Position sensitive scintillator gamma-ray array for fragmentation facilities

STAR

Stefanos Paschalis
University of York

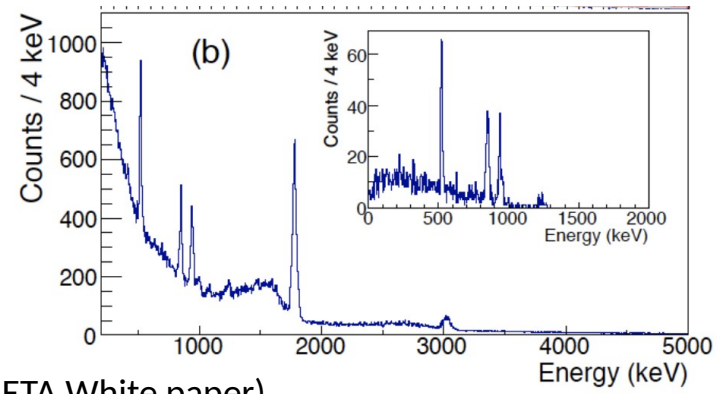
NP Community Meeting, January 2020

Physics motivation for an intermediate energy resolution array

Shell evolution of exotic nuclei at fragmentation facilities

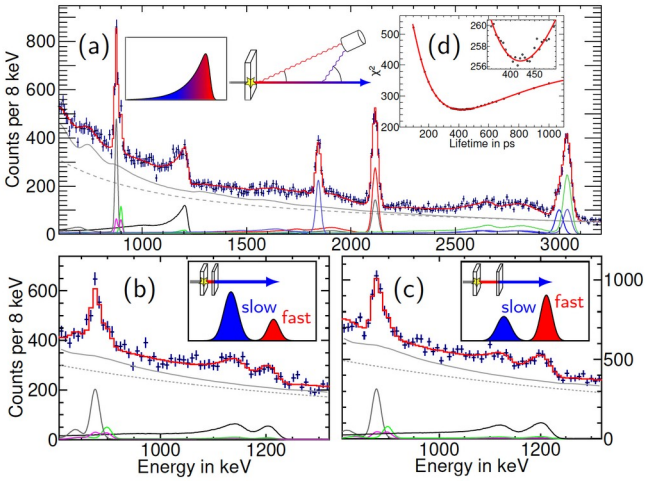
- Resolving medium complexity level schemes (a few gamma rays) from reactions of fast moving (beta>0.3) exotic nuclei towards the driplines with high efficiency
- Lifetime measurements

Expected spectrum from neutron removal from ^{57}Ca



(From GRETA White paper)

Plunger experiment ^{21}O

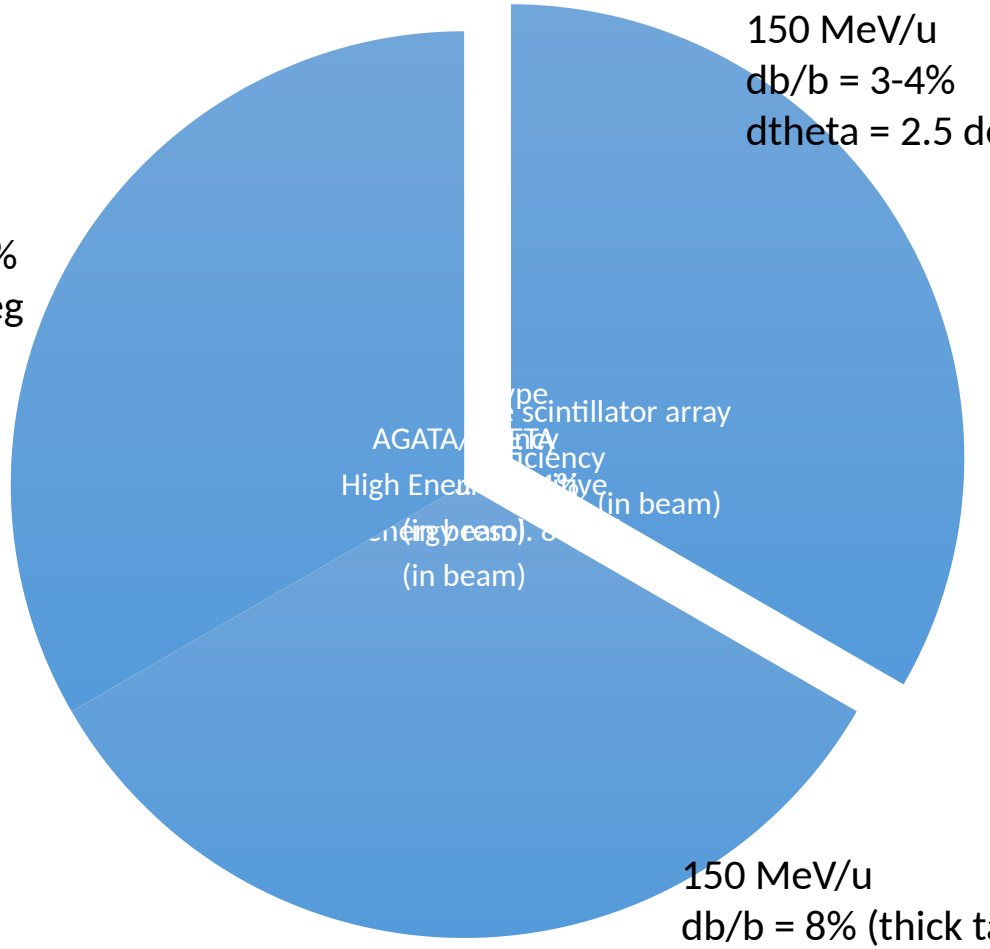


Facilities

- RIBF RIKEN (primarily)
- Certainly suitable for FRIB and FAIR (but competition with AGATA / GRETA would limit the physics scope)

The strong community interest for a high resolution gamma-ray spectroscopy at RIKEN was also demonstrated by the response to the recent HiCARI call for proposals

Gamma-ray arrays in fragmentation facilities



150 MeV/u
db/b = 3-4%
dtheta = 2.5 deg (□ ~1cm FWHM)

150 MeV/u
db/b = 1-1.5%
dtheta = 1 deg

150 MeV/u
db/b = 8% (thick targets, high luminosity)
dtheta = 7.5 deg (□size of crystal)

Gamma-ray arrays in fragmentation facilities

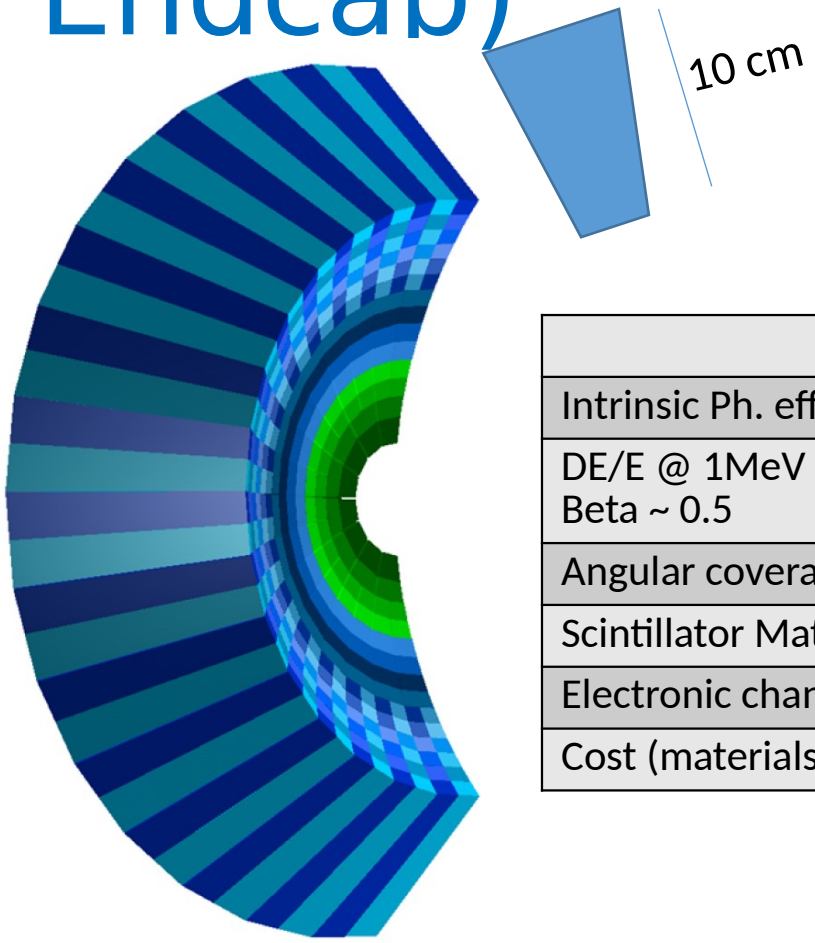
(scaling by efficiency to have only price-resolution variable and add simple CsI(Tl) array for comparison)

	Efficiency @ 1 MeV	In beam resolution @ 1 MeV	Price (M€) (very approx. materials only)	Available at Facilities
HPGe (Agata/Greta)	15%	>1 %	20	Europe US
Novel scintillator based	15%	3-4 %	2	proposed for RIBF, Japan
CsI based non position sensitive	15%	>8.0%	0.3	Everywhere

Advantages

- Where the HPGe supreme energy resolution (ER^* ~0.2%) is compromised due to beam properties (ER^* > 1.0 %) and NaI/CsI arrays (ER^* ~8%) are inadequate
- Where high counting rate dictates detector response time
- Where fast timing <1ns is essential

Conceptual design (based on the CALIFA Endcap)

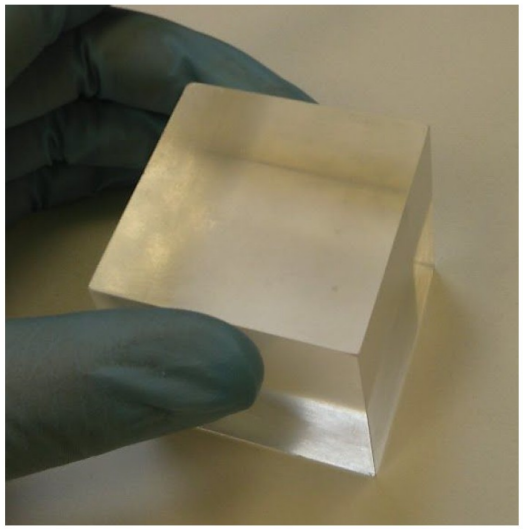


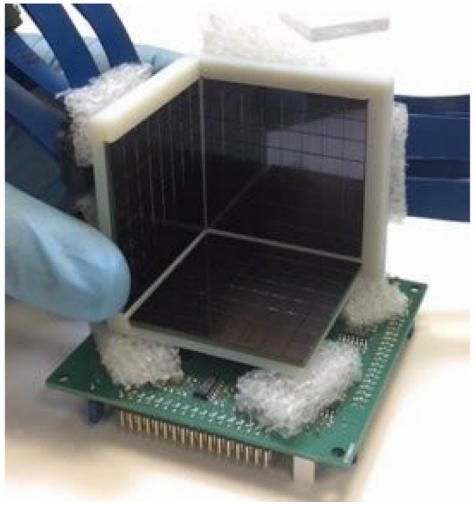
- ✓ Less passive material
- ✓ Better uniformity
- ✓ Additional Depth of Interaction

	Stage 1
Intrinsic Ph. eff. (@1 MeV)	15%
DE/E @ 1MeV Beta ~ 0.5	3.5%
Angular coverage (deg)	7 – 45
Scintillator Material (cm^3)	15000
Electronic channels & photosensors	15000
Cost (materials)	£2.0M

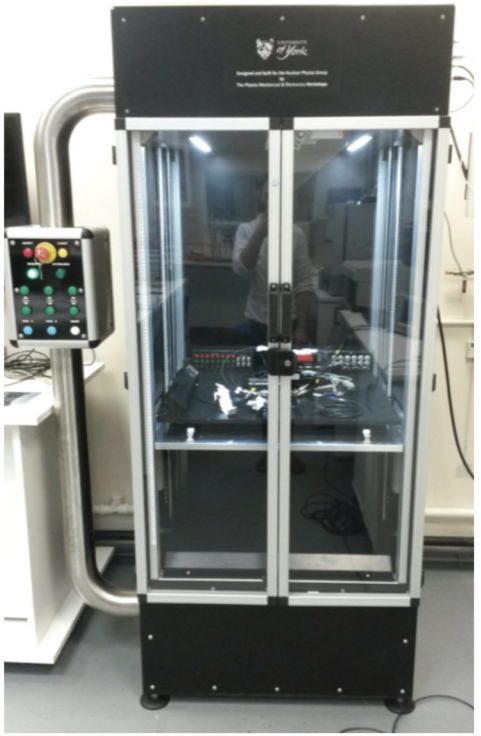
Performance and cost based on $CeBr_3$ scintillator

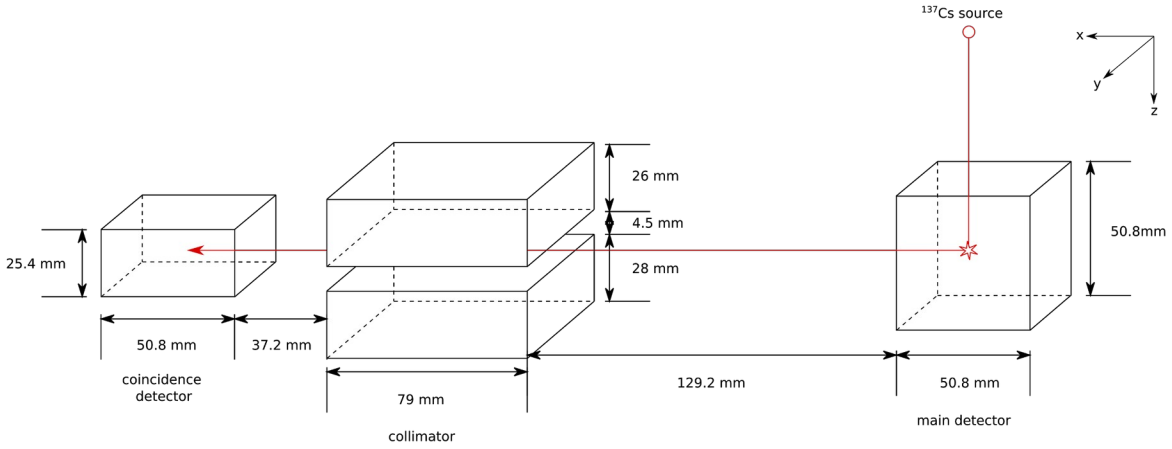
Developments through York STFC IPS project (Kromek industrial partner)



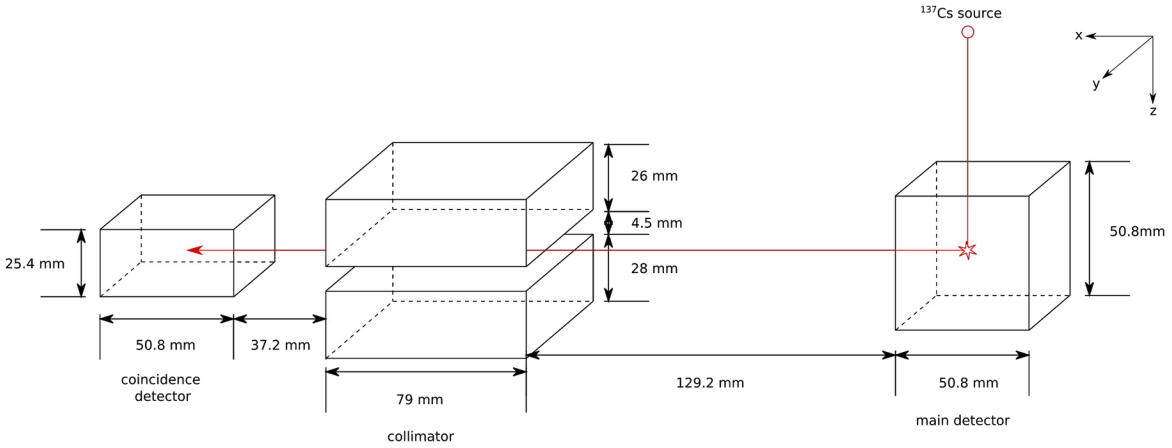


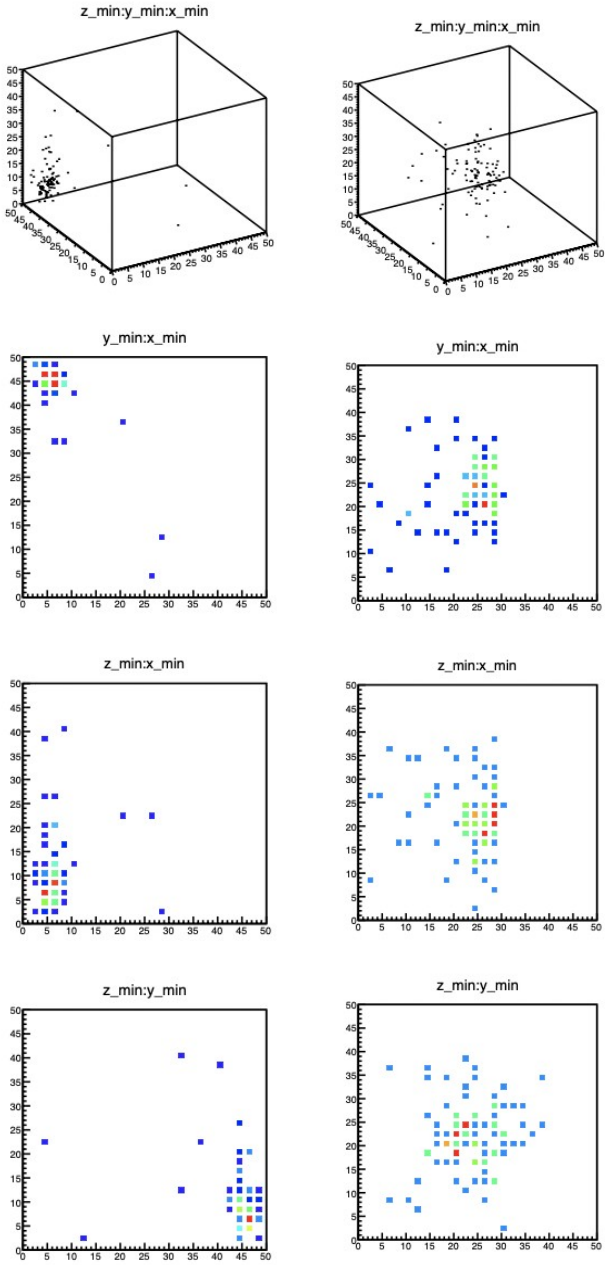
York scanning table





Performance
(Results from IPS project)





Pos. Res. < 1 cm FWHM at 400keV

Linkages with ongoing projects

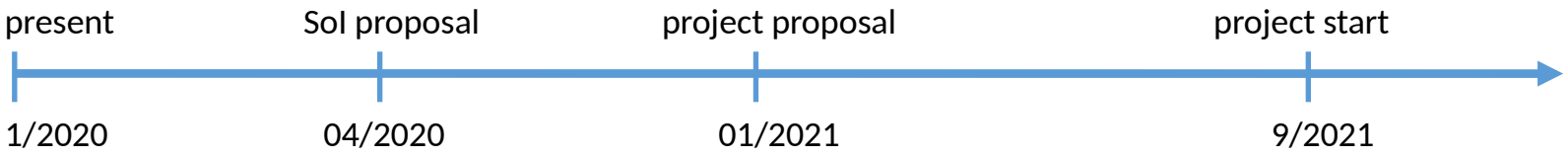
- NANA array (UK: NPL - Surrey) - scintillator array for nuclear data measurements
- FAst TIMing Array (FATIMA) - fast-timing scintillator array part of the earlier NuSTAR project
- CALIFA - scintillator-based system for reaction studies
- PARIS array
- AGATA – HPGE array

What parallel developments are going on at RIKEN?

- CATANA
- GaGG-based scintillator under consideration (fast scintillator but ER similar to CsI(Tl))

➢ UK – RIKEN collaboration

STAR project: scintillator array



Developments within the project:

Dedicated electronic readout
Mechanical infrastructure

Performance:

dE 3.5% at 1 MeV and β~0.5
Eff. > 15% (stage 1)

Approx. cost for proposed array:

Equipment and materials £2.0M
Staff time £1.5M

Physics aimed at fast beam facilities:

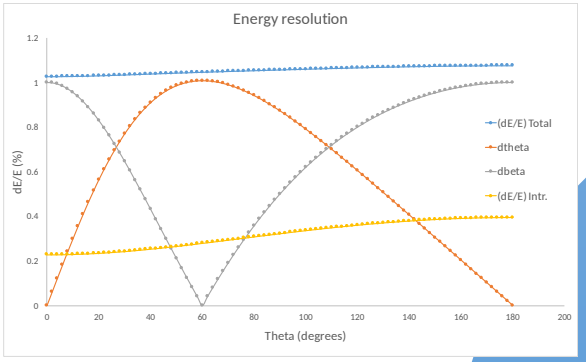
RIBF primarily
(Also suitable for FRIB and FAIR)

Contact: stefanos.paschalis@York.ac.uk

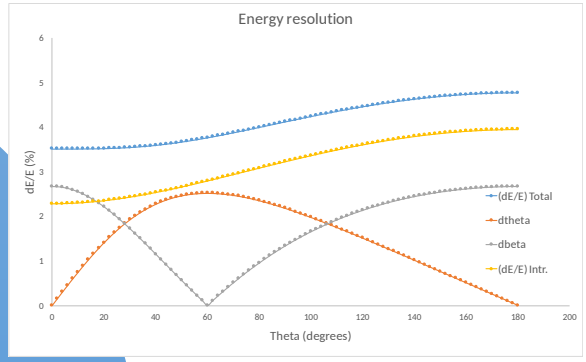
Work packages

- WP1: Detector assembly and Characterisation
- WP2: Electronics, Data Acquisition
- WP3: Mechanical Design
- WP4: Physics Performance (simulations) and analysis software
- WP5: Project Management

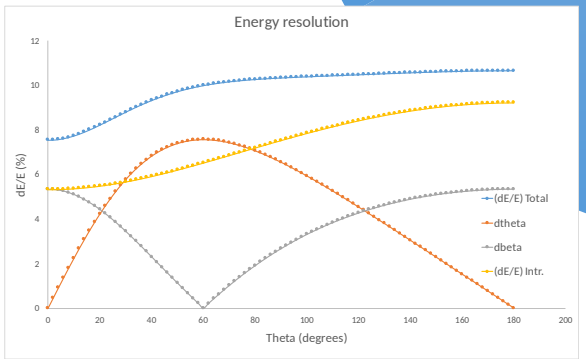
Gamma-ray arrays in fragmentation facilities



150 MeV/u
db/b = 1.5%
dtheta = 1 deg



150 MeV/u
db/b = 4% (allows for thicker targets)
dtheta = 2.5 deg (□ ~1cm FWHM)



150 MeV/u
db/b = 8% (thick targets, high luminosity)
dtheta = 7.5 deg (□size of crystal)

Work packages

- WP1: Detector assembly and Characterisation
- WP2: Electronics, Data Acquisition and analysis software
- WP3: Mechanical Design (6 months)
- WP4: Physics Performance (simulations)
- WP5: Project Management

Costs	WP1	WP2	WP3	WP4	WP5
Staff					
Equip					
Other					
Total					