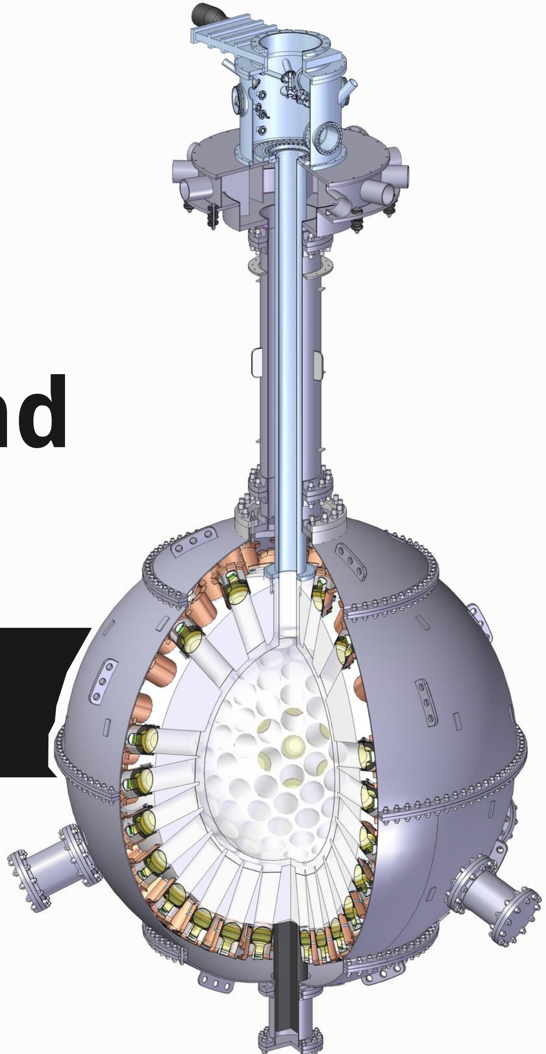
Surface Alpha Background Mitigation in DEAP-3600

2014 Canadian Association of Physicists (CAP) Congress

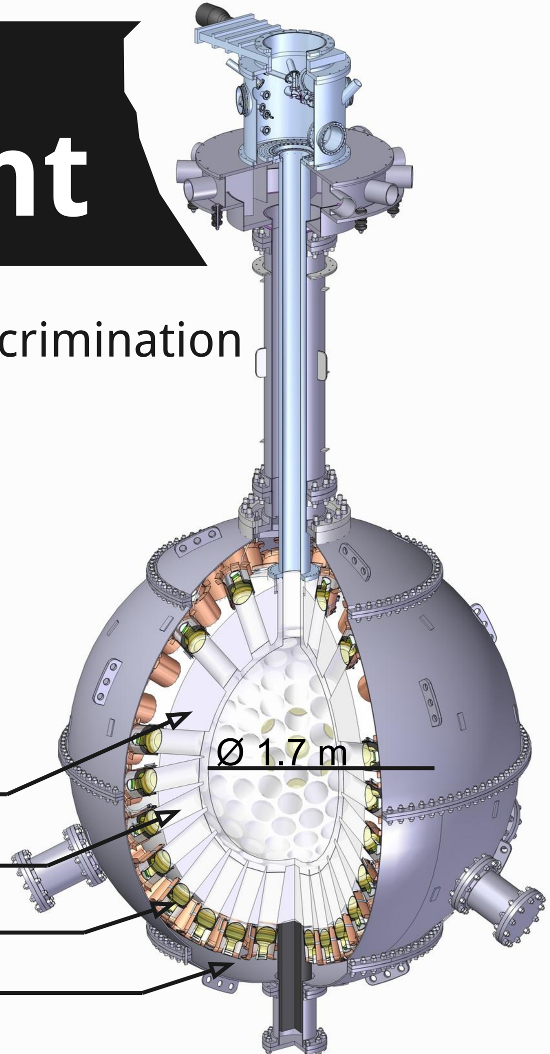
Joshua E Bonatt, on behalf of the DEAP collaboration
Queen's University



DEAP-3600 Experiment

Dark matter **E**xperiment using **A**rgon **P**ulse-shape discrimination

- **Located at SNOLAB in Sudbury, Ontario**
- **Single phase liquid argon detector**
- **3600 kg of active mass, 1000 kg fiducial mass**
- **Spin independent sensitivity of 10^{-46} cm^2 for 100 GeV WIMPs**



MINING FOR KNOWLEDGE
CREUSER POUR TROUVER... L'EXCELLENCE

DEAP-3600 Collaboration

Queen's University

Laurentian University
Université Laurentienne

TRIUMF

Science & Technology Facilities Council
Rutherford Appleton Laboratory

Carleton University

SNOLAB
MINING FOR KNOWLEDGE
CREUSER POUR TROUVER... L'EXCELLENCE

University of Alberta
Quaecumque Vera

Royal Holloway University of London

US
University of Sussex

Overview

Resurfacer

- What is it?
- What does it do?
- Why do we need it?

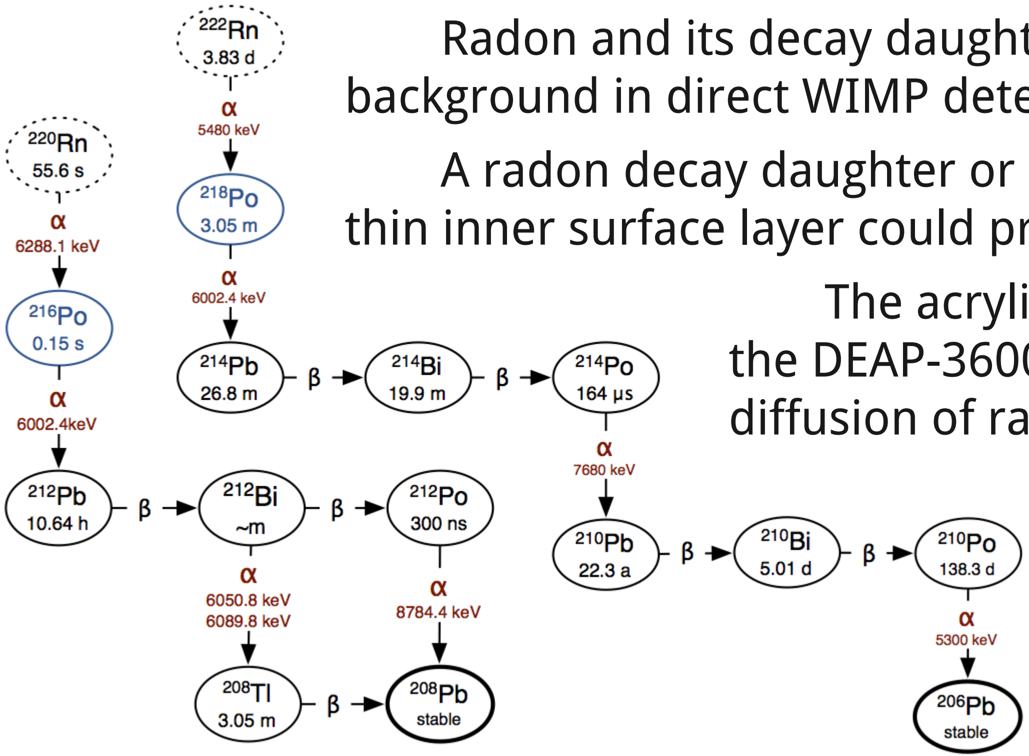
Surface Alpha Backgrounds

- What are they?
- Where do they come from?
- How are these and other backgrounds cut?
- How can using GAr help us understand them?

Neck Design

- Do we want a TPB coating on the acrylic flowguides?

Radioactive Backgrounds



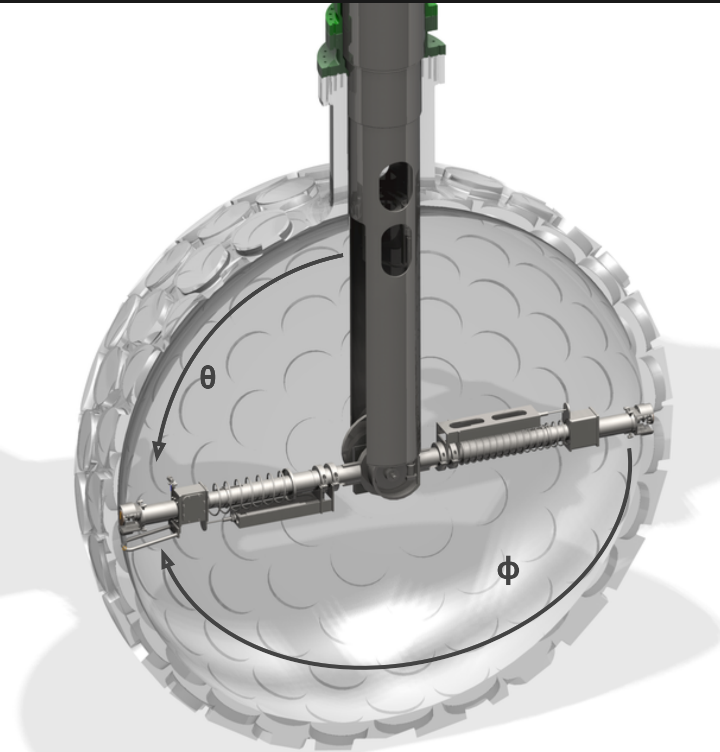
Radon and its decay daughters are a well known source of background in direct WIMP detection experiments.

A radon decay daughter or an alpha particle emitted from a thin inner surface layer could produce a WIMP-like signal.

The acrylic vessel, which is the central part of the DEAP-3600 detector, is susceptible to surface diffusion of radon when exposed to natural air.

This diffusion layer must be removed in order to produce a sufficiently low background-level experiment.

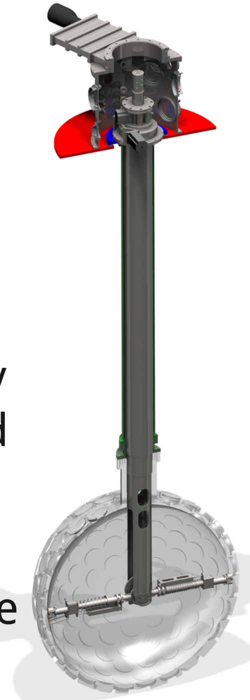
Resurfacer



To remove diffused isotopes from the inner acrylic vessel, the Resurfacer was designed to remove approximately **1 mm of acrylic from the interior surface**.

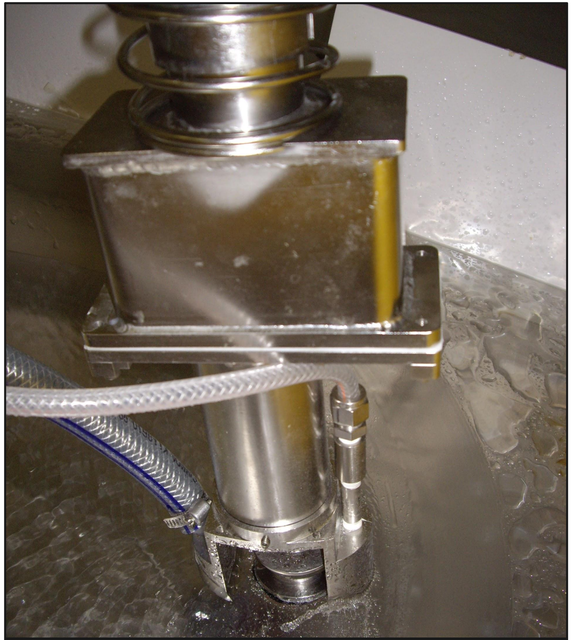
N_2 purging and UPW flushing are active during resurfacing. Like everything near or in the inner detector, appropriately **low-radon emanation materials** are used only.

Commissioning and testing has been carried out at Queen's University, and more recently on site at SNOLAB.

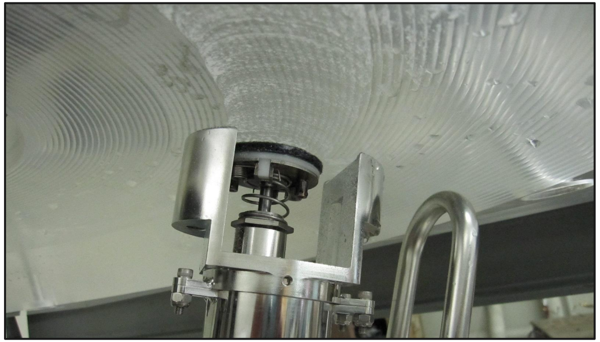


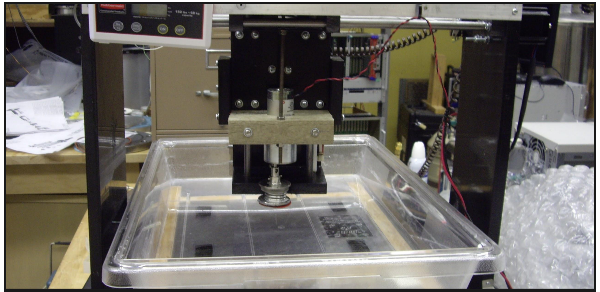
Resurfacer

Picture showing only South acrylic test block in place



UPW flushing and Acrylic/UPW extraction lines

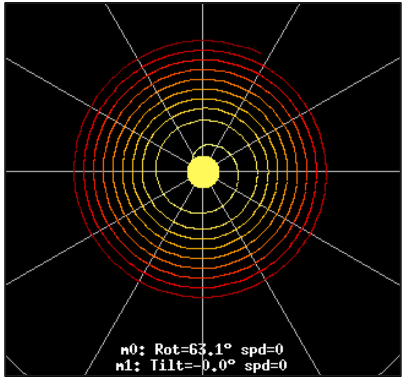


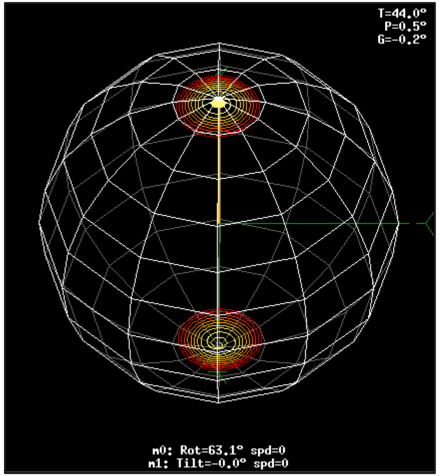


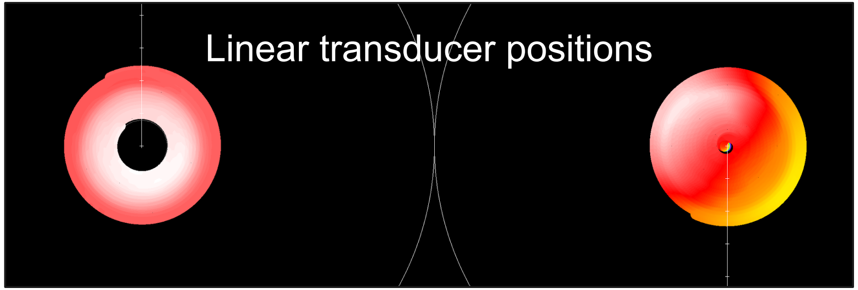
XY table for sandpaper longevity testing

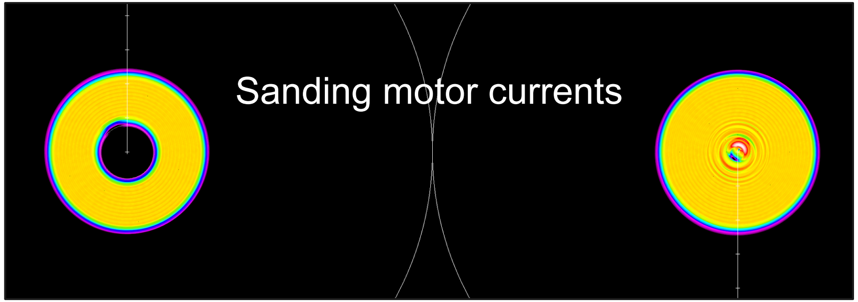
Resurfacer Monitoring

A live computer program GUI and post-analysis methods are employed to understand sanding quality of both the Resurfacer and its sandpaper samples.









Resurfacer Monitoring

To verify uniform and accurate removal,

- **Linear displacement transducers** to directly measure radial variation and change.
- **Sanding head motor currents**; the removal rate is proportional to the force applied, and the force being applied is proportional to the current supplied.
- **Extraction line filters** to collect acrylic dust for weighing and assaying (10.7 kg expected).
- **Gas phase run** may also get accurate, updated ^{210}Pb g/g assay to review new surface. Current bulk ^{210}Pb assay is 2.2×10^{-19} g/g (< 0.1 fiducial events in three years).

Resurfacer Estimated Runtime

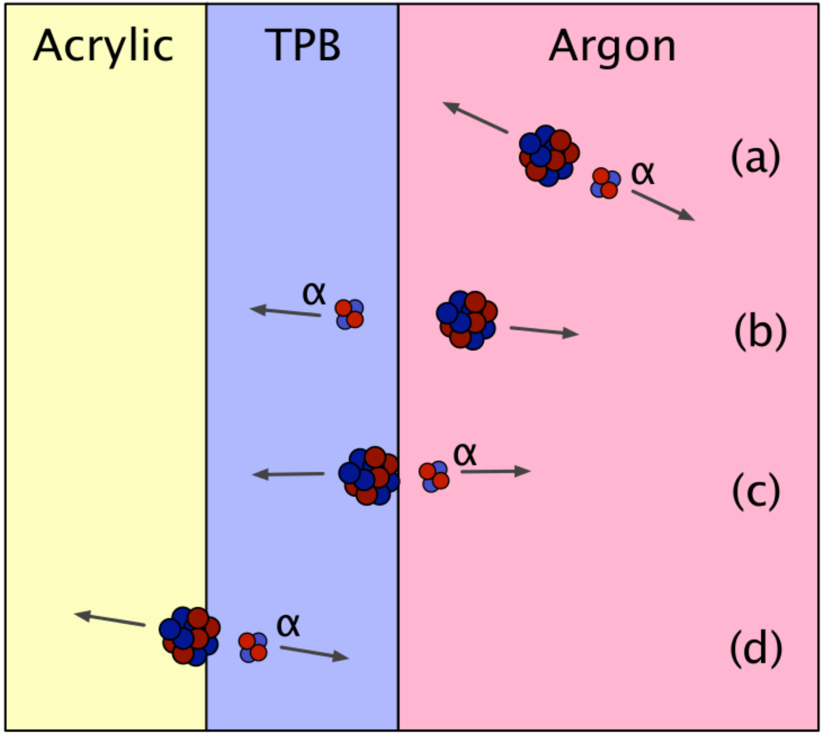
Based on commissioning tests at Queen's University,

< 500 hours of operational runtime to remove 1 mm of acrylic, assuming **12 g/hr acrylic removal rate** with 20% loss of sanding efficiency**.**
Or, **3 weeks of recurrent sanding,** underground shifts permitting.

Results are from acrylic blocks and sandpaper-specific studies (North and South blocks account for 5% of the total AV surface, 0.47 m^2 at 21.5° vs 9.1 m^2). Equatorial sanding tests were also performed, though are not presented here.

Further testing to be finalized on site at SNOLAB, with updates from Pietro Giampa (F1-5, 2014 CAP).

Surface Alpha Backgrounds



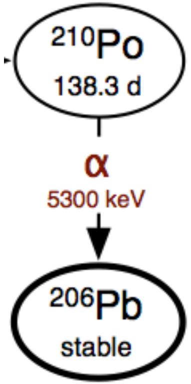
(a) Nucleus and alpha into Ar

(b) Alpha into TPB, Nucleus into Ar

(c) Nucleus into TPB, Alpha into Ar

(d) Nucleus into Acrylic, Alpha into TPB

Surface ^{210}Polonium alpha events have been simulated with GEANT4 to study the signature of these backgrounds in the inner detector.



Mitigating Surface Backgrounds

To remove most acrylic surface backgrounds,

Resurface the inner acrylic vessel (AV)

Hand sand the acrylic flowguides (Neck)

This will remove diffused surface contamination during construction, but bulk material activity still presents a constant background rate. So,

- ➢ **Characterize surface alpha events** in AV and Neck, and event discrimination and tagging.
- ➢ **Cleanliness analysis** and assay of newly resurfaced av and acrylic flowguides in gaseous argon phase.
- ➢ **TPB deposition in the flowguide**? Compare and contrast neck events with and without the wavelength shifter to determine viability.

Mitigating Surface Backgrounds

Methods to reduce radioactive backgrounds

Fiducialization

- ➢ Limit understood events to a geometry within bulk medium.
- ➢ Event reconstruction determines likely location of event.

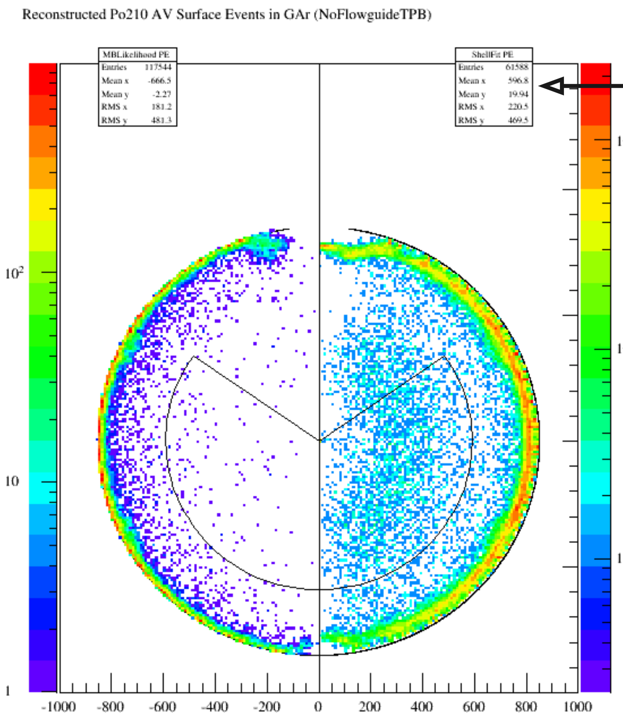
Energy region of interest

- ➢ Number of photoelectrons (PE) detected by the PMTs depends on the energy of the event and the efficiency of the PMTs involved.

Scintillation light ratios

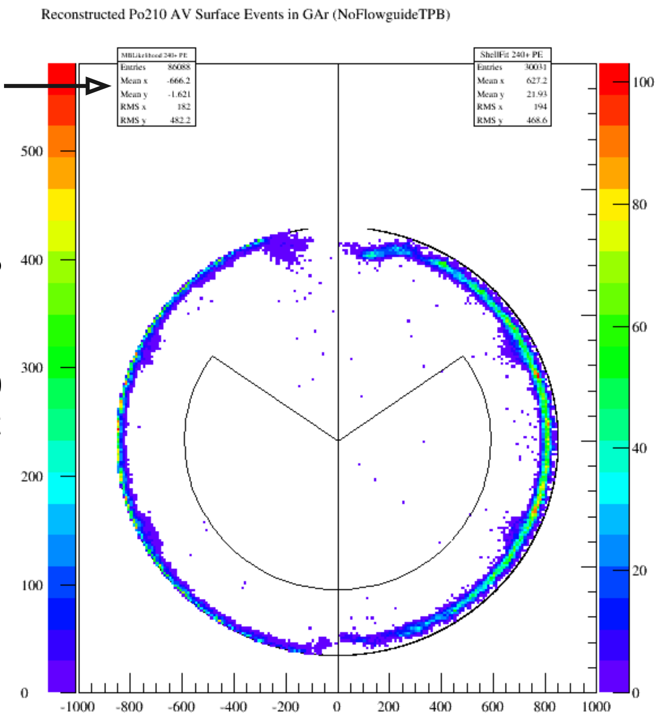
- ➢ Separating PMT prompt and late light signals is an integral part of DEAP's pulse shape discrimination (PSD), eliminating almost all electron recoil interactions.
- ➢ Fprompt is the fraction of charge in the calibrated waveform sum falling in a defined prompt window over the total charge of the waveform sum.

Fiducial and PE Cuts



Before cuts within a specified PE region

After cuts within a specified PE region



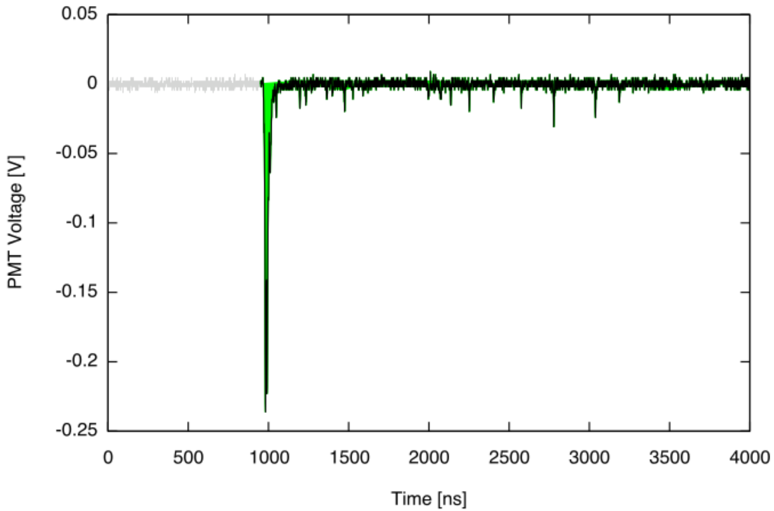
In LAr, expected WIMP events fall within a 120-240 PE region of interest. In GAr, this region shifts to above 240 PE because of increased light yield in gas phase.

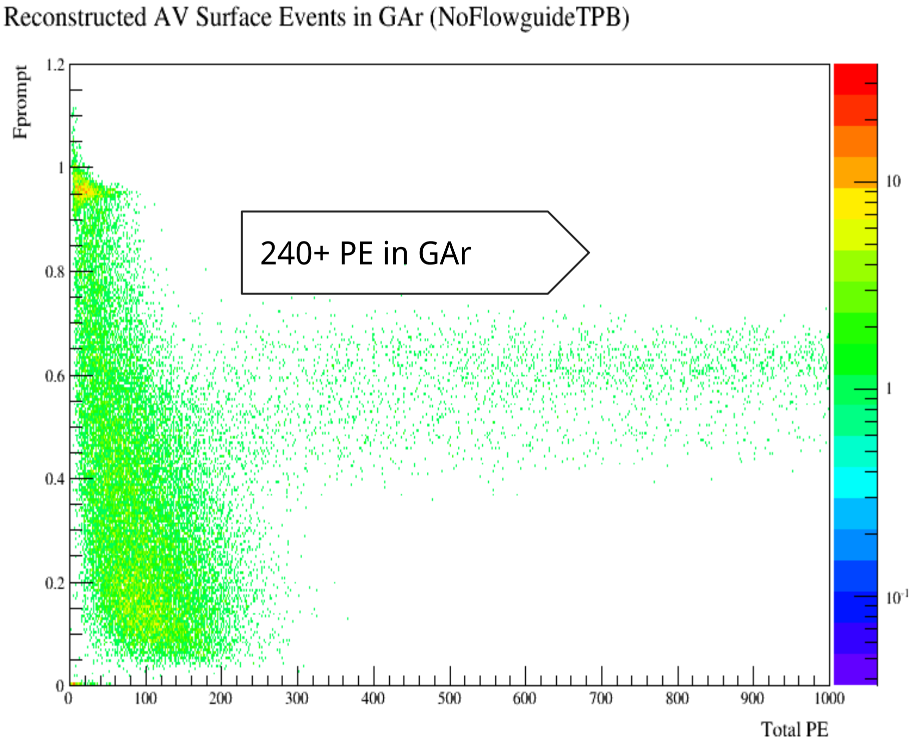
The fiducial volume is a sphere with a spherical cone removed to eliminate neck event leakage.

Fprompt and PE Cuts

A two-dimensional region of interest

For example, in DEAP, the region of interest in LAr currently lies within **120-240 PE and near 0.8 Fprompt.**



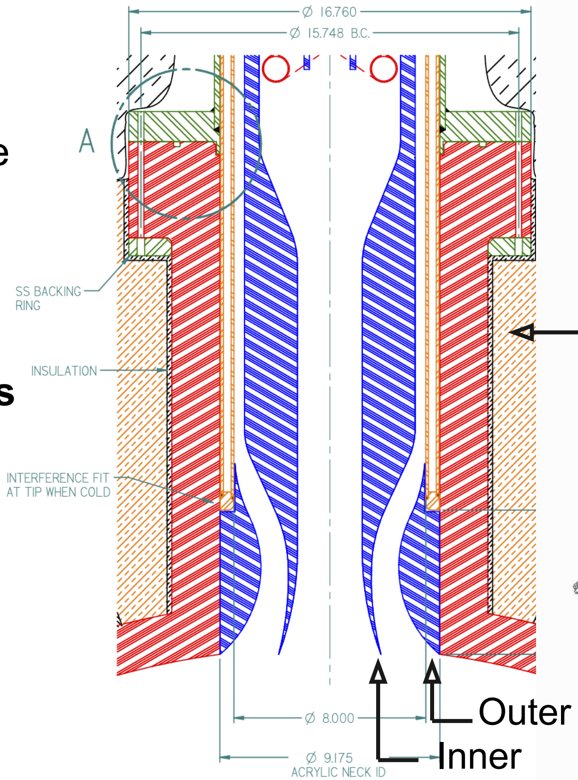


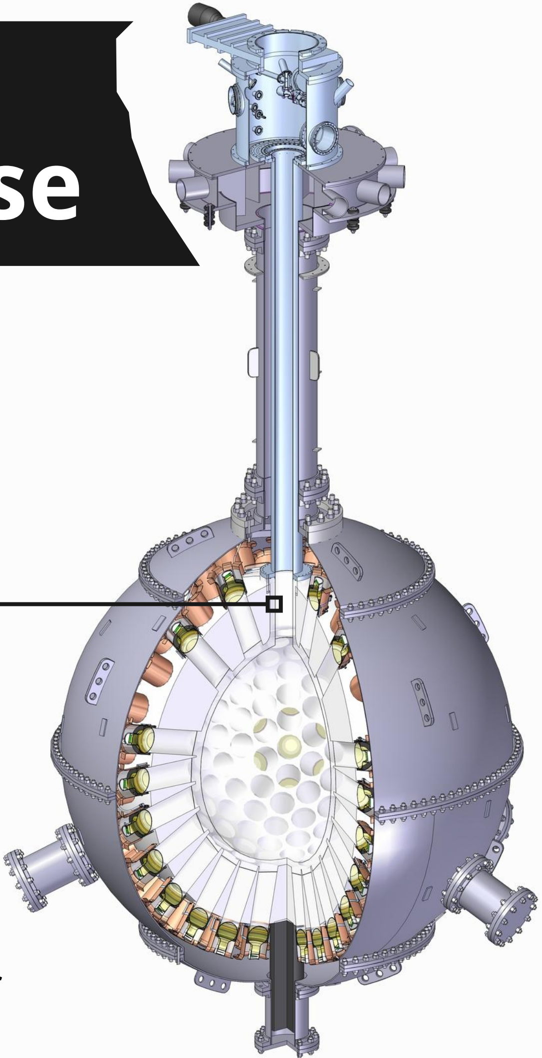
Utilizing the Gaseous Phase

The acrylic flowguides and other lower neck components are naturally weak for cleanliness of the inner detector.

Data taking with gaseous argon before the liquid phase could help assess the level of contamination in the components of the neck.

Events from the neck are also poorly reconstructed due to poor PMT coverage, so controlling backgrounds at least in terms of geometry is integral. Can TPB deposition on the flowguide help?





Utilizing the Gaseous Phase

Assuming an upper limit of ^{210}Pb content of 2.2×10^{-19} g/g, one should expect 1057.84 events with greater than 240 PE in three years running from the flowguides. Or,

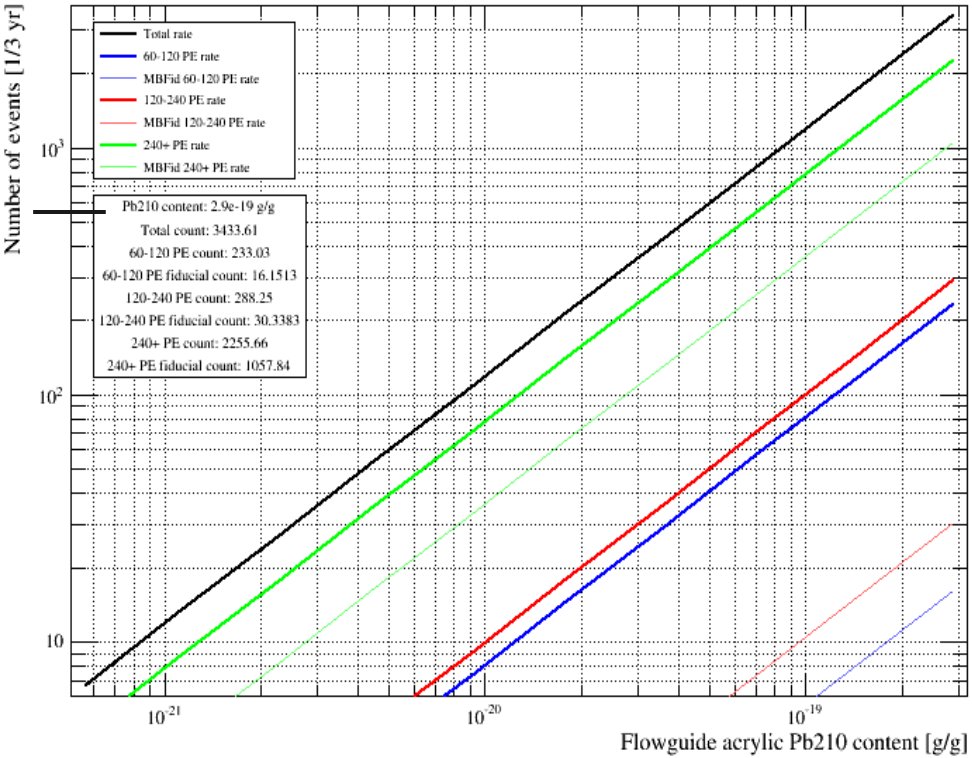
2.06 ± 1.4 full events per day
0.96 ± 0.9 fiducial events per day

From the inner AV (not shown),

212.4 ± 14.6 full events per day
0 fiducial events per day

All interesting data come from the neck region since the use of fiducial volume shields surface alphas originating from the AV.

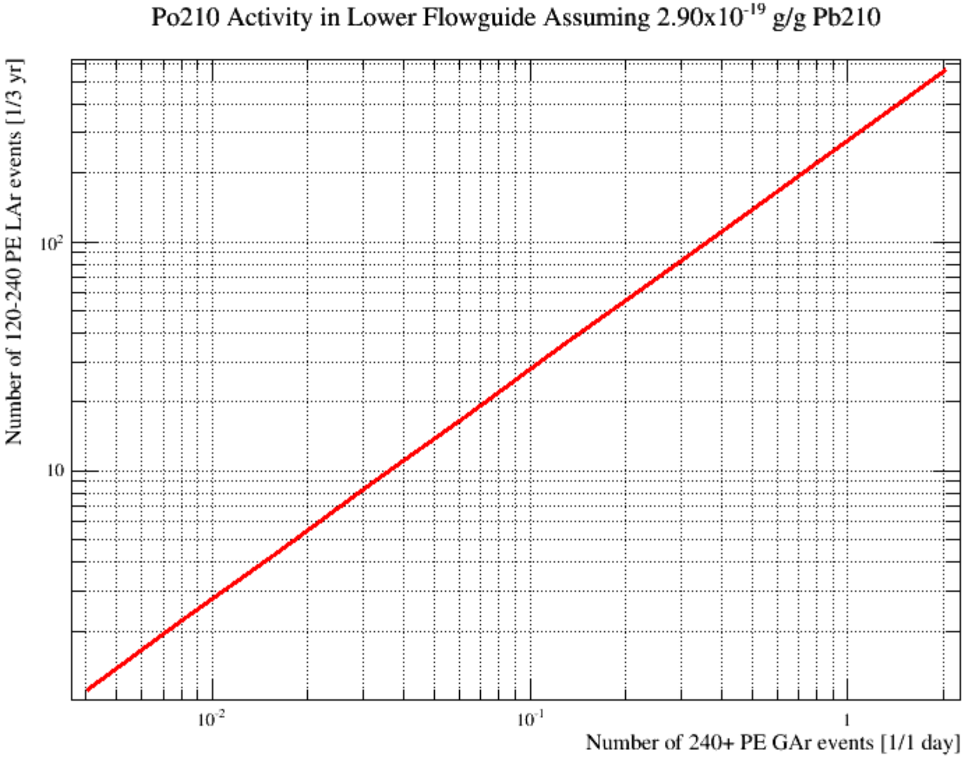
A 2-3 week gas run should accumulate enough data to better understand contamination levels, but not currently defined.



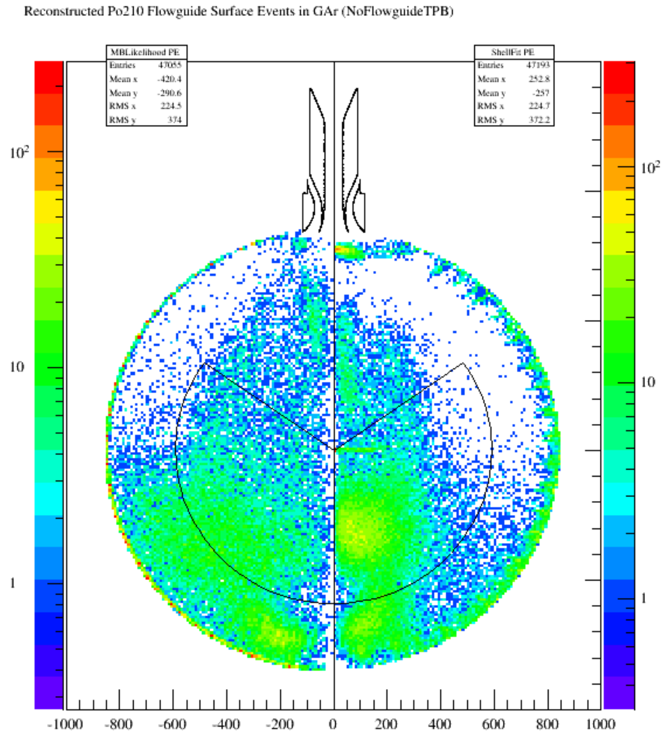
Projecting GAr to LAr

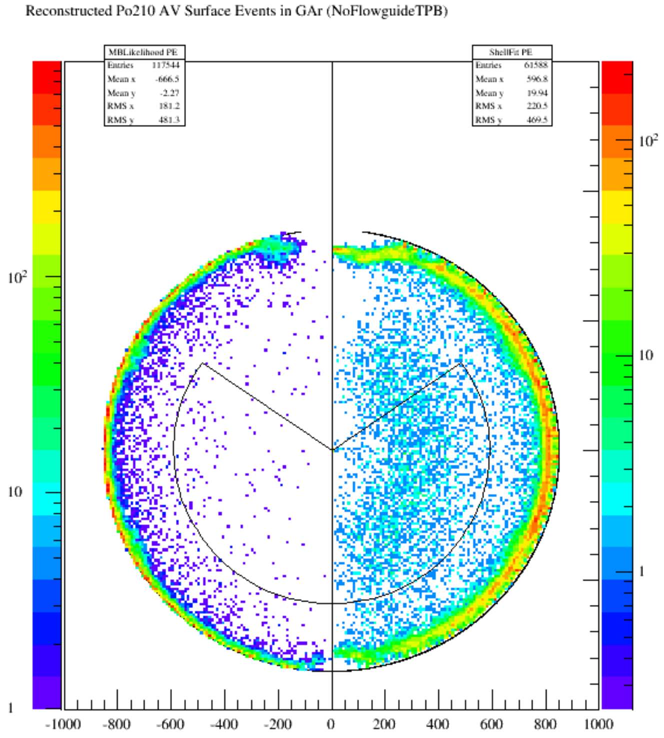
A detected rate of 2 events per day from the acrylic flowguides in gaseous argon corresponds to an **expected rate of 569 in liquid argon**, without fiducialization.

Liquid argon simulations were performed for this, though data not shown.

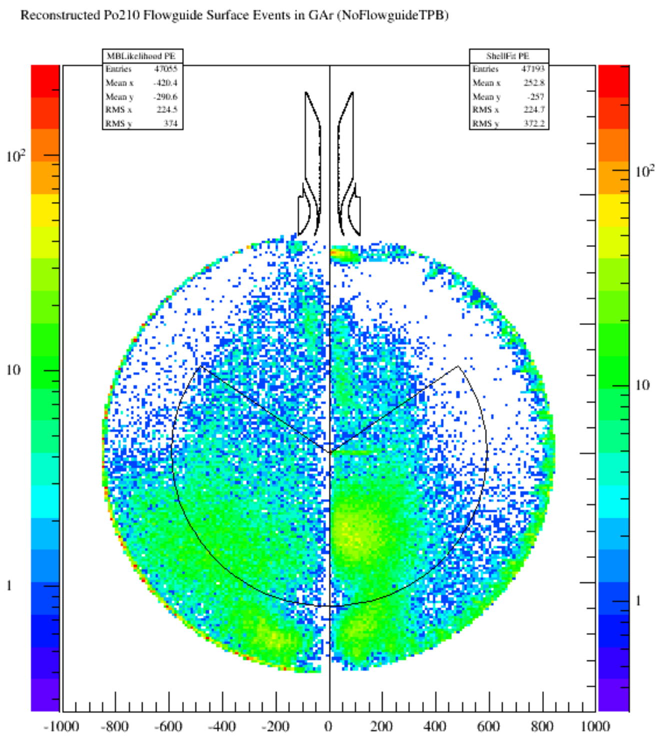


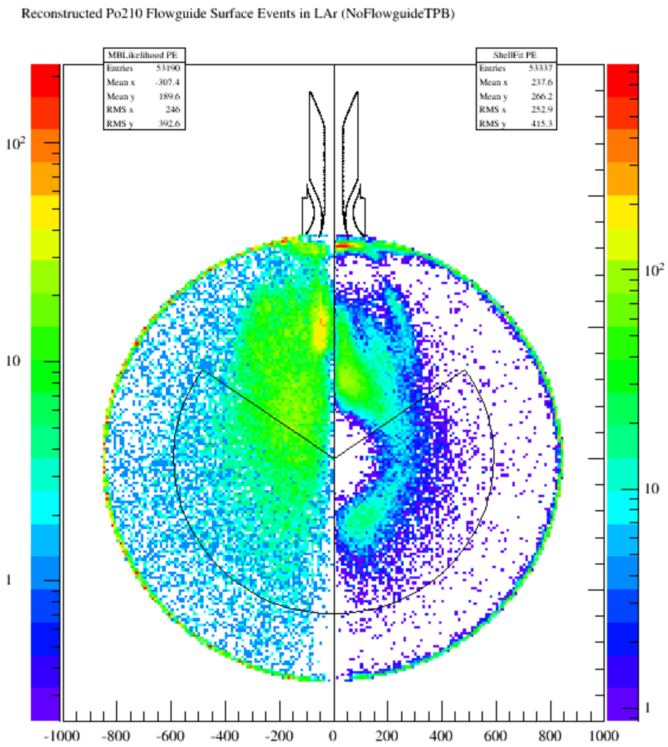
Contrasting Neck and AV





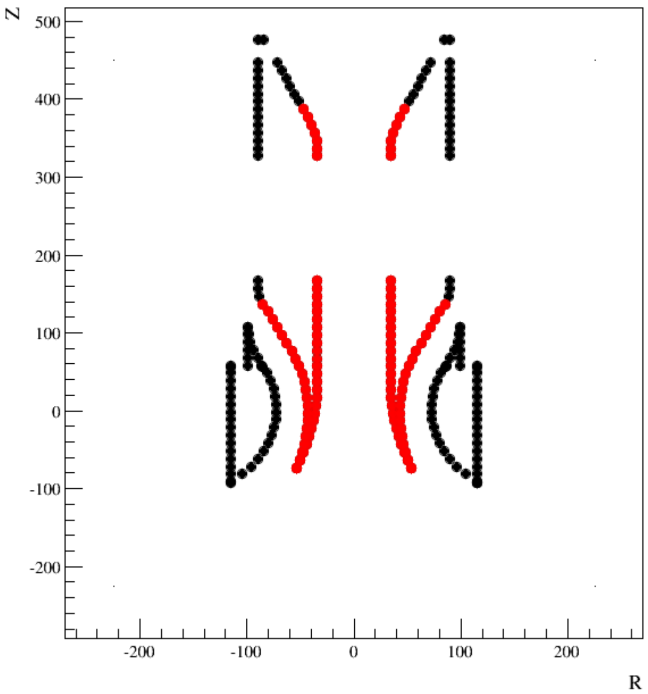
Contrasting GAr and LAr

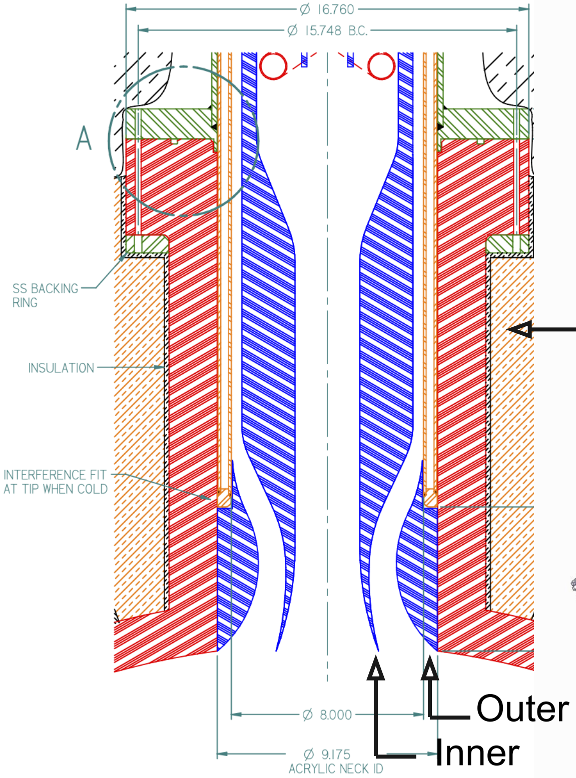


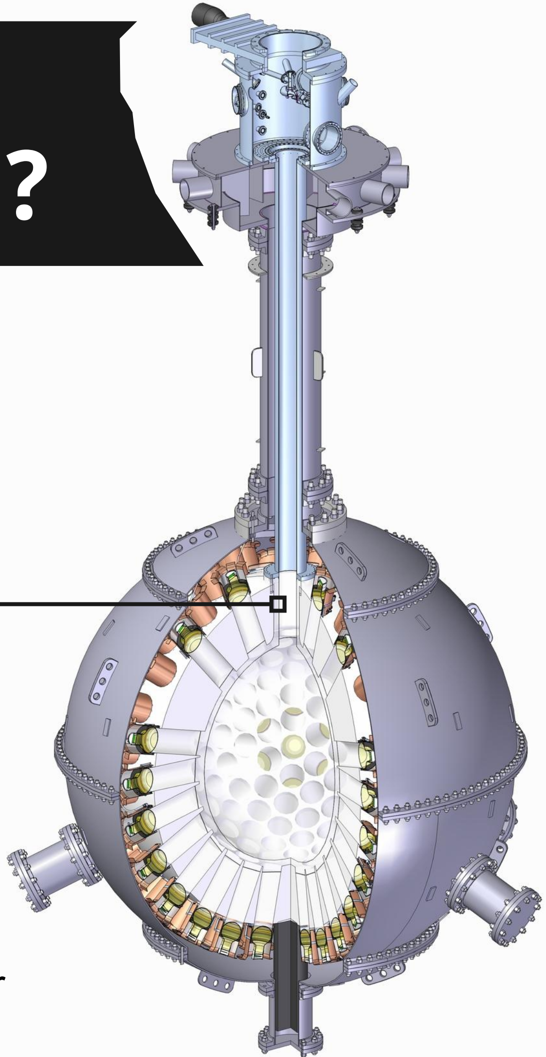


Flowguide TPB Deposition?

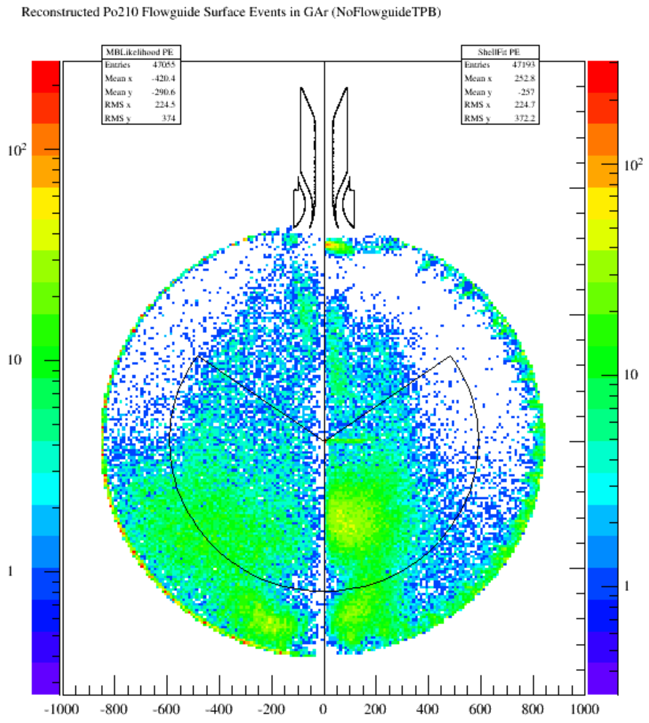
2 Micron-thick TPB Deposition Layer in Lower Acrylic Flowguides

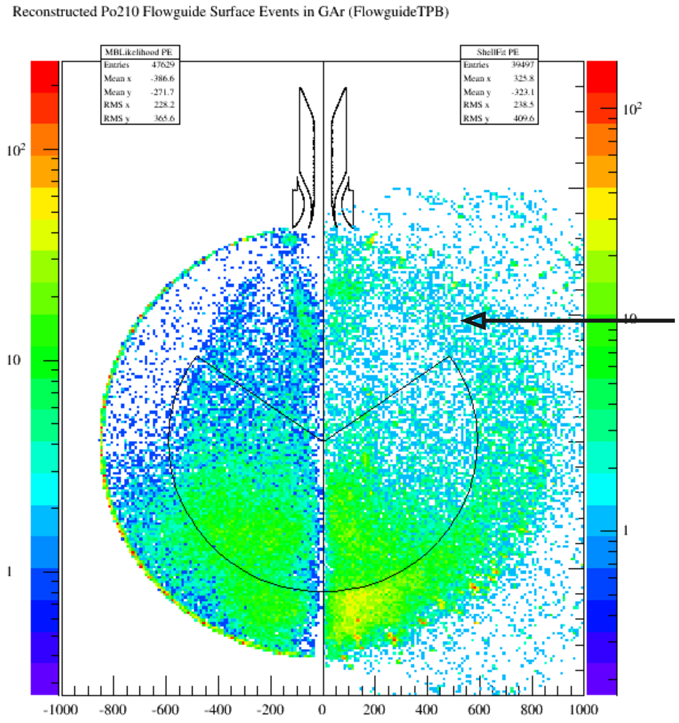






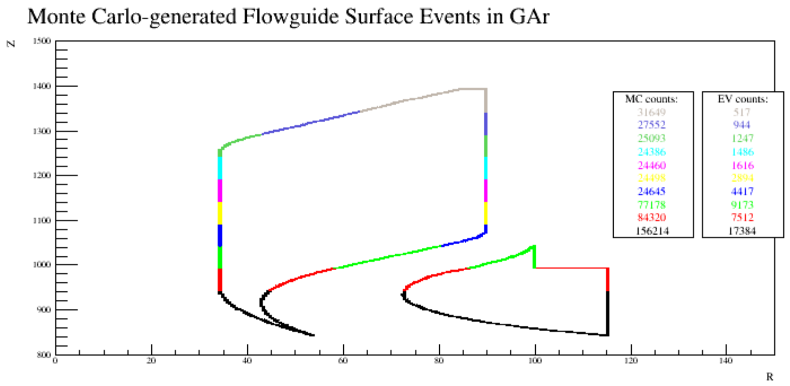
Flowguide TPB Deposition?



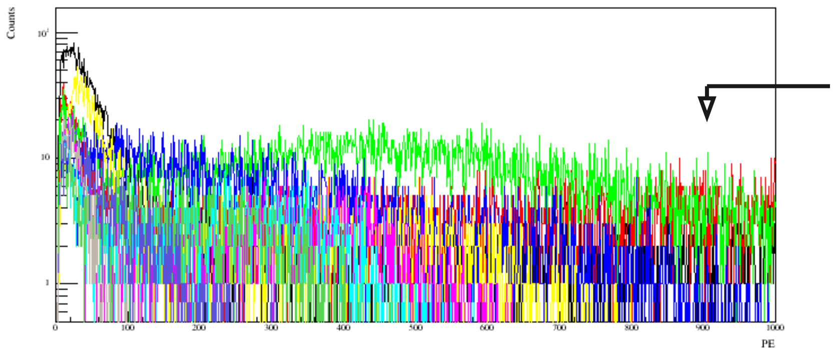


Misreconstruction with this fitting method, though has been recently corrected. Study almost finalized.

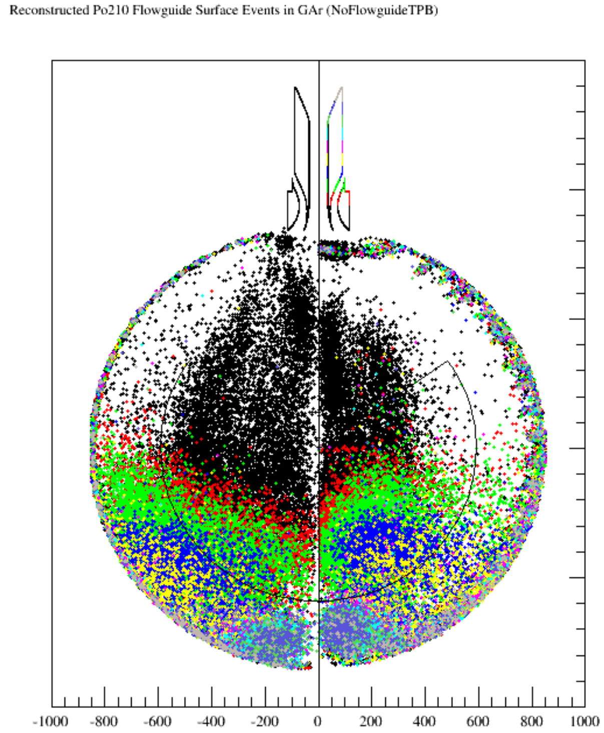
Solid Angle and MFP Effects?



Radial regions also studied, though not finalized.



PE for respective radial height from AV.



Conclusions and the Future

Resurfacer to remove 1 mm of diffused surface contamination, bringing activity to bulk AV levels

- ➢ Less than 500 hours in situ operational runtime.
- ➢ Final commissioning on site at SNOLAB.

Several methods to immediately eliminate most backgrounds

- ➢ Position, energy and prompt cuts reduce most (all) α, β and non-WIMP NR radiations.

Assaying resurfaced and flowguide acrylic in gaseous phase

- ➢ Understand ^{210}Pb,Po contamination to understand acrylic.
- ➢ Must determine length of runtime to achieve reasonable confidence levels.

Eventual understanding of neck leakage events

- ➢ Potential TPB coating to shift energy and/or visibility of neck events.
- ➢ Creation of original neck fitter to tag signature neck events.