Scintillator-based Gamma-ray array for fragmentation facilities

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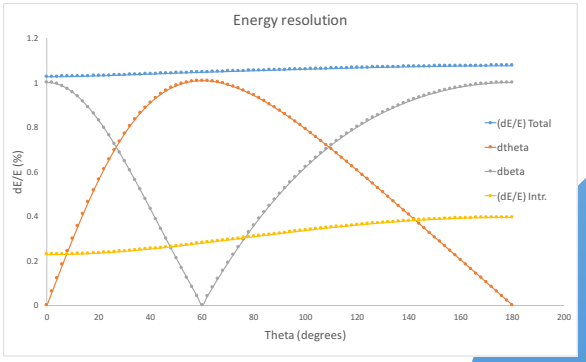
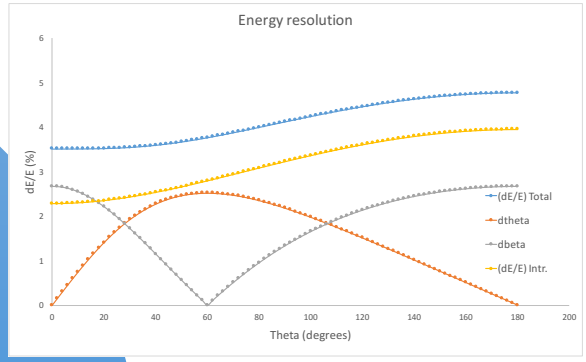
Gamma-ray arrays in fragmentation facilities



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

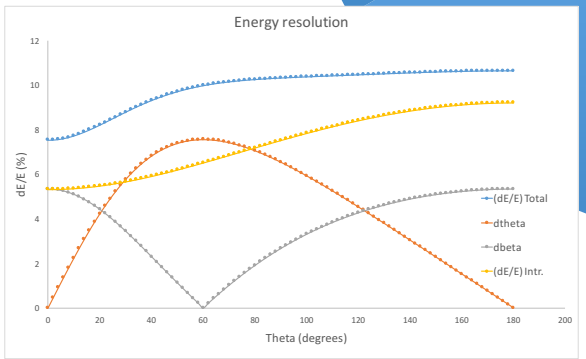
AGATA/GRETINA
High Ener. Res. 1%
(in beam)

Position sensitive scintillator array
High efficiency
Medium En. Res. 3-4%
(in beam)



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

CAESAR-type
High efficiency
Non position sensitive
Low energy resol. 8-10%
(in beam)



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

Physics motivation for an intermediate energy resolution array

→ e.g. Shell evolution in neutron-rich nuclei

- Medium complexity level schemes (a few gamma rays) such as those emerging from e.g. knockout reactions of exotic nuclei towards the driplines (but not at the driplines where there is only one or two bound states)

i.e. ….where HPGe (ER=0.2%) may be an overkill and NaI/CsI (ER>7-8%) arrays inadequate.

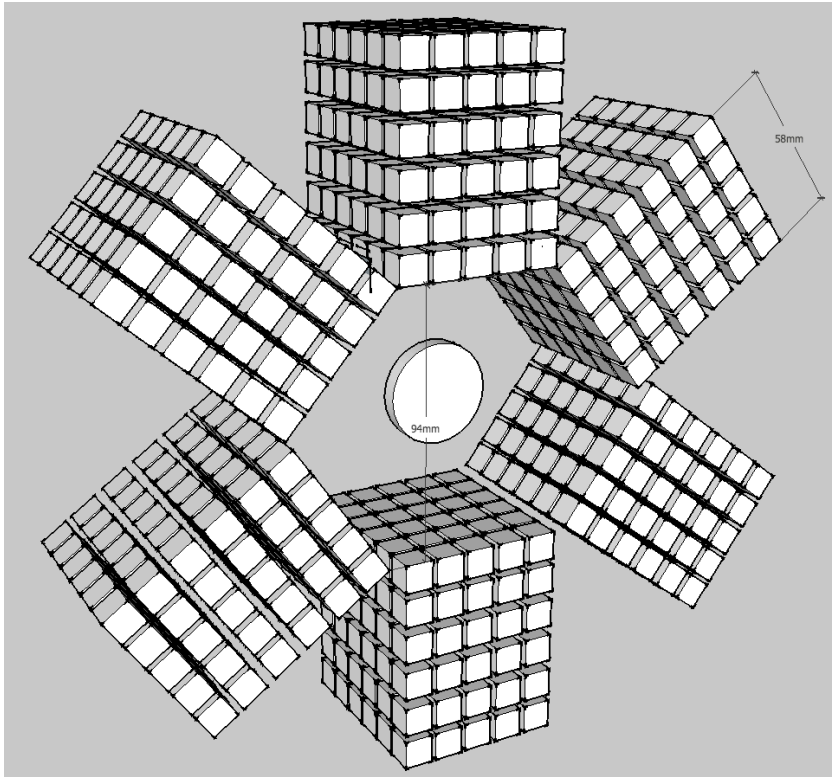
Novel-scintillator based array

Scintillator based array (3-4%) readout by SiPM

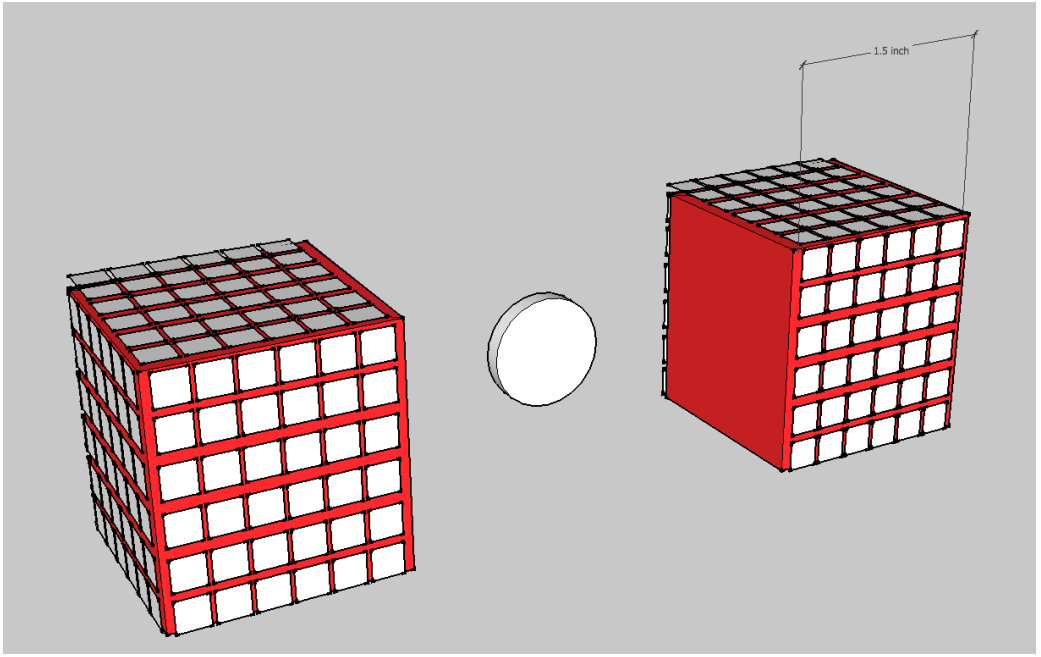
- Good position information needed for Doppler correction (Either high granularity or position reconstruction within the crystal)
- Basic tracking capability
- Large efficiency
- Medium cost compared to HPGe

Two concepts for good position information

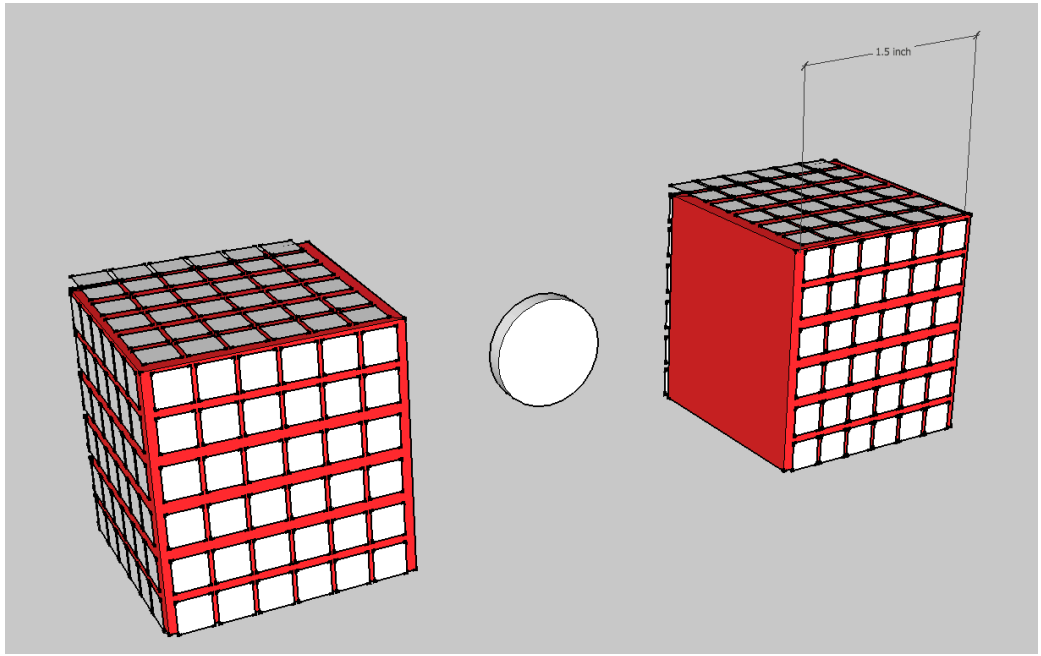
High granularity
(needs more passive materials)



Or reconstruction in monolithic crystals
(York/Kromek STFC/IPS funding for handheld devices)



Array for nuclear structure experiments (back of the envelop estimates for 1 pi coverage)



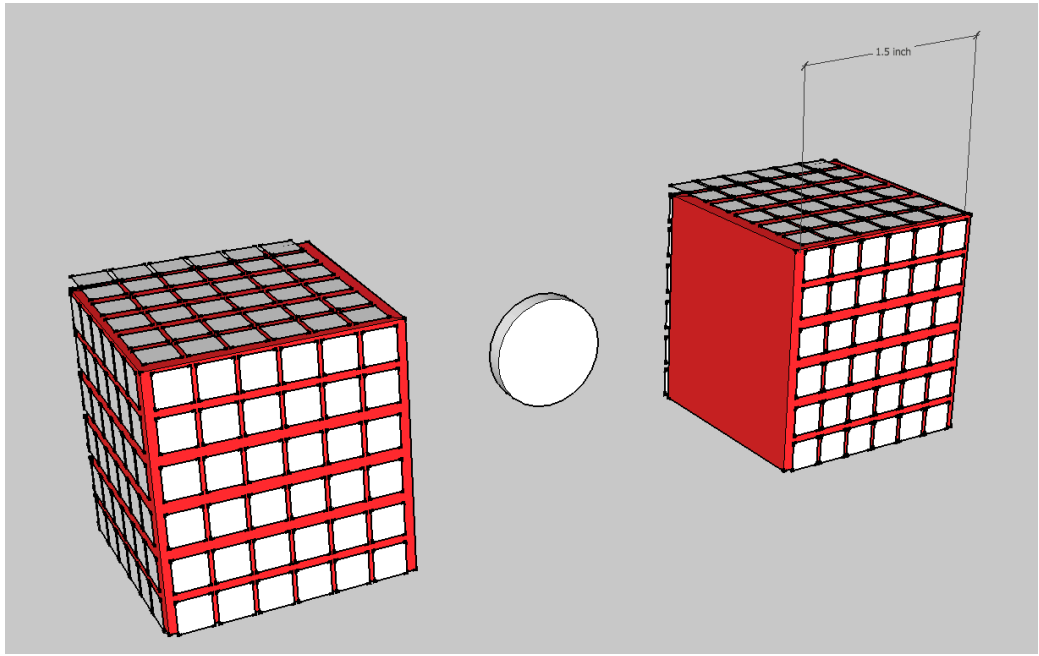
GRETINA/AGATA Ge arrays give **1%** energy resolution at high energy beam facilities and <7% efficiency.
(about 10k cm^3 of HPGe)

Assuming 10k cm^3 of a dense scintil.
(e.g. $LaBr_3$/CLLB/$CeBr_3$)

Eff. > 10 % (due to higher Z and density)

Resolution:
3 - 4 % @ 1 MeV for scintillators

Development:
It all comes down to how much it will cost



GRETINA/AGATA Ge arrays give **1%** energy resolution at high energy beam facilities **at a cost of >10 M€** and <7% efficiency. (about 10k cm^3 of HPGe)

Assuming 10k cm^3 of a dense scintil. (e.g. $LaBr_3$/CLLB/$CeBr_3$)

Eff. > 10 % (due to higher Z and density)

Resolution:
3 - 4 % @ 1 MeV for scintillators

<100 €/cm^3 → <**1.0 M€**
SiPM + electr. 100 €/chan. → **1.0 M€**

Conclusion

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

	Efficiency @ 1 MeV	Material needed (approx.)	In beam resolution @ 1 MeV	Price (M€) (very approx. materials only)	
HPGe (Full agata)	10% (3/2 Pi scaled)	About 15-20k cm^3	>1 %	15	Existing technology
Novel scintillator based	10%	10k cm^3 or less	3-4 %	<2	Reasonable development
CsI based non position sensitive	10%	10k cm^3	>8.0%	0.2	Traditional monolithic crystal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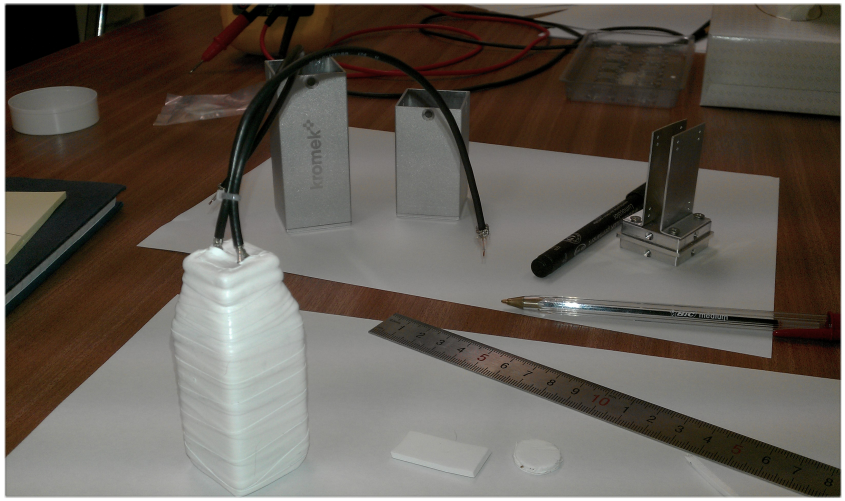
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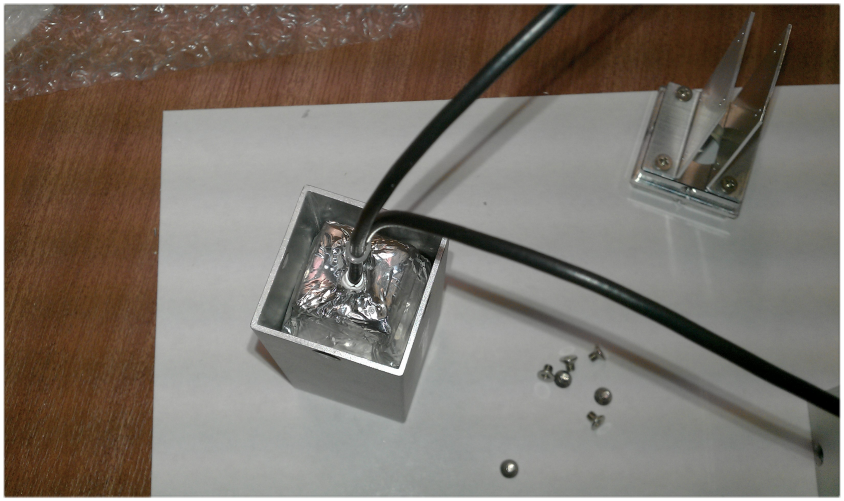
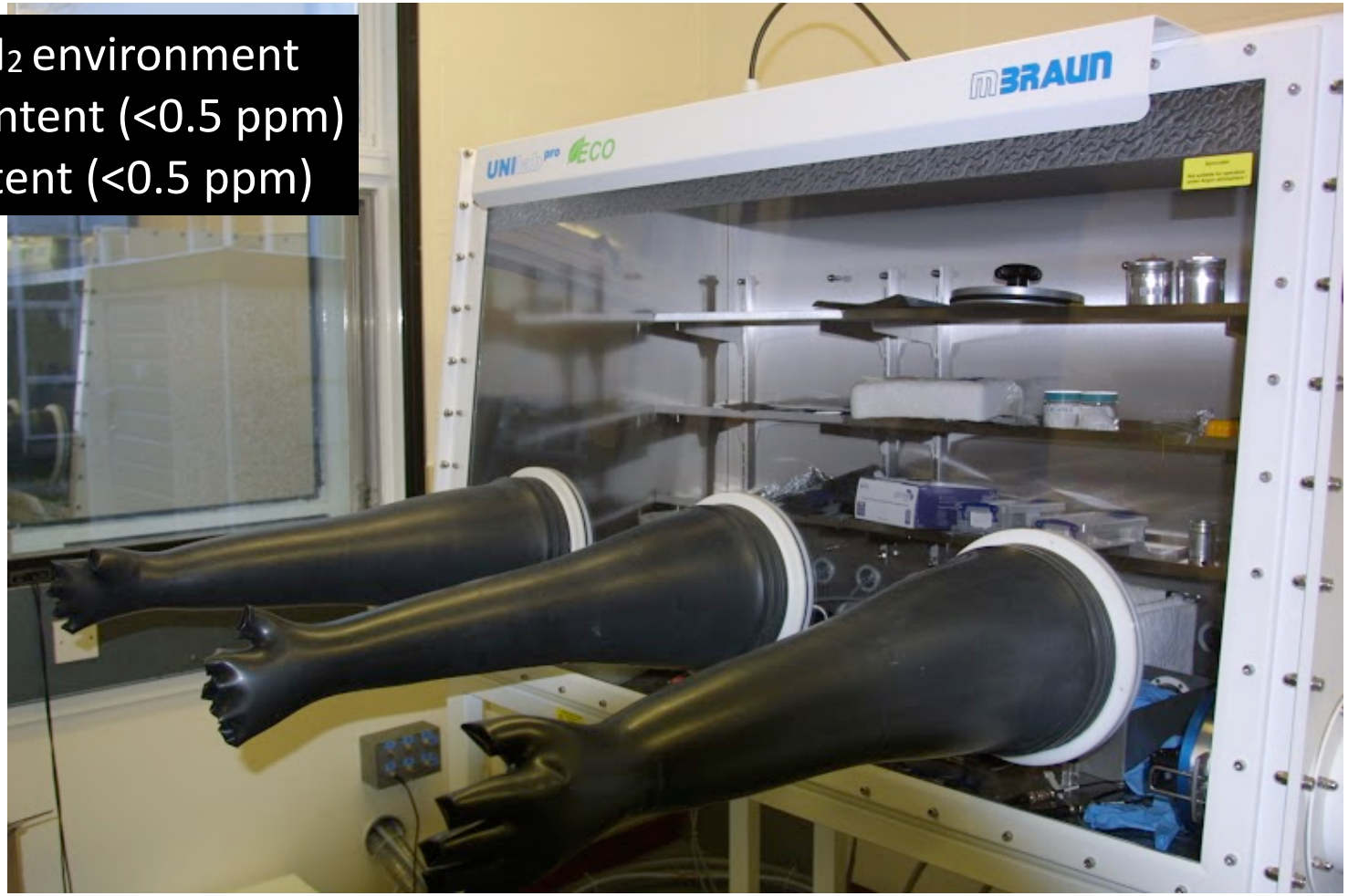


Kromek D3S

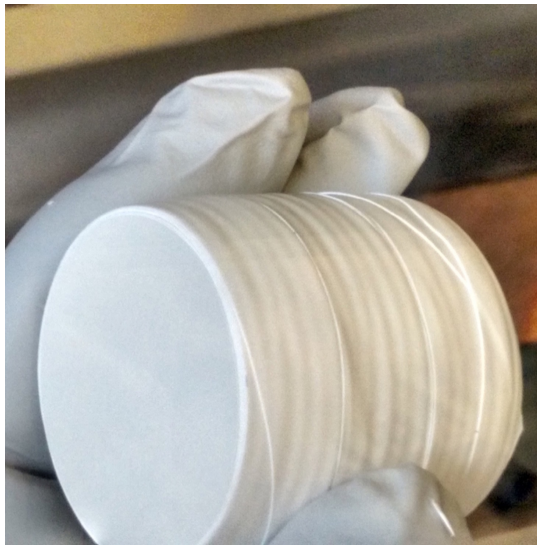
Handling hygroscopic materials (our in-house workhorse)

Regulated N_2 environment
Low H_2O content (<0.5 ppm)
Low O_2 content (<0.5 ppm)



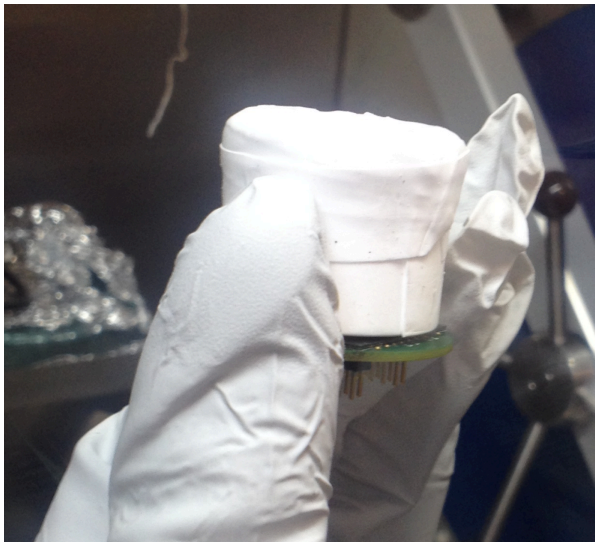
Preparing bare $CeBr_3$ crystal

In collaboration with Kromek



wrapped $CeBr_3$ crystal

coupled to PMT



coupled to SiPM array

Ongoing relevant projects

In collaboration with Kromek

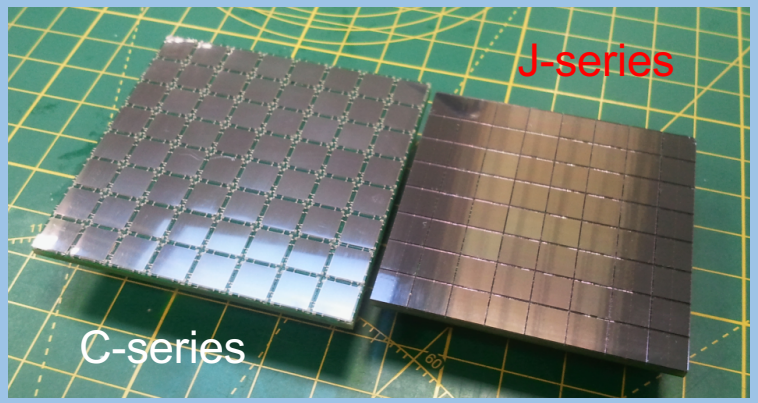
Handling of hygroscopic crystals and position reconstruction of γ-ray interaction in bulk scintillator crystals

- An STFC funded IPS project £300k (fEC) in collaboration with Kromek, starts in January 2017

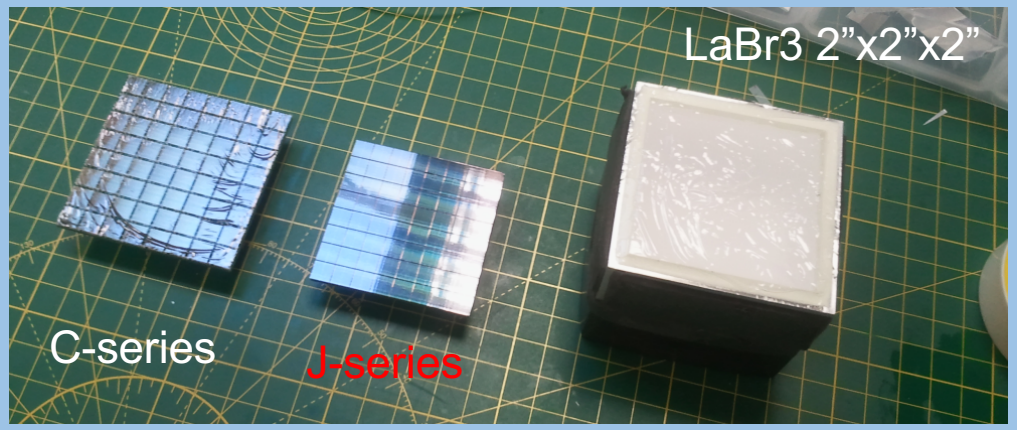
J-Series Family

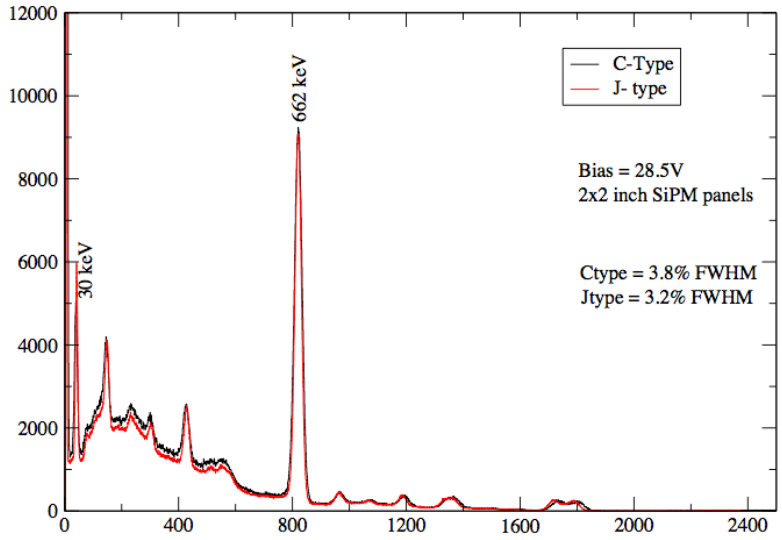
High-Density Fill Factor Silicon Photomultipliers – highlights:

- Optimized for high-performance timing applications, such as ToF-PET
- >50% PDE at 420nm, facilitated by high-density fill factor microcells
- Ultra-low dark count rates of 35kHz/mm2 typical
- Signal rise time and the microcell recovery time have been improved, and in addition, the J-Series sensors feature SensL's unique 'fast output' terminal
- Exceptional breakdown voltage uniformity of ±250mV over all J-Series products
- Temperature stability of 21.5mV/°C, negating the need for active voltage control
- Bias voltage of <30V
- Available in a reflow solder compatible TSV chip-scale package that has close to zero deadspace and is ferrous-metal free
- 3mm and 6mm sensor sizes

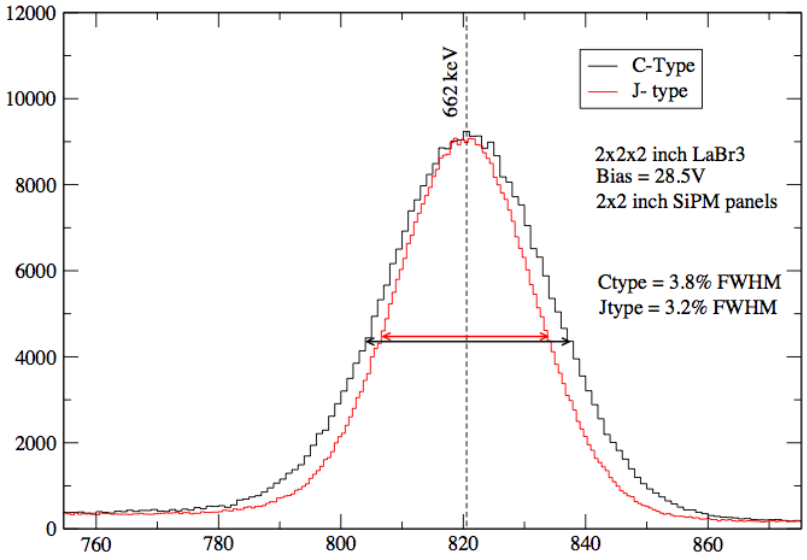


sensl.com/products/sipmarrays/arrayj





SensL J-series



Conclusions

- Can meet the need for a medium- to high-resolution gamma-ray spectroscopy in radiation facilities with a Gamma-ray array based on position sensitive novel scintillators with a moderate cost
- UK has the technological know how for constructing such array
- UK has world-leadership in use of SiPM coupled to scintillator
- Strong industrial involvement from the outset