CNS

UT Sakai-G

ICHOR Project

Grant-in-Aid of MEXT

Physics Programs in the SHARAQ project

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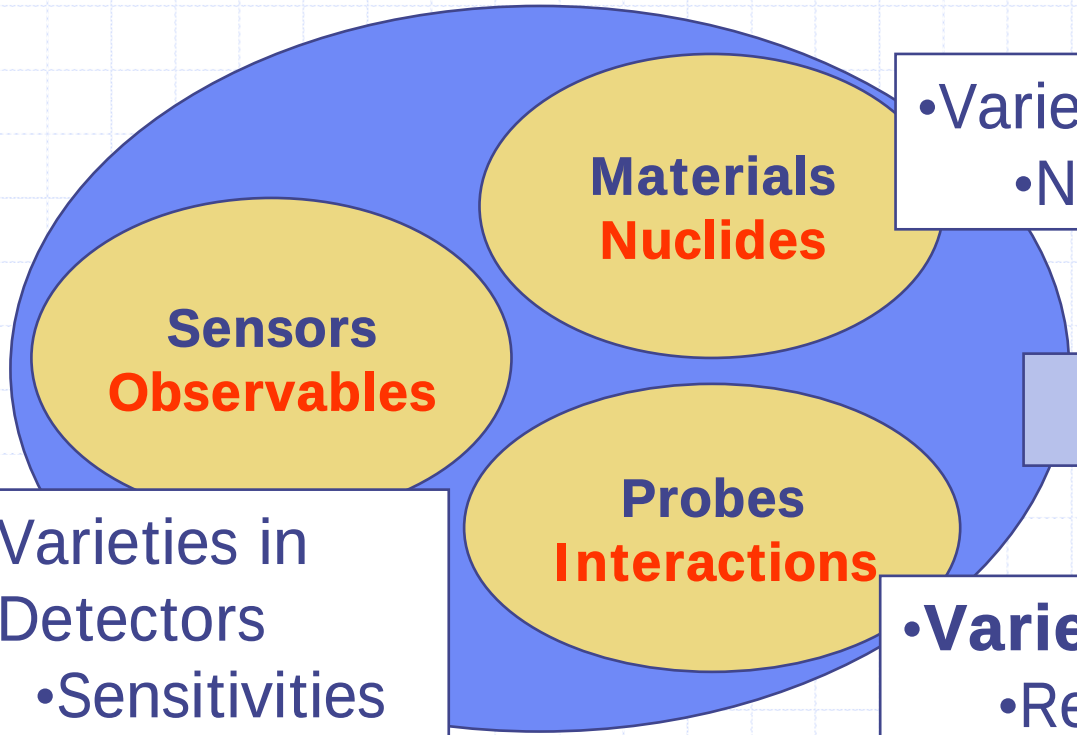
Introduction

- Exp. Studies of Nuclear Many-body System



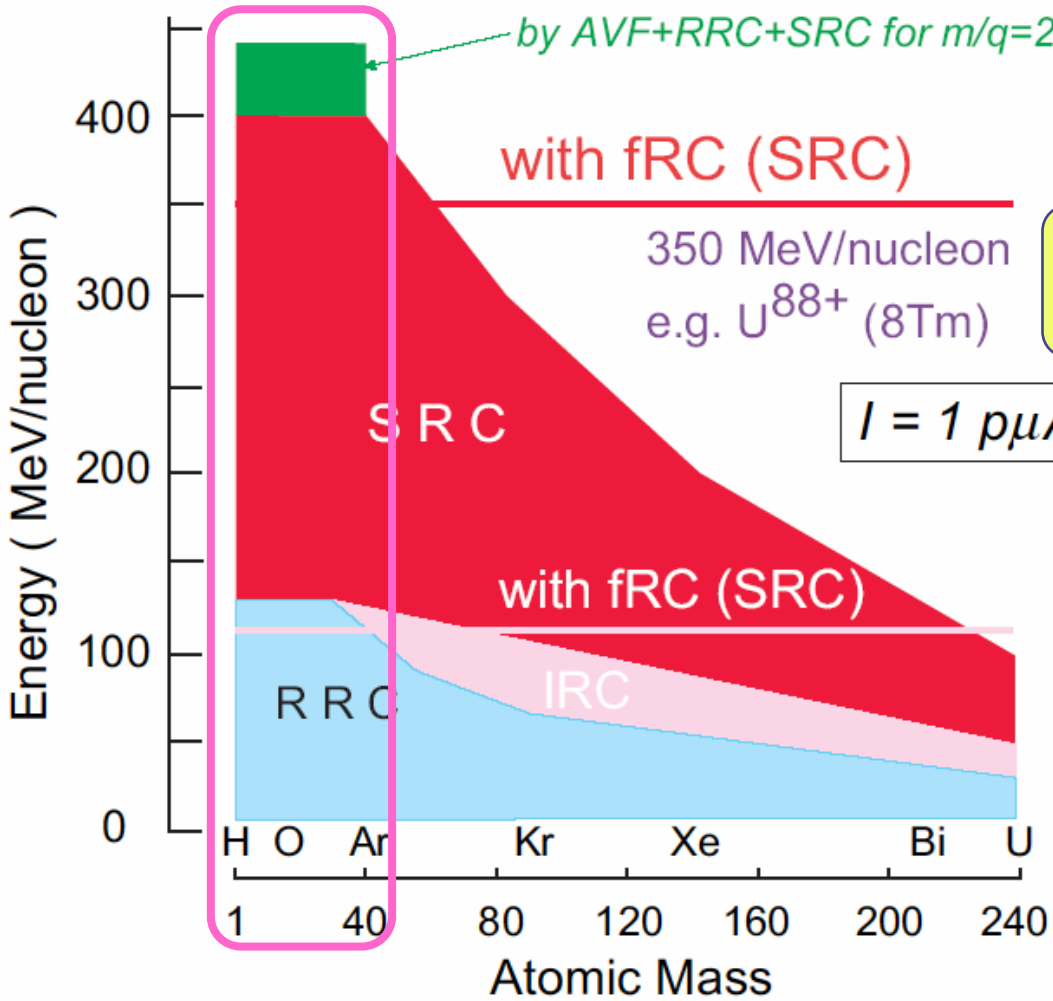
- Varieties in Detectors
  - Sensitivities

- Varieties in Nuclei
  - N-/P-rich Nuclei

RIBF

- **Varieties in Probes**
  - Reactions using **various quantum numbers**

Energy region in RIBF ⇒ Direct Reactions



200-300 MeV/nucleon

I = 1 pμA (goal)

Motivation

- Response of Nuclear System using Intermediate-Energy direct reactions (150-400 A MeV)
  - Studies using New Quantum Probe—RI beam— Large Isospin and Mass Excess、Various J^{π}
    - Controlling Transferred Momenta, Q-values, Spin, Isospin
    - ΔS, ΔT, q-ω
    - Accessing kinematical area/conditions inaccessible by stable nuclear beam
  - Ordinary kinematics

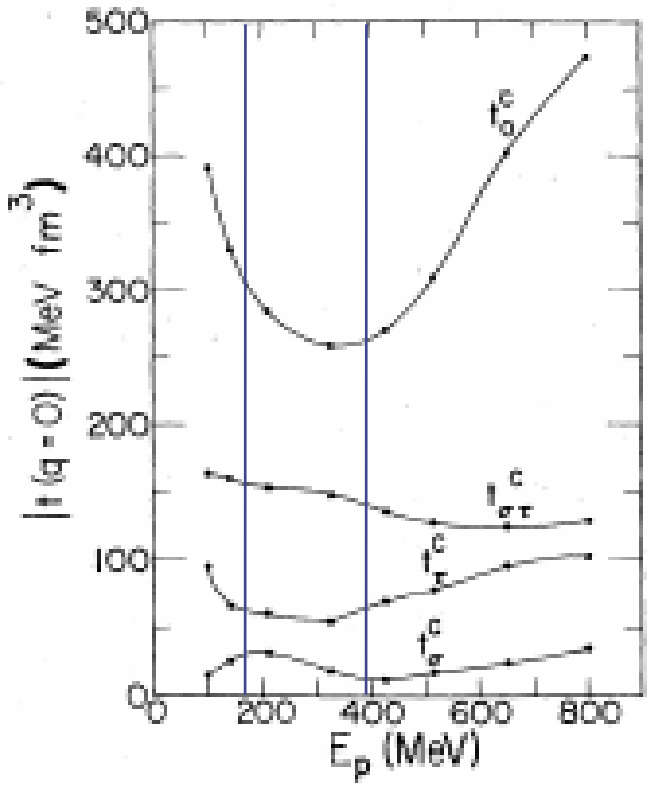
    -> High Resolution Spectrometer + High Quality RI Beam

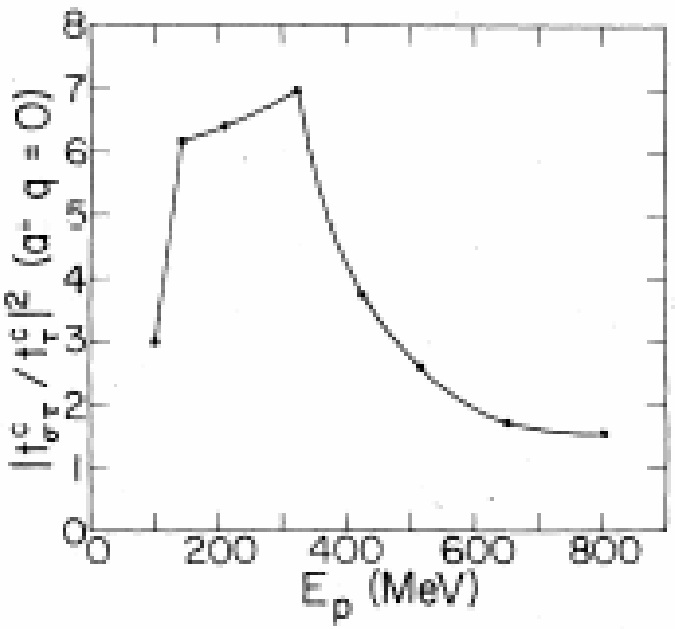
    + (Detectors of decaying particles)
  - Asymmetric nuclear System studied using stable probes
    - Inverse kinematics + Invariant Mass / γ-decay / Recoil

      and **High-resolution missing-mass spectroscopy**

Effective Probes in RIBF

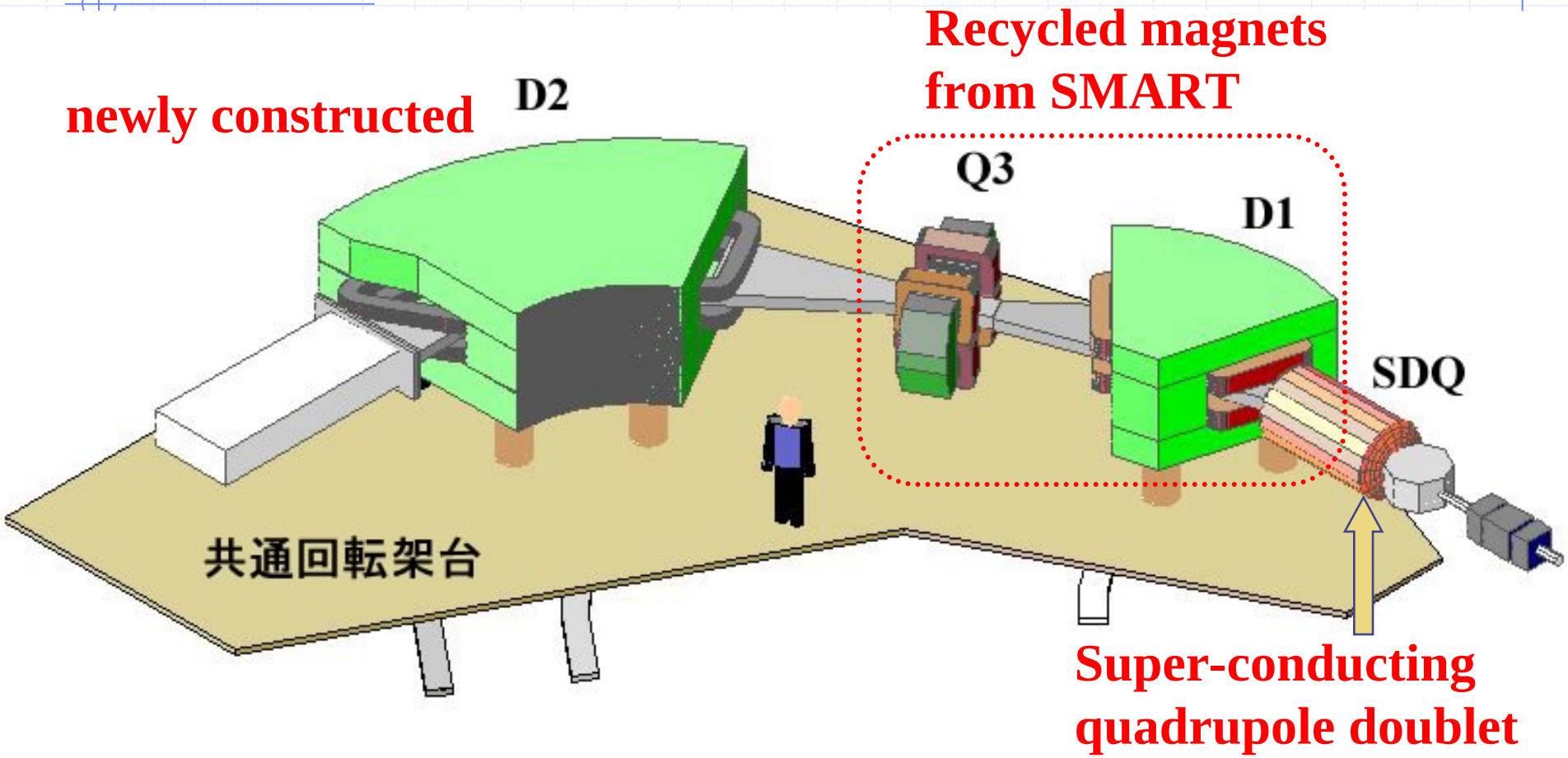
- Int. E Direct reactions (150-400 A MeV)
  - Weak Distortion :Minimal central force
  - Effective Interaction : Spin-Isospin modes



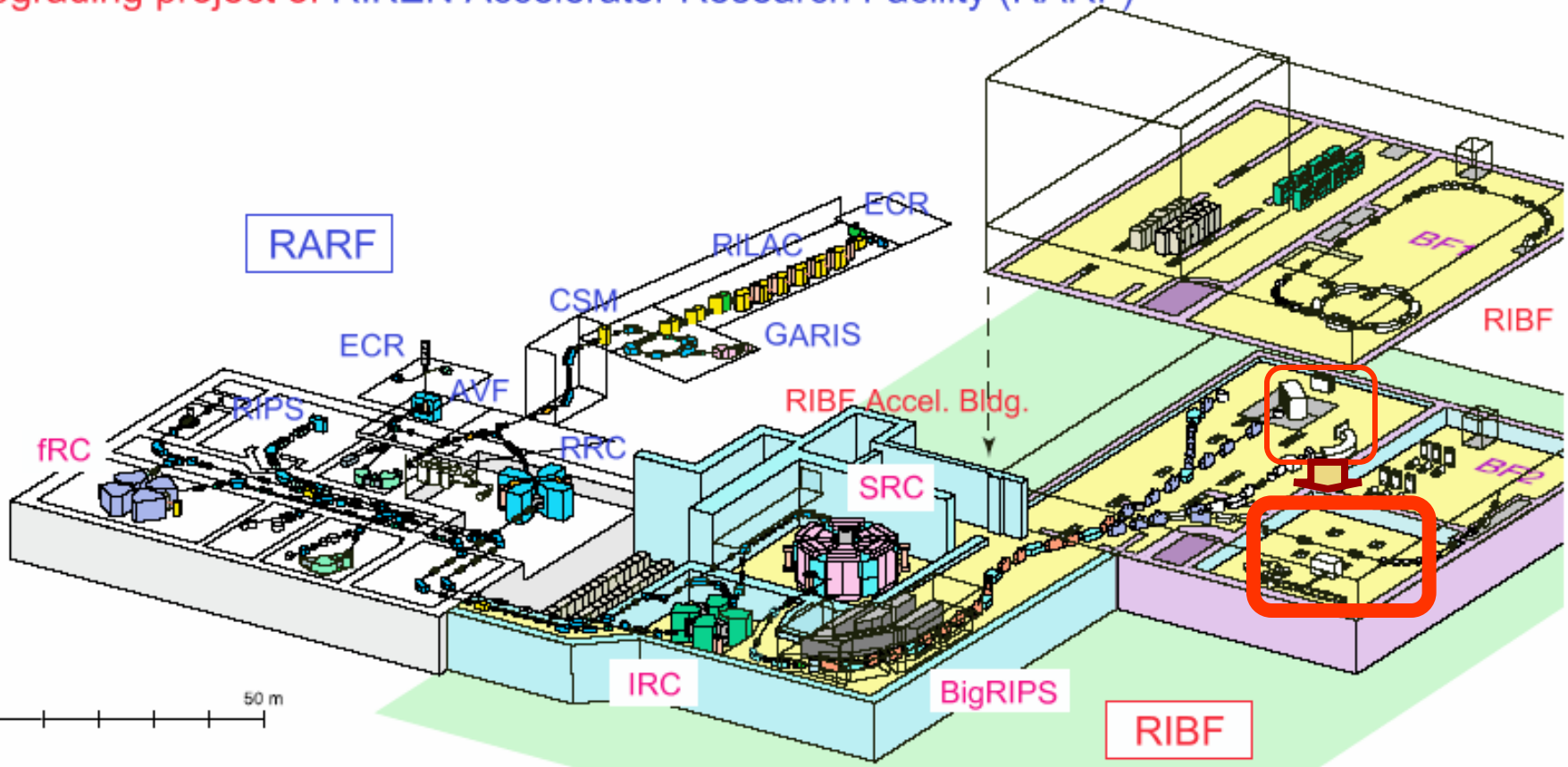


SHARAQ Spectrometer

QQDQD



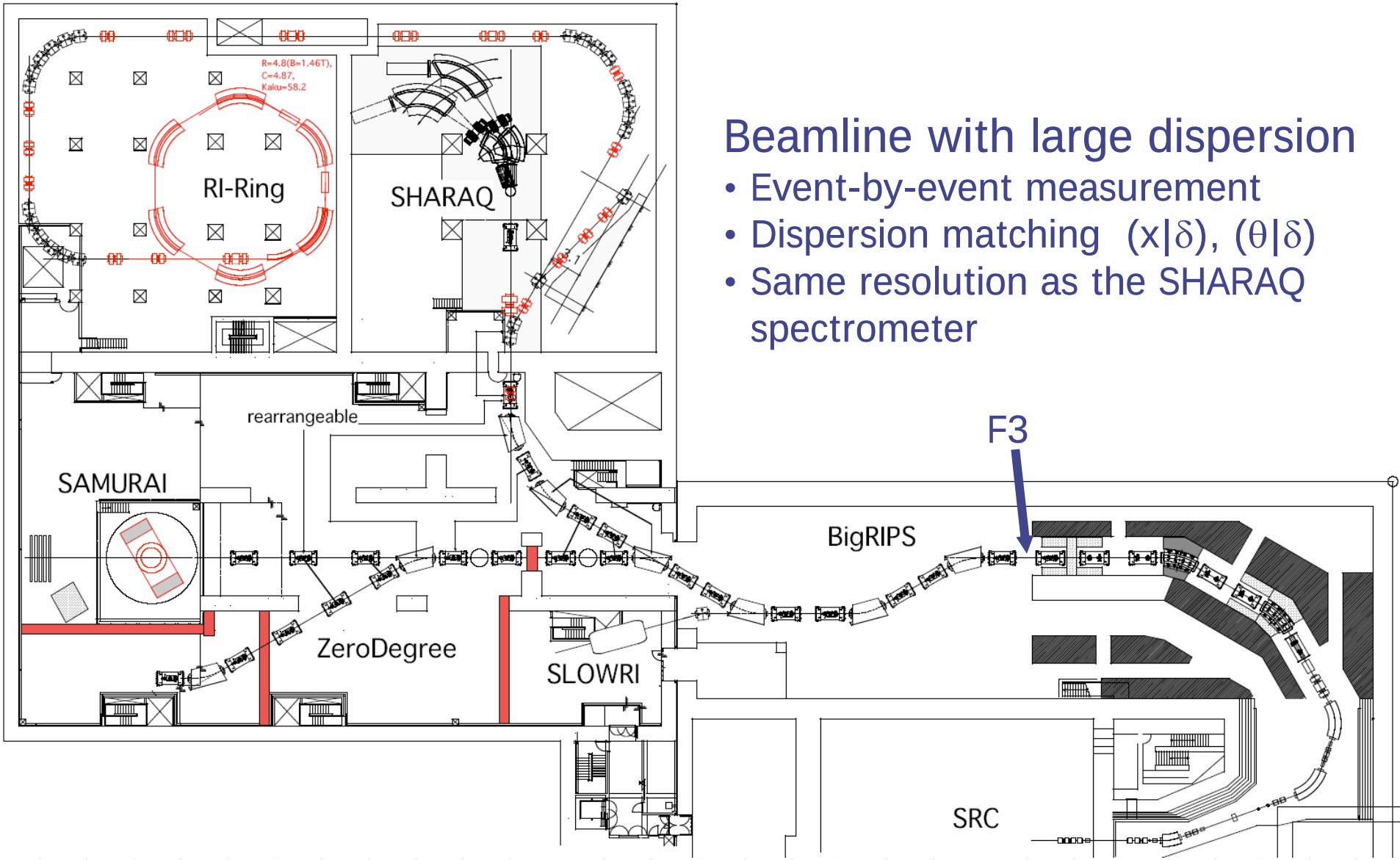
RI Beam Factory (RIBF):
Upgrading project of RIKEN Accelerator Research Facility (RARF)



RIBF RI beam generator
featuring superconducting ring cyclotron (SRC)
and projectile fragment separator (BigRIPS)
will be commissioned late in 2006.

RIBF RI beam experiments
will be started in 2007,
with colored experimental inst

Installation site



Beamline with large dispersion

- Event-by-event measurement
- Dispersion matching $(x|\delta)$, $(\theta|\delta)$
- Same resolution as the SHARAQ spectrometer

Specification

dispersion (D)	**5.86 m**
horizontal magnification (M_x)	**0.40**
D/M_x	**14.7 m**
momentum resolution (image size 1mm)	**1/14700**
vertical magnification (M_y)	**0.0**
angular resolution	**< 1 mrad**
vertical acceptance	**± 3 deg**
for spot size 60mm ×10mm (in dispersion matching operation)	
horizontal acceptance	**± 1deg**
solid angle	**2.7 msr**
for spot size of 10mm ×10mm	
solid angle	**4.8 msr**
Bρ (max)	**6.8 Tm**

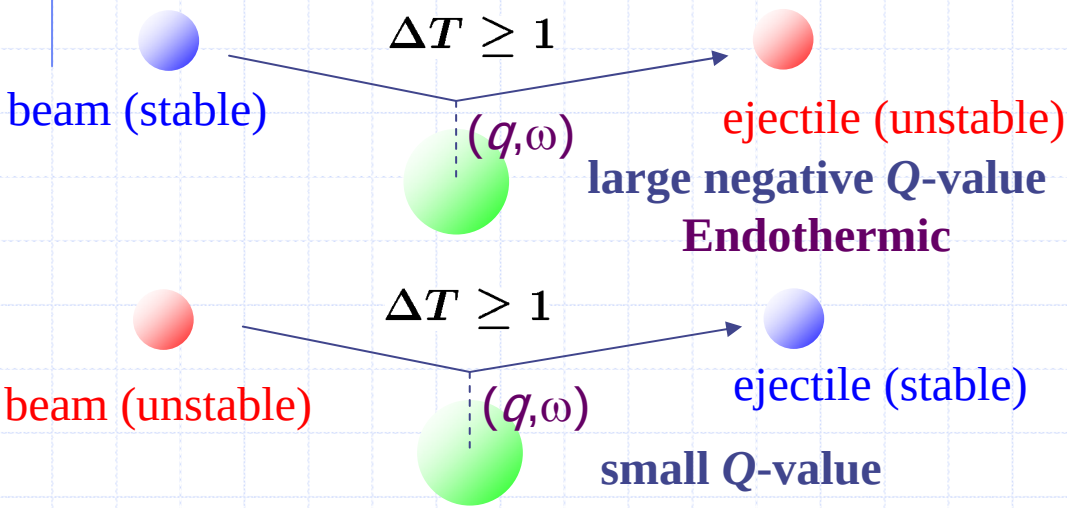
440MeV/u for A/Z=2

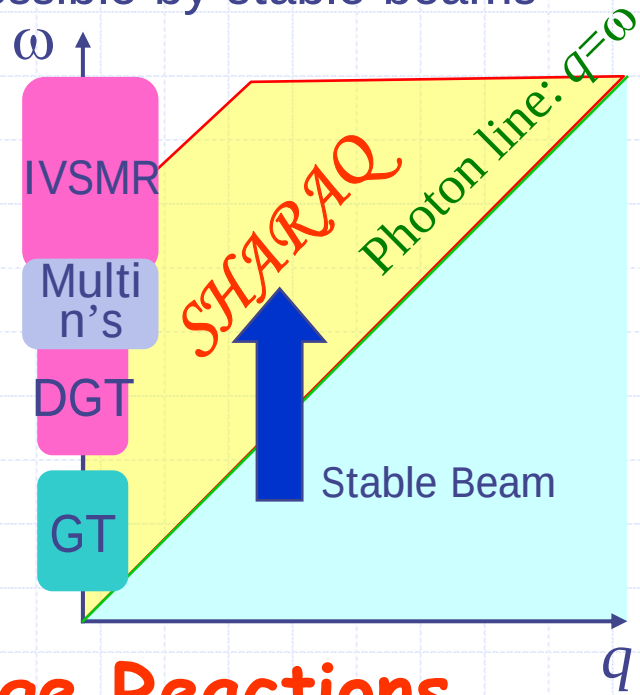
SHARAQ

Spectroscopy with with High-resolution Analyzer & RadioActive Quantum beams

RI Beam (E = 150—400 MeV/A) as a new PROBE to nuclear systems

- Large Isospin — iso-tensor excitations
- Large internal energy — (q,ω) inaccessible by stable beams





Exothermic Charge Exchange Reactions

Isovector Spin Monopole Resonance

Breathing (compressive) mode

spin-isospin density ($\langle\sigma\tau\rangle$) oscillates

$\Leftrightarrow$ "spin-isospin compressibility"

propagation velocity of "spin-isospin sound"

$$\mathcal{O}_{\mathrm{IVSMR}} = \sum r_i^2 \sigma_i \tau_i$$

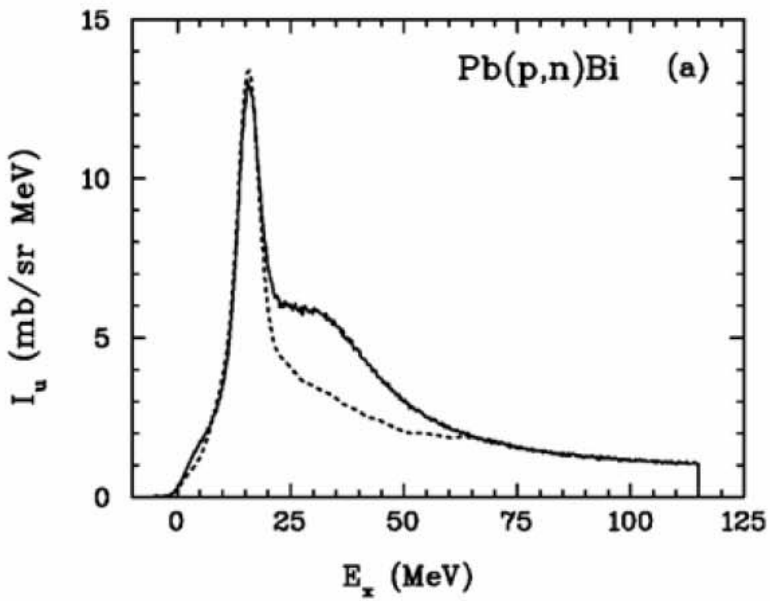
One data indicative of its existence

^{208}Pb(p,n) @795MeV (LAMPF)

D.L. Prout et al., PRC **63** (2000) 014603.

(^{3}He,t) data from RCNP

R.G.T.Zegers et al. PRL **90** (2003) 202501.



New Spin-Isospin Modes in nuclei: IVSMR

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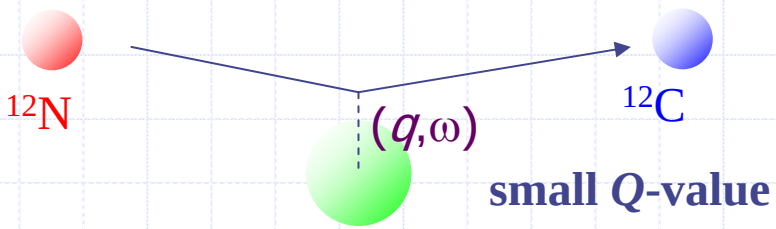
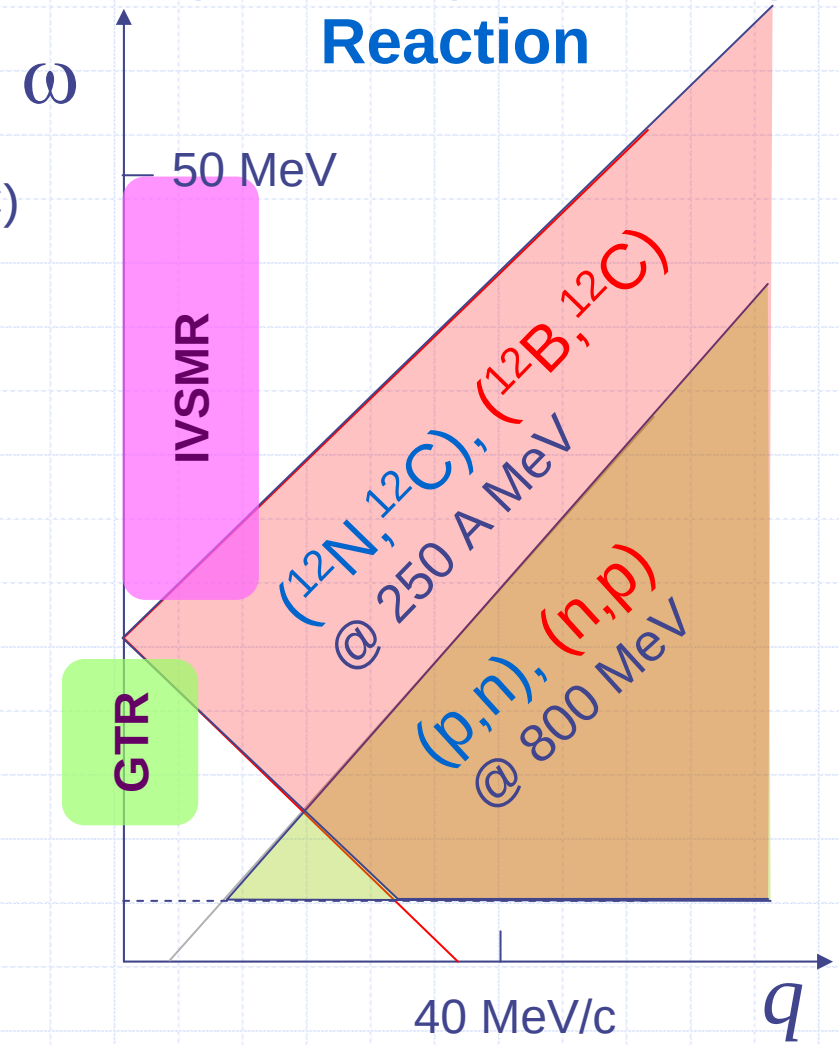
- IsoVector Spin-Monopole Resonance (IVSMR)
  - β^- & β^+ directions
    - (^{12}N (1$^+$) ,^{12}C), (^{12}B (1$^+$),^{12}C)
    - Q=+17 MeV/ +13 MeV
  - Compression mode with $\sigma\tau$
    - $O \sim r^2\sigma\tau$
  - Ex, width
    - Spin compressibility of nuclear matter
- GT strengths @ higher Ex



Single Charge Exchange Reaction



New Spin-Isospin Modes in nuclei: DGTS

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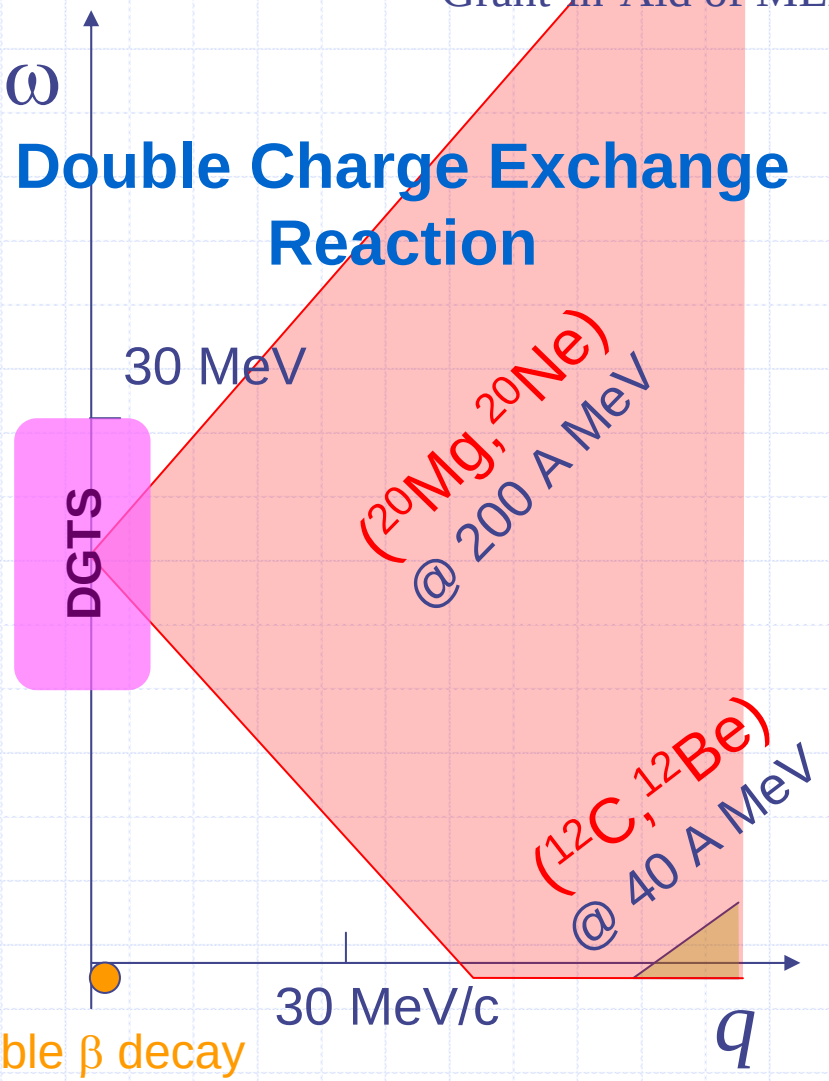
- Double Gamow-Teller States (DGTS)
  - Not yet discovered
  - Two-phonon response

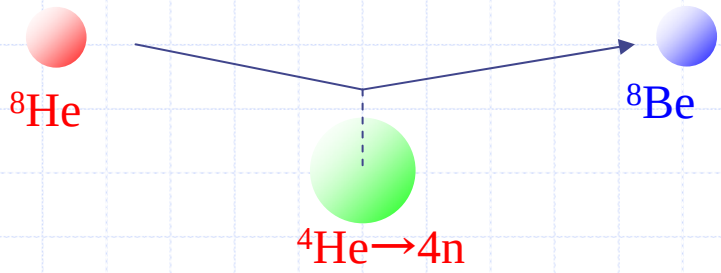
    $E_{DGTS} = 2E_{GTS}$?

    $\Gamma_{DGTS} = 2^{1/2}\Gamma_{GTS}$?
  - Nuclear matrix elements for double beta decay
  - (^{20}Mg,^{20}Ne)

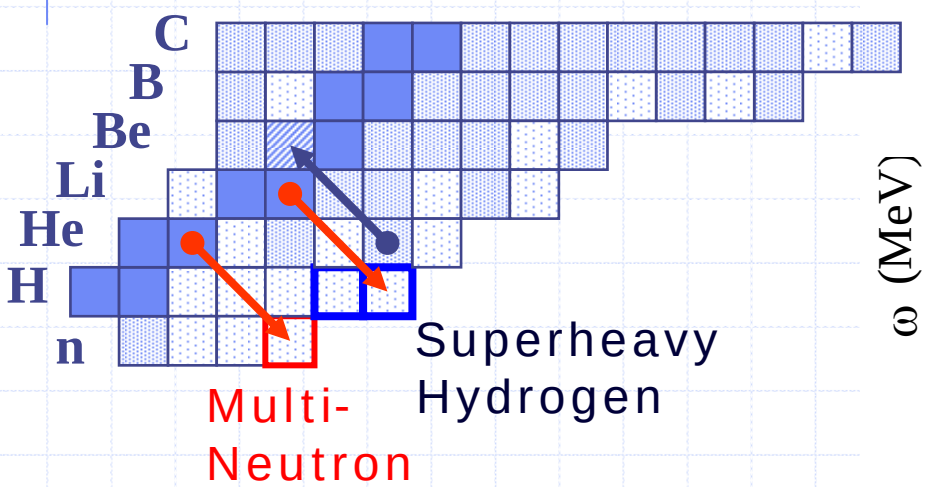
    (^{9}C(3/2$^-$),^{9}Be(3/2$^-$))

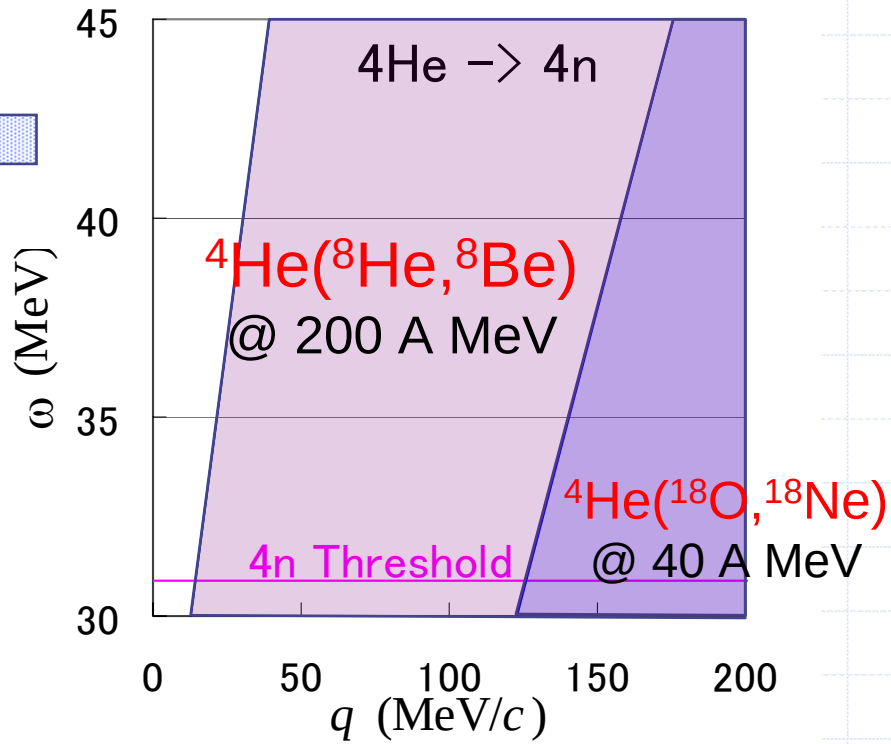


Multi-neutron system



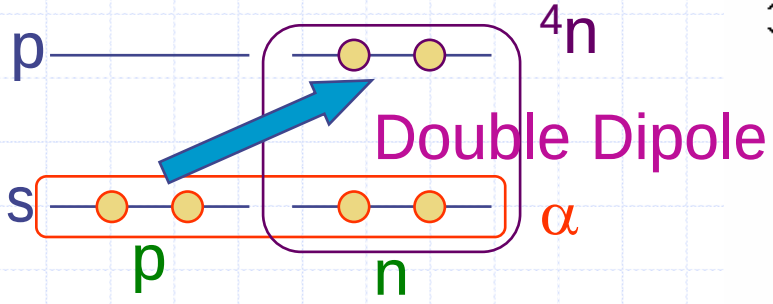
- ^{3,4}n ; ^{6,7}H with **small q**
  - Resonant states?
  - Correlation in multi-body scattering states?
    - Correlation ⇔ Spectral shape

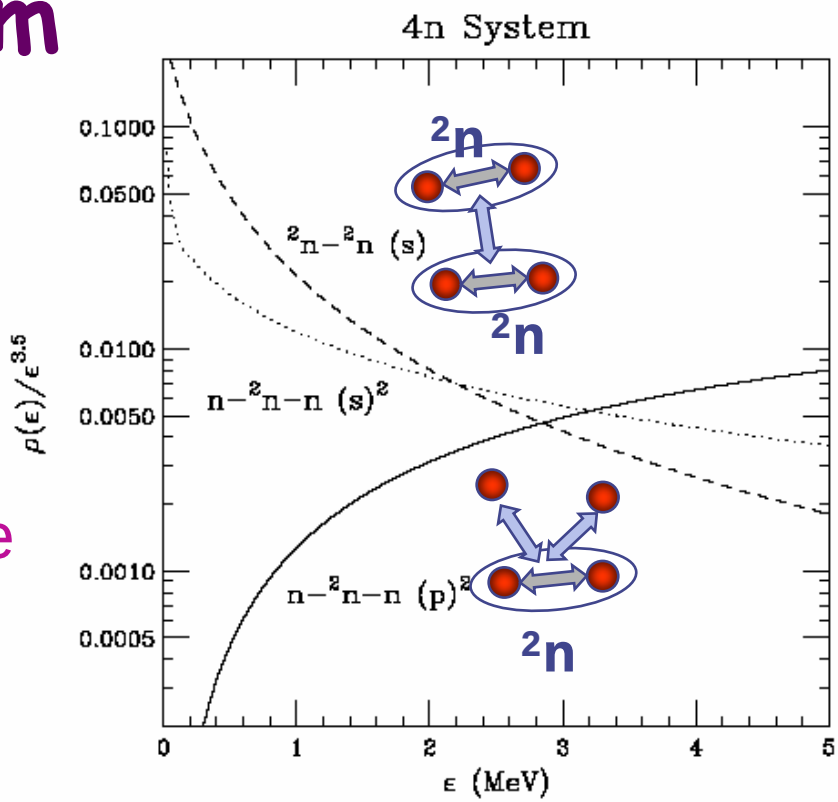




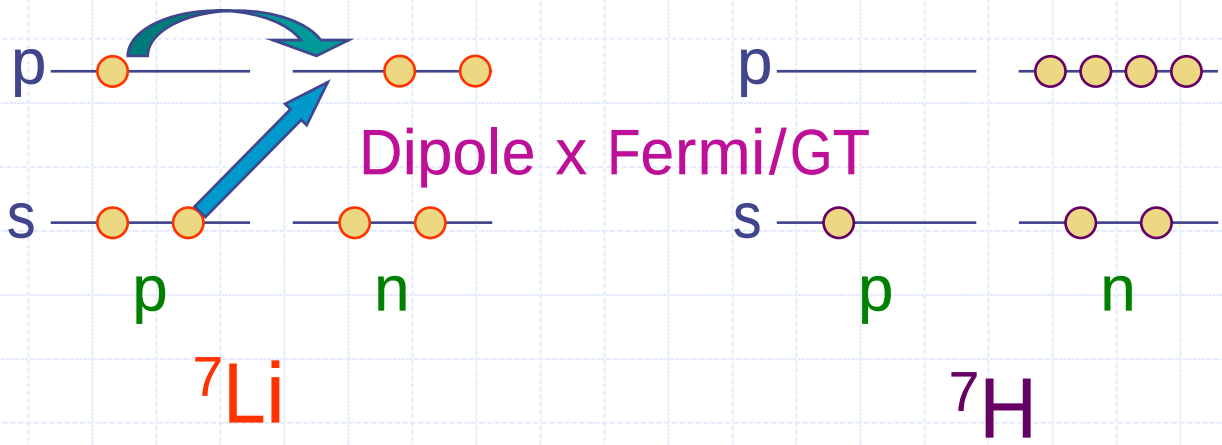
Multi-neutron system

$^{3,4}He(^{8}He,^{8}Be)^{3,4}n$





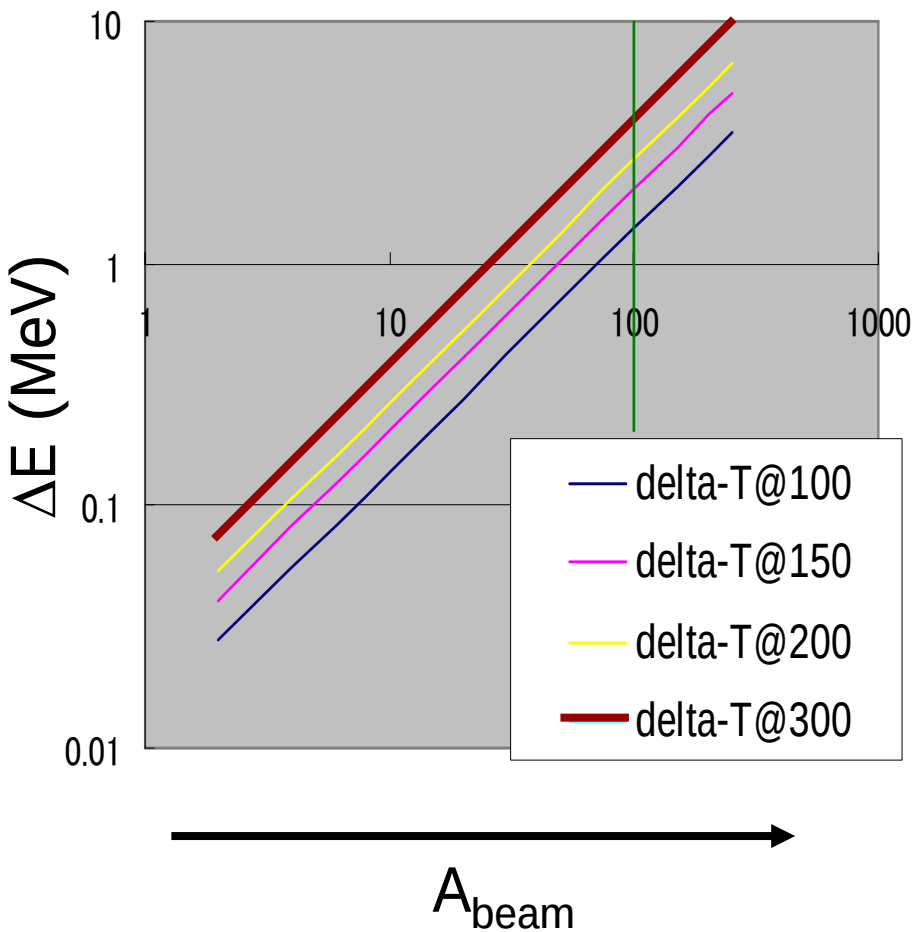
$^{6,7}Li(^{8}He,^{8}Be)^{6,7}H$

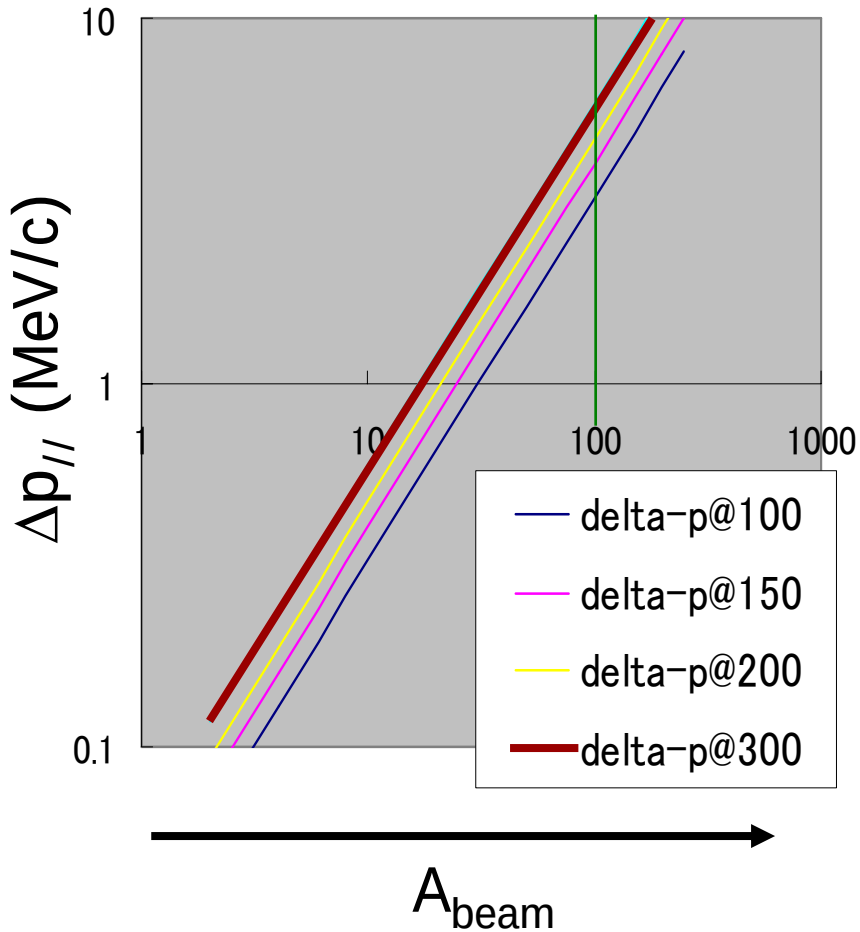


Other possible researches using SHARAQ spectrometer

Condition:
$\Delta p/p = 1/13700$
angular resolution < 1 mrad

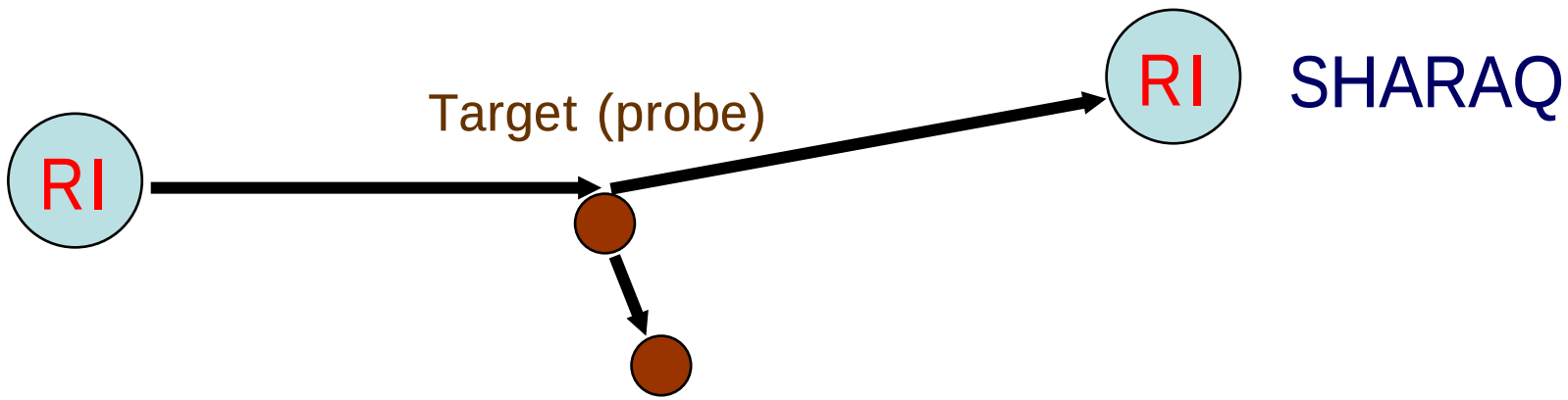
$\Delta p_{\perp} \sim 10\ \Delta p_{//}$





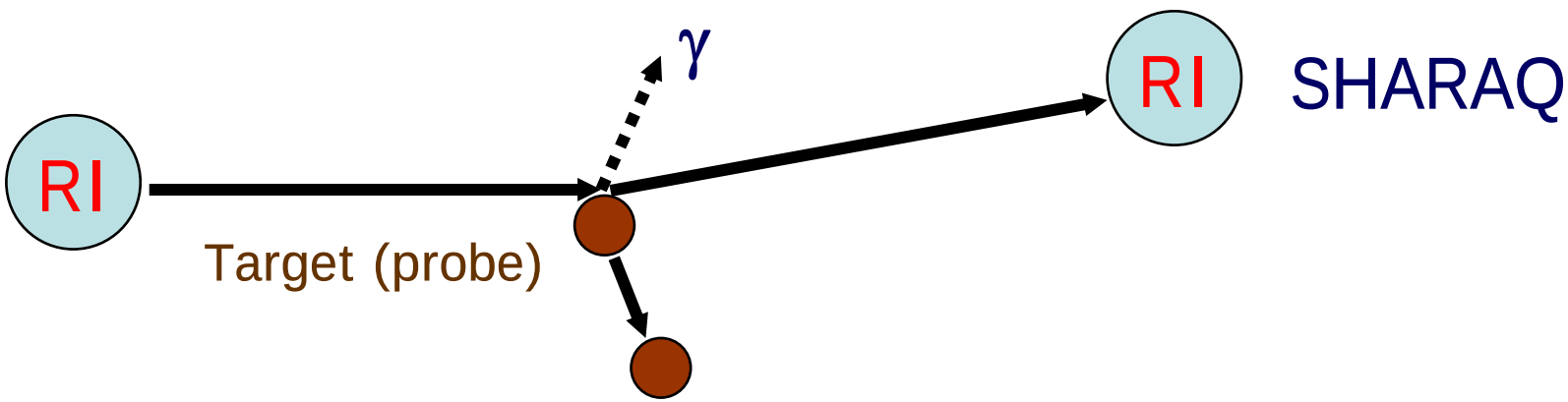
Other possible researches using SHARAQ spectrometer

- Elastic scattering of exotic nuclei
  - Optical potential (OP) :
    - Systematics in Radii (Isospin dependence)
    - Input for reaction calculation such as
      - ^{70}Ni+^{208}Pb (~1mg/cm^2) <= multiple-scattering
        - Grazing angle ~ 1deg@200A MeV [2deg@100A MeV]
  - Reaction cross section from OP
  - LS pot. by pol. p target

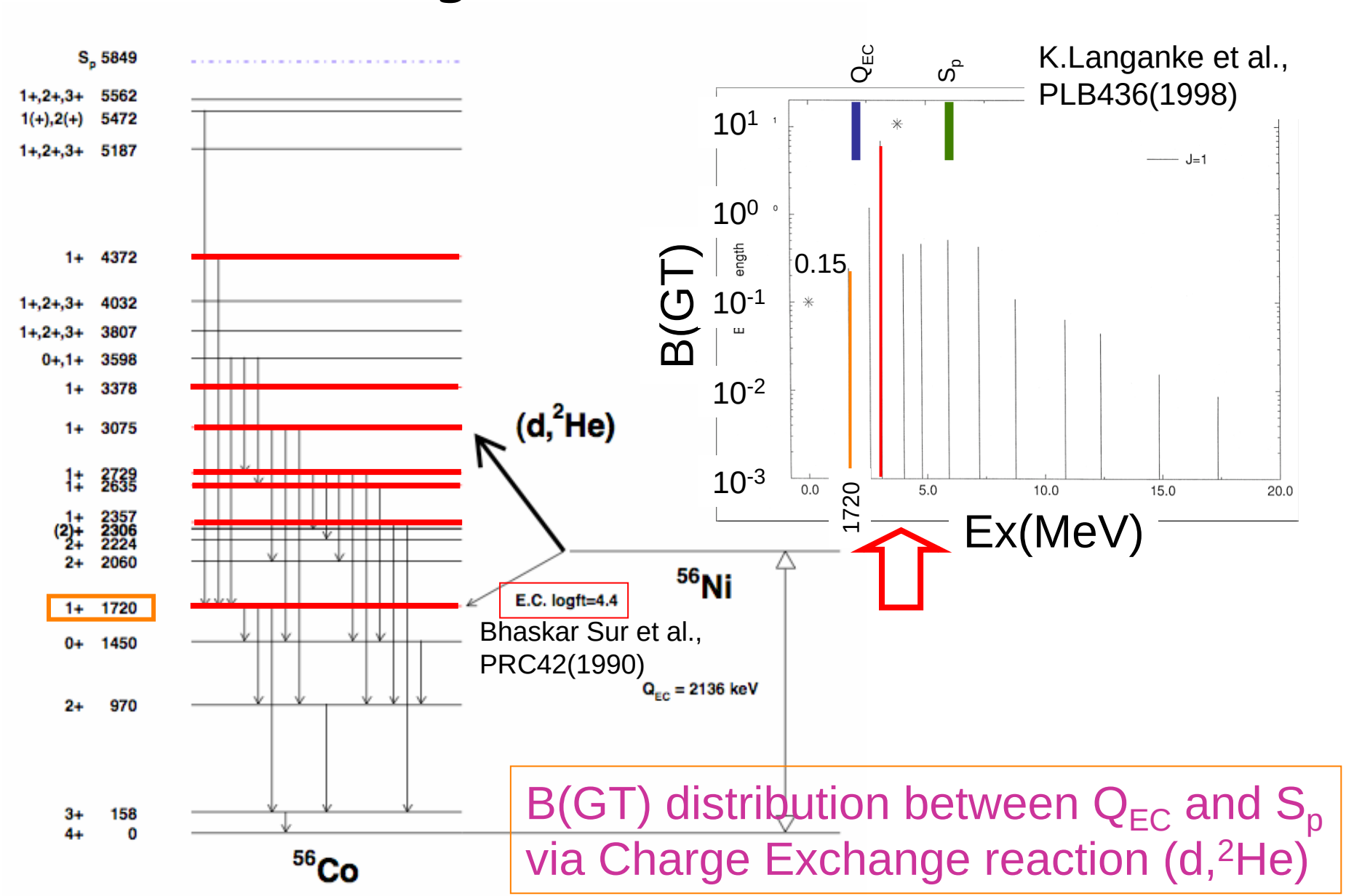


Other possible researches using SHARAQ spectrometer

- Inelastic scattering / Charge exchange of exotic nuclei
  - Direct relation to beta decay (p,n), (d,2n), (d,2p) [low Ex]
    - Missing mass + High resolution γ-spectroscopy
  - Highly excited states [combination of γ array]
    - $\Delta q \sim 70$ MeV/c & $\Delta Ex \sim 3$ MeV for A=100, T/A=250
    - γ array for better ΔEx / cascade γ-decay
    - Missing mass spectroscopy for direct γ-decay : (p,p'γ)
      - Measurement of recoil (proton, neutron, deuteron, …)
  - Nuclear responses / Pigmy resonances



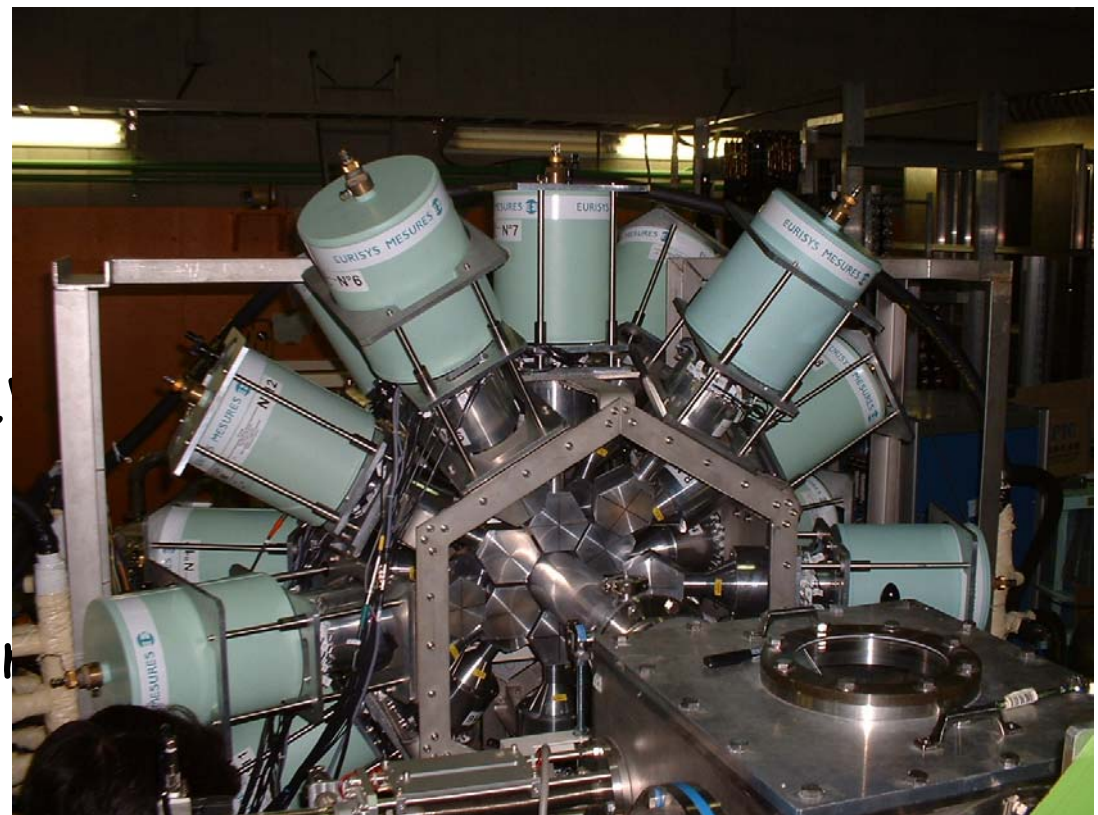
GT+ strength measurement on ^{56}Ni

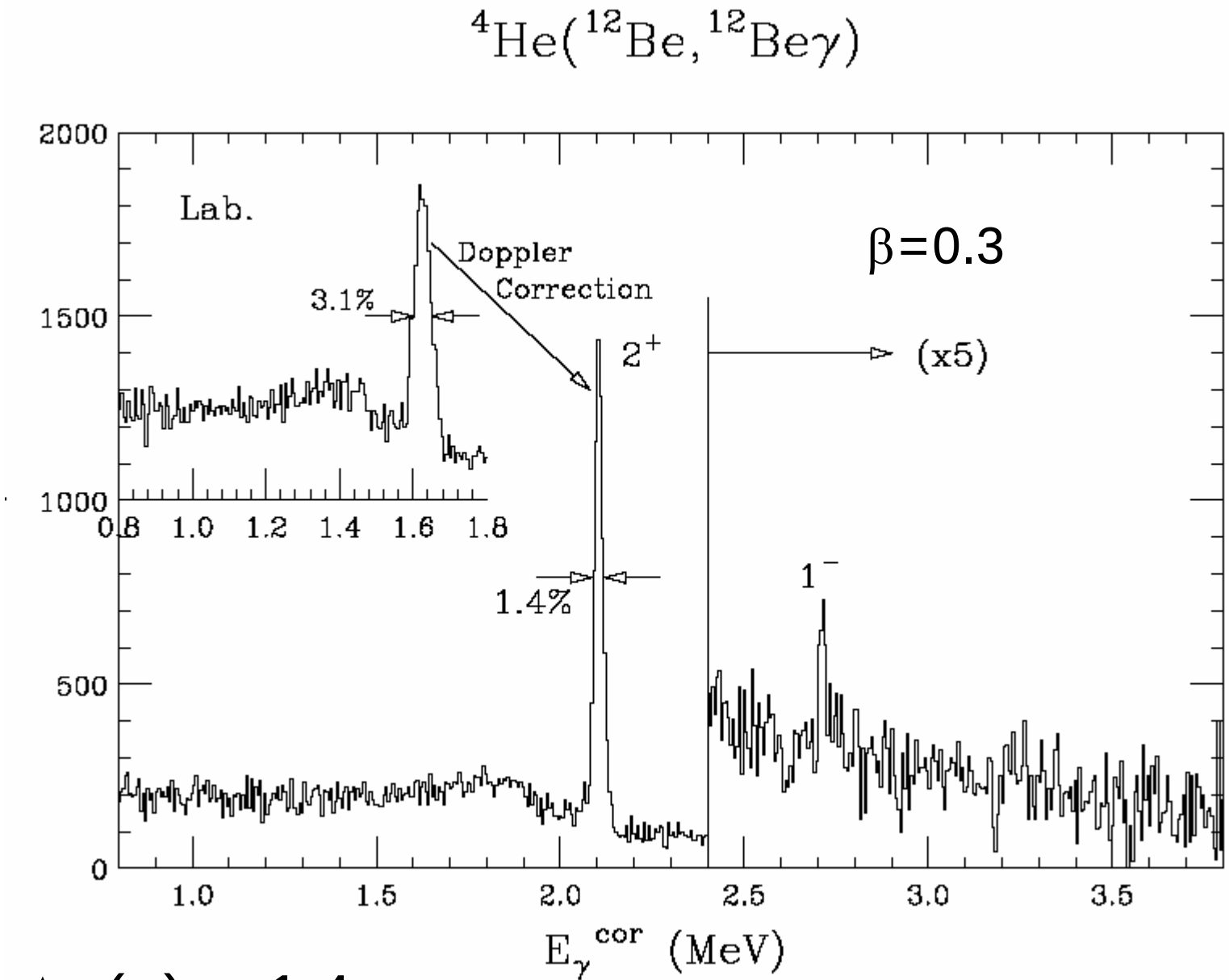


CNS GRAPE @RIBF

(Gamma-Ray detector Array with Position and Energy sensitivity)

- 18x2 segmented Ge detectors
- High Resolution
  - 2.5 keV intrinsic resolution for 1.3 MeV γ
- High Sensitivity
  - $\varepsilon\Omega$ ~ 3 % for 1 Me
- Position Sensitive
  - Resolution of Doppler Correctio 2 %

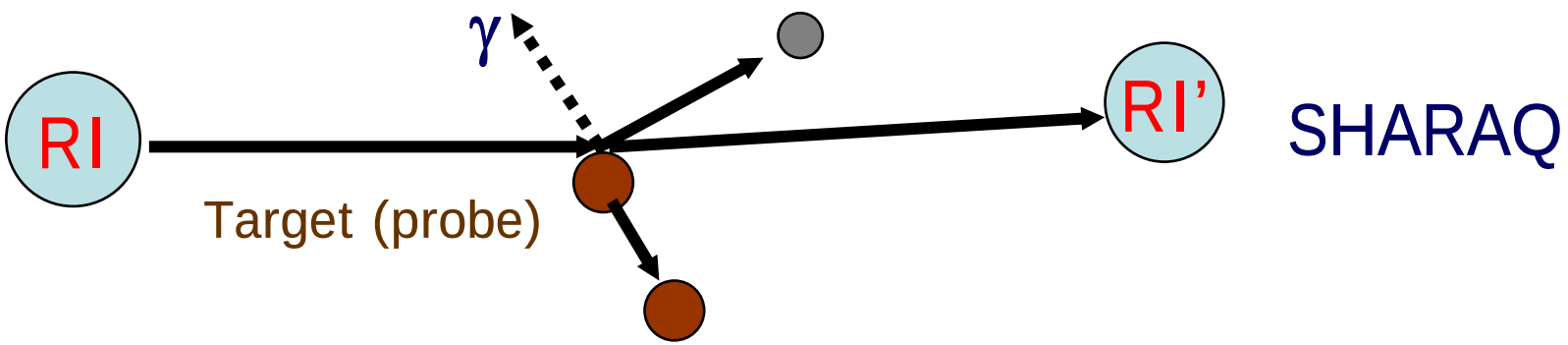




Δz (σ) ~ 1.4 mm

Other possible researches using SHARAQ spectrometer

- Spectroscopic factors (leading particle + γ) [cf. MSU S800exp]
  - Ground state configuration (knockout)
    - upto A=200 ($\Delta p_{//} < 10$ MeV/c)
  - Excited single-particle states (transfer) [T/A < 100 MeV]
    - High J orbitals
    - Intruders



- Responses for exotic quantum number transfer
  - 0^+ -> 0^- ; high spin isomer beam or ejectile J^+ <=> 0^+; …
- …

Detector system

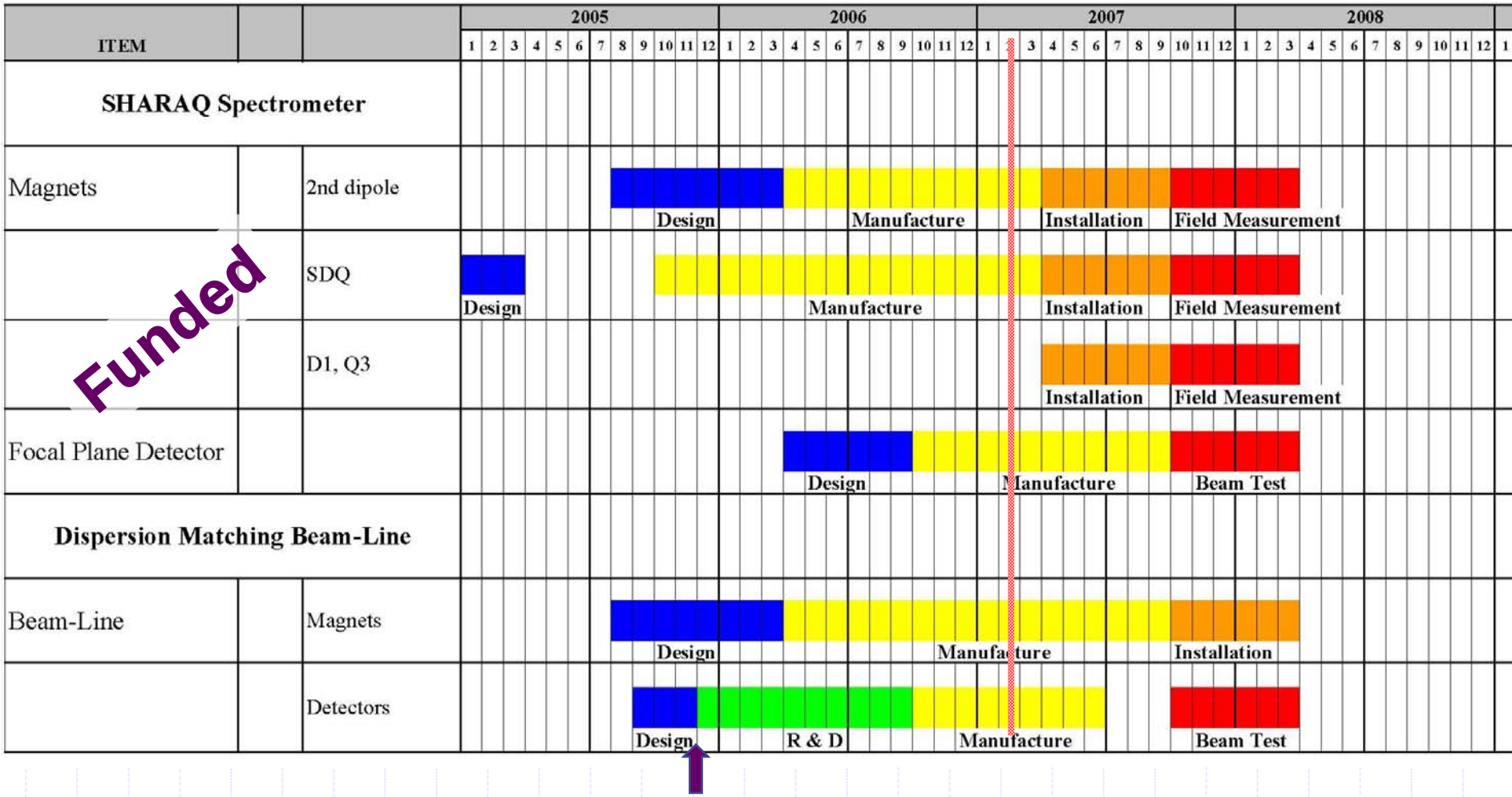
- Focal Plane Detectors
  - Cathode Readout Drift Chambers / trigger counters / ion chamber
- Tracking detectors in the beam line
  - For tuning (Dispersion matching) / for event-by-event counting
  - Thin ($t/L_R \sim 10^{-4}$); Counting rate ~ 10^6; resolution~0.3mm (FWHM)
- Combination with High resolution/Sensitivity γ–detector array depending on experiments
  - CNS-GRAPE (Ge array) / DALI2 / etc.
  - Recoil detectors etc.

Detectors to be considered

- Recoil detectors
  - Low-E charged particles with good angular resolution
  - Neutron detector
- Gamma-ray detector array (in addition to DALI2, GRAPE)
  - High energy γ
  - Delayed γ detectors @ focal plane
- Beam dump for primary-beam experiment
- Active target / mult-layer targets
- …

Combination with good detectors makes SHARAQ much more effective!

Schedule



WS of technical aspects