2015.09.15 COMEX5

Study of Gamow-Teller transition from ^{132}Sn via the (p,n) reaction in inverse kinematics

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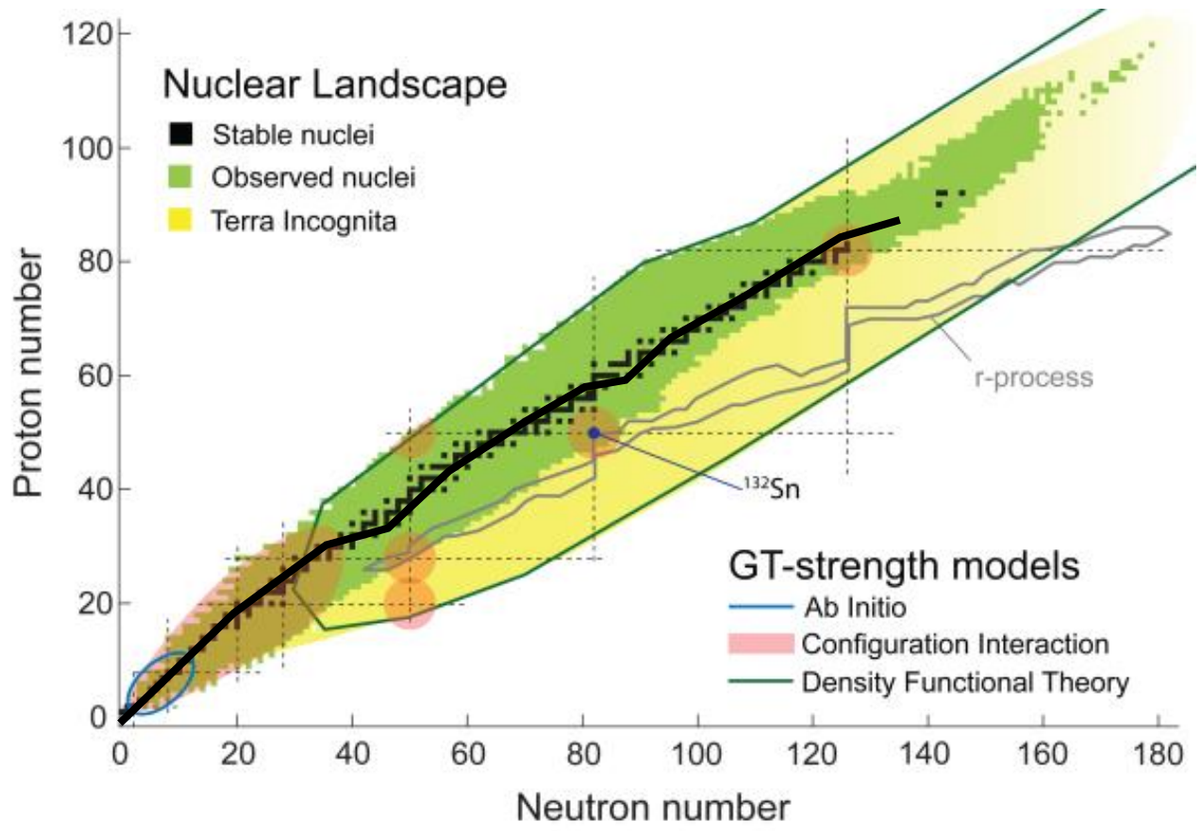
Motivation

- **Exotic property of unstable nuclei**
  - Neutron halo, skin (low density)

    <—> density saturation
  - Magic number breaking

- **Comprehensive nuclear models**
  - Nuclear EOS (equation of state)
  - r-process



➡ **Need many information of ground state & excitation state**

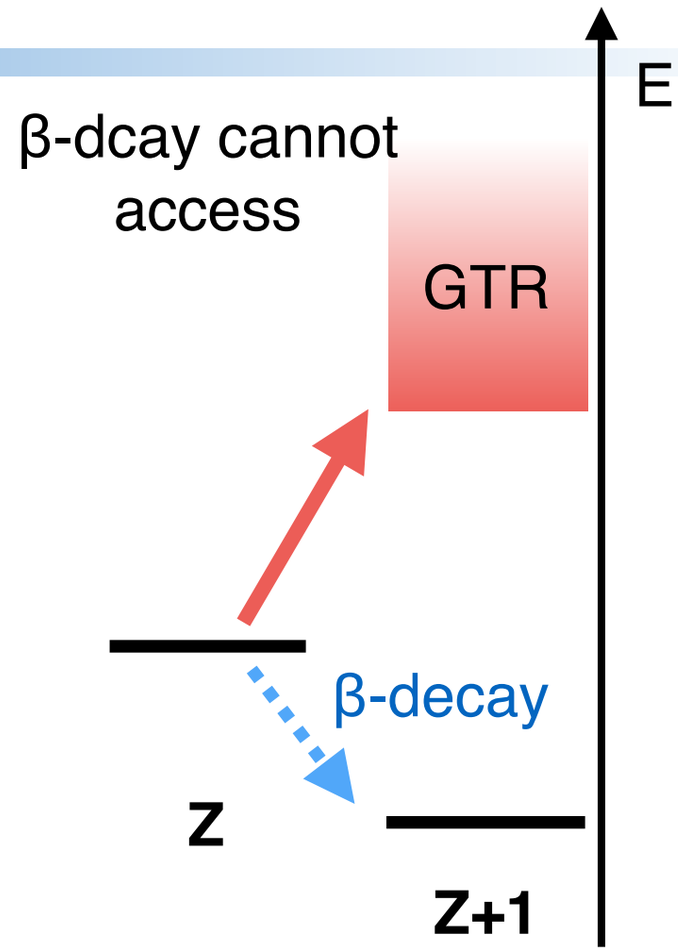
✳ **Lack of the knowledge of excitation state of unstable nuclei**

- Gamow-Teller resonance, Spin Dipole resonance, Giant Dipole resonance etc…

➡ **Measure spin-isospin excitation at any (A,Z)**

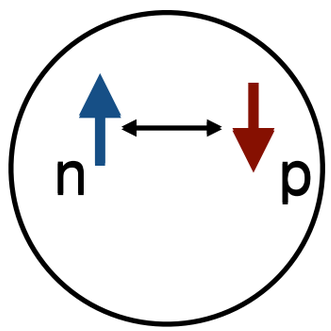
Gamow-Teller transition

- **Gamow-Teller (GT) transition**
  - **One of the most simplest mode of nuclear excitations**
    - Isospin-flip (ΔT=1), Spin-flip (ΔS=1)
    - No angular momentum transfer (ΔL=0)
      - Operator : $\beta^{\pm}_{GT} = \sigma_{\mu}\tau_{\pm}$
    - Strength : B(GT)
      - **Directly connect with a half life of β-decay**



- **GT Resonances (GTR) : High excitation mode**
  - Collective motion in spin-isospin space
  - **Cannot access by β-decay due to Q-value**

GTR

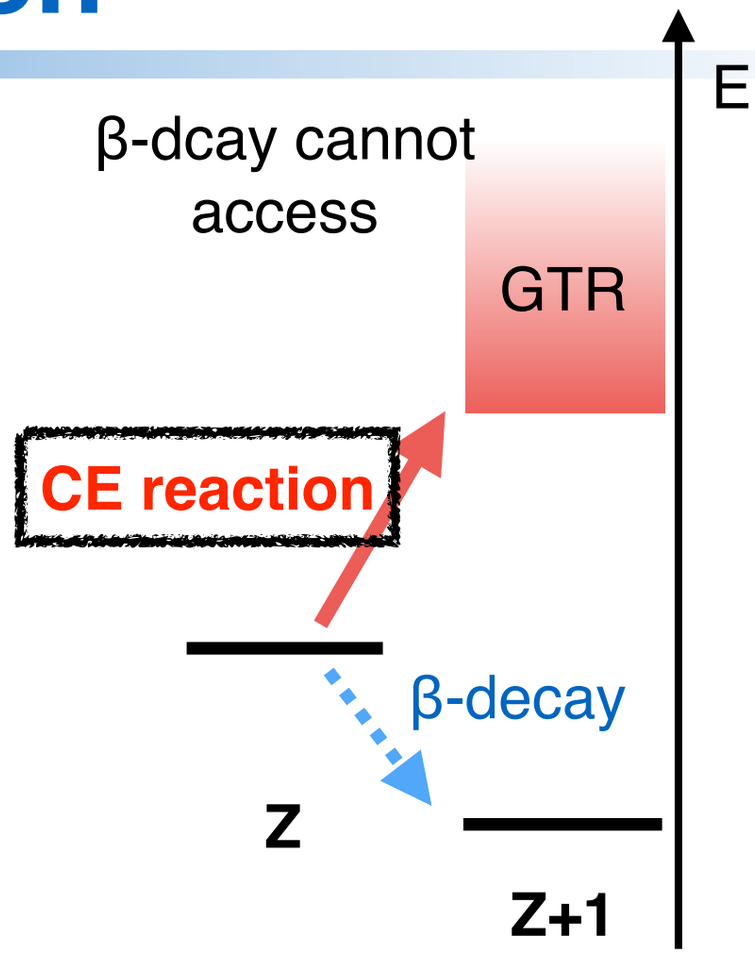


ΔS=ΔT=1, ΔL=0

Charge Exchange (CE) reaction

- **CE reaction at intermediate energy**
  - **can access any Ex. energy**
    - β decay is limited by Q-window
  - **Selectivity to ΔT=1, ΔS=1**
    - Gamow-Teller (GT), Spin-Dipole (SD) etc..
  - **Proportionality**

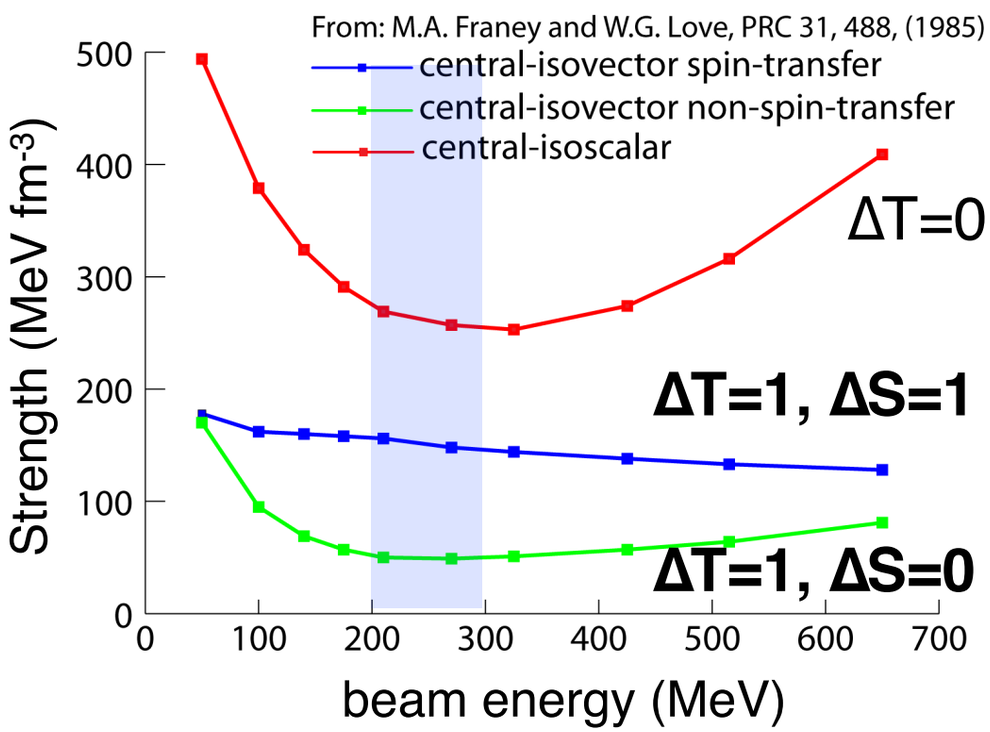
CE c.s. → $$\frac{d\sigma}{d\Omega}(q=0) = \hat{\sigma} B(GT)$$



▸ **Powerful tool to study GTR**

- **Limited to stable, low-lying state in light unstable-nuclei**

➡ **CE reactions for RI beams are required**



(p,n) CE reactions for RI beam

- **Missing mass spectroscopy with RI beam**
  - Detect recoil neutron, residual is used just tag for (p,n) reaction.

➡ **High statistics**

- RI beam (~10^6) x thick target (~100mg/cm^2) x large n-detector acceptance (FPL~1m)

  ～ Stable p-beam (160nA) x 100mg x acceptance (FPL~100m)

➡ **Simple kinematics**

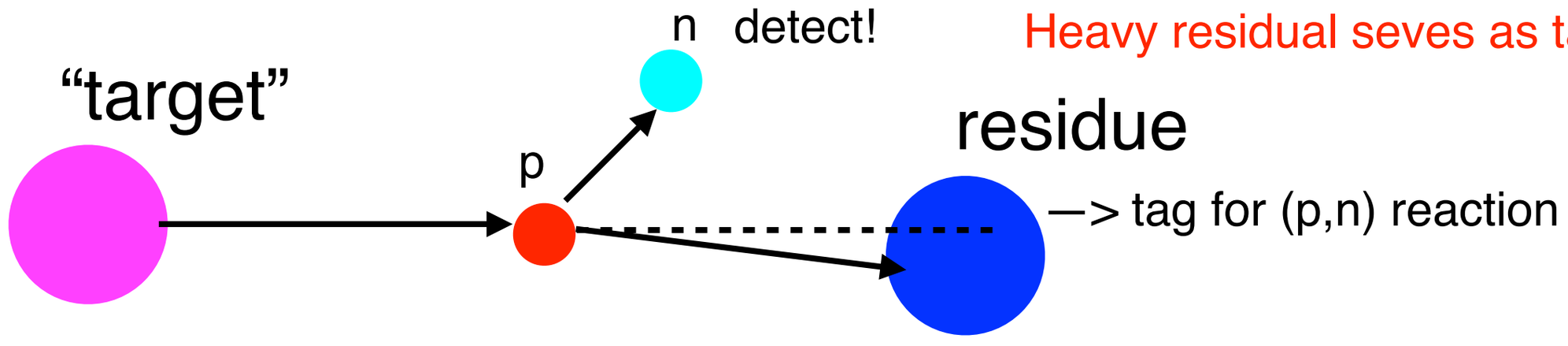
- all kinematics information from the measurement of neutron (2 body kinematics)

➡ **Extensive**

- can be applied to any mass region and to any excitation energy region

✶improve S/N ratio by tagging of (p,n) reaction

Observables from recoiled n only
Heavy residual seves as tag



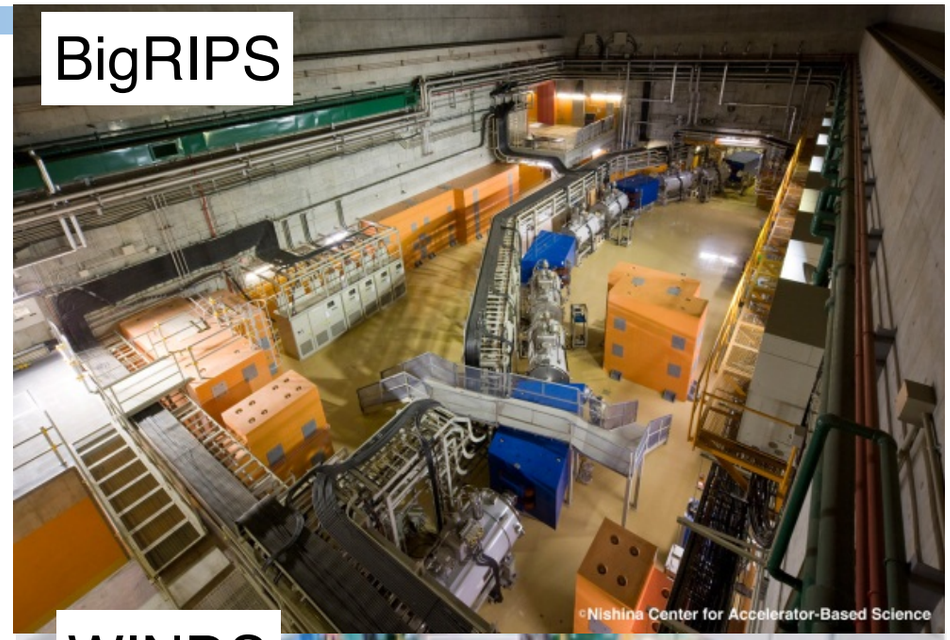
Efficient measurements can be performed even with RI beam

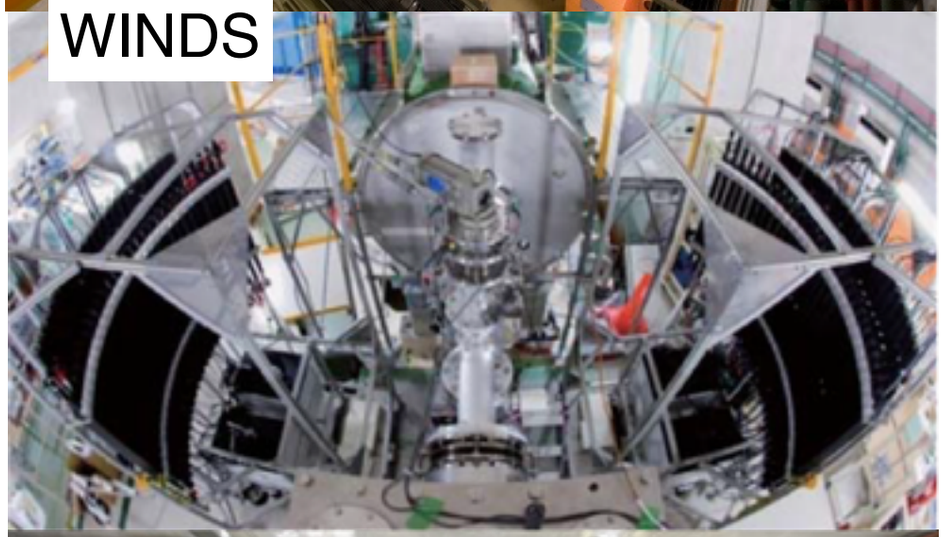
(p,n) measurement with WINDS + SAMURAI

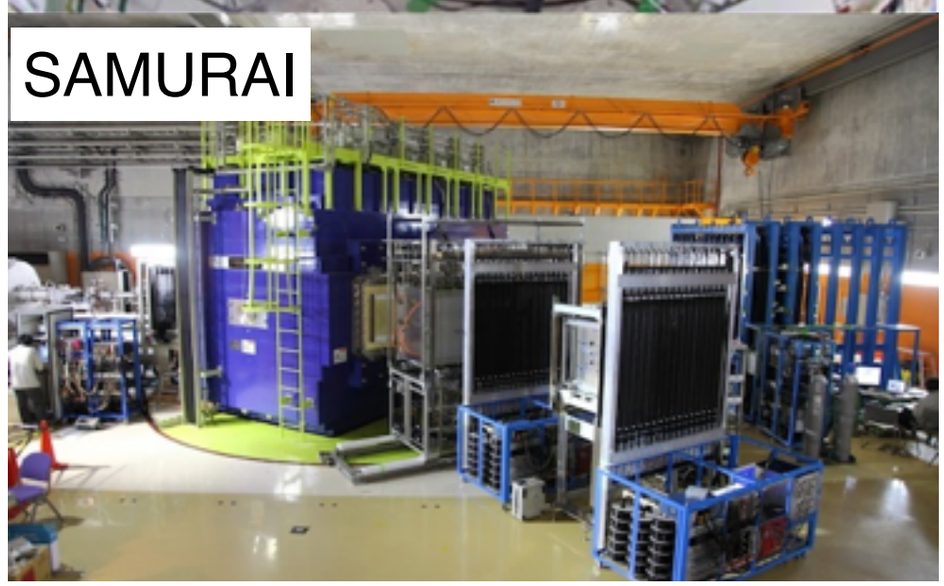
- **Beam**
  - High Intensity : >10^4 pps
  - Intermediate kinetic energy : 200~300 MeV/u
    - **can access to far from the stability line**

- **Neutron detection**
  - WINDS(Wide angle Inverse kinematics Neutron Detectors for SHARAQ) : 73 scintillators
    - **cover wide angular range**

- **Residue tag**
  - SAMURAI
  - Large acceptance
    - **measure all decay particle in one setting**







Overview of (p,n) studies for RI beam

Z

Overview will given by
Sasano's talk on Wednesday

N=Z line
-> Isoscalar pairing

performed @RIBF SAMURAI, April 2014
(spokesperson : M. Sasano, R. Zegers)

^{132}Sn
double magic nuclei far from stability
Key nucleus for
nuclear models in A~100 region

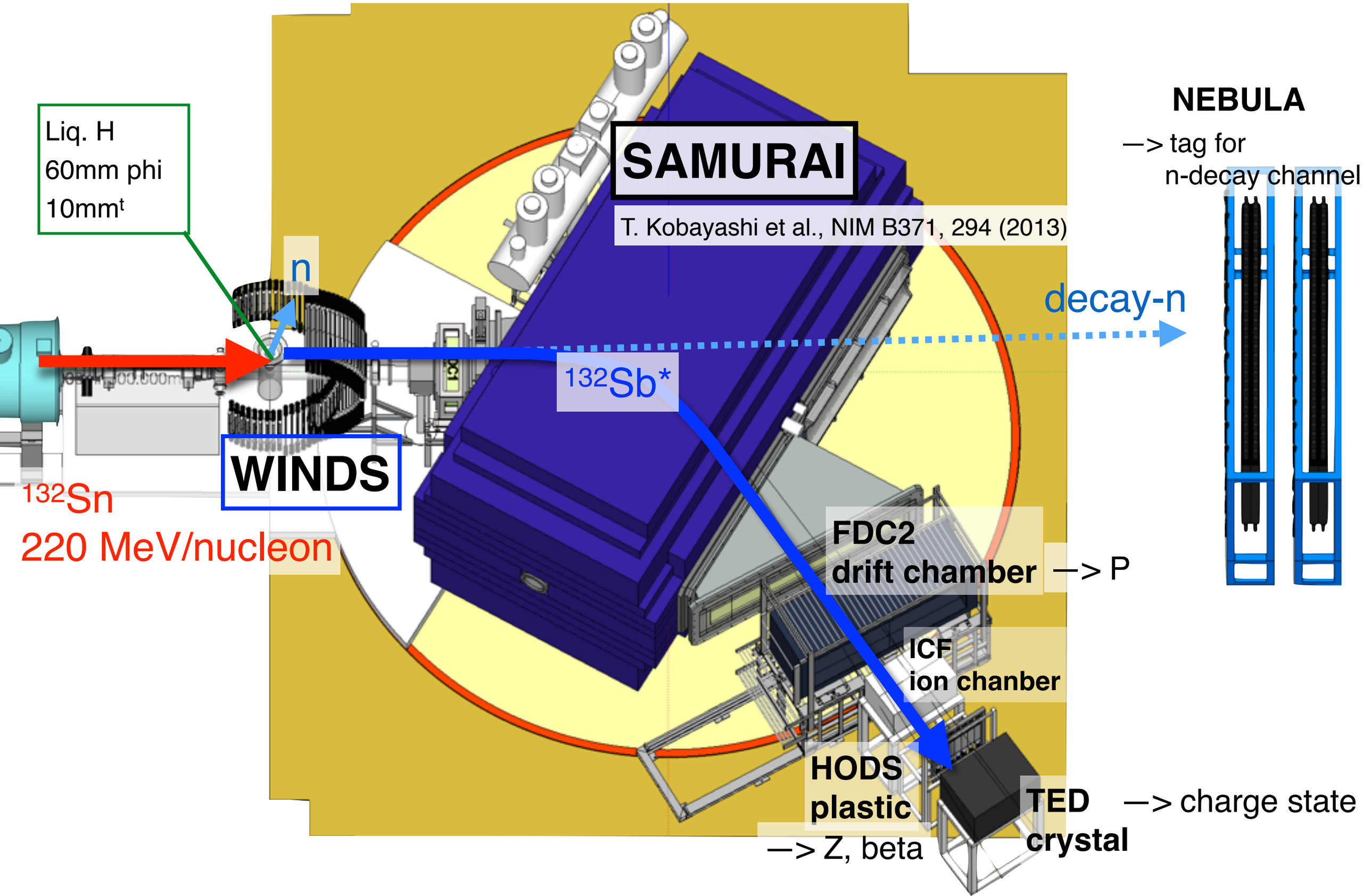
^{56}Ni@NSCL
M.Sasano et. al.,

^{8}He H.Sakai et al.,
^{12}Be K. Yako et al.,

N

^{11}Li, ^{14}Be, …, L.Stuhl (exp. approved) poster session

Experimental setup



Slow neutron detection with WINDS

- **Wide angular coverage**
  - 61 plastic scintillators (600x100x30mm³) : 1° resolution

    ＋ 12 ELENS bars (1000x45x10mm³) : 0.3° resolution

    L. Stuhl et al., NIMA 736, 1 (2014)

  ➡ θlab = 20 —120° , FPL = 900,1100mm

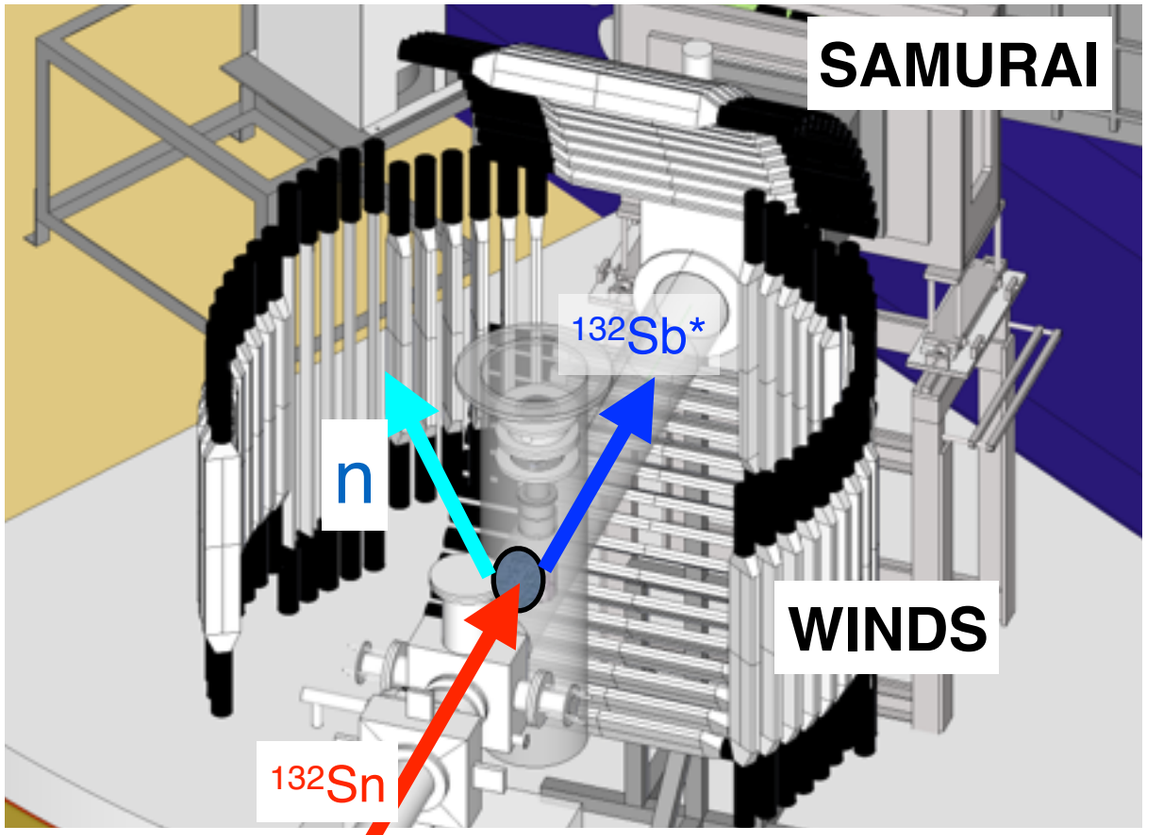
- **Energy coverage**
  - TOF : 20 — 250 ns ※cut fast component
  - Neutron energy : 0.2 — 15 MeV

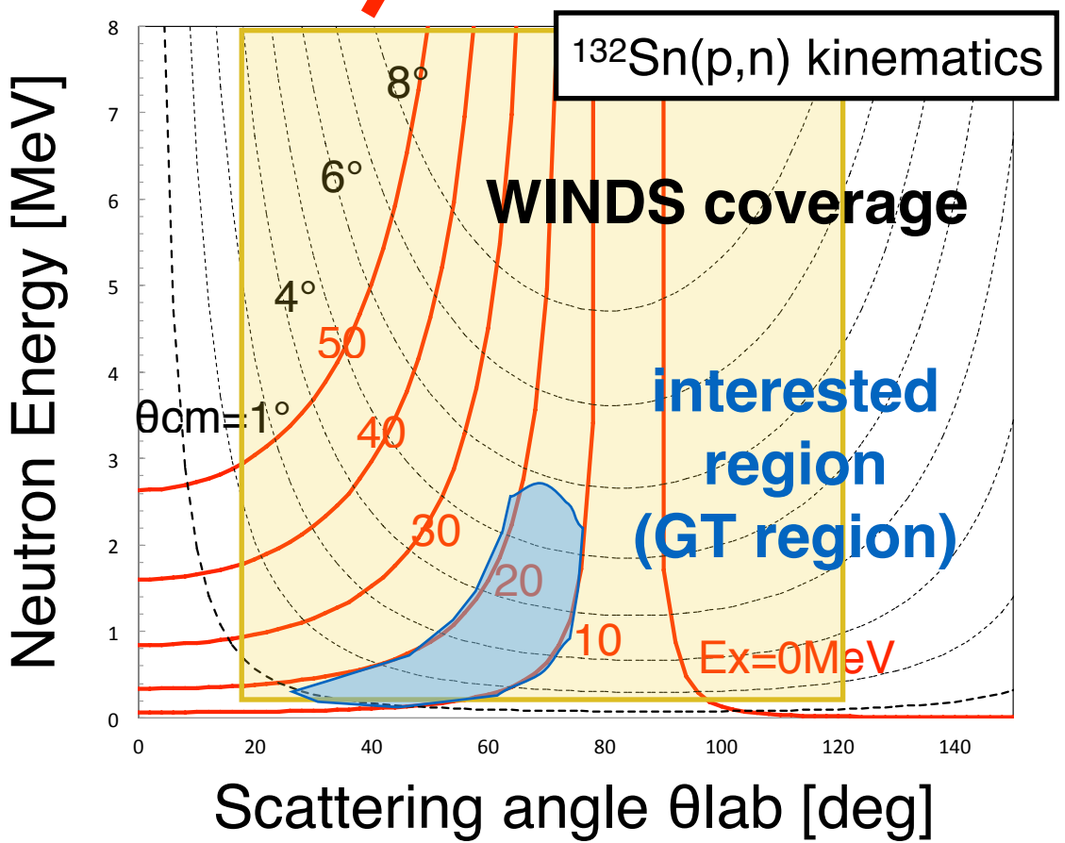
- **Low threshold**
  - Threshold was set to ~30 keVee

  ➡ ε = 20—40% for 200 keV neutron energy

  ➡ Overall efficiency : 10-15% at forward angle

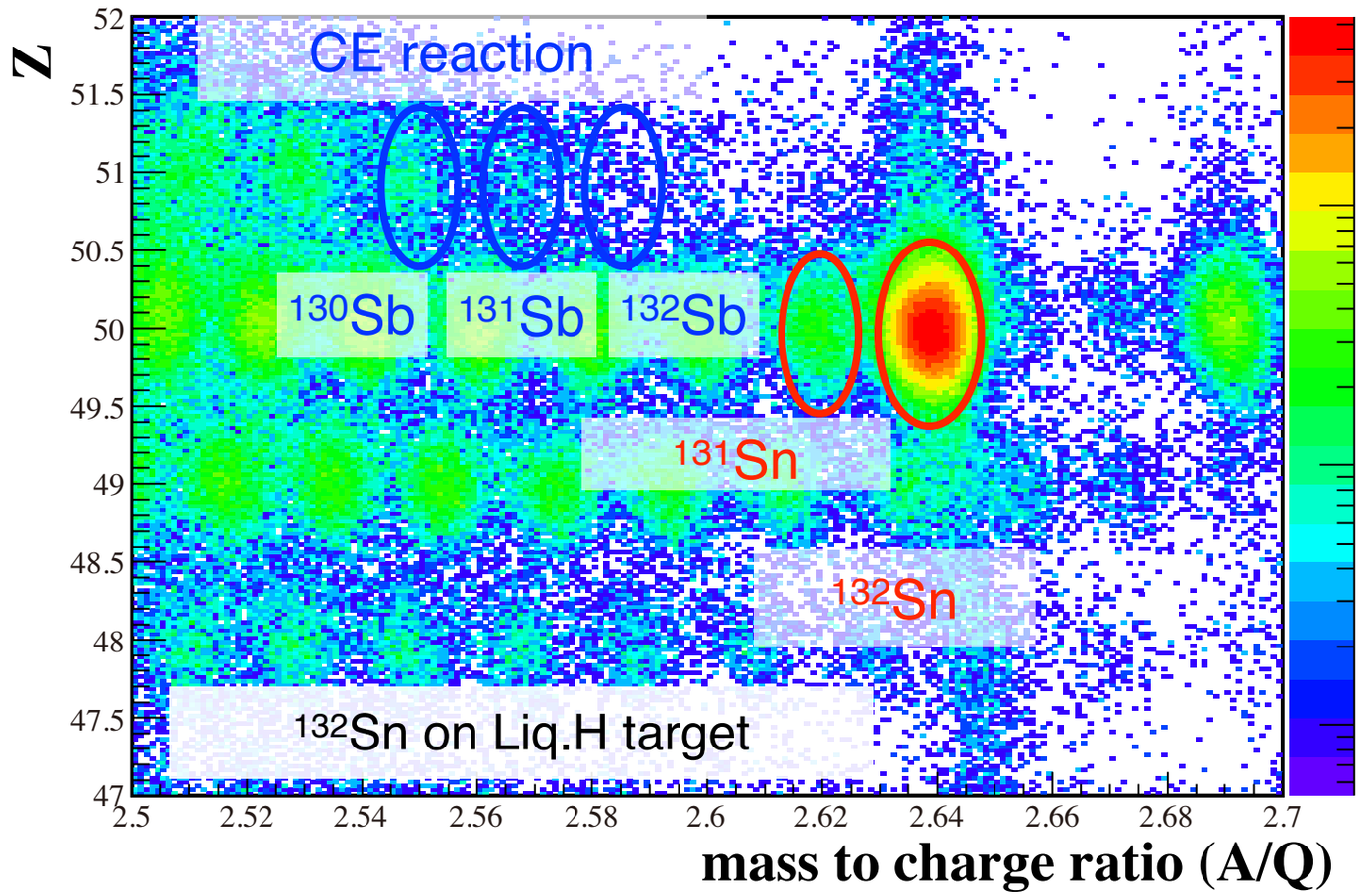
➡ **We can reconstruct excitation energy spectrum up to 30MeV for θcm = 1~10deg.**





Result ～PID of heavy residues～

- **TOF**
  - plastic counter SBT1,2 and HODS
  - resolution : $\sigma_t \sim 60$ ps
- **ΔE**
  - plastic counter HODS (5mm)
  - resolution : $\sigma_{\Delta E}/\Delta E \sim 0.9$ %
- **Bρ**
  - drift chamber BDC1,2, FDC1,2
  - SAMURAI magnet : 2.56T
  - resolution : $P/\sigma_P \sim 1300$



- **σ_A = 0.16 6.1σ separation**
- **σ_Z = 0.22 4.5σ separation**

Charge Exchange (CE)reaction
^{132}Sn(p,n)^{132}Sb

Decay channel
Ex>6.0MeV : ^{132}Sb—> ^{131}Sb+n
Ex>9.8MeV : ^{132}Sb —> ^{131}Sn+p
Ex>13.7MeV : ^{132}Sb —> ^{130}Sb +2n

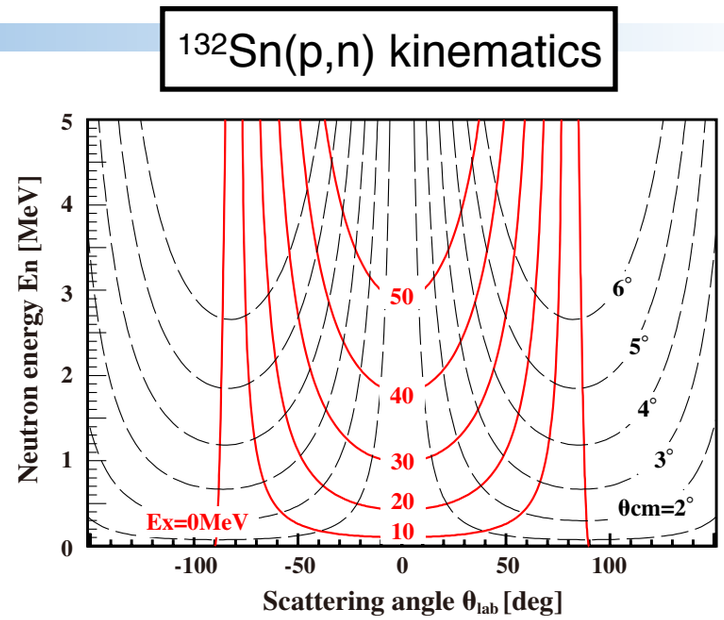
Large acceptance of SAMURAI
—> all decay channel was measured with good resolution

Kinetic curves

- **Neutron energy T_n vs Scattering angle θ_{lab}**

✓ kinematics correlation of (p,n) reaction was clearly seen

➡ **successfully measure high Ex~20MeV**



132Sn(p,n)132Sb*

γ-decay channel

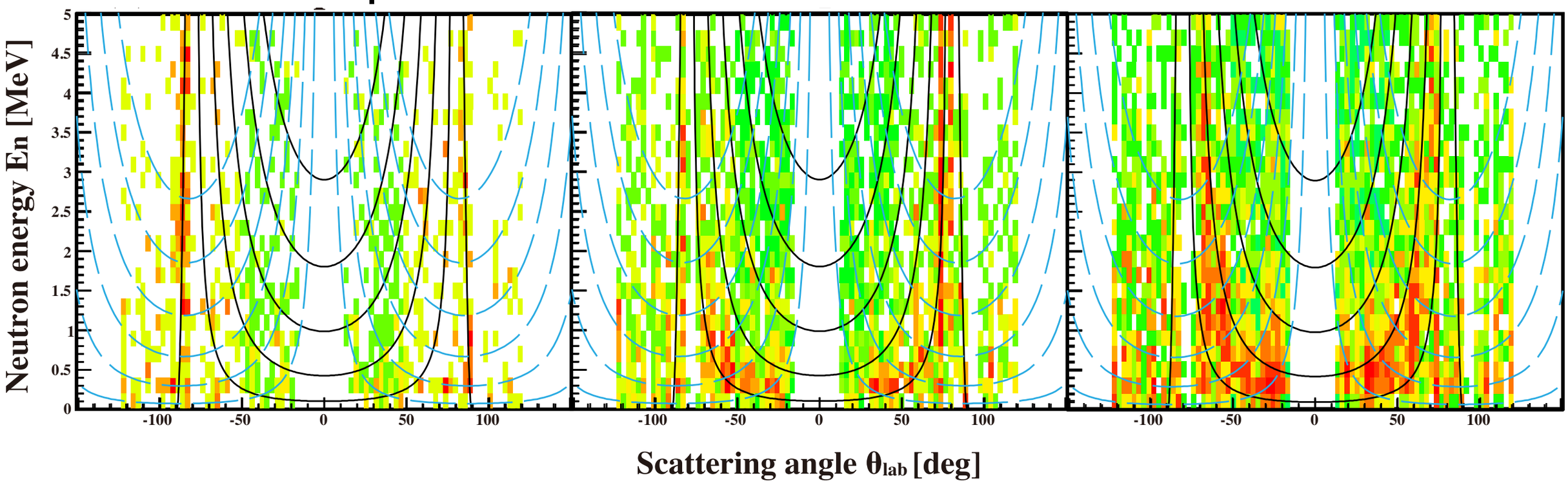
132Sb*->132Sb+**γ**

1n-decay channel : Ex>6.0MeV

132Sb*->131Sb+**n**

2n-decay channel : Ex<13.7MeV

132Sb*->130Sb+**2n**



Summary

- **GTR study at any Ex & (A,Z)**

- **WINDS + SAMURAI setup for (p,n) reaction on unstable nuclei**
  - WINDS : wide angular coverage θ_{lab} 20— 120deg (4π configuration)
  - SAMURAI : Large acceptance

- **^{132}Sn(p,n) experiment was performed**
  - successfully measure all decay channel with good resolution σA ~0.16, σZ~0.24
  - can be access to high Ex energy ~20MeV
  - **(p,n) study can be extended to A~100 region**

- **Perspective**
  - 132Sn(p,n) study
    - angular distribution θcm=2-10° —> B(GT) distribution on 132Sn
  - (p,n) reactions on ^{11}Li, ^{24}O, ^{48}Cr, ^{64}Ge (N=Z)

Collaborators

M. Sasano, H. Baba, W. Chao, M. Dozono, N. Fukuda, N. Inabe, T. Isobe, D. Kamaeda, T. Kubo, M. Kurata-Nishimura, E. Milman, T. Motobayashi, H. Otsu, V. Panin, W. Powell, M. Sako, H. Sato, Y. Shimizu, H. Sakai, L. Stuhl, H. Suzuki, T. Suwat, H. Takeda, T. Uesaka, K. Yoneda, J. Zenihiro,

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