Quarterly T-REX Update

John R.M. Annand

University of Glasgow
VIA VERITAS VITA

ESS Detector Group

Multi-Grid Publications

2 articles published in NIM-A

- Test of VMM3A readout of MG
- Neutron interactions in MG structural materials

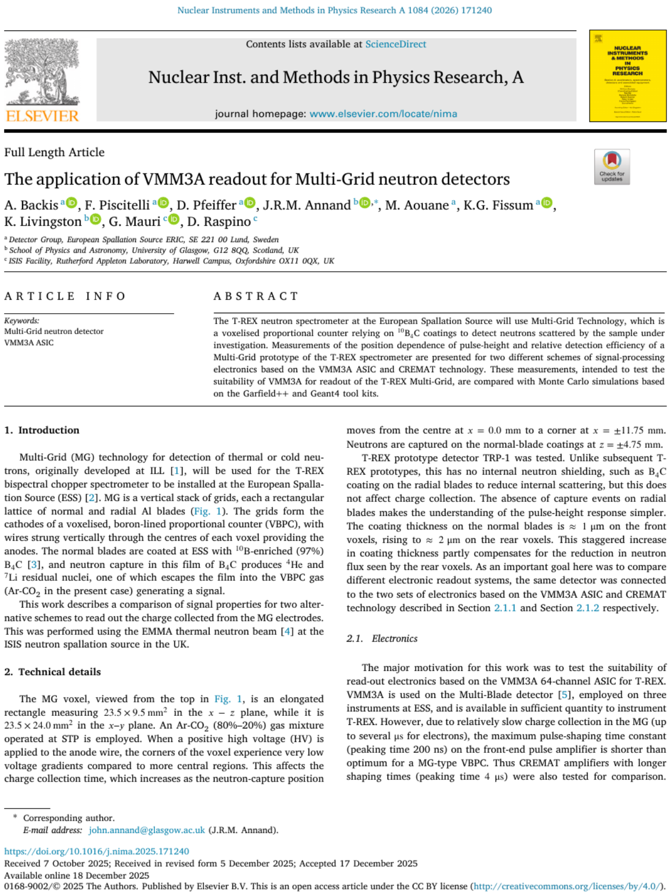
1 Publication in preparation, possibly JINST

- Alpha background from grid materials

2 further publications planned

- Description of the Geant4 and Garfield++ simulations of T-REX
- Report of the 2025 Runs at EMMA...test effect of Al/B_4C composite radial blades on internal scattering.

Published Articles Nucl. Instr. Meth. A



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Full Length Article

The application of VMM3A readout for Multi-Grid neutron detectors

A. Backis [a], F. Piscitelli [a], D. Pfeiffer [a], J.R.M. Annand [b],*, M. Aouane [a], K.G. Fissum [a],
K. Livingston [b], G. Mauri [c], D. Raspino [c]

[a] *Detector Group, European Spallation Source ERIC, SE 221 00 Lund, Sweden*
[b] *School of Physics and Astronomy, University of Glasgow, G12 8QQ, Scotland, UK*
[c] *ISIS Facility, Rutherford Appleton Laboratory, Harwell Campus, Oxfordshire OX11 0QX, UK*

ARTICLE INFO

Keywords:
Multi-Grid neutron detector
VMM3A ASIC

ABSTRACT

The T-REX neutron spectrometer at the European Spallation Source will use Multi-Grid Technology, which is a voxelised proportional counter relying on $^{10}B_4C$ coatings to detect neutrons scattered by the sample under investigation. Measurements of the position dependence of pulse-height and relative detection efficiency of a Multi-Grid prototype of the T-REX spectrometer are presented for two different schemes of signal-processing electronics based on the VMM3A ASIC and CREMAT technology. These measurements, intended to test the suitability of VMM3A for readout of the T-REX Multi-Grid, are compared with Monte Carlo simulations based on the Garfield++ and Geant4 tool kits.

1. Introduction

Multi-Grid (MG) technology for detection of thermal or cold neutrons, originally developed at ILL [1], will be used for the T-REX bispectral chopper spectrometer to be installed at the European Spallation Source (ESS) [2]. MG is a vertical stack of grids, each a rectangular lattice of normal and radial Al blades (Fig. 1). The grids form the cathodes of a voxelised, boron-lined proportional counter (VBPC), with wires strung vertically through the centres of each voxel providing the anodes. The normal blades are coated at ESS with ^{10}B-enriched (97%) B_4C [3], and neutron capture in this film of B_4C produces ^{4}He and ^{7}Li residual nuclei, one of which escapes the film into the VBPC gas (Ar-CO_2 in the present case) generating a signal.

This work describes a comparison of signal properties for two alternative schemes to read out the charge collected from the MG electrodes. This was performed using the EMMA thermal neutron beam [4] at the ISIS neutron spallation source in the UK.

2. Technical details

The MG voxel, viewed from the top in Fig. 1, is an elongated rectangle measuring $23.5 \times 9.5\,\mathrm{mm}^2$ in the $x - z$ plane, while it is $23.5 \times 24.0\,\mathrm{mm}^2$ in the x–y plane. An Ar-CO_2 (80%–20%) gas mixture operated at STP is employed. When a positive high voltage (HV) is applied to the anode wire, the corners of the voxel experience very low voltage gradients compared to more central regions. This affects the charge collection time, which increases as the neutron-capture position moves from the centre at $x = 0.0$ mm to a corner at $x = \pm 11.75$ mm. Neutrons are captured on the normal-blade coatings at $z = \pm 4.75$ mm.

T-REX prototype detector TRP-1 was tested. Unlike subsequent T-REX prototypes, this has no internal neutron shielding, such as B_4C coating on the radial blades to reduce internal scattering, but this does not affect charge collection. The absence of capture events on radial blades makes the understanding of the pulse-height response simpler. The coating thickness on the normal blades is ≈ 1 µm on the front voxels, rising to ≈ 2 µm on the rear voxels. This staggered increase in coating thickness partly compensates for the reduction in neutron flux seen by the rear voxels. As an important goal here was to compare different electronic readout systems, the same detector was connected to the two sets of electronics based on the VMM3A ASIC and CREMAT technology described in Section 2.1.1 and Section 2.1.2 respectively.

2.1. Electronics

The major motivation for this work was to test the suitability of read-out electronics based on the VMM3A 64-channel ASIC for T-REX. VMM3A is used on the Multi-Blade detector [5], employed on three instruments at ESS, and is available in sufficient quantity to instrument T-REX. However, due to relatively slow charge collection in the MG (up to several µs for electrons), the maximum pulse-shaping time constant (peaking time 200 ns) on the front-end pulse amplifier is shorter than optimum for a MG-type VBPC. Thus CREMAT amplifiers with longer shaping times (peaking time 4 µs) were also tested for comparison.

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* Corresponding author.
E-mail address: john.annand@glasgow.ac.uk (J.R.M. Annand).

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Full Length Article

Neutron interaction properties of structural materials for multi-grid neutron detectors

A. Backis [a], C.-C. Lai [a], M. Aouane [a], P.P. Deen [a], K.G. Fissum [a], J.R.M. Annand [b],*,
K. Livingston [b], D. Raspino [c]

[a] *European Spallation Source ERIC, SE-221 00 Lund, Sweden*
[b] *School of Physics and Astronomy, University of Glasgow G12 8QQ, Scotland, UK*
[c] *ISIS Facility, Rutherford Appleton Laboratory, Harwell Campus, Oxfordshire OX11 0QX, UK*

ARTICLE INFO

Keywords:
Multi-grid neutron detectors
Structural materials

ABSTRACT

The T-REX neutron time-of-flight spectrometer at the European Spallation Source will use Multi-Grid Technology, which relies on thin B_4C coatings on the Al blades of the grids to detect scattered thermal neutrons. Following a Monte Carlo study of internal shielding to suppress neutron multiple scattering in T-REX, the neutron transmission and scattering properties of 12 shielding-material samples have been measured at the ISIS spallation neutron source. Neutron transmission was measured on the EMMA beam line at wavelengths 0.5–4.7 Å, using a 2D-position-sensitive, neutron GEM detector, while neutron scattering was measured for 6 of the samples at the Merlin spectrometer, at wavelengths 0.72, 1.28, 1.85 and 2.41 Å. The present tests show that a B_4C/Al composite material, plated with Ni to stop intrinsic alpha background, is an effective neutron absorber, suitable for incorporation in the Multi-Grid structures which detect the neutrons in inelastic neutron spectrometers.

1. Introduction

Multi-Grid (MG) technology for detection of sub-eV neutrons, originally developed at ILL [1], will be used in the T-REX bispectral chopper spectrometer which is under construction at the European Spallation Source (ESS) [2]. The Multi-Grids are stacks of grids, each a rectangular lattice of normal and radial Al blades (Fig. 1). The grids form the cathodes of a voxelised proportional counter (VPC), with wires strung through the centres of each grid voxel providing the anodes. The normal blades are coated with ^{10}B-enriched B_4C, and neutron capture in the B_4C film produces ^{4}He and ^{7}Li ions, one of which escapes into the VPC gas (e.g. Ar-CO2) giving a detectable signal. Al is the main structural material for both the grids, their support mechanics and the gas containment vessels, as its neutron absorption cross section is relatively low. Nevertheless neutrons can scatter internally in the Al and other nearby materials before they eventually convert and this distorts the time-of-flight (TOF) and angle-of-detection measurement, thereby distorting the energy and momentum-transfer measurement by the spectrometer.

Internal neutron scattering can be suppressed by installation of internal shielding [3–5], at the sides and rear of the MG and on the radial blades of the grids. Monte Carlo simulations of neutron scattering from Vanadium into T-REX [6] indicate that internal shielding materials based on B_4C can result in a major reduction in internal scattering within the spectrometer. Scintered B_4C sheet would be a possibility for side and rear shields, but structurally this is a difficult material and it is unsuitable for radial blades, which must be electrically conductive. A number of materials containing B_4C are available and their shielding effectiveness has been investigated using the Geant4 [7] model of T-REX. Subsequently neutron transmission and scattering properties of good candidate shielding materials were measured at the EMMA [8] and MERLIN [9] beam lines of the neutron-spallation facility ISIS and compared to Geant4 simulations of these test measurements.

2. Neutron transmission tests at EMMA

Measurements of neutron transmission through samples of shielding material were performed on the EMMA beam line, with the Fermi chopper powered down to produce a white neutron beam. A schematic of the experimental setup is shown in Fig. 2 (left plot), while the neutron wavelength spectrum is displayed in Fig. 2 (right plot, sample out). The samples are listed in Table 1.

The neutron beam was collimated by movable B_4C jaws, set to produce a rectangular aperture of $25 \times 50\,\mathrm{mm}^2$. It then passed through a low efficiency beam monitor (BM), the sample under study, and a

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* Corresponding author.
E-mail address: john.annand@glasgow.ac.uk (J.R.M. Annand).

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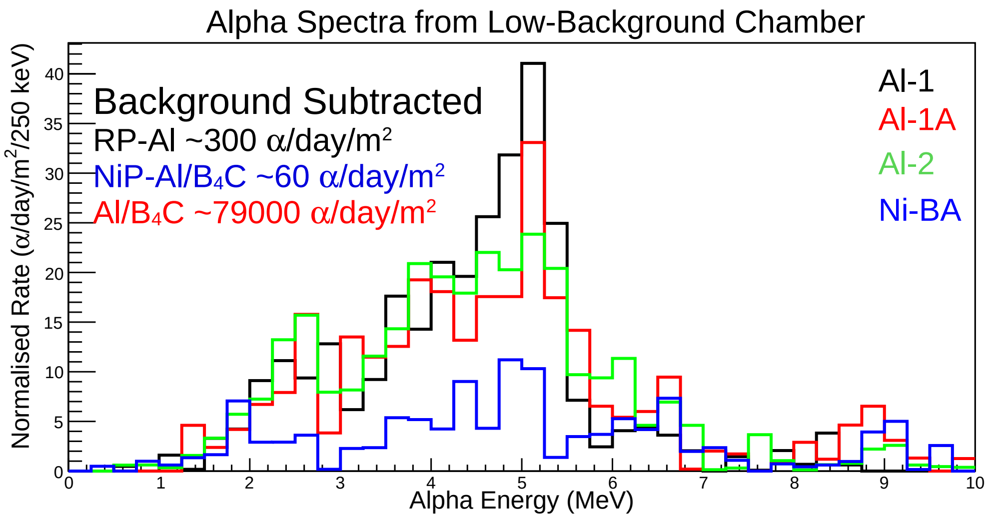
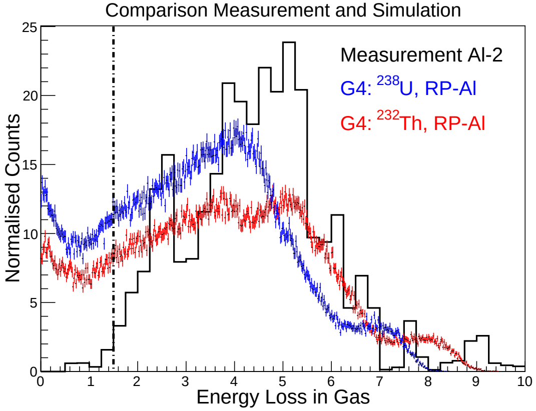
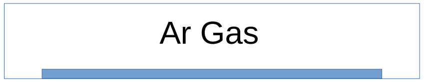
Alpha Background in Multi-Grid Neutron Detectors







G4 Model of Krakow Detector

Ar Gas

Sample Sheet

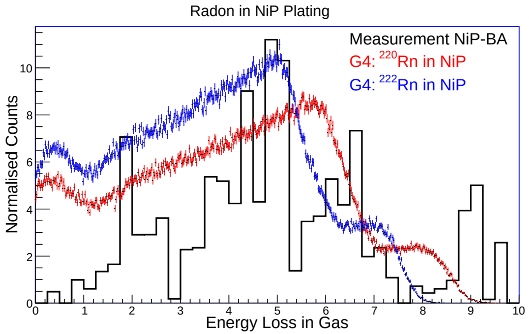
Detector threshold nominal 1.5 MeV

- Follows on from: *J.Birch et al., JINST 10, 2015, 10019*
- Comparison alpha emission from radio-pure Al, Al/B_4C composite and NiP-plated Al/B_4C
- Measurements at large-area ionisation drift chamber in Krakow.
- Geant4 simulation of effect of NiP-plating thickness.
- Background measurements T-REX prototypes at Utgård. RP-Al or Ni-Al/B_4C radial blades

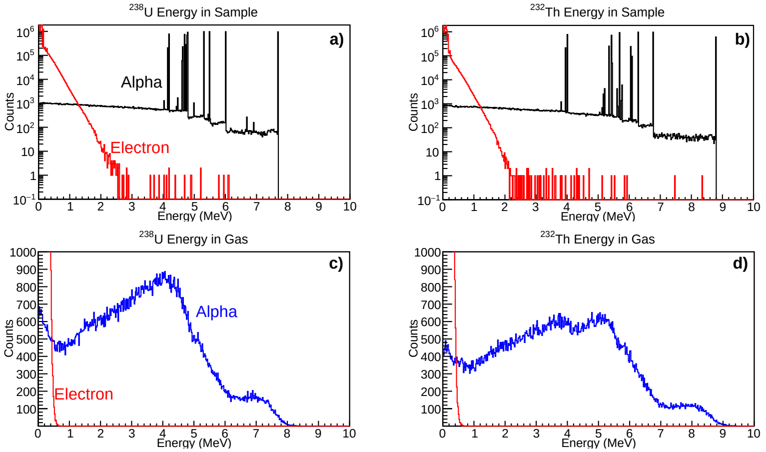
Simulation of Alpha Background

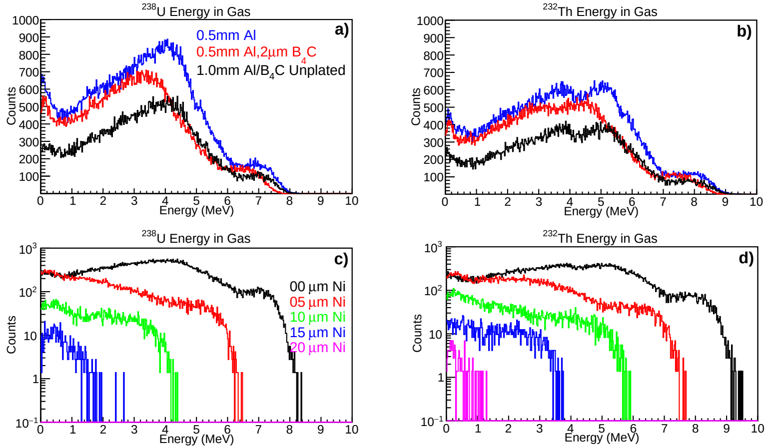
G4RadioActiveDecay

- Alpha emission: input Z and A primary isotope.
- Assume ^{238}U and ^{232}Th primary emitters
- Decay chains from ENDF
- Record energy loss of alphas and electrons in sample & detector gas



Radon effect NiP-Al/B$_4$C

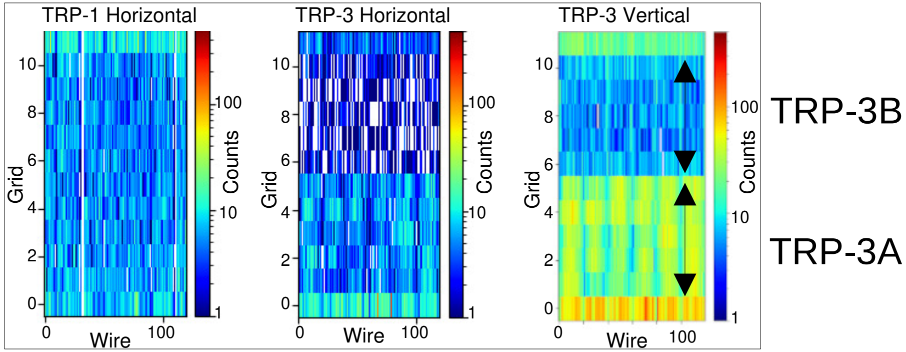


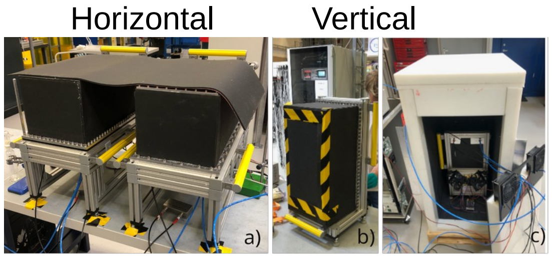


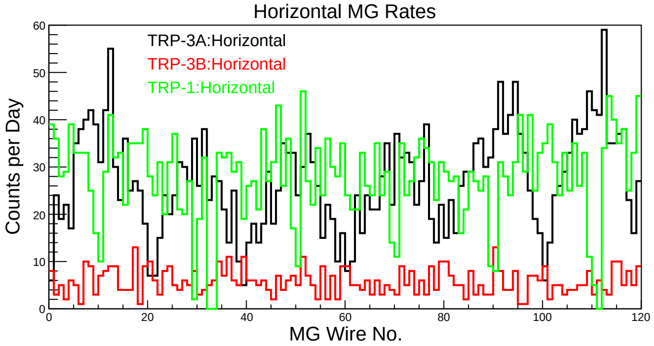
- Alpha cannot escape 25 μm NiP plating if decay happens inside sample.
- Radon can diffuse out of Al/B$_4$C into NiP or Surface or Gas

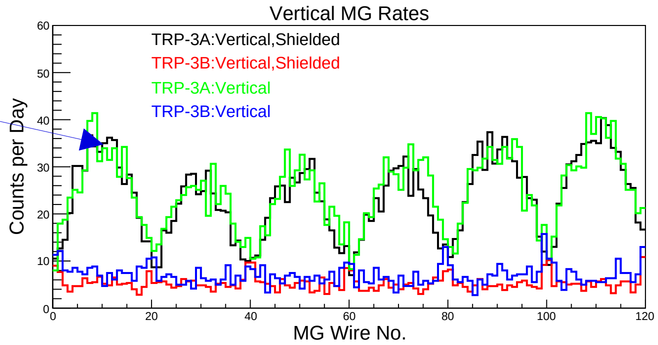
Alpha Background: Utgård Tests

2D projection of wire/grid counts









- Two prototypes tested: TRP-1, TRP-3
- TRP-1 RP-Al radial blades
- TRP-3A Ni electroplated Al/B$_4$C
  Ni plate thinner at middle of blade
- TRP-3B NiP electroless Al/B$_4$C
  NiP thickness uniform
- Small cosmic neutron component of TRP-3B background

T-REX Simulation Update

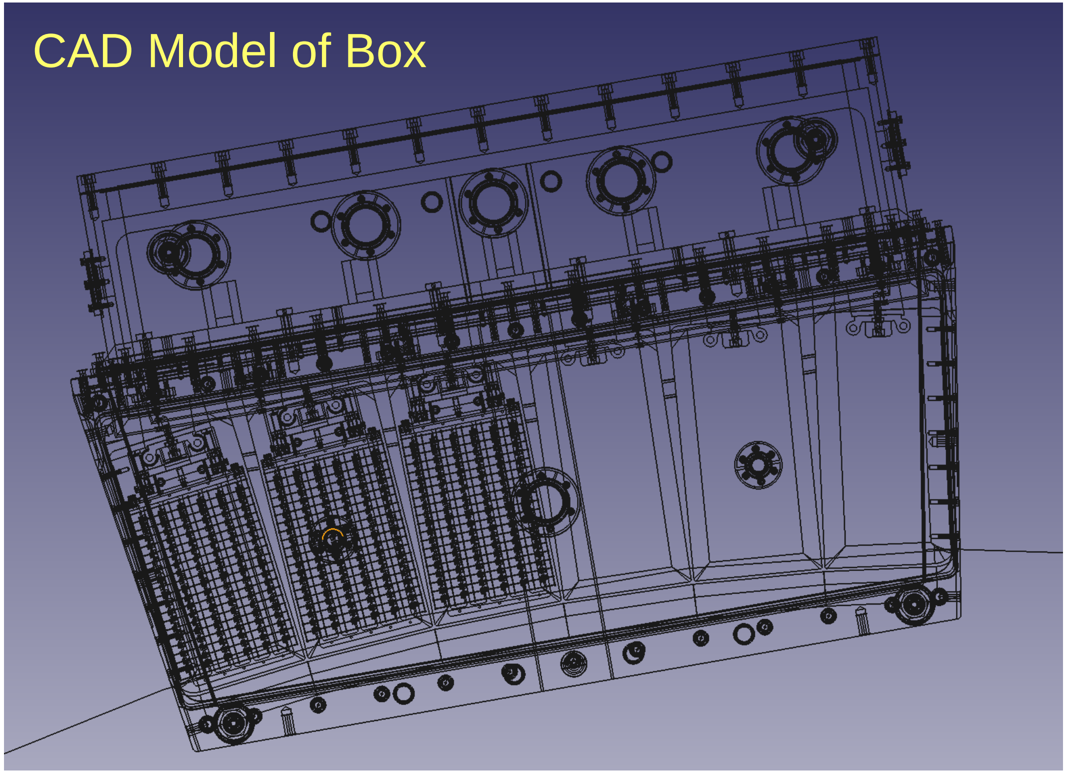
- Extension of Ncrystal description of materials (for EMMA tests)
- T-REX geometry derived from CAD drawings of T-REX
- More realistic model of T-REX boxes which contain the Multi-Grid columns
- More realistic model of support structures which hold the MG columns in place
- 1st approximation of cryostat structures around the sample
- McStas calculation of TOF structure of chopped beam (from Mo Aouane)
- Effect of extra shielding Vanes

To Do…

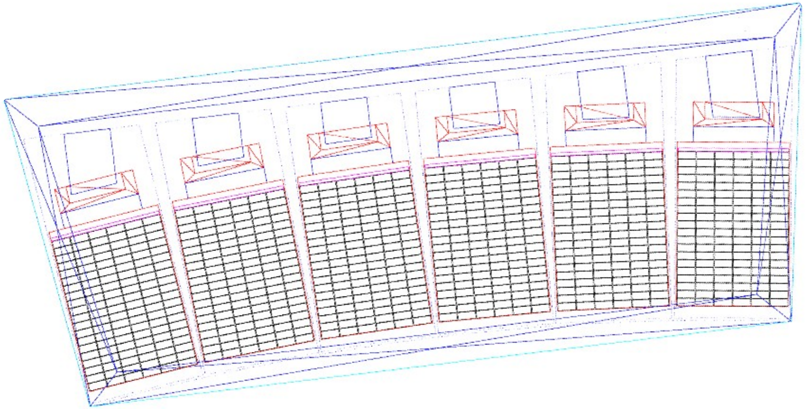
- Outer vacuum tank
- Specification of the beam monitors to be used at T-REX ?

T-REX Single Box

PRELIMINARY



Geant-4 Model of Box

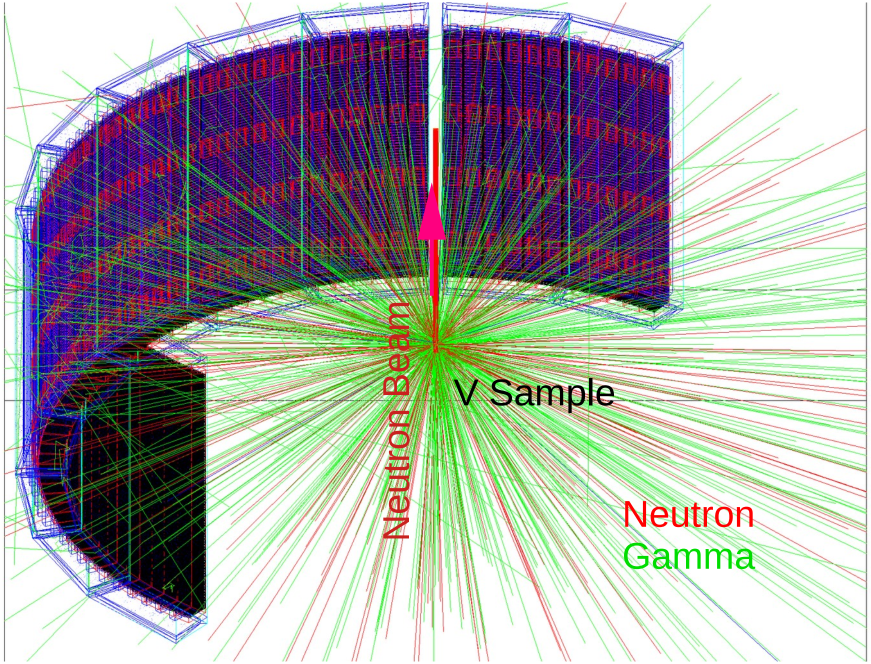


- Dimensions from CAD
- Multi-Grids modeled “exactly”
- Box and MG support structures approximations of CAD
- Model location and amount of bulk material as accurately as possible (in progress)

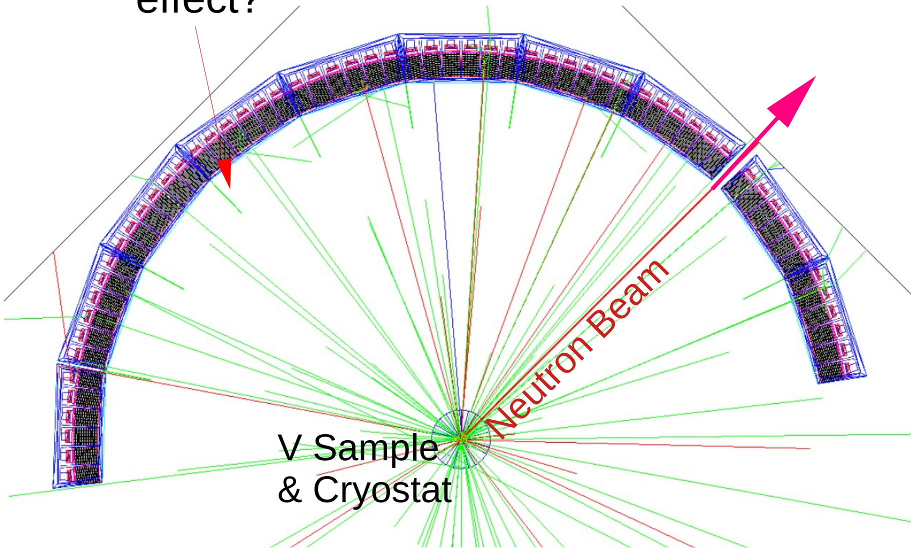
Conversion stp to gdml not practical at this level of complexity. Overlapping volumes (confuse tracking algorithms). Even if geometry perfect, tracking would be extremely slow.

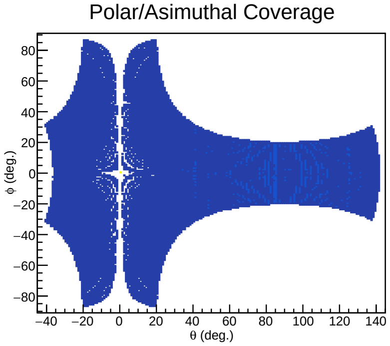
TREX 10 Box Version

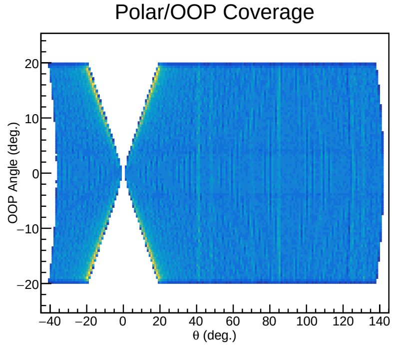
PRELIMINARY



Do protruding shielding vanes have significant effect?





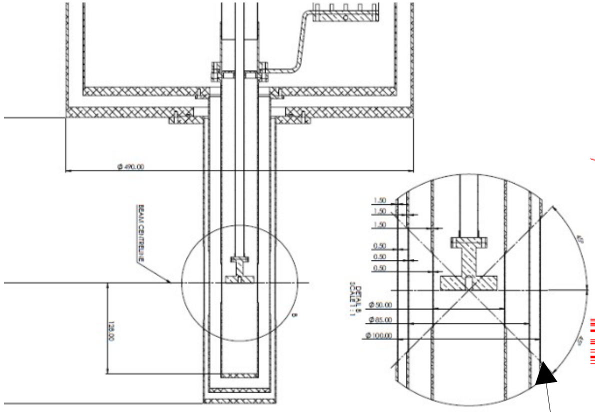


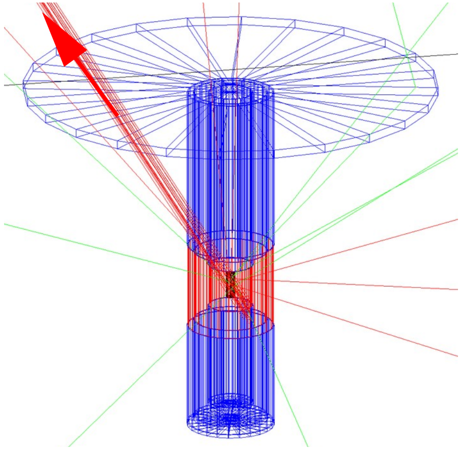
Vanes protrude around 400mm beyond front face of Box. Does this fit mechanically??
Material either: 4mm Al/B_4C or Cd sheet.
Attenuation factor 4mm Al/B_4C is 99.8% @ 1 Å

Sample Cryostat

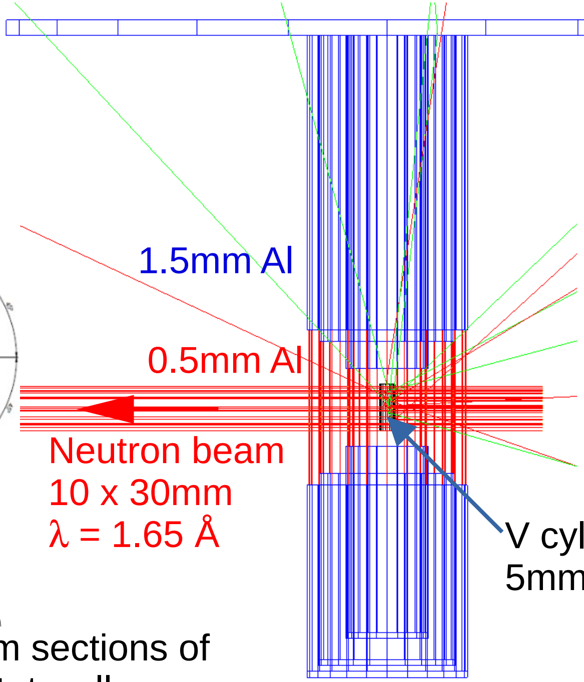
PRELIMINARY

Detail of Cryostat





0.5mm sections of cryostat walls span out-of-plane coverage -45 to +45 deg.

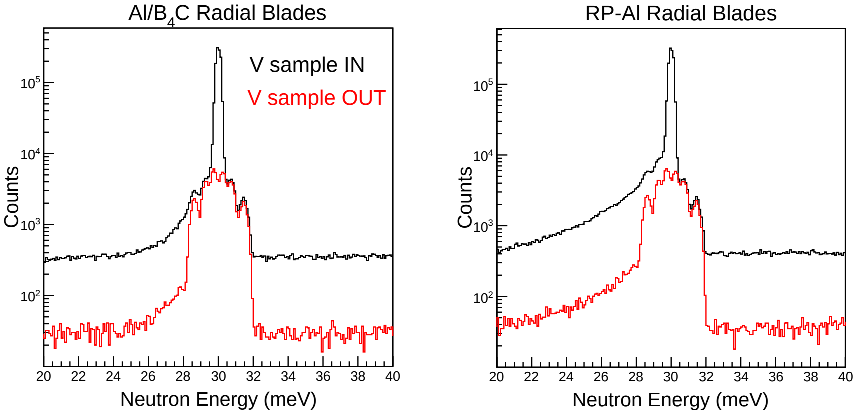


1.5mm Al

0.5mm Al

Neutron beam
10 x 30mm
λ = 1.65 Å

V cylinder
5mm radius



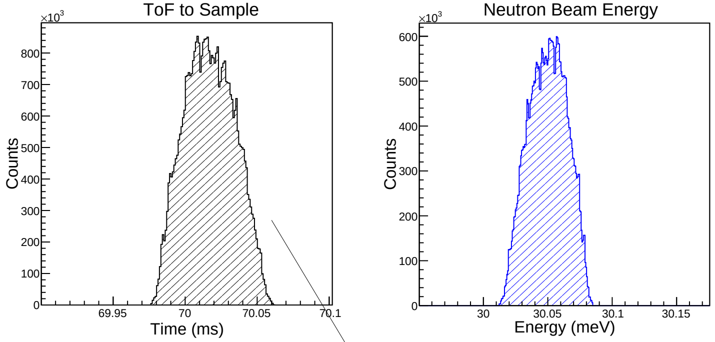
Contribution of cryostat walls to neutron energy spectrum

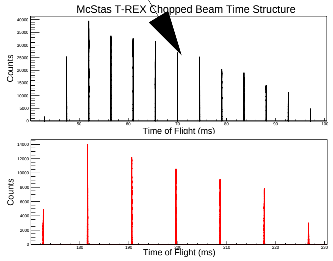
Neutron Time Structure

PRELIMINARY

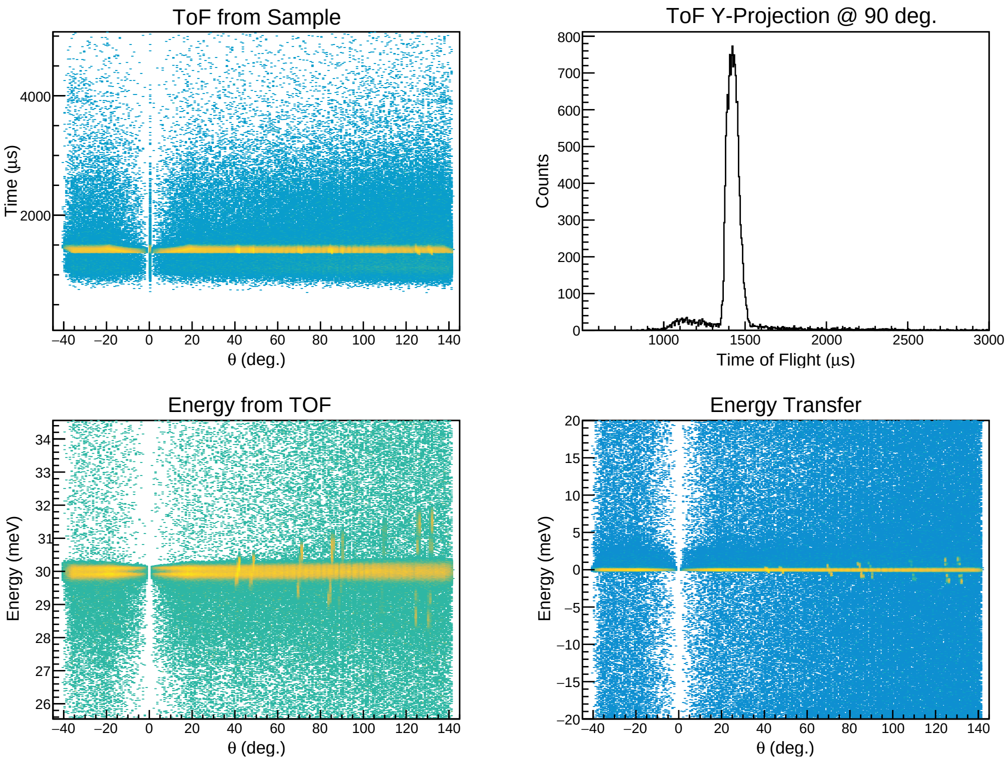
Beam time structure

- McStas calculations (Mo Aouane)
- 2 chopper settings provided
- ToF @ sample position
- Start with ToF peak at ~70 ms or 30 meV



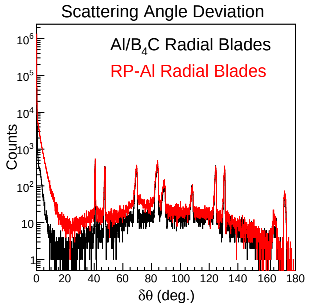


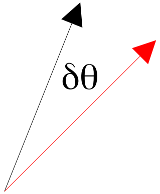
Detector Hits: ToF from sample to detector



Multiple Scattering: Effect of Shielding Vanes

PRELIMINARY



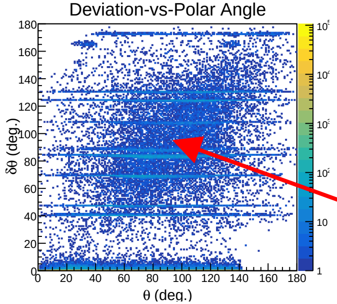


True Scattered Neutron Vector

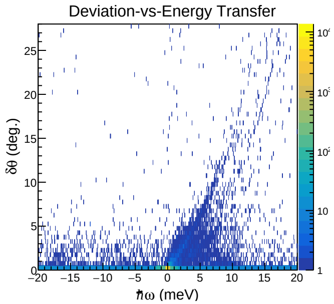
Vector from detector hit pos

$\delta\theta < 0.2^\circ$ Direct Scatter

$\delta\theta > 0.2^\circ$ Multiple Scatter

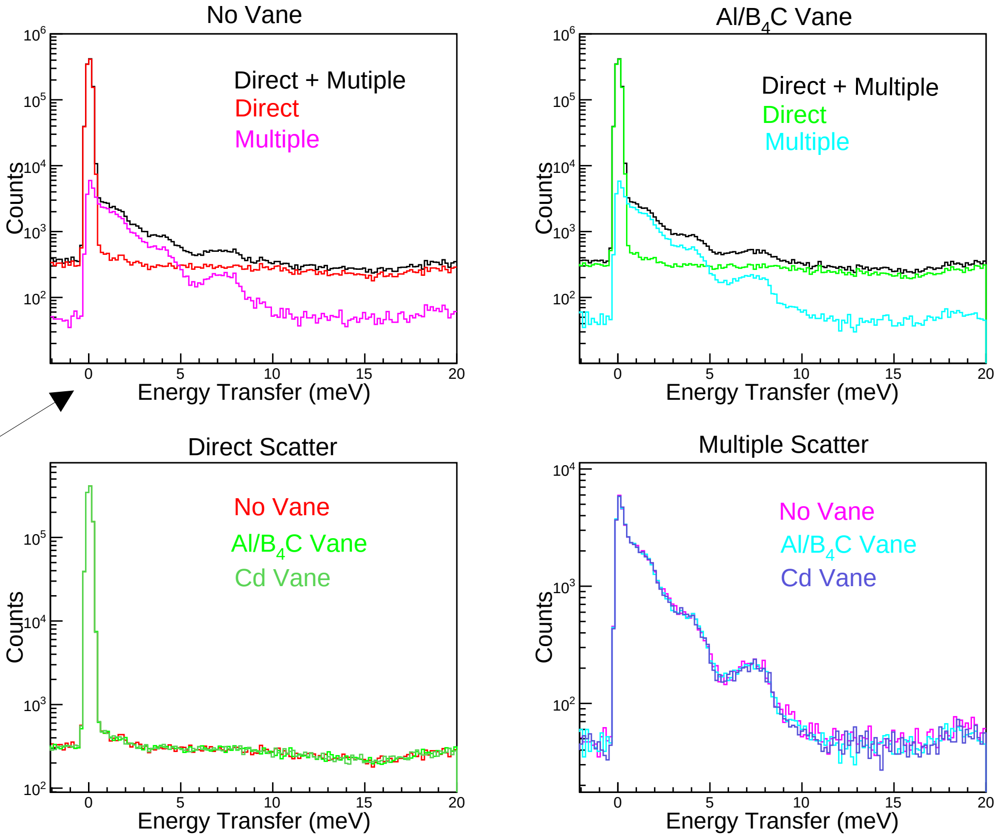


Neutron interaction in cryostat Al walls



- Select events: single neutron scatter in V sample
- Vanes are 4mm thick
- No vane support structures

MG Radial Blades NiP-Al/B$_4$C



Summary

- Work on publications continues, alpha-background article well advanced, probably submit to JINST.
- Geant-4 T-REX model updated
- McStas chopped beam ToF structure (start with peak at 30 meV, 1.65 Å)
- MG box geometry based on CAD drawings
- Simple model of cryostat added (optional inclusion)
- Calculating effect of shielding vanes between boxes in progress (preliminary calculations suggest very small effect)