Status Report
TTbar resonances
Angular Distributions

NTUA

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Z prime physics

- Motivation:
  - Additional U(1)’ gauge symmetries and associated Z’ gauge bosons are one of the most motivated extensions of the SM
  - It is difficult to reduce the rank of an extended gauge group that contains the SM

- In the SM the neutral current interactions of the fermions are described by the Lagrangian:

$$-L_{\mathrm{NC}}^{\mathrm{SM}} = gJ_3^\mu W_{3\mu} + g' J_Y^\mu B_\mu = eJ_{em}^\mu A_\mu + g_1 J_1^\mu Z_{1\mu}^0$$

- In the extension to SU(2) x $U(1)_Y$ x $U(1)'^n$, $n \geq 1$

$$-L_{\mathrm{NC}} = eJ_{em}^\mu A_\mu + \sum_{\alpha=1}^{n+1} g_\alpha J_\alpha^\mu Z_{\alpha\mu}^0,$$

where g_1, $Z_{1\mu}^0$ and J_1^μ are the respectively the gauge coupling, boson and current for the SM. In a similar way g_a , $Z_{a\mu}^0$ for a=2,…n+1 are the gauge couplings and bosons for the additional U(1)’s.

The gauge currents will become:

$$J_\alpha^\mu = \sum_i \bar{f}_i \gamma^\mu [\epsilon_L^\alpha(i) P_L + \epsilon_R^\alpha(i) P_R] f_i$$
$$= \frac{1}{2} \sum_i \bar{f}_i \gamma^\mu [g_V^\alpha(i) - g_A^\alpha(i)\gamma^5] f_i.$$

Z prime physics

- The chiral couplings e_L , e_R are the $U(1)_a$ charges of the left and right handed components of the fermions and $g_{V,A} = e_L \pm e_R$ are the corresponding vector and axial couplings

- It is more convenient to specify the charges of the left chiral components of both the fermion f and the antifermion f^c with Q_{af} , Q_{afc} :

$$\epsilon_L^\alpha(f) = Q_{\alpha f}, \qquad \epsilon_R^\alpha(f) = -Q_{\alpha f^c}.$$

- For example in the SM one has: $Q_{1u} = \frac{1}{2} - \frac{2}{3}\sin^2\theta_W$ and $Q_{1u^c} = +\frac{2}{3}\sin^2\theta_W$

- The additional gauge couplings and charges are extremely model dependent

- The gauge covariant derivative will become: $D_\mu \phi_i = \left(\partial_\mu + ieq_iA_\mu + i\sum_{\alpha=1}^{n+1} g_\alpha Q_{\alpha i} Z^0_{\alpha\mu}\right)\phi_i,$

  Where the q_i , Q_{ai} , are respectively the electric and $U(1)_a$ charges of the ϕ_i

Z prime physics-Masses and mass mixings

- The electrically neutral photon field is massless while the $Z_{a\mu}^0$ develops a mass term $L_Z^{mass} = \frac{1}{2} M_{\alpha\beta}^2 Z_{\alpha\mu}^0 Z_\beta^{0\mu}$
  Where

$$M_{\alpha\beta}^2 = 2 g_\alpha g_\beta \sum_i Q_{\alpha i} Q_{\beta i} |\langle \phi_i \rangle|^2$$

- Diagonilizing the mass matrix one obtains n+1 massive eigenstates $Z_{\alpha\mu}$ with mass M_α :

$$Z_{\alpha\mu} = \sum_{\beta=1}^{n+1} U_{\alpha\beta} Z_{\beta\mu}^0$$

- But $Z_{a\mu}$ couples to $\sum_\beta g_\beta U_{\alpha\beta} J_\beta^\mu$ and the most studied case is where n =1 and we get a mass matrix:

$$\begin{aligned} M_{Z-Z'}^2 &= \begin{pmatrix} 2g_1^2 \sum_i t_{3i}^2 |\langle \phi_i \rangle|^2 & 2g_1 g_2 \sum_i t_{3i} Q_i |\langle \phi_i \rangle|^2 \\ 2g_1 g_2 \sum_i t_{3i} Q_i |\langle \phi_i \rangle|^2 & 2g_2^2 \sum_i Q_i^2 |\langle \phi_i \rangle|^2 \end{pmatrix} \\ &\equiv \begin{pmatrix} M_{Z^0}^2 & \Delta^2 \\ \Delta^2 & M_{Z'}^2 \end{pmatrix}. \end{aligned}$$

Variables

- We employ the dijet angular variable χ from the rapidities of the two leading jets
- Why χ?
  - The distributions associated with the final states produced via QCD interactions are relatively flat in comparison with the distributions of the BSM models or new particles, which typically peak at low values of x

- We can measure the variable χ in two ways

1. By measuring the difference of the rapidities of the two leading jets such as the corresponding rapidity in the ZMF is:

$$y^* = \frac{1}{2}(y_1 - y_2)$$

X is defined as $\chi = e^{|y^*|} = e^{|y_1 - y_2|}$ (1) and can be measured by creating the TLorentzVector, boost it to the ZMF and find the rapidity difference of the two leading jets

We also define $y_{Boost} = 0.5(y_1 + y_2)$ which specifies the longitudinal boost by which the dijet CM frame is boosted with respect to the detector frame

2. By measuring the scattering angle θ* (angle between top quark and z-axis in the Zero Momentum Frame)

We define as $y^* = \frac{1}{2}\ln(\frac{1+|cos\theta^*|}{1-|cos\theta^*|})$ and from (1) we can find that:

$$\chi = \frac{1 + |cos\theta^*|}{1 - |cos\theta^*|}$$

Response Matrices

- Selection:
  - Parton: partonPt > 500*, |partonEta|< 2.4, mTTbarParton > 1000
  - Reco: jetPt>500, |jetEta| < 2.4, nLeptons ==0
  - Btagging Medium working point
  - Top tagger mva > 0.3
  - Jet mass soft Drop (120, 220)GeV
  - Jets are matched

- Response matrix of χ_{reco}, χ_{parton} with {1,2,3,4,5,6,8,10,13,16} as variable binning

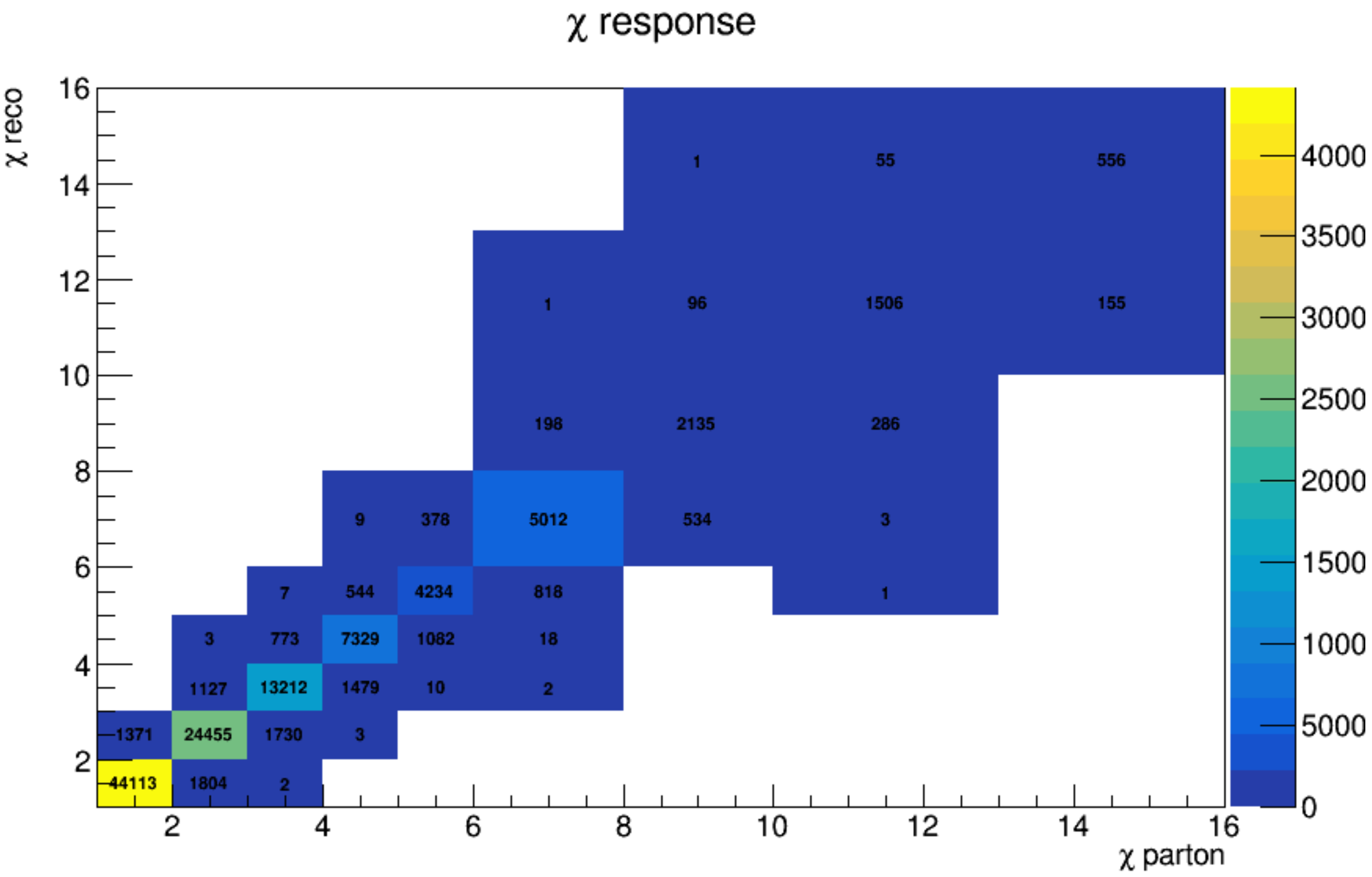
- The same binning is then used to find the response matrices in different mass (mTTbar) regions
  - [1000-1600]GeV
  - [1600-2200]GeV
  - [2200-3000]GeV
  - [3000-3600]GeV
  - [3600-6000]GeV

- Stability, Efficiency for χ distribution

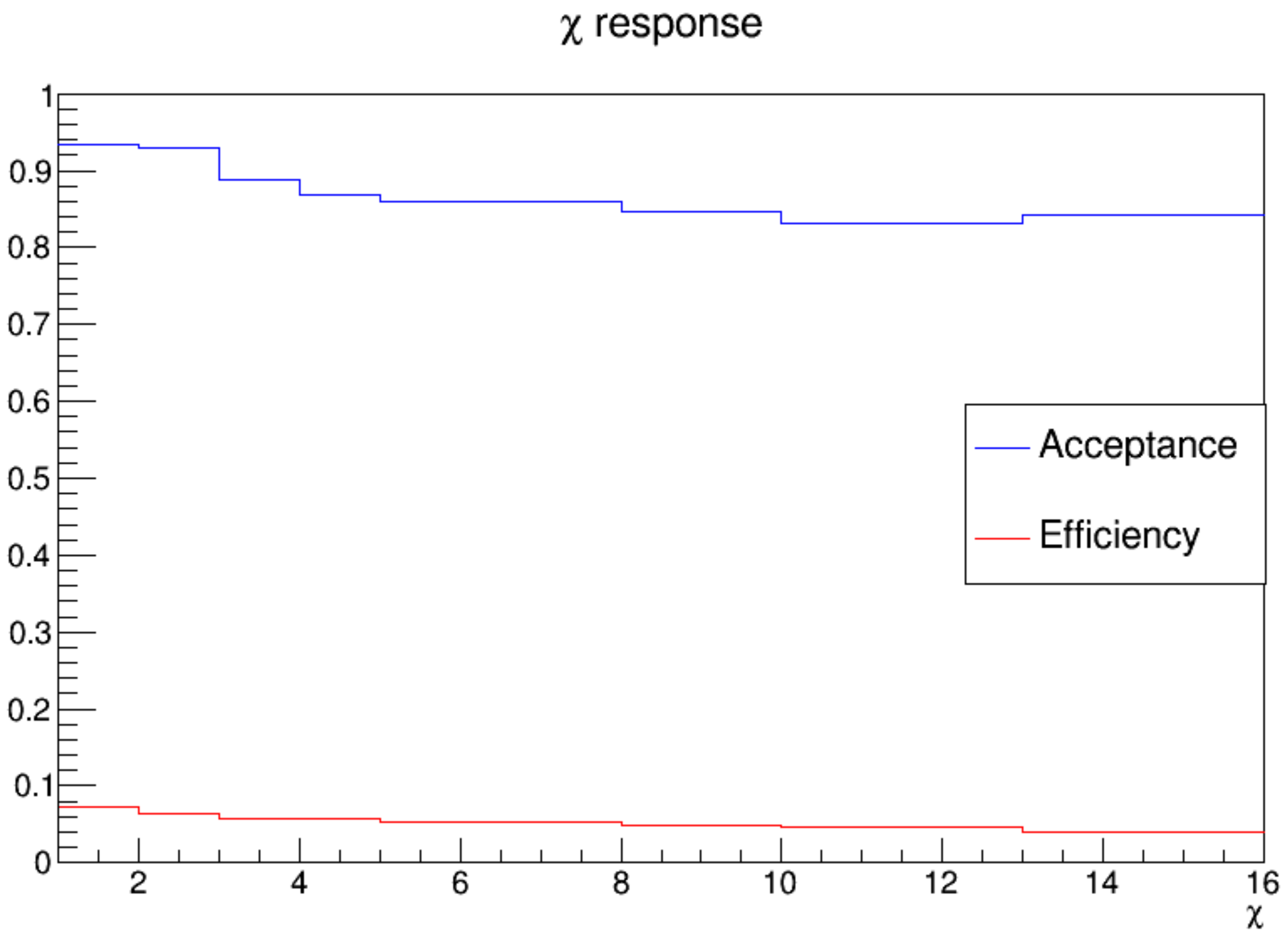
- Acceptance and purity for χ

*By applying the Pt to be more than 500, we get more similar results with ATLAS

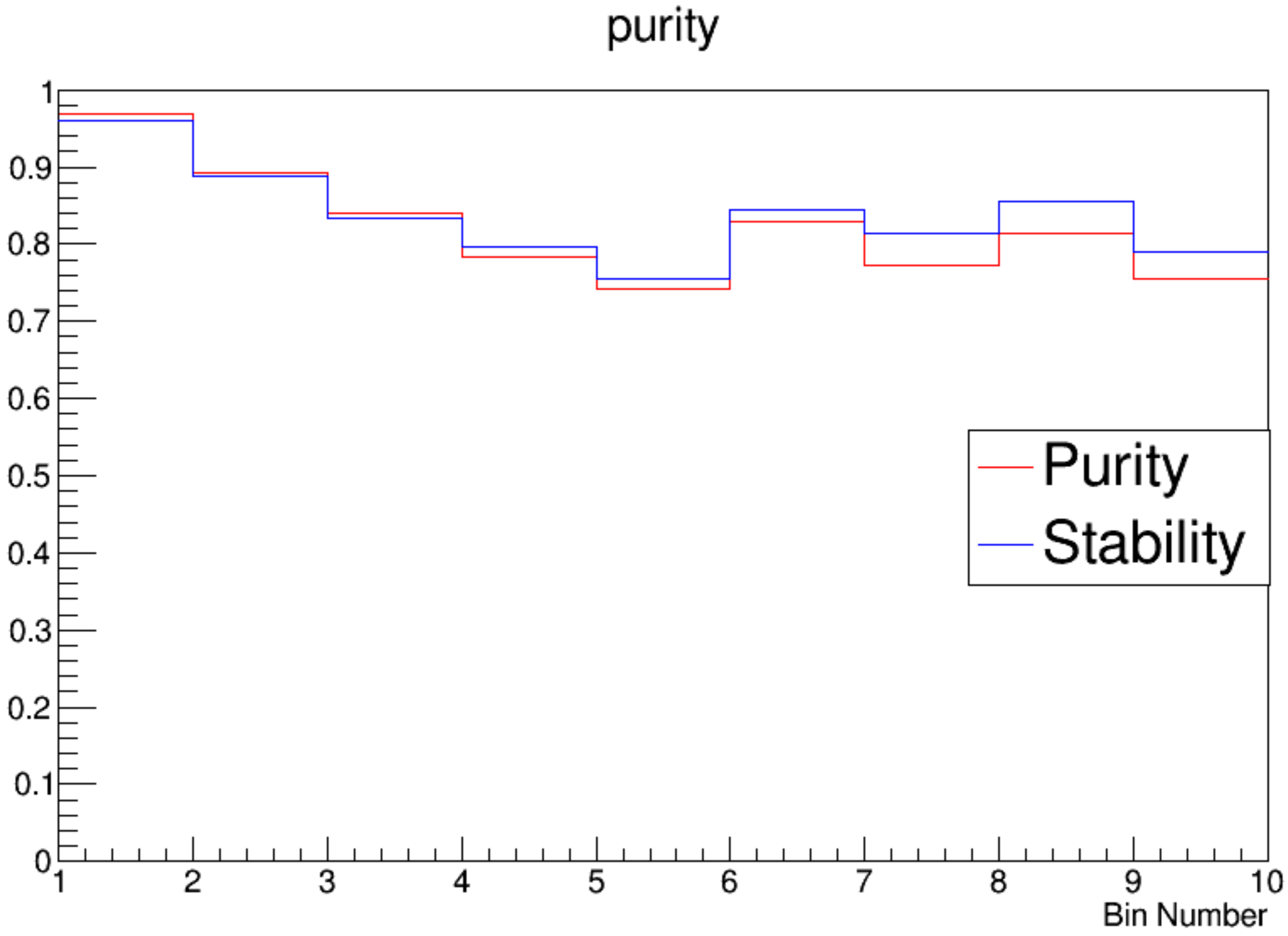
Response Matrix for χ

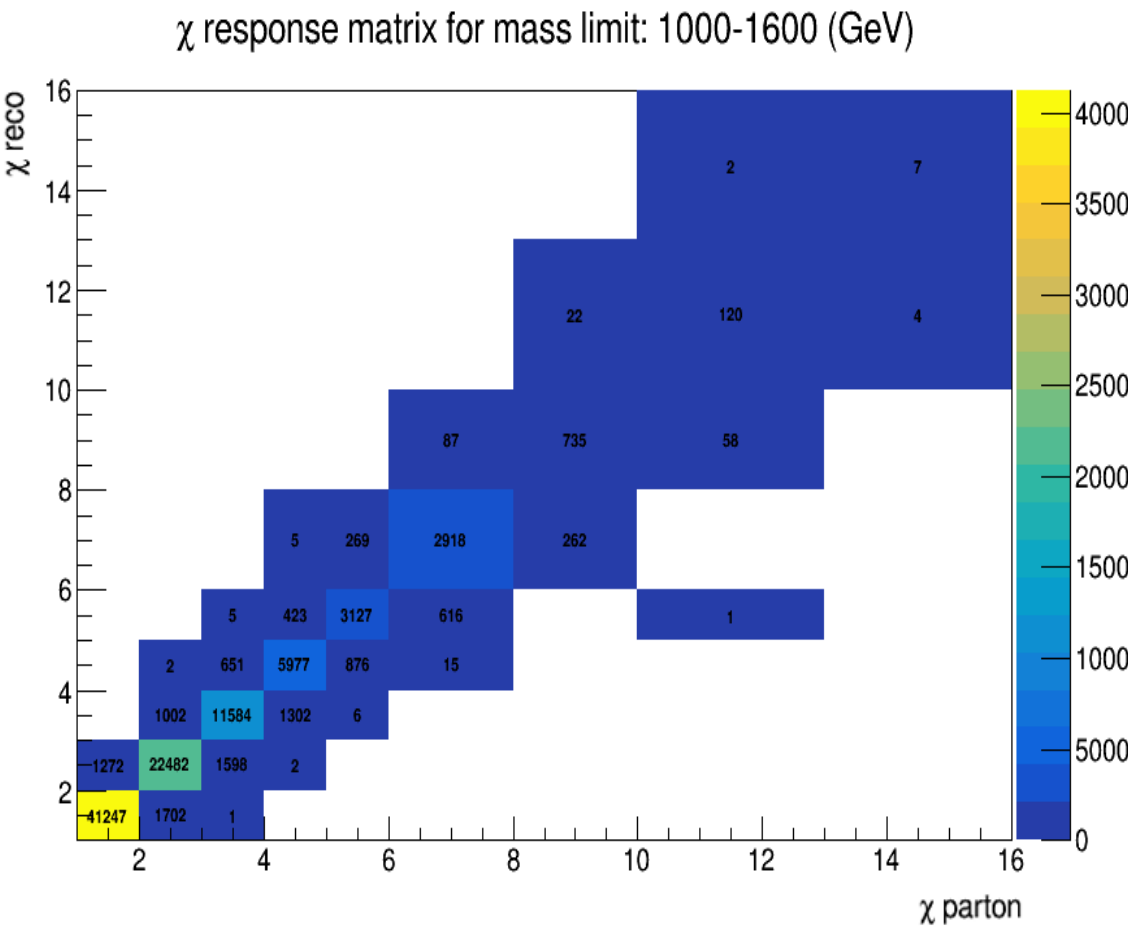


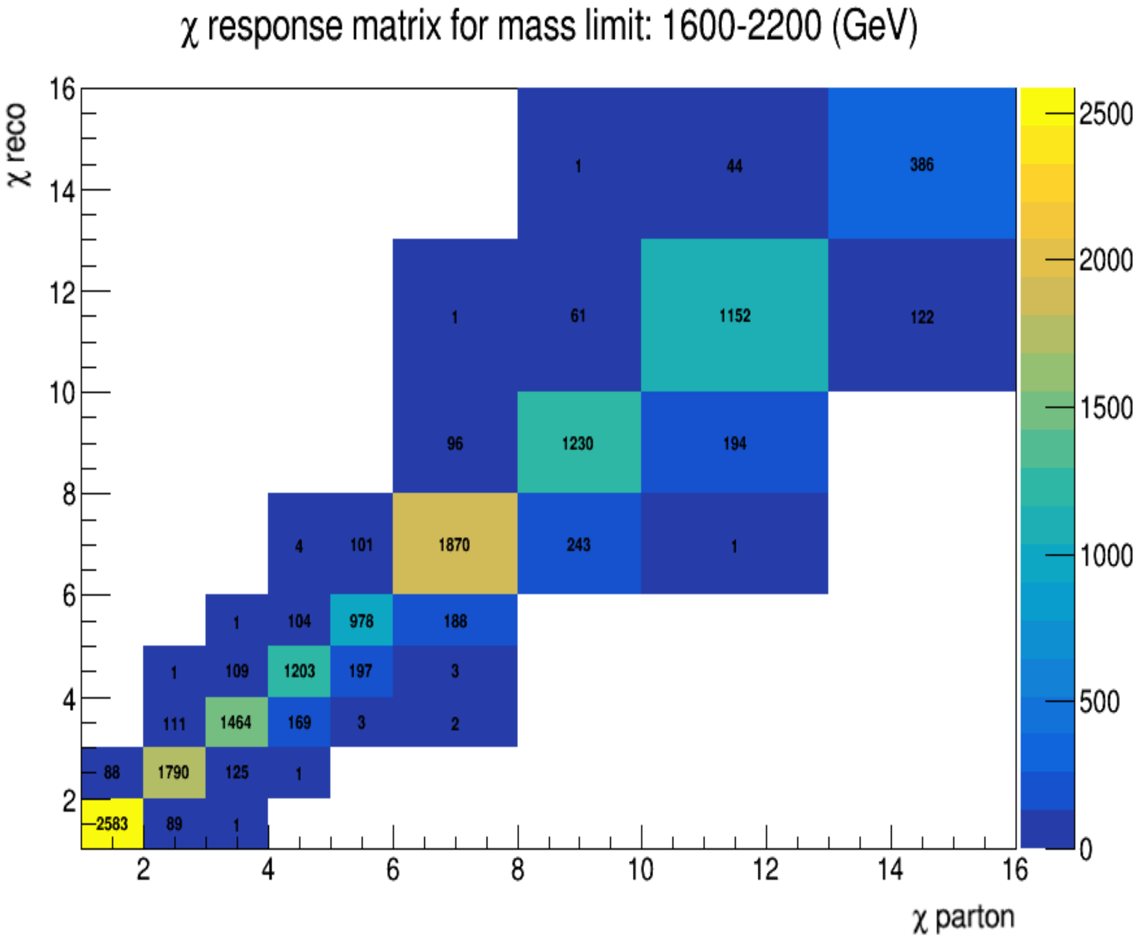
Efficiency and Acceptance for chi distribution

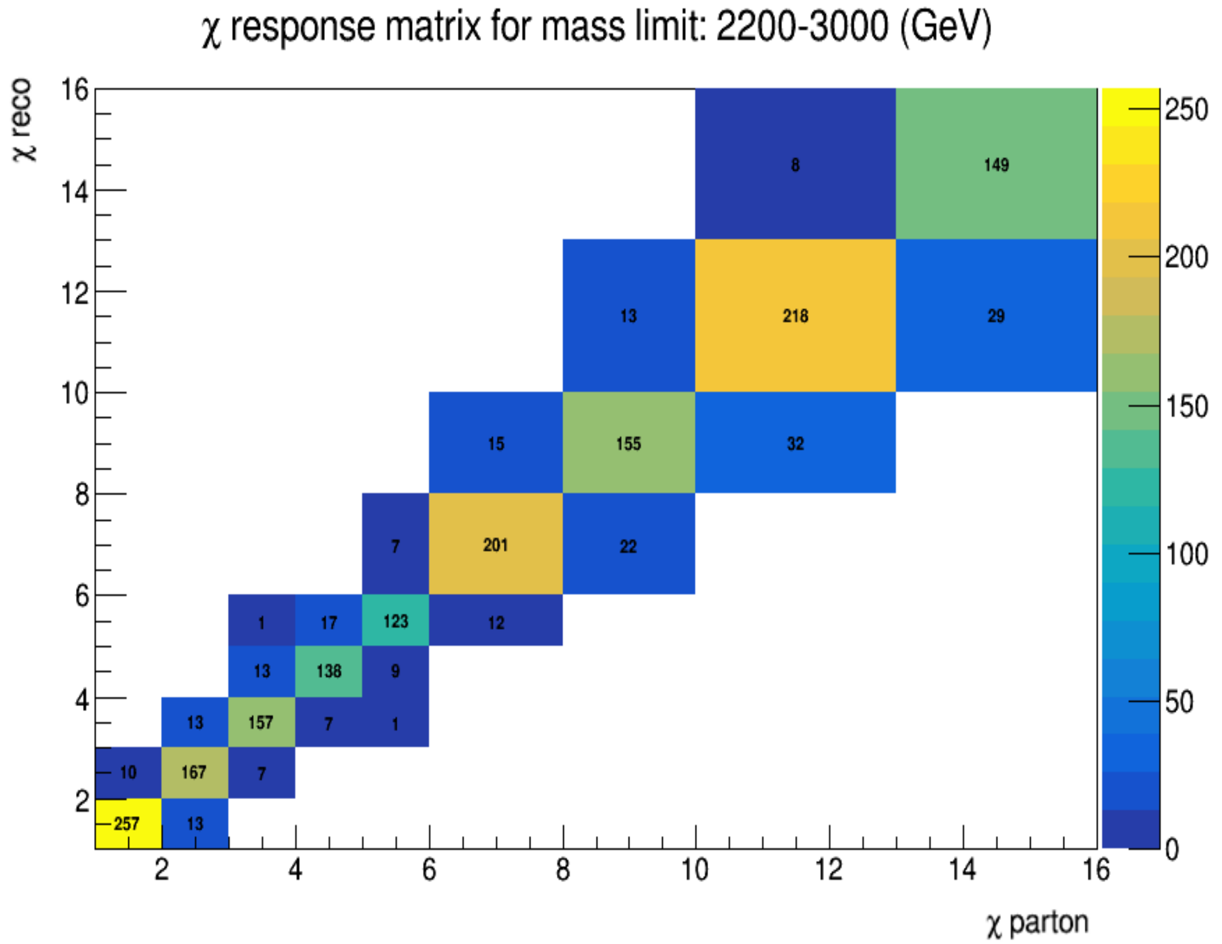


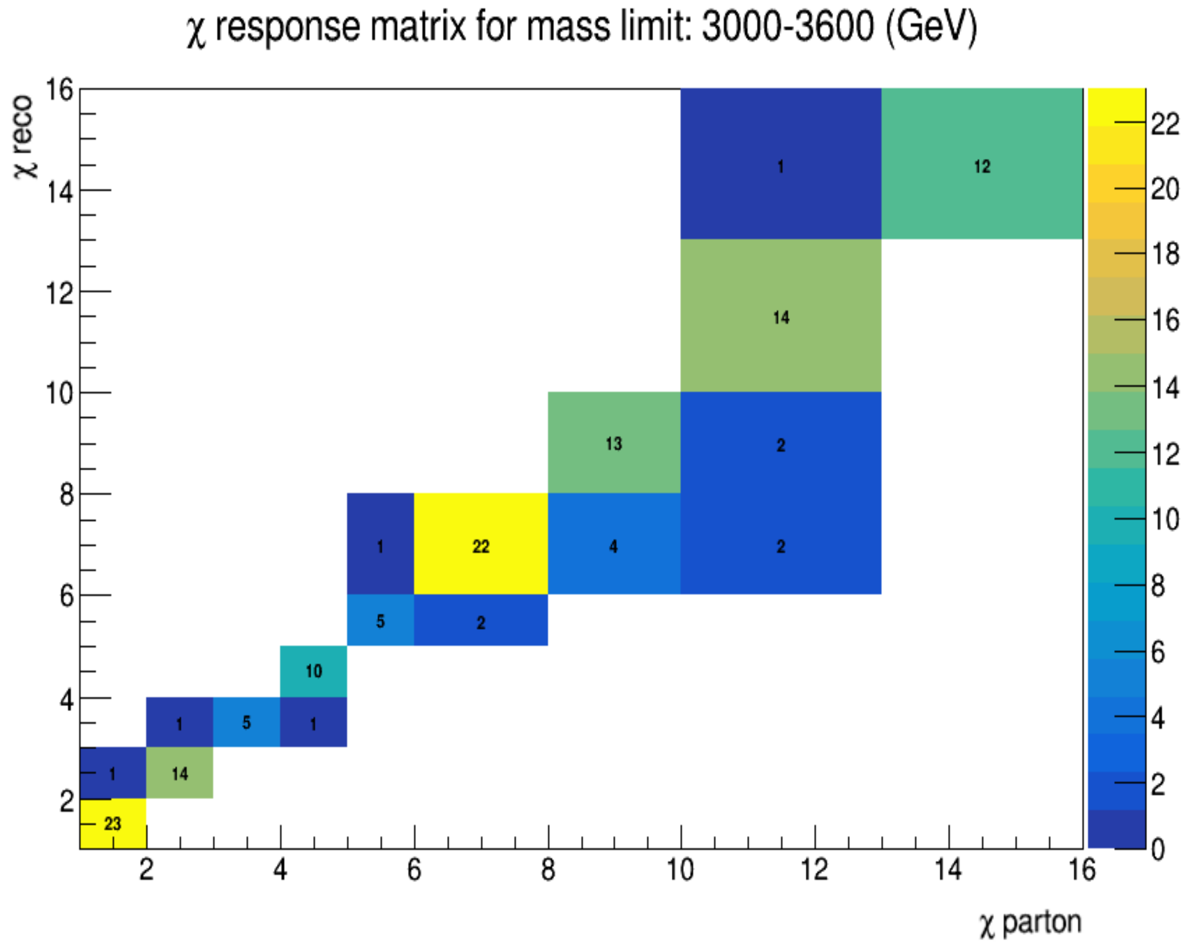
Purity and Stability for chi distribution



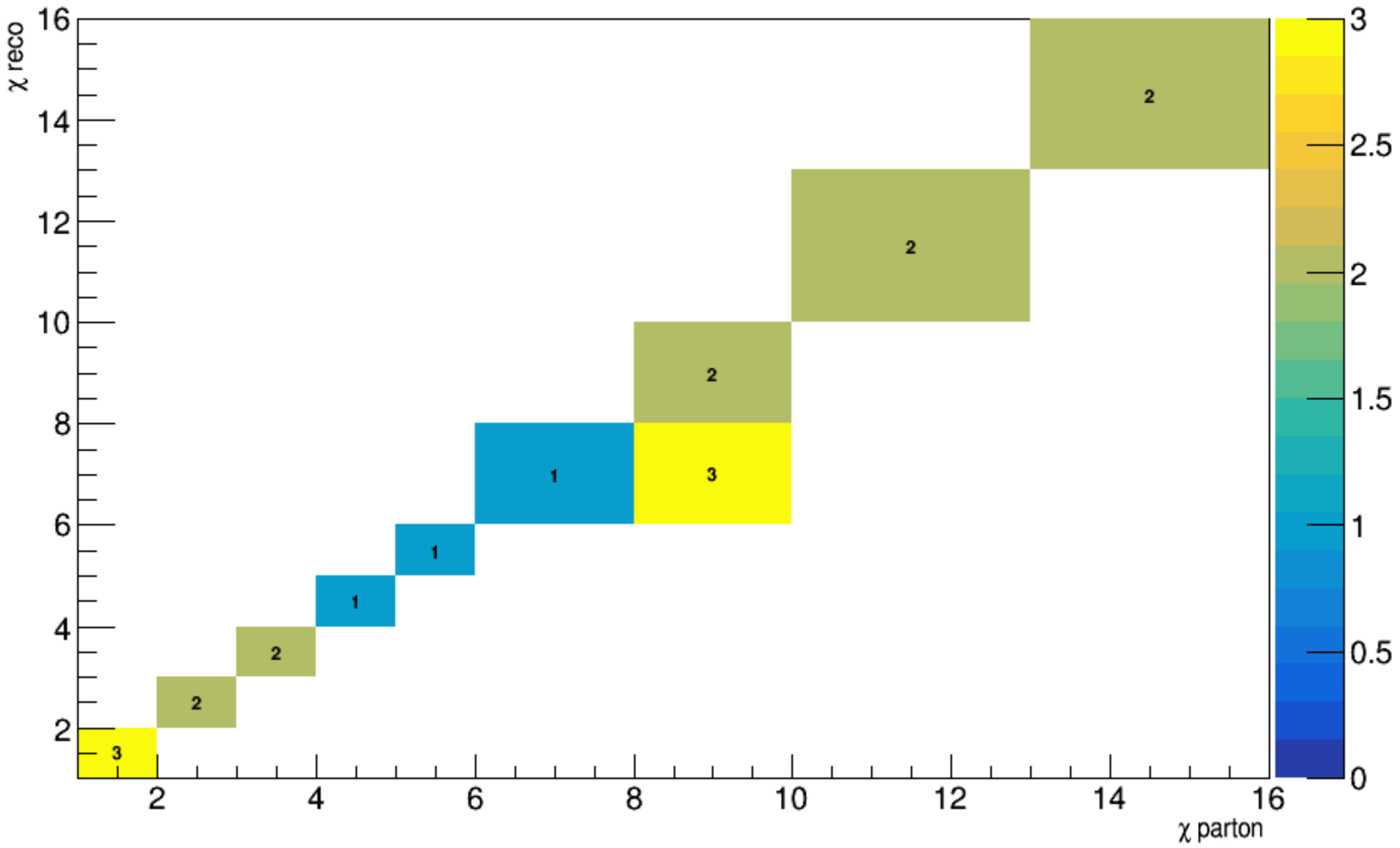

χ response matrix for mass limit: 1000-1600 (GeV)
χ reco
χ parton


χ response matrix for mass limit: 1600-2200 (GeV)
χ reco
χ parton

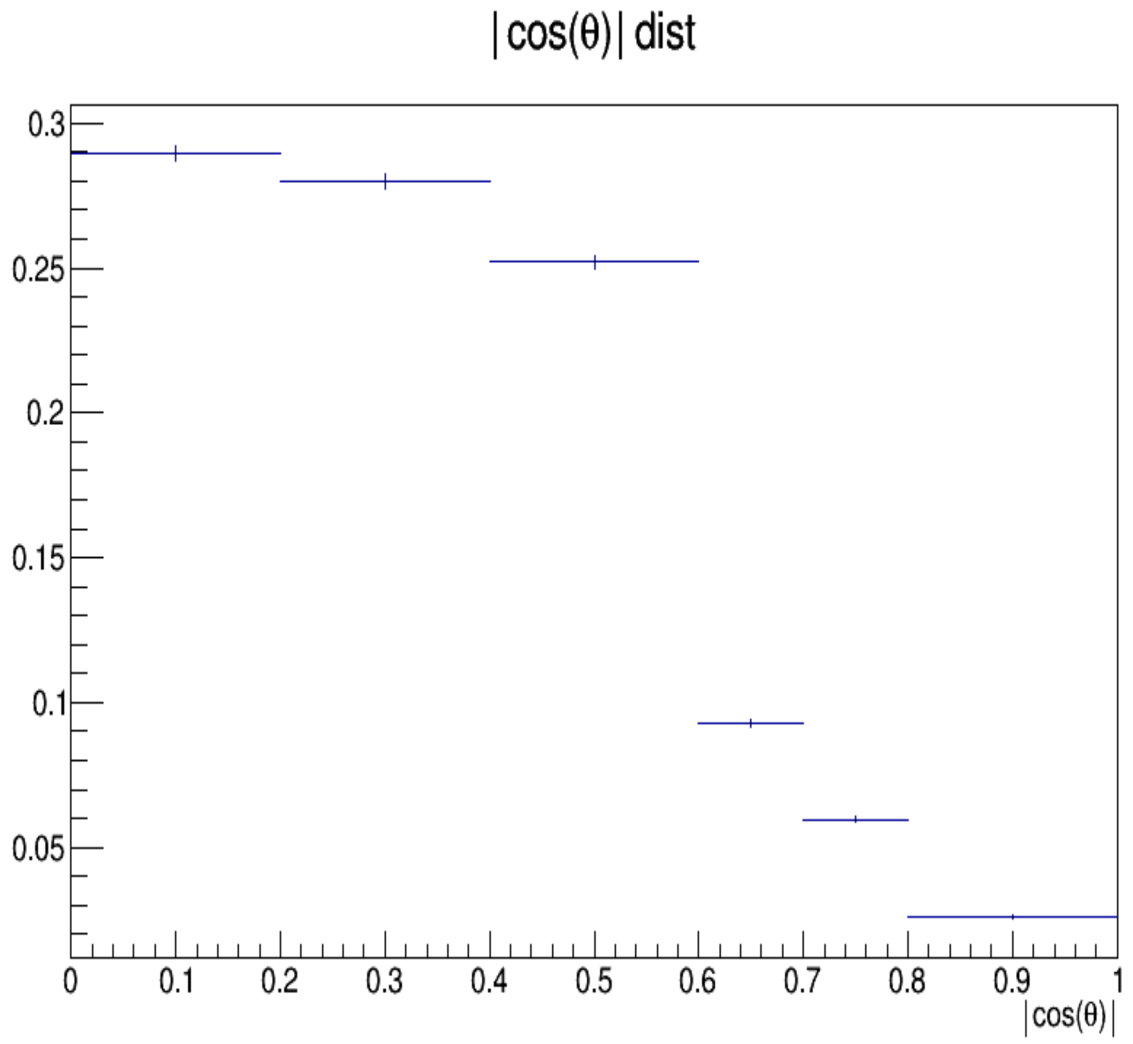

χ response matrix for mass limit: 2200-3000 (GeV)
χ reco
χ parton
8
149
13
218
29
15
155
32
7
201
22
1
17
123
12
13
138
9
13
157
7
1
10
167
7
257
13

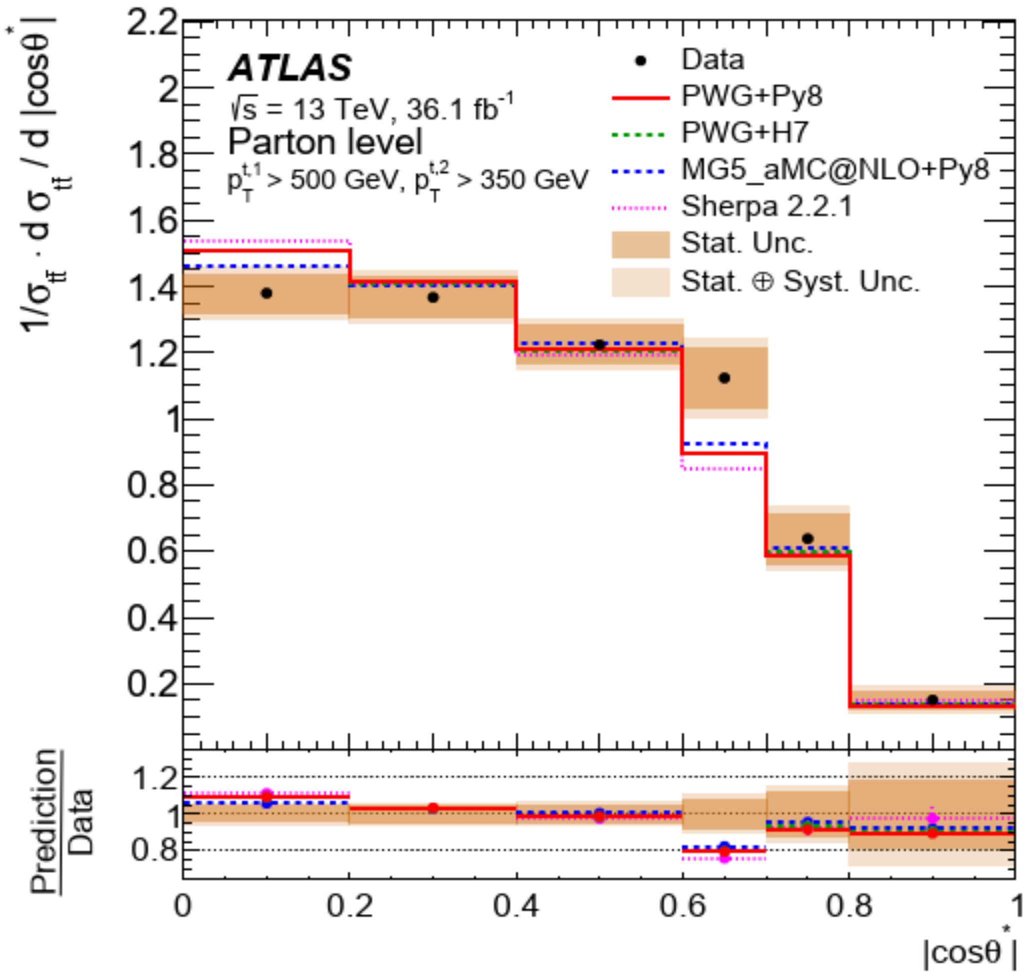

χ response matrix for mass limit: 3000-3600 (GeV)
χ reco
χ parton
1
12
14
13
2
1
22
4
2
5
2
10
1
5
1
1
14
23

χ response matrix for mass limit: 3600-6000 (GeV)

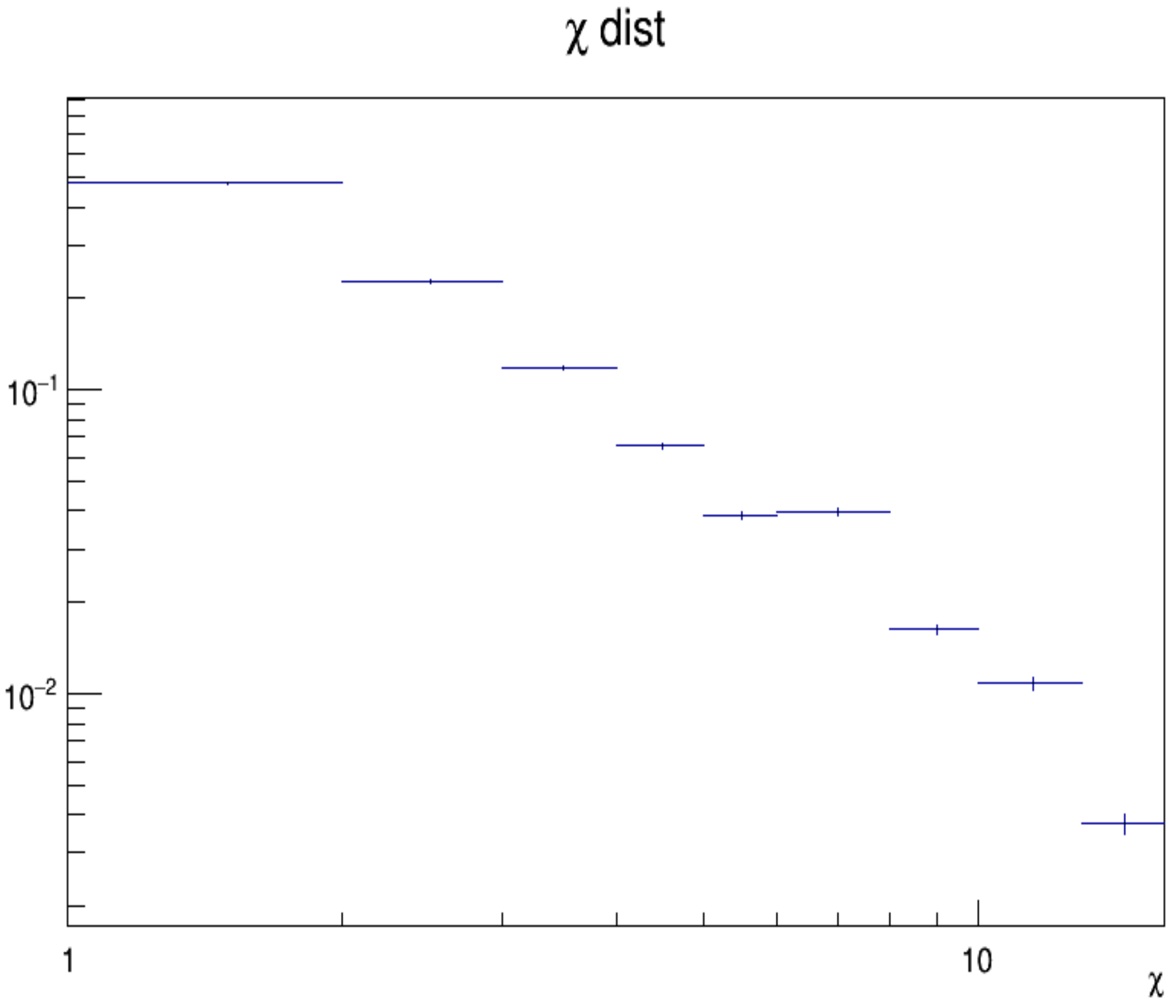


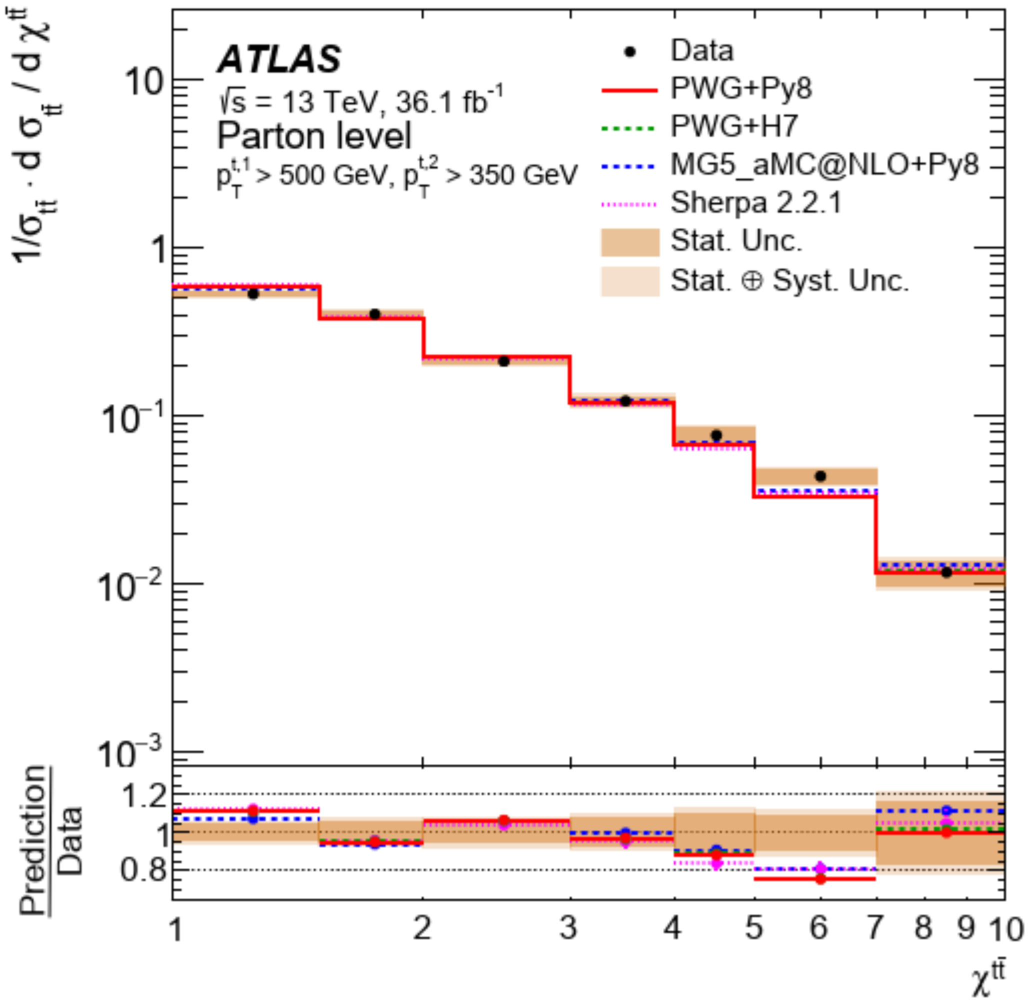
Comparisons with ATLAS |cosθ| distributions





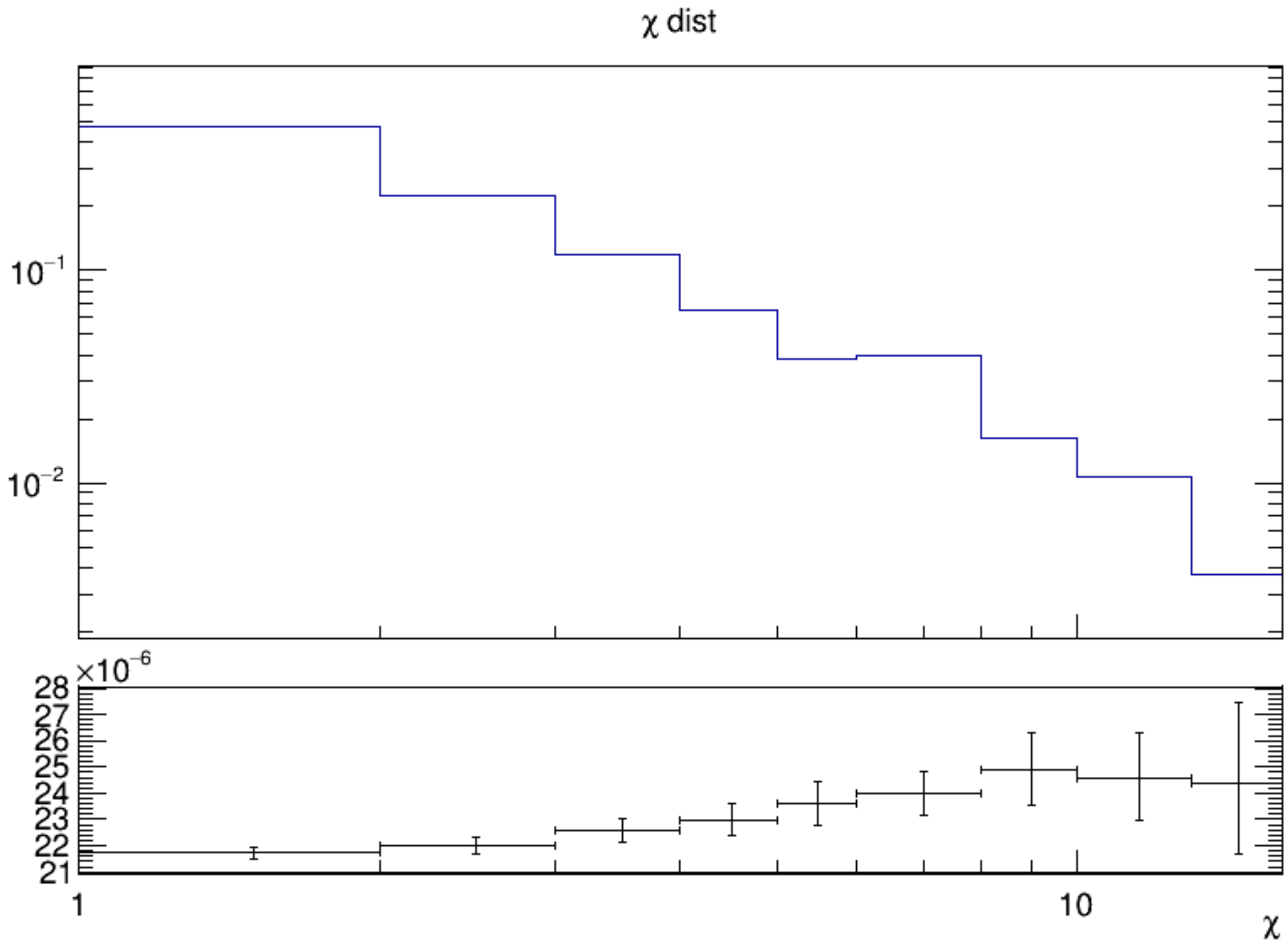
Comparisons with ATLAS χ distributions





Comparison on how to measure x value

- $e^{|2y^*|}$
- $\chi = \frac{1+|cos\theta^*|}{1-|cos\theta^*|}$
- No difference



QCD Measurement vs Search

- In exotica searches, an $|y_{Boost}|<1.19$ cut is applied
- Are there any differences when we don't aply the cut?