



Alpha particle backgrounds from the neck of the DEAP-3600 dark matter detector

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for the DEAP-3600 collaboration

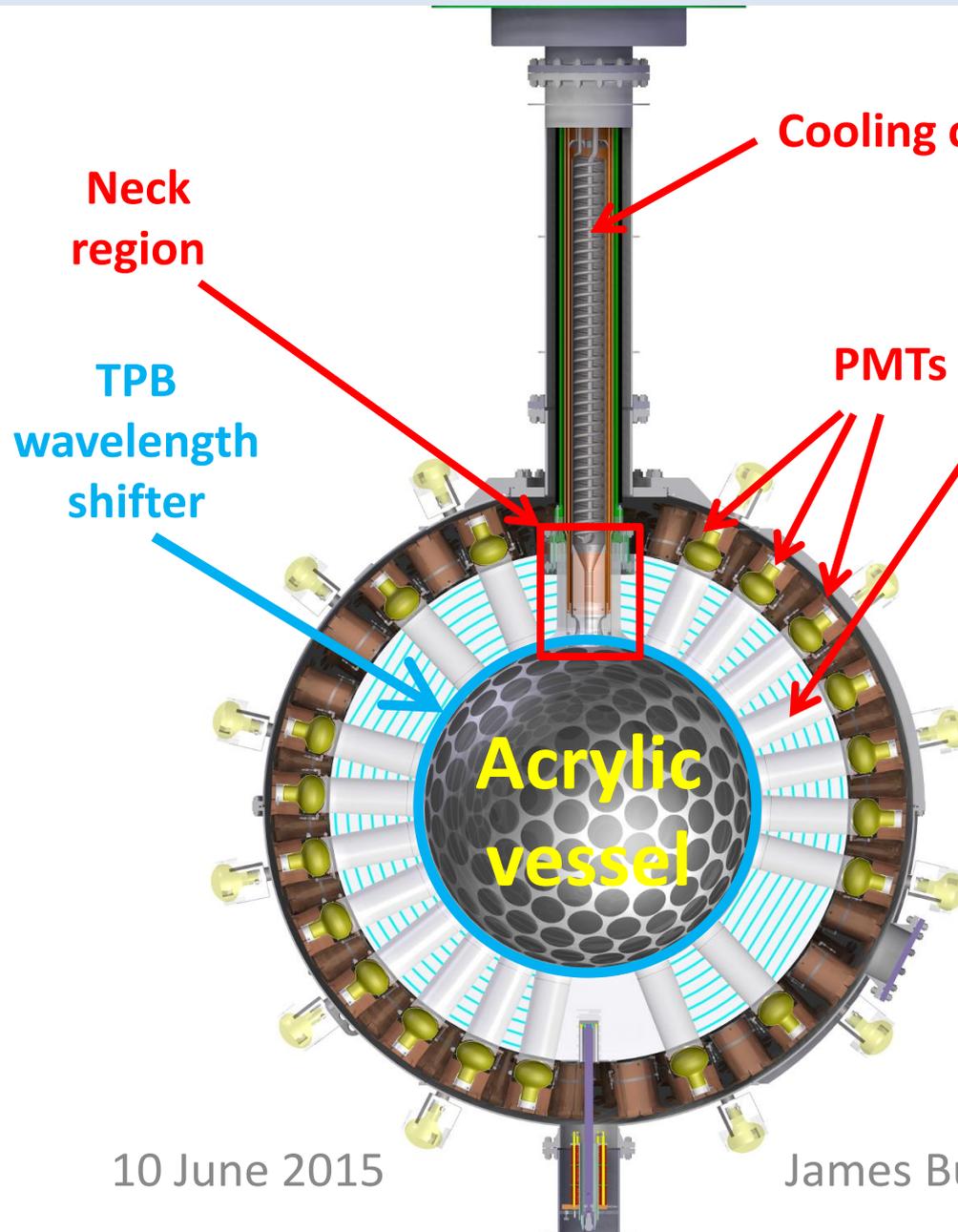


CAP Congress, 16 June 2015

Overview

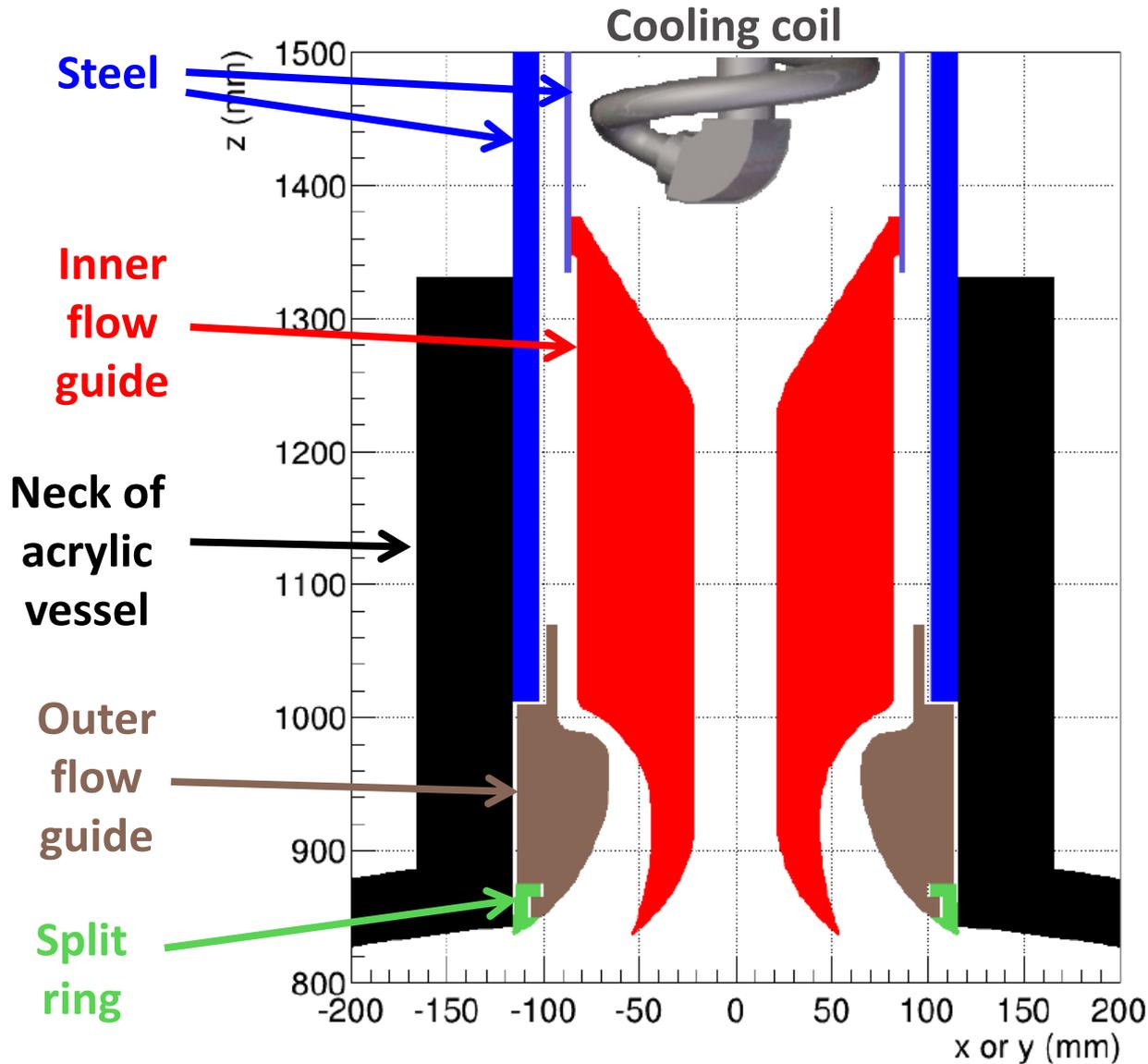
- Neck region of the DEAP-3600 detector
- Radioactive contamination in DEAP-3600
- Mitigating neck alpha particle backgrounds:
 - Material selection and construction process
 - Choosing shape of components
 - Analysis of backgrounds

The DEAP-3600 detector



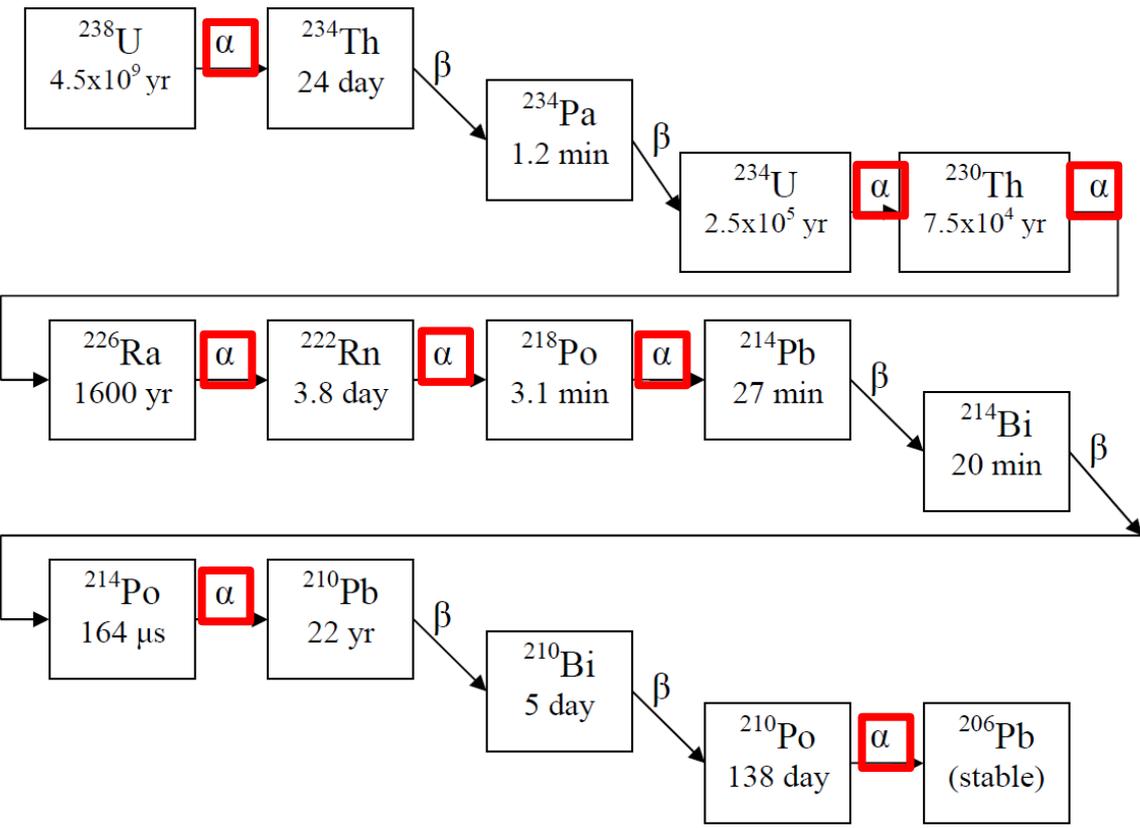
- Located at SNOLAB, 2 km below ground.
- Searching for WIMP nuclear recoils from 1 T liquid argon scintillator.
- Single phase operation with 255 PMTs (Hamamatsu R5912), 32% QE, 71% coverage
- Cooled through a neck region.

The DEAP-3600 detector: neck region



- Very carefully designed geometry.
- Acrylic flow guides to direct warm liquid argon up and cool liquid argon down.
- Same acrylic as main vessel.
- No line of sight from steel to spherical acrylic vessel, except for the cooling coil.
 - Steel has $\sim 10^3$ more radioactivity than DEAP acrylic.
- Roughly 15 m of welds in contact with argon.
 - 5 m in cooling coil,
 - 10 m in neck steel.

Where do the alpha particle backgrounds come from?

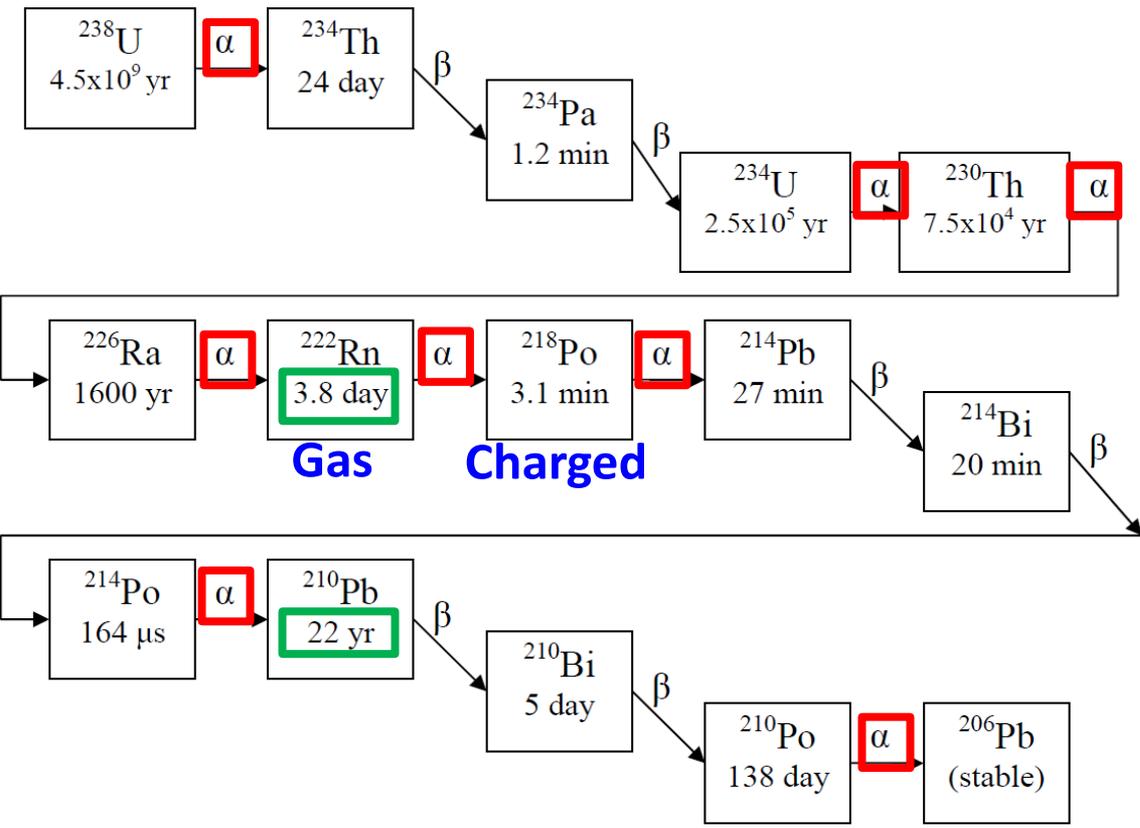


Bulk contamination from ^{238}U and ^{232}Th chains in equilibrium.

- Clean acrylic monitored for years before construction.

Figure from J. Lidgard, 2008, Masters Thesis

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Bulk contamination from ^{238}U and ^{232}Th chains in equilibrium.

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Surface contamination

- Exposure to air during construction.
- From liquid argon: none thanks to carbon trap.
- Weld emanation.

Figure from J. Lidgard, 2008, Masters Thesis

Why do alpha particles cause a background?

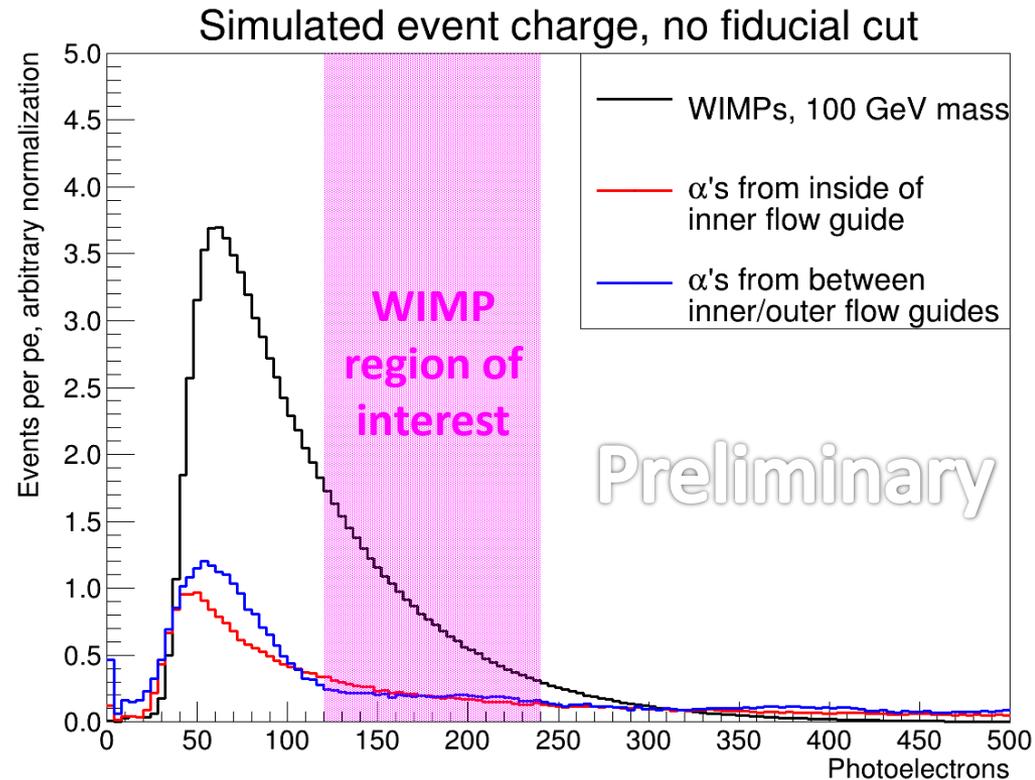
- Radioactive decays in detector materials release alpha particles.
 - Energies are 4-9 MeV.
 - 5 MeV alpha's have a range of $\sim 35 \mu\text{m}$ in acrylic.

- Alpha particle in liquid argon produces 1000's of photons.
 - Shadowed events with obstructed line of sight can look like WIMPs.

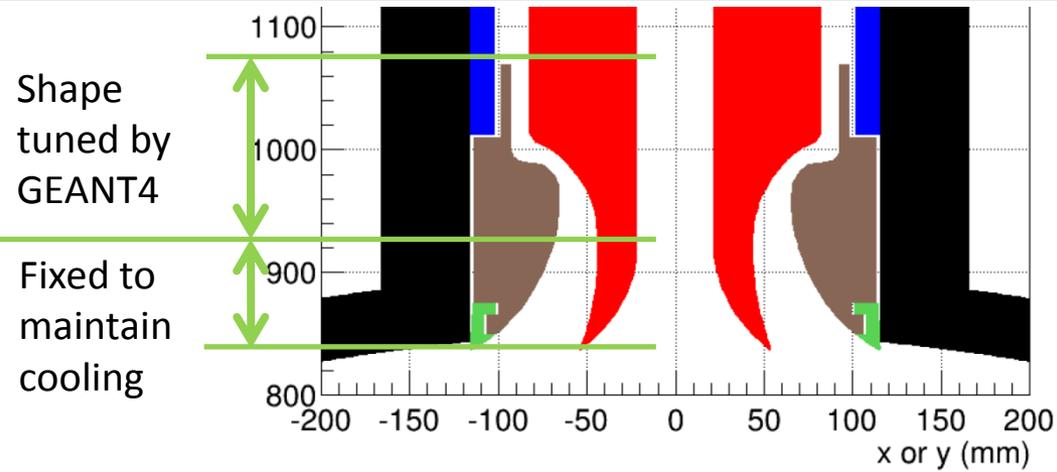
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- DEAP-3600 goal: < 0.2 alpha particle background events in 3 yrs.

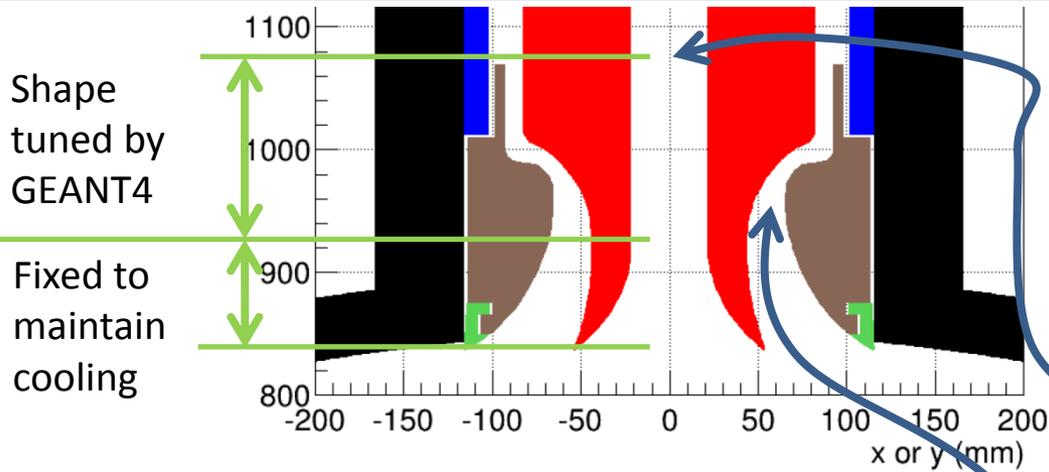


Mitigation by GEANT4 tuning and analysis

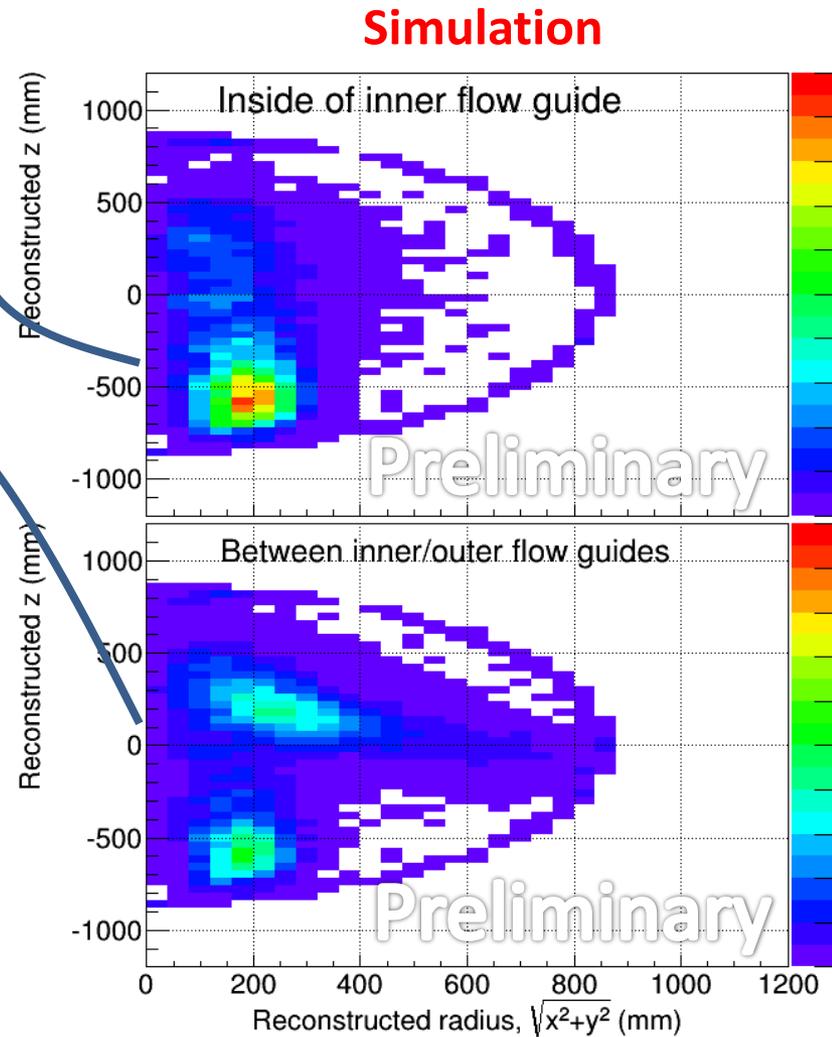


- Flow guide geometry tuned by GEANT4 background simulations.
- Alpha particle decays in the neck have non-uniform position reconstruction.

Mitigation by GEANT4 tuning and analysis

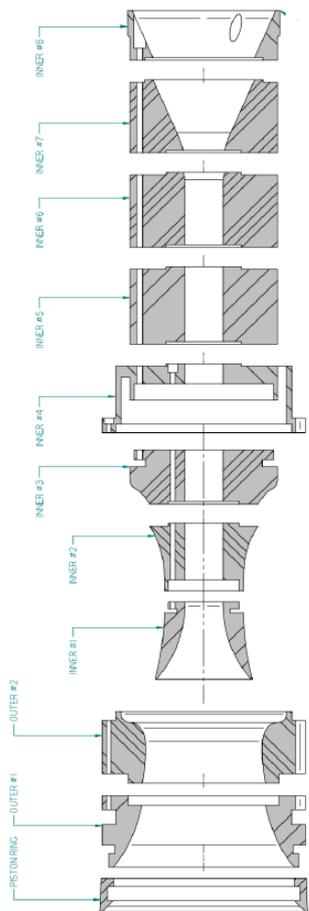


- Flow guide geometry tuned by GEANT4 background simulations.
- Alpha particle decays in the neck have non-uniform position reconstruction.
- Radial cut removes most neck backgrounds, while maintaining a one-tonne fiducial.
- Pattern recognition using PMT light distribution and timing is under development.
 - See poster by Courtney Mielnichuk.

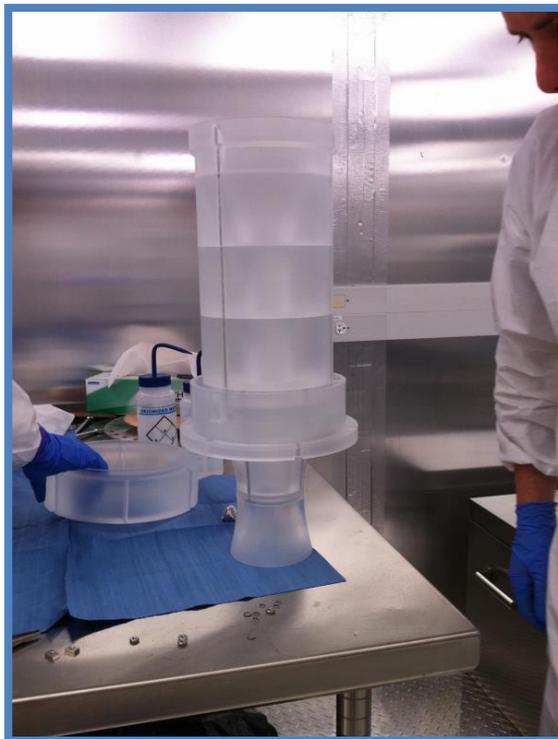


Machining neck flow guides

- Nov/Dec 2014: acrylic pieces machined in low radon environment at the University of Alberta and annealed in same air.
 - Radon level $\sim 0.3 \text{ Bq/m}^3$ compared to $\sim 15 \text{ Bq/m}^3$ outside.



Inner flow guide

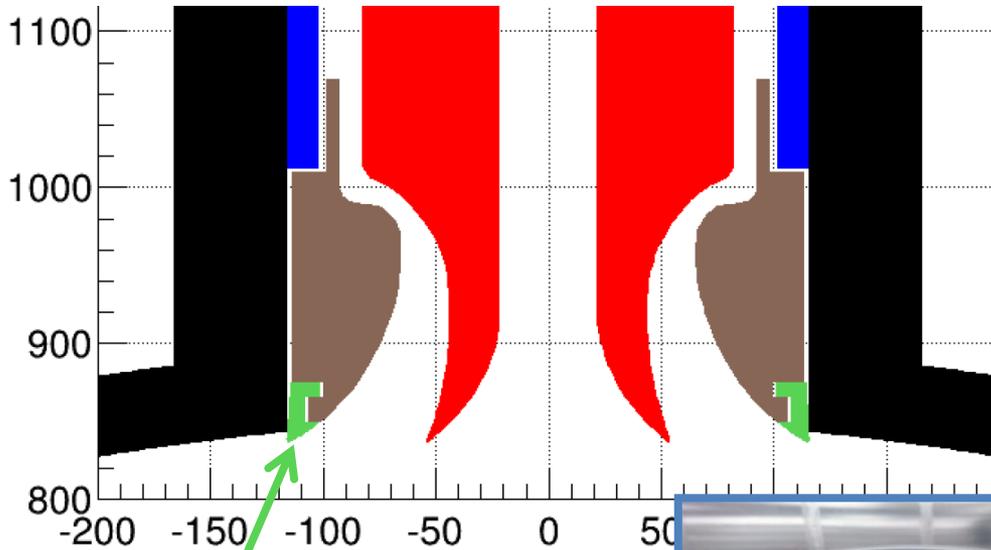


Inner & outer flow guides

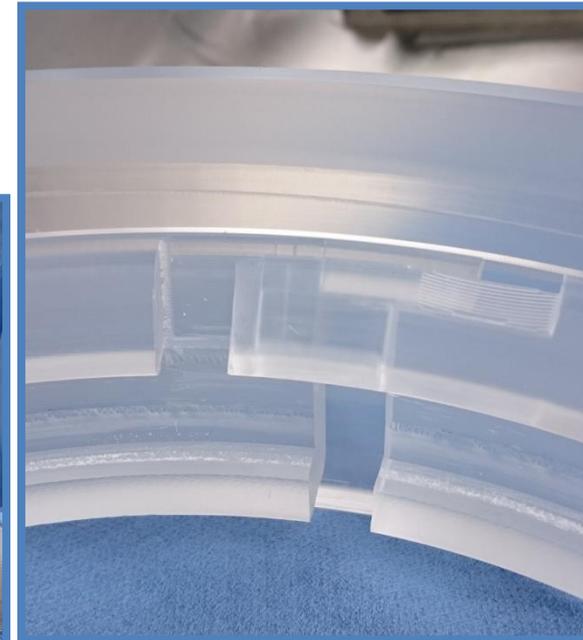


Covering up the acrylic vessel neck

- Spherical part of acrylic vessel was sanded with resurfacer.
 - Neck of acrylic vessel was sanded with separate device.
 - Gap between neck and outer flow guide was covered up.



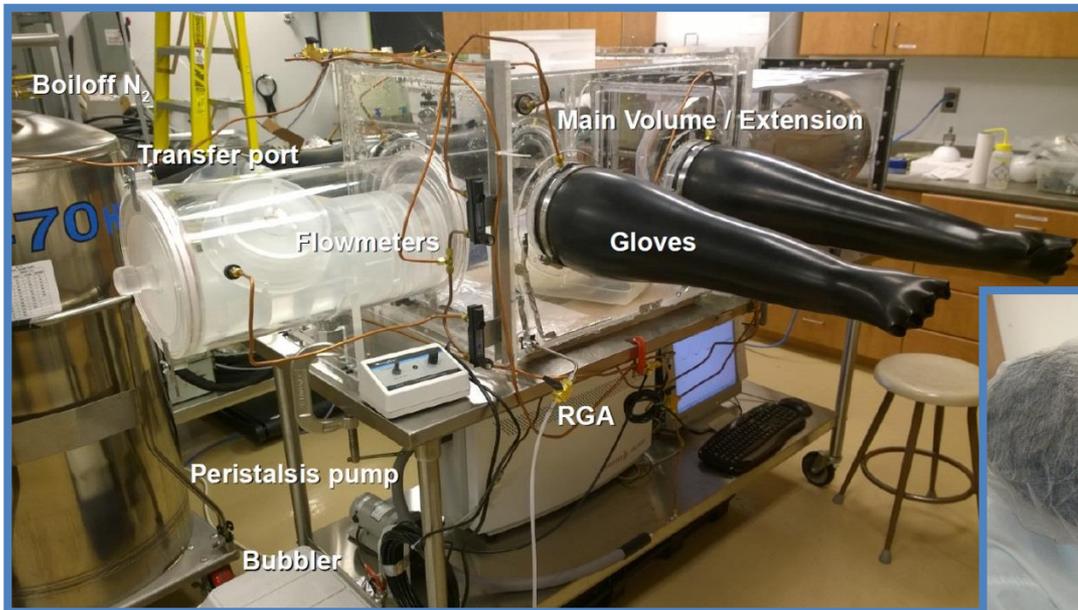
Split ring,
eliminates
~12 events
in 3 years



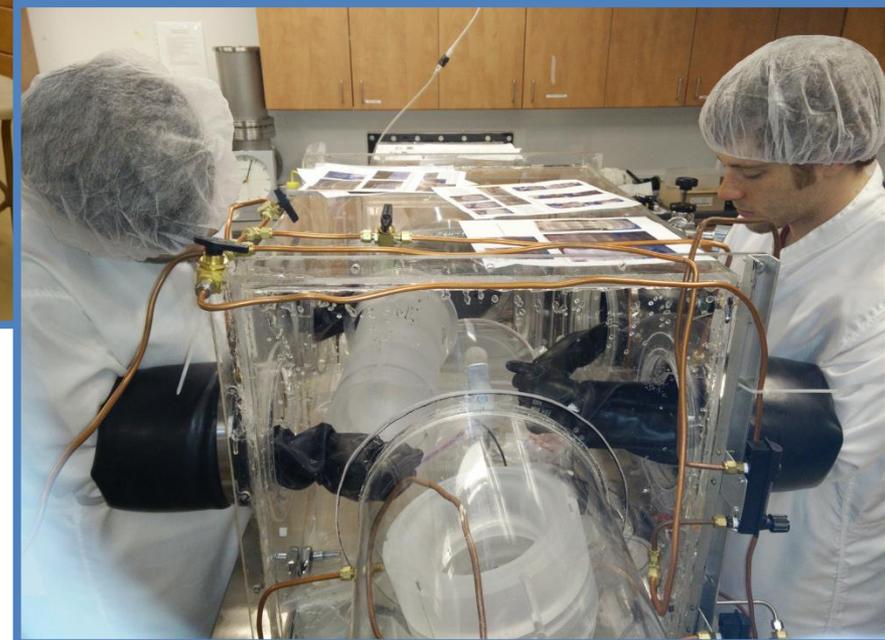
Sanding flow guides

- Mar-Jun 2015: Hand sanded flow guide pieces in a nitrogen purged glovebox to remove embedded radon daughters.

Glovebox at Queen's University



Flow guide pieces in glove box



Summary

- Gone to great lengths to minimize alpha particle backgrounds.
 - Selected clean materials.
 - Machined and sanded in clean environments.
 - Designed geometry carefully.
- Looking forward to argon data to verify the background rates.



The DEAP collaboration



~60 collaborators in Canada, the UK, and Mexico



Thanks to CFI, NSERC, the provinces of Alberta and Ontario, and SNOLAB for funding and support.

Backup: 232 Th chain

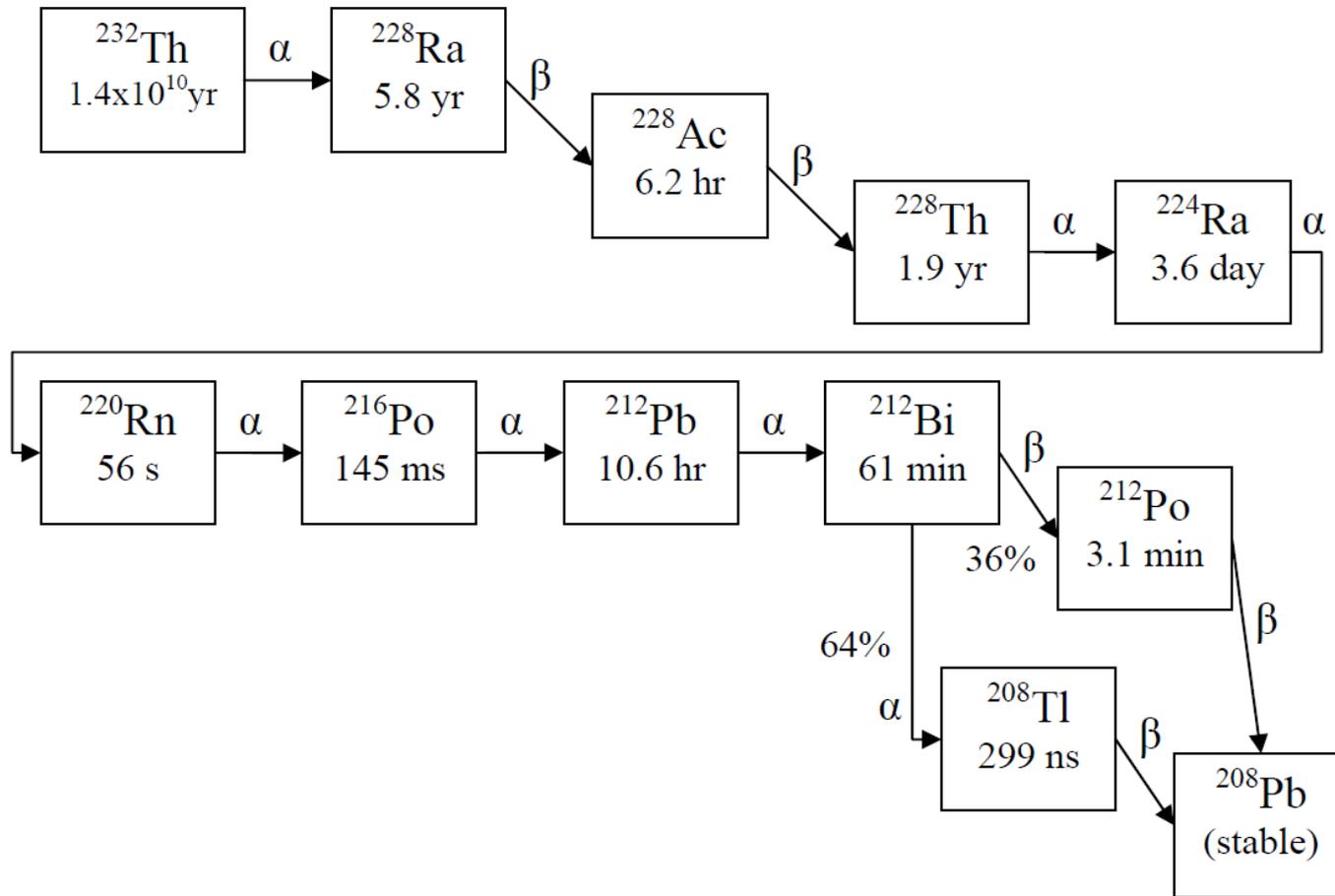


Figure 2.4: Thorium-232 decay chain