Nuclear Physics Projects

January 2019

The Nuclear Physics Strategy document

- Scope and range of Physics
- Current projects
- Future projects
- Other issues
- 10 year horizon

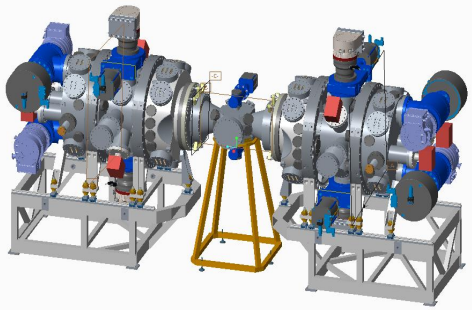
- Last revision June 2018

https://stfc.ukri.org/about-us/how-we-are-governed/advisory-boards-panels-committees/nuclear-physics-advisory-panel/

Existing projects: ISOL-SRS

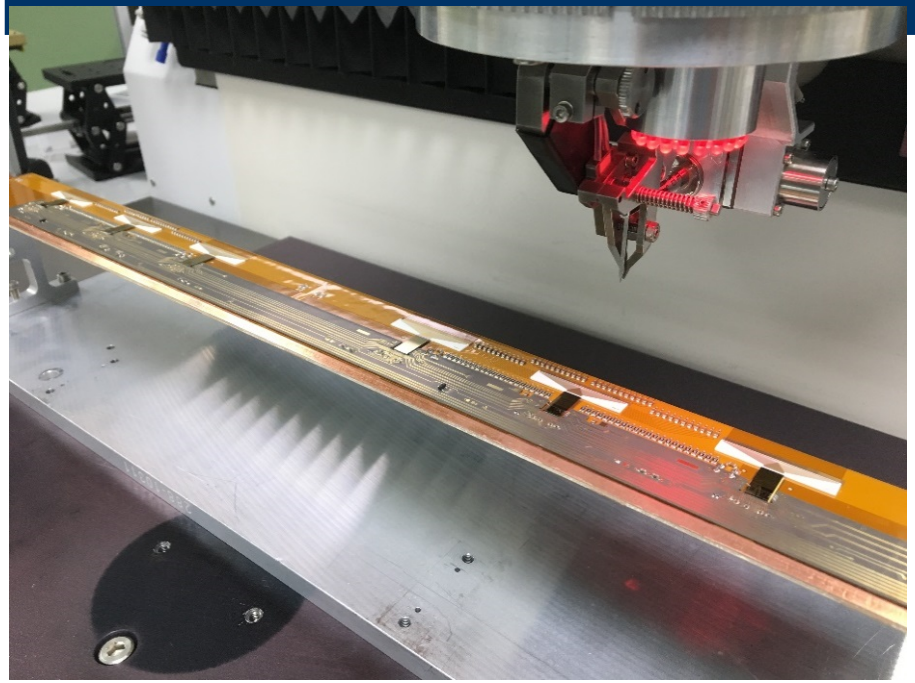
- ISOL-SRS: Two spectrometers for precision measurements of charged particles emitted in nuclear reactions induced by radioactive ion beams
  - ISOLDE Solenoidal Spectrometer (ISS), is based on the novel helical orbital spectrometer concept and will take radioactive beams from HIE-ISOLDE at CERN
  - Spectrometer will be operated within the ultra high vacuum (UHV) of the CRYRING low-energy storage ring at FAIR
  - Both spectrometers will employ high granularity silicon-detector systems with ASIC-based readout

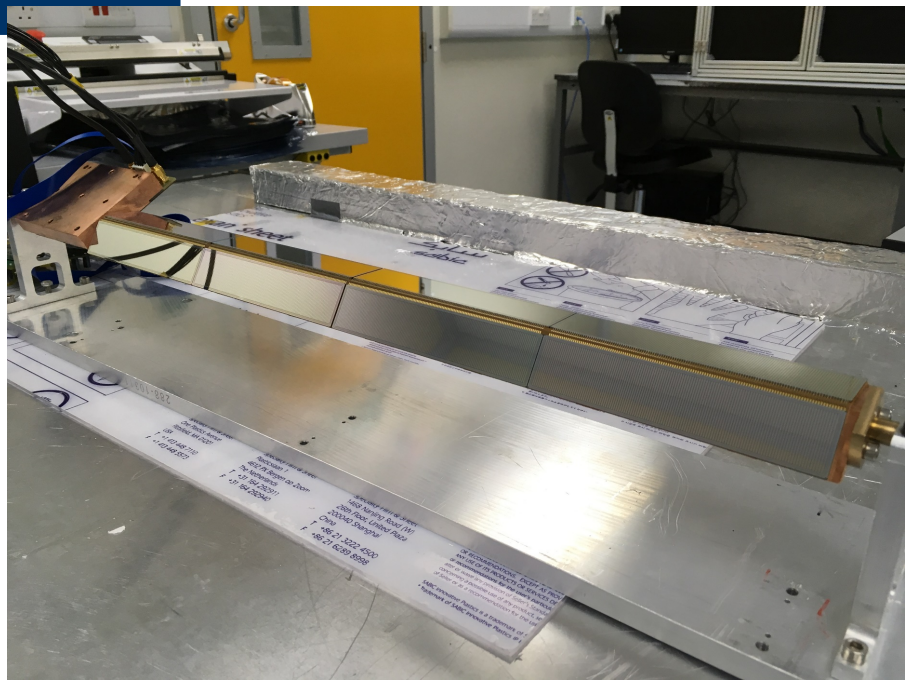
ISOLDE Solenoidal Spectrometer

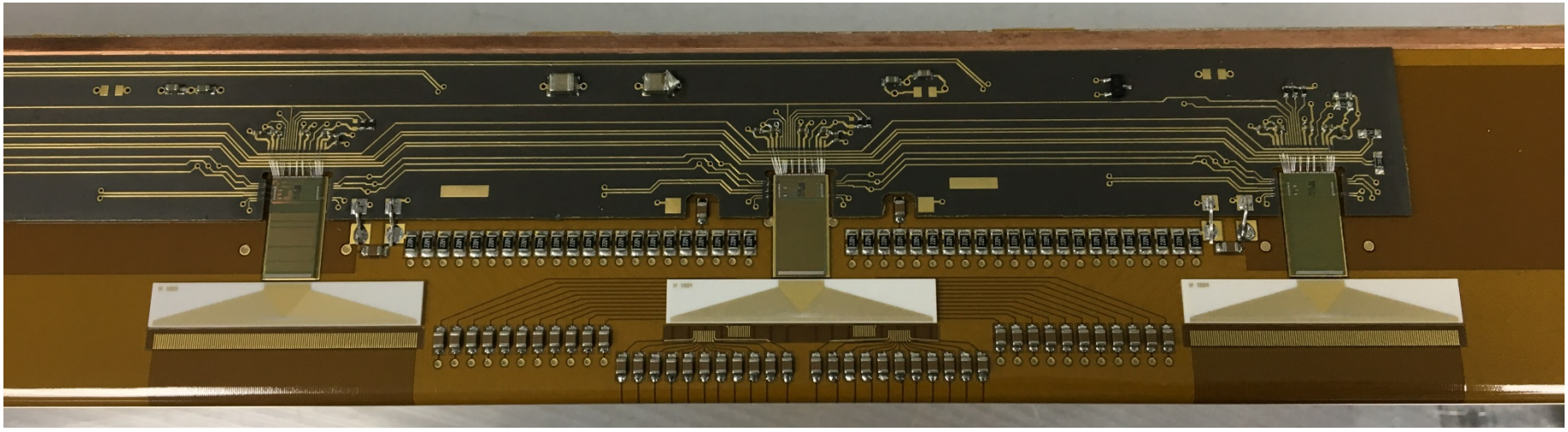


ISOL-SRS Project Update

ISOLDE Solenoidal Spectrometer

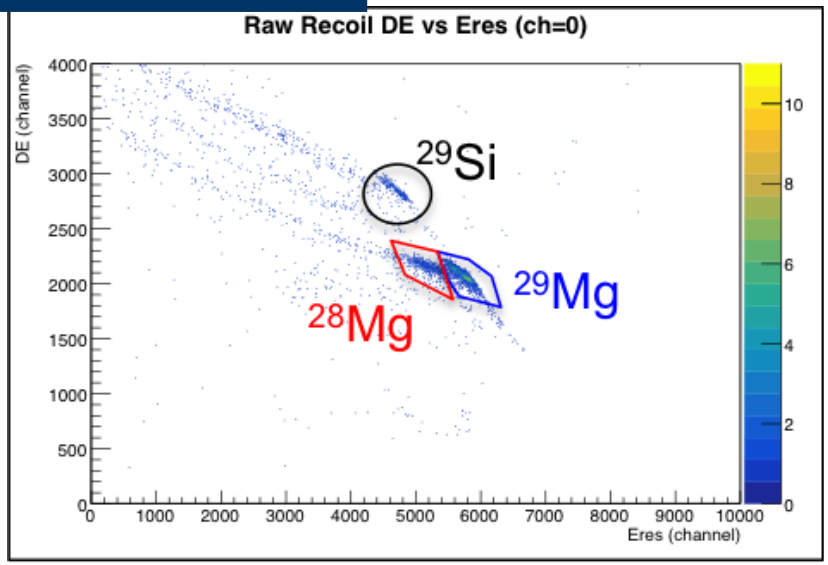


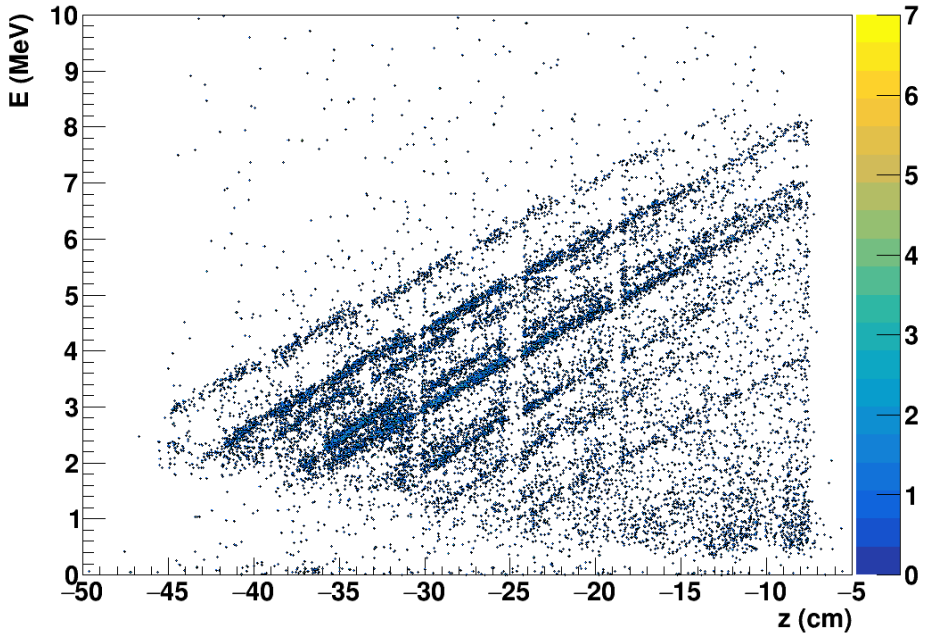


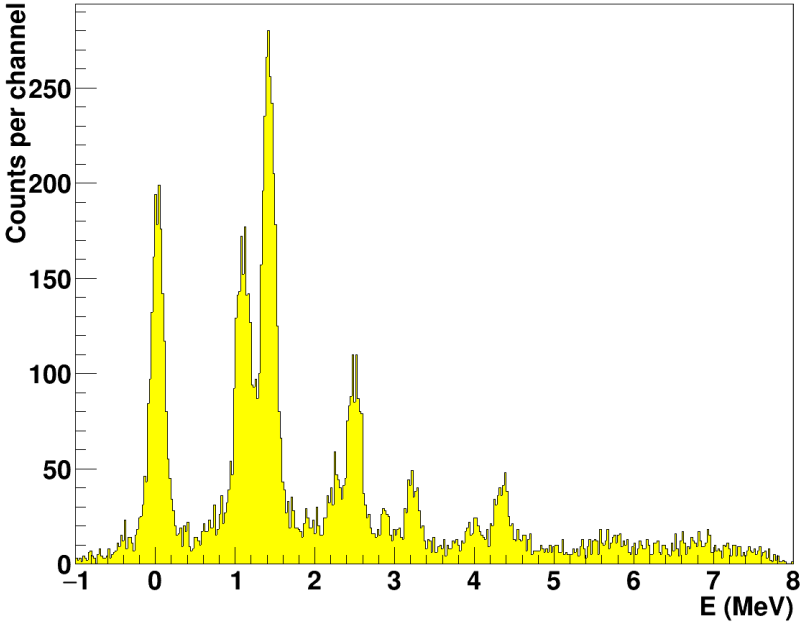


ISOL-SRS Project Update

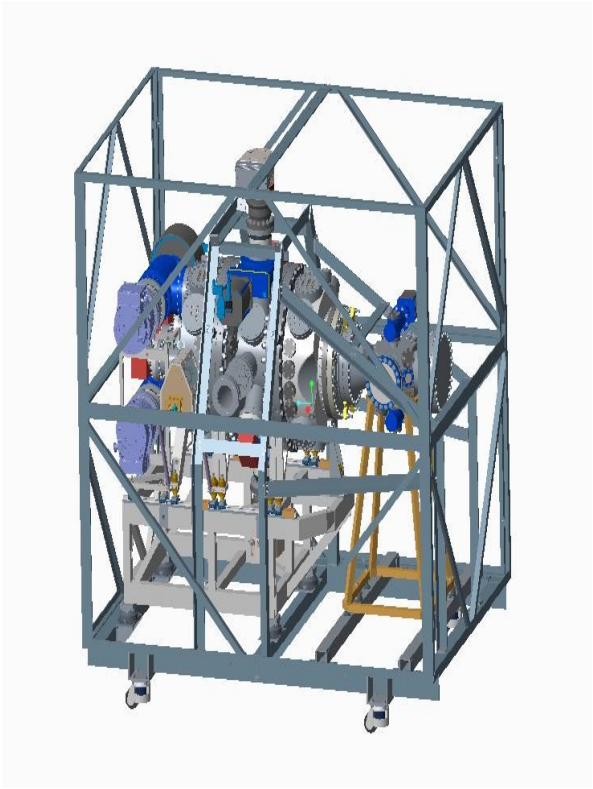
ISOLDE Solenoidal Spectrometer

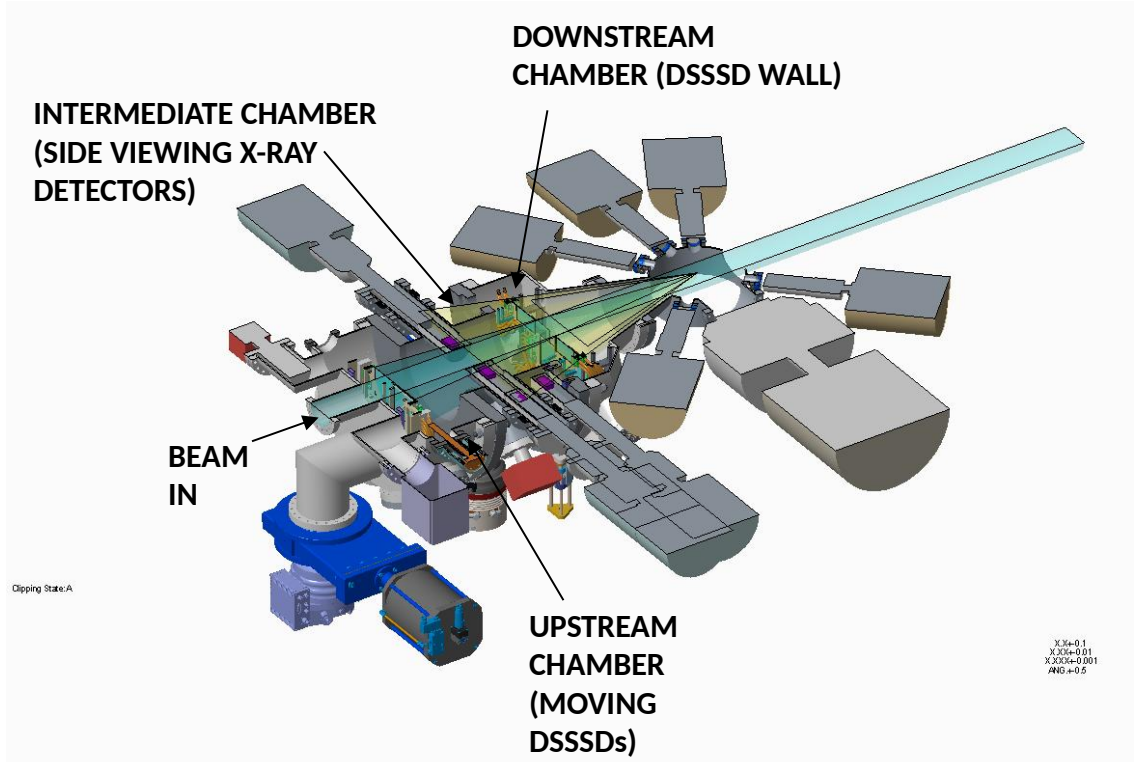






CRYRING Array for Reaction Measurements (CARME)





Technical Design Review (TDR)

- approved by SPARC collaboration – Jan 2018
- approved by FAIR ECE – Oct 2018

XHV chamber tender deadline imminent

Existing projects: Jlab Upgrade

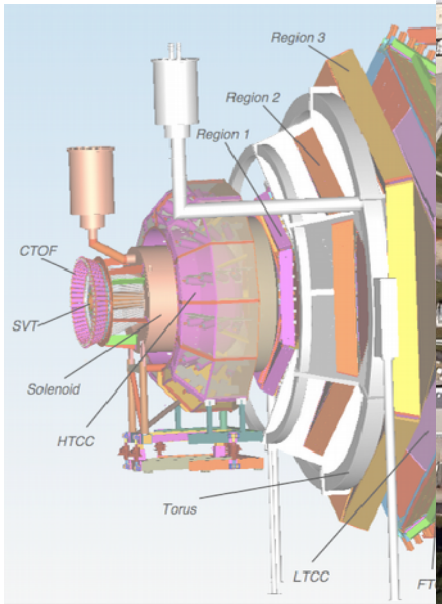
Key elements of

- a Forward Tagger for CLAS12 in Hall B
- the Super Bigbite Spectrometer (SBS) in Hall A

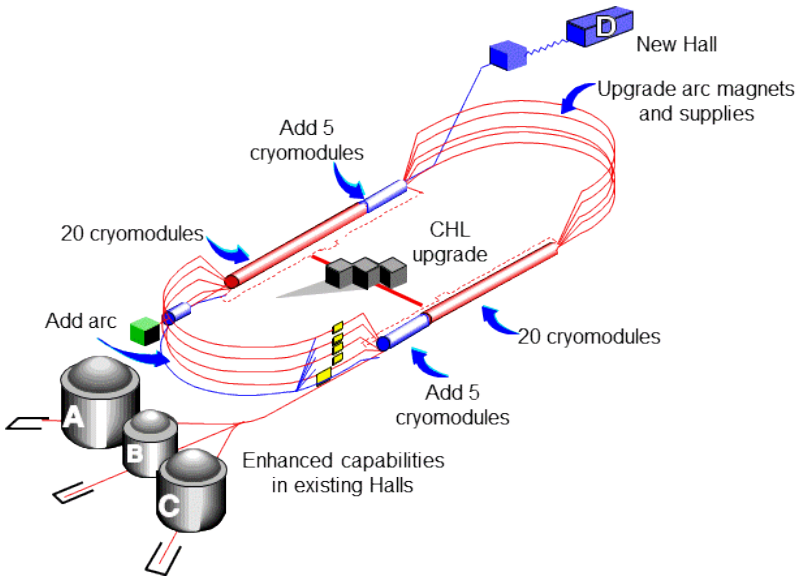
University of Glasgow

THE UNIVERSITY OF EDINBURGH

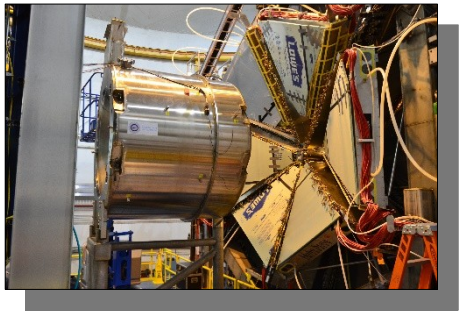
UNIVERSITY of York



12 GeV CEBAF Upgrade Project is Complete!



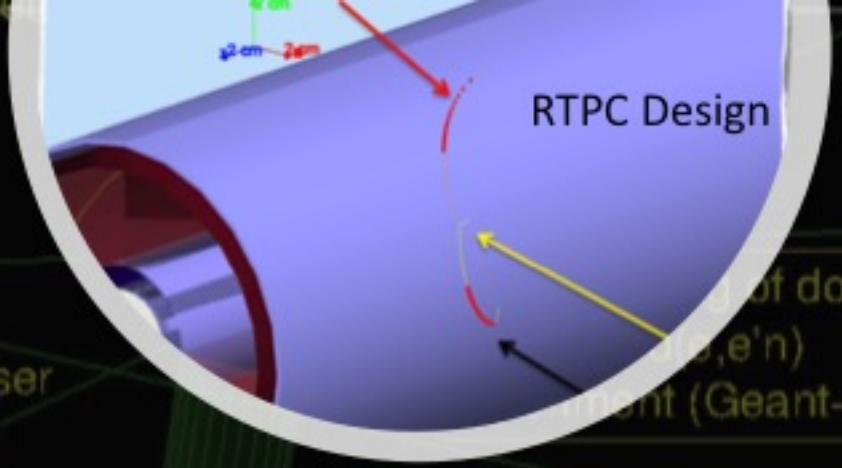
- Double maximum Accelerator energy to 12 GeV and add 10th arc – DONE
- Add new experimental Hall D – DONE
- Civil construction including utilities – DONE
- Upgrade experimental equipment in Hall C – DONE
- Upgrade experimental equipment in Hall B – DONE



Project Status:

- **Complete!**
- **Total Project Cost = $338M**
- **All Key Performance Parameters demonstrated**
- **All Level 2 milestones complete**
- **All project scope has been delivered**
- **Final task completed: cool down of last superconducting magnet with energization test**

Project Completion Approved September 27, 2017

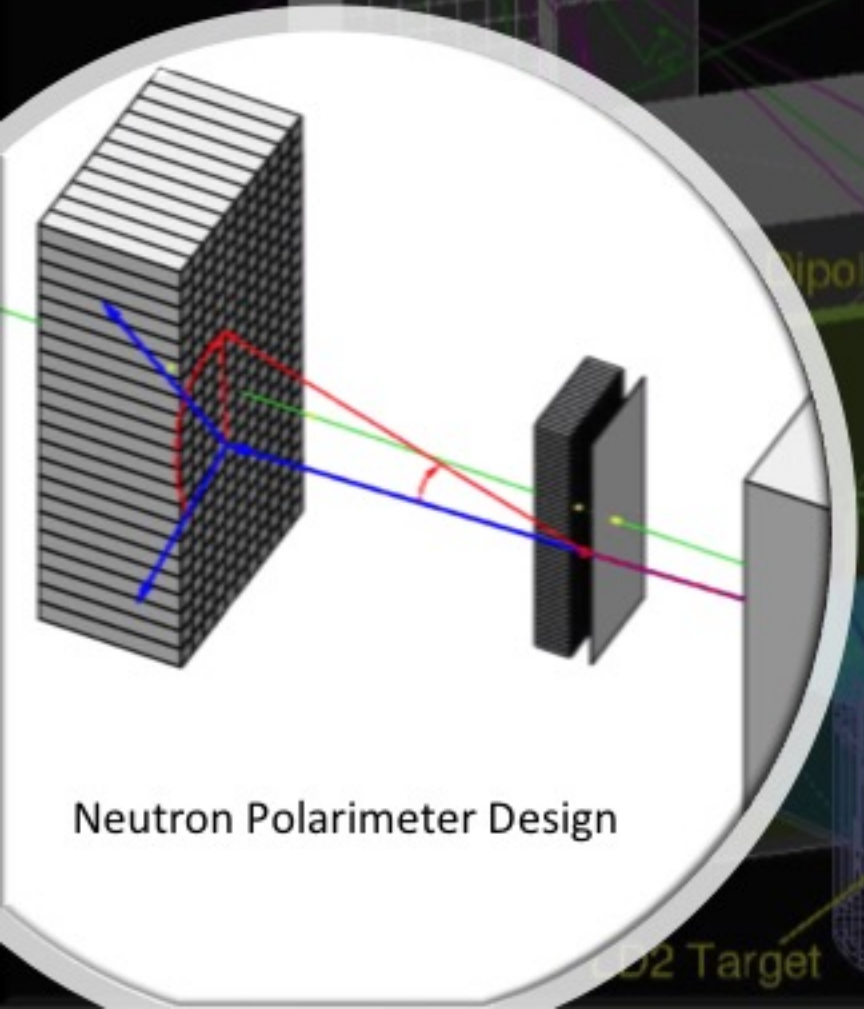


Analyser

BigBite Electron Arm

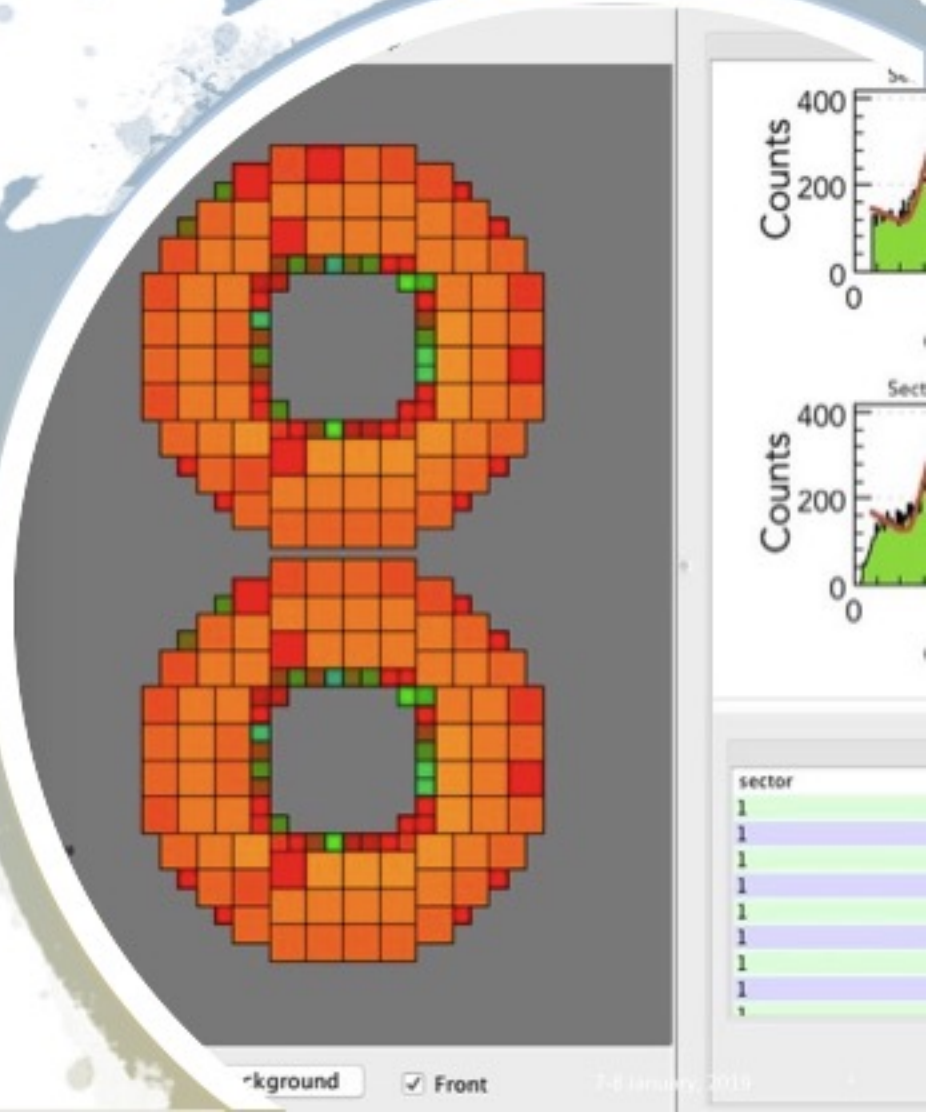
Timing Hodoscope

Hall A



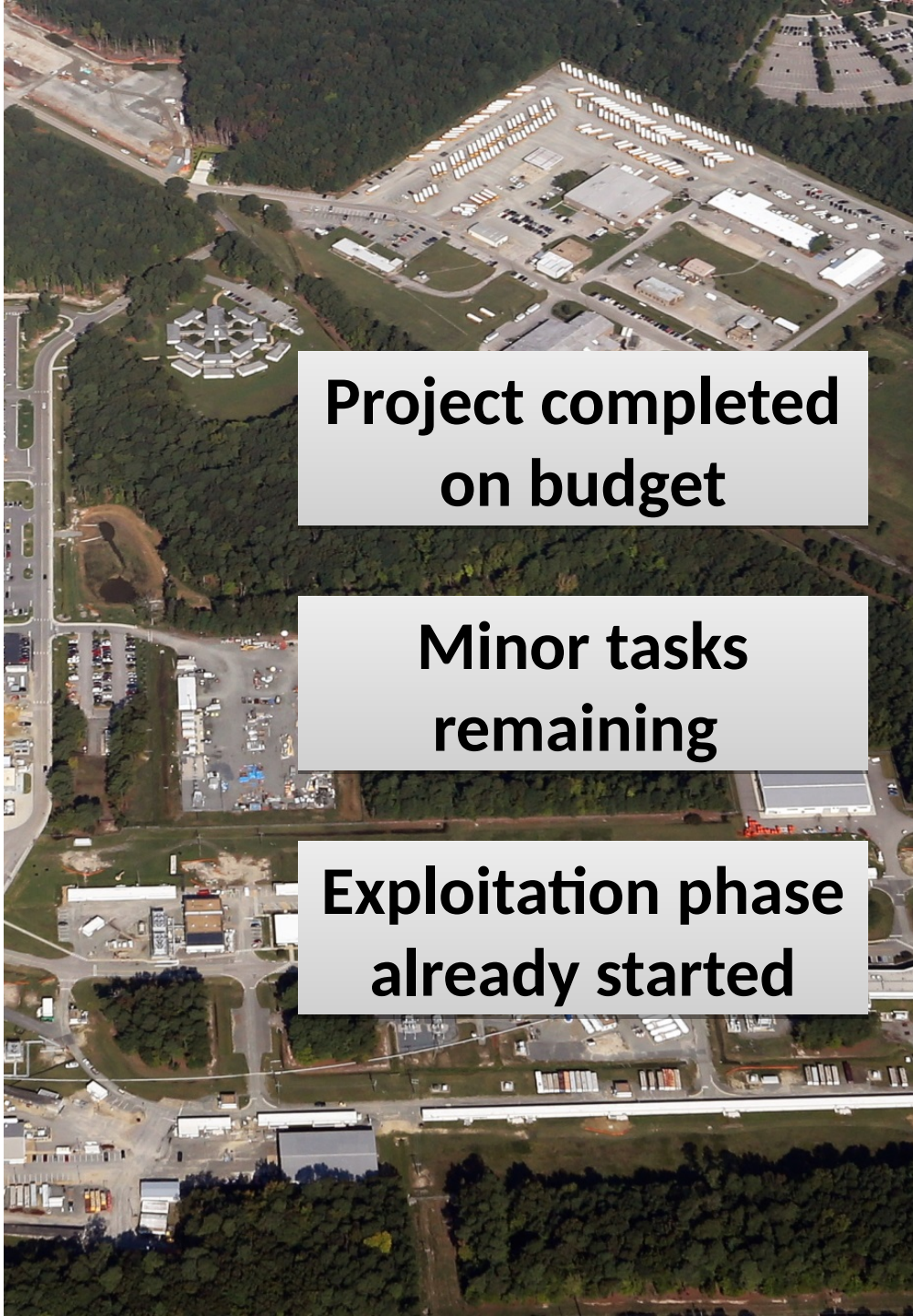
Neutron Polarimeter Design

Electronics Readout for New Spectrometers



Hall B:
- Forward Tagger Hodoscope
- Slow Controls

JLab Upgrade Summary



University of Glasgow

The University of Edinburgh

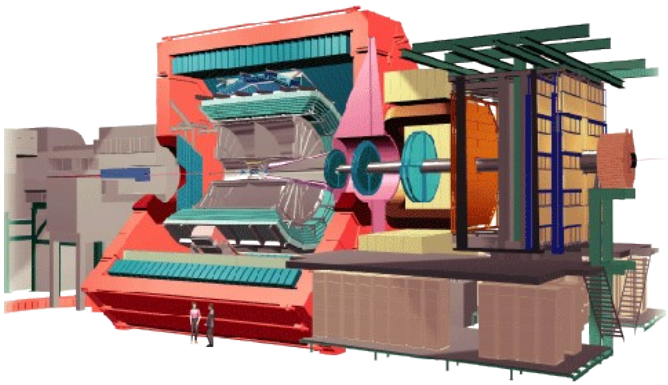
University of York

7-8 January 2019

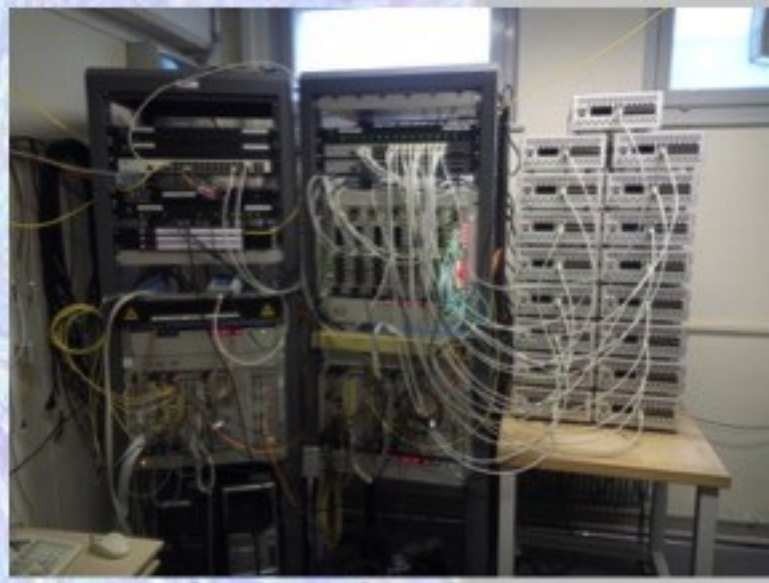
NP Community Meeting, Warwick

Existing projects: ALICE upgrade

- ALICE upgrade
- Upgrade of the Inner Tracking system and Trigger



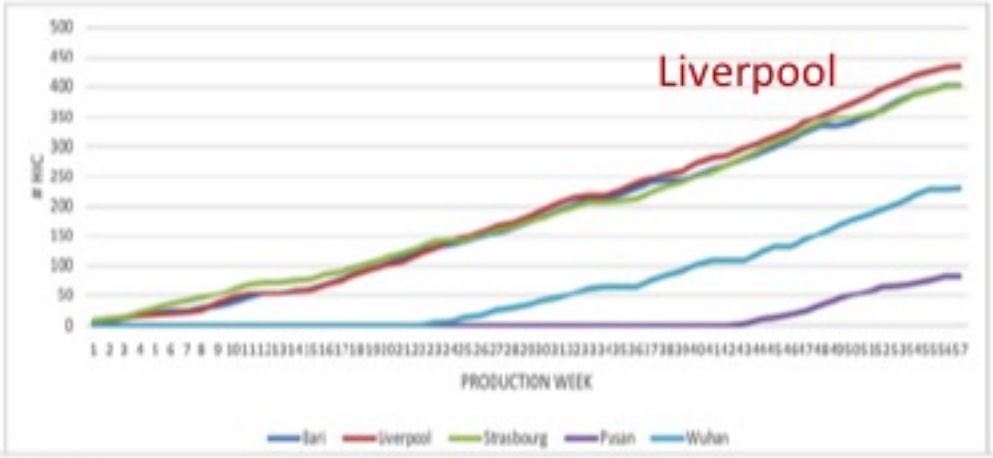
ALICE Trigger Upgrade Status (Birmingham)



- **Phase I production completed April 2018 (23 boards)**
- **Extensive testing carried out during 2018.**
- Three boards with minor problems repaired.
- Extensive stress (aging) tests carried out on three boards.
- Jitter and skew measures under extreme conditions taken place.
- **Boards exceed ALICE specifications**
- 7 boards delivered to sub-detector groups (with FM & SW)
- Minor modifications made to PCB design
- **Phase II production to begin late January 2019 (31 boards)**
- **Trigger Upgrade in Good Shape**

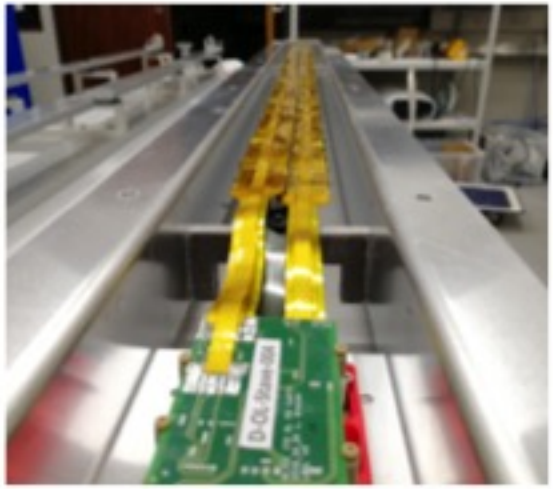
ALICE Inner Tracking System (ITS) Upgrade

is progressing very well



Modules Production (at Liverpool, LSDC)

- Liverpool is leading (quantity and yield).
- Completion of quota on schedule (March 2019), but were asked to continue for few more months.



Staves Production (at Daresbury, ETC)

- First 4 assemblies shipped to CERN before Xmas.
- Good yield and nominal production rate of 1 stave every 2 weeks achieved.
- Completion on schedule (September 2019).

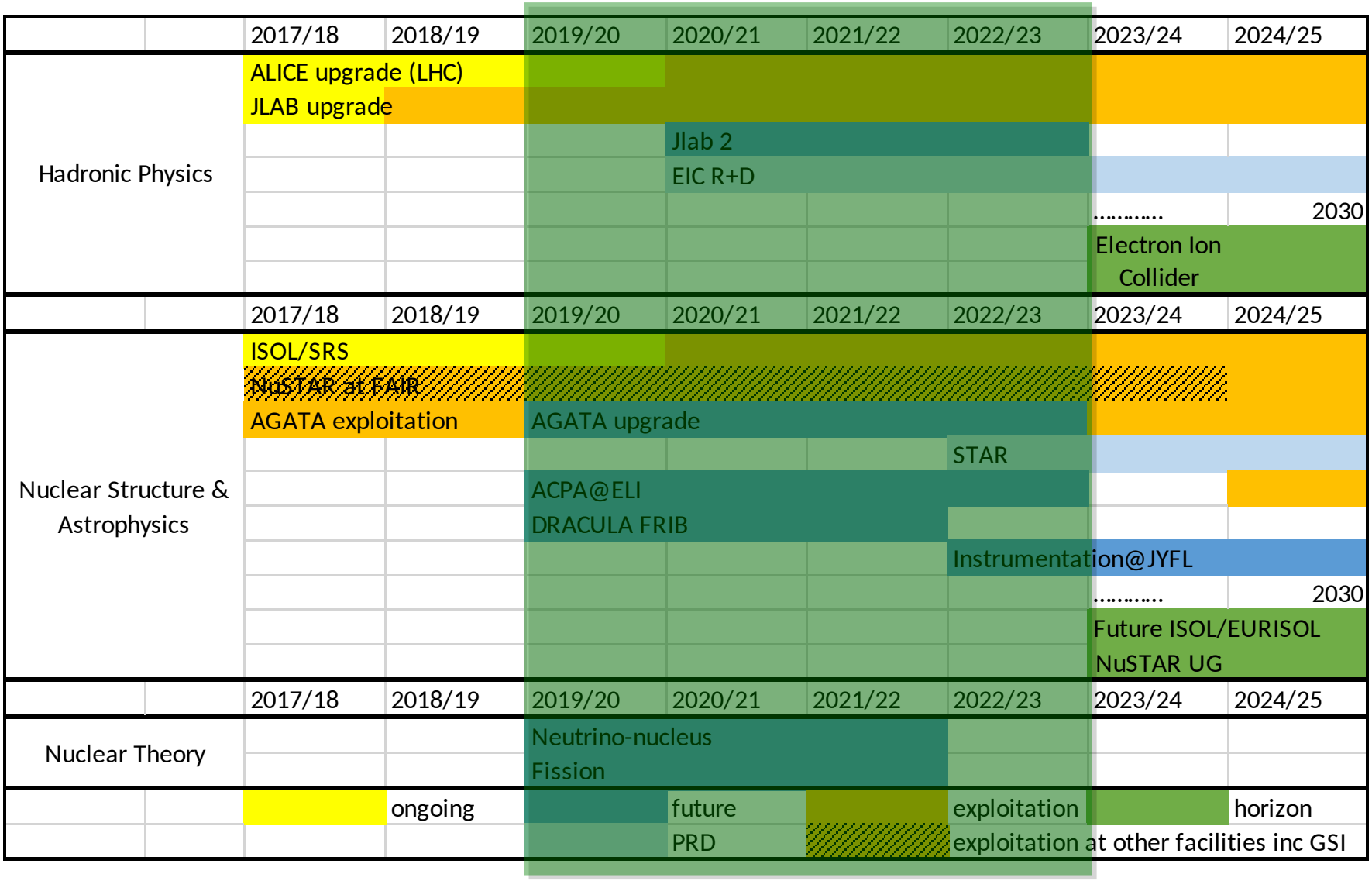
Integration and Commissioning (at CERN)

- Assembly of Outer Layers started before Xmas.
- Major testing and commissioning phase starting in Spring 2019.

Science & Technology Facilities Council
Daresbury Laboratory

UNIVERSITY OF LIVERPOOL

STFC project line £3.65M in the period up to 2022/2023



Future projects and opportunities

Near-term

- Advance charged-particle array (ACPA@ELI)
  - Silicon based granular array with a focus on **ELI-NP** Gamma-beam applications
- DRACULA
  - Direct Reaction Array for the Core Understanding of Light-nuclei and Astrophysics
  - Silicon based granular array with a focus on **FRIB** for use with GRETA
- AGATA: Precision Spectroscopy of Exotic Nuclei
  - Beyond 1pi
  - Additional gamma detectors and optimisation of signal decomposition
  - Focus on **SPES** and **FAIR** (HISPEC)

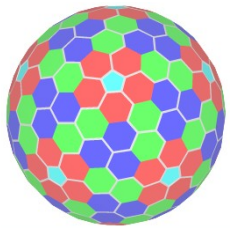
FAIR
Facility for Antiproton and Ion Research in Europe GmbH

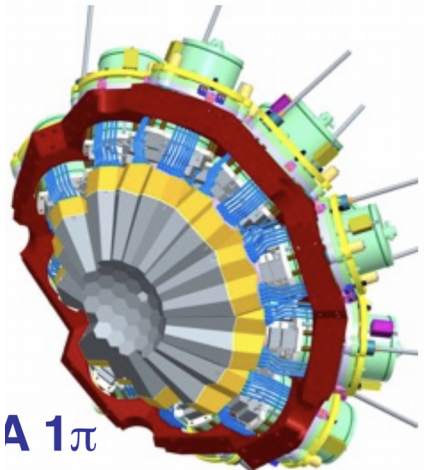
AGATA
ADVANCED GAMMA TRACKING ARRAY

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

SPES Project

AGATA: Precision Spectroscopy of Exotic Nuclei





AGATA at SPES (2022-2025)

Precision spectroscopy with high-intensity exotic beams.

Relatively high beam intensities:
e.g. ^{134}Te 8.5x10^{9}; ^{132}Sn: 7.5x10^{7}; ^{94}Rb: 7.0x10^{8} (pps)

INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Legnaro

SPES Project

Physics opportunities:
- Nucleon transfer
- Multinucleon transfer and deep-inelastic experiments
- Coulomb excitation
- β decay spectroscopy
- Fusion evaporation (high intensities and energies)

AGATA at FAIR: (> 2025)

Precision spectroscopy with high-intensity fragmentation beams.

Fragmentation beams:
- Competitive especially for heavy fragment beams
- Strong population of isomeric

Precision spectroscopy:
- < 1.5% energy resolution at β~0.5
- Gamma-gamma capability
- High-β lifetime techniques

FAIR
Facility for Antiproton and Ion Research in Europe GmbH

Reaction techniques:
- Nucleon knockout – esp. 2N knockout
- Multi-nucleon removal/fragmentation
- Coulomb excitation

NEW AGATA Project Grant – SOI Approved

SOI: Submitted Nov 2017, Feedback from SB Jan 2018, Programme Evaluation submission May 2018, more info August 2017, invitation to make PPRP bid late Nov 2018, PPRP deadline end Jan 2019

SOI estimate: £4.0M

Key points:

- Bid meets our commitment under the current MoU (to contribute to 60-detector array)
- Case aimed at SPES and FAIR with a case for a 90-detector array (its growing!)

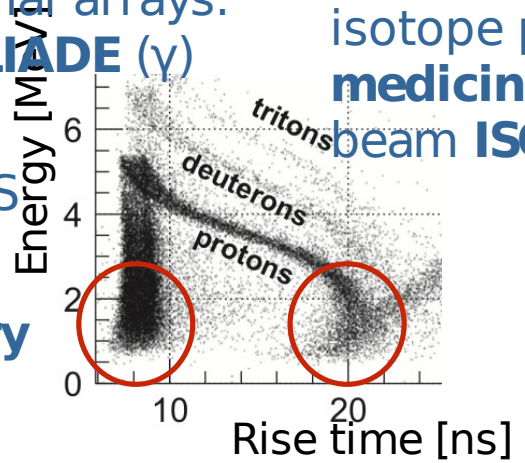
WP1 Capital Equipment: (York, UWS). Two AGATA units (6 detectors) associated infrastructure.
WP2 Electronics and Data Acquisition: (Daresbury, Liverpool).
WP3 Mechanical Design: (Daresbury)
WP4 Pulse-Shape Analysis (PSA) (Liverpool, York)
WP5 Experiment Design and Array Performance: (York, Daresbury)
WP6 Project Management (York, Daresbury, Liverpool, UWS)

Institutions (involved in Project): York (Bentley, Paschalis, Petri), Daresbury (Simpson, Labiche, Lazarus…), Liverpool (Harkness-Brennan, Boston A, Nolan, Boston H,…), UWS (Smith)

The Advanced Charged-Particle Array @ ELI-NP GBS

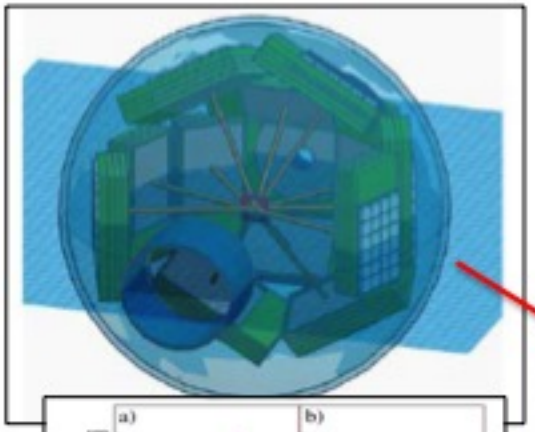
- Compact, segmented (DSSSD) silicon array with digital PSA for light-ion v.s. electron selectivity and low-energy capabilities.
- Timing: 2020-2024 (accepted SOI)
- Full submission April 2019, awaiting Jan 2019 EU Commission report addressing current dispute with (part of) EuroGammaS. Full EU+Romania commitment and funding extended appropriately.
- Potential coupling to external arrays: **ELIGANT-GN** (γ+n) and **ELIADE** (γ)
- ACPA@ELI demonstrator installed at ELI-NP and HIγS for ^{7}Li(γ,t)α (2017)
- **York, Liverpool, Daresbury Birmingham, West of Scotland, Shef eld H.,**

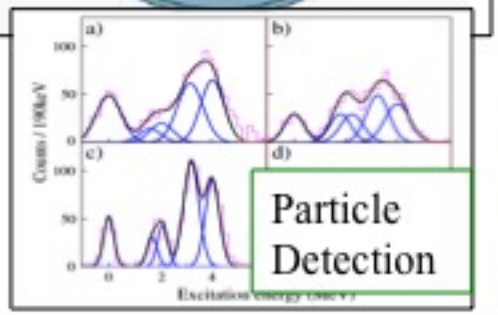
- **Clustering and light-ion dynamics**, including: 7Li(γ,t)α; 9Be(γ,n)2α; and 12C(γ,3α) for nuclear structure/dynamics and **Big Bang Nucleosynthesis**
- **Collective phenomena**, including Pygmy dipole resonances and the impact of **deformation** on alpha capture.
- **Fission dynamics** and barrier heights, including their impact on: neutron-star r-process; isotope production for **nuclear medicine**; and selectivity in γ-beam **ISOL production**.



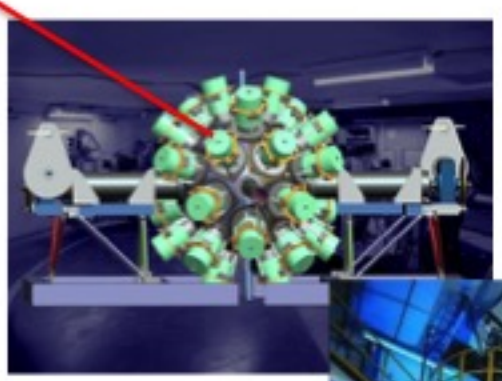
ELI & ACPA Collab.: Tuturica et al., 10.1016/j.nima.2018.12.048
Mengoni et al. NIMA 764:241 (2014)
Diget, et al. ,J. Inst, 6:P02005 (2011)

Direct Reaction Array for the Core Understanding of Light-nuclei and Astrophysics

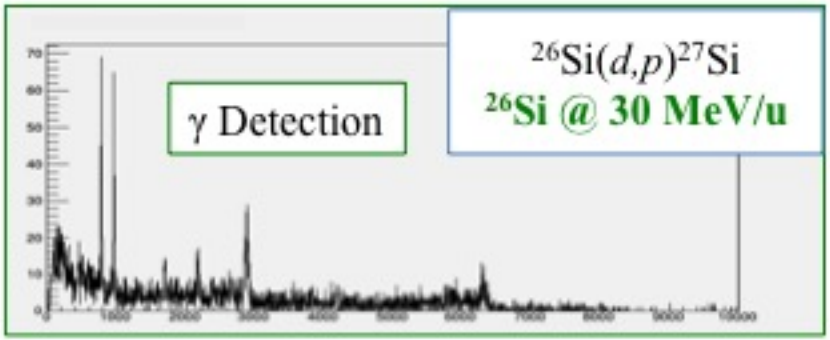


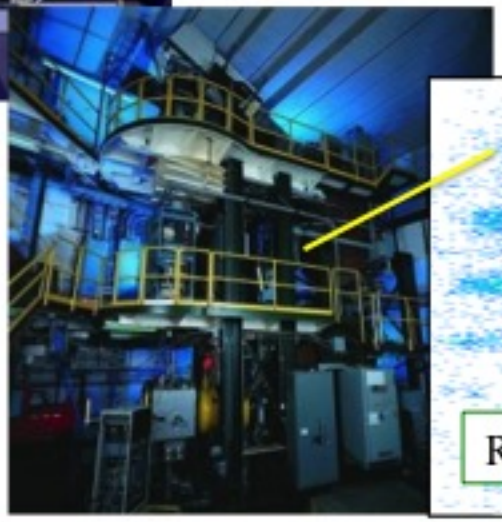


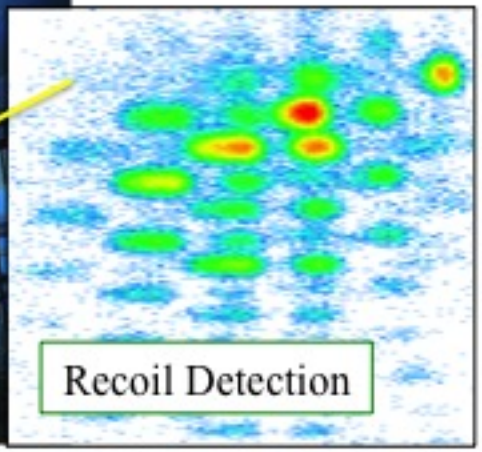
- **DIGITAL** Charged-particle array for reaction studies at **FRIB** (RIBs @ 30 – 50 MeV/u)
- Si telescopes backed with CsI provide necessary stopping for high-energy light particles

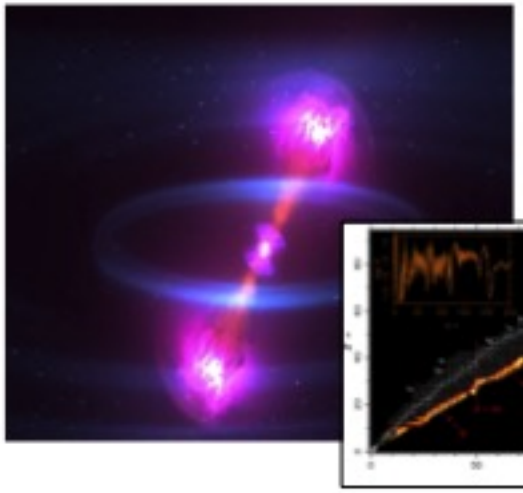


- γ's detected in **GRETA** 4π array for high-resolution and **S800** used for recoils





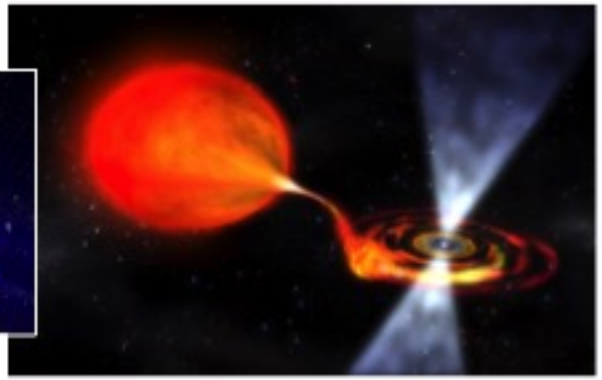




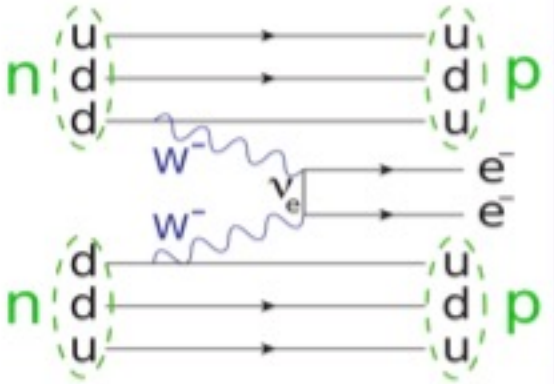
- Direct investigation of *r* process reactions and insight into neutron star mergers [e.g. ^{76}Ni(*d*,*p*)^{77}Ni as a surrogate for (n,γ) reactions around ^{78}Ni]

- Study of *rp* process and X-ray bursts – targets of the ESA's ATHENA satellite [e.g. resonance strengths in the ^{56}Ni(α,*p*) reaction via ^{56}Ni(^{6}Li,*d*)]

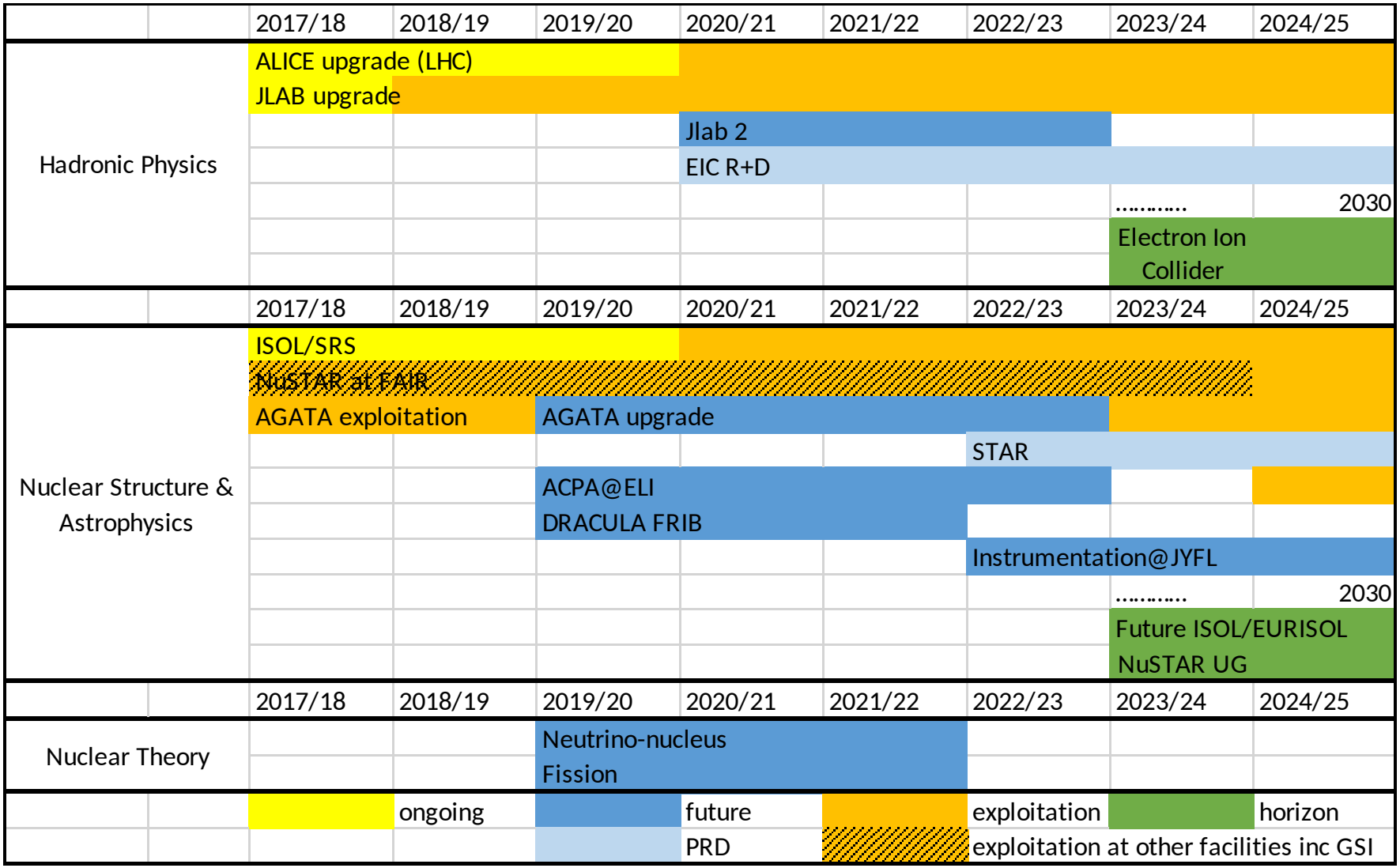
- Electron capture processes in core collapse supernovae to determine explosion mechanism [e.g. unique (*d*,^{2}He) reactions on unstable nuclei @ 100 MeV/u]



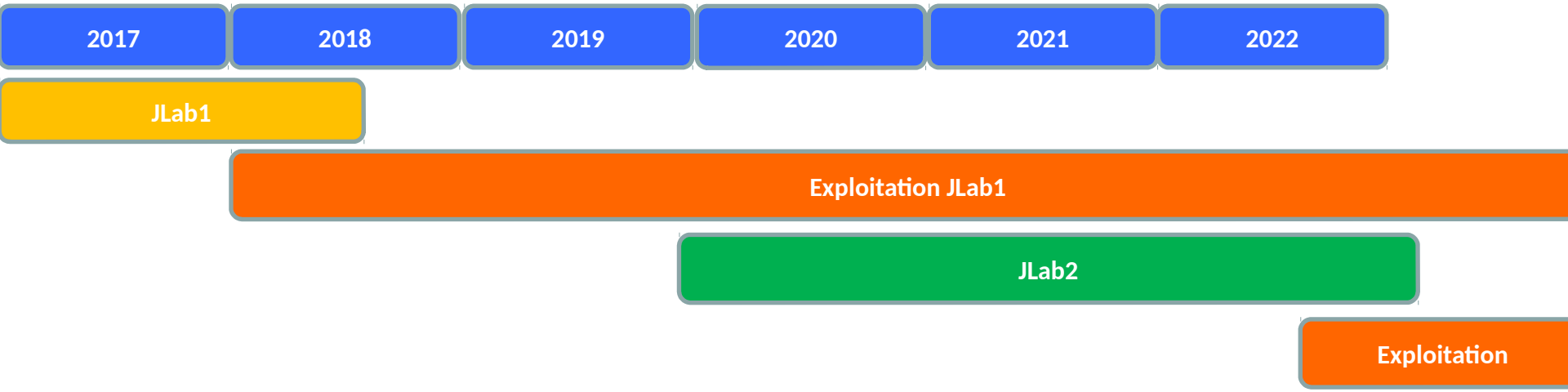
- Investigate configurations of valence nucleons that play a key role double β-decay transitions [e.g. perform globally unique (*d*,3He) reactions on medium-mass nuclei that are targets of $0\nu2\beta$ experiments]



Roadmap for existing projects and future opportunities



JLab2 Project



- Consolidate UK's leading role in next generation JLab science

  -> Compact γ sources. 3-4 orders of magnitude increase in intensity

  -> Electromagnetically generated strange hadron beams of unprecedented intensity and purity

- Existing JLab detector systems utilized in the new science programme

University of Glasgow

University of York

JLab2 Project

Compact γ source in Hall A

Utilise intense beams for nucleon structure studies (e.g. nucleon Compton scattering)

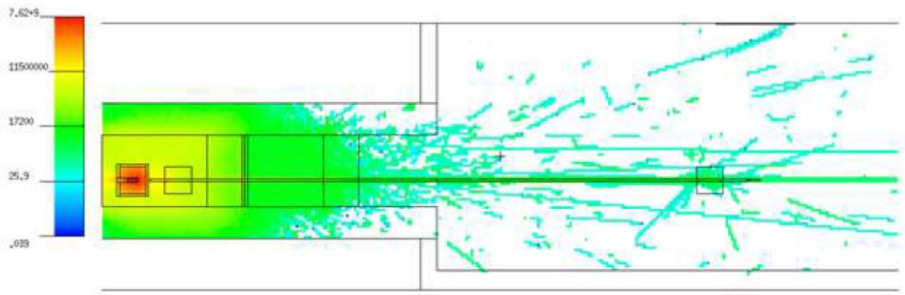
- Achieve double-polarization data not within reach of current electron/photon beam facilities
- Reach new regimes of momentum transfer in nucleon structure studies
- UK PI's on key proposals

Hi-Lumi CLAS 12

Enable CLAS12 to run at full JLab luminosity -> increasing science output (or decreasing beamtime) by over an order of magnitude,

Novel experimental trigger developments, DAQ developments

K↓long Facility



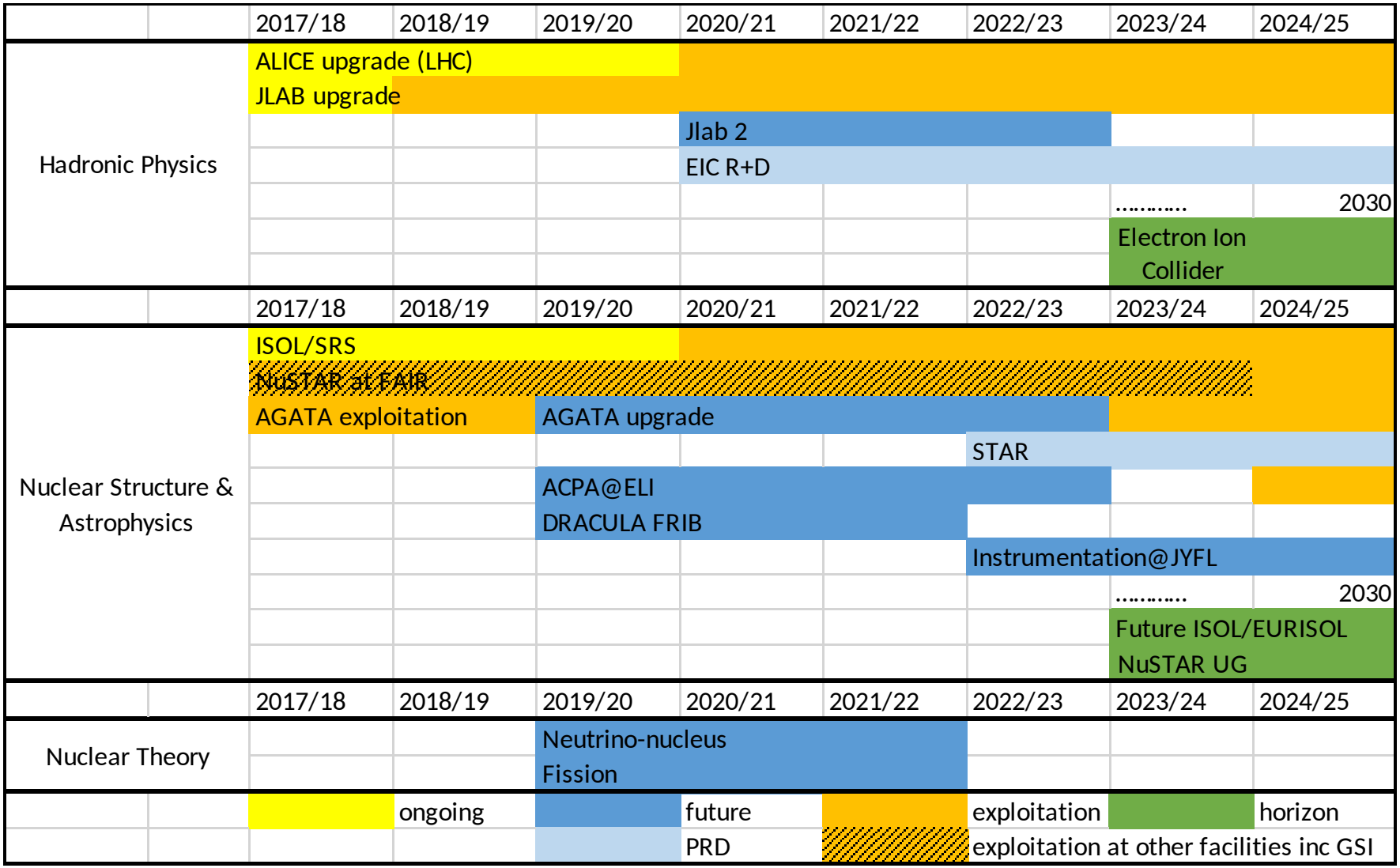
Next generation EM produced neutral Kaon beam:

- 30 institutions (EU, USA,China, Russia)
- One of largest collaborations assembled at Jlab
- UK CoPI for proposal
- UK leads R&D and construction for Kaon beam monitor ($0.8M out of $8M total cost)

Kaon beam - key for progress in strange quark sector

Double- and triple-strange baryons (Ξ, Ω)
-> Challenge to non-perturbative QCD
-> Pivotal role in quark-gluon to hadron transition in early universe
CP violation, exotic states (e.g. hexaquarks), ..

Roadmap for existing projects and future opportunities



The Electron-Ion Collider (EIC)

World's first polarised electron-proton/light ion and electron-nucleus collider.
Two sites under consideration: Jefferson Lab and Brookhaven National Lab, USA.

- **2007 Nuclear Physics Long Range Plan** *"The EIC is embodying the vision of reaching the next QCD frontier"*
- **2012 EIC White Paper,** *Eur. Phy. J. A 52, 9 (2016)*
- **2015 Nuclear Physics Long Range Plan** *"high-energy, high-luminosity polarised EIC as the highest priority for new facility construction following completion of FRIB"*
- **2017-18 National Academies of Science (NAS) Review:** *"the science questions that an [EIC] would answer are centra to completing our understanding of atomic nuclei… An EIC can* ***uniquely*** *address three profound questions about nucleons … and how they are assembled to form the nuclei of atoms"*

- Next stage: ***CD0*** (formally establishing mission need), expected within ~ a year.
- Construction some time in 2020s!
- European meetings of the EIC Users Group (EICUG): Trieste, Italy (2017)

EICUG2019, Paris, France
July 22-26, 2019

UK involvement

✦ Glasgow, Birmingham, York, Liverpool, Derby, Daresbury, Cockcroft, John Adams Institute

FUNDED:

✦ **Horizon-2020 European Integrating Initiative in Hadron Physics funds: 325k€**

"Challenges for next-generation DIS facilities" ***(2019-23), half of the funds to UK***

Spokespeople: Daria Sokhan (Glasgow) and Francesco Bossi (CEA Saclay, France)

Glasgow, Birmingham, York, INFN, Saclay, CNRS, …

A collaborative European effort focussed on EIC detector R&D and simulations.

✦ **DoE funds through EIC detector R&D programme: $250k over past 3 years.**

"Precision Central Silicon Tracking & Vertexing for the EIC" ***(ongoing: 2017-19)***

Birmingham: Laura Gonella, Peter Jones, Paul Newman, Phil Allport, H. Wennlöf

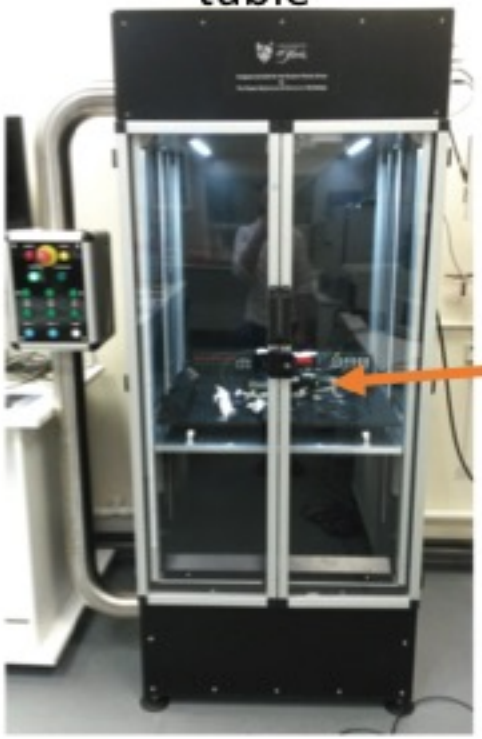
Successful collaboration of nuclear, particle and instrumentation groups, synergies with existing R&D projects. Collaboration with RAL.

Accelerator R&D in ERL technology: synergies with currently funded projects (UK-FEL), direct relevance for EIC. **3 new PhD projects funded, started 2018** (Cockcroft), SOIs in preparation

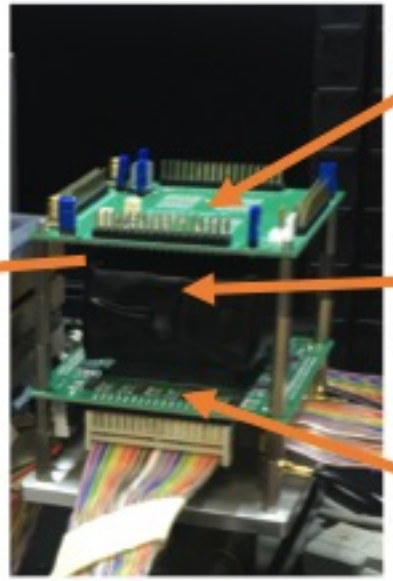
EIC: one of the 52 priority projects in the **UKRI Developing a World Class Research Programme** initiative.

Results from York IPS project

York scanning table

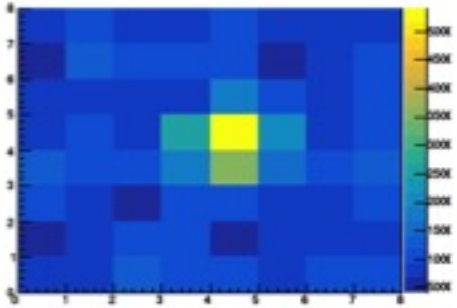


Multiface scintillator readout

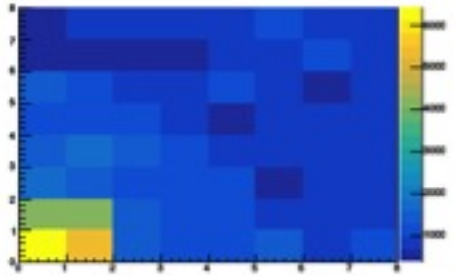


position reconstruction of gamma-ray interaction

Centre illumination



Corner illumination



STAR Project

STAR project: scintillator array

Developments within the project:
Electronic readout
mechanical infrastructure

Performance:
dE 4% at 662 keV and high β
Eff. > 20%

Approx. cost for ½π array:
Equipment and materials £2.5M
Staff time £1.0M

Physics aimed at fast beam facilities:
RIBF, FRIB, FAIR

Contact: stefanos.paschalis@York.ac.uk

UKRI opportunities

- Nuclear Physics Priority projects
  - EIC including Hadron Research Centre
  - ISOLDE storage ring and new target station
  - AGATA 4π
  - DRACULA inc upgrades for the S800 focal plane

- Detector/characterisation centre of excellence building on leadership in sensors for photons and light charge particles