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Probing new physics in the coupling of the top quark to the Z boson

Under the supervision of Pedro Silva and Michelle Gallinaro

Motivation

Goal: study $t\bar{t} + Z$ production and set limits on anomalous couplings

Unexplored couplings

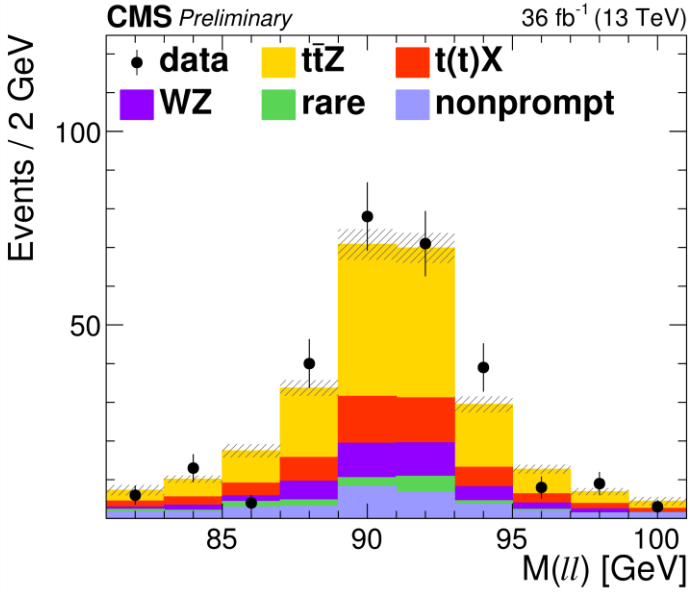
BSM models predictions

- Sizable dipole moments
- Deviations of the vector and axial coupling from their SM values

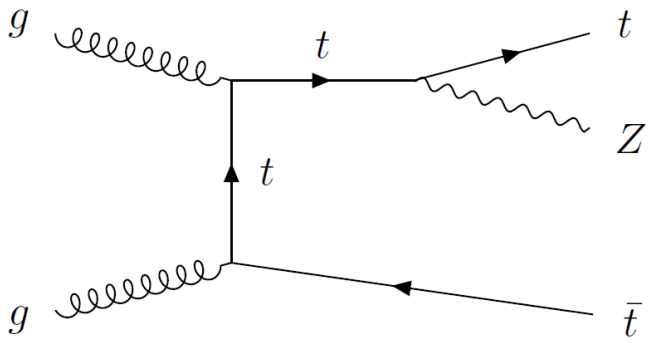
$pp \to t\bar{t}V$

Recently accessible

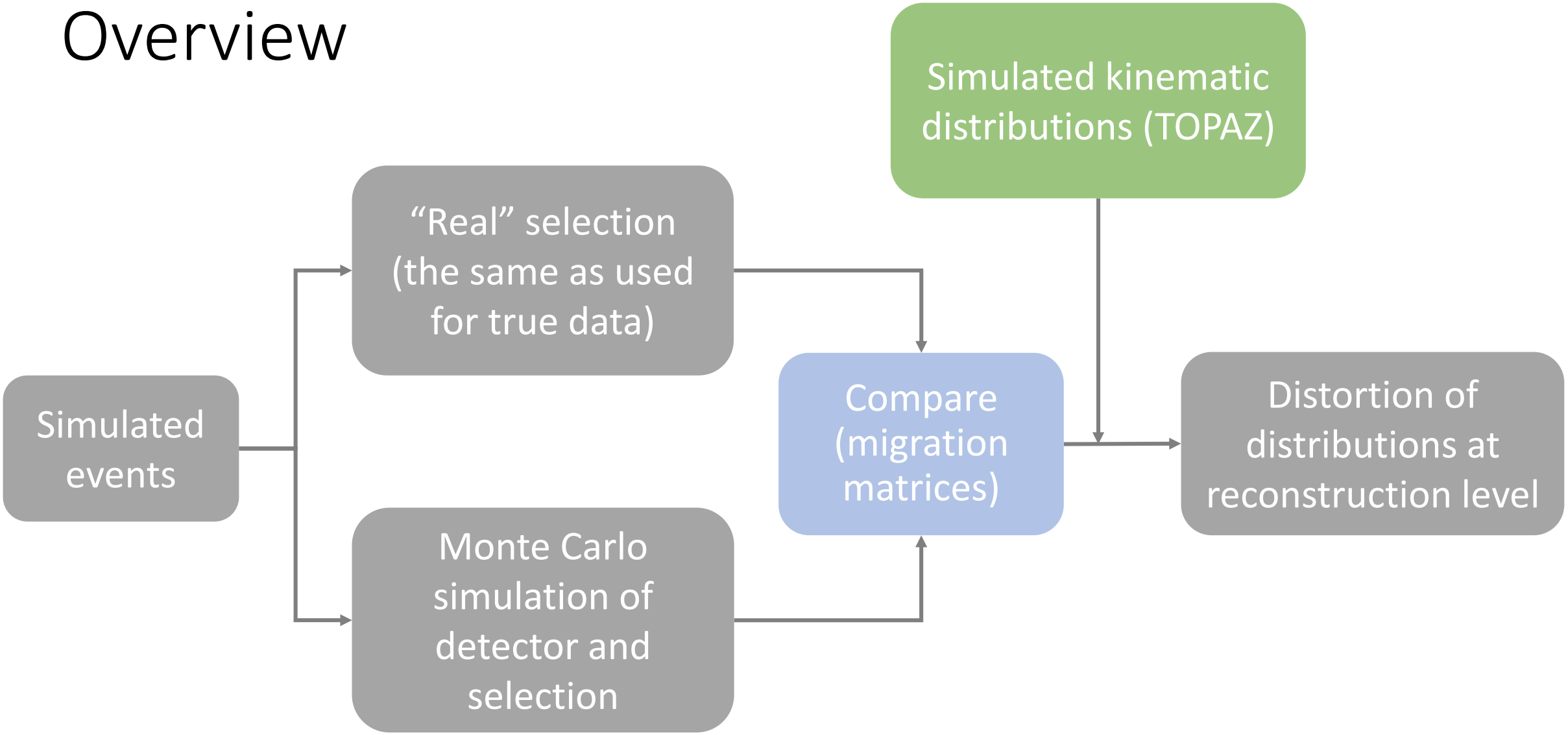
Direct probe



$$\sigma(t\bar{t}Z) = 1.00^{+0.09}_{-0.08}(\text{stat.})^{+0.12}_{-0.10}(\text{sys.})\ \text{pb}$$



Overview


Simulated kinematic distributions (TOPAZ)
"Real" selection (the same as used for true data)
Simulated events
Compare (migration matrices)
Distortion of distributions at reconstruction level
Monte Carlo simulation of detector and selection

Top anomalous couplings

$$\mathscr{L}_{t\bar{t}Z} = e\bar{u}(p_t)\left[\gamma^\mu\left(C^Z_{1,V} + \gamma_5 C^Z_{1,A}\right) + \frac{i\sigma^{\mu\nu}q_\nu}{M_Z}\left(C^Z_{2,V} + i\gamma_5 C^Z_{2,A}\right)\right] v(p_{\bar{t}})Z_\mu$$

TOPAZ

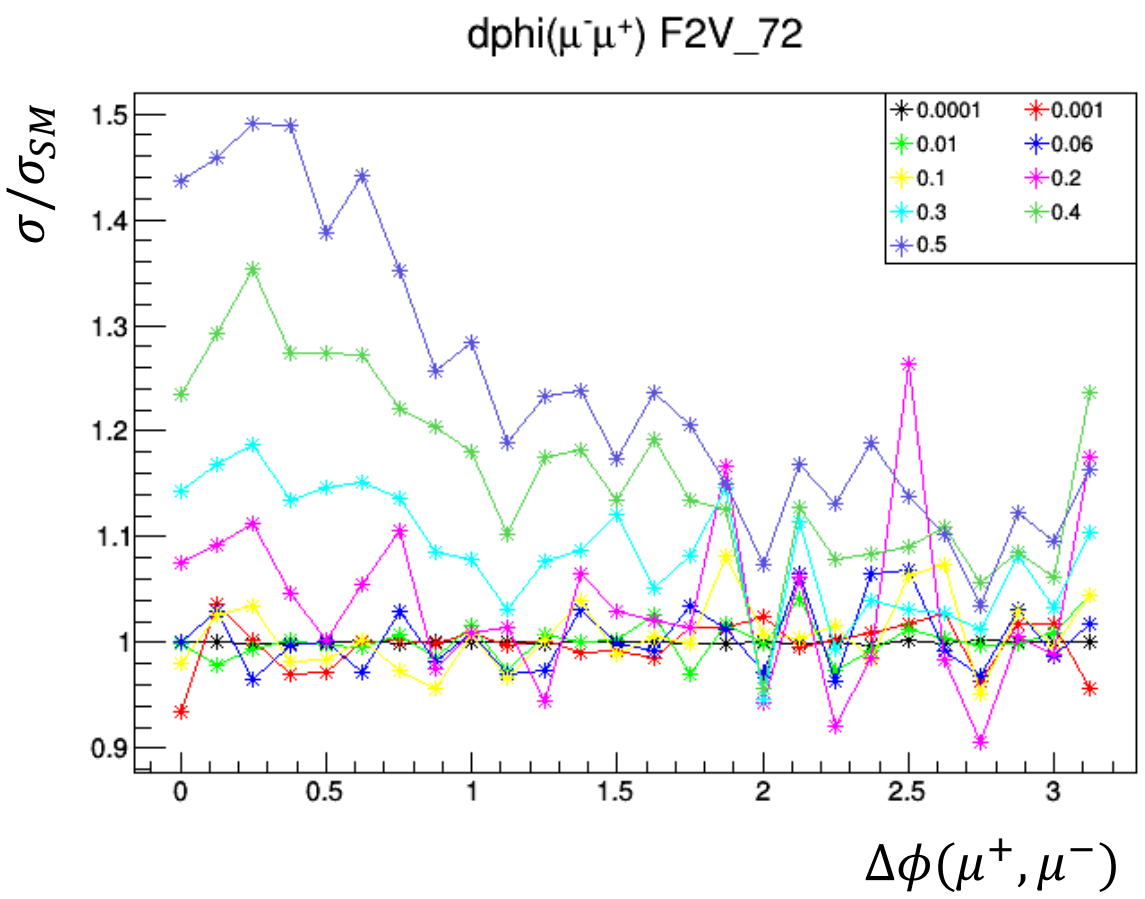
Raoul Röntsch, Markus Schulze

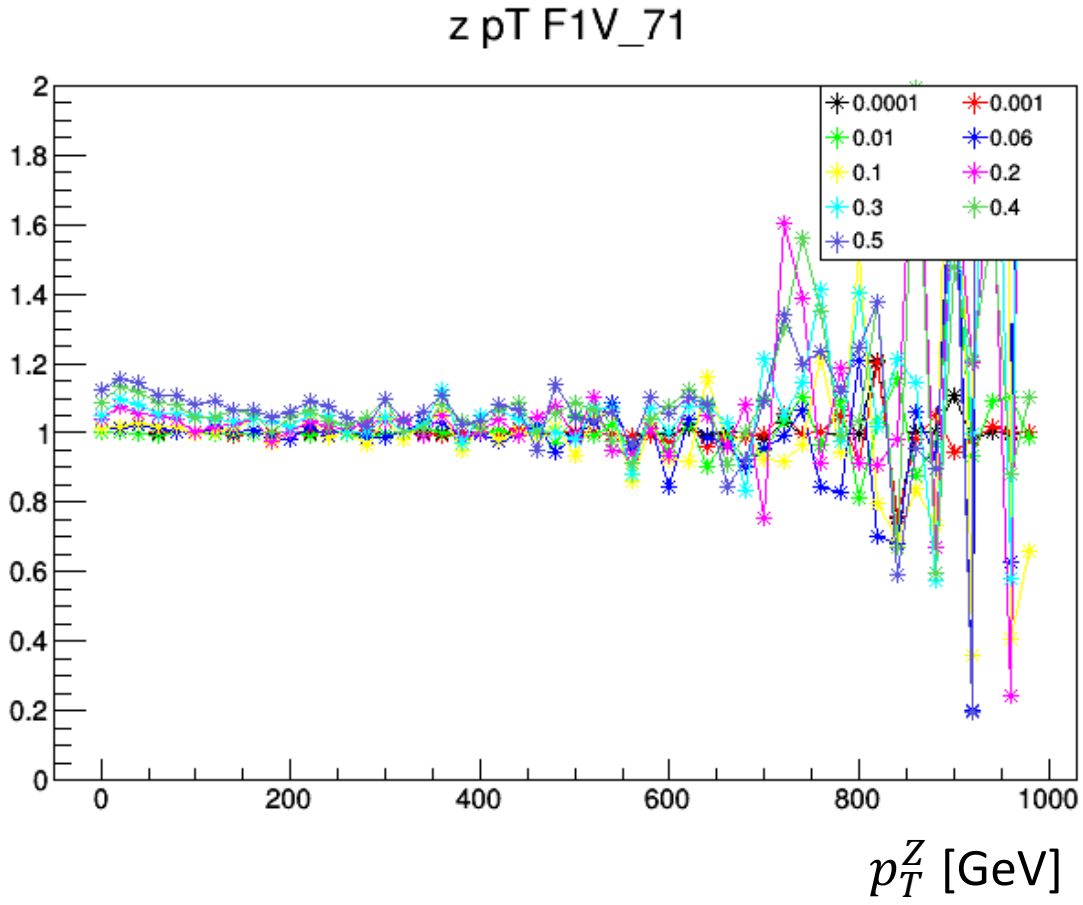
- Anomalous couplings
- Energy and initial state
- Top and Z decay modes
- Production process
- Cuts

Event selection

Cut	Value
p_T^l	> 20 GeV
p_T^j	> 30 GeV
R_{lj}	> 0.3
R_{ll}	> 0.3
$\lvert y^l \rvert$	< 2.4
$\lvert y^j \rvert$	< 2.4
$\lvert m_{ll} - M_Z \rvert$	< 20 GeV

Anomalous couplings influence on kinematic distributions





Event reconstruction – final state signature

$$t\bar{t}Z \rightarrow b\bar{b}W^{+}W^{-}Z \rightarrow b\bar{b}q\bar{q}\ l^{\pm}\nu\ l^{+}l^{-}$$

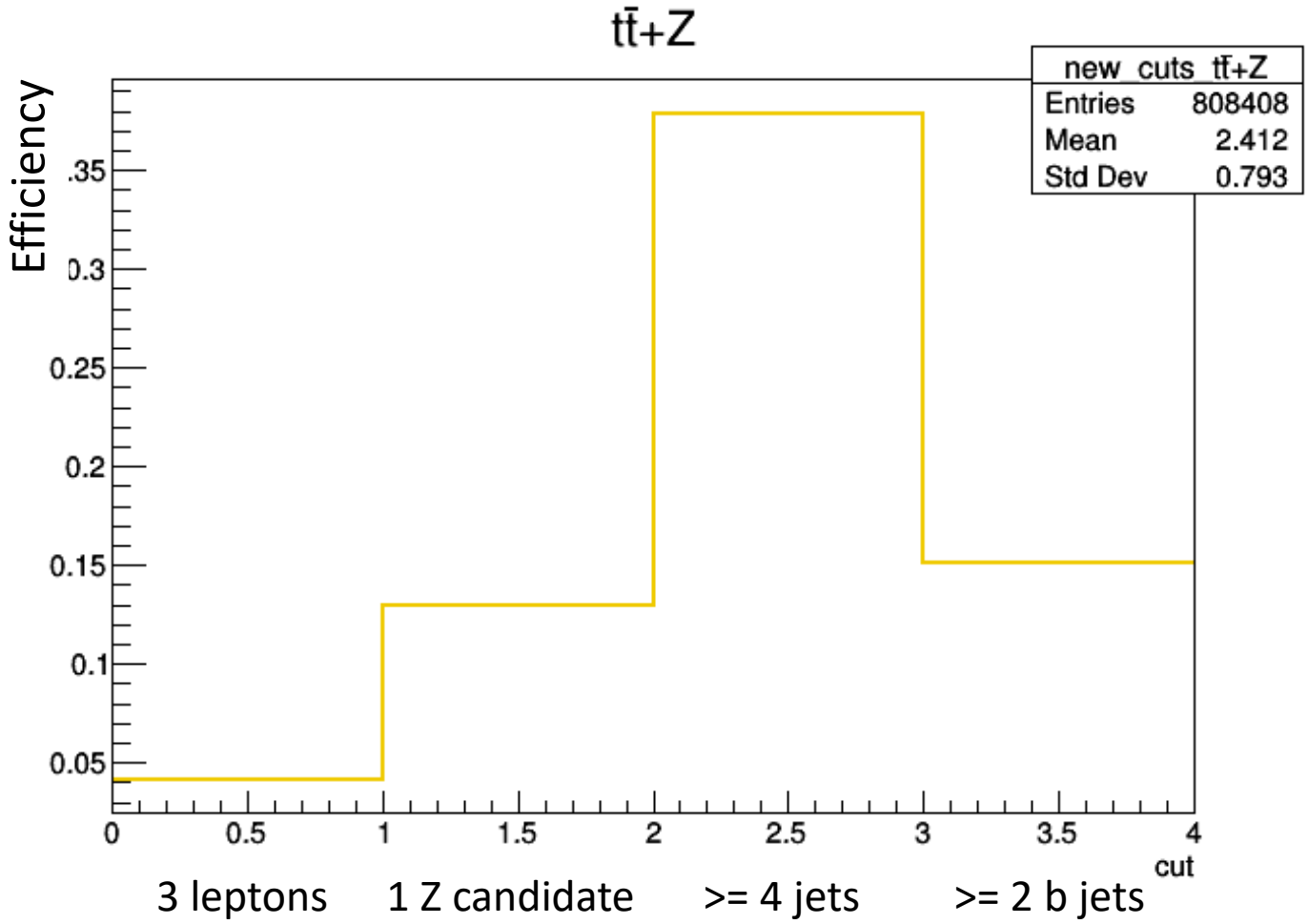
- 3 charged leptons
- 1 Z candidate
- 4 jets
- 2 b tagged jets
- MET

Same flavour

Opposite charge

$|M_Z - m_{ll}| < 10$ GeV

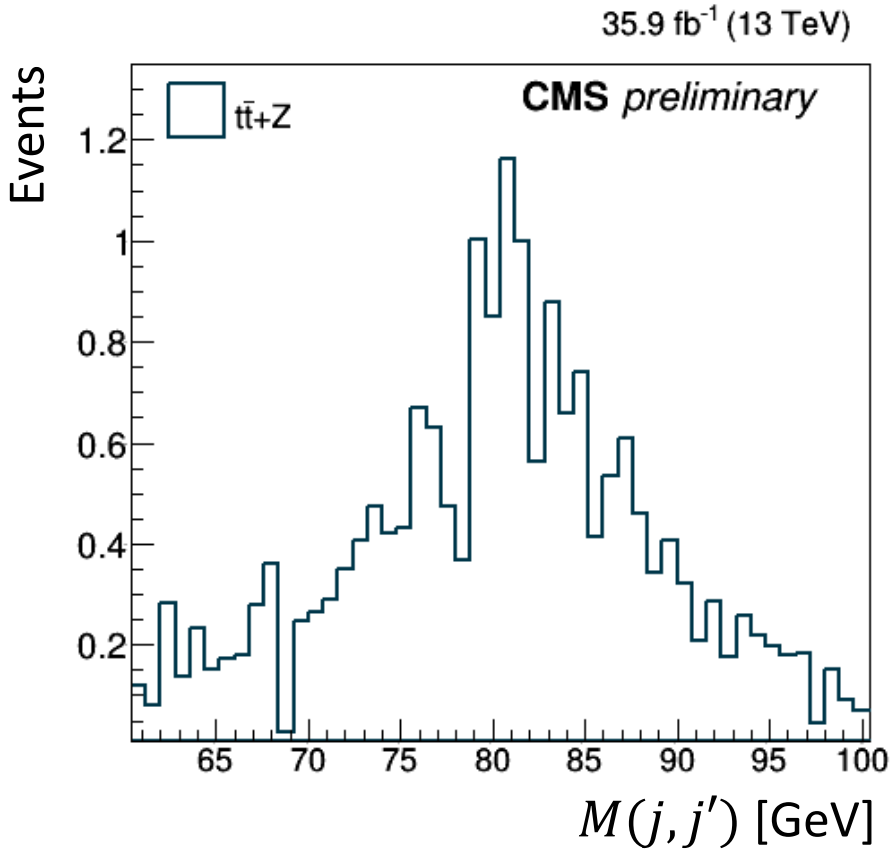
Cuts efficiency



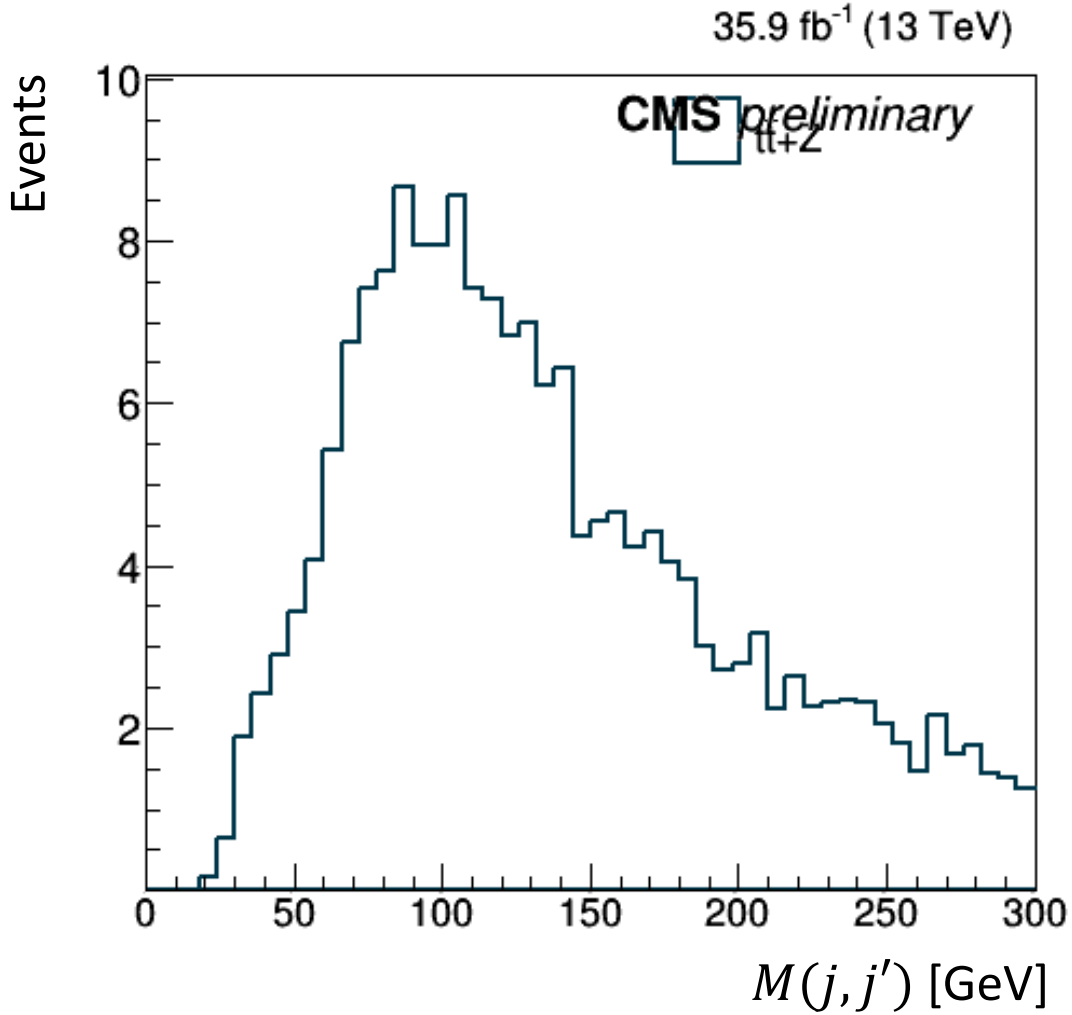
$$Eff = \frac{N_{ev}(pass\ cut)}{N_{ev}(total)}$$

Reconstructed kinematics

W from $q\bar{q}$

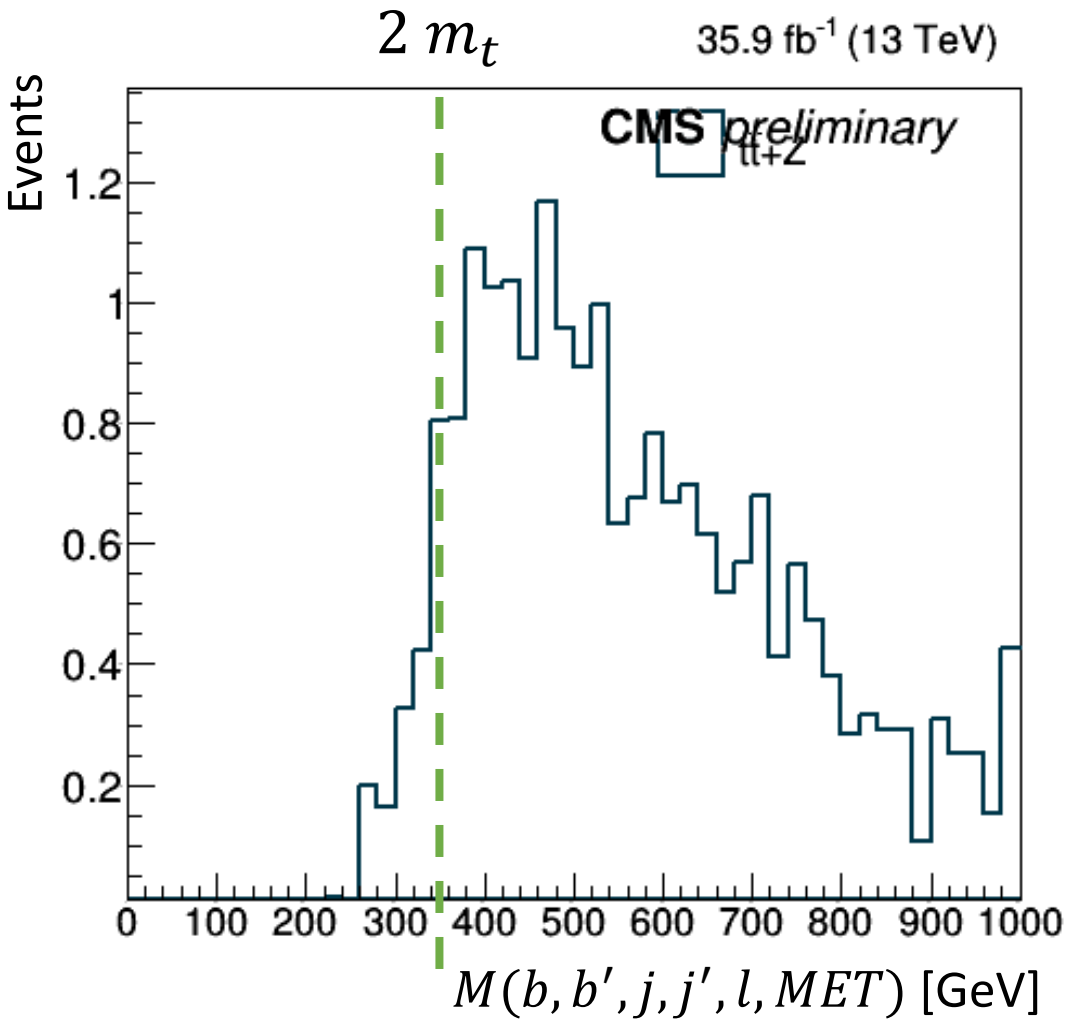


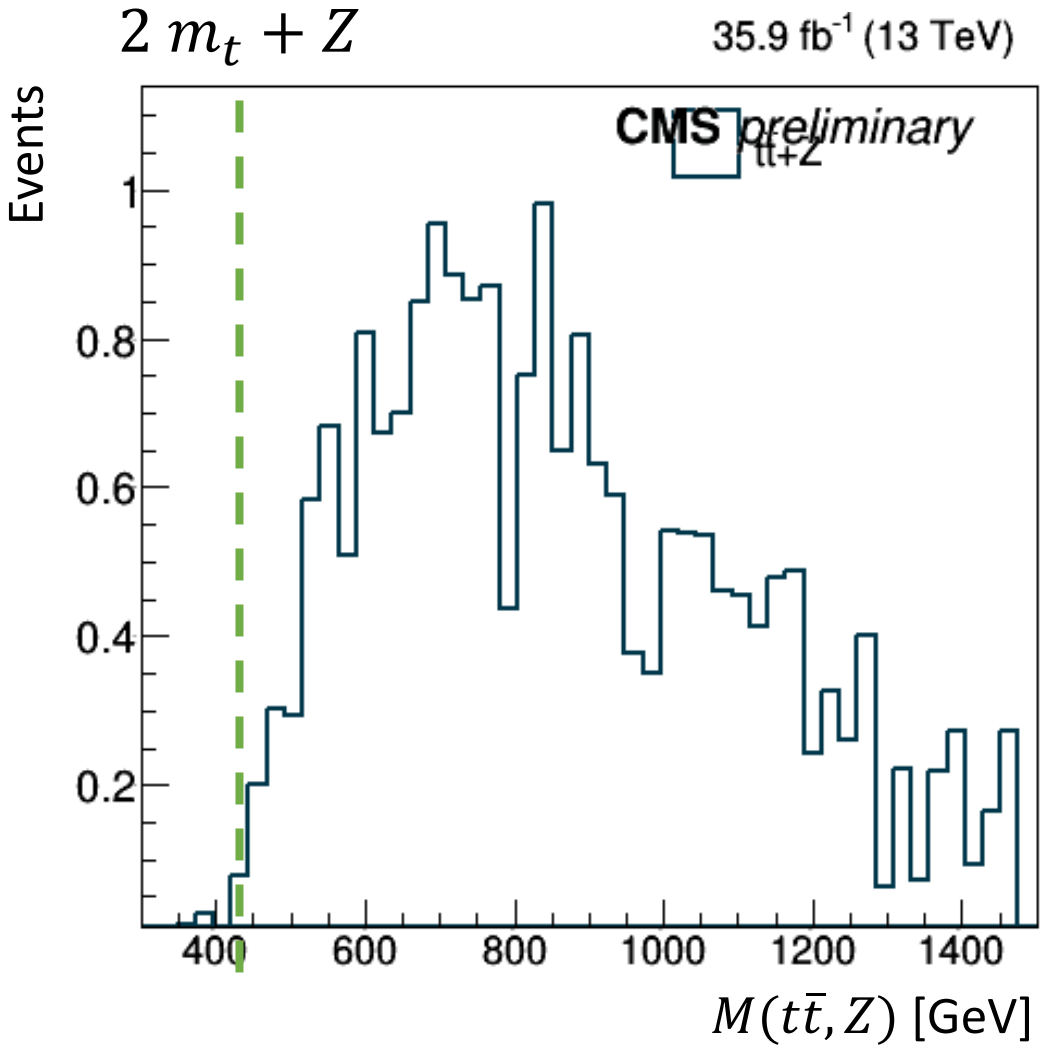
All possible light jets' pairs combinations (even if they don't reconstruct the W mass)



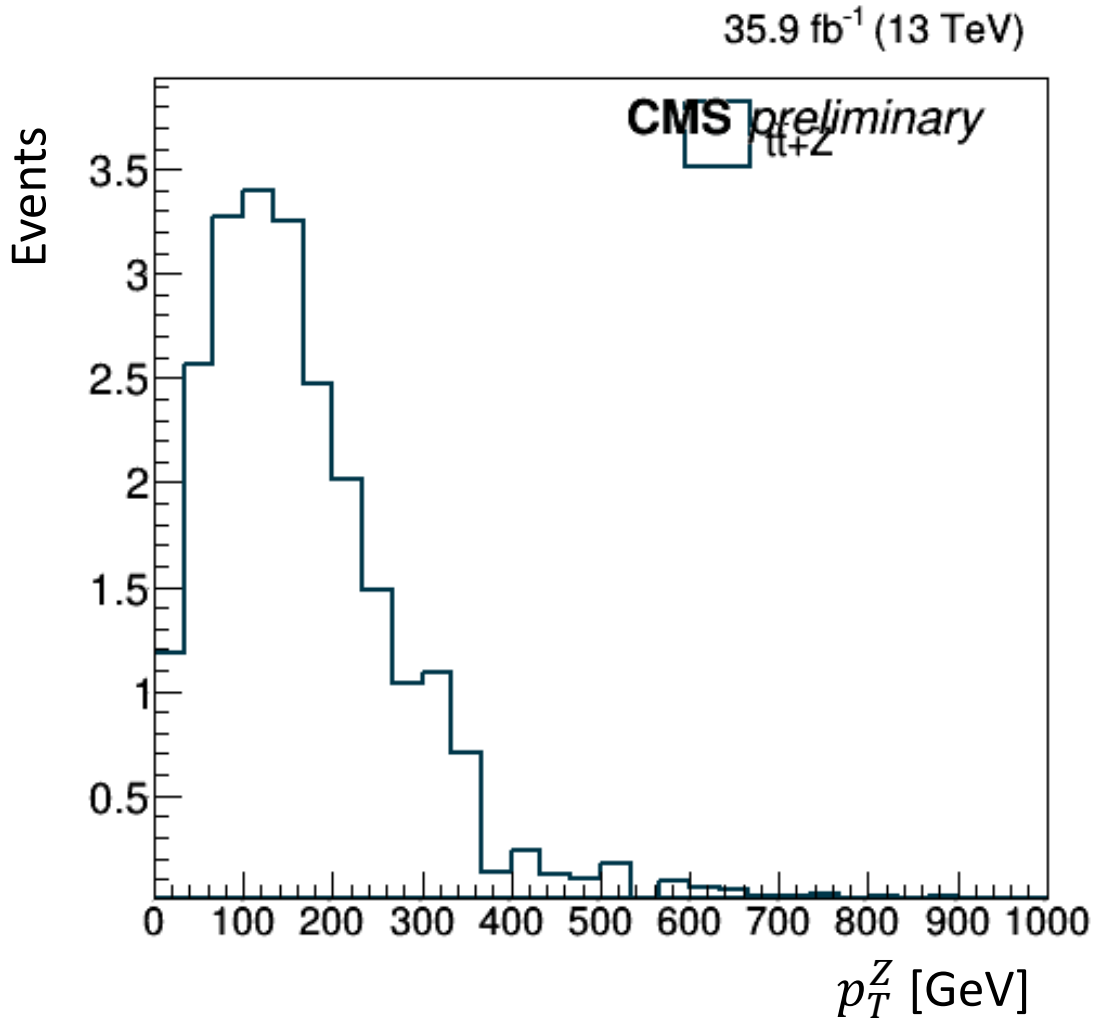
- Invariant mass closest to the W mass
- Don't overlap ($\Delta R > 0.4$) with b tagged jets

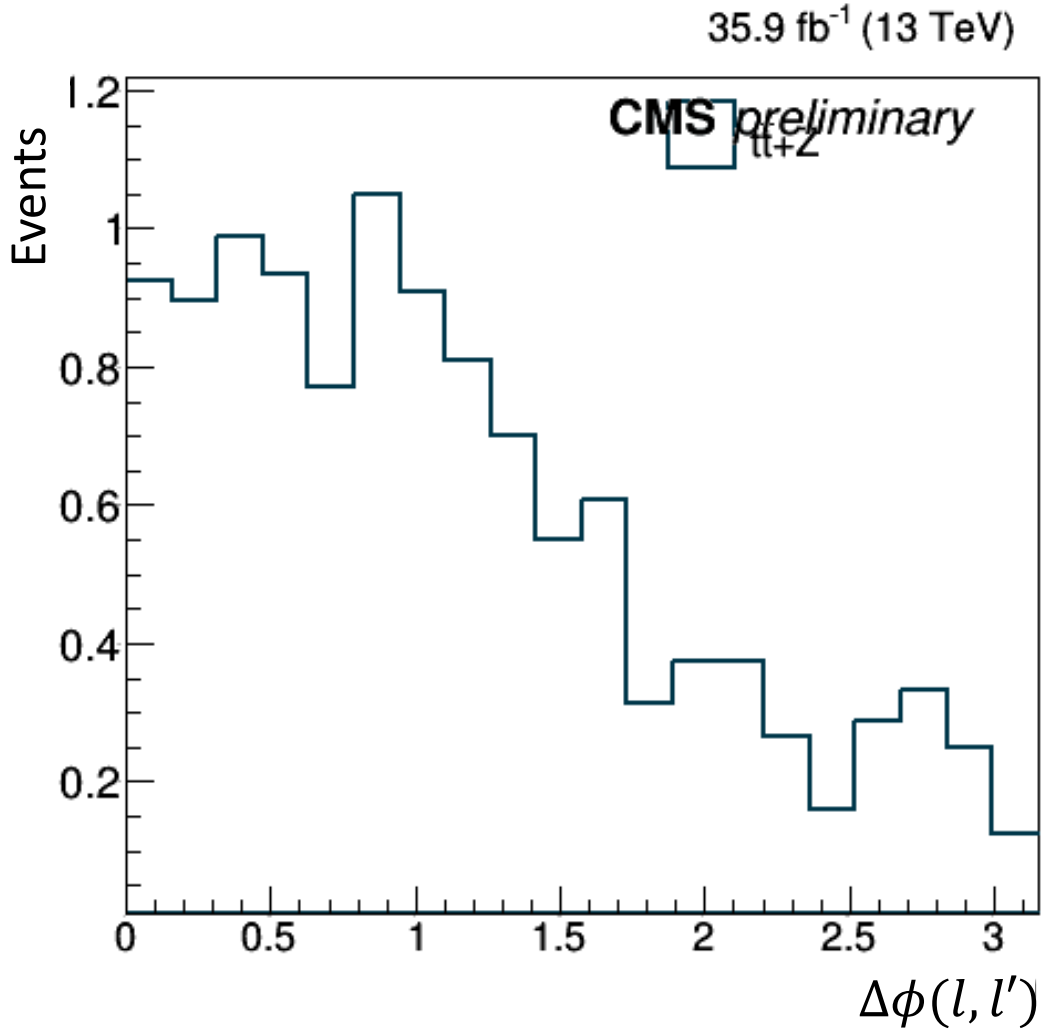
$t\bar{t}$ and $t\bar{t} + Z$





Z p_T and $\Delta\phi(l^+, l^-)$

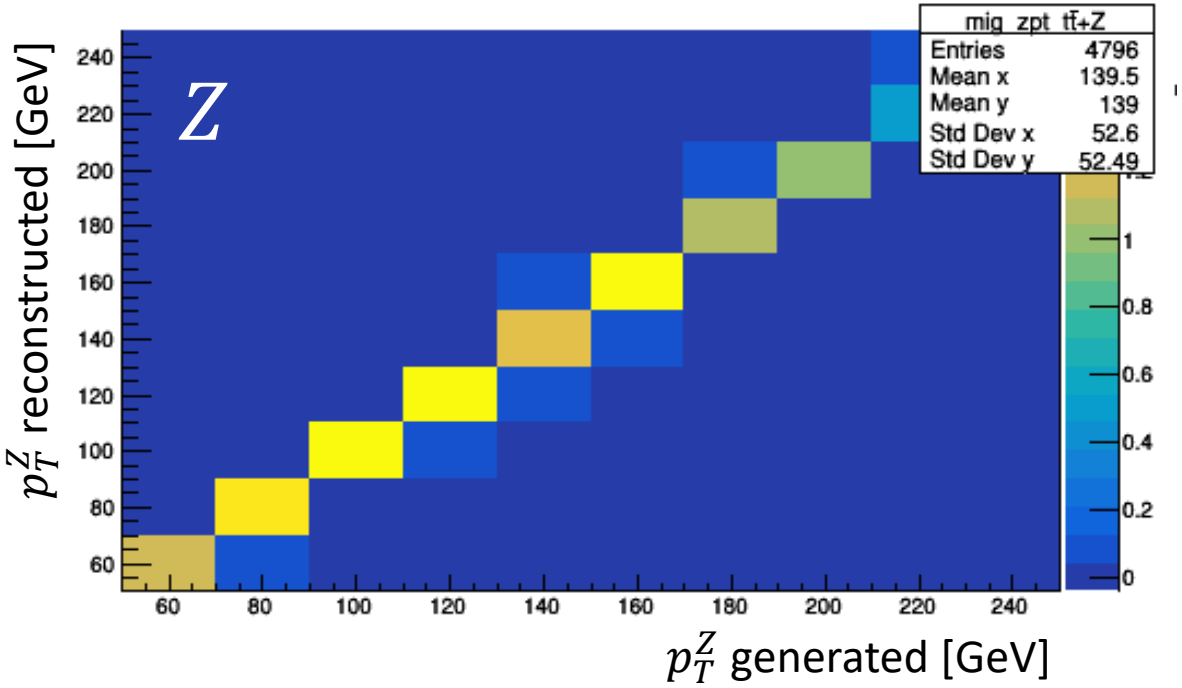


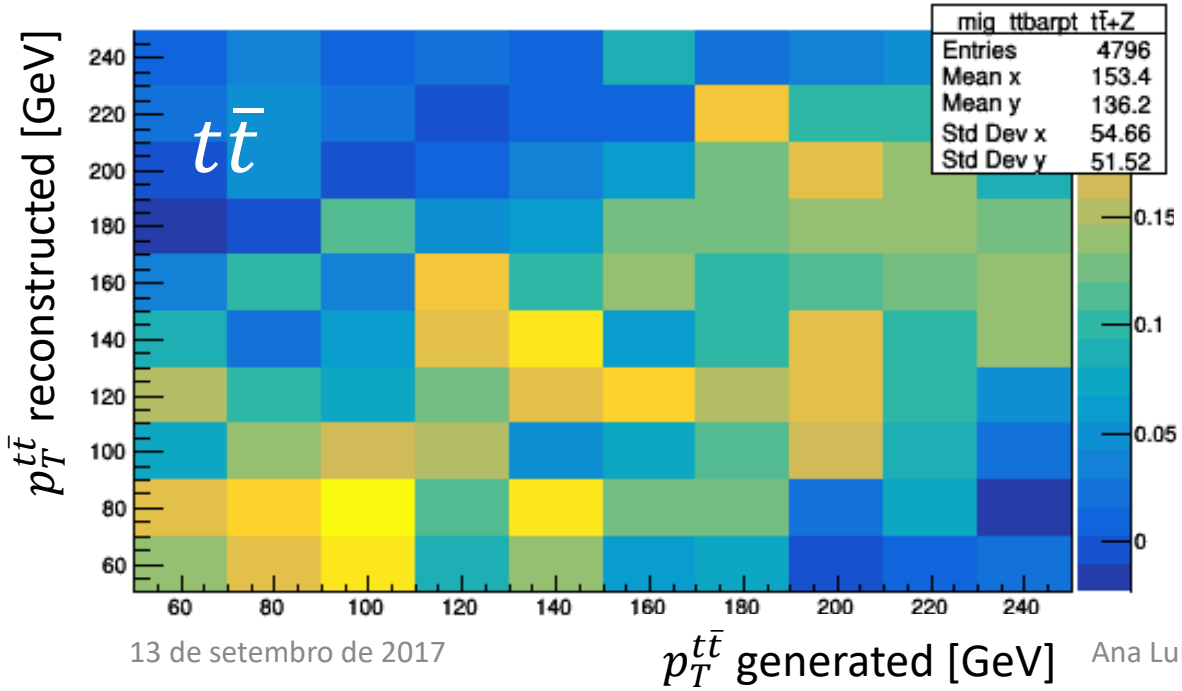


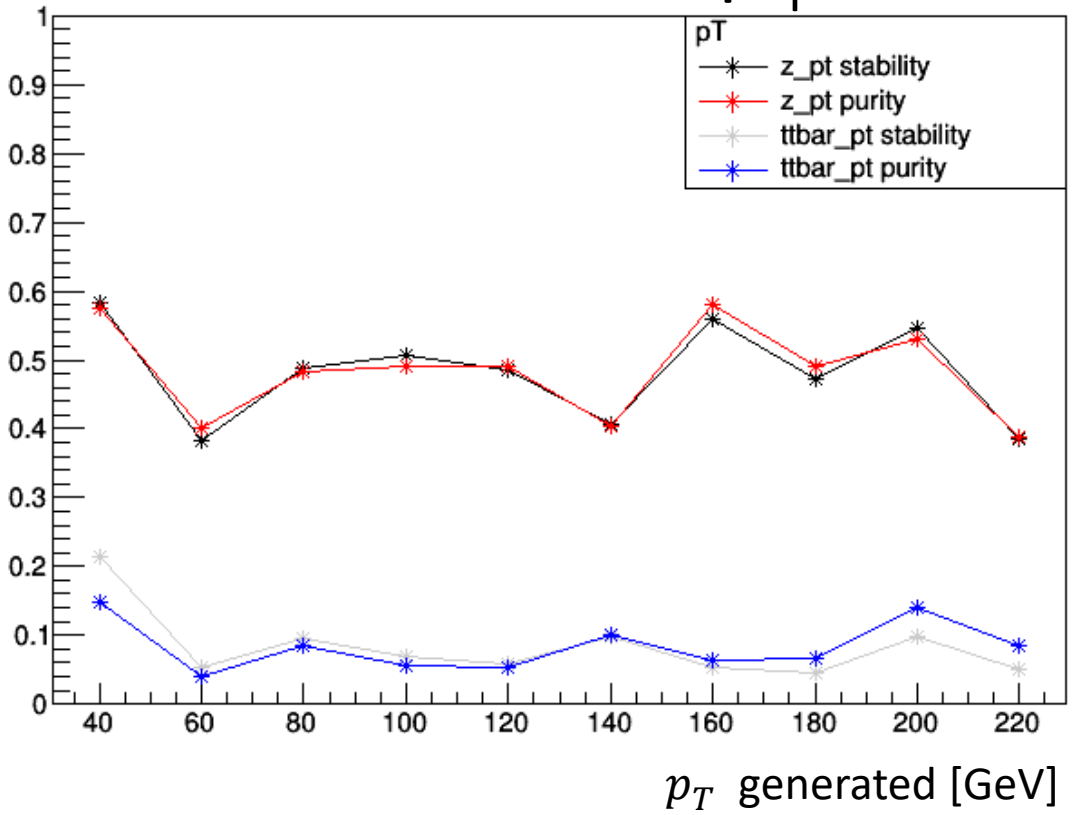
Migration matrices

Comparing reconstructed and generated events

Z and $t\bar{t}$ p_T







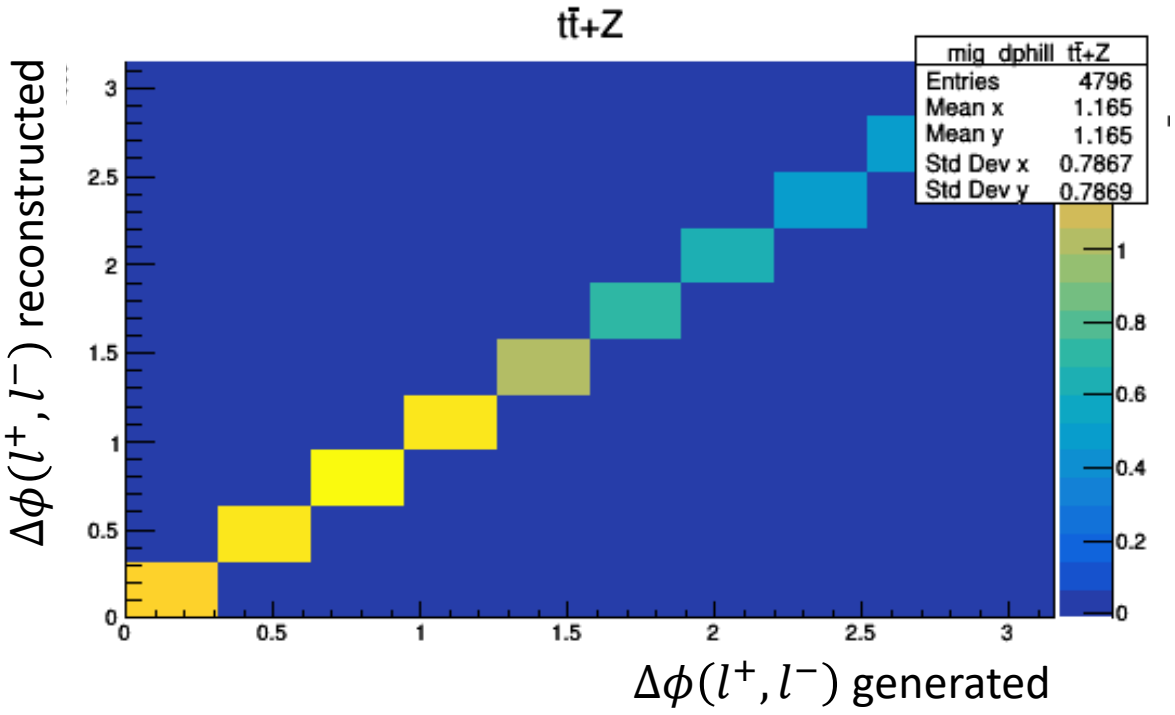
Stability

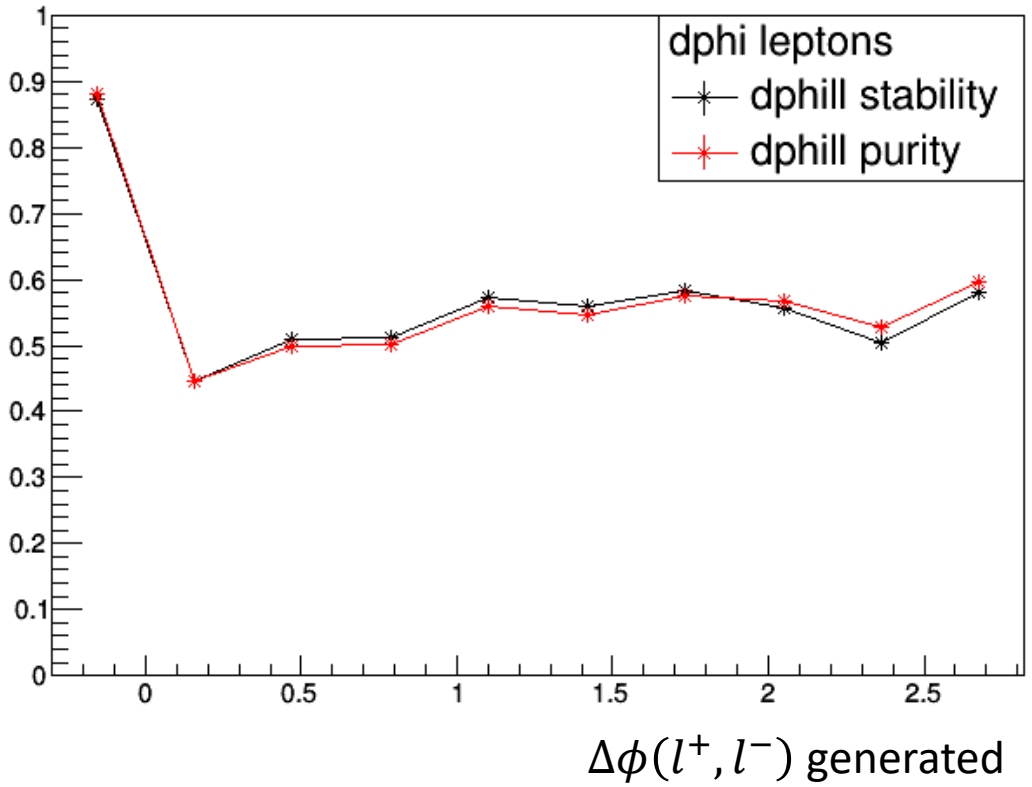
$$\frac{N_{gen\&reco}}{N_{gen}}$$

Purity

$$\frac{N_{gen\&reco}}{N_{reco}}$$

$\Delta\phi(l^+, l^-)$ of Z candidates



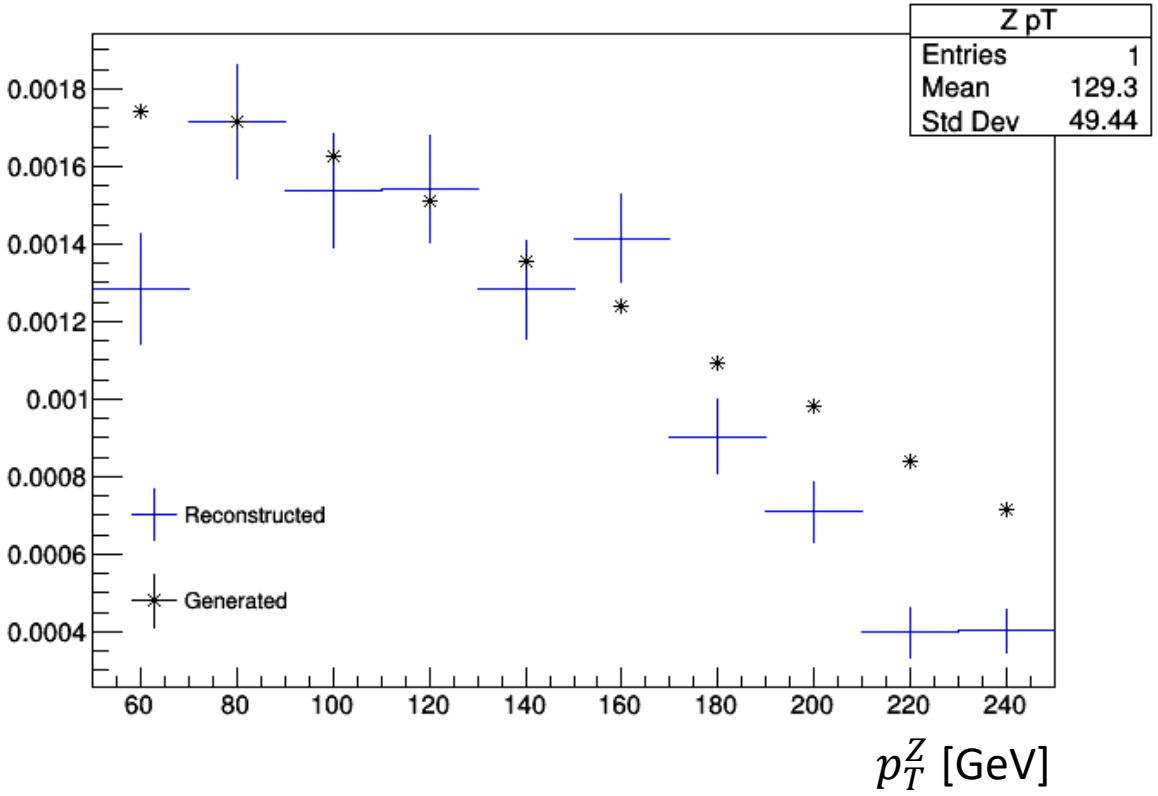


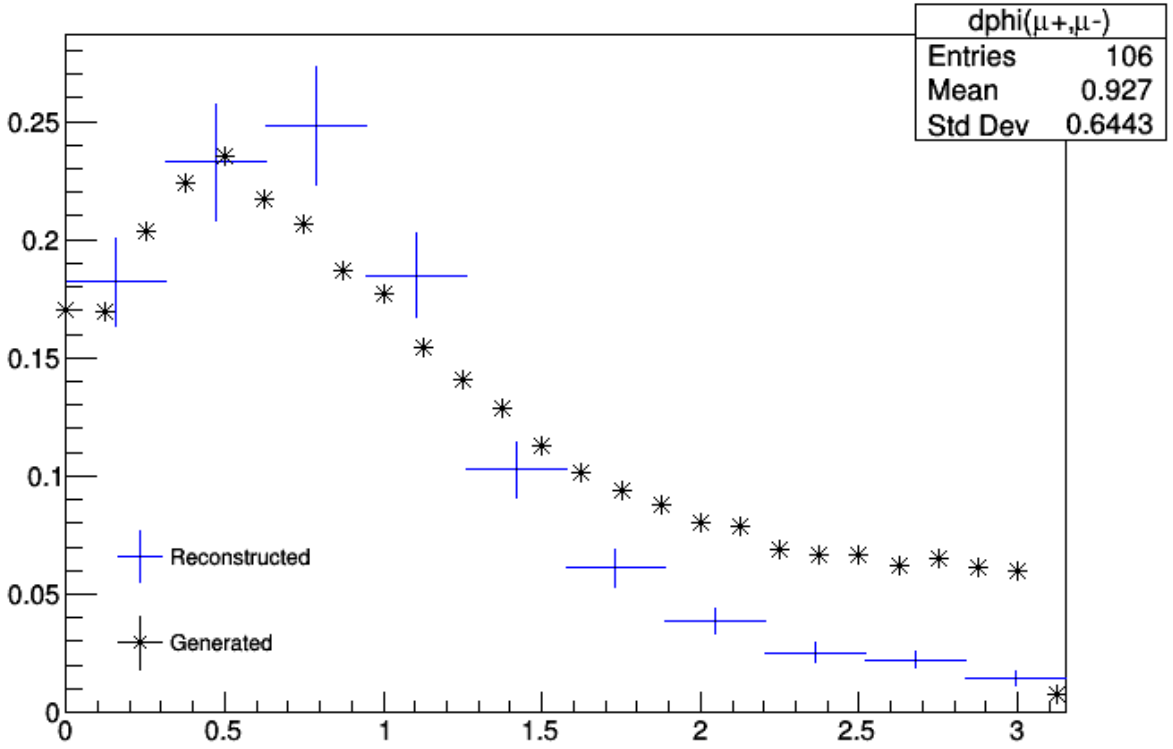
Reconstructed anomalous distributions

Z pT and $\Delta\phi(l^+, l^-)$

Distributions obtained for $C_{2,A} = 0.2$

$$\mathscr{L}_{t\bar{t}Z} = e\bar{u}(p_t)\left[\gamma^\mu\left(C^Z_{1,V} + \gamma_5 C^Z_{1,A}\right) + \frac{i\sigma^{\mu\nu}q_\nu}{M_Z}\left(C^Z_{2,V} + i\gamma_5 C^Z_{2,A}\right)\right] v(p_{\bar{t}})Z_\mu$$





Leptons in the Z mass window $\Delta\phi(l^+, l^-)$

To be continued…

Further explore other kinematic distributions in terms of discriminatin power

Determine necessary luminosity to probe anomalous couplings

Extend analysis to real data

Obrigada

Backup

TOPAZ internal parameters

Parameter	Value
m_t	173 GeV
m_b	0 GeV
M_Z	91.1876 GeV
M_W	80.385 GeV
Γ_Z	2.4952 GeV
Γ_W^{LO}	2.0455 GeV
Γ_t^{LO}	1.4957 GeV
G_F	1.166379×10^{-5} GeV^{-2}