Detector Array for Low Intensity radiation

DALI and DALI2

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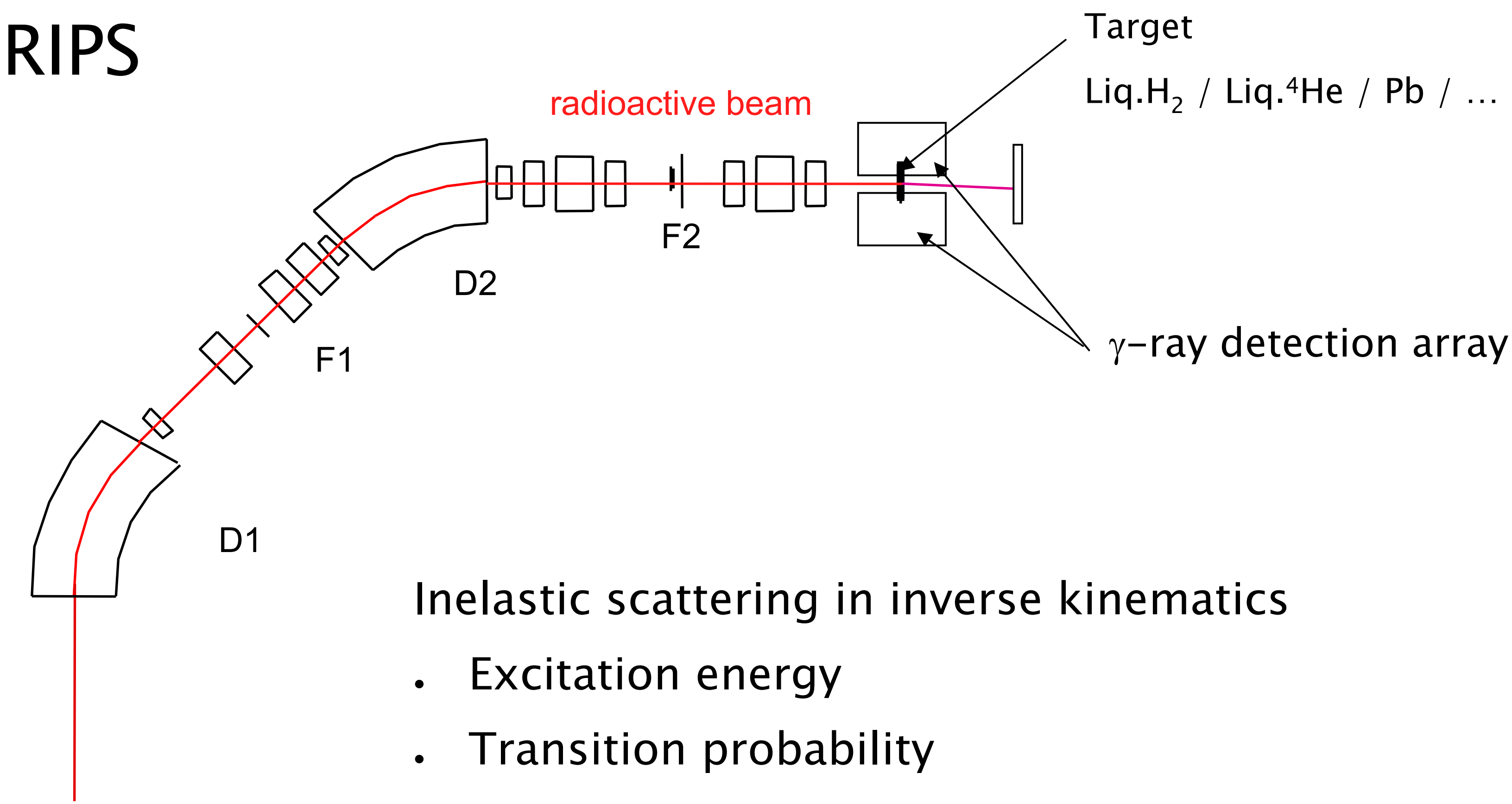
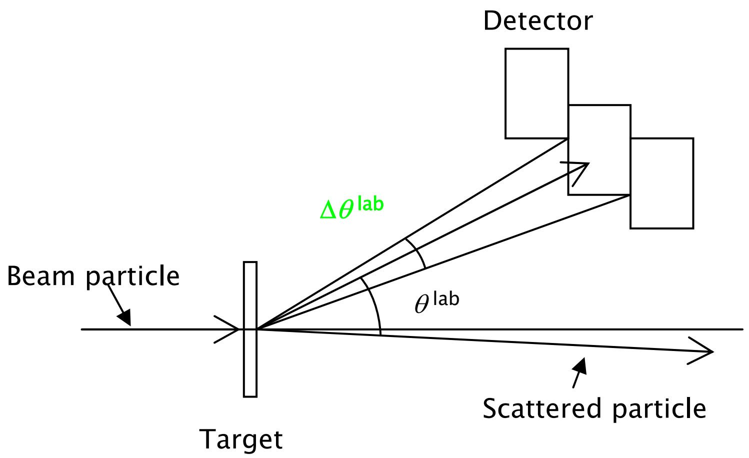
γ–RAY SPECTROSCOPY WITH UNSTABLE NUCELI



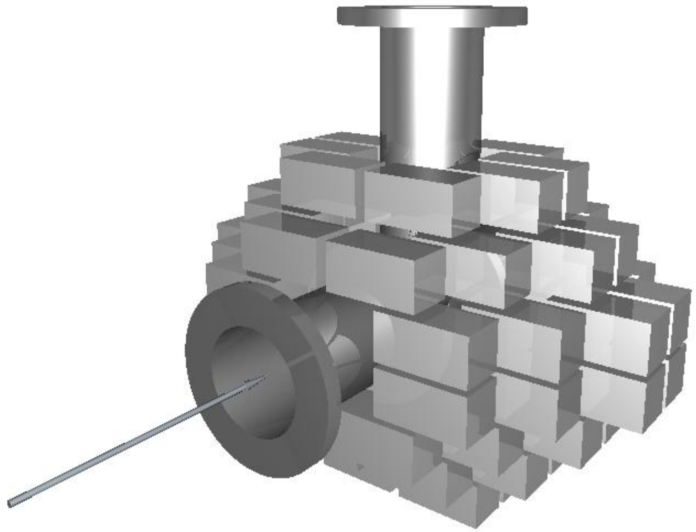
Inelastic scattering in inverse kinematics

- Excitation energy
- Transition probability
- Angular distribution for particle–γ

- Unstable nuclei
  - Low Beam intensity
    → High detection efficiency
- Fast secondary beams
  - RARF ($\beta \sim 0.3$) and RIBF ($\beta \sim 0.6$)
    → Doppler Shift
    Depending on the emission angle
    → High angular resolution for High energy resolution



DALI



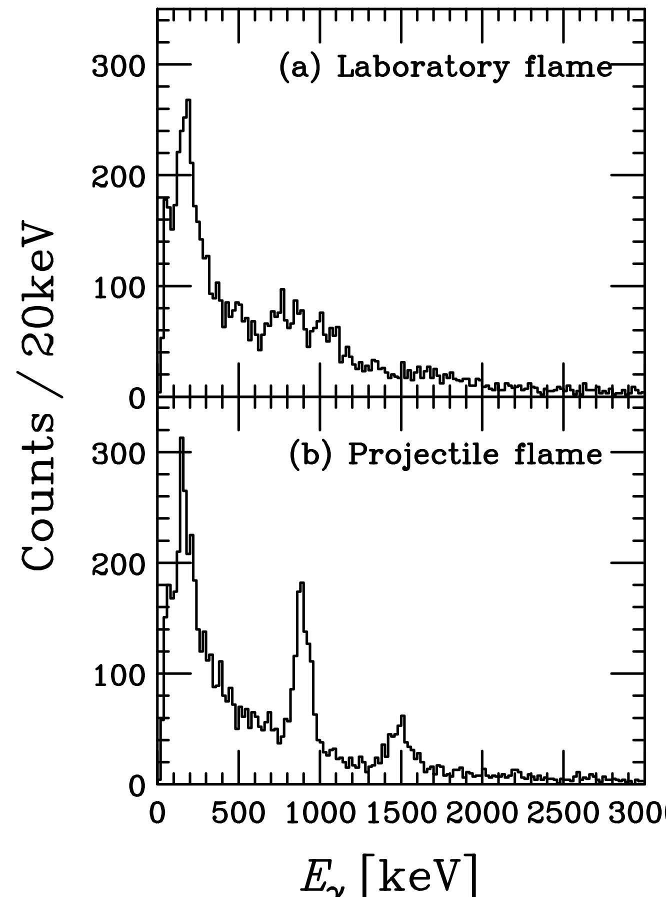
Previous system (typical spec.)

up to 68 NaI(Tl) detectors

angular resolution : ~15 degree

efficiency : about 15% for 1MeV

^{32}Mg(p,p') β~0.3



H.Hasegawa, Master's thesis, Rikkyo Univ., 2003

DEVELOPMENT of A NEW ARRAY

MOTIVATION:

- For More neutron-rich nuclei : Low Intensity
- For using at RIBF : Fast beam

REQUIREMENTS:

- Higher Efficiency
- Higher Angular Resolution

↔ • High Energy Resolution

• Angular Distribution measurements

↓

160 NaI(Tl) Detectors

Large Volume and Many Segments

DOPPLER SHIFT and BROADENING

$$E_\gamma^{\mathrm{proj}} = \gamma\left(1-\beta\cos\theta^{\mathrm{lab}}\right)E_\gamma^{\mathrm{lab}}$$

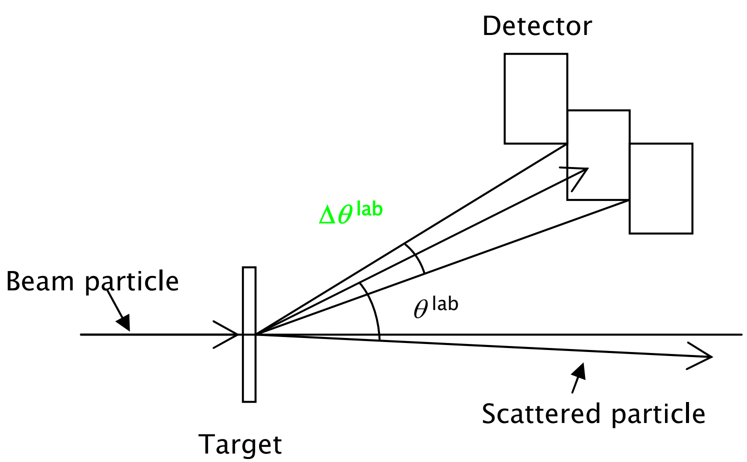
$$\left(\frac{\Delta E_\gamma^{\mathrm{proj}}}{E_\gamma^{\mathrm{proj}}}\right)^2 = \left(\frac{\beta\sin\theta^{\mathrm{lab}}}{1-\beta\cos\theta^{\mathrm{lab}}}\right)^2\left(\Delta\theta^{\mathrm{lab}}\right)^2 + \left(\frac{\beta\gamma^2\left(\beta-\cos\theta^{\mathrm{lab}}\right)}{1-\beta\cos\theta^{\mathrm{lab}}}\right)^2\left(\frac{\Delta\beta}{\beta}\right)^2 + \left(\frac{\Delta E_\gamma^{\mathrm{lab}}}{E_\gamma^{\mathrm{lab}}}\right)^2$$

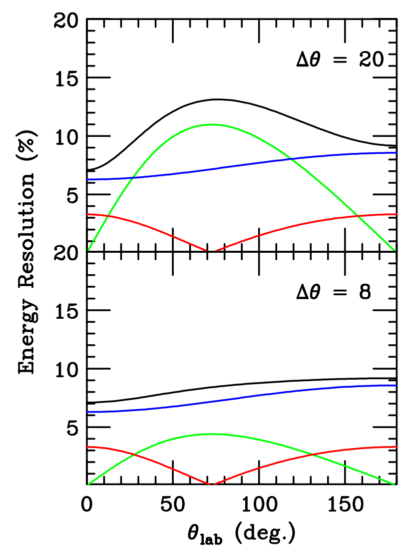
Detector arrangement

Beam velocity or

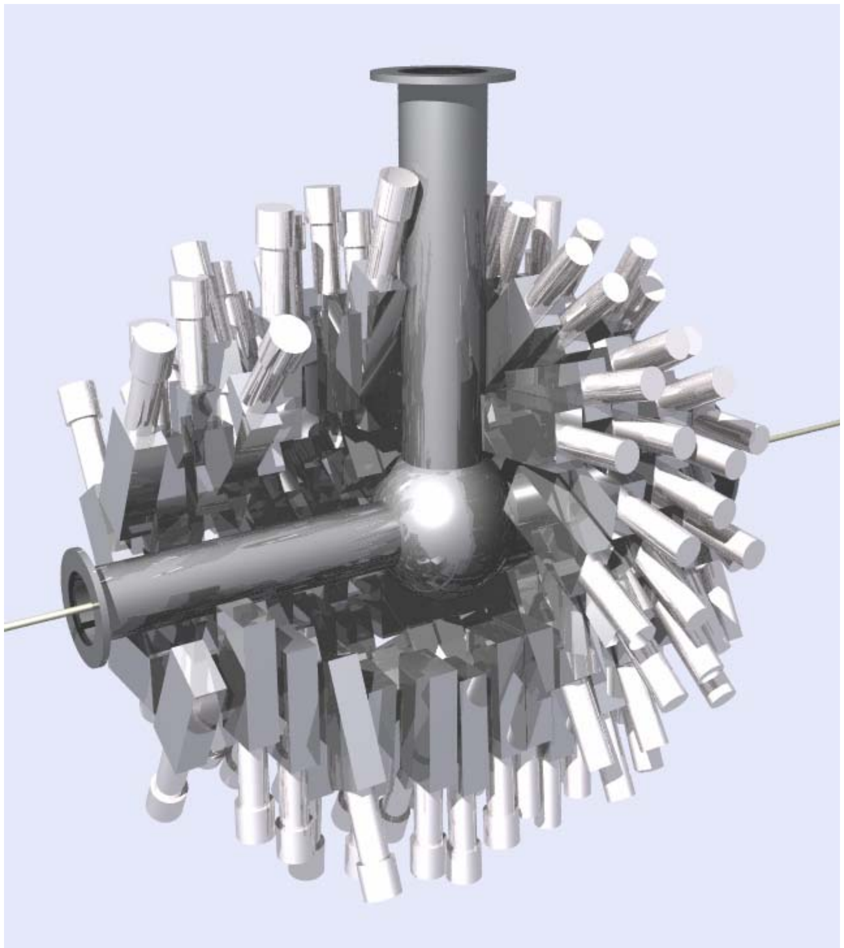
Target thickness

Intrinsic resolution





OVERVIEW – DALI2 –



160 NaI(Tl) detectors

Each detector
- 4.5 x 8 x 16 (cm^3)
- $\Delta E/E$ ~ 9% @ 662keV

Array
- 16 layers
- 6~14 detectors in each layer

SPECIFICATION

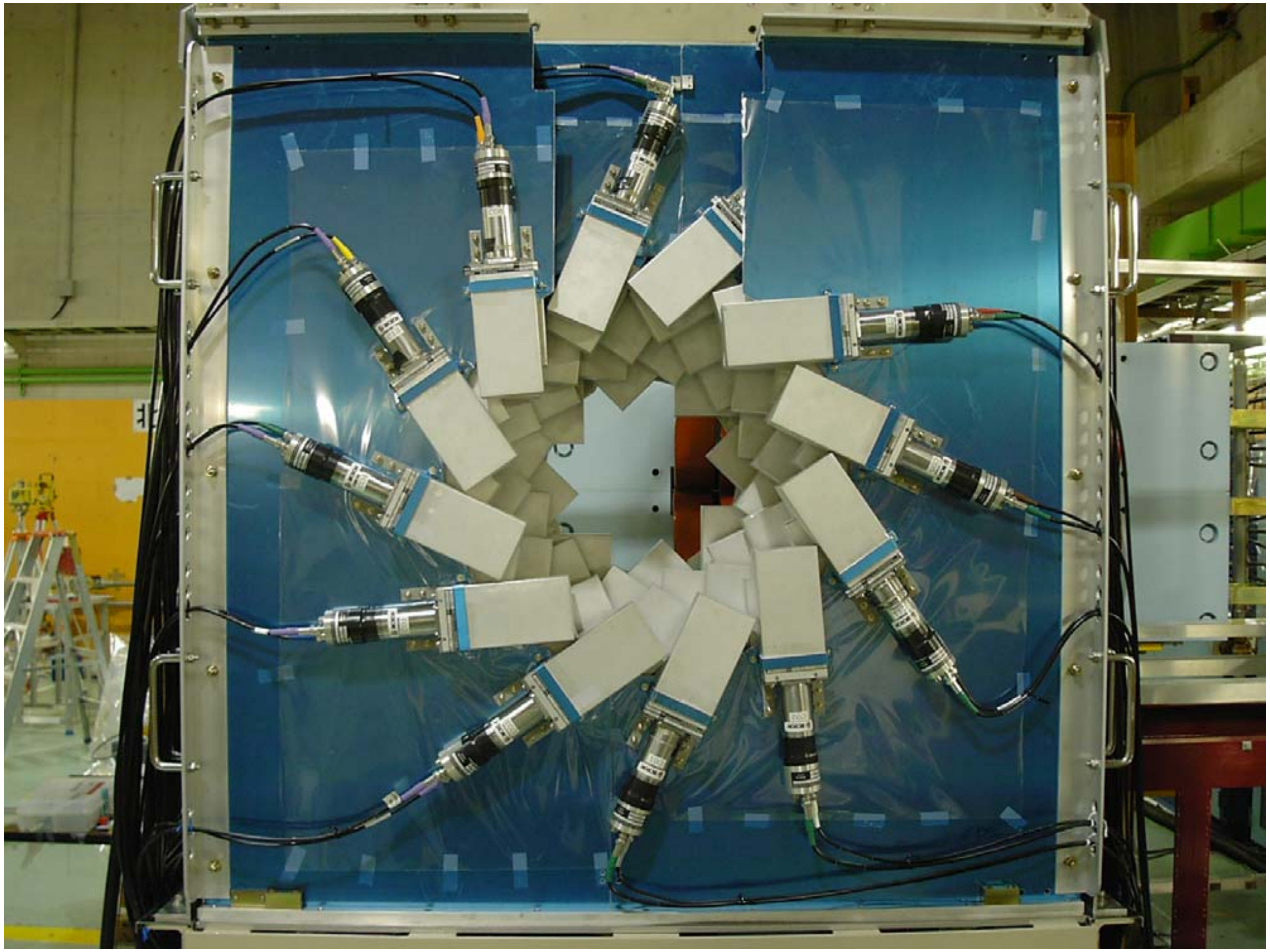
SAINT-GOBAIN x 80 detectors

- 45 x 80 x 160 (mm)
- About 8%@662keV (^{137}Cs)

SCIONIX x 80 detectors

- 40 x 80 x 160 (mm)
- About 9%@662keV(^{137}Cs)

Half of DALI2

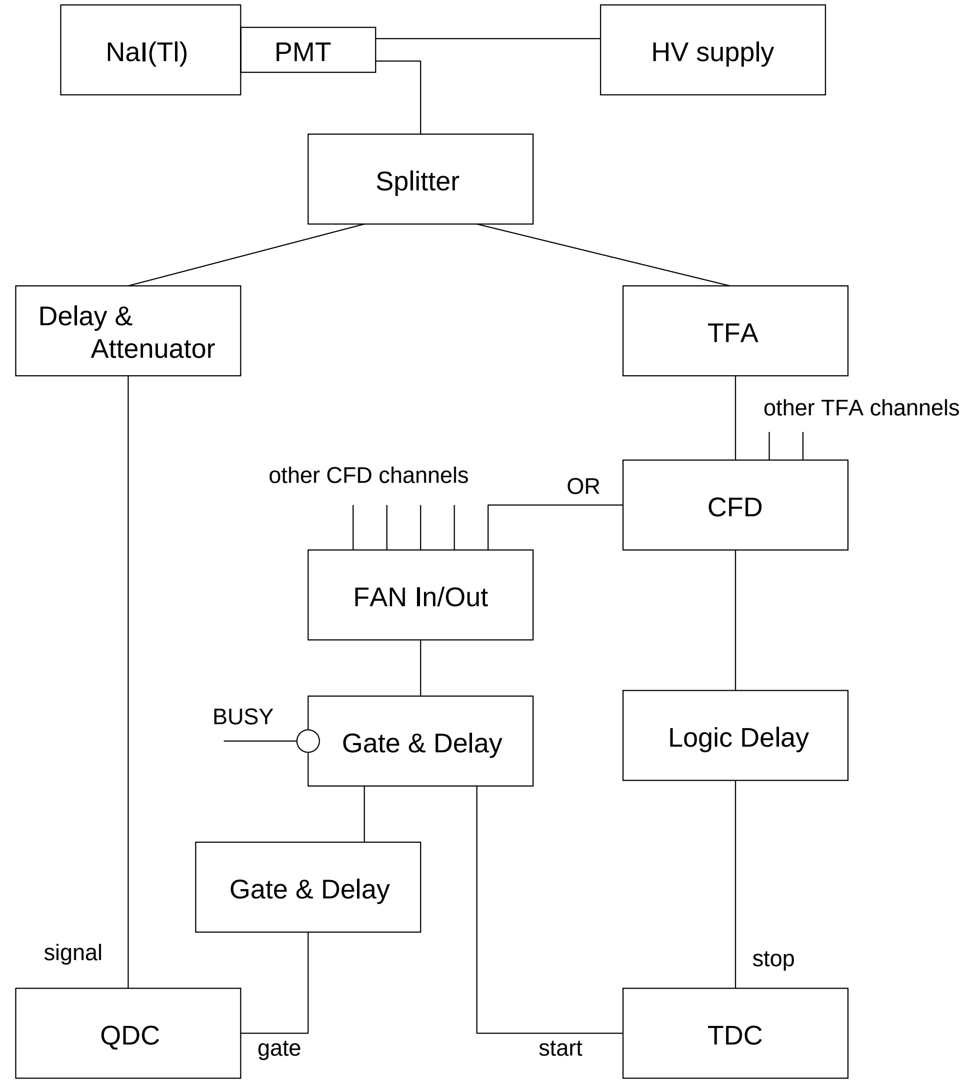


EXPERIMENT ROOM (E6 RIPS beam-line)

DALI  and DALI2 

	DALI	DALI2
Arrangement	Brick wall like	Hedgehog like
Size	6 x 6 x 12 (cm^3)	4.5 x 8 x 16 (cm^3)
# of Detectors	68	160
Volume	~ 30 liter	~ 90 liter
# of Layers	6 – 8	16
Angular resolution	~ 15 degree	~ 8 degree
Energy resolution (β~0.3)	12% @ 1MeV	8% @ 1MeV
Efficiency (β~0.3)	15% @1MeV	21% @1MeV

CIRCUIT



Att. : 6-10dB or NONE

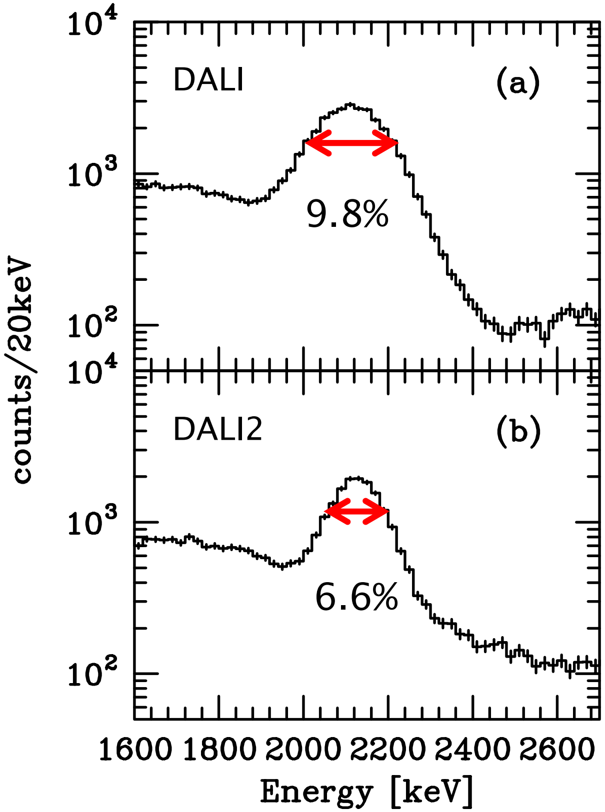
TFA : rise time ～ 50ns

QDC : GATE Width 500ns

Dynamic range
~100kev - ~5MeV

IMPROVEMENT of ENERGY RESOLUTION

$^{12}Be(\alpha,\alpha')^{12}Be^*$



$E\gamma = 2100$ keV, $\beta \sim 0.3$

(a) : DALI ($\Delta\theta\sim15°$)

$\Delta E/E = 9.8\%$ (FWHM)

(b) : DALI2 ($\Delta\theta\sim8°$)

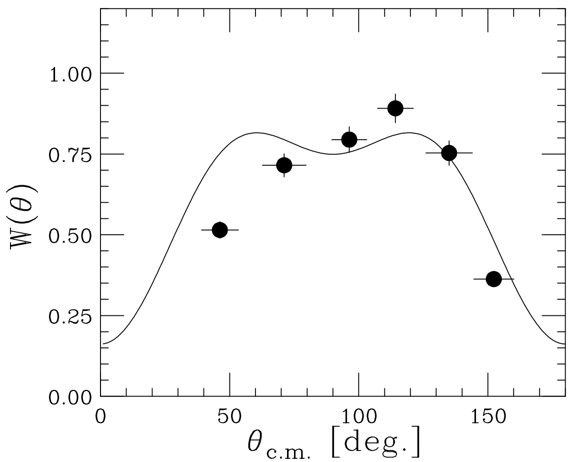
$\Delta E/E = 6.6\%$ (FWHM)

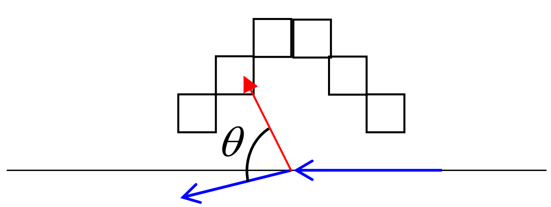
IMPROVEMENT of ANGULAR DISTRIBUTION

DALI

$^{36}Si(Be,Be')^{36}Si^{*}$

E(2+) = 1399 keV

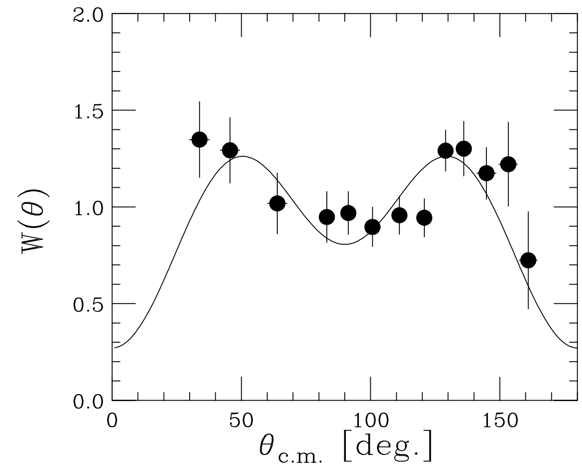


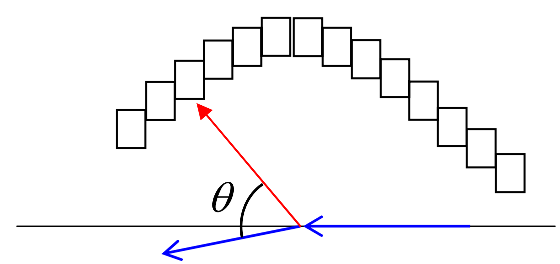


DALI2

$^{16}C(p,p')^{16}C^{*}$

E(2+) = 1766 keV



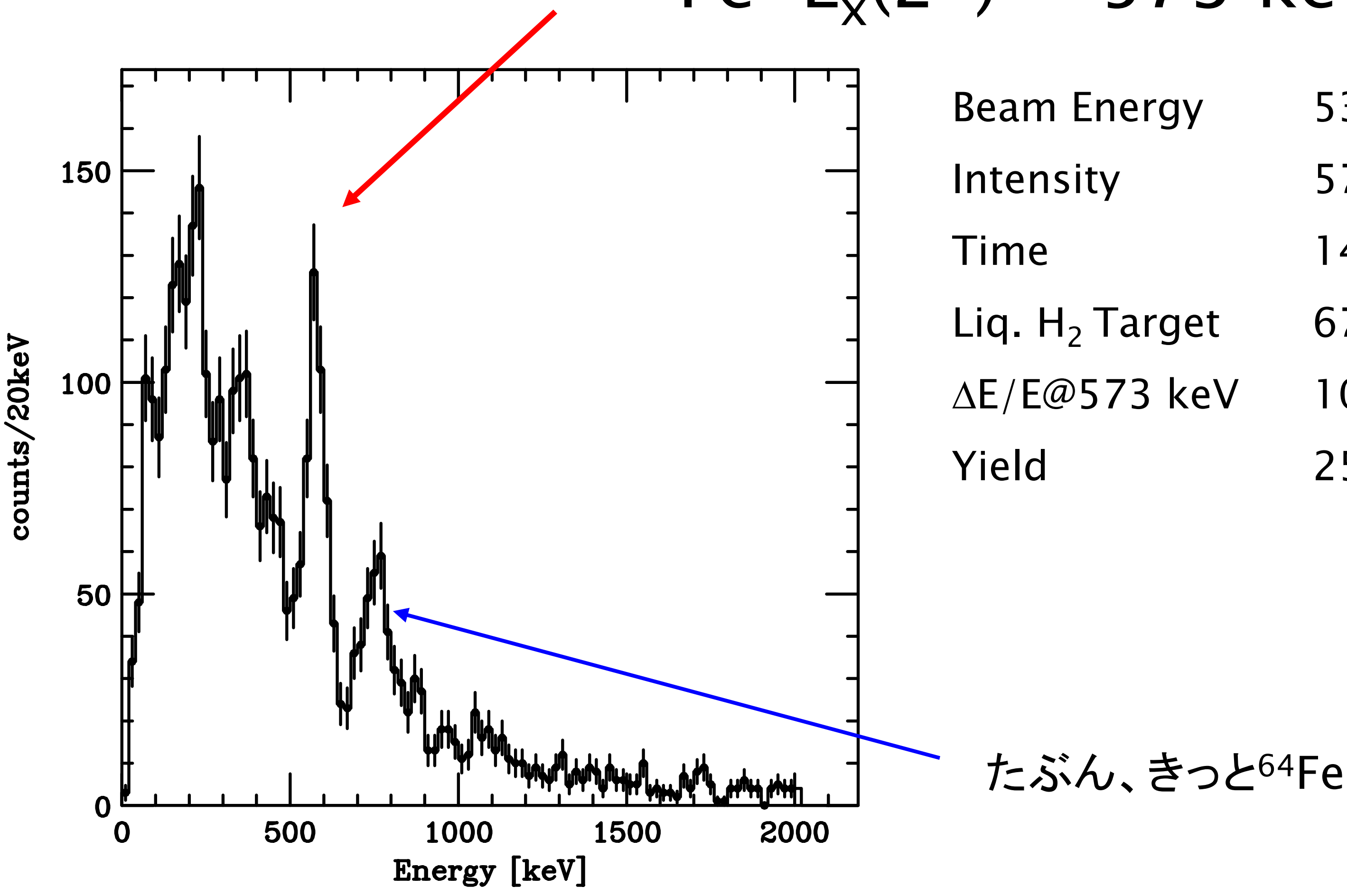


PAST EXPERIMENTS with DALI2

- $^{12}Be(\alpha,\alpha')^{12}Be^*$, $^{12}Be(\alpha,t)^{13}B^*$ (CNS, Rikkyo, RIKEN)
- ^{54}Ni, ^{50}Fe, ^{46}Cr Coulex (Rikkyo, RIKEN)
- $^{27}F(p,p')^{27}F^*$, $^{16}C(p,p')^{16}C^*$ (ATOMKI, Tokyo, RIKEN)
- $^{4}He(^{22}O,^{23}F^*)$ (CNS, RIKEN)
- $^{26}Ne(Pb,Pb)^{26}Ne^*$ (Orsay, TIT, RIKEN)
- $^{78-82}Ge$ Coulex (Tokyo, RIKEN)
- $^{19}C(p,p')^{19}C^*$ (ATOMKI, RIKEN)
- $^{22}O(d,p)^{23}O$ (ATOMKI, RIKEN)
- などなど。

EXAMPLES – $^{66}Fe(p,p')^{66}Fe^{*}$ –

$^{66}Fe^{*}$ $E_x(2^+)$ = 573 keV



Beam Energy	53.07 AMeV
Intensity	57 cps
Time	14 hours
Liq. H_2 Target	67–86mg/cm^2
ΔE/E@573 keV	10%
Yield	250 counts

Efficiency and Resolution

GEANT3 simulation

with target chamber and holder

β = 0.3(RARF), 0.6(RIBF)

$E\gamma$ = 0.5, 1.0, 2.0 MeV

	0.5 MeV	1.0 MeV	2.0 MeV
Eff. (β=0.3)	34%	21%	12%
Res. (β=0.3)	11.6%	8.0%	6.5%
Eff. (β=0.6)	31%	18%	8%
Res. (β=0.6)	14.8%	12.3%	9.8%

SUMMARY

- We have developed DALI2 for in-beam γ-ray spectroscopy with fast unstable nuclei (@RIBF).
- The performance is improved compared with DALI.
  - Energy Resolution $\Delta E/E \sim 8\%$@1MeV
  - Detection Efficiency $\varepsilon \sim 21\%$@1MeV
- Several experiments have already done with DALI2 and we are planning experiments with low intensity beam and/or measuring γ-γ coincidence.

COMING EXPERIMENTS with DALI2

- Inelastic scattering of ^{64}Cr (running)
- $\gamma-\gamma$ coincidence of ^{32}Mg and ^{34}Si
- Inelastic scattering of ^{42}Si

With Liquid hydrogen and/or helium targets

FUTURE EXPERIMENTS in RIBF

Efficiency and Energy resolution : 18% and 12% for 1MeV (β~0.6)
Target : More neutron-rich nuclei (ex. ^{78}Ni >0.1 cps)

Possible array for higher efficiency and energy resolution is the combination of DALI and DALI2. → '1+2=3' DALI3?