Search for the Higgs Boson in the WH Channel at the Tevatron DØ Experiment

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Outline

- Introduction
- Analysis Strategy
- b Tagging
- Multivariate Technique
- Final Result

Higgs Boson Production and Decay

Higgs Mechanism

Explanation of the origin of mass by electroweak symmetry breaking

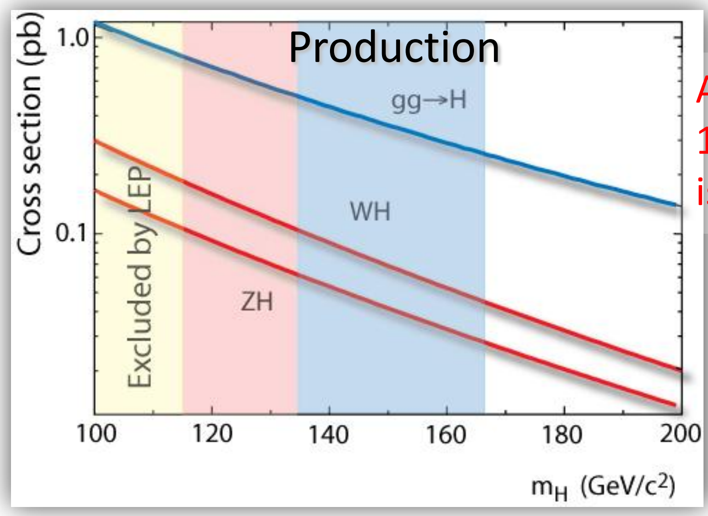
→ Higgs Boson

Higgs production cross section < *1 pb*

Compared to:

- *12 pb* WW
- *7 pb* top quark pair
- *3 pb* single top quark
- *2 pb* ZZ

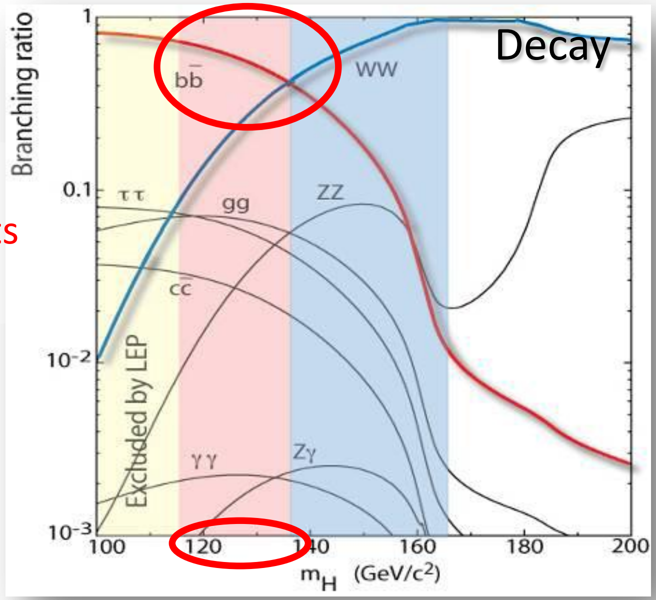
W+jets : main background for WH



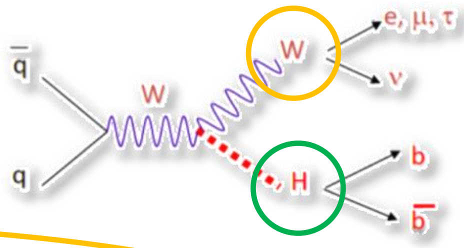
At the Tevatron:
1 of 10^{12} $p\bar{p}$ events
is a Higgs boson

Low mass (m_H < 135 GeV):

1. **Associated production** with a **W** or Z
2. Decay in **b quark pairs**



Event Selection



Topology:

Lepton (e, μ) + $\not{E}_T$ (υ) + 2 b jets

We require one *lepton* with p_T > 15 GeV + missing E_T > 20 GeV

and two b-jets with p_T > 20 GeV

and the sum of their p_T s (H_T) > 60 GeV

Dataset: **5.3 fb^{-1}** of DØ data

Analysis split by lepton flavor

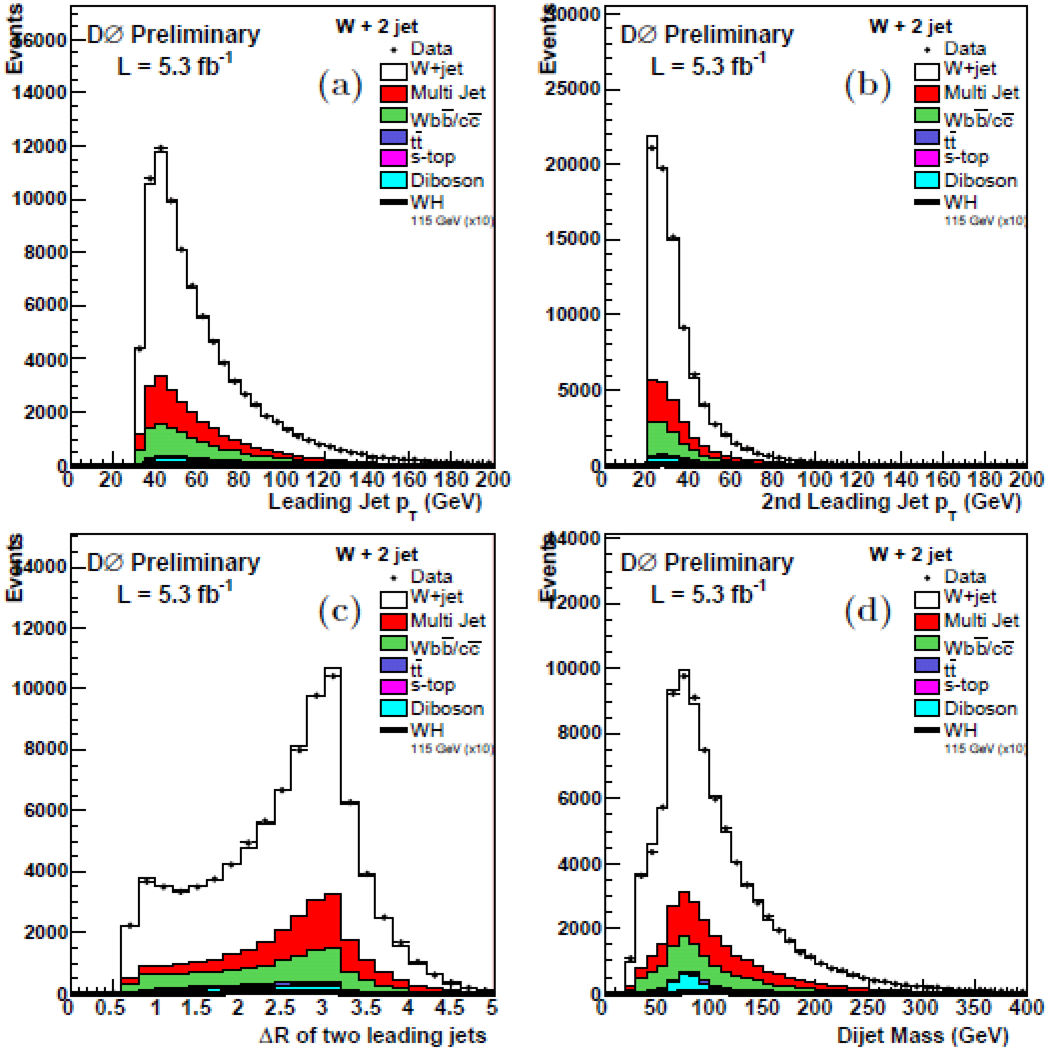
WH Analysis Strategy

Analysis Procedure

- Event selection according to the desired topology
- Construction of a model to describe the analyzed data
  - *Estimation of the multijet background from data*
  - *Monte Carlo Modeling of the background and signal contributions*
- Check of the obtained distributions
- b jet tagging
- Application of a multivariate technique to improve sensitivity

- Limit calculation for $\sigma(p\bar{p} \rightarrow WH) \times \mathcal{B}(H \rightarrow b\bar{b})$

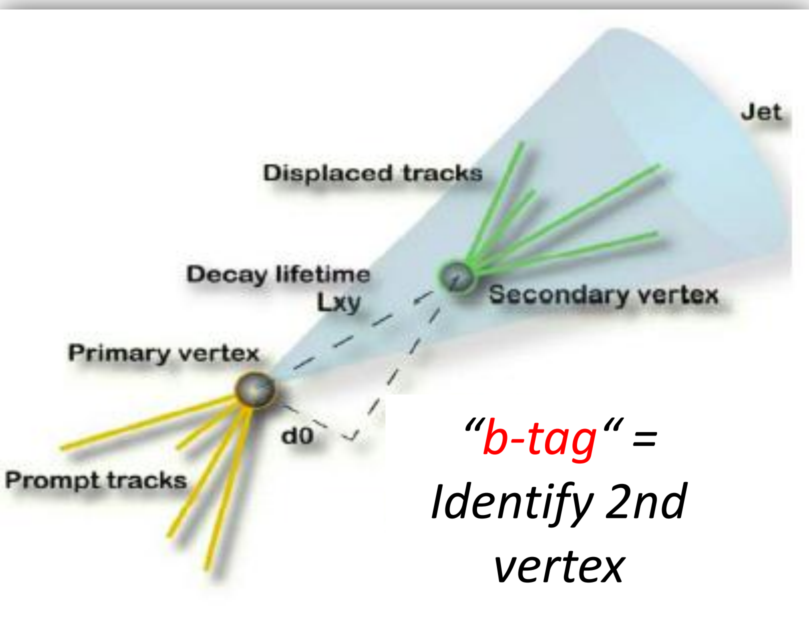
Preselection



S/B ~ 1:4000

Background Reduction: Tagging of b jets

Identification of b-quark jets is crucial for low mass Higgs analyses



"b-tag" = Identify 2nd vertex

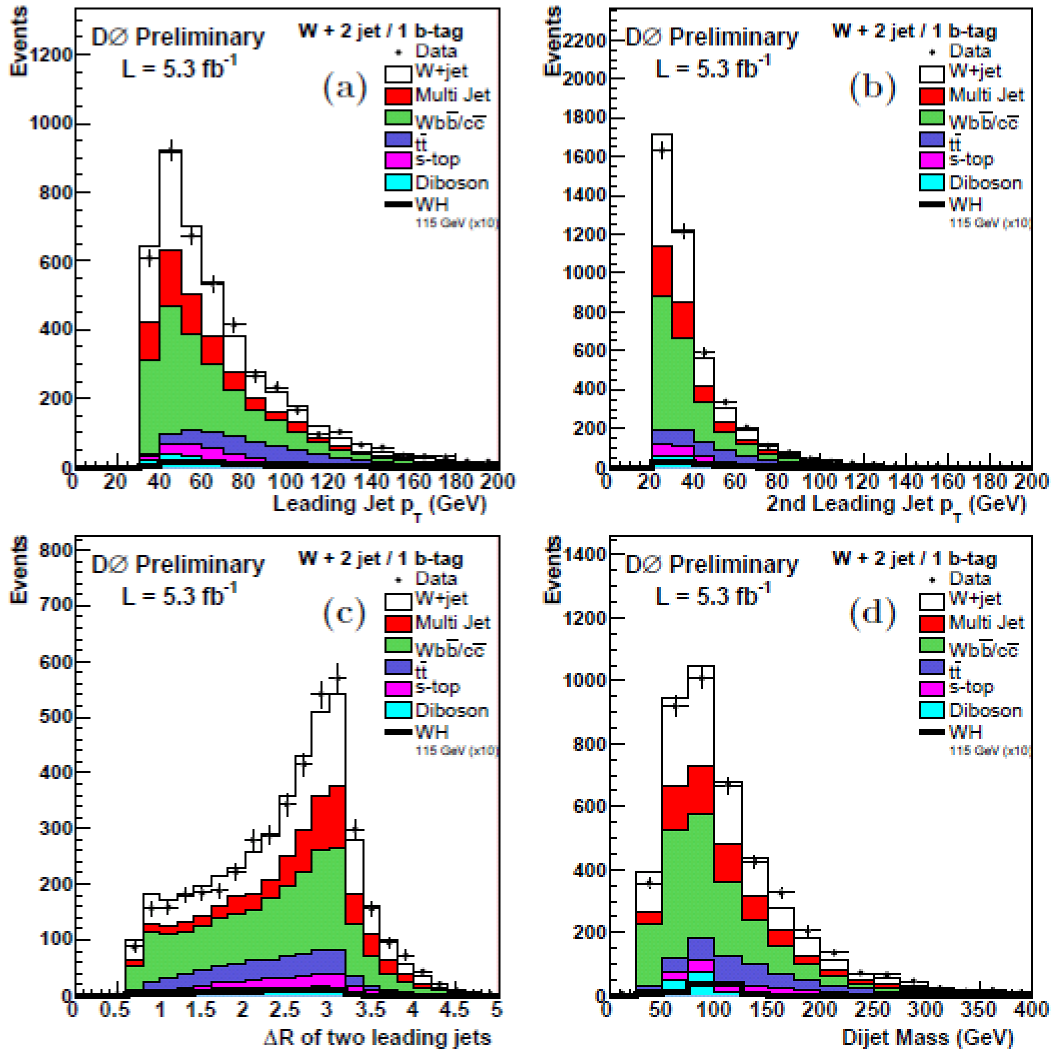
Secondary Vertex tagger,
Jet probability Tagger
➔ Neural Network tagger

Neural Network
flavor separators (reject c vs b)

NN-tagger 50-70% efficient
with 0.3-3% misidentification rate

b-tagged Results

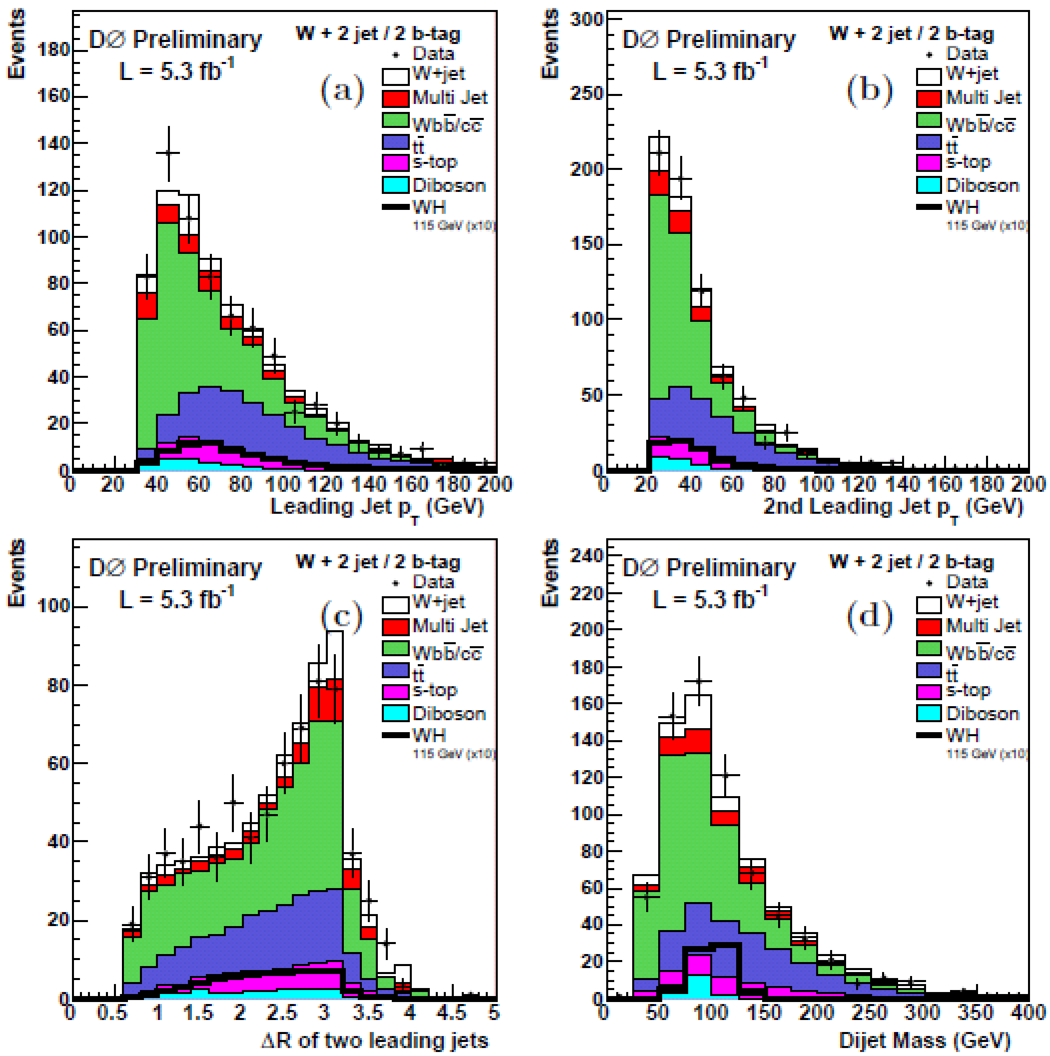
Single Tag



S/B ~ 1:400

b-tagged Results

Double Tag



S/B ~ 1:100

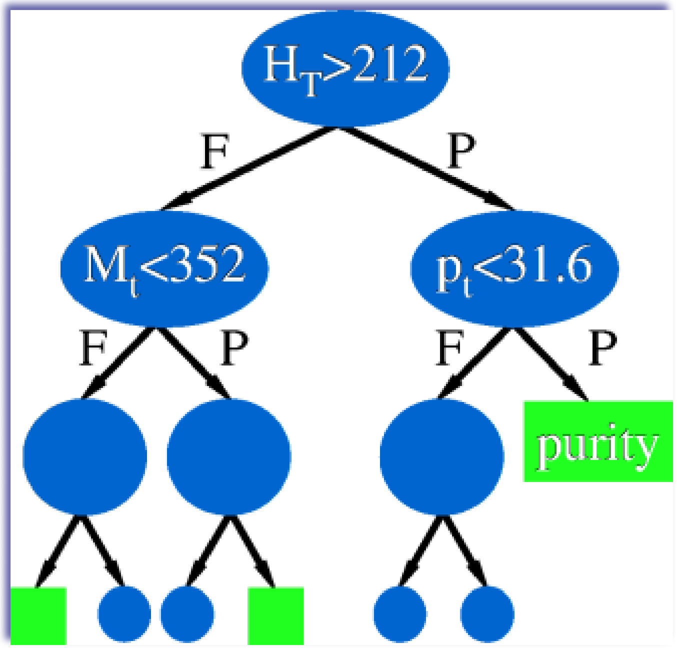
Multivariate Analysis: Random Forest

Signal / Background ratio is << 1

➔Introduction of advanced techniques of data analysis

Random Forest

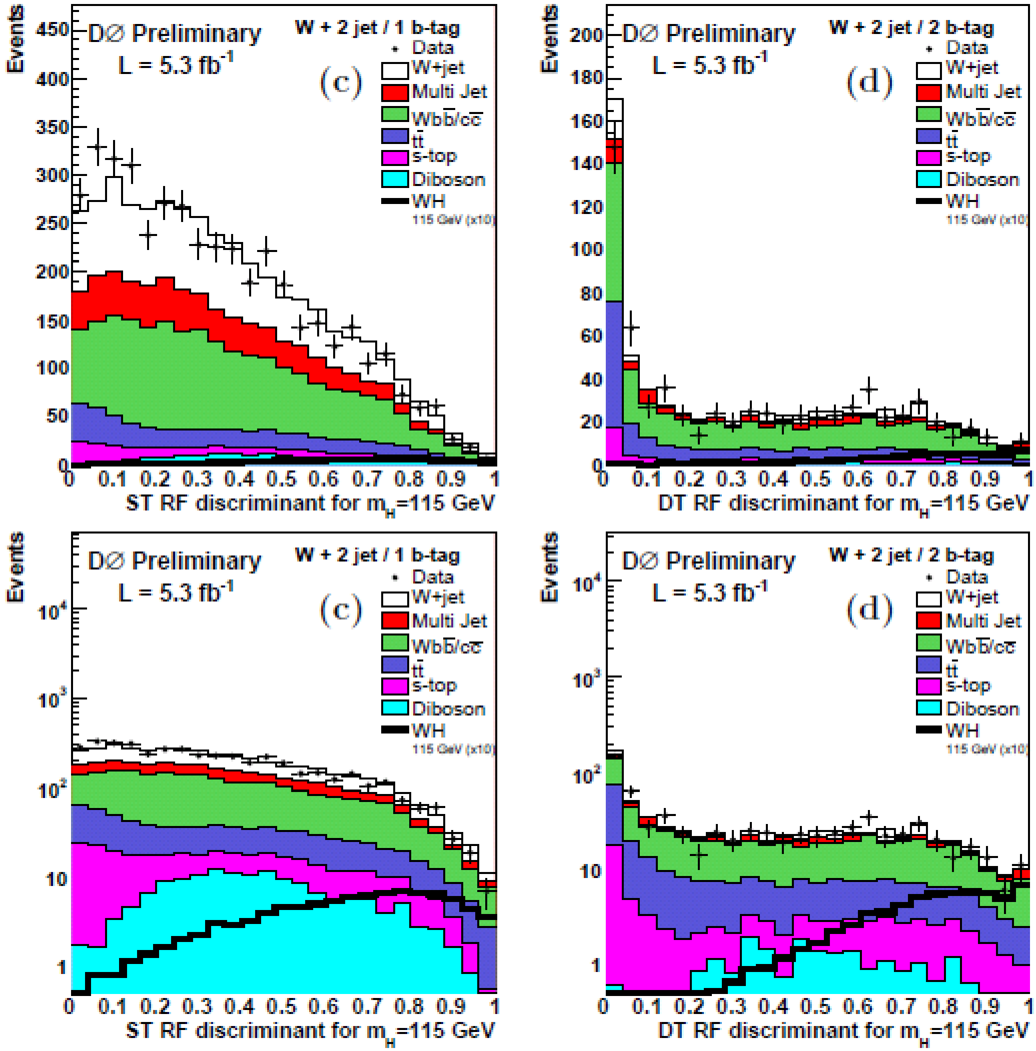
- Classify events into signal and background according to specific cuts on a number of variables
- Randomly choose a subset of events and variables for each tree
- Combine many trees to avoid training instabilities



Random Forest Output

Linear Scale

Log Scale



1 tag

2 tag

Limit Setting

No signal observed:

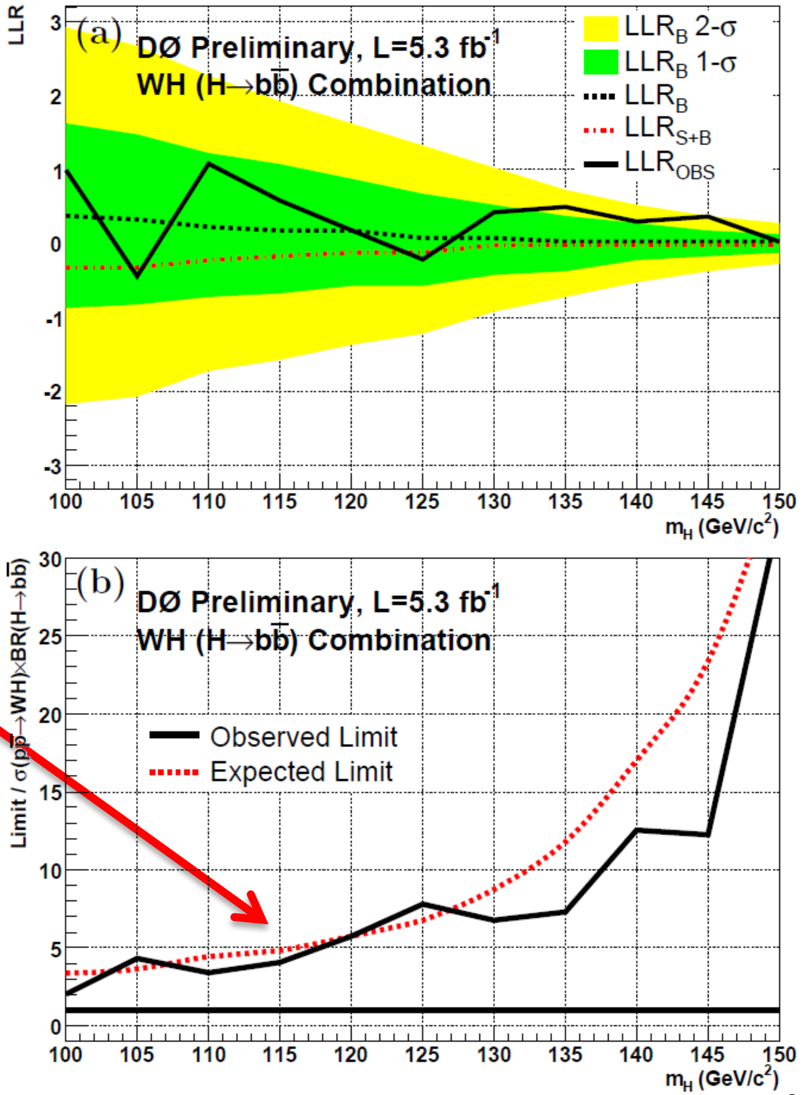
We set limits on σ (pp→WH) x $\mathcal{B}$ (H→b$\bar{b}$)

in units of the SM prediction

using a modified Frequentist approach (**CL_s method**)

WH Analysis Limits

m_H (GeV)	expected 95% C.L. Limit/SM	observed 95% C.L. Limit/SM
100	3.4	2.0
105	3.6	4.3
110	4.4	3.4
115	4.8	4.1
120	5.7	5.7
125	6.8	7.8
130	8.7	6.8
135	11.8	7.3
140	17.0	12.6
145	23.4	12.2
150	36.2	32.7



Conclusion

- The Higgs mechanism could explain the origin of mass
- Discovery or exclusion is crucial for particle physics
- WH analysis one of the most important analyses in the low mass region
- Competitive results using a Random Forest method
- With increasing luminosity and ongoing efforts of improvement a SM Higgs exclusion or evidence at low mass possible at the Tevatron in the coming year(s)

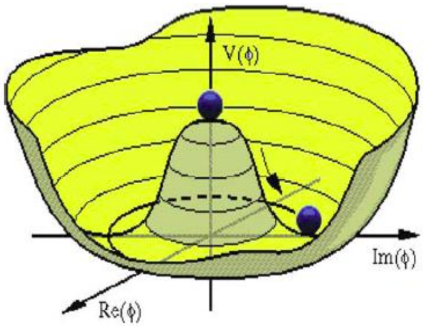
BACKUP

The Standard Model

The $SU(2)_L \times U(1)_Y$ electroweak symmetry is not an exact symmetry of the vacuum, otherwise *particles* were *massless*.

From experiments we know: **particles have a mass!**

→ modify our theory



Introduction of the **Higgs mechanism**

Why?
Simplest model that conserves gauge invariance.

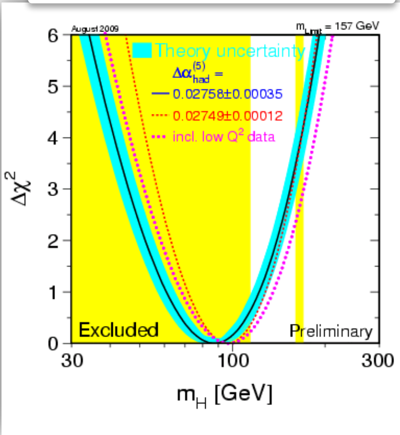
→ Introduces a new particle: the **Higgs boson**

But not the only solution, e.g. SUSY

Higgs Mass

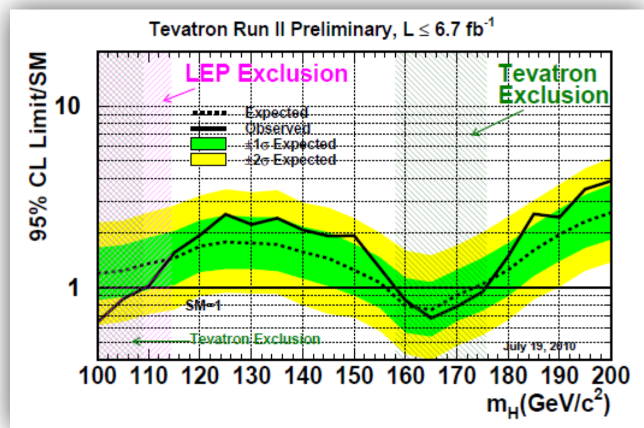
The **Higgs mass is not known** from theory
But: Experimental constraints

Precision EW fit:
$m_H < 157$ GeV

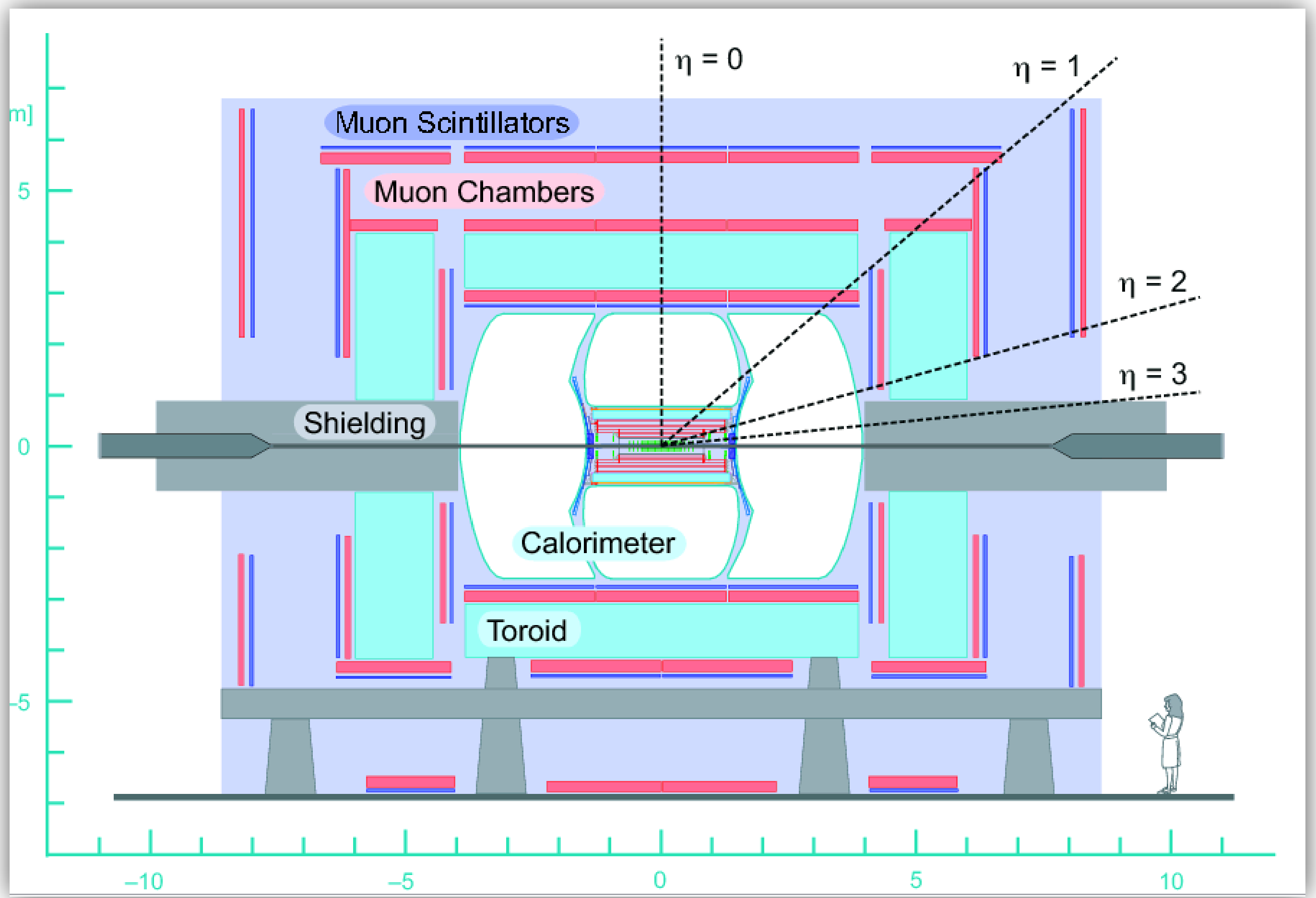


- **Indirect limits**:
  Electroweak precision measurements.
  Constraints from top quark, W boson masses

- **Direct limits**:
  LEP: $m_{Higgs} > 114$ GeV @ 95% C.L.
  TEV: $m_{Higgs} \neq [158;175]$ GeV @ 95% C.L.



DØ Detector



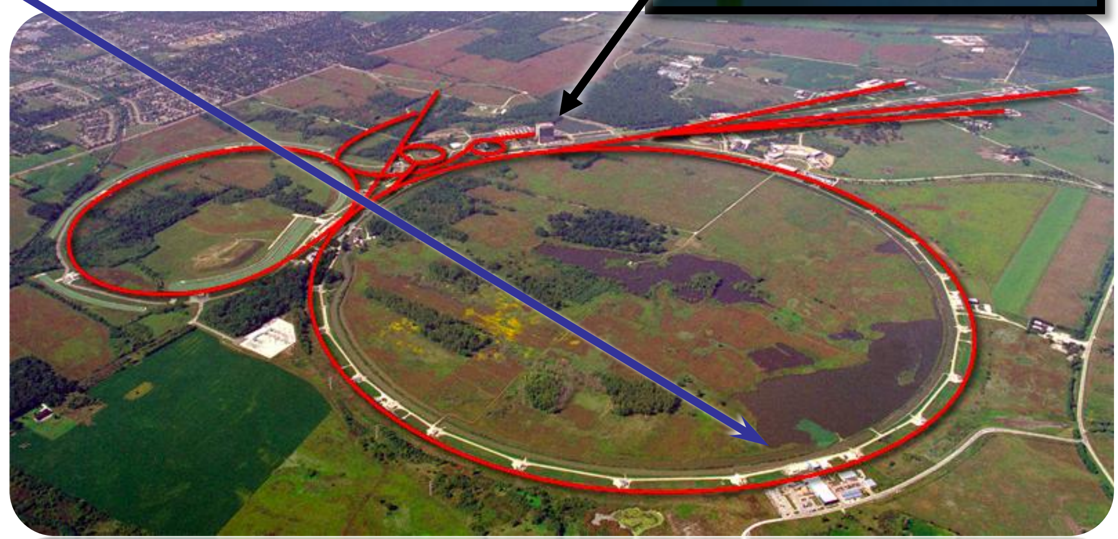
η = 0
η = 1
η = 2
η = 3
Muon Scintillators
Muon Chambers
Shielding
Calorimeter
Toroid
m]
5
0
-5
–10
–5
0
5
10

Fermilab, the Tevatron and DØ

The Tevatron at Fermilab is currently the world‘s most powerful particle accelerator (that works ;-))

Proton – Antiproton collisions with a center of mass energy of 1.96 TeV

Two experiments: CDF et **DØ**



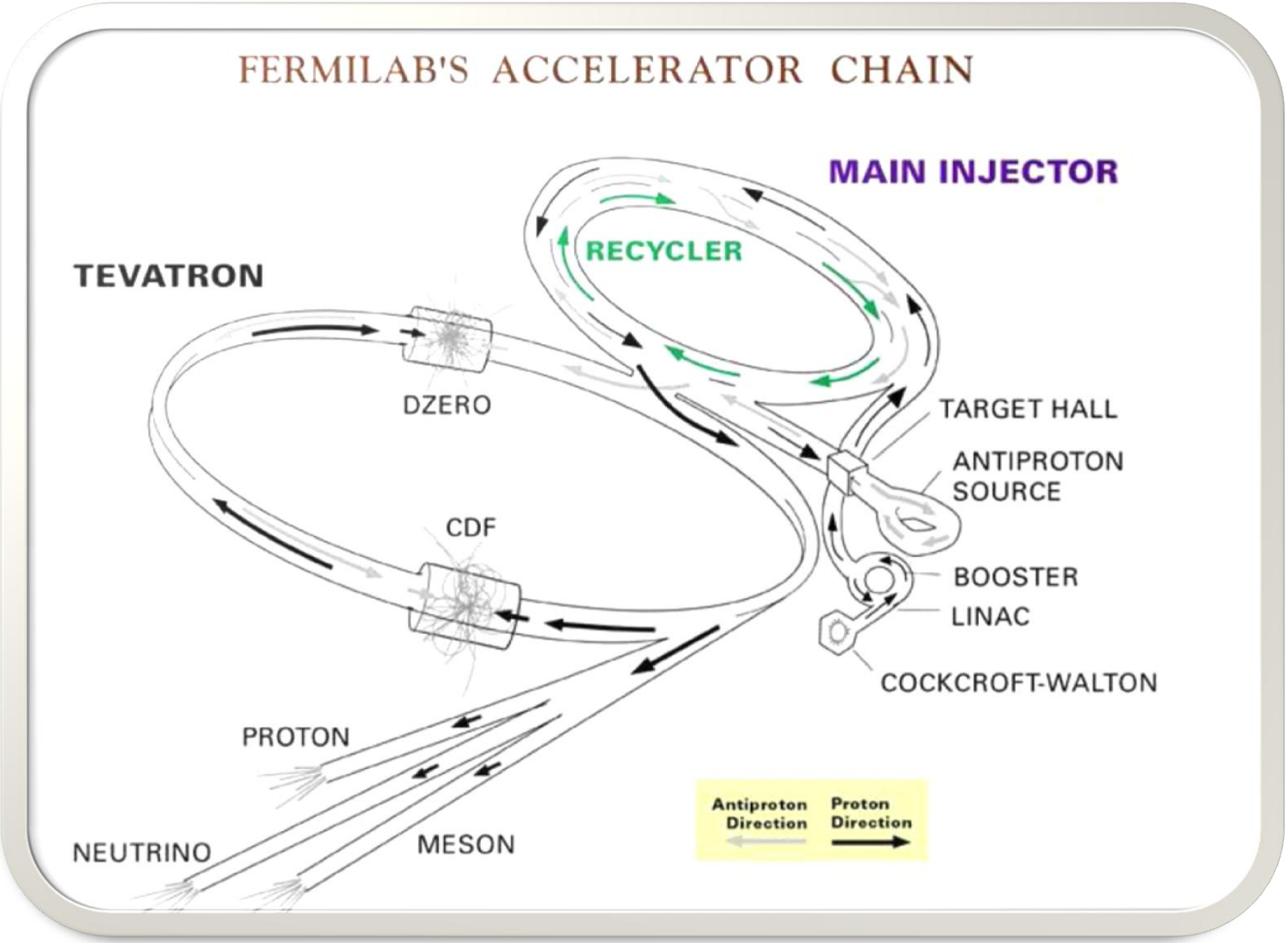
<u>Important discoveries at Fermilab</u>:

Bottom Quark (1977),

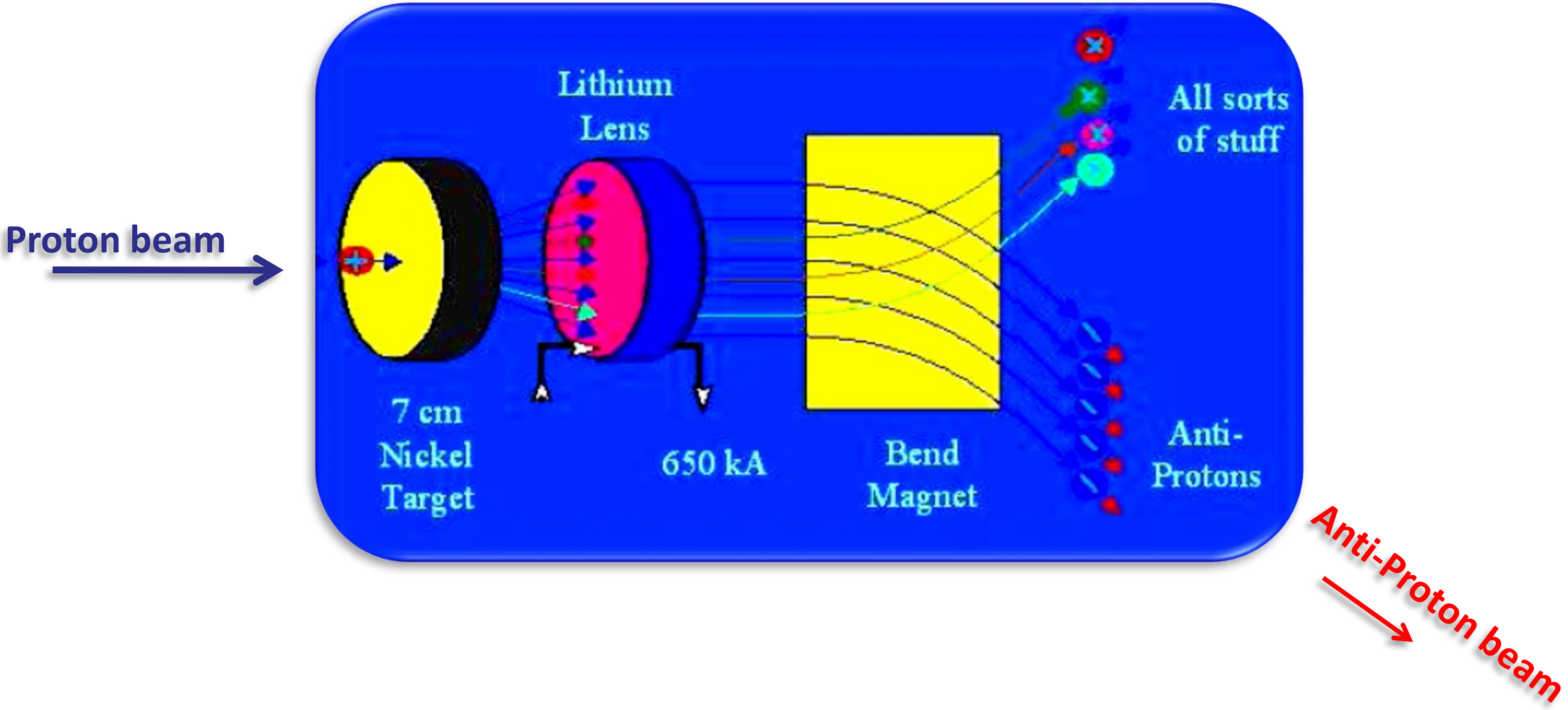
Top Quark (1995) and

Tau Neutrino (2000)

Tevatron


FERMILAB'S ACCELERATOR CHAIN
MAIN INJECTOR
RECYCLER
TEVATRON
DZERO
CDF
TARGET HALL
ANTIPROTON SOURCE
BOOSTER
LINAC
COCKCROFT-WALTON
PROTON
NEUTRINO
MESON
Antiproton Direction
Proton Direction

How are Anti-Protons created at the Tevatron?



Data and MonteCarlo

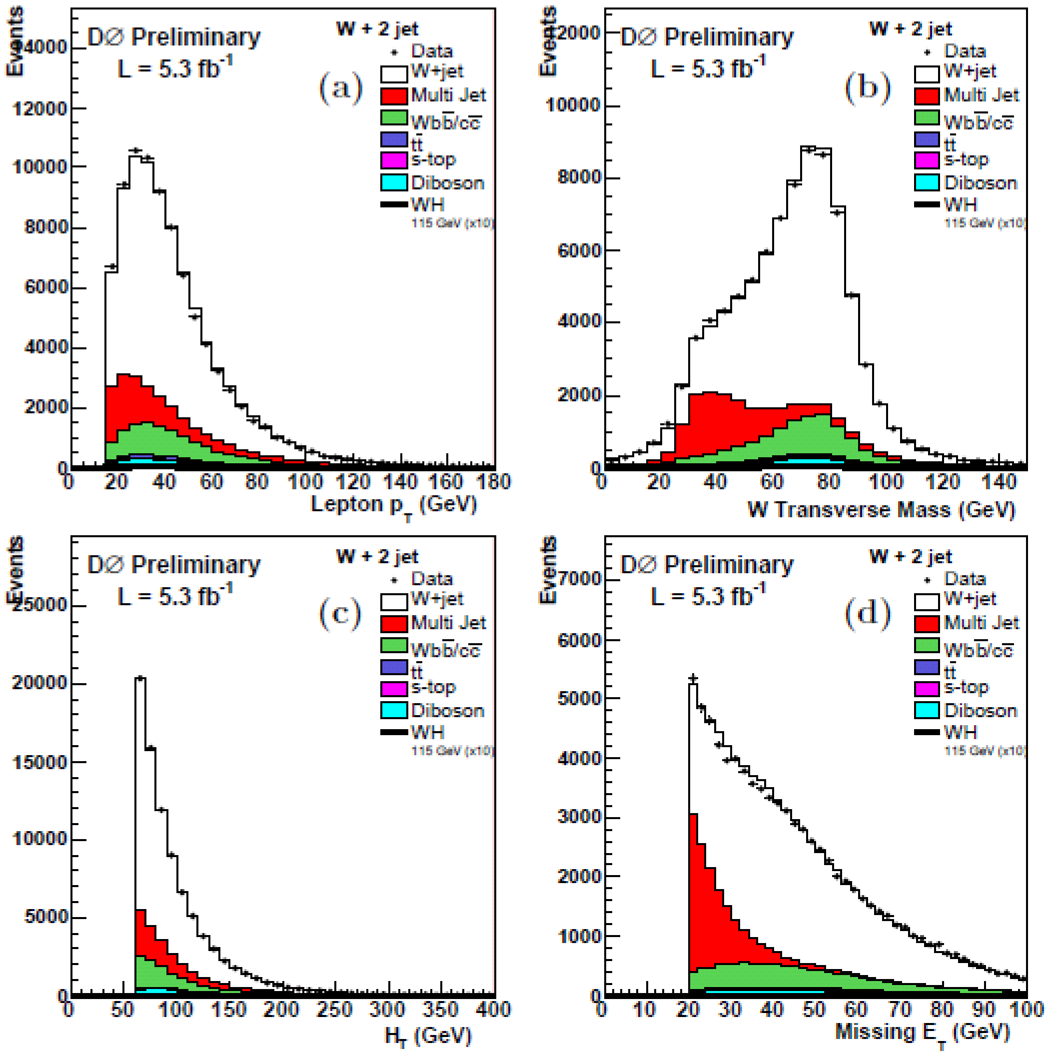
The **DATASET** we use is the full DØ “Run IIb“ dataset with **$5.3\ fb^{-1}$**

The *simulated dataset* consists of many samples for the different background processes

• **Exclusive WW/WZ/ZZ processes**	PYTHIA
• **Exlusive WH $\rightarrow \ell\nu\ b\bar{b}$**	PYTHIA
• **Exlusive ZH $\rightarrow \ell\ell\ b\bar{b}$**	PYTHIA
• **W + jets and Z + jets**	ALPGEN+PYTHIA
• **$t\bar{t}$**	ALPGEN+PYTHIA
• **single top**	COMPHEP

The simulated background samples are normalized to the SM predictions for their cross sections
Except: W + jets is normalized to data

Preselection



Limit Setting Procedure

Method: ***two hypotheses*: background only (b) or signal plus background (s+b)**
using Poisson statistics to account for systematic uncertainties

Test statistics of the type **log-likelihood ratio (LLR)**

$$LLR = -2 \ln \frac{p(\mathrm{data}|H_1)}{p(\mathrm{data}|H_0)},$$

We use the CL_S modified frequentist approach

$$CL_b = p(LLR \geq LLR_{obs}|H_0)$$
$$CL_{s+b} = p(LLR \geq LLR_{obs}|H_1)$$

$$CL_s = \frac{CL_{s+b}}{CL_b}$$