

Layout Optimization Studies for FD2-VD

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Photon Detector Simulation
and Physics WG meeting

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Goals

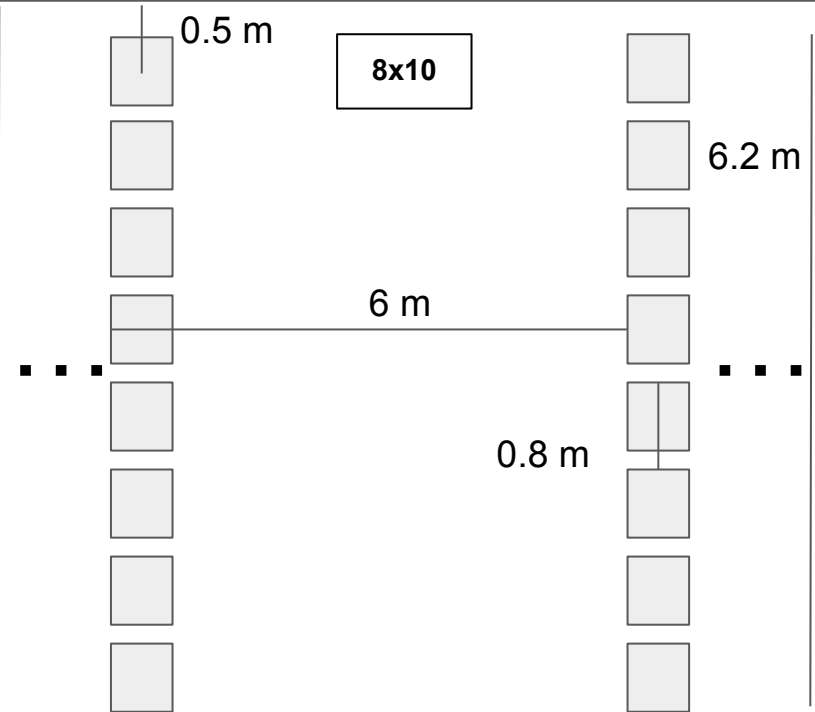
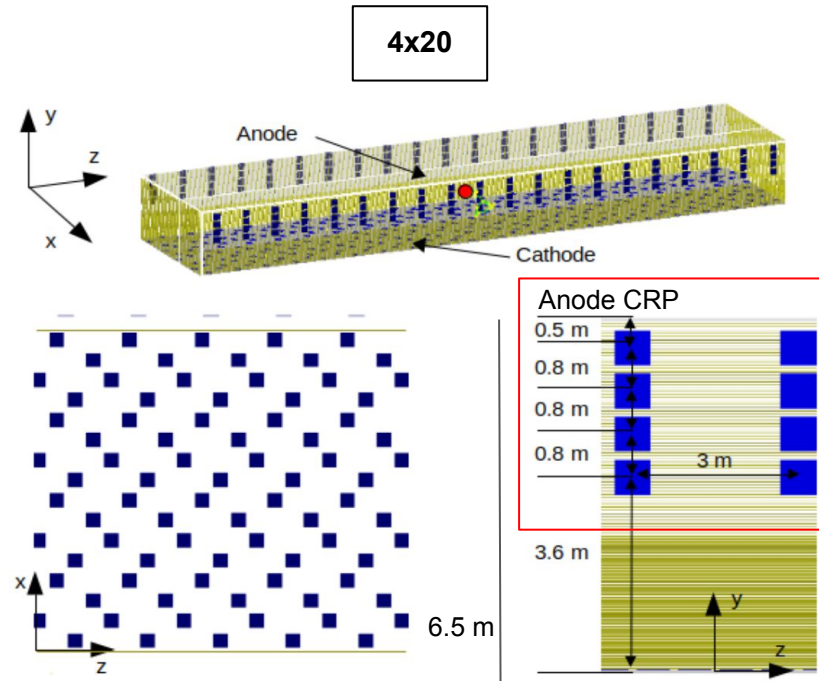
Study different configurations to optimize the membrane X-ARAPUCA layout of the reference design.

For fixed number of membrane X-ARAPUCAs:

- Build LY maps of grid layouts and compare $\langle LY \rangle$ and $LY_{\min}$.
- Optimize X-ARAPUCA vertical spacing (currently 80 cm).
- Study effect of position in the buffer region (between the field cage and cryostat wall).
- Alternative layout shapes (pyramidal).

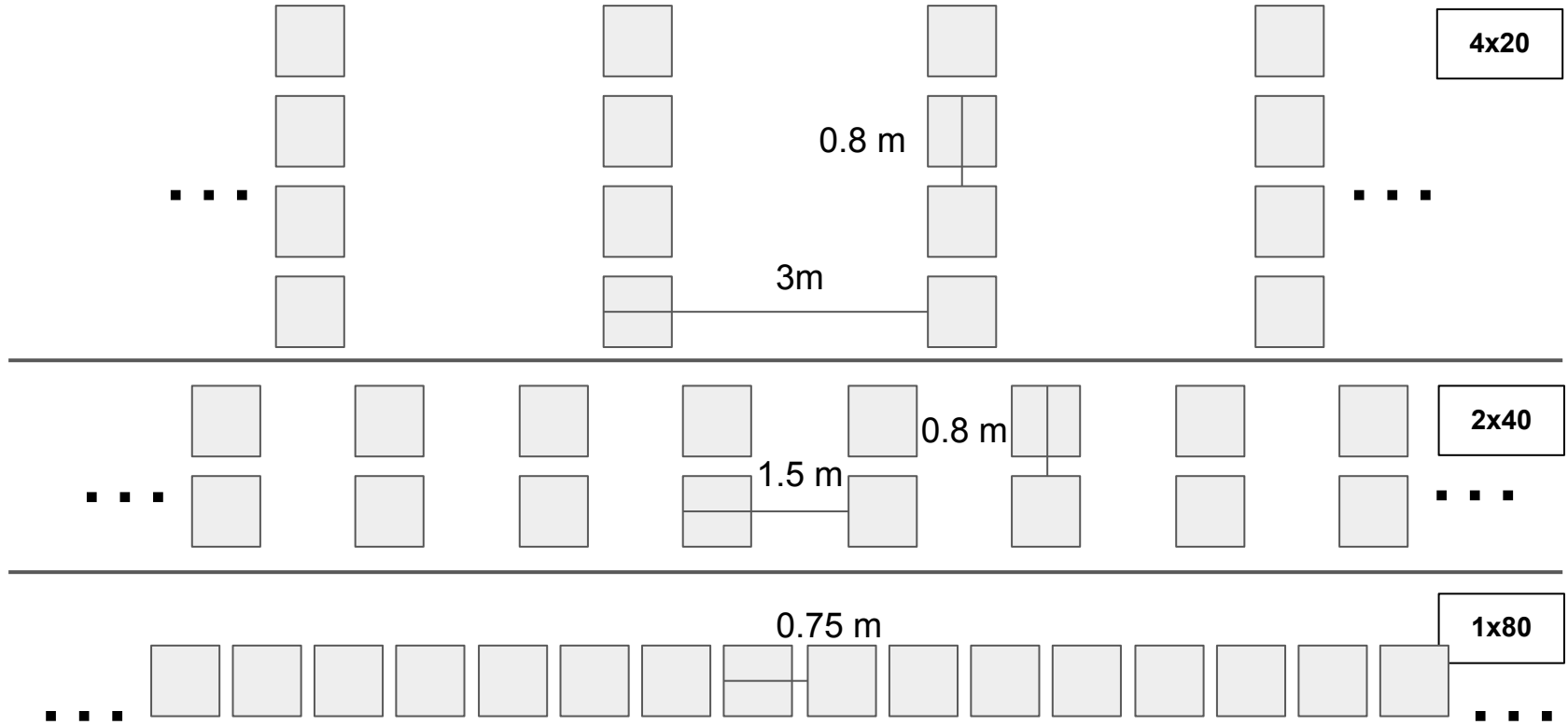
Alternative X-ARAPUCA Grid Arrangements

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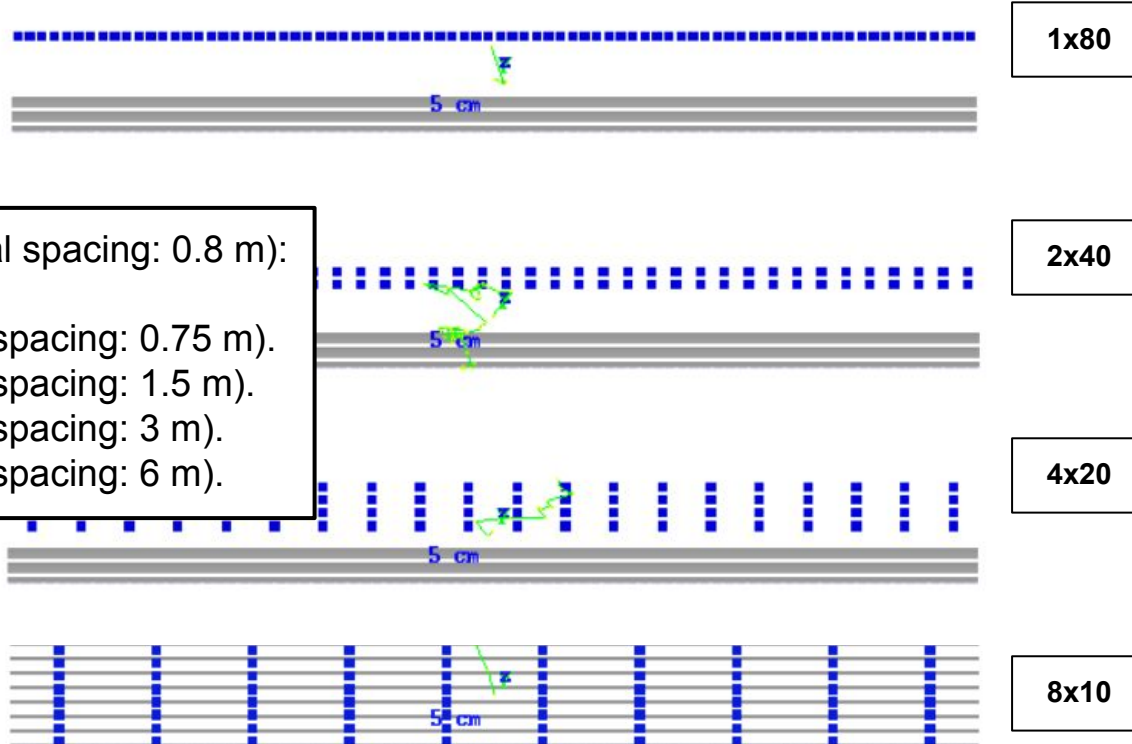
Not to scale.

Alternative X-ARAPUCA Grid Arrangements



Not to scale.

Alternative X-ARAPUCA Grid Arrangements

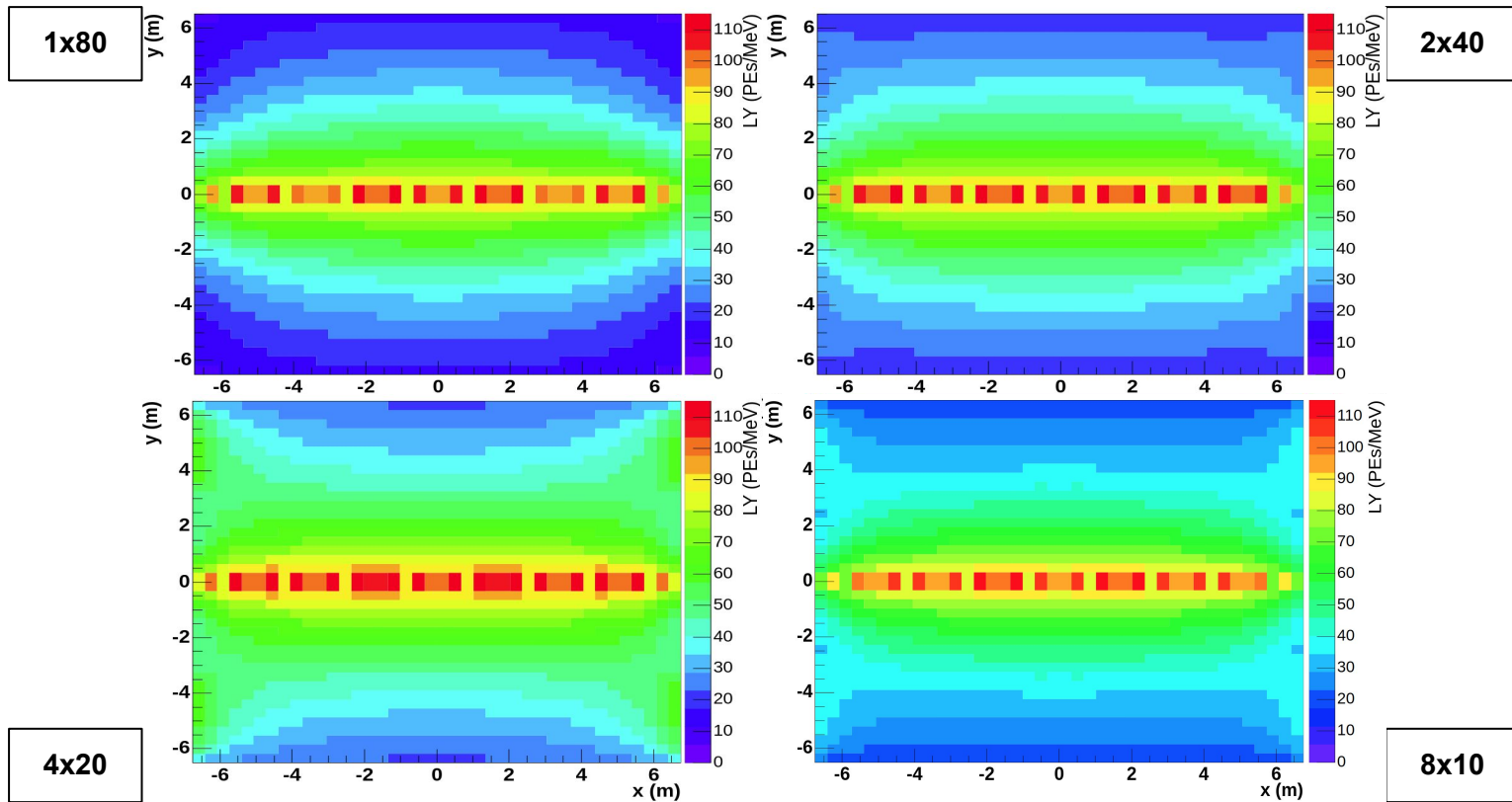


Arrangements (vertical spacing: 0.8 m):

- 1x80 (horizontal spacing: 0.75 m).
- 2x40 (horizontal spacing: 1.5 m).
- 4x20 (horizontal spacing: 3 m).
- 8x10 (horizontal spacing: 6 m).

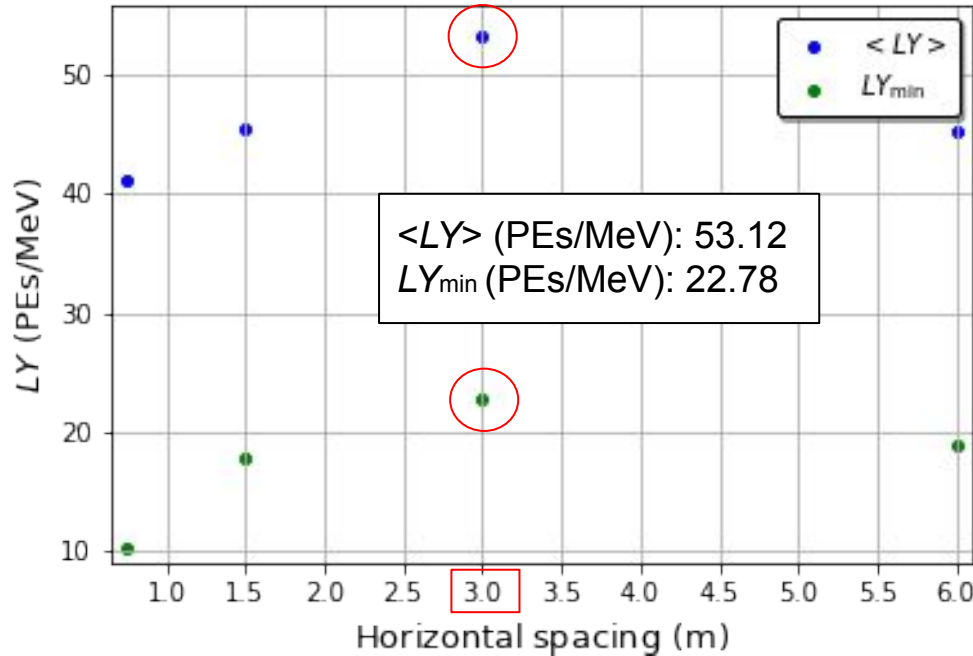
Notice the change in the field cage profiles (all with the same width, 7.5 mm) for the 8x10 layout.

Alternative X-ARAPUCA Grid Arrangements



Here using fixed scale for comparison (0 - 115). Averaged over $z = 0 - 3.0$ m.

Alternative X-ARAPUCA Grid Arrangements

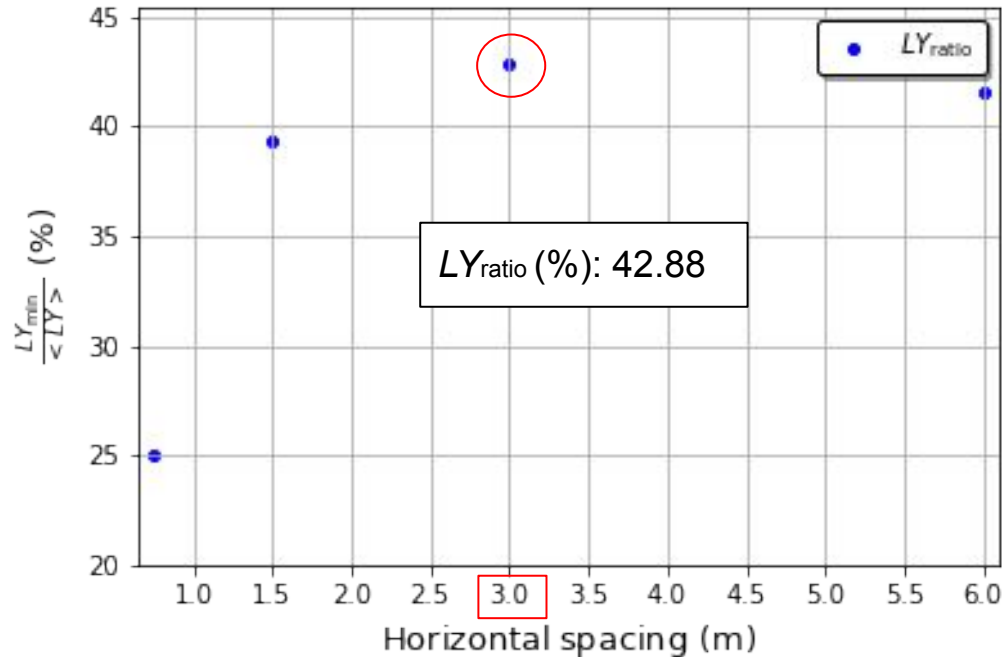


Arrangements

- 1x80 (horizontal spacing: 0.75 m).
- 2x40 (horizontal spacing: 1.5 m).
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- 8x10 (horizontal spacing: 6 m).

Higher results for the original 4x20 (reference design from CDR) arrangement.

Alternative X-ARAPUCA Grid Arrangements

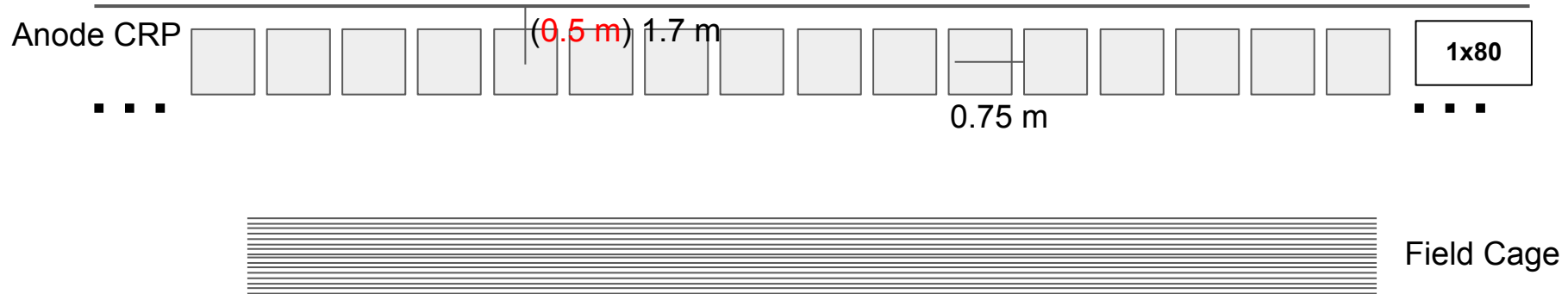
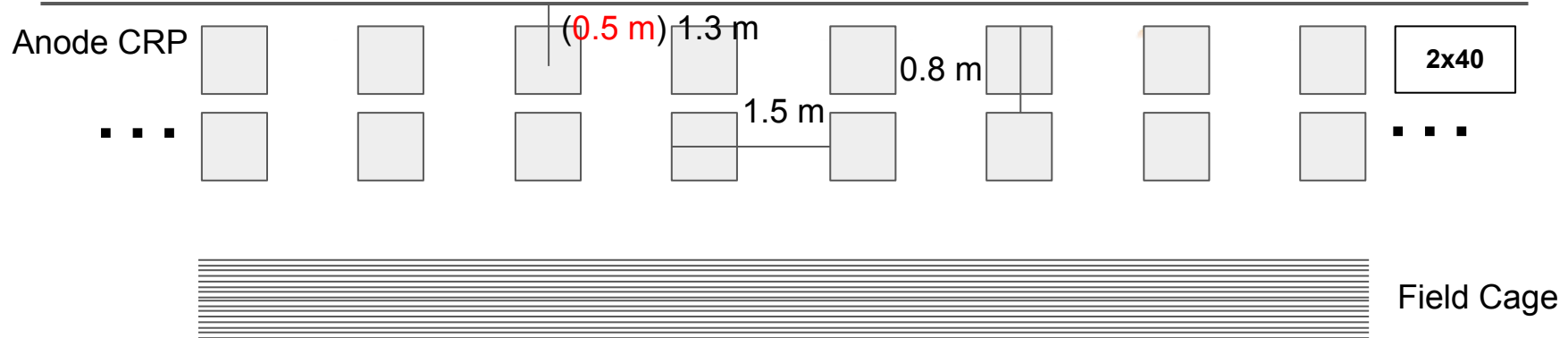


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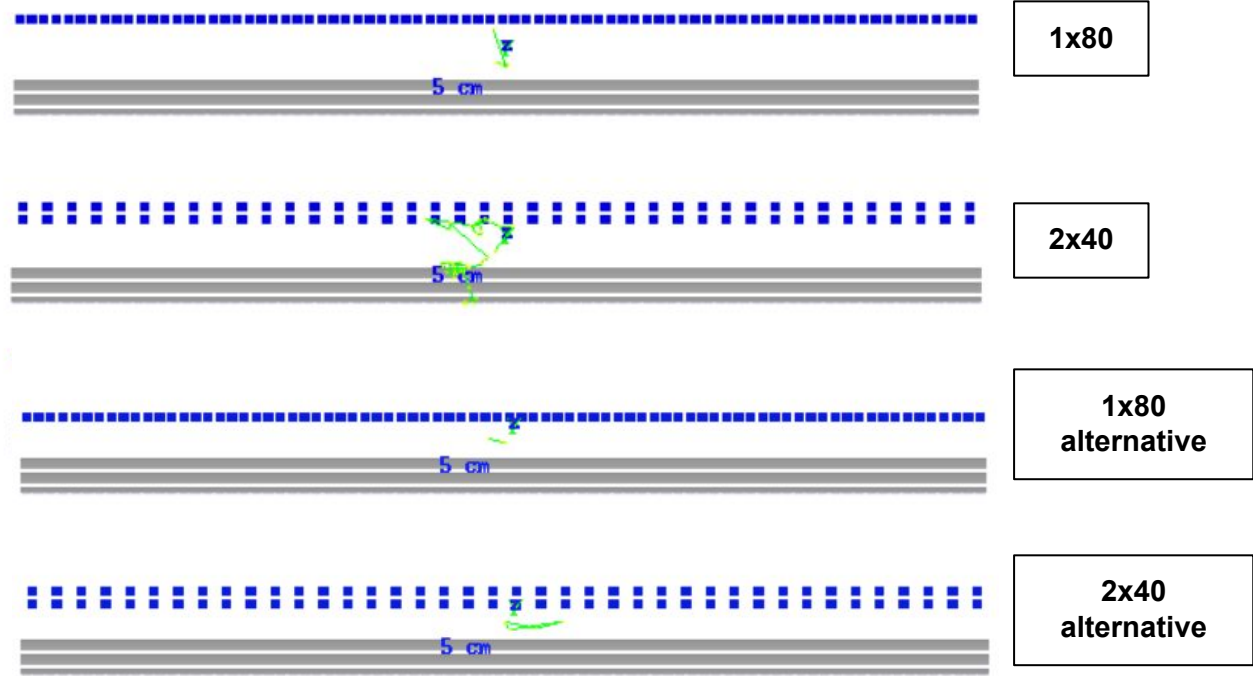
Best ratio for the original 4x20 (reference design from CDR) arrangement.

Alternative X-ARAPUCA Grid Arrangements



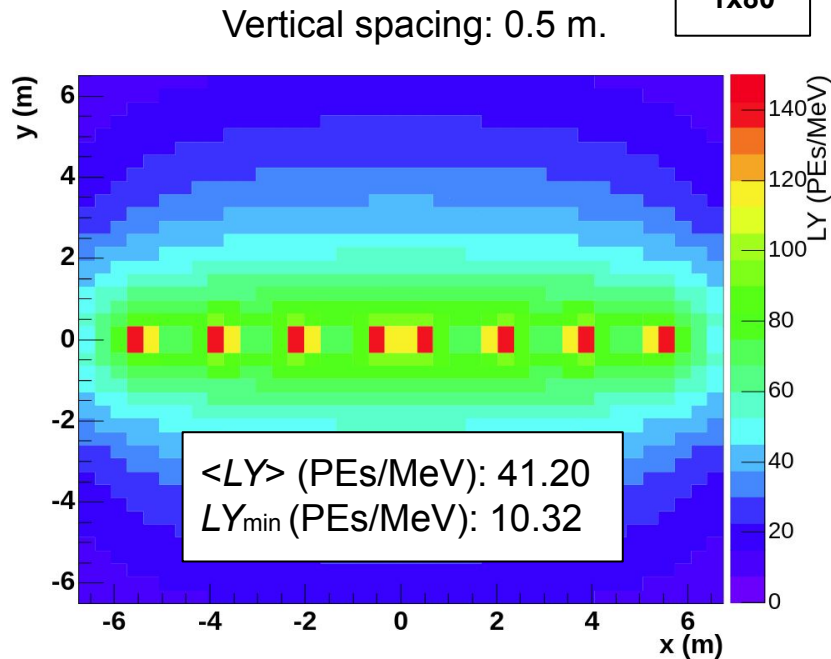
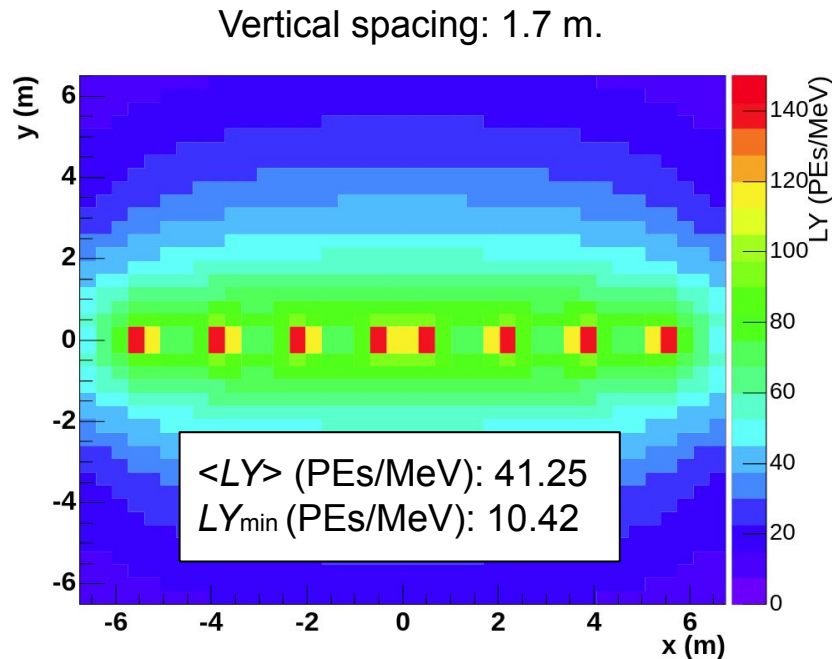
Not to scale.

Alternative X-ARAPUCA Grid Arrangements



Alternative X-ARAPUCA Grid Arrangements

Also the effect of vertically centering the X-ARAPUCA rows has been studied:

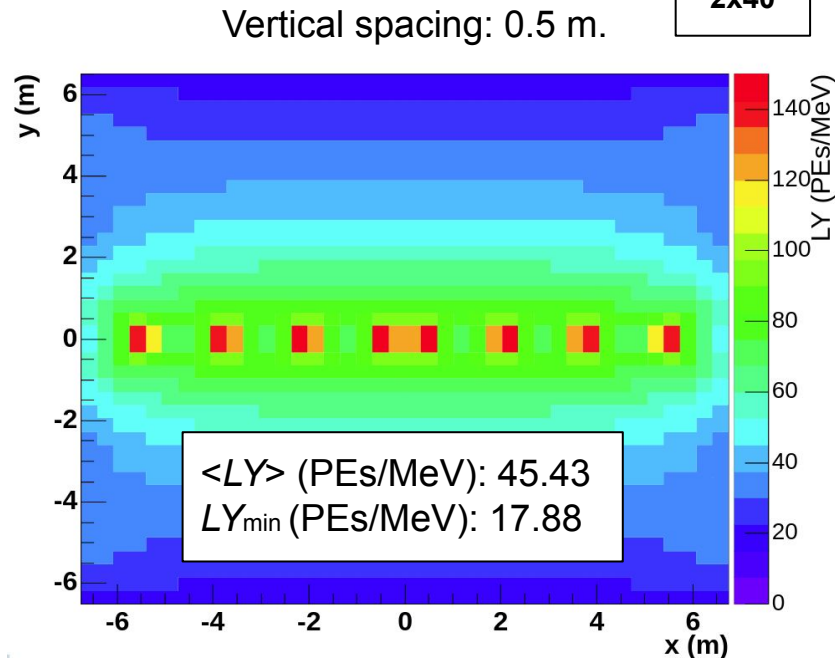
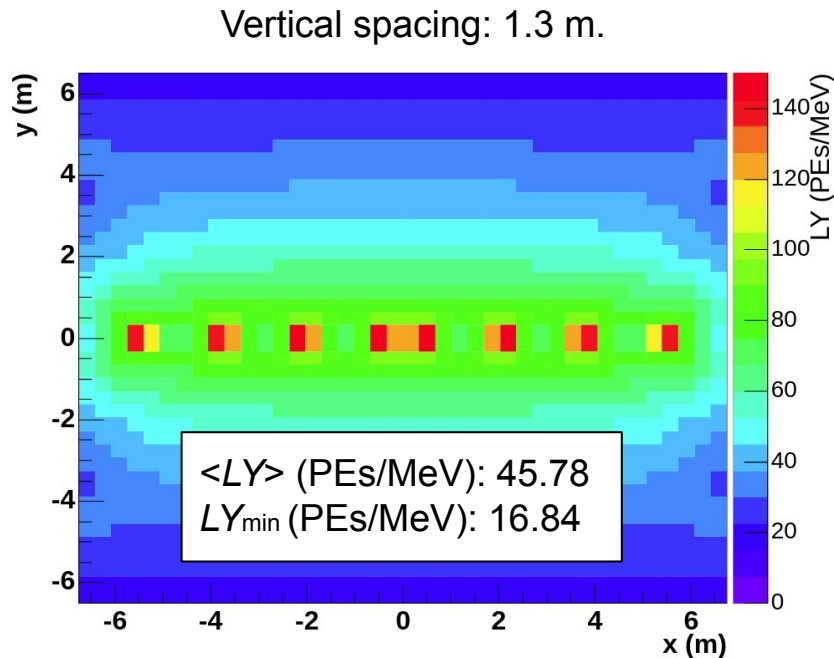


1x80

Here using fixed scale for comparison (0 - 150). Averaged over $z = 0 - 1.5$ m.

Alternative X-ARAPUCA Grid Arrangements

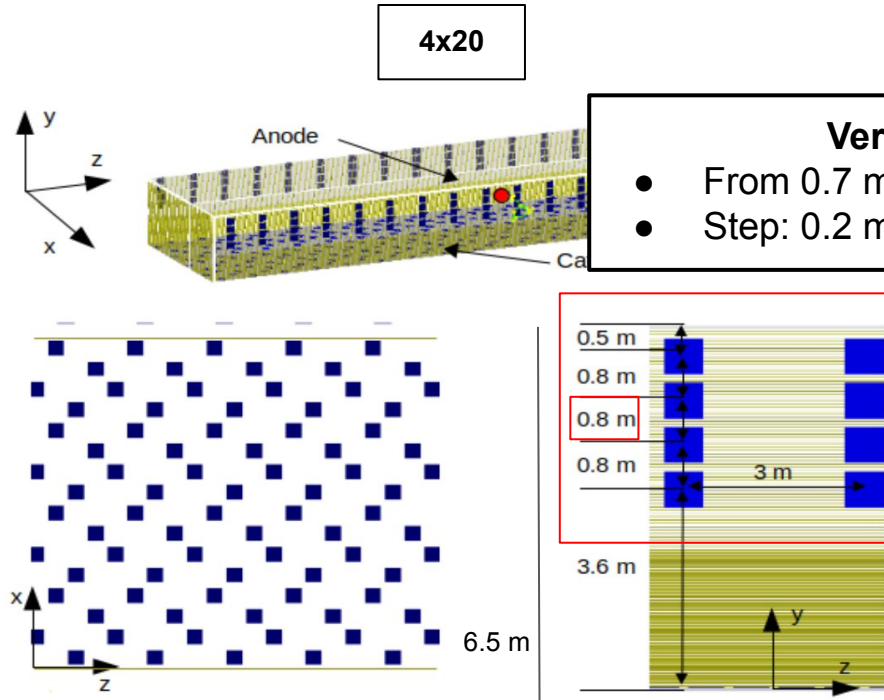
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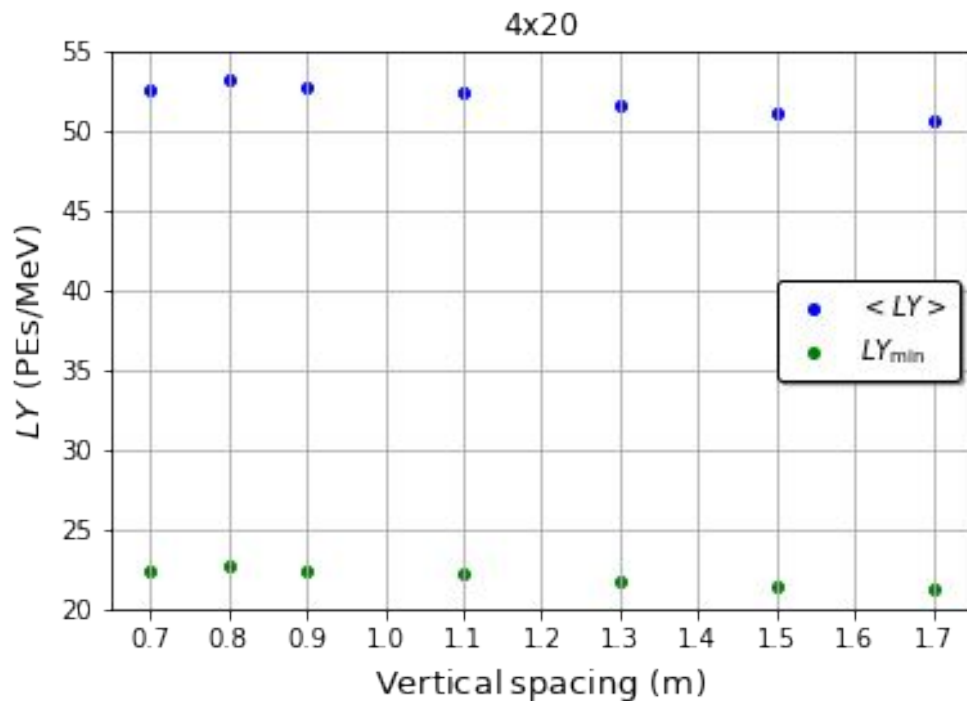
Reference Design Tuneup

Reference Design Tuneup: vertical spacing

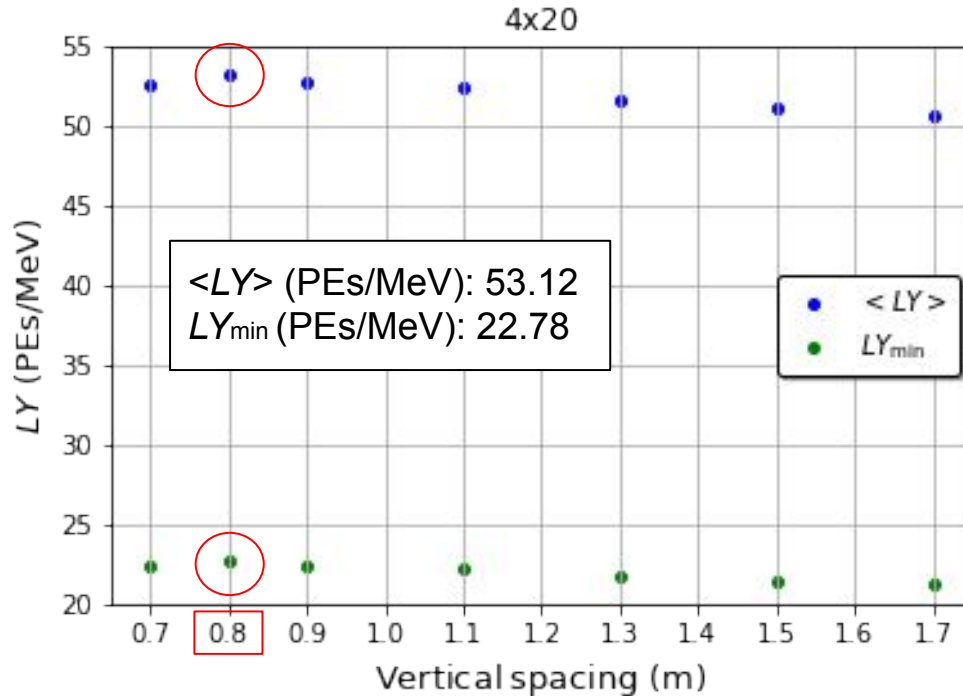


- Vertical spacing**
- From 0.7 m to 1.7 m
 - Step: 0.2 m.

Reference Design Tuneup: vertical spacing

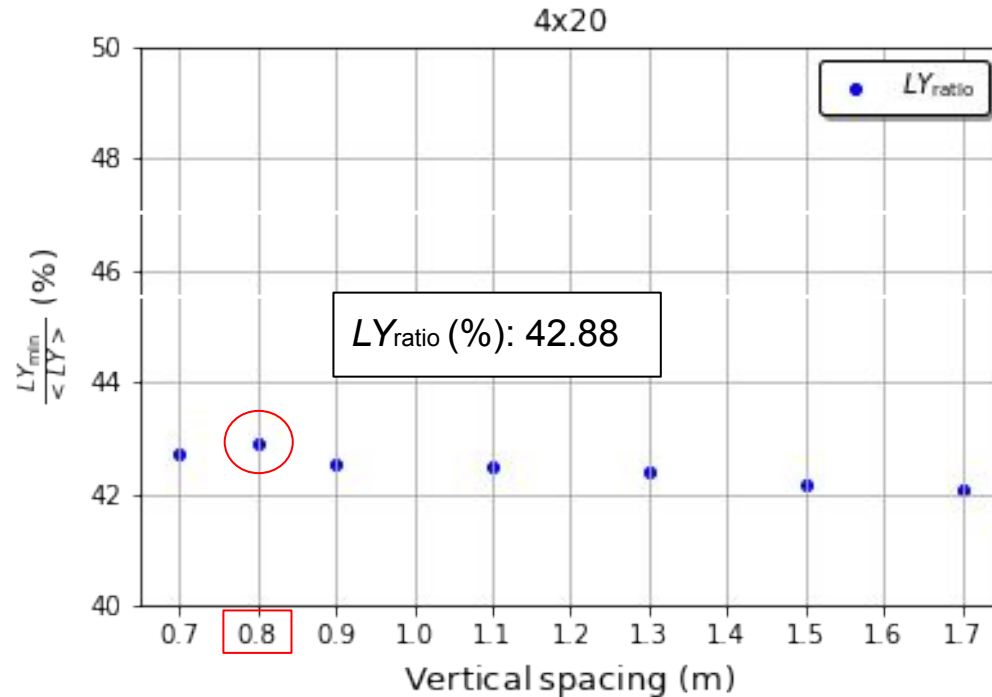


Reference Design Tuneup: vertical spacing



Higher results for the original 4x20 (reference design from CDR) arrangement.

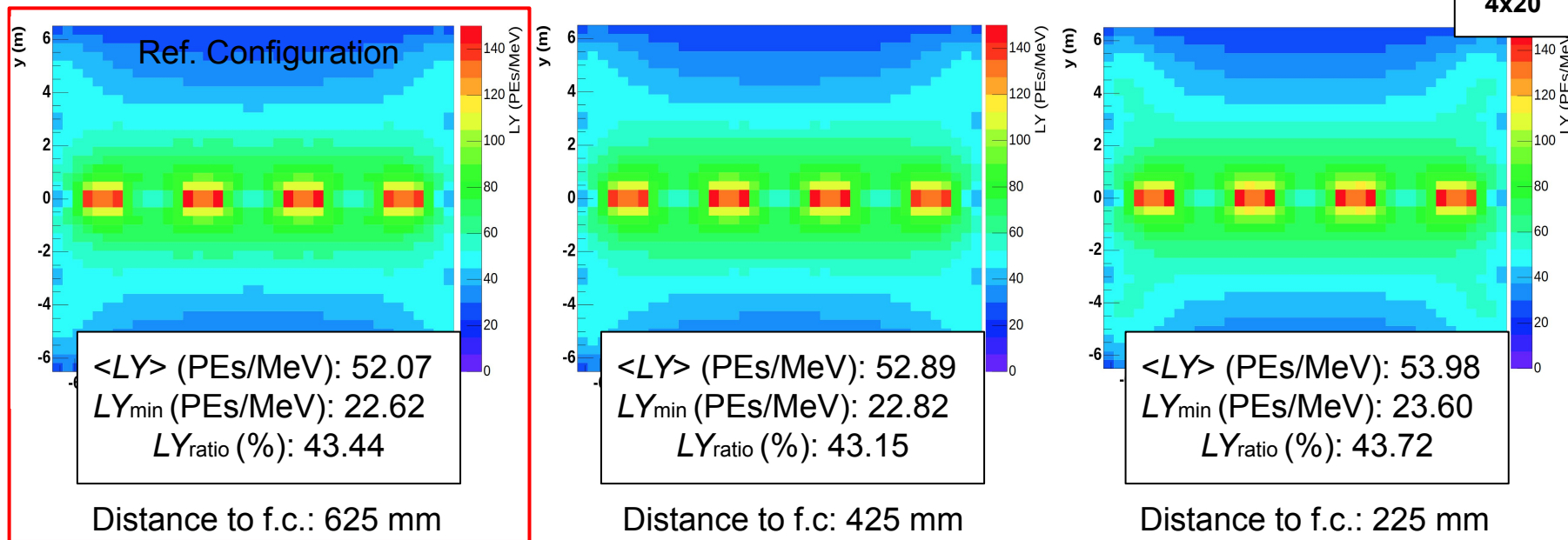
Reference Design Tuneup: vertical spacing



Best ratio for the original 4x20 (reference design from CDR) arrangement.

Reference Design Tuneup: distance to field cage optimization

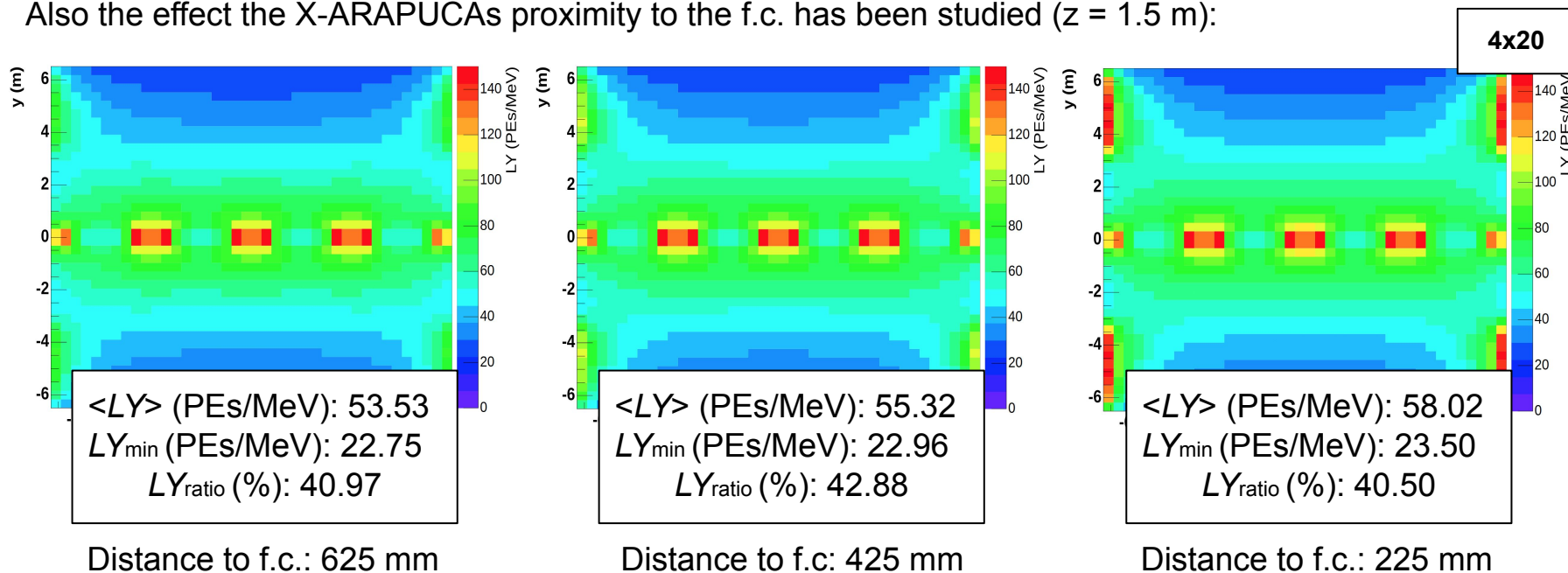
Also the effect the X-ARAPUCAs proximity to the f.c. has been studied ($z = 0$ m):



Here using fixed scale for comparison (0 - 150). For $z = 1.5$ m (z position of the X-ARAPUCAs).

Reference Design Tuneup: distance to field cage optimization

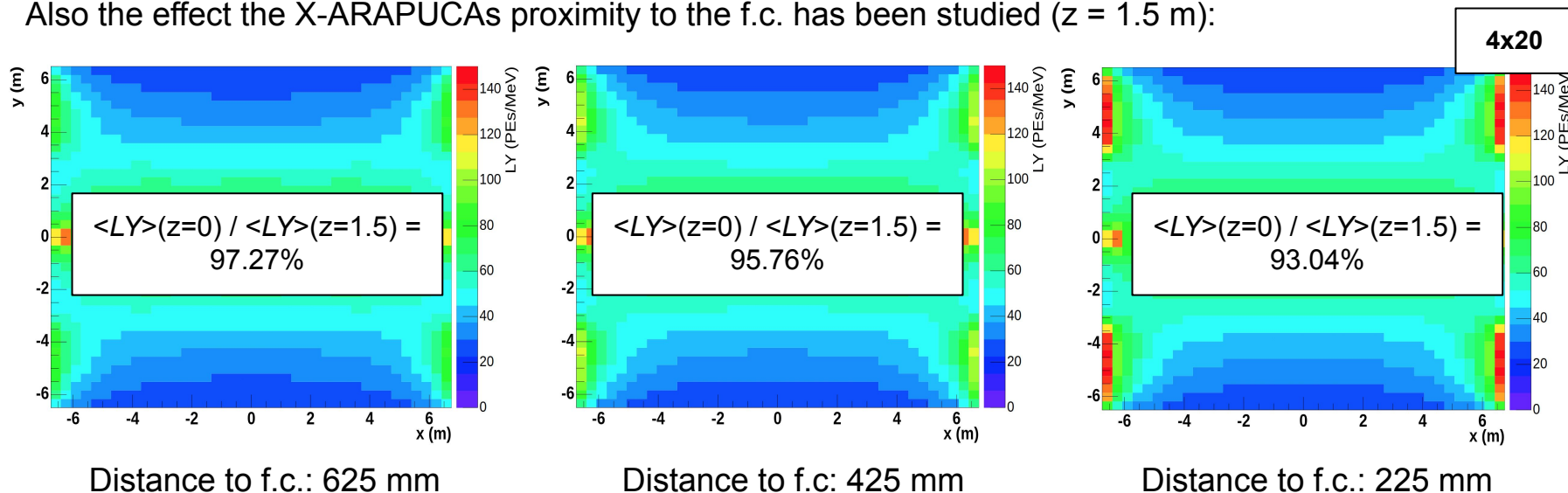
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Here using fixed scale for comparison (0 - 150). For $z = 1.5$ m (z position of the X-ARAPUCAs).

Reference Design Tuneup: distance to field cage optimization

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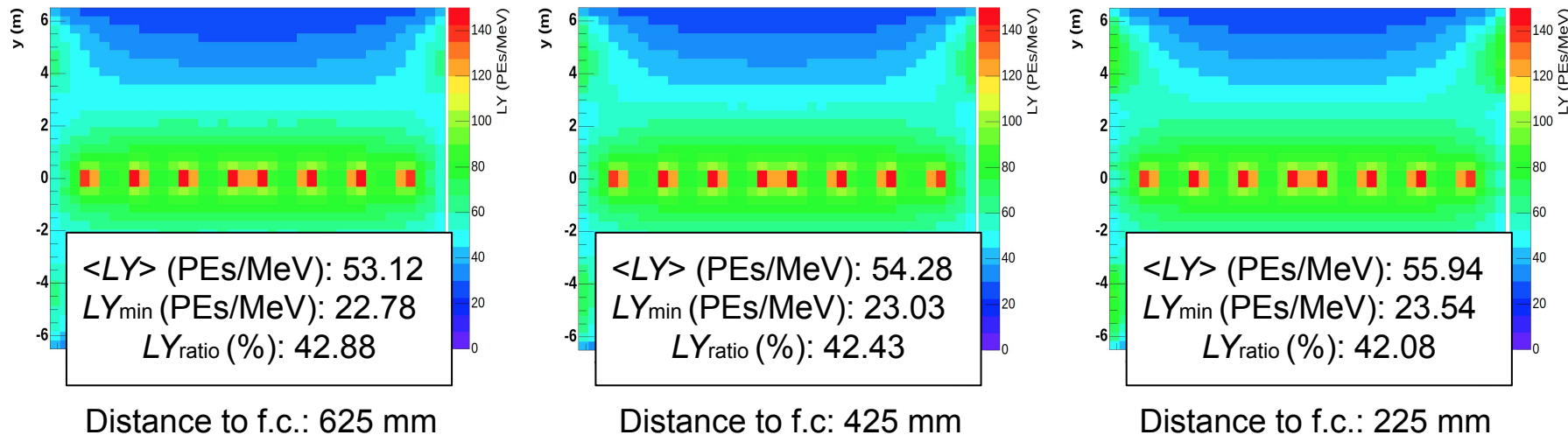
The inhomogeneity of the $\langle LY \rangle$ over the z direction increases from 1.46 PE (97.27%) to 4.04 PE (93.04%).

Here using fixed scale for comparison (0 - 150). For $z = 1.5$ m (z position of the X-ARAPUCAs).

Reference Design Tuneup: distance to field cage optimization

4x20

Also the effect the X-ARAPUCAs proximity to the f.c. has been studied (mean z):



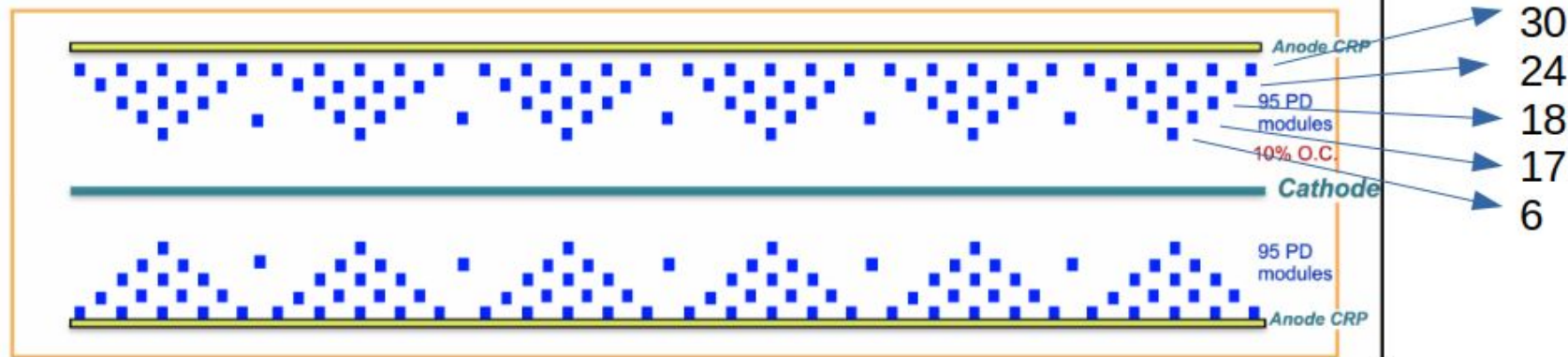
The increase in inhomogeneity only provides a 5.31% improvement in the $\langle LY \rangle$ (approaching the X-ARAPUCAs by 40 cm).

Here using fixed scale for comparison (0 - 150). Averaged over $z = 0 - 1.5$ m.

Other Alternative Arrangements

Motivation for alternative layouts

Study performed by
L. Paulucci & F. Marinho



4x20 arrangement

$\langle LY \rangle$ (PEs/MeV): 43.9

$LY_{\min}$ (PEs/MeV): 21.9

LY_{ratio} (%): 49.89

80 PDs per quadrant

Pyramidal arrangement

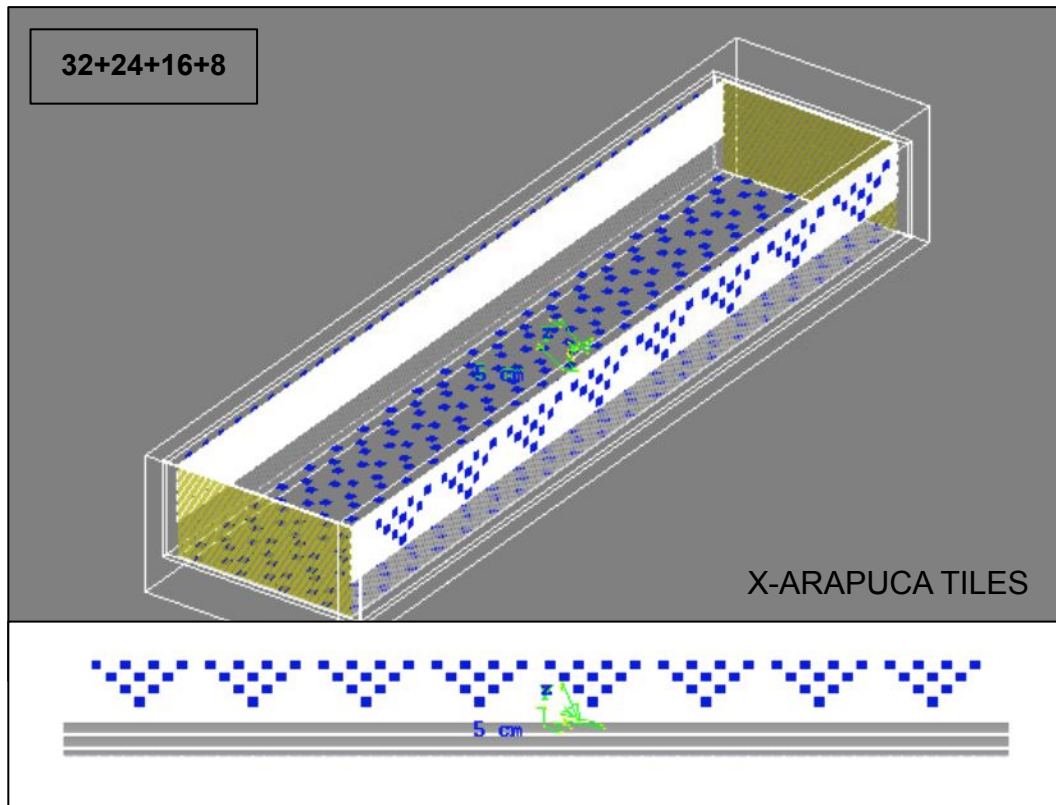
$\langle LY \rangle$ (PEs/MeV): 44.9

$LY_{\min}$ (PEs/MeV): 22.7

LY_{ratio} (%): 50.56

95 PDs per quadrant

Pyramidal Designs



Layout Parameters:

- 8 identical 4+3+2+1 pyramidal arrangements of X-ARAPUCA tiles.
- H. spacing 1.8 m between tiles (inside the arrangement).
- V. spacing 0.8 m between tiles.

Simulation Output:

(For mean $z = 0 - 3.5$ m)

- $\langle LY \rangle$ (PEs/MeV): 52.81
- $LY_{\min}$ (PEs/MeV): 22.74
- LY_{ratio} (%): 43.06

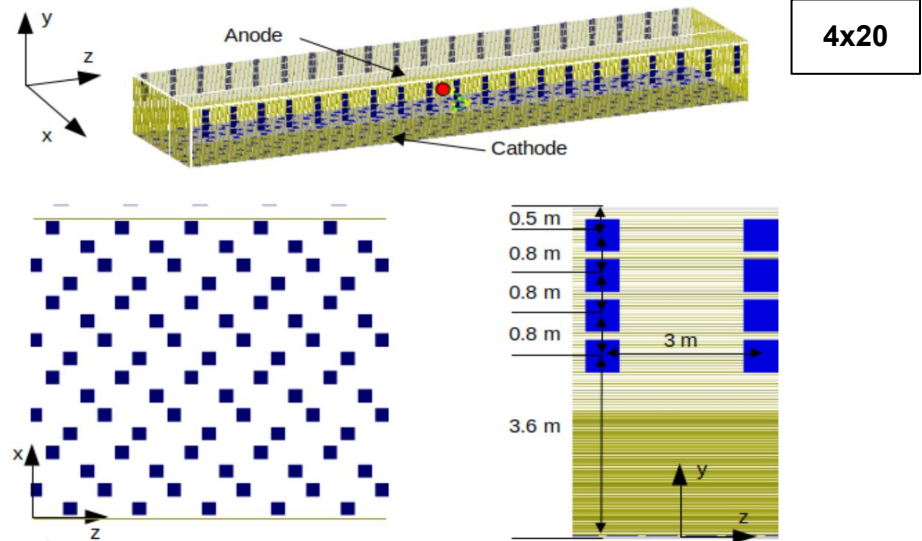
4x20 For comparison ($z = 0 - 3$ m):

- $\langle LY \rangle$ (PEs/MeV): 53.12
- $LY_{\min}$ (PEs/MeV): 22.78
- LY_{ratio} (%): 42.88

Conclusions

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- Higher Light Yield values and best Light Yield ratio ($LY_{\min}/\langle LY \rangle$) for the original 4x20 arrangement of membrane X-ARAPUCAs, for fixed number of modules (80 per quadrant).
- No significant improvements:
 - Varying vertical spacing.
 - Varying distance to field cage.
 - With pyramidal layout explored so far.

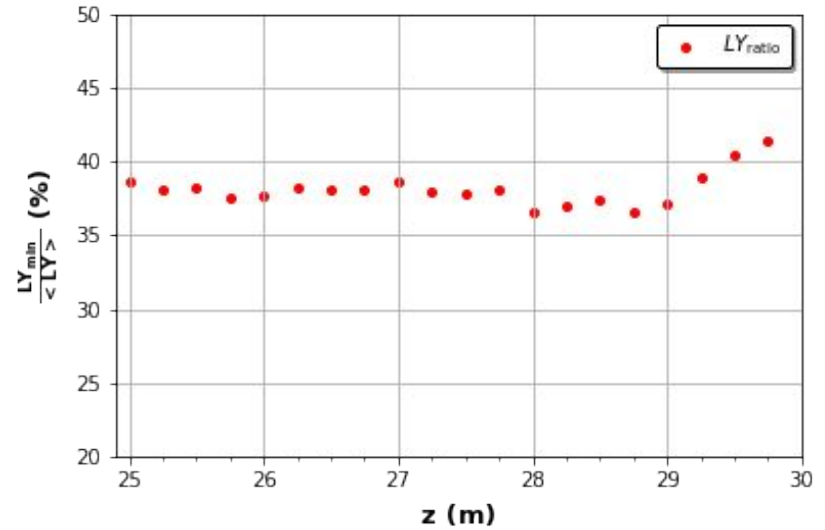
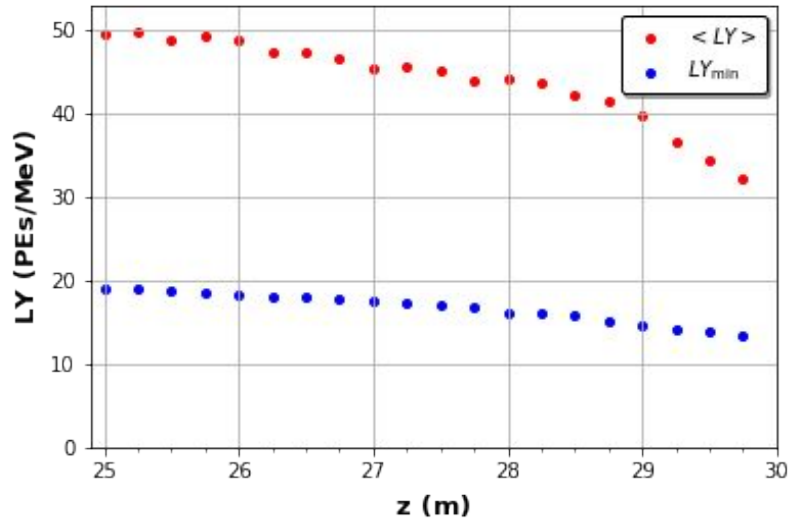


Next Steps

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- Explore a pyramidal design (32+24+16+8) with doubled vertical spacing (1.6 m) between the X-ARAPUCA tiles.
- Investigate border effects ($z = 25 - 30$ m).
- Further investigate the effects of the different field cage profile width (23 mm and 7.5 mm).
- Run simulations of selected designs with a thinner grid to better estimate the analysis errors.
- Your suggestions!

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Next steps

Ar

FC profile	Thick	Thin
Membrane fraction	0.86 %	1.02 %
Cathode fraction (with 90 % transmission)	4.97 (4.47) %	4.86 (4.37) %

Xe

FC profile	Thick	Thin
Membrane fraction	1.89 %	2.18 %
Cathode fraction (with 90 % transmission)	7.51 (6.76) %	7.15 (6.44) %

47% Ar 53% Xe

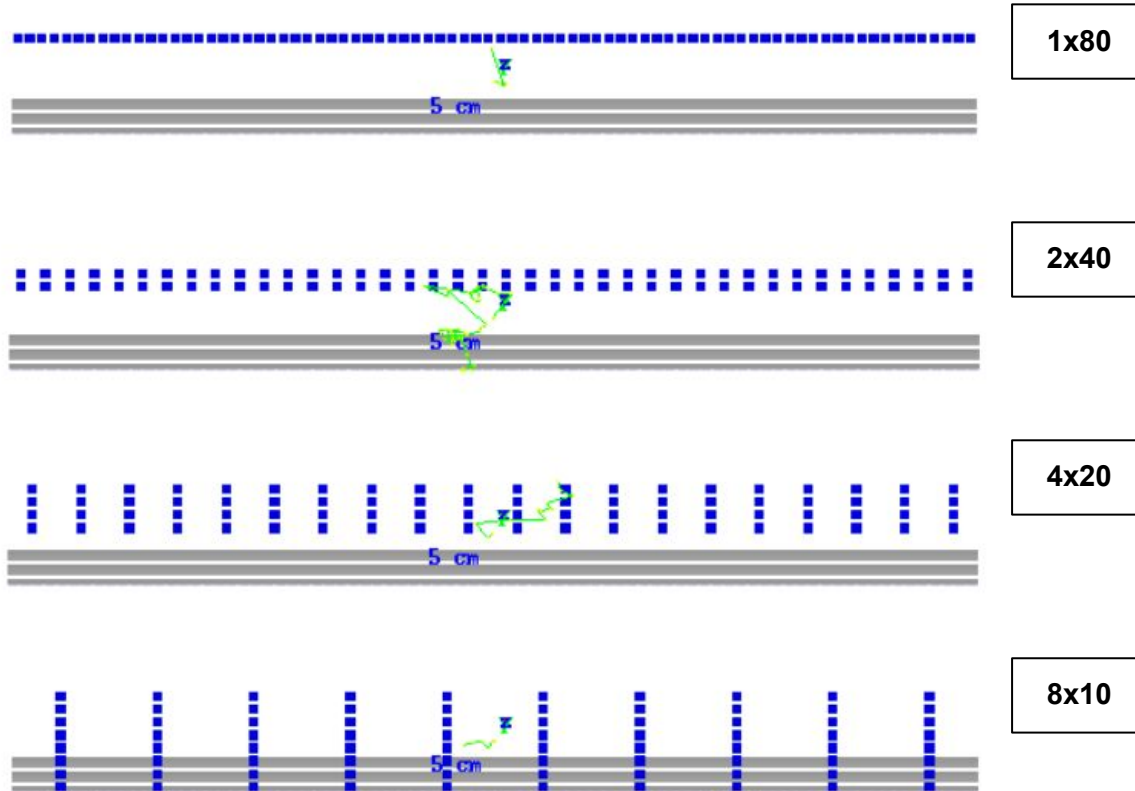
FC profile	Thick	Thin
Membrane fraction	1.41 %	1.63 %
Cathode fraction (with 90 % transmission)	6.32 (5.68) %	6.07 (5.47) %

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Backup

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8x10

