Science & Technology Facilities Council

UK Nuclear Physics Programme

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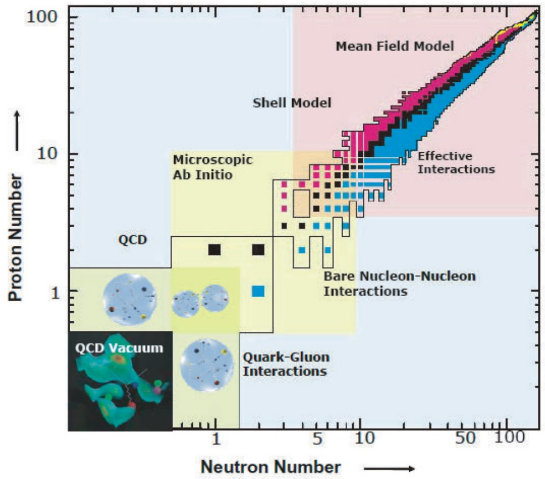
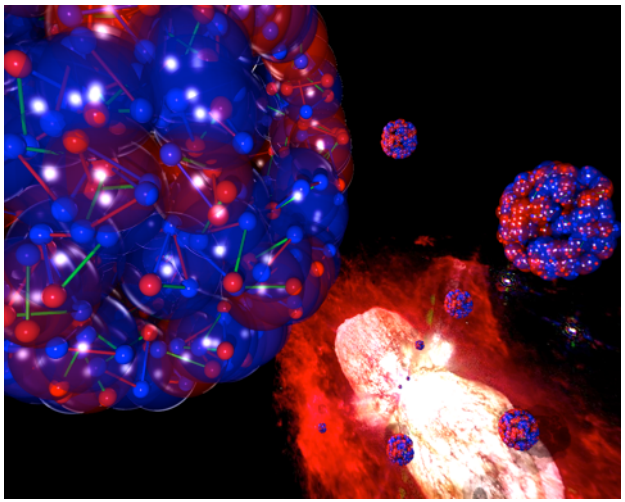
UNIVERSITY OF LIVERPOOL

THE UNIVERSITY of EDINBURGH

Outline of presentation

- UK Nuclear Physics Community
- Funding Mechanisms
- Our Science (present and future)
- Applications of Nuclear Physics





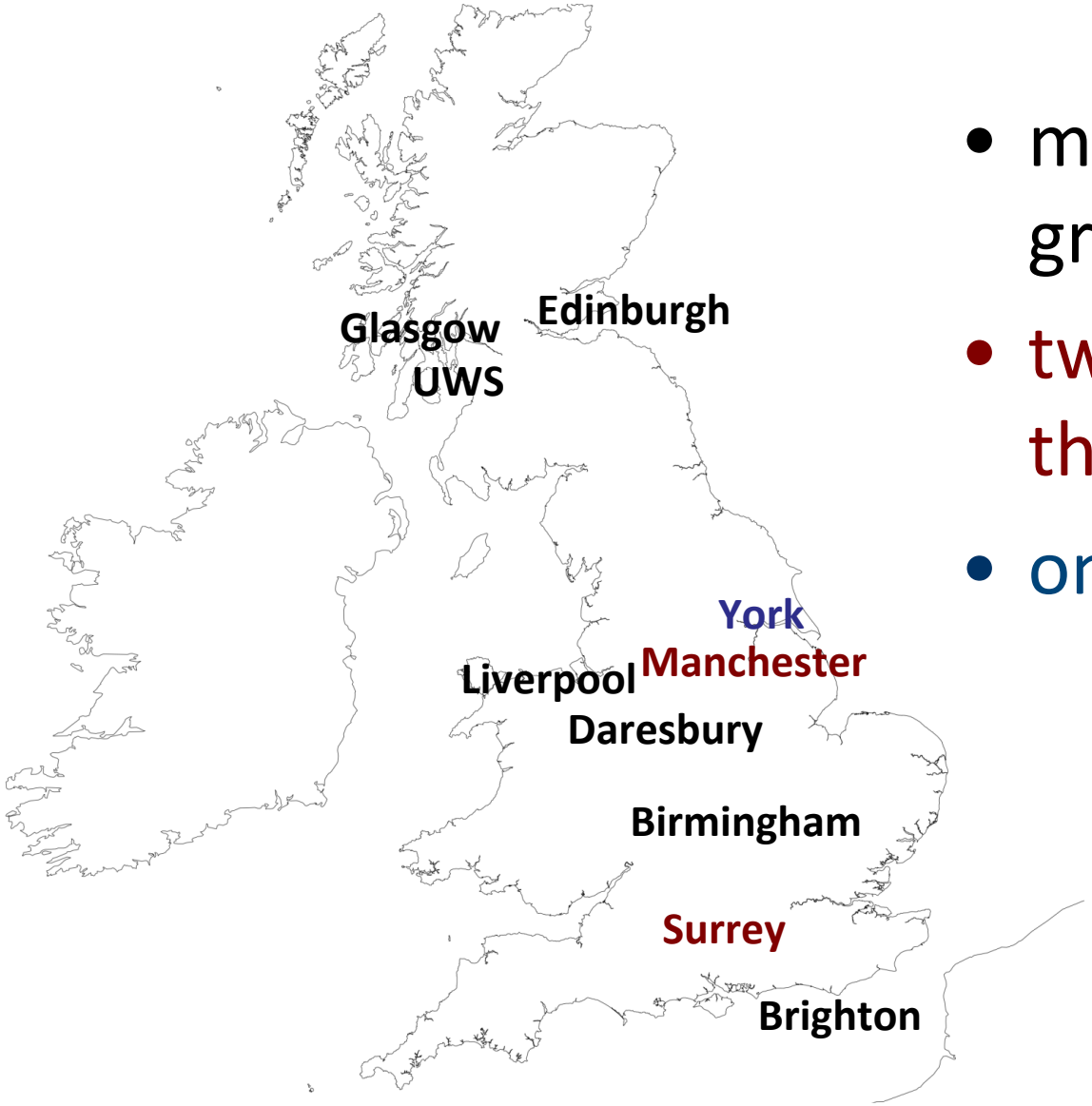
Introduction

- Nuclear Physics moved to STFC in 2008
- Nuclear Physics research is funded through Nuclear Physics Grants mechanism
- R&D Project and Instrumentation Funds
- Application & Outreach
- Nuclear Engineering remains in EPSRC

Size of UK Community

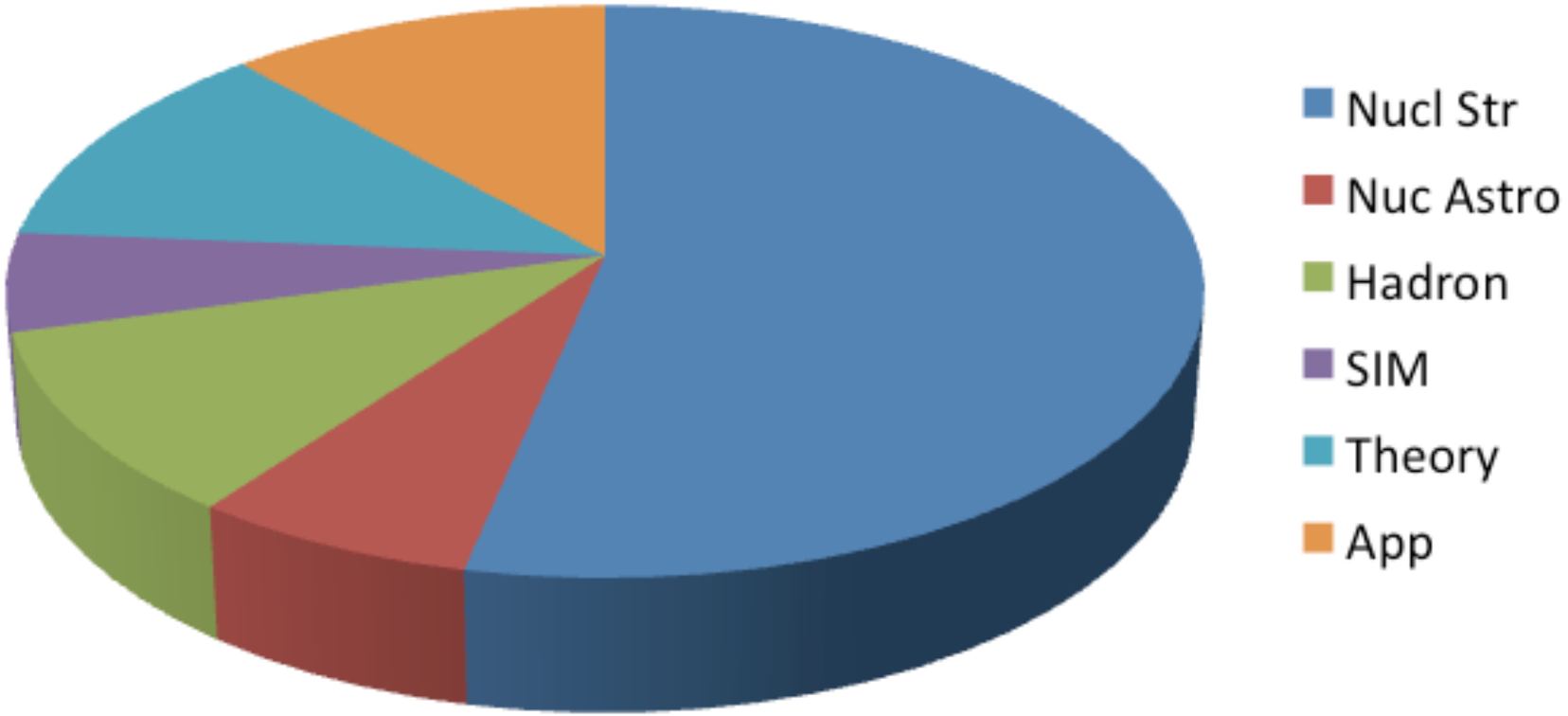
- **50 Academic/Faculty Staff carrying out nuclear physics research**
  - Number has been slowly increasing over a few years
  - All (except 3 at STFC Daresbury) are University funded
- **(5-year) Rutherford Fellowships are available from STFC on a competitive basis**
- **60 Research and Professional Staff supporting the academic staff**
- **90 Research Students working with the academic staff**

Locations of UK Nuclear Physics Groups

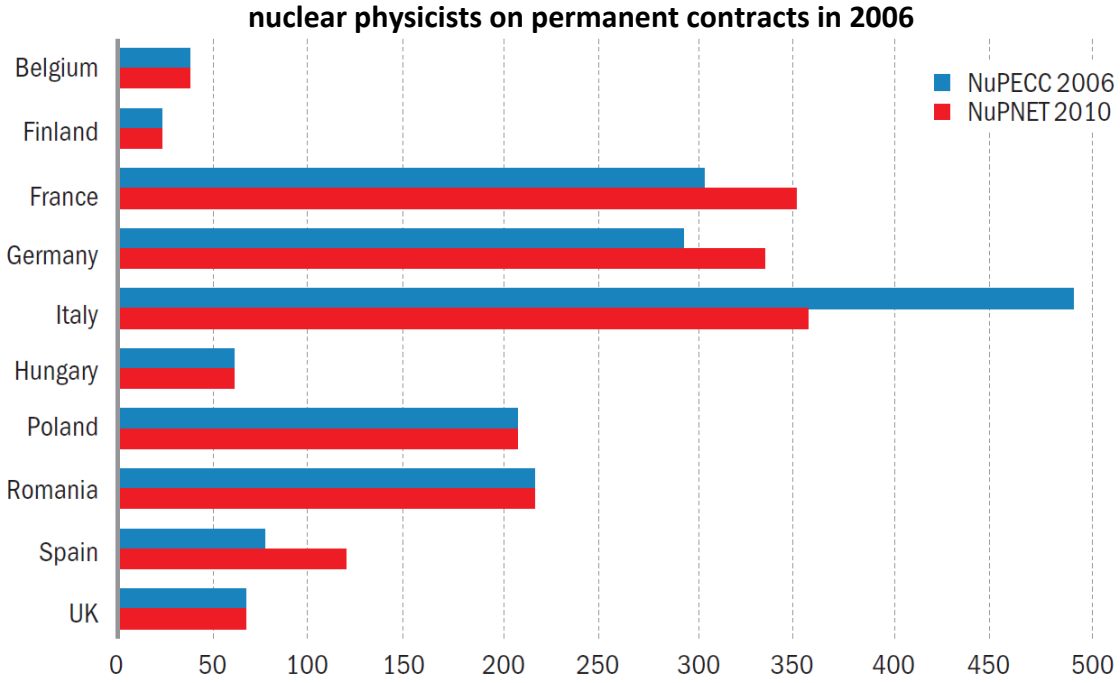


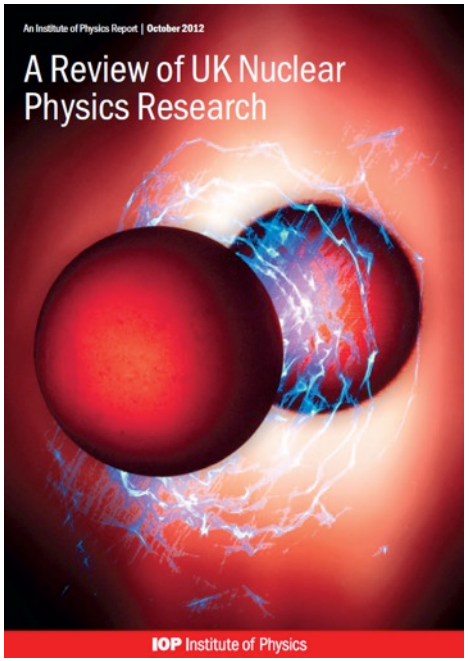
- mostly experimental groups
- two (established) theory groups
- one new chair (York)

Theme areas by academic staff



Nuclear Physics Communities in Europe





Year	Nuclear physics			Particle physics			Astronomy		
	Total	Academics	Fellows	Total	Academics	Fellows	Total	Academics	Fellows
2008	65	50	15	278	221	57	407	307	100
2004	48	42	6	164	142	23	264	186	78
1999		42			153			241	
1996		46			142			215	

www.iop.org/publications/**iop**/2012/file_58792.pdf

Cross-Community Comparison

Nuclear Physics : Particle Physics : Astronomy

1 4 6

UK Annual budget

- Nuclear Physics Research £5-7M, last 2-3 years
- NP Studentships/Fellowships £1.1M
- Income from KE applications…

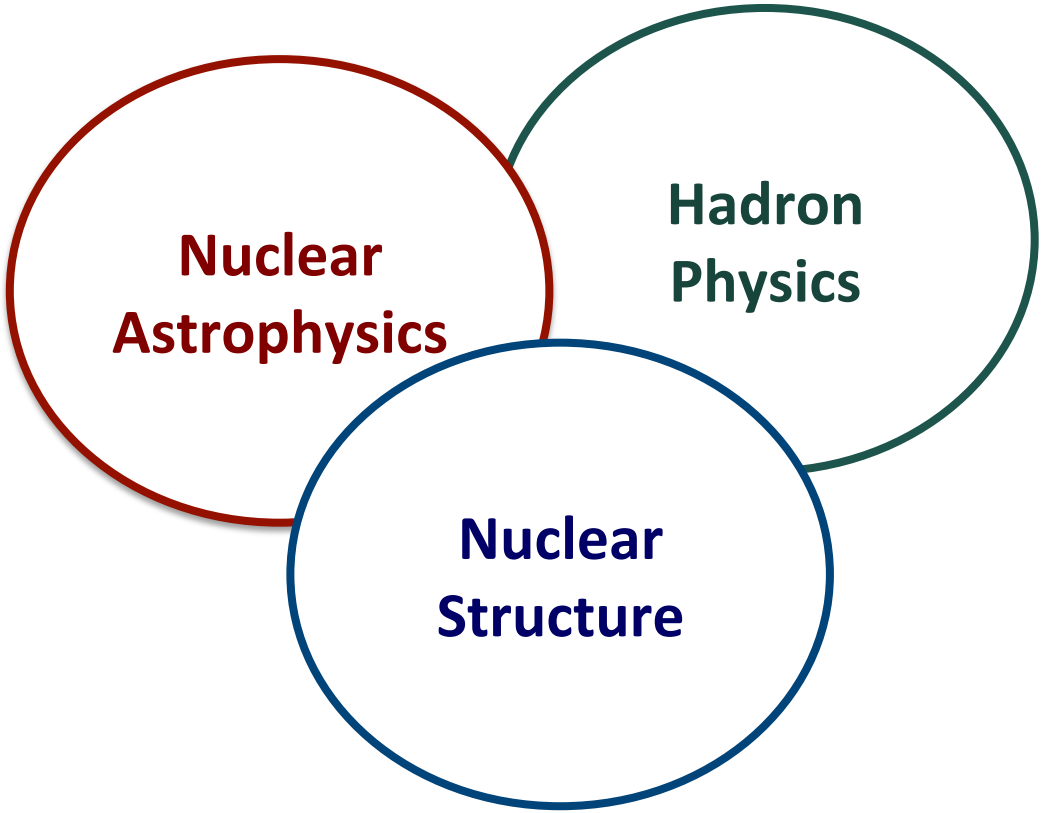
(Source IOP Review 2012)

STFC Funding Sources

- Consolidated grants – currently 4 years – one application date
  - Exploitation, travel, small equipment, PDRAs, academic time
- Project grants – larger equipment projects (3-5 years)
  - Existing and past projects: NUSTAR, AGATA, ~~PANDA~~
  - Future projects under view by STFC: ALICE upgrade, ISOL-SRS, JLab upgrade
- R&D grants (1-2 years)
  - Equipment development (~£500k)
- Applications (KE) grants (1-3 years)
  - Funding for people and equipment for range of topics
- Research students (3.5 years)
  - Funding for fees and stipend - STFC, Universities, self funding ….

Our Science

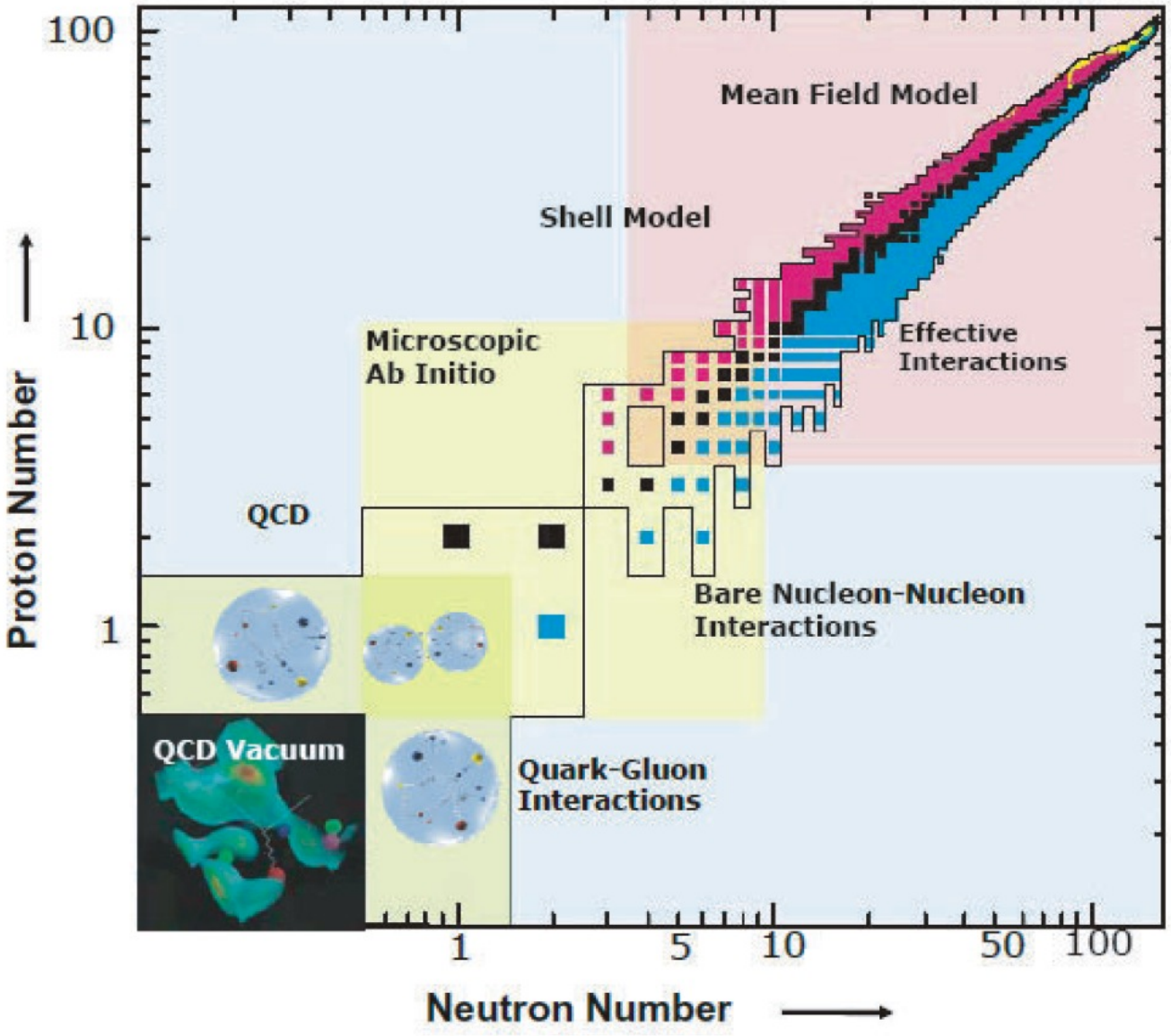
- varied and inter-disciplinary
- breadth of projects vital for vibrant community
- different facilities needed for full exploitation



Science Questions

- What are the Origins of the Elements?
- What is the Nature of Nuclear Matter?
- How do the properties of hadrons and the quark-gluon plasma emerge from fundamental interactions?

Our Science

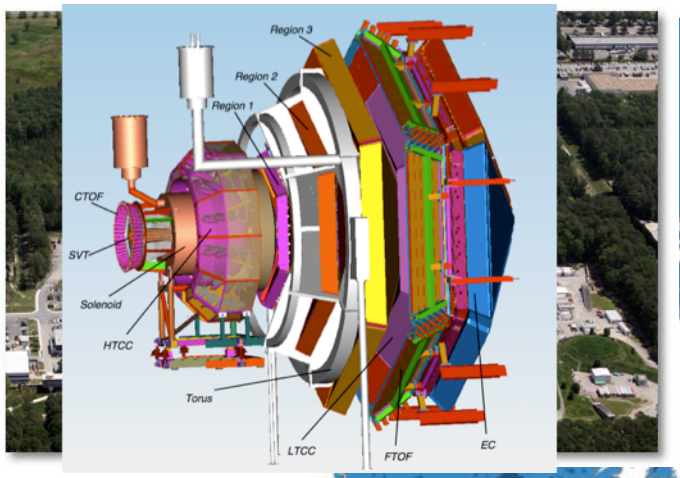

100
10
1
Proton Number
Mean Field Model
Shell Model
Microscopic
Ab Initio
Effective
Interactions
QCD
Bare Nucleon-Nucleon
Interactions
QCD Vacuum
Quark-Gluon
Interactions
1
5
10
50
100
Neutron Number

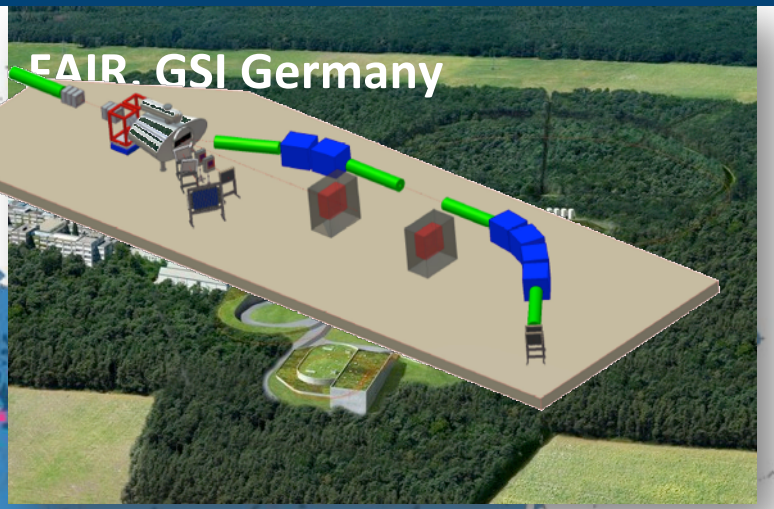
The Basic Facts….

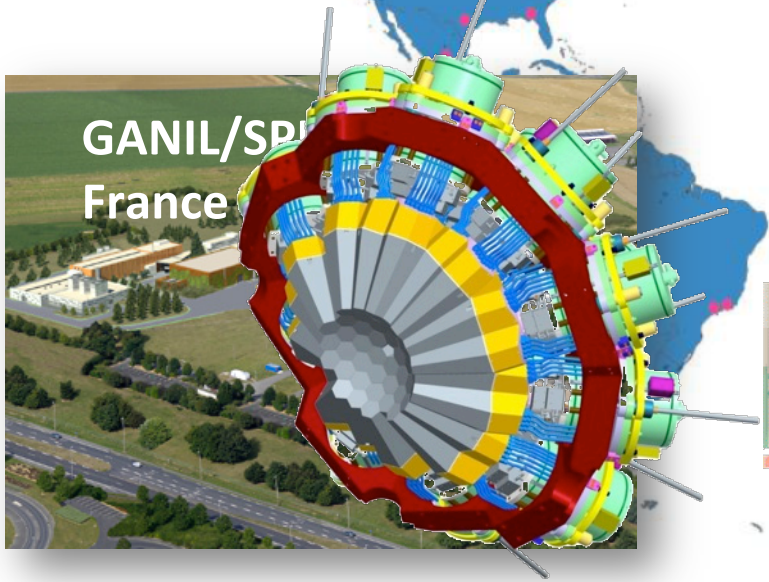
- No major accelerator facilities in the UK
- Majority of work takes place within national and international collaborations
- Expertise in developing state-of-the-art instrumentation for international collaborations

UK Nuclear Physics Worldwide

UK Nuclear Physics Worldwide







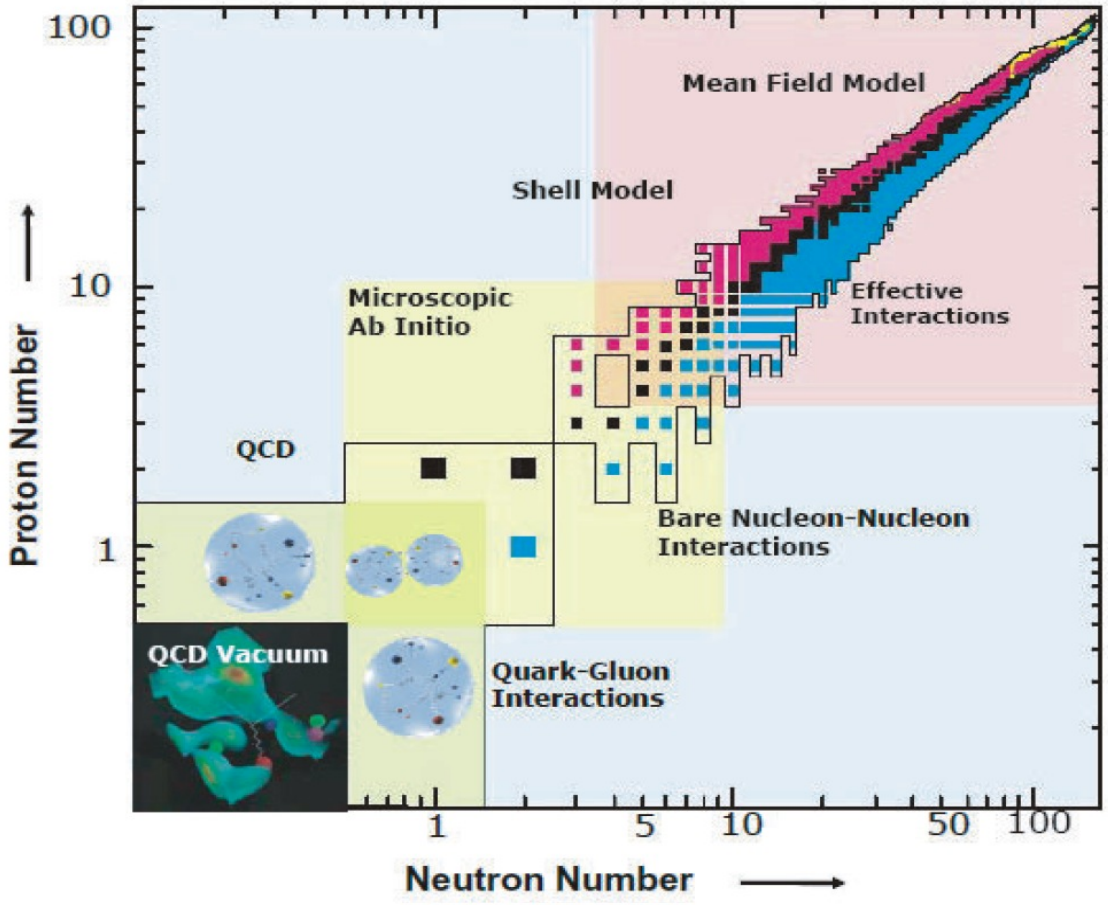
Exploitation Facilities

- Argonne National Lab (US)
- DESY (Germany)
- Florida State University (US)
- Gran Sasso (Italy)
- ILL Grenoble (France)
- iThemba Labs (South Africa)
- JAEA (Japan)
- Australian National Facility (ANU)
- Jyväskylä (Finland)
- Legnaro (Italy)
- Mainz (Germany)
- Max Lab (Sweden)
- Michigan State University (US)
- Munich (Germany)
- Notre Dame (US)
- Orsay (France)
- RCNP (Japan)
- RIKEN (Japan)
- Texas A&M (US)
- TRIUMF (Canada)

source: NPAP Report for the Programmatic Review, 2012

Ongoing Nuclear Physics Projects

- **NuSTAR @ FAIR**
  - HISPEC (inc AGATA)
  - DESPEC
  - R^3B



HISPEC (High Energy Spectroscopy)

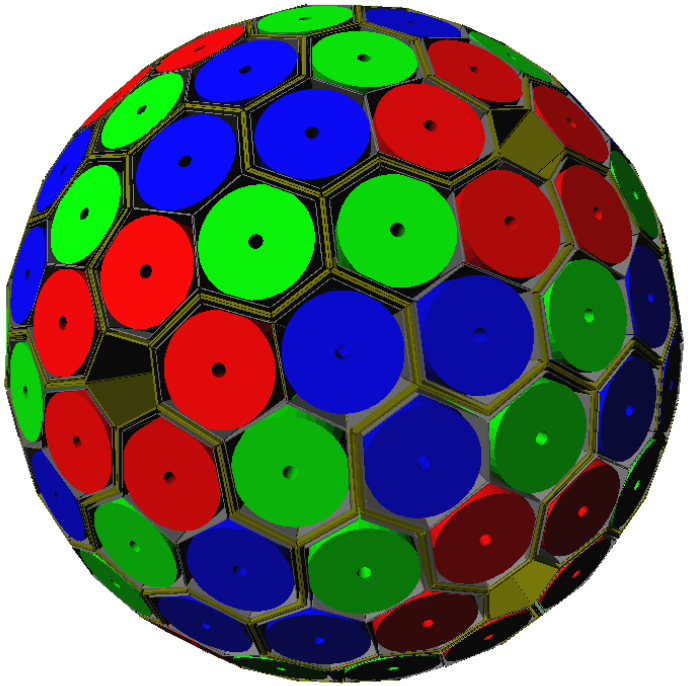
Physics Case:

Nuclear Structure
studies of exotic nuclei

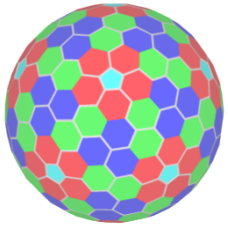
high-energy beams of
very exotic (n-rich) nuclei

AGATA γ-ray array

AGATA Array

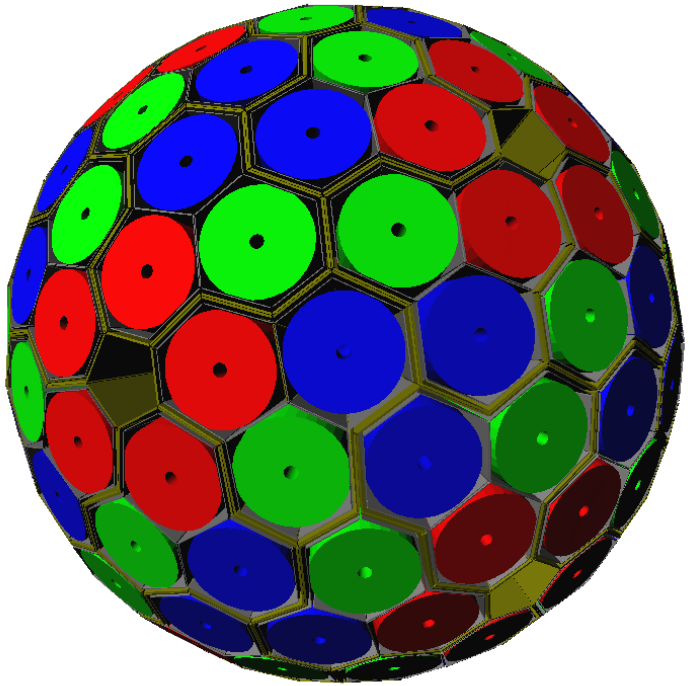


The AGATA Spectrometer



Steering Committee Chairperson: G. De Angelis INFN LNL
vice-Chairperson: Faisal Azaiez

12 Countries
>40 Institutions



Main features of AGATA

Efficiency:	**43% (M_γ=1)**	**28% (M_γ=30)**
today's arrays	~10% (gain ~4)	5% (gain ~1000)
Peak/Total:	**58% (M_γ=1)**	**49% (M_γ=30)**
today	~55%	40%
Angular Resolution:	**~1º →**	
FWHM (1 MeV, v/c=50%)		**~ 6 keV**
today		~40 keV
Rates:	**3 MHz (M_γ=1)**	**300 kHz (M_γ=30)**
today	1 MHz	20 kHz

AGATA's Deployment

Intense stable beams

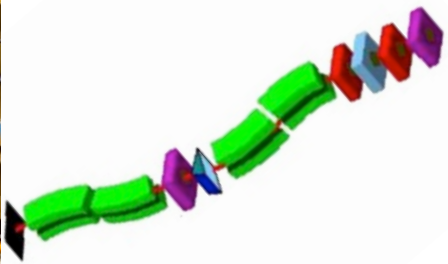
2010 → INFN LNL
15 detectors

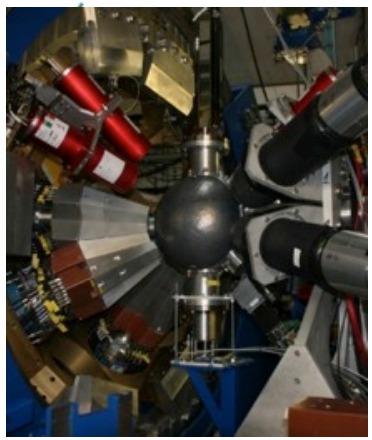
AGATA D.+PRISMA

Total Eff $_{Nominal}$. ~2.6%

Fast Fragmentation beams

2012 2014→ GSI/FAIR
25 detectors



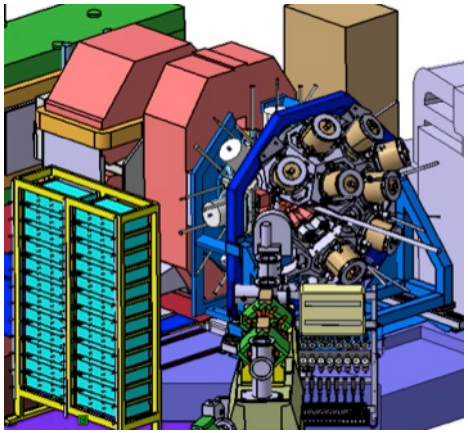


AGATA @ FRS

Total Eff. (β=0.5) ~ 10%

ISOL and stable beams

2014- 16→ GANIL/SPIRAL
45 detectors



AGATA @GANIL

Total Eff ~ 8% to 14%

DESPEC (Decay Spectroscopy)

Physics Case:

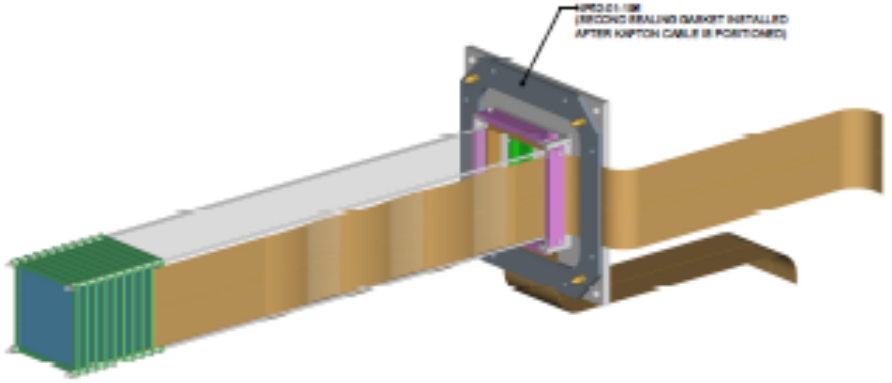
Nuclear Structure and
Nuclear Astrophysics

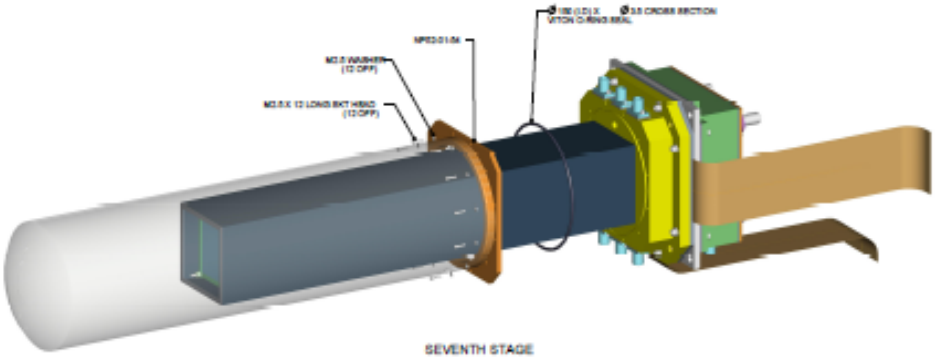
r-process nuclei and heavy element nucleosynthesis

decay spectroscopy

- Si-detector array AIDA
- FATIMA γ-ray array

Advanced Implantation Detector Array (AIDA)





FATIMA for DESPEC

- **FATIMA = FAst TIMing Array**
  - A high efficiency, gamma-ray detection array for precision measurements of nuclear structure in the most exotic and rare nuclei.

- **Specs.**
  - Good energy resolution.
  - Good detection efficiency
  - Excellent timing qualities (~100 picoseconds).

- **31x $LaBr_3$ 1.5” x 2” crystals for array already bought**

- **lifetimes of excited nuclear states; precision tests of shell model theories of nuclear structure**

Final design, three rings of 12 $LaBr_3$ detectors surrounding AIDA stopper

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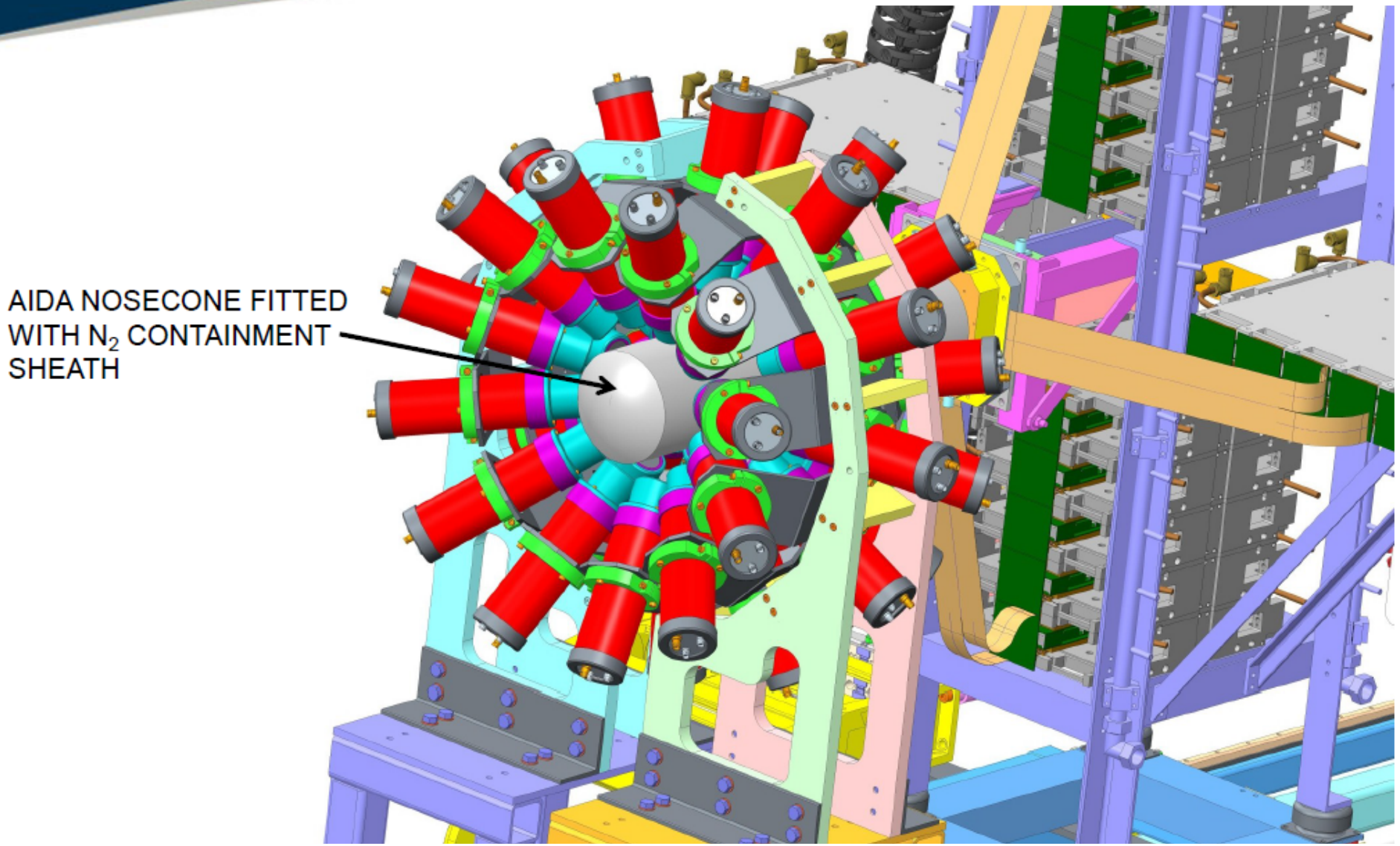
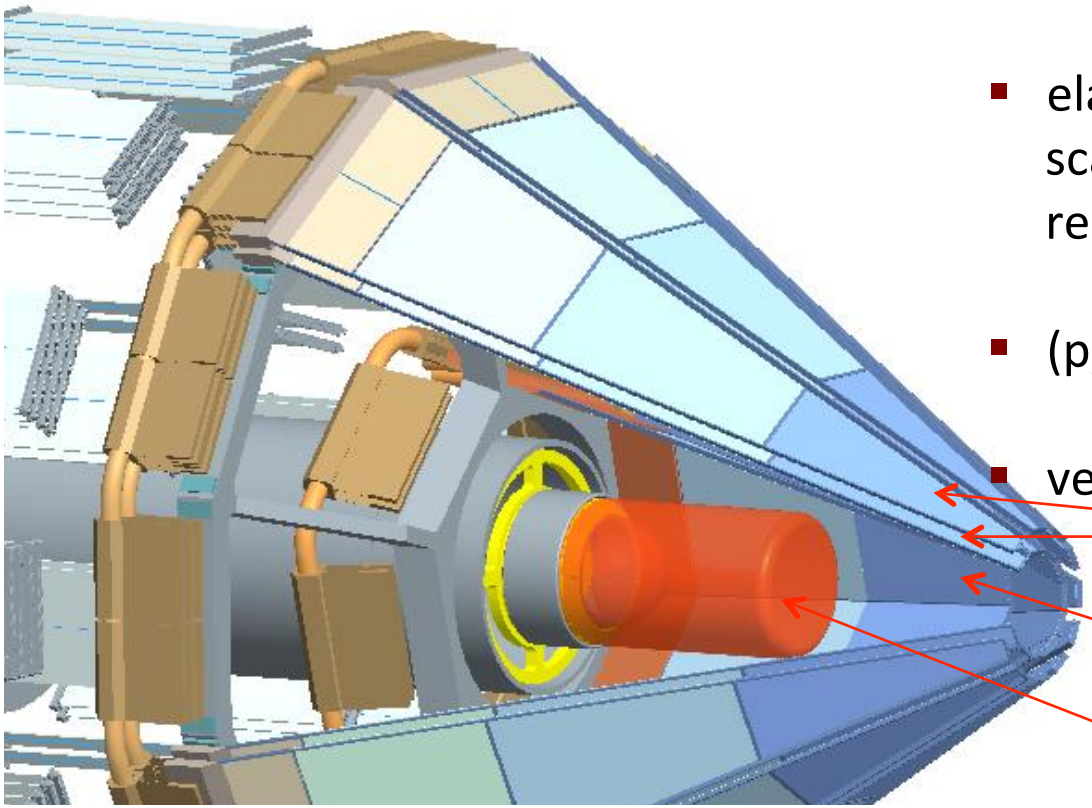


R^3B: Reactions with Relativistic Radioactive Beams

Physics Case:

Structure of nuclei at extreme of existence



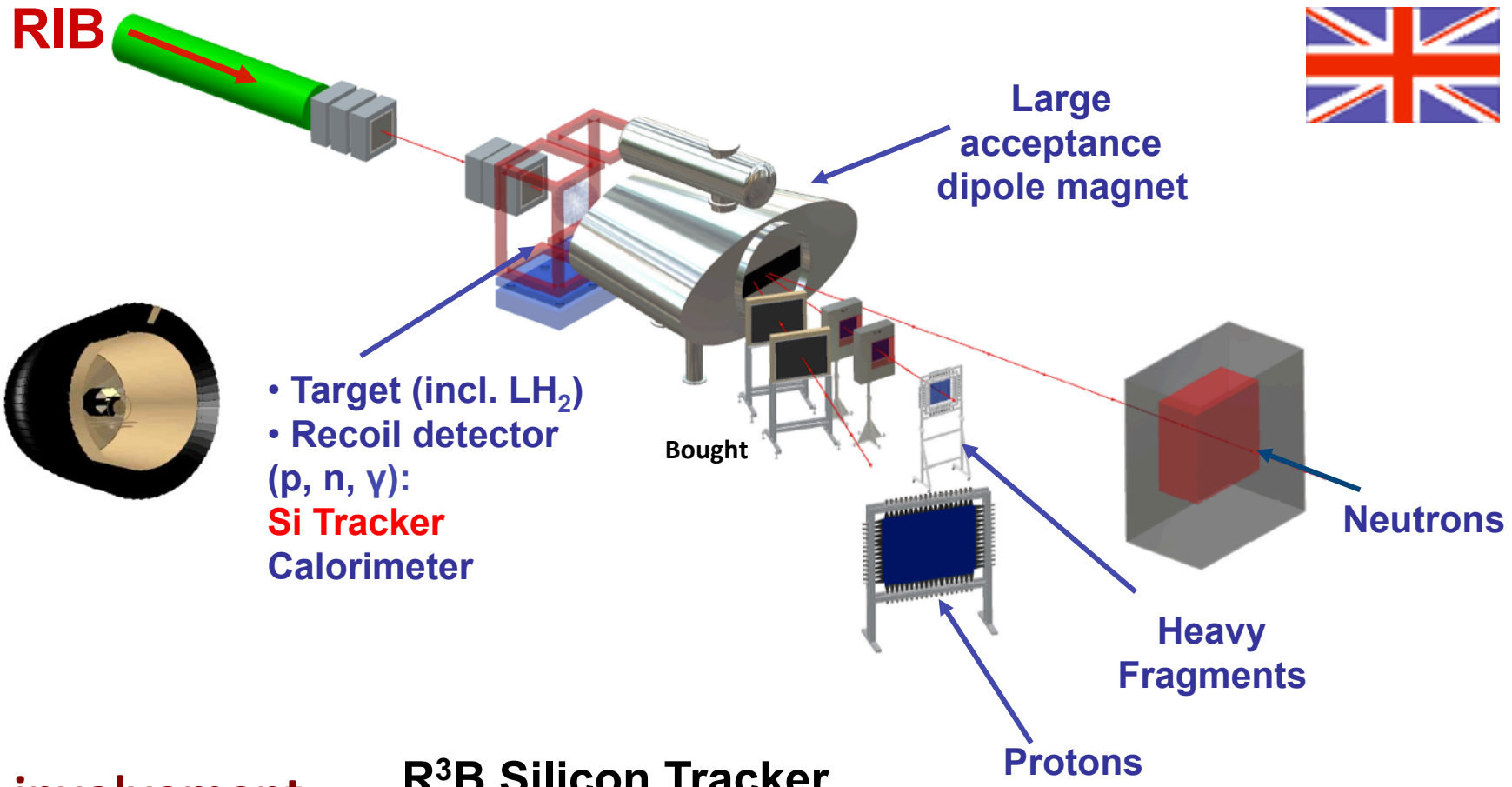
R3B Silicon tracker (Edinburgh, RAL, Birmingham, Liverpool, Surrey, STFC Daresbury):

- coincident detection of recoil with heavy fragments, neutrons and γ-rays
- elastic, inelastic and quasi-free scattering, knockout and breakup reactions
- (p,2p) reactions in inverse kinematics
- vertex reconstruction

outer layers (x2): 300 µm double-sided silicon strip detectors (DSSD)

inner layer: 100 µm DSSDs

The R³B Experiment



UK involvement:

- 8 institutions
- 16 academics

R³B Silicon Tracker

To be built by Spring 2016 for the R³B experiment at FAIR

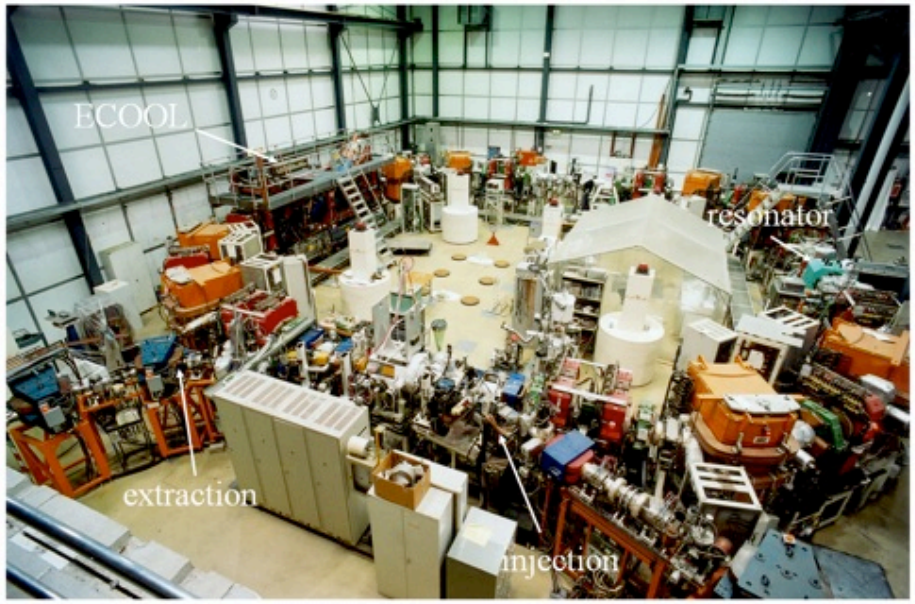
Fully funded NUSTAR/R³B grant ~ £5M
(Liverpool, Daresbury, Birmingham, Edinburgh, Surrey)
Project leader: Roy Lemmon

Future project

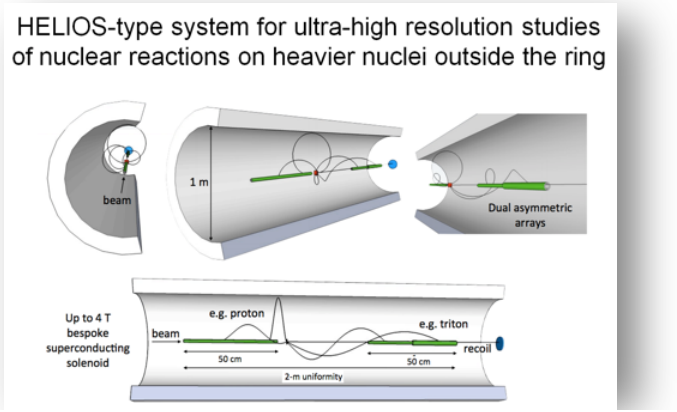
Nuclear Physics Proposed Projects

- **part of European initiative (TSR@ISOLDE)**
- **internal spectrometer**
  - Si detectors in UHV
- **external spectrometer**
  - HELIOS

The heavy ion storage ring TSR
MPIK Heidelberg



Circumference: 55m



UK involvement:

- 8 institutions
- 32 academics
- £4.2M funds requested

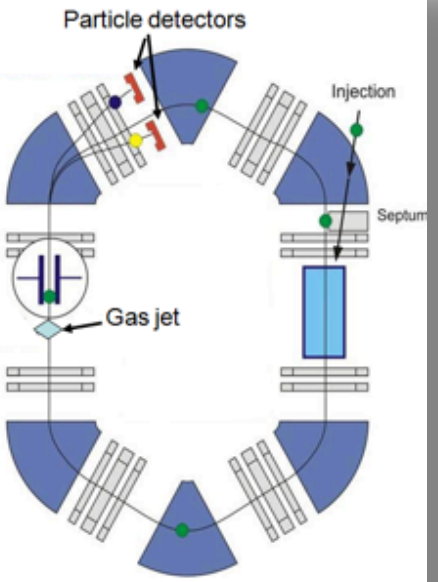
Nuclear Physics Proposed Projects

Physics Case:

- **ISOL-SRS**

Reactions Studies for Nuclear Astrophysics
ISOL beams (10^3-10^6 pps) x10^6 boost in intensity

Measurements of (p,γ) or (α,γ) rates in the Gamow window for the explosive astrophysical p-process using inverse kinematics.



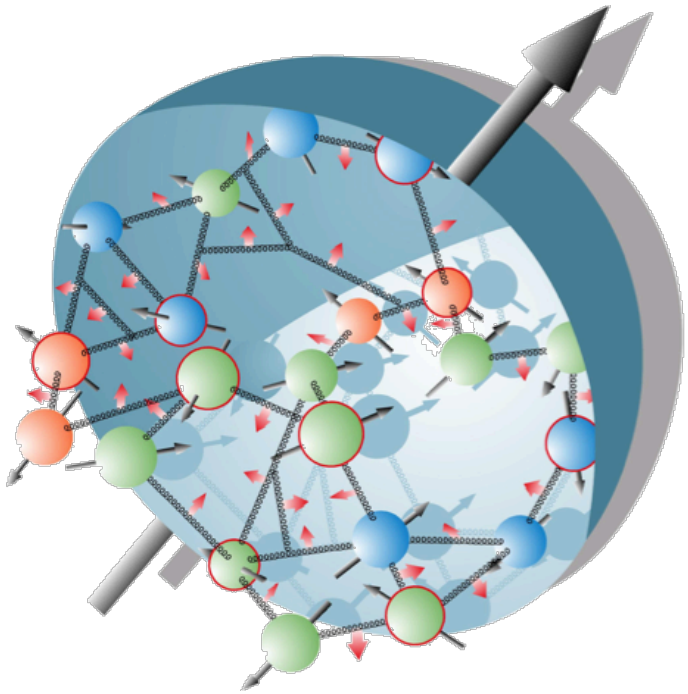
Advantages:

- **Applicable to radioactive nuclei**
- **Detection of ions via in-ring particle detectors (low background, high efficiency)**

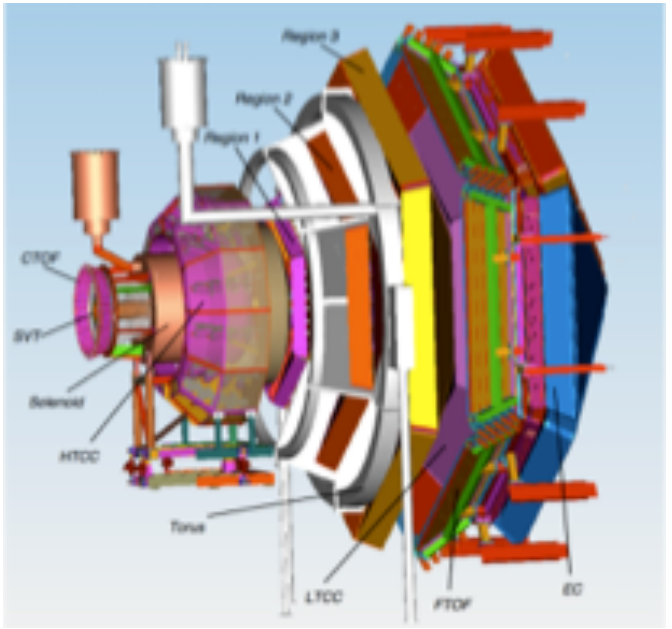
Nuclear Physics Proposed Projects

Physics Case:

Hadron Spectroscopy
Nucleon Structure



- **JLab CLAS and Hall A Upgrade**



UK involvement:

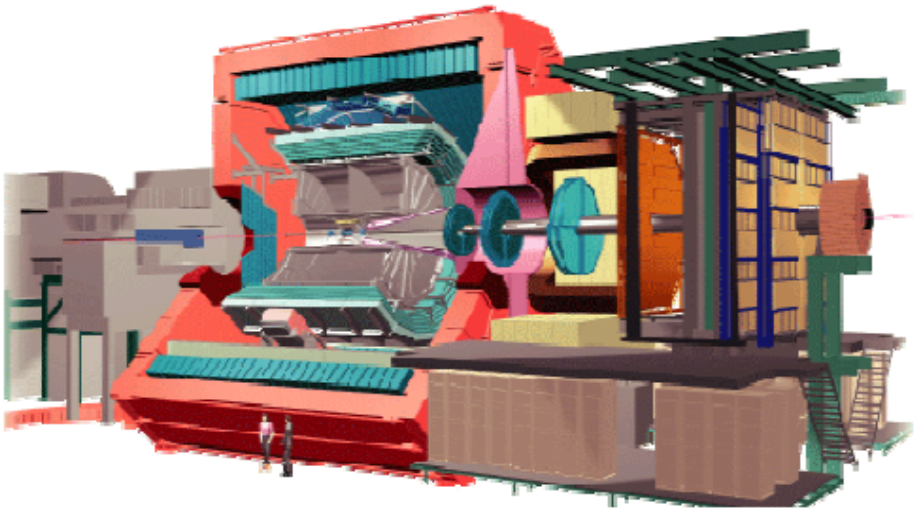
- 2 institutions
- 4 academics
- £1.5M funds requested

Nuclear Physics Proposed Projects

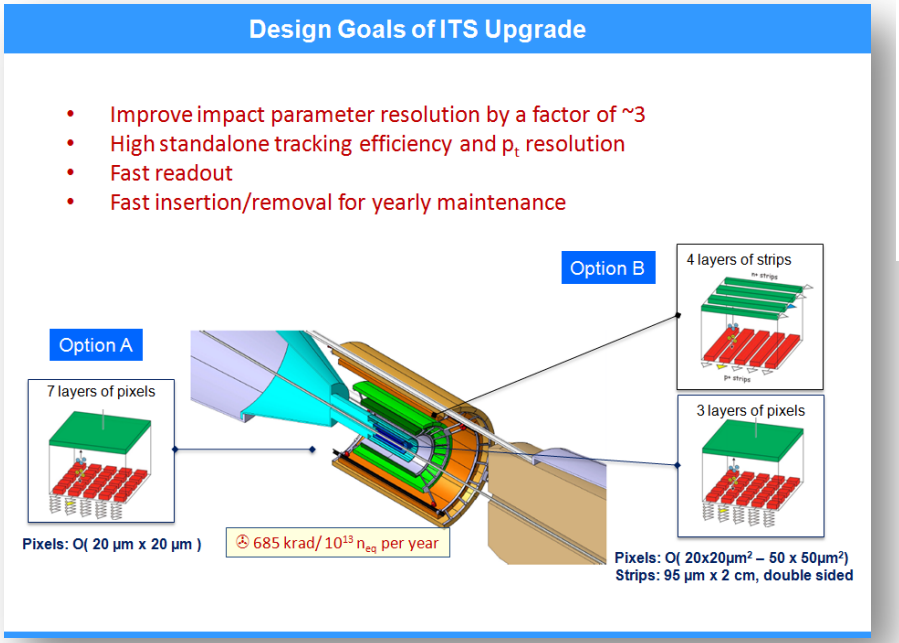
Physics Case:

Nature of Hadronic Matter and Quark Gluon Plasma

- **ALICE upgrade**



Schematic of the ALICE detector at the LHC.

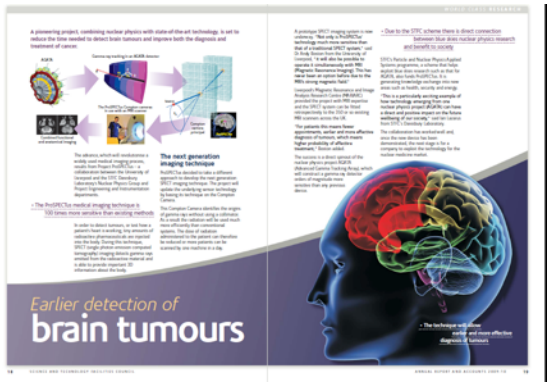


UK involvement:

- 2 institutions
- 4 academics
- £4.2M funds requested

Sensors: Knowledge Exchange

Direct application in medical security and energy areas as evidenced by funding from: CLASP, EPSRC/TSB, NERC, MRC, NHS, NNL (NDA), AWE



PROSPECTUS

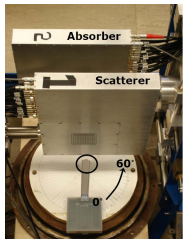
- Novel SPECT imaging system

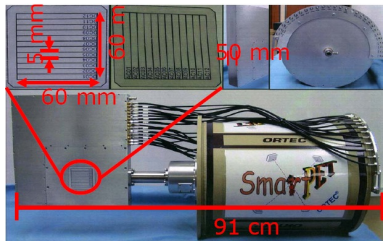
NNL

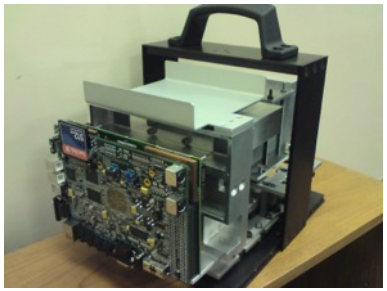
- Nuclear Decommissioning applications

Detector R&D

- Energy resolution & MDA

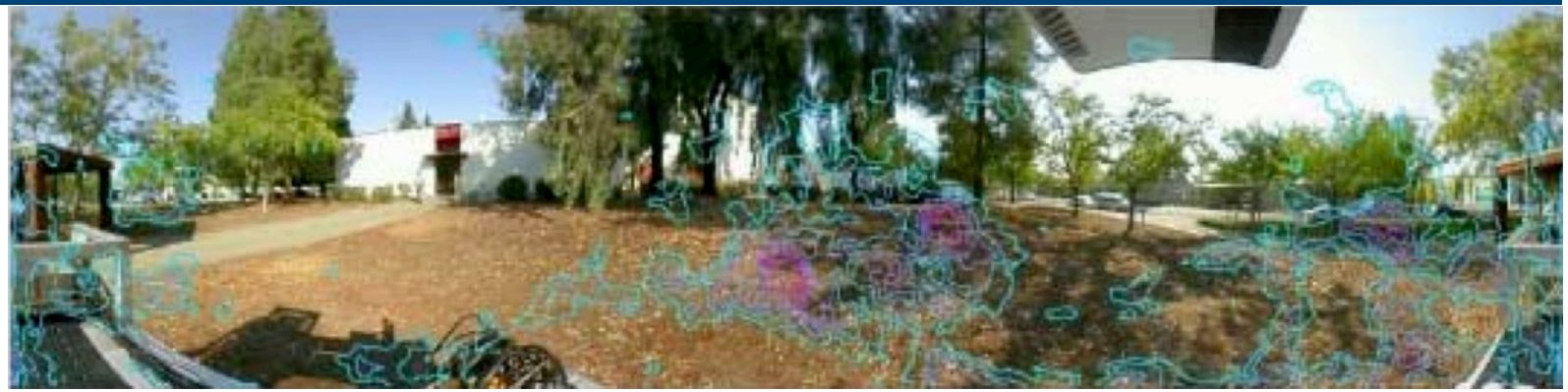






All projects are collaborations with industrial partners. All involve contributions from parts of STFC.

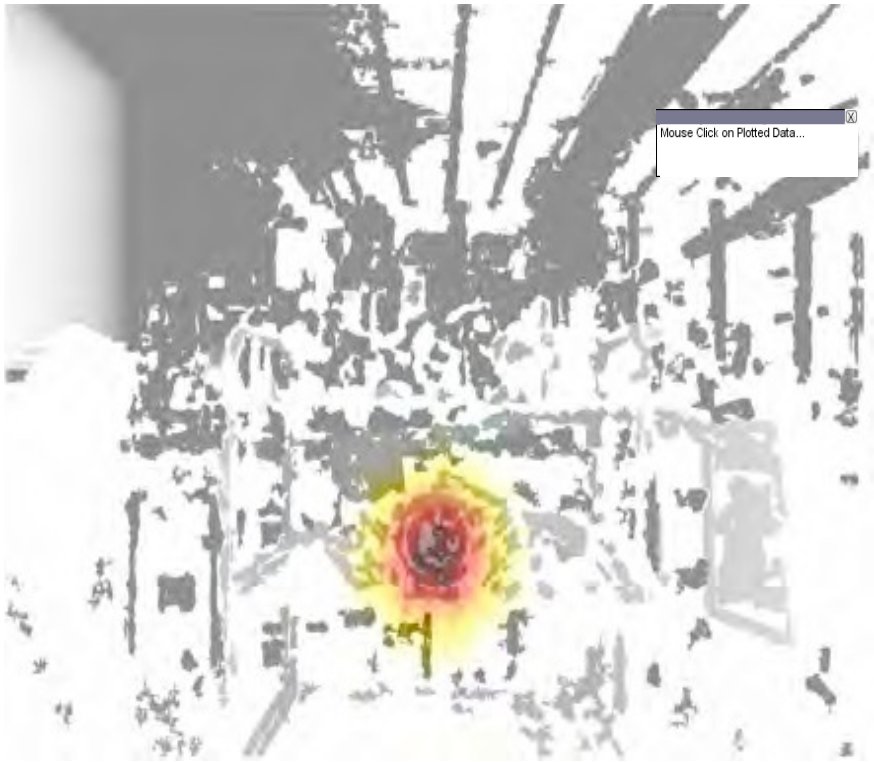
Location and Identification…



Courtesy K. Vetter LBL (work @ LLNL)

- ability to locate and identify radioactive material with high precision
- quantification of waste into low/intermediate/high brackets
- wide range of activities from ~37kBq -> MBq
- many open challenges and opportunities

The potential: 3D Gamma & Optical Stereoscopic image fusion



137Cs source
1.5m standoff

NATIONAL NUCLEAR LABORATORY

Science & Technology Facilities Council

A Compton Camera provides 3D source location

Masters Level Training

- Nuclear Science and Technology (8 Universities Consortium led by Manchester)
- Physics and Technology of Nuclear Reactors (Birmingham)
- Radiation Metrology (Surrey)
- Radiation and Environmental Protection (Surrey, Liverpool)

- 90 – 100 students per year
- Industry Continuing Professional Development (200 people/ year)

Source: IOP Review 2012

Concluding Remarks

- UK Nuclear Physics: small but vibrant community
- actively involved in many international projects
- recognized leadership and expertise
- active engagement with industry
- strong professional development and training programmes