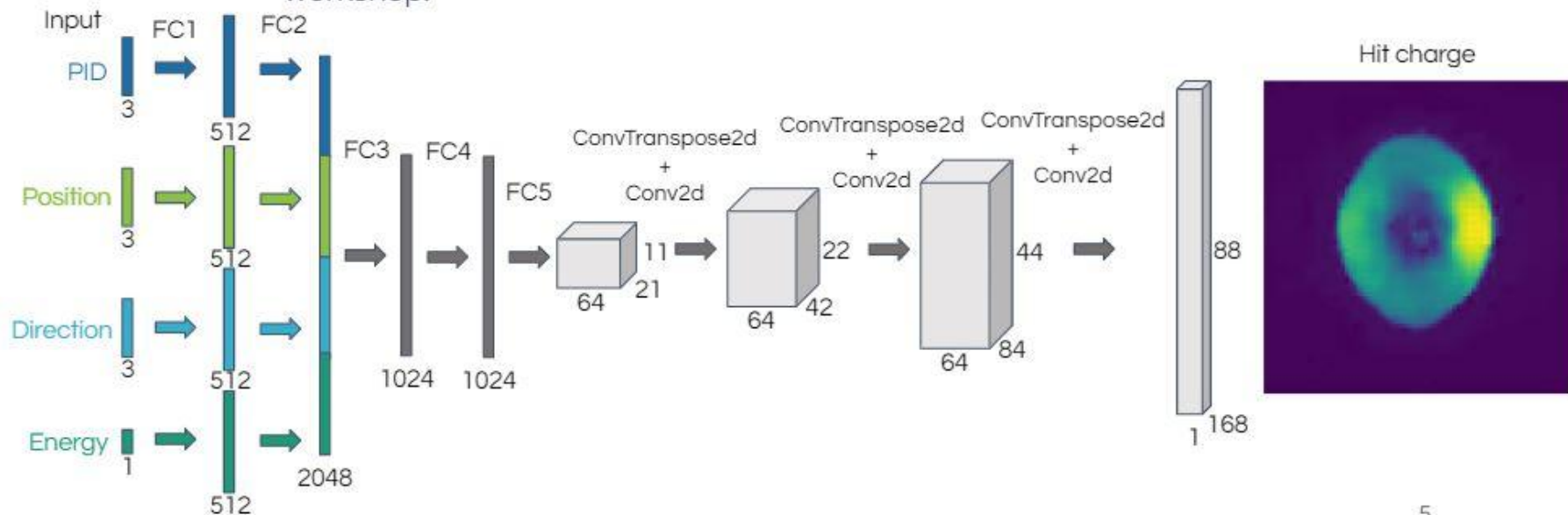


Event Reconstruction

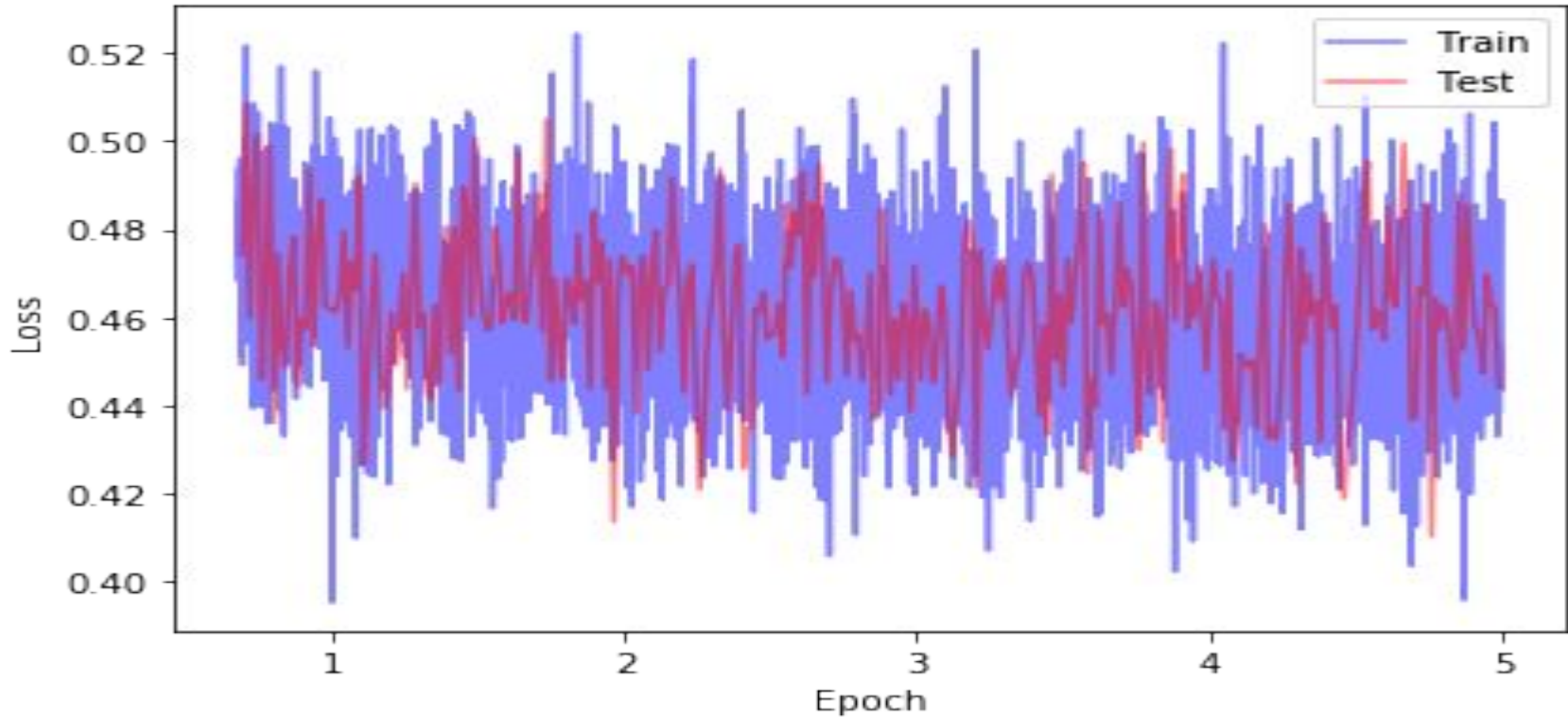
T2K

Generating rings with CNNs

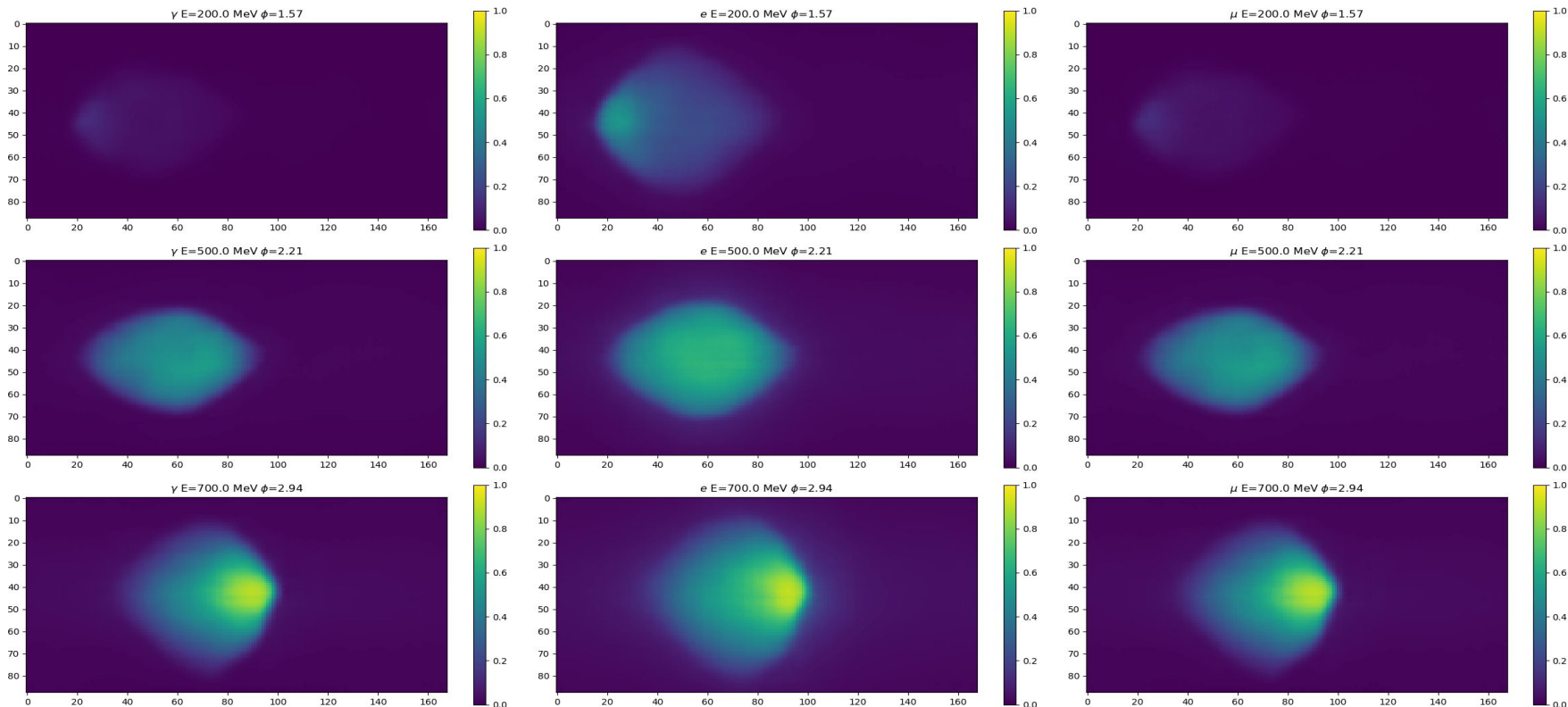
- Follow network architecture described in arXiv:1411.5928 as close as possible, output is the observed (mean) charge at each PMT in the barrel.
 - Almost certainly not optimal, just want to see if it works.
 - Implemented in PyTorch, based on Kazu Terao's examples from the WatChMaL workshop.



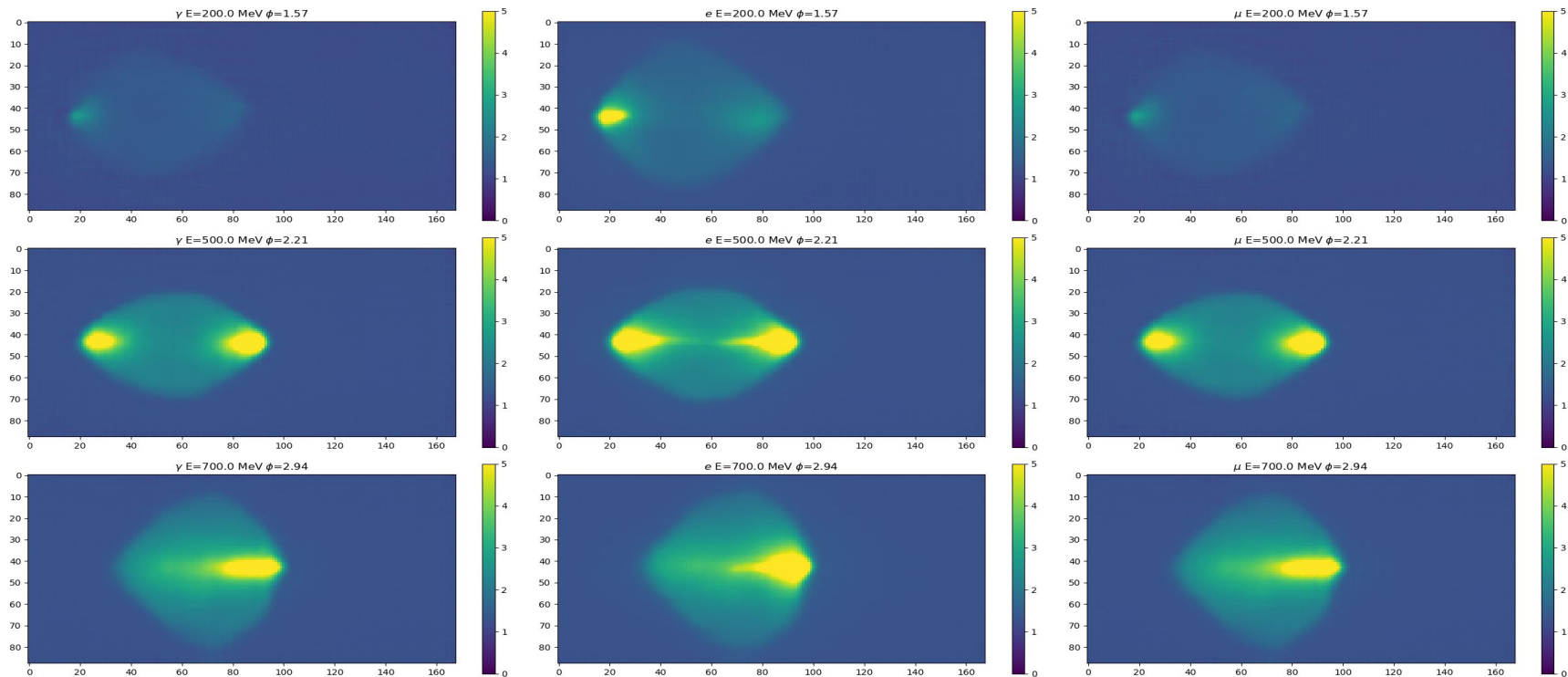
Layer 2(FC1), Node = 3, Time = 3 hours and 40 min



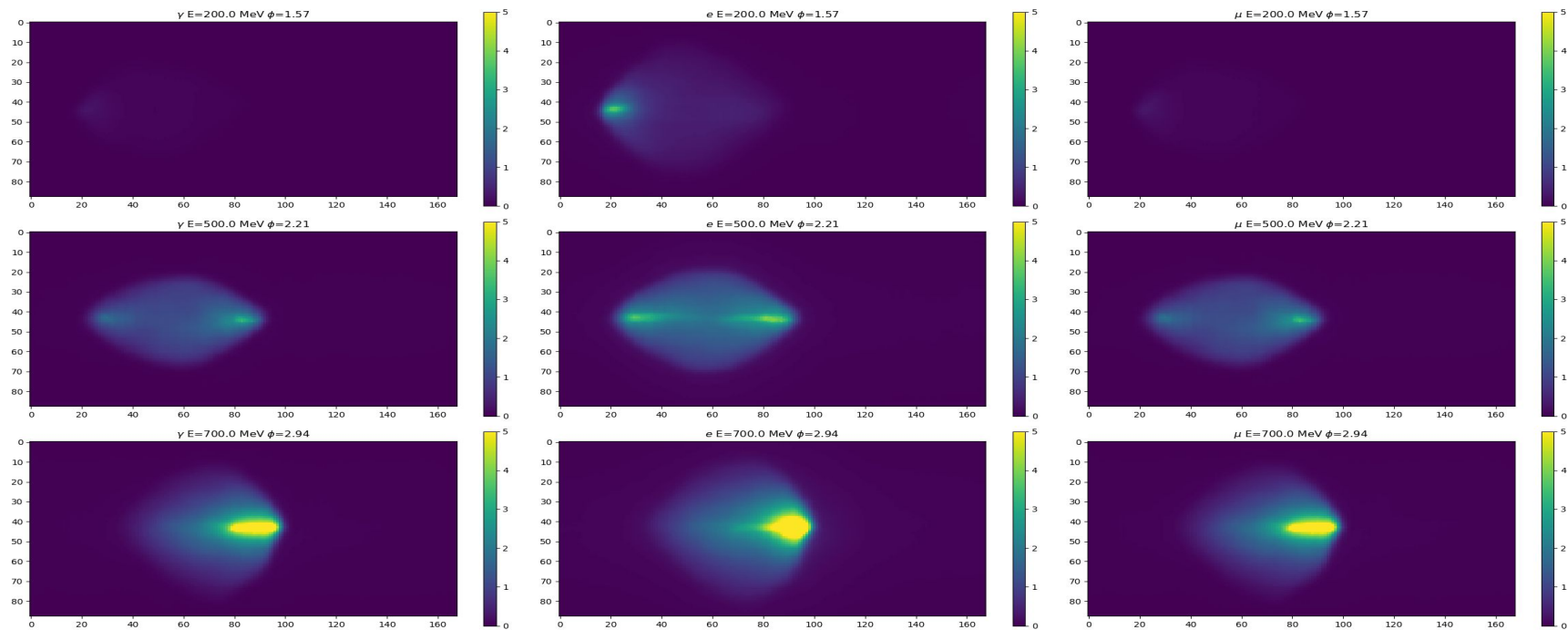
Predicted Hit Probability



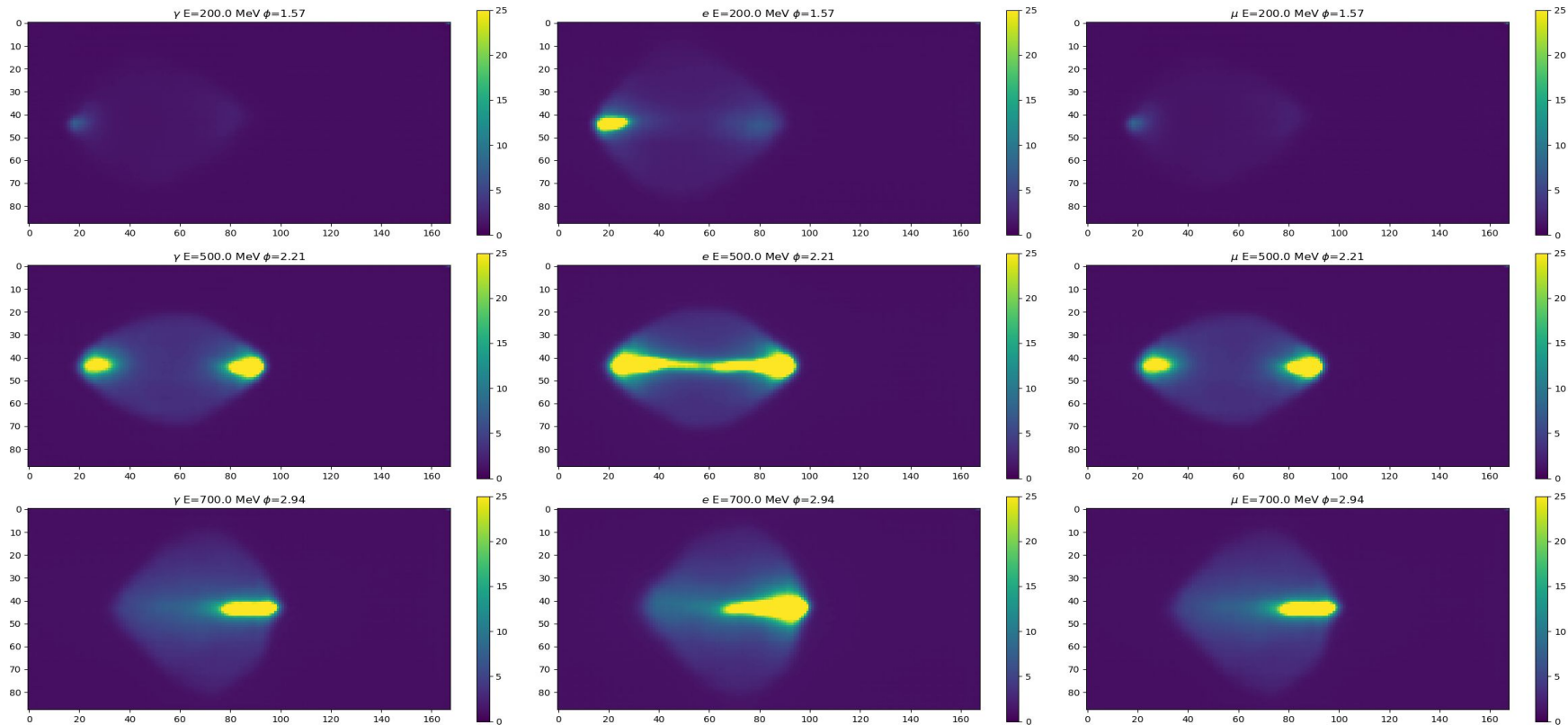
Predicted Charge



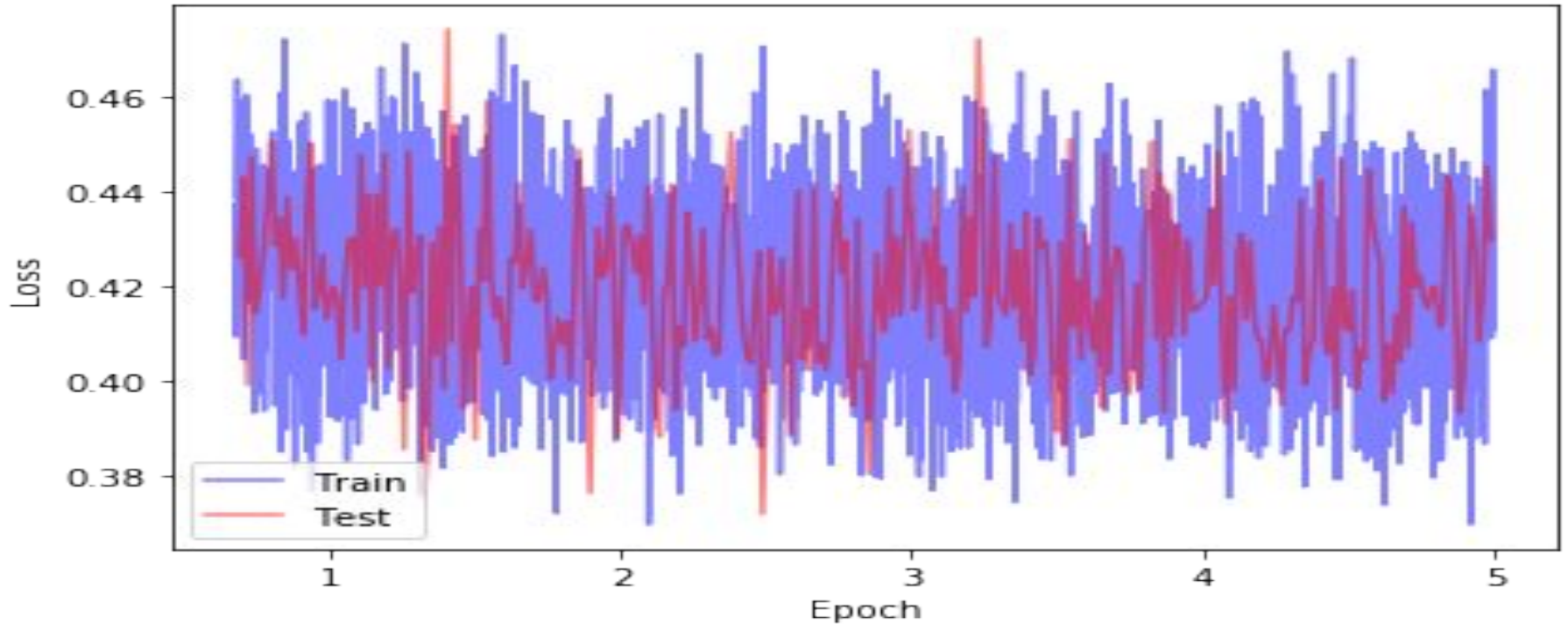
Expected mean charge (Predicted Charge X Predicted Hit Probability)



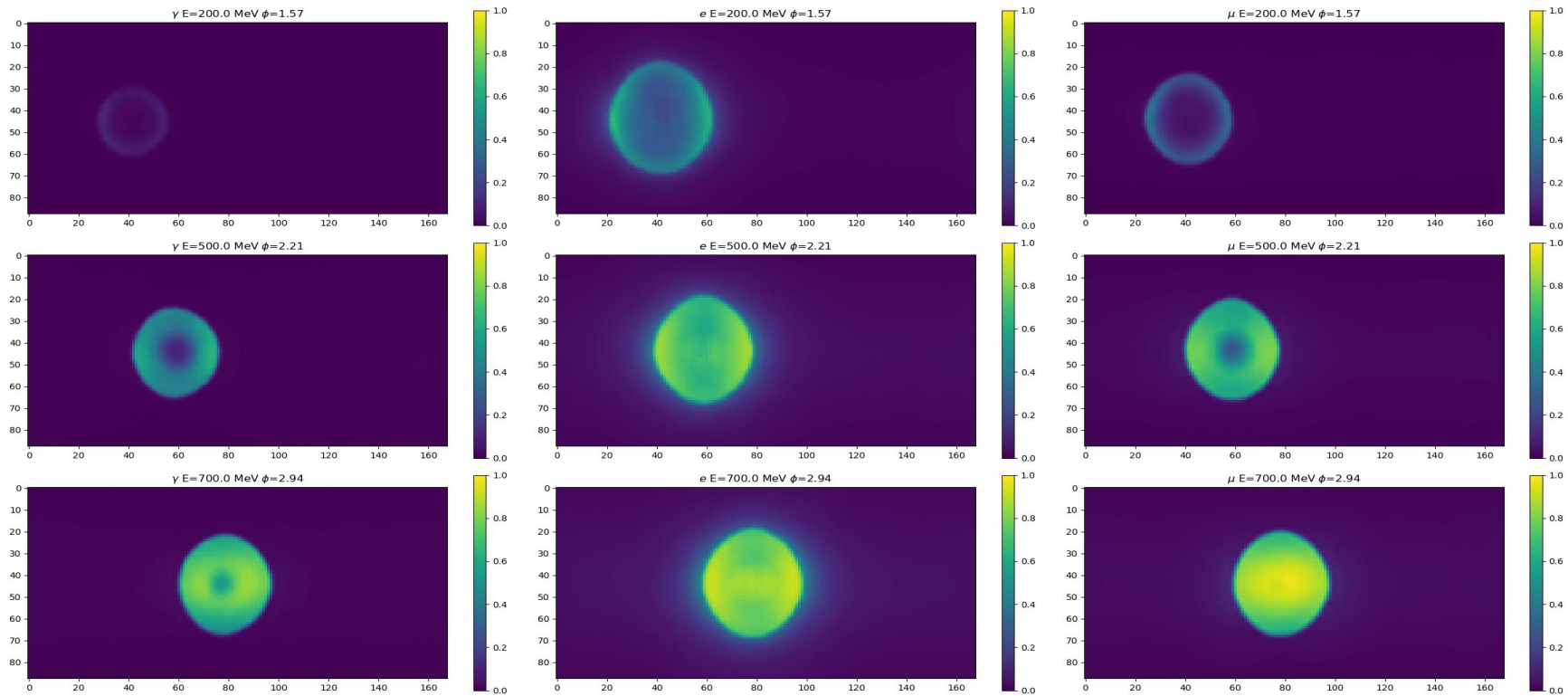
Predicted Variance of Charge



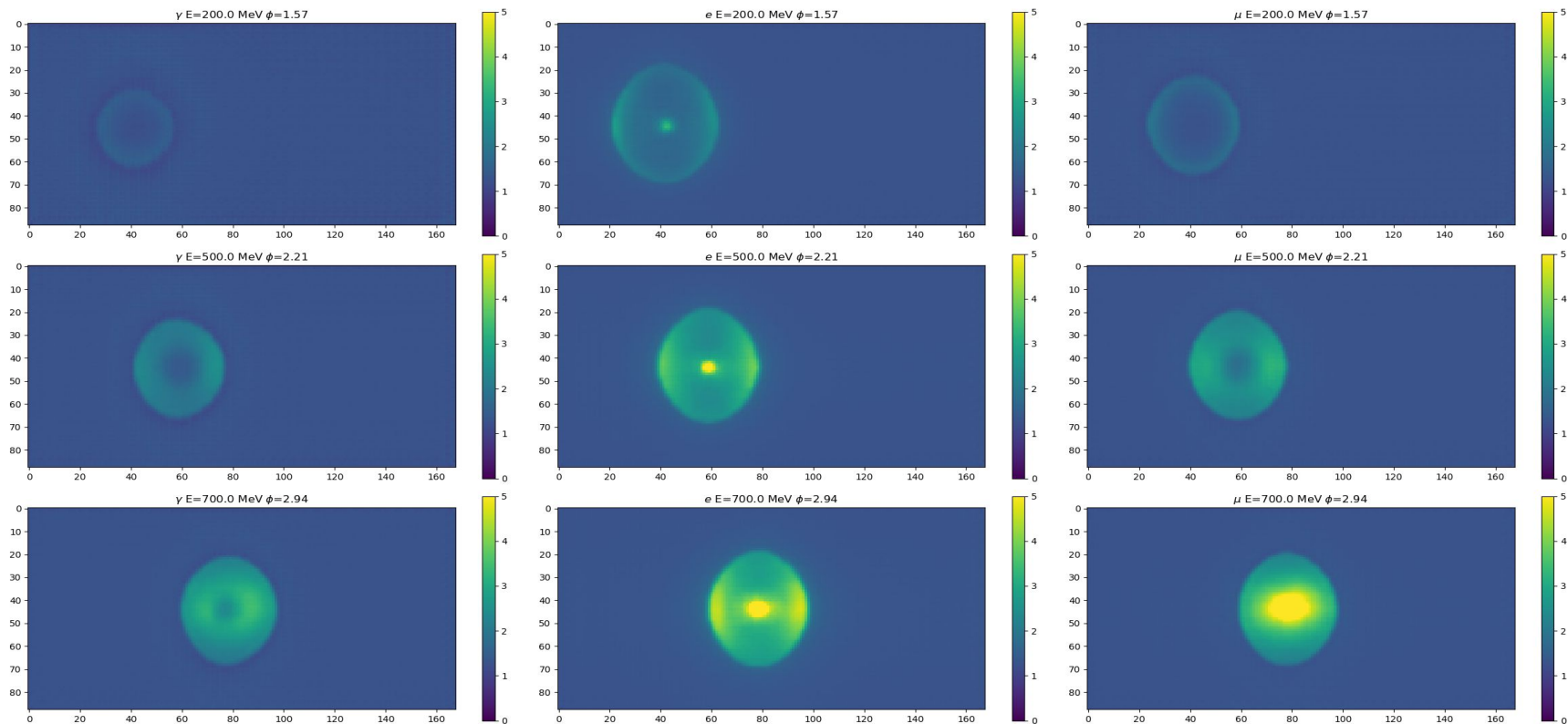
Layer 2(FC1), Node =10 , Time = 2 hours and 44 min



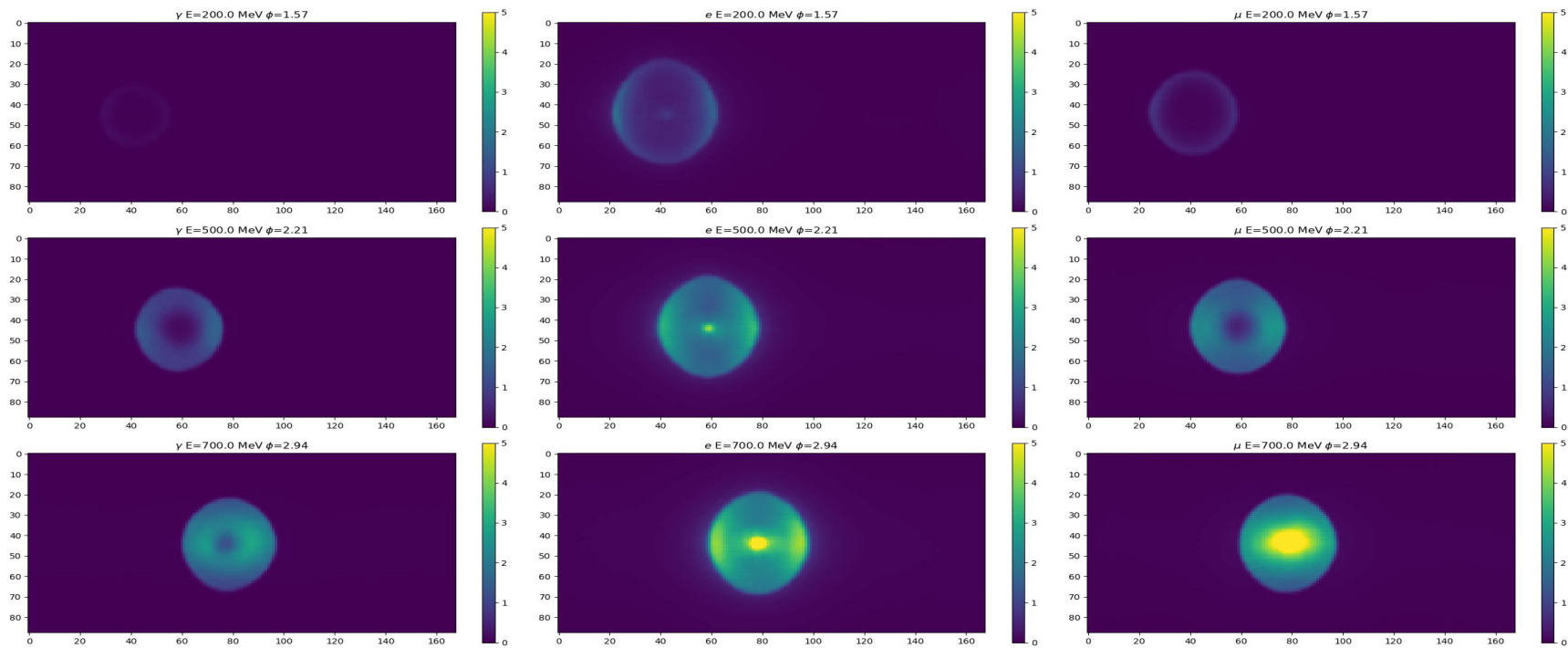
Predicted Hit Probability



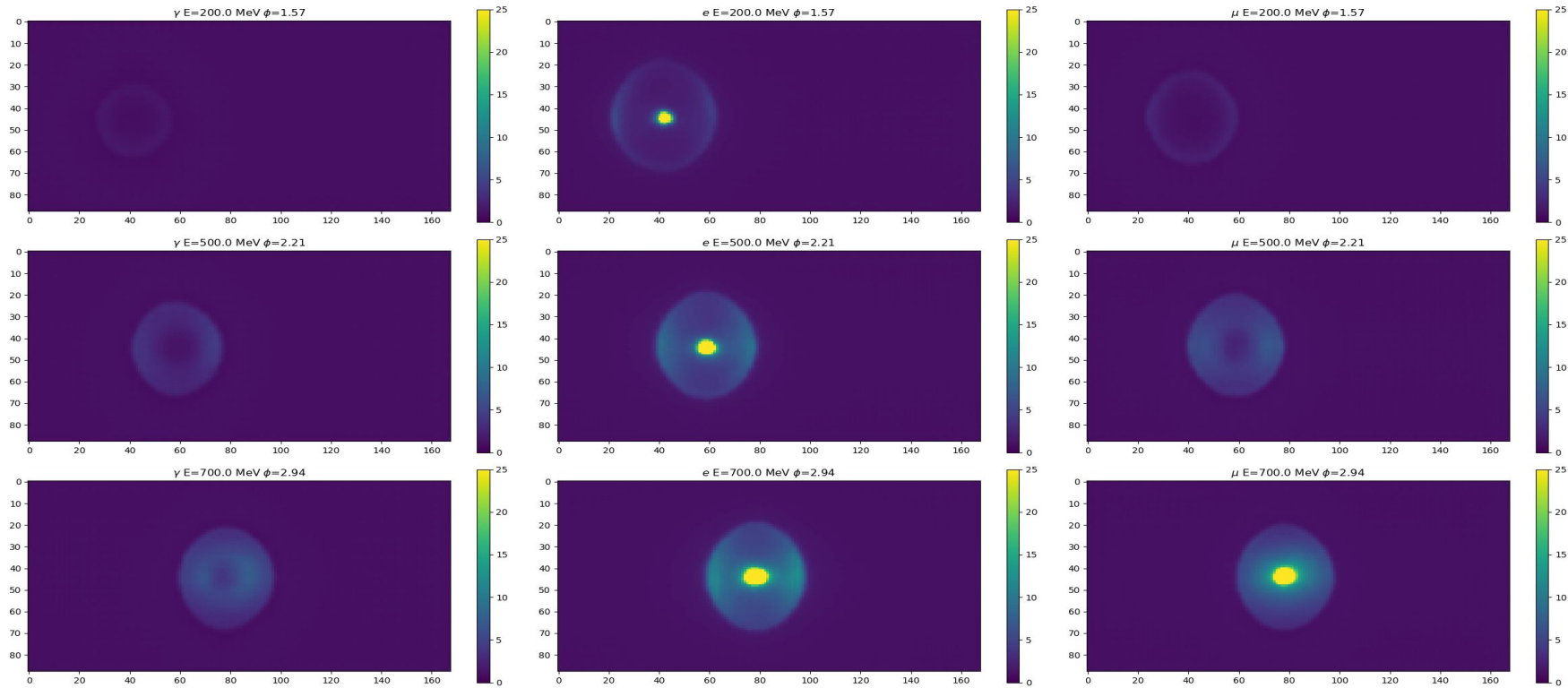
Predicted Charge



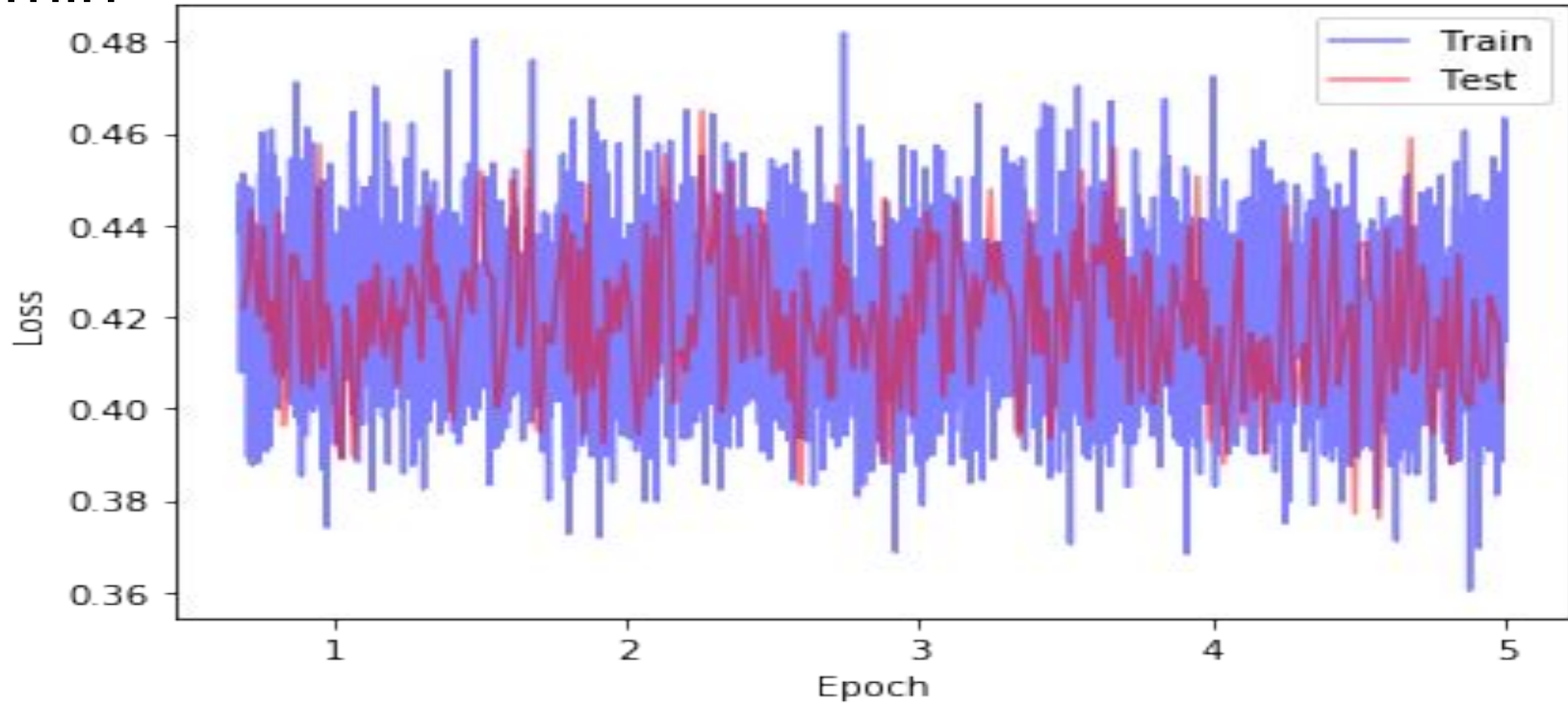
Expected mean charge (Predicted Charge X Predicted Hit Probability)



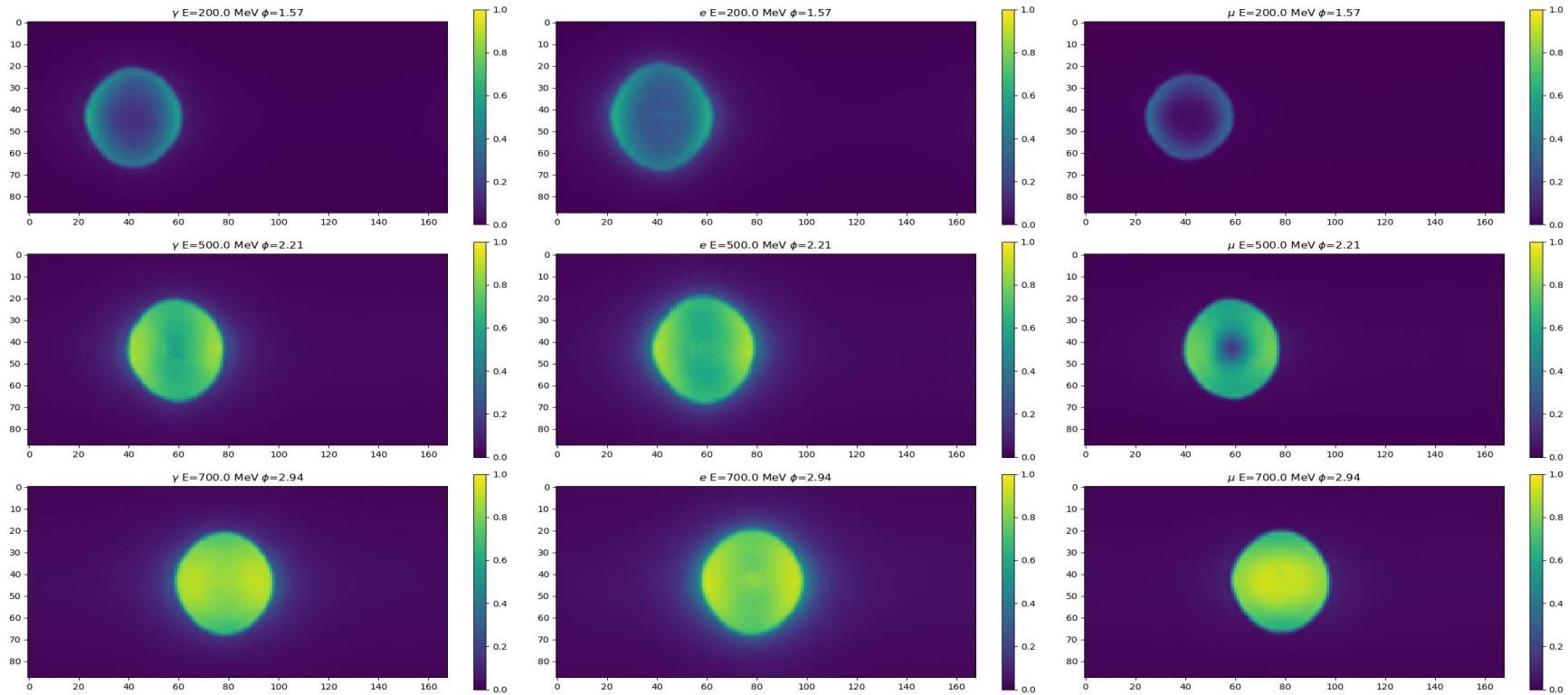
Predicted Variance of Charge



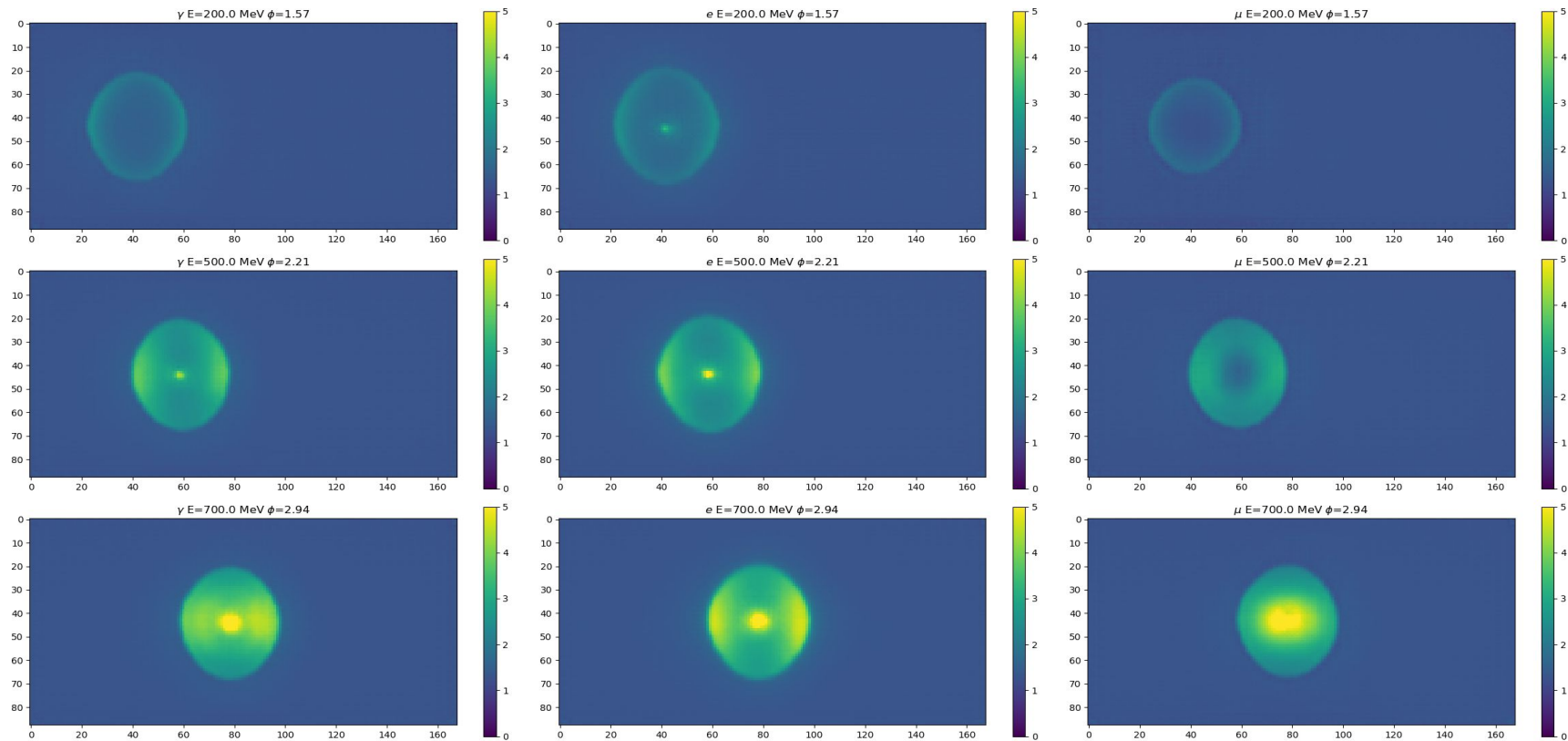
Layer 2(FC1), Node = 30 , Time = 2 hours and 41 min
min



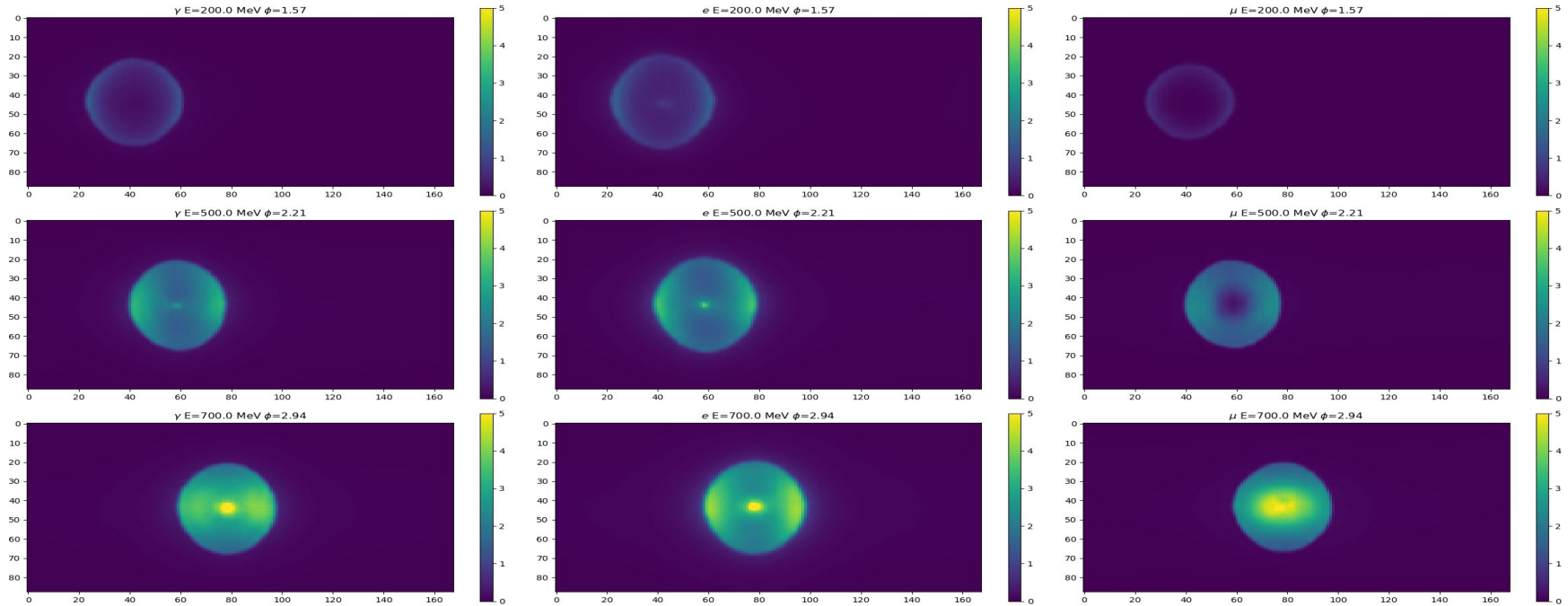
Predicted Hit Probability



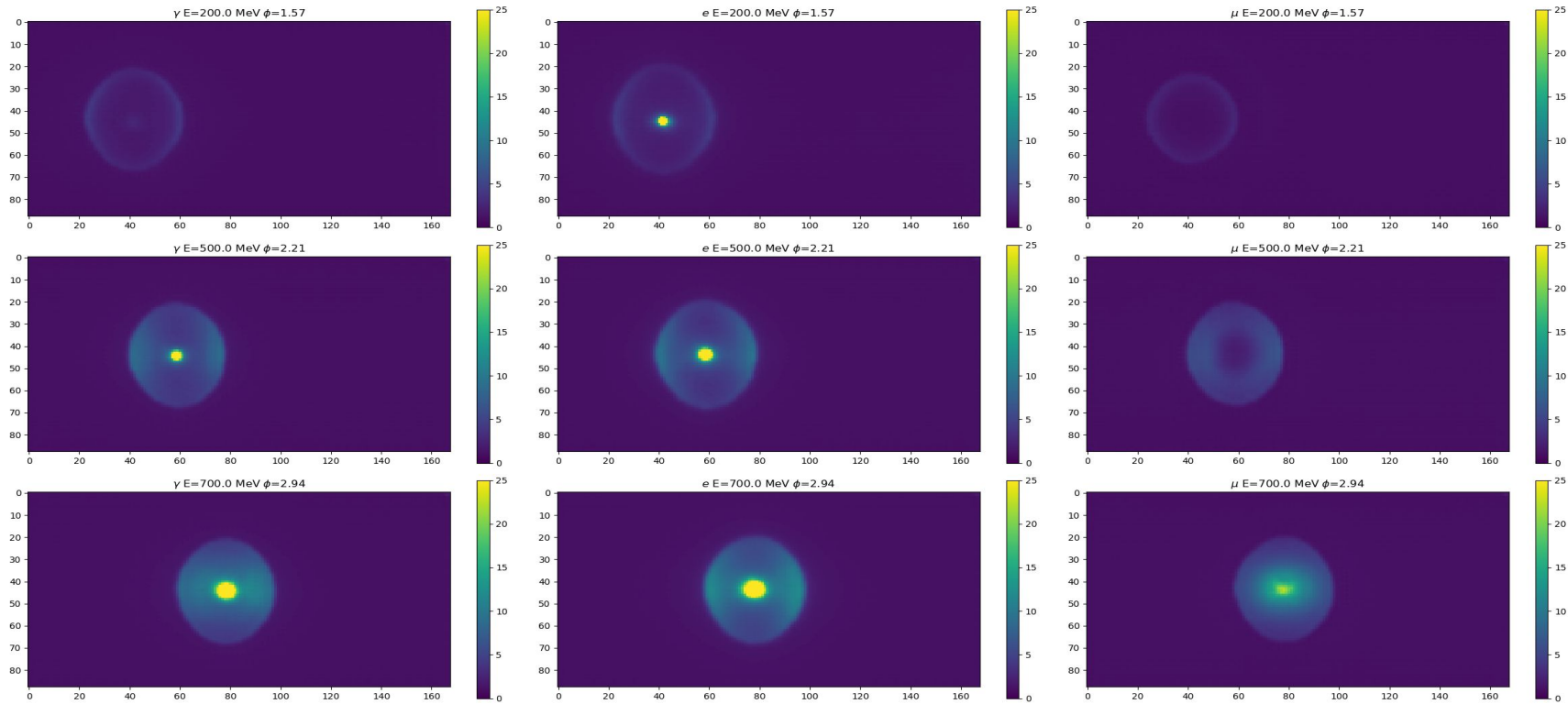
Predicted Charge



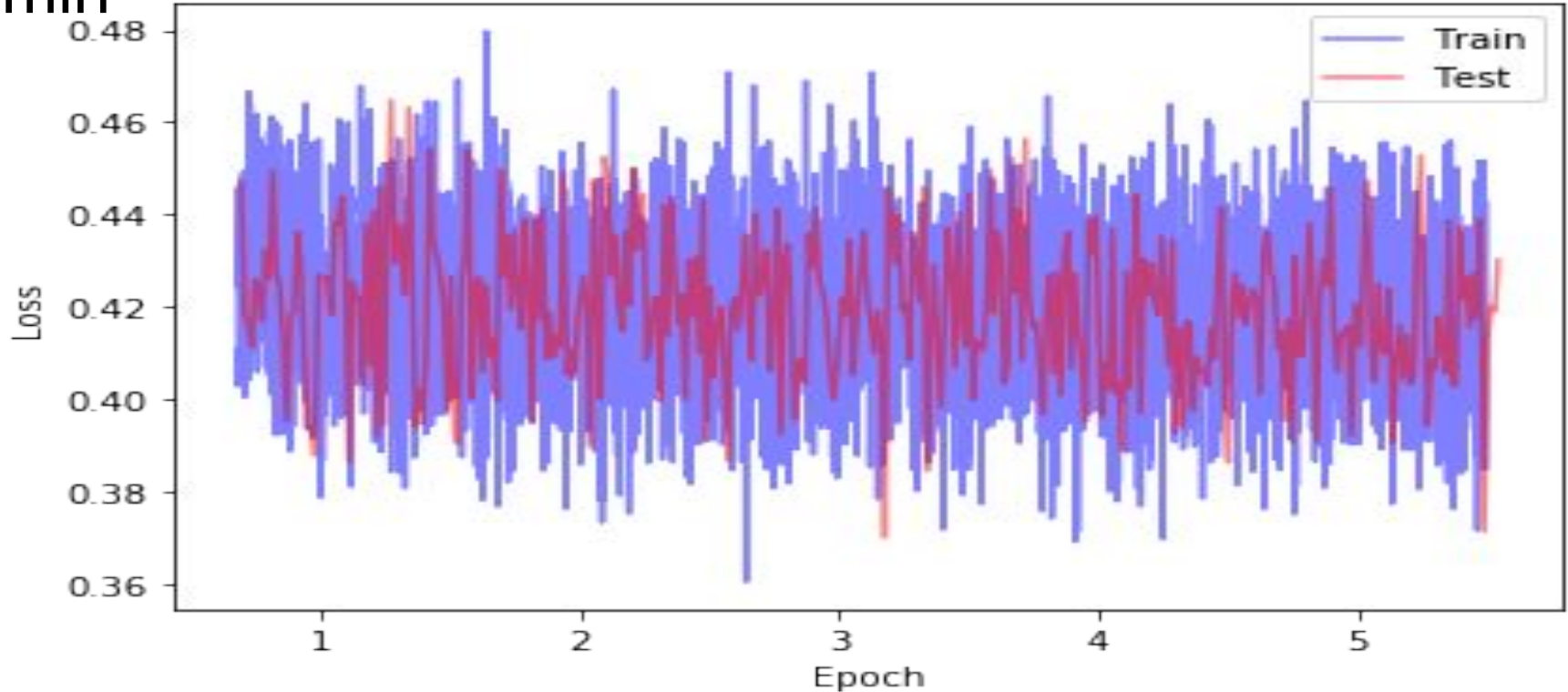
Expected mean charge (Predicted Charge X Predicted Hit Probability)



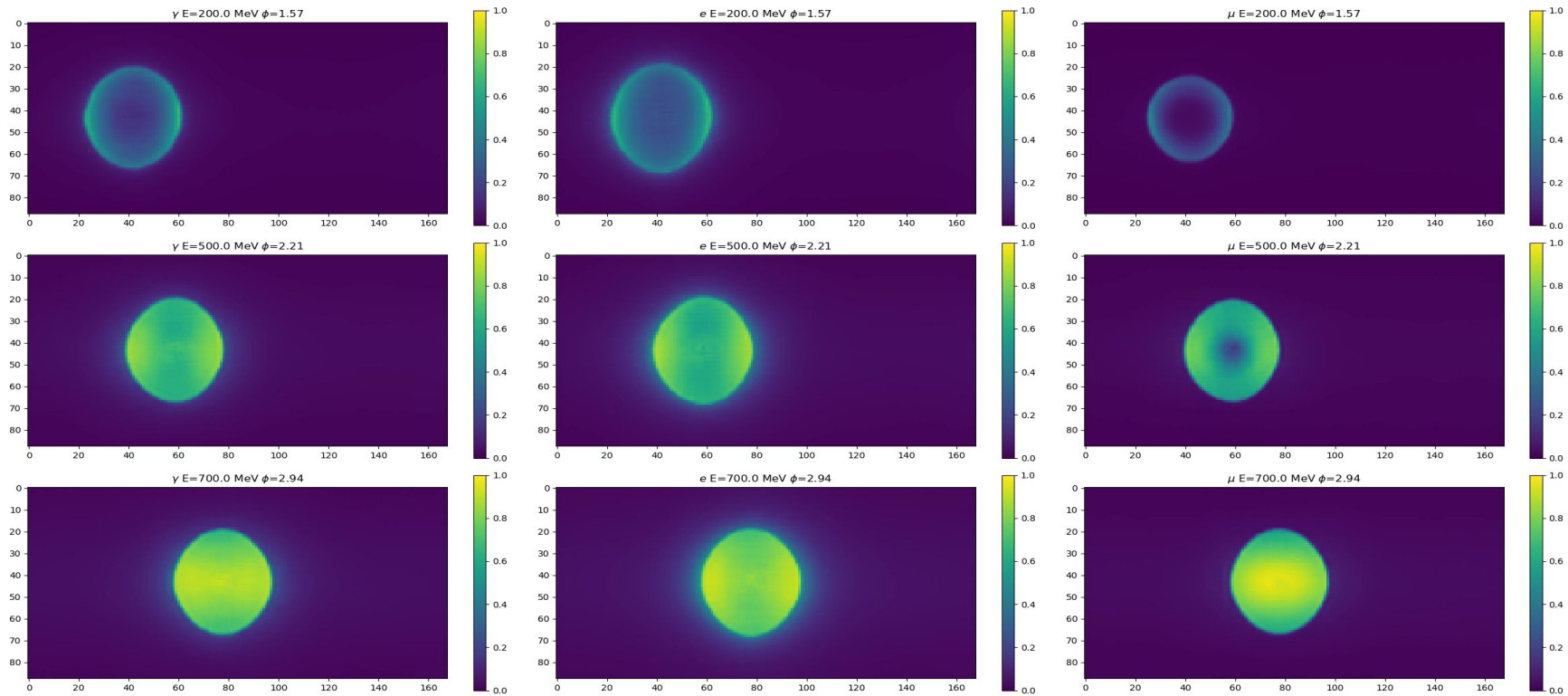
Predicted Variance of Charge



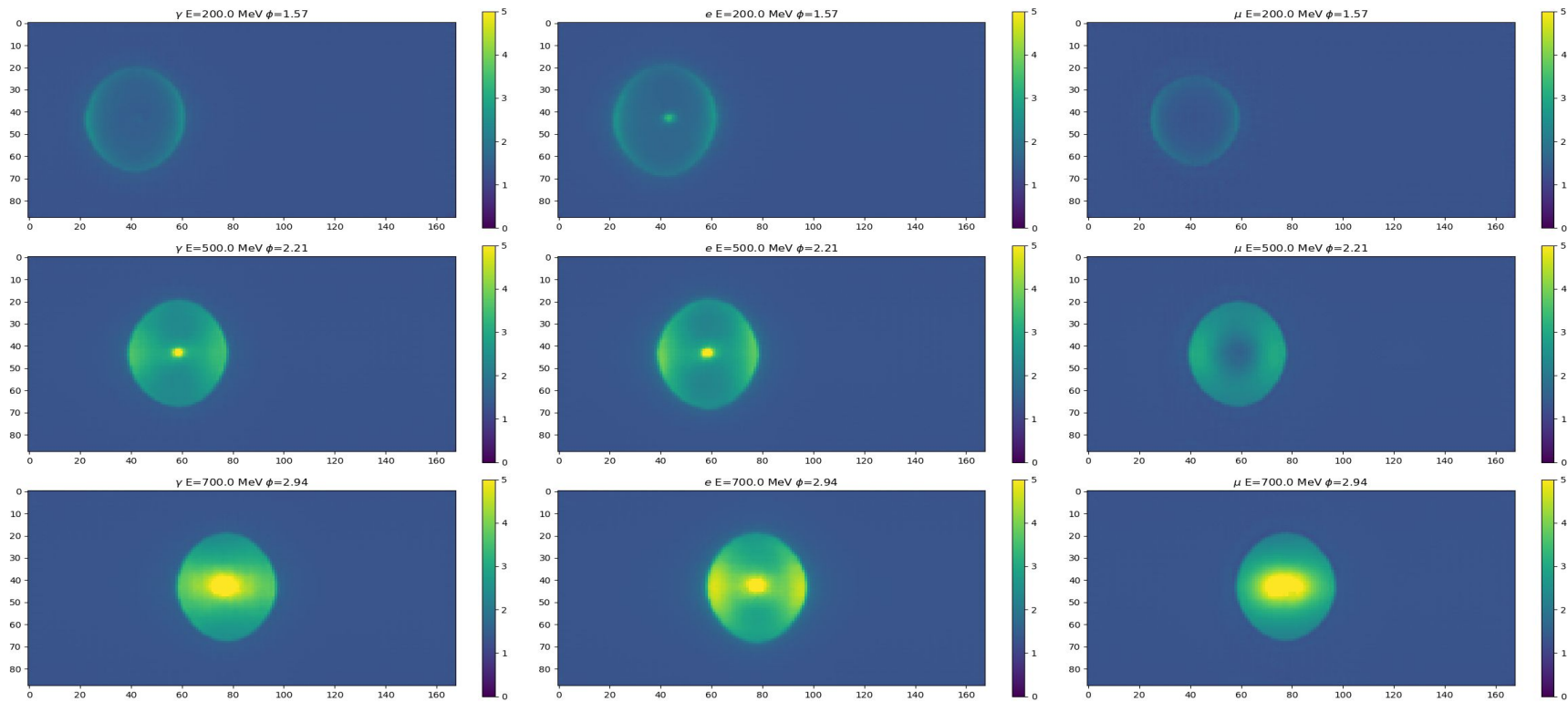
Layer 2(FC1), Node = 50, Time = 2 hours and 45 min



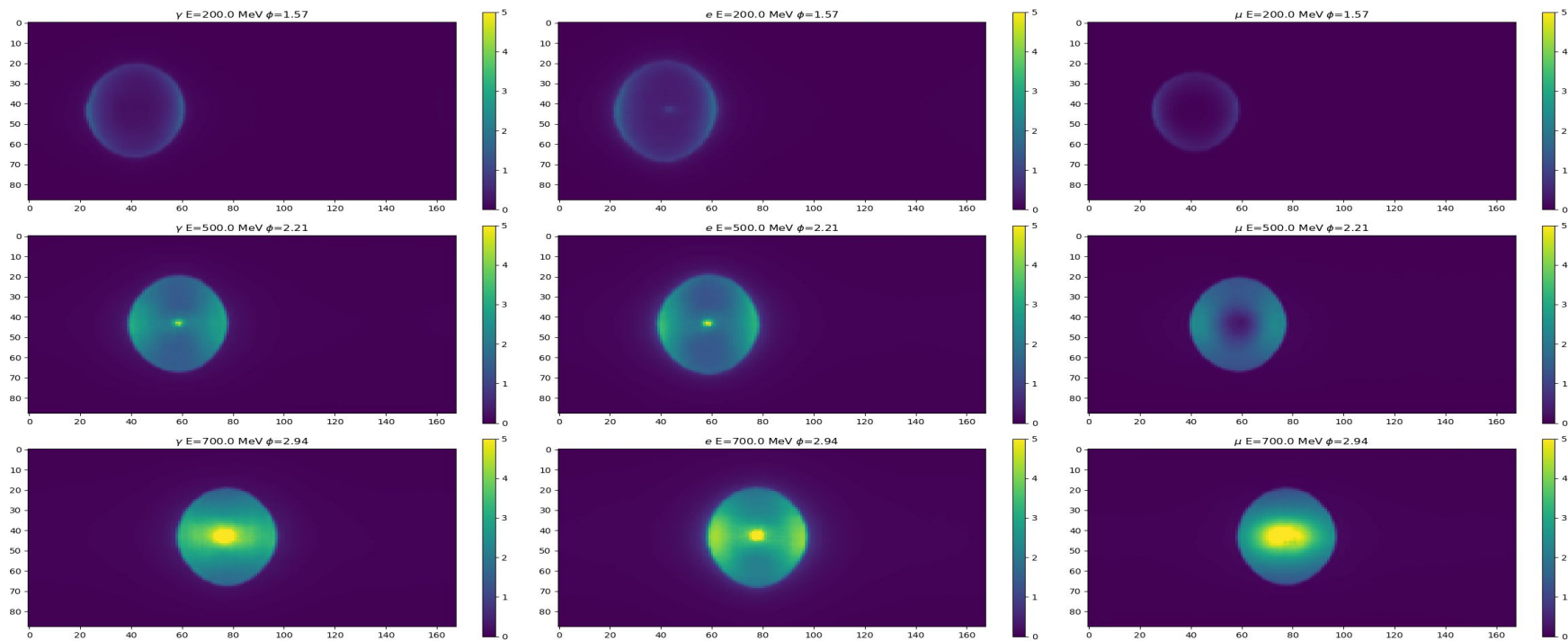
Predicted Hit Probability



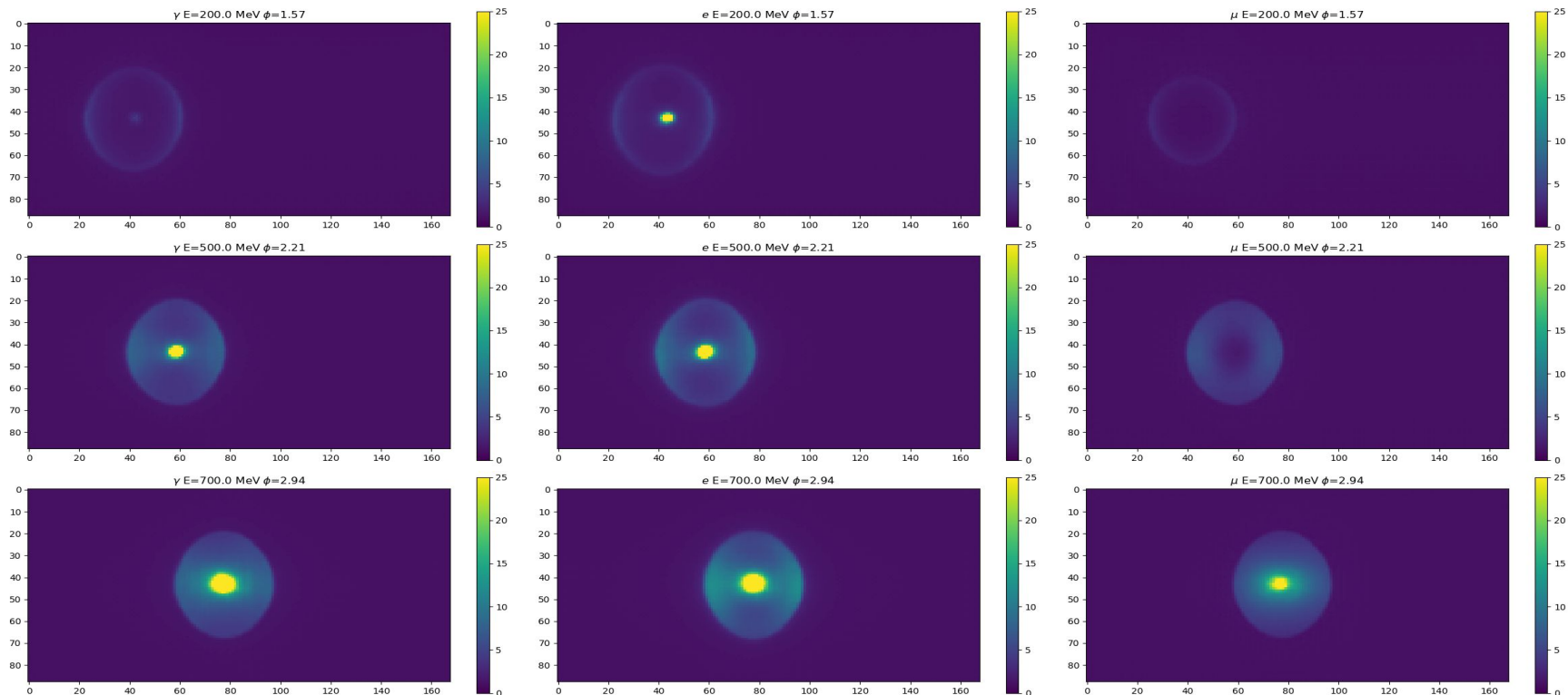
Predicted Charge



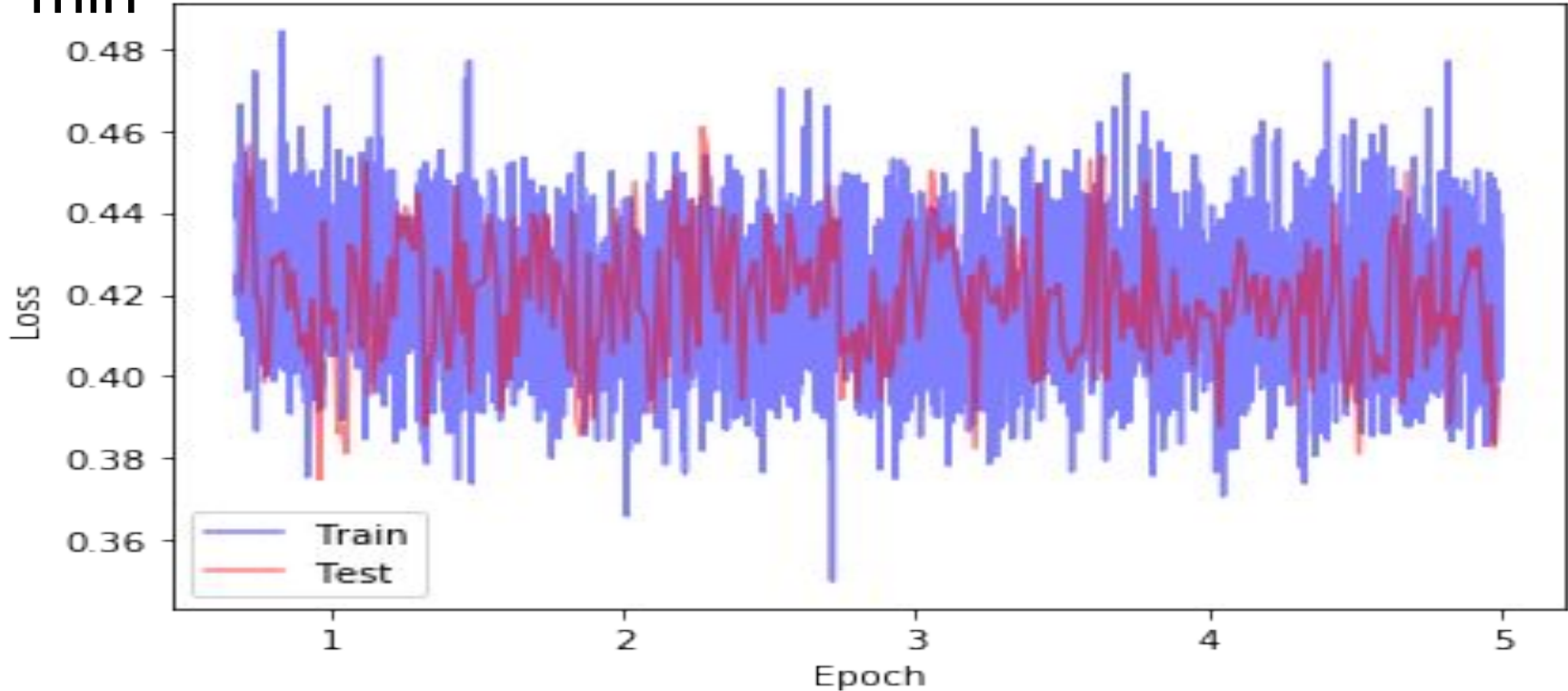
Expected mean charge (Predicted Charge X Predicted Hit Probability)



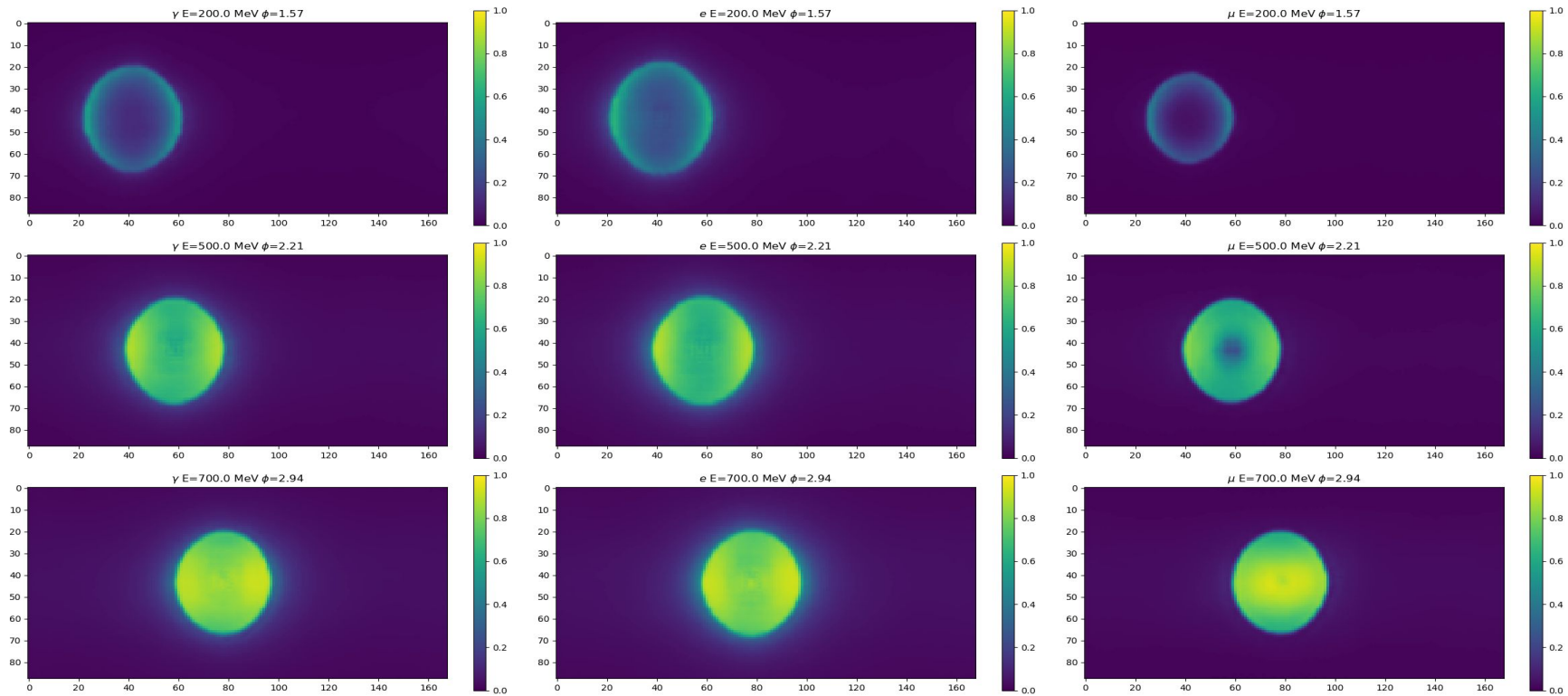
Predicted Variance of Charge



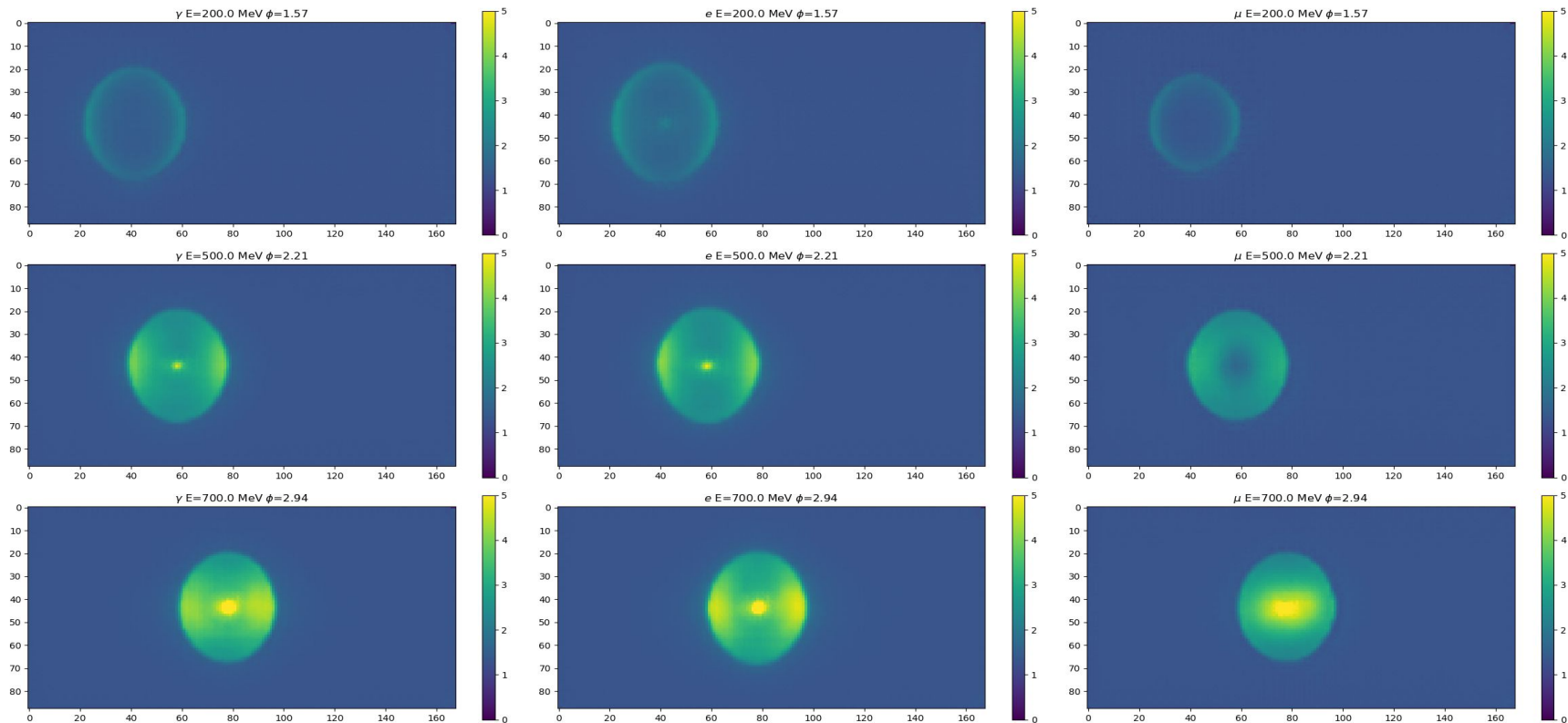
Layer 2(FC1), Node = 100 , Time = 3 hours and 57 min



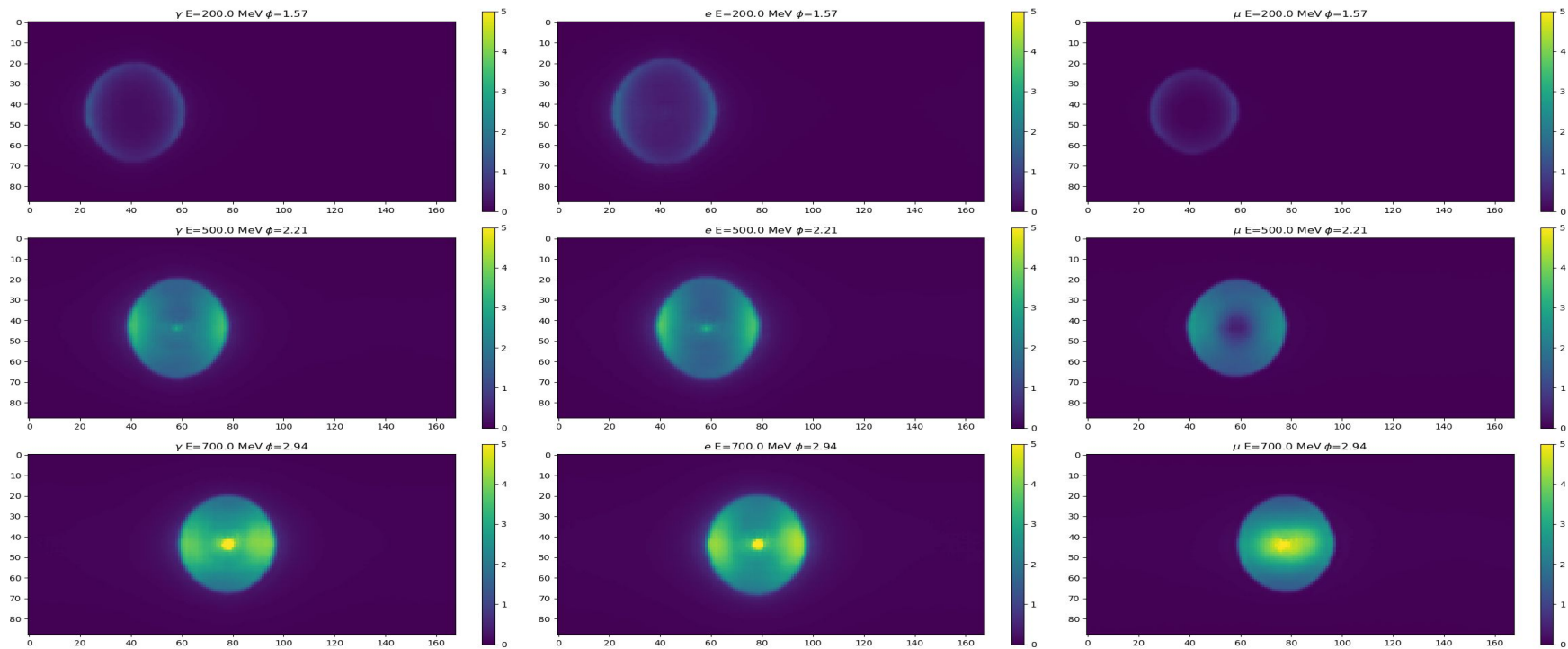
Predicted Hit Probability



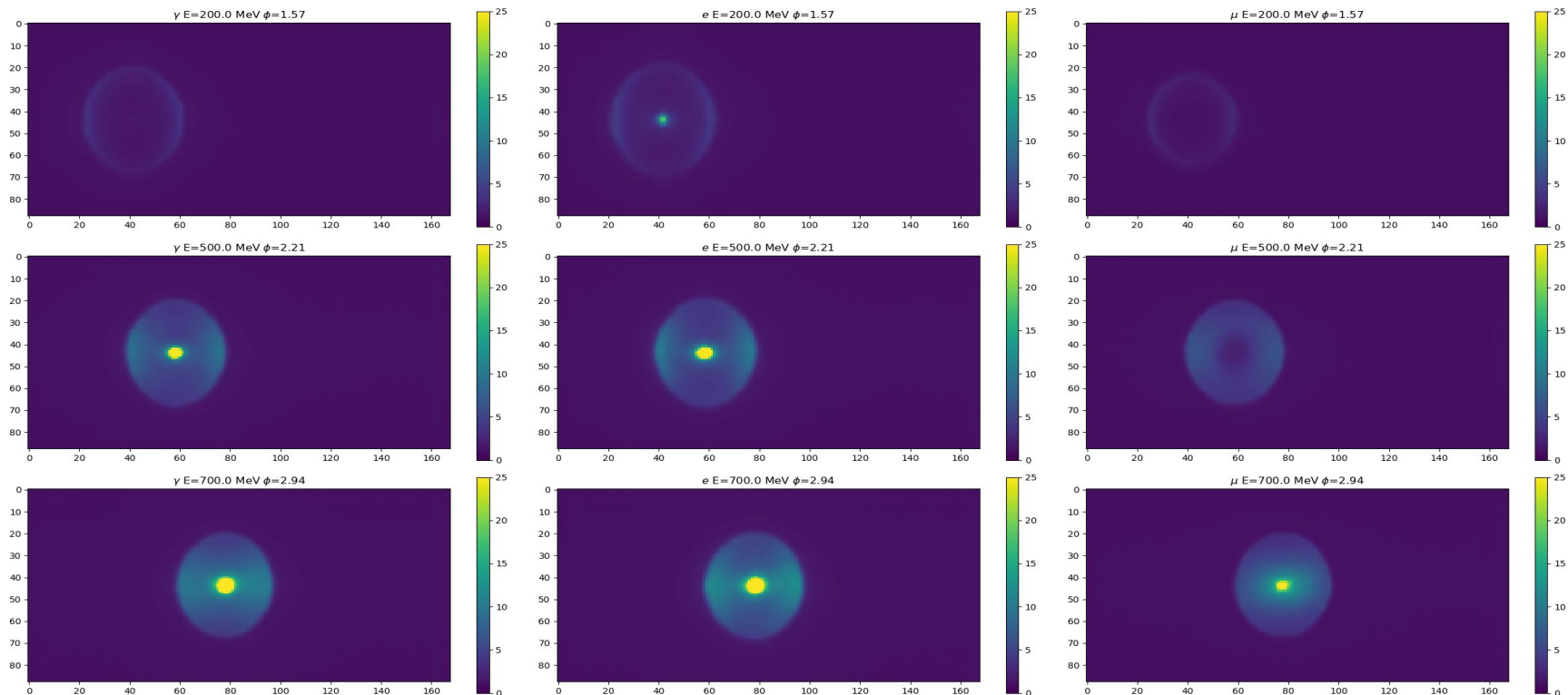
Predicted Charge



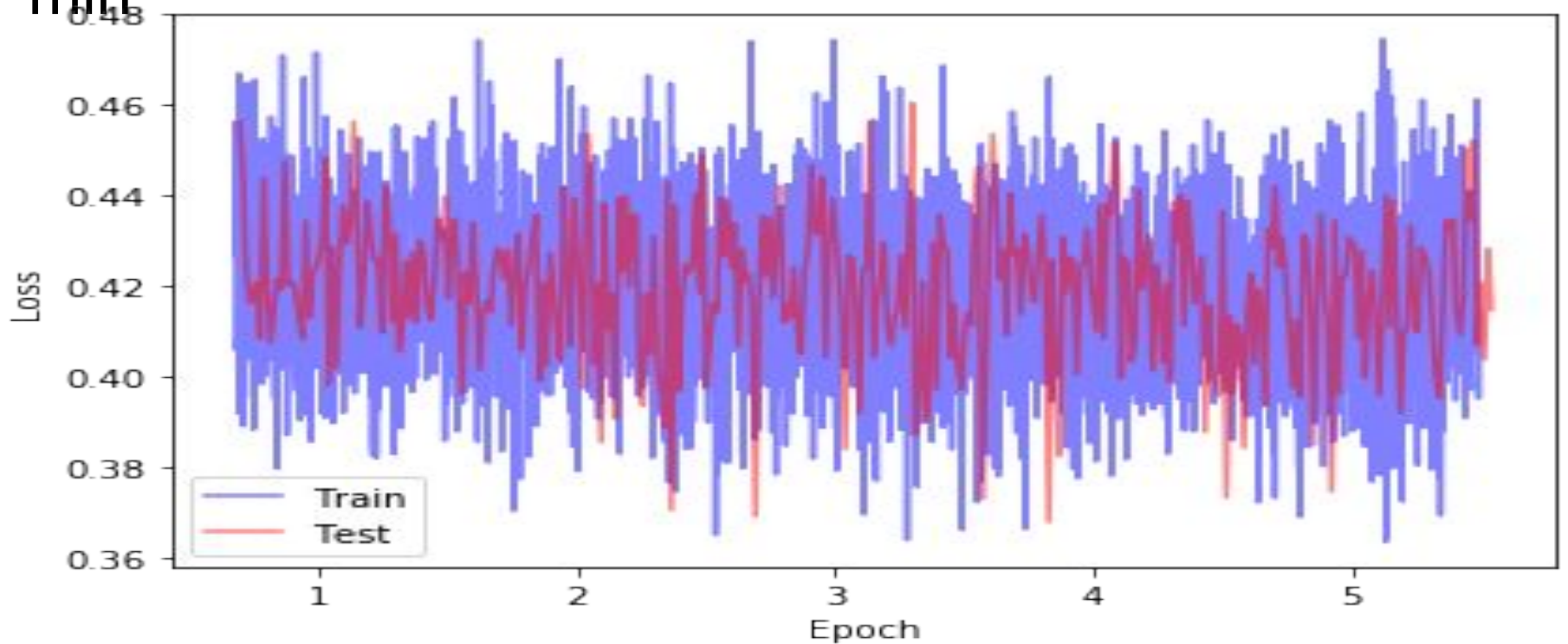
Expected mean charge (Predicted Charge X Predicted Hit Probability)



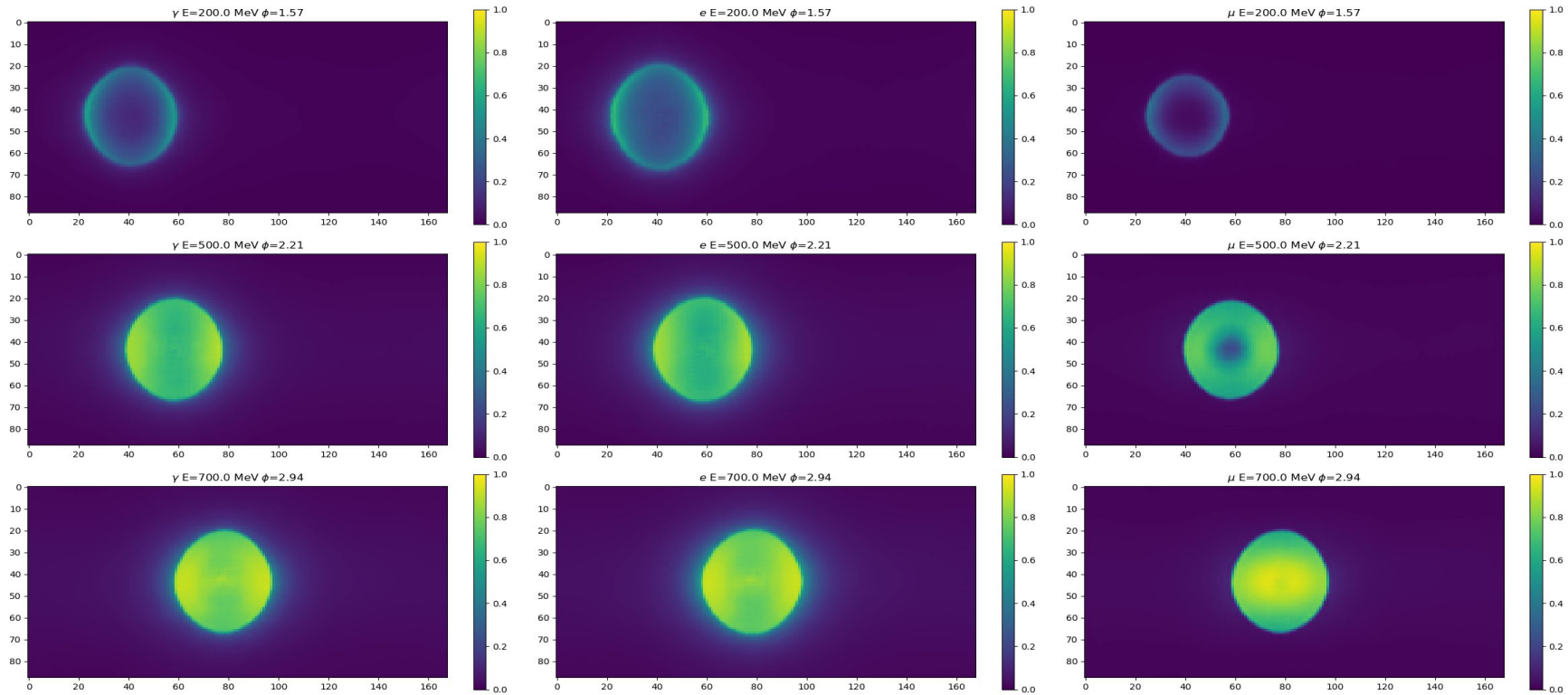
Predicted Variance of Charge



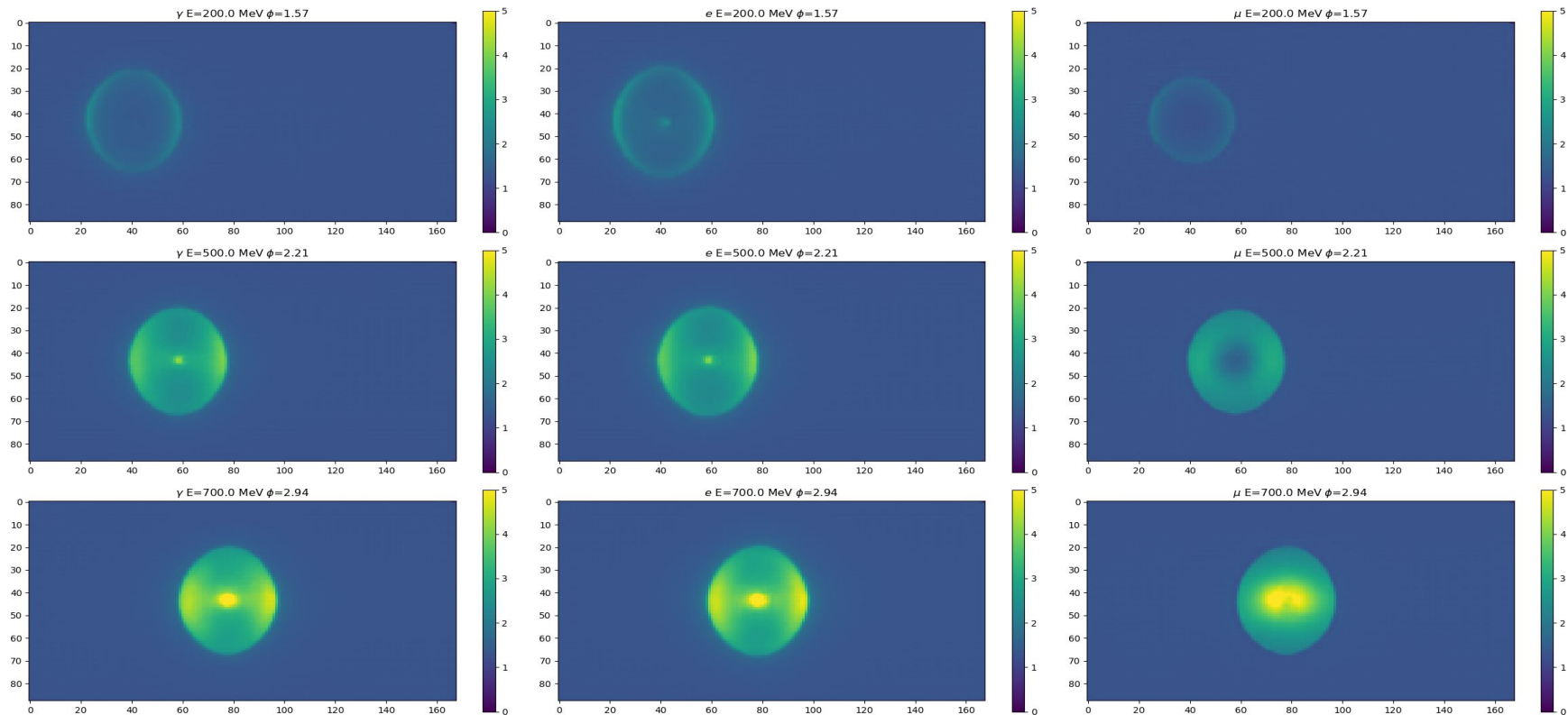
Layer 2(FC1), Nodes = 176, Time = 3 hours and 10 min



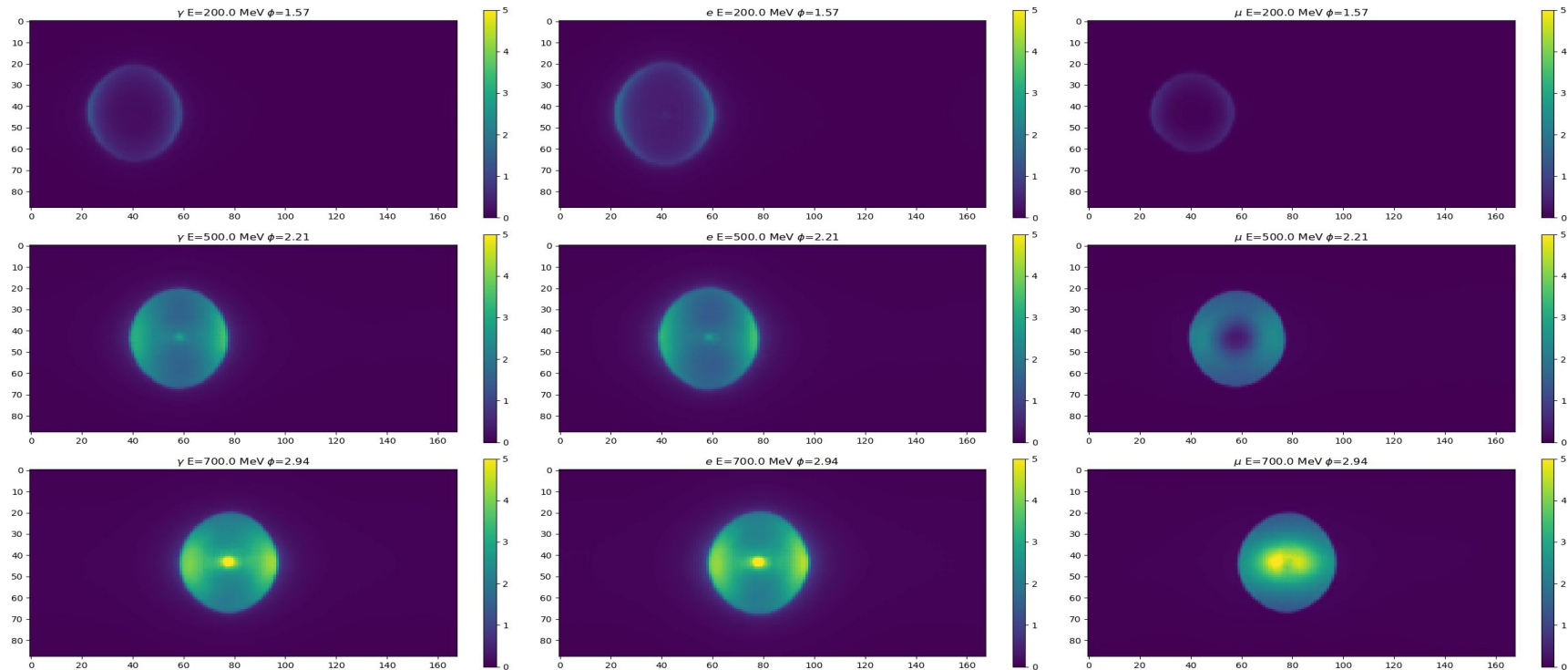
Predicted Hit Probability



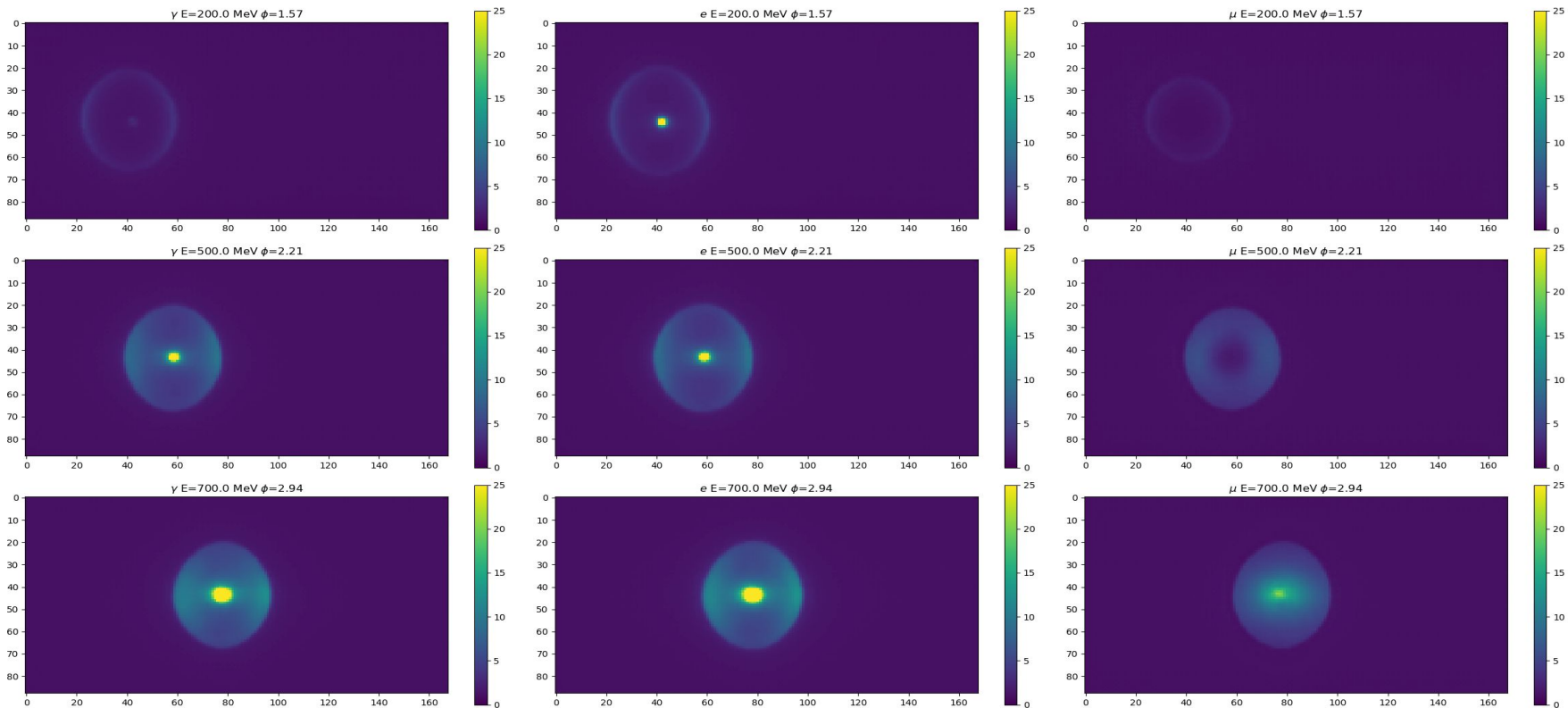
Predicted Charge



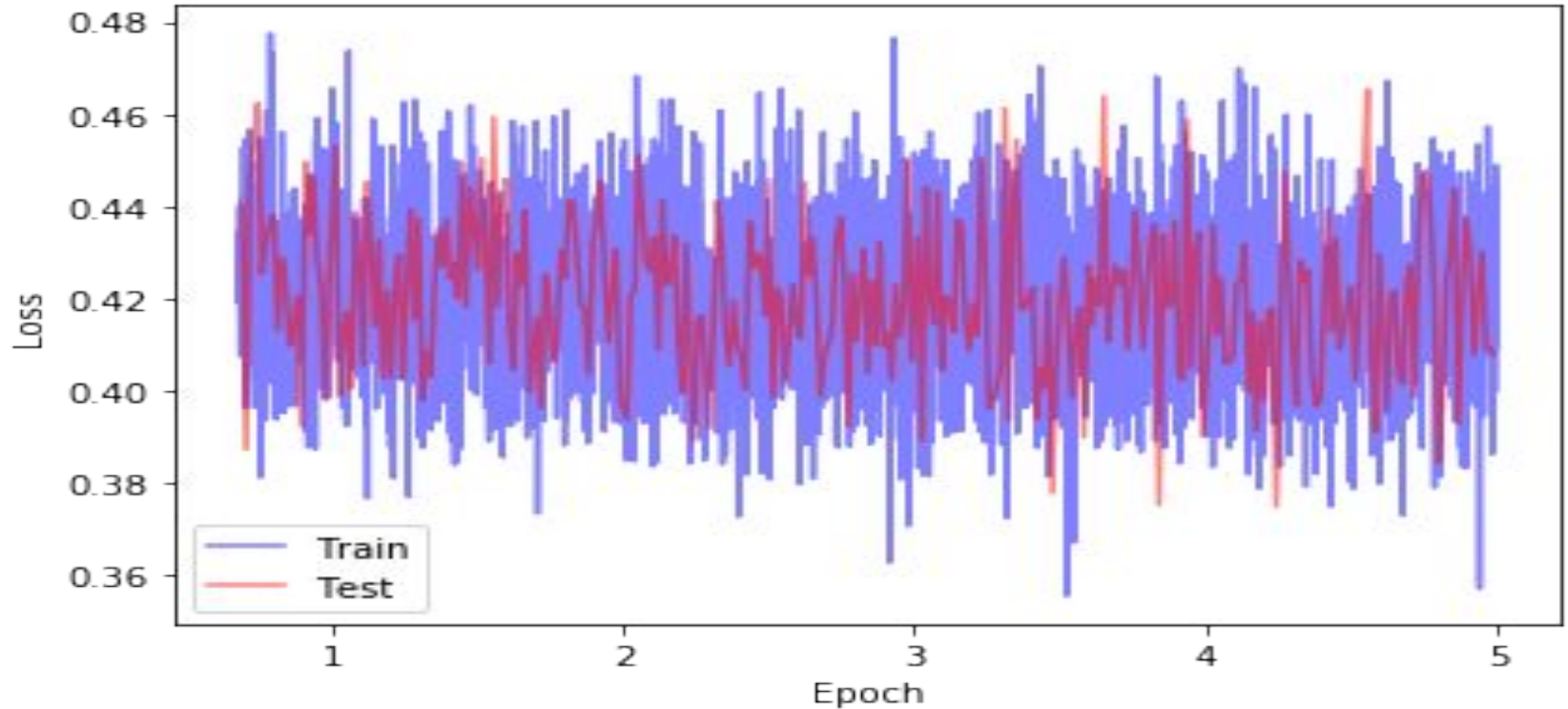
Expected mean charge (Predicted Charge X Predicted Hit Probability)



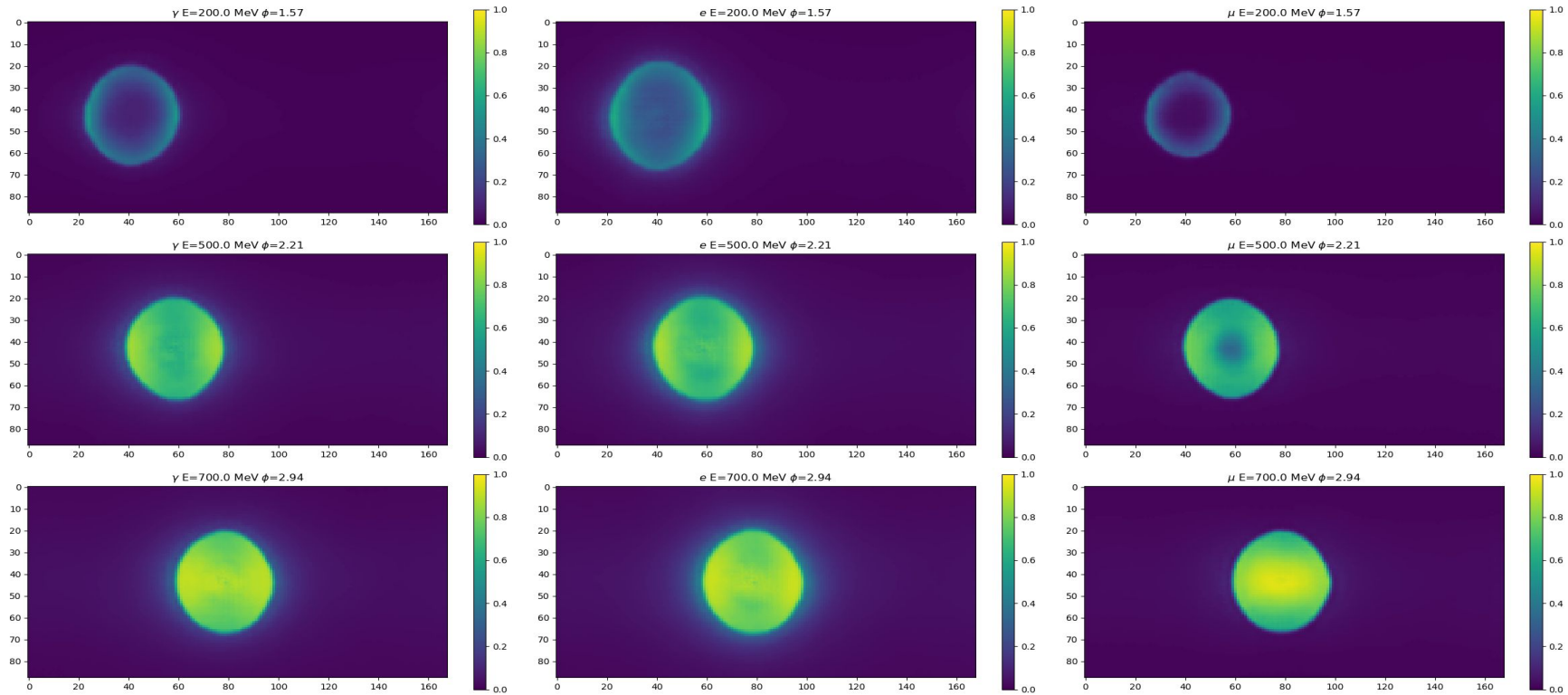
Predicted Variance of Charge



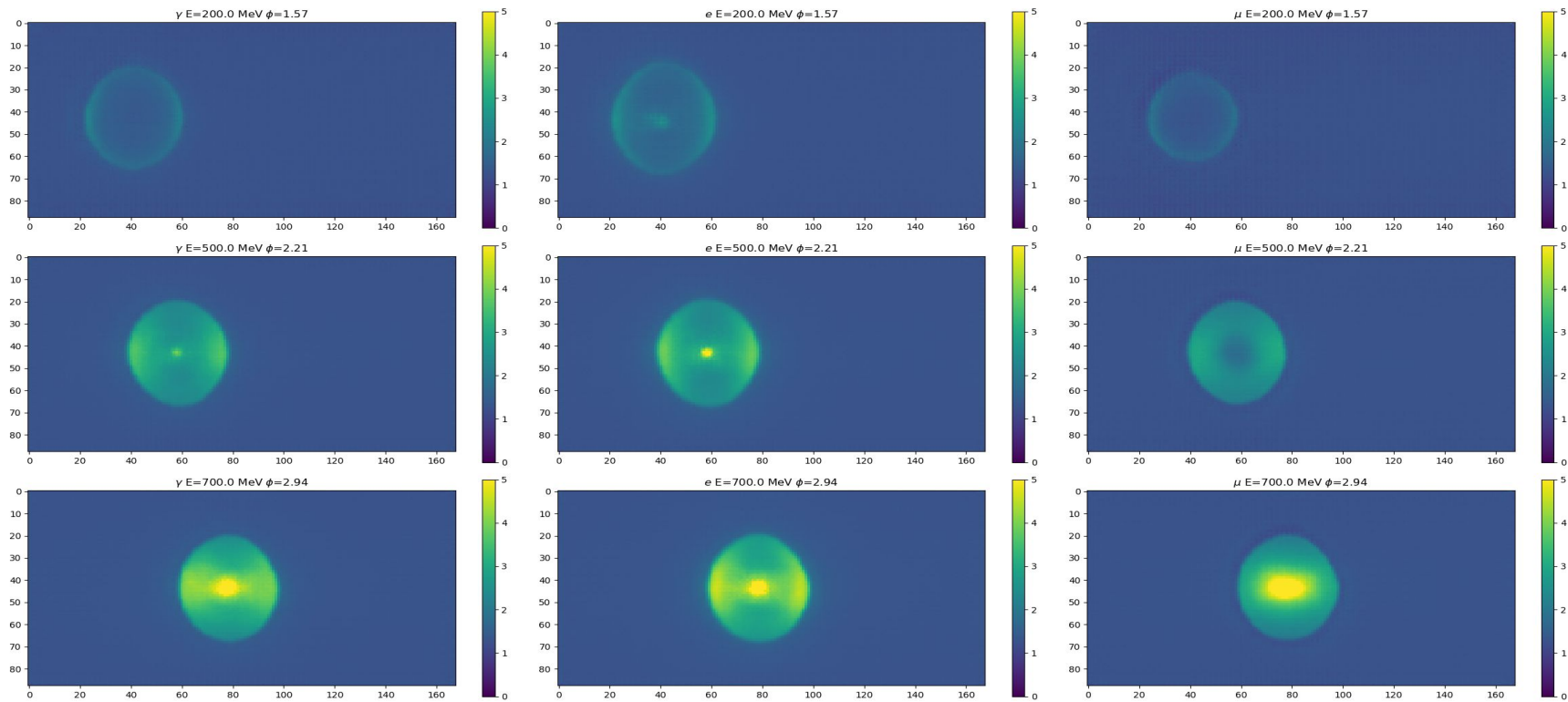
Layer 2(FC1), Node = 298, Time =



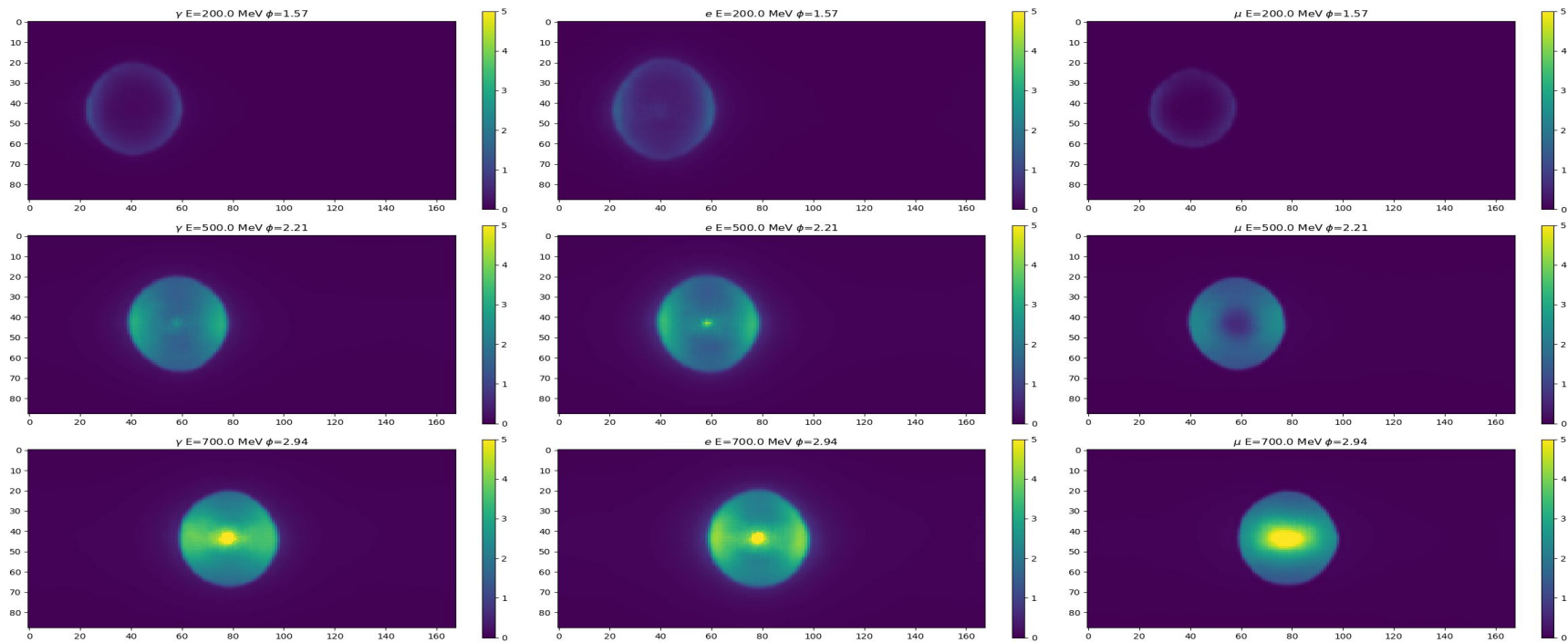
Predicted Hit Probability



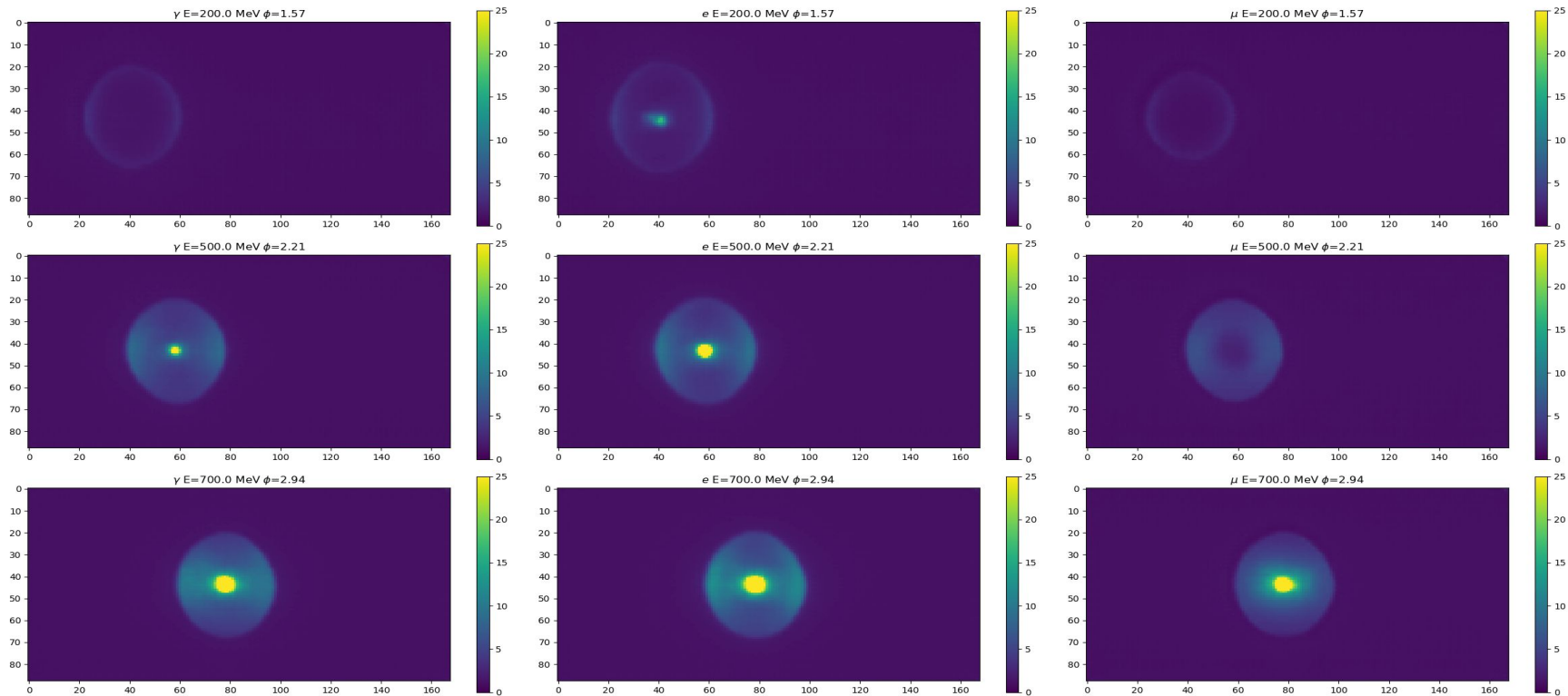
Predicted Charge



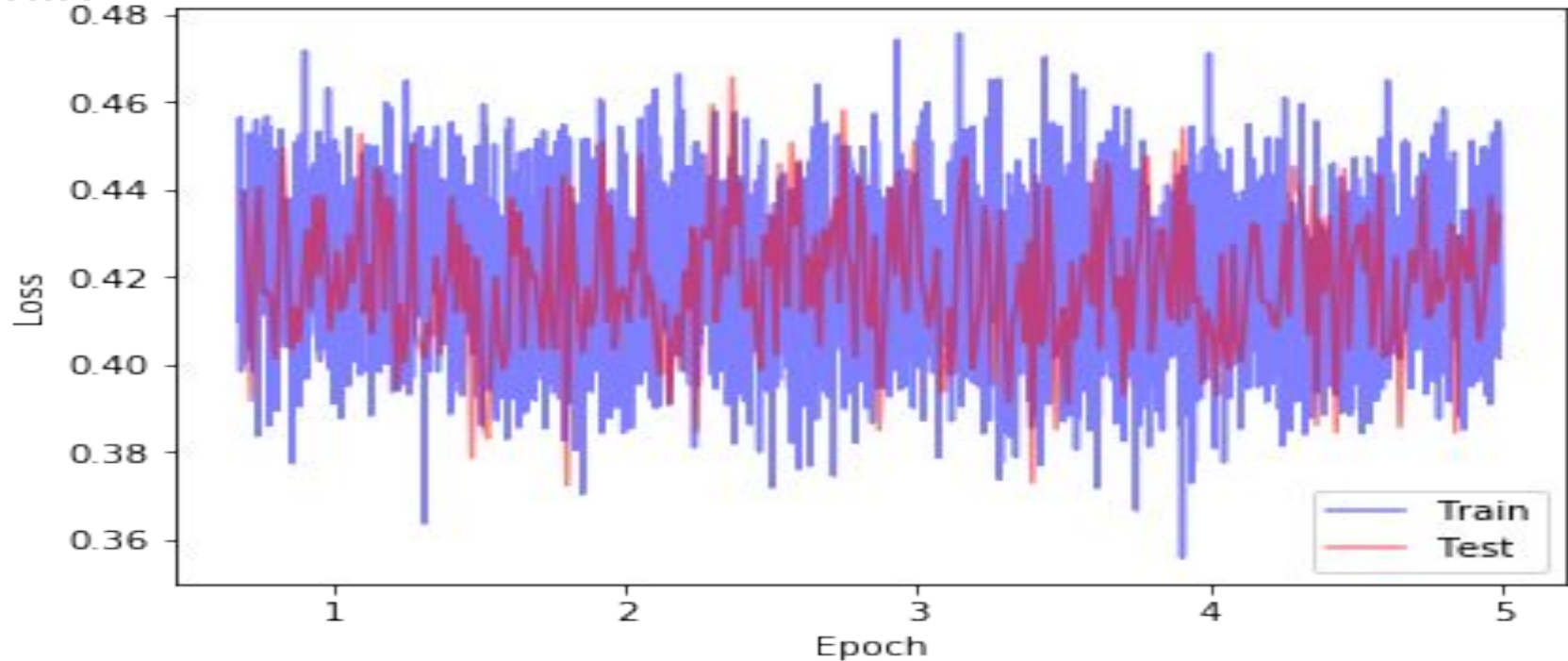
Expected mean charge (Predicted Charge X Predicted Hit Probability)



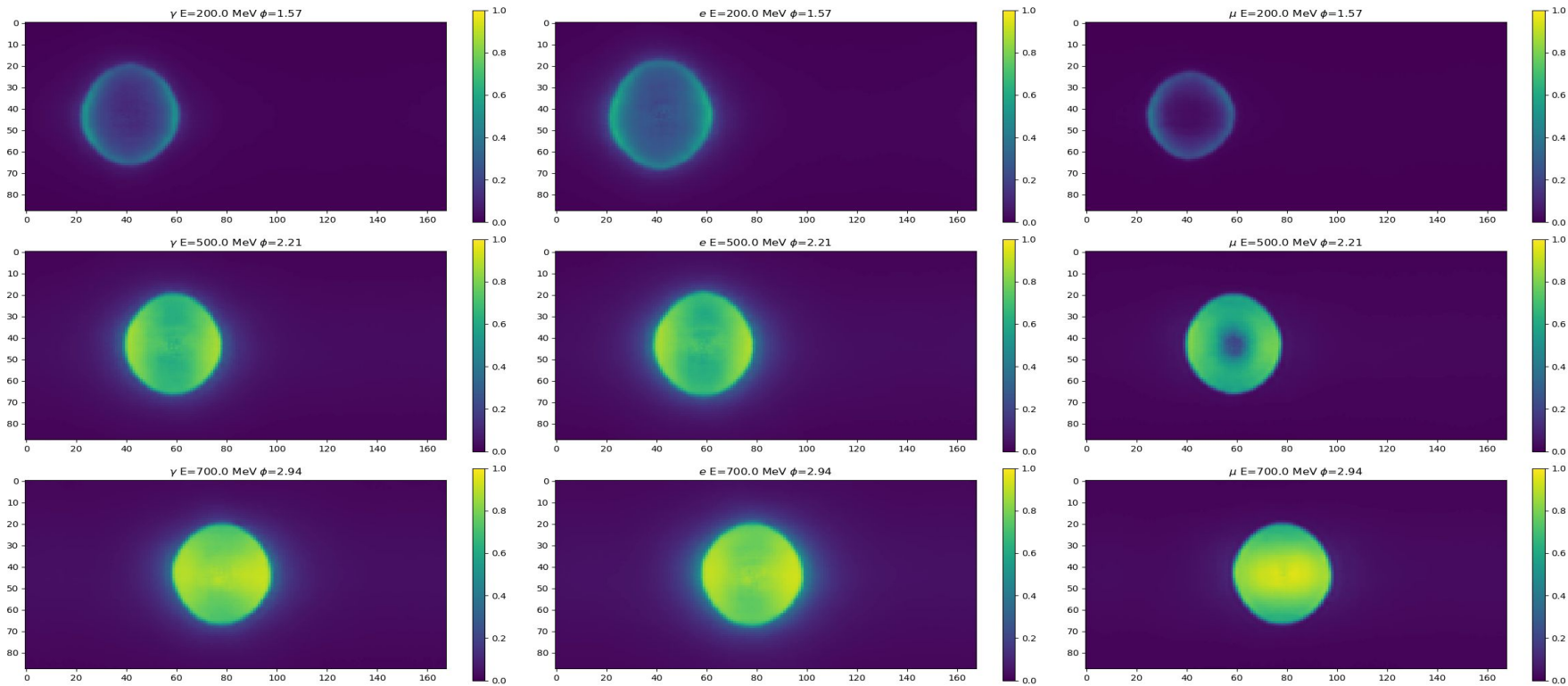
Predicted Variance of Charge



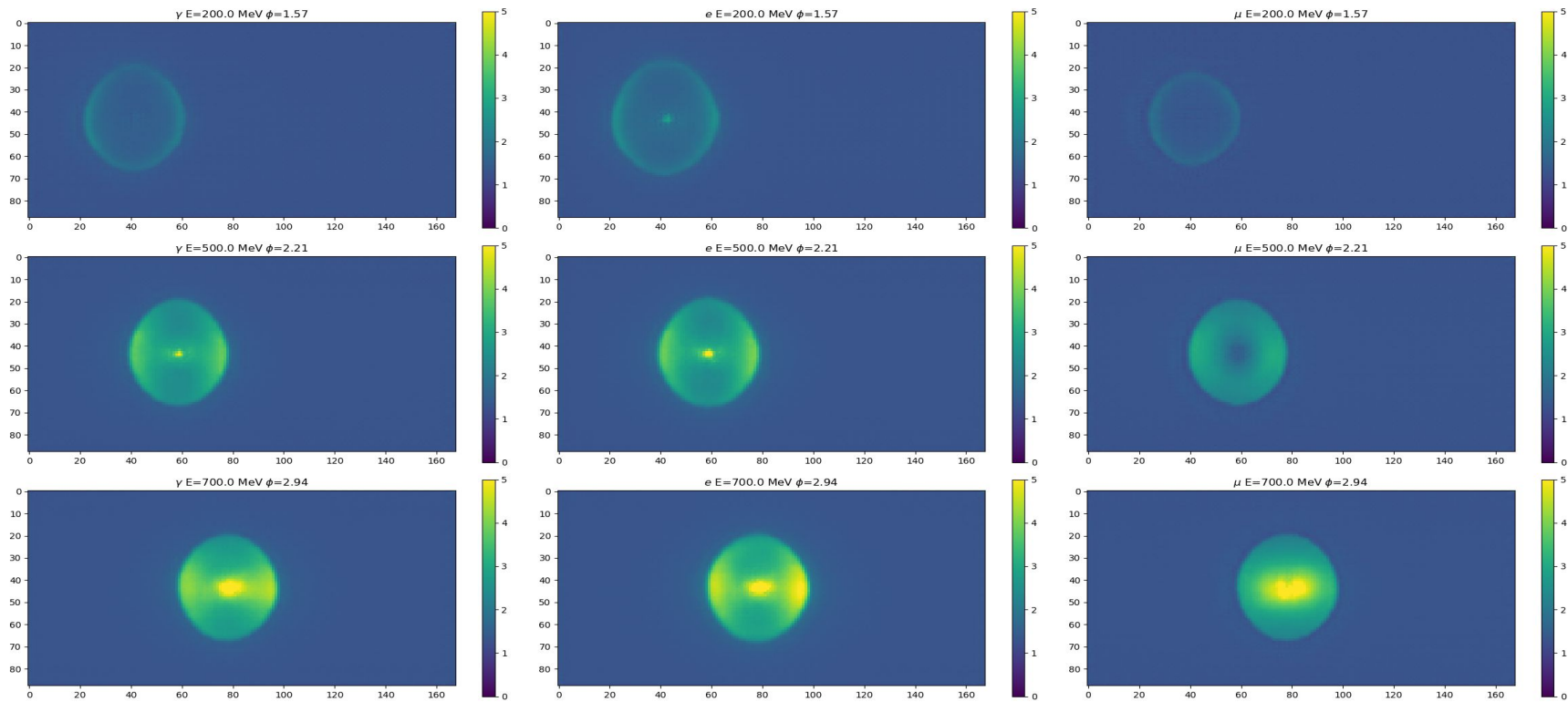
Layer 2(FC1), Node = 400, Time = 2 hours and 44 min



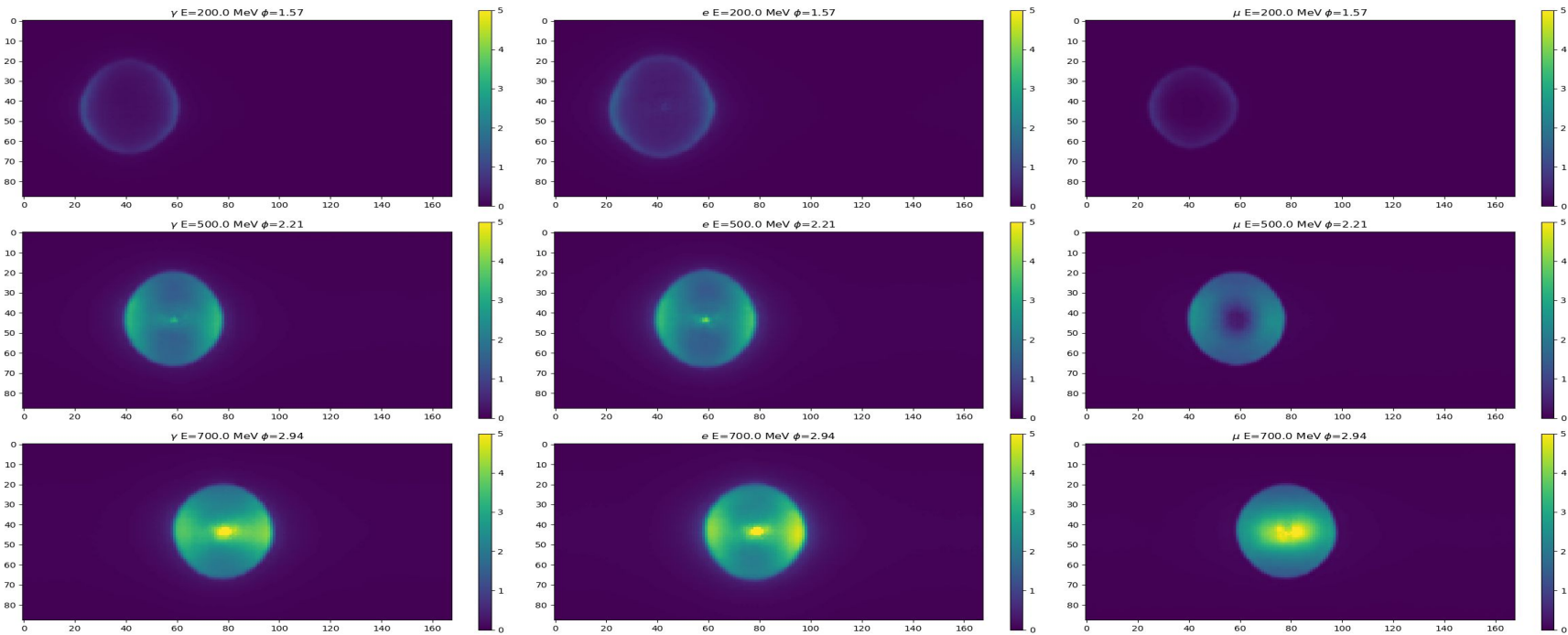
Predicted Hit Probability



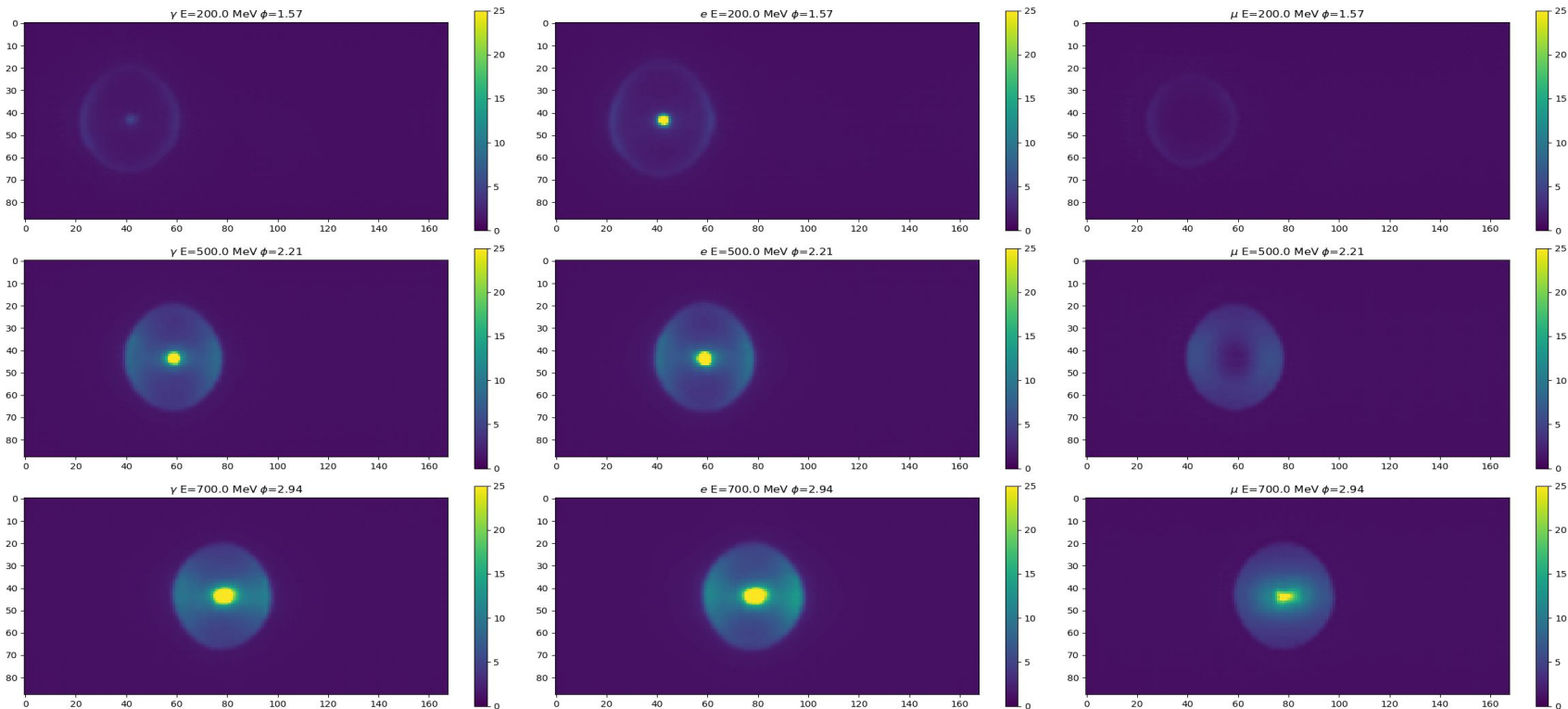
Predicted Charge



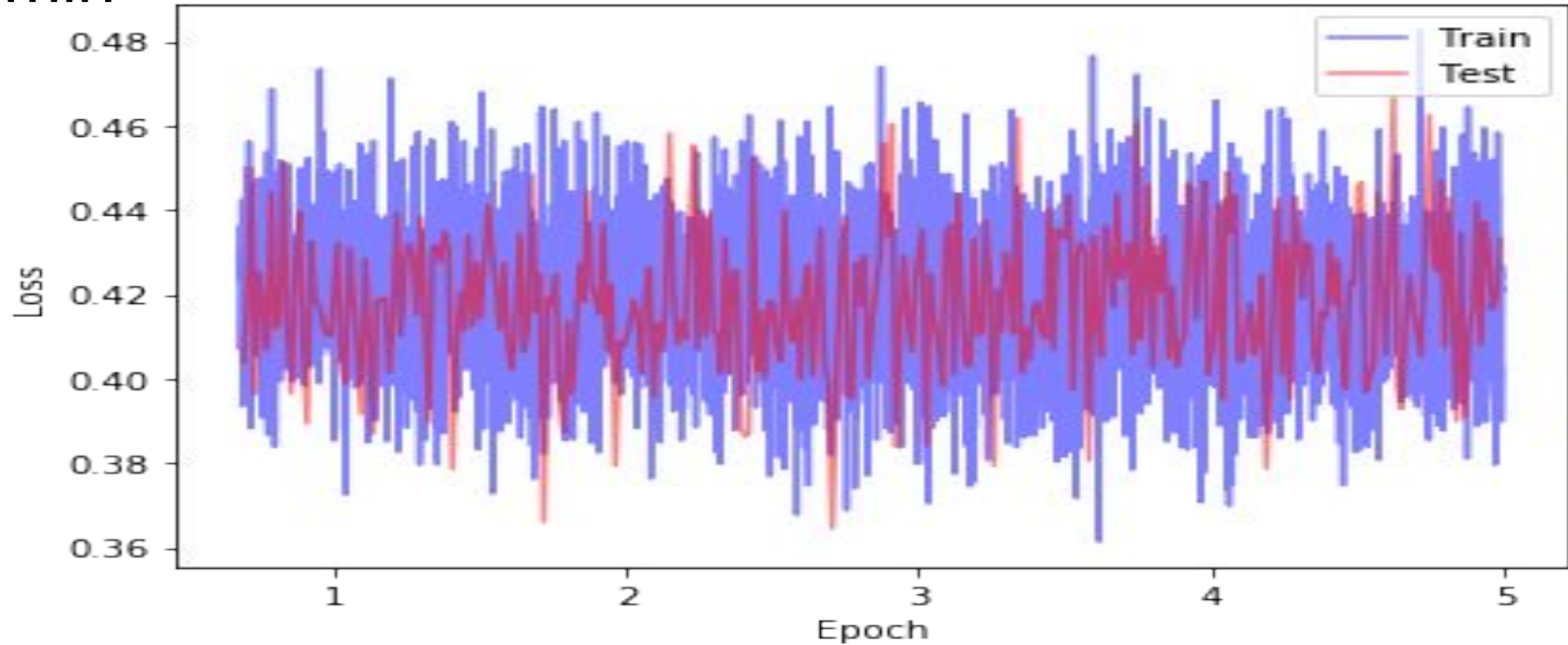
Expected mean charge (Predicted Charge X Predicted Hit Probability)



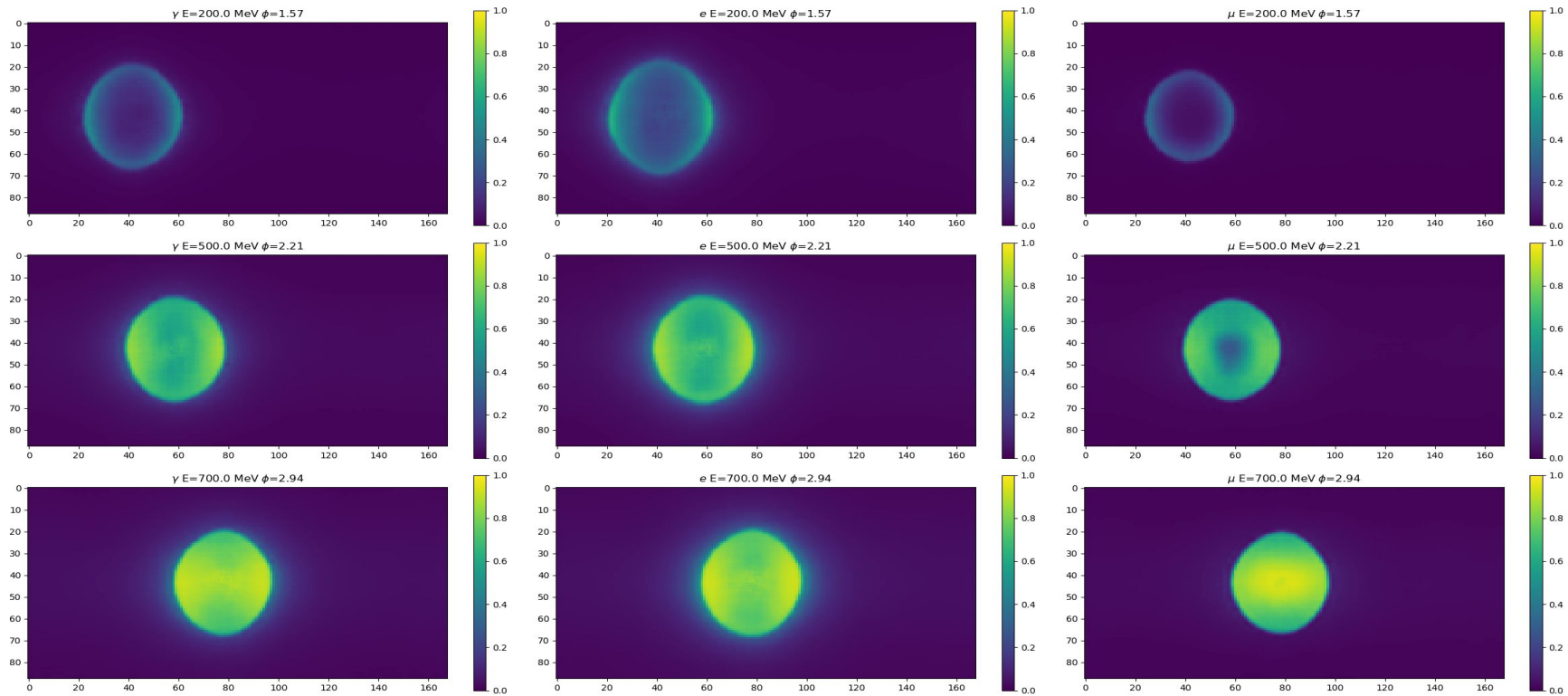
Predicted Variance of Charge



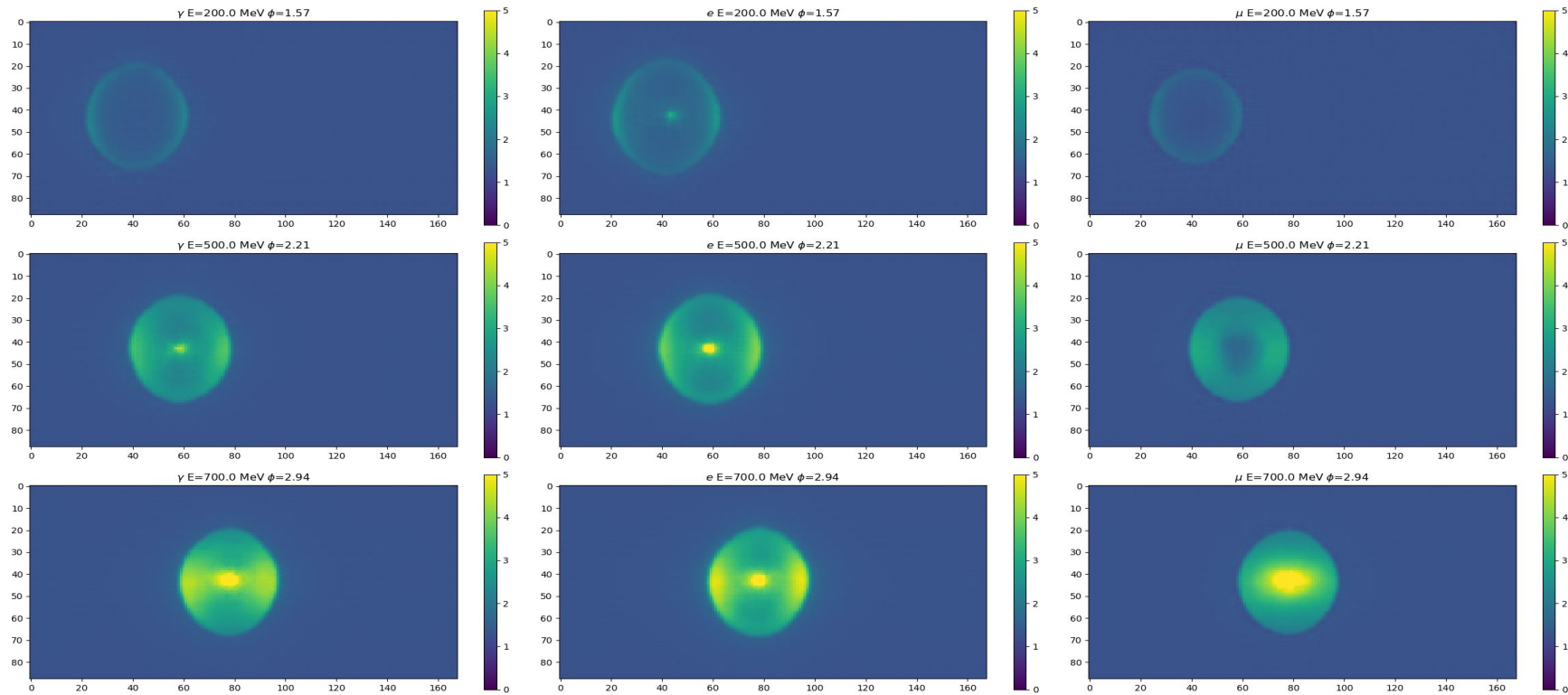
Layer 2(FC1), Node = 516 , Time = 2 hours and 43 min



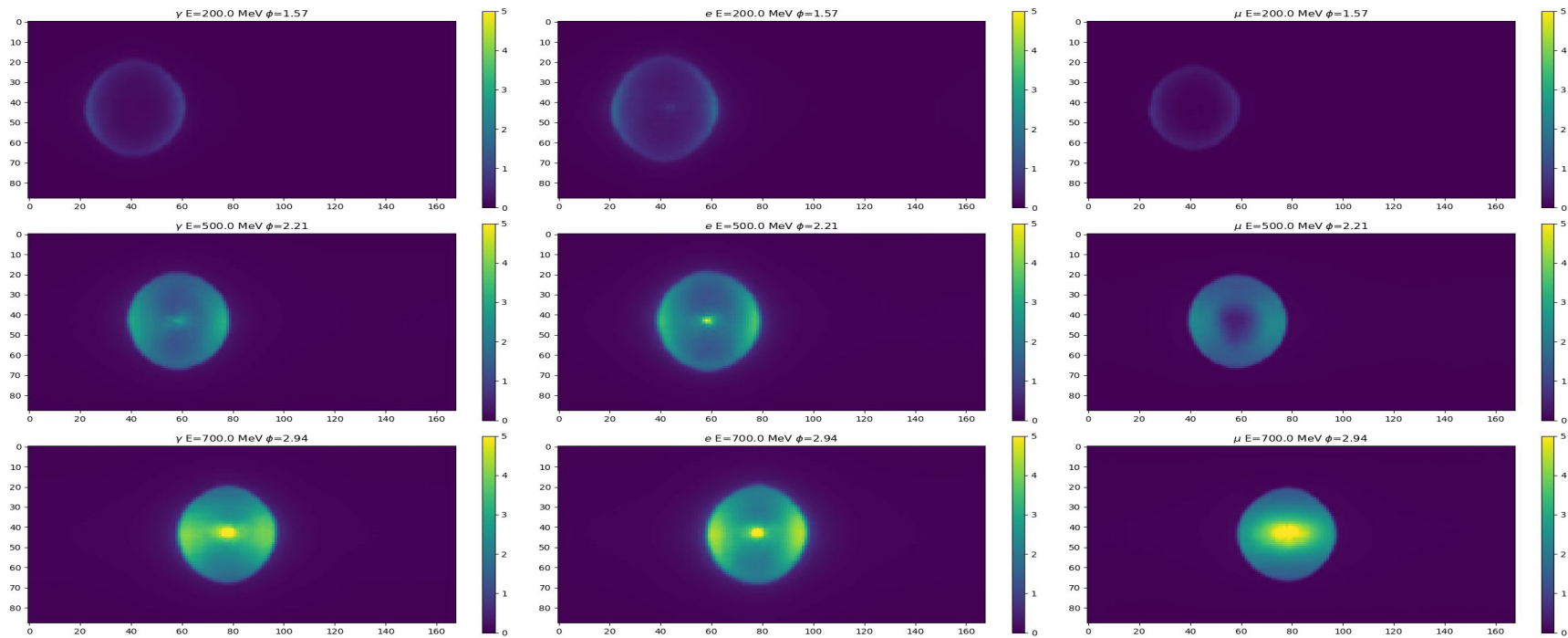
Predicted Hit Probability



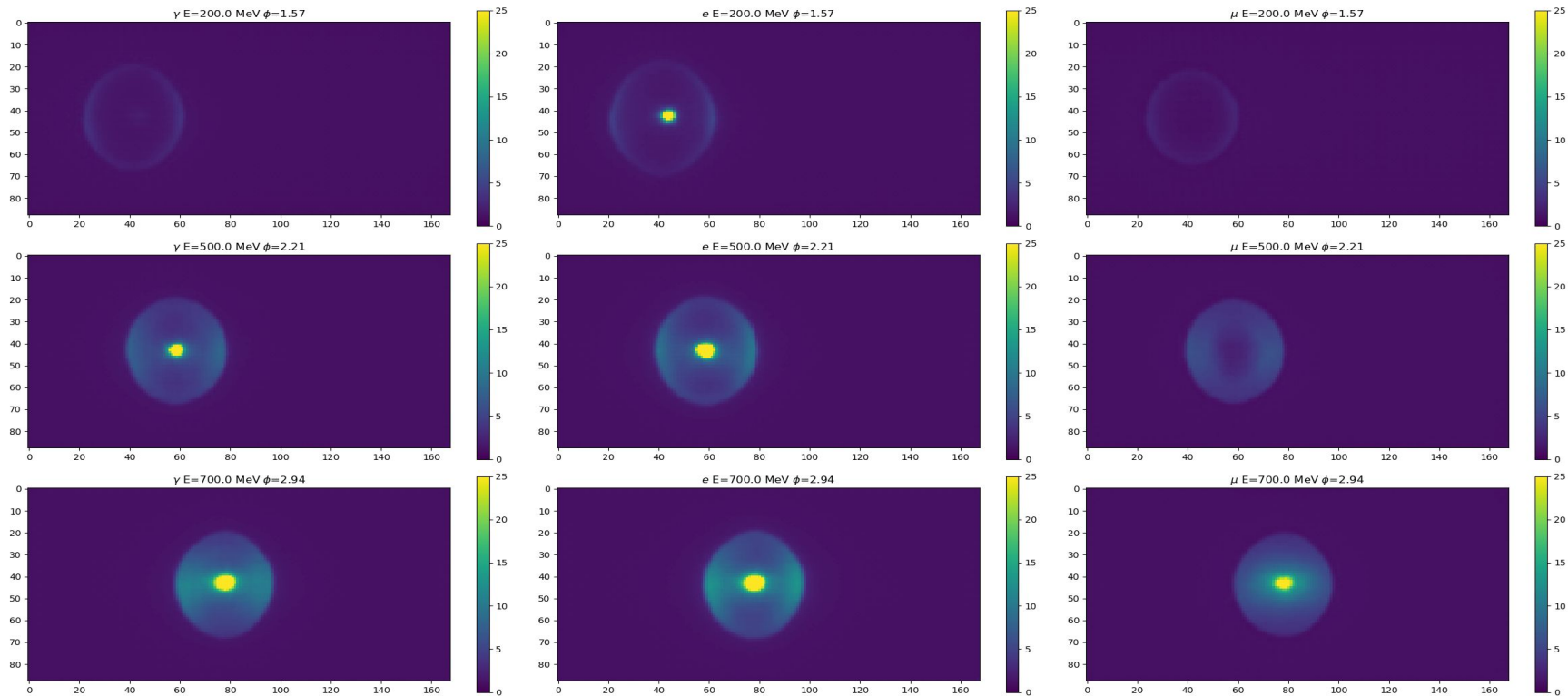
Predicted Charge



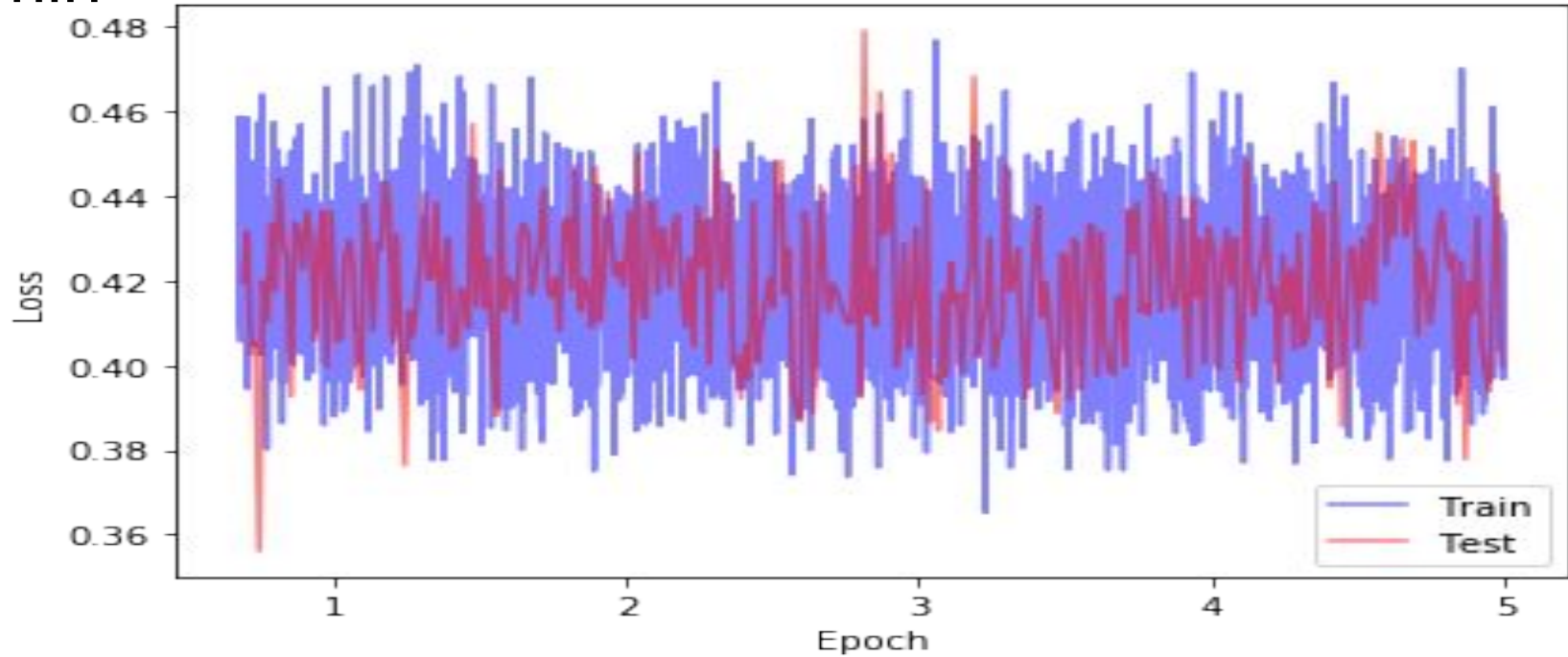
Expected mean charge (Predicted Charge X Predicted Hit Probability)



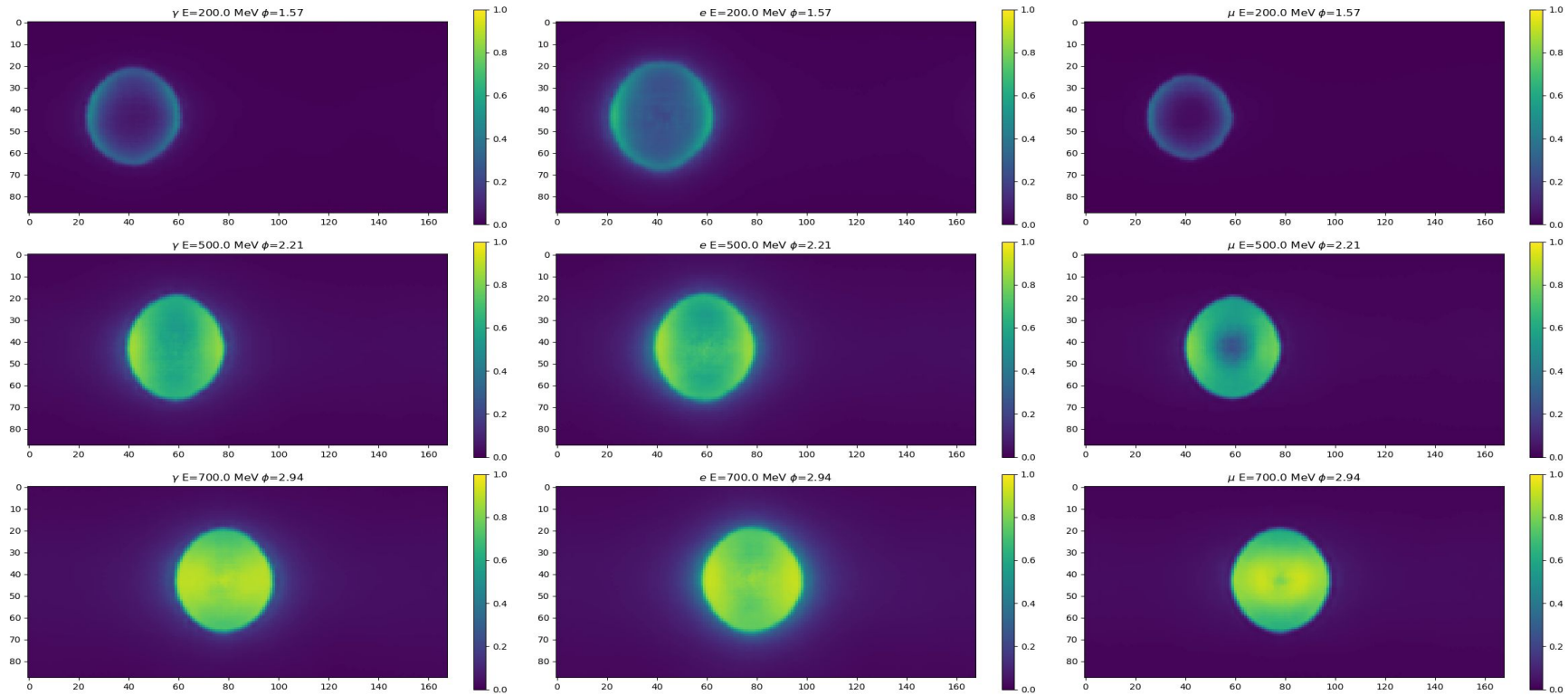
Predicted Variance of Charge



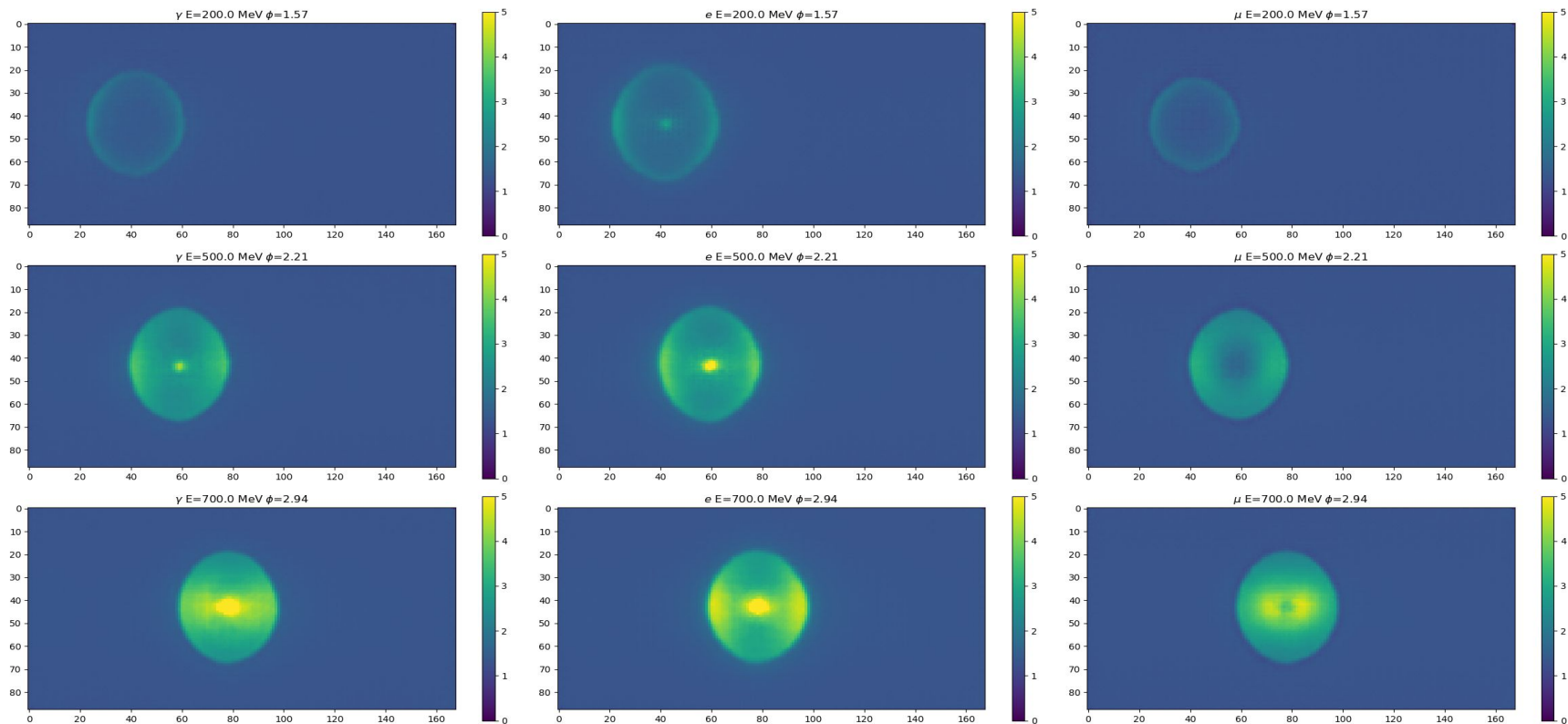
Layer 2(FC1), Node = 800, Time = 2 hours and 43 min



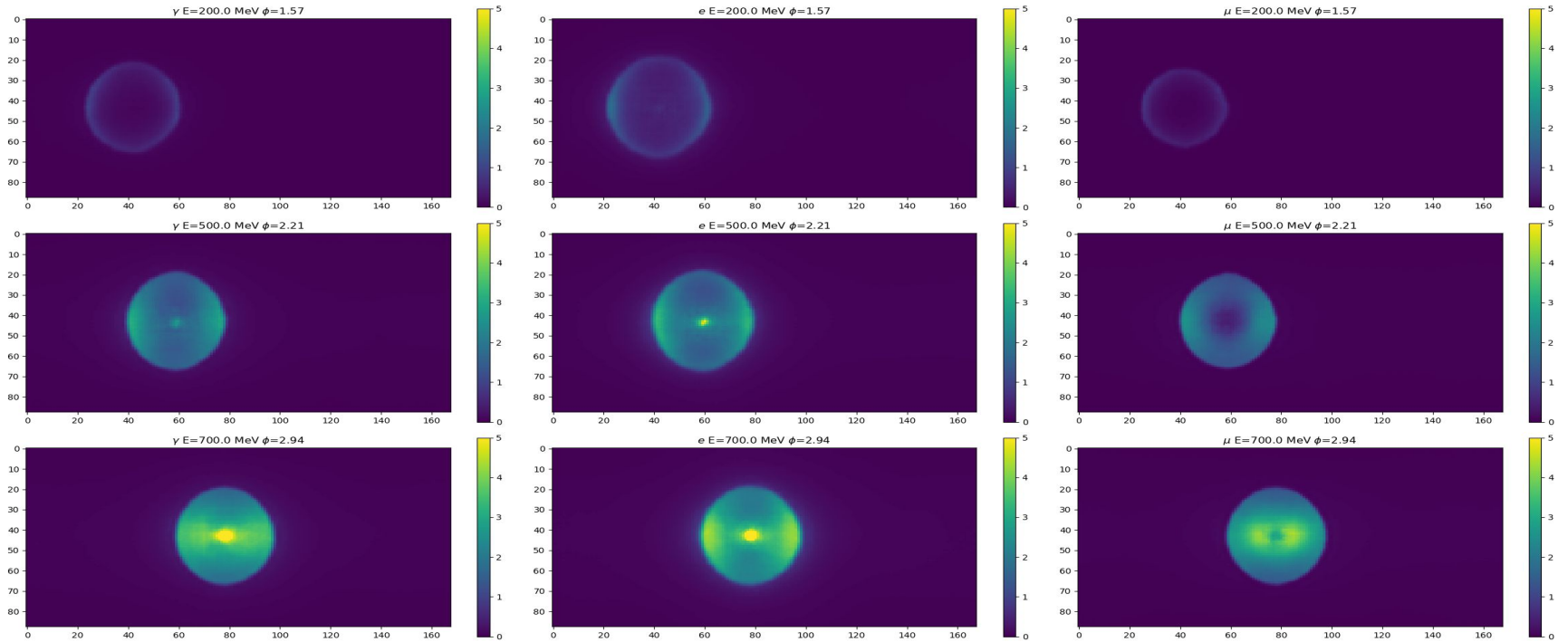
Predicted Hit Probability



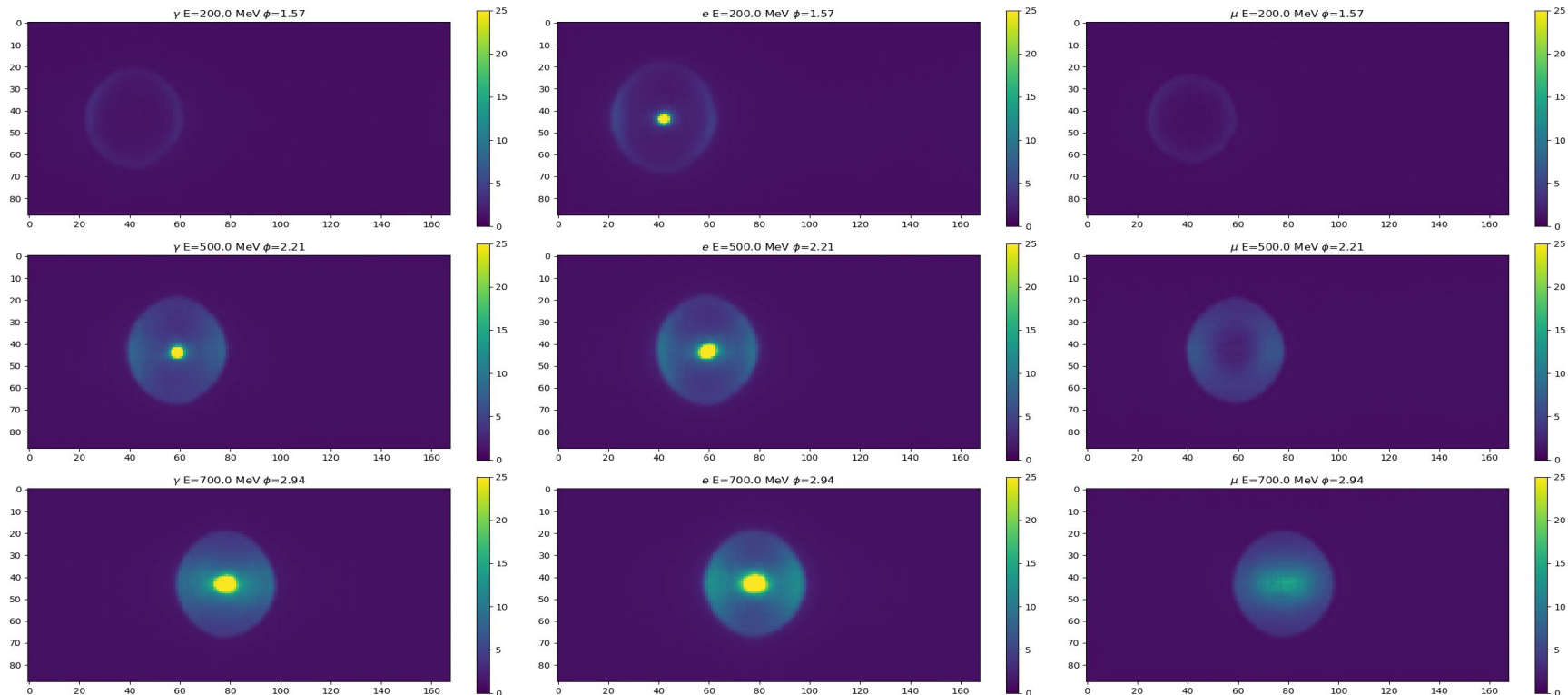
Predicted Charge



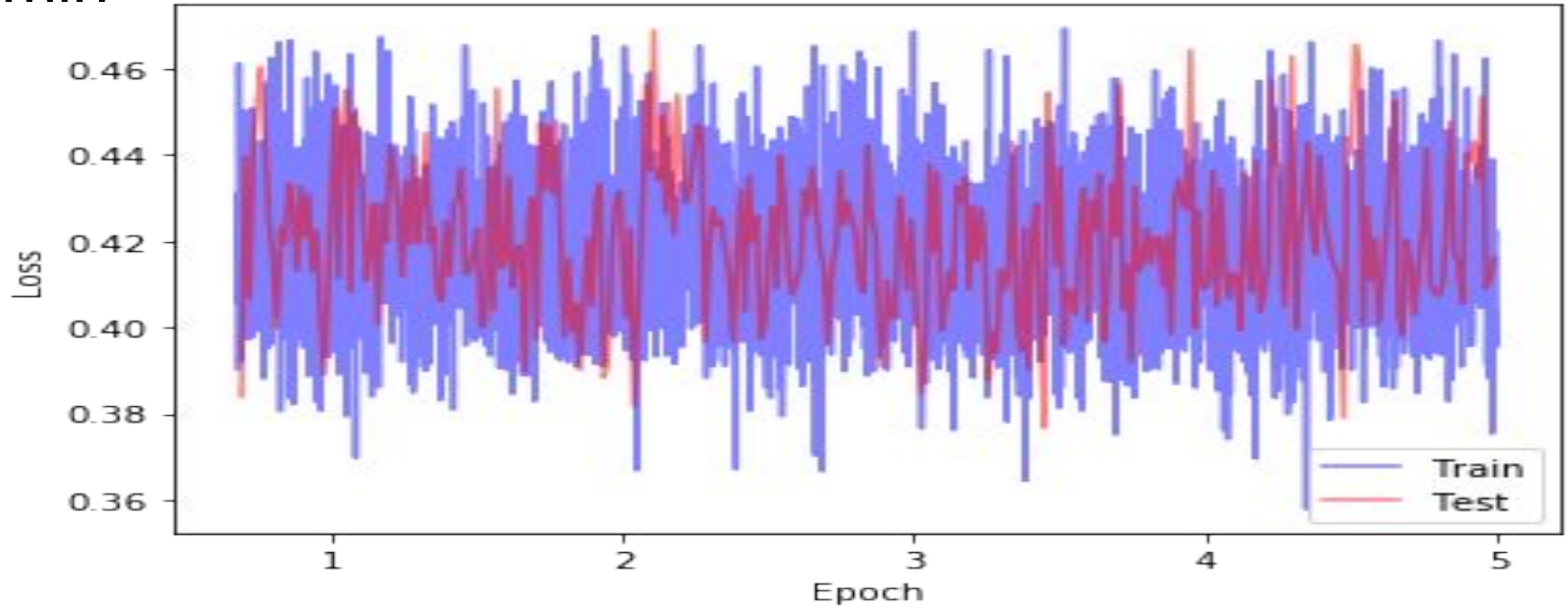
Expected mean charge (Predicted Charge X Predicted Hit Probability)



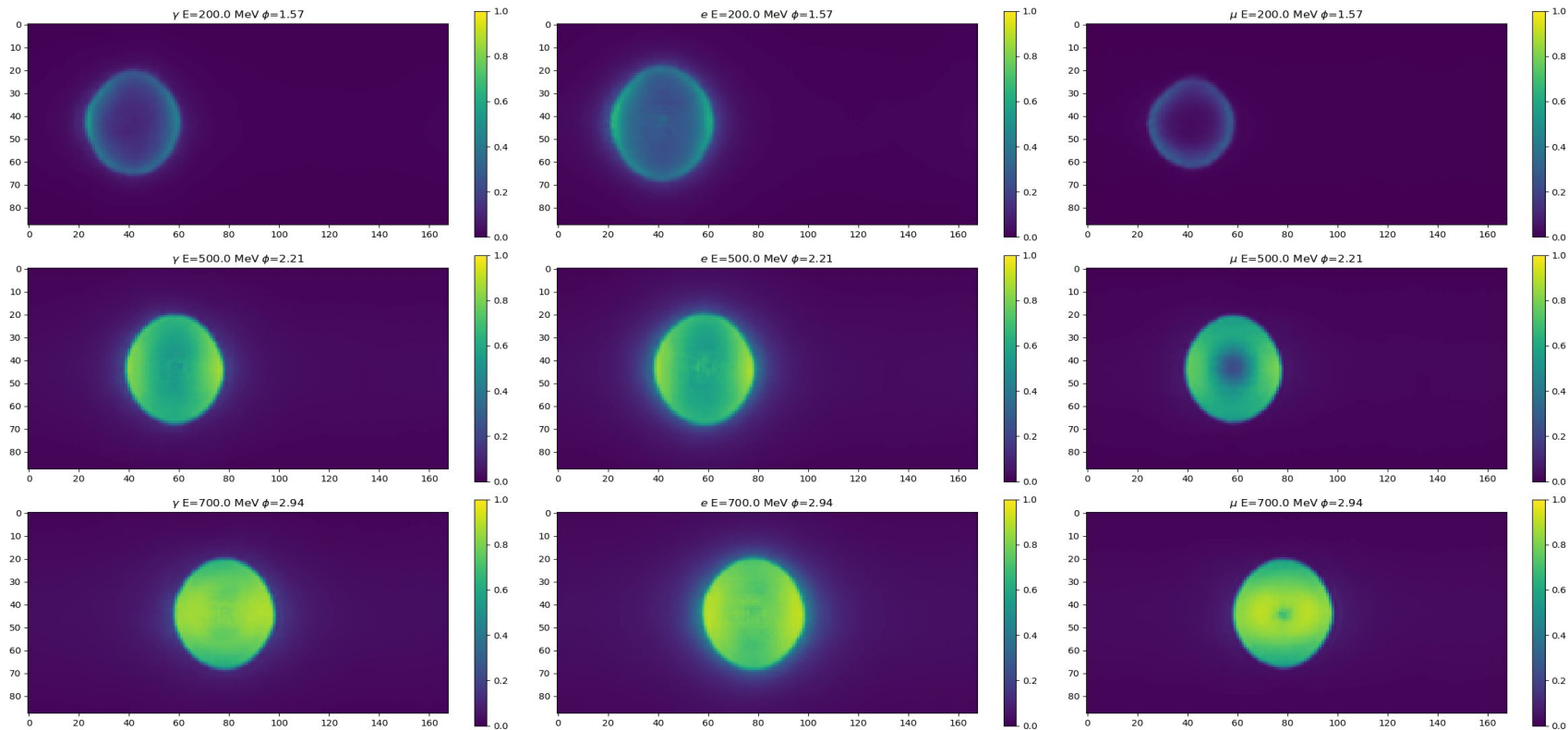
Predicted Variance of Charge



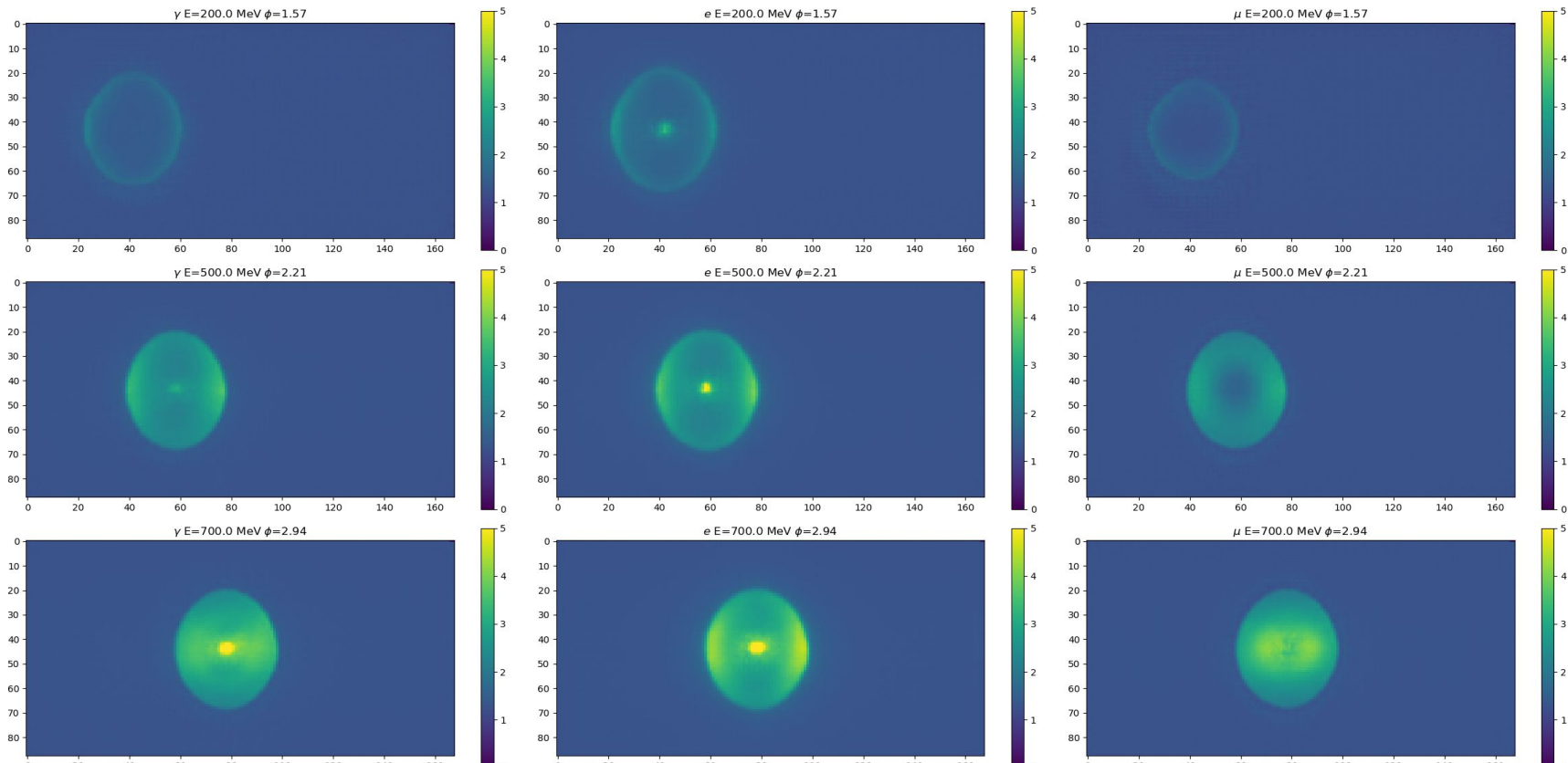
Layer 2(FC1), Node = 1000 , Time = 2 hours and 43 min



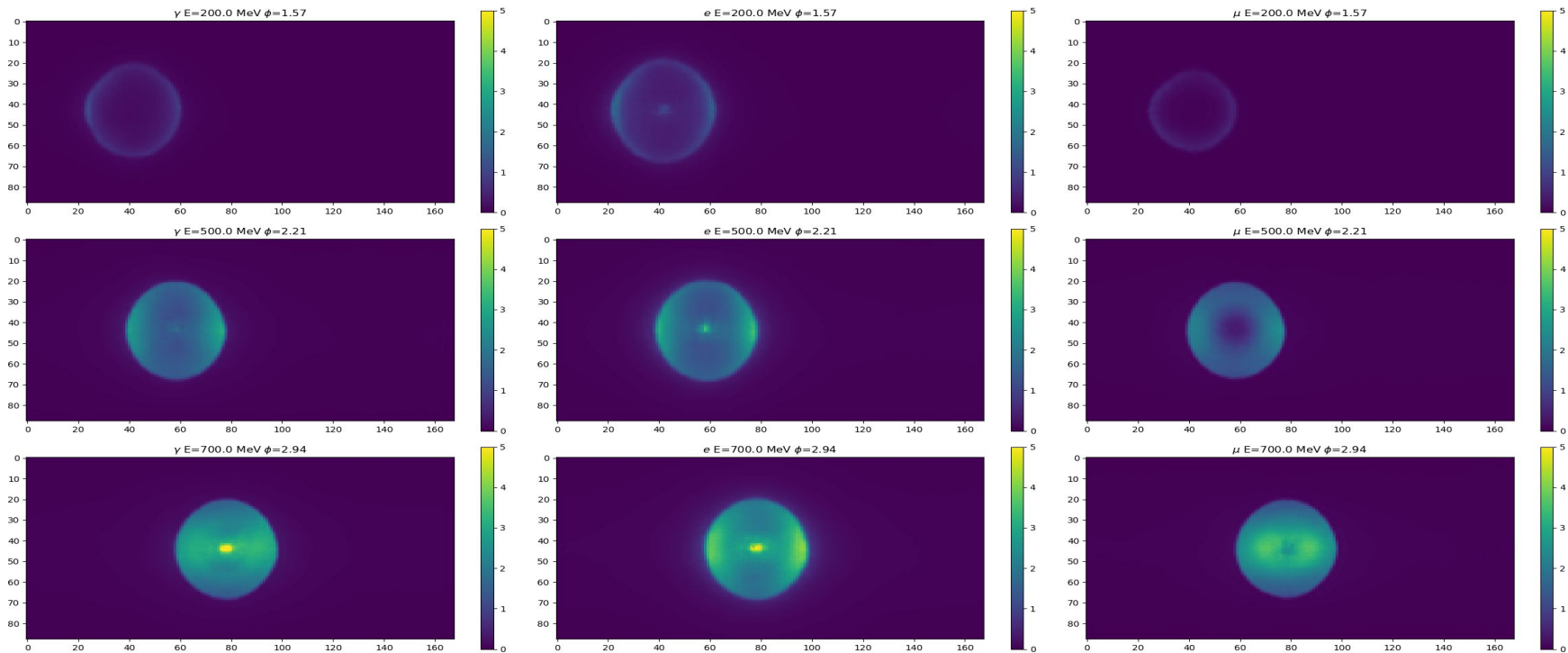
Predicted Hit Probability



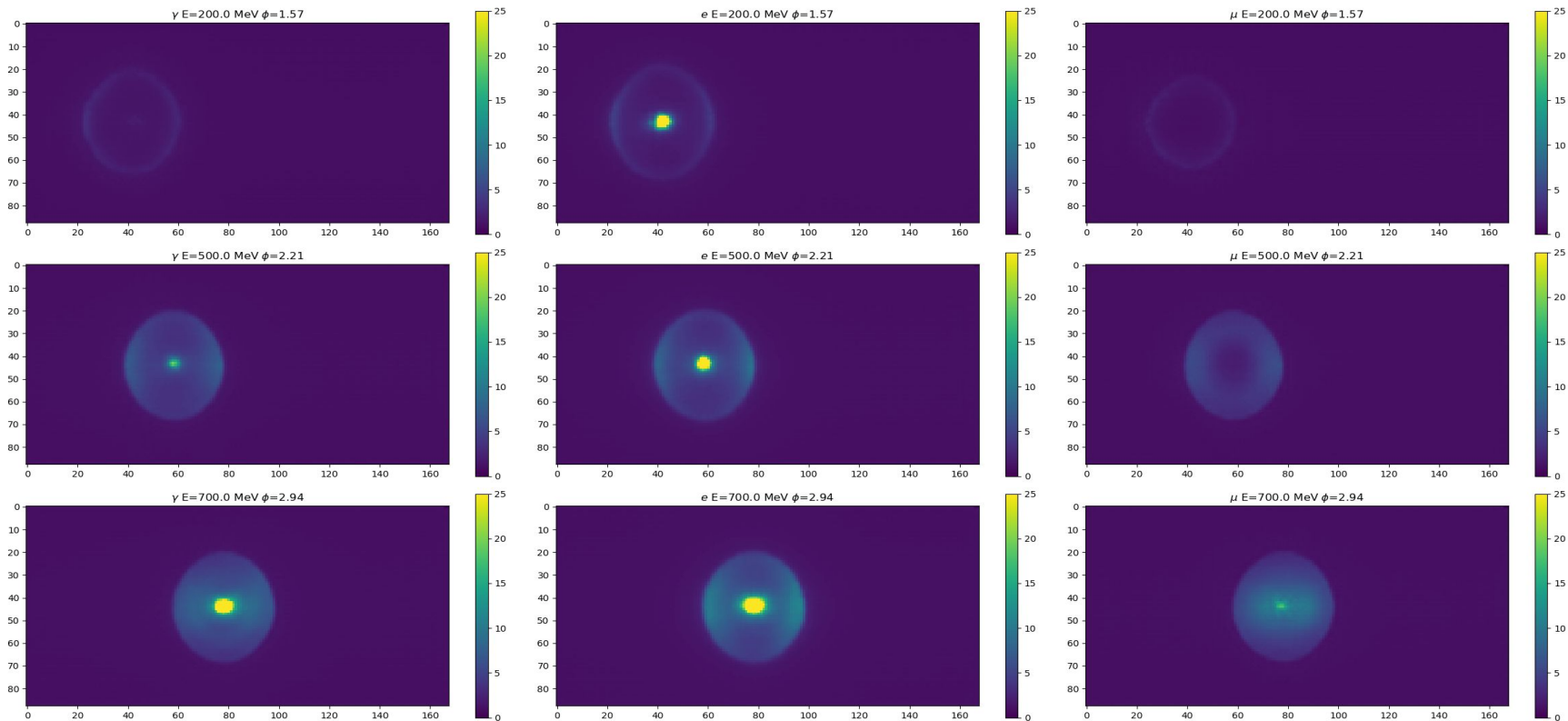
Predicted Charge



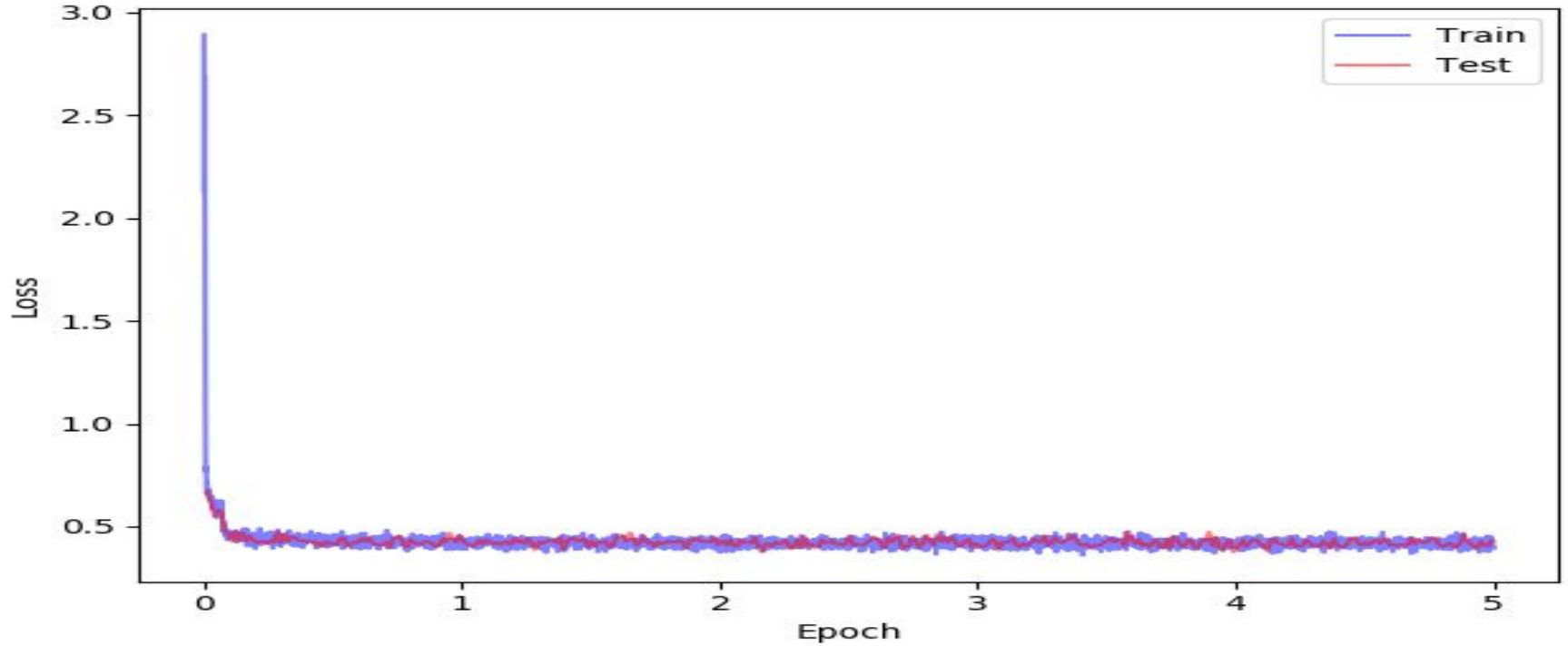
Expected mean charge (Predicted Charge X Predicted Hit Probability)



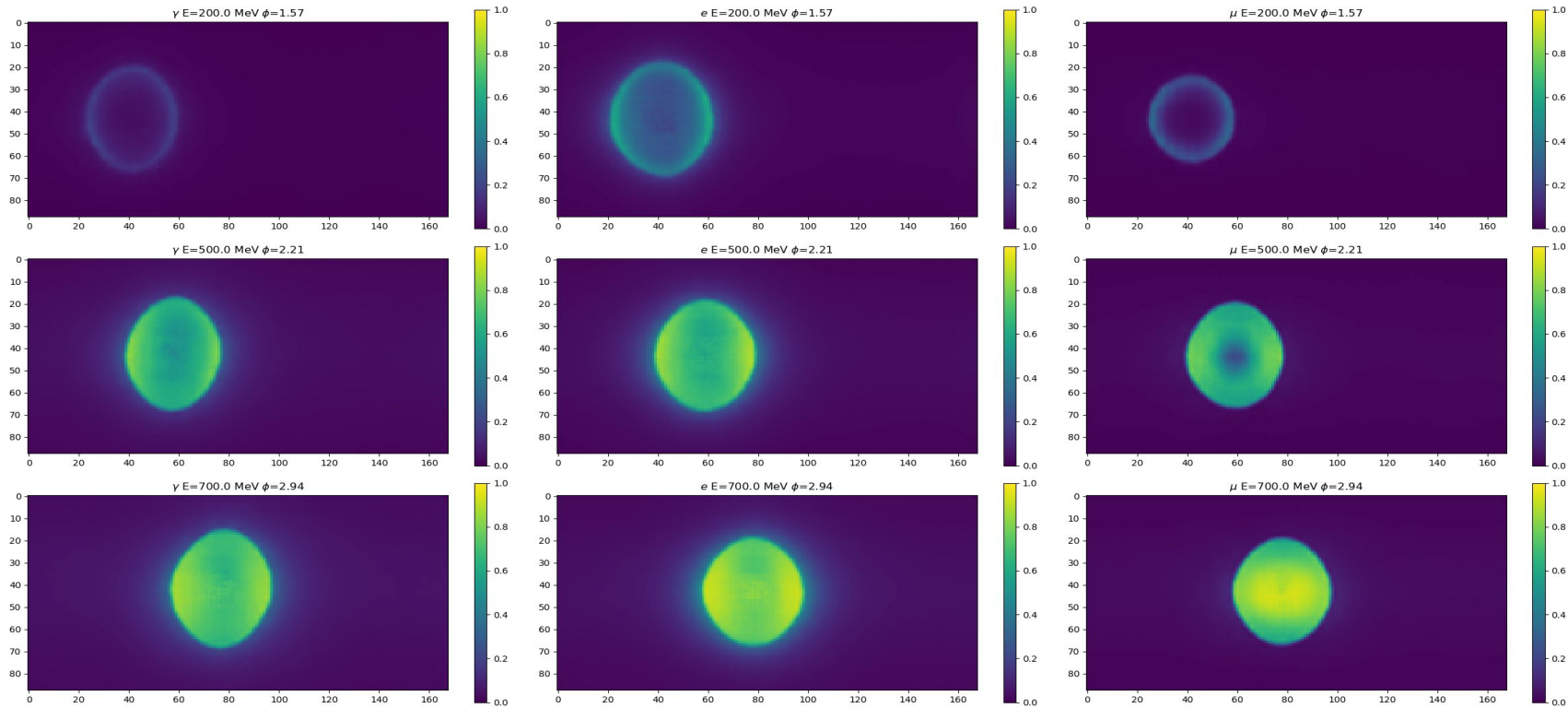
Predicted Variance of Charge



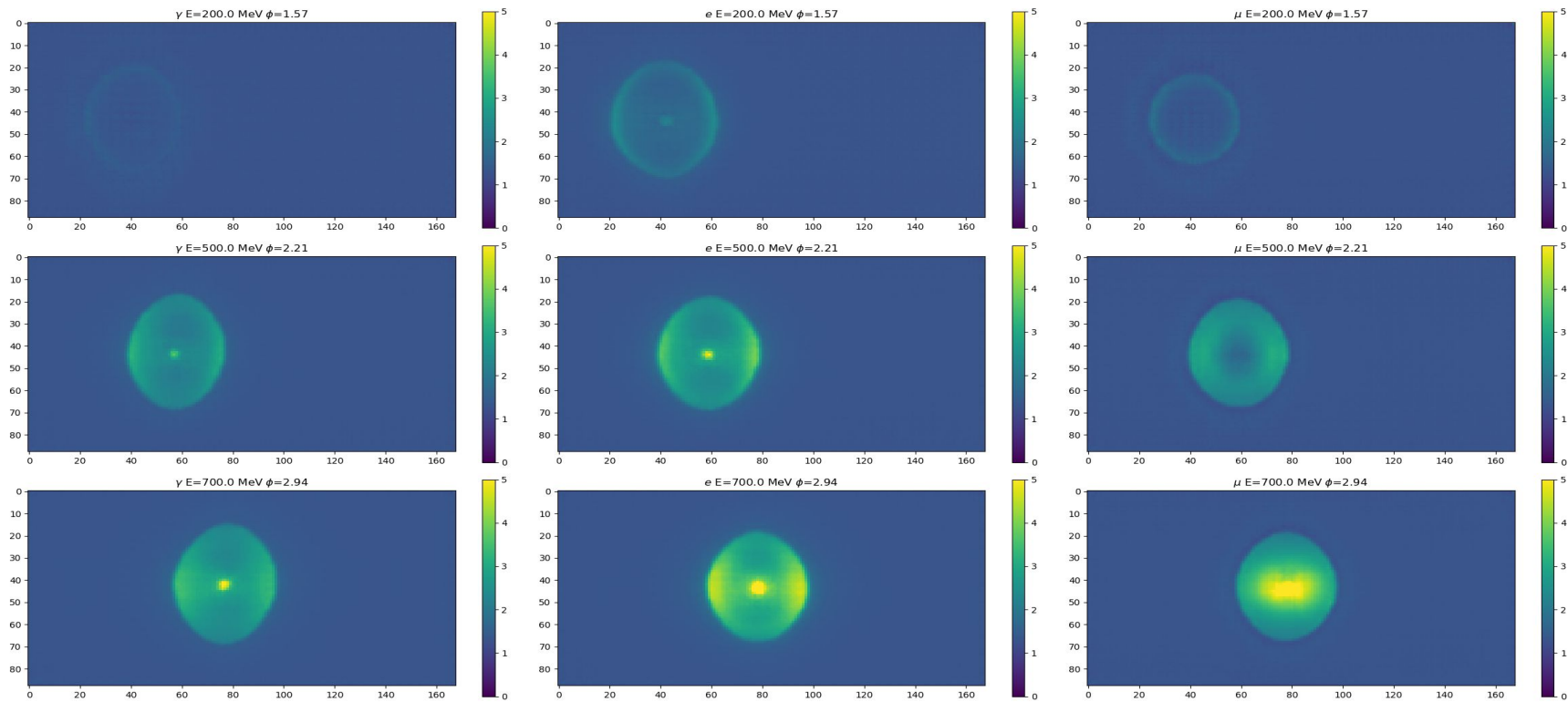
Without layer 2(FC1), Time = 3 hours and 25 min



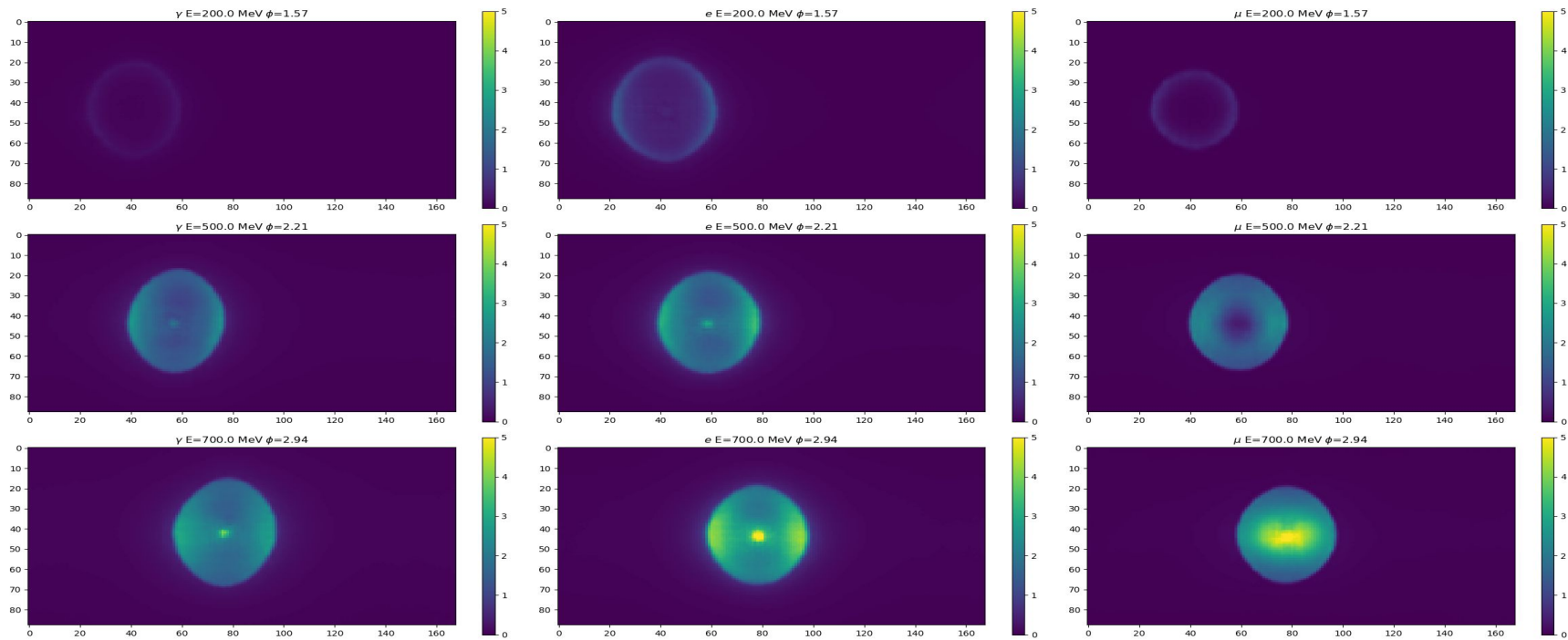
Predicted Hit Probability



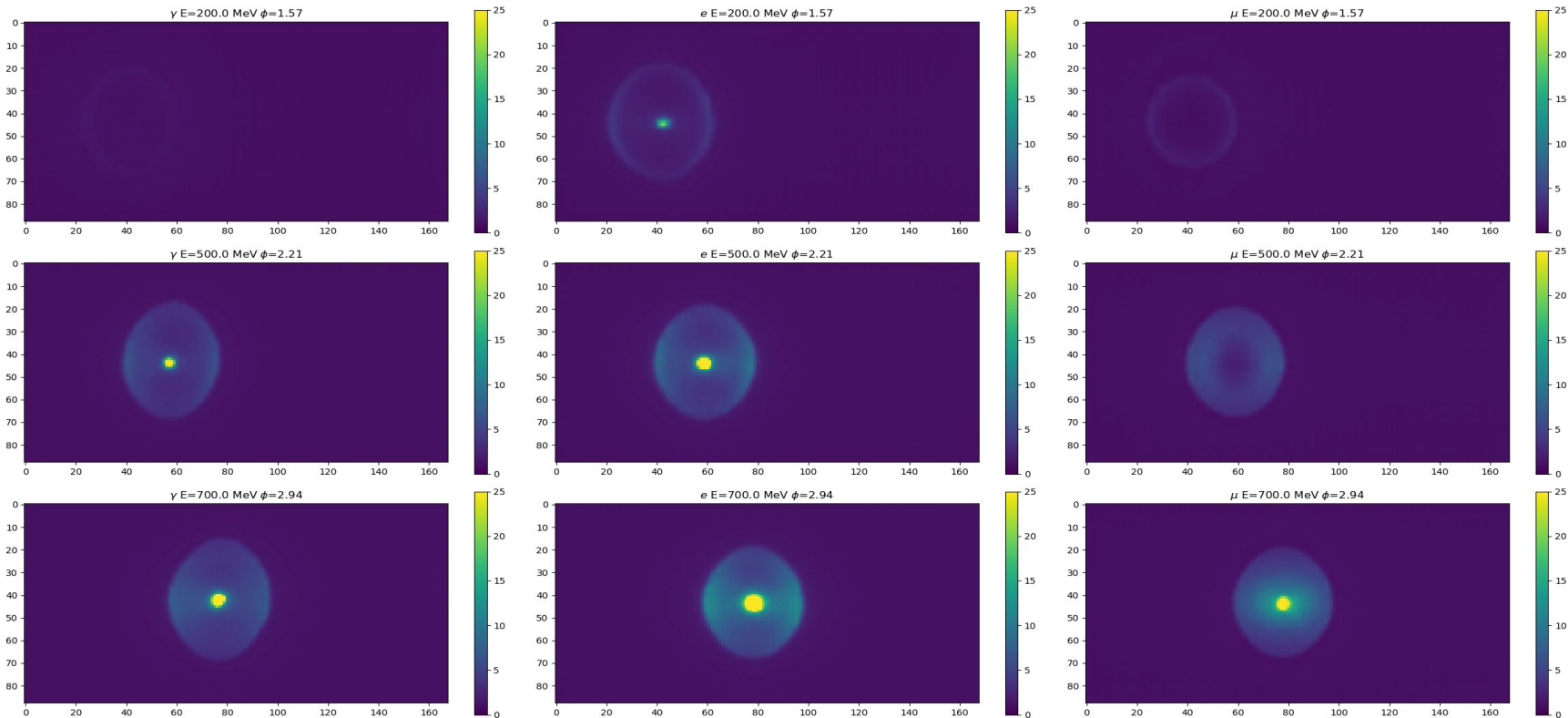
Predicted Charge



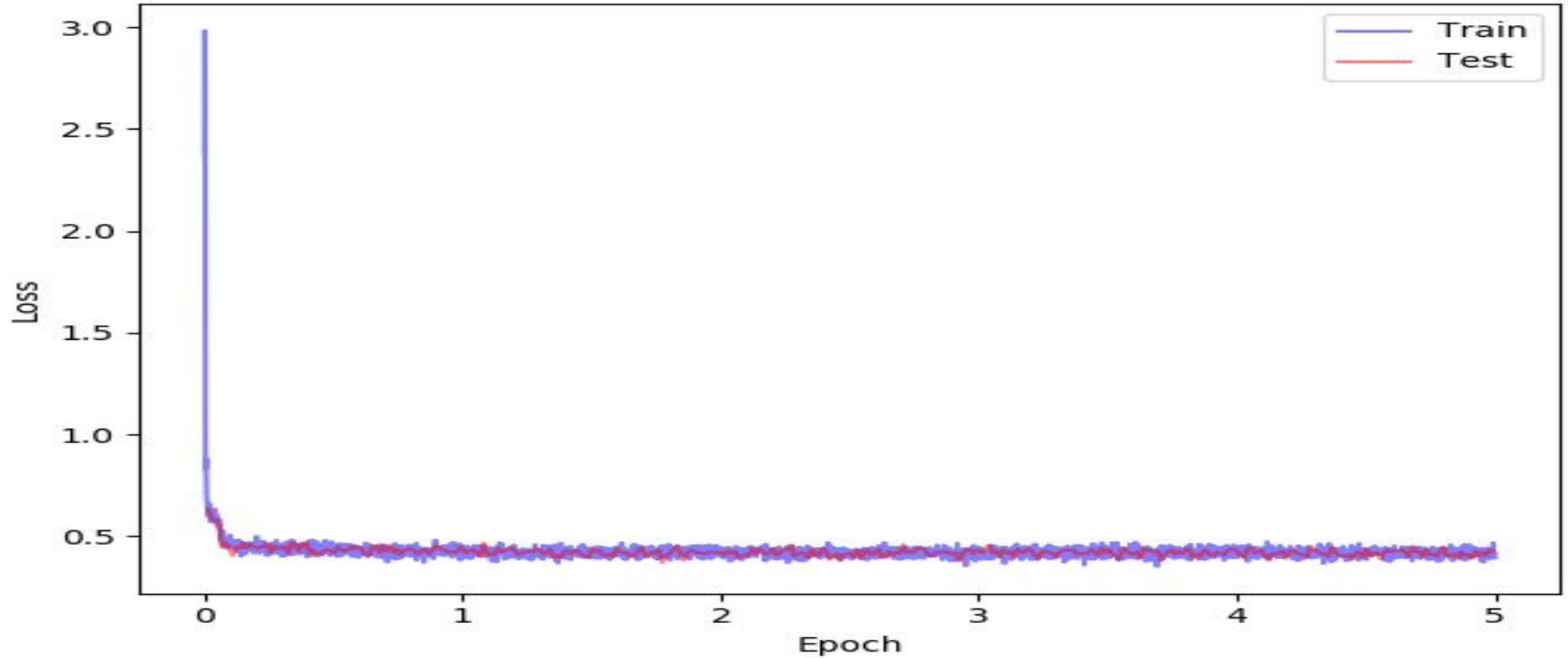
Expected mean charge (Predicted Charge X Predicted Hit Probability)



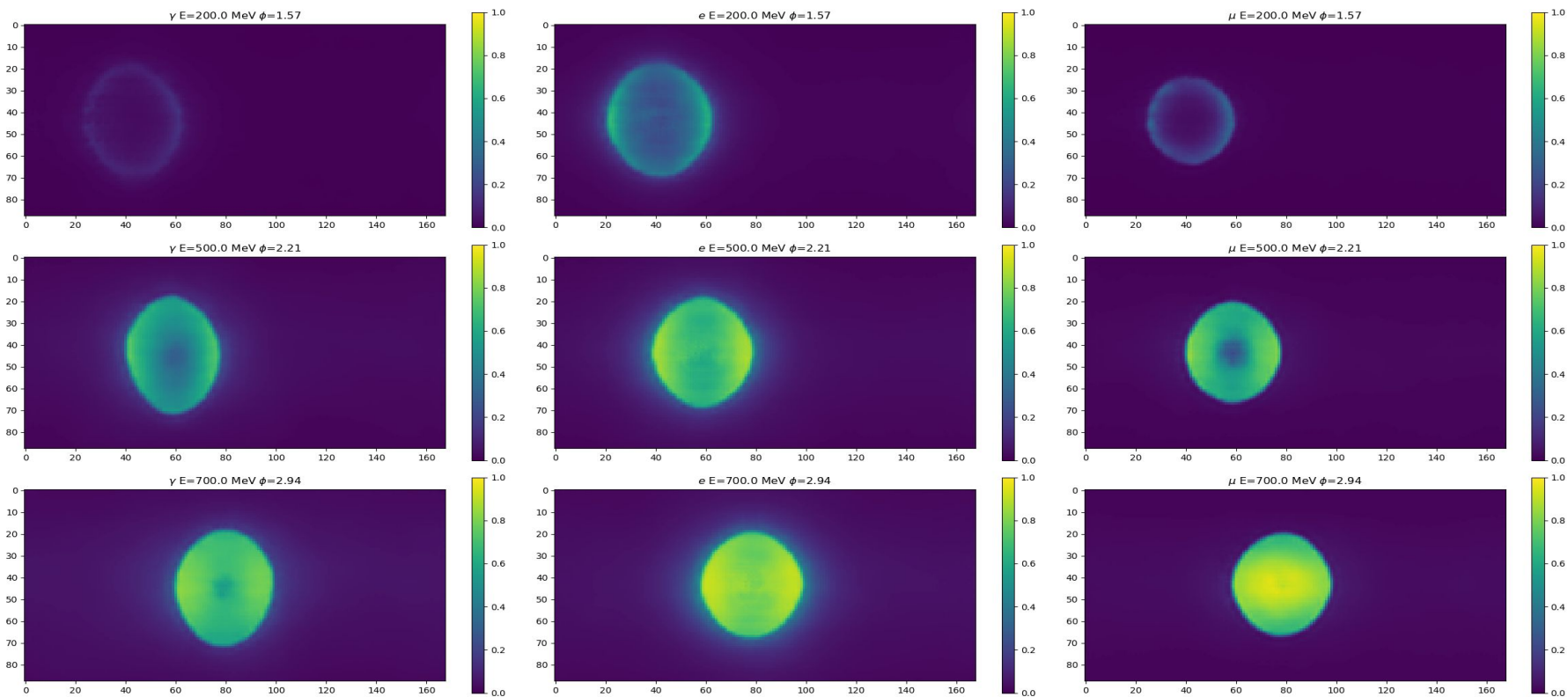
Predicted Variance of Charge



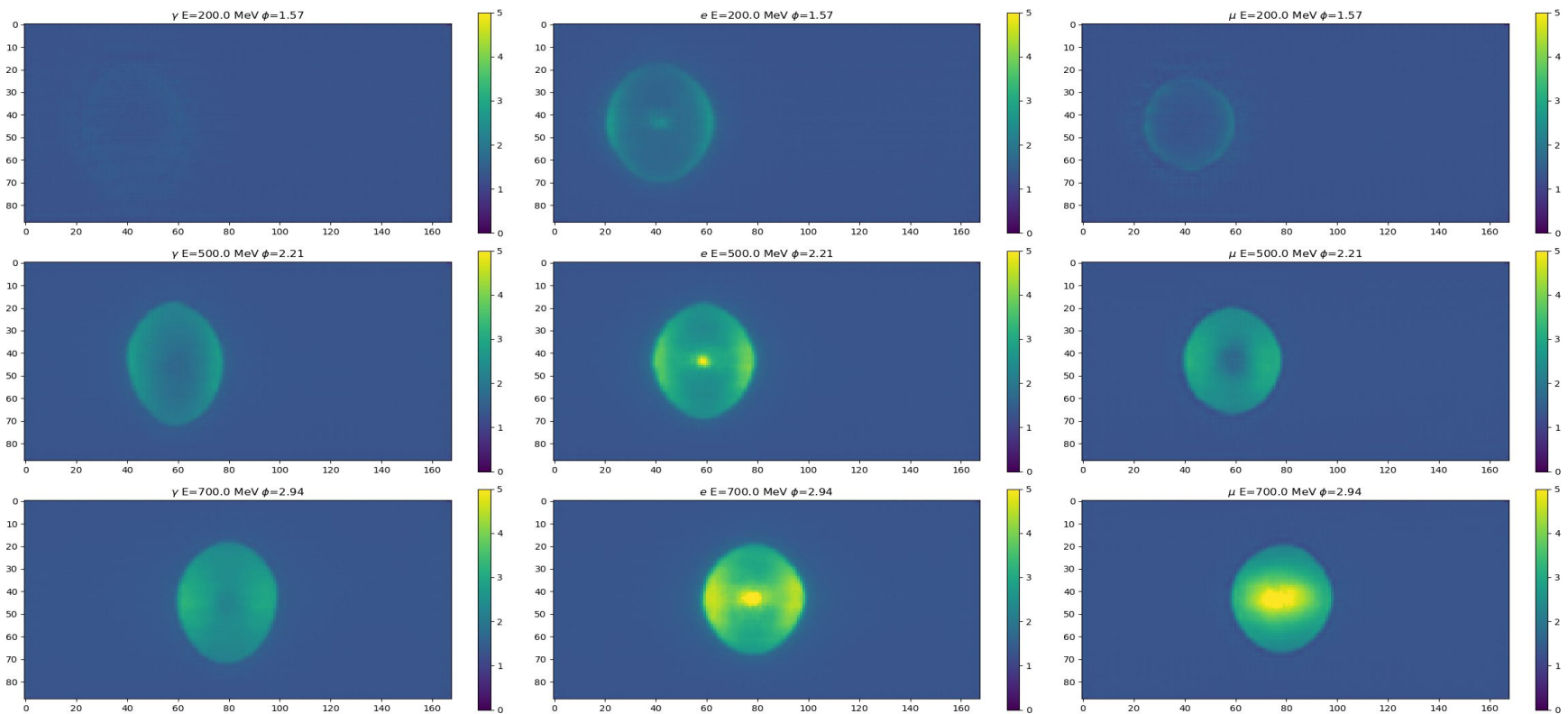
Without 2nd(FC1) and 3rd Layer(FC2)



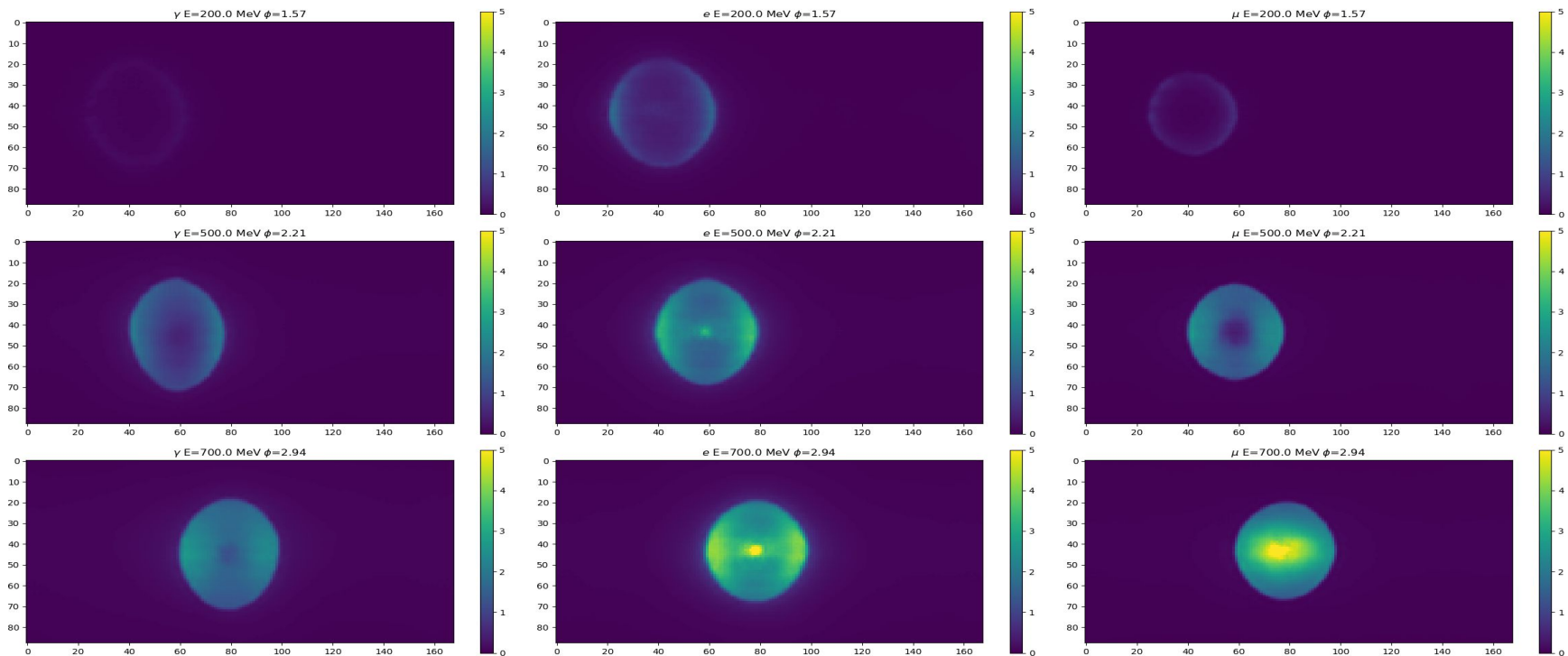
Predicted Hit Probability



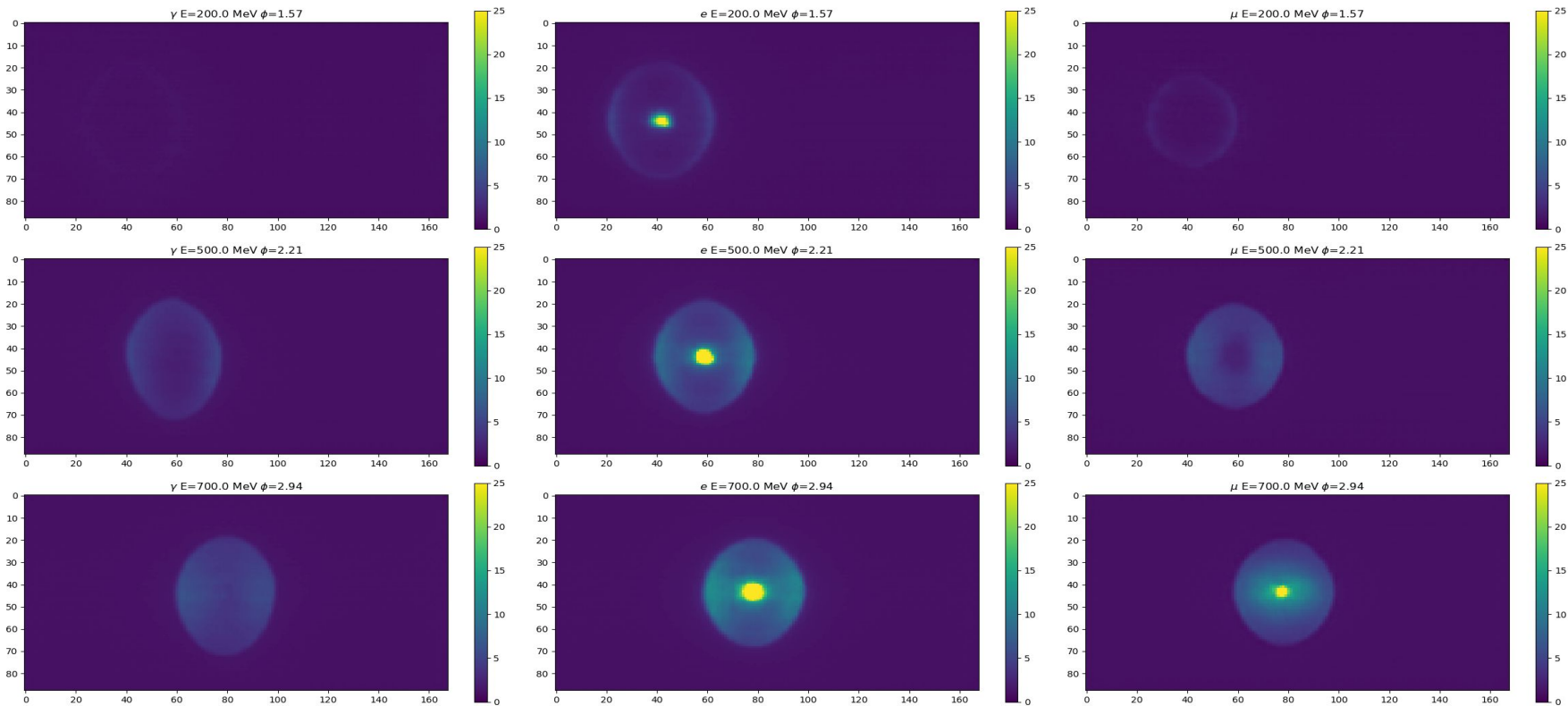
Predicted Charge



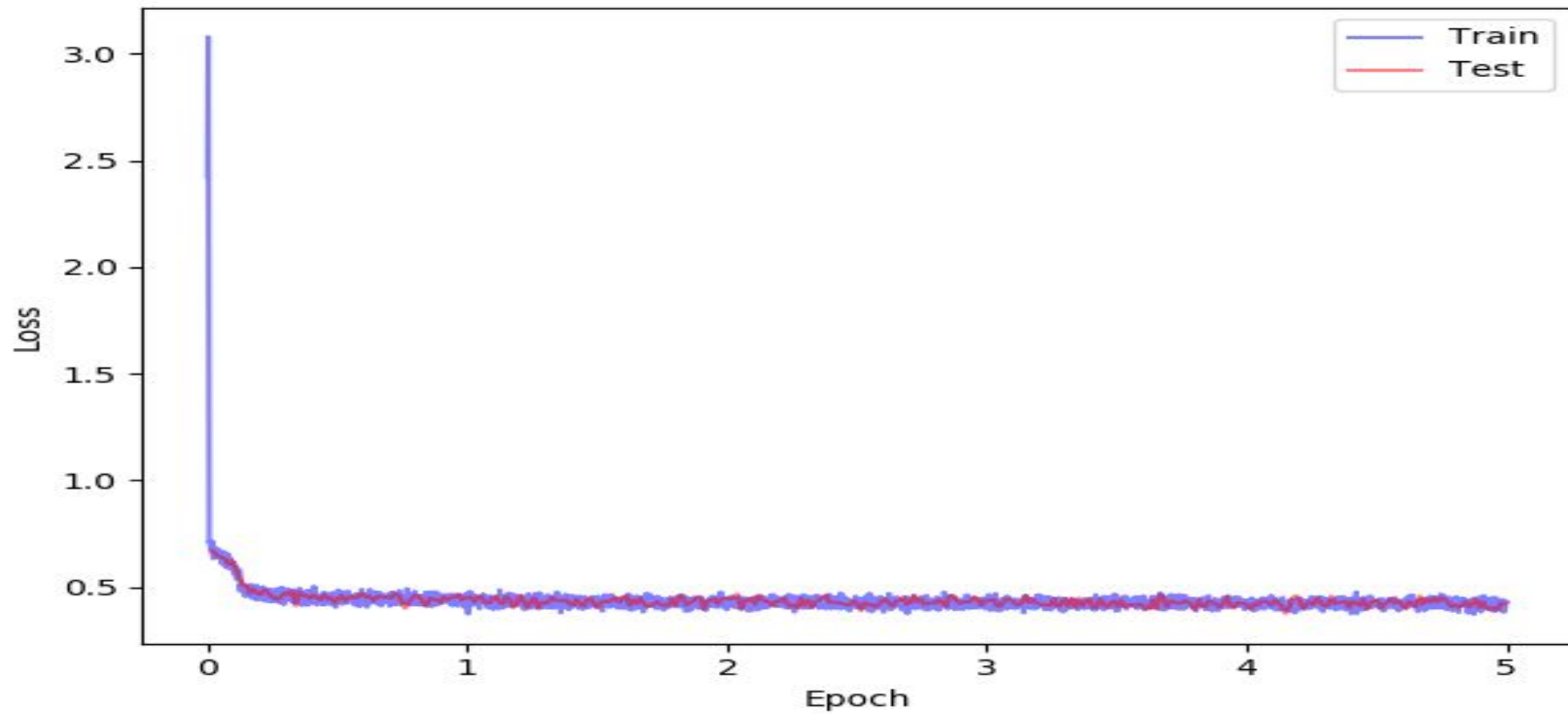
Expected mean charge (Predicted Charge X Predicted Hit Probability)



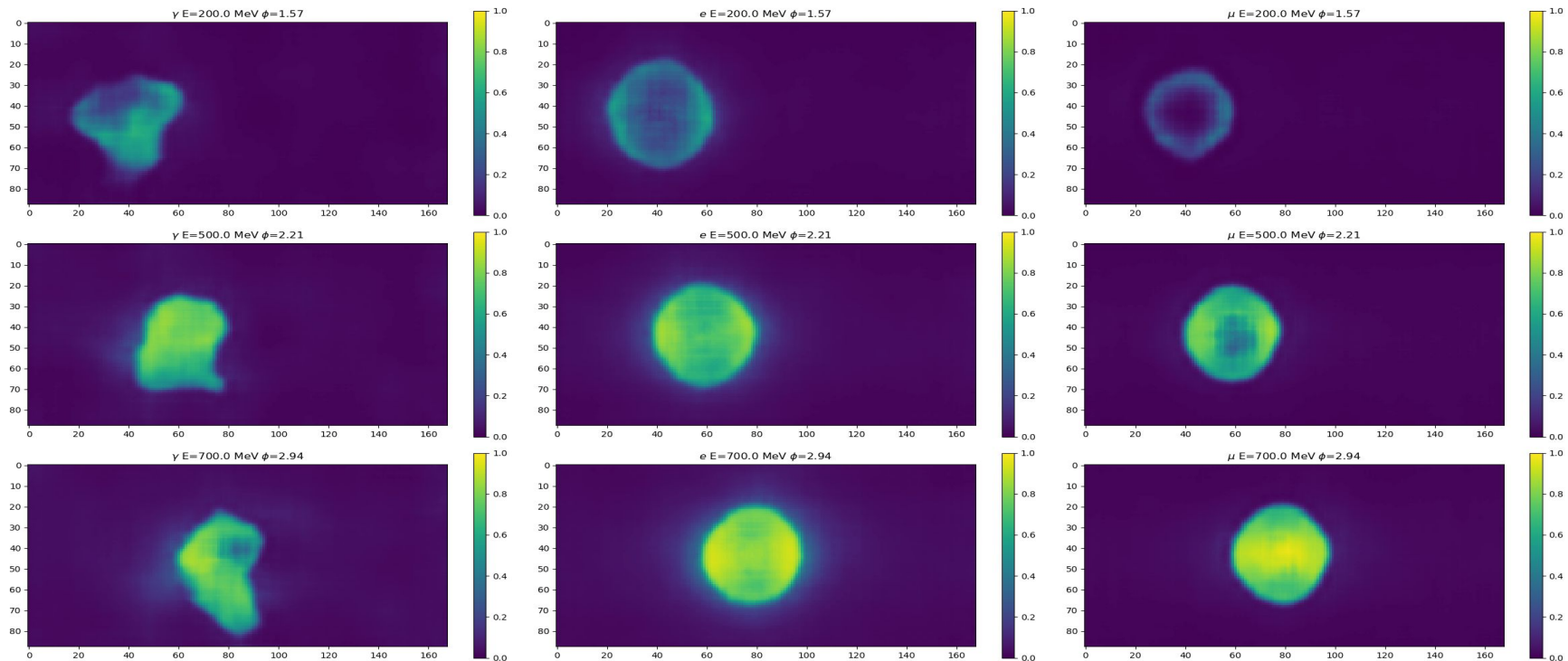
Predicted Variance of Charge



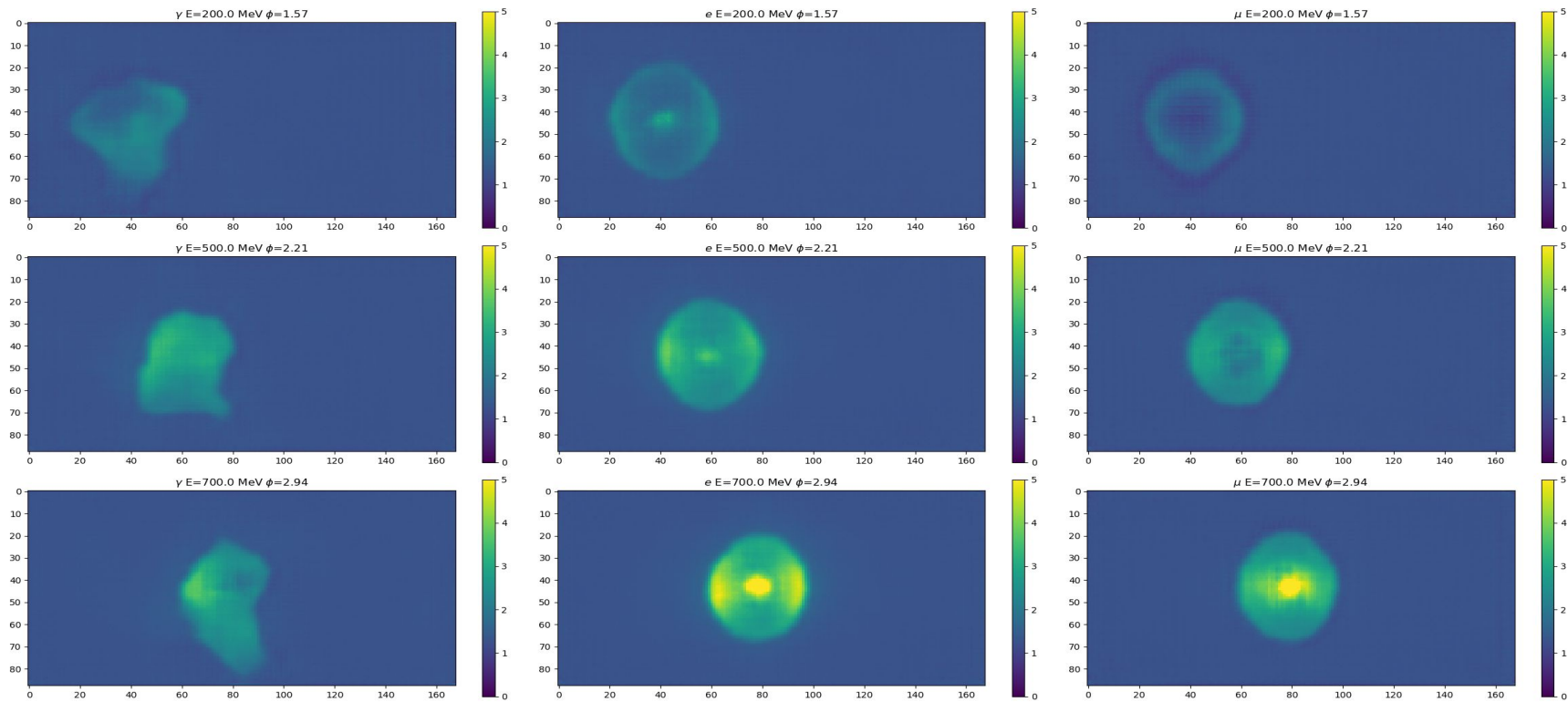
Without FC layers



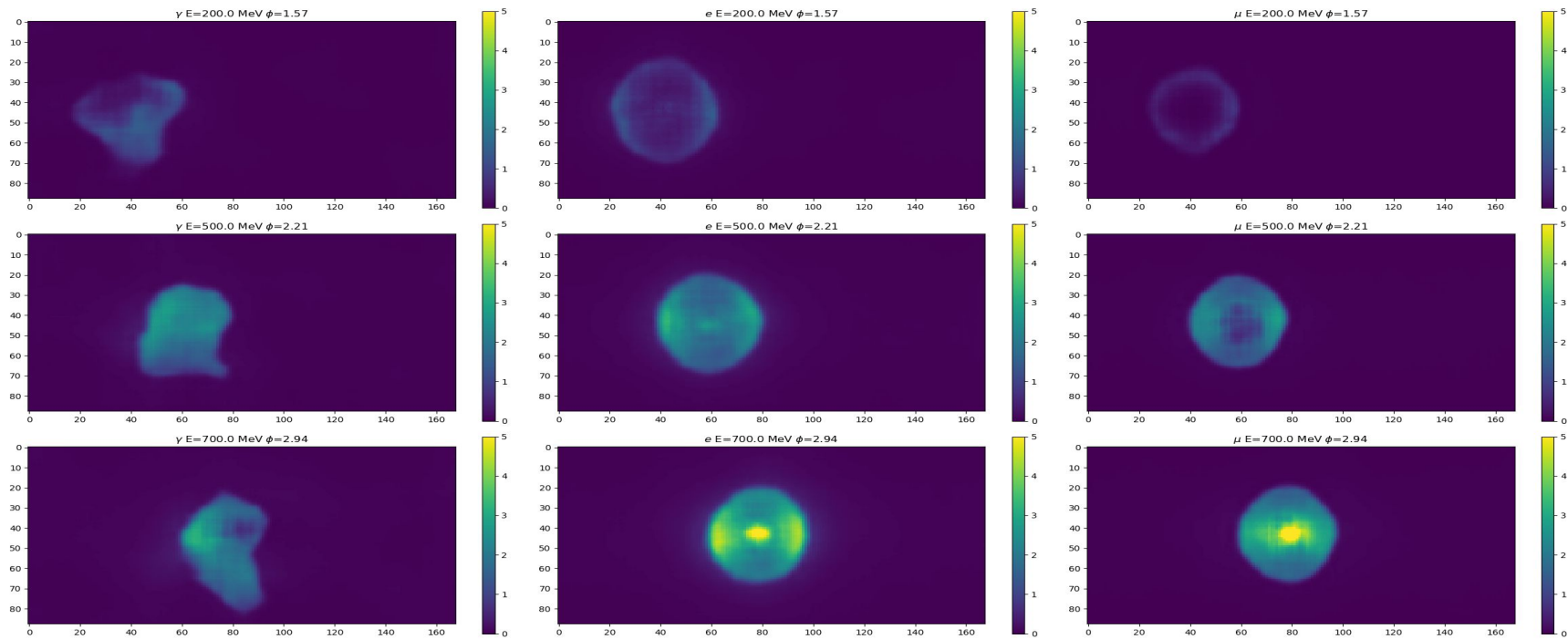
Predicted Hit Probability



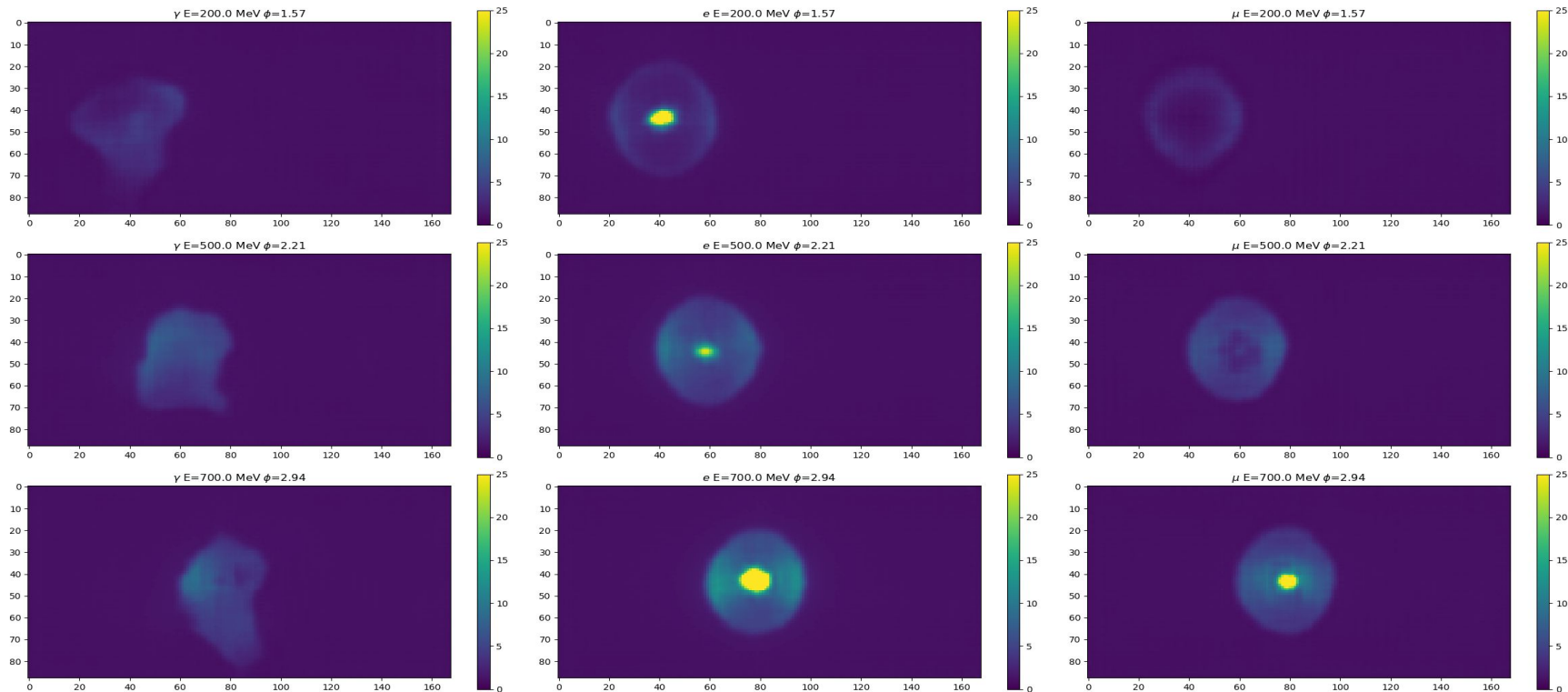
Predicted Charge



Expected mean charge (Predicted Charge X Predicted Hit Probability)

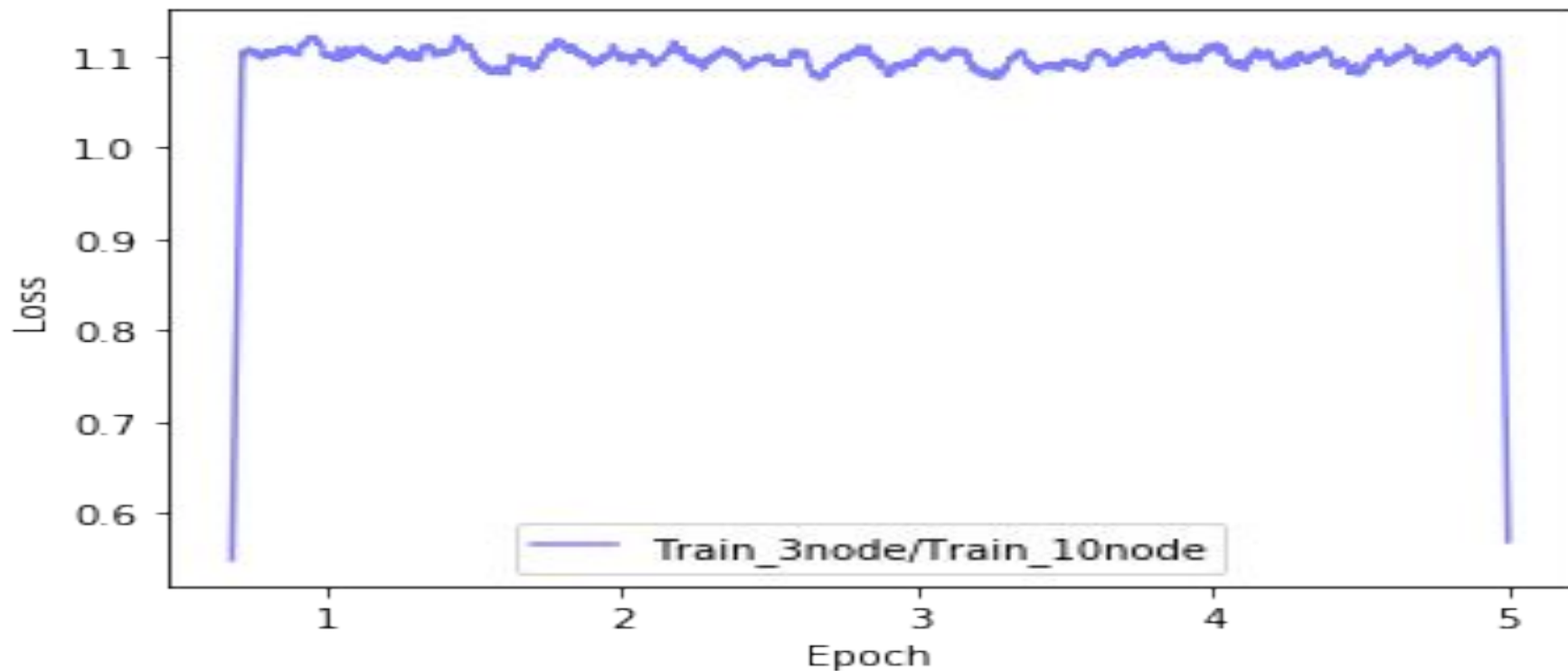


Predicted Variance of Charge

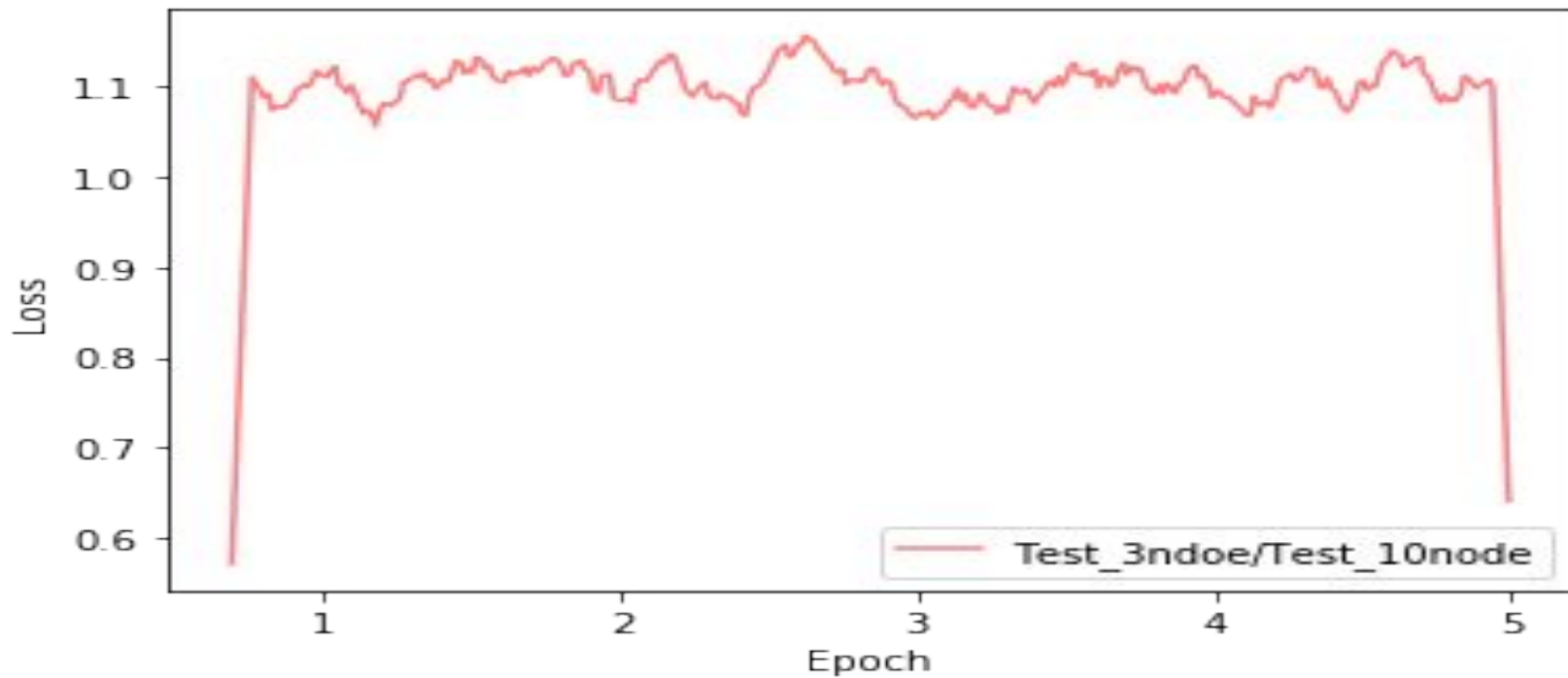


Comparisons

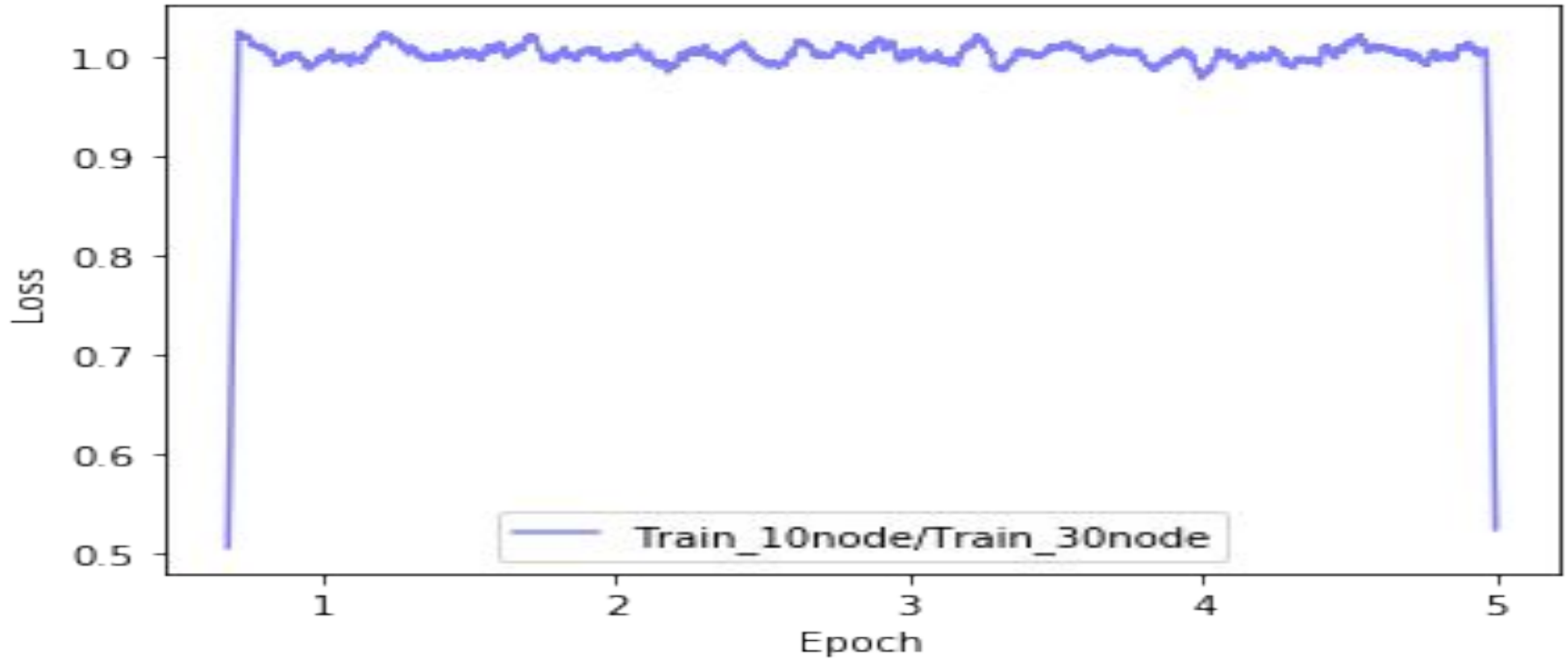
3n/10n (Training) (Window = 50)



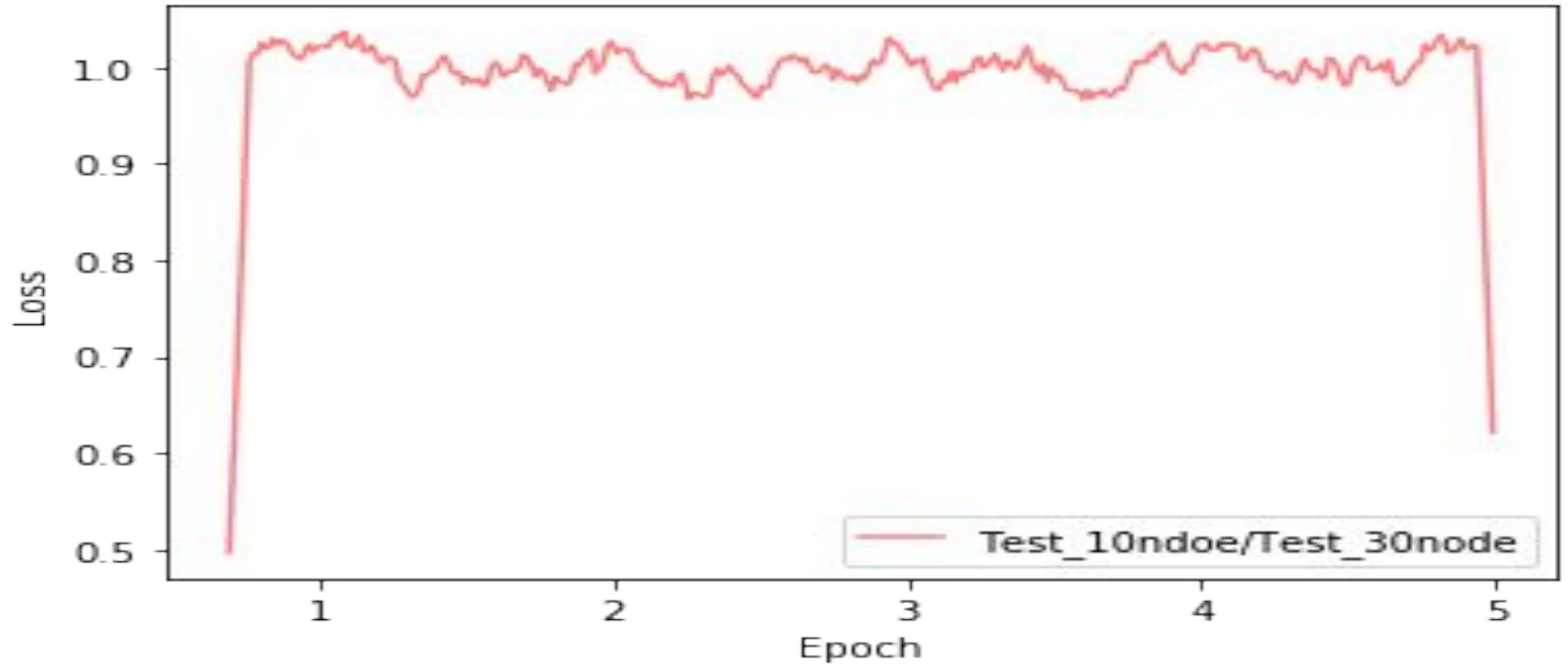
3n/10n (Test) (Window =10)



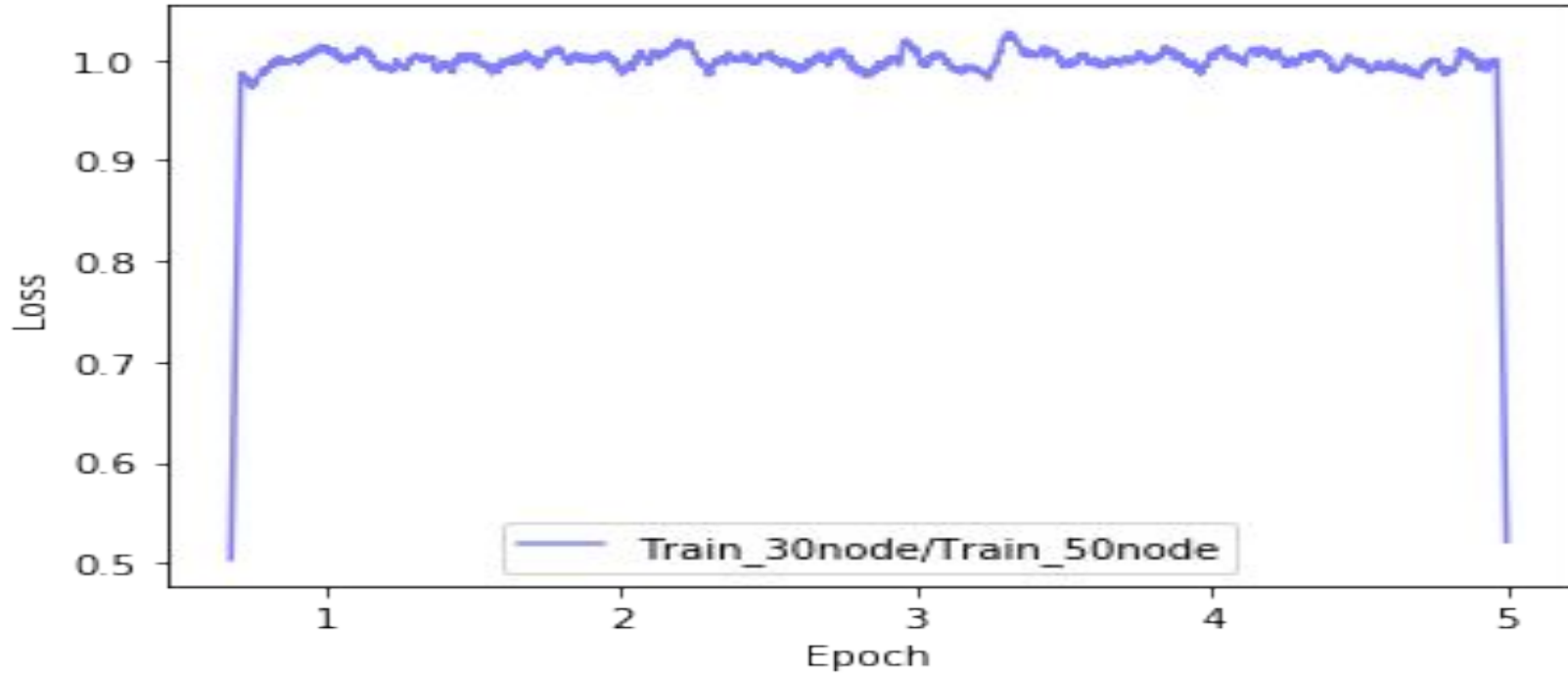
10n/30n (Training) (Window = 50)



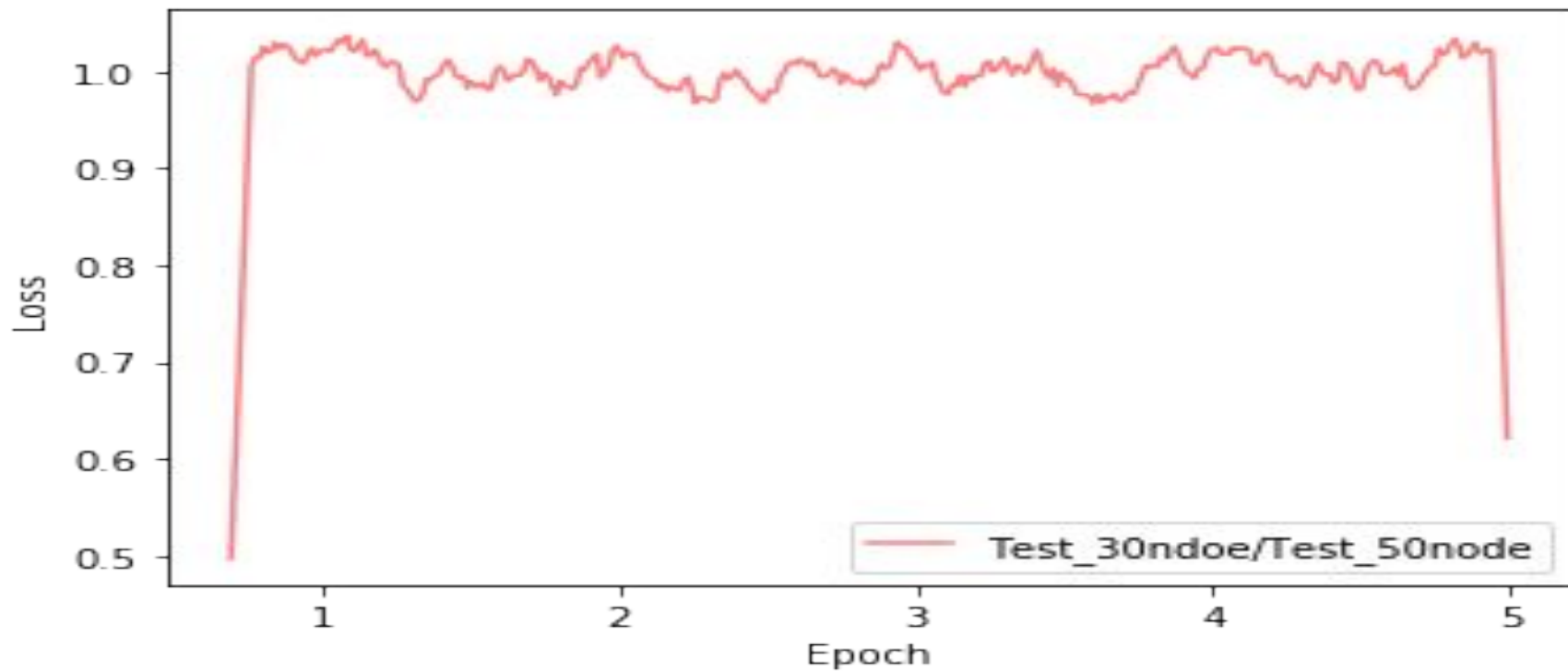
10n/30n (Test) (Window =10)



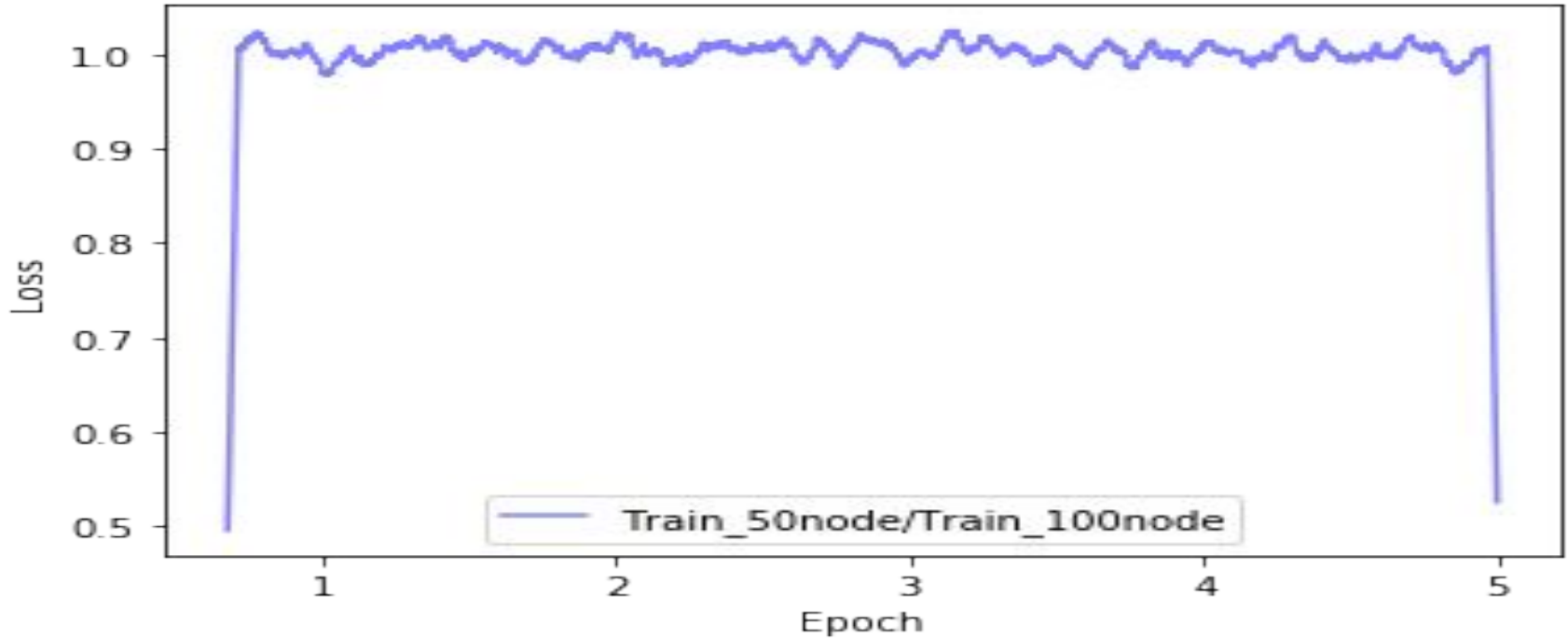
30n/50n (Training) (Window =50)



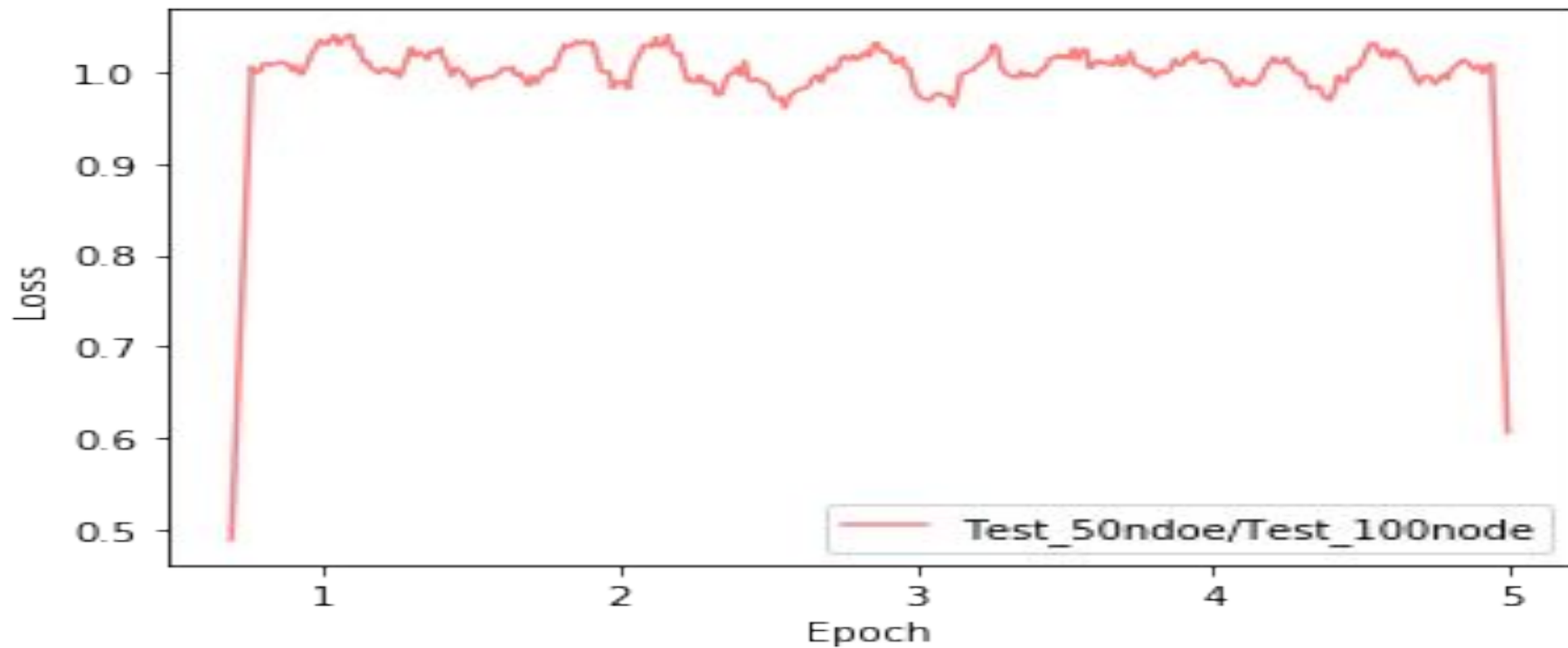
30n/50n (Test) (Window =10)



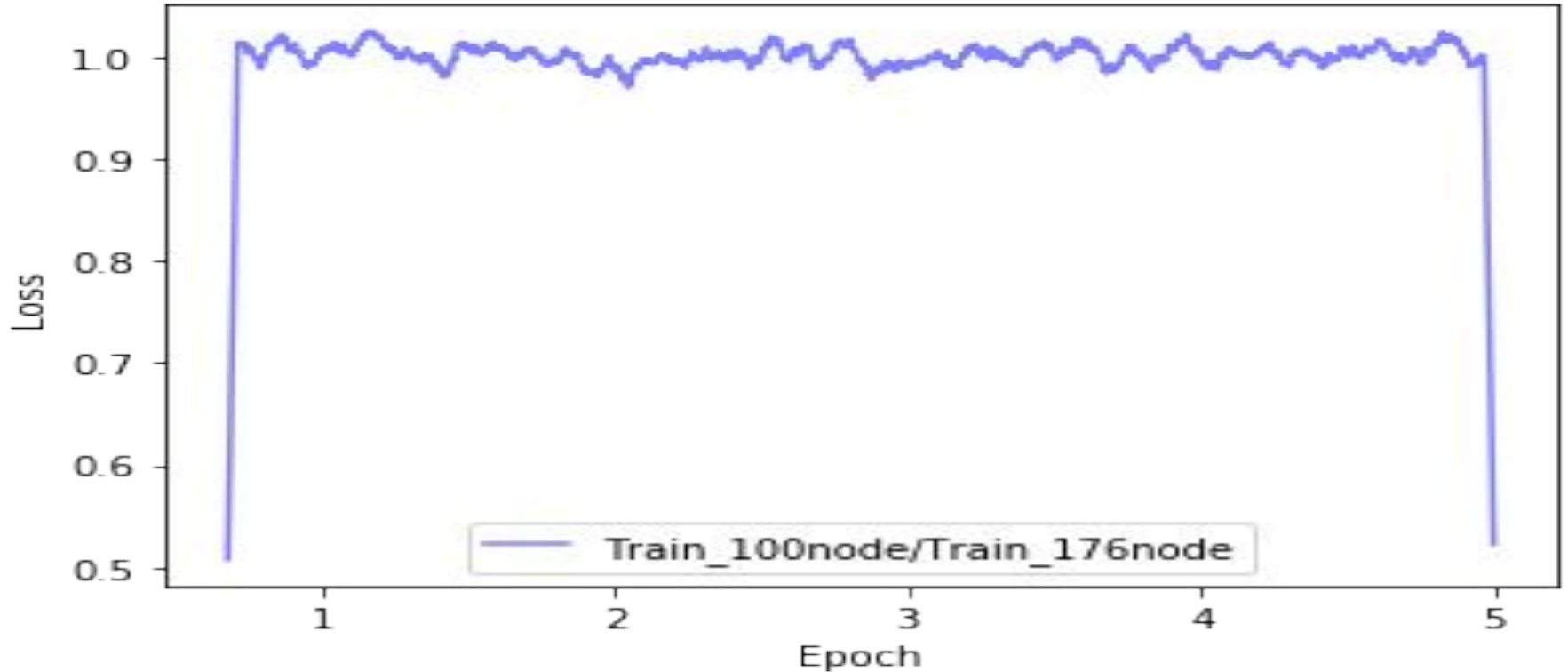
50n/100n (Training) (Window = 50)



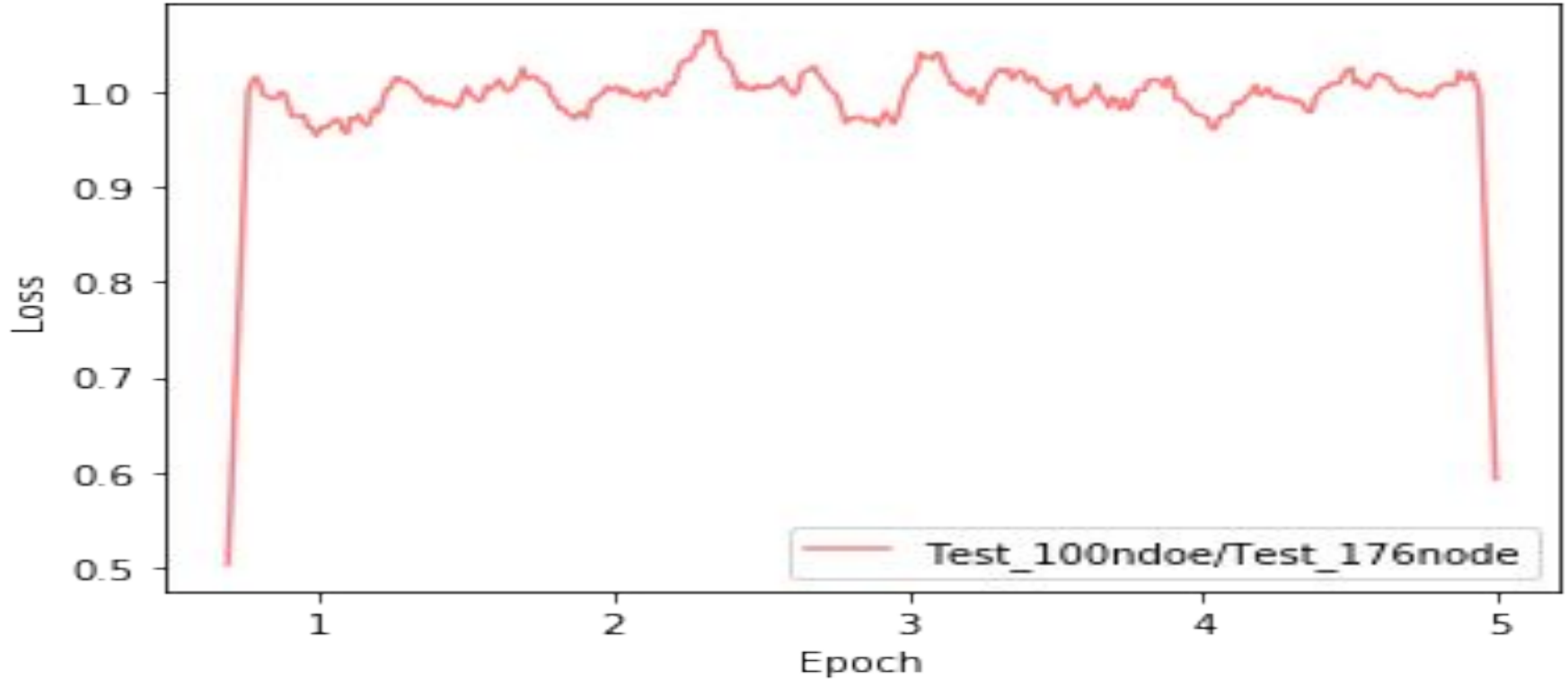
50n/100n (Test) (Window = 10)



100n/176n (Training) (Window = 50)



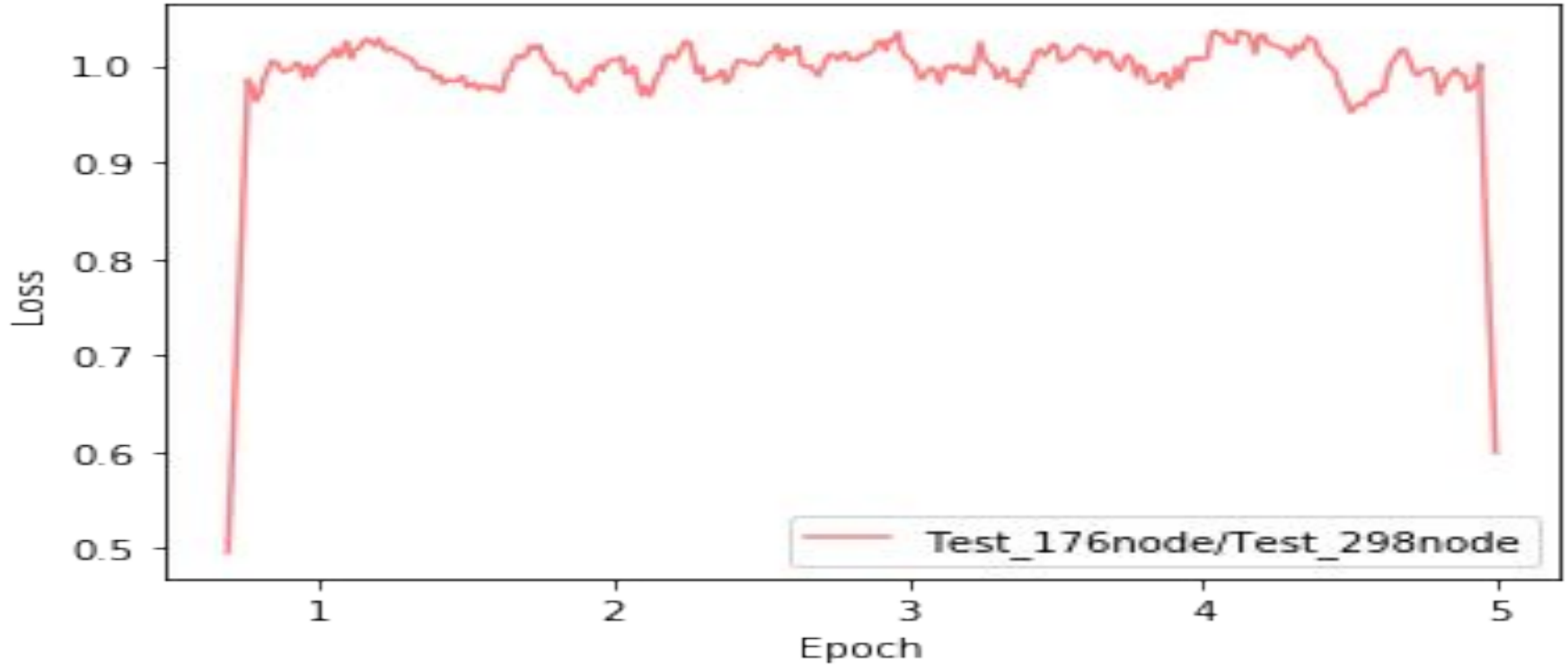
100n/176n (Test) (Window = 10)



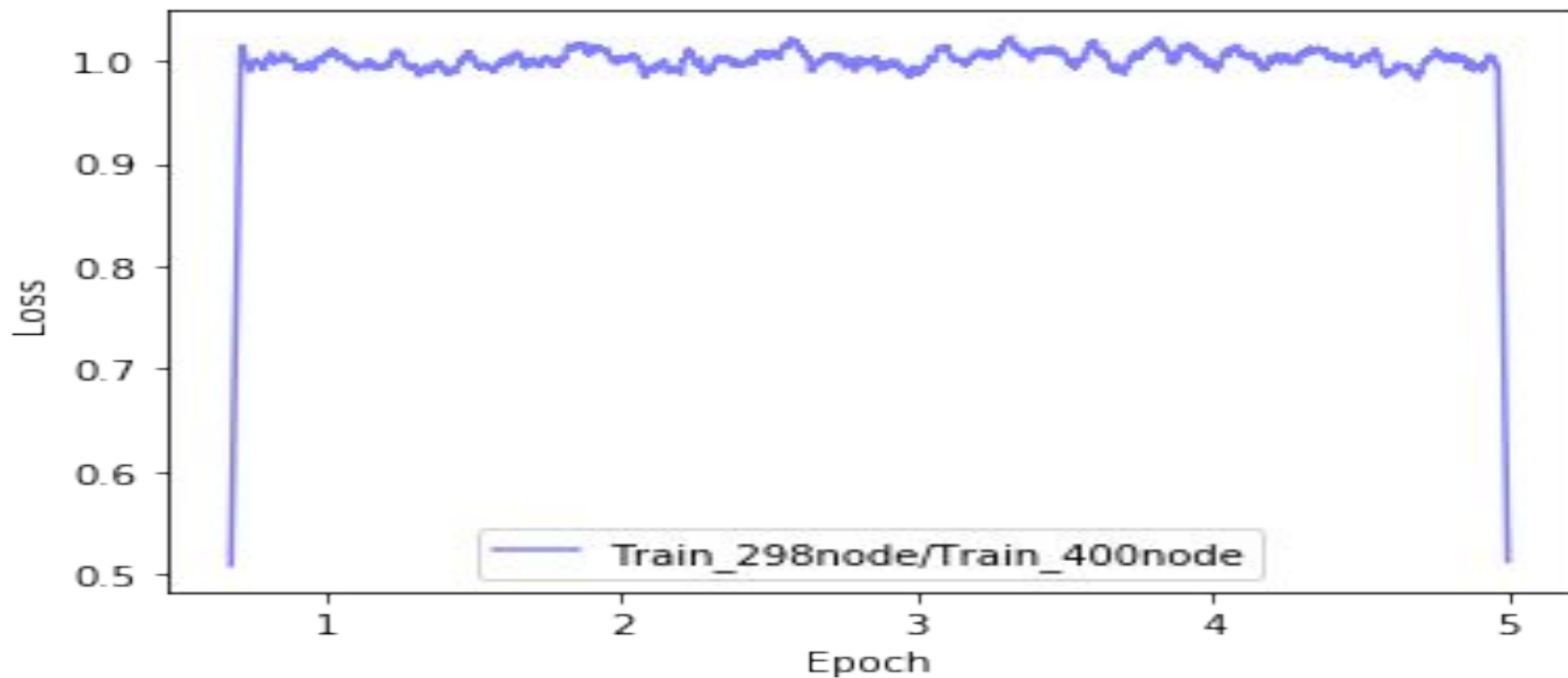
176n/298n (Training) (Window = 50)



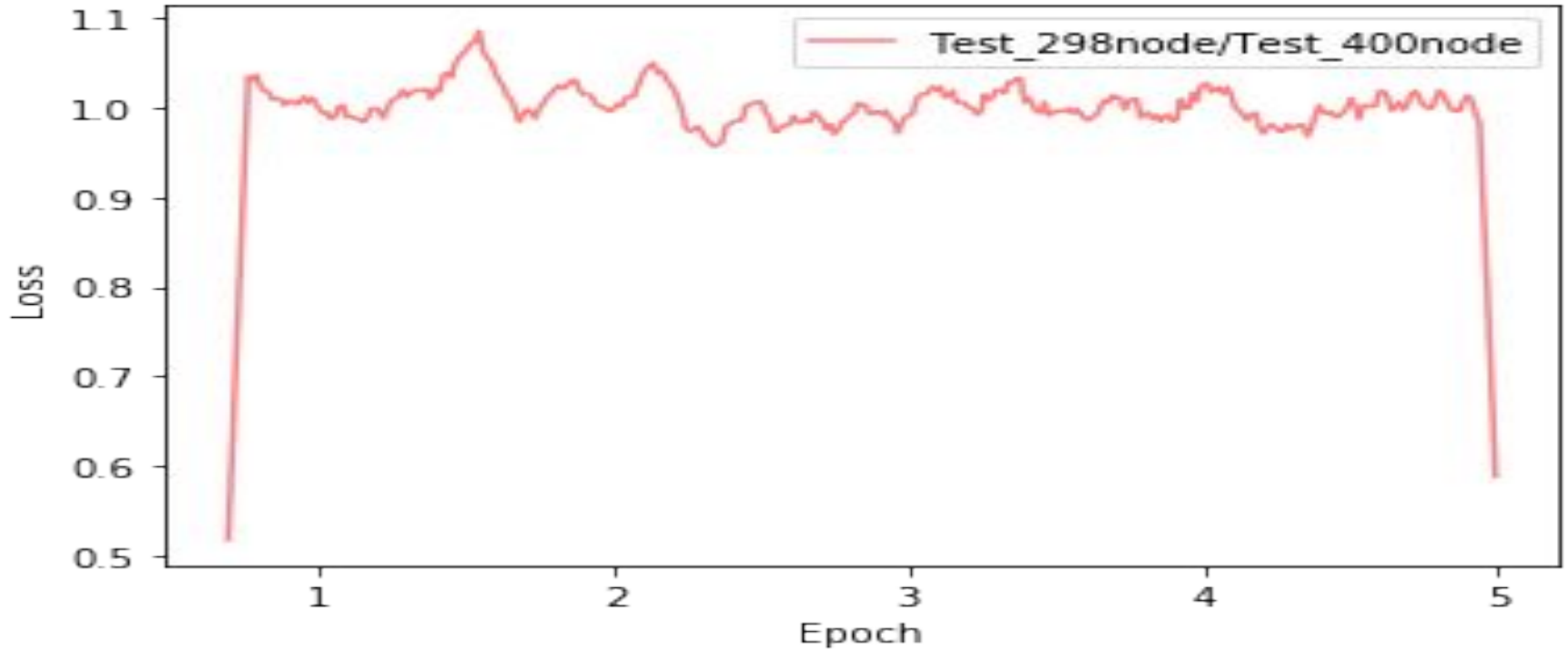
176n/298n (Test) (Window = 10)



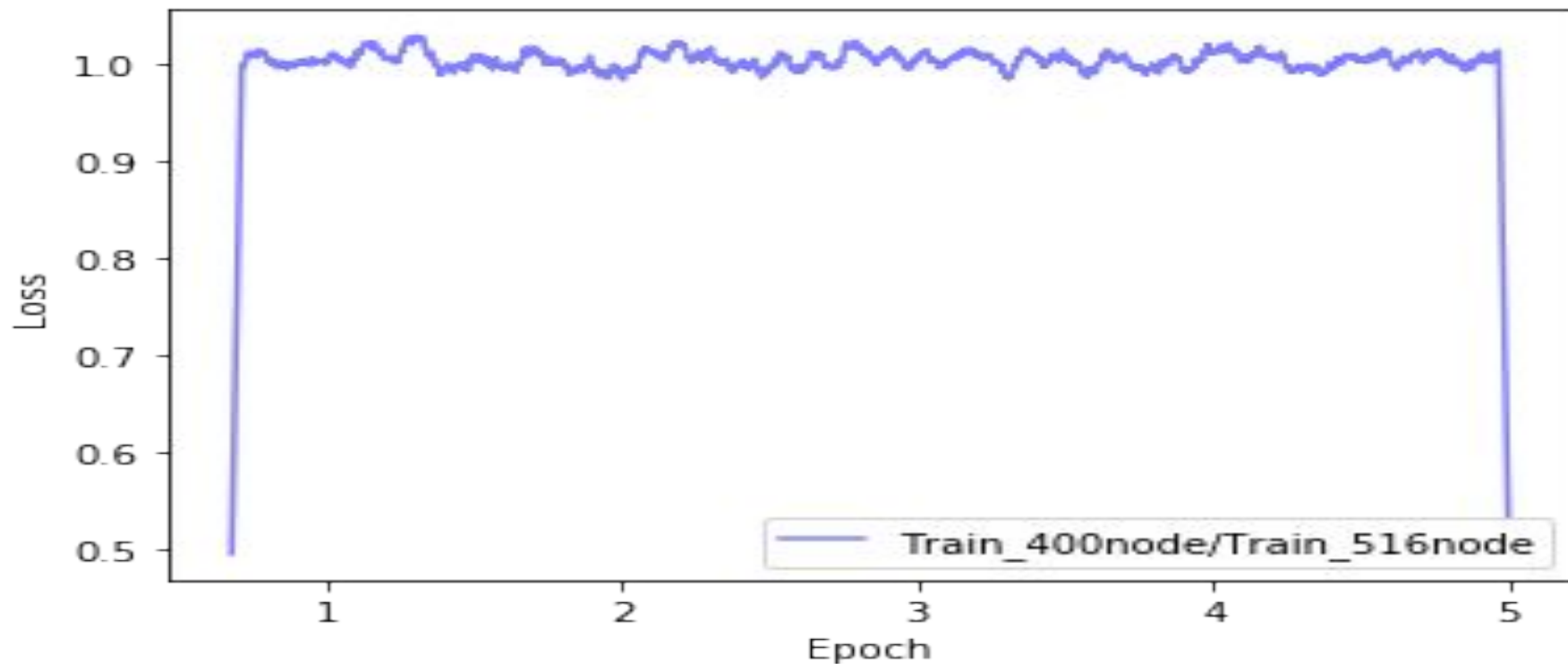
298n/400n (Training) (Window = 50)



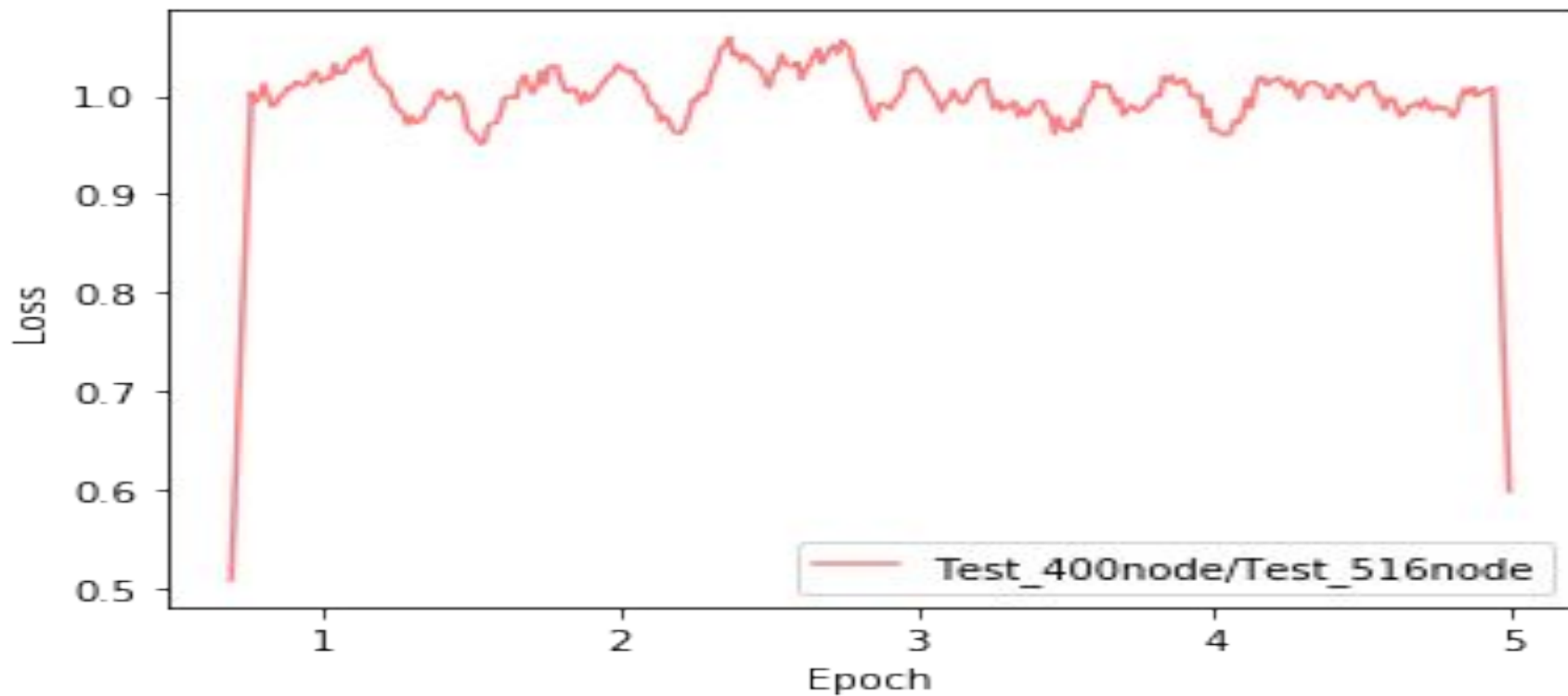
298n/400n (Test) (Window = 10)



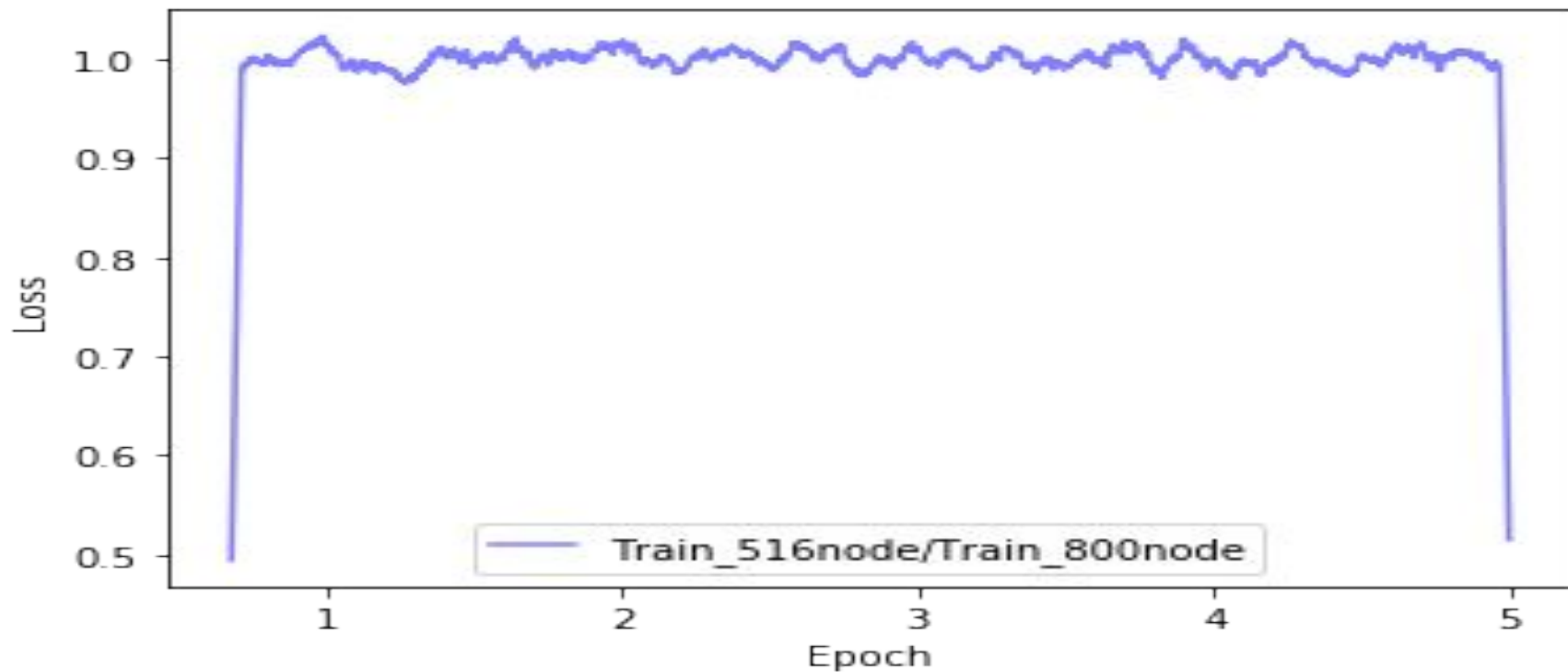
400n/516n (Training) (Window = 50)



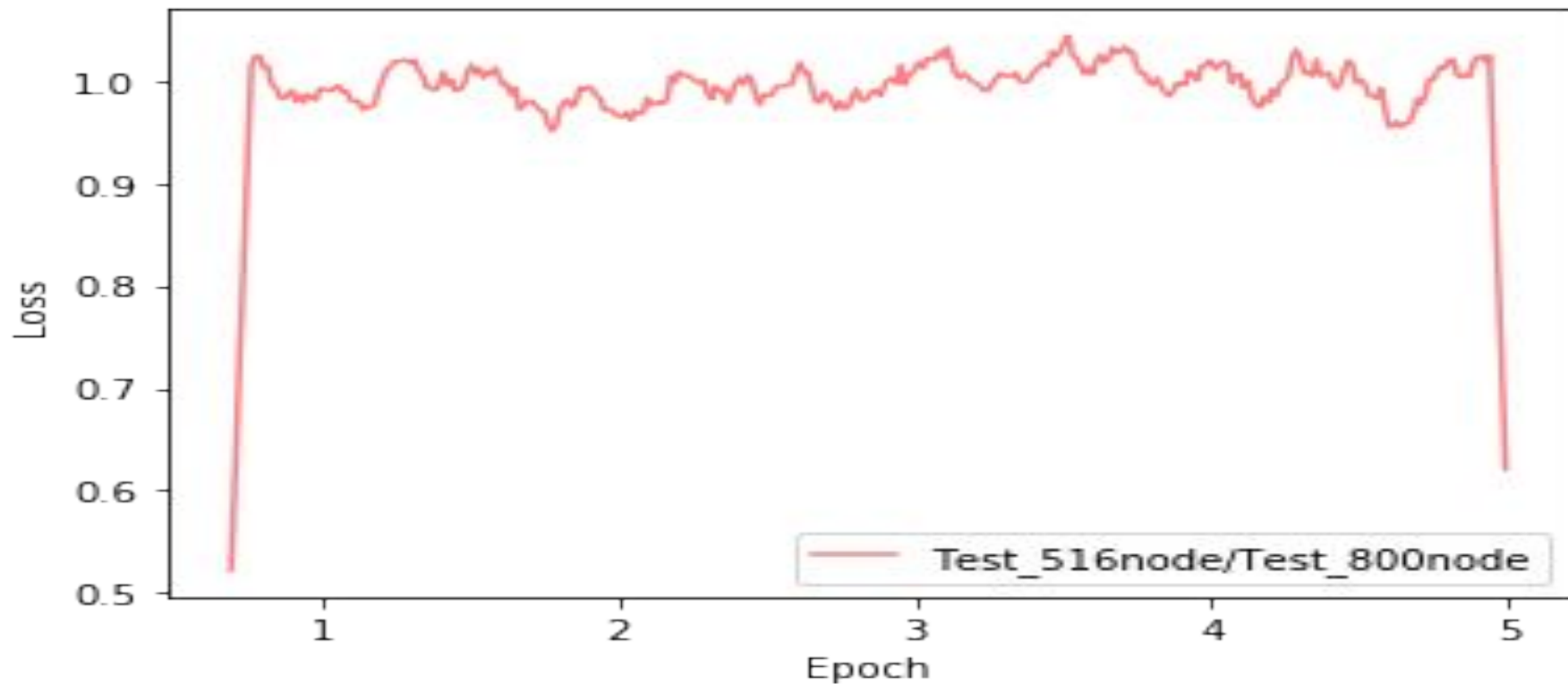
400n/516n (Test) (Window = 10)



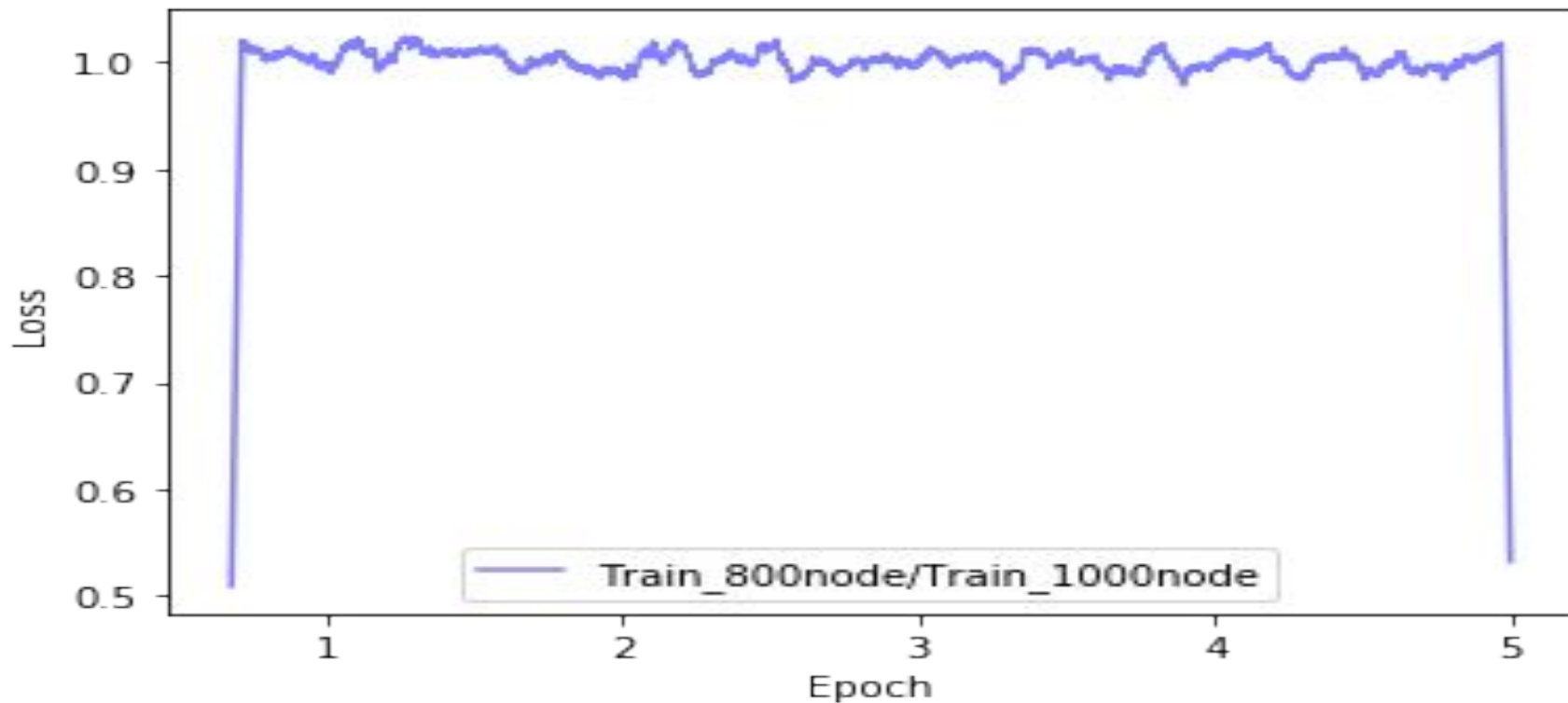
516n/800n (Training) (Window =50)



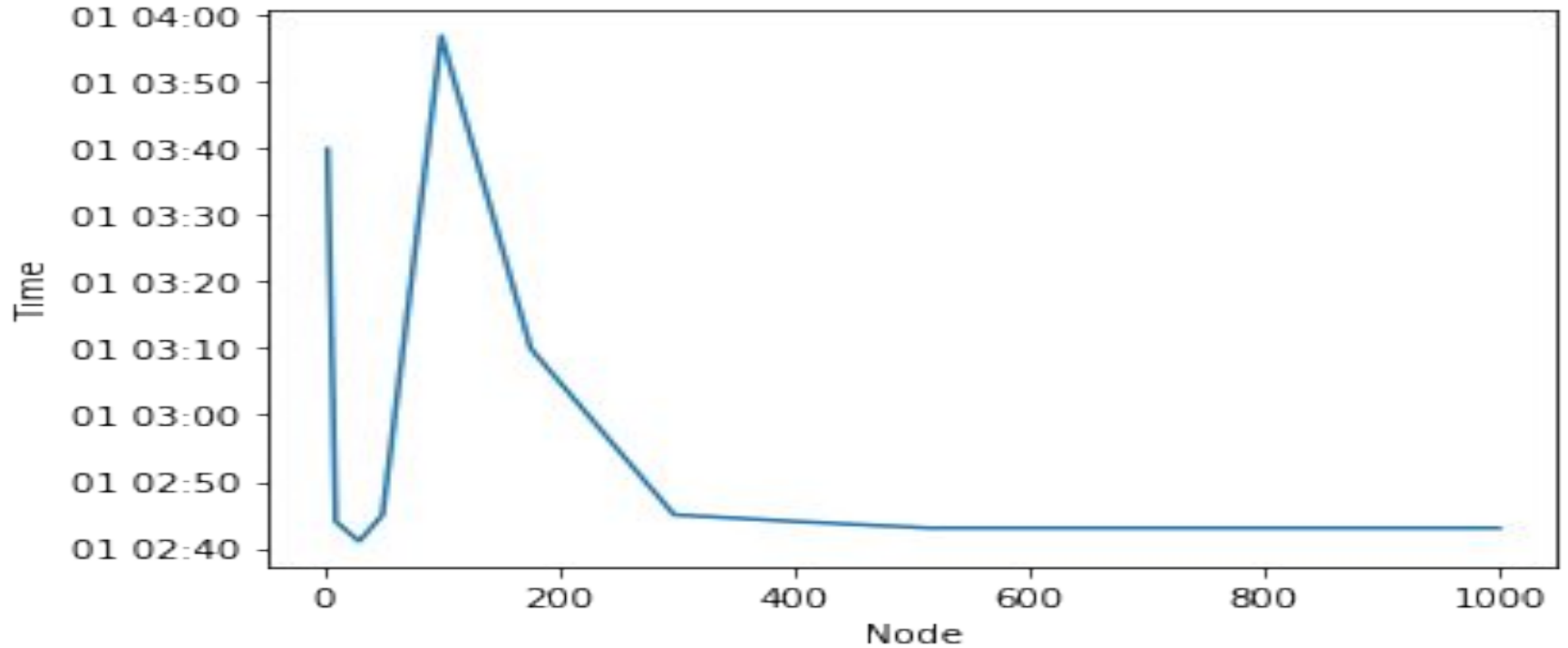
516n/800n (Test) (Window =10)



800n/1000n (Training) (Window =50)



Node vs Time



Average of Loss from Epoch 4 to 5

node	Training	Test	Training/Test
3	0.4576	0.4577	0.9999
10	0.4177	0.4172	1.001
30	0.4172	0.4145	1.006
50	0.4185	0.4156	1.006
100	0.4184	0.4154	1.007
176	0.4175	0.4169	1.001
298	0.4184	0.4171	1.003
400	0.4188	0.4187	1.000
516	0.4177	0.4202	0.9941
800	0.4189	0.4207	0.9957

Train

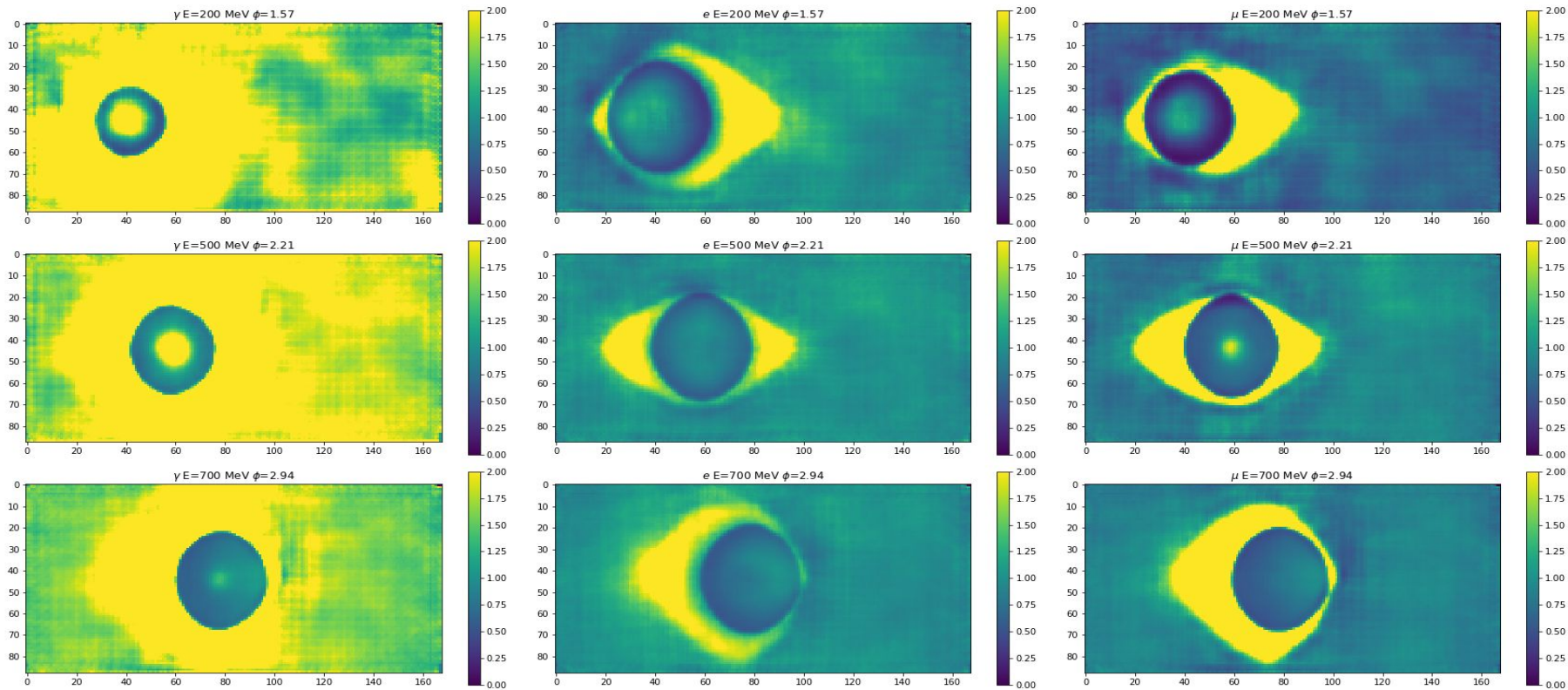
Node	2-3	3-4	4-5
3	0.4598 ± 0.0179	0.4591 ± 0.0175	0.4576 ± 0.0181
10	0.4204 ± 0.0163	0.4194 ± 0.0162	0.4177 ± 0.0172
30	0.4194 ± 0.0165	0.4188 ± 0.0160	0.4172 ± 0.0167
50	0.4198 ± 0.0171	0.4194 ± 0.0161	0.4185 ± 0.0166
100	0.4184 ± 0.0167	0.4188 ± 0.0160	0.4184 ± 0.0168
176	0.4198 ± 0.0166	0.4185 ± 0.0169	0.4175 ± 0.0156
298	0.4196 ± 0.0169	0.4198 ± 0.0173	0.4184 ± 0.0164
400	0.4204 ± 0.0162	0.4179 ± 0.0170	0.4188 ± 0.0154
516	0.4196 ± 0.0167	0.4176 ± 0.0174	0.4177 ± 0.0168
800	0.4195 ± 0.0160	0.4180 ± 0.0164	0.4189 ± 0.0157
1000	0.4197 ± 0.0165	0.4187 ± 0.0163	0.4187 ± 0.0164

Test

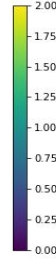
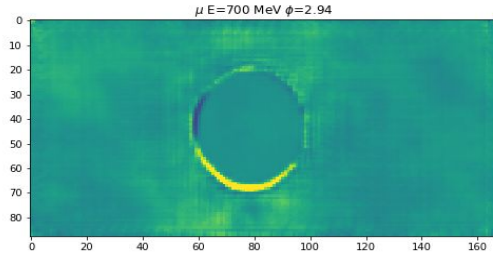
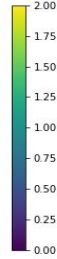
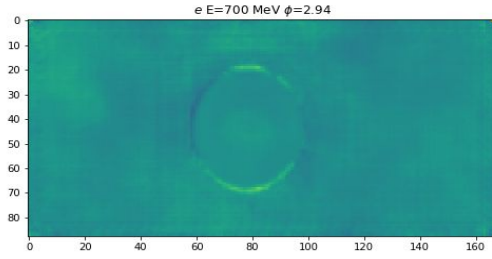
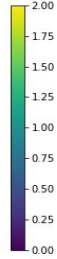
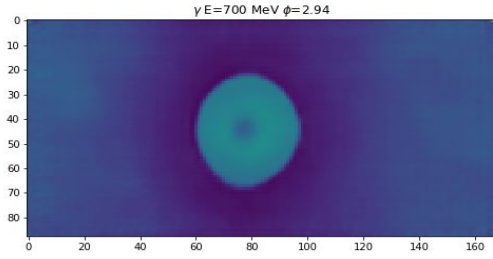
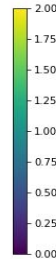
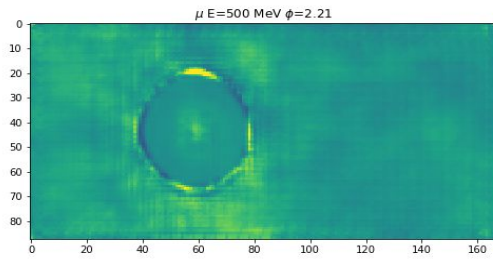
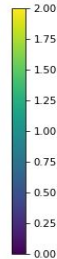
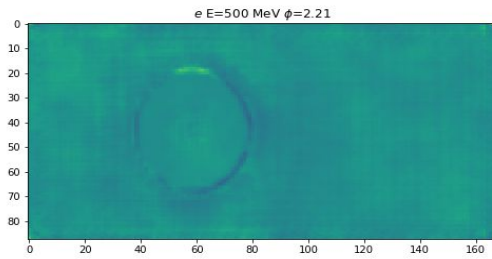
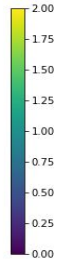
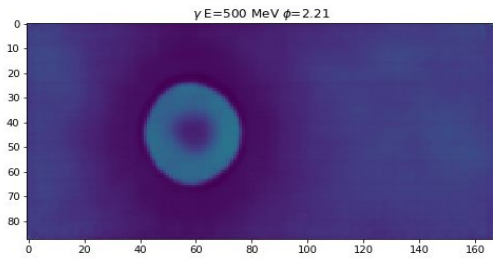
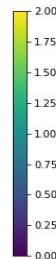
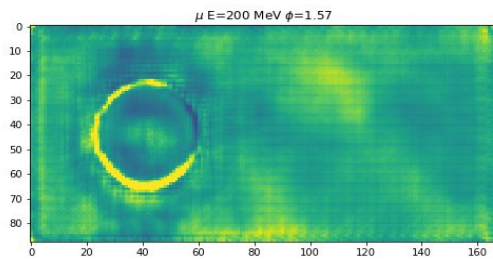
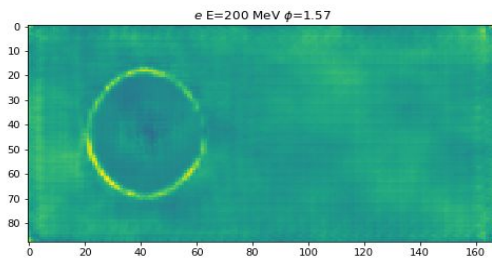
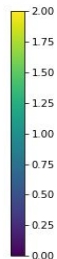
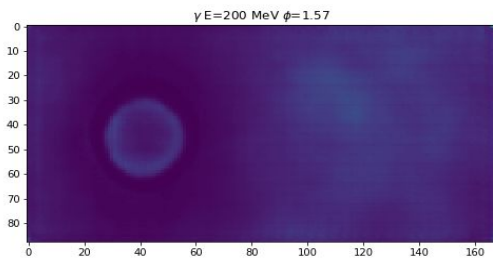
Node	2-3	3-4	4-5
3	0.4615 ± 0.0166	0.4601 ± 0.0174	0.4577 ± 0.0191
10	0.4175 ± 0.0166	0.4199 ± 0.0167	0.4172 ± 0.0145
30	0.4194 ± 0.0172	0.4230 ± 0.0150	0.4145 ± 0.0158
50	0.4212 ± 0.0155	0.4211 ± 0.0161	0.4156 ± 0.0143
100	0.4212 ± 0.0158	0.4191 ± 0.0143	0.4154 ± 0.0145
176	0.4202 ± 0.0179	0.4180 ± 0.0179	0.4170 ± 0.0171
298	0.4188 ± 0.0143	0.4190 ± 0.0182	0.4171 ± 0.0167
400	0.4224 ± 0.0170	0.4174 ± 0.0168	0.4187 ± 0.0149
516	0.4161 ± 0.0182	0.4207 ± 0.0171	0.4202 ± 0.0182
800	0.4209 ± 0.0187	0.4164 ± 0.0167	0.4207 ± 0.0166
1000	0.4220 ± 0.0166	0.4166 ± 0.0173	0.4222 ± 0.0178

Image comparison (Hit Prob)

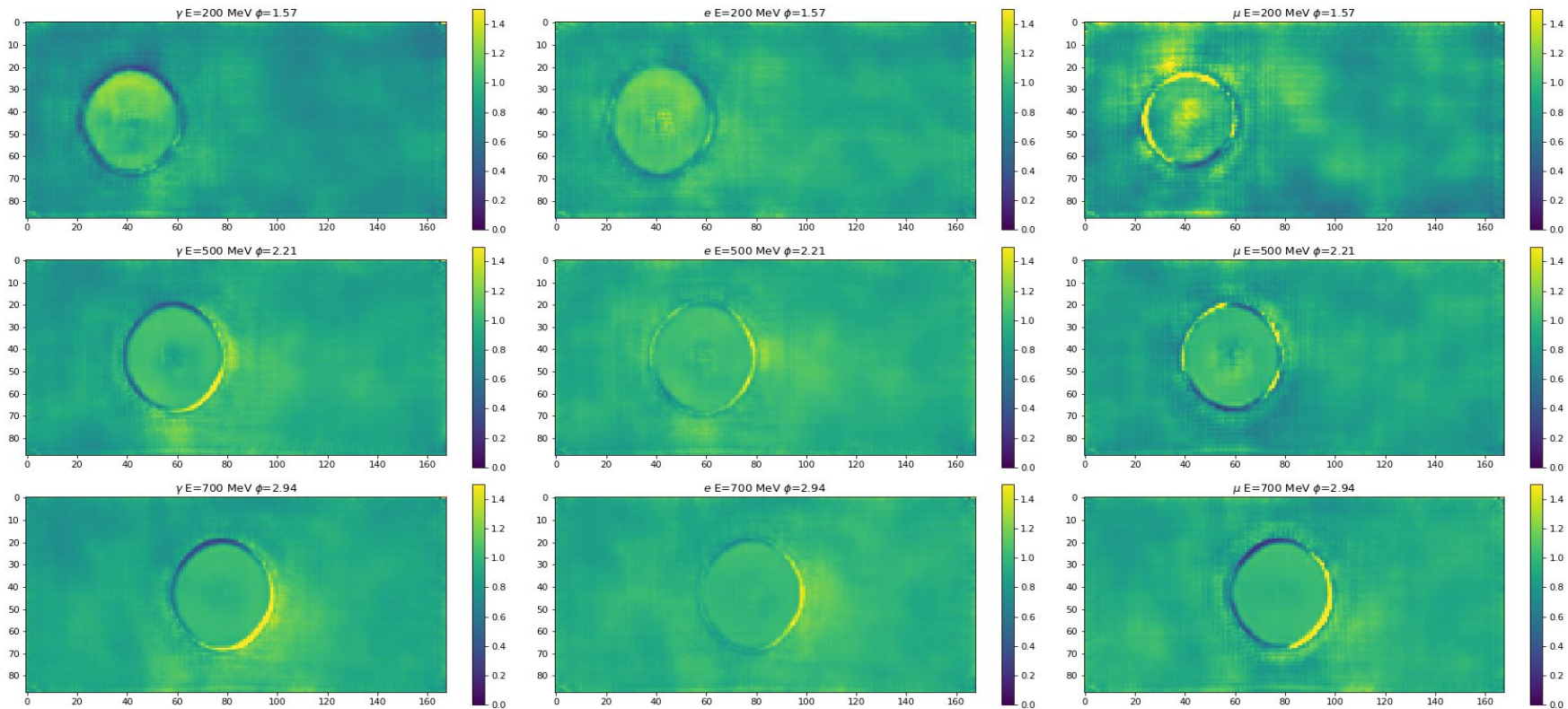
3N/10N



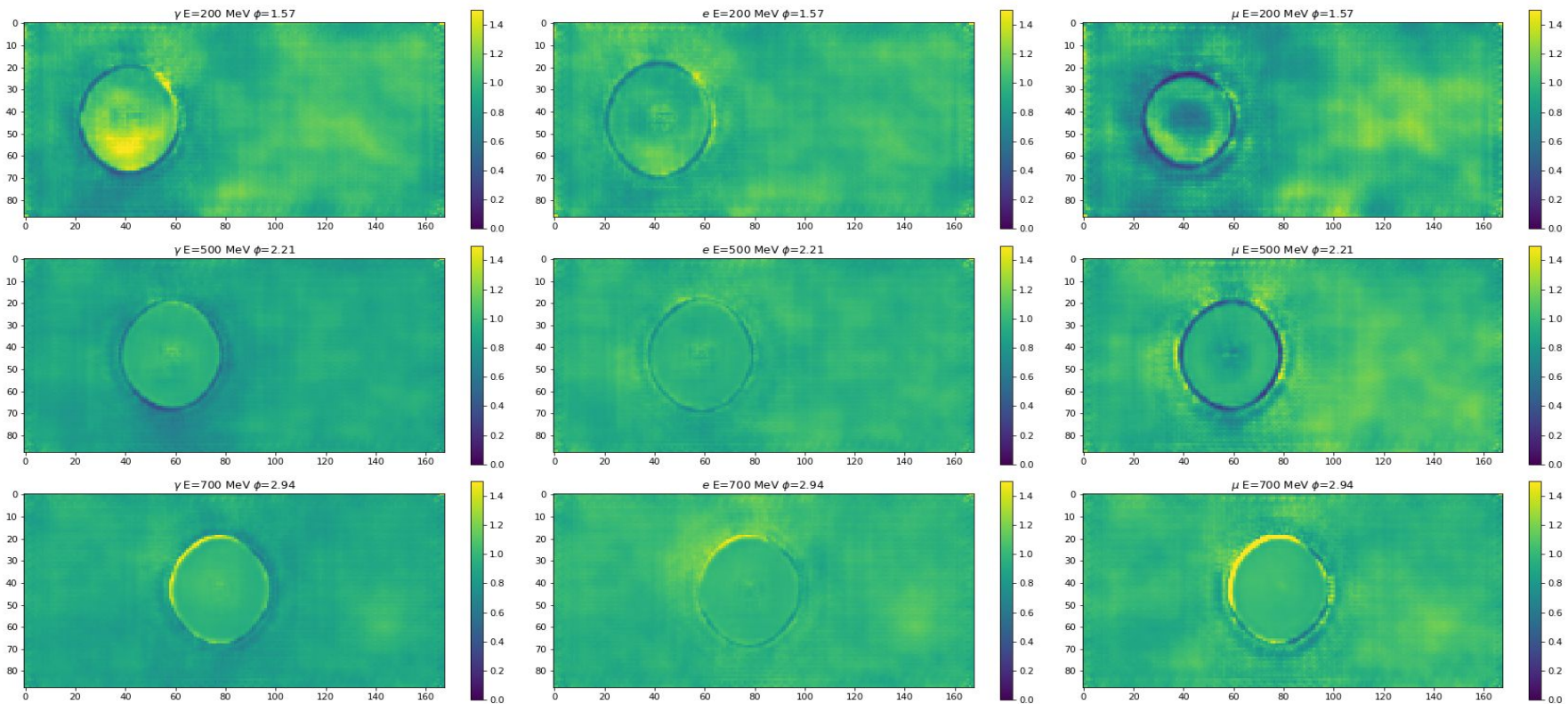
10N/30N



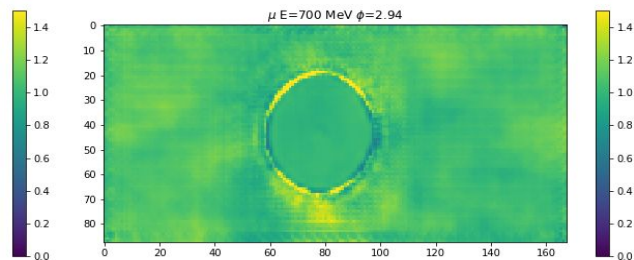
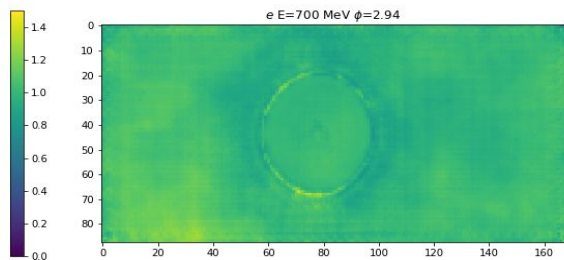
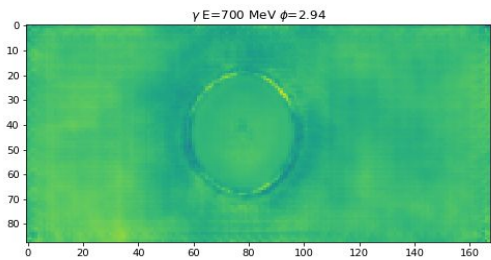
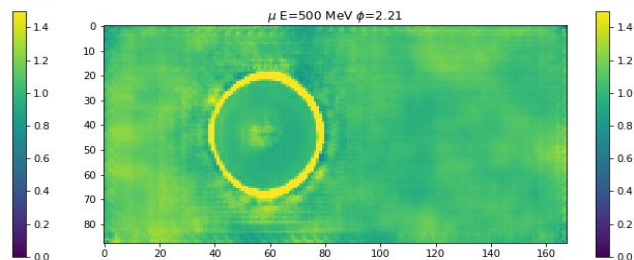
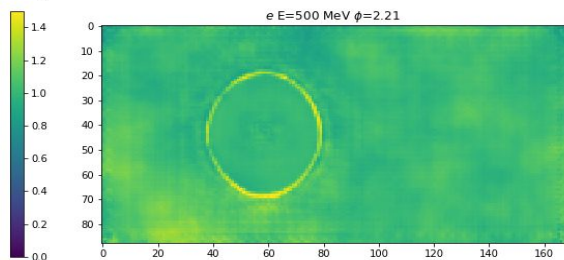
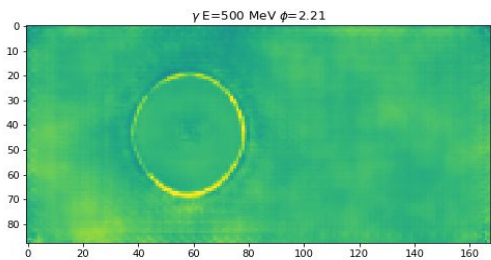
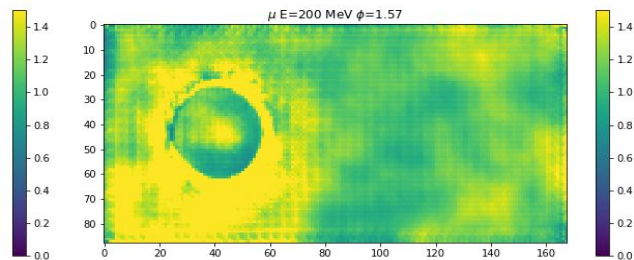
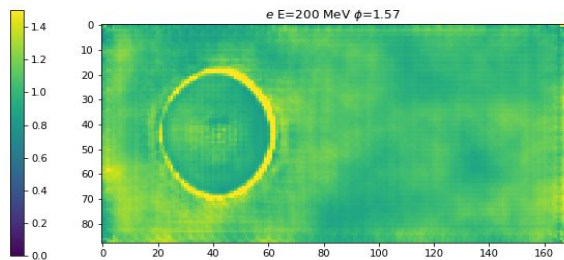
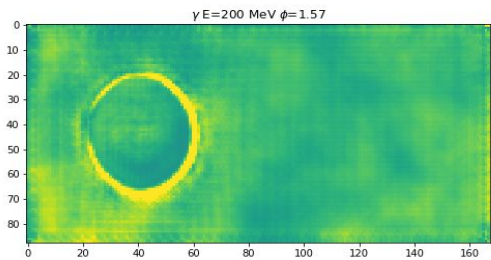
30N/50N



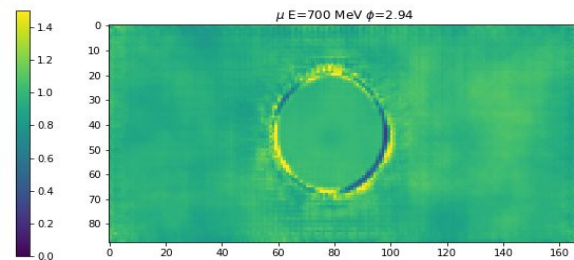
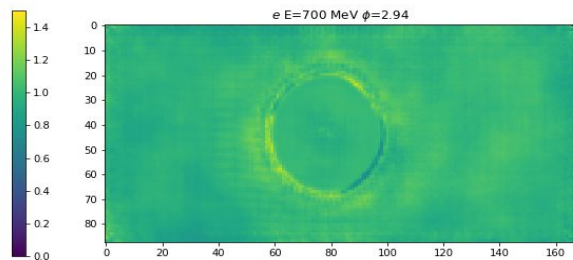
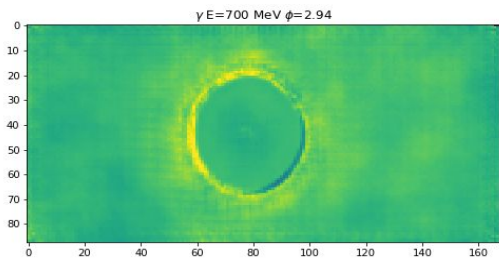
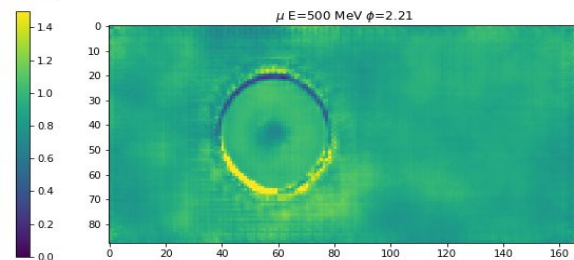
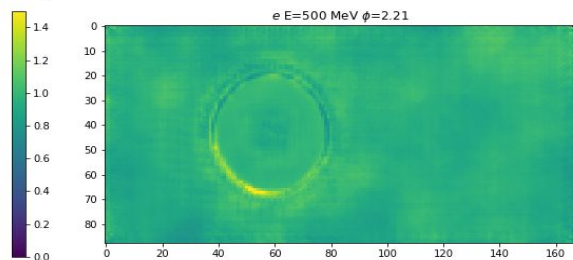
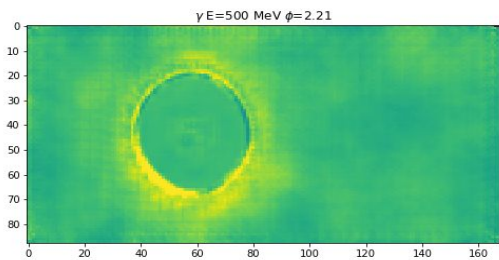
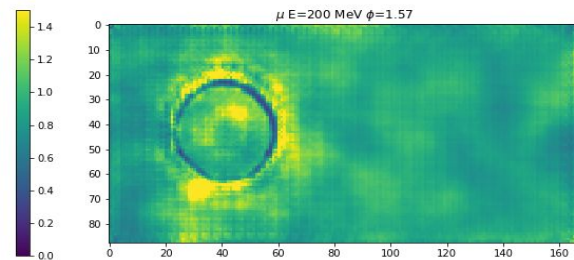
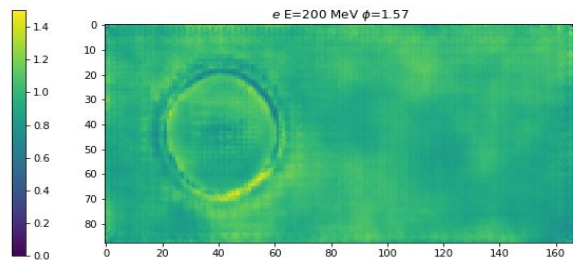
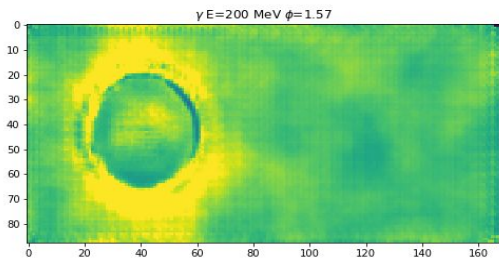
50N/100N



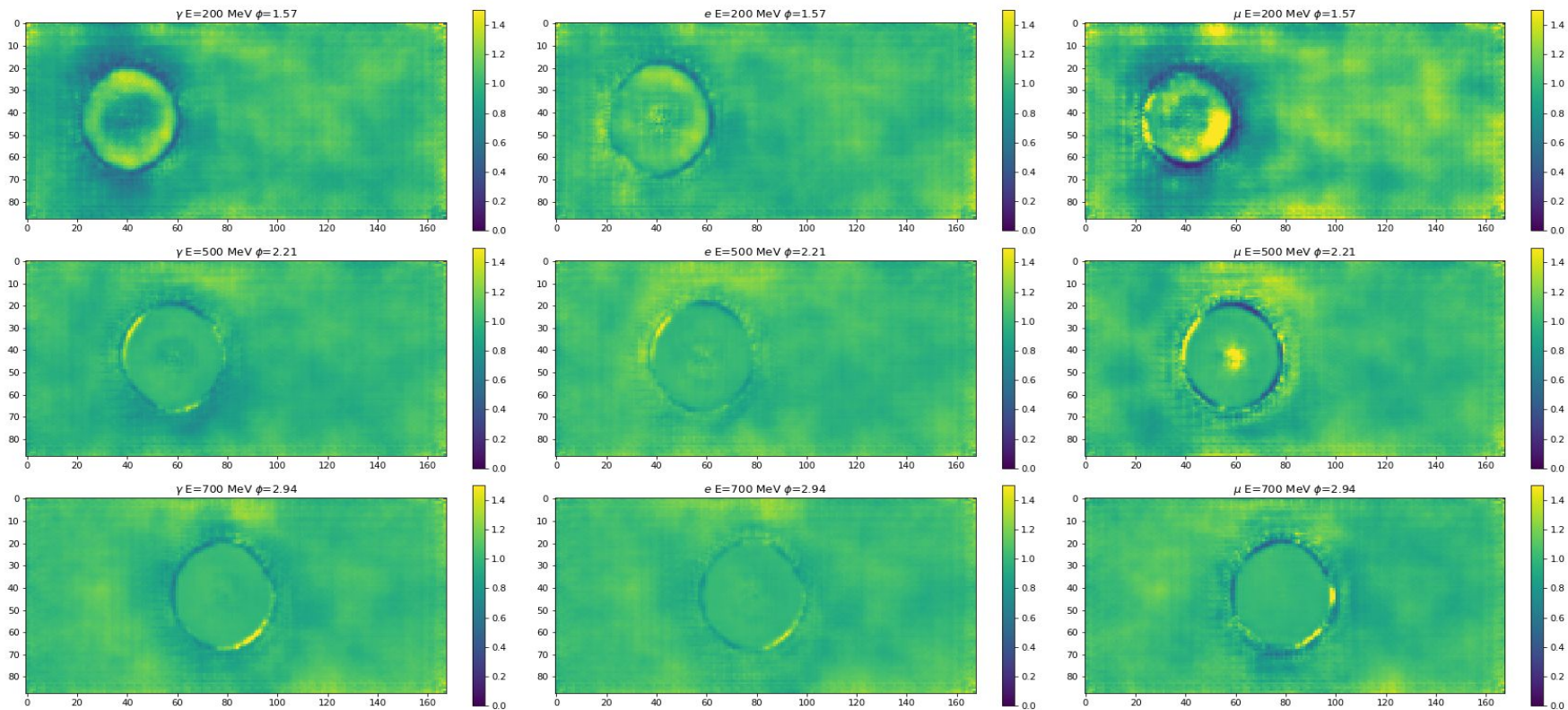
100N/176N



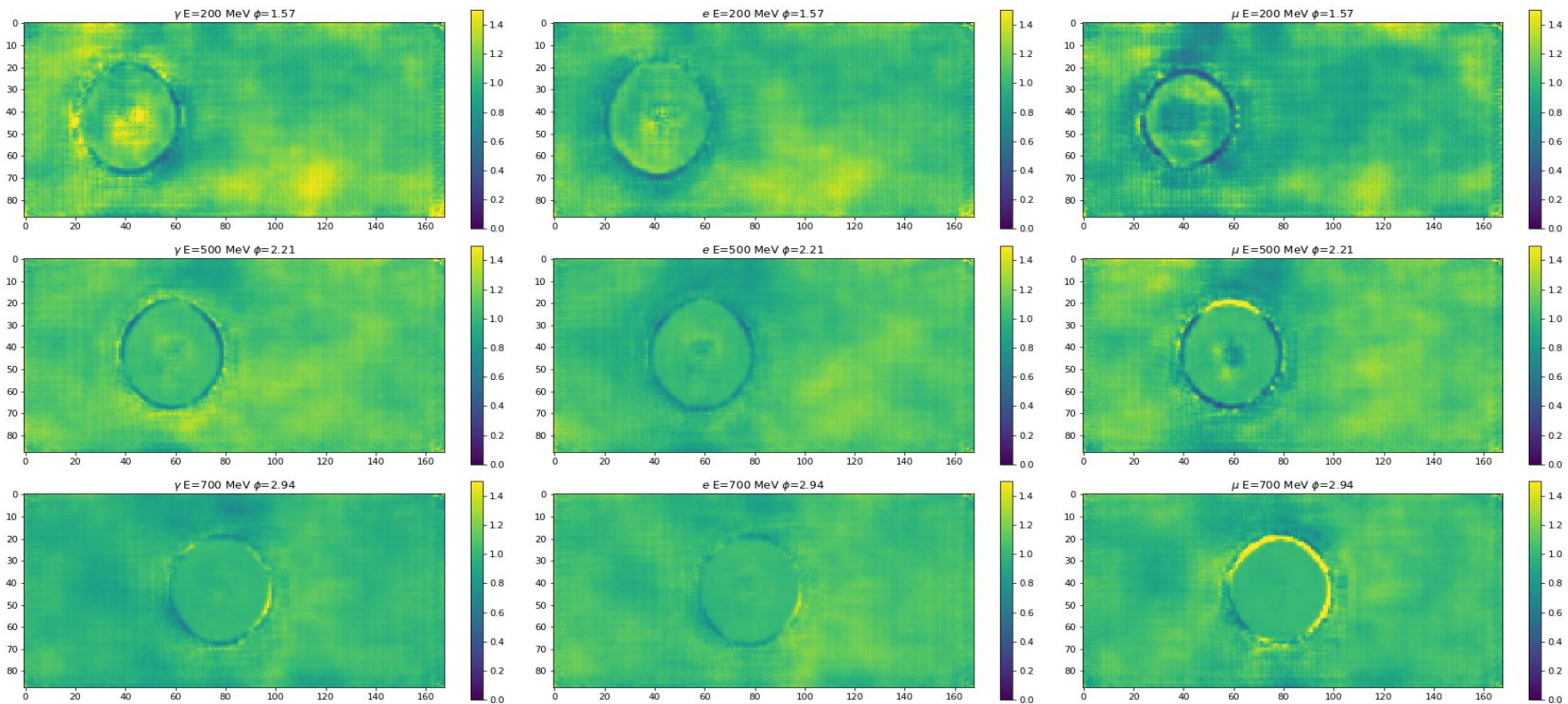
176N/298N



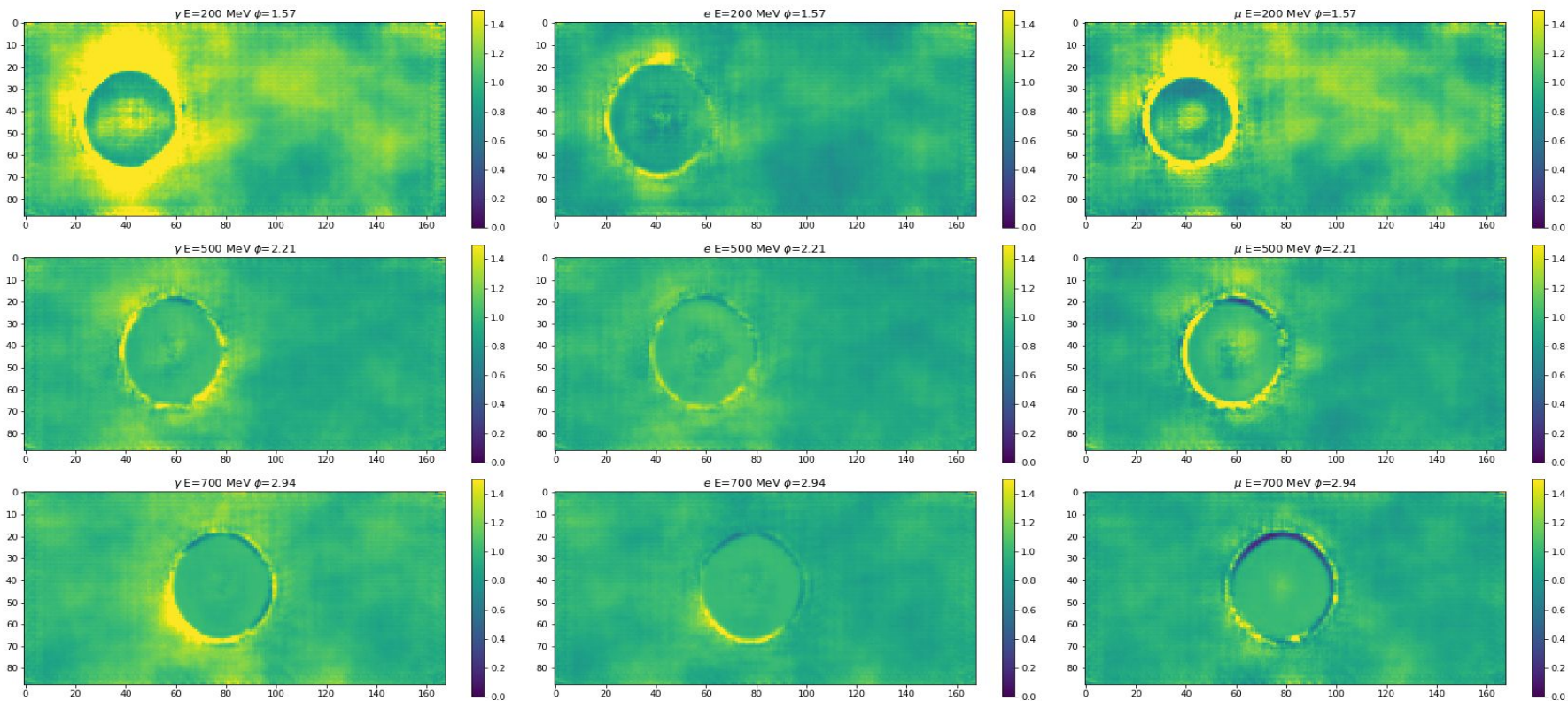
298N/400N



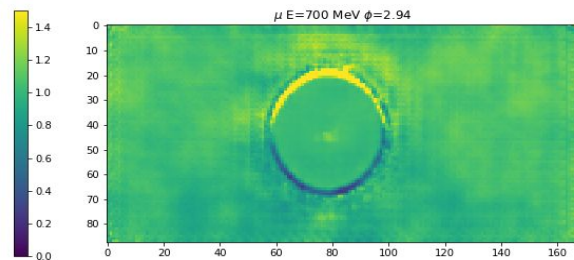
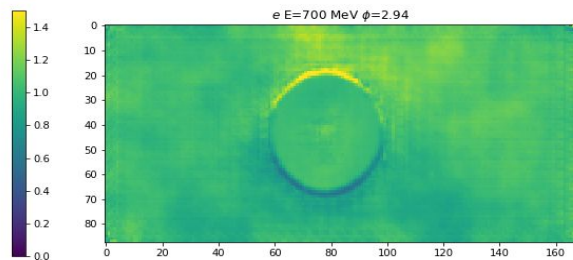
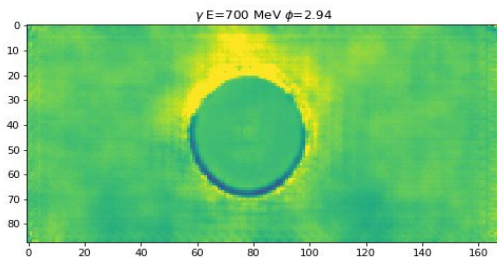
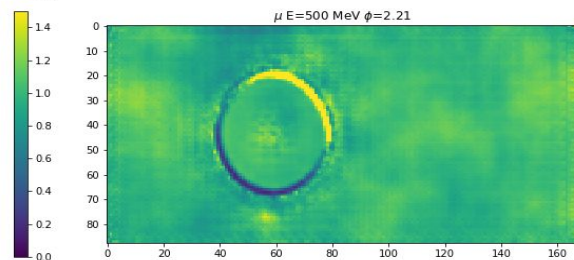
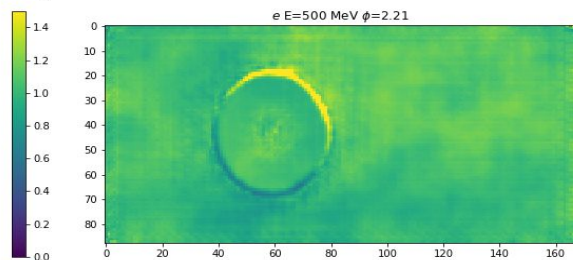
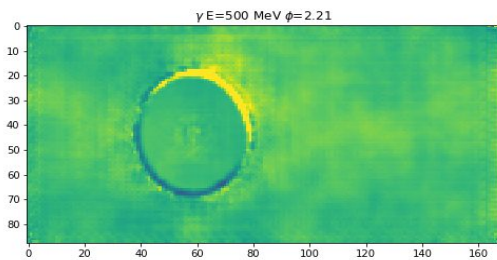
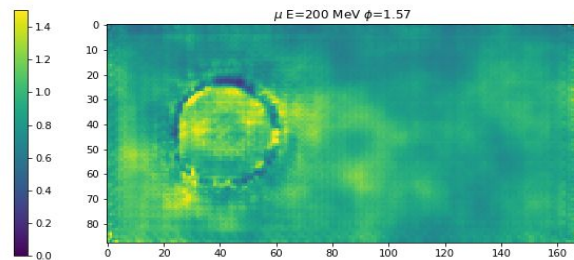
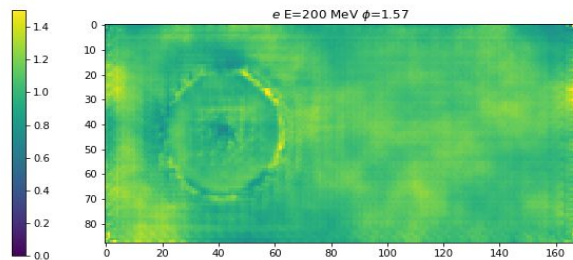
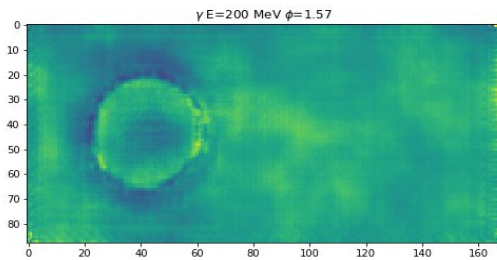
400N/516N



516N/800N

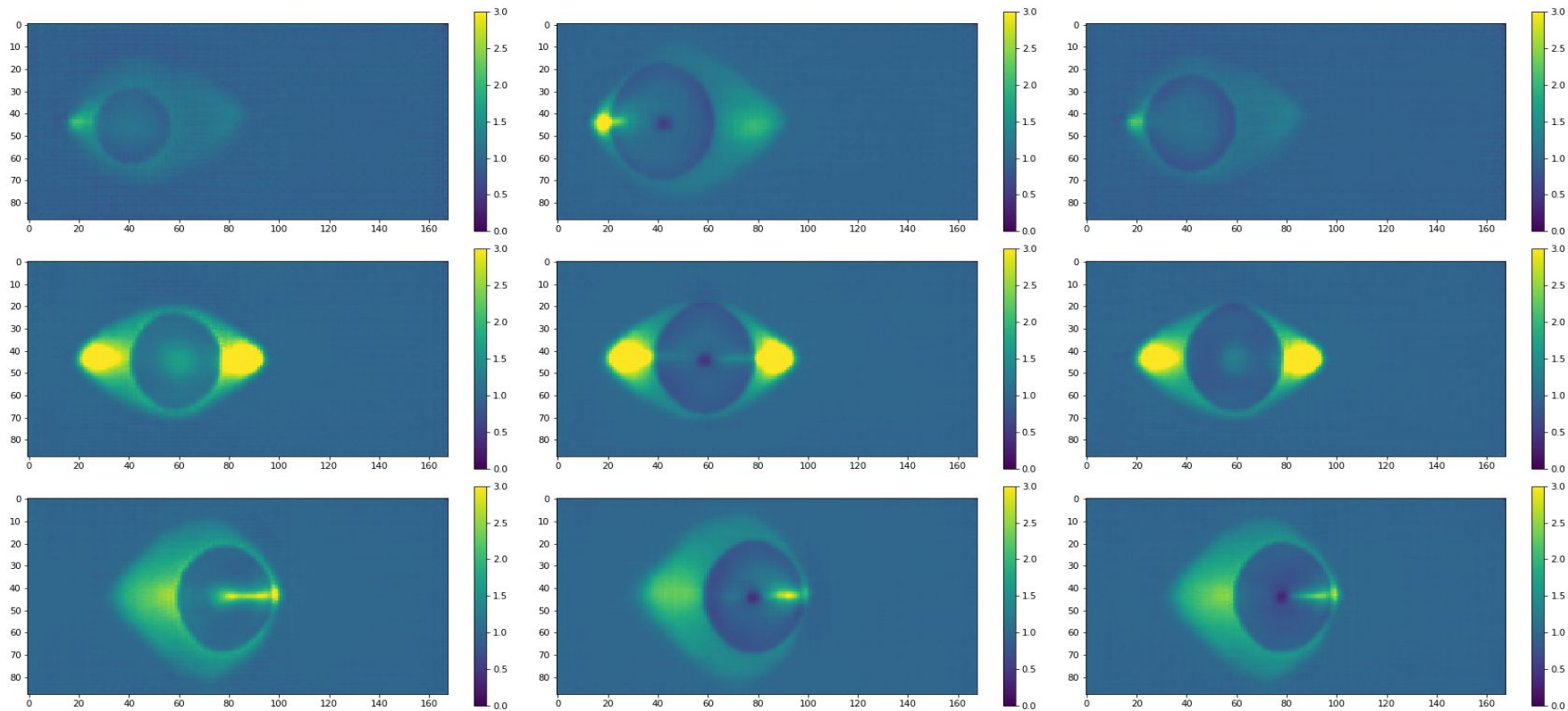


800N/1000N

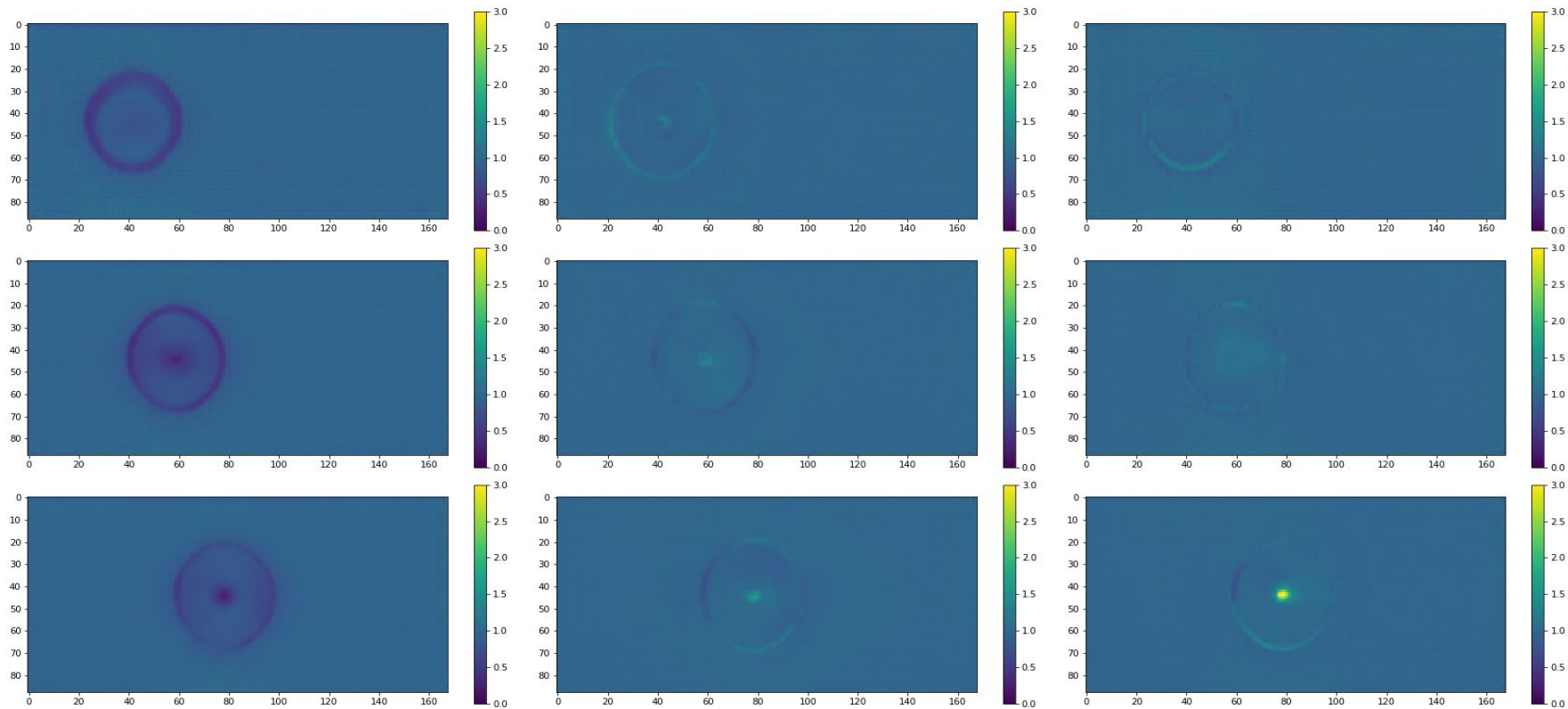


Mean of charge (Image Comparison)

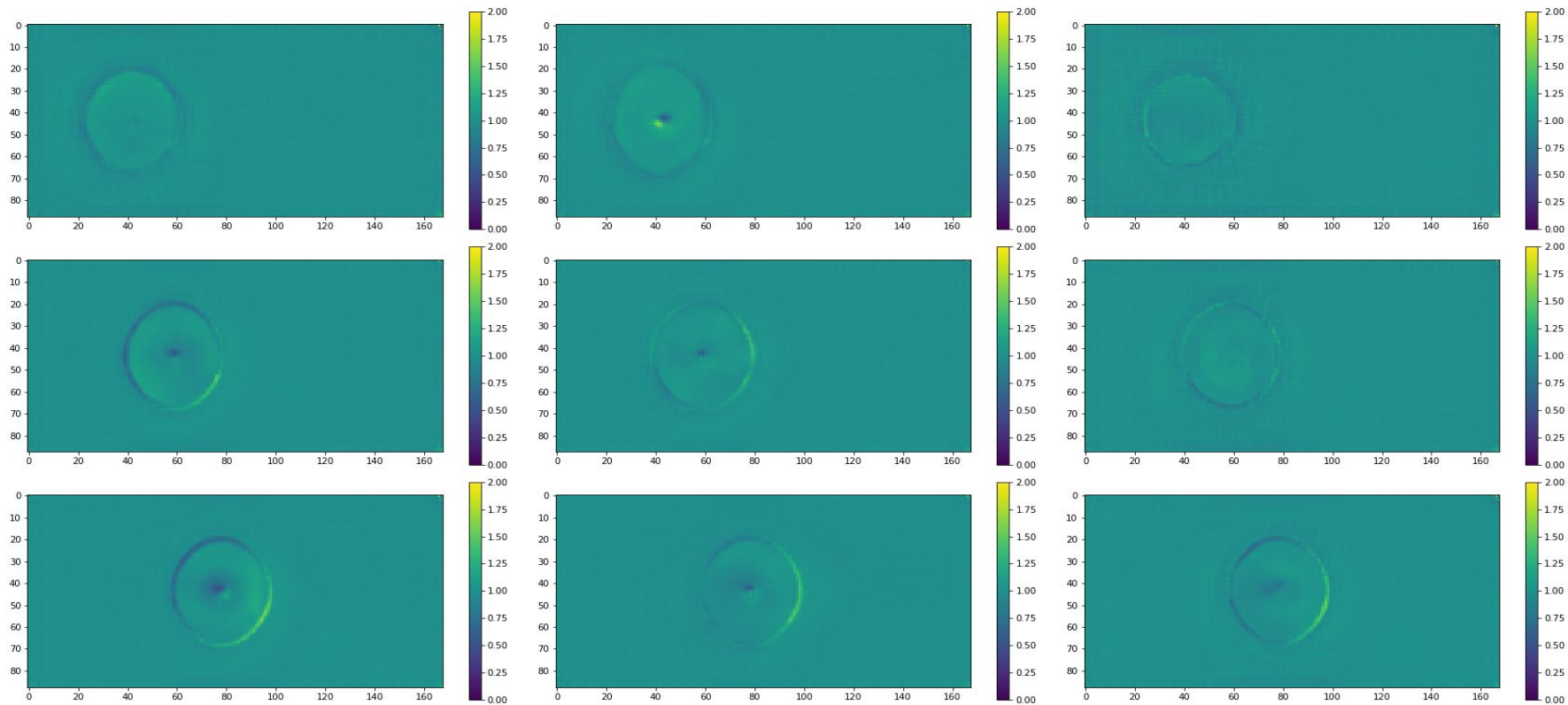
3N/10N



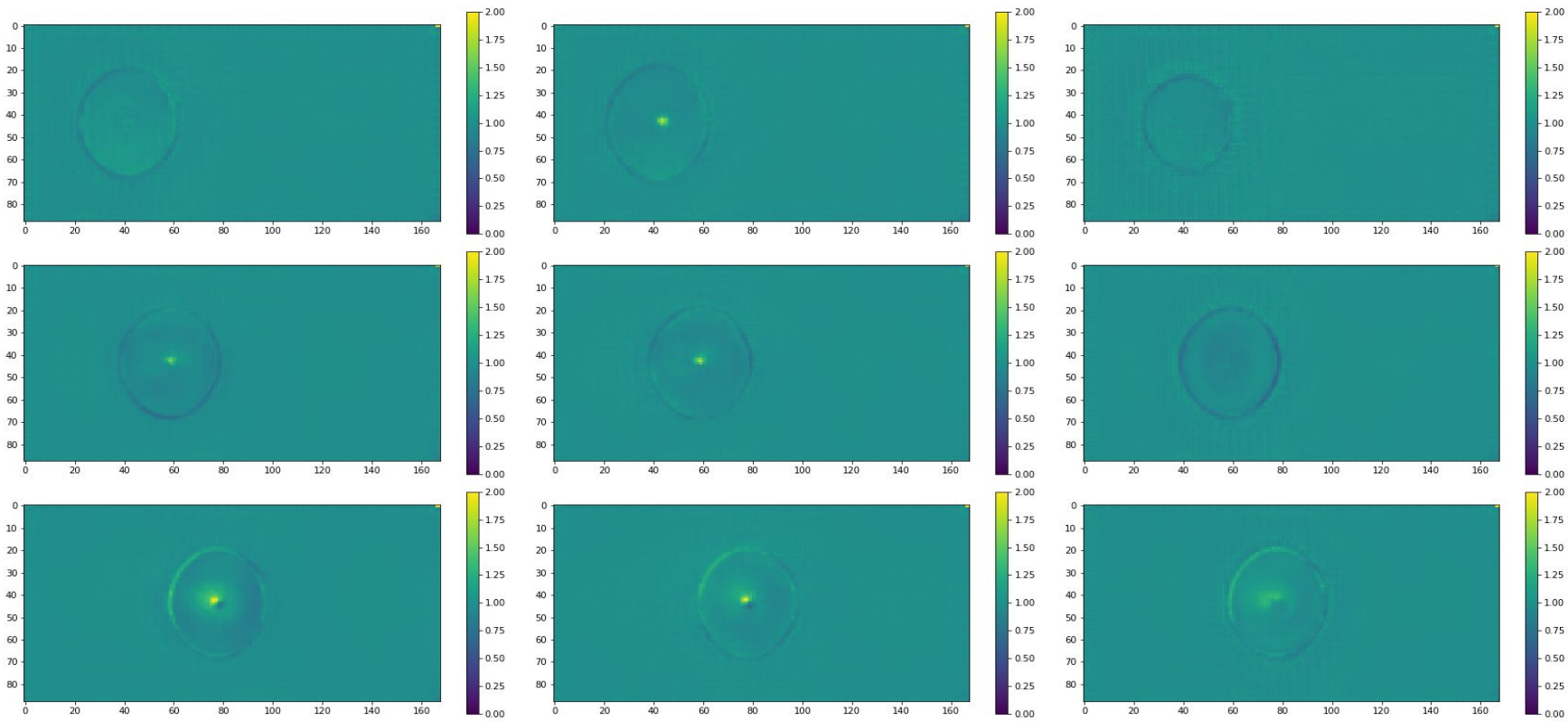
10N/30N



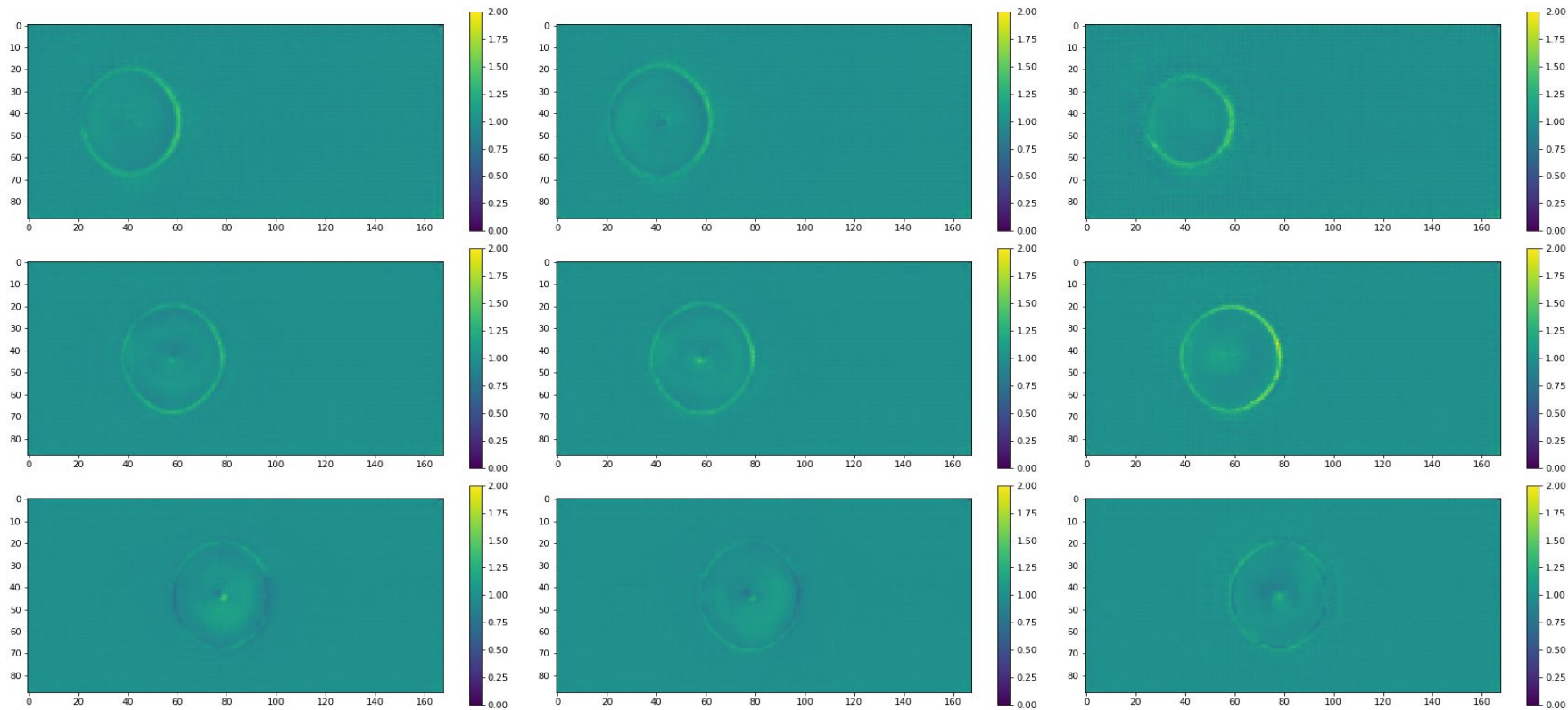
30N/50N



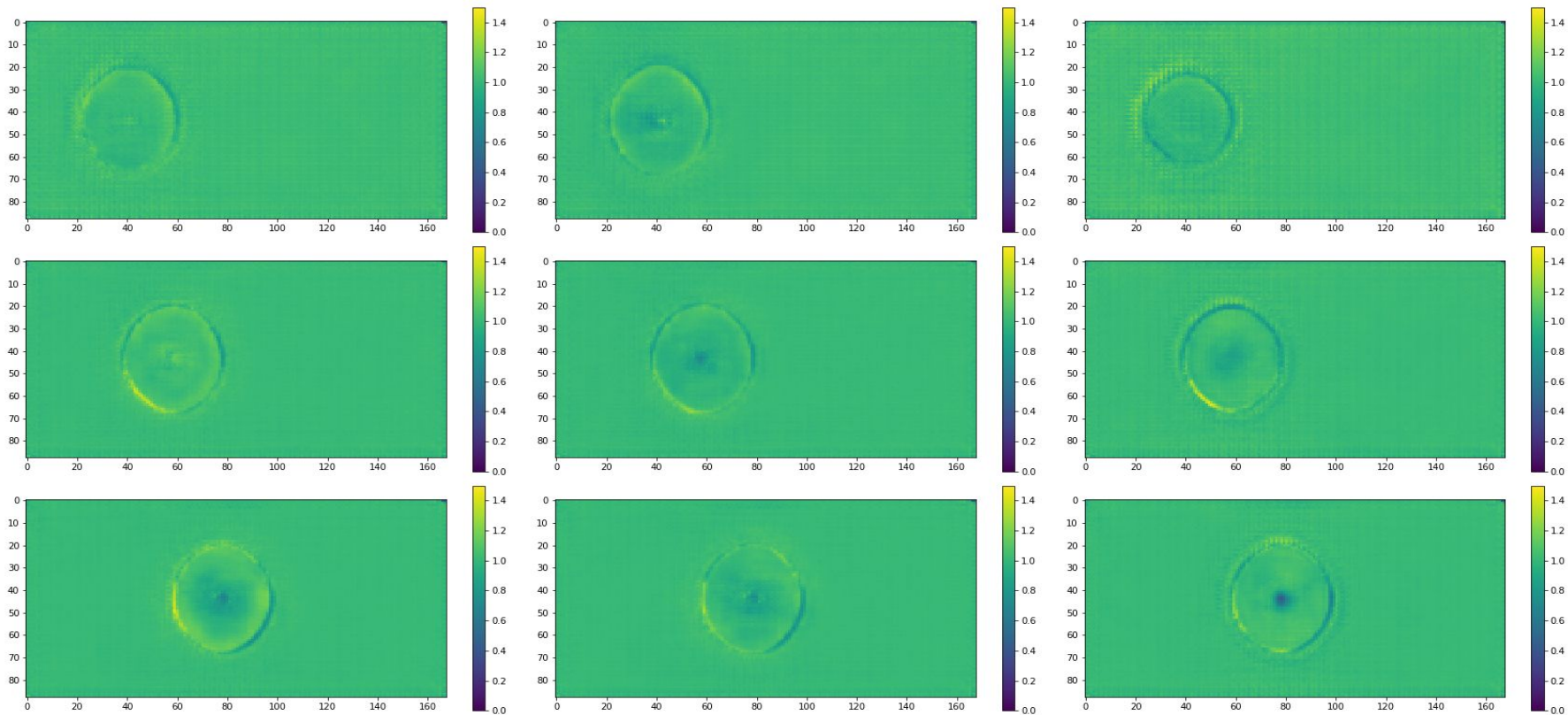
50N/100N



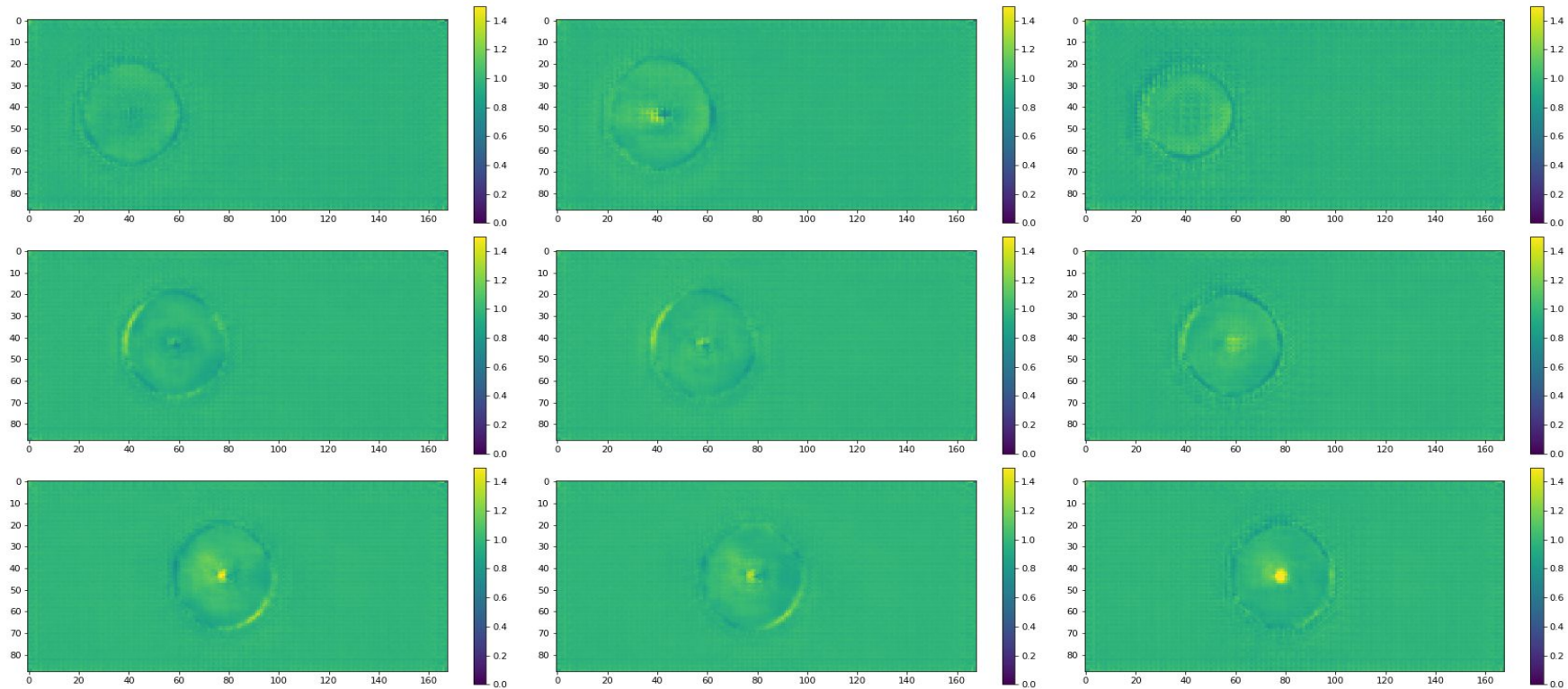
100N/176N



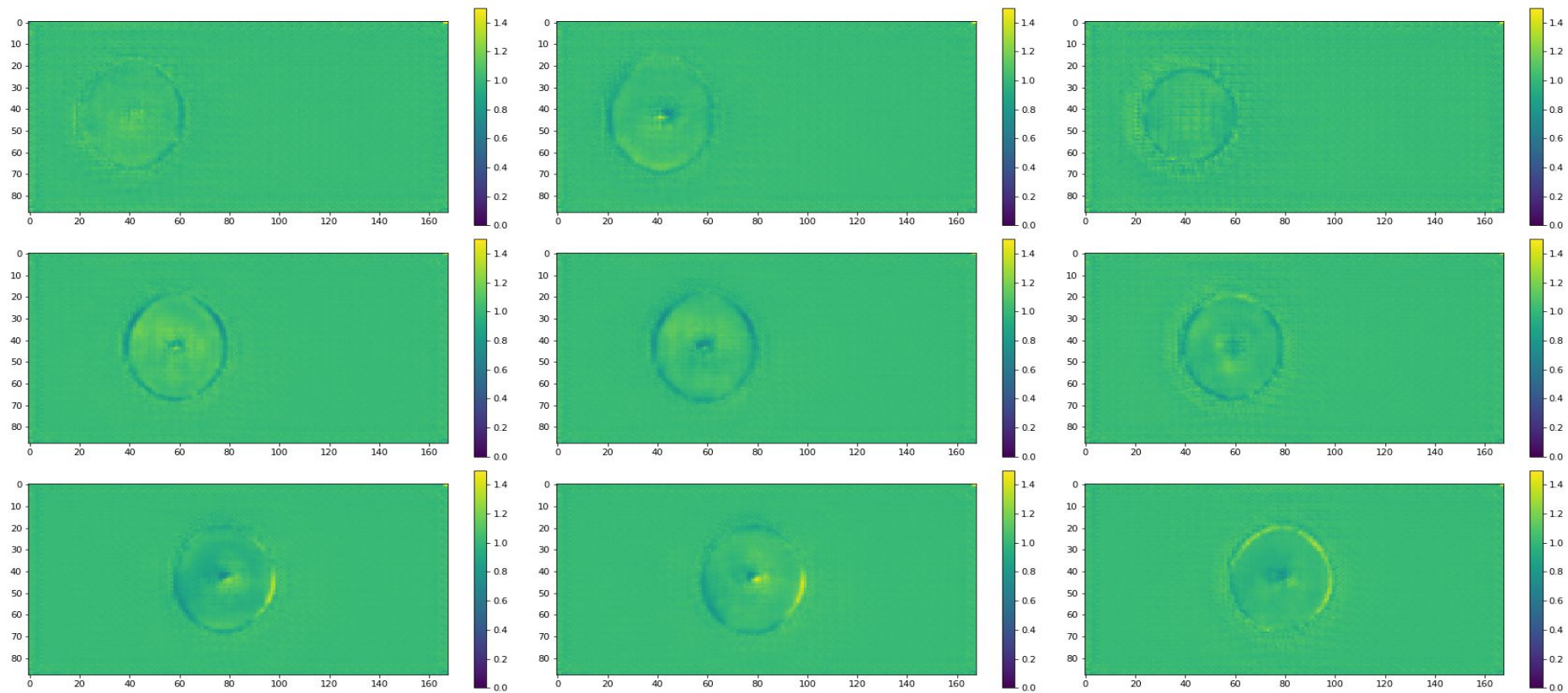
176N/298N



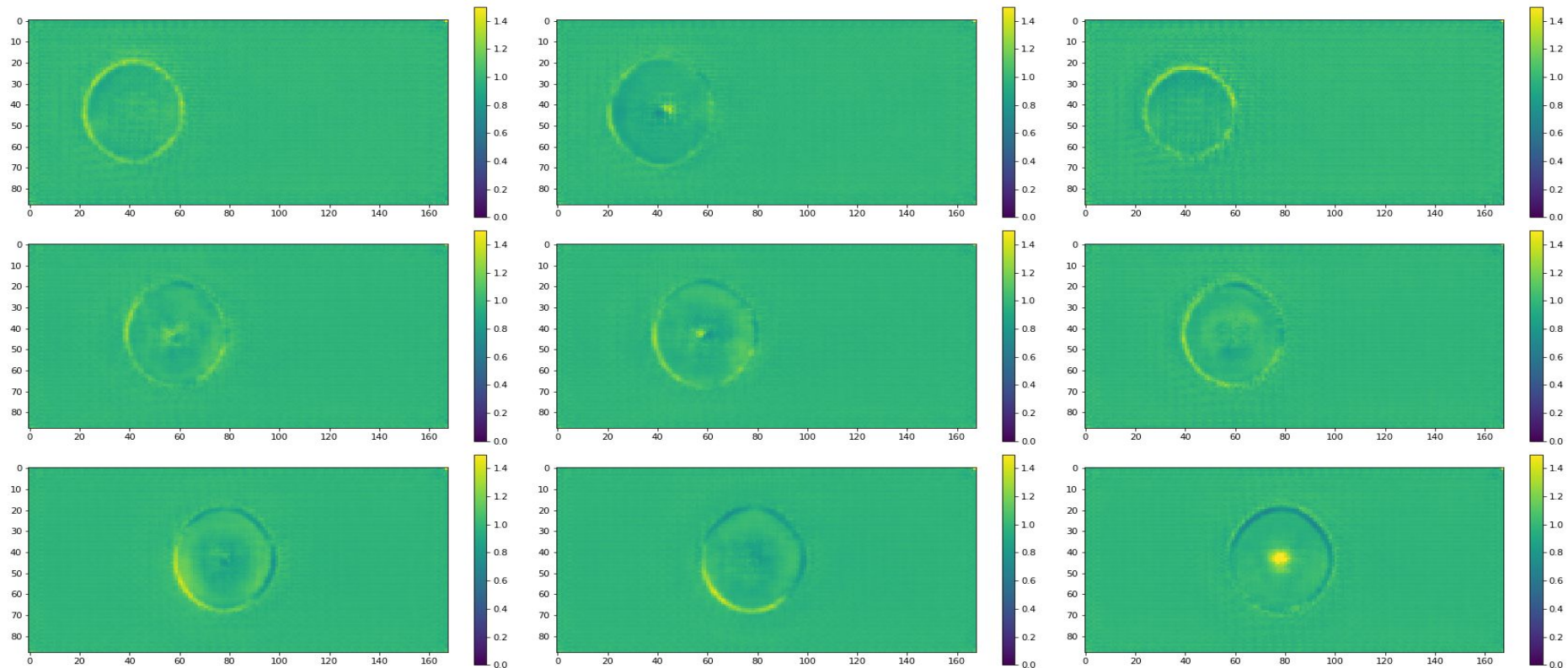
298N/400N



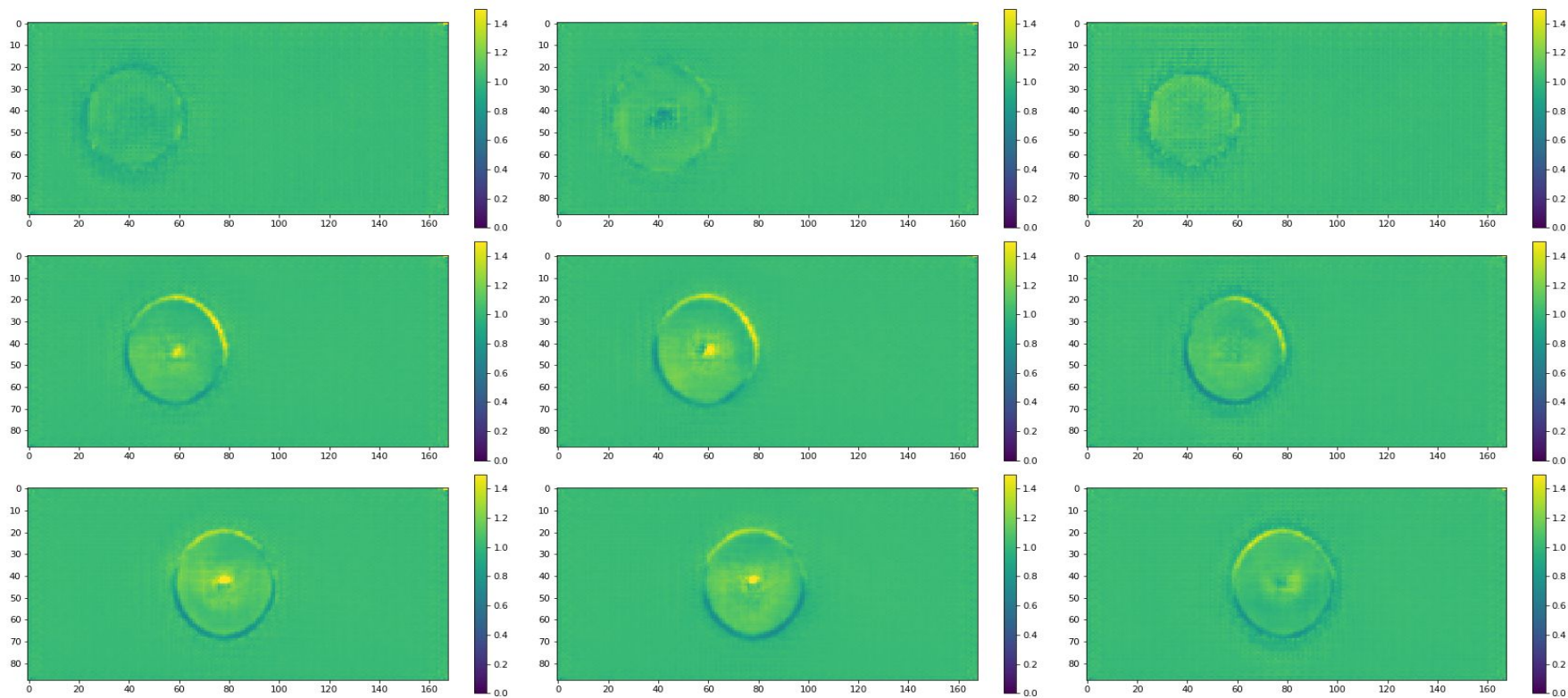
400N/516N



516N/800N

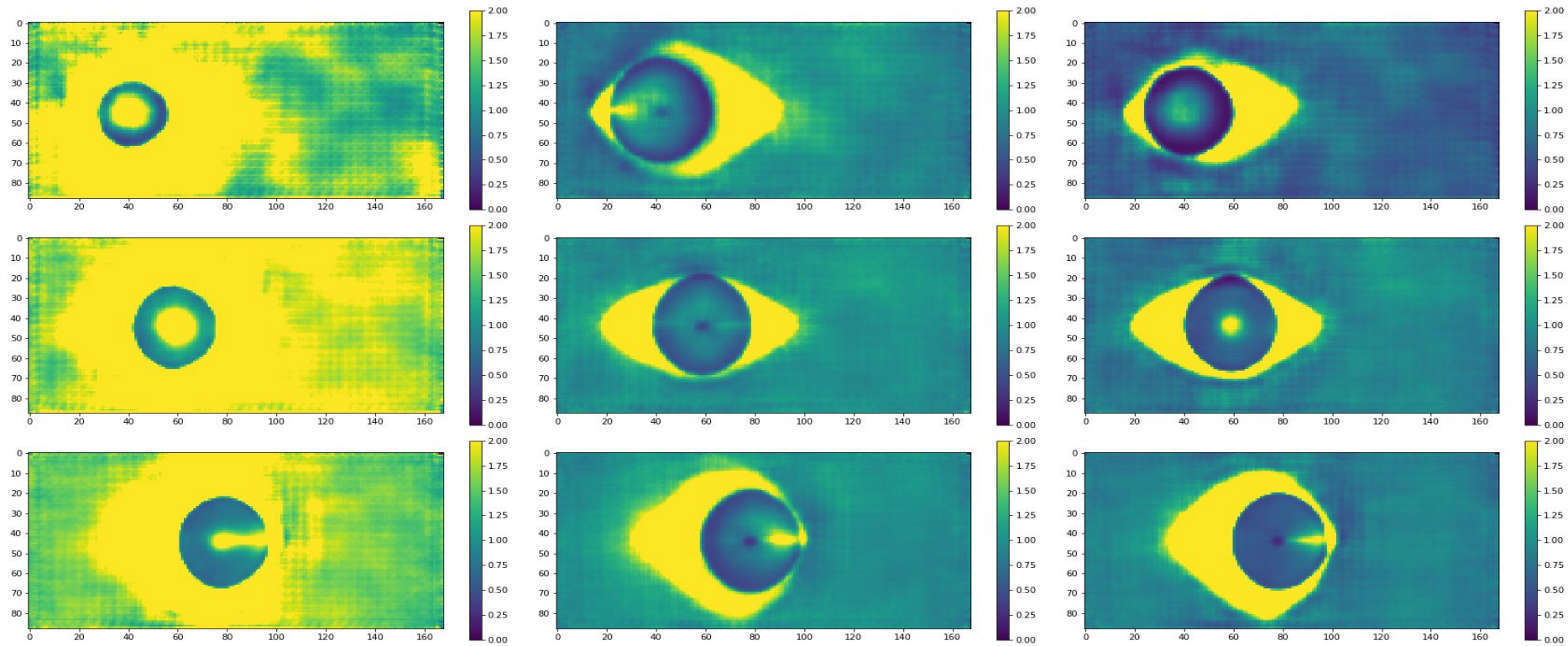


800N/1000N

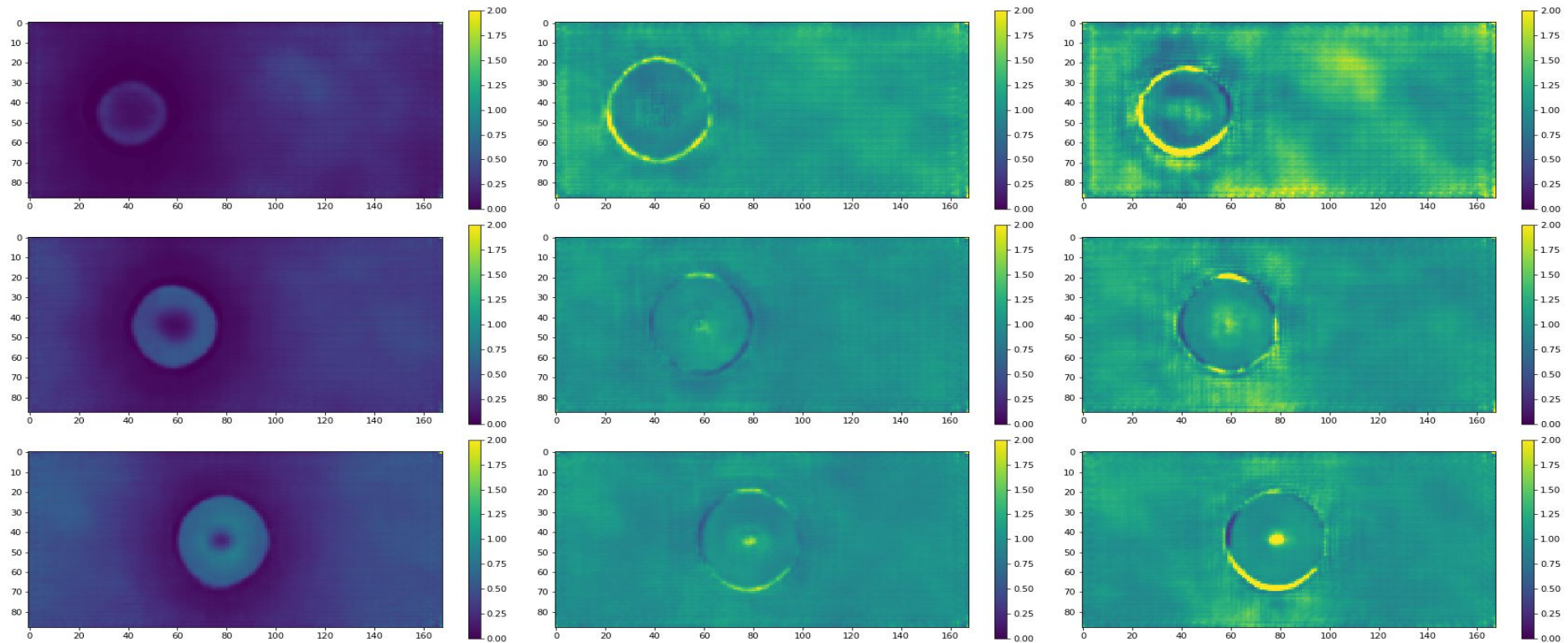


Predicted Charge X Predicted Hit Probability (Image Comparison)

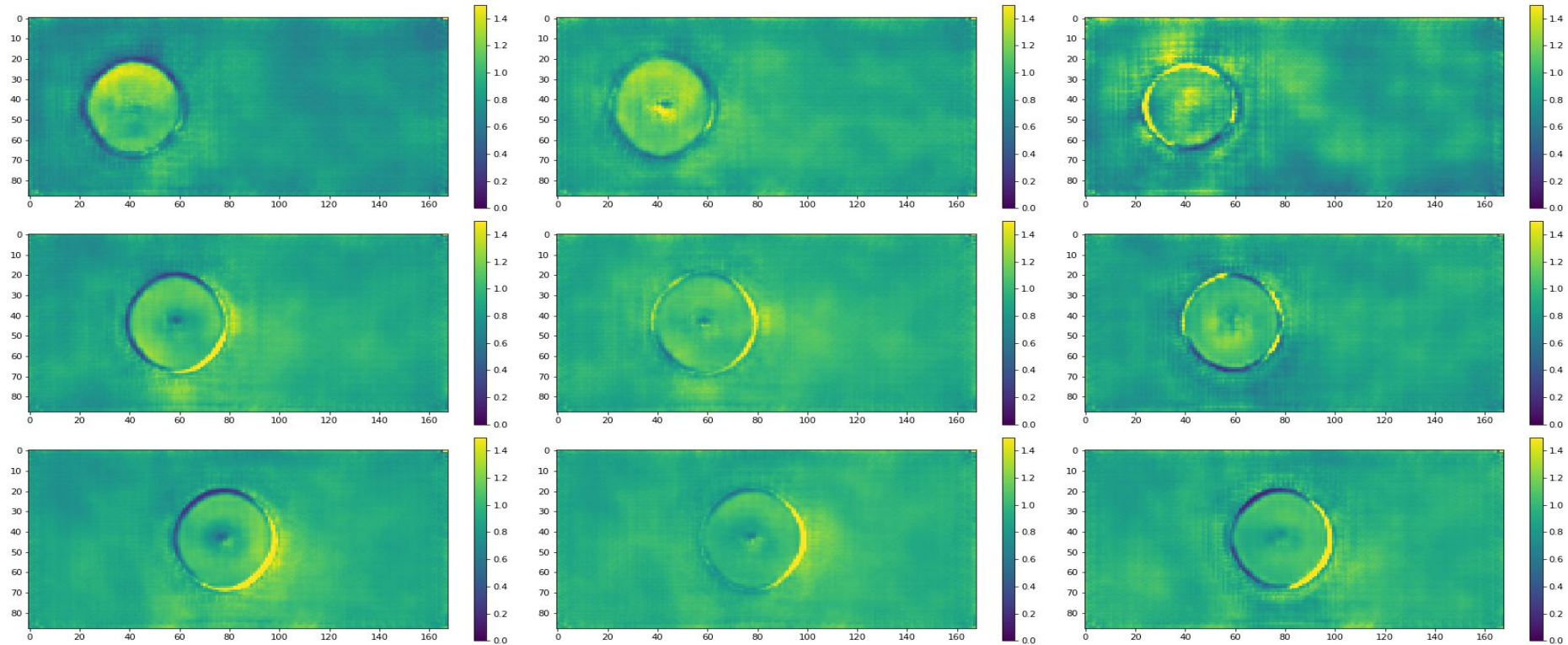
3N/10N



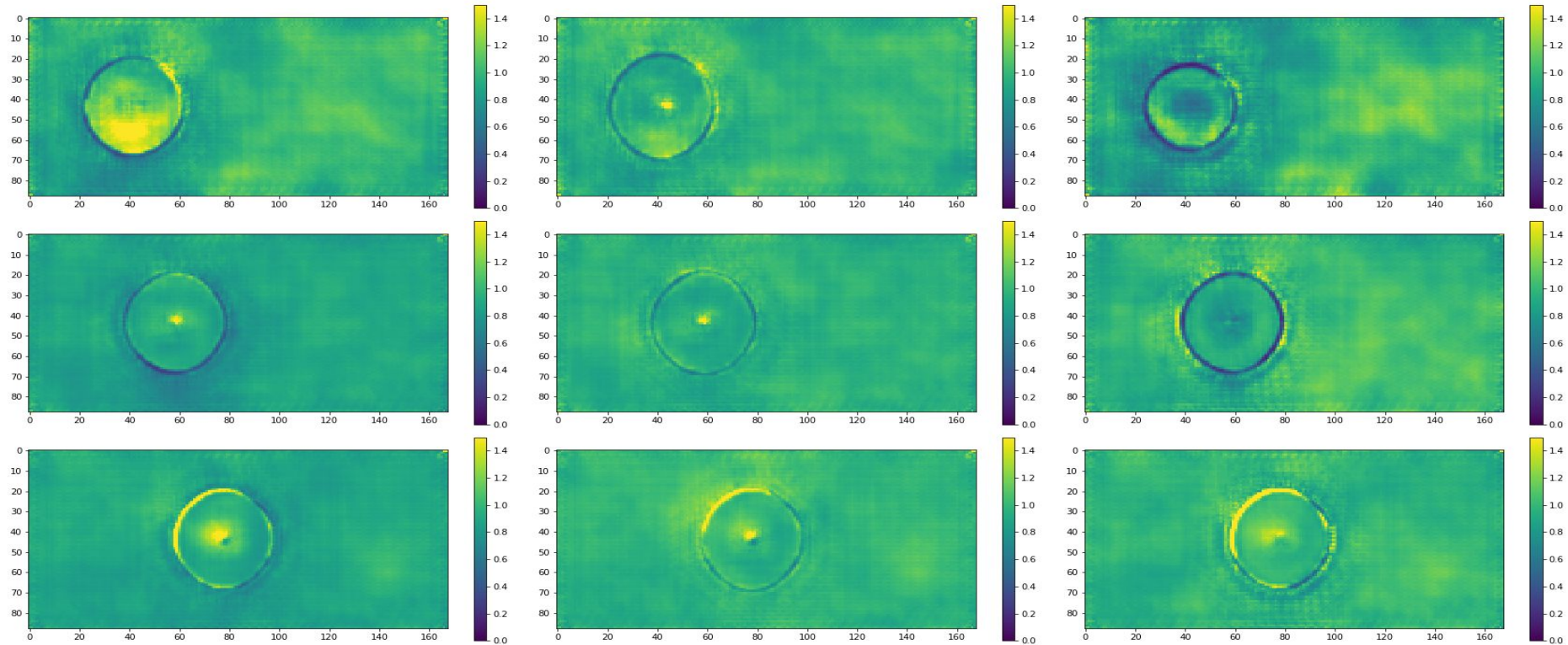
10N/30N



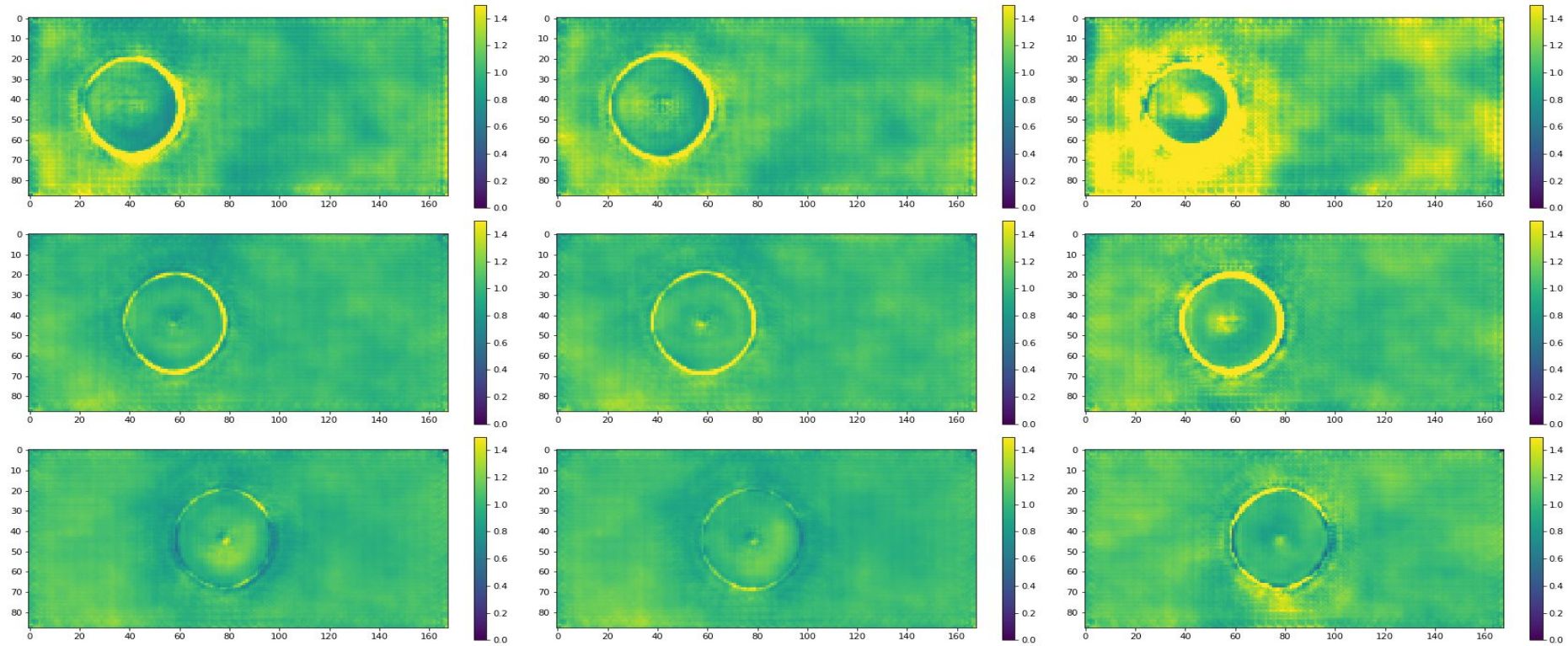
30N/50N



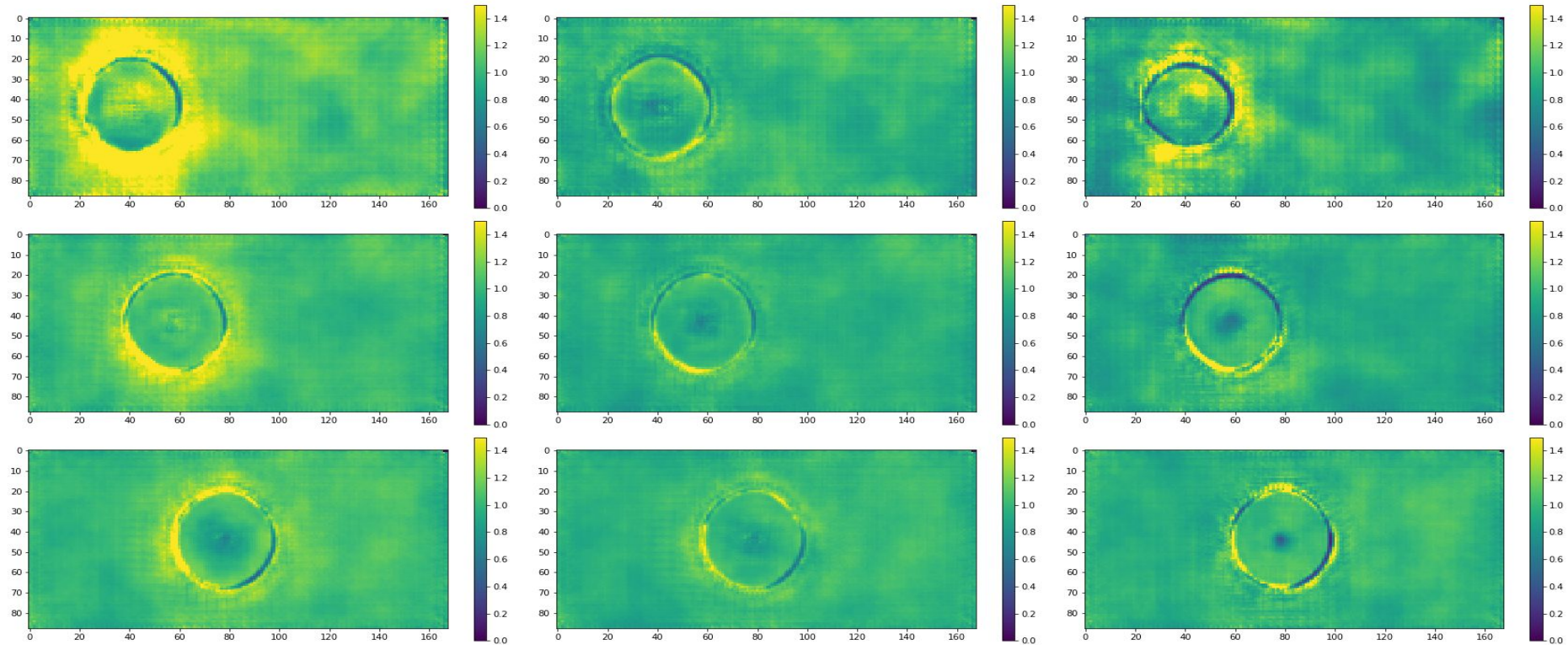
50N/100N



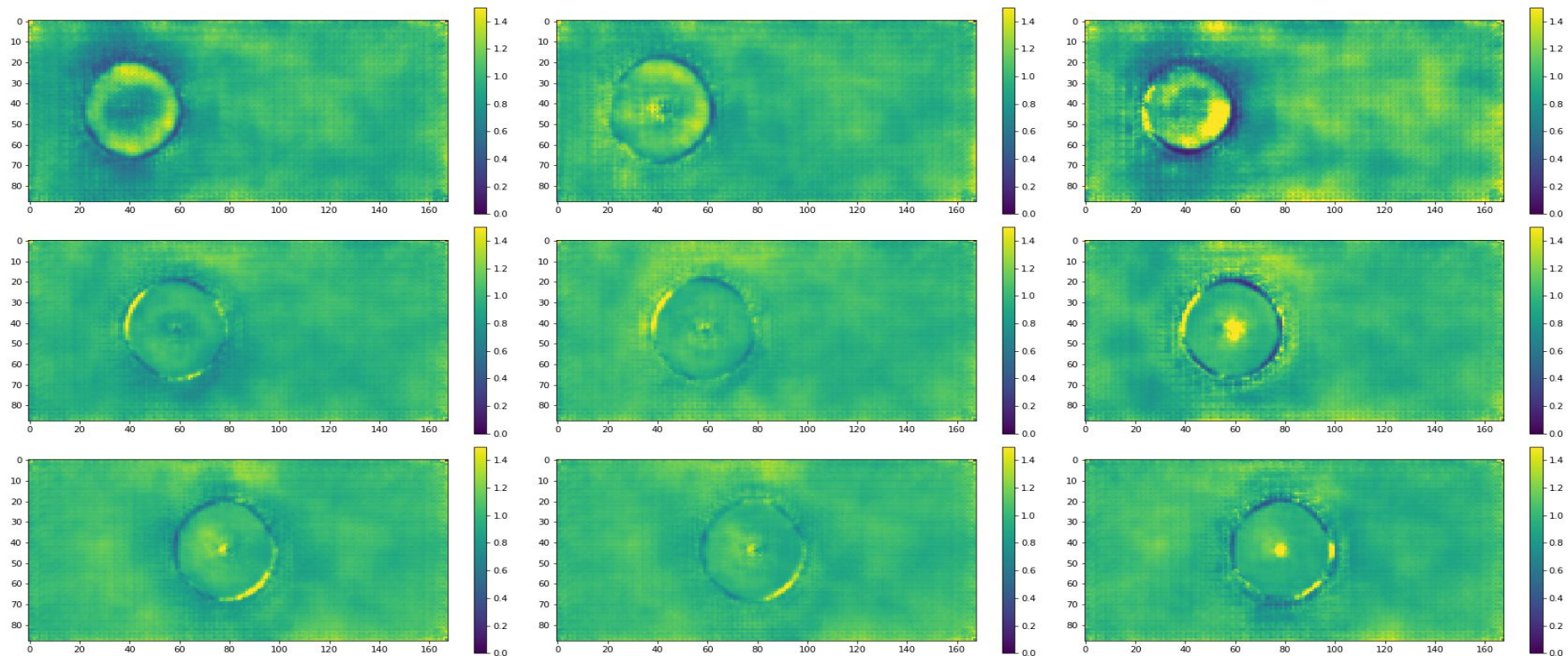
100N/176N



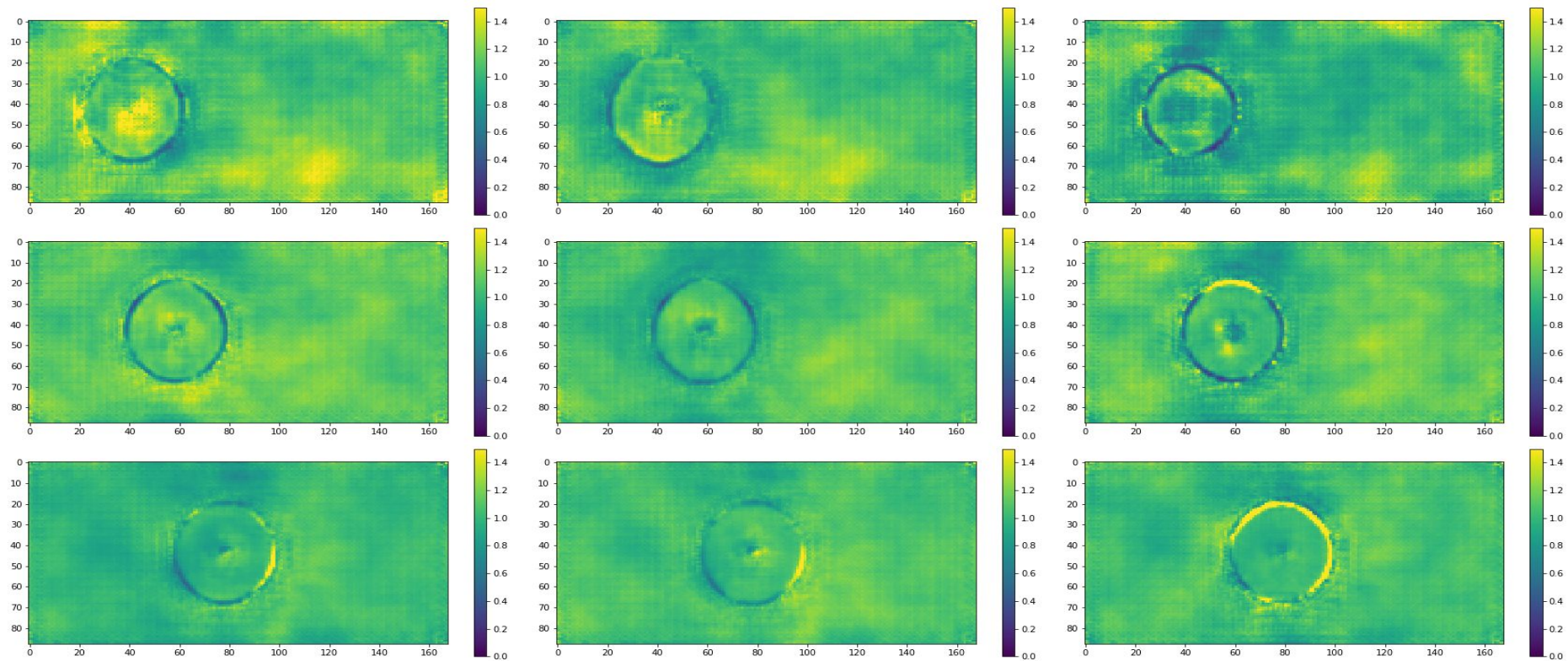
176N/298N



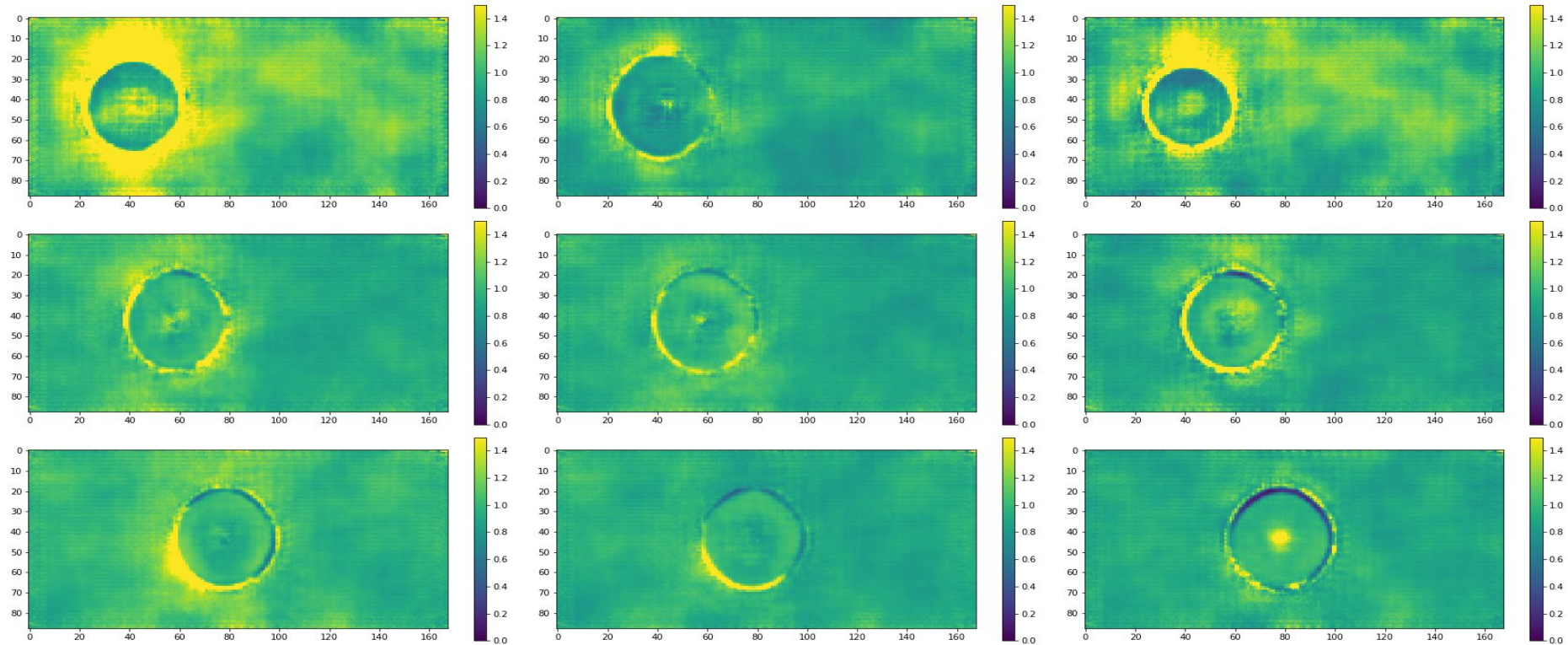
298N/400N



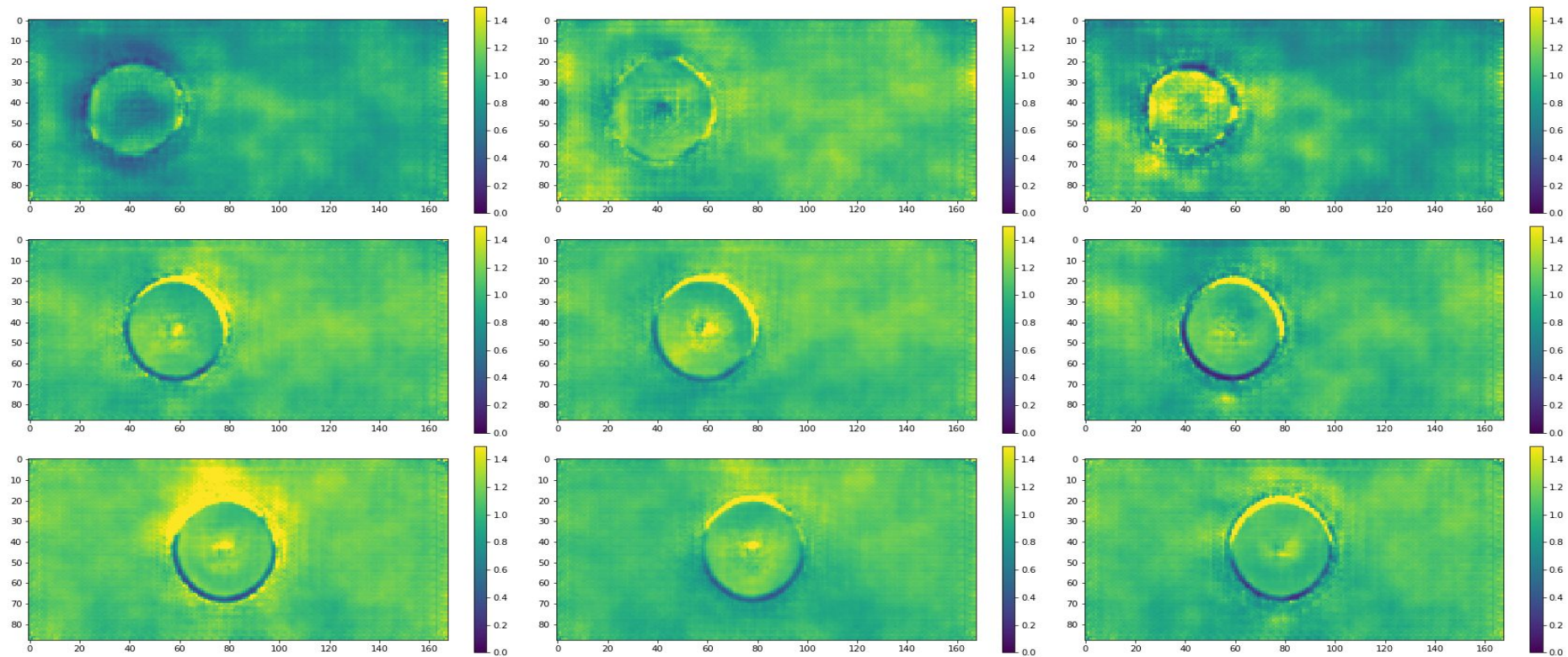
400N/516N



516N/800N

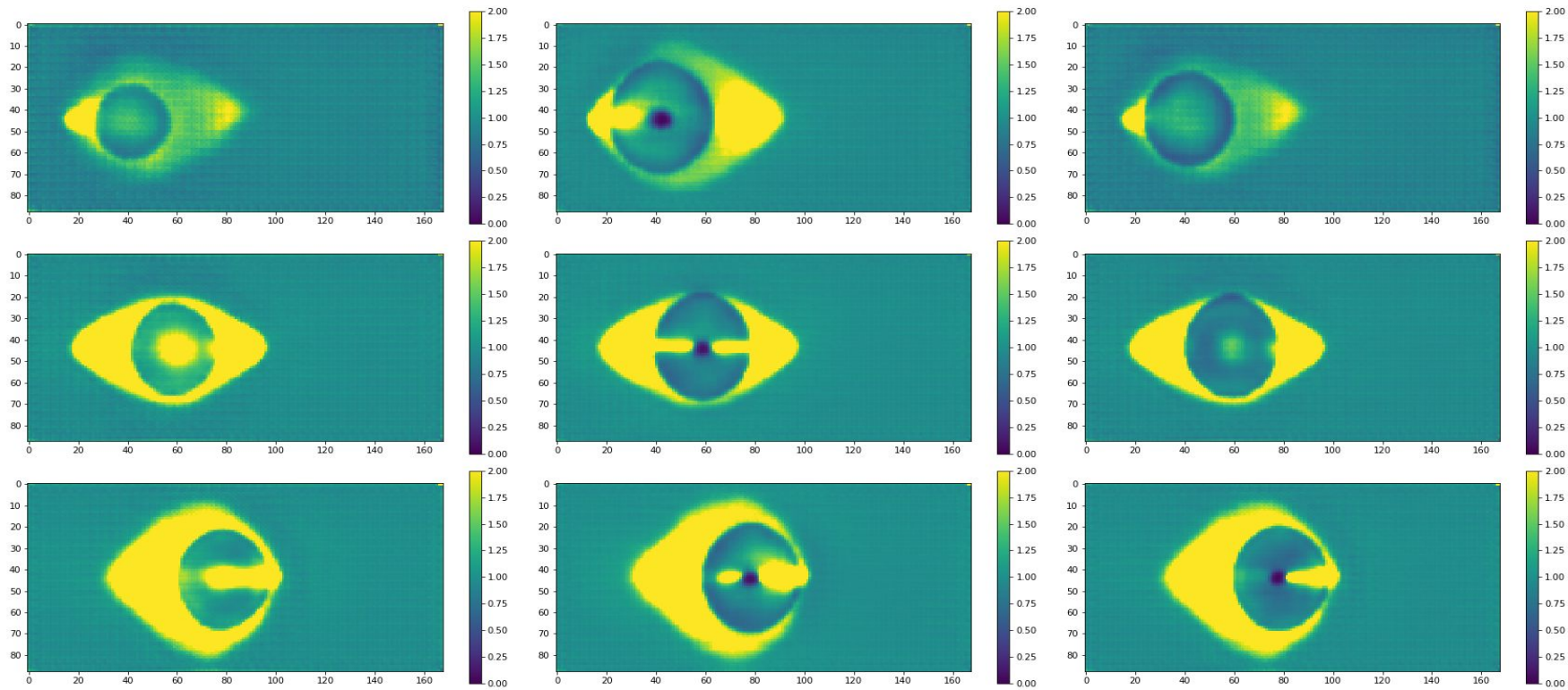


800N/1000N

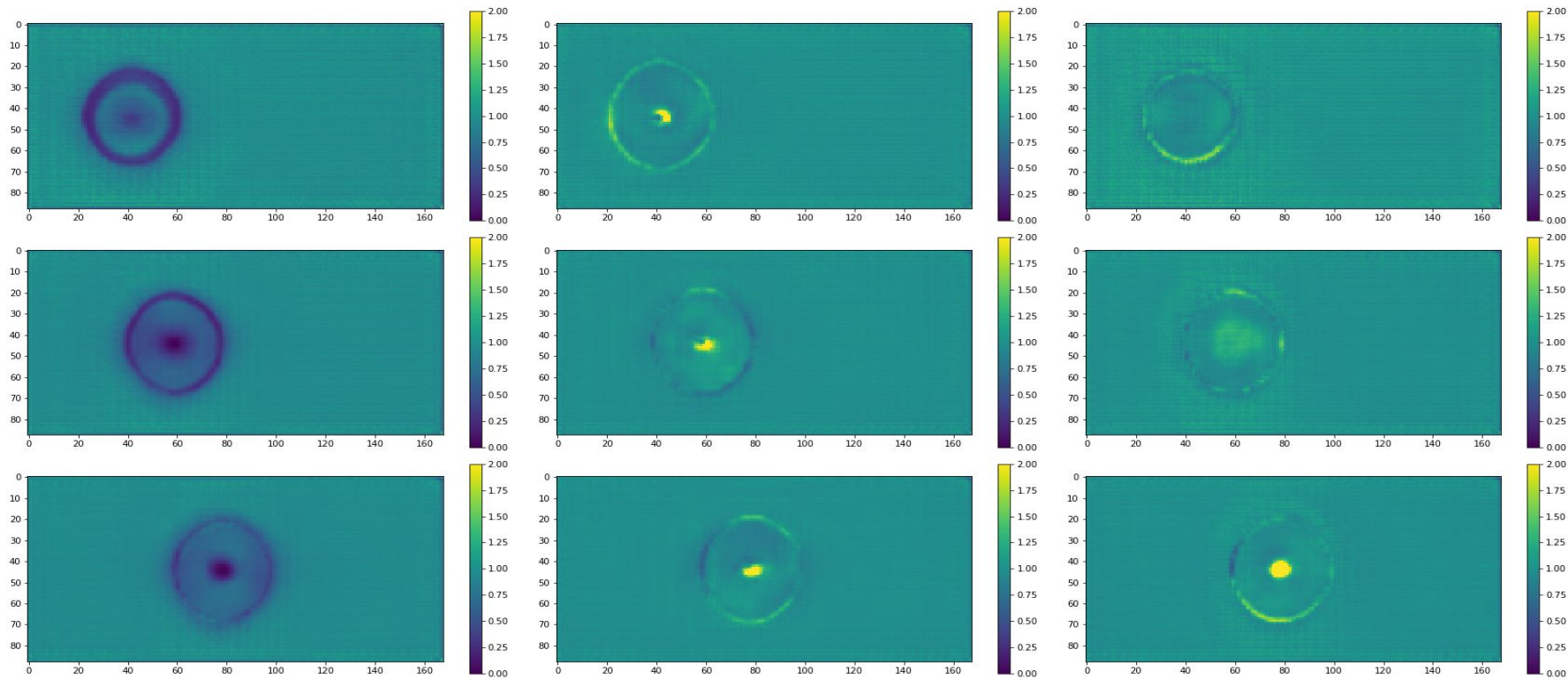


Predicted Variance(Image Comparison)

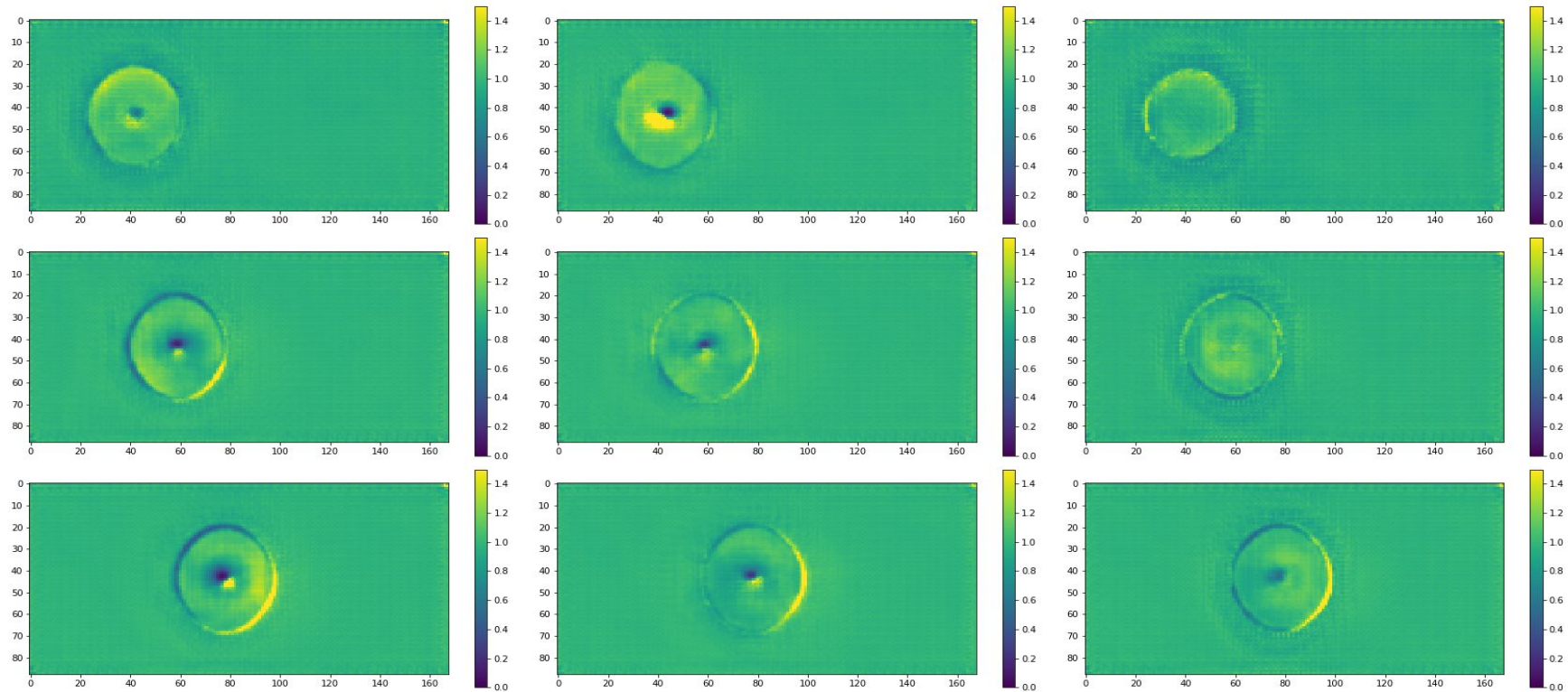
3N/10N



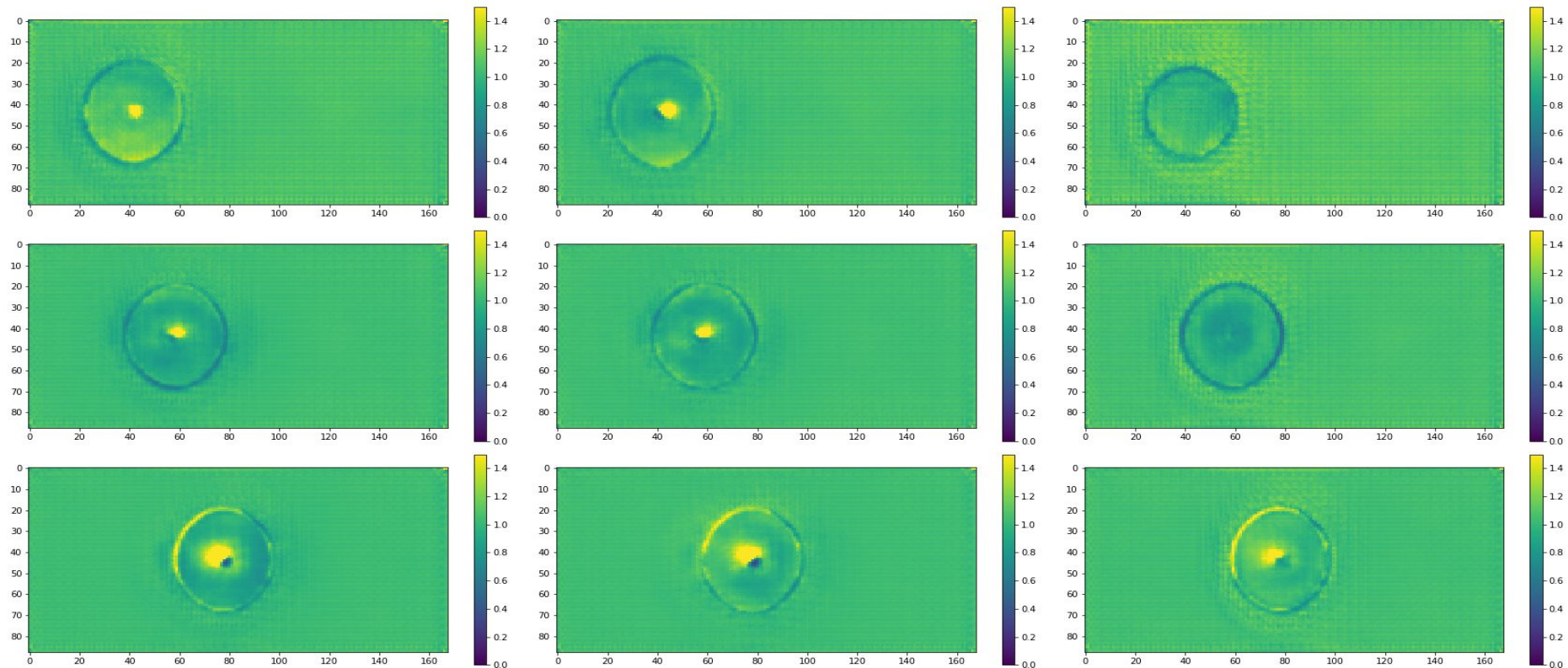
10N/30N



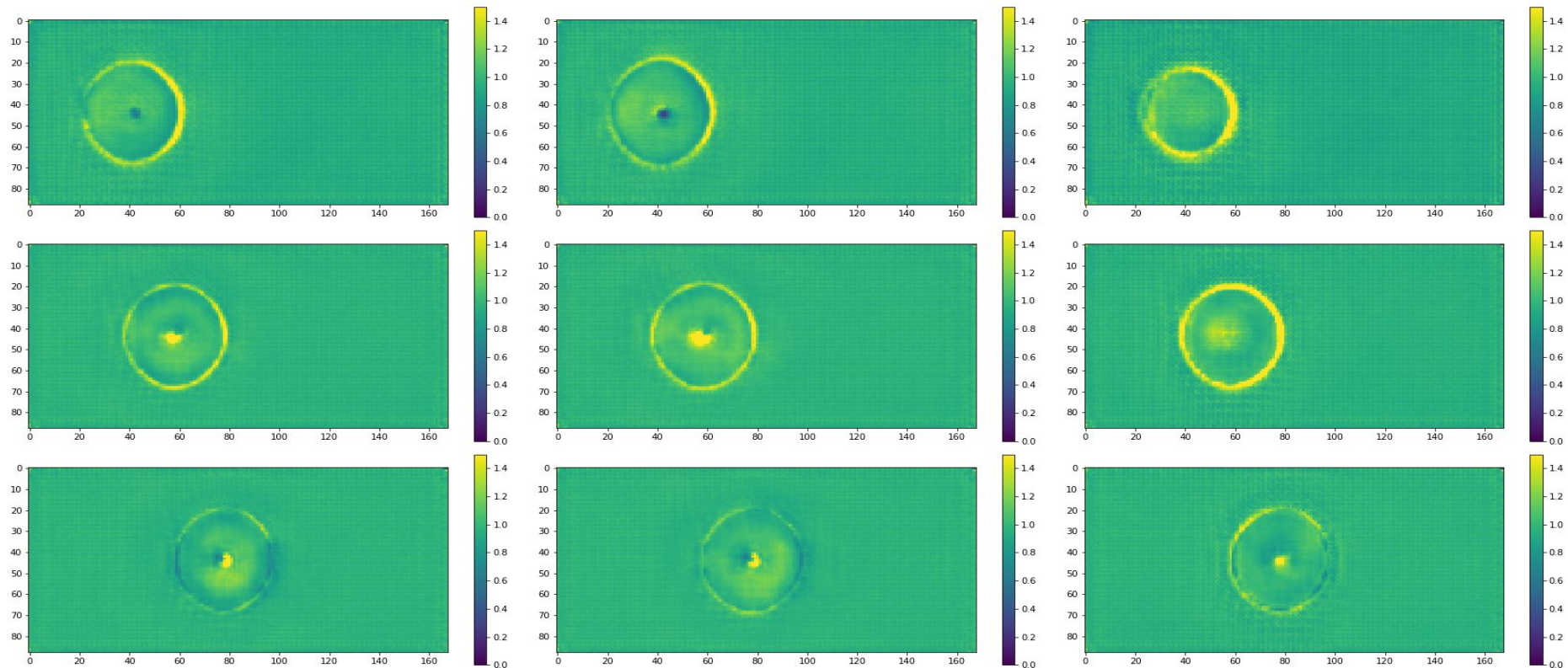
30N/50N



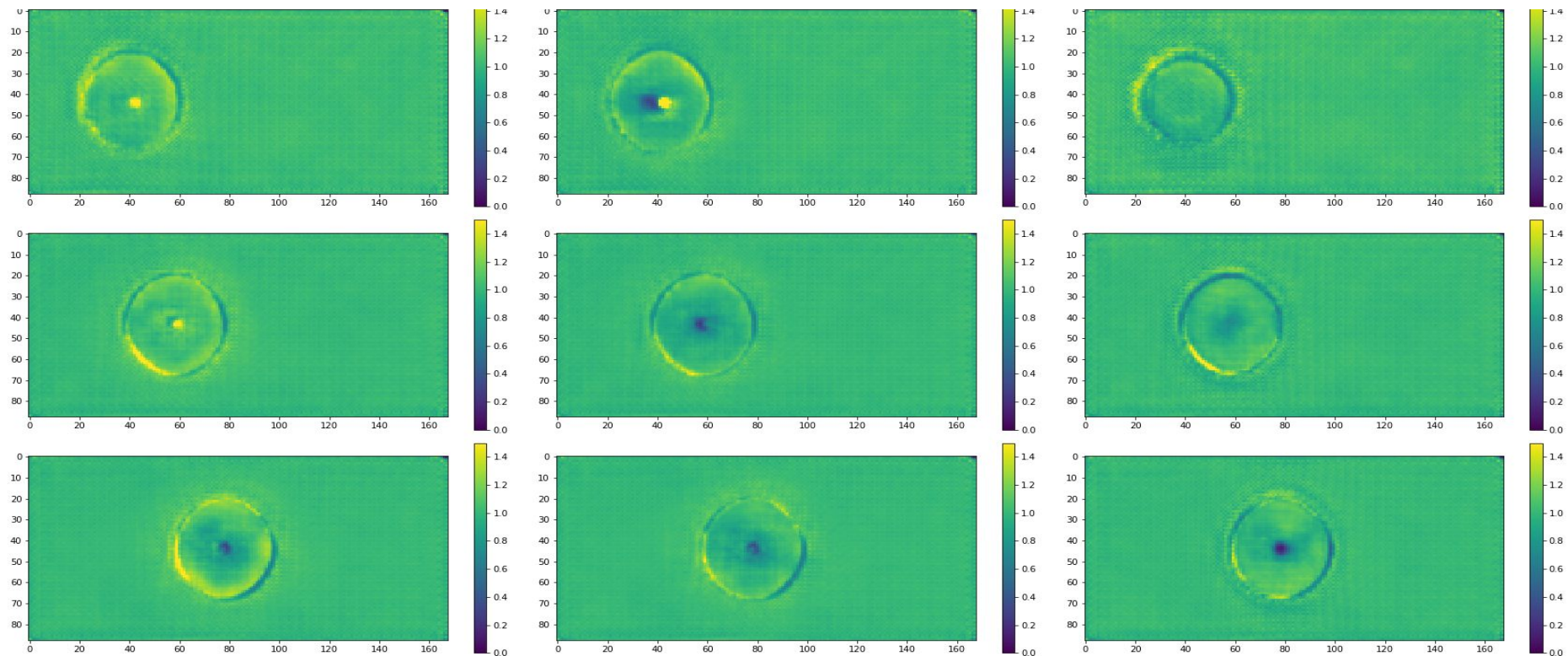
50N/100N



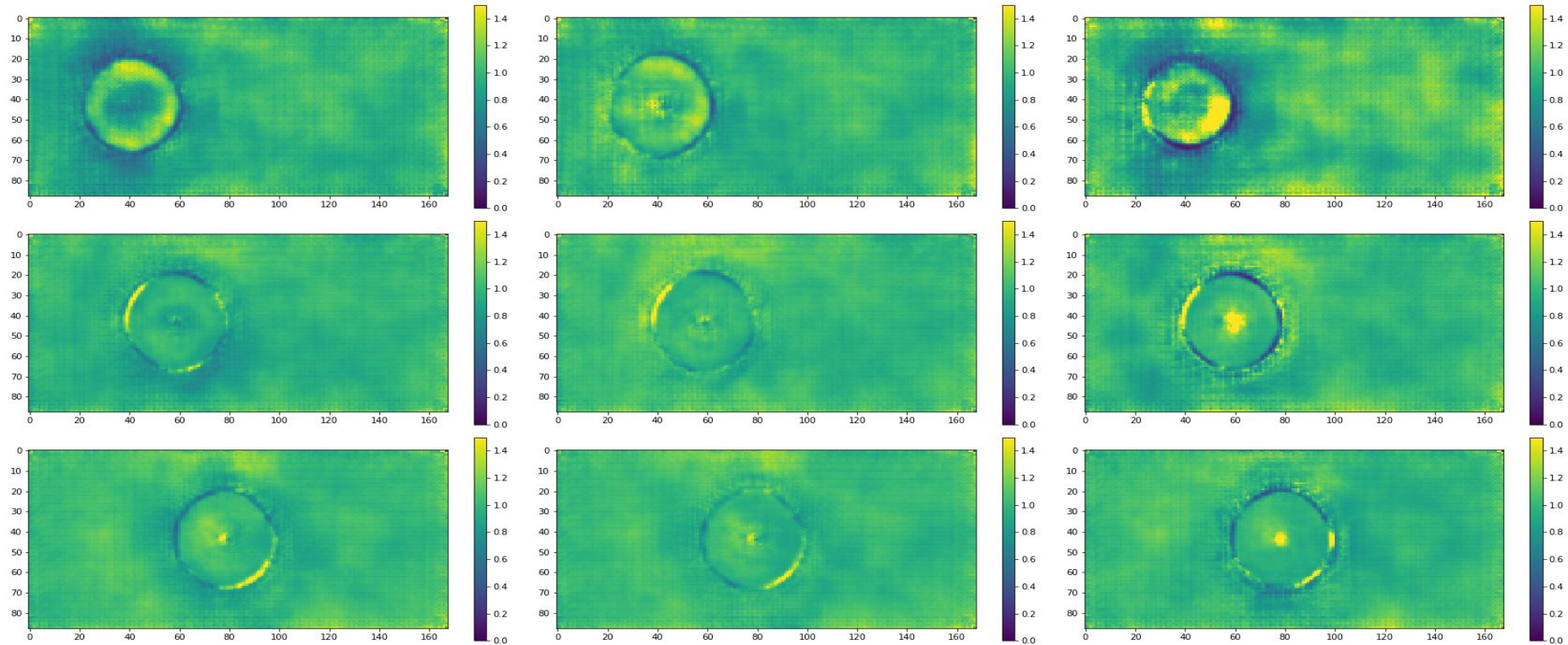
100N/176N



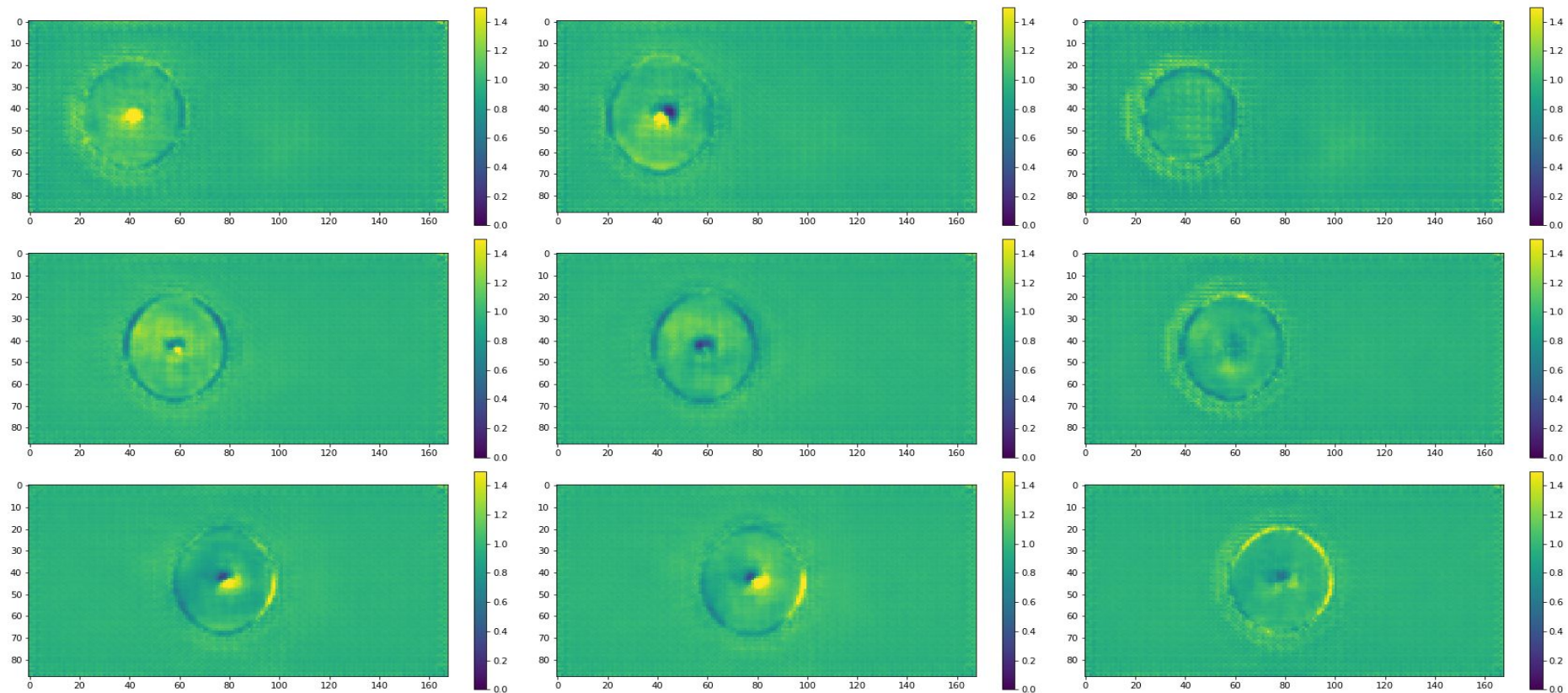
176N/298N



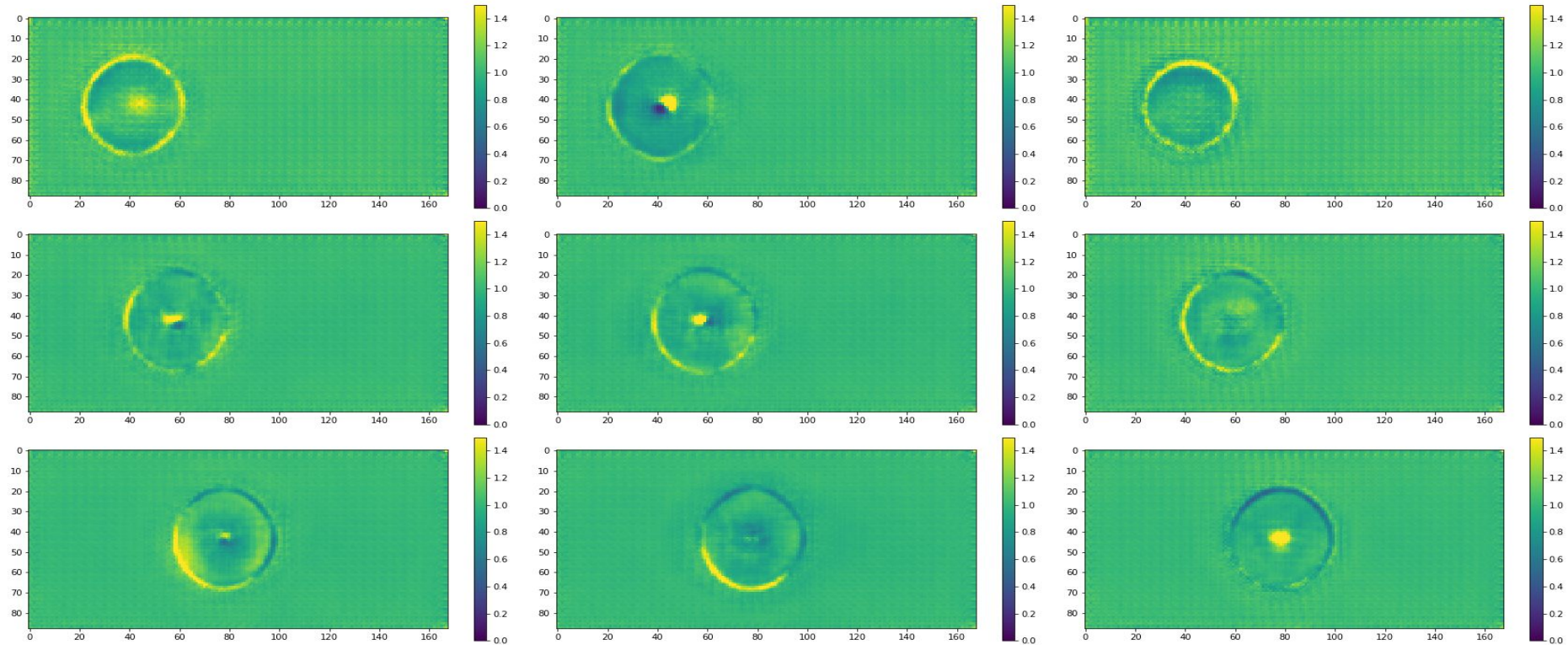
298N/400N



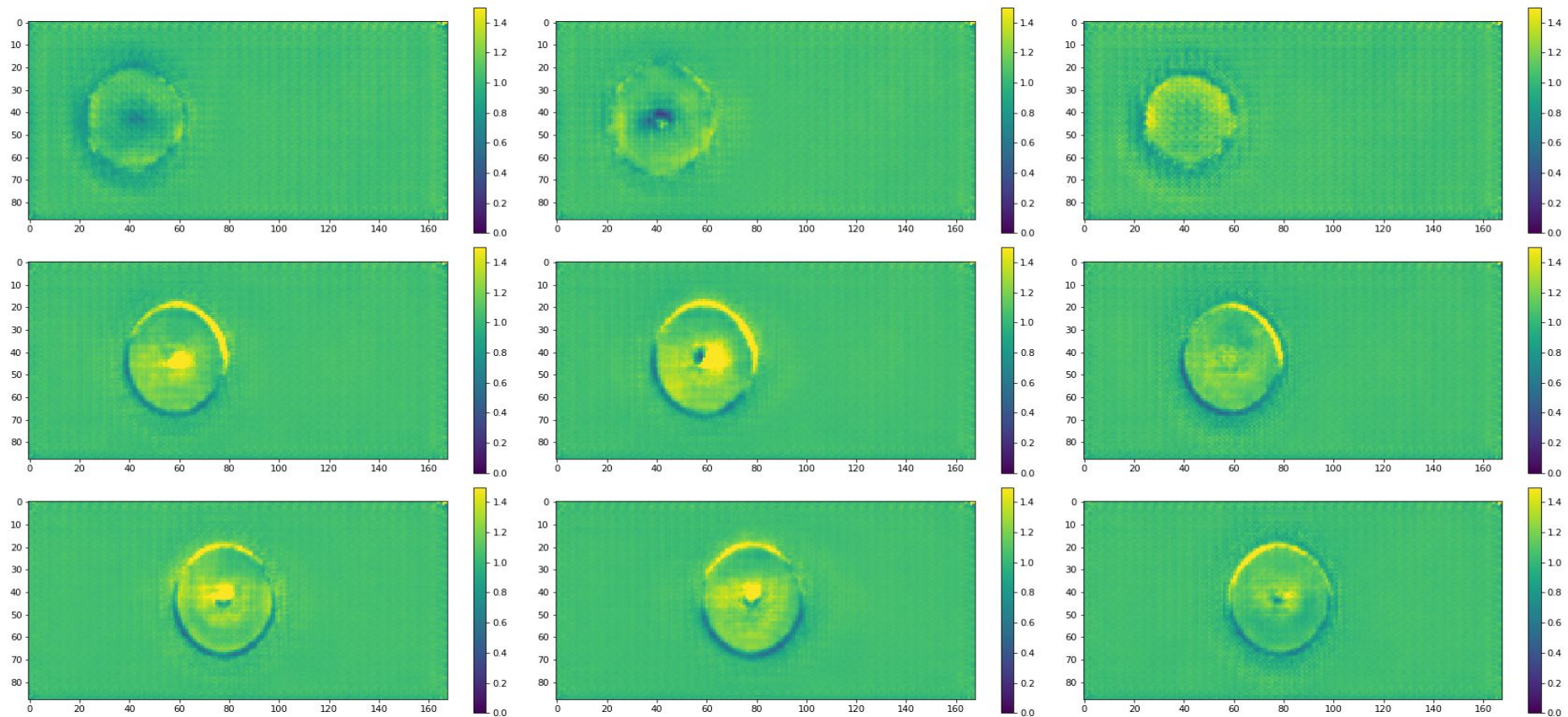
400N/516N



516N/800N



800N/1000N



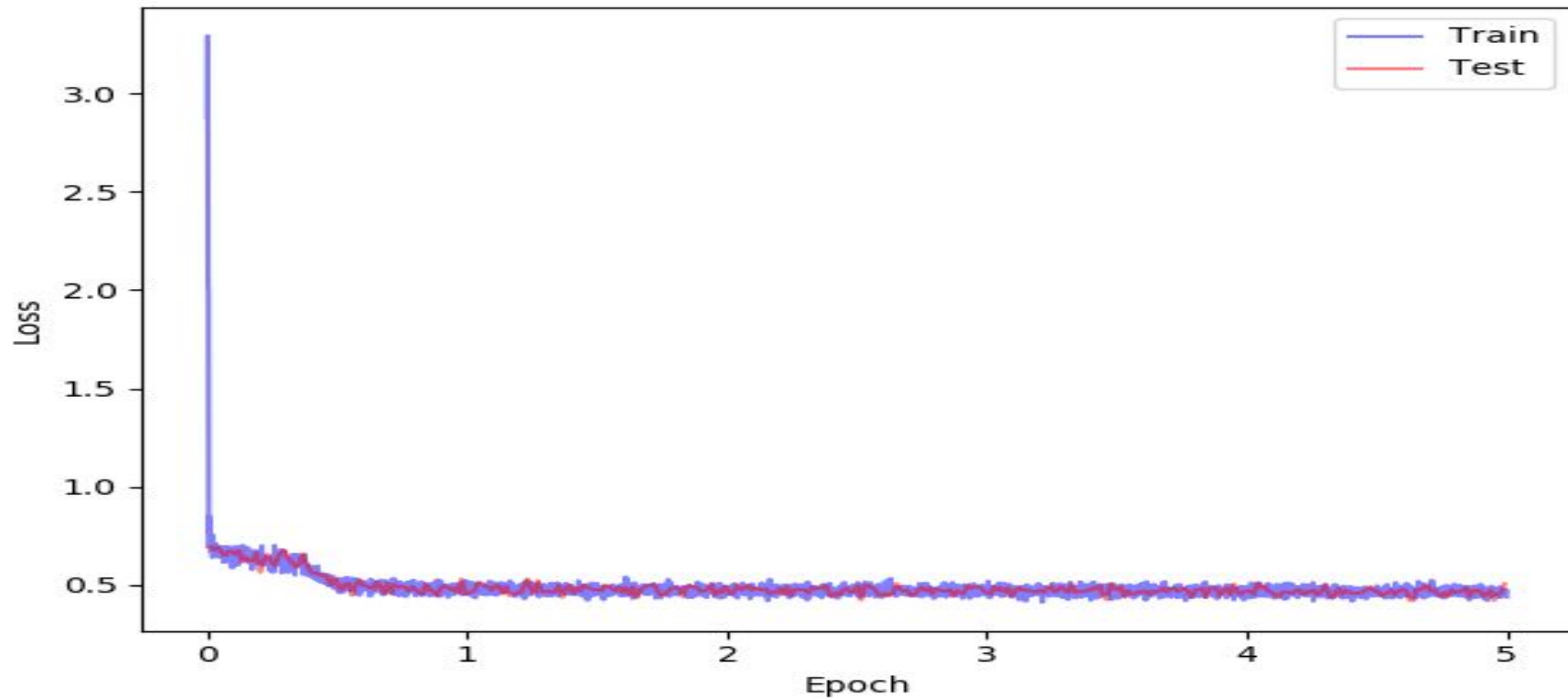
Summary

Summary

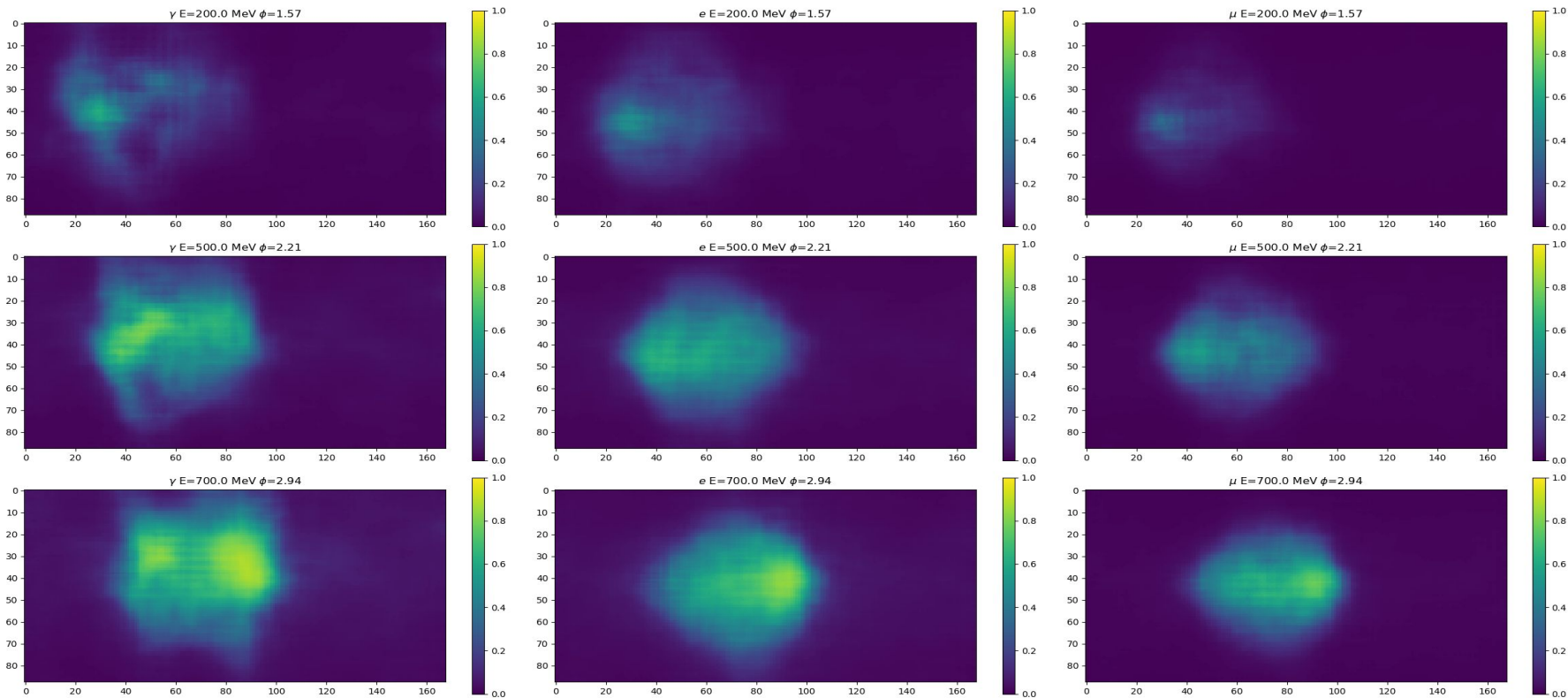
1. 3 node produces bad quality images but 10 node produces high quality images and we could see that difference in the loss function comparison also. Rest of node images are quite similar and comparison in their loss function is approximately 1.
2. Having 3 node in layer 2 is worse than having no layer 2. We produces good images without layer than having layer 2 with 3 node.
3. The time is real time not GPU time.

Analysis with FC1 layer

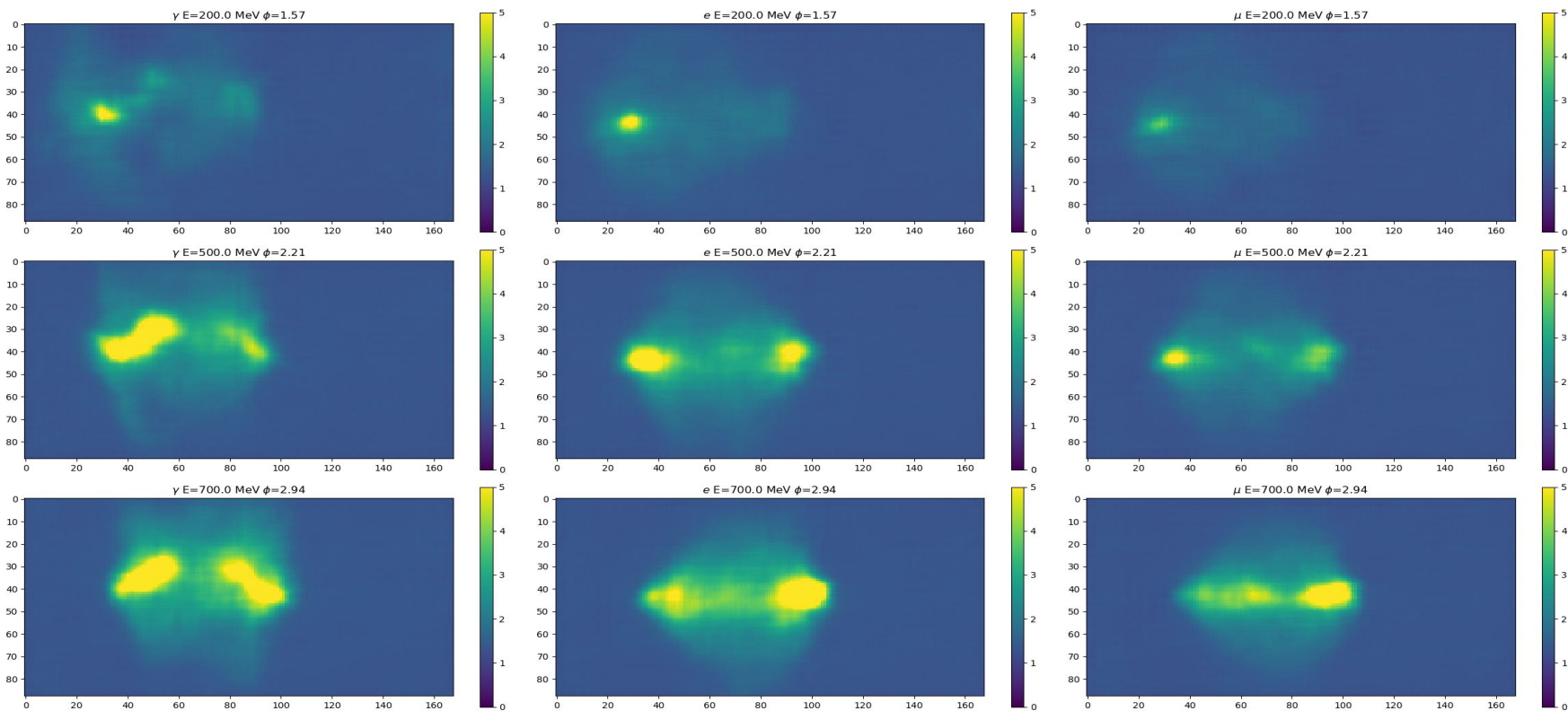
Node = 3, Time = 3 hours and 43 min



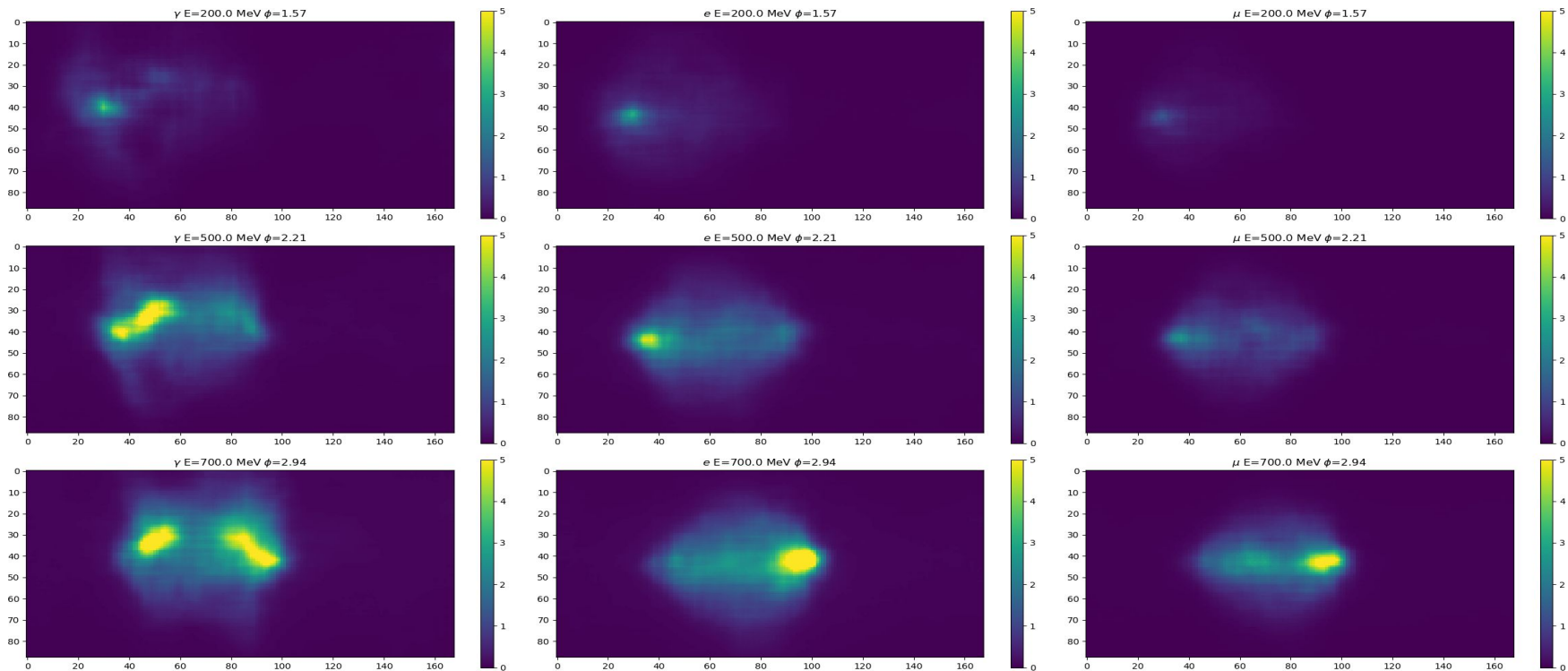
Predicted Hit Probability



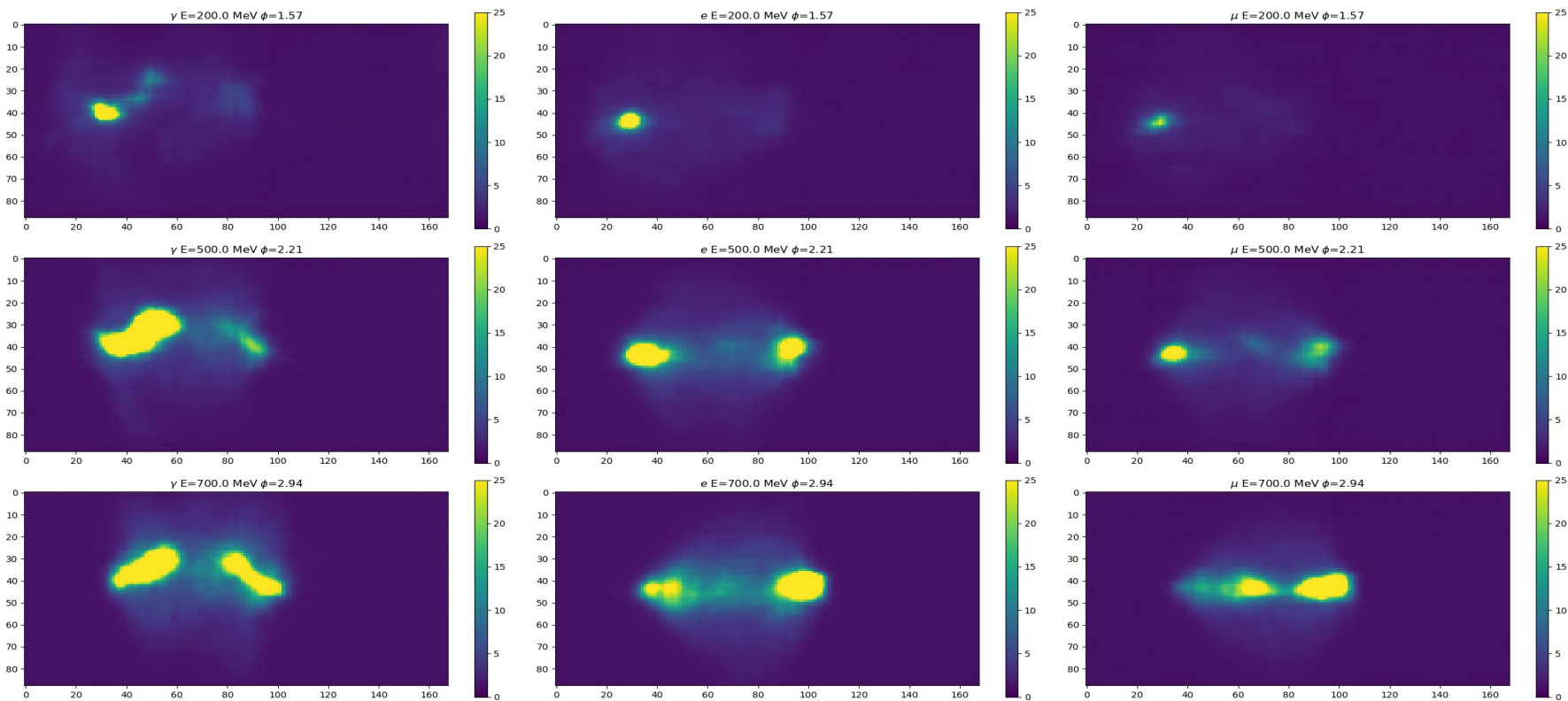
Predicted Charge



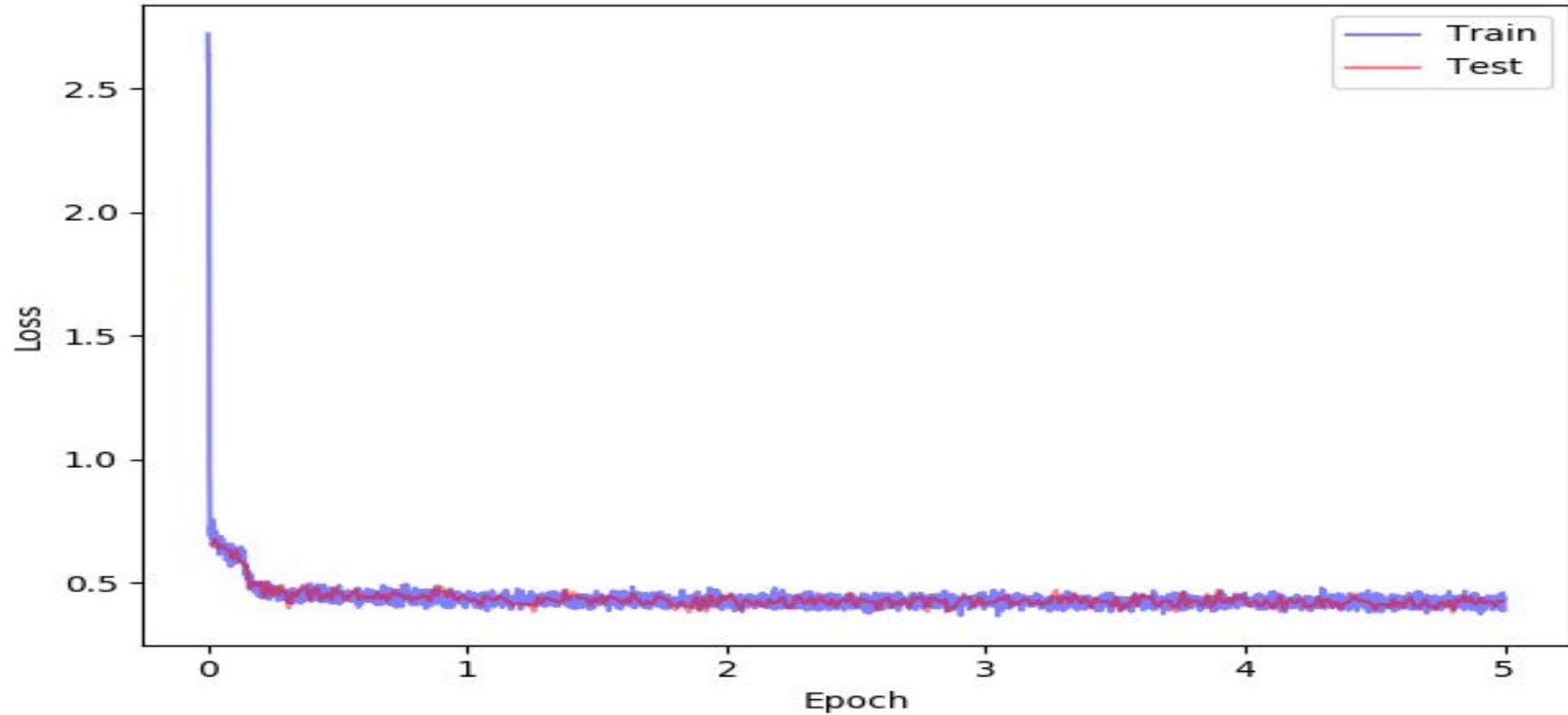
Expected mean charge (Predicted Charge X Predicted Hit Probability)



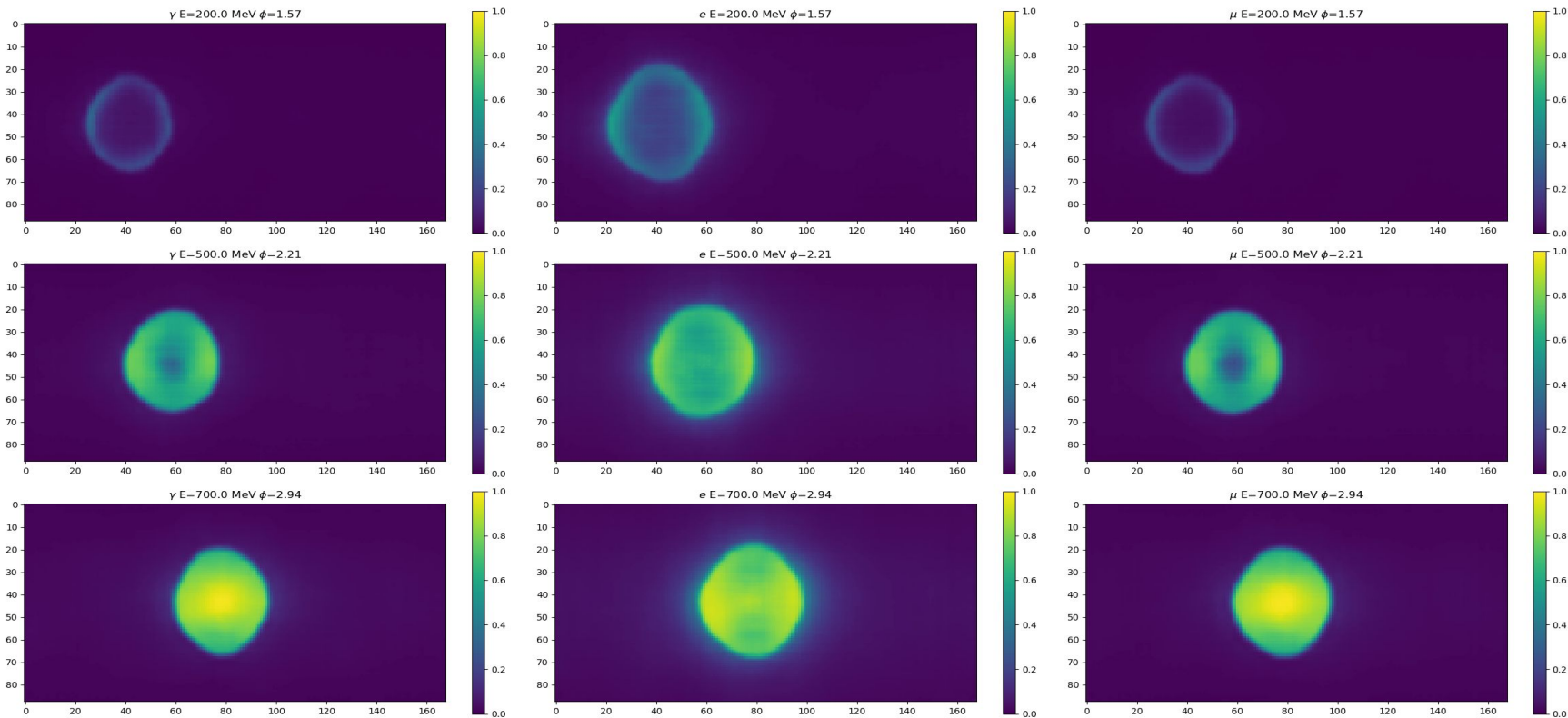
Predicted Variance of Charge



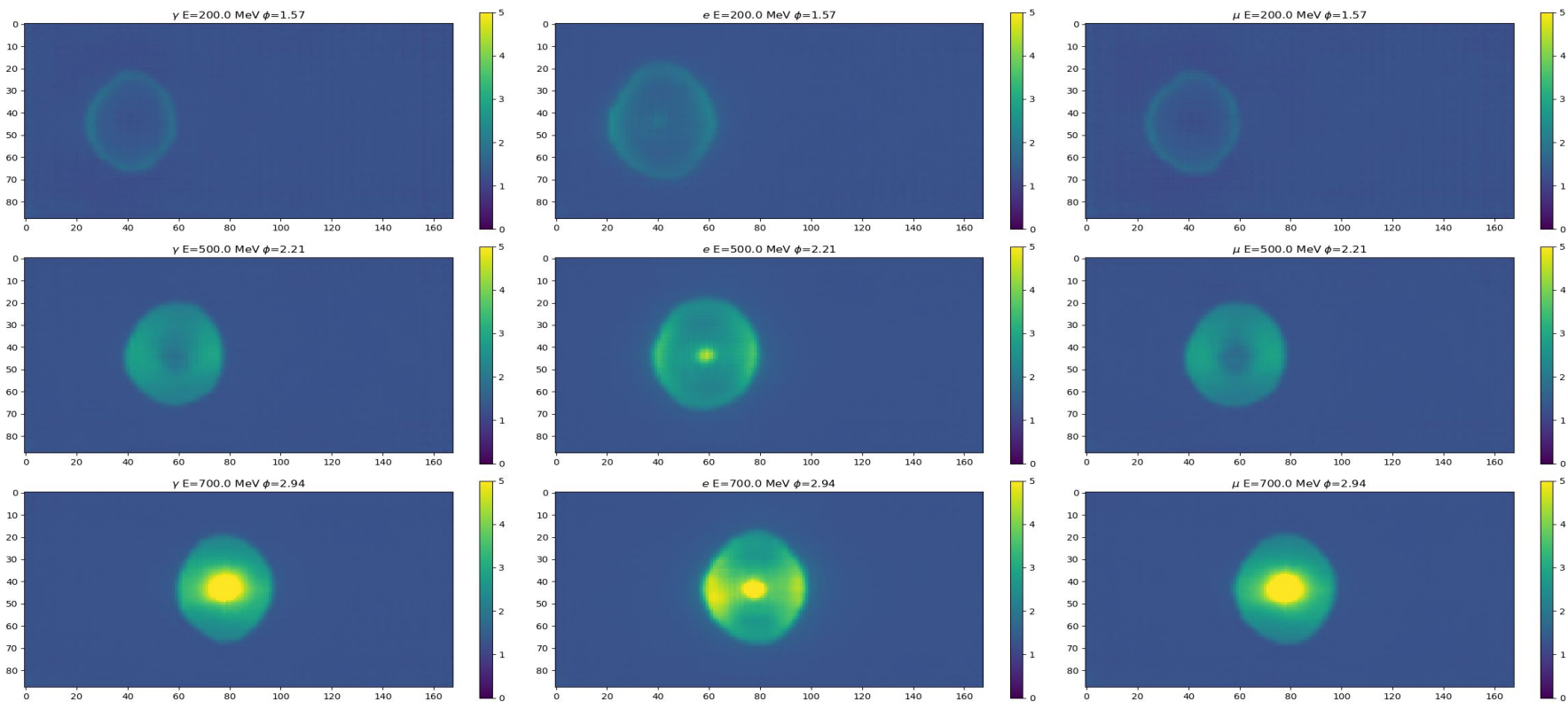
Node = 10 , Time = 3 hours and 9 min



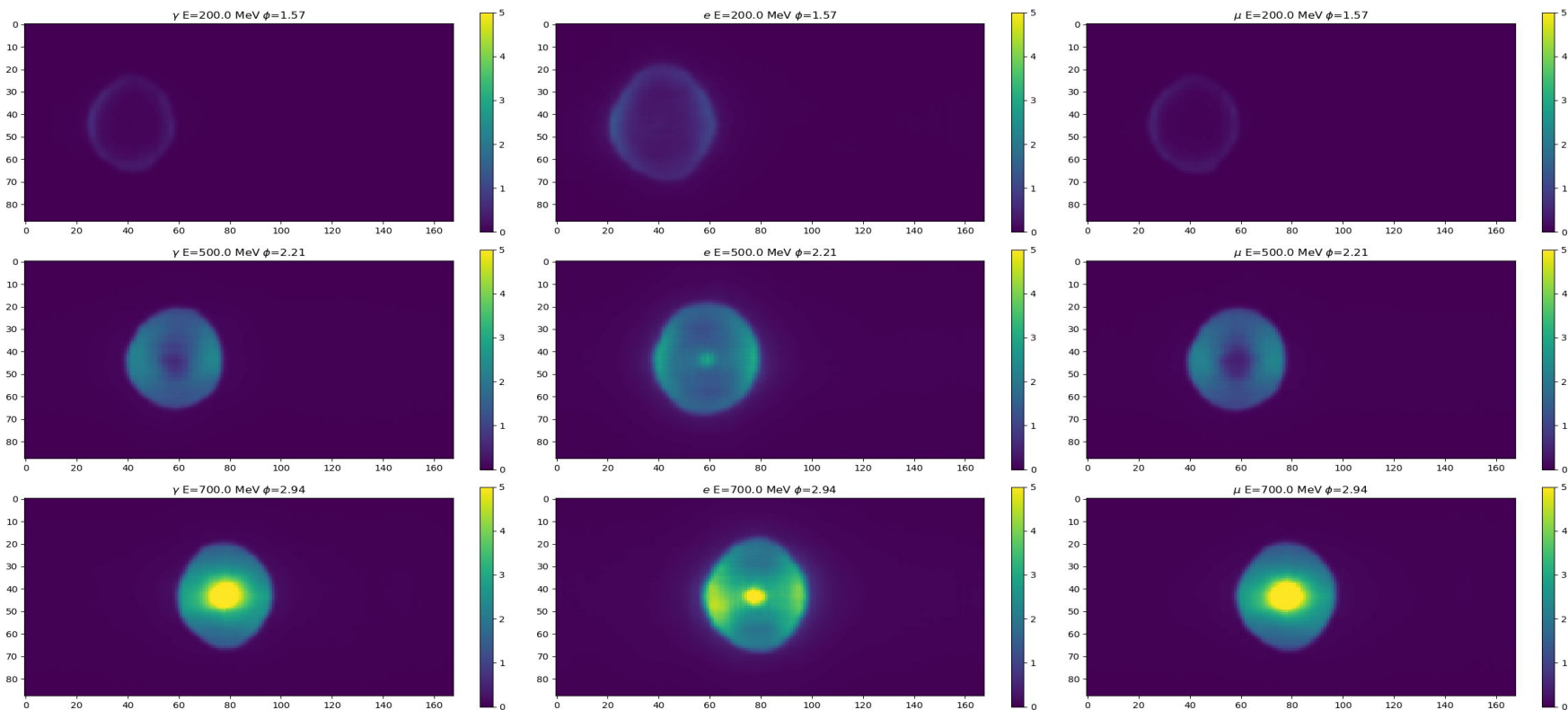
Predicted Hit Probability



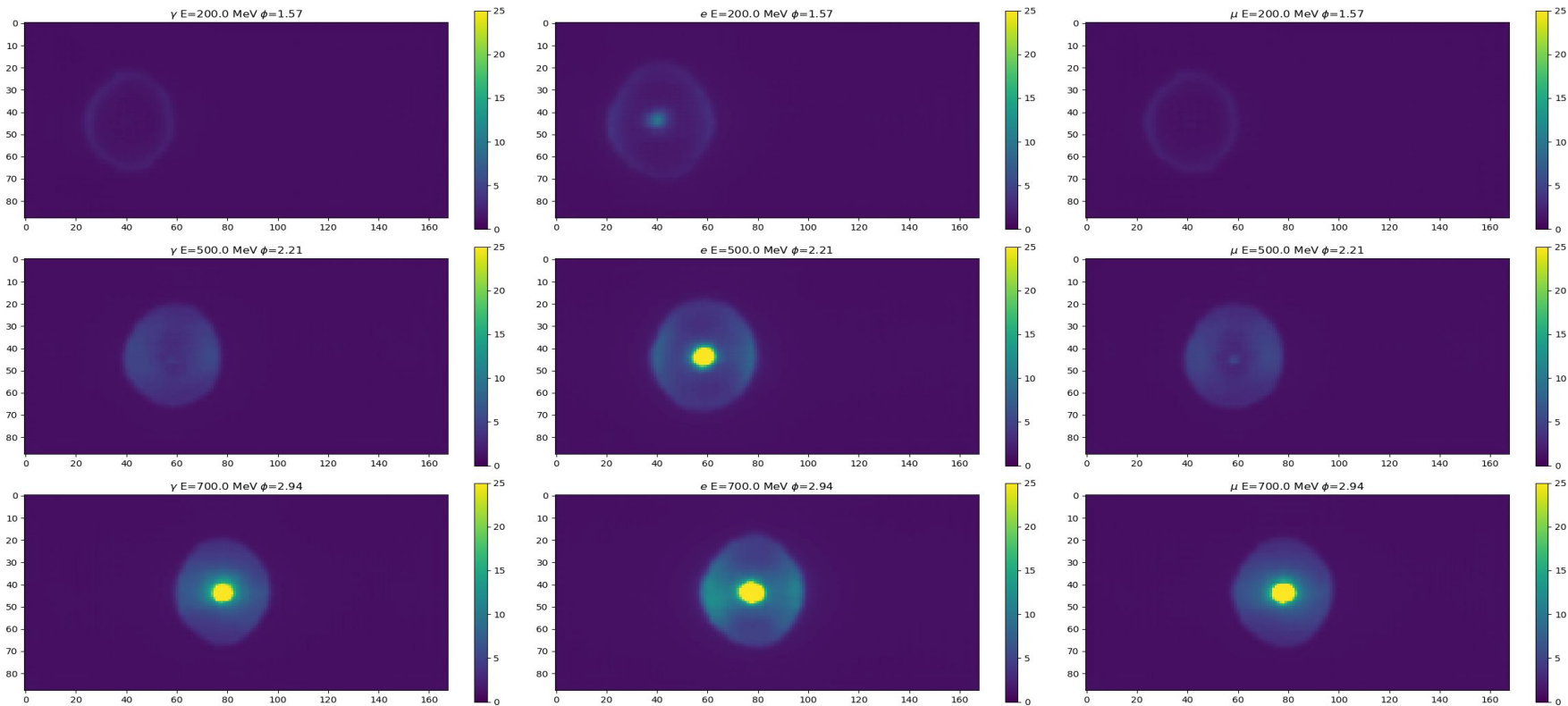
Predicted Charge



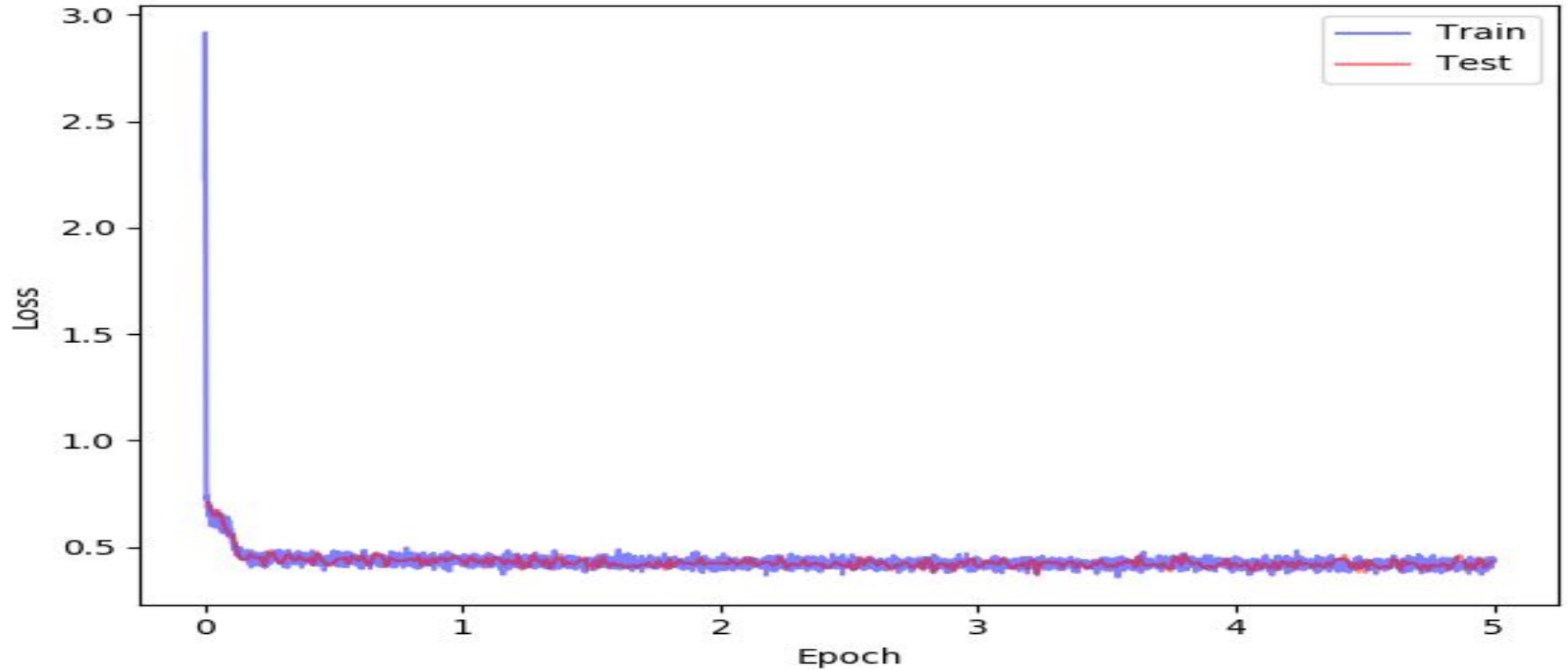
Expected mean charge (Predicted Charge X Predicted Hit Probability)



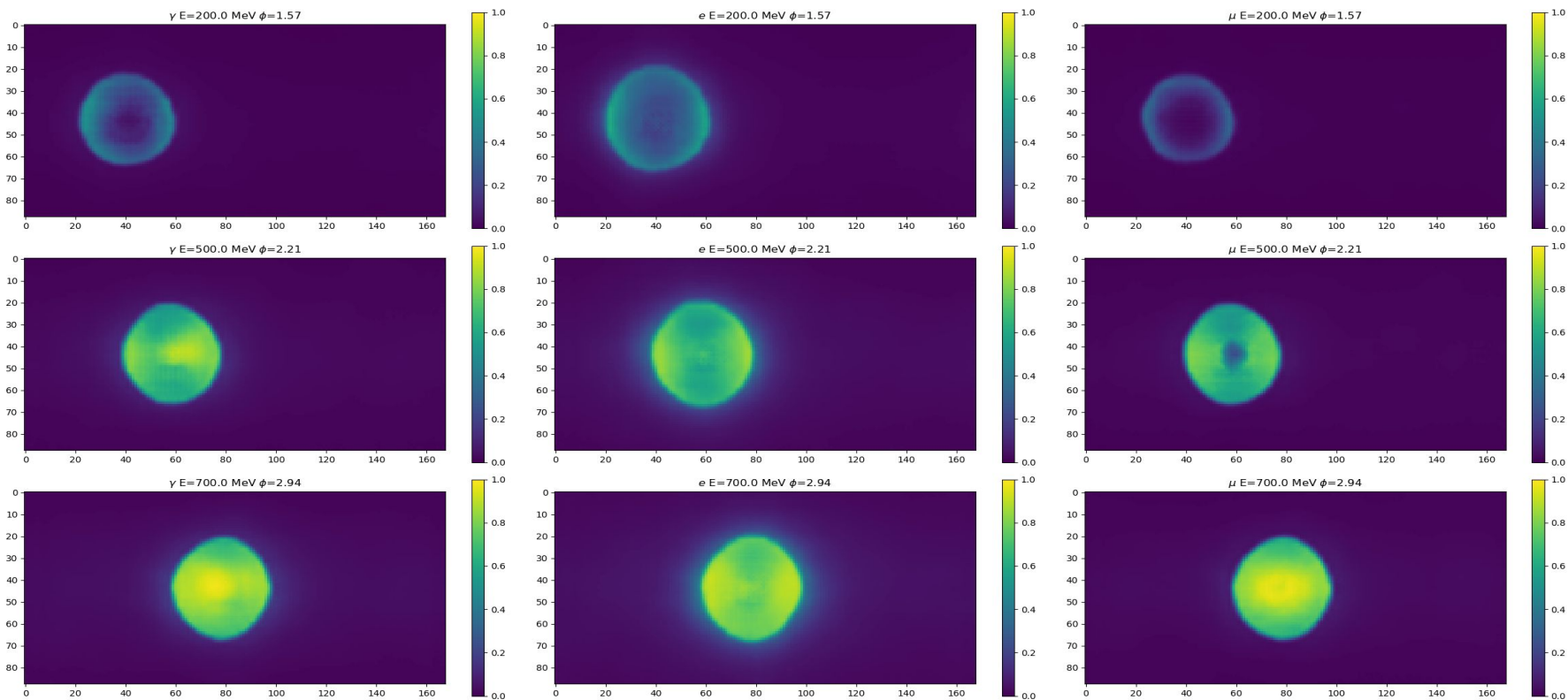
Predicted Variance of Charge



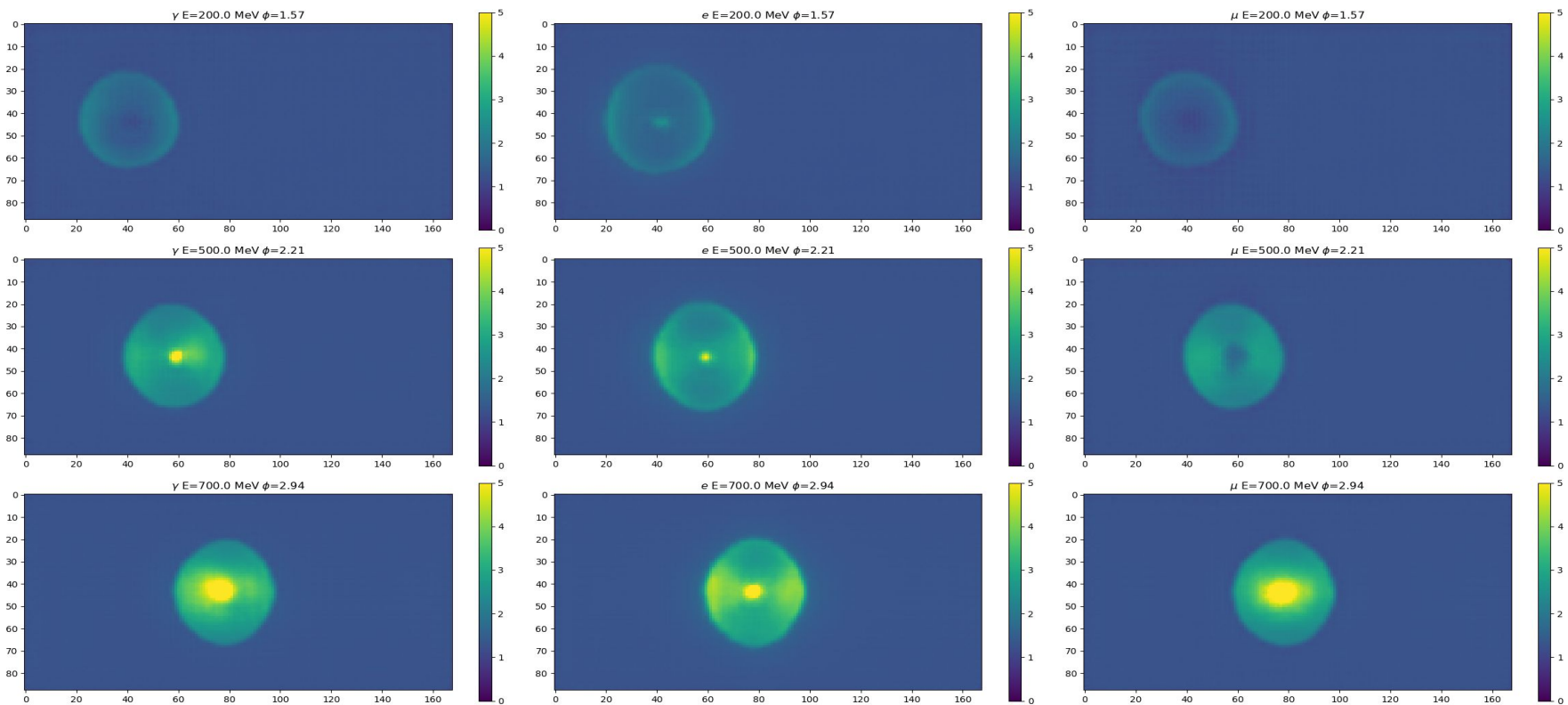
Node = 30 , Time = 3 hours and 9 min



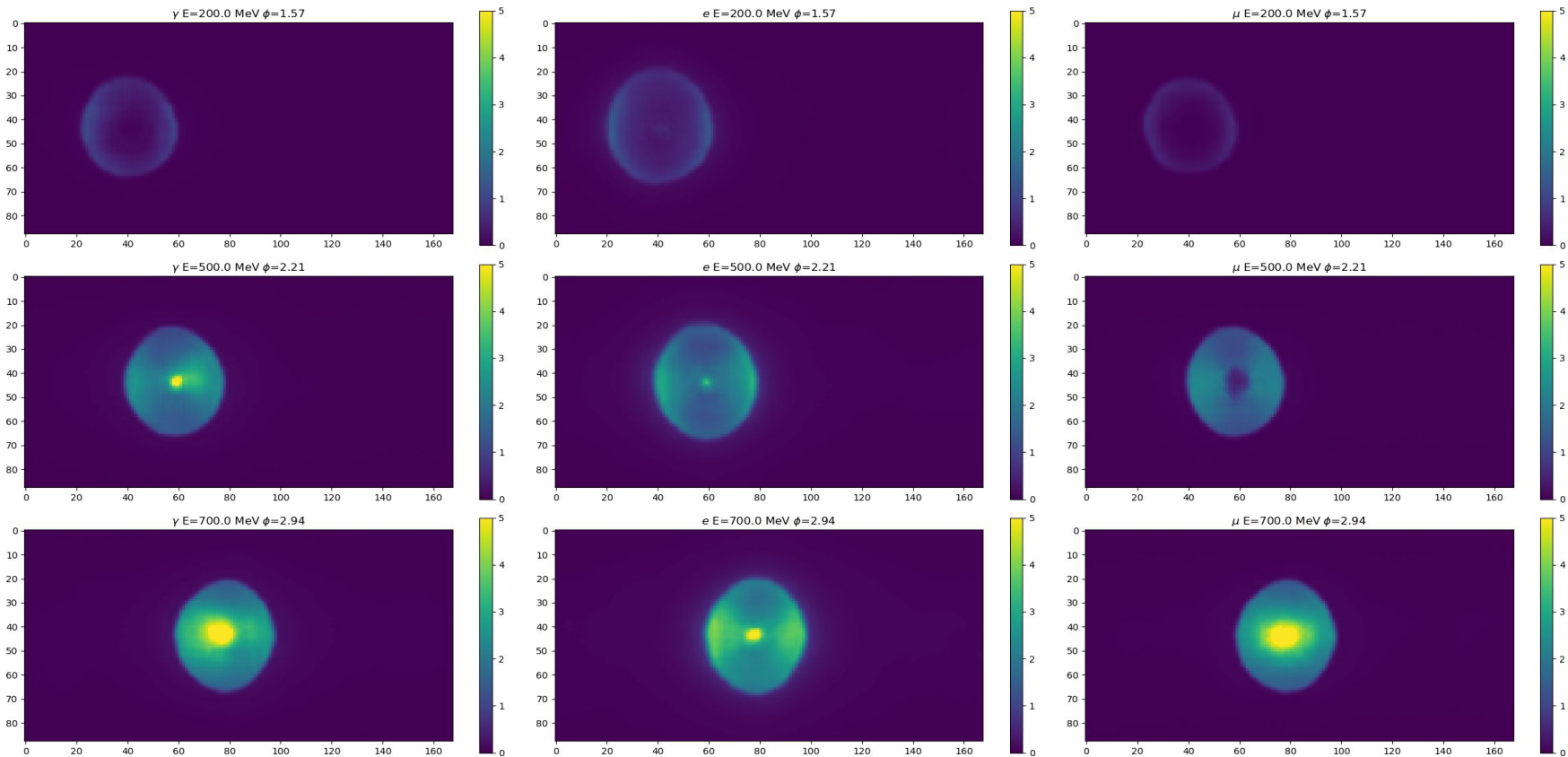
Predicted Hit Probability



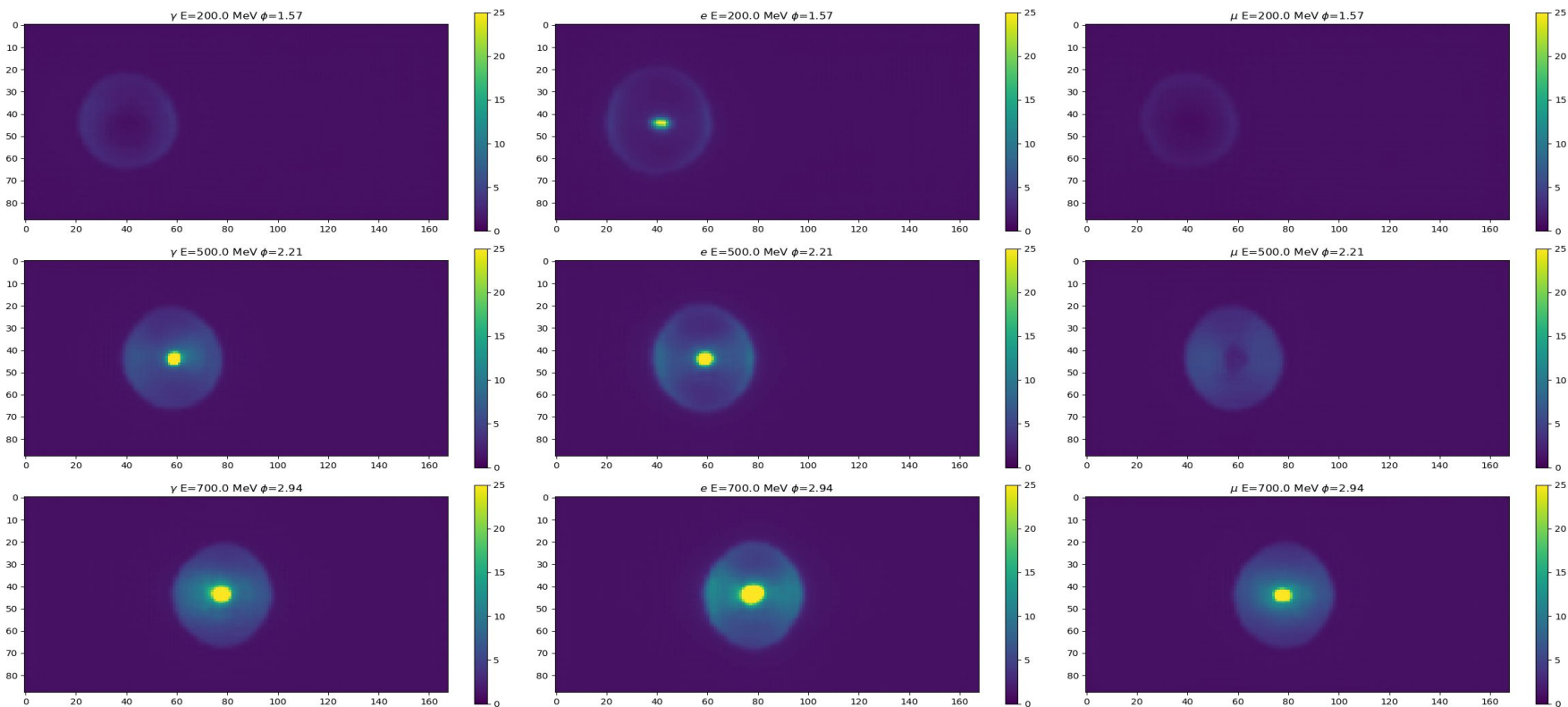
Predicted Charge



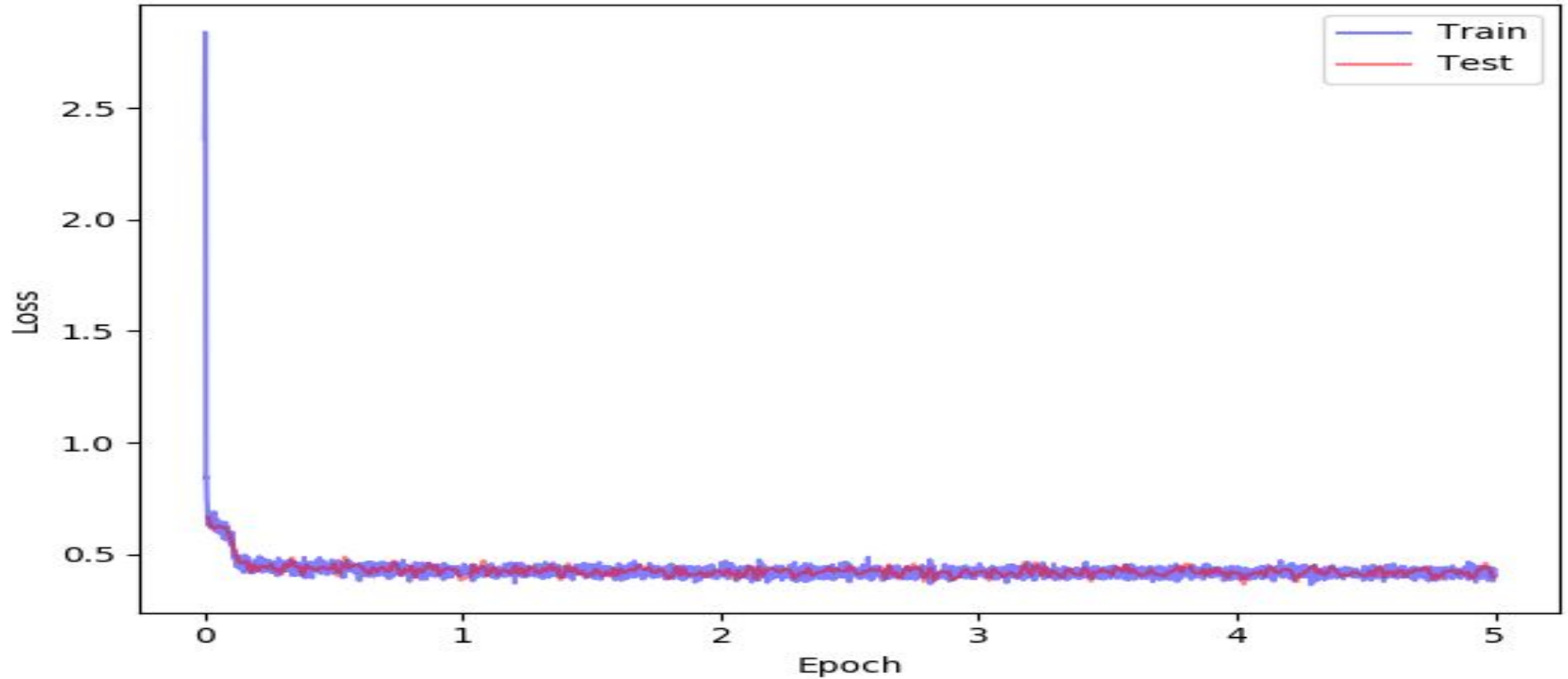
Expected mean charge (Predicted Charge X Predicted Hit Probability)



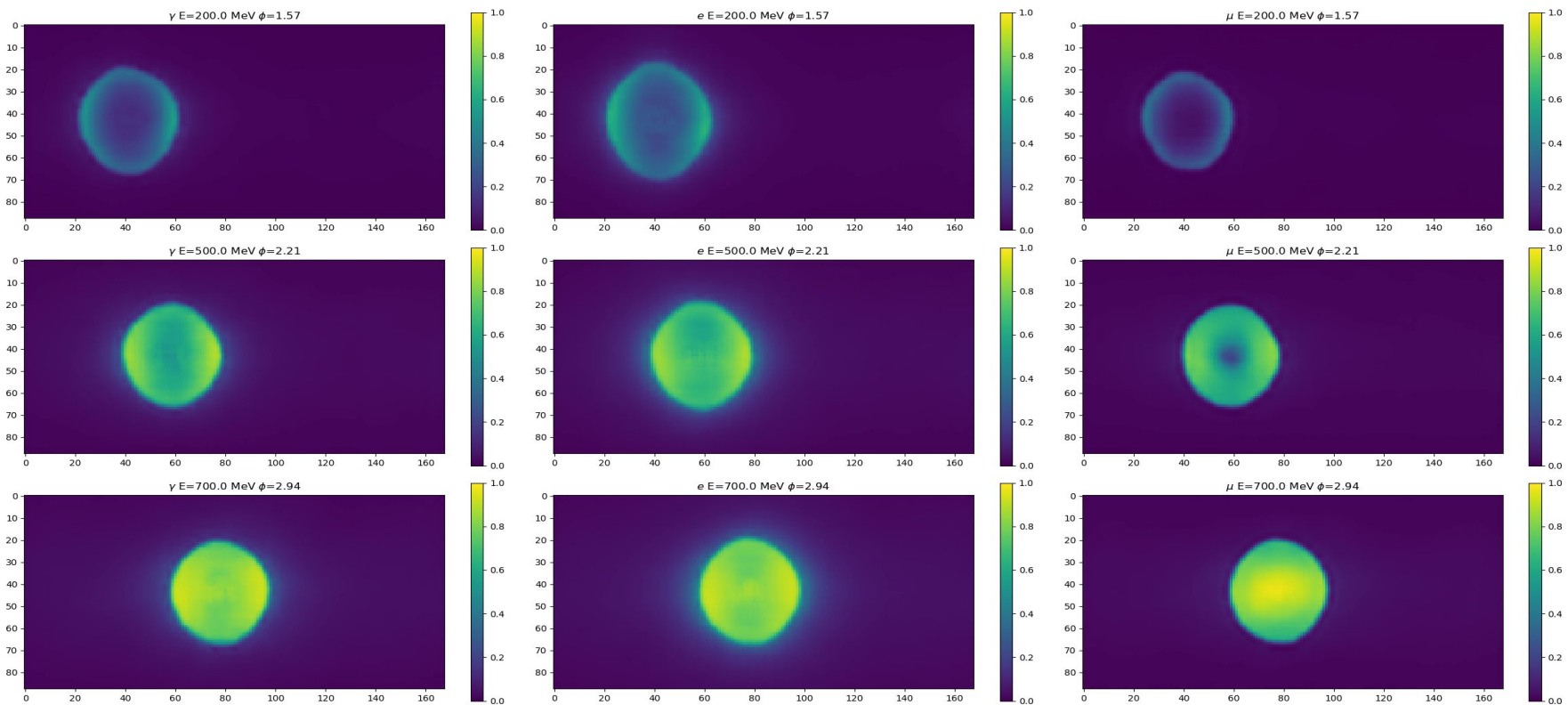
Predicted Variance of Charge



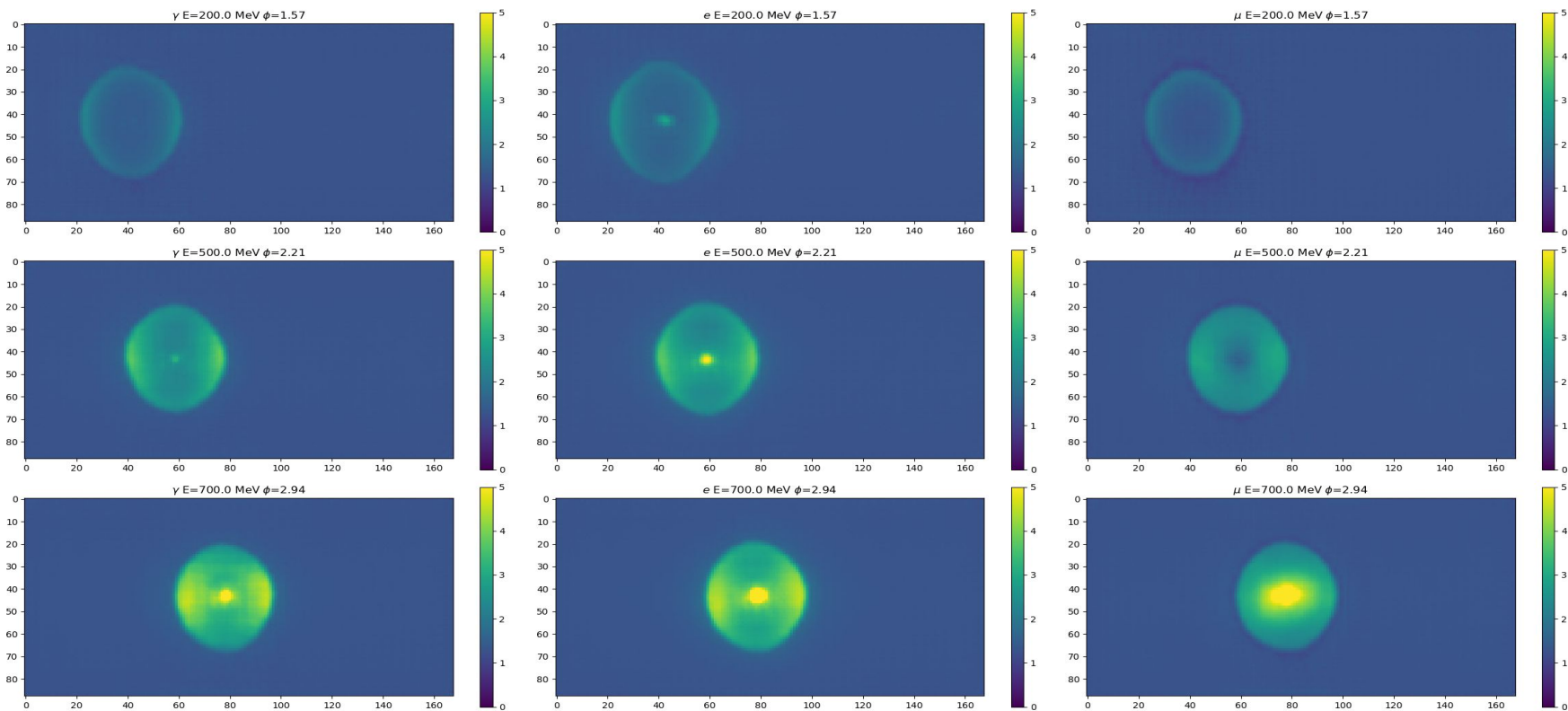
Node = 50 , Time = 2 hours and 9 min



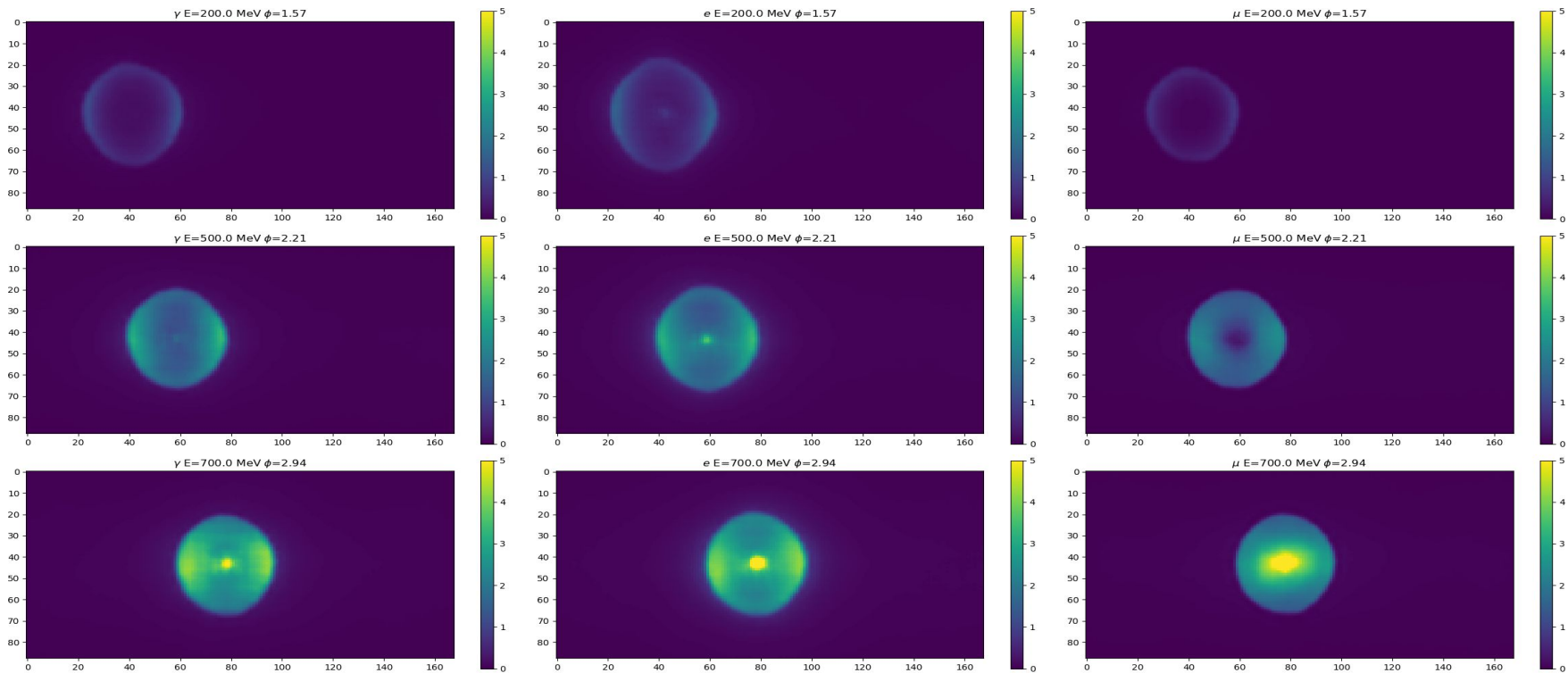
Predicted Hit Probability



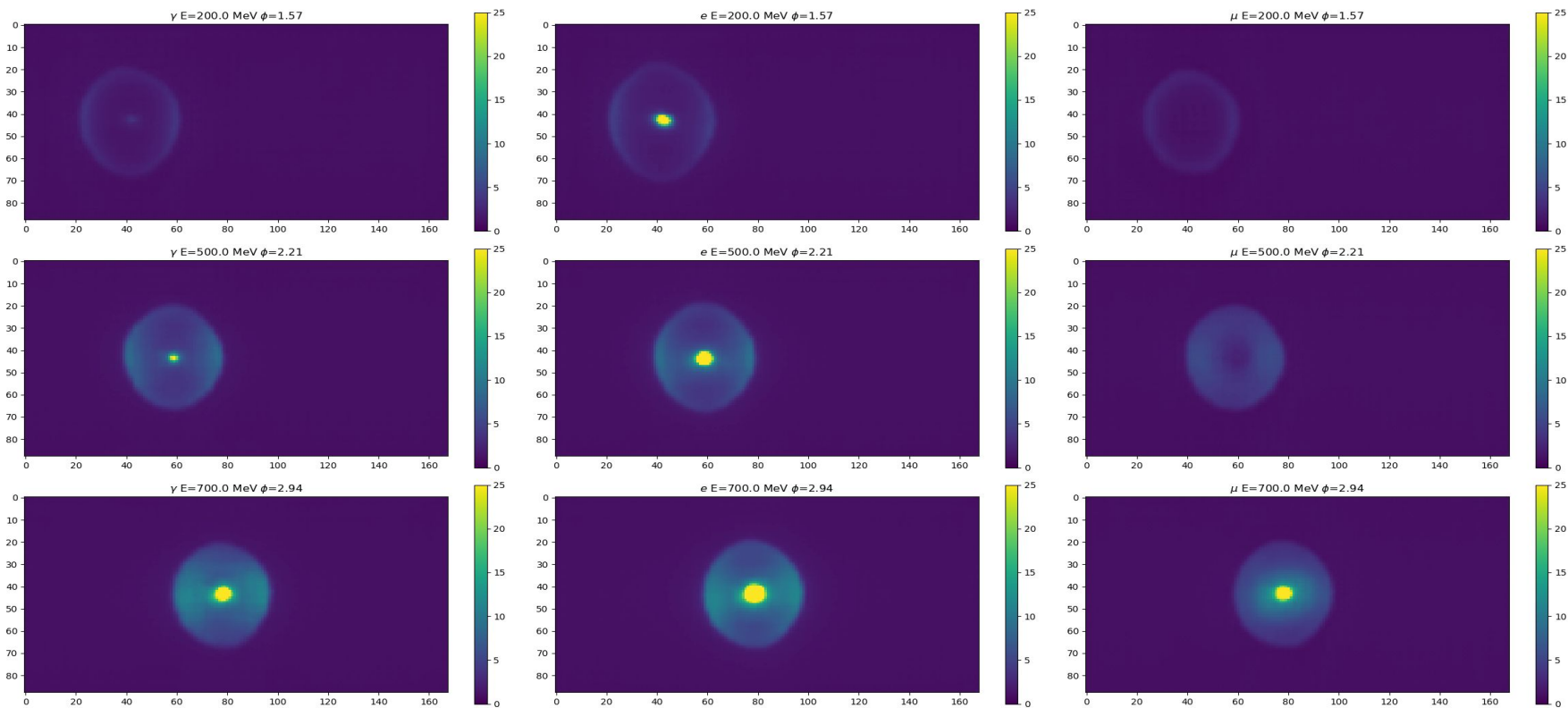
Predicted Charge



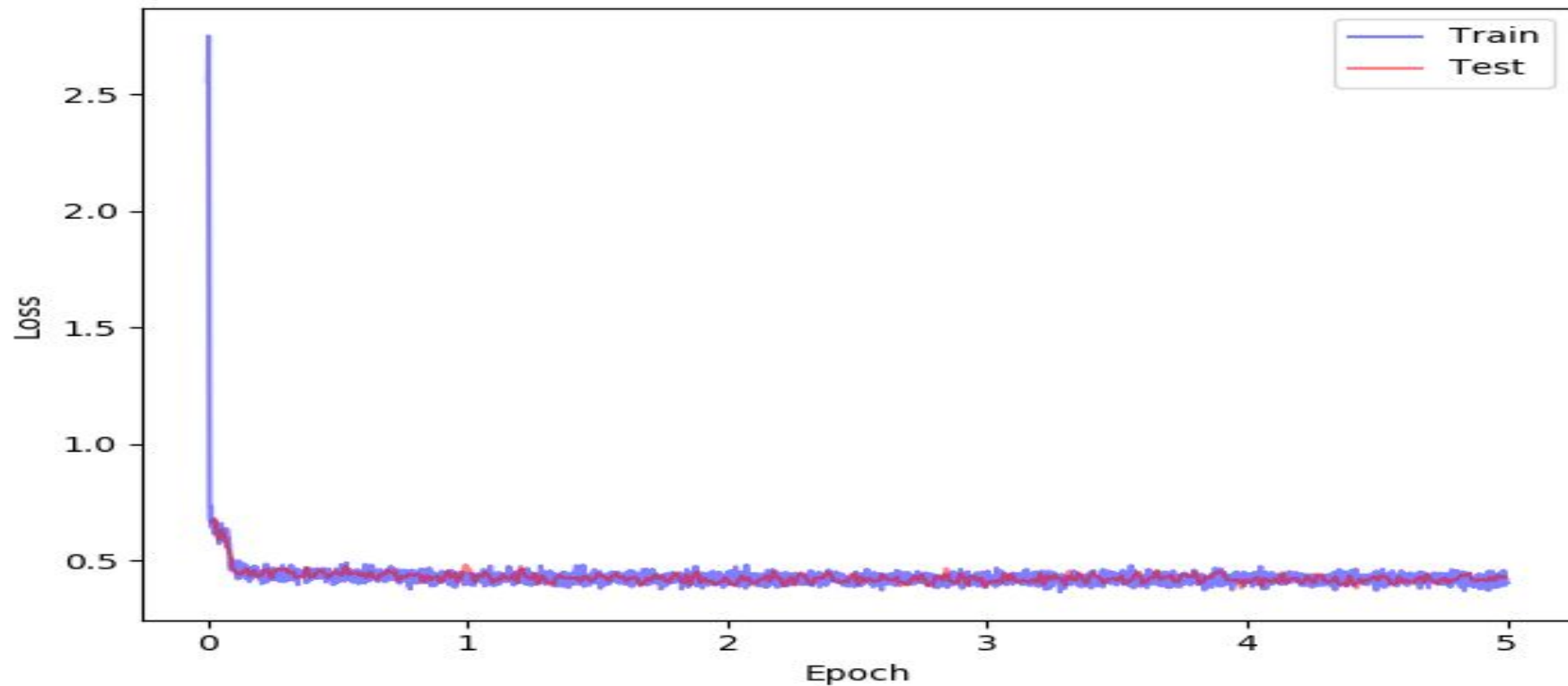
Expected mean charge (Predicted Charge X Predicted Hit Probability)



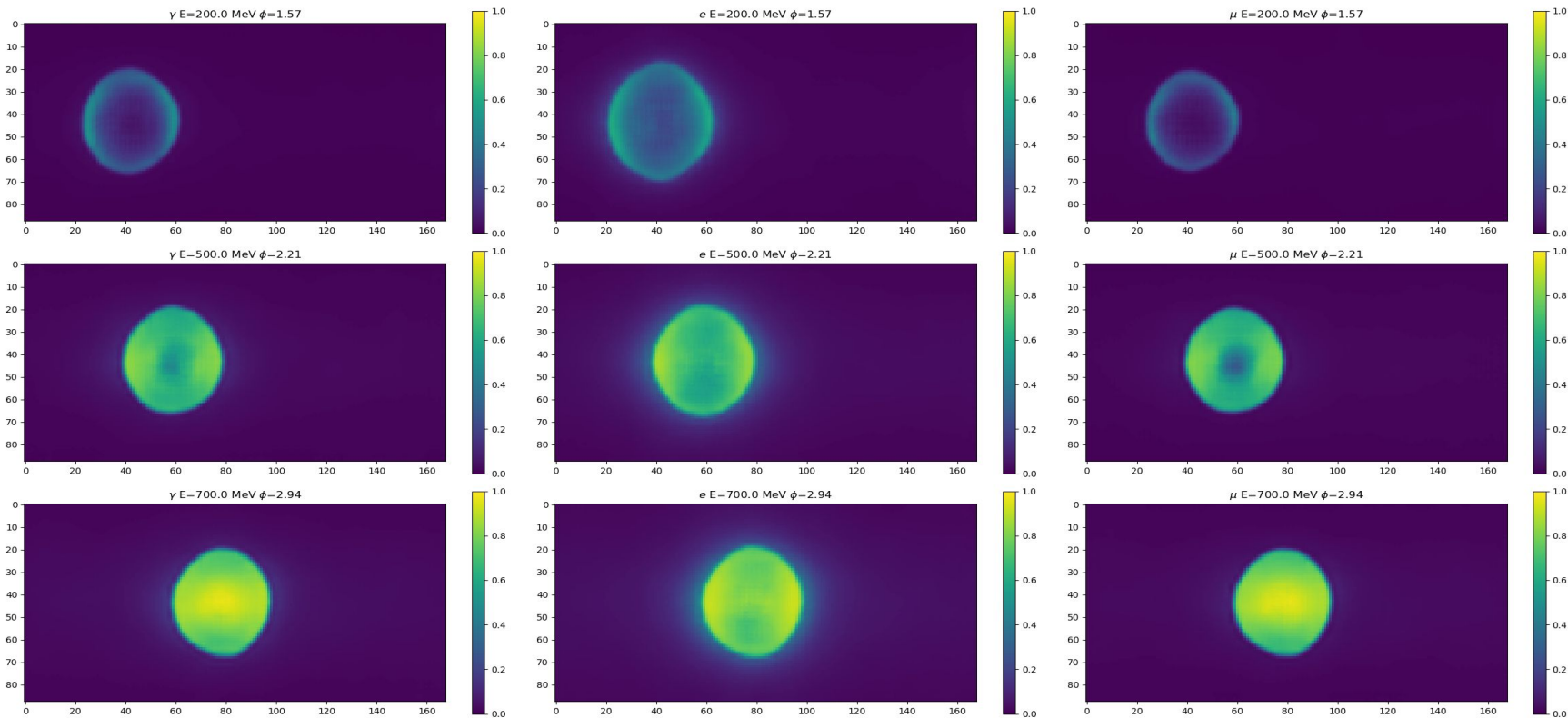
Predicted Variance of Charge



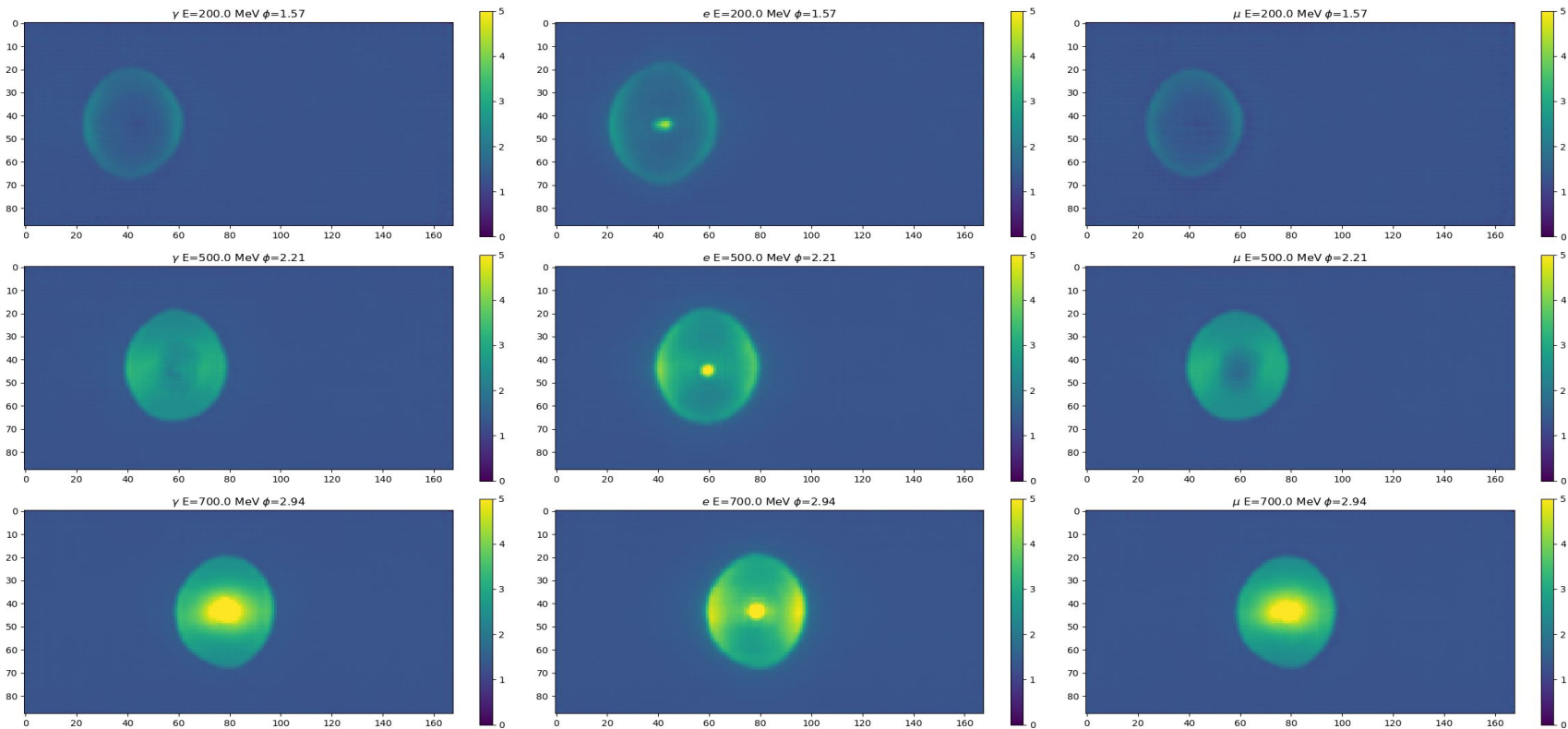
Node = 100, Time = 2 hours and 8 min



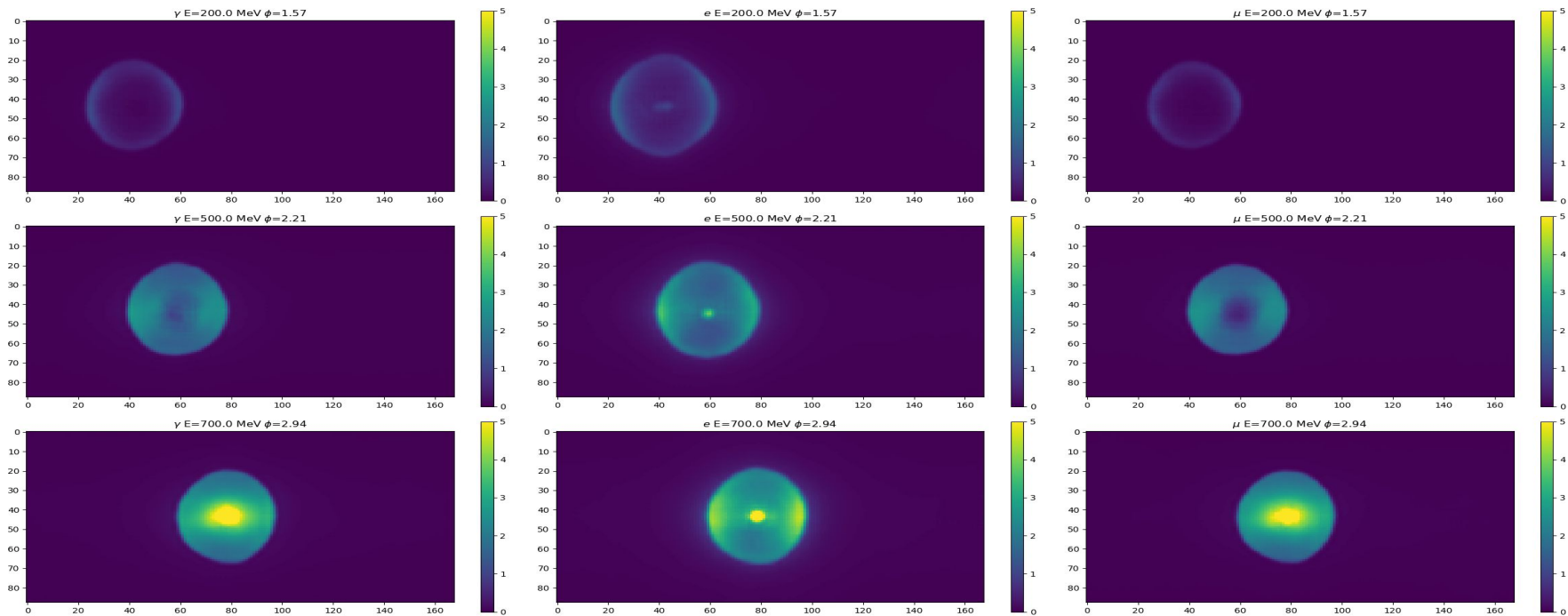
Predicted Hit Probability



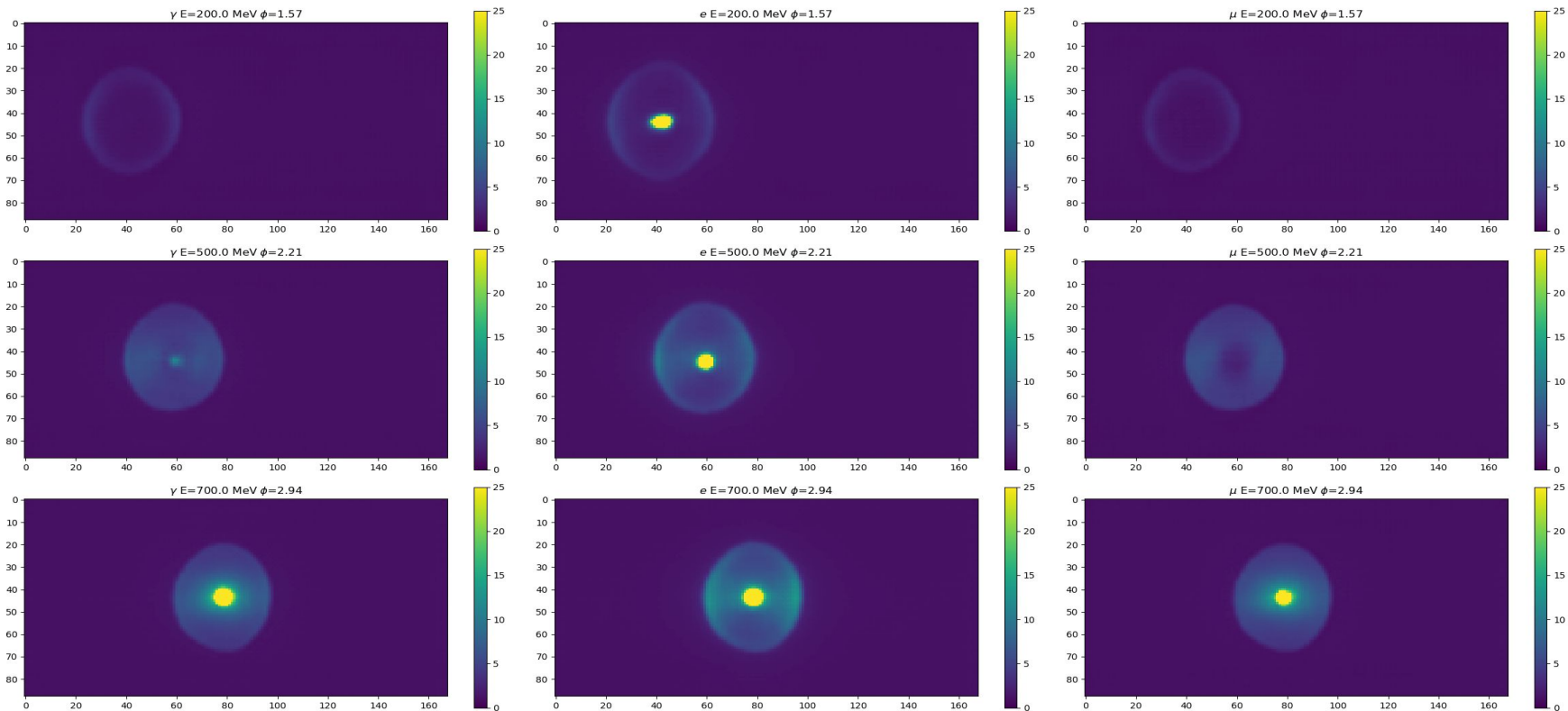
Predicted Charge



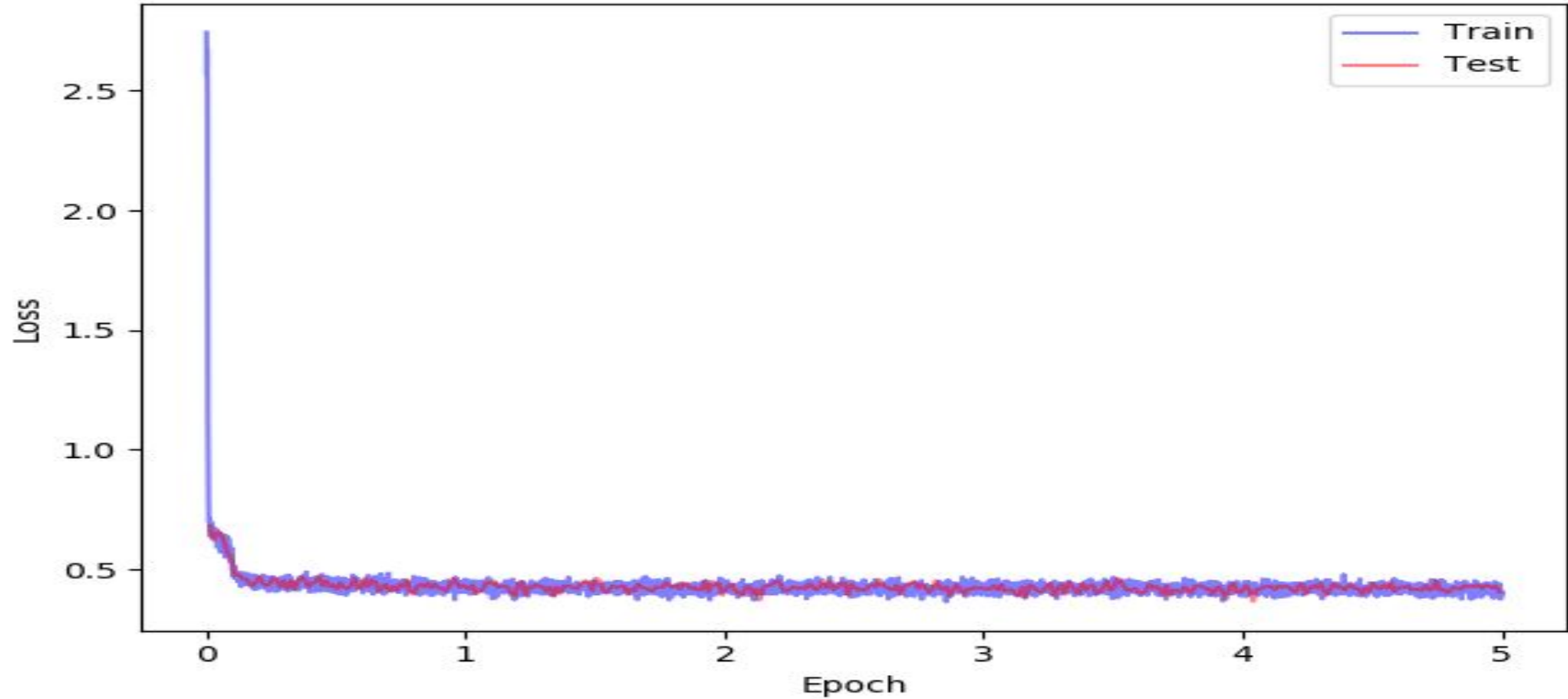
Expected mean charge (Predicted Charge X Predicted Hit Probability)



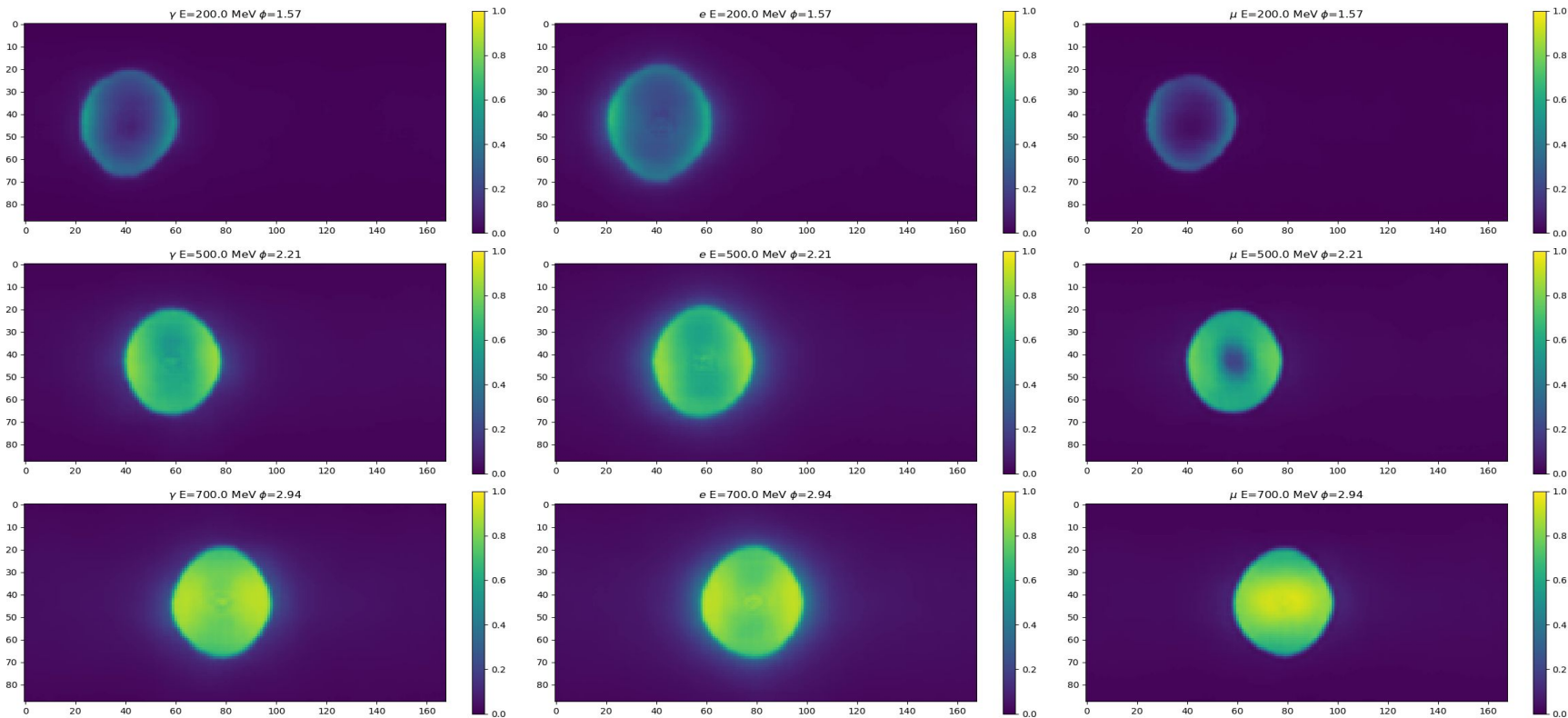
Predicted Variance of Charge



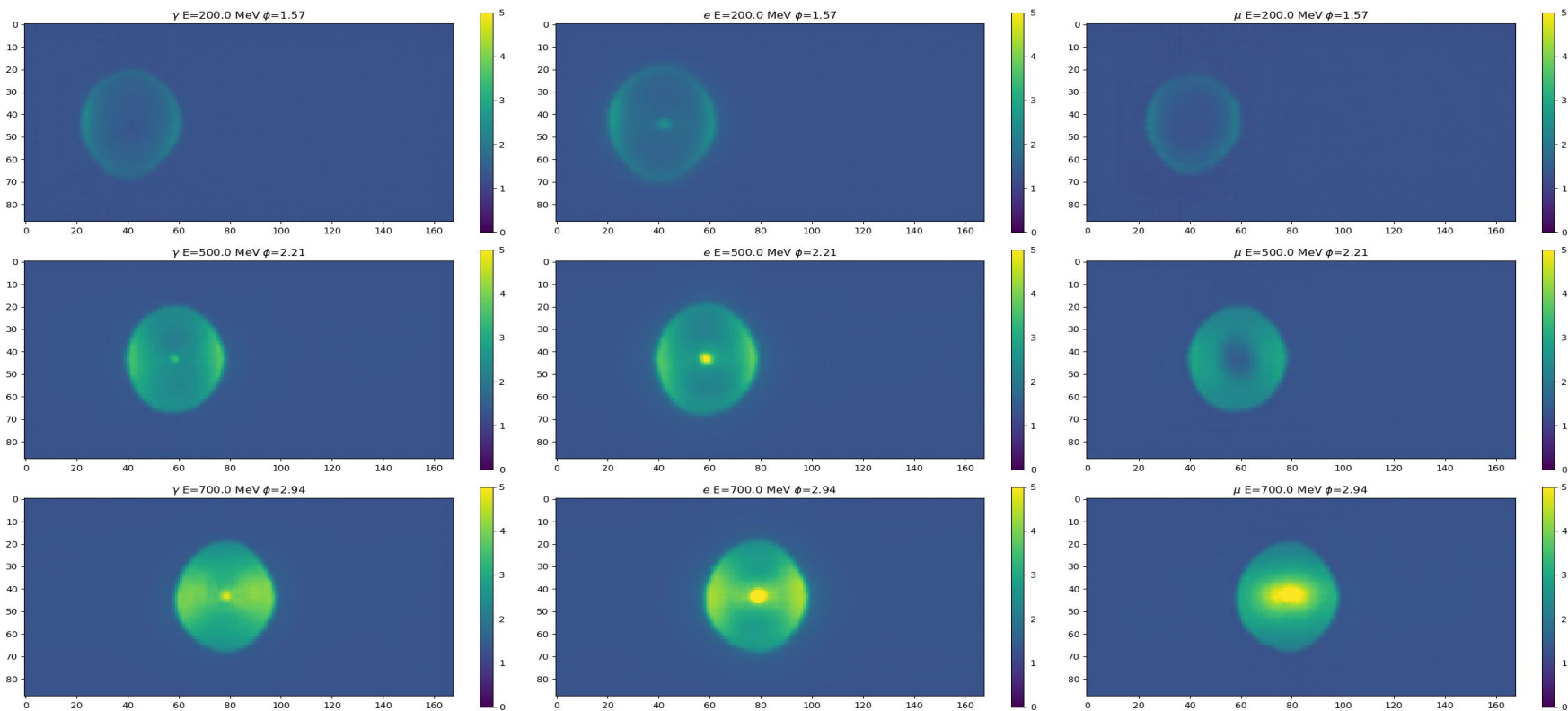
Node = 156 , Time = 2 hours and 9 min



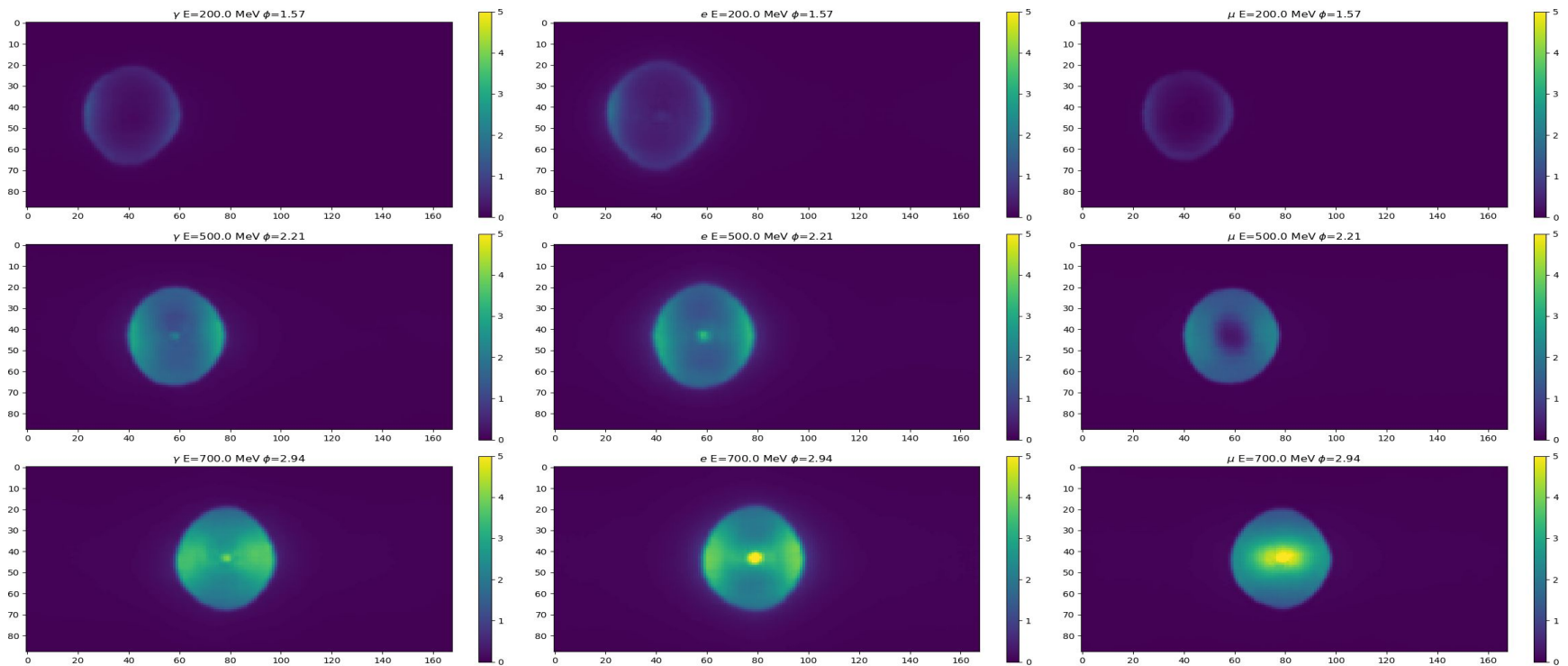
Predicted Hit Probability



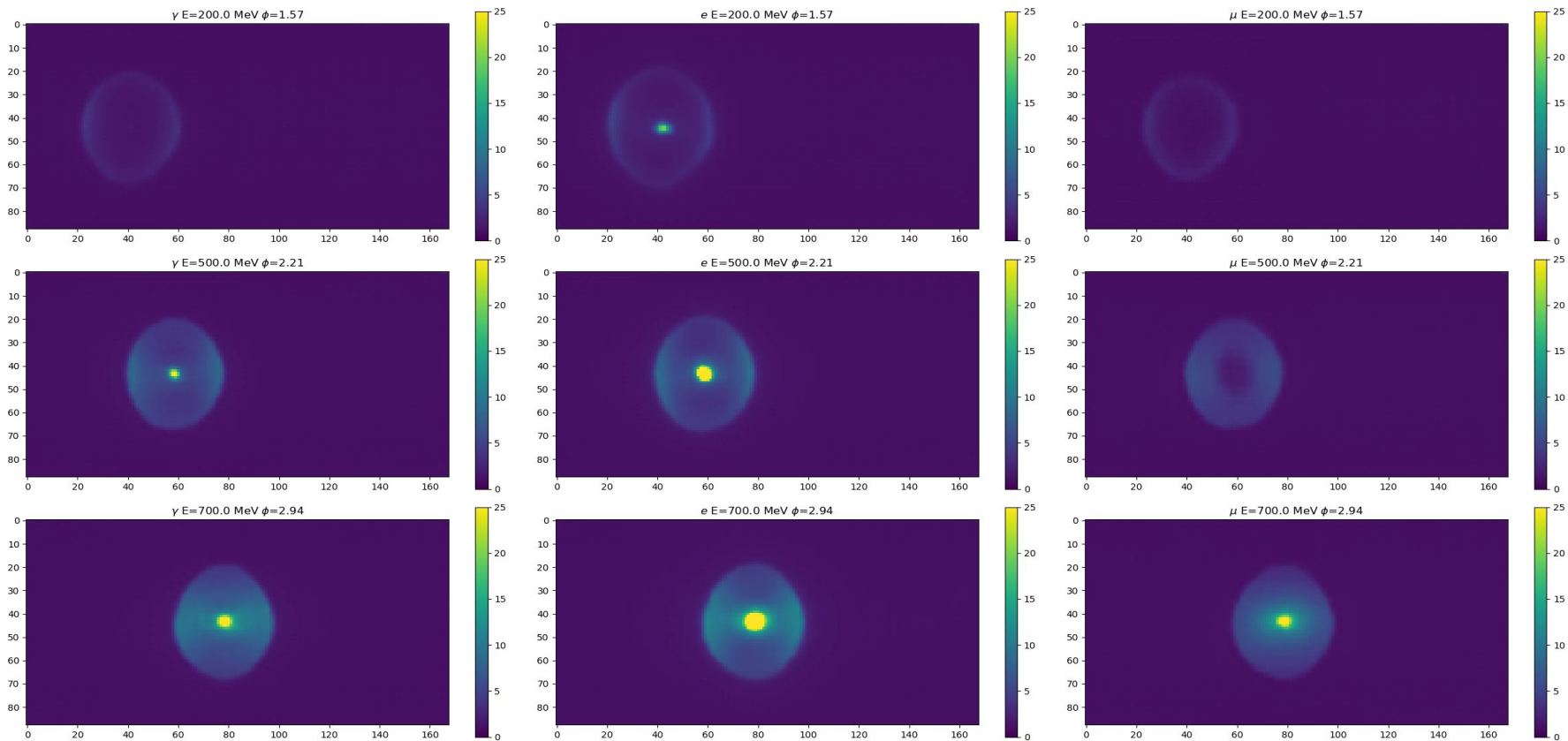
Predicted Charge



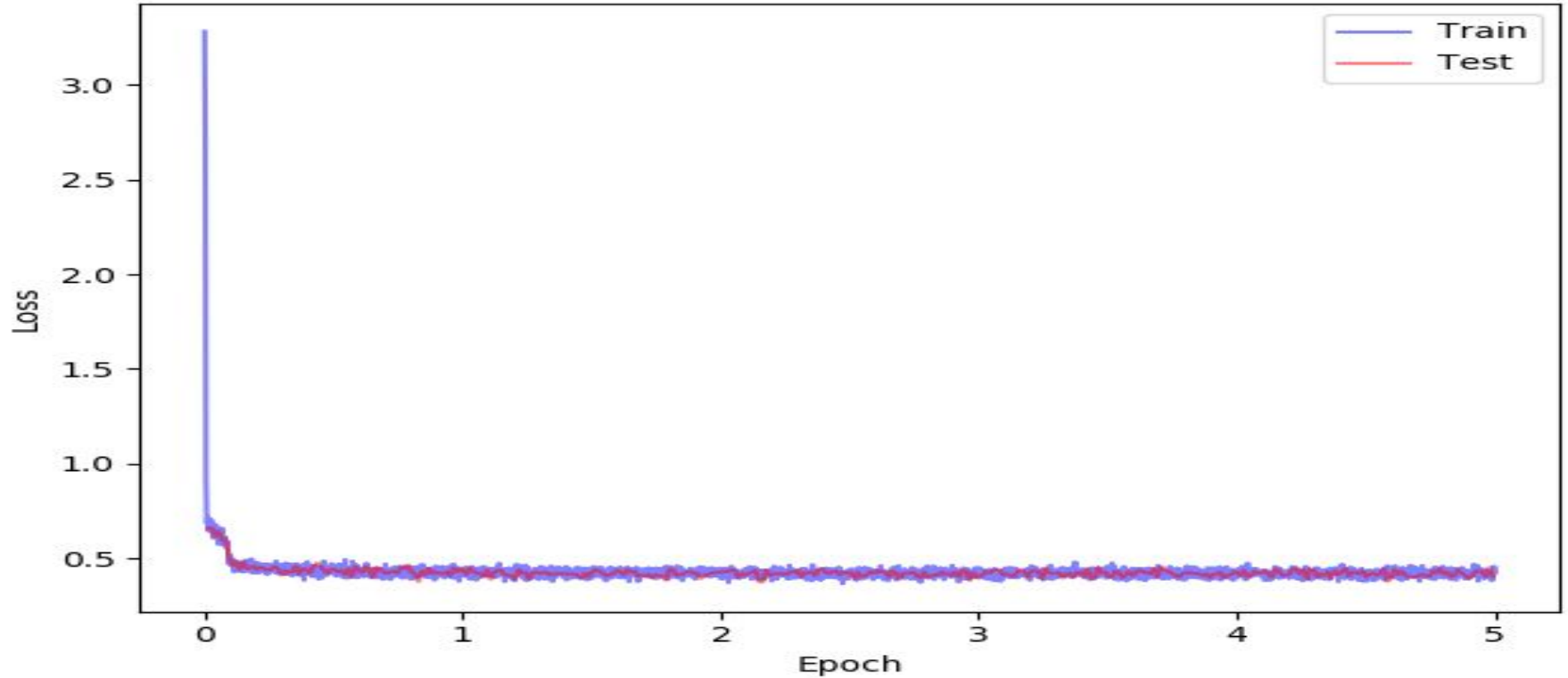
Expected mean charge (Predicted Charge X Predicted Hit Probability)



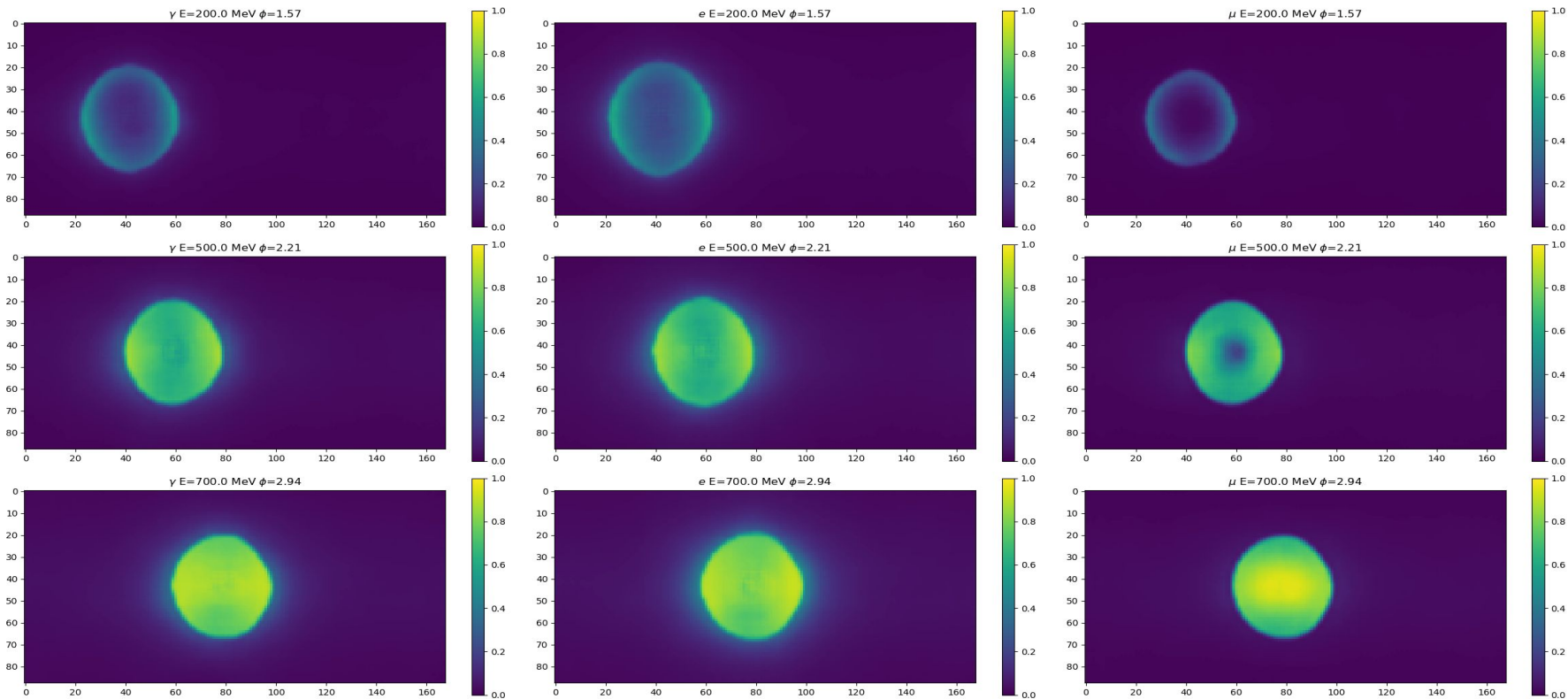
Predicted Variance of Charge



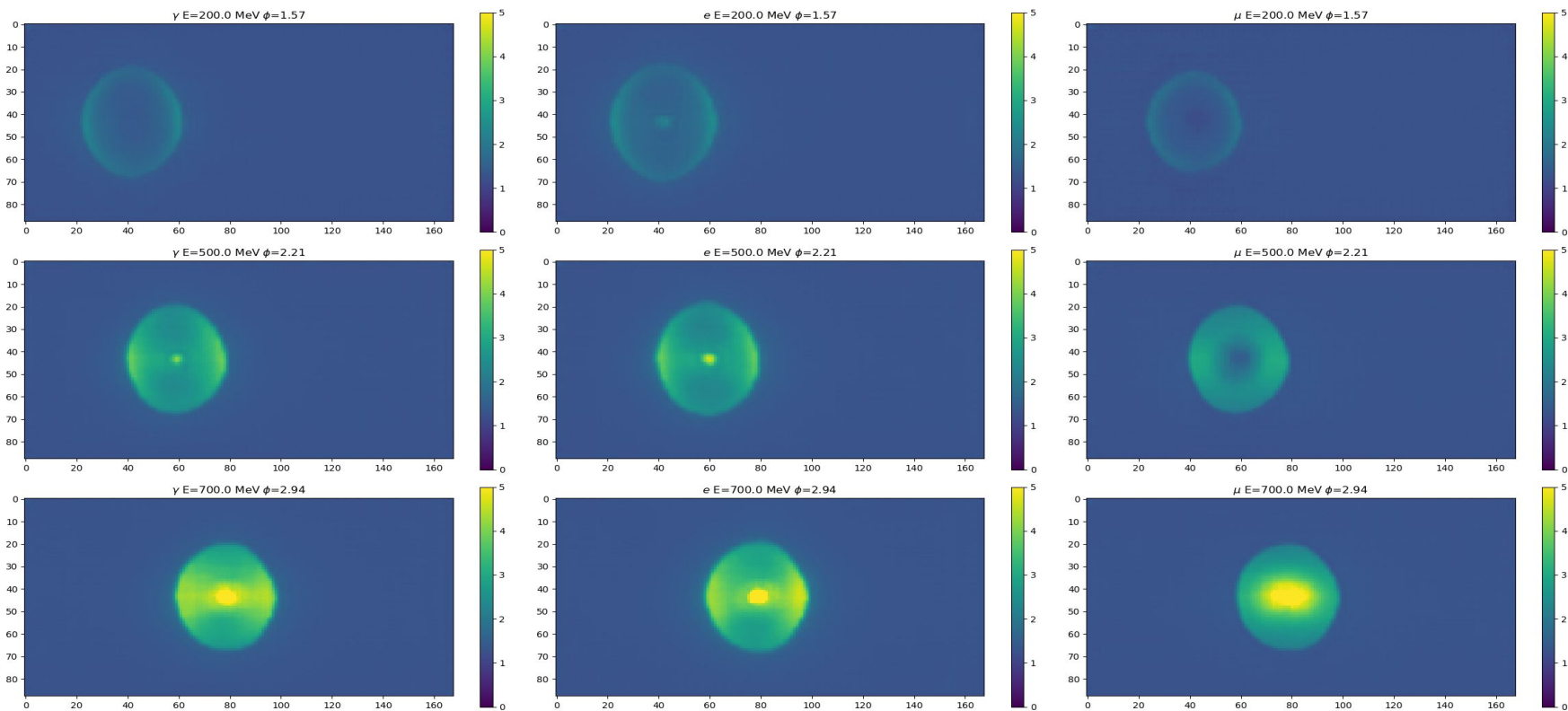
Node = 298 , Time = 2 hours and 13 min



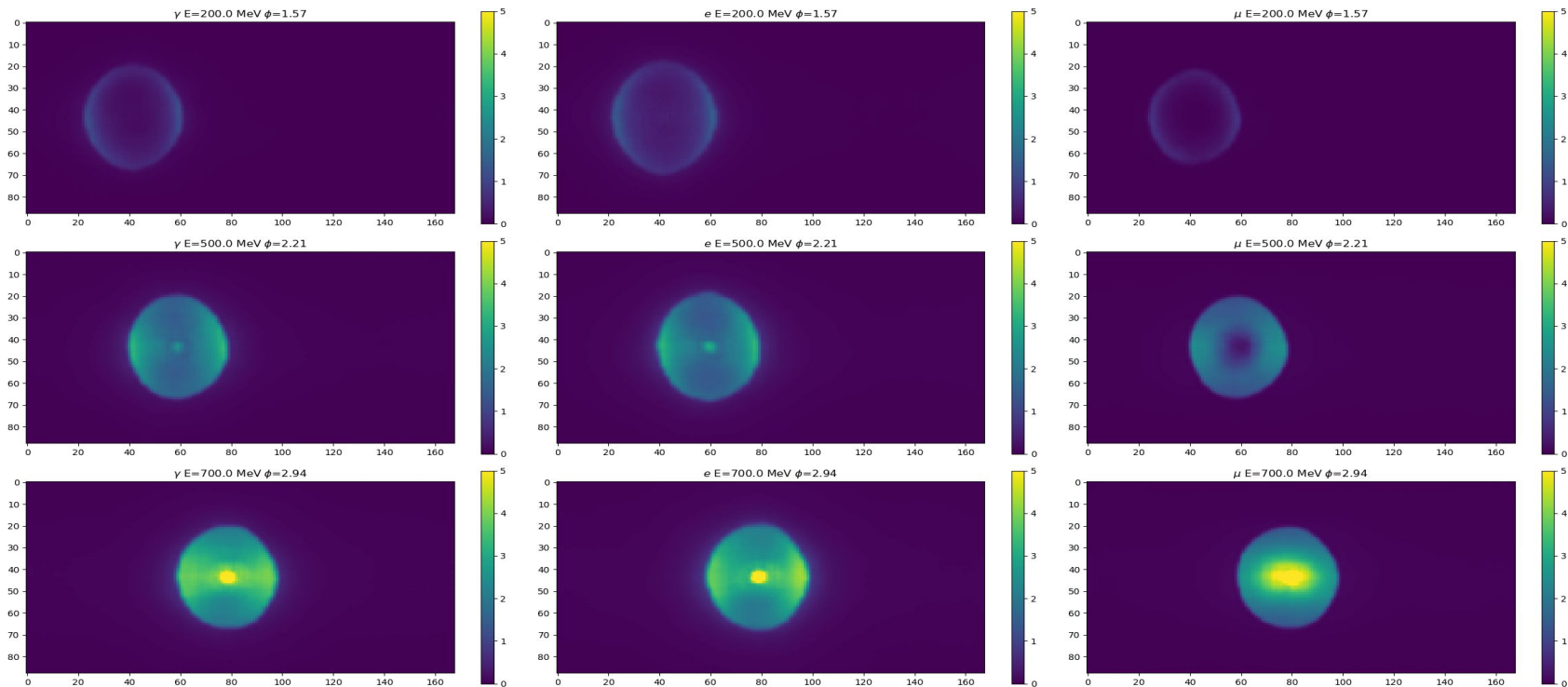
Predicted Hit Probability



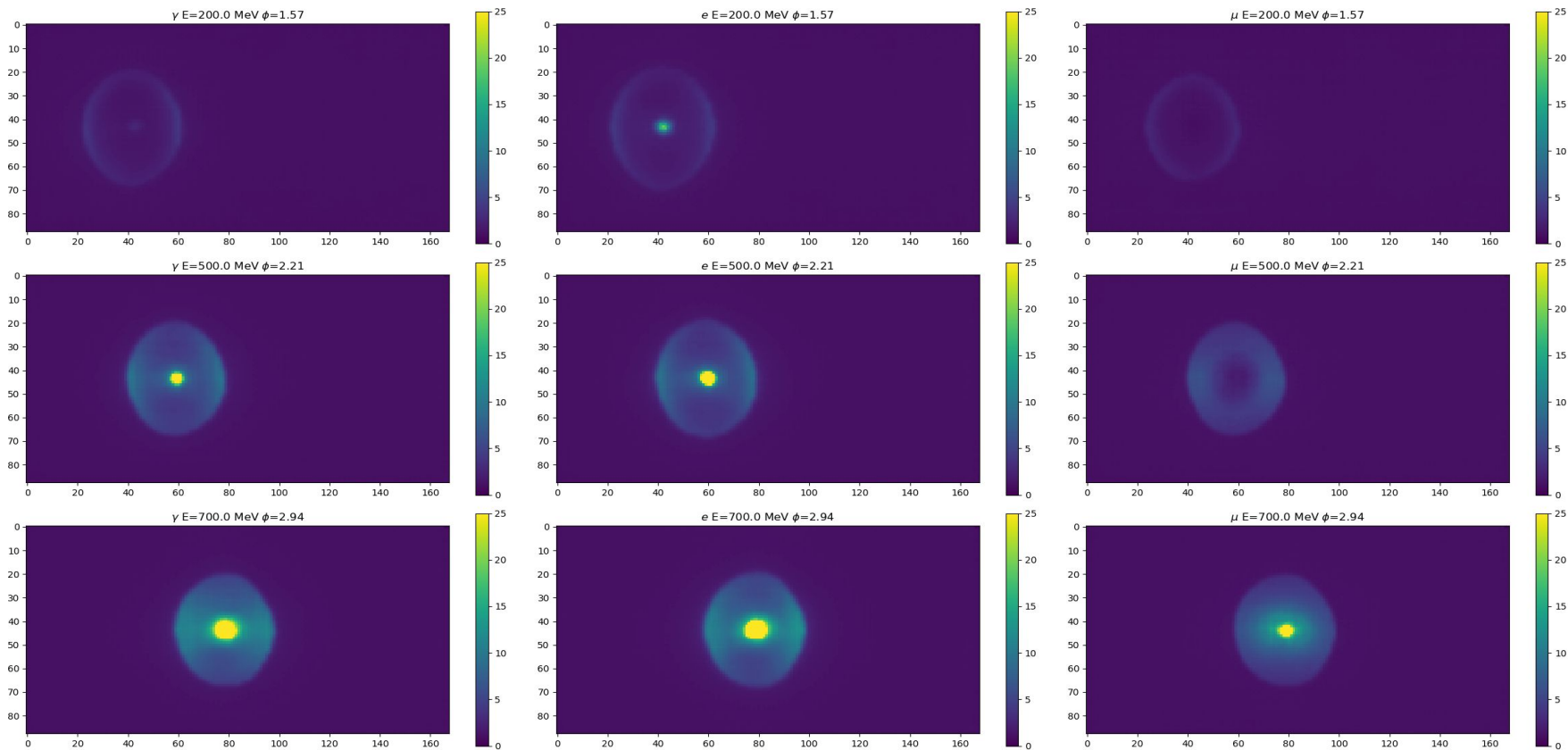
Predicted Charge



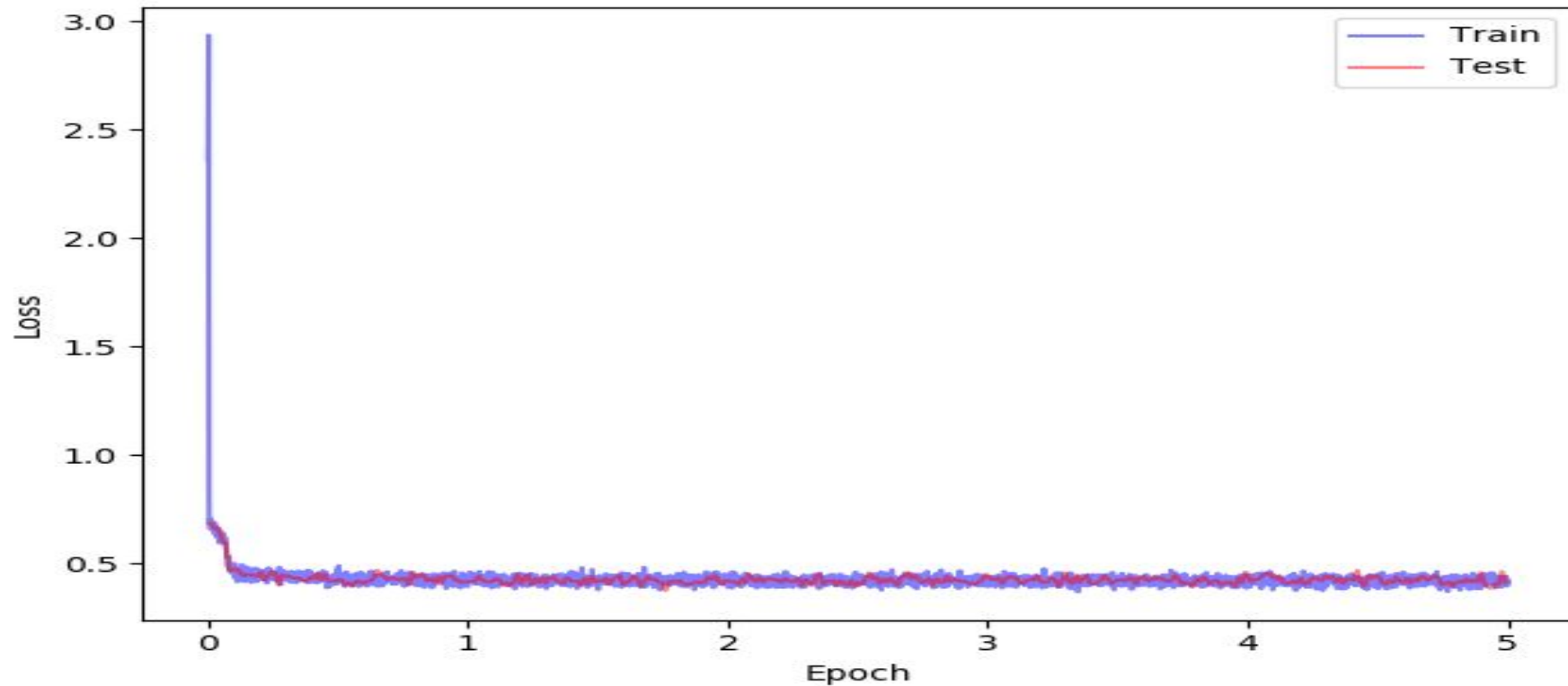
Expected mean charge (Predicted Charge X Predicted Hit Probability)



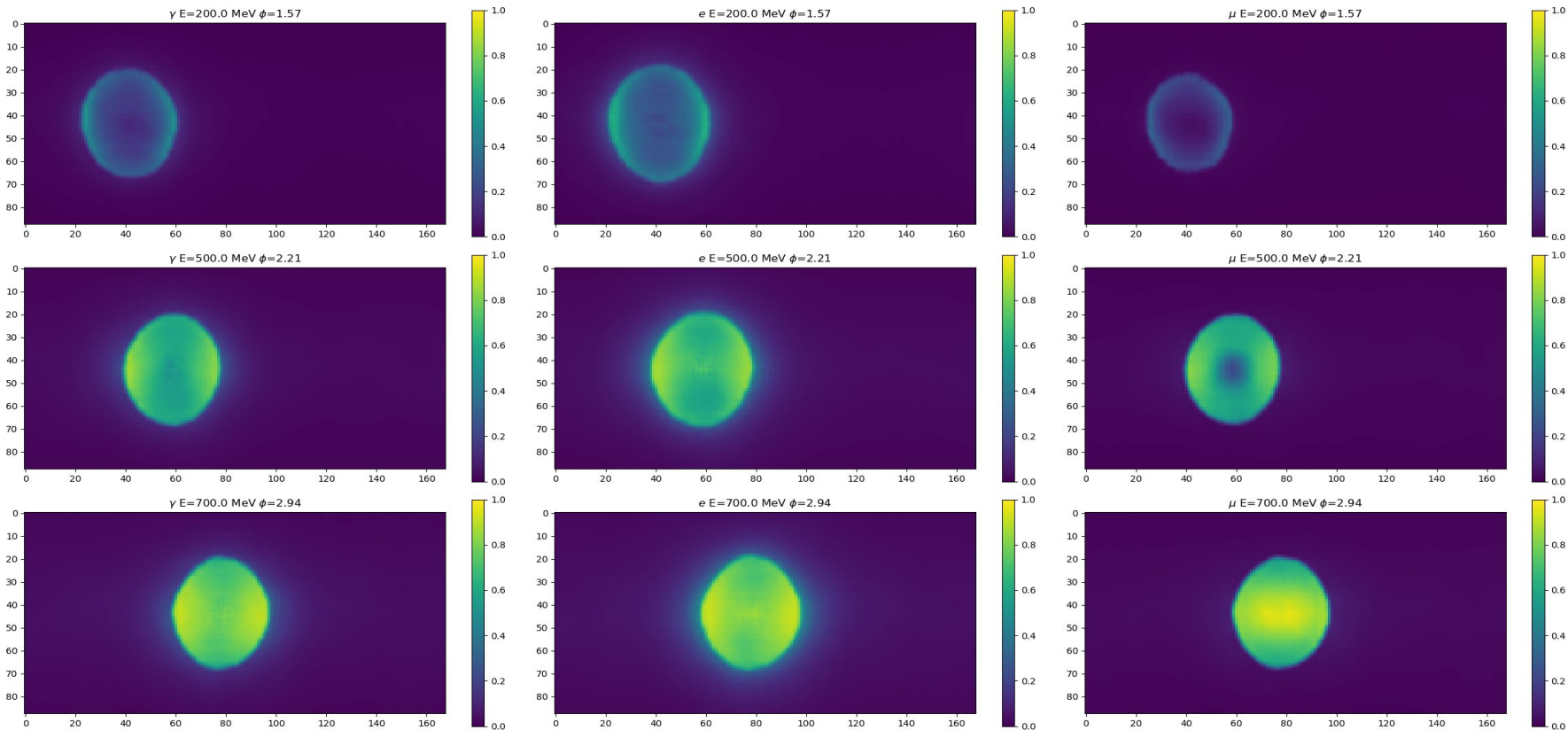
Predicted Variance of Charge



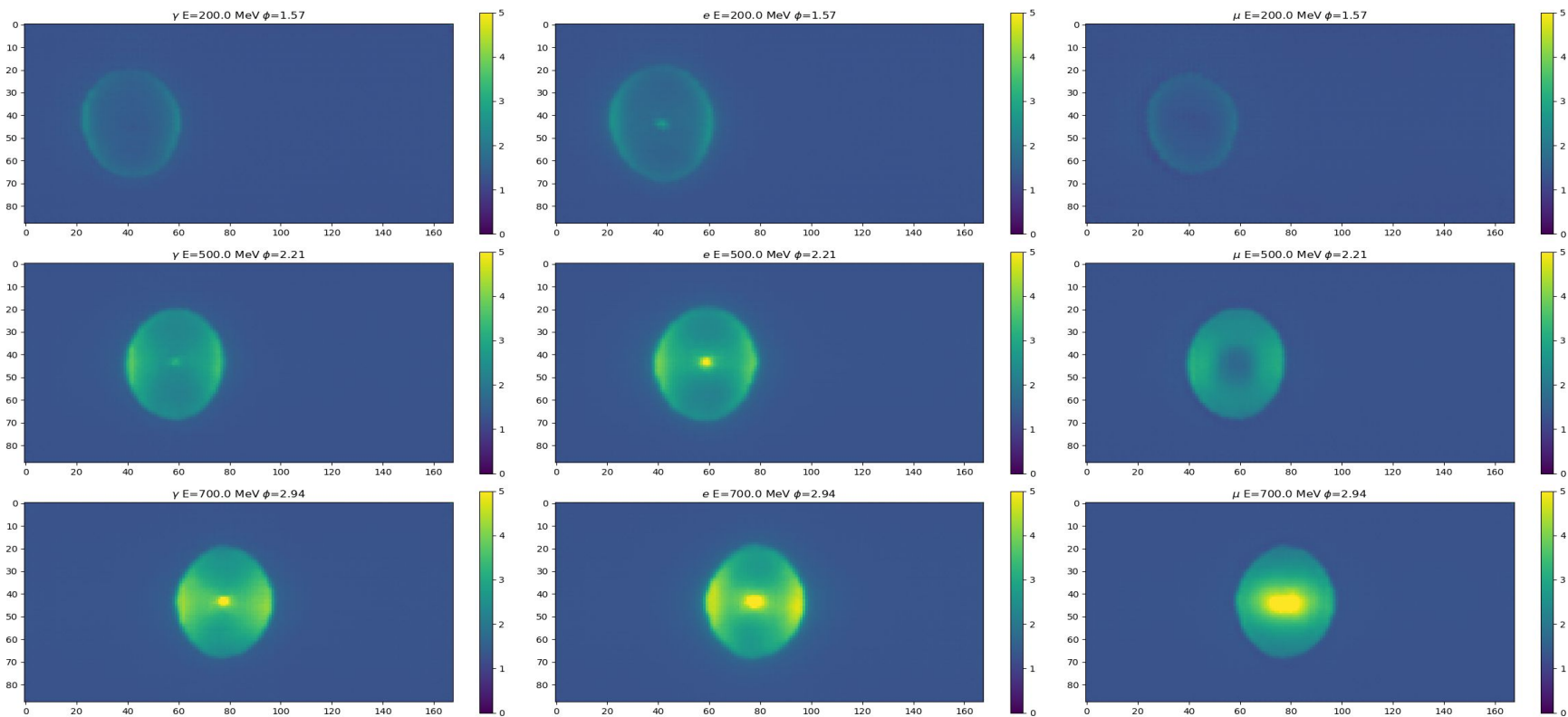
Node = 400 , Time = 2 hours and 14 min



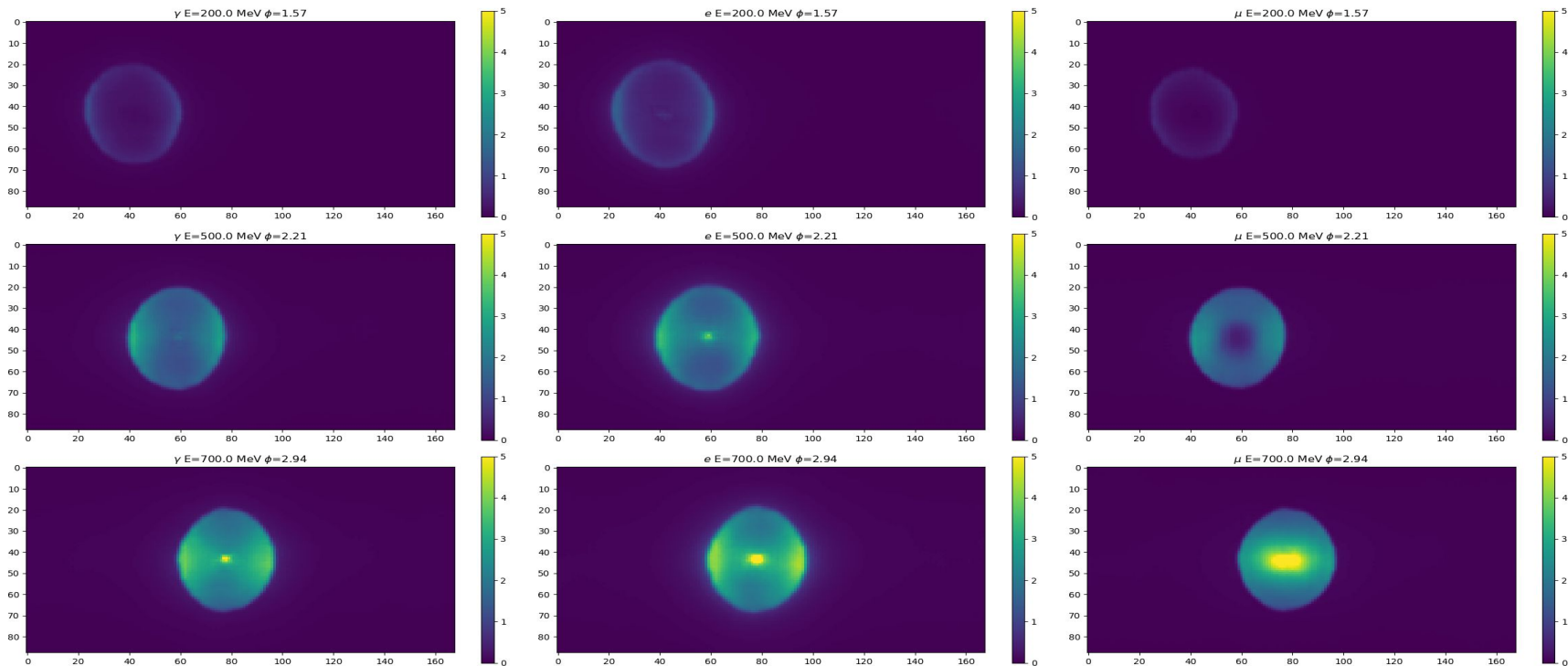
Predicted Hit Probability



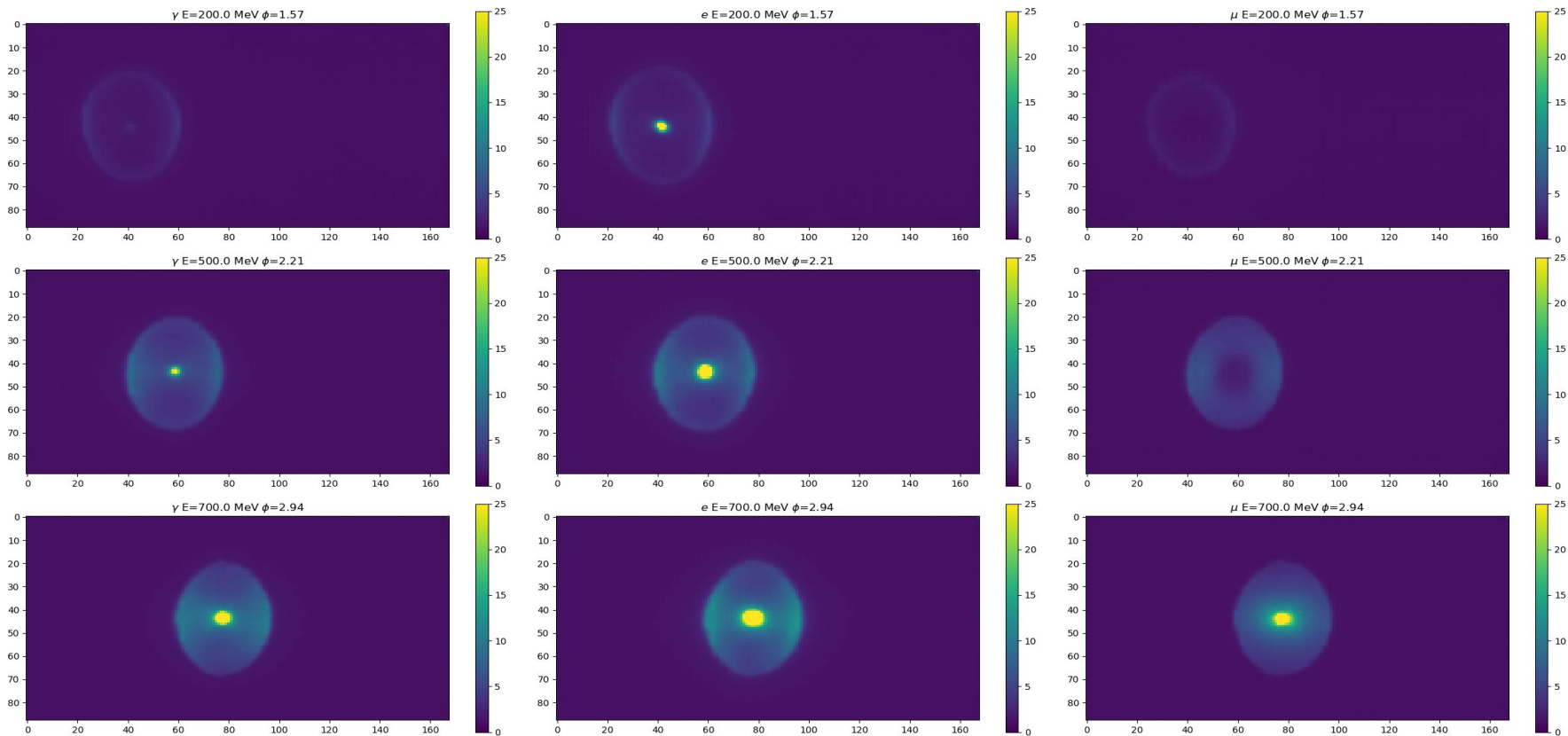
Predicted Charge



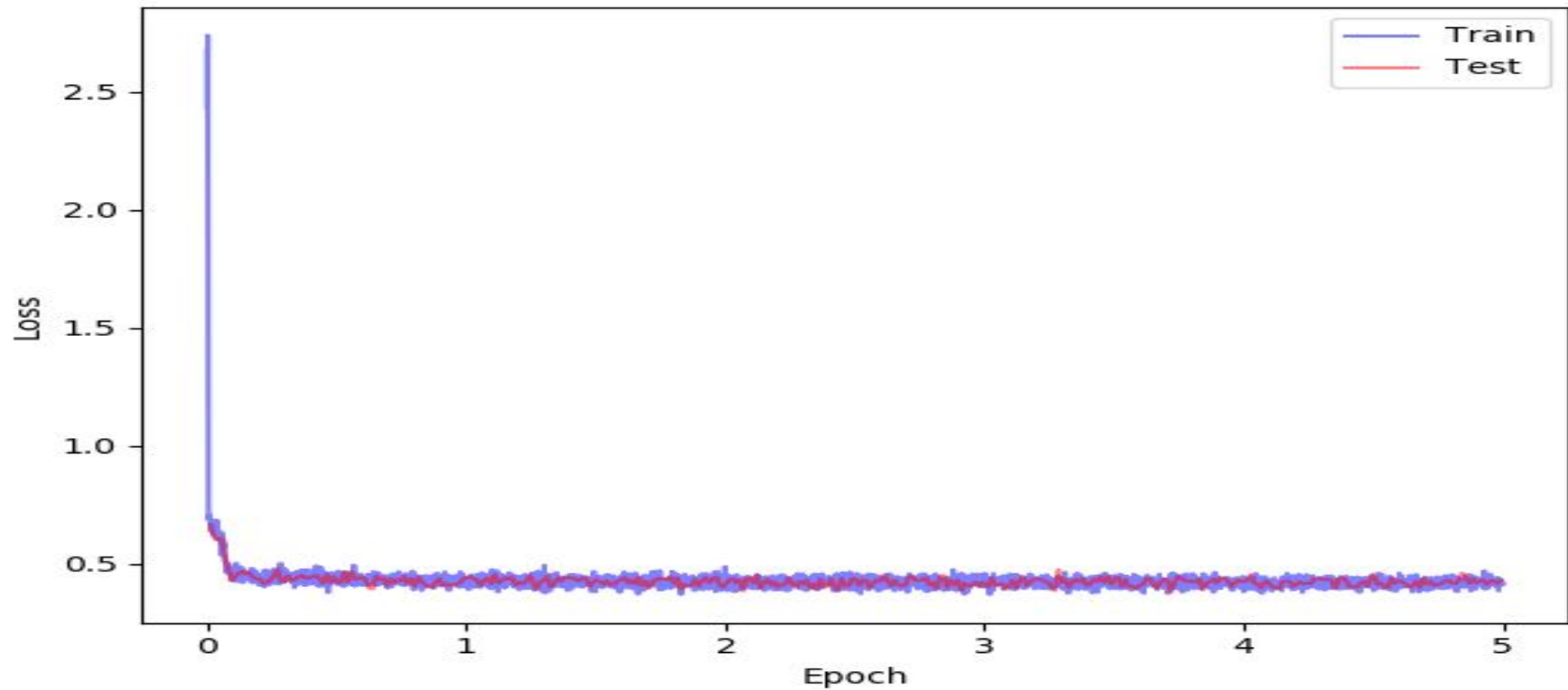
Expected mean charge (Predicted Charge X Predicted Hit Probability)



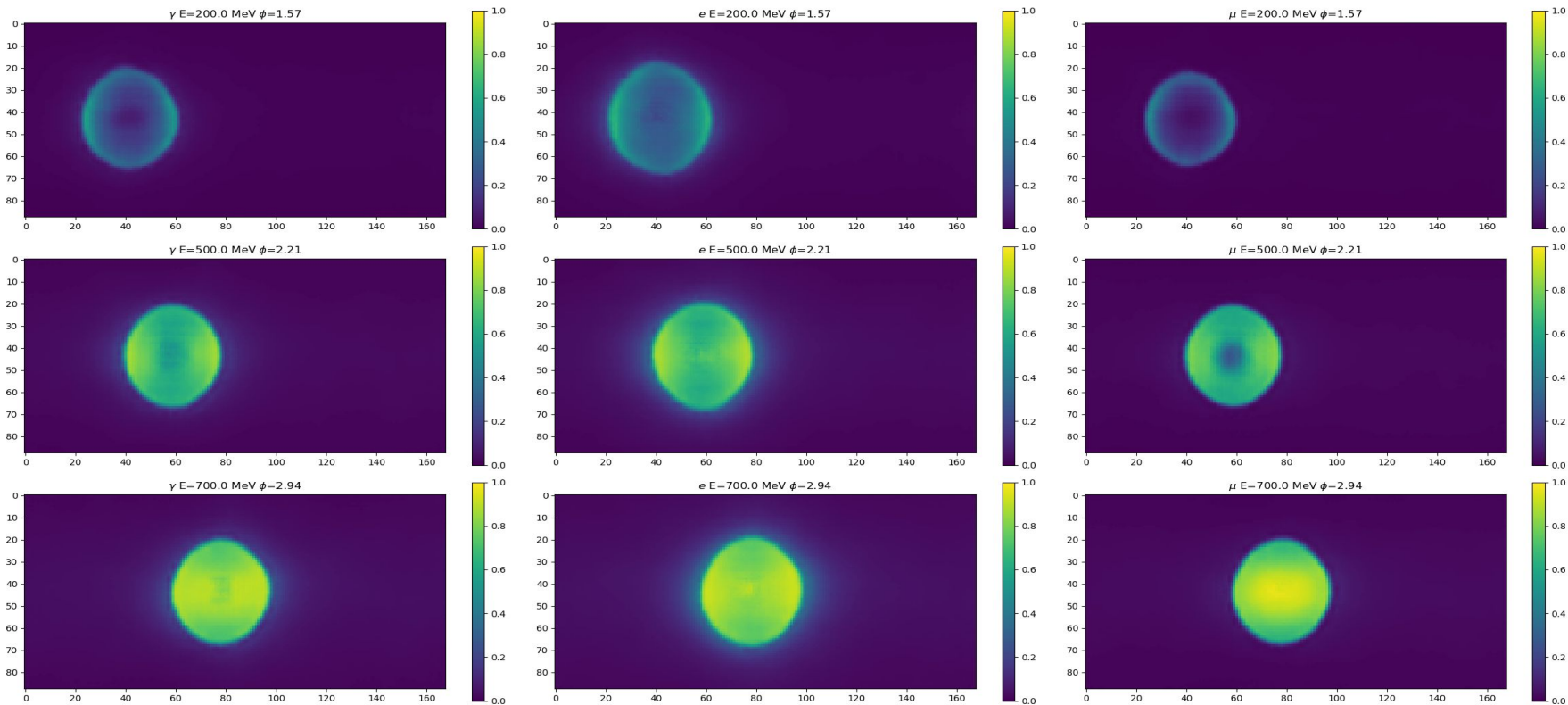
Predicted Variance of Charge



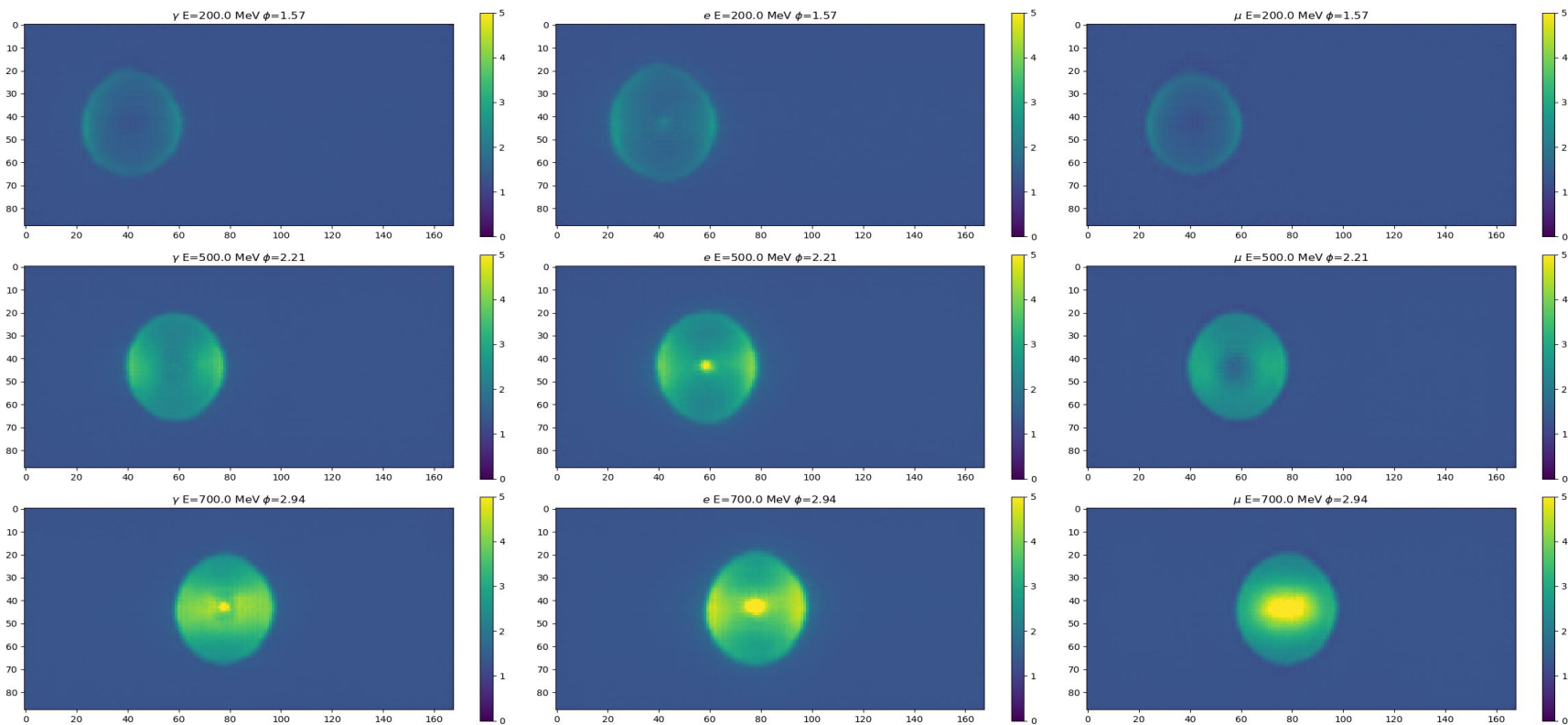
Node = 516, Time = 2 hours and 18 min



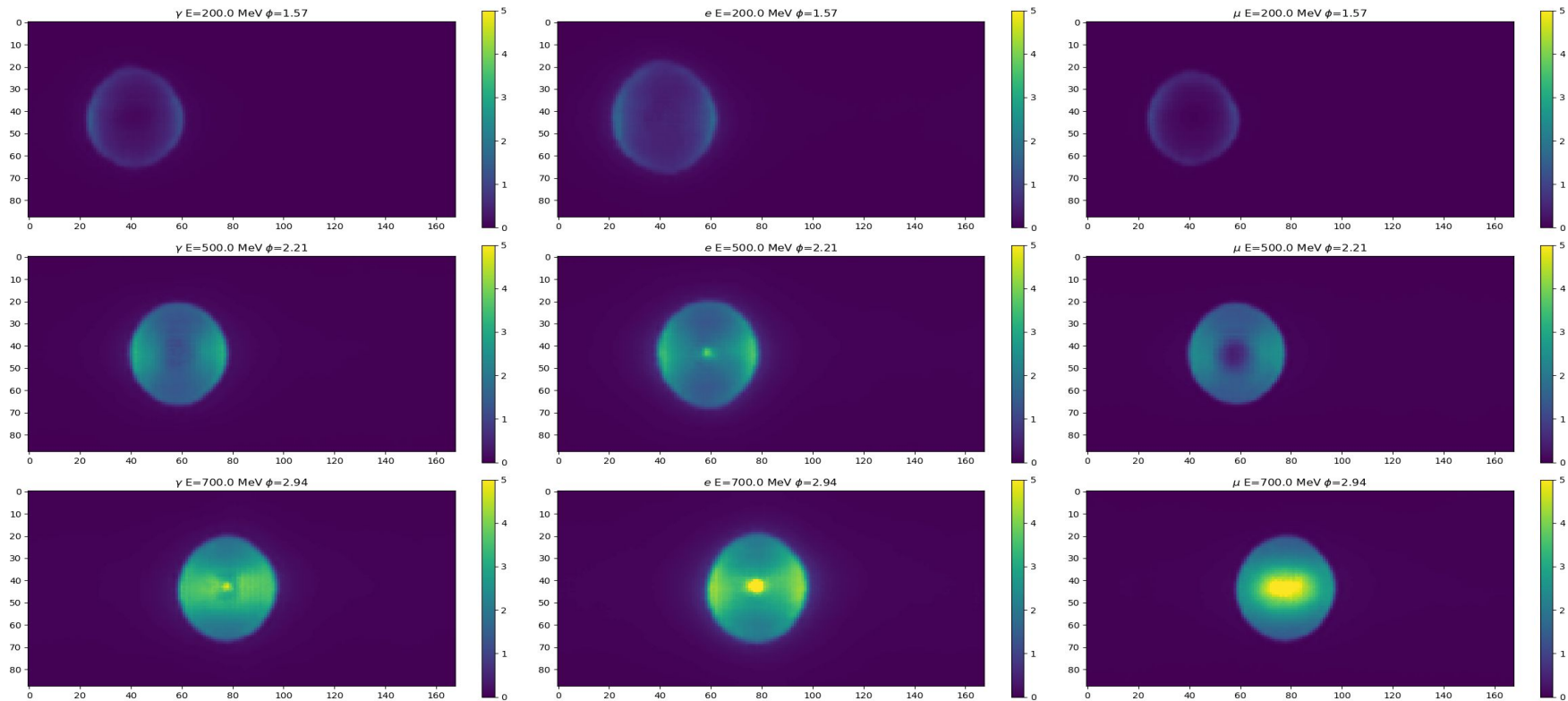
Predicted Hit Probability



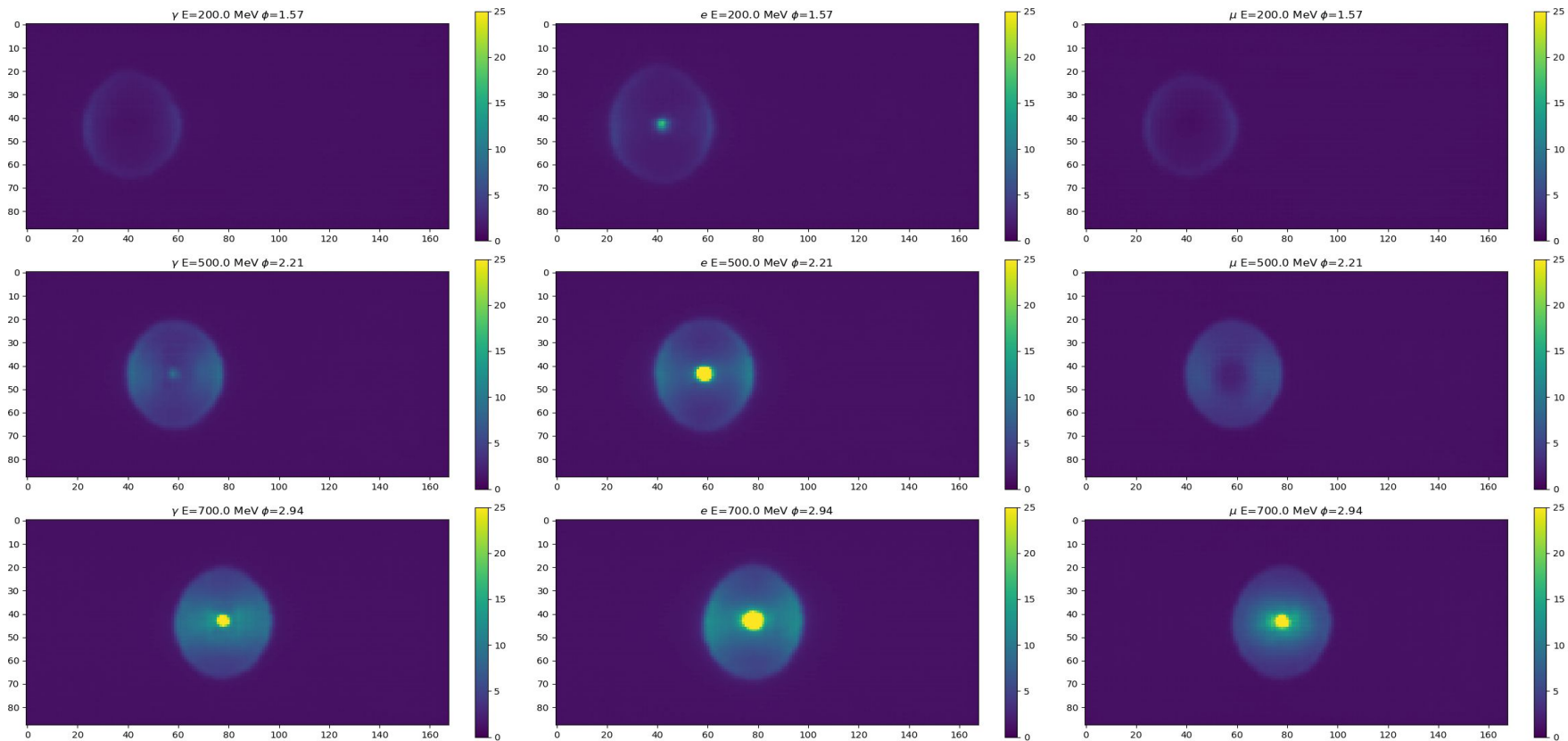
Predicted Charge



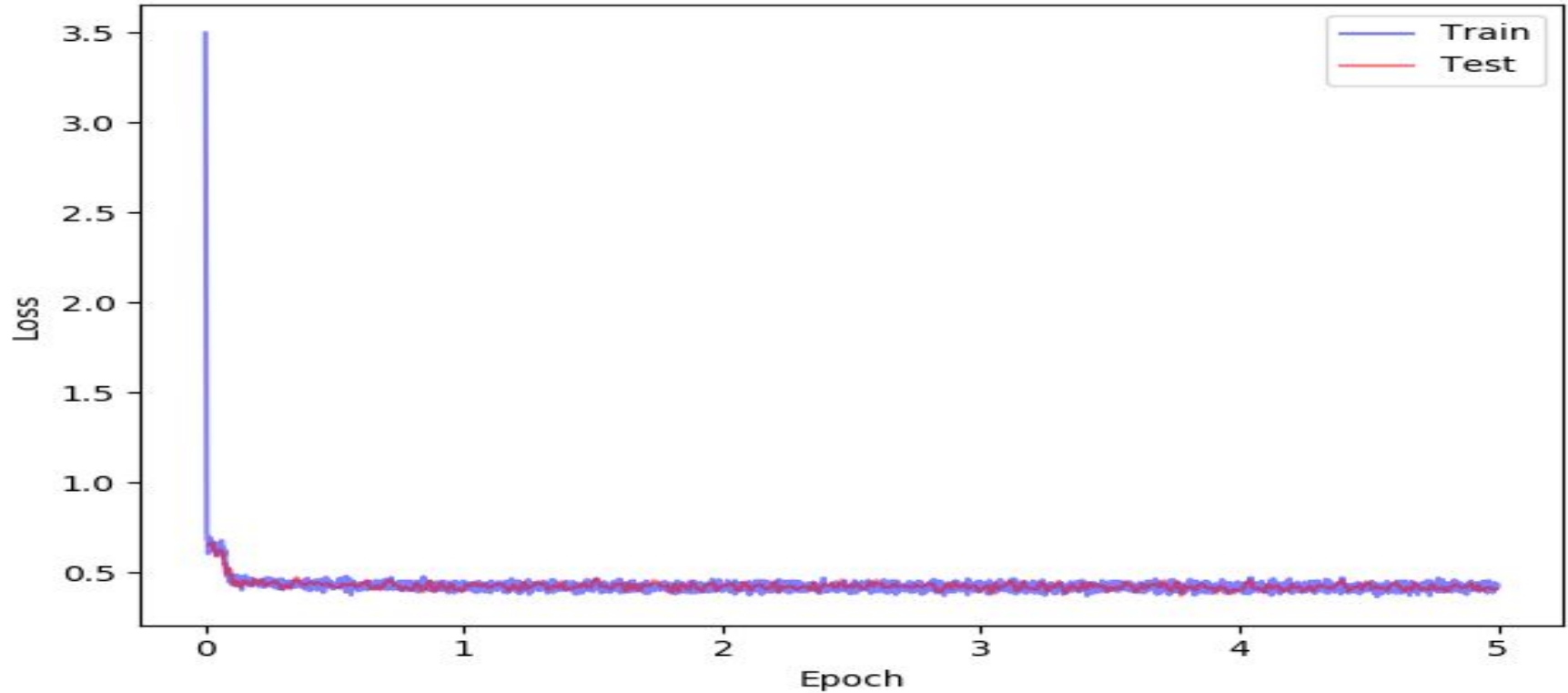
Expected mean charge (Predicted Charge X Predicted Hit Probability)



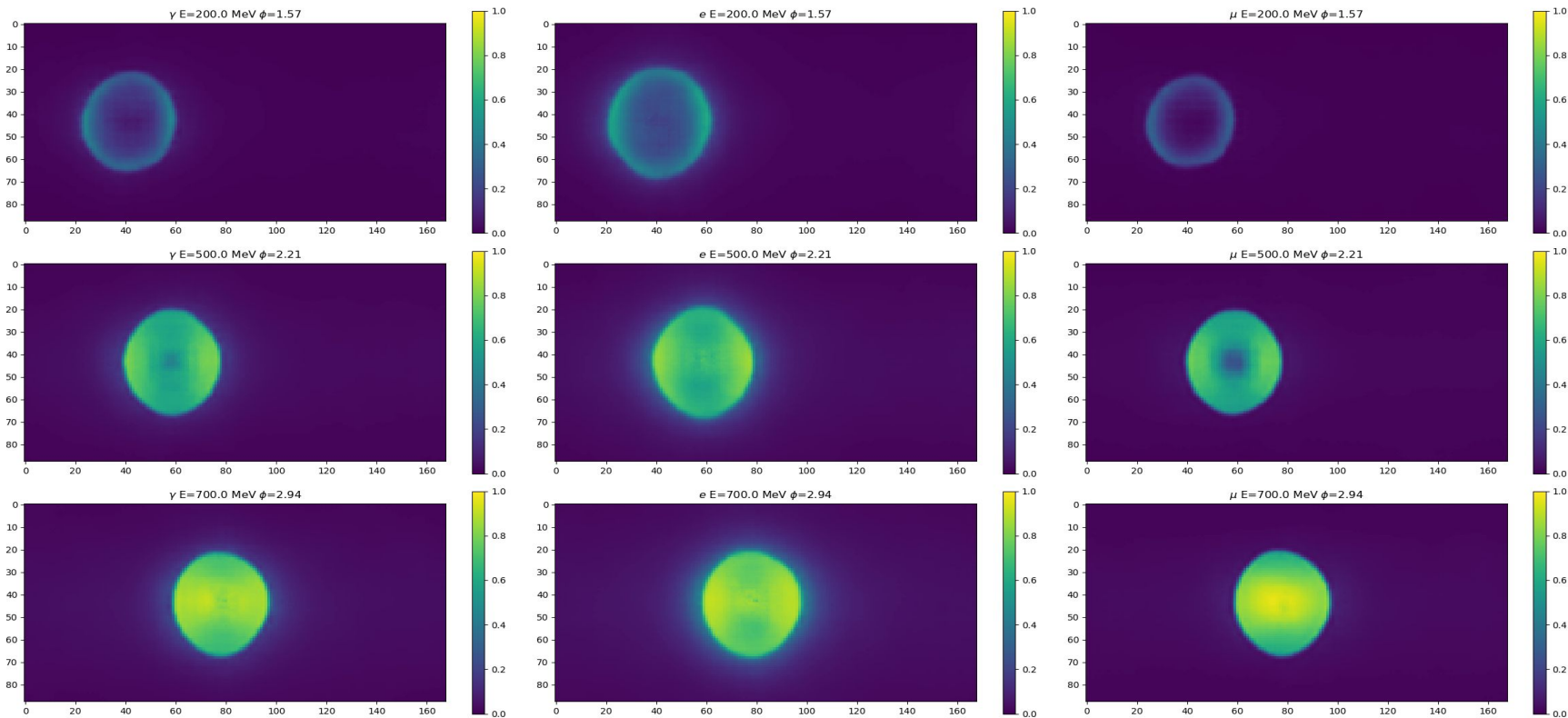
Predicted Variance of Charge



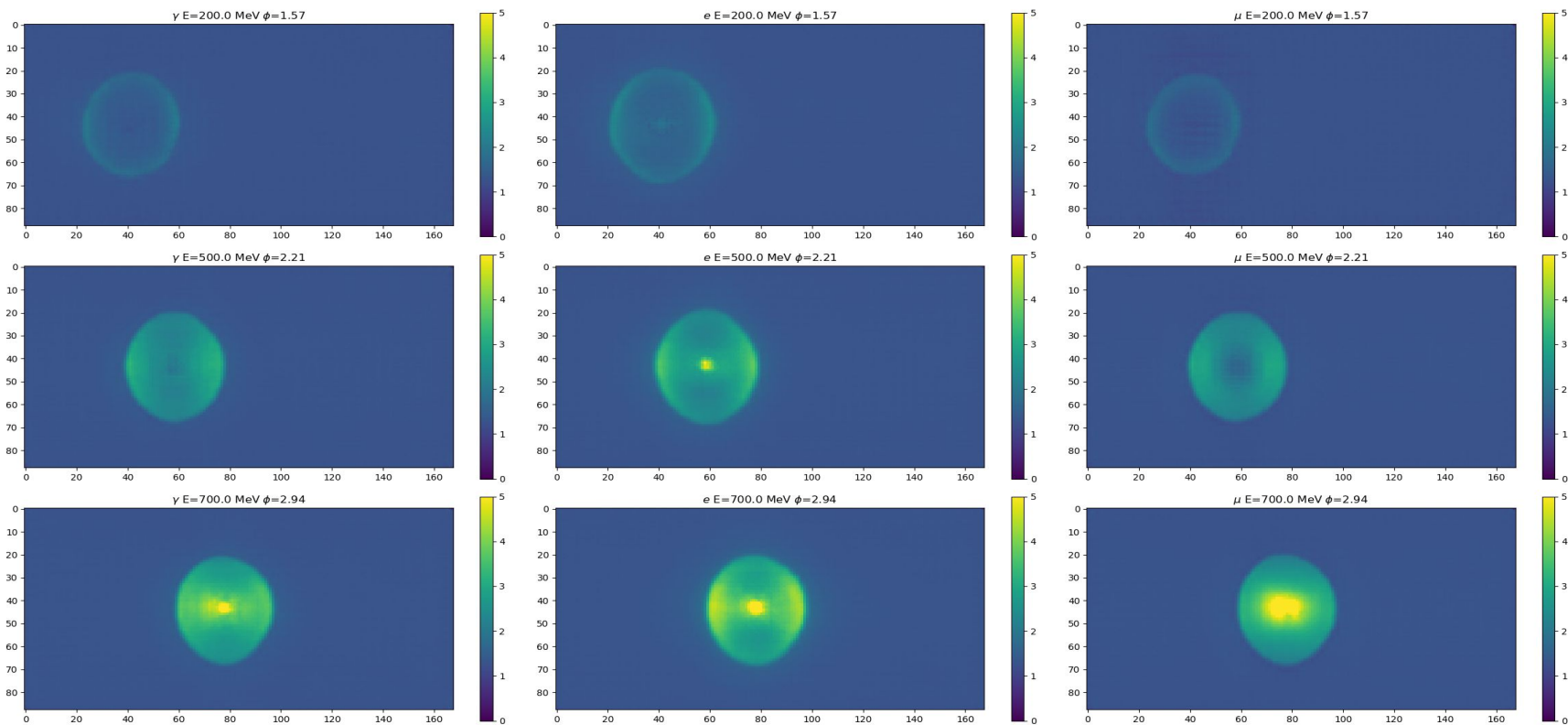
Node = 800, Time = 2 hours and 23 min



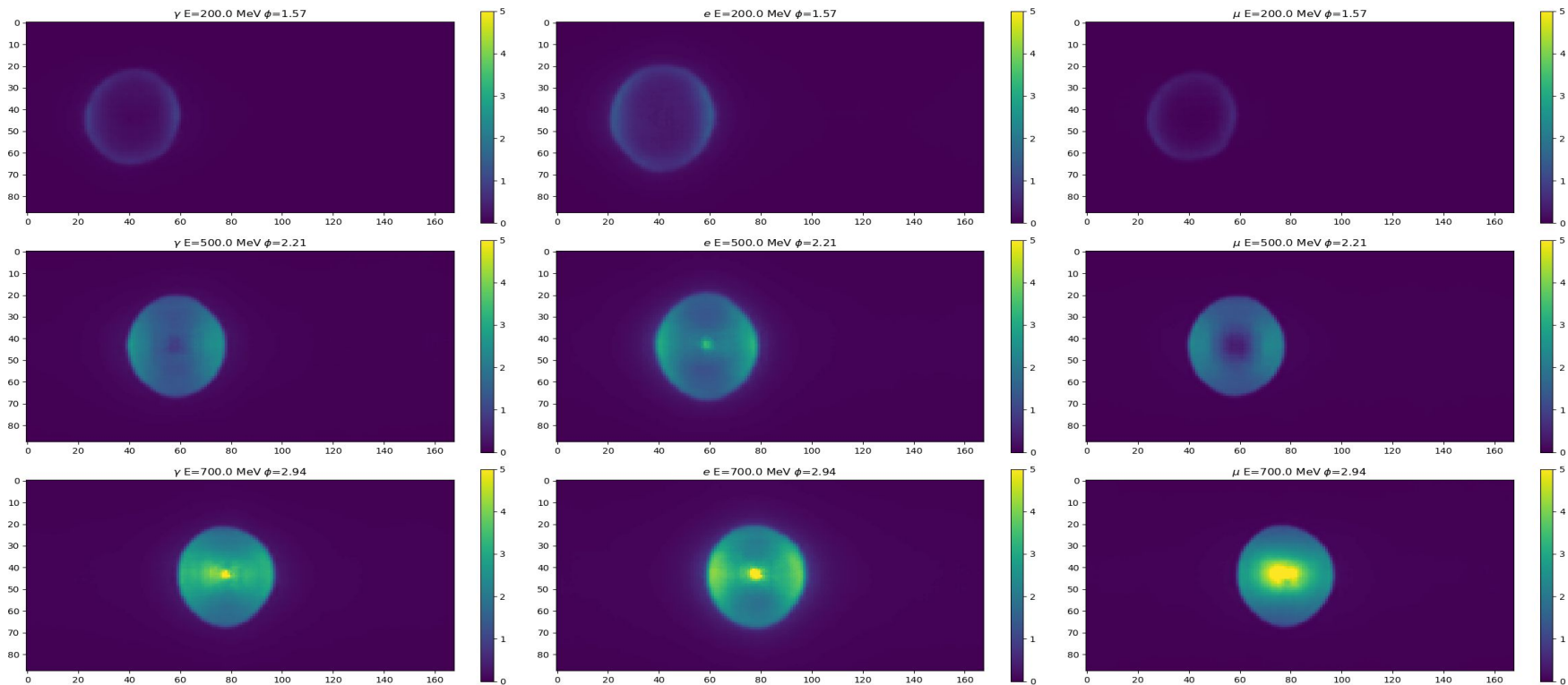
Predicted Hit Probability



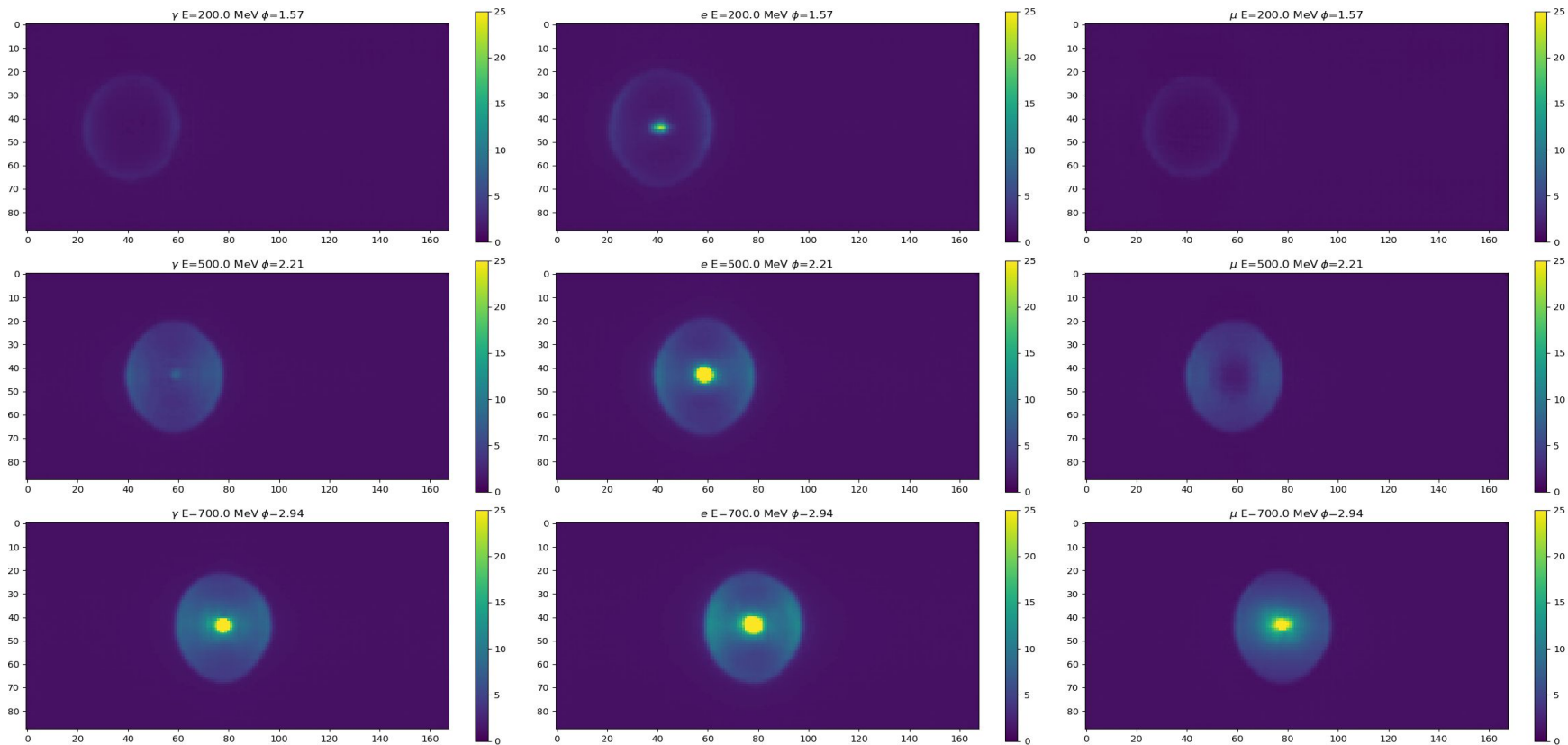
Predicted Charge



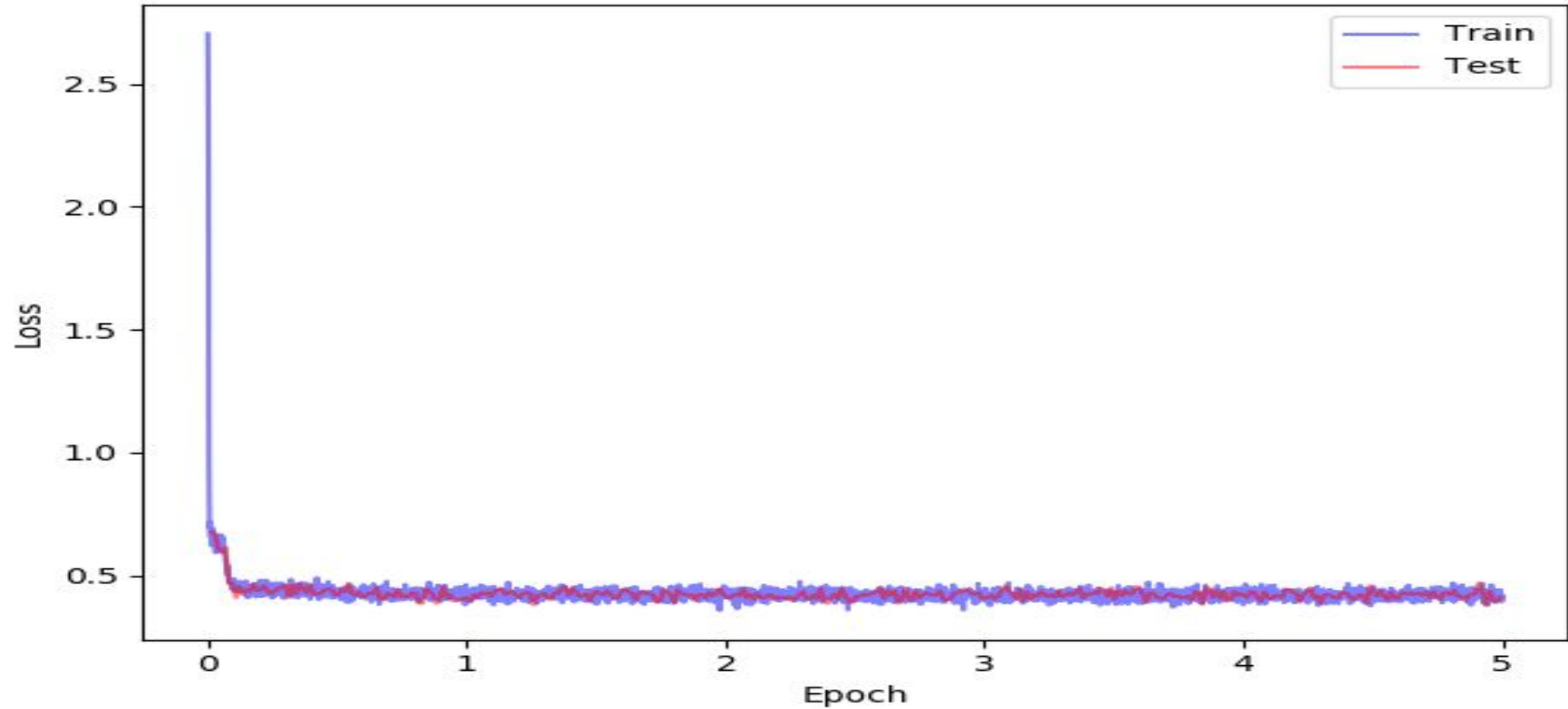
Expected mean charge (Predicted Charge X Predicted Hit Probability)



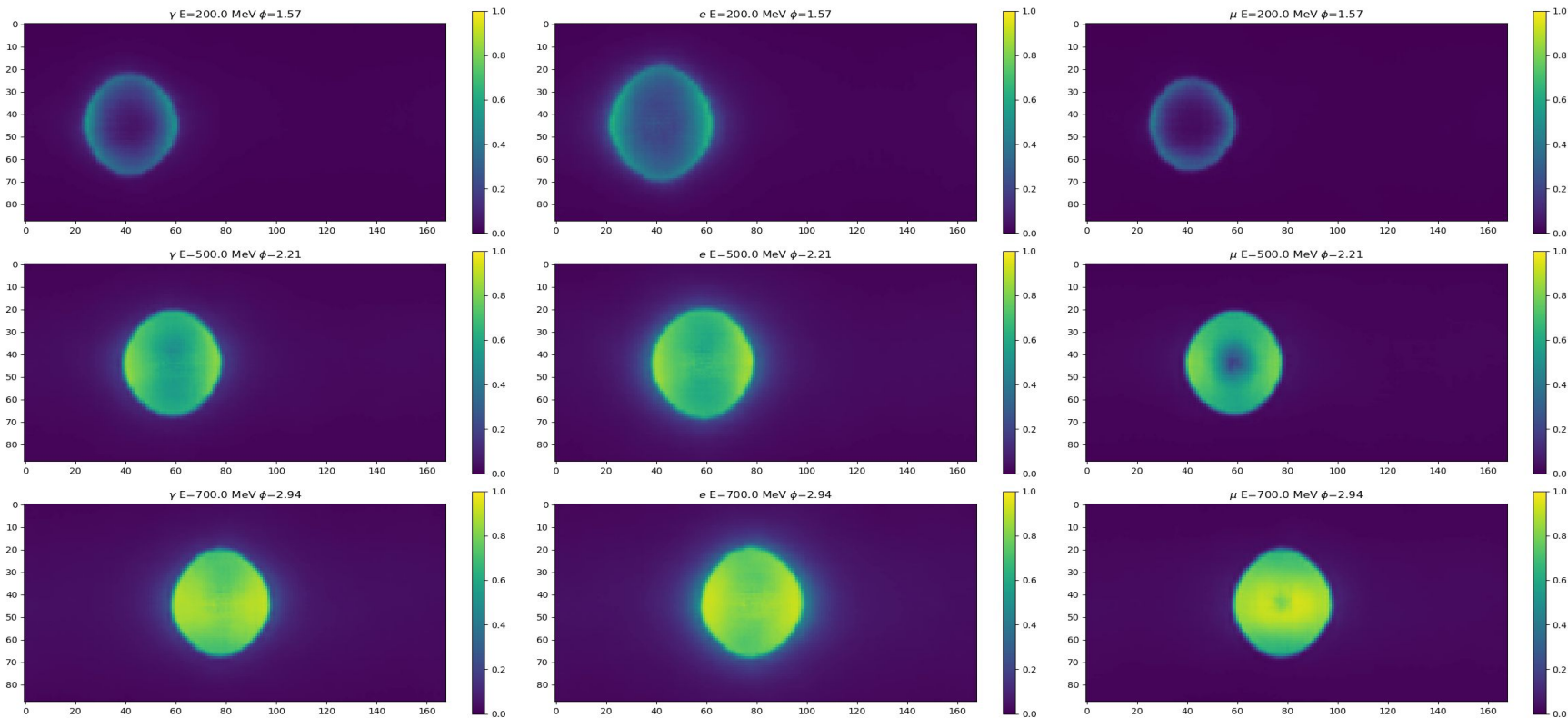
Predicted Variance of Charge



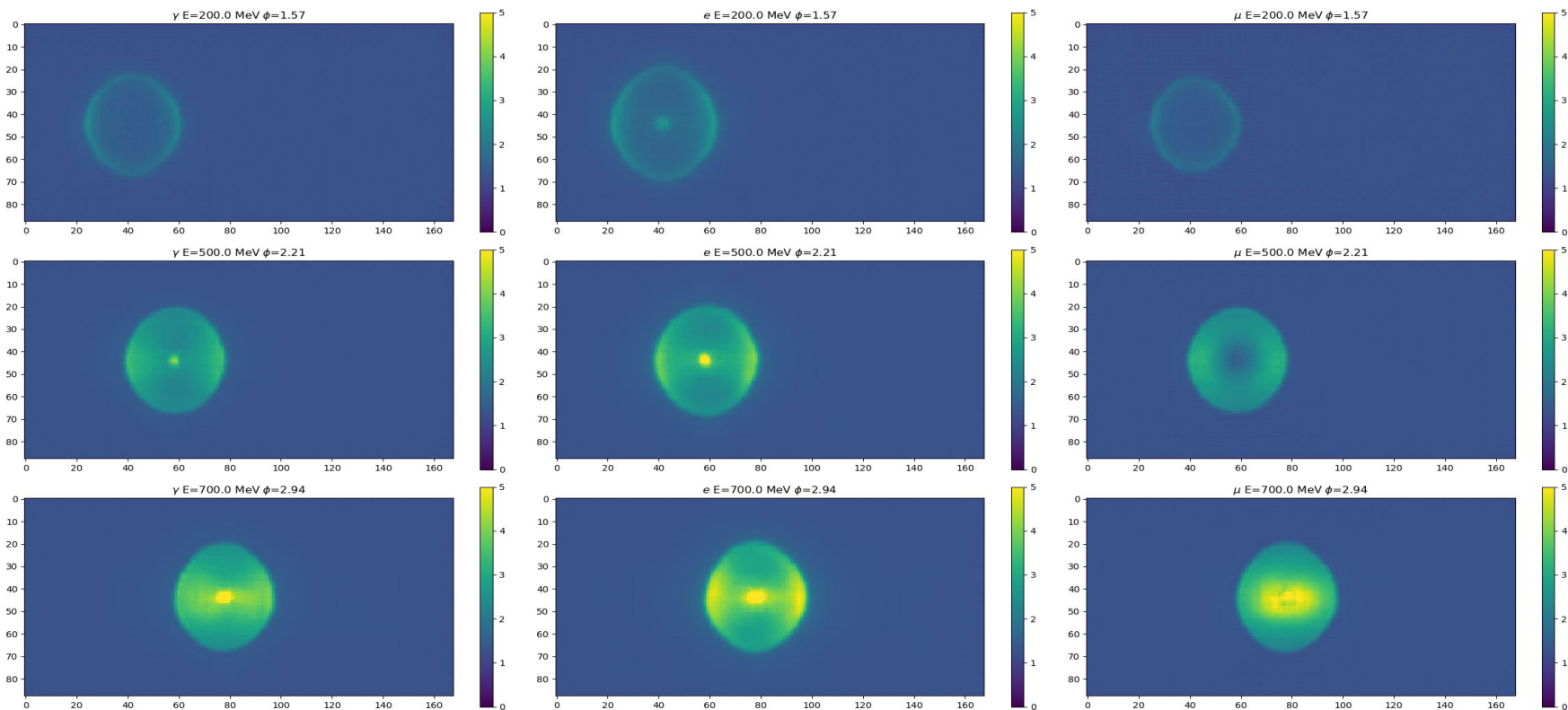
Node = 1000, Time = 2 hours and 29 min



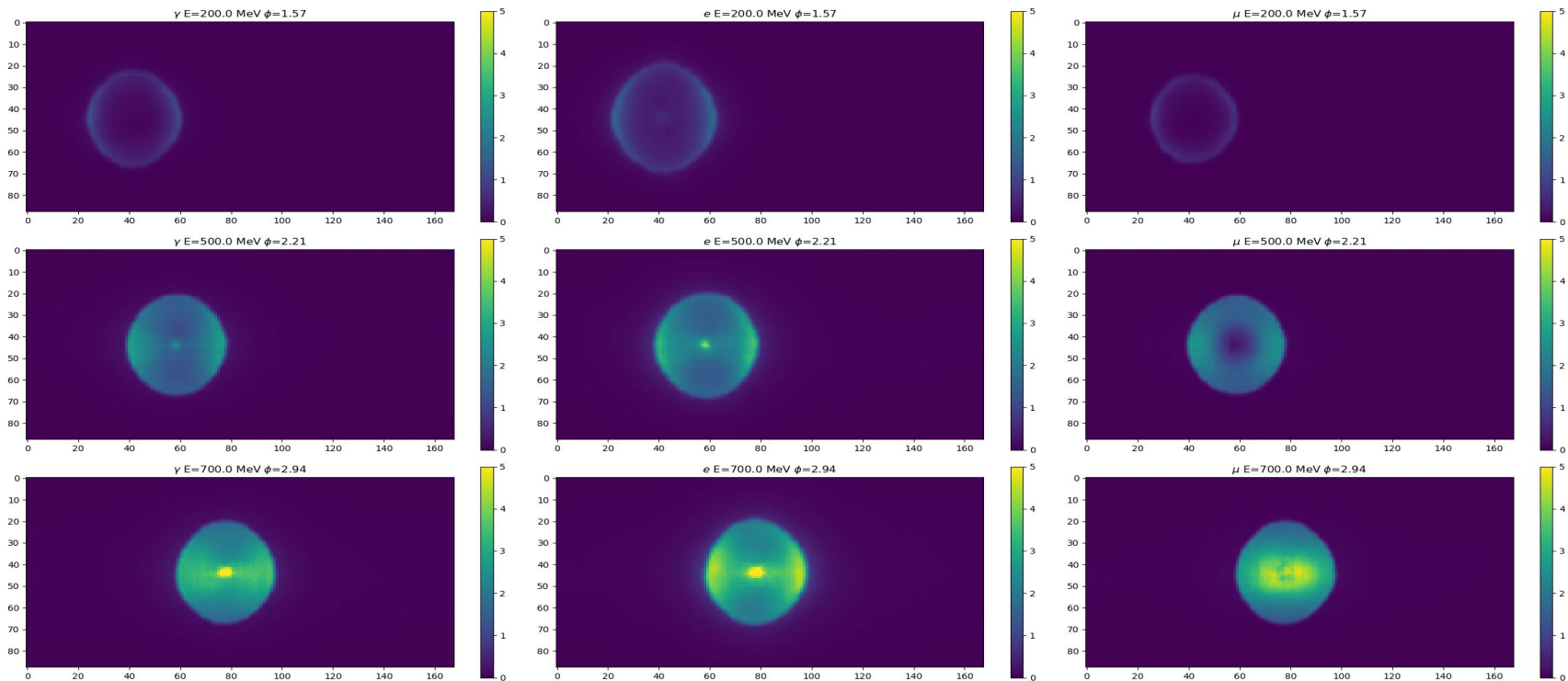
Predicted Hit Probability



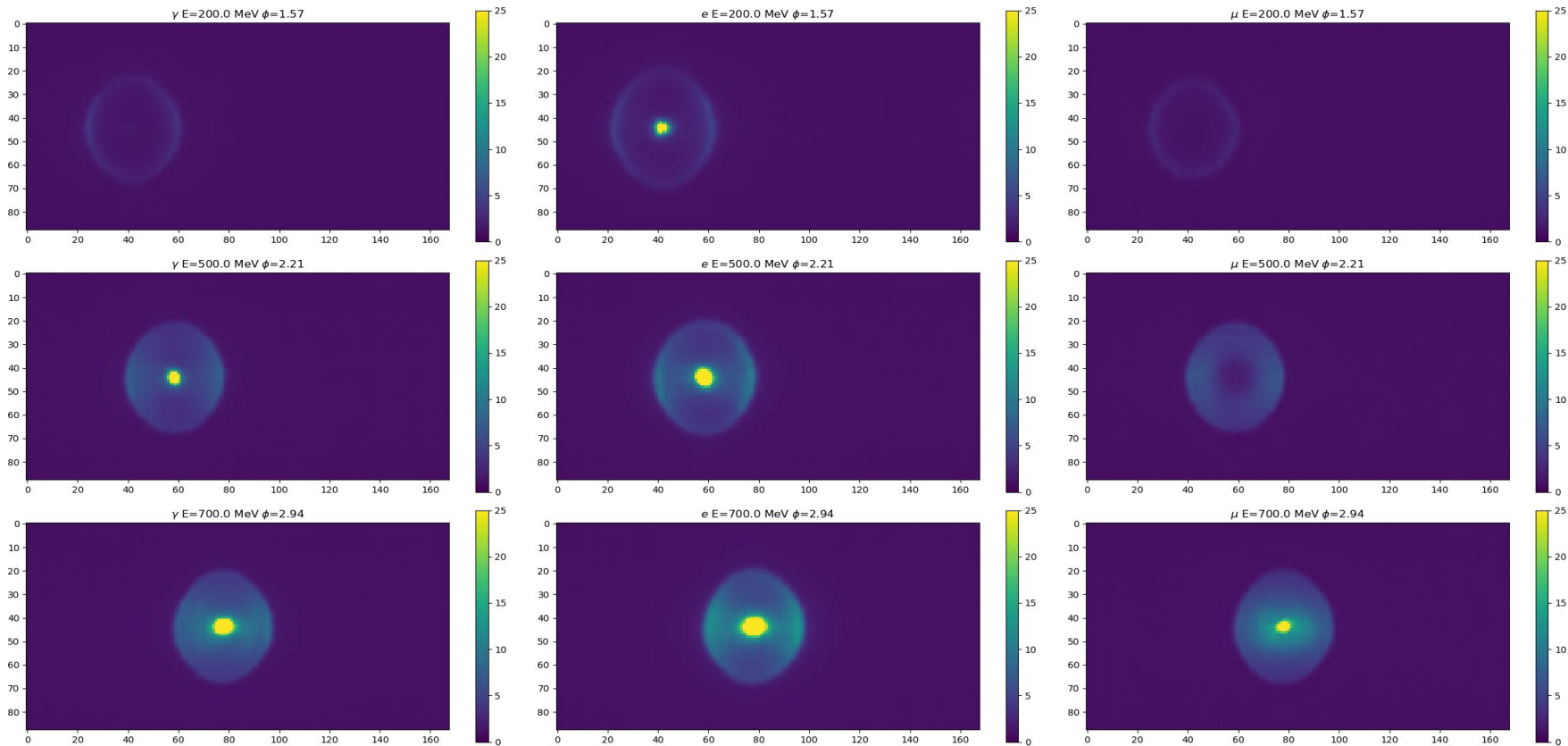
Predicted Charge



Expected mean charge (Predicted Charge X Predicted Hit Probability)



Predicted Variance of Charge



Train

Node	2-3 Epoch	3-4 Epoch	4-5 epoch	Average
3	0.4713 \pm 0.0173	0.4704 \pm 0.0182	0.4667 \pm 0.0171	0.4694
10	0.4247 \pm 0.0171	0.4228 \pm 0.0163	0.4218 \pm 0.0169	0.4231
30	0.4226 \pm 0.0166	0.4208 \pm 0.0162	0.4195 \pm 0.0171	0.4210
50	0.4193 \pm 0.0171	0.4185 \pm 0.0161	0.4181 \pm 0.0161	0.4186
100	0.4196 \pm 0.0160	0.4190 \pm 0.0167	0.4193 \pm 0.0165	0.4193
156	0.4198 \pm 0.0165	0.4190 \pm 0.0163	0.4184 \pm 0.0169	0.4191
298	0.4190 \pm 0.0168	0.4196 \pm 0.0165	0.4185 \pm 0.0169	0.4190
400	0.4190 \pm 0.0164	0.4187 \pm 0.0157	0.4172 \pm 0.0170	0.4183
516	0.4206 \pm 0.0174	0.4195 \pm 0.0164	0.4188 \pm 0.0158	0.4196
800	0.4193 \pm 0.0169	0.4190 \pm 0.0169	0.4187 \pm 0.0176	0.4190
1000	0.4196 \pm 0.0164	0.4182 \pm 0.0167	0.4196 \pm 0.0162	0.4191

Test

Node	2-3 Epoch	3-4 Epoch	4-5 epoch	Average
3	0.4721±0.0174	0.4712±0.0168	0.4648±0.0183	0.4694
10	0.4230±0.0164	0.4264±0.0177	0.4180±0.0148	0.4225
30	0.4209±0.0153	0.4205±0.0162	0.4177±0.0174	0.4197
50	0.4208±0.0179	0.4211±0.0172	0.4187±0.0169	0.4202
100	0.4177±0.0173	0.4223±0.0164	0.4166±0.0140	0.4188
156	0.4231±0.0165	0.4170±0.0170	0.4213±0.0136	0.4205
298	0.4179±0.0151	0.4192±0.0152	0.4184±0.0162	0.4185
400	0.4199±0.0147	0.4208±0.0145	0.4218±0.0172	0.4208
516	0.4185±0.0171	0.4208±0.0170	0.4197±0.0146	0.4196
800	0.4228±0.0153	0.4187±0.0186	0.4180±0.0156	0.4198
1000	0.4174±0.0154	0.4222±0.0160	0.4192±0.0163	0.4196

