Mizuche MC study neutron

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Contents

- Calc mean free path
- Event display of neutron event
  - momentum = 1GeV (kinetic = 432MeV)
  - momentum = 1.5GeV (kinetic = 830MeV)
  - momentum = 2GeV (kinetic = 1.27GeV)
- Efficiency curve to neutron

MC setting

- Tank with water in FV
- Neutron :
  - absolute momentum : 400 MeV/c → kinetic energy = 432 MeV
  - vertex : 0, 0, -90cm (タンク上流10cm)
    - 前のスタディと同じ
  - direction : 0, 0, 1
    - 前のスタディと同じ

Mean free path of n+p

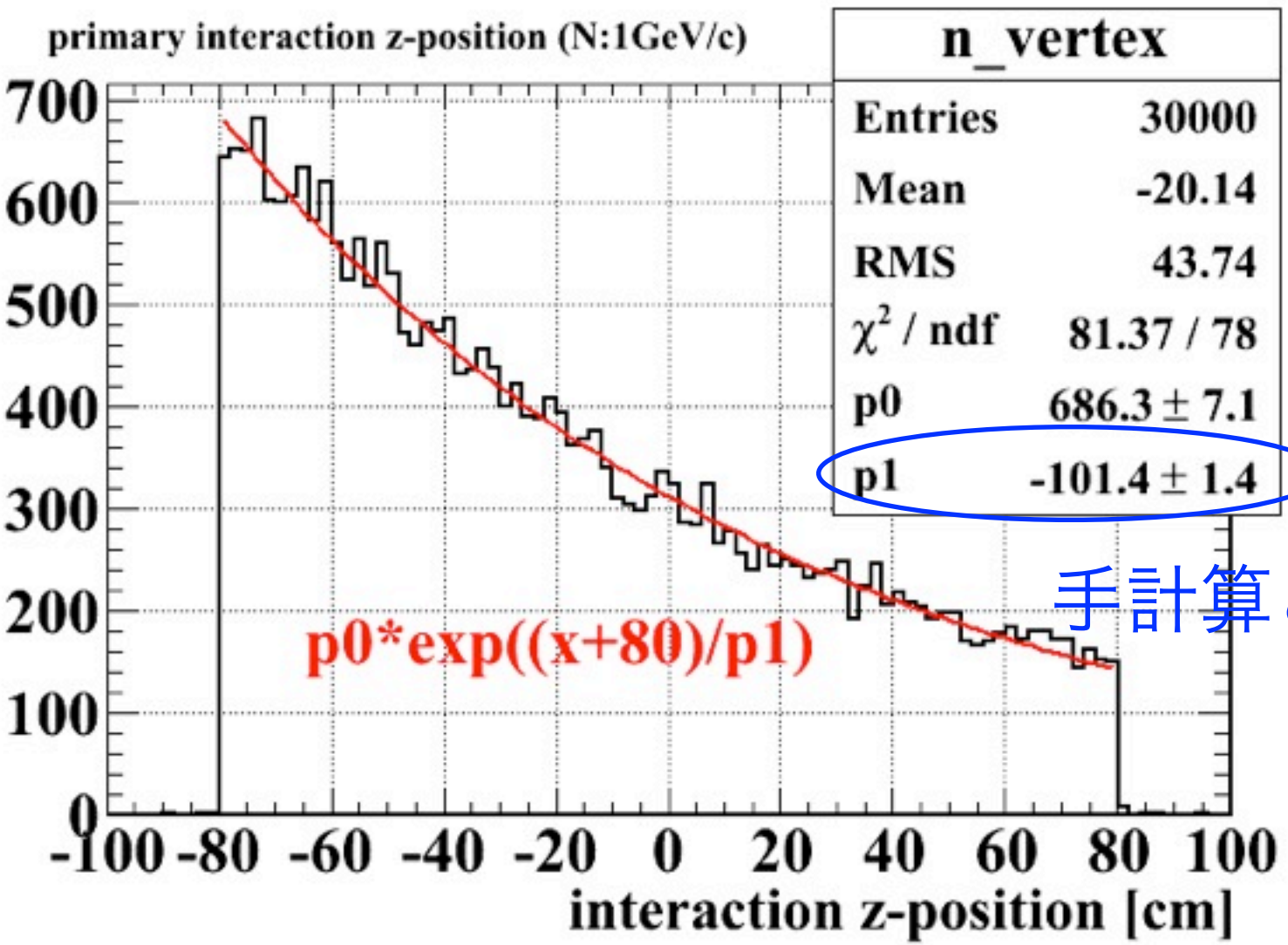
- Plab = 1GeV/c → σelastic ~ 30mbarn = $30e^{-27}$cm
- 酸素原子核内のpとも反応すると考え、
  - # of proton/cm^3 = 1.00[g/cm^3] / 18.02[g/mol] × 10 protons/nucleus × $6.02e^{23}$ = $3.34e^{23}$
- 1cmでの反応確率 = $3.34e^{23}$ * $30e^{-27}$ ~ 0.01
- 平均自由工程 ~ 100 cm

MC study

- neutron の primary interaction point を拾ってくる。
- そのうち、z-position [cm] をプロットし、expでフィット。mean free path を求める。

primary interaction vertex-z

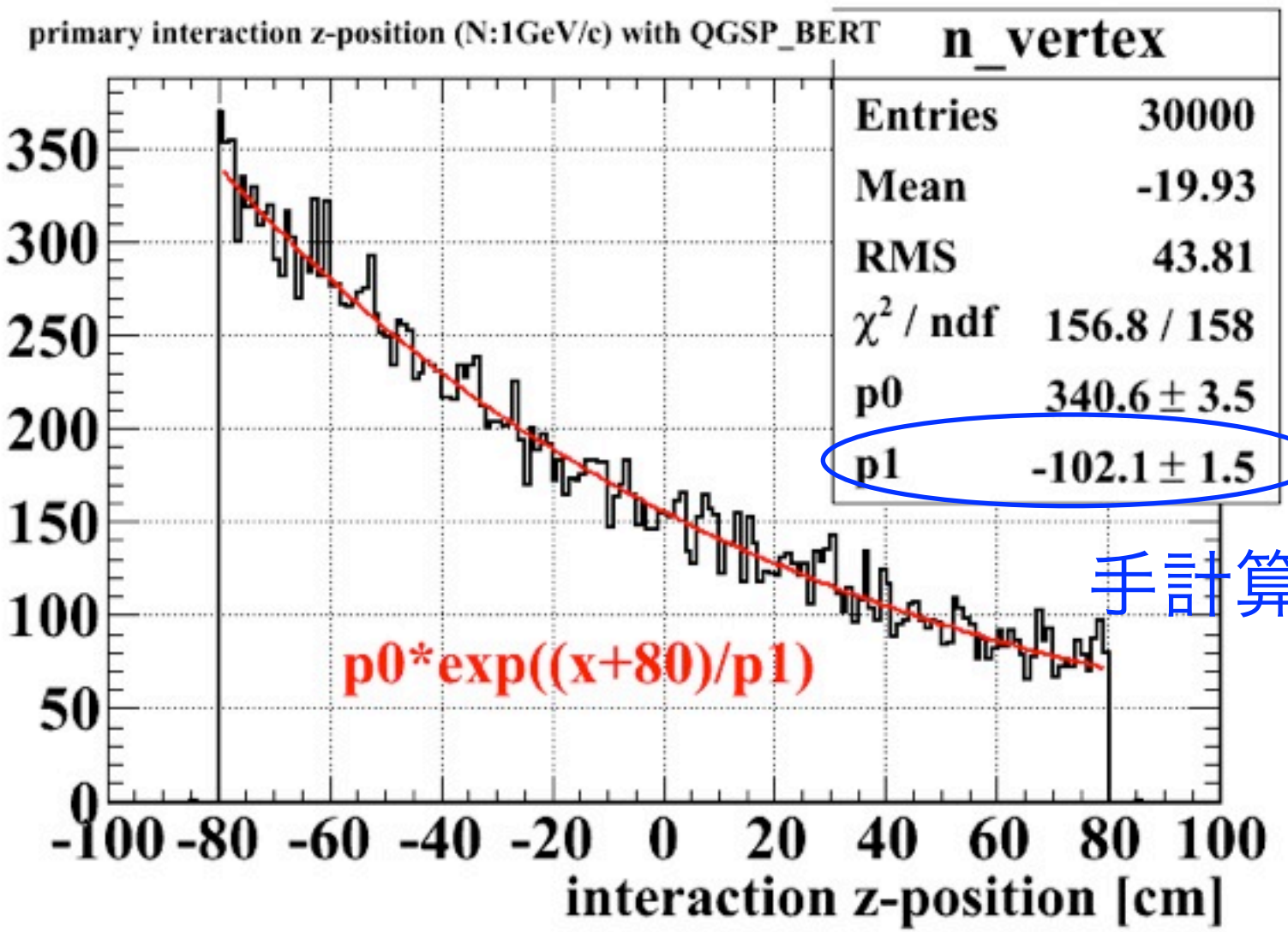
custom physics list



手計算とほぼ一致

primary interaction vertex-z

QGSP_BERT (no cherenkov)



手計算とほぼ一致

Event display

- ある運動量の中性子を打ち込んだ際のイベントディスプレイを確認。
  - とりあえず今は、np の反応で生成される primary particle の情報を書き出すのみ。

Cerenkov threshold

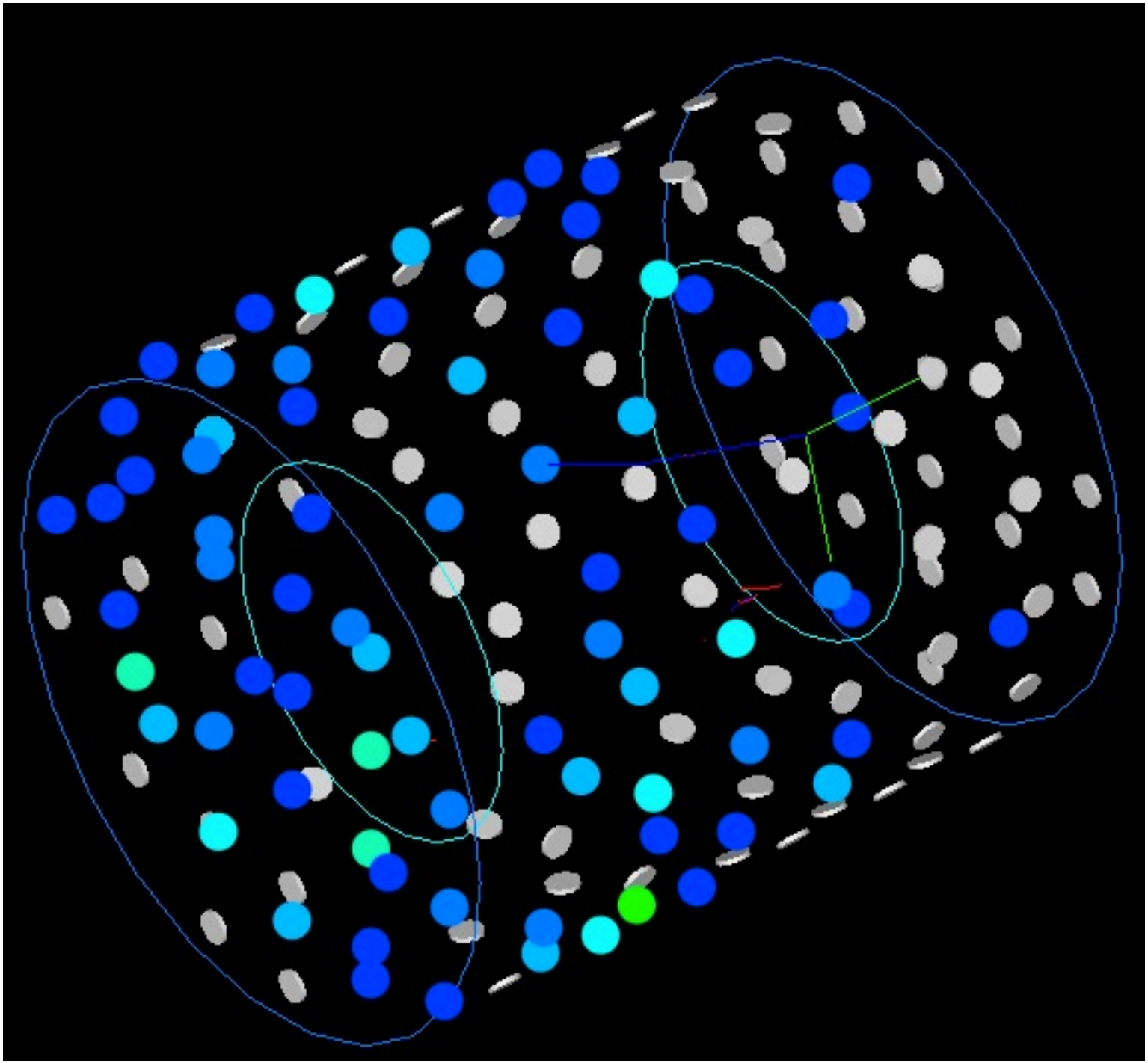
n = 1.33 (water)

particle	Kinetic threshold [MeV]
proton	484
muon	54
pion	72
electron	0.26

Neutron momentum = 1GeV (Kinetic energy = 432MeV)

- 粒子のトラックは以下の場合のみプロット
  - 打ち込んだ中性子
  - 荷電粒子

line color:
init neutron :
green
+ : blue
- : red



Event #1

Generate
photo:10966
pe:2124

Measure
pe:151

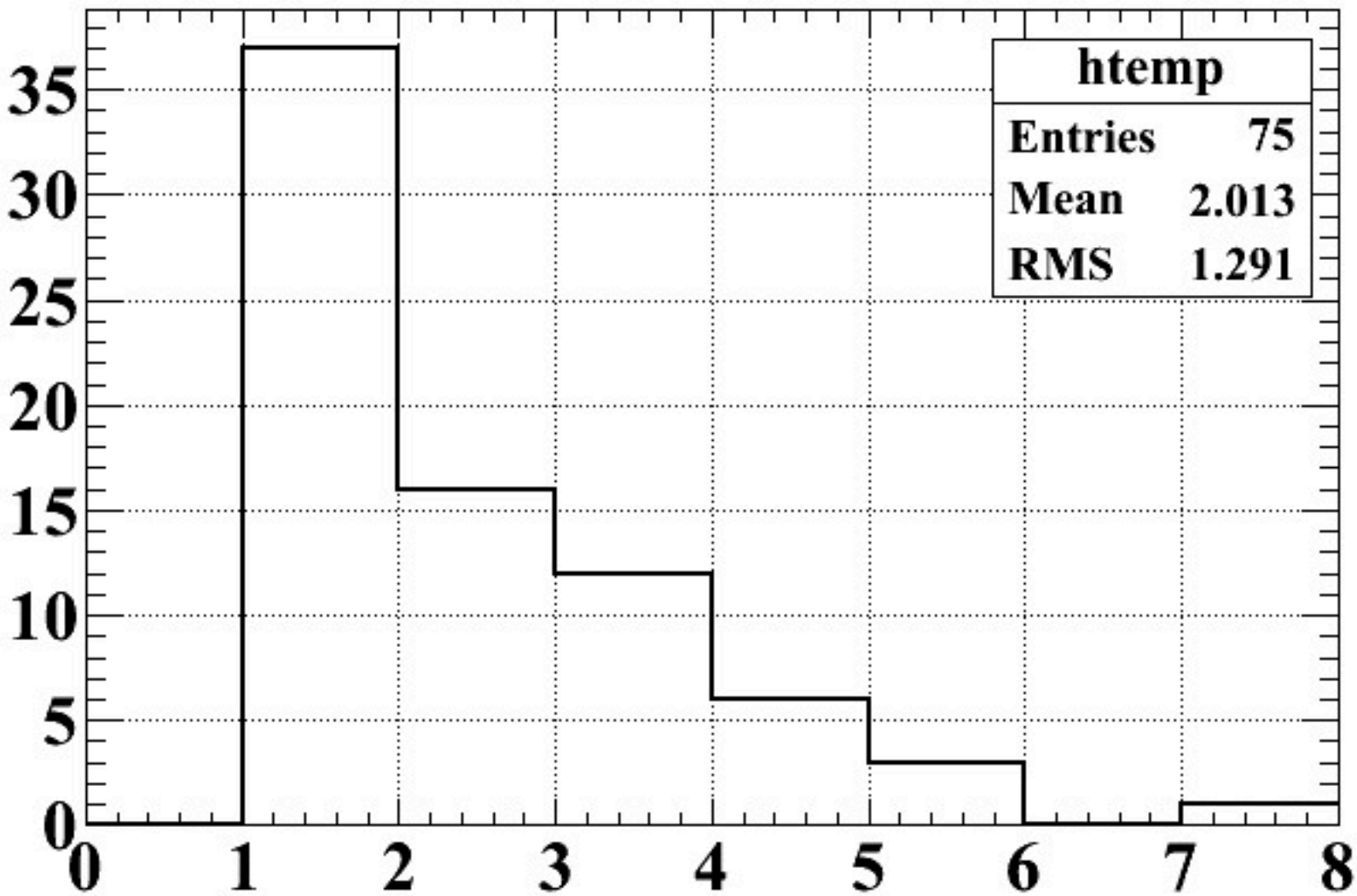
line color:
init neutron :
green
+ : blue
- : red
(not draw
optical
photon)

Generated particle at primary interaction

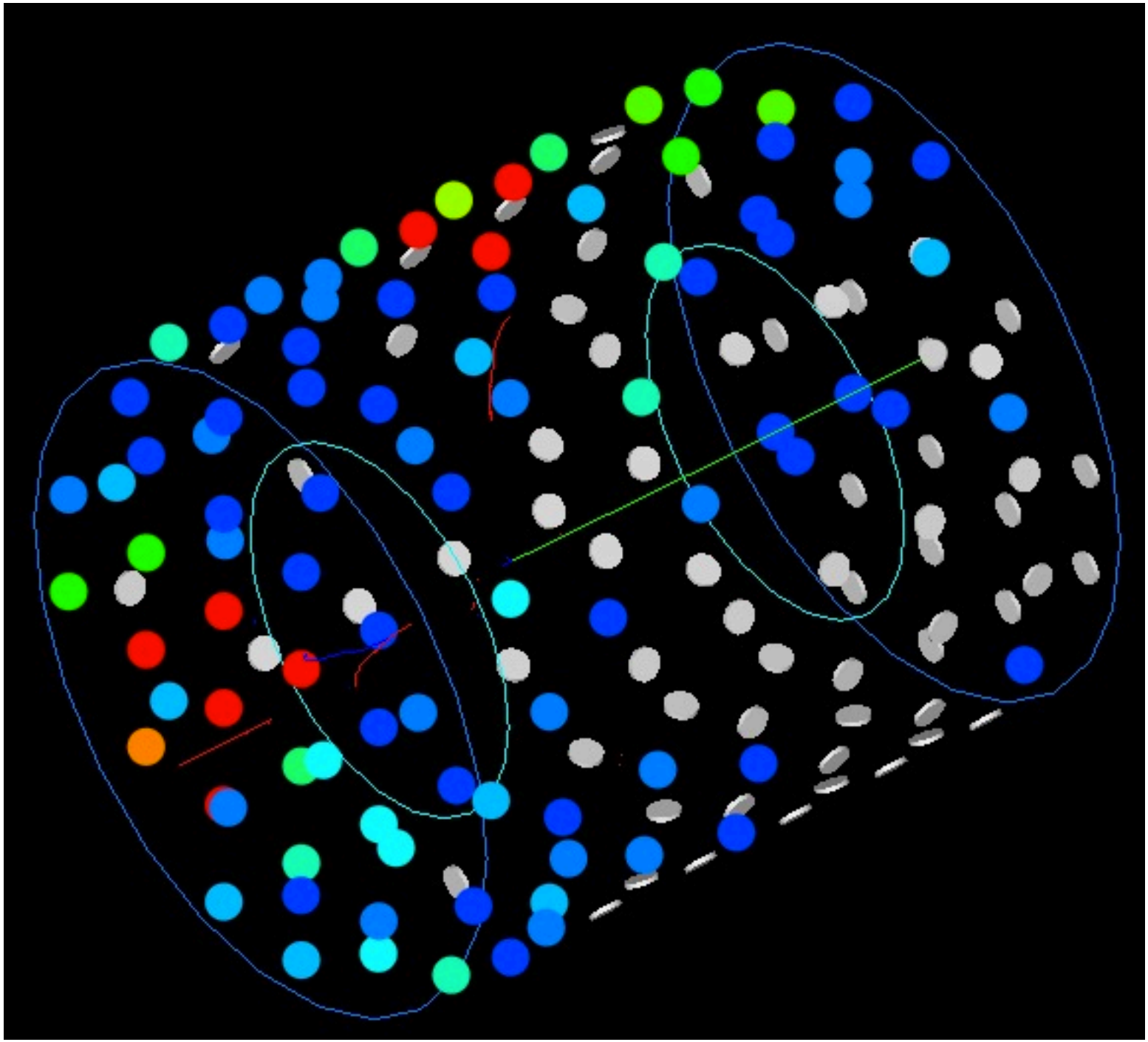
```
Track ID : 2
Parent ID : 1
Particle : proton
Kinetic : 322.778
Vertex point : 0, 0, -582.975
MomentumDirection : -0.462312, -0.0533412, 0.885112

Track ID : 3
Parent ID : 1
Particle : neutron
Kinetic : 54.2085
Vertex point : 385.745, 44.507, -331.192
MomentumDirection : 0.947138, -0.253155, -0.197086

Track ID : 4
Parent ID : 1
Particle : gamma
Kinetic : 52.1991
Vertex point : 385.745, 44.507, -331.192
MomentumDirection : -0.270887, -0.226247, 0.935646
```

unit
energy : MeV
length : mm

Measured p.e. distribution



p.e. at each PMT



Event #2

Generate
photo:37588
pe:7166

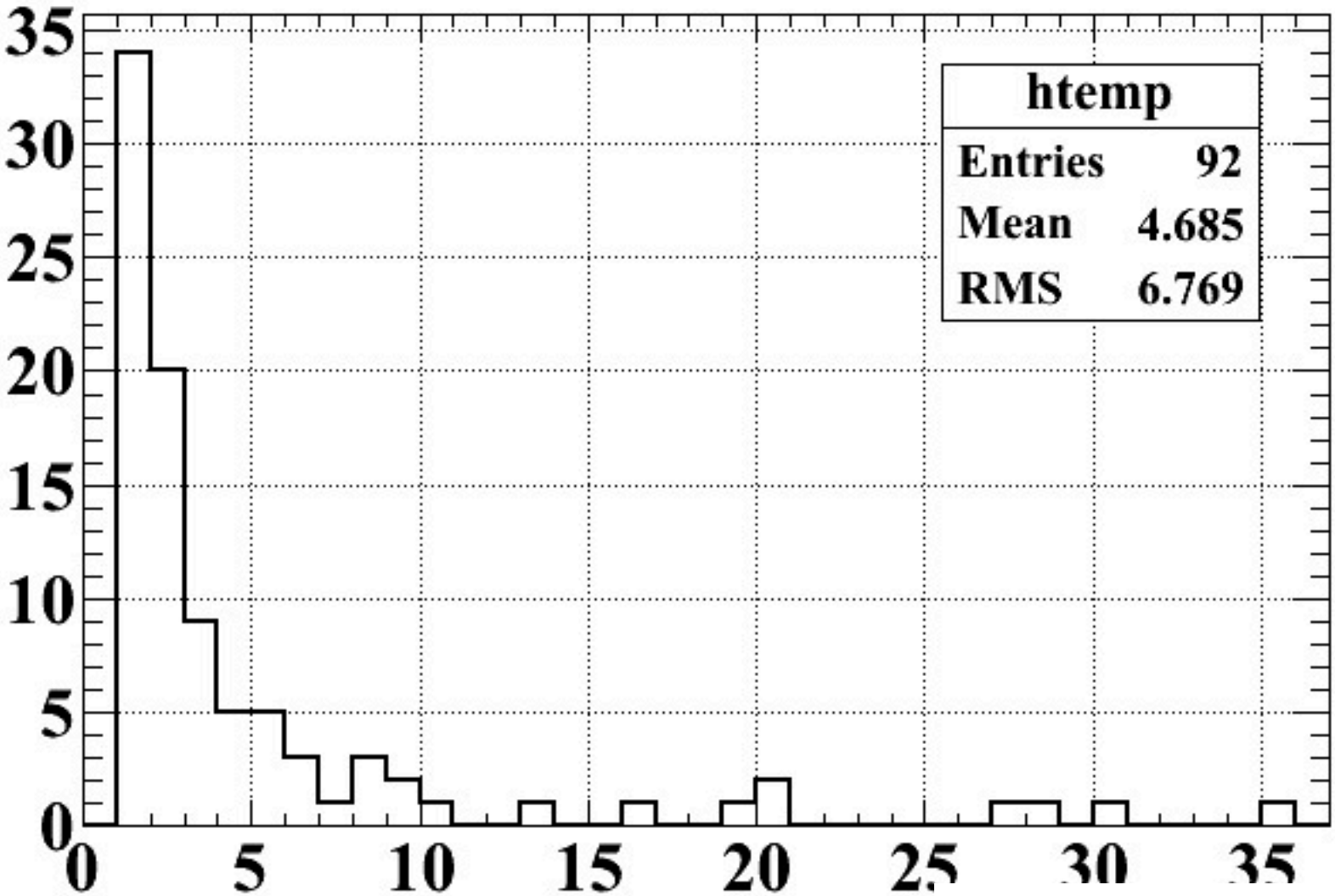
Measure
pe:431

```
Track ID : 2
Parent ID : 1
Particle : proton
Kinetic : 52.9789
Vertex point : 11.5177, 18.0577, 175.857
Direction : 0.0871377, 0.175284, 0.980654

Track ID : 3
Parent ID : 1
Particle : pi0
Kinetic : 37.1904
Vertex point : 11.5177, 18.0577, 175.857
Direction : -0.335239, 0.277291, 0.900402

Track ID : 4
Parent ID : 1
Particle : neutron
Kinetic : 0.001
Vertex point : 11.5177, 18.0577, 175.857
Direction : 0.952794, -0.173303, 0.249299

Track ID : 5
Parent ID : 1
Particle : neutron
Kinetic : 0.001
Vertex point : 11.5177, 18.0577, 175.857
Direction : 0.497736, -0.863473, 0.0816847

Track ID : 6
Parent ID : 1
Particle : proton
Kinetic : 0.967901
Vertex point : 11.5177, 18.0577, 175.857
Direction : 0.825284, 0.547878, -0.136879

Track ID : 7
Parent ID : 1
Particle : proton
Kinetic : 7.48173
Vertex point : 11.5177, 18.0577, 175.857
Direction : -0.814727, 0.571973, -0.0952188
```

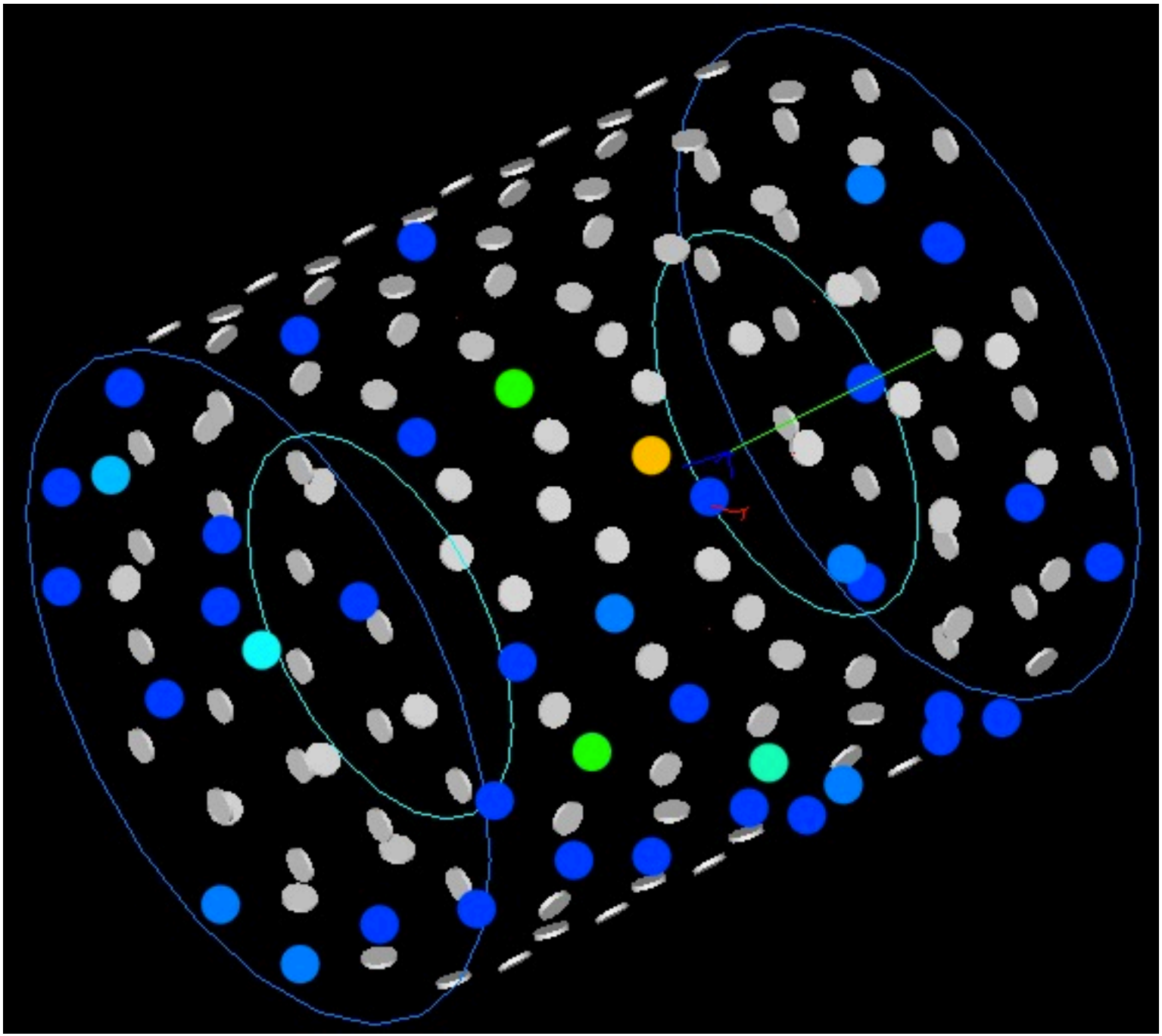
```
Track ID : 8
Parent ID : 1
Particle : neutron
Kinetic : 1.79956
Vertex point : 11.5177, 18.0577, 175.857
Direction : -0.981658, -0.190477, -0.00814378

Track ID : 9
Parent ID : 1
Particle : proton
Kinetic : 36.4618
Vertex point : 11.5177, 18.0577, 175.857
Direction : -0.846534, 0.490187, 0.207597

Track ID : 10
Parent ID : 1
Particle : neutron
Kinetic : 4.04254
Vertex point : 11.5177, 18.0577, 175.857
Direction : 0.136549, -0.249167, 0.958786
```

```
Track ID : 11
Parent ID : 1
Particle : neutron
Kinetic : 14.5946
Vertex point : 11.5177, 18.0577, 175.857
Direction : -0.896401, 0.0481301,
-0.440623

Track ID : 12
Parent ID : 1
Particle : neutron
Kinetic : 33.944
Vertex point : 11.5177, 18.0577, 175.857
Direction : -0.141699, -0.712929, 0.686771

Track ID : 13
Parent ID : 1
Particle : triton
Kinetic : 9.14999
Vertex point : 11.5177, 18.0577, 175.857
Direction : -0.25377, -0.941977, 0.219728

Track ID : 14
Parent ID : 1
Particle : neutron
Kinetic : 66.5874
Vertex point : 11.5177, 18.0577, 175.857
Direction : -0.114754, 0.150802, 0.981881
```

Measured p.e. distribution



p.e. at each PMT



Event#3

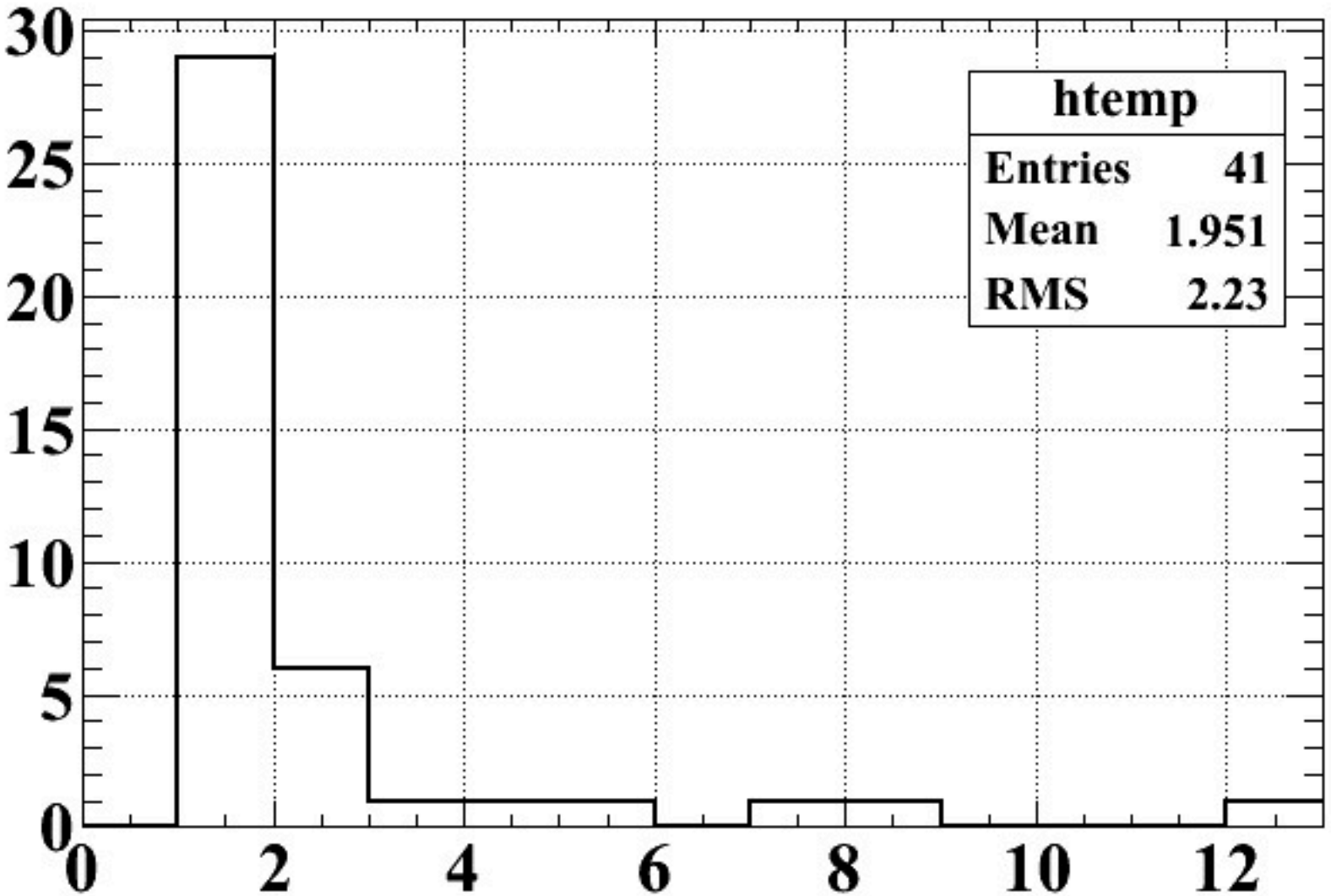
Generate
photo:5816
pe:1131

Measure
pe:80

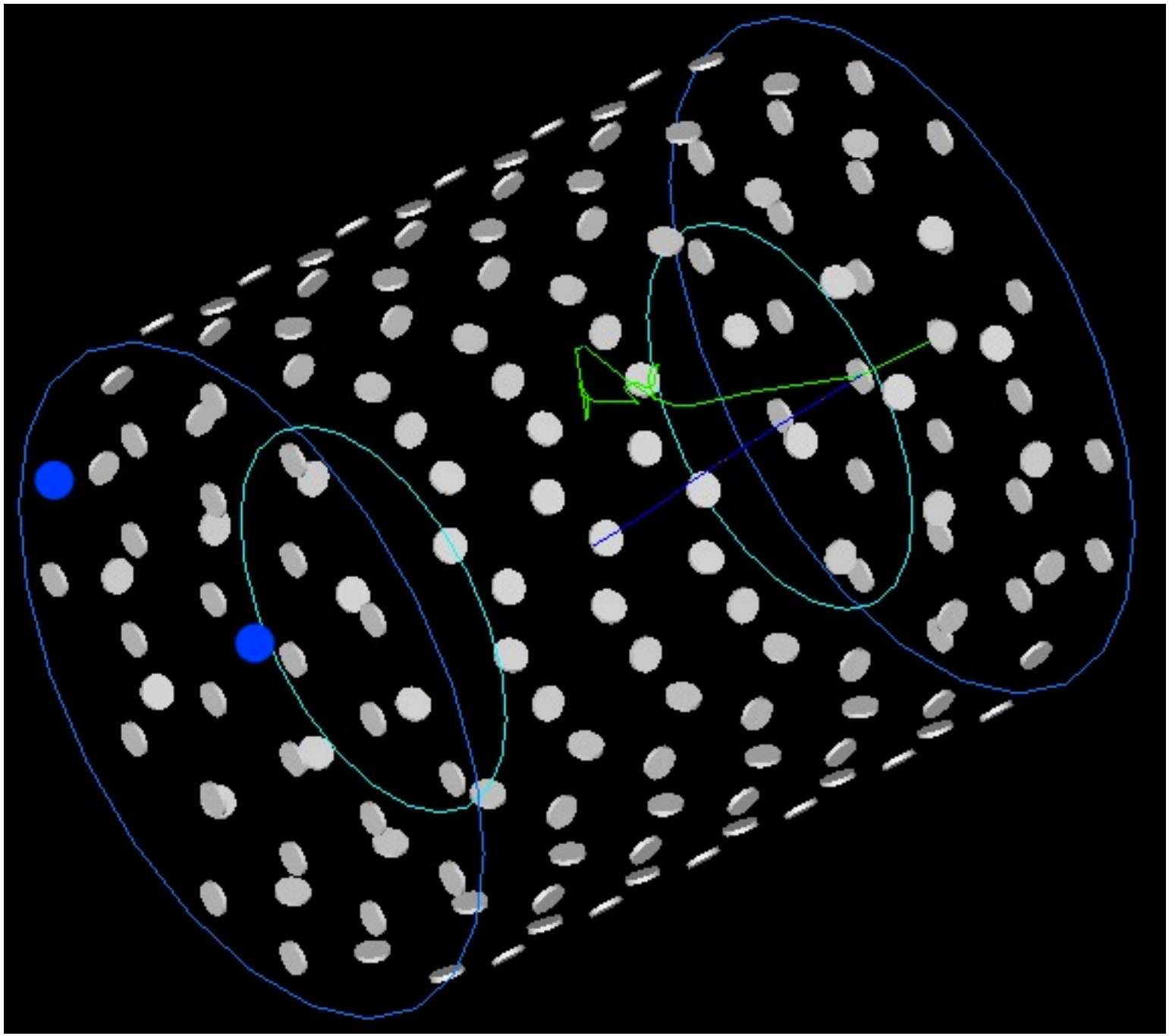
```
Track ID : 2
Parent ID : 1
Particle : proton
Kinetic : 185.945
Vertex point : 0, 0, -361.49
Direction : 0.275681, 0.381438, 0.882329

Track ID : 3
Parent ID : 1
Particle : proton
Kinetic : 87.1873
Vertex point : 0, 0, -361.49
Direction : 0.705718, -0.478693, 0.522317

Track ID : 4
Parent ID : 1
Particle : proton
Kinetic : 0.001
Vertex point : 0, 0, -361.49
Direction : 0.642735, 0.124889, 0.75584

Track ID : 5
Parent ID : 1
Particle : proton
Kinetic : 0.001
Vertex point : 0, 0, -361.49
Direction : 0.178369, 0.830156, 0.528228

Track ID : 6
Parent ID : 1
Particle : proton
Kinetic : 0.845548
Vertex point : 0, 0, -361.49
Direction : 0.610541, -0.659313, 0.438801

Track ID : 7
Parent ID : 1
Particle : proton
Kinetic : 66.1846
Vertex point : 0, 0, -361.49
Direction : -0.358441, -0.587702, 0.725345

Track ID : 8
Parent ID : 1
Particle : proton
Kinetic : 33.2073
Vertex point : 0, 0, -361.49
Direction : 0.767921, -0.384865, -0.512032

Track ID : 9
Parent ID : 1
Particle : neutron
Kinetic : 37.4457
Vertex point : 0, 0, -361.49
Direction : -0.32382, -0.796162, -0.511142
```

```
Track ID : 10
Parent ID : 1
Particle : neutron
Kinetic : 6.83185
Vertex point : 0, 0, -361.49
MomentumDirection : 0.225218, -0.449959, 0.864184

Track ID : 11
Parent ID : 1
Particle : neutron
Kinetic : 5.44043
Vertex point : 0, 0, -361.49
MomentumDirection : -0.274741, -0.167059, 0.946894
```

Measured p.e. distribution



p.e. at each PMT



Event#4

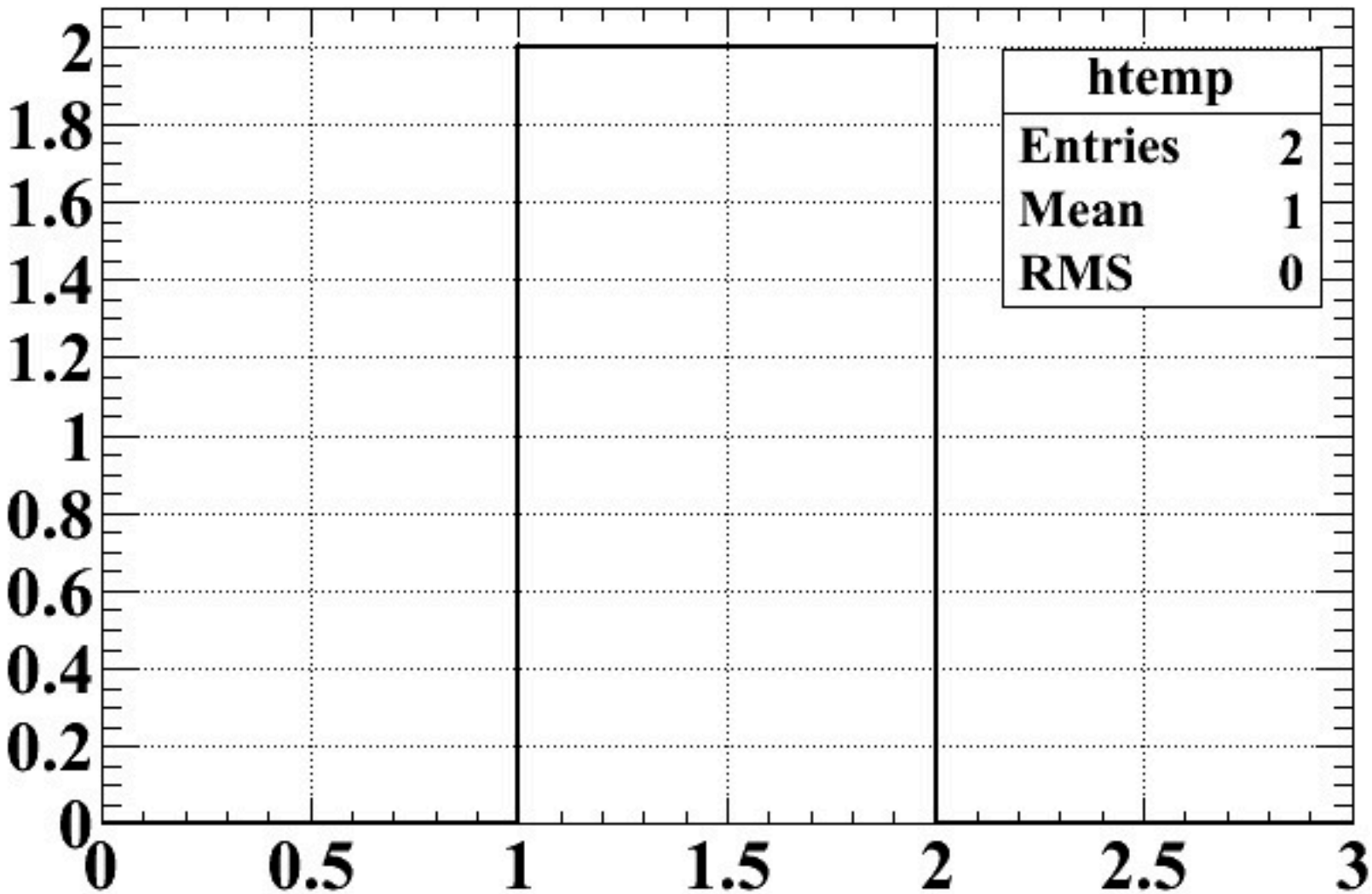
Generate
photo:428
pe:93

Measure
pe:2

```
Track ID : 2
Parent ID : 1
Particle : proton
Kinetic : 404.569
Vertex point : 0, 0, -701.145
Direction : 0.197447, 0.119514, 0.973001

Track ID : 3
Parent ID : 1
Particle : O16[0.0]
Kinetic : 0.261252
Vertex point : -332.321, -201.268, -558.236
Direction : -0.0094579, -0.89639, -0.443166

Track ID : 4
Parent ID : 1
Particle : O16[0.0]
Kinetic : 0.312313
Vertex point : -363.341, -205.951, -531.366
Direction : -0.102352, -0.993365, 0.0524437

Track ID : 5
Parent ID : 1
Particle : proton
Kinetic : 4.14481
Vertex point : -387.287, -195.676, -510.108
Direction : 0.343911, 0.174371, 0.92267

Track ID : 6
Parent ID : 1
Particle : proton
Kinetic : 19.0442
Vertex point : -546.65, -143.024, -465.327
Direction : -0.667956, 0.673116, 0.317411

Track ID : 7
Parent ID : 1
Particle : O16[0.0]
Kinetic : 0.153158
Vertex point : -579.008, -171.984, -471.154
Direction : -0.91545, 0.40038, 0.0405883

Track ID : 8
Parent ID : 1
Particle : O16[0.0]
Kinetic : 0.76476
Vertex point : -586.831, -363.936, -503.713
Direction : 0.204392, -0.969625, 0.134358

Track ID : 9
Parent ID : 1
Particle : proton
Kinetic : 1.78533
Vertex point : -606.562, -328.97, -523.701
Direction : -0.336723, 0.243055, -0.909693
```

```
Track ID : 10
Parent ID : 1
Particle : proton
Kinetic : 1.07882
Vertex point : -614.798, -295.929, -510.383
MomentumDirection : 0.122847, 0.950984, 0.283792

Track ID : 11
Parent ID : 1
Particle : proton
Kinetic : 0.224456
Vertex point : -589.71, -303.778, -494.77
MomentumDirection : 0.408806, -0.25026, 0.877638

Track ID : 12
Parent ID : 1
Particle : gamma
Kinetic : 6.37541
Vertex point : -434.611, -249.308, -549.162
MomentumDirection : -0.742464, -0.656974, 0.130887

Track ID : 13
Parent ID : 1
Particle : gamma
Kinetic : 1.62459
Vertex point : -434.611, -249.308, -549.162
MomentumDirection : 0.0504574, 0.519237, -0.853139
```

Measured p.e. distribution

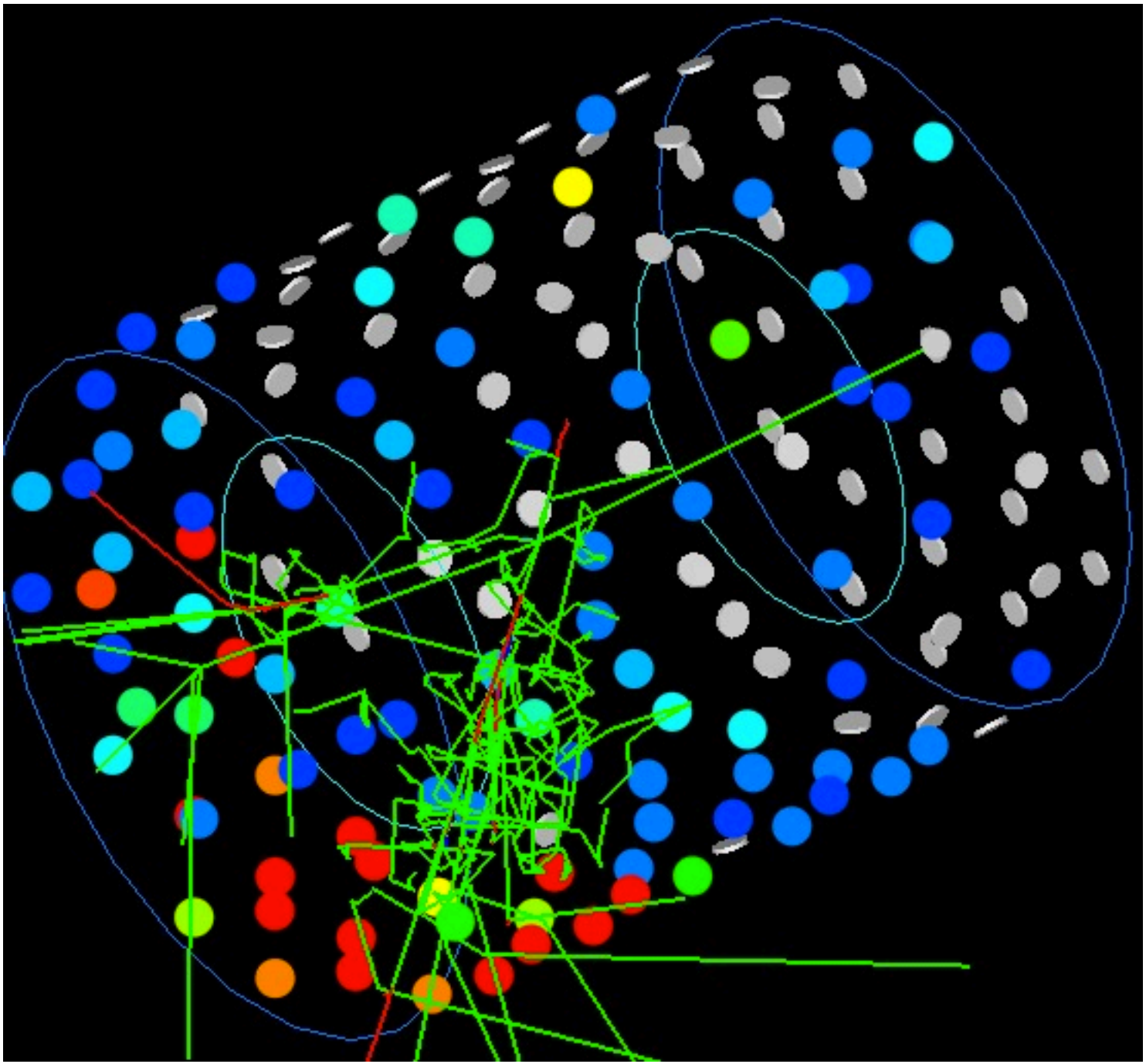


p.e. at each PMT

Neutron momentum = 1.5GeV (Kinetic energy = 830MeV)

- 先ほどのトラック描写では、生成された中性粒子が見えなかった
- 今後は”optical photon”以外の粒子のトラックを描写するように変更。

line color:
0 : green
+ : blue
- : red



Event#1

Generate
photo:67598
pe:12860

Measure
pe:760

line color:
0 : green
+ : blue
- : red

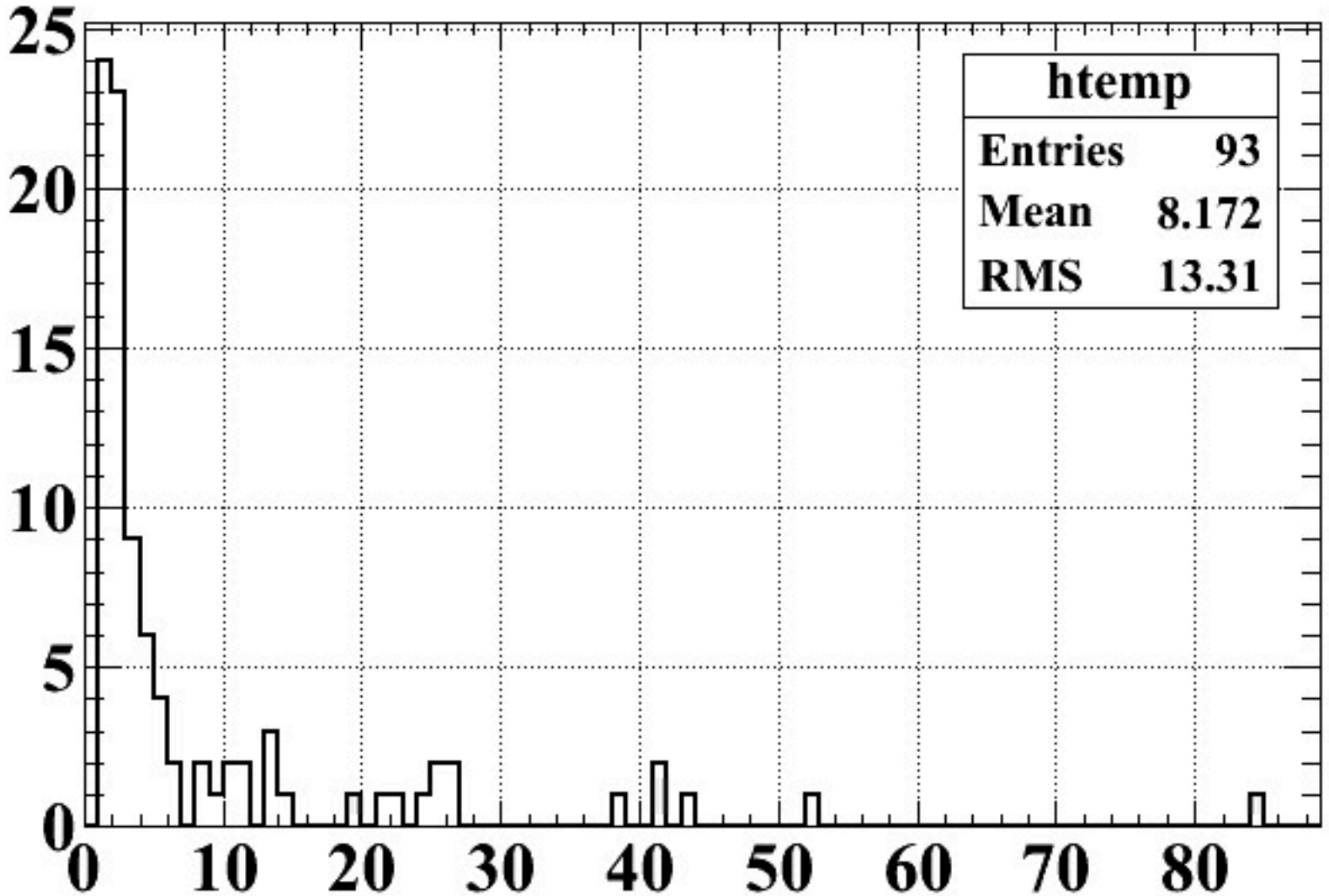
(not draw
optical
photon)

Generated particles at primary interaction

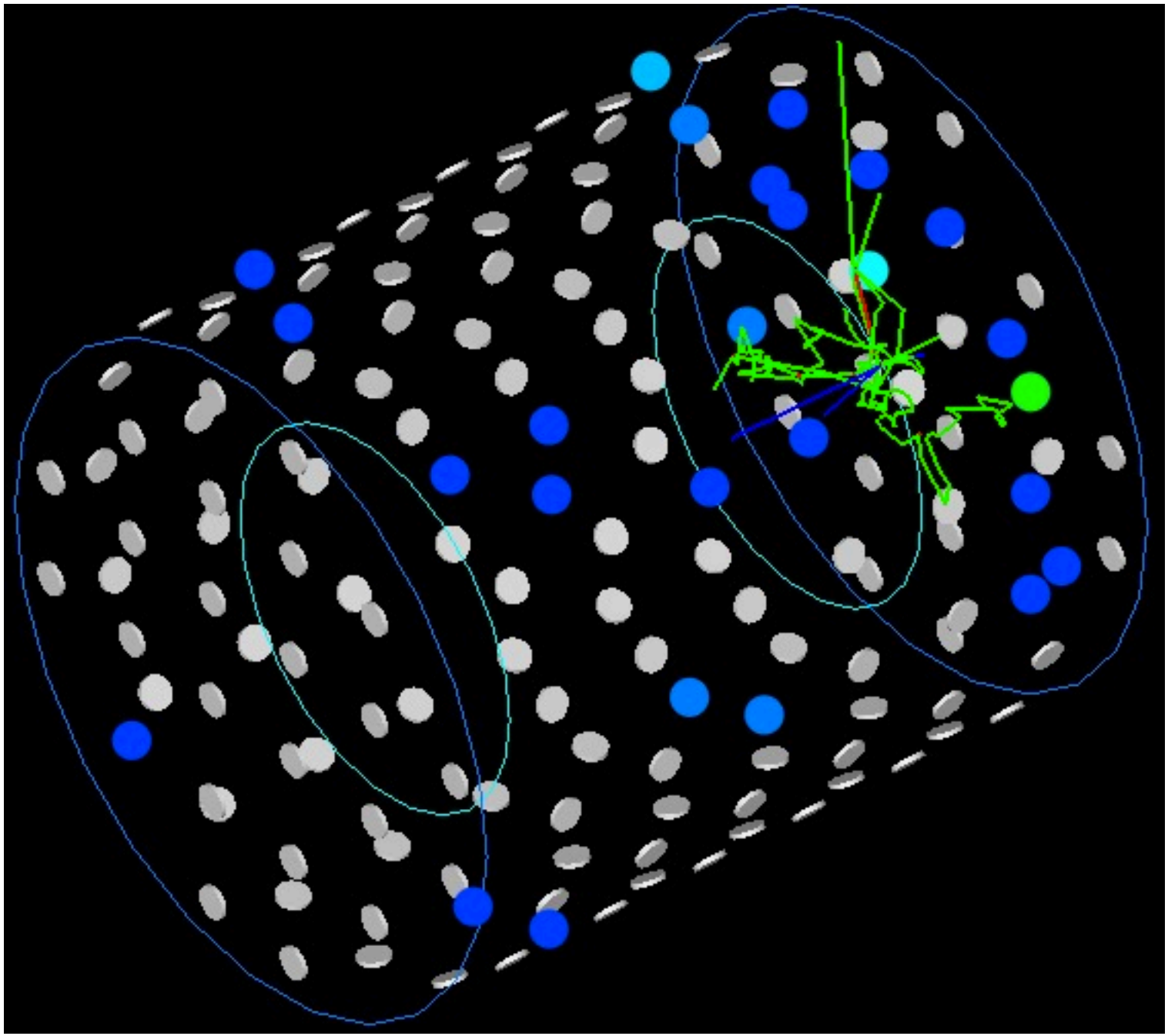
```
Track ID : 2
Parent ID : 1
PID : neutron
Kinetic : 151.27
Vertex : 0, 0, 59.4523
Direction : -0.313766, 0.390934, 0.865287

Track ID : 3
Parent ID : 1
PID : pi0
Kinetic : 135.706
Vertex : 0, 0, 59.4523
Direction : 0.320796, -0.66451, 0.674919

Track ID : 4
Parent ID : 1
PID : proton
Kinetic : 6.15737
Vertex : 0, 0, 59.4523
Direction : -0.0961869, -0.570298, 0.815787

Track ID : 5
Parent ID : 1
PID : proton
Kinetic : 0.001
Vertex : 0, 0, 59.4523
Direction : -0.0115083, 0.454856, 0.89049

Track ID : 6
Parent ID : 1
PID : proton
Kinetic : 19.8468
Vertex : 0, 0, 59.4523
Direction : 0.543388, -0.635774, -0.548198

Track ID : 7
Parent ID : 1
PID : neutron
Kinetic : 13.706
Vertex : 0, 0, 59.4523
Direction : -0.144942, -0.881406, 0.449573

Track ID : 8
Parent ID : 1
PID : proton
Kinetic : 73.4887
Vertex : 0, 0, 59.4523
Direction : -0.959374, -0.220603, 0.175884

Track ID : 9
Parent ID : 1
PID : neutron
Kinetic : 52.4059
Vertex : 0, 0, 59.4523
Direction : -0.494684, -0.514726, -0.700247
```

```
Track ID : 11
Parent ID : 1
PID : neutron
Kinetic : 28.2943
Vertex : 0, 0, 59.4523
Direction : -0.255686, 0.900054, -0.352885

Track ID : 12
Parent ID : 1
PID : neutron
Kinetic : 143.664
Vertex : 0, 0, 59.4523
Direction : -0.139249, 0.000215168, 0.990257
```

measured p.e. distribution



p.e. at each PMT



Event#2

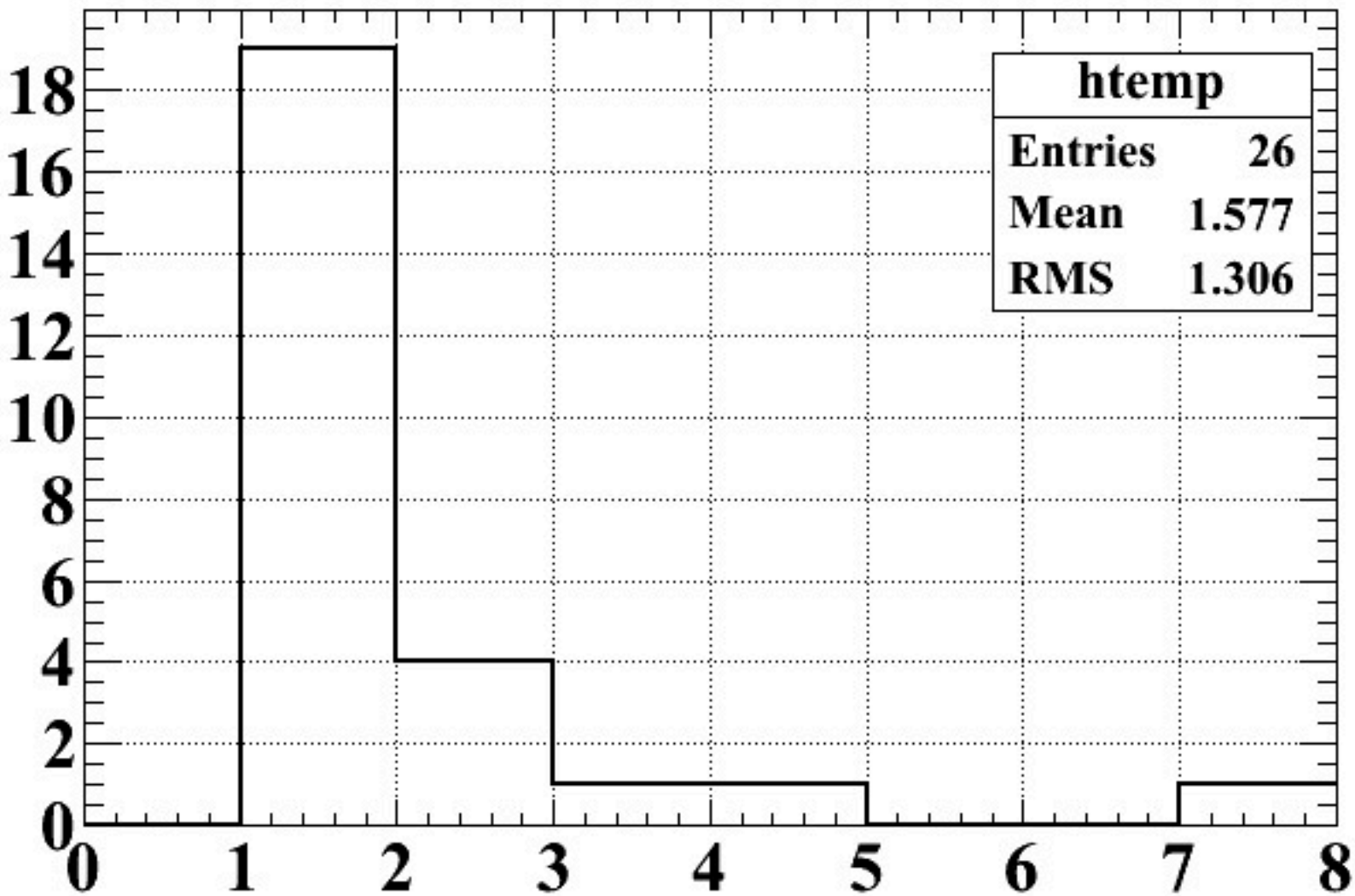
Generate
photo:2980
pe:582

Measure
pe:41

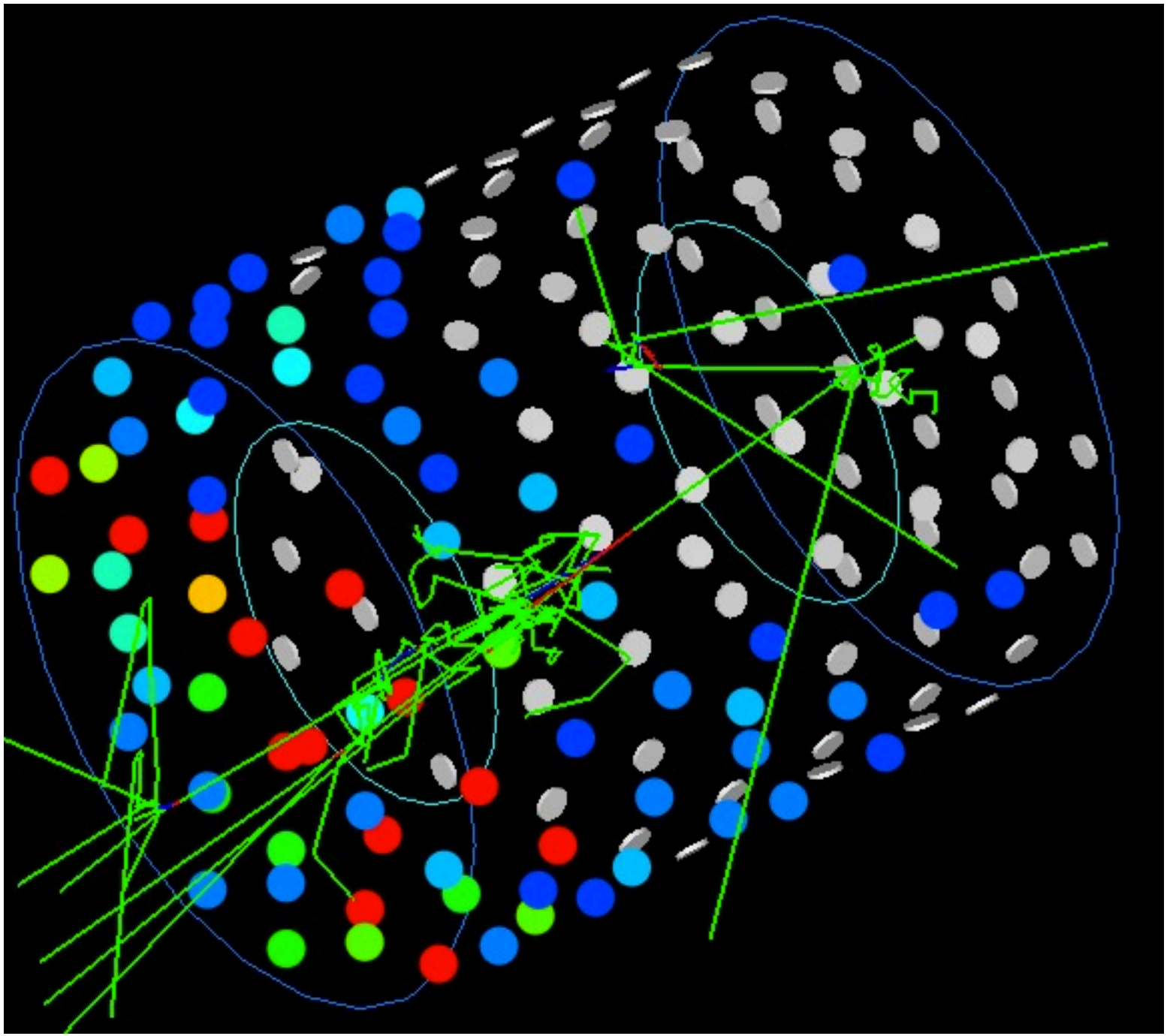
line color:
0 : green
+ : blue
- : red

```
Track ID : 2
Parent ID : 1
PID : proton
Kinetic : 261.244
Vertex : 0, 0, -722.592
Direction : 0.122089, 0.136995, 0.983019

Track ID : 3
Parent ID : 1
PID : proton
Kinetic : 152.666
Vertex : 0, 0, -722.592
Direction : 0.158045, -0.175678, 0.971678

Track ID : 4
Parent ID : 1
PID : pi-
Kinetic : 78.5577
Vertex : 0, 0, -722.592
Direction : -0.527092, 0.840408, -0.126047

Track ID : 5
Parent ID : 1
PID : neutron
Kinetic : 0.001
Vertex : 0, 0, -722.592
Direction : 0.561363, -0.131955, 0.816982

Track ID : 6
Parent ID : 1
PID : proton
Kinetic : 0.742138
Vertex : 0, 0, -722.592
Direction : 0.836523, -0.422962, 0.348327

Track ID : 7
Parent ID : 1
PID : neutron
Kinetic : 55.3292
Vertex : 0, 0, -722.592
Direction : 0.770972, 0.628548, -0.102611

Track ID : 8
Parent ID : 1
PID : neutron
Kinetic : 92.1725
Vertex : 0, 0, -722.592
Direction : -0.750062, 0.616603, -0.239181

Track ID : 9
Parent ID : 1
PID : proton
Kinetic : 22.6536
Vertex : 0, 0, -722.592
Direction : 0.973006, 0.184797, 0.138234

Track ID : 10
Parent ID : 1
PID : proton
Kinetic : 5.16477
Vertex : 0, 0, -722.592
Direction : 0.941306, 0.314018, 0.123836
```

measured p.e. distribution



p.e. at each PMT



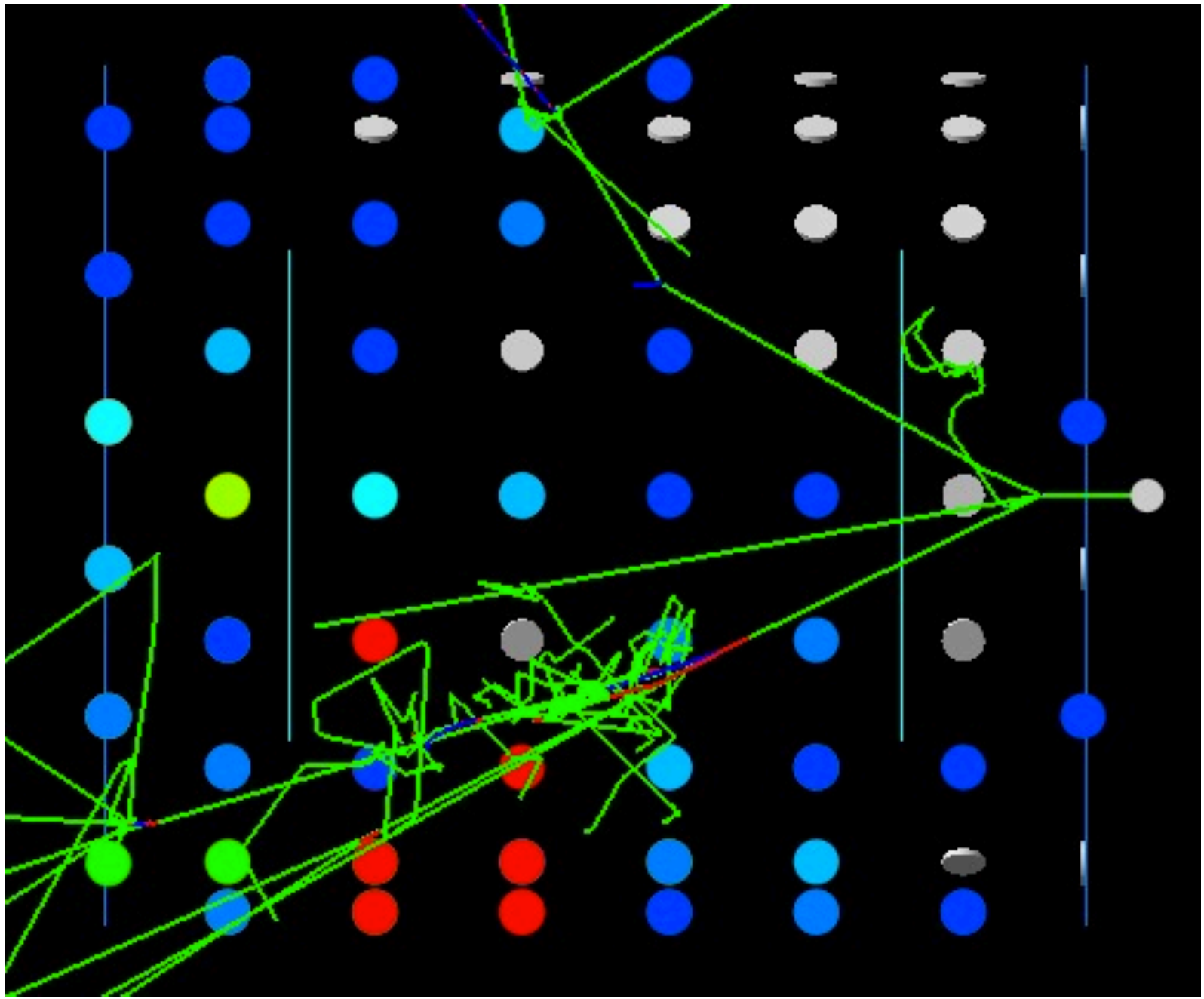
Event#3

Generate
photo:39326
pe:7575

Measure
pe:523

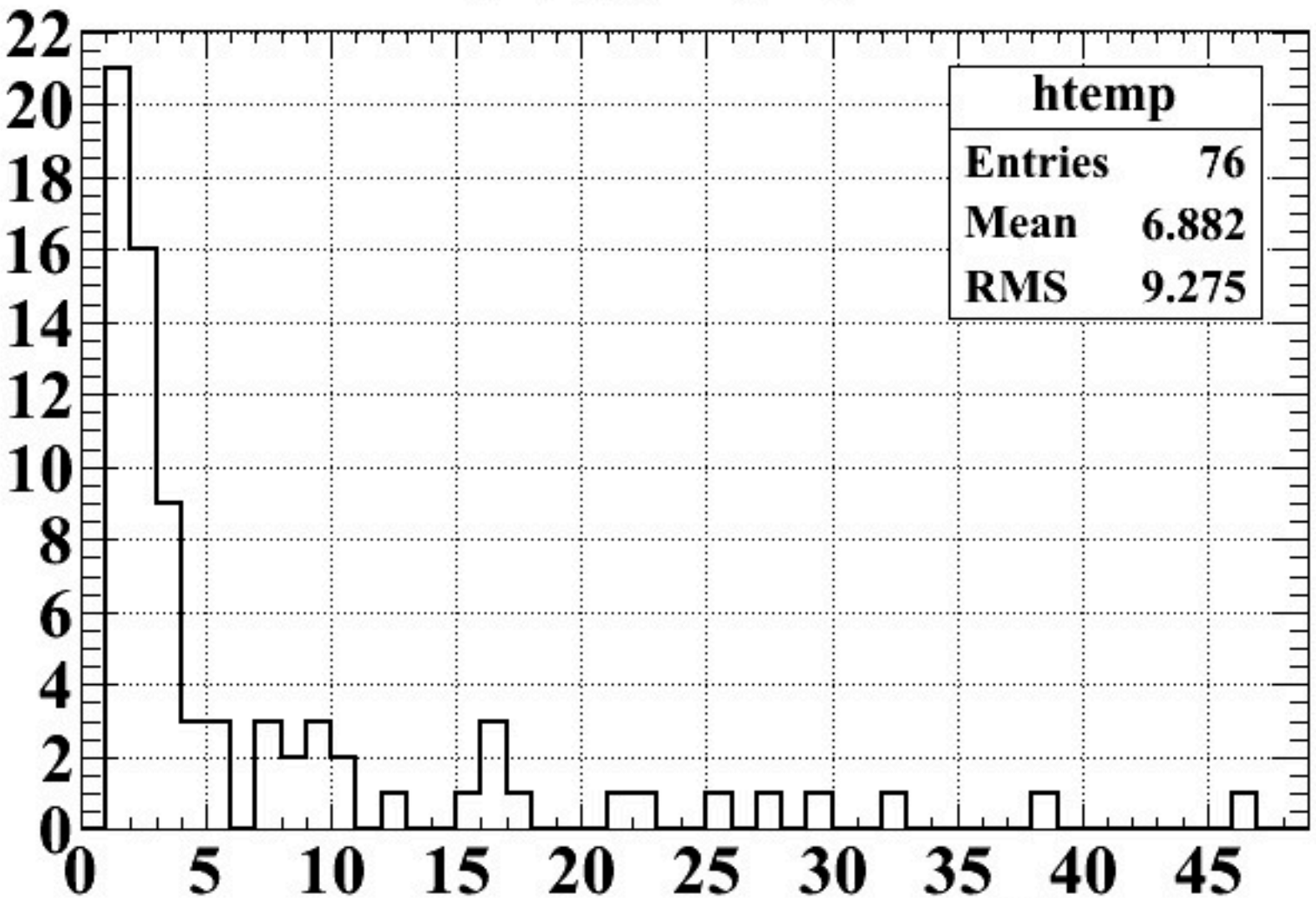
line color:
0 : green
+ : blue
- : red

横から見てみた

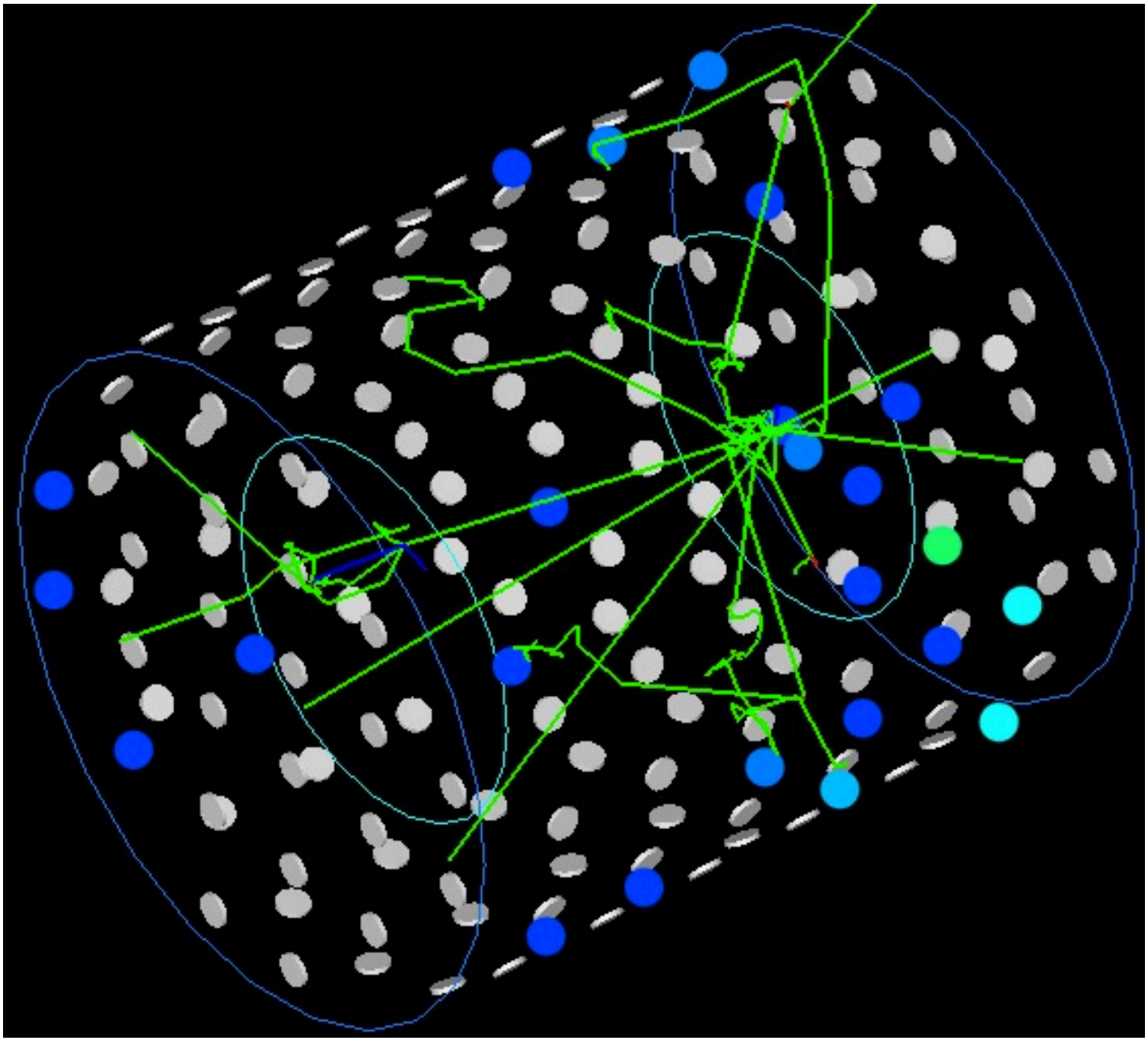


```
Track ID : 2
Parent ID : 1
PID : neutron
Kinetic : 235.932
Vertex : 0, 0, -724.734
Direction : 0.0692397, 0.420471, 0.90466

Track ID : 3
Parent ID : 1
PID : pi0
Kinetic : 280.689
Vertex : 0, 0, -724.734
Direction : -0.0748154, -0.407223, 0.910259

Track ID : 4
Parent ID : 1
PID : proton
Kinetic : 0.001
Vertex : 0, 0, -724.734
Direction : 0.771245, 0.434623, -0.465063

Track ID : 5
Parent ID : 1
PID : proton
Kinetic : 0.590775
Vertex : 0, 0, -724.734
Direction : 0.38279, 0.186203, 0.904876

Track ID : 6
Parent ID : 1
PID : proton
Kinetic : 25.2256
Vertex : 0, 0, -724.734
Direction : -0.200128, 0.902379, 0.381656

Track ID : 7
Parent ID : 1
PID : neutron
Kinetic : 96.8748
Vertex : 0, 0, -724.734
Direction : -0.220562, -0.32538, 0.9195
```

measured p.e. distribution



p.e. at each PMT



Event#4

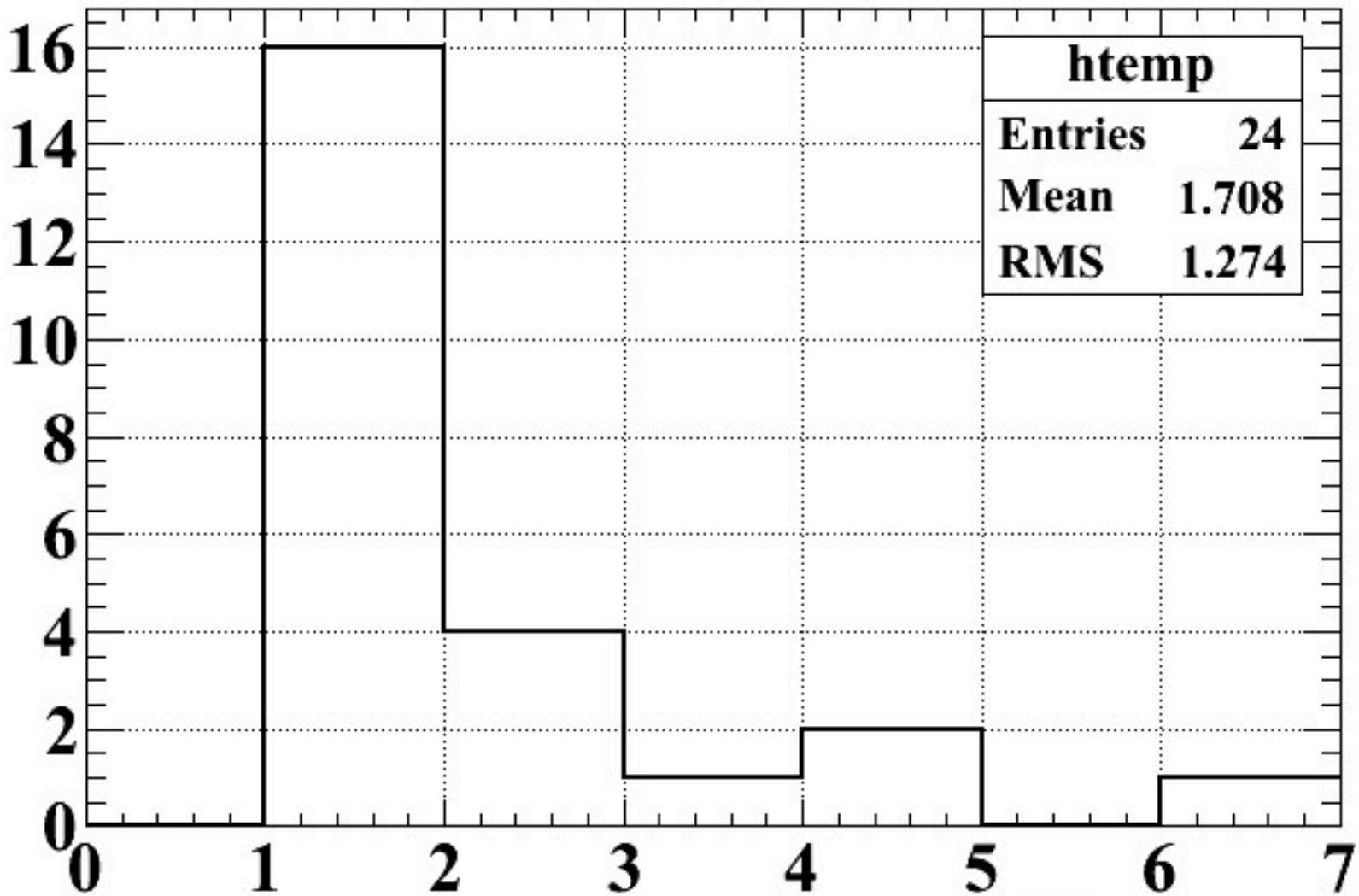
Generate
photo:3072
pe:567

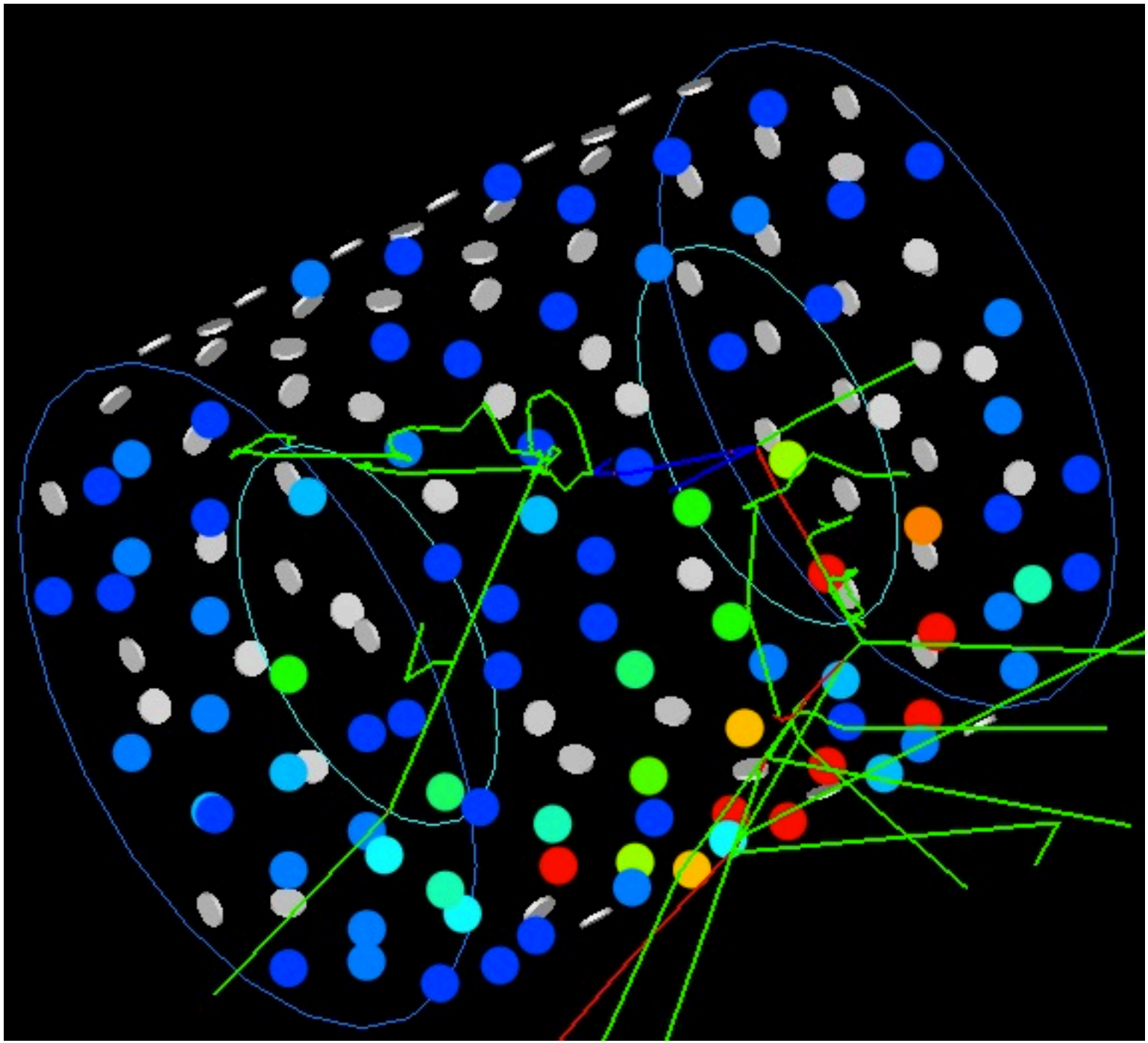
Measure
pe:41

```
Track ID : 2
Parent ID : 1
PID : neutron
Kinetic : 36.9458
Vertex : 0, 0, -484.029
Direction : 0.229128, -0.244313, 0.942237

Track ID : 3
Parent ID : 1
PID : pi0
Kinetic : 99.2655
Vertex : 0, 0, -484.029
Direction : 0.554967, 0.0581892, 0.829835

Track ID : 4
Parent ID : 1
PID : neutron
Kinetic : 0.280486
Vertex : 0, 0, -484.029
Direction : 0.233051, 0.293602, 0.927084

Track ID : 5
Parent ID : 1
PID : proton
Kinetic : 0.001
Vertex : 0, 0, -484.029
Direction : 0.147597, -0.484107, 0.862471

Track ID : 6
Parent ID : 1
PID : neutron
Kinetic : 0.001
Vertex : 0, 0, -484.029
Direction : 0.540776, 0.371676, -0.754598

Track ID : 7
Parent ID : 1
PID : neutron
Kinetic : 3.26378
Vertex : 0, 0, -484.029
Direction : -0.839959, 0.287664, 0.460128

Track ID : 8
Parent ID : 1
PID : proton
Kinetic : 1.37069
Vertex : 0, 0, -484.029
Direction : 0.951095, 0.235826, -0.19951

Track ID : 9
Parent ID : 1
PID : proton
Kinetic : 89.5638
Vertex : 0, 0, -484.029
Direction : -0.725051, 0.239054, -0.645875
```

```
Track ID : 10
Parent ID : 1
PID : neutron
Kinetic : 1.76905
Vertex : 0, 0, -484.029
Direction : 0.304407, -0.940465, 0.151199

Track ID : 11
Parent ID : 1
PID : proton
Kinetic : 6.53246
Vertex : 0, 0, -484.029
Direction : -0.476344, 0.660253, 0.580657

Track ID : 12
Parent ID : 1
PID : proton
Kinetic : 1.1232
Vertex : 0, 0, -484.029
Direction : 0.170173, 0.982743, 0.0725082

Track ID : 13
Parent ID : 1
PID : proton
Kinetic : 8.52159
Vertex : 0, 0, -484.029
Direction : 0.757386, 0.342628, 0.555854

Track ID : 14
Parent ID : 1
PID : neutron
Kinetic : 19.4437
Vertex : 0, 0, -484.029
Direction : -0.0952111, 0.966705, 0.237519

Track ID : 15
Parent ID : 1
PID : neutron
Kinetic : 1.43227
Vertex : 0, 0, -484.029
Direction : -0.266172, 0.123723, 0.955953

Track ID : 16
Parent ID : 1
PID : proton
Kinetic : 5.15745
Vertex : 0, 0, -484.029
Direction : -0.540212, -0.268084, 0.797685

Track ID : 17
Parent ID : 1
PID : deuteron
Kinetic : 17.4438
Vertex : 0, 0, -484.029
Direction : -0.169525, -0.452158, 0.875679

Track ID : 18
Parent ID : 1
PID : neutron
Kinetic : 323.28
Vertex : 0, 0, -484.029
Direction : -0.390358, -0.164494, 0.905849
```

measured p.e. distribution





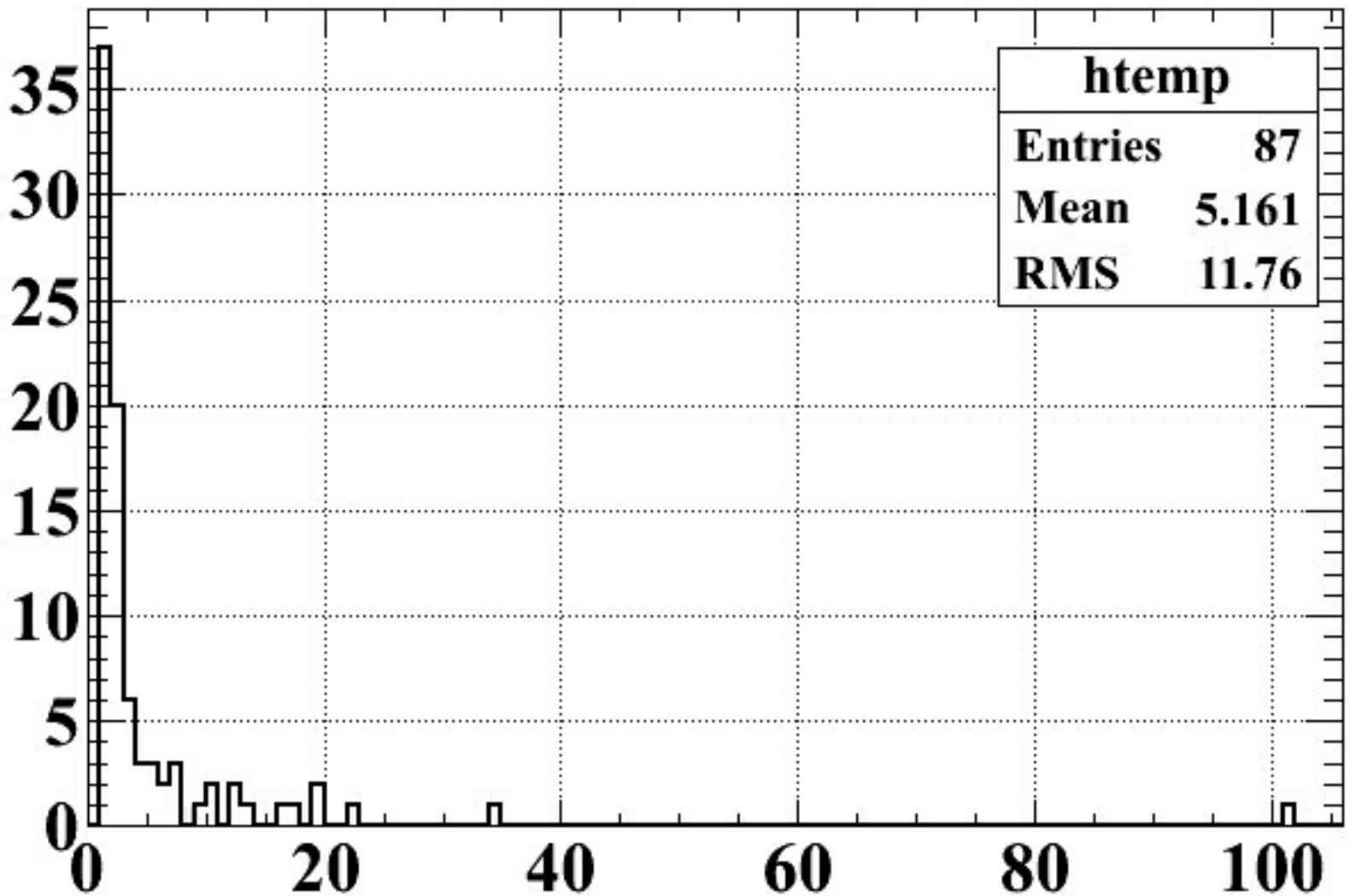
Event#5

Generate
photo:28397
pe:5523

Measure
pe:449

```
Track ID : 2
Parent ID : 1
PID : O16[0.0]
Kinetic : 0.724538
Vertex : 0, 0, -579.518
Direction : -0.977377, 0.204284, 0.0547904

Track ID : 3
Parent ID : 1
PID : proton
Kinetic : 175.892
Vertex : 11.3259, -2.36726, -461.841
Direction : -0.0846536, -0.0902916, 0.992311

Track ID : 4
Parent ID : 1
PID : proton
Kinetic : 330.077
Vertex : 11.3259, -2.36726, -461.841
Direction : -0.342488, 0.00810046, 0.939487

Track ID : 5
Parent ID : 1
PID : pi-
Kinetic : 185.432
Vertex : 11.3259, -2.36726, -461.841
Direction : 0.917949, 0.0716812, 0.390168
```

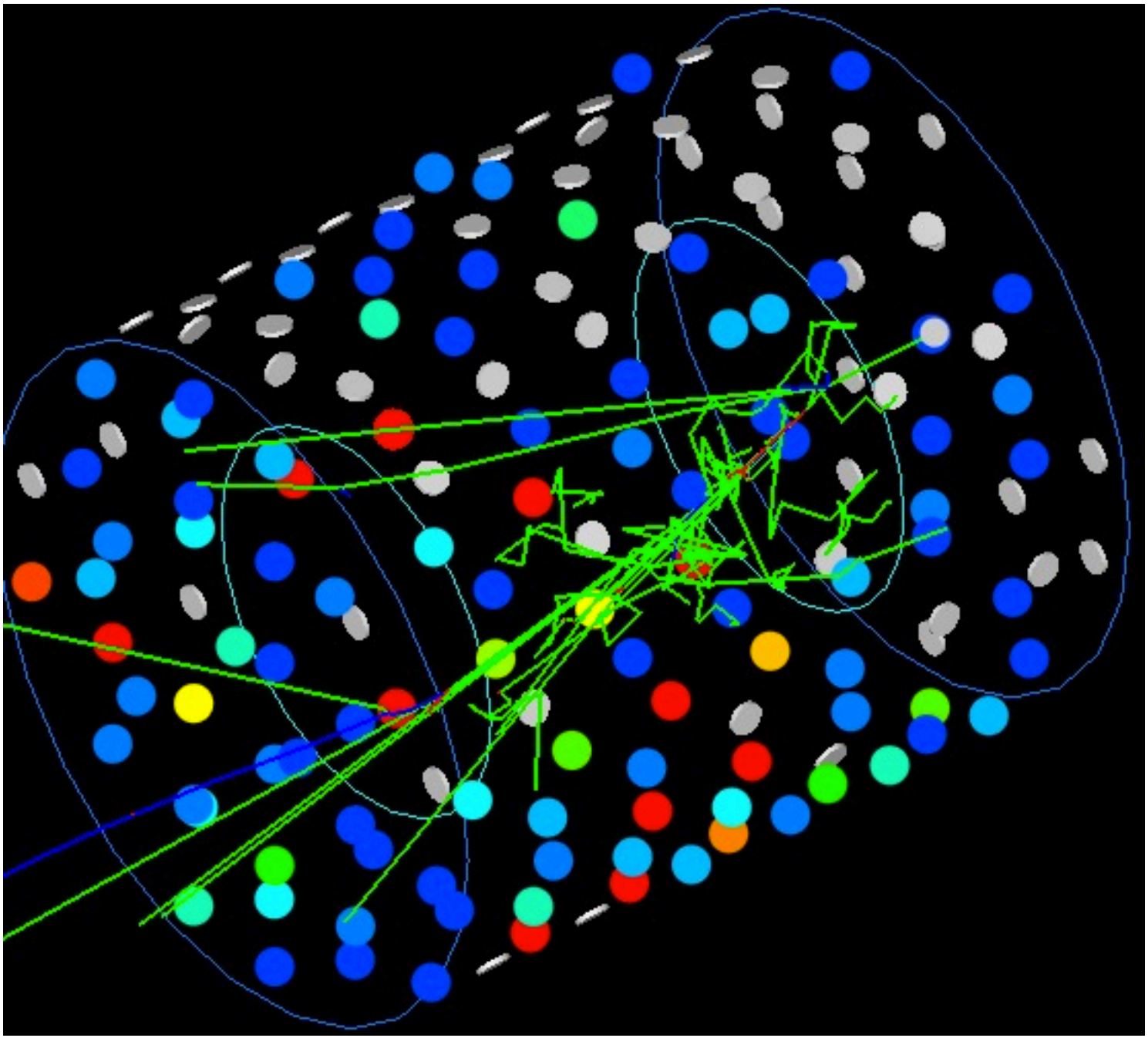
measured p.e. distribution



p.e. at each PMT

Neutron momentum = 2.0GeV (Kinetic energy = 1.27GeV)

- さらに高エネルギーの中性子を打ち込んで、Cerenkov threshold を超える運動エネルギーを持った陽子がどの程度生成されるか。



Event#1

Generate
photo:43546
pe:8303

Measure
pe:994

line color:
0 : green
+ : blue
- : red

Generated particles at primary interaction

Track ID : 2
Parent ID : 1
PID : proton
Kinetic : 116.158
Vertex : 0, 0, -642.257
Direction : -0.27937, 0.188065, 0.941586

Track ID : 3
Parent ID : 1
PID : pi0
Kinetic : 266.91
Vertex : 0, 0, -642.257
Direction : -0.475261, -0.575866, 0.665211

Track ID : 4
Parent ID : 1
PID : proton
Kinetic : 5.09933
Vertex : 0, 0, -642.257
Direction : 0.0431366, 0.322498, 0.945587

Track ID : 5
Parent ID : 1
PID : proton
Kinetic : 1.49612
Vertex : 0, 0, -642.257
Direction : -0.989156, -0.0152261, 0.146077

Track ID : 6
Parent ID : 1
PID : proton
Kinetic : 14.2611
Vertex : 0, 0, -642.257
Direction : 0.892705, -0.308718, -0.328286

Track ID : 7
Parent ID : 1
PID : proton
Kinetic : 20.3506
Vertex : 0, 0, -642.257
Direction : 0.688162, 0.458197, 0.562573

Track ID : 8
Parent ID : 1
PID : deuteron
Kinetic : 15.9969
Vertex : 0, 0, -642.257
Direction : 0.856741, -0.24659, 0.452976

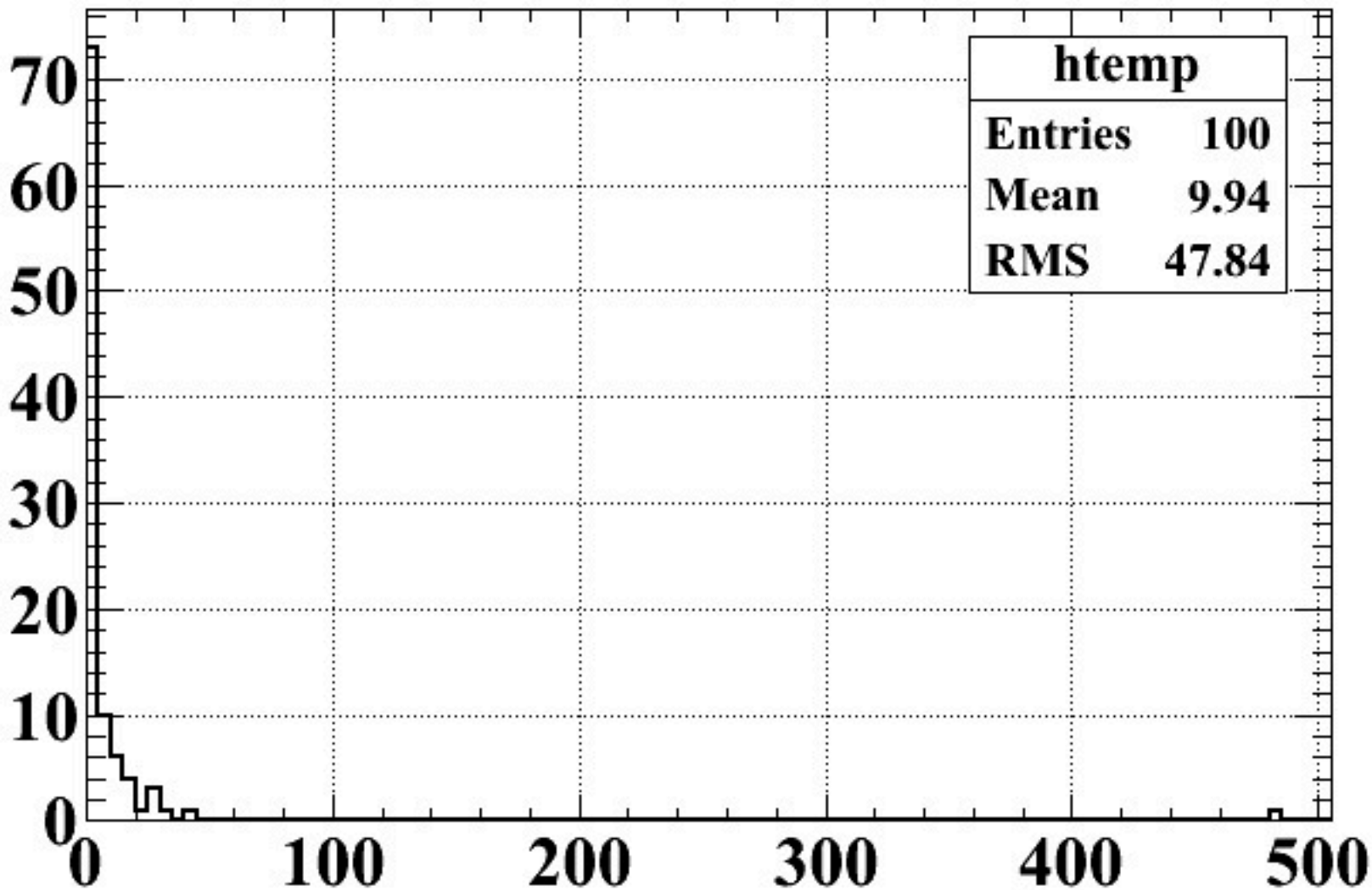
Track ID : 9
Parent ID : 1
PID : triton
Kinetic : 102.757
Vertex : 0, 0, -642.257
Direction : -0.716231, 0.229535, -0.659035

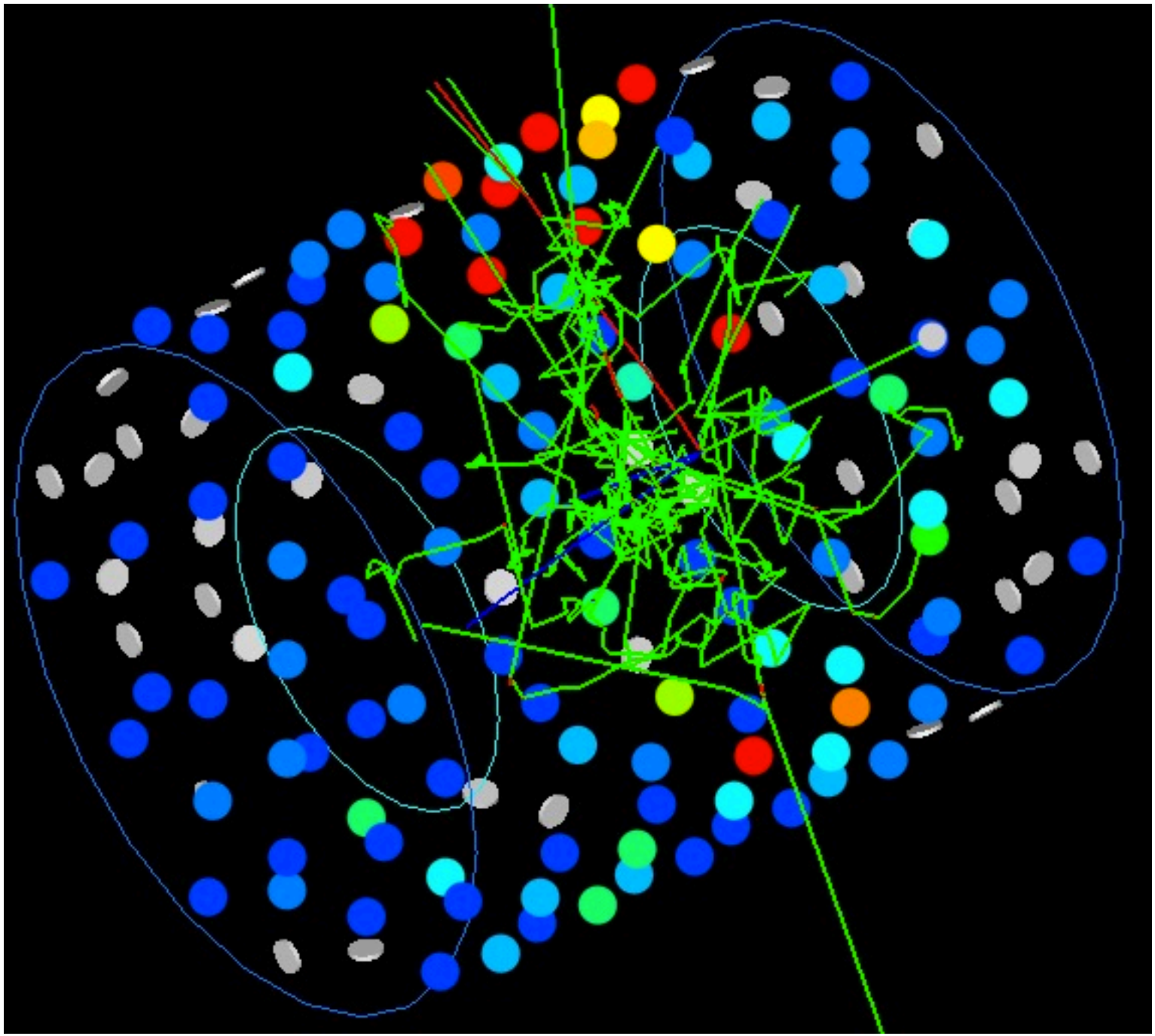
Generated particles at primary interaction

```
Track ID : 10
Parent ID : 1
PID : neutron
Kinetic : 499.612
Vertex : 0, 0, -642.257
Direction : 0.0854371, 0.373961, 0.923501
```

← 高エネルギー中性子がさらに内部で反応

Measured p.e.


htemp
Entries 100
Mean 9.94
RMS 47.84
70
60
50
40
30
20
10
0
0
100
200
300
400
500
p.e. at each PMT



Event#2

Generate
photo:39070
pe:7475

Measure
pe:483

Track ID : 2
Parent ID : 1
PID : proton
Kinetic : 466.659 ← 惜しい...
Vertex : 0, 0, -328.215
Direction : 0.0295922, -0.175878, 0.983967

Track ID : 3
Parent ID : 1
PID : proton
Kinetic : 228.859
Vertex : 0, 0, -328.215
Direction : -0.115747, 0.0209972, 0.993057

Track ID : 4
Parent ID : 1
PID : pi-
Kinetic : 184.269
Vertex : 0, 0, -328.215
Direction : -0.898613, 0.43155, -0.0791181

Track ID : 5
Parent ID : 1
PID : neutron
Kinetic : 0.259749
Vertex : 0, 0, -328.215
Direction : -0.779731, -0.194744, 0.595058

Track ID : 6
Parent ID : 1
PID : proton
Kinetic : 0.707593
Vertex : 0, 0, -328.215
Direction : 0.0641695, 0.635285, 0.769607

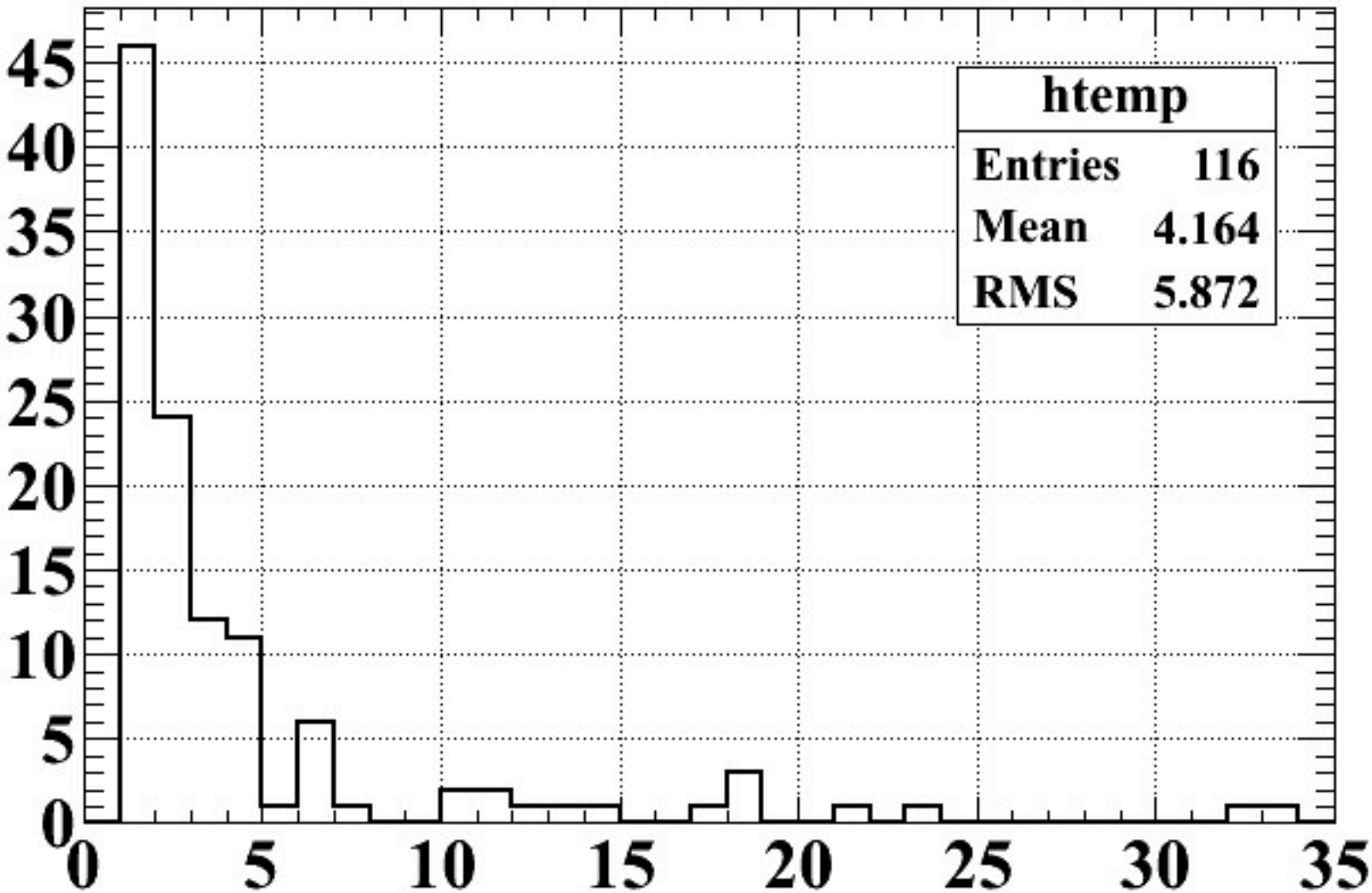
Track ID : 7
Parent ID : 1
PID : proton
Kinetic : 3.32165
Vertex : 0, 0, -328.215
Direction : 0.863008, -0.403855, -0.303511

Track ID : 8
Parent ID : 1
PID : neutron
Kinetic : 47.452
Vertex : 0, 0, -328.215
Direction : -0.799432, -0.0152032, -0.600564

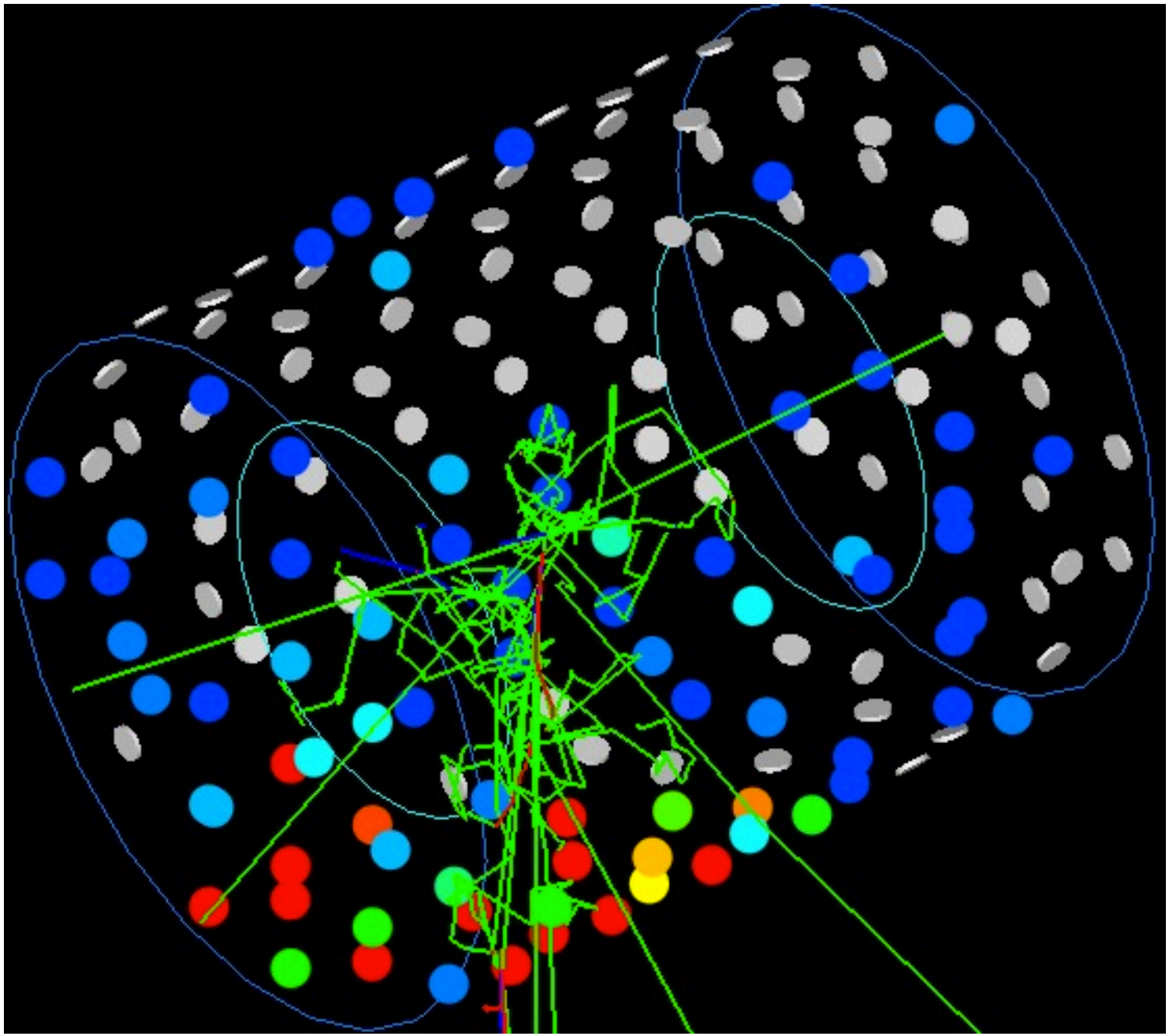
Track ID : 9
Parent ID : 1
PID : neutron
Kinetic : 15.1742
Vertex : 0, 0, -328.215
Direction : -0.493952, -0.644351, 0.583801

```
Track ID : 10
Parent ID : 1
PID : neutron
Kinetic : 26.3517
Vertex : 0, 0, -328.215
Direction : -0.583345, 0.375642, -0.72014

Track ID : 11
Parent ID : 1
PID : triton
Kinetic : 89.0517
Vertex : 0, 0, -328.215
Direction : -0.444159, 0.895802, 0.0162001

Track ID : 12
Parent ID : 1
PID : deuteron
Kinetic : 9.55689
Vertex : 0, 0, -328.215
Direction : 0.637303, 0.762898, 0.108771
```

Measured p.e.



p.e. at each PMT

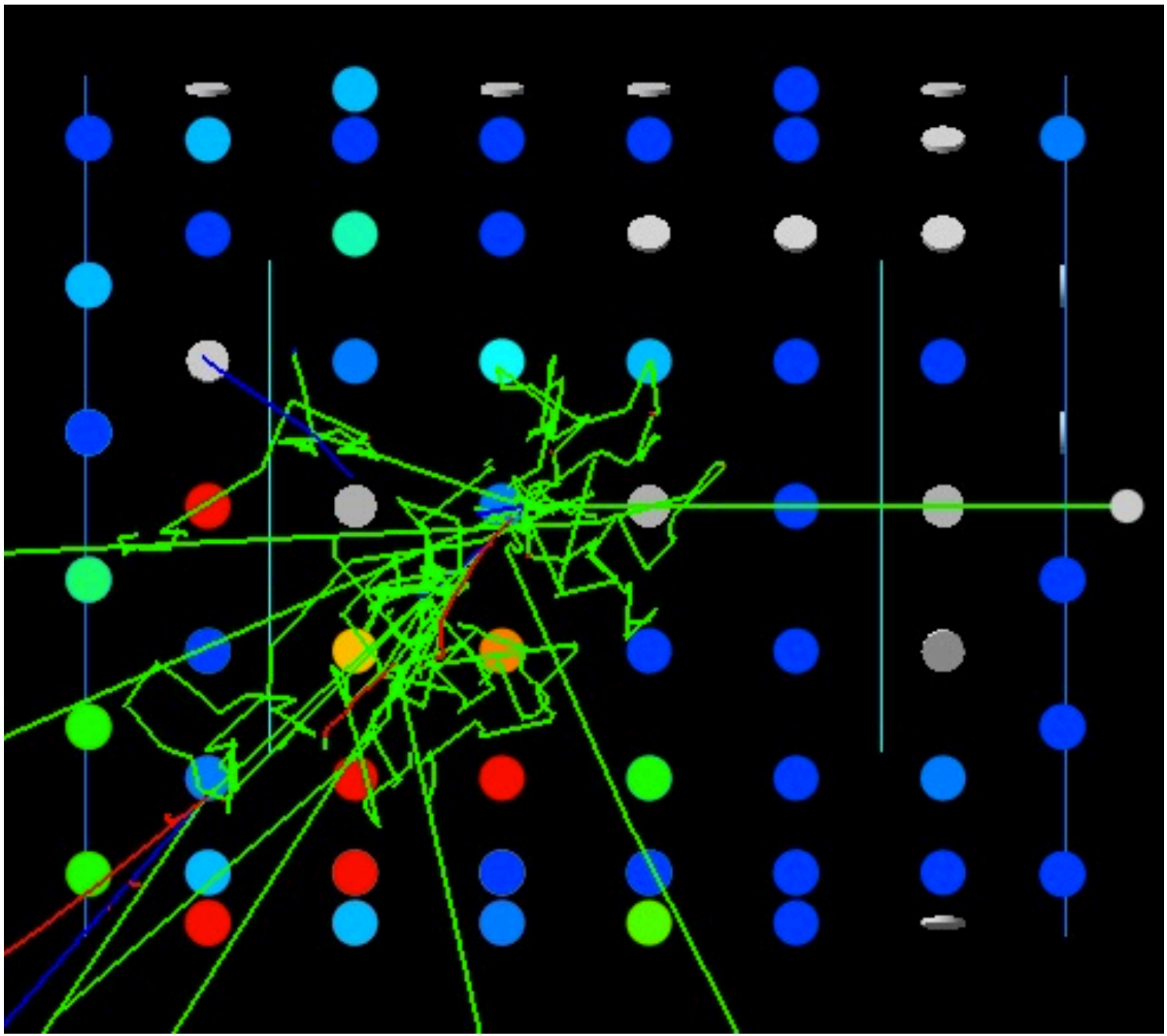


Event#3

Generate
photo:43262
pe:8101

Measure
pe:538

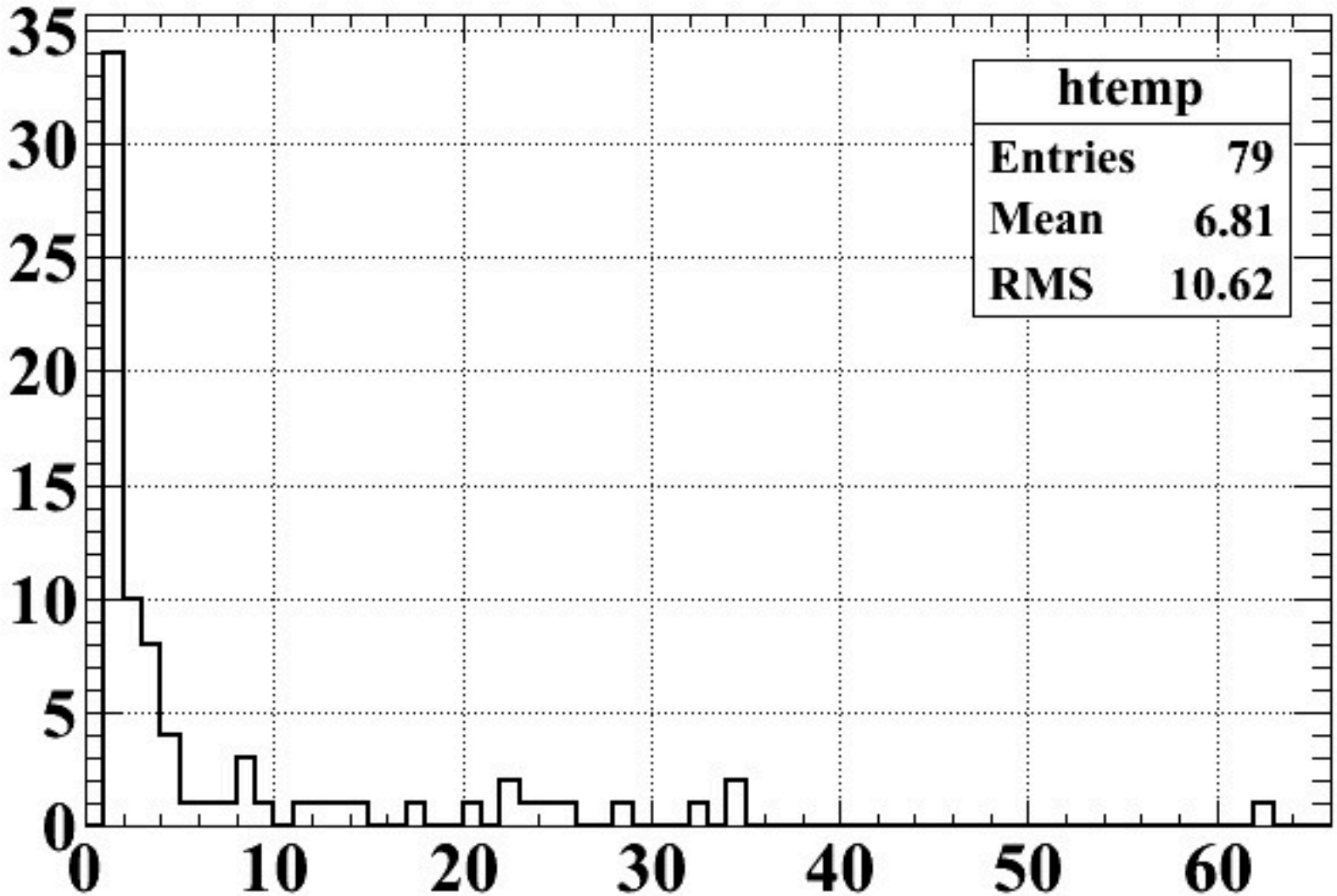
横から見てみた



```
Track ID : 2
Parent ID : 1
PID : proton
Kinetic : 111.288
Vertex : 0, 0, 85.3503
Direction : -0.470736, -0.166414, 0.866438

Track ID : 3
Parent ID : 1
PID : pi0
Kinetic : 348.507
Vertex : 0, 0, 85.3503
Direction : 0.314672, -0.529223, 0.787975

Track ID : 4
Parent ID : 1
PID : proton
Kinetic : 8.4544
Vertex : 0, 0, 85.3503
Direction : -0.514538, 0.548917, 0.658742

Track ID : 5
Parent ID : 1
PID : proton
Kinetic : 0.001
Vertex : 0, 0, 85.3503
Direction : -0.511975, -0.827663, -0.229902

Track ID : 6
Parent ID : 1
PID : proton
Kinetic : 1.78198
Vertex : 0, 0, 85.3503
Direction : -0.151972, -0.0315535, 0.987881

Track ID : 7
Parent ID : 1
PID : proton
Kinetic : 0.001
Vertex : 0, 0, 85.3503
Direction : -0.599045, 0.755257, 0.265955

Track ID : 8
Parent ID : 1
PID : neutron
Kinetic : 21.1644
Vertex : 0, 0, 85.3503
Direction : 0.713059, -0.640738, -0.284609

Track ID : 9
Parent ID : 1
PID : proton
Kinetic : 38.7849
Vertex : 0, 0, 85.3503
Direction : 0.160705, -0.855177, 0.492795
```

```
Track ID : 10
Parent ID : 1
PID : proton
Kinetic : 33.718
Vertex : 0, 0, 85.3503
Direction : -0.500862, -0.42787, 0.752373

Track ID : 11
Parent ID : 1
PID : deuteron
Kinetic : 5.38038
Vertex : 0, 0, 85.3503
Direction : -0.9836, -0.0248029, -0.17865

Track ID : 12
Parent ID : 1
PID : neutron
Kinetic : 0.0465642
Vertex : 0, 0, 85.3503
Direction : -0.0976395, 0.993566, -0.0573791

Track ID : 13
Parent ID : 1
PID : neutron
Kinetic : 0.728924
Vertex : 0, 0, 85.3503
Direction : 0.382092, -0.450757, -0.806737

Track ID : 14
Parent ID : 1
PID : neutron
Kinetic : 3.11067
Vertex : 0, 0, 85.3503
Direction : 0.902501, -0.396512, -0.168138

Track ID : 15
Parent ID : 1
PID : neutron
Kinetic : 19.1437
Vertex : 0, 0, 85.3503
Direction : 0.780357, 0.374074, -0.50111

Track ID : 16
Parent ID : 1
PID : neutron
Kinetic : 10.0929
Vertex : 0, 0, 85.3503
Direction : -0.746164, -0.66366, -0.0528631

Track ID : 17
Parent ID : 1
PID : neutron
Kinetic : 0.283466
Vertex : 0, 0, 85.3503
Direction : -0.0500815, -0.272034, -0.960984
```

Track ID : 18
Parent ID : 1
PID : neutron
Kinetic : 412.795 ← 高エネルギー中性子がさらに内部で反応
Vertex : 0, 0, 85.3503
Direction : 0.205733, 0.321136, 0.924416



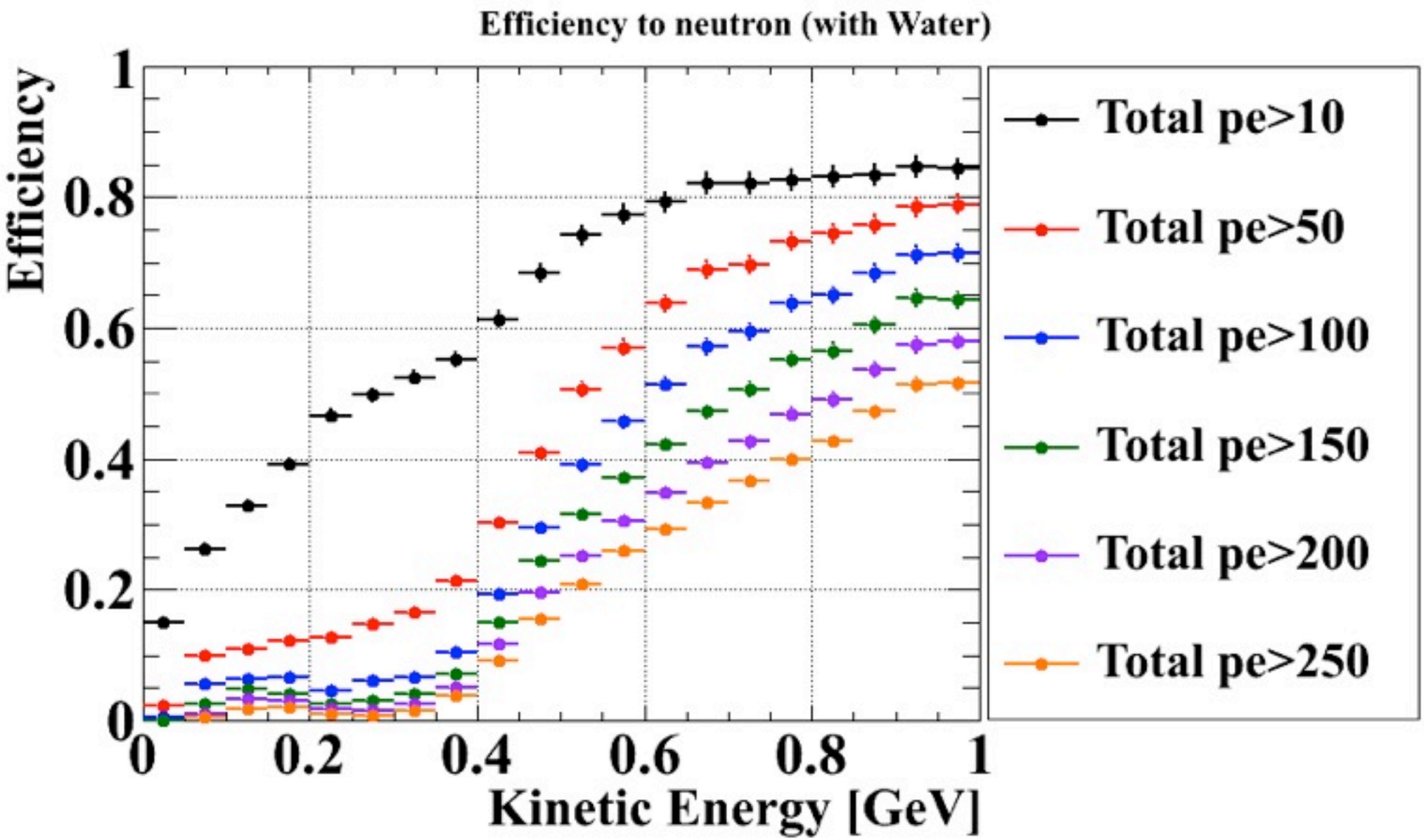
p.e. at each PMT

- Thresholdを超えるような陽子は見られなかった。
- チェレンコフ光を出す粒子として電子以外では π+, π- が見られた。
- π0 → 2γ → electron によるチェレンコフ光も無視できない。
- 将来的には、“チェレンコフ光を出した粒子”を拾ってこれるようにしたい。

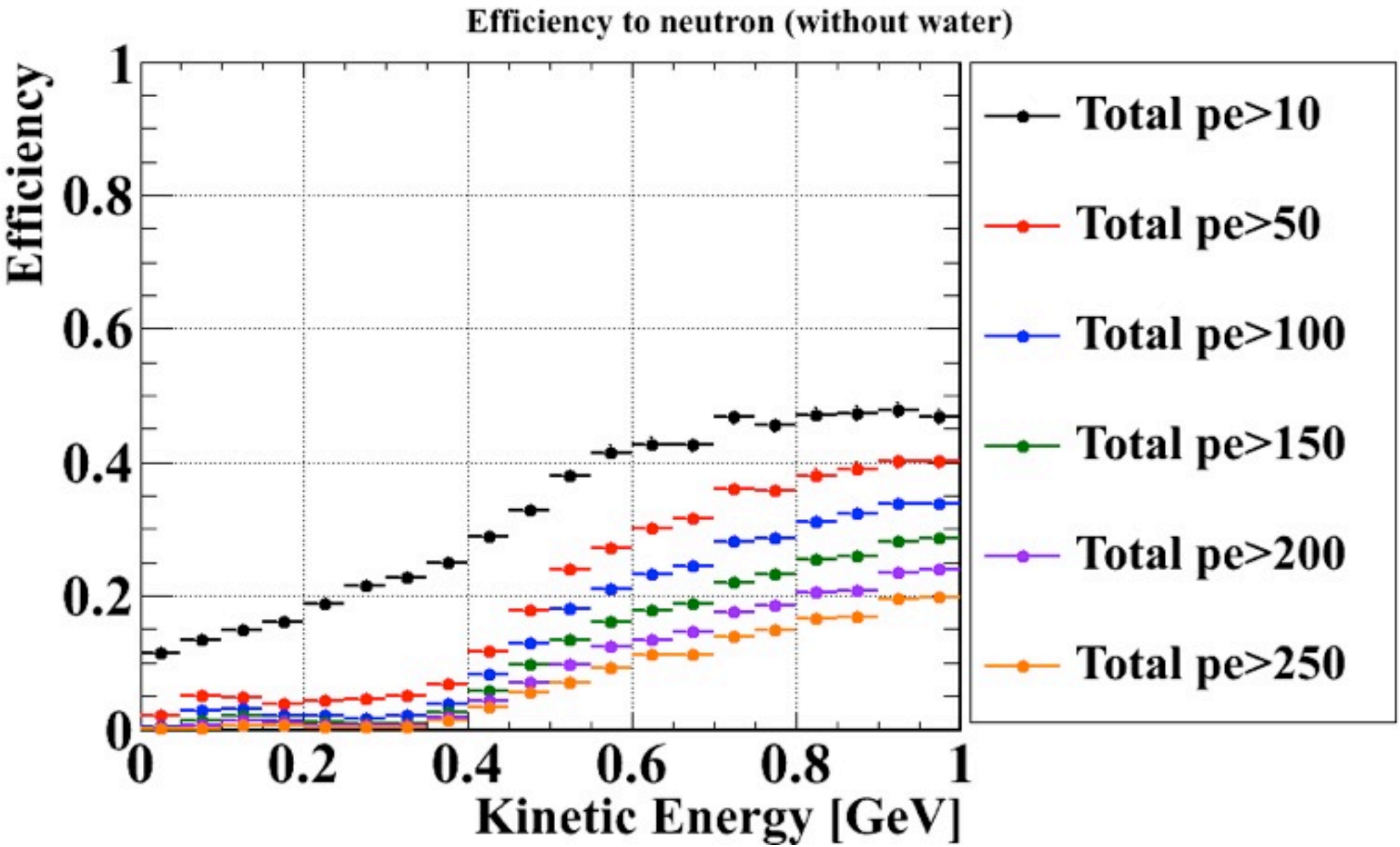
Efficiency curve

- Kinetic energy : 0 ~ 1 GeV の範囲での検出効率を計算
  - 検出効率 = (# of events after cut)/(# of generated events)
- エネルギー以外の設定は冒頭の説明と同じ
  - vertex = 0,0,-90cm
  - direction = 0,0,1

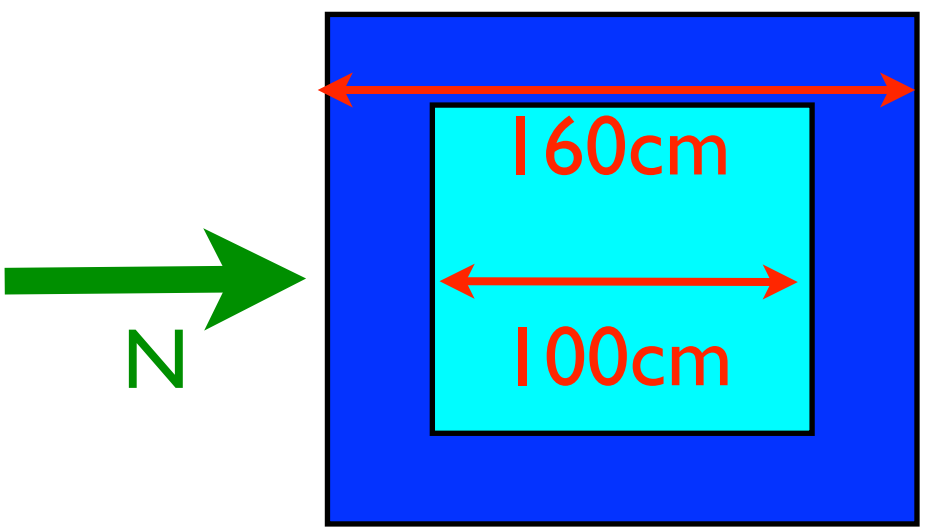
Efficiency with water



Efficiency without water



- 低エネルギー領域では、検出効率は低いが、高エネルギー領域においては50%程度もある。
- ぱっと見て水がない場合の検出効率はある場合の半分程度(カット、エネルギー領域によるが)
  - 反応確率：(水なし)/(水あり) = (1-exp(-60/100))/(1-exp(-160/100)) ~ 0.57
- タンク内の水と反応したイベントのみを選ぶと、水ありなしで同じような検出効率になるかもしれない。



In future ?

- πの生成と検出効率の関係性
  - πが生成されたイベントのみ選ぶ
  - πのエネルギーに対する検出効率
    - (π+ or π-) , π0 で区切る