Fragment Formation in GeV-Energy Proton and Light Heavy-Ion Induced Reactions

Tetsuya MURAKAMI

Department of Physics
Kyoto University
for
KEK-PS E288/E337/E393
and NIRS-HIMAC P052
Collaboration

M.Haga, M.Haseno, Y.Hirai, H.Ito,
M.Itoh, T.Kawabata, K.Kimura,
F.Kosuge, S.Kouda, R.Kubohara,
S.Mihara, K.Miyazaki, S.Morinobu,
R.Muramatsu, J.Murata, Y.Nagasaka,
K.Nakai, H.Nakamura, H.Ochiishi,
Y.Okuno, Y.Ohkuma, T.Shibata,
Y.Shibata, Y.Sugaya, E.Takada,
H.Takeda, K.H.Tanaka, Y.Tanaka,
Y.J.Tanaka, M.Uchida, K.Ushie,
Y.Yamanoi, and K.Yasuda

Multifragmentation

Formation of

Intermediate Mass Fragments

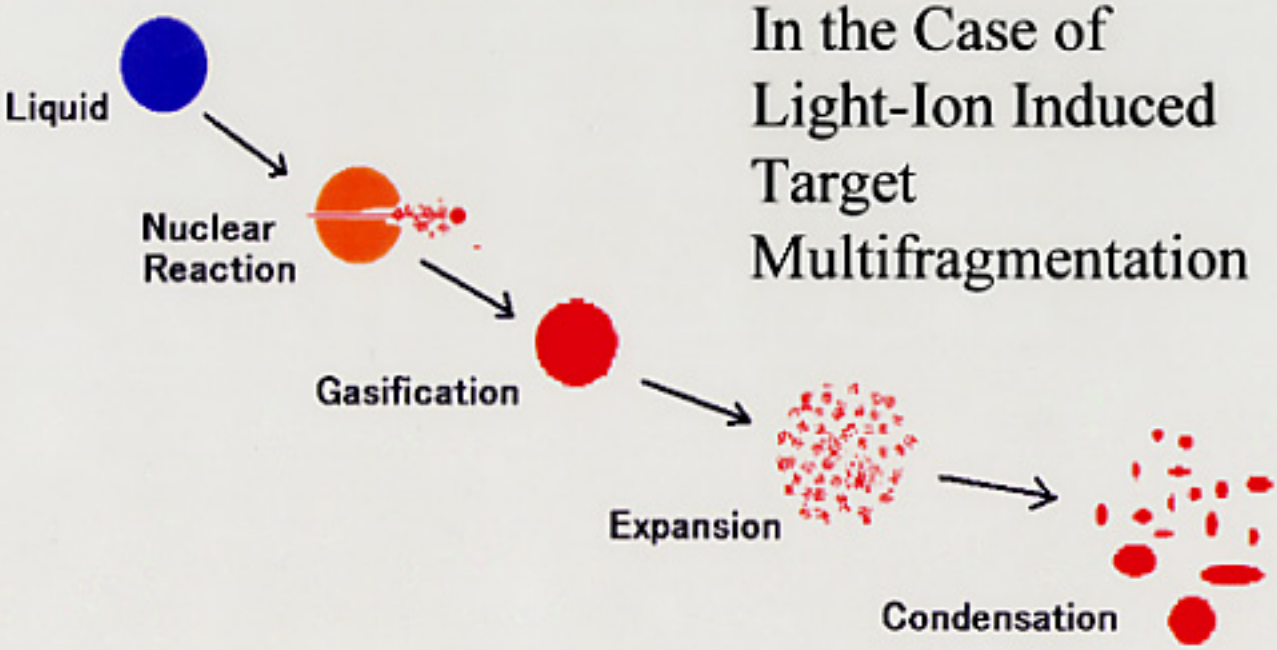
(IMF: $Z_{target}/3 \geqq Z_{IMF} \geqq 3$)

Li,Be,B,C,N~Ne,Na,Mg~Ar

at High Energy Nuclear Reactions

Decay of Highly Excited Nucleus!?

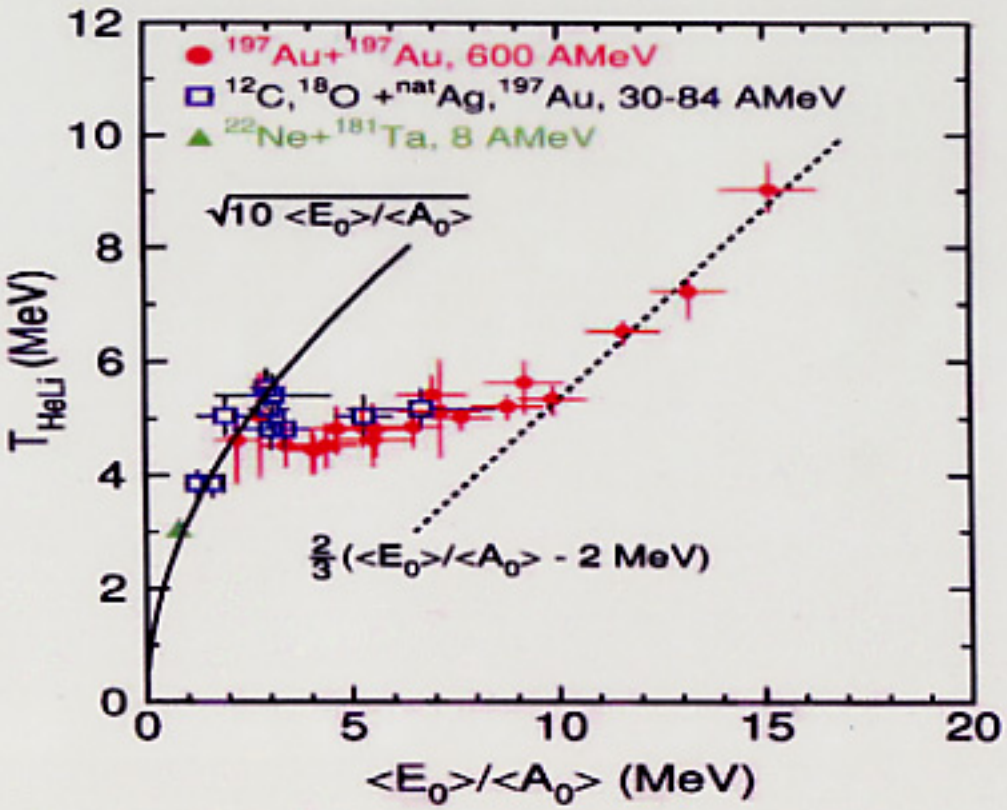
~ 100 MeV ~ 1 GeV



In the Case of Light-Ion Induced Target Multifragmentation

Physics of Multifragmentation

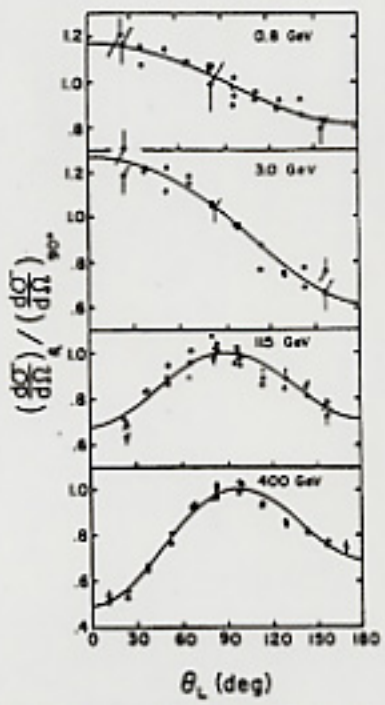
- Property of Nuclear Matter
  - Liquid-Gas Phase Transition.
  - Extraction of Caloric Curve and/or Phase Diagram of the Nuclear Matter.
- Reaction Mechanisms at High Energies
  - Some Exotic Phenomena in the IMF Emission at ~10 GeV.
  - Appearance of the Sideward Peaking in the IMF Angular Distribution.



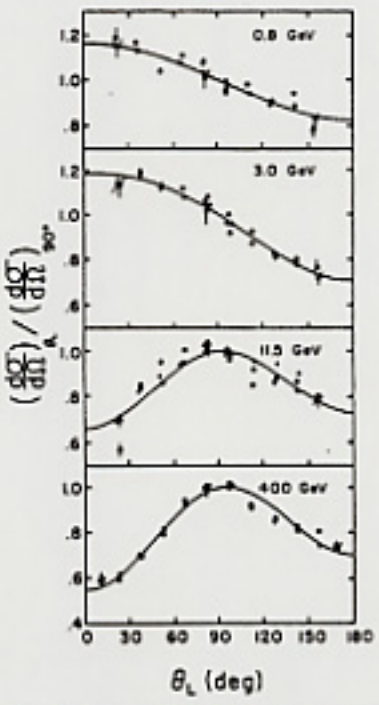
GeV Energy Domain

Something is happening

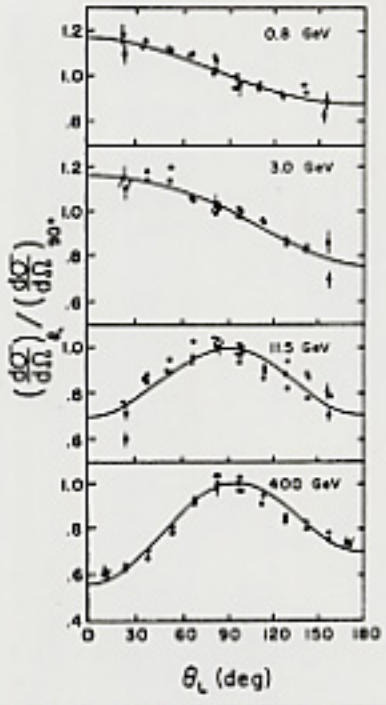
$^{238}U(p,X)$



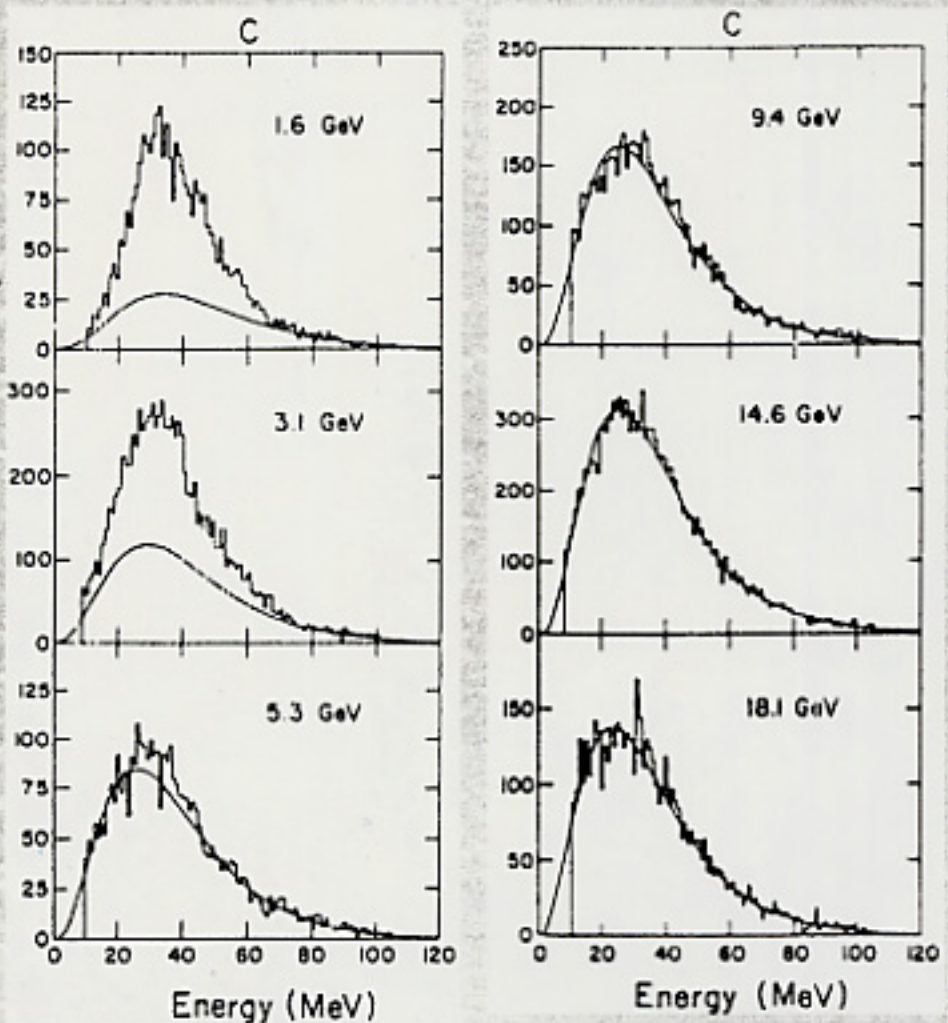
$^{44}Sc^{m}$

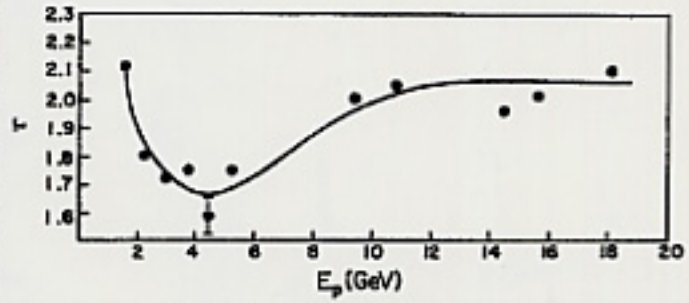


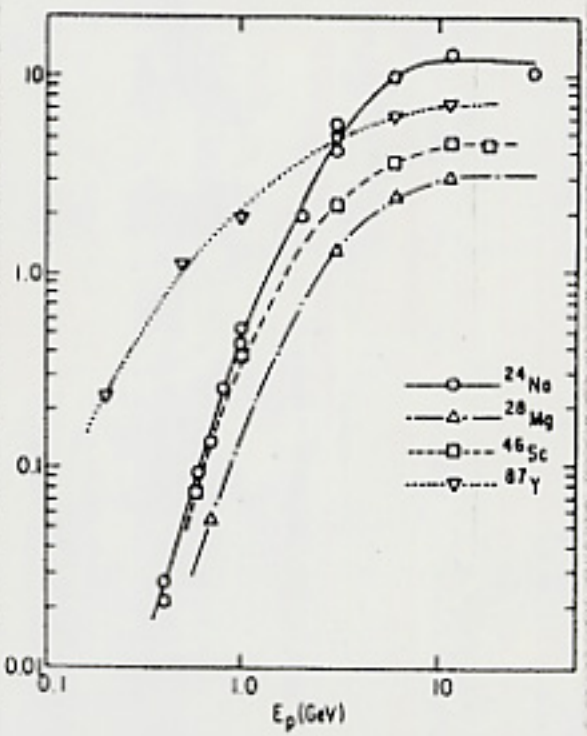
^{47}Sc



^{48}Sc







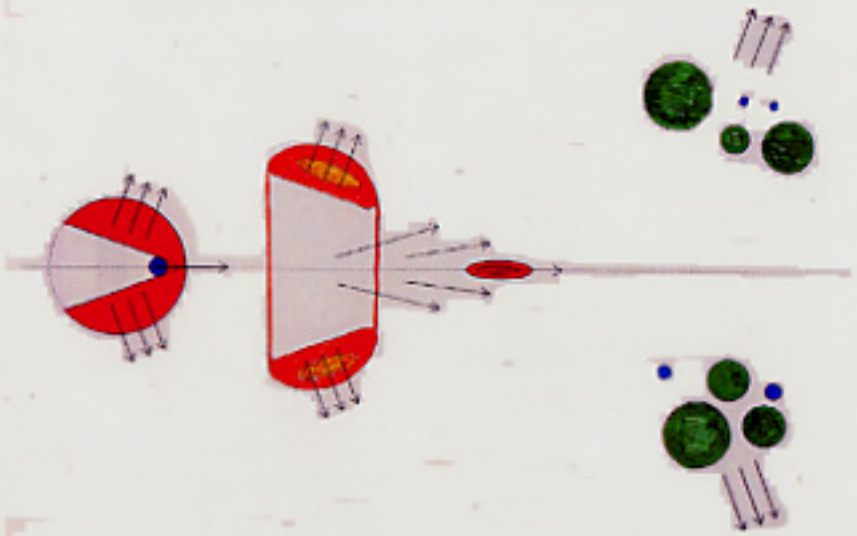
Xe(p,C)

^{197}Au(p,X)

Origin? of the Sideward Peaking

Shock Wave?

Glassgold et al.
Ann. of Phys.,
6(1950)436

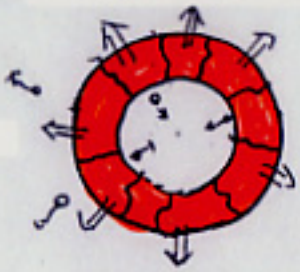


Doughnut/Disc Nucleus?

Maruyama & Niita,
PTP97(1997)579

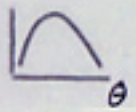
RQMD Calculation

(1) expansion > attraction



multifragmentation

sideward peak



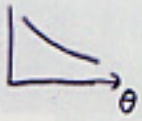
(2) attraction > expansion

hot nucleus

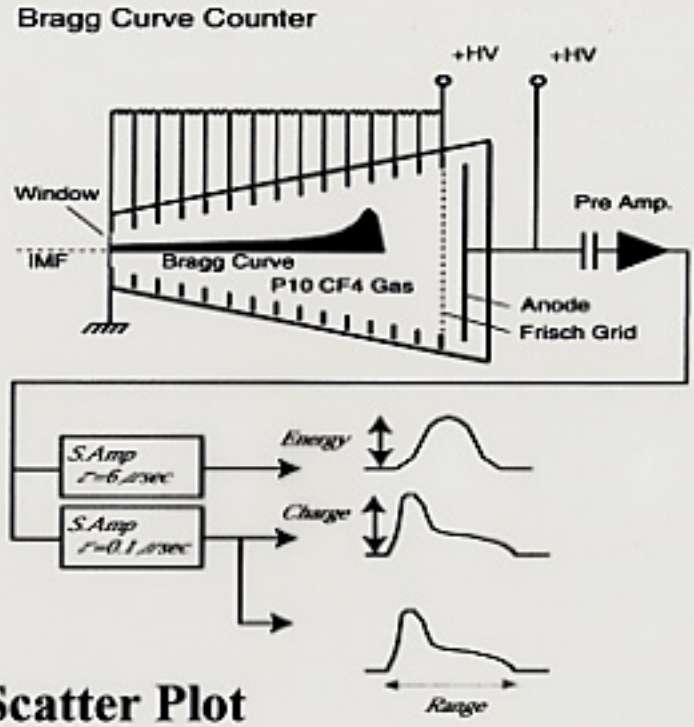
evapolation, fission

⇒ isotropic decay

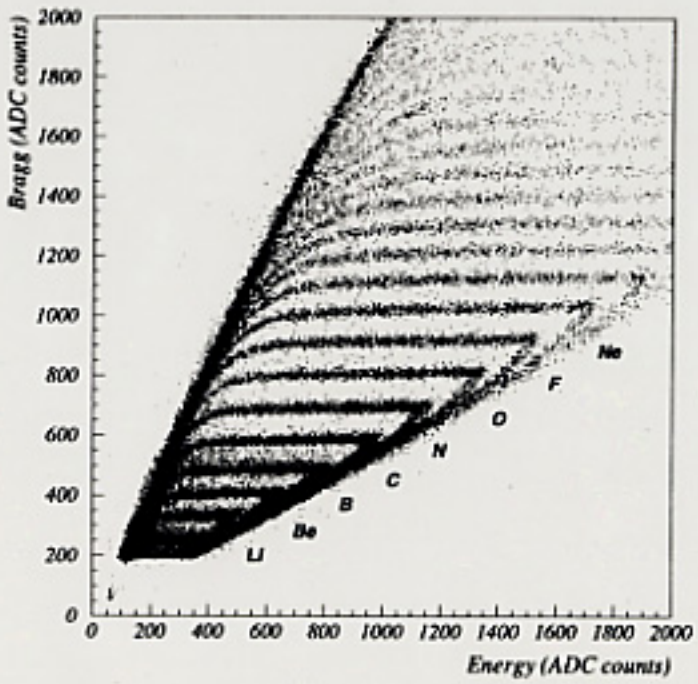
forward peak



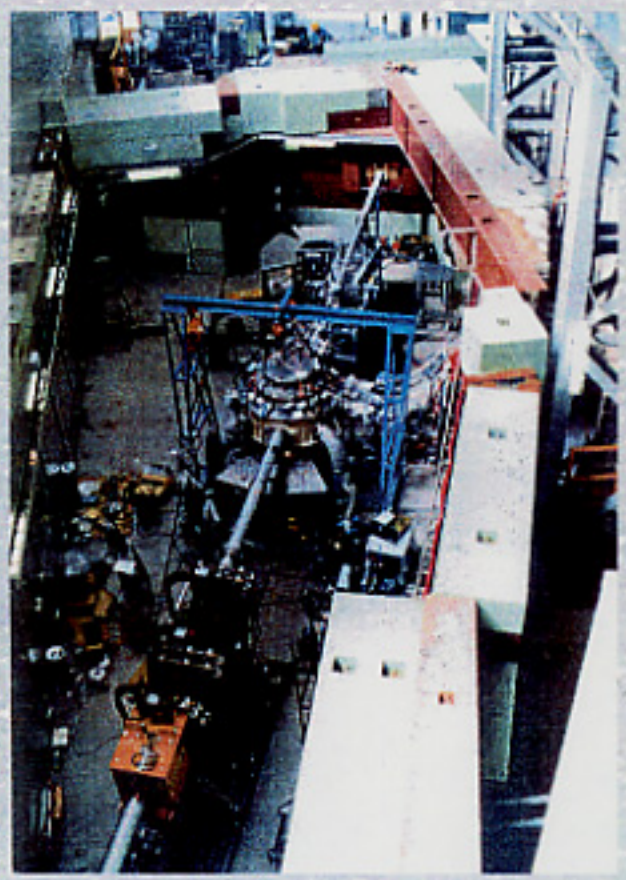
Experiments
1, Bragg Curve Counter



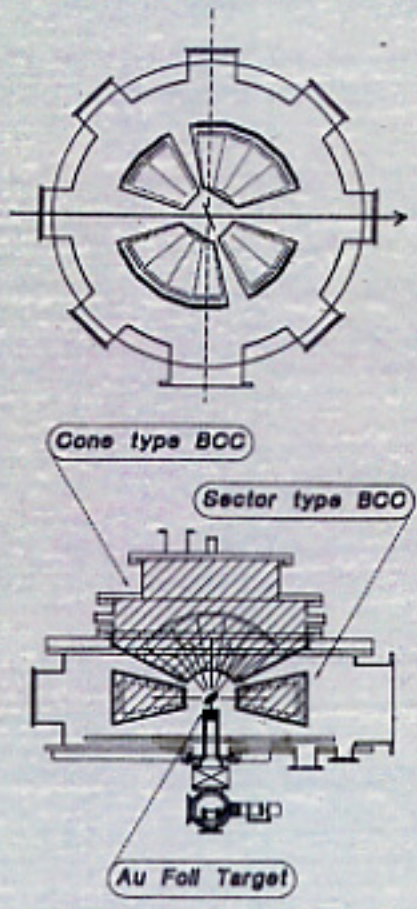
Energy-Charge Scatter Plot



Setup



Detector



Proton Experiment:

Beam intensity 1×10^9pps
Spill 0.5 or 1.0 sec.
Repetition 2.6 or 4.0 sec.
Target Ag, Sm, Tm, Au
($\sim$0.6 mg/cm^2)

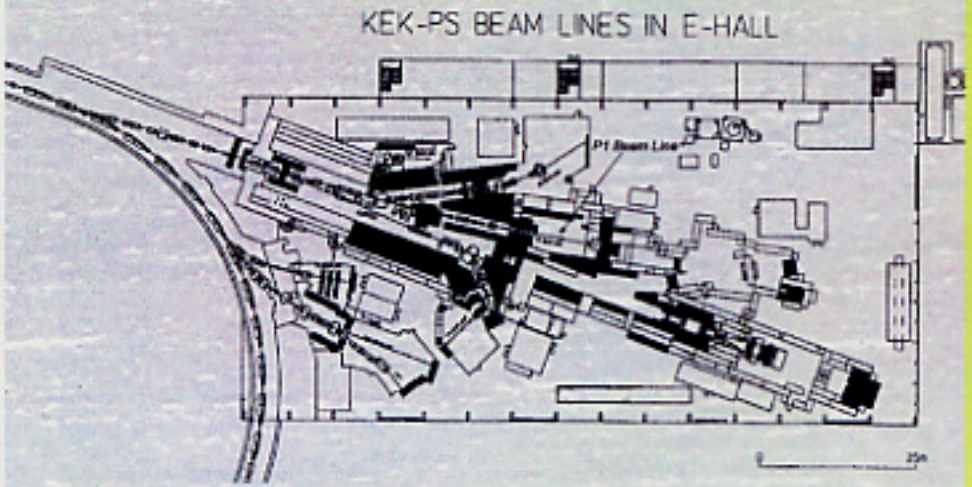
Light Heavy-Ion Experiment:

Beam intensity 7.5×10^8pps
Spill 0.8 sec.
Repetition 3.3 sec.
Target Ag, Au

covering nearly 20% of 4π

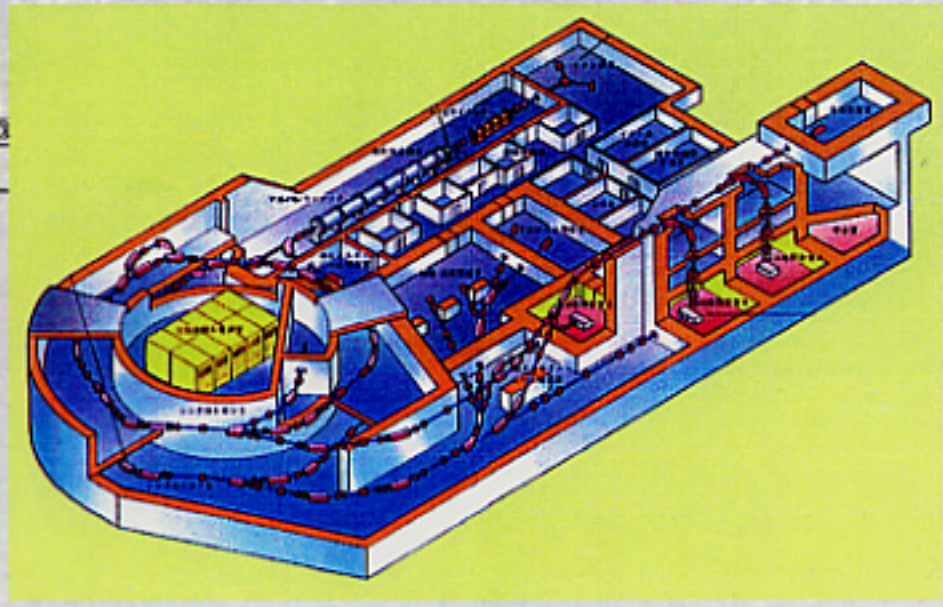
Experiments

Proton Experiment @ KEK-PS



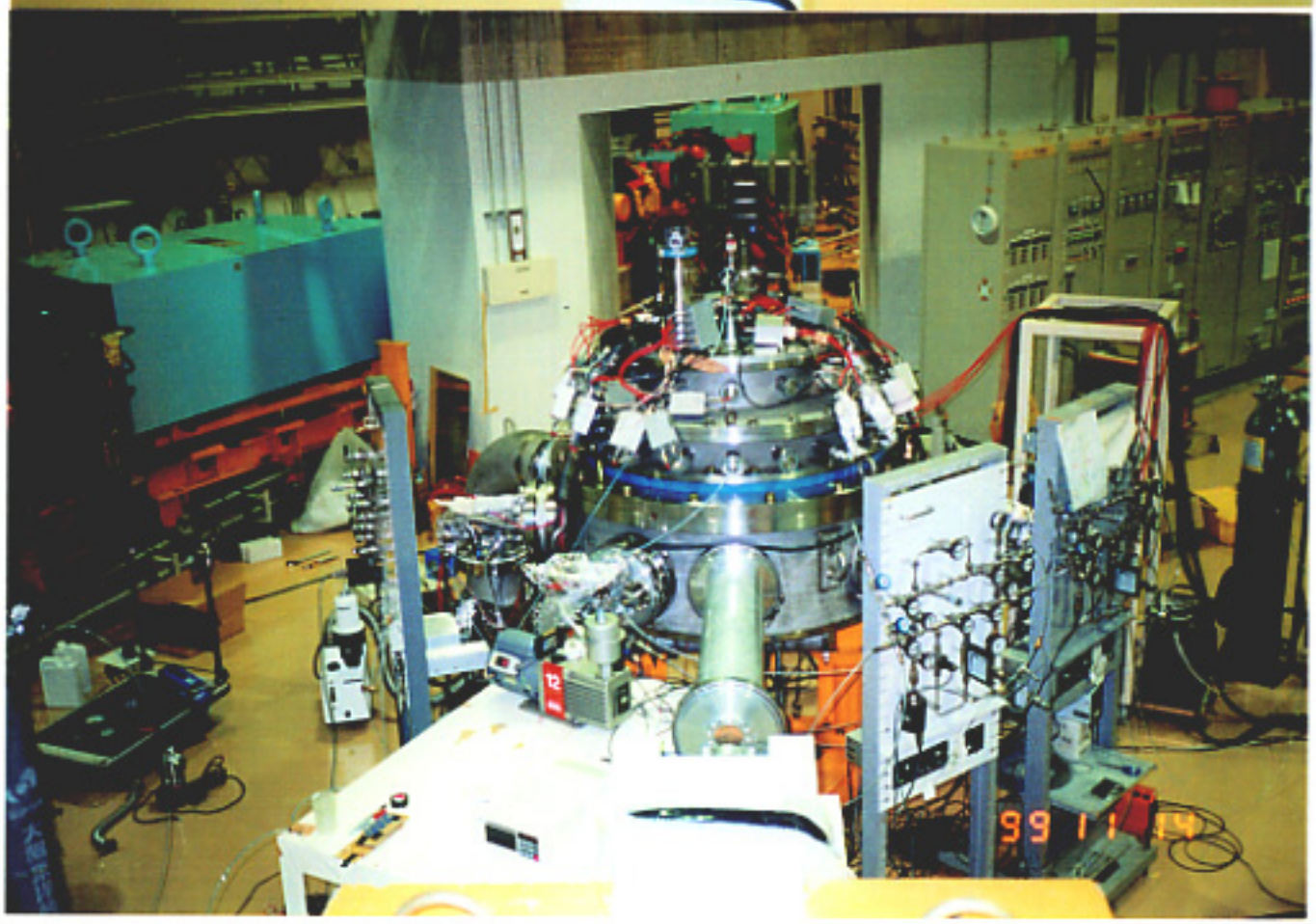
Light Heavy Ion Experiment @ NIRS-HIMAC

(National Institute of Radiological Sciences-Heavy Ion Medical Accelerator in Chiba)



Heavy Ion Beam : Range < 30 cm in human body!!

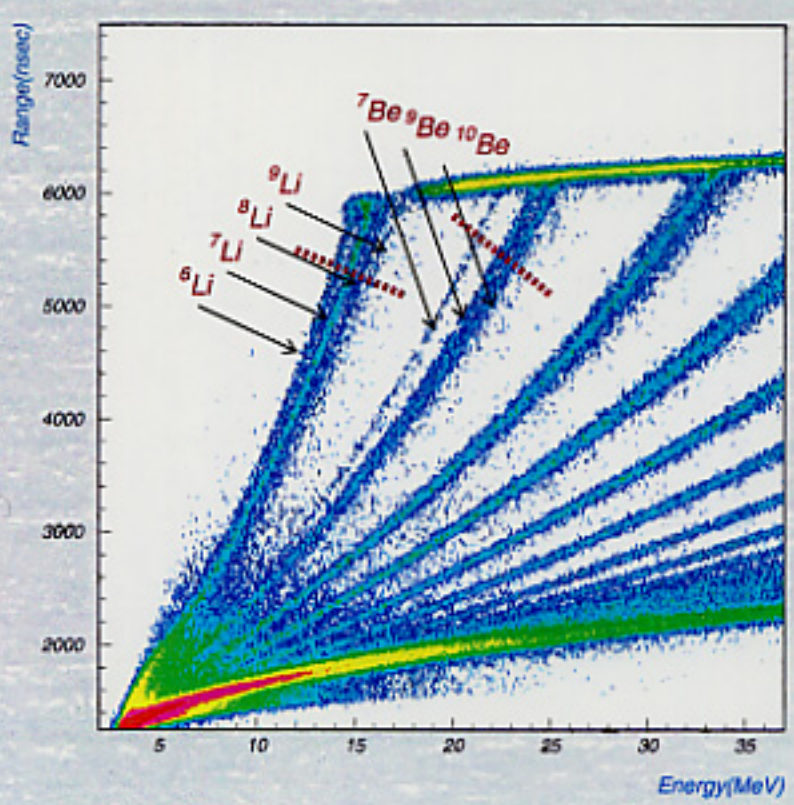

99 11 15

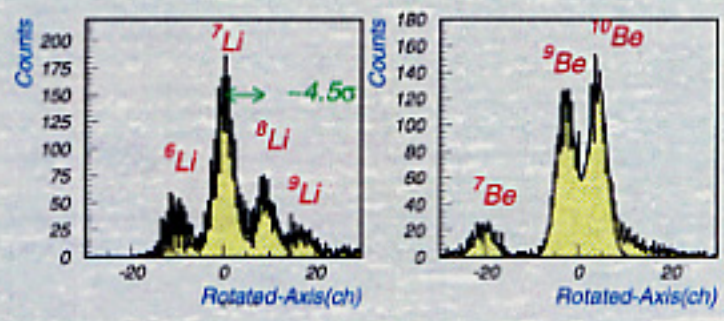

99 11 14

Beam Summary

- Light projectiles
  - Proton
    - 12 GeV
    - 8 GeV
  - Alpha (Inclusive only)
    - 20 GeV
- Light heavy-ions
  - ^{20}Ne
    - 12 GeV (600 MeV/u)
    - 8 GeV (400 MeV/u)
  - ^{16}O
    - 8 GeV (500 MeV/u)

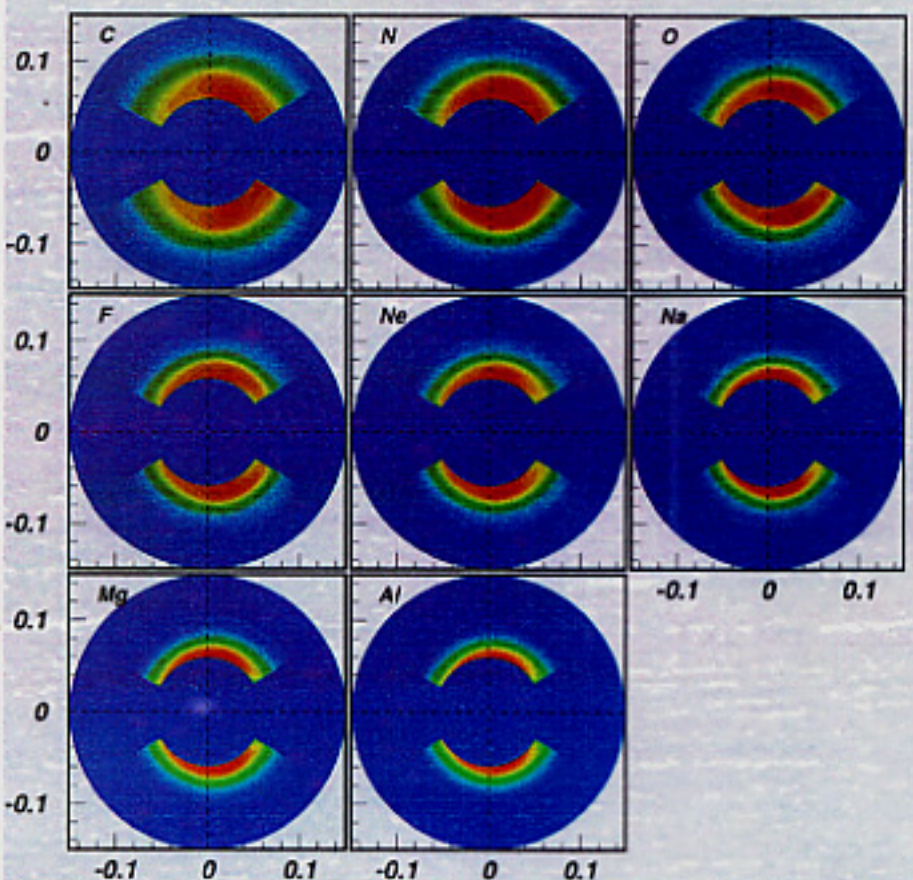
Isotope Separation



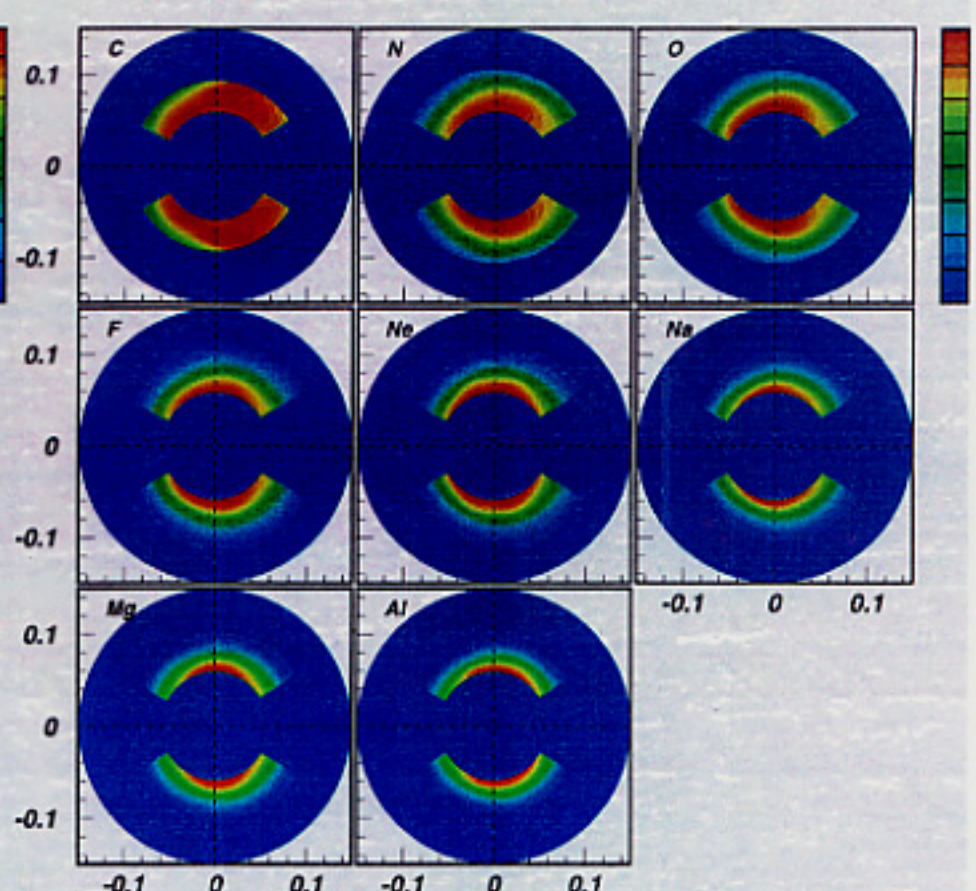


Invariant Cross Section

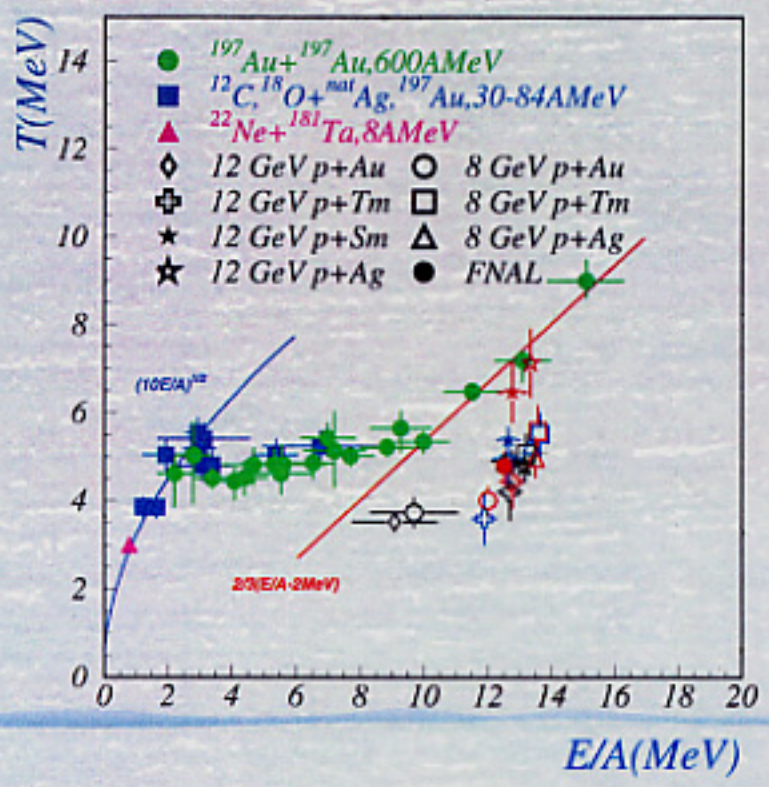
Au(p,X) at 12 GeV Flow Diagram



Au(α,X) at 20 GeV Flow Diagram



Caloric Curve



- Onset of phase transition around 8-12 GeV?
- Some Difference from GSI data

Density Effect???

Where to investigate?