

Análise dos Processos Gerados pelo PYTHIA e EPOS LHC

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Resumo

Colisões pp no referencial do CM.

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1 PYTHIA 82

1.1 $E_{\text{LAB}} = 20 \text{ TeV} \rightarrow \sqrt{s} = 193.73 \text{ GeV}$

- 10000 Colisões pp.
- Referencial do CM.
- $\sqrt{s} = \sqrt{2m_p E_{\text{LAB}}} = 193.73 \text{ GeV}$.
- **SoftQCD**: Single Diffractive, Double Diffractive, Non Diffractive e Elastic.

```

*----- PYTHIA Event and Cross Section Statistics -----*
| Subprocess                               Code |      sigma +- delta      |
|                               |      (estimated) (mb)    |
| non-diffractive                  101 | 2.852e+01 0.000e+00 |
| p p -> p p elastic                102 | 9.359e+00 5.345e-08 |
| p p -> X p single diffractive 103 | 4.627e+00 0.000e+00 |
| p p -> p X single diffractive 104 | 4.627e+00 0.000e+00 |
| p p -> X X double diffractive 105 | 4.167e+00 0.000e+00 |
# sum                               | 5.130e+01 5.345e-08 |
*----- End PYTHIA Event and Cross Section Statistic-----*

```

$$\sqrt{s} = 193.73 \text{ GeV} : \sigma_{\text{pp}} = 51.3 \text{ mb}$$

(1)

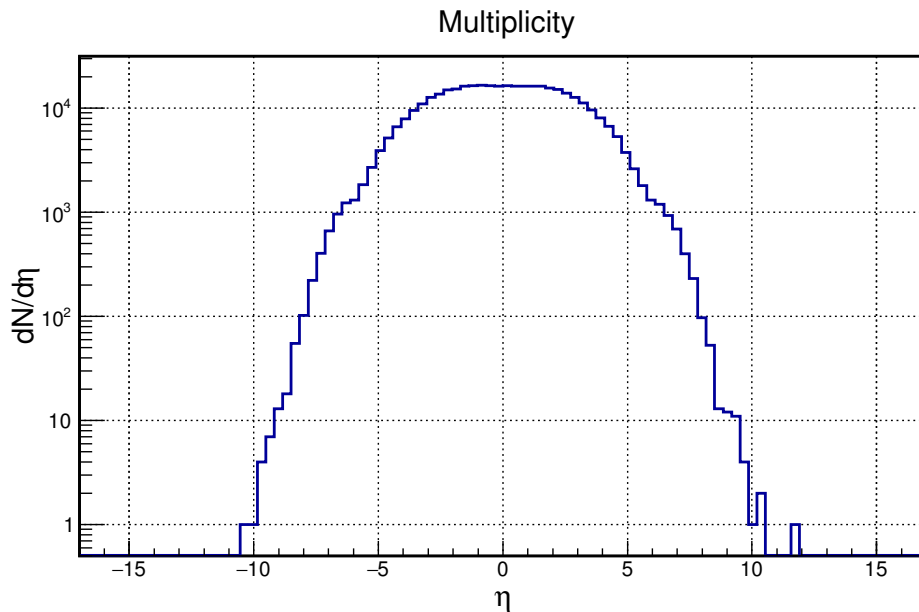


Figura 1: Referencial do CM

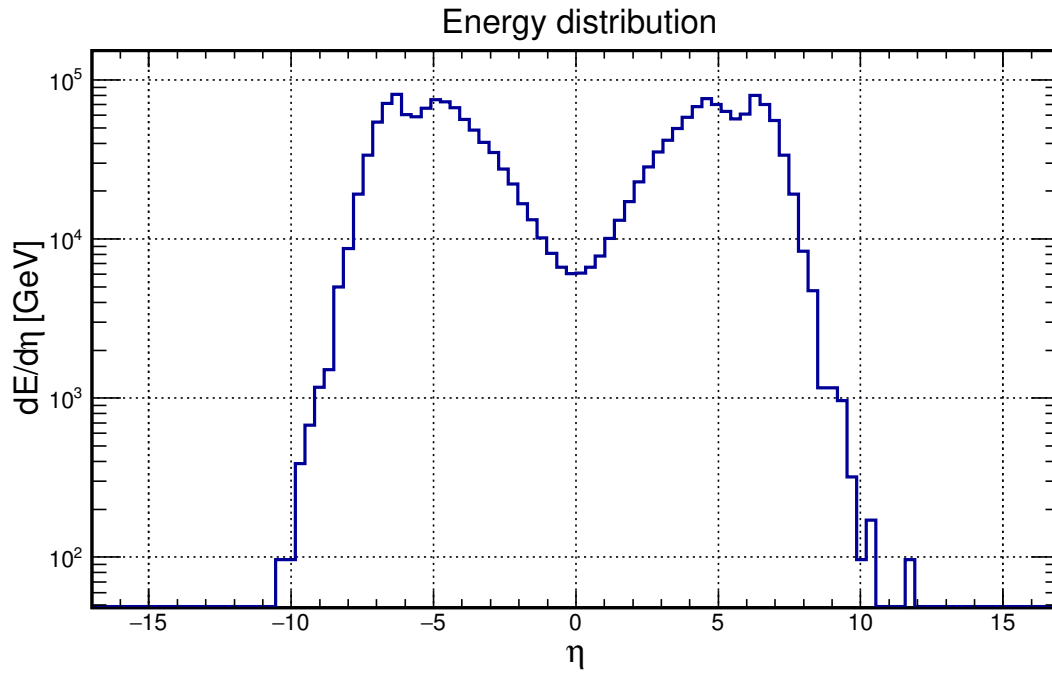


Figura 2: Referencial do CM

1.1.1 Single Diffractive (SD)

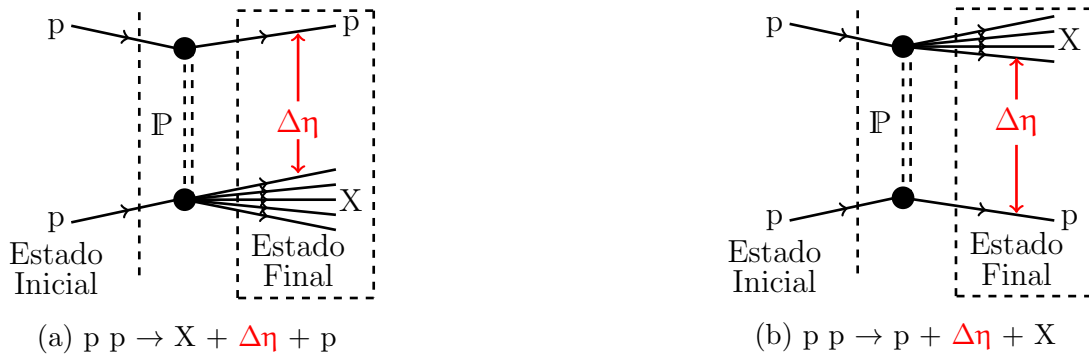


Figura 3: Diagramas de Feynman para Difração Simples (subprocessos Elementares).

```

*----- PYTHIA Event and Cross Section Statistics -----*
| Subprocess                               Code |      sigma +- delta      |
|                                           | (estimated) (mb)        |
| p p -> X p single diffractive 103 | 4.627e+00 3.840e-09 |
| p p -> p X single diffractive 104 | 4.627e+00 0.000e+00 |
# sum                                     | 9.255e+00 3.840e-09 |
*----- End PYTHIA Event and Cross Section Statistic -----*
    
```

$$\sqrt{s} = 193.73 \text{ GeV} : \sigma_{pp}^{\text{SD}} = 9.3 \text{ mb}$$

(2)

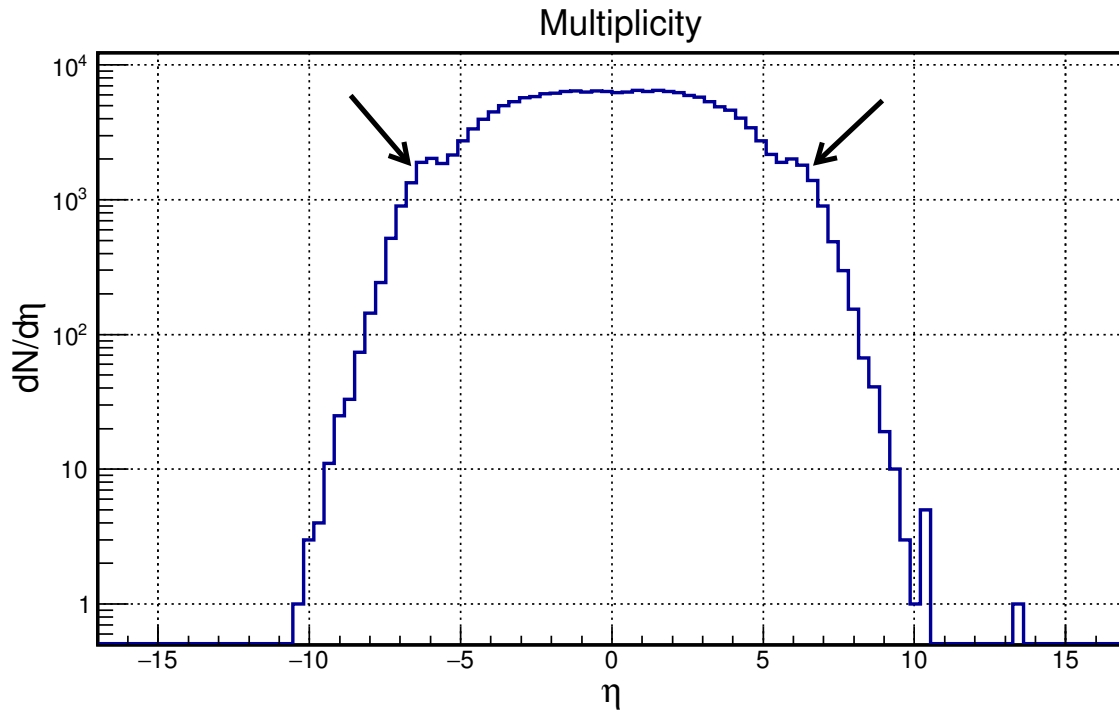


Figura 4: Referencial do CM

1.1.2 Single Diffractive (SD)(Caso especial 1 evento)

```

*----- PYTHIA Event and Cross Section Statistics -----*
| Subprocess                Code |      sigma +- delta      |
|                            |      (estimated) (mb)    |
| p p -> X p single diffractive 103 | 4.627e+00 4.627e+00 |
| p p -> p X single diffractive 104 | 0.000e+00 0.000e+00 |
# sum                        | 4.627e+00 4.627e+00 |
*----- End PYTHIA Event and Cross Section Statistic-----*

*----- PYTHIA Info Listing -----*

Beam A: id = 2212, pz = 9.686e+01, e = 9.686e+01, m = 9.383e-01.
Beam B: id = 2212, pz = -9.686e+01, e = 9.686e+01, m = 9.383e-01.

Process A B -> X B single diffractive with code 103 is 2 -> 2.
It has s = 3.753e+04, t = -1.135e-01, u = -3.724e+04,
      pT = 3.355e-01, m3 = 1.706e+01, m4 = 9.383e-01,
      theta = 3.491e-03, phi = 5.199e+00.

*----- End PYTHIA Info Listing -----*
    
```

Sistema Difractivo $m_X = 17 \text{ GeV}$

(3)

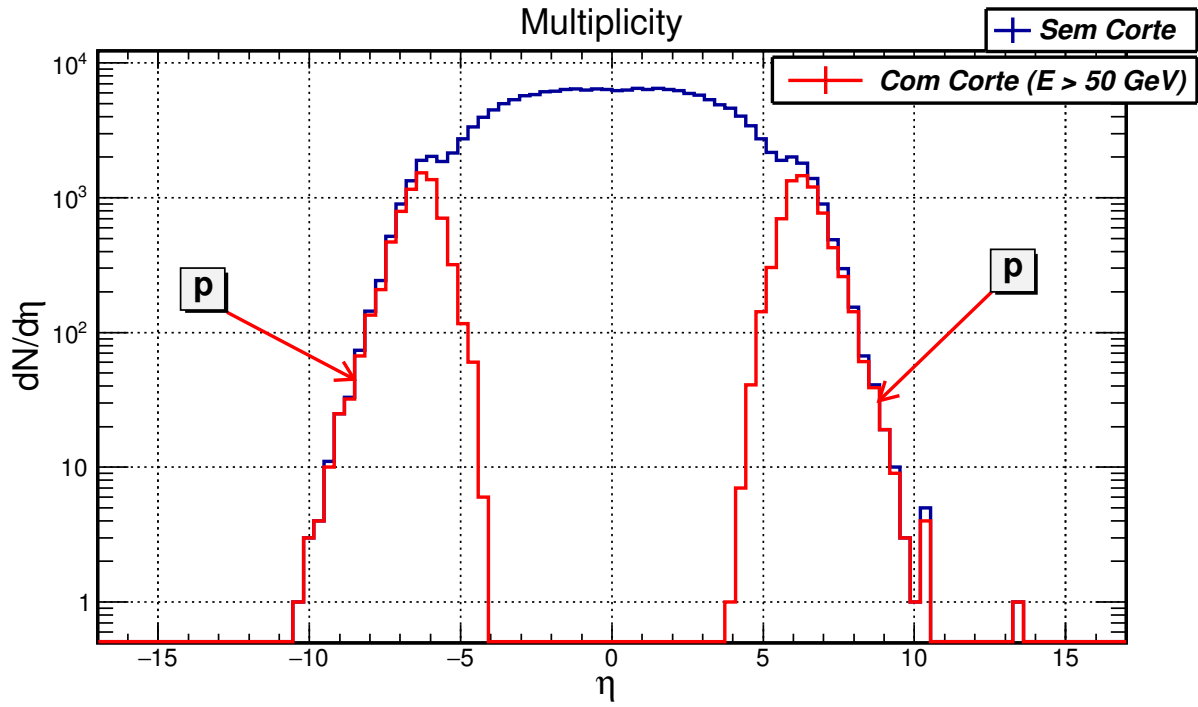


Figura 5: O GAP esperado para processos de difração simples é preenchido com partículas proveniente dos sistemas difrativos ($\mathbf{X}=\{\gamma, \pi^+, \pi^-, n, K^+\}$), produzidos por processos de hadronização ou decaimento. Na **curva vermelha** a maior parte são prótons. O corte em energia de 50 GeV somente foi usado para analisar a configuração dos eventos, ou seja, os prótons carregam uma fração significativa da energia do evento. Referencial do CM.

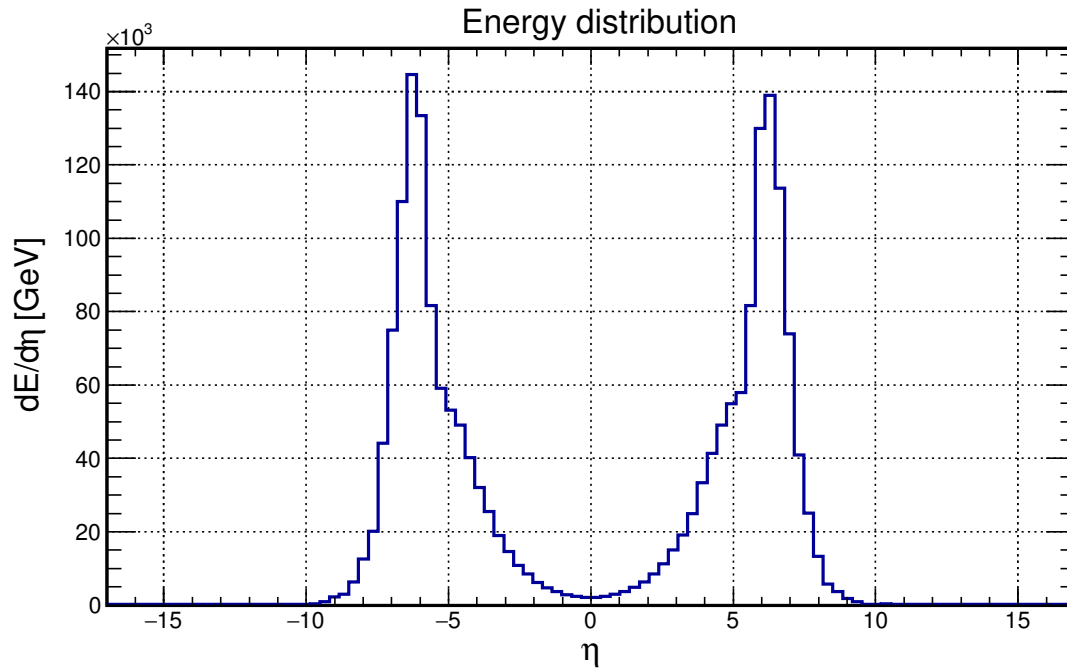


Figura 6: Referencial do CM

```

*----- PYTHIA Event Listing (complete event) -----*
// status positive is Particle in the Final State
# [GeV]
id  name /*status*/  px      py      pz      e      m
90(system)  -11      0      0      0    193.730  193.730
2212  (p+)  -12      0      0    96.860  96.865  0.938
2212  (p+)  -12      0      0   -96.860  96.865  0.938
(p_diff+)-15    0.157  -0.297  96.111  97.614  17.062
//2212  p+   14   -0.157  0.297  -96.111  96.116  0.938
21    (g)  -24    0.123  -0.232  -0.556  0.615  0.000
2     (u)  -63   -0.148  -0.432  95.939  95.940  0.325
2101 (ud_0)-63    0.183  0.367    0.728  1.059  0.650
2     (u)  -71   -0.148  -0.432  95.939  95.940  0.325
21    (g)  -71    0.123  -0.232  -0.556  0.615  0.000
2101 (ud_0)-71    0.183  0.367    0.728  1.059  0.650
111   (pi0) -83   -0.040  0.112    5.381  5.384  0.135
#211   pi+   83   -0.209  -0.077    9.701  9.704  0.140
311   (K0)  -83    0.846  0.030   34.445  34.459  0.498
-311  (Kbar0)-83   -0.306  -0.235    6.462  6.493  0.498
311   (K0)  -83   -0.562  -0.517   33.188  33.200  0.498
-313(K*bar0)-83   -0.310  0.193    4.025  4.138  0.885
#-211   pi-   84    0.279  0.098    0.312  0.452  0.140
2214(Delta+)-84    0.218  0.070    2.516  2.956  1.534
223  (omega) -84    0.241  0.029    0.081  0.829  0.788
#130   K_L0   91    0.846  0.030   34.445  34.459  0.498
310   (K_S0)-91   -0.306  -0.235    6.462  6.493  0.498
310   (K_S0)-91   -0.562  -0.517   33.188  33.200  0.498
#-321   K-    91   -0.137  -0.162    2.361  2.421  0.494
#211   pi+    91   -0.173  0.356    1.665  1.717  0.140
#2212  p+    91    0.321  0.414    2.236  2.481  0.938
111   (pi0) -91   -0.103  -0.344    0.280  0.475  0.135
#22   gamma   91   -0.024  0.021    3.913  3.913  0.000
#22   gamma   91   -0.016  0.090    1.468  1.471  0.000
#211   pi+    91   -0.072  0.035   -0.103  0.191  0.140
#-211   pi-    91    0.248  -0.197    0.024  0.347  0.140
111   (pi0) -91    0.065  0.191    0.160  0.291  0.135
#211   pi+    91   -0.186  -0.197    5.689  5.698  0.140
#-211   pi-    91   -0.119  -0.039    0.773  0.795  0.140
#211   pi+    91   -0.444  -0.162   14.853  14.861  0.140
#-211   pi-    91   -0.118  -0.355   18.335  18.339  0.140
#22   gamma   91   -0.023  -0.274    0.225  0.355  0.000
#22   gamma   91   -0.080  -0.070    0.054  0.119  0.000
#22   gamma   91    0.072  0.166    0.182  0.257  0.000
#22   gamma   91   -0.008  0.025   -0.022  0.034  0.000
Charge sum:      Momentum sum:
2.000      0.000  0.000      0.000  193.730  193.730
*----- End PYTHIA Event Listing -----*
    
```

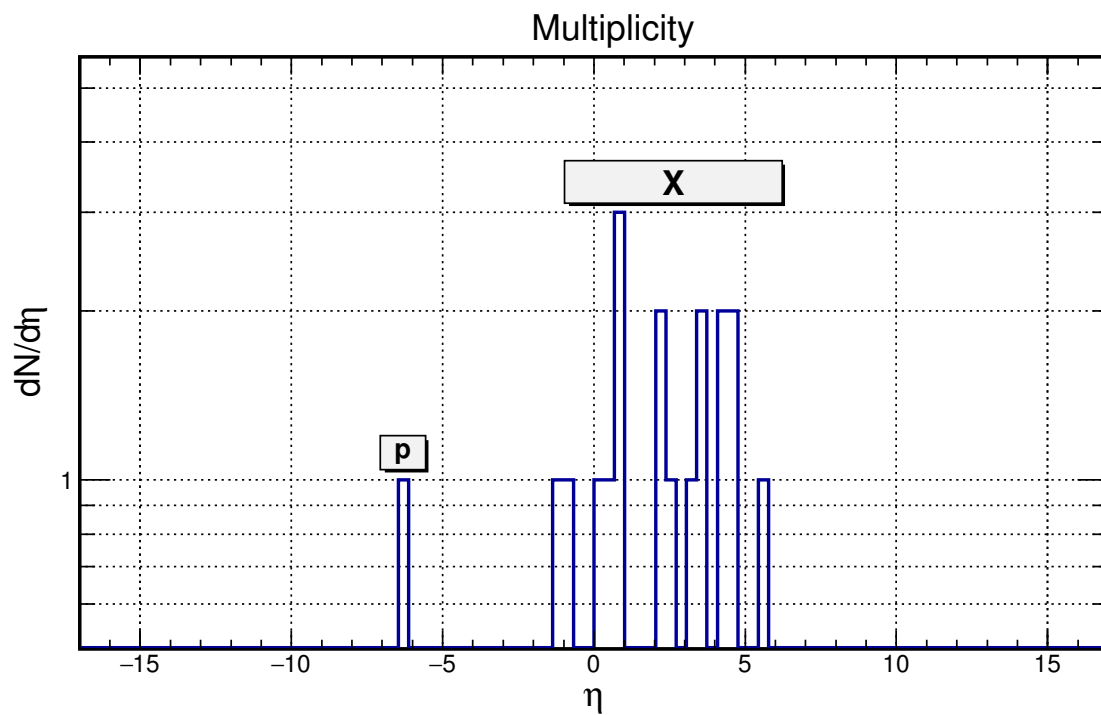


Figura 7: Referencial do CM

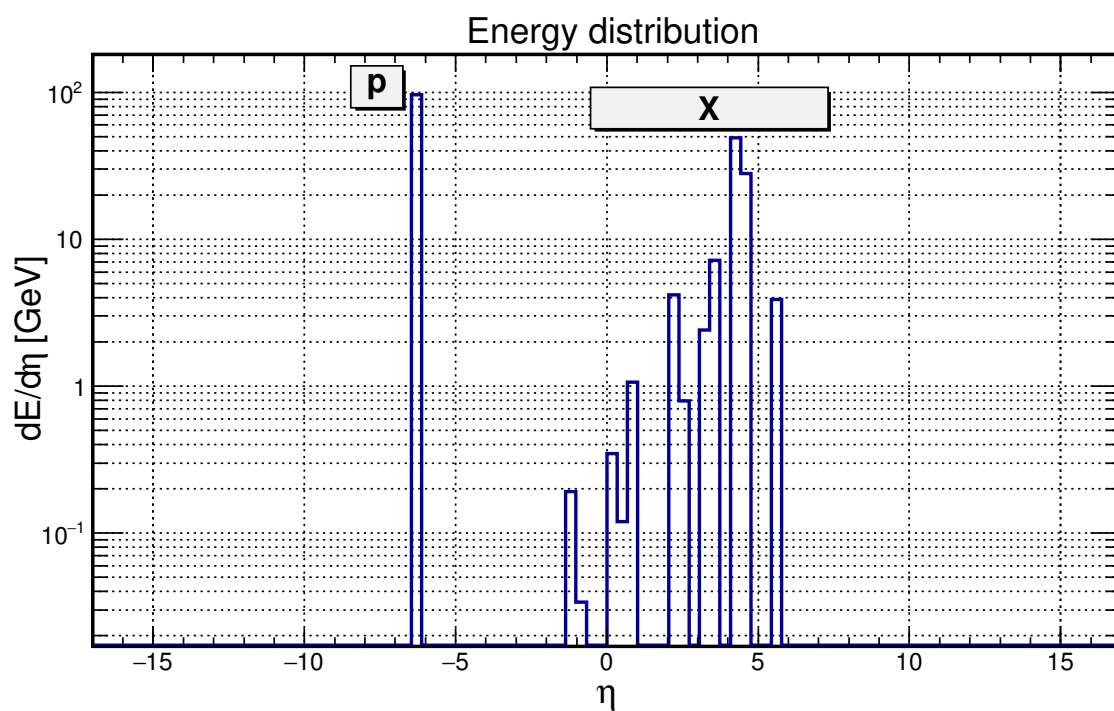


Figura 8: Referencial do CM

1.1.3 Double Diffractive (DD)

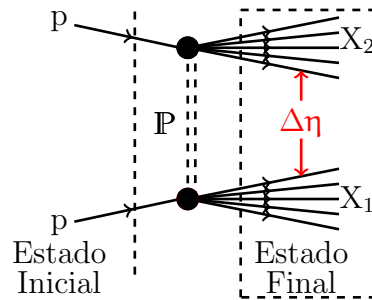


Figura 9: $p \rightarrow X_1 + \Delta\eta + X_2$.

```

-----  PYTHIA Info Listing  -----

Beam A: id =    2212, pz =   9.686e+01, e =   9.686e+01, m =   9.383e-01.
Beam B: id =    2212, pz =  -9.686e+01, e =   9.686e+01, m =   9.383e-01.

Process A B -> X X double diffractive with code 105 is 2 -> 2.
It has s =   3.753e+04,    t =  -1.308e-01,    u =  -3.752e+04,
      pT =   3.609e-01,    m3 =   3.254e+00,    m4 =   1.718e+00,
      theta =  3.727e-03,  phi =   5.426e+00.

-----  End PYTHIA Info Listing  -----

```

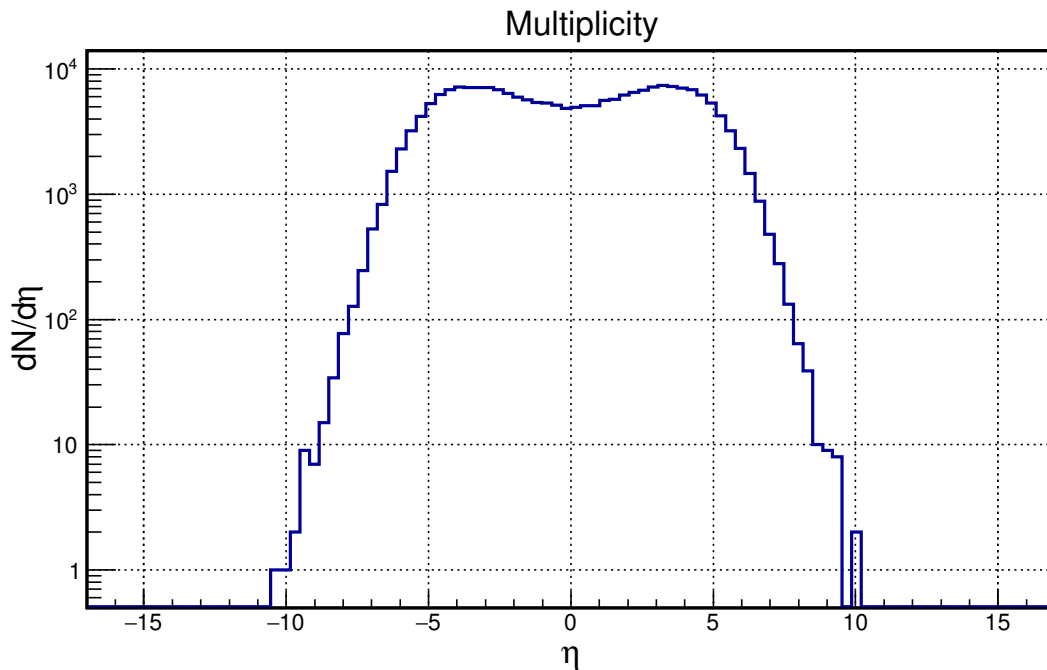


Figura 10: Referencial do CM

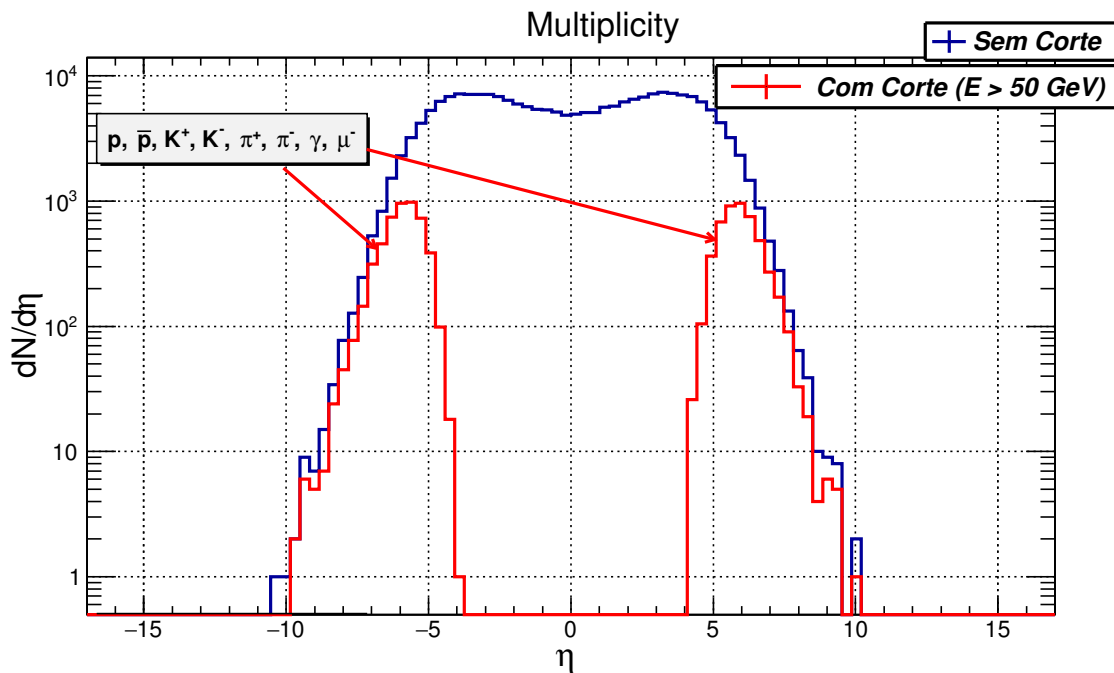


Figura 11: O GAP esperado para processos de difração dupla é preenchido com partículas proveniente dos sistemas difrativos ($\mathbf{X}_1, \mathbf{X}_2 = \{p, \bar{p}, \gamma, \pi^\pm, n, K^\pm, \mu^\pm\}$), produzidos por processos de hadronização ou decaimento. Na **curva vermelha** a maior parte são prótons. O corte em energia de 50 GeV somente foi usado para analisar a configuração dos eventos, ou seja, os prótons carregam uma fração significativa da energia do evento. Referencial do CM

1.2 $E_{\text{LAB}} = 100 \text{ TeV} \rightarrow \sqrt{s} = 433.20 \text{ GeV}$

- 1000 Colisões pp.
- Referencial do CM.
- $\sqrt{s} = \sqrt{2m_p E_{\text{LAB}}} = 433.20 \text{ GeV}$.
- **SoftQCD**: Single Diffractive, Double Diffractive, Non Diffractive e Elastic.

1.2.1 Single Diffractive (SD)

```

*----- PYTHIA Event and Cross Section Statistics -----*
| Subprocess                               Code |      sigma +- delta      |
|                                           | (estimated) (mb)        |
| p p -> X p single diffractive 103 | 5.023e+00 0.000e+00 |
| p p -> p X single diffractive 104 | 5.023e+00 3.824e-09 |
# sum                                     | 1.005e+01 3.824e-09 |
*----- End PYTHIA Event and Cross Section Statistic -----*
    
```

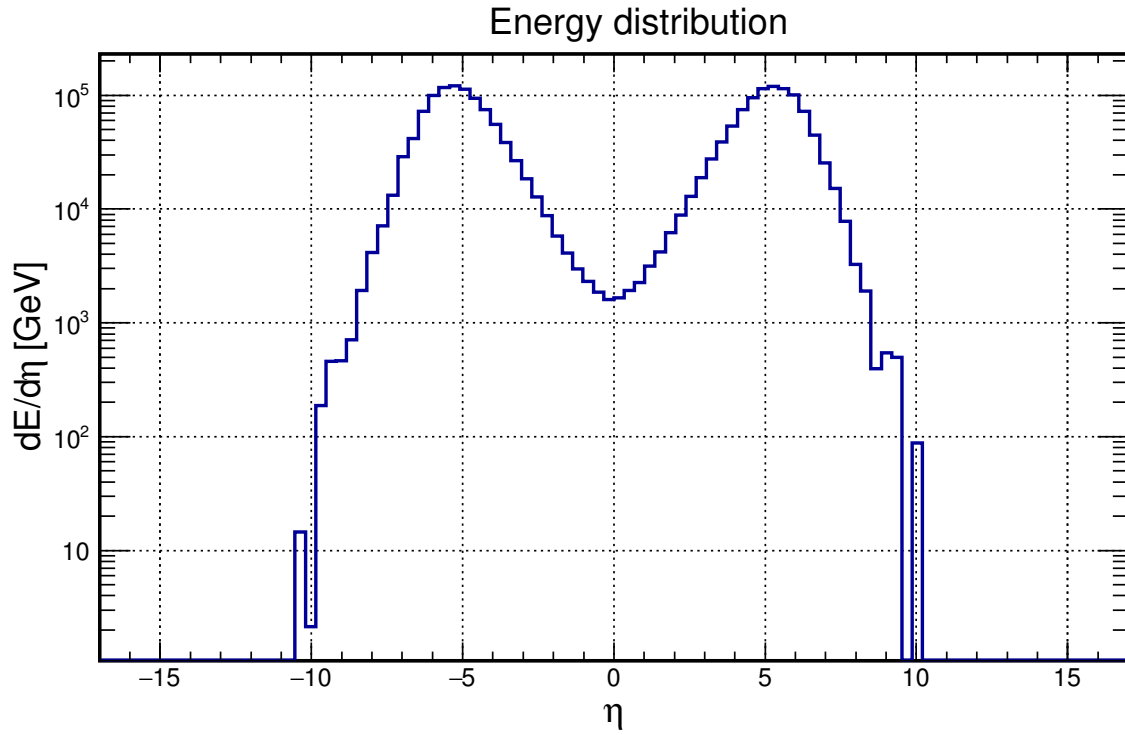


Figura 12: Referencial do CM

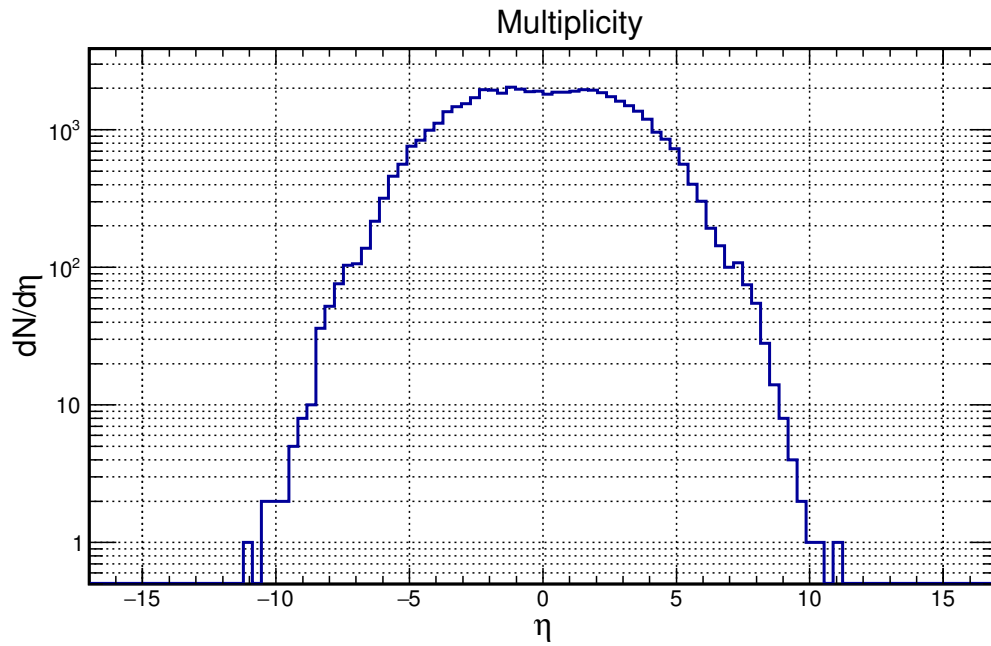


Figura 13: Referencial do CM

$$\sqrt{s} = 433.20 \text{ GeV} : \sigma_{pp}^{\text{SD}} = 10.05 \text{ mb}$$

(4)

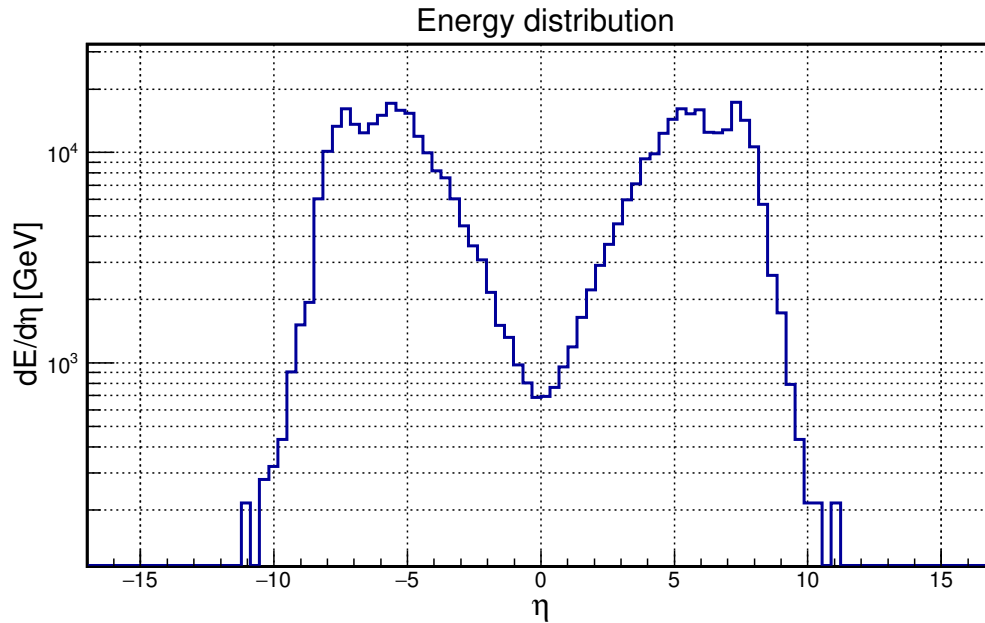


Figura 14: Referencial do CM

```

*-----  PYTHIA Info Listing  -----*

Beam A: id =    2212, pz =   2.166e+02, e =   2.166e+02, m =   9.383e-01.
Beam B: id =    2212, pz =  -2.166e+02, e =   2.166e+02, m =   9.383e-01.

Process A B -> A X single diffractive with code 104 is 2 -> 2.
It has s =   1.877e+05,    t =  -3.177e-01,    u =  -1.859e+05,
      pT =   5.609e-01,    m3 =   9.383e-01,    m4 =   4.205e+01,
      theta =  2.614e-03,  phi =   7.244e-01.

Diffractive system on side B:
In 1: id =    21, x =   2.080e-01, pdf =   2.894e-01 at Q2 =   2.595e-01.
In 2: id =    21, x =   4.167e-01, pdf =   5.563e-01 at same Q2.
Subprocess g g -> g g with code 111 is 2 -> 2.
It has sHat =   1.532e+02,    tHat =  -2.599e-01,    uHat =  -1.530e+02,
      pTHat =   5.094e-01,    m3Hat =   0.000e+00,    m4Hat =   0.000e+00,
      thetaHat =  8.239e-02,  phiHat =   4.664e+00.
      alphaEM =   7.439e-03,  alphaS =   5.397e-01    at Q2 =   8.417e-01.

*-----  End PYTHIA Info Listing  -----*
    
```

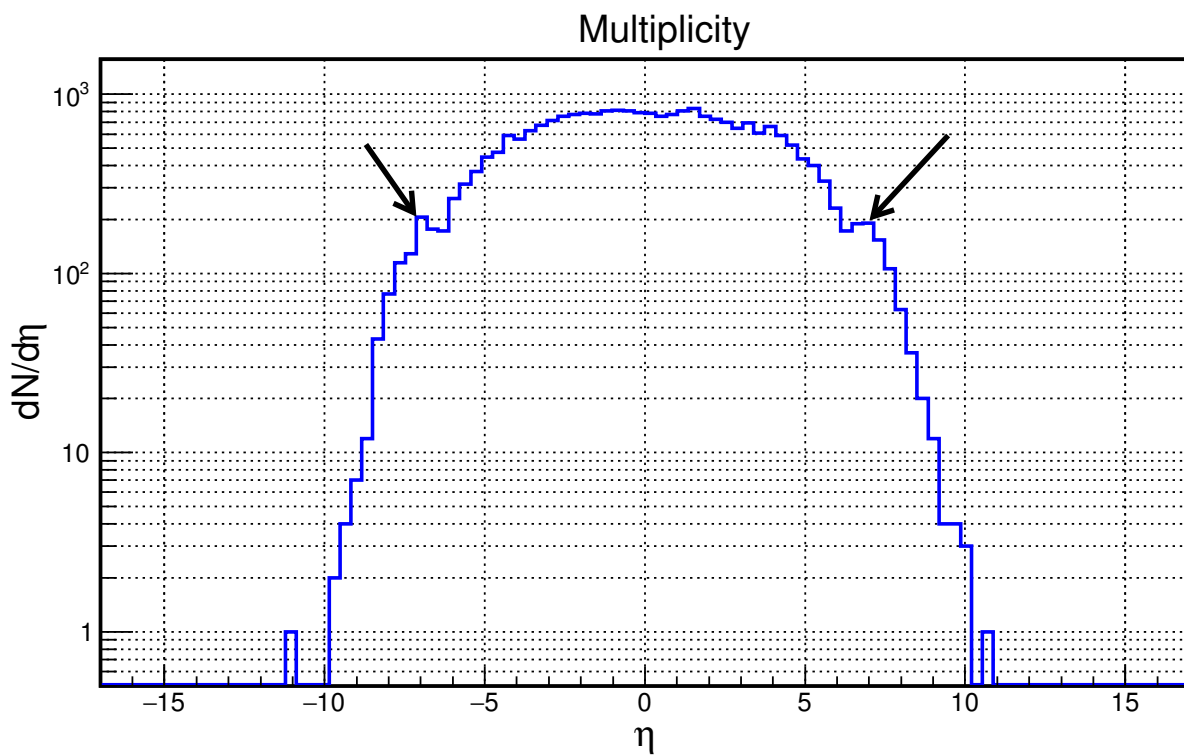


Figura 15: Referencial do CM

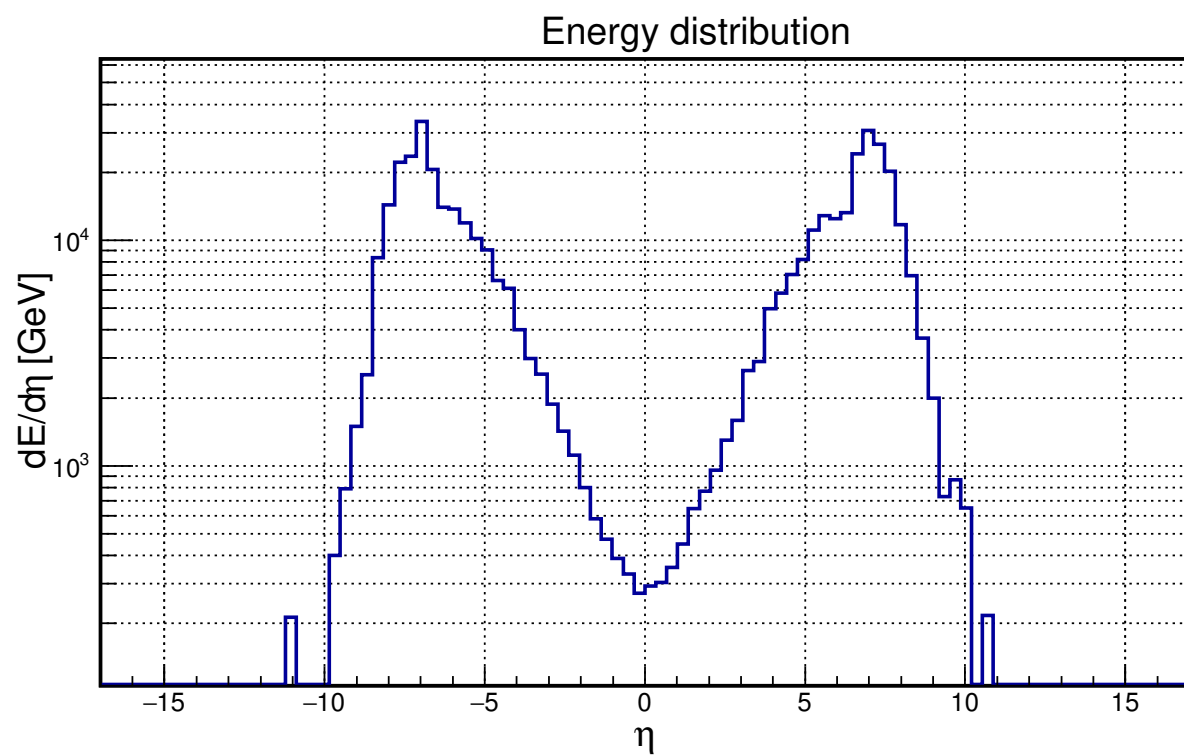


Figura 16: Referencial do CM

1.2.2 Double Diffractive (DD)

```

*----- PYTHIA Event and Cross Section Statistics -----*
| Subprocess                               Code |      sigma +- delta      |
|                               |      (estimated) (mb)    |
| p p -> X p single diffractive 103 | 5.028e+00 0.000e+00 |
# sum                               | 5.028e+00 0.000e+00 |
*----- End PYTHIA Event and Cross Section Statistic-----*
    
```

$$\sqrt{s} = 433.20 \text{ GeV} : \sigma_{pp}^{\text{DD}} = 5.03 \text{ mb}$$

(5)

```

----- PYTHIA Info Listing -----*

Beam A: id = 2212, pz = 2.166e+02, e = 2.166e+02, m = 9.383e-01.
Beam B: id = 2212, pz = -2.166e+02, e = 2.166e+02, m = 9.383e-01.

Process A B -> X X double diffractive with code 105 is 2 -> 2.
It has s = 1.877e+05, t = -2.286e-01, u = -1.871e+05,
      pT = 4.543e-01, m3 = 2.993e+00, m4 = 2.244e+01,
      theta = 2.103e-03, phi = 9.130e-01.

Diffractive system on side B:
In 1: id = 21, x = 9.085e-02, pdf = 2.358e-01 at Q2 = 6.224e-02.
In 2: id = 21, x = 1.813e-02, pdf = 1.549e+00 at same Q2.
Subprocess g g -> g g with code 111 is 2 -> 2.
It has sHat = 8.292e-01, tHat = -6.779e-02, uHat = -7.614e-01,
      pTHat = 2.495e-01, m3Hat = 0.000e+00, m4Hat = 0.000e+00,
      thetaHat = 5.799e-01, phiHat = 3.950e+00.
      alphaEM = 7.420e-03, alphaS = 6.730e-01 at Q2 = 5.043e-01.

----- End PYTHIA Info Listing -----*
    
```

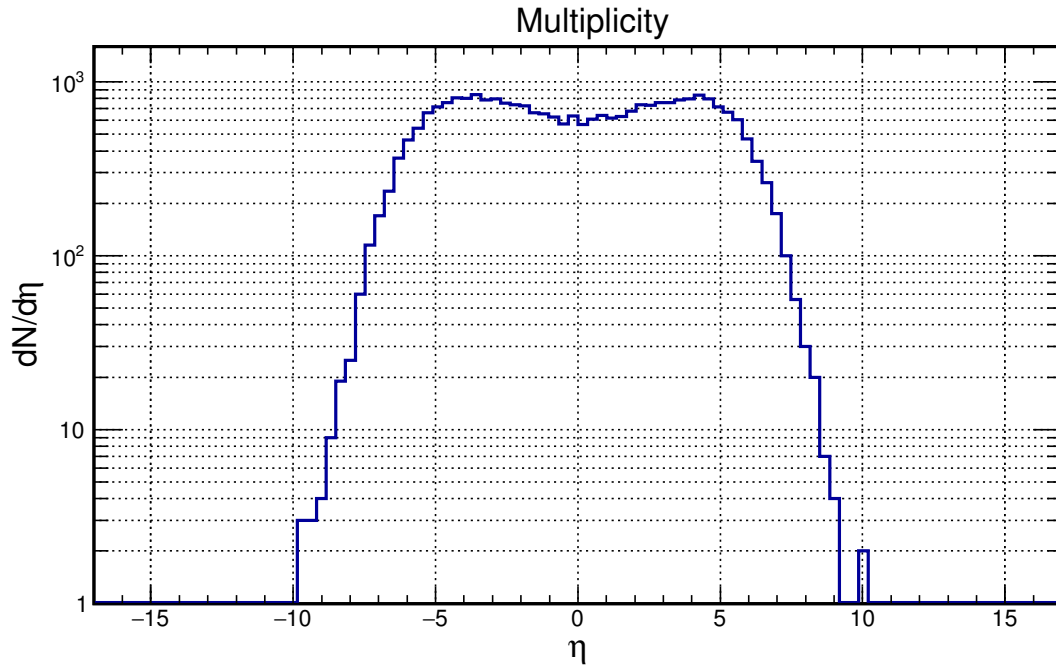


Figura 17: Referencial do CM

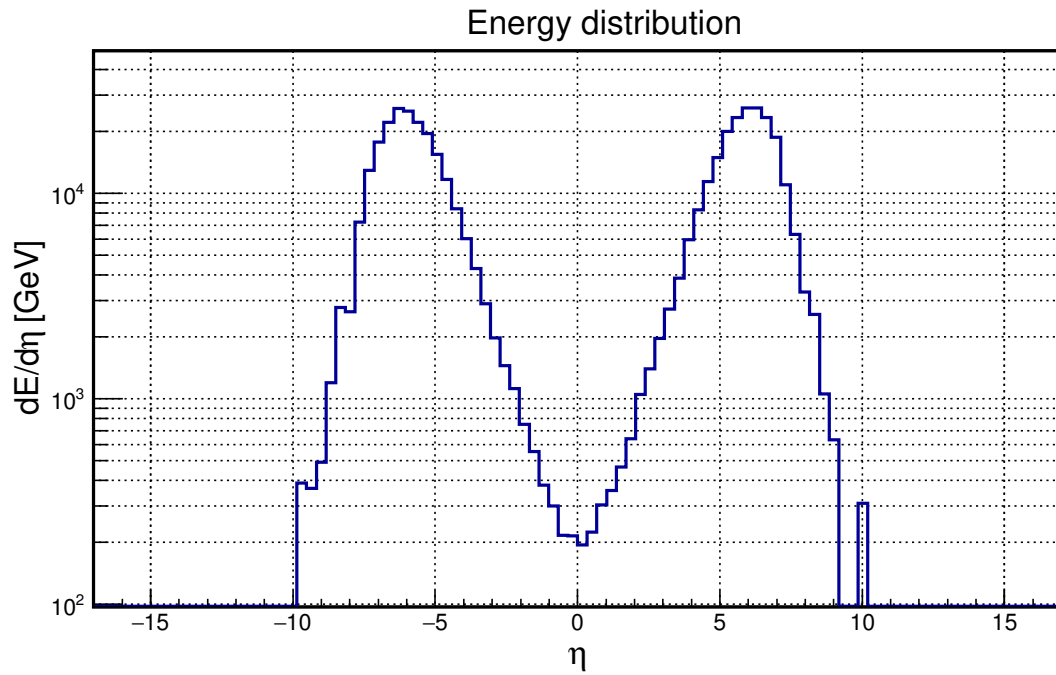


Figura 18: Referencial do CM

1.3 $E_{\text{LAB}} = 432 \text{ TeV} \rightarrow \sqrt{s} = 900 \text{ GeV}$

- 10k Colisões pp.
- Referencial do CM.

- $\sqrt{s} = \sqrt{2m_p E_{\text{LAB}}} = 900 \text{ GeV}$.
- **SoftQCD**: Single Diffractive, Double Diffractive, Non Diffractive e Elastic.

1.3.1 RIVET: ATLAS 2010 S8591806 [1]

- Charged particles at 900 GeV in ATLAS
- Beams: p+ p+ Beam energies: (450.0, 450.0) GeV Run details:
- pp QCD interactions at 900 GeV including diffractive events.

The first measurements with the ATLAS detector at the LHC. Data were collected using a minimum-bias trigger in December 2009 during proton-proton collisions at a centre of mass energy of 900 GeV. The charged-particle density, its dependence on transverse momentum and pseudorapidity, and the relationship between transverse momentum and charged-particle multiplicity are measured for events with at least one charged particle in the kinematic range $|\eta| < 2.5$ and $p_{\perp} > 500 \text{ MeV}$. All data is corrected to the particle level.

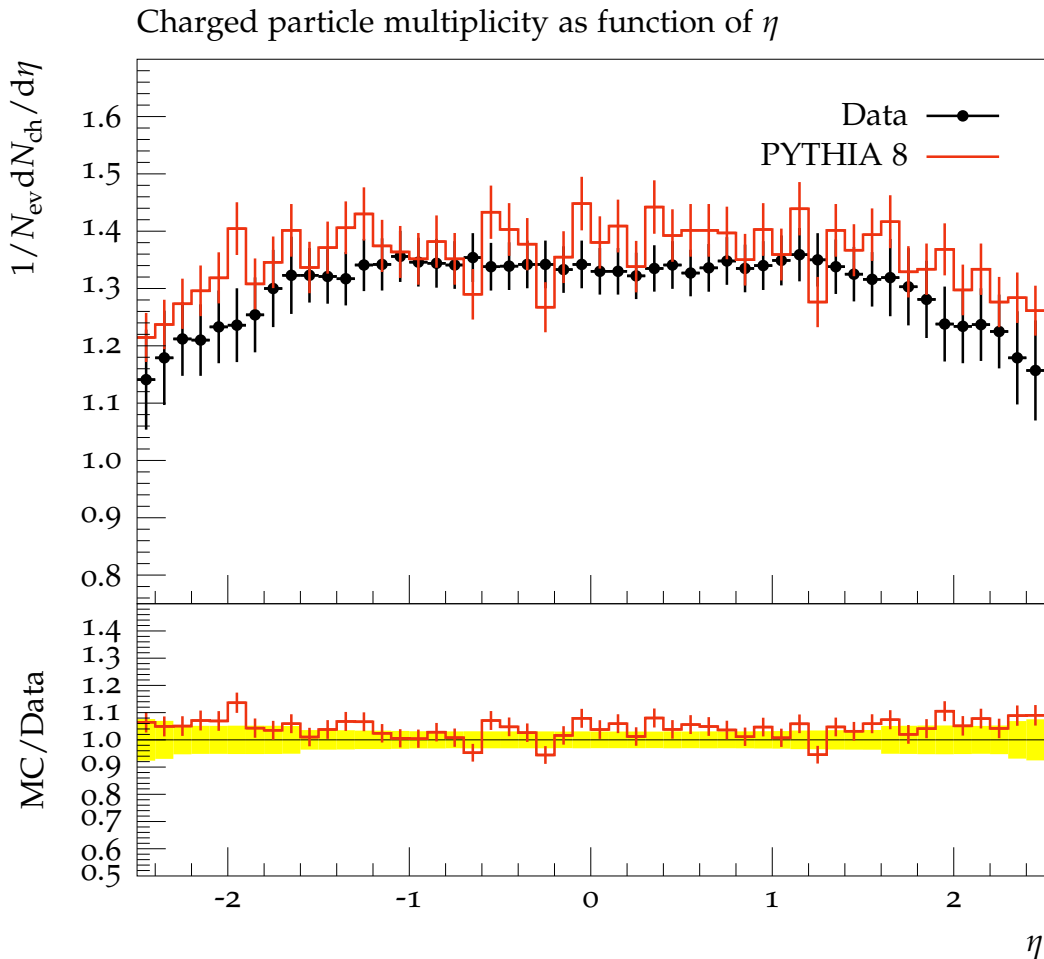


Figura 19: Referencial do CM

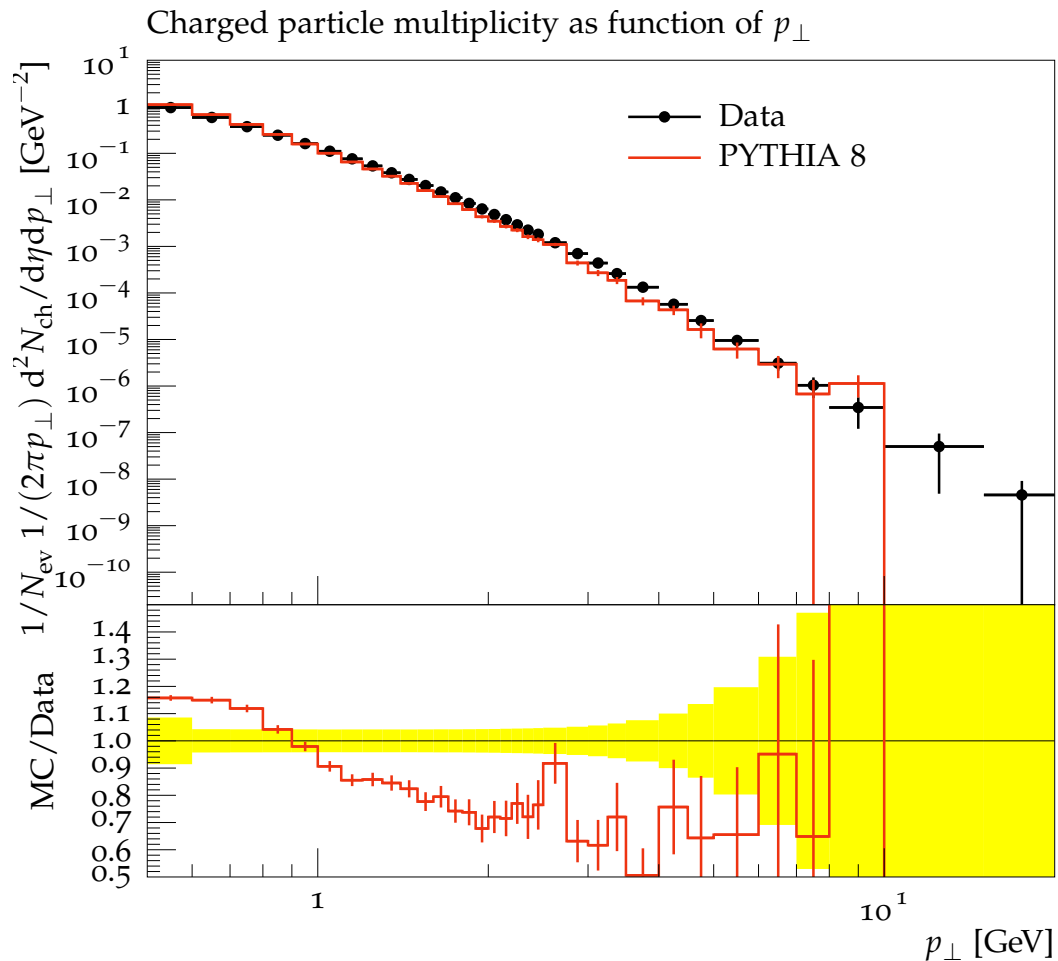


Figura 20: Referencial do CM

2 EPOS LHC

2.1 Colisão pp: $E_{\text{LAB}} = 120 \text{ TeV} \rightarrow \sqrt{s} = 1.6 \text{ TeV}$

- 1000 Colisões pp.
- $E_{\text{LAB}} = 120000 \text{ GeV} = 120 \text{ TeV}$
- $m_p = 0.9383 \text{ GeV}$, $m_C = 11 \text{ GeV}$
- $\sqrt{s} = \sqrt{m_p^2 + m_C^2 + 2E_{\text{LAB}}m_C} = 1.6 \text{ TeV}$
- Referencial do CM.

```
$ bin/crmc -o root -p800 -P-800 -n1000 -m0
```

```
>> crmc <<
```

```
seed:                        861492214 (automatic)
projectile id:                1 (p)
projectile momentum:          800
target id:                    1 (p)
```



```

target momentum:          -800

number of collisions:      1000
parameter file name:      crmc.param
output file name:         crmc_eposlhc_861492214_p_p_800.root
HE model:                  0 (EPOS-LHC)
#####
#           EPOS LHC           K. WERNER, T. PIEROG           #
#                               Contact: tanguy.pierog@kit.edu   #
#####
#           WARNING: This is a special retuned version !!!      #
#           Do not publish results without contacting the authors. #
#####

```

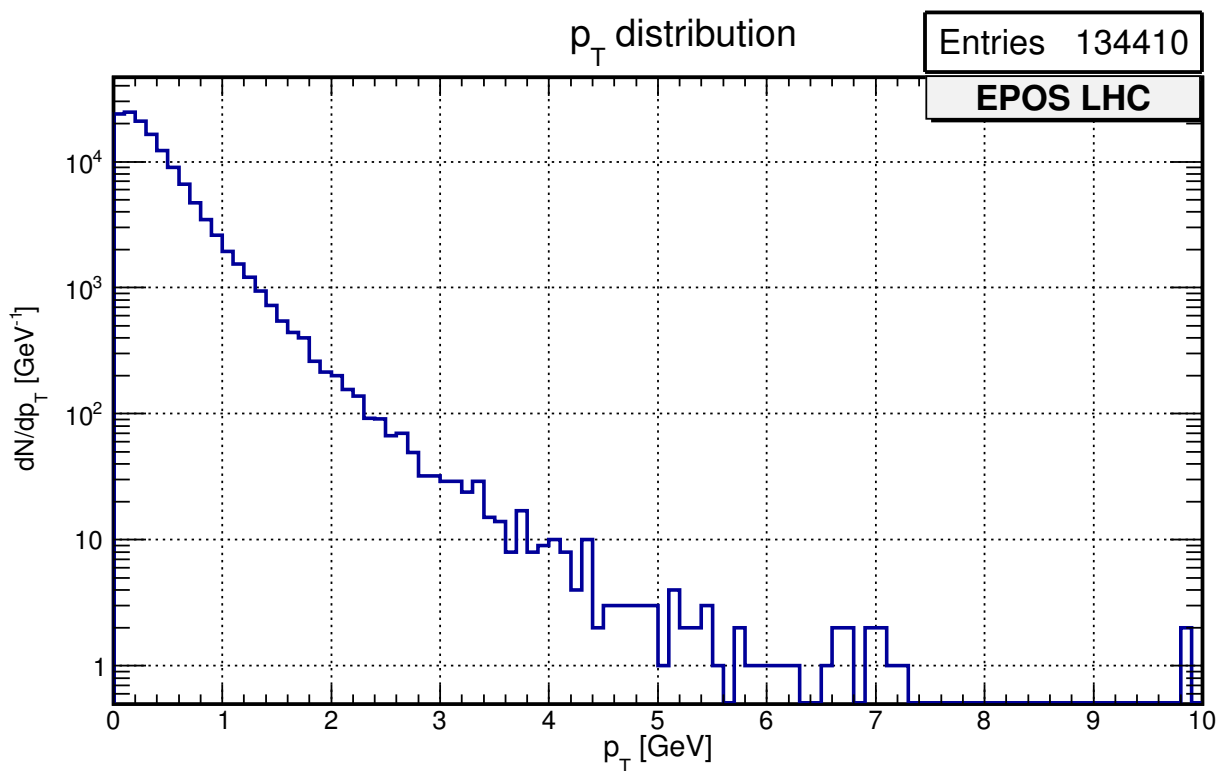


Figura 21: EPOS LHC: colisões pp

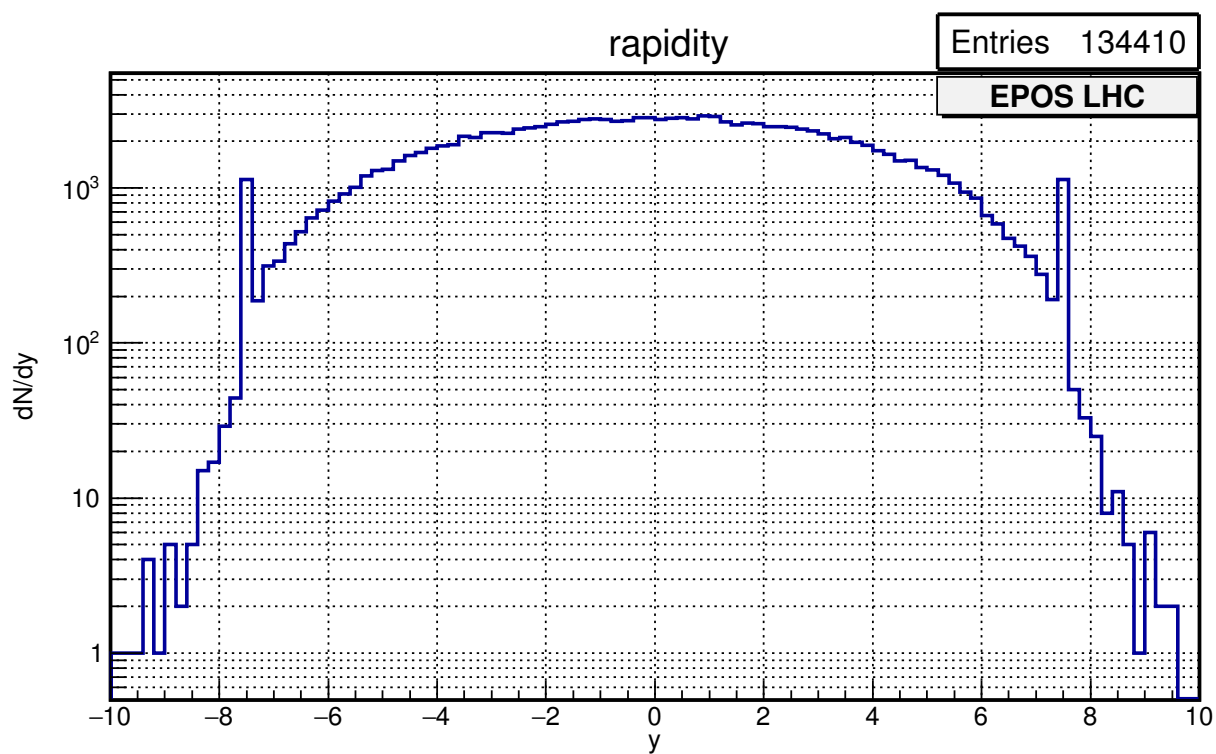


Figura 22: EPOS LHC: colisões pp

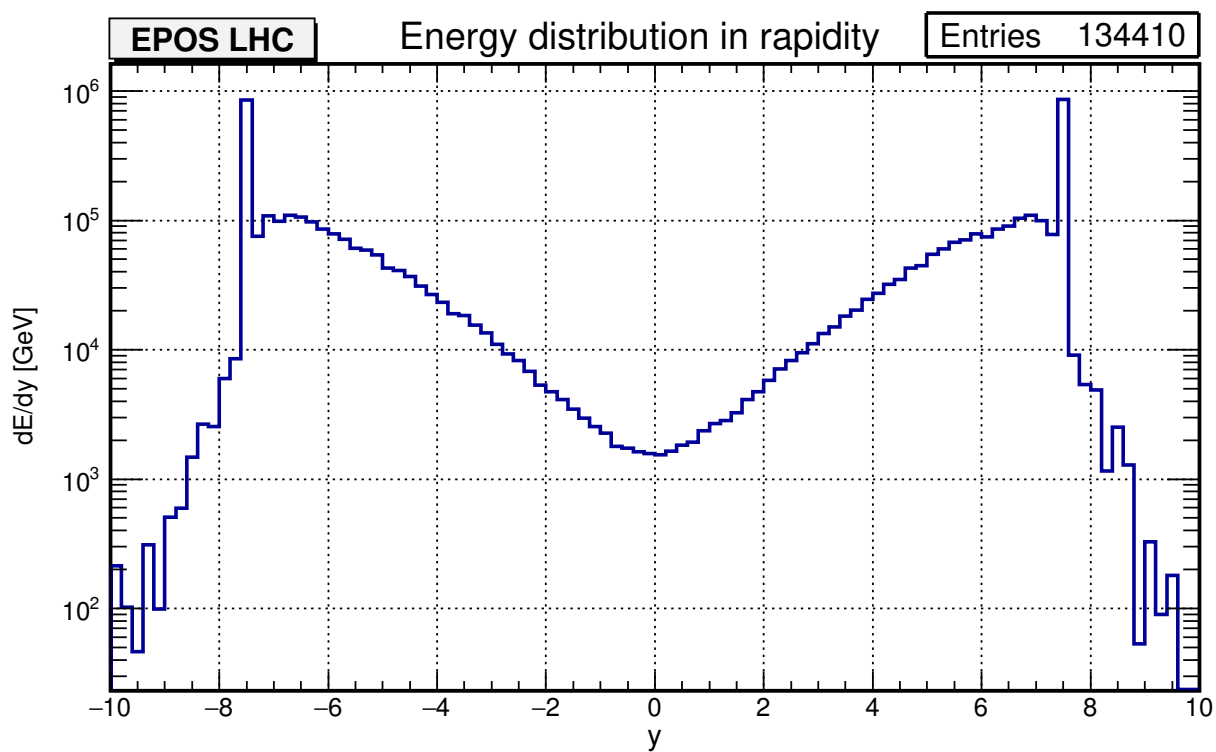


Figura 23: EPOS LHC: colisões pp

2.2 Colisão próton-Carbono: $E_{\text{LAB}} = 120 \text{ TeV} \rightarrow \sqrt{s} = 1.6 \text{ TeV}$

- 1000 Colisões próton-Carbono p-C
- $E_{\text{LAB}} = 120000 \text{ GeV} = 120 \text{ TeV}$
- $m_p = 0.9383 \text{ GeV}$, $m_C = 11 \text{ GeV}$
- $\sqrt{s} = \sqrt{m_p^2 + m_C^2 + 2E_{\text{LAB}}m_C} = 1.6 \text{ TeV}$
- Referencial do CM

```
$ bin/crmc -o root -p800 -P-800 -n1000 -m0 -i2212 -I12
```

```
>> crmc <<
```

```
seed:                416075184 (automatic)
projectile id:        2212 (p)
projectile momentum:  800
target id:            12 (C)
target momentum:     -800

number of collisions: 1000
parameter file name:  crmc.param
output file name:     crmc_eposlhc_416075184_p_C_800.root
HE model:             0 (EPOS-LHC)
```

```
#####
#           EPOS LHC           K. WERNER, T. PIEROG           #
#                               Contact: tanguy.pierog@kit.edu   #
#####
#           WARNING: This is a special retuned version !!!     #
#           Do not publish results without contacting the authors. #
#####
```

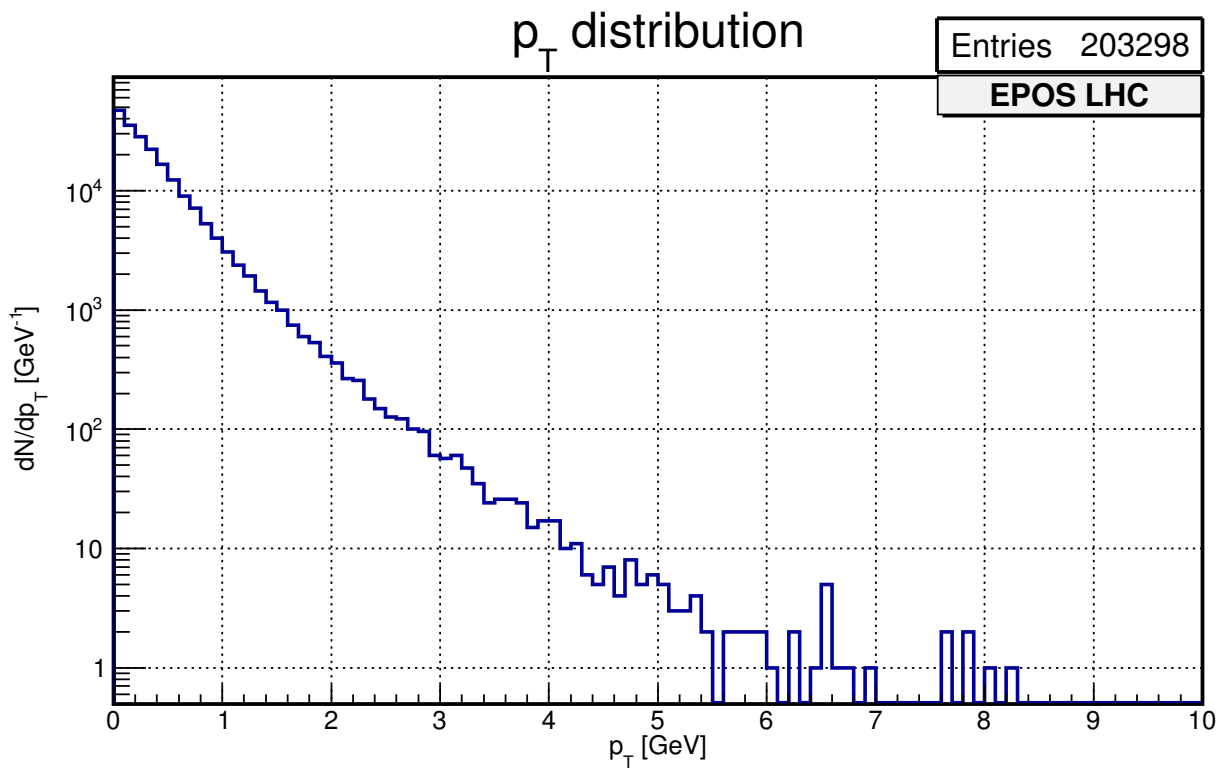


Figura 24: EPOS LHC: colisões p-C

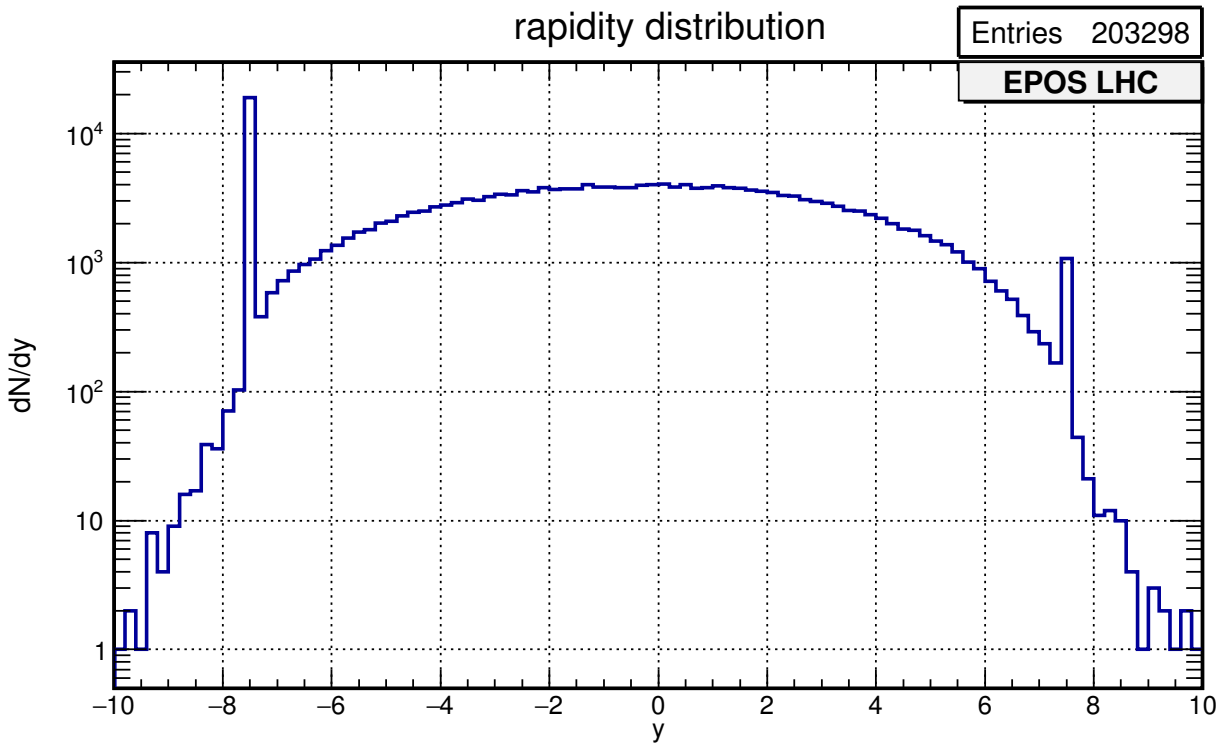


Figura 25: EPOS LHC: colisões p-C

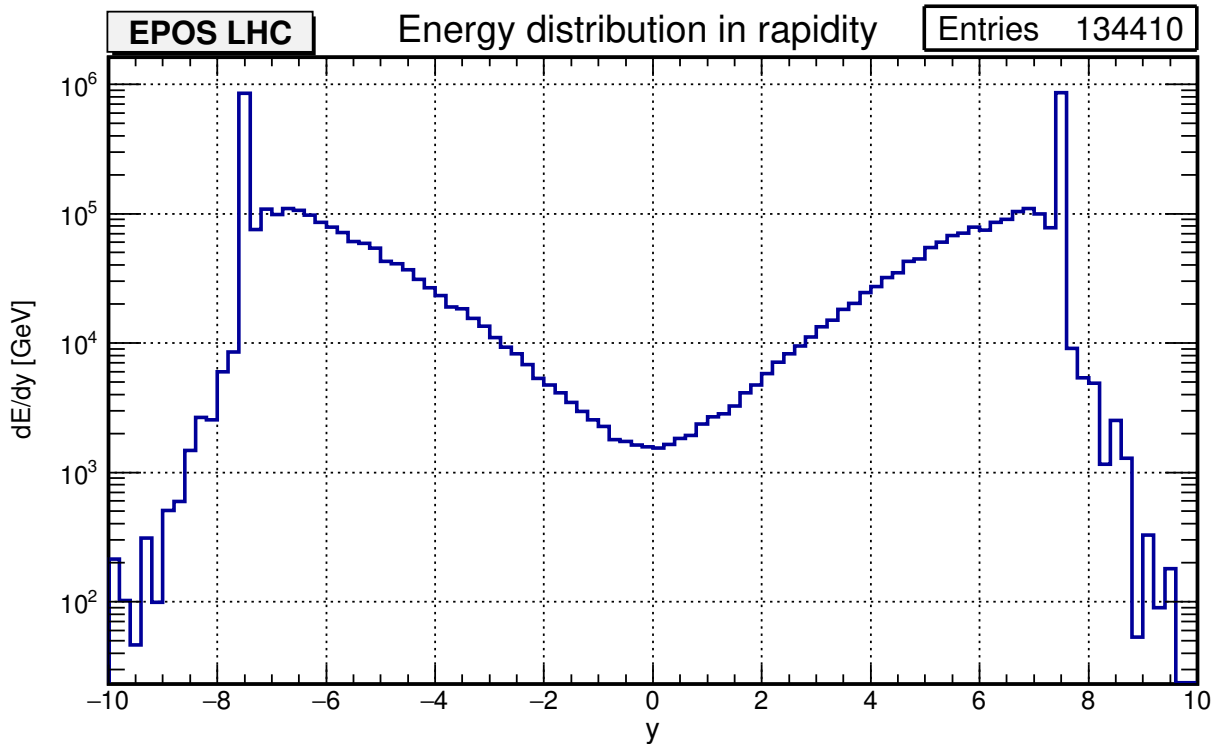


Figura 26: EPOS LHC: colisões p-C

2.3 Colisão próton-Chumbo: $E_{\text{LAB}} = 120 \text{ TeV} \rightarrow \sqrt{s} = 1.6 \text{ TeV}$

- 1000 Colisões próton-Chumbo p-Pb
- $E_{\text{LAB}} = 120000 \text{ GeV} = 120 \text{ TeV}$
- $m_p = 0.9383 \text{ GeV}$, $m_{\text{Pb}} = 11 \text{ GeV}$
- $\sqrt{s} = \sqrt{m_p^2 + m_C^2 + 2E_{\text{LAB}}m_C} = 1.6 \text{ TeV}$
- Referencial do CM.

```
$ bin/crmc -o root -p800 -P-800 -n1000 -m0 -i2212 -I822080
>> crmc <<

seed:                98795356 (automatic)
projectile id:        2212 (p)
projectile momentum:  800
target id:            822080 (A=208, Z=82)
target momentum:     -800

number of collisions: 1000
parameter file name:  crmc.param
output file name:     crmc_eposlhc_98795356_p_Pb_800.root
HE model:             0 (EPOS-LHC)
```

```
#####
#           EPOS LHC           K. WERNER, T. PIEROG           #
#                               Contact: tanguy.pierog@kit.edu   #
#####
#           WARNING: This is a special retuned version !!!     #
#           Do not publish results without contacting the authors. #
#####
```

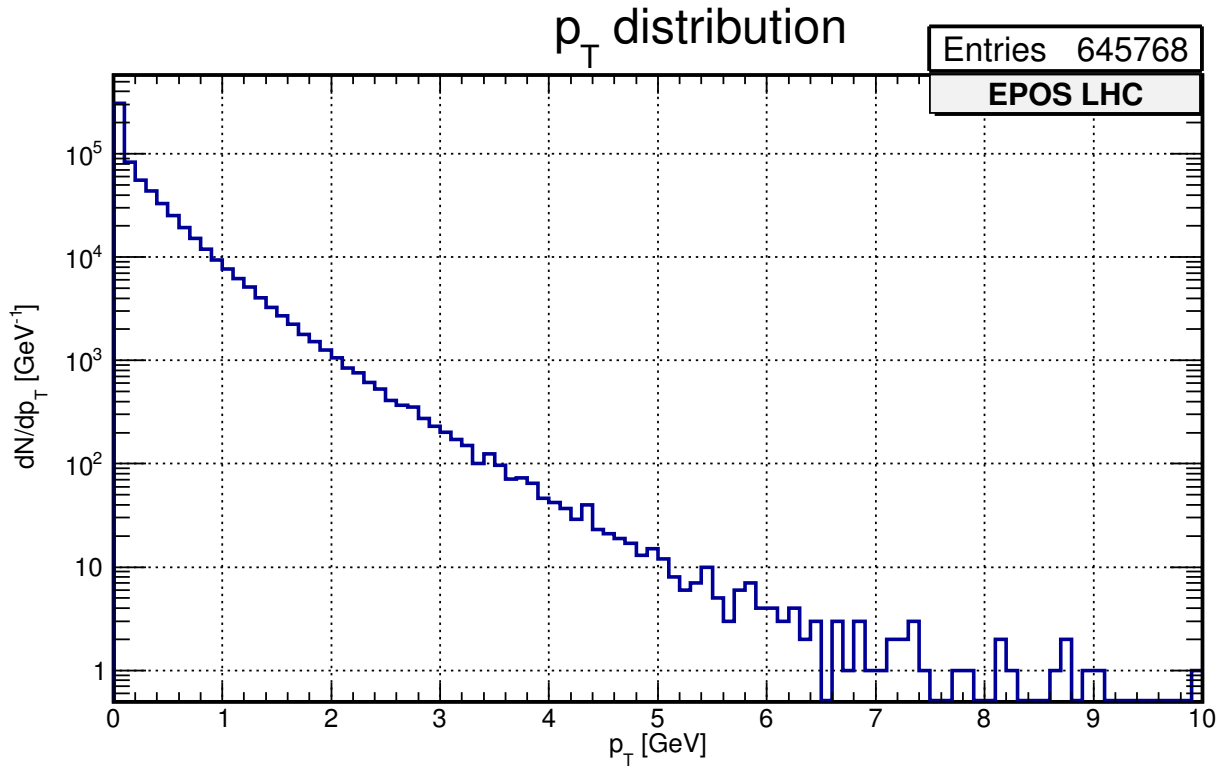


Figura 27: EPOS LHC: colisões p-Pb

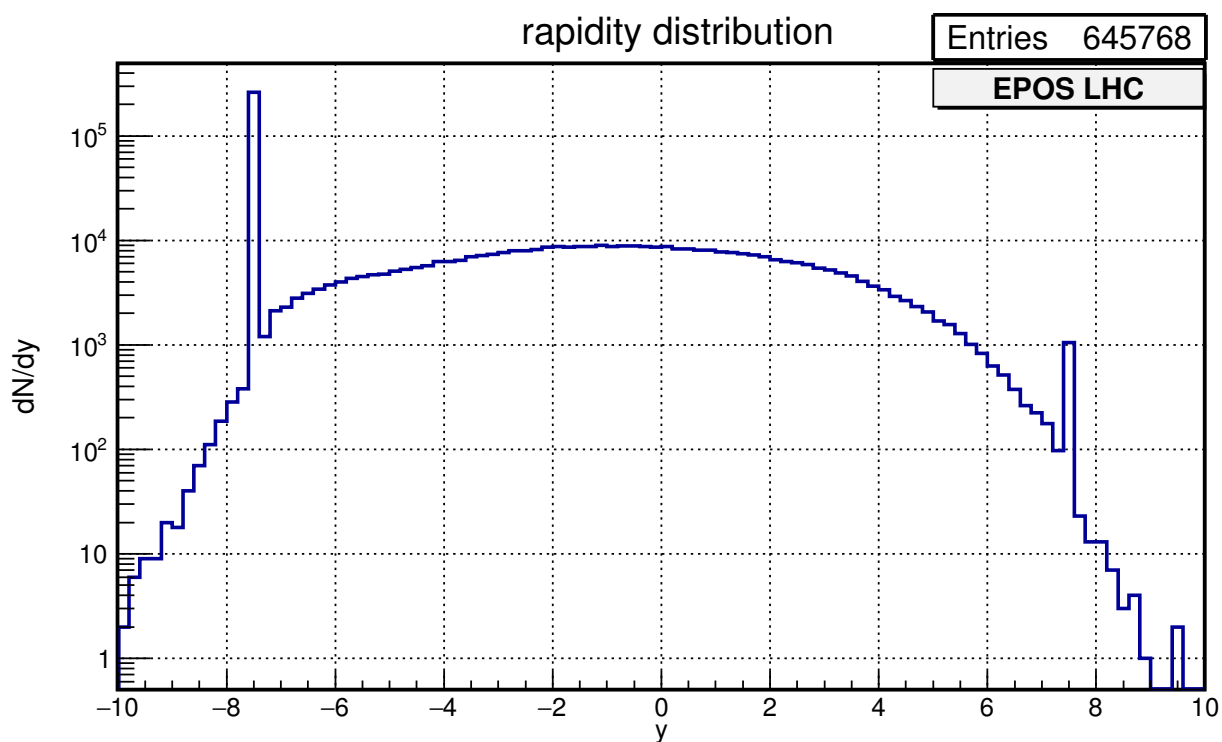


Figura 28: EPOS LHC: colisões p-Pb

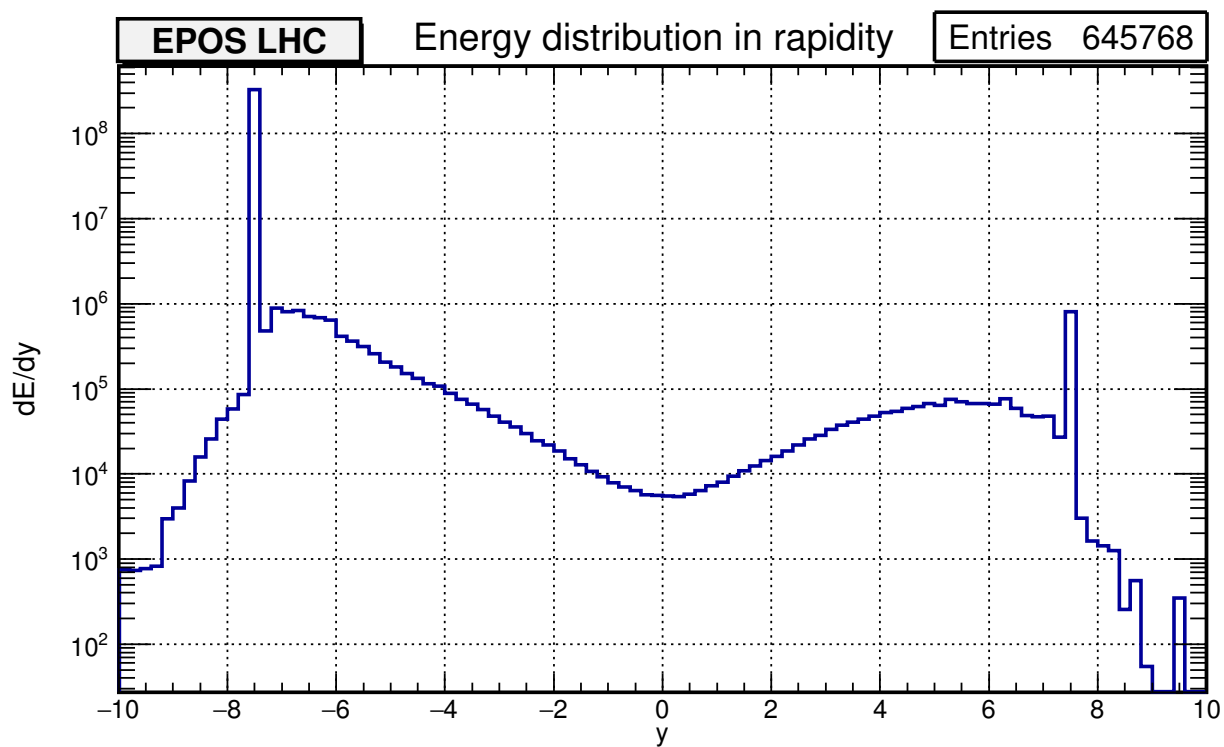


Figura 29: EPOS LHC: colisões p-Pb

Referências

- [1] G. Aad et al. “Charged-particle multiplicities in pp interactions at $\sqrt{s} = 900$ GeV measured with the ATLAS detector at the LHC”. Em: *Phys. Lett. B* 688 (2010), pp. 21–42. DOI: [10.1016/j.physletb.2010.03.064](https://doi.org/10.1016/j.physletb.2010.03.064). arXiv: [1003.3124](https://arxiv.org/abs/1003.3124) [hep-ex].