UNIVERSITY OF LIVERPOOL

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Innovate UK

REACTOR MONITORING WITH T2K ANTI-NEUTRINO TECHNOLOGY

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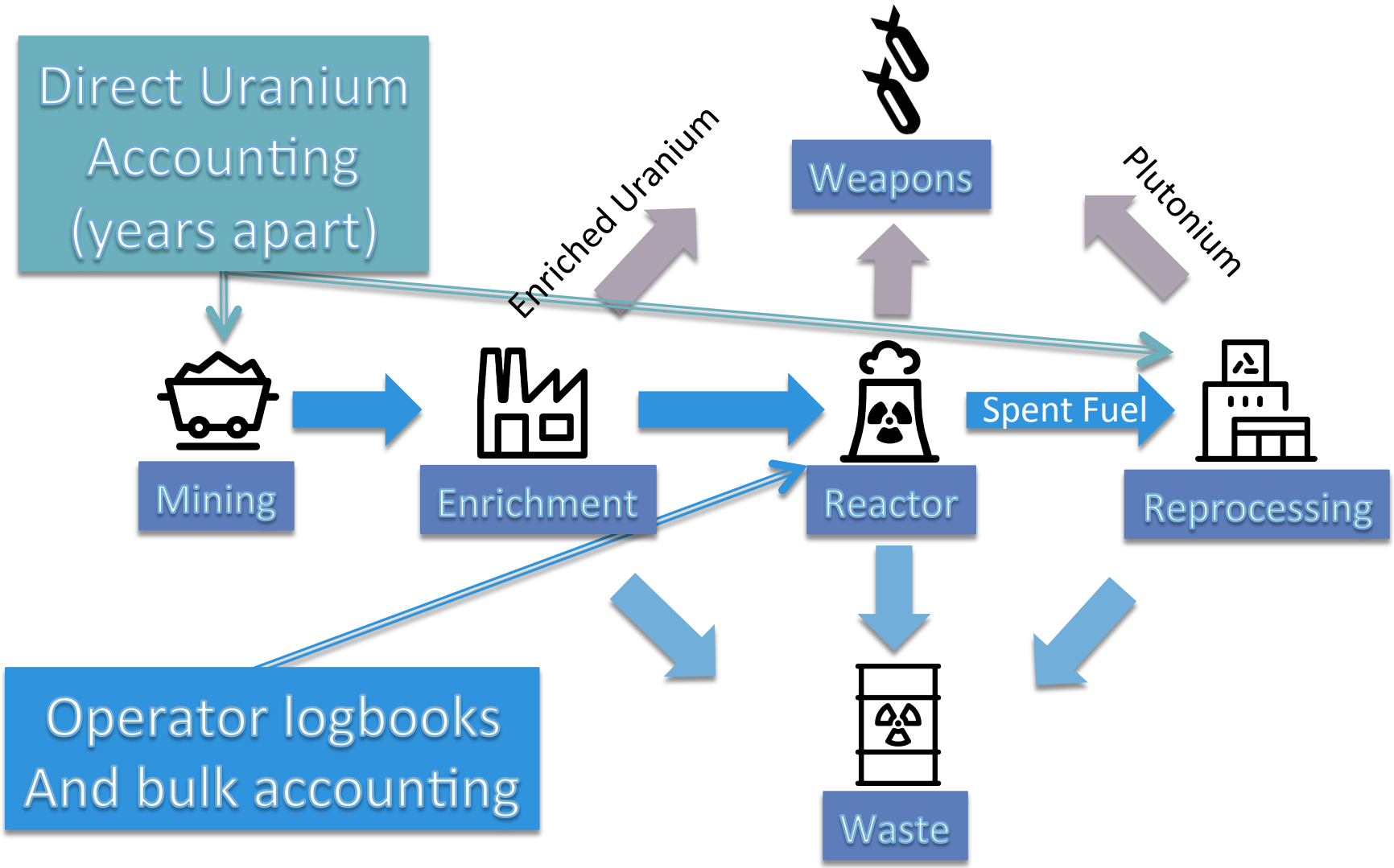
IOP HEPP & APP Meeting 2016

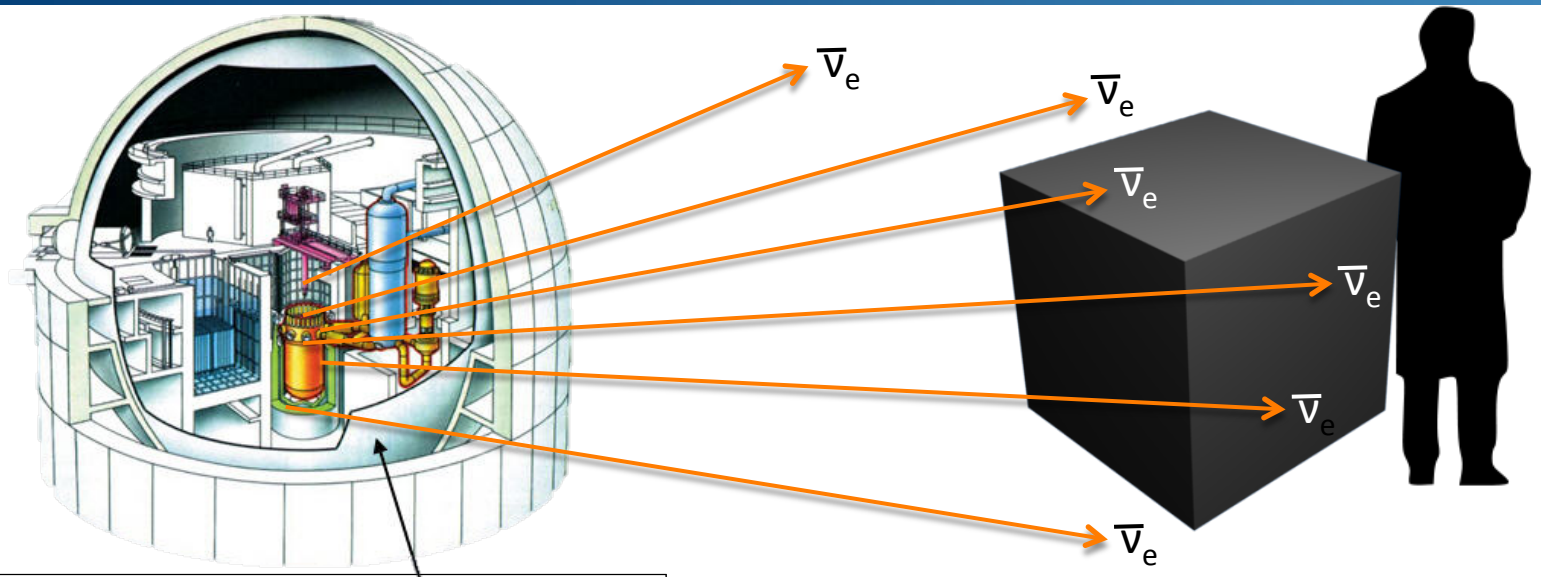
Overview

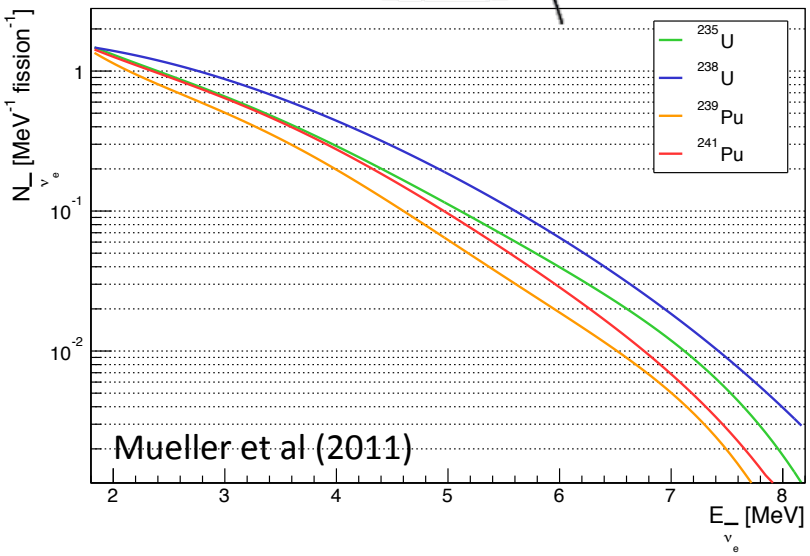
- Introduction
- Liverpool Detector
- Results
- Outlook

Introduction: Fissile Material Accountancy



INTRODUCTION: REACTOR ANTI-NEUTRINOS





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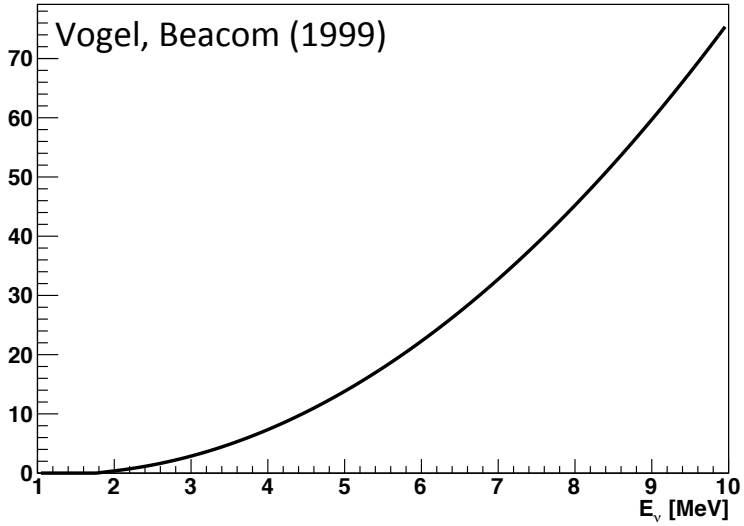

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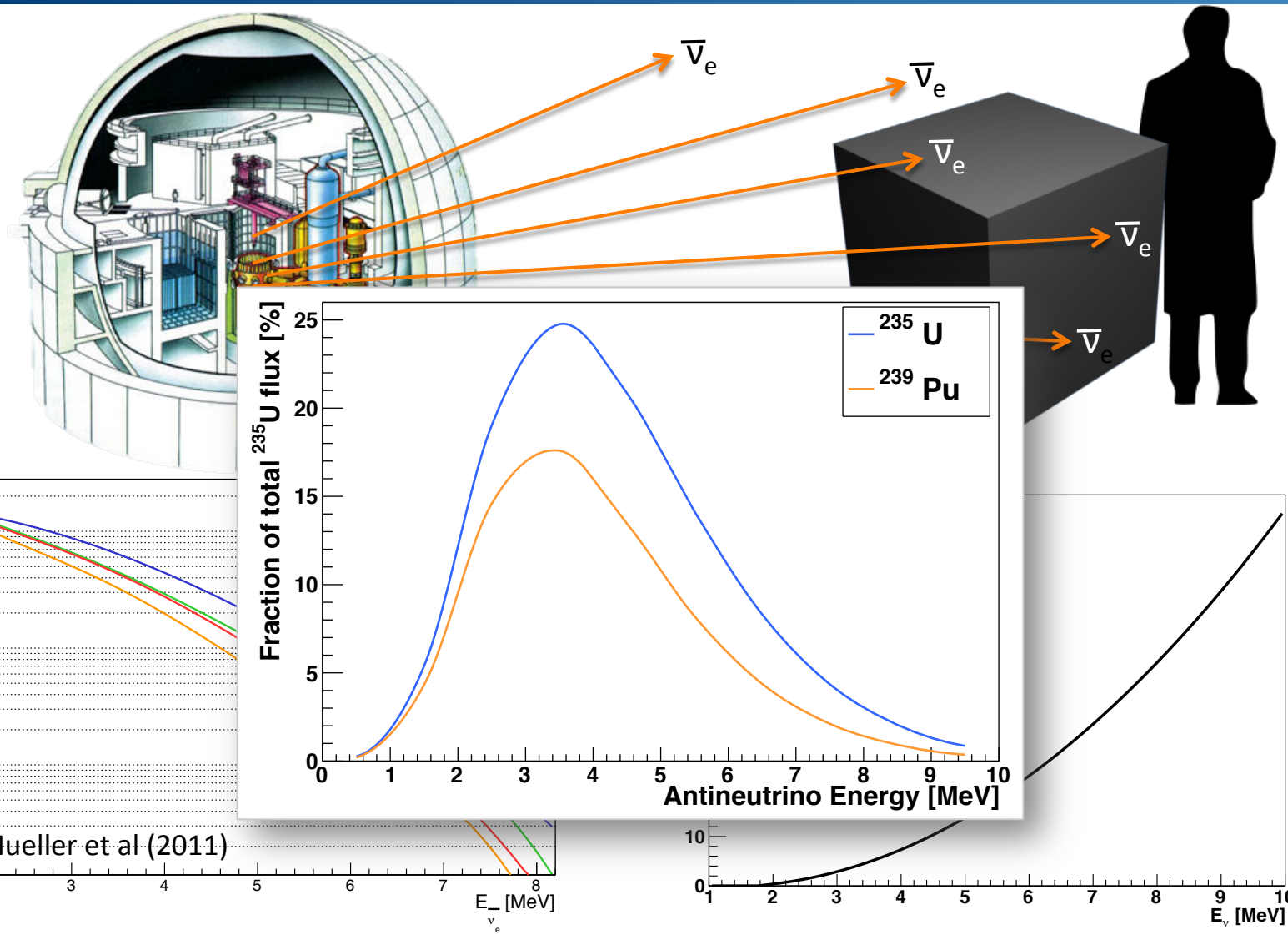
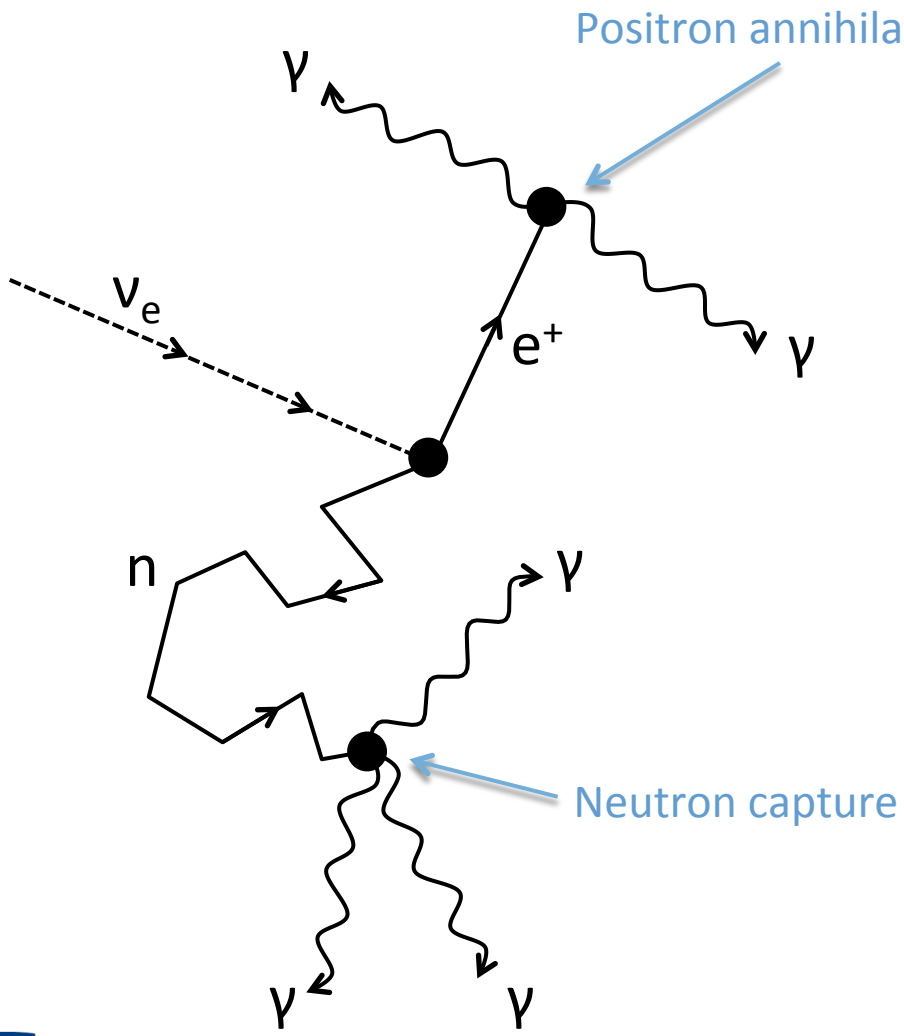


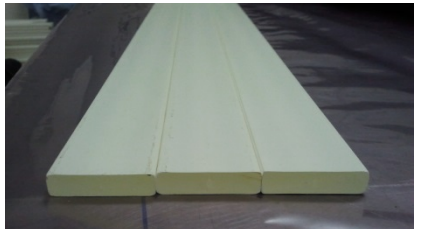
Introduction: Reactor Anti-Neutrinos

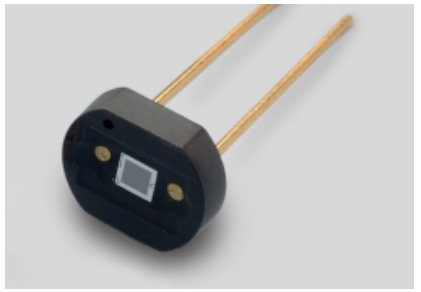


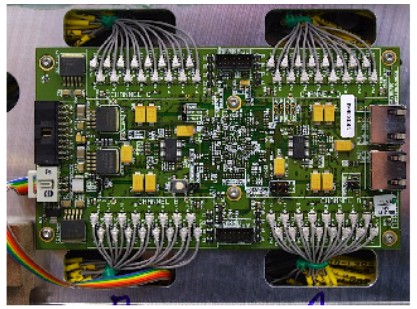
- Signal:
  - Inverse β decay: $\overline{\nu}_e + p \rightarrow n + e^+$
  - Prompt e^+ track
  - Delayed *n* capture creates 8 MeV γ cascade (avg. 10 μs delay)

Introduction: T2K Near Detector ECal

- T2K Near Detector ECal:
  - Pb/plastic scintillator sampling calorimeter
  - Wavelength shifting fibre
  - Multi-Pixel Photon Counter SiPM as readout
  - FPGA-based readout boards
- Built in the UK, shipped to Japan – highly robust

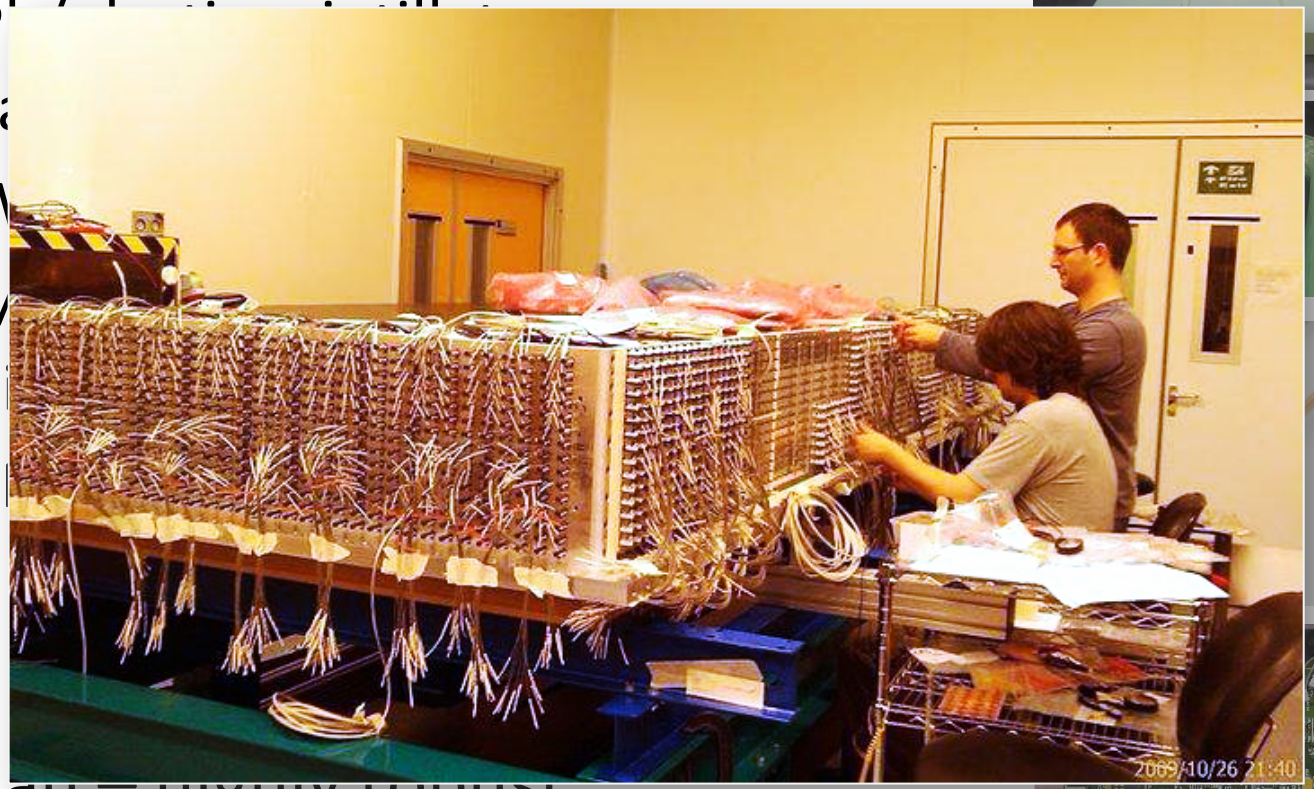


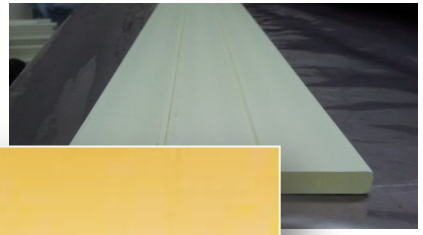


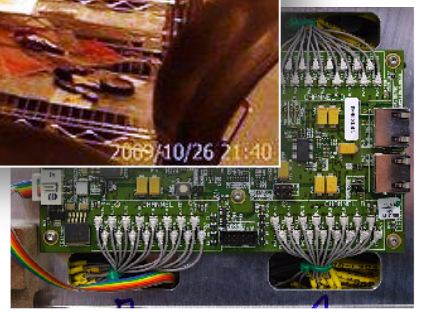


INTRODUCTION: T2K NEAR DETECTOR ECAL

- T2K Near Detector ECal:
  - P
    sa
  - W
  - M
    Si
  - F
- Bui
  Japan – highly robust

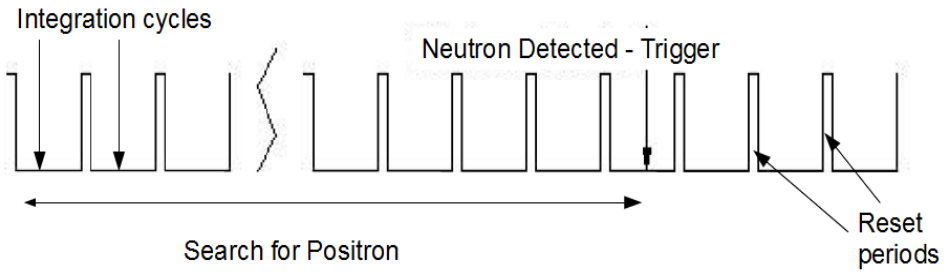






LIVERPOOL DETECTOR: ADAPTING T2K TECH

- Pb ➔ Gd sheets for neutron capture
- Pulsed operation ➔ triggered operation
- Cosmic ray veto
- Adapted housing, cooling and shielding



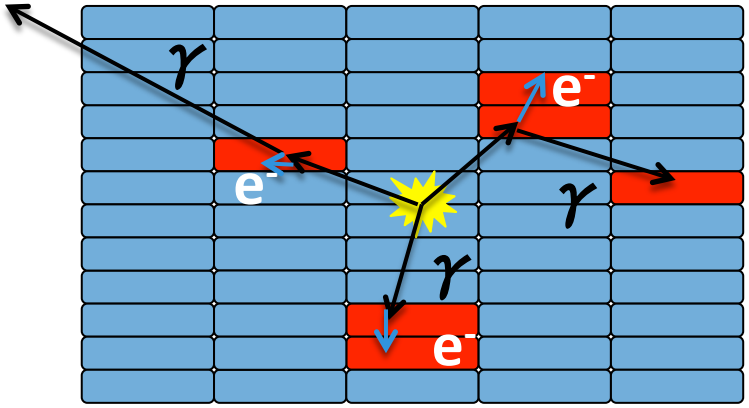
LIVERPOOL DETECTOR: TRIAL AT WYLFA

- Full-scale prototype:
  - 1.7m x 1.7m x 0.8m
  - ca. 2000 channels
  - ca. 1 ton active mass
- Mobile lab inside climate-controlled container
- Deployed on site ca. 60m distance from core
- Communication via dial-up modem for DQ

LIVERPOOL DETECTOR: TRIAL AT WYLFA

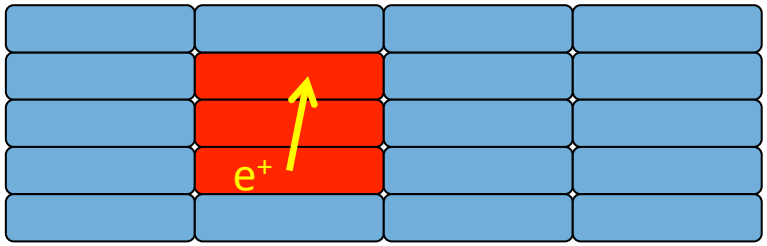
LIVERPOOL DETECTOR: PARTICLE SIGNATURE

Neutron



- 8 MeV γ cascade upon capture
- Causes multiple Compton scatters
- Spatially diffuse hits coincident in time

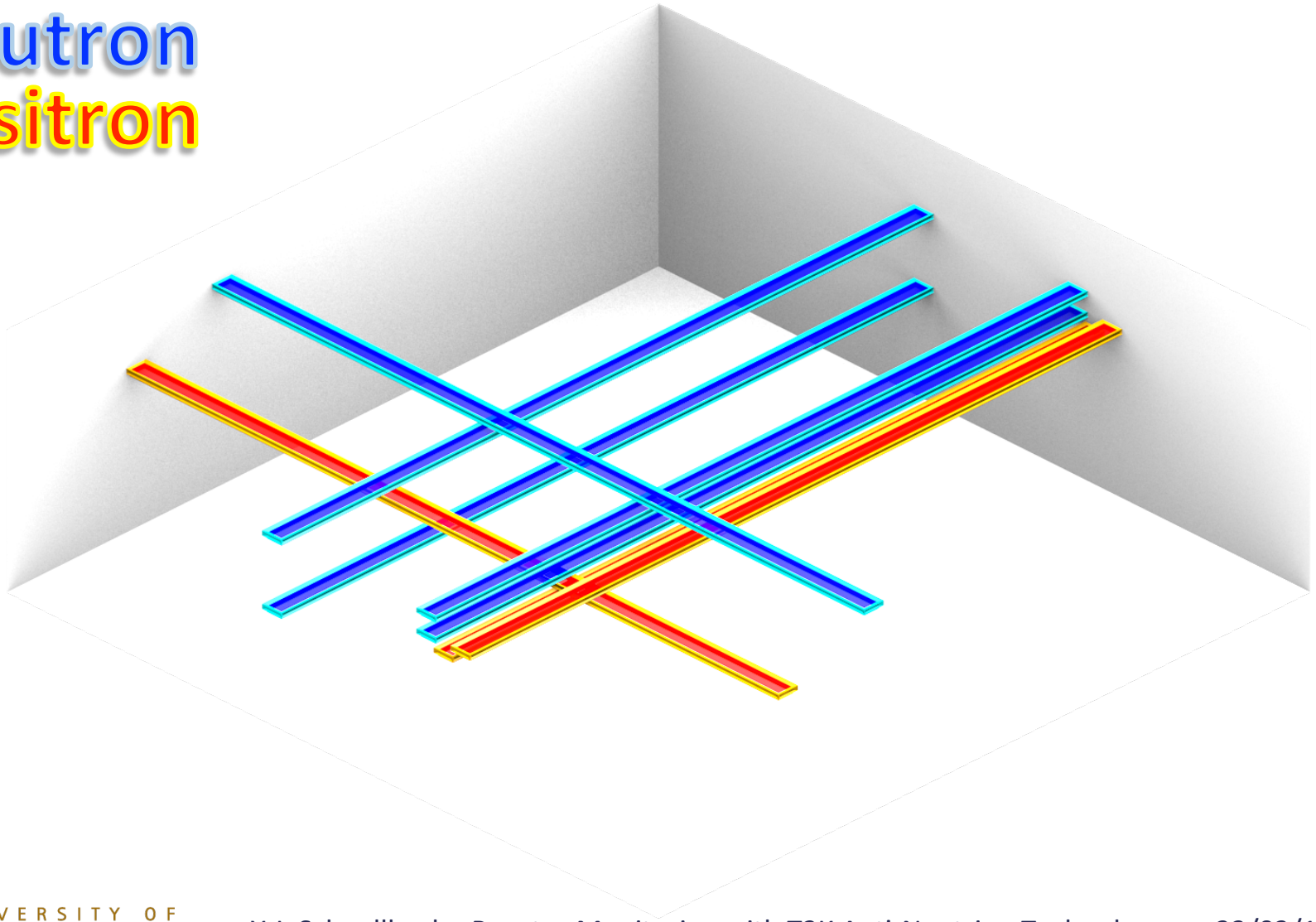
Positron



- Contained track
- Concurrent in time
- dE/dx ≈ 1.8 MeV/cm
- E_{max} ≈ 8 MeV

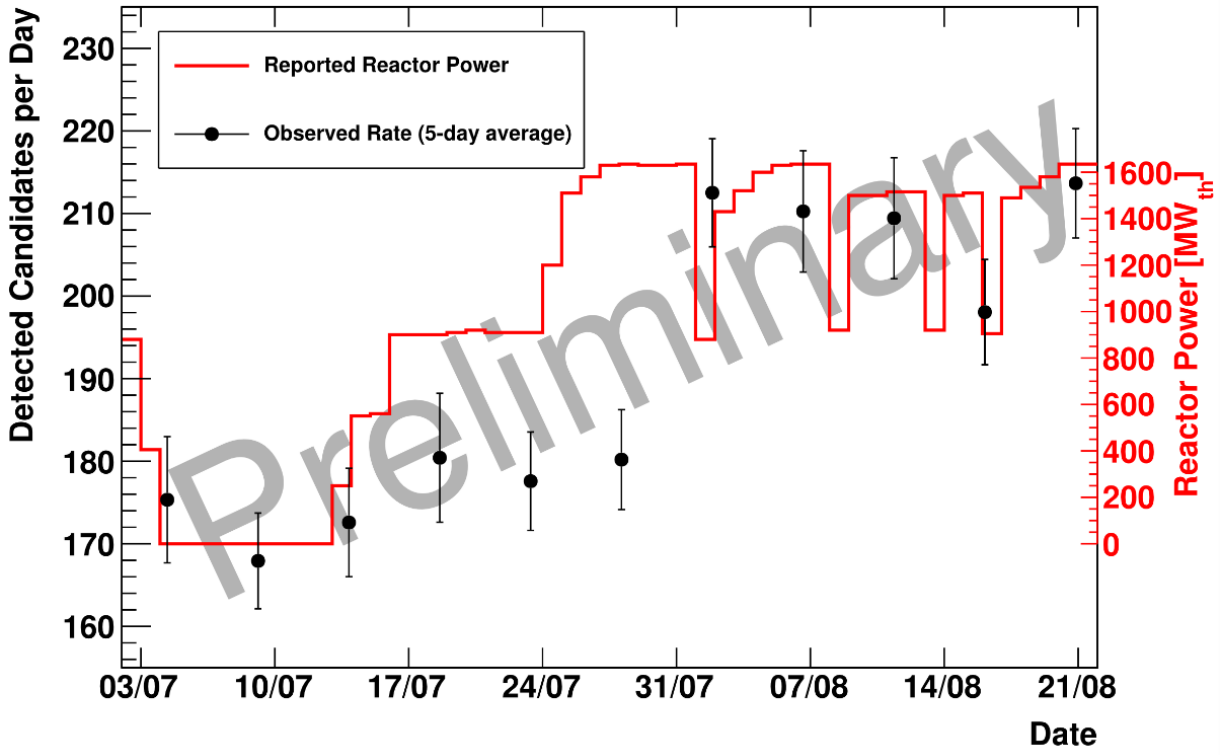
Results: Candidate Event

Neutron
Positron



RESULTS: PRELIMINARY OBSERVATION

- Reactor turn-on
- 1.6 GW^{th} power
- Operating aboveground
- 20 ft. ISO Container
- 60m core distance



Outlook: Current Work & Upgrade

- Post-Wylfa Work:
  - Wylfa was shutdown permanently 31st Dec 15
  - Mobile lab & detector returned to Liverpool
  - Background studies underway
- Innovate-UK Upgrade:
  - John Caunt Scientific as partner
  - Upgraded detector (VIDARR)
  - Custom electronics (100% live)
  - 50% more active mass & channels
  - Update to current-gen SiPMs
- Collaboration with National Nuclear Laboratory (NNL)

SUMMARY

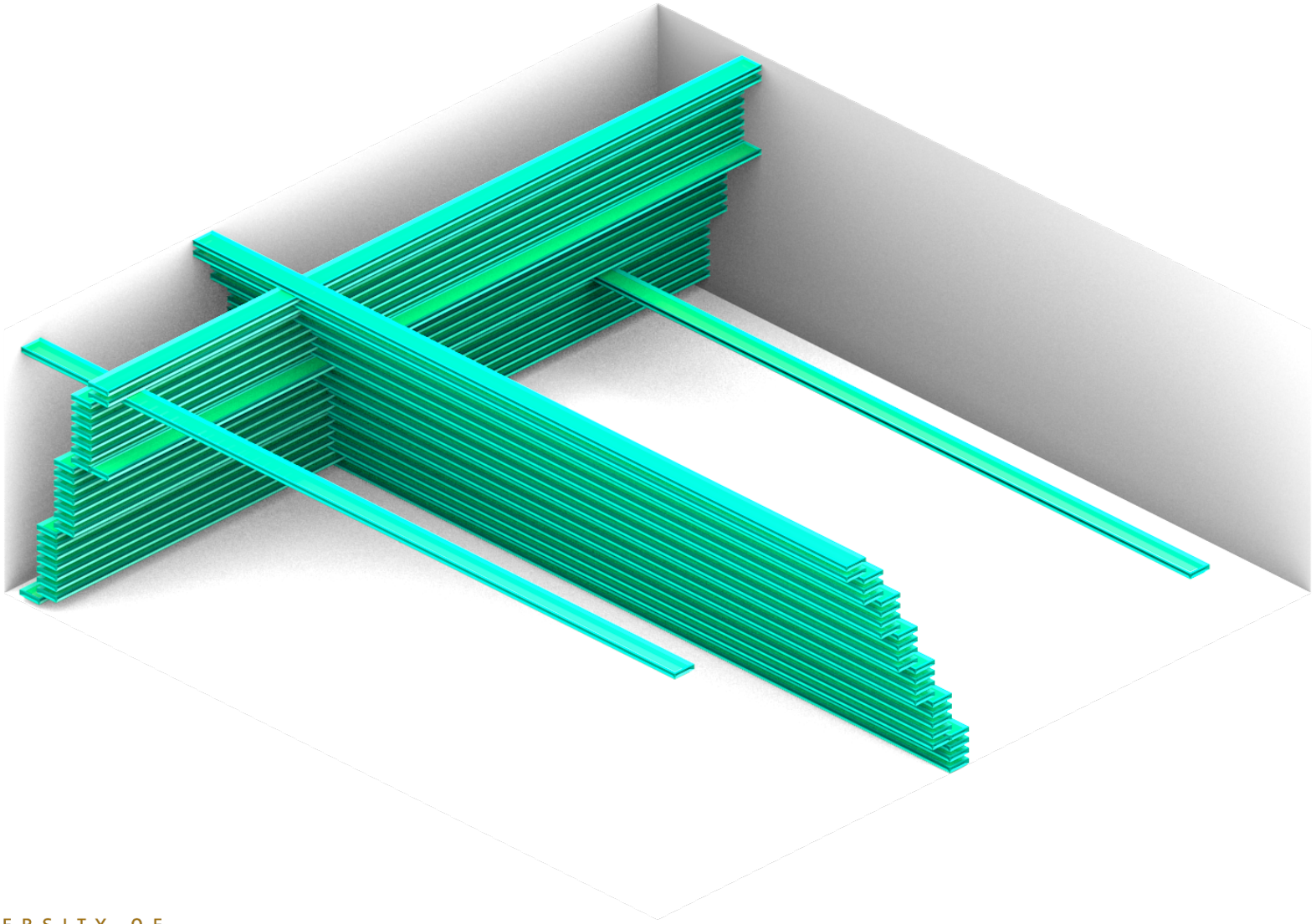
- Compact reactor anti-neutrino detector developed
- Example of applied particle physics!
- Deployed on site, running autonomously
- Preliminary results are promising
- Field trial analysis and upgrade underway

BACKUP SLIDES

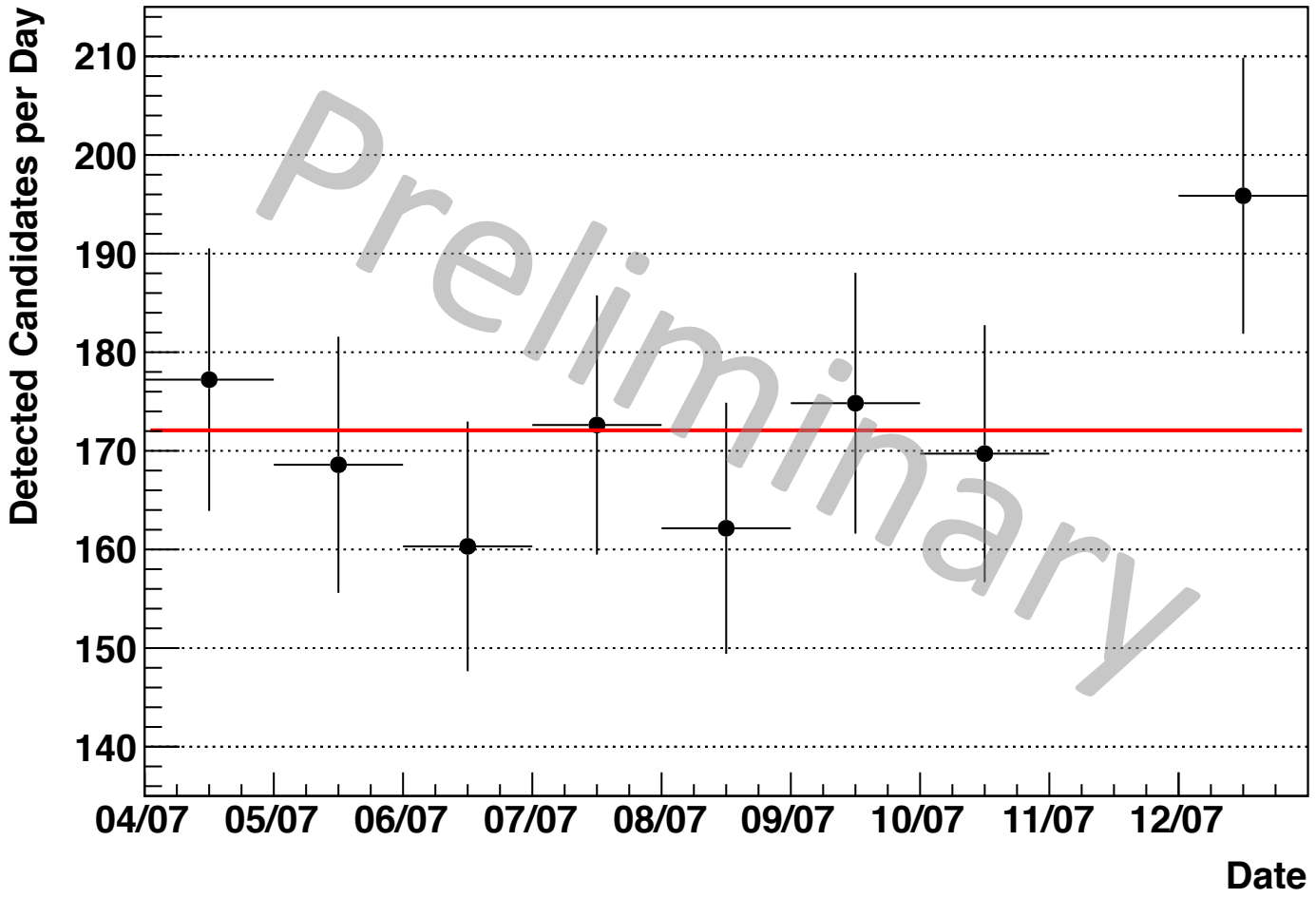
SAFEGUARDS-FRIENDLY DESIGN

Requirement	Solution	
Inert construction	Plastic scintillator	✔
Non-liquid	Plastic scintillator	✔
Easy operation	Low voltage SiPMs (< 120 V)	✔
Cheap	Extruded plastic	✔
Portable	Detector & services in ISO container	✔
Robust	Proven T2K ECal design	✔
Aboveground operation	Integrated cosmic ray veto	✔
Easy deployment	ISO container only requires 3-phase power plug	✔

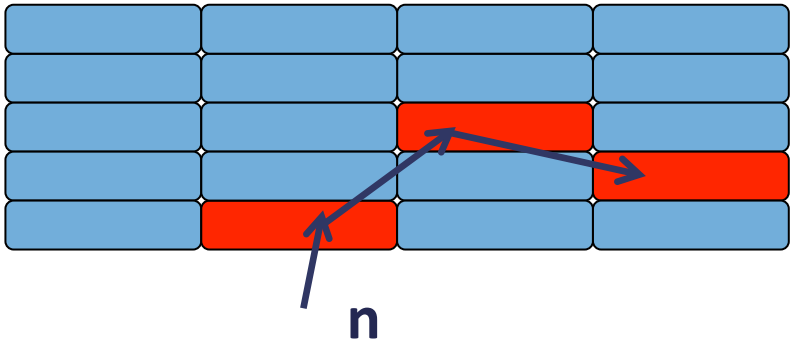
Cosmic Muon Track



Reactor Off Measurement



Fast Neutron



- Spatially separated hits
- Concurrent in time
- High dE/dx recoils
- Concentrated around detector edges