Soft Dipole Mode in Ca & Ni Regions

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＊Giant Dipole Resonance

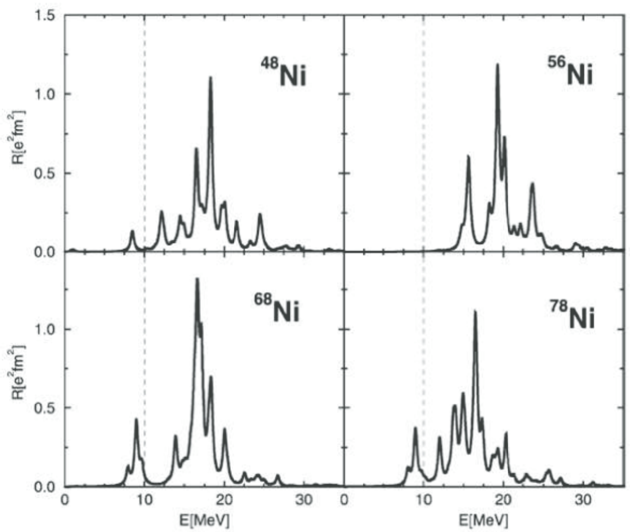
＊Collective excitation : ~ oscillation of neutrons against protons

＊Soft Dipole (Pygmy) Mode

for nuclei with isospin asymmetry, with extra neutrons

response at energy below GDR

~ oscillation of extra neutrons against the core

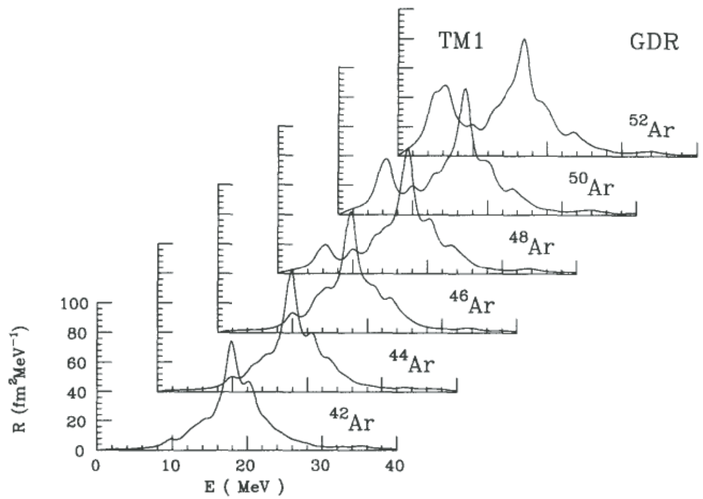


＊Light halo nuclei : ^{11}Li, ^{11}Be, ^{14}Be, ^{19}C...

single-particle nature via electromagnetic excitation

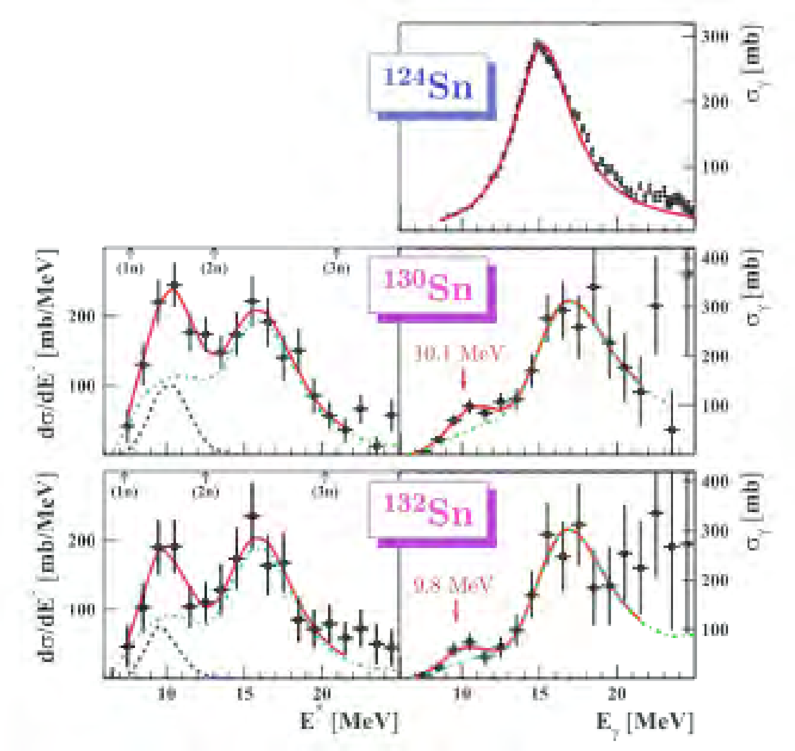
＊Heavier neutron-rich nuclei

collective excitation via EM excitation



1-2. Soft Dipole Mode in Sn Region

* EM excitation exp. at LAND/GSI (2005), $^{129-132}$Sn @500MeV/A



* Low-lying strength
  i.e. soft (Pygmy) dipole mode
  observed
  at Ex ~ 10MeV
  few % of TRK sum rule
* strength related to
  evolution of neutron skin
  symmetry energy

followup exp's @GSI

^{68}Ni / RISING : published

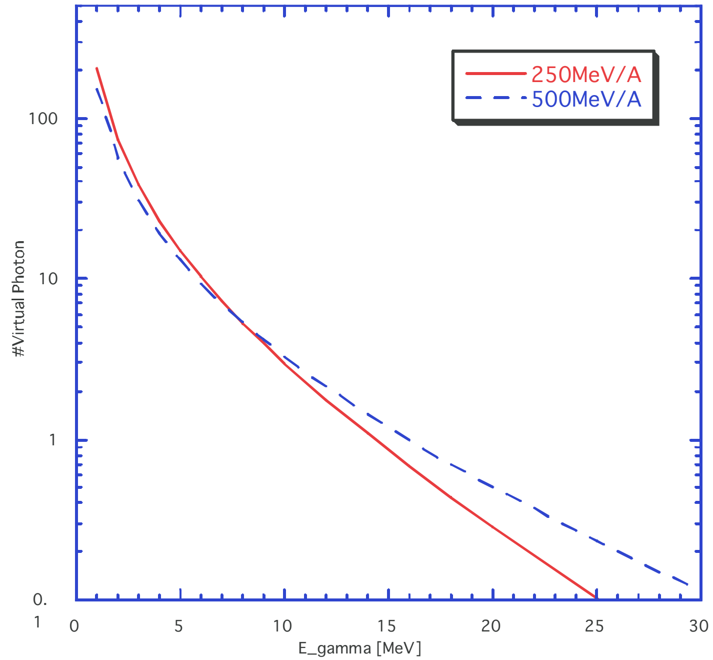
-^{72}Ni / LAND : under analysis

2-1. Electro Magnetic Excitation of Soft Dipole Modes at RIBF

* Purposes :
    * collective excitation of soft dipole mode in Ni & Ca regions

        ~@250 MeV/A
    * performance of the spectrometer system up to A~80 (z~28)
        * Rigidity resolution ~0.1%

virtual photon



* Experimental design follows

2-2. Mass Range ＊ using "mixed" beam since primary beam too weak

$^{50-54}$Ca from ^{82}Se

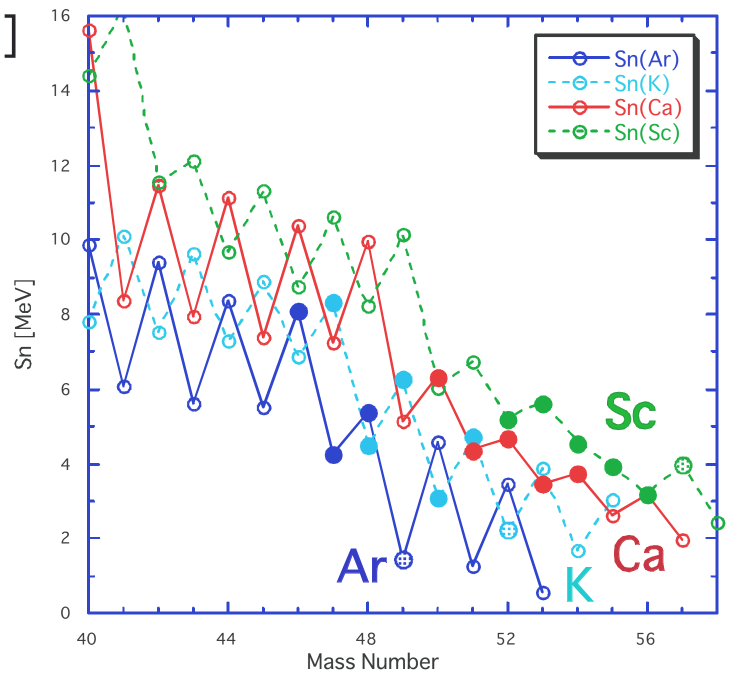
$^{72-76}$Ni from ^{86}Kr

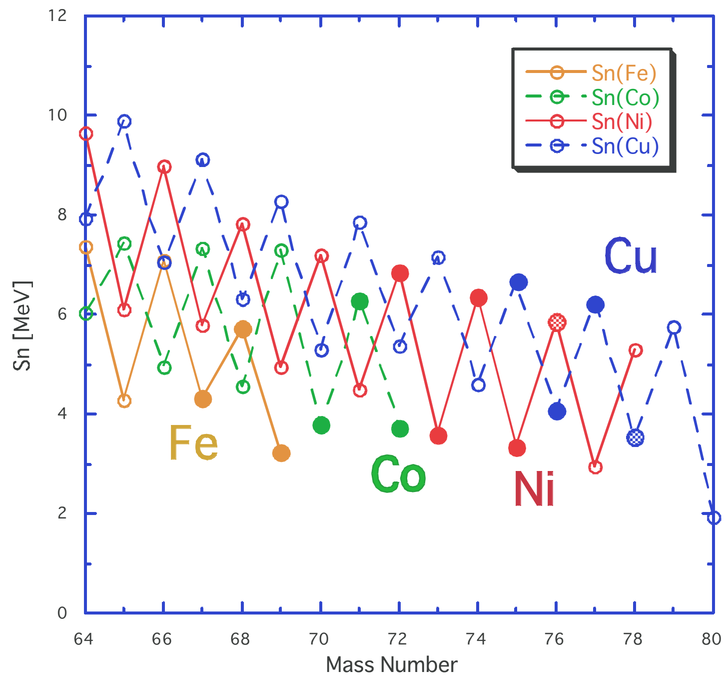
Beam intensity @30pnA

								59V 204	60V 261	61V 93.9
						56Ti 474	57Ti 510	58Ti 178	59Ti 38.7	60Ti 5.7
				53Sc 279	54Sc 1002	55SC 354	56Sc 75.6	57Sc 11		
			50Ca 266	51Ca 1119	52Ca 714	53Ca 157.5	54Ca 23	55Ca 2.3			
	47K 197	48K 1530	49K 1224	50K 336	51K 49.2	52K 5.1					
45Ar 1896	46Ar 2265	47Ar 741	48Ar 110.7	49Ar 12.2							
44Cl 1698	45Cl 309	46Cl 30.6									

								78Zn 29.7	79Zn 58.8	80Zn 14.1
						75Cu 65.4	76Cu 138	77Cu 58.2	78Cu 11.9	
				72Ni 45.9	73Ni 122.7	74Ni 66.3	75Ni 21.6	76Ni 4.3	77Ni 0.52	78Ni 0.034
		69Co 12.1	70Co 113.4	71Co 61.2	72Co 19	73Co 4.4				
66Fe 7.8	67Fe 75.6	68Fe 75.9	69Fe 22.5	70Fe 4.6						
65Mn 64.8	66Mn 29.7	67Mn 6.4								

S_n [MeV]

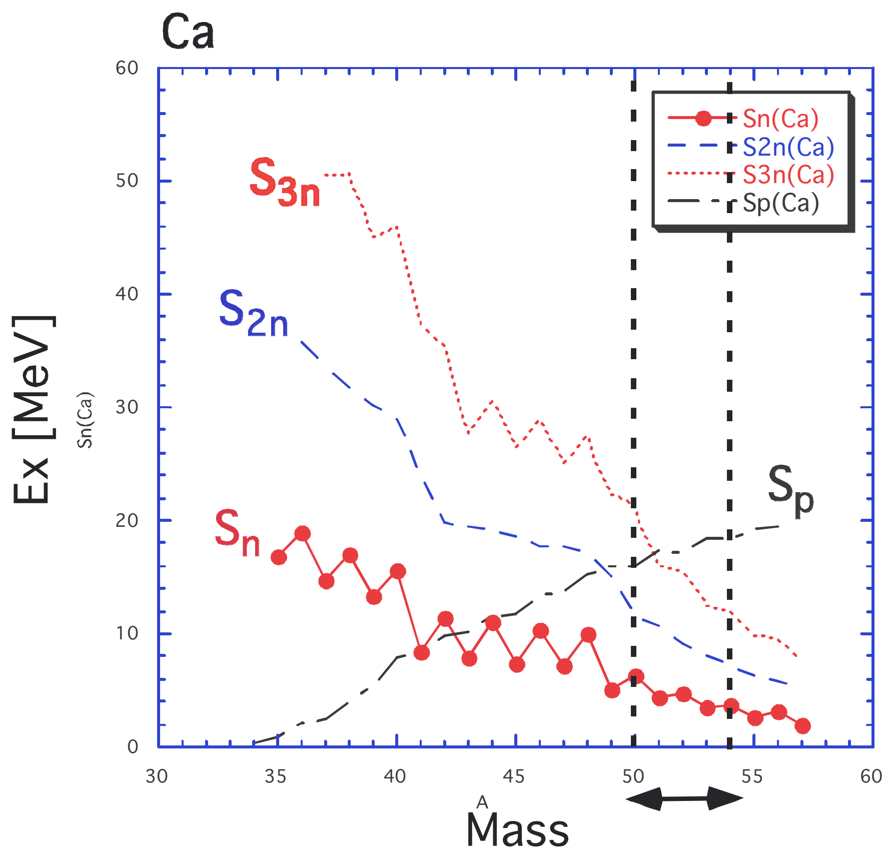


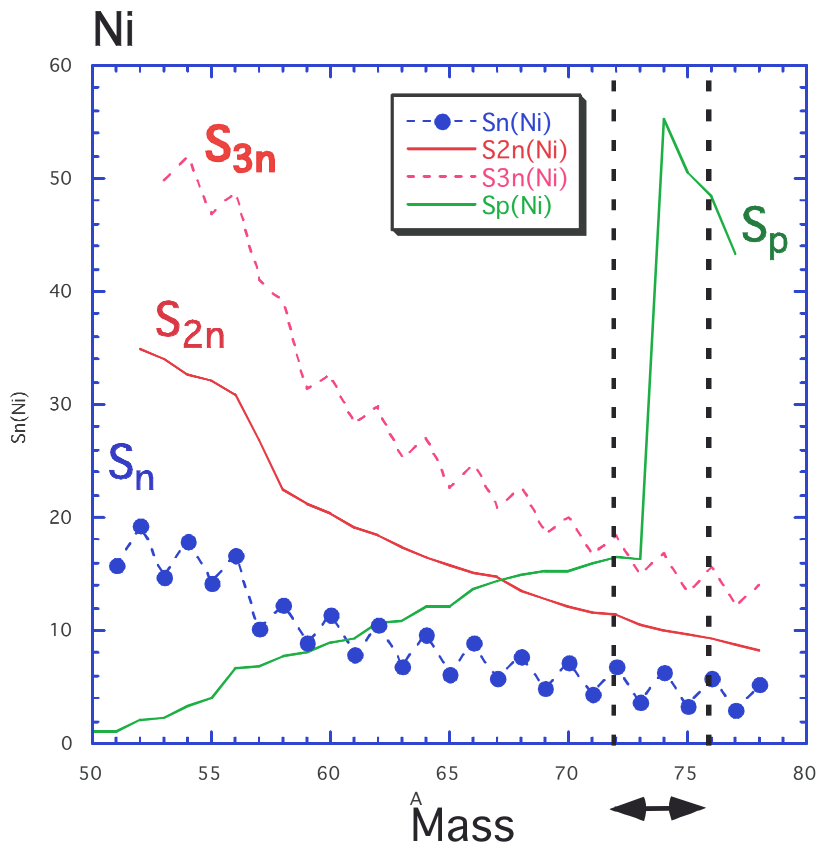


2-3. Excitation Energy Range

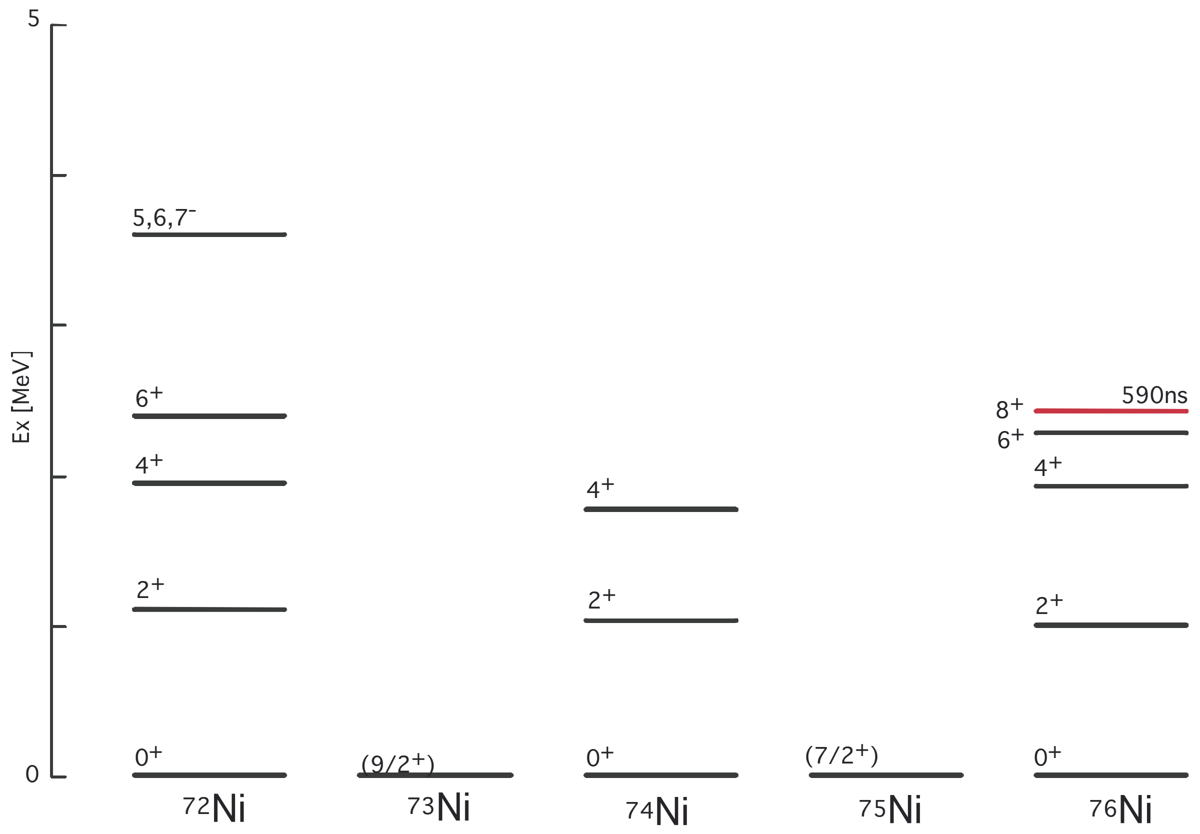
* $S_n < E_x < S_{3n}$ by detecting 1n & 2n

$^{A}Ni^{*} \rightarrow {}^{A-1}Ni + n,\ {}^{A-2}Ni + 2n$





$^{72\text{-}76}$Ni

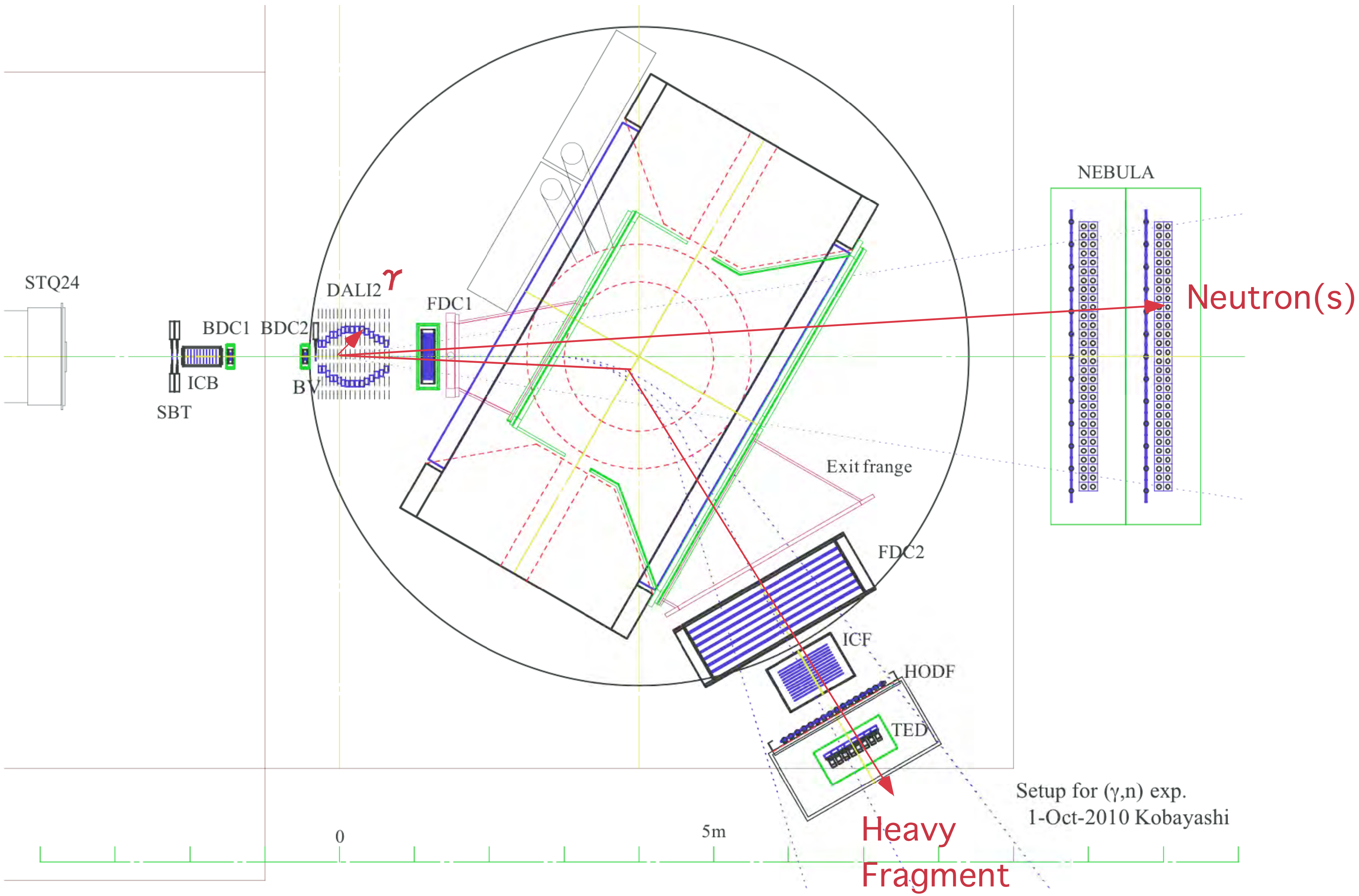


^{67,68,69}Fe : ^{67}Fe $1/2^-$(Ex=387keV) 75 μs

^{70,71,72}Co : ^{70}Co 3^+(Ex=?) 0.5s

^{75,76,77}Cu : ^{76}Cu two isomers 0.64,1.27ss

3-1. Experimental Setup @ spring 2012



3-2. Secondary Beams

* detector debugging/tuning for z~20
    * Ca/Ar isotopes <-- ^{48}Ca @350MeV/A(200pnA)
* data taking, @250MeV/A

production target: Be 2.0 g/cm^2, degrader: 3mm, wide mass slit

45Ar	46Ar	47Ar	48Ar	49Ar	50Ar
20	110	110	40	9	1

<-- 350MeV/A ^{82}Se (30pnA?)

source material ?

50Ca	51Ca	52Ca	53Ca	54Ca	55Ca
350	1070	730	180	30	3

72Ni	73Ni	74Ni	75Ni	76Ni	77Ni
46	123	66	21	4.3	0.5

<-- 350MeV/A ^{86}Kr (30pnA)

limited by 1st stripper
gas stripper?

mixed mode :

total rate < few x 10kHz
also important for stability monitor of CsI

3-3 : Yield Estimate

* Soft dipole mode (assumption)
  * strength : 5% of TRK sum rule
  * excitation energy : Ex ~6 MeV (Ca), ~9 MeV (Ni)
* Excitation cross section : ~0.5 b (Ca), 0.2b (Ni)
* Neutron detection eff. : ~40 % (Ca), ~36% (Ni)
* Target : Pb : 1 g/cm^2 (θ_{MCS} ~4 mrad)、 C : 1 g/cm^2
* Yield : ~84/h (^{48}Ar), ~50/h (^{74}Ni)
* Total=5K events : 2.5 days (Ar/Ca), 4.2 days (Ni)

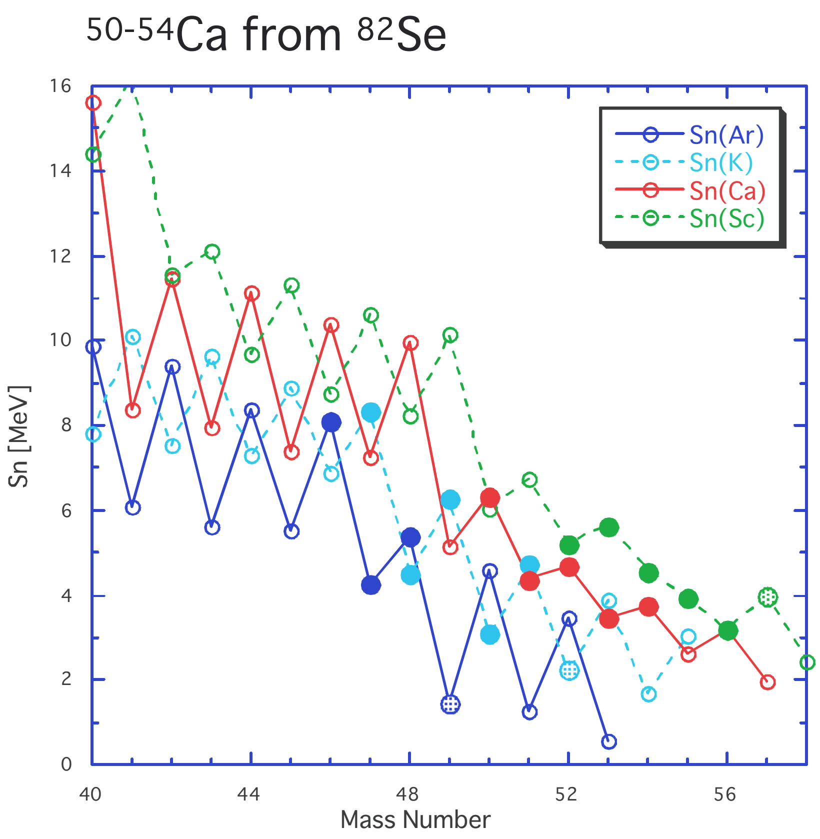
  1.1 Kevt (^{49}Ar), 0.3 Kevt (^{76}Ni)
* (+ part of normal GDR)
* + C & empty (estimation not final) : ? target in/out ratio

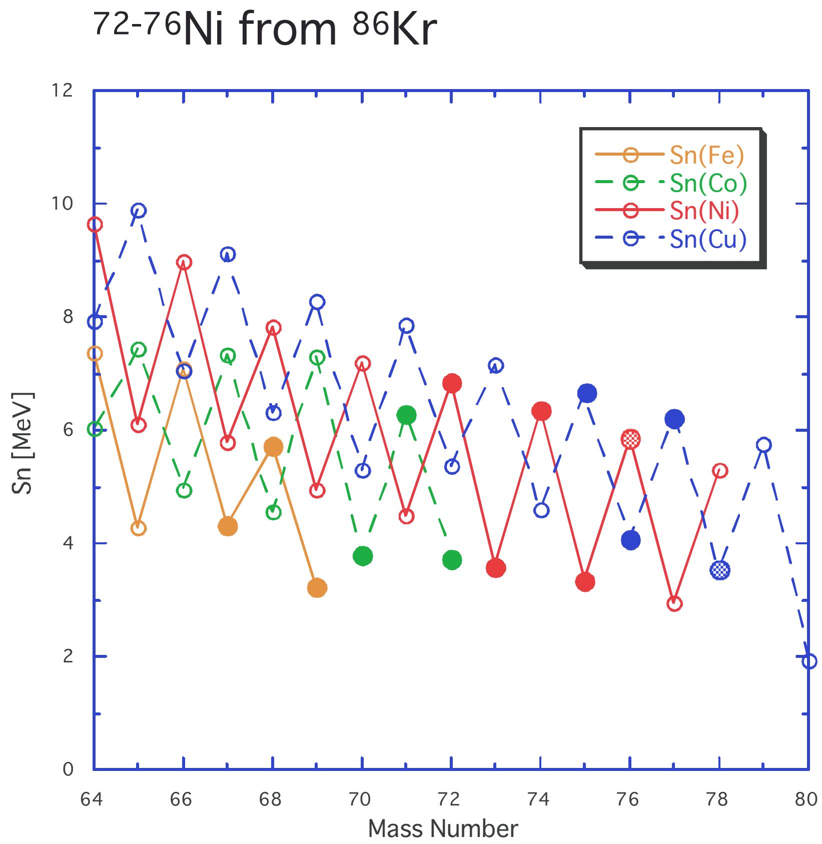
  ~ 5-6 days (Ca/Ar), ~ 8-9 days (Ni)

  ~0.5 days for σ_I measurement

3-4. Measurable Mass Range

＊"Mixed" beam closed circles : can be measured in one setting





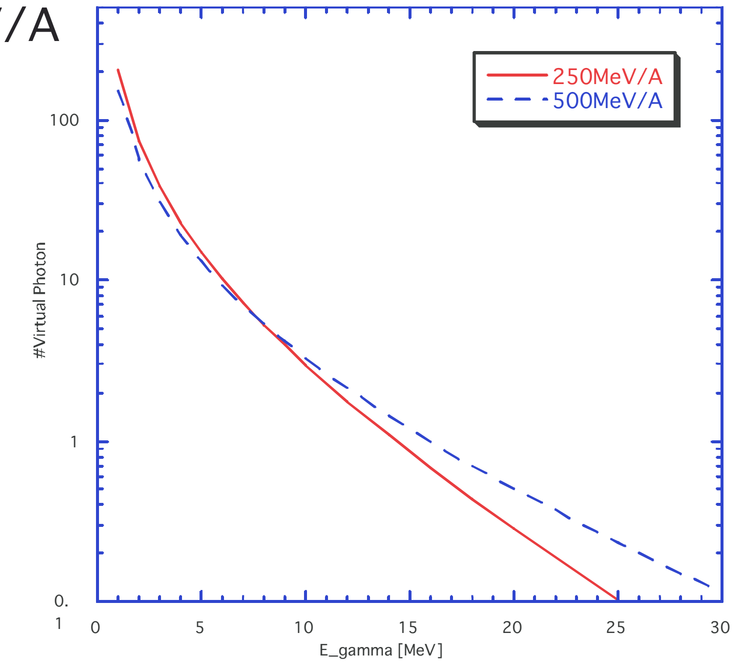
＊interaction cross section measurement : possible with the same setup

3-5. Comparison (with LAND/GSI)

	RIBF		LAND/GSI
* Beam Energy :	250 MeV/A	.vs.	>500 MeV/A
* Virtual Photon:			
* $Eff_{neutron}$:	~40%		~100%
* Beam intensity:	"factory"		.

need more primary beams >>30pnA : ^{82}Se, ^{86}Kr

	RIBF	LAND/GSI
* PID:	probably better	
* target thickness:		thicker
* γ detectors	(DALI2)	CsI-array



4. Summary

* Electromagnetic excitation/breakup for soft dipole mode in Ca & Ni regions

  experimental conditions : estimated

  "mixed" beam experiments

  like to have more intense primary beams >>30pnA

    ^{82}Se: or better primary for Ca regions

    more intensity for ^{86}Kr

  range : $^{50\text{-}54(55)}$Ca, $^{72\text{-}75(76)}$Ni

* better with other information

  interaction cross section measurement : possible with the same setup

* ???'s

  γ decay after neutron emission

  magnetic field map