KJ-00005

Target effect of fragmentation reactions at intermediate energy

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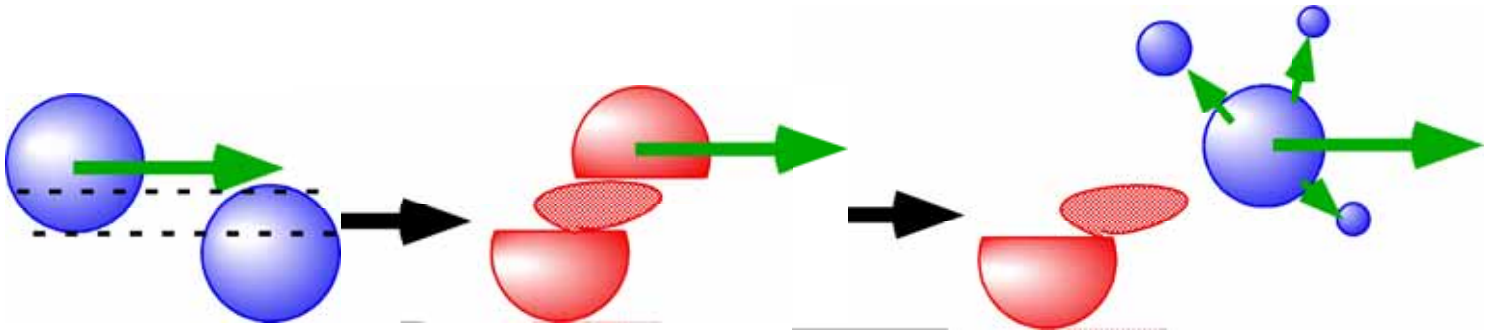
Motivation

- Study on production of projectile-like fragments (PLF)
  - Production mechanism
  - Application of RIB to various fields

- Systematic measurements of
  - Momentum distribution
  - Production cross section ($\sigma_{Prod.}$)

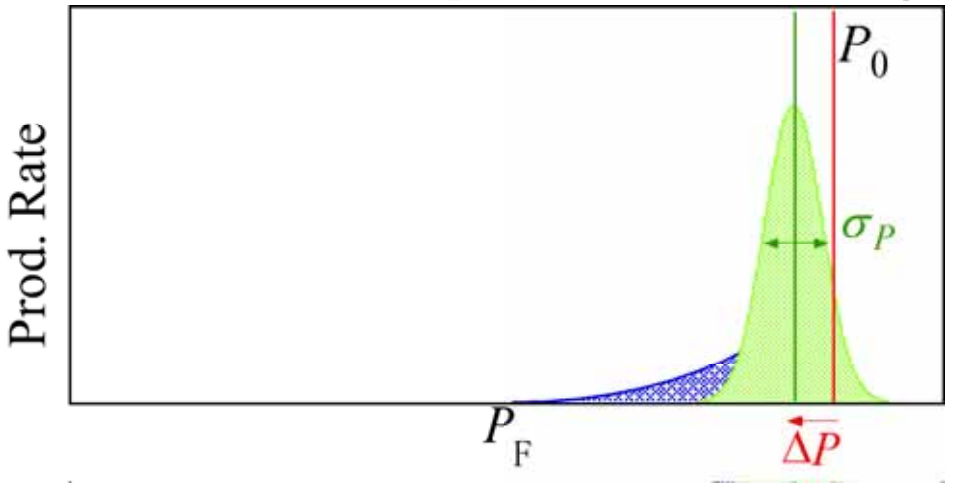
Projectile fragmentation process



Formation of pre-fragment

De-excitation of pre-fragment

Momentum distribution of projectile-like fragment (PLF)



Methods to estimate $\sigma_{Prod.}$ of PLF

1. Empirical formulation

EPAX2 $$S = S_2(A_P^{1/3} + A_T^{1/3} + S_1)$$

2. Statistical model

Statistical abrasion-ablation model

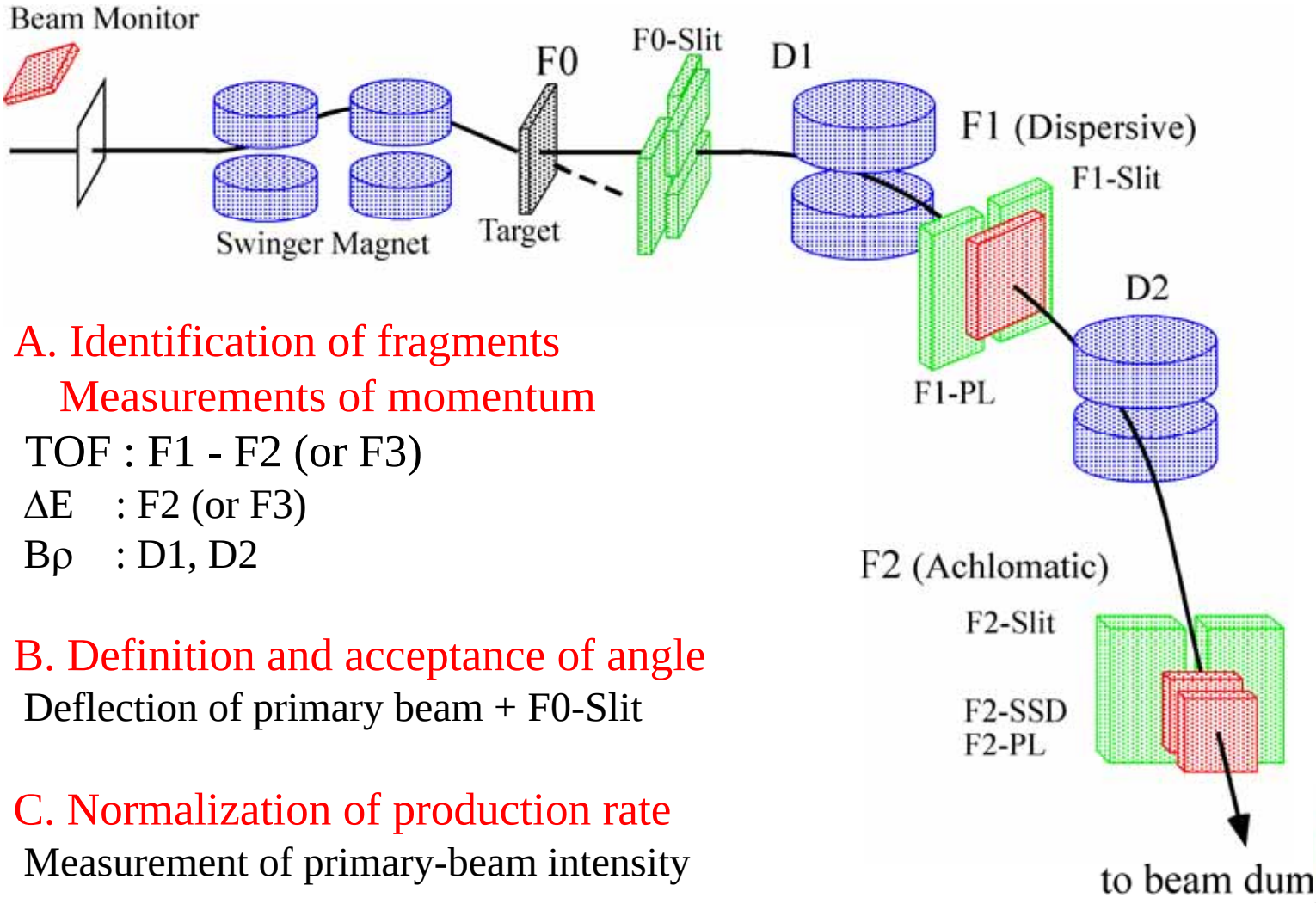
T.Brohm and K.H.Schmidt Nucl. Phys A569 (1994)821
D.Q.Fang, W.Q.Shen, J.Feng et.al Phys. ReV. c61 (2000) 044610

3. Microscopic model

QMD, AMD

Experimental setup

HIMAC-NIRS



A. Identification of fragments
Measurements of momentum

TOF : F1 - F2 (or F3)

ΔE : F2 (or F3)

Bρ : D1, D2

B. Definition and acceptance of angle

Deflection of primary beam + F0-Slit

C. Normalization of production rate

Measurement of primary-beam intensity

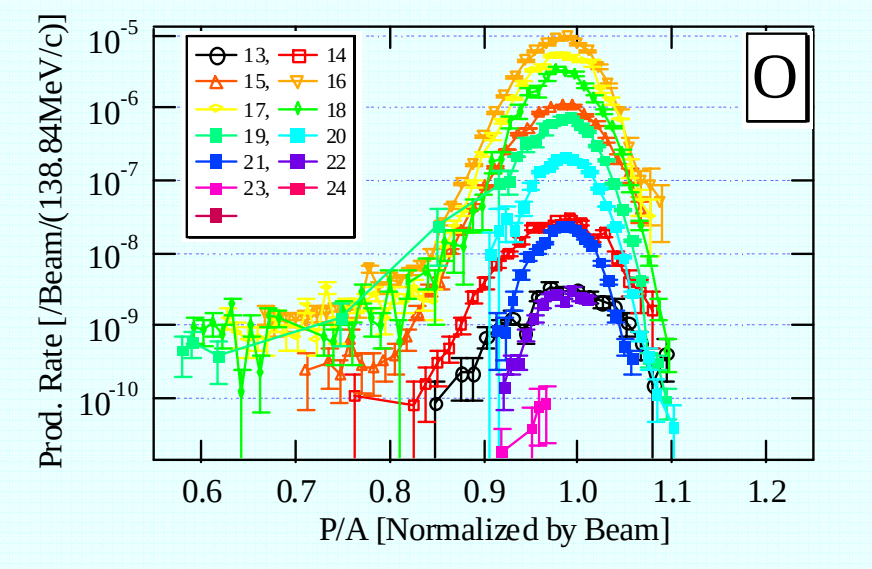
Measurements

^{40}Ar (290MeV/A) + ^{12}C (1.0 mm)
^{27}Al (0.8 mm)
^{93}Nb (0.5 mm)
^{197}Au (0.333 mm)

Measurements of P_L, P_T distributions

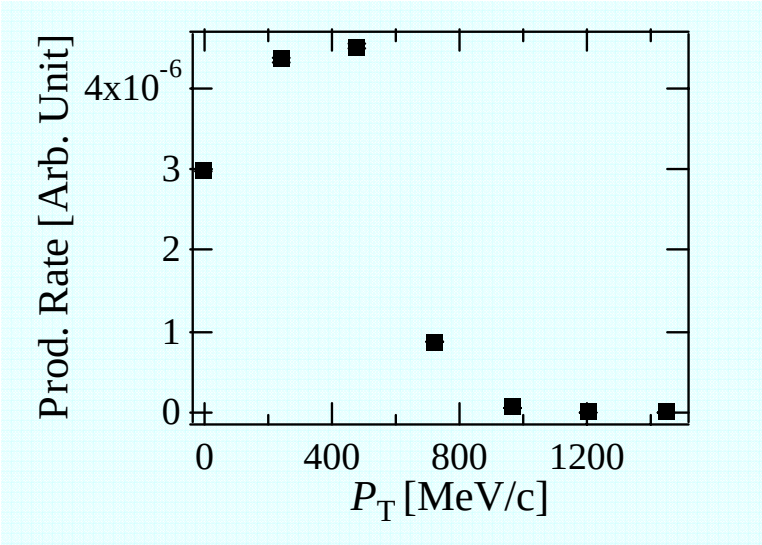
P_L distribution ⟵ $B\rho$ distribution
P_T distribution ⟵ Angular distribution

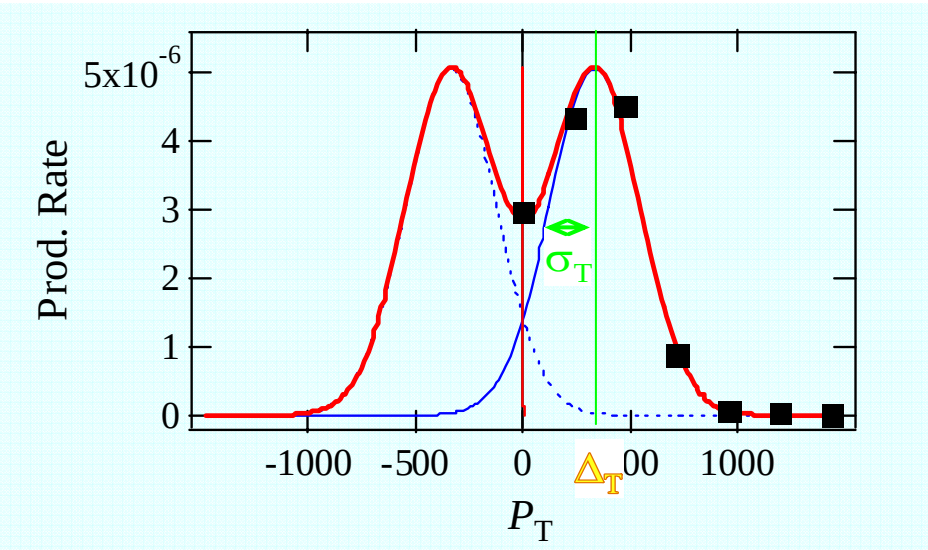
Ar + Au → ^{A}O

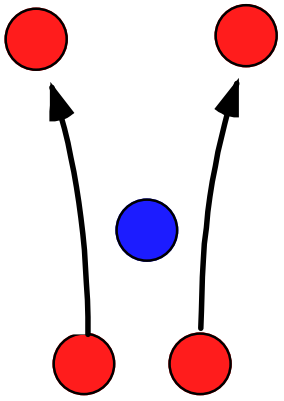


Angular distribution of PLF

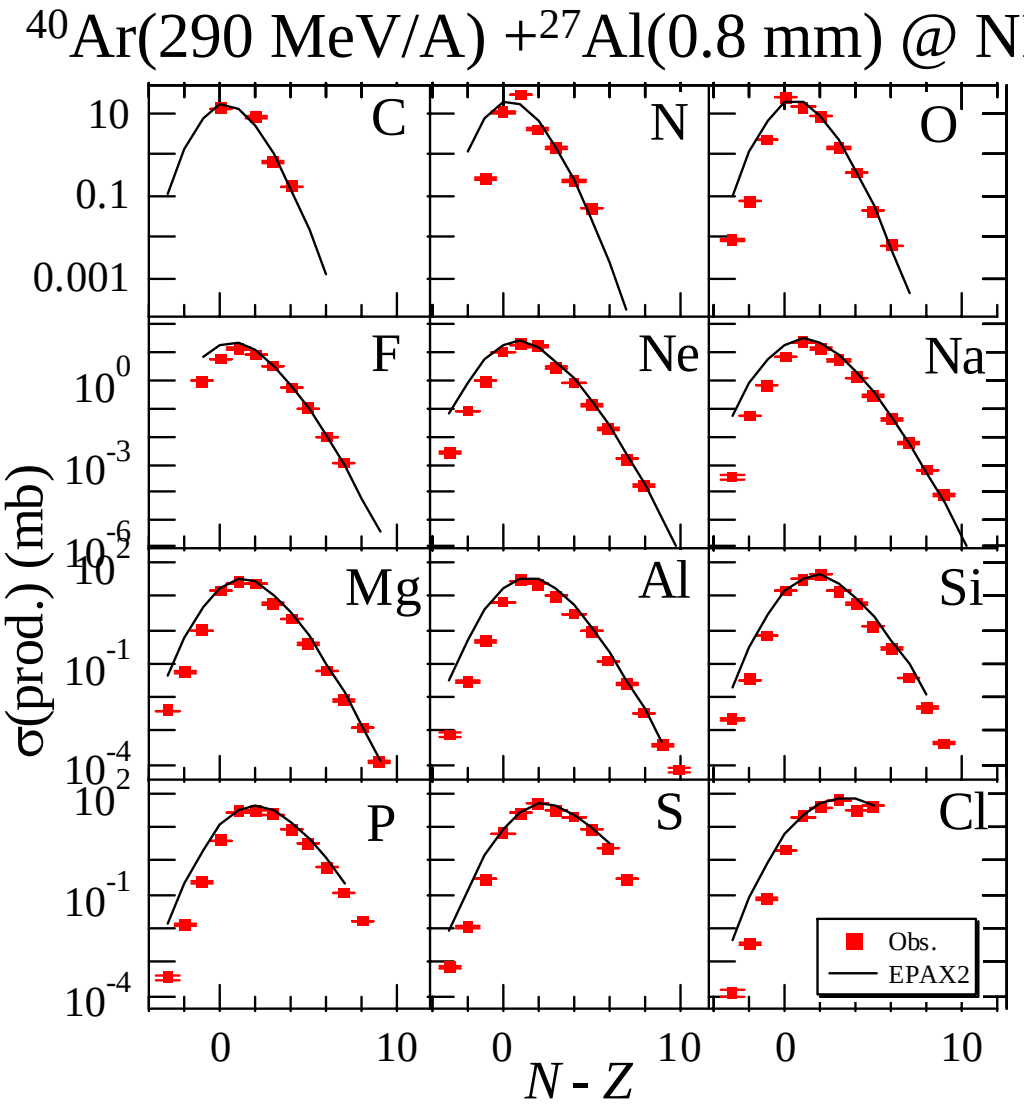
^{40}Ar(290 MeV/A) +^{197}Au(0.333mm) → ^{39}Cl



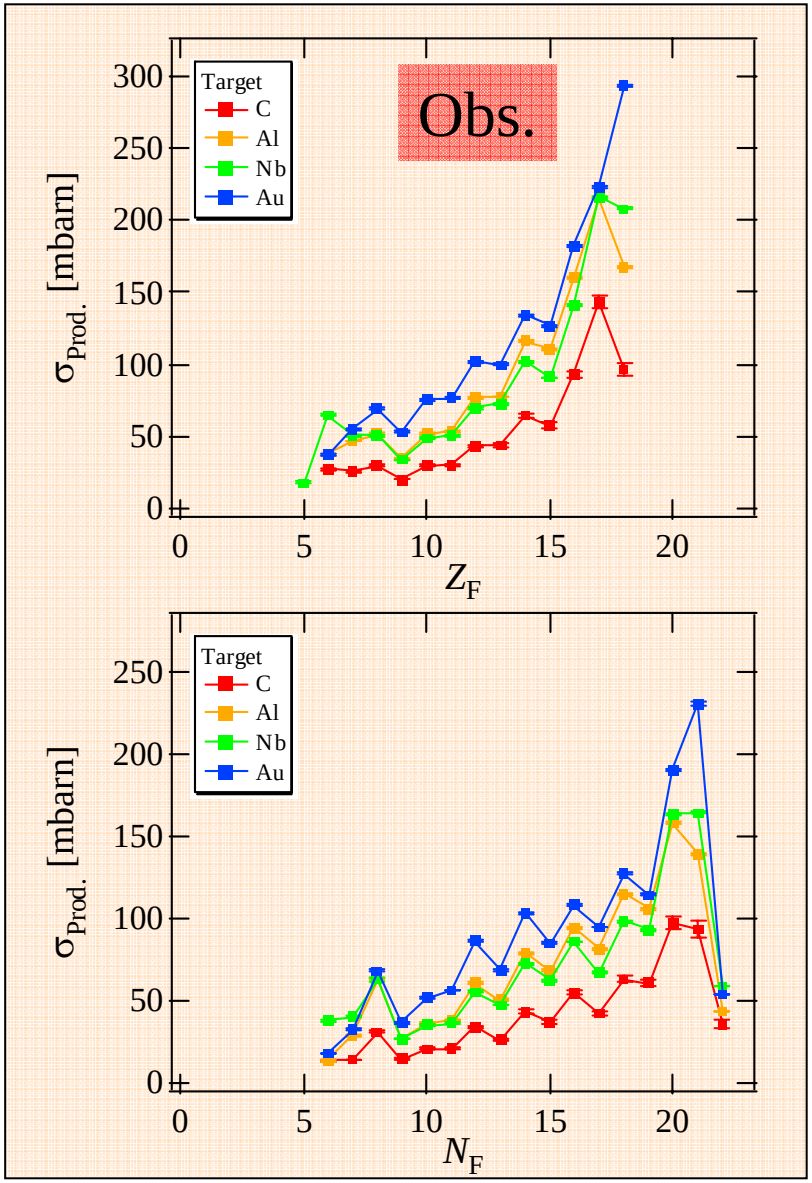


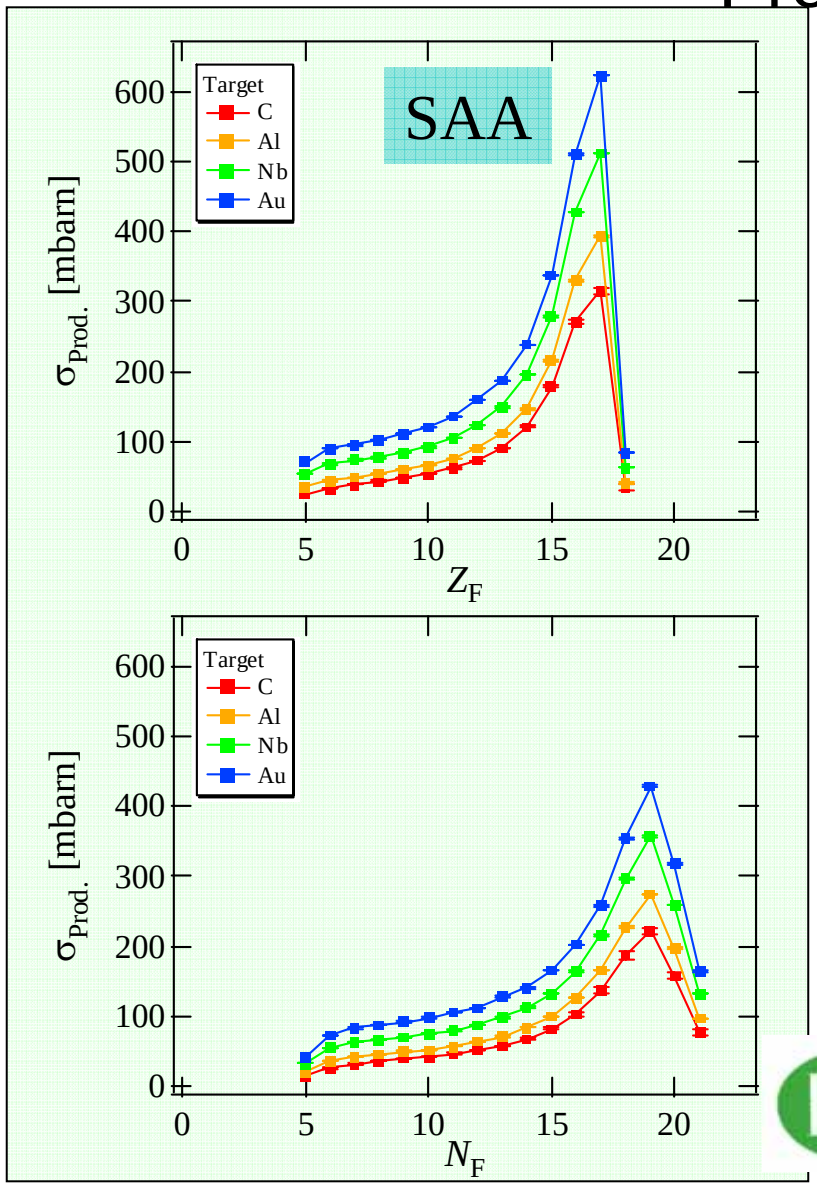


Observed $\sigma_{Prod.}$ of PLF



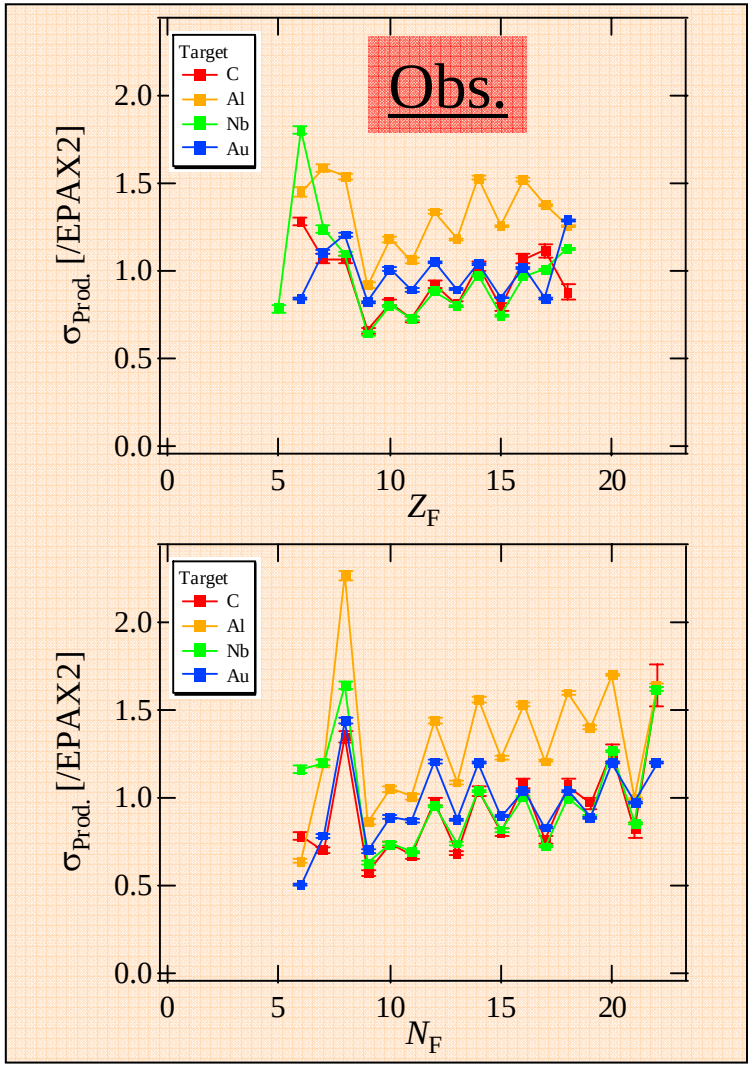
Isotopic/Isotonic distribution of $\sigma_{Prod.}$ 1

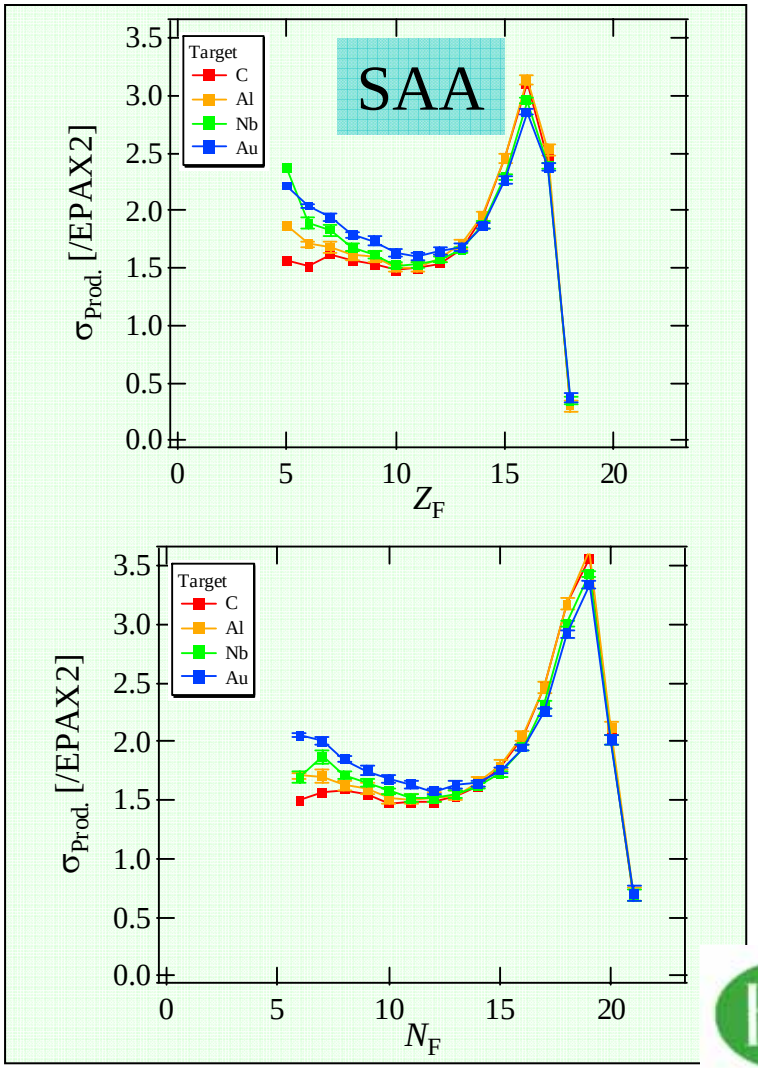




Isotopic/Isotonic distribution of $\sigma_{Prod.}$ 2

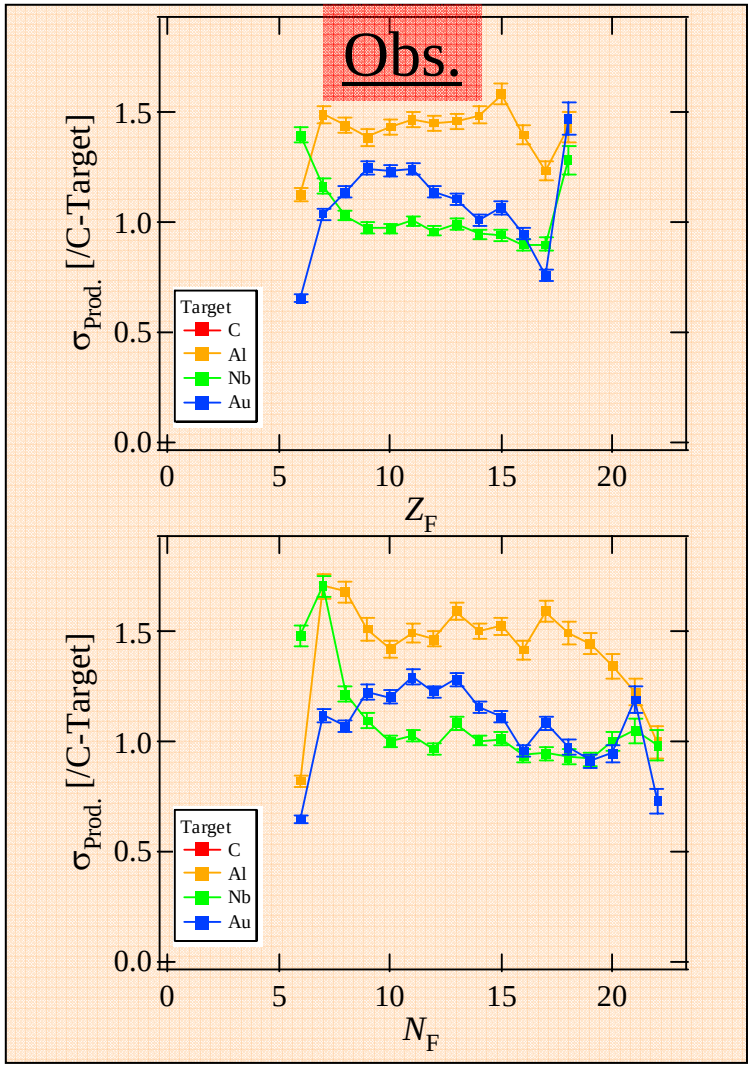
$\sigma(\text{Obs.})/\sigma(\text{EPAX2})$

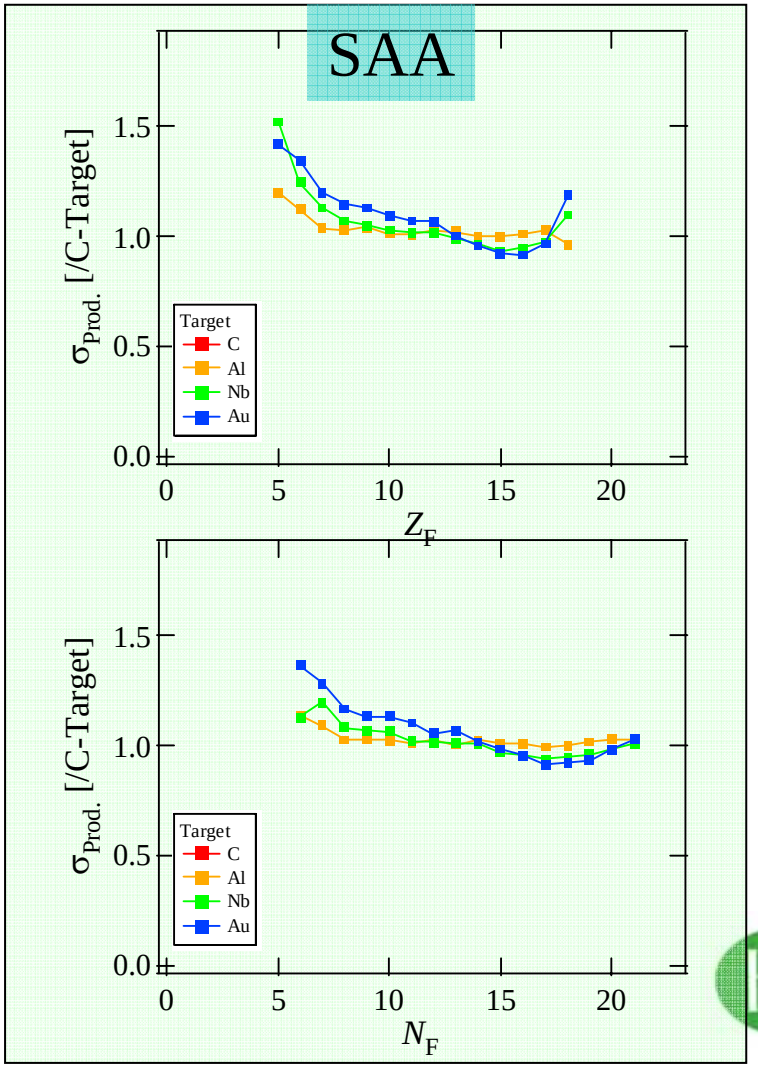




Isotopic/Isotonic distribution of $\sigma_{Prod.}$ 3

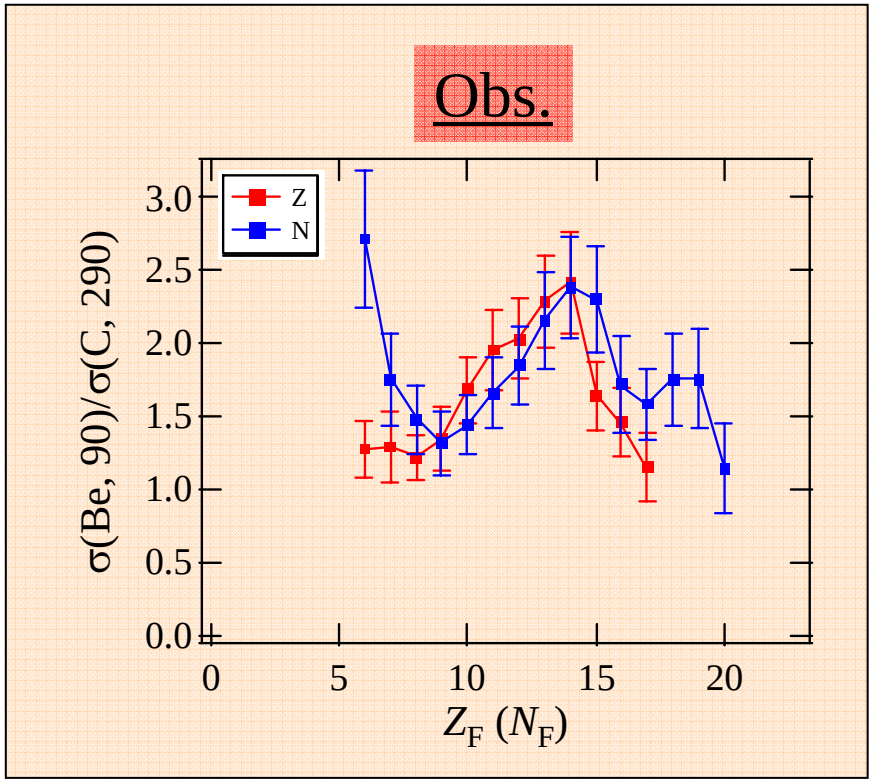
$$\frac{\sigma(\mathrm{Al, Nb, Au})}{\sigma(\mathrm{EPAX2})} \Big/ \frac{\sigma(\mathrm{C})}{\sigma(\mathrm{EPAX2})}$$

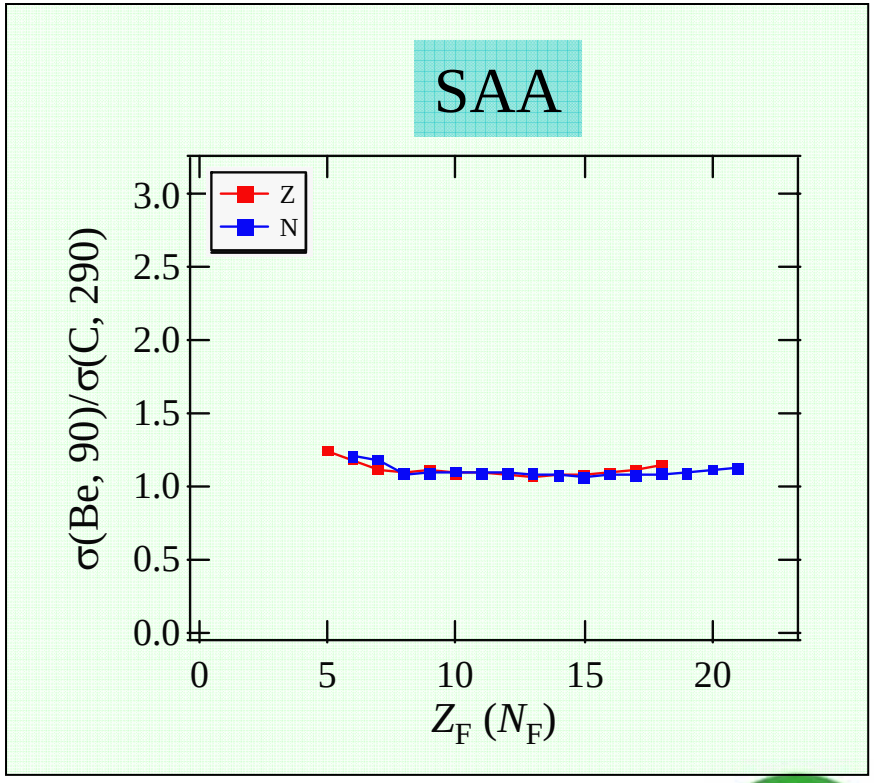




Isotopic/Isotonic distribution of $\sigma_{Prod.}$ 4

Energy dependence : $\dfrac{\sigma(\mathrm{Be}, 90)}{\sigma(\mathrm{Be}, \mathrm{EPAX2})} \Big/ \dfrac{\sigma(\mathrm{C}, 290)}{\sigma(\mathrm{C}, \mathrm{EPAX2})}$





Conclusion

- σ_{Prod} of PLF measured for ^{40}Ar + ^{12}C, ^{27}Al, ^{93}Nb, ^{197}Au at 290 MeV/u

- Isotopic/isotonic distribution of σ_{Prod}

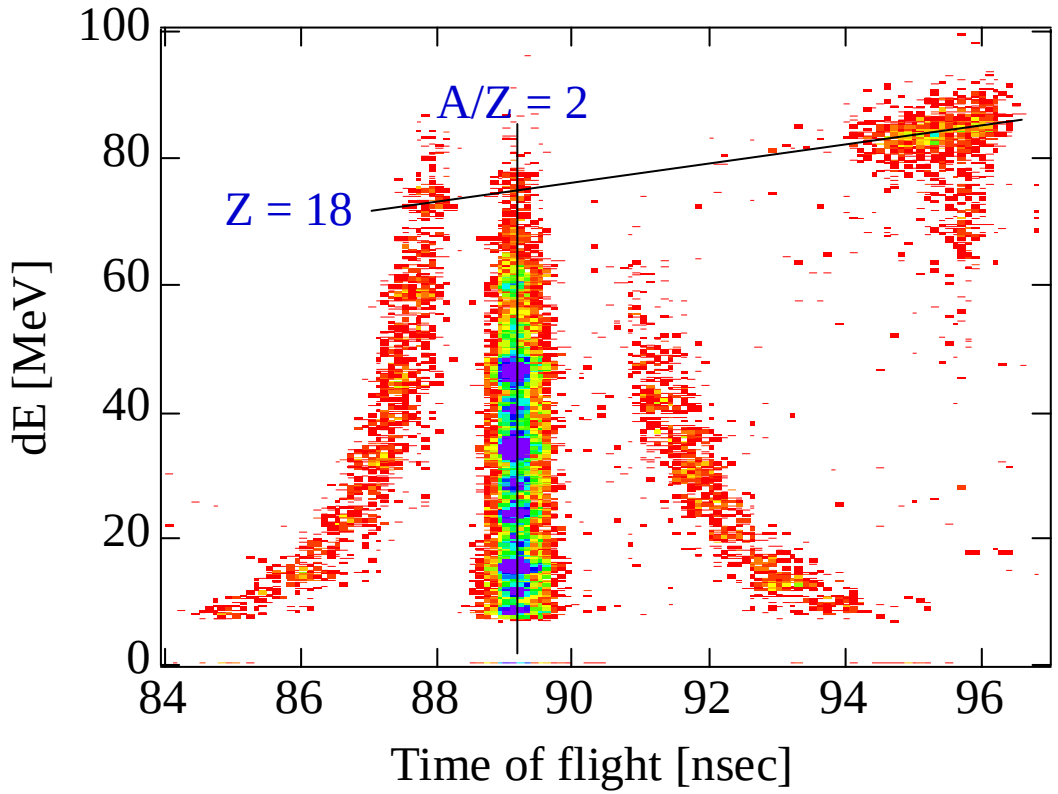
  Pair and shell effect

  Target effect

- Enhancement of productivity for IMF at 90 MeV/u

Particle identification

^{40}Ar (290MeV/A) + ^{197}Au (0.333 mm)



Bρ = 4.996 [T-m]
Δθ = 26 [mrad]
$\Delta P/P_0$ = 1 [%]

Momentum distribution

SD of momentum distributions

$$\sigma_L^{\,2} = \sigma_I^{\,2} \qquad \sigma_T^{\,2} = \sigma_I^{\,2} + \sigma_D^{\,2} + \sigma_C^{\,2}$$

1) Fermi momentum of nucleons

$$\sigma_L^{\,2} = \frac{F(A-F)}{A-1}\sigma_0^{\,2} \qquad \sigma_0 = 90\ \mathrm{MeV/c}$$

2) Deflection of projectile in target nucleus

$$\sigma_D^{\,2} = \frac{F(A-F)}{A(A-1)}\sigma_{1\perp}^{\,2} \qquad \sigma_{1\perp} = 195\ \mathrm{MeV/c}$$

3) Coulomb final state interaction

$$\sigma_C^{\,2} = \pm\frac{\sqrt{2\pi}}{4}(Z_A - Z_F)C_0\sigma_{D\perp} +$$

$$C_0^{\,2}(Z_A - Z_F)\{\frac{1}{3} + \frac{Z_A - Z_F - 1}{8}\}$$