Towards the first observation of isoscalar giant monopole resonances in unstable tin isotopes with CNS Active Target (CAT)

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Nucleon systems

1	A	∞
proton neutron	atomic nuclei = protons + neutrons	neutron star ~ neutrons
1fm 1.4g/cm^3 (Sun)	several fm ~10^{14}g/cm^3	10km >10^{14}g/cm^3

These many body systems are with different size with two components, which is governed by Equation of State of nuclear matter

Determination of EoS for symmetric and asymmetric matter

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COMEX5

Key words

- Isoscalar giant monopole resonance
  - cf. Keynote talks in this conferences and others
- Kτ (isospin dependence of incompressibility at saturation density of asymmetric matter)
  - can be directly extracted via experiments
  - experiment plan of 132Sn(d,d')
  - pilot experiment of 132Xe(d,d')
- CAT Active target system
  - Newly developed for high luminosity exp.
- High luminosity
  - (= <u>beam intensity</u> x target thickness)

Kτ

$$\mathcal{E}(\rho,\alpha) = \mathcal{E}(\bar{x}_0,\alpha) + \frac{1}{2}[(1+3\bar{x}_0)^2\mathcal{E}''(\bar{x}_0,\alpha)]\bar{x}^2 + \cdots$$
$$\equiv \varepsilon_0(\alpha) + \frac{1}{2}K_0(\alpha)\bar{x}^2 + \cdots,$$

$$\varepsilon_0(\alpha) = \varepsilon_0 + \varepsilon_\tau\alpha^2 + \mathcal{O}(\alpha^4) = \varepsilon_0 + J\alpha^2 + \mathcal{O}(\alpha^4)$$

$$K_0(\alpha) = K_0 + K_\tau\alpha^2 + \mathcal{O}(\alpha^4)$$
$$= K_0 + \left(K_{\rm sym} - 6L - \frac{Q_0}{K_0}L\right)\alpha^2 + \mathcal{O}(\alpha^4)$$

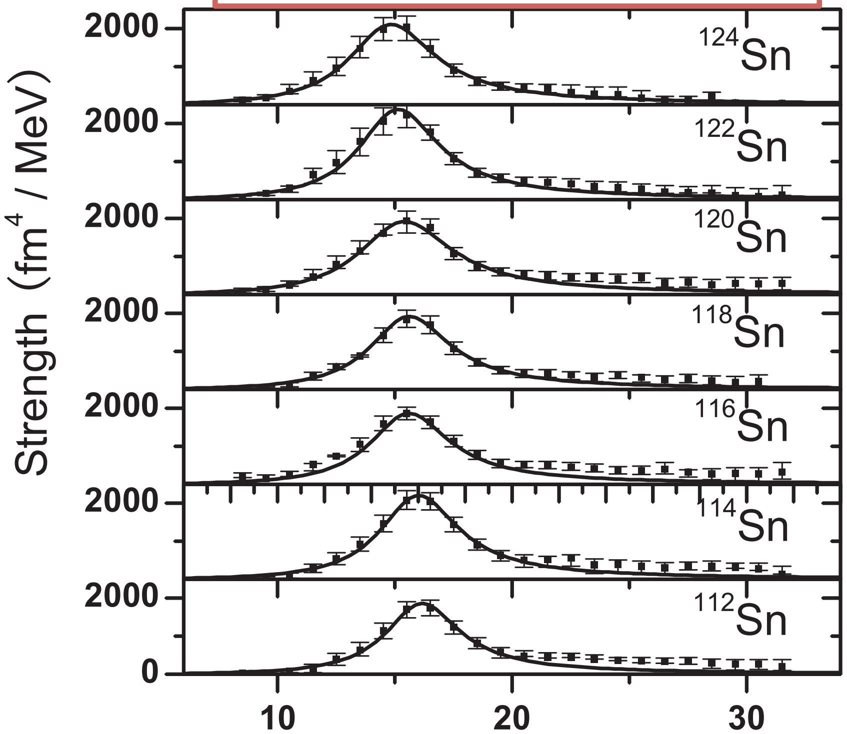
$$K_A \sim K_{\rm vol}(1 + cA^{-1/3}) + K_\tau[(N-Z)/A]^2 + K_{\rm Coul}Z^2A^{-4/3},$$

Measurement of KA by changing asymmetry (N-Z)/A ~ isospin

Experimental Value of Kτ

$$K_A \sim K_{\rm vol}(1 + cA^{-1/3}) + K_\tau[(N-Z)/A]^2 + K_{\rm Coul}Z^2A^{-4/3},$$

(α,α') measurement at RCNP



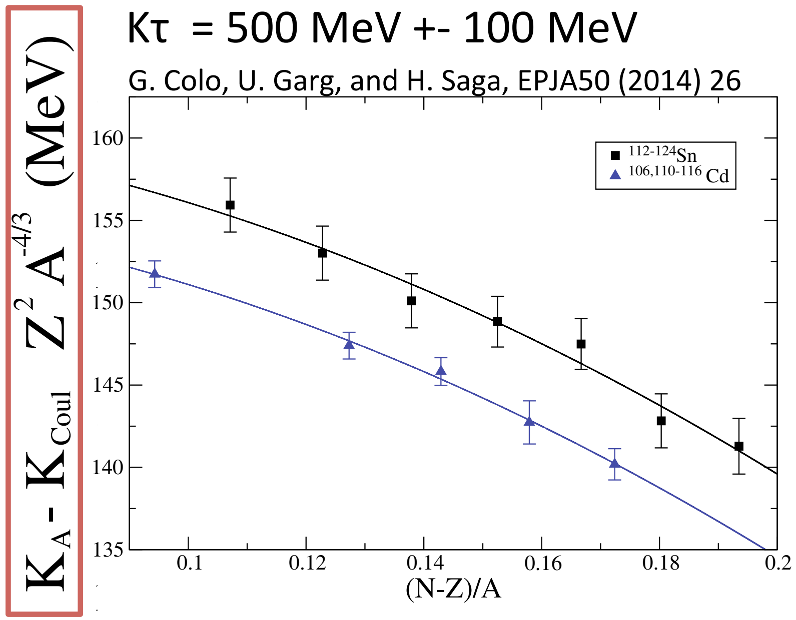
T. Li et al., PRL99 (2007) 162503

ignore the slight change of $A^{-1/3}$

fitting a + b $(N-Z)^2/A^2$: b = Kτ

Kτ = 500 MeV +- 100 MeV

G. Colo, U. Garg, and H. Saga, EPJA50 (2014) 26



Data:

D. Patel et al. PLB718 (2012) 447

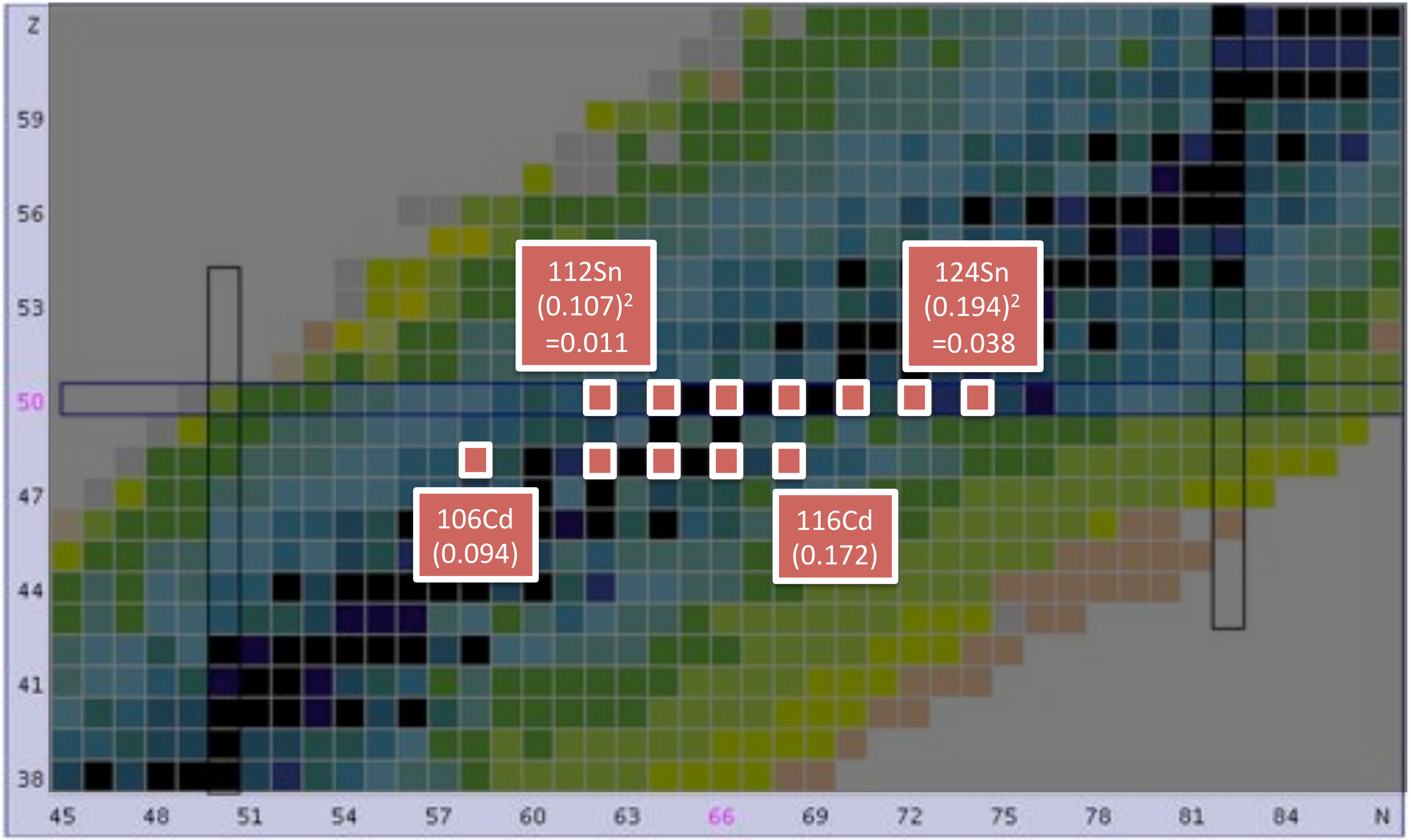
T. Lie et al., PRC81 (2010) 034309

Kτ ~ 500-550 MeV +-100MeV

Ktau project

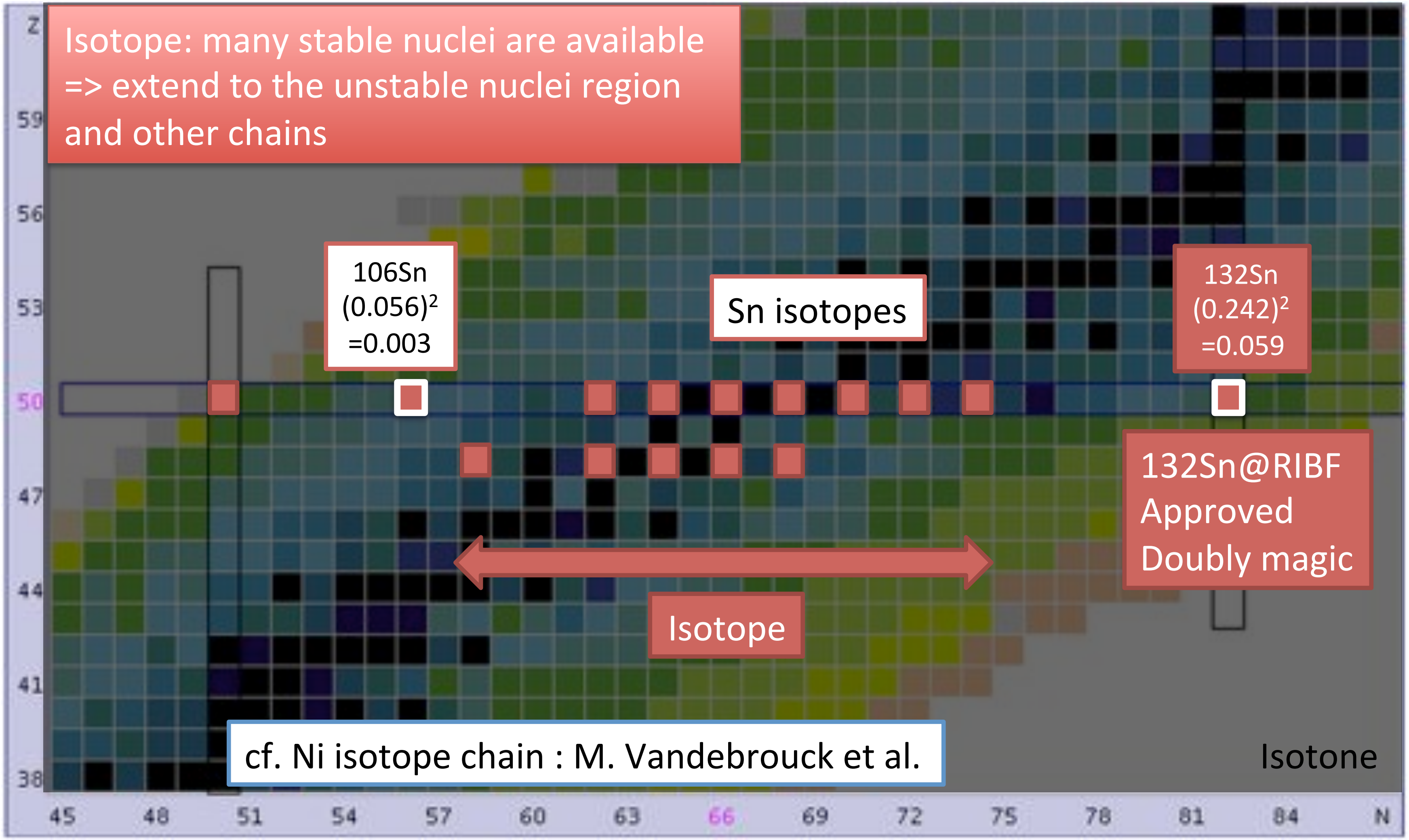
not official

$$K_A \sim K_{\rm vol}(1 + cA^{-1/3}) + K_\tau[(N-Z)/A]^2 + K_{\rm Coul} Z^2 A^{-4/3},$$

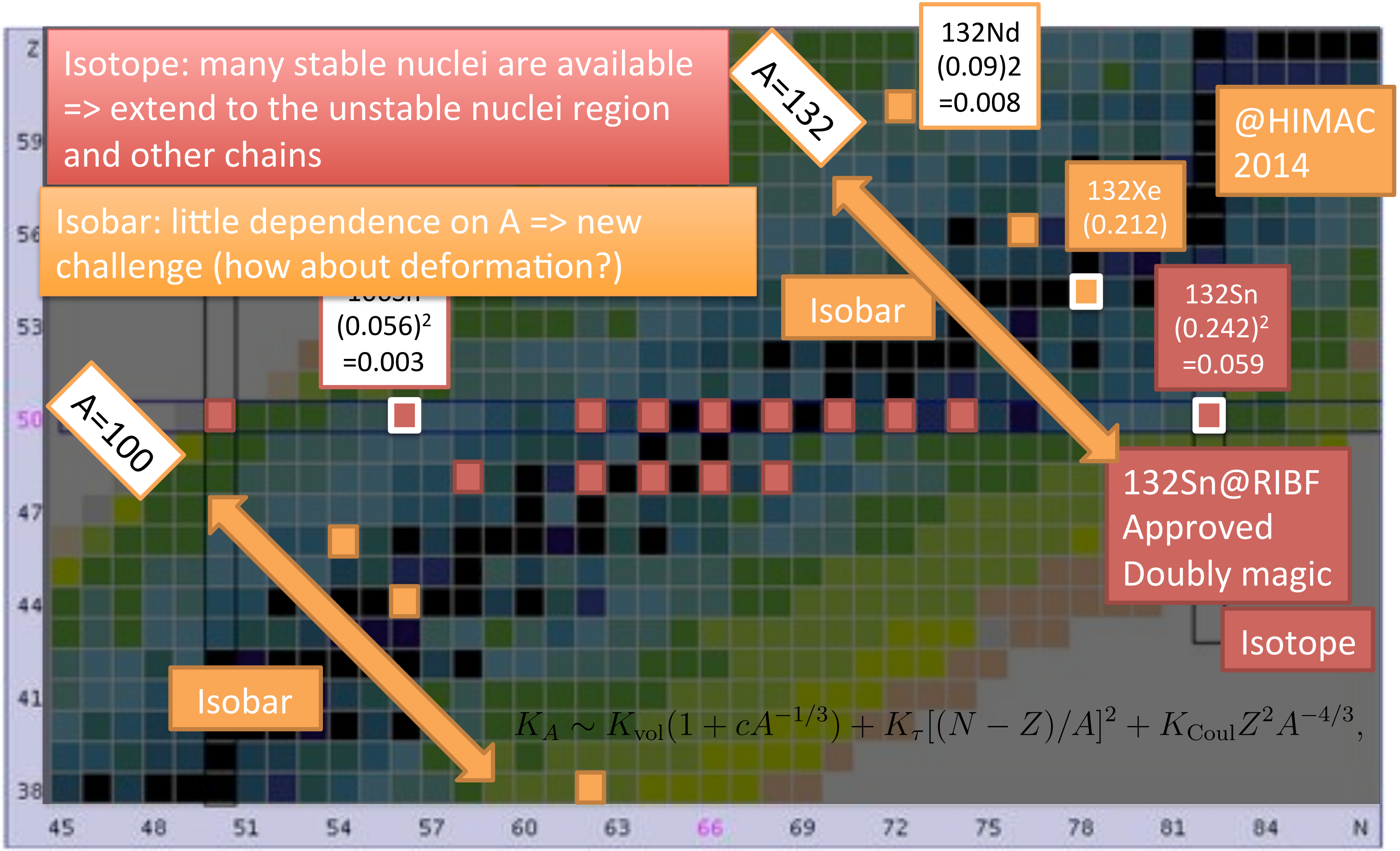


Ktau Project

$$K_A \sim K_{\mathrm{vol}}(1 + cA^{-1/3}) + K_\tau[(N-Z)/A]^2 + K_{\mathrm{Coul}} Z^2 A^{-4/3},$$



Ktau Project



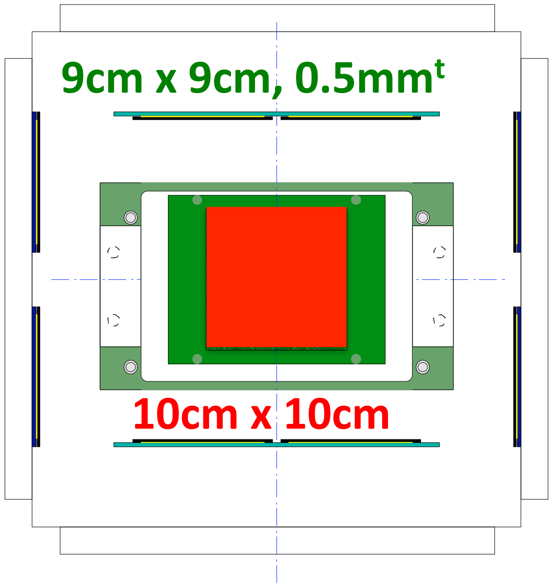
PLAN:
ISGMR IN 132SN VIA (D,D')

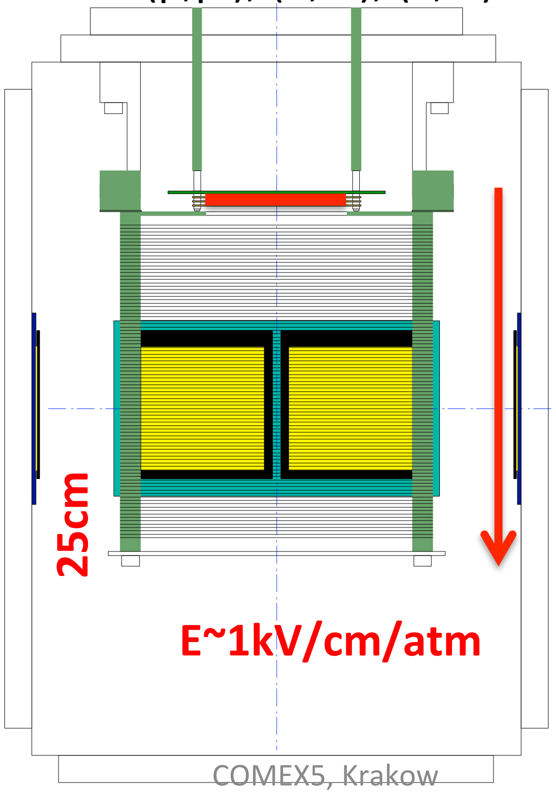
CNS Active Target (CAT)

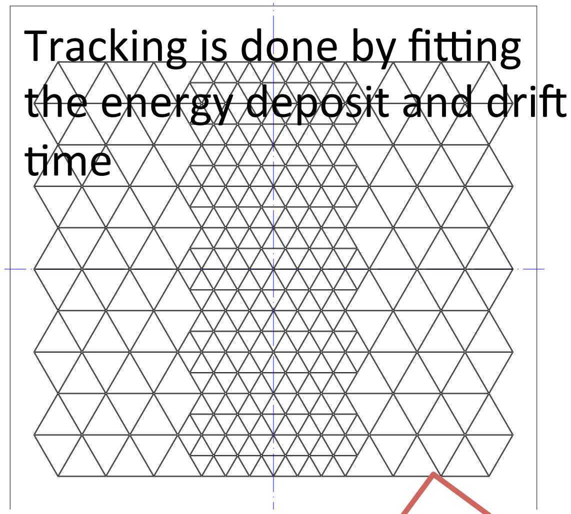
- **TPC** and **Si array**
  - 0.4 atm. pure deuterium gas
  - Gas Electron Multiplier (GEM) : required gain ~ 10^4
  - 300 um resolution achieved

> 100 kcps beam injection
Thickness = 0.1 mg/cm^2

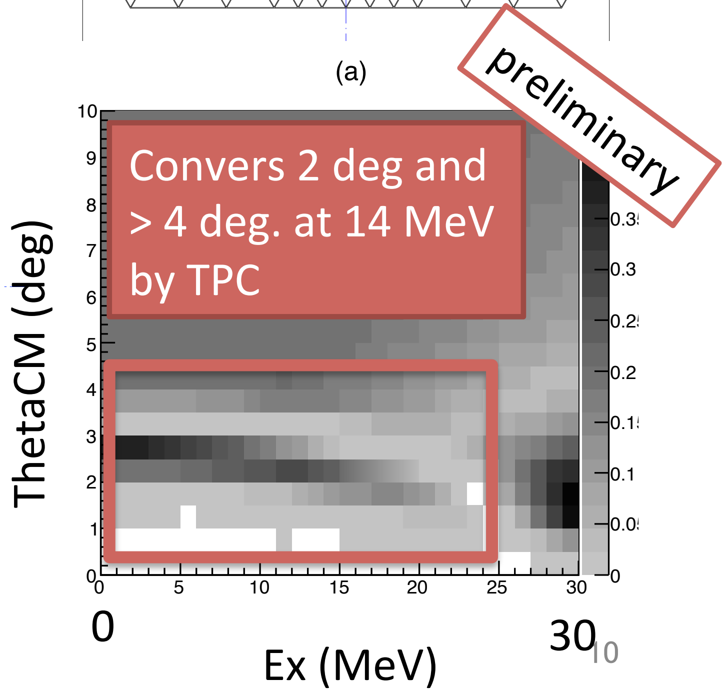
⇒ high luminosity
⇒ (p,p'), (d,d'), (a,a')



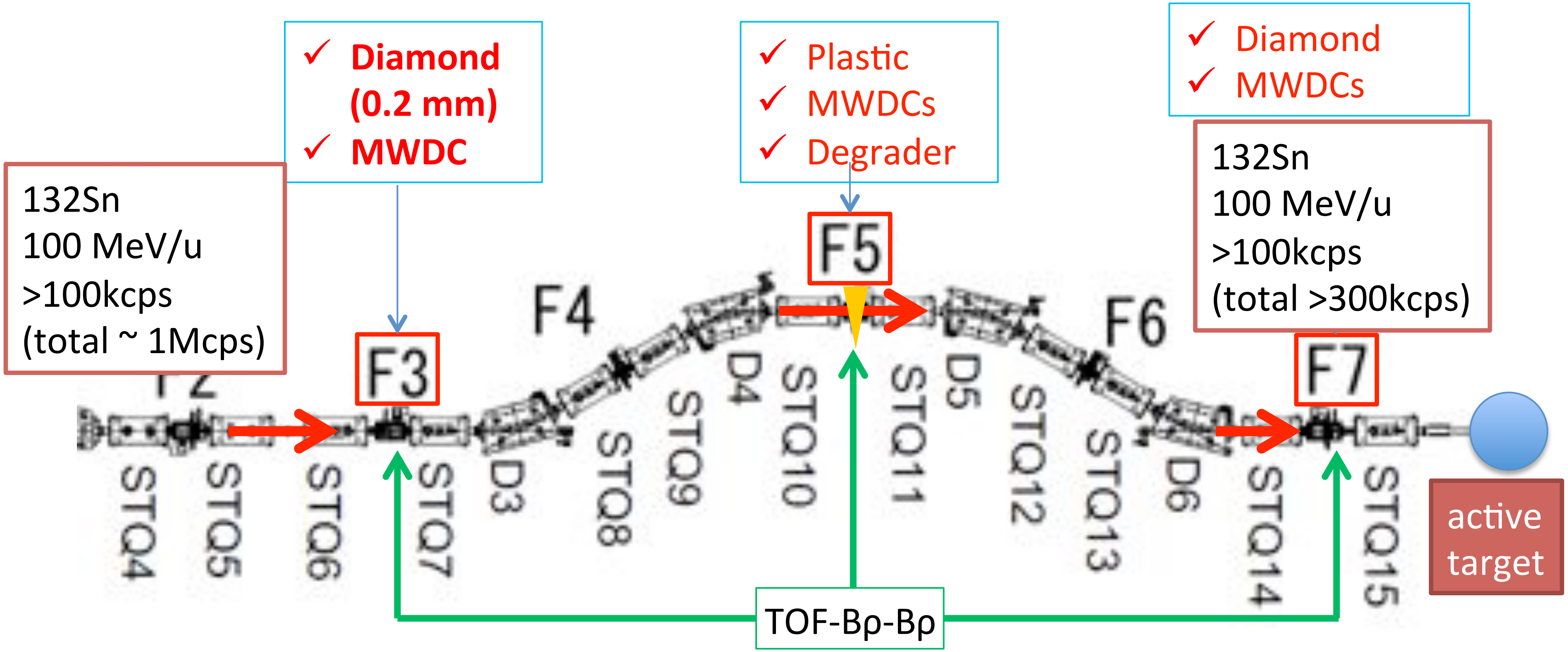




(a)



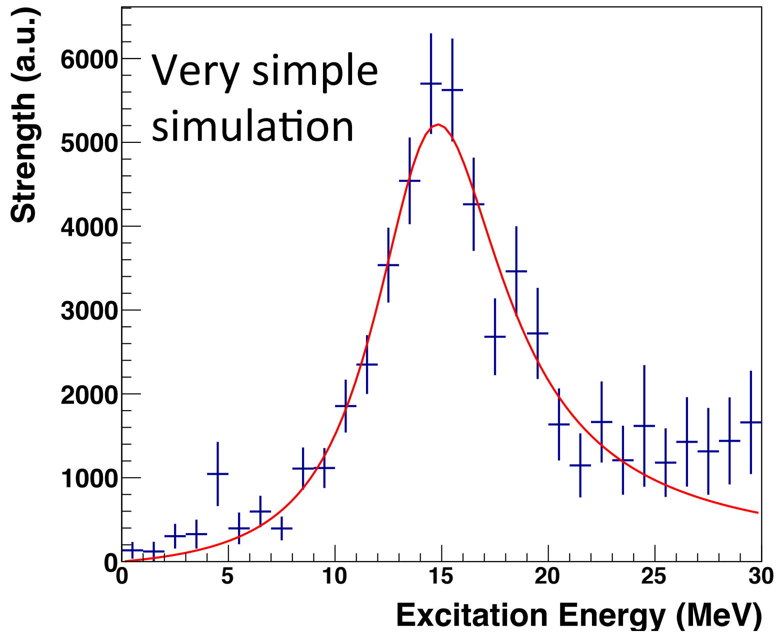
RIBF113 experiment 132Sn(d,d') at RIBF (in near future)



luminosity = 10^5 cps x 10^{20}cm^{-2} ~ 0.01 mb^{-1}s^{-1}

Yield and Error Estimation

Expected strength distribution



10 days w/ **100kcps 132Sn beam (>300kcps in total)**

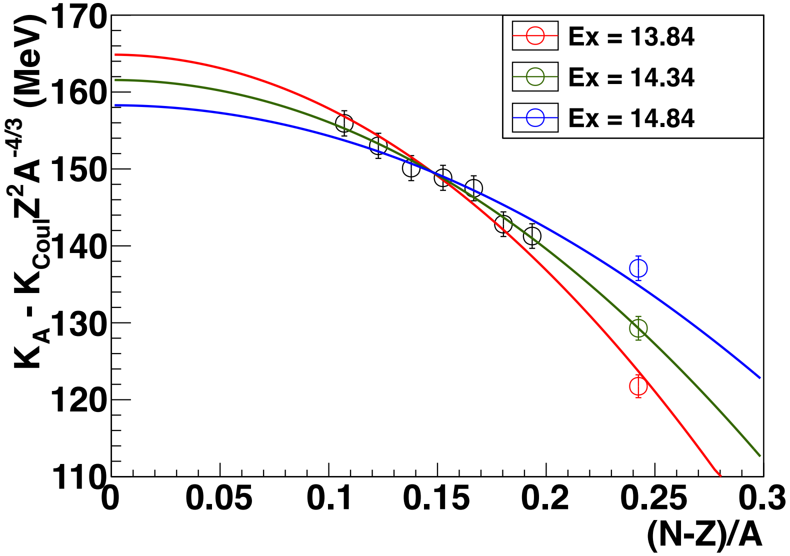
$\delta Ex = 1$ MeV ,$\delta\theta_{CM} = 0.5$ deg

Total cross section is calculated using OM.

Only monopole / spherical Bessel

$\Rightarrow dE_{GMR} \sim 0.17$ MeV

Extraction of Kτ



⇒ error of Kτ can be reduced to 50 MeV from 70 MeV.

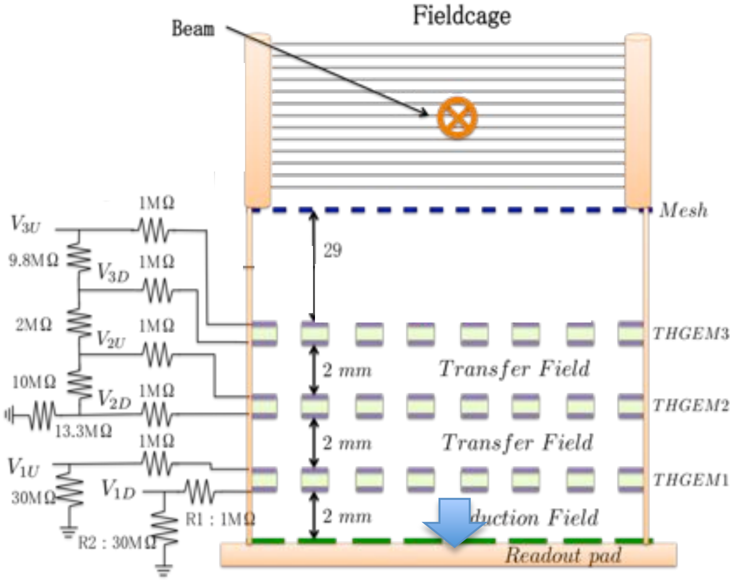
⇒ 0.5 MeV difference in E_{GMR} corresponds to 80 MeV difference in Kτ

OPERATION WITH HIGH RATE BEAM AND 132XE(D,D')

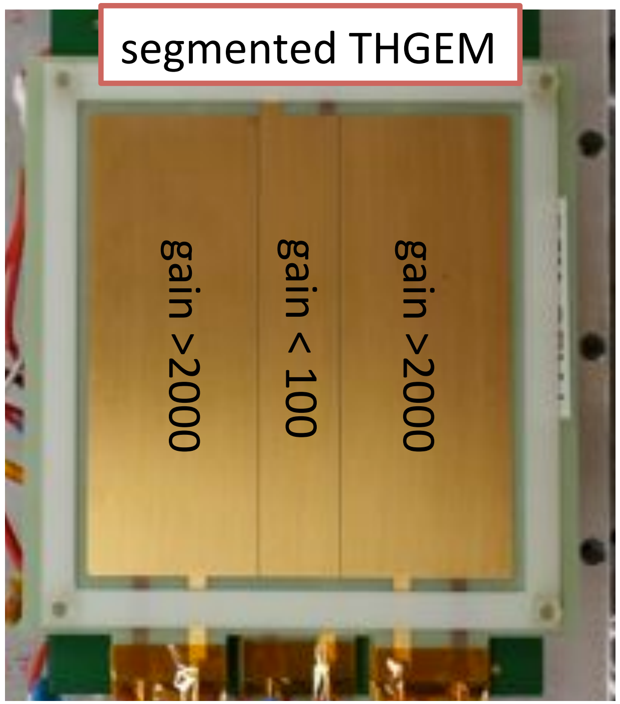
Operation with high-intensity beams

w/ beam intensity of 10^6 cps
=> O(1) mA at last THGEM.

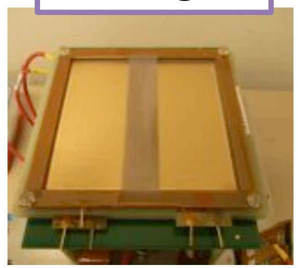
large energy deposit by beam caused discharge of THGEM
because of too much gain for beam region
=> reduction of effective gain



~1mA



mesh grid



Segmented THGEM provides better energy resolution than mesh grid along the beam path.
=> stable with up to the 500-kcps 100-MeV/u 132Xe beam

132Xe(d,d') at HIMAC

As a study of nuclear incompressibility in isobars and test for the high-intensity beam injection

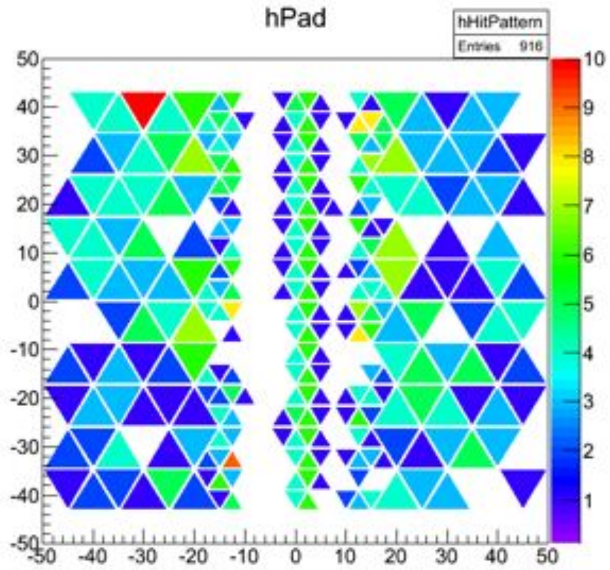
- HIMAC (22th – 25th Jan, 2015)
  - 132Xe
    - 100MeV/u
    - **500 kcps**
      - 10^6 ppp with 2-sec extraction
  - 3 GEMs with 0.4-atm deuterium

Synchrotron at Chiba prefecture in Japan
Mainly used for radiotherapy

132Xe(d,d') at HIMAC

- HIMAC (22th – 25th Jan, 2015)
  - 132Xe
    - 100MeV/u
    - **500 kcps**
      - 10^6 ppp with 2-sec extraction
  - Huge number of delta rays

Hit pattern for one event



delta-ray energy distribution

$$\frac{d^2N}{dTdx} = \frac{1}{2} Kz^2 \frac{Z}{A} \frac{1}{\beta^2} \frac{F(T)}{T^2} \qquad T_{\max} = \frac{2m_e c^2 \beta^2 \gamma^2}{1 + 2\gamma m_e/M + (m_e/M)^2}$$

$$F(T) = (1 - \beta^2 T/T_{\max})$$

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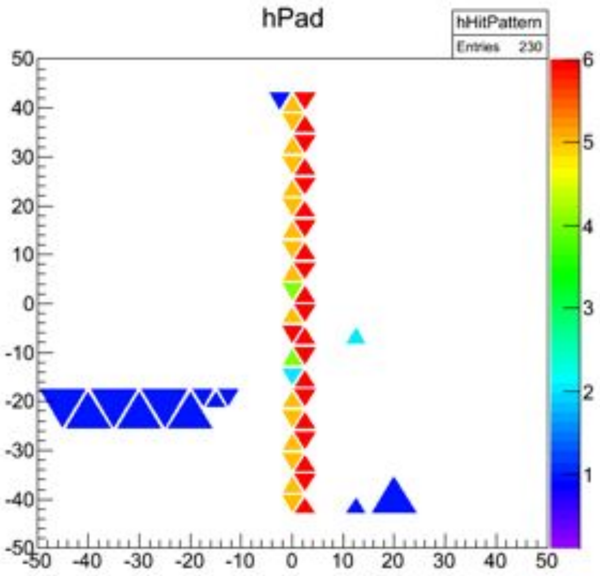
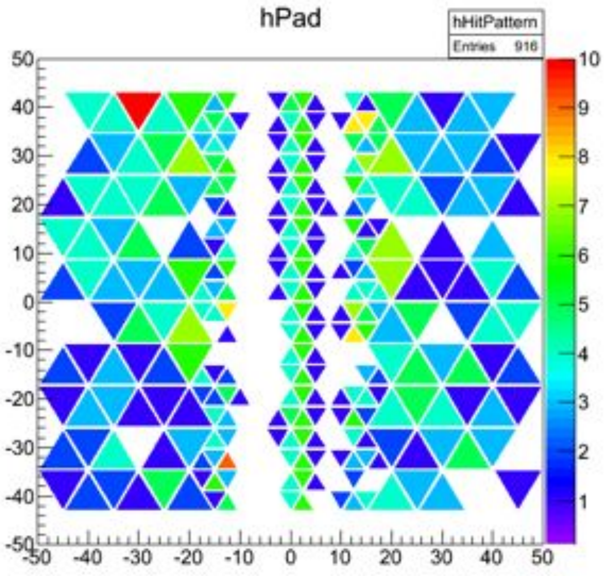
132Xe(d,d') at HIMAC



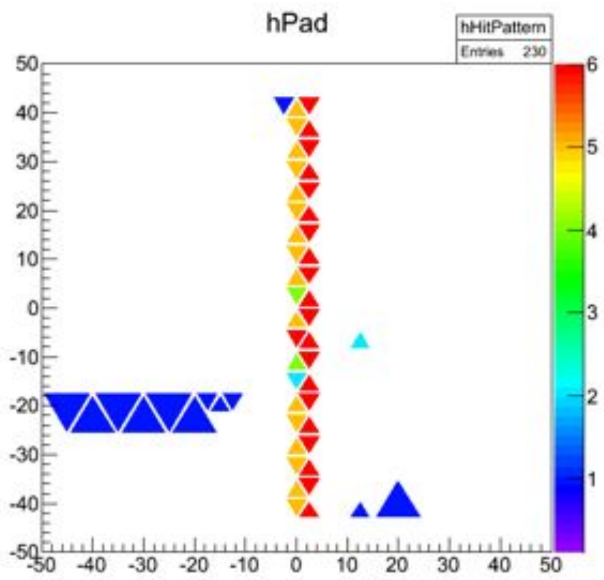
Cut by pulse height (or charge)



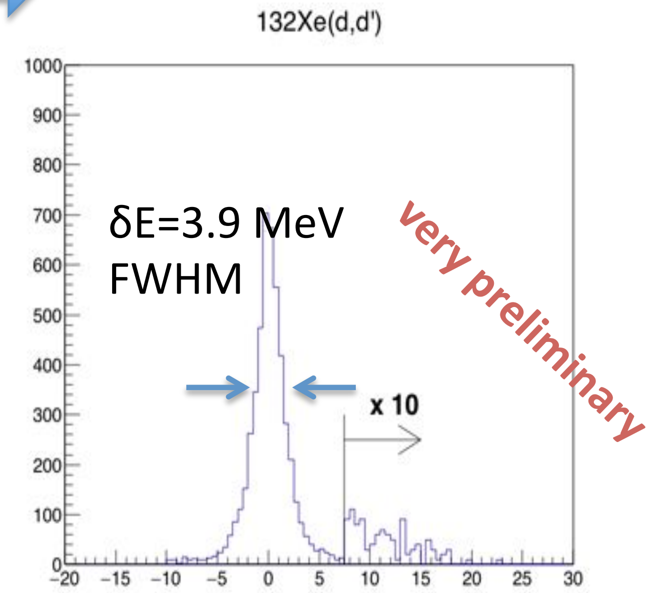
Hit pattern for one event

132Xe(d,d') at HIMAC

Tracking and accumulate events



Cut by pulse height (or charge)



w/ tracking using charge and drift time taking the effect of diffusion into account
w/o correction of efficiency
- less than 1/10 of total data
- need to check the uniformity and stability of gain

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Summary and outlook

- CNS Active Target (CAT) is developed for the measurement of deuteron (or alpha) inelastic scattering.
  - Worked with **the high intensity beams up to 500 kcps**.
  - Achievable luminosity is 0.01 mb-1s-1
- Measurement of 132Xe(d,d') (and 14O) was performed at HIMAC.
  - Elastic peak is observed. The excitation energy resolution is **3.8 MeV FWHM** (preliminary).
- ISGMR in 132Sn will be studied via (d,d') reaction using CAT in near future.
  - Systematic measurement of ISGMR can be performed at RIBF.
    - 132Sn, 106Sn, A=132 isobar etc.

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Collaborators

- CAT development
  - **S. Ota, H. Tokieda, C.S. Lee, Y.N. Watanabe**, R. Kojima, Y. Aramaki, S. Michimasa, H. Matsubara, M. Dozono, M. Takaki,Y. Kiyokawa, (CNS) J. Zenihiro (RIKEN)
- with help by
  - H. Yamaguchi, K. Yako (CNS) H. Otsu, T. Uesaka (RIKEN)
  - E. Takada (NIRS)
- H307 (140)
  - CAT developper (left)
  - Y. Kubota, T. Nakao, T. Nichi, Y. Tanaka, K. Okochi, A. Obertelli, A. Corsi, C. Santamaria, J. Gibelin, Y. Matsuda, Y. Maeda
- H307 (132Xe)
  - CAT developperY. Maeda, S. Gotanda, xxx, U. Garg, Y. Guputa, T. Peach
- RIBF113 (132Sn) to be done
  - S. Ota, U. Garg et al.