# Uniformity Improvements

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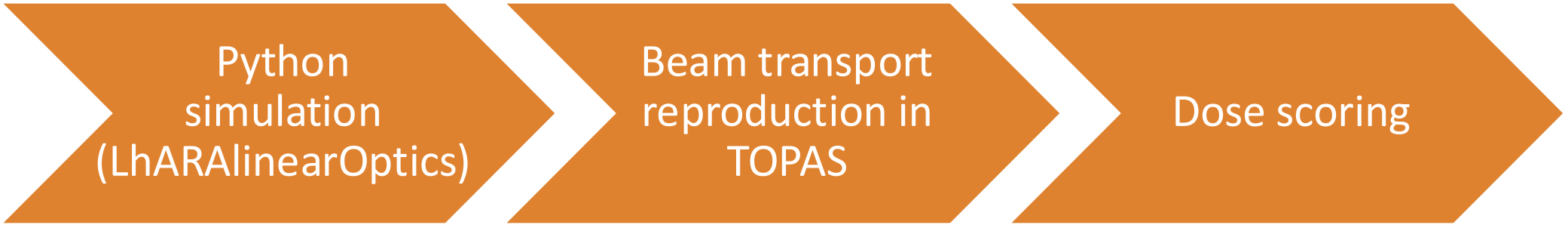
# Simulation environment

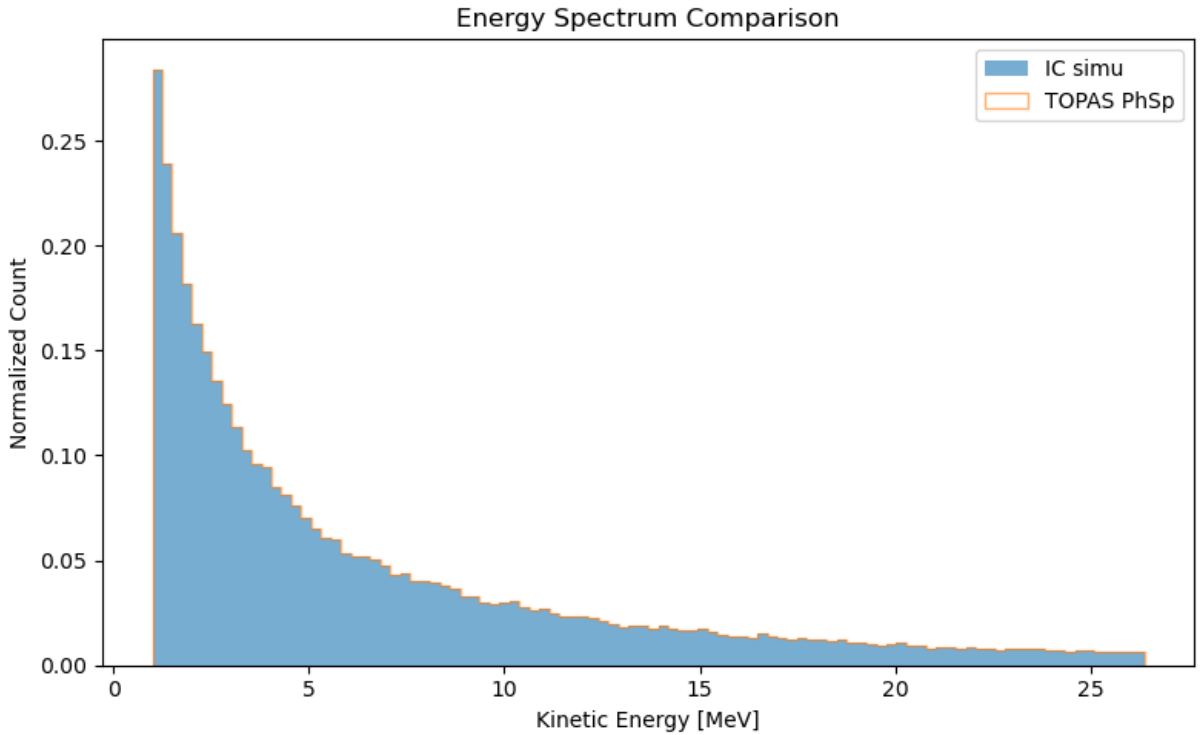
- B Faddegon, J Ramos-Méndez, J Schümann, A McNamara, J Shin, J Perl, H Paganetti. "The TOPAS Tool for Particle Simulation, a Monte Carlo Simulation Tool for Physics, Biology and Clinical Research." Phys Med. 2020 Apr 02; 72:114-121. PMID: 32247964. PMCID: PMC7192305
- Perl, J Shin, J Schümann, B Faddegon, H Paganetti. "TOPAS: an innovative proton Monte Carlo platform for research and clinical applications." Med Phys. 2012 Nov; 39(11):6818-37.

# Simulation environment



# Simulation environment

Source: Simulated by LhARAlinearOptics and translated to TOPAS

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TOPAS ASCII Phase Space

Number of Original Histories: 2000000
Number of Original Histories that Reached Phase Space: 11750
Number of Scored Particles: 13047

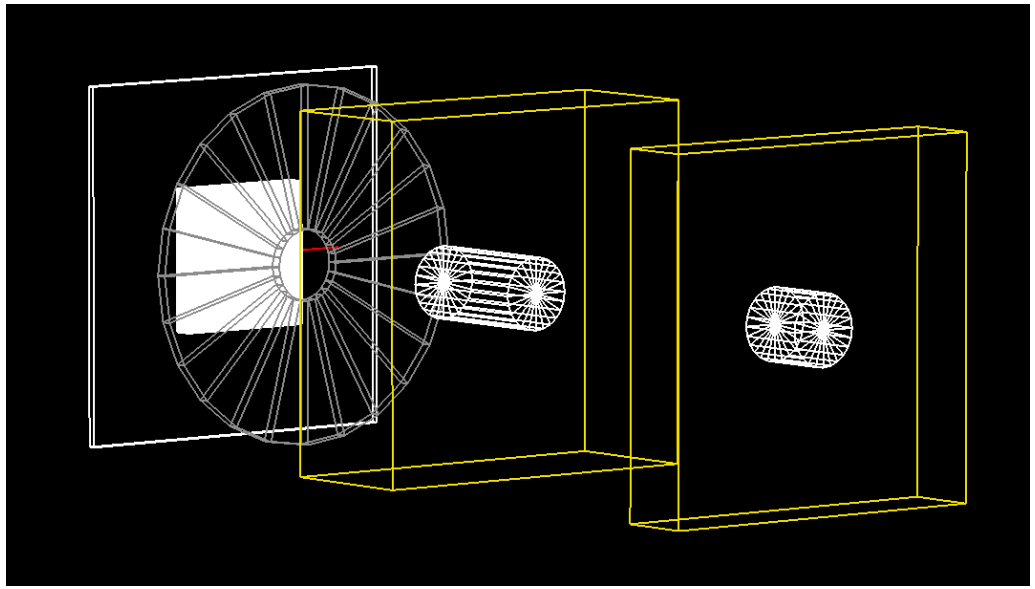
Columns of data are as follows:
 1: Position X [cm]
 2: Position Y [cm]
 3: Position Z [cm]
 4: Direction Cosine X
 5: Direction Cosine Y
 6: Energy [MeV]
 7: Weight
 8: Particle Type (in PDG Format)
 9: Flag to tell if Third Direction Cosine is Negative (1 means true)
10: Flag to tell if this is the First Scored Particle from this History (1 means true)

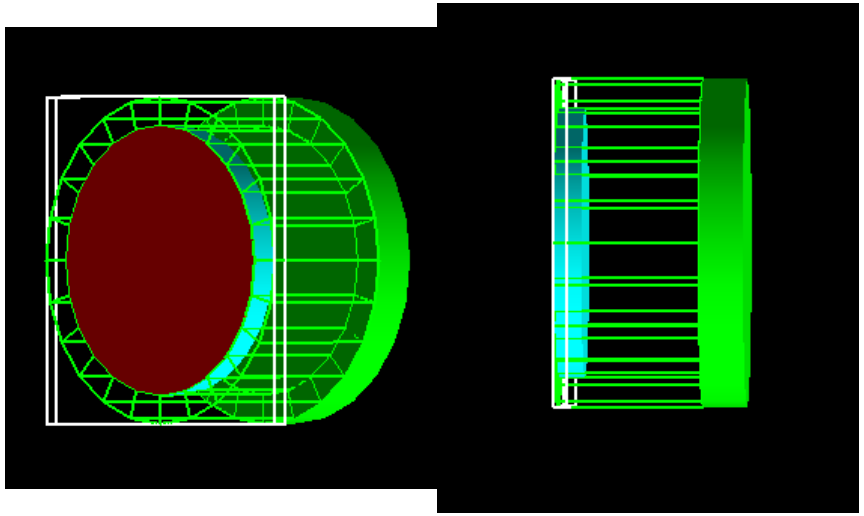
Number of e-: 1301
Number of nu_e: 3
Number of gamma: 7
Number of proton: 11736

Minimum Kinetic Energy of e-: 0 MeV
Minimum Kinetic Energy of nu_e: 0.849123 MeV
Minimum Kinetic Energy of gamma: 0.510999 MeV
Minimum Kinetic Energy of proton: 3.63798 MeV

Maximum Kinetic Energy of e-: 0.0206843 MeV
Maximum Kinetic Energy of nu_e: 1.46728 MeV
Maximum Kinetic Energy of gamma: 7.23584 MeV
Maximum Kinetic Energy of proton: 10.8455 MeV
```

# Simulation setup





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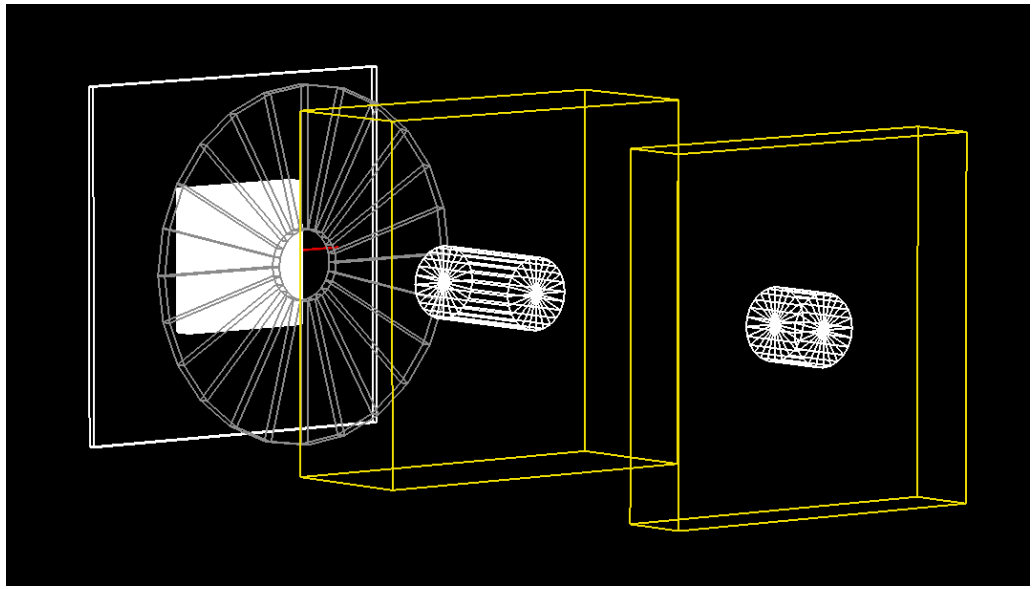
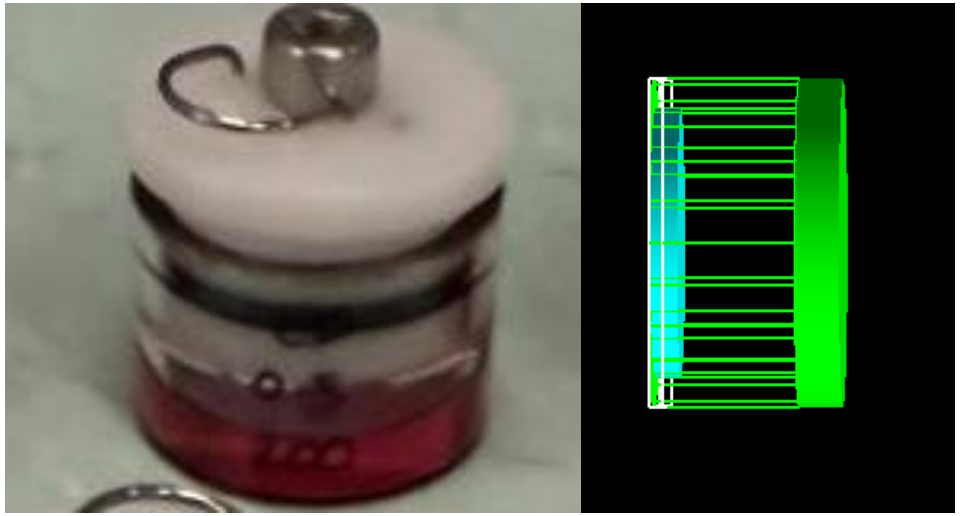
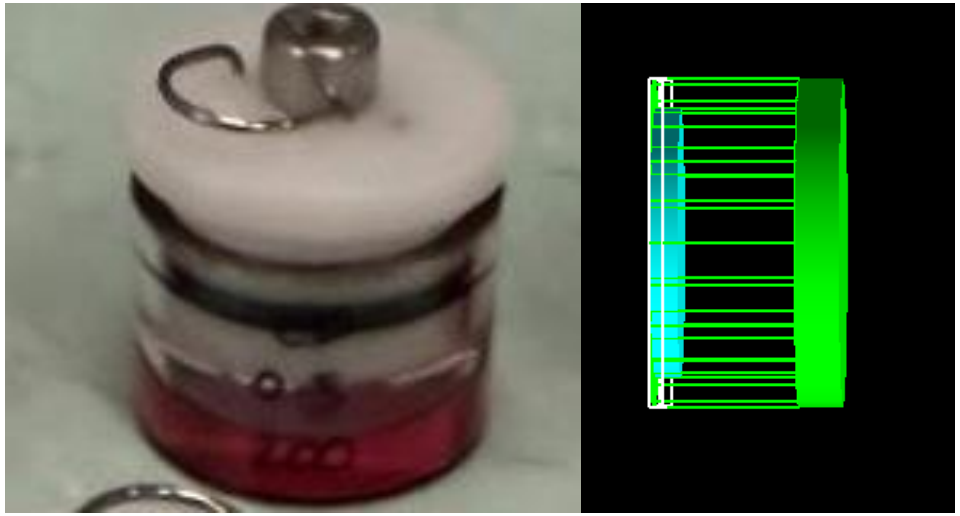


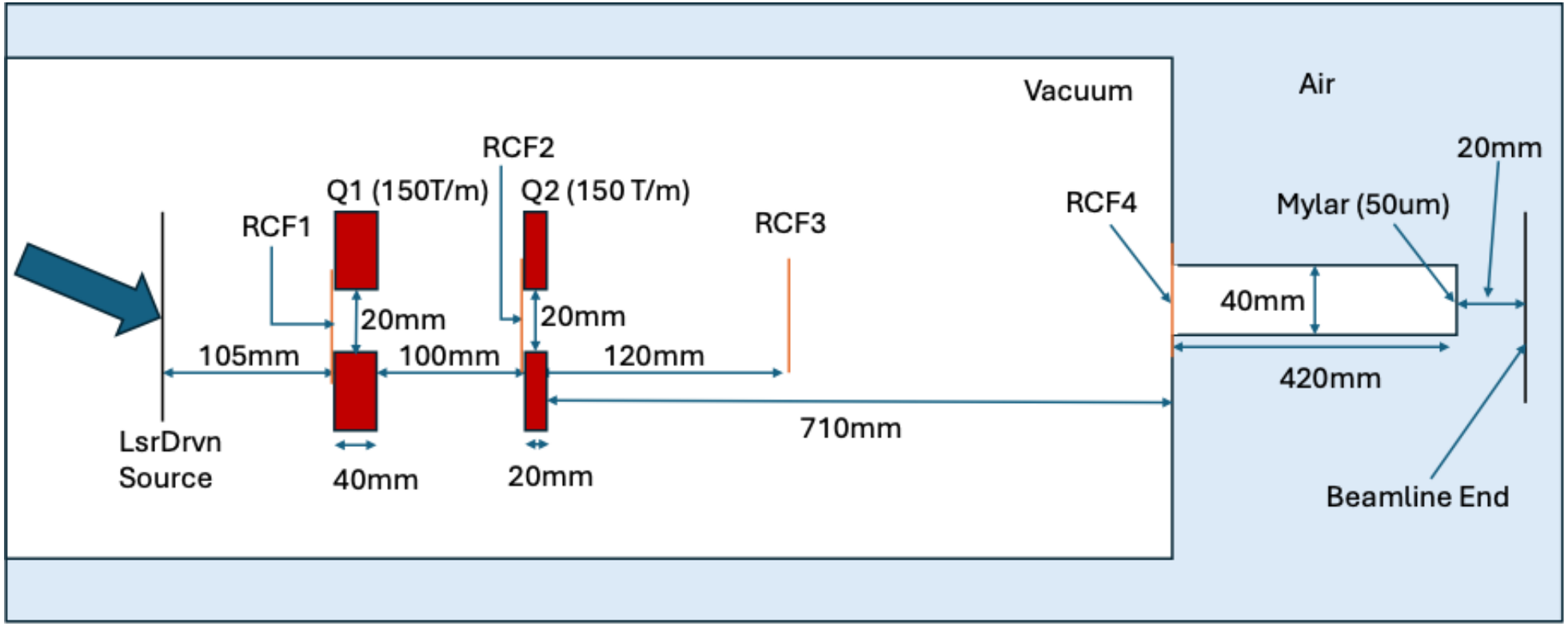


# Simulation setup

- 1.86 mm water height (depth)
- 18.5mm internal diameter
- 22.5mm external diameter
- Scoring through the whole water depth
- 100 million particles



# Results from actual setup



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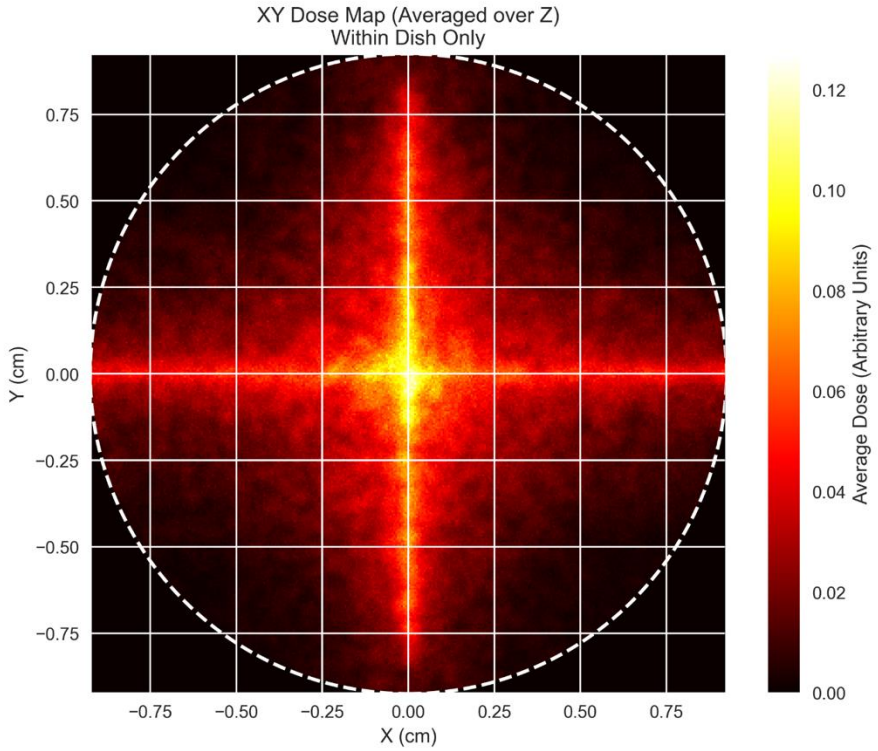
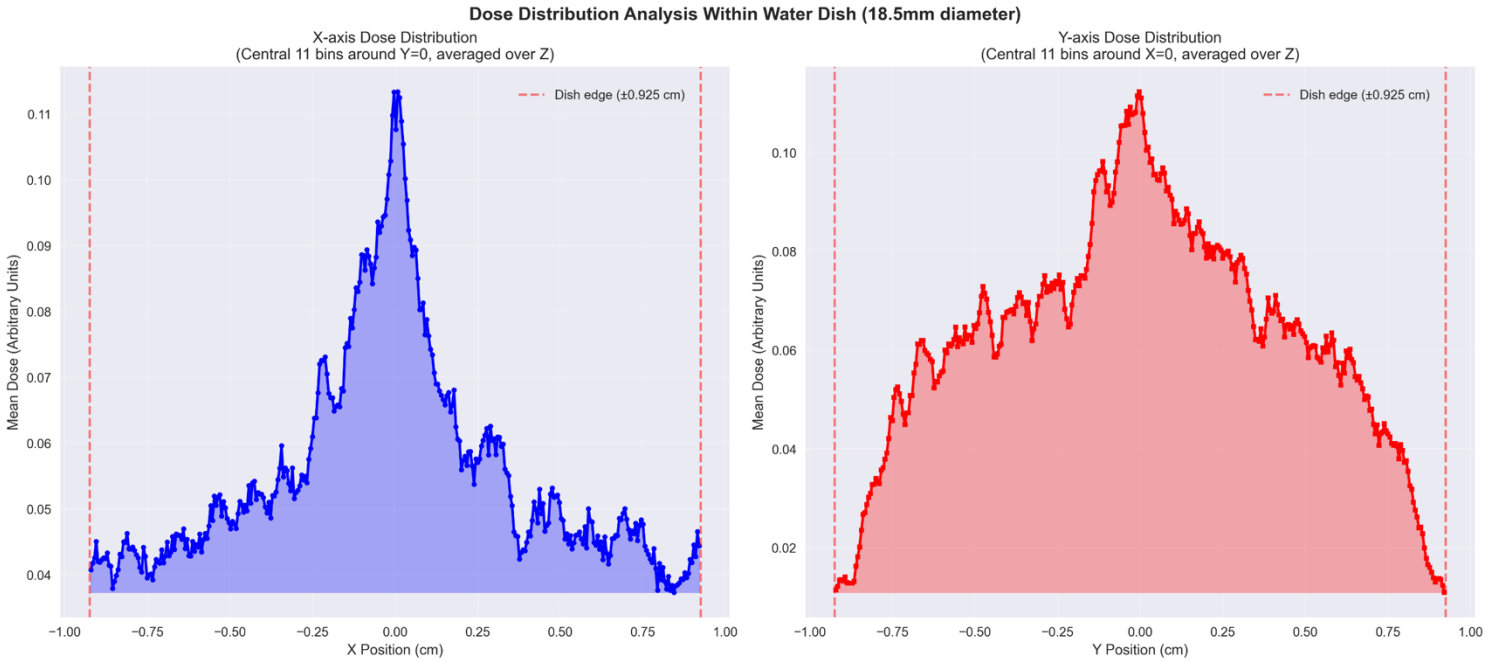
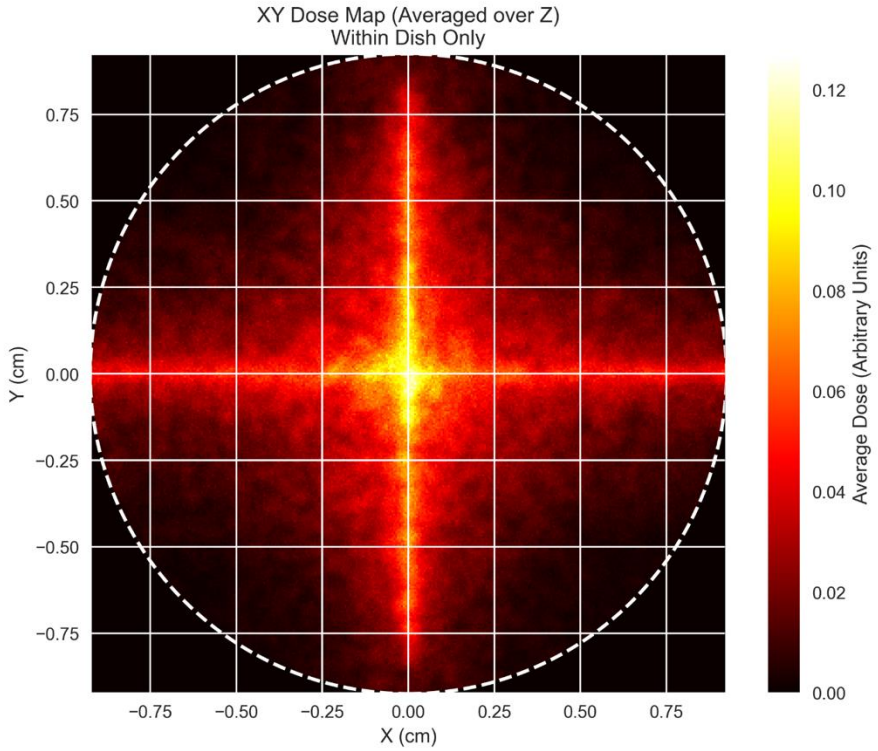
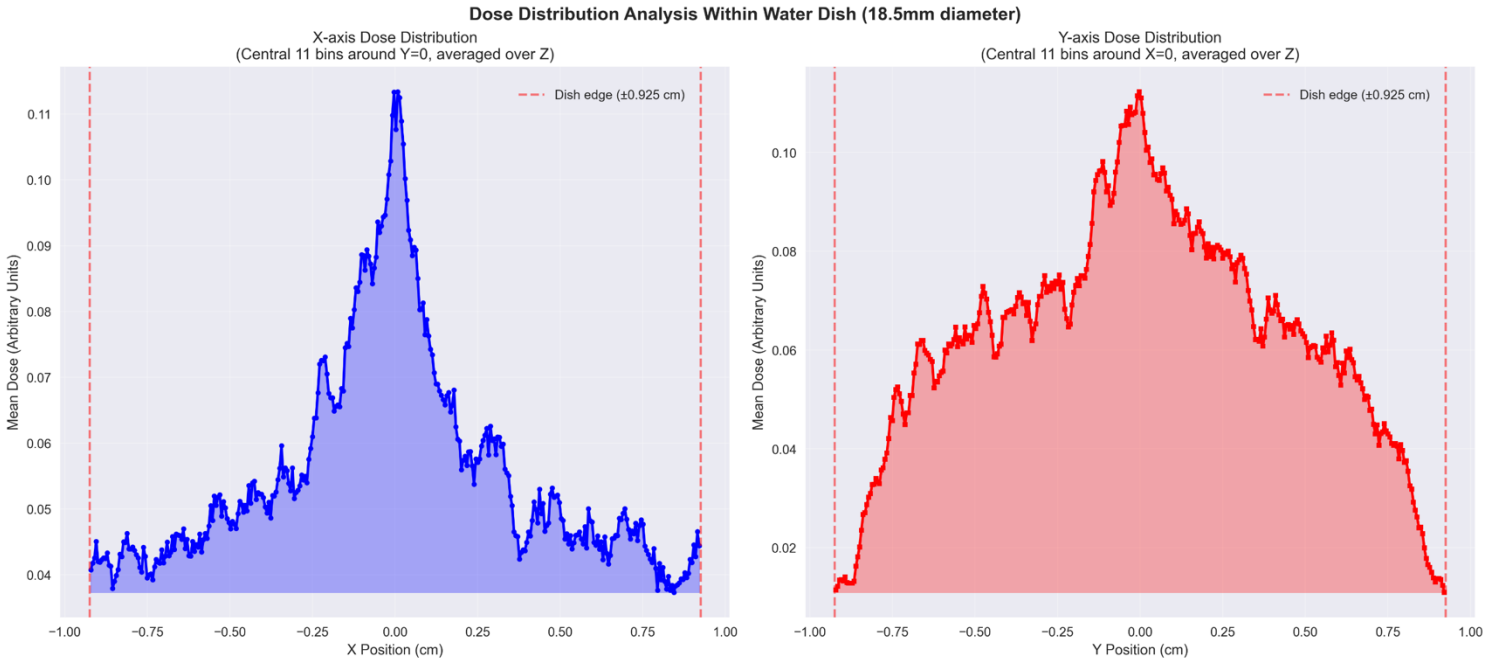



- Integration width of 620um (11 voxels) in the transversal directions
-Dose distributions integrated in the Z direction
- Units: Gy/primary particle. Not representative of actual doses that will be delivered.

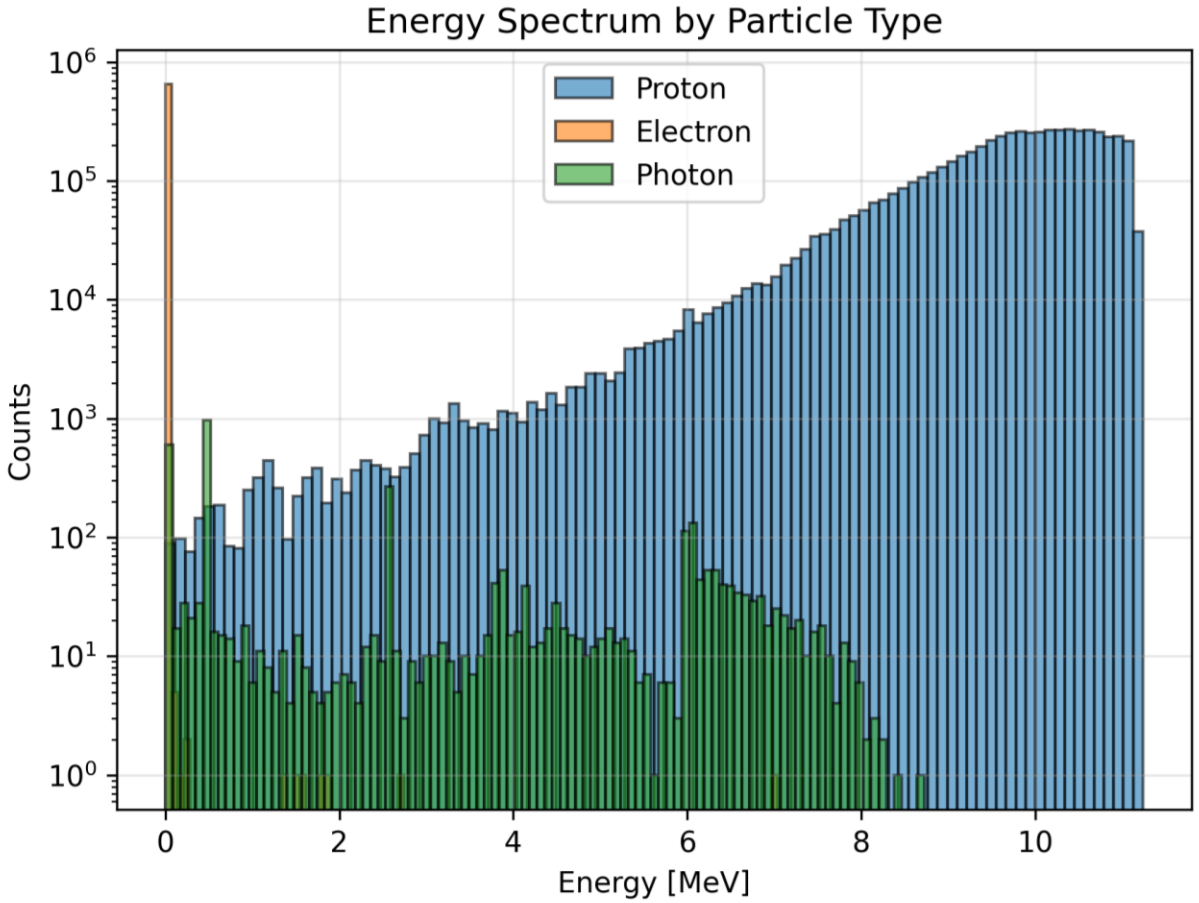
# Results from actual setup



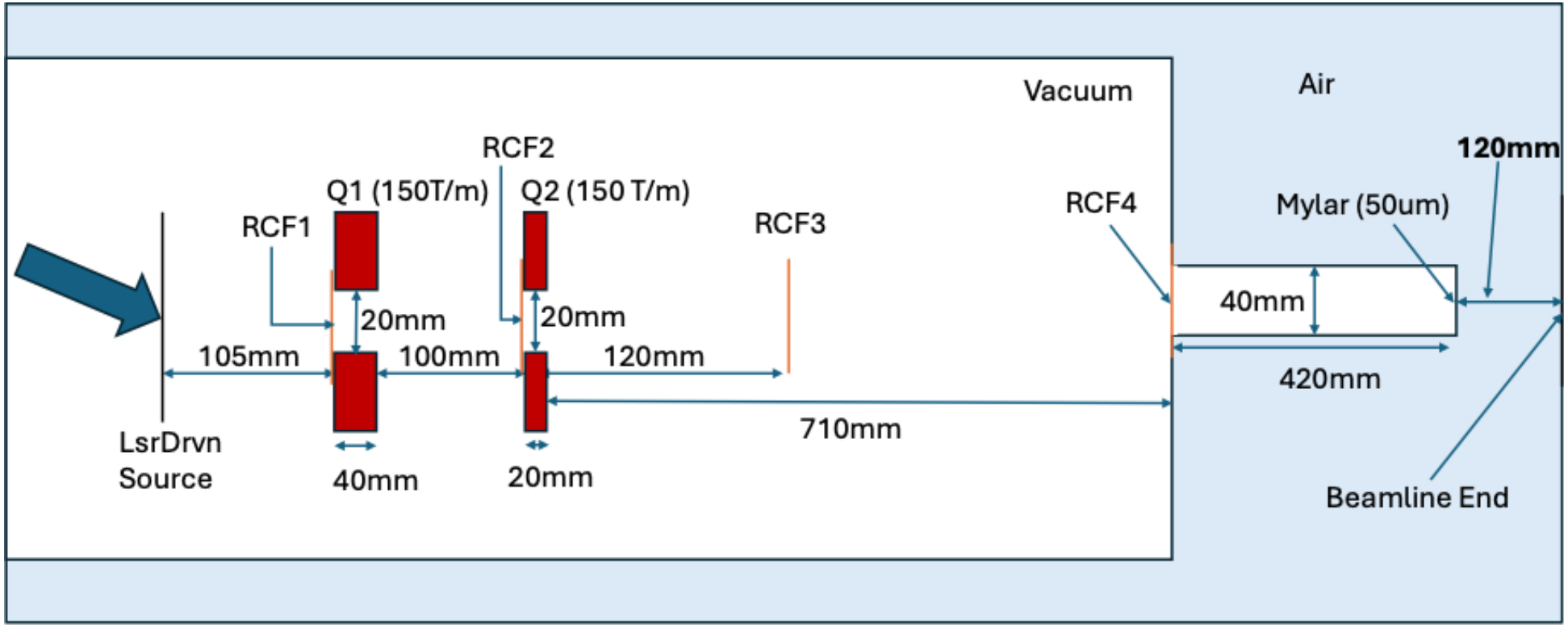

- Mean dose in dish: 0.021 Gy
- Max dose in dish: 0.217 Gy
- Min dose in dish: 0.00 Gy
- Standard deviation in dish: 0.019 Gy
- Uniformity (Coefficient of Variation [CV]) in dish: 90.79%

# Results from actual setup




Proton: Mean = 9.663 MeV
Std = 1.138 MeV

# Setup 2: Max dish distance (12.2 cm)



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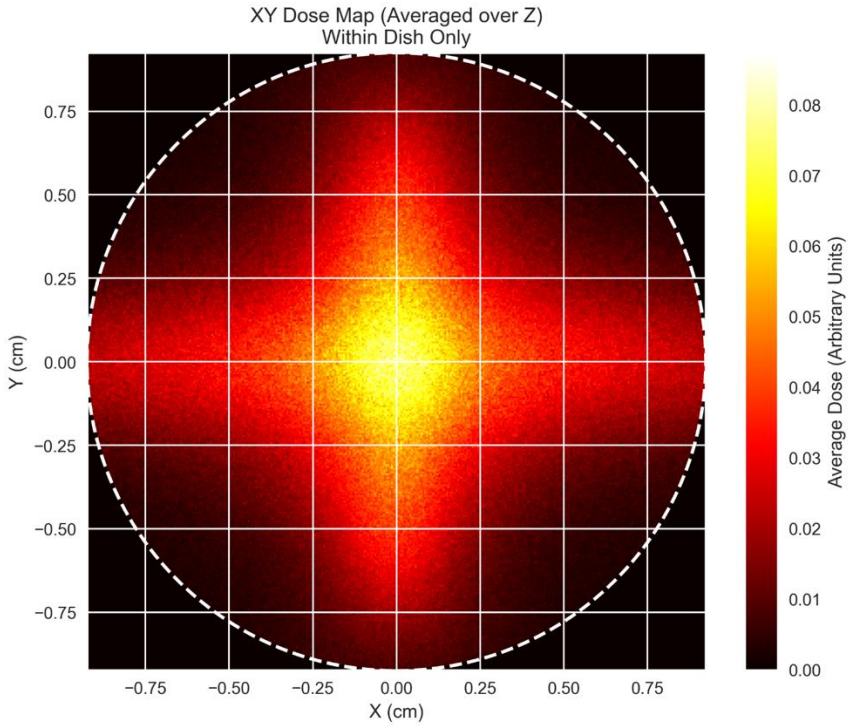
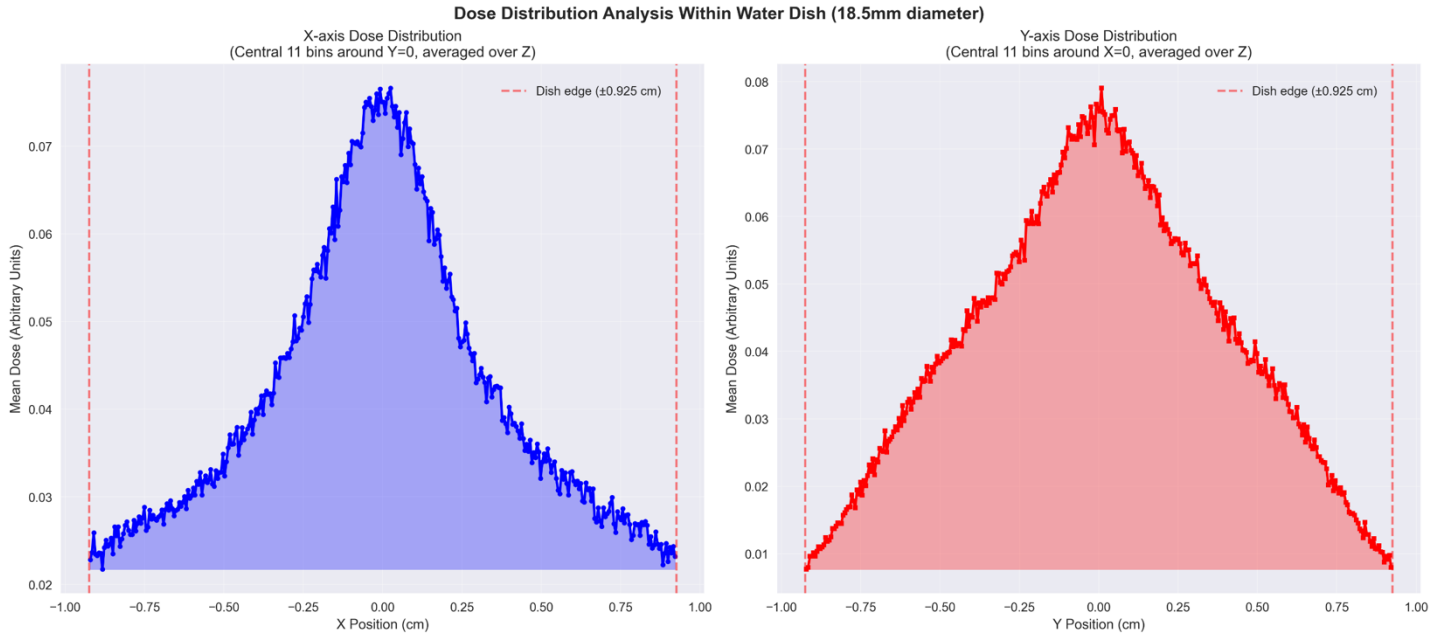
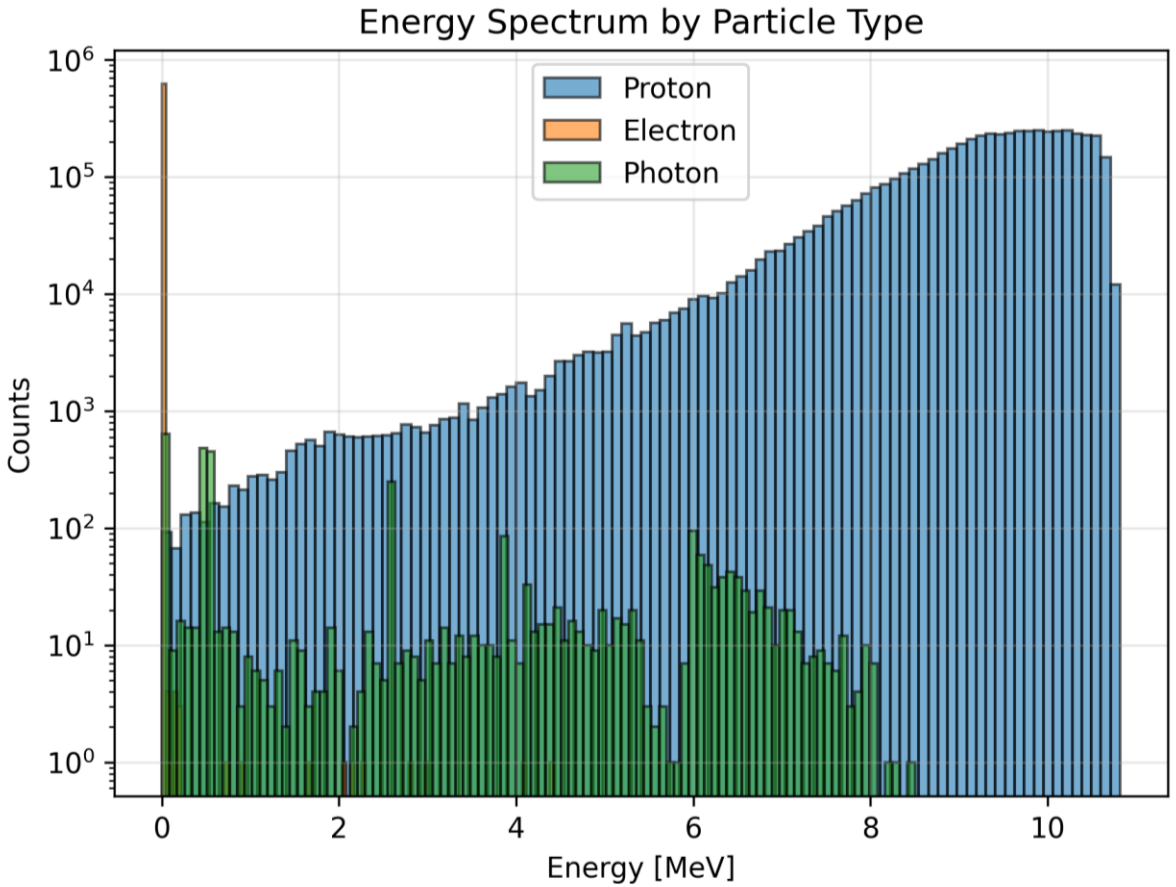


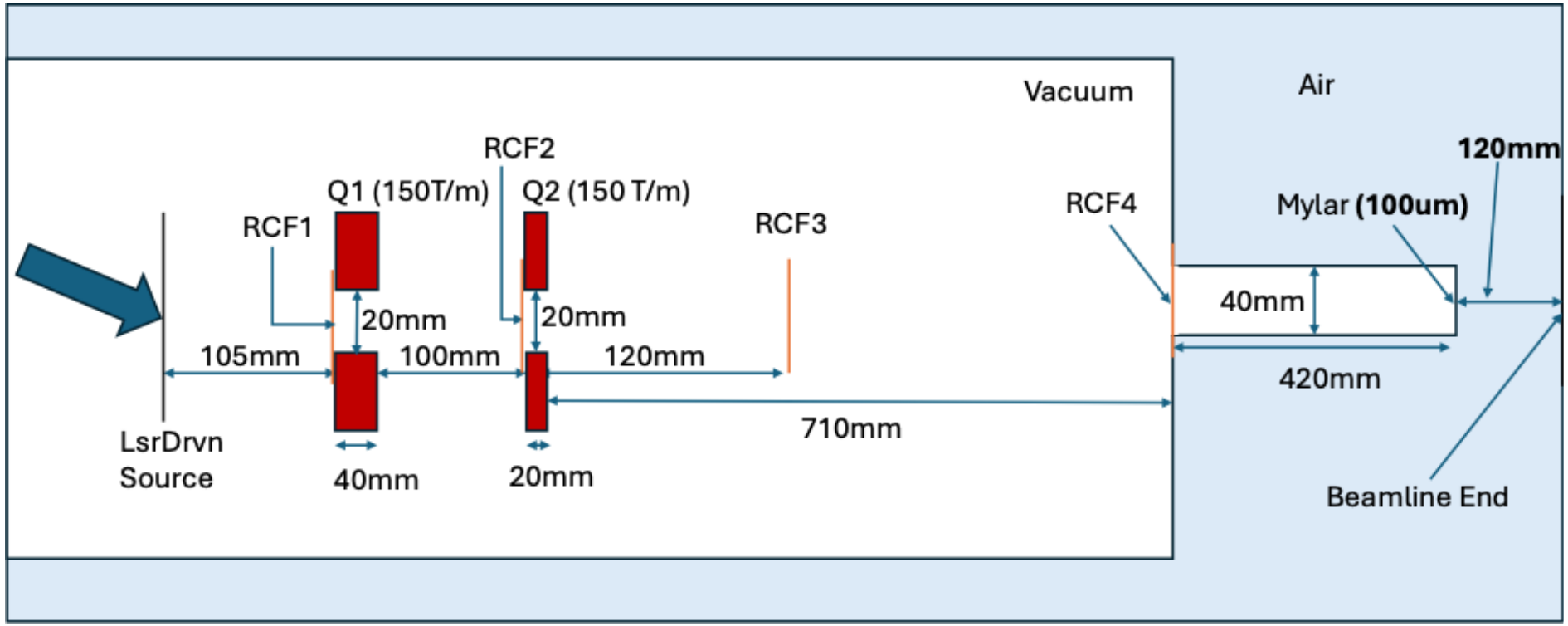

- Mean dose in dish: 0.022 Gy
- Max dose in dish: 0.145 Gy
- Min dose in dish: 0.000 Gy
- Standard deviation in dish: 0.018 Gy
- Uniformity (CV) in dish: 81.13%

# Setup 2: Max dish distance (12.2 cm)




Proton: Mean = 9.236 MeV
Std = 1.139 MeV

# Setup 3: Max dish distance + Thicker Exit Mylar (100 um)



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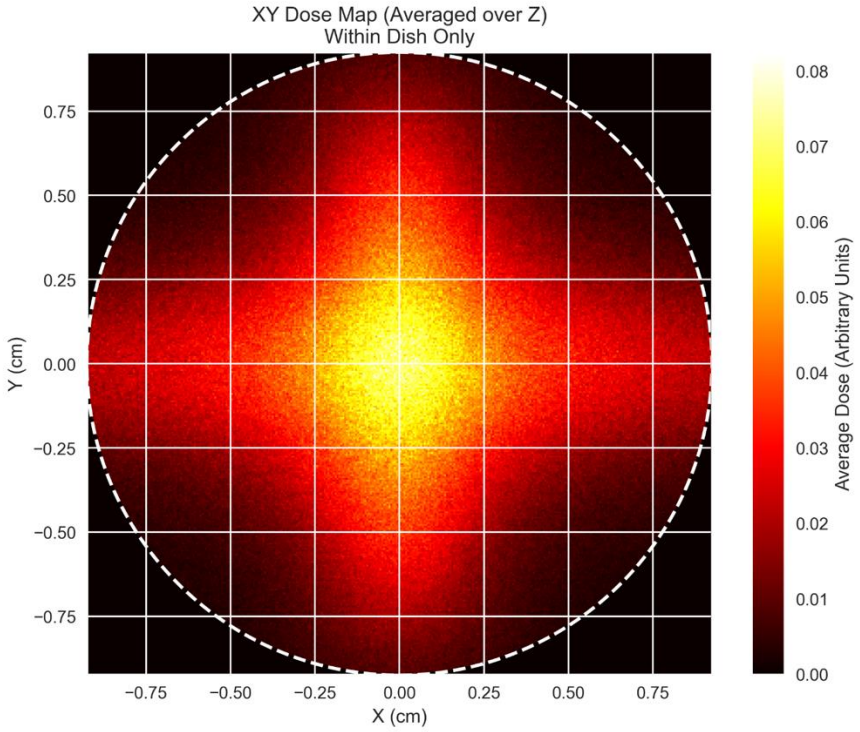
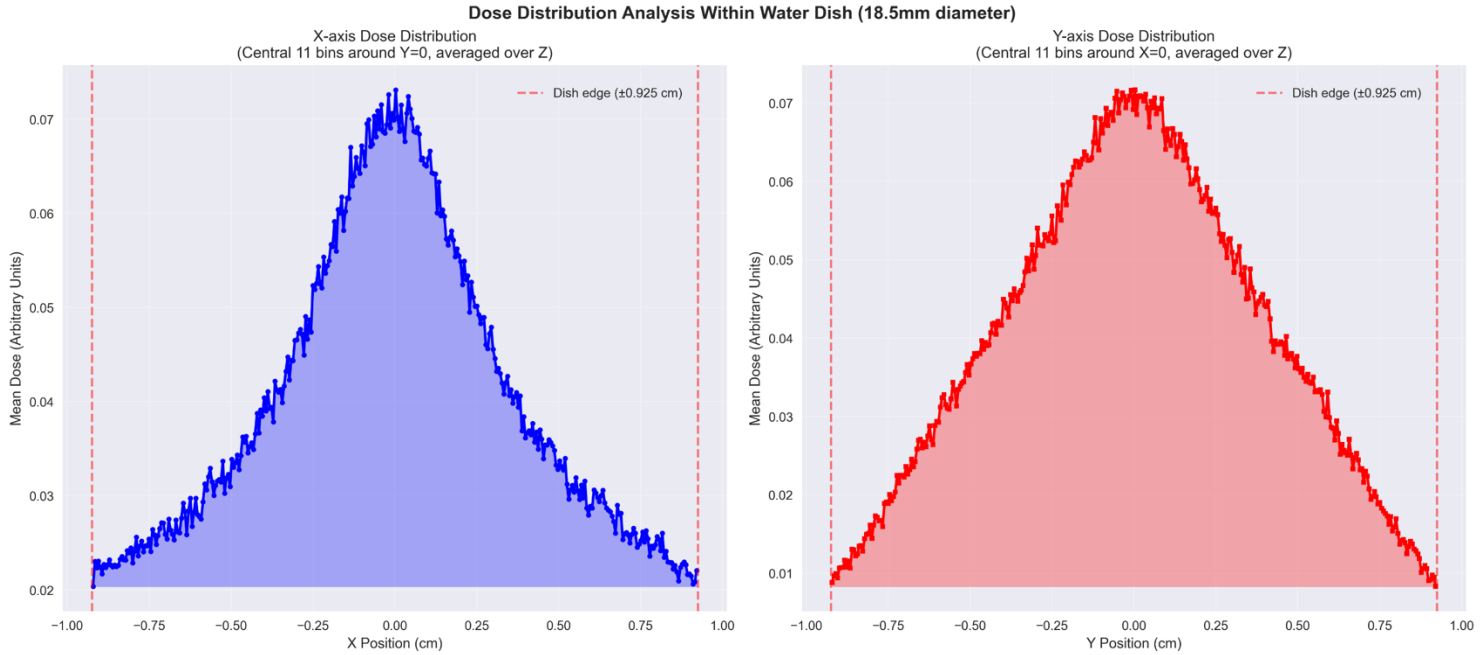
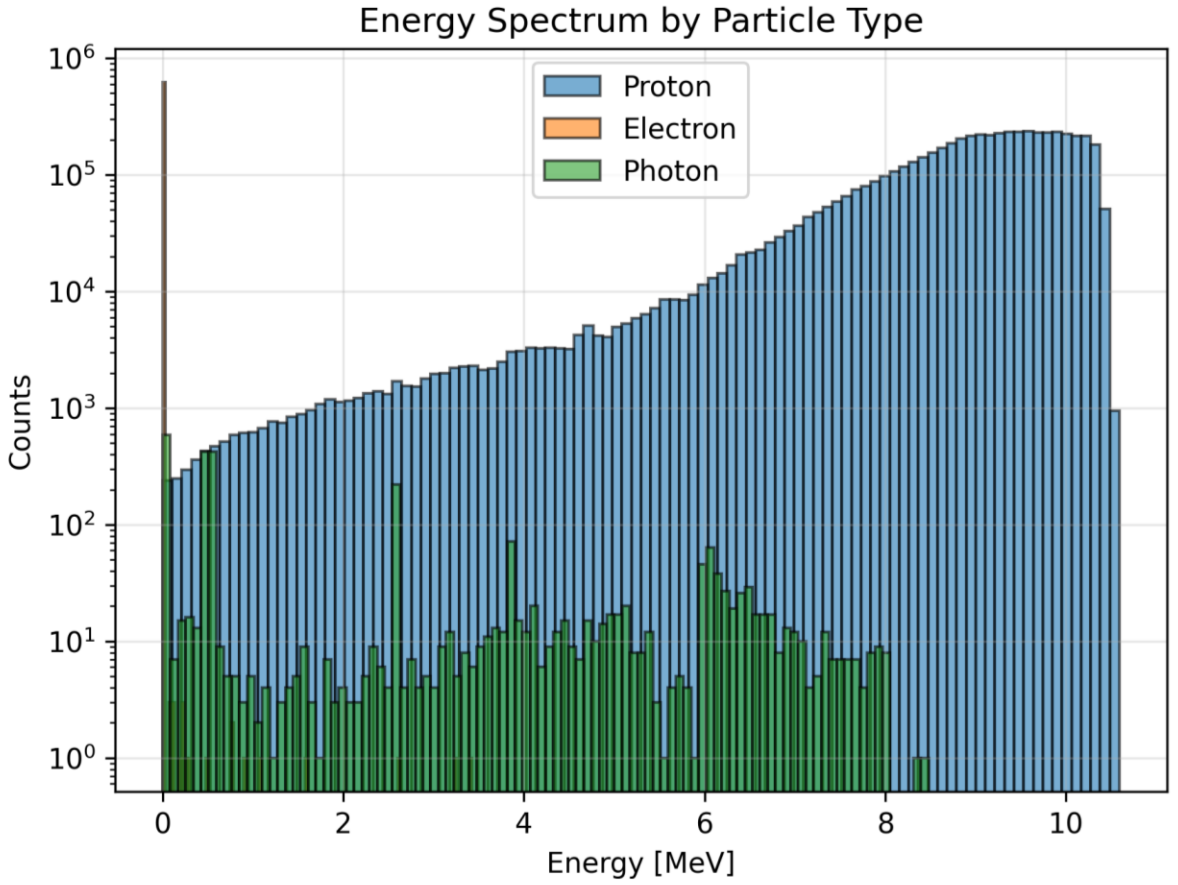


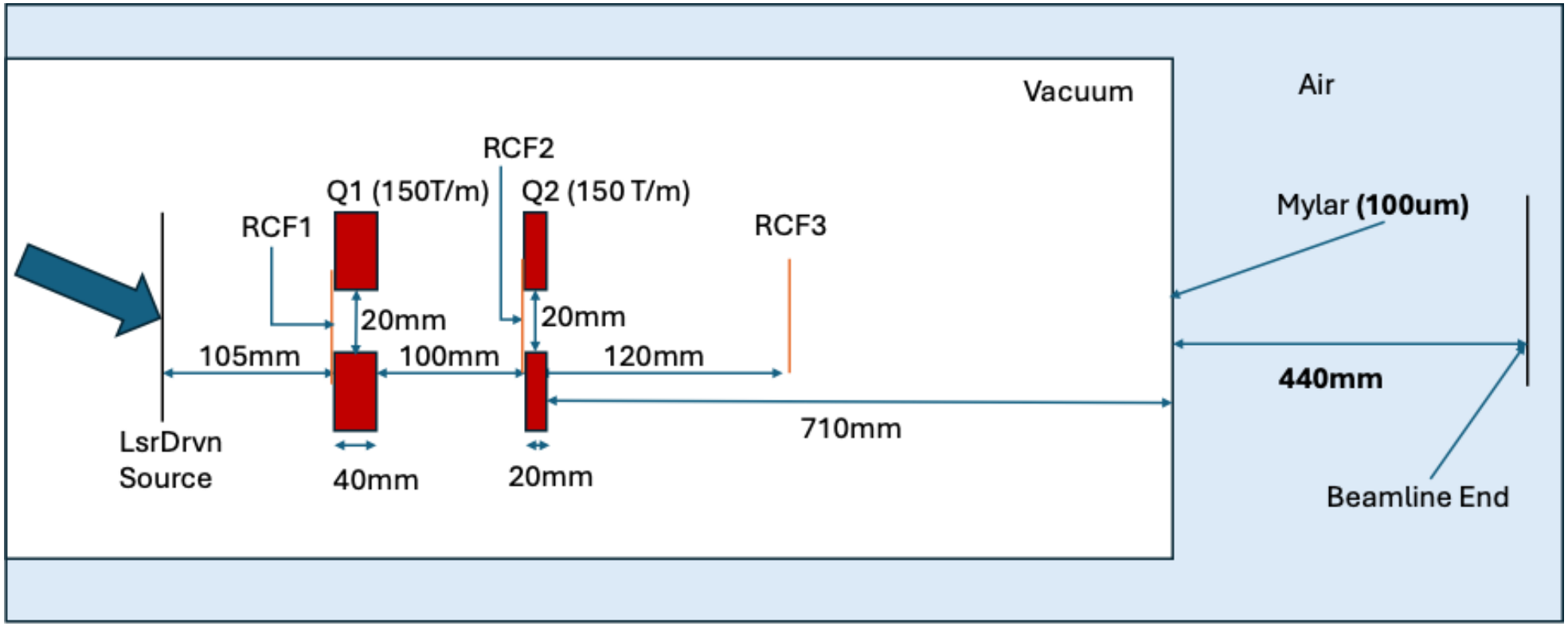

- Mean dose in dish: 0.022 Gy
- Max dose in dish: 0.132 Gy
- Min dose in dish: 0.000002 Gy
- Standard deviation in dish: 0.017 Gy
- Uniformity (CV) in dish: 76.85%

# Setup 3: Max dish distance + Thicker Exit Mylar (100 um)

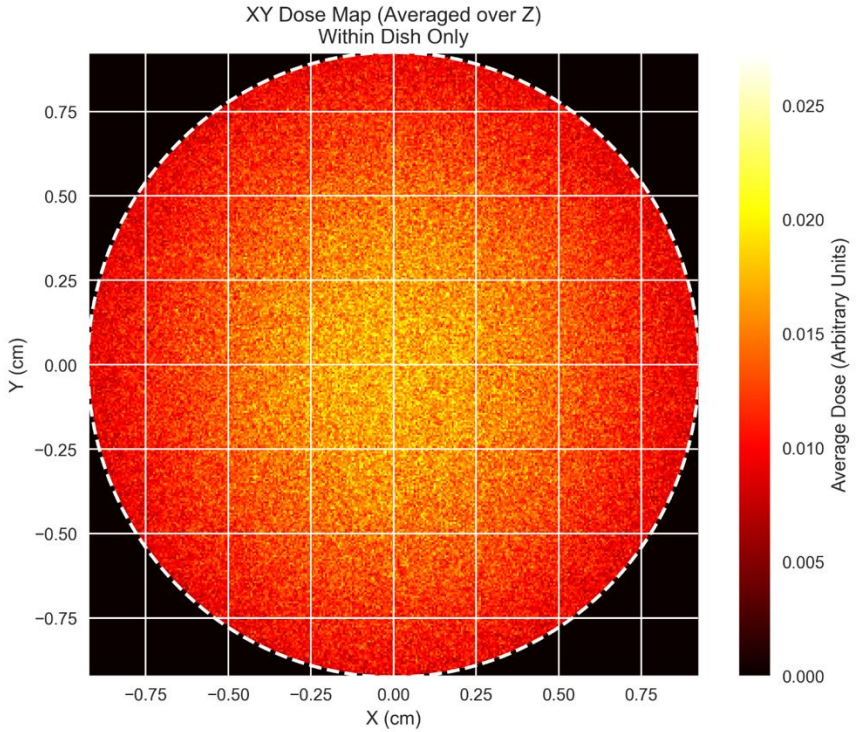


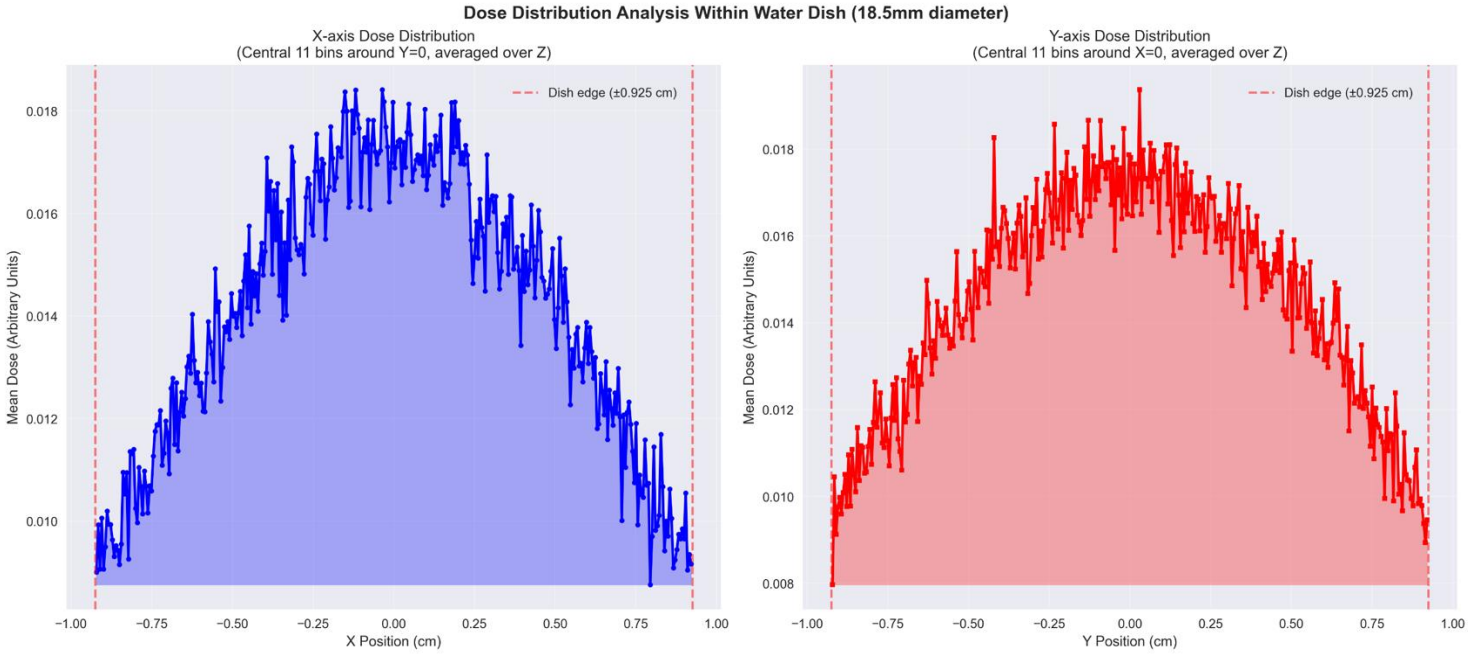

Proton: Mean = 8.881 MeV
Std = 1.234 MeV

# Setup 4: Max dish distance + Thicker exit mylar + No vacuum tube



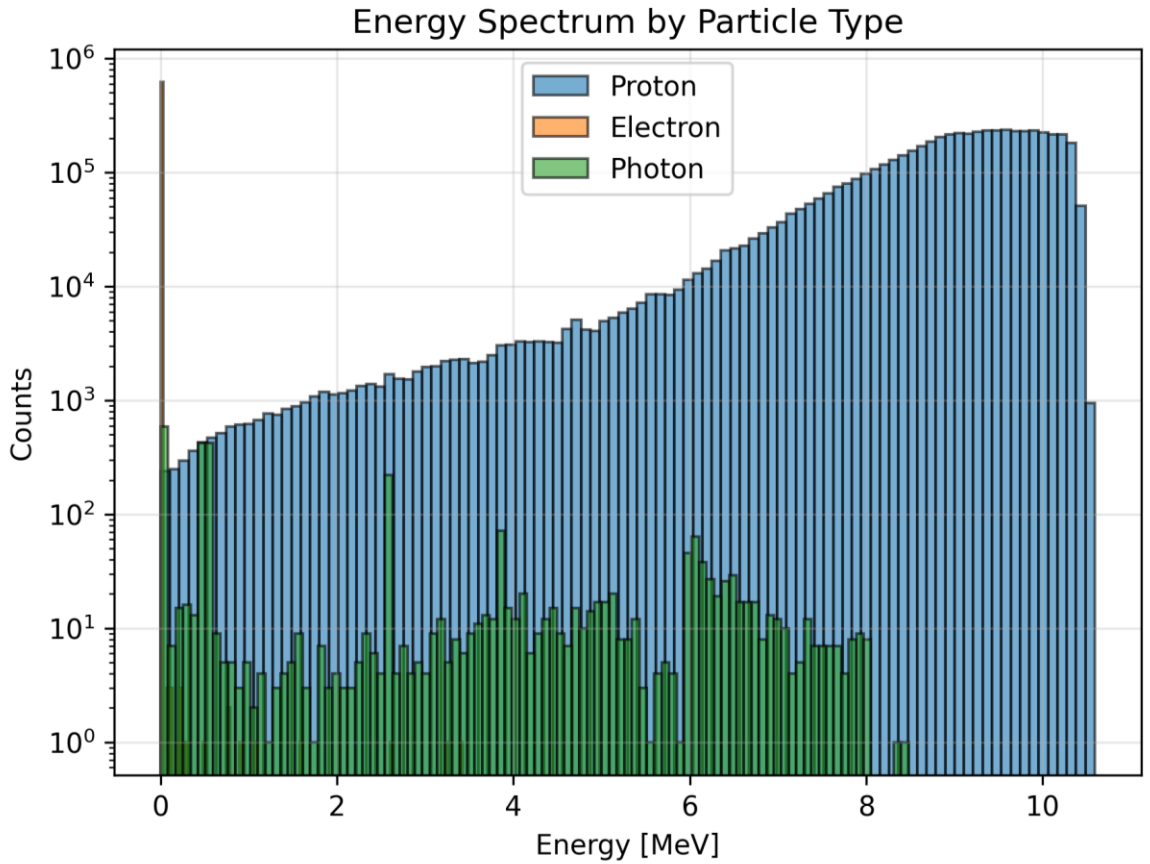
# Setup 4: Max dish distance + Thicker exit mylar + No vacuum tube



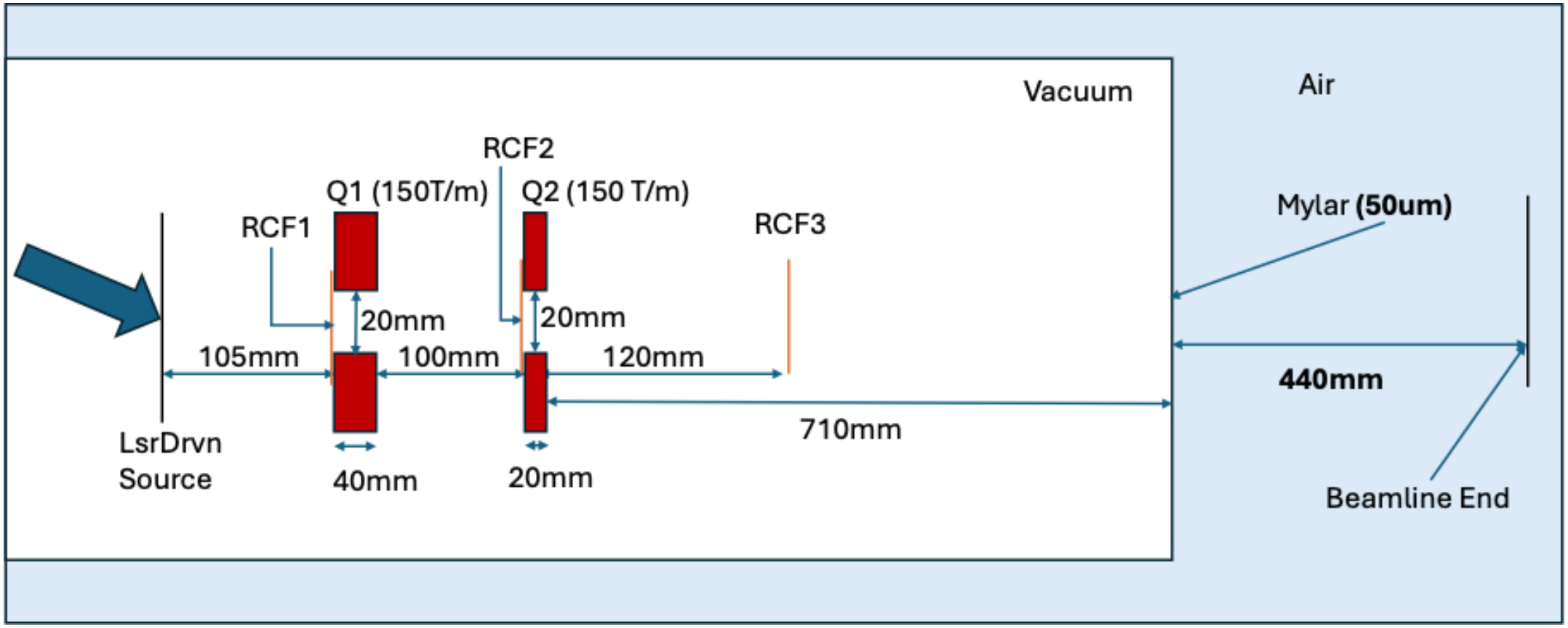

- Mean dose in dish: 0.0128 Gy
- Max dose in dish: 0.0453 Gy
- Min dose in dish: 0.00 Gy
- Standard deviation in dish: 0.0046 Gy
- Uniformity (CV) in dish: 35.93%

# Setup 4 Max dish distance + Thicker exit mylar + No vacuum tube

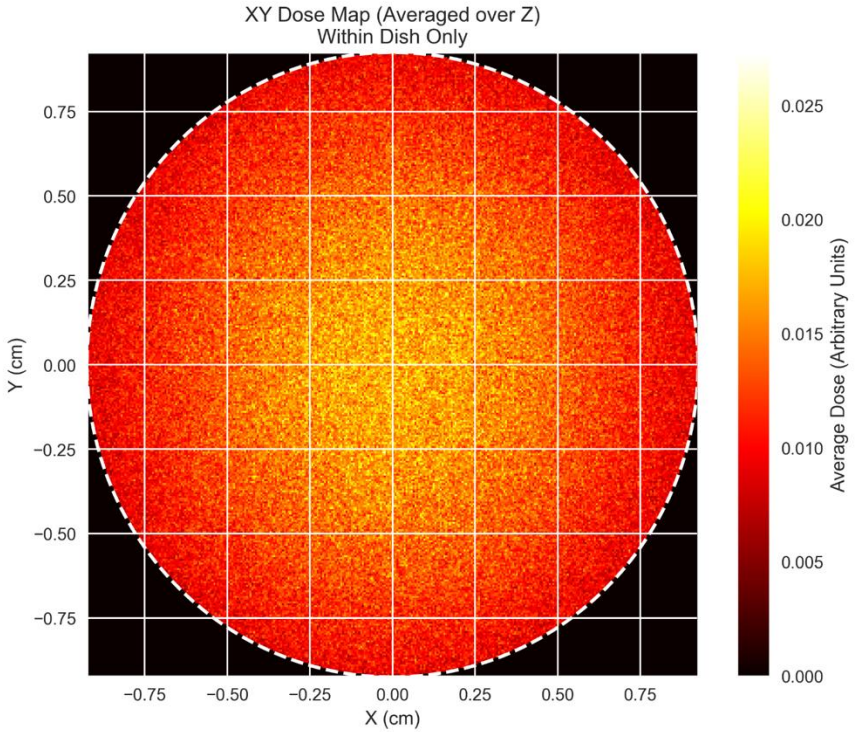


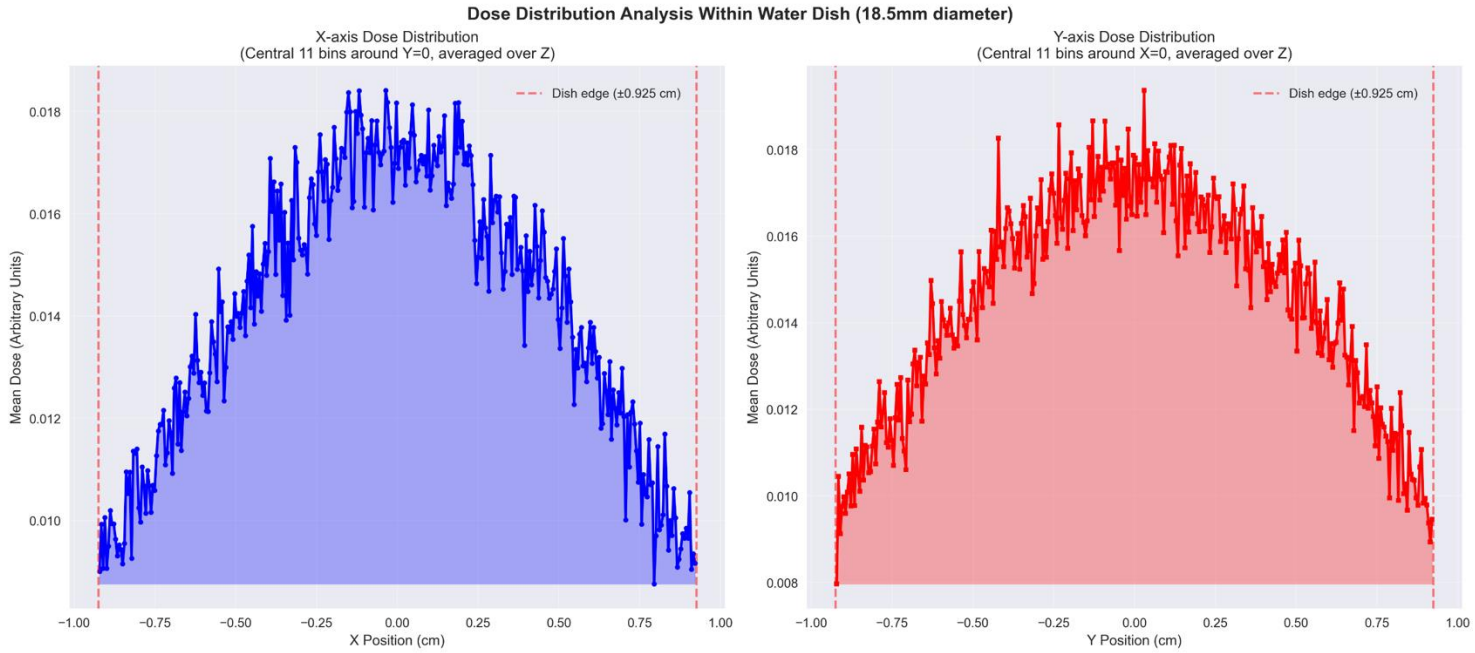

Proton: Mean = 6.923 MeV
Std = 1.493 MeV

# Setup 5: Max dish distance + Normal exit mylar (50 um) + No vacuum tube



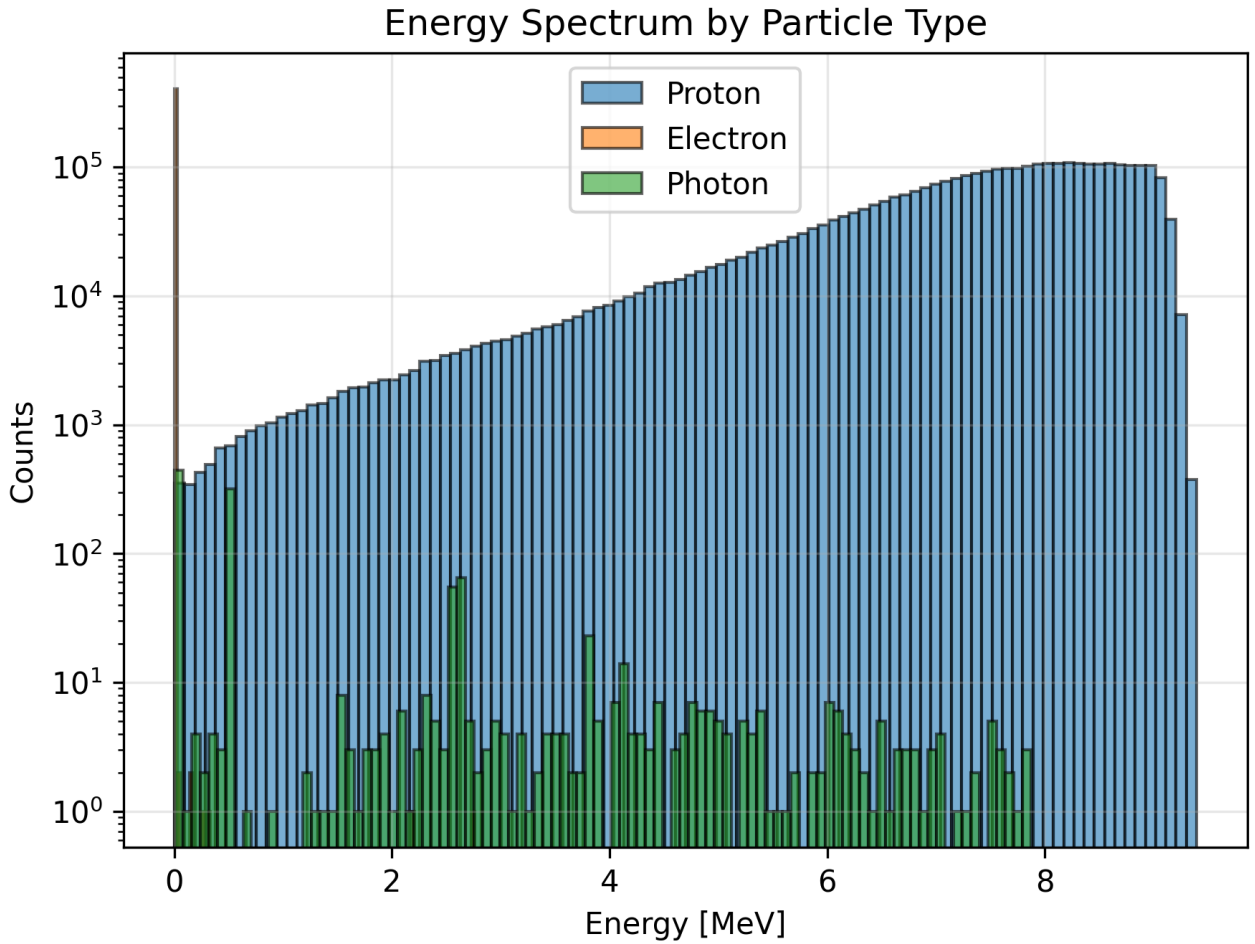
# Setup 5: Max dish distance + Normal exit mylar (50 um) + No vacuum tube




- Mean dose in dish: 0.0150 Gy
- Max dose in dish: 0.0486 Gy
- Min dose in dish (non-zero): 0.000024 Gy
- Standard deviation in dish: 0.0051 Gy
- Uniformity (CV) in dish: 33.81%

# Setup 5: Max dish distance + Normal exit mylar (50 um) + No vacuum tube




Proton: Mean = 7.300 MeV
Std = 1.466 MeV

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