用DSAM和GCDM法测量原子核能级寿命

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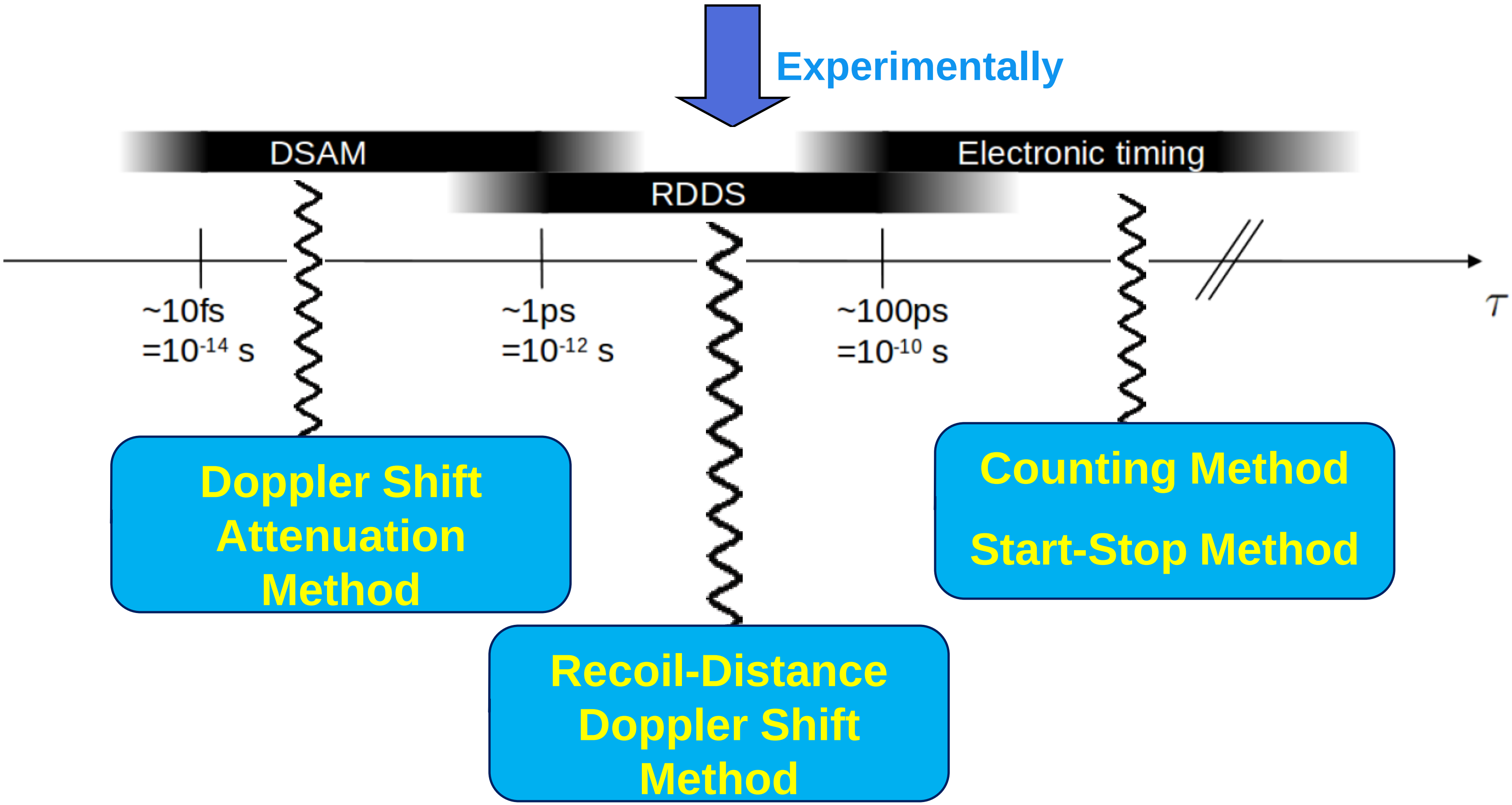
2019-10-10

中科院近代物理研究所

The lifetime of nuclear excited state

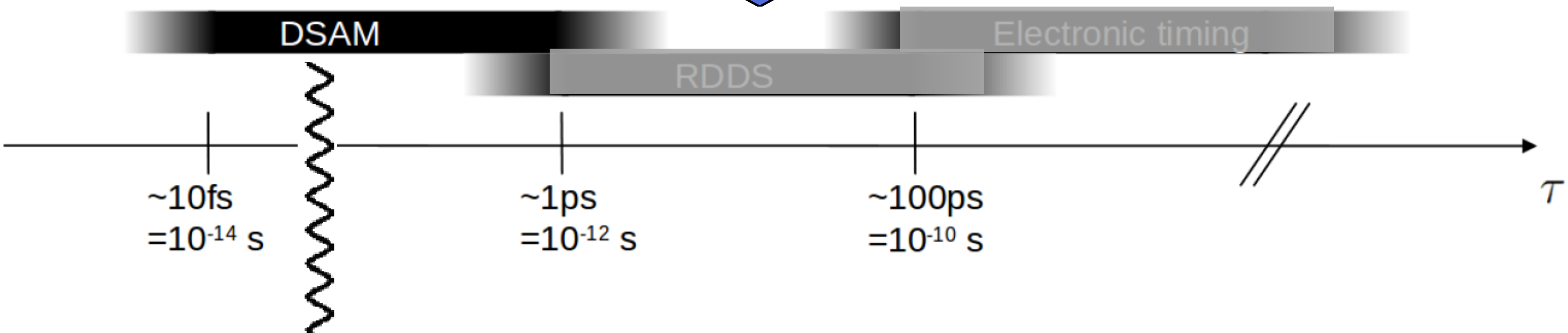
Determines the reduced electromagnetic transition probability, can be used to test nuclear structure models

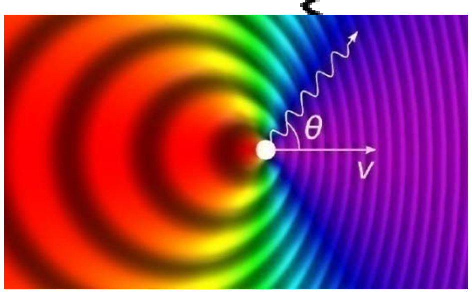


DSAM -- details

Determines the reduced electromagnetic transition probability, can be used to test nuclear structure models

Experimentally





$$E_\gamma = E_0 \frac{\sqrt{1-\beta^2}}{1-\beta cos\theta}, \quad \beta = \frac{v}{c}$$

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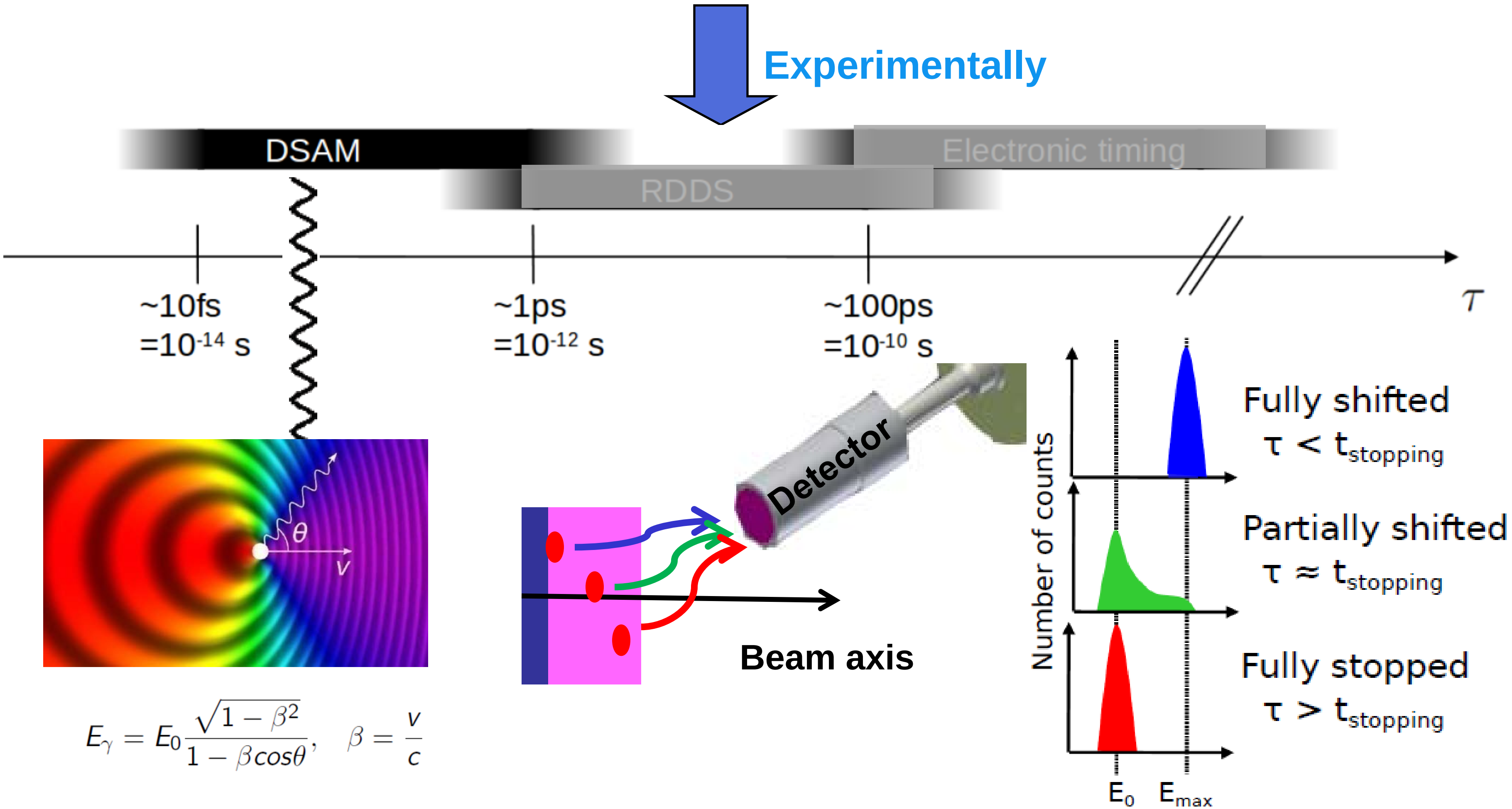

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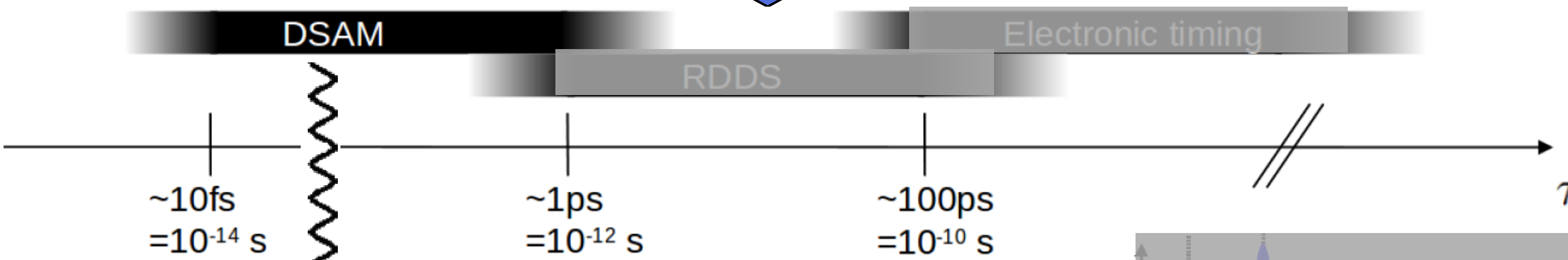

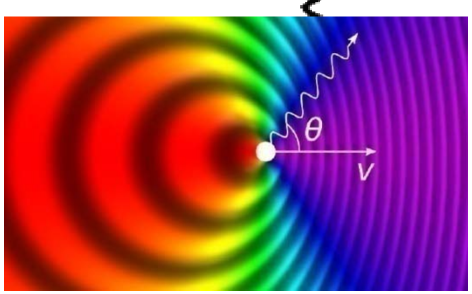

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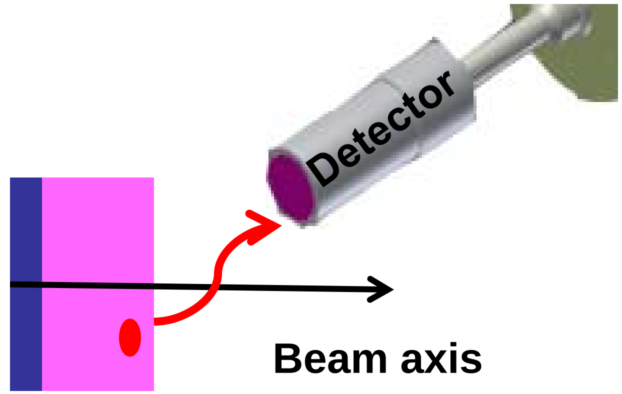

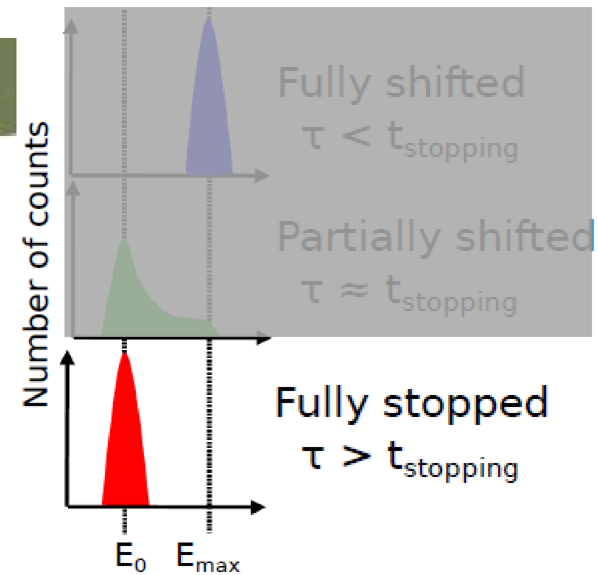

DSAM -- details

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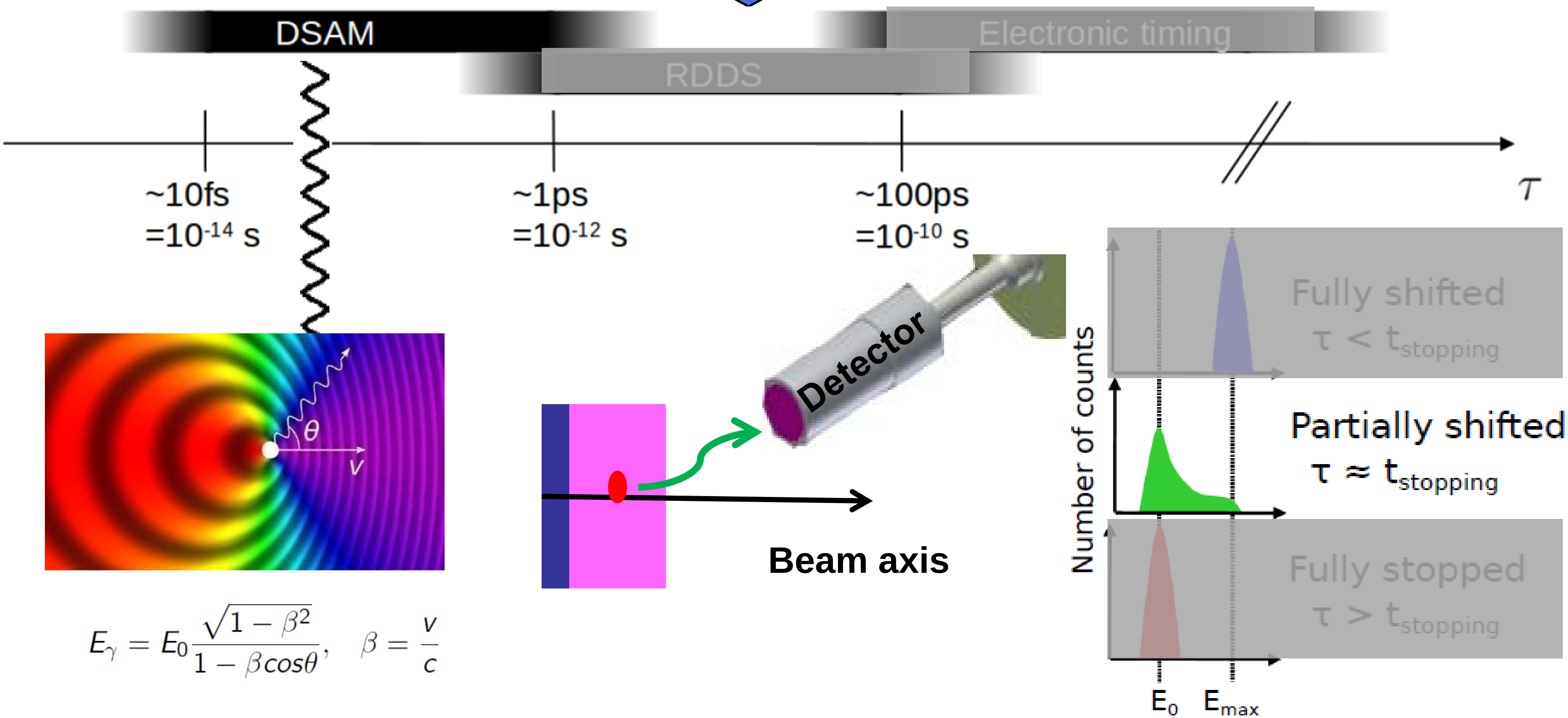

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DSAM -- details

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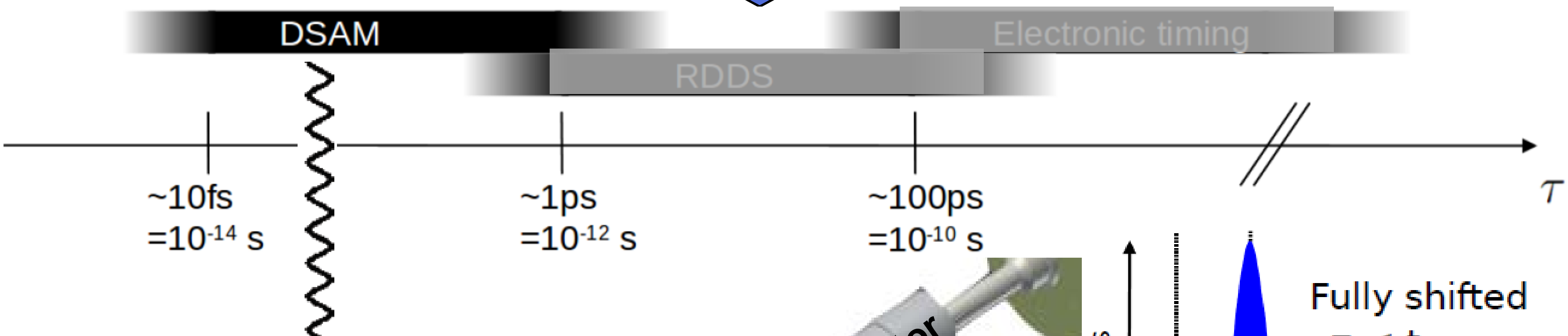
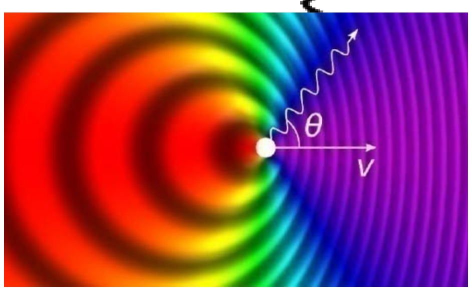
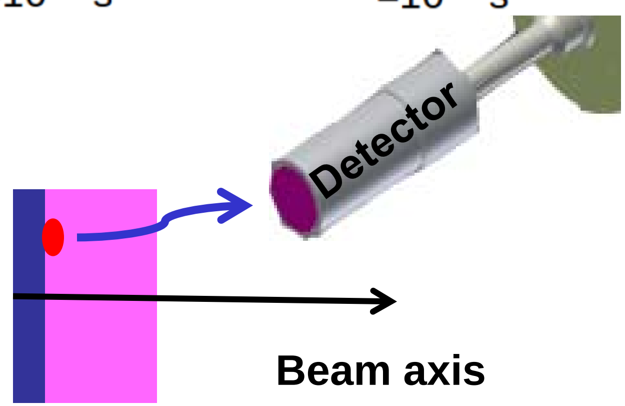
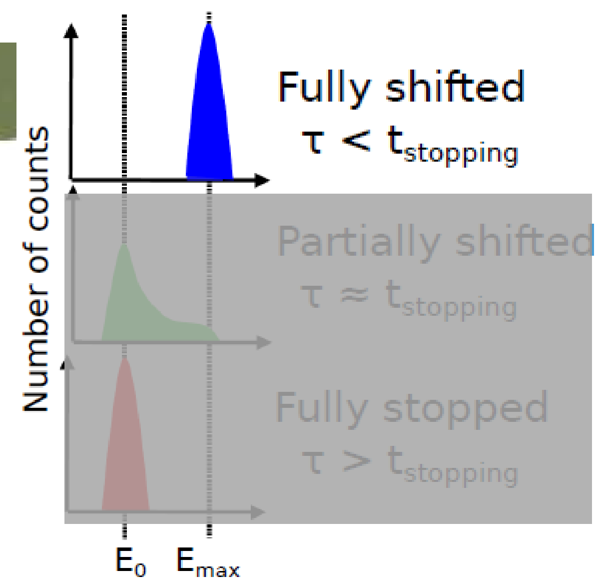




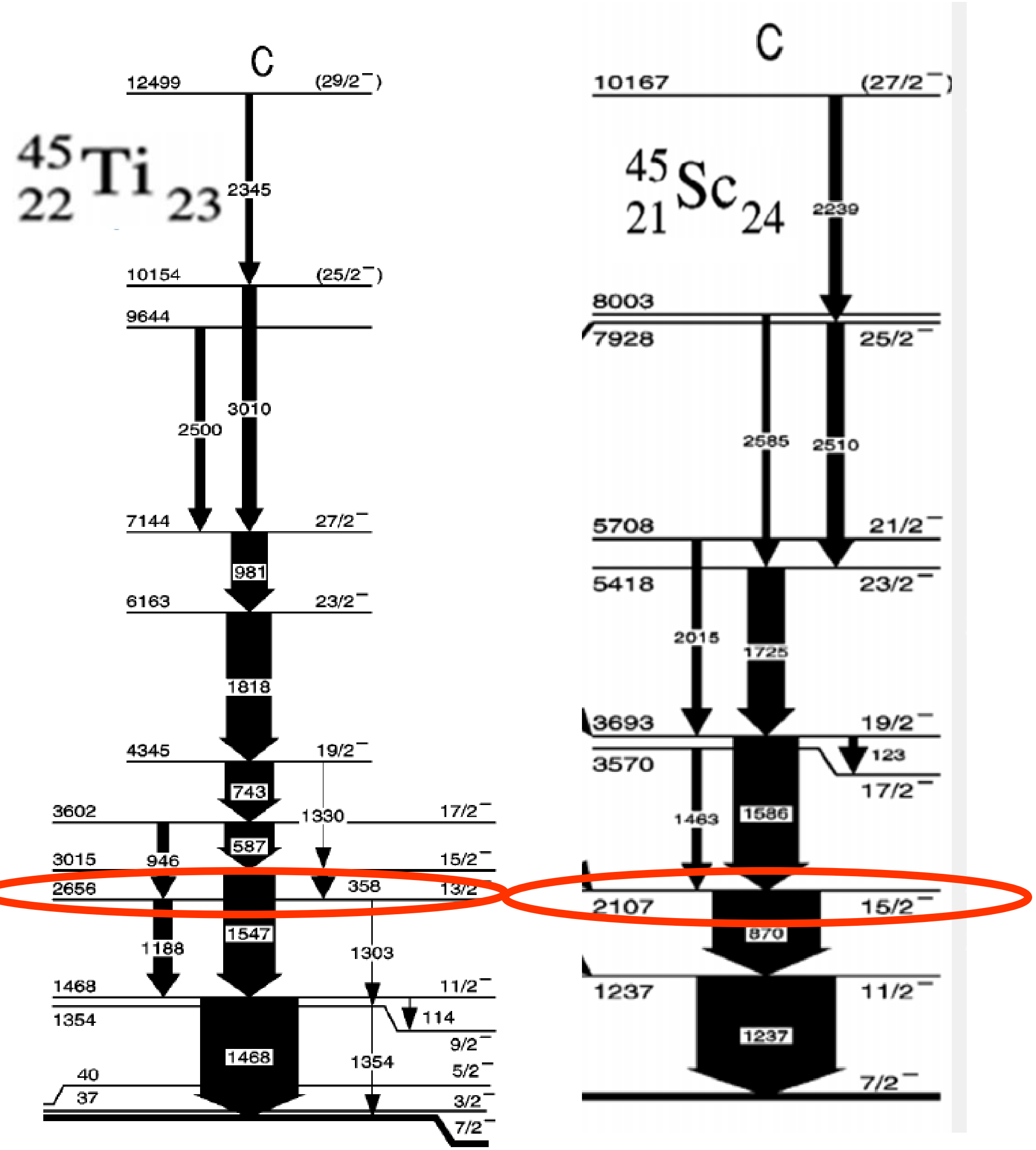




$$E_\gamma = E_0 \frac{\sqrt{1-\beta^2}}{1-\beta cos\theta}, \quad \beta = \frac{v}{c}$$

The lifetime information in ^{45}Ti and ^{45}Sc

in some states, only the limit of lifetime is known



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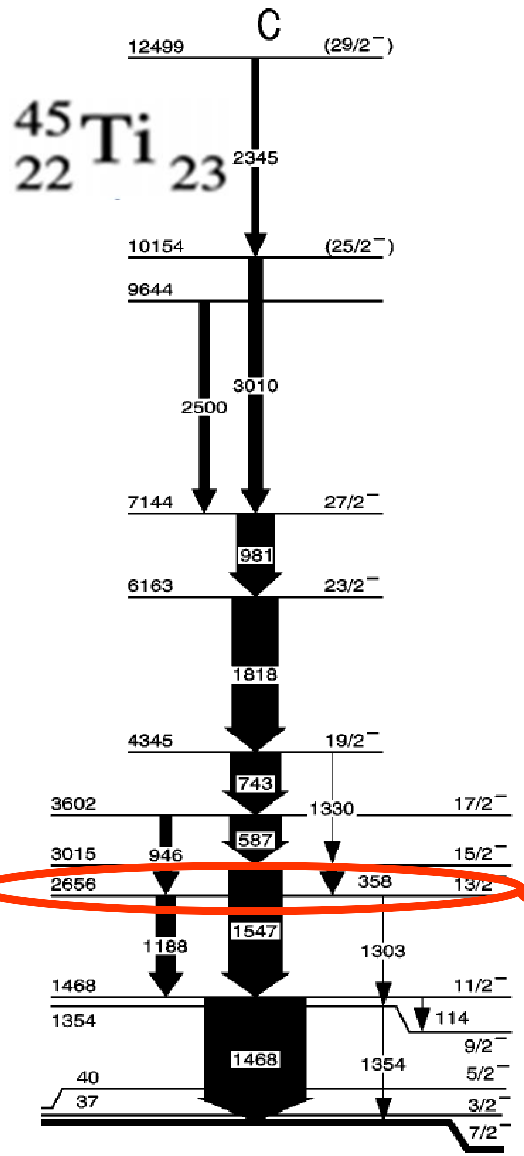
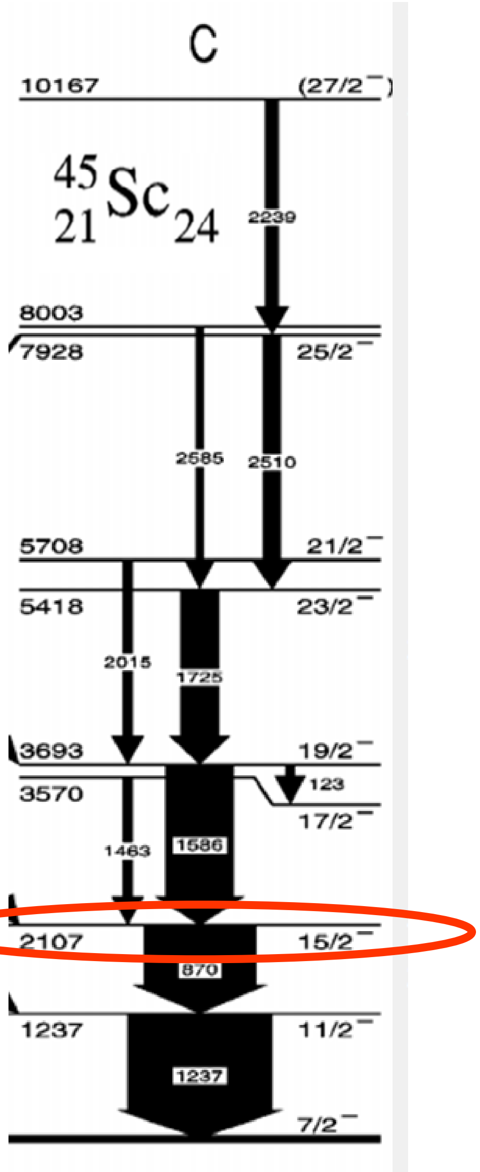
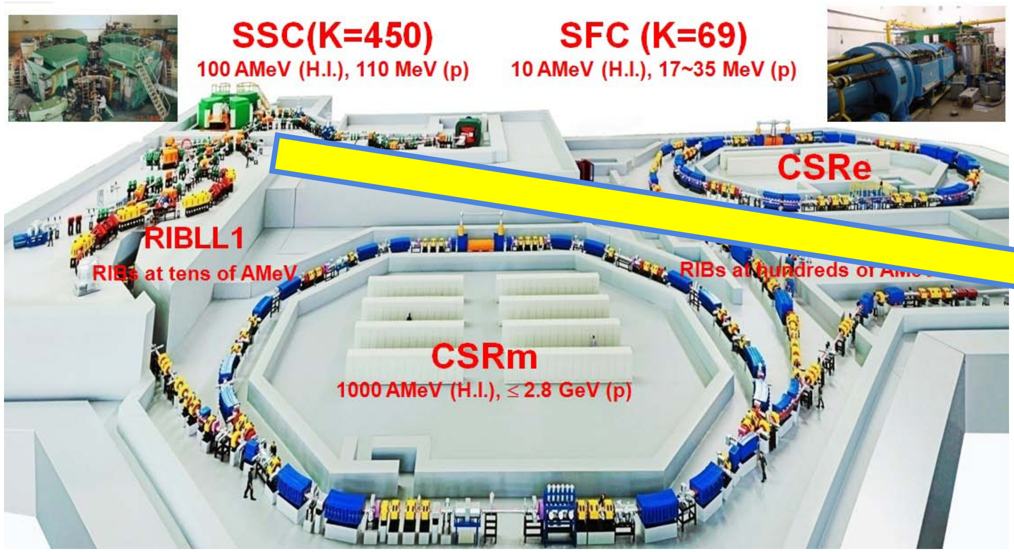
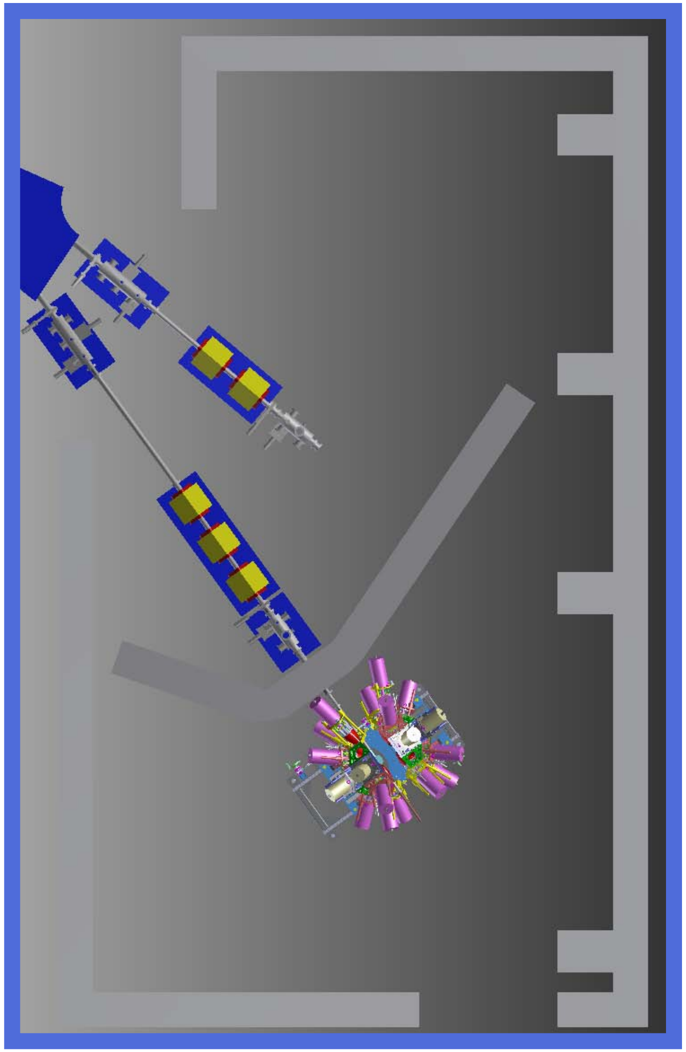




We planed to get lifetimes with high precision, to futher study the nuclear structure

TL2 beam line at HIRFL





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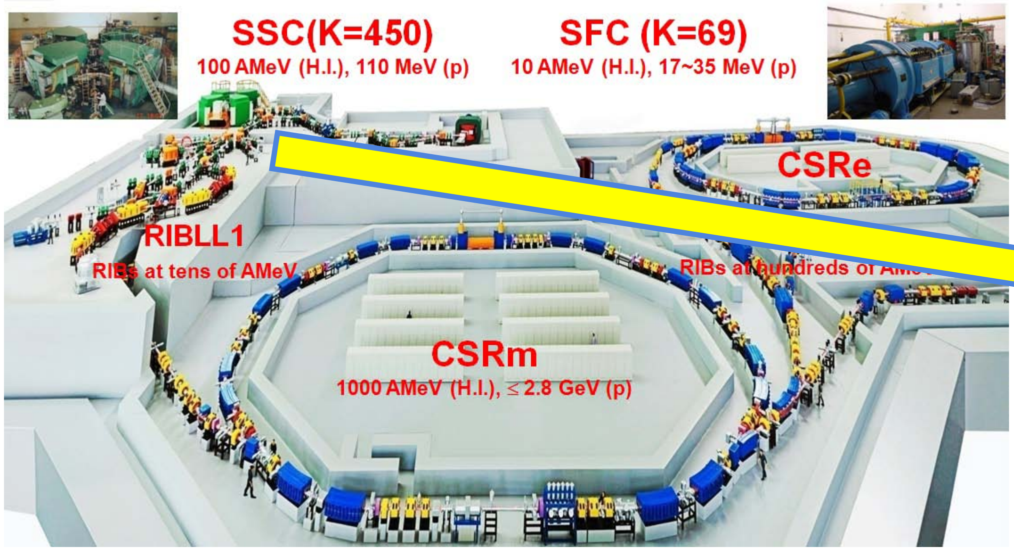
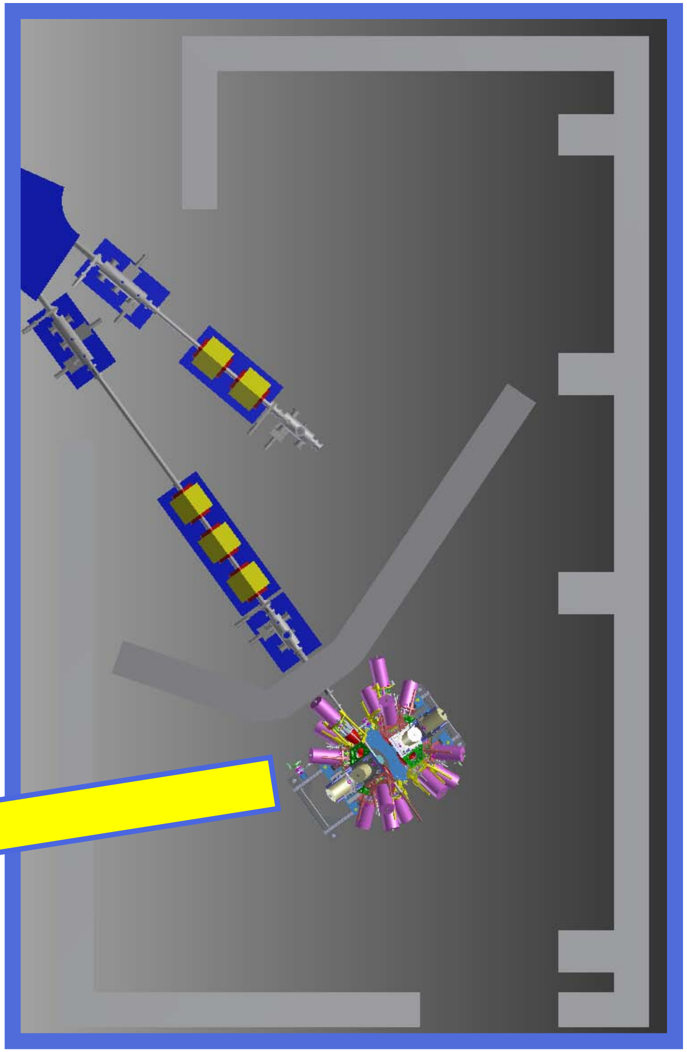
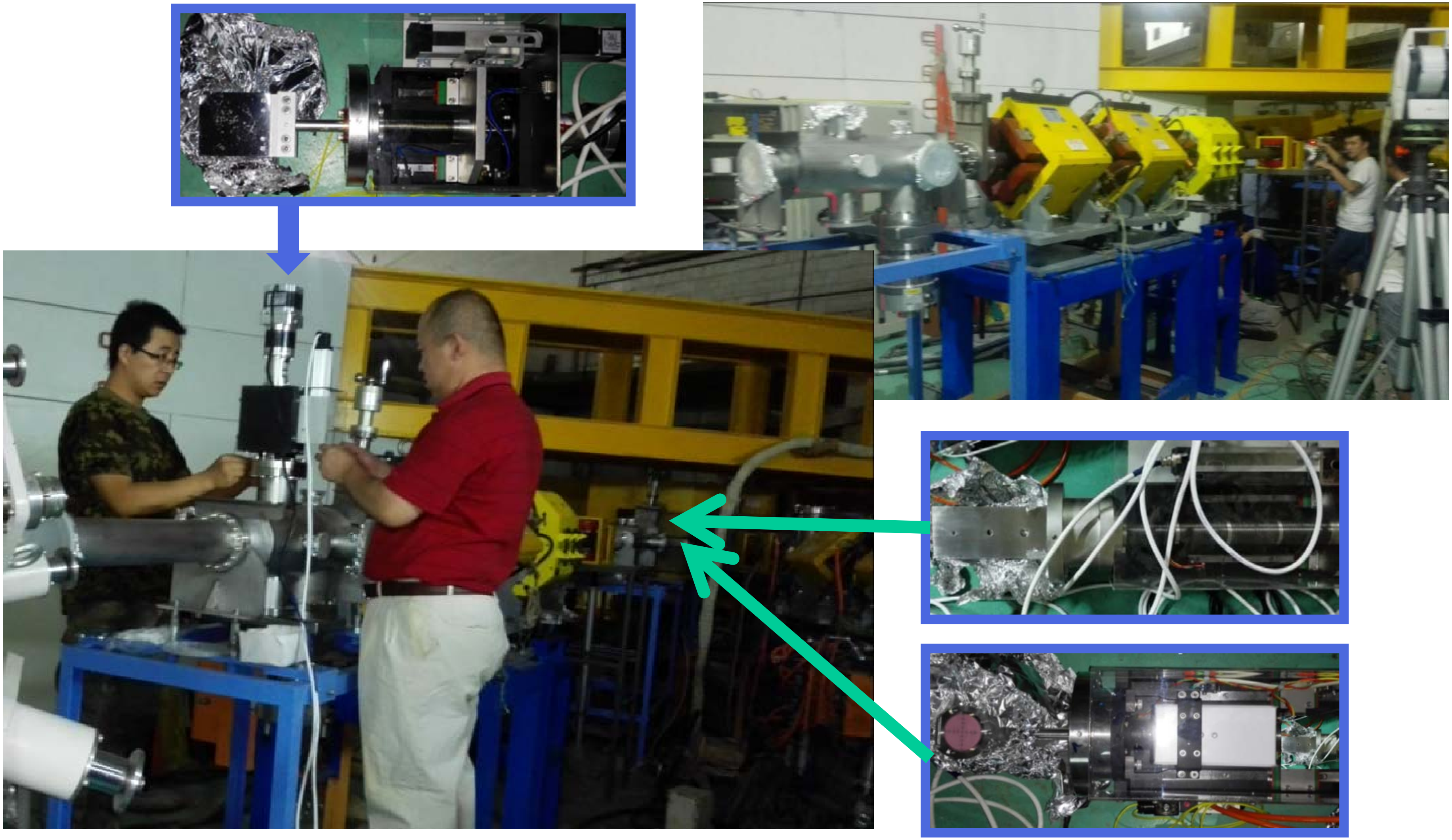
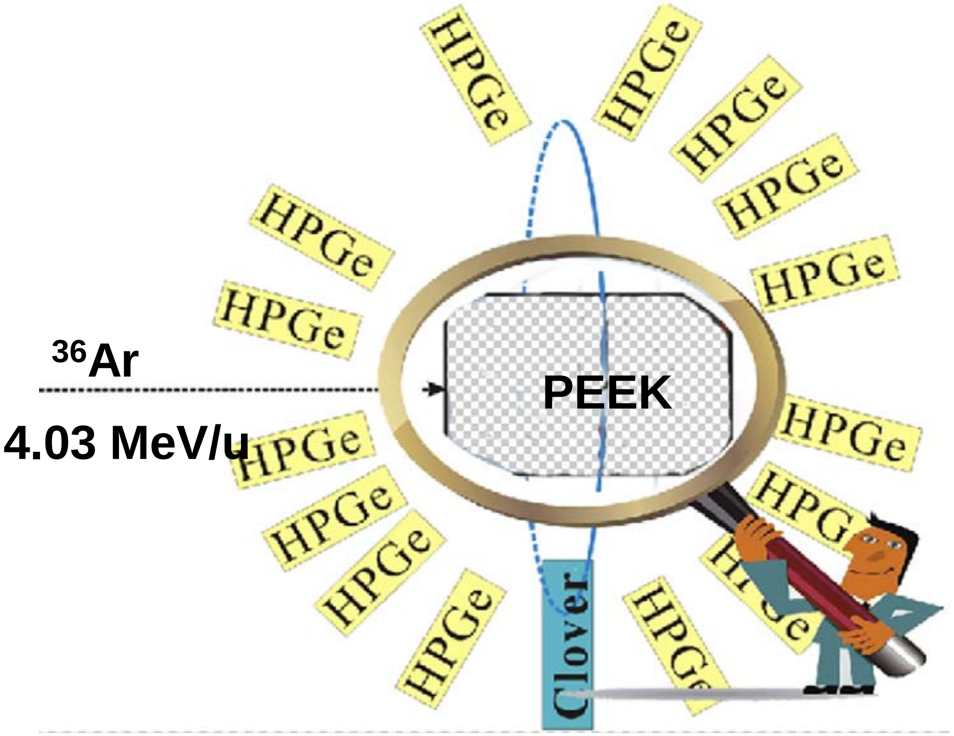




The diaphragms and slits

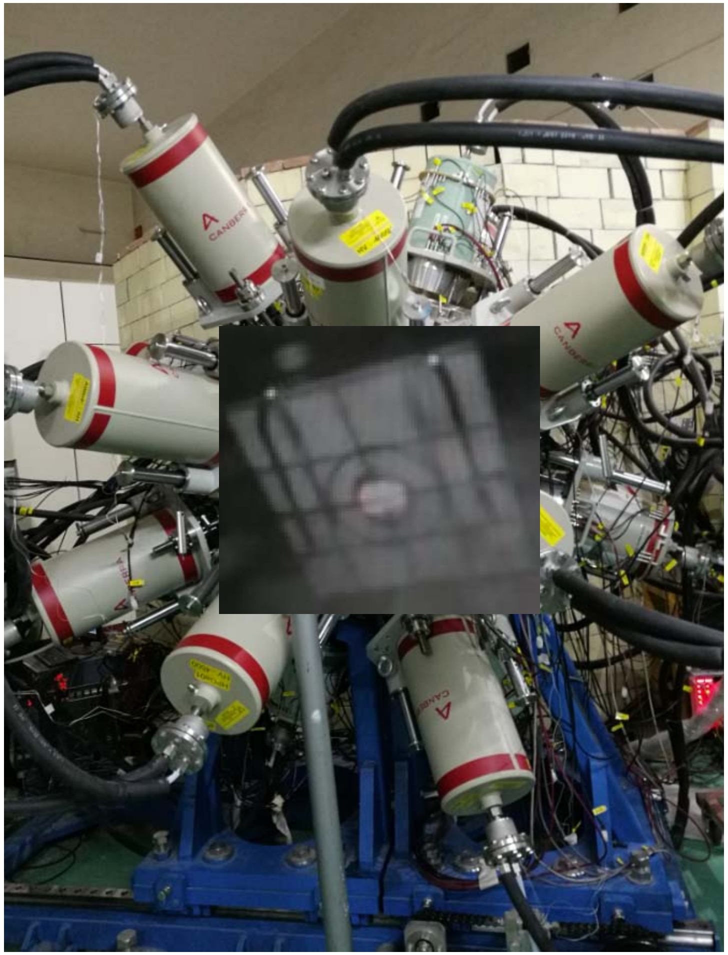


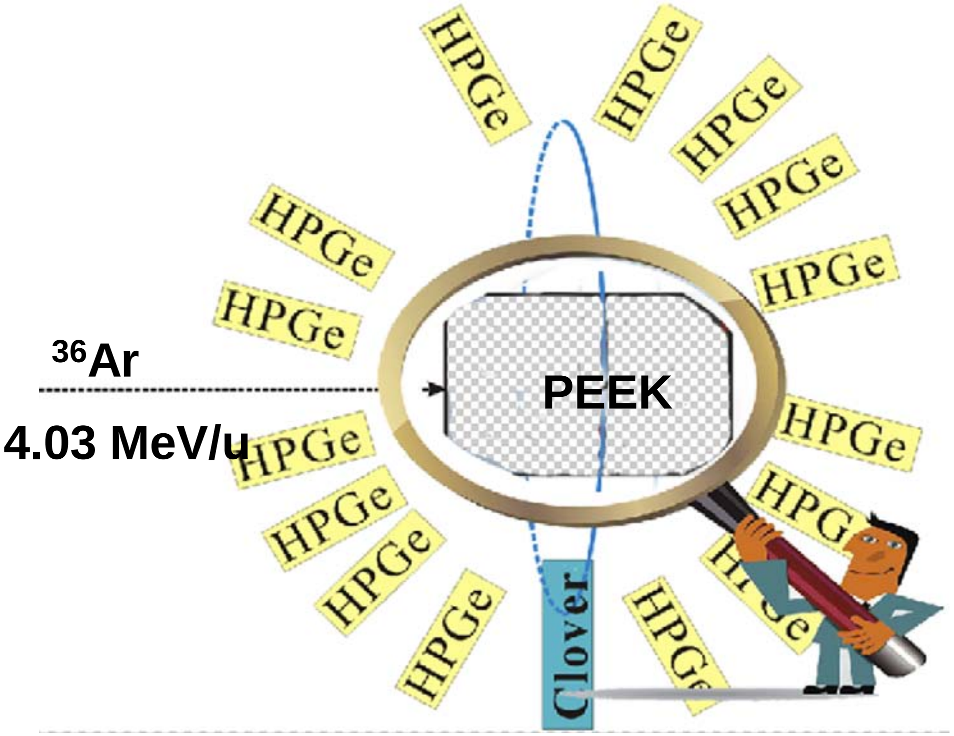
Commissioning run



15 HPGe + 6Clover

Commissioning run

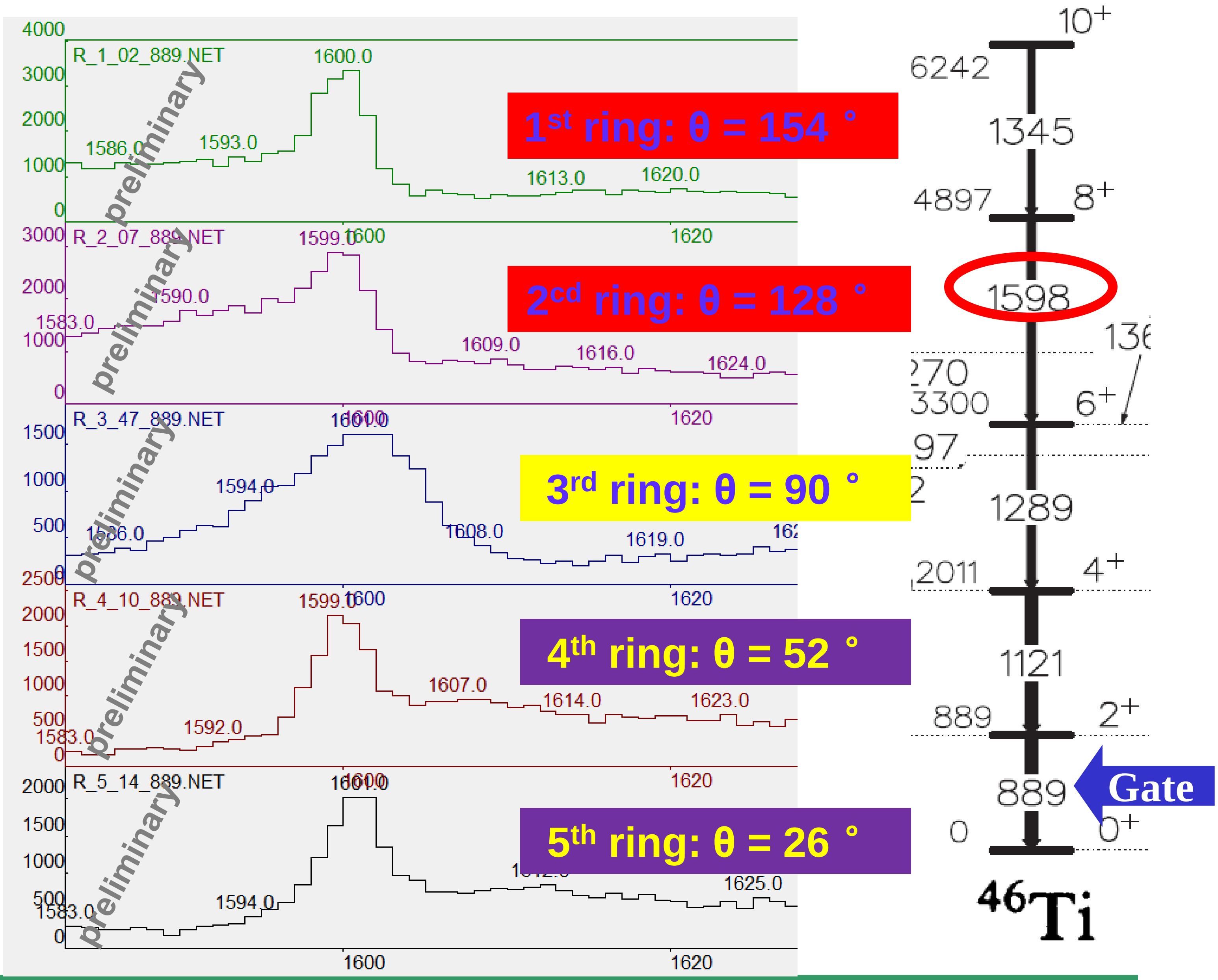




15 HPGe + 6Clover

Beam spot: phi 6.5 mm

Exp results - DSAM



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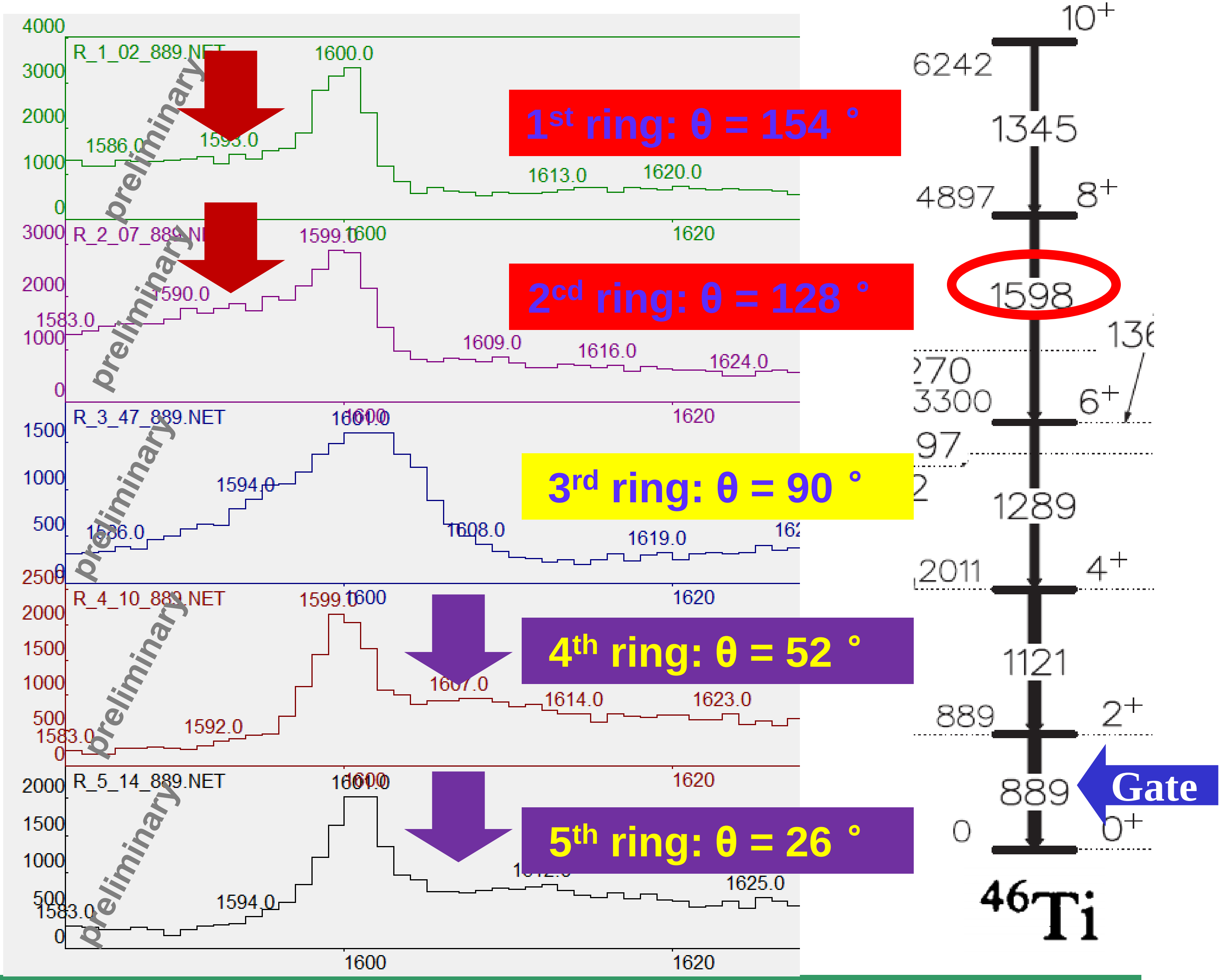


1st ring: θ = 154 °

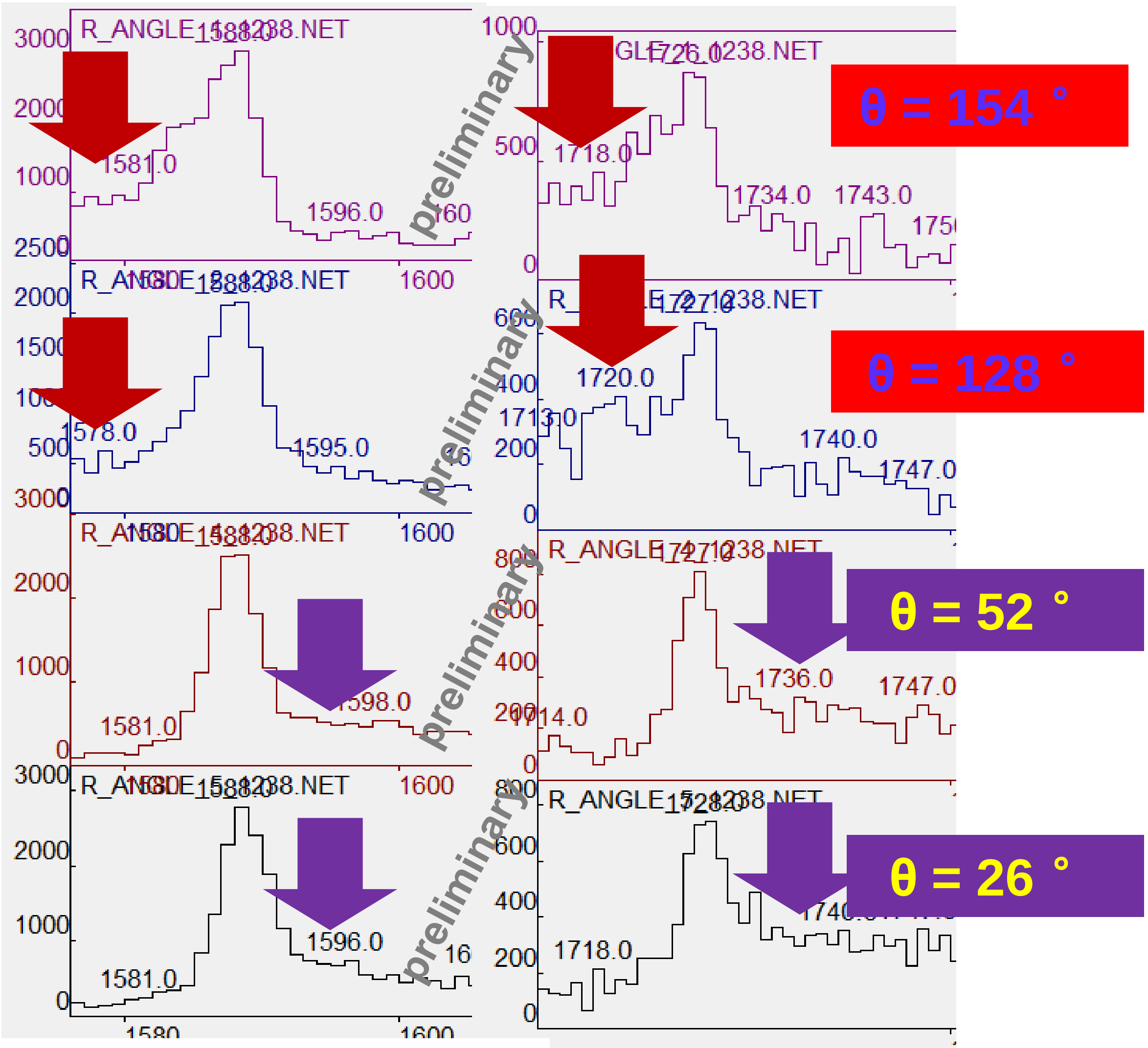
2cd ring: θ = 128 °

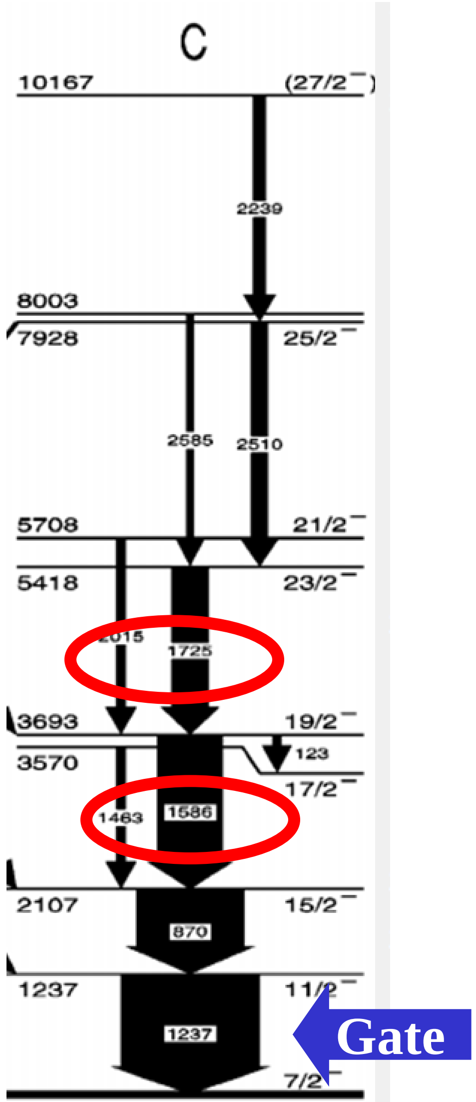
3rd ring: θ = 90 °

4th ring: θ = 52 °

5th ring: θ = 26 °

Exp results - DSAM



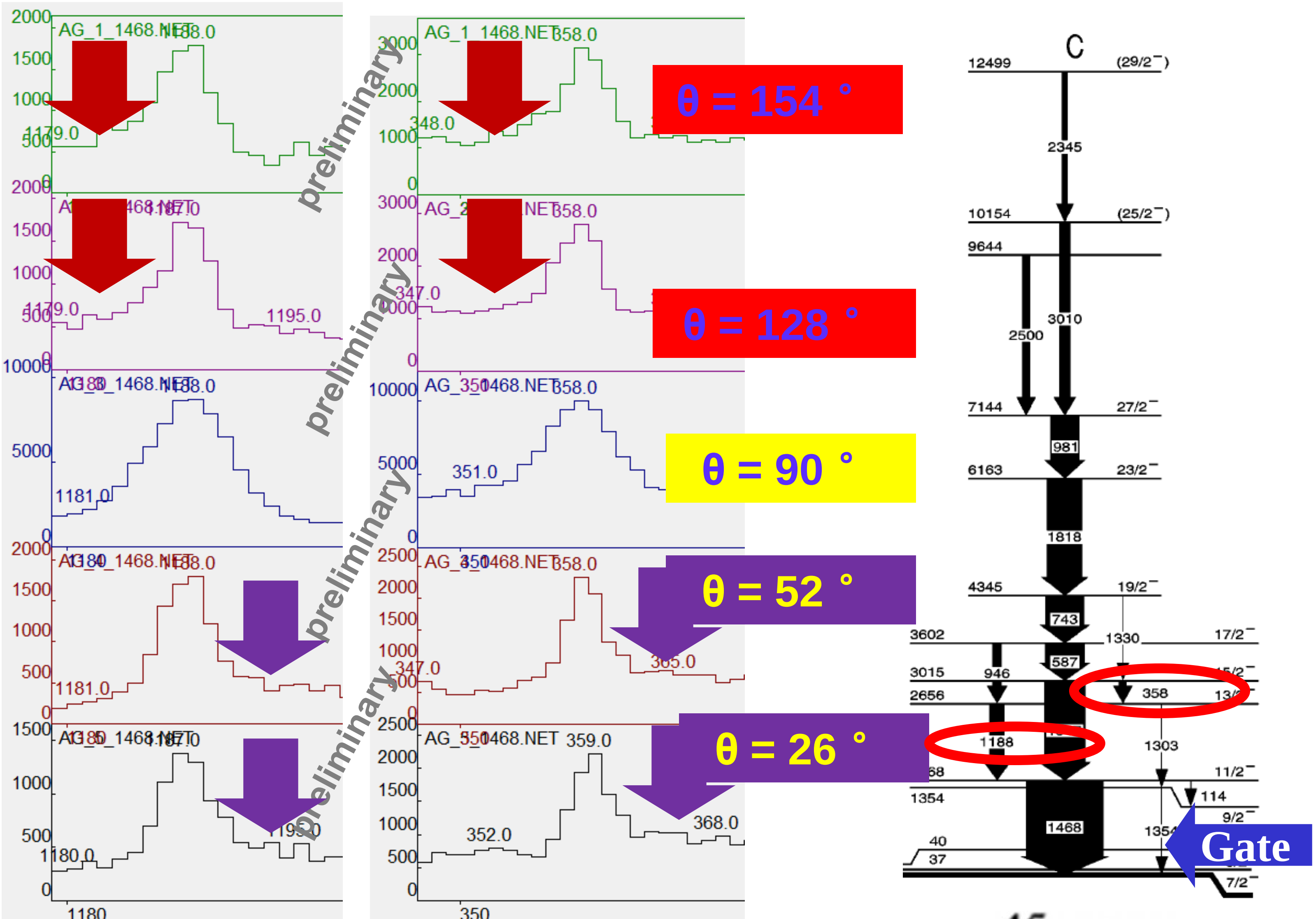


$^{45}_{21}Sc_{24}$

E(level)[†]	J^{π}[‡]	$T_{1/2}$[#]
2106.2[a] 5	≤7/2	
2106.3[@] 3	$15/2^-$	>1.4 ps

$T_{1/2}$: other: >6 ps (DSAM) from (α,pγ).

Exp results - DSAM



$^{45}_{22}\mathrm{Ti}_{23}$

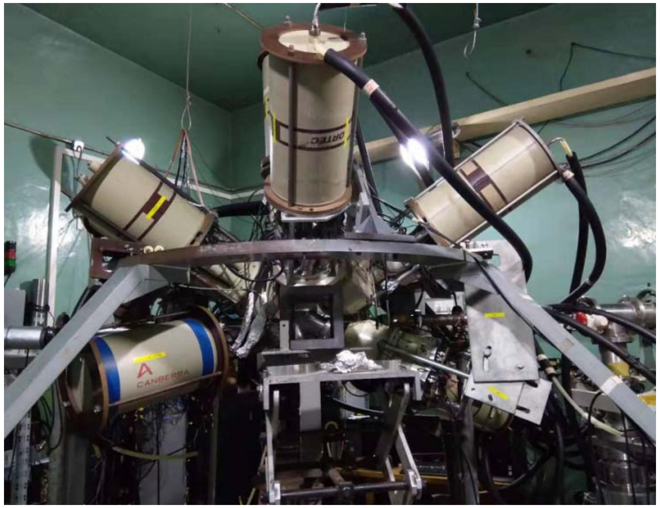
2656.66[e] *18*	13/2⁻	<0.17[h] ps	

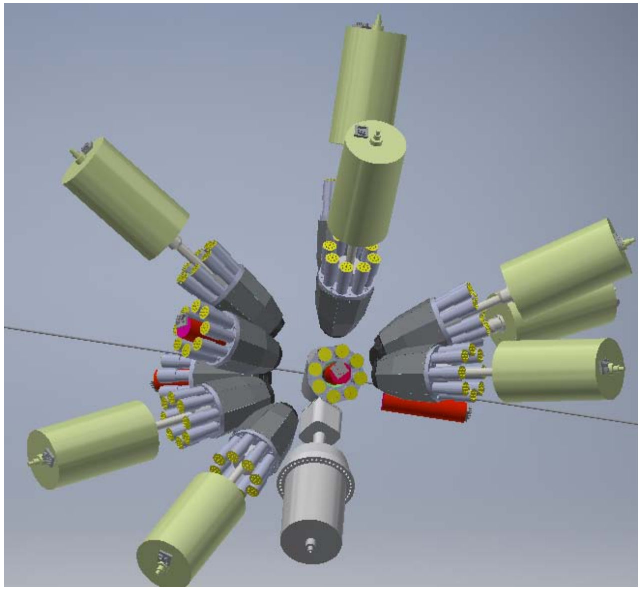
Lifetime measurement at CIAE

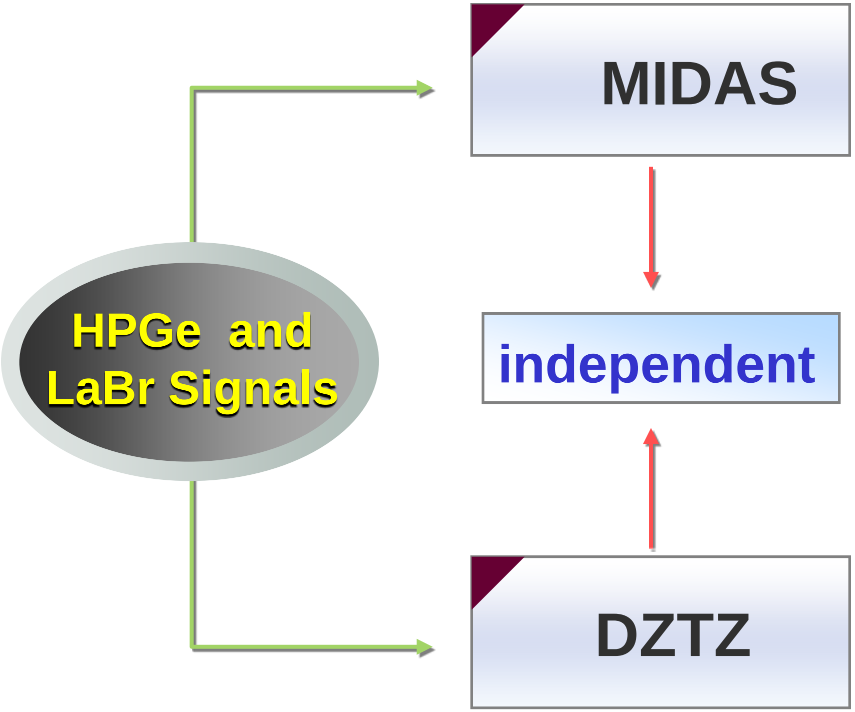
Reaction: $^{12}C + {}^{96}ZrO_2$

Beam: ^{12}C, 41.8 MeV，5pnA

Detector: 3AC-LaBr + 6AC-HPGe + 1AC-Clover







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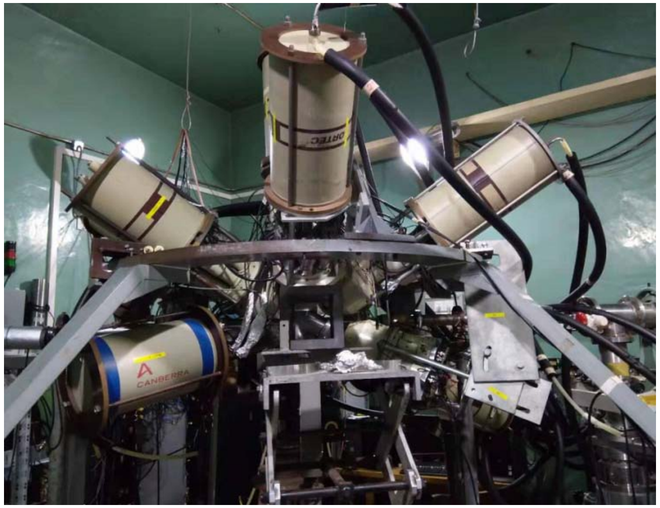

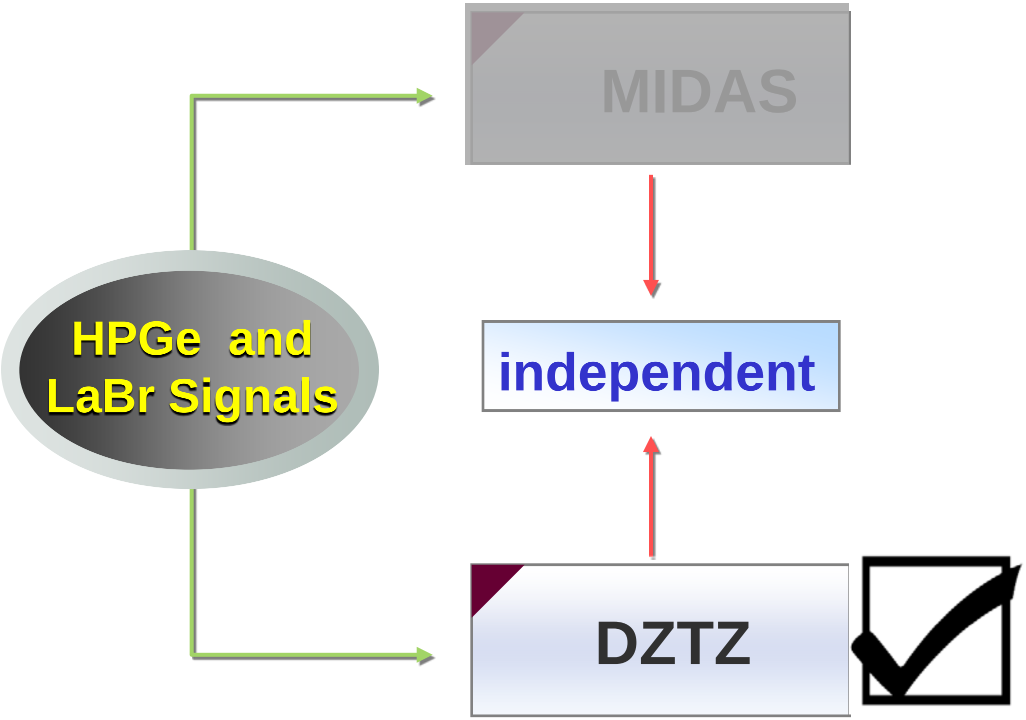

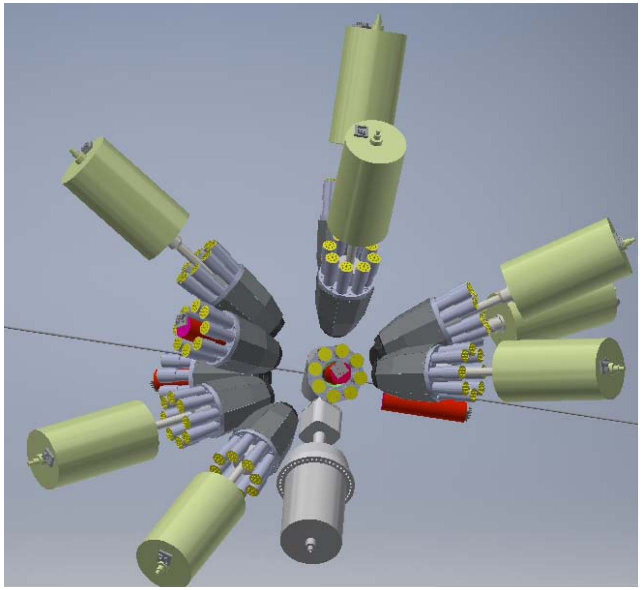

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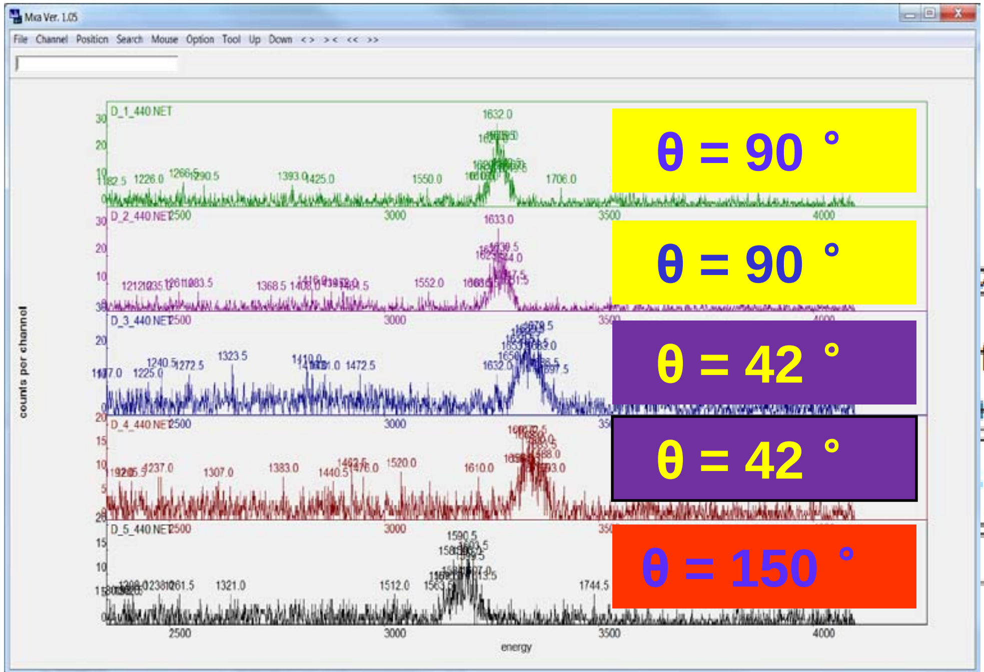
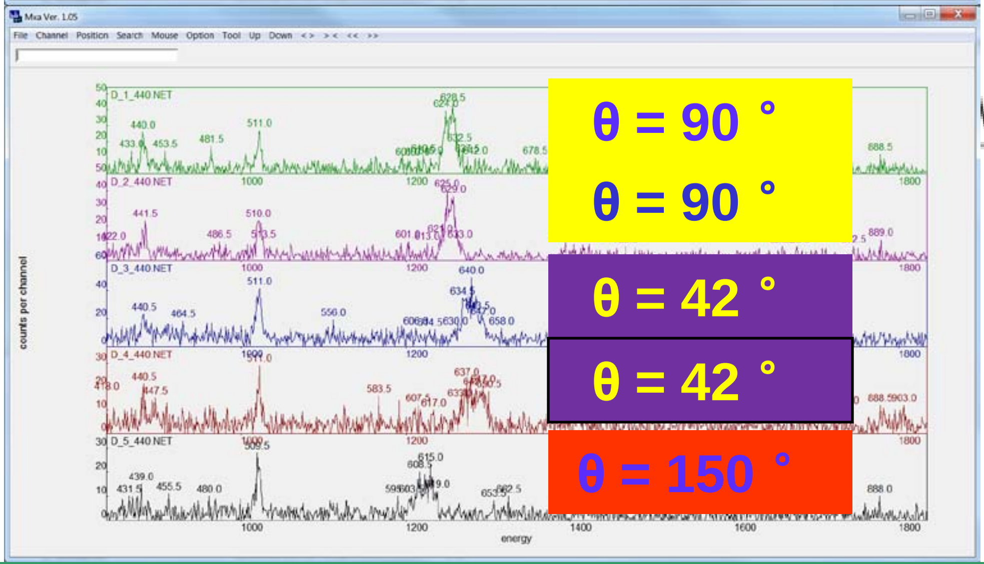
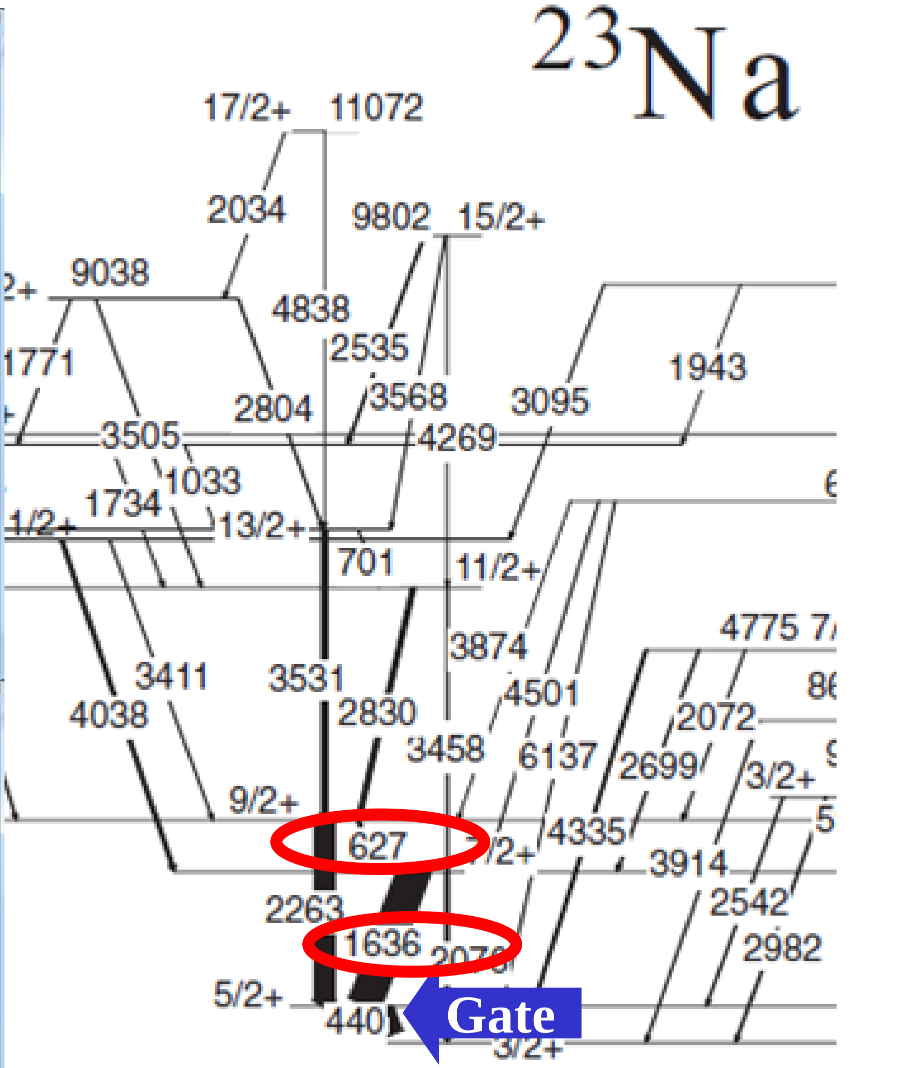
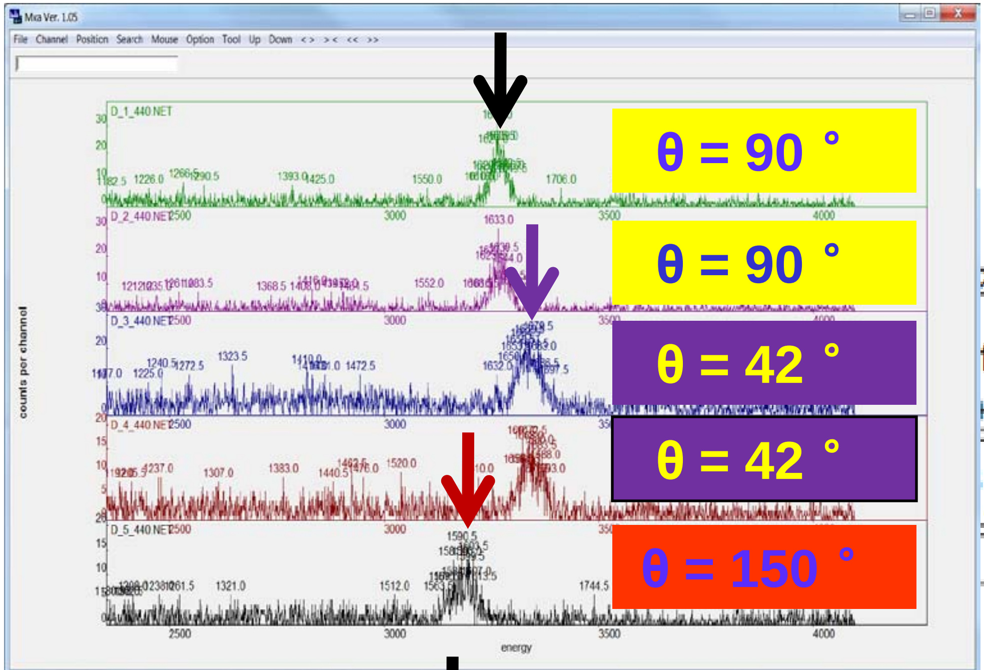


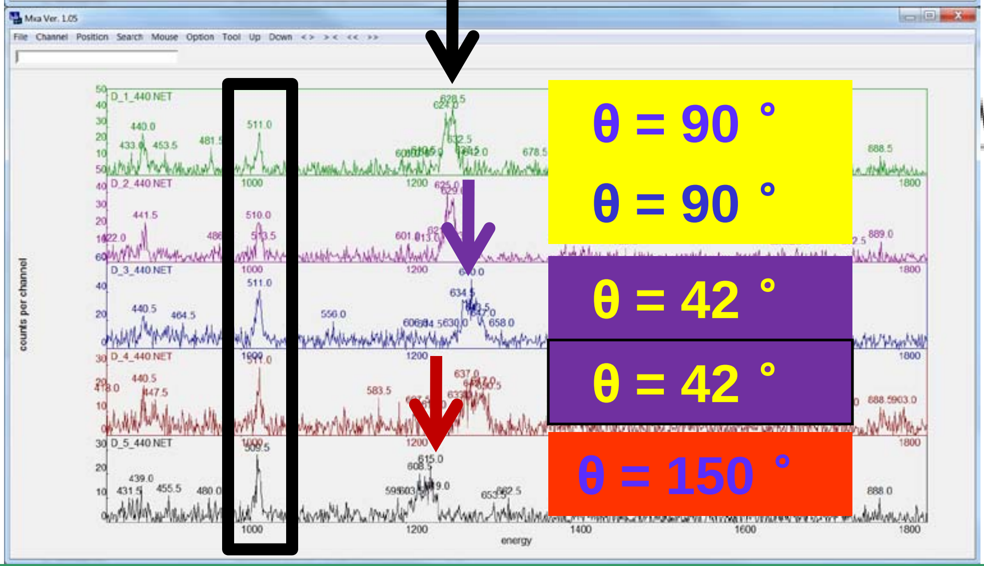


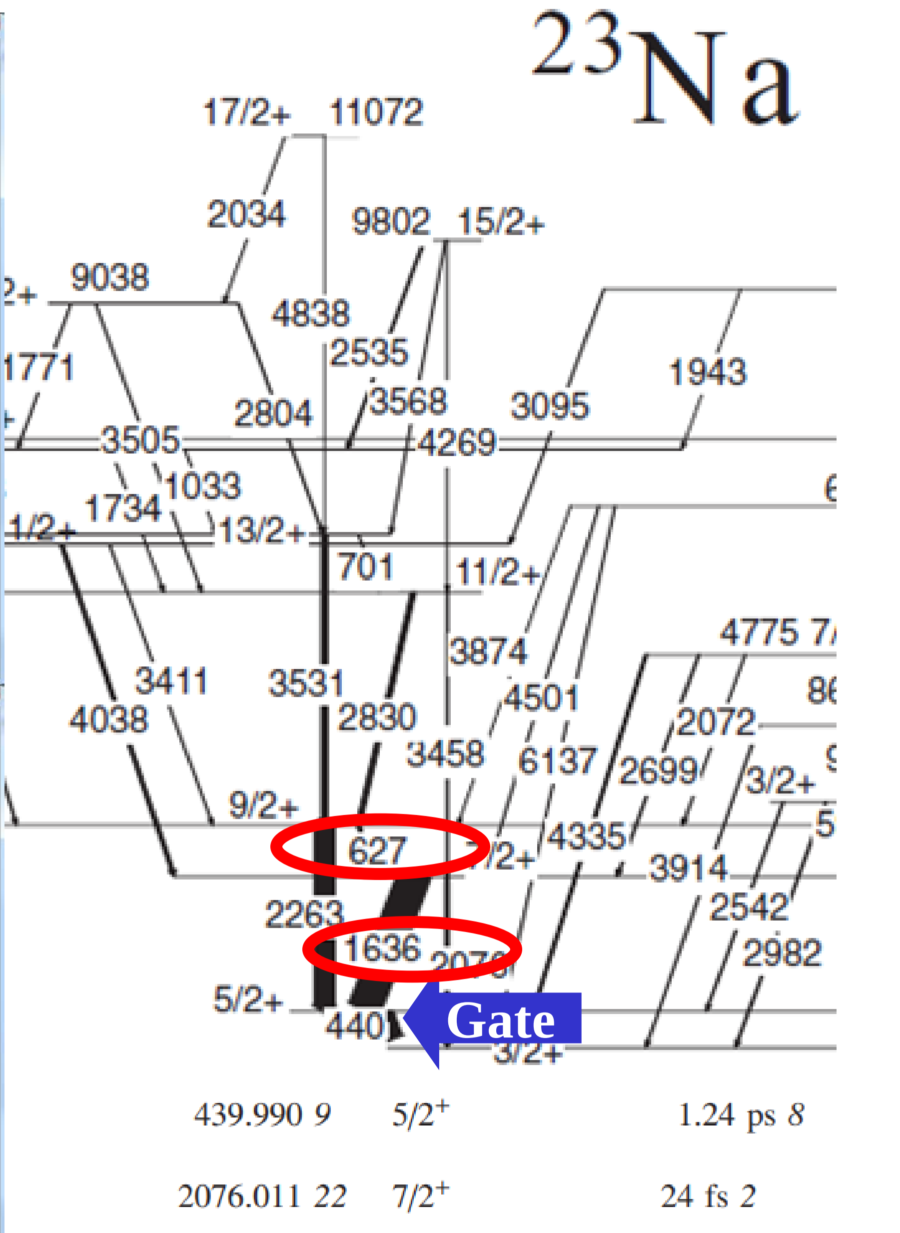


439.990 9	$5/2^+$	1.24 ps 8
2076.011 22	$7/2^+$	24 fs 2

Exp results - DSAM







The lifetime of nuclear excited state

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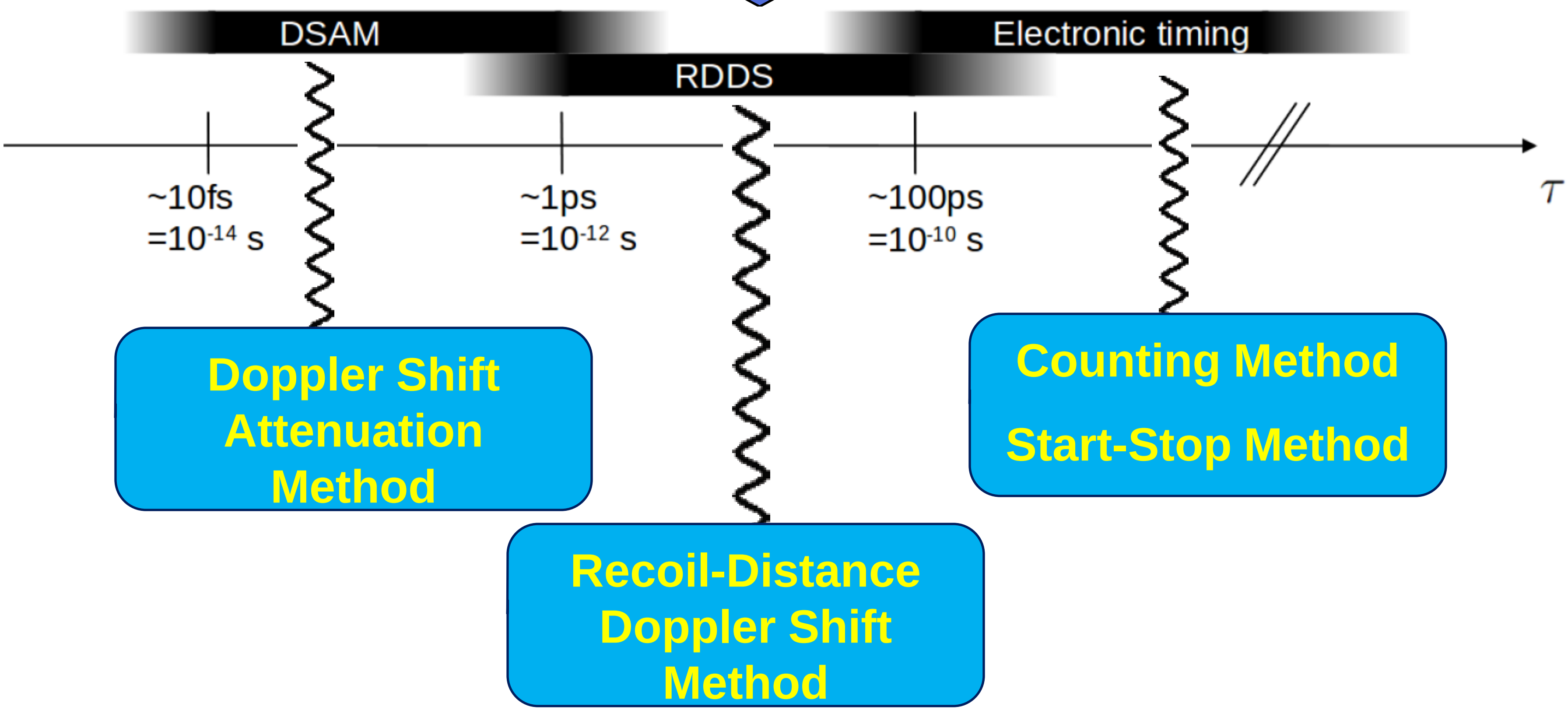
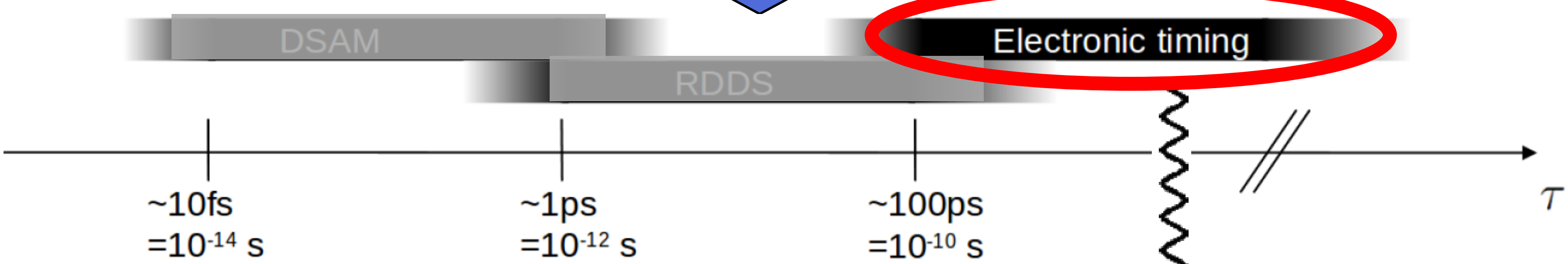
Experimentally



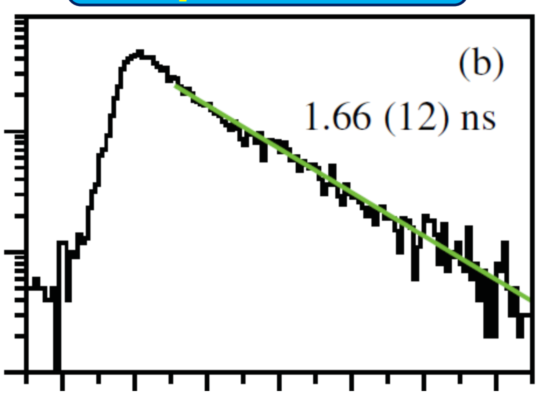
Electronic timing -- details

Determines the reduced electromagnetic transition probability, can be used to test nuclear structure models

Experimentally

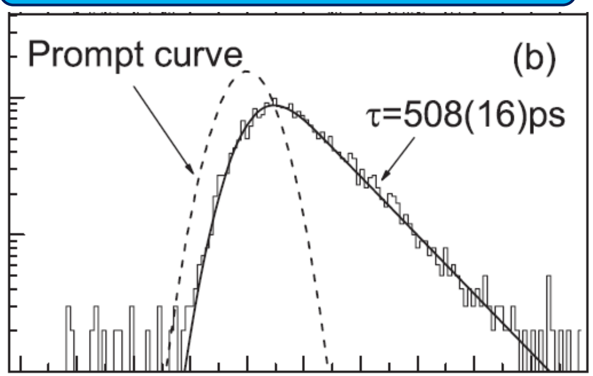


Slope Method



S. Kisyov, *et al.* PRC 84, 014324 (2011)

Convolution Method



C. B. Li, *et al.* PRC 86, 057303 (2012)

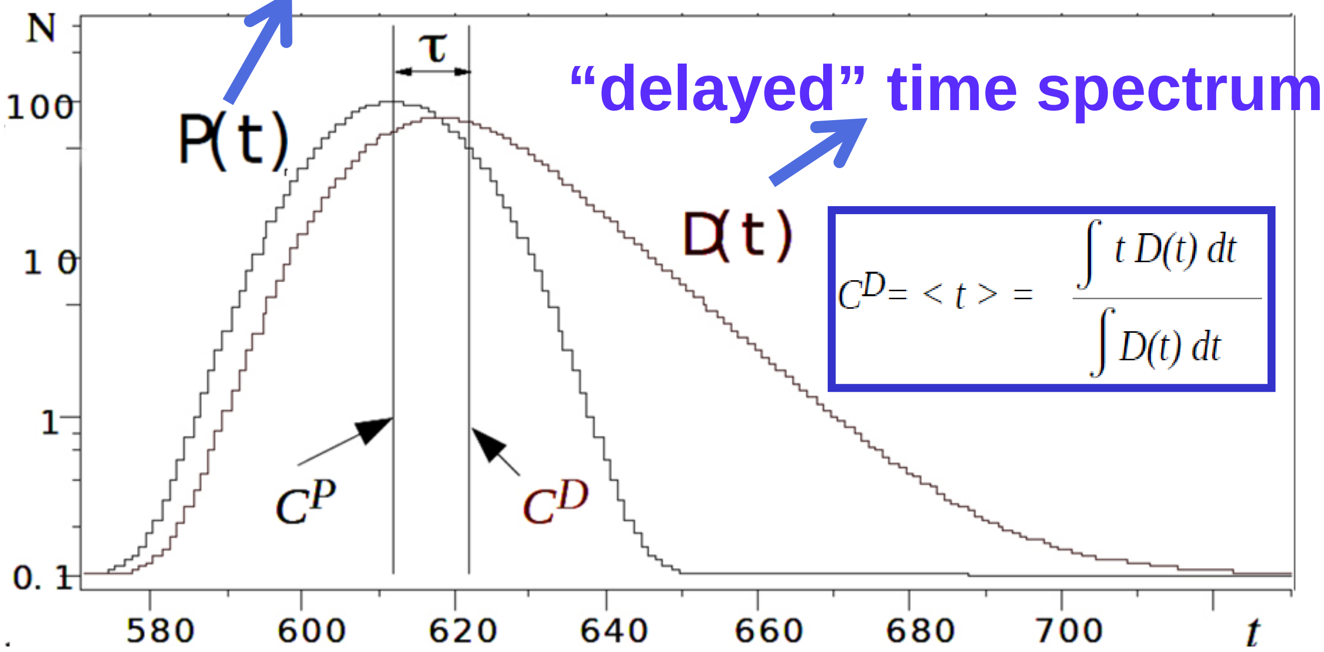
Generalized Centroid Difference Method

J.-M. Régis, *et al. NIM A 763, 210 (2014)*

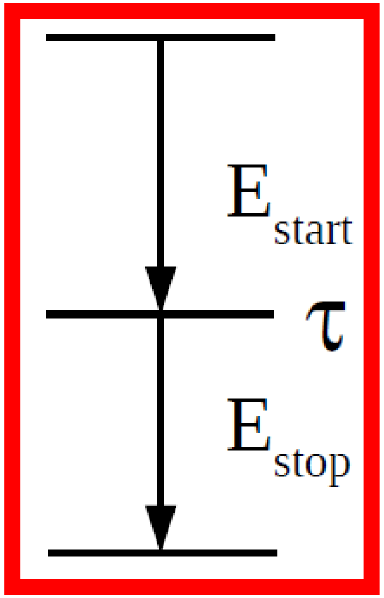
The Generalized Centroid Difference Method

Prompt time spectrum

"delayed" time spectrum



$$C^D = \langle t \rangle = \frac{\int t\, D(t)\, dt}{\int D(t)\, dt}$$

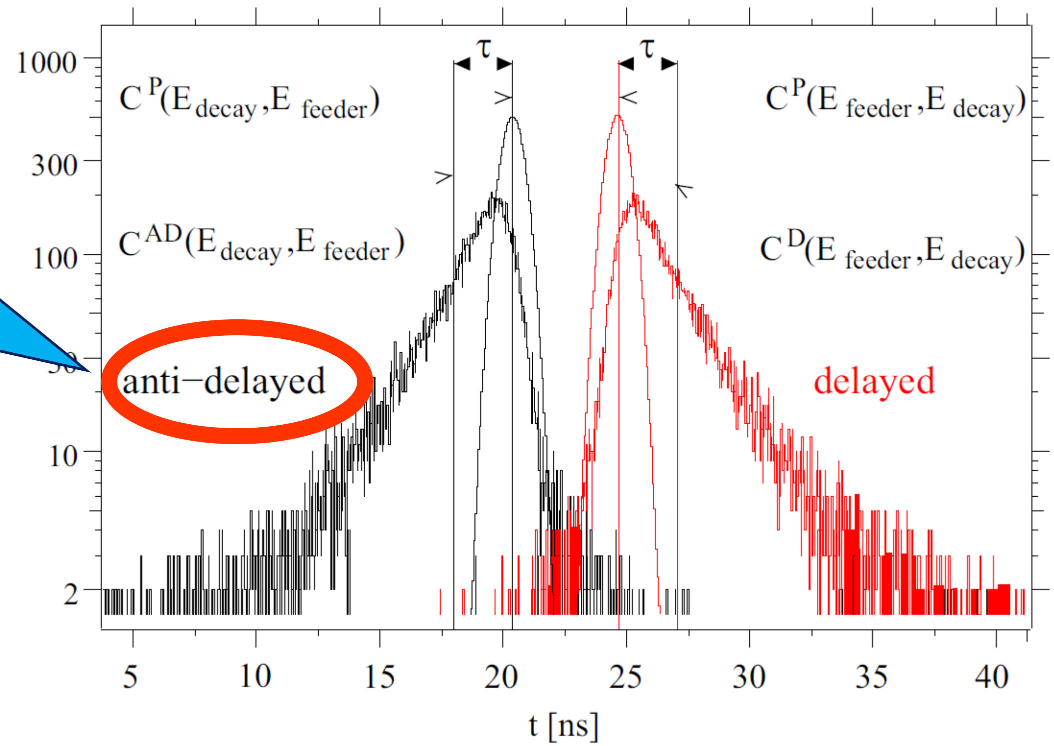


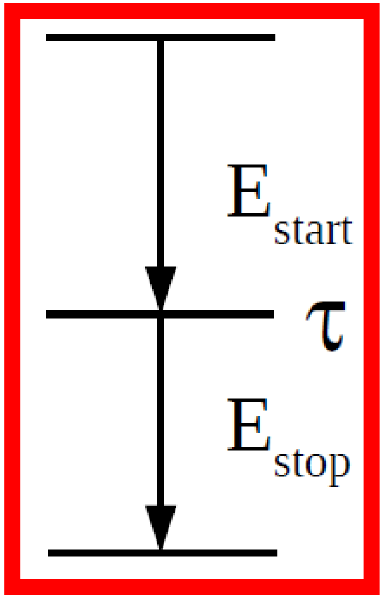
Assuming no background contributions:

$$\tau = C^D(E_{start}, E_{stop}) - C^P(E_{start}, E_{stop})$$

The Generalized Centroid Difference Method

Switch the feeder and decay transition





$$\Delta C\,(E_{\text{feeder}}, E_{\text{decay}}) = C^{D}(E_{\text{feeder}}, E_{\text{decay}}) - C^{AD}(E_{\text{decay}}, E_{\text{feeder}})$$

$$= \text{PRD}\left(E_{\text{feeder}}, E_{\text{decay}}\right) + 2\tau$$

$$\text{PRD}\,(E_{\text{feeder}}, E_{\text{decay}}) = C^{P}(E_{\text{feeder}}, E_{\text{decay}}) - C^{P}(E_{\text{decay}}, E_{\text{feeder}})$$

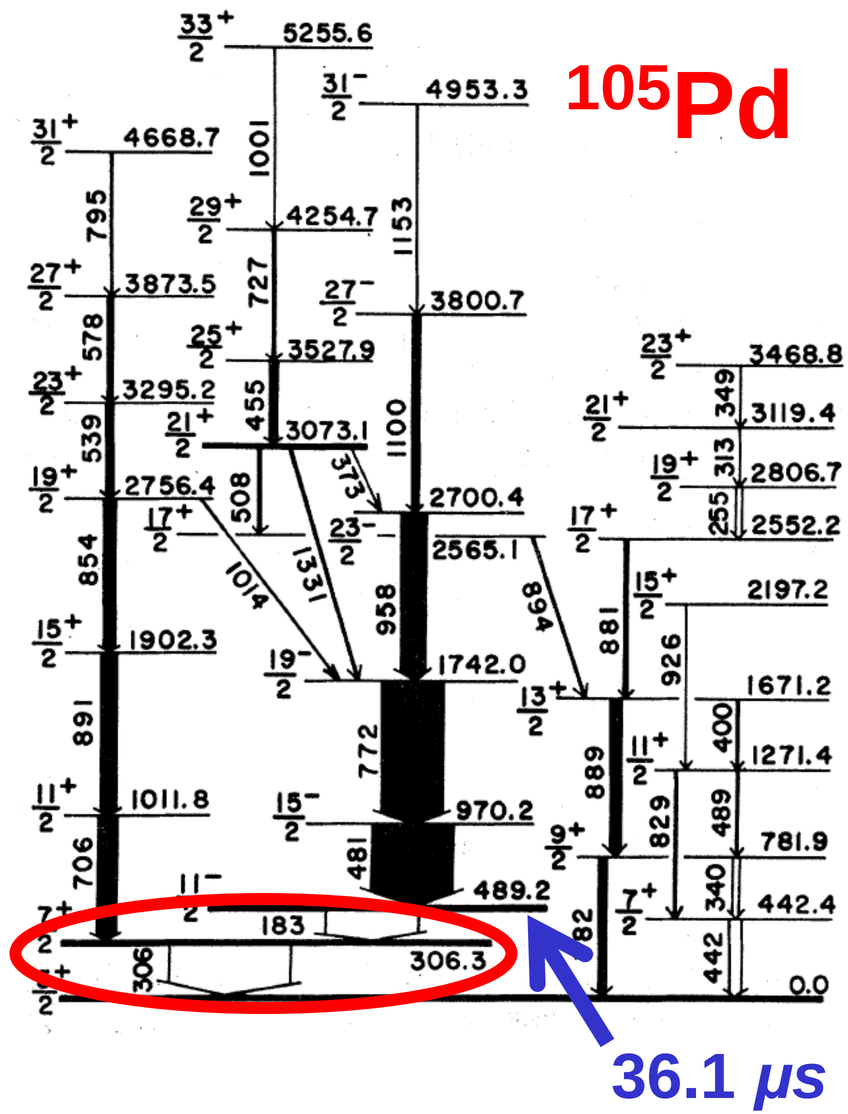
Can be determined using ^{152}Eu source

J.-M. Régis, *et al. NIM A 823，72 (2016)*

l forbidden transition in ^{105}Pd

$7/2^+$ state arising from $\nu g_{7/2}$

$5/2^+$ state arise from $\nu d_{5/2}$



<u>**Studying the *l* forbidden transition is helpful in understanding the structure, as well as testing the nuclear models**</u>

Lifetime measurement at CIAE

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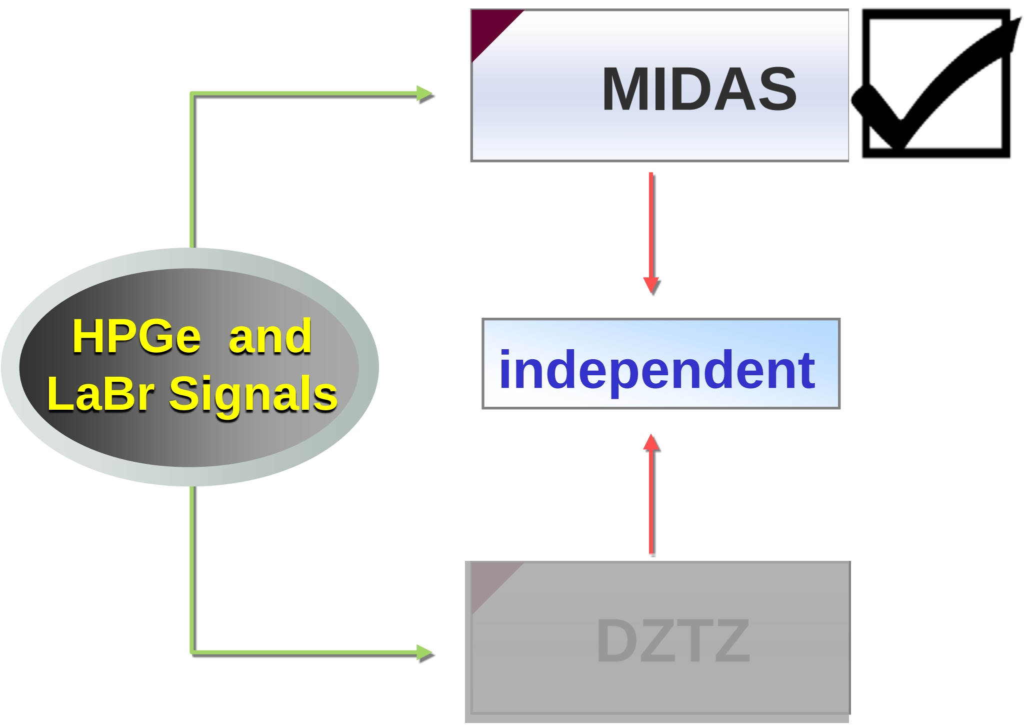
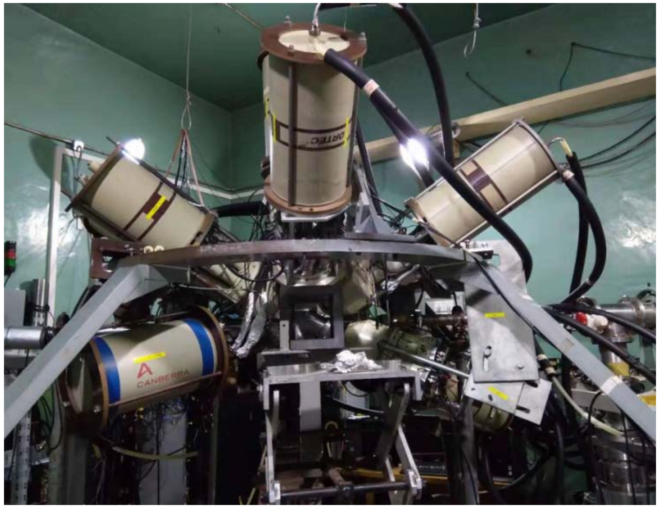
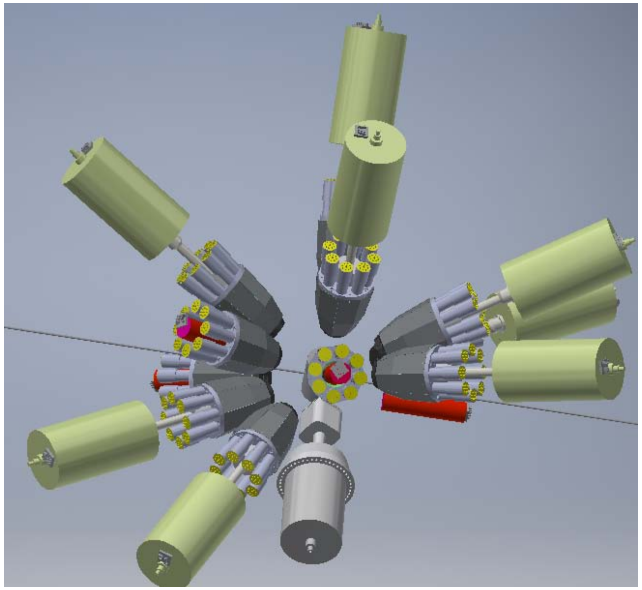
Beam: ^{12}C, 41.8 MeV，5pnA

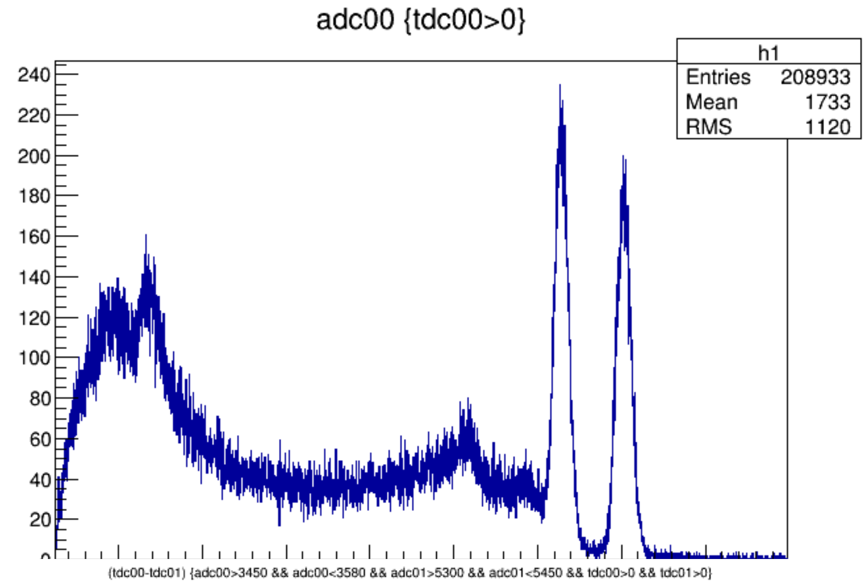
Detector: 3AC-LaBr + 6AC-HPGe + 1AC-Clover



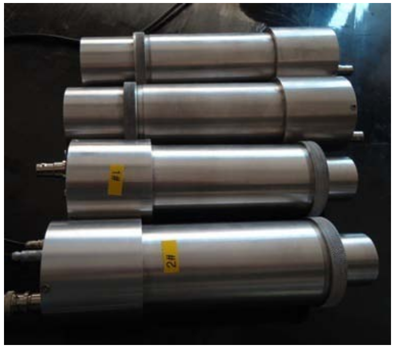




LaBr performance test

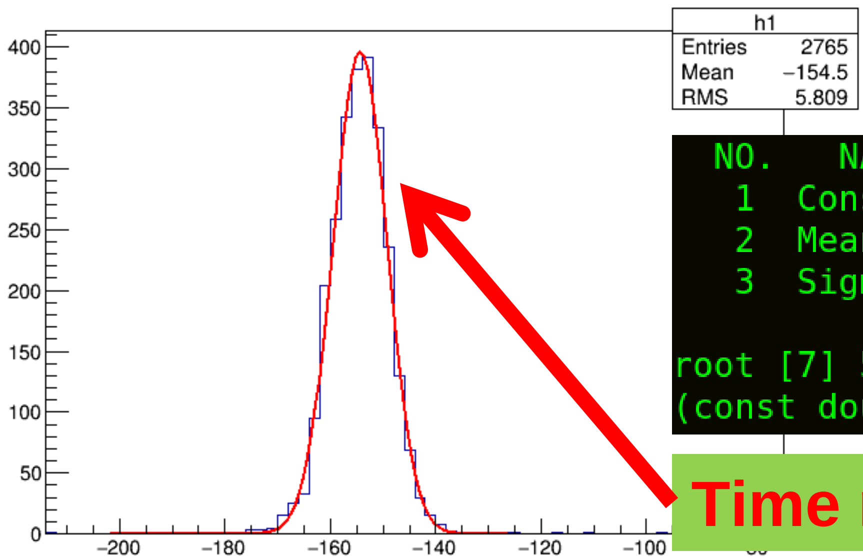


$LaBr_3(Ce)$ crystal



Picture of detectors

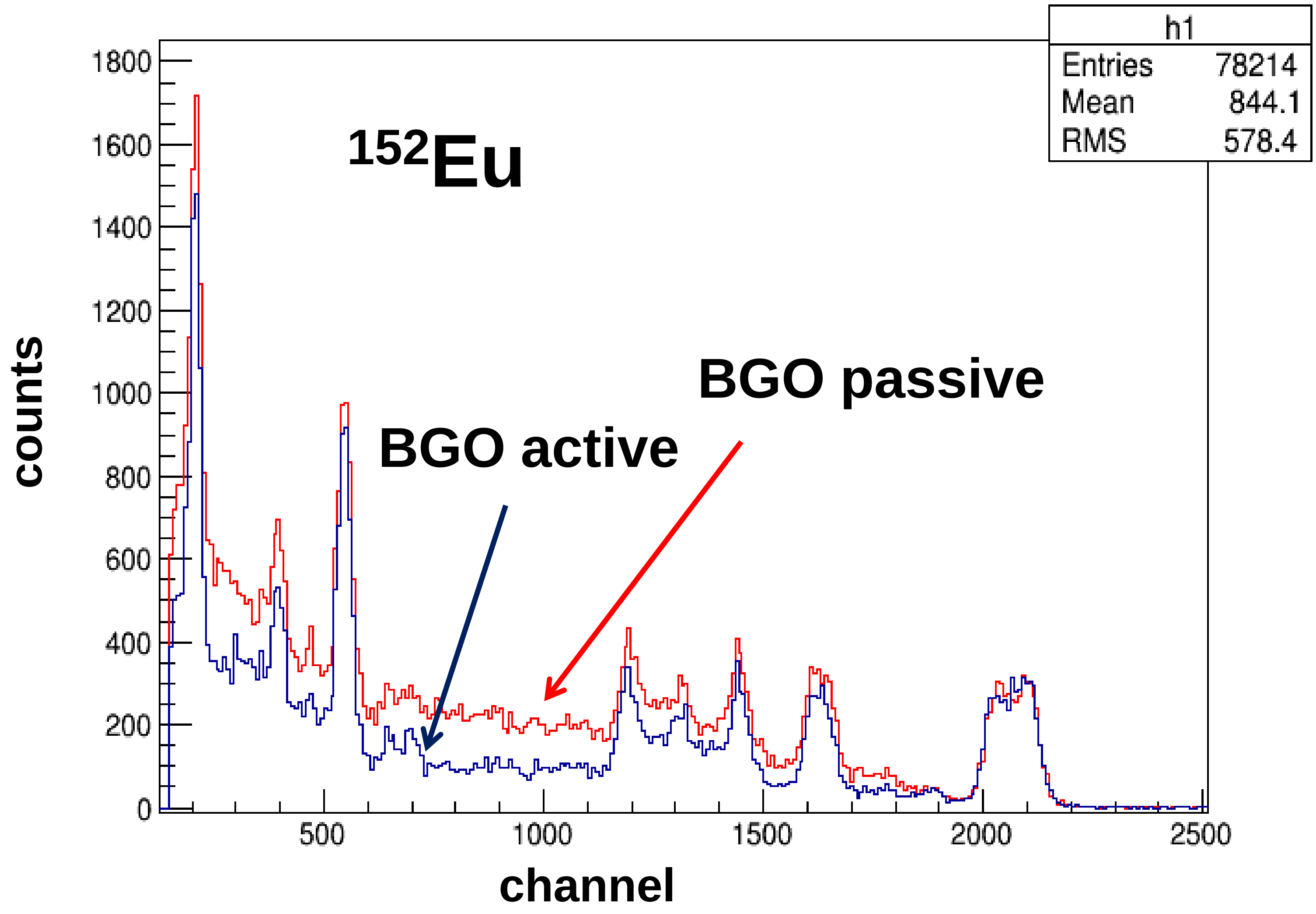
$LaBr_3(Ce)$ detector



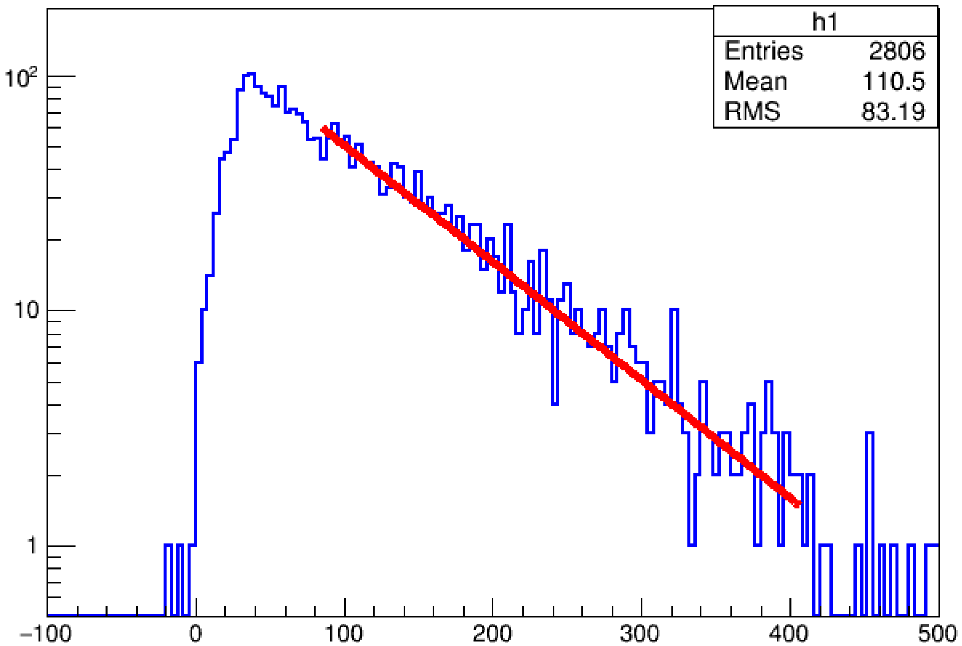

```
  NO.    NAME         VALUE              ERROR
   1   Constant     3.96314e+02    9.93133e+00
   2   Mean        -1.54411e+02    1.01790e-01
   3   Sigma        5.14260e+00    7.90737e-02

root [7] 5.14260e+00*24.414*2.36
(const double)2.96301389903999961e+02
```

Time resolution:296 ps (FWHM)

LaBr + BGO_AC performance test

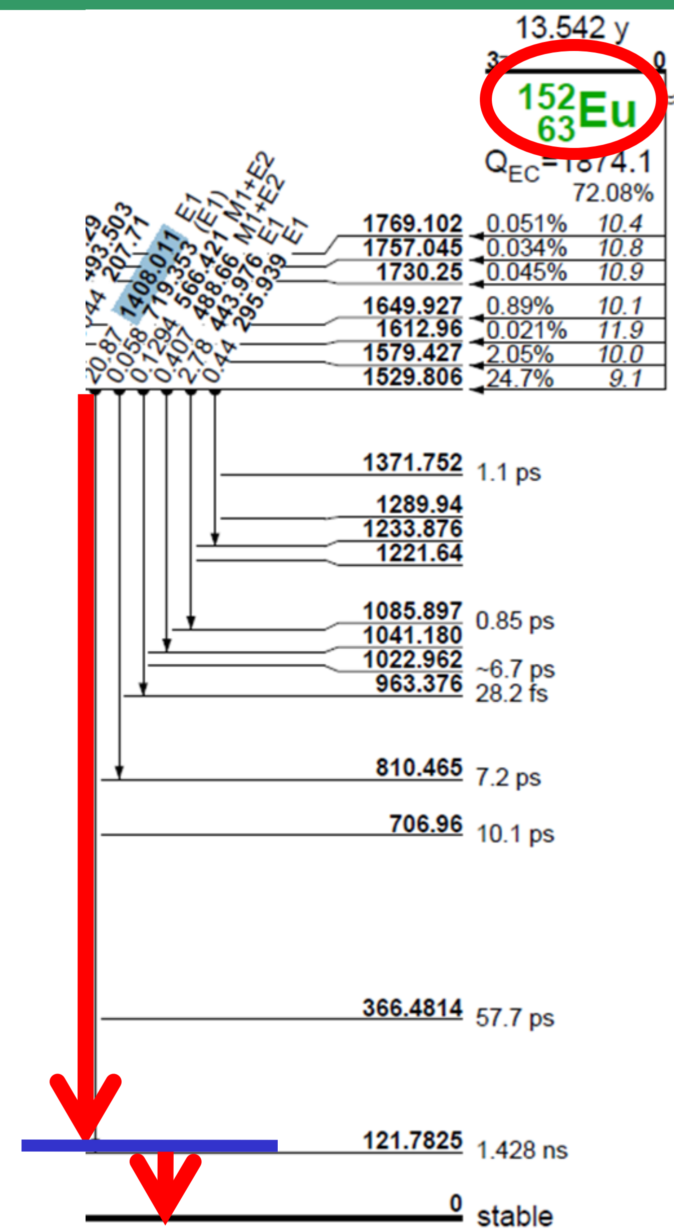


LaBr + BGO_AC performance test

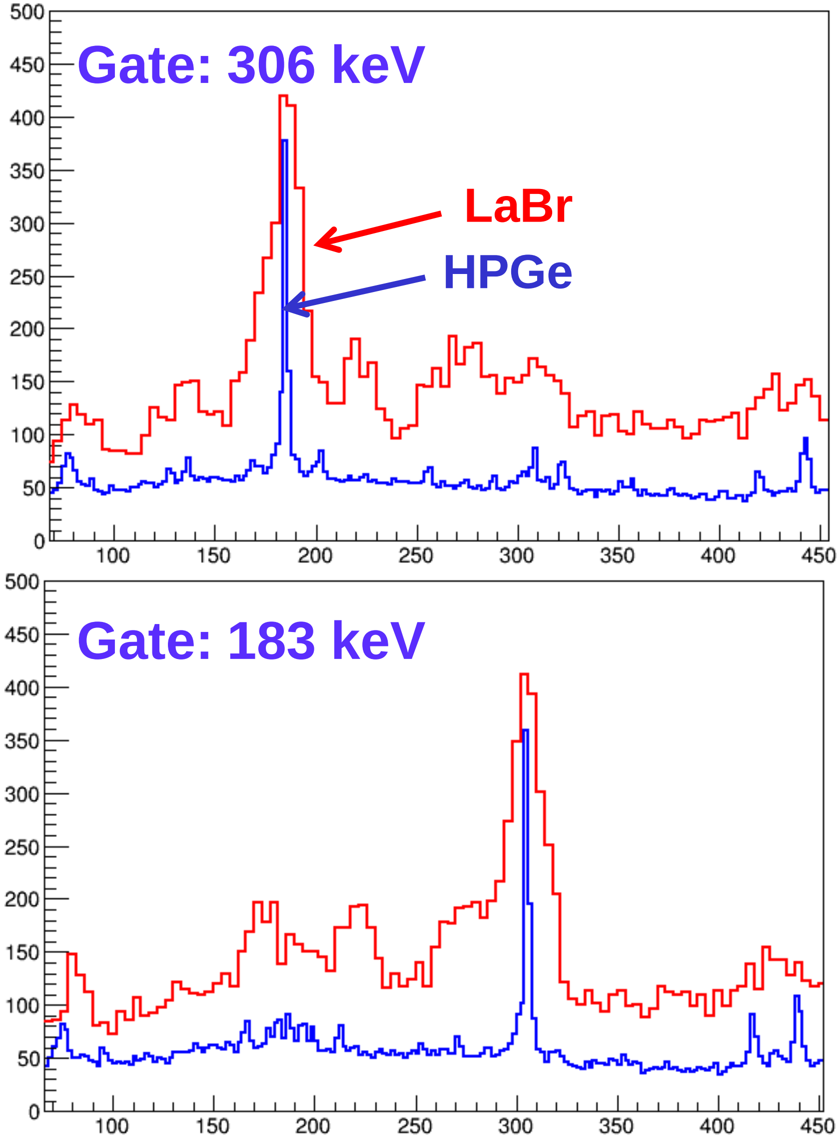



```
NO.   NAME        VALUE           ERROR
 1   Constant    5.08150e+00    6.85747e-02
 2   Slope      -1.15371e-02    3.84877e-04

root [13] 0.693/1.15371e-02*24.414
(const double)1.466477884390357 99e+03
```

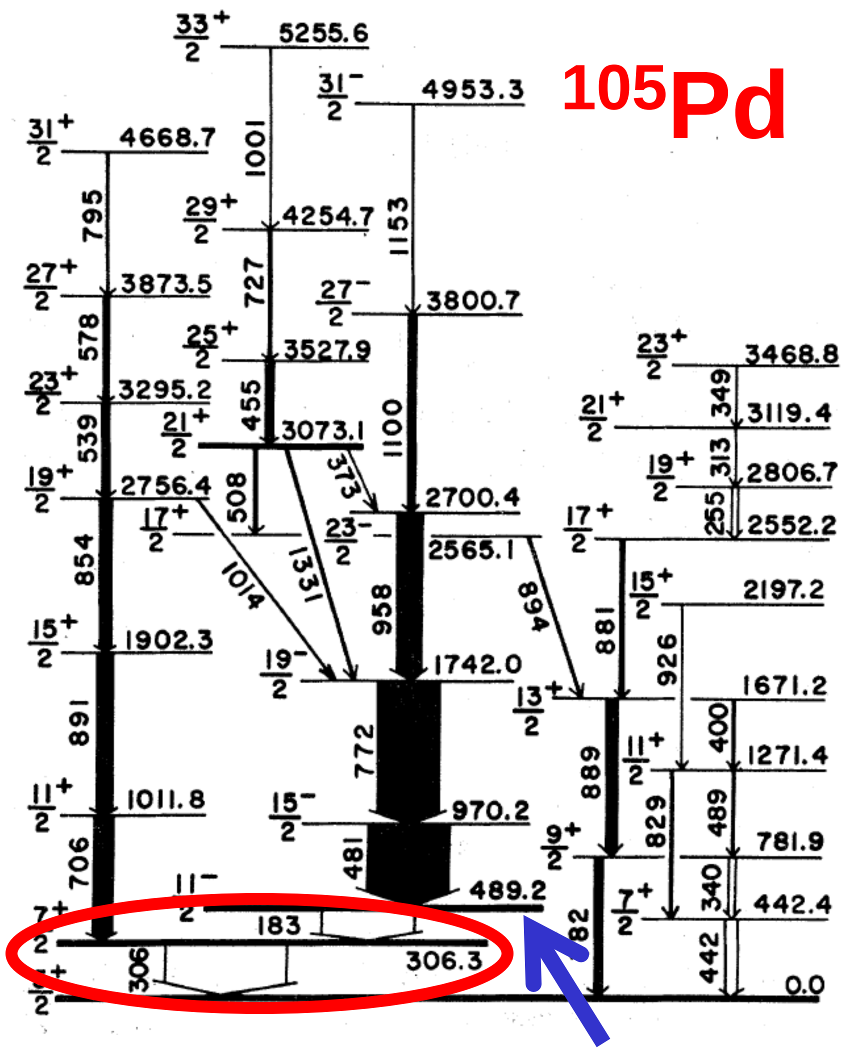
	Experiment	VS	Literature
$T_{1/2}$	1.466 ns		1.428 ns



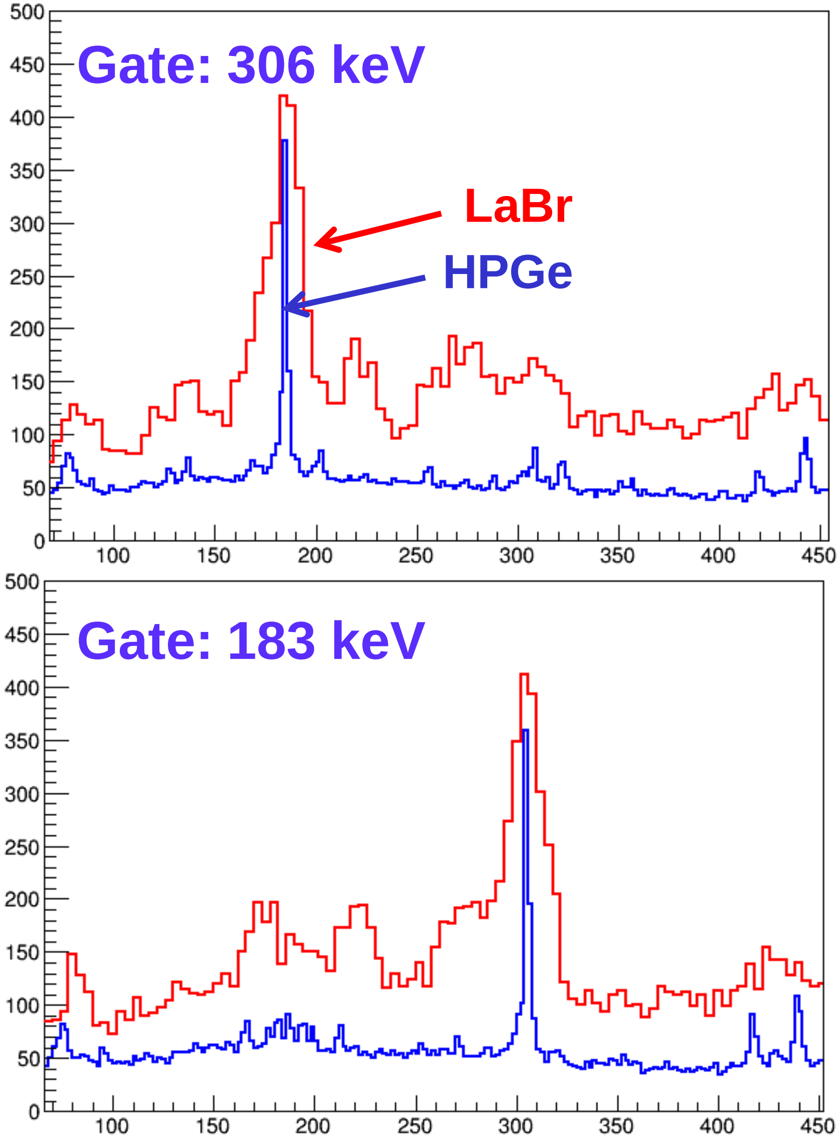
In-beam spectra



Gated spectra from ^{105}Pd

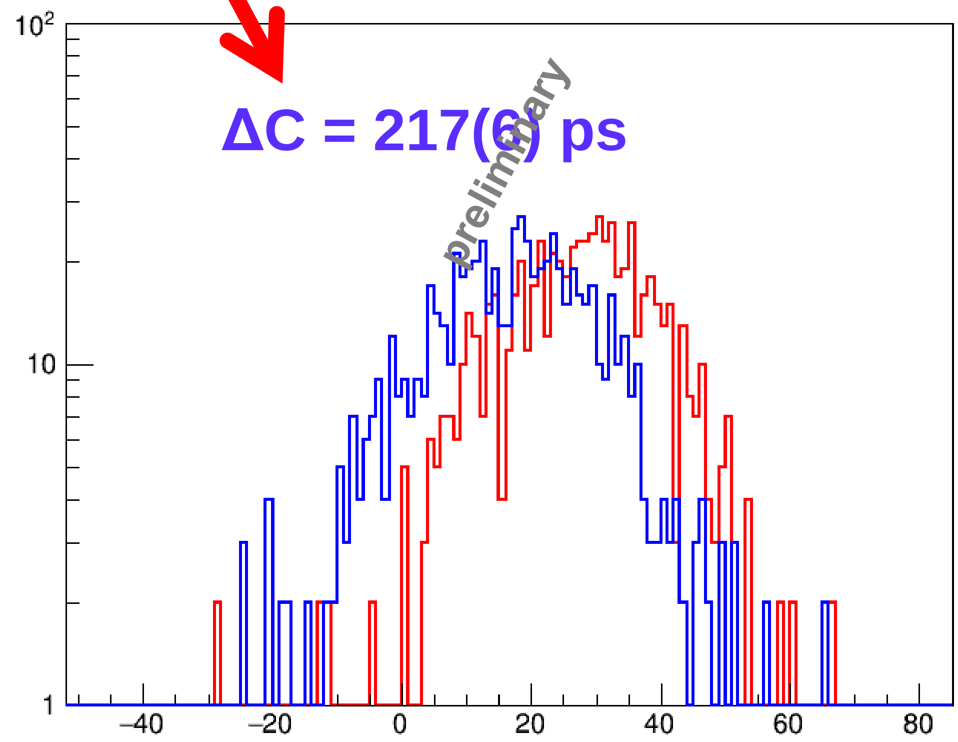


Time difference spectra

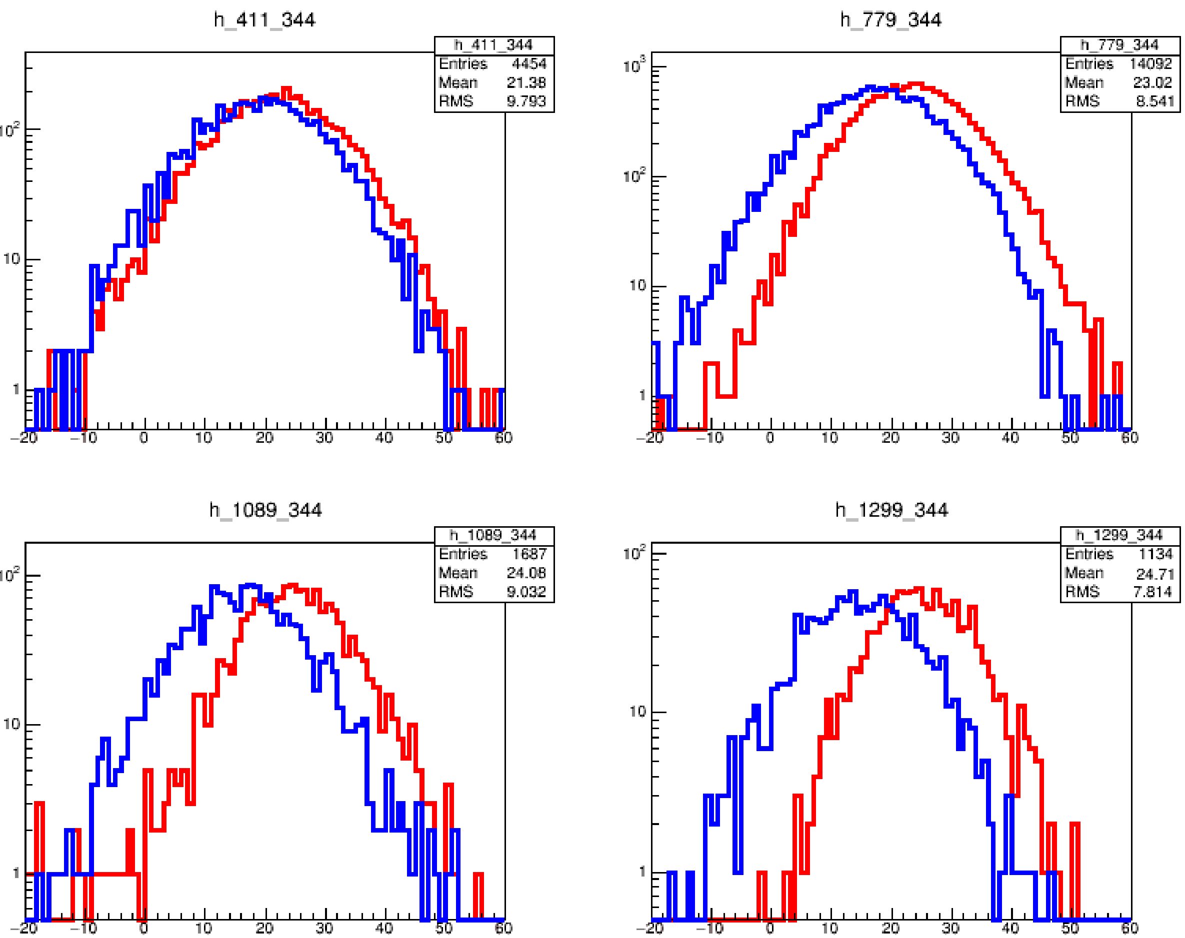


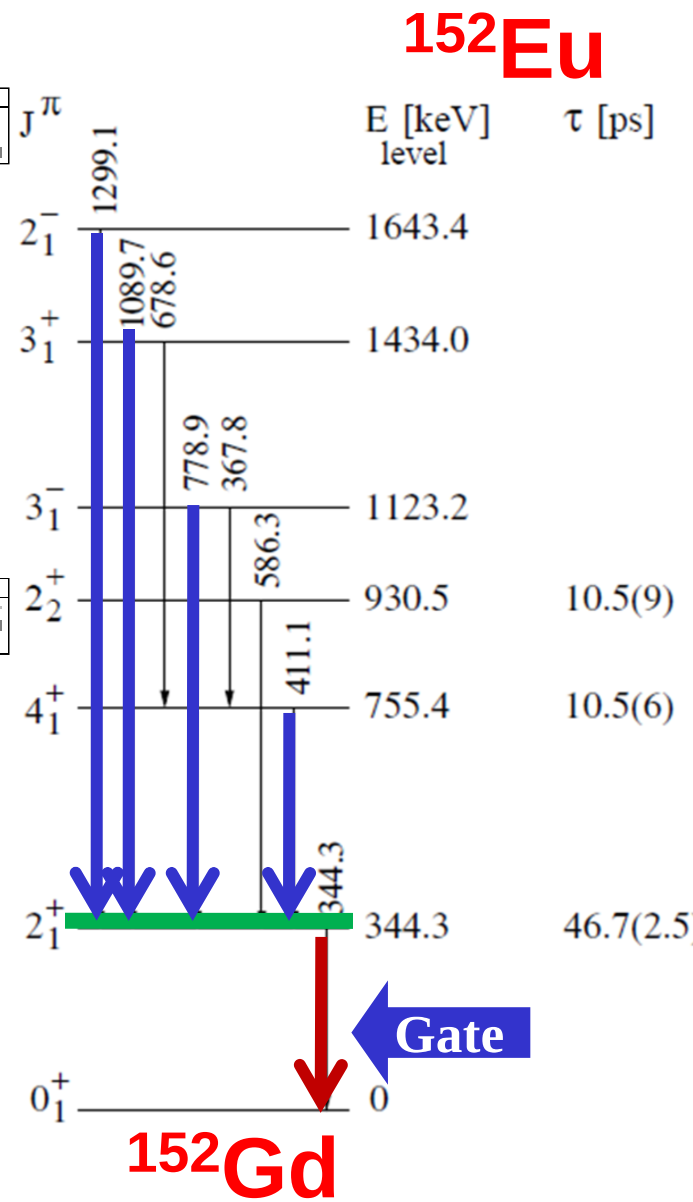
Gated spectra from ^{105}Pd

$$\Delta C(E_{\text{feeder}}, E_{\text{decay}}) = C^{D}(E_{\text{feeder}}, E_{\text{decay}}) - C^{AD}(E_{\text{decay}}, E_{\text{feeder}})$$
$$= \text{PRD}(E_{\text{feeder}}, E_{\text{decay}}) + 2\tau$$



PRD curve from ^{152}Eu





TDC difference with respect to 344 keV of ^{152}Eu

Formula to extract lifetime

$$\Delta C_{\mathrm{FEP}} = \Delta C_{\mathrm{exp}} + \tfrac{1}{2}[t_{\mathrm{corr}}(\mathrm{feeder}) + t_{\mathrm{corr}}(\mathrm{decay})]$$

where

$$t_{\mathrm{corr}}(\mathrm{feeder}) = \left[\frac{(\Delta C_{\mathrm{exp}} - \Delta C_{\mathrm{BG}})}{p/b}\right]_{\mathrm{feeder}},$$

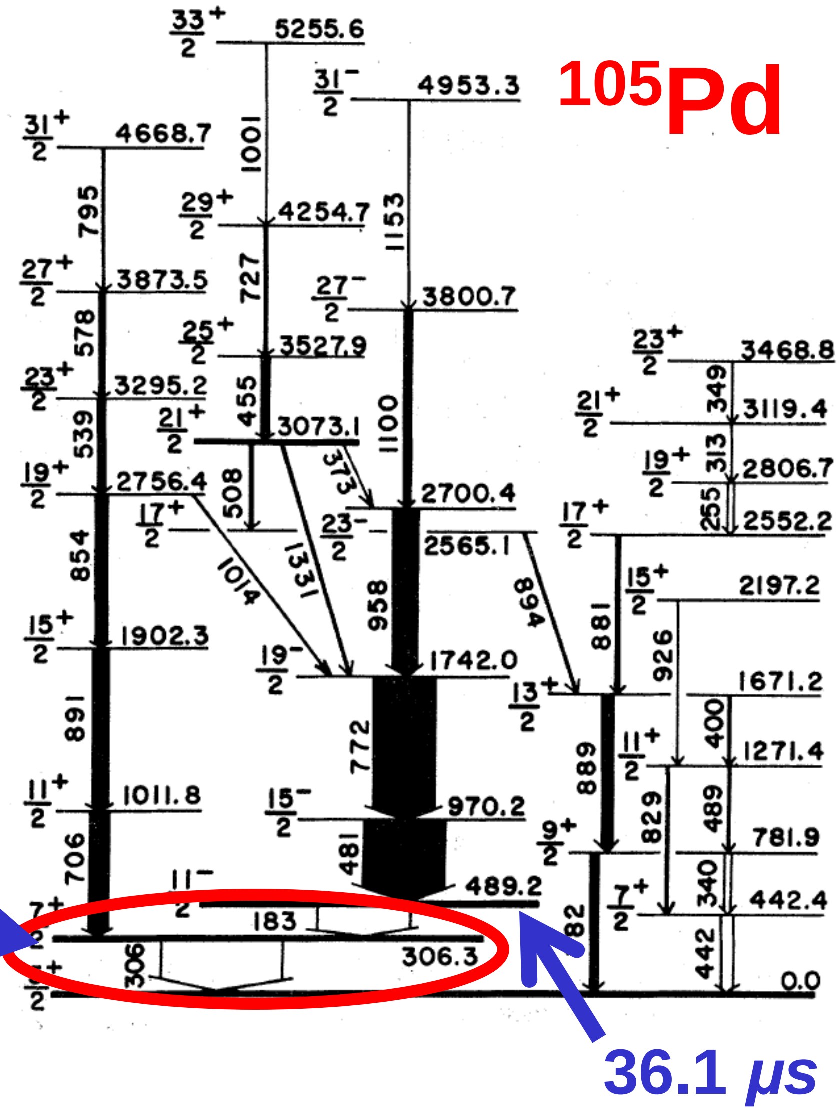
$$t_{\mathrm{corr}}(\mathrm{decay}) = \left[\frac{(\Delta C_{\mathrm{exp}} - \Delta C_{\mathrm{BG}})}{p/b}\right]_{\mathrm{decay}},$$

and

$$\tau = \tfrac{1}{2}(\Delta C_{\mathrm{FEP}} - \mathrm{PRD}).$$

τ = 130(7) ps

preliminary



Deduced B(M1) value

$$\tau(M1) = \tau(1 + \alpha_{Tot})(1 + \delta^2)$$

α = 0.01896

δ = 0.055

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The $B(M1; 7/2^+ \rightarrow 5/2^+)$ value in unit of μ_N^2 is calculated by the formula

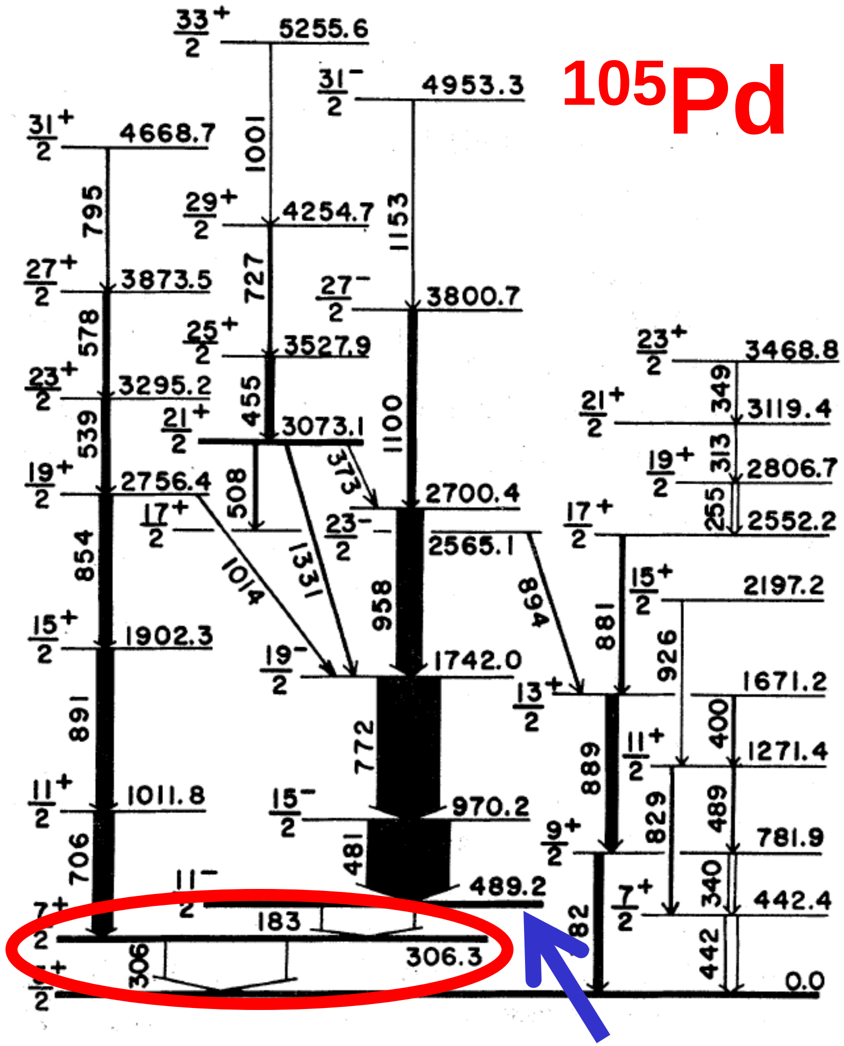
$$B(M1)\downarrow = \frac{5.687 \times 10^7}{(E_\gamma)^3 \tau_{M1}}, \qquad (5)$$

B(M1;7/2⁺ -> 5/2⁺)

= 1.49(8) × 10^{-2} μ_N^2

= 0.83(5) × 10^{-2} W.u.

preliminary



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谢谢