Simulations for the Dynamic Range of the EMC

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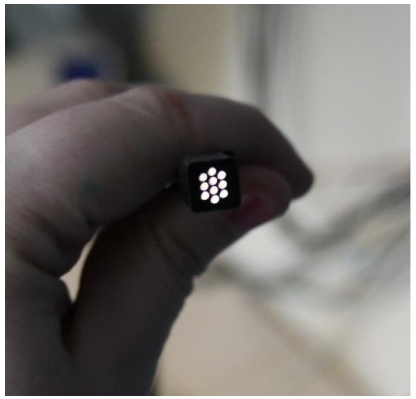
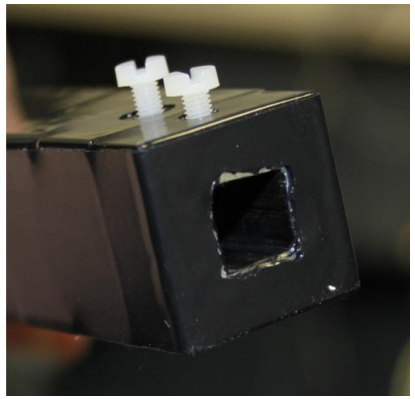
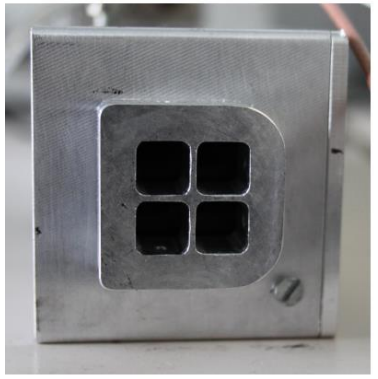
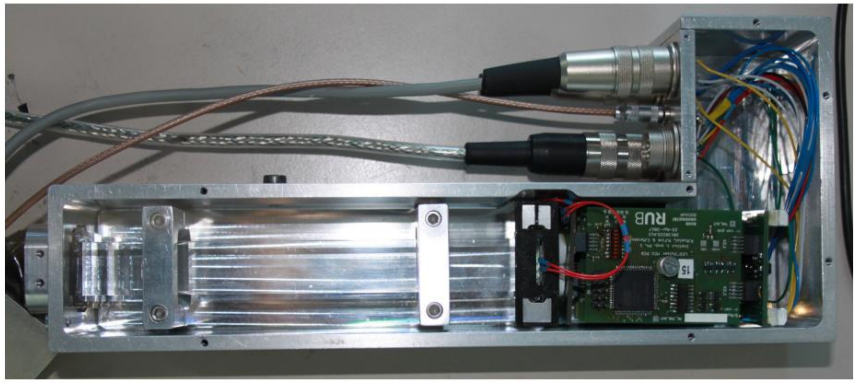
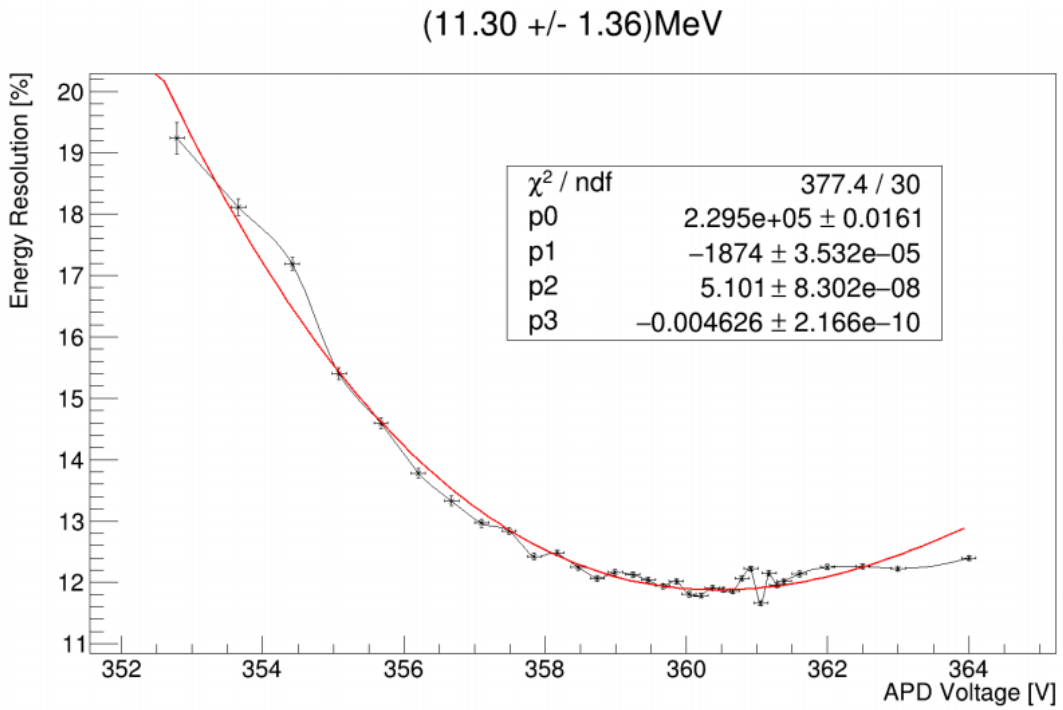
- EMC : high energy resolution is needed, especially in MeV range
- 2019: Measurements with prototype LED lightpulser from Bochum
- One single LAAPD glued with optical grease to type-6 crystal + APFEL-ASIC + SADC (ver. 2.0) inside a climate chamber (-25°C)
- Trying to determine optimal bias voltage/gain for optimal energy resolution[1]

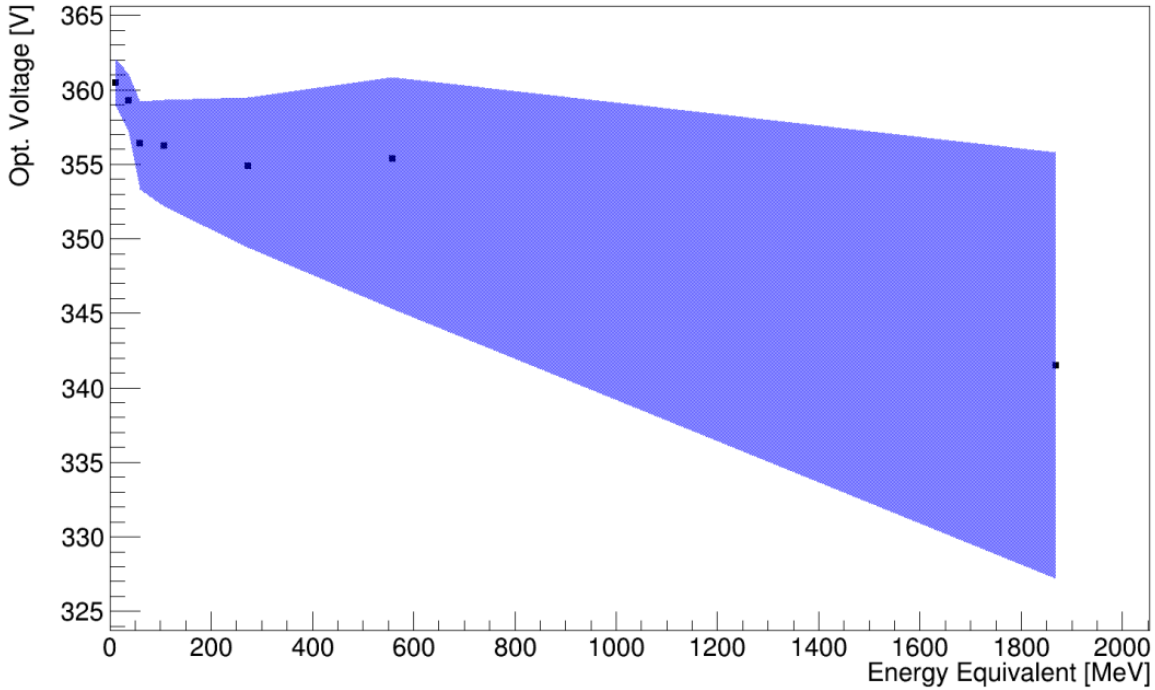


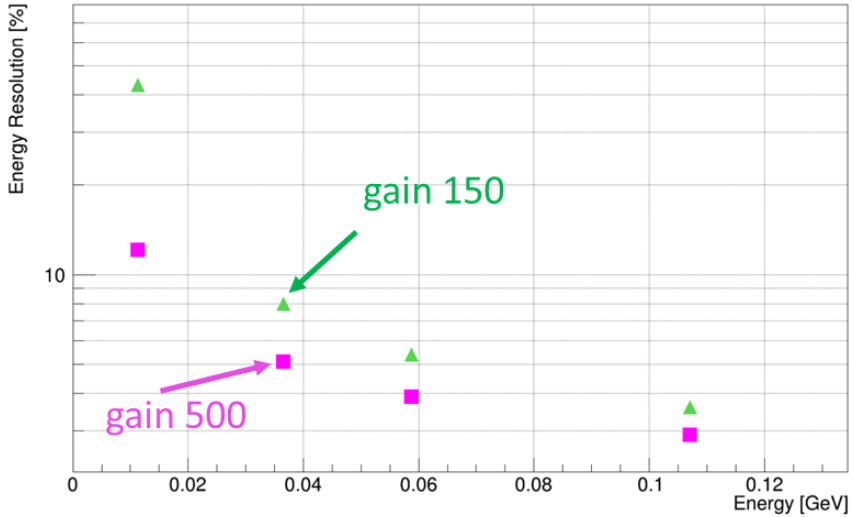








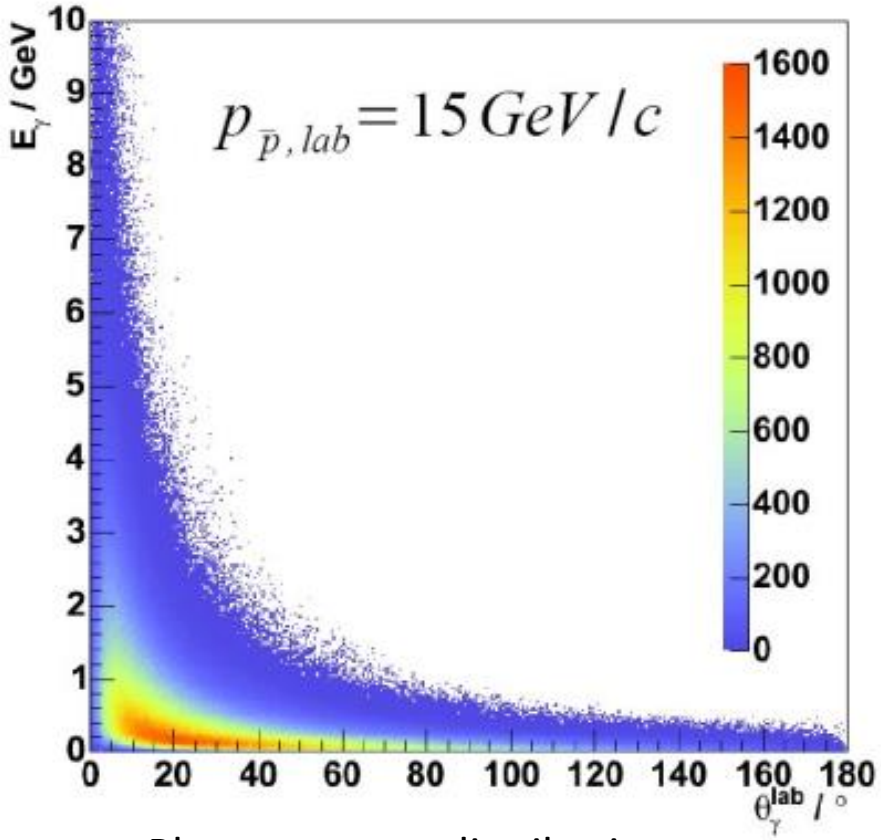




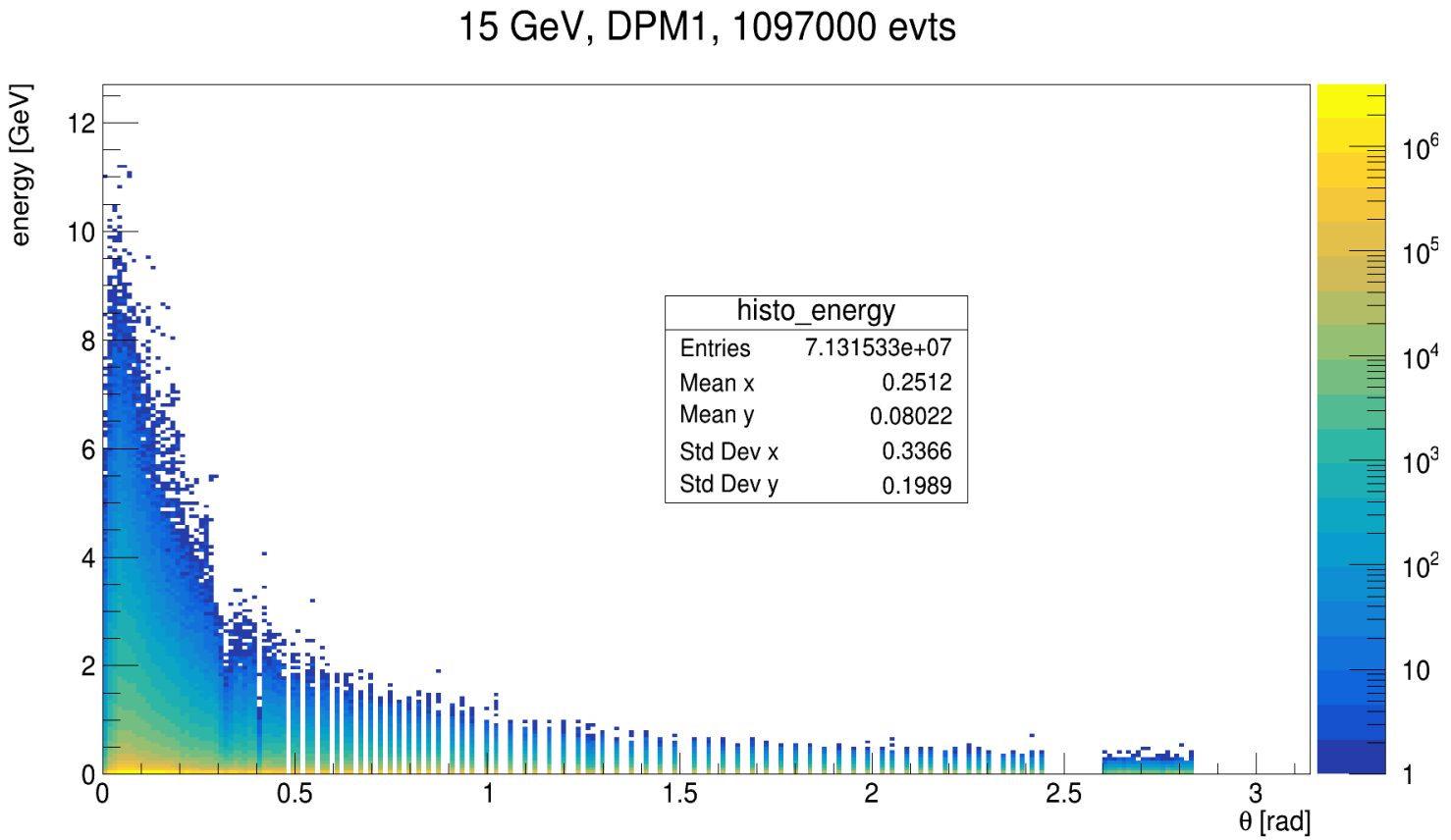
- Results supported by a study done by Aniko [2] with a matrix of BEC like crystals
- However: limited by dynamic range of APFEL-ASIC

- So far used: Simulated photon energy distribution from the EMC TDR [3] from 2008

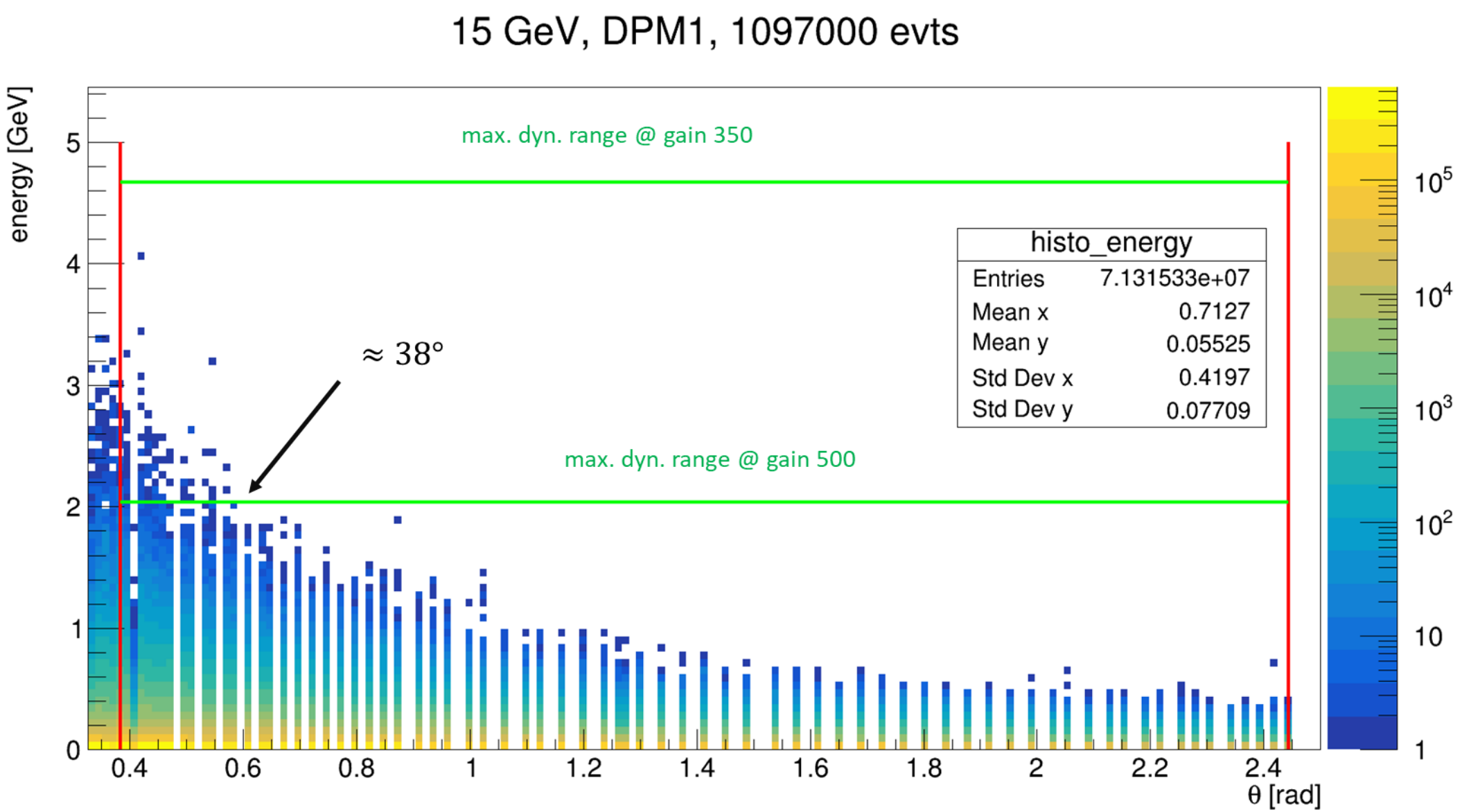
- However: Since then changes have been made to the simulation framework -> new simulations with the DPM1 background & one of the latest pandaroot versions (jun19):



Photon energy distribution

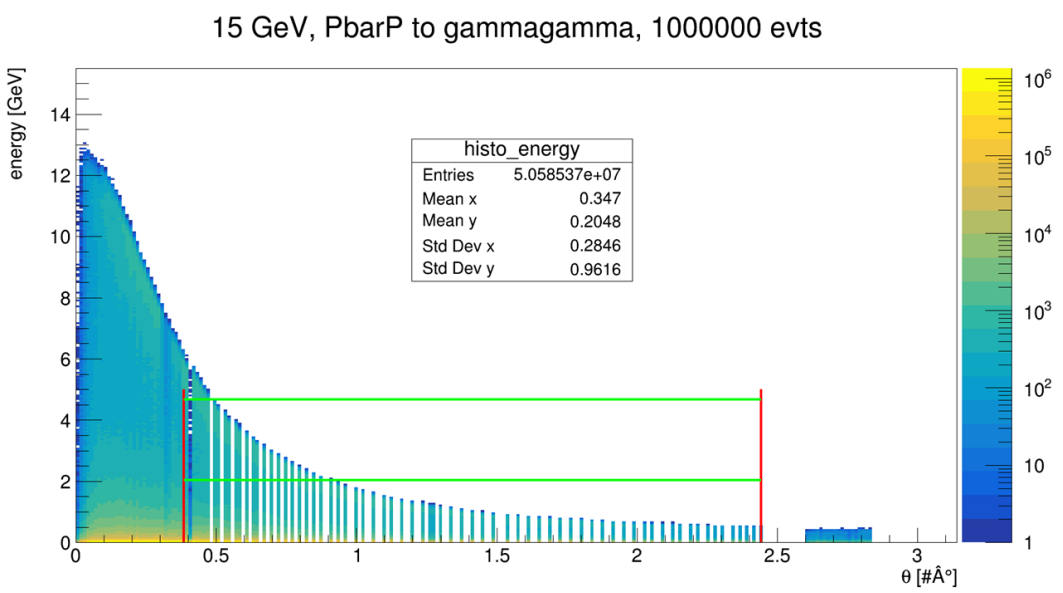


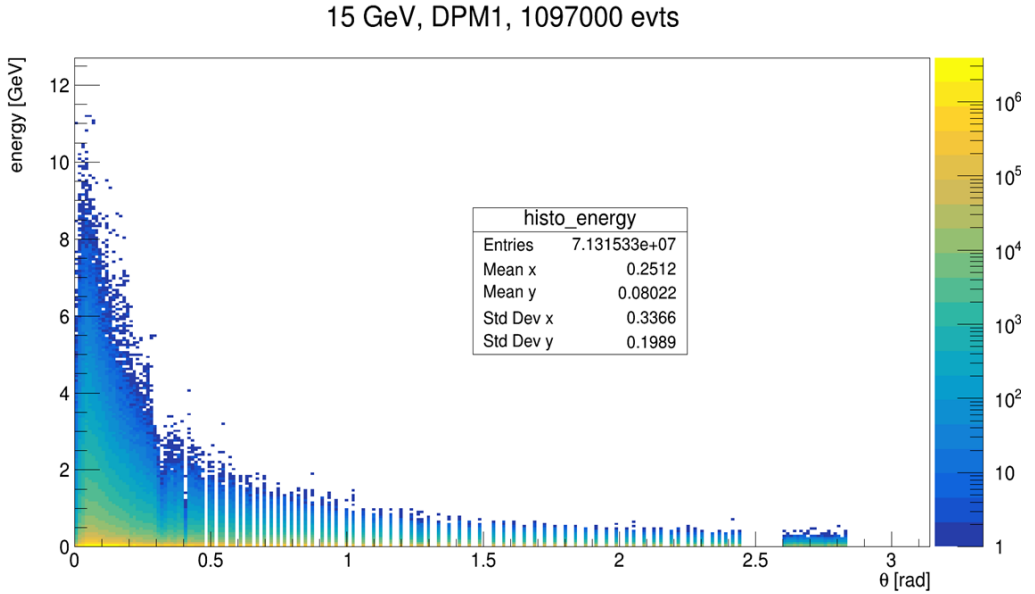
Deposited energy in crystal

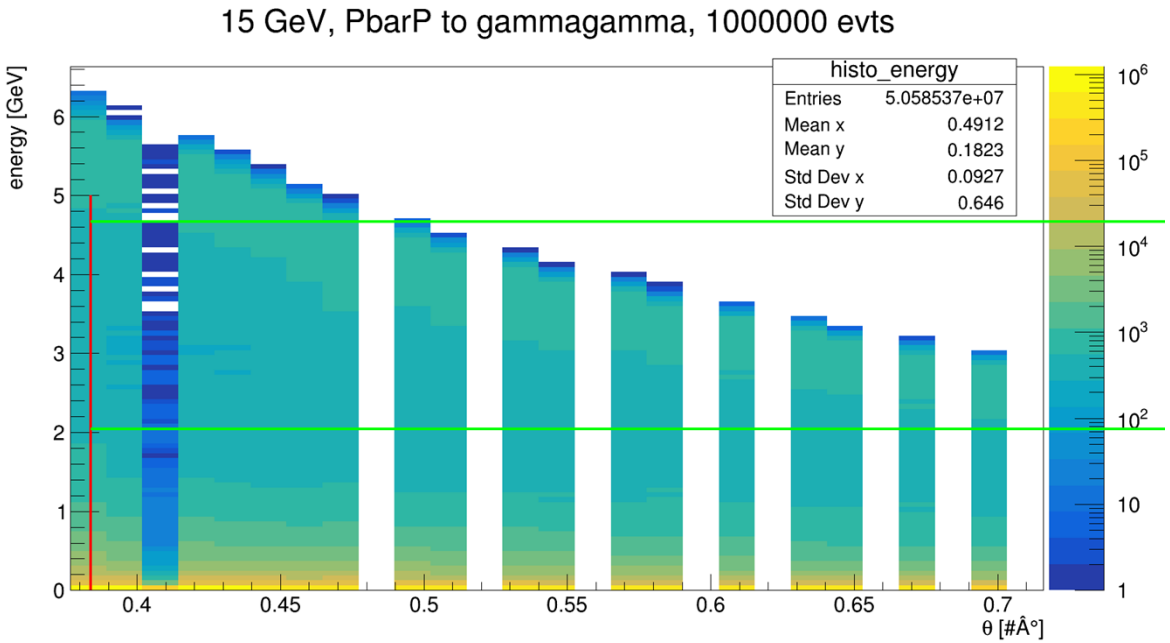

15 GeV, DPM1, 1097000 evts
energy [GeV]
θ [rad]
max. dyn. range @ gain 350
max. dyn. range @ gain 500
≈ 38°
histo_energy
Entries 7.131533e+07
Mean x 0.7127
Mean y 0.05525
Std Dev x 0.4197
Std Dev y 0.07709

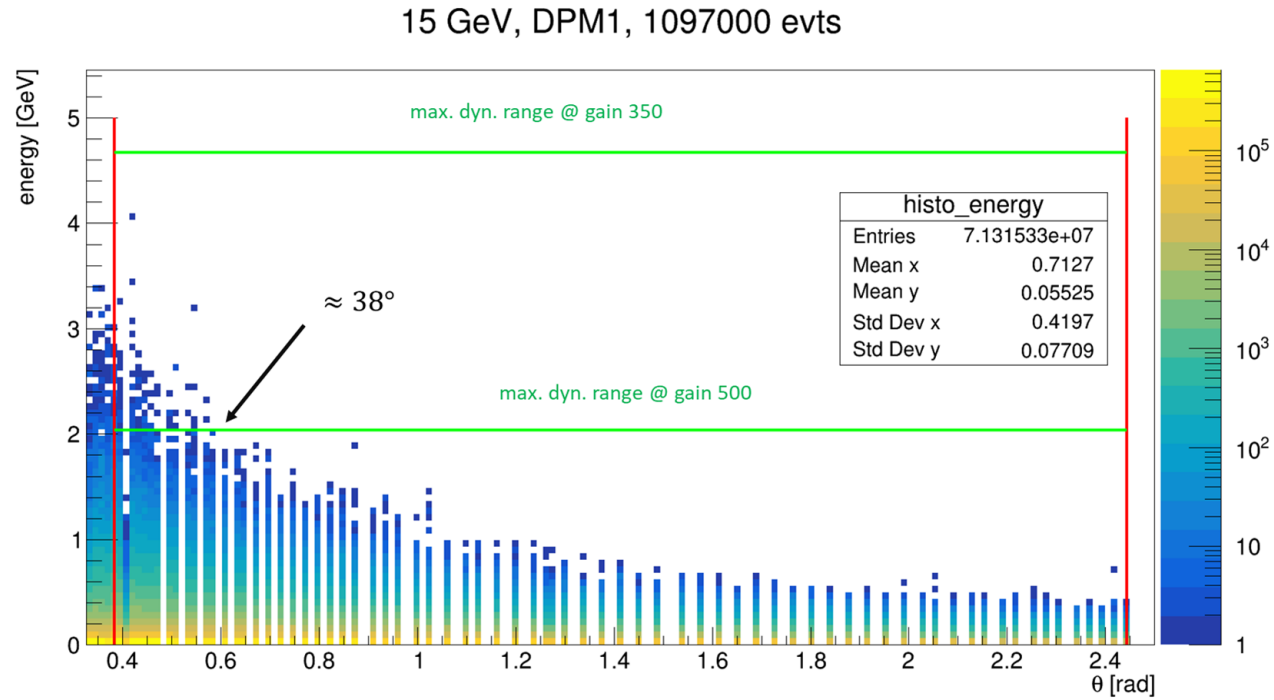
Last Collaboration Meeting:

- Using DPM1 might not be ideal
- Better: Use decay like: pbarp to gammagamma for higher energies
- 1M events with pbarp to gammagamma @ 15 GeV



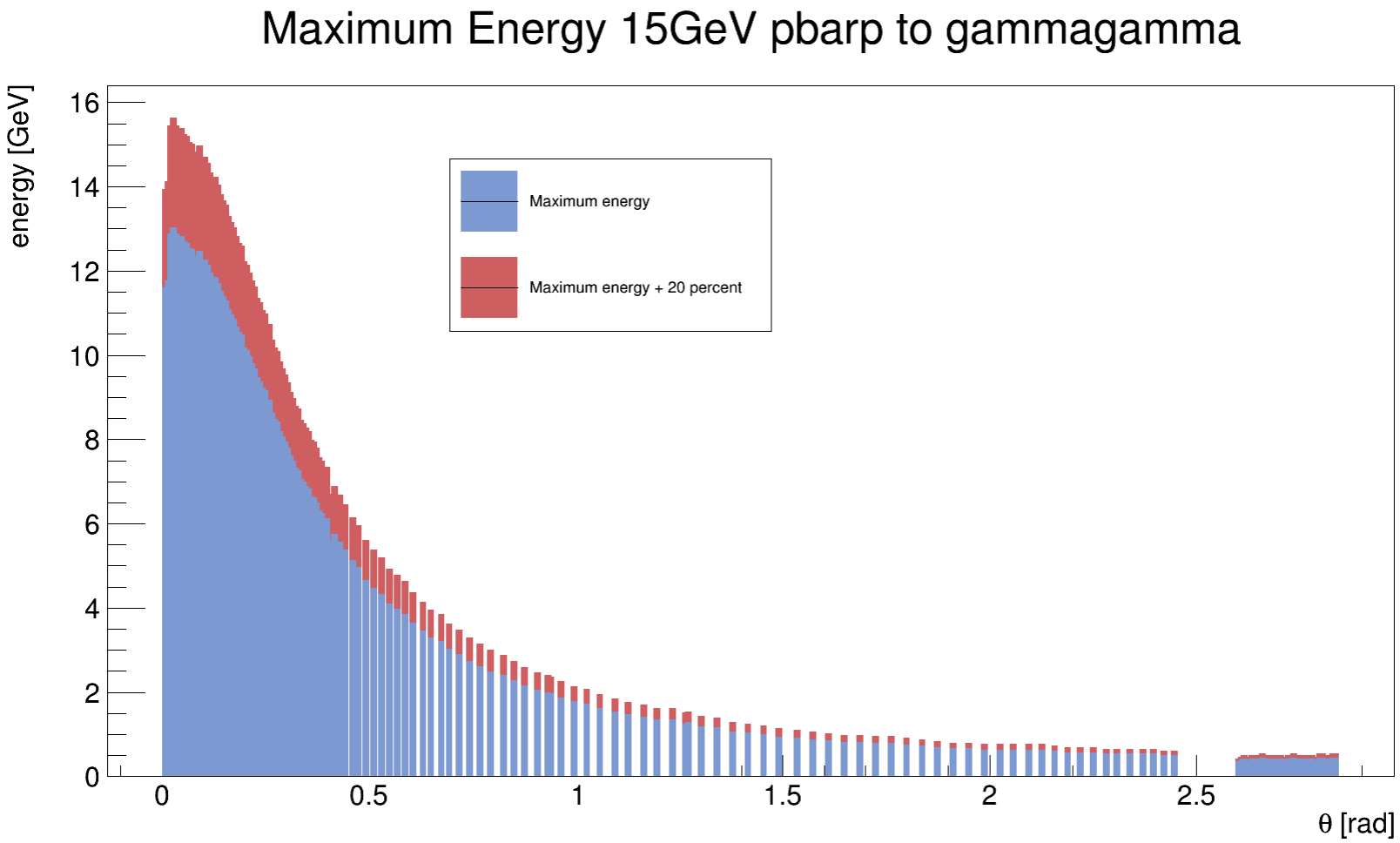



15 GeV, PbarP to gammagamma, 1000000 evts
histo_energy
Entries 5.058537e+07
Mean x 0.4912
Mean y 0.1823
Std Dev x 0.0927
Std Dev y 0.646
energy [GeV]
θ [#Â°]


15 GeV, DPM1, 1097000 evts
max. dyn. range @ gain 350
max. dyn. range @ gain 500
≈ 38°
histo_energy
Entries 7.131533e+07
Mean x 0.7127
Mean y 0.05525
Std Dev x 0.4197
Std Dev y 0.07709
energy [GeV]
θ [rad]

New Simulation

- Maximum Energy + 20% safety margin



Discussion

Reminder[4]

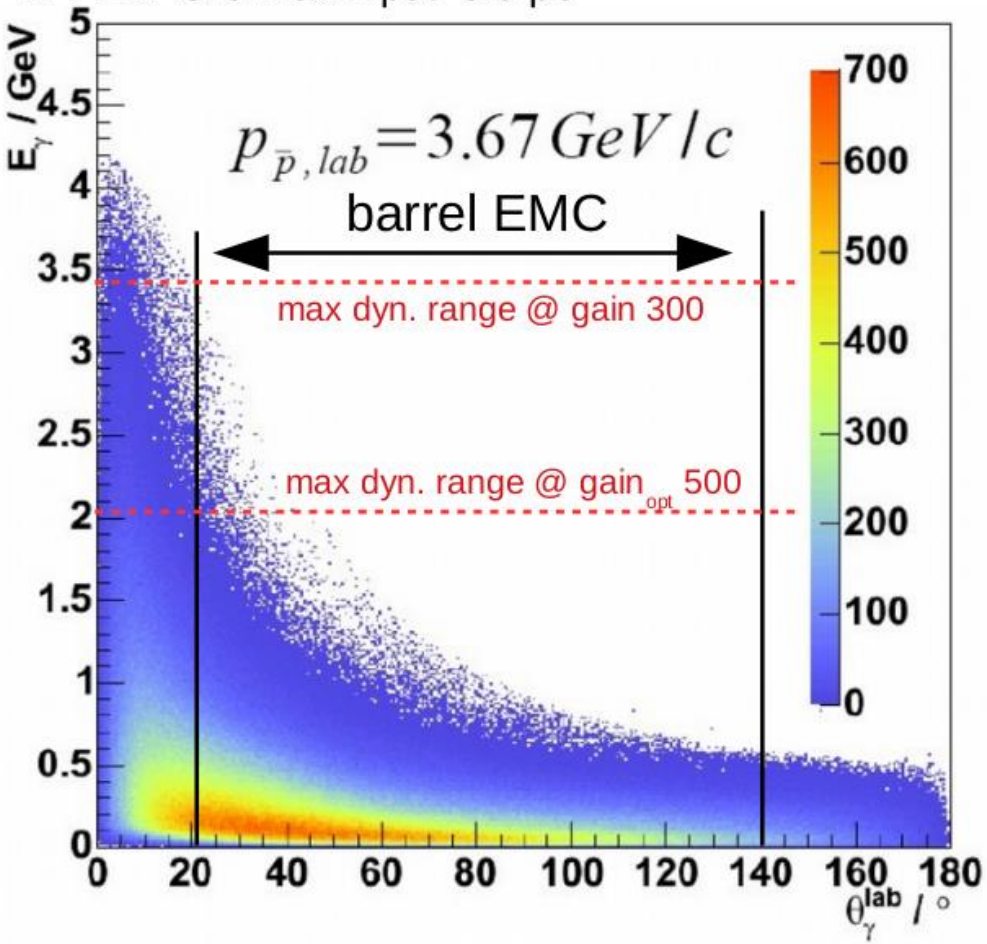
PWO-II LY @ -25°C: 100 PMT-phe/MeV (LY@18°C X4)

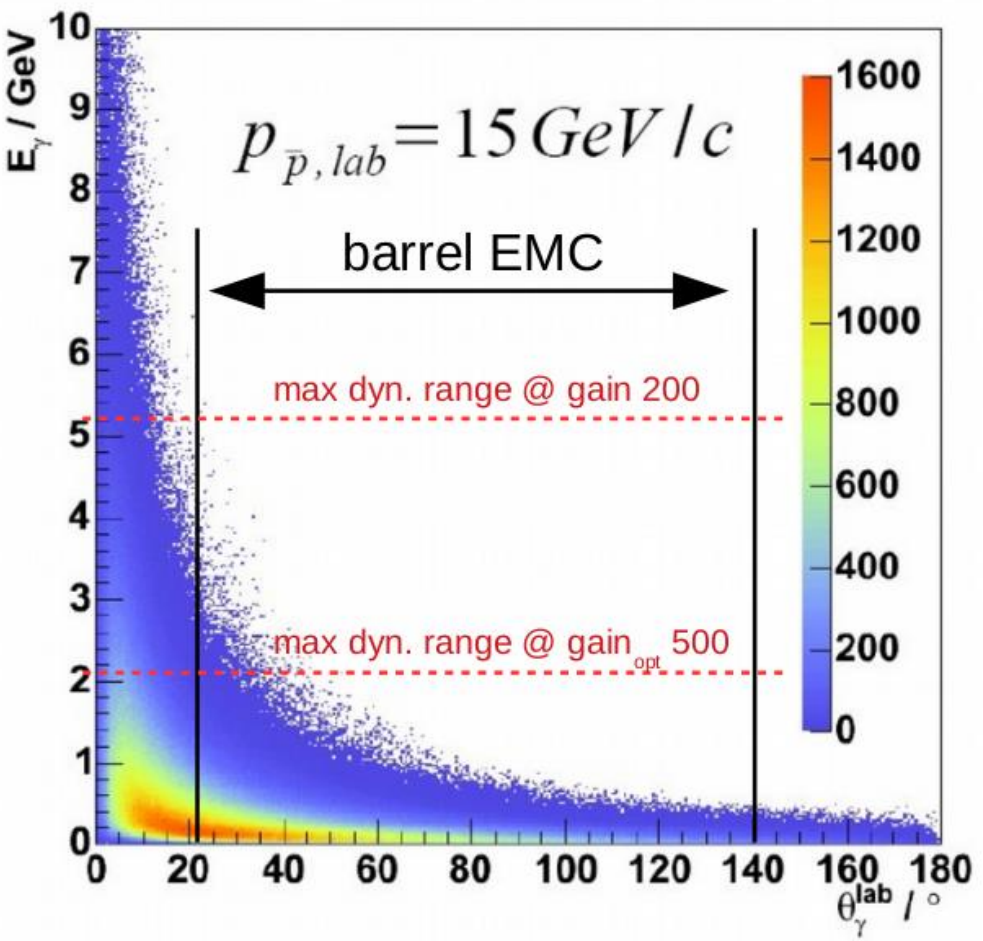
APD covers ~13% crystal endface

PMT QE = 20%, LAAP QE= 80% → 52 APD-phe/MeV

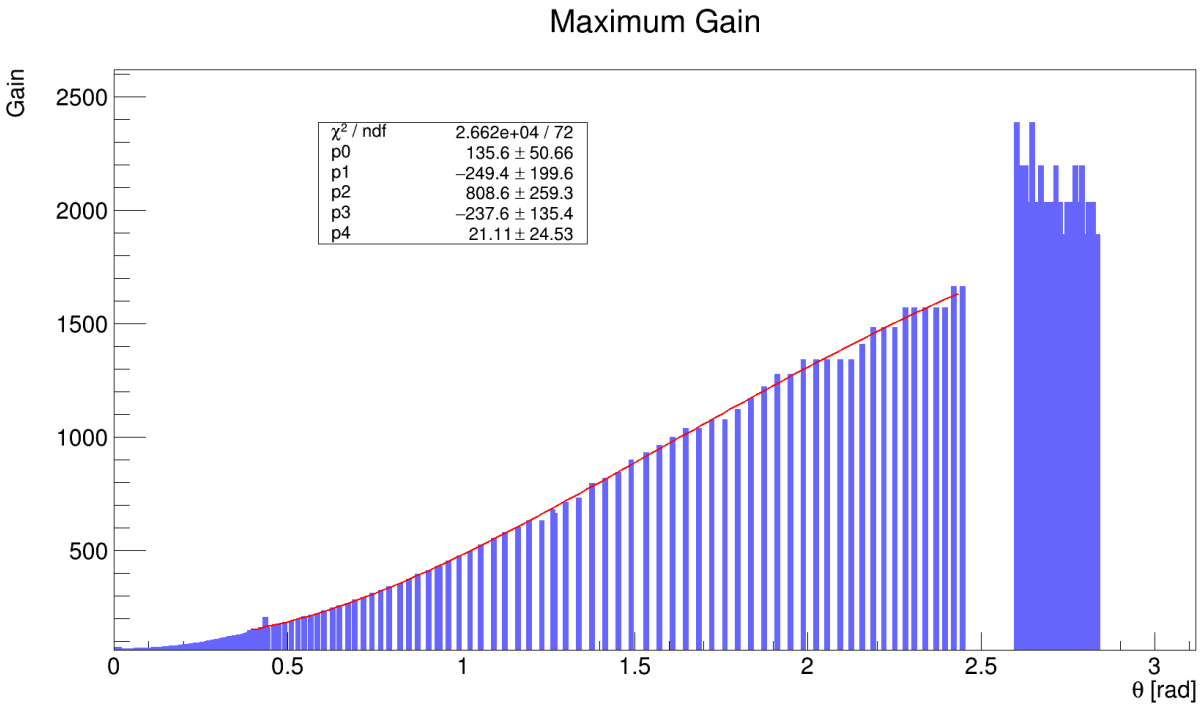
APFEL ASIC max Input: 8.5 pC

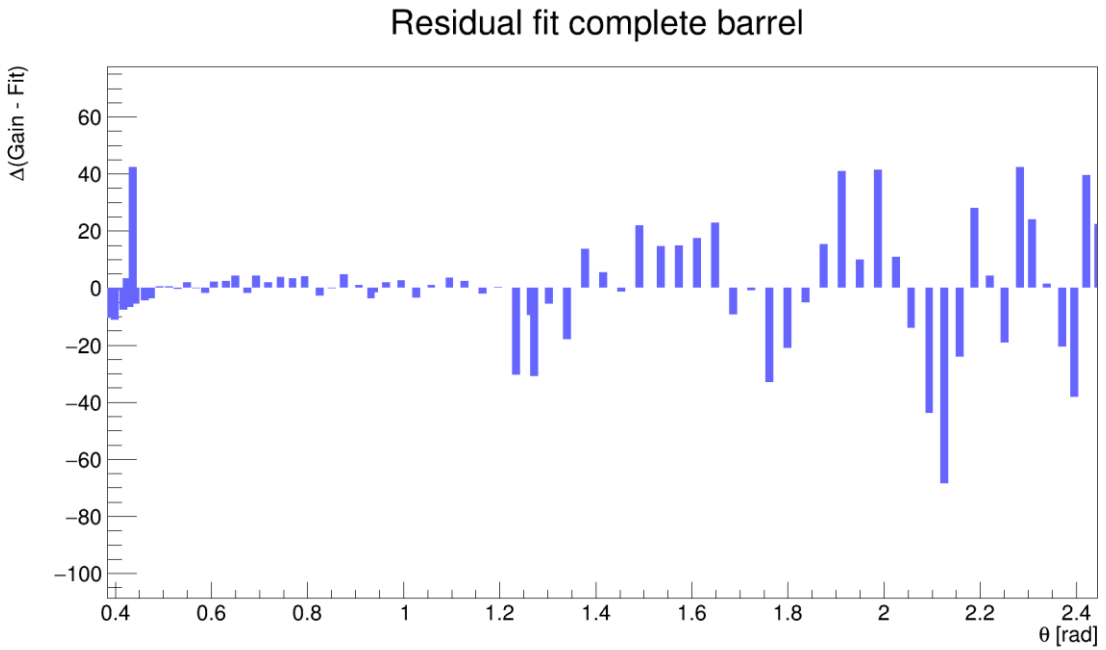
$$E_{max}(gain_{opt}500) = \frac{8.5\,10^{-12}C}{52 \cdot 1.6 \cdot 10^{-19}\,C/MeV \cdot 500} = 2043.3\,MeV$$



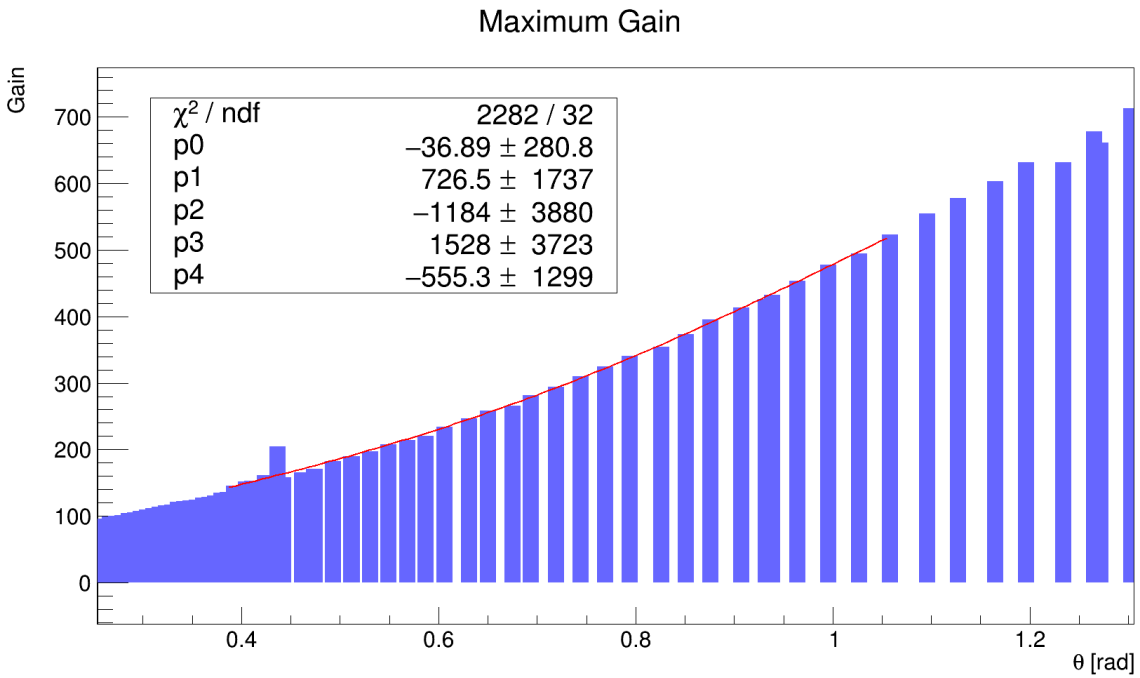


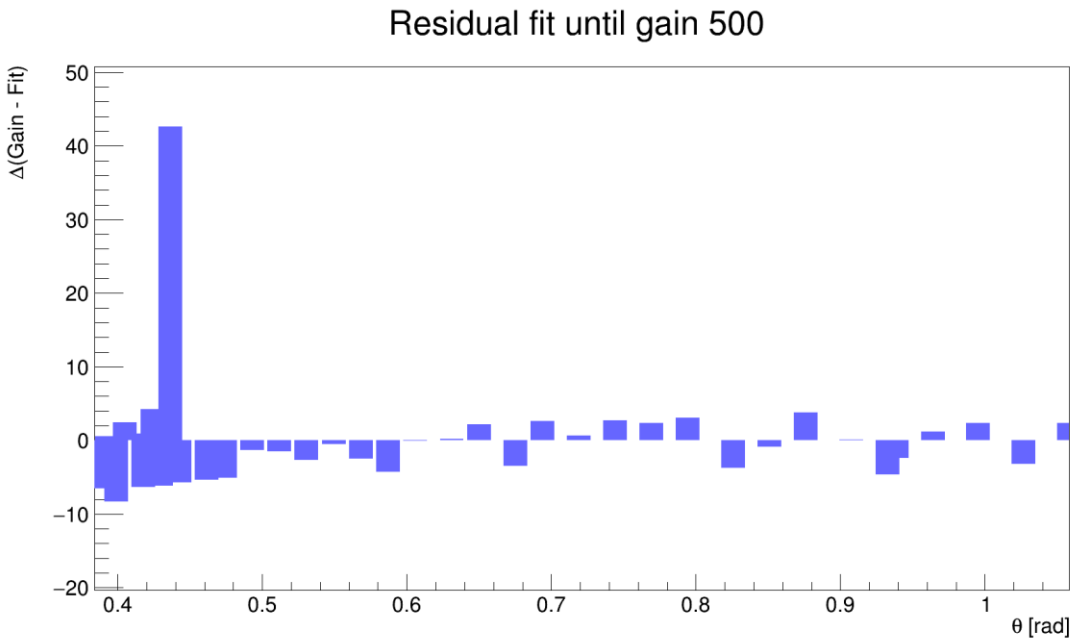
Parametrisation of Gain

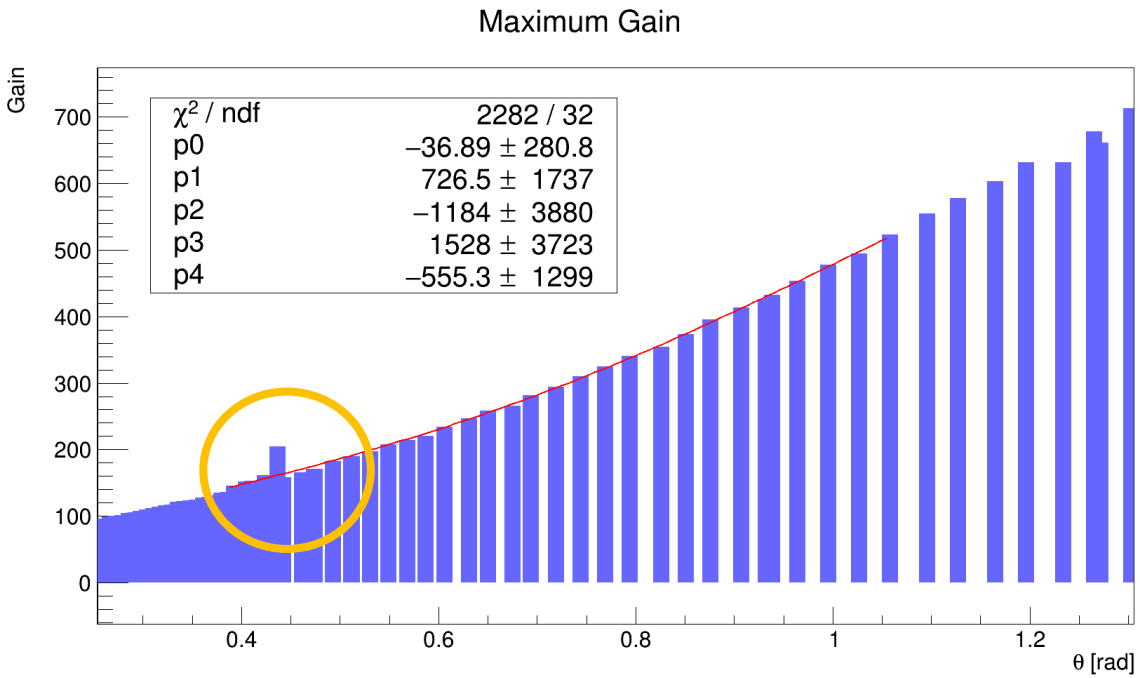




- 4th degree polinomial seems to work well
- Fit for entire barrel not optimal


Maximum Gain
Gain
χ² / ndf 2282 / 32
p0 −36.89 ± 280.8
p1 726.5 ± 1737
p2 −1184 ± 3880
p3 1528 ± 3723
p4 −555.3 ± 1299
θ [rad]


Residual fit until gain 500
Δ(Gain - Fit)
θ [rad]


Maximum Gain
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p0 −36.89 ± 280.8
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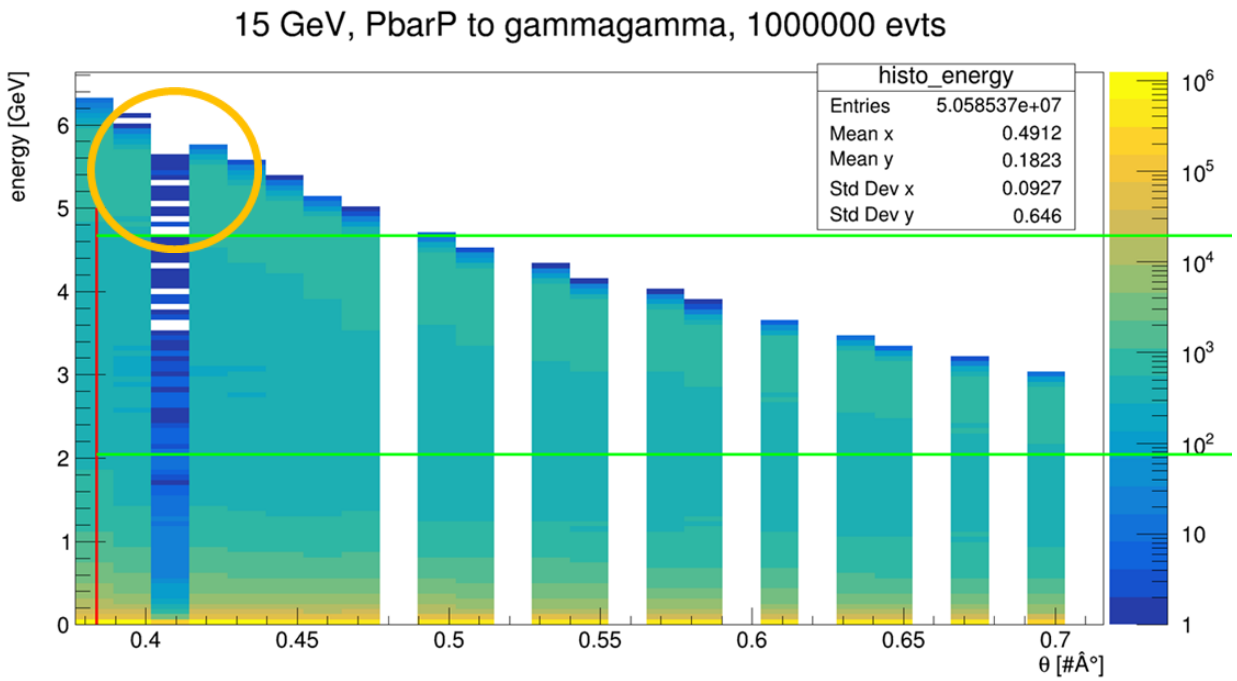
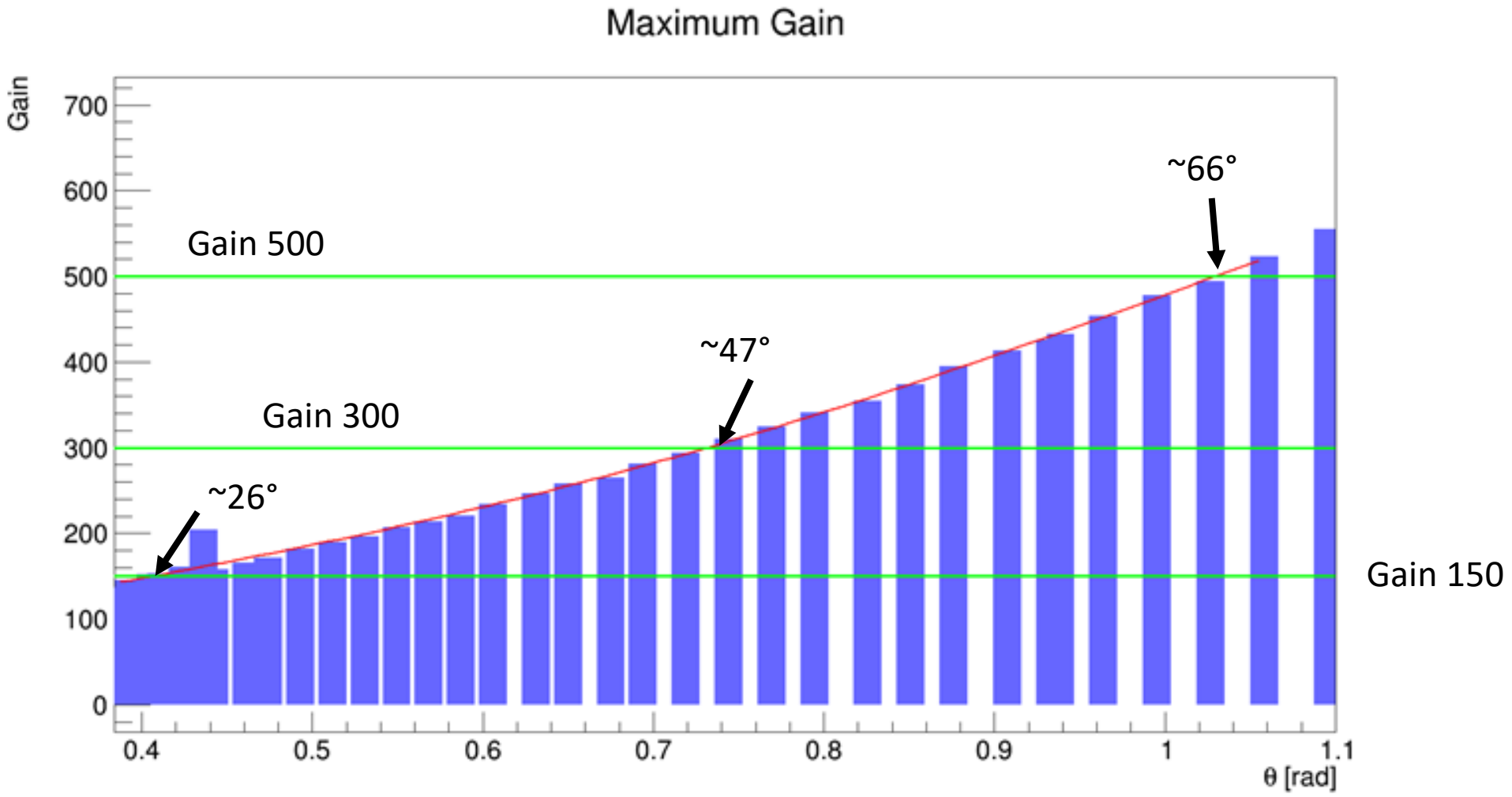
p3 1528 ± 3723
p4 −555.3 ± 1299
θ [rad]


15 GeV, PbarP to gammagamma, 1000000 evts
histo_energy
Entries 5.058537e+07
Mean x 0.4912
Mean y 0.1823
Std Dev x 0.0927
Std Dev y 0.646
energy [GeV]
θ [#Â°]

Proposal

- Use three different gains for different areas of barrel



Proposal

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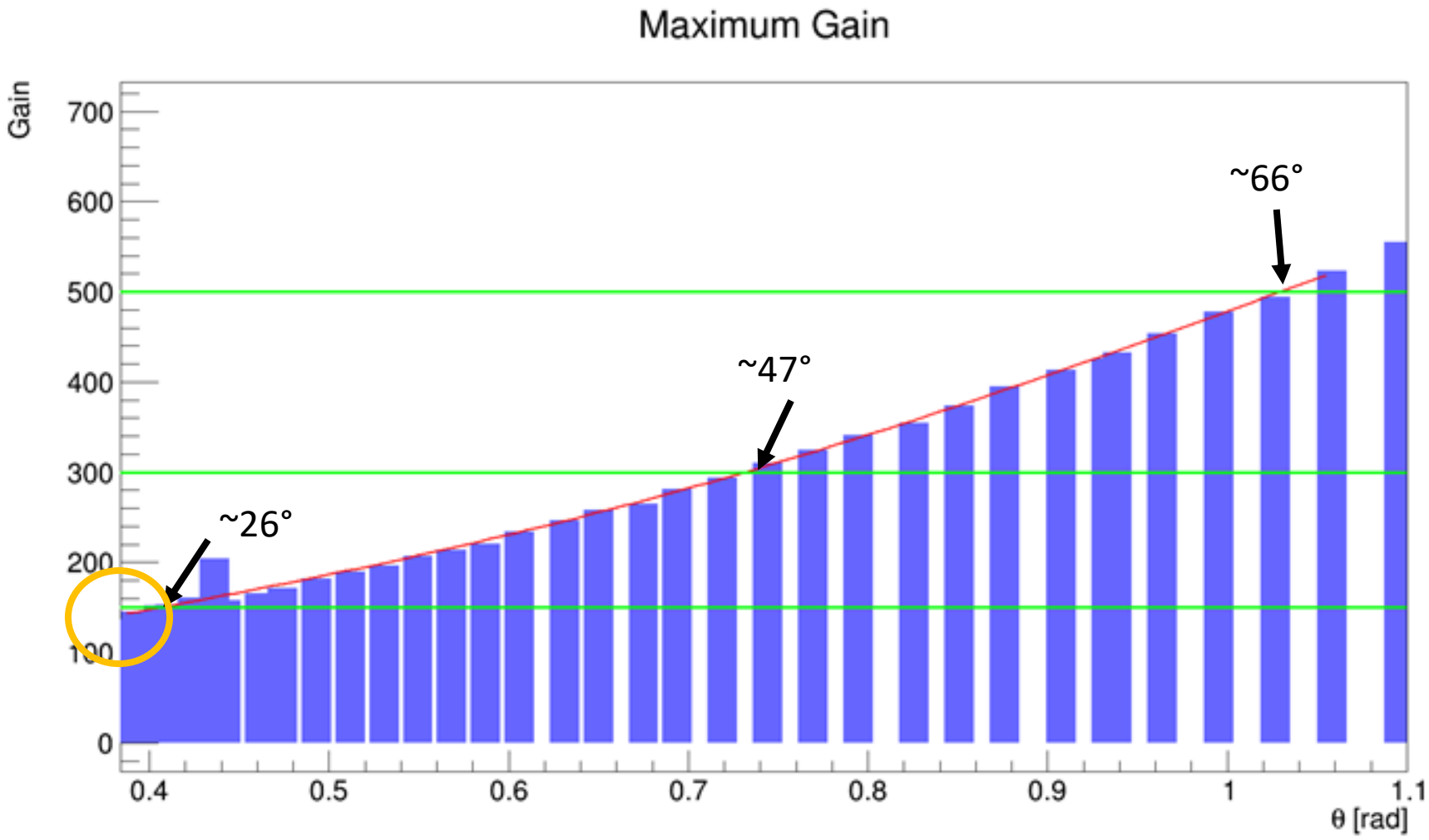
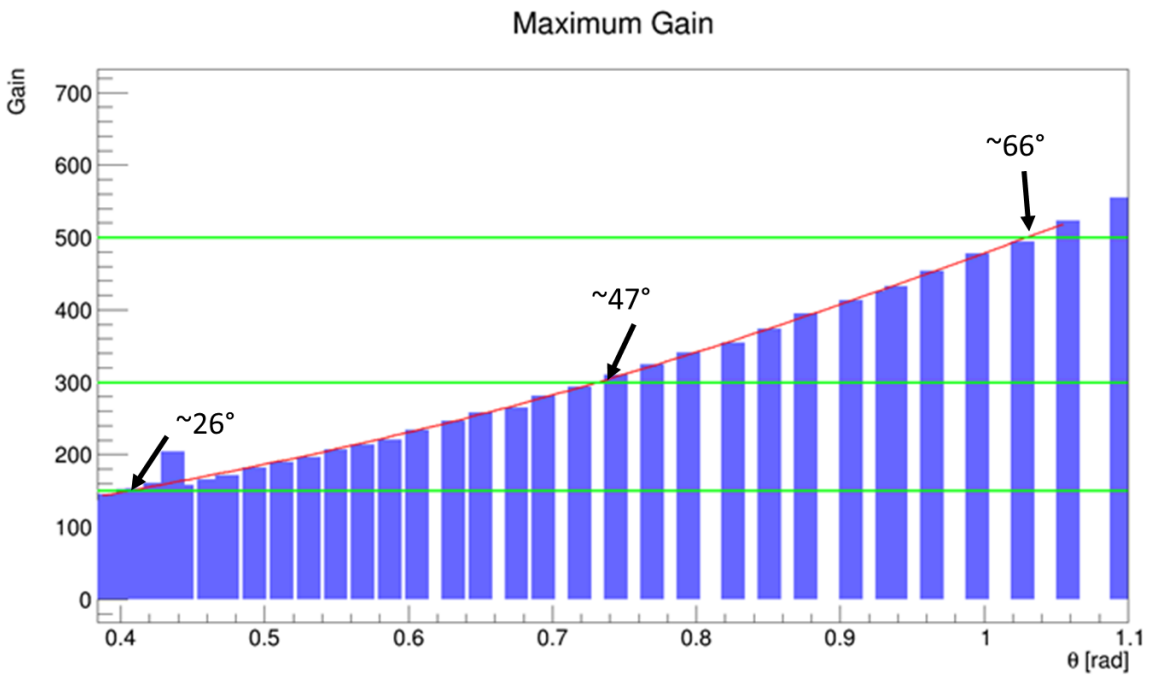
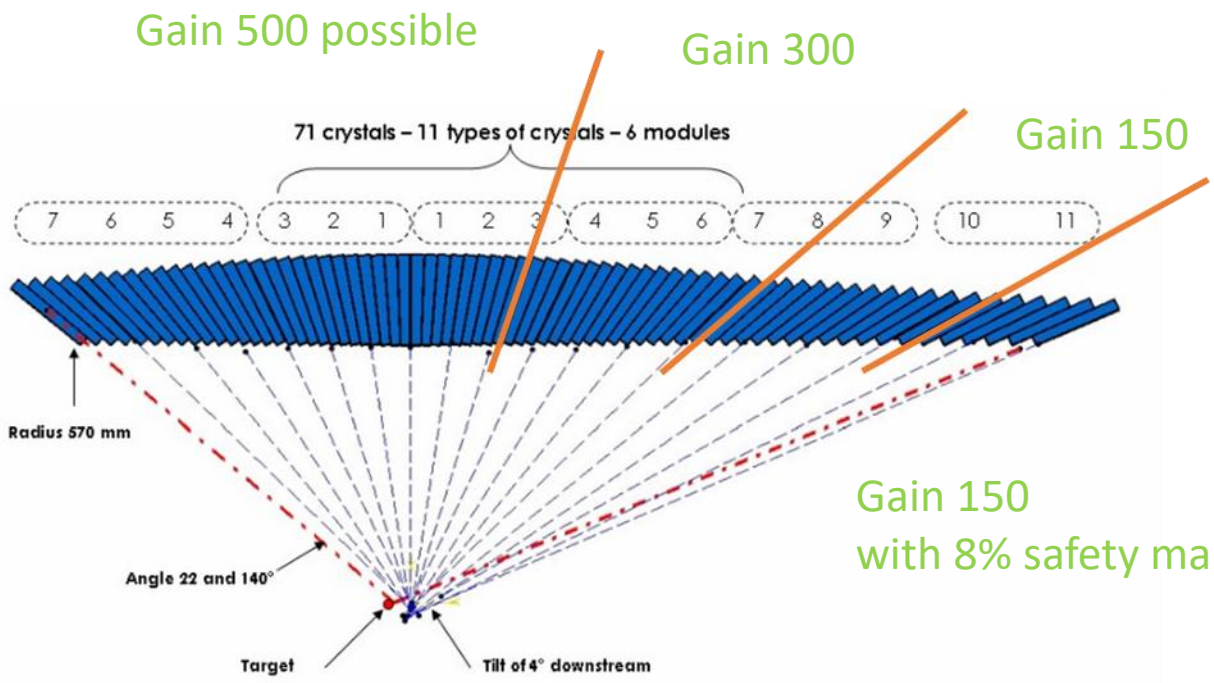
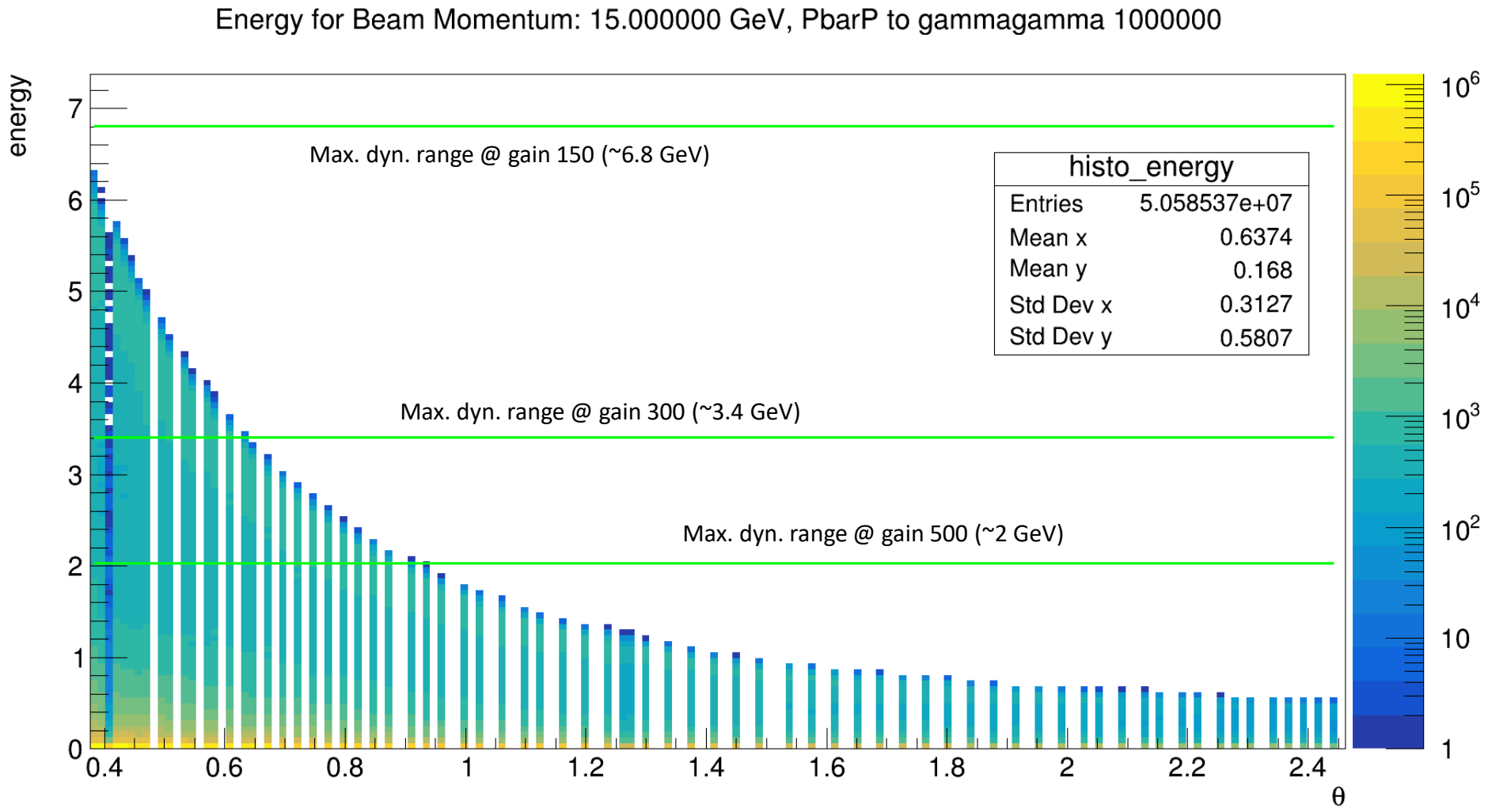


Proposal


Maximum Gain
Gain
700
600
500
400
300
200
100
0
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
θ [rad]
~26°
~47°
~66°


Gain 500 possible
Gain 300
Gain 150
71 crystals – 11 types of crystals – 6 modules
7 6 5 4 3 2 1 1 2 3 4 5 6 7 8 9 10 11
Radius 570 mm
Angle 22 and 140°
Target
Tilt of 4° downstream
Gain 150
with 8% safety margin


Energy for Beam Momentum: 15.000000 GeV, PbarP to gammagamma 1000000
energy
θ
Max. dyn. range @ gain 150 (~6.8 GeV)
Max. dyn. range @ gain 300 (~3.4 GeV)
Max. dyn. range @ gain 500 (~2 GeV)
histo_energy
Entries 5.058537e+07
Mean x 0.6374
Mean y 0.168
Std Dev x 0.3127
Std Dev y 0.5807

Summary

- Higher gain improves energy resolution, especially for lower energies

- Proposal: three different „gain“ ranges:
  - Gain 500 can be used (even with 20% margin) down to $\Theta \approx 66°$
  - Gain 300 can be used (even with 20% margin) down to $\Theta \approx 47°$
  - Gain 150 can be used with 20% margin down to $\Theta \approx 26°$, with 8% margin for rest of barrel

Outlook

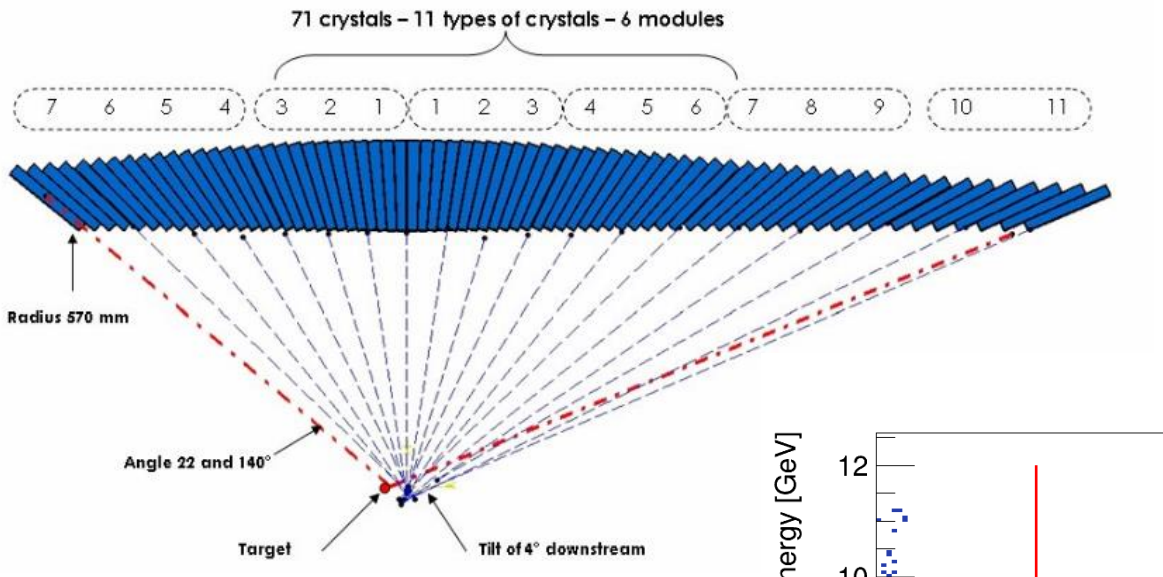
- Considerations taken into account for APD matching?

- Same considerations for lower energies

Thank you for your attention

Sources

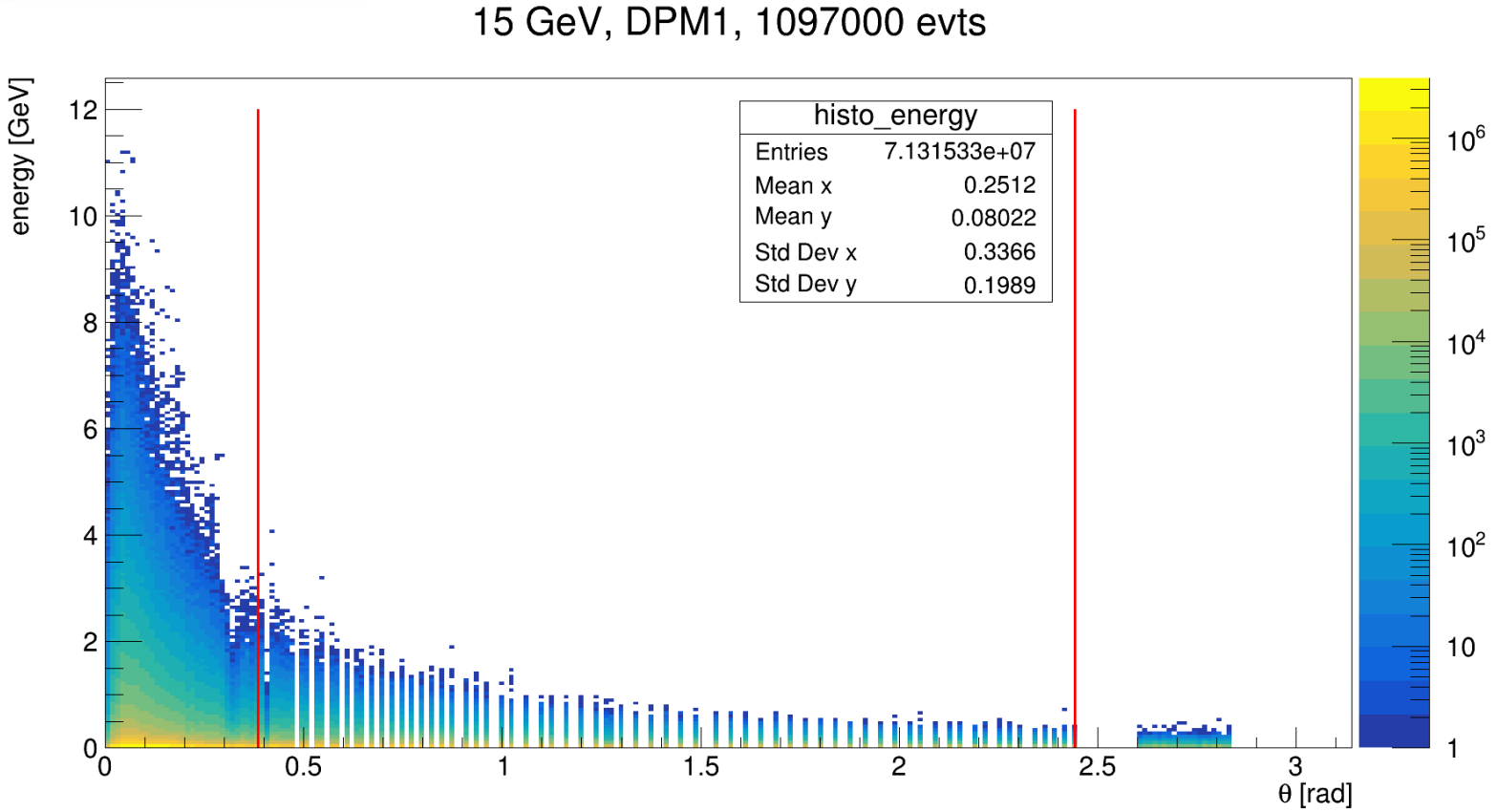
- [1] : Large Area Avalanche Photodiode Gain Optimization for the APFEL ASIC Preamplifiers of the PANDA Calorimeter, Bachelorthesis, Kim Tabea Giebenhain, 2019
  - https://www.uni-giessen.de/fbz/fb07/fachgebiete/physik/institute/iipi/arbeitsgruppen/ag-brinkmann/forschung/theses
- [2] : Revision of the PANDA Calorimeter Front-End operating parameters by means of high energetic photons, Masterthesis, Aniko Tim Falk, 2020
  - https://www.uni-giessen.de/fbz/fb07/fachgebiete/physik/institute/iipi/arbeitsgruppen/ag-brinkmann/forschung/theses
- [3]: Technical Design Report for: PANDA Electromagnetic Calorimeter, Rainer Novotny et al, 8th August 2008
  - https://panda.gsi.de/publication/re-tdr-2008-001
- [4]: Talk by Dr. Markus Moritz, 6th November 2019

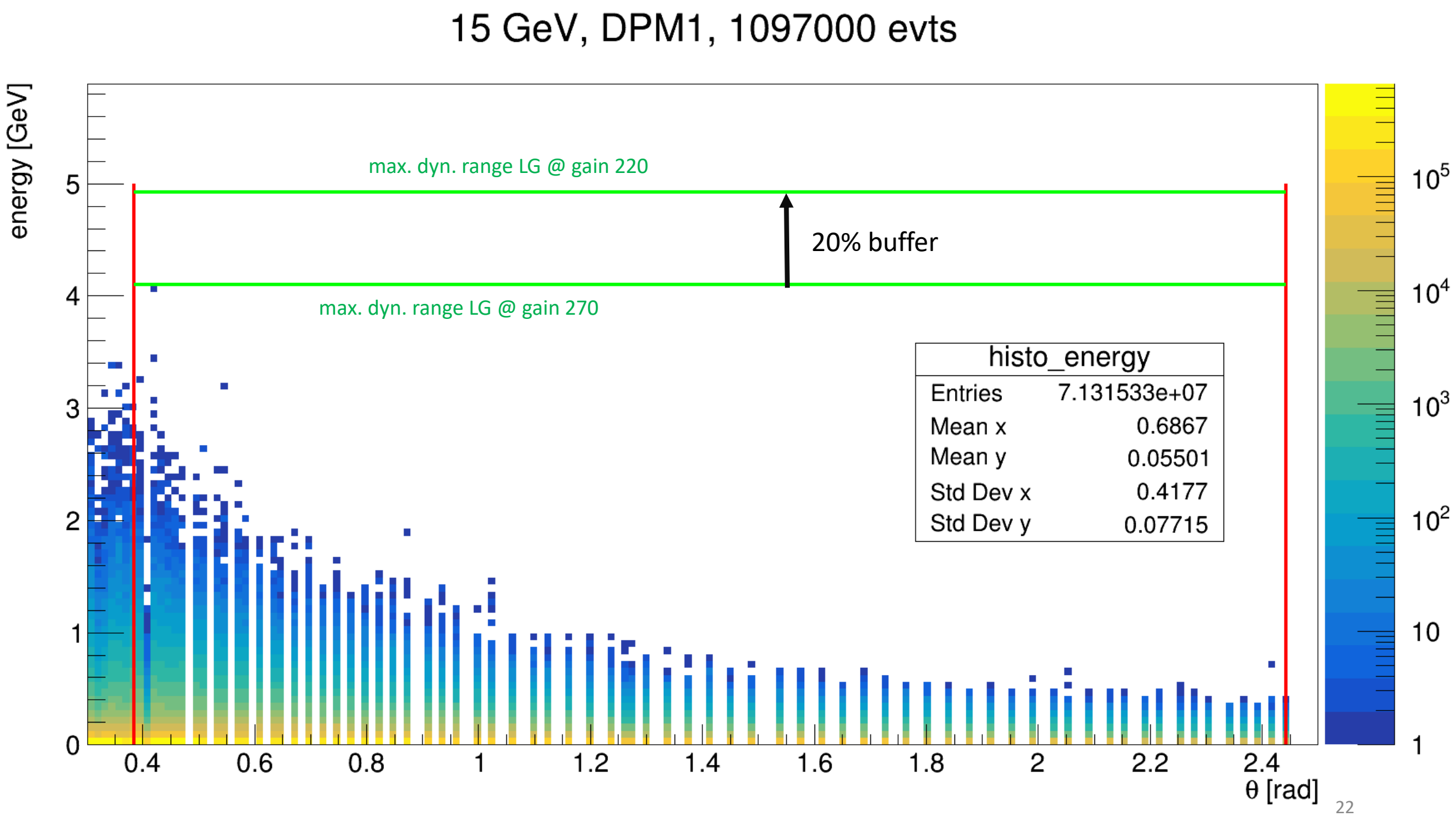


- The EMC covers angles between 22° and 140° with 71 different crystal rows

- On average this leaves a gap of ~ 1.7° (0.03 rads)

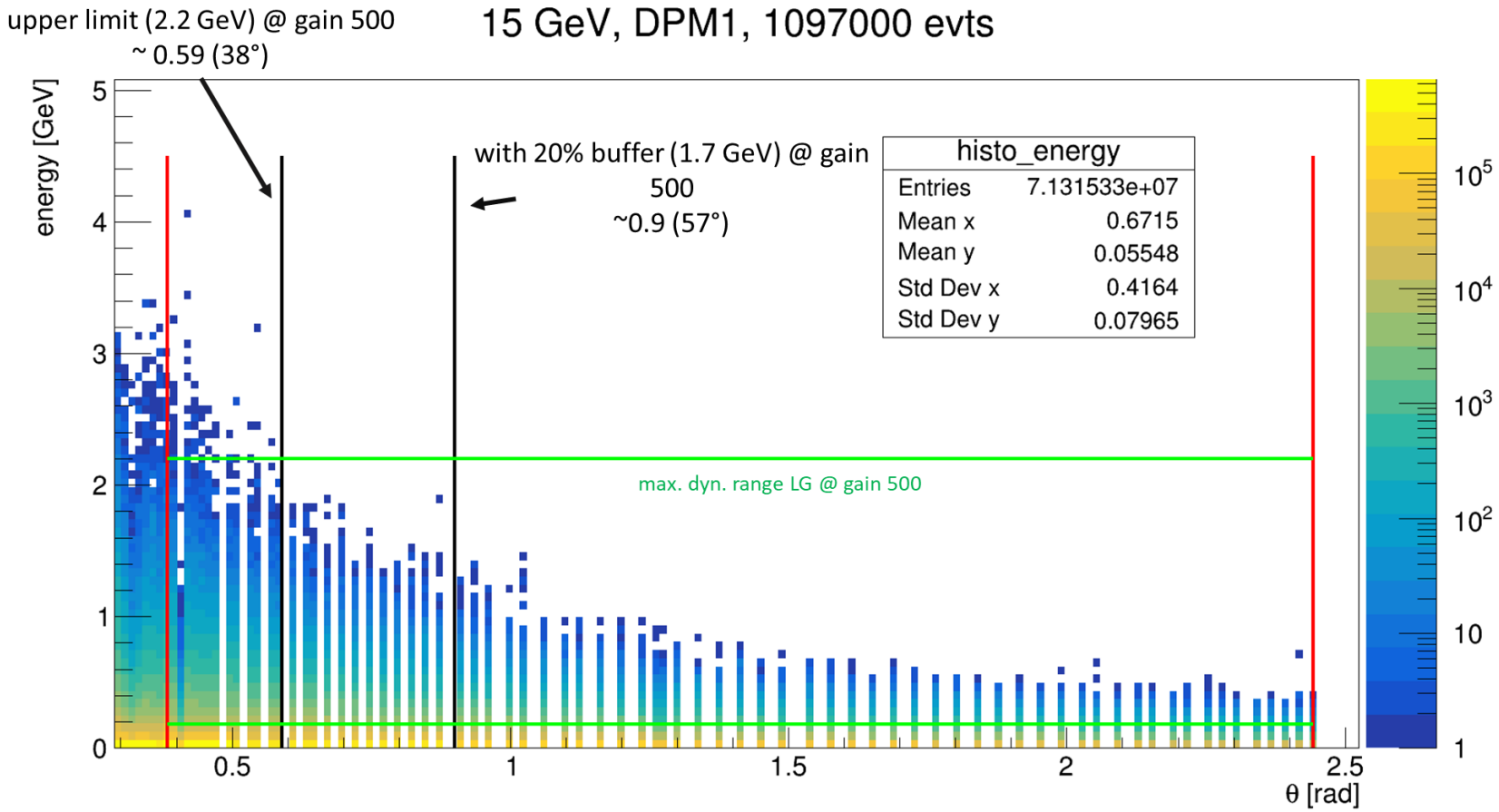
- This can be seen with the simulation




15 GeV, DPM1, 1097000 evts
energy [GeV]
θ [rad]
max. dyn. range LG @ gain 220
max. dyn. range LG @ gain 270
20% buffer
histo_energy
Entries 7.131533e+07
Mean x 0.6867
Mean y 0.05501
Std Dev x 0.4177
Std Dev y 0.07715

- New measurement during beamtime 2019 with crystal matrix by Aniko[2]
  - Mostly backward endcap like crystals, calibrated with muons (MVP = 28.1MeV)

- Dynamic range is limited: rough estimation yields $\approx 2.2\ GeV$ LG limit & $\approx 184\ MeV$ HG limit at gain 500

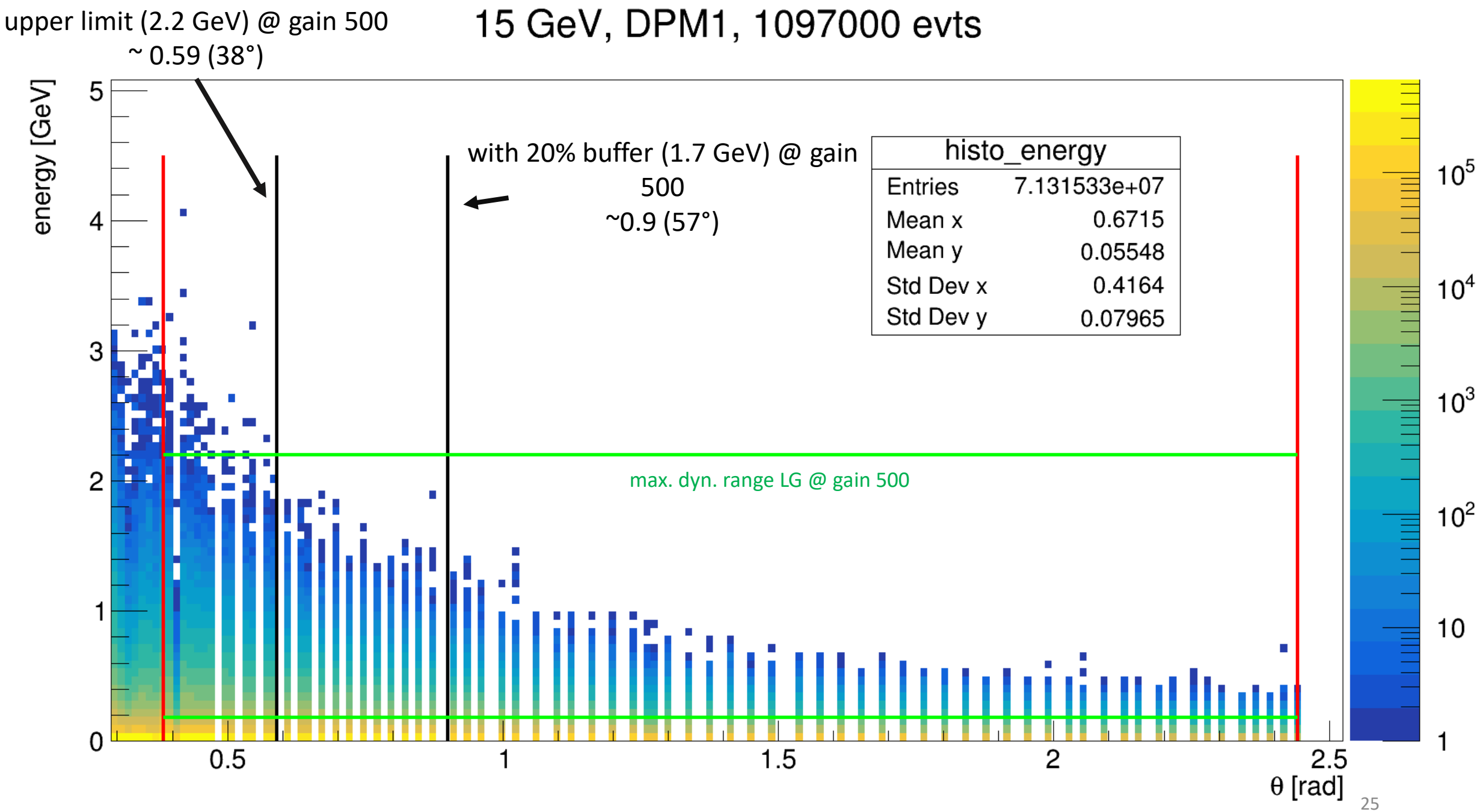


- Dynamical Range is limited: rough estimate
- linearer Range until 7500 ADC channels
- Highest MVP for muons in ADC channels in HG @ gain 500 : 1150 ADC channels
- Factor between LG and HG ~ 12

- $E_{\max(LG)} = \frac{7500\ ADC\ channels}{1150\ ADC\ channels} * 12\ * 28.1\ MeV$
-
- $E_{\max(HG)} \approx 184\ MeV$

- Other energies can be approximated by scaling:

- $Gain_{\max} = \frac{2.2\ GeV}{E_{\max}} * 500$


upper limit (2.2 GeV) @ gain 500
~ 0.59 (38°)
15 GeV, DPM1, 1097000 evts
with 20% buffer (1.7 GeV) @ gain 500
~0.9 (57°)
histo_energy
Entries 7.131533e+07
Mean x 0.6715
Mean y 0.05548
Std Dev x 0.4164
Std Dev y 0.07965
max. dyn. range LG @ gain 500
energy [GeV]
θ [rad]