Vertical Drift - Alternative PDS design

Tagging efficiency of 10 MeV events with membrane only solution

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PDS Conceptual Design Discussion II
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Configuration and MC simulations

Configuration

- 63x63 cm^2 X-ARAPUCA tiles arranged in columns on two longitudinal cryostat walls only, 20 columns/wall.
- Every column contains 18 tightly stacked tiles with 2 cm vertical spacing and 65 cm of free space above and below the cathode plane.
- Tiles on the cathode and above/below anodes simulated as well but masked offline in this study.
- X $\in$ (-735,735) cm, transversal, horizontal
- Y $\in$ (-650,650) cm, perpendicular to the cathode, vertical
- Z$\in$ (-3000,3000) cm, longitudinal, horizontal
- Middle of the TPC $(x_0,y_0,z_0) = (0,0,0)$. FC $x = 675$ cm. Cryostat wall $x = 735$ cm. Anodes $y = \pm 650$ cm.

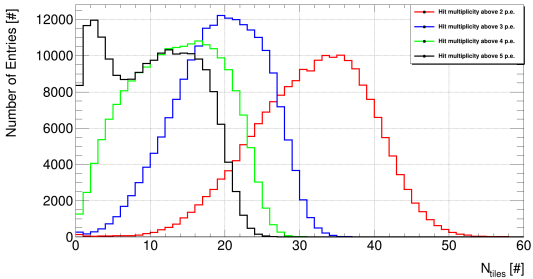
MC Simulations in FLUKA

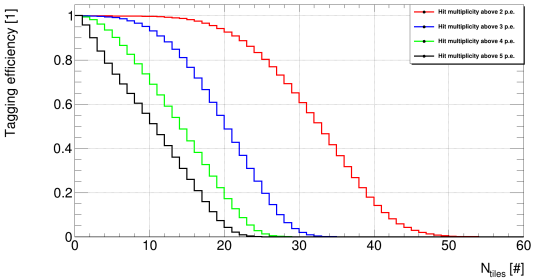
- 24.000 p/MeV (fast component @ 128nm, slow component @ 175 nm)
- Cathode transparency 0 %, real field cage structure, Rayleight scattering $\lambda_{Ar} = 0.9$ m $\lambda_{Xe} = 7$ m
- Due to symmetries, events are generated in one eight of the full detector (only positive coordinates).
- Datasamples: 10 MeV (200k events) uniformly distributed electrons, 39Ar (1M events, also between FC and Cryostat)
- Tiles detection efficiency applied offline on the photon-by-photon basis ($Eff_{PD} = 3.5$ %)

Tile Multiplicities

Tagging Efficiency

- Assuming existence of external trigger from TPC, estimate tagging efficiency of 10 MeV events
- Multiplicities (number of hit tiles) for different p.e. thresholds are compared
- Cumulative distributions show the ratio of detected events for given trigger

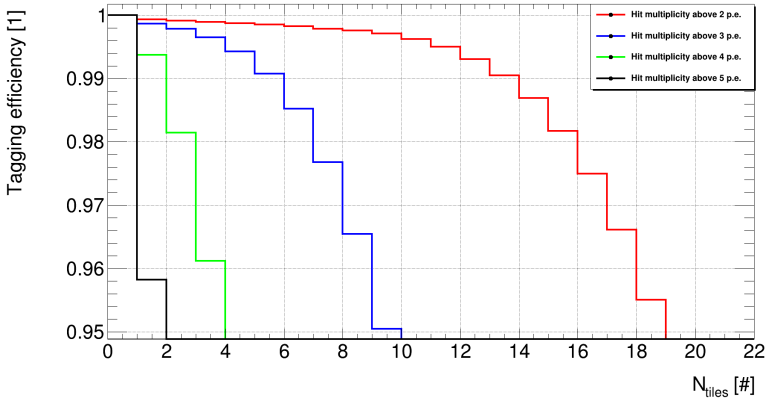




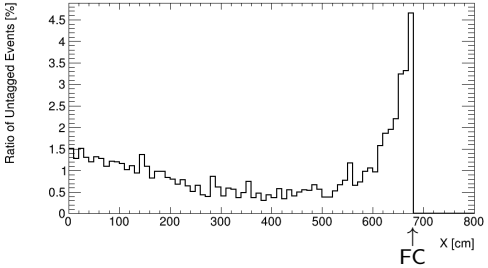
Tagging Cut Suggestions

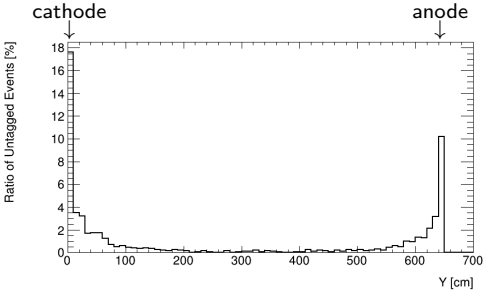
Block Title

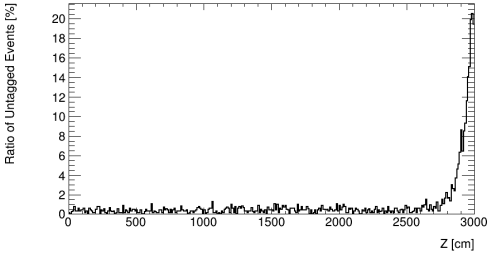
- Targeting overall 99 % tagging efficiency, two possible tagging combinations can be used
  - $(M_T, N_{pe}) = (13,2)$ - much more background robust, requires detectability of 2 p.e. signal with tiles
  - $(M_T, N_{pe}) = (5,3)$ - less background robust, easier to detect

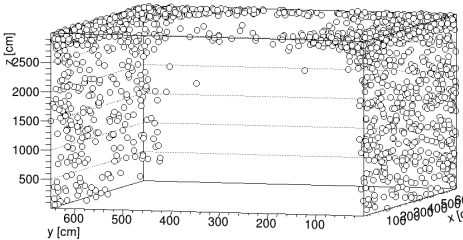


Where is located that 1 % of untagged events?





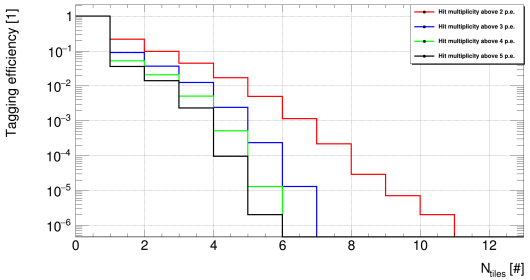


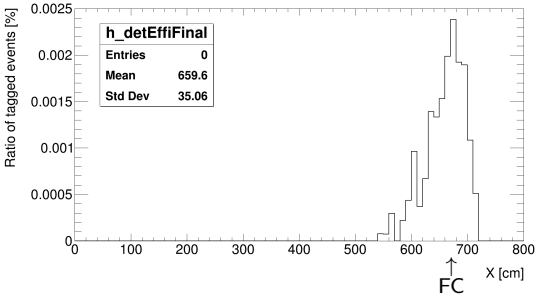


Tagging Background

^{39}Ar

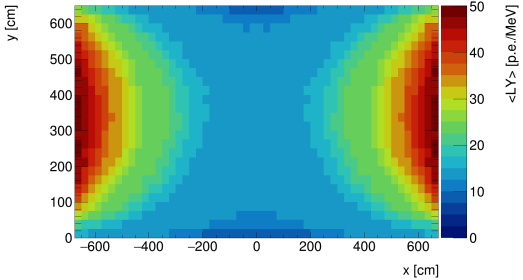
- Energy spectrum E = (0 - 500) keV
- Total activity order of 10^7 Bq
- With 10^{-2} tagging efficiency still 100 background events in 1 ms acquisition window in the whole detector
- Simulated also between FC and cryostat walls (30 % of tagged events)
- Tagged events up to 1.2 m within the sensitive volume

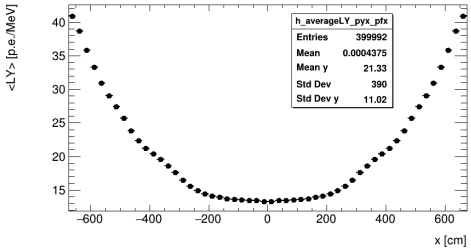


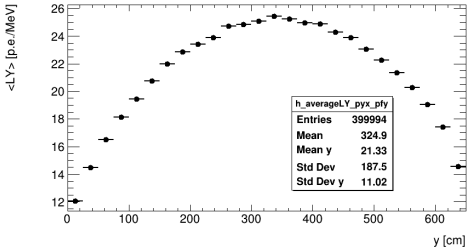


LY Maps

- Integrated over all Z positions (includes edge effects)
- $< LY > = 21.3$ p.e./MeV
- $< LY >_{min} = 7.7$ p.e./MeV
- Higher values than Laura presented **BUT**
  - More tiles
  - $Eff_{PD} = 3.5\,\%$
  - Shorter distance (FC-Cryo)







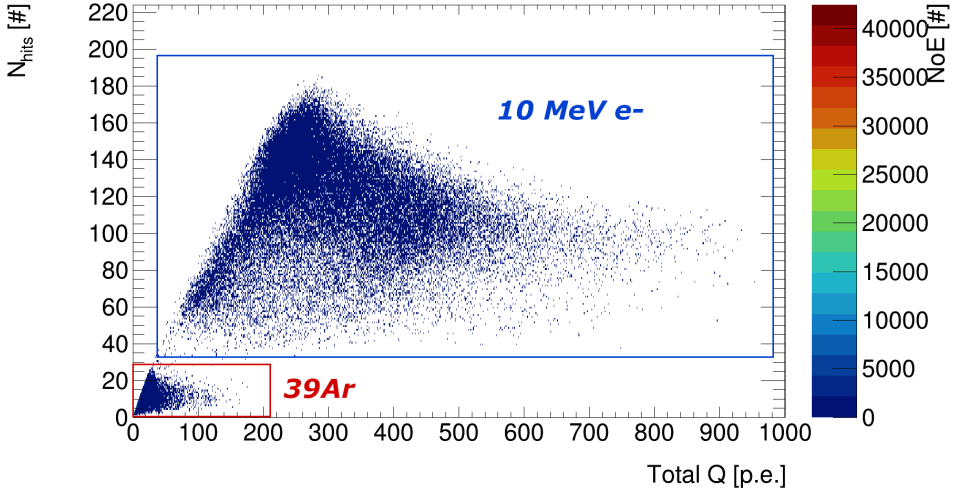
Summary

Results

- Two possible tagging cuts were found to achieve 99 % tagging efficiency of 10 MeV events in the whole volume
- High multiplicity of $(M_T, N_{pe}) = (13,2)$ option provides excellent suppression of ^{39}Ar
- If 2 p.e. signal is not detectable (David Warner says it should be 1.5 p.e.), additional ^{39}Ar suppression techniques have to be introduced to remain 99 % tagging efficiency
- For 5 MeV events, 90 % tagging efficiency is achievable

The End

^{39}Ar Suppression

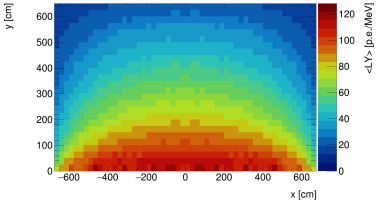


LY for Different Configurations with New MC

Cathode Only

$< LY >= 55.6$ p.e.

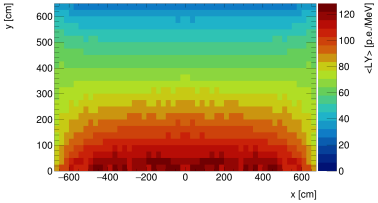
$< LY >_{min} = 12.8$ p.e.



Cathode + 18 cryo tiles

$< LY >= 73.8$ p.e.

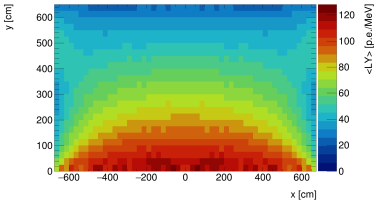
$< LY >_{min} = 30.1$ p.e.



Cathode + 8 cryo tiles (4 upper most and 4 lower most)

$< LY >= 63.0$ p.e.

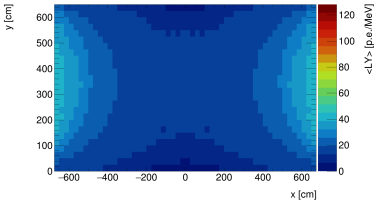
$< LY >_{min} = 24.9$ p.e.



Cryo Only

$< LY >= 18.5$ p.e.

$< LY >_{min} = 5.3$ p.e.



Cathode Only

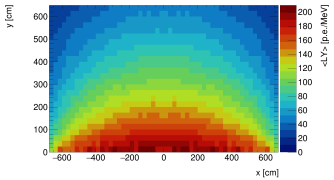
Comparison

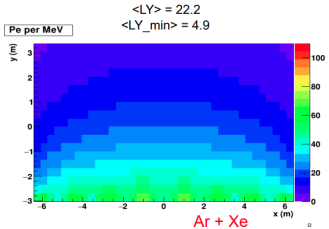
- With new MC much better agreement but still 2.5x more light per MeV
- Large disagreement even very close to the cathode → there are differences already on the level of light production.
- Completely different profile in Y direction → different absorption and scattering properties are probably used.
- The LY very close to the cathode should be given only by the solid angle and X-ARAPUCA detection efficiency (our numbers work and we don't know why Laura gets "so small" numbers)

Old MC

$< LY >= 93.5$ p.e.

$< LY >_{min} = 22.0$ p.e.

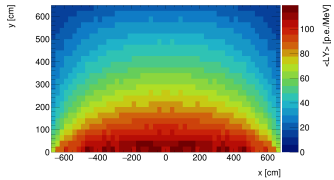




New MC

$< LY >= 55.6$ p.e.

$< LY >_{min} = 12.8$ p.e.



"Membrane" Only = Cryostat walls

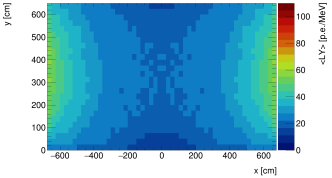
Comparison

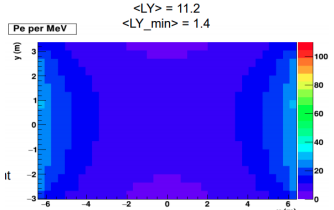
- Different configurations
  - Laura - 8 tiles on cryo only (probably), 90 cm from FC (how?)
  - we - 18 tiles, 65 cm from FC

Old MC

$< LY >= 27.8$ p.e.

$< LY >_{min} = 13.7$ p.e.





New MC

$< LY >= 18.5$ p.e.

$< LY >_{min} = 5.3$ p.e.