

Development of Simulations for the BUTTON Testbed 18/05/2023

Student: Alexander Morgan

Supervisor: Jon Coleman

General Overview

- $\bar{\nu}_e$ detectors utilise inverse beta decay
- Incoming $\bar{\nu}_e$ interacts with a proton in a medium producing a prompt positron and delayed neutron
- Nuclear Reactors produce around $10^{20} \text{ s}^{-1} \text{ GW}_{\text{TH}}^{-1}$
 - Typical energy $\sim 1.8 - 10 \text{ MeV}$
 - Detection technology holds non-proliferation prospects
 - Cherenkov detectors have poor resolution in this range
- Future prospect: WbLS detection medium
 - Lower detection range, higher light yield

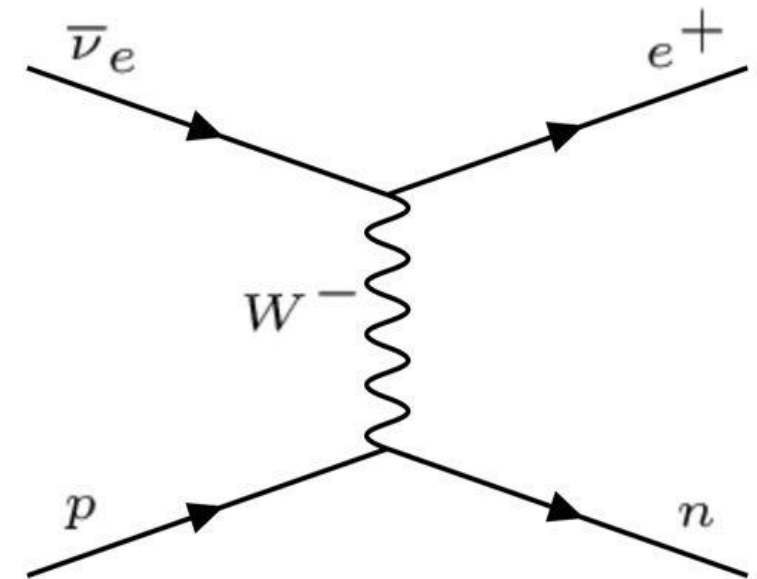


Fig 1: IBD Feynman Diagram

BUTTON + Simulations

- BUTTON (Boulby Underground Technology Testbed for Observing Neutrinos) is a 30-tonne anti-neutrino Cherenkov testbed - created following end of WATCHMAN
- Aims to assess feasibility of detector at Boulby and de-risk future large detector experiments
- Testbed for novel detection technology
 - Water based liquid scintillator (WbLS)
 - Large Area Picosecond Photodetectors (LAPPDs)
- Potential plans to expand to BUTTON-100
- Simulations benchmark expected results for BUTTON + inform design
 - Simulations aim to benchmark BUTTON's response. Ran in RATPAC, a framework built on GEANT4
 - Will discuss optical properties, PMT encapsulations and backgrounds

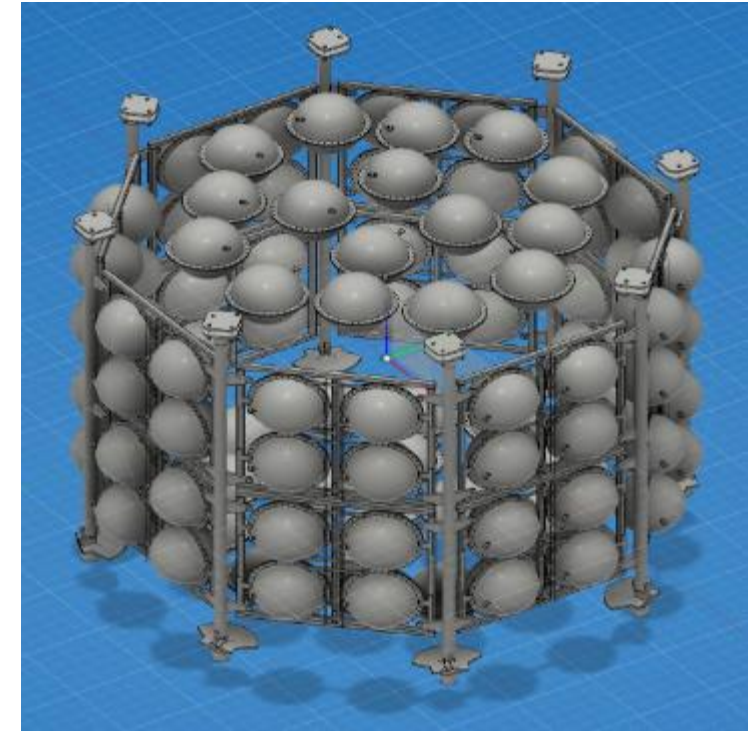


Fig 2: Model of BUTTON-30's PMTs and frame

Reflections

- Introduced reflections from tank, Tyvek liner and frame and observed significant decrease in resolution
 - Demonstrated by widening of time-profile
- Discussions regarding inclusion of Tyvek Liner
 - Tyvek: polyethylene fibre also used in SuperK
- One factor in supporting introduction of Tyvek liner - prevents reflections from tank

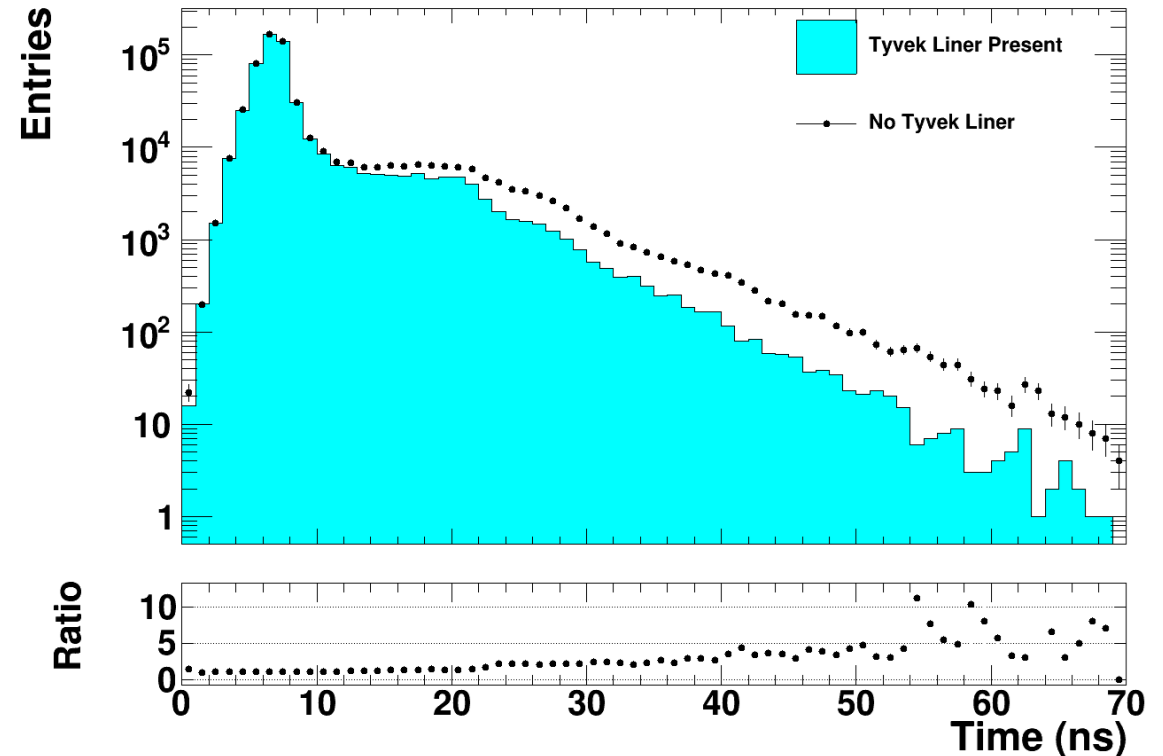
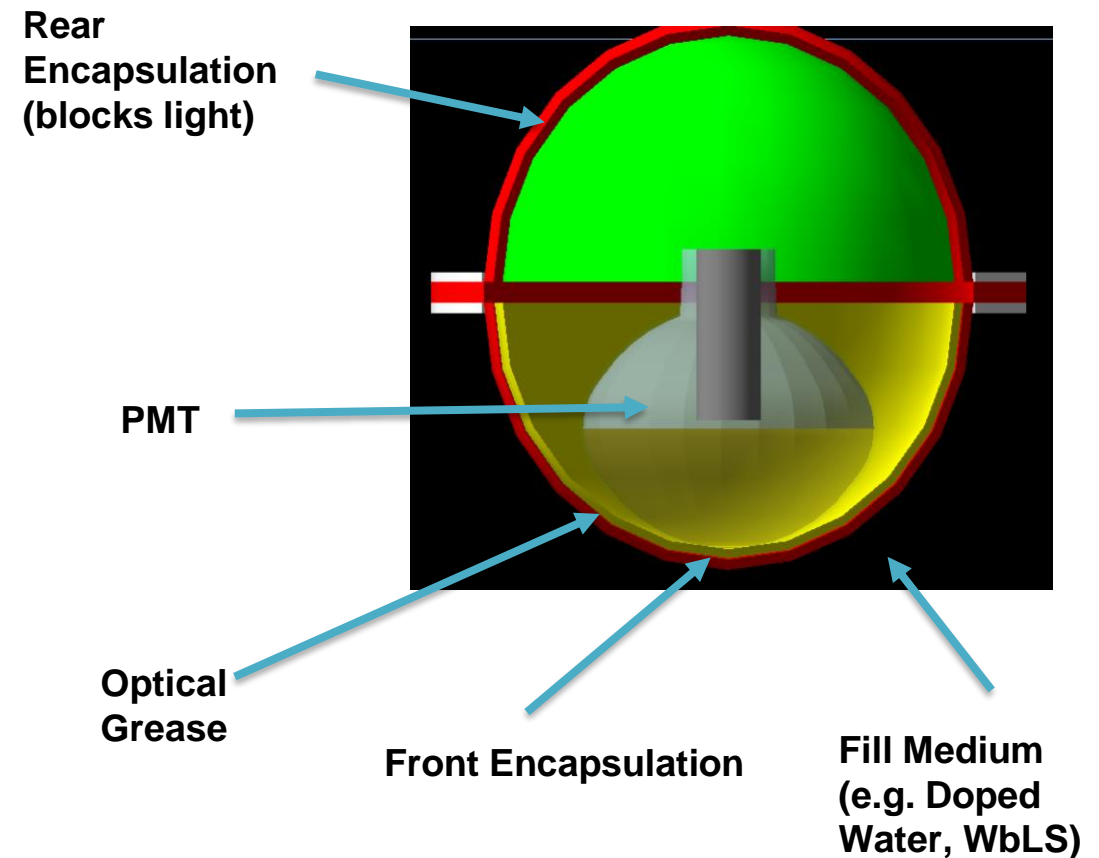


Fig 3: Time profile for Monte Carlo simulation of 50,000 3 MeV electrons generated at the centre of the detector geometry

Encapsulations + Acrylic

- Each PMT in BUTTON enclosed by Ultraviolet Transparent (UVT) acrylic encapsulation
 - Protect PMTs
 - WbLS- material incompatibility with some plastics and metals
 - Gd- can form deposits
- Previous encapsulations hold over from WATCHMAN- updated for BUTTON



Encapsulations + Acrylic

- BUTTON encapsulations made of Ultraviolet Transparent acrylic (UVT)
- Necessary to validate simulation properties with expected optical properties
- Performed study and implemented optical properties based on measurements carried out during WATCHMAN era
- Some uncertainty w.r.t experimental data- in near future measuring optical properties of UVT and implementing these results

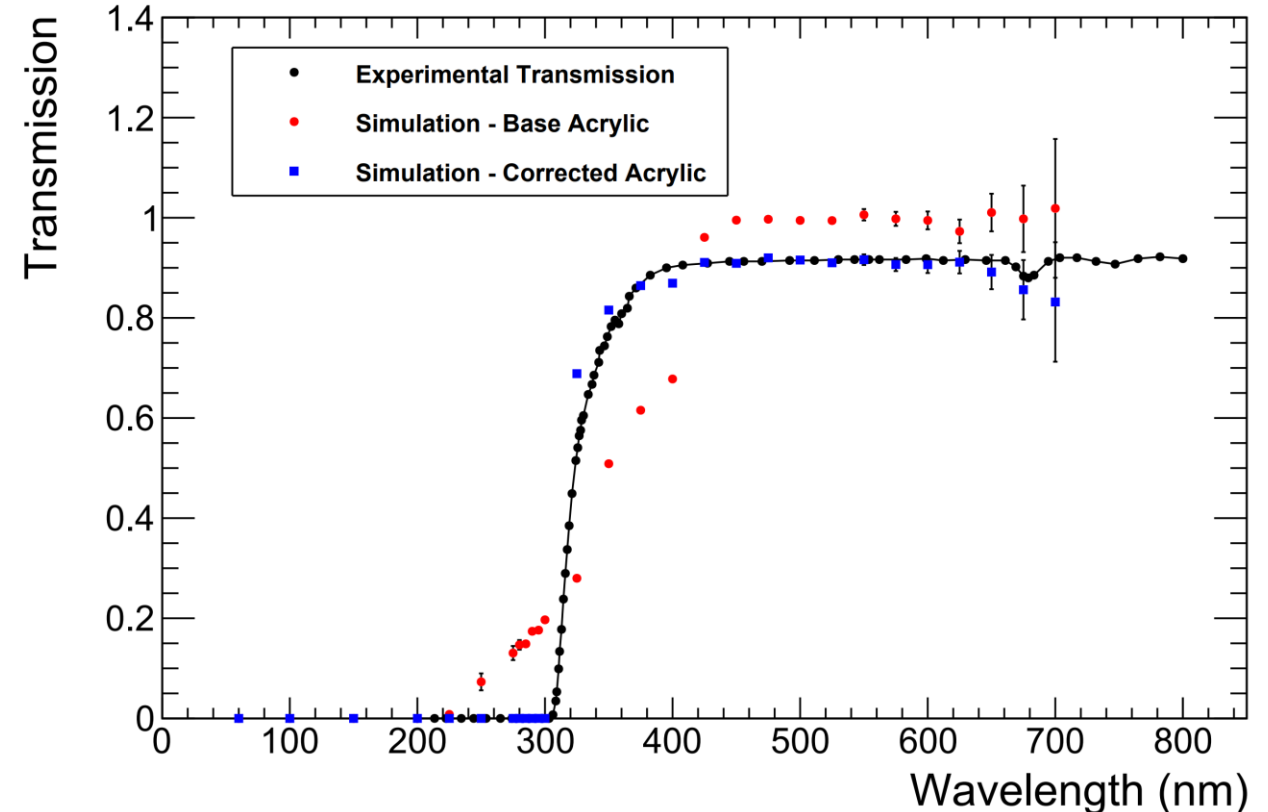
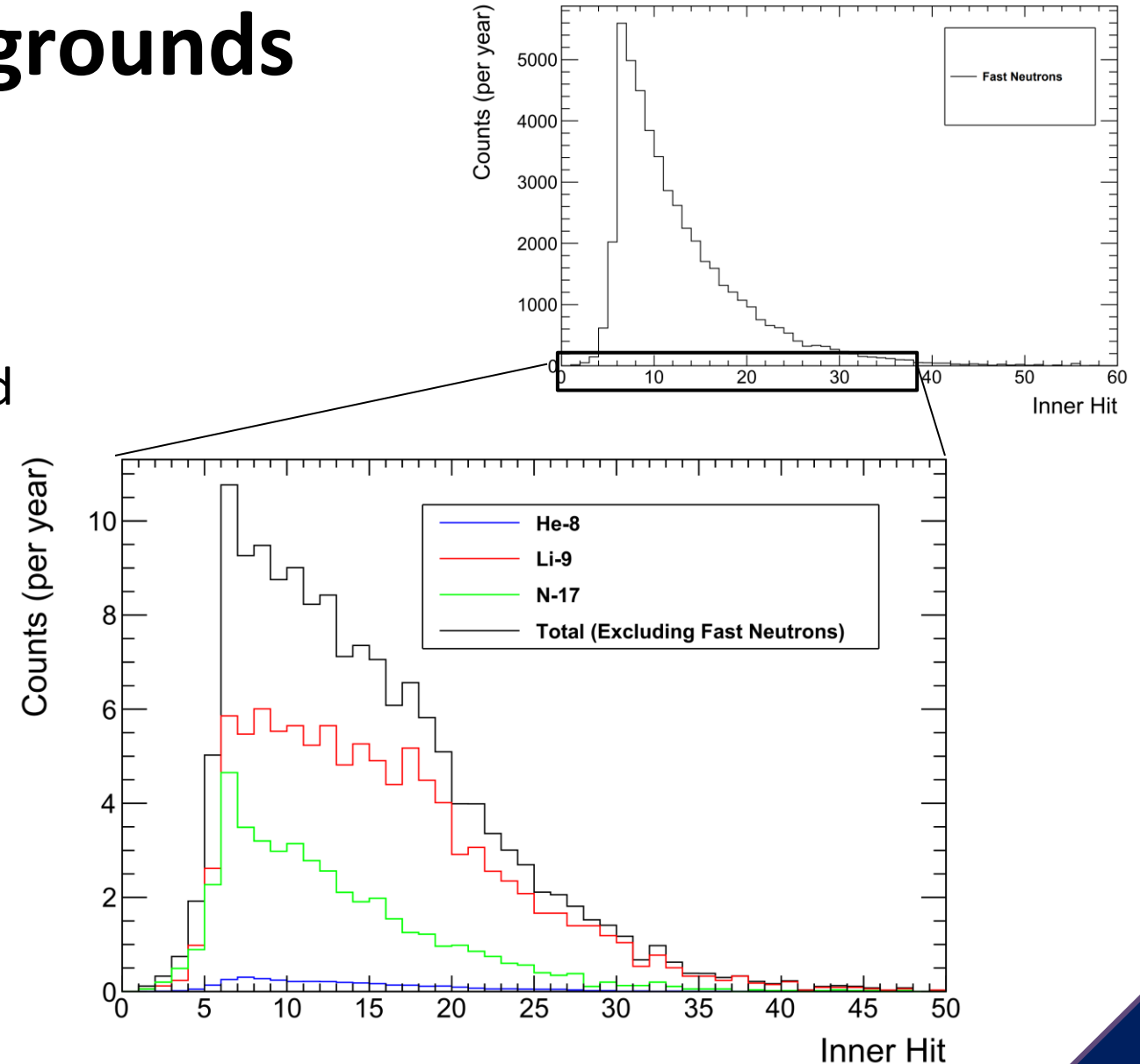


Fig 4: Transmission of UVT acrylic per experimental data compared to within the simulation

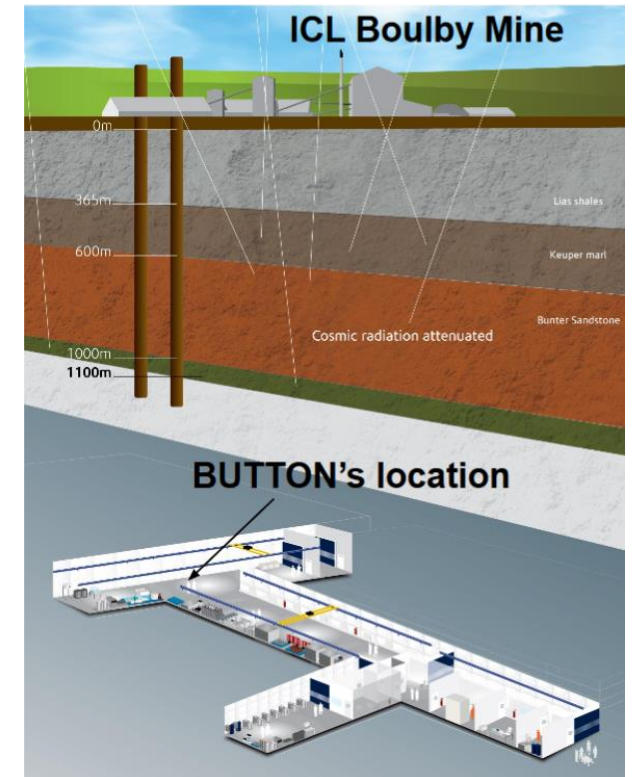
Backgrounds

- Undertaking investigation into BUTTON backgrounds
- Key backgrounds: Li-9, He-8, N-17 and Fast Neutrons
- Rate of interactions based on study for WATCHMAN
- Fast neutrons dominant compared to others
- Will perform analysis on BUTTON's sensitivity to fast neutrons



Summary + Future Work

- Working on simulations for BUTTON
- Main focus on reflections + optical properties
 - Generated BUTTON encapsulations
 - Defined optics for detector materials
- Implemented new UVT acrylic based on experimental results for BUTTON's encapsulations
 - Will be performing measurements to validate this
- Ongoing work on simulating backgrounds
 - Analyse BUTTON's sensitivity to backgrounds (particularly fast neutrons)



Thank you for listening

Any questions?