

A first look at the B mixing with a Top Tag

12/03/2014

Martino Margoní, Paolo Ronchese

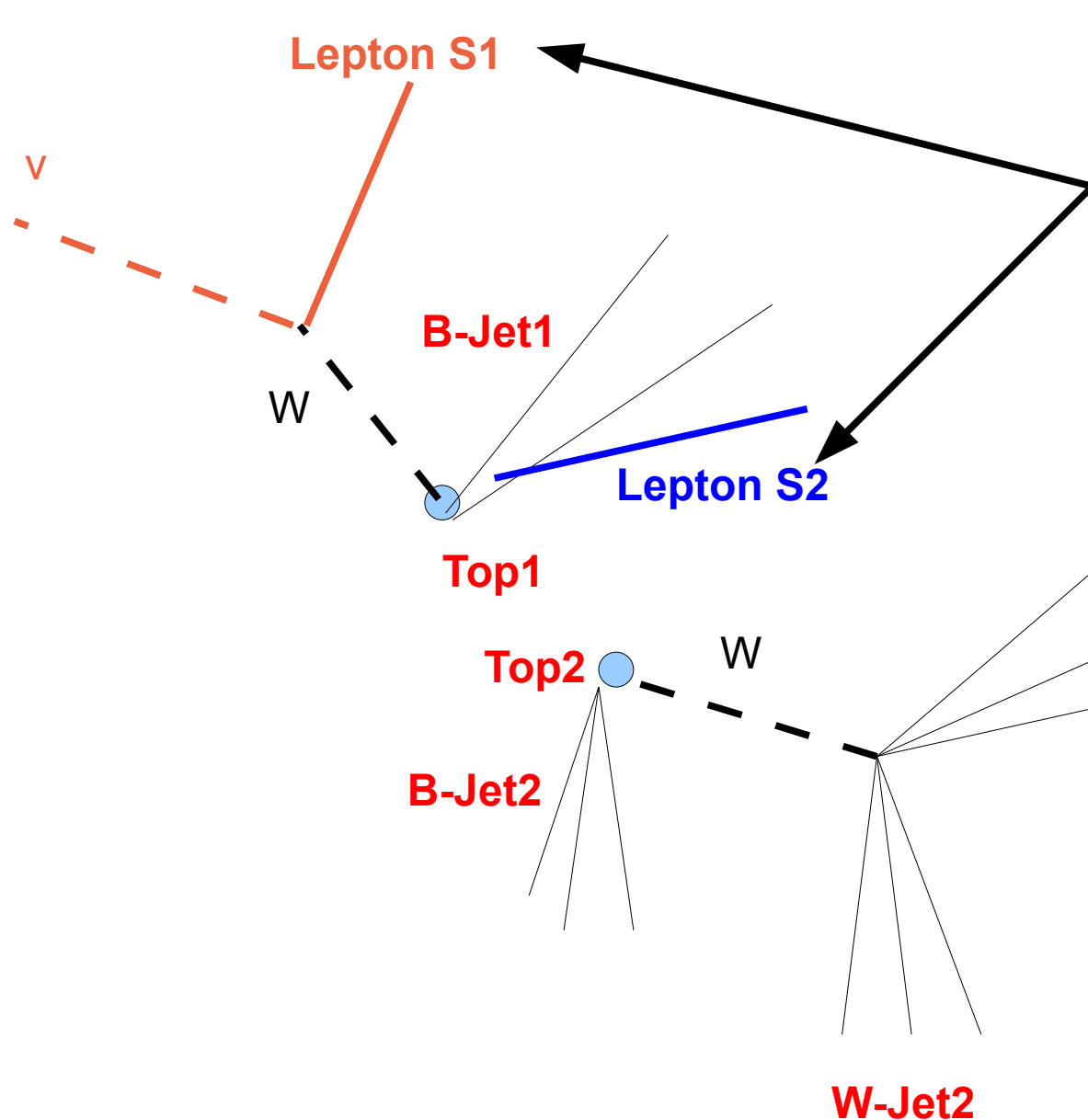
On behalf of the B_PHYS Padova Group

- Motivation
- Preliminary MC Study for event reconstruction:
 - ✦ Identification of the lepton from Top sl decay
 - ✦ Association of the lepton from B decay to the parent Top
- Next Steps

Motivation

- Semileptonic top decays $t\bar{t}$, $t \rightarrow lb\nu$, $\bar{t} \rightarrow \bar{b}X$
 - ✦ lepton tags the flavor of both the B-jets at the production time
- Arxiv 1212.4611 [Gedalia, Isidori et al.]: 3σ test of the D0 anomaly with 50 fb^{-1} at 14 TeV ($\delta A_{sl} \sim 0.15\%$)
- At the moment: measurement of the integrated B mixing probability χ
- Interests:
 - ✦ Original Analysis
 - ✦ Compare $\chi(m_t)$ with $\chi(m_Z)$: test QCD factorization
 - ✦ Provide clean sample of muons to study the spectrum for the “standard” dilepton mixing Padova Analysis

Analysis Strategy



● B mixing obtained exploiting the charge correlation between leptons **S1** (from top sl decay) and **S2** (from B sl decay)

● Lepton **S2** has to be assigned to one of the two B-jets using topological and kinematic quantities

Analysis Strategy

● Triggers Used in this exercise on MC:

HLT_Mu17_Mu8_*

HLT_Mu17_Ele8_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_*

HLT_Mu8_Ele17_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_*

HLT_Ele17_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_Ele8_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_*

$P_T(\text{lept } 1) > 17 \text{ GeV}$

$P_T(\text{lept } 2) > 8 \text{ GeV}$

● Analysis Items (partially correlated):

✦ $t\bar{t}$ events selection and BKG suppression (Paolo)

✦ Signal study on MC (Martino)

✦ Identification of the S1 tagging lepton from $t \rightarrow W \rightarrow (\tau) \rightarrow l$

✦ Identification of the S2 lepton from $t \rightarrow b \rightarrow (c) \rightarrow l$ and
association to the right parent top

✦ $b \rightarrow l$ / $b \rightarrow c \rightarrow l$ separation (Student, A. Boletti since yesterday)

✦ Likelihood definition ($P_{T,rel}$ + other discriminant variables) (All)

✦ Closure test on Signal/Full MC

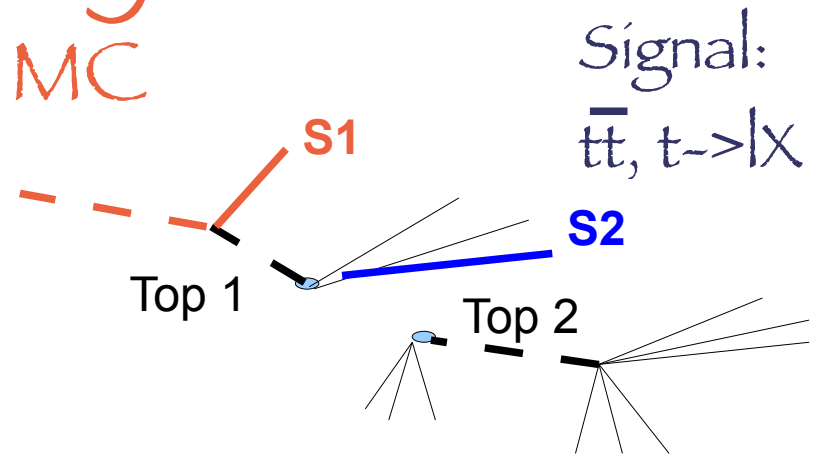
✦ Measurement on Data

First Studies on Signal MC

Lepton classification in signal MC

● Top-correlated classes:

- ✦ S1: $t \rightarrow W \rightarrow l$, $t \rightarrow W \rightarrow \tau \rightarrow l$
- ✦ S2: $t \rightarrow b \rightarrow l$, $t \rightarrow b \rightarrow c \rightarrow l$
- ✦ B1: $t \rightarrow W \rightarrow c \rightarrow l$, $t \rightarrow W \rightarrow \text{light} \rightarrow l$, $t \rightarrow b \rightarrow \text{light} \rightarrow l$



● Non-top-correlated classes

- ✦ B2: $b \rightarrow l$, $b \rightarrow c \rightarrow l$ (3.5% of S2, dilute the sample)
- ✦ B3: $c \rightarrow l$, $\text{light} \rightarrow l$

● Leptons with no link to generation (from GEANT) not considered yet

Event Selection

- Missing $E_T > 20$ GeV
- At least one isolated lepton:
 - Isolation < 0.3
 - Z^0 veto $|M(l^+l^-) - MZ^0| > 15$ GeV
- $PT(\text{Jet}) > 20$ GeV
- W (hadr.): all Jet pairs surviving b-veto CSV < 0.7
- B-jets candidates:
 - At least one jet surviving udsc-veto CSV > 0.3
 - At least one jet having a muon
- Best combination chosen according to W and Top masses χ^2

Resulting Selection Fraction (%)

	m-sig	m-bkg	e-sig	e-bkg
tts	18.71	6.41	18.9	6.93
qcd	0.0	0.98	0.0	0.41
dy 1	0.0	1.85	0.0	0.07
dy 2	0.0	0.22	0.0	0.08

tts = tt, $t \rightarrow lX$, inclusive b decay

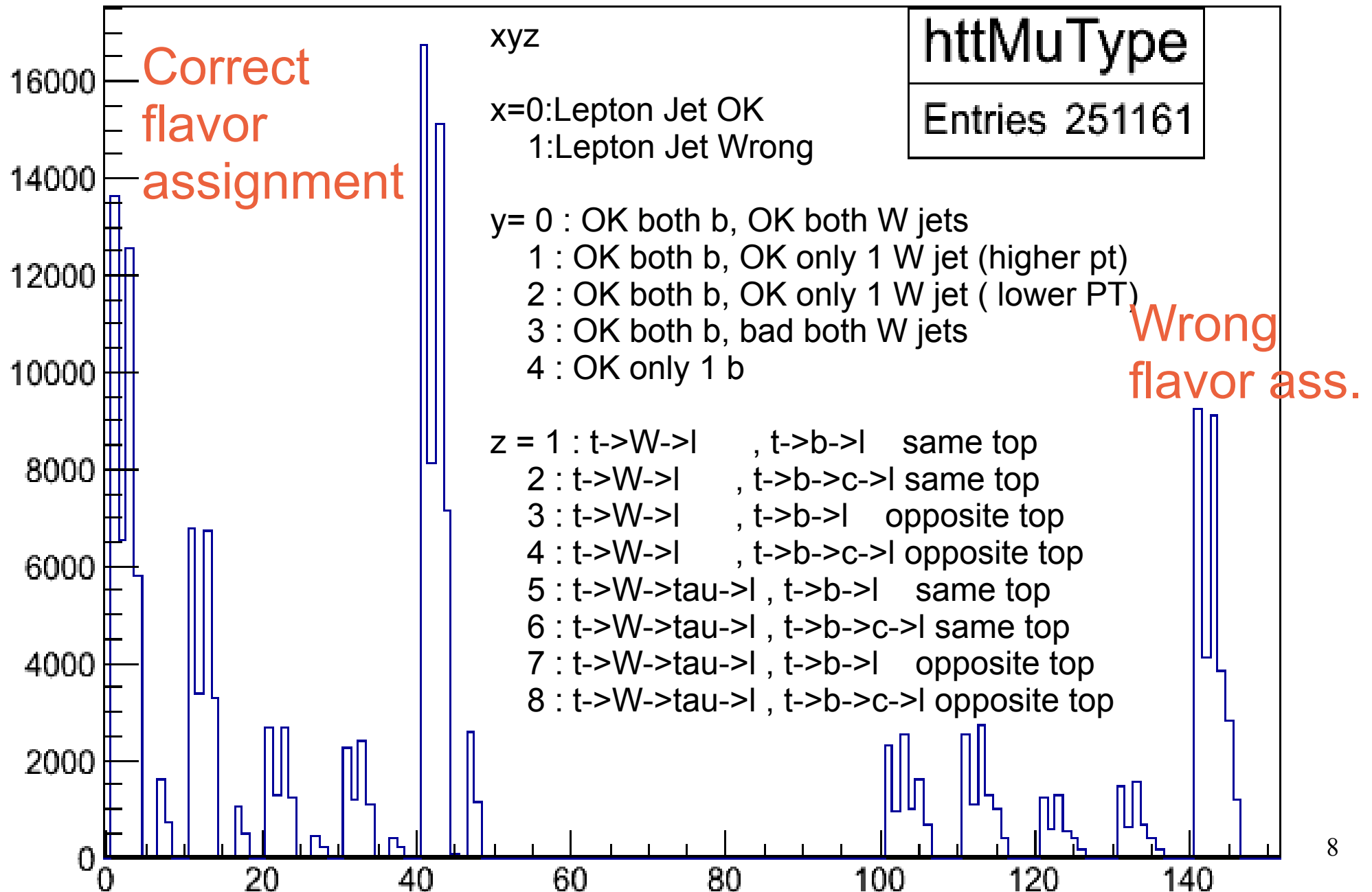
dy1 = Drell-Yan with $10 \text{ GeV} < M(l\bar{l}) < 50 \text{ GeV}$

dy2 = Drell-Yan with $M(l\bar{l}) > 50 \text{ GeV}$

Signal = tt, $t \rightarrow lX$, $b \rightarrow lY$

BKH = non tt, $b \rightarrow lY$ OR fake leptons

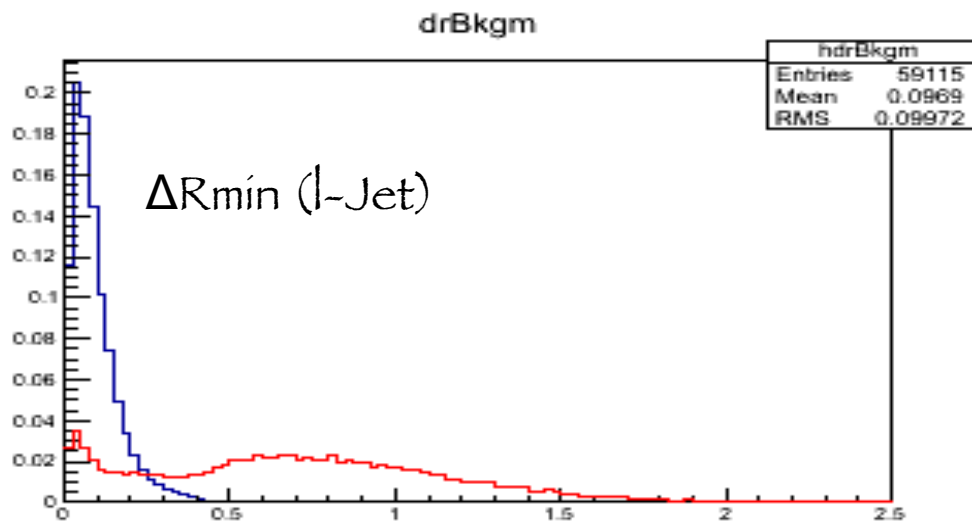
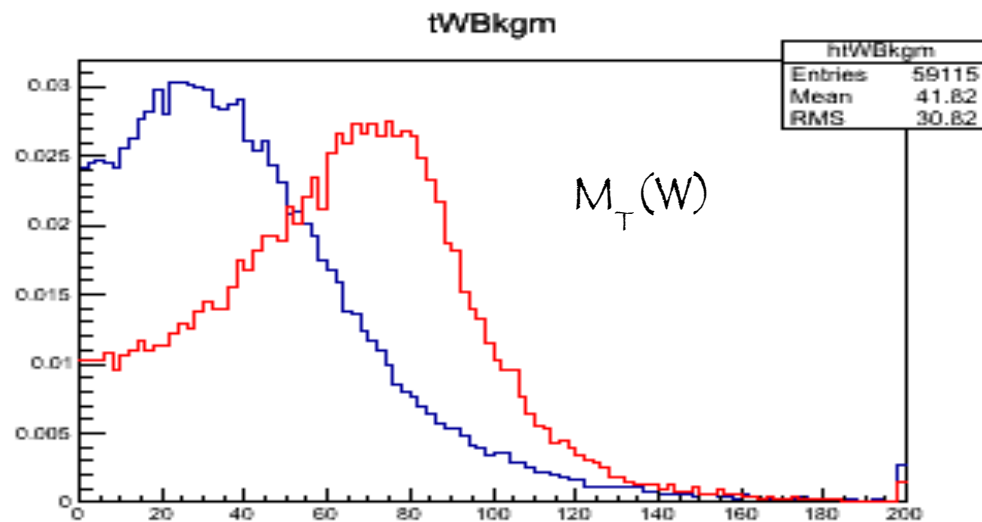
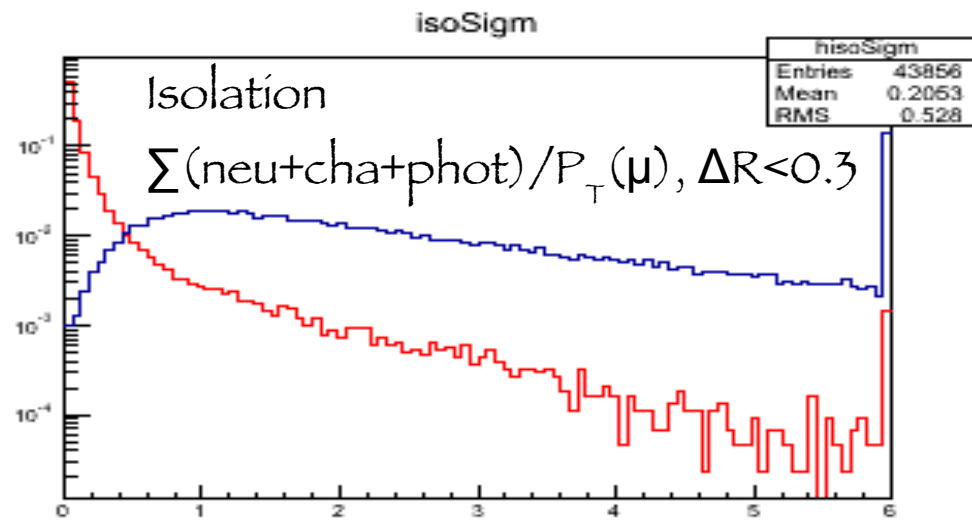
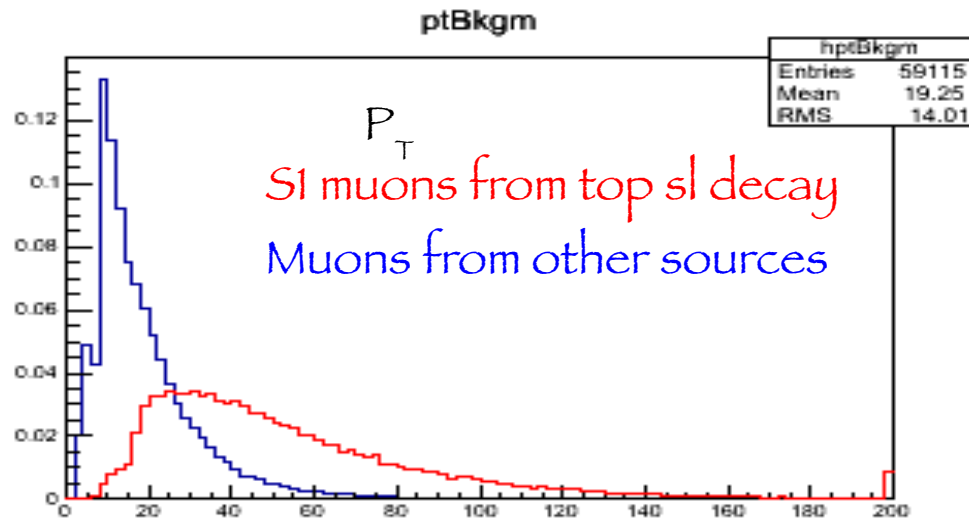
Event Classification



*Identification of the S_1 leptons
and BKG reduction*

SI muons from top SI decays

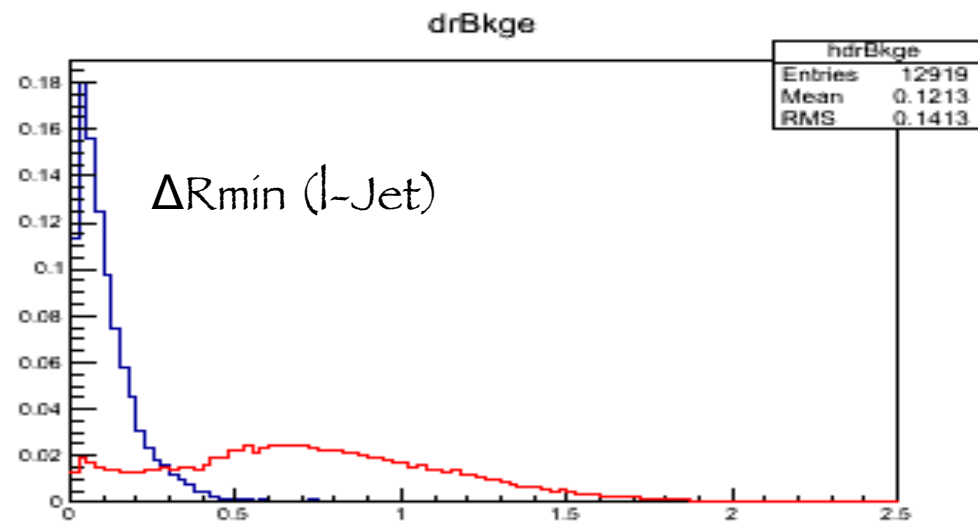
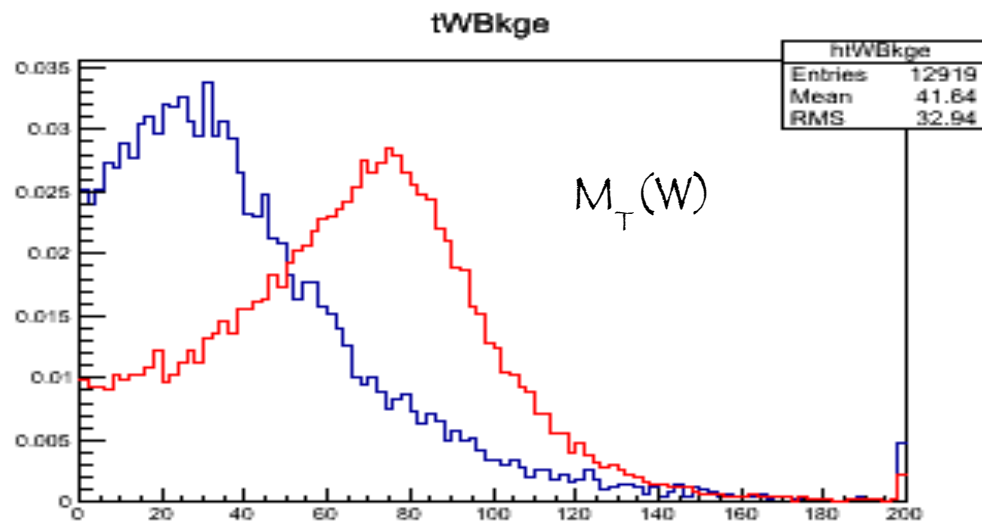
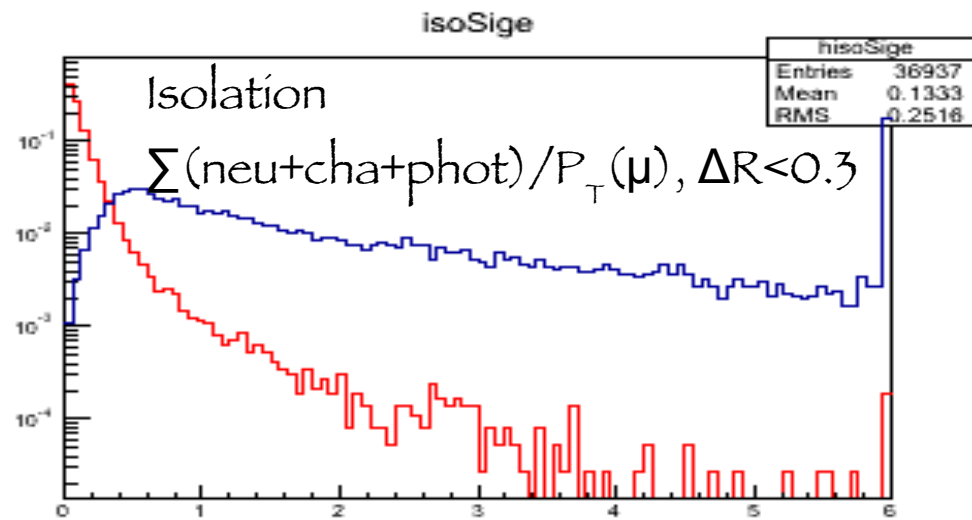
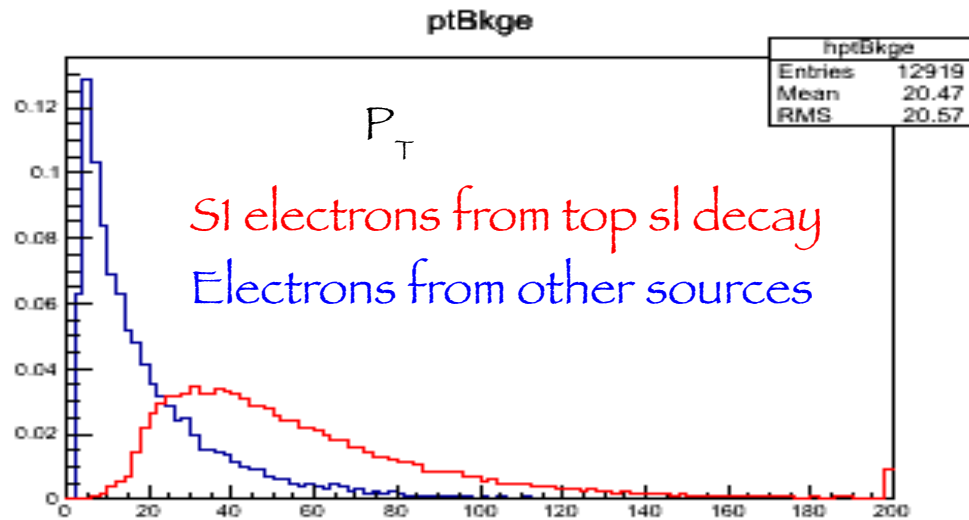
MC tt with only one $t \rightarrow lX$ decay



Reconstructed quantities, no cut applied on P_T at the moment

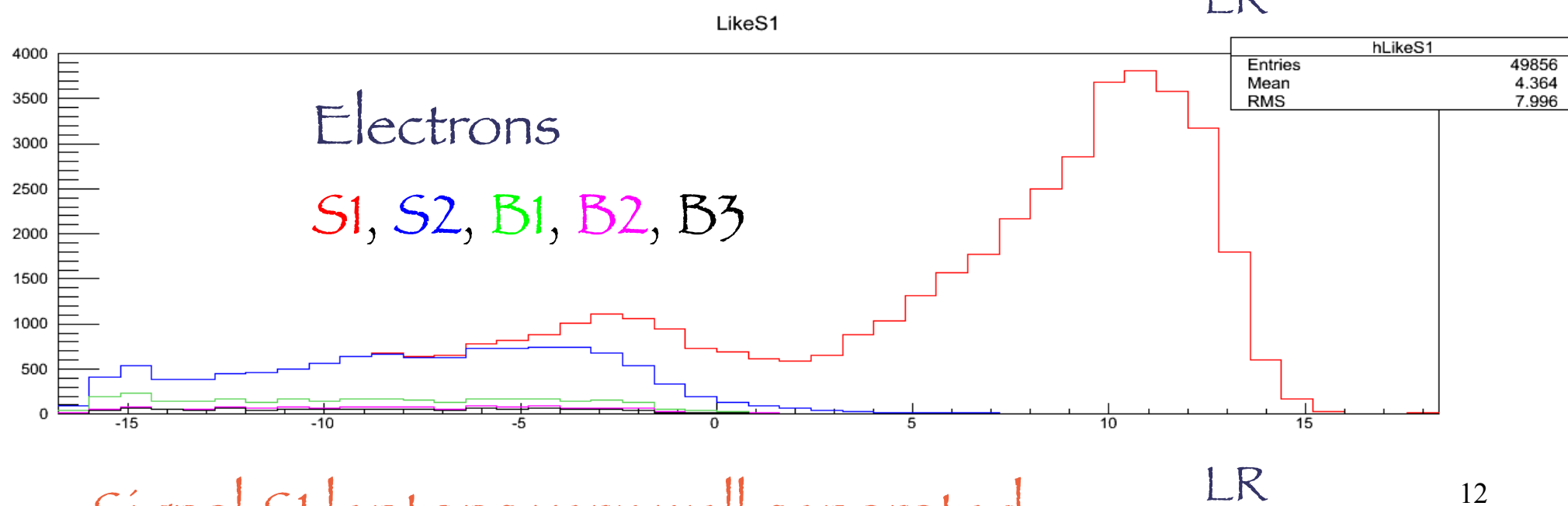
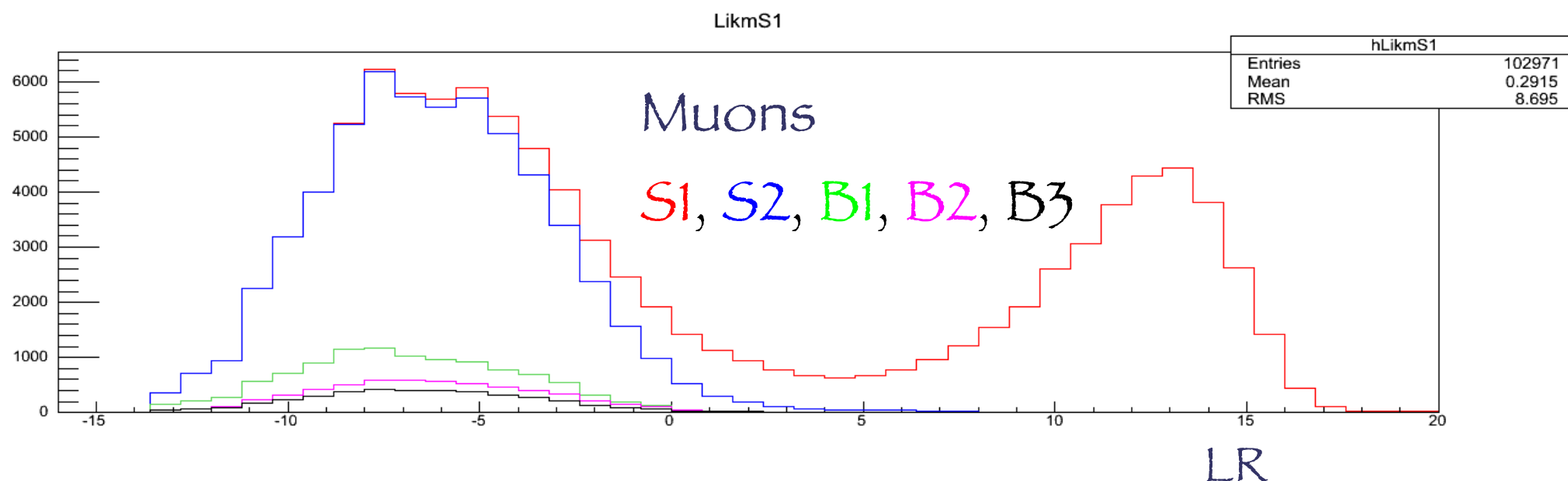
Sl electrons from top sl decays

MC tt with only one $t \rightarrow lX$ decay



Reconstructed quantities, no cut applied on P_T at the moment

Likelihood Ratio from the 4 vars.

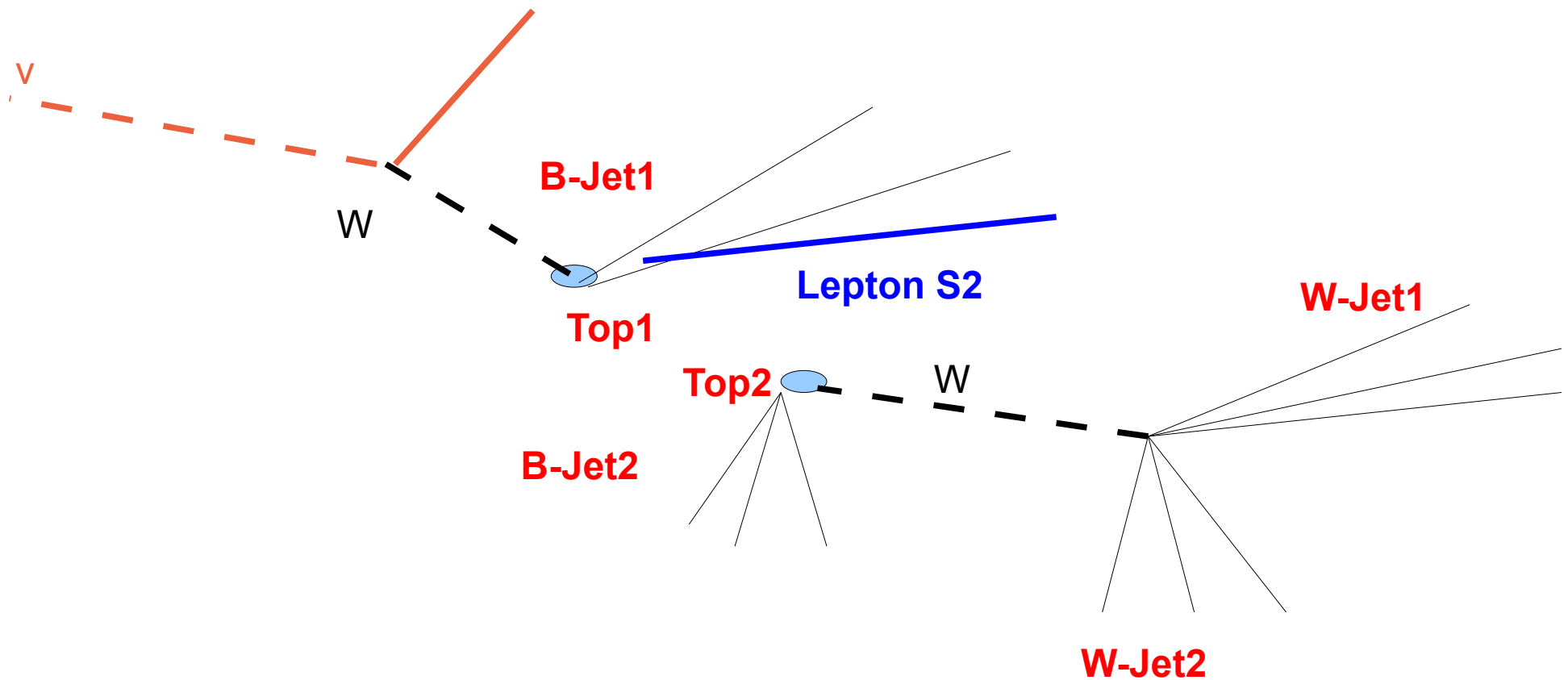


Signal S1 leptons very well separated

Identification of the S_2 leptons and association to the right top parent

[Only reconstructed muons and electrons with link to S_2
leptons in generation used in what follows]

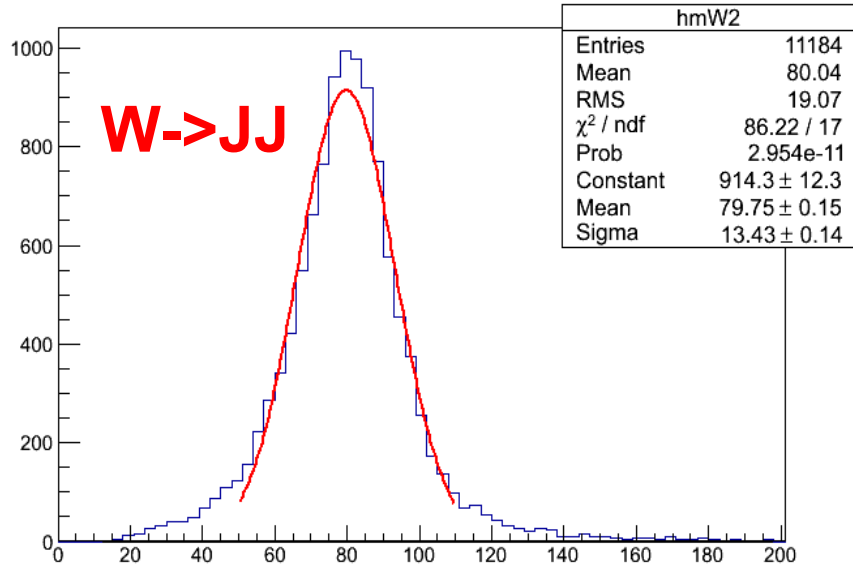
Event Reconstruction



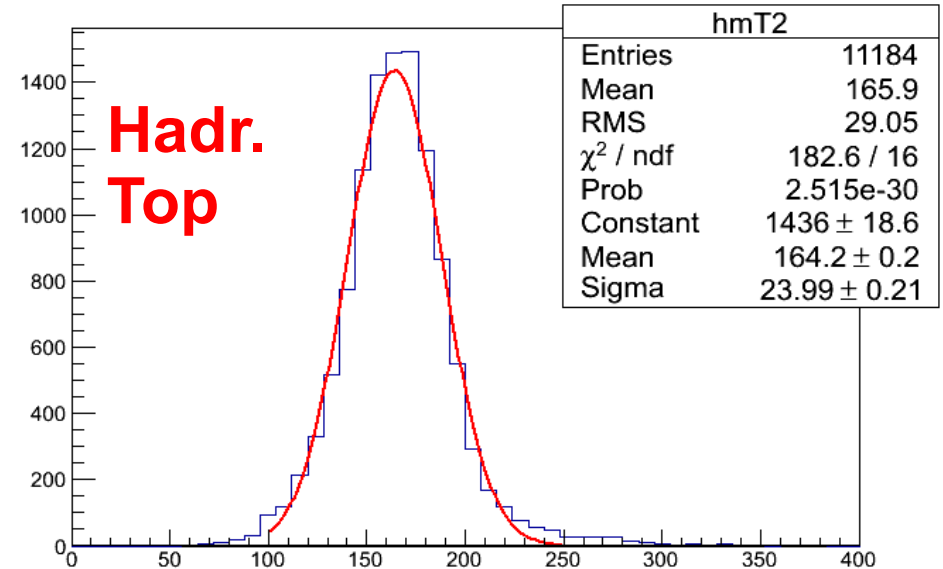
- Event topology studied using generation informations
 - Definition of variables useful in the reconstruction of the right “ordered quadruplet” of jets:
 (B-Jet 1 [from sl Top], B-Jet 2 [from hadr. Top],
 W-Jet 1 [higher P_T], W-Jet 2 [lower P_T])

Event Reconstruction [with link to generation]

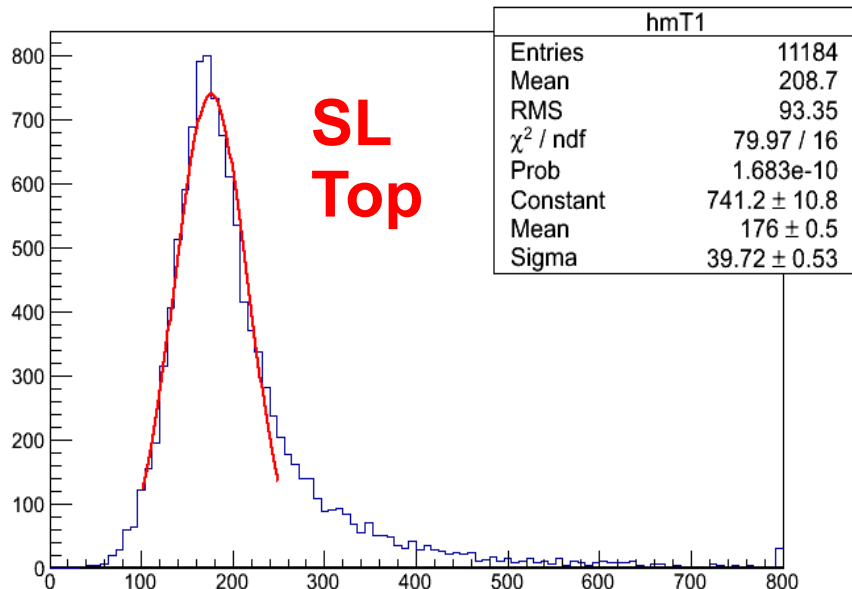
mW2



mT2



mT1



- Invariant mass from reco 4-momenta of jets, lepton and neutrino
- $E_z(\nu)$ obtained by constraining the $W(l\nu)$ mass
- Jet-parton association based on ΔR and parton P_T , starting from the highest $P_{T, \text{jet}}$

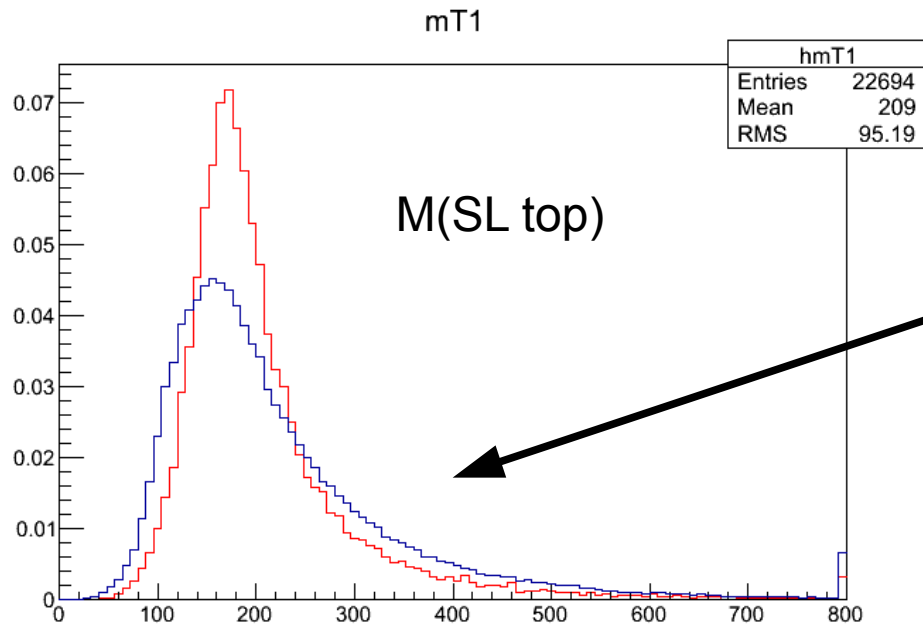
Event Reconstruction in 2 Steps

- Step 1: In the following, only the possible combinations of 4 jets formed starting from the first $N=6$ jets ordered in P_T are considered. [$\epsilon \approx 70\%$ to have the right combination using $N=6$, $\epsilon \approx 33\%$ using $N=4$]. Exploiting the relevant topological quantities, a probability is assigned to every 4-jets combination to be the right one using a Likelihood Ratio approach. All the combinations are then ordered based on this probability.
- Step 2: The $S2$ lepton is assigned to the right Top parent by considering the highest probability combination in which the lepton jet has been classified as one of the two B-jets. Some other topological variables are added at this level in a Likelihood Ratio.
- Both the steps are based on a Likelihood-Ratio approach (to be moved to MVA)

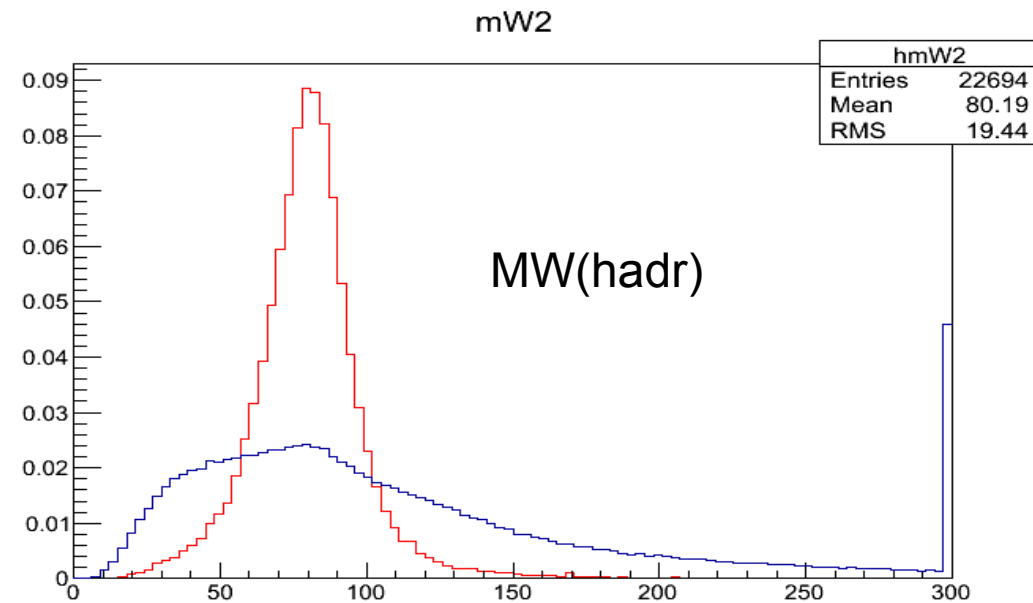
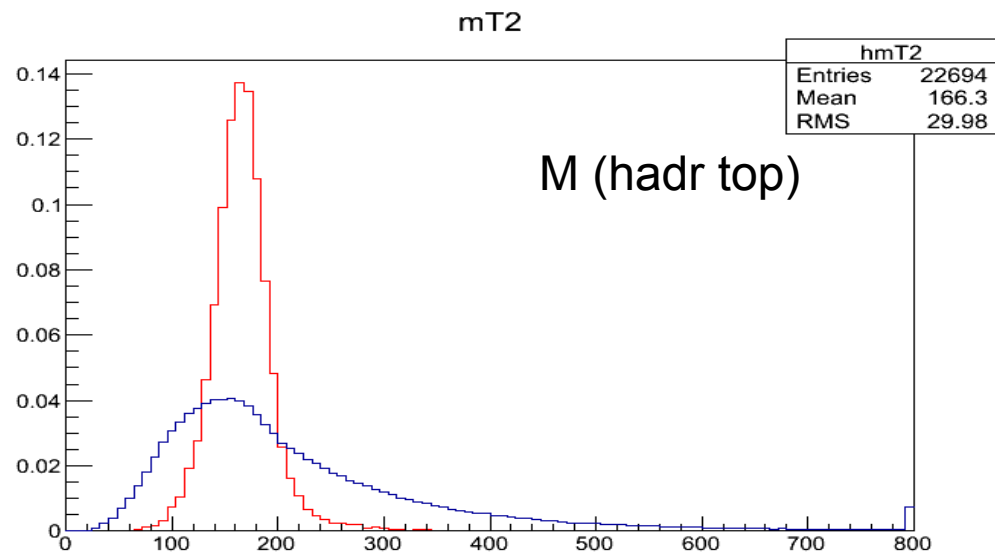
Event reconstruction [with no link to generation]

Right combination

Wrong combinations



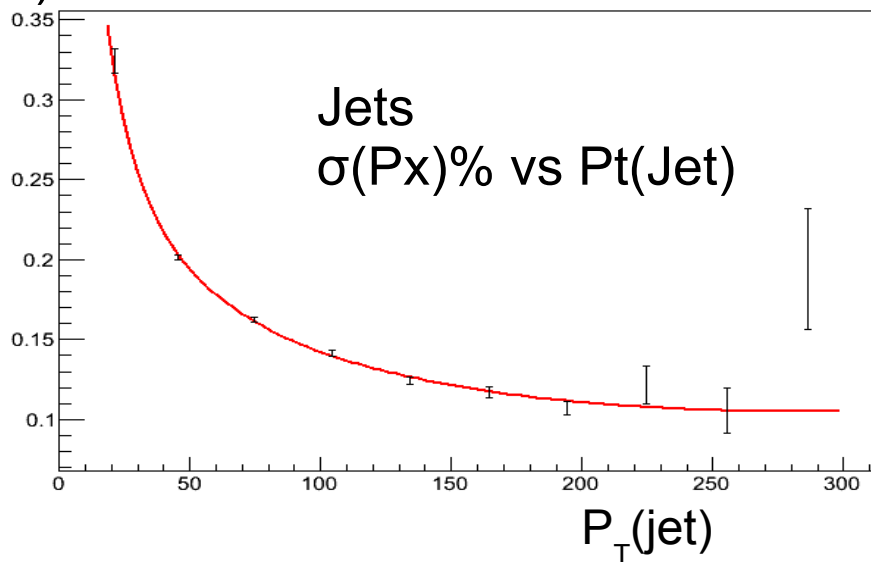
$E_z(\nu)$ for the M(SL Top)
obtained by constraining
the $W(l\nu)$ mass to the PDG



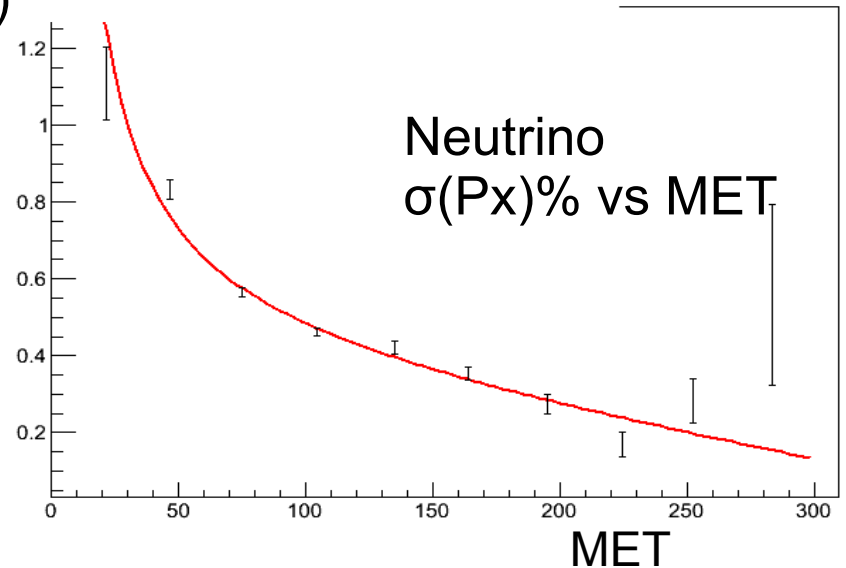
χ^2 of event reconstruction

- Important quantity: χ^2 of the 3 invariant masses: W, top(sl), top(hadr)
- 4-momenta resolution of jets, lepton and neutrino parameterized on MC in terms of $P_T(\text{jets})$, $P_T(\text{lepton})$ and MET(neutrino)

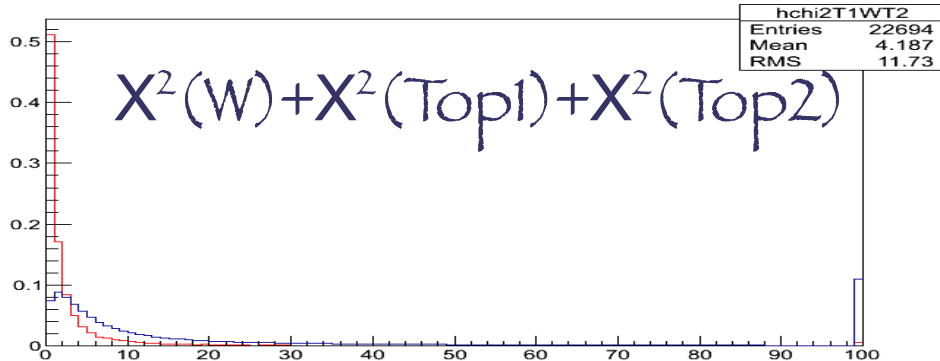
$\sigma(P_x)$



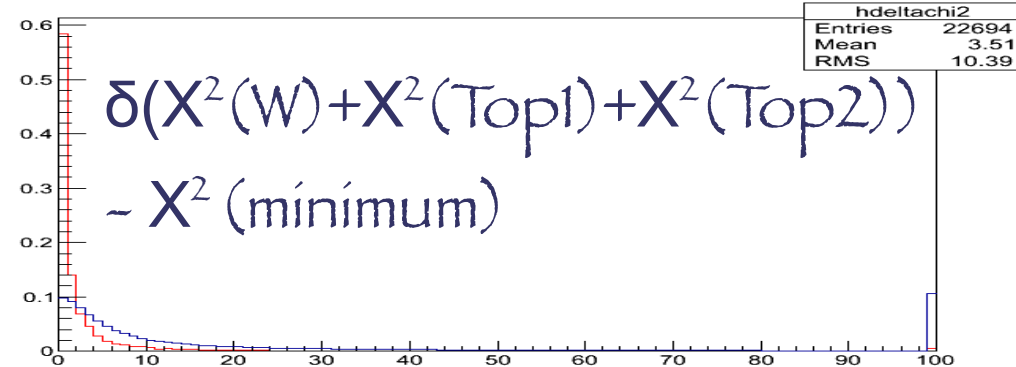
$\sigma(P_x)$



chi2T1WT2

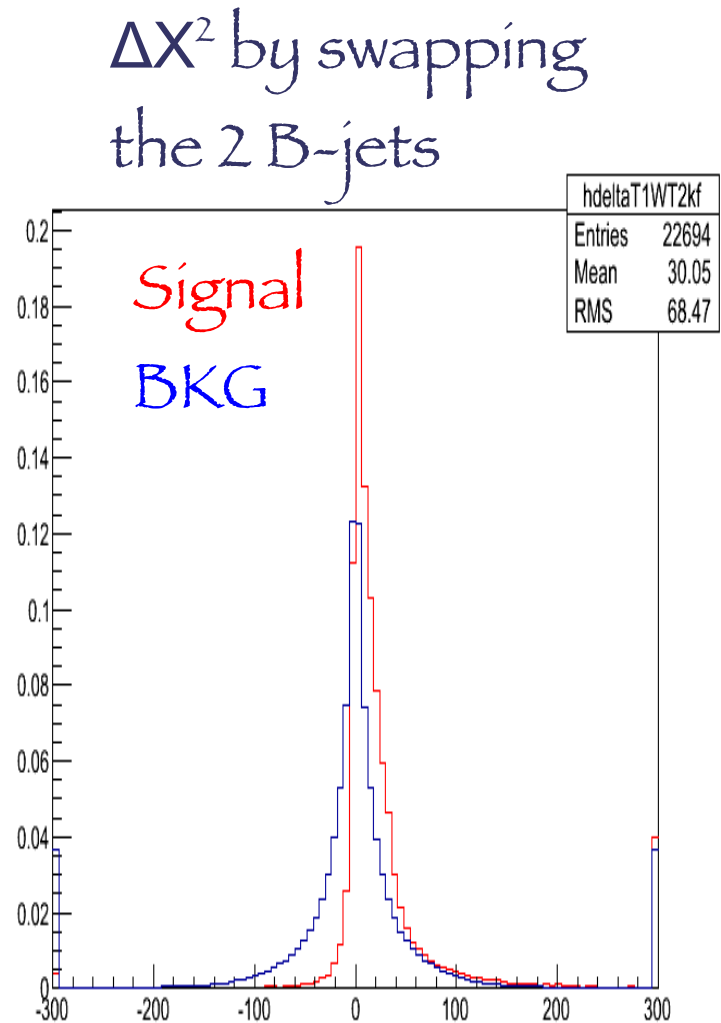
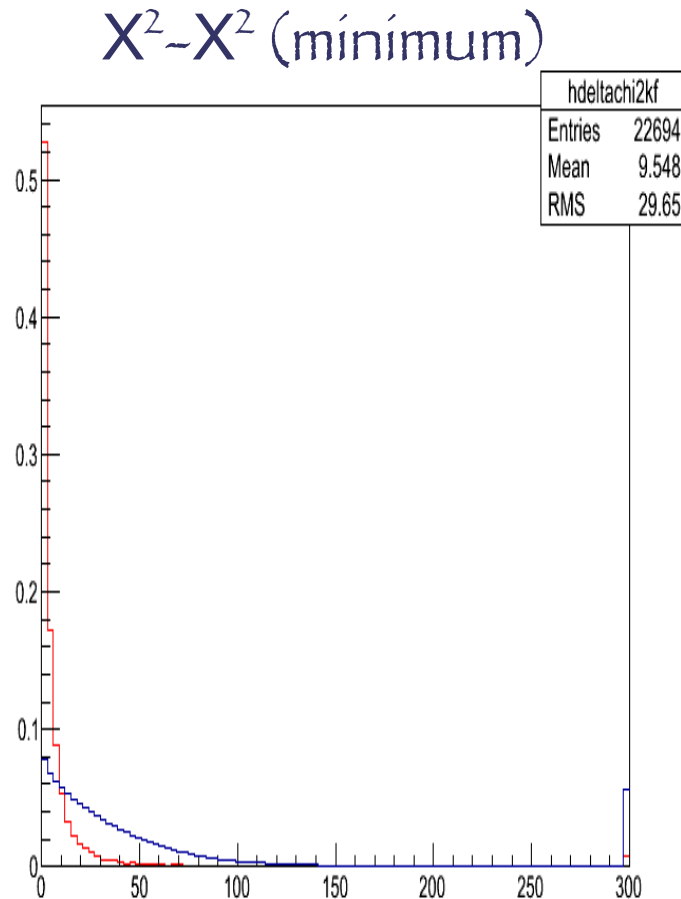
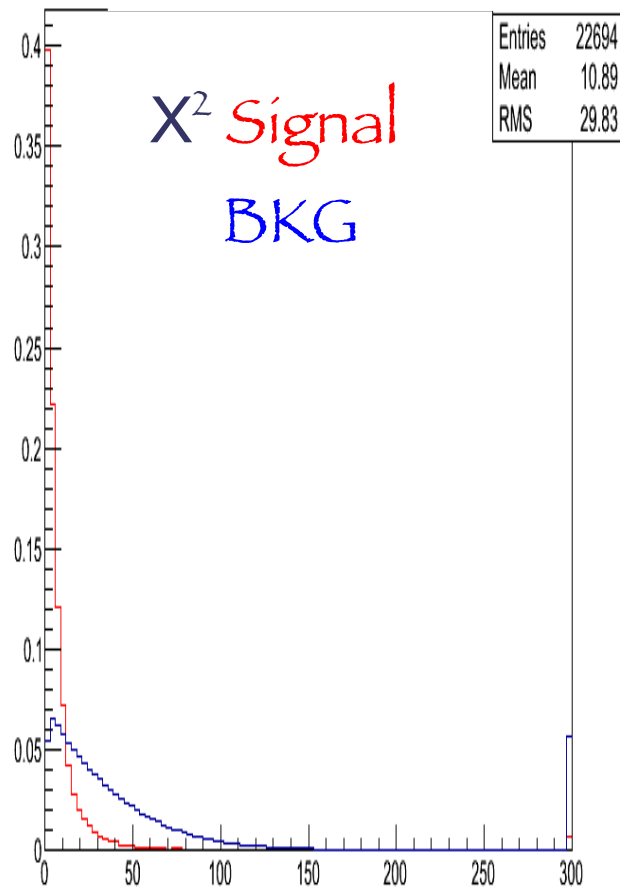


deltachi2



χ^2 of Kinematic Fit (TKinFitter)

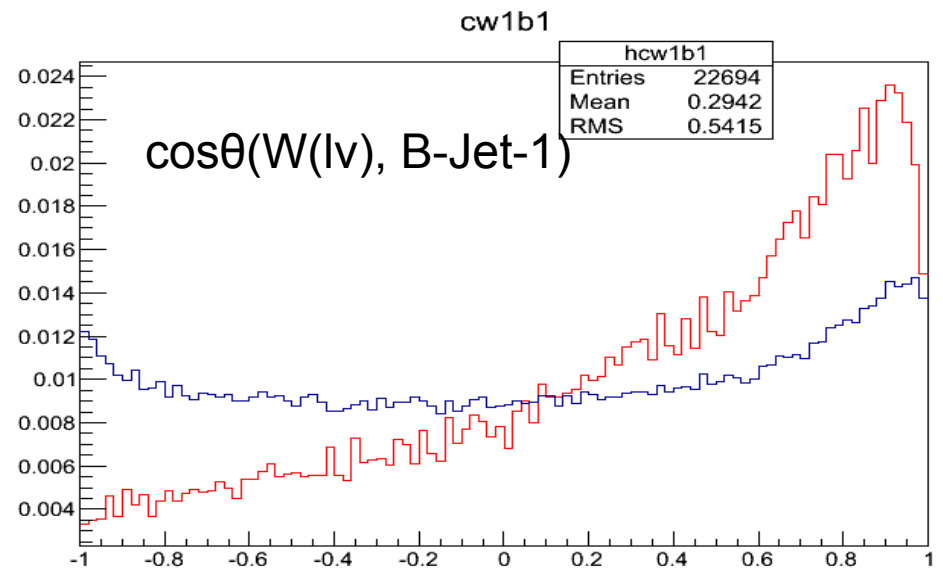
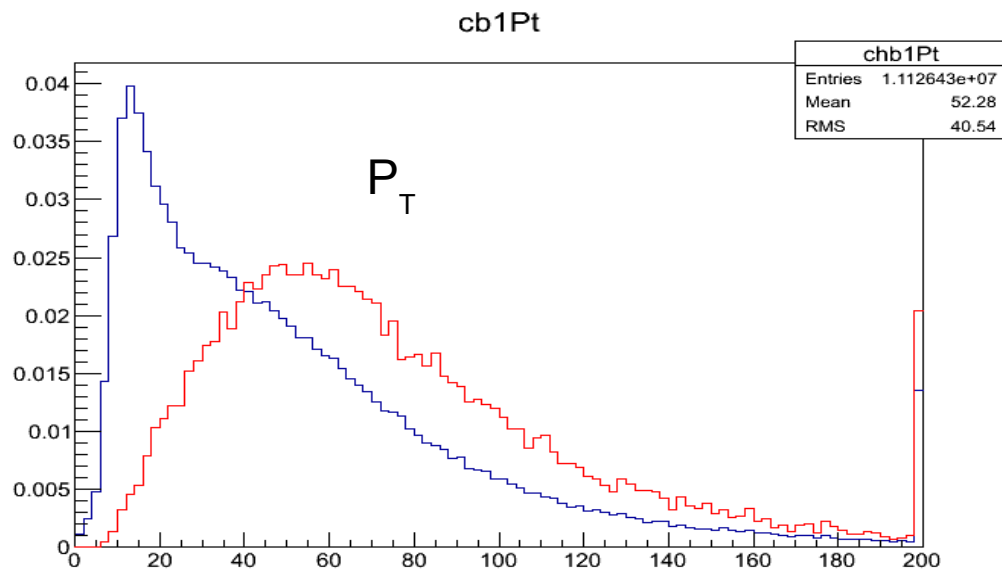
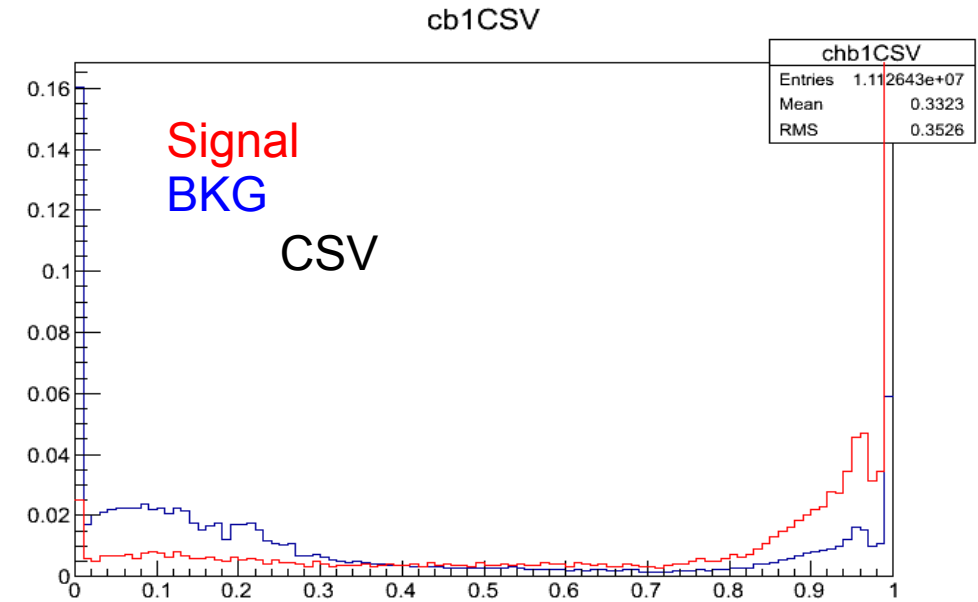
TKinFitter Package used to constrain the 3 invariant masses:
M(SL Top), M(hadr W), M(hadr Top) to the world average



Some variables in the Step 1 Likelihood

After refitting

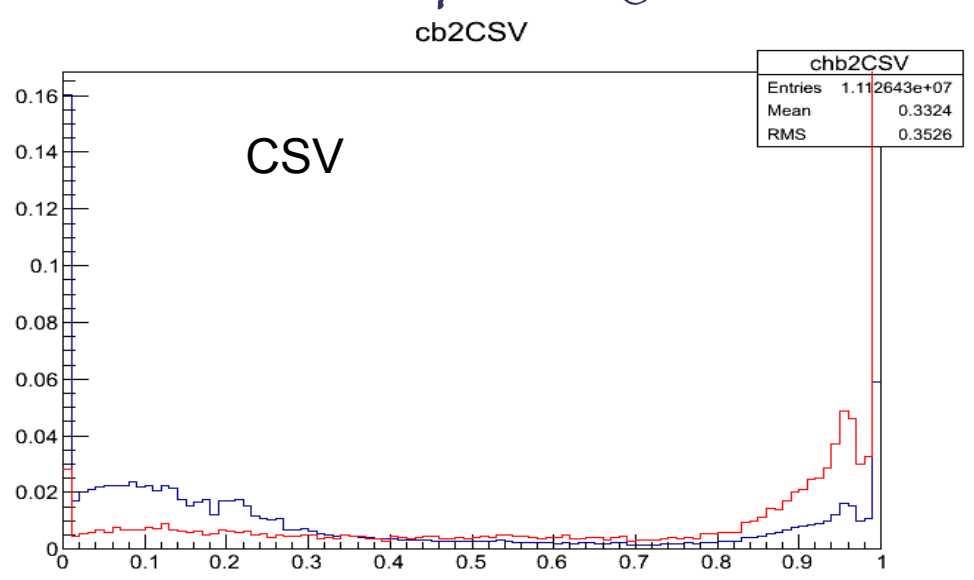
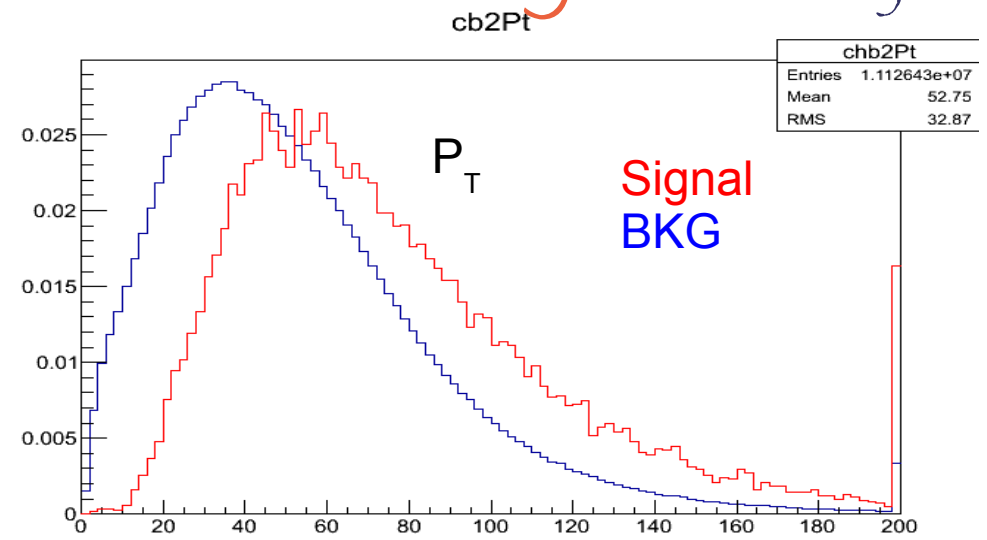
B-Jet from semileptonic top decay



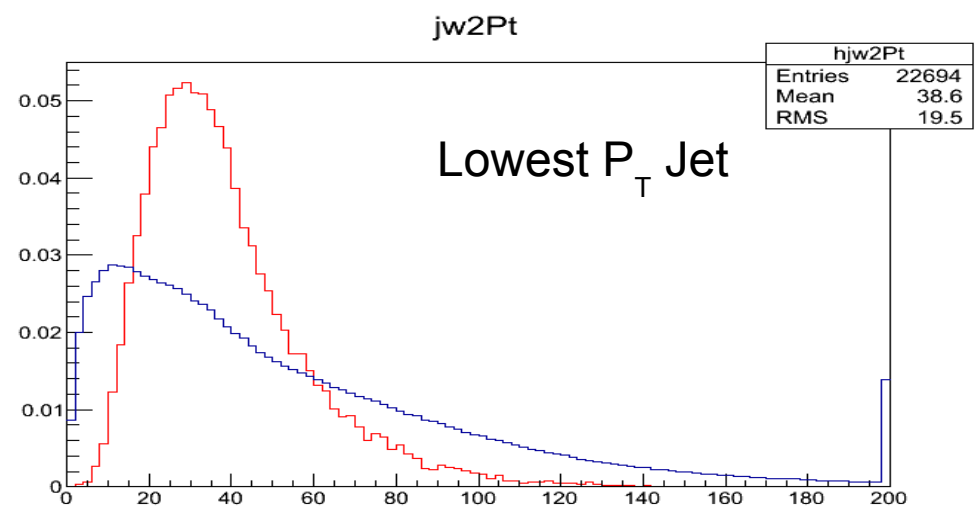
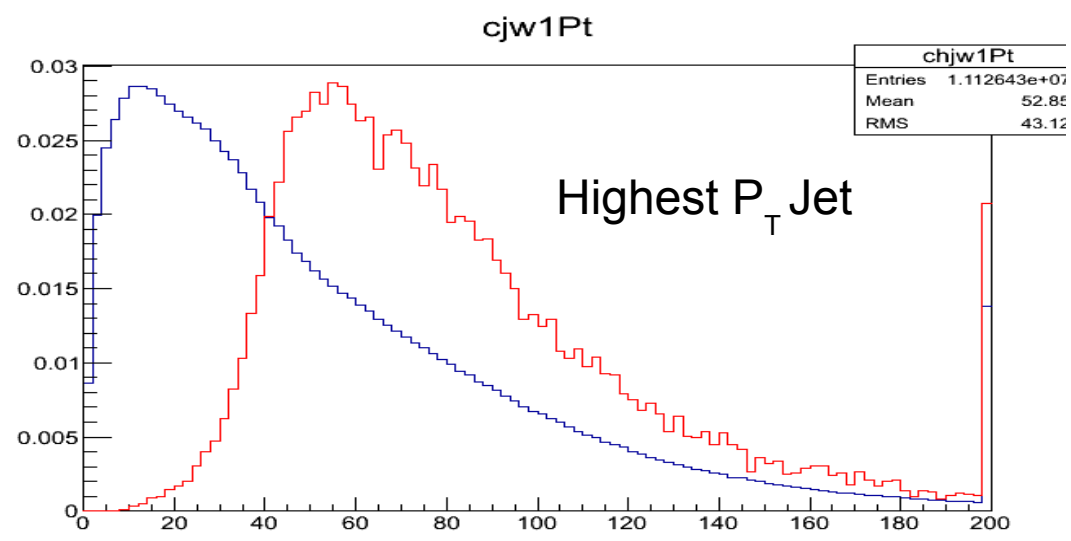
Some variables in the Step 1 Likelihood

After refitting

B-jet from hadronic top decay



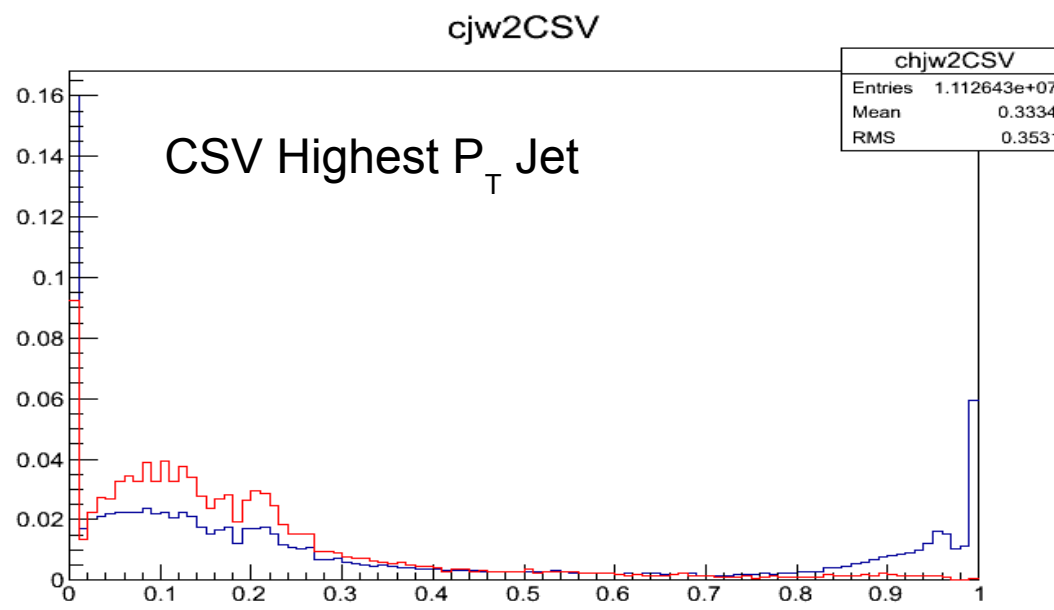
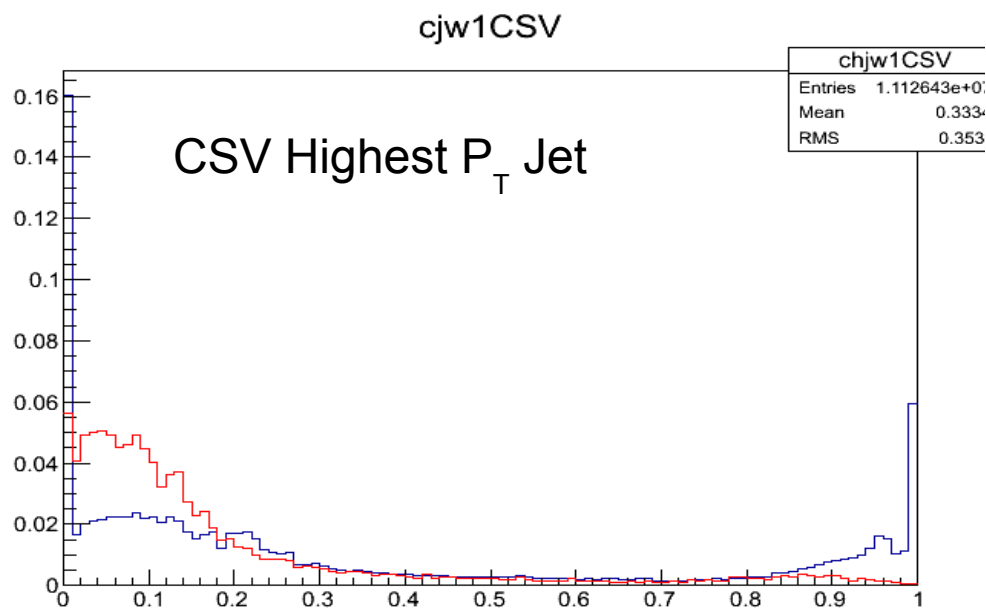
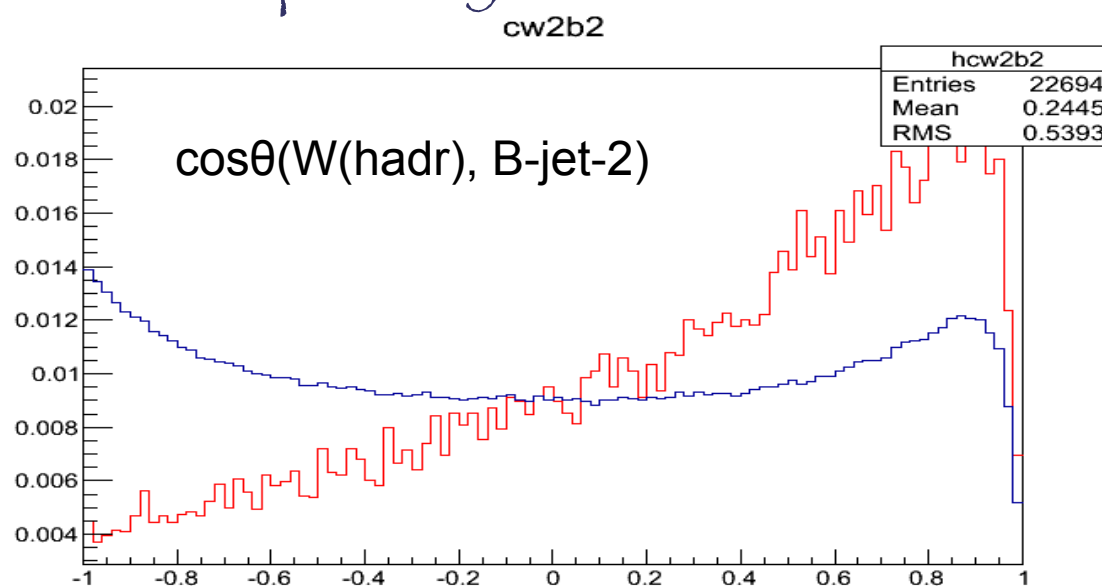
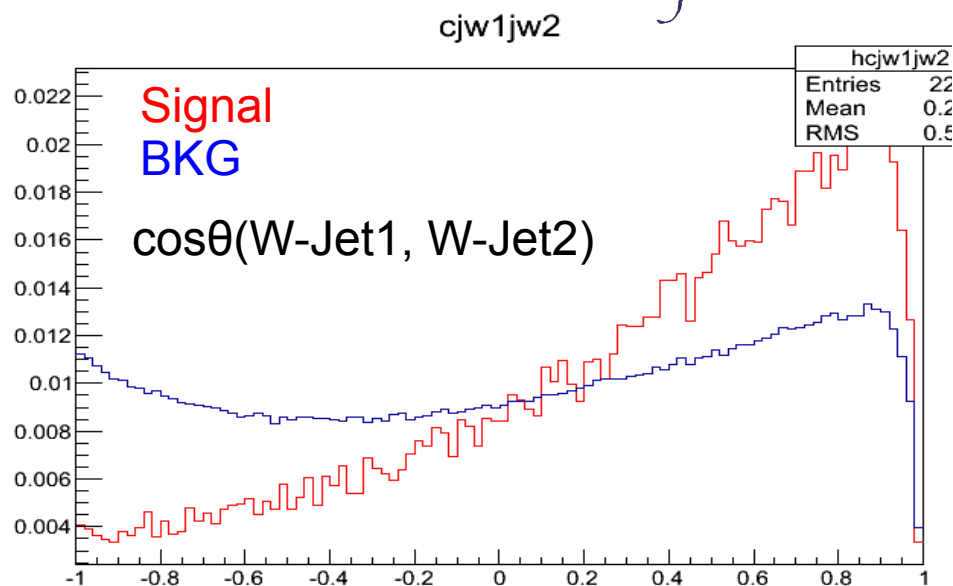
W-jets from hadronic top decay



Some variables in the Step 1 Likelihood

After refitting

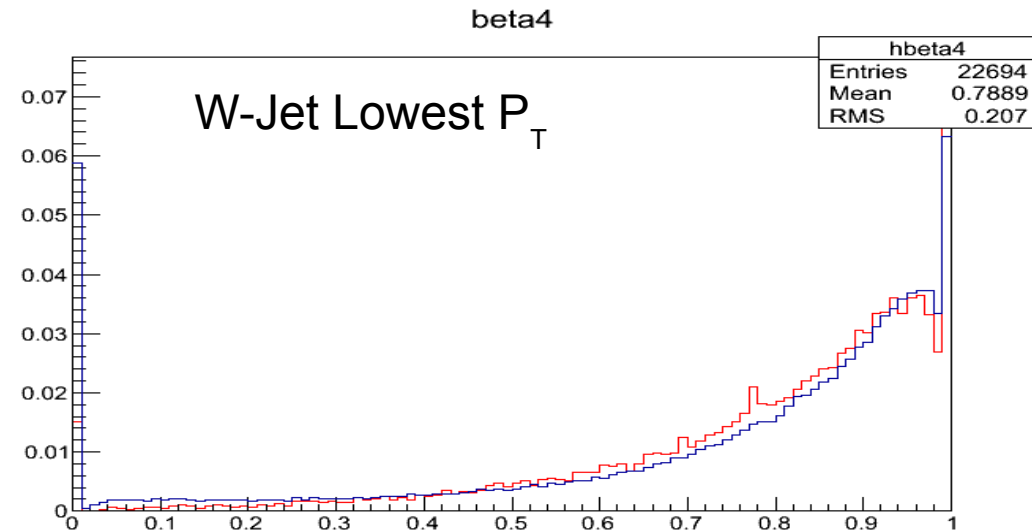
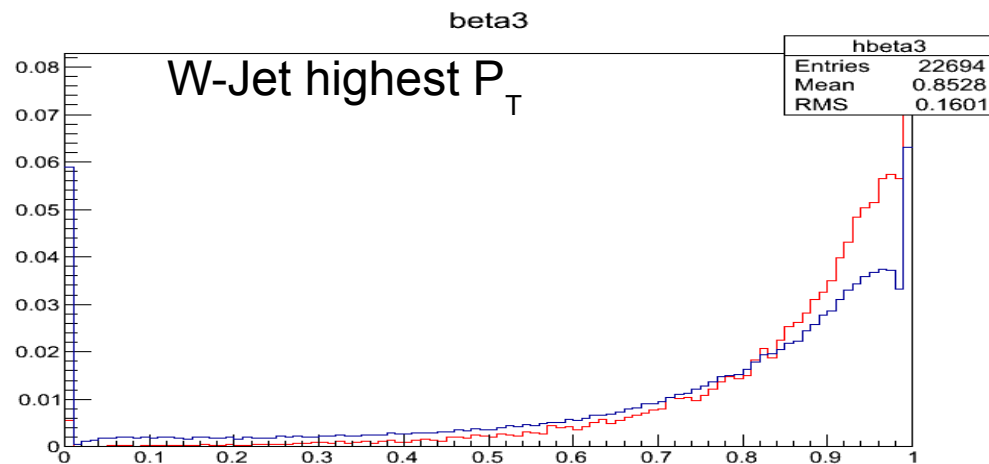
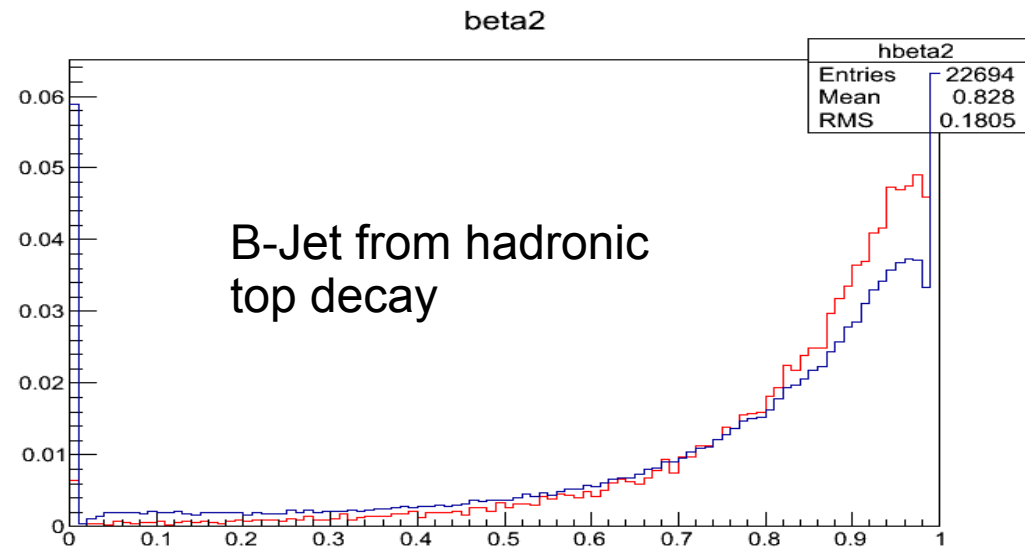
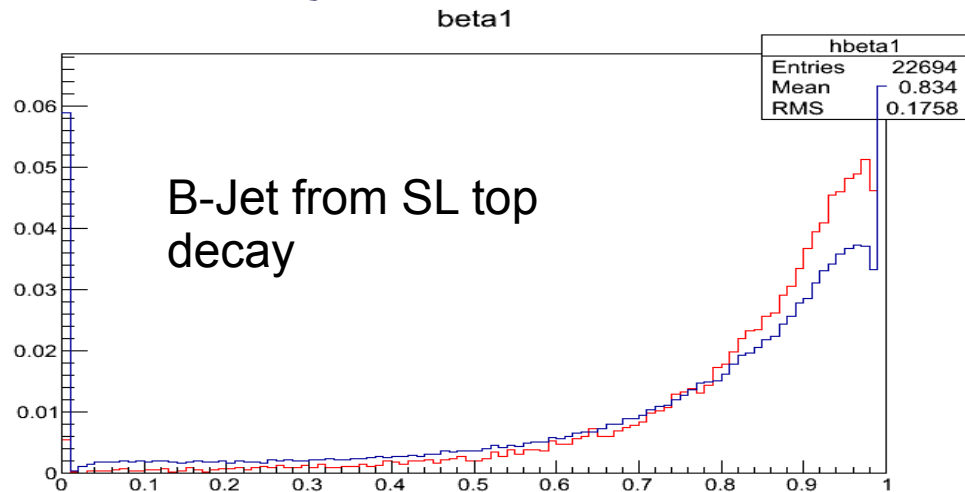
W-jets from hadronic top decay



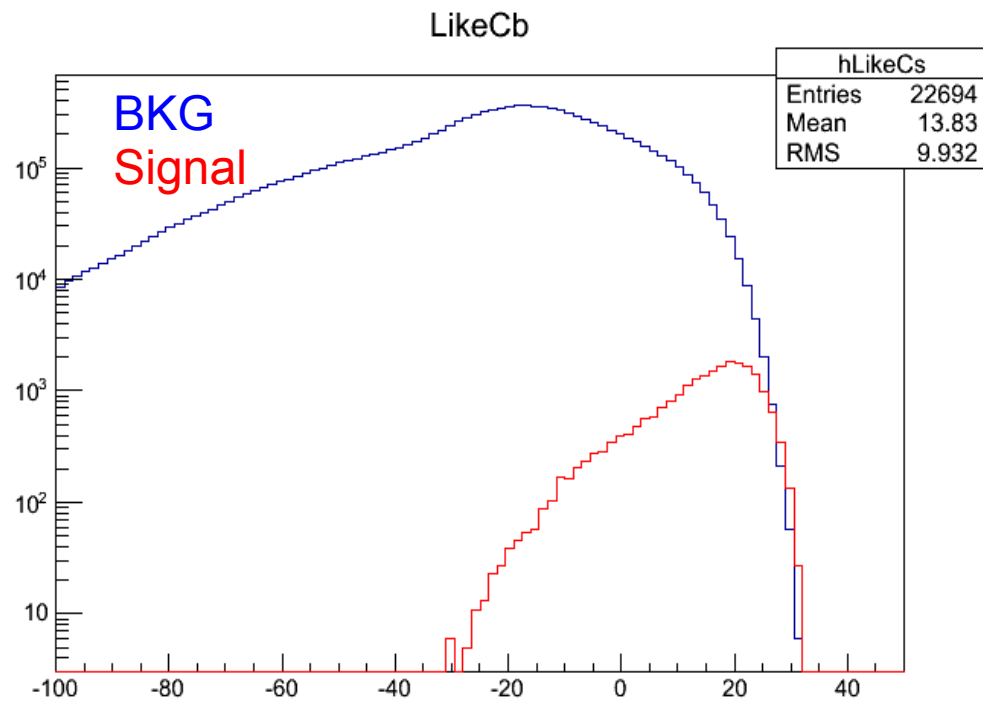
Some variables in the Step 1 Likelihood

After refitting

Beta Variable: function of the number of tracks in a jet coming from the Primary Vertex



Step 1 Likelihood



● Using the first $N=6$ jets in PT, the max Likelihood combination is the right one 30% of times

● Starting from the Step 1 Likelihood all the 4-jets combinations are ordered according to their probability to be the right one

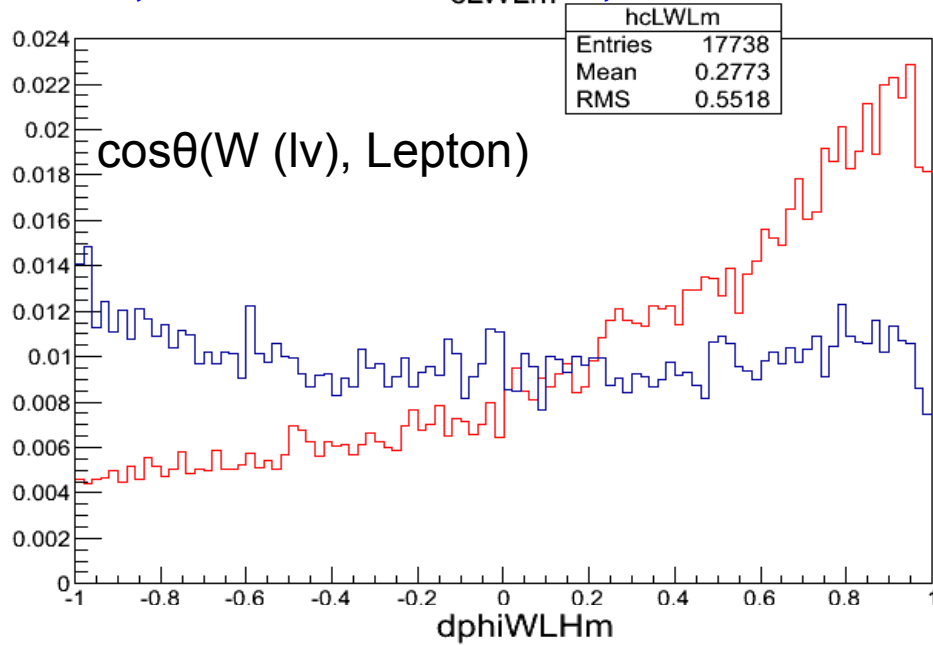
● The hadronic W is constructed using the two jets classified to come from W decay in the same combination.

Some Variables in the Step 2 Likelihood

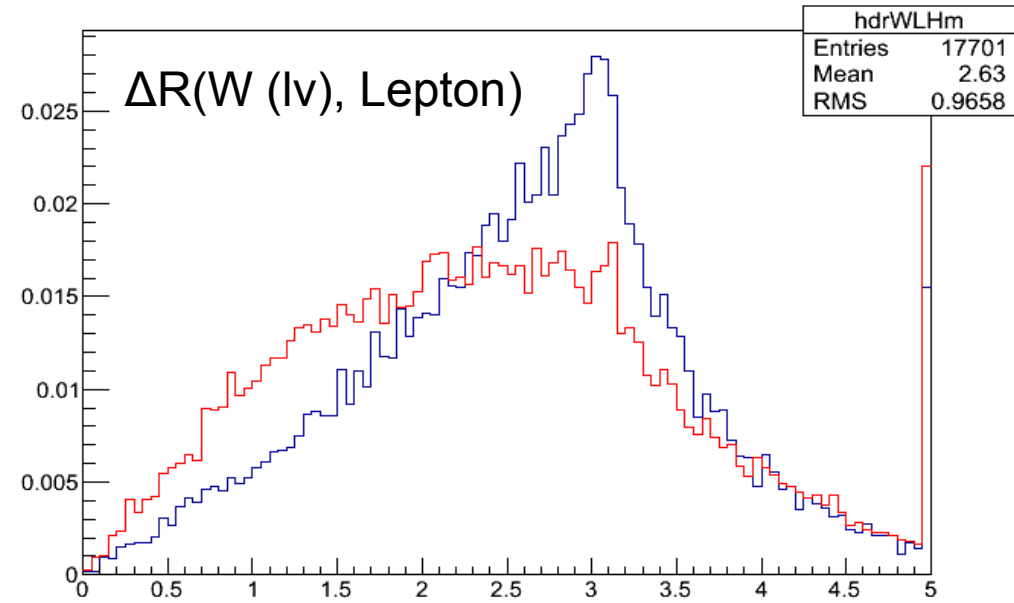
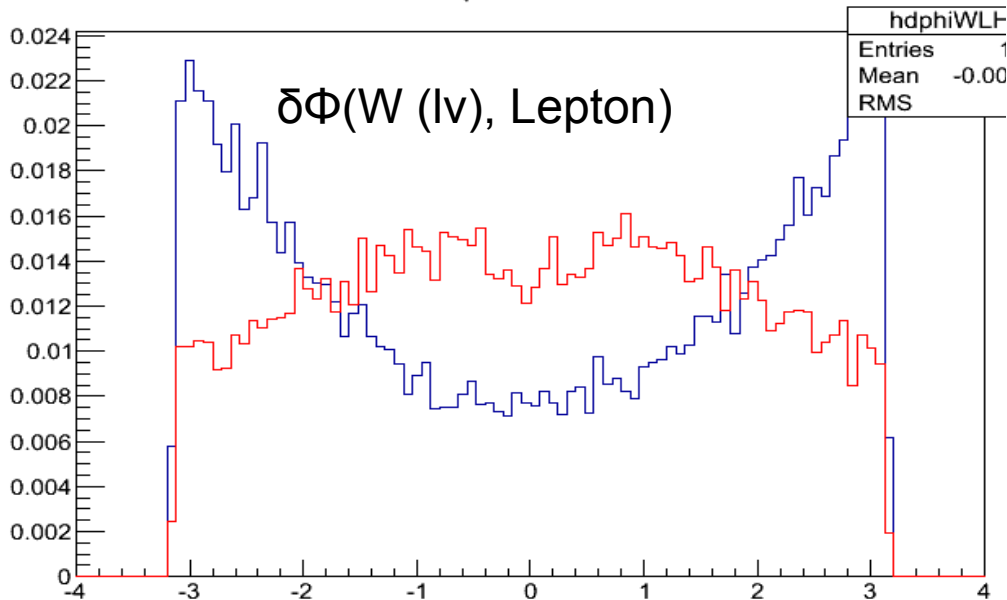
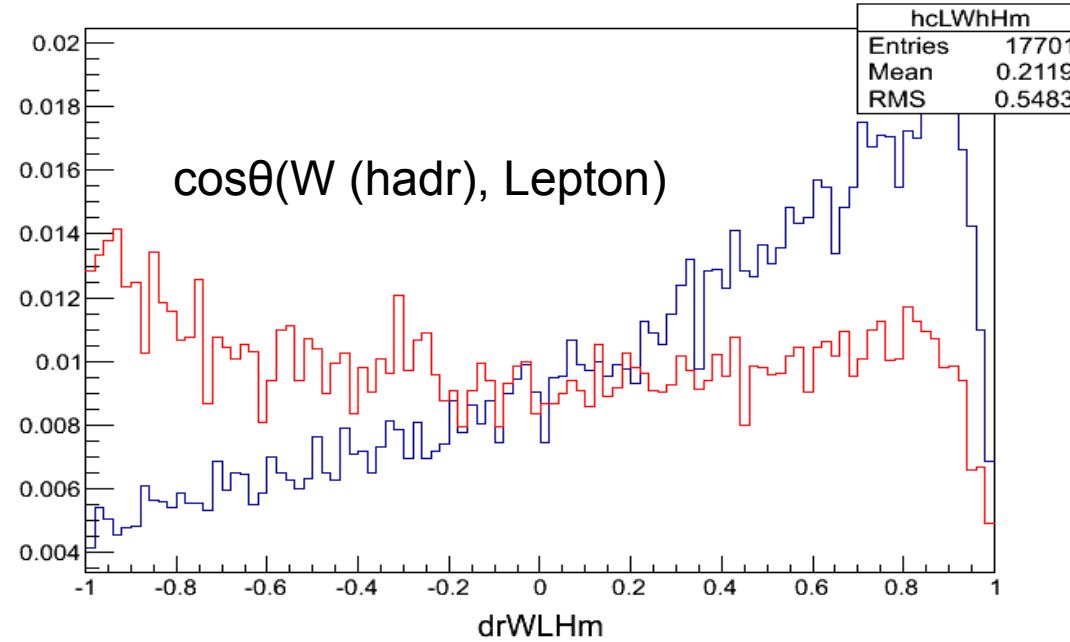
S2 Lepton from semileptonic top

S2 Lepton from hadronic top

cLWLm



cLWhHm



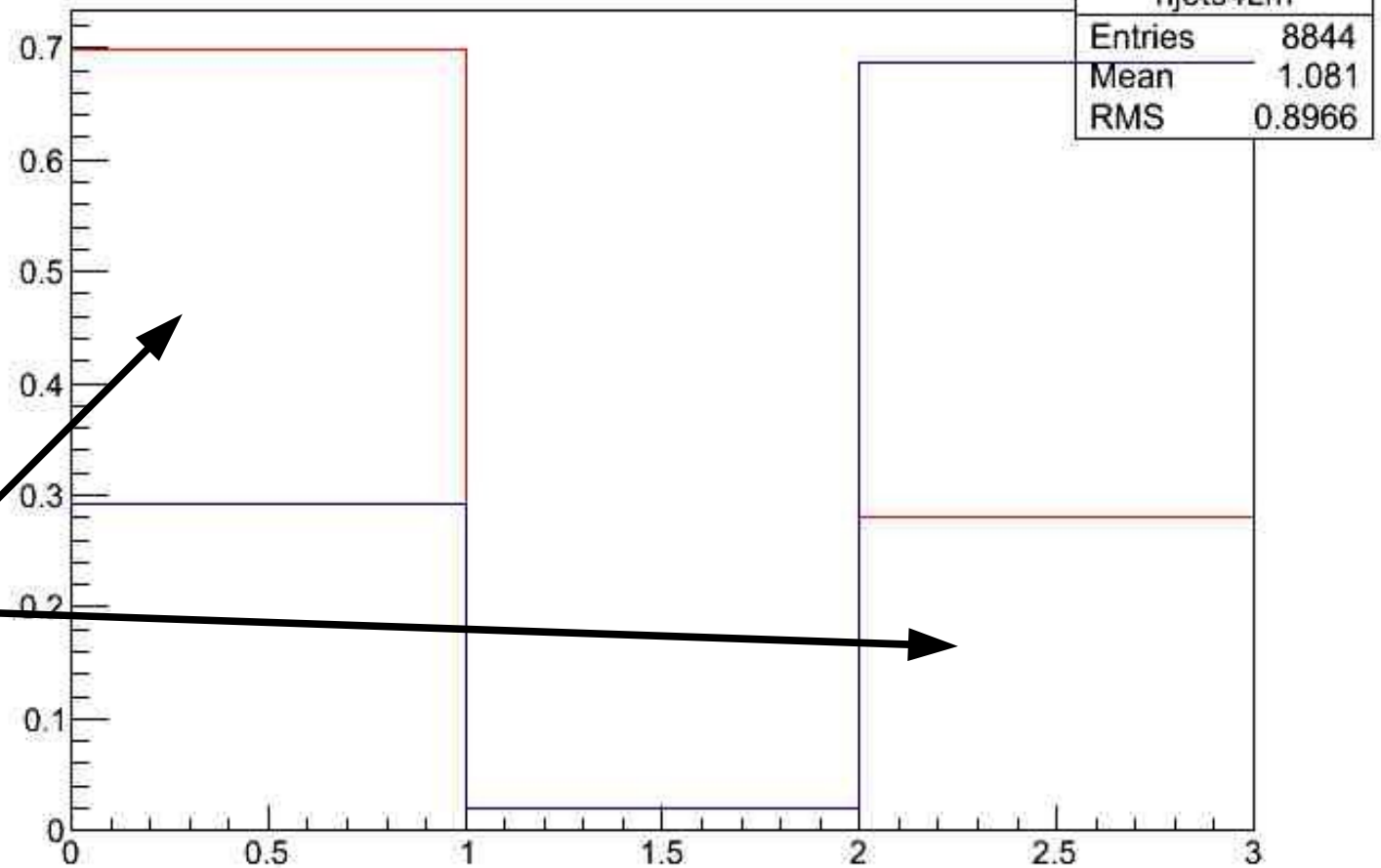
S2 Lepton Jet

jets4Lm

S2 Lepton from
semileptonic top

S2 Lepton from
hadronic top

$\omega \sim 30\%$



Classification
from Step 1

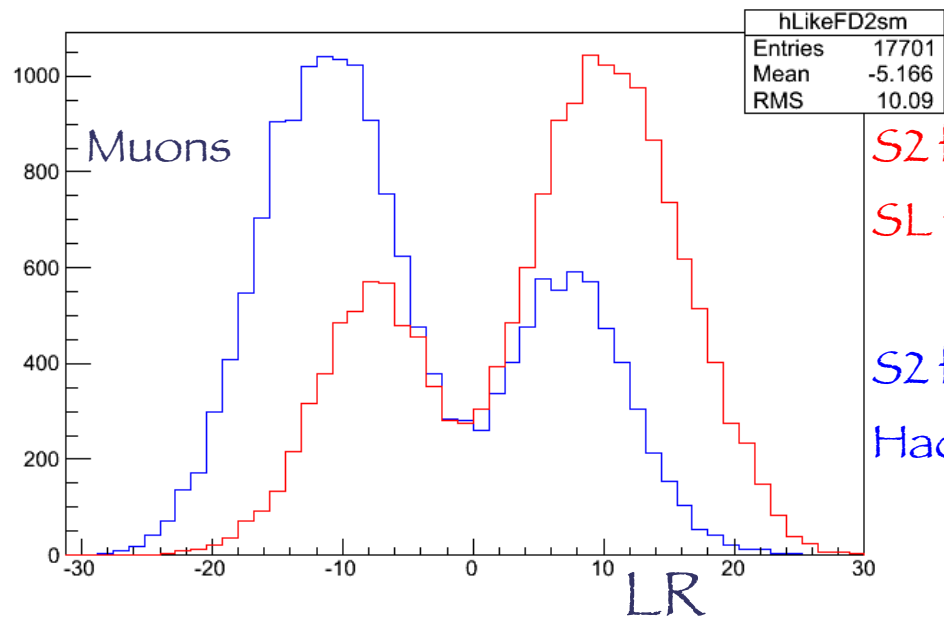
B-Jet from
semileptonic
top

Not
classified

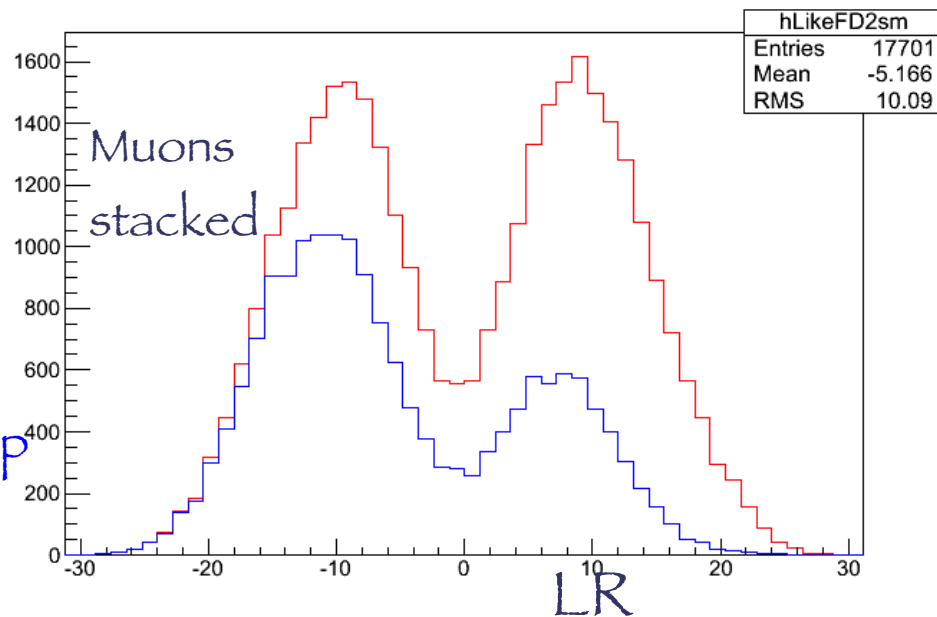
B-Jet from
hadronic top ₂₆

Step 2 Likelihood

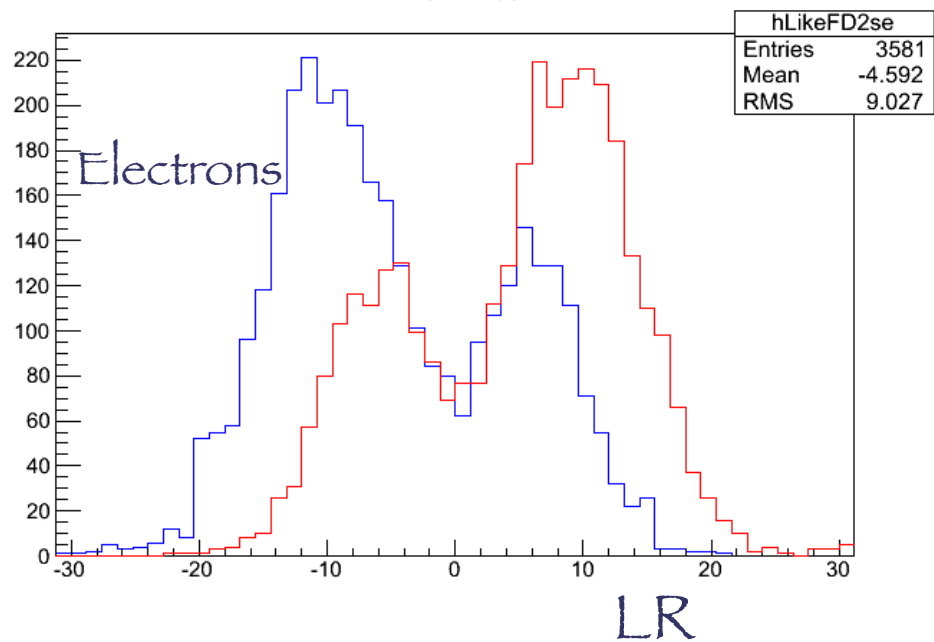
LikeFD2sm



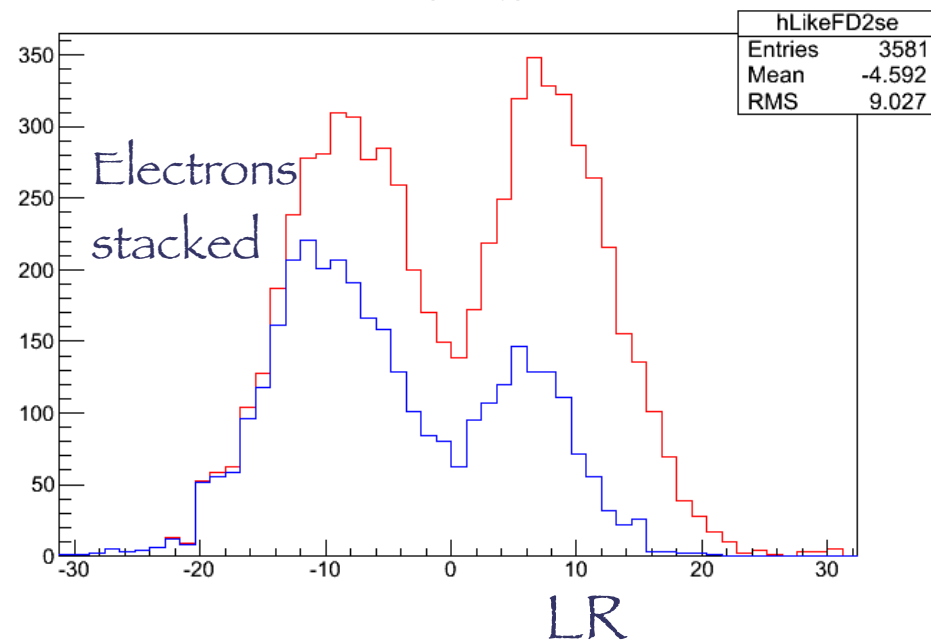
LikeFD1sm



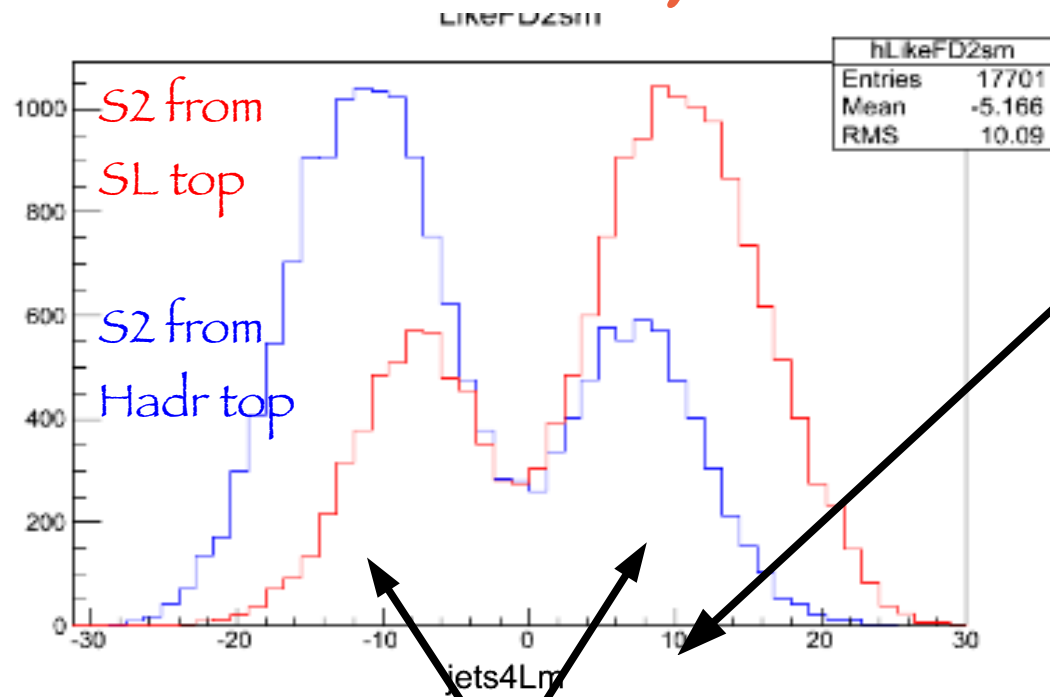
LikeFD2se



LikeFD1se

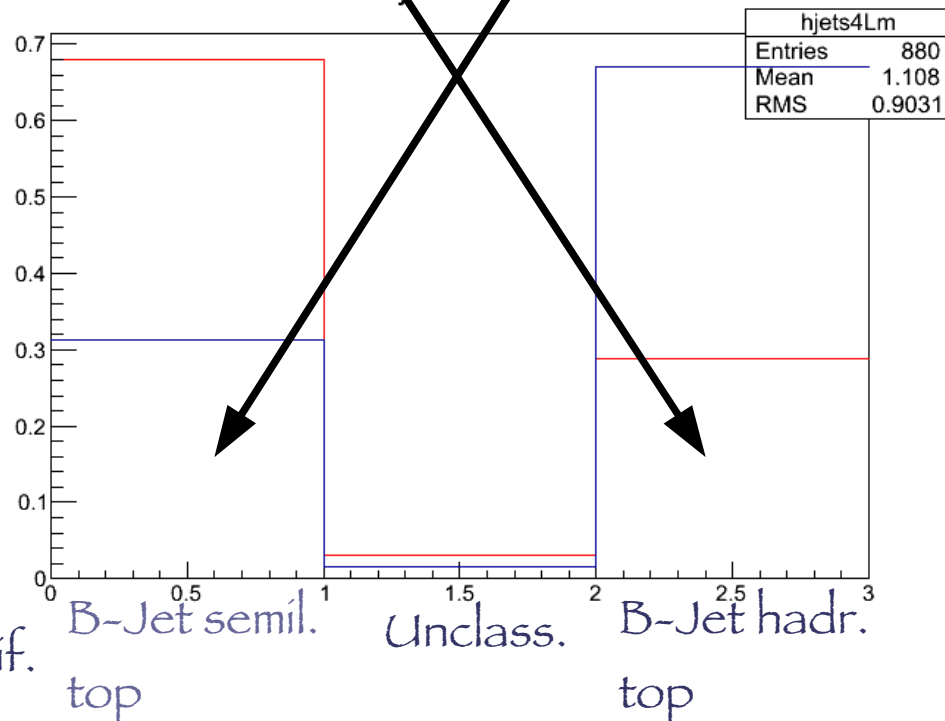


Step 2 Likelihood



- Peak due to wrong B-jet-Top association from Step 1

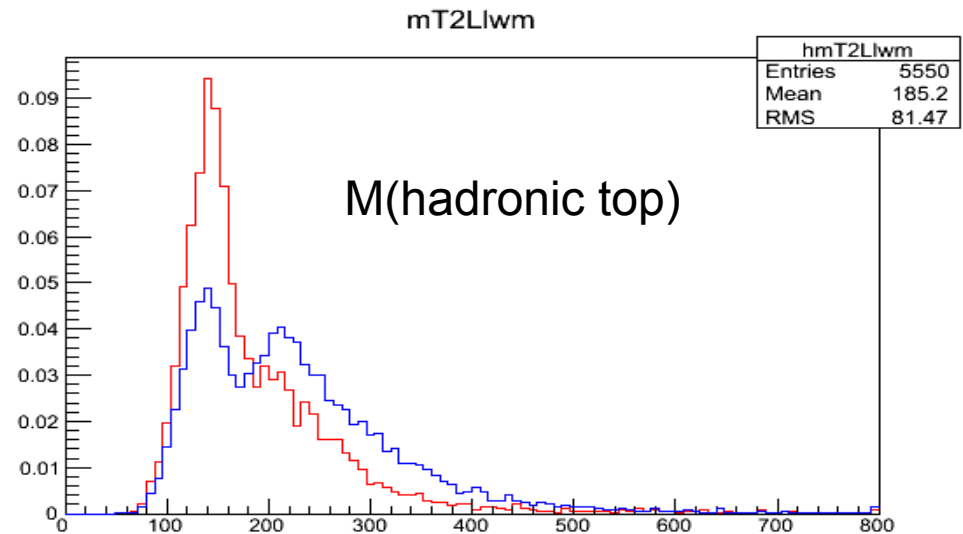
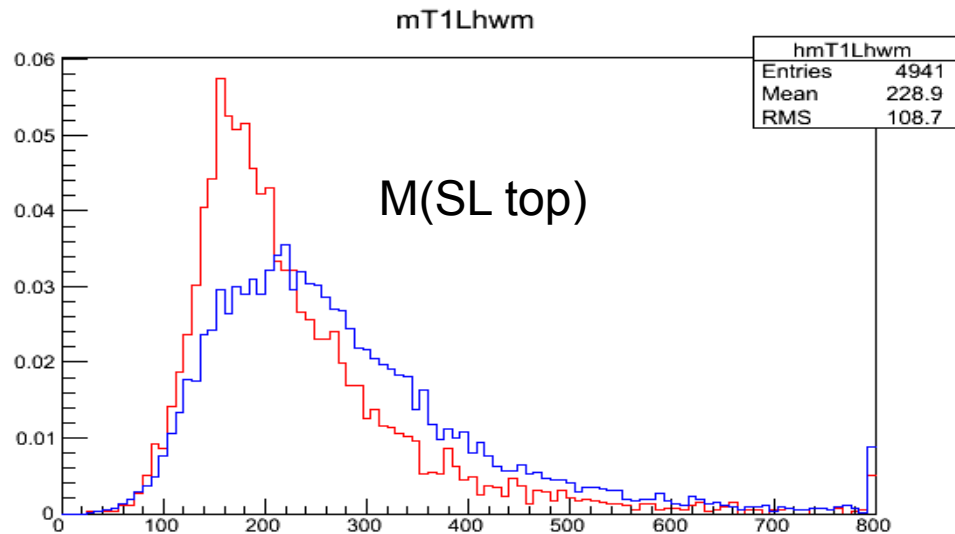
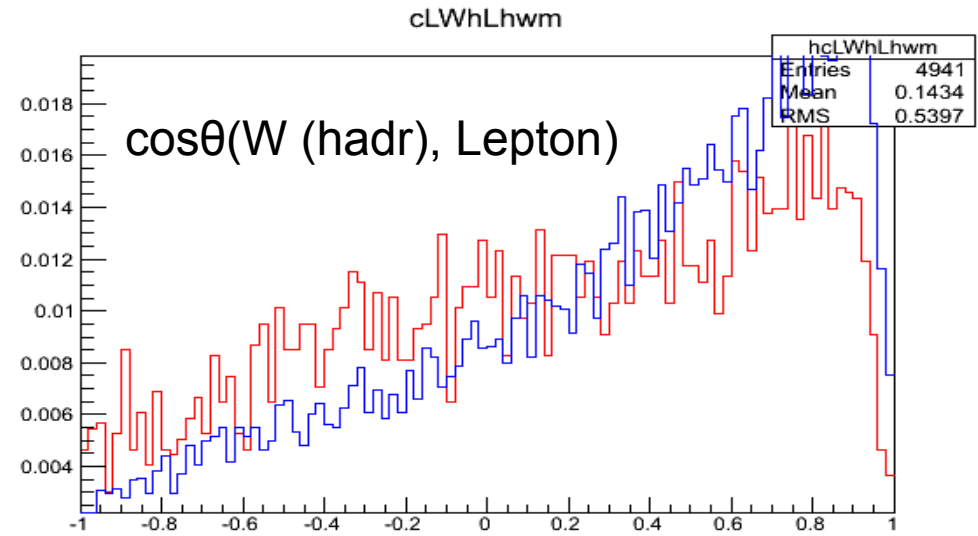
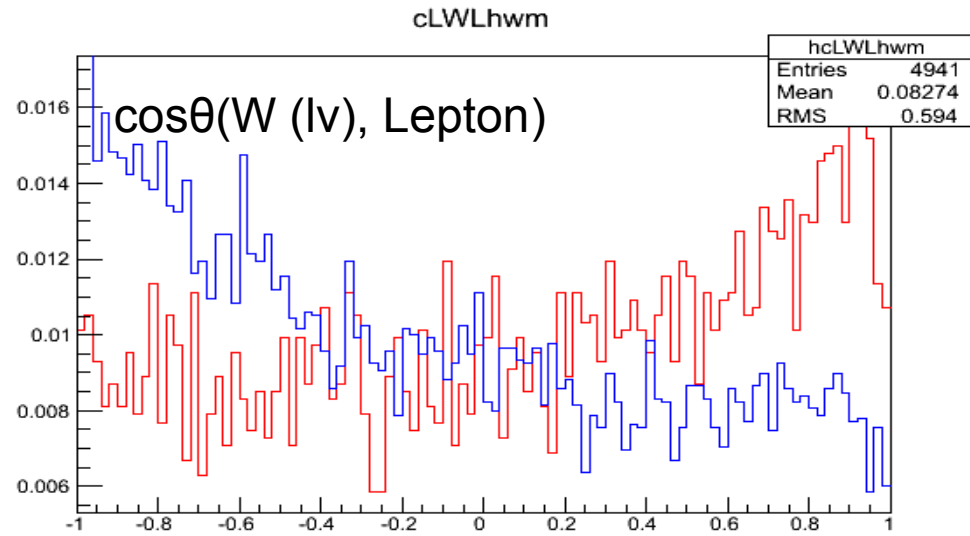
- Caveat: Jet-parton association & decay reconstruction in MC to be investigated



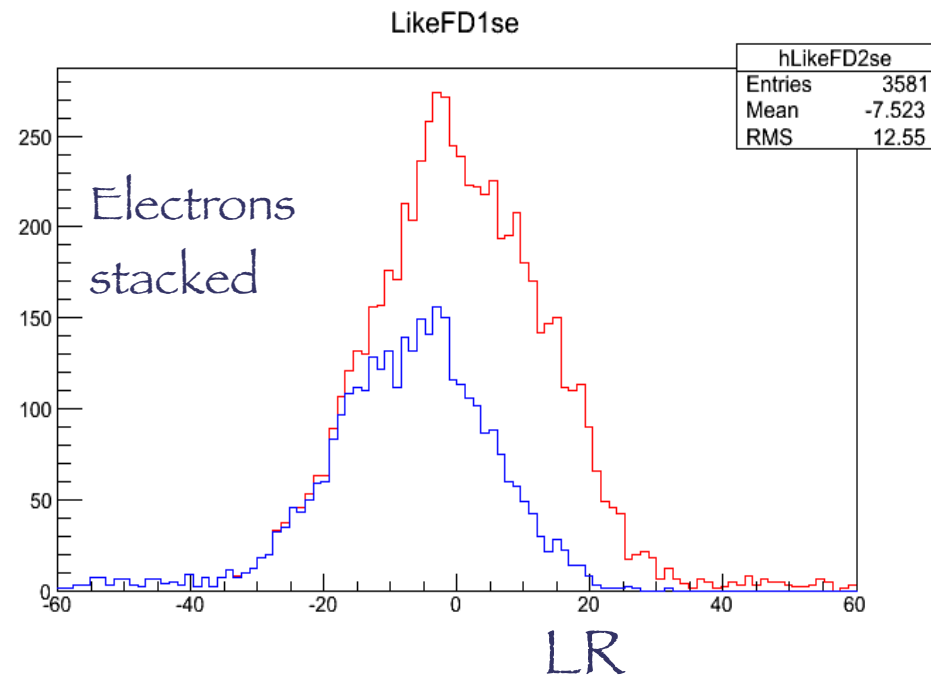
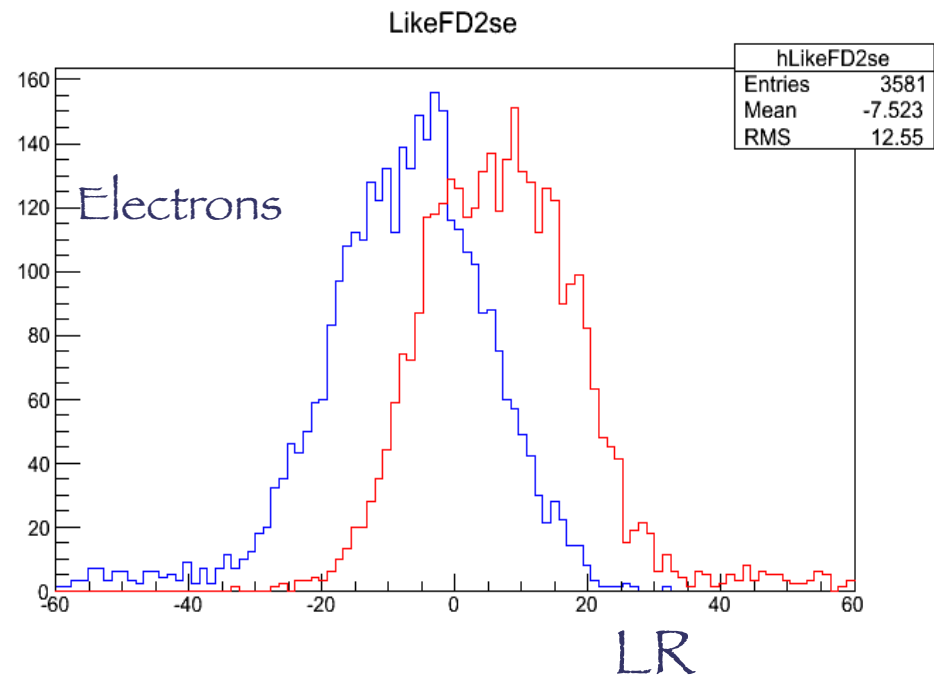
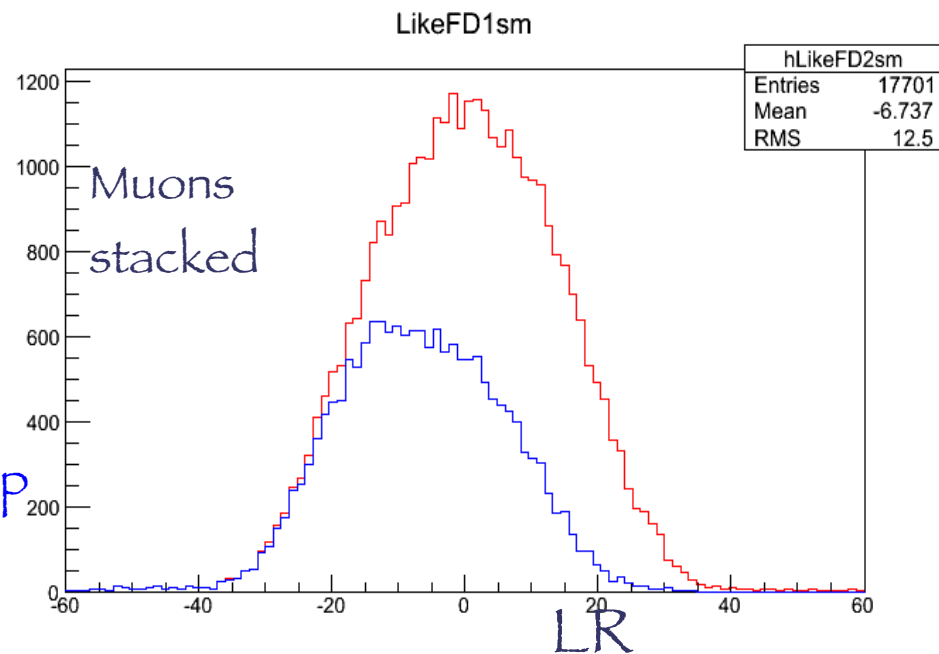
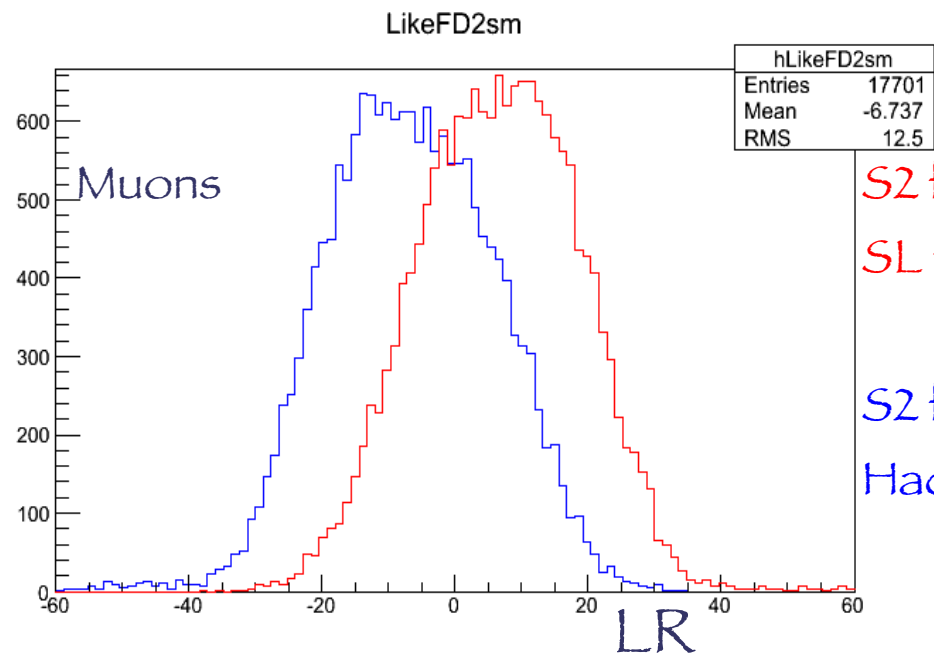
- Try to reduce the wrong-associations comparing variables for **right** and **wrong** B-jet-Top association

Try to improve the separation

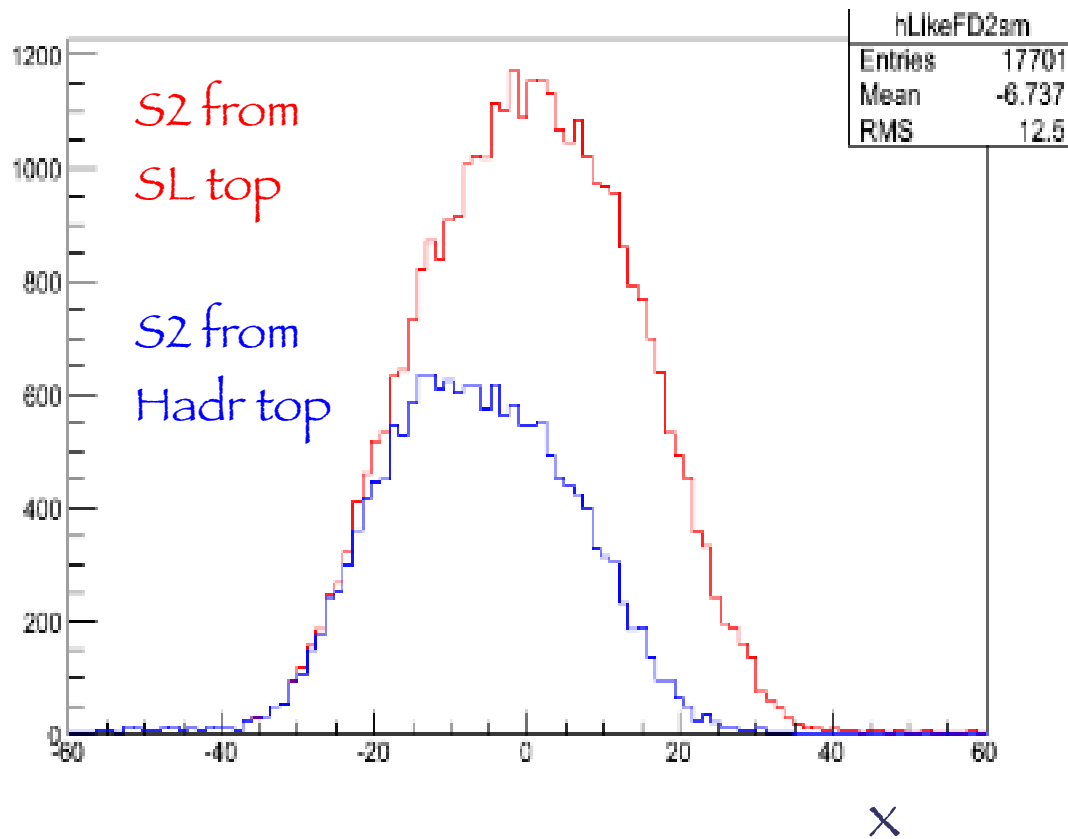
Some variables for events with **right** or **wrong** B-jet-Top association



Resulting LR: still $W=30\%$...



Fitting Strategy



●...in any case, the two samples can be separated statistically

● The fractions $f_{SL}(x)$ and $f_{HAD}(x) = 1 - f_{SL}(x)$ of the two samples can be fitted in terms of the MVA discriminating variable “x”

● PDF for the Likelihood fit to \bar{X}_b can be defined as a function of “x”:

$$\mathcal{L} = f_{SL}(x) * \text{PDF}_{SL}(\bar{X}_b) + (1 - f_{SL}(x)) * \text{PDF}_{HAD}(\bar{X}_b)$$

➤ Statistical separation of the two opposite flavor components

Next Steps

- Improve/debug the lepton-top parent association at the generation level & jet-parton association
- Try to reduce the wrong association peak in the Step 2 Likelihood
- Use a MVA instead of a L-R to manage with the correlations between variables
- Include leptons from BKG sources
- Study the BKG MC (W+charm, QCD,...)
- Study the separation between direct and cascade b decays (Alessio Boletti, “sinergy” with Jacopo study)
- Define the Likelihood PDF for the extraction of $\bar{\chi}_b$

Backup

Expected Statistics

- CMS Analysis with semileptonic top, data 2012, i.e.
CMS PAS TOP-13-008 (W helicity):

- ✦ 200 K evts after selection

- ✦ 50% with $W \rightarrow \mu$, the same with $W \rightarrow e$

- ✦ $\epsilon_{\text{HLT}}(\mu) \approx 62\%$, $\epsilon_{\text{HLT}}(e) \approx 53\%$

- ✦ $\text{BR}(b \rightarrow l) \approx 10\%$

- ✦ $\epsilon_{\text{lepton from } b} \sim 40\%$

}

230 K top quarks
9 K events $b \rightarrow \mu$
with top tag

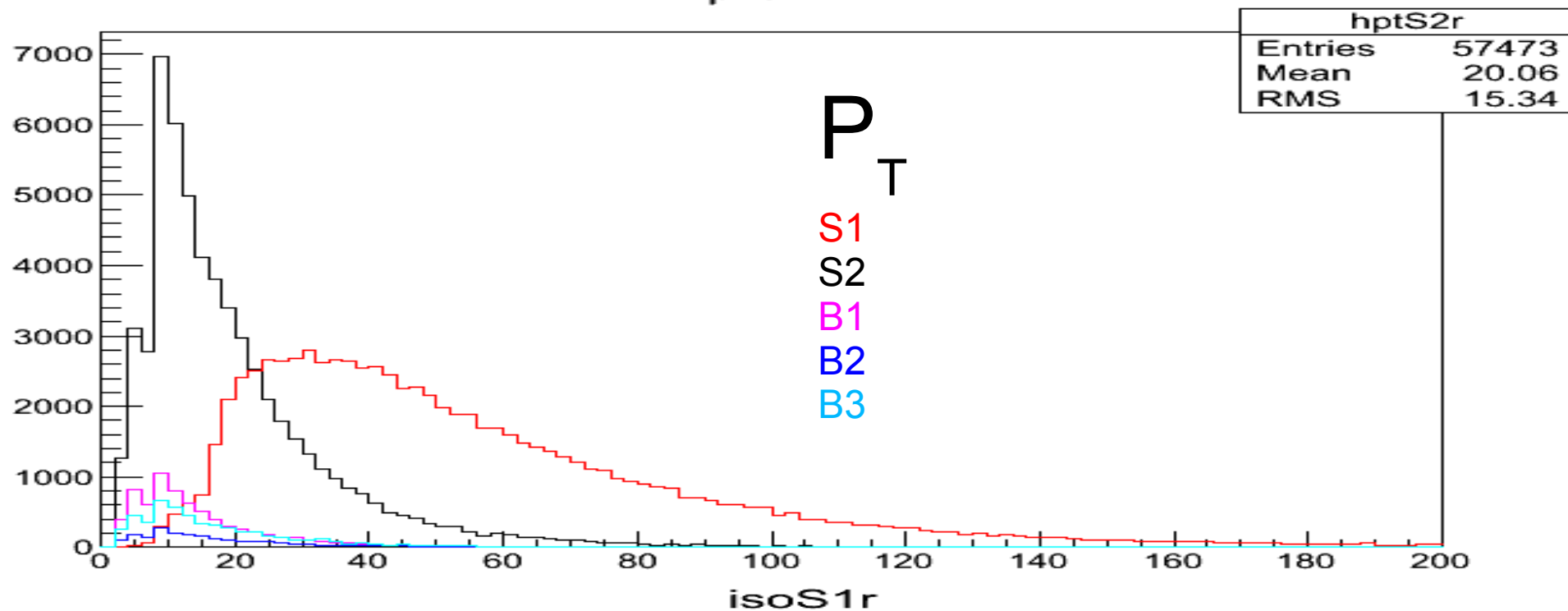
- To be considered also cascade decays $b \rightarrow c \rightarrow l$ (... and maybe $b \rightarrow e$?)

- Rough estimate ~ 12 K evts (2012)

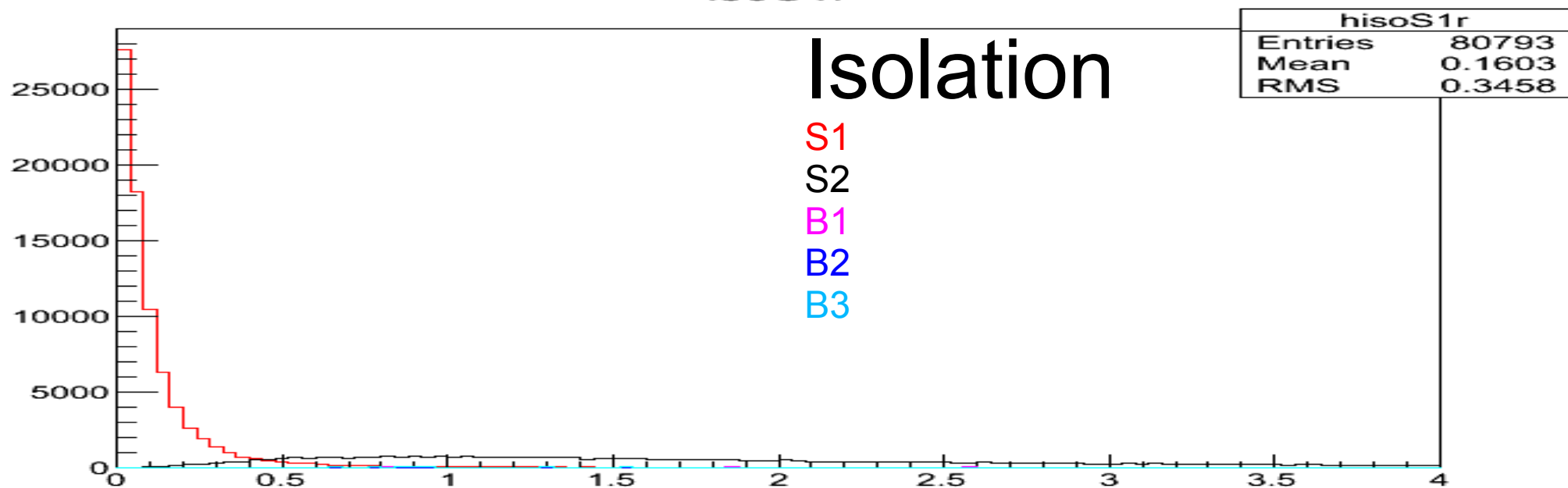
- ✦ $\delta\chi \sim 0.0035$ (without taking into account BKG and dilution...)

Leptons from the different Classes

ptS2r

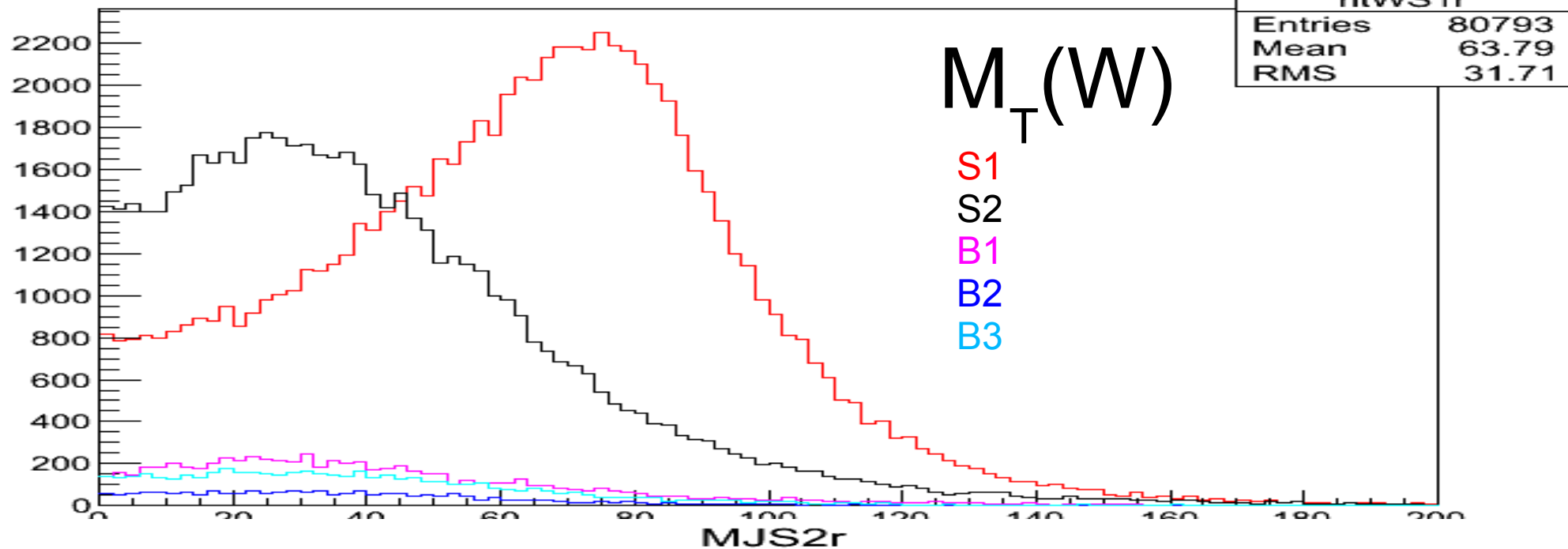


isoS1r

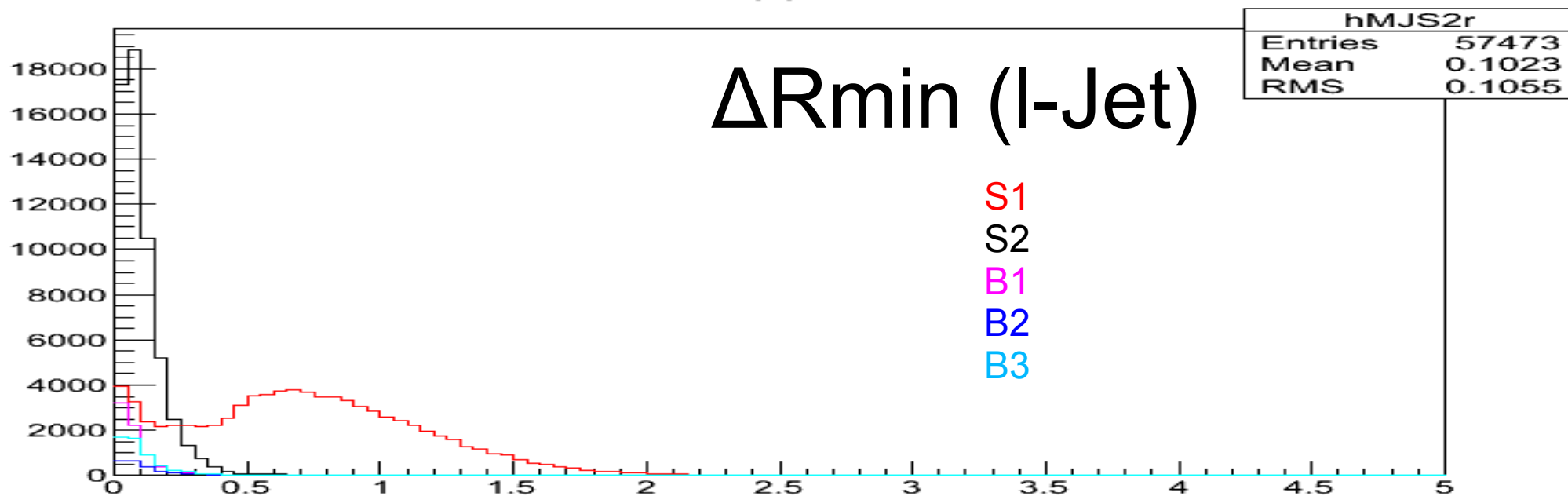


Leptons from the different Classes

tWS1r

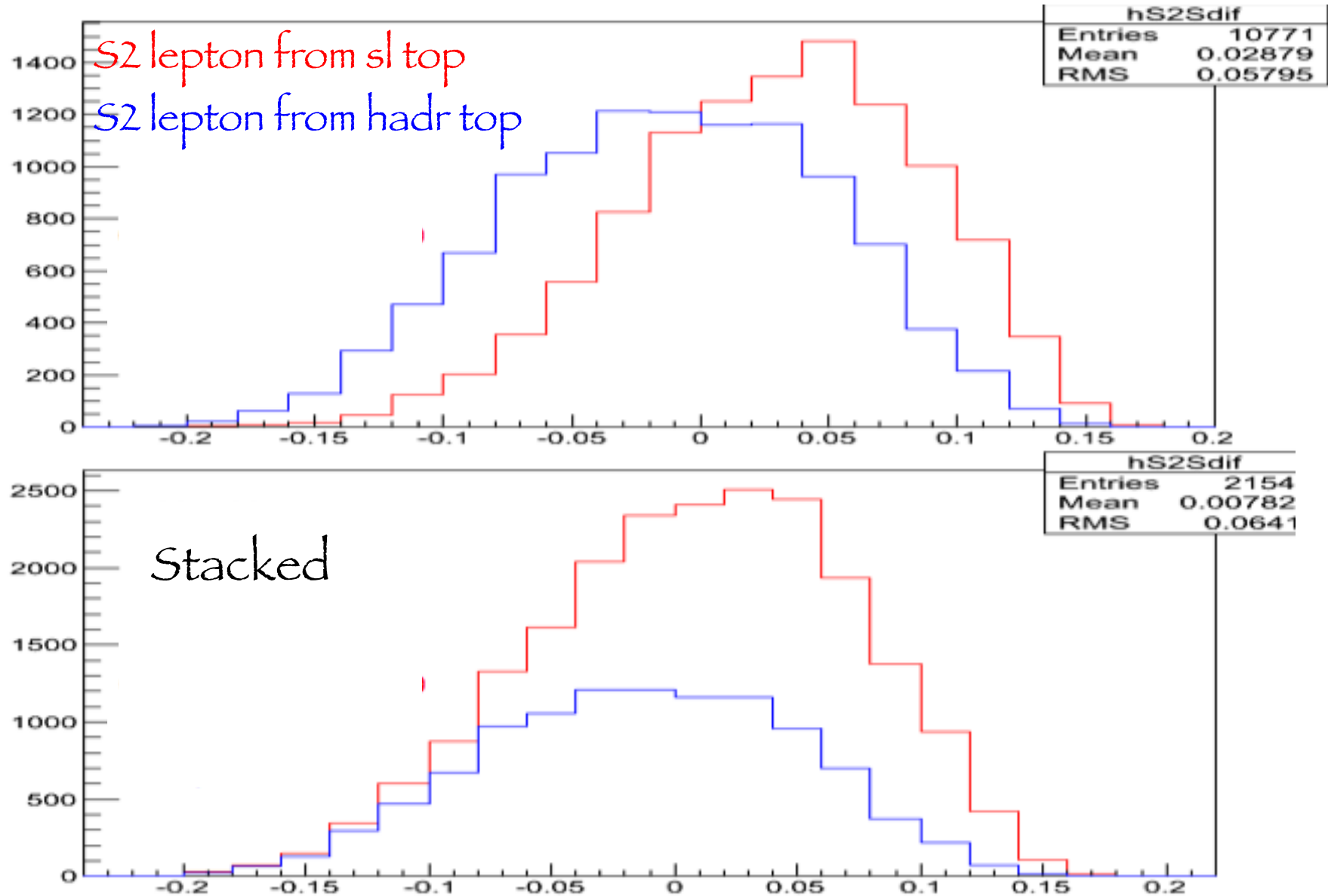


$\Delta R_{\min} (\text{l-Jet})$



S2 lepton - Top association

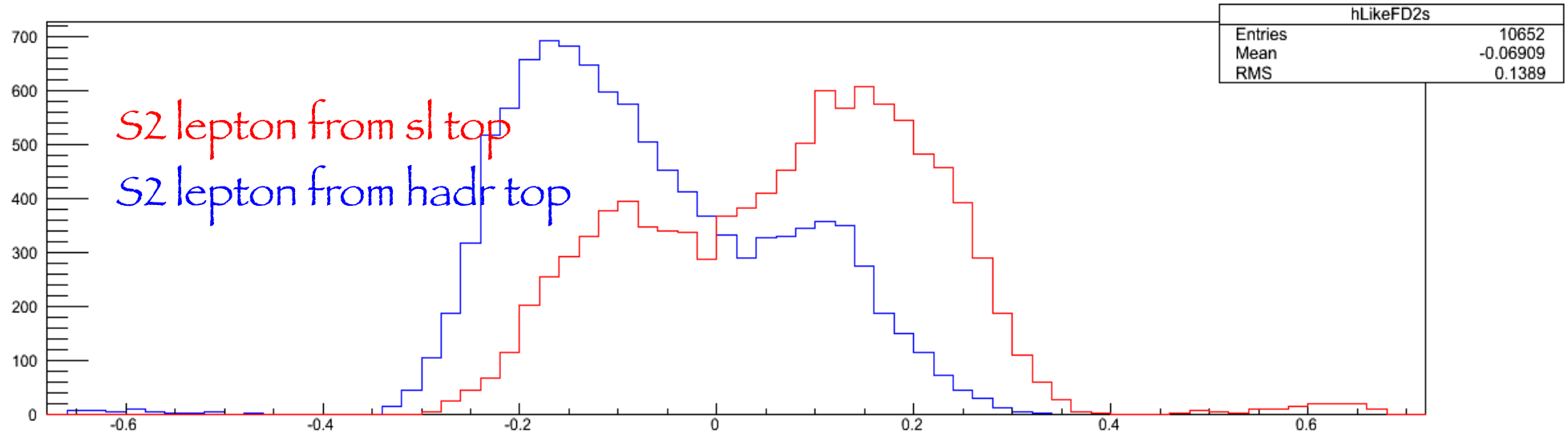
Likelihood using only angular variables



S2 lepton - Top association

Without Kinematic Fit

LikeFD2s



LikeFD1s

