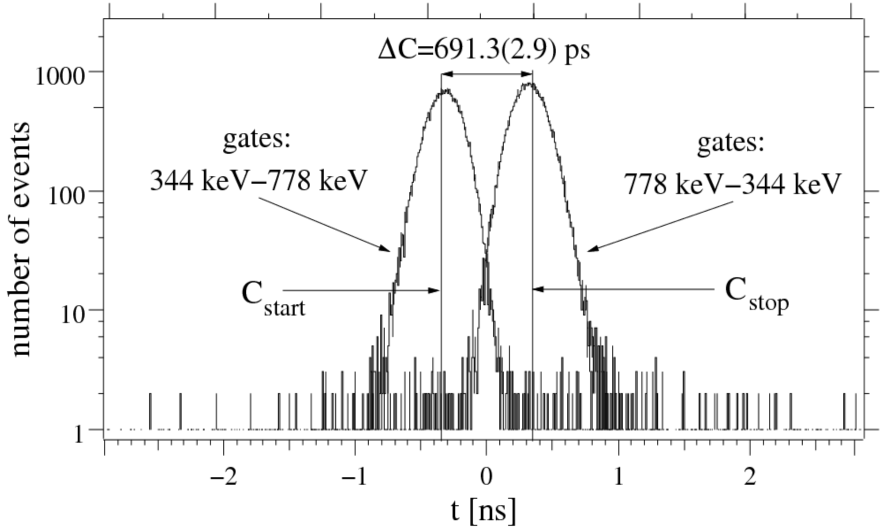
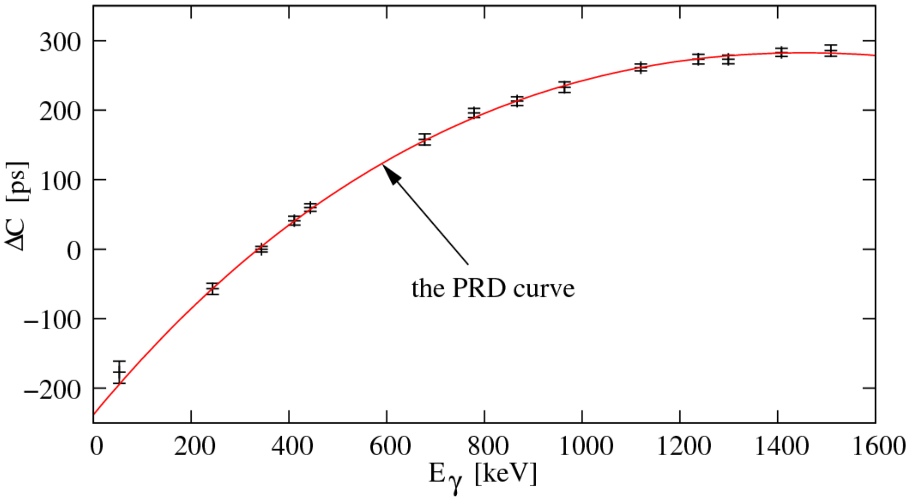
Fast Timing Workshop at Brighton

11.01.2011

- the mirror symmetric centroid difference (MSCD) method



- calibration of the „prompt“ time response



J.-M. Régis, IKP, University of Cologne

The γ–γ fast timing technique

time resolution $\delta t := FWHM/\sqrt{2}$ of the prompt response function (PRF)

→ limitation for the slope method or the deconvolution method, respectively.

e.g., $\delta t \sim 200$ ps @ 511 keV and $\delta t \sim 150$ ps @ 1333 keV
for 1"x1" $LaBr_3(Ce)$ crystal + XP20D0 photomultiplier tube (PMT)

M. Moszynski et al., NIM A **567** (2007)

- response linearity ?

Applying higher PMT voltage, the time resolution can be improved.

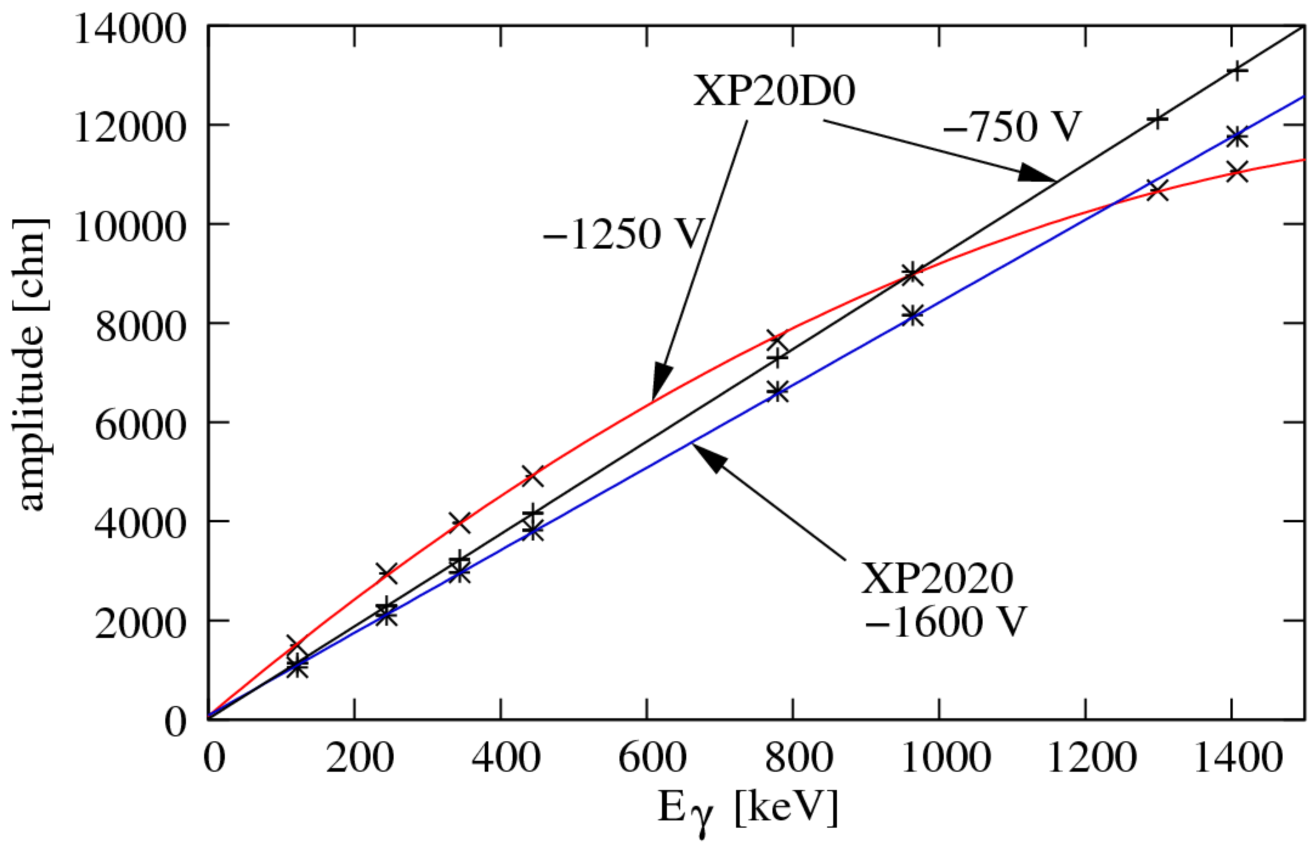
But, non-linear response of the PMT output pulse can be obtained!

- to measure beneath the time resolution, the **centroid shift method** can be used.

Absolute time resolving power of **$\delta\tau \sim$ 3-5 ps** is obtainable.

⇒ determination of the „**prompt curve**“ (PRF centroid vs. energy)

The PMT response non-linearity

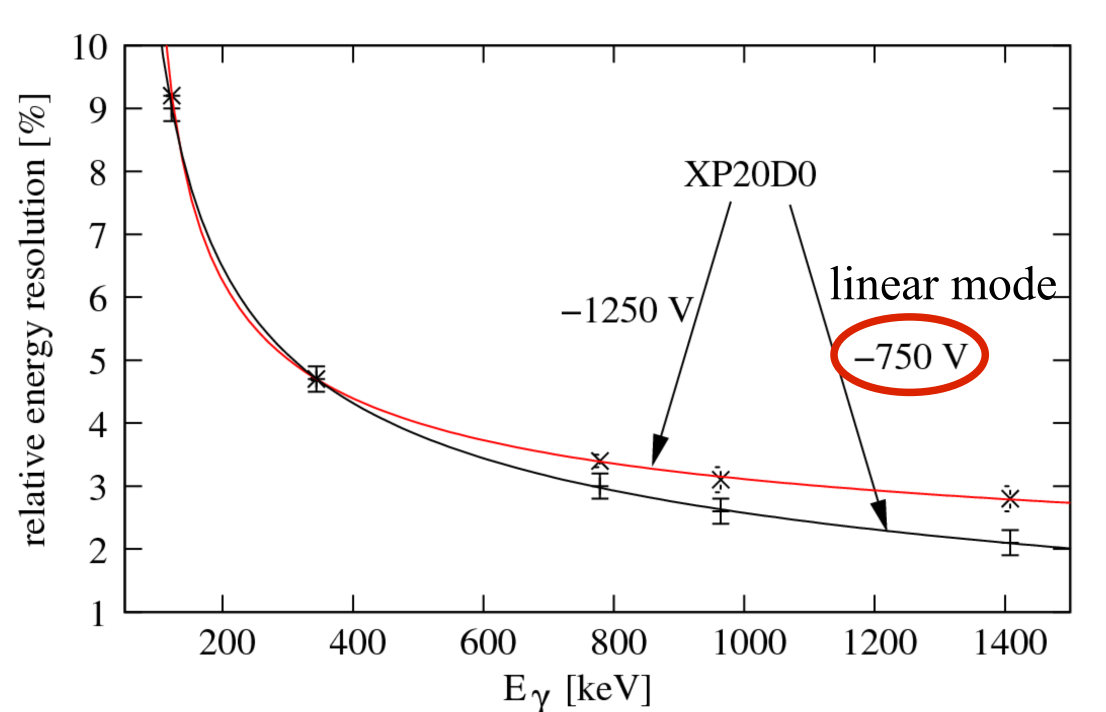


The non-linear response A(E) of the XP20D0 is very well described using: $A(E)=aE^2+bE+c$

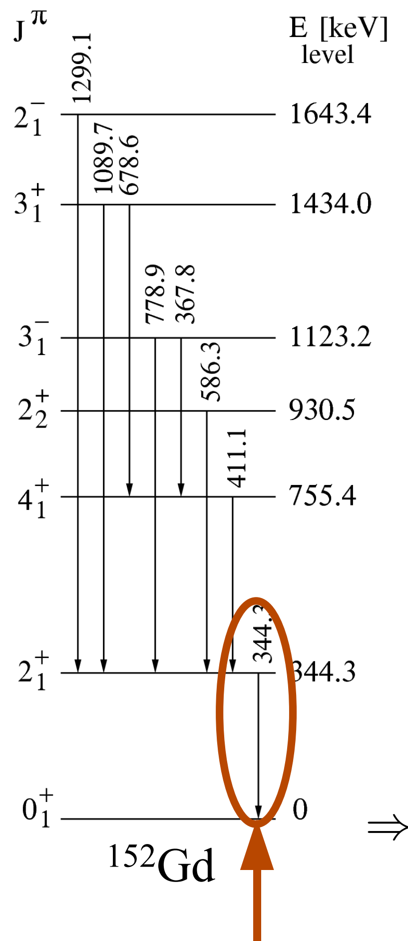
Deviations of both the linear and the non-linear operation $\leq 1\%$

The linear operation of the XP20D0 is only useful for $E_\gamma > 70$ keV
(unless using the anode pulse)

J.-M. Régis, PhD thesis (2011)

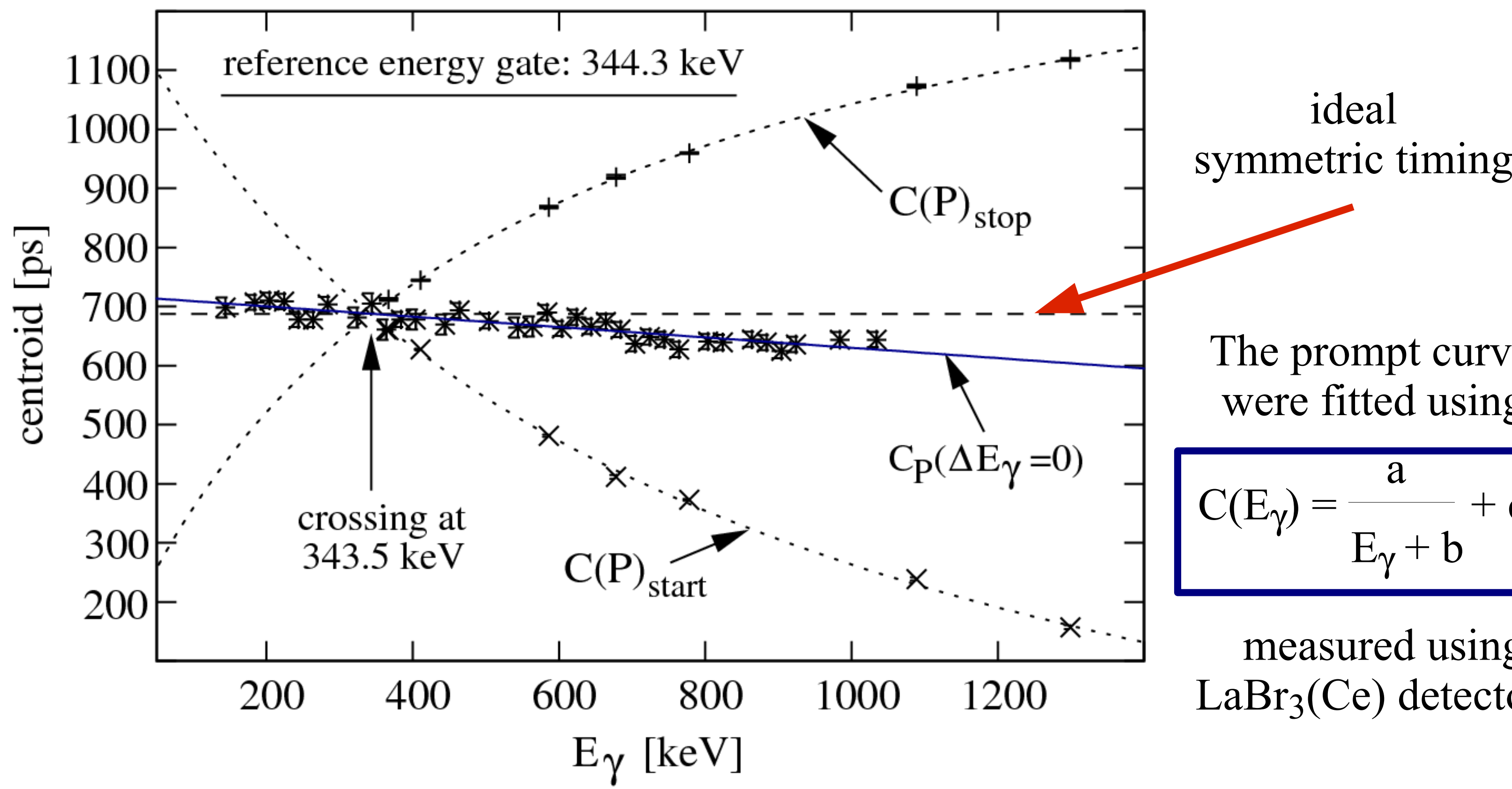


XP20D0
linear mode
–1250 V
–750 V
relative energy resolution [%]
E$_\gamma$ [keV]
10
9
8
7
6
5
4
3
2
1
200
400
600
800
1000
1200
1400



J π
E [keV]
level
2$_1^-$
3$_1^+$
3$_1^-$
2$_2^+$
4$_1^+$
2$_1^+$
0$_1^+$
1643.4
1434.0
1123.2
930.5
755.4
344.3
0
1299.1
1089.7
678.6
778.9
367.8
586.3
411.1
344.3
^{152}Gd
⇒

The two prompt curves of a γ–γ fast timing setup



The prompt curves were fitted using:

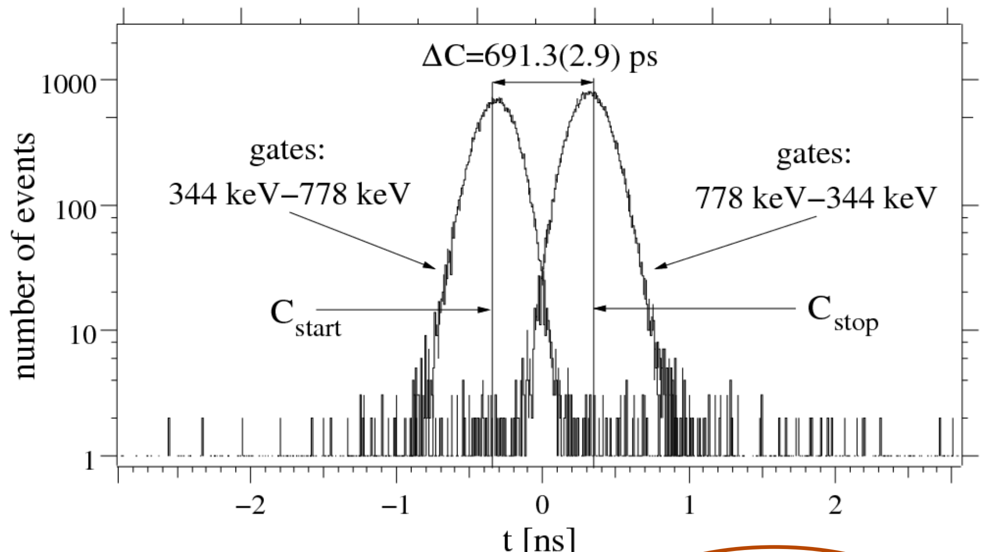
$$C(E_\gamma) = \frac{a}{E_\gamma + b} + c$$

measured using $LaBr_3(Ce)$ detectors.

The timing of the two detectors of a real γ–γ fast timing setup is asymmetric.

J.-M. Régis et al., NIM A **622** (2010)

The Mirror Symmetric Centroid Difference (MSCD) method



The combined time-walk is described by the prompt response difference (PRD):

$PRD(E_\gamma)=C_P(E_\gamma)_{stop}-C_P(E_\gamma)_{start}$

$\Delta C(\Delta E)=C_{stop}-C_{start}=PRD(\Delta E)+2\tau$

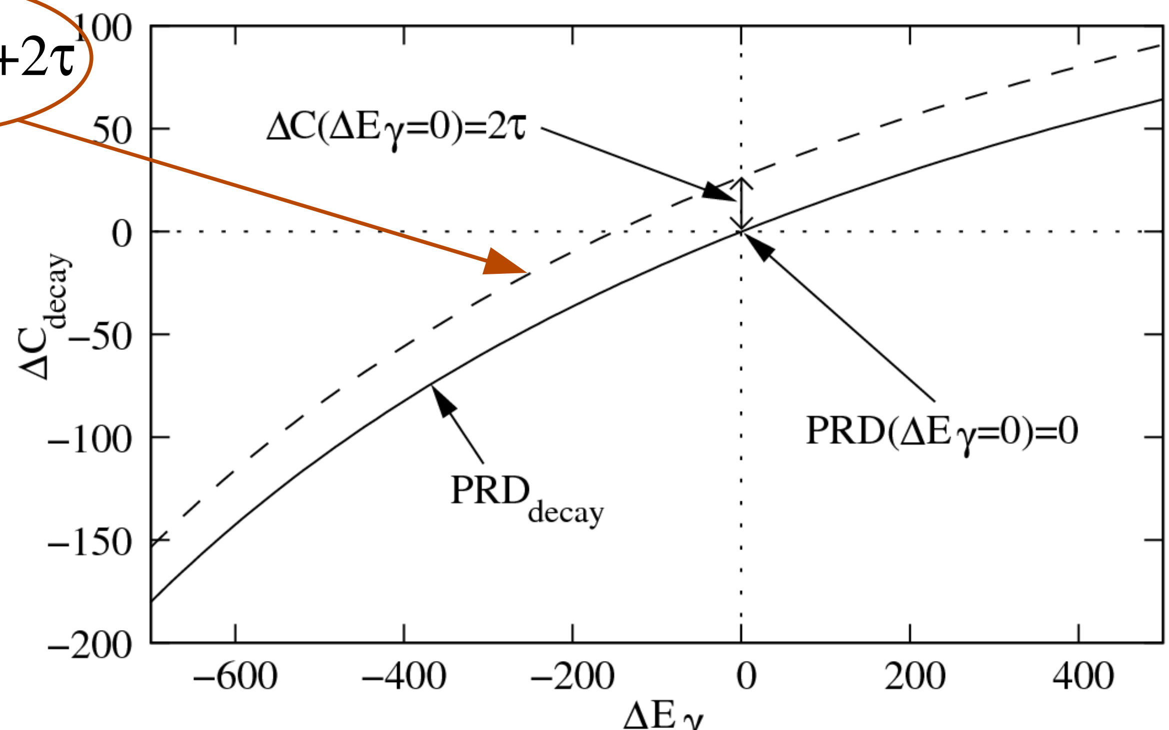
$\Delta E=E_{feeder}-E_{decay}$

Direct picosecond lifetime determination possible: $\Delta C(\Delta E=0)=2\tau$

The PRD is mirror symmetric:

$PRD(\Delta E)_{decay}=-PRD(-\Delta E)_{feeder}$

The (ΔC,ΔE)-diagram:



J.-M. Régis et al., NIM A **622** (2010)

Advantages in using the MSCD method:

- cancellation of the timing asymmetry

- cancellation of the „electronic drift“ (shift due to thermal fluctuations)

- additional universal prompt calibration point: PRD(ΔE=0)=0

- due to mirror symmetry, a centroid difference can be used twice (E_{feeder} and E_{decay})

- in γ-γ timing, the PRD curve is independent of the experimental geometry

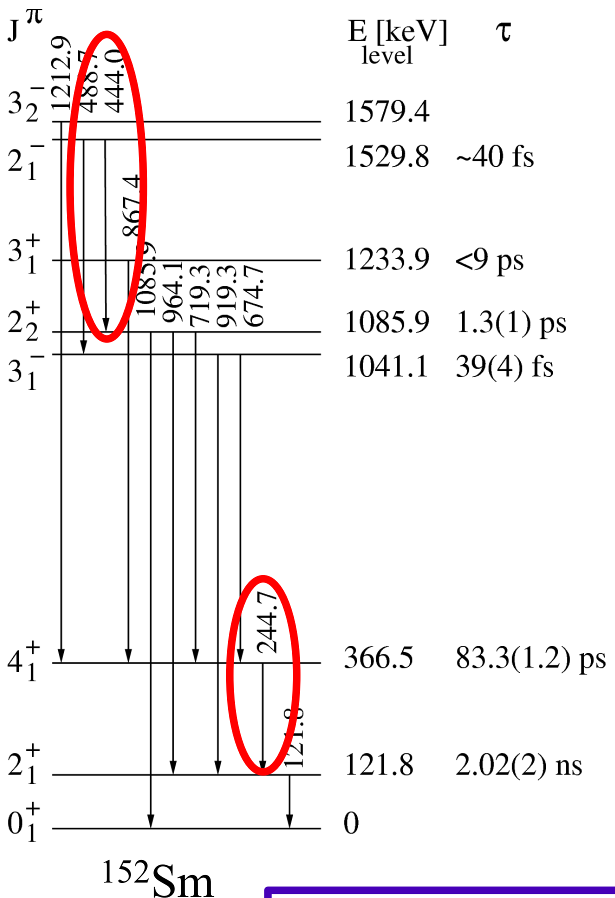
- statistics is increased

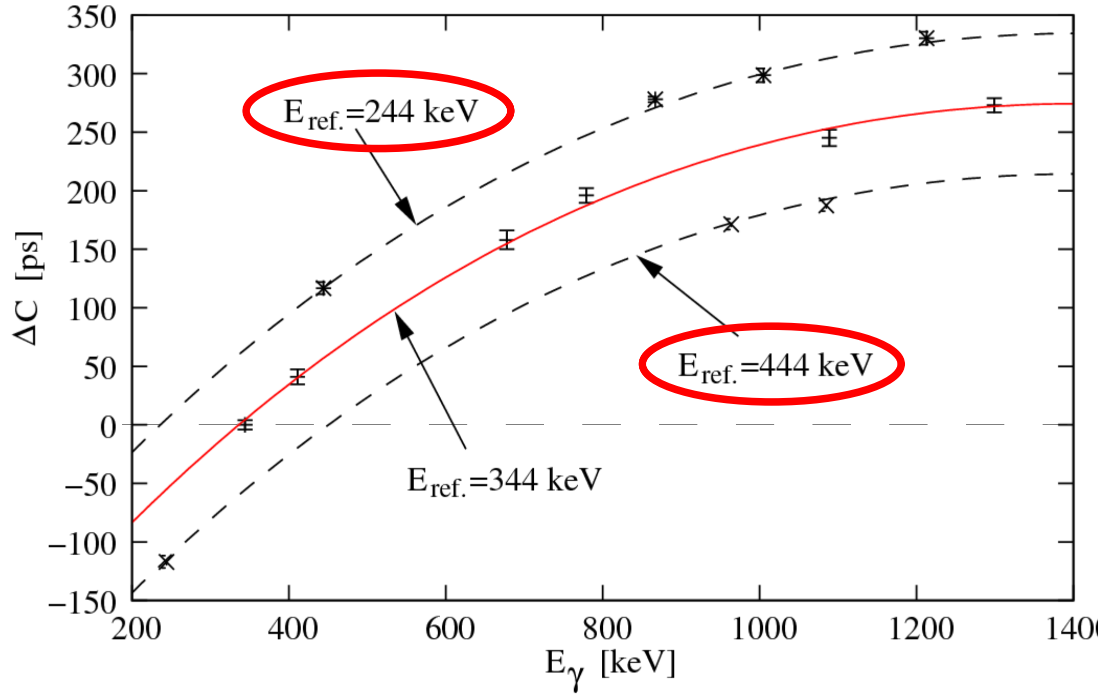
- corollary, the total error is reduced

- the PRD for any energy combination is derived from the PRD curve

- analysis is simplified

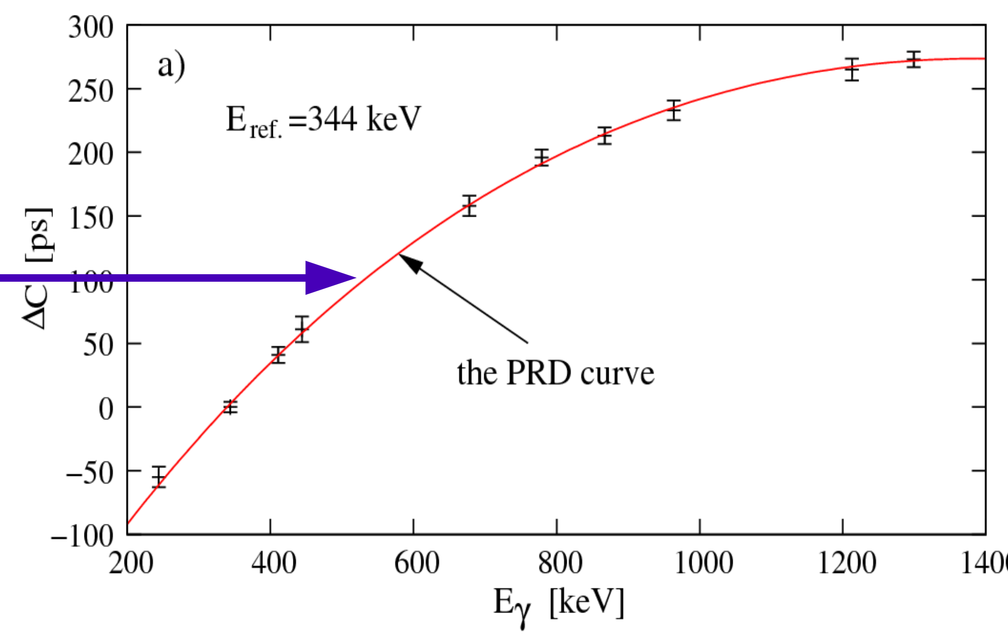
The MSCD method; calibration of the PRD curve using the ^{152}Eu source

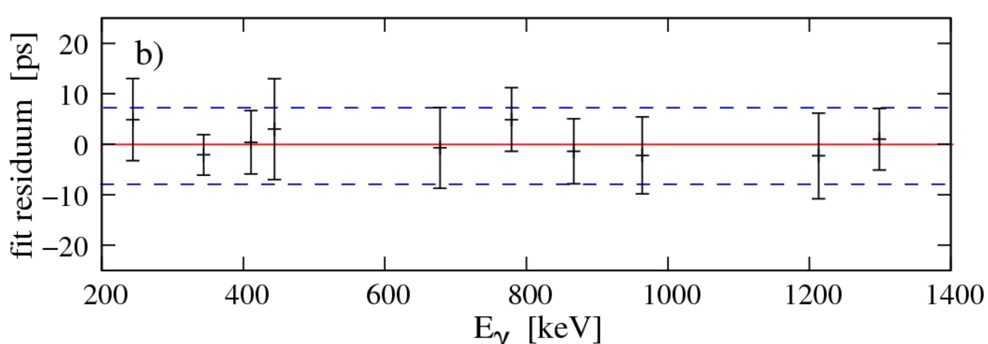




$$\Rightarrow \text{PRD}=\Delta C-2\tau$$

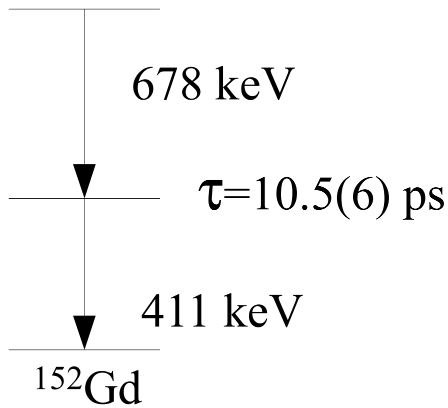
$$\text{PRD}(E_\gamma) = \frac{a}{E_\gamma + b} + cE_\gamma + d$$

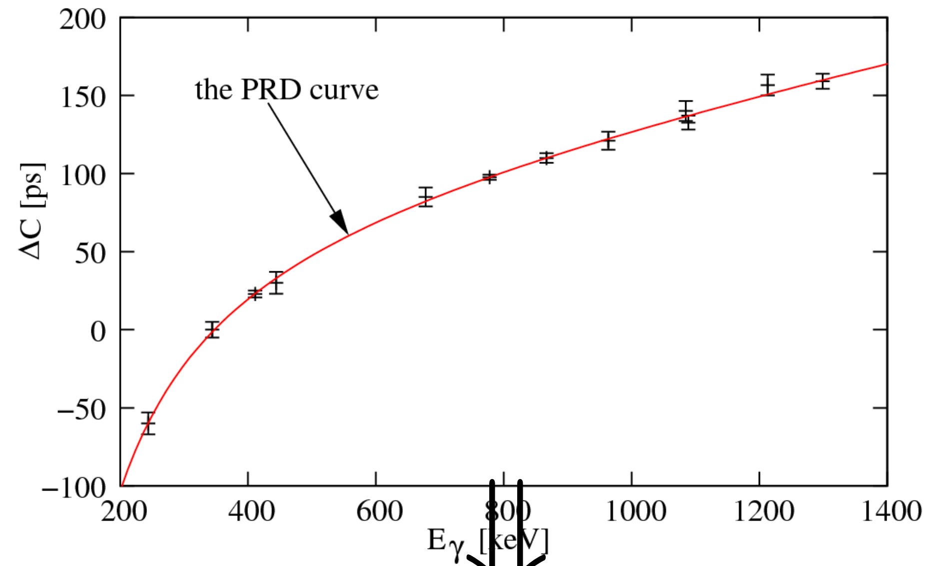




J.-M. Régis, PhD thesis (2011)

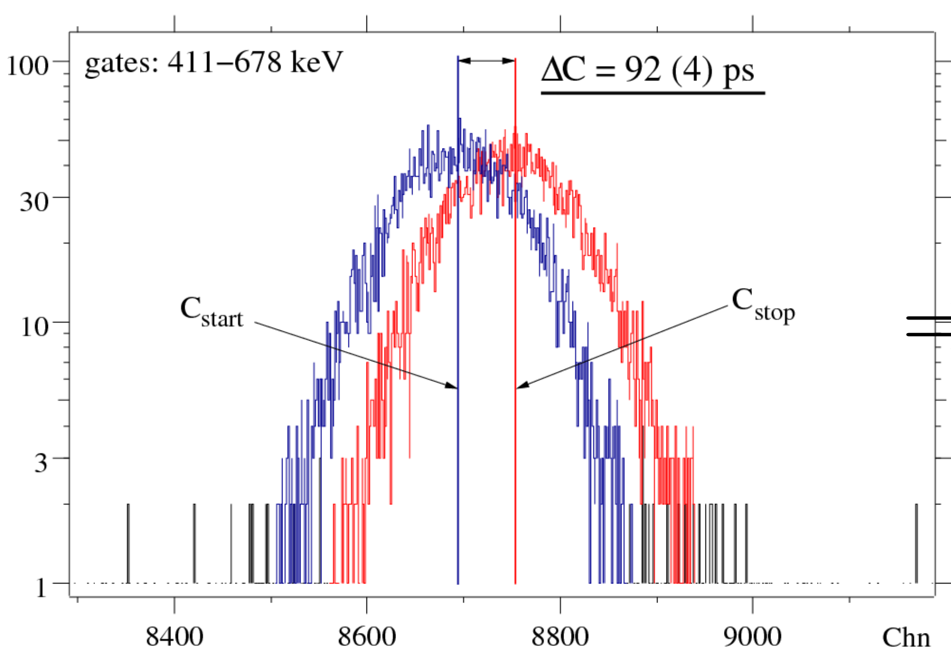
Lifetime determination using the MSCD method





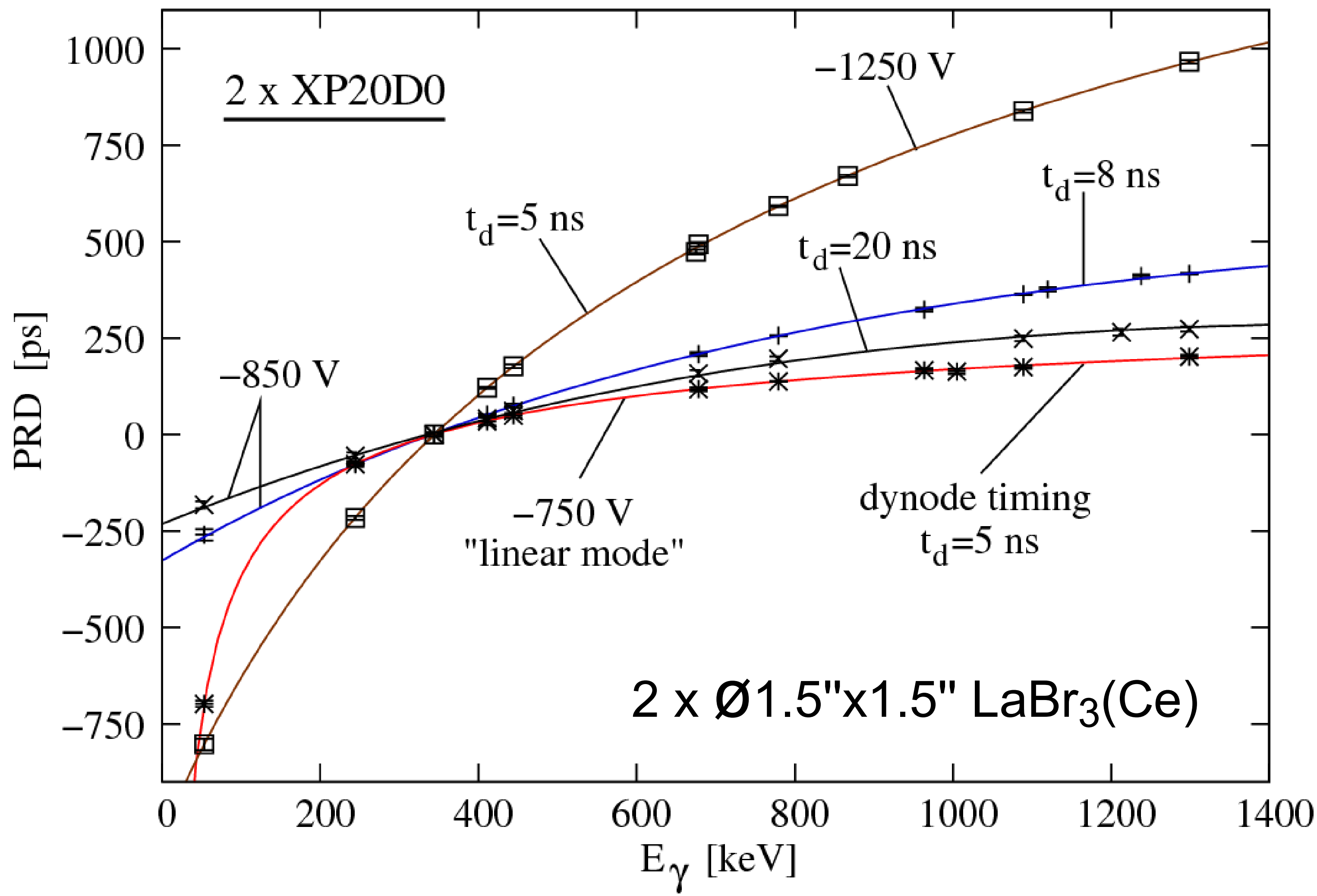
PRD(678-411) = – PRD(411-678)

:= PRD(678)-PRD(411) = 68 (7) ps



⇒ $\tau = |\Delta C - PRD|/2 = 12\ (4)$ ps

The PRD curves for different PMT operation and CFD shaping delay time t_d

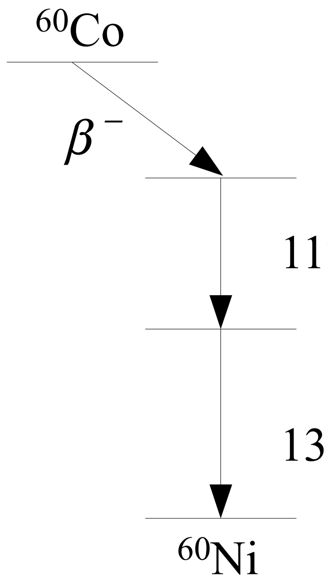


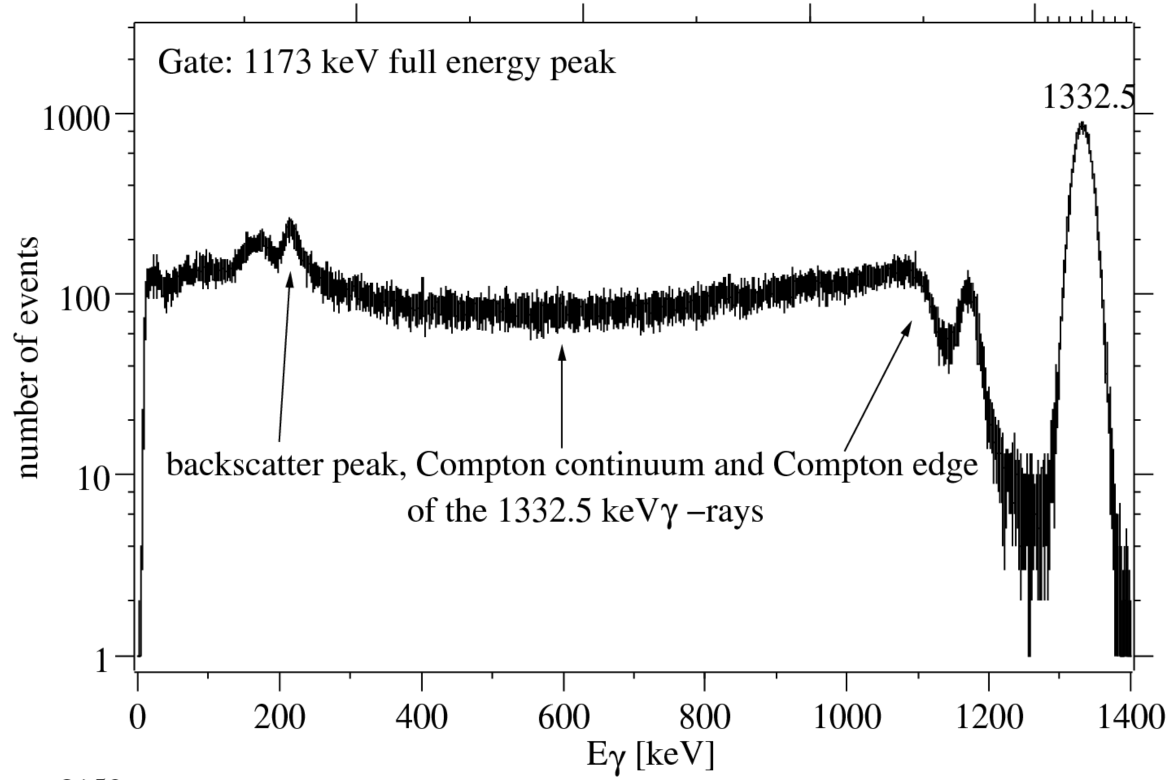
In any case, the PRD curve is calibrated using: $$PRD(E_\gamma) = \frac{a}{E_\gamma + b} + cE_\gamma + d$$

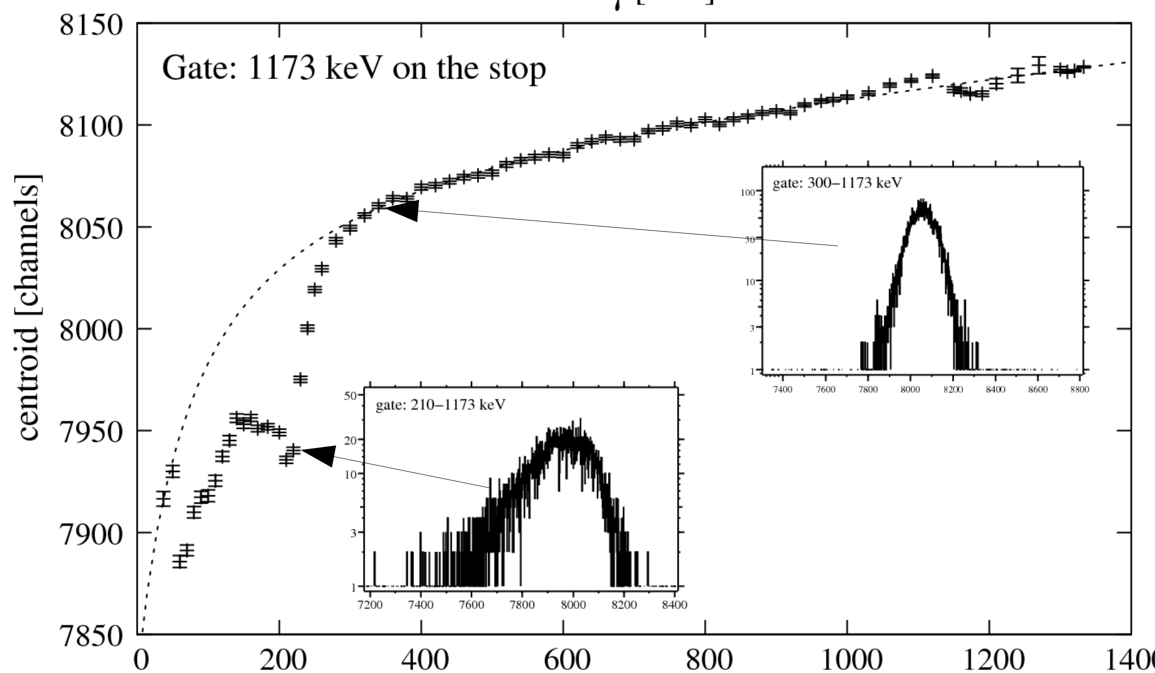
Limitation for 50 keV < E_γ < 1510 keV: $\delta\tau \sim$ 3-5 ps

J.-M. Régis, PhD thesis (2011)

Time-walk analysis using the prompt ^{60}Co source







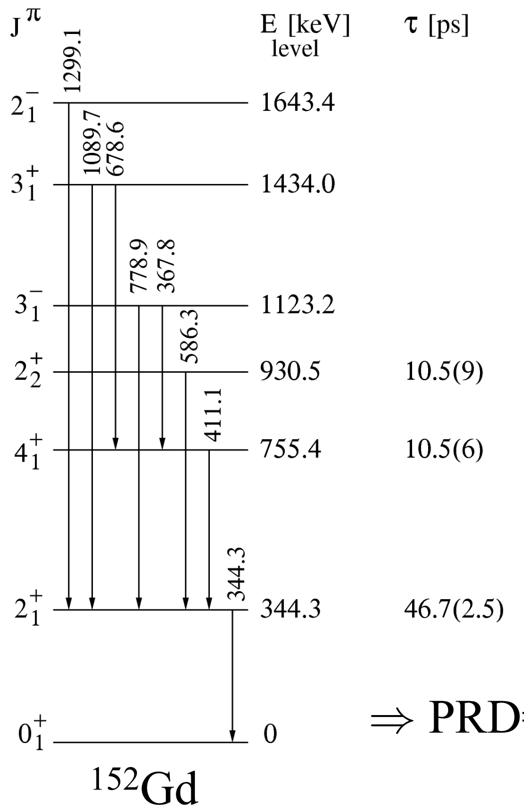
For $E_\gamma > 300$ keV,
the prompt curve is fitted using:

$$C(E_\gamma) = \frac{a}{E_\gamma + b} + cE_\gamma + d$$

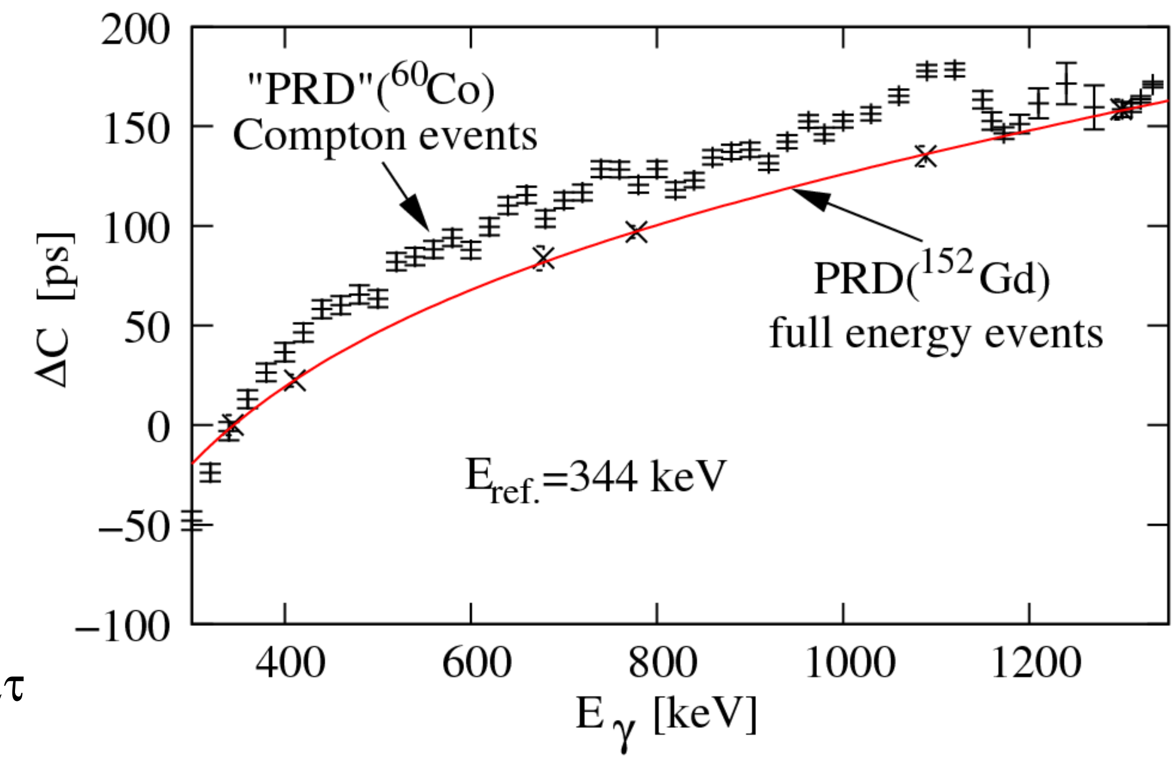
J.-M. Régis, PhD thesis (2011)

Time-walk analysis using standard γ-ray sources

Comparison of the PRD curve obtained due to full energy events and due to Compton events:



⇒ PRD=ΔC-2τ



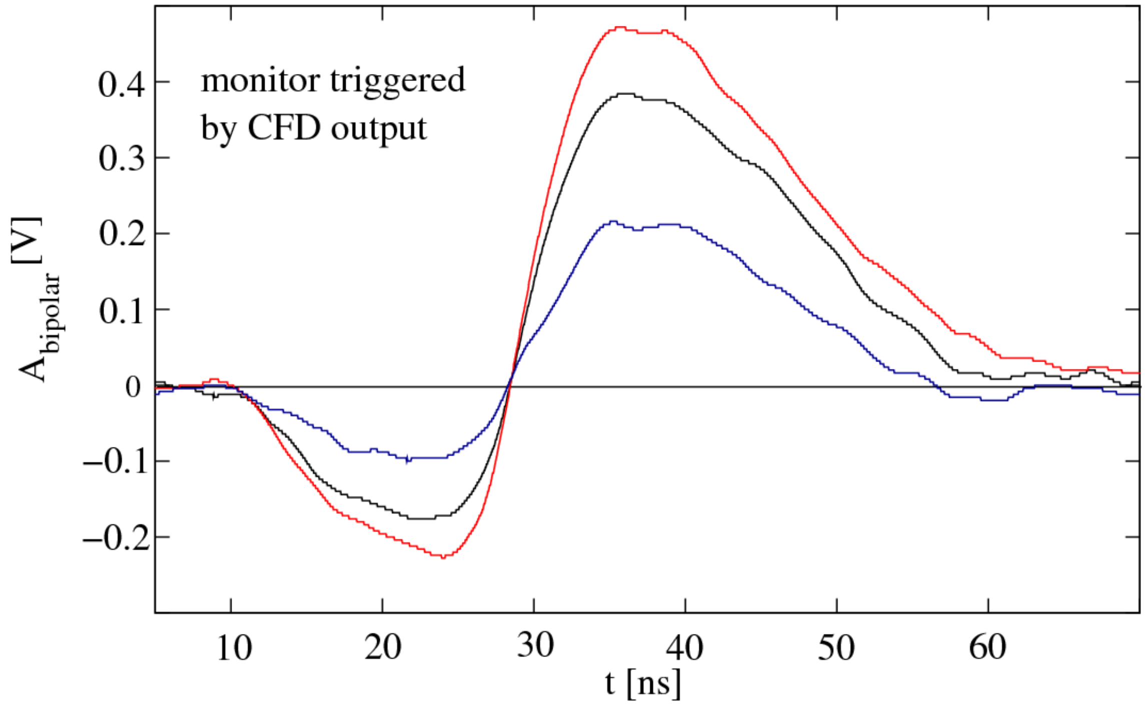
Due to multiple Compton interactions, the full energy events are artificially delayed relative to Compton events.

⇒ Only full energy events reproduce the true prompt curve or PRD curve, respectively.

J.-M. Régis, PhD thesis (2011)

Energy dependency of the prompt response function

The CFD is used to minimize time jitter due to statistical amplitude variation.



The slope of the bipolar CFD pulse at zero crossover depends on the amplitude.

For linear response: $dA/dt \propto E_\gamma$

=> time-walk due to charge sensitivity of the zero crossover comparator related to the inverse of the slope

=> CFD time jitter also related to the inverse of the slope (includes amplitude variation + noise)

=> Position (centroid) and FWHM of the PRF are dependent on the amplitude (energy)

T. J. Paulus, IEEE Trans. Nucl. Sci. NS-32/3 (1985)