# In-beam isomer spectroscopy with LaBr$_3$ crystal

## -With an isomer state in $^{15}$C -
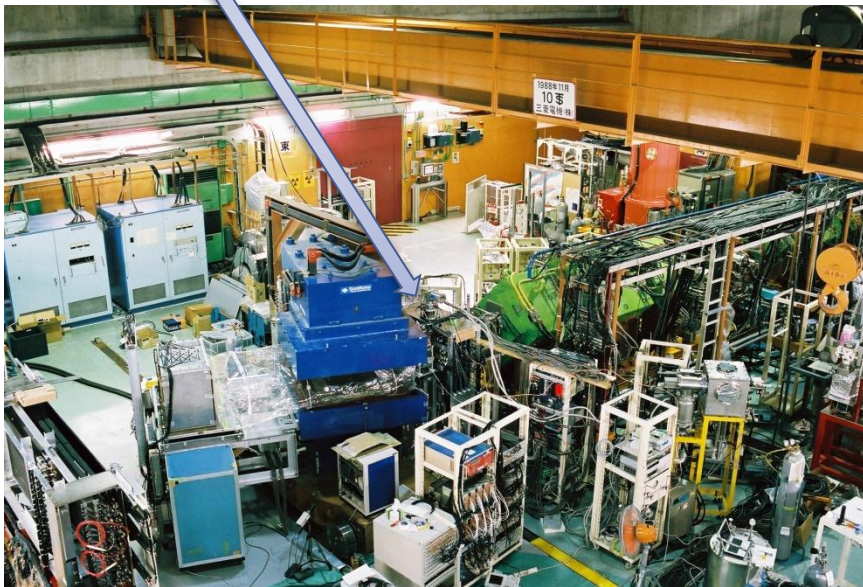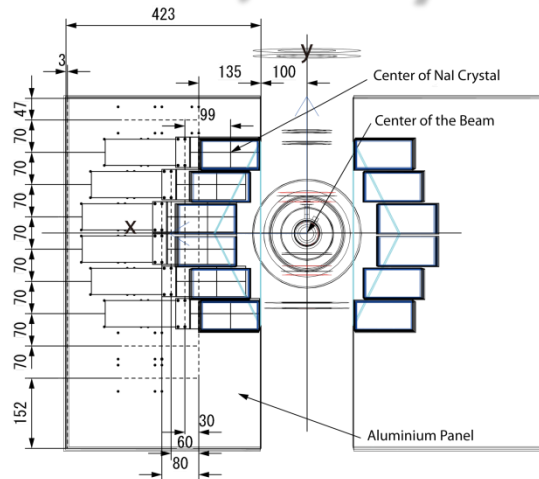
Jongwon Hwang (Seoul National University)

# Contents

## In-beam isomer spectroscopy

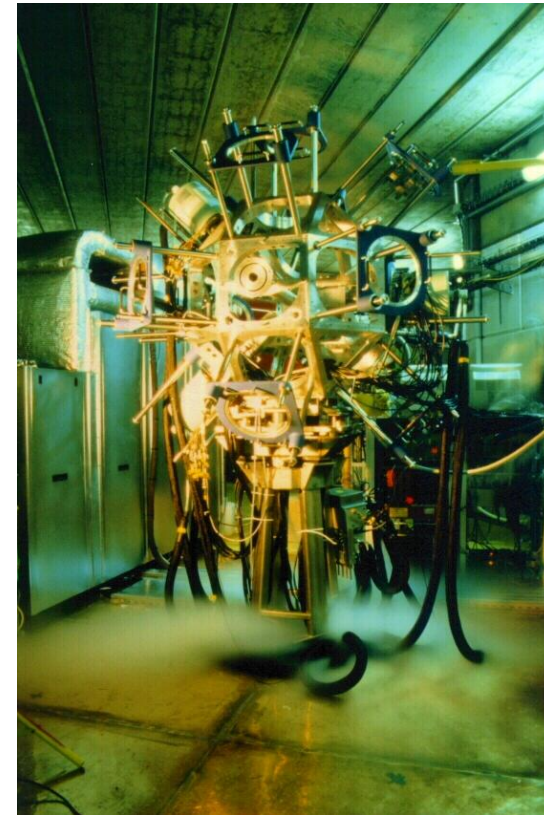- In-beam $\gamma$-ray spectroscopy

- Problem : Doppler broadening

- Solution : Guessing a decay point

- Simulation : Using GDALI

- Result
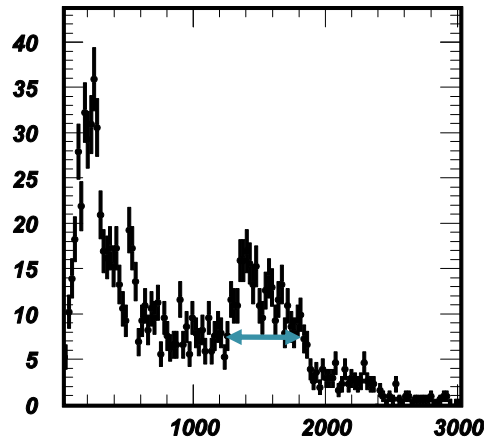
# In-beam $\gamma$-ray spectroscopy



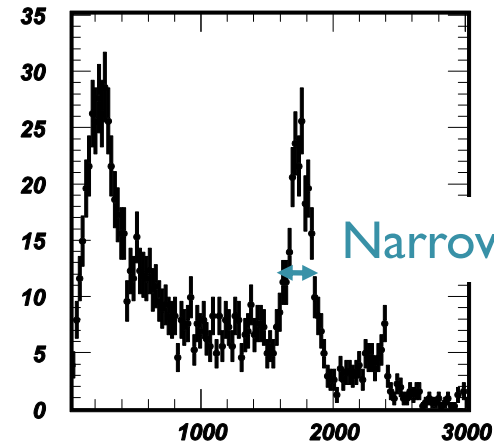Side View of DALI



RIPS : Experimental Setup



EXOGAM
at GANIL

# Problem : Doppler broadening



**Normal case**
$(1766, 2^+)$ in $^{16}C$

Doppler Correction

Narrower

γ-ray from $^{16}C^*$

γ-ray from $^{16}C^*$ (Doppler Corrected)
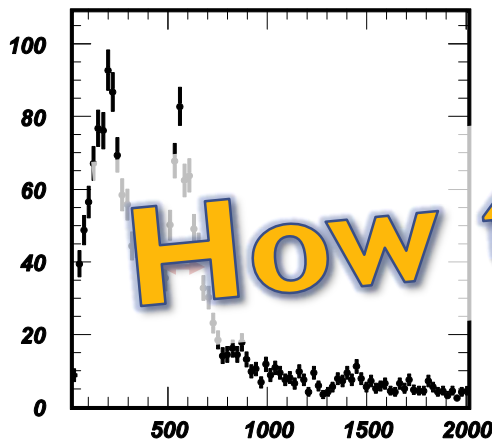
**Isomer case**
$(740, 5/2^+)$ in $^{15}C$
with $T_{1/2}$ ...6 ns

Doppler Correction

Still Broad!

## How to Solve IT?
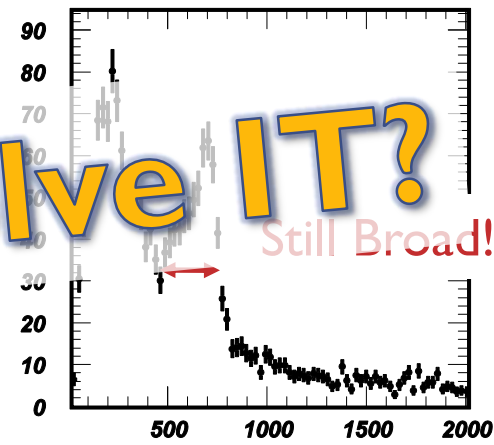
γ-ray from $^{15}C^*$

γ-ray from $^{15}C^*$ (Doppler Corrected)
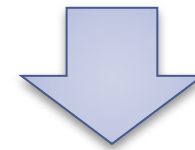
# Solution : Guessing a decay point

- Using timing difference between reaction and $\gamma$-ray detection
  - ◦ Assumptions : 1. Reaction occurs at the center of the target.
    2. Fragments move along the z-axis (beam center).

NaI (($X_N, Y_N, Z_N$) or ($R_N, \theta_N$))
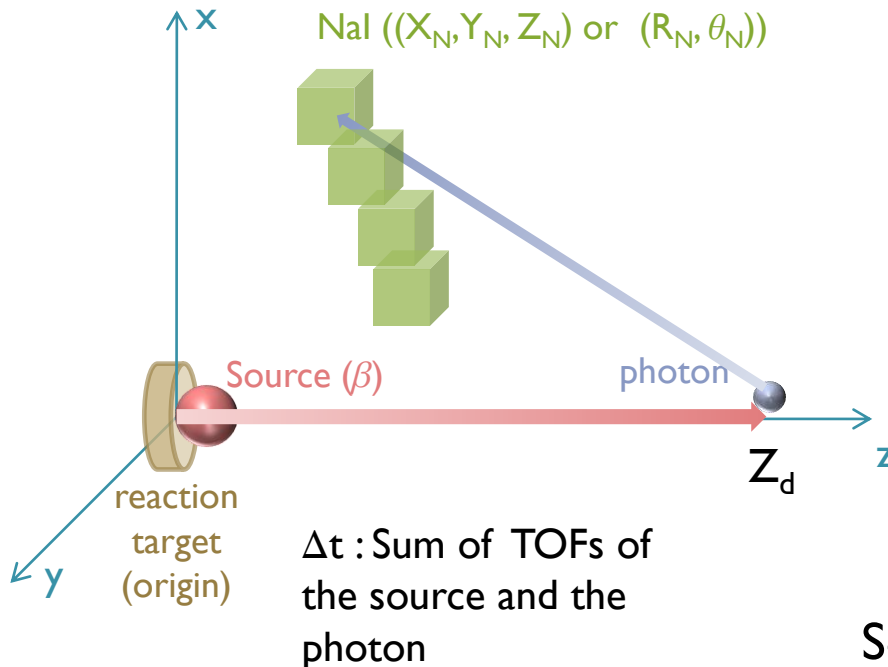
$$\Delta t = (\text{TOF of a source}) + (\text{TOF of a photon})$$

$$= \frac{Z_d}{c\beta} + \frac{\sqrt{X_N^2 + Y_N^2 + (Z_N - Z_d)^2}}{c}$$

$$= \frac{Z_d}{c\beta} + \frac{\sqrt{R_N^2 + Z_d^2 - 2R_N Z_d \cos\theta_N}}{c}$$

Source ($\beta$)

photon

$Z_d$

z

x

reaction
target
(origin)

y

$\Delta t$ : Sum of TOFs of
the source and the
photon

Solve this **quadratic eq.**, and
we can get **the decay point $Z_d$**.

# Simulation : Using GDALI

- ## GDALI : GEANT code for DALI

### Source

- $\gamma$-ray from $(740, 5/2^+)$ in $^{15}C$ with $T_{1/2}$=2.61ns

### Position of reaction and velocity of $^{15}C$

- Randomly chosen among the experimental result ($\beta \approx 0.4$)

### Two cases : time resolution

- **NaI(TI) : ~ 2.5ns**
- **LaBr$_3$:Ce : ~ 0.2ns**

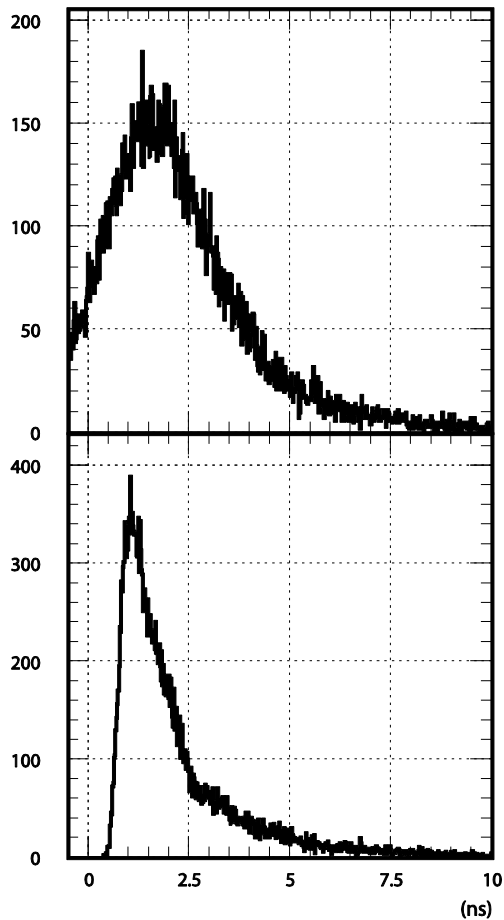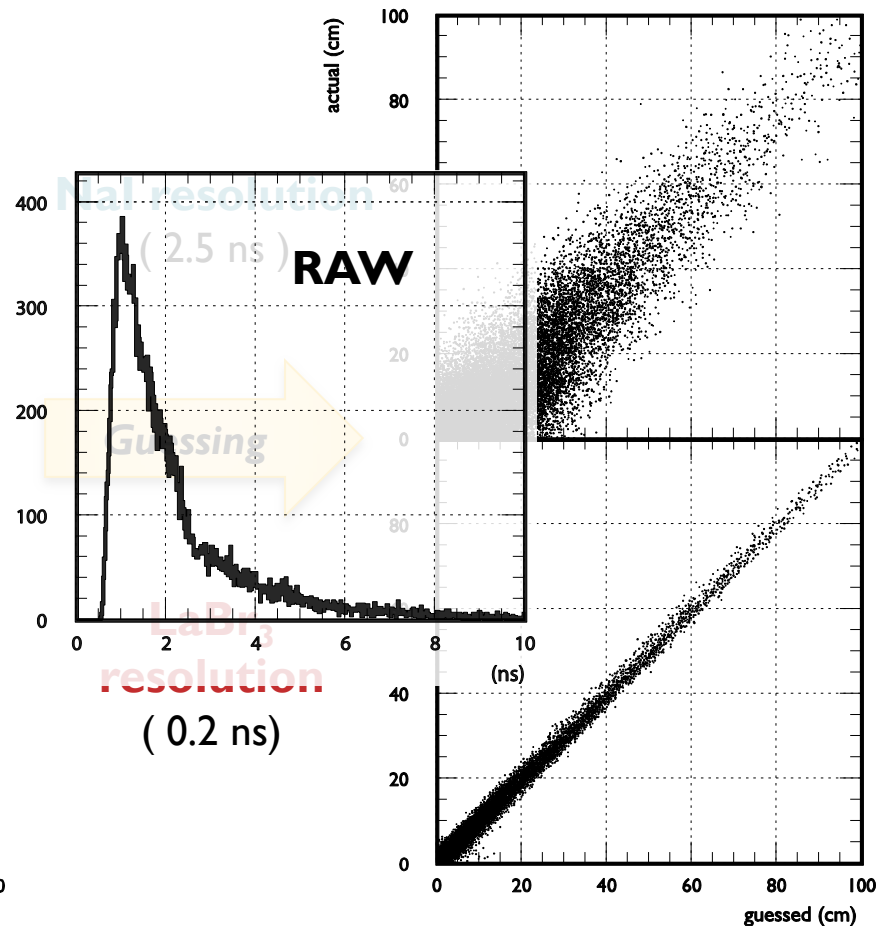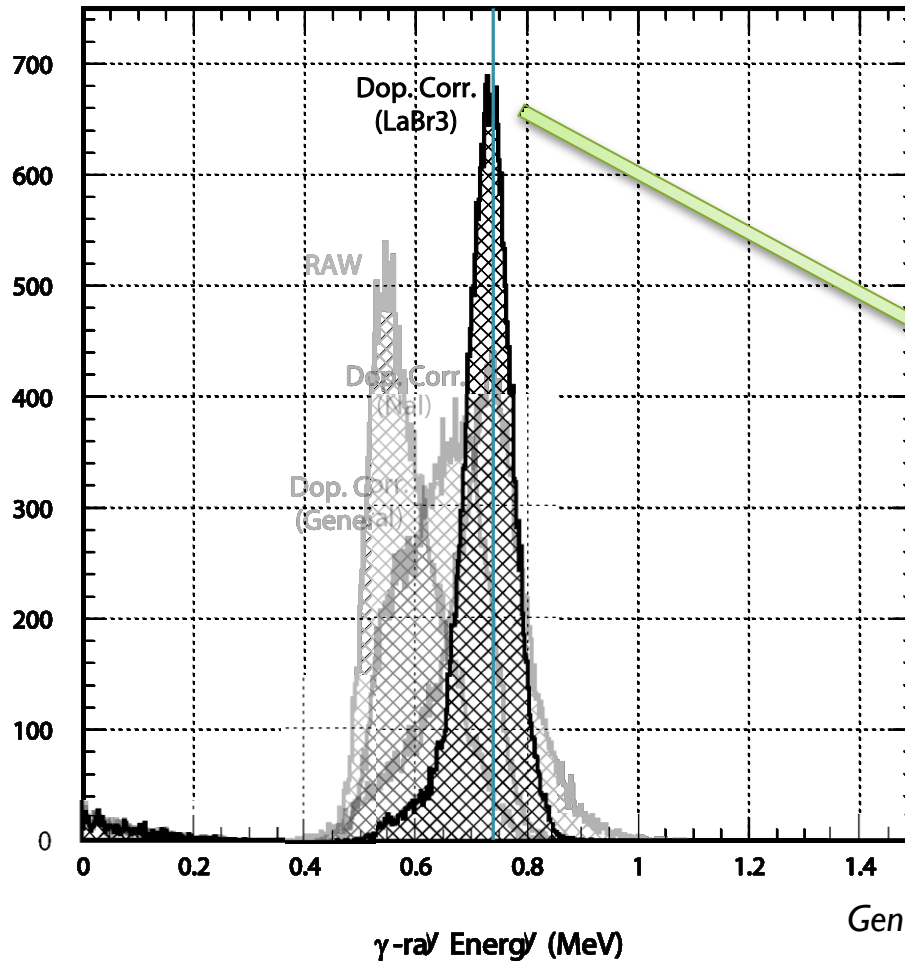| Timing difference | ➔ | Guessing the position of the decay | ➔ | Correcting the Doppler broadening |

J.Hwang, Seoul National University

# Result : $\Delta t \rightarrow Z_d$

**Timing Difference**
(Reaction $\sim \gamma$-ray detection)

**Decay Position**
( $x$ : guessed, $y$ : actual )



NaI resolution
( 2.5 ns )  **RAW**

*Guessing*

LaBr$_3$
resolution
( 0.2 ns)

# Result : Doppler correction



| Gaussian fit | NaI Reso. | LaBr3 Reso. |
|---|---|---|
| Mean | 0.7235 | 0.7302 |
| Standard Dev. | 0.07623 | 0.04186 |
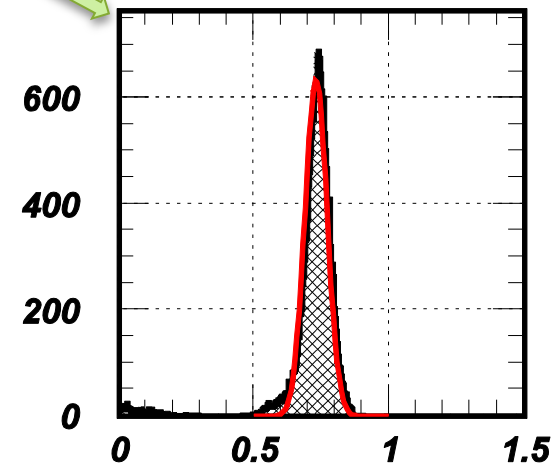
*General method : Assume that **the decay position is at the center of the target.***

# Result : Accuracy of correction

**Event rate (%)**

$$(0.74\text{MeV})\times 0.95 \leq E_\gamma \leq (0.74\text{MeV})\times 1.05$$



Bar chart values:
- Raw: 0.118
- Dop. Corr. (General method): 0.563
- Dop. Corr. (NaI resolution): 1.097
- Dop. Corr. (LaBr3 resolution): 1.663 — Best!
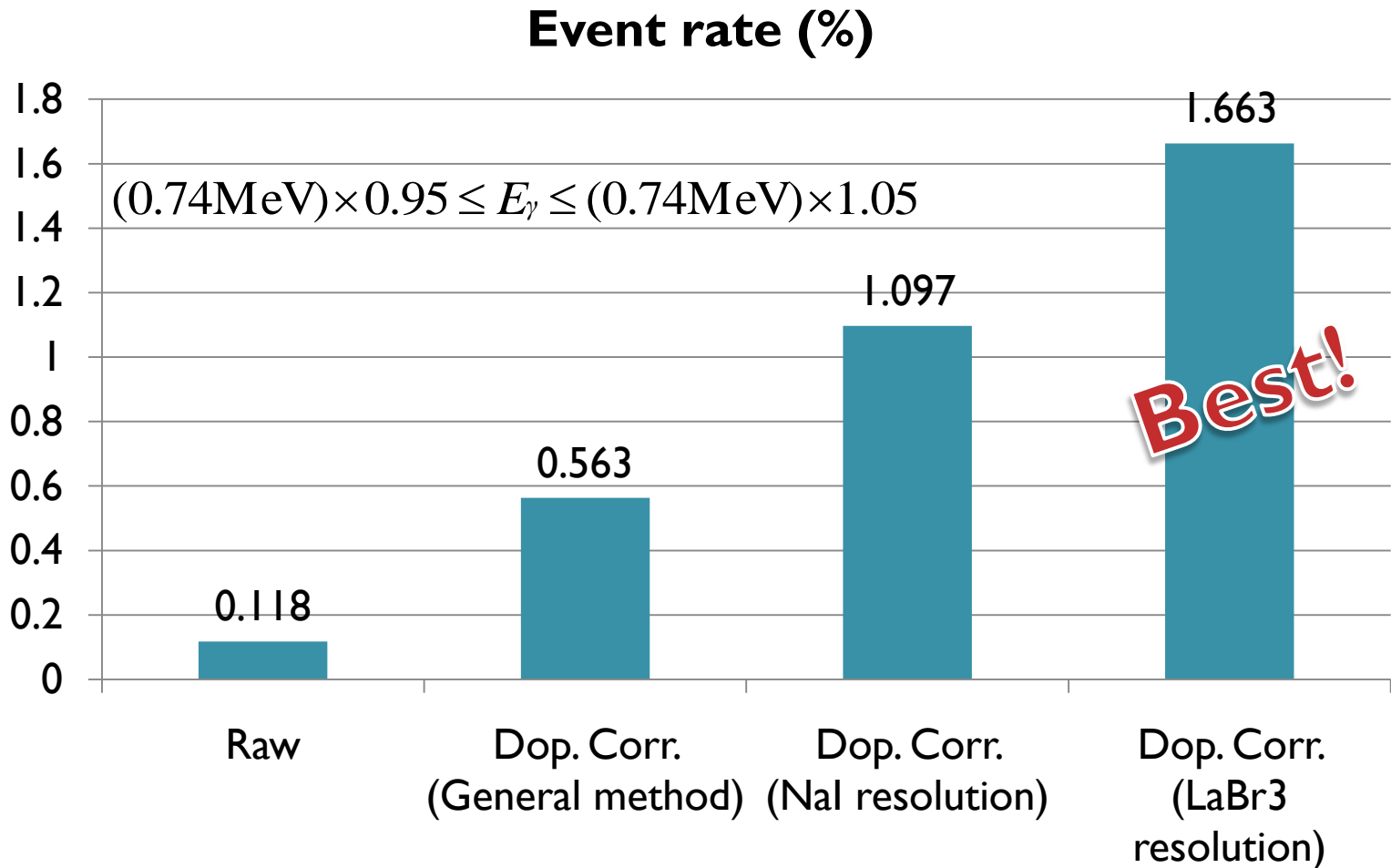
*General method : Assume that **the decay position is at the center of the target.***

# Summary

- In-beam isomer spectroscopy
  - Doppler broadening : (Isomer) » (General)
    - Due to the **unknown distributed** decay point
    - Guessing it by using the **timing difference**
  - Simulation for different time resolutions
    - **Higher** time resolution
      → Guessing the decay point **more precisely**
      → Compensating Doppler broadening **better**
  - **LaBr3** is cut out for **'in-beam isomer spectroscopy'.**

# **Thank you.**