DAIMAJIN (Large-Acceptance Multiparticle Spectrometer)

T. Kobayashi, T. Nakamura, T. Uesaka, N. Iwasa

[1] Function of facility & physics motivation

Three kinds of configurations :

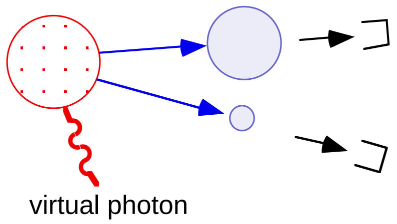

Fig. 1A

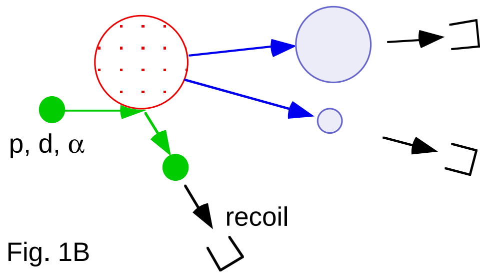

Fig. 1B

(Mode 1) Detection of projectile fragments and projectile-rapidity nucleons in coincidence, using heavy target [Fig-1A].

●Method:

Electromagnetic excitation :

excite the projectile by virtual photons from the heavy target,

Observation :

unbound excited states by detecting decay particles via invariant-mass method.

●Motivation :

Giant resonance at high excitation-energy region :

collective excitation in the unbalanced system.

Soft resonance at low excitation-energy region :

new collective states?

Electromagnetic breakup reactions :

single particle properties of weakly-bound valence nucleons.

Inverse reaction of (γ,p) proton/neutron radiative-capture reactions :

astrophysical reactions in explosive nucleosynthesis.

(Mode 2) Detection of leading projectile fragment and target-rapidity nucleons in coincidence, using light target [Fig-1B].

●Method :

Direct reactions : (p,p), (p,p’), (p,n), (α,α’), (p,pN) etc.

Observation :

light recoil particles in the target-rapidity region to identify the direct reaction by missing-mass method, and

leading heavy to tag the decay mode of the residual nucleus.

●Motivation :

Elastic scattering : density distribution

Low-lying discrete states : single-particle properties.

High-lying collective states : compressive mode?

Exotic resonances beyond the drip line.

(Mode 3) High-resolution measurement for polarized deuteron beam

● Method :

(d,d) and (d,p) reactions

using high-energy polarized deuteron beams on a few-nucleon system

● Motivation :

Short range-part of the two-nucleon interaction

Three-nucleon forces

[2] Requirements

(1) Incident beam

RI beams :

Fully stripped, mass number A<100

energy of 250-300 AMeV (max. magnetic rigidity of 2.2 GeV/c)

Primary deuteron beams :

Polarized beam from 500 MeV to 880 MeV

(2) Requirements from physics :

● Projectile-rapidity nucleon(proton & neutron)s from high-lying continuum :

○ Acceptance : assuming two-body decay

Nucleon decay energy up to 8 MeV :

angular acceptance $\theta_N < \pm 10°$, momentum acceptance $\Delta p / p < \pm 20\%$.

○ Resolution :

$\sigma(E_{rel}) / E_{rel} \approx 0.3 MeV / 3 MeV$ for low-lying states &

$\sigma(E_{rel}) / E_{rel} \approx 0.5 MeV / 8 MeV$ for high-lying giant resonance :

velocity : $\sigma_\beta / \beta \approx 6 \times 10^{-3}$, opening angle : $\sigma(\theta_{12}) \approx 5 mrad$, momentum : $\sigma_p / p \approx 1\%$

○ Sweeper :

For projectile-rapidity neutron measurement:

high bending power as charged-particle sweeper

● Heavy projectile fragment : under the same condition

○ Acceptance :

angular acceptance $\theta_F < 170 / A_F mrad$, momentum acceptance : $\Delta p_F / p_F < \pm 20 / A_F \%$

○ Resolution :

for invariant mass : $\sigma_R / R \le 1\%$

for particle identification (PID) : $\sigma_A / A_F \le 0.2/100$

rigidity resolution : $\sigma_R / R \le 1/700$, velocity resolution : $\sigma_\beta / \beta \approx 9 \times 10^{-4}$

●Polarized deuteron-induced reactions

○ Acceptance :

$\theta_{H,V} \le \pm 50 mrad$ ($\Delta\Omega \approx 10$msr)

○ Resolution :

For separating ^{3}He(d,p)^{4}He reactions from ^{16}O(d,p),^{28}Si(d,p) backgrounds :

$\sigma_p / p \le 1/10000$

(3) Other requirements

[3] Design

(1) Basic component & summary of requirements

●Large-acceptance magnetic spectrometer

Momentum resolution :

$\sigma_R / R \le 1/700$ for heavy fragment

$\sigma_p / p \approx 1\%$ for projectile-rapidity proton

$\sigma_p / p \le 1/10000$ for polarized deuteron-induced reactions

Momentum acceptance :

for leading fragment & protons in coincidence : $p_{\max} / p_{min} \ge 2 \sim 3$

for projectile-rapidity protons : $\Delta p / p < \pm 20\%$

Velocity and charge resolution :

$\sigma_Z \le 0.2$ & $\sigma_\beta / \beta \approx 9 \times 10^{-4}$

Angular acceptance :

Projectile-rapidity neutrons & protons : $\theta_N < \pm 10°$

Charged-particle sweeper

●Forward neutron Hodoscope

Velocity resolution : $\sigma_\beta / \beta \approx 6 \times 10^{-3}$

Angular resolution : $\sigma(\theta_{12}) \approx 5 mrad$

Multi-neutron detection capability : for 2n, 3n decay channels

●Detector system in the target region

Charged-particle detectors for direct reactions on light targets

High-efficiency gamma-ray detectors for Giant-resonance studies

(2) Current design

(2-1) Experimental Setup : horizontal [Fig.2A] & vertical [Fig.2B]

(2-2) Spectrometer magnet [Fig.3]

H-type super-conducting magnet with round poles for

Large bending power : maximum field of 3T and field integral of 7 Tm

bend 2.2 GeV/c particles by 53 degrees

moderate momentum resolution of $\sigma_R/R \le 1/770$(first order) at R=2.2 GeV/c

Assume: $\sigma(x_T) \approx 0.5\text{mm}$, $\sigma(x_D) \approx 0.3\text{mm}$, $\sigma(x'_D) \approx 1\text{mrad}$

option : momentum resolution of $\sigma_p/p \le 1/10000$ (first order) at R=2.2 GeV/c

by adding quadrupoles as QQQD or QQD

large opening angle for projectile-rapidity neutrons

moderate vertical force between coils : less than 650 t w/o coil links

symmetric configuration for stable operation

vacuum chamber installed between gaps

on the rotatable table for various experimental configuration

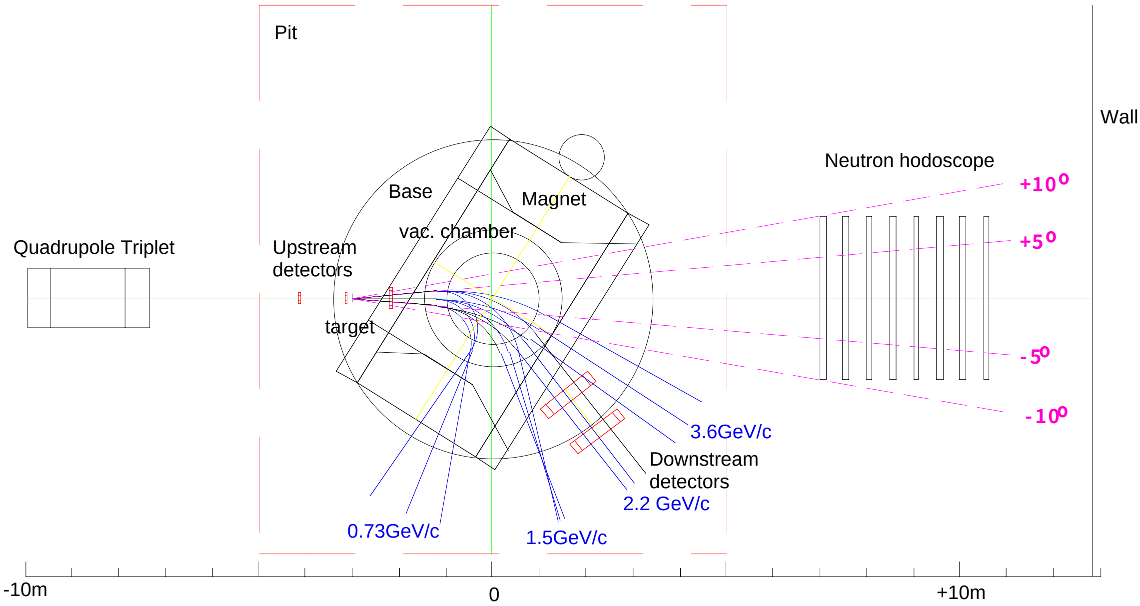

Fig. 2A : Experimental Setup (Plan view)

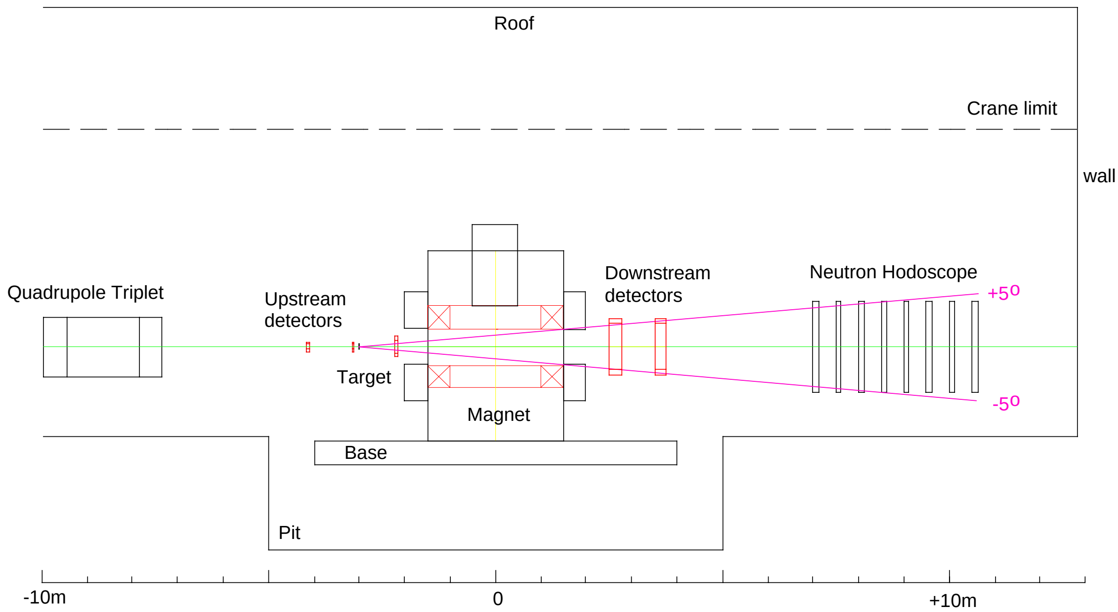

Fig. 2B : Experimental Setup (Side view)

(2-2’) Cooling system for superconducting magnet

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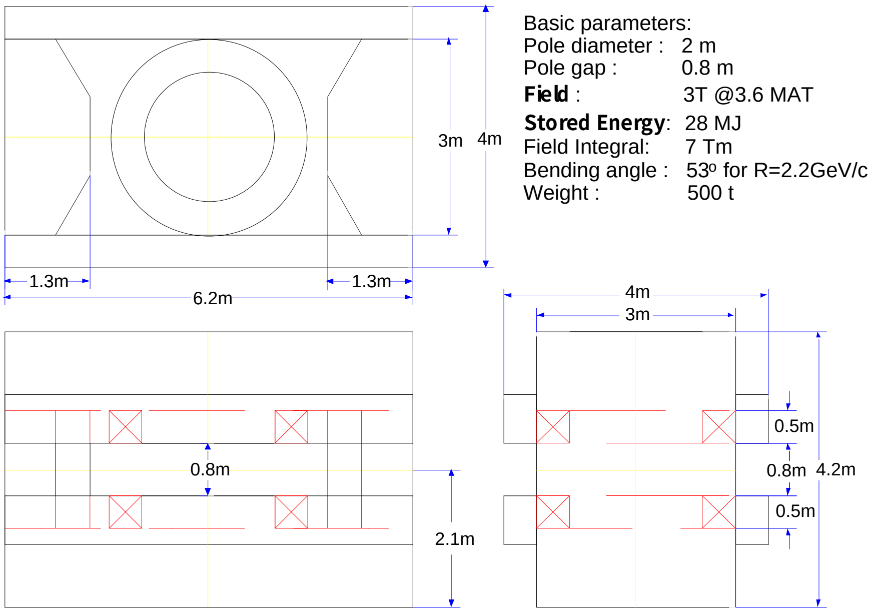

Fig.3 : Superconducting spectrometer magnet

(2-3) Upstream detectors : in vacuum

two sets of beam position detectors : beam phase space measurement

PPACS ? Low-pressure MWPC's?

start-timming detector ?

thin detector to get good target-in/target-out ratio

$\sigma_T \approx 1nsec$ for drift chamber start signal, $\sigma_T \approx 0.1nsec$ for TOF start signal

position detector after the target :

angle measurement for leading fragment with $\sigma_\theta < 1mrad$ resolution

(2-4) Downstream drift chambers for momentum analysis

type : hexagonal cell structure, 10mm drift distance, for tracks with large incident angle

active area : 100cm x 100cm

configuration : 10 planes, xx'uu'(+30^o)xx'vv'(-30^o)xx'

readout channels : about 500 channels/set via multi-hit TDC

less than 1mrad(rms) angular resolution necessary to get $\sigma_R/R \leq 1/770$.

(2-5) Detector for charge measurement

plastic scintillator hodoscope for Z<20

multiple-sampling ionization chamber ? for Z>20 :

large area? , high rates? need developments?

(2-6) Detector for velocity measurement ?

thin start detector with good timming resolution :

plastic scintillator hodoscope : $\sigma_T \approx 0.1nsec$ over L=8m, $\Leftrightarrow \sigma_\beta/\beta \approx 2\times10^{-3}$

$\Leftrightarrow$PID limited to $A < 38$

Development of high-precision velocity measurements : necessary

(2-7) Neutron Hodoscope

velocity resolution of $\sigma_\beta/\beta \approx 6\times10^{-3} \Leftrightarrow L_{TOF} = 10m$, $\sigma_{TOF} = 0.25nsec$, thickness $L_{\det} = 12cm$

angular resolution of $\sigma(\theta_{12}) \approx 5mrad \Leftrightarrow L_{TOF} = 10m$ & position resolution of $\sigma_x \approx 5cm$

current design:

slat : 12cm x 12cm x 170cm with 2 PM's, covering ±5° vertically @L=10m

45(30) slats/ layer :

covering 420(350)cm horizontal, ie. ±15(10)°horizontally @L=10m

detection efficiency ≈ 70% / 8 layers for 1n channel, 30% / 8 layers for 2n channel

total 360(240) slats

acceptance : example of acceptance for neutrons [Fig.4]

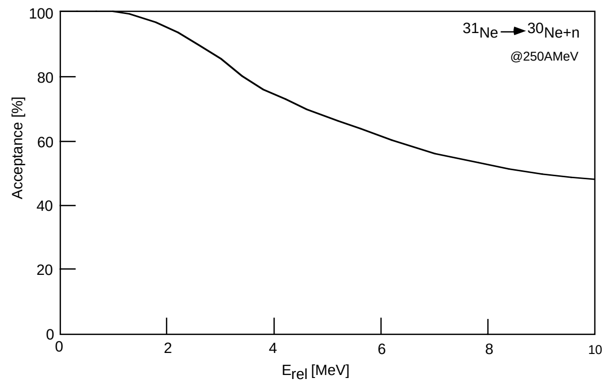

Fig.4 : Acceptance for neutrons

(2-8) QQD option for high resolution measurement

1st order calculation by adding quadrupole doublets before the dipole magnet:

Dispersion :	3.4m
Horizontal magnification :	0.7
Vertical magnification :	3.8

Momentum resolution of $\sigma_p / p \leq 1/10000$ could be achieved

with 10msr solid angle acceptance.

Need to be re-calculated for Quadrupole triplets.

For polarized deuteron measurement,

Faraday cup and concrete shield to dump the deuteron primary beam is necessary.

(3) Items to be further studied

1. Structure of the vacuum chamber & exit window
2. Reduction of fringing field
3. Increase the angular acceptance of projectile-rapidity protons
4. Detector configuration for protons and projectile fragments in coincidence

[4] Rough Cost Estimate

1. Superconducting magnet with rotatable base, vacuum chamber :
   few (several) x 100 MY? need detailed cost estimate
2. Cooling systems for superconducting magnet : ?
3. Neutron Hodoscope : 200 MY

○45 slats/layer x 8 layers = 360 slats

4. Downstream detectors : 74 MY + ?

○drift chambers : 60 MY

20 MY(chamber)/set + 10 MY(500channels)/set, x 2 sets

○drift chamber platform : 2 MY

○Plastic scintillator hodoscope : 12 MY

0.6MY/slat x 20 slats

○Multiple sampling ionization chamber : ?

○High-resolution velocity detector : ?

5. Upstream detectors : 4 MY

○PPAC or LP-MWPC for beam tracking

○PPAC of LPMWPC for fragment tracking:

○start detector :

6. Upstream detector for (γ,p) measurement : 13 MY

○Si-Strip detector & readout

7. Movable mechanism for Quadrupole triplet : 15 MY

8. Beam dump for deuteron beam : 50 MY

[5] Comparison with other facilities

(5-1) Virtual photons : RIBF(250AMeV) vs. GSI(800AMeV) : [Fig.5]

$E_{rel} < 7MeV$: $N_{E1}(250AMeV) > N_{E1}(800AMeV)$

$E_{rel} = 10MeV$: $N_{E1}(250AMeV)/N_{E1}(800AMeV) = 0.8$

as far as RIBF provides 100 times more intensity, Y(RIBF)/Y(GSI)≈few x 10

This is also true for other Coulomb-Breakup experiments.

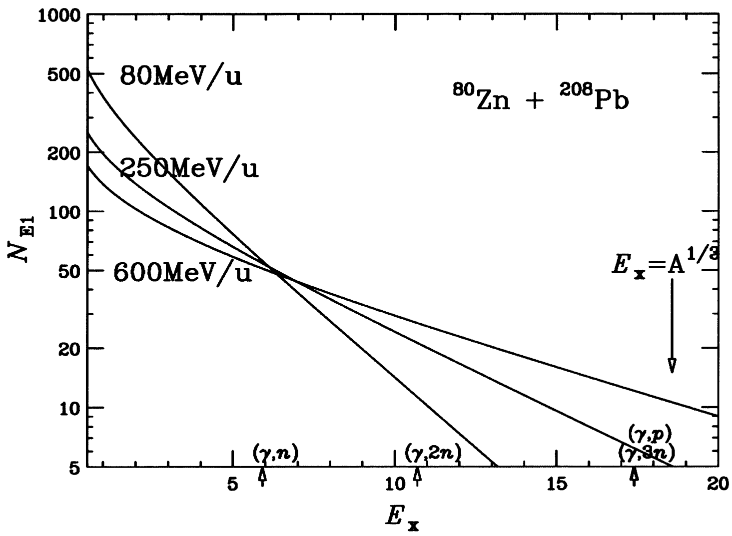

Fig. 5 : Comparison of E1 virtual photon

(5-2) Polarized deuteron measurement: RIBF & Nucleotron @JINR

For beam energies below 1 GeV, RIBF provides much better beam for experiment.

[6] Typical (Initial) measurements

○$^{31}Ne(\gamma, ^{30}Ne+n)$: single particle states around N=20

○$^{79}Ni(\gamma, ^{78}Ni+n)$, $^{81}Zn(\gamma, ^{80}Zn+n)$, $^{83}Ga(\gamma, ^{82}Ga+n)$: single particle states around N=50

○$^{22}Si(\gamma, ^{21}Al+p)$: single particle states around Z=16

○$^{3}He(d,p)\,^{4}He$: polarization correlation measurement between 500-800 MeV