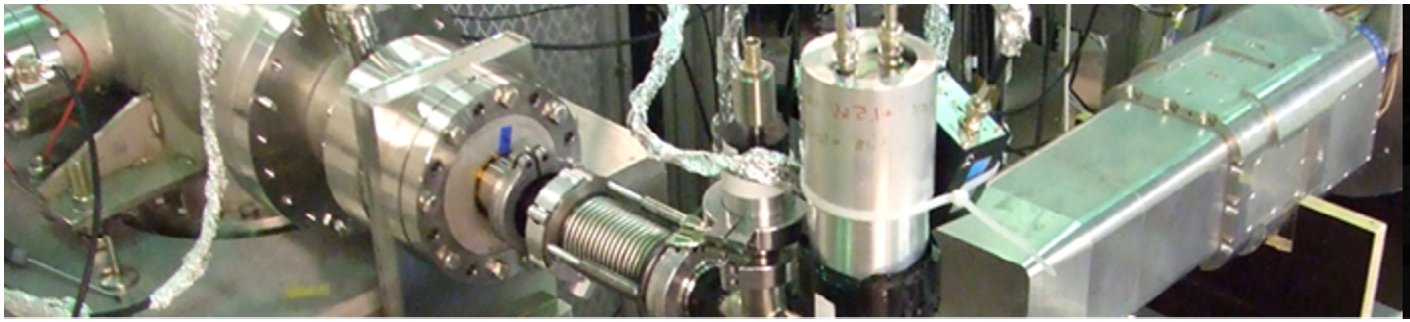
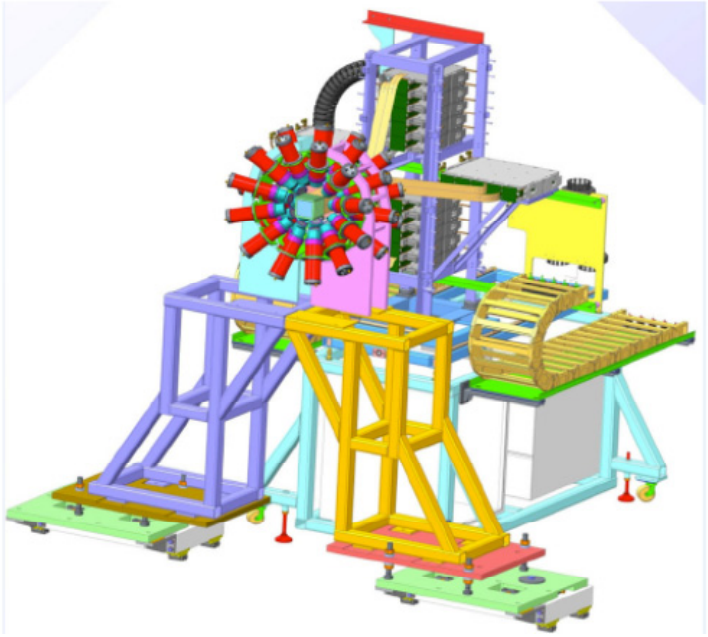


University of Brighton

Nuclear Physics
Research Group

Developments and perspectives with the FATIMA array.



Alison Bruce

Outline

- What is FATIMA?
- What physics can you get from FATIMA?
- Examples of the use of FATIMA
- Plans for FATIMA

What is FATIMA?

FATIMA = FAst TIMing Array = Array of $LaBr_3(Ce)$ detectors for use at FAIR

FAIR/NUSTAR/HISPEC-DESPEC/FATIMA
FAIR-TAC NUSTAR HISPEC-DESPEC FATIMA

March 2015

Technical Report for the Design, Construction and Commissioning of FATIMA, the FAst TIMing Array

What is FATIMA?

FATIMA = FAst TIMing Array = Array of $LaBr_3(Ce)$ detectors f

TDR approved July 2015

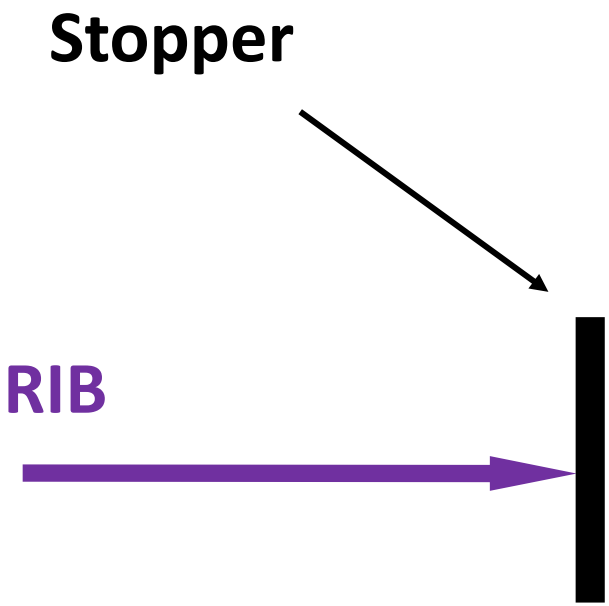
R/HISPEC-DESPEC/FATIMA
STAR HISPEC-DESPEC FATIMA

March 2015

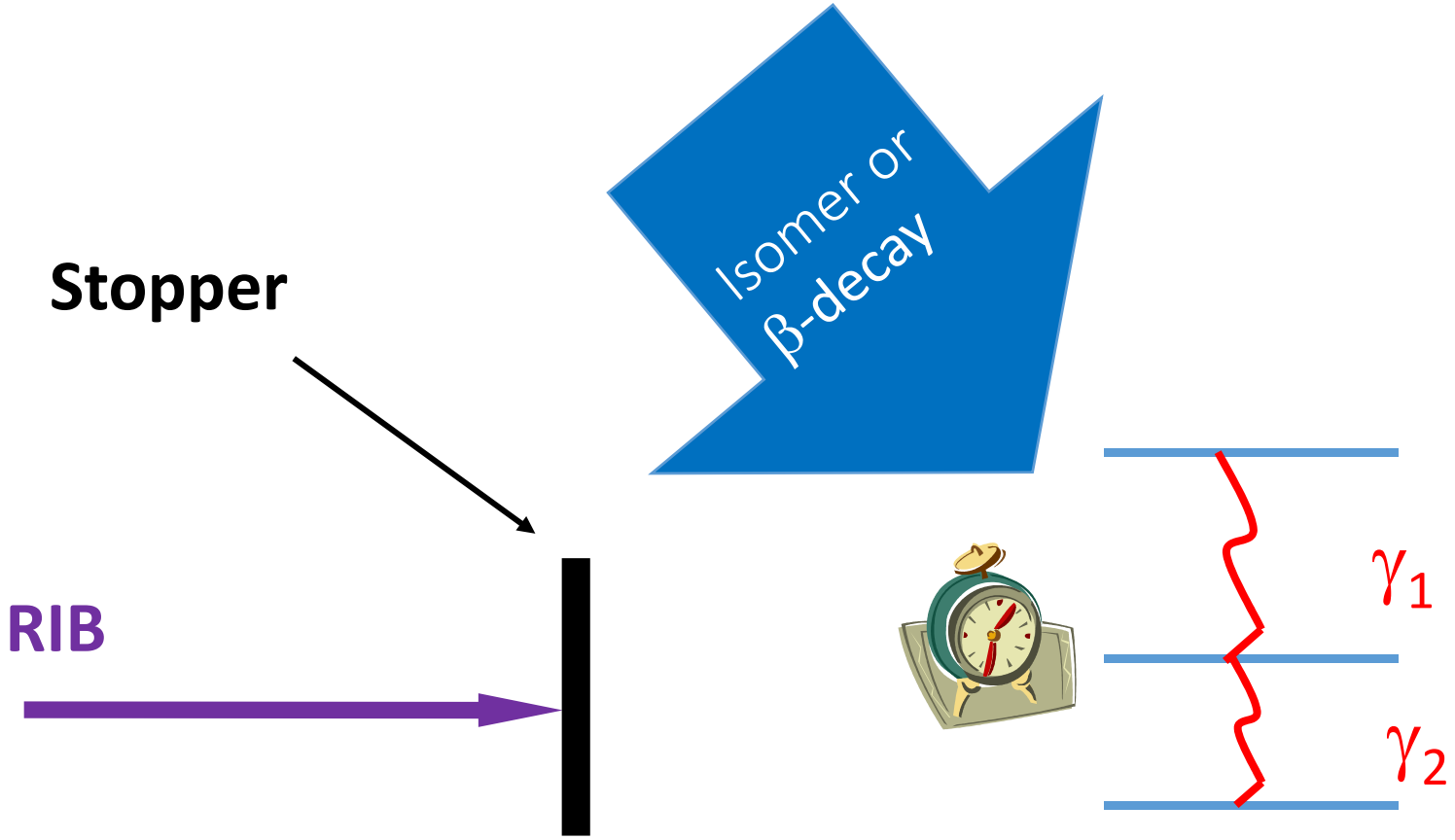
ical Report for the Design,
on and Commissioning of FATIMA, the
FAst TIMing Array

What physics can you get from FATIMA?

What physics can you get from FATIMA?



What physics can you get from FATIMA?

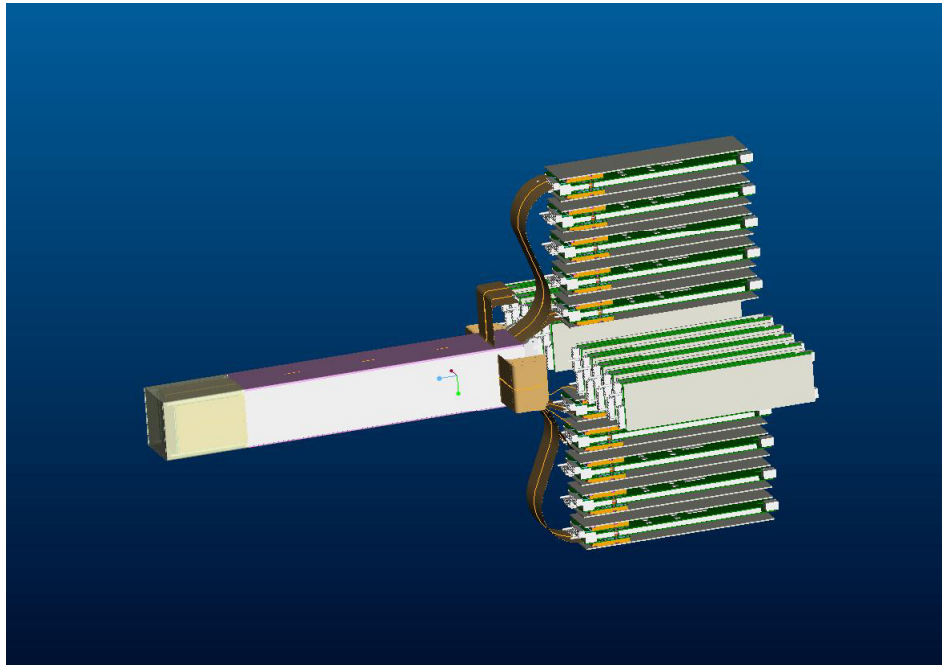


Precision tests of wavefunctions by measuring level lifetimes.

Active stopper..AIDA

Advanced Implantation Detector Array

- Uses 12 x 8cm x 8cm DSSSD



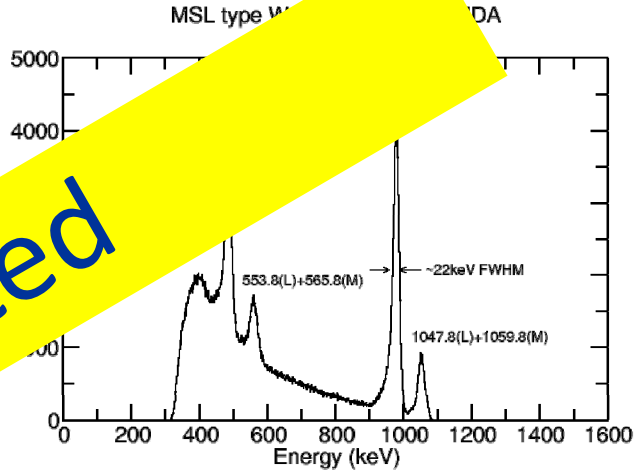
- Measures position of implant
- Fast overload recovery (~μs}
- Time stamping

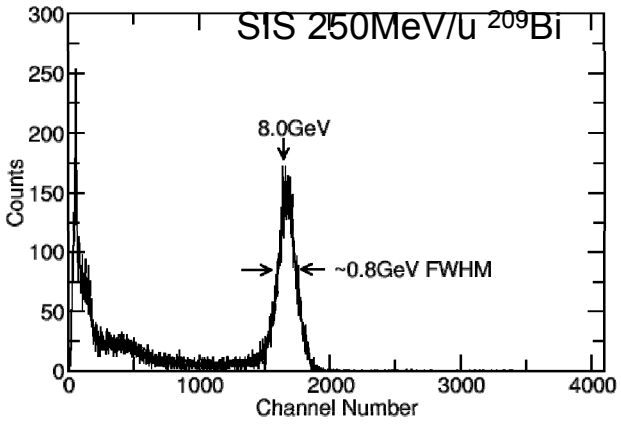
http://www2.ph.ed.ac.uk/~td/DSSD/

Active stopper..AIDA

Advanced Implantation Detector Array

- Uses 12 x 8cm x 8cm DSSSD



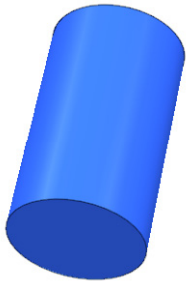


TDR approved, tested

Science & Technology Facilities Council

THE UNIVERSITY of LIVERPOOL

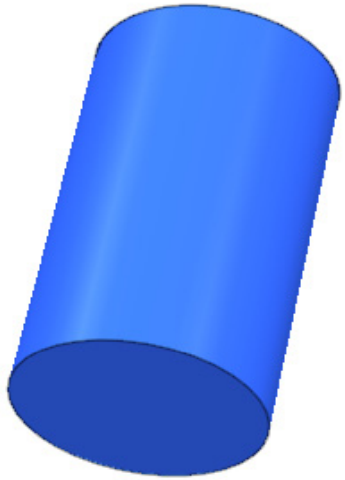
Timing resolution of cylindrical crystals



ø1”x1”

FWHM 200 ps

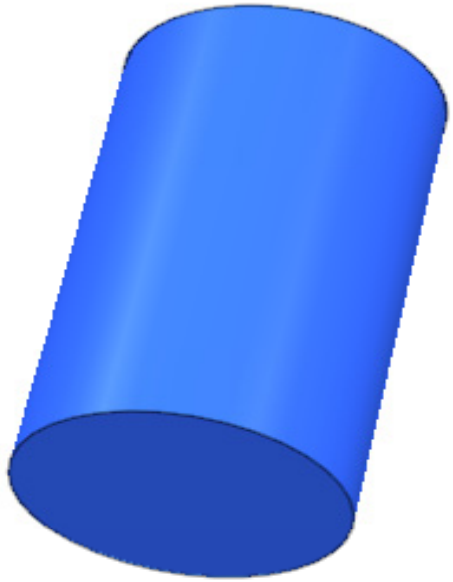
FWHM 150 ps



ø1.5”x1.5”

360 ps

180 ps



ø2”x2”

450 ps at 511 keV

300 ps at 1332 keV

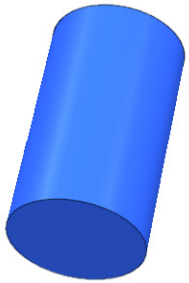
N. Mărginean et al. *Eur. Phys. J A 46, 329-336,* 2010.

I. Deloncle et al. *J. Phys.:Conf. Series 205,* 012044, 2010.

M. Moszynski et al. *Nucl. Instr. Methods A 567,* 2007.

L.M. Fraile et al. ISOLDE Workshop, Fast timing results at ISOLDE, http://indico.cern.ch/getFile.py/access?contribId=36&sessionId=8&resId=0&materialId=slides&confId=67060, November, 2009.

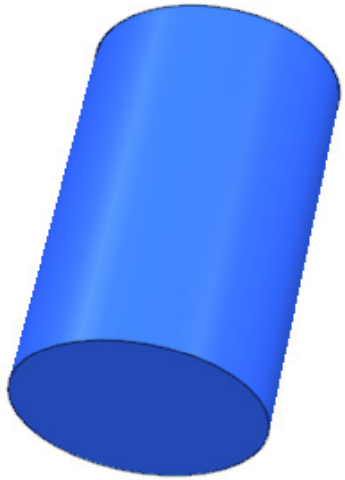
Timing resolution of cylindrical crystals



ø1”x1”

FWHM 200 ps

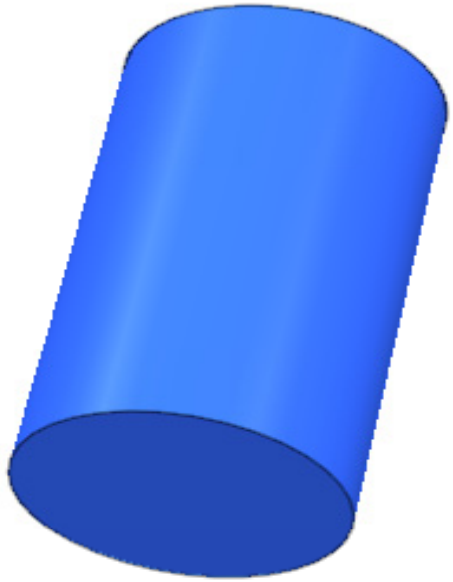
FWHM 150 ps



ø1.5”x1.5”

360 ps

180 ps



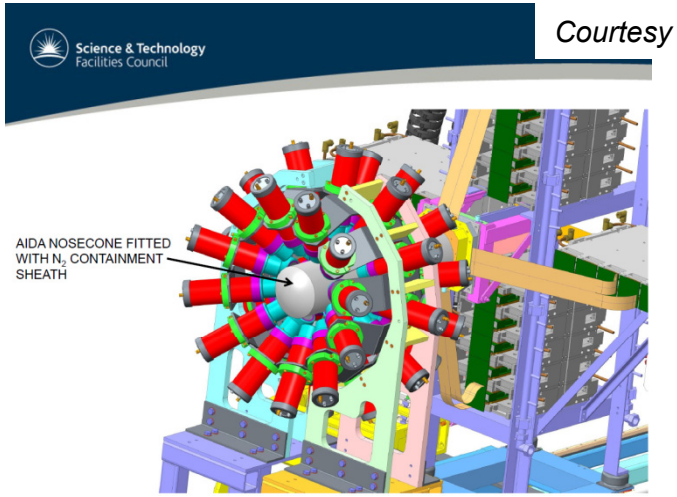
ø2”x2”

450 ps at 511 keV

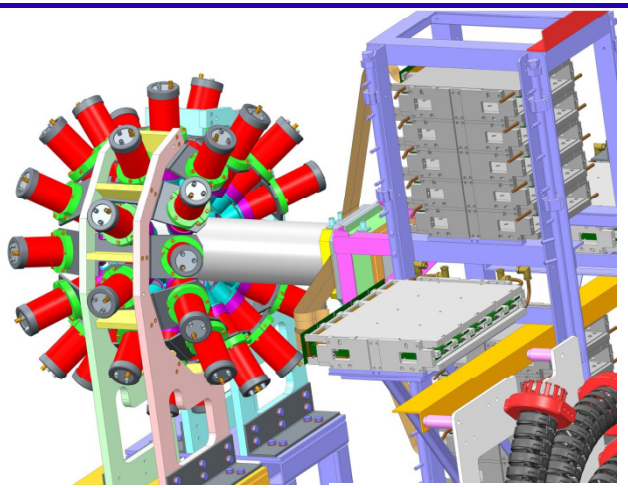
300 ps at 1332 keV

Trade off between resolution and efficiency

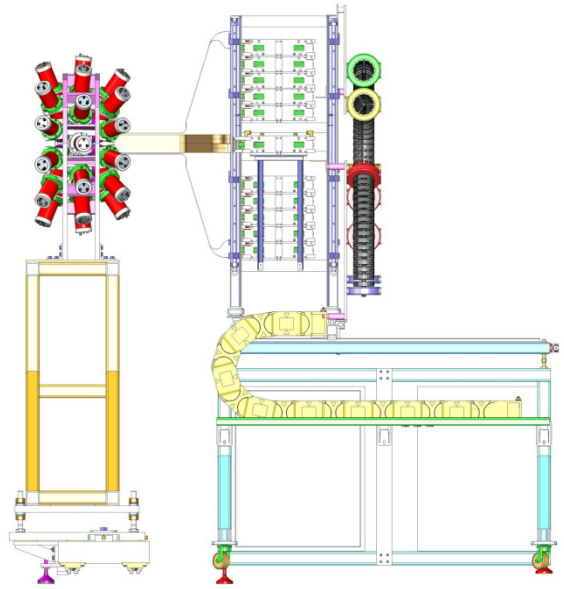
Final Design: ø1.5”x2”



Courtesy of I.Burrows



Courtesy of I.Burrows

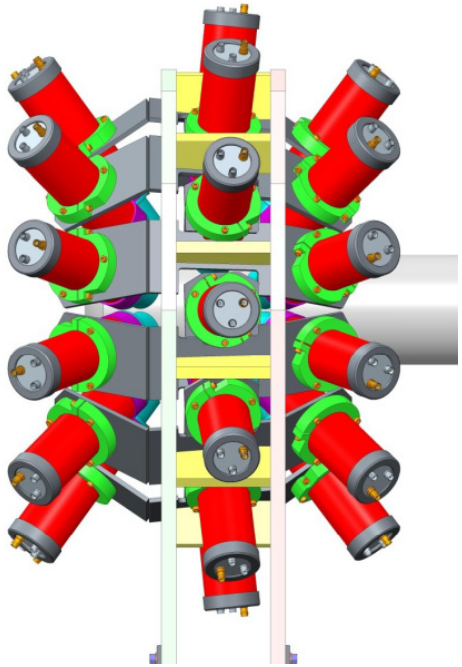


Courtesy of I.Burrows

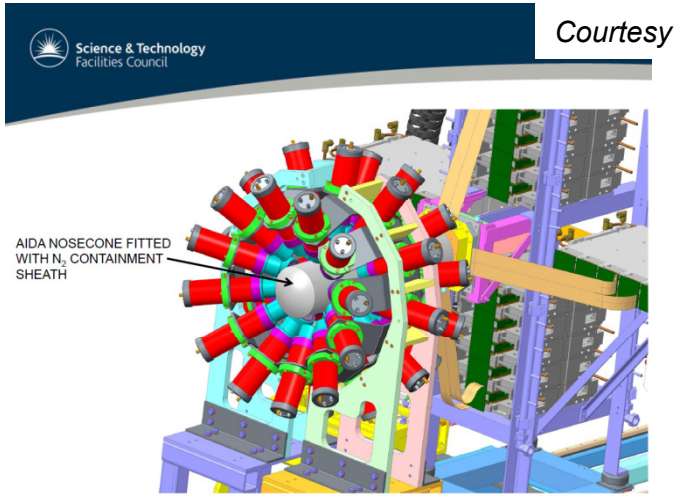
Expected full-energy peak efficiencies are:

~ 5% at 500 keV
~ 3 % at 1000 keV
~ 1 % at 2000 keV
~ 0.5 % at 4000 keV

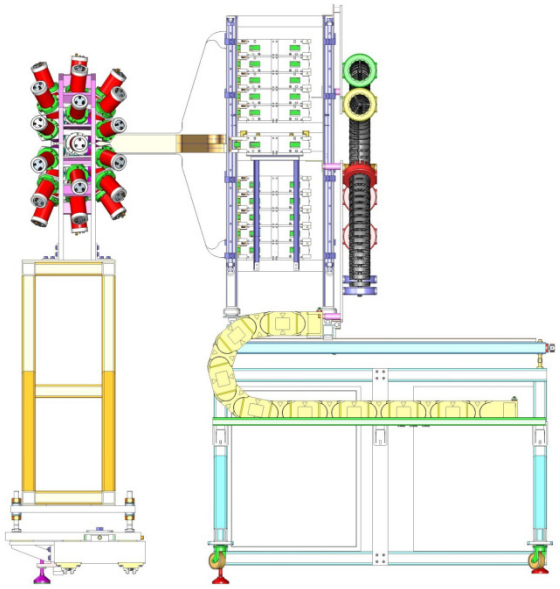
Courtesy of I.Burrows



Final Design: ø1.5”x2”



Courtesy of I.Burrows



Courtesy of I.Burrows

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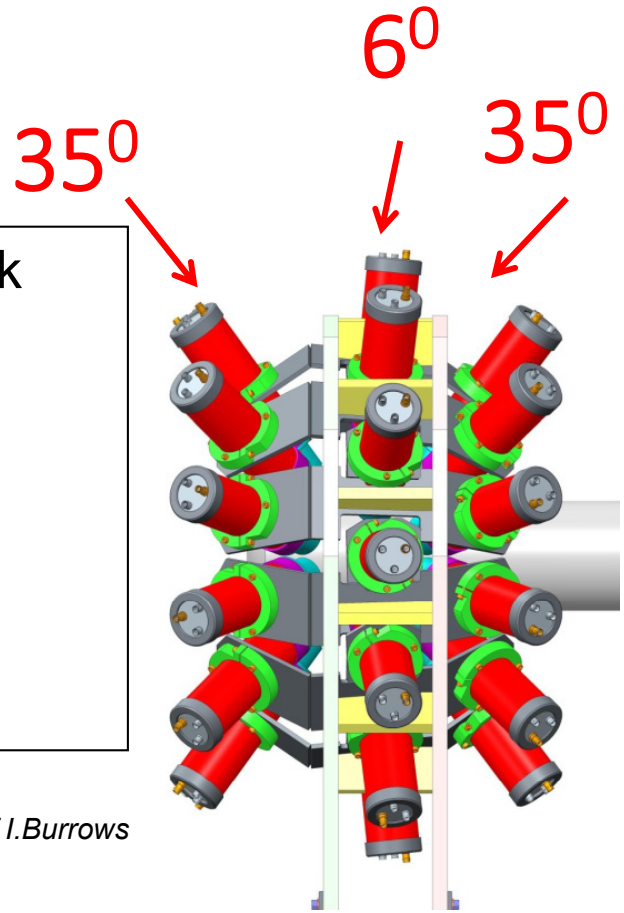
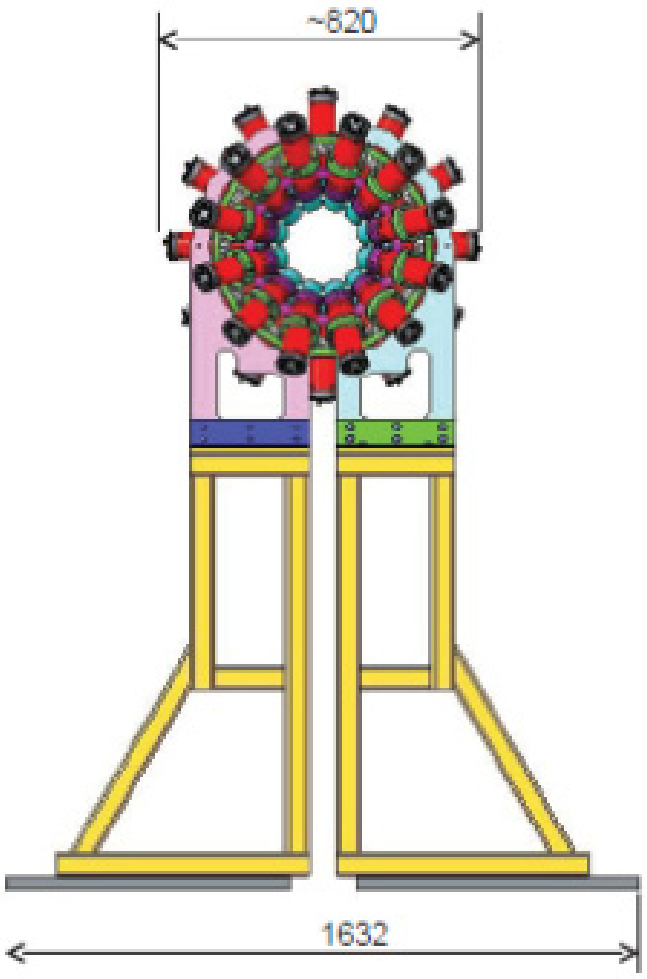


Courtesy of I.Burrows

Fast-timing array



Examples of the use of FATIMA:

Feb 2013: 8 detectors used at ILL for the EXILL campaign to study fission fragments

April/May 2013: Used in Bucharest as part of the ROSPHERE array
– see talk by N Marginean on Thursday

May 2013: 18 detectors used at RIKEN in coincidence with the EURICA (germanium detector) array

August 2015: Used at Jyvaskyla at the focal plane of RITU

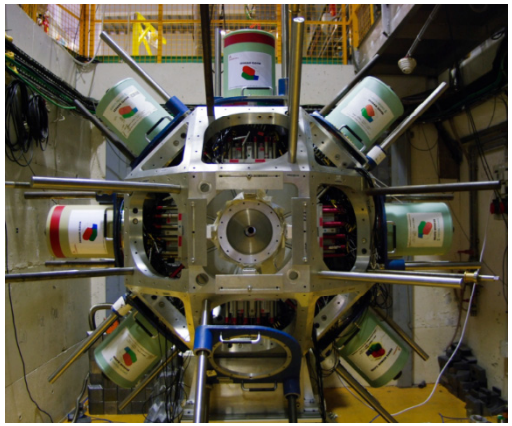
December 2015/January 2016: Used at Argonne in coincidence with half of the Gammasphere array

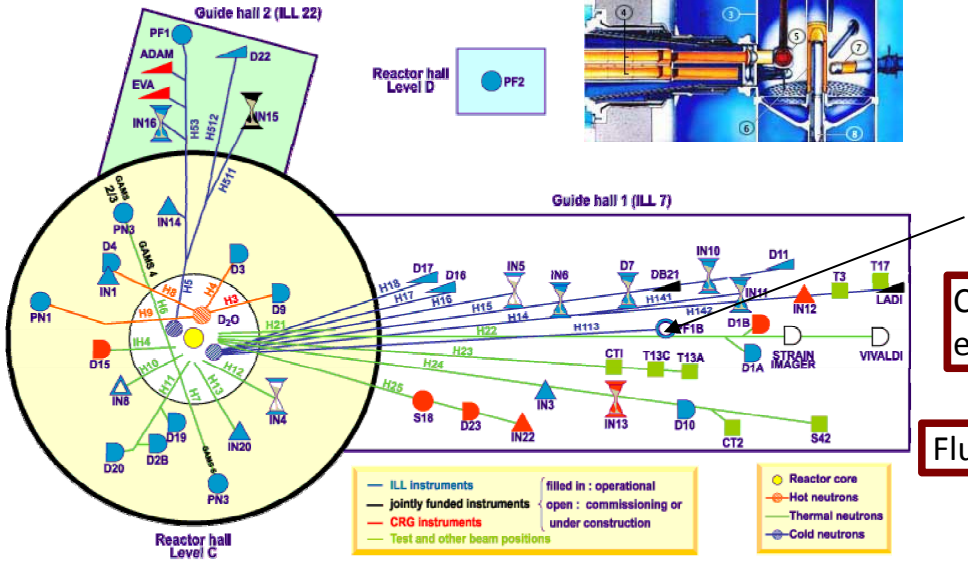
EXILL and FATIMA at ILL

EXILL = Exogam at Institut Laue Langevin 11.2012-4.2013

High Flux Reactor of the Institut Laue Langevin in Grenoble France

8 Clover detectors of EXOGAM





PF1B

Cold neutrons have meV energies

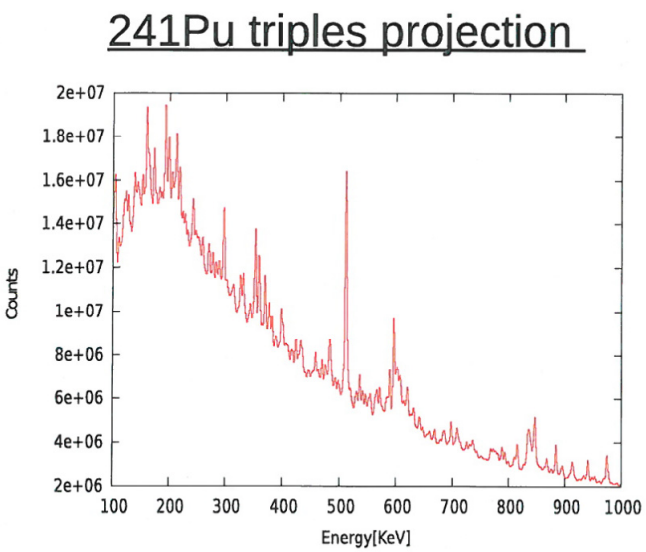
Flux up to 1.3 x 10^{10} n/s/cm^2

EXILL and FATIMA at ILL

FATIMA + EXOGAM
8 Ge Clover detectors from EXOGAM with BGO shields
16 LaBr3(Ce) scintillators from FATIMA

(n,fission) EXILL&FATIMA experiments

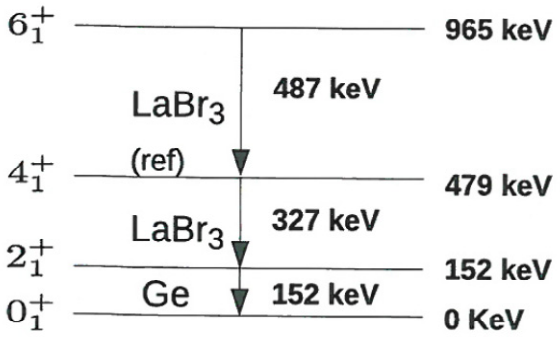
^{235}U ^{241}Pu J.M. Régis (Köln)

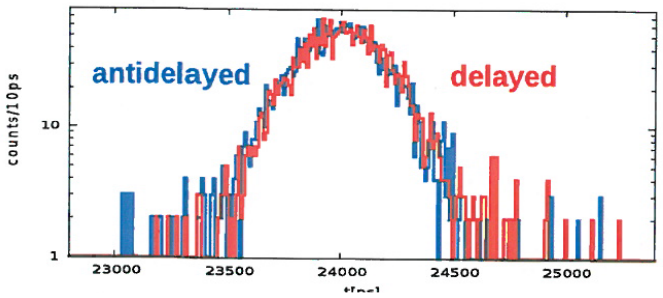


Yields per ^{241}Pu fission: ^{98}Zr 1.6 10^{-2}; ^{100}Zr 4.3 10^{-2}; ^{102}Zr 2.5 10^{-2}.

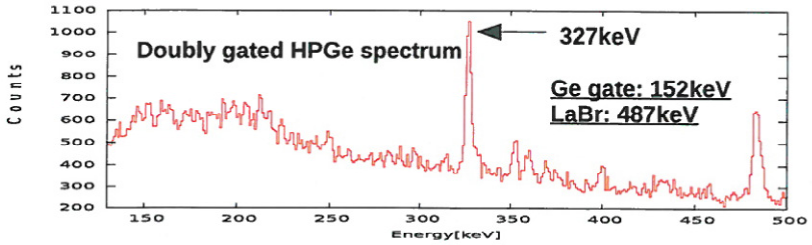
EXILL and FATIMA at ILL

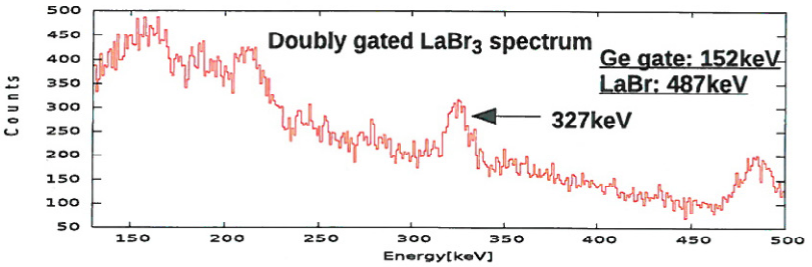
Lifetime analysis for 4^+ state in ^{102}Zr





$$\tau = 21(15)\ ps$$





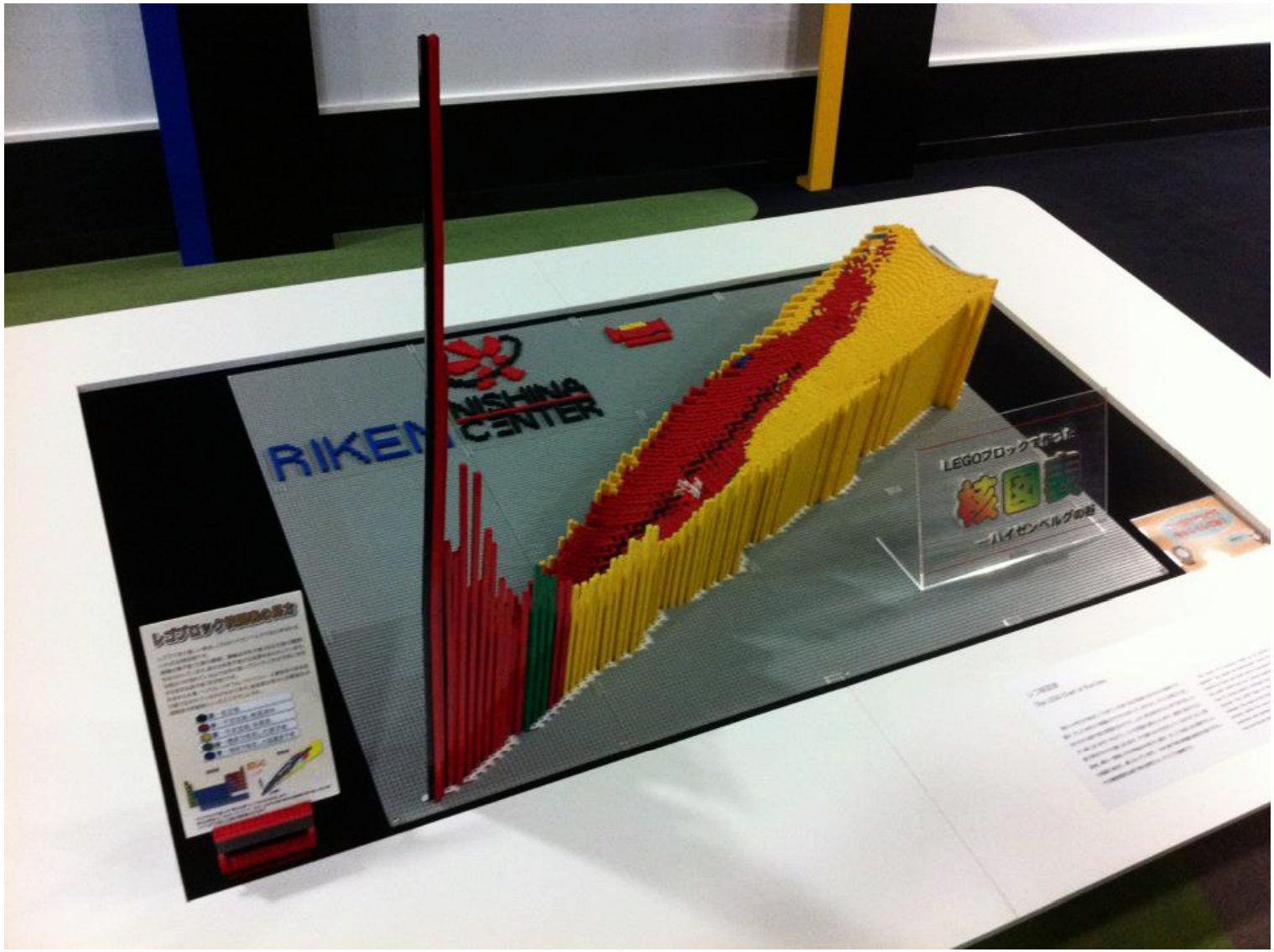
J.Jolie, J.M.Regis (Köln)
to be published

EXILL and FATIMA at ILL

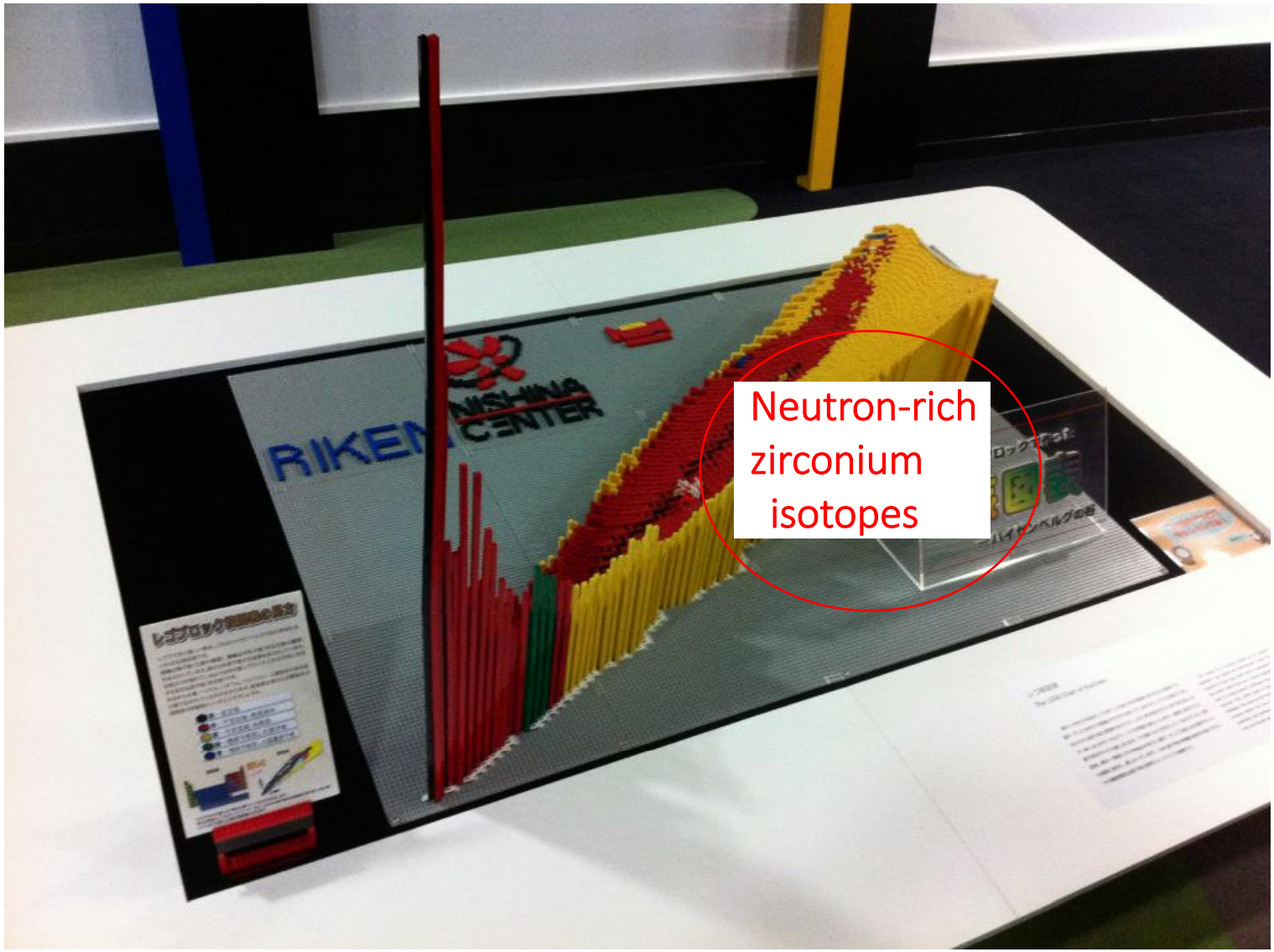
Nuclei		Experiment		Literature
^{102}Zr	2^+	τ = 2.64(10) ns	$T_{1/2}$ = 1.83(7) ns	$T_{1/2}$ = 1.8(4) ns
	4^+	τ = 21(15) ps	$T_{1/2}$ = 15(11) ps	Not Known
	6^+	τ = 13(11) ps	$T_{1/2}$ = 9(8) ps	Not Known
^{100}Zr	2^+	τ = 965(30) ps	$T_{1/2}$ = 668(20) ps	$T_{1/2}$ = 590(30) ps
	4^+	τ = 25(10) ps	$T_{1/2}$ = 17(7) ps	$T_{1/2}$ = 37(3) ps
^{98}Zr	2^+	τ = 12(9) ps	$T_{1/2}$ = 9(6) ps	$T_{1/2}$ < 11ps
	4^+	τ < 20 ps		$T_{1/2}$ = 20(6) ps

J.Jolie, J.M.Regis (Köln)
to be published

Lifetime measurements at RIKEN



Lifetime measurements at RIKEN



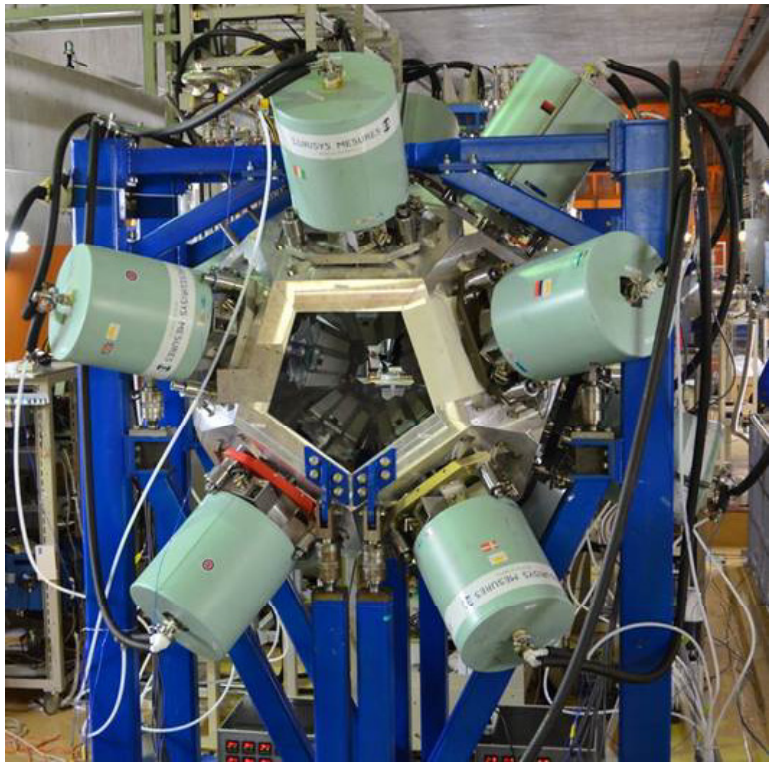
Active stopper = WAS3ABi

Active silicon stopper array:
5 DSSSDs, 1 mm thick
60x40 strips, each 1 mm wide
Spacing: 0.5 mm
Pos. res.: 1 mm
Time res.: ~200 ns

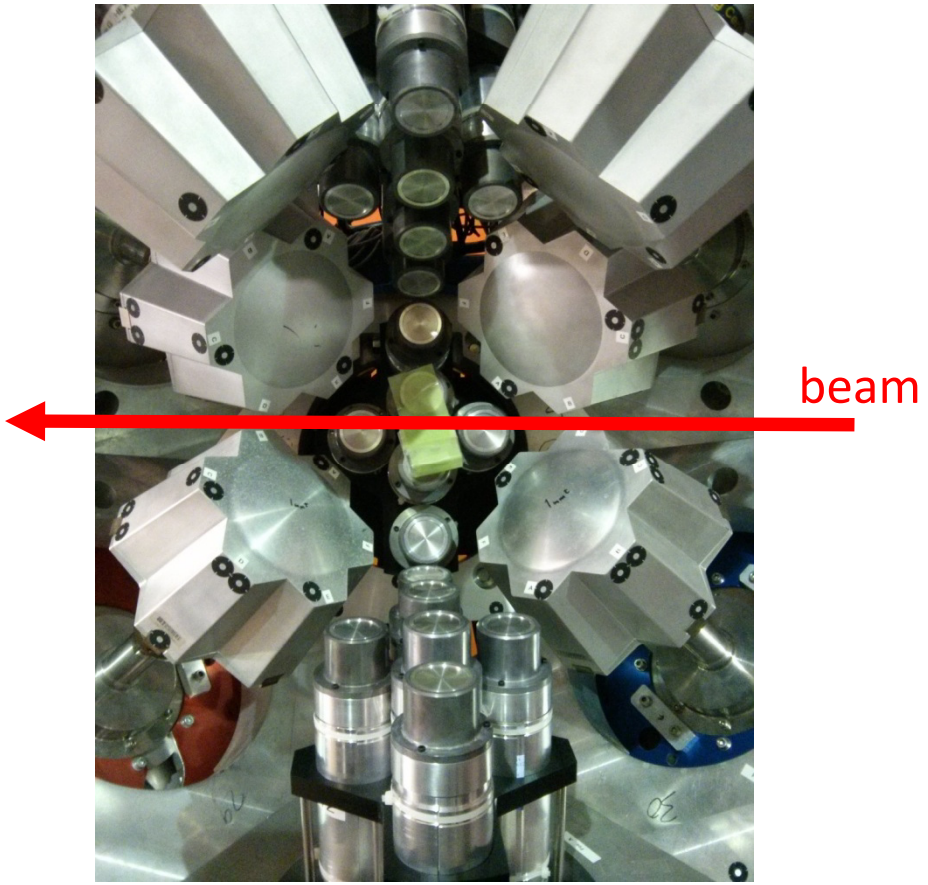
Beta-plastics:
2 mm thick, 65x45 mm^2 area
~1 mm up- and downstream of WAS3ABi
BC-418
Time res.: ~200 ps
Efficiency: ~30%

EURICA @ RIKEN

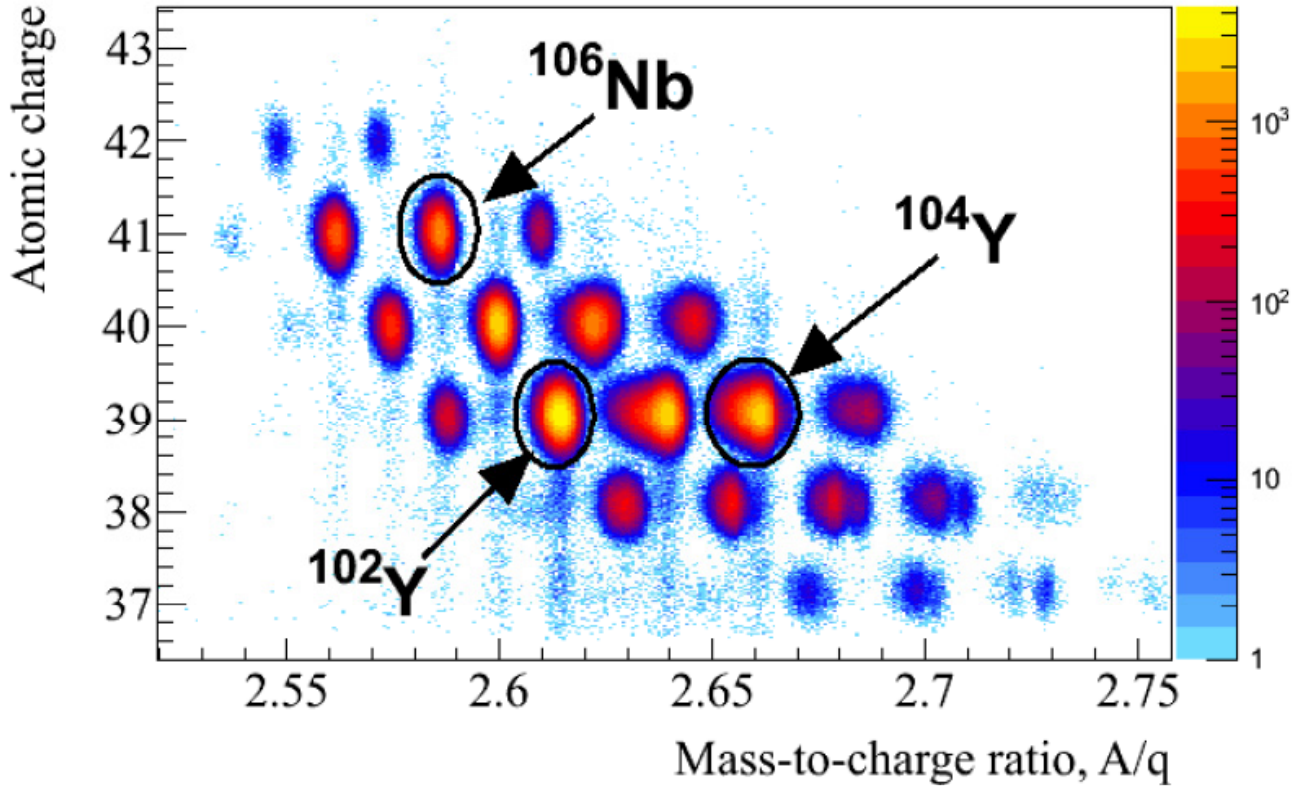
12 RISING clusters



18 $LaBr_3(Ce)$ detectors
Total efficiency ~2% at 500 keV

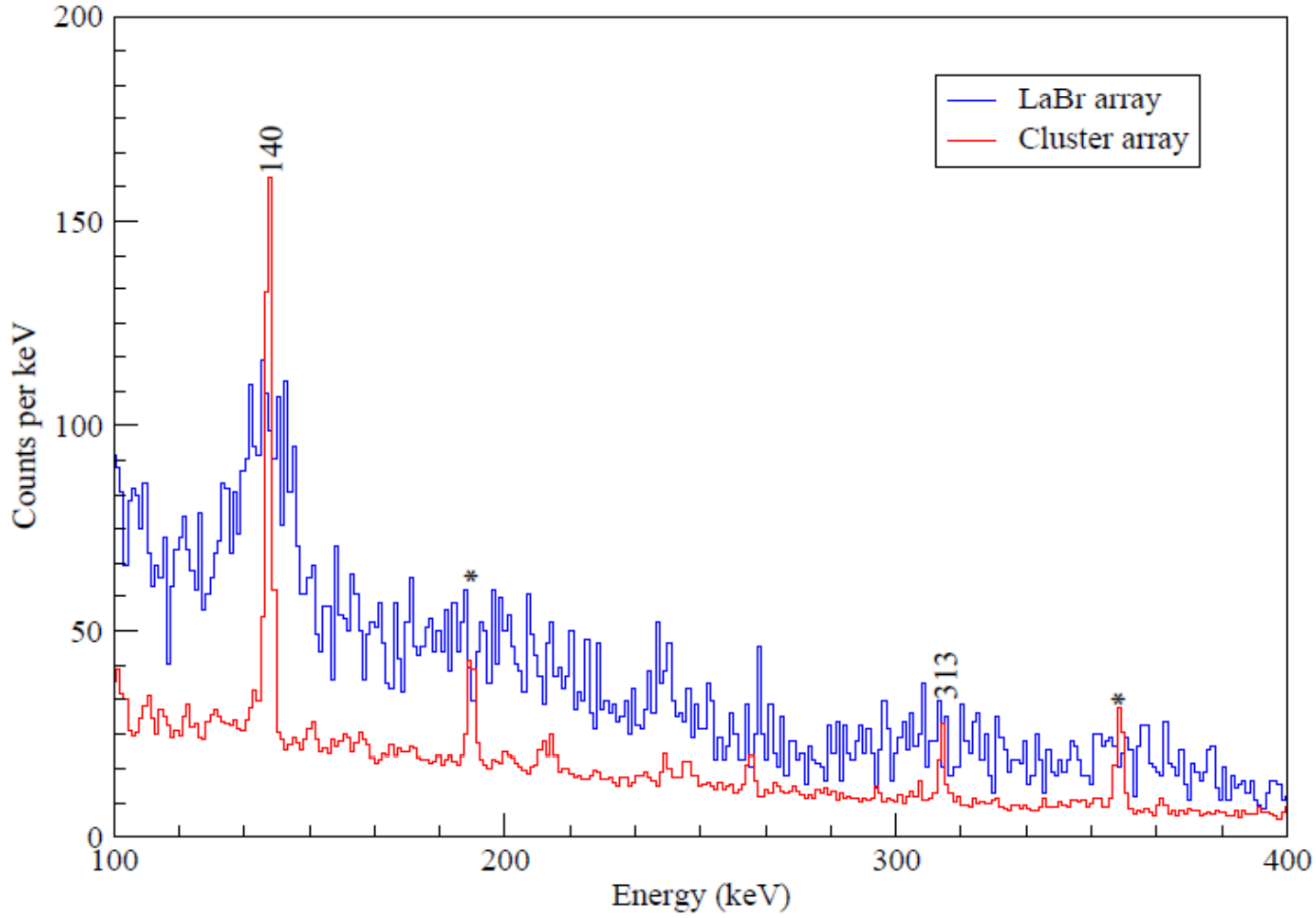


PID plot for ^{104}Y



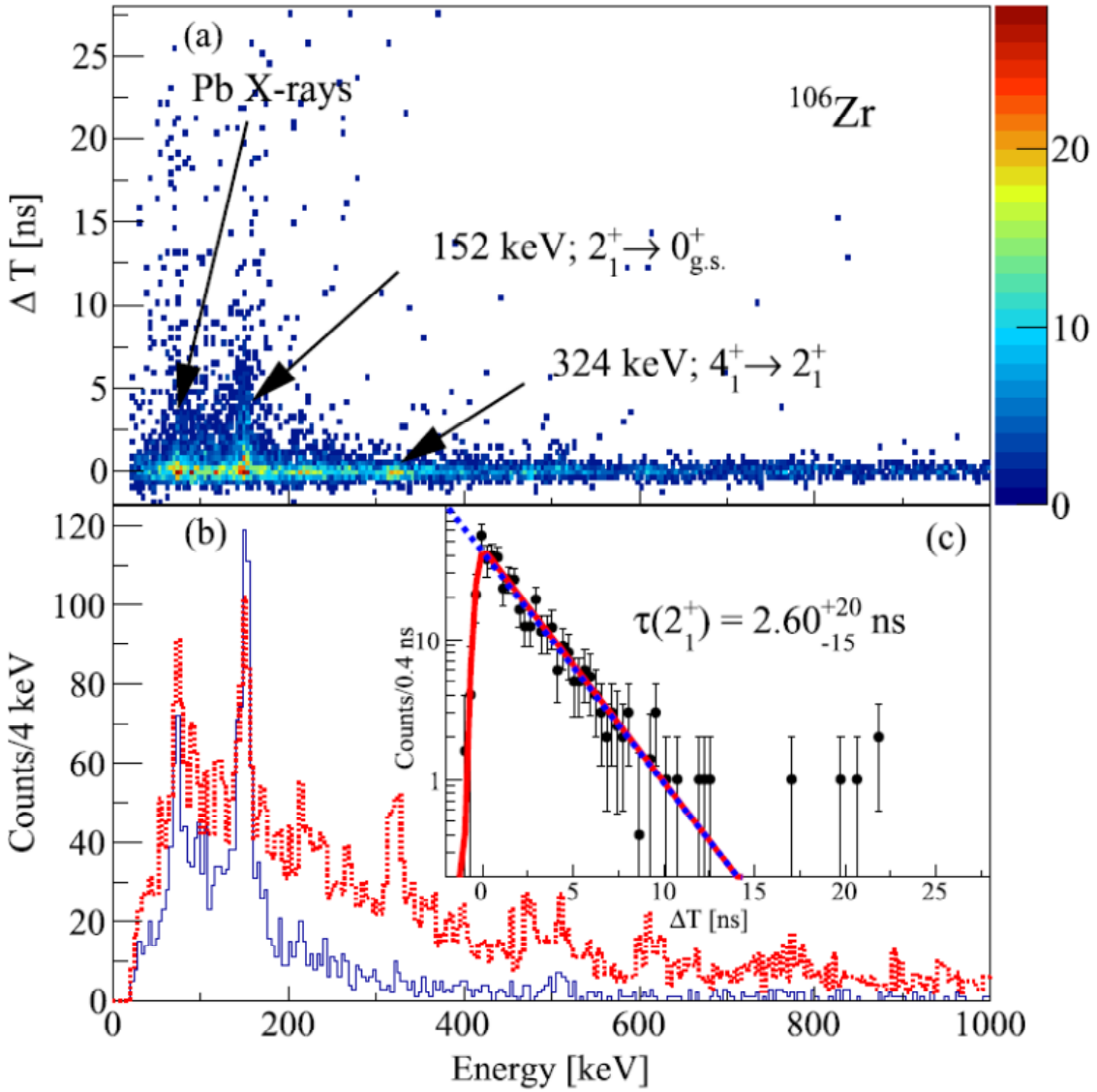
3.8 x 10^5 ^{104}Y ions

^{104}Zr: Fragment – β correlation time set at 5 $t_{1/2}$ = 5 * 200 ms



Cluster spectrum scaled

Results for ^{106}Zr: Fragment – β correlation time set at 0.3s

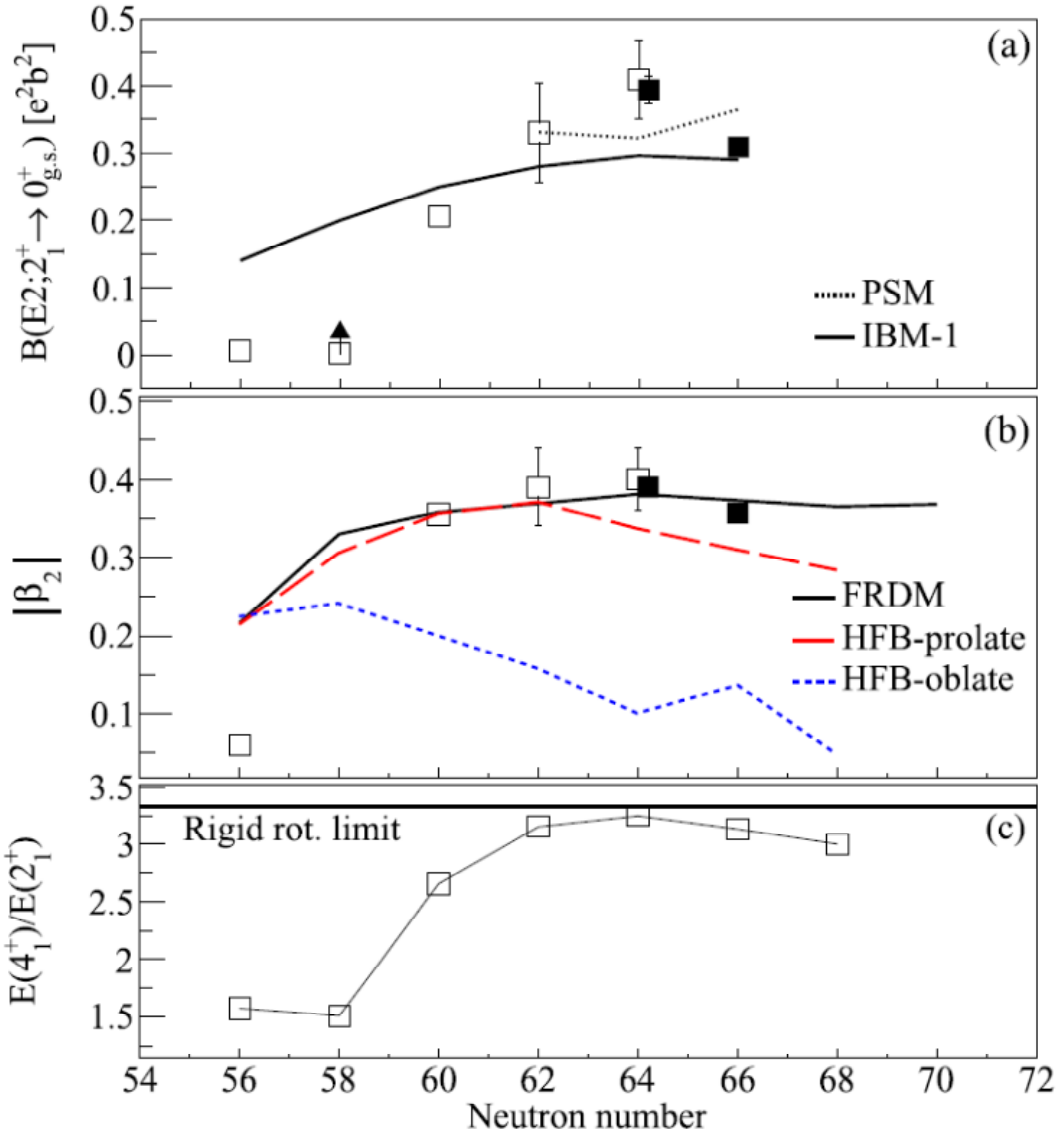


Blue = delayed

Red = prompt

F.Browne at al., Physics Letters B 750 (2015) 448-452

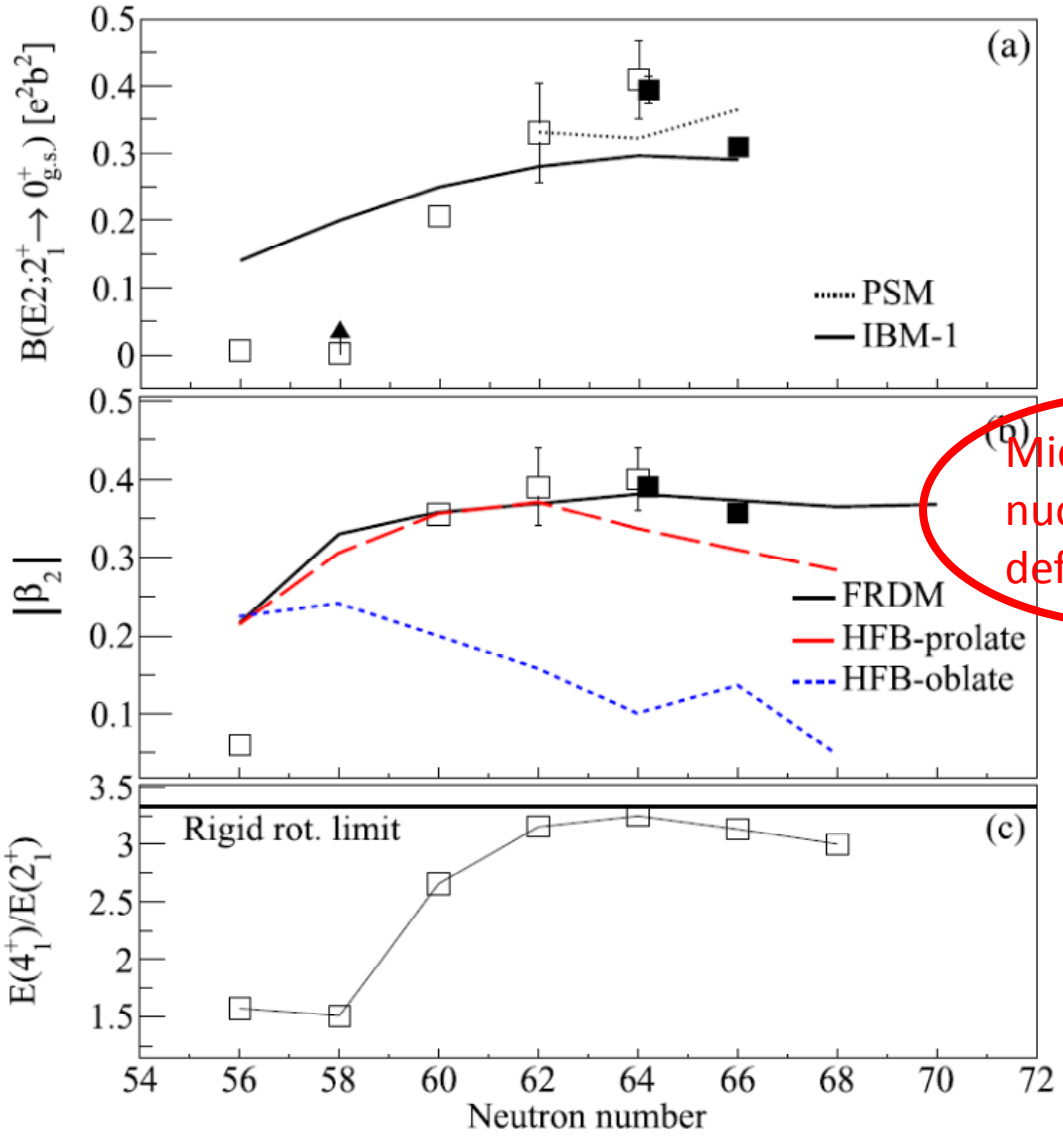
Extracted deformations:



PSM:
Liu et al., NPA858 (2011)11.
IBM-1:
Böyükata et al.,
JPG37 (2010) 105102.
FRDM:
Moller at al.,
ADNDT59(1995)185.
HFB:
Rodríguez-Guzmán et al.,
PLB691(2010)202.

F.Browne at al.,
Physics Letters B 750
(2015) 448-452

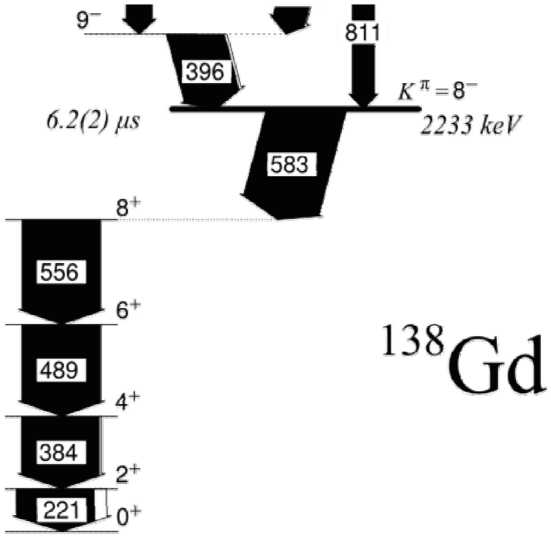
Extracted deformations:

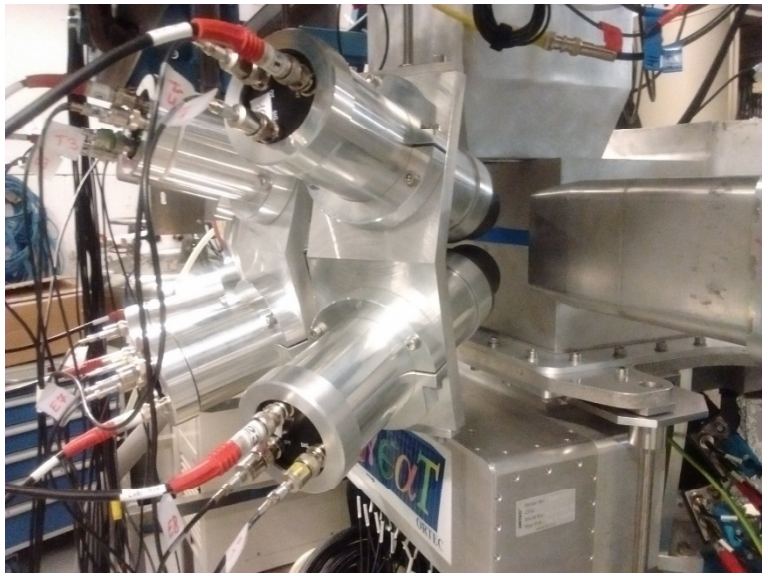


Mid-shell N=64 nucleus is most deformed

F.Browne at al., Physics Letters B 750 (2015) 448-452

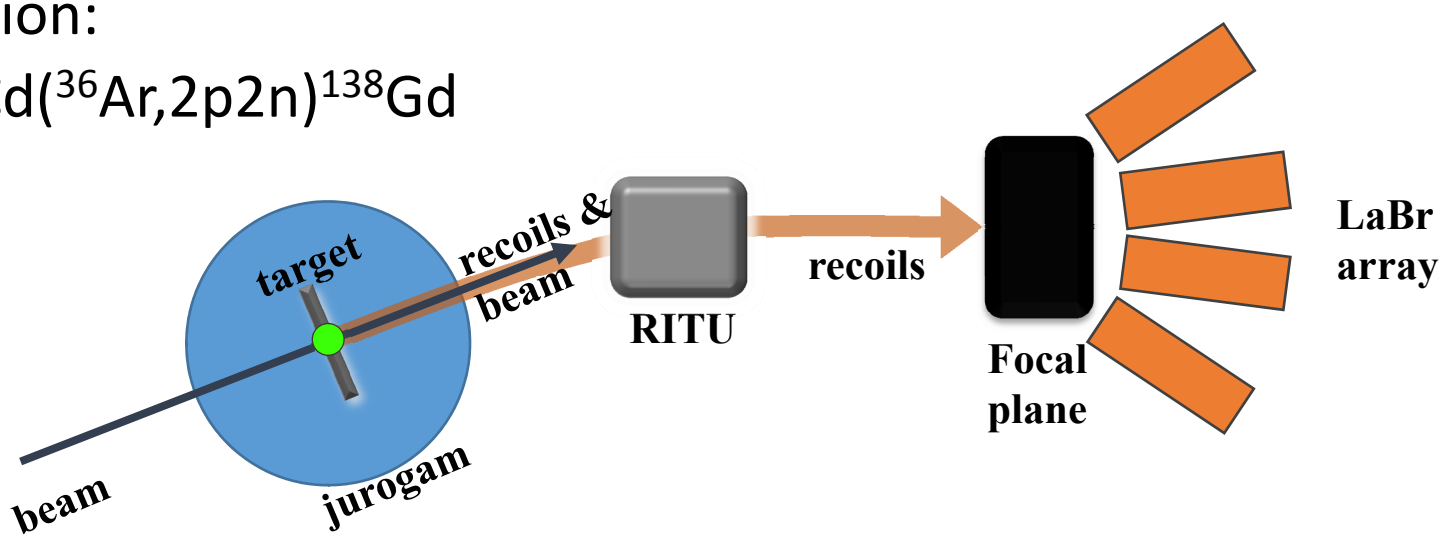
LaBr Array at JYFL,first expt with an extended source





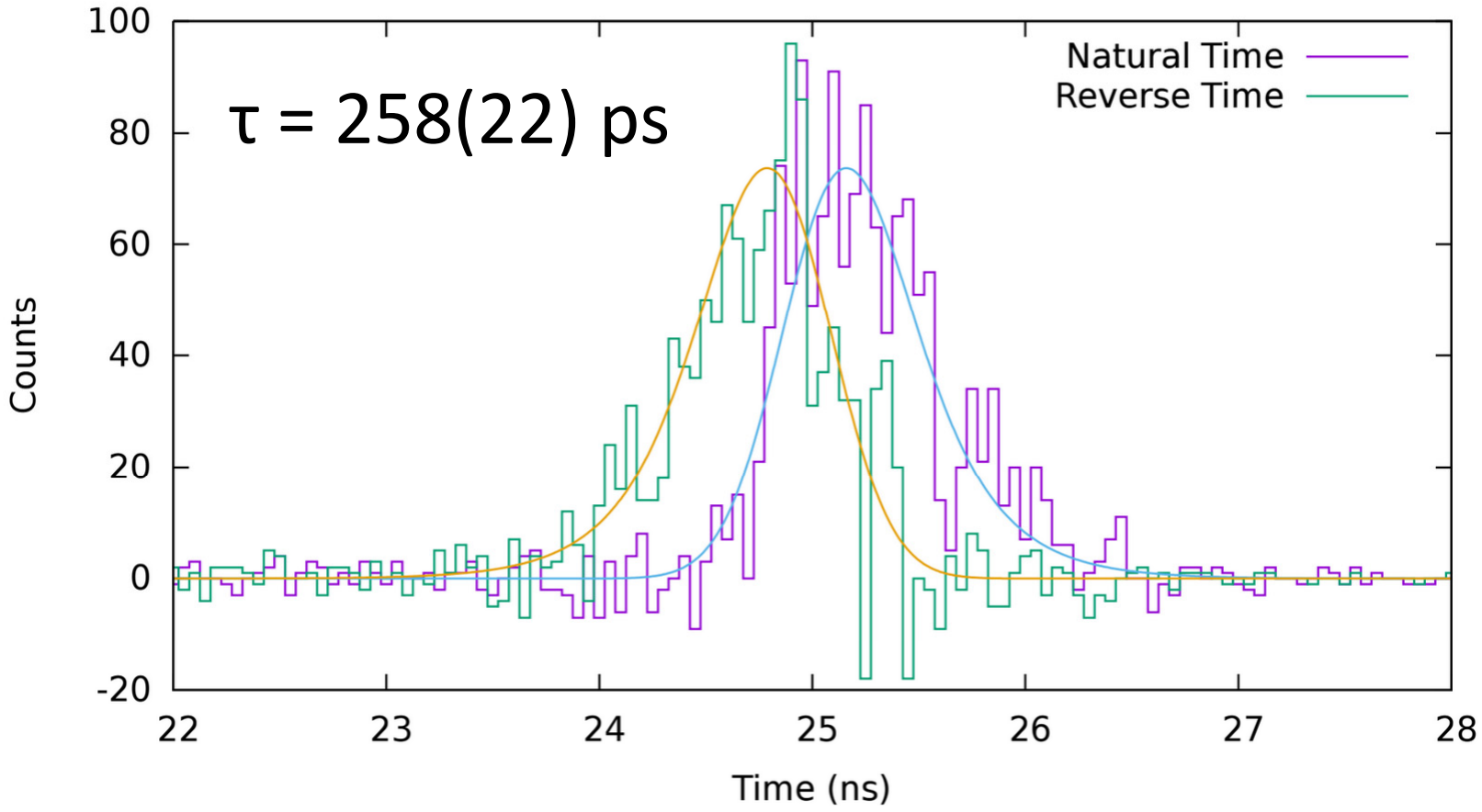
Reaction:

- $^{106}Cd(^{36}Ar,2p2n)^{138}Gd$



LaBr Array at JYFL,first expt with an extended source

Results – ^{138}Gd 2^+



LaBr Array at JYFL,first expt with an extended source

^{138}Gd – (this work: 258(22) ps)

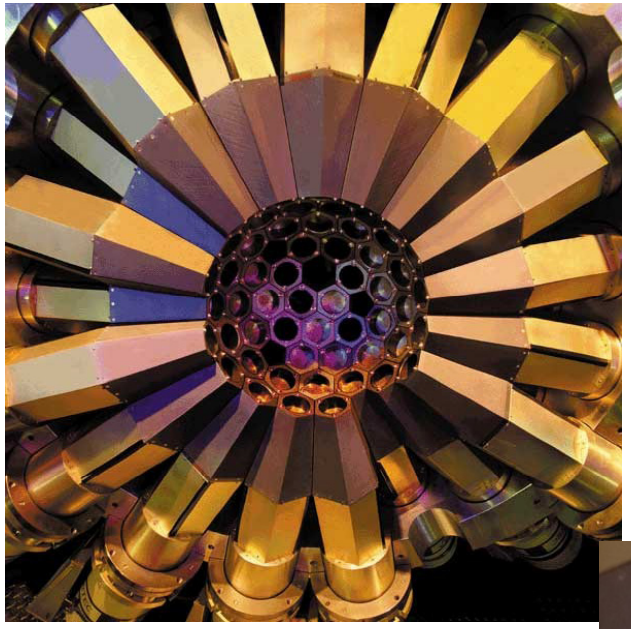
308(17) ps – MG Procter

(doi: 10.1103/PhysRevC.84.024314)

305(30) ps – PJ Bishop

(doi: 10.1088/0305-4616/14/7/016)

FATIMA and Gammasphere (^{252}Cf source)

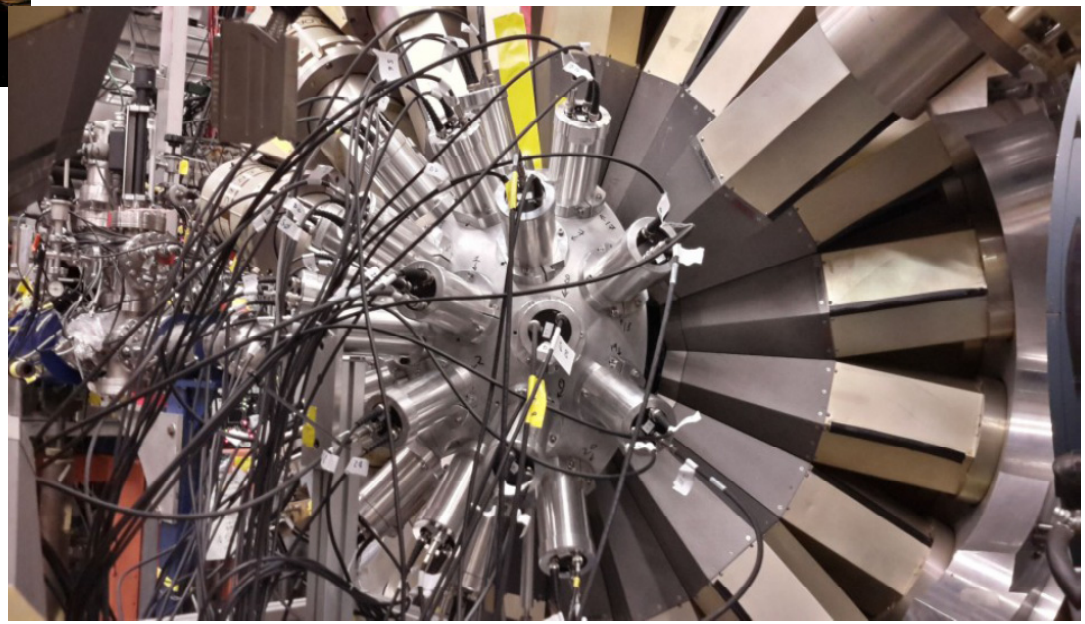


One hemisphere of Gammasphere
(51 Ge detectors)

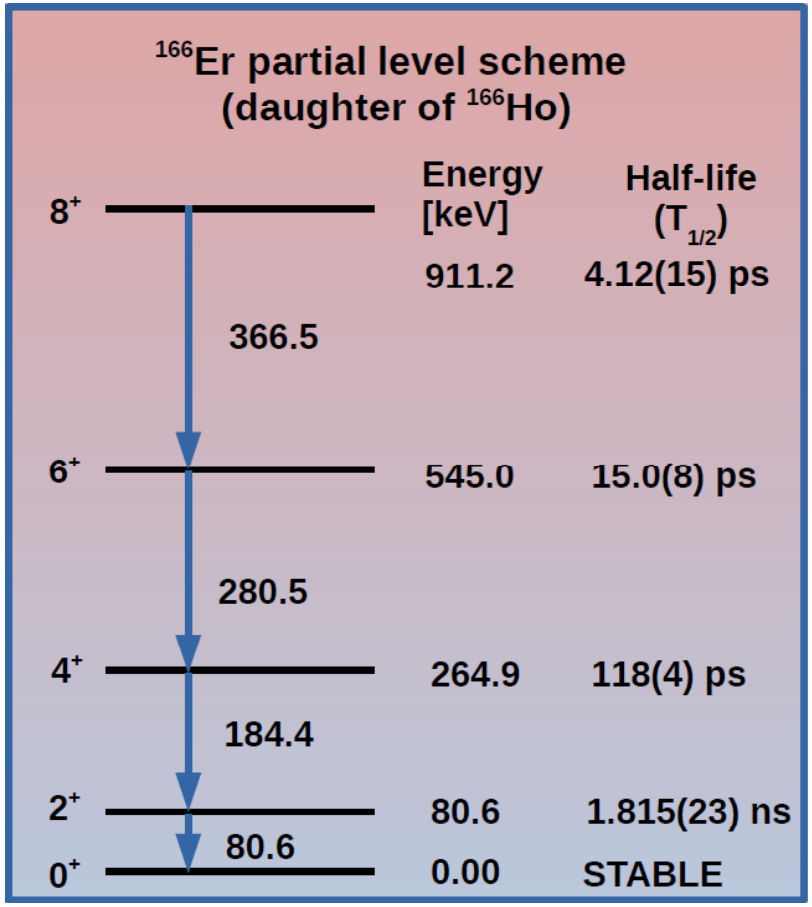
Measure triples: Ge-$LaBr_3$-$LaBr_3$

One hemisphere of the
FATIMA array

(25 $LaBr_3$(Ce) detectors)

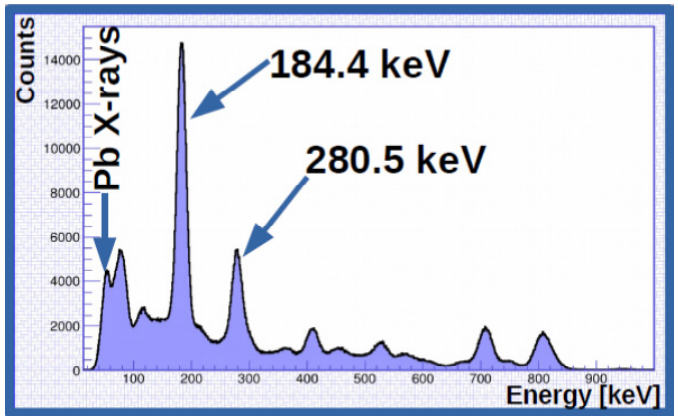


FATIMA and Gammasphere (^{252}Cf source)

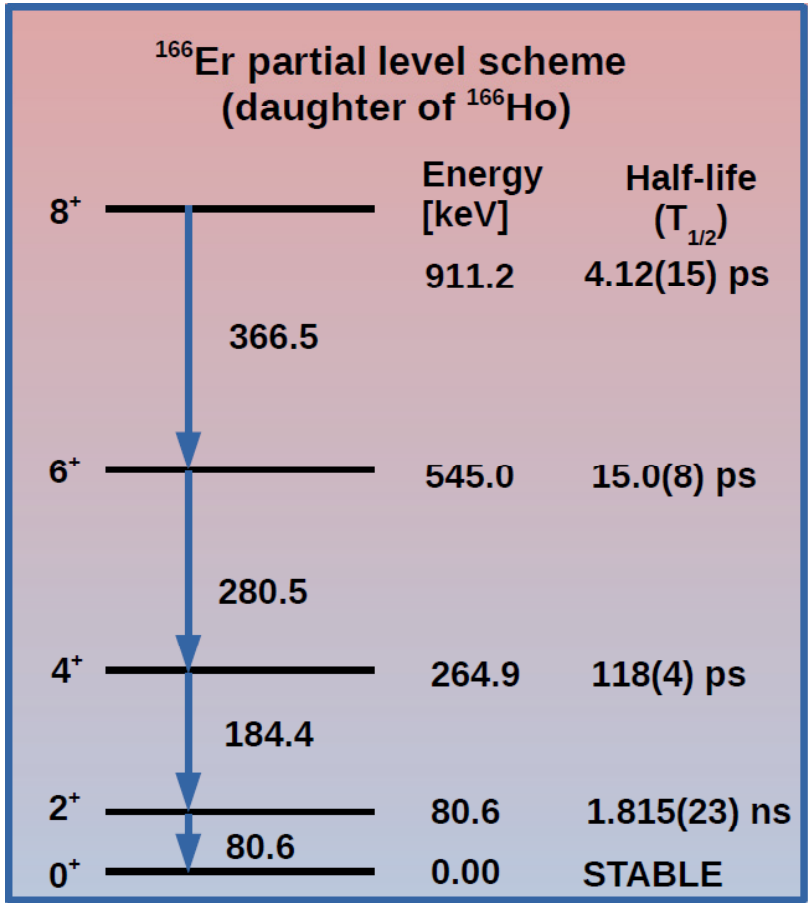


Test looking at levels in ^{166}Er from decay of ^{166}Ho source

$LaBr_3$(Ce) spectrum gated on 80.6 keV in Gammasphere

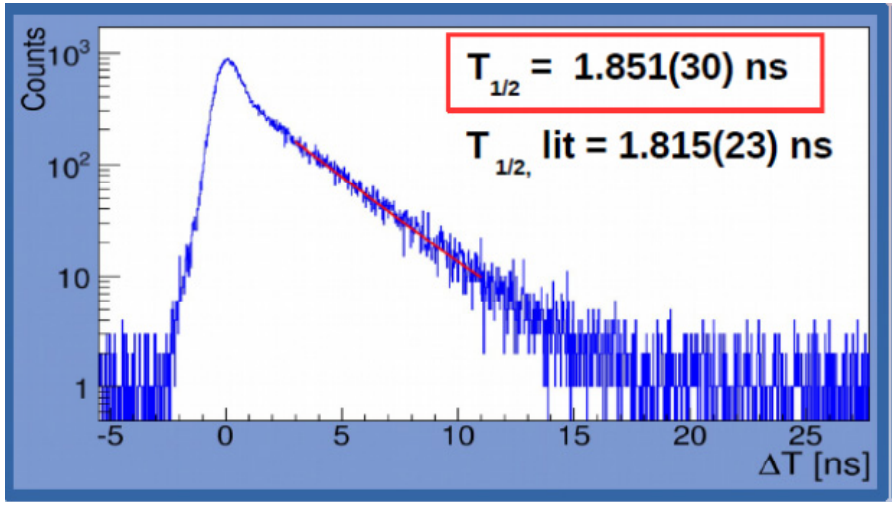


FATIMA and Gammasphere (^{252}Cf source)

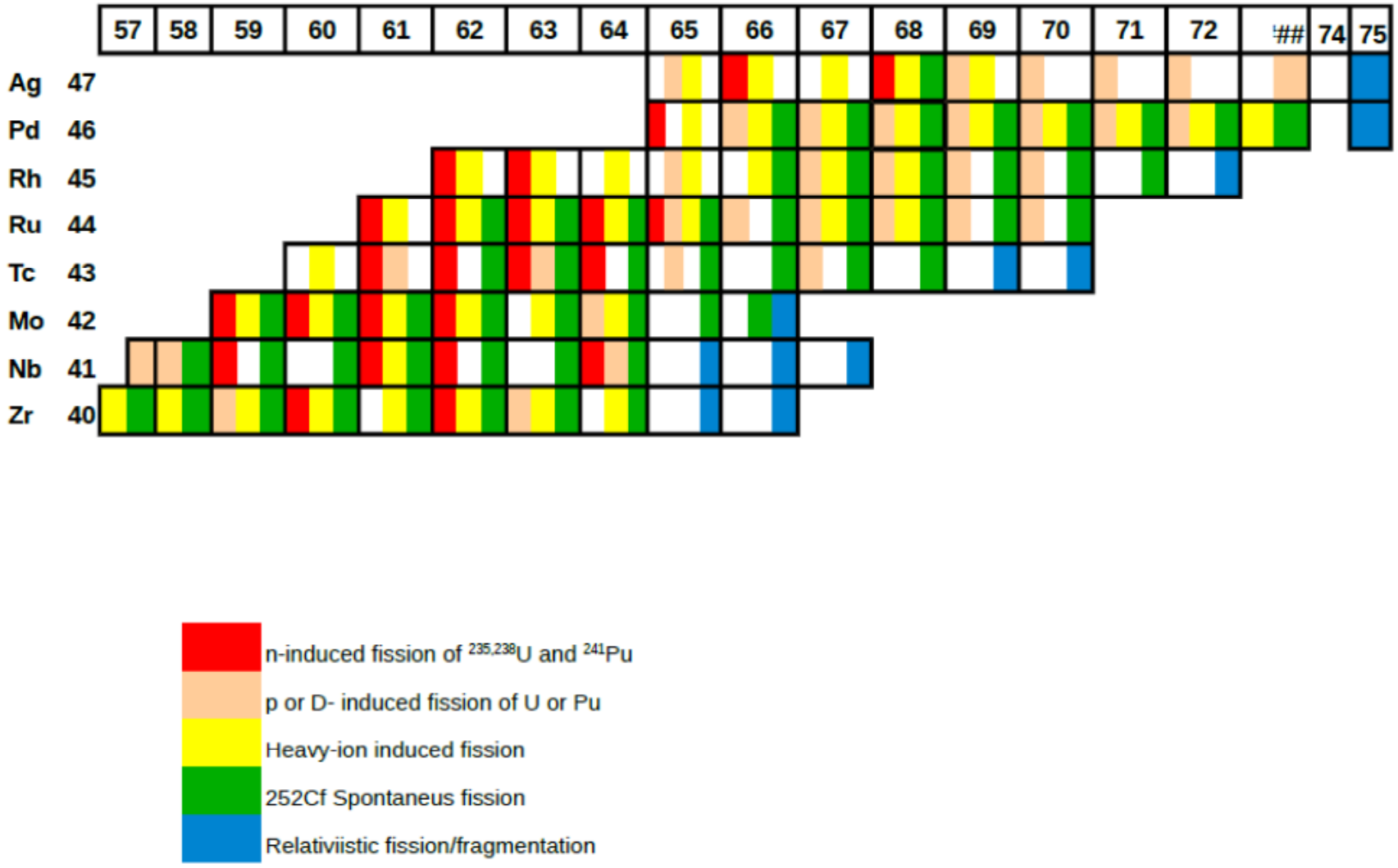


Test looking at levels in ^{166}Er from decay of ^{166}Ho source

184/80 time profile.



FATIMA and Gammasphere (^{252}Cf source)



FATIMA and Gammasphere (^{252}Cf source)

Plans for FATIMA

Aug - Sept / Oct 2016 ? ~ 8 for Jyvaskyla ^{140}Dy isomer expt.

late Sept 2016 ~36 $LaBr_3$ to Orsay for the STELLA / Andromede campaign (on and off until ~mid 2017)

Early-mid 2017 ~22 $LaBr_3$ to GANIL for AGATA runs (Xe+Er, N~60 fission fragments, Os/W region (latter 2 with VAMOS)

Later 2017 - early 2018 ~36 $LaBr_3$ at Orsay for NuBALL

2018 36 (??) $LaBr_3$ Phase 0 at GSI/FAIR

2018 onwards some (up to 36?) $LaBr_3$ back to GANIL for AGATA+NEDA experiments (N~Z in-beam, ^{88}Ru, ^{94}Pd etc.)

Members of the HISPEC-DESPEC **FATIMA** Collaboration

Brighton, United Kingdom, University of Brighton
A. Bruce, O. Roberts[1]

Bucharest, Romania, IFIN-HH
N. Marginean, D. Ghita, R. Lica, R. Marginean, C. Mihai

Cologne, Germany, University of Cologne
J. Jolie, J.-M. Régis

Daresbury, United Kingdom, STFC Daresbury Laboratory
J. Simpson, M. Labiche, I. Lazarus

Guildford, United Kingdom, University of Surrey
S. Lalkovski, Zs. Podolyak, P. Regan

Madrid, Spain, Universidad Complutense
L.M. Fraile, B. Olaizola[2], V. Paziy, J.M. Udías, V. Vedia

Manchester, United Kingdom, University of Manchester
D. Cullen

Paisley, United Kingdom, University of West Scotland
G. Simpson, J.F. Smith

Sofia, Bulgaria, University of Sofia
S. Lalkovski[3], S. Kisyov[4]

Warsaw, Poland, NCBJ, Swierk
H. Mach[†]

Associated Members

Darmstadt, Germany, Technical University of Darmstadt
Th. Kröll, S. Ilieva, A. Ignatov, H.-B. Rhee, G. Fernández Martínez

Grenoble, France, LPSC
G. Simpson[‡]

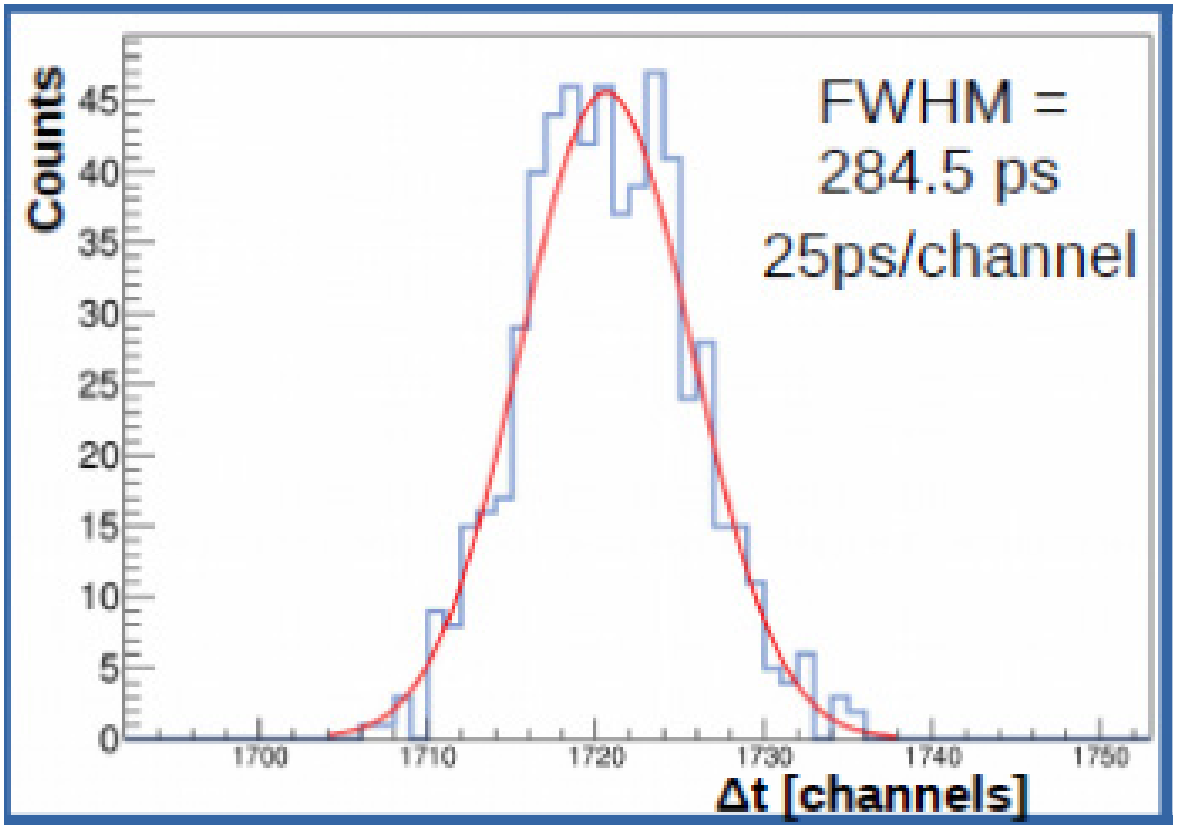
Saclay, France, CEA Saclay
W. Korten, B. Bruyneel

FATIMA Spokesperson: Luis Mario FRAILE, Univ. Complutense Madrid, lmfraile@ucm.es

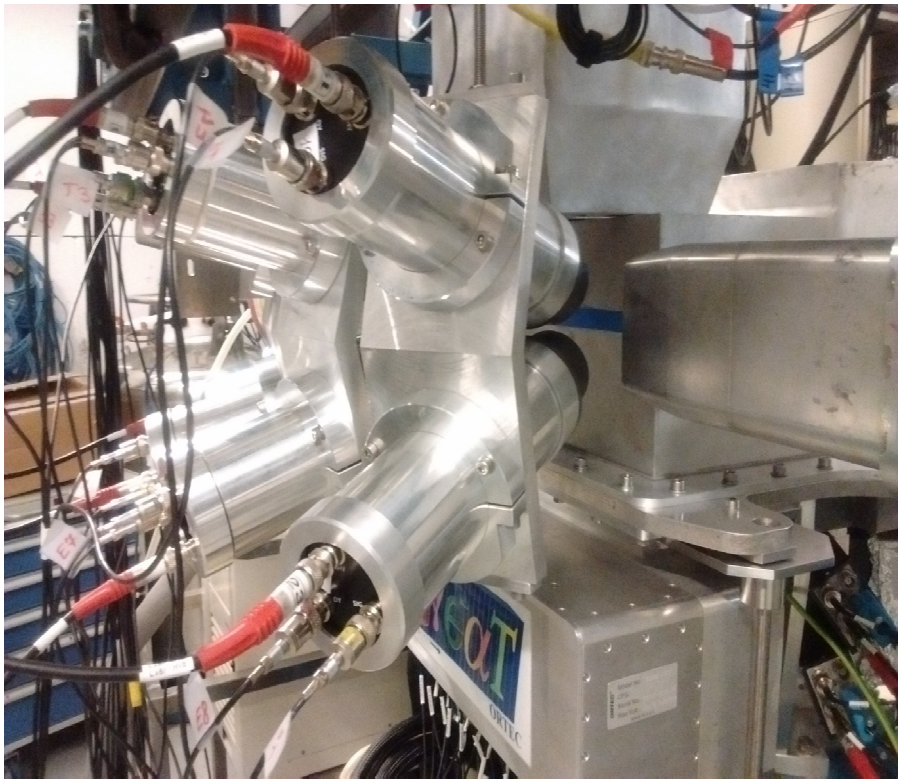
FATIMA and Gammasphere (^{252}Cf source)

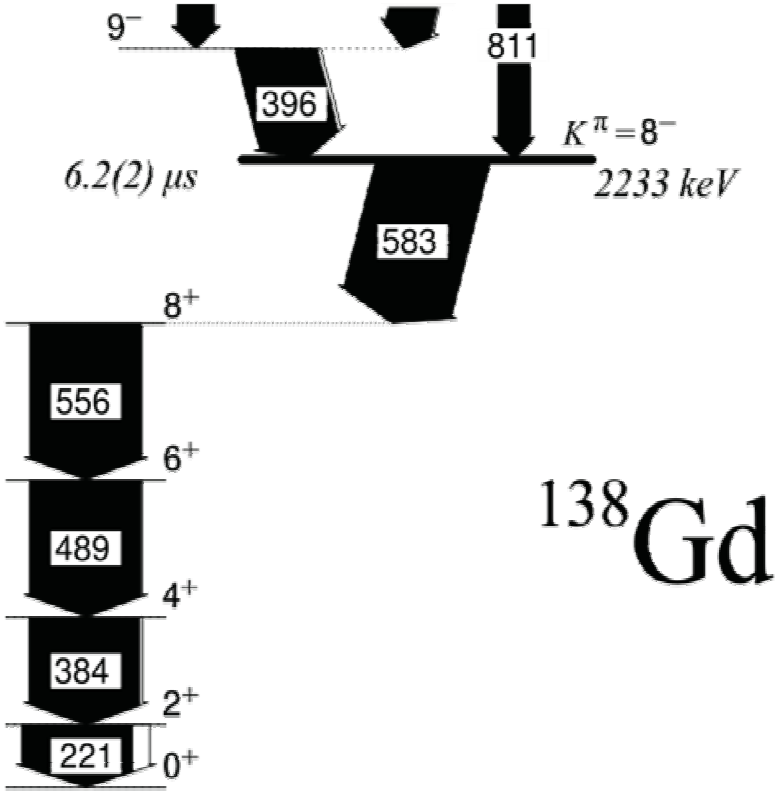
- 41 people directly involved
- 13 different affiliations
- 56 days between set-up and measurement
- 76 detectors used (51 HPGe + 25 $LaBr_3$:Ce)
- ~ 690 hours of effective measuring time (around 30 days)
- ~ 18 Tera bytes of raw data (4 Tb when compressed)
- ~ 8 billions events collected with FATIMA

FATIMA and Gammasphere (^{252}Cf source)



LaBr Array at JYFL,first expt with an extended source



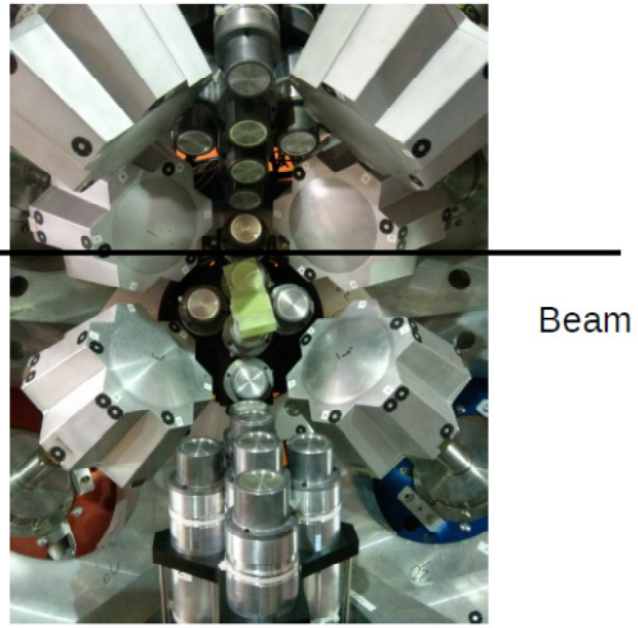


Michael Mallaburn, Dave Cullen – University of Manchester

β–γ timing:

University of Brighton

Beta-plastics:
2 mm thick, 65x45 mm^2 area
~1 mm up- and downstream of WAS3ABi
BC-418
Time res.: ~200 ps
Efficiency: ~30%



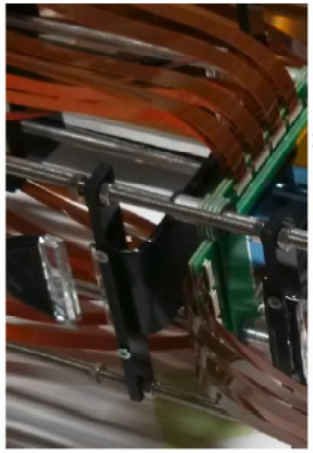
$LaBr_3$(Ce) array:
18 cylindrical crystals
Ø= 38.1 mm, length = 50.8 mm
Lead shield: passive anti-compton
Ave. distance from array centre:
~25 cm
Efficiency @ ~150 keV ~4%

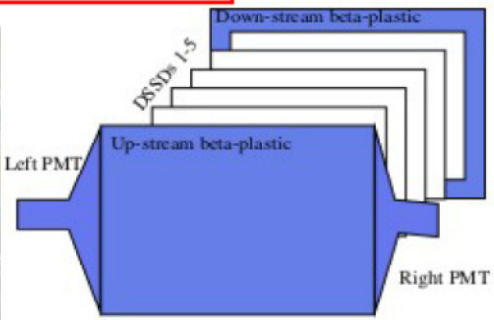
β–γ timing:

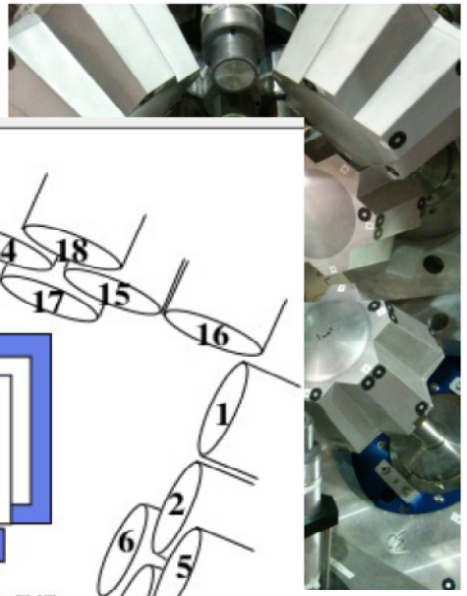
University of Brighton

Beta-gamma timing set-up

Beta-plastics:
2 mm thick, 65x45 mm² area
~1 mm up- and downstream of WAS3ABi
BC-418
Time res.: ~200 ps
Efficiency: ~30%



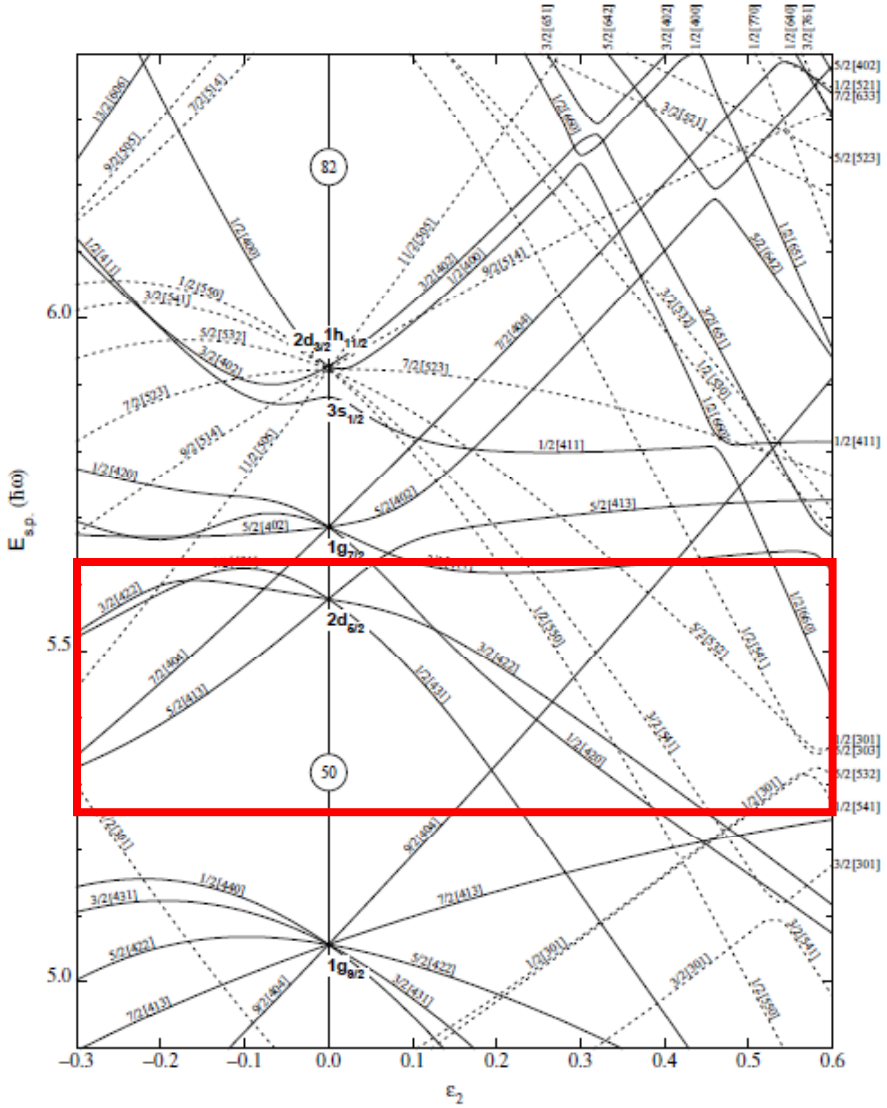




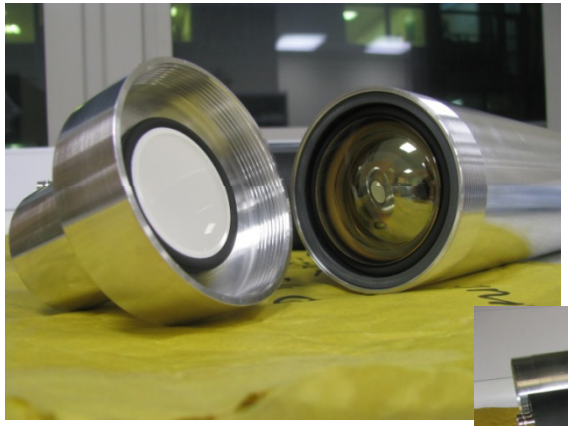
50.8 mm
anti-compton
Ave. distance from array centre:
~25 cm
Efficiency @ ~150 keV ~4%

From Spins to Shapes

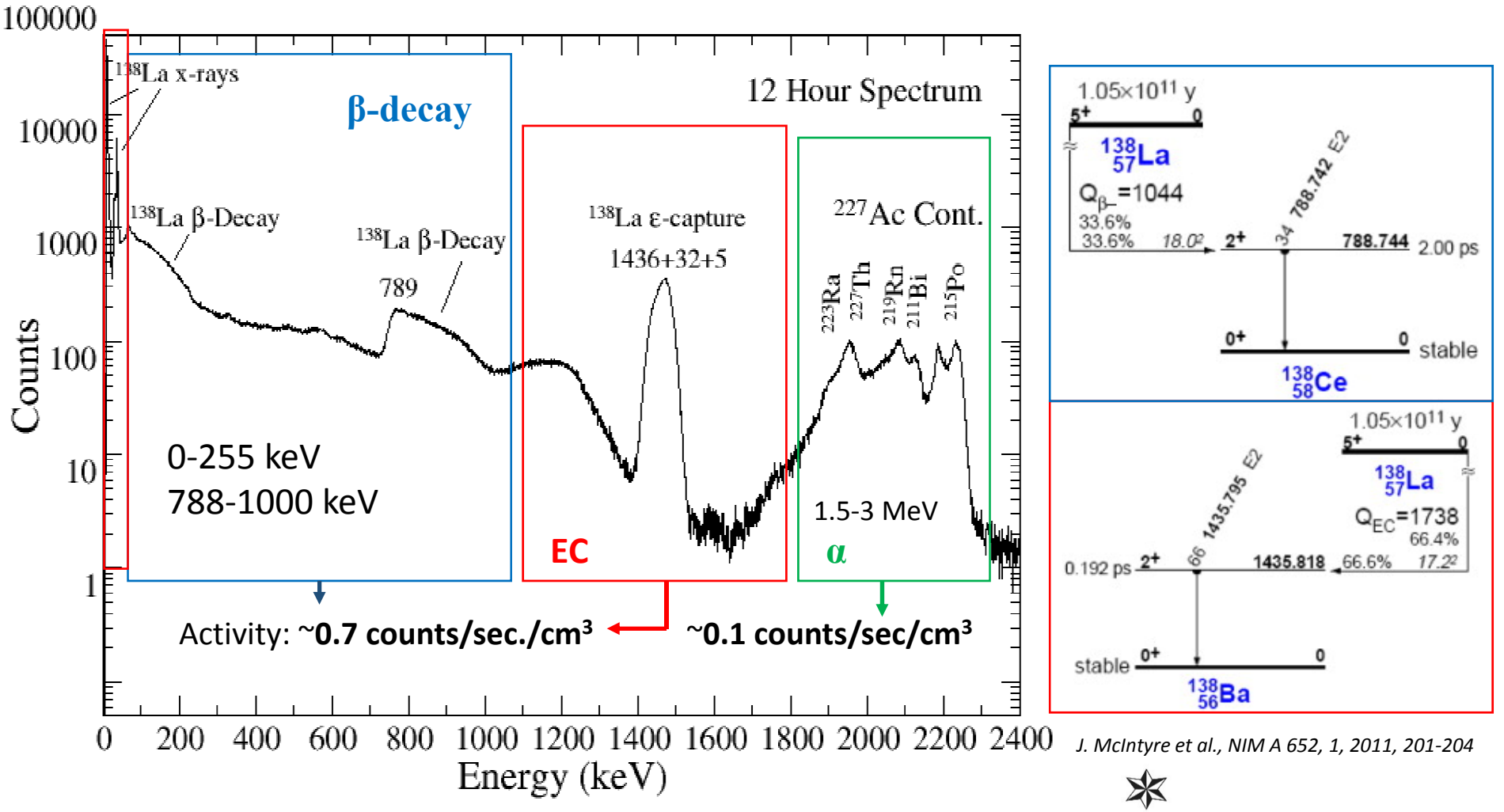
University of Brighton



Ordered, received and tested 36 detectors



Detector Characterisation



J. McIntyre et al., NIM A 652, 1, 2011, 201-204

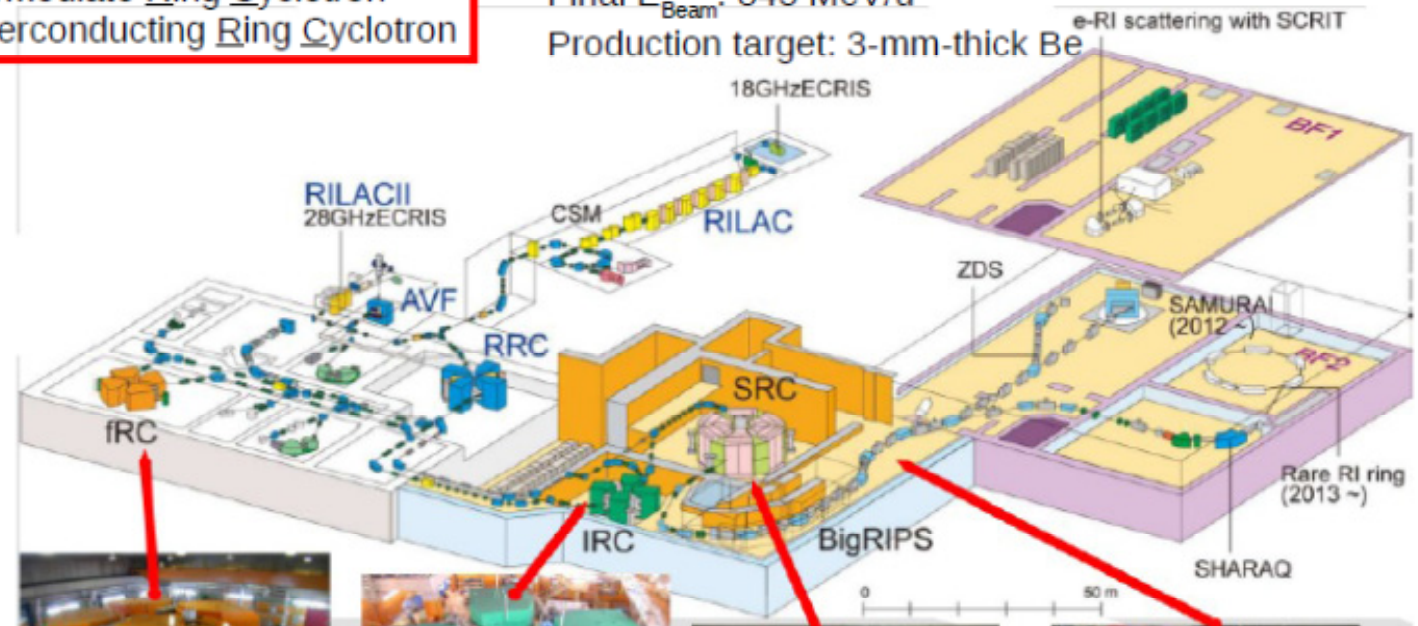
University of Brighton

Experimental set up

Accelerator system

fixed-frequency Ring Cyclotron
Intermediate Ring Cyclotron
Superconducting Ring Cyclotron

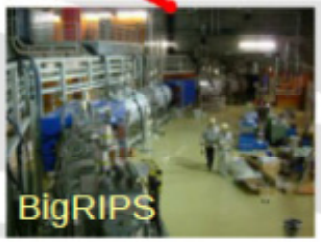
$I_{Beam}(^{238}U)$: ~10 pnA
Final E_{Beam}: 345 MeV/u
Production target: 3-mm-thick Be



K-value :570 MeV
E_{Beam}: 50.7 MeV/u

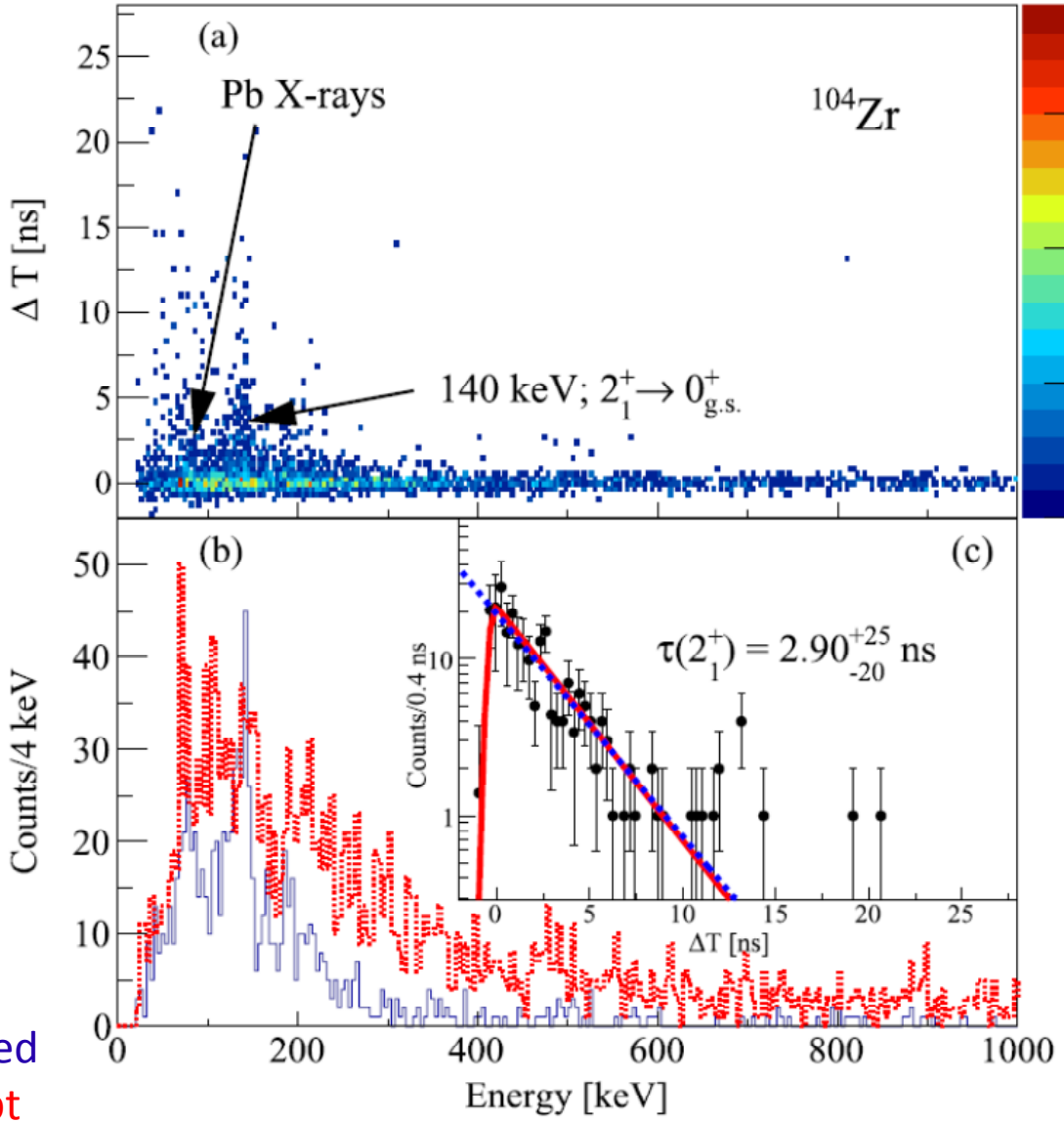
K-value: 980 MeV
E_{Beam}: 127 MeV/u

K-value: **2600 MeV**
E_{Beam}: **345 MeV/u**



Results for ^{104}Zr

University of Brighton



In good agreement with previous value of 2.9(4) ns

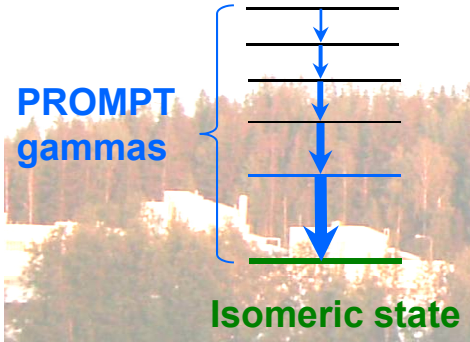
Hwang et al. Phys Rev C73 (2006) 044316

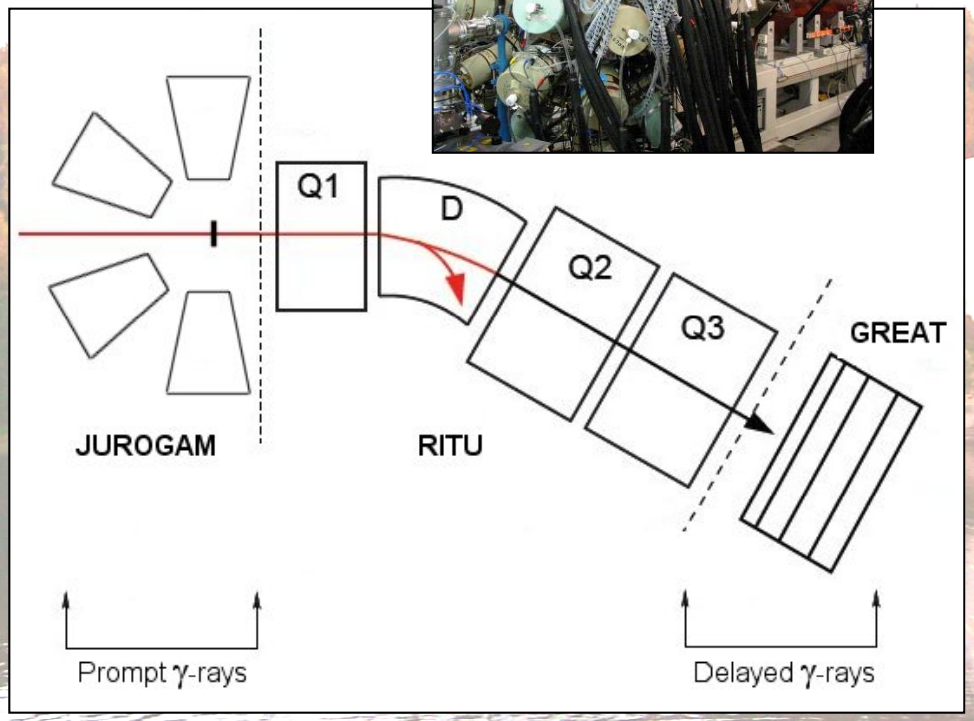
F.Browne at al., Physics Letters B 750 (2015) 448-452

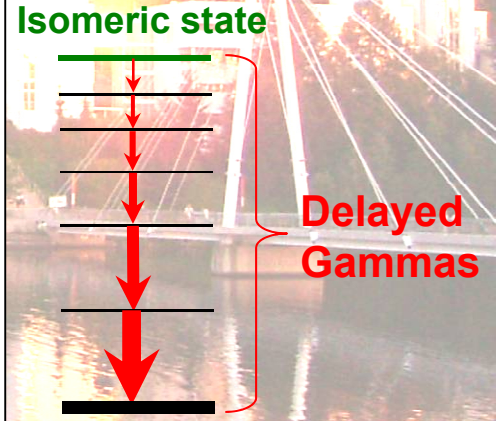
Blue = delayed
Red = prompt

Tagging Methods at Jyväskylä

- JUROGAM, RITU, GREAT and the TDR.



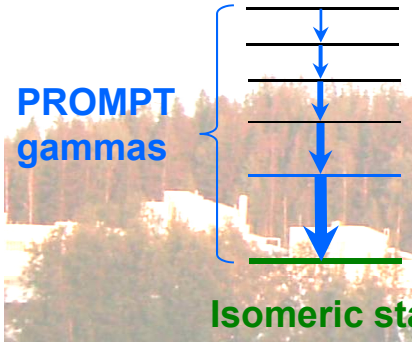


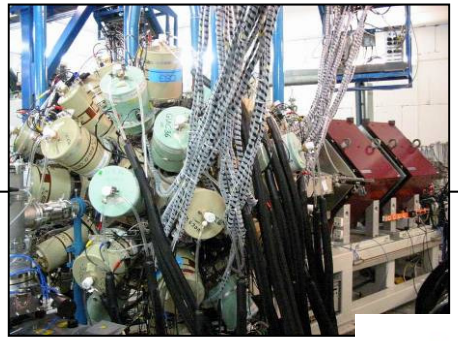


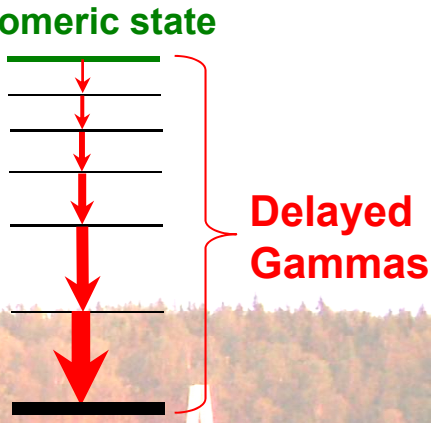
Trigger-less Data Acquisition System

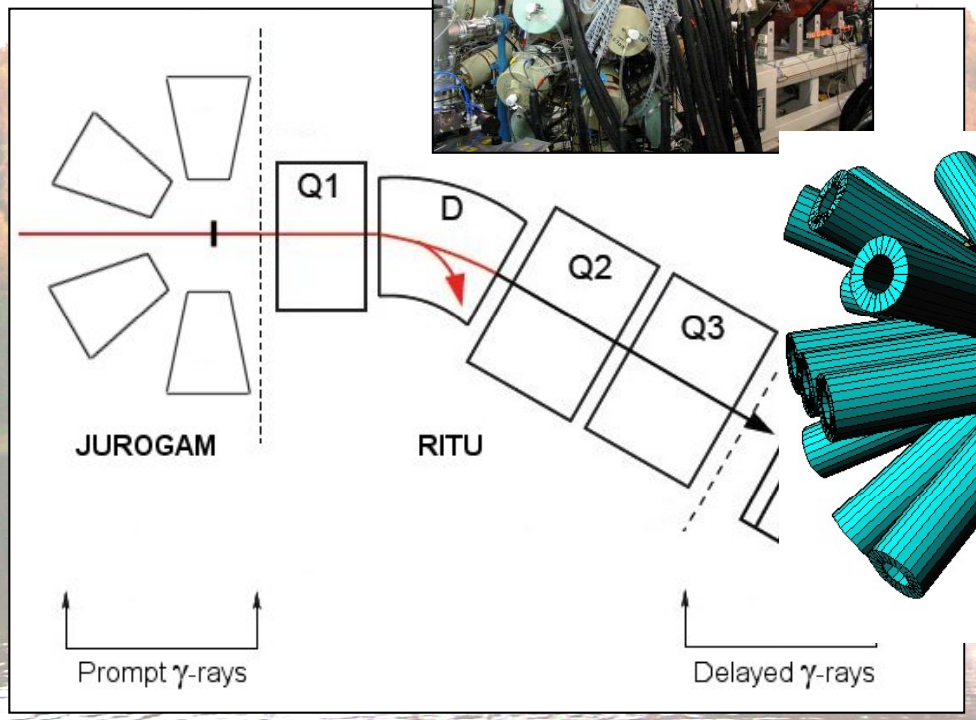
Fast Timing Methods at Jyväskylä

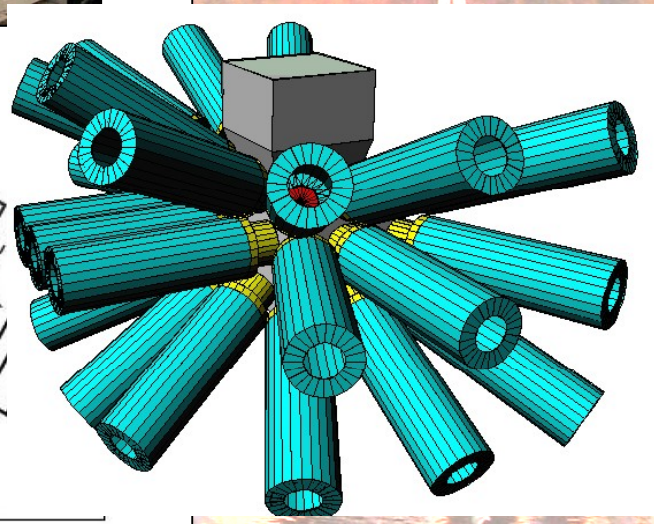
- JUROGAM, RITU, GREAT and the TDR.



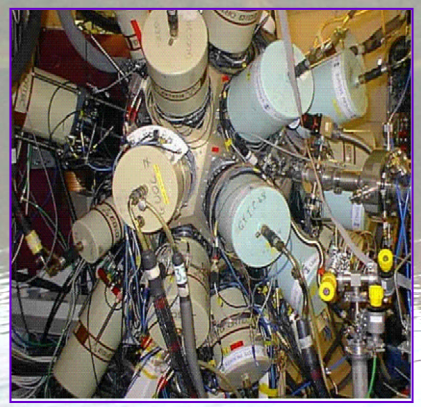








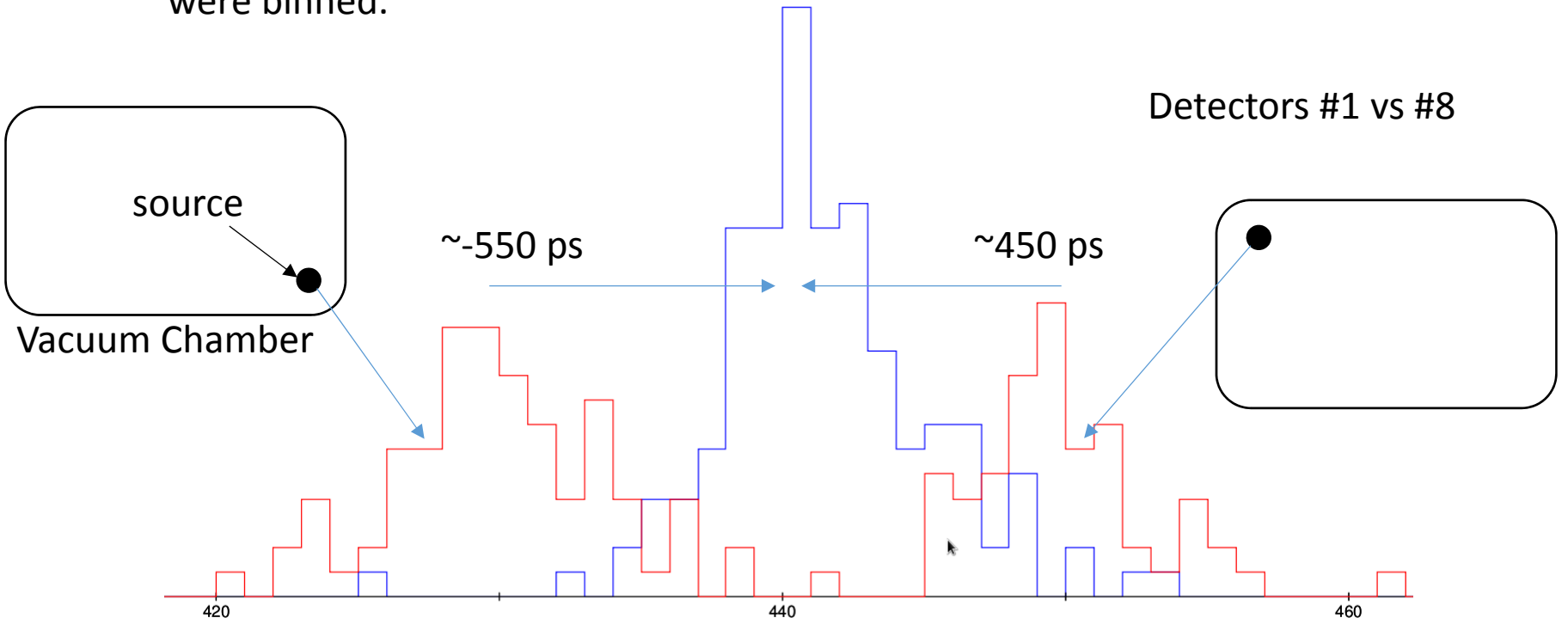
$LaBr_3$ Array



Trigger-less Data Acquisition System

TOF Correction

A ^{152}Eu source was placed at each corner of the DSSD vacuum chamber and data was taken.
Energy gates on prompt transitions were set and coincident tac signals were binned.



The red plot is uncorrected and shows how counts are spread.
The blue plot is the same data with a correction applied.

Michael Mallaburn – University of Manchester

Active stopper..AIDA

Advanced Implantation Detector Array

- Uses 12 x 8cm x 8cm DSSSD