A likelihood ratio algorithm to remove localized alpha particle backgrounds in DEAP-3600

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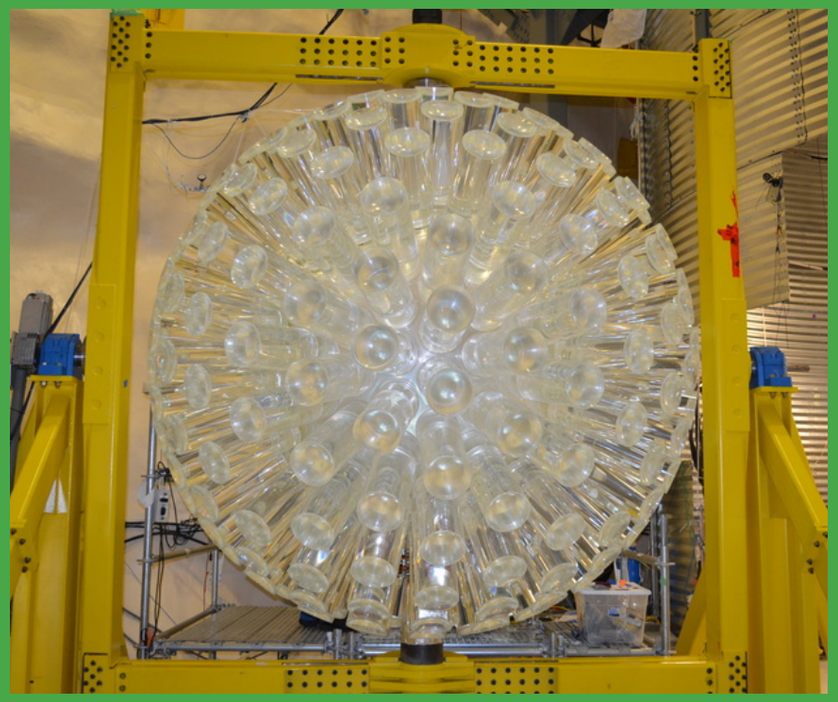
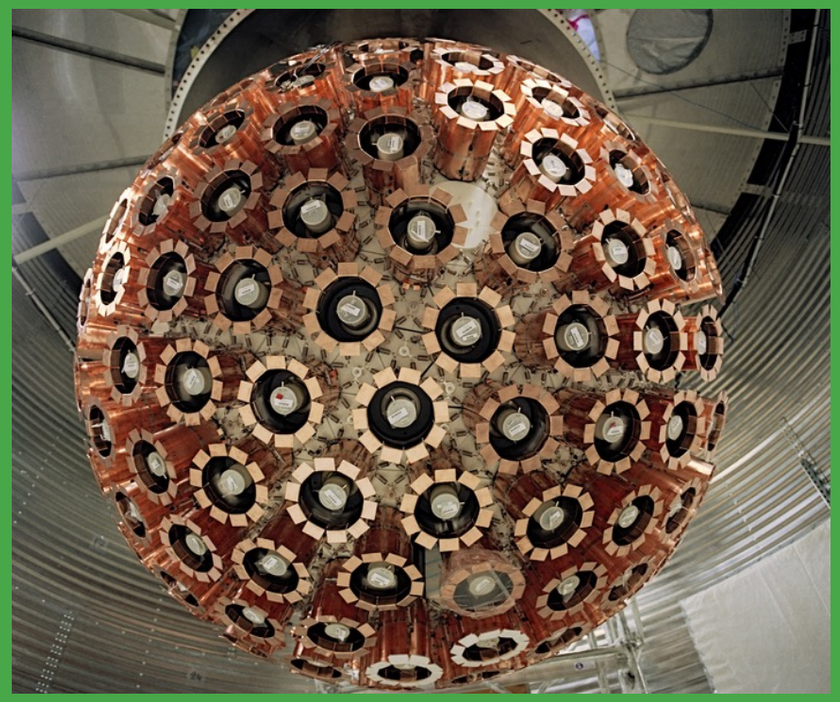
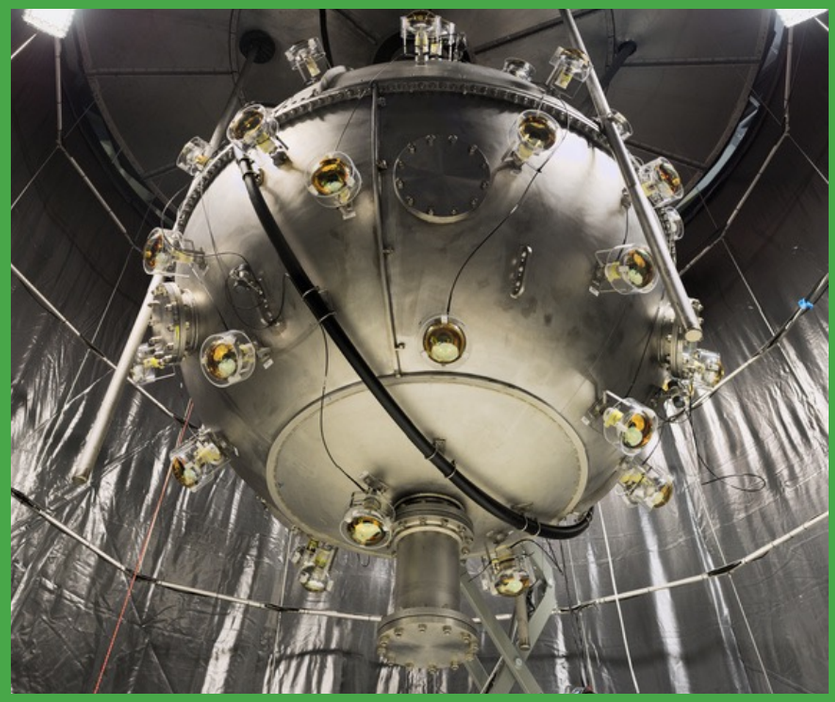
for the DEAP-3600 Collaboration
WNPCC - February 17, 2017

DEAP-3600 Overview

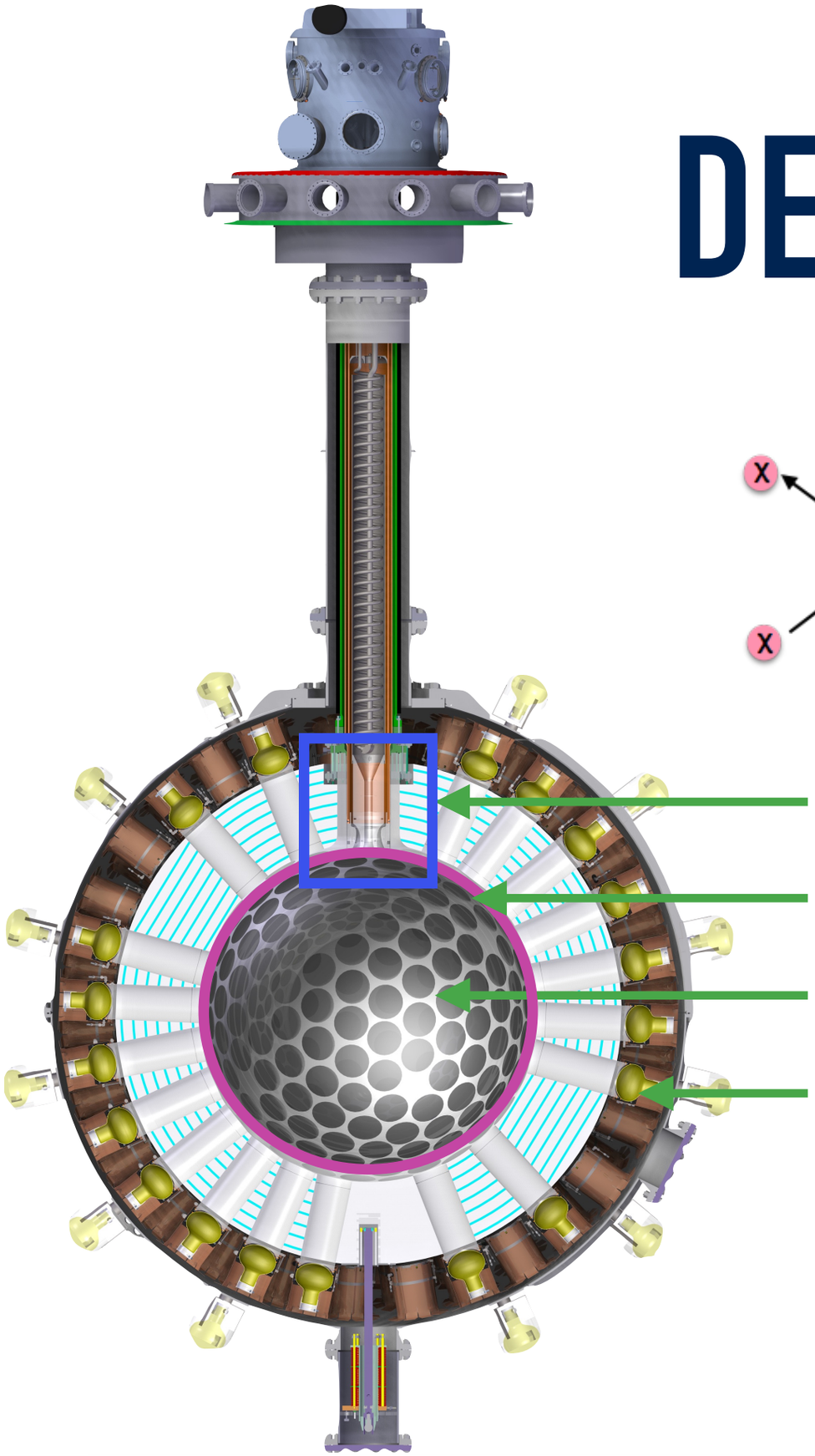


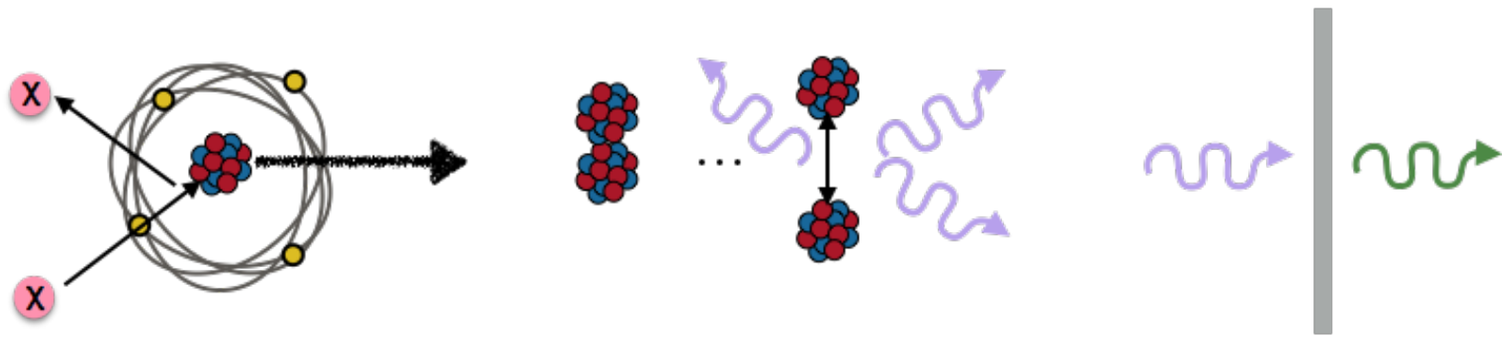




- 3600 kg liquid argon to search for Weakly Interacting Massive Particles (WIMPs)
- 2 km underground at SNOLAB
- current configuration contains ~ 3260 kg of liquid argon

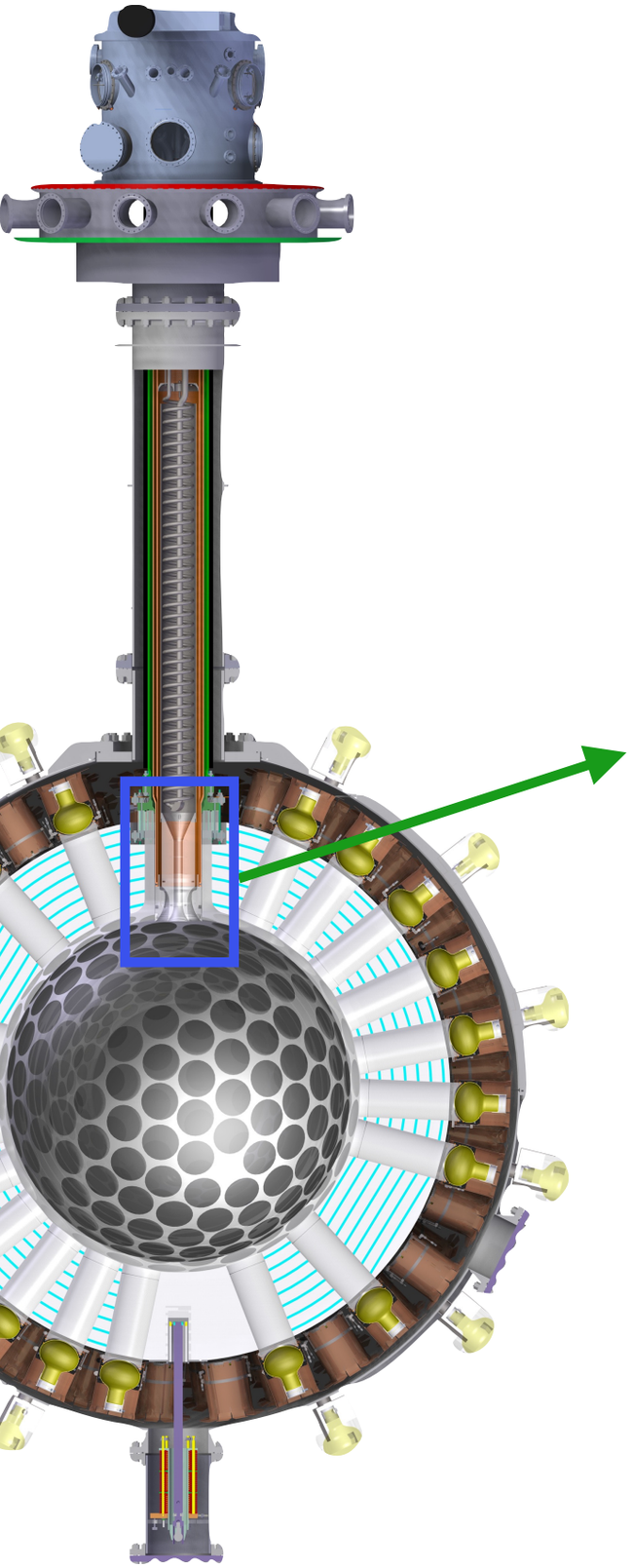
DEAP-3600 Detector

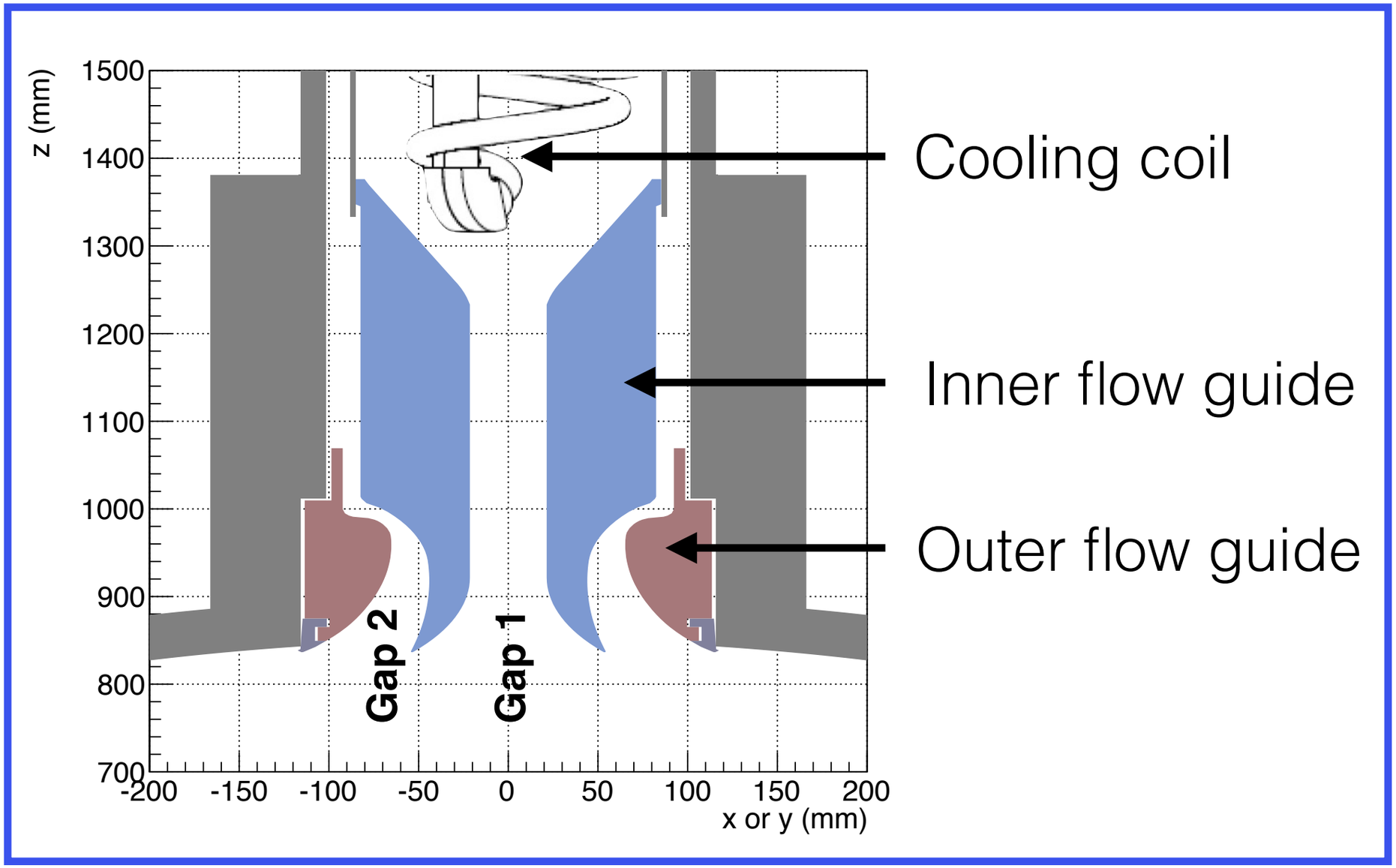




- WIMP scatters off an argon nucleus
- unstable argon dimers decay emitting photons
- UV photons are shifted to visible

Neck Region




z (mm)
1500
1400
1300
1200
1100
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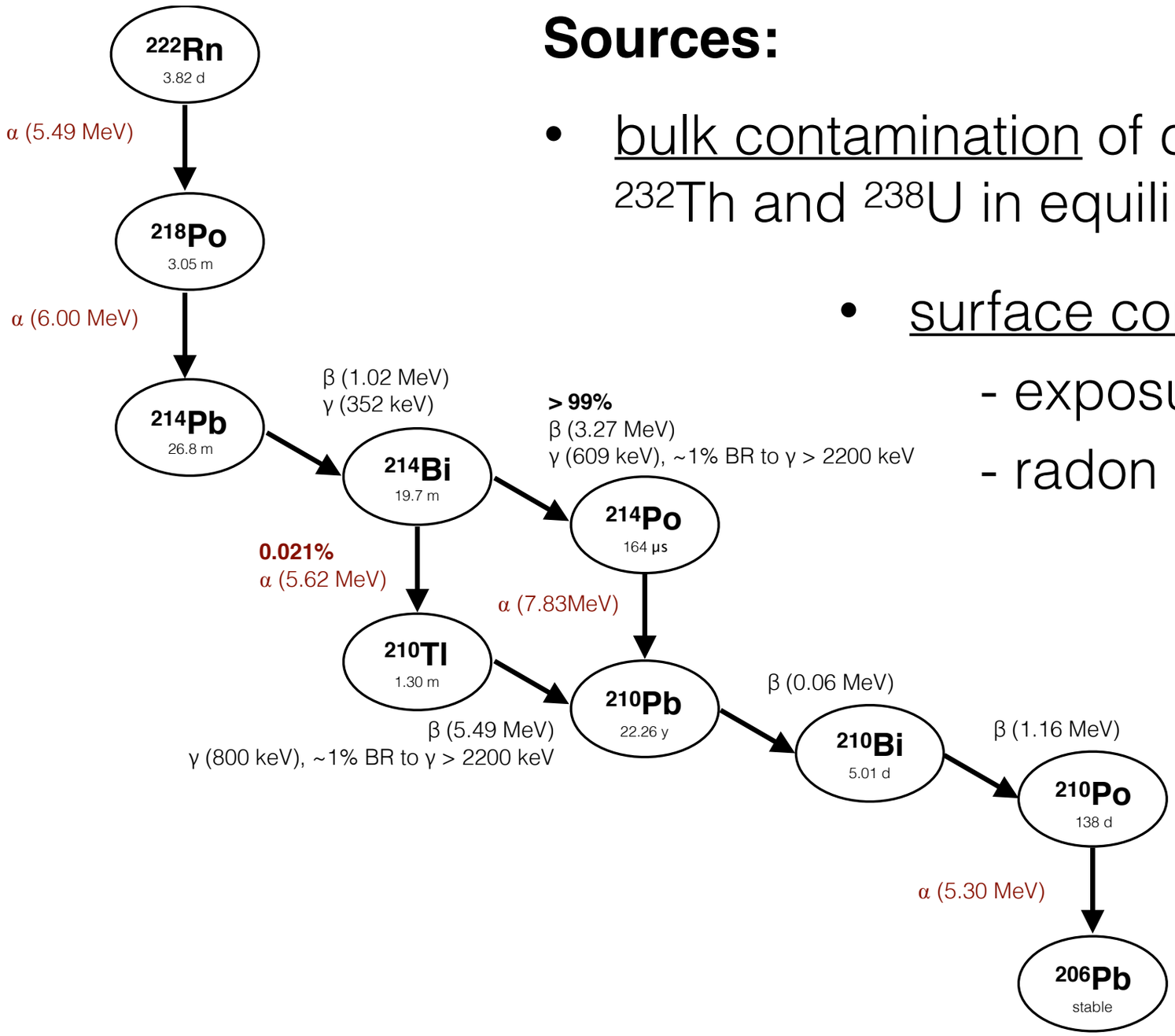
700
-200
-150
-100
-50
0
50
100
150
200
x or y (mm)
Gap 2
Gap 1
Cooling coil
Inner flow guide
Outer flow guide

Alpha Decays in the Detector



Sources:

- <u>bulk contamination</u> of detector materials from ^{232}Th and ^{238}U in equilibrium

  - <u>surface contamination</u>
    - exposure to air during construction
    - radon in the liquid argon

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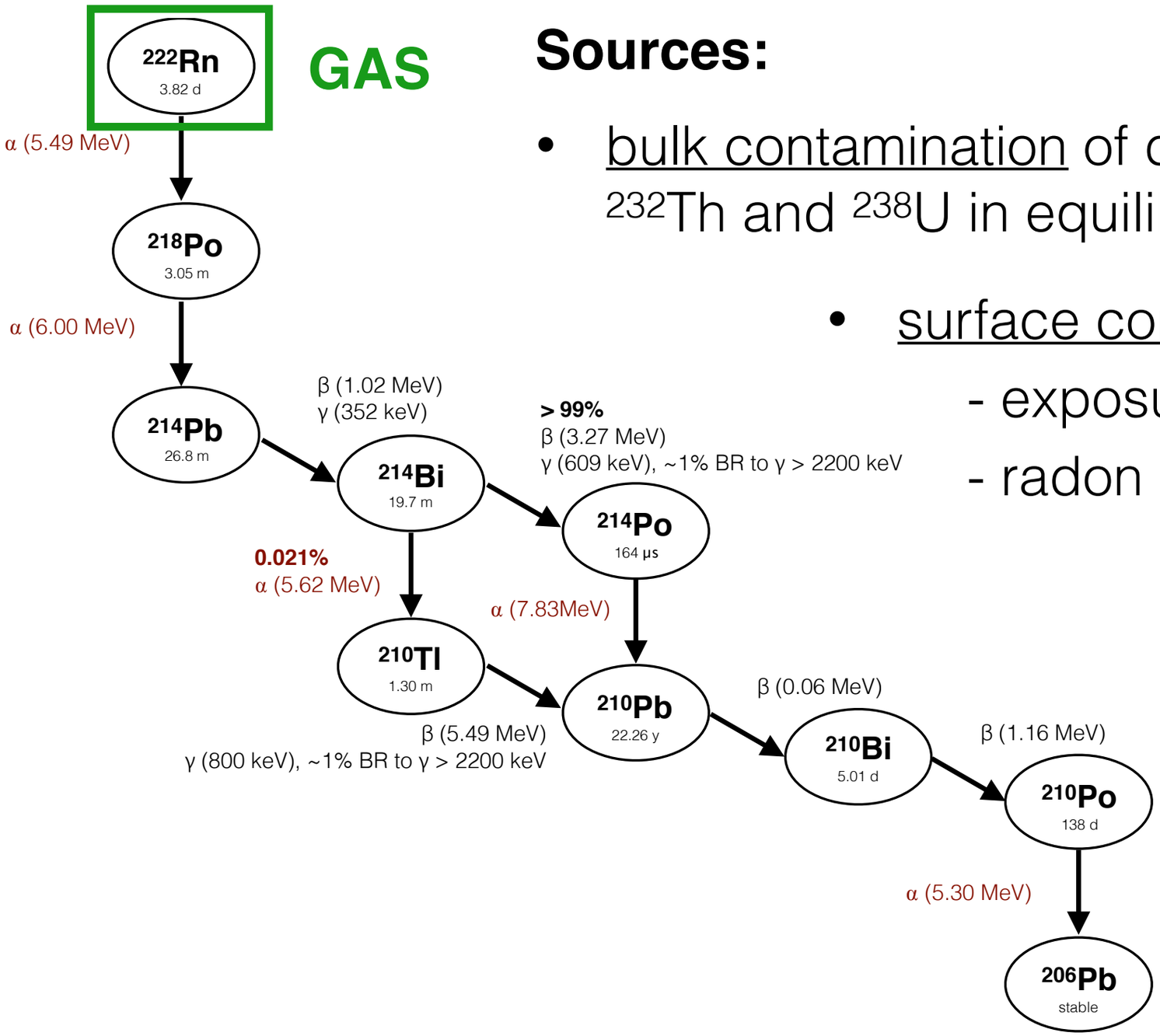

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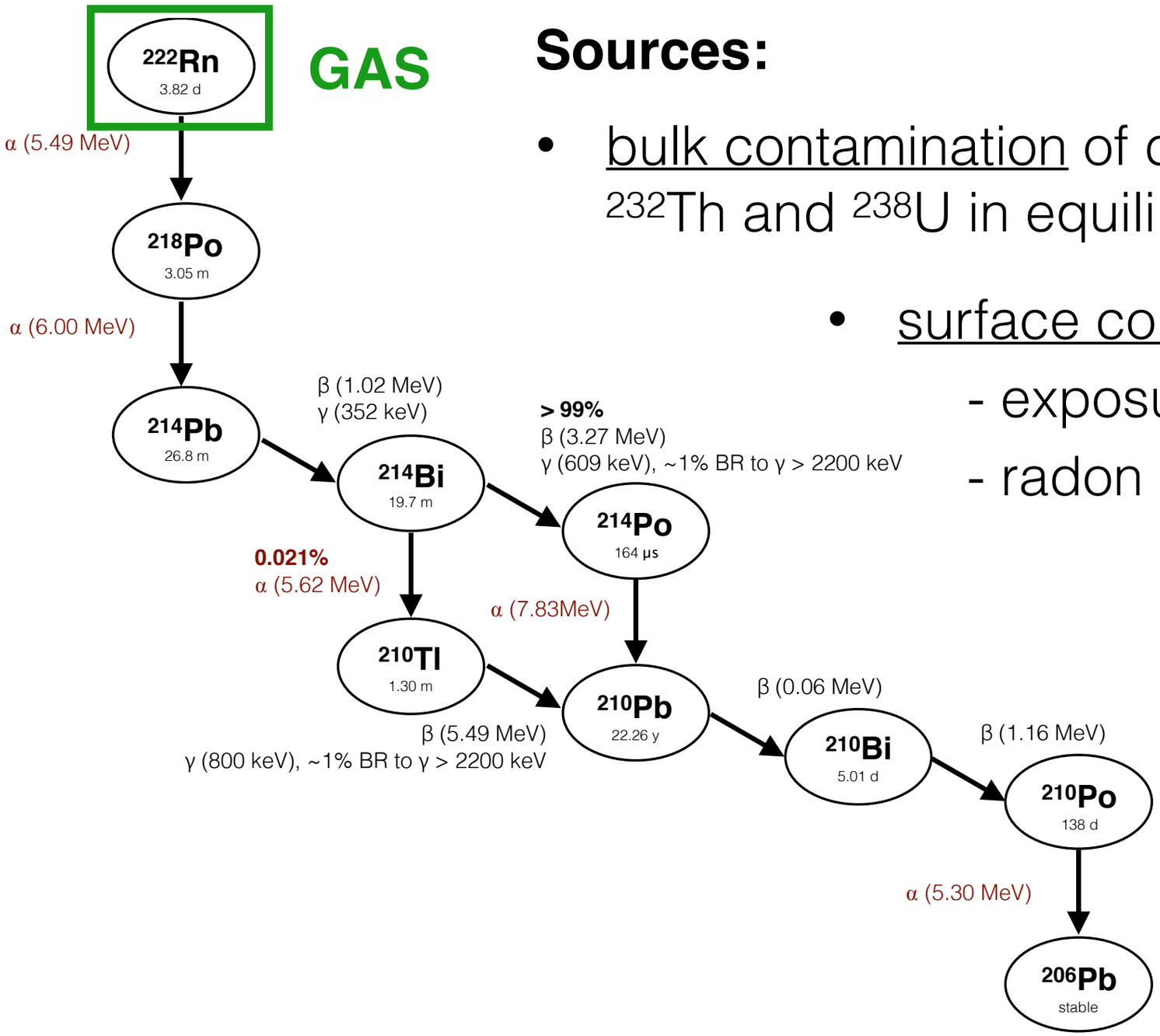

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- scintillation from an alpha recoil can mimic a WIMP signal
- alpha's with energies between 5 and 8 MeV

Removing Alpha Backgrounds

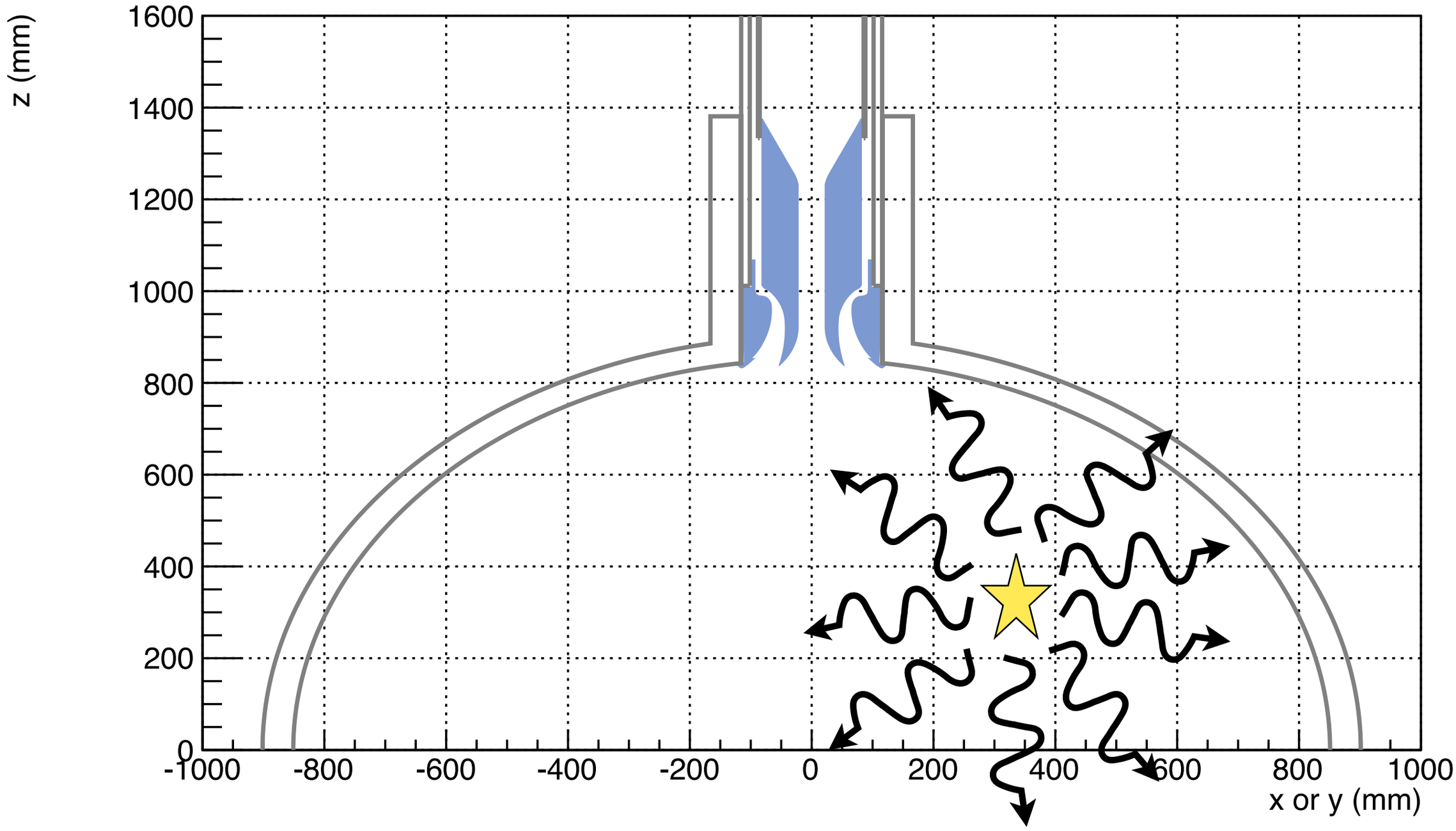
Target alpha background: <0.6 events in 3000 kg yrs

<u>Reduction techniques:</u>

- strict materials selection
  - parts per trillion of uranium and thorium in acrylic
- limited exposure to mine air
- robotic sanding of inner acrylic vessel surface and hand sanding of acrylic surfaces in the neck region

- **additional cuts to remove events from alpha decays**

Energy Cut


z (mm)
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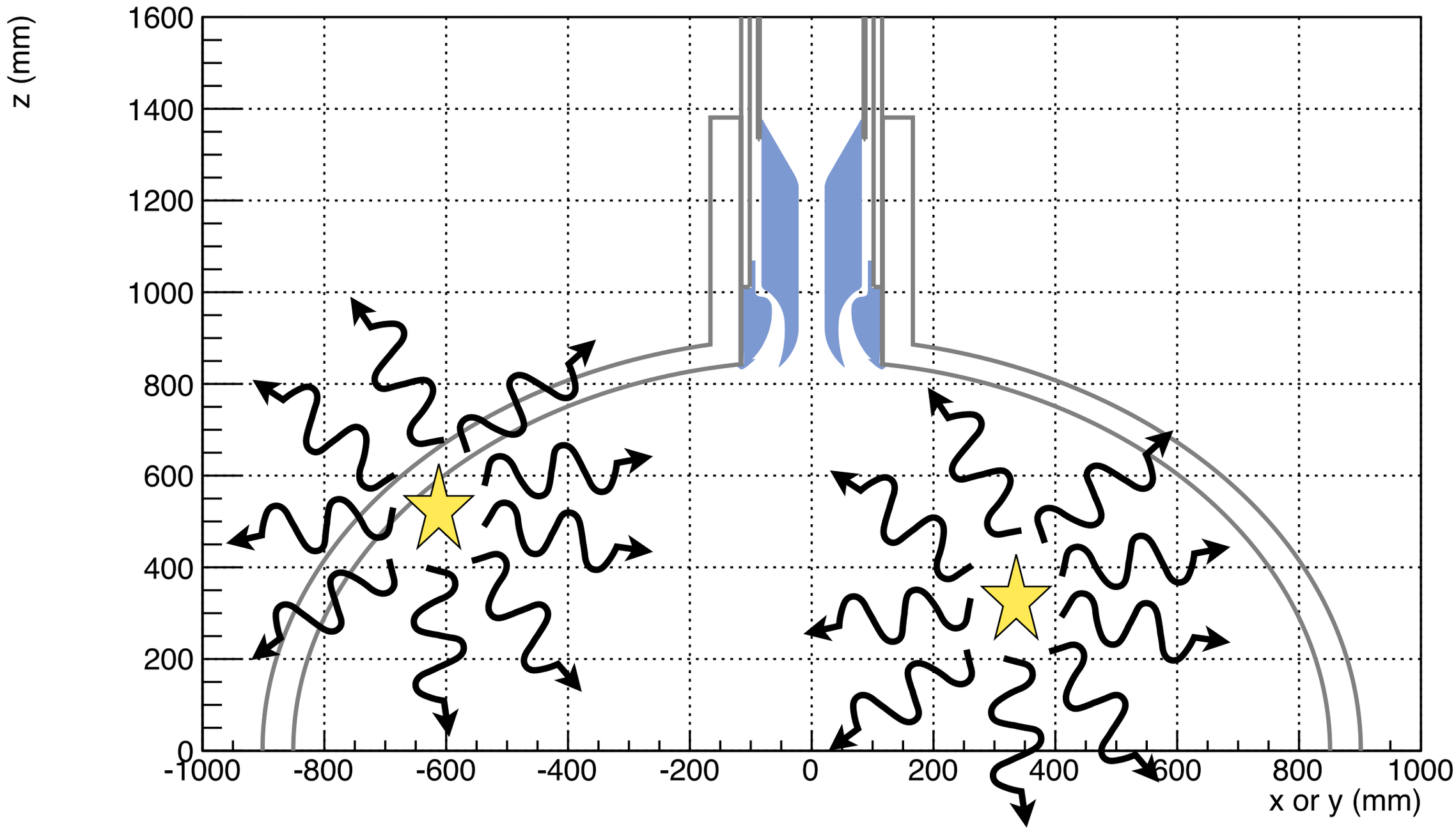
x or y (mm)

Energy Cut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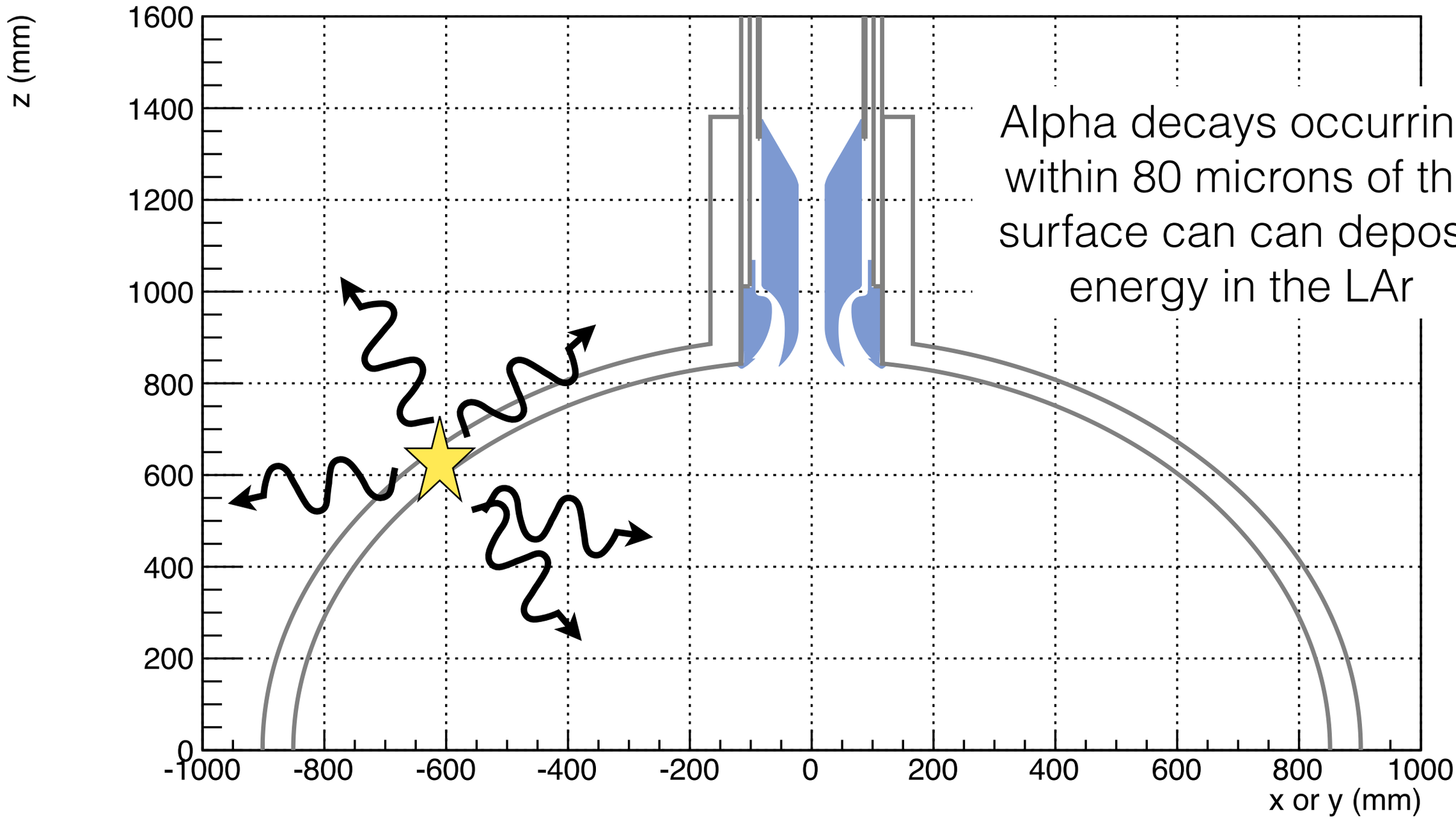
Fiducial Volume Cut



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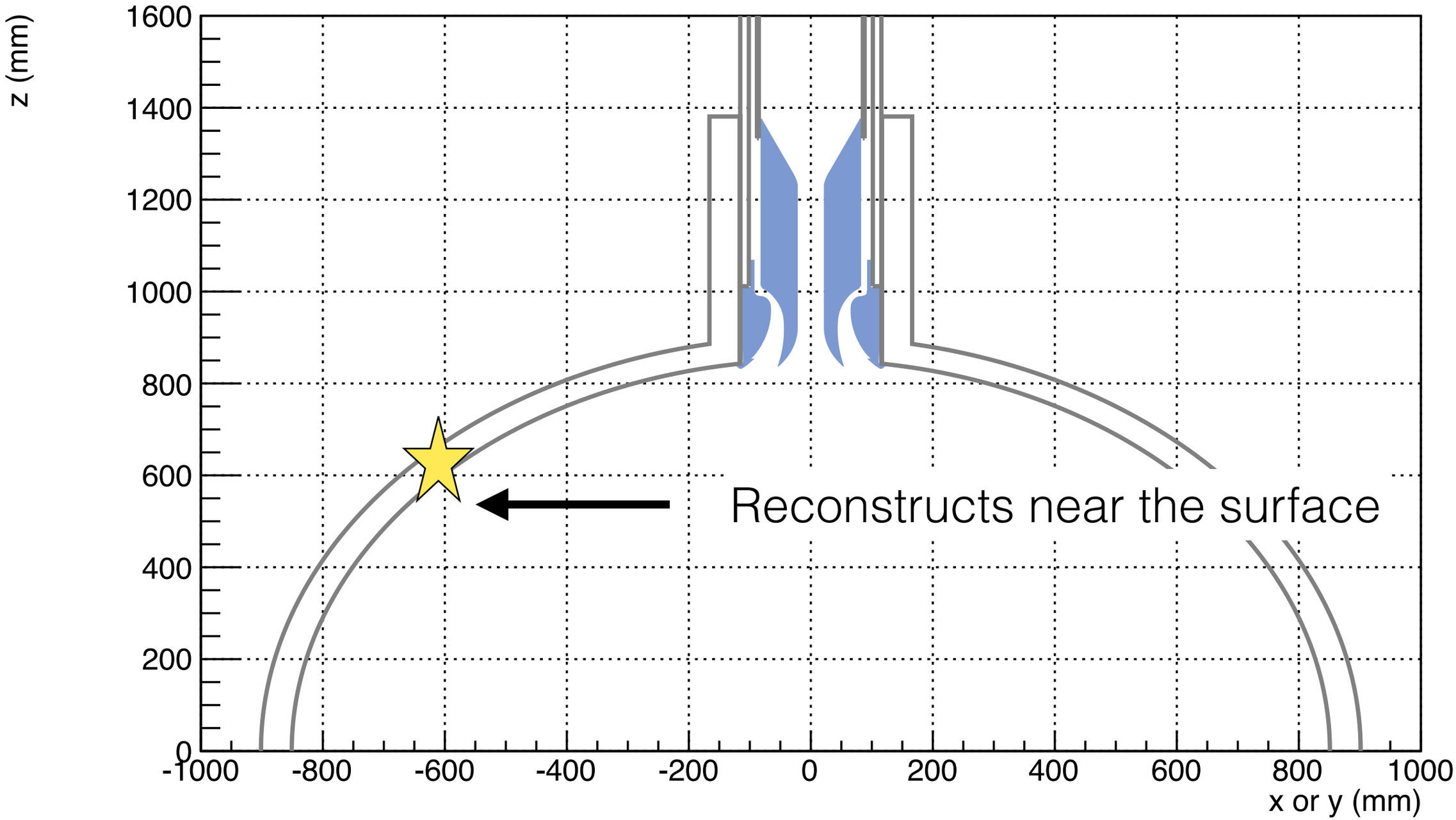

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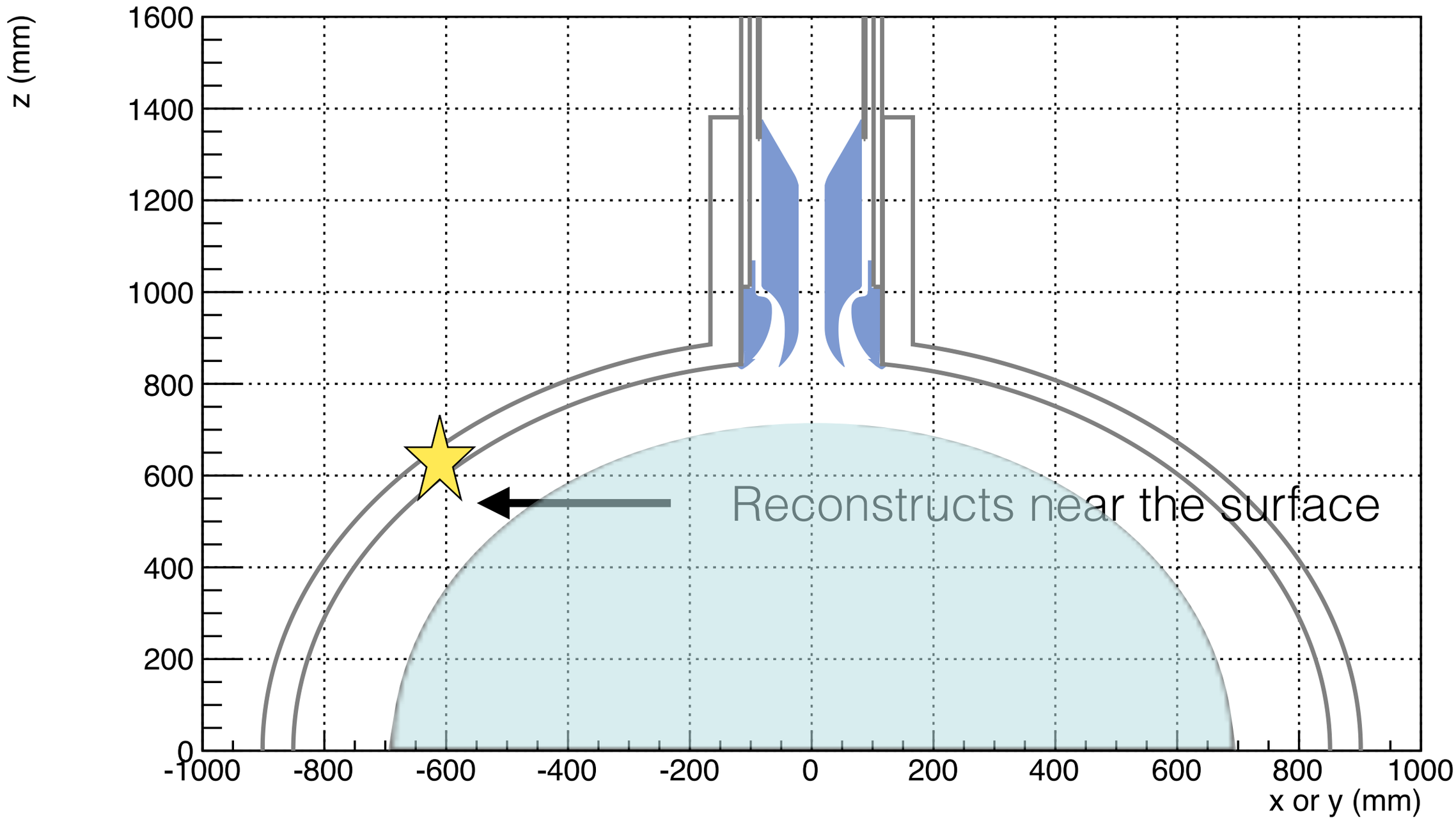
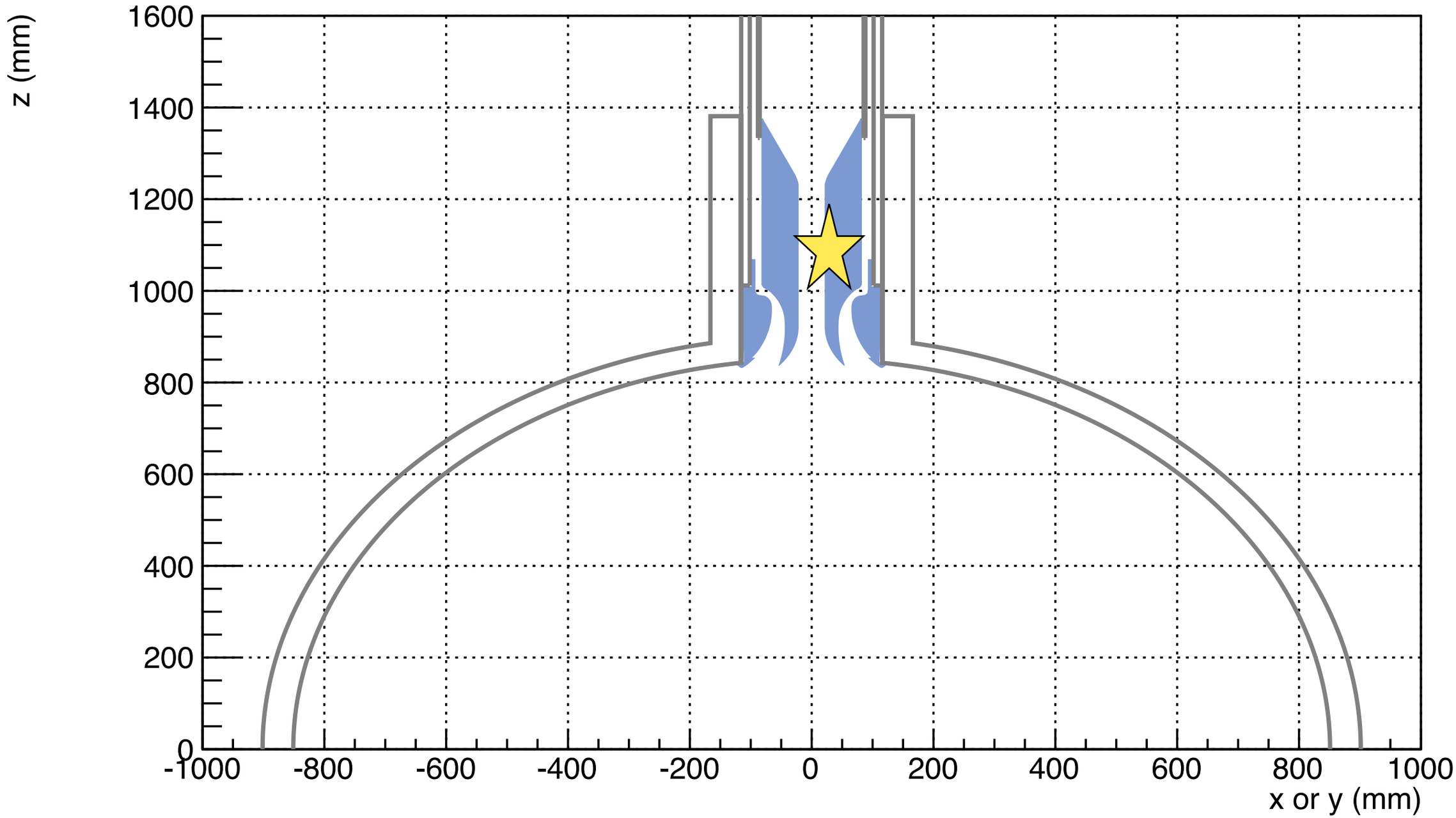


Alpha Decays in the Neck



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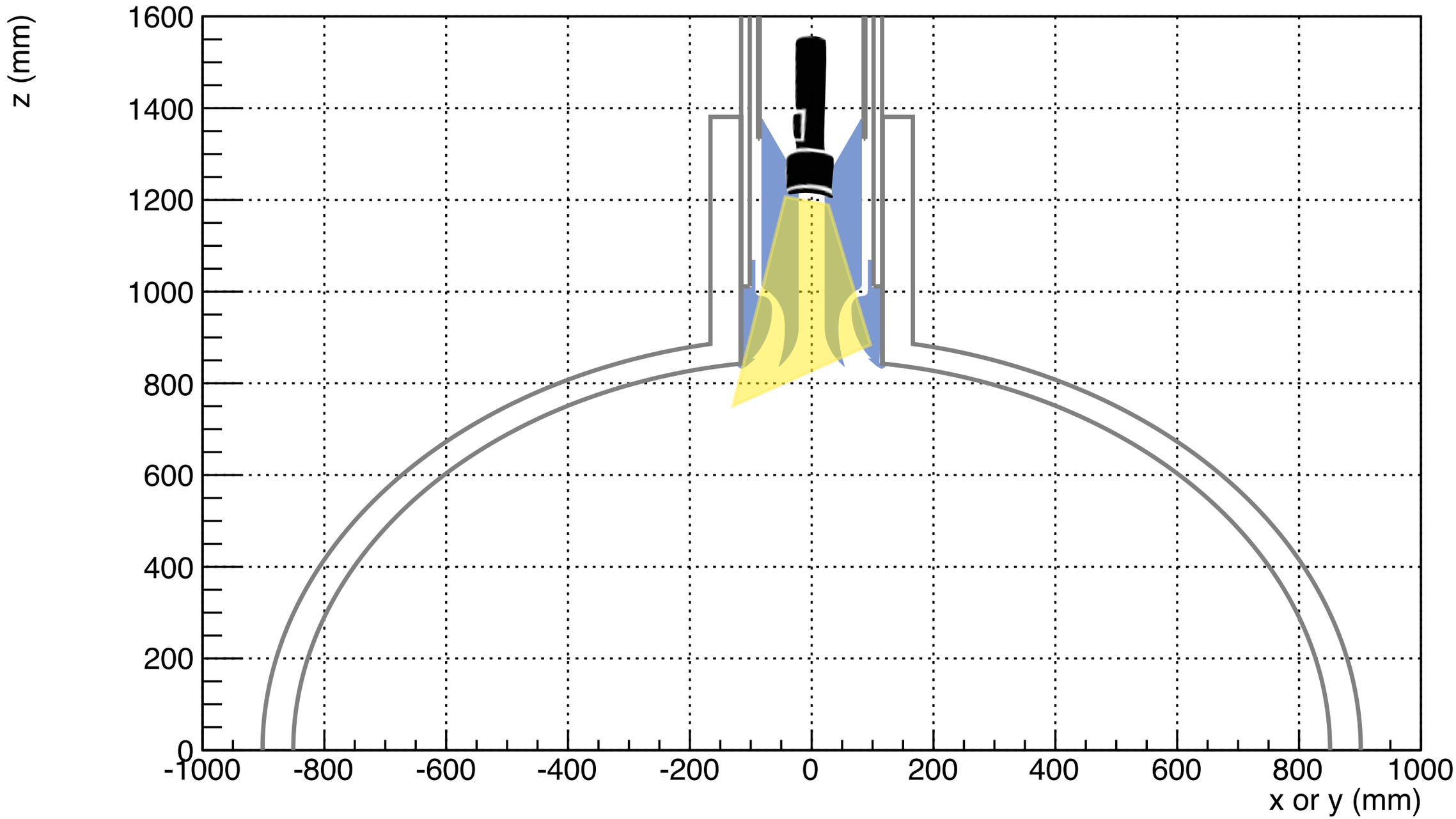

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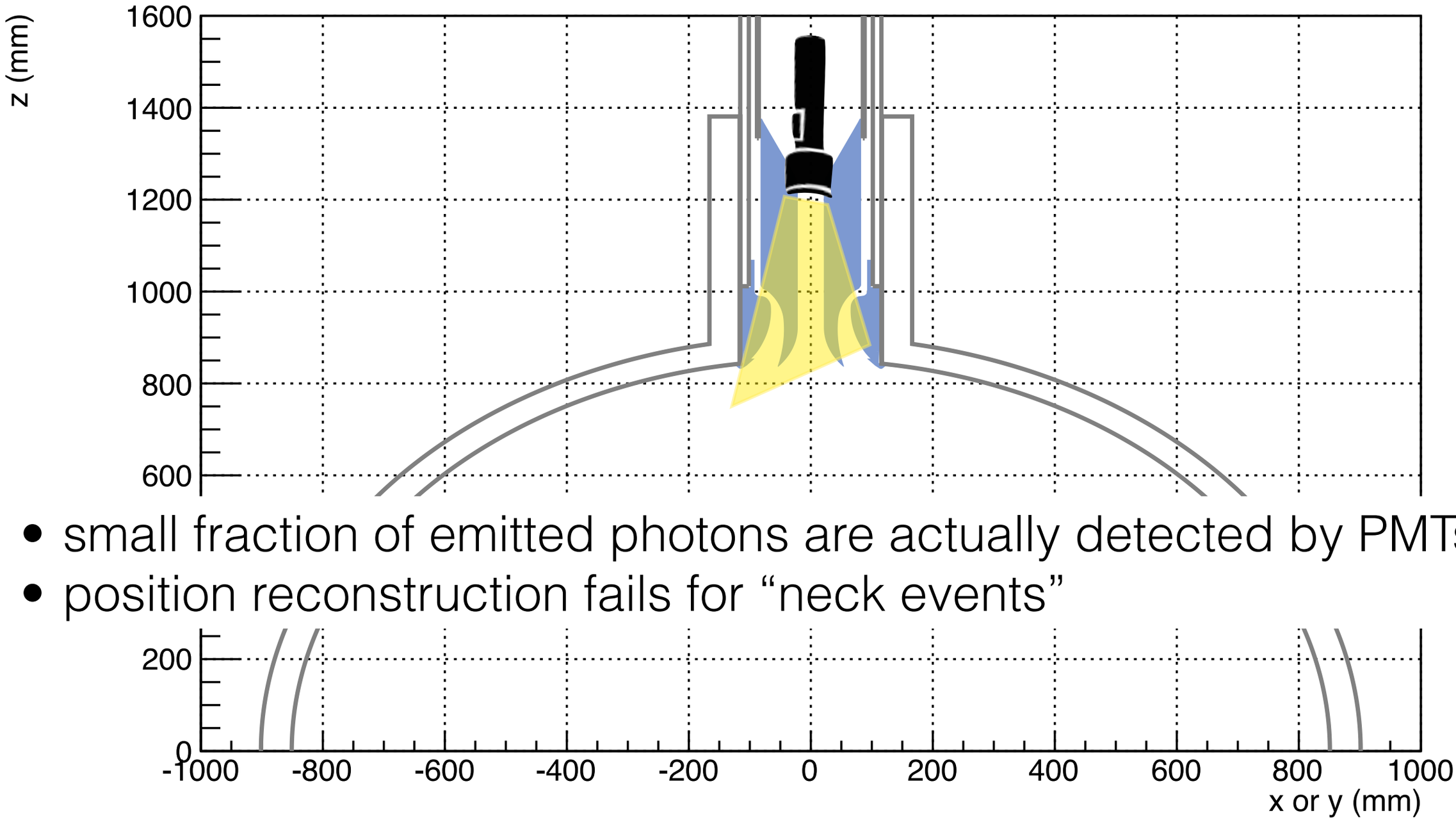
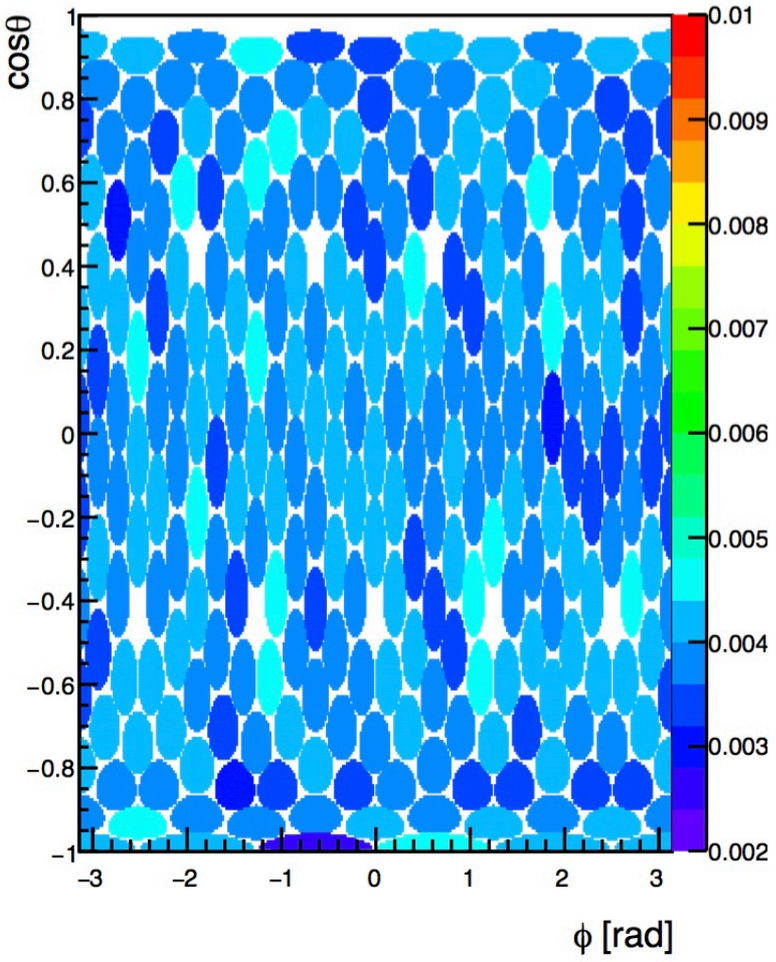


- small fraction of emitted photons are actually detected by PMTs
- position reconstruction fails for “neck events”

Charge Distribution in Neck Events

Fraction of charge in an events as a function of PMT location

WIMPs



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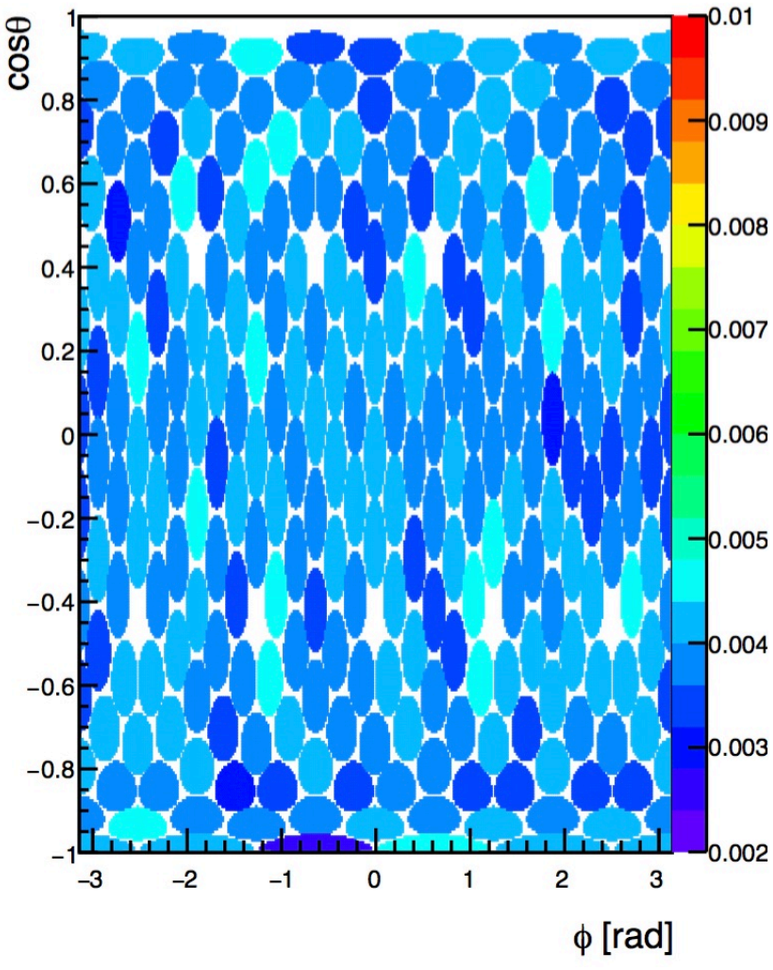
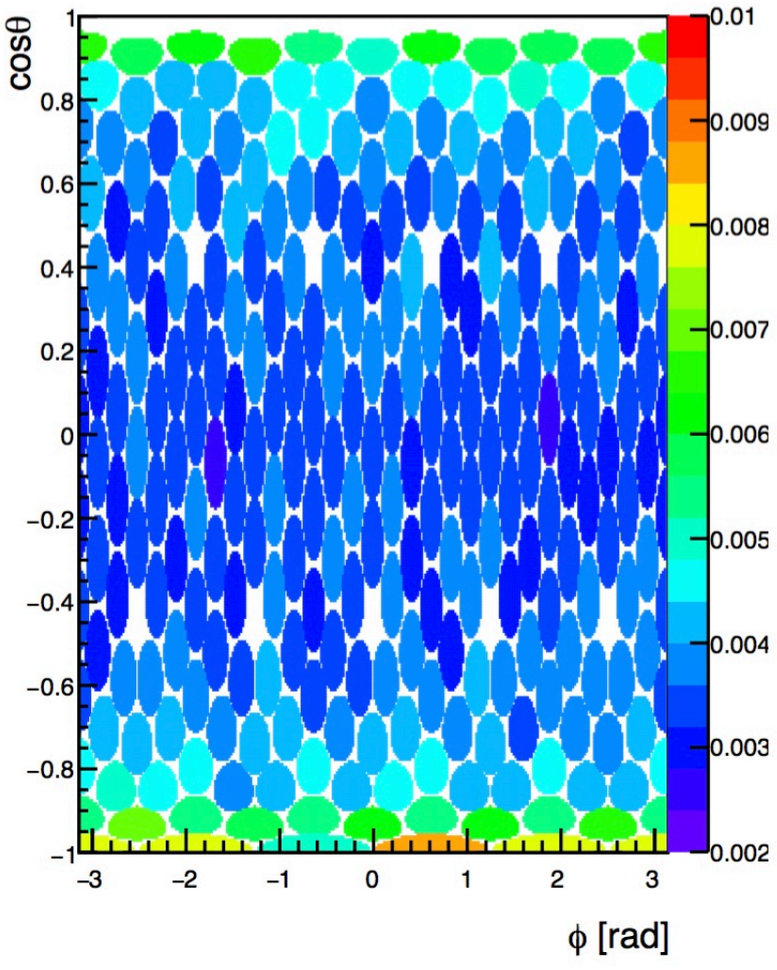


alpha's in Gap 1



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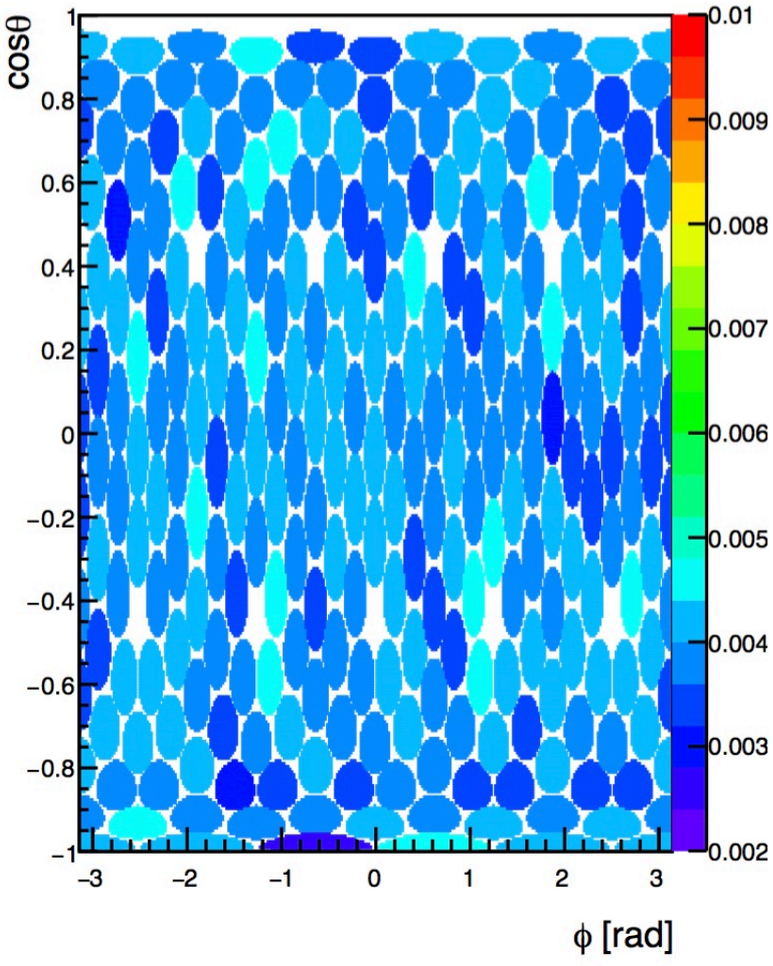

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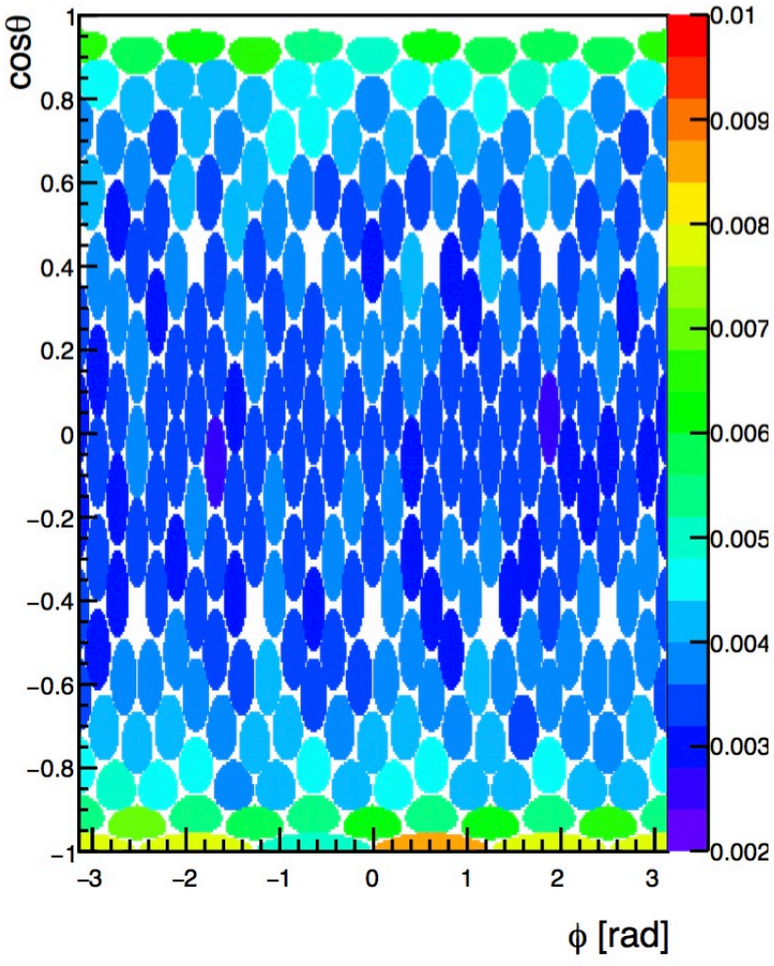
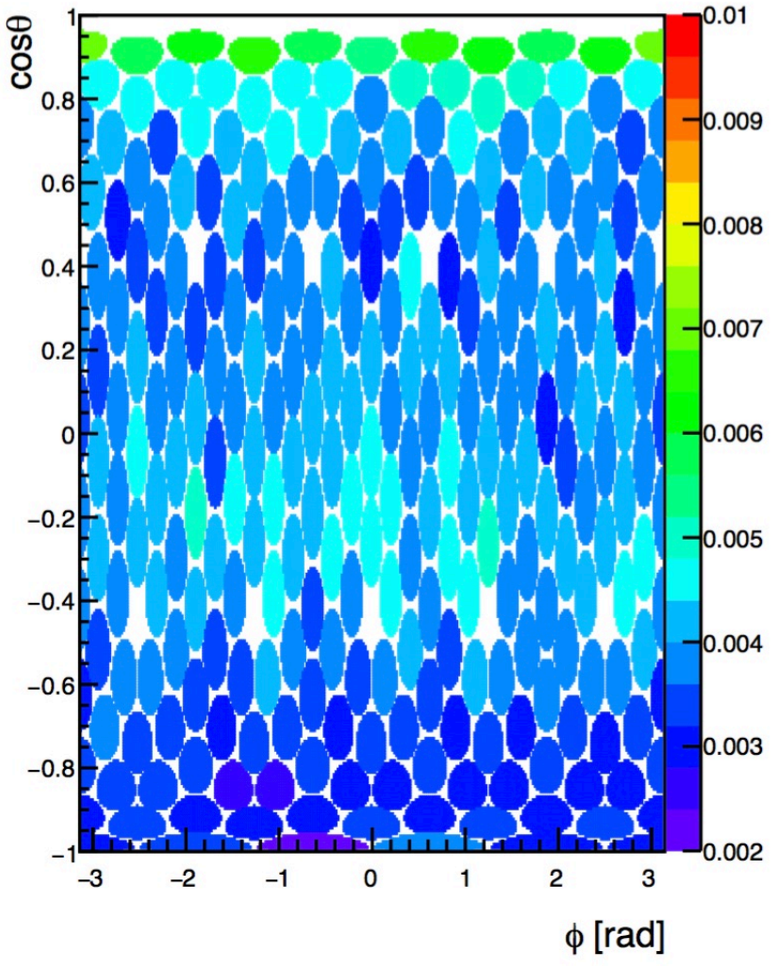
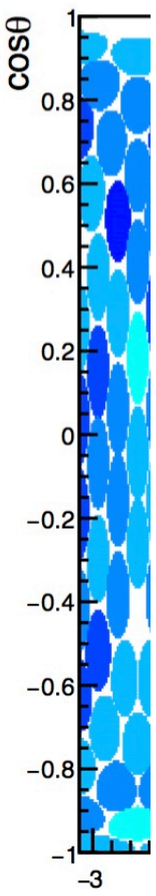


alpha's in Gap 2



Charge distribution in neck events

Fra



$$log(\mathrm{LR}) = \sum_{i=0}^{255} N_i(log(P_{\chi,i}) - log(P_{neck,i}))$$

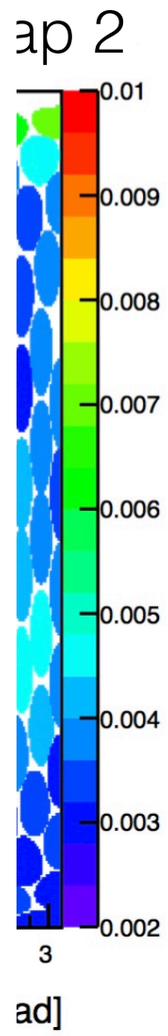
where

i is the PMT number

N_i is the number of PE measured in PMT i

$P_{\chi,i}$ is the probability of measuring 1 PE in PMT i

$P_{neck,i}$ is the probability of measuring 1 PE in PMT i

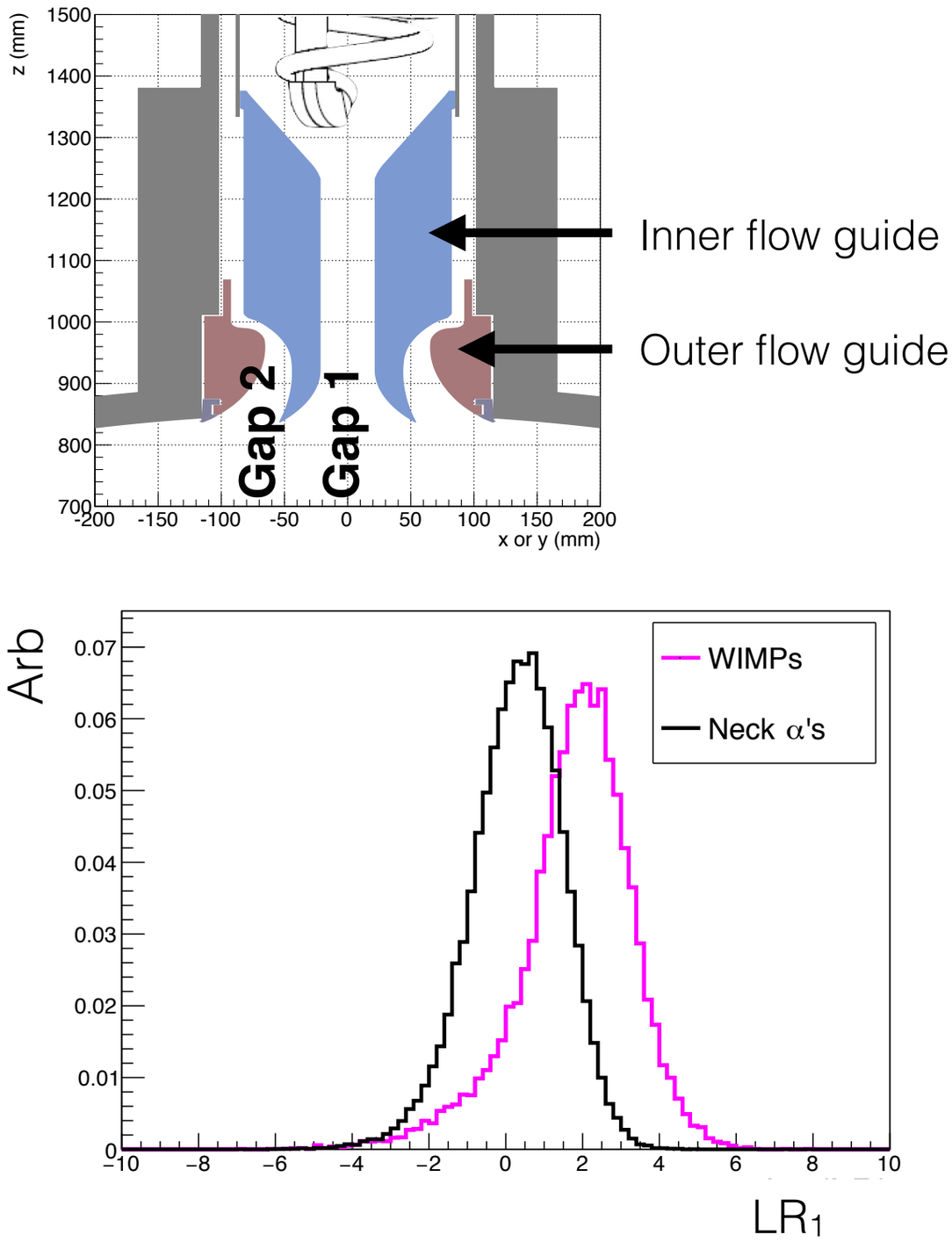


Likelihood Ratio

- Calculate 2 likelihood ratios from simulation of full detector:

$$LR_1 : P_{gap1} \text{ and } P_\chi$$

$$LR_2 : P_{gap2} \text{ and } P_\chi$$



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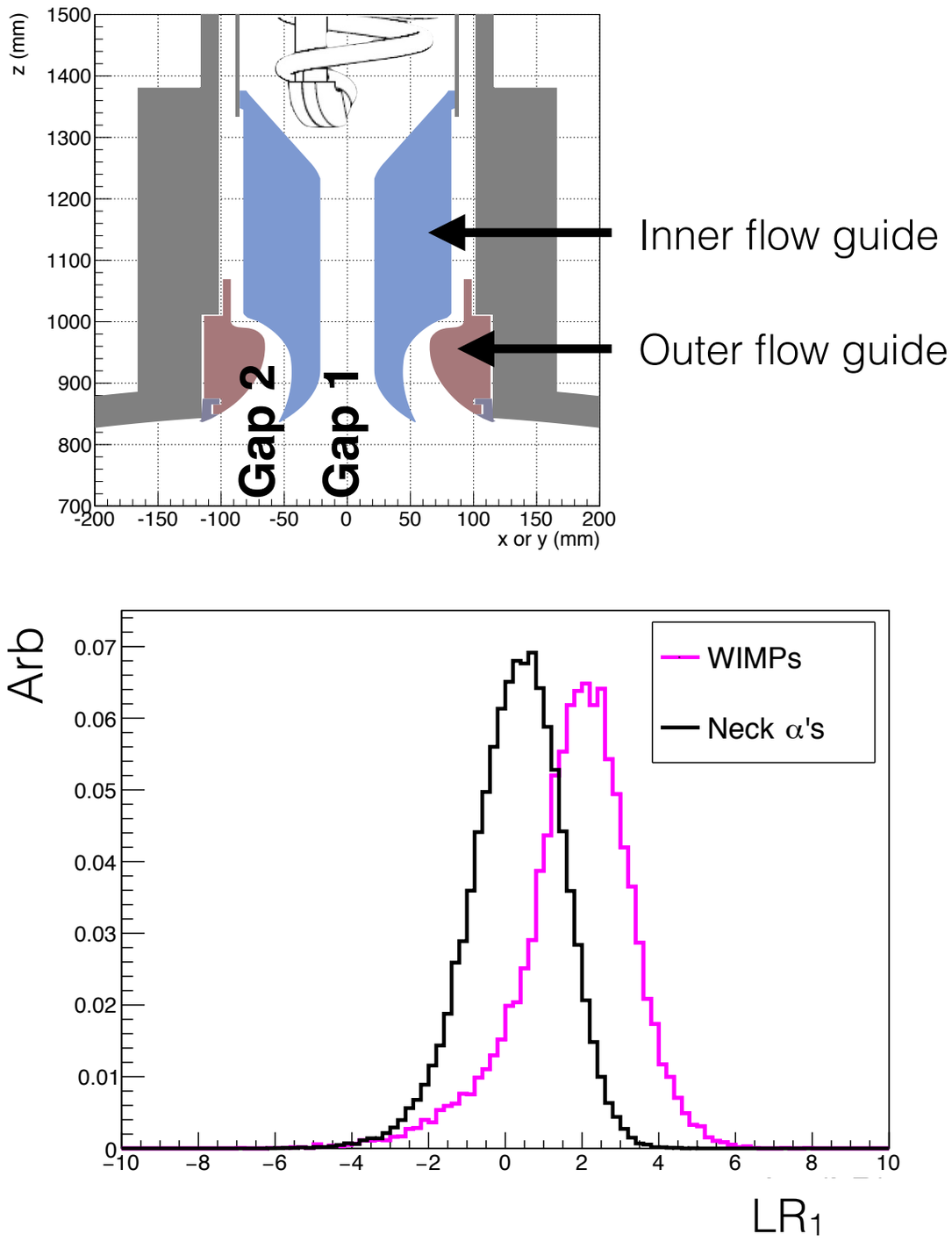

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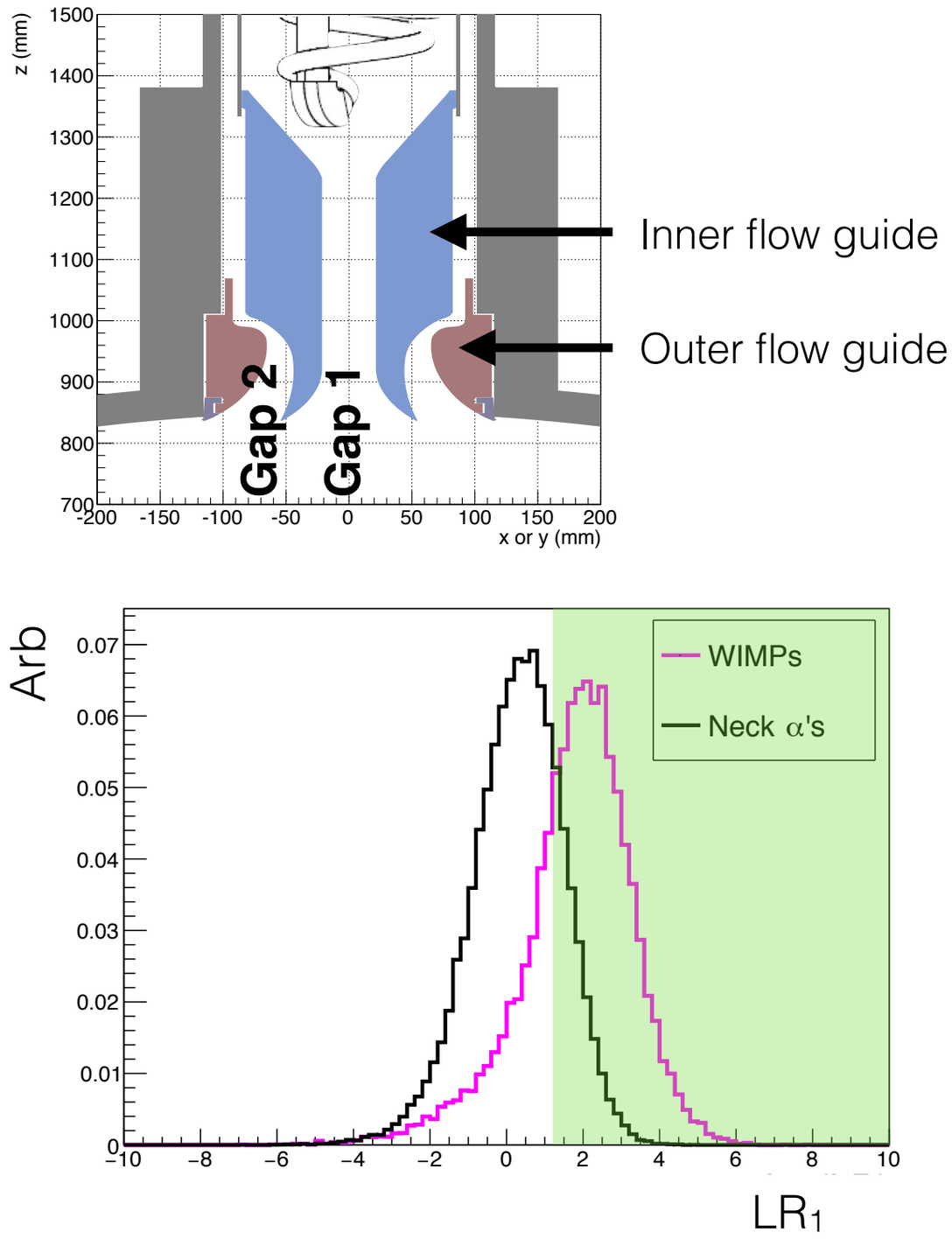

Survival Fraction

- Survival fraction:

  Number of events with

  $$LR_1 > x \text{ and } LR_2 > y$$

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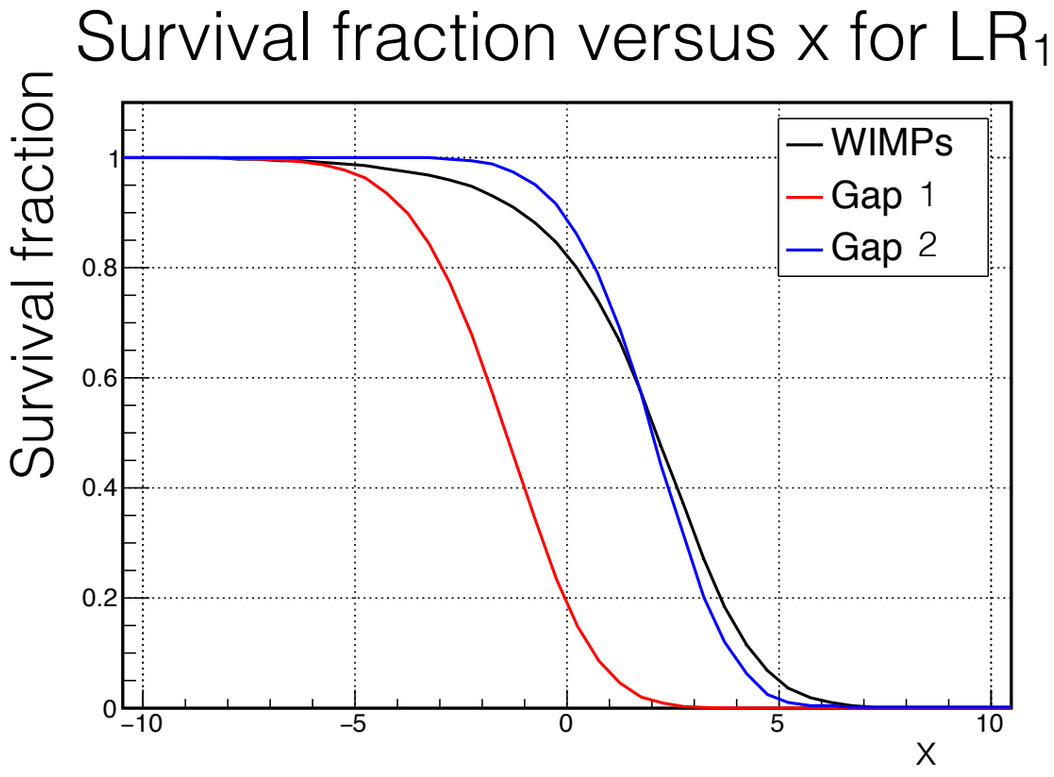
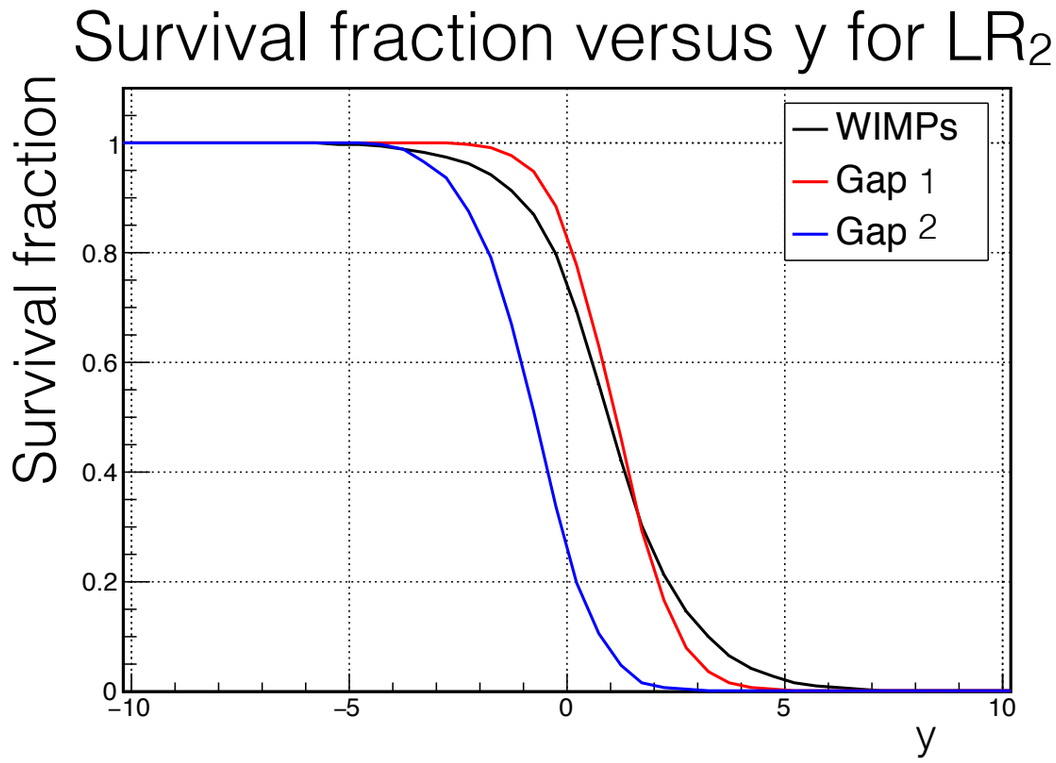
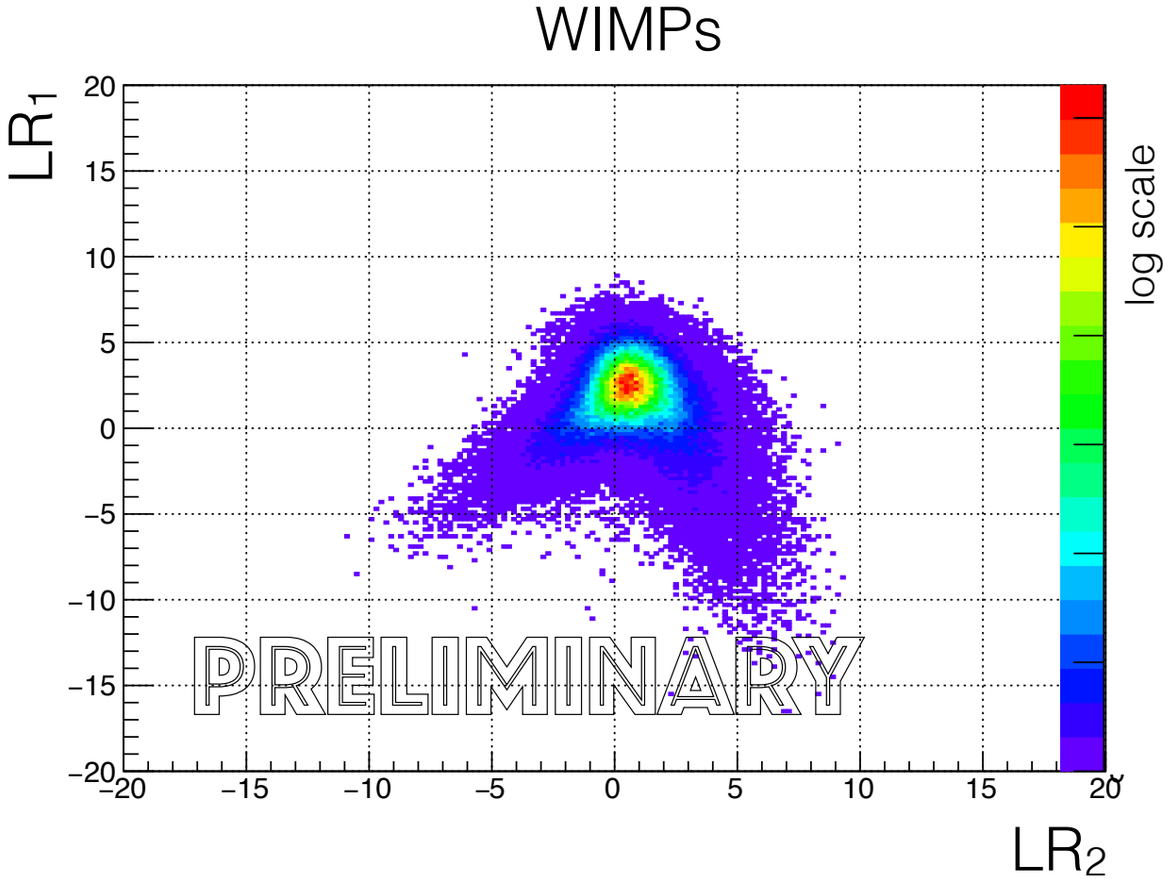
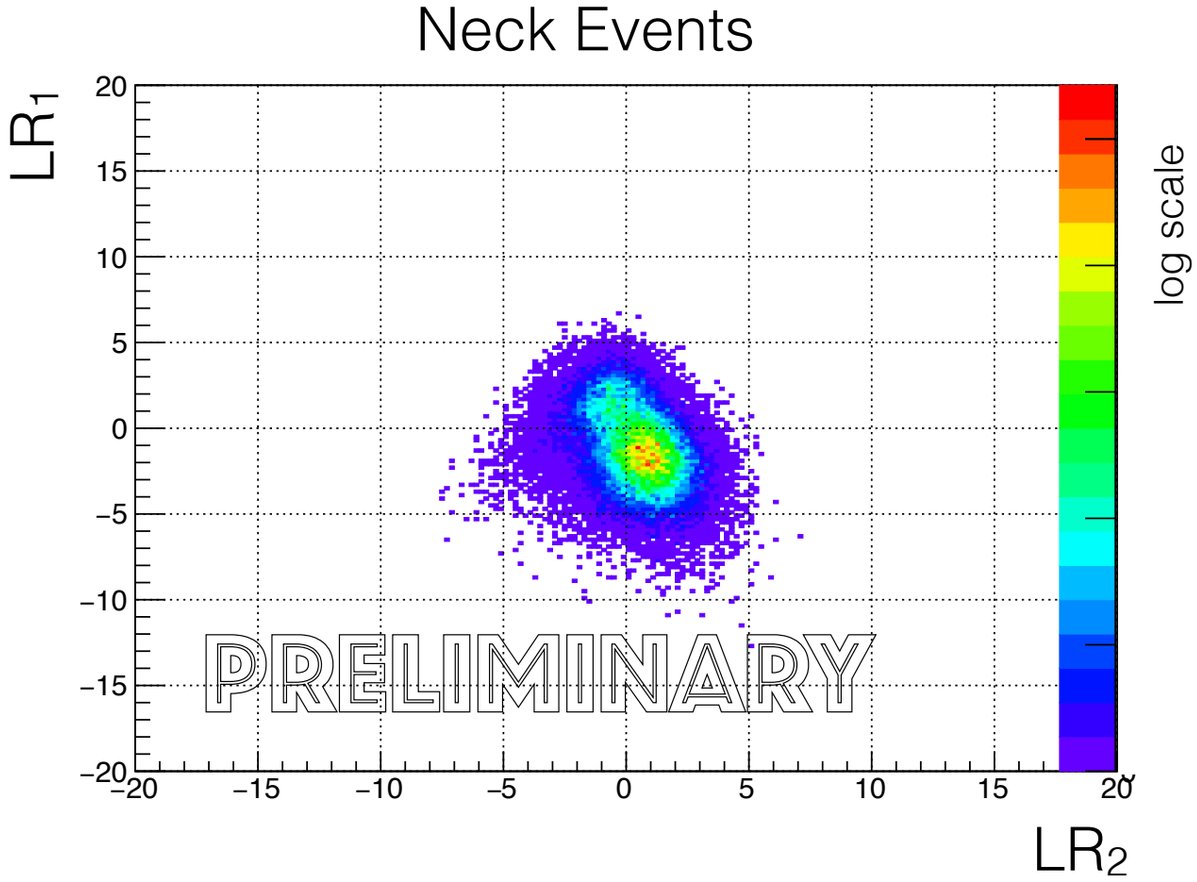




Likelihood Ratio Cut in Simulation

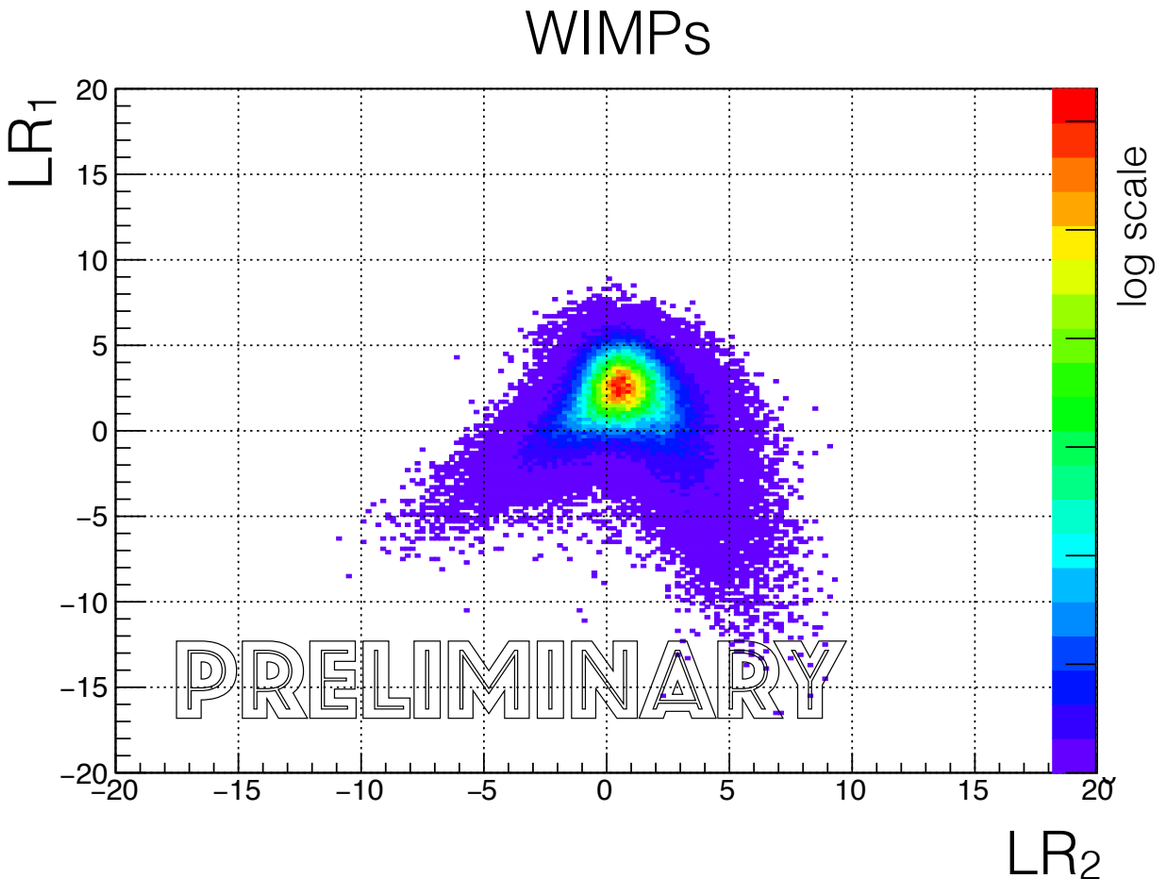


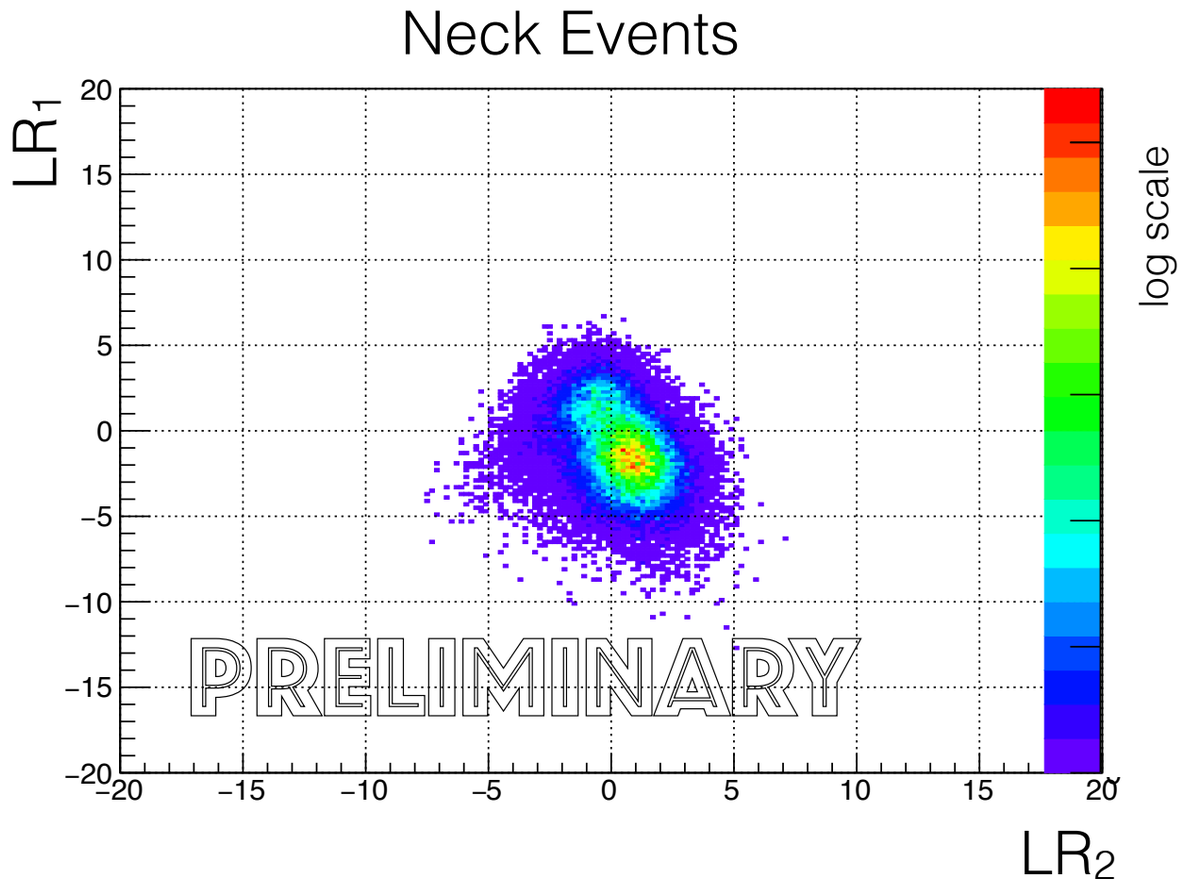


$$LR_1 > x \text{ and } LR_2 > y$$

Maximize WIMPS, Minimize Neck Events

Likelihood Ratio Cut in Simulation





WIMP acceptance = 28% (equivalent to 1000 kg fiducial mass)

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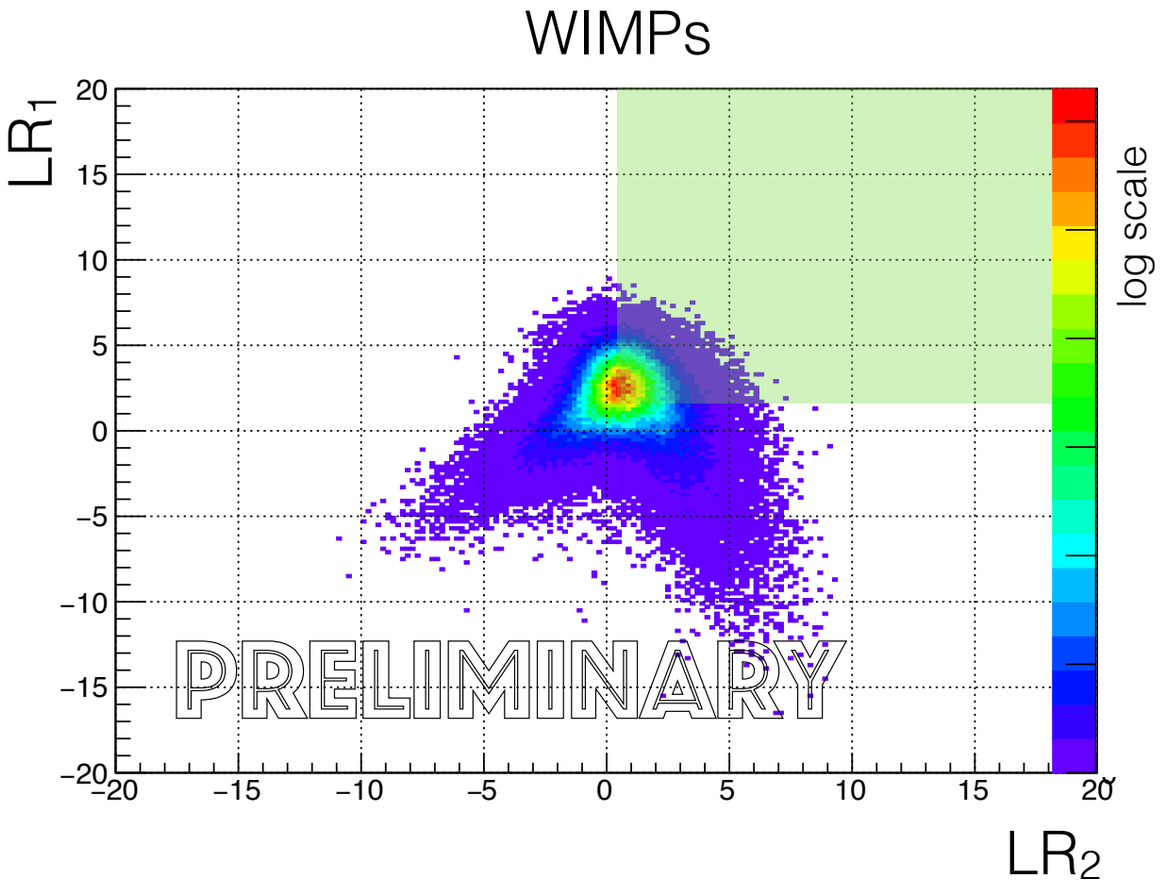

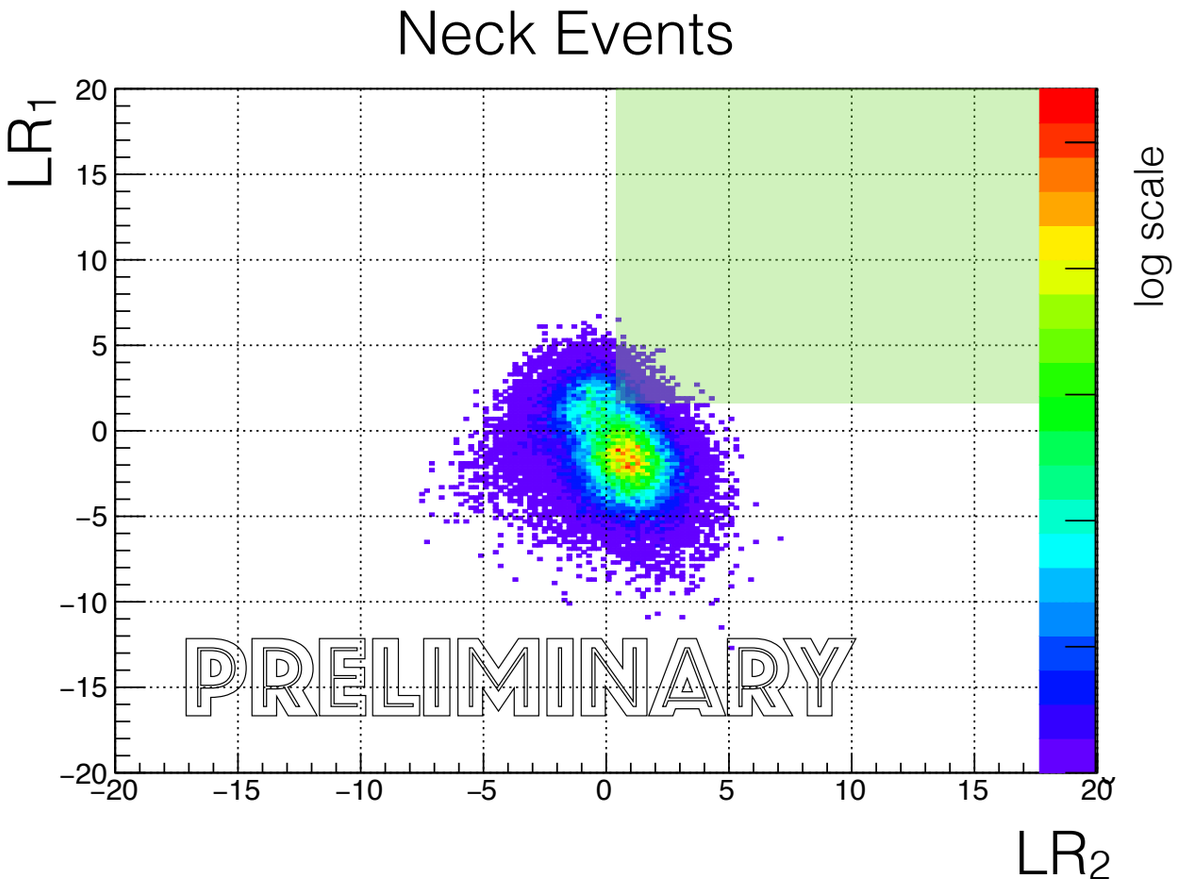

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$LR_1 > 1.8$ and $LR_2 > 0.5$

Neck Event Survival Fraction = 1.6%

(compare to 23% survival fraction for spherical fiducial cut with same WIMP acceptance)

Summary

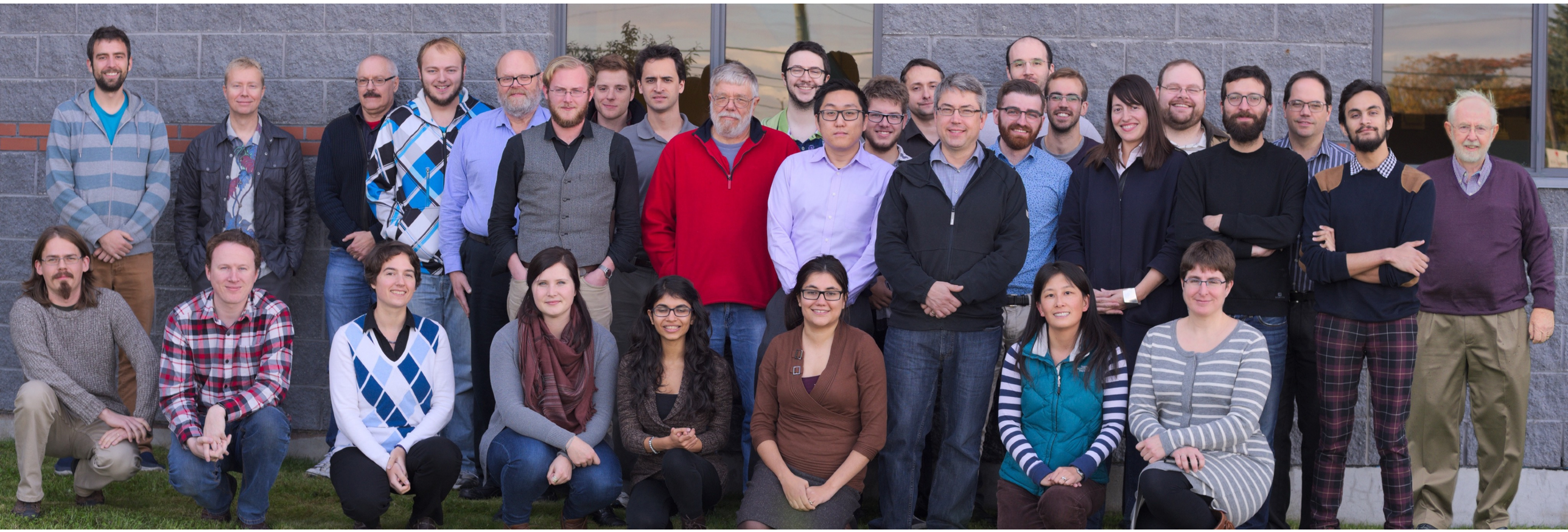
- neck events are a background concern for DEAP-3600

- likelihood ratio developed based on charge distribution of neck events in simulation

- rejection of neck events is correlated with WIMP acceptance

- currently studying the distribution of the likelihood ratio in commissioning data

Thank you



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