The Geant4 simulation of the n-^{3}He experiment

Outcome and Validation

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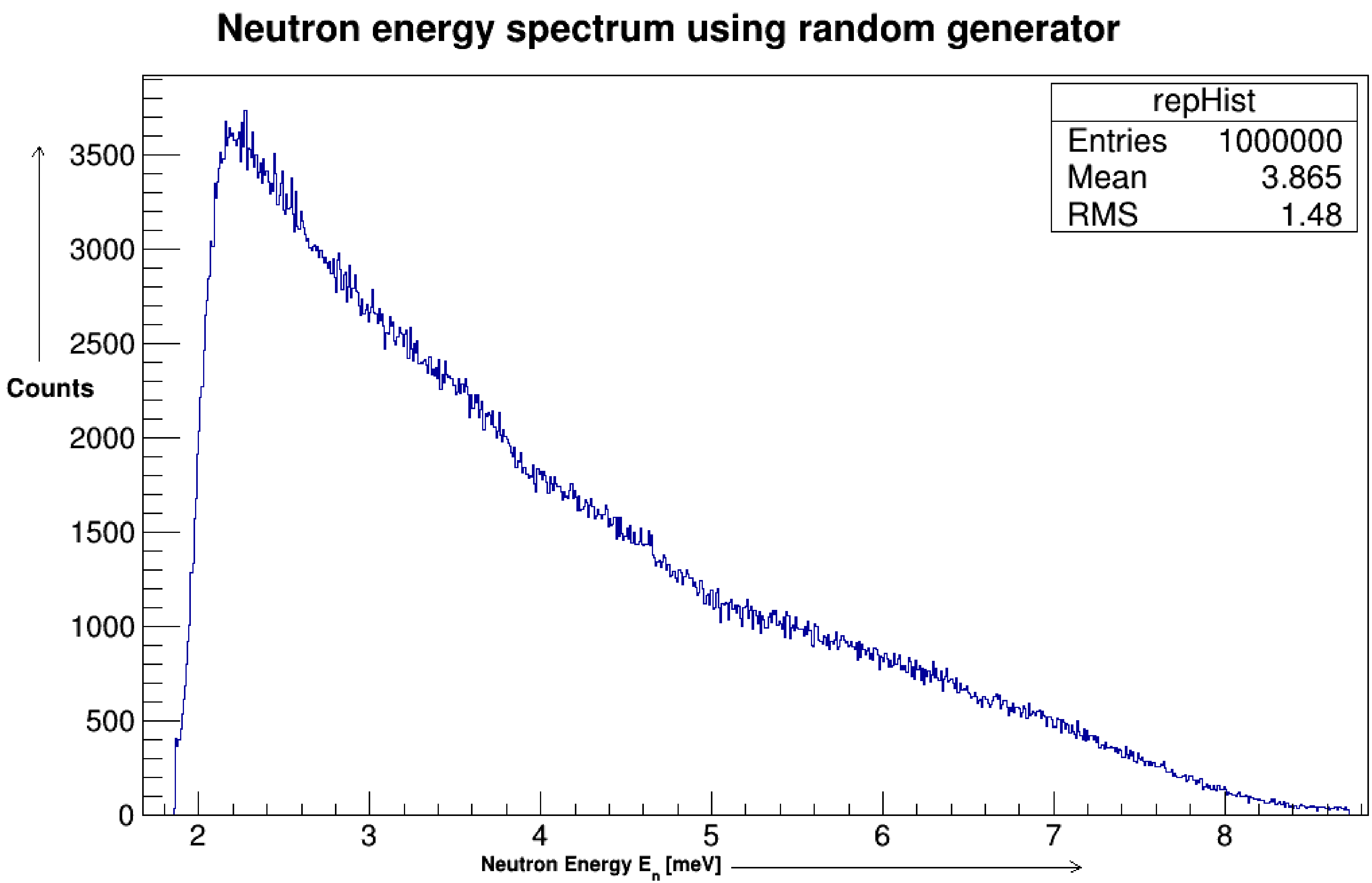
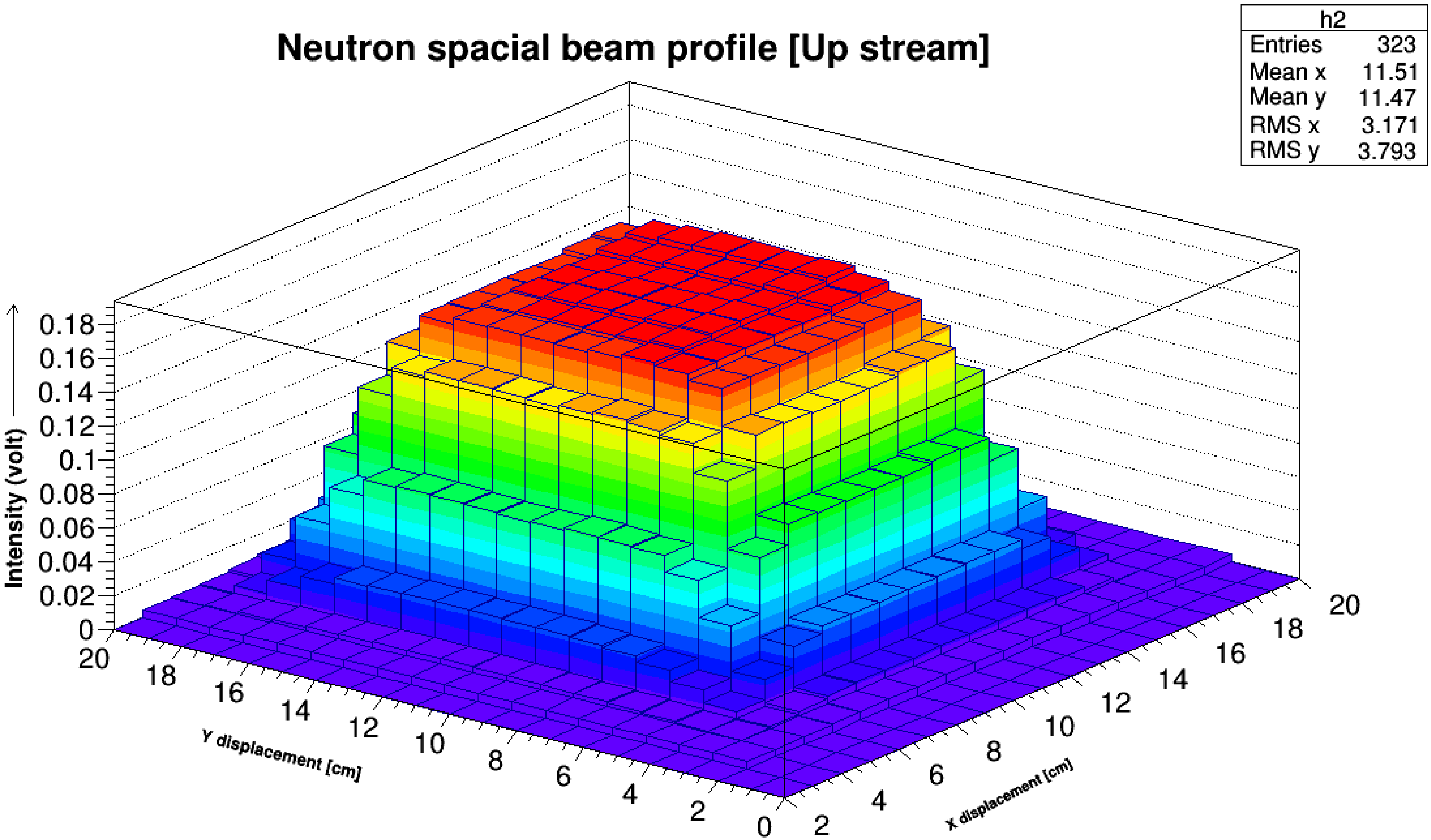
Towards more realistic neutrons source

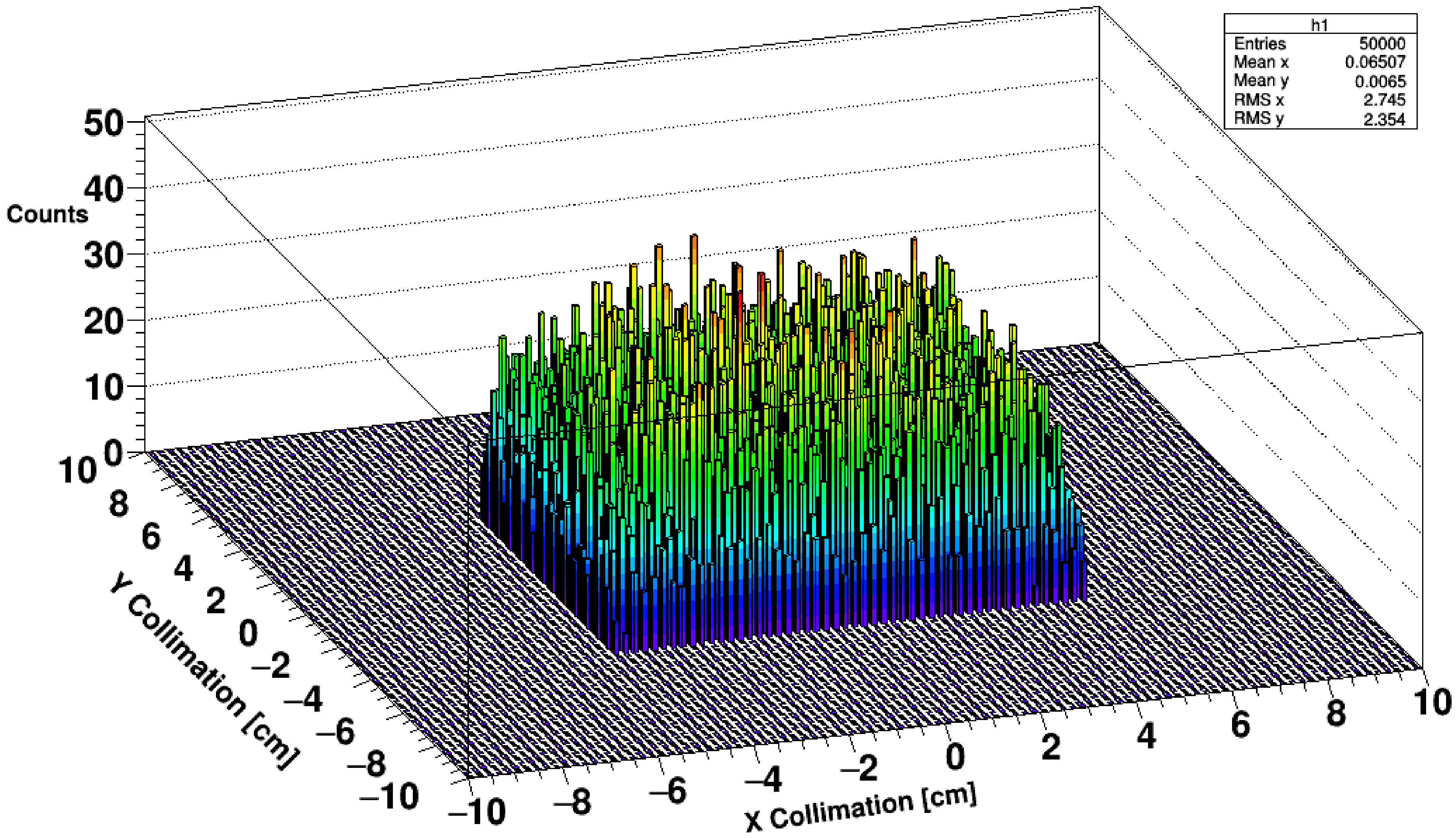
Neutron Energy Distribution from Geant4



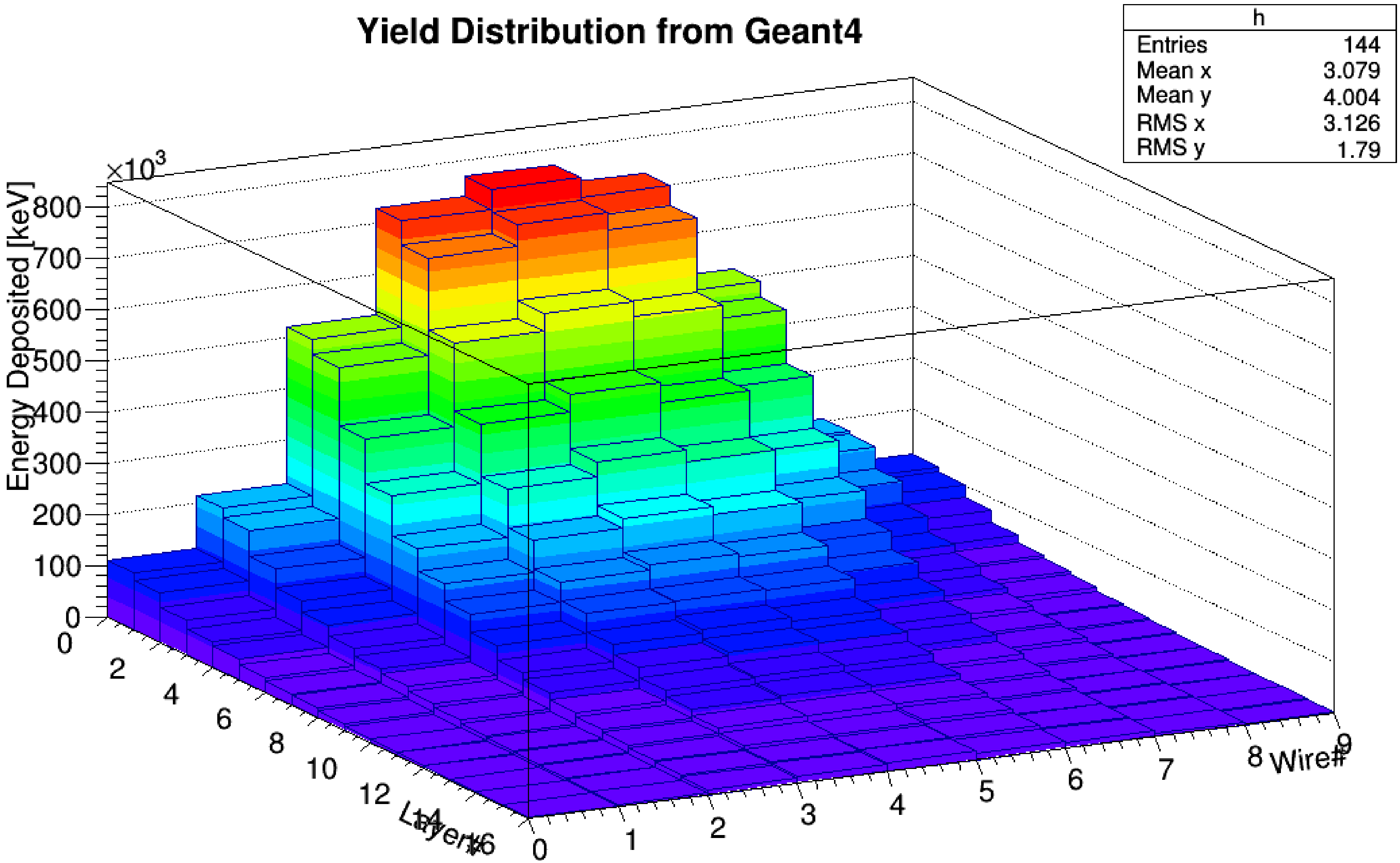
Spacial distribution from beam scan



Neutron position distribution on XY plane

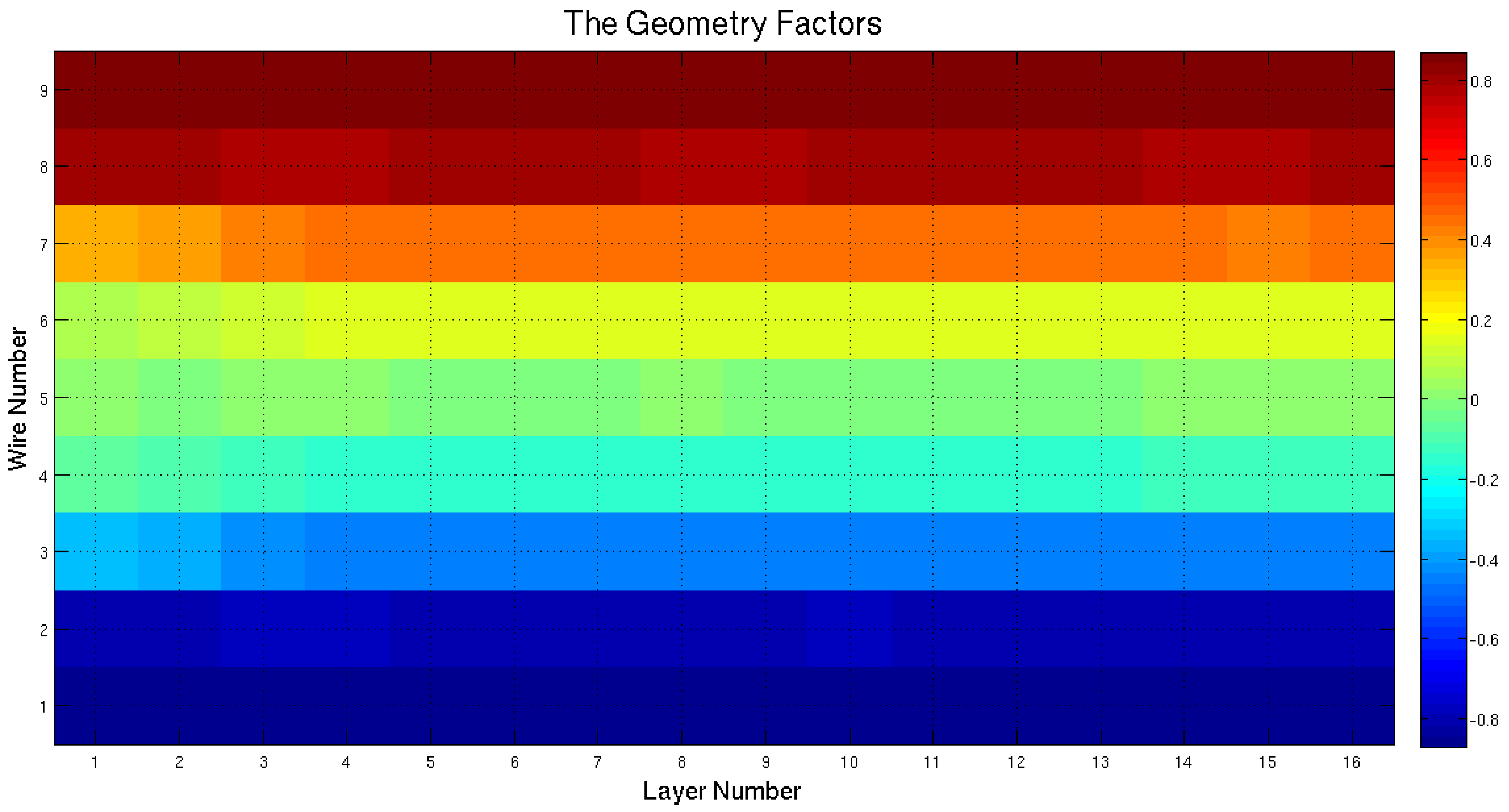


The Outcome



Yield Distribution from Geant4
h
Entries 144
Mean x 3.079
Mean y 4.004
RMS x 3.126
RMS y 1.79
×10^3
Energy Deposited [keV]
0
100
200
300
400
500
600
700
800
0
2
4
6
8
10
12
14
16
Layer#
0
1
2
3
4
5
6
7
8
9
Wire#

The Geometry Factors for the n-^{3}He Experiment



Validation of the simulation

List of validation attempts

1 .Conservation of energy

2. Ionization Curve / Energy Range Relation

3. Cross section

4. 1/v dependence of cross section

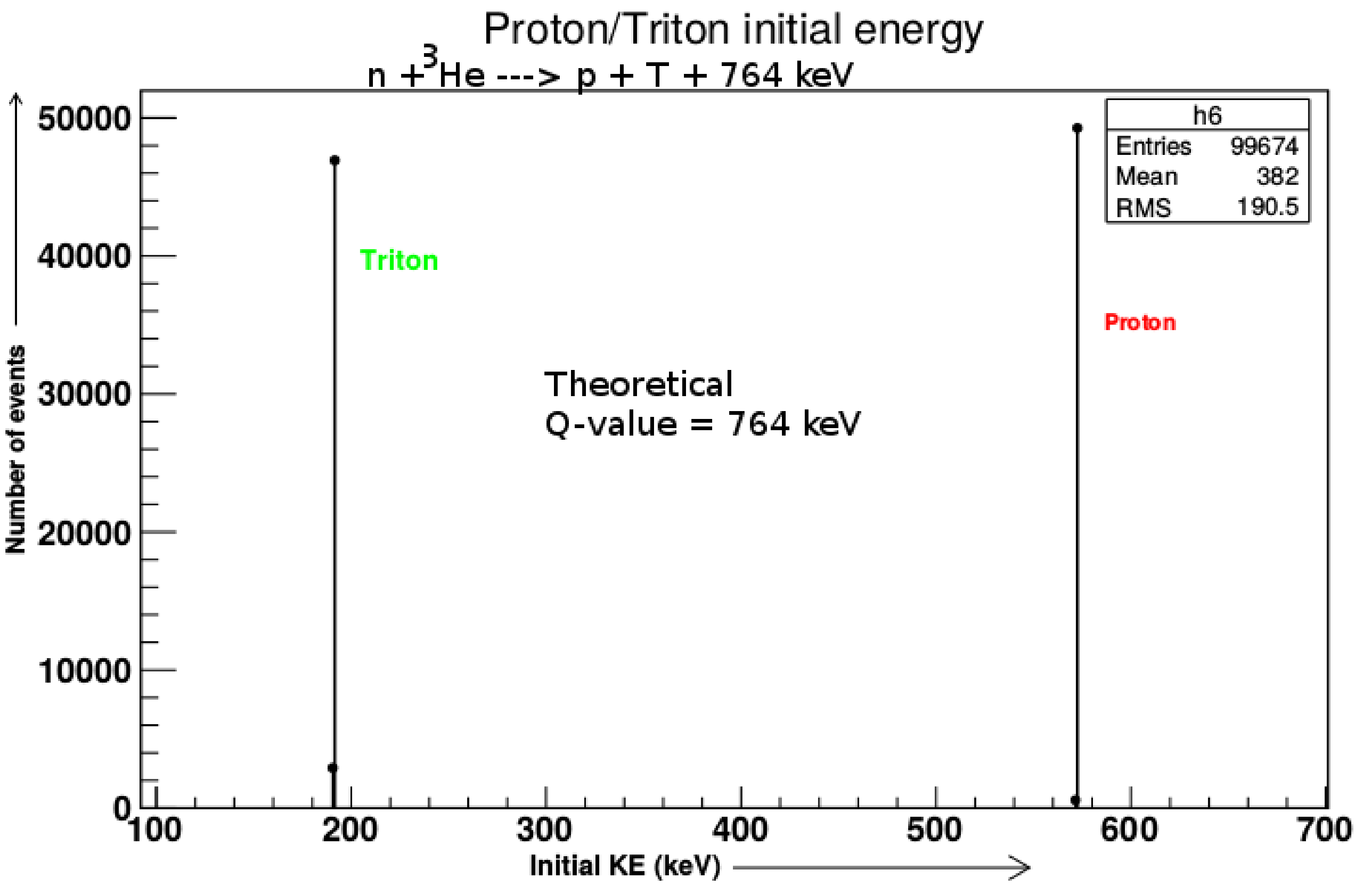
5. Yield in the chamber

6. Comparison with collimation scan data

Validation attempt#1

Conservation of Energy

Conservation of energy

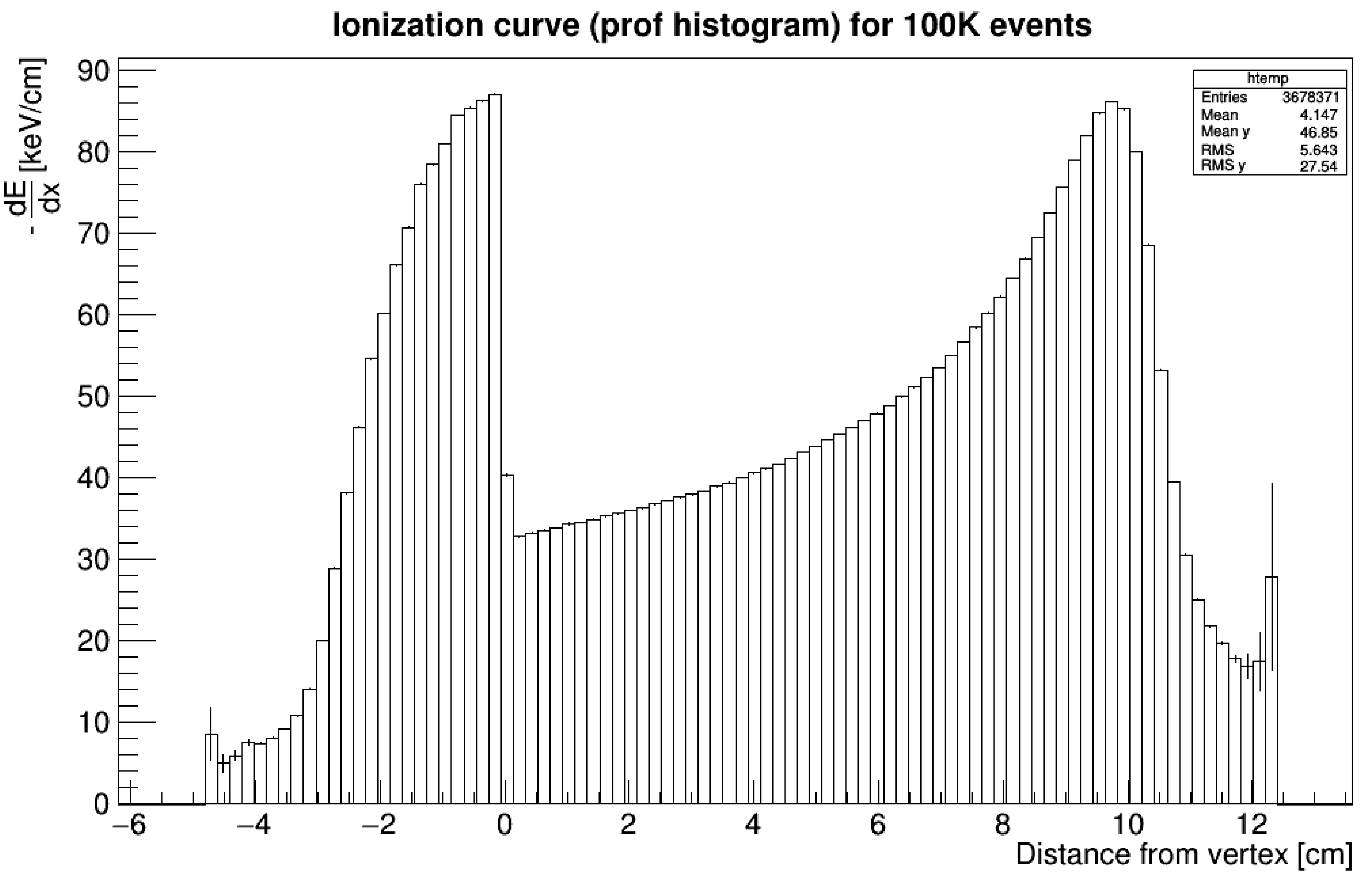


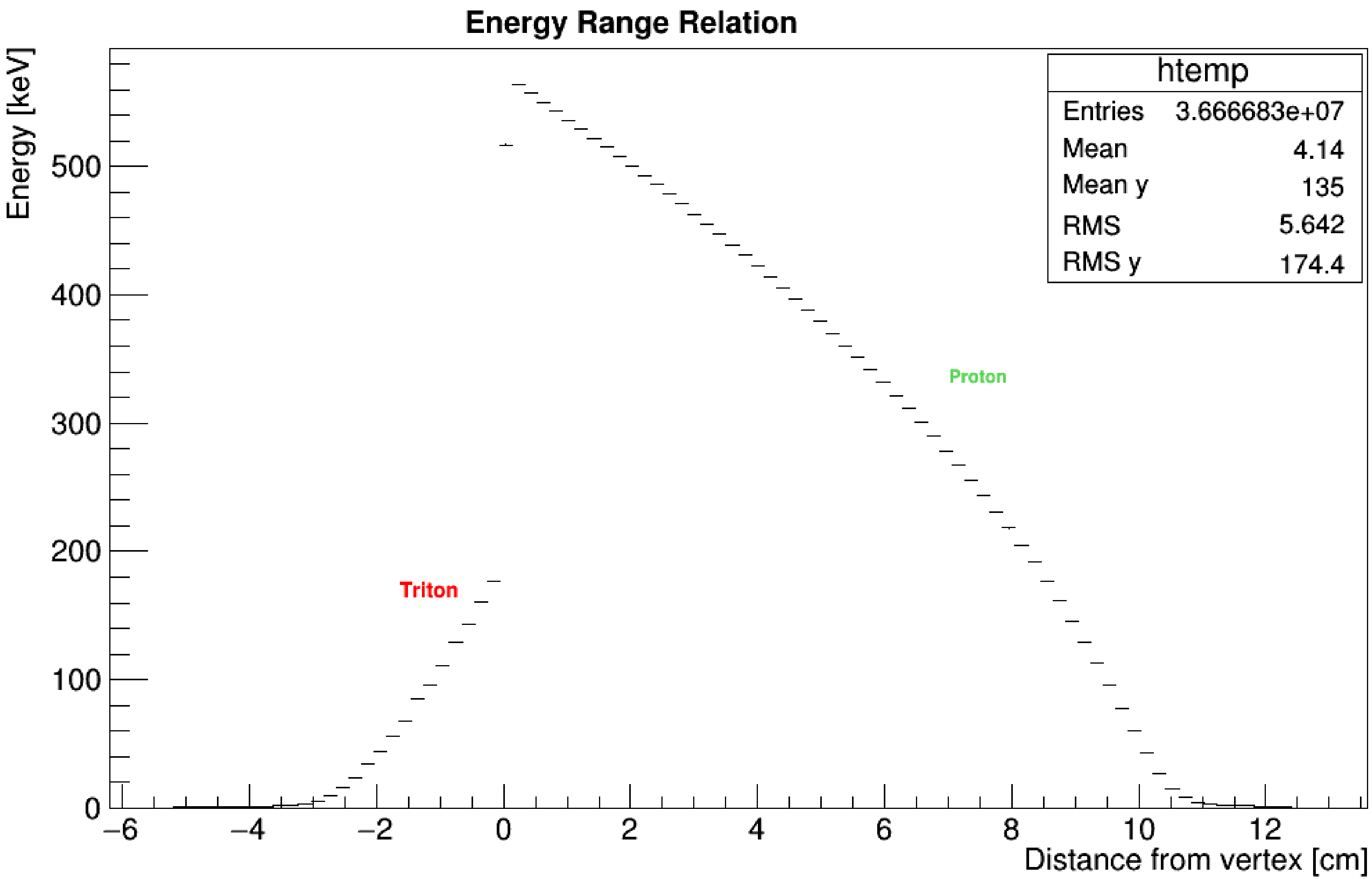
Validation attempt #2

Ionization Curve / Energy Range Relation

Compare simulated curved with the curve generated using SRIM

Ionization curve



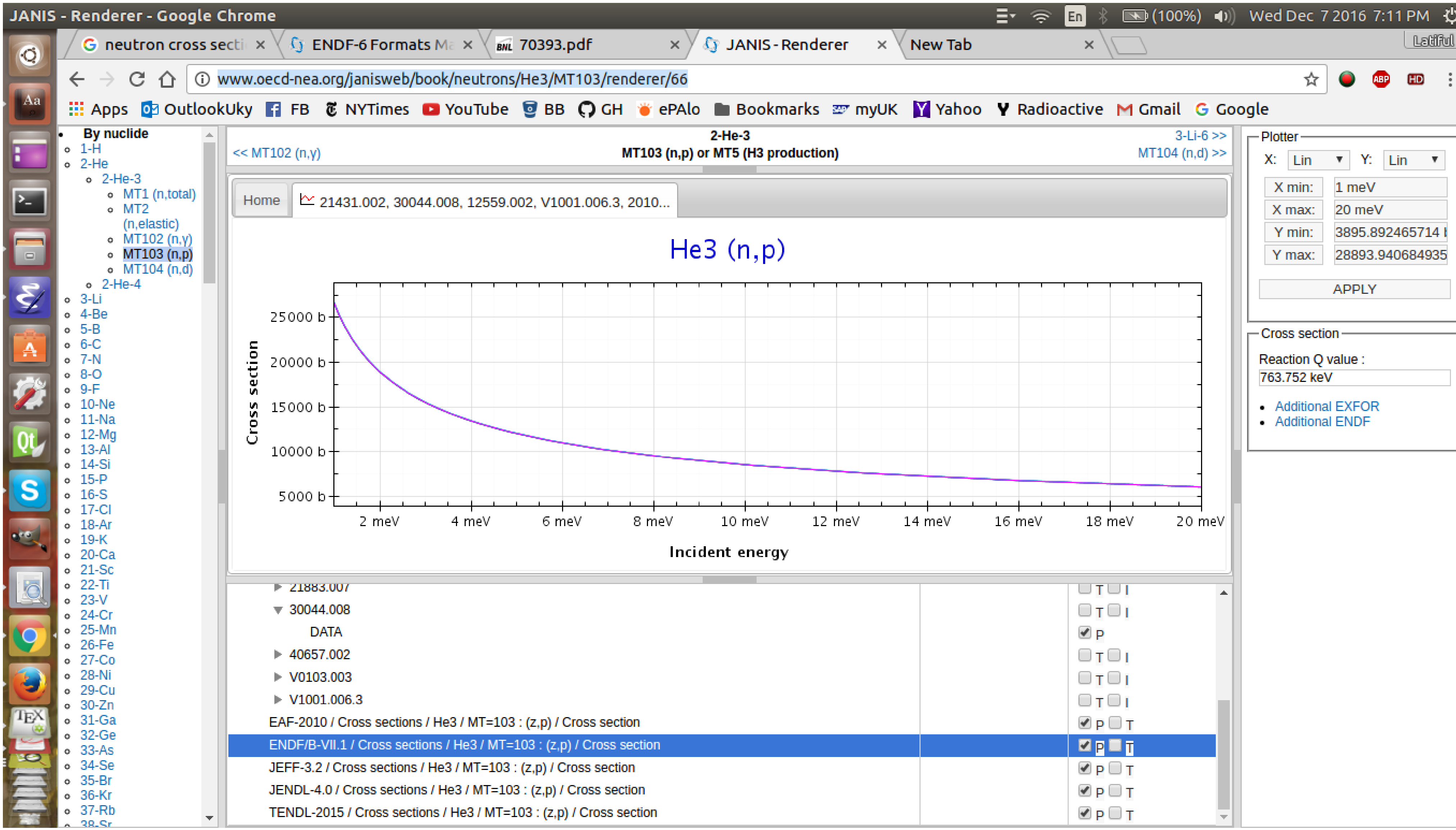


Energy Range Relation
htemp
Entries 3.666683e+07
Mean 4.14
Mean y 135
RMS 5.642
RMS y 174.4
Energy [keV]
500
400
300
200
100
0
Proton
Triton
−6
−4
−2
0
2
4
6
8
10
12
Distance from vertex [cm]

Validation attempt #3

Reaction Cross Section

http://www.oecd-nea.org/janisweb/book/neutrons/He3/MT103/renderer/176


JANIS - Renderer - Google Chrome
www.oecd-nea.org/janisweb/book/neutrons/He3/MT103/renderer/66
By nuclide
1-H
2-He
2-He-3
MT1 (n,total)
MT2 (n,elastic)
MT102 (n,y)
MT103 (n,p)
MT104 (n,d)
2-He-4
2-He-3
<< MT102 (n,y)
MT103 (n,p) or MT5 (H3 production)
3-Li-6 >>
MT104 (n,d) >>
Home
21431.002, 30044.008, 12559.002, V1001.006.3, 2010...
He3 (n,p)
Cross section
Incident energy
25000 b
20000 b
15000 b
10000 b
5000 b
2 meV
4 meV
6 meV
8 meV
10 meV
12 meV
14 meV
16 meV
18 meV
20 meV
Plotter
X: Lin
Y: Lin
X min: 1 meV
X max: 20 meV
Y min: 3895.892465714
Y max: 28893.940684935
APPLY
Cross section
Reaction Q value :
763.752 keV
Additional EXFOR
Additional ENDF
30044.008
DATA
40657.002
V0103.003
V1001.006.3
EAF-2010 / Cross sections / He3 / MT=103 : (z,p) / Cross section
ENDF/B-VII.1 / Cross sections / He3 / MT=103 : (z,p) / Cross section
JEFF-3.2 / Cross sections / He3 / MT=103 : (z,p) / Cross section
JENDL-4.0 / Cross sections / He3 / MT=103 : (z,p) / Cross section
TENDL-2015 / Cross sections / He3 / MT=103 : (z,p) / Cross section

Getting cross section from simulation

The number of capture at position x inside the chamber is related to the capture cross section as –

$$I(x) = I_0 e^{-N\sigma x}$$

where,
N = density of nuclei in the volume (nuclei/cm^3)
σ = The capture cross-section (barn, 1 barn =$10^{-28} m^2$)
I_0 = Initial beam intensity
I(x) = Beam intensity at distance x
Linearizing the equation we can write,

$$lnI(x) = -N\sigma x + lnI_0$$

Assuming the ^{3}He as ideal gas, we can use ideal gas equation PV= nRT to get the density of nuclei in this relation.
For our experiment,

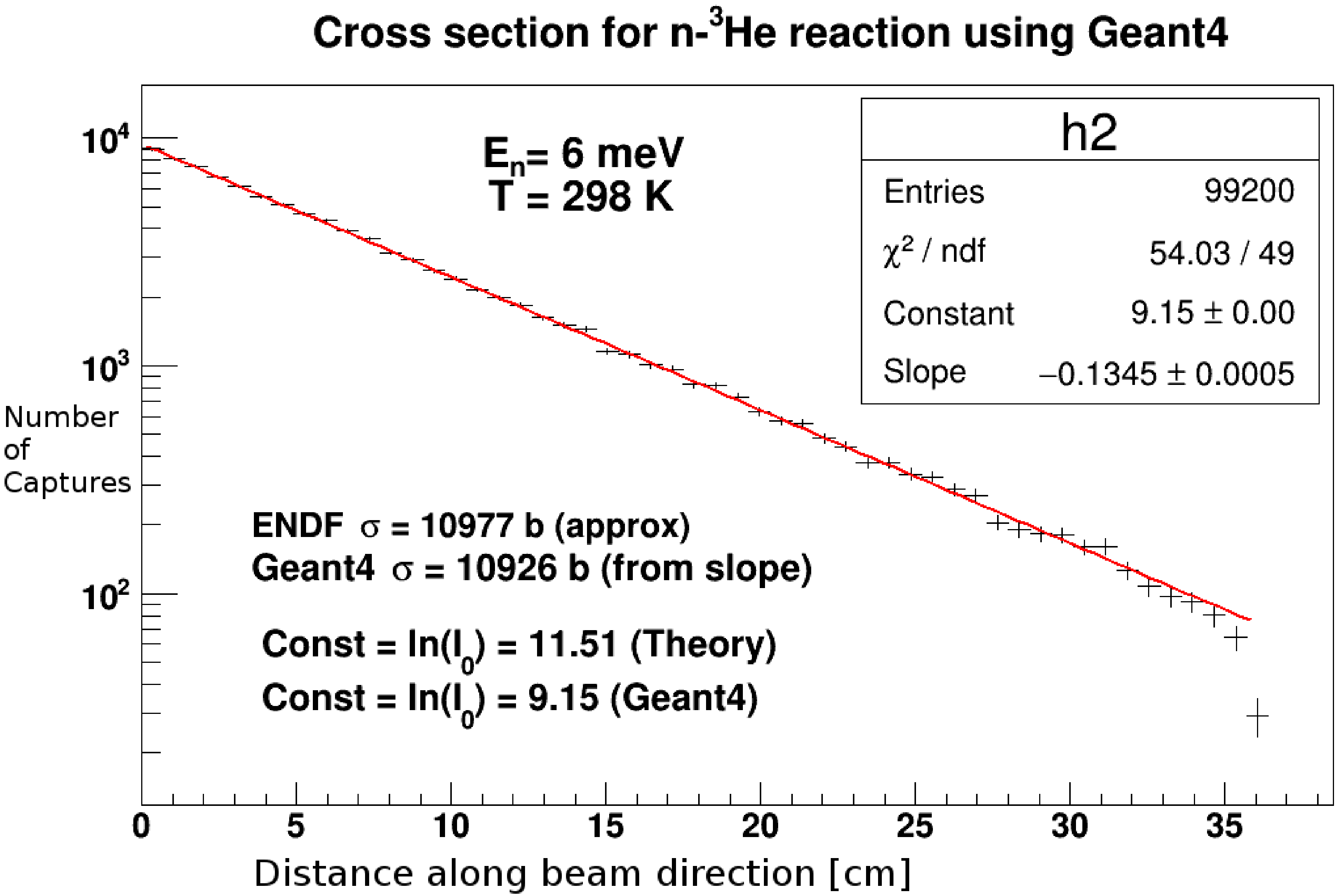
Getting cross section from simulation

P= 0.5 atm
R = molar gas constant = 82.057338(47) $cm^3 atm\ K^{-1}\ mol^{-1}$
T = 298 K

$$\frac{n}{V} = \frac{P}{RT}$$
$$= \frac{0.5}{82.057338 \times 298}$$
$$= 2.044 \times 10^{-5} mole\, cm^{-3}$$
$$= 2.044 \times 10^{-5} \times 6.022140857 \times 10^{23}\, nuclei\, cm^{-3}$$

So N = 12.3092559 $\times 10^{18}$ nuclei cm^{-3}

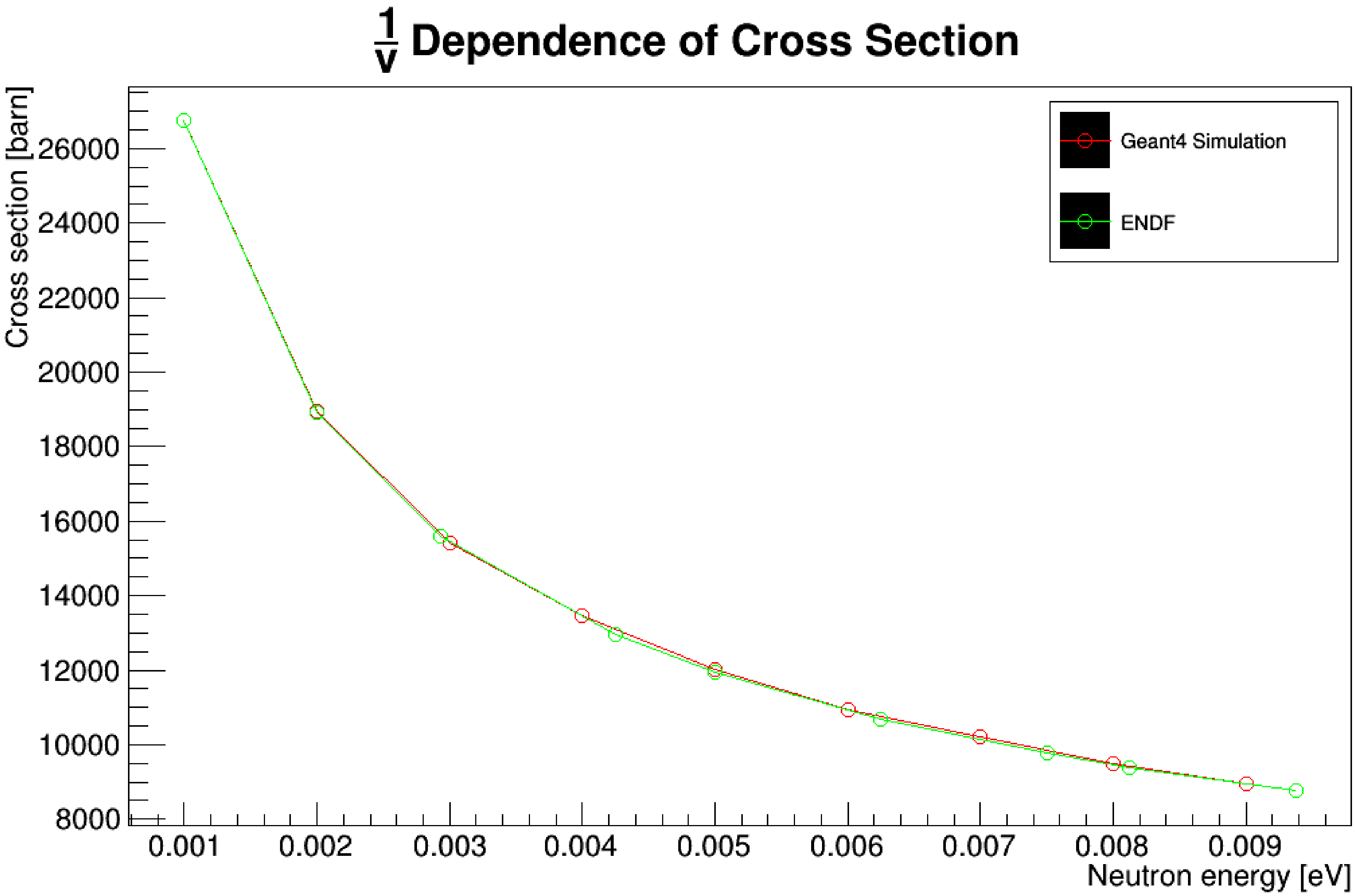
So if we make a plot for lnI(x) vs x and do a linear fit, then the slope and constant from that fit will correspond to :
slope = -Nσ_n
$\sigma = \frac{-slope}{N}$
and
constant = lnI_0



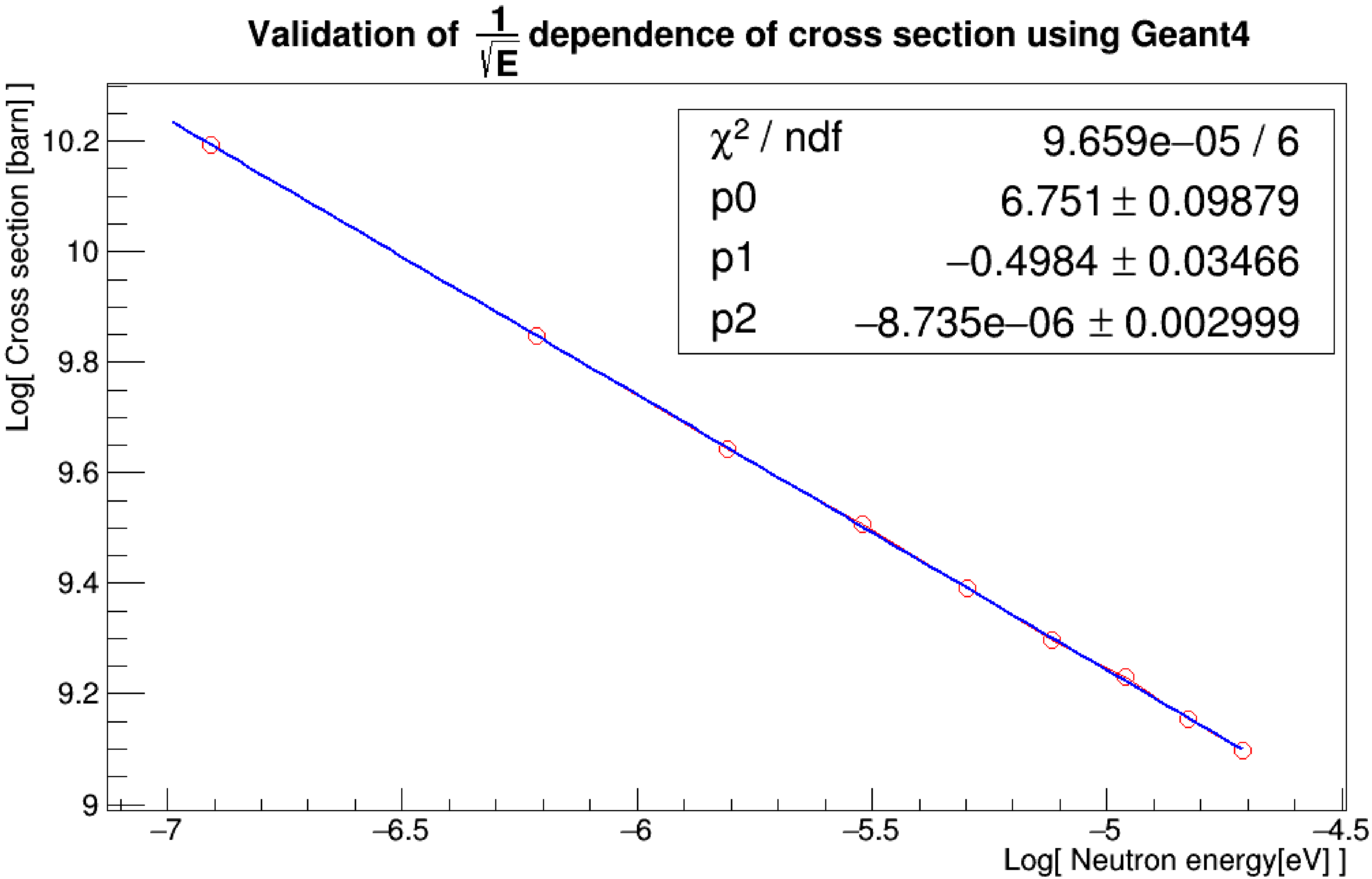
Cross section for n-3He reaction using Geant4
h2
Entries 99200
χ2 / ndf 54.03 / 49
Constant 9.15 ± 0.00
Slope −0.1345 ± 0.0005
En= 6 meV
T = 298 K
ENDF σ = 10977 b (approx)
Geant4 σ = 10926 b (from slope)
Const = ln(I0) = 11.51 (Theory)
Const = ln(I0) = 9.15 (Geant4)
Number of Captures
Distance along beam direction [cm]

Validation attempt #4

1/v Dependence of cross section



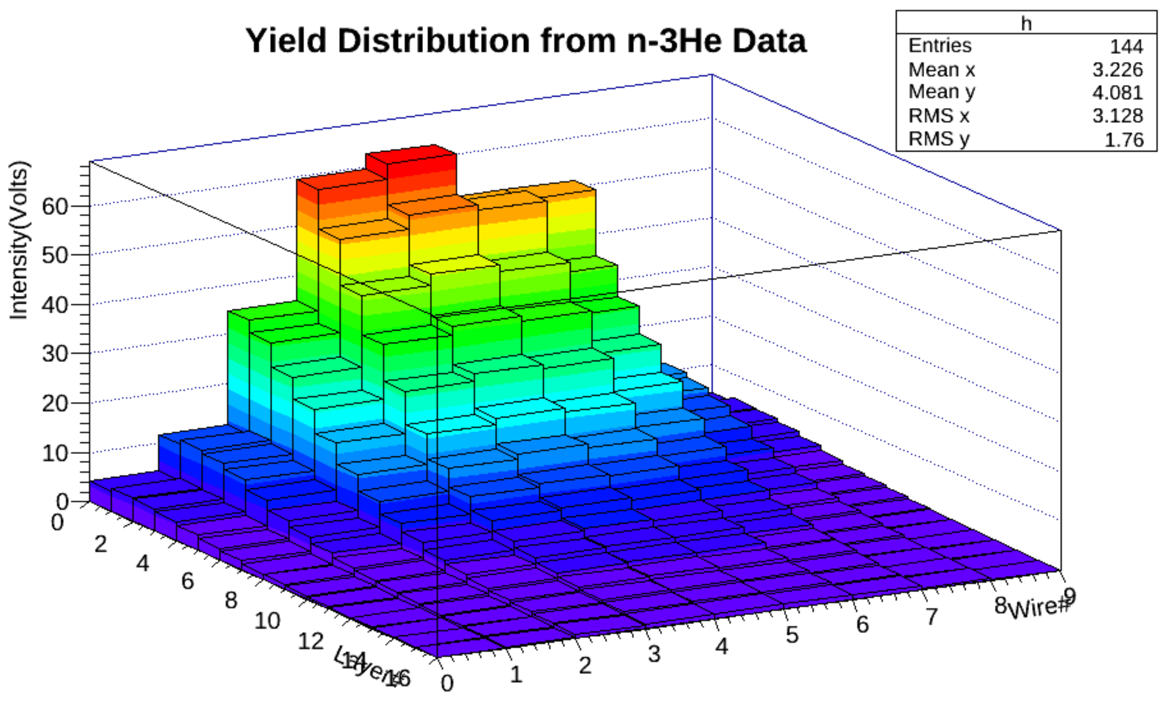
$\frac{1}{v}$ Dependence of Cross Section
Cross section [barn]
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
Neutron energy [eV]
Geant4 Simulation
ENDF

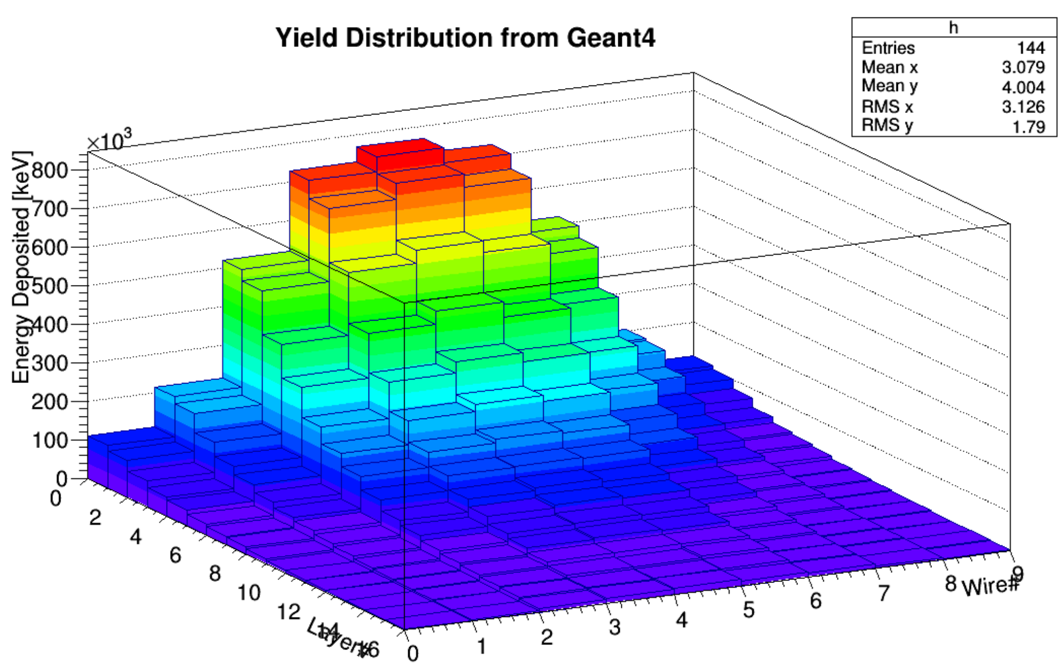


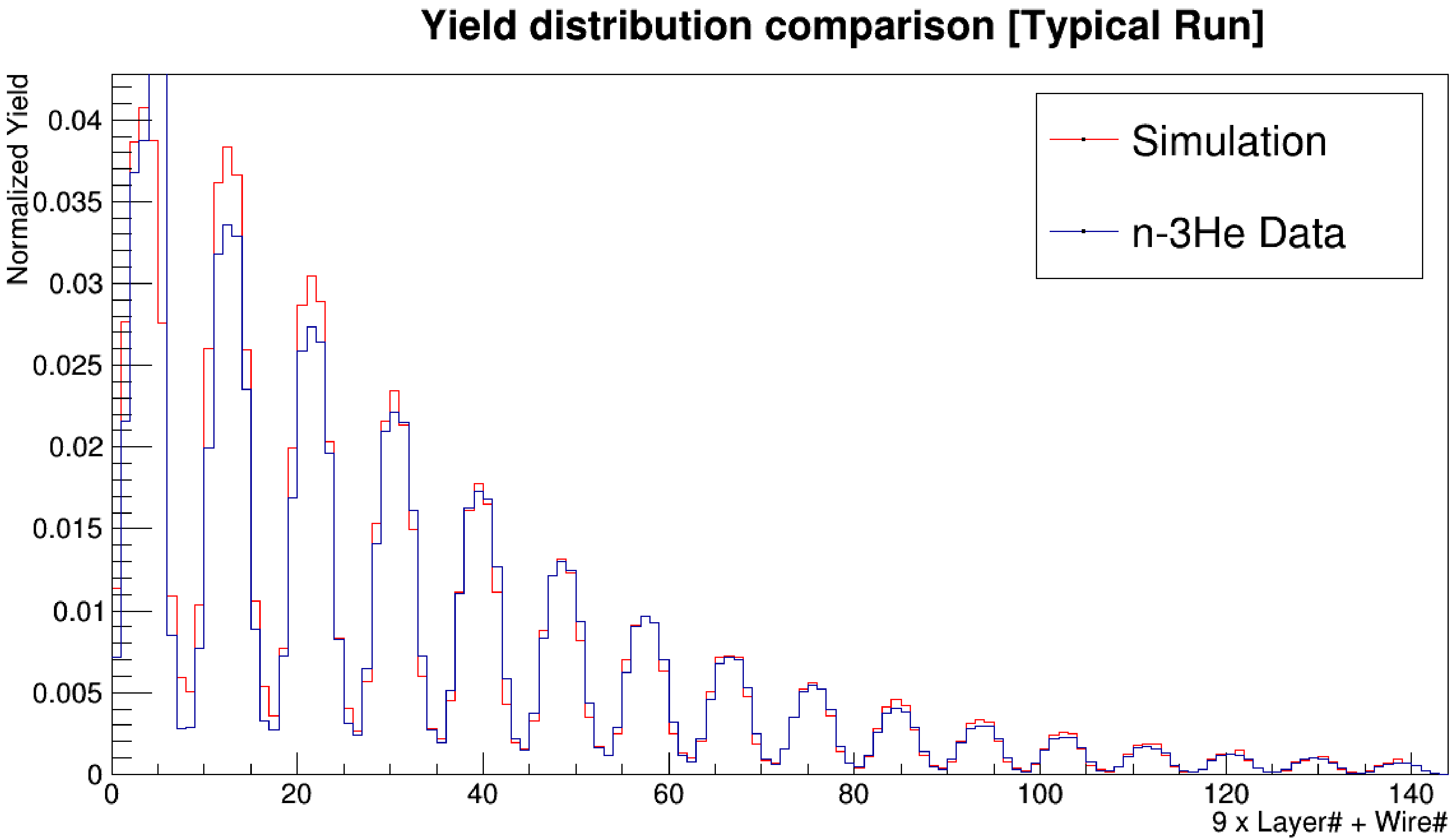
Validation of $\frac{1}{\sqrt{E}}$ dependence of cross section using Geant4
χ^2 / ndf 9.659e−05 / 6
p0 6.751 ± 0.09879
p1 −0.4984 ± 0.03466
p2 −8.735e−06 ± 0.002999
Log[Cross section [barn]]
10.2
10
9.8
9.6
9.4
9.2
9
−7
−6.5
−6
−5.5
−5
−4.5
Log[Neutron energy[eV]]

Validation attempt #5

Comparison of yield from simulation vs data

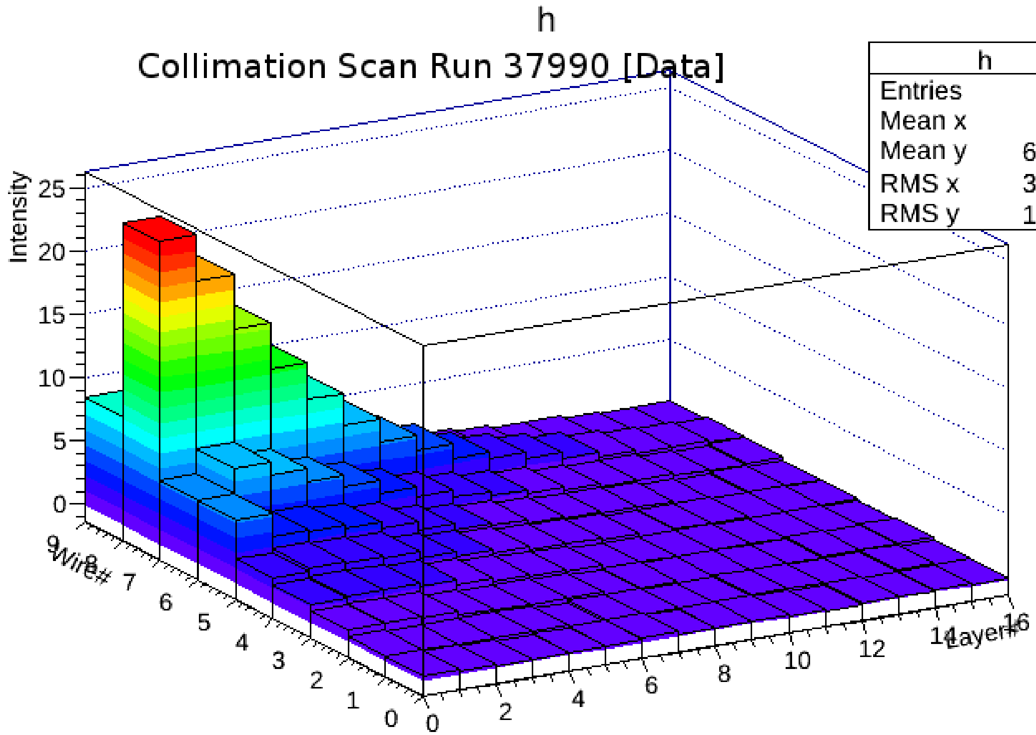

Yield Distribution from n-3He Data
h
Entries 144
Mean x 3.226
Mean y 4.081
RMS x 3.128
RMS y 1.76
Intensity(Volts)
Layer#
Wire#

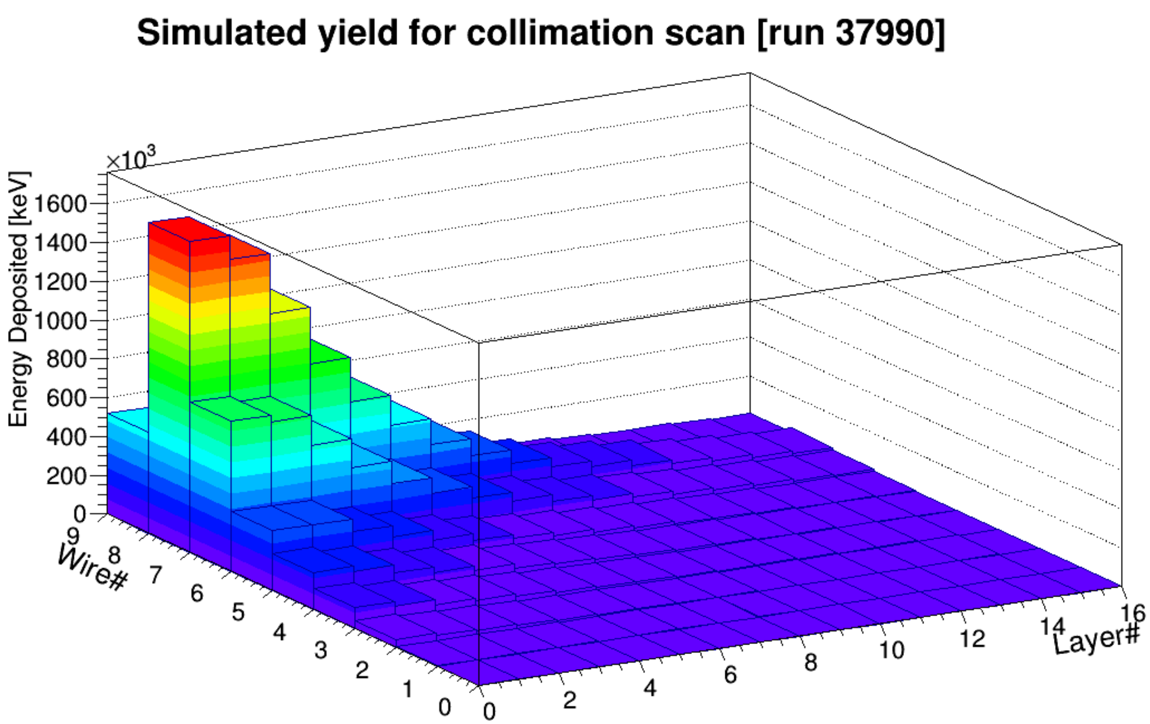

Yield Distribution from Geant4
h
Entries 144
Mean x 3.079
Mean y 4.004
RMS x 3.126
RMS y 1.79
Energy Deposited [keV]
×10³
Layer#
Wire#

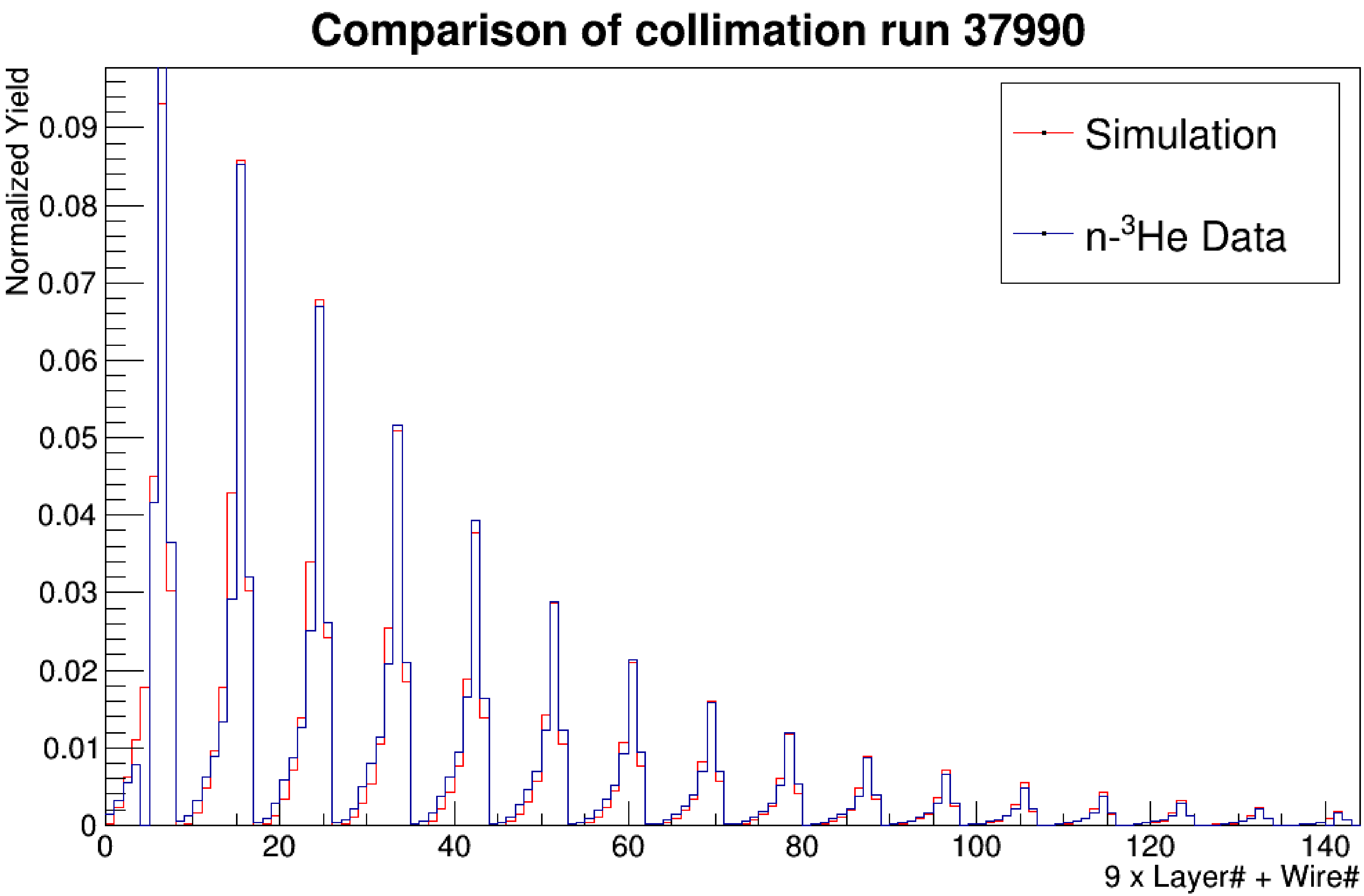

Yield distribution comparison [Typical Run]
Normalized Yield
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
20
40
60
80
100
120
140
9 x Layer# + Wire#
Simulation
n-3He Data

Validation attempt #6

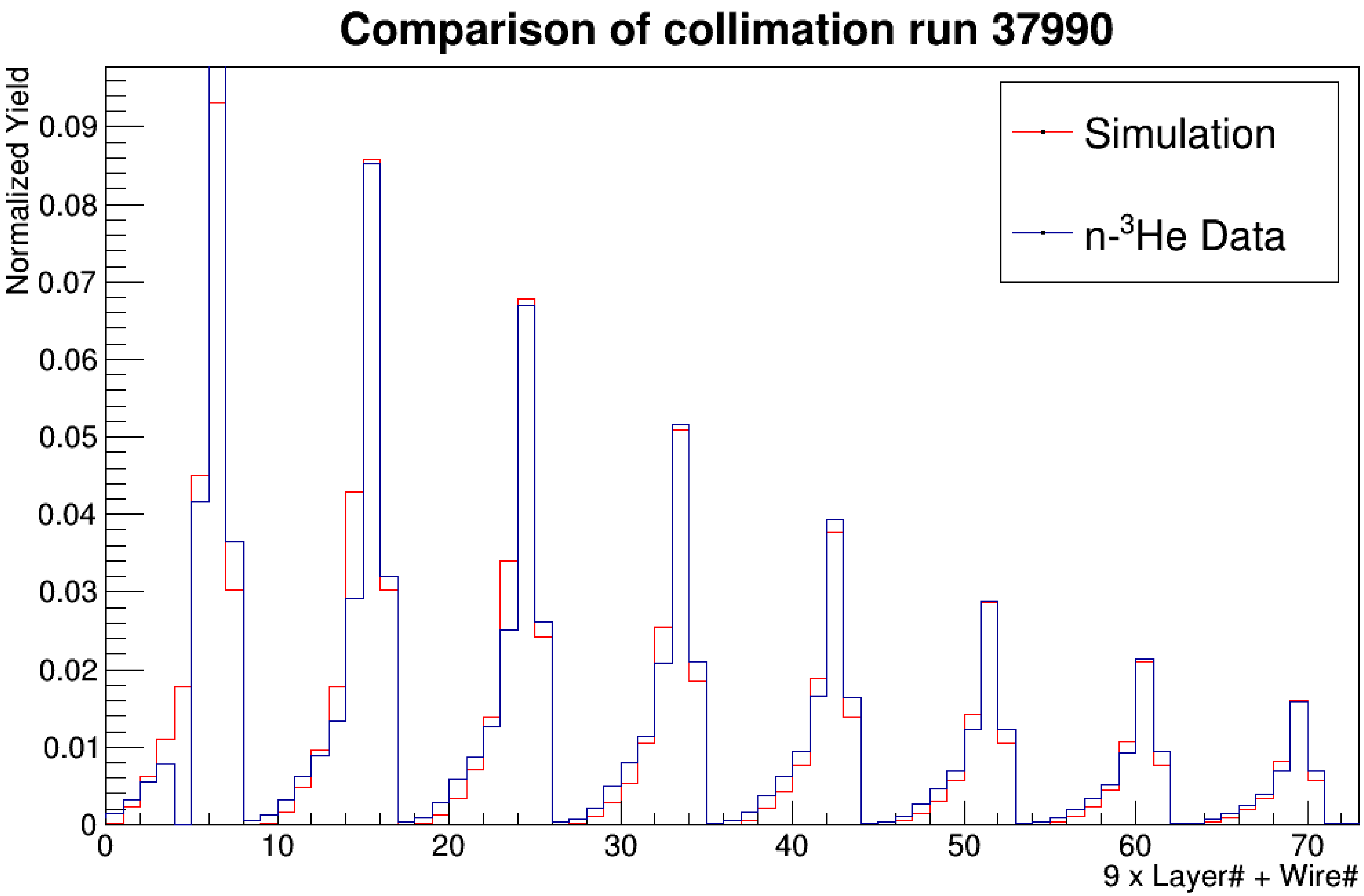
Comparison with collimation scan data

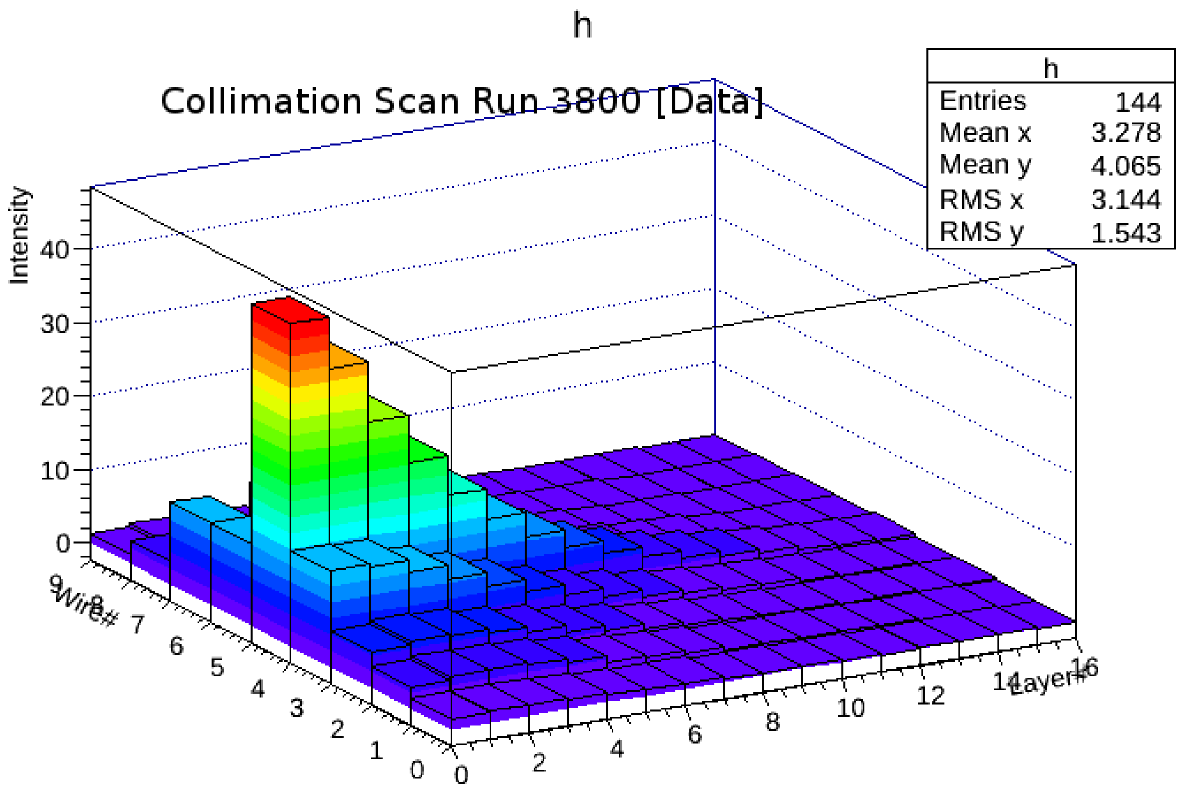

h
Collimation Scan Run 37990 [Data]
h
Entries 144
Mean x 3.21
Mean y 6.348
RMS x 3.153
RMS y 1.528
Intensity
Wire#
Layer#

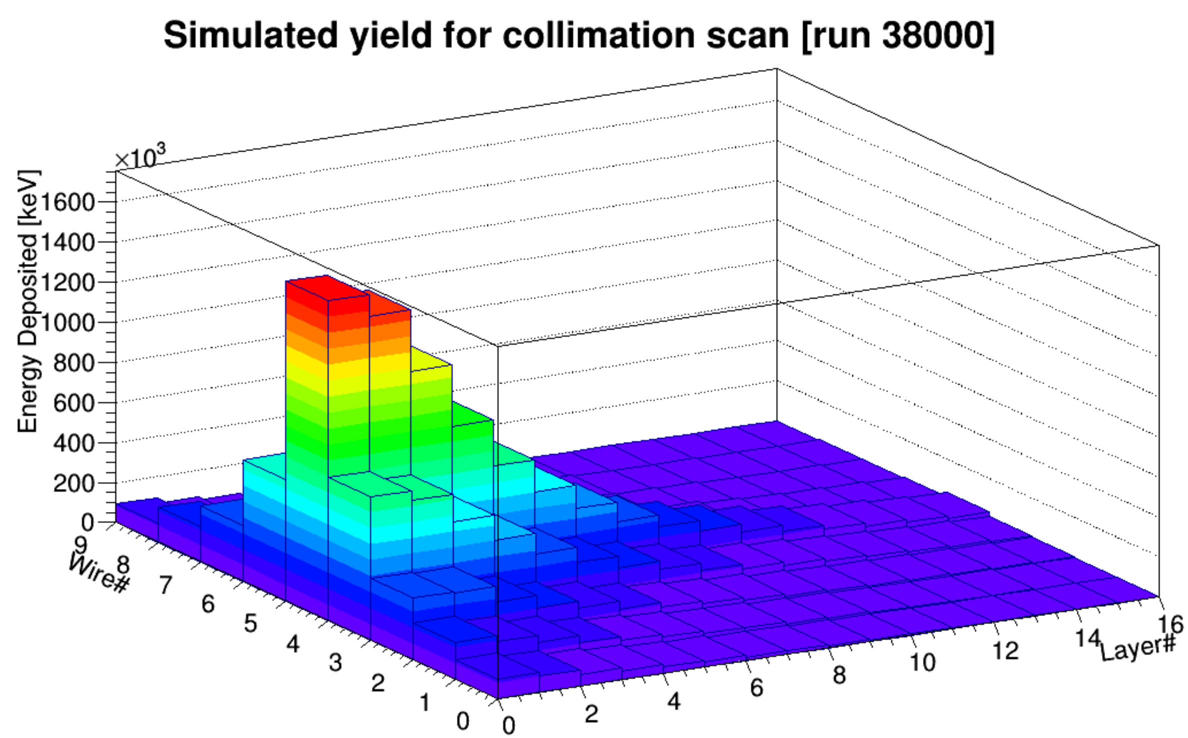

Simulated yield for collimation scan [run 37990]
$\times 10^3$
Energy Deposited [keV]
Wire#
Layer#

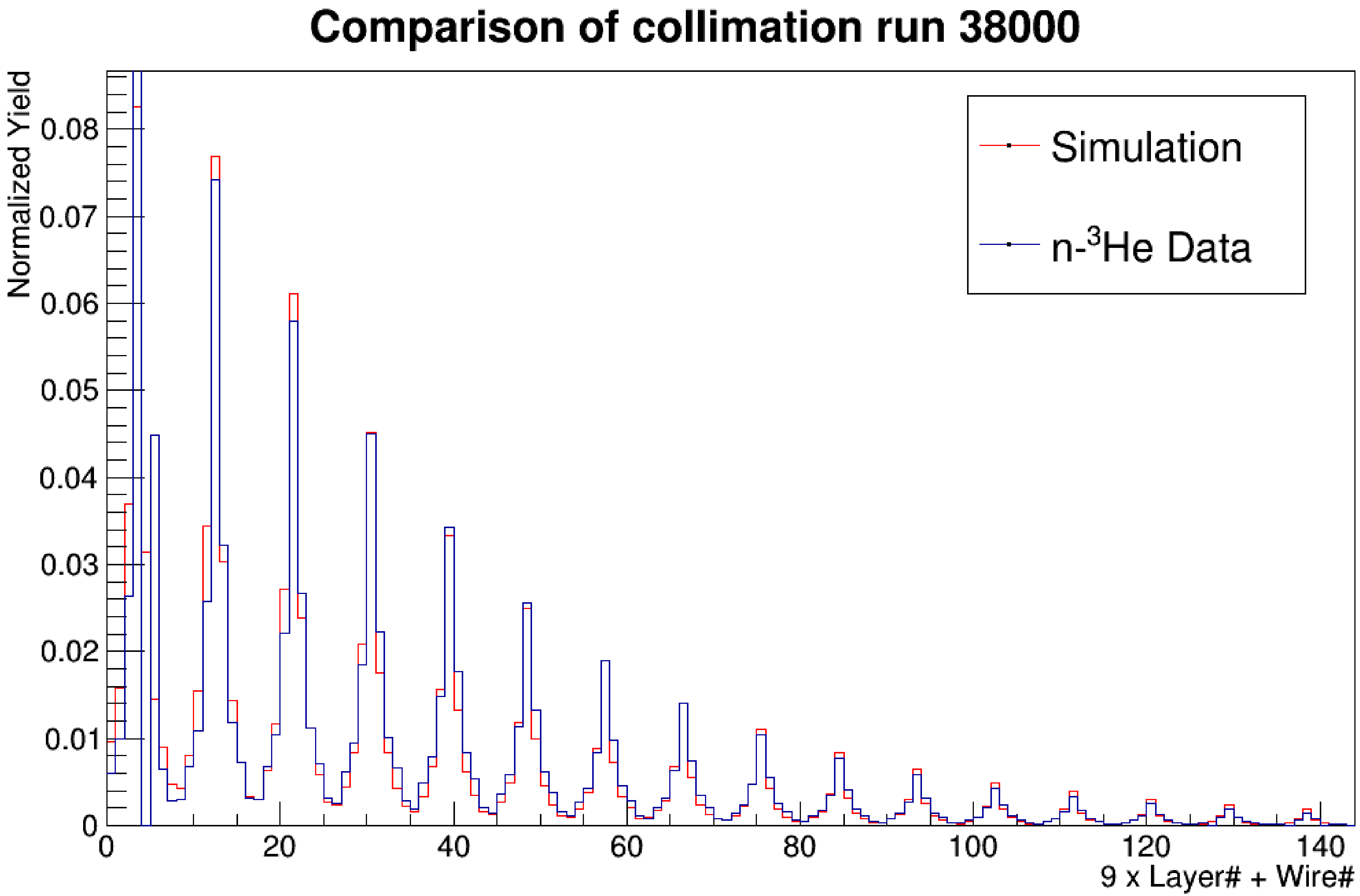


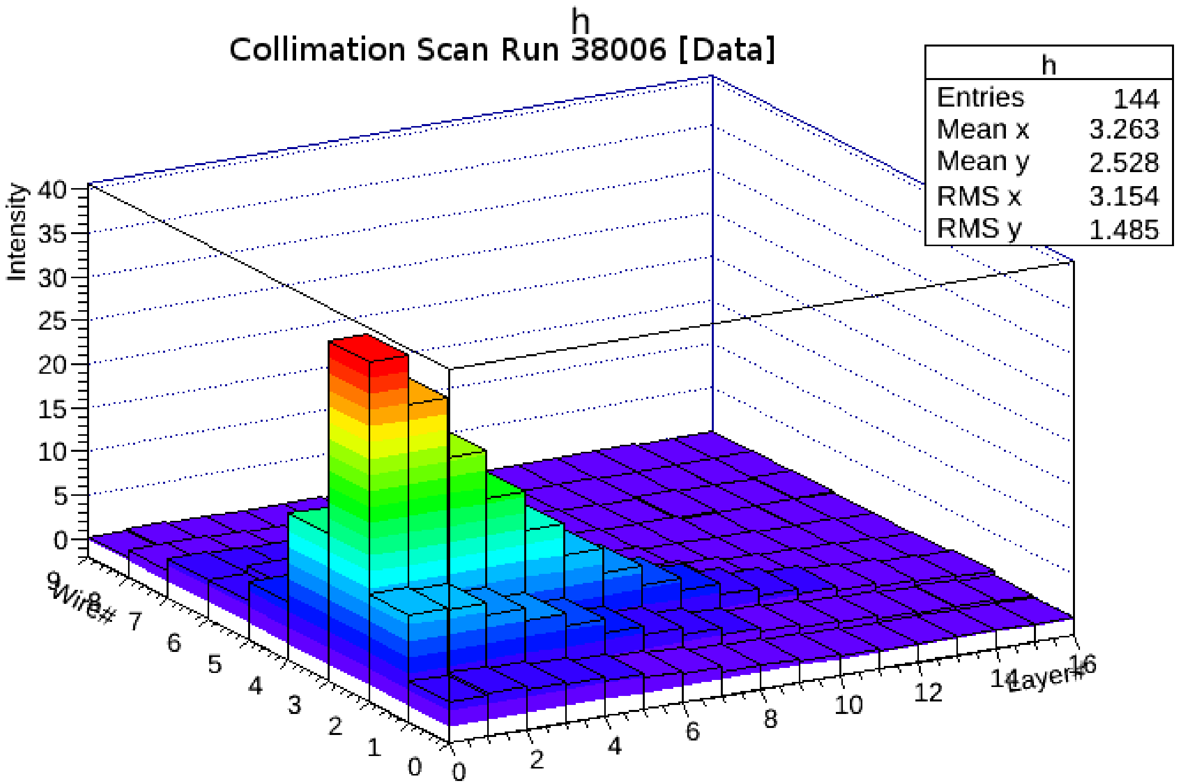
Comparison of collimation run 37990
Normalized Yield
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
120
140
9 x Layer# + Wire#
Simulation
n-3He Data

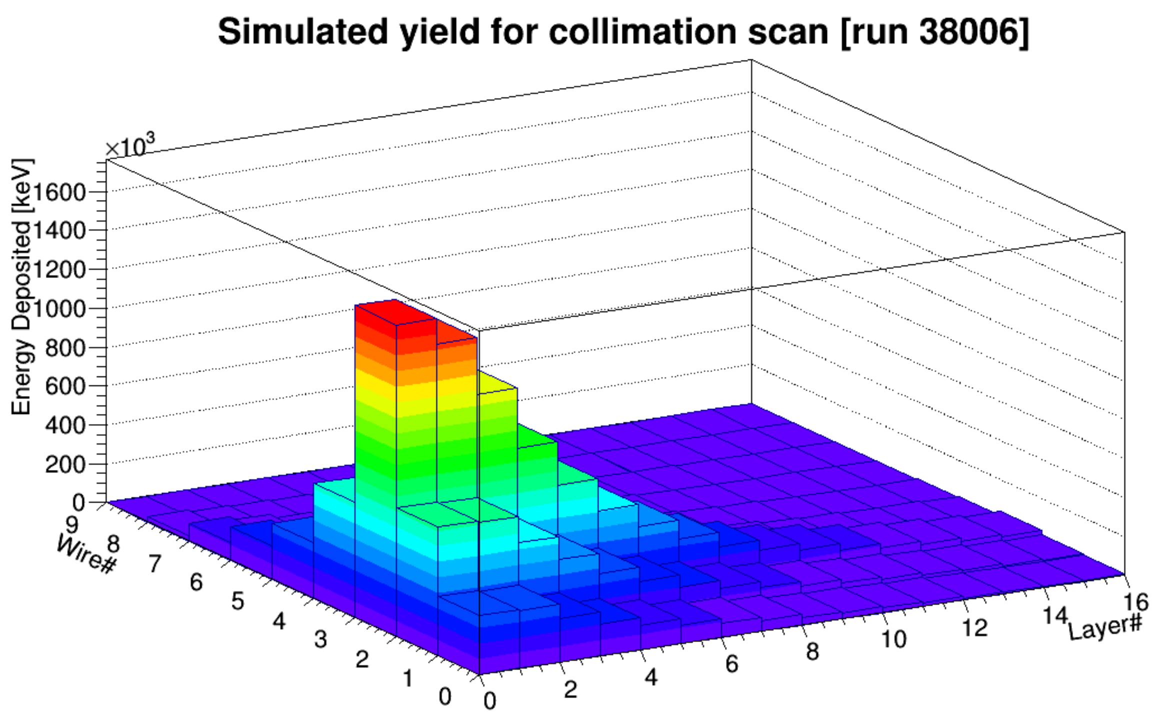

Comparison of collimation run 37990
Normalized Yield
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
10
20
30
40
50
60
70
9 x Layer# + Wire#
Simulation
n-3He Data

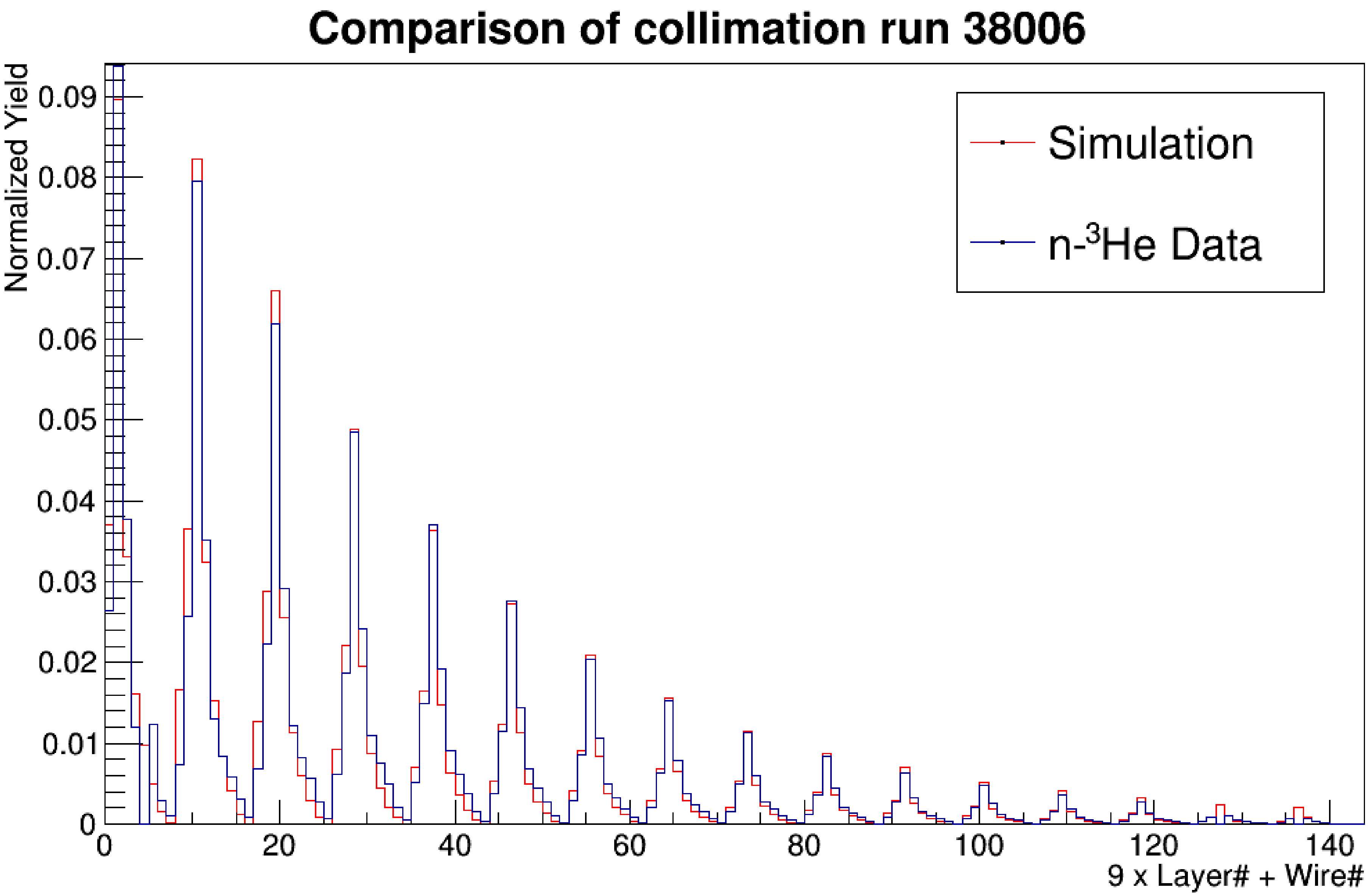

h
Collimation Scan Run 3800 [Data]
h
Entries 144
Mean x 3.278
Mean y 4.065
RMS x 3.144
RMS y 1.543
Intensity
Wire#
Layer#


Simulated yield for collimation scan [run 38000]
×10^3
Energy Deposited [keV]
Wire#
Layer#


Comparison of collimation run 38000
Normalized Yield
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
20
40
60
80
100
120
140
9 x Layer# + Wire#
Simulation
n-3He Data


h
Collimation Scan Run 38006 [Data]
h
Entries 144
Mean x 3.263
Mean y 2.528
RMS x 3.154
RMS y 1.485
Intensity
Wire#
Layer#


Simulated yield for collimation scan [run 38006]
Energy Deposited [keV]
Wire#
Layer#


Comparison of collimation run 38006
Simulation
n-3He Data
Normalized Yield
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
120
140
9 x Layer# + Wire#