# In-beam $\gamma$-ray Spectroscopy of $^{97}$Cd

## CNS Summer School 2021

GAO, Ting

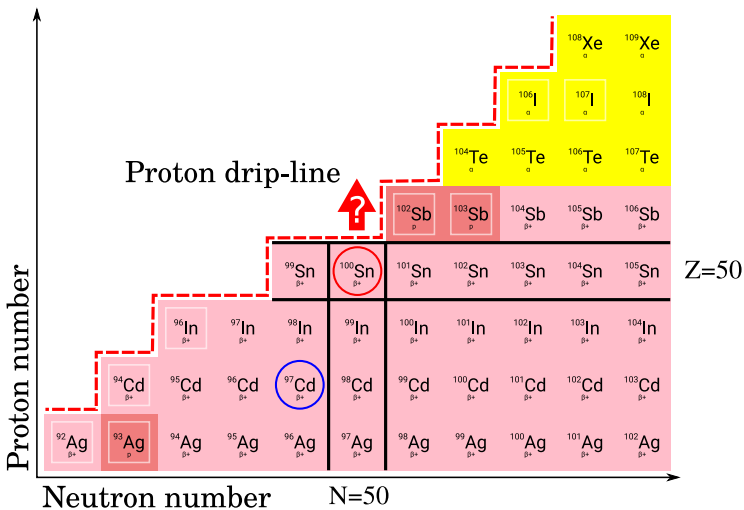Department of Physics
The University of Hong Kong

17 August, 2021

# Table of Contents

Bac. mot.
●○

Exp. met.
○○○○○○

Exp. res.
○○○○

The. res.
○○

Sum.
○○

# In the near $^{100}$Sn region



Proton drip-line

Z=50

Proton number

Neutron number          N=50

# Rapid proton capture (rp) process



**proposed endpoint** α-emitters in the Te-Xe range

**region of high deformation**

**dripline**

stable isotope

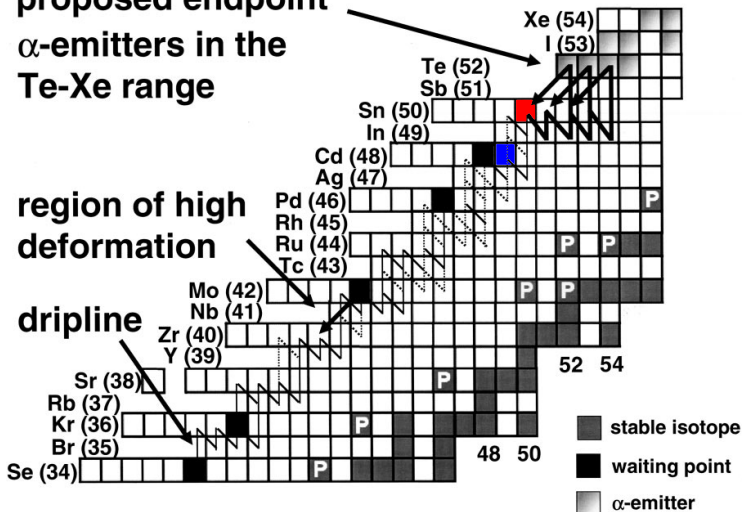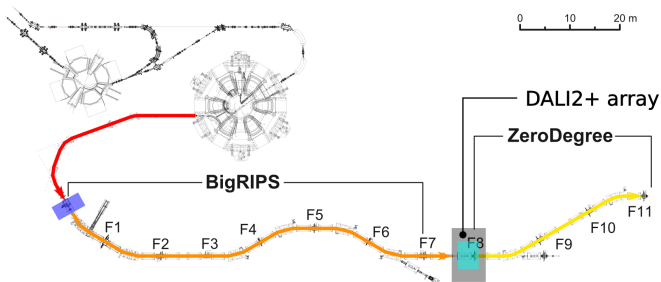waiting point

α-emitter

Diagram retrieved from Phys. Rev. C **67**, 034310 (2003)

# BigRIPS and ZeroDegree Spectrometer



## Experiment info

|      | Beam           | Target      | Energy         | Intensity      |
|------|----------------|-------------|----------------|----------------|
| Pri. | $^{124}$Xe     | $^9$Be      | ~345 MeV/u     | ~140 pnA       |
| Sec. | $^{100}$In     | $C/CH_2$    | ~147 MeV/u     | ~122 cps       |
| Sec. | $^{99}$Cd      | $C/CH_2$    | ~145 MeV/u     | ~690 cps       |

Diagram retrieved from RIKEN website.

# PID technique



PPAC x 2                PPAC x 2        PPAC x 2
Plastic scintillation counter            Plastic scintillation counter
                                         Ion chamber/Si detectors
                                         Ge detectors
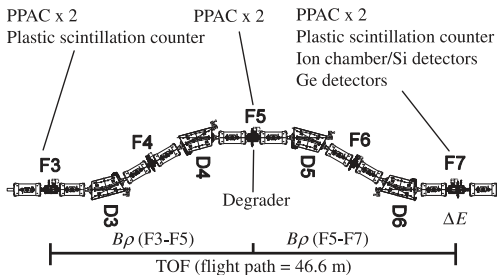
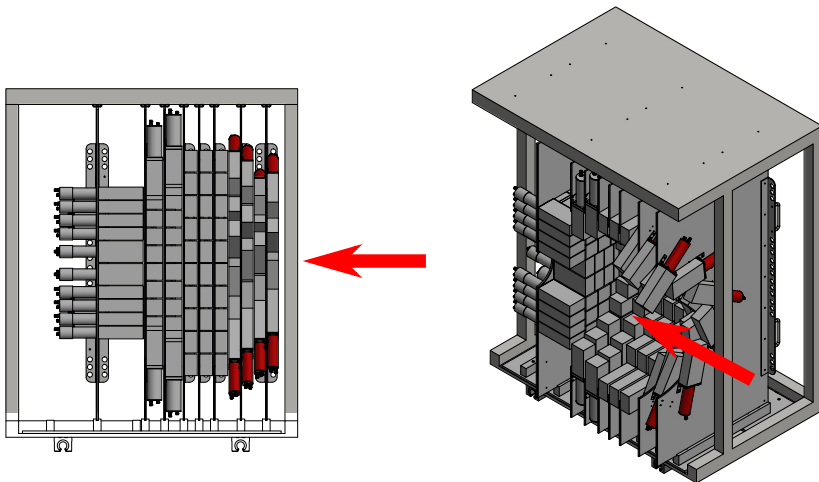## TOF, $B_\rho$, and $\Delta E$ method

$$TOF = \frac{L}{\beta \cdot c} \quad \Rightarrow \quad TOF = \frac{L_{35}}{\beta_{35} c} + \frac{L_{57}}{\beta_{35} c}$$

$$\frac{A}{Q} = \frac{B_\rho}{\beta \gamma} \frac{c}{m_u} \quad \Rightarrow \quad \frac{\beta_{35} \gamma_{35}}{\beta_{57} \gamma_{57}} = \frac{B_{\rho 35}}{B_{\rho 57}}$$

$$\frac{dE}{dx} = \frac{4\pi e^4 Z^2}{m_e v^2} Nz \left[ \ln\left(\frac{2m_e v^2}{I}\right) - \ln\left(1 - \beta^2\right) - \beta^2 \right]$$

Retrieved from NUCL INSTRUM METH B **317** (2013) 323–332.

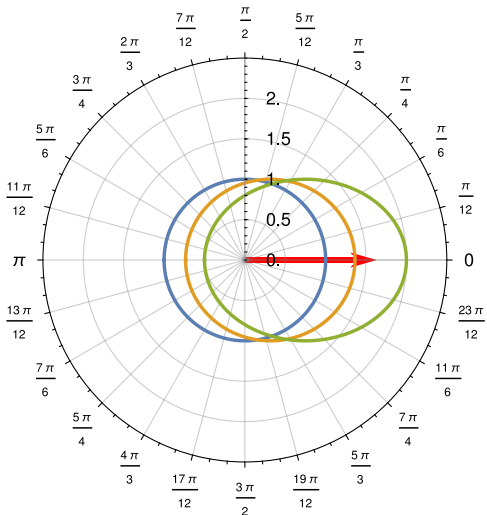# DALI2+ NaI(Ti) $\gamma$-ray detection array



226 NaI detectors, covering from $16°$ to $123°$.
Diagrams retrieved from SUNFLOWER Collaboration.

# Aberration effect



$\beta = 0$

$\beta = 0.3$

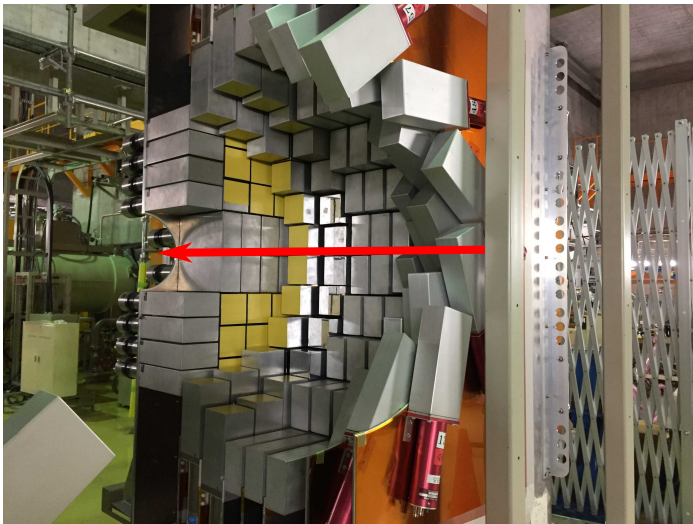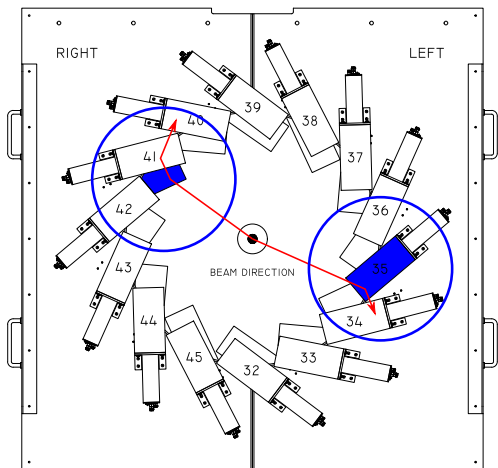$\beta = 0.6$

# DALI2+ NaI(Ti) $\gamma$-ray detection array



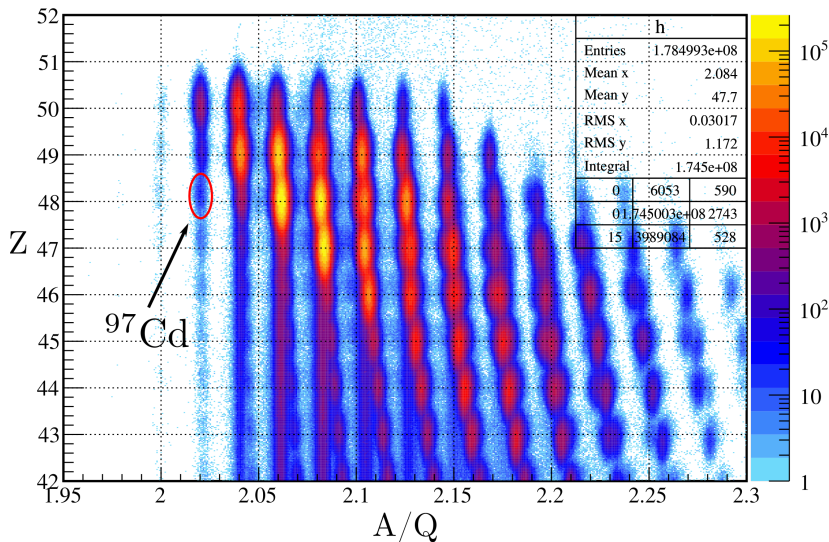Photo retrieved from Dr. Sidong Chen.

# Add-back technique



Specifications:

| | |
|---|---|
| $\beta$ | $= 0.6$ |
| $E_\gamma$ | $= 1$ MeV |
| $r_{a.b.}$ | $= 15$ cm |
| eff. | $\approx 34\%$ |
| FWHM | $\approx 85$ keV |

Diagram retrieved from DALI2+ configuration drawing.
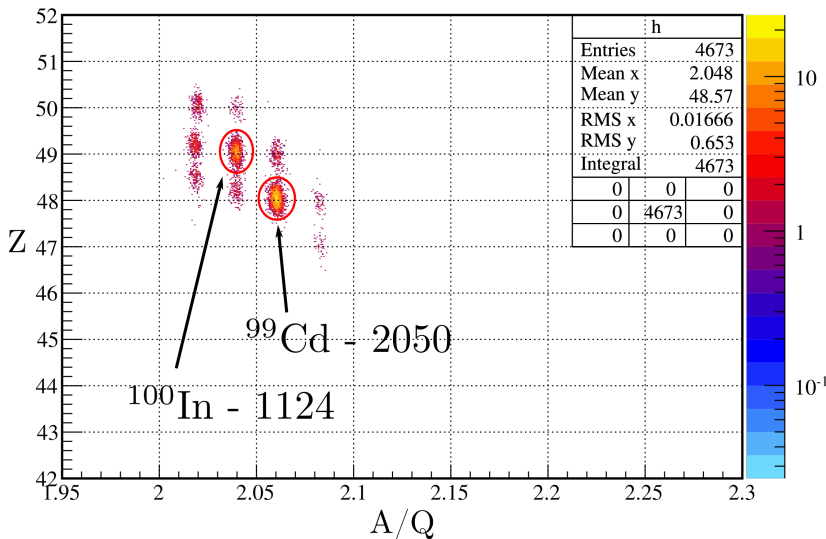Data retrieved from RIKEN Accel. Prog. Rep. **53** (2019) 35.

# Particle identification (PID)
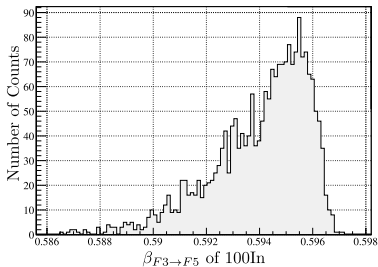
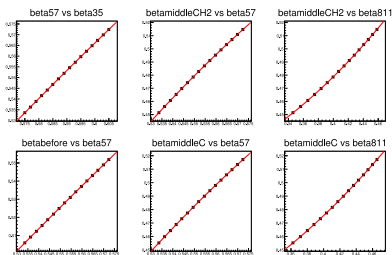## ZeroDegree PID removed FC7 pile up

# Particle identification (PID)

BigRIPS PID gated on 97Cd at ZeroDegree

# Relativistic Doppler shift correction



(a) $\beta$ value distribution.



(b) LISE simulation and fitting.

## Formular and assumption

$$E_{CM} = E_{lab}\frac{1 - \beta\cos(\theta_{lab})}{\sqrt{1 - \beta^2}}$$

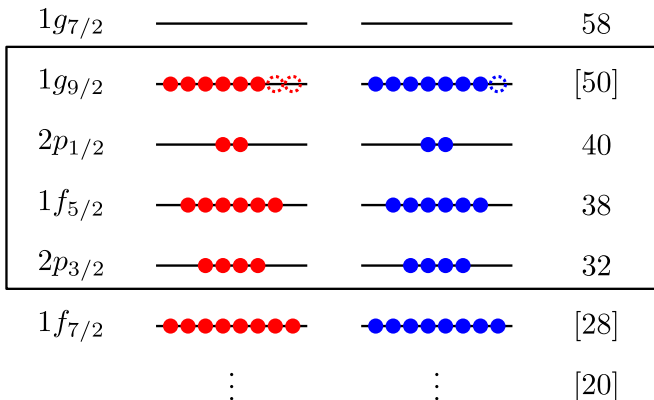Assume all $^{97}$Cd decay at the center of the target.

## Fitted spectrum

$100\mathrm{In} \rightarrow 97\mathrm{Cd}$ with $\mathrm{CH}_2$ target, assuming 0 ps half-life $\qquad \chi_r^2 \approx 0.79$

Unpublished data have been taken off.

# Theoretical calculation model space

$$^{97}_{48}\text{Cd}_{49}$$



| | | |
|---|---|---|
| $1g_{7/2}$ | | 58 |
| $1g_{9/2}$ | | [50] |
| $2p_{1/2}$ | | 40 |
| $1f_{5/2}$ | | 38 |
| $2p_{3/2}$ | | 32 |
| $1f_{7/2}$ | | [28] |
| | | [20] |

# Summary of level schemes

Unpublished data have been taken off.

## To sum up

### Current status

- $^{97}$Cd $\gamma$-ray spectrum has been constructed.
- Energy info of proposed transitions have been extracted by fitting with simulated detector response function.
- Theoretical level schemes have been calculated from different interactions.
- Eventually, the first level scheme of $^{97}\mathrm{Cd}$ will be proposed after further investigation.

# Acknowledgments
## RIKEN $^{100}$Sn In-beam $\gamma$ collaboration