Fast Electronics Scintillation Timing (FEST)

Use of a small $LaBr_3$ scintillator array at Yale.

Rare earth B(E2) systematics.

Advantages vs. conventional scintillators.

Prospects for CARIBU decay experiments, in the context of planning toward FRIB.
→ („Super Scintillator“ Working Group)

B(E2) Systematcs of Rare-Earth Nuclei

Interacting Boson Approximation (IBA) deformed rotors with fixed boson charge:

$$B(E2:0_1^+ \longrightarrow 2_1^+) = e_B^2 N(2N+3)$$

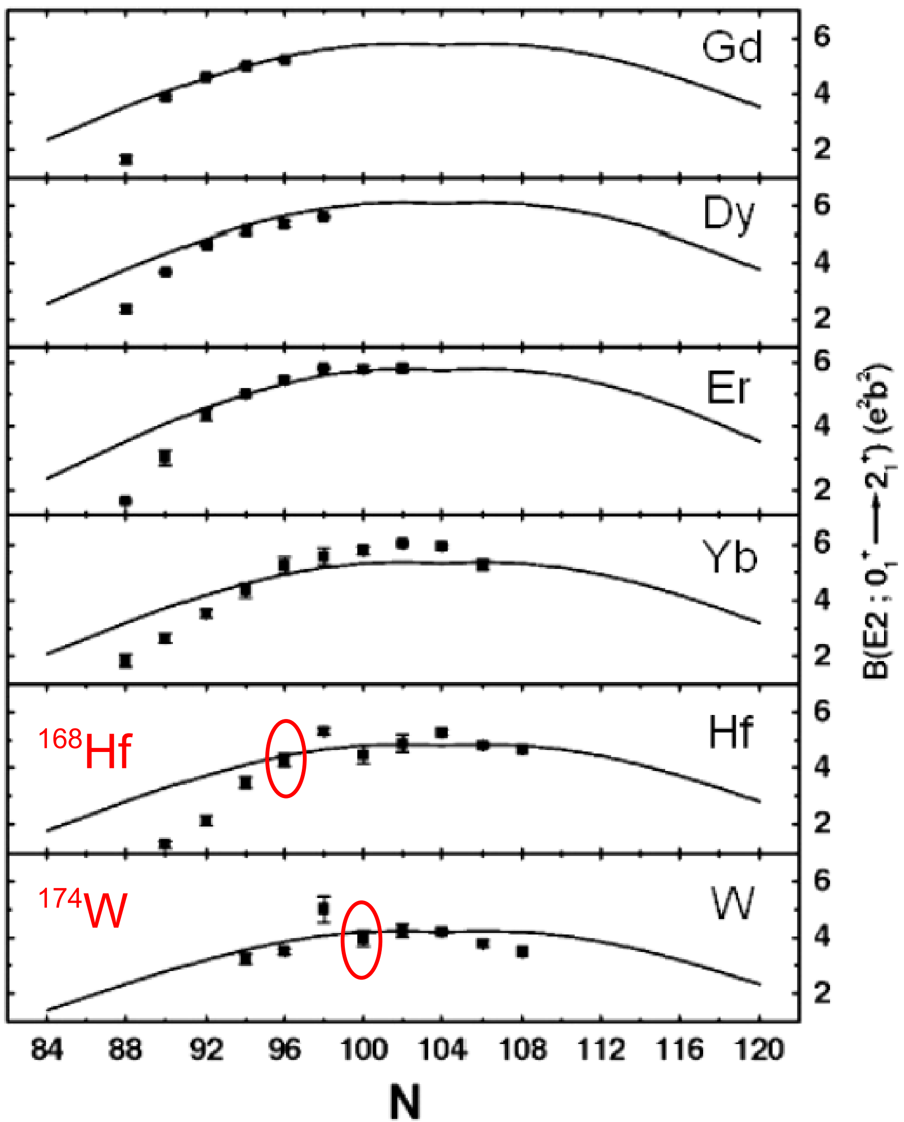
$$N = N_\pi + N_\nu$$

Apparent saturation in rare-earth region led to introduction of "effective valence nucleons"

$$N_{\pi,\nu} \longrightarrow N_{\pi,\nu}^{eff}$$

$$N_{\pi,\nu}^{eff} = N_{\pi,\nu}(1 - N_{\pi,\nu} f)$$

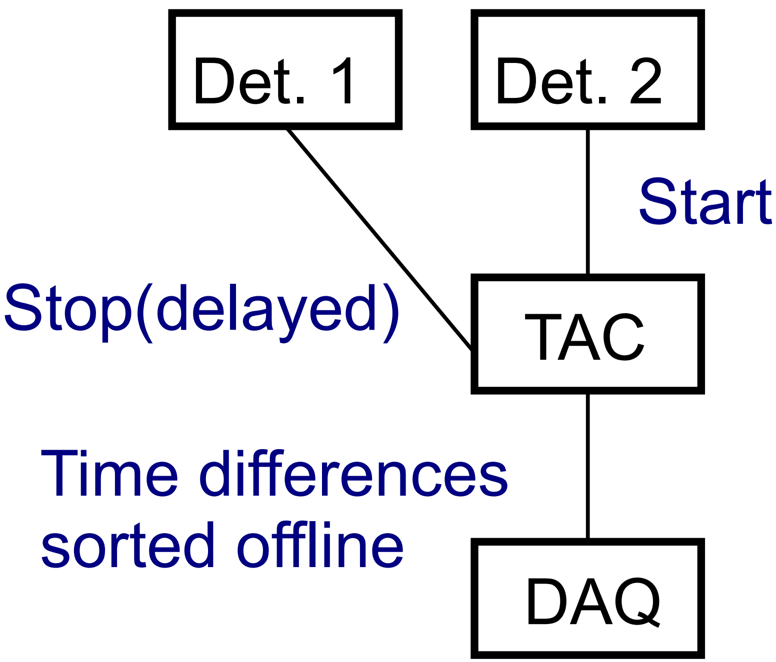
Figure from J.-y. Zhang et al. Phys. Rev. C 73, 037301 (2006)

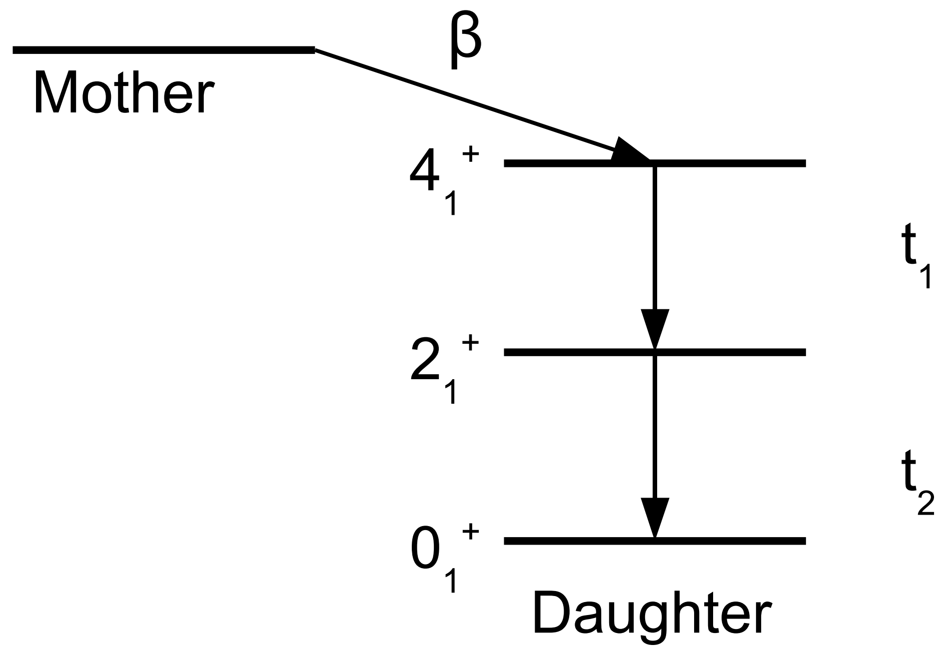


Fast Timing Method

Straight forward, with or without β-gate,

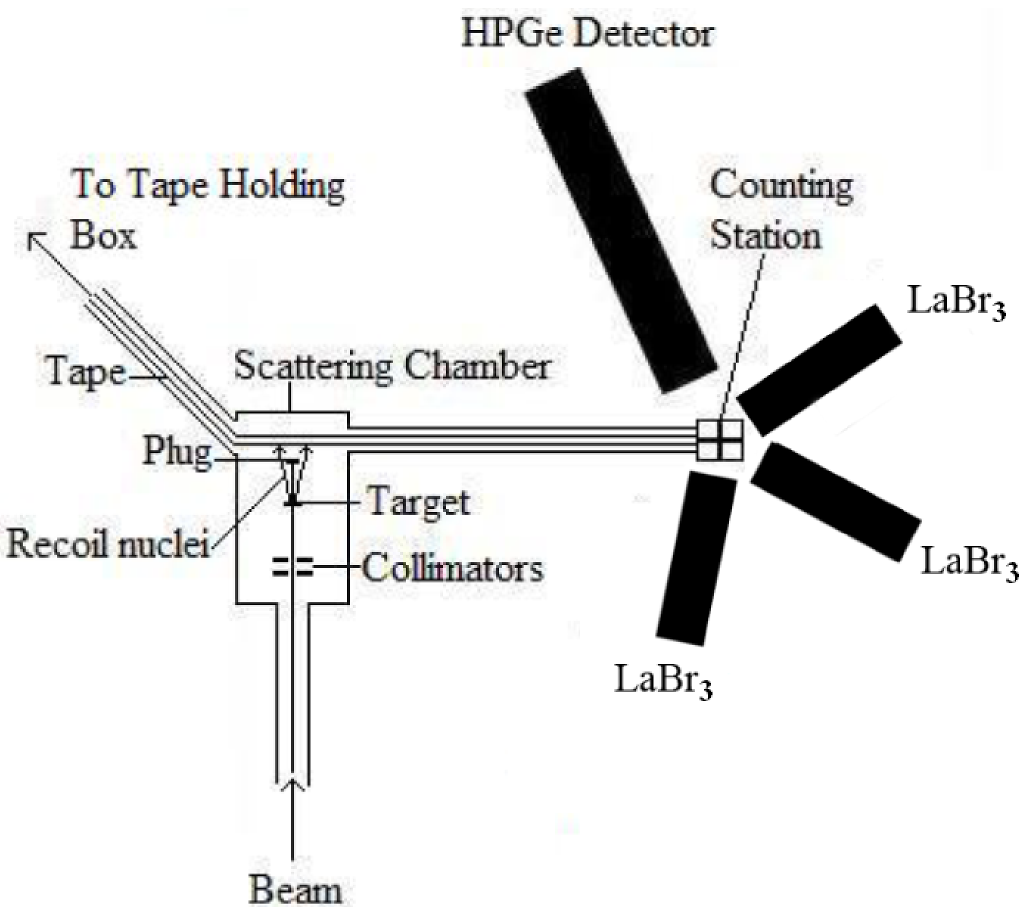
$$B(E2) \propto \frac{1}{\tau}$$





$t_2 - t_1 \sim \exp(\lambda = 1/\tau)$

Moving Tape Collector Setup



3 $LaBr_3$ Scintillators:
1.5“x1.5“ cylindrical

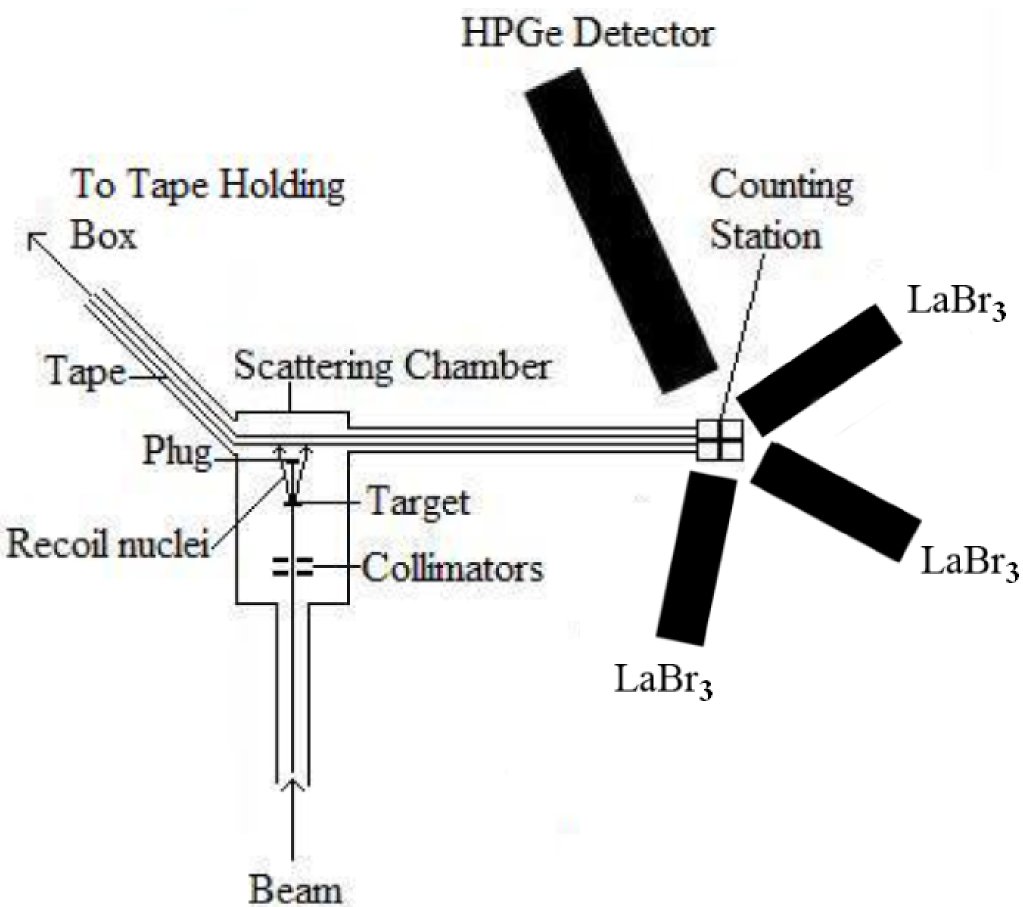
Supplied by University of Cologne

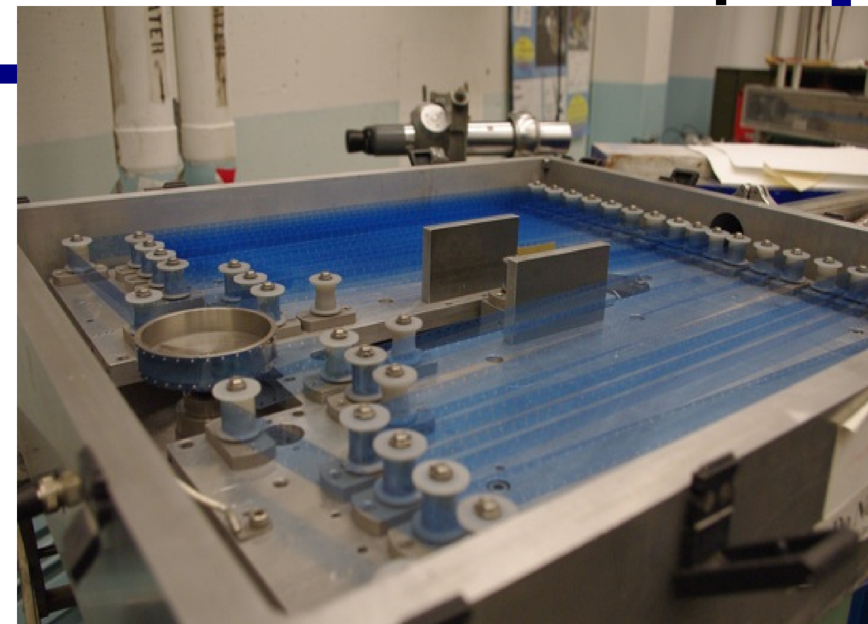
Time resolution comparable to BaF_2

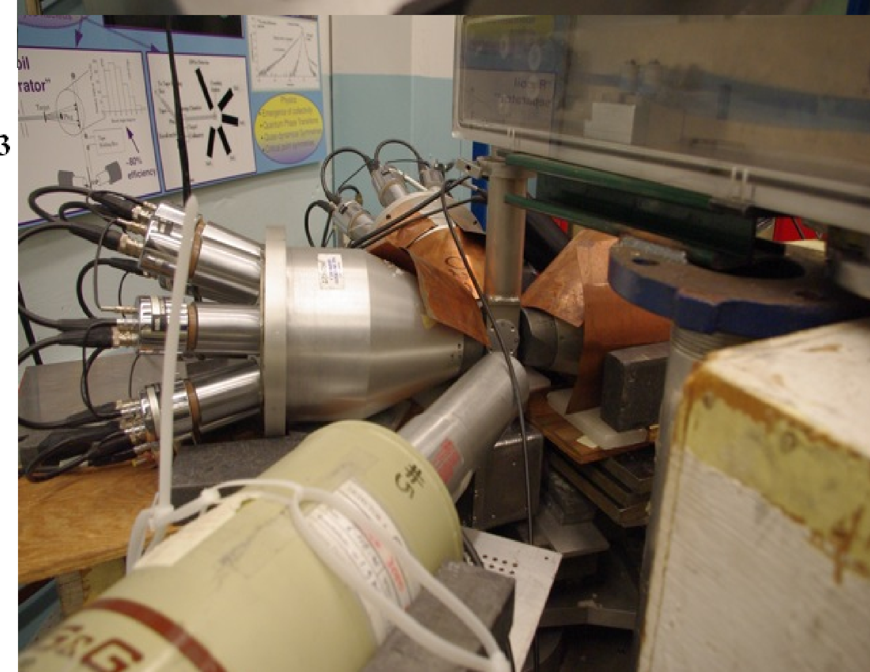
...but superior (min. 3%) energy resolution

3 detectors allow for 6 permutations

Moving Tape Collector Setup







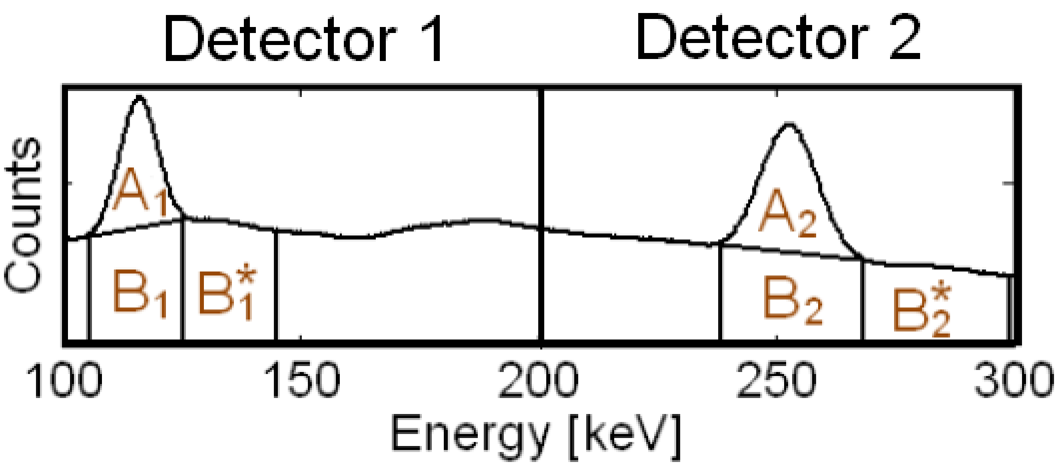
BGO suppression would be great!
(didn't use shields in the end – too much distance to the probe)

Background Subtraction

Divide energy gates into peak and background (A+B)

$B_1 \approx B_2^*$

do not Bg gate on Compton's!



$$A_1A_2 = (A_1+B_1)(A_2+B_2)$$
$$- B_1(A_1+B_2) - (A_1+B_1)B_2$$
$$+ B_1B_2$$

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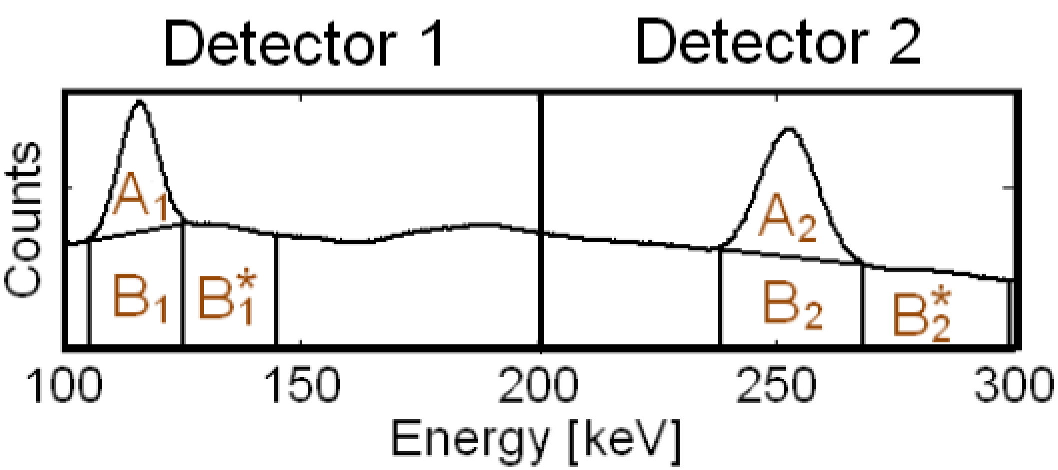
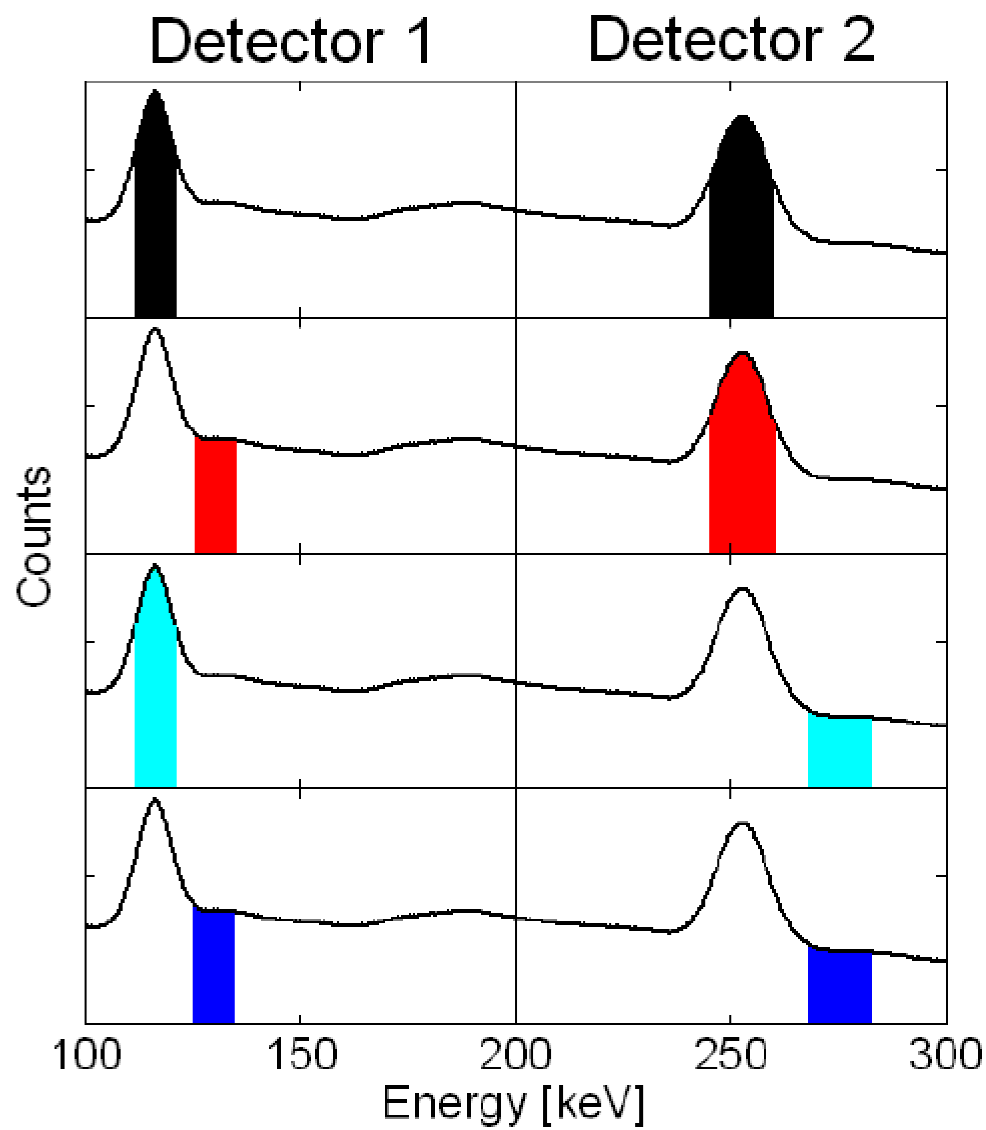
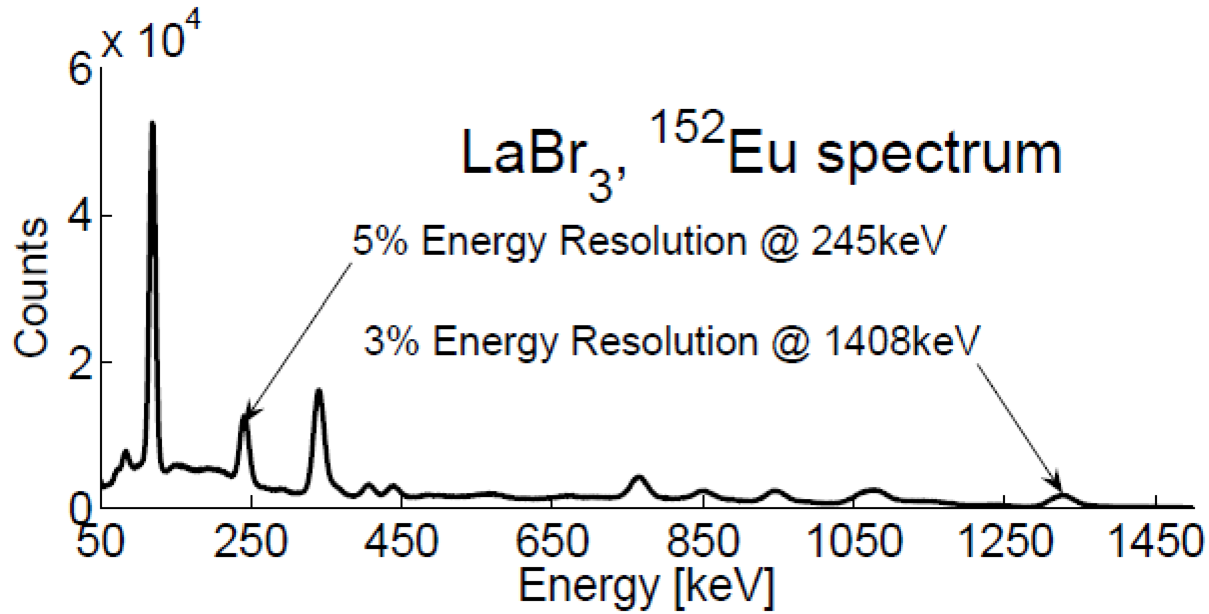


$$A_1A_2 = (A_1+B_1)(A_2+B_2) - B_1(A_1+B_2) - (A_1+B_1)B_2 + B_1B_2$$

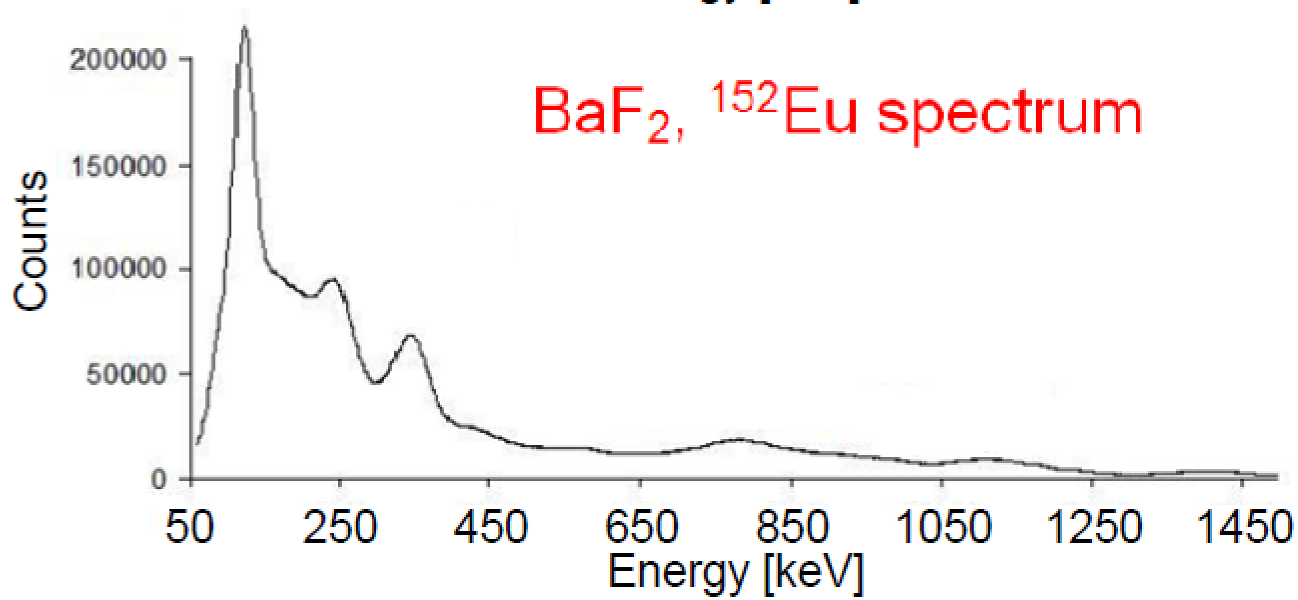


^{152}Eu Source Test



separable peaks,

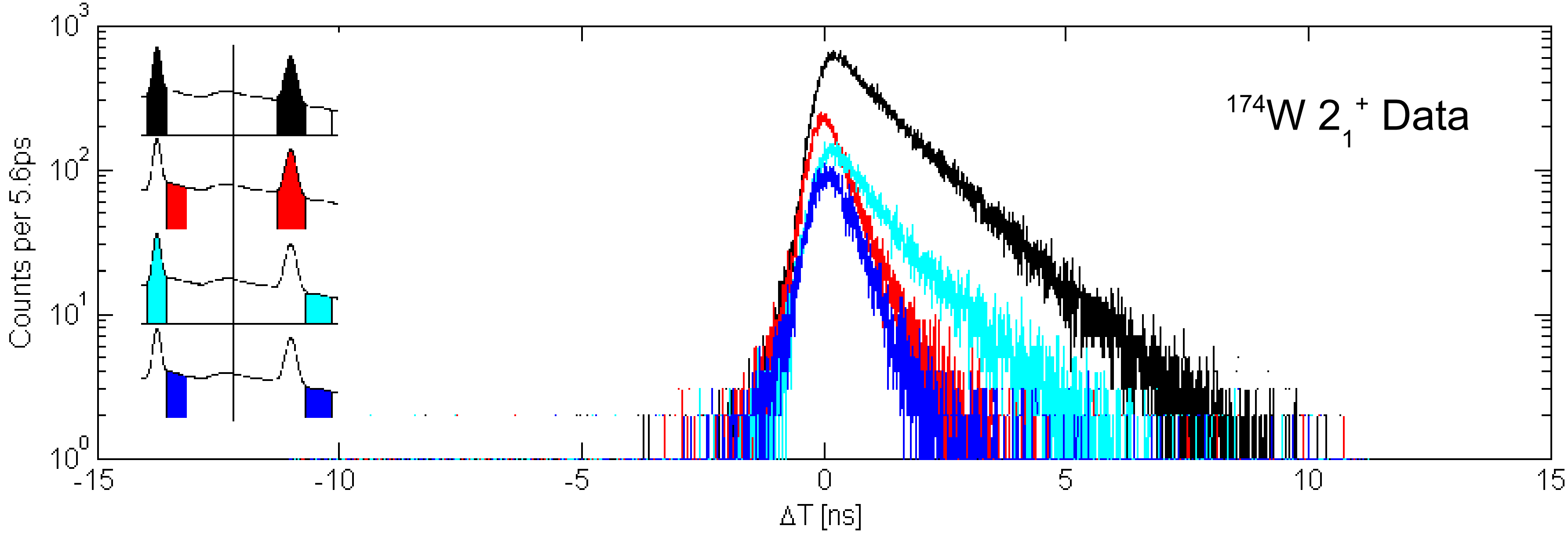
background visible

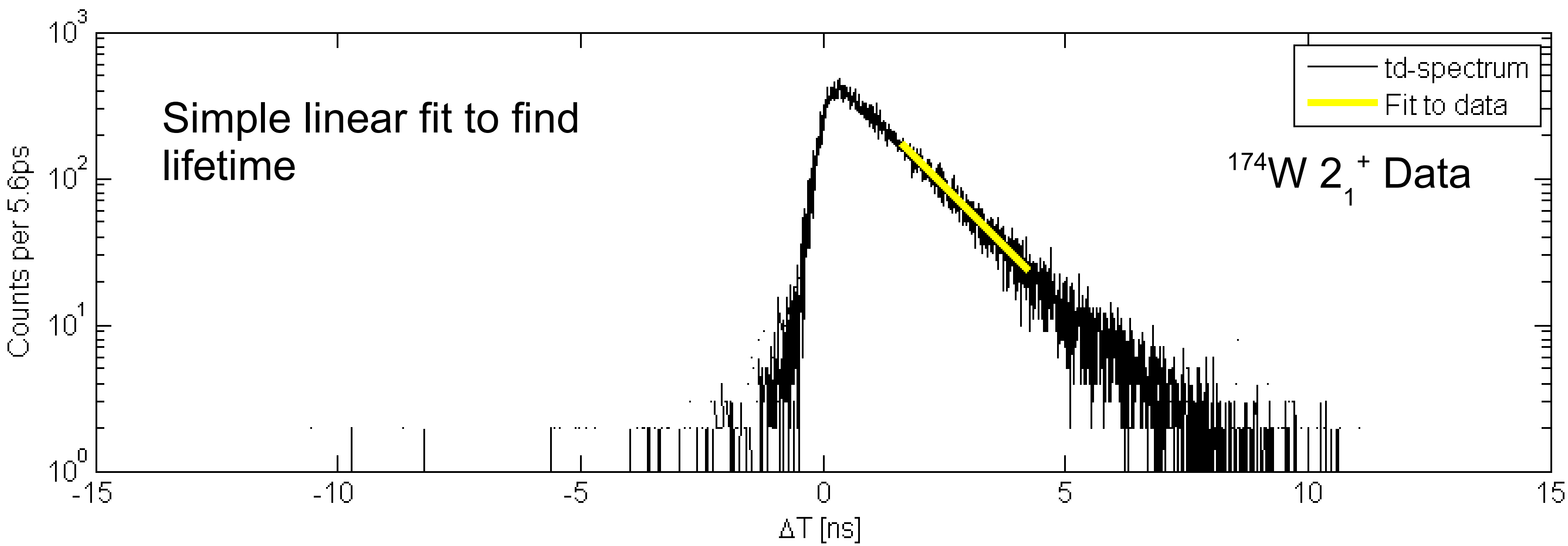


peaks overlap,

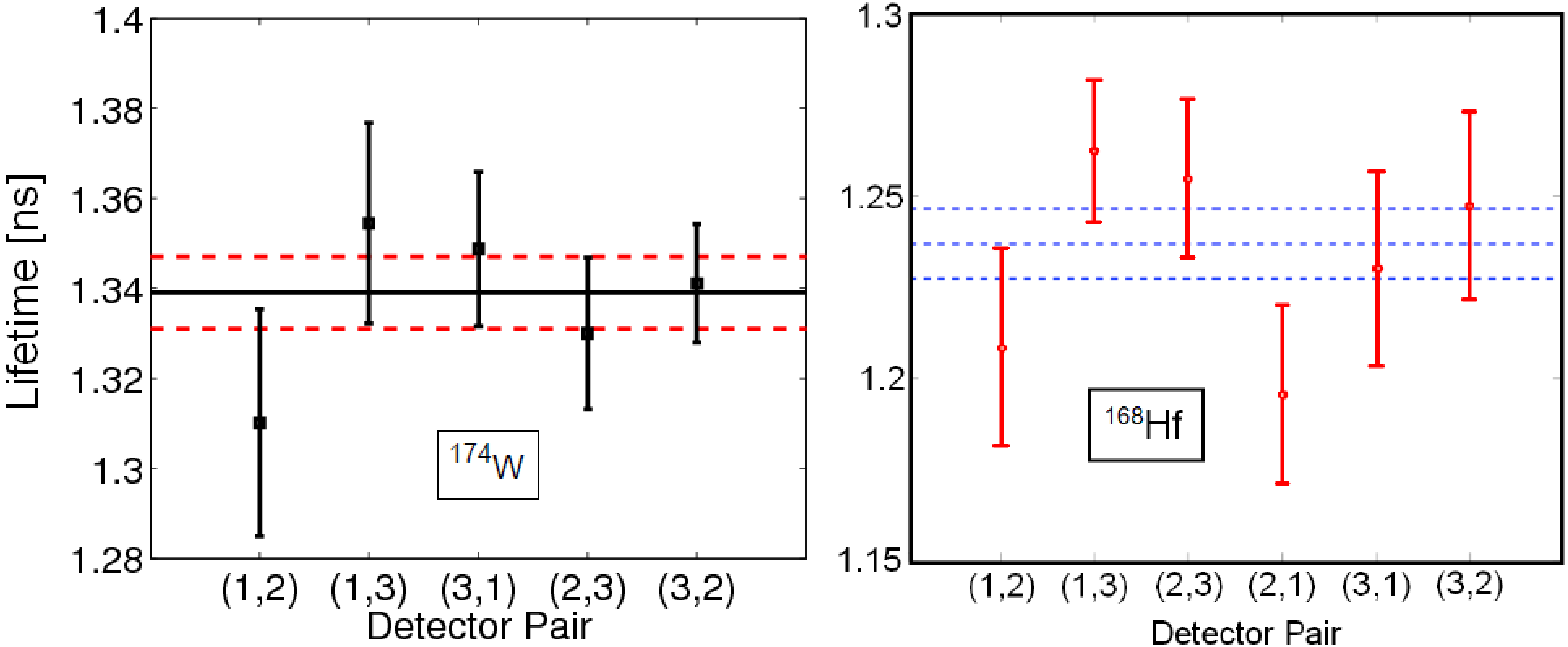
background ?

^{174}W Sample t-d Spectra





Lifetime vs. Detector Pair



^{174}W 2_1^+ (Nathan Cooper et. al.)

$\tau = 1.339(8)$ns

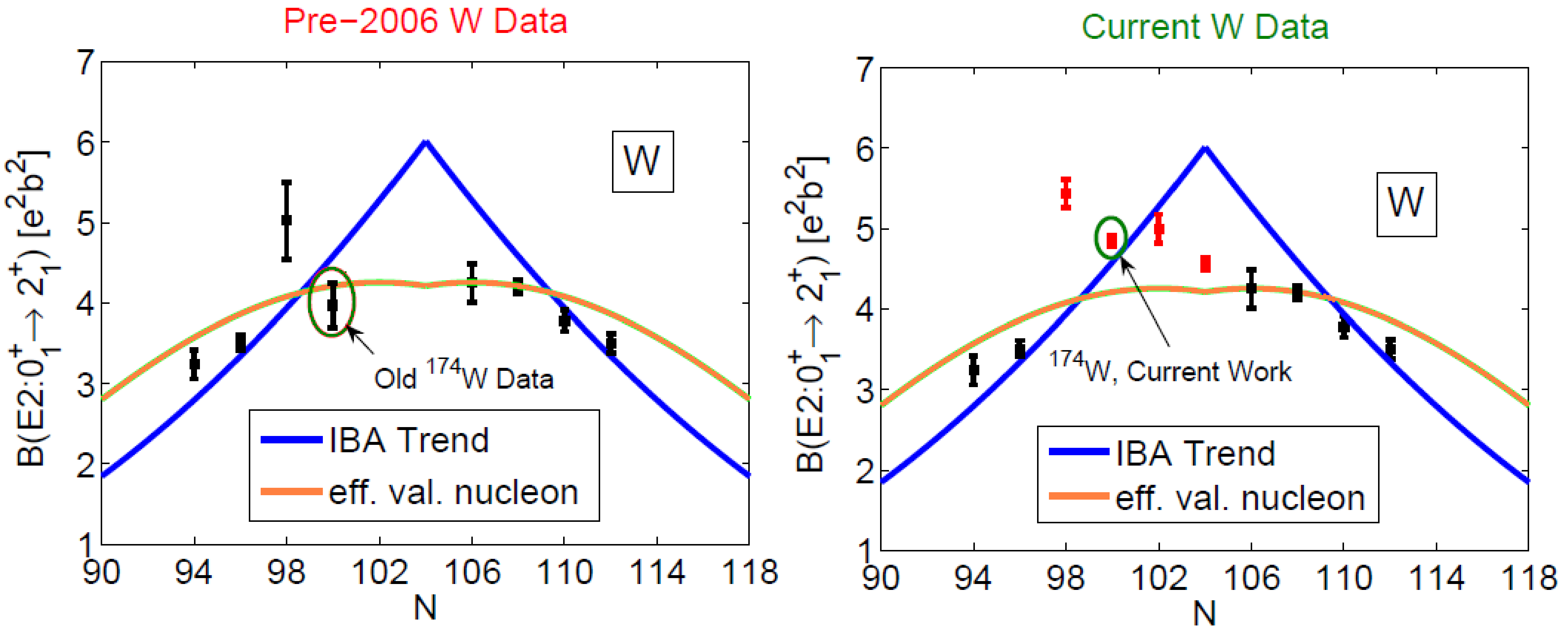
$\tau_{lit} = 1.64(10)$ns

^{168}Hf 2_1^+ (Marco Bonett-Matiz et. al.)

$\tau = 1.237(10)$ns

$\tau_{lit} = 1.28(6)$ns

Revised W Systematics

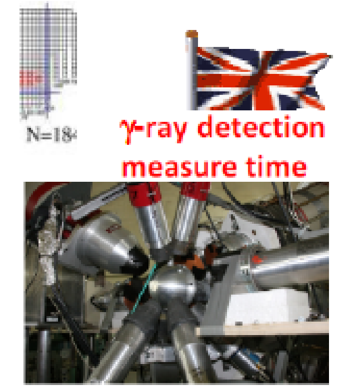


=> Things seem a bit more complicated than anyone expected

^{176}W : J.-M. Regis et al. NIM A 606 (2009)
^{172}W, ^{178}W : M. Rudigier et al. Nucl. Phys. A 847 (2010)

DeSPEC = Decay Spectroscopy Collaboration at FAIR,

Part of the NuSTAR umbrella collaboration (one of the 4 main, Pillars of FAIR)



DEPSEC Fast-Timing Array

Paddy Regan, Surrey

- Could operate in 'passive stopper' (isomer) mode or

- Surrounding AIDA Si array for beta tagging.

- 'Compact box' geometry with (upto) 36 $LaBr_3$ detectors surrounding 'stopper' at final focus of GSI/FAIR FRS.

or **Combine European and US Scintillator Arrays for Campaigns?**

- More granular 'spherical' geometry ('prompt flash problem').

- UK NuSTAR has funds for (up to) 36 $LaBr_3$ detectors (or 24 depending on price variations and size) plus digital EDAQ- Additional money/detectors in Europe from Spain, Germany (Koln), Romania (Bucharest); Bulgaria (Sofia) etc….

- Operate with large efficiency Ge in specific cases for high-resolution gating?

Next step: 4-page write-up to the FRIB SAC with status report, input based on this workshop

Science:

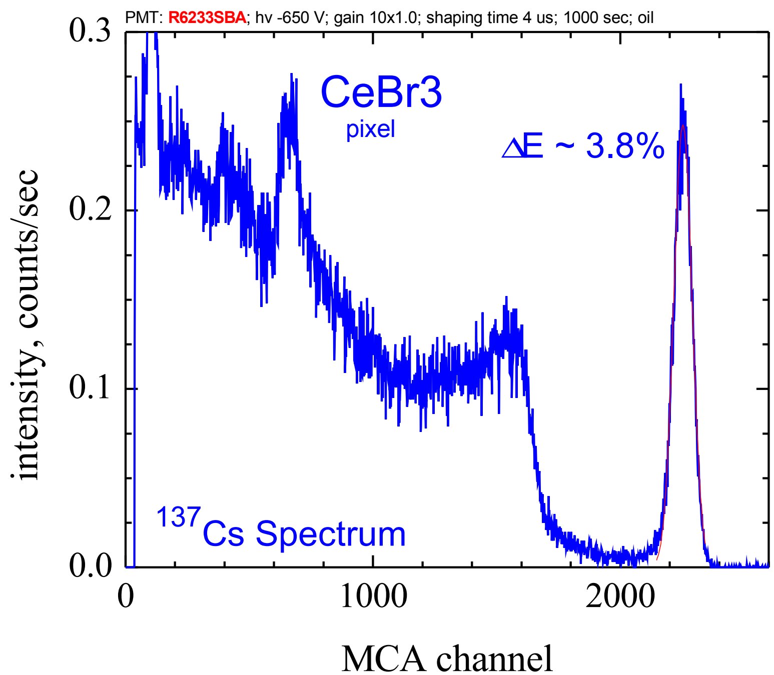
Summary FRIB Scinti Working Group, Rutgers Workshop

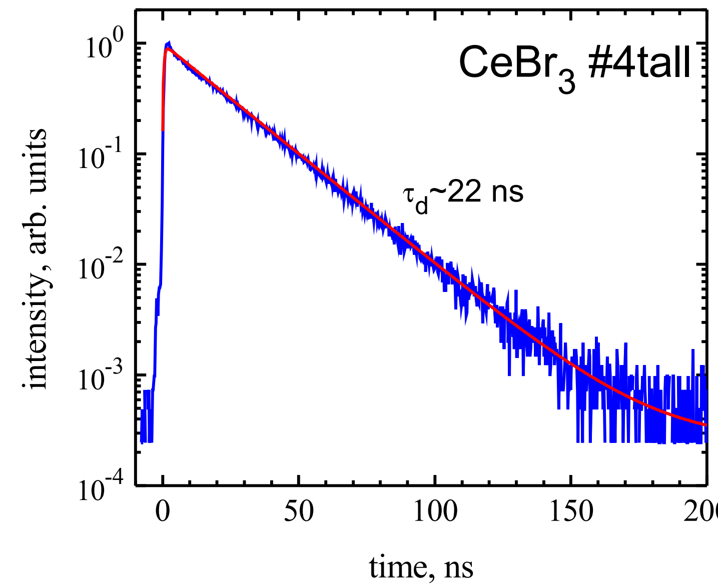
- First (second) excited state lifetime in transitional /deformed regions e.g. n-rich A~90-100 etc.
- High-efficiency gamma-counting at decay stations (existing&future) [be careful: Ge resolution may win over Scintillator efficiency]
- Isomer lifetimes
- beta-delayed neutron emission
- (p,n), (d,n) etc. transfer reactions -> single-particle configurations
- beta-decay strength measurements

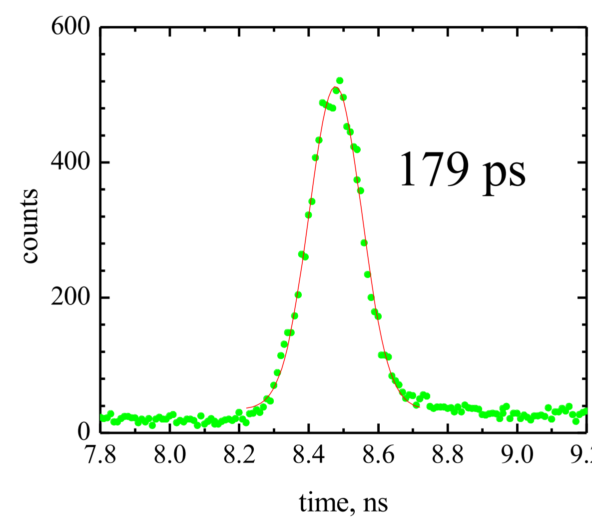
Proposed Equipment, R&D:
(overarching question to Scint. R&D: how big can you grow them?)

- Scalable array of $LaBr_3$ detectors, to be packed closely or used separately, stand-alone or in combination with other (Ge, ...) detectors for spectroscopy / fast timing
- alternative materials ? $CeBr_3$ promising, similar to $LaBr_3$ properties
- Neutron Arrays: ideally with detectors with gamma-neutron discr.
- Total Absorption Spectrometer

$CeBr_3$ – Competition to $LaBr_3$







Energy Resolution @ 662 keV – 3.8%

Linearity – Less than 10% deviation

Sharmistha Mukhopadhyay, RMD

CARIBU – FEST ?

FEST-application to isotopes from CARIBU, recently shown: powerful combination with high-res Ge detectors
(Argonne, Bucharest, ...)

e.g., E2 evolution in transitional regions (Zr/Mo/Ru...),
N>82 Ce-Ba region [intruder configurations, shape-coexistence, phase transition?],
isomer studies (!!)

Intensities not so diffrent from „normal“ beta-decay... with 10^9 pps beam an 1b x-section: about 10,000 parents per second produced
... should be in range for some CARIBU isotopes

Moving Tape to get rid of daughter activity!
Maybe another moving tape application? (-> pert. ang. corr. g factors)

Zvi Berant

Perturbed Angular Correlations

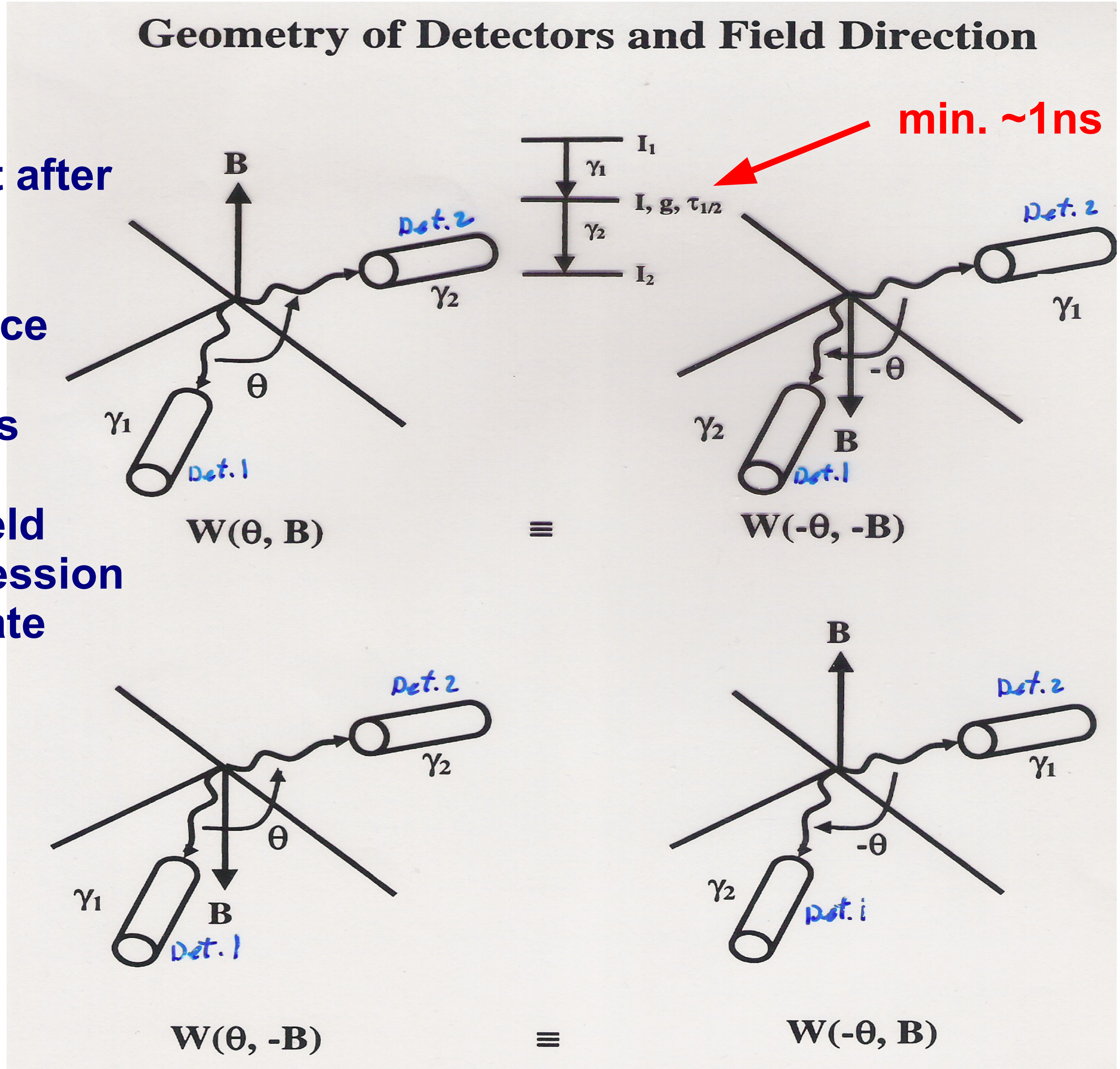
after β-decay for g factor measurements

no alignment after β-decay

=> coincidence needed, 1^{st} γ aligns

external B field causes precession of intermediate state

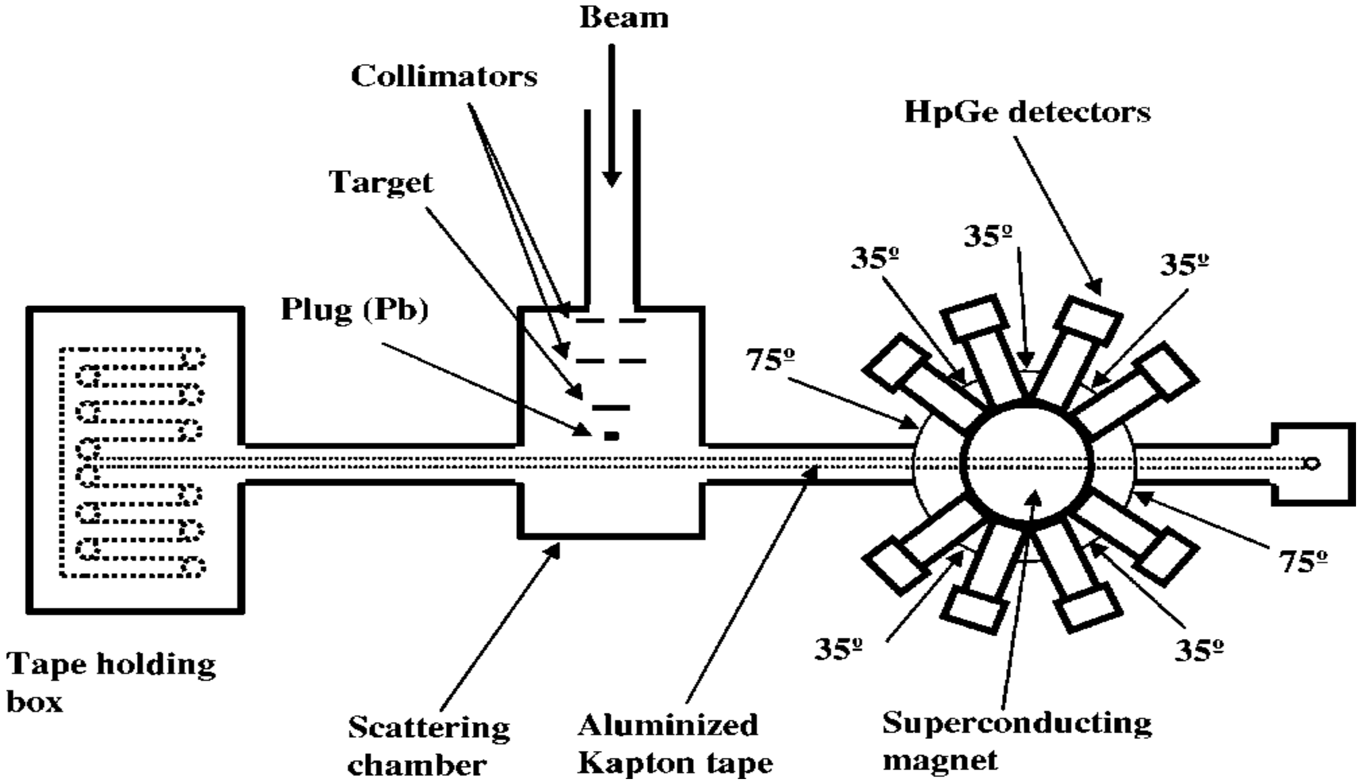
=> g factor



EXPERIMENTAL SYSTEM

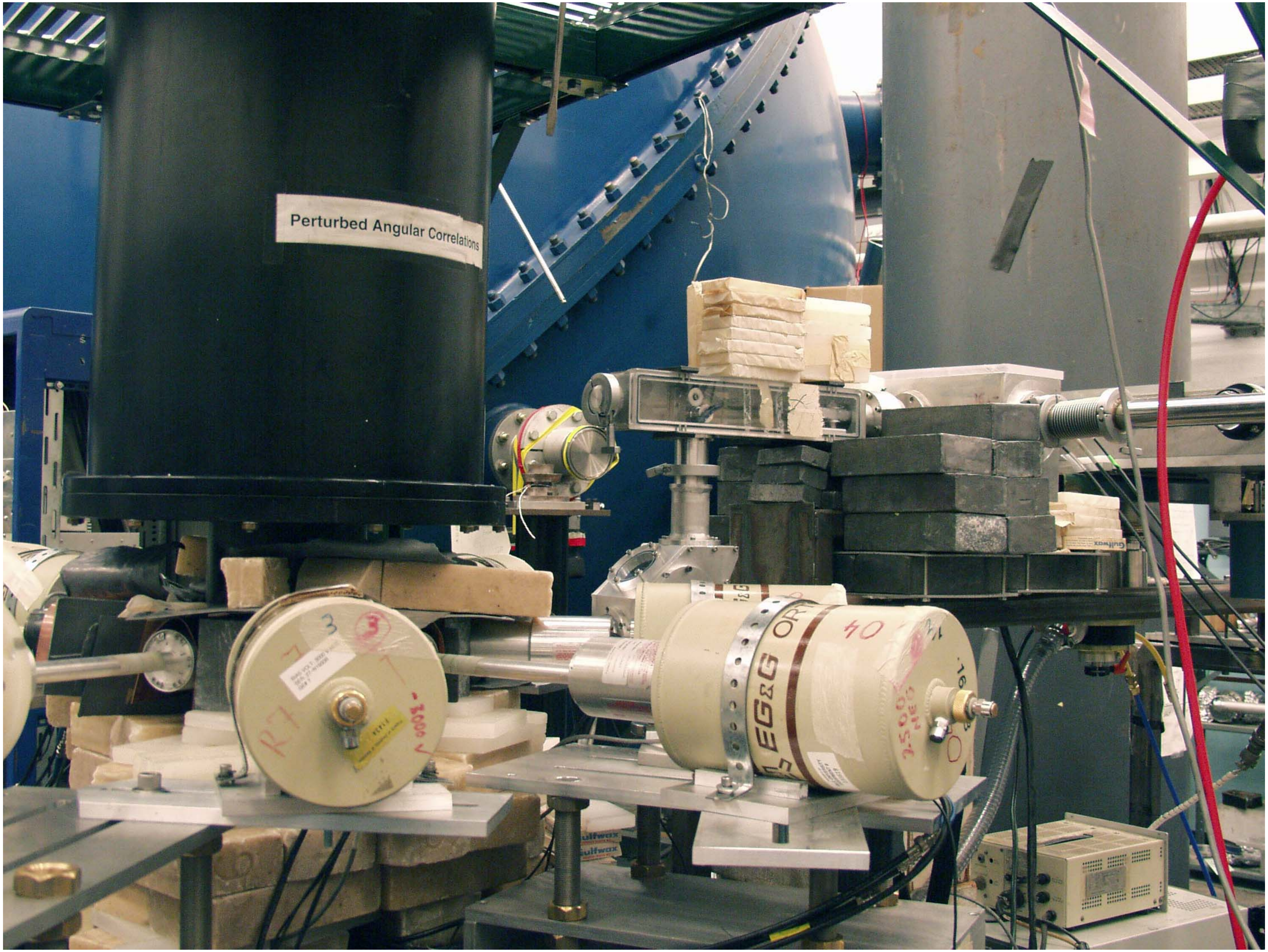
Superconducting Assembly for Magnetic Moment Measurements at Yale (SAMMY)

Moving Tape Collector + Superconducting Magnet (6 T)
8 HPGe detector



Schematic description of the experimental system

SAMMY



worth a thought for intense rare isotopes ...

CARIBU – FEST ???