Measurements of exotic nuclei for explosive nuclear astrophysics

Helena May David

University of Edinburgh

Image credit: NASA/Dana Berr

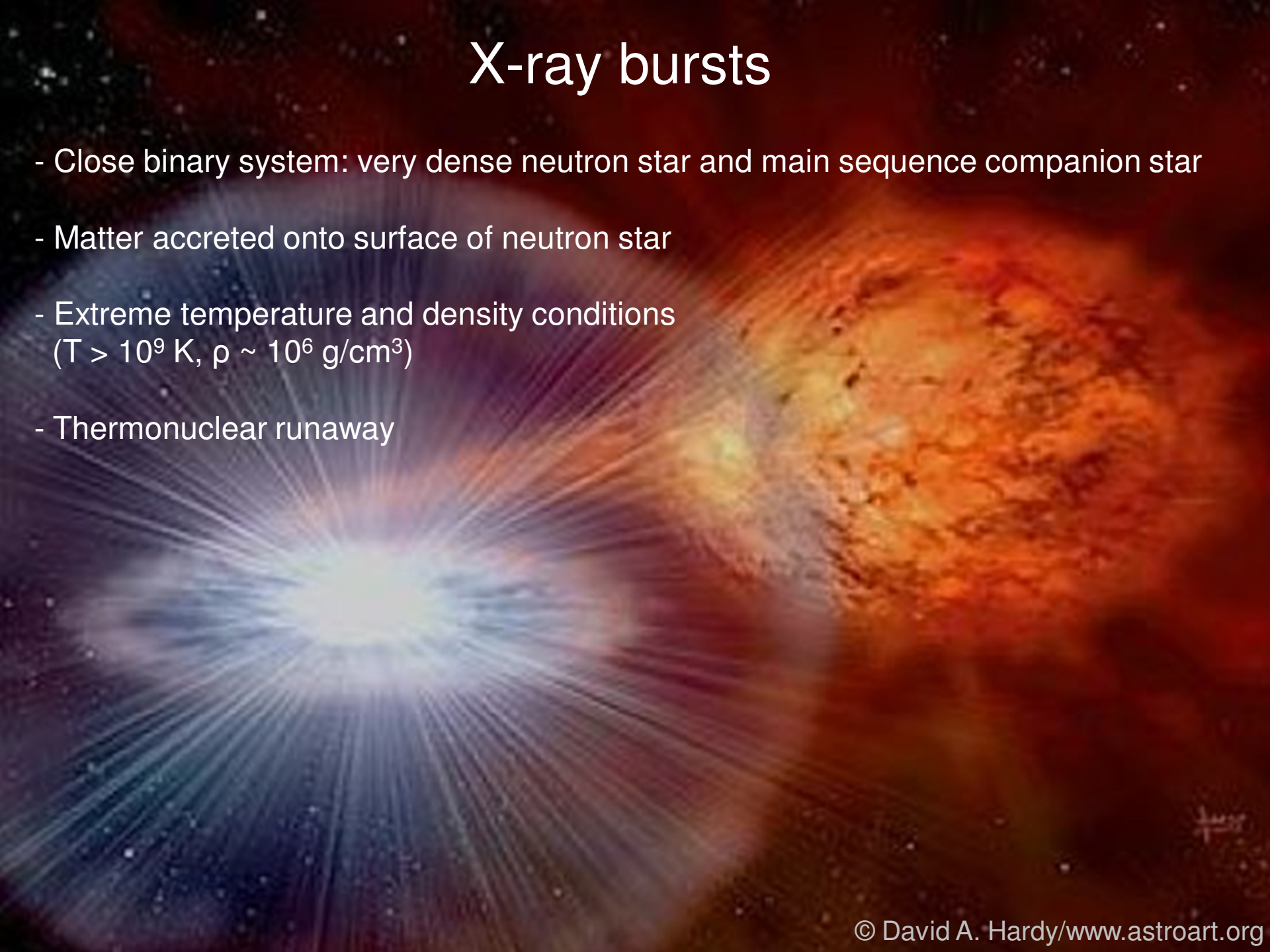
X-ray bursts

- Close binary system: very dense neutron star and main sequence companion star

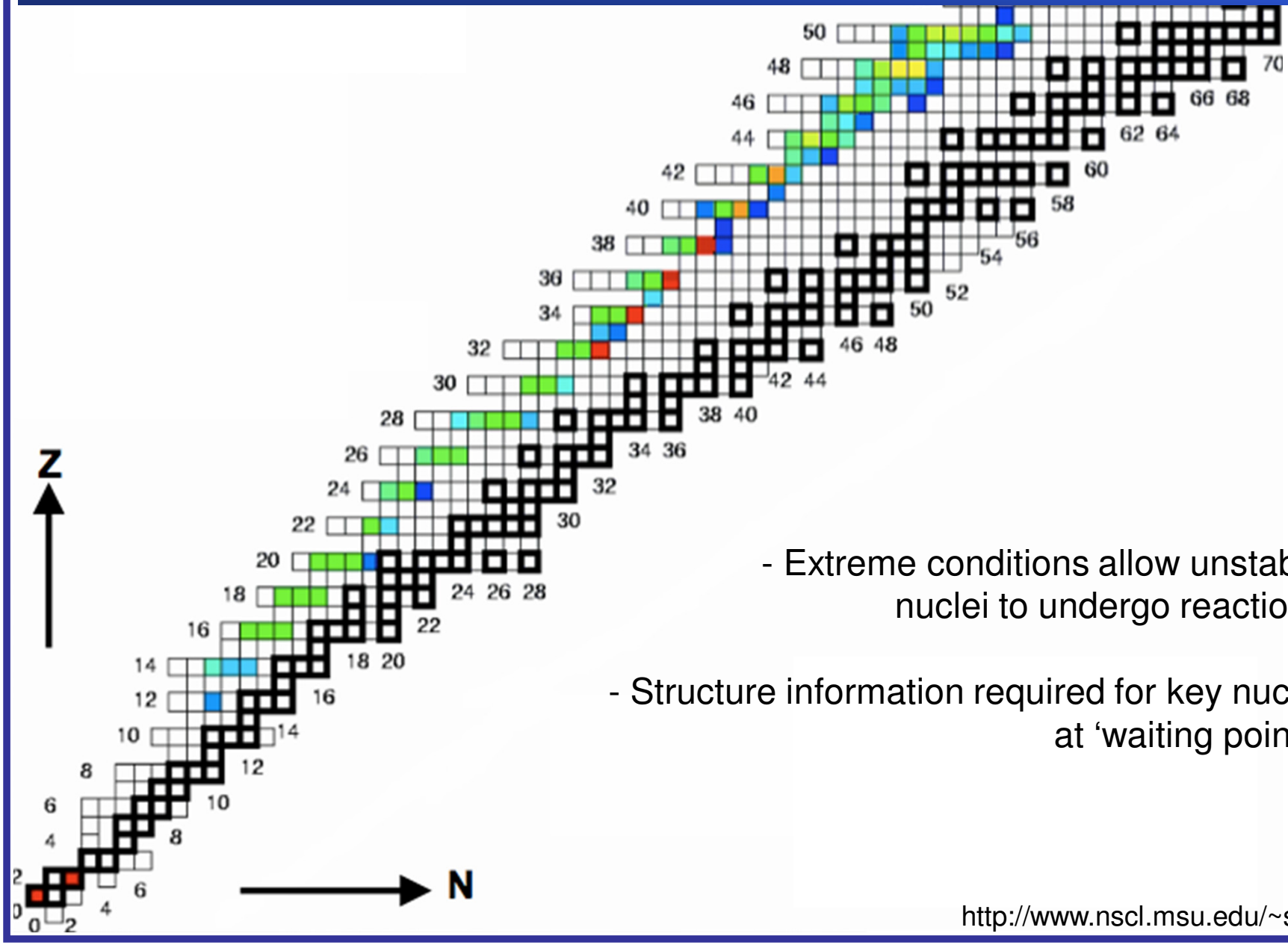
- Matter accreted onto surface of neutron star

- Extreme temperature and density conditions
  ($T > 10^9$ K, $\rho \sim 10^6$ g/cm^3)

- Thermonuclear runaway



The rp-process

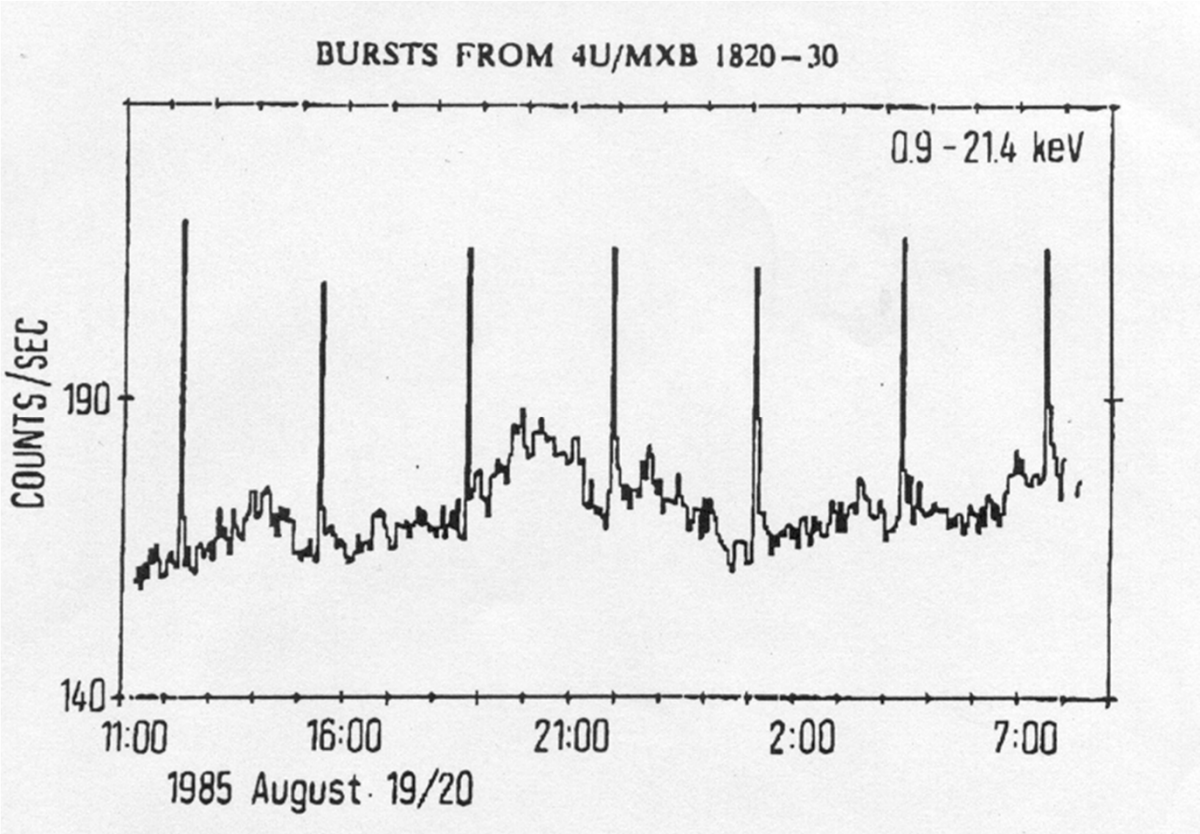


- Extreme conditions allow unstable nuclei to undergo reactions

- Structure information required for key nuclei at ‘waiting points’

http://www.nscl.msu.edu/~schatz/

X-ray burst properties



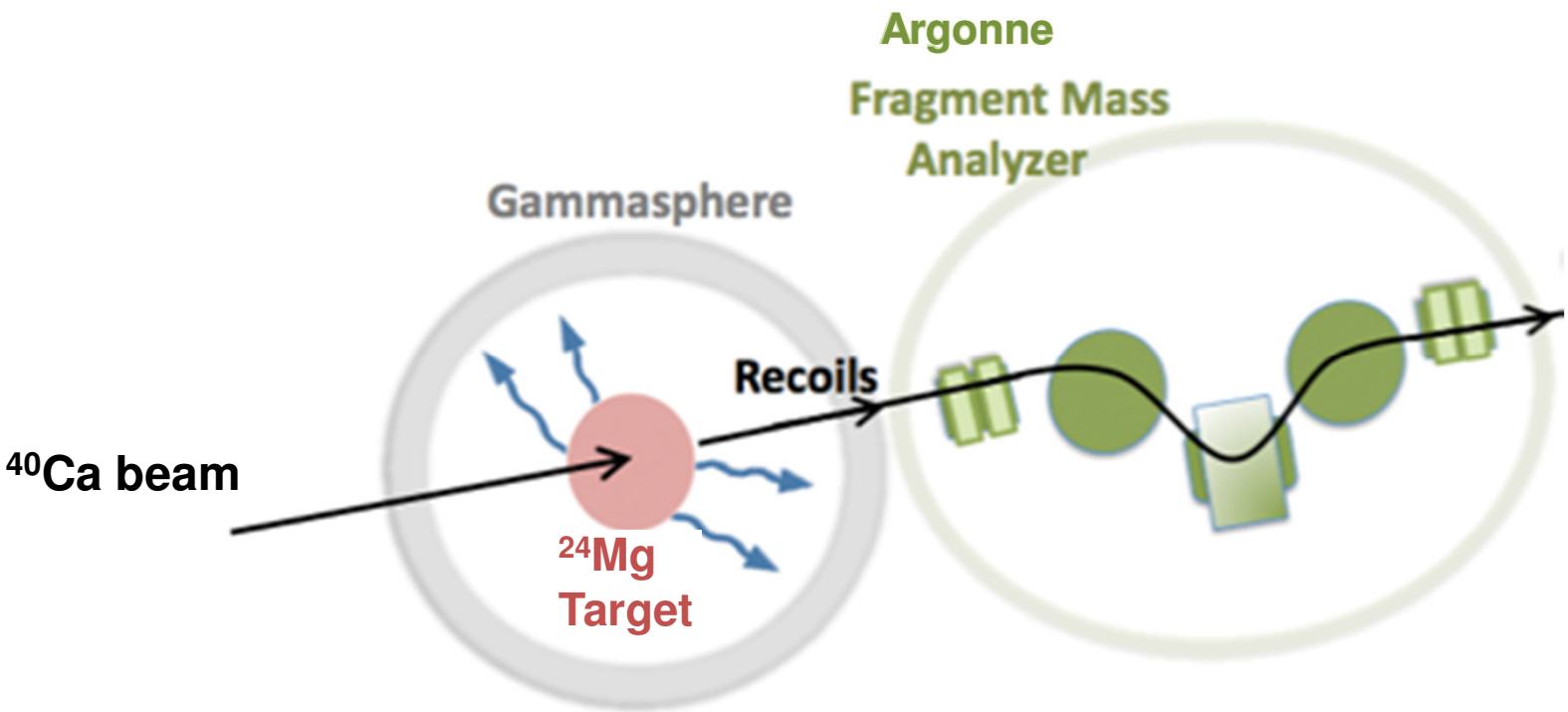
- Burst recurrence time of hours to days

- Burst duration of tens to hundreds of seconds

- Peak luminosity ~ 3 x 10^{38} erg/s (10^5 times more than the sun!)

Figure from Lewin, W.H.G., van Paradijs, J. & Taam, R.E., 1993, Sp Sci Rev, 62, 223

Producing exotic rp-nuclei

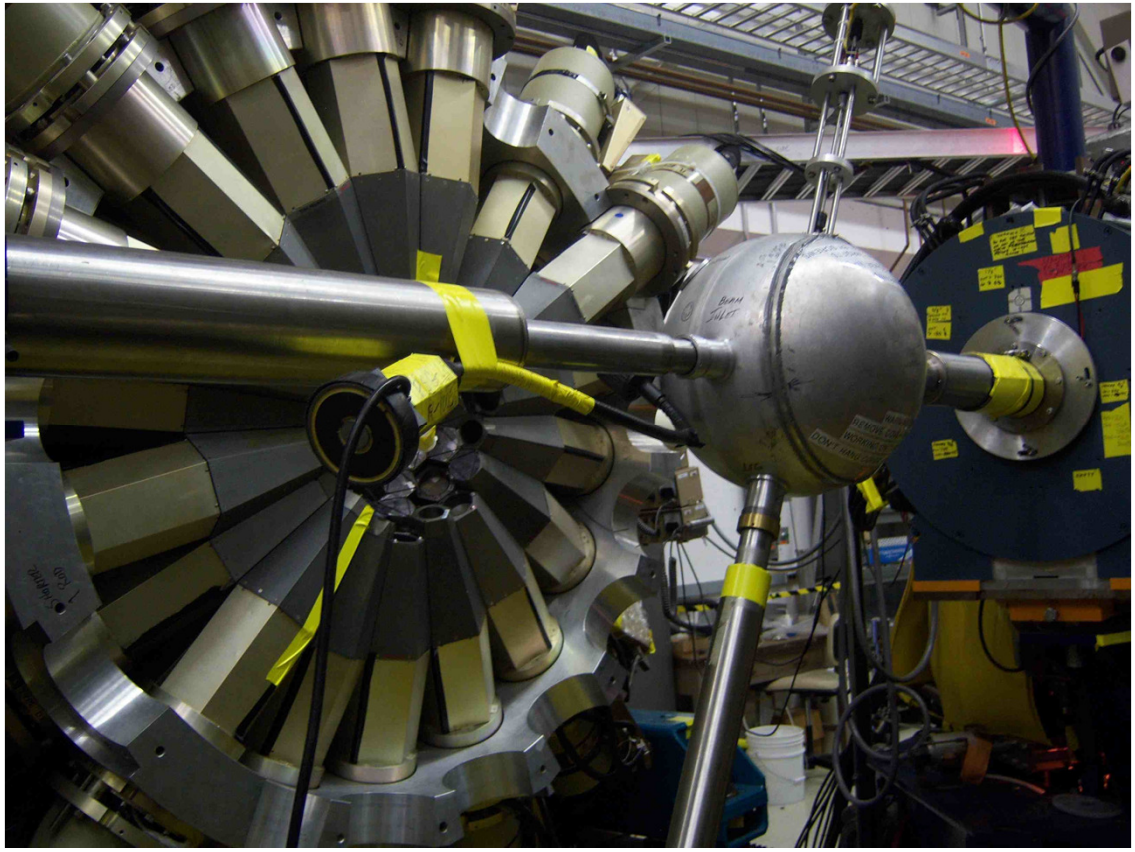


- Compound nucleus formed in fusion reaction

- Mass A=62 fusion evaporation products analysed at 0° by Argonne FMA

Gammasphere

- an array of ~100 HPGe ϒ-ray detectors with almost 4π geometric coverage



- ϒ-rays from nuclei of interest swamped by background from other nuclei which are produced much more prolifically

- Need more selectivity

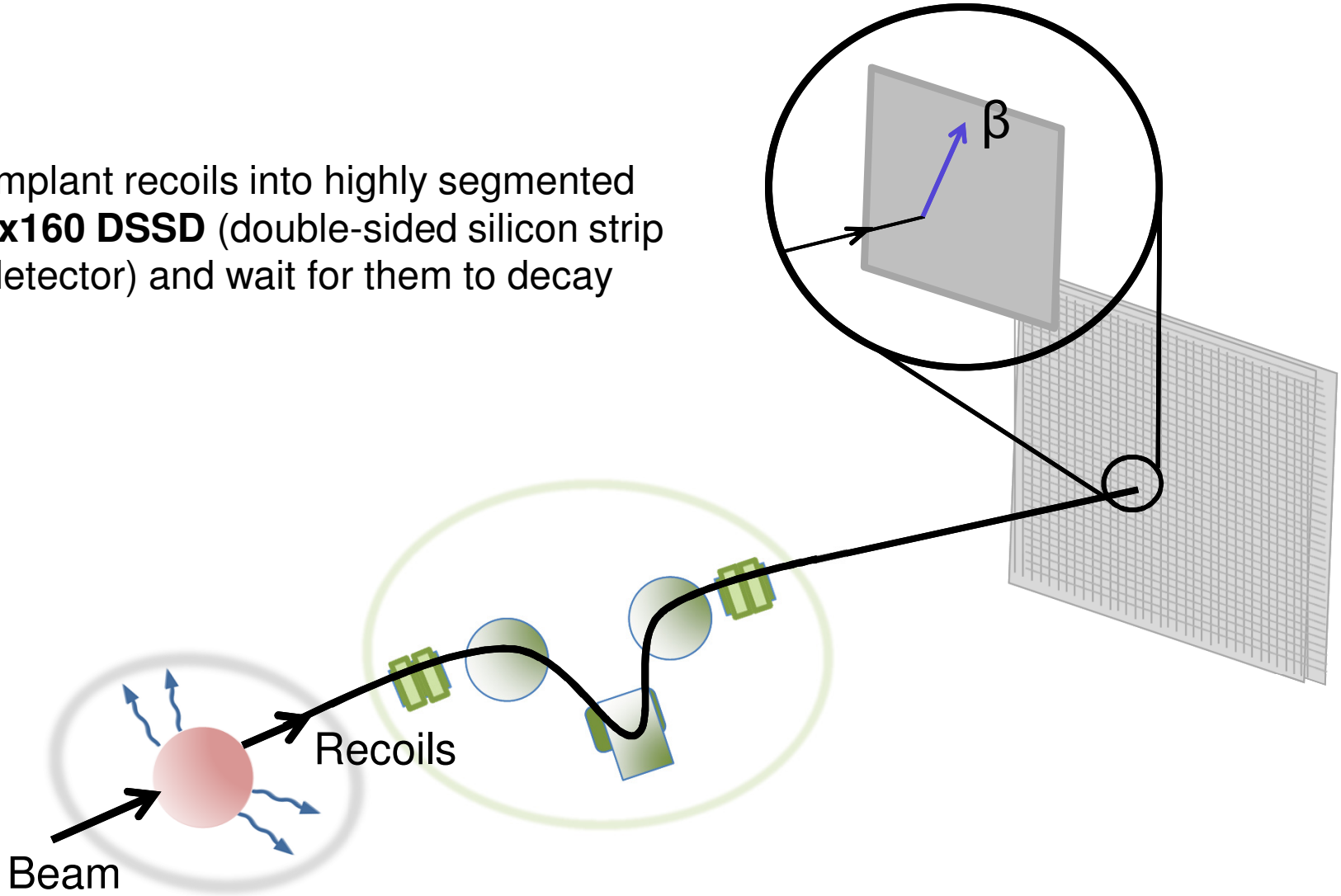
What next?

- Take advantage of **fast β-decays** exhibited by many exotic nuclei in the region of the rp-process

$$^{62}\mathrm{Ge} \xrightarrow{\tau_{1/2} \sim 100\mathrm{ms}} {}^{62}\mathrm{Ga} \xrightarrow{\tau_{1/2} \sim 100\mathrm{ms}} {}^{62}\mathrm{Zn} \xrightarrow{\tau_{1/2} \sim 9\mathrm{hrs}} {}^{62}\mathrm{Cu}$$

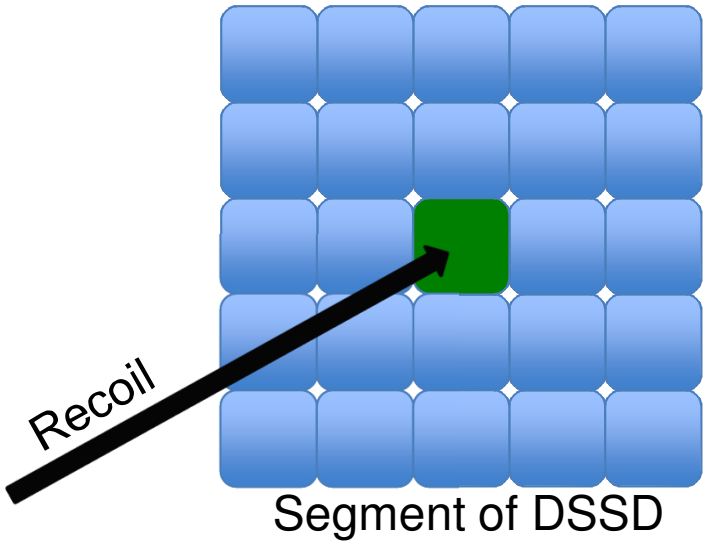
New highly segmented implantation detector

- Implant recoils into highly segmented **160x160 DSSD** (double-sided silicon strip detector) and wait for them to decay

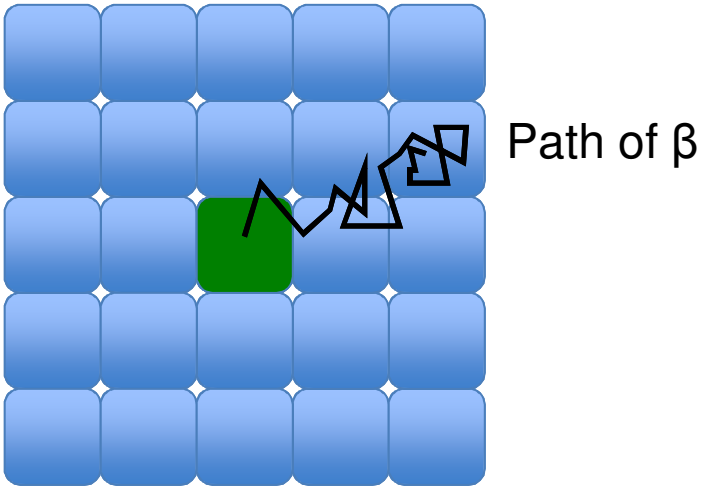


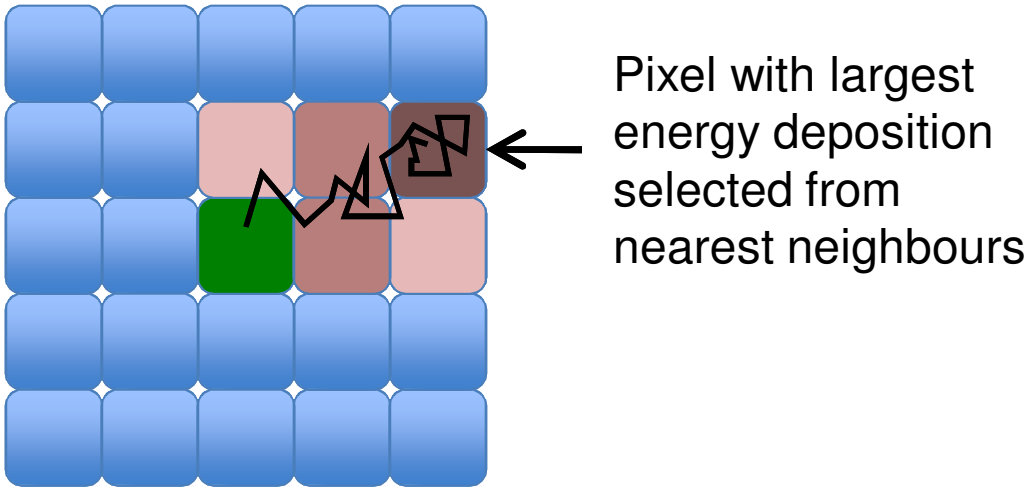
Looking for correlations

Recoils are implanted into DSSD

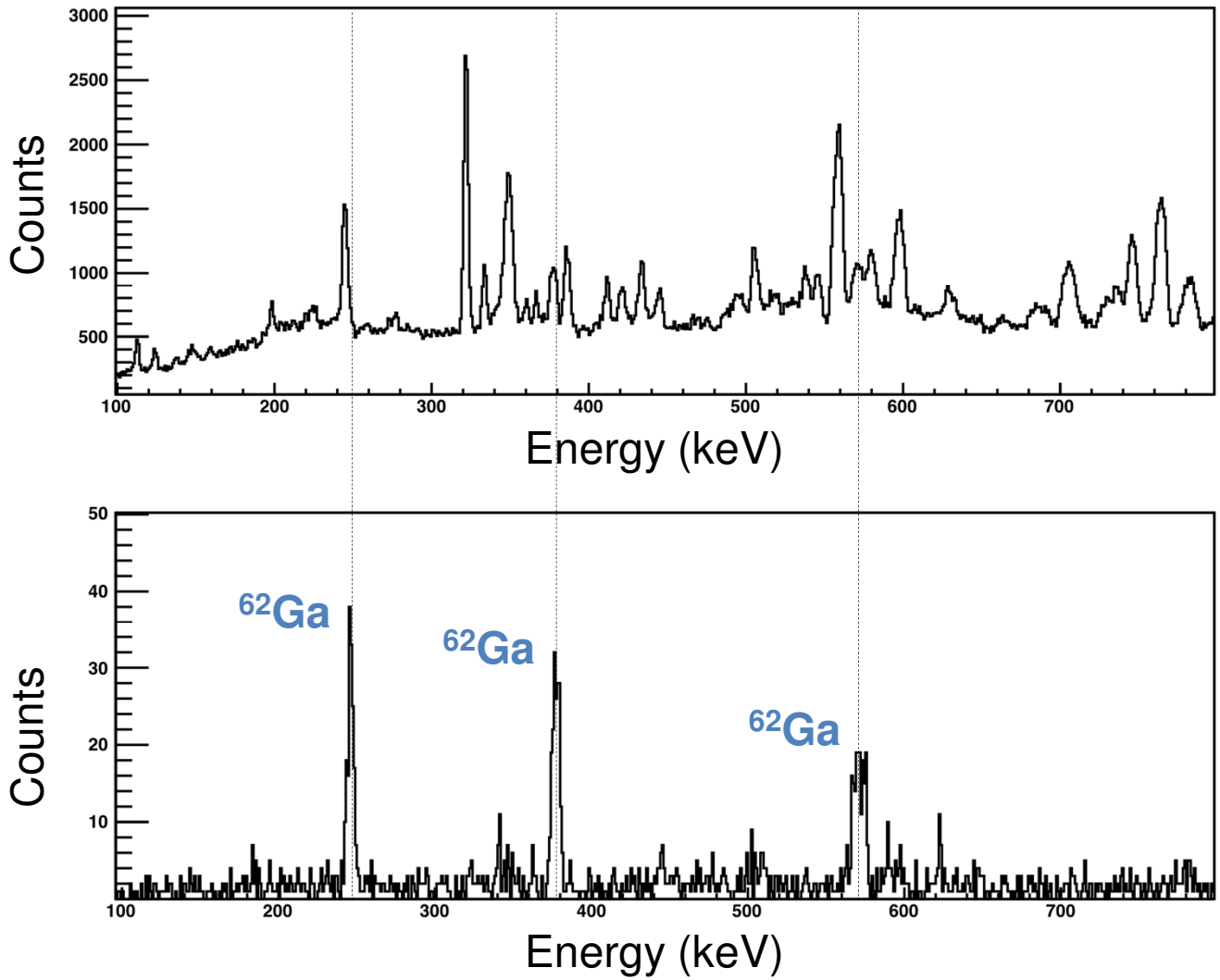


Subsequent β-decay





Results from test experiment



ϒ spectrum measured in coincidence with implanted recoils which were followed by fast decays

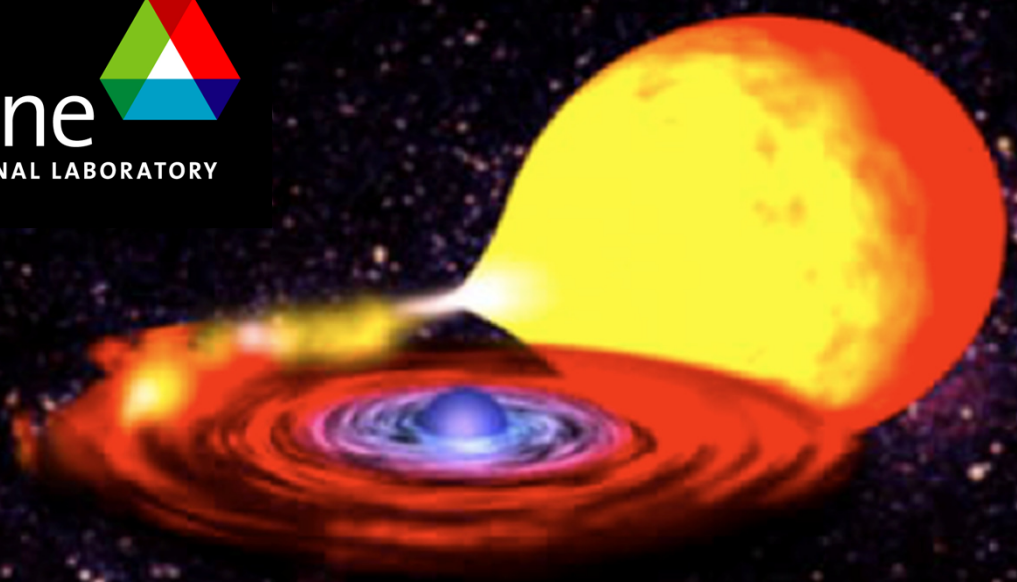
Conclusions

- New method provides high selectivity on fast β-emitters

- Ability to produce very clean ϒ-ray spectra of exotic nuclei

- Intention is to extend the new method to more exotic nuclei at key rp-process waiting points

Thank you



University of Edinburgh &
Argonne National Laboratory collaboration

G.Lotay, P.J. Woods, D. Seweryniak, M. Carpenter, H.M. David, T. Davinson, R.V.F Janssens, T. Lauritson, C.J. Lister, Z. Liu, J.P. Wallace and S. Zhu