Search for exclusive top quark pair production at the LHC

Summer Internship

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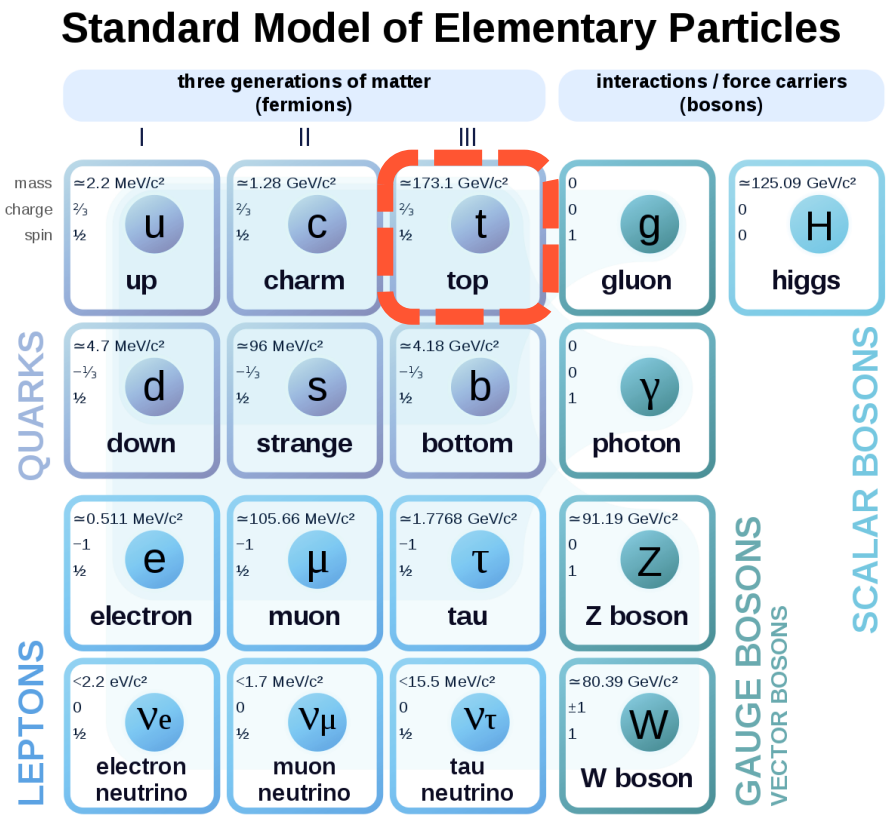
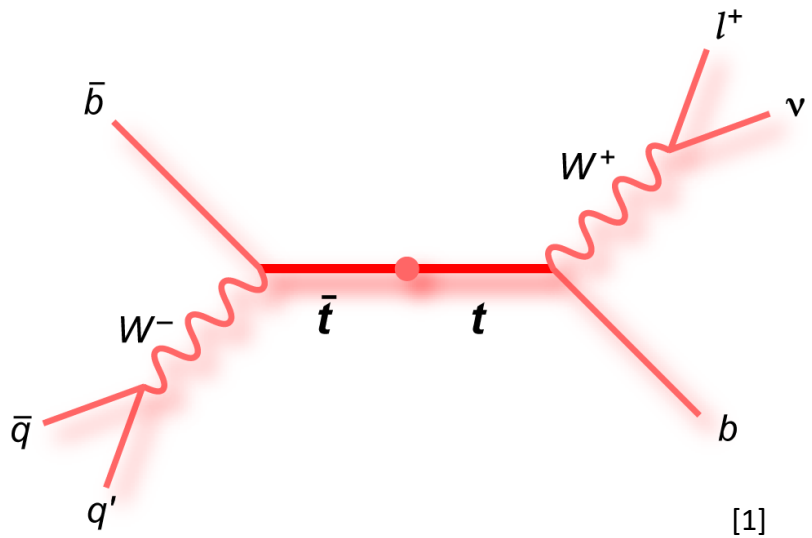
The Top Quark



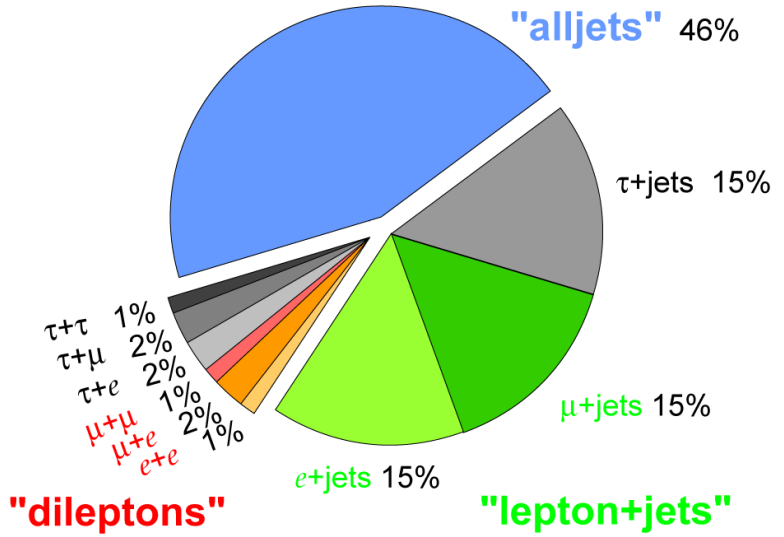
- Heaviest of Standard Model particles
- Produced at the LHC mainly in $t\bar{t}$ pairs

Brief Introduction



[1]

Top quark -> b-quark + W boson

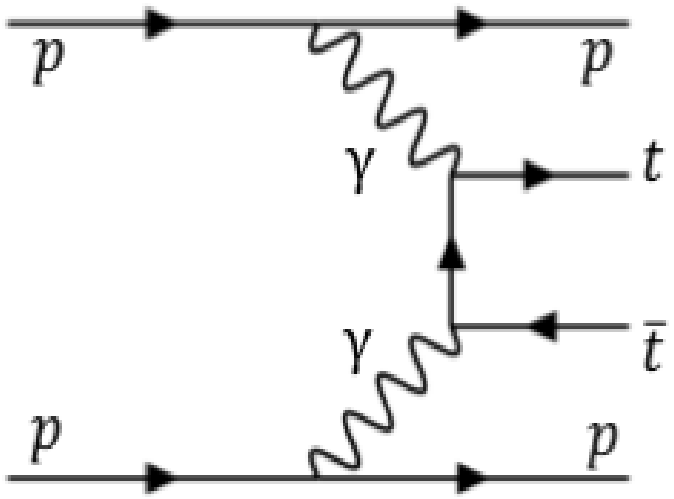


[1]

We are interested in the dileptonic decaying channel

[1] https://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_feynman_diagrams.html

Exclusive $t\bar{t}$

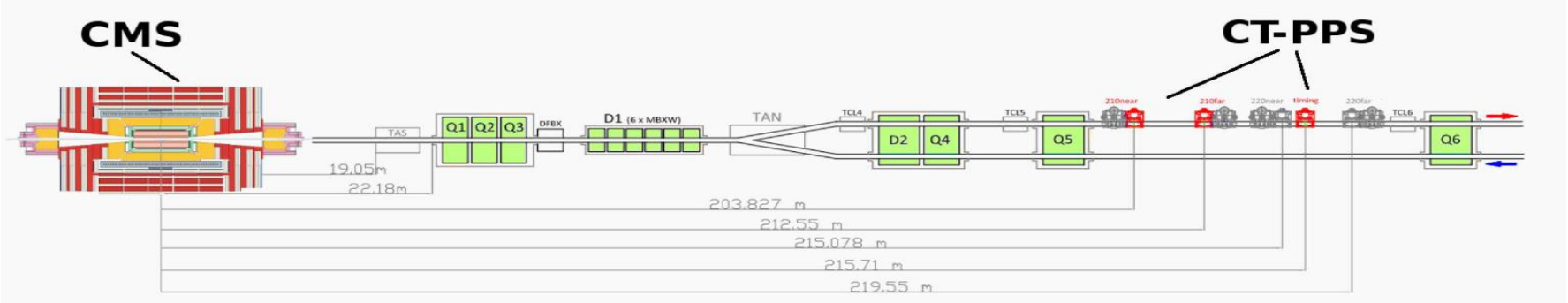


- Dileptonic decaying channel
- Photon-photon interaction
- Missing transverse energy (met) due to neutrinos
- Protons preserved and detected by the PPS (allow the kinematic reconstruction even with met)

PPS Detector

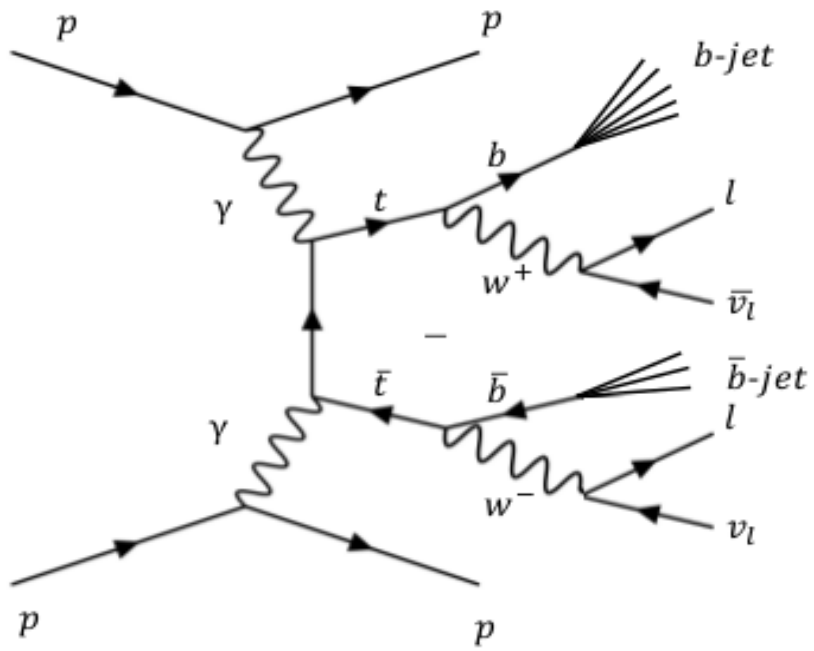
(Precision Proton Spectometer)

- LHC magnets bend scattered protons outside of the beam envelope
- Roman Pots placed a few mm from the beamline
- Detect protons at about ± 200 m of the IP (positive and negative sides)



$$\vec{F} = q(\vec{v} \times \vec{B})$$

Central Selection



Require for leptons:

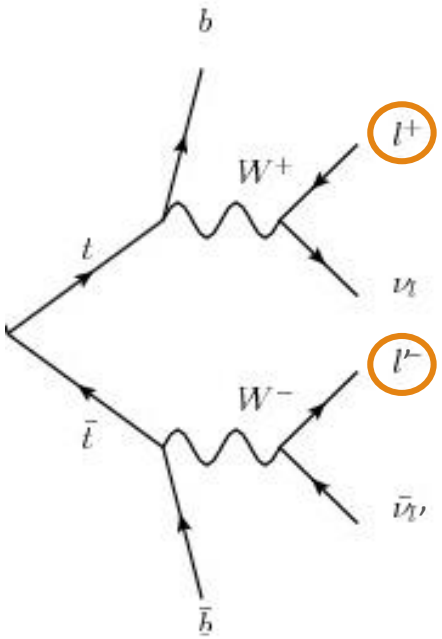
- ≥ 2
- $|\eta| \leq 2.5$
- $p_T \geq 13$ GeV

Require for jets:

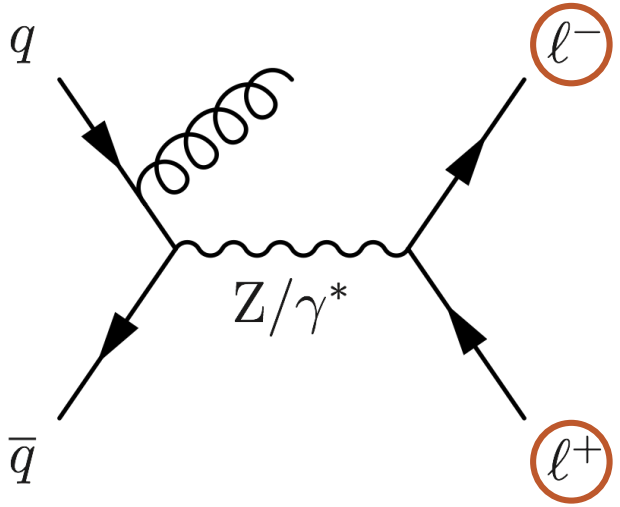
- ≥ 1
- ≥ 1 b-jet

Main Background

Inclusive $t\bar{t}$



Drell-Yan

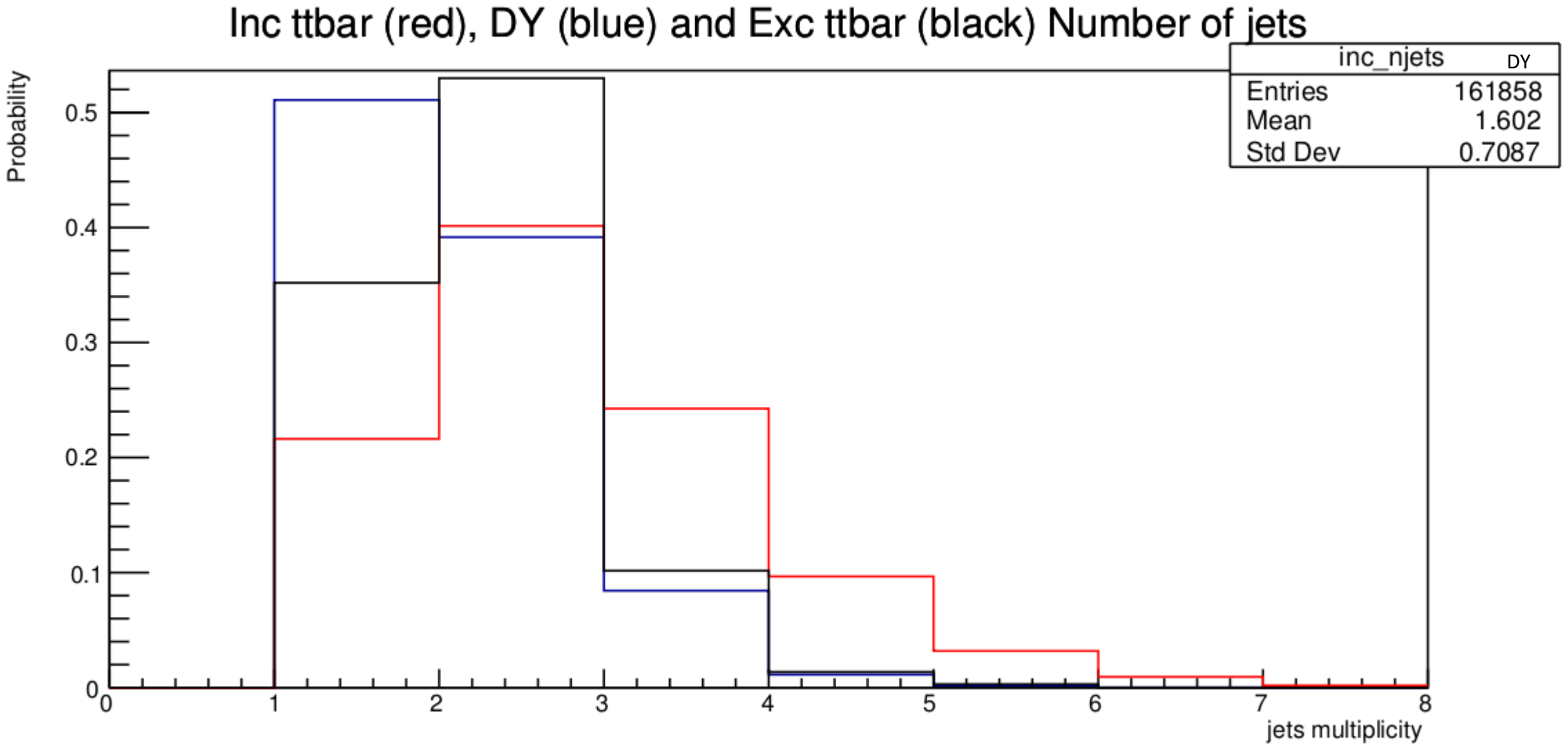


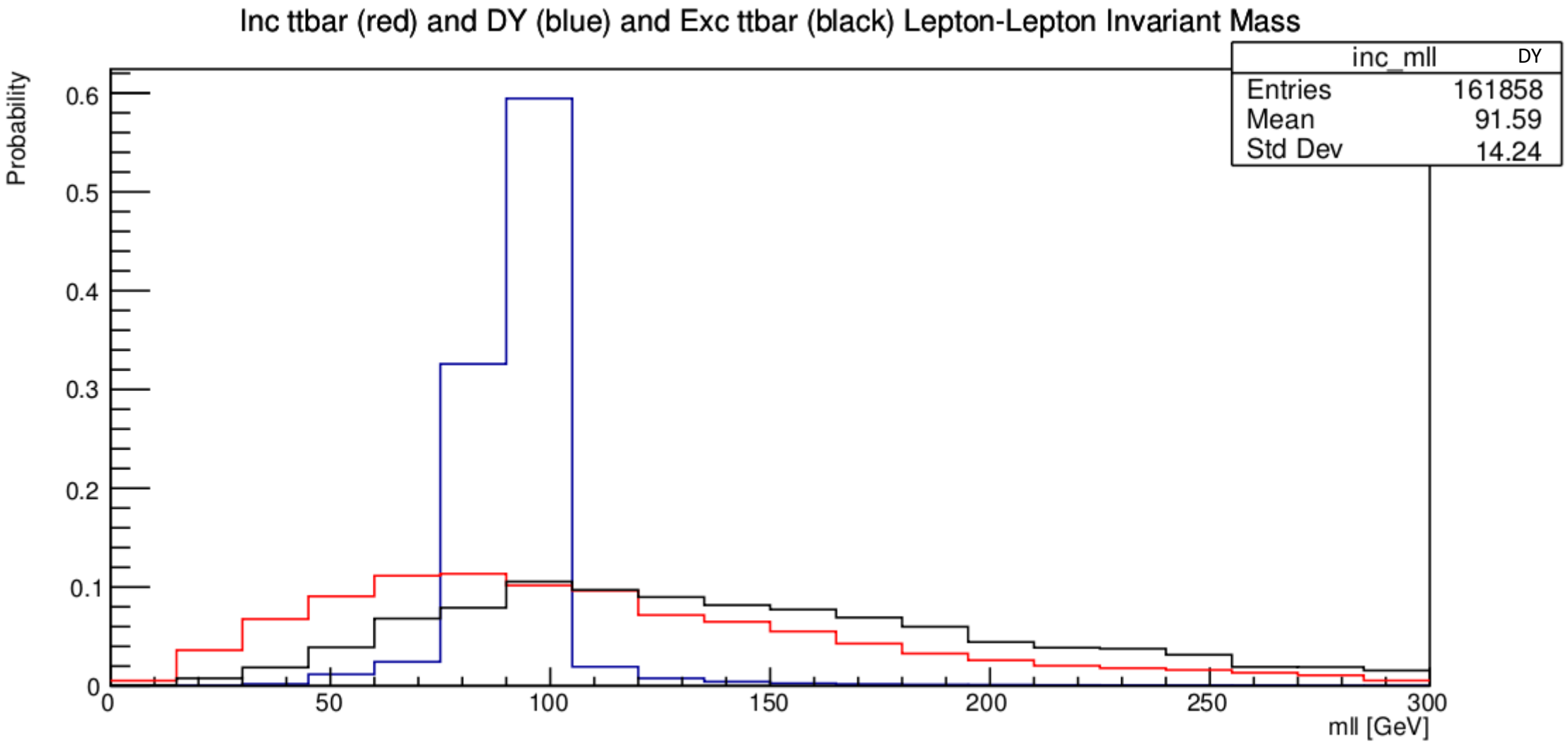
Kinematic Analysis

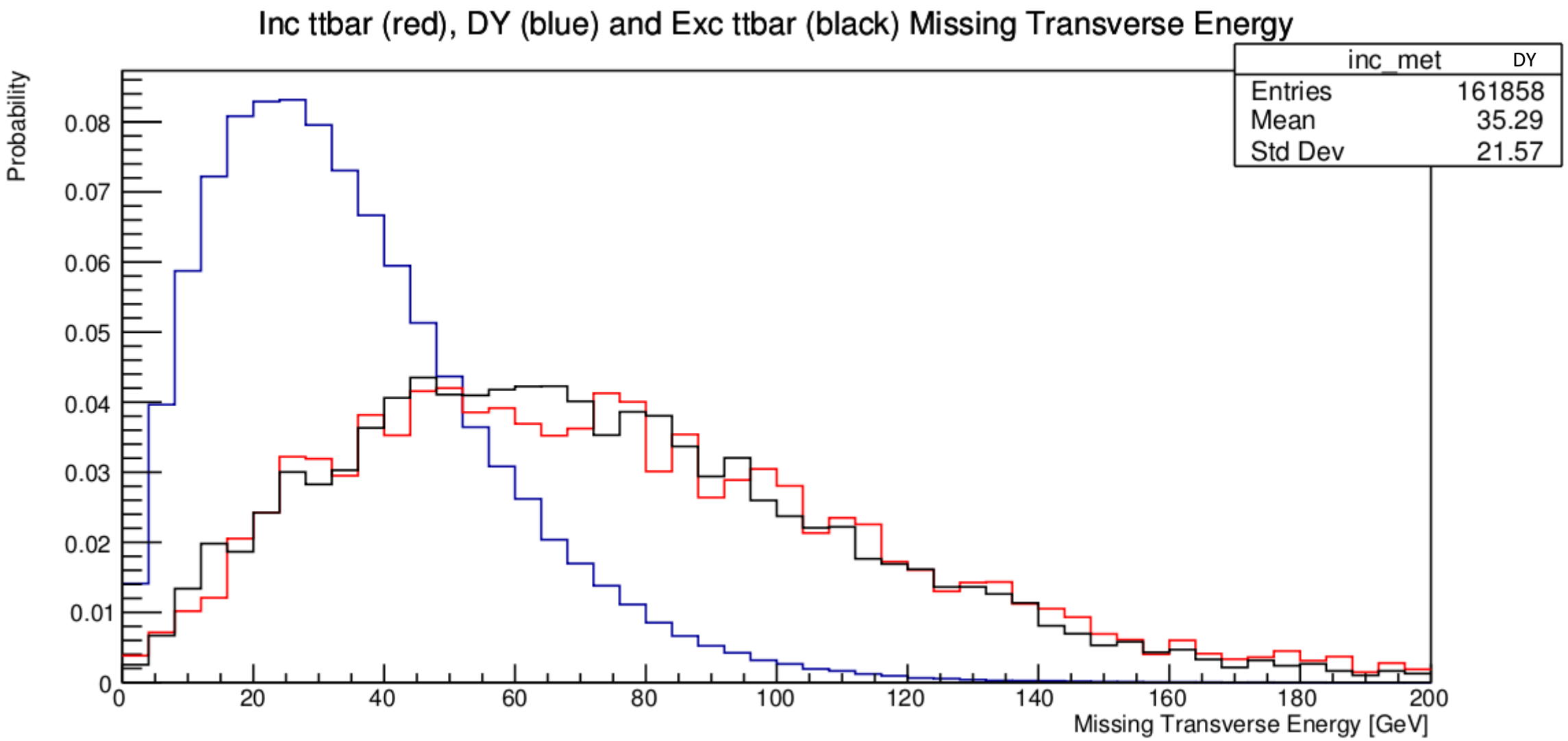
- Monte Carlo samples from 2017
  - Inclusive $t\bar{t}$
  - Drell-Yan
  - Exclusive $t\bar{t}$
- $\sqrt{s}$=13 TeV

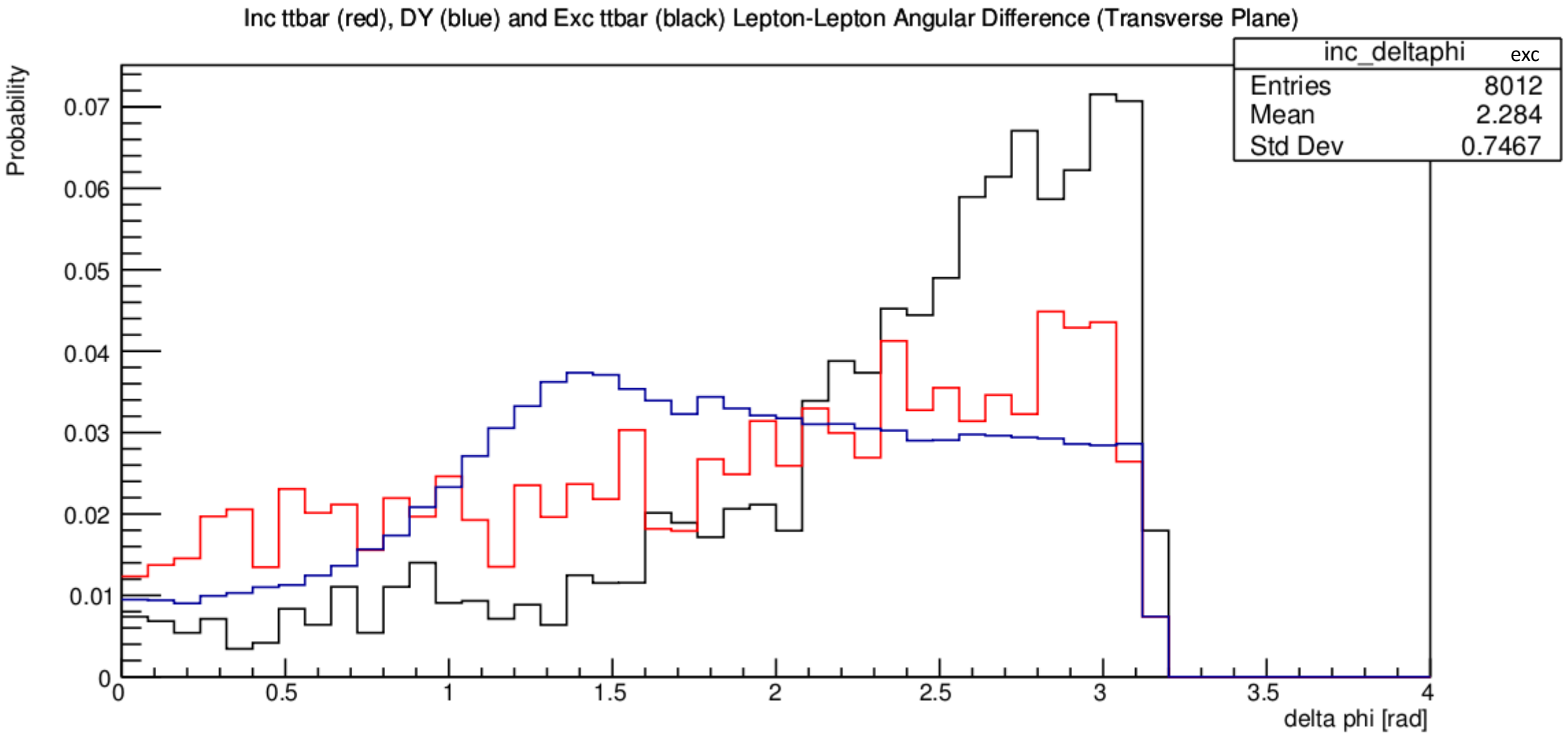
Tools for multivariable analysis on real data

Central Detector


Inc ttbar (red), DY (blue) and Exc ttbar (black) Number of jets
inc_njets
DY
Entries 161858
Mean 1.602
Std Dev 0.7087
Probability
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
jets multiplicity


Inc ttbar (red) and DY (blue) and Exc ttbar (black) Lepton-Lepton Invariant Mass
inc_mll
DY
Entries 161858
Mean 91.59
Std Dev 14.24
Probability
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
mll [GeV]


Inc ttbar (red), DY (blue) and Exc ttbar (black) Missing Transverse Energy
inc_met DY
Entries 161858
Mean 35.29
Std Dev 21.57
Probability
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0 20 40 60 80 100 120 140 160 180 200
Missing Transverse Energy [GeV]


Inc ttbar (red), DY (blue) and Exc ttbar (black) Lepton-Lepton Angular Difference (Transverse Plane)
inc_deltaphi
exc
Entries 8012
Mean 2.284
Std Dev 0.7467
Probability
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.5
1
1.5
2
2.5
3
3.5
4
delta phi [rad]

PPS - Roman Pots

Forward Tracks IN PPS

- From each track we get the momentum loss of the proton
- Reconstruct tracks on both sides (ξ_1 and ξ_2)
- We can reconstruct the **mass** and **rapidity** of the system

$$\xi = \frac{p_i - p_f}{p_i}$$

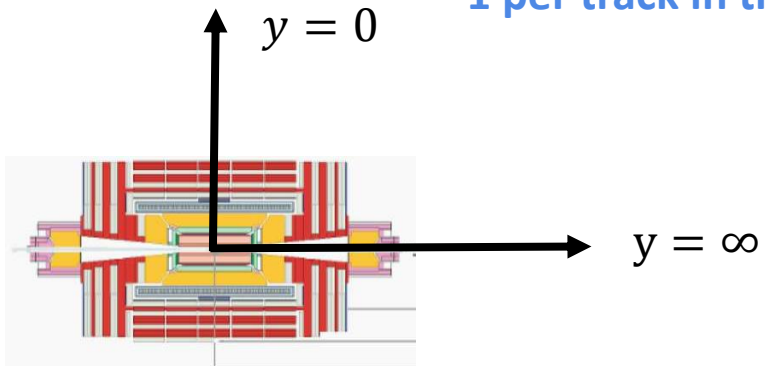
1 per track in the RP

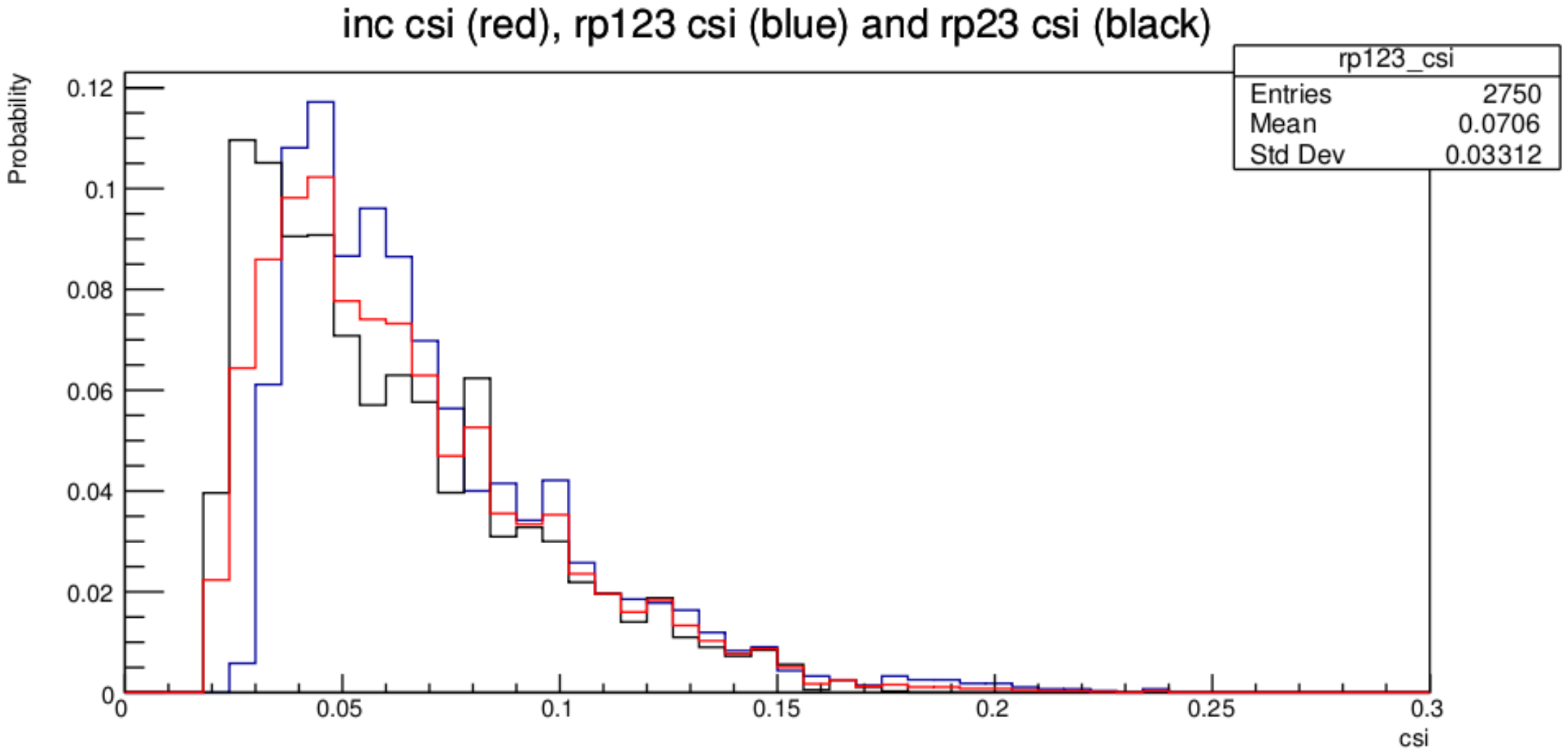
for every possible combination

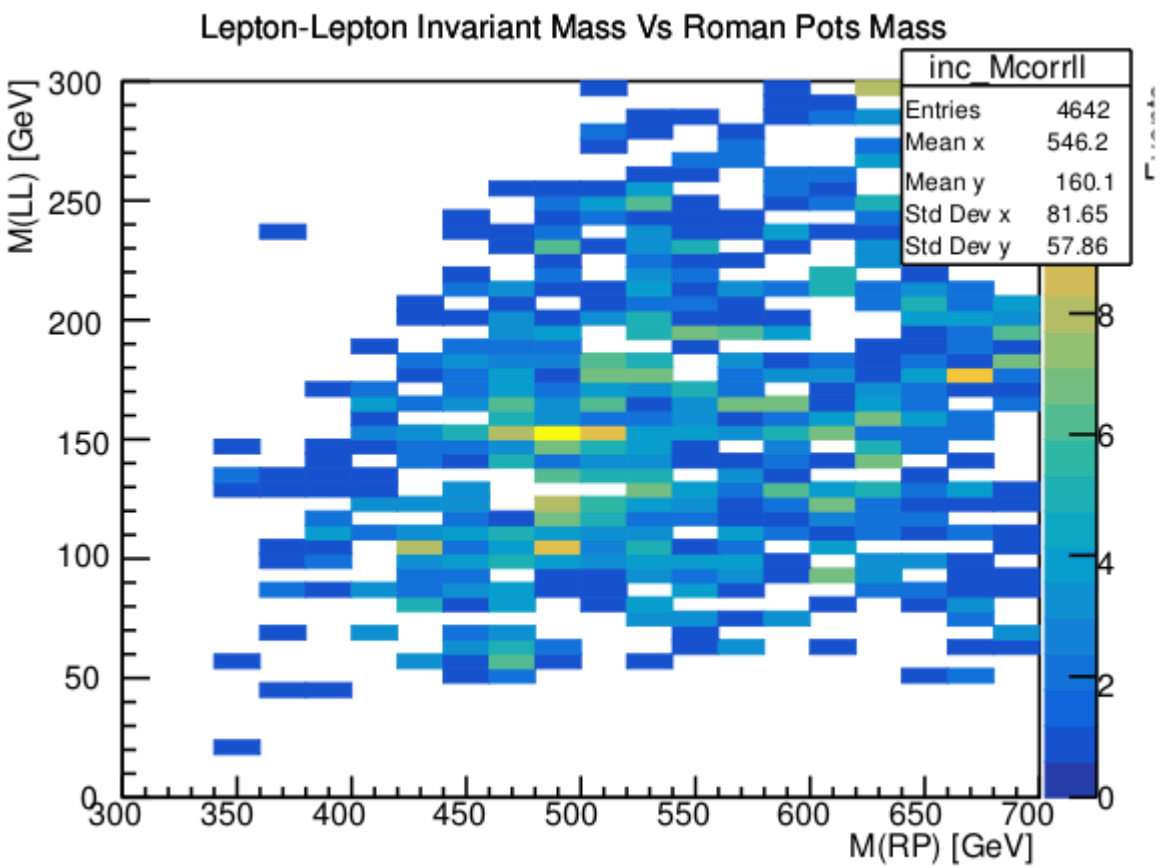
$$m_{RP} = \sqrt{s\xi_1\xi_2}$$

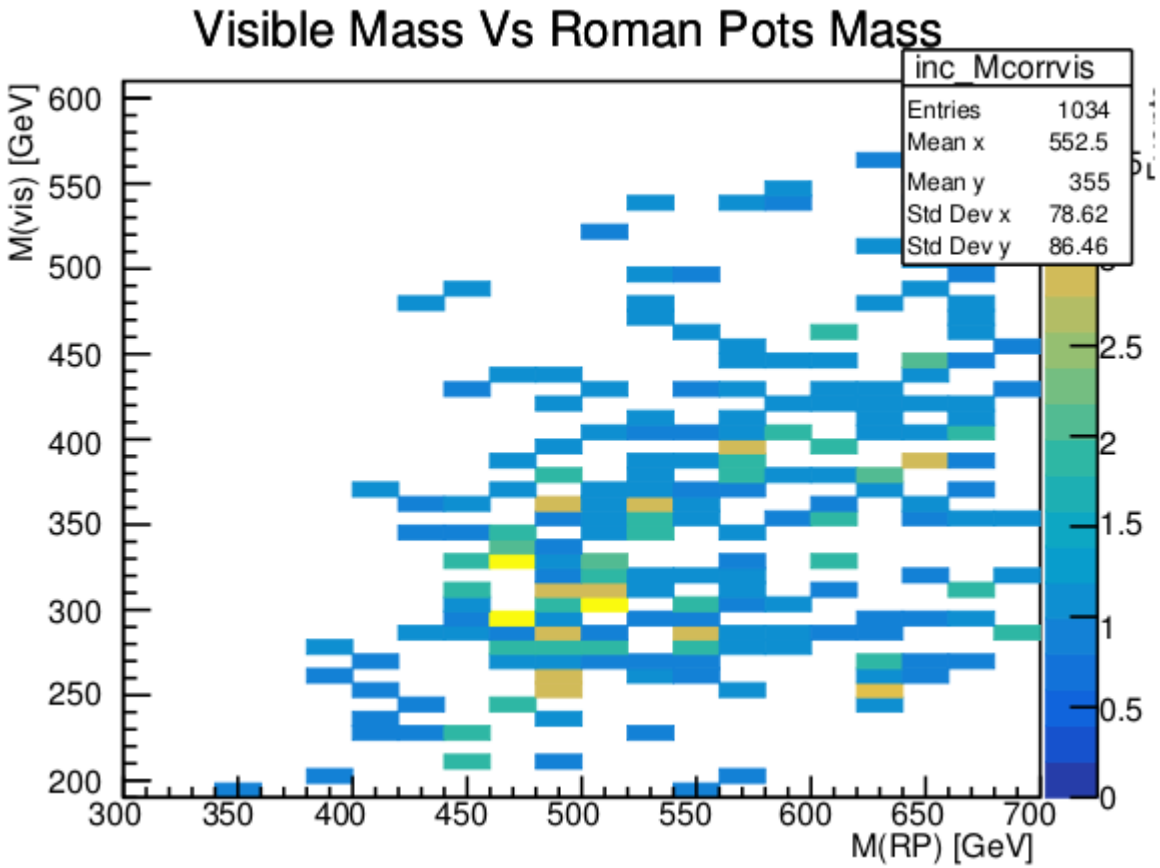
$$y_{RP} = \frac{1}{2}\ln\left(\frac{\xi_1}{\xi_2}\right)$$

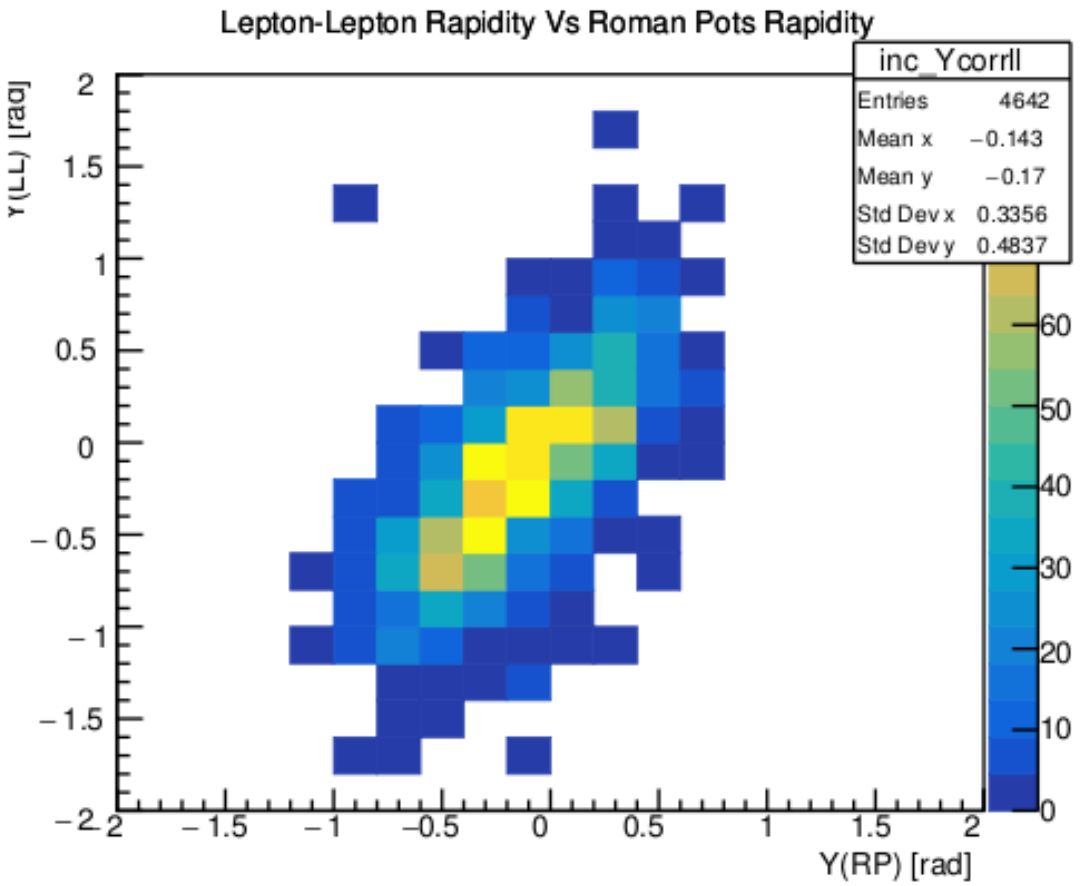
check which mass and rapidity values are compatible with what we are looking for!

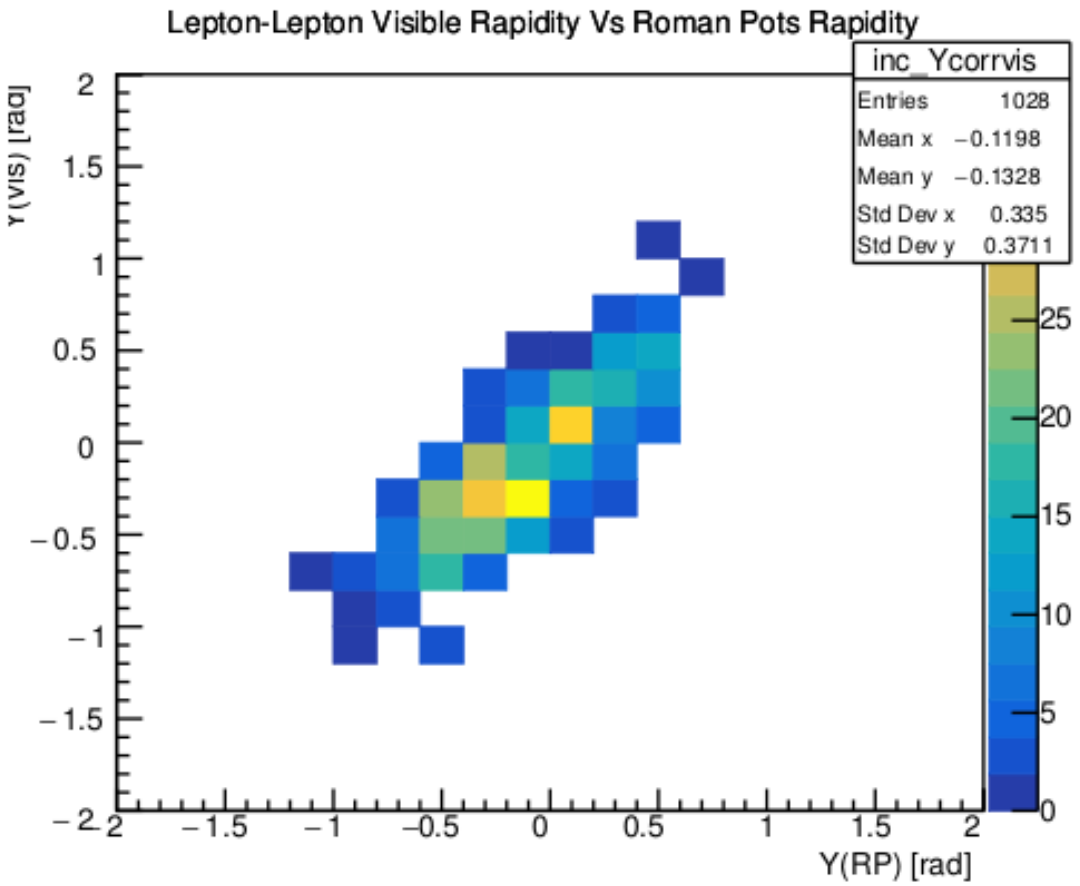



inc csi (red), rp123 csi (blue) and rp23 csi (black)
rp123_csi
Entries 2750
Mean 0.0706
Std Dev 0.03312
Probability
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.05
0.1
0.15
0.2
0.25
0.3
csi


Lepton-Lepton Invariant Mass Vs Roman Pots Mass
inc_Mcorrll
Entries 4642
Mean x 546.2
Mean y 160.1
Std Dev x 81.65
Std Dev y 57.86
M(LL) [GeV]
M(RP) [GeV]


Visible Mass Vs Roman Pots Mass
inc_Mcorrvis
Entries 1034
Mean x 552.5
Mean y 355
Std Dev x 78.62
Std Dev y 86.46
M(vis) [GeV]
M(RP) [GeV]


Lepton-Lepton Rapidity Vs Roman Pots Rapidity
inc_Ycorrll
Entries 4642
Mean x −0.143
Mean y −0.17
Std Dev x 0.3356
Std Dev y 0.4837
Y(LL) [rad]
Y(RP) [rad]


Lepton-Lepton Visible Rapidity Vs Roman Pots Rapidity
inc_Ycorrvis
Entries 1028
Mean x −0.1198
Mean y −0.1328
Std Dev x 0.335
Std Dev y 0.3711
Y(VIS) [rad]
Y(RP) [rad]

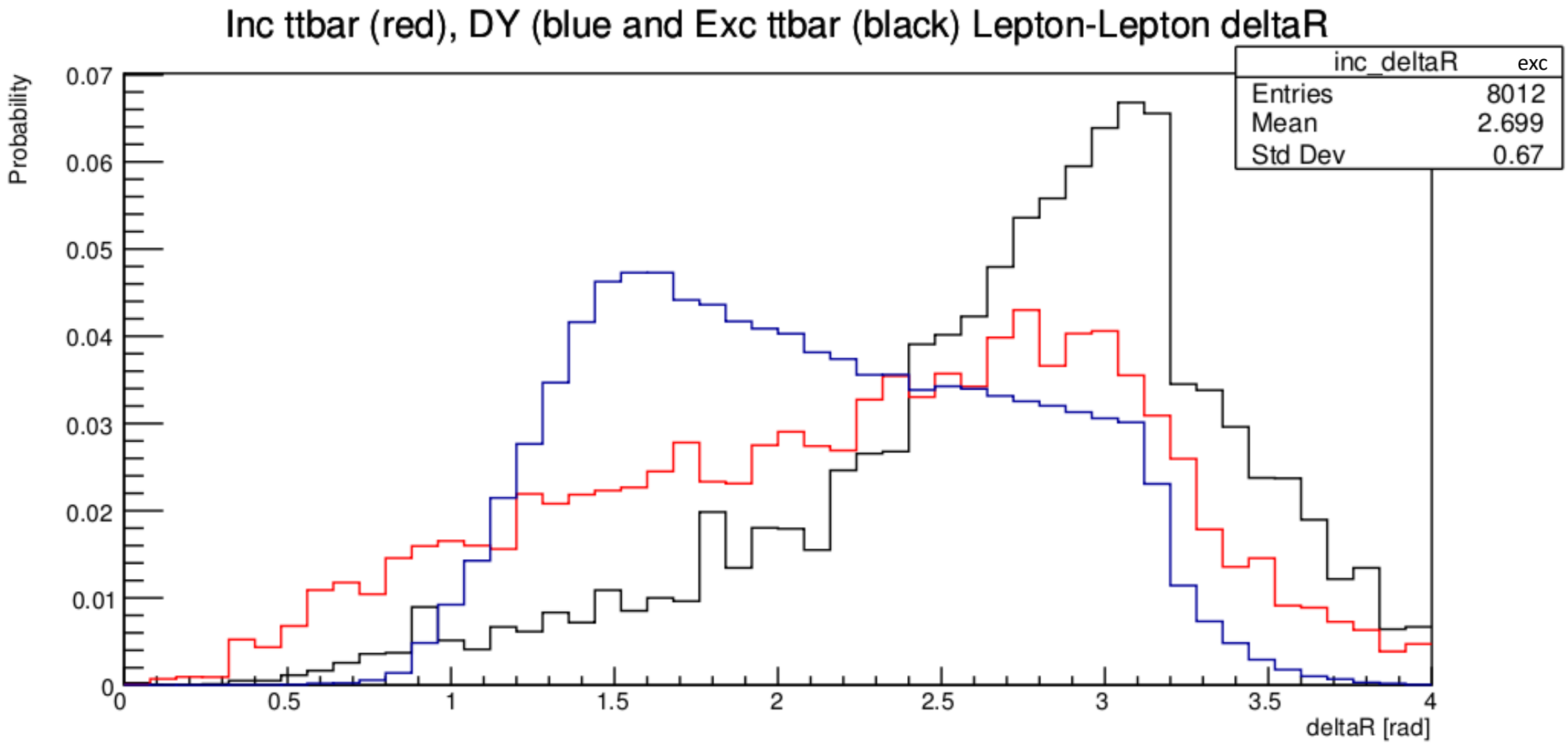
Conclusions and Future Work

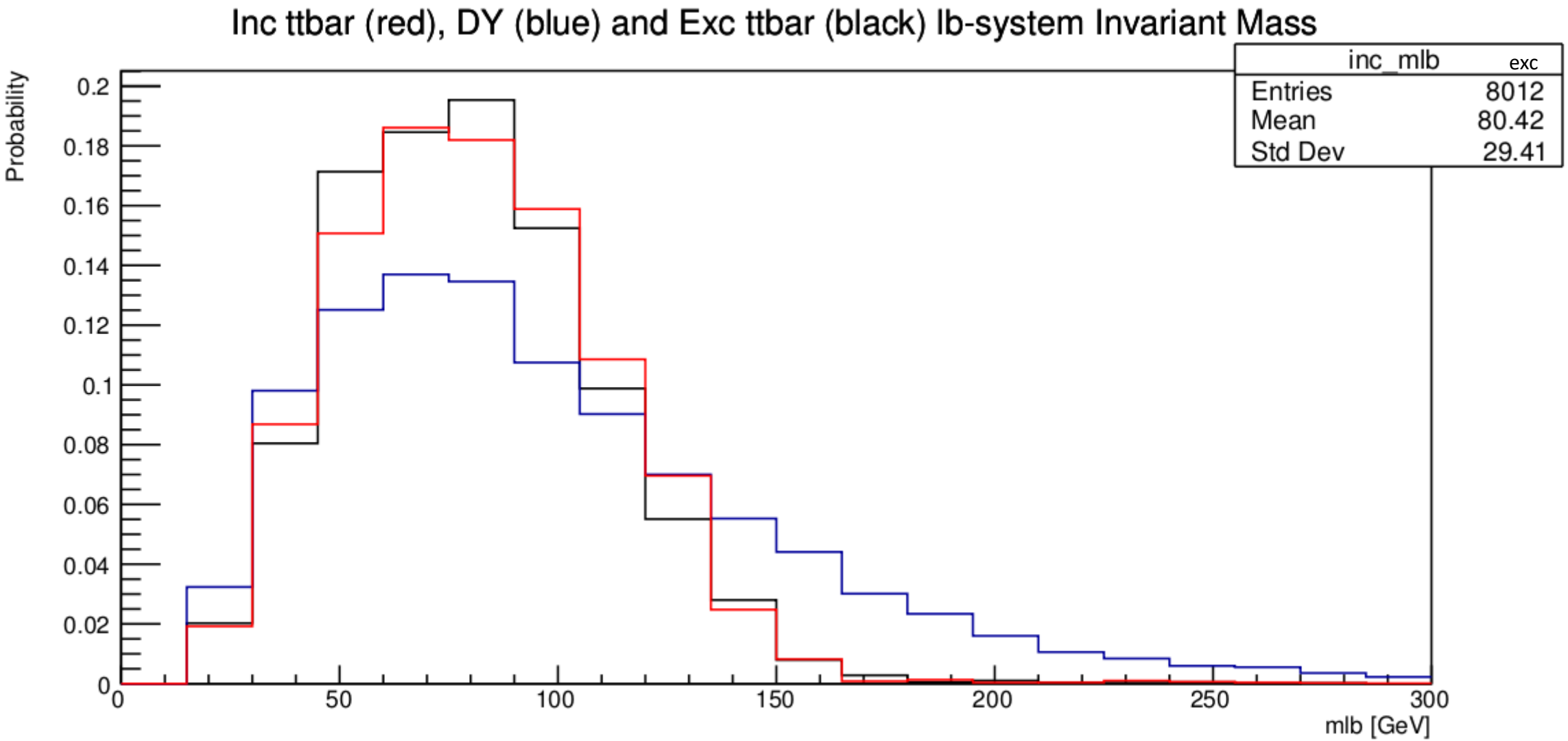
- Developed skills in Root and C++
- Understood the basis of a physics analysis
- Applied a kinematic analysis to a new Monte Carlo signal sample

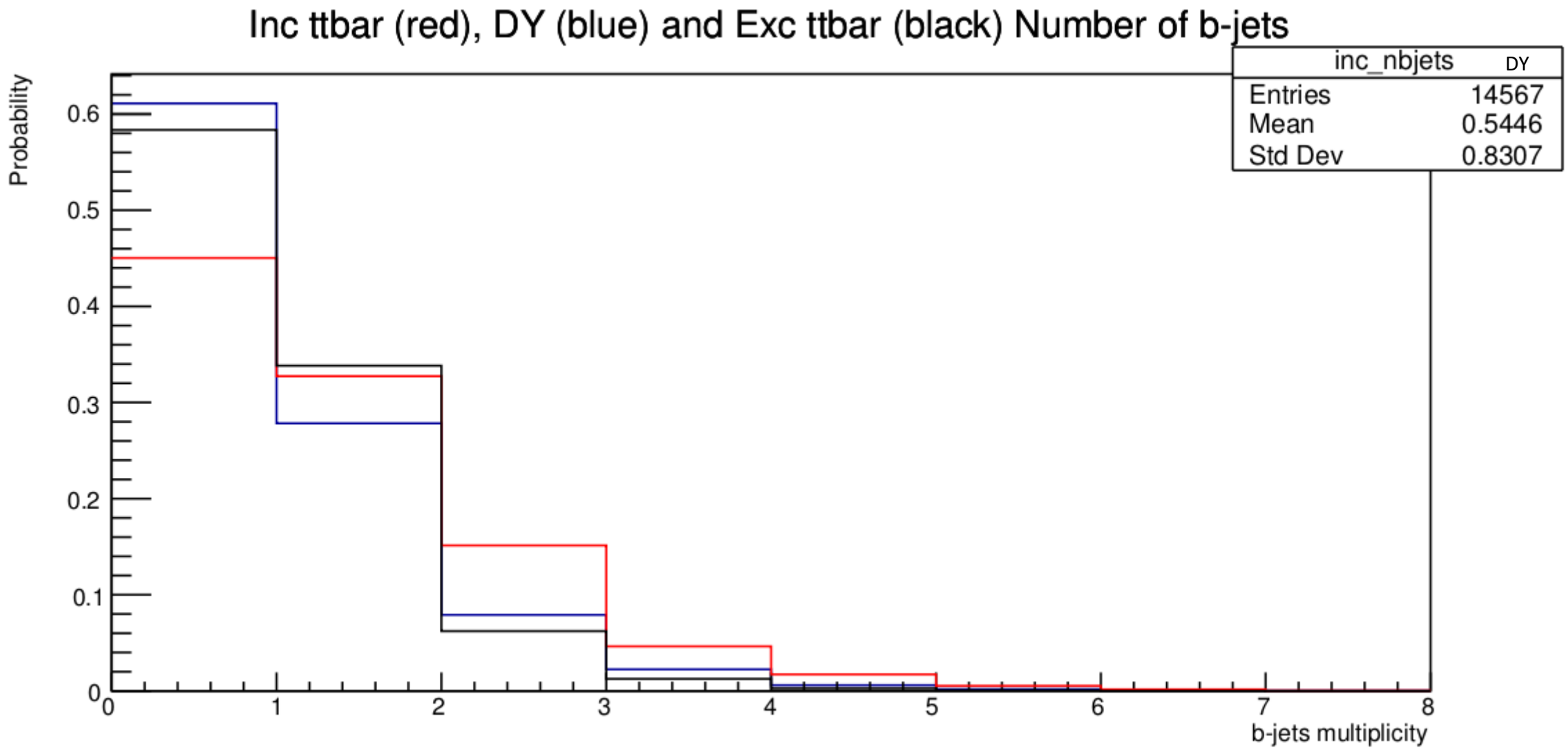
- Apply a MVA on real data
- Explore the correlations enhanced by PPS

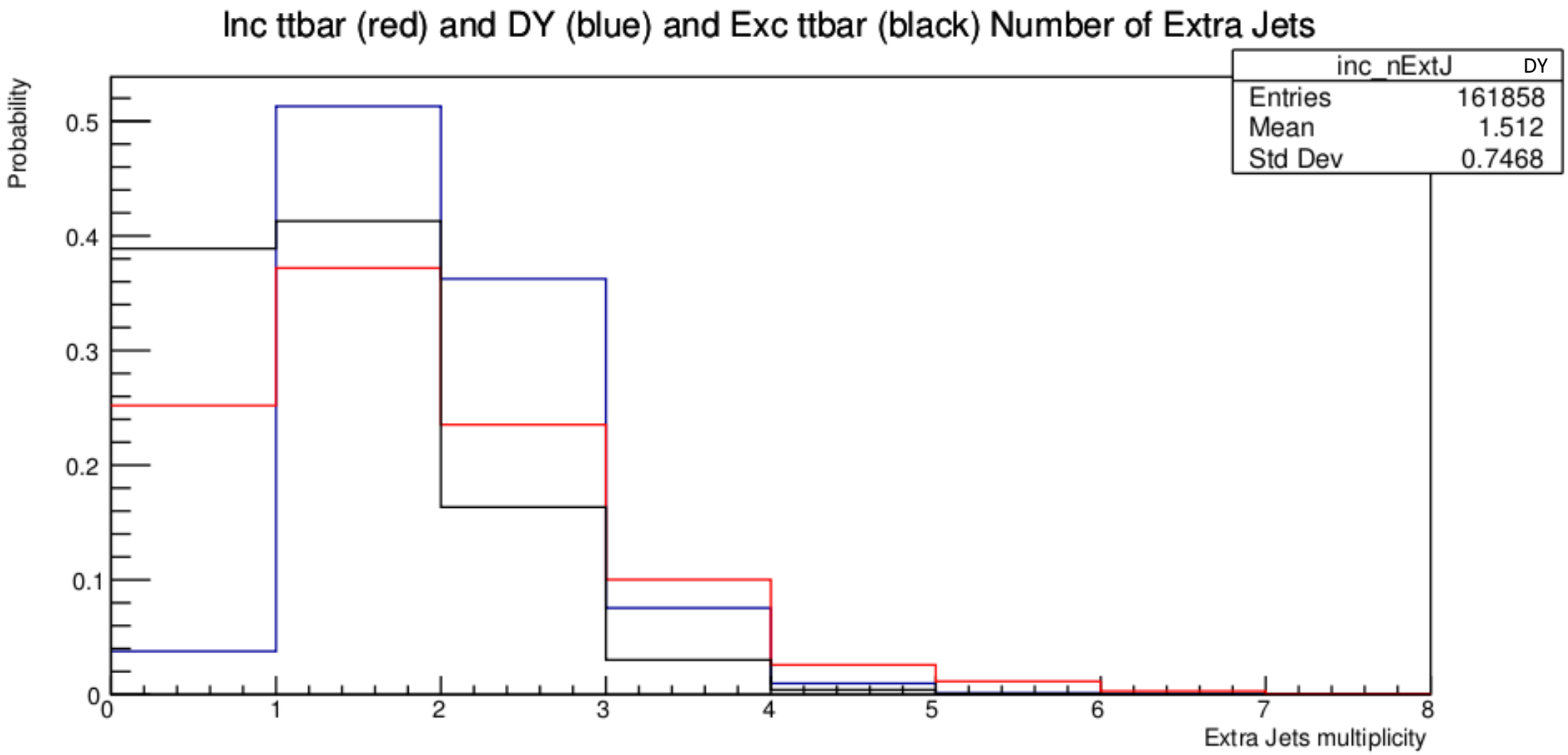
Thank you!

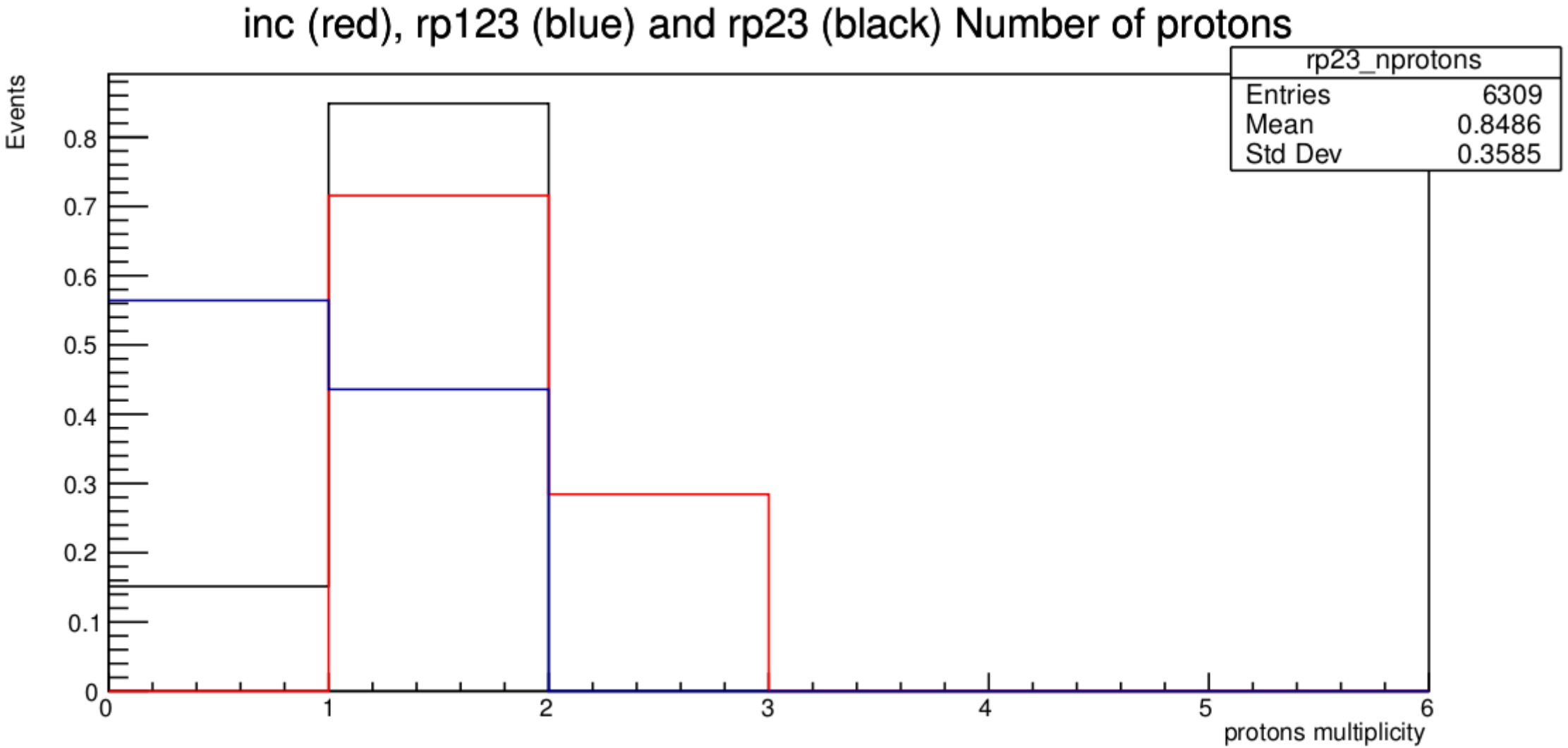
Backup

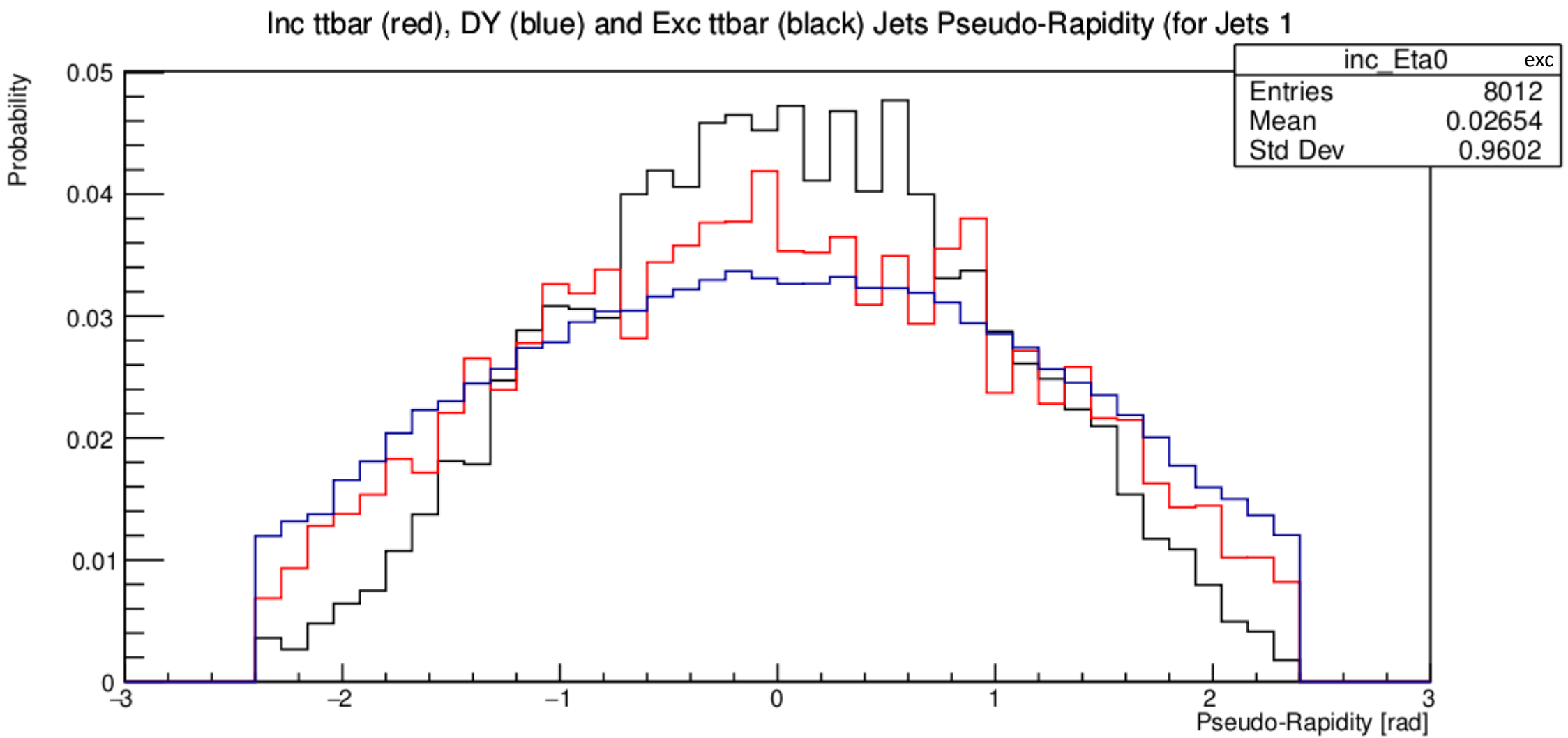

Inc ttbar (red), DY (blue and Exc ttbar (black) Lepton-Lepton deltaR
inc_deltaR
exc
Entries 8012
Mean 2.699
Std Dev 0.67
Probability
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.5
1
1.5
2
2.5
3
3.5
4
deltaR [rad]

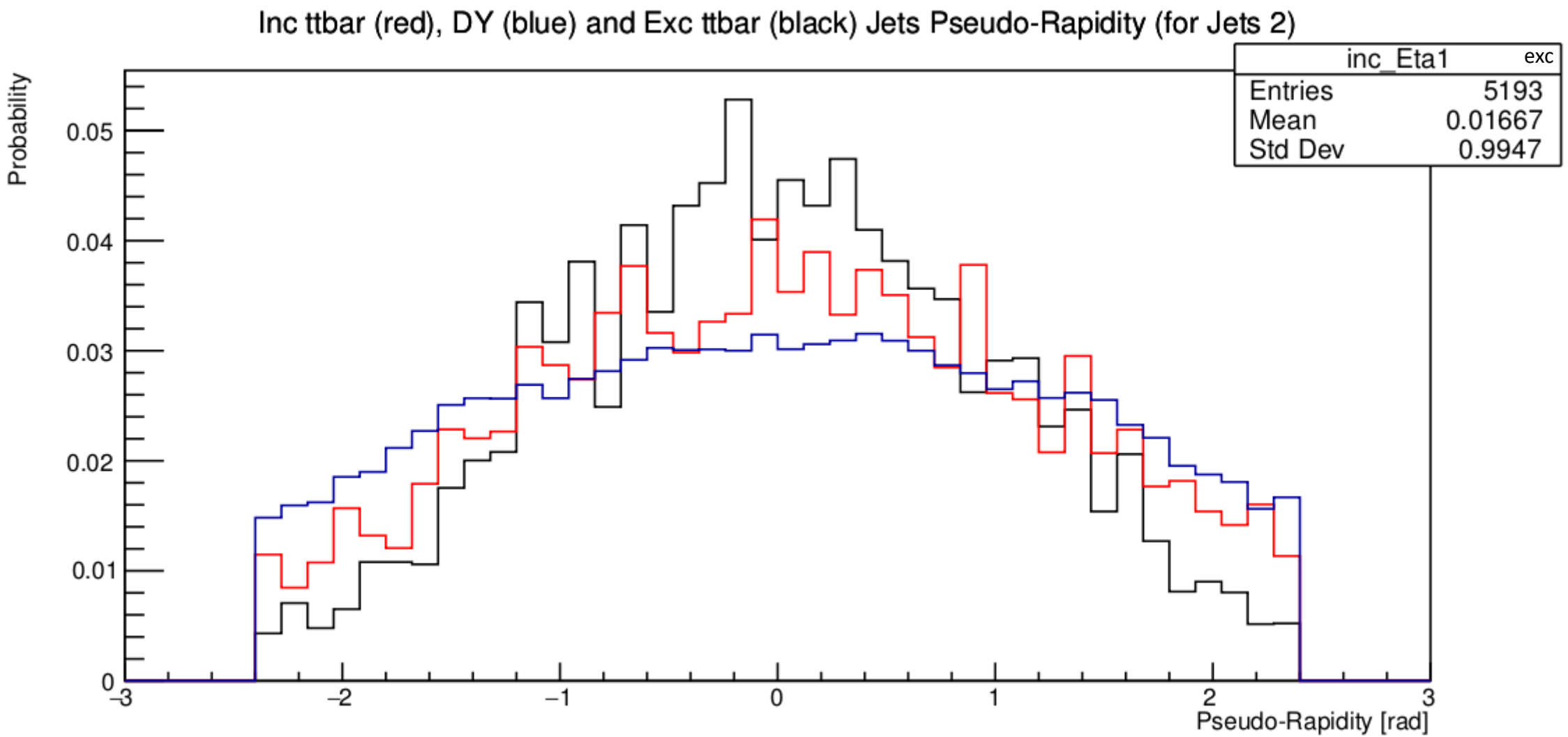

Inc ttbar (red), DY (blue) and Exc ttbar (black) lb-system Invariant Mass
inc_mlb
exc
Entries 8012
Mean 80.42
Std Dev 29.41
Probability
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
50
100
150
200
250
300
mlb [GeV]

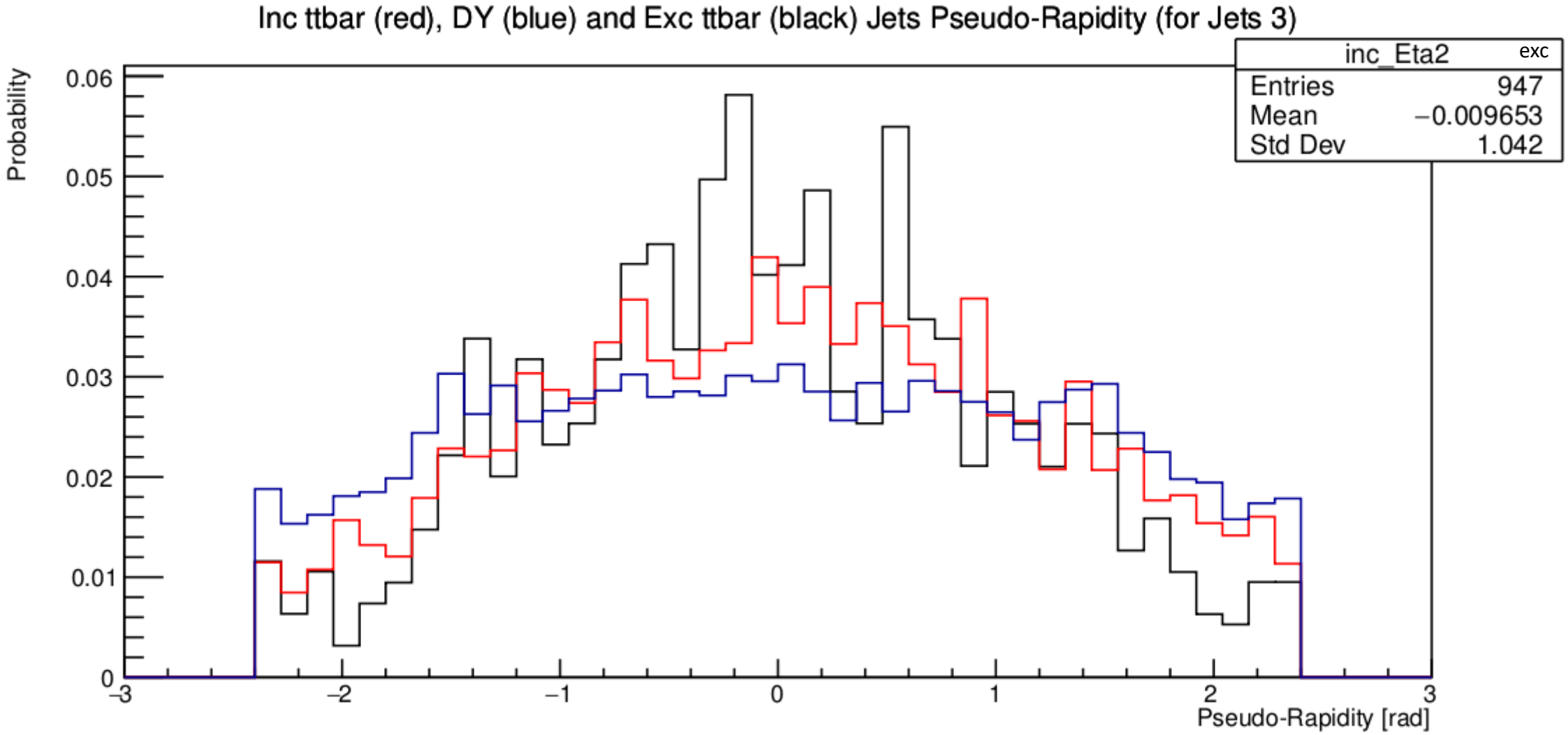

Inc ttbar (red), DY (blue) and Exc ttbar (black) Number of b-jets
inc_nbjets DY
Entries 14567
Mean 0.5446
Std Dev 0.8307
Probability
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
b-jets multiplicity


Inc ttbar (red) and DY (blue) and Exc ttbar (black) Number of Extra Jets
inc_nExtJ DY
Entries 161858
Mean 1.512
Std Dev 0.7468
Probability
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
Extra Jets multiplicity


inc (red), rp123 (blue) and rp23 (black) Number of protons
rp23_nprotons
Entries 6309
Mean 0.8486
Std Dev 0.3585
Events
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
1
2
3
4
5
6
protons multiplicity


Inc ttbar (red), DY (blue) and Exc ttbar (black) Jets Pseudo-Rapidity (for Jets 1
inc_Eta0
exc
Entries 8012
Mean 0.02654
Std Dev 0.9602
Probability
0.05
0.04
0.03
0.02
0.01
0
−3
−2
−1
0
1
2
3
Pseudo-Rapidity [rad]


Inc ttbar (red), DY (blue) and Exc ttbar (black) Jets Pseudo-Rapidity (for Jets 2)
inc_Eta1
exc
Entries 5193
Mean 0.01667
Std Dev 0.9947
Probability
0.05
0.04
0.03
0.02
0.01
0
−3
−2
−1
0
1
2
3
Pseudo-Rapidity [rad]


Inc ttbar (red), DY (blue) and Exc ttbar (black) Jets Pseudo-Rapidity (for Jets 3)
inc_Eta2
exc
Entries 947
Mean −0.009653
Std Dev 1.042
Probability
0.06
0.05
0.04
0.03
0.02
0.01
0
−3
−2
−1
0
1
2
3
Pseudo-Rapidity [rad]