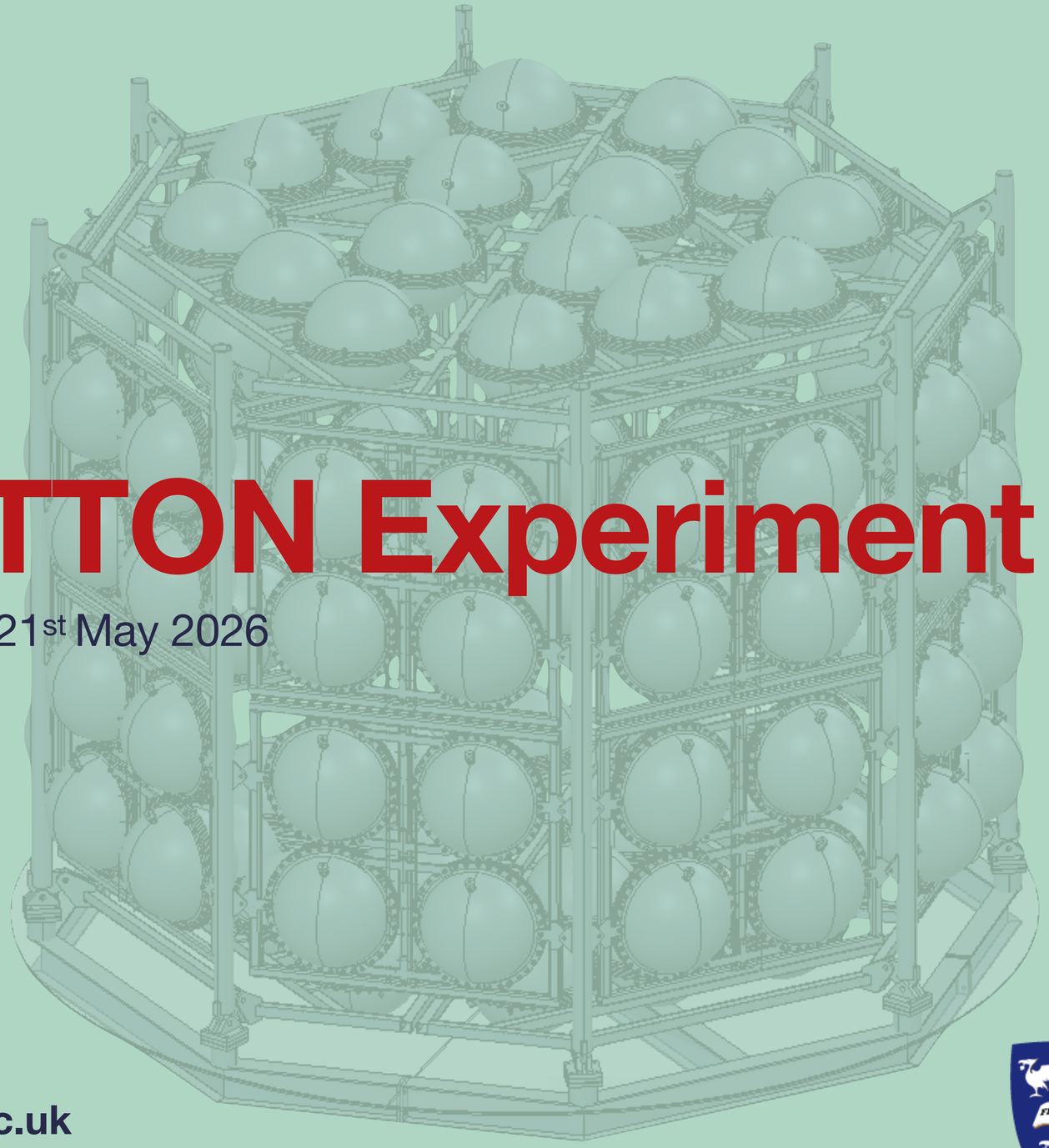

# The BUTTON Experiment

HEP Annual Meeting: 21st May 2026

**Adam Tarrant**
**a.s.tarrant@liverpool.ac.uk**

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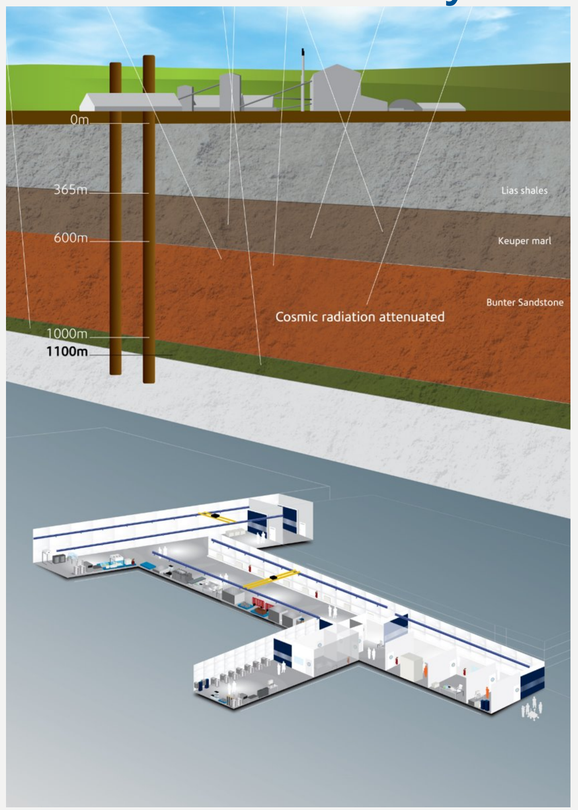
# BUTTON Collaboration

## ~50 members across 15 institutions

Jan 2025 Boulby collaboration meeting

ICL Boulby Mine




THE UNIVERSITY of EDINBURGH

University of Sheffield

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AWE

UKRI Science and Technology Facilities Council

Funded in the UK by STFC from the UKRI Fund for International Collaboration

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# BUTTON at Liverpool

**Carl**

- DAQ Co-lead
- Electronics & Firmware

**Kieren**

- Tank Design & construction
- PSUP
- Water-systems

**Jon**

- BUTTON-30 Project Coordinator & Lead PI

**Jonathan**

- Optical Systems

**Neil**

- Light Injectors

**Adam**

- Simulation and Analysis
- Calibration



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# BUTTON Goodbyes

**James**

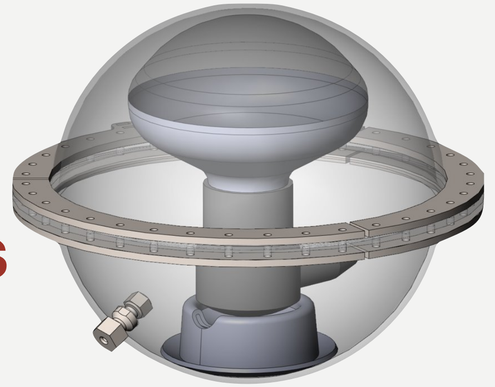
- Left for a job in industry

**Adam**

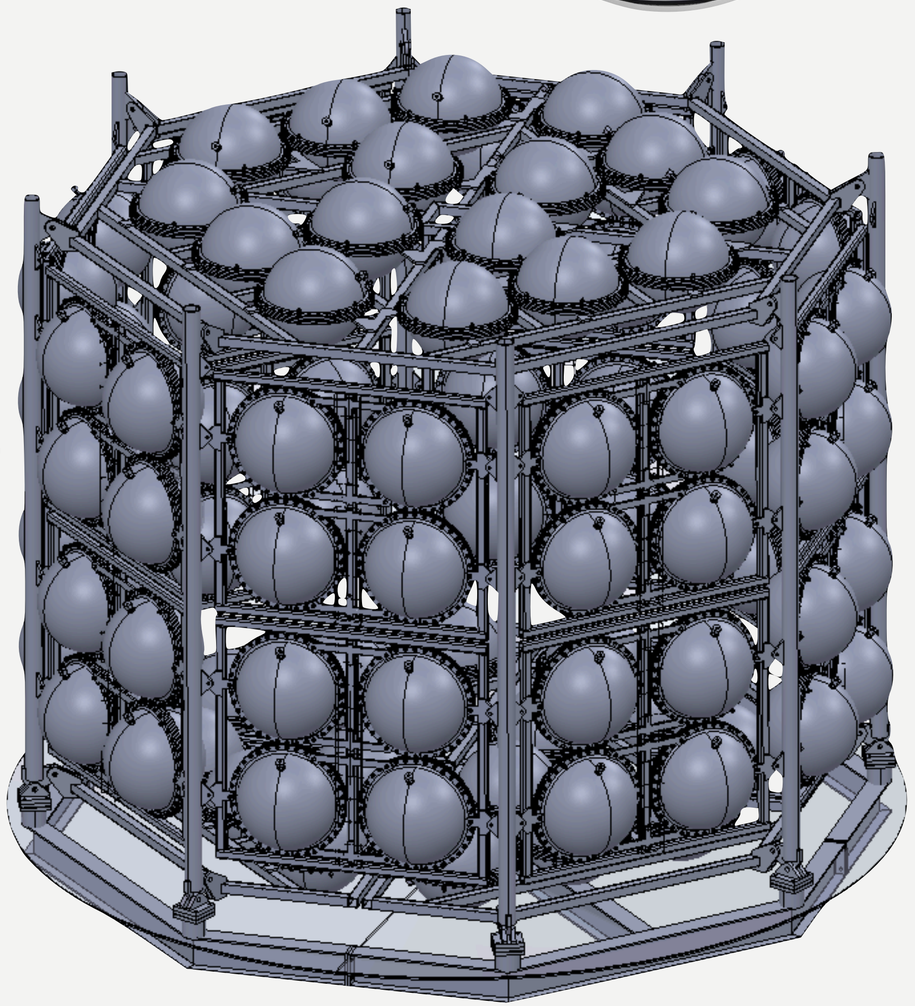
- ‘Unofficially’ leaving in July for Queen Marys working on XLZD

# BUTTON

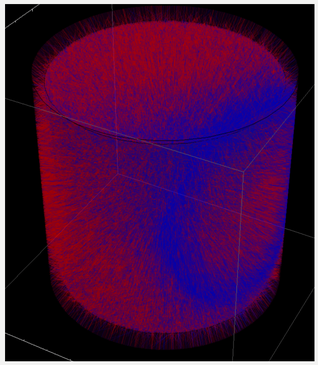
## Boulby Underground TesTbed (for) Observing Neutrinos



- Develop technologies for low background detectors (MeV)
- 30 tonne (r=1.8 m, h=2.7 m) water-Gd/WbLS-Gd tank
  - Gadolinium improves detection of neutrons
- 96 10”  Encapsulated Hamamatsu R7081 PMTs
  - Encapsulation protects PMTs from different fill materials
- Potential for novel photosensor deployment
- First underground deployment of WbLS
- Testing the scaling up of the technology



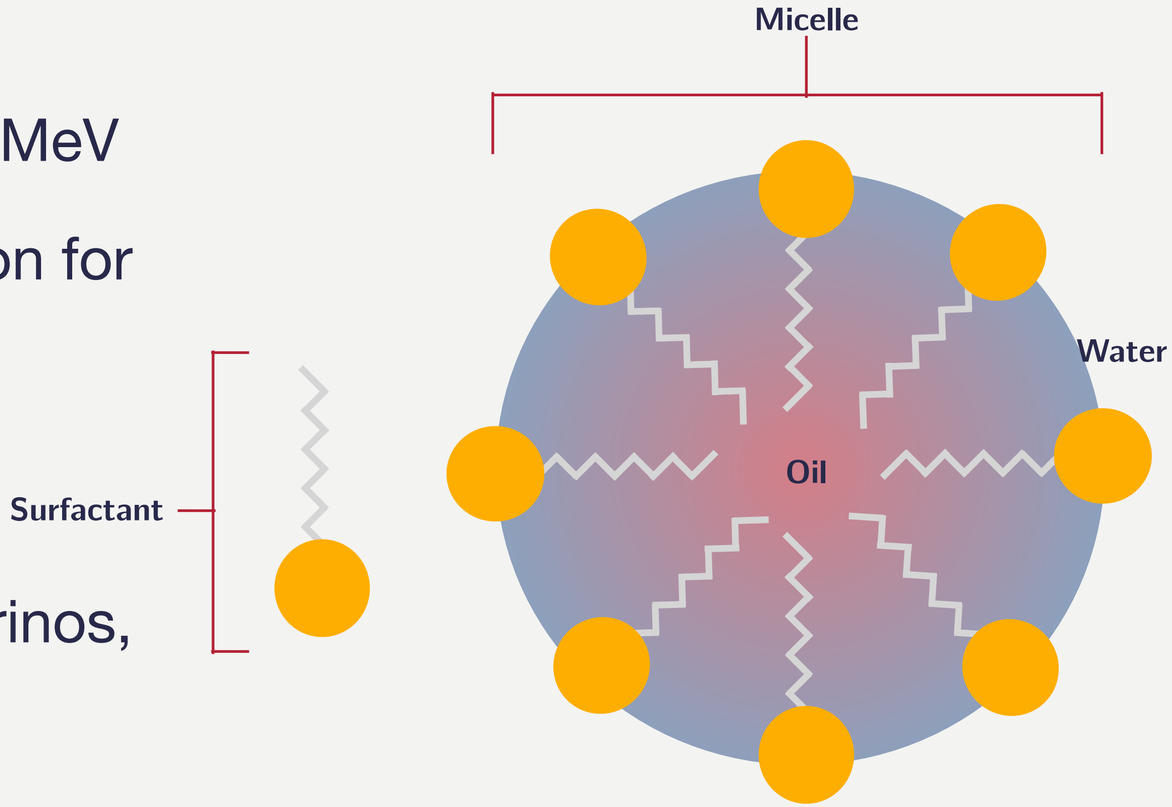
B. Land (Berkeley)



# Water-based Liquid Scintillator

## A Cherenkov scintillator hybrid

- Why not mix water and scintillator?
- 1% scintillator gives ~100 optical photons/MeV
- Keeps the particle identification and position for high energy events
- Lower detection threshold
- Proposed studies from reactor monitoring, neutrinoless double beta decay, solar neutrinos, diffuse supernova backgrounds …
- Potential for use in dark matter vetos (DarkSPHERE, XLZD)



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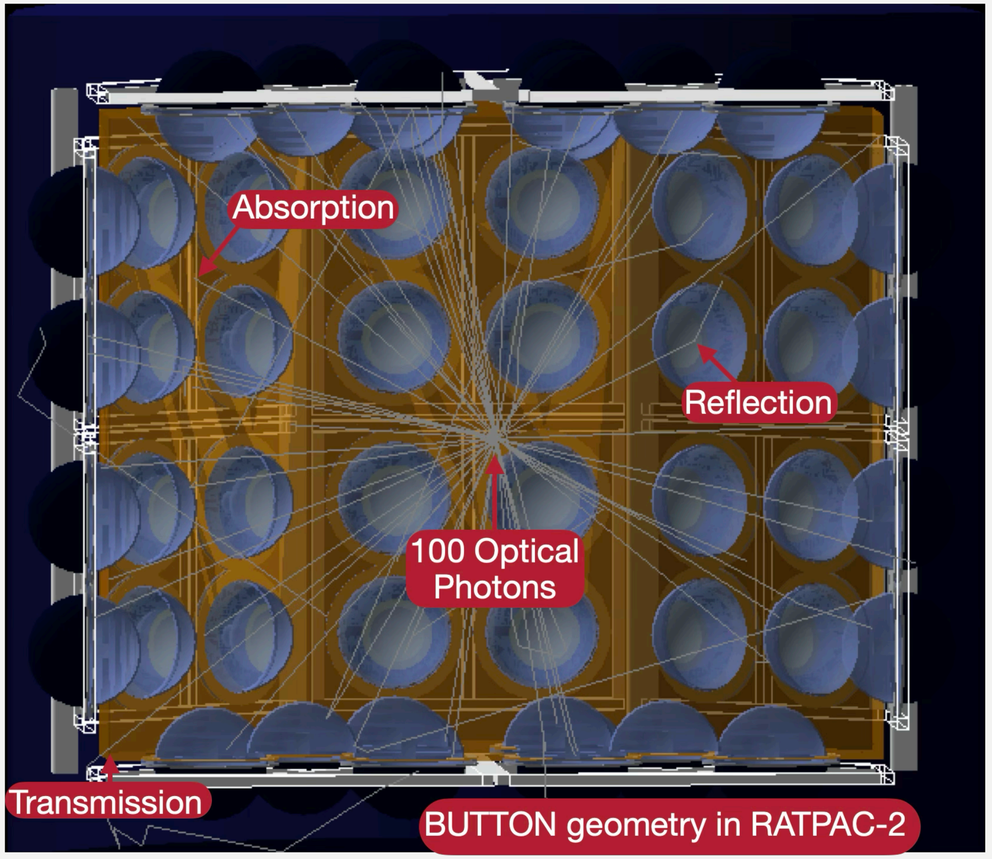
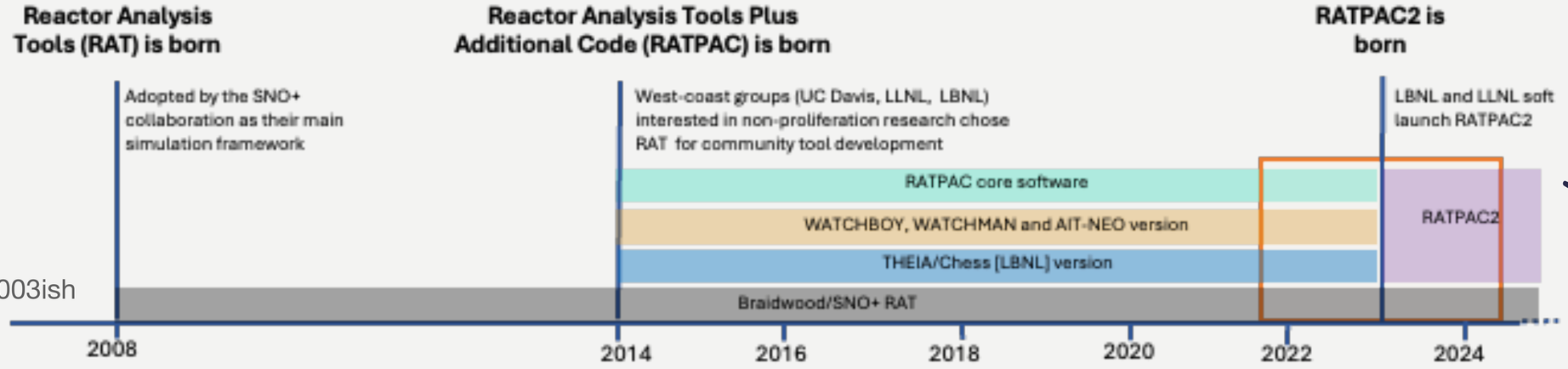
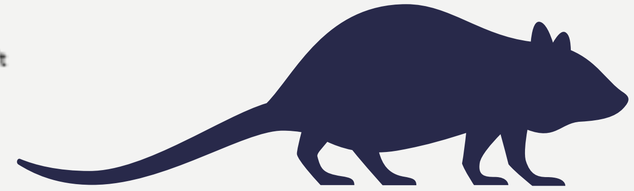
# BUTTON Simulation - RATPAC2

- Sequential Monte Carlo (MC) generator developed by many experiments and collaborators
- Every aspect of the detector can be modelled from optical properties to waveform digitisation
- User can define parameters in JSON file format
- Easy parameterisation of events at the macro level (including arrays and text files) —>Easy studies of systematics




[1]



(1) Marc Bergevin, MC Status, BUTTON Collaboration Meeting, LLNL, 01/15/2025



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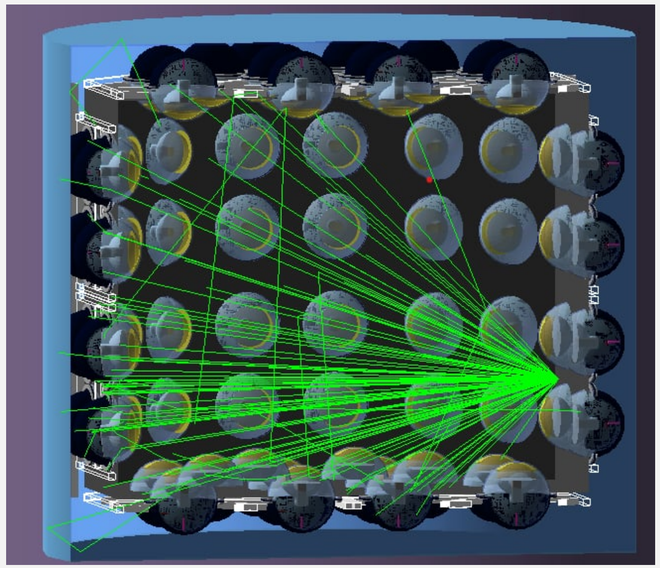
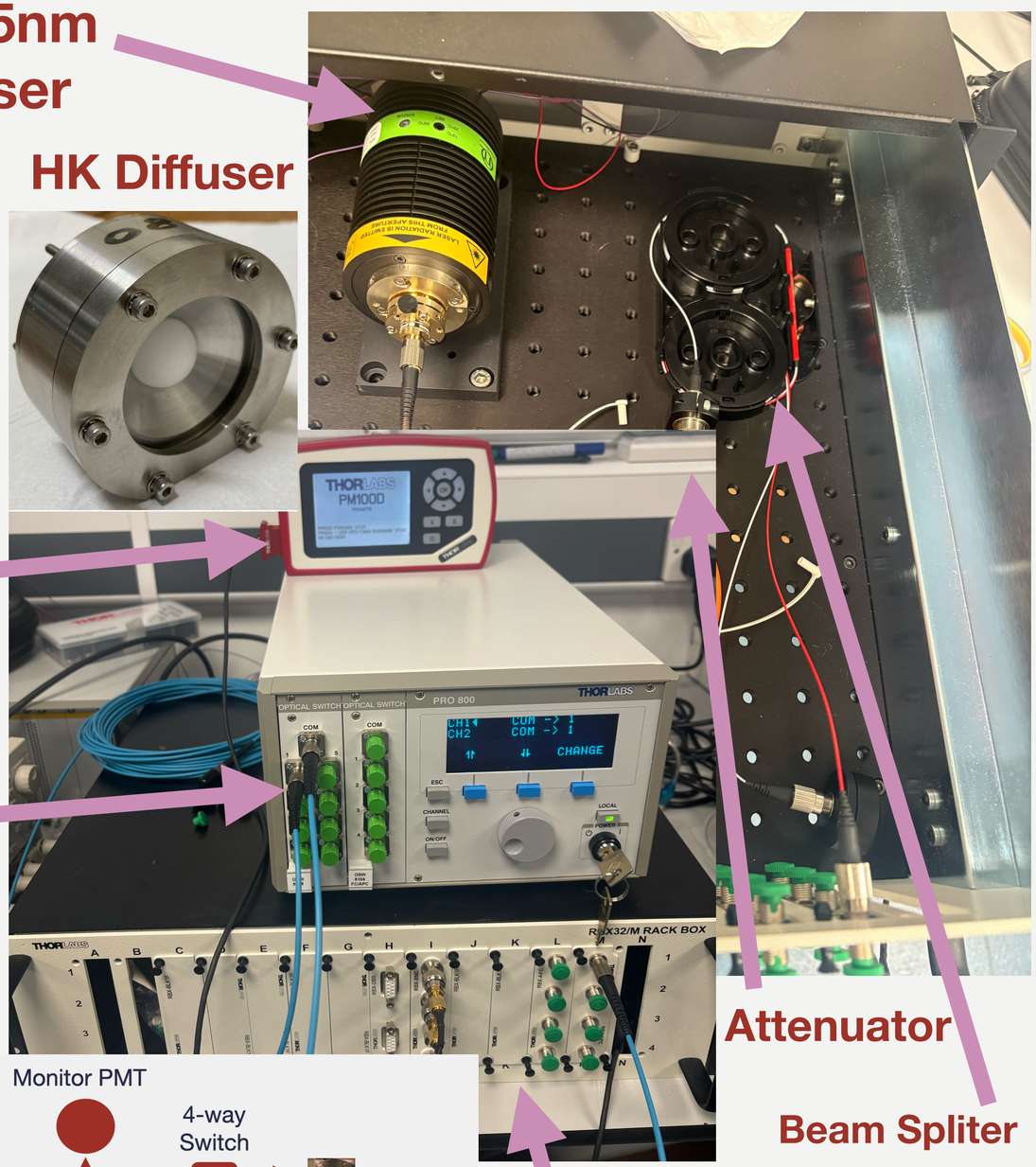
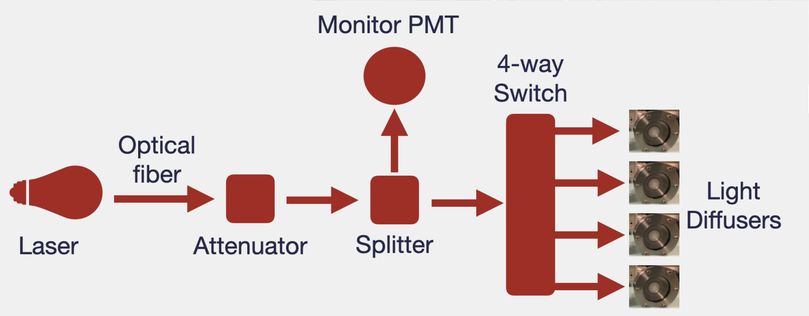
# Light Diffusers Cone

- Light diffuser is a PTFE dome with a 40° opening angle designed for Hyper-K
- Act as a standard candle to calibrate PMTs and monitor water parameters
- Developed the laser system in Chemistry Lab ~ 200 photons per pulse
- Developed in parallel with Hyper-K system
- Simulation of light diffusers to compare to date



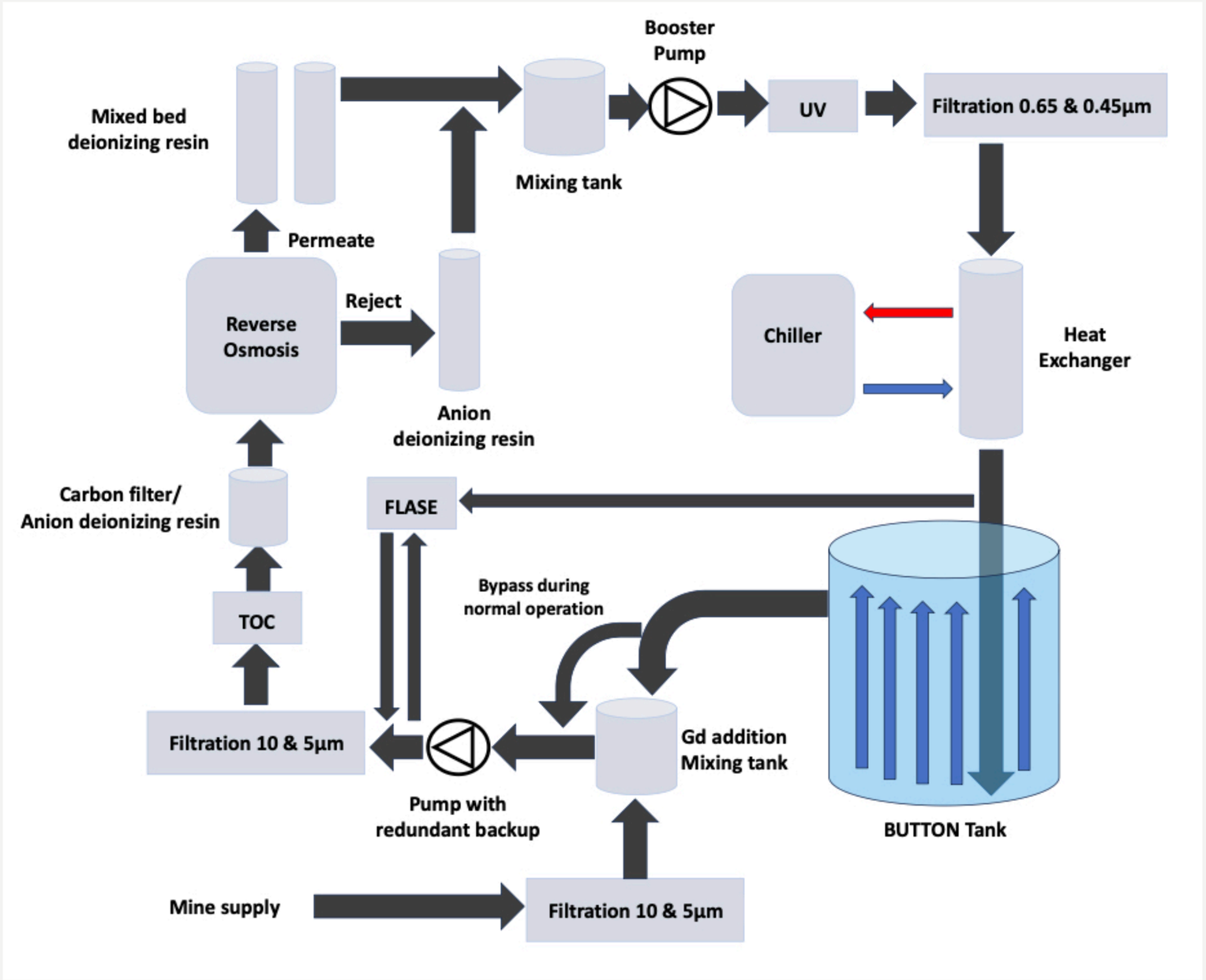


# BUTTON Construction Finished


# Water System

- Designed and Built at Liverpool
- Type 1 grade laboratory water
- Gd Compatible and WbLS Upgradable
- Running rate of 21 litre/ min = one full tank circulation a day



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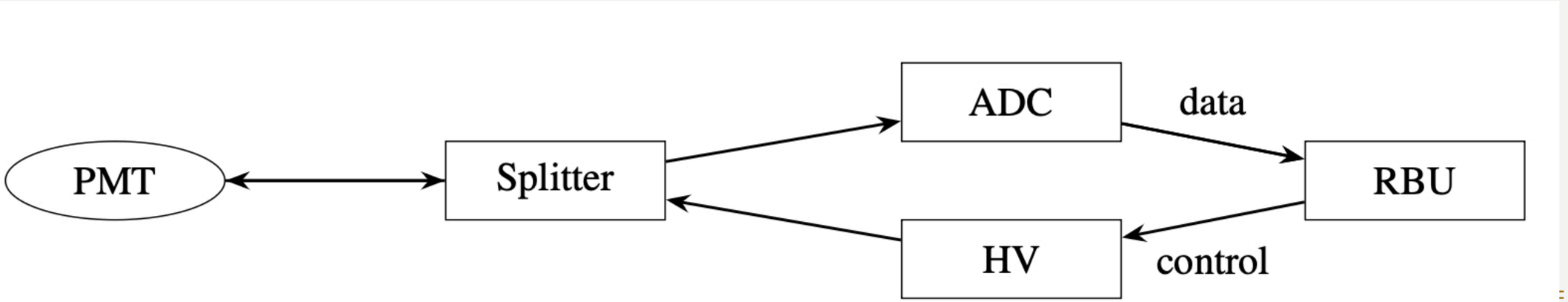
# BUTTON DAQ

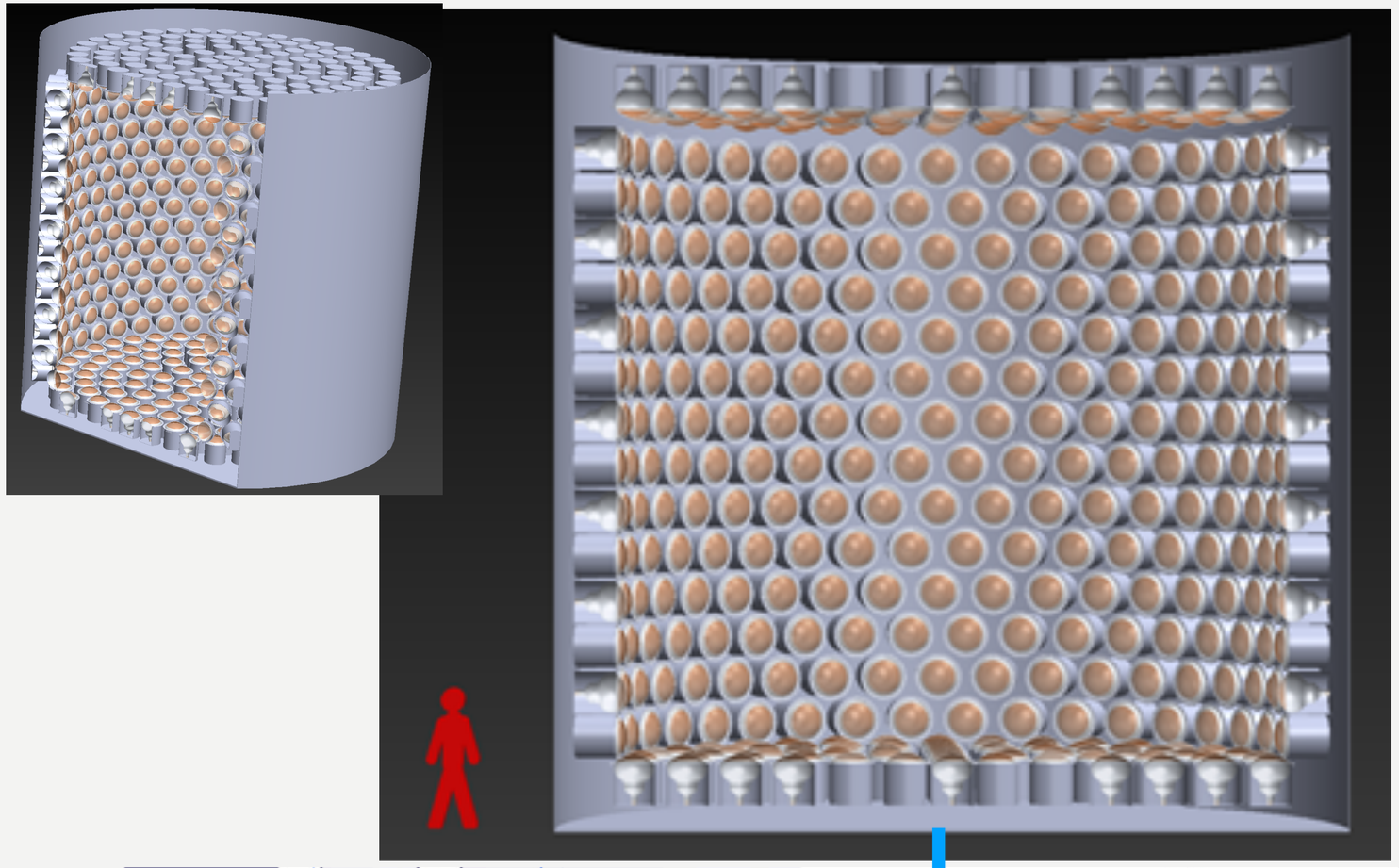
- CAEN V1730 series digitizers are used providing 16 channels per module with signal rate —> 500 MS/s
- TOOLDAQ is used to process signals and also acts as slow control
- Trigger designed to use a dynamic 100 ns time window
- Trigger rate of 50 Hz resulting in 1 terabytes of data a day
- Is a supernova ready system

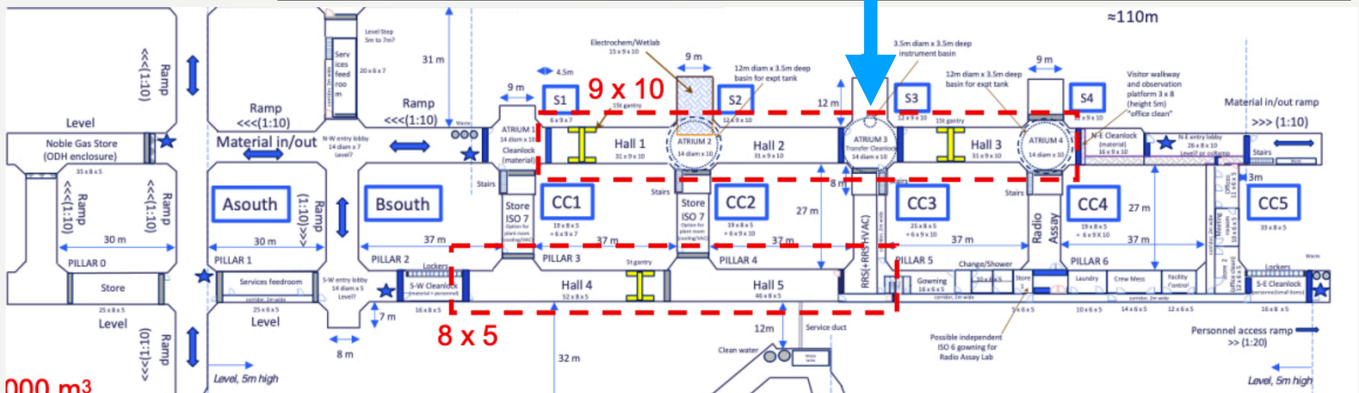


# 1kilo-tonne tank

## After BUTTON

- Expansion of Boulby gives us a unique opportunity to for growth
- Can fit around a 11 by 11 m tank
- Liverpool deeply involved with the design phase of this experiment
- Salt Cavern has been excavated including tank atrium
- Physics goals:
  - Reactor neutrino studies
  - Supernova neutrinos
  - Diffuse Supernove neutrinos
  - Full at scale deployment of WbLS

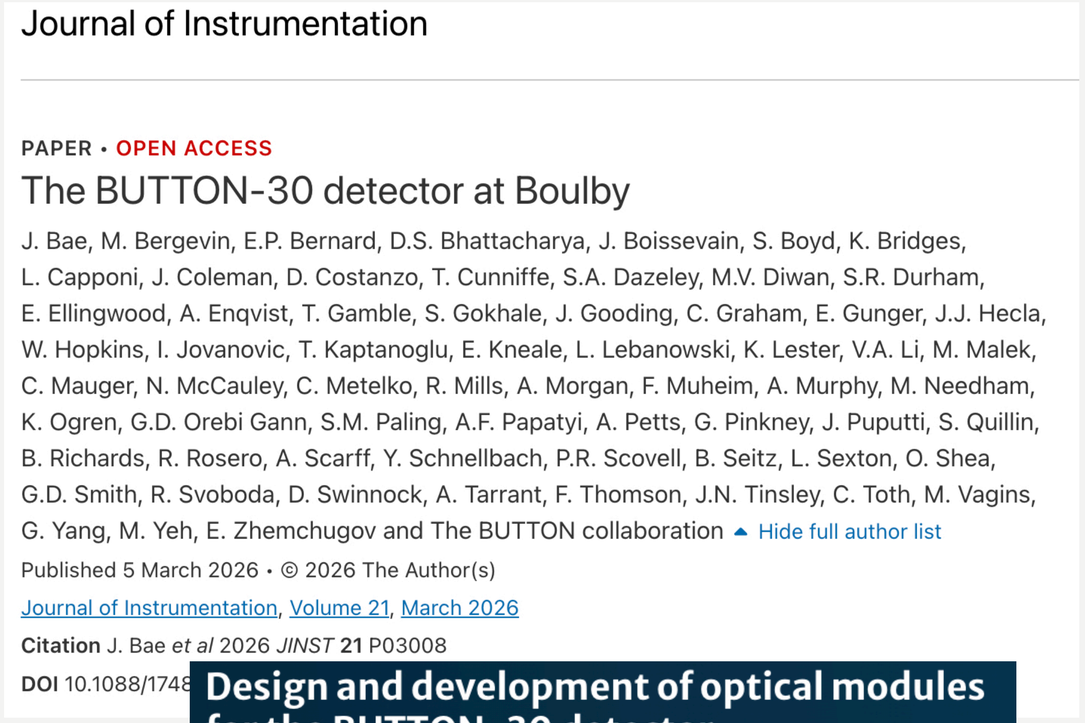




# Conclusions

## BUTTON Future

- BUTTON finally fully built and being commissioned
- First two BUTTON papers published
- UKRI/STFC Fund for international Collaboration has now ended
  - Working on no-cost extension
  - Waiting for STFC Bucket 2
- We are still working to maintain the water system and DAQ
  - Meet monthly with US collaborators
  - Collaboration is preparing for the prospect of funding becoming available



Journal of Instrumentation

PAPER • OPEN ACCESS

The BUTTON-30 detector at Boulby

J. Bae, M. Bergevin, E.P. Bernard, D.S. Bhattacharya, J. Boissevain, S. Boyd, K. Bridges, L. Capponi, J. Coleman, D. Costanzo, T. Cunniffe, S.A. Dazeley, M.V. Diwan, S.R. Durham, E. Ellingwood, A. Enqvist, T. Gamble, S. Gokhale, J. Gooding, C. Graham, E. Gunger, J.J. Hecla, W. Hopkins, I. Jovanovic, T. Kaptanoglu, E. Kneale, L. Lebanowski, K. Lester, V.A. Li, M. Malek, C. Mauger, N. McCauley, C. Metelko, R. Mills, A. Morgan, F. Muheim, A. Murphy, M. Needham, K. Ogren, G.D. Orebi Gann, S.M. Paling, A.F. Papatyi, A. Petts, G. Pinkney, J. Puputti, S. Quillin, B. Richards, R. Rosero, A. Scarff, Y. Schnellbach, P.R. Scovell, B. Seitz, L. Sexton, O. Shea, G.D. Smith, R. Svoboda, D. Swinnock, A. Tarrant, F. Thomson, J.N. Tinsley, C. Toth, M. Vagins, G. Yang, M. Yeh, E. Zhemchugov and The BUTTON collaboration ▲ Hide full author list

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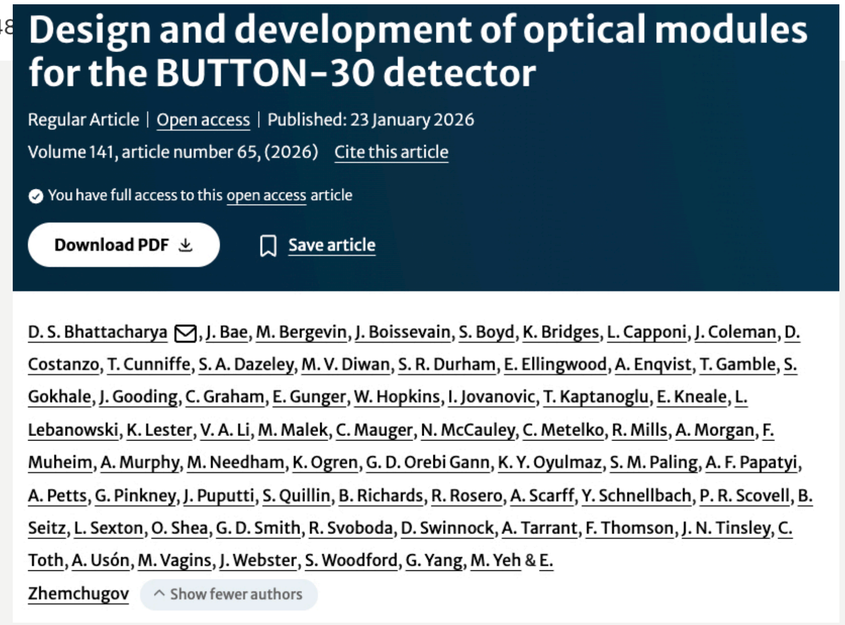
**DOI** 10.1088/1748



Design and development of optical modules for the BUTTON-30 detector

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Volume 141, article number 65, (2026) Cite this article

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D. S. Bhattacharya, J. Bae, M. Bergevin, J. Boissevain, S. Boyd, K. Bridges, L. Capponi, J. Coleman, D. Costanzo, T. Cunniffe, S. A. Dazeley, M. V. Diwan, S. R. Durham, E. Ellingwood, A. Enqvist, T. Gamble, S. Gokhale, J. Gooding, C. Graham, E. Gunger, W. Hopkins, I. Jovanovic, T. Kaptanoglu, E. Kneale, L. Lebanowski, K. Lester, V. A. Li, M. Malek, C. Mauger, N. McCauley, C. Metelko, R. Mills, A. Morgan, F. Muheim, A. Murphy, M. Needham, K. Ogren, G. D. Orebi Gann, K. Y. Oyulmaz, S. M. Paling, A. F. Papatyi, A. Petts, G. Pinkney, J. Puputti, S. Quillin, B. Richards, R. Rosero, A. Scarff, Y. Schnellbach, P. R. Scovell, B. Seitz, L. Sexton, O. Shea, G. D. Smith, R. Svoboda, D. Swinnock, A. Tarrant, F. Thomson, J. N. Tinsley, C. Toth, A. Usón, M. Vagins, J. Webster, S. Woodford, G. Yang, M. Yeh & E. Zhemchugov ^ Show fewer authors



**Thanks for listening**

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# Back up

# Key terms

- WGd —> Water + Gadolinium
- WbLS —> WGd (this presentation) + LAB + PPO
- LS —> LAB + PPO + Gd (in this presentation/Simulation but more possible options)

[1] https://arxiv.org/abs/1606.07538

# Neutrino Detectors

## Low background and low energy detection

- Two classes for low energy (0.1-10 MeV) neutrino detectors

Cherenkov detectors (water (WGd))

Advantages

- Great position and direction reconstruction
- Can reconstruct energy of event
- Long attenuation length

Disadvantages

- Limited by Cherenkov threshold 0.8 MeV electron events (total = 4 MeV [1] (SK solar limit with background))
- Poor energy resolution at low energy due to low light yield

Liquid Scintillator (LS)

Advantages

- No energy threshold
- Sensitive to lower energy events (more light per MeV (higher light yield)
- Improved energy resolution (better discrimination from background)

Disadvantages

- Expensive to buy in large quantities
- More challenging to handle and dispose
- Short attenuation length

# Boulby Underground Laboratory

Science and Technology Facilities Council

Boulby Underground Laboratory





- UK's deep underground science facility
- Operated by STFC in partnership with ICL-UK (mine operators)
- 1.1m depth (2805 mwe)
- Rock-salt —> low-background environment
- Reduced cosmic ray flux vs surface ($10^6$)



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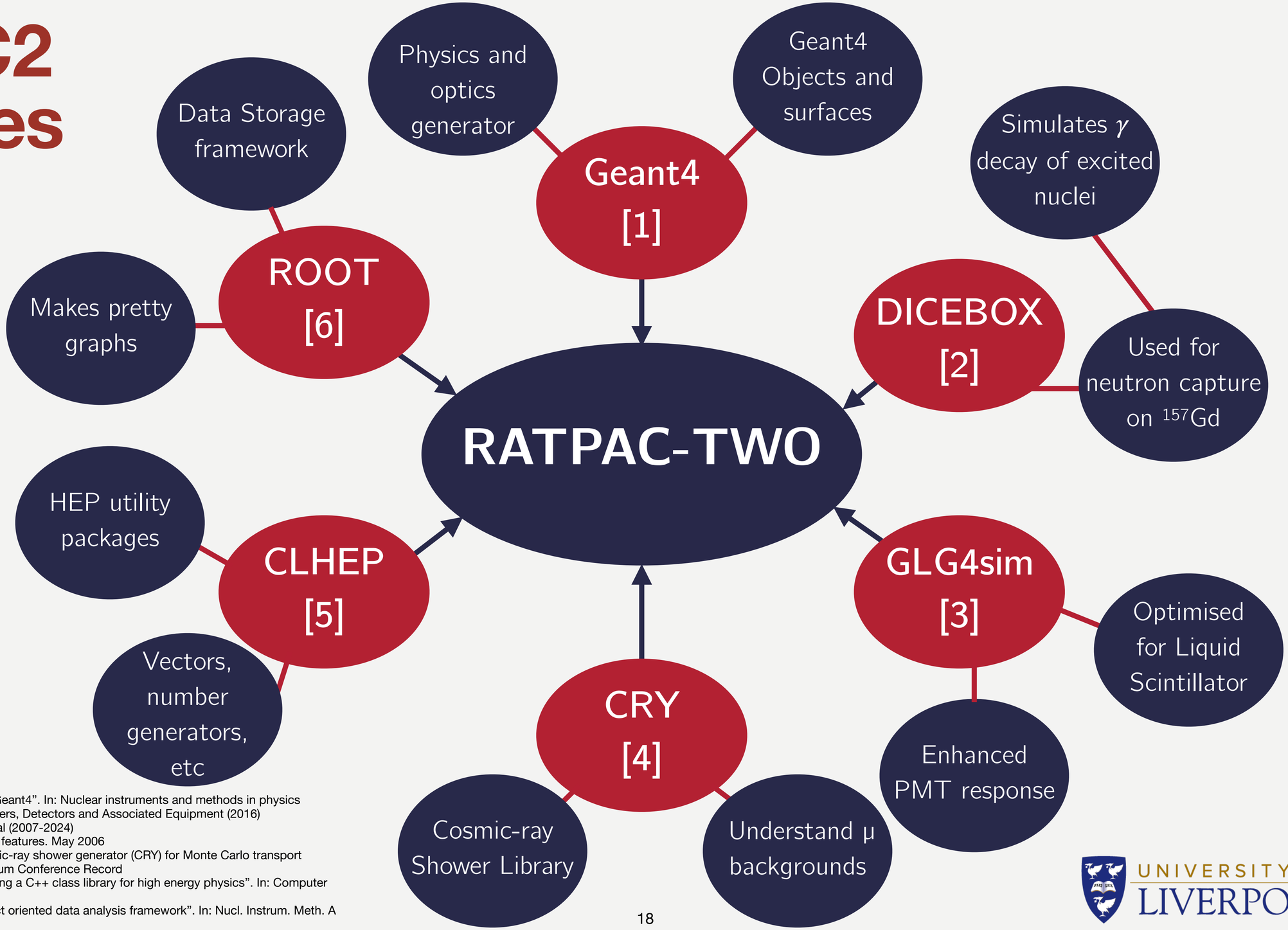
# RATPAC2 Packages





(1) John Allison et al. “Recent developments in Geant4”. In: Nuclear instruments and methods in physics research section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2016)
(2) M. Krticka. “DICEBOX Version 1.0”. In: Manual (2007-2024)
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(6) R. Brun and F. Rademakers. “ROOT: An object oriented data analysis framework”. In: Nucl. Instrum. Meth. A 389 (1997)




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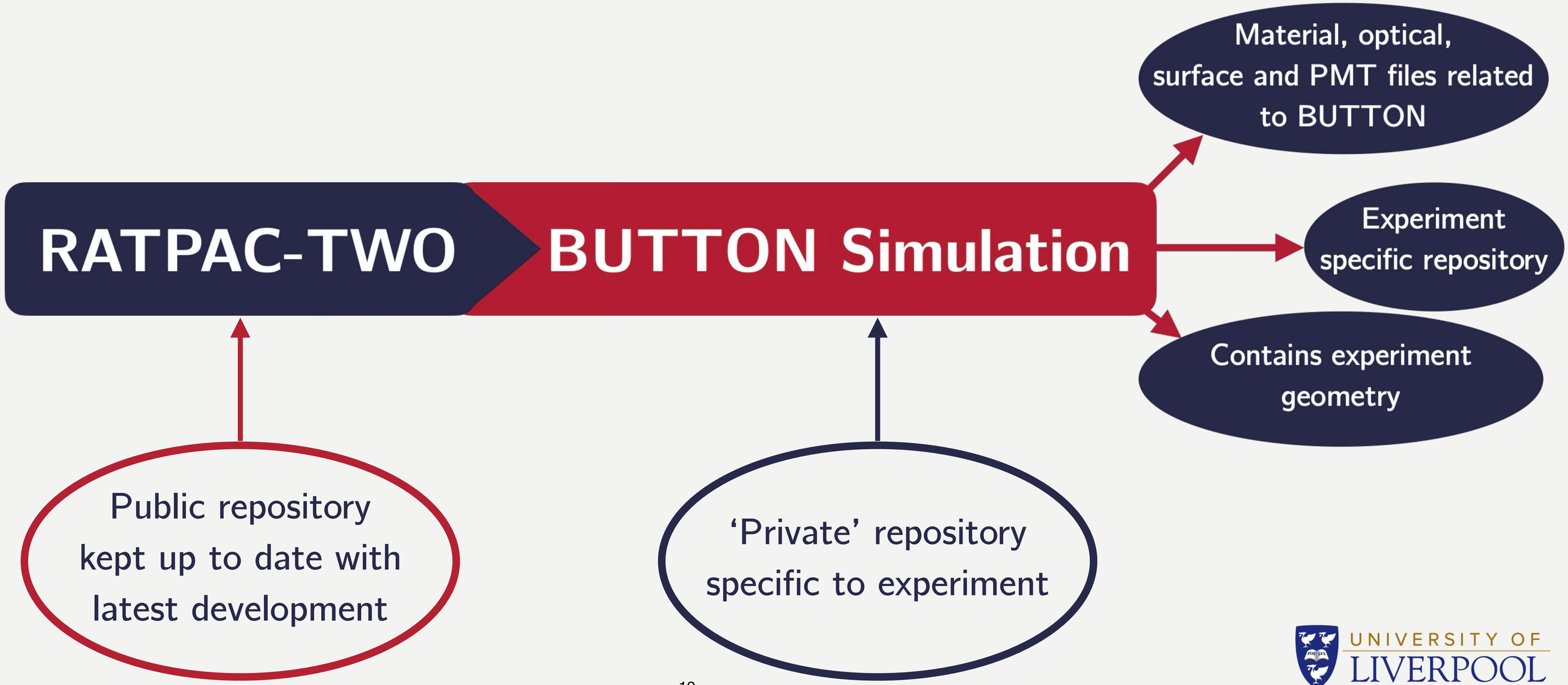
# BUTTON Simulation



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