Double and single charge exchange reactions on ^{48}Ca by ^{12}C beam at 250 A MeV”

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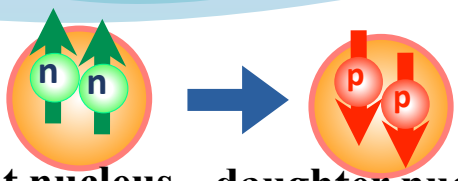
Double Gamow–Teller transition



parent nucleus ^{A}Z daughter nucleus $^{A}(Z+2)$

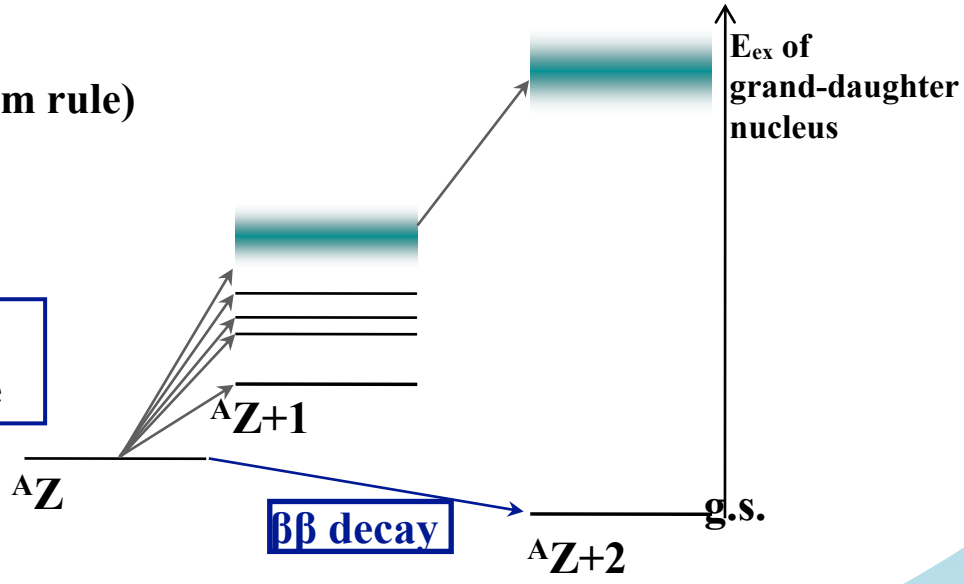
Double Gamow–Teller transition

- sequential occurrence of Gamow–Teller transition

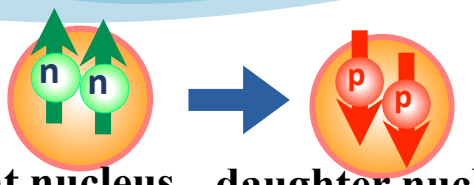
double β decay ($^{A}Z \rightarrow .^{A}(Z+2) + 2e^{-} + 2\bar{\nu}_e$)

- **the only process observed so far as double Gamow–Teller transition**
- **limited to transition around g.s. (~10^{-4} of sum rule)**
- **observed for ~ 10 nuclei (^{136}Xe, ^{48}Ca,…)**

✓ **experimental information about Double Gamow–Teller transition is scarce**



Double Gamow–Teller transition



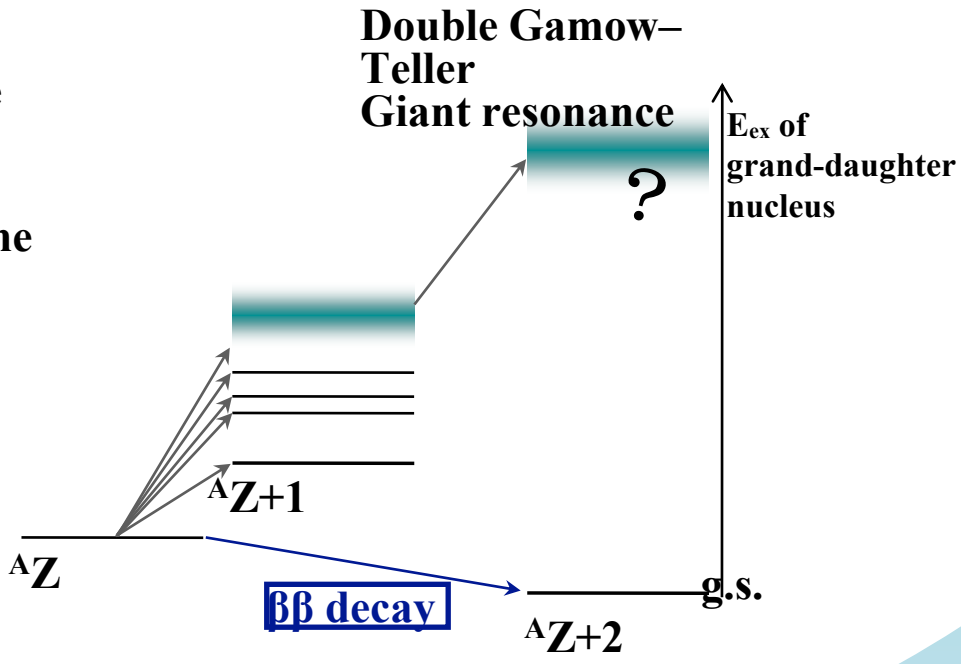
parent nucleus ^{A}Z daughter nucleus $^{A}(Z+2)$

Double Gamow–Teller transition

- sequential occurrence of Gamow–Teller transition

<u>double Gamow–Teller giant resonance (DGTGR)</u>
is expected to exist at high energy region

- **DGTGR will occupy most part of sum rule**
- **experimentally unobserved so far**
- **DGTGR information give a constrain on the nuclear matrix element (NME) for neutrinoless double beta decay (0νββ)**
  - **NME relates m_ν and the lifetime of 0νββ**
  - **current value of NME has large uncertainty**

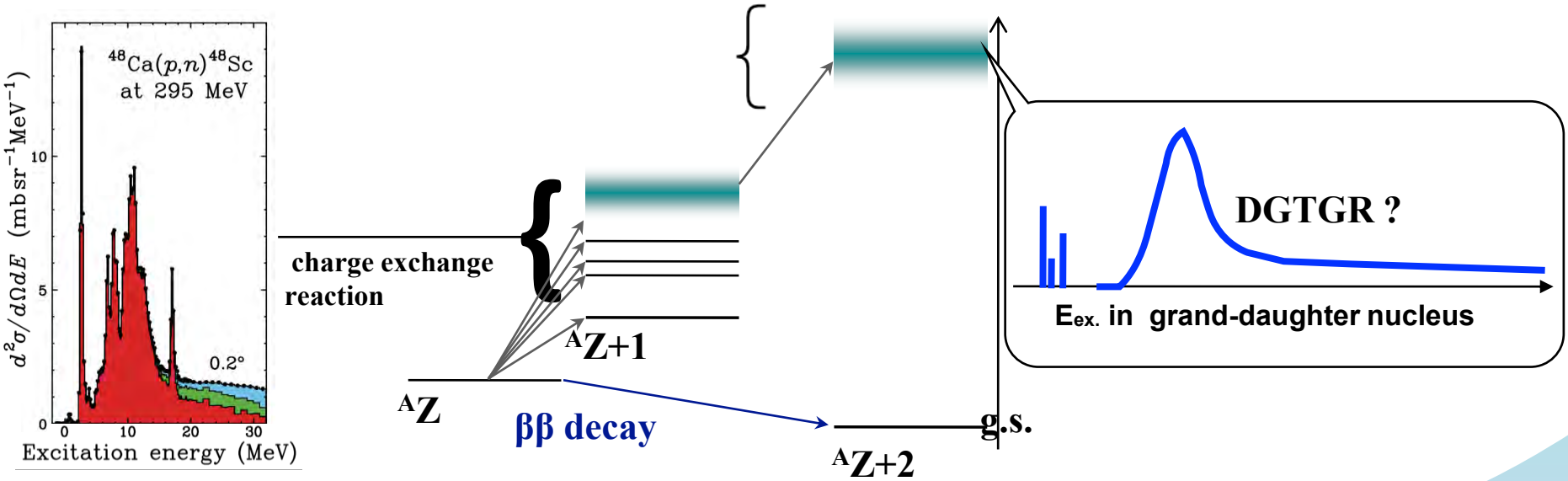


aim of this research :
first observation of DGTGR

Double charge exchange reaction

Single Gamow–Teller giant resonances: populated by **charge exchange reactions** ((p,n), (n,p), …)

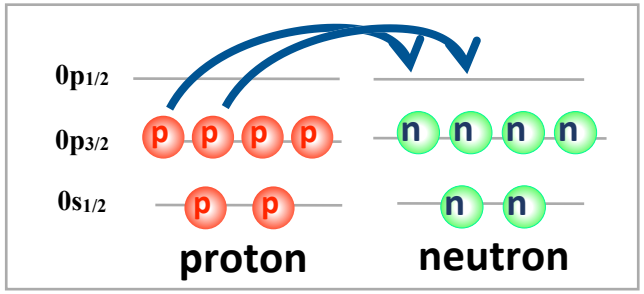
DGTGR will be populated by **double charge exchange** reaction



(^{12}C, ^{12}Be(0^+_2)) reaction

Double charge exchange utilize heavy ion : (^{12}C, ^{12}Be(0^+_2))

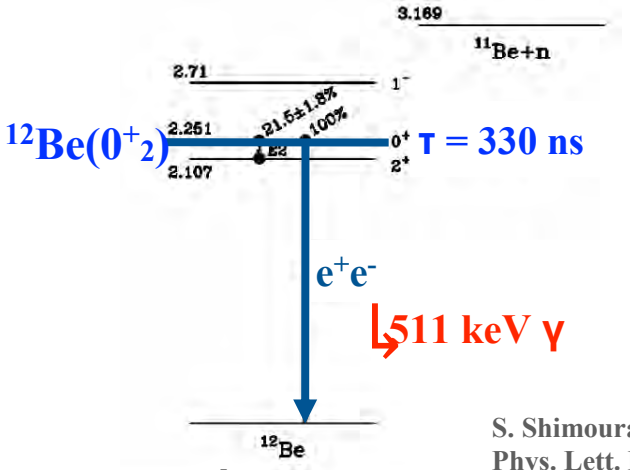
- **Transition strength will be strong**



^{12}C($0^+_{g.s.}$) → ^{12}B($1^+_{g.s.}$) → ^{12}Be(0^+_2)

all states are dominated by $0\hbar\omega$ configurations

- **^{12}Be(0^+_2) is a long-life isomer state**



S. Shimoura et al.,
Phys. Lett. B 654, 87 (2007)

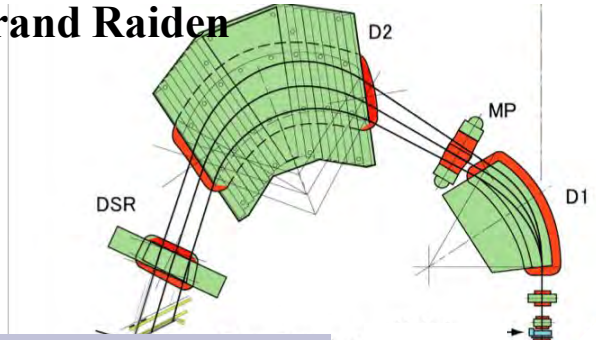
delayed photons are used in TD of isomeric state

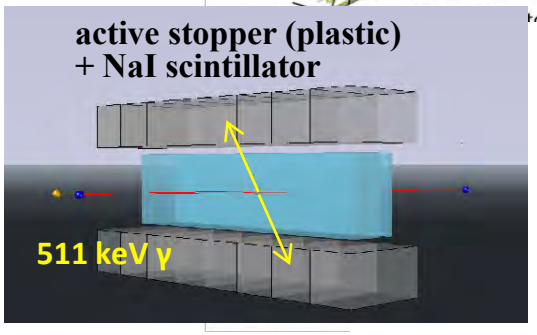
Coincidence measurement with 511-keV photons -> select DGT event

previous measurement at RCNP

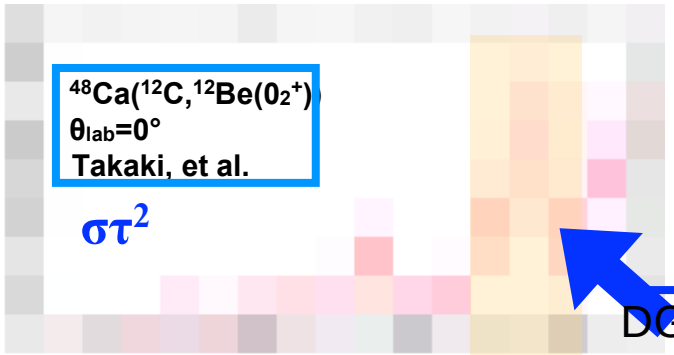
M. Takaki et al.

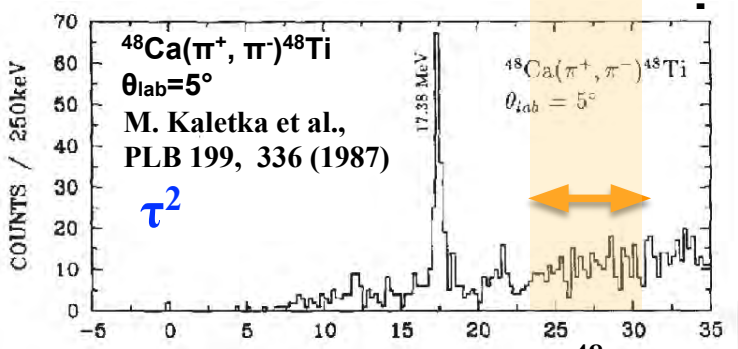
Grand Raiden

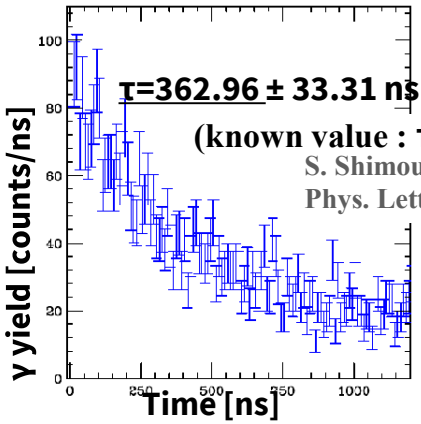




100 MeV/u,
16 pnA ^{12}C beam





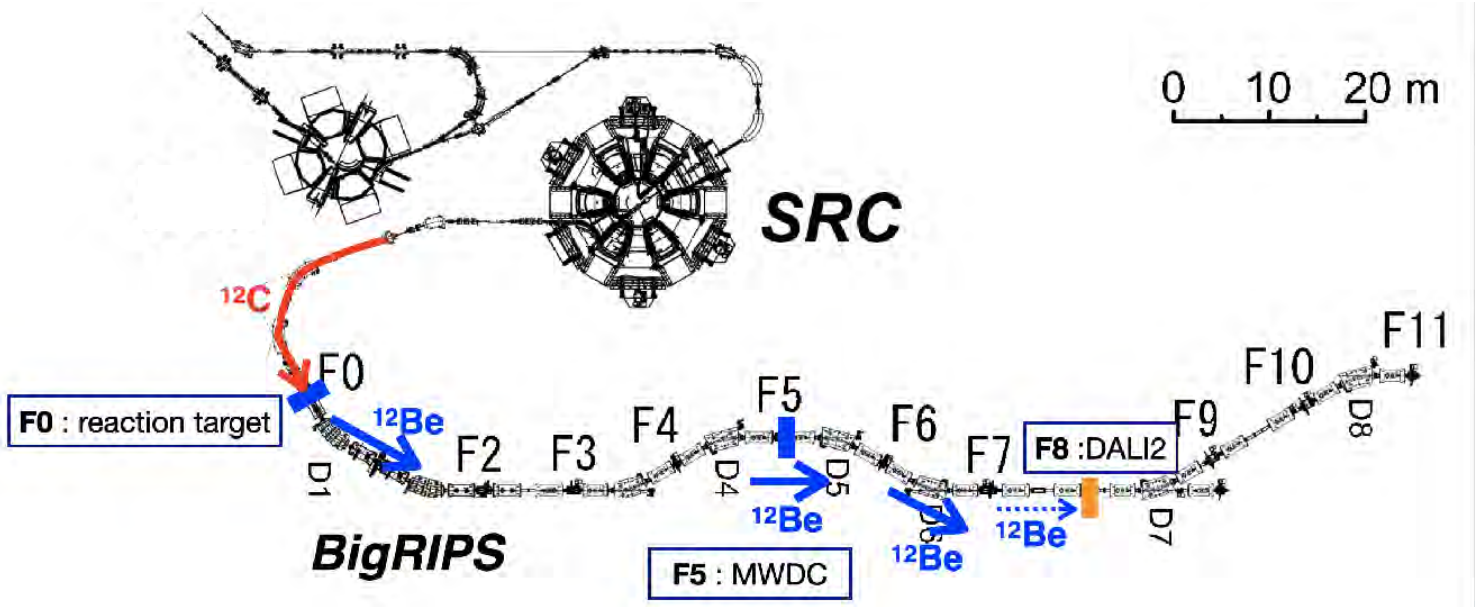


◎ ID of ^{12}Be(0$^+_2$) by γ measurement
△ Statstics
△ BG γ from ^{12}C (stopper)

(^{12}C, ^{12}Be(0^+_2)) meas. at RIBF BigRIPS

RIBF BigRIPS is suitable for measurement of (^{12}C, ^{12}Be(0^+_2))

- **intense ^{12}C primary beam from SRC**
- **BigRIPS F0-F5 as a spectrometer (established by piA group)**
- **BG (^{3}H, ^{6}He, ^{9}Li) eliminated by degraders**
- **511-keV photons from ^{12}Be(0^+_2) are detected by DALI2**



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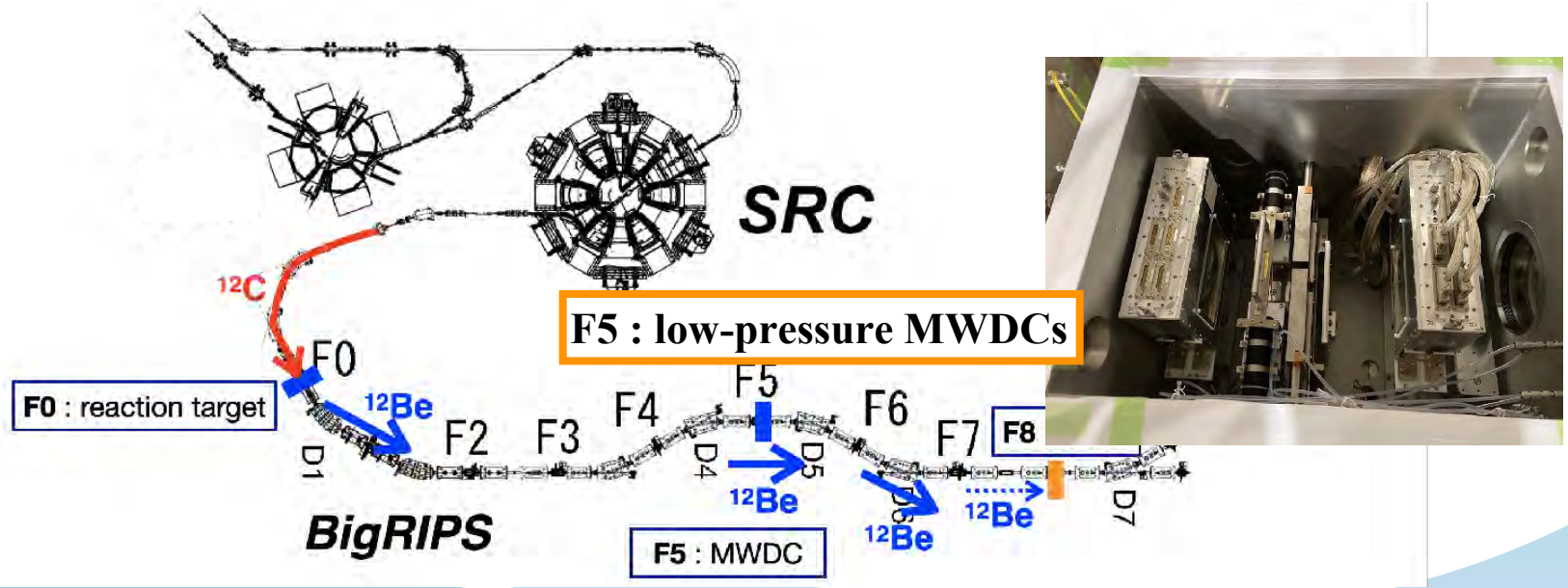

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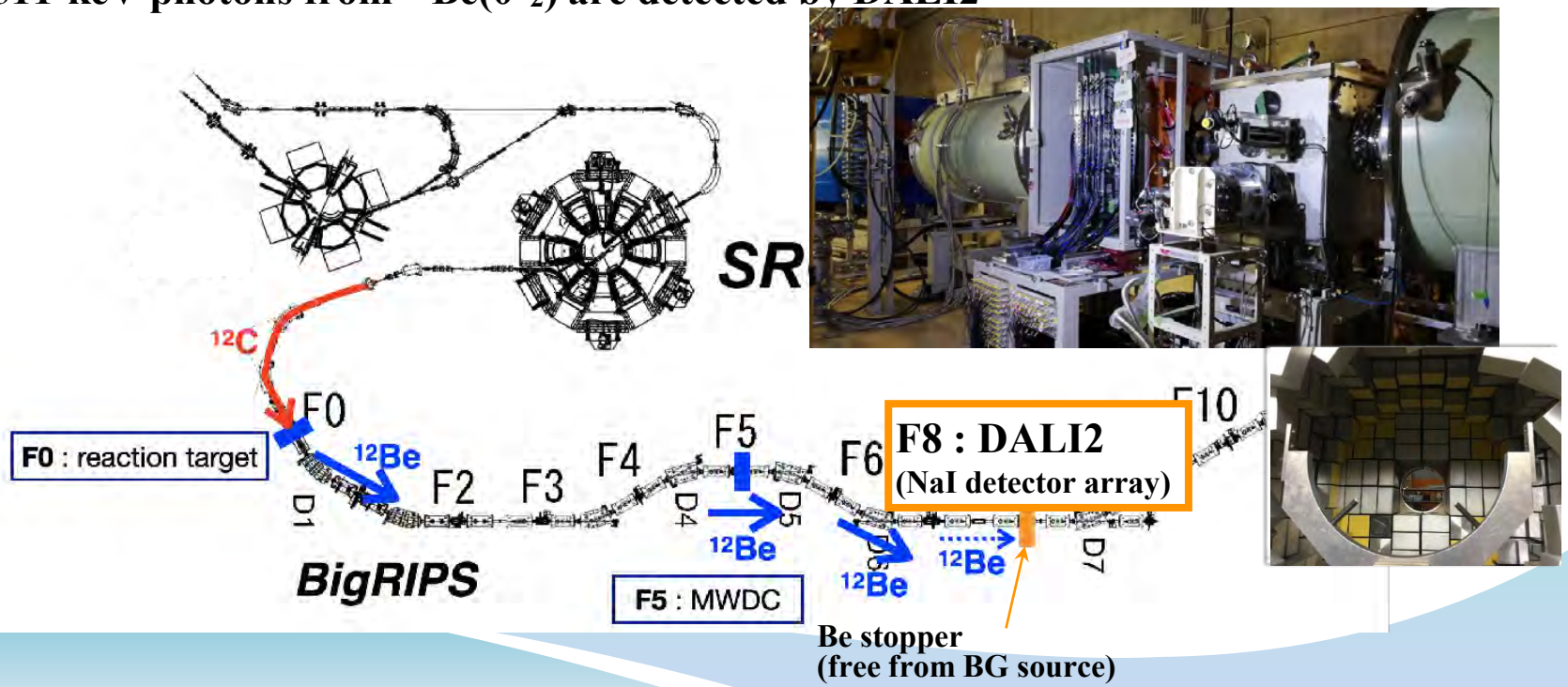


Measurement at RIBF

21th-29th May 2021

Single ch-x reaction (^{12}C, ^{12}B)

Double ch-x reaction

- Targets : ^{48}Ca 10 mg/cm^2, ^{116}Cd 40 mg/cm^2
- ^{48}Ca target was sandwiched by graphene sheets (4 μm) for preventing oxicidation / nitrization
- Beam intensity : 500 pnA
- ^{48}Ca : 40 hours, ^{116}Cd : 20 hours, ^{12}C BG : 2 hours

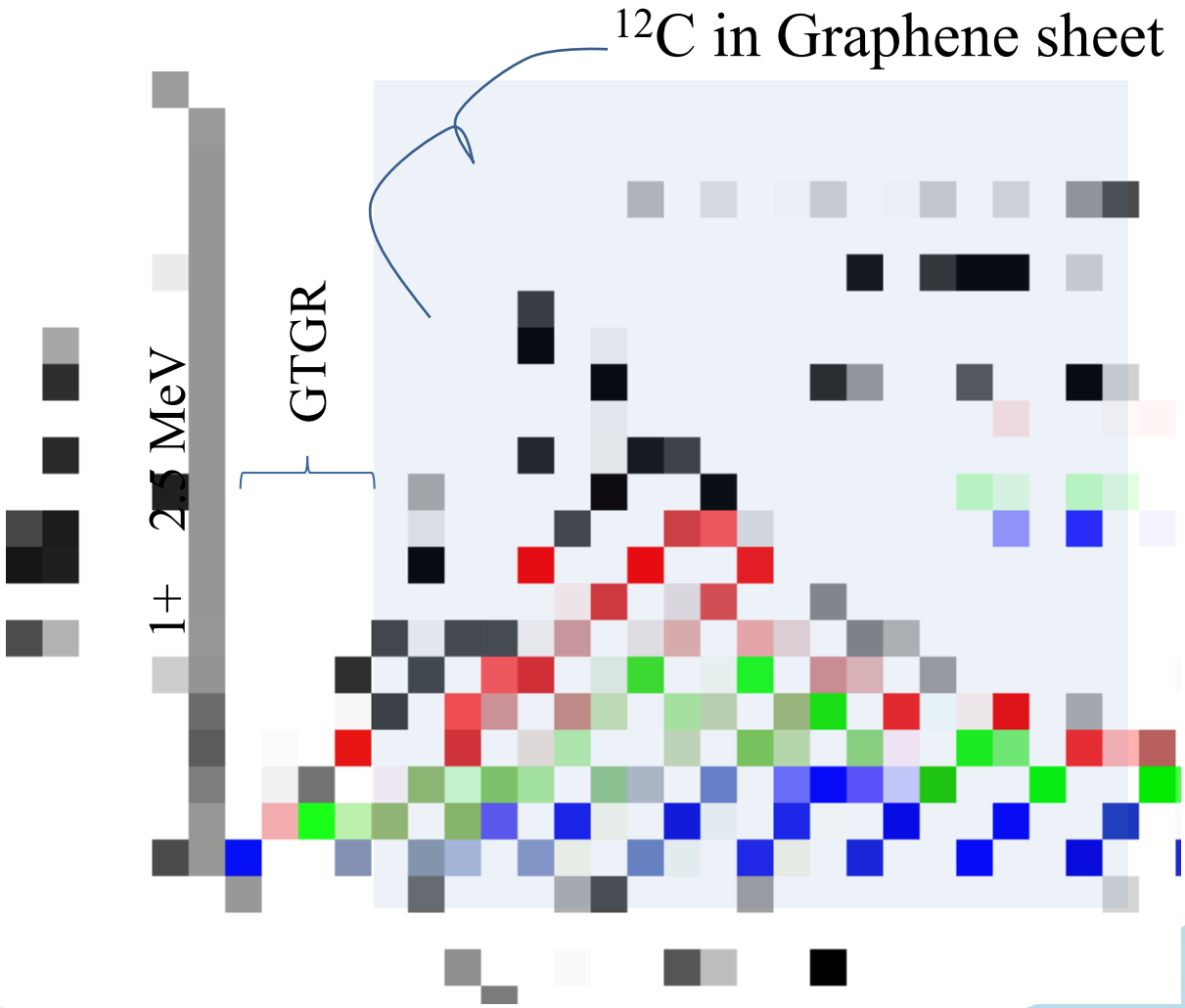
Result: Single Ch-X data

- c.s. up to 14 MeV
  @ 0deg
  ~ 3mb/sr

- ^{12}C contribution above 15 MeV

Angular dist.

- Forward peak
  GT ($\Delta L=0$)

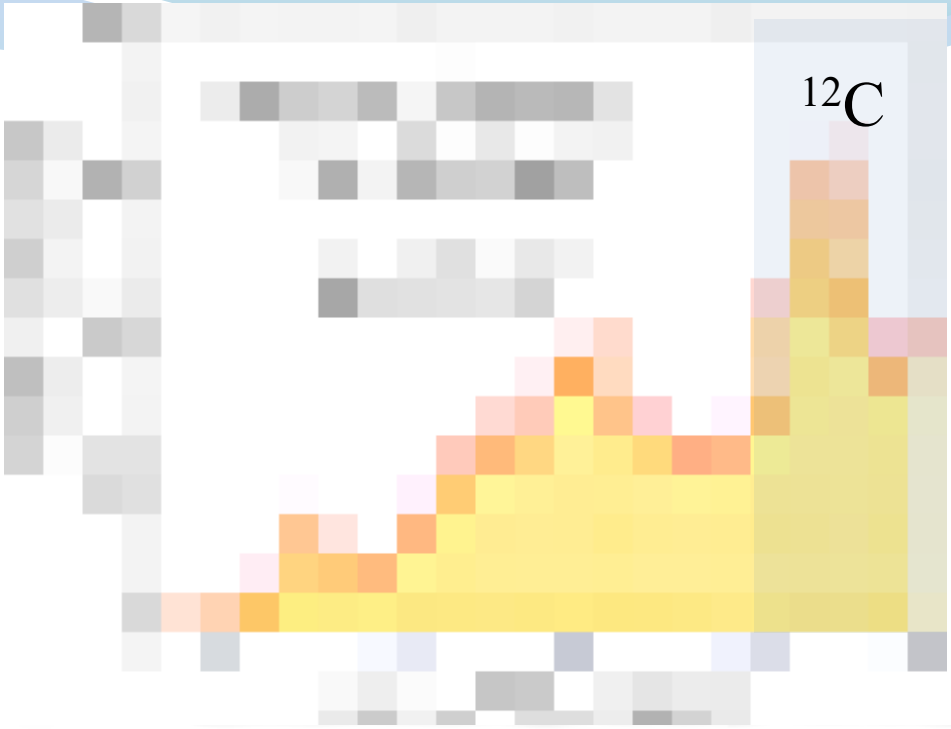


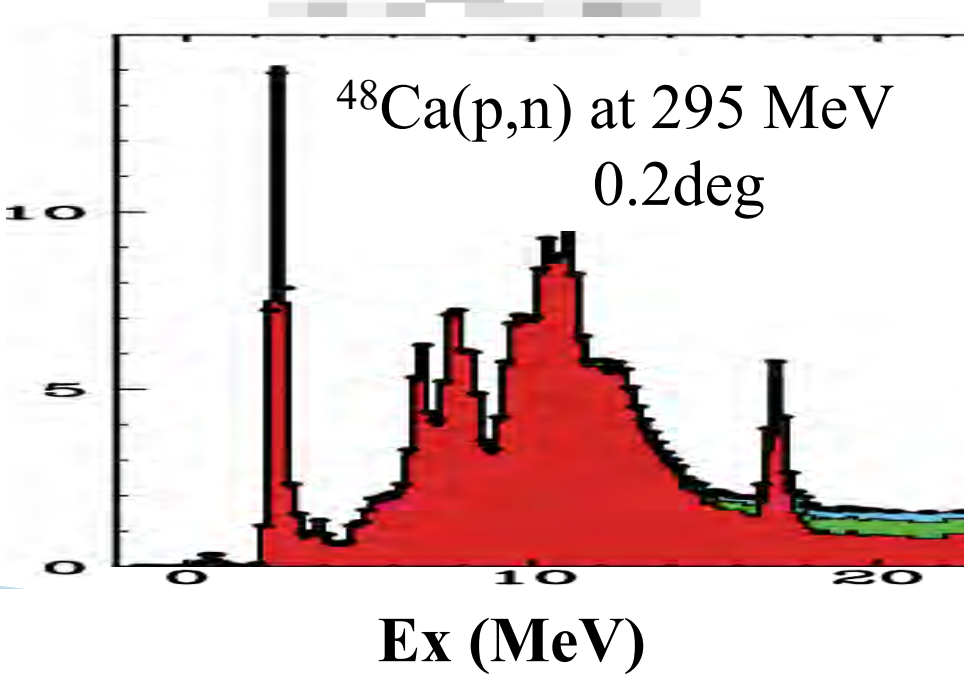
Single ch-x data

… spectrum at 0 deg.

Comparison with (p,n)…
reasonable correspondence.

Larger beam momentum
-> large momentum transfer
for the same scatt. angle.
-> larger contribution from
finite ΔL components.





Calculation of diff. c.s. : FOLD/DWHI

- Transition form factors by FOLD

  Double-folding the effective NN interaction over the transition densities of the projectile-ejectile and the target-residual systems.

  $$F_{\alpha\beta}(R) = \int d\xi_p d\xi_t \ \rho_p(\xi_p) V^\tau(R, \xi_p, \xi_t) \rho_t(\xi_t)$$

  - Franey-Love int.

  Transition densities are constructed from single particle wave-functions and one-body transition densities (OBTD)

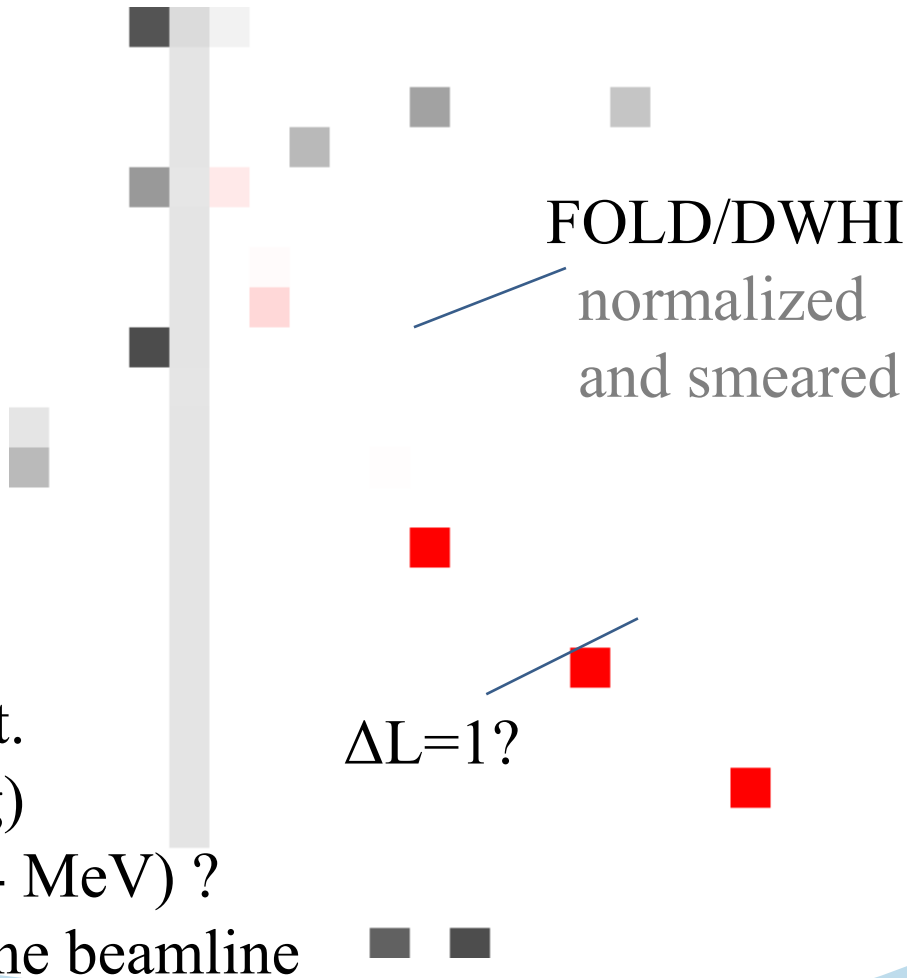
  - Radial w.f.: Woods-Saxon
  - OBTD from shell model (OXBASH)

- Optical model parameters by double-folding-model procedure by using a complex Gaussian-parametrization of G-matrix int. CEG07b (T. Furumoto et al., PRC 85,044607 (2012))

Angular distribution

Ex=2.5 MeV bin:
1+ is the main component

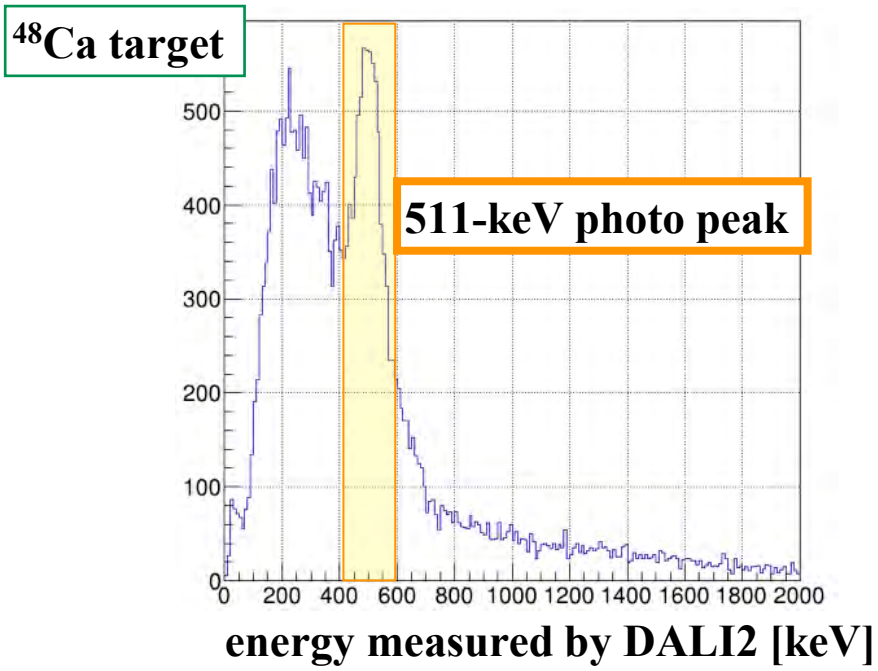
FOLD/DWHI calc
- Projectile (^{12}C, ^{12}B) transition density from Cohen-Kurath int.
- Target Simple (f7/2, f7/2)

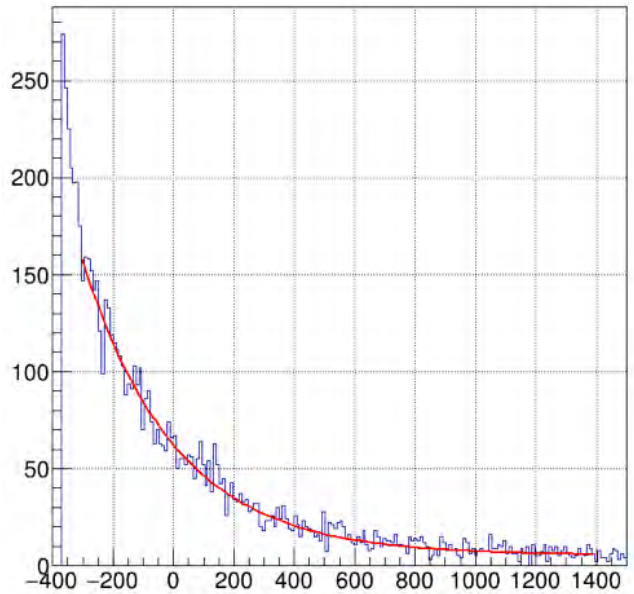


Comparison…
- Smearing of calc. angl. dist. was necessary (σ = 0.3 deg)
- ΔL=1 component (2- at 1.4 MeV) ?
- Ion-optical parameters of the beamline is being checked from calib. data.

Results – identifying ^{12}Be(0^+_2)

511-keV photons from ^{12}Be(0^+_2) were observed by DALI2





DALI eff. ~ 30%

fit function : $a \cdot \exp(-t/\tau) + (\text{flatBG})$

decay constant τ = 306 ± 8.0 ns
(cf. known value = 330 ns)

S. Shimoura et al.,
Phys. Lett. B 654, 87 (2007)

Double ch-x data

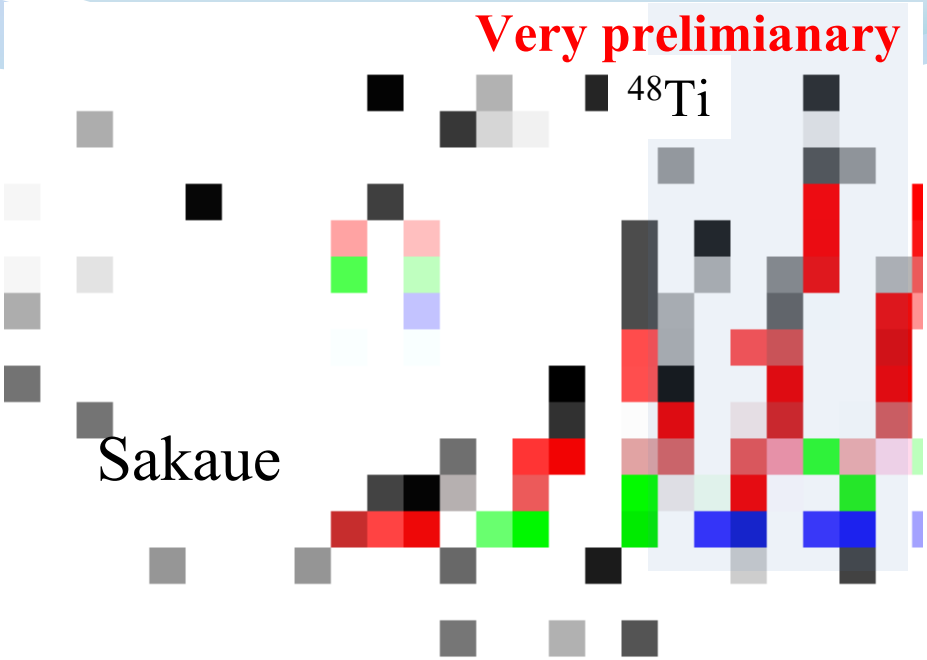
First touch…
uncertainty of Ex~ ±2MeV

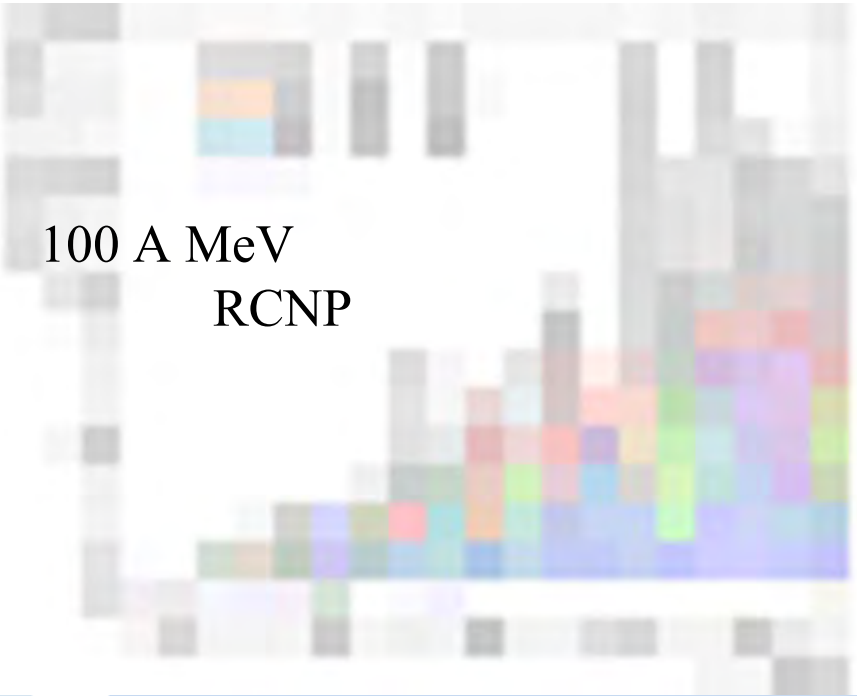
c.s. up to 40 MeV @ 0deg
~ 1μb/sr

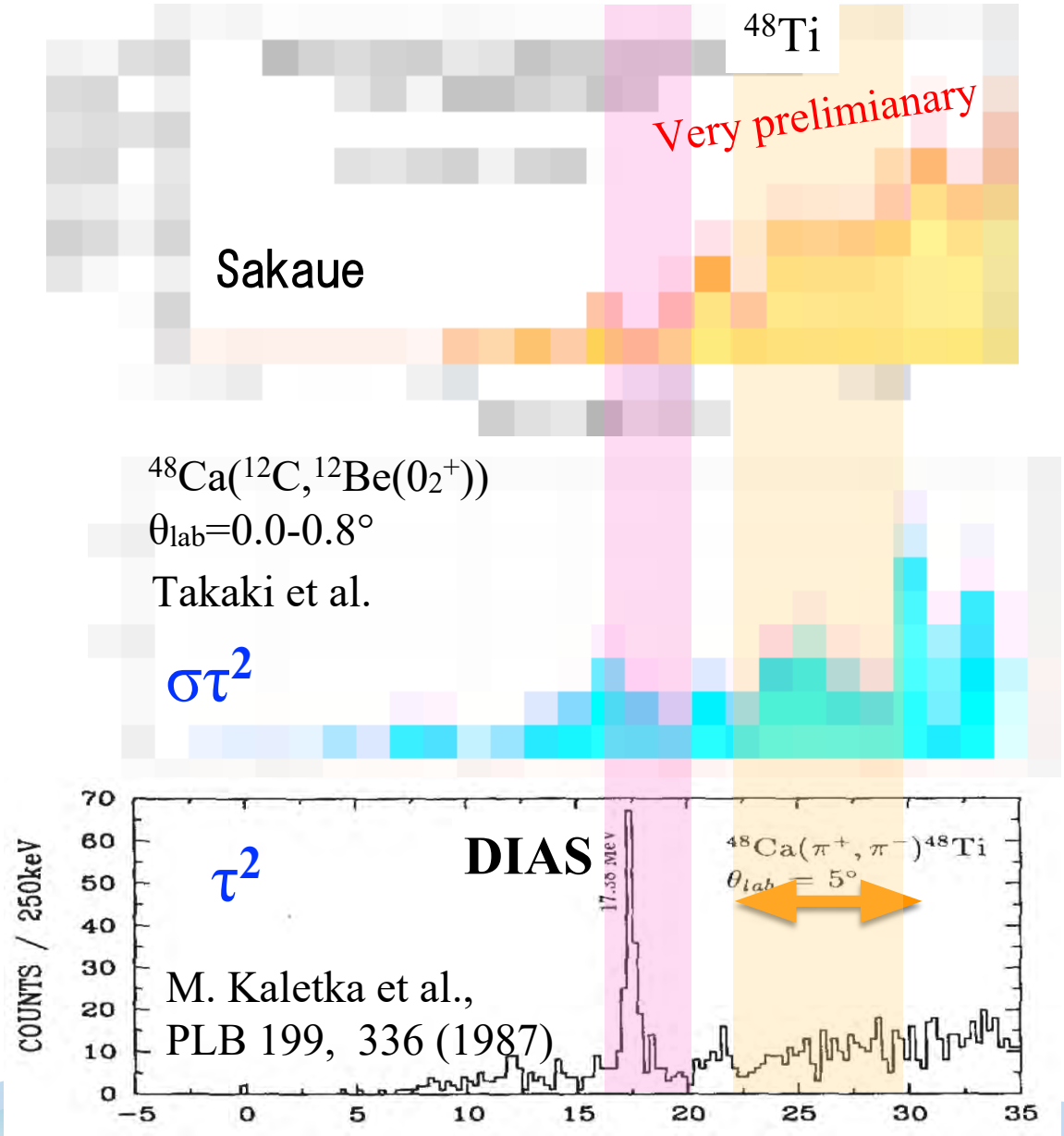
Forward-peaking nature stands out at 250 A MeV

- Is 0-deg spectrum dominated really by ΔL=0 excitations?
- Is reaction mechanism different
  from 100 MeV?
  from single Ch-X?
- Data ?

Very prelimianary







Compareson with RCNP data

Advantage:
- no b.g. subtraction in photon detection side

Disadvantage:
- statistics

Summary

- We are aiming at first observation of Double Gamow–Teller Giant Resonance (DGTGR)
- Double charge exchange reaction using heavy ion : (^{12}C, ^{12}Be(0^{+}_{2}))
- RIBF-BigRIPS is suitable

  … intense ^{12}C primary beam with dispersion matching optics

  … BigRIPS separater as a spectrometer

  … delayed-gamma detection by DALI2
- first experiment at RIBF in May 2021

  … dispersion matching worked well / good event identification with DALI2

  Data reduction is in progress.

First touch of the data

- Single Ch-X data

  Reasonable 0deg spectrum with GT transitions. (12C,12B) is a good spectroscopic tool.

- Double Ch-X data

  0deg: Similar structure as we saw in RCNP data (100 AMeV) is observed.

  Angular dist.: strong forward-peaking nature. Even stronger than single Ch-X.