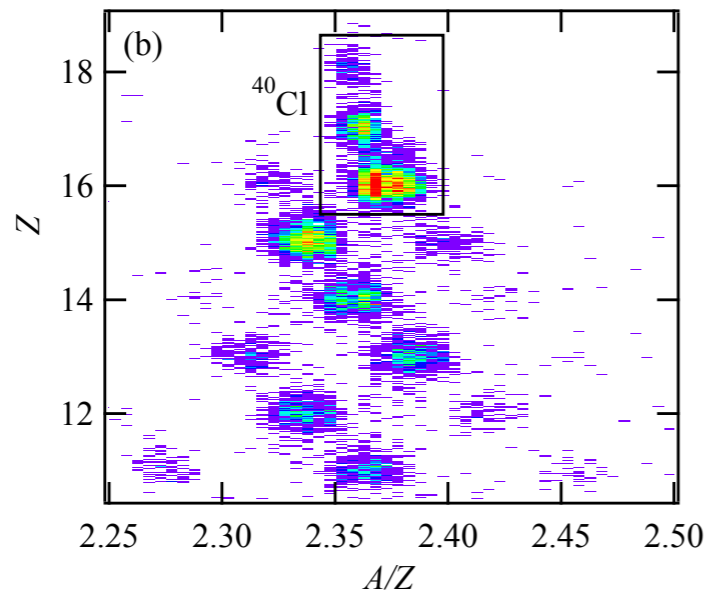
# まとめ

- 290 MeV/uで観測した表面反応生成物の角度分布
  - 偏向現象
    - 斥力的核力を示唆
    - しかし、断定はできない。
- より精度の高い測定のために
  - H380実験@HIMAC施設を実施予定
  - $E = 100 \sim 400 \text{ MeV}/c$ , より高い角度分解能

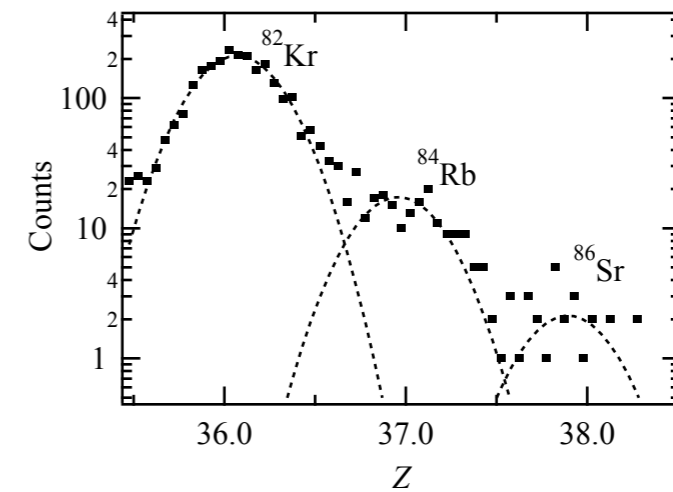
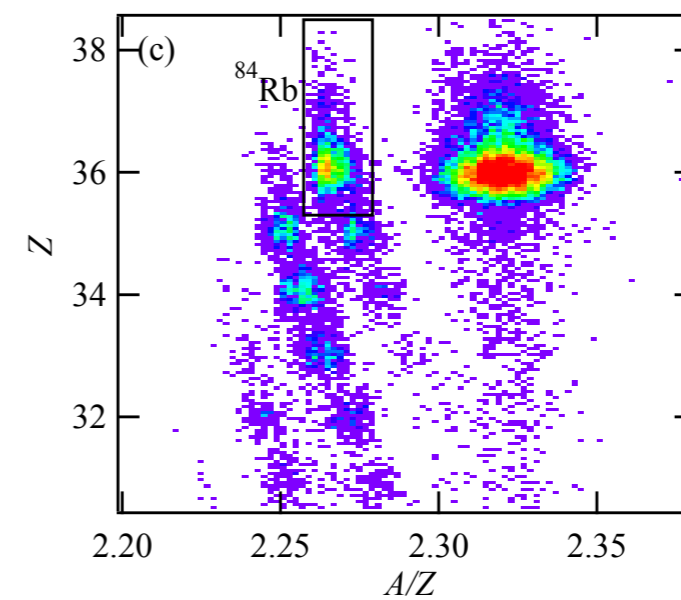
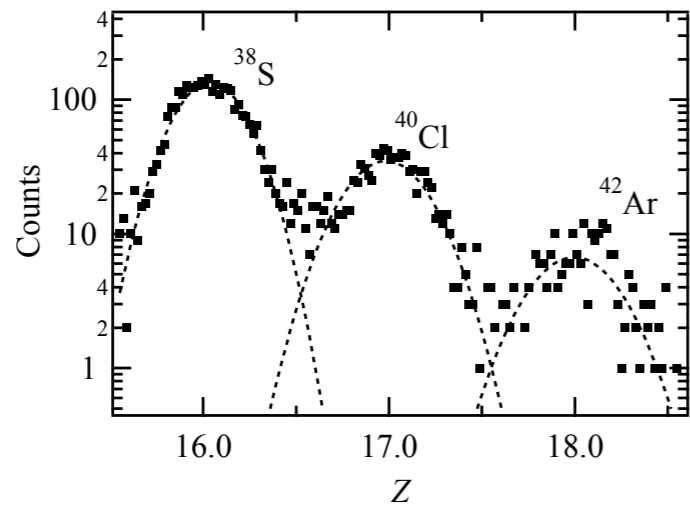
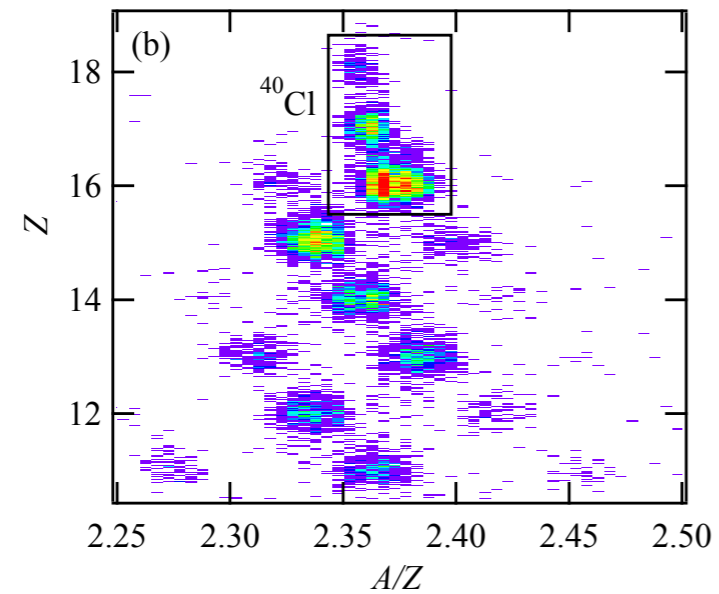


質疑用

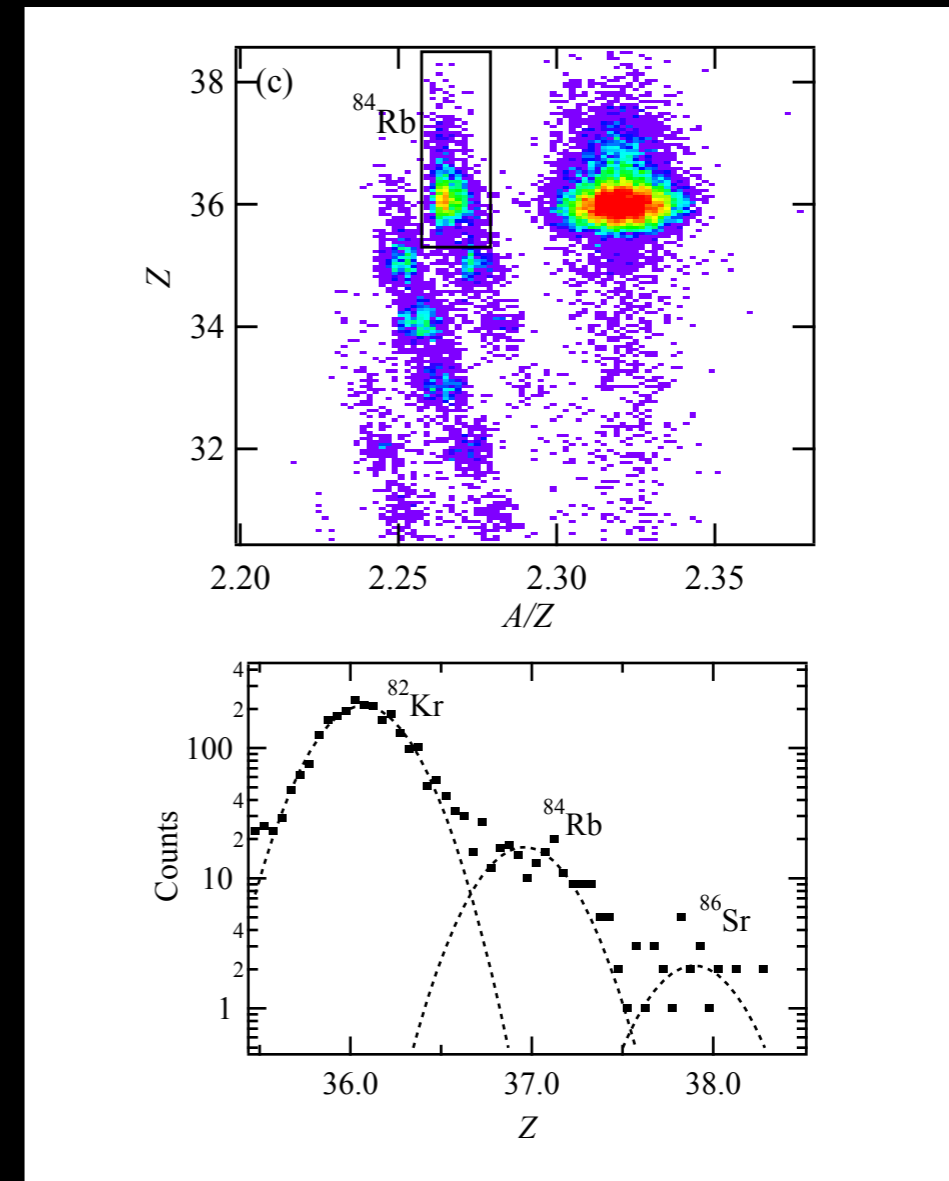
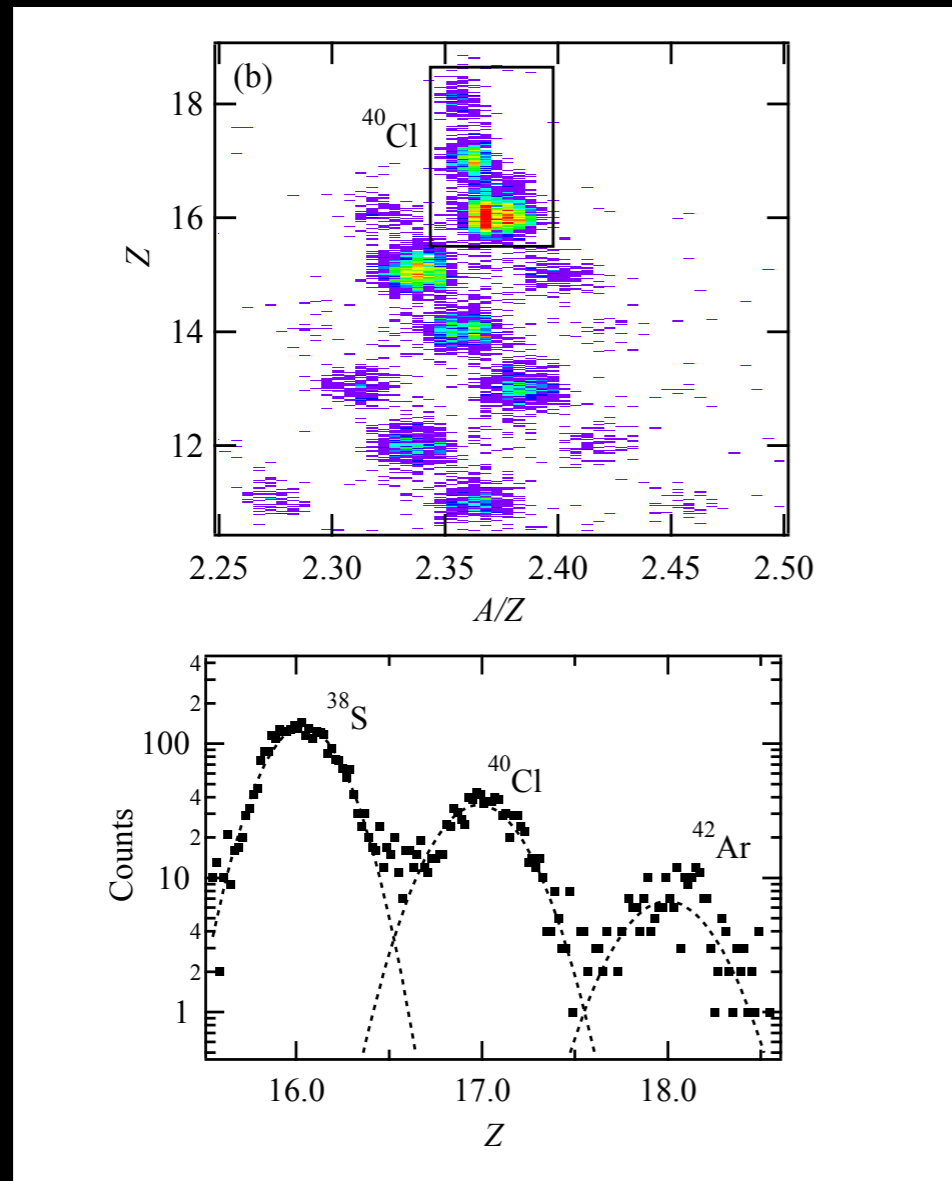
# Identification of reaction products



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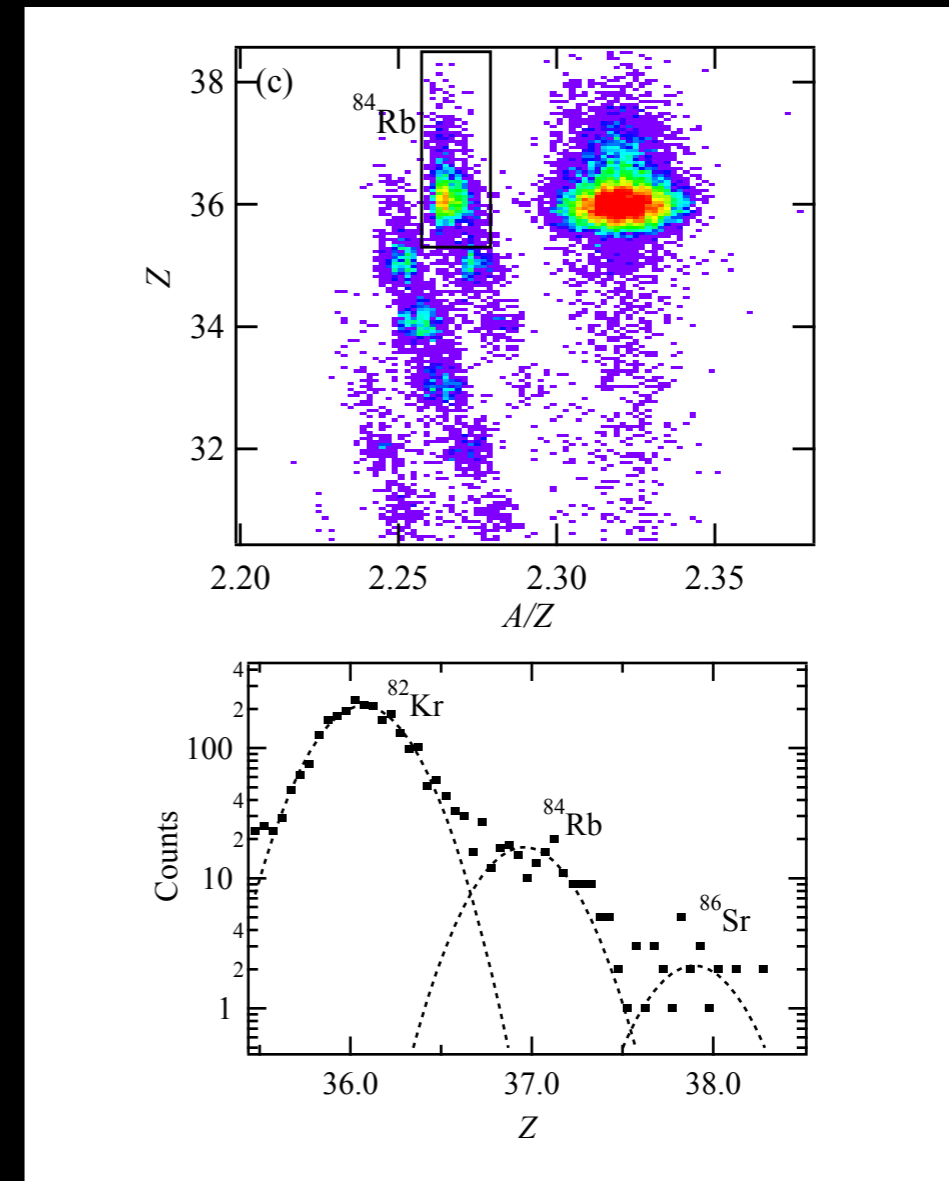
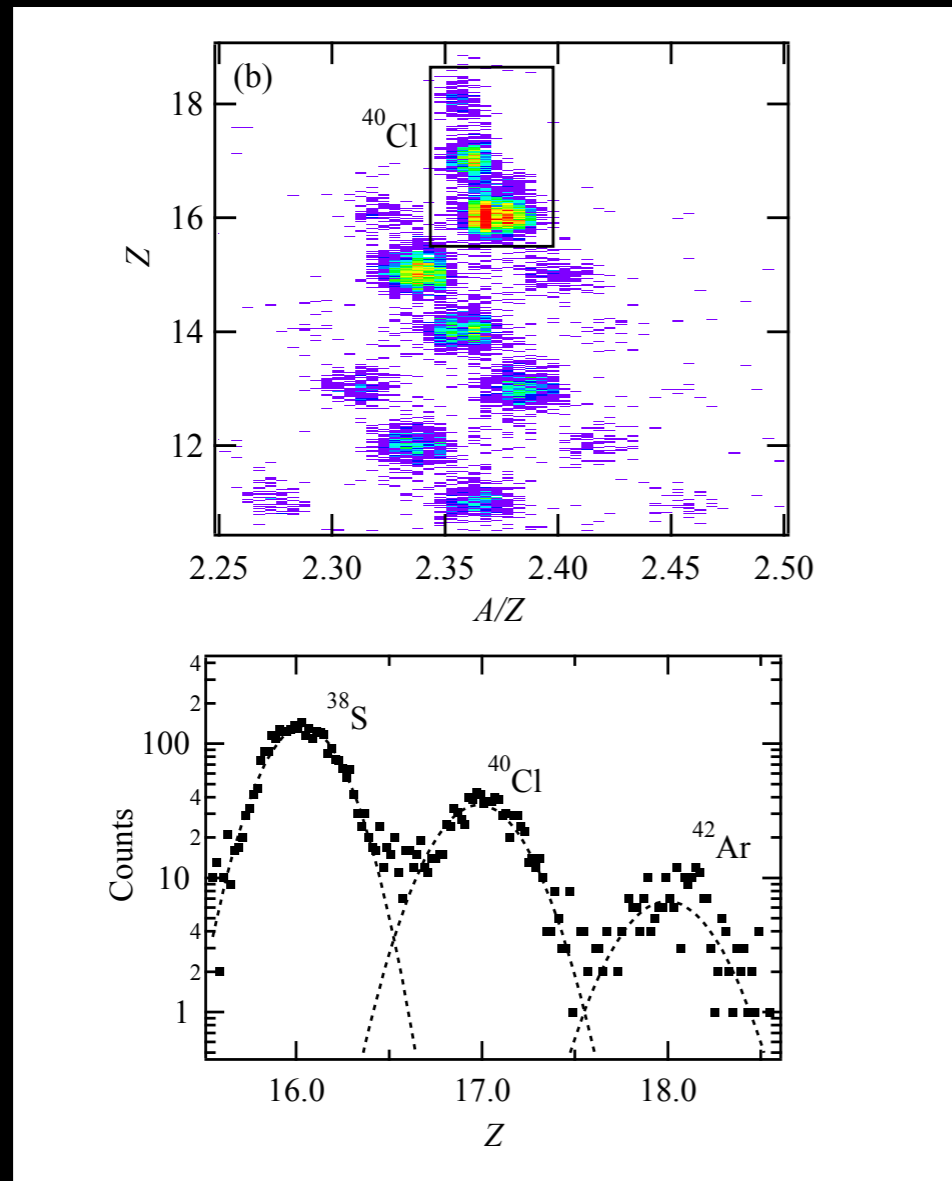


Ambiguities in counting :

$\sim 1\%$

$\sim 10\%$

# Identification of reaction products



Ambiguities in counting :

$\sim 1\%$

$\sim 10\%$

Prod. rate = Counting rate / Primary-beam intensity  $\rightarrow$  Ang. Dist.