# WH→lvbb using DLM and Discriminant Analysis at CDF

Masakazu Kurata, Shinhong Kim
University of Tsukuba
Kunitaka Kondo
Waseda University

On behalf of the CDF Collaboration

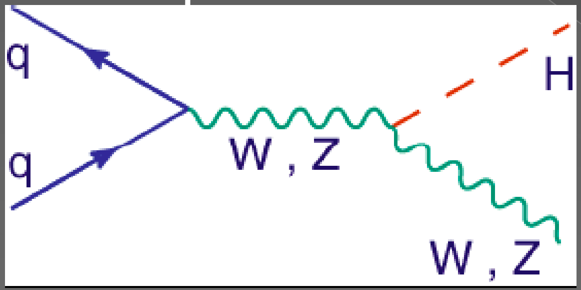
KEKセミナー, 09/04/2012

# Outline

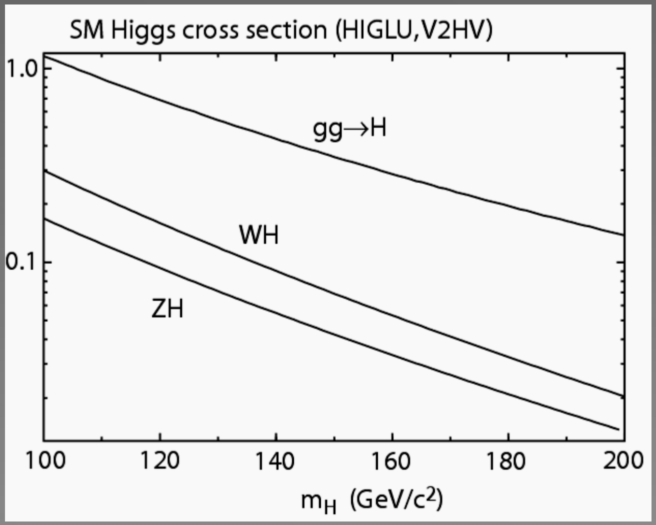
- Introduction
- Tevatron & CDF detector
- Event selection
  - b-tagging
- DLM analysis
- Discriminant Analysis using DLM
  - Result from DLM – input variables
  - Strategy for the final discriminant
- Systematics error – on signal & backgrounds
- Final result
- Summary of CDF Higgs Search

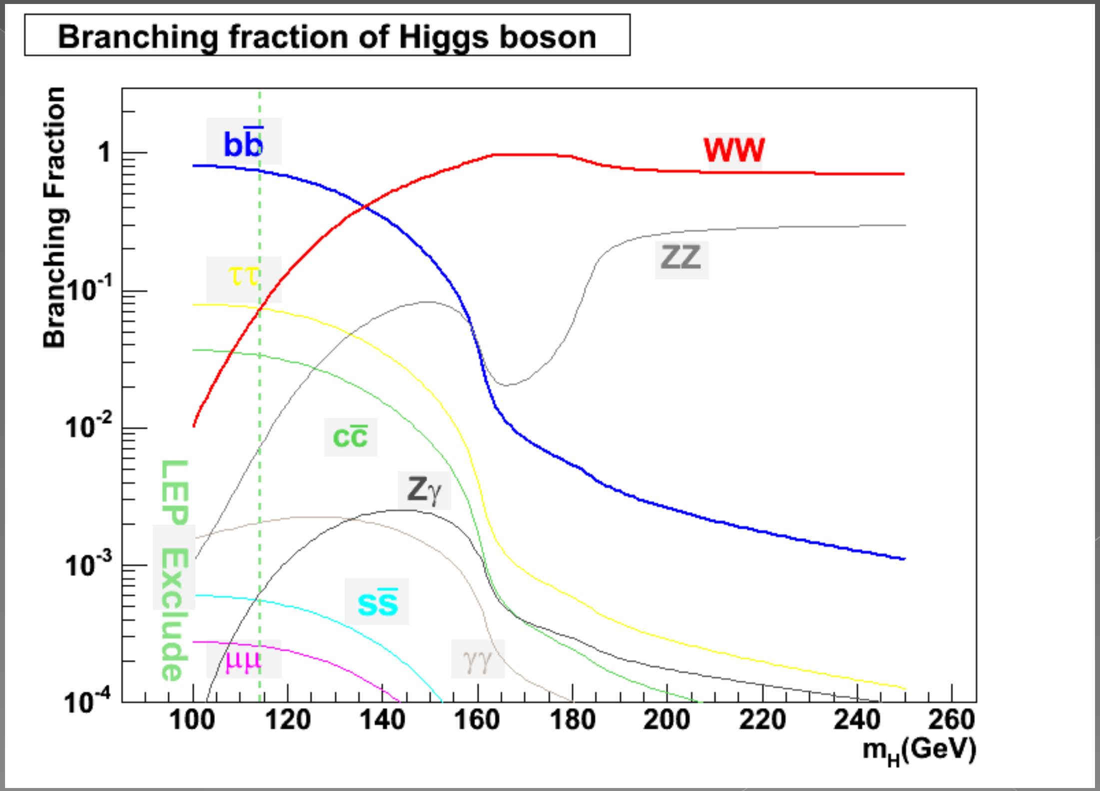
# Introduction

- Higgs associate W→WH→lνbb process is a strong channel at Tevatron
  - It is a golden channel for low mass($m_H$<135GeV) because Higgs dominantly decays into b quark pair(b-tagging is >50% efficient)
  - By requiring one lepton, large QCD background can be suppressed
  - The process is distinct from other backgrounds




Higgs associated



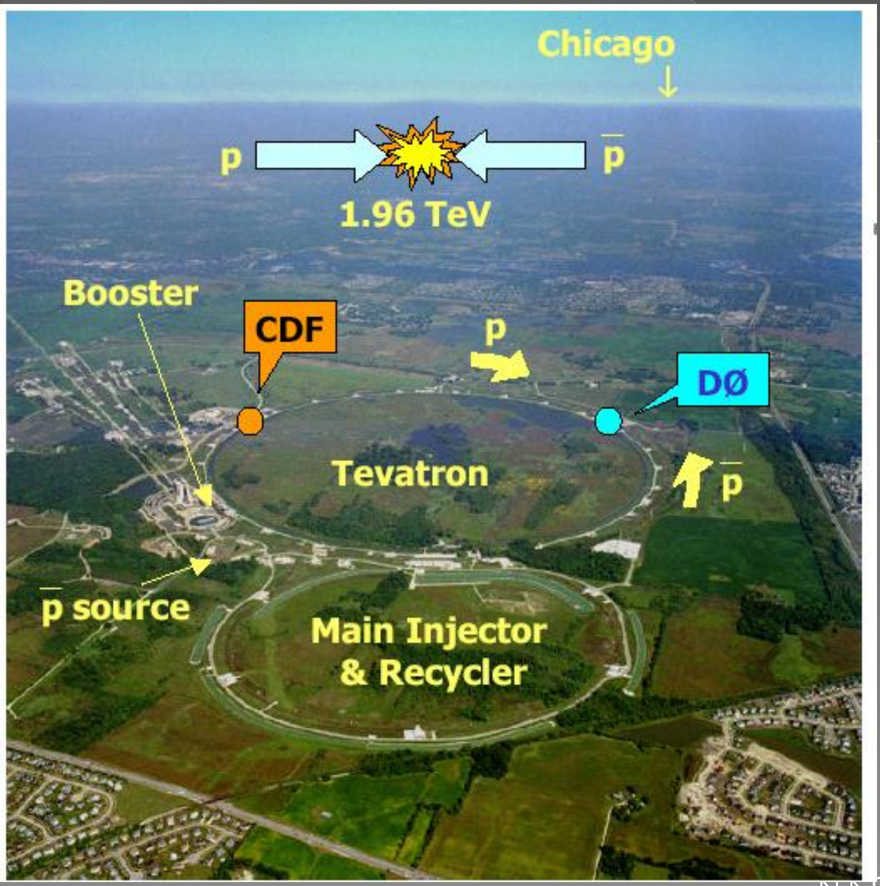



# WH analysis and DLM

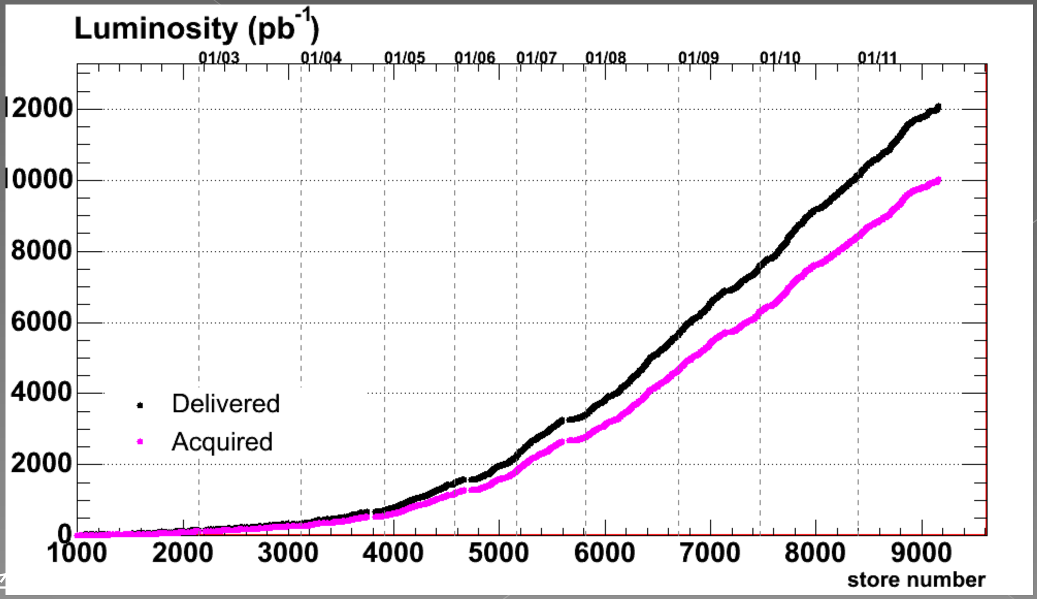
- At CDF, various techniques used to search for WH process:
  - The purpose is to separate signal from backgrounds
  - Neural Network
  - Matrix Element
- Main challenge: develop a technique to separate signal from backgrounds
  - We developed a new technique for extracting signal information
  - Establish Dynamical Likelihood Method(DLM)
  - We calculate a discriminant based on DLM to evaluate upper limit on cross section for WH
- DLM was used for top analysis so far
  - Top mass measurement
  - ttbar resonance search

# Tevatron

- $p\bar{p}$ collision @$\sqrt{s} = 1.96$TeV
- Run-II Operation: from Summer 2001 to Autumn 2011
  - Last Run was on Sep. 30, 2011
- Two multi purpose Detectors: CDF & D0

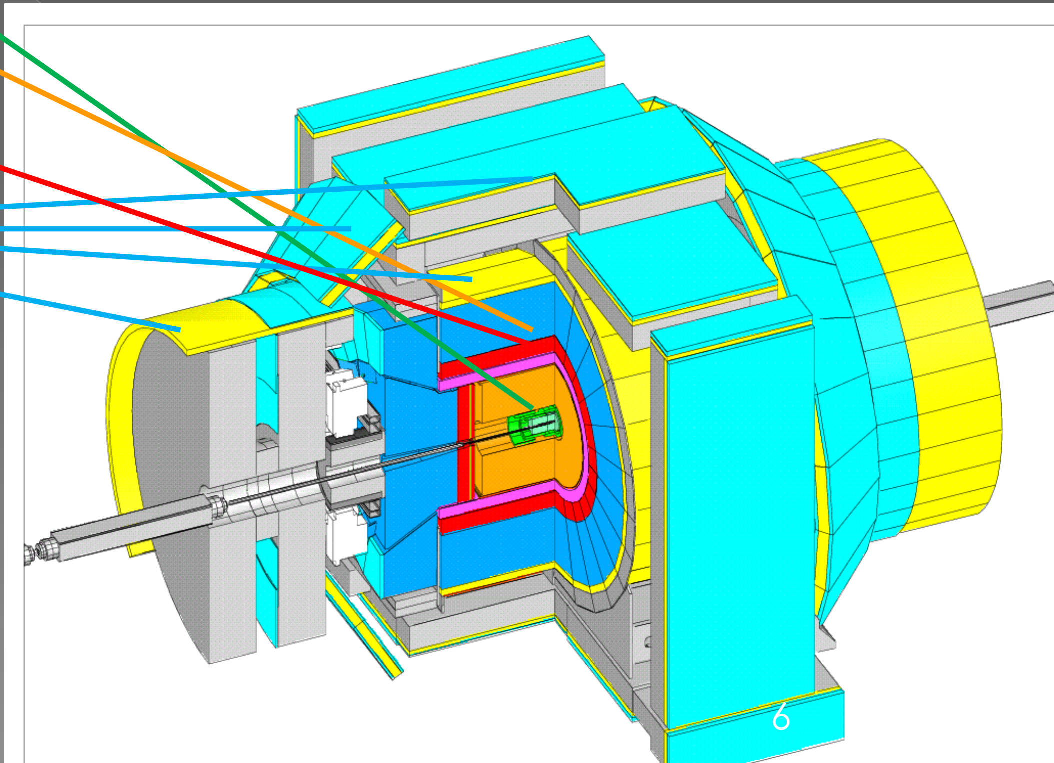



- Luminosity
  - 12fb$^{-1}$ delivered
  - 10fb$^{-1}$ collected



# CDF detector

- Multipurpose detector
  - Top/EWK measurements, Higgs and New Phenomena searches, B physics
  - Silicon - Finding secondary vertex: b-tagging
  - COT – precision tracking
  - Calorimeter
    - EM – for e/γ measurement
    - Had – jet energy
  - Solenoid - 1.5T field
  - Muon system

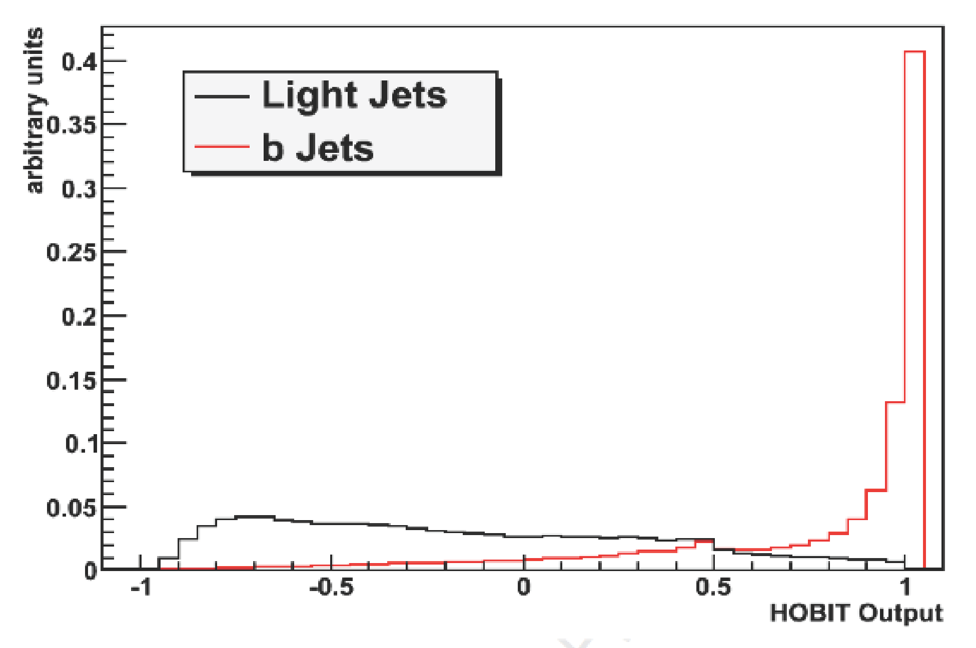


# Event selection and data

- Event selection is based on the standard criteria of WH analysis at CDF
  - Use the events with central lepton or plug electron
    good quality Isolated track
  - Selection cuts: **2jets + 1 lepton + large MET**
    - Jet: 2jets with Et>20GeV and $|\eta_{det}|<2.0$
    - Lepton: Et>20 GeV and require tight lepton selection
      or Isolated track Selection
    - Missing Et>20GeV (for central electron & Isolated Track)
      Et>25 GeV (for plug)
      Et>10GeV (for muon)
  - b-tag to reject large background events
    - 5 b-tag categories: Double tag(3 categories) and Single tag(2)
- Data and Monte Carlo
  - Data: Full dataset - evaluate expected sensitivity for 9.4 $fb^{-1}$
  - MC: Pythia or MadGraph+Pythia (for EWK)
    Alpgen+Pythia (for W+jets)

# b-tagging

- b-tagging is the important point to search for Higgs boson at CDF
  - By 2010, CDF had 5 types of b-taggers
- Incorporating the knowledge of previous taggers into one
  - The Higgs Optimized b-Identification Tagger(HOBIT)
    - A multivariate b-tagger
  - HOBIT is trained with VH and W+LF MC samples

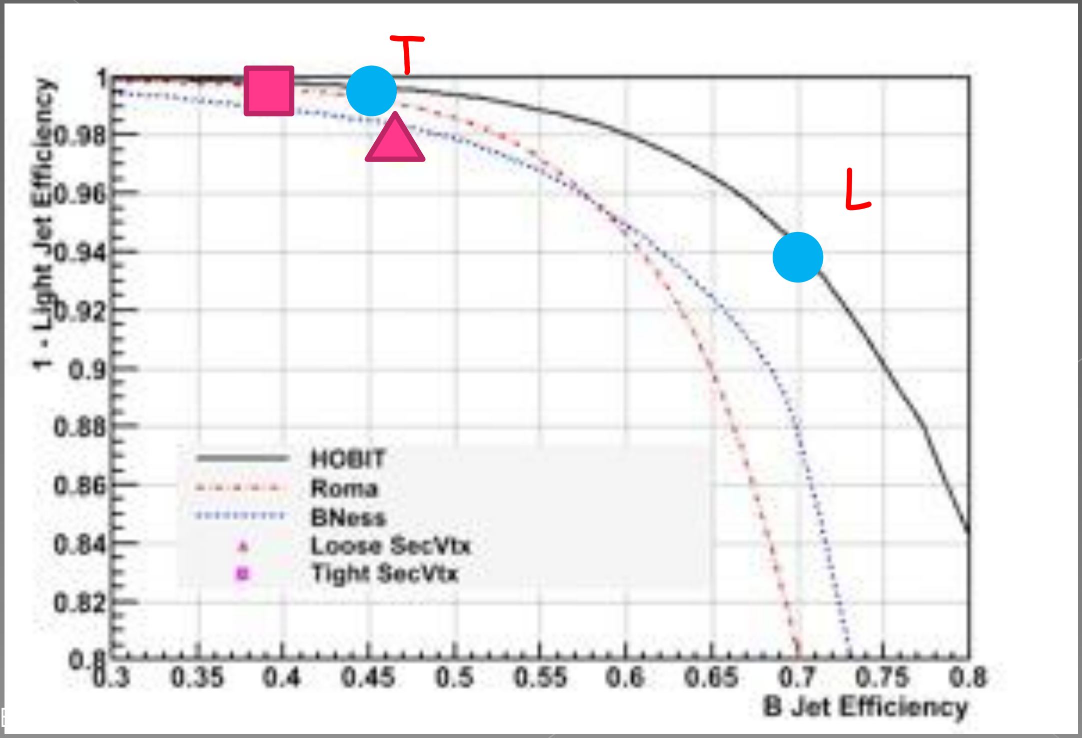



| LF Tag Eff. | HOBIT Eff. | SecVtx Eff. |
|---|---|---|
| ~1% | 54% | 39% |
| ~3% | 59% | 47% |

# b-tagging on the analysis

- For HOBIT, several operation points (9) were provided
- For the analysis, only 2 points are used:
  - Tight – output>0.98
  - Loose – output>0.72
- Using these operation points, 5 orthogonal tagging categories are composed: TT, TL, LL, T, L
- Improvement of the result is >12% with HOBIT

| Operation Point | LF tag | HOBIT Eff. |
|---|---|---|
| Tight | ~1% | 45% |
| Loose | ~6% | 70% |



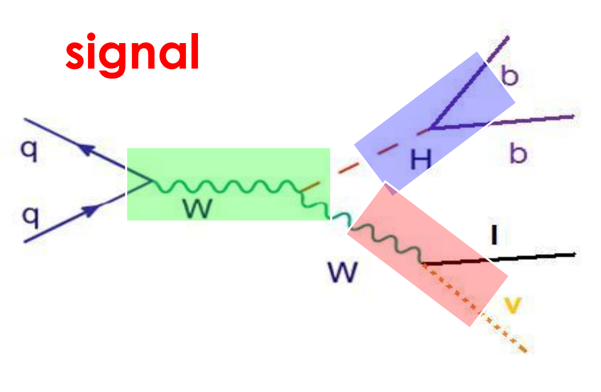
# Dynamical Likelihood Method

- We use DLM method to separate signal and Backgrounds
- DLM is a method to extract signal events from data by evaluating matrix elements as likelihood function.
  - DLM is applicable to processes for which matrix elements can be calculated theoretically : WH, Single top, Wbb
- Formulation:

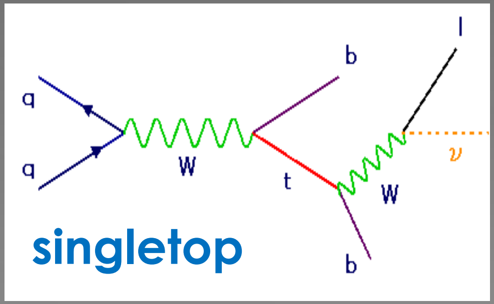
Likelihood function of DLM:

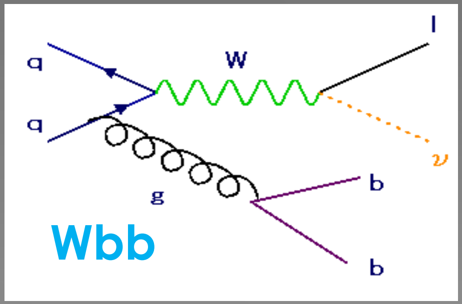
$$L_{path}(\alpha, x \mid y) = N \frac{d\sigma}{d\Phi} w(x \mid y)$$

$$\overline{L} = \frac{1}{n_{path}} \sum_{k}^{n_{path}} L_{path}^{(k)}(\alpha, x \mid y)$$




w(x|y): transfer function
⇒ a probability density function for x (parton momenta) when y (observed quantities) is given.

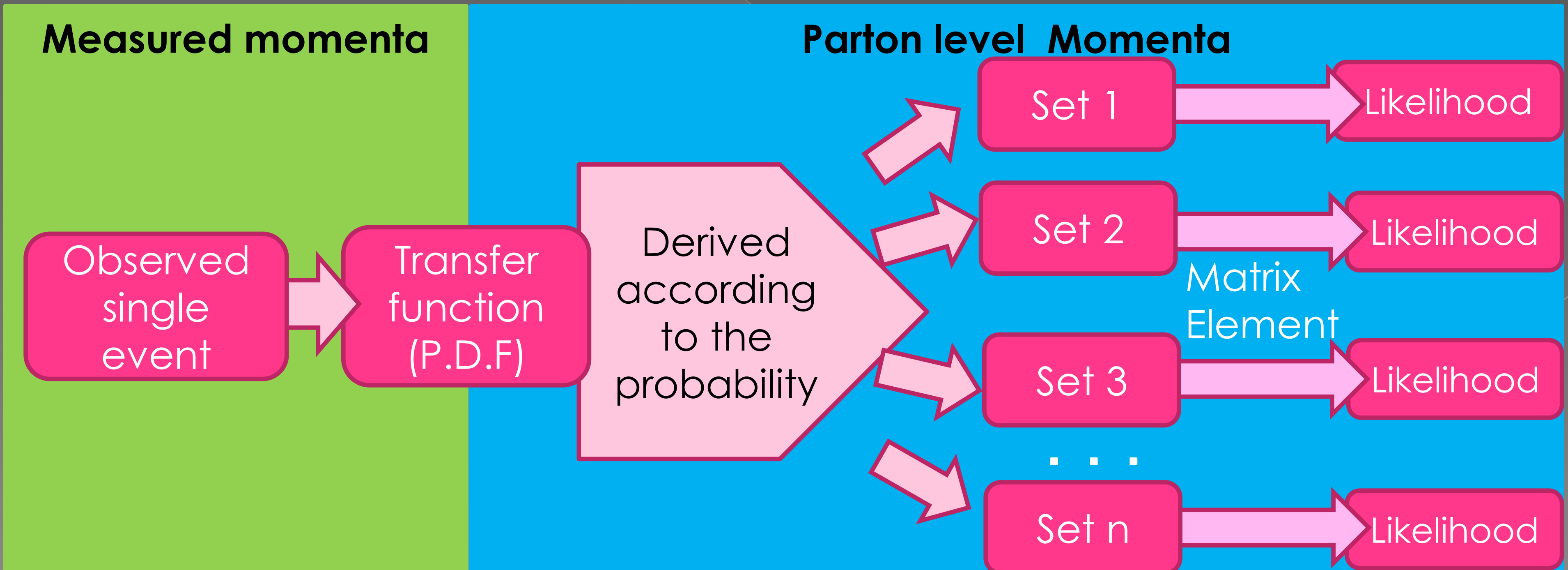


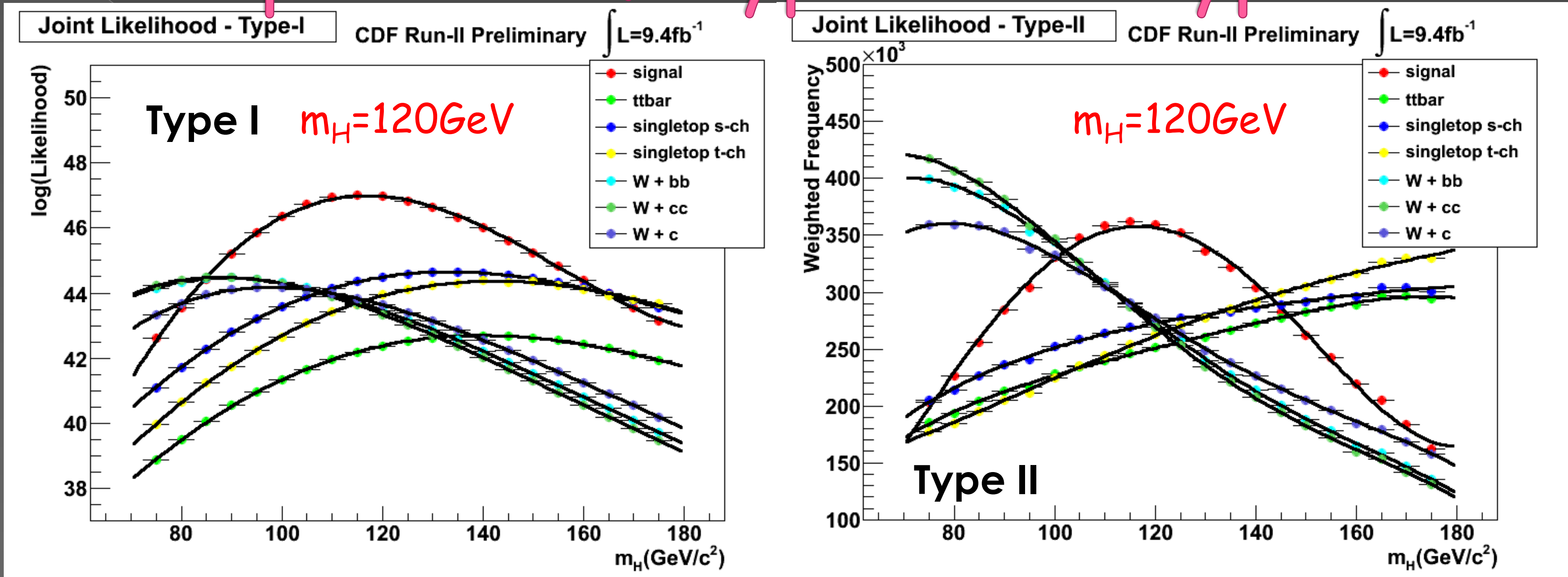

Relationship between parton level and detector measurement

# Summary of DLM

- **Basic idea of DLM**
  - Given the single event, Parton level Momenta set can be obtained randomly according to the probability of Transfer Functions(P.D.F)
  - We can calculate Matrix Element using parton level momenta set.
  - We can treat statistically by accumulating the results of many parton level momenta sets
  - Likelihood of each momenta set is given by $L_{path}(\alpha, x \mid y) = N \frac{d\sigma}{d\Phi} w(x \mid y)$



# Comparison of Type I and Type II




Mean value of Event ensemble O(1000)

$$L_{joint} = \frac{1}{n_{event}} \sum_{i}^{n_{event}} \overline{L_{eve}} \quad @each\ Higgs\ mass$$

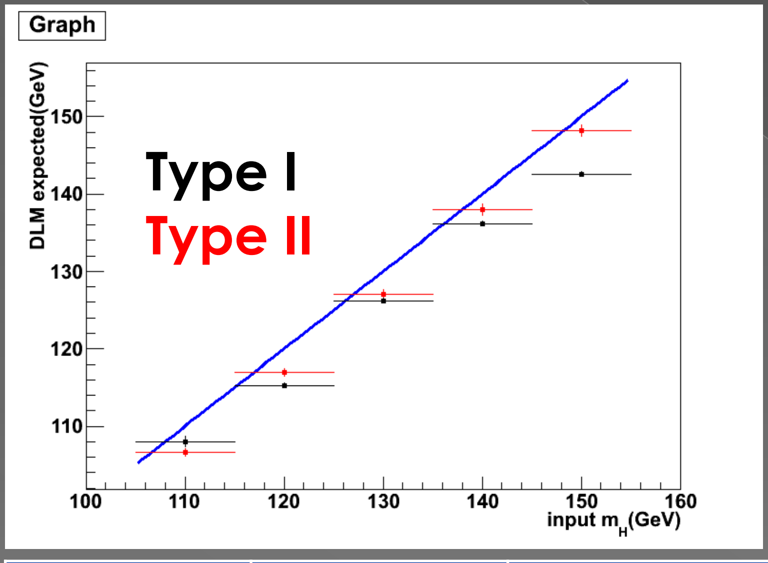
For the better discrimination of signal and backgrounds,

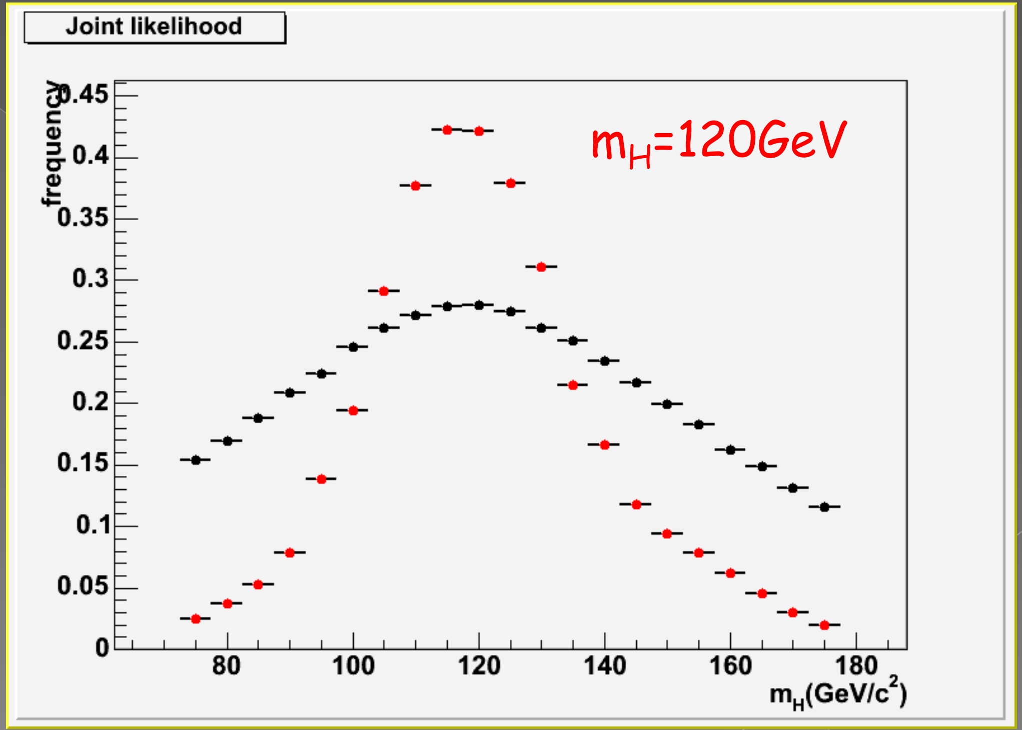
- Shape information should be obtained from Type II
  - Because the signal shape is quite different from backgrounds
- Absolute value information should be obtained from Type I
  - Basically, signal likelihood is higher than backgrounds at whole Higgs mass range

seem good

# Property of Type-I & Type-II

- Linearity check – MC mass input vs. DLM expected Higgs mass
  - Linearity is well reserved when using Type II
- Shape check- TypeII has shaper distribution than Type I




| MC Higgs mass(GeV/c²) | DLM expected Type I(GeV/c²) | DLM expected Type II(GeV/c²) |
|---|---|---|
| 110 | 108.0±0.7 | 106.6±0.5 |
| 120 | 116.2±0.3 | 117.0±0.5 |
| 130 | 125.2±0.2 | 127.0±0.6 |
| 140 | 136.2±0.2 | 138.0±0.7 |
| 150 | 142.6±0.2 | 148.2±0.7 |

# Input variable candidates for MVA

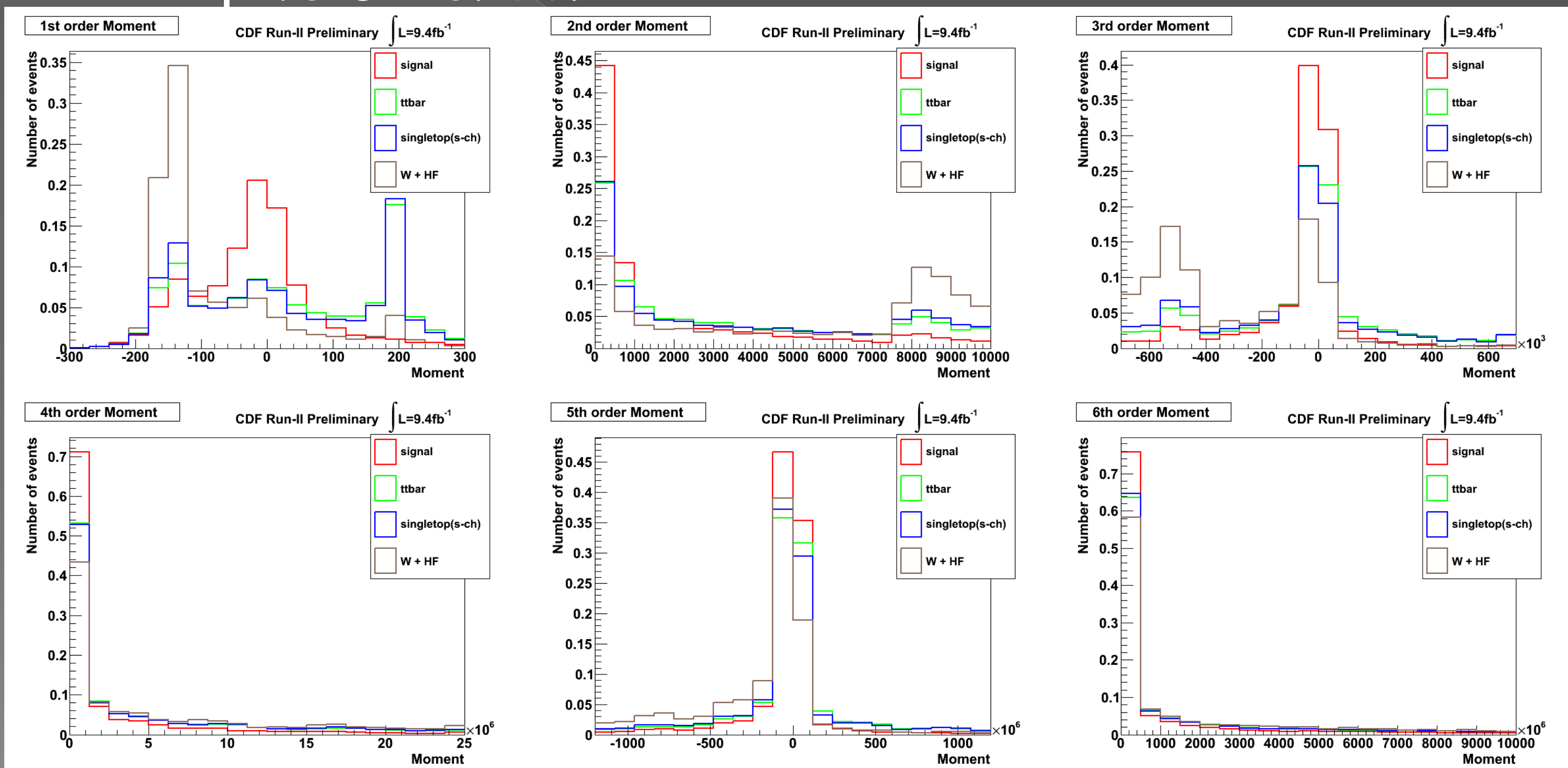
- Extract the signal feature with 2 points
  - Higgs mass dependence shape
    - Evaluate Localized Moment – use up to 6th order

      $\int (m_H - m_{H0})^n \cdot f_{event}(m_H) dm_H$ nth-order moment

      - As $m_{H0}$, expected mass of signal from DLM is used
  - Absolute value of likelihood
    - Several kinds of likelihood can be obtained from DLM result with signal Matrix Element
      - Maximum likelihood on Higgs mass dependence
      - Likelihood@ DLM expected Higgs mass
      - Higgs part likelihood @ maximum likelihood of overall Matrix Element
      - W part liielihood @ maximum likelihood of overall Matrix element
    - Likelihoods as a result of DLM with Wbb & singletop(s-ch) Matrix Element
      - All the parameters(mass, width, etc) in the Matrix Element are set

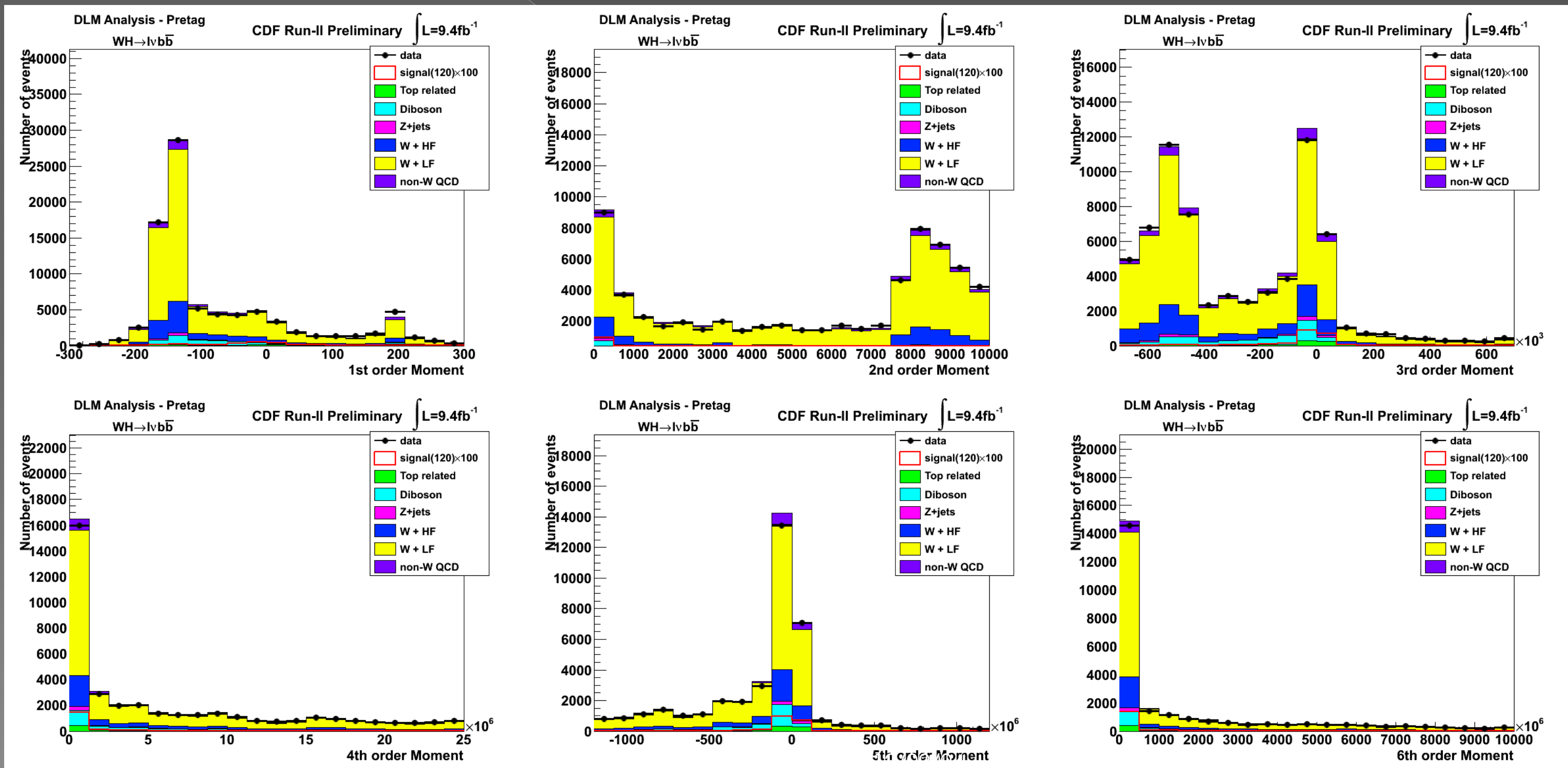
# Localized moment around signal

- Localized moment around signal expected mass for each process
  - $\int (m_H - m_{H0})^n \cdot f_{event}(m_H) dm_H$ nth-order moment
  - Up to 6th order



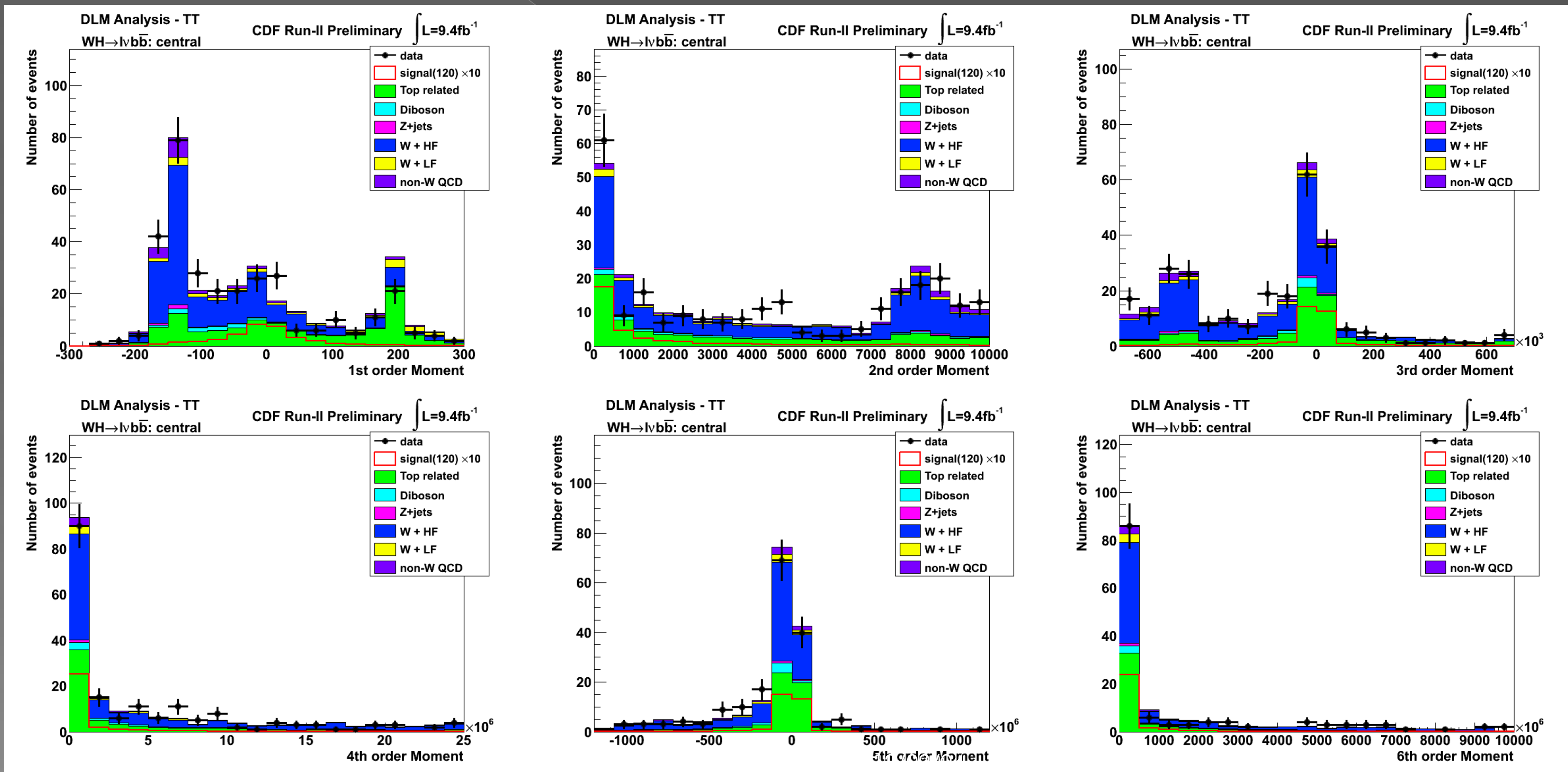
# Localized moment

- Distribution check with pretag events
  - Up to $6^{th}$ order
  - $3^{rd}$, $4^{th}$ and $5^{th}$ order moments have strong separation power
    - These moments are adopted as the input variables by most of the discriminants



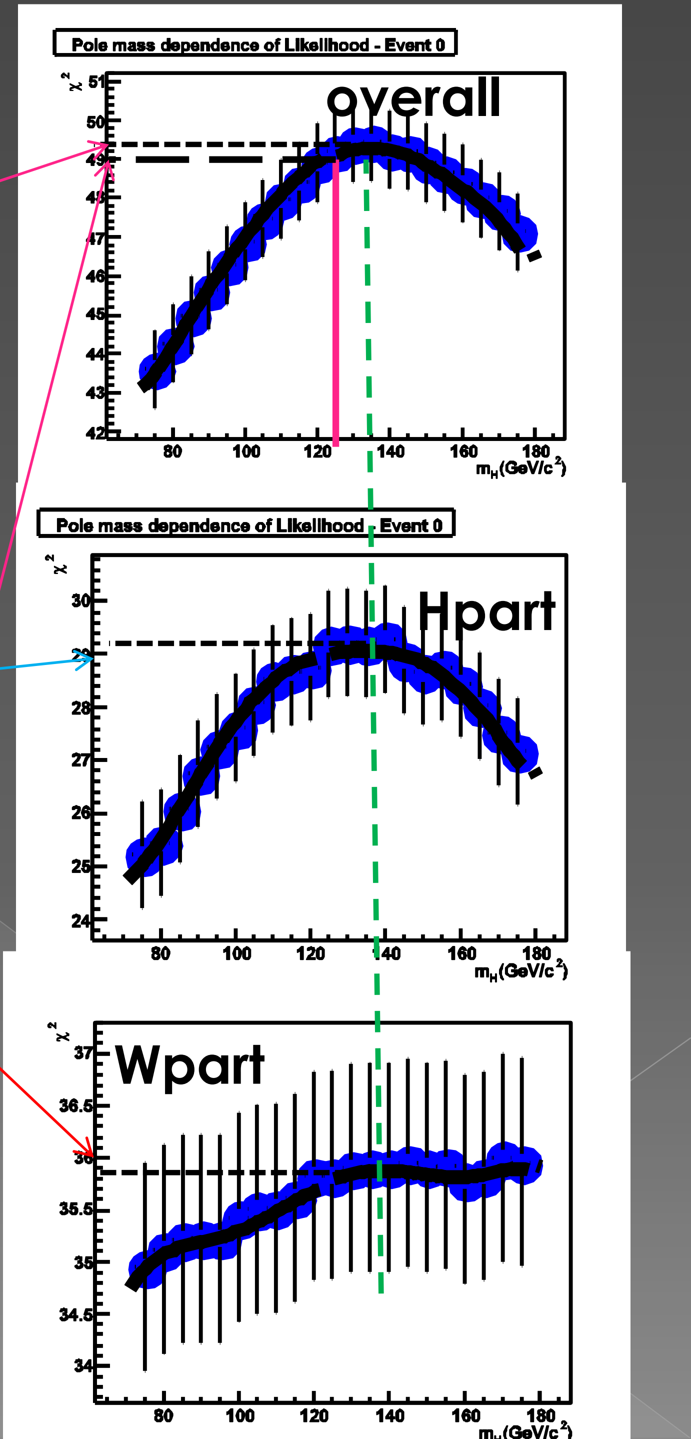
# Localized moment

- Signal region – most sensitive category(TT)
  - Up to 6$^{th}$ order
  - 3$^{rd}$, 4$^{th}$ and 5$^{th}$ order moments have strong separation power
    - These moments are adopted as the input variables by most of the discriminants



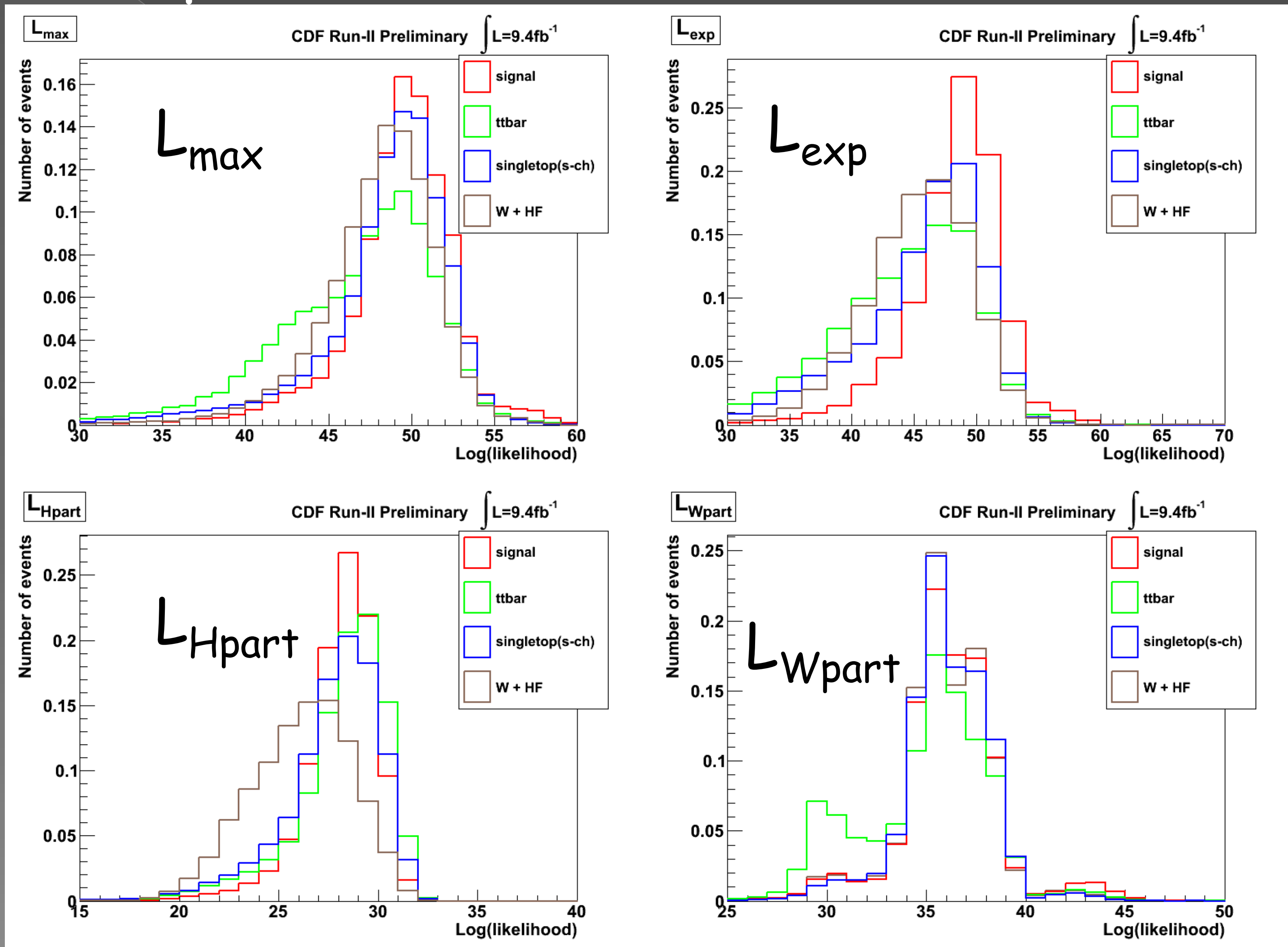
# Likelihood used

- Maximum likelihood: $L_{max}$
  - Use them event-by-event
- Expectation value of likelihood
  - Wbb : $L_{Wbb}$
  - singletop(s-ch): $L_{stop}$
- Higgs part likelihood : $L_{Hpart}$ @maximum likelihood in overall
  - vertex of Higgs decay & T.F.
- W part likelihood: $L_{Wpart}$ @maximum likelihood in overall
  - vertex of W decay & T.F.
- Likelihood @ DLM expected mass: $L_{exp}$
  - Expected mass means the result of event ensemble



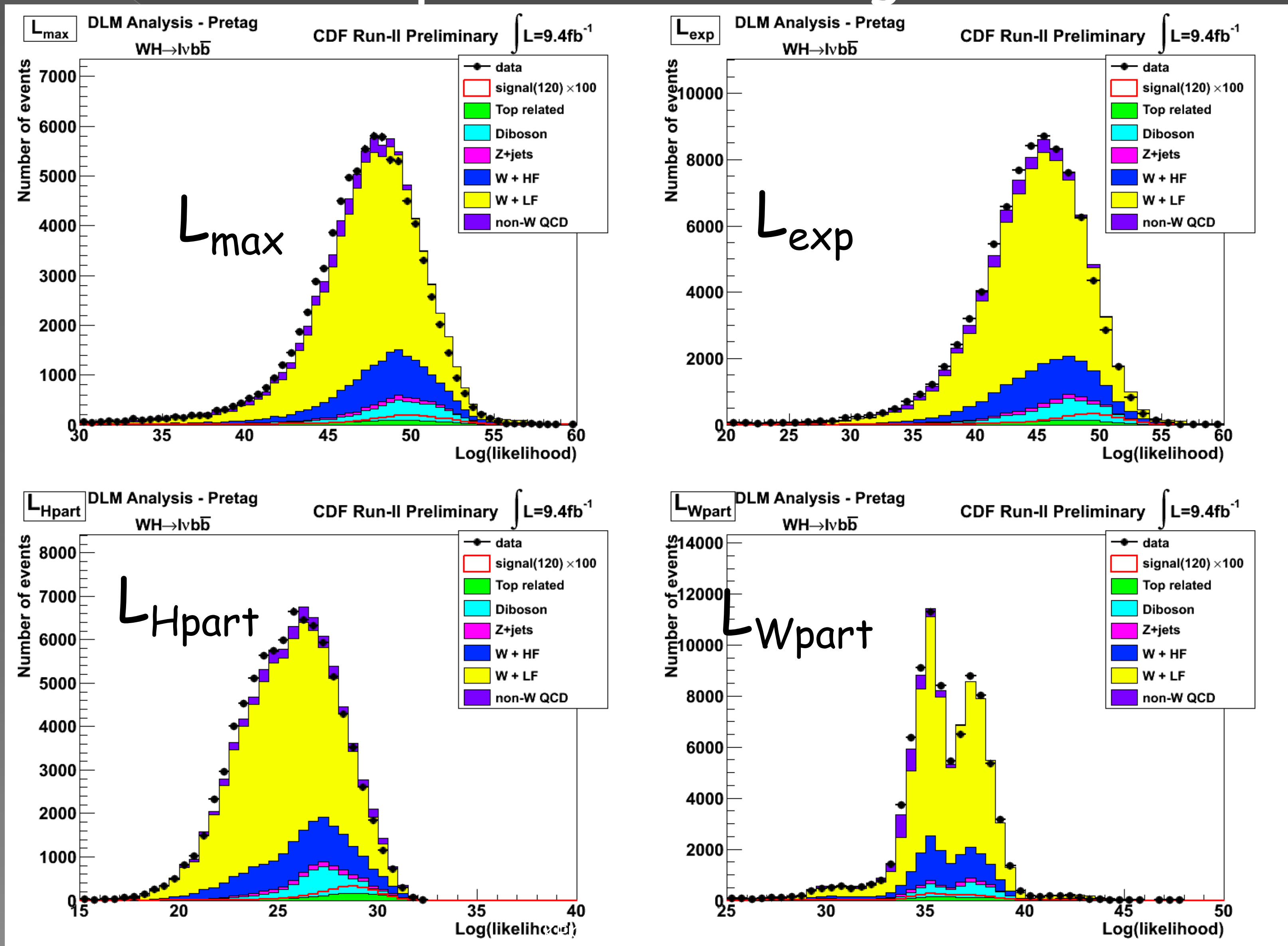
# Likelihood – from signal M.E

- Comparison of the distribution



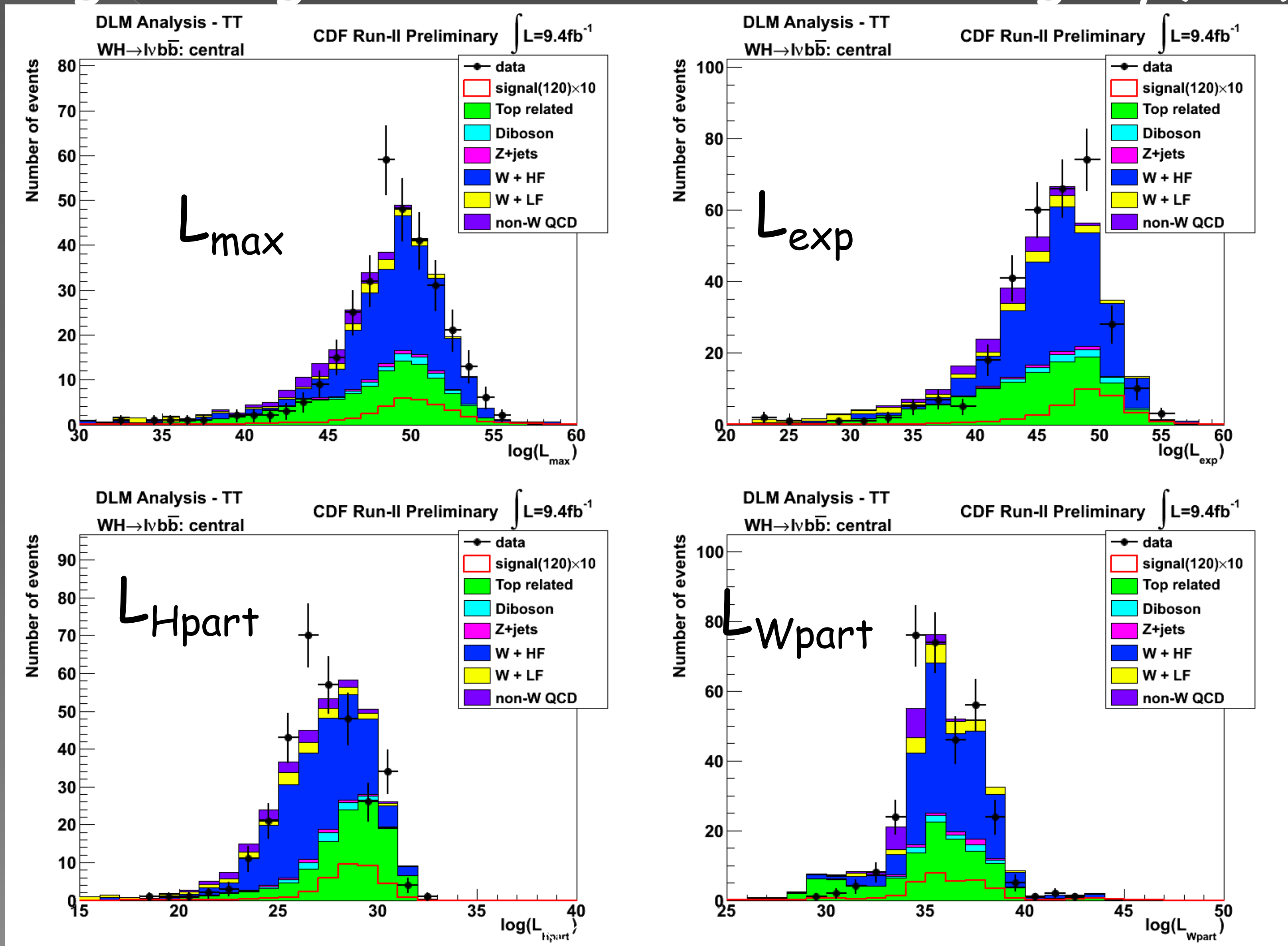
# Likelihoods – from signal M.E

- For the sample before b-tag



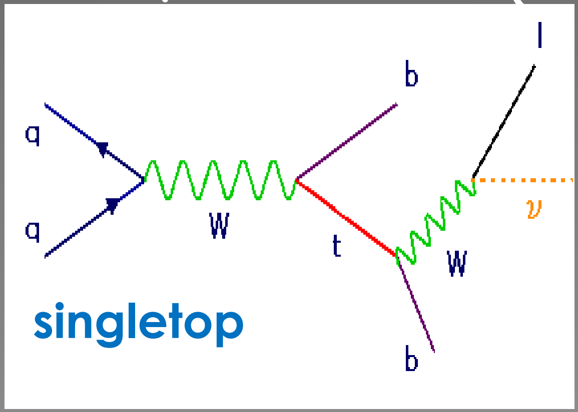
# Likelihoods – from signal M.E

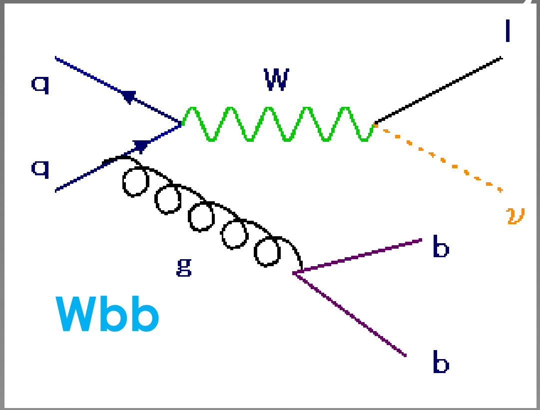
- Signal region – most sensitive category(TT)



# DLM with Singletop & Wbb bases

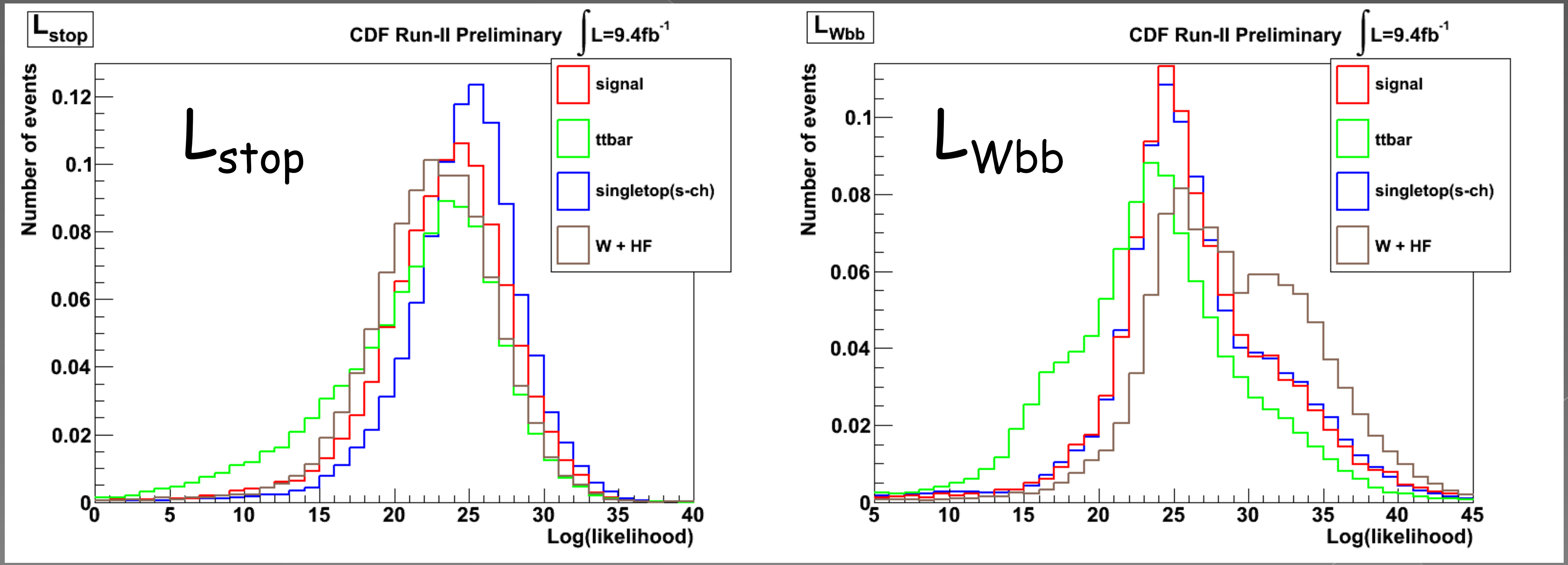
- To improve performance, DLM is used with background matrix elements:
  - Singletop (sch, leading order)
  - Wbb(leading order)
- Optimize transfer functions for each background process using MC
- Same procedure when performing DLM with signal ME($1.0 \times 10^6$paths)
- Background processes don't have any dependence of certain variable. So they only have the expectation value of likelihood ( this means the integration of phase space)



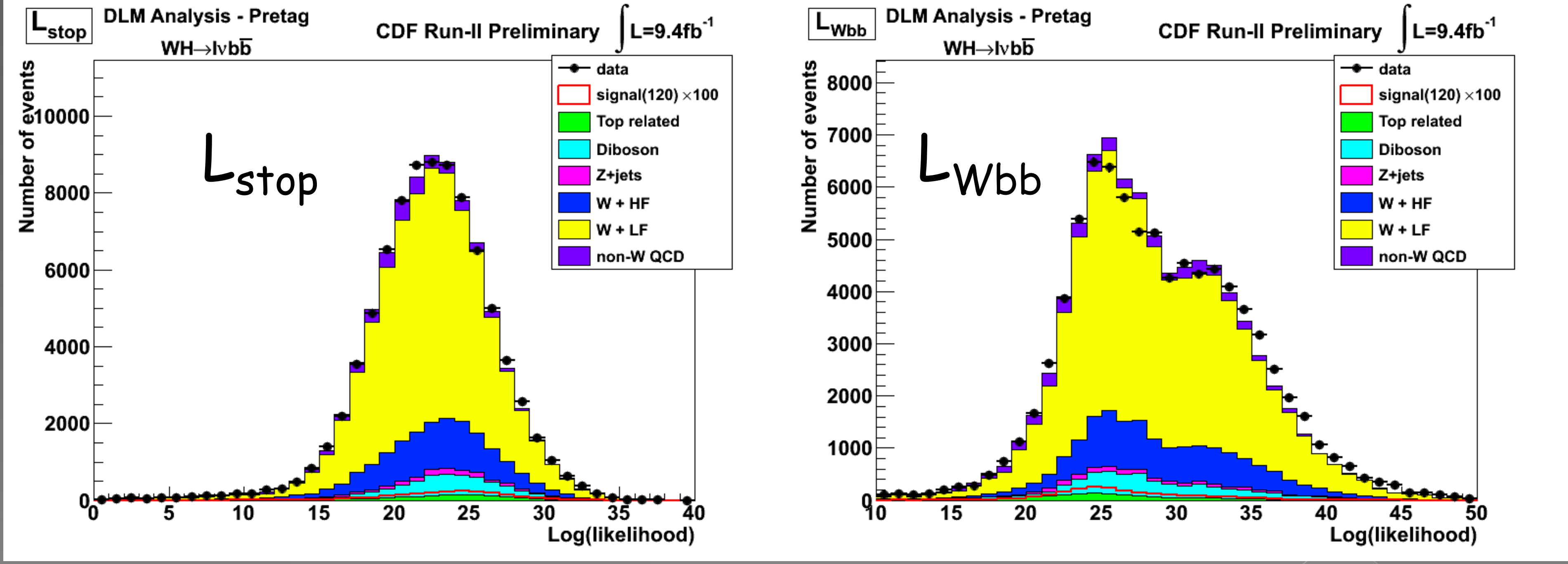
# Likelihood - from Wbb & Stop M.E

- Comparison of the distribution
  - Perform DLM using Wbb(leading order) or singletop(s-ch) Matrix Elements



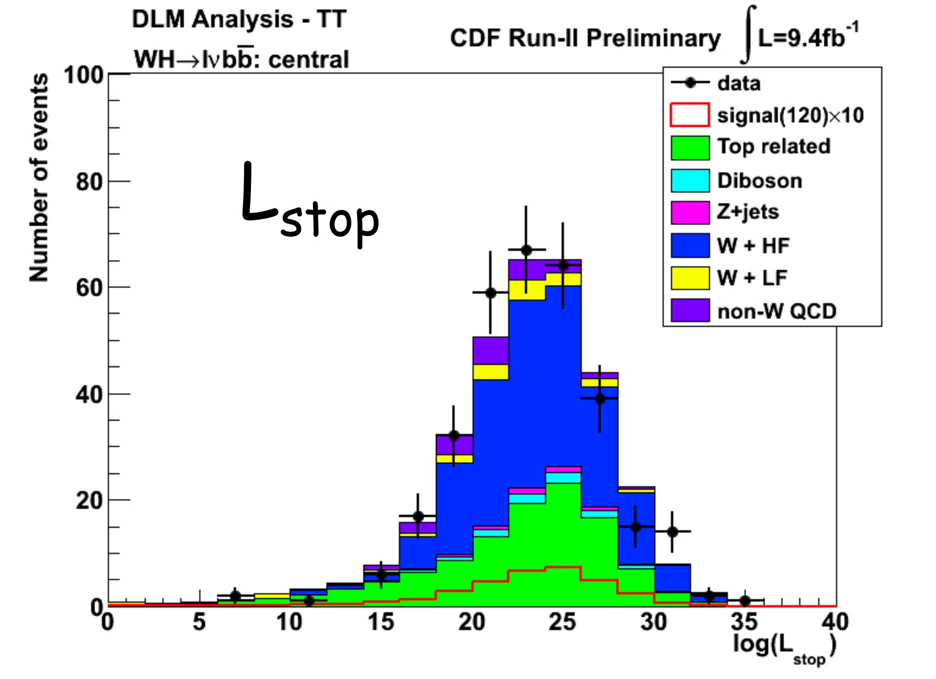
# Likelihood – from Wbb & Stop M.E

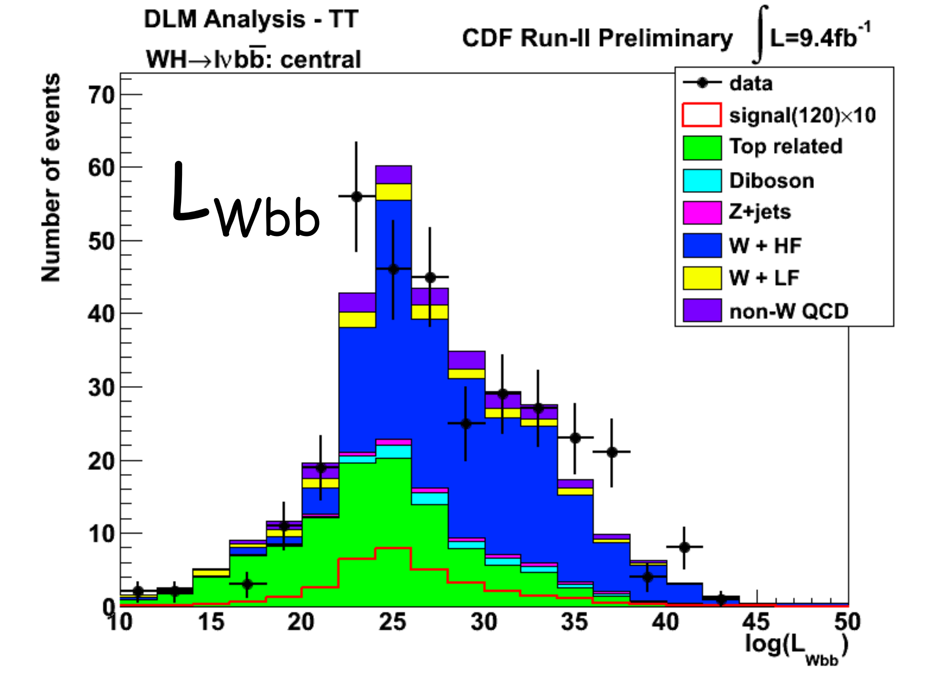
- DLM result of the sample before b-tag
  - Perform DLM using Wbb(leading order) or singletop(s-ch) Matrix Elements



# Likelihood – from Wbb & Stop M.E

- DLM result of the sample before b-tag
  - Perform DLM using Wbb(leading order) or singletop(s-ch) Matrix Elements
- Signal region – most sensitive category(TT)

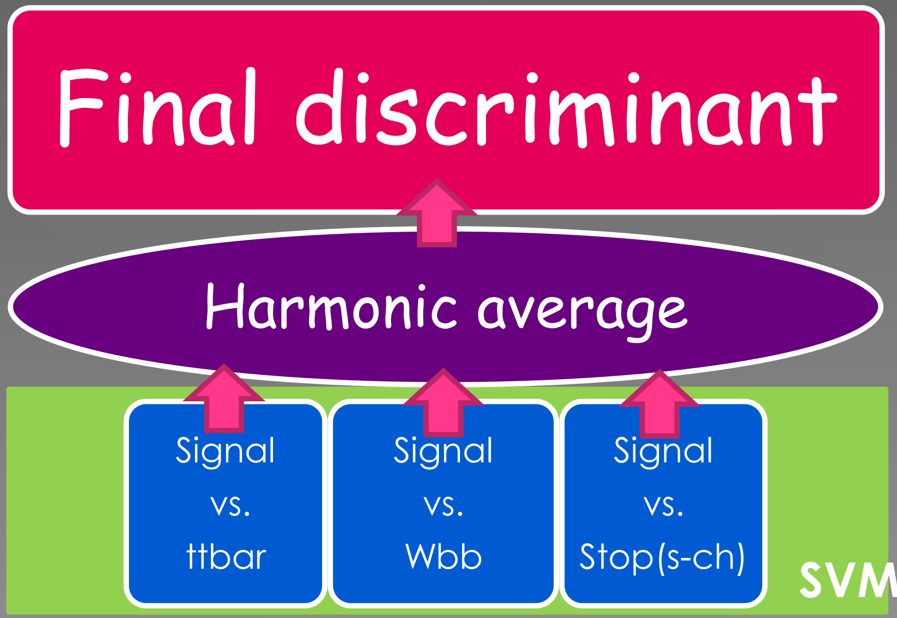


# Making discriminant for double tag case

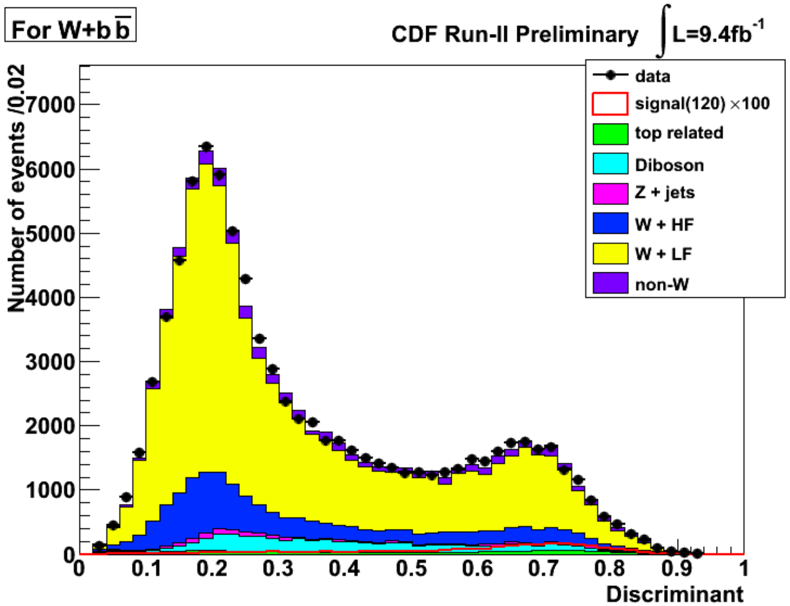
- Using Support Vector Machine to separate signal from background
  - 3-type discriminants are made using SVM
    - Signal vs. ttbar ($d_{ttbar}$) or Wbb ($d_{Wbb}$) or singletop(s-ch) ($d_{stop}$)
  - Final discriminant is obtained by calculating weighted harmonic average of those 3-type discriminants:

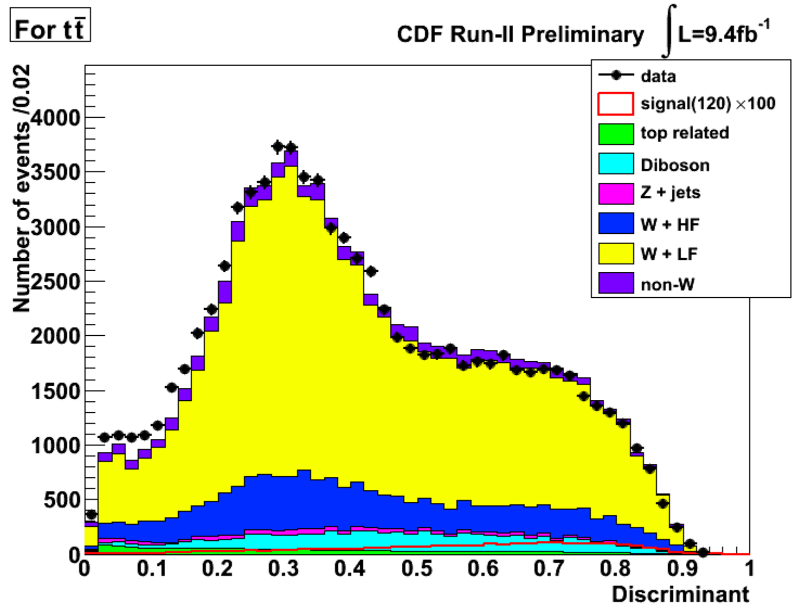
$$d_{final} = \frac{a+b+c}{\frac{a}{d_{ttbar}} + \frac{b}{d_{Wbb}} + \frac{c}{d_{stop}}}$$ weight is determined to maximize S/N(ROC)

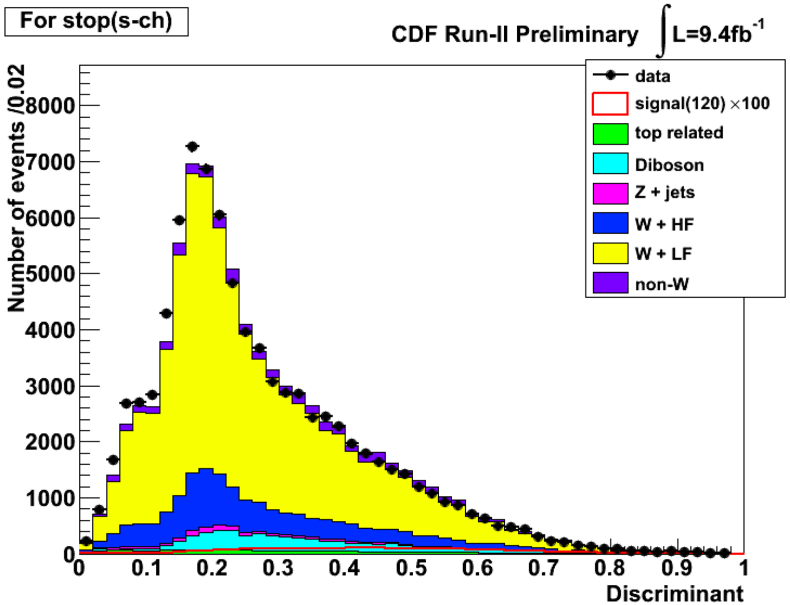



- Signal event requires high scores of these 3-type discriminants
  - Harmonic average can impose strict condition
  - Harmonic average obtains maximum S/N

# Apply to the sample before b-tag



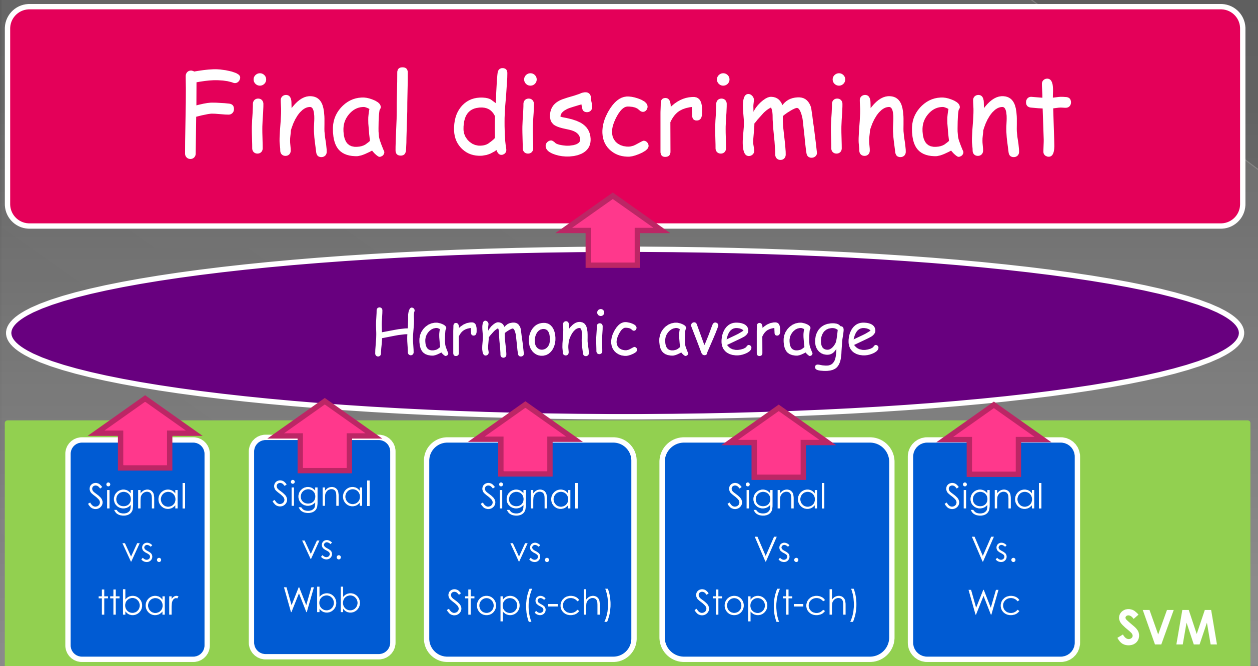




Output result after training
Apply TT tag SVM discriminant
to pretag

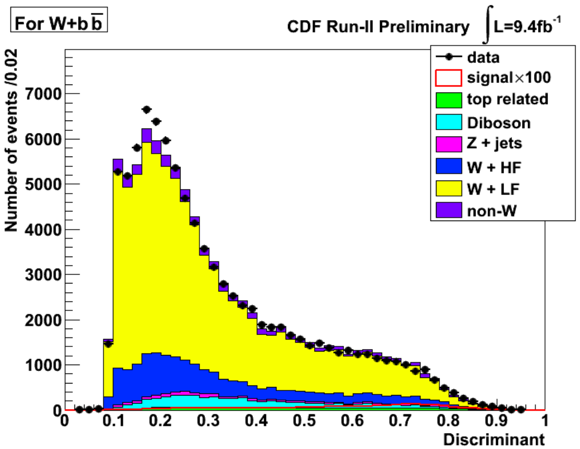
# Making discriminant for 1 tag case

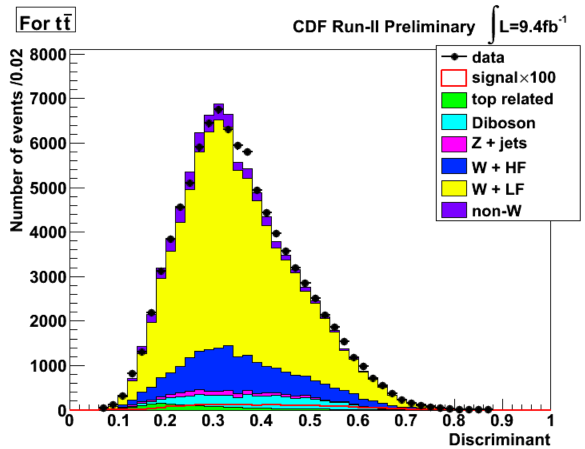
- Almost same method as double tag case
  - 5-type discriminants are made using SVM
    - Signal vs. ttbar ($d_{ttbar}$)
    - Signal vs. Wbb ($d_{Wbb}$)
    - Signal vs. singletop(s-ch) ($d_{stopsch}$)
    - Signal vs. singletop(t-ch) ($d_{stoptch}$)
    - Signal vs. Wc ($d_{Wc}$)
  - harmonic average is used as final discriminanat:

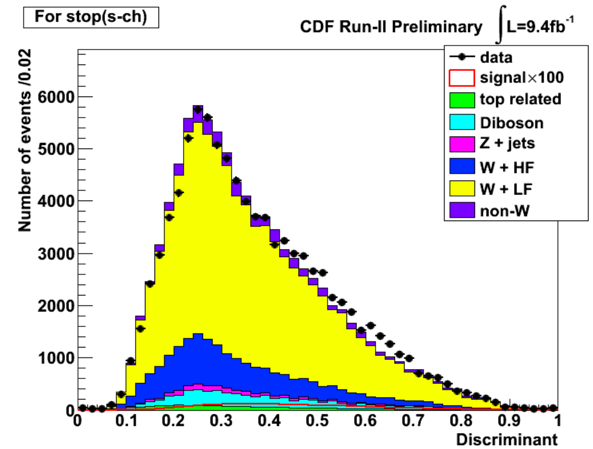
$$d_{final} = \frac{a+b+c+d+e}{\frac{a}{d_{ttbar}}+\frac{b}{d_{Wbb}}+\frac{c}{d_{stop}}+\frac{d}{d_{stoptch}}+\frac{e}{d_{Wc}}}$$

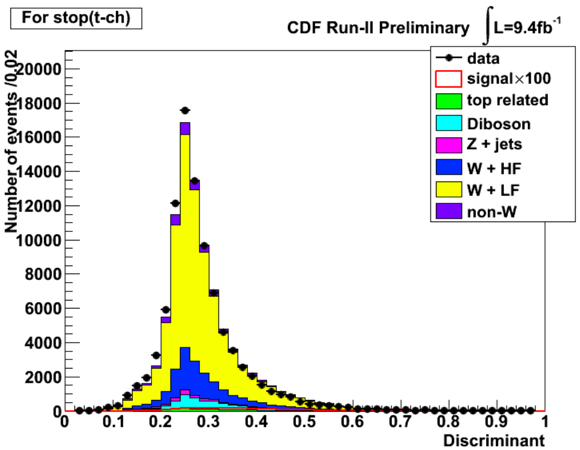


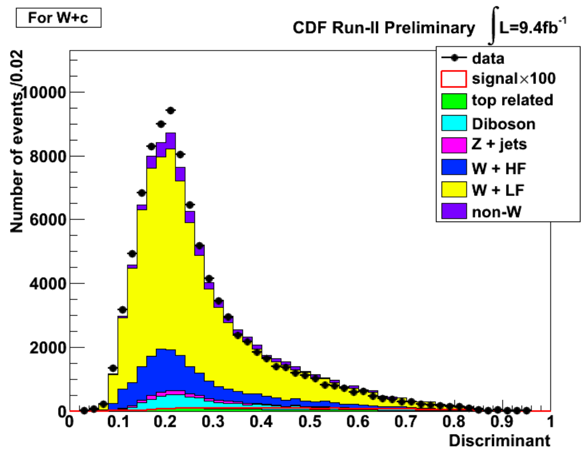
# Apply to the sample before b-tag



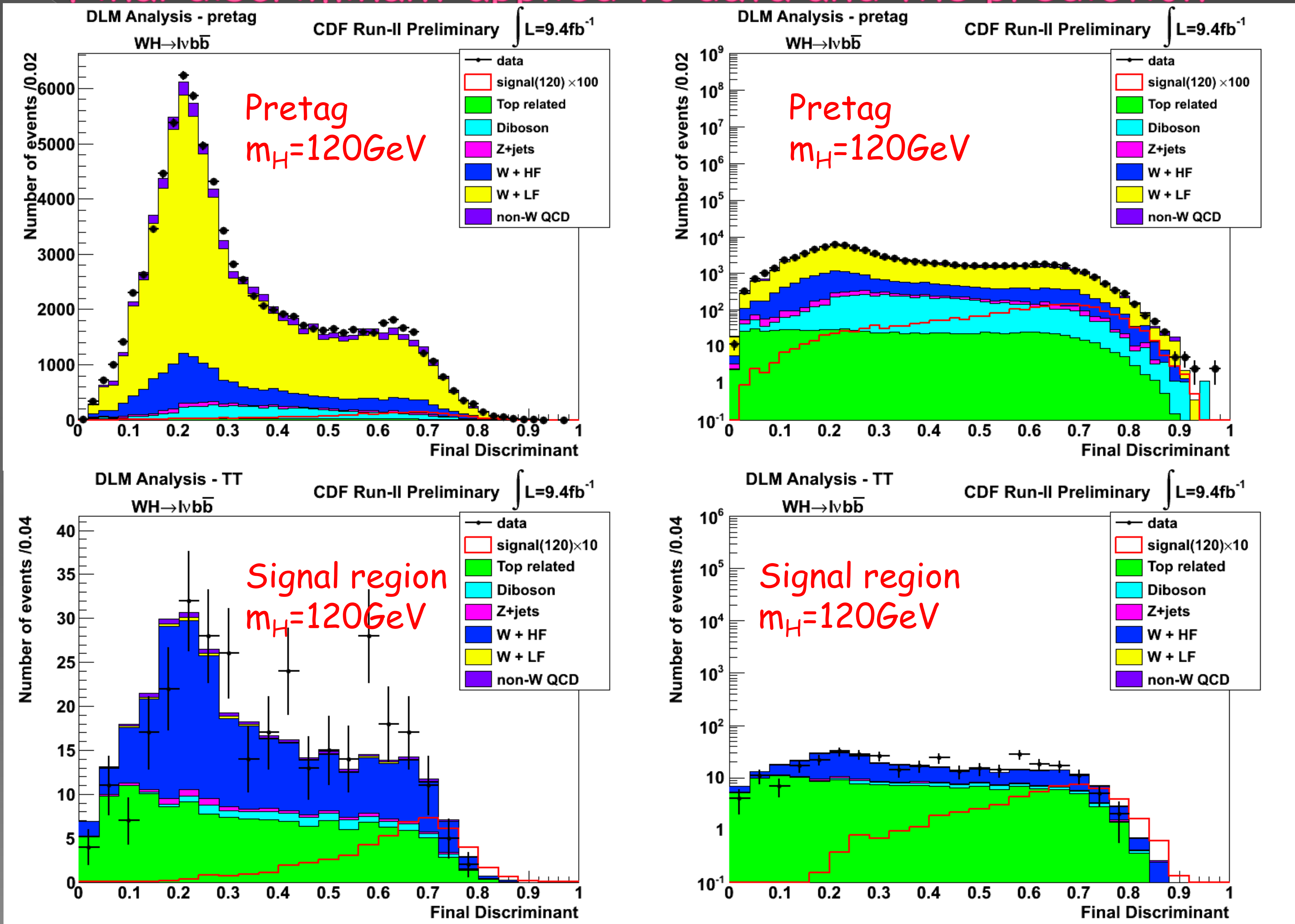



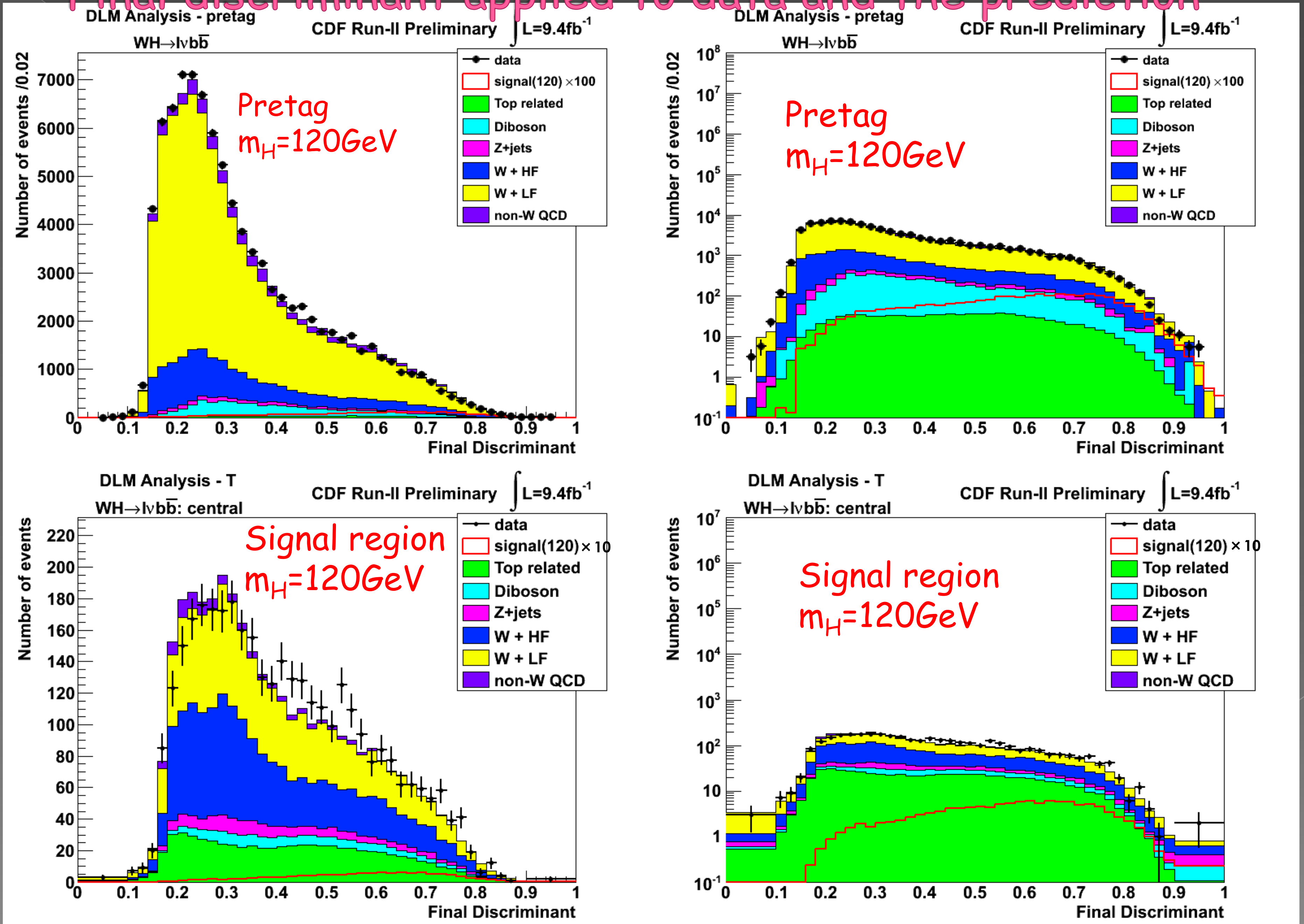




Output result of T tag case
Apply to pretag

# Final discriminant applied to data and the prediction



# Final discriminant applied to data and the prediction



# Systematics summary on signal

| Source | Error (%) | | | | |
|---|---|---|---|---|---|
| | TT | TL | LL | T | L |
| Stat. | 0.7 | 0.7 | 0.7 | 0.4 | 0.4 |
| JES | 2.4 | 1.4 | 1.0 | 1.6 | 2.2 |
| ISR/FSR | 5.2 | 3.8 | 5.7 | 3.4 | 2.9 |
| PDF | 1.4 | 1.4 | 1.2 | 1.1 | 0.7 |
| b-tagging | 8.0 | 7.2 | 6.4 | 4.0 | 3.2 |
| Luminosity | 6 | 6 | 6 | 6 | 6 |
| Lepton ID SF | 2 | 2 | 2 | 2 | 2 |
| Trigger | $\sim 1$ | $\sim 1$ | $\sim 1$ | $\sim 1$ | $\sim 1$ |

Table 11: Summary of systematic uncertainties on the acceptance in central lepton events

| Source | Error (%) | | | | |
|---|---|---|---|---|---|
| | TT | TL | LL | T | L |
| Stat. | 1.7 | 1.9 | 1.9 | 1.0 | 1.0 |
| JES | 1.4 | 1.2 | 3.4 | 4.6 | 2.2 |
| ISR/FSR | 12.6 | 4.1 | 5.6 | 3.4 | 2.8 |
| PDF | 2.9 | 2.5 | 1.2 | 1.1 | 1.0 |
| b-tagging | 8.0 | 7.2 | 6.4 | 4.0 | 3.2 |
| Luminosity | 6 | 6 | 6 | 6 | 6 |
| Lepton ID SF | 2 | 2 | 2 | 2 | 2 |
| Trigger | $\sim 1$ | $\sim 1$ | $\sim 1$ | $\sim 1$ | $\sim 1$ |

Table 12: Summary of systematic uncertainties on the acceptance in PHX electron events

| Source | Error (%) | | | | |
|---|---|---|---|---|---|
| | TT | TL | LL | T | L |
| Stat. | 1.7 | 1.2 | 1.2 | 1.0 | 1.0 |
| JES | 4.0 | 3.8 | 6.4 | 1.0 | 2.2 |
| ISR/FSR | 3.7 | 3.2 | 2.8 | 1.6 | 2.2 |
| PDF | 1.2 | 1.2 | 0.8 | 0.8 | 0.9 |
| b-tagging | 8.0 | 7.2 | 6.4 | 4.0 | 3.2 |
| Luminosity | 6 | 6 | 6 | 6 | 6 |
| Track Reco. | 4.95 | 4.95 | 4.95 | 4.95 | 4.95 |
| Trigger | 2 | 2 | 2 | 2 | 2 |

Table 13: Summary of systematic uncertainties on the acceptance in Isolated Track events

Main source on signal:

- Luminosity
- b-tagging uncertainty

# Systematics summary on backgrounds

Typical value – Eroor varies for each tag category & lepton type

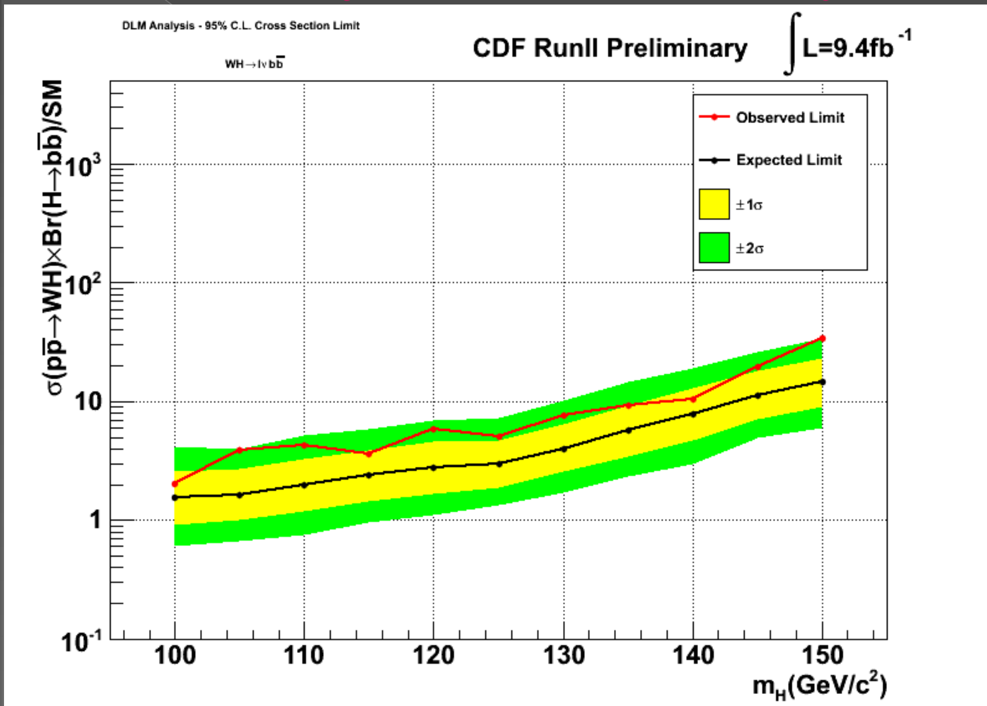
| Source | Error (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $t\bar{t}$ | singletop | $W+b\bar{b}$ | $W+c\bar{c}$ | Mistag | Diboson | Z+jets | nonW |
| JES | 4-7 | 1-3 | 6-8 | 8-10 | | 2-6 | 3-6 | |
| ISR/FSR | 4-9 | 1-3 | | | | | | |
| PDF | 1-2 | 1 | | | | 3 | 5 | |
| HF fraction | | | 38 | 38 | | | | |
| Mistag rate | | | | | 28 | | | |
| Z+jets cross section | | | | | | | 7 | |
| Fit | | | | | | | | 40 |
| Luminosity | 6 | 6 | | | | 6 | 6 | |
| Trigger(central & plug) | 1 | 1 | | | | 1 | 1 | |
| Trigger(Isolated Track ) | 2 | 2 | | | | 2 | 2 | |
| Lepton ID (central & plug) | 2 | 2 | | | | 2 | 2 | |
| Reconstruction (Isolated Track) | 4.95 | 4.95 | | | | 4.95 | 4.95 | |
| b-tag(TT) | 8.0 | 8.0 | 8.0 | 8.0 | | 8.0 | 8.0 | |
| b-tag(TL) | 7.2 | 7.2 | 7.2 | 7.2 | | 7.2 | 7.2 | |
| b-tag(LL) | 6.4 | 6.4 | 6.4 | 4,3 | | 6.4 | 6.4 | |
| b-tag(T) | 4.0 | 4.0 | 4.0 | 4.0 | | 4.0 | 4.0 | |
| b-tag(L) | 3.2 | 3.2 | 3.2 | 4,3 | | 3.2 | 3.2 | |

Table 4: Summary of systematic uncertainties on the backgrounds

Main source on backgrounds:

- Heavy Flavor Fraction uncertainty
- nonW(Fake) uncertainty
- B-tagging
- luminosity

# The preliminary result of upper limit




@$m_H$=125GeV
Exp. 2.97 × SM Obs. 5.05 × SM

| $m_H$(GeV) | Obs. | $-2\sigma$ | $-1\sigma$ | median | $+1\sigma$ | $+2\sigma$ |
|---|---|---|---|---|---|---|
| 100 | 2.05 | 0.60 | 0.91 | 1.54 | 2.57 | 4.22 |
| 115 | 3.89 | 0.67 | 1.00 | 1.64 | 2.69 | 4.01 |
| 110 | 4.27 | 0.76 | 1.19 | 1.97 | 3.26 | 5.18 |
| 115 | 3.59 | 0.97 | 1.45 | 2.39 | 3.92 | 5.83 |
| 120 | 5.87 | 1.10 | 1.66 | 2.78 | 4.61 | 6.95 |
| 125 | 5.05 | 1.35 | 1.90 | 2.97 | 4.76 | 7.34 |
| 130 | 7.64 | 1.72 | 2.58 | 4.03 | 6.50 | 10.19 |
| 135 | 9.37 | 2.33 | 3.44 | 5.67 | 9.24 | 14.49 |
| 140 | 10.39 | 3.01 | 4.77 | 7.83 | 12.85 | 19.11 |
| 145 | 19.52 | 4.95 | 7.10 | 11.11 | 18.08 | 26.15 |
| 150 | 33.92 | 5.98 | 8.96 | 14.59 | 23.09 | 33.98 |

Table 1: The numbers of the upper limit of Higgs production cross section

# Summary on the Analysis

- DLM is being established to analyze $WH \rightarrow l\nu bb$ process
  - Signal information can be extracted effectively
  - Performance check is OK for Higgs analysis
- New b-tagging algorithm boost the Higgs acceptance
  - HOBIT improve the result of >12% from old b-taggers
- Expected upper limit is calculated using Discriminant
  - Discriminants are obtained by Support Vector Machine and incorporate SVM output into the final discriminant
- The result is comparable to the other WH analysis
  - $2.97 \times$ SM(Exp.), while $5.05 \times$ SM(Obs.) @$m_H$=125GeV
- Plan to be published

# Summary of Higgs search at CDF

# Channels of CDF analysis

- To improve the sensitivity, many Higgs production/decay channels are analyzed at CDF → combine the results

| Channel | Luminosy used |
|---|---|
| WH→lνbb | 9.45 |
| ZH→lνbb | 9.45 |
| ZH→ννbb | 9.45 |
| WH→lνττ/ZH→llττ | 8.3 |
| H→ττ | 6.2 |
| H→γγ | 10.0 |
| VH→jjbb | 9.45 |
| ttH→WWbbbb | 9.45 |
| H→WW→lνlν | 9.7 |
| H→WW→lνтν | 9.7 |
| H→VWW→lll + X | 9.7 |
| H→VWW→l±l±+ X | 9.7 |
| H→ZZ→llll | 9.7 |

- Dominant processes are:
  - Low mass ($m_H$<135GeV)
    VH process and H→bb
  - High mass ($m_H$>135GeV)
    gluon fusion and H→WW→lνlν

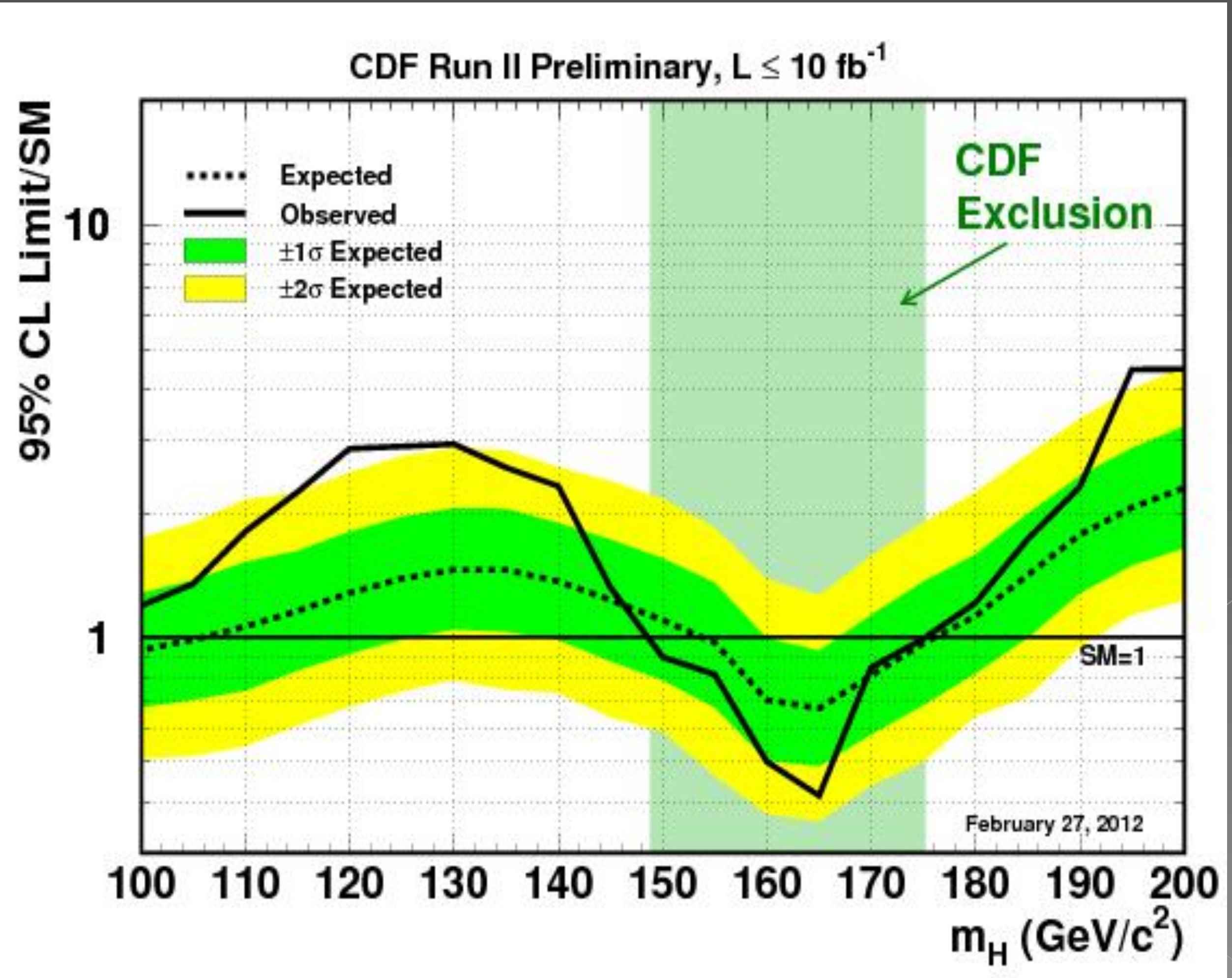
- Other processes contribute ～10%

# General Strategy for the analyses

- Maximize the acceptance – triggers & leptons
- Separation of signal from backgrounds
  - Optimize MVA technique
  - Neural Net, Boosted Decision Tree, Matrix Element, etc.
  - Some analyses use MVA output into another MVA
- Improve b-jet energy measurement (low mass analyses)
  - *b*-jet energy correction based on NN
- Improve b-tagging - HOBIT
  - Algorithms based on MVA.
- Divide analysis sample into high/low purity subsamples, and combine them at last
  - Divide due to lepton and *b*-tag quality

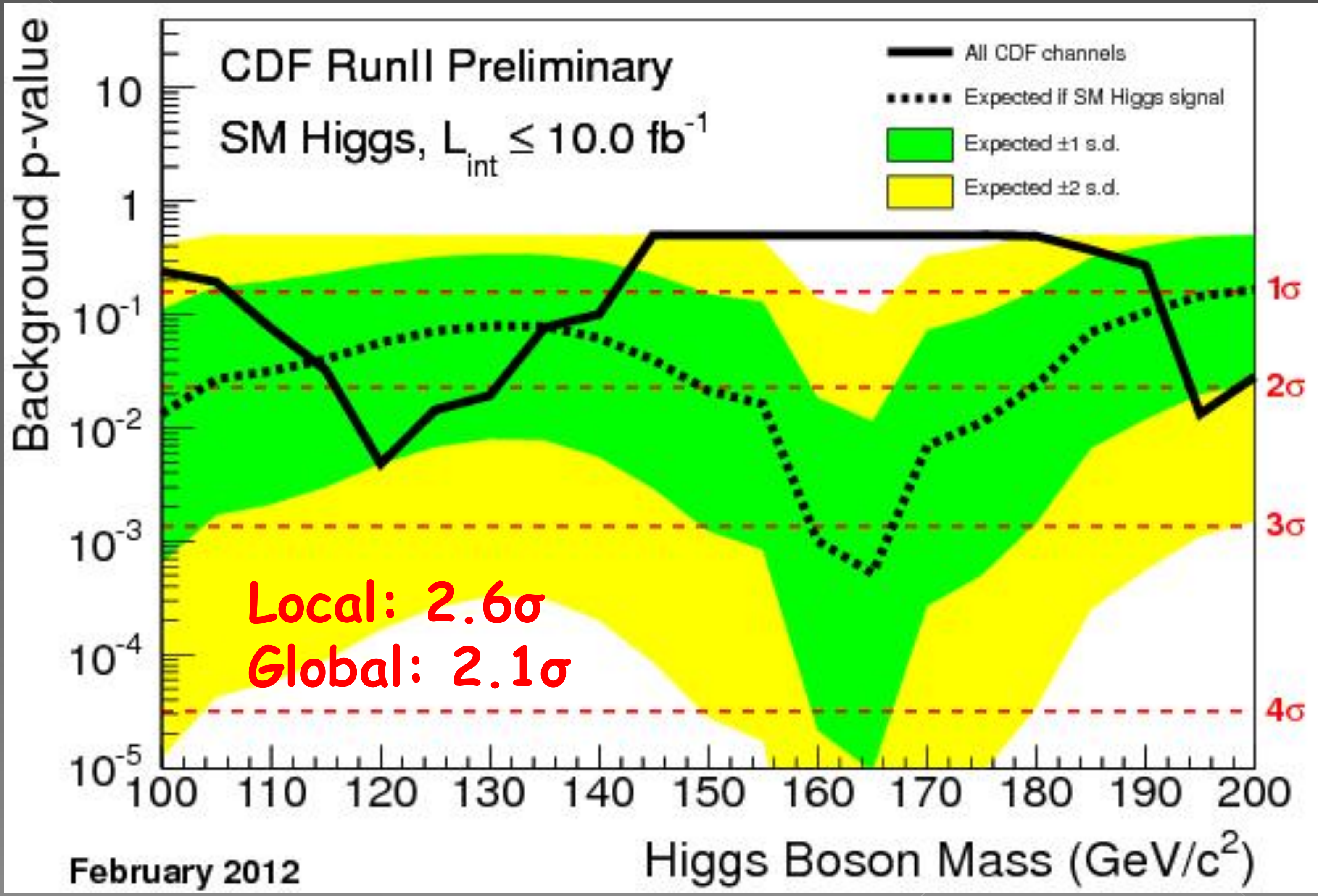
# CDF Higgs result

- Exclusion:
  - $m_H$<96.9GeV
  - 148.8GeV<$m_H$<175.2GeV
- Largest excess: 2.6σ@120GeV



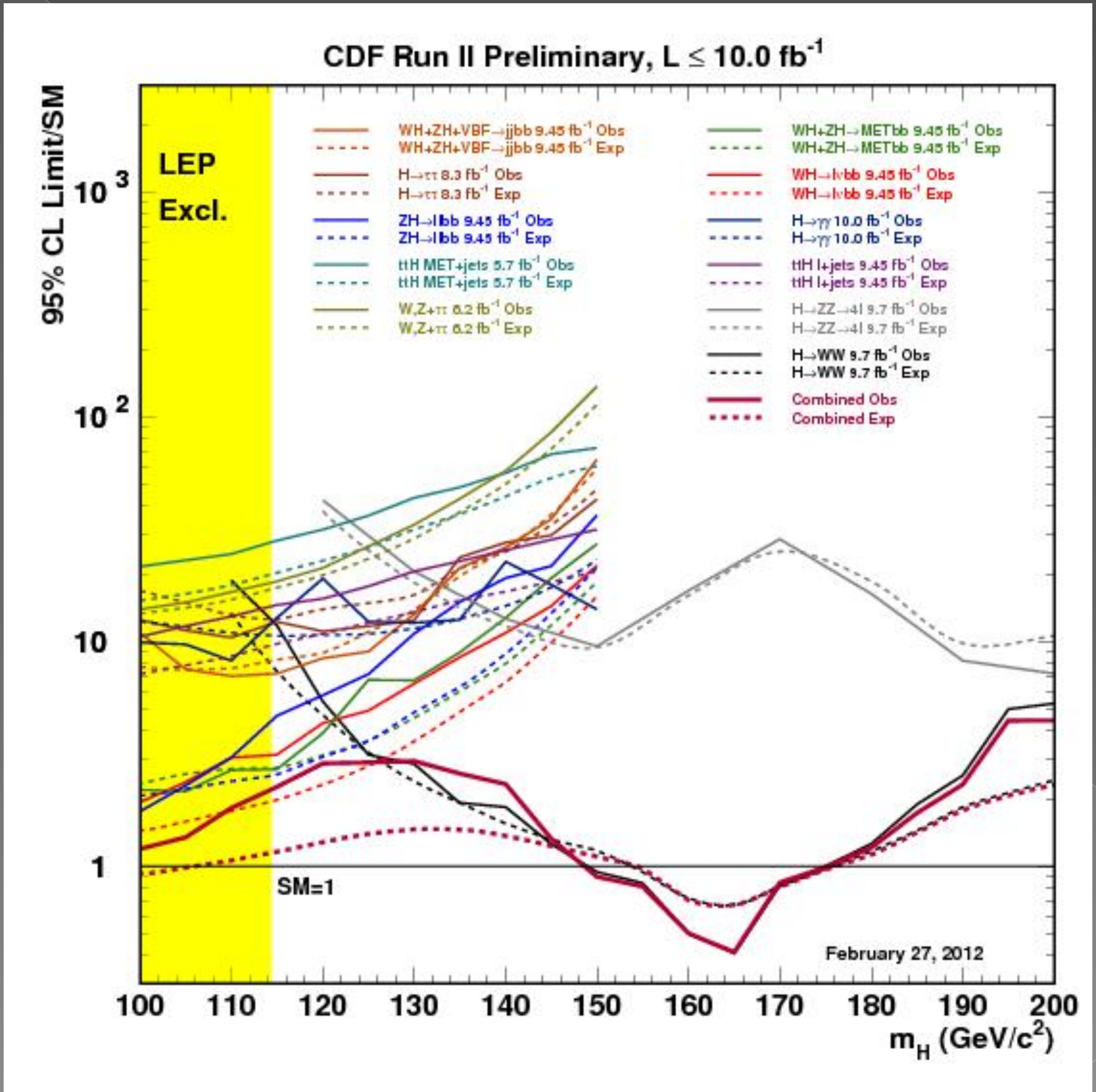
# Excess significance

- Is the excess consistent with background only assumption?



# Contribution of each channel

- So many channels are analyzed for better sensitivity



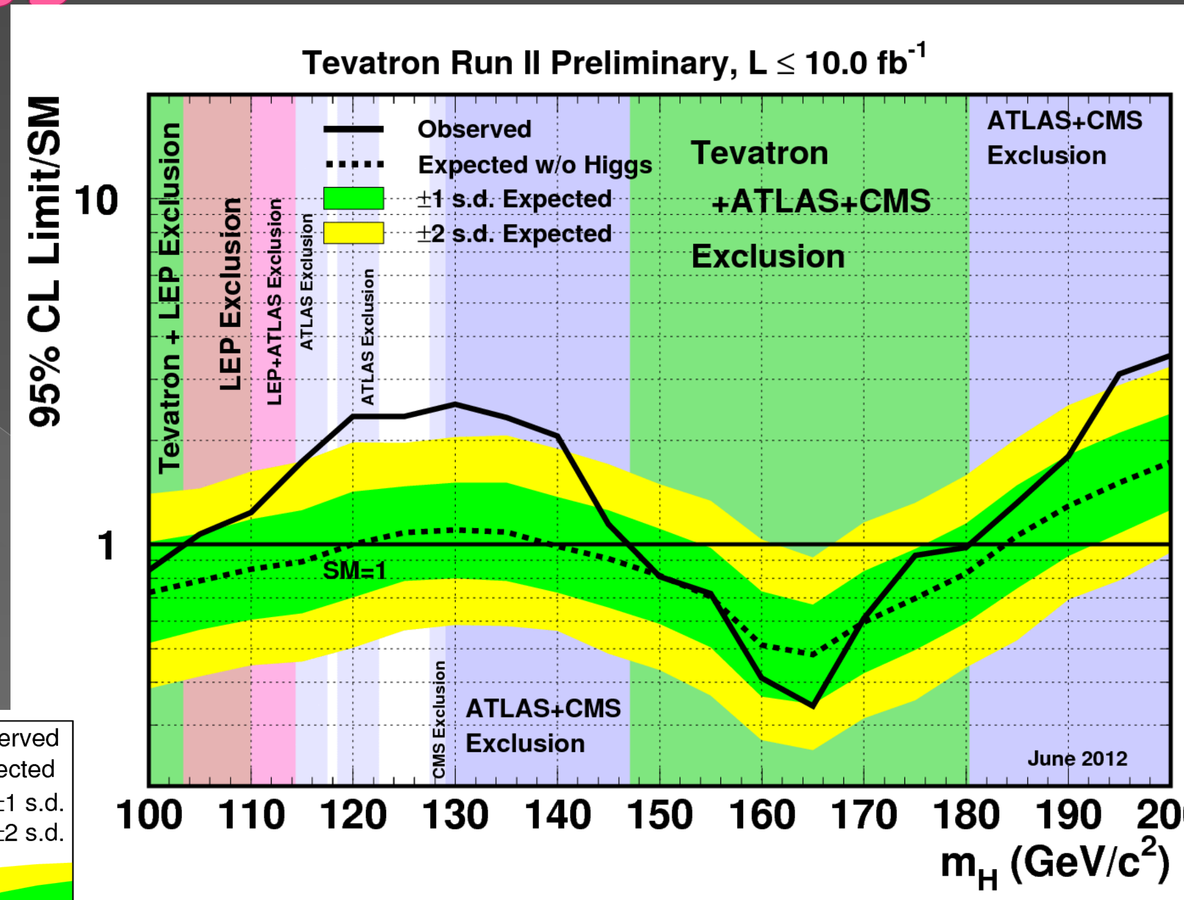
# Tevatron Higgs result

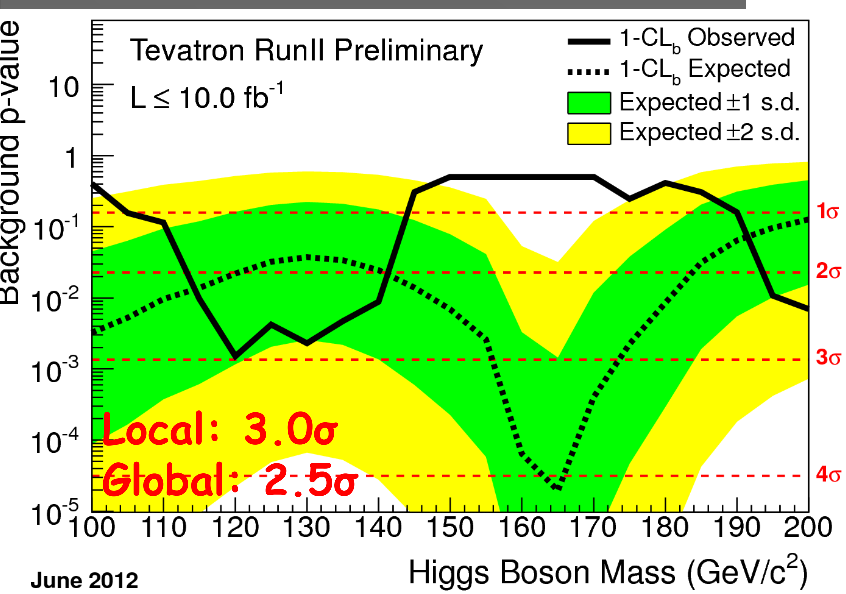
Expected sensitivity < 1.15 × SM for $m_H$<185 GeV

Exclusion:

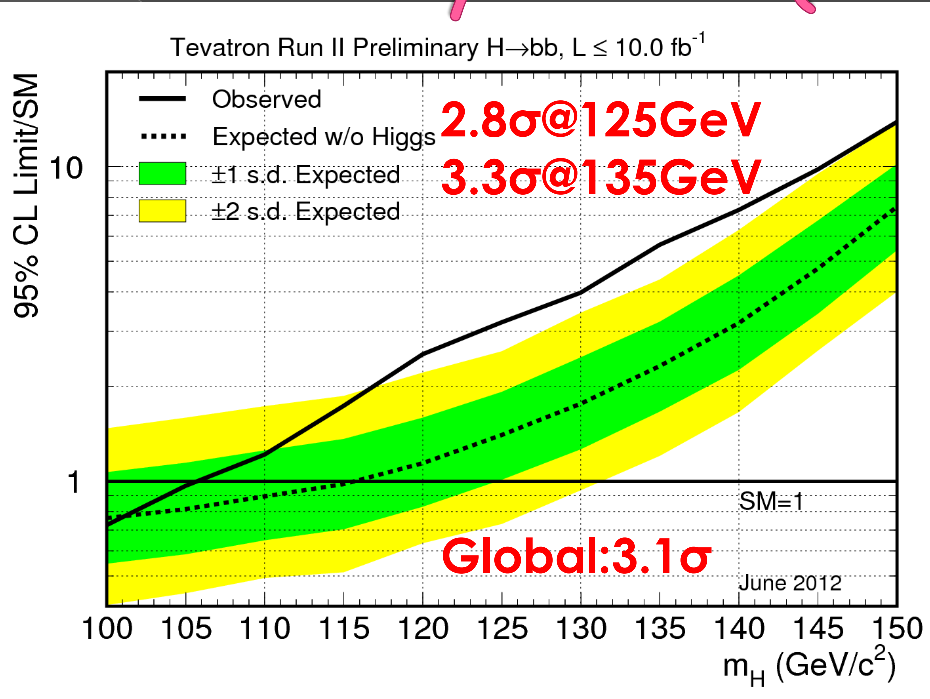
100<$m_H$<103GeV

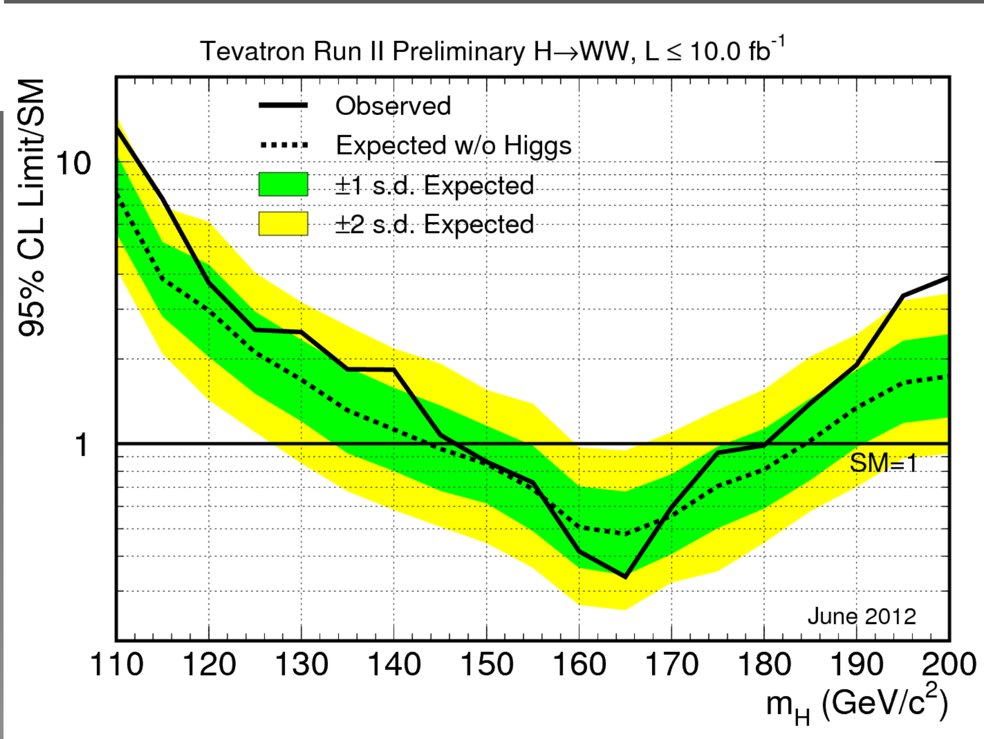
147<$m_H$<180GeV



# Decay Mode(H→bb, H→WW)



# Summary

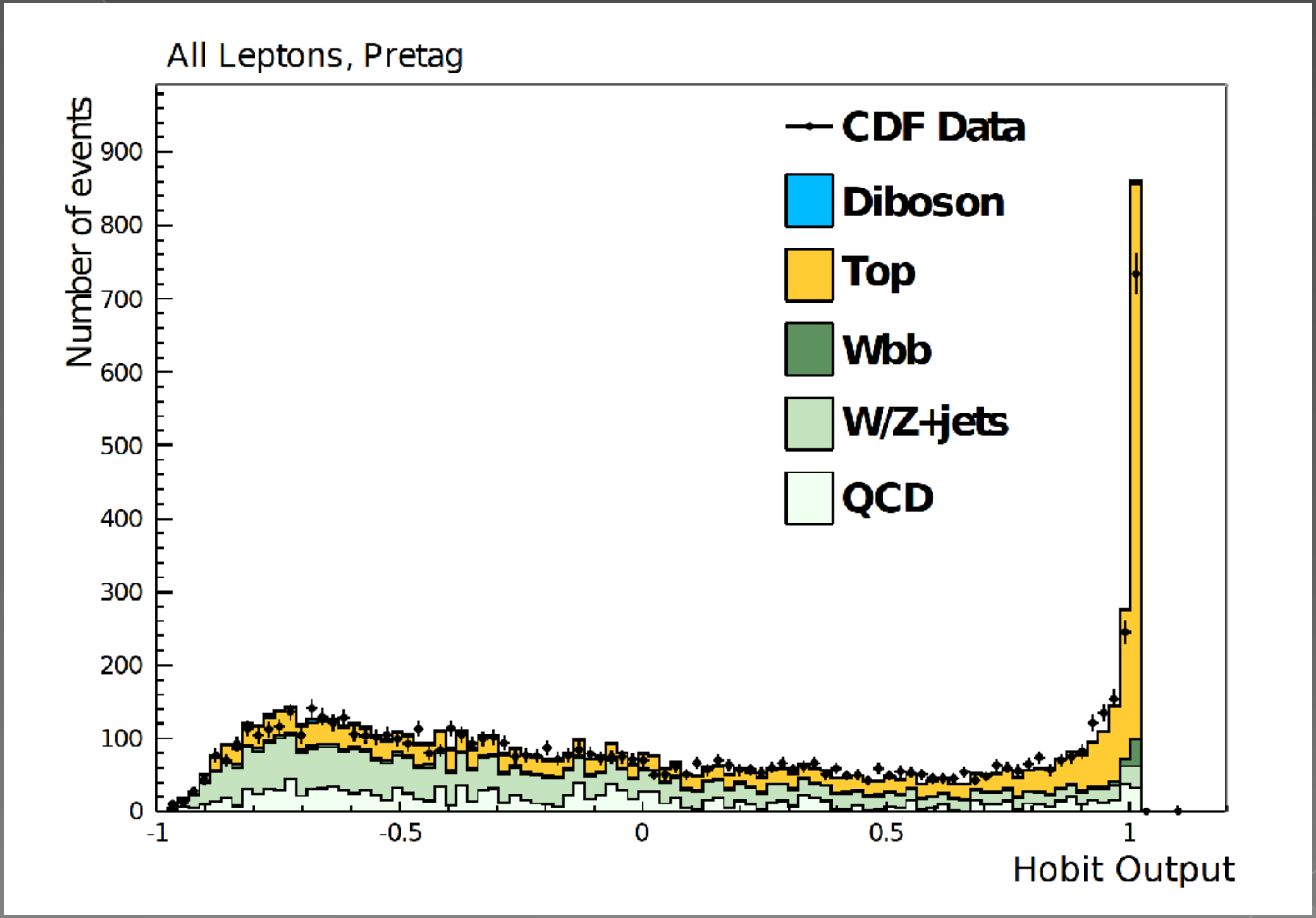
- Most of the channels use Full dataset for Higgs search
  - CDF excludes $m_H$<96.9GeV & 153.8GeV<$m_H$<176.1GeV
  - The largest excess is 2.6σ@120GeV at CDF
  - Global significance at CDF is 2.1σ
  - Tevatron excludes 100GeV<$m_H$<103GeV & 147GeV<$m_H$<180GeV
  - 2.5σ excess is seen at 115GeV<$m_H$<135GeV at Tevatron
  - On H→bb search, the evidence of Higgs can be seen

- Results are available:
  - Tevatron:
    - http://tevnphwg.fnal.gov/results/SM_Higgs_Summer_12/
    - http://tevnphwg.fnal.gov/results/Higgs_bb_Summer_12/
  - CDF
    - http://www-cdf.fnal.gov/physics/new/hdg/Results.html

# Backups

# HOBIT validation

- HOBITagger Validation plot



# How to parameterize T.F.

- Transfer variables(T.V.) : variables to analyze easier

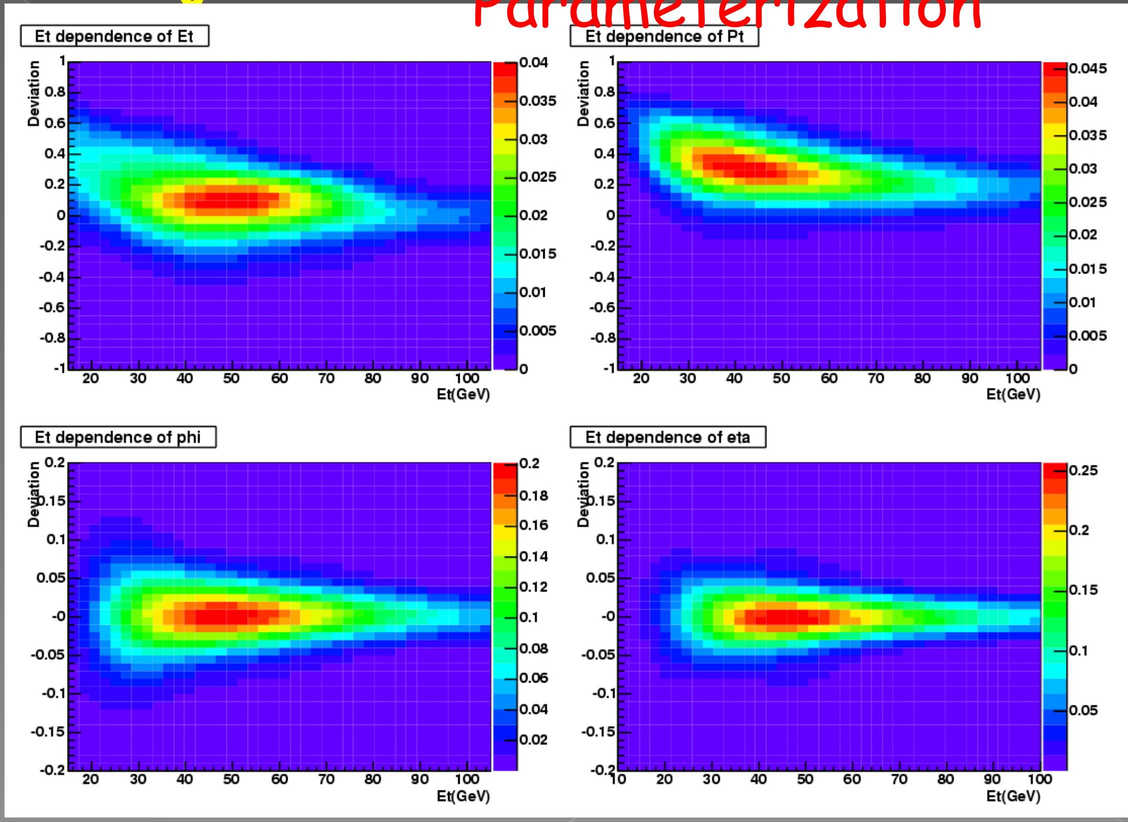
| Variable | Use for analyzing T.F. |
|---|---|
| Et | $\xi_{Et} = \dfrac{Et(parton) - Et(measure)}{Et(parton)}$ |
| φ | $\xi_{\varphi}=\varphi(measure)-\varphi(parton)$ |
| η | $\xi_{\eta}=\eta(measure)-\eta(parton)$ |

- Make each Transfer Function at 3 Higgs mass ranges:
  - Low mass($m_H$<=120GeV)
  - Middle mass(120<$m_H$<140GeV)
  - High Mass($m_H$>=140GeV)
    - This division is because there was a mass dependence of transfer function when checking expected mass
- ξ distribution has Et and η dependence due to detector resolution →parameterization
  - So divide transfer variables into each Et(η) bin and obtain Et(η) dependence of all the fitting parameters

# Transfer functions

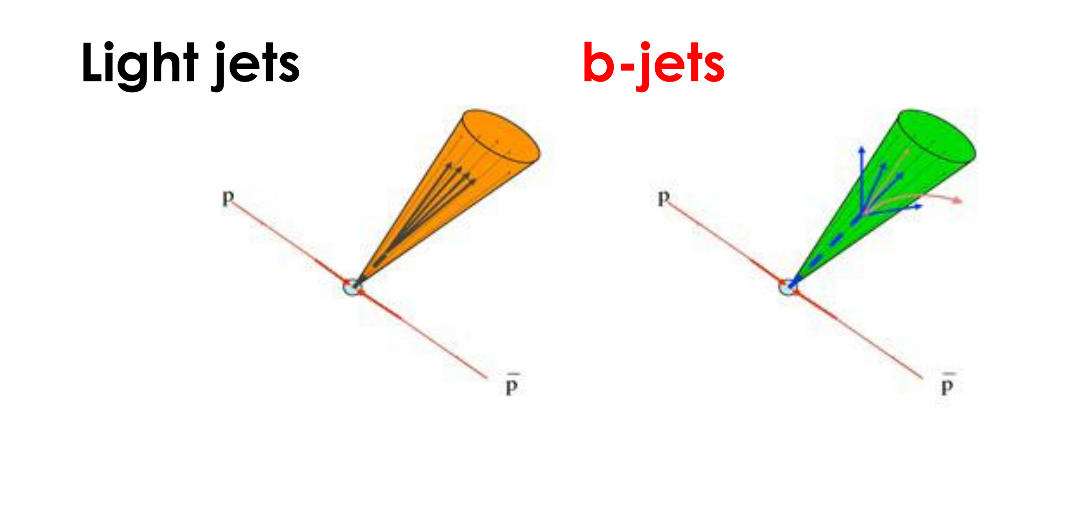
- They have Energy and angular dependence
  - ⇒parameterize with Et and η
- Divide into each Et bin and obtain Et dependence of all the fitting parameters
- e.g.) Et dependence of jets

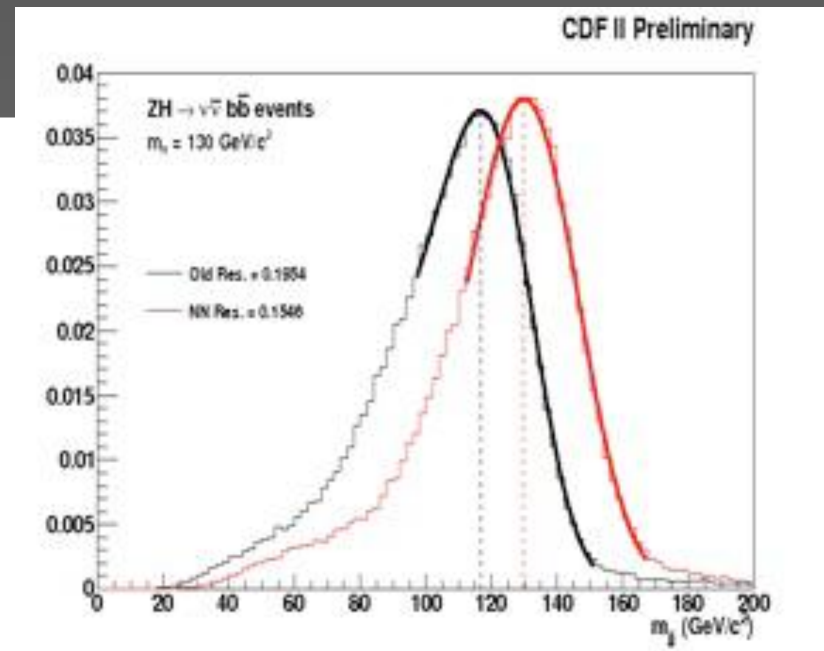
Parameterization



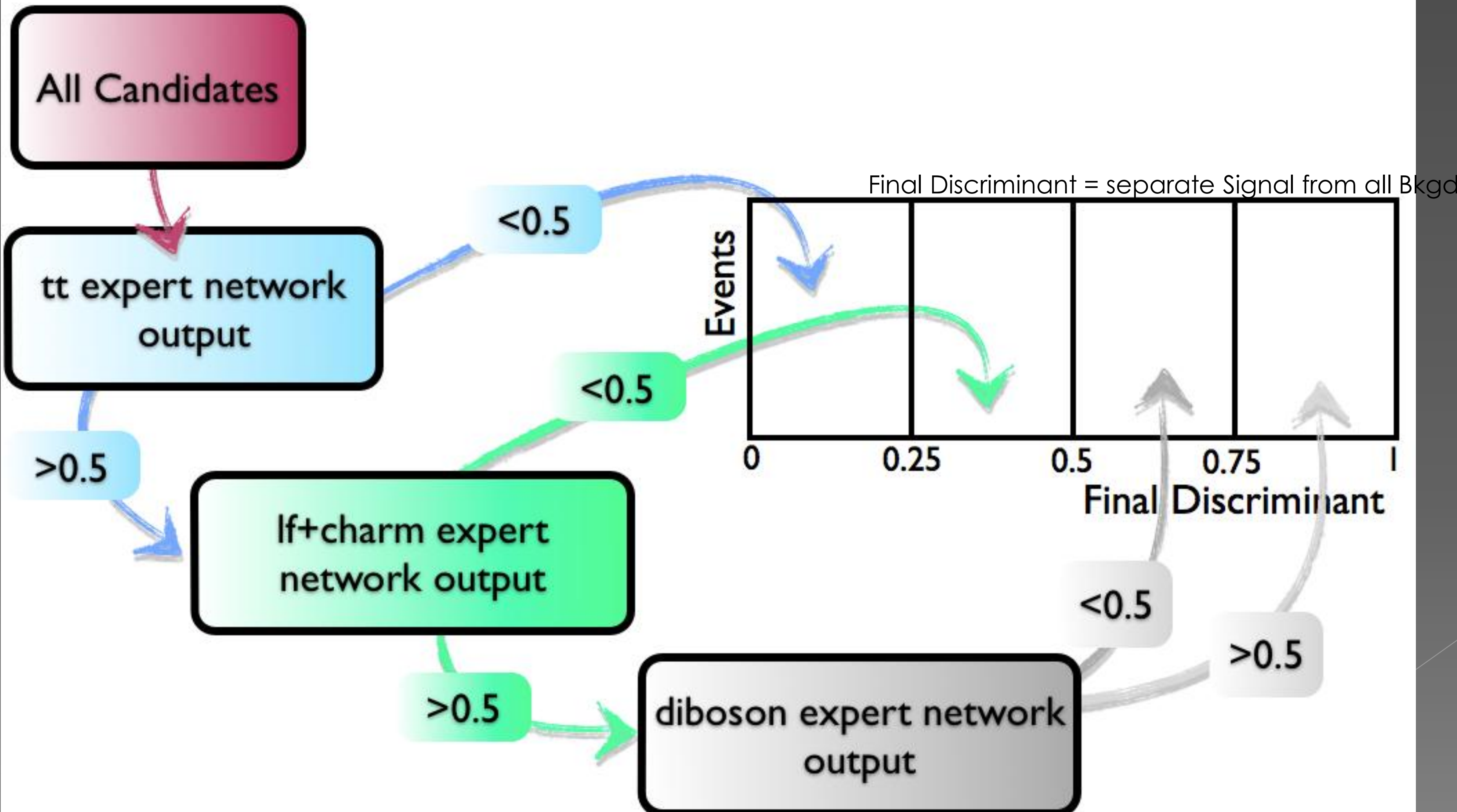
# b-jet resolution

- b-jets property is quite different from light flavored jets
- Use MVA technique to improve the b-jet resolution - ～20% improvement

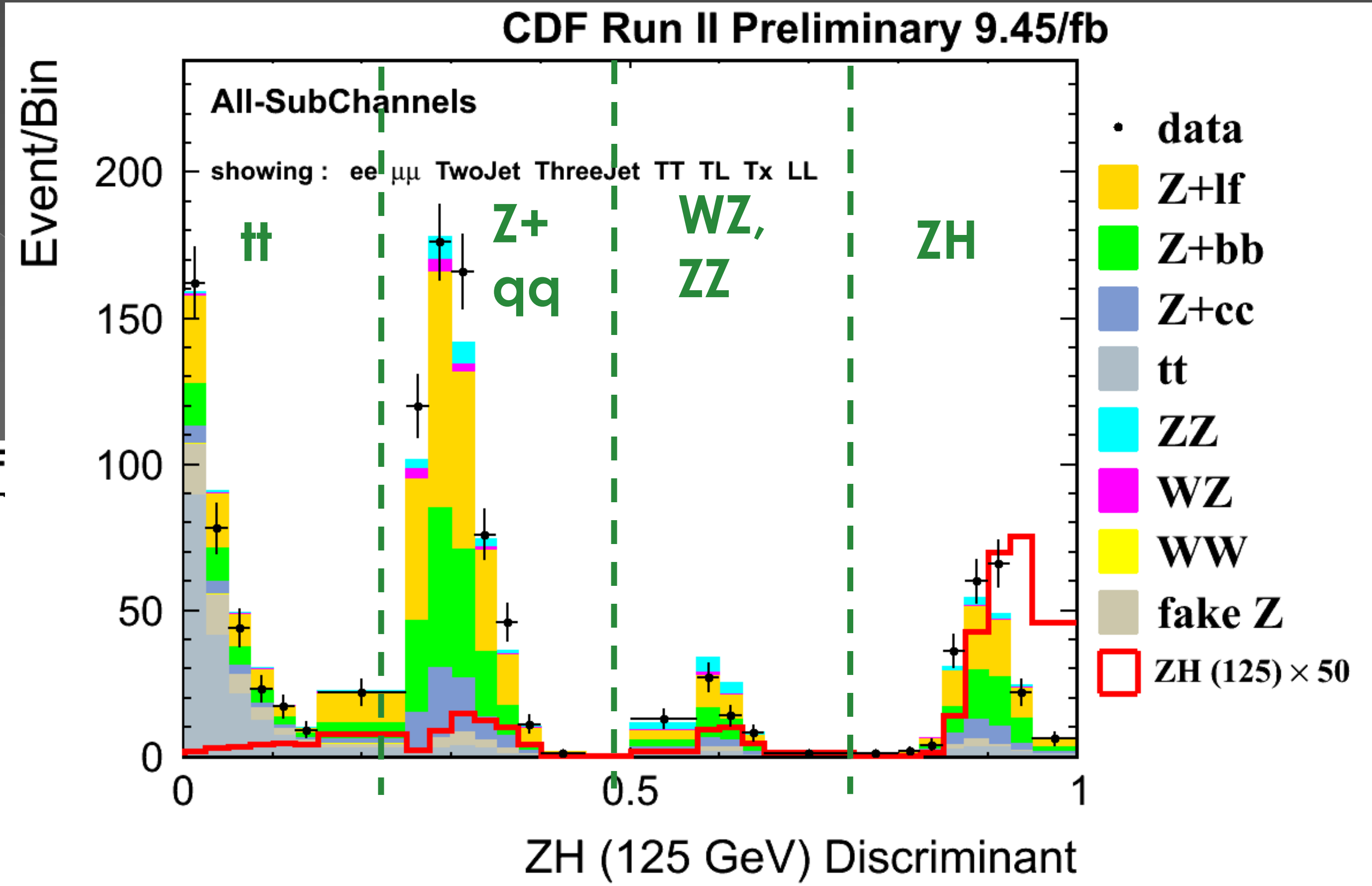


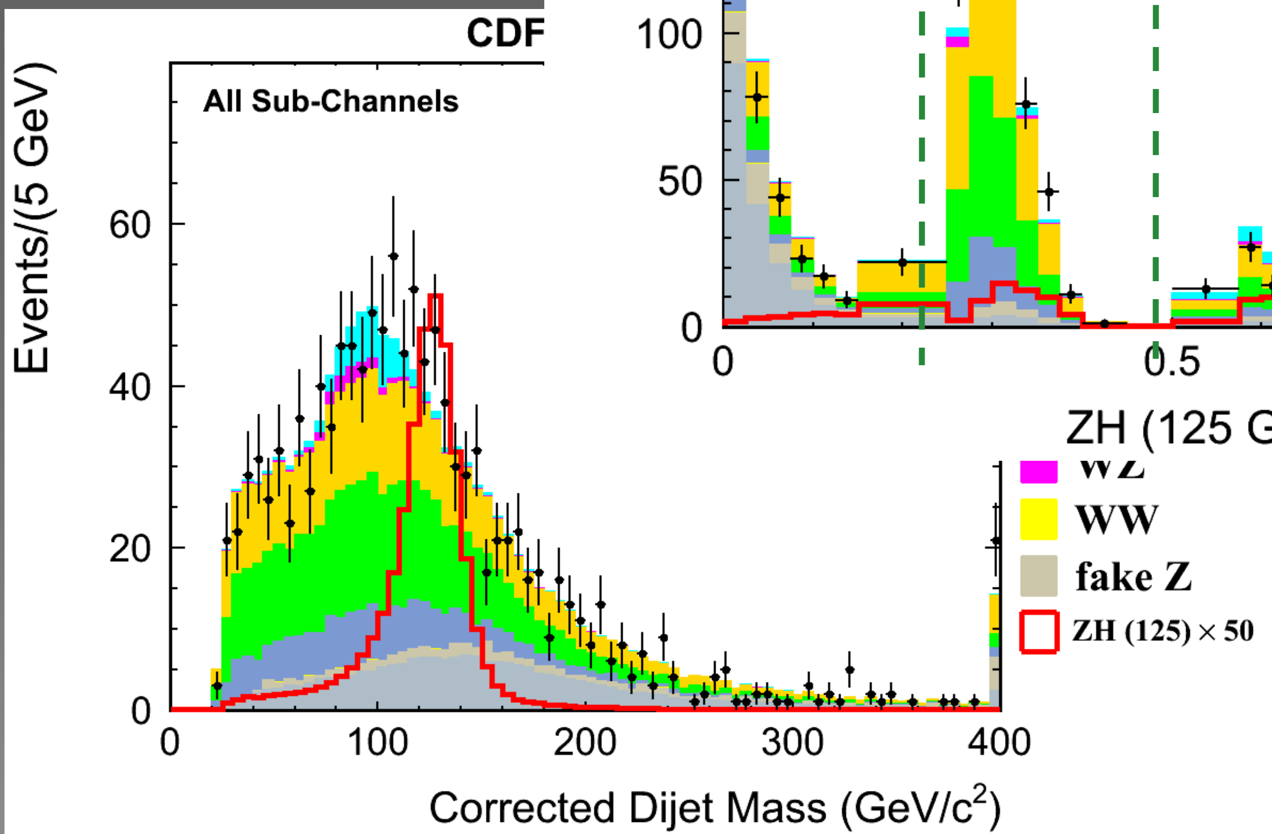



# CDF: $ZH \to l^+l^-b\bar{b}$ Channel



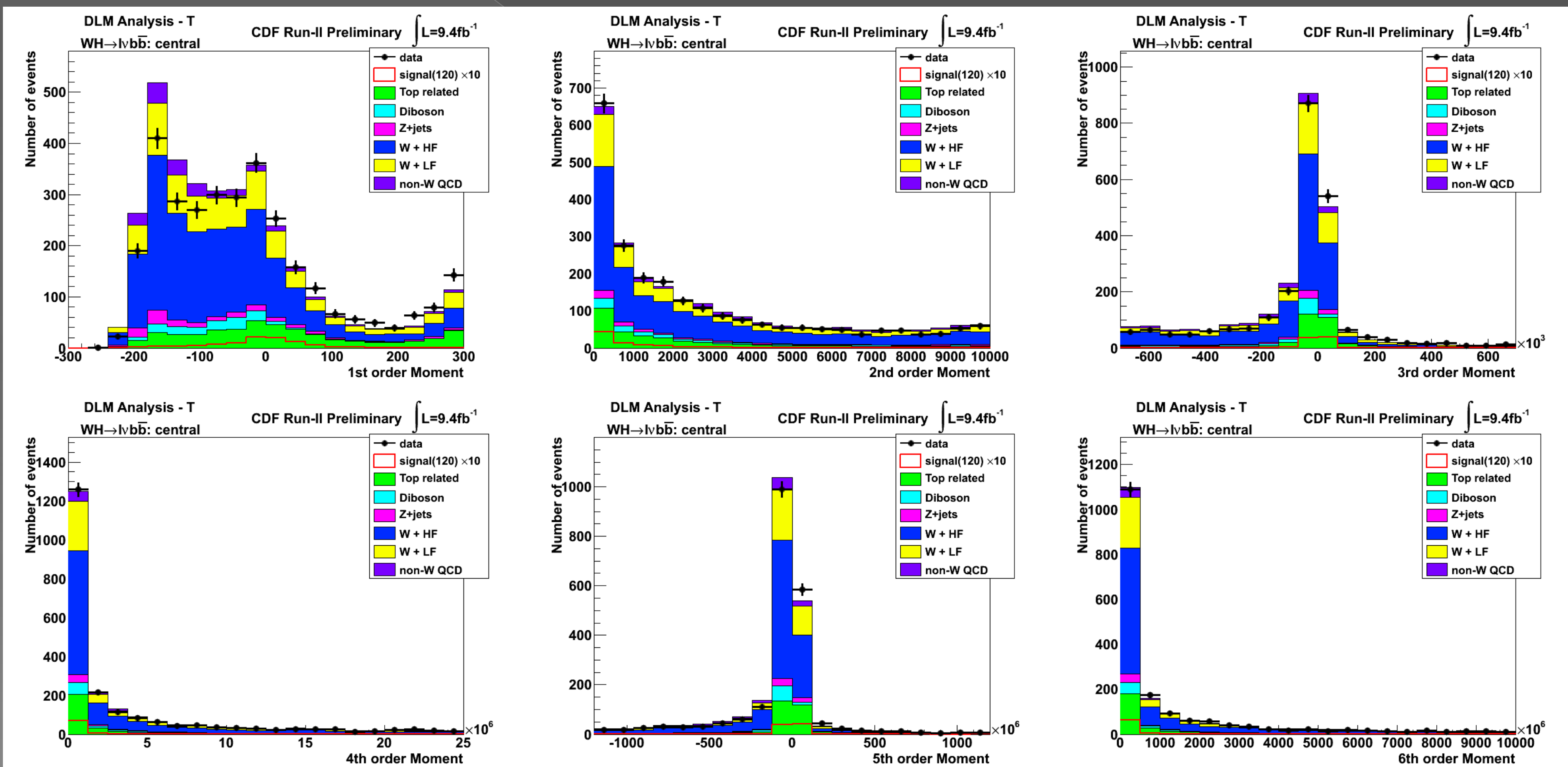
# CDF: $ZH \rightarrow l^+l^-b\bar{b}$ Channel



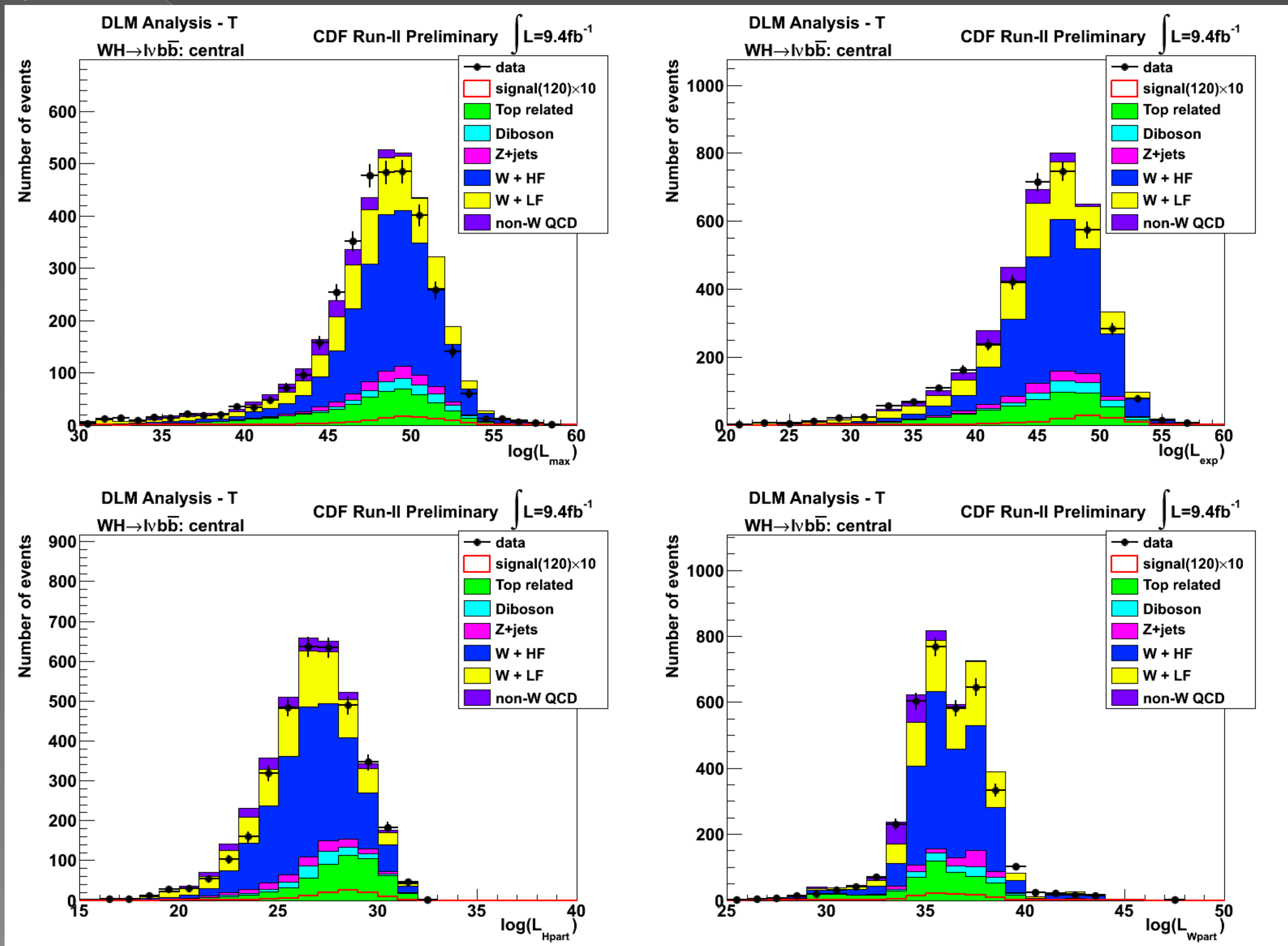
# Localized moment

- Distribution with High stat. tag category(T)
  - Central leptons
  - Localized moment around Higgs expected mass of $m_H$=120GeV case(117.01GeV)



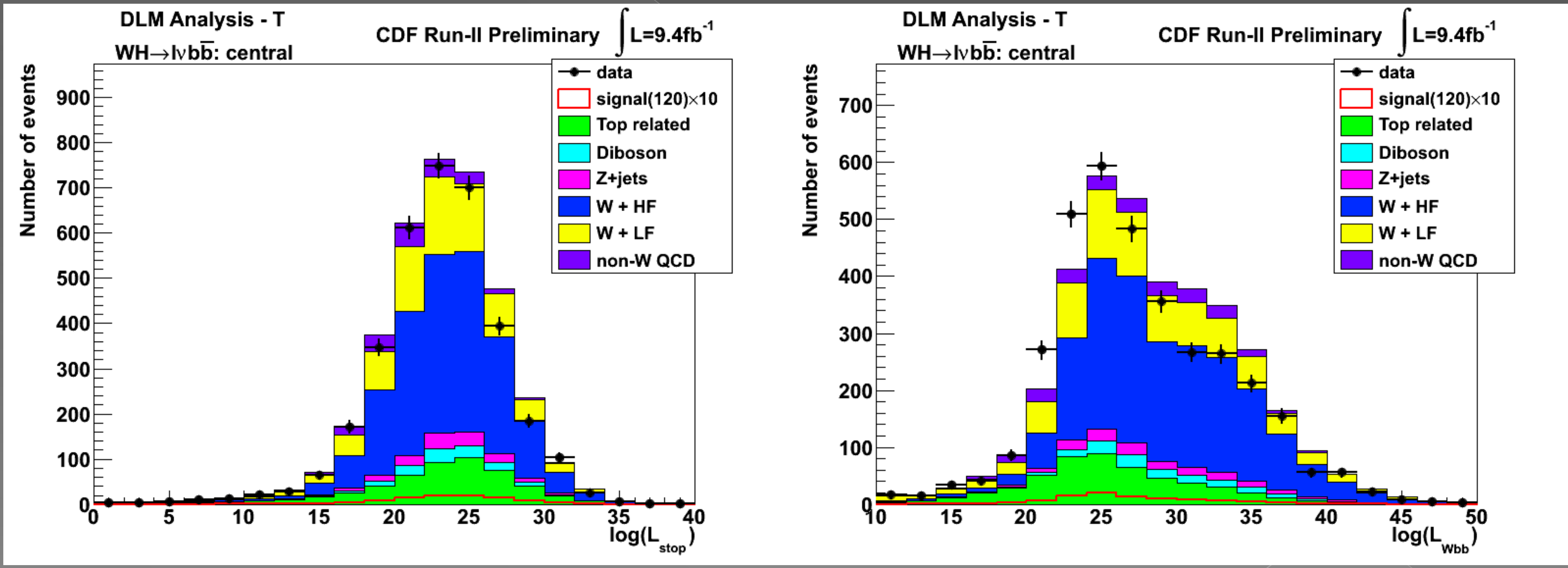
# Likelihoods – from signal M.E.

- Distribution of High stat. tag category(T)
  - mH=120GeV



# Likelihood – from Wbb & Stop M.E

- Distribution check – high stat. tag category(T)
  - Perform DLM using Wbb(leading order) or singletop(s-ch) Matrix Elements



# Old b-tagging technique

- B hadrons fly from primary vertex, and produce secondary vertex
  - Secvtx tag – finding secondary vertex
  - Jetprob – use impact parameter $d_0$ and no secondary vertex required
  - Other taggers – based on N.N.