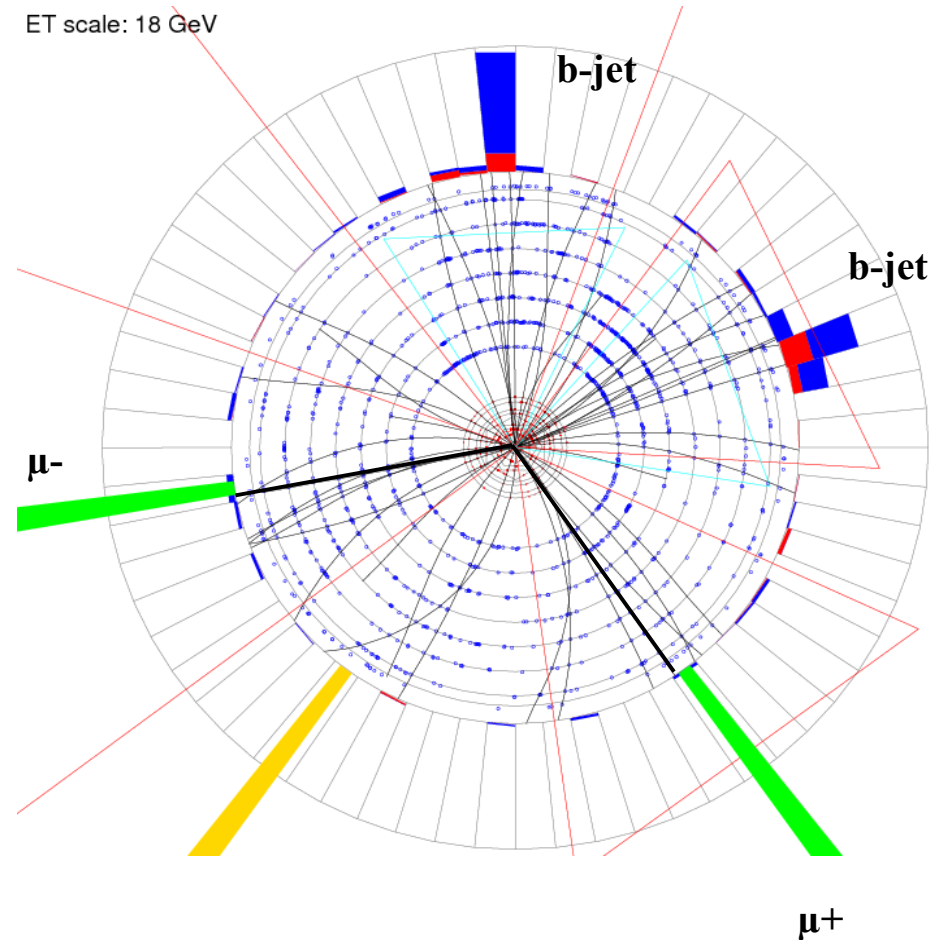
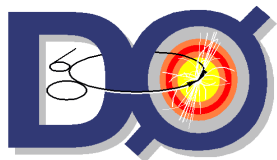


The Search for the SM Higgs Boson at DØ

Dr. Andy Haas
Columbia University
DØ / ATLAS

U. Penn
Particle Physics Seminar
February 5, 2008



The Standard Model

3 families of matter

3 forces

- "gauge symmetries":
 $U(1)_Y \times SU(2)_L \times SU(3)_C$

Massive W,Z gauge bosons

Quarks	<i>u</i> up	<i>c</i> charm	<i>t</i> top
	<i>d</i> down	<i>s</i> strange	<i>b</i> bottom
Leptons	ν_e e- Neutrino	ν_μ μ- Neutrino	ν_τ τ- Neutrino
	<i>e</i> electron	μ muon	τ tau
			I II III The Generations of Matter

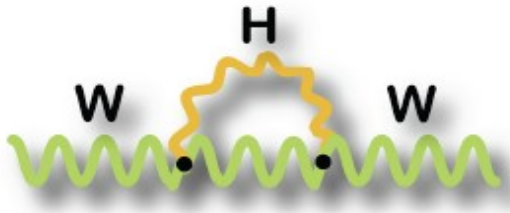
Scalar Higgs field, non-zero VEV

- W,Z get masses through "Higgs mechanism"
- Fermions can get Yukawa masses: $-\frac{1}{v} m_f \bar{\Psi}_f \phi_h \Psi_f$

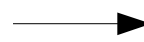
Higgs boson: excitation of the Higgs field - m_H

Higgs Mass Constraints

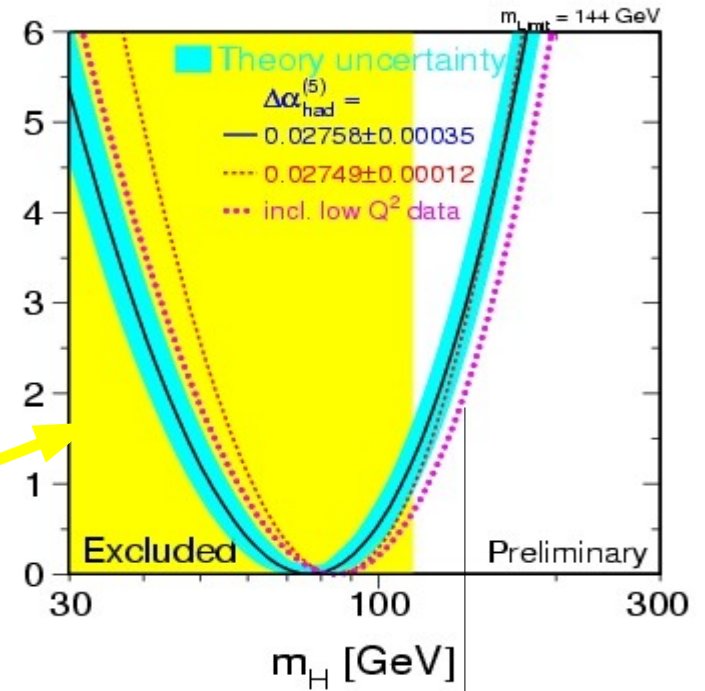
EW variables sensitive to m_H via radiative corrections:



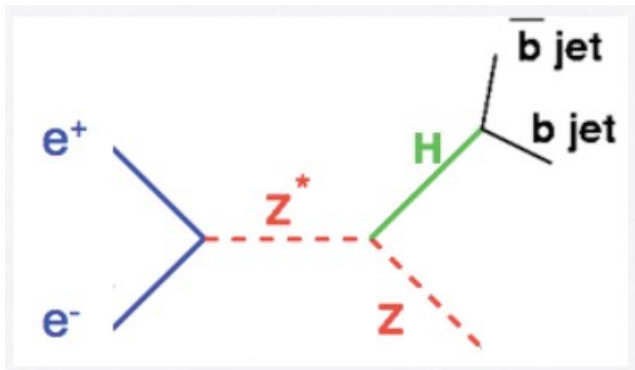
$$\log \frac{m_H}{m_Z}$$



$\Delta\chi^2$



LEP II direct: $m_H > 114.4$ GeV

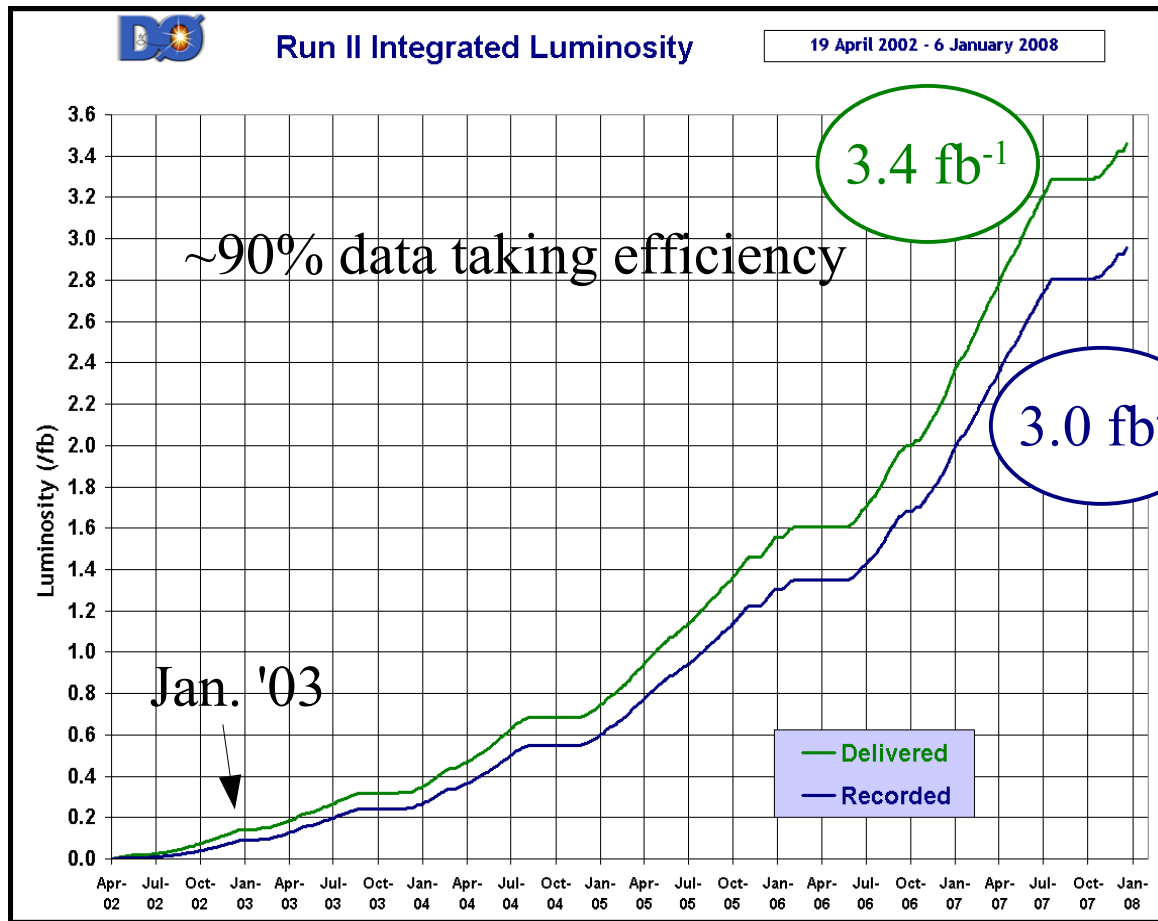


$m_H < 144$ GeV
(at 95% CL)

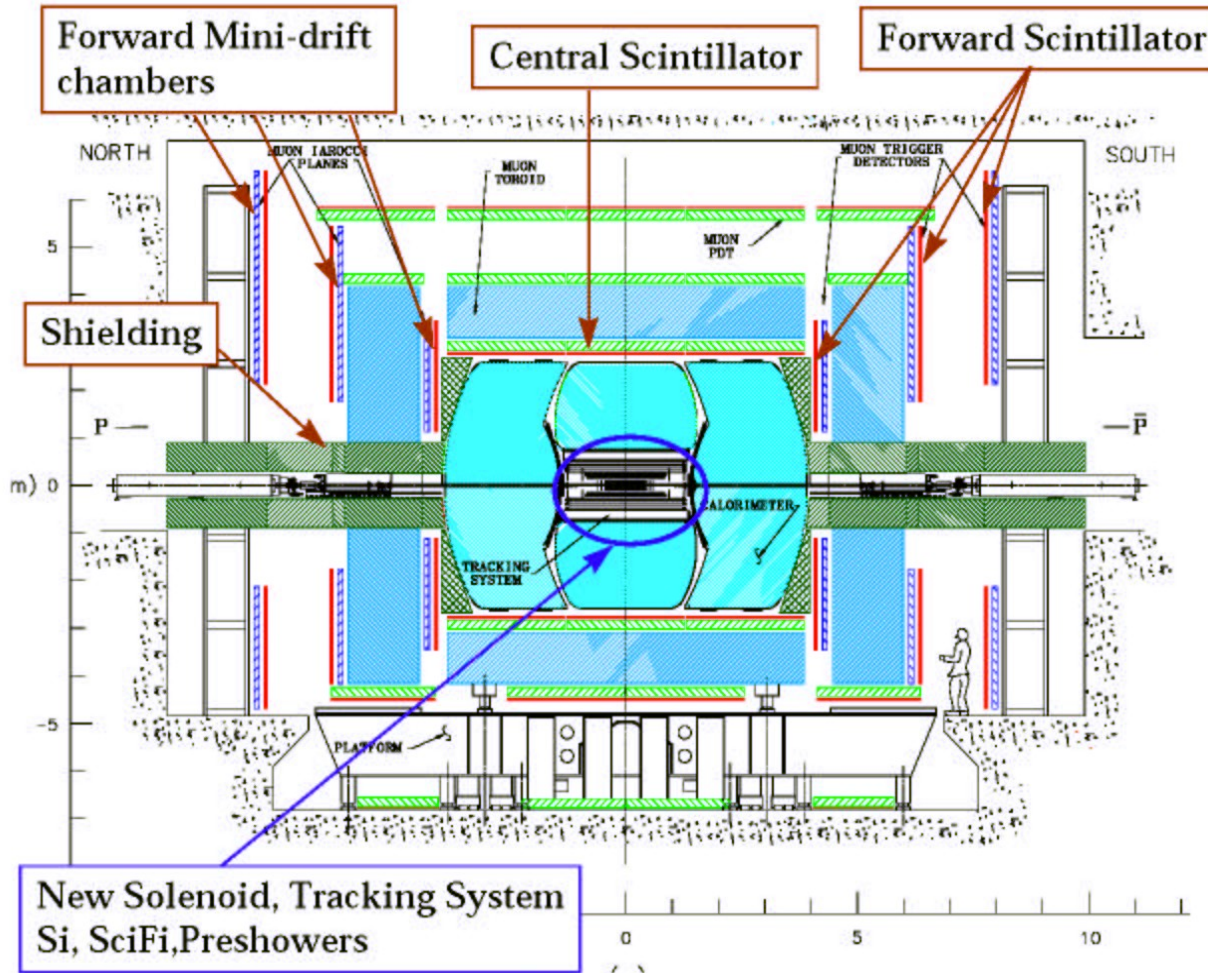
$m_H < 182$ GeV (including direct limit)

The Tevatron at Fermilab

Running (again) since ~2003
proton on anti-proton
 $\sqrt{s}=1.96$ TeV



The DØ Detector



Retained from Run I

- LAr calorimeter
- Central muon detector
- Muon toroid

New for Run II

- Magnetic tracker
- 2 T solenoid
- Silicon vertex tracker
- Scintillating fiber tracker

b-jet tagging

- Preshower detectors
- Forward muon detector
- Front-end electronics
- Trigger and DAQ

1000 Hz

Level 3
Trigger Farm

100 Hz

The DØ Collaboration

600 physicists from 18 nations

100 postdocs and 140 students



2005-2007
~20 people
~10 students

Track/Vertex **b-Tagging**

Muon Calorimetry

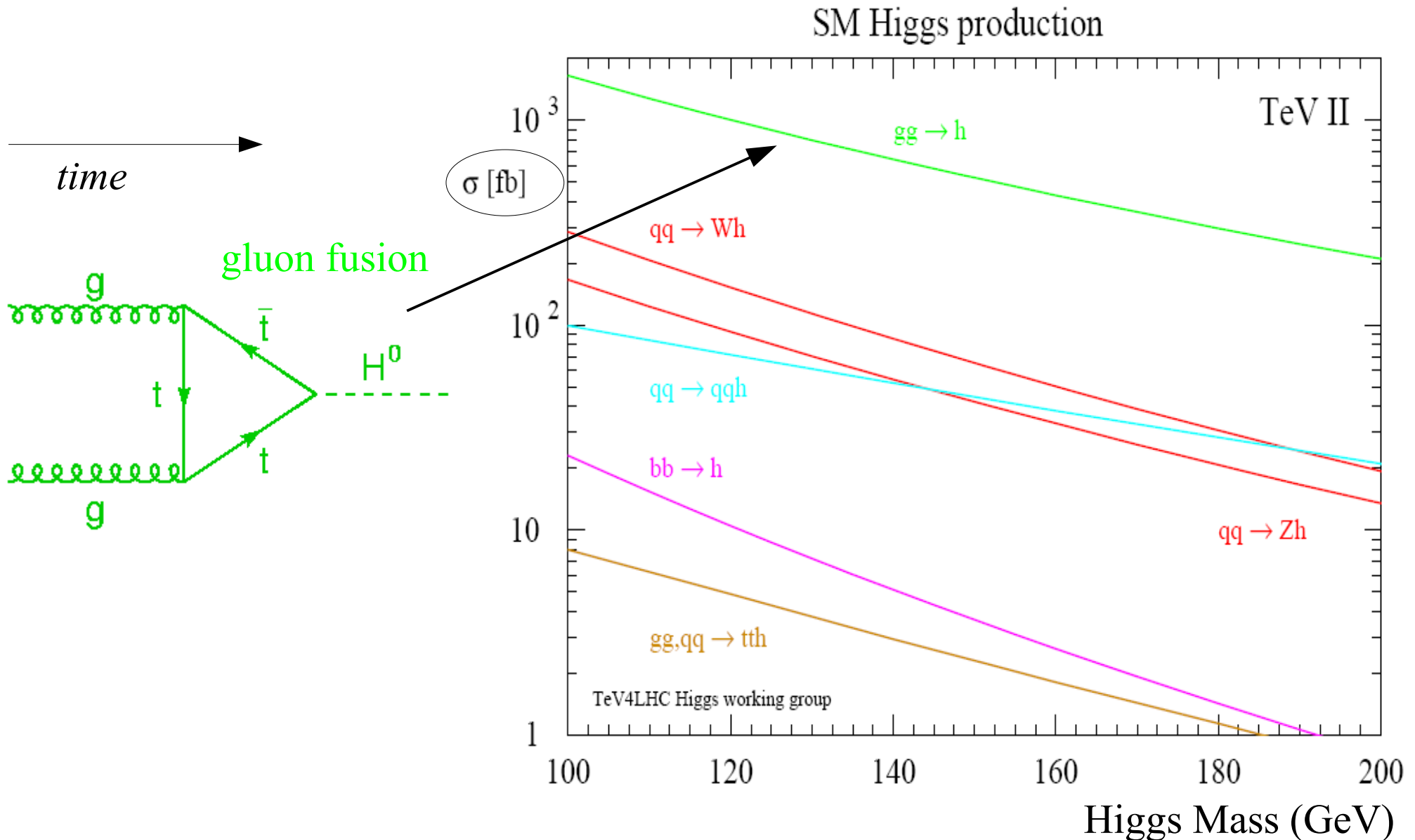
2007-
~200 people
~70 students

b-Physics Top **Higgs**

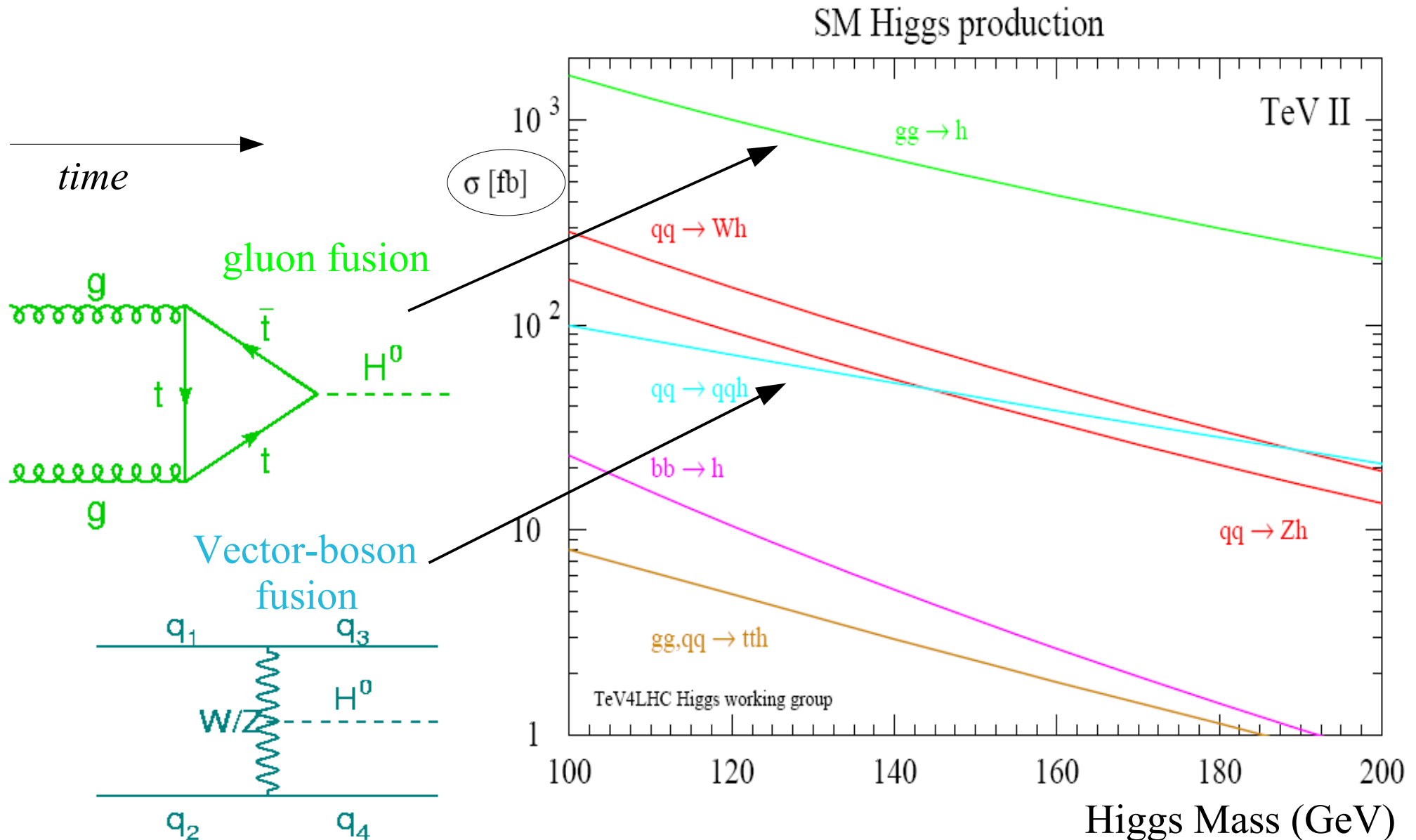
New Phenomena W/Z QCD

Finding the Higgs is now the main goal for DØ

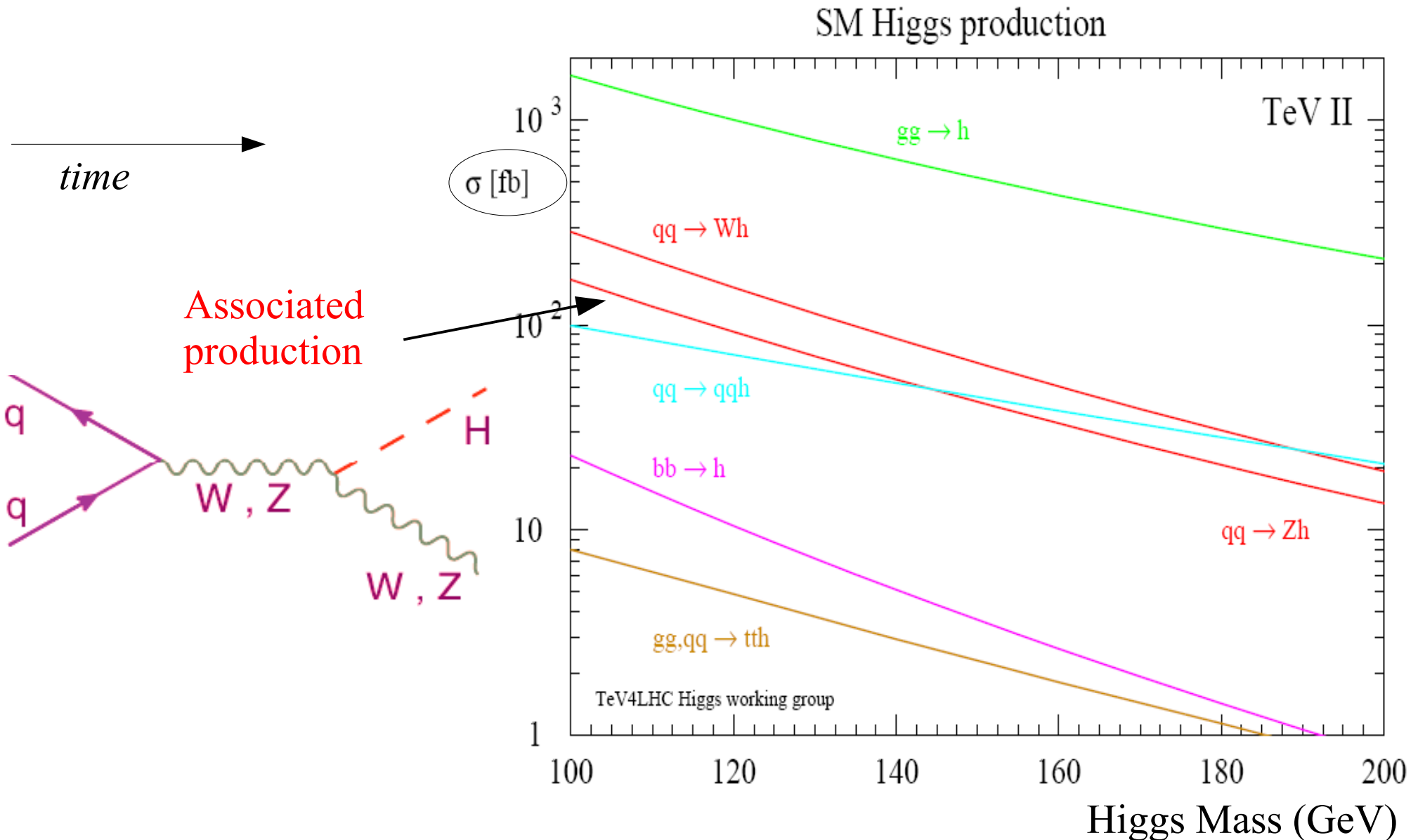
Higgs Production at the Tevatron



Higgs Production at the Tevatron



Higgs Production at the Tevatron



Higgs Decays

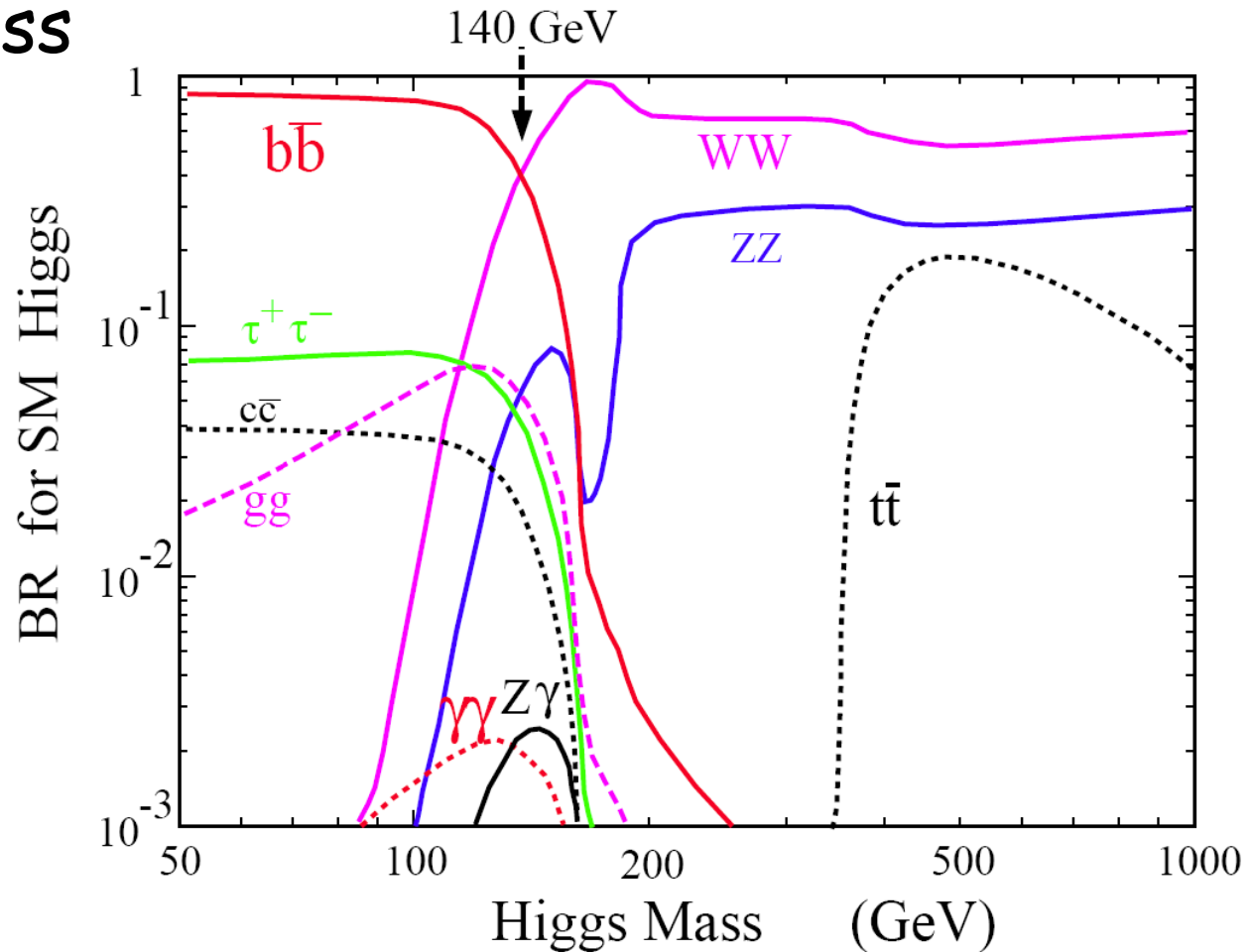
Coupling \propto fermion mass

$$-\frac{1}{v} m_f \bar{\Psi}_f \phi_h \Psi_f$$

Main channels:

- WW (high mass)
- bb (low mass)

Need good b-jet tagging!



Main Higgs Analyses

$H \rightarrow bb$
(low mass)

$H \rightarrow WW$
(high mass)

$p\bar{p} \rightarrow H$

~~$H \rightarrow bb$~~

$H \rightarrow WW \rightarrow$
 $ee/e\mu/\mu\mu + MET$

$p\bar{p} \rightarrow WH$

$WH \rightarrow Wbb \rightarrow$
 $e/\mu + bb$

$W/Z + H \rightarrow W/Z + WW \rightarrow$
 $l^+l^- l^+ / l^+l^+jj + MET$

$p\bar{p} \rightarrow ZH$

$ZH \rightarrow Zbb \rightarrow$
 $ee/\mu\mu + bb$
 $MET + bb$

Main Higgs Analyses

$H \rightarrow bb$
(low mass)

$H \rightarrow WW$
(high mass)

$p\bar{p} \rightarrow H$

~~$H \rightarrow bb$~~

$H \rightarrow WW \rightarrow$
 $ee/e\mu/\mu\mu + MET$

$p\bar{p} \rightarrow WH$

$WH \rightarrow Wbb \rightarrow$
 $e/\mu + bb$

$W/Z + H \rightarrow W/Z + WW \rightarrow$
 $l^+l^- l^+ / l^+l^+jj + MET$

$p\bar{p} \rightarrow ZH$

$ZH \rightarrow Zbb \rightarrow$
 $ee/\mu\mu + bb$
 $MET + bb$

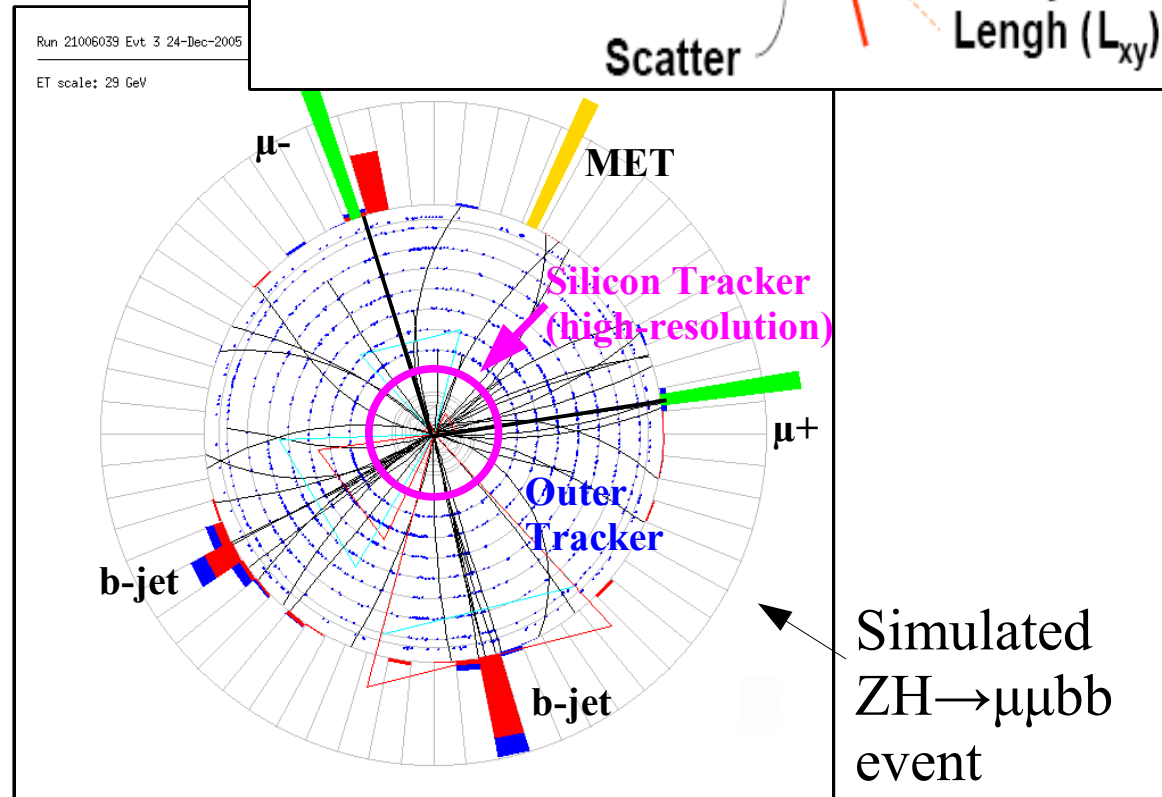
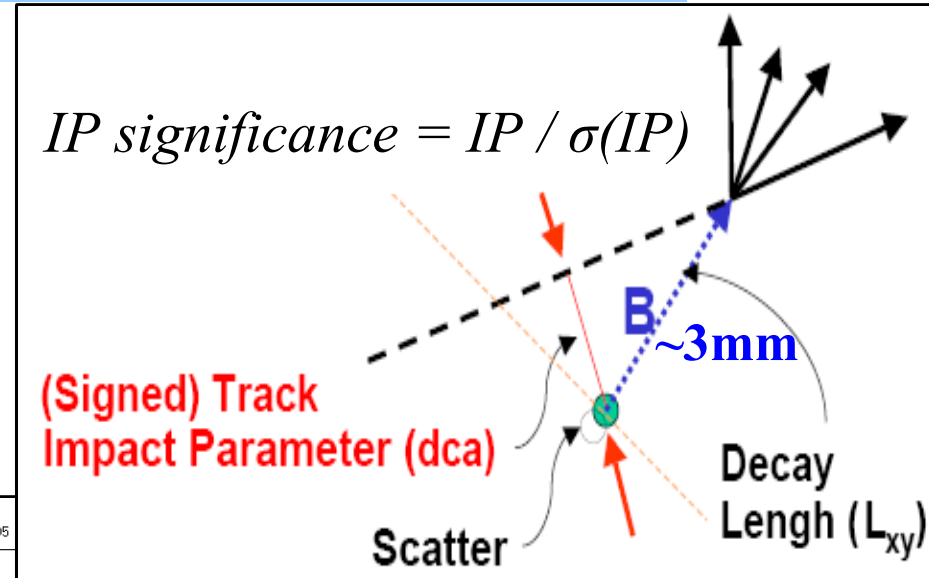
b-Jet Tagging

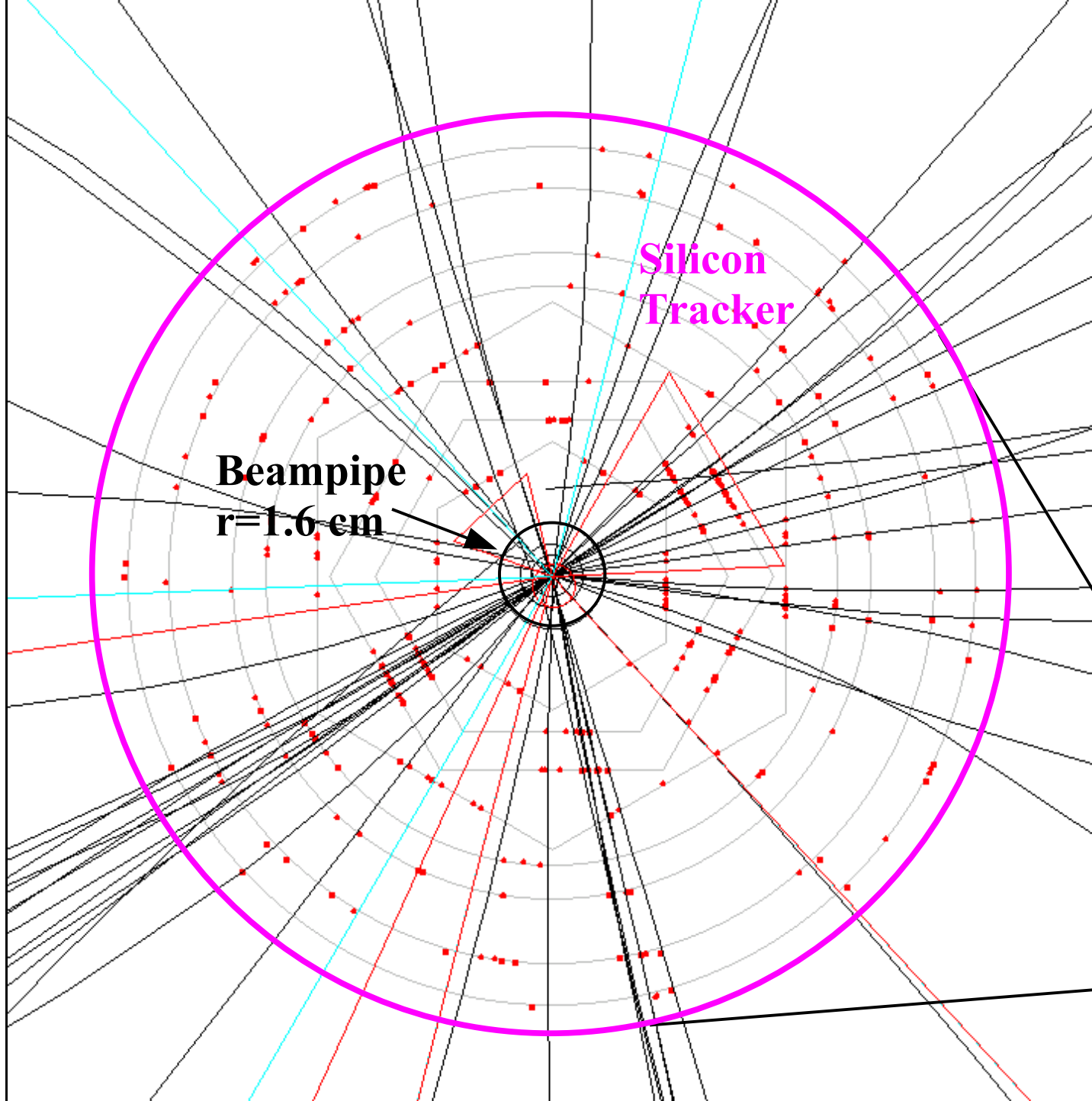
B hadrons are "long"-lived

- Reconstruct charged particles tracks
- Reconstruct "vertices" where tracks overlap

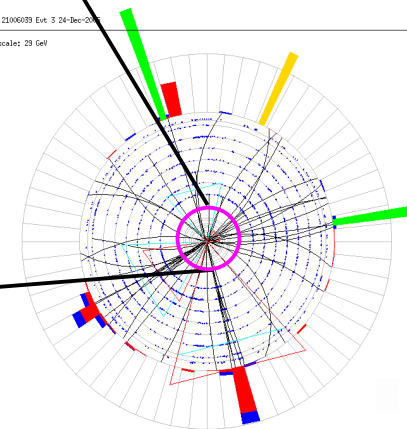
Identify jets with:

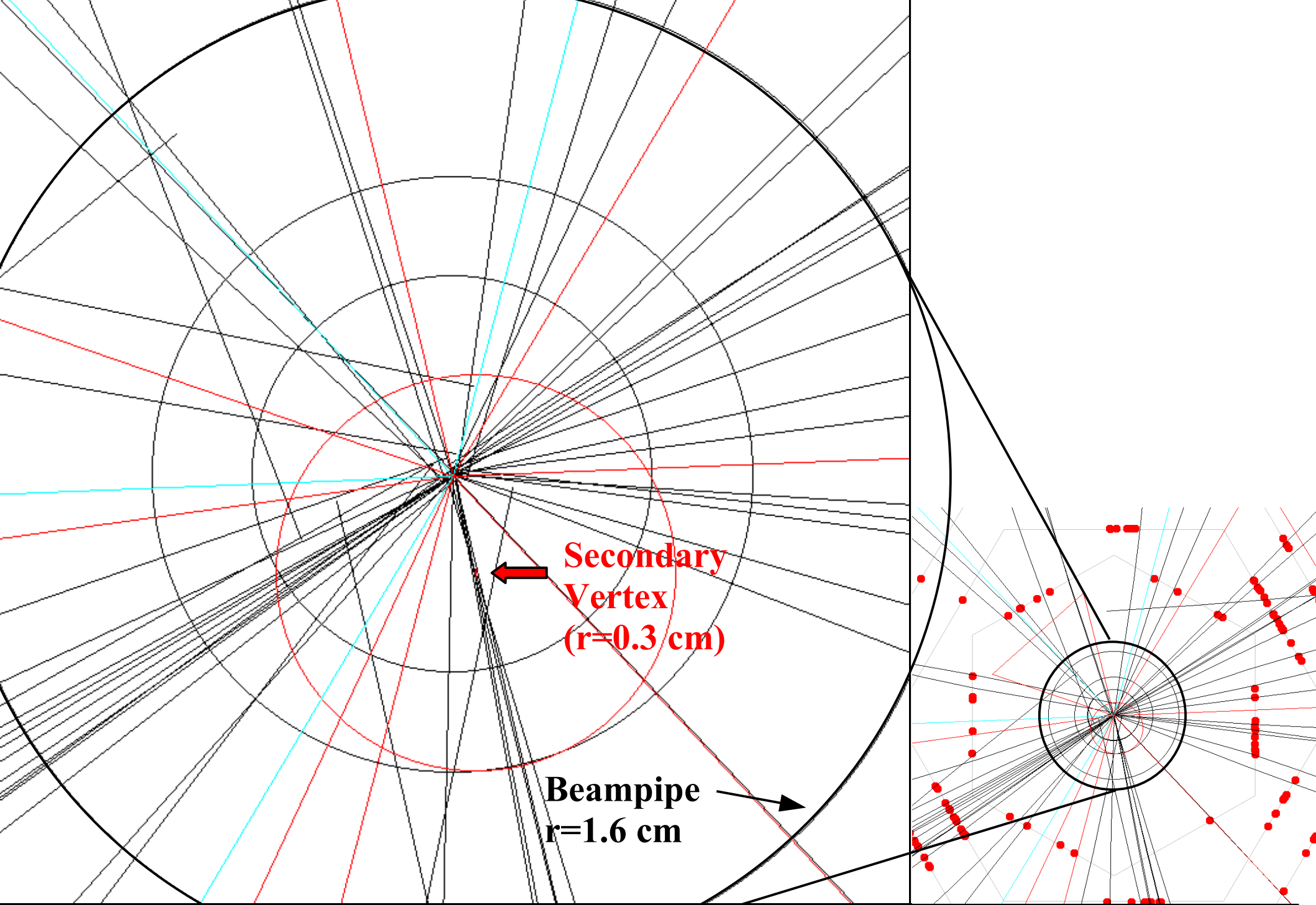
- large impact parameter significance tracks
- large decay length significance vertices





Run 2100693 Ev4.3 24-Dec-07
ET scale: 29 GeV



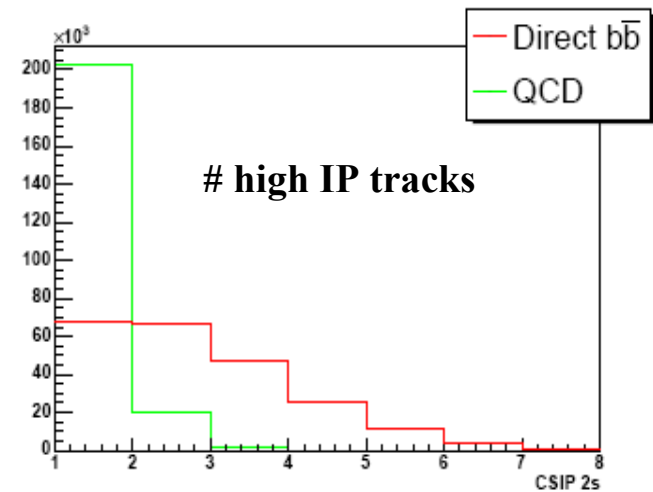
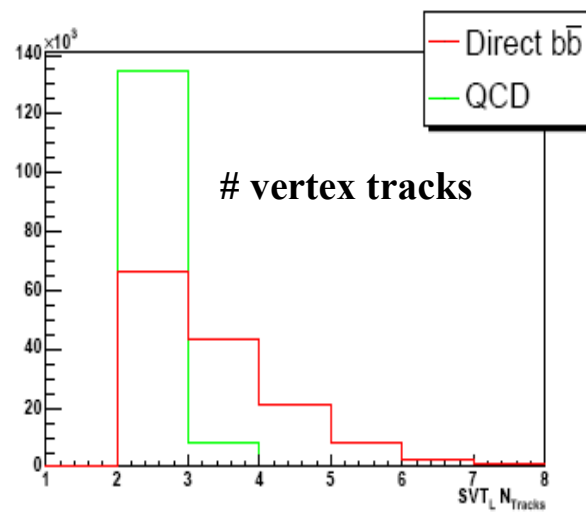
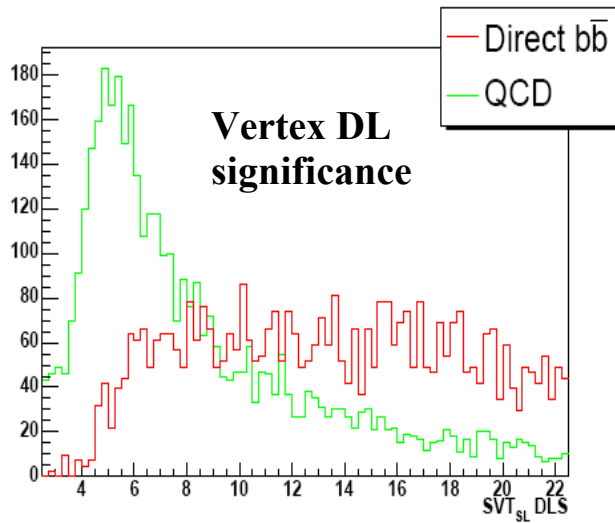
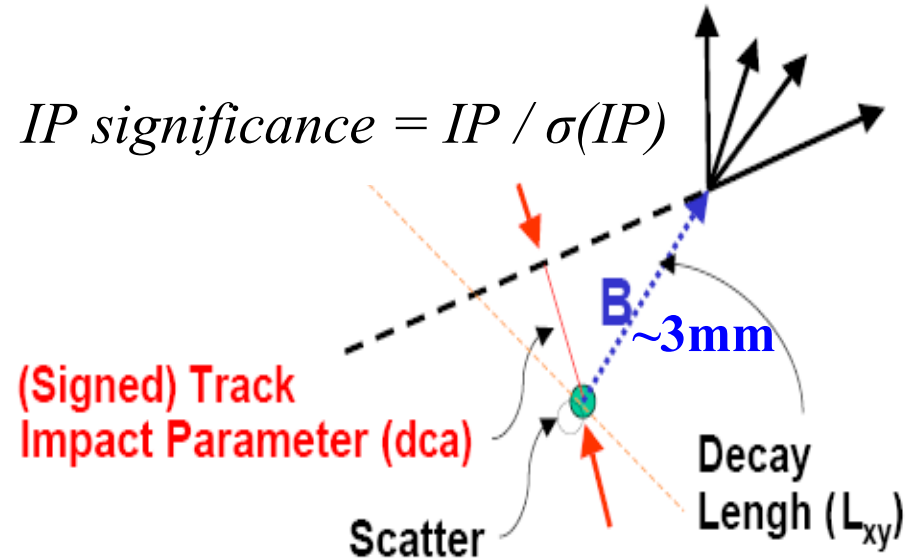


b-Jet Tagging

Many variables with separation power:

- Vertex: *DLS*, #tracks, #vertices, mass, chi2
- #high IP sig. tracks, combined light-jet prob.

$$IP\ significance = IP / \sigma(IP)$$

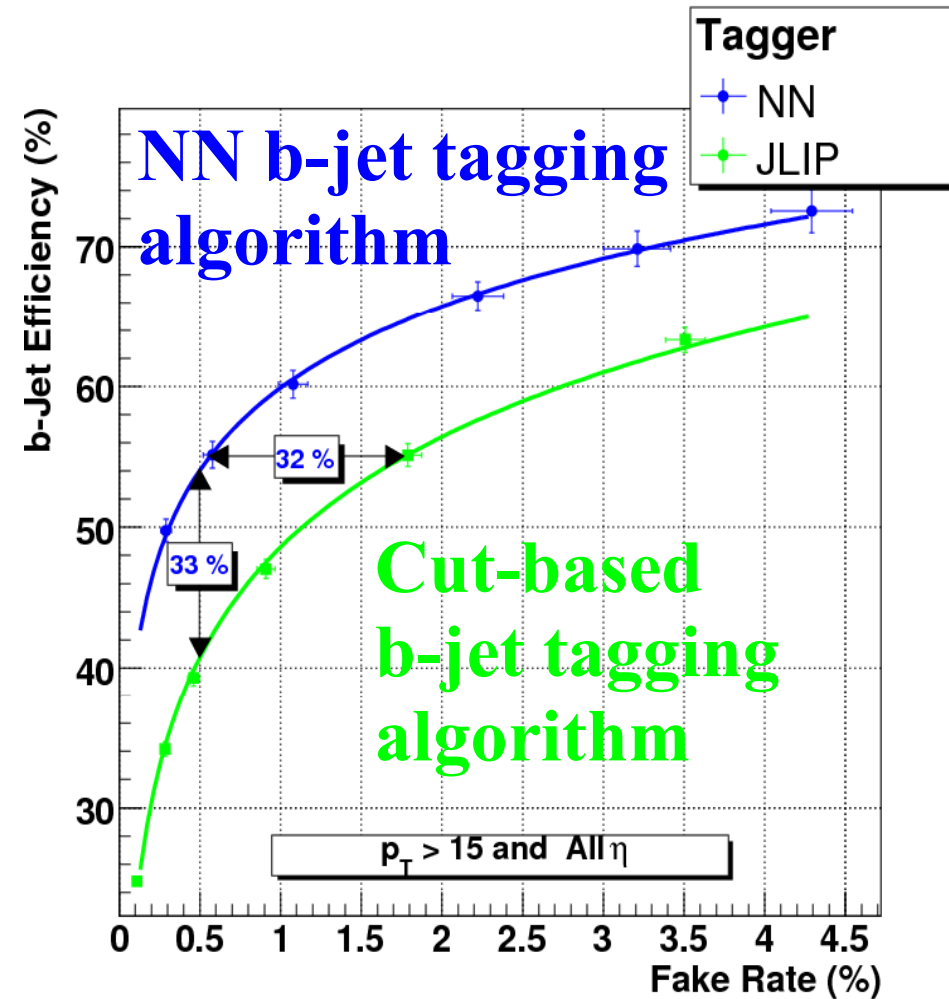
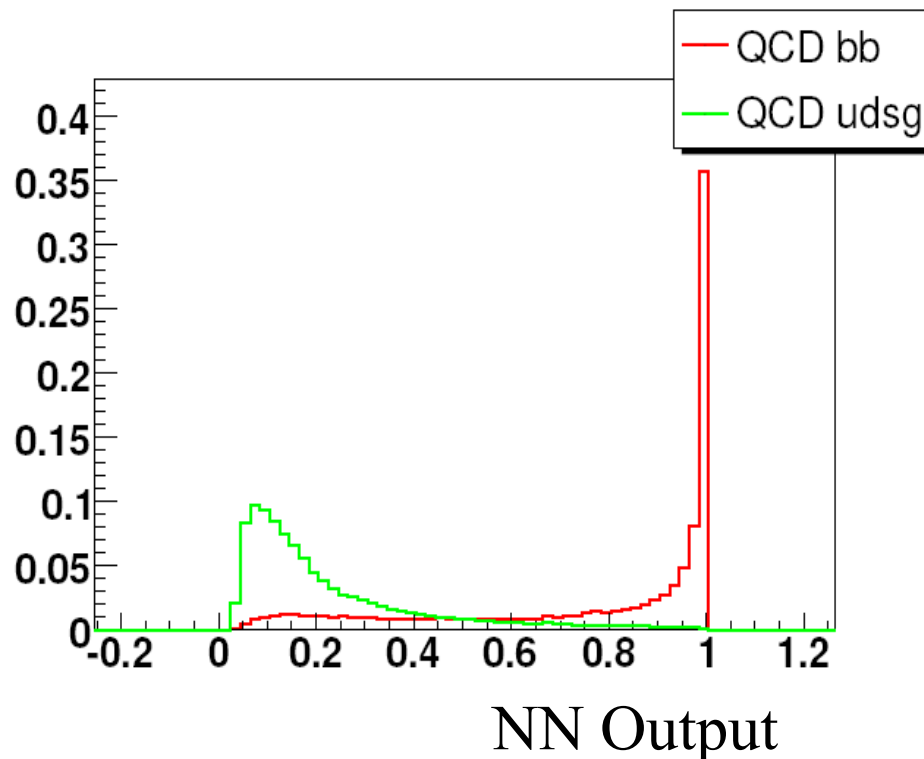


Neural Network b-Jet Tagging

Train NN on simulated events

- optimized inputs, training method, network topology

Test NN eff. and fake rate using data



Equivalent to 2.5x as much data for a double-b-tag analysis!

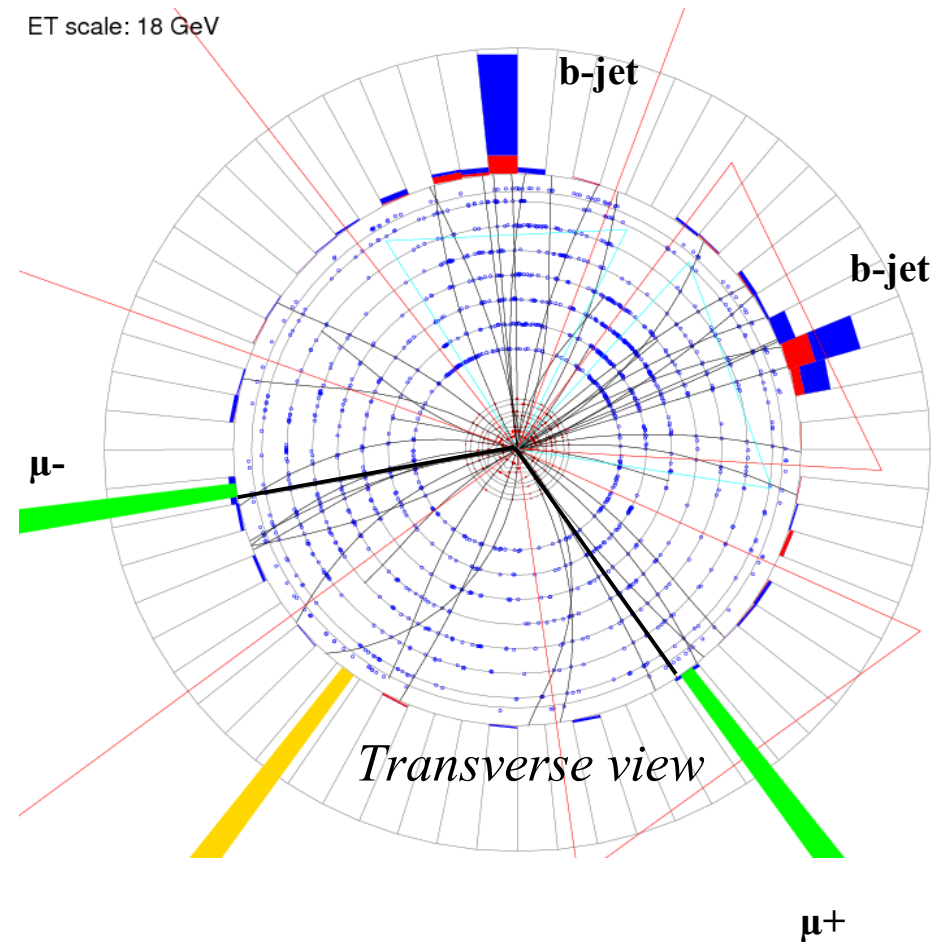
ZH $\rightarrow \mu^+ \mu^- b b$ Search

Easy to observe Z decay

- reduces backgrounds
- provides trigger

Good b-tagging is essential

Reconstruct Higgs mass
from two b-jets



Z + 2 jets

Select events:

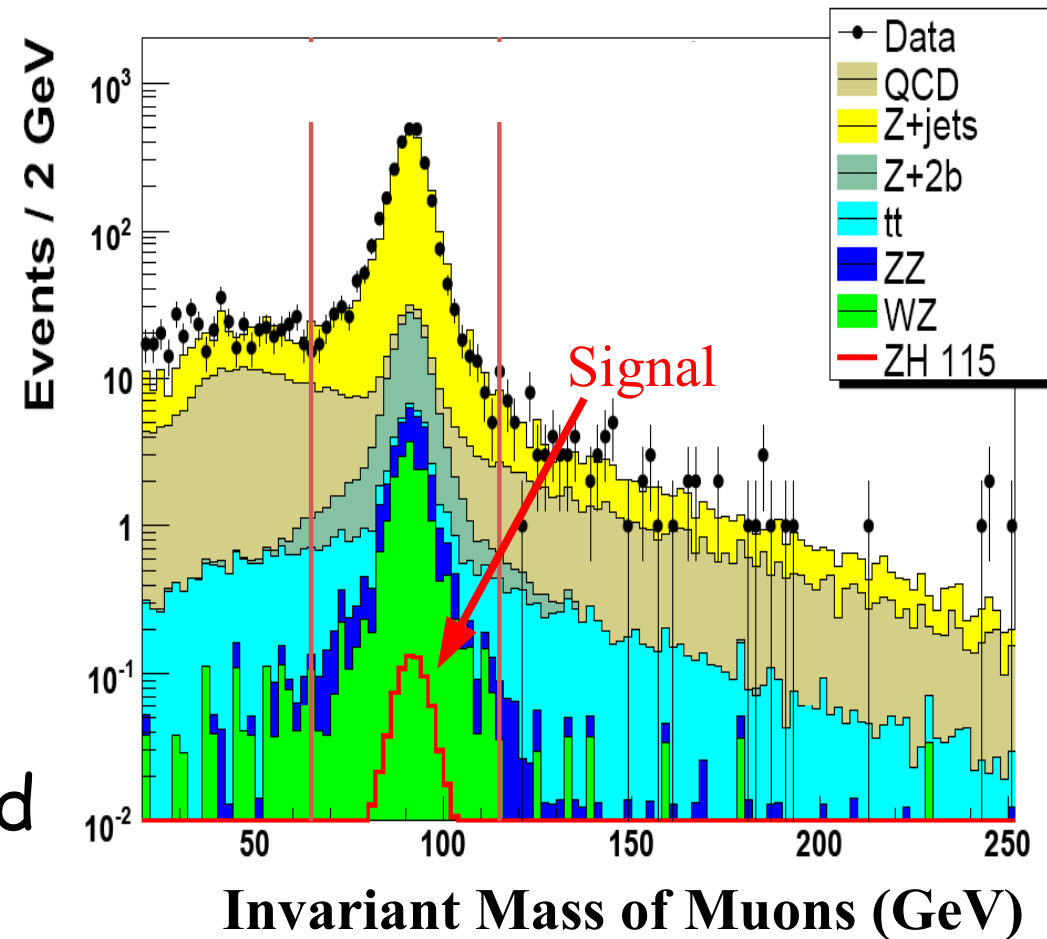
- 2 μ , isolated*,
 $p_T > 10$ GeV, $|\eta| < 2$
- ≥ 2 jets, $p_T > 15$ GeV
- $65 < m_Z < 115$ GeV

Good agreement of data /
simulation at Z peak

- Trigger eff. $\sim 100\%$

QCD background determined
from (less-isolated) data

Main background: Z+jets

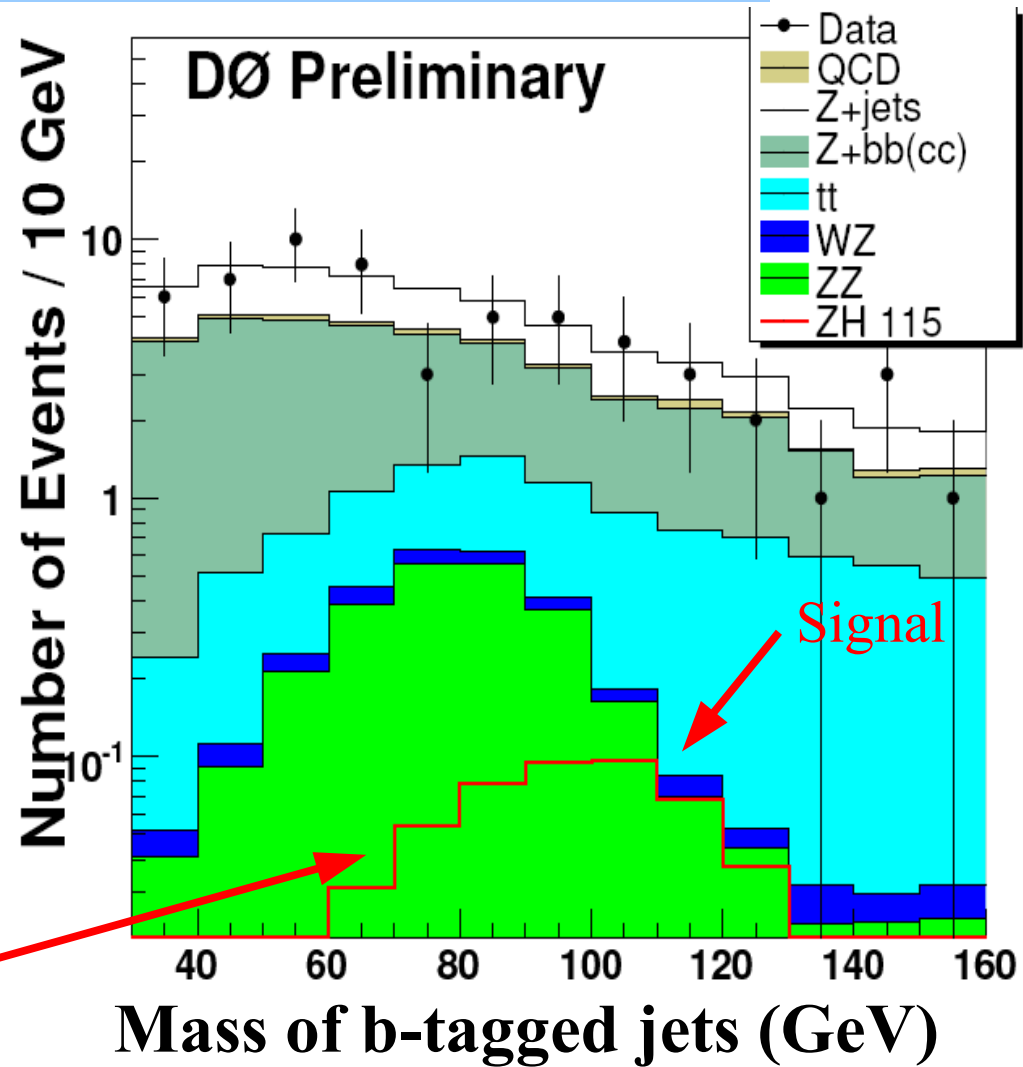
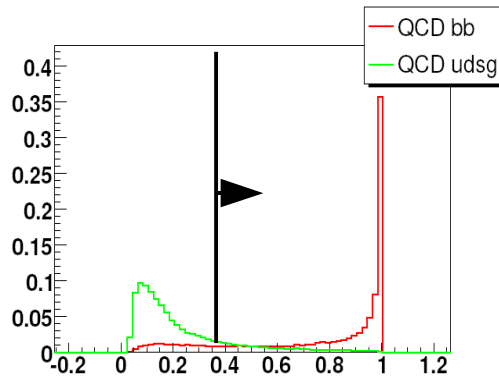


$$*scalediso = (cal\ iso + trk\ iso) / p_T$$
$$scalediso_1 \times scalediso_2 < 0.1$$

Z + 2 b-jets

Require ≥ 2 "NN b-tags"

NN tag cut for optimal expected limit:
 $\sim 65\%$ eff., $\sim 2\%$ fake



Higgs \rightarrow bb forms bump in di-b-jet mass spectrum

Di-b-jet mass resolution is key!

Single b-tag

Also use events with a single
"tight" NN b-tag:

~40% eff., ~0.5% fake

(AND NOT two "loose" tags)

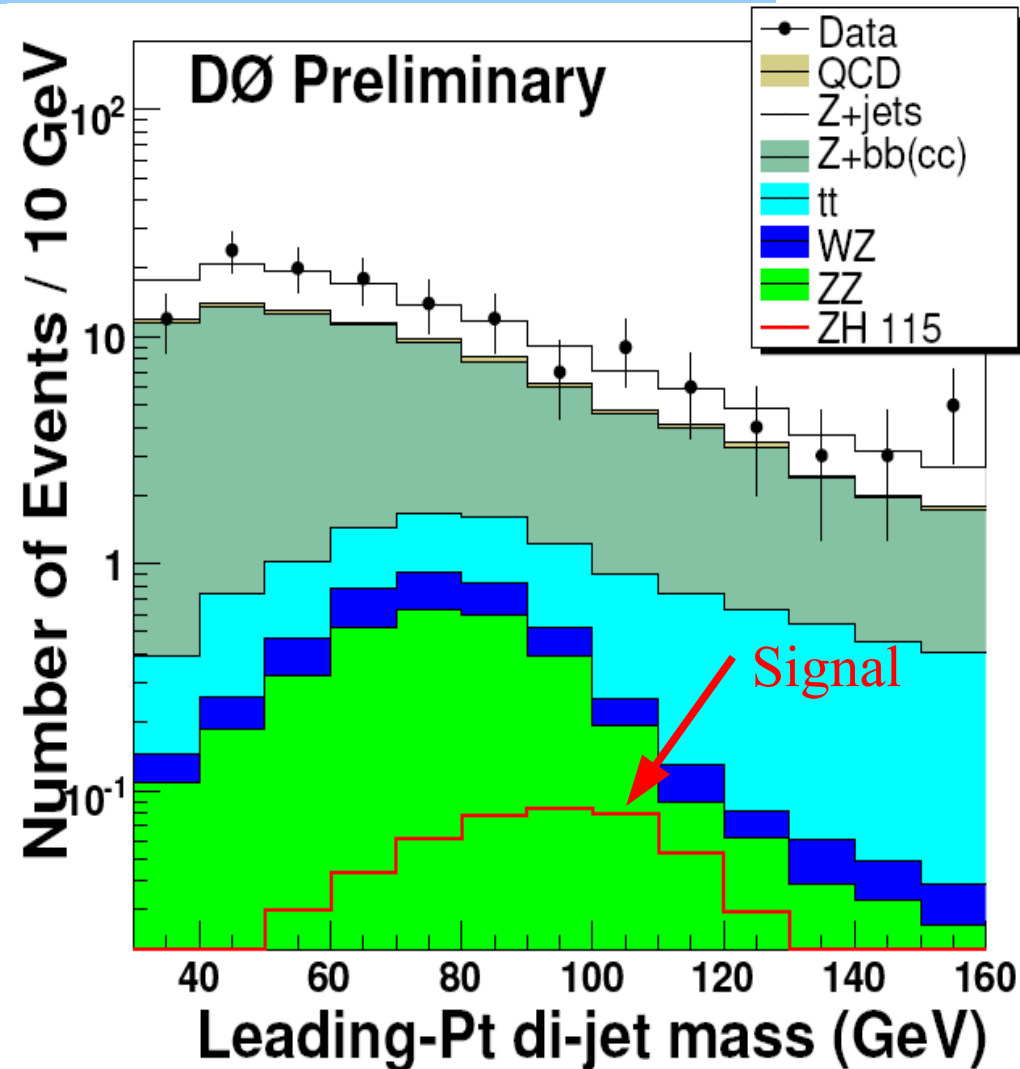
- Orthogonal event sample!

Compared to double-b-tag:

- Similar amount of signal
- Double amount of background

Like having 25% more data

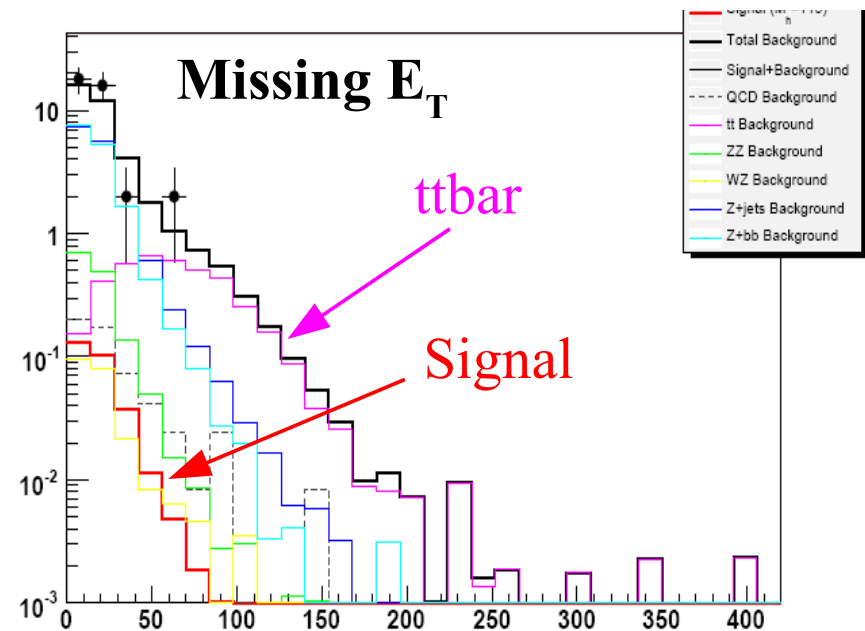
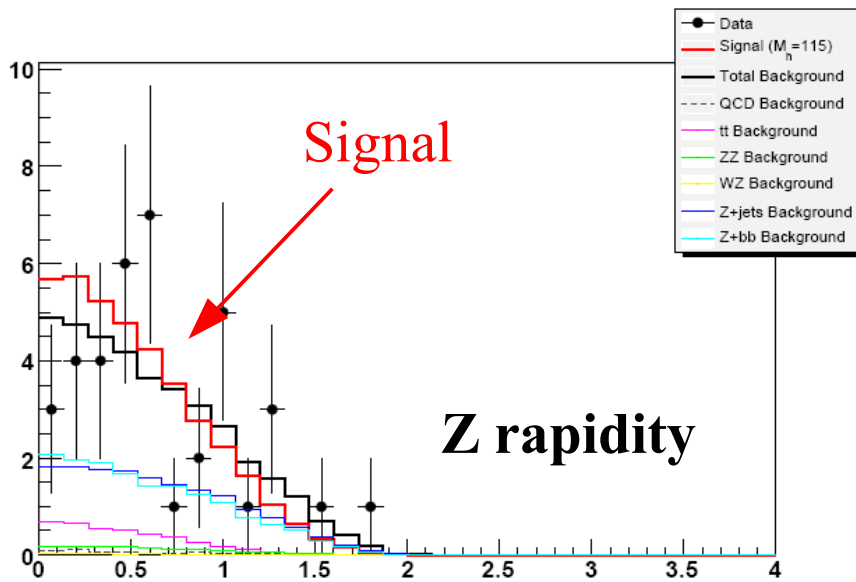
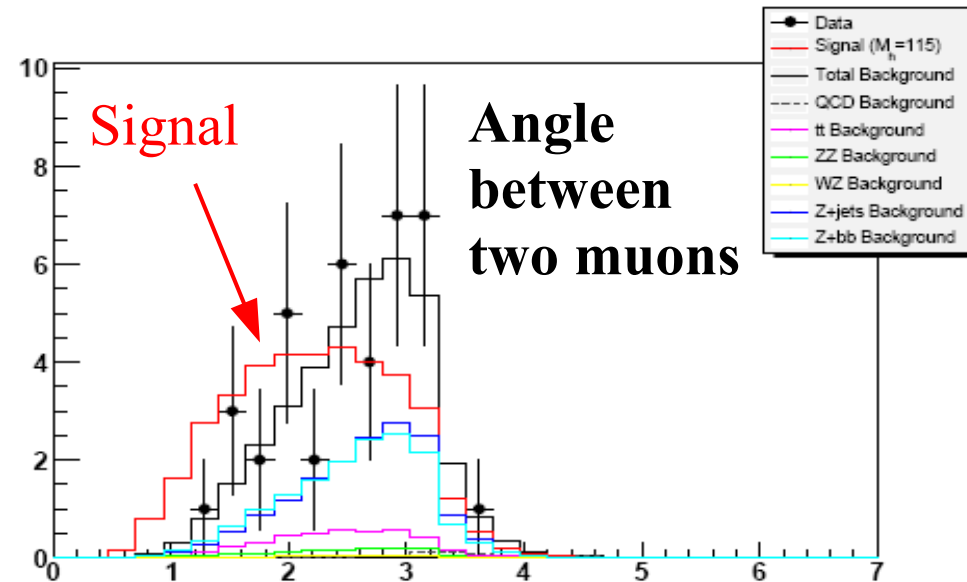
Combine during limit-setting



Additional Variables

Di-b-jet mass is the best variable

Other variables also have some separation power

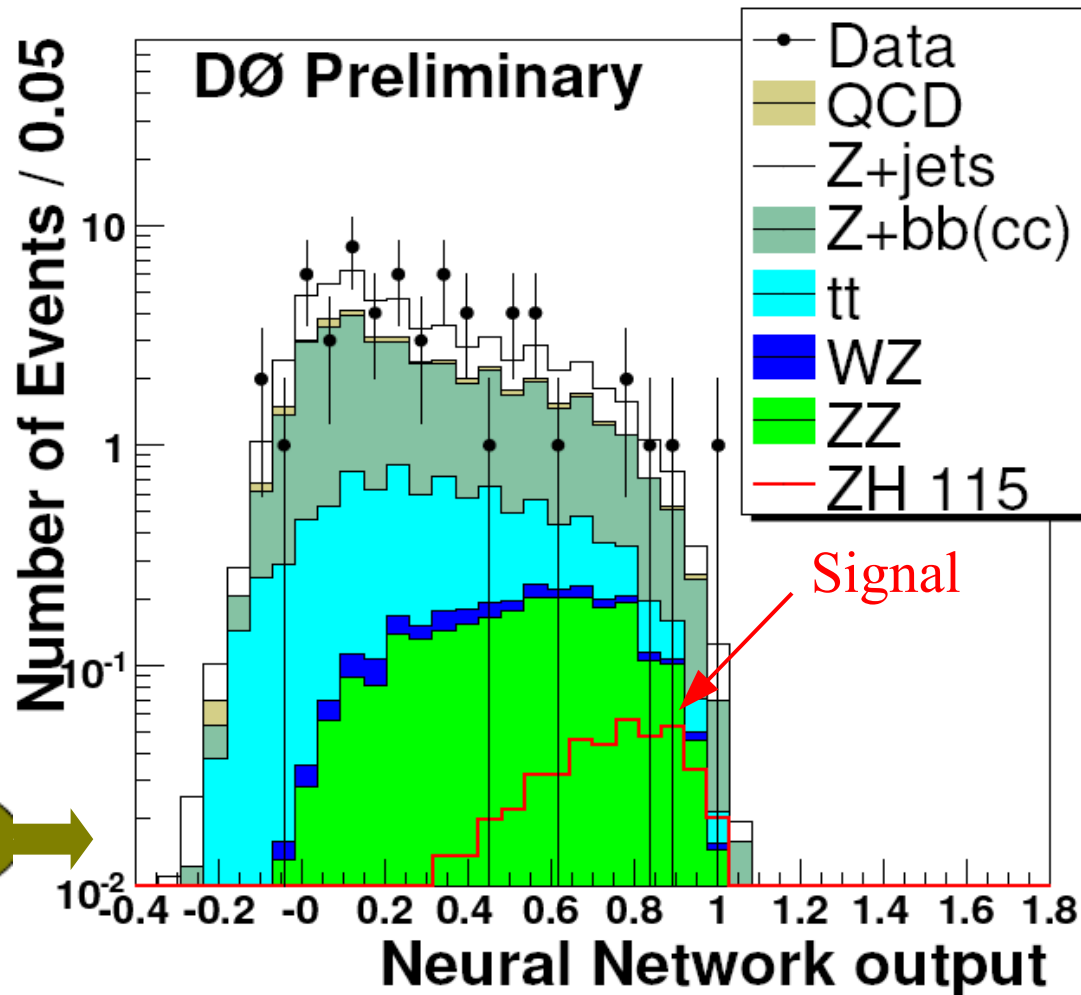
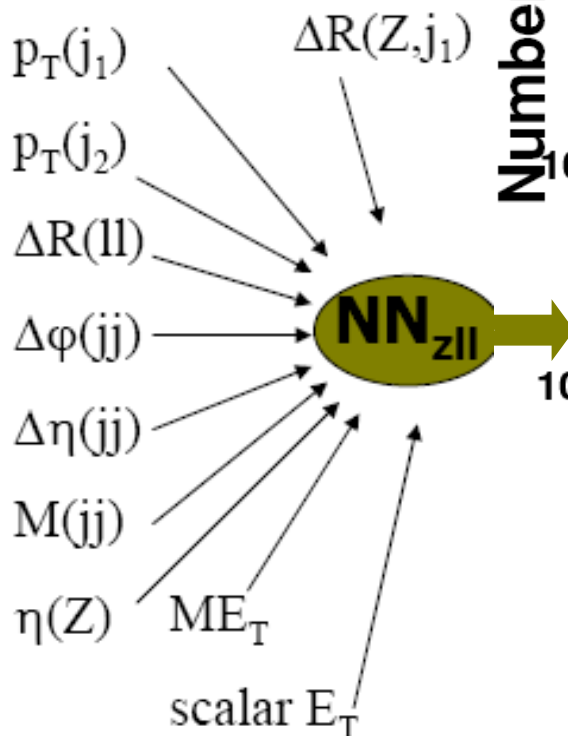


Neural Net Event Selection

Combine variables with NN

Separate NN for
single/double b-tag

Train for
each m_H



*Sensitivity 37% greater than
using M_{bb} alone!*

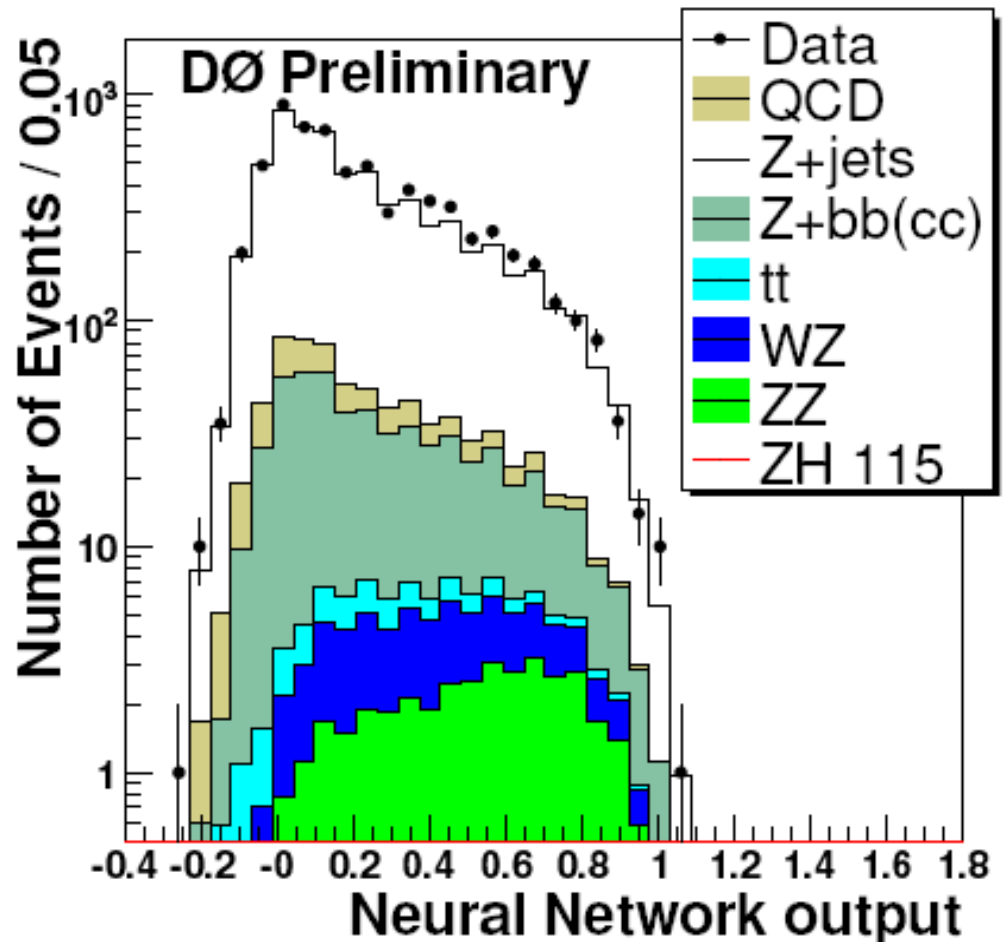
Neural Net Cross-Checks

All input variables are well-modeled

Also check shape of NN output *before b-tagging*

- High statistics
- Negligible signal

Variables / correlations are well-modeled in Z+jets

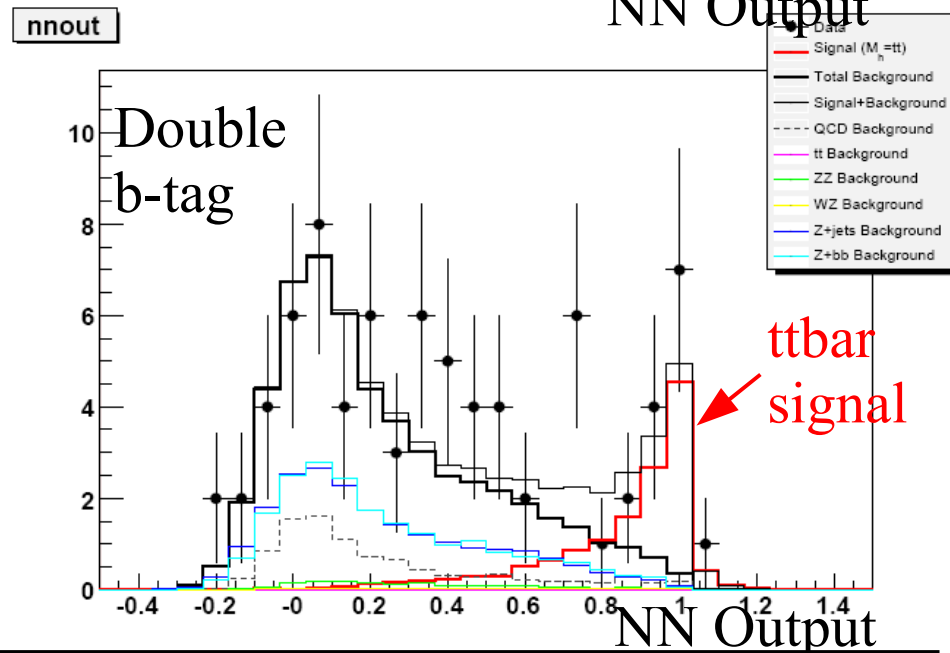
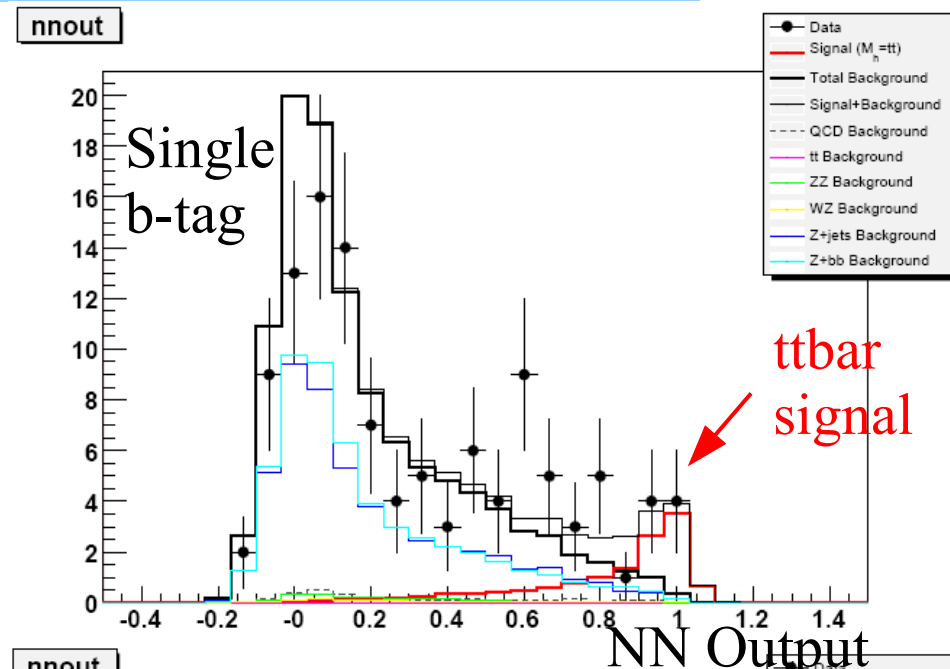


Neural Net Cross-Checks

Train NN on $t\bar{t}b\bar{a}r$ as *signal*

- A "standard candle"
- Cross-section well-known

Expected $t\bar{t}b\bar{a}r$ is observed in both single and double b-tag channels

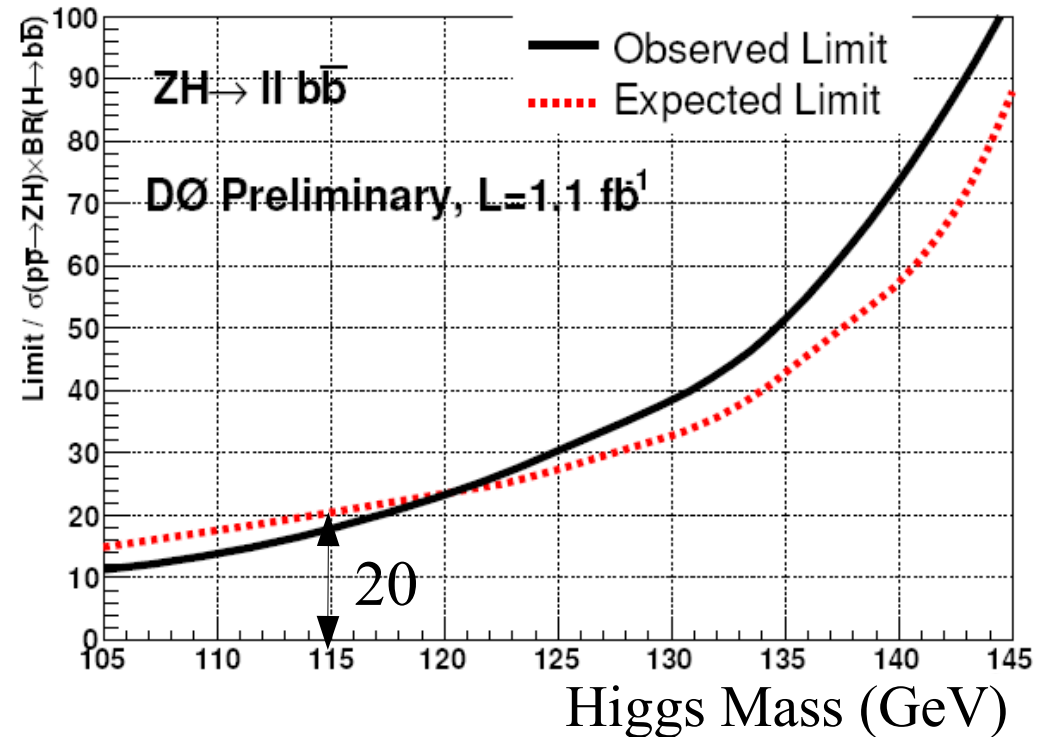


ZH \rightarrow $l^+ l^- b b$ Limits

Use whole shape of NN outputs to set limits

Need $\sim 20x$ more sensitivity to see the Higgs in this channel alone (at 115 GeV)

- Other channels
- Combine with CDF
- More data (2.4 fb^{-1} this winter)
- Reduced systematics
- Further improvements in analysis technique

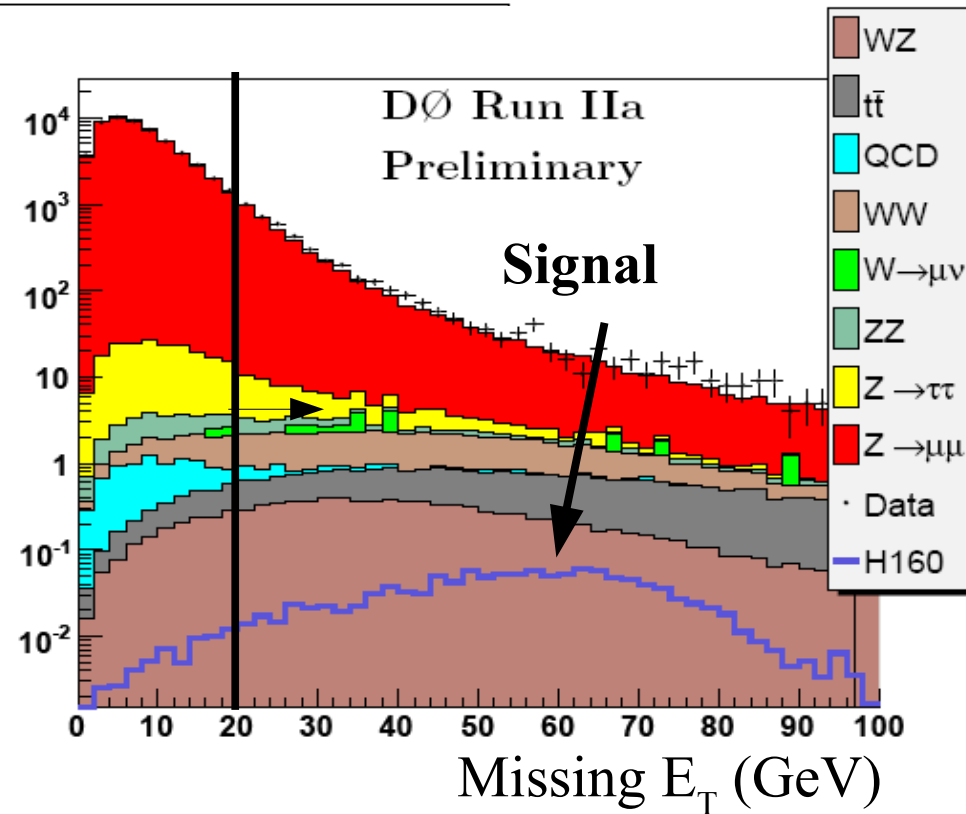


$H \rightarrow W^+W^- \rightarrow \mu^+ \mu^- + \text{MET}$

Select events:

- 2 μ , isolated, $p_T > 10 \text{ GeV}$, $|\eta| < 2$
- ~~≥ 2 jets, $p_T > 15 \text{ GeV}$~~
- $\text{MET} > 20 \text{ GeV}^*$
- $\text{MET "scaled"} > 5$
- Min μ transverse mass $> 20^*$
- $15 < m_{\mu\mu} < 70^*$

* (depending on m_H)

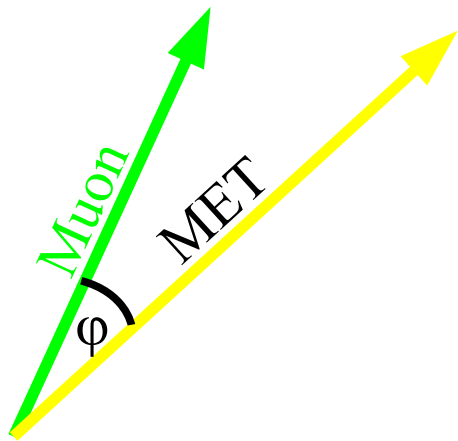


$$\mathcal{E}_T^{\text{Scaled}} = \frac{\mathcal{E}_T}{\sqrt{\sum_{\text{jets}} (\Delta E^{\text{jet}} \cdot \sin \theta^{\text{jet}} \cdot \cos \Delta\phi(\text{jet}, \mathcal{E}_T))^2}}$$

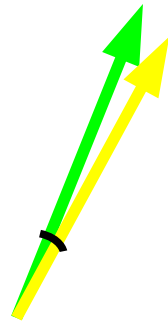
*MET projected
onto jet direction*

$H \rightarrow W^+W^- \rightarrow \mu^+ \mu^- + \text{MET}$

High transverse mass:
Real W event

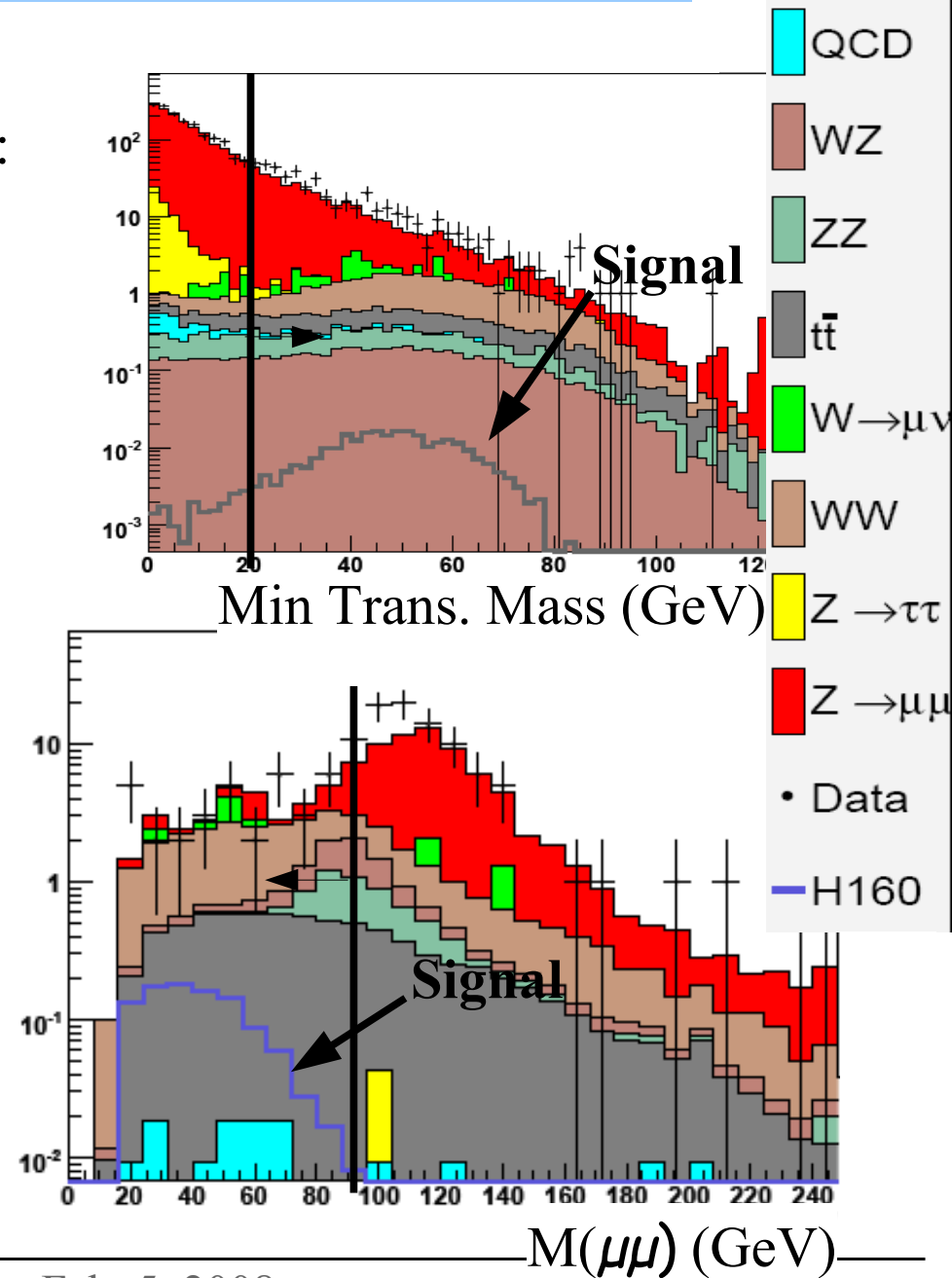


Low transverse mass:
Mis-measured muon



Main backgrounds after pre-selection:

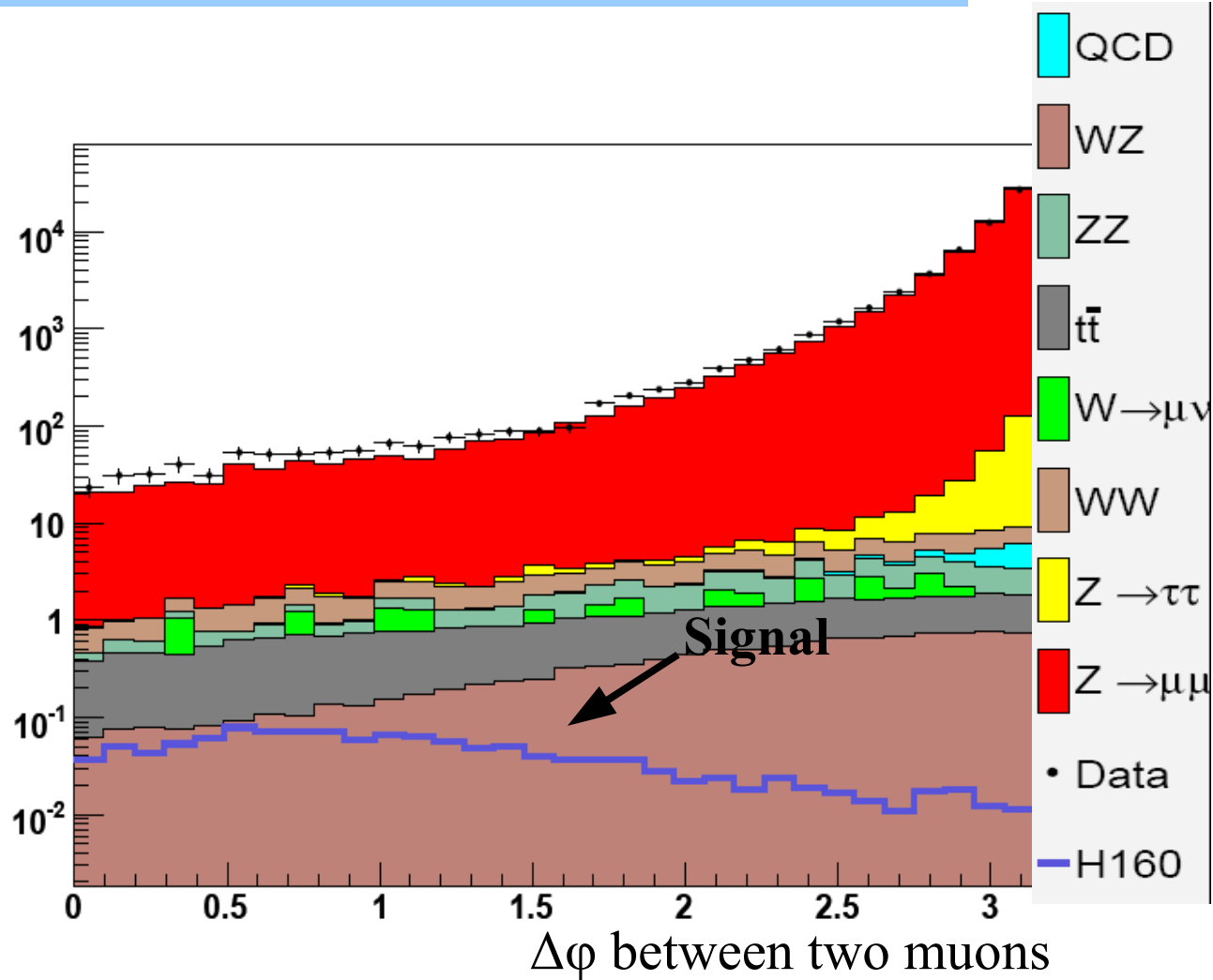
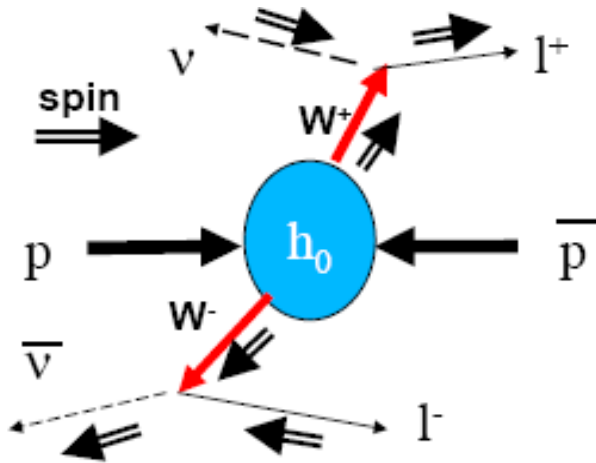
- **Z+jets : Fake MET**
- **W+jets : Jet \rightarrow Muon**
- **WW : Nearly irreducible**
- **tt : Two b-jets**



$H \rightarrow W^+W^- \rightarrow \mu^+ \mu^- + \text{MET}$

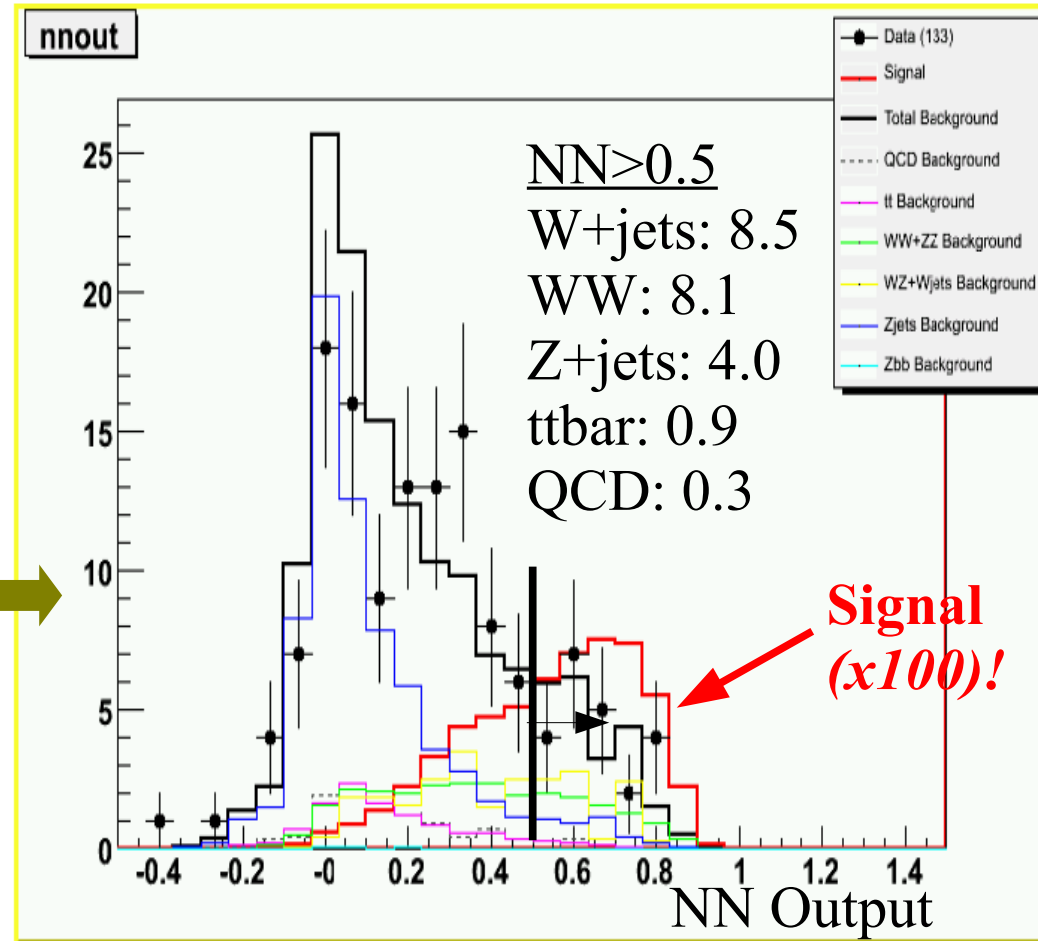
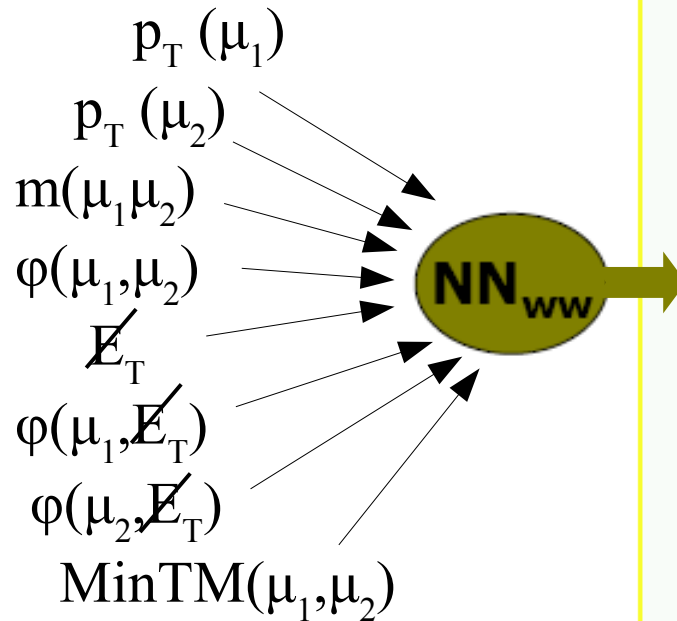
Higgs is a scalar

- Muons from W's tend to be more aligned



$H \rightarrow W^+W^- \rightarrow \mu^+ \mu^- + \text{MET}$

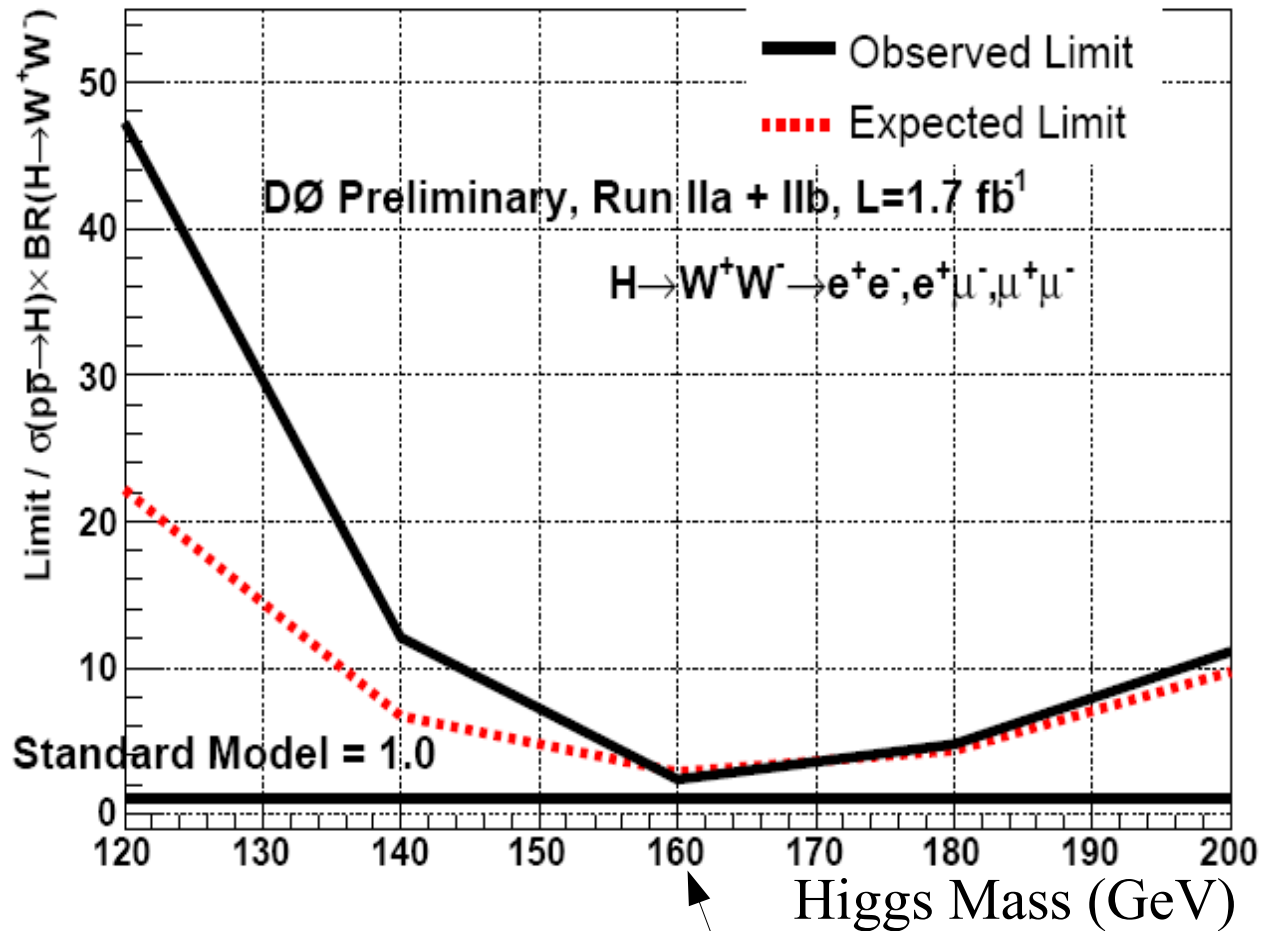
Train a NN for each simulated signal m_H



$H \rightarrow W^+W^- \rightarrow \mu^+ \mu^- + \text{MET}$

Combine with ee ,
 $e\mu$ channels

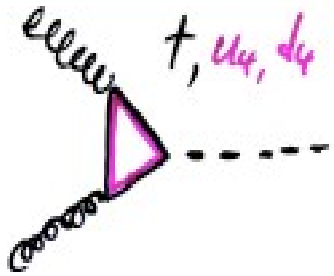
Only 3x away from
SM cross-section
(at $m_H = 160 \text{ GeV}$)



- Combine with CDF
- More data (2.4 fb^{-1} this winter)
- Further improvements in analysis technique

3x SM

4th Generation

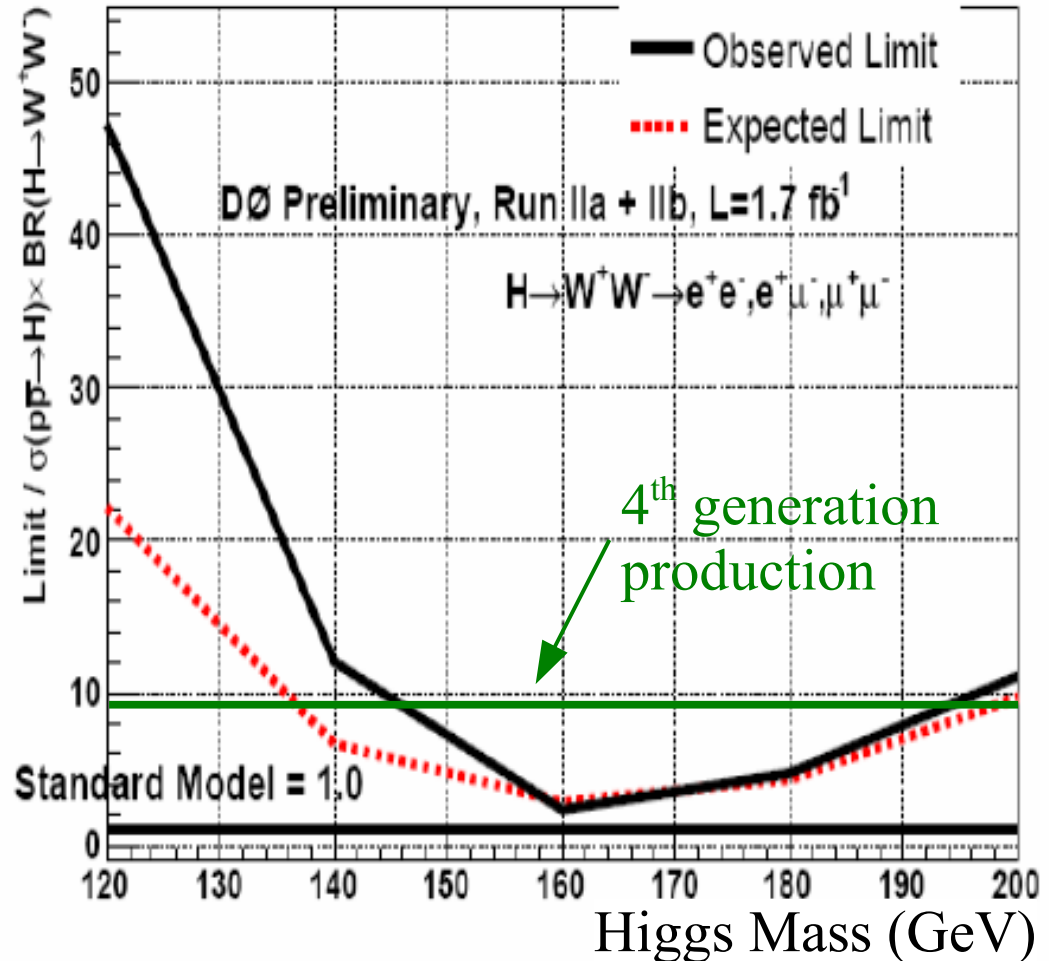


AMPLITUDE $\times 3$
OVER SM

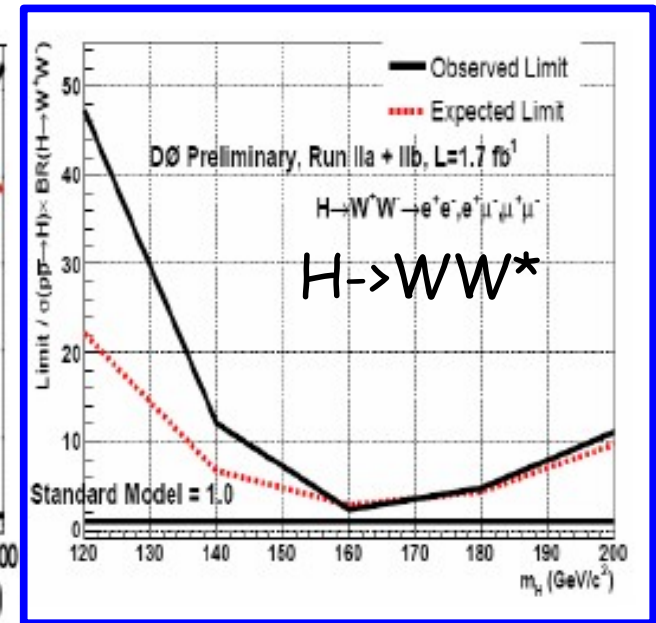
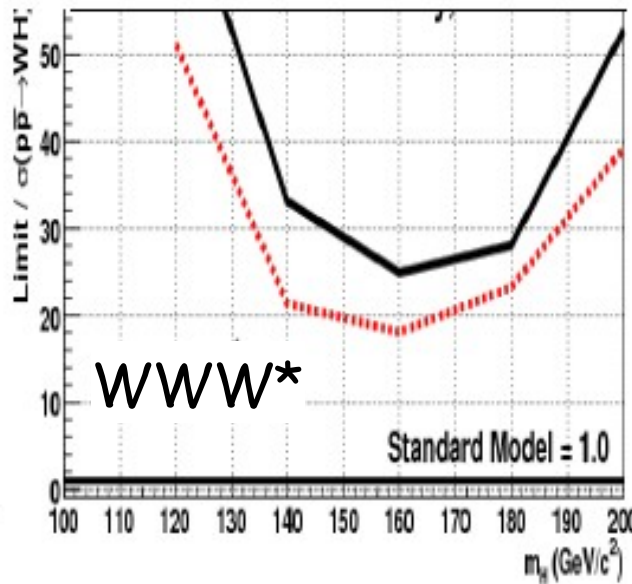
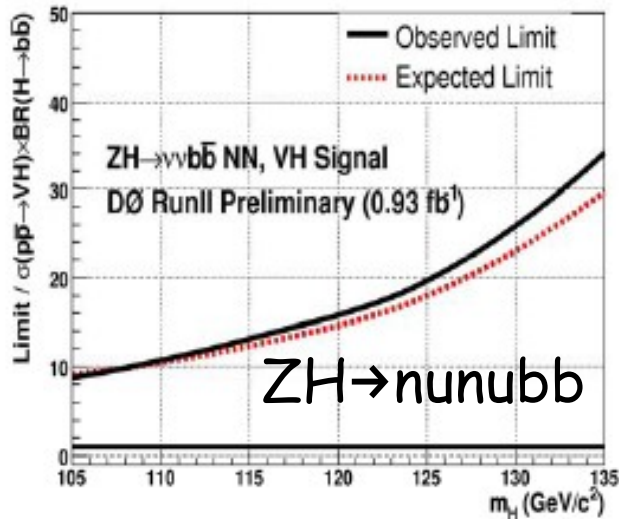
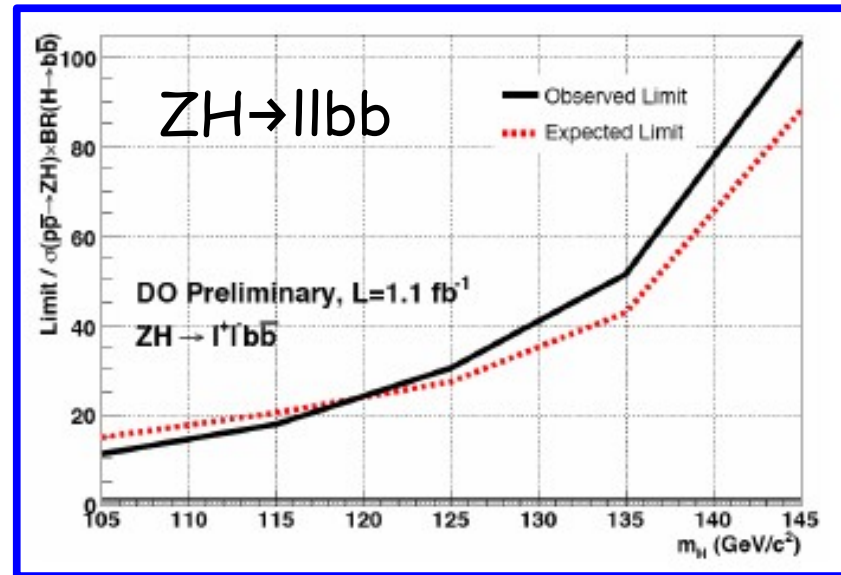
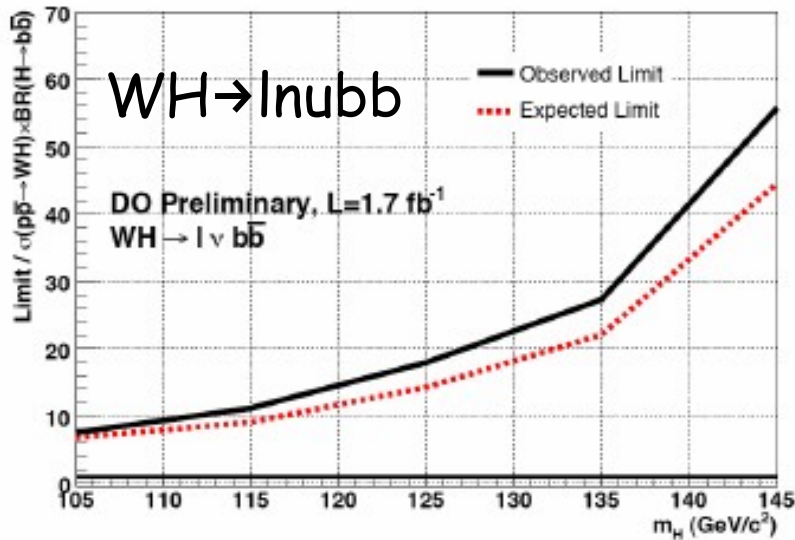
9x more $gg \rightarrow H$ production!

Already excluding from
145-195 GeV

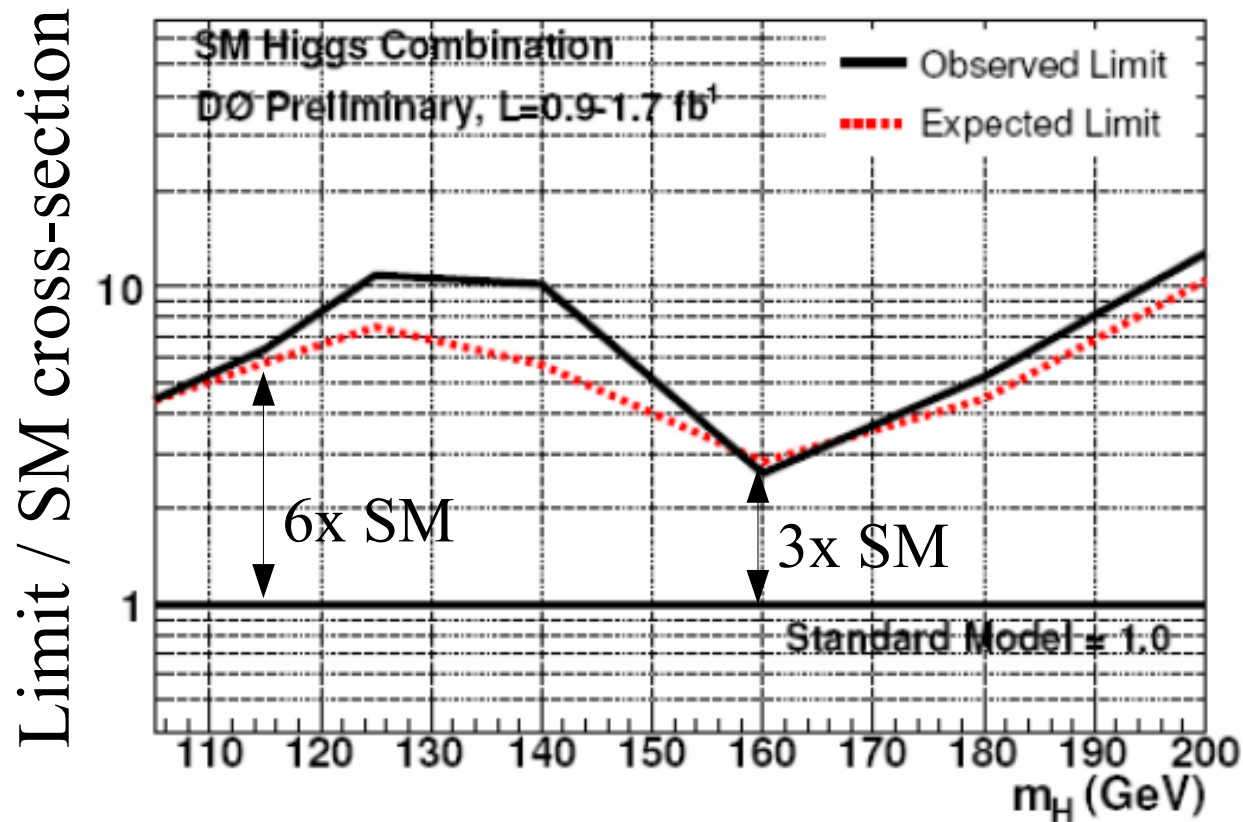
Sensitive up to
260 GeV by 2010



DØ Results in Main Higgs Channels



Combining the Channels



Low mass (115 GeV)

ZH → llbb 20x SM

WH → lnubb 10x SM

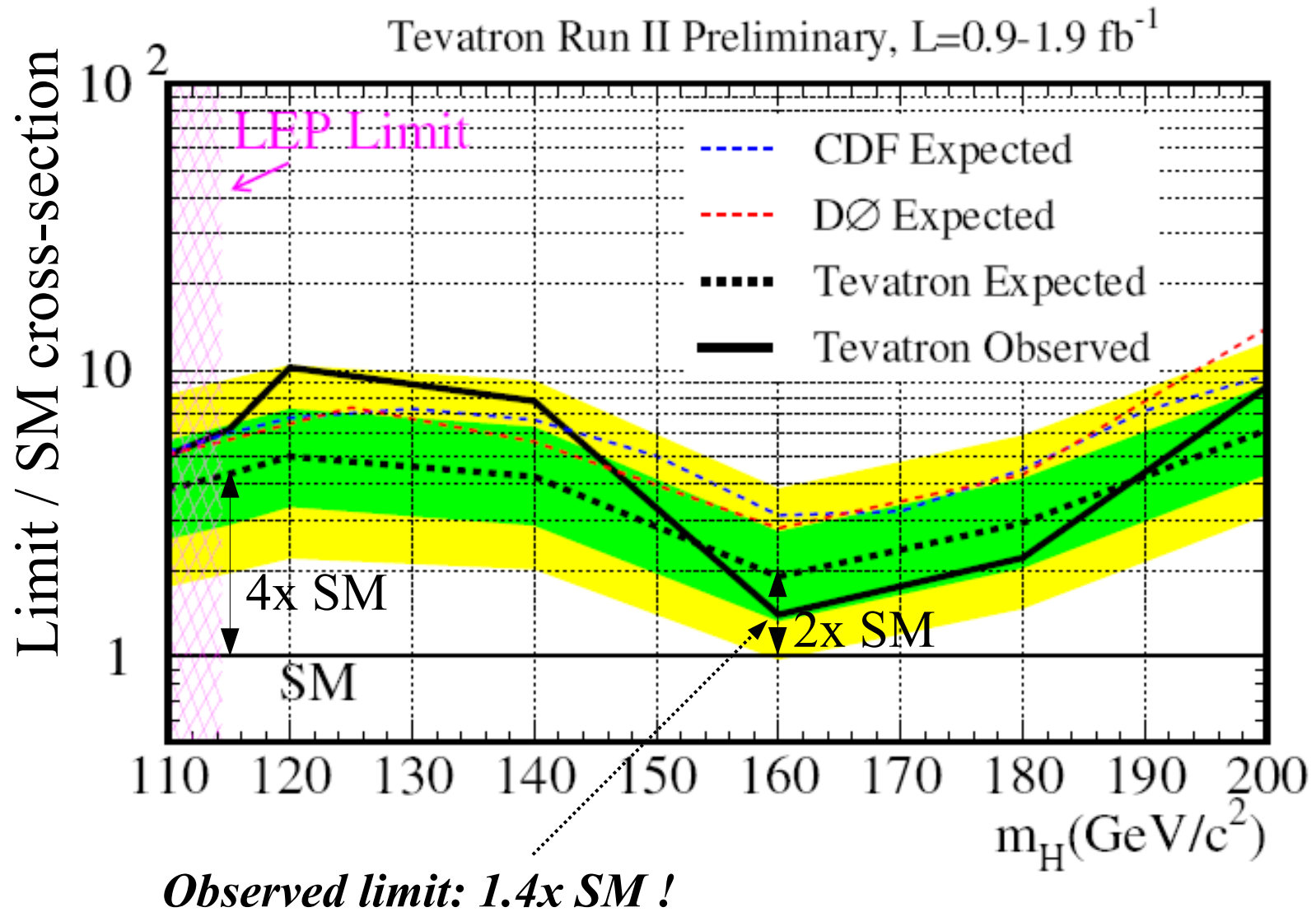
ZH → nunubb 12x SM

High mass (160 GeV)

H → WW* → ll 3.1x SM

WWW* 18x SM

Combining the Experiments



Improving Sensitivity

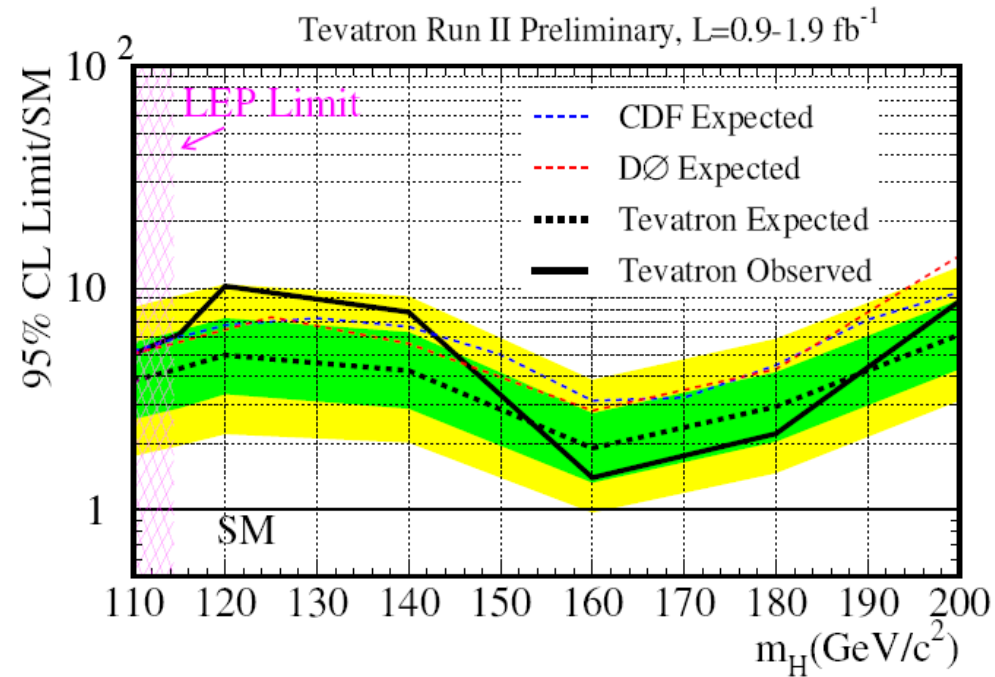
With no improvements, would need much more luminosity to be sensitive:

- $\sim 20 \text{ fb}^{-1}$ at 115 GeV
- $\sim 7 \text{ fb}^{-1}$ at 160 GeV

Expect 6.8 fb^{-1} by 2010

Improvements underway:

- Di-jet mass resolution
- Lepton efficiency
- Further improvements in analysis technique...
- Matrix Element techniques
- Better b-tagging



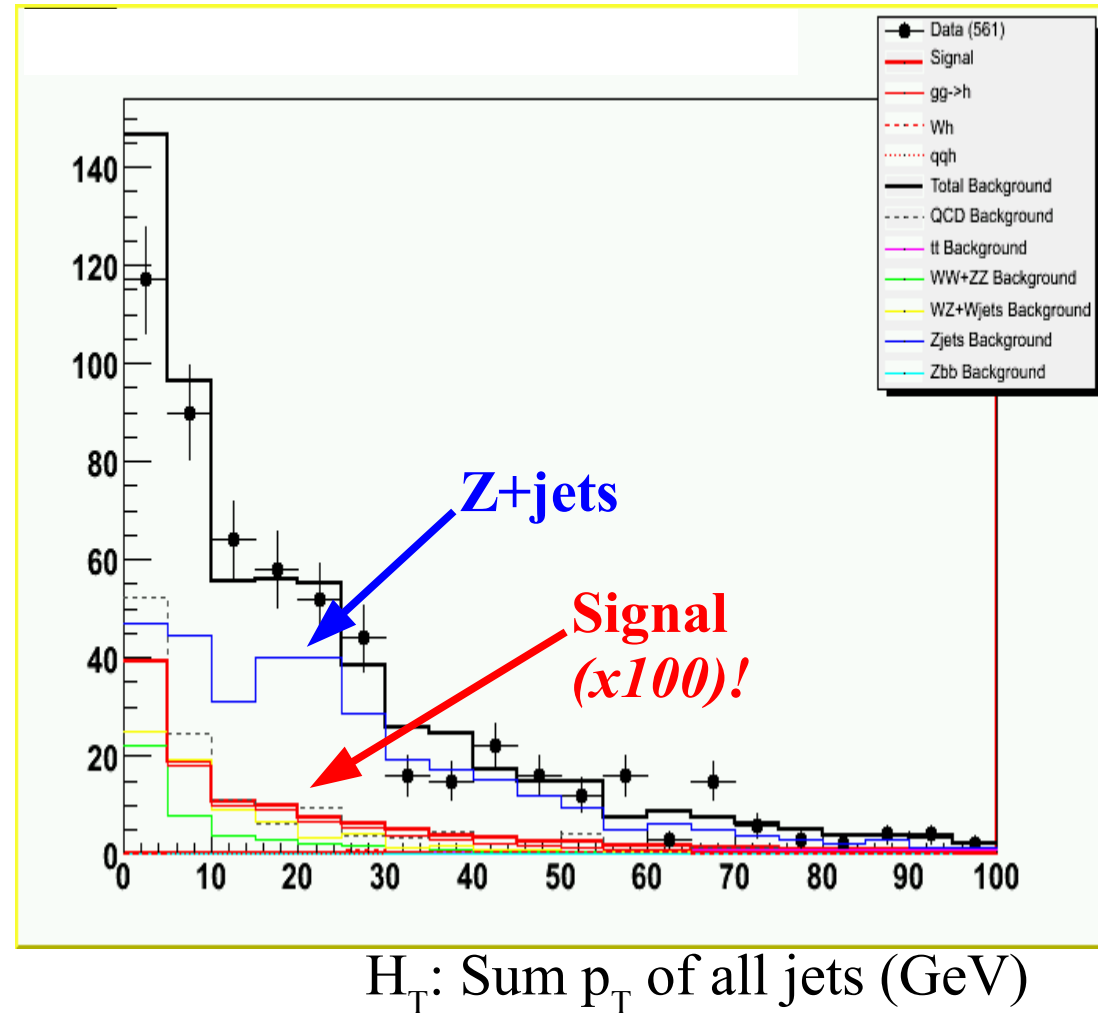
Reducing Backgrounds to $H \rightarrow WW$

Z+jets:

MET likely comes from mis-measured jet(s)

- Look at H_T , the scalar sum of the jets' p_T

Useful as an additional NN variable to reduce Z+jets background



Reducing Backgrounds to $H \rightarrow WW$

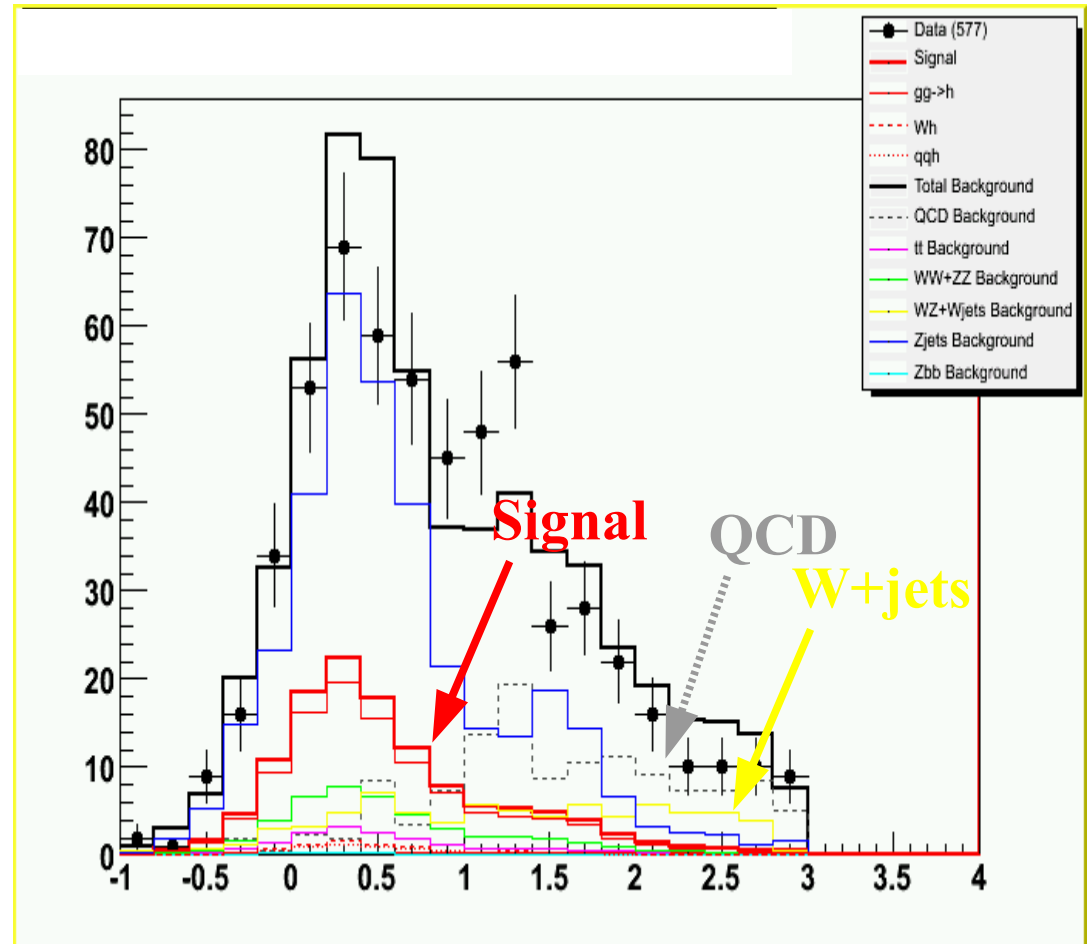
W +jets, QCD:

Muon(s) comes from a jet

Usually a low- p_T muon
incorrectly matched to
a high- p_T track

- Look at the worst χ^2
between track, muon

Useful as an additional
NN variable to reduce
QCD and W +jets

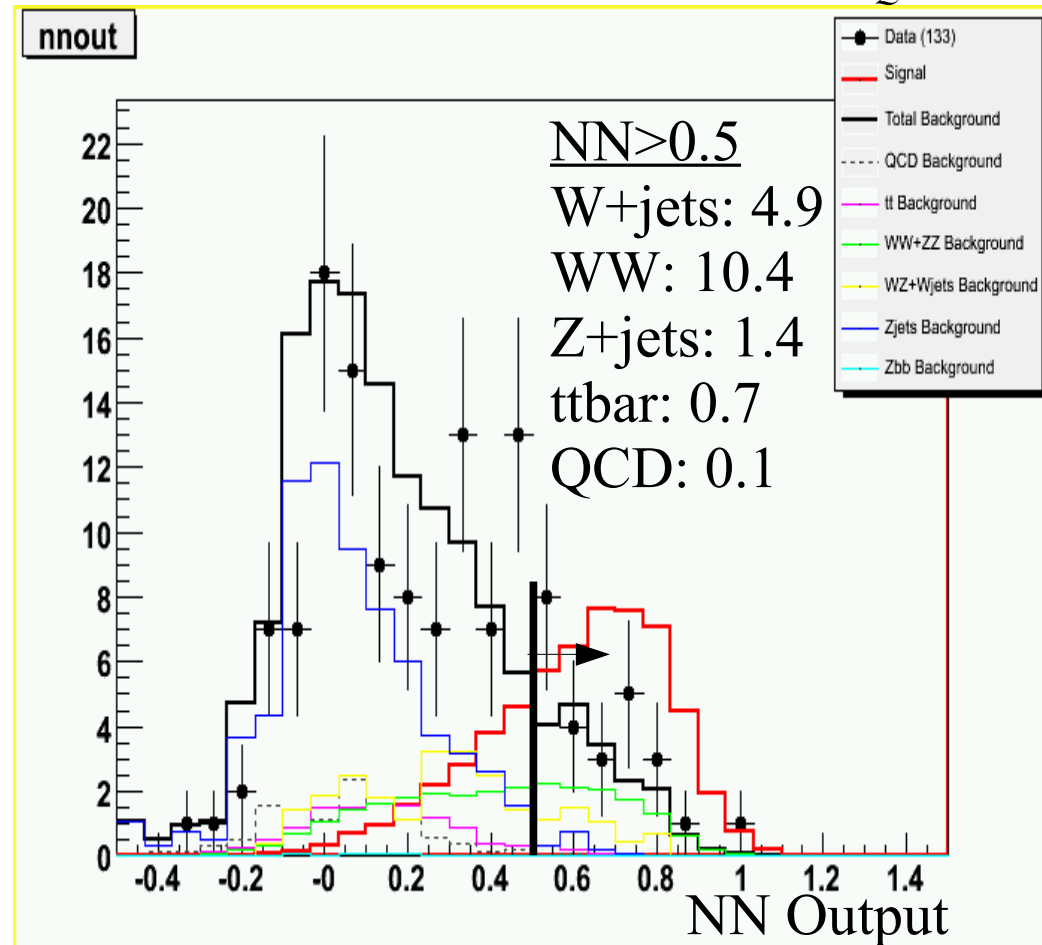
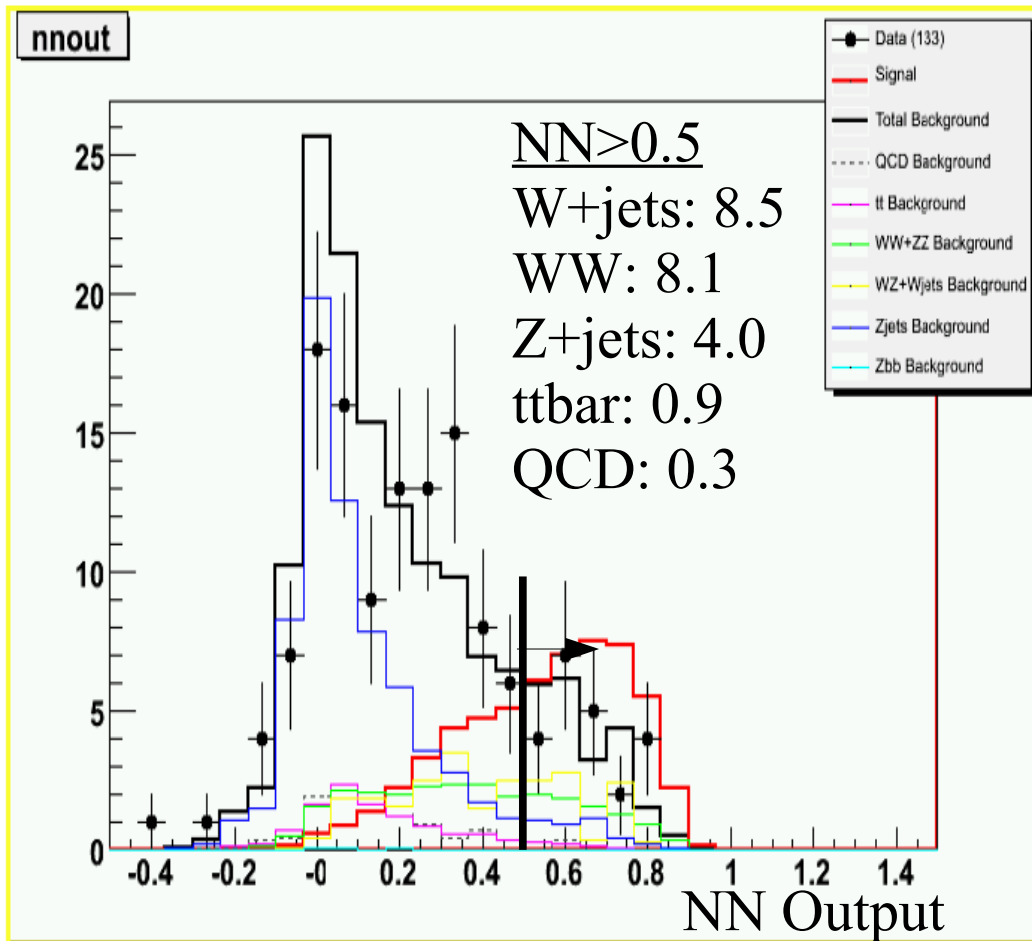


$\text{Log}_{10}(\text{Max}(\text{Chi}2 \text{ match of track to muon}))$

Reducing Backgrounds to $H \rightarrow WW$

Original NN

Using additional variables: $H_T, p_T(\mu_1, \mu_2),$
 $UE, SET, \chi^2(track, \mu), Min(\mu_Q)$

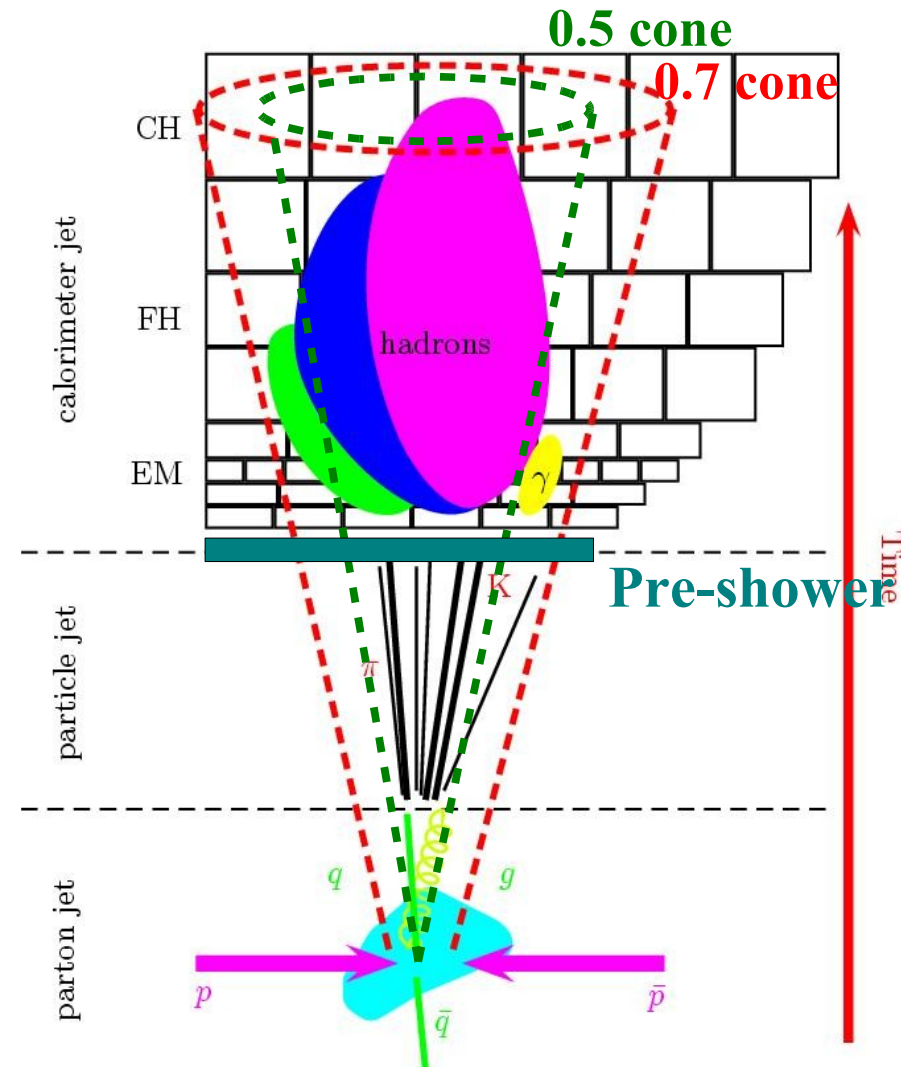


Sensitivity improved by 30%

Di-jet Mass Resolution

Undertaking a major effort to improve jet energy resolution

- Add "pre-shower" energy
- Correct for jet "width"
- Track-based corrections
- (H1-style) cell energy weighting
- Multiple jet-cone sizes
 - 0.5 less sensitive to noise, pileup, overlap
 - 0.7 captures more jet energy
 - *Jet-by-jet showering / FSR correction*



Average Cone Jets

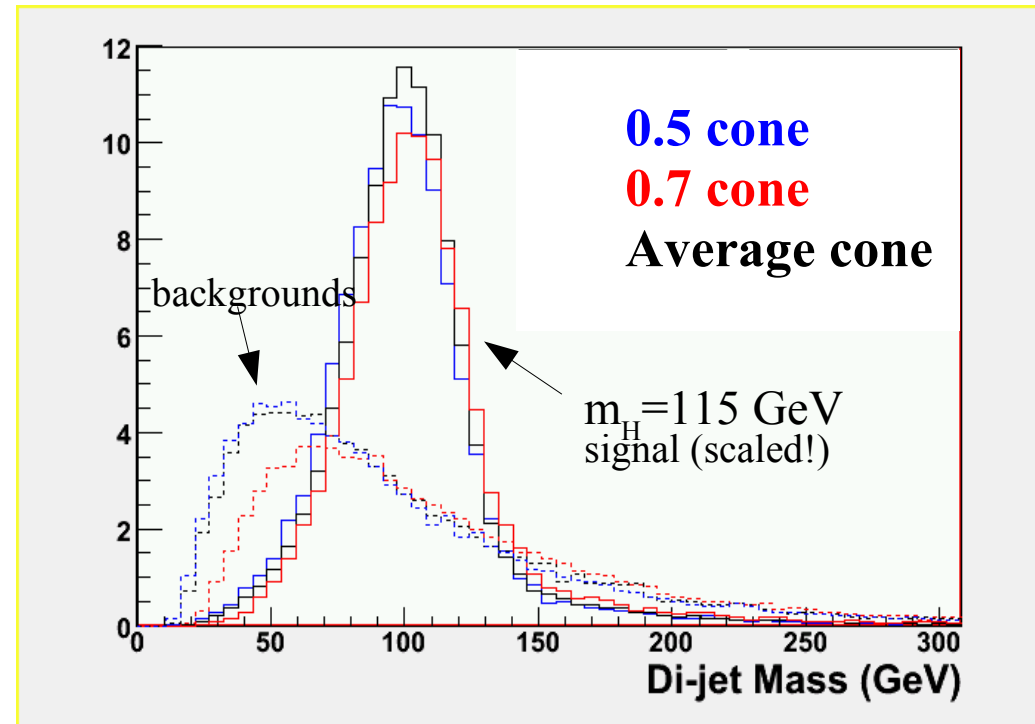
Use 0.5 cone jets for event selection and b-tagging

Match to 0.7 cone jet and average their 4-vectors

~8% di-jet mass resolution improvement

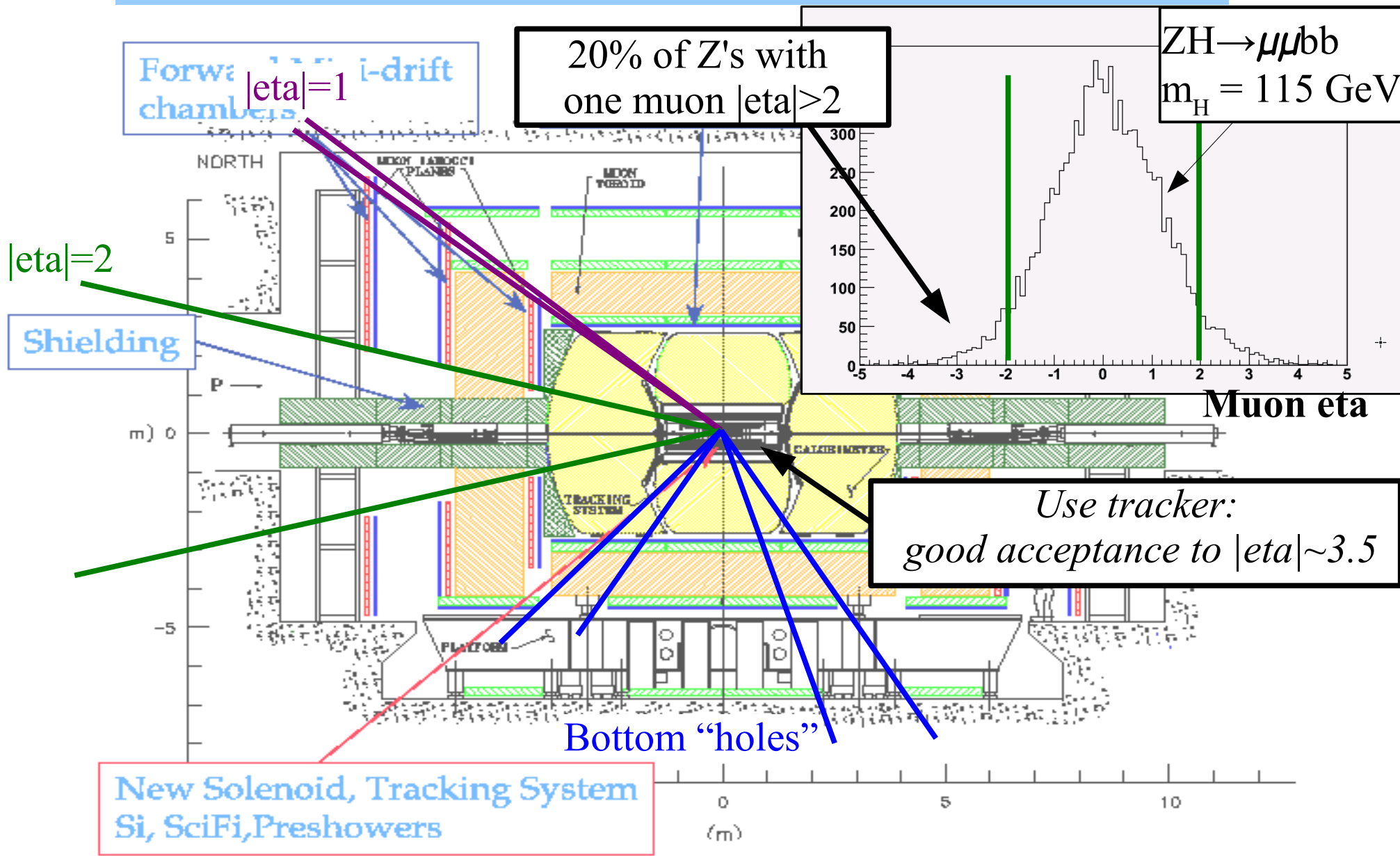
- angles are also measured better

~5% energy resolution improvement in γ +jet and di-jet data

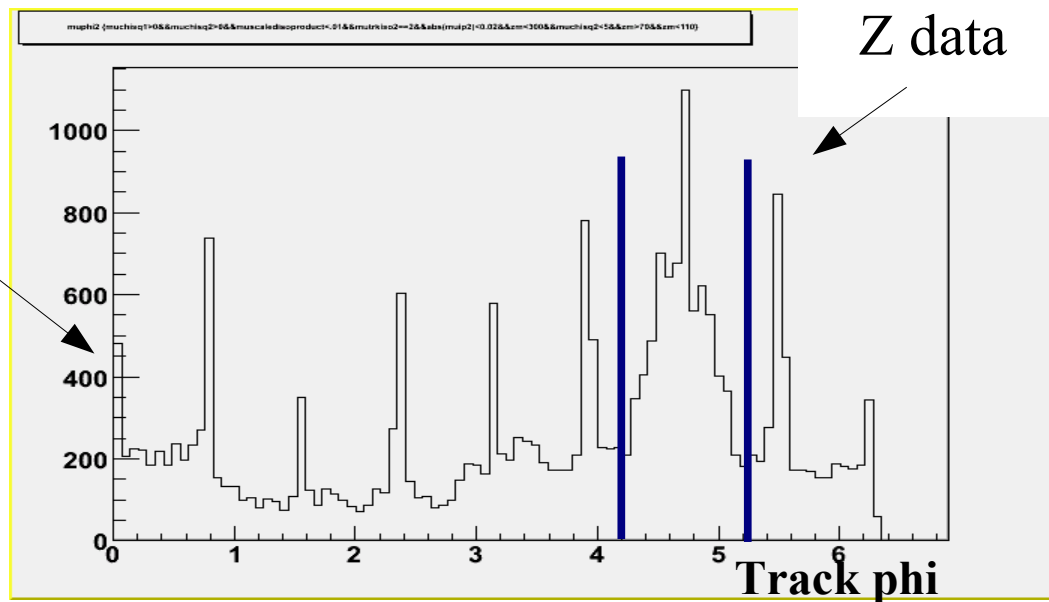
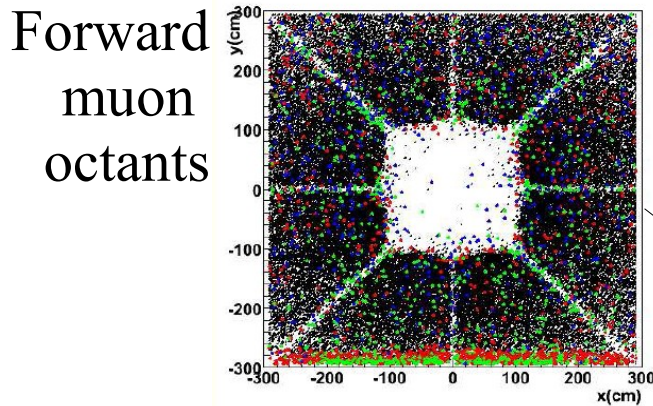
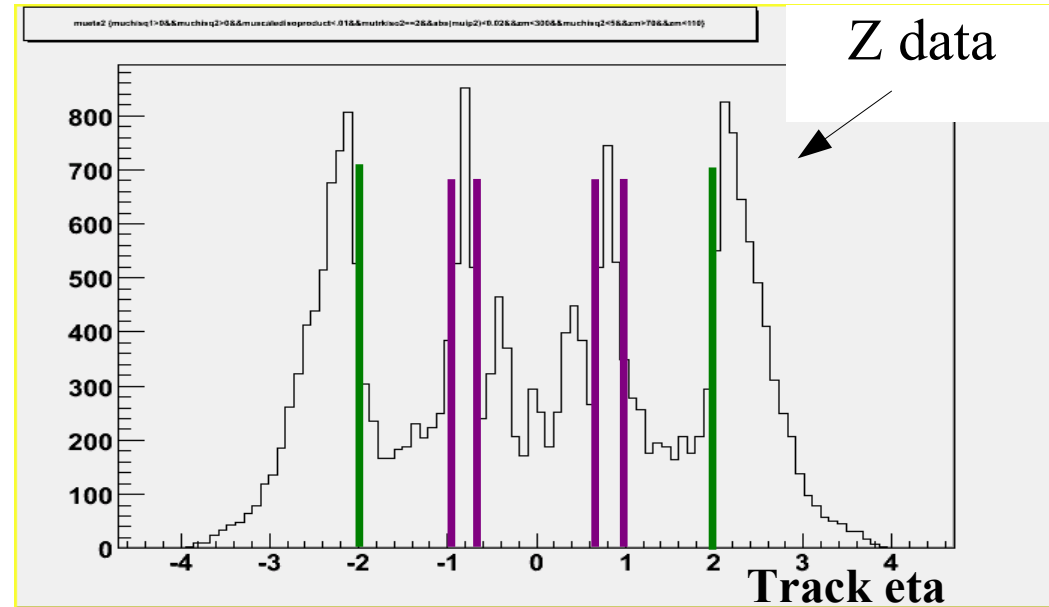
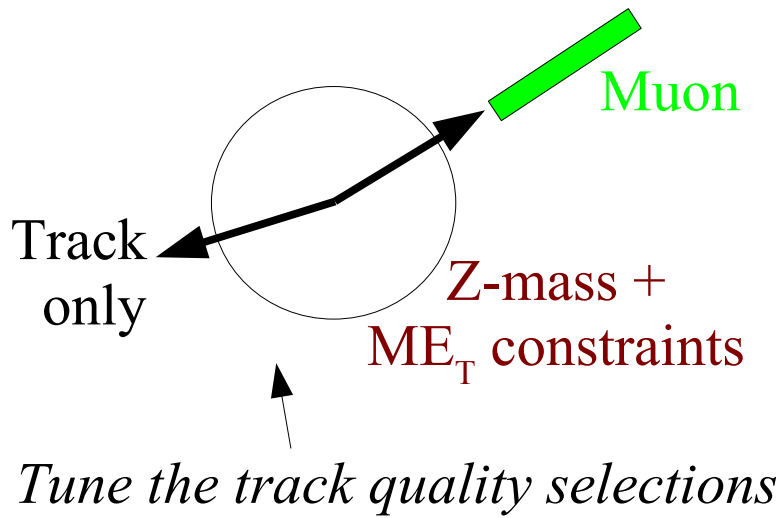


*8% more sensitivity
for low-mass Higgs searches*

Muon Acceptance



Muon Efficiency



Muons recovered in regions with poor muon acceptance

Muon Efficiency

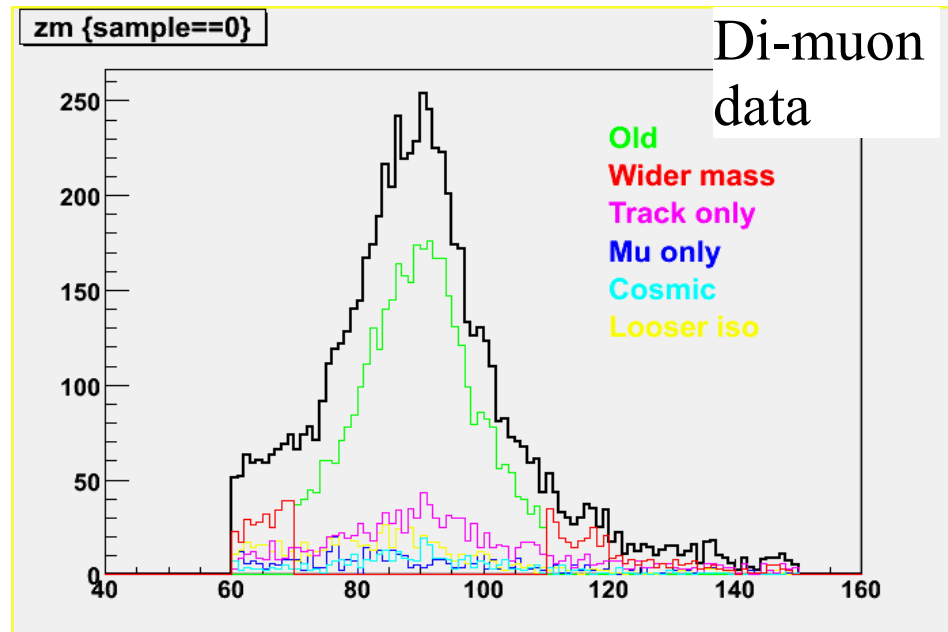
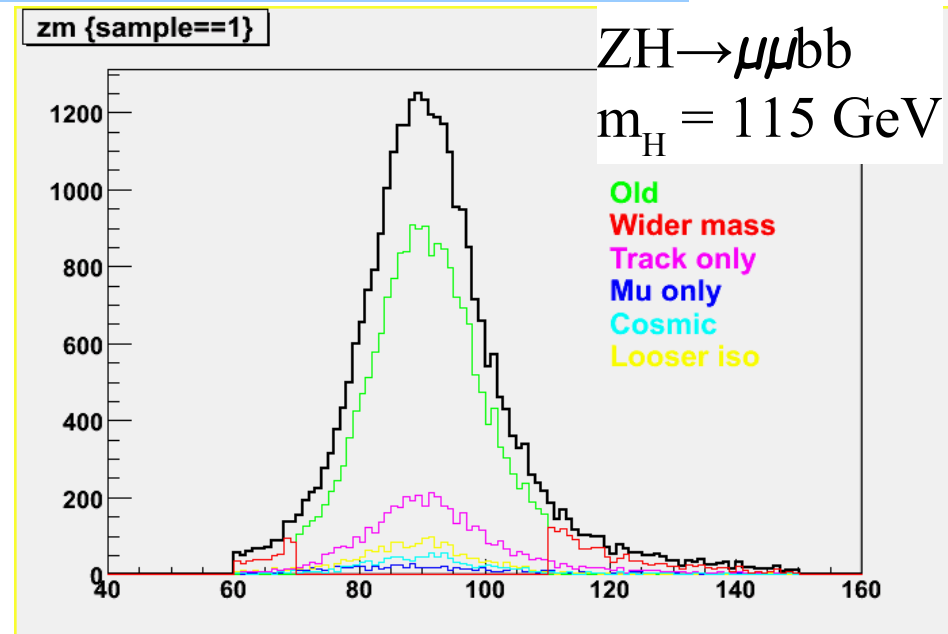
Combine track-only muon with:

- wider Z mass window
- muons with no central track
- muons failing timing criteria
- looser muon isolation

At pre-selection:

- ~60% more $ZH \rightarrow \mu\mu b\bar{b}$ signal
- ~90% more background

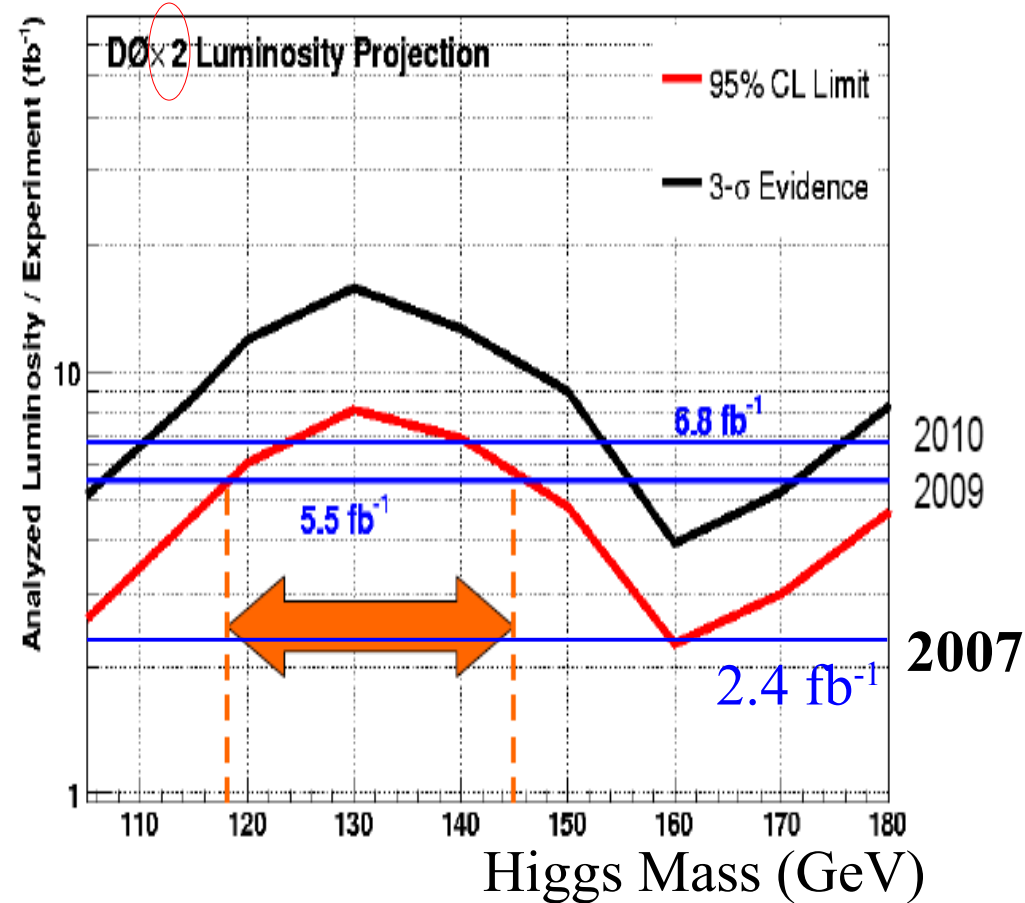
*Equivalent to 30% more data
after training NN*



Sensitivity Estimates

- Di-jet mass resolution (20%)
- Lepton efficiency (10%)
- Improved analyses (?%)
- Matrix Element (20%)
- Better b-tagging
 - Semi-leptonic tagging (5%)
 - Silicon Layer-0 (8%)

Should be sensitive to
 $m_H = 160 \text{ GeV}$ ~now



May be sensitive up to 200 GeV by 2010

A Bigger Atom Smasher

Tevatron



LHC

proton on *proton*

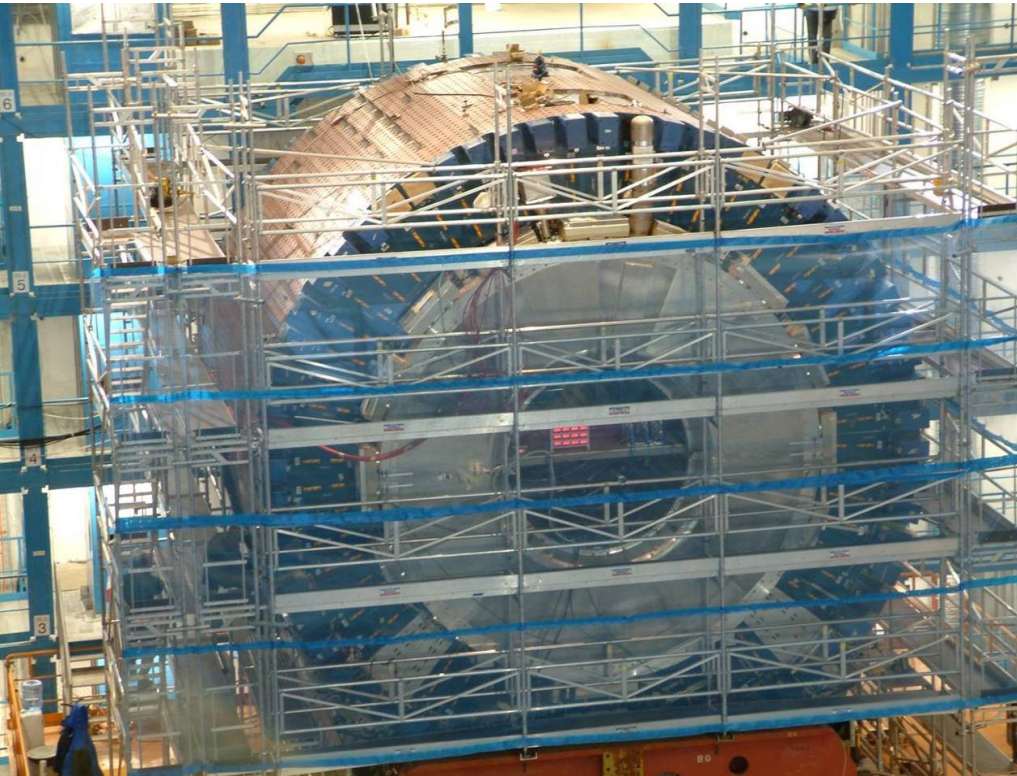
7x Tevatron energy
~100x the luminosity

Collisions this fall?

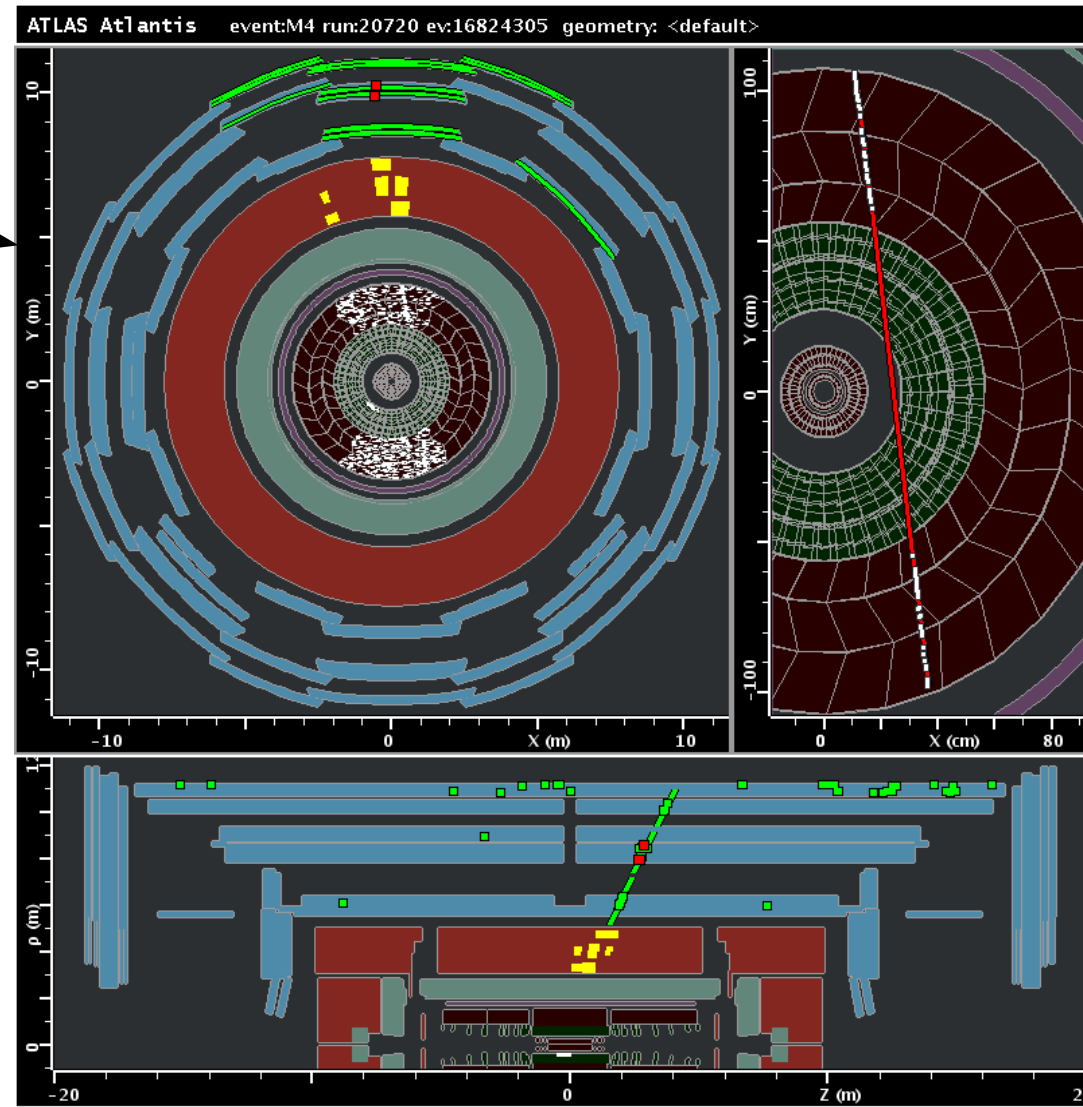


ATLAS

Taking cosmic data with
all detector subsystems



Barrel LA_r / Tile calorimeter



Higgs at the LHC

Discovery possible in whole mass range after 30/fb (~2011)

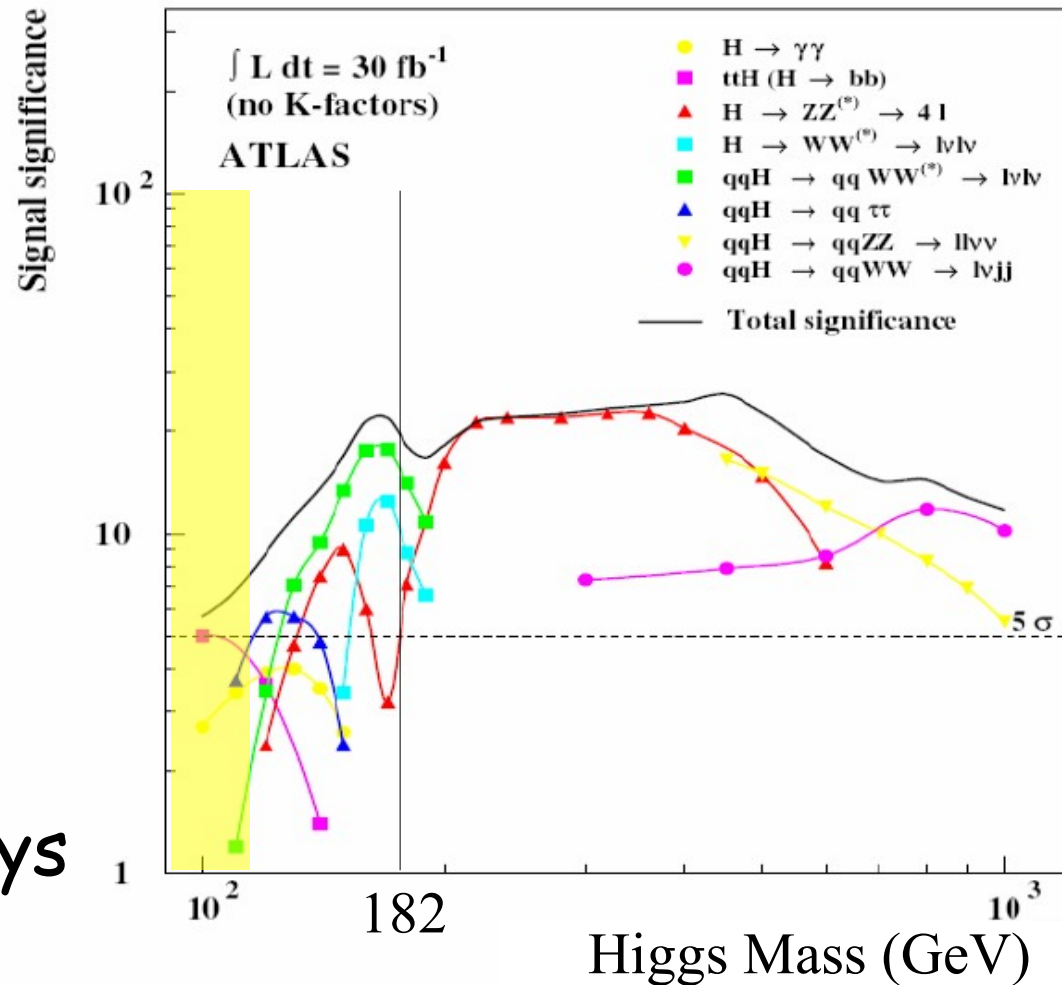
$m_H < \sim 130$ GeV difficult

Complimentary...

TeV: W/Z+H : H \rightarrow bb decays

LHC: H, qqH : H \rightarrow TT/ $\gamma\gamma$ decays

- ttH(\rightarrow bb) is very hard



First Physics with ATLAS

"Re-discover" the SM: (W,Z,top)

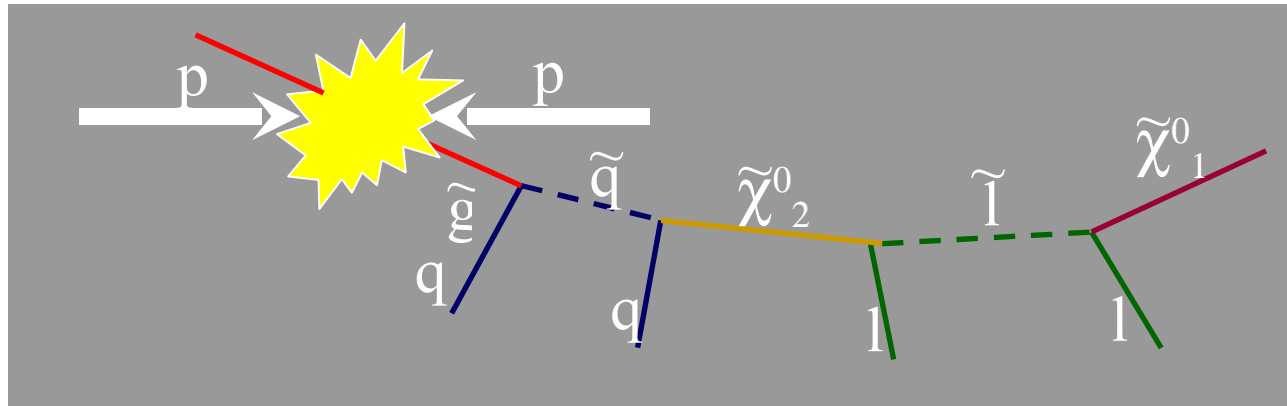
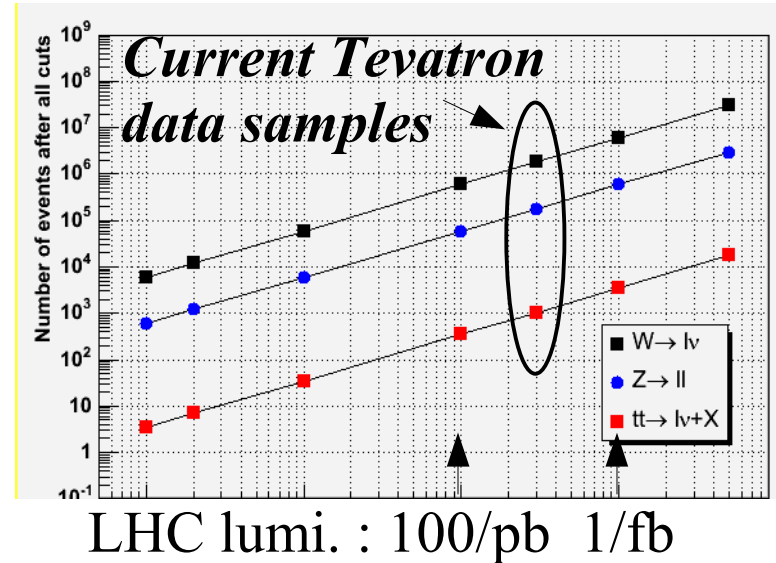
- Calibrate the detector
- Tune simulations

Keep it simple at first...

- Di-muons, Missing E_T

7x more energy

- $H \rightarrow WW \rightarrow \mu\mu$
- SUSY?
- New phenomena?



Experience and methods from the Tevatron will be vital to successful LHC analyses!

Conclusions

$D\emptyset$ (with help from CDF) is closing in on the SM Higgs

- NN b-tagging, single/double b-tag, NN event selection, ...
- May be sensitive to SM Higgs at 160 GeV *this winter*

Continuing to improve our analysis techniques

- Better di-b-jet mass res., lepton ID, background rejection, ...
- Possible to be sensitive up to 200 GeV by 2010

The LHC starts this year

- Light Higgs boson by ~2011: race with the Tevatron ?!
- Also a huge opportunity for other new physics (SUSY, etc.)

An exciting time for high-energy physics!

Backup

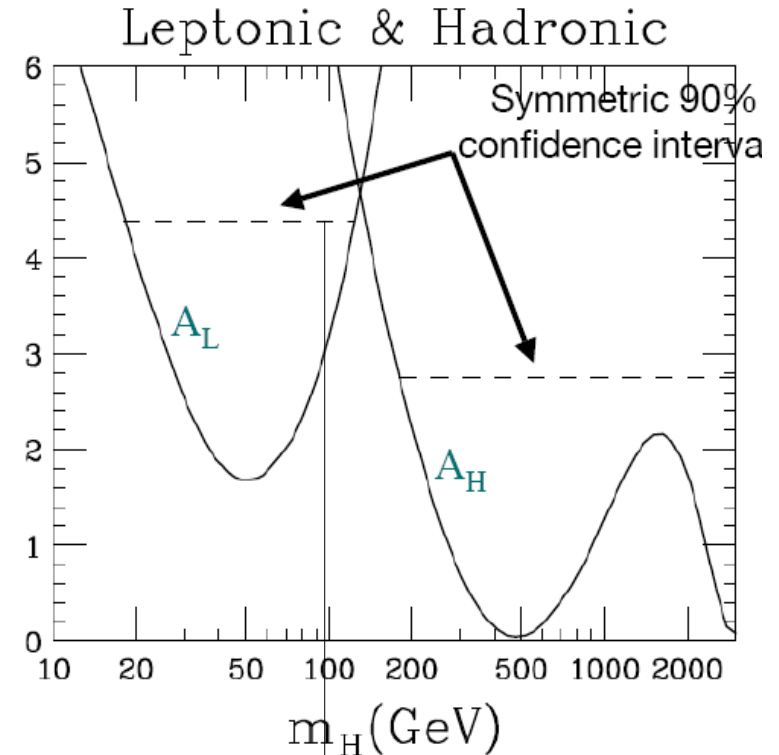
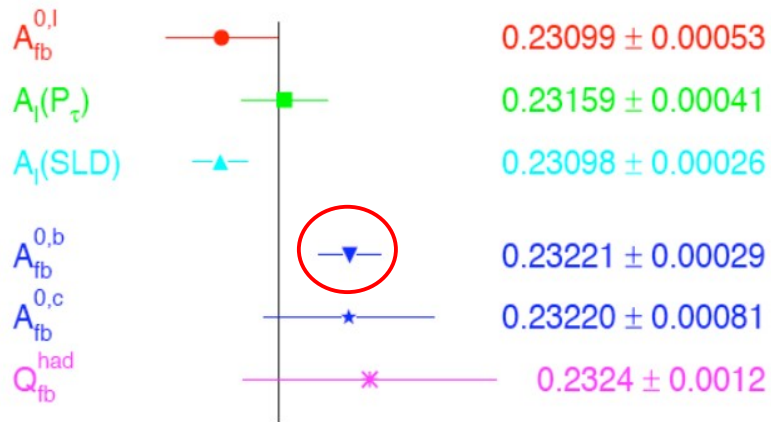
Precision EW Constraints

EW variables sensitive to m_H via radiative corrections:

$$\log \frac{m_H}{m_Z}$$

LEP II: $m_H > 114.4 \text{ GeV}$

$\sin^2 \theta_{\text{eff}}^{\text{lept}}$: most important observable for m_H fit

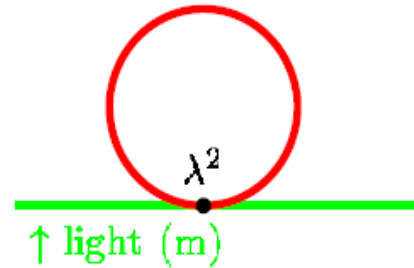


$m_H < 97 \text{ GeV}$
(at 95% CL)
(leptonic only)

Why is the Higgs so Light?

The Higgs mass is *unstable*

- Large radiative corrections (it's a scalar)

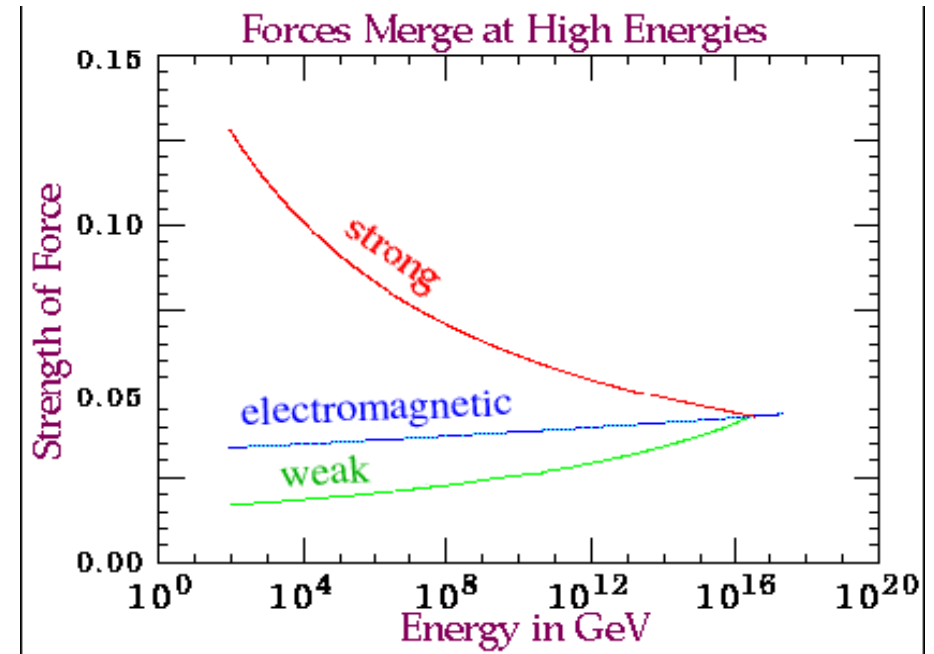


$$\Rightarrow \delta m^2 \sim \lambda^2 \cdot M^2$$

$$\begin{matrix} \lambda & \lambda & \lambda \\ 10^2 & 10^{-1} & 10^{16} \end{matrix}$$

Hierarchy problem:

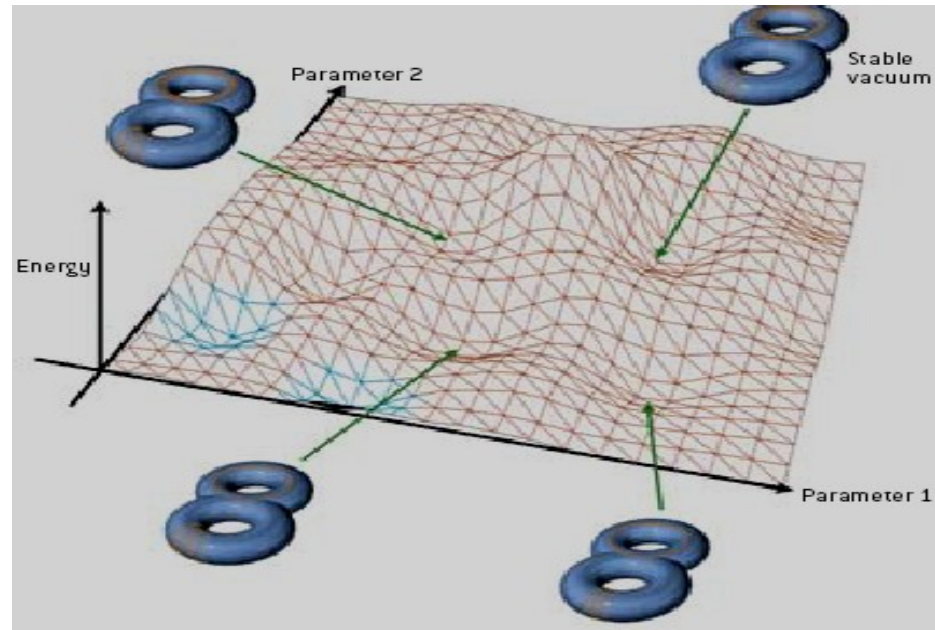
$$m_H \ll m_{GUT}$$



Why is the Higgs so Light?

We wouldn't be here if it wasn't

- A small Higgs VEV seems necessary for life

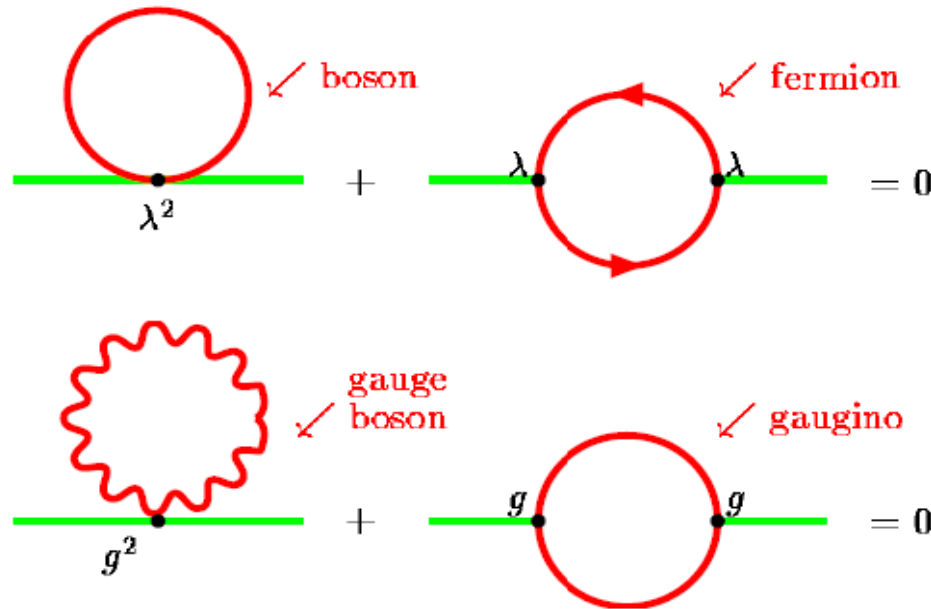


Same reason for a small cosmological constant?

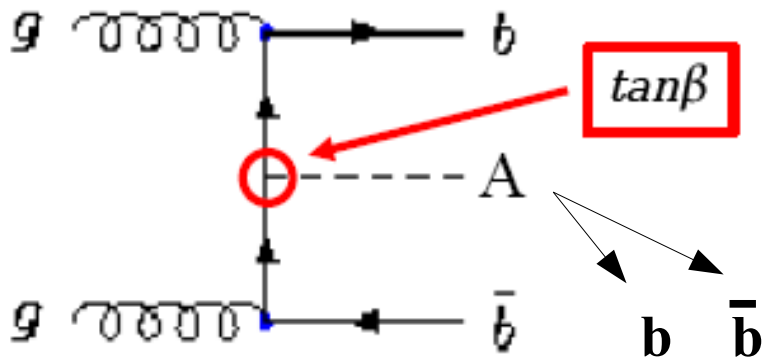
Why is the Higgs so Light?

New physics: Supersymmetry

- Particles come in fermion-boson pairs
- Corrections to Higgs mass nearly cancel, if boson and fermion masses are similar



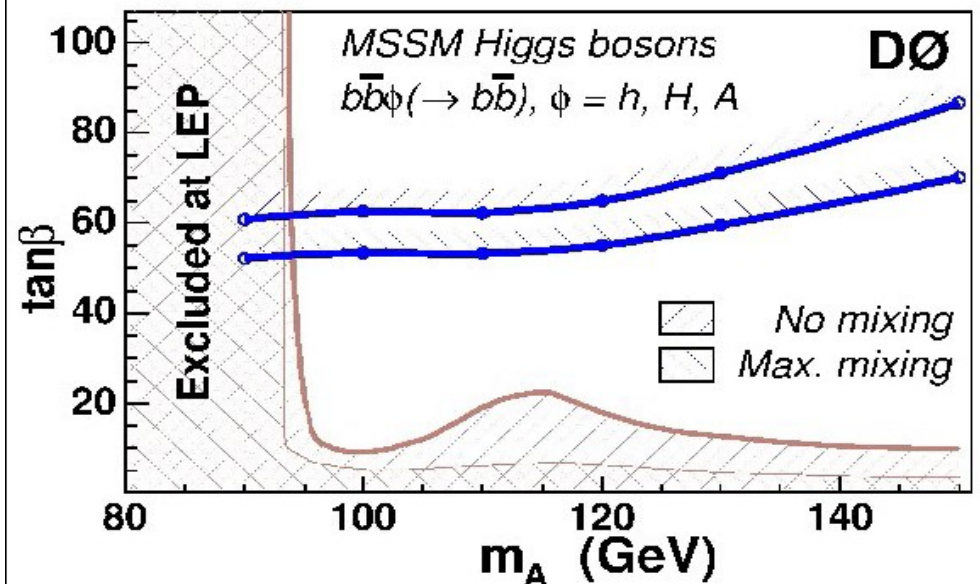
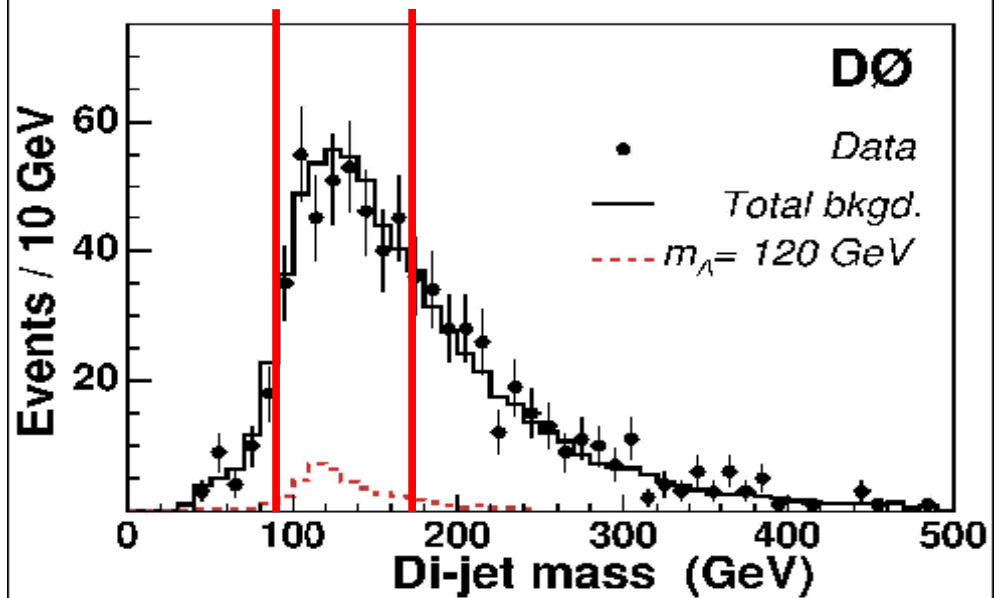
DØ SUSY Higgs Search



Search for bbb bump on bbb background

Interpret as limits in $m_A / \tan\beta$ plane

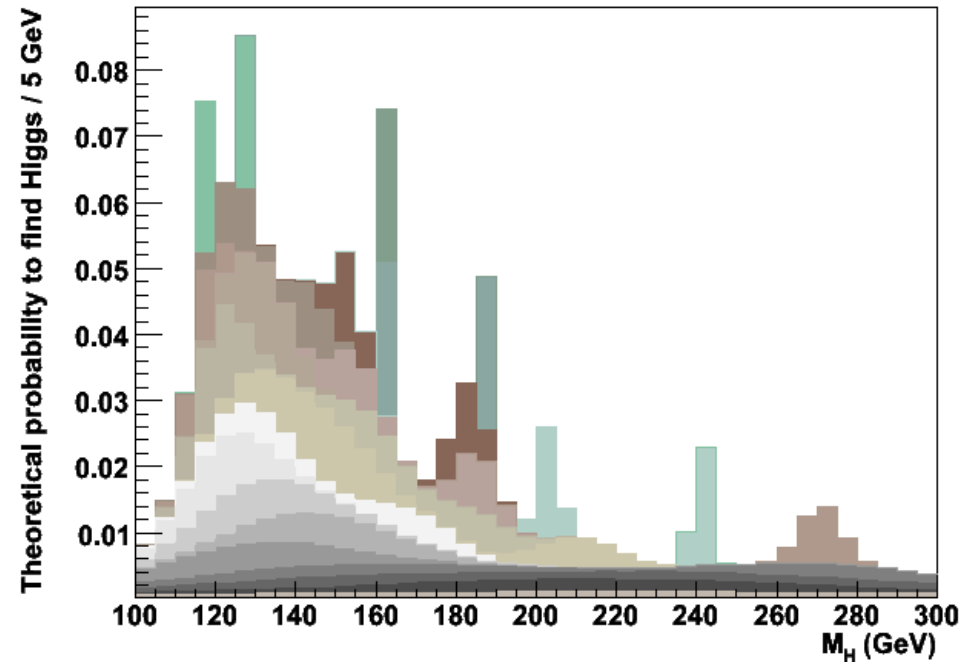
PRL 95, 151801 (2005)



Why is the Higgs so Light?

616 papers on hep-ph in 2007 on "Higgs"

Lots of great ideas
Need experimental input



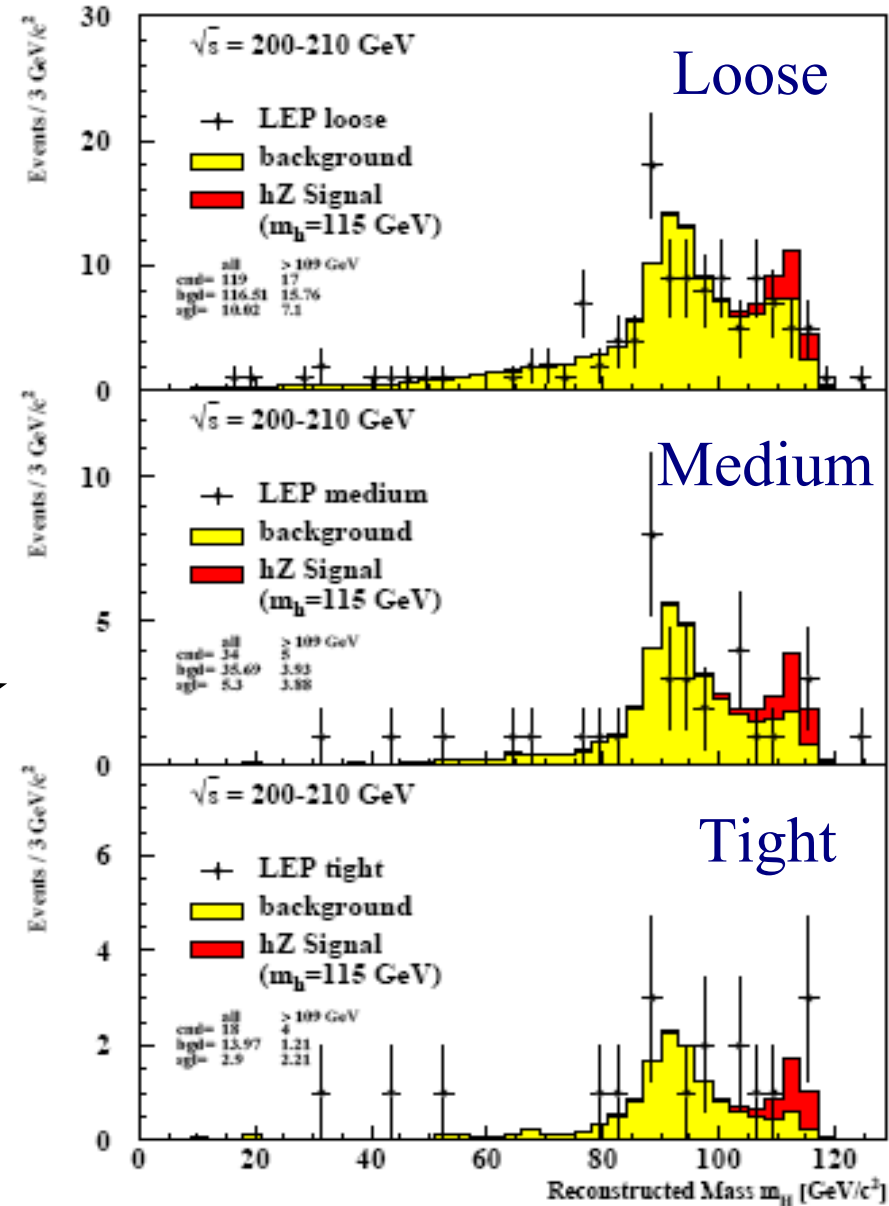
LEP @ CERN in 2000

Circular $e^+ e^-$ collider
 Maximum E of 200-210 GeV



A good, but not the only variable...

Look for $e^+ e^- \rightarrow Z+H(-\rightarrow bb)$
 Slight excess around 115 GeV
 Higgs mass > 114.4 GeV



Limit Setting

- ◁ In the absence of signal, we set limits on Standard Model Higgs boson production

- × We calculate limits via the CLs prescription:

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

- × Using a Log-Likelihood Ratio test statistic:

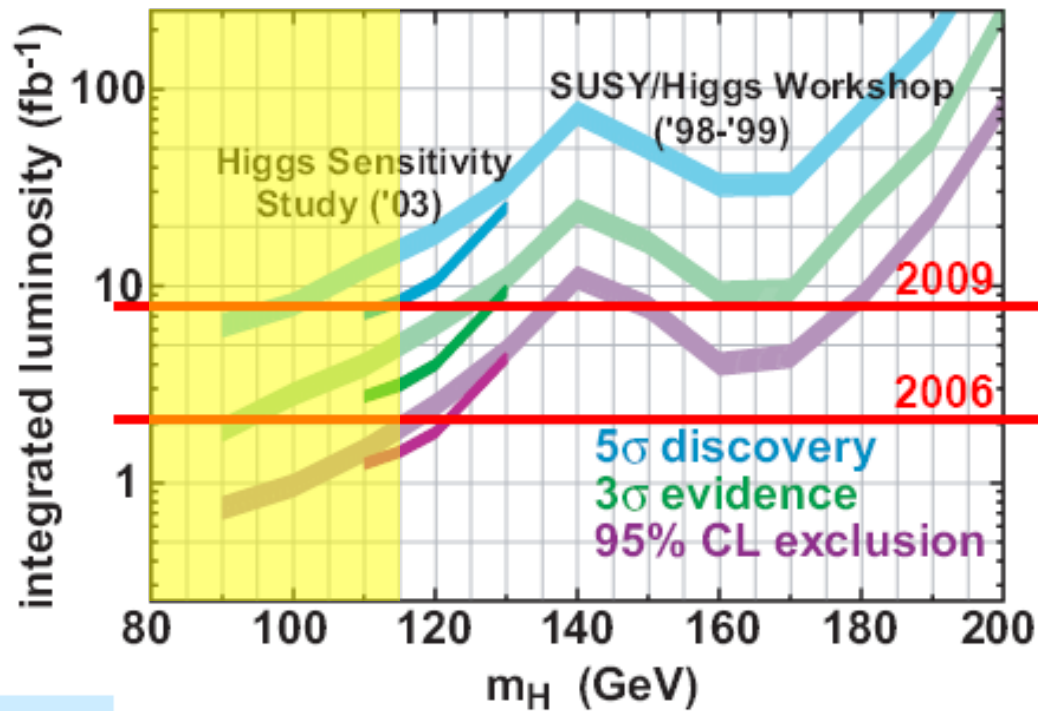
$$Q(\vec{s}, \vec{b}, \vec{d}) = \prod_{i=0}^{N_{Chan}} \prod_{j=0}^{N_{bins}} \frac{(s+b)_{ij}^{d_{ij}} e^{-(s+b)_{ij}}}{d_{ij}!} \bigg/ \frac{b_{ij}^{d_{ij}} e^{-b_{ij}}}{d_{ij}!} \quad LLR = -2 \times \text{Log} Q$$

d_{ij} refers to "data" for model being tested: Observed events, or expected Background or Signal+Background

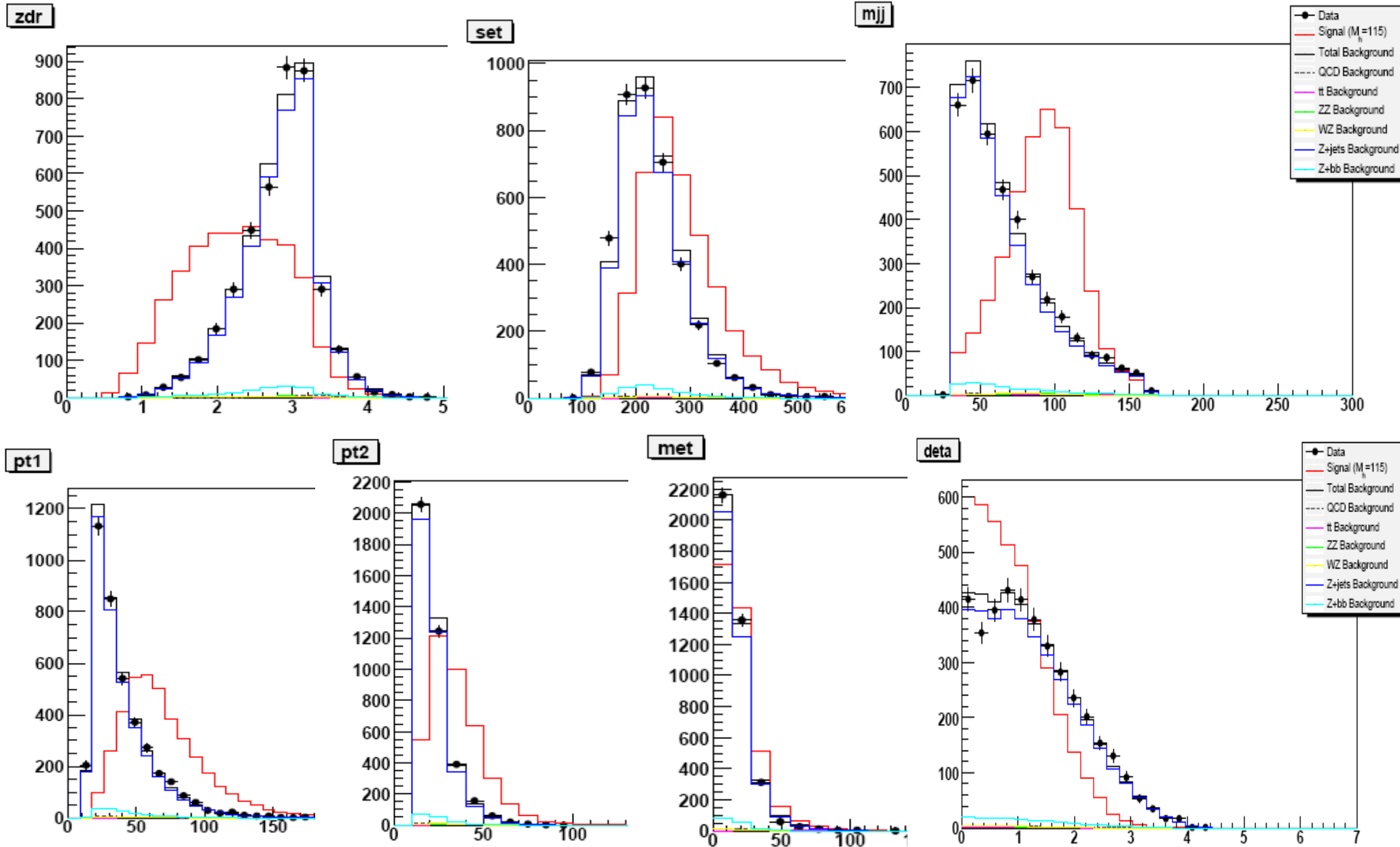
- ◁ Distributions of simulated outcomes are populated via Poisson trial with mean values given by B-only or S+B hypotheses
- × Systematics are folded in via Gaussian marginalization
- × Correlations held amongst signals and backgrounds

Sensitivity

2003 study



ZH $\rightarrow\mu\mu b\bar{b}$ Pre-b-tagging

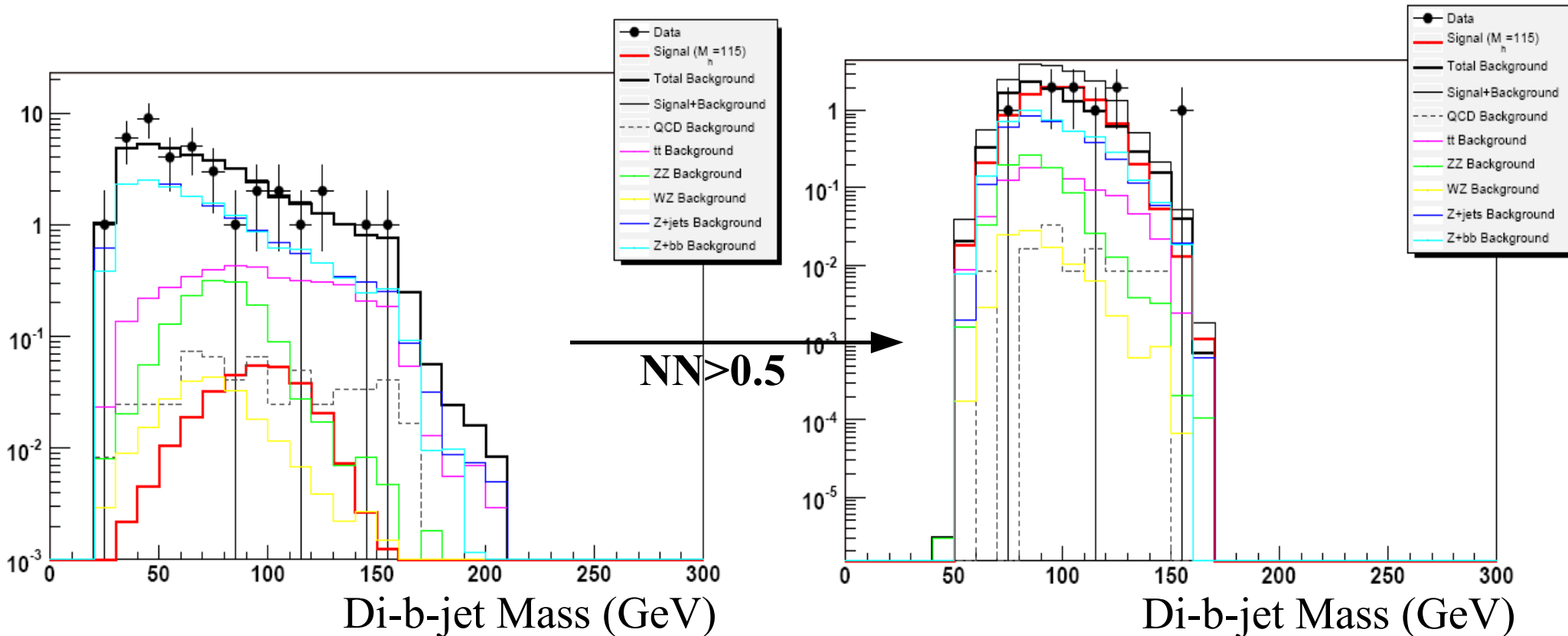


Neural Net Cross-Checks

Study variable shapes *after* cutting on NN output (>0.5)

NN is selecting signal-like region of phase-space

- No separation power remains



Systematic Uncertainties

Luminosity, 6.1%

Lepton ID, 2%

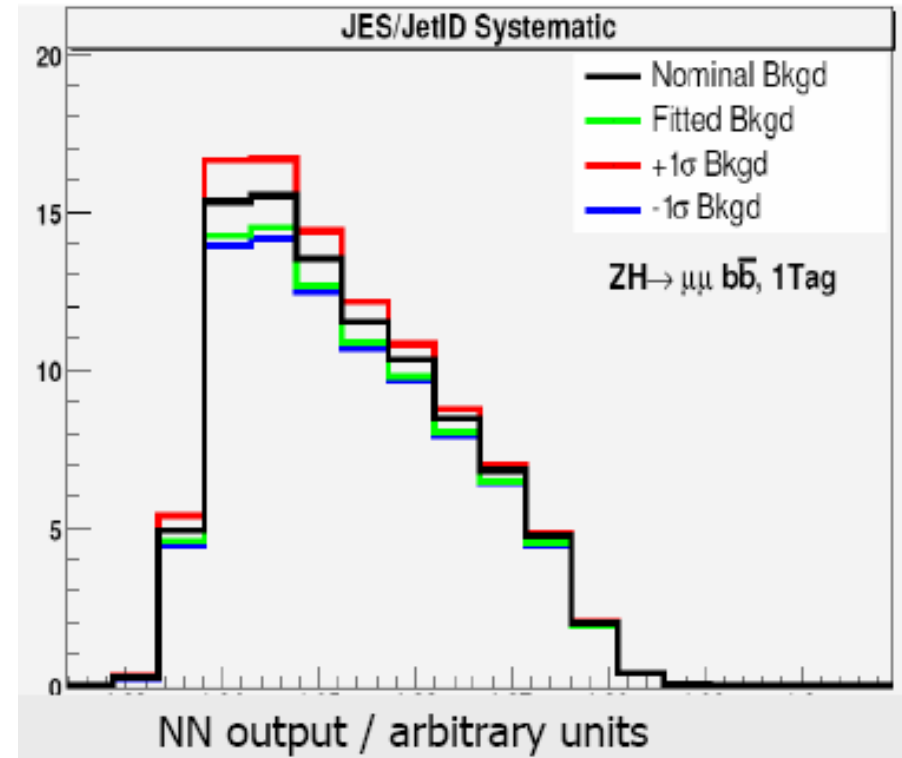
Background cross-sections, 5-30%

QCD estimation, 20%

Jet-energy scale*

b-tagging*

** Affects shape of NN output as well as normalization*



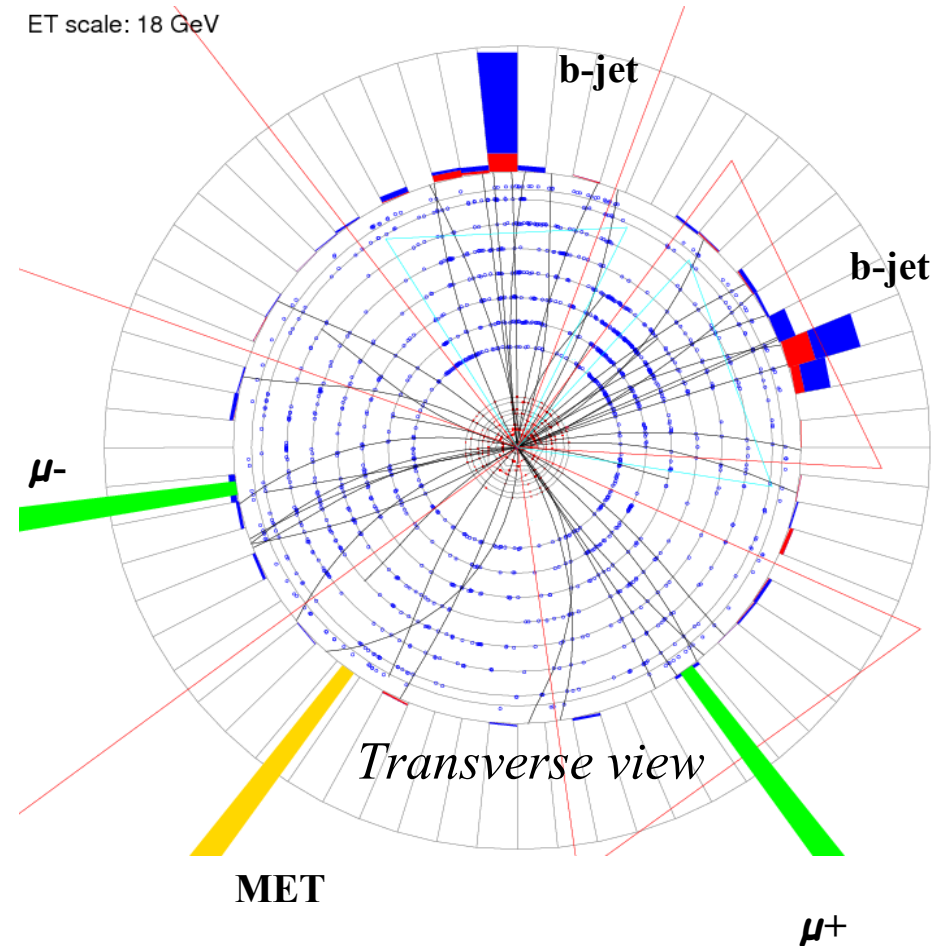
Event Kinematics

No true MET in $\mu\mu b\bar{b}$ events

Should assign observed MET to some combination of muons and jets - correct their p_t 's

Depends on:

- angles between MET, muons, and jets
- p_t balance of Z and di-jets
- invariant mass constraint of Z and $H \rightarrow b\bar{b}$



Too complicated for NN

Matrix Elements

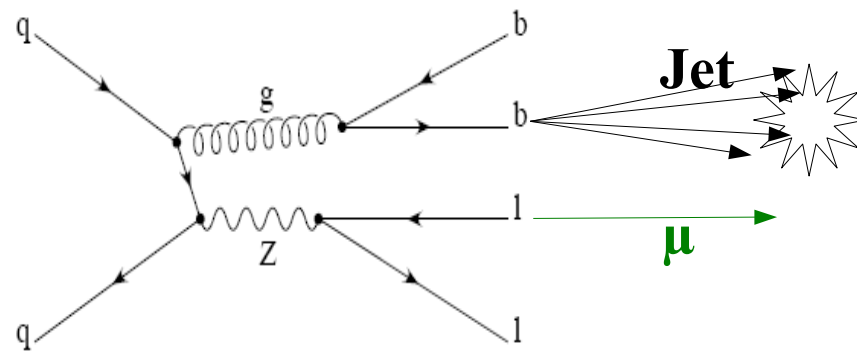
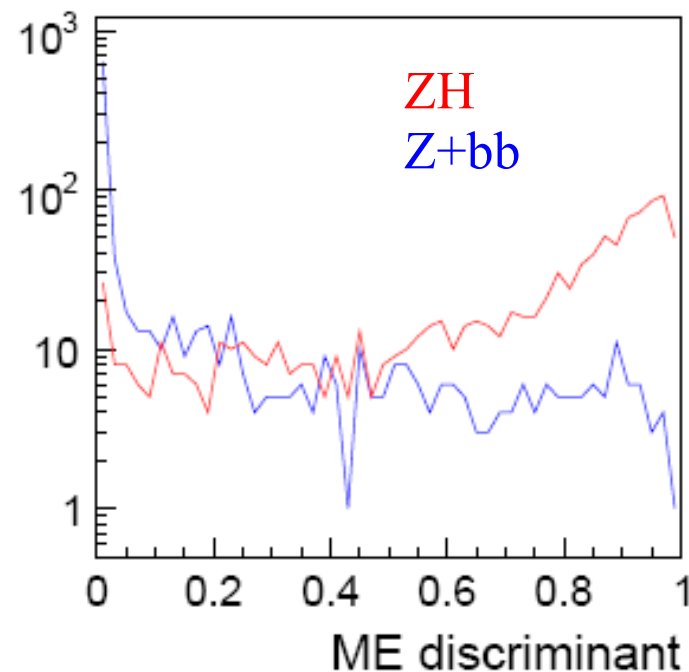
Calculate "cross-section" for an observed event to be from Z+bb or Z+(H->bb)

Use MC integration methods

Include as inputs to NN

$$p(m) = \int dx f_{\Phi} \cdot \sum_{a,b} f_a f_b |M_{ab}(k(m,x))|^2 \cdot T(k(m,x), m)$$

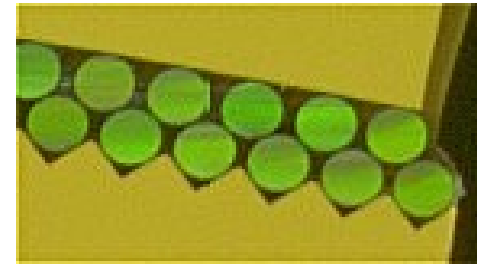
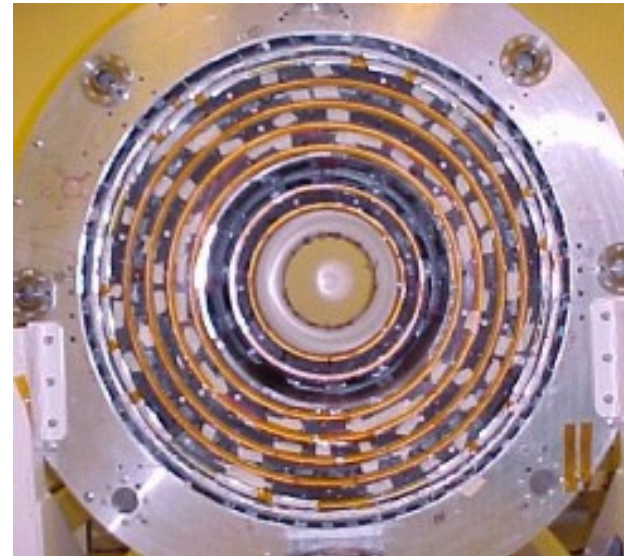
- ▷ m : detector measurement of event.
- ▷ x : integration parameters
- ▷ $k(x,m)$: parton solution given m and x .
- ▷ f_{Φ} : phase-space factors.
- ▷ $f_a f_b$: PDFs from MCFM.
- ▷ M_{ab} : matrix element from MCFM.
- ▷ T : transfer functions



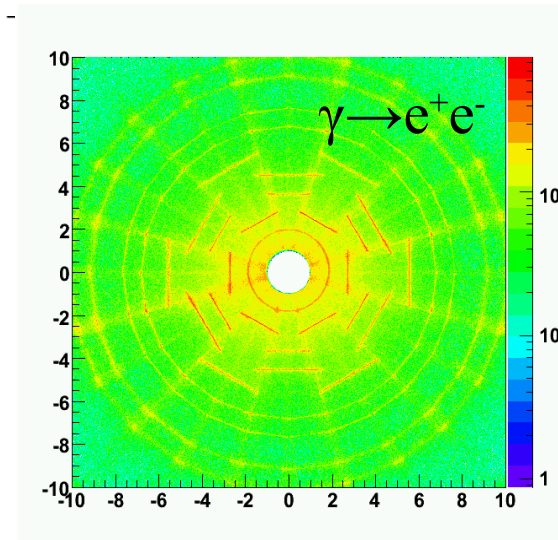
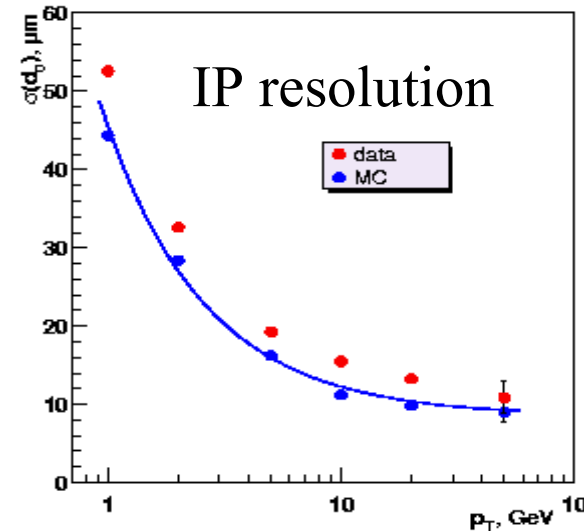
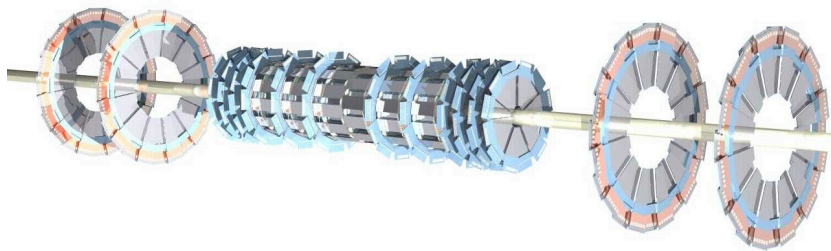
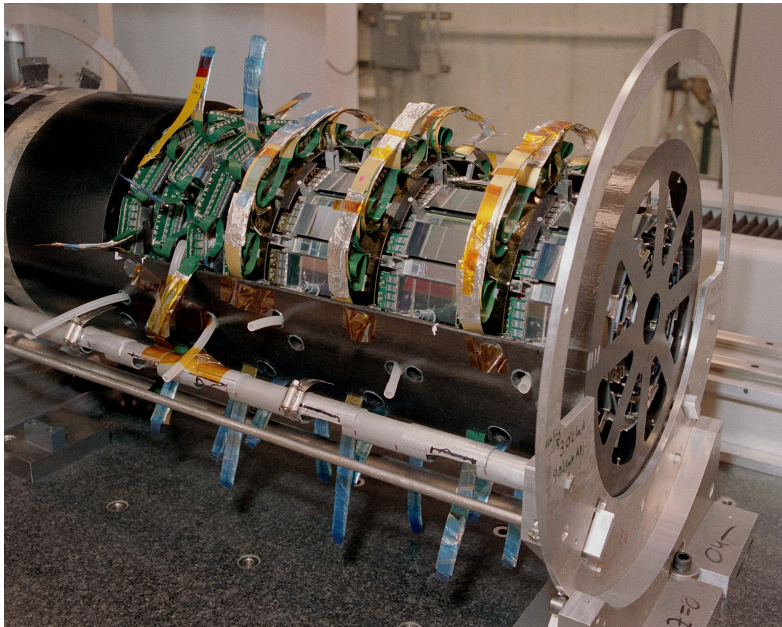
$$\text{MET} = \mu_1 + \mu_2 + j_1 + j_2 + \sigma(\text{MET})$$

Tracking

Central Fiber Tracker



Silicon Microstrip Tracker

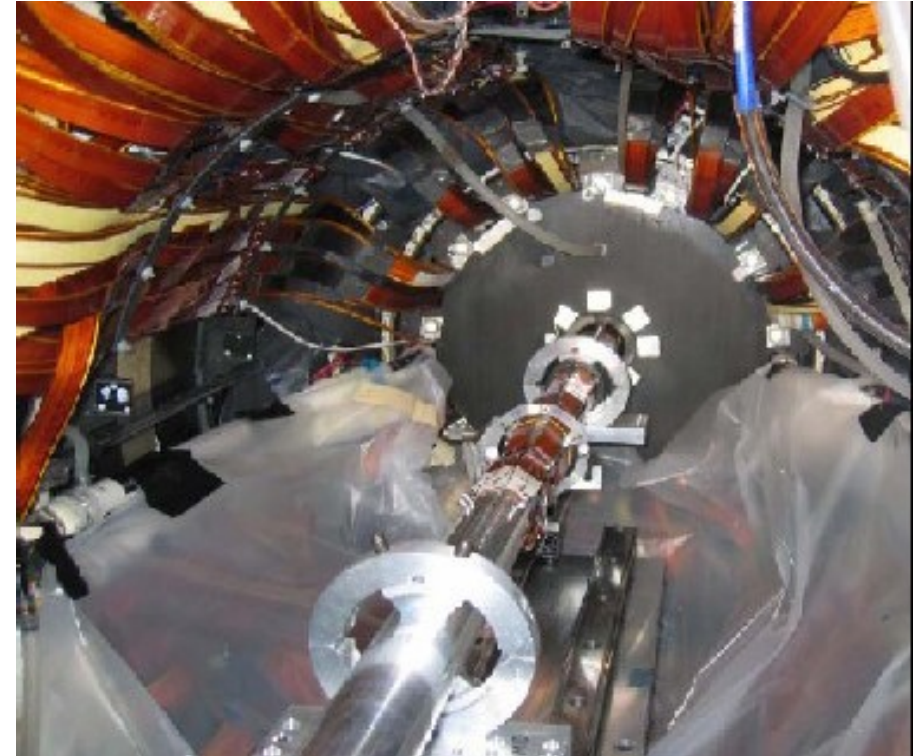


Layer 0 of Silicon Tracker

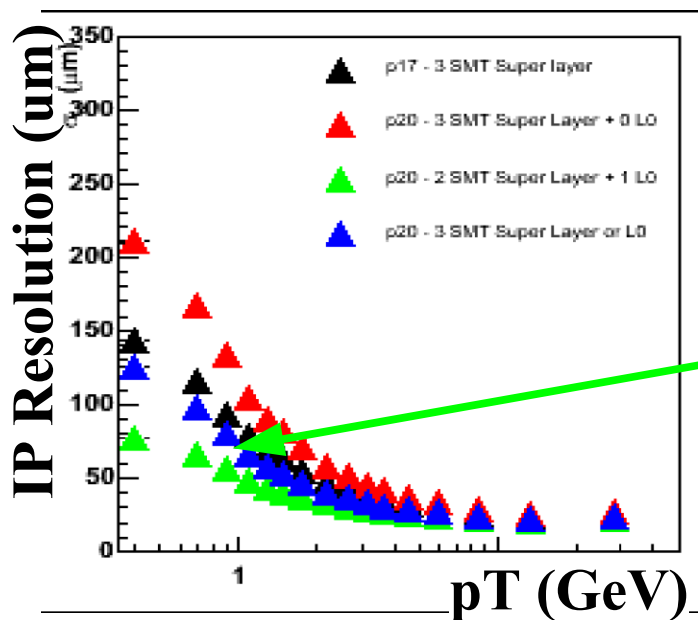
Silicon detectors mounted
just outside the beampipe

Installed fall '06

Better track impact-
parameter resolution
-> Better b-jet tagging

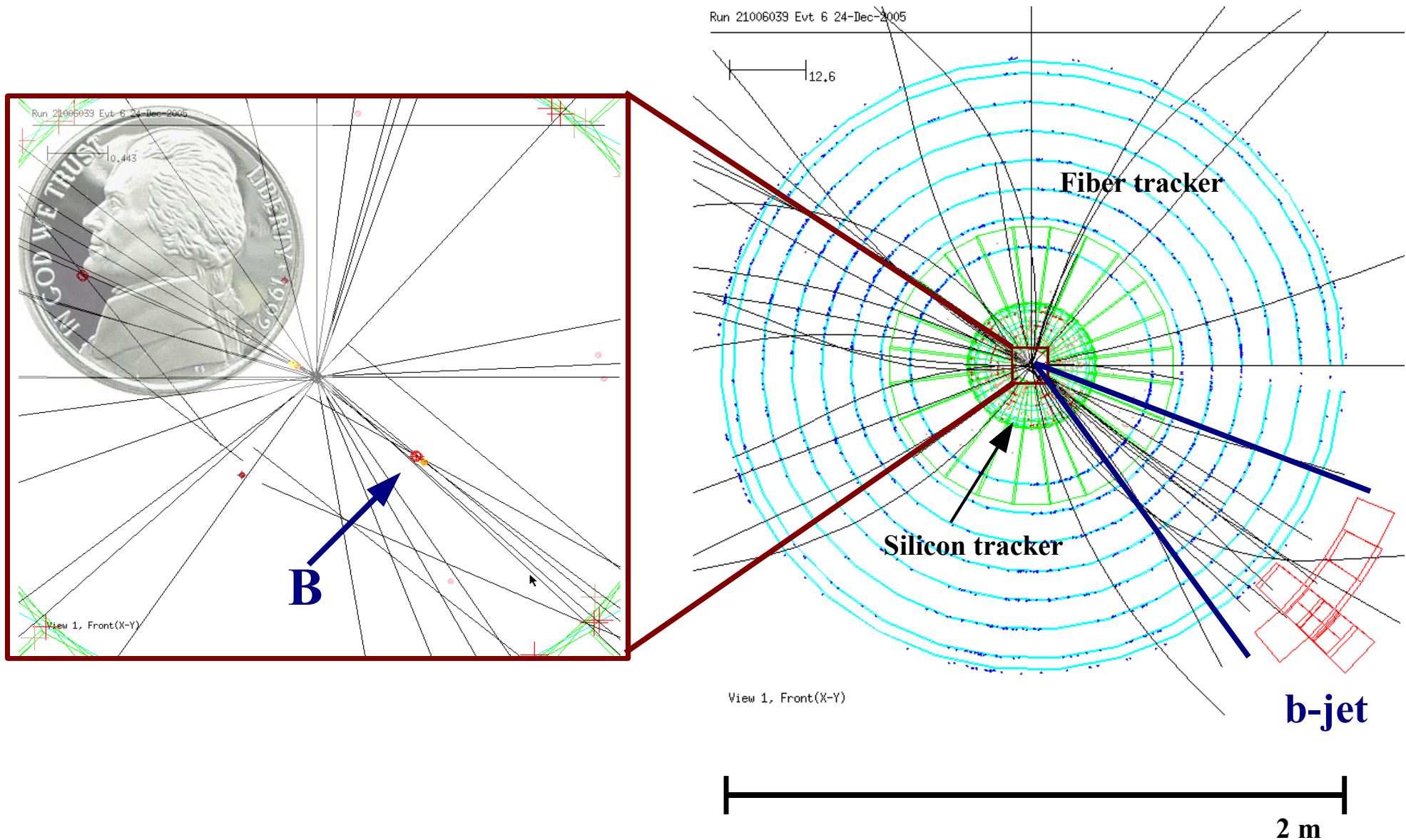


Layer 0 being inserted into the silicon tracker



**Effect of Layer 0
in recent data**

b-Jet Tagging Reality



b-Tagging Measurement

System 8 method:

$$\begin{aligned}n &= n_b + n_{uds} \\ p &= p_b + p_{uds} \\ n^{SLT} &= \varepsilon_b^{SLT} n_b + \varepsilon_{uds}^{SLT} n_{uds} \\ p^{SLT} &= \varepsilon_b^{SLT} p_b + \varepsilon_{uds}^{SLT} p_{uds} \\ n^{NN} &= \varepsilon_b^{NN} n_b + \varepsilon_{uds}^{NN} n_{uds} \\ p^{NN} &= \beta \varepsilon_b^{NN} p_b + \alpha \varepsilon_{uds}^{NN} p_{uds} \\ n^{SLT,NN} &= \kappa_b \varepsilon_b^{SLT} \varepsilon_b^{NN} n_b + \kappa_{uds} \varepsilon_{uds}^{SLT} \varepsilon_{uds}^{NN} n_{uds} \\ p^{SLT,NN} &= \kappa_b \beta \varepsilon_b^{SLT} \varepsilon_b^{NN} p_b + \kappa_{uds} \alpha \varepsilon_{uds}^{SLT} \varepsilon_{uds}^{NN} p_{uds}\end{aligned}$$

- Correlation coefficients, measured in MC:

α - Ratio of the *uds*-tagging efficiencies in the two samples.

β - Ratio of the *b*-tagging efficiencies in the two samples.

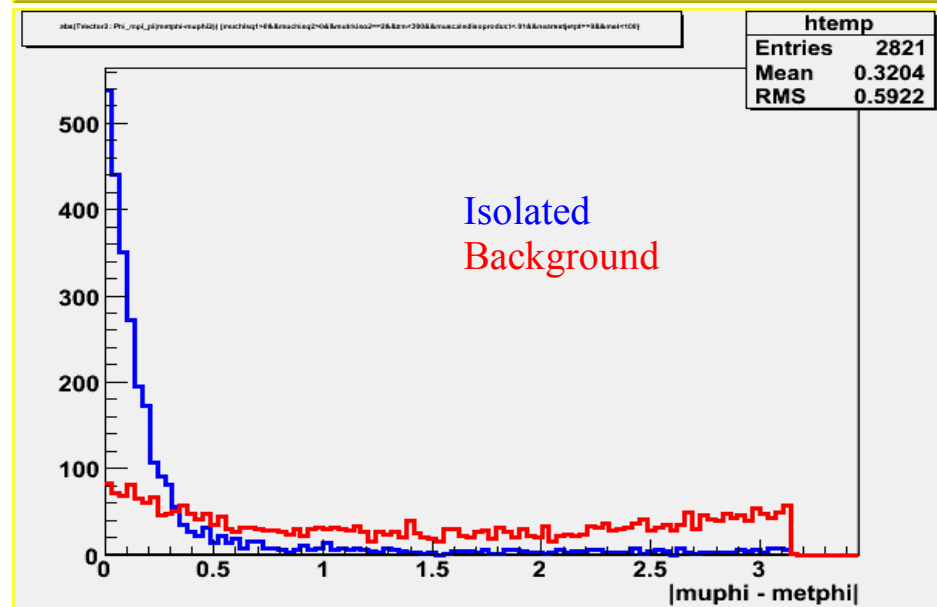
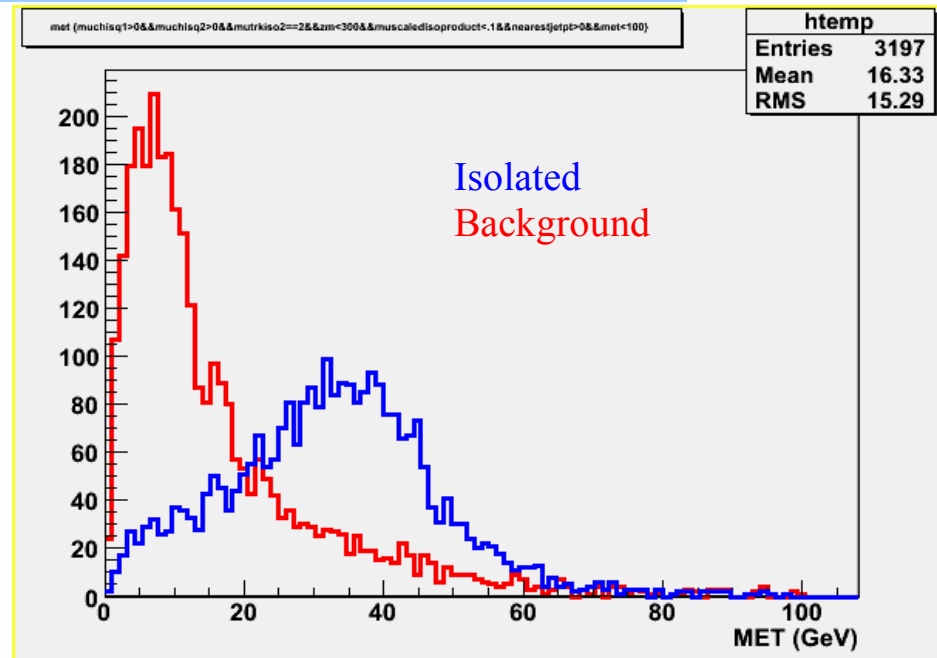
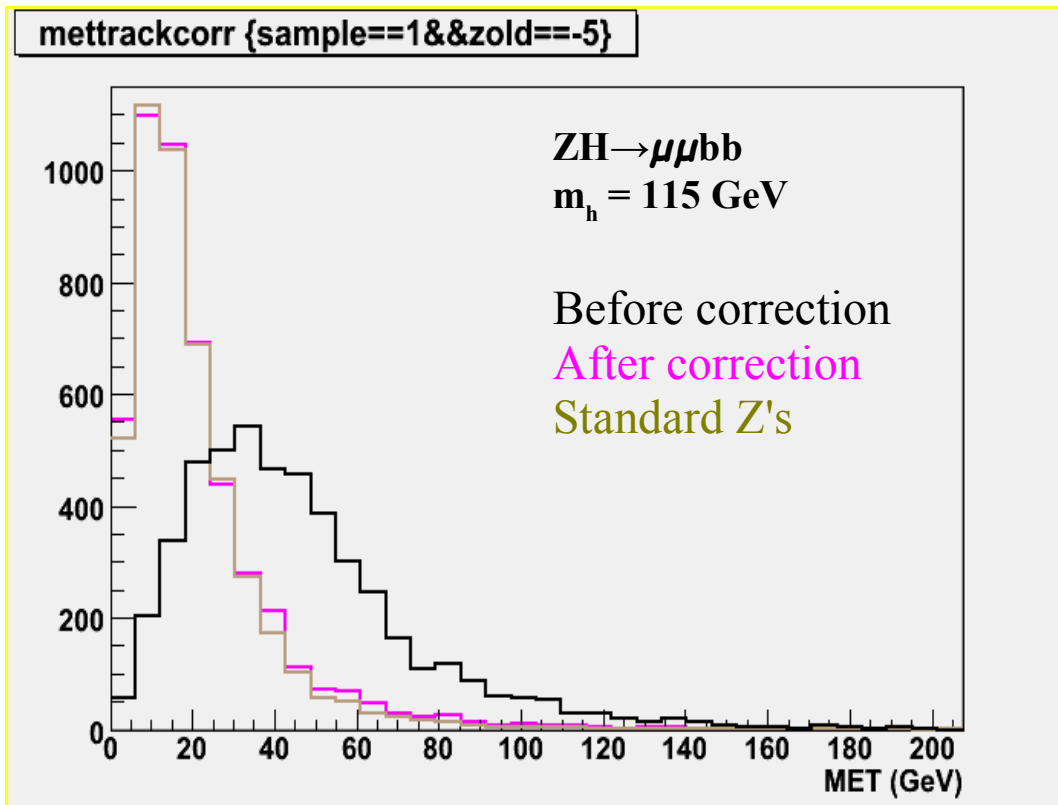
κ_b - Correlations between the NN tagger and the SLT tagger on *b*-jets.

κ_{uds} - Correlations between the NN tagger and the SLT tagger on *uds*-jets.

p_{TRel} - Ratio of the SLT tagging efficiencies on *c* and *uds*-jets.

Lepton Efficiency

MET from non-reconstructed muon is present
 And points in the direction of the isolated track

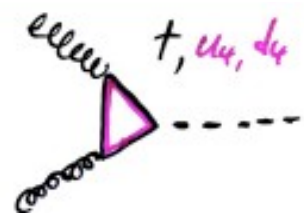


4th Generation

9x more $gg \rightarrow H$ production!

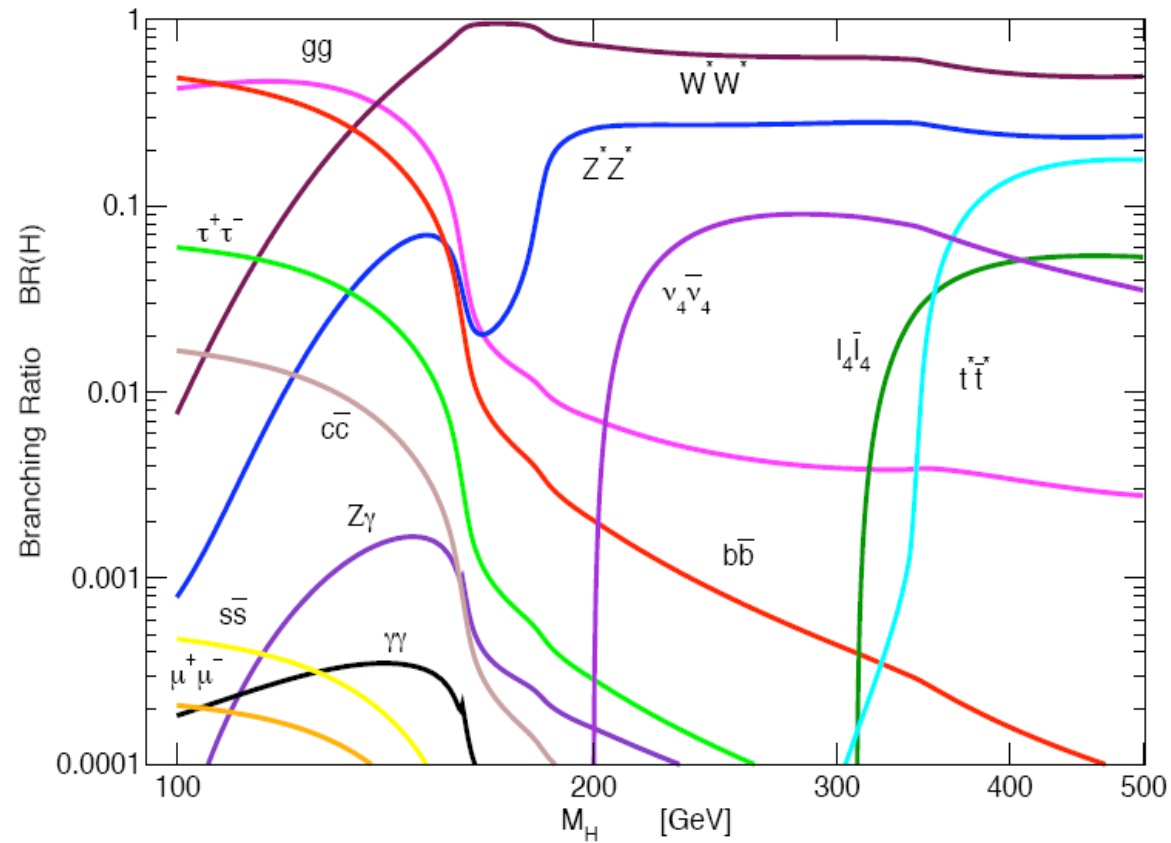
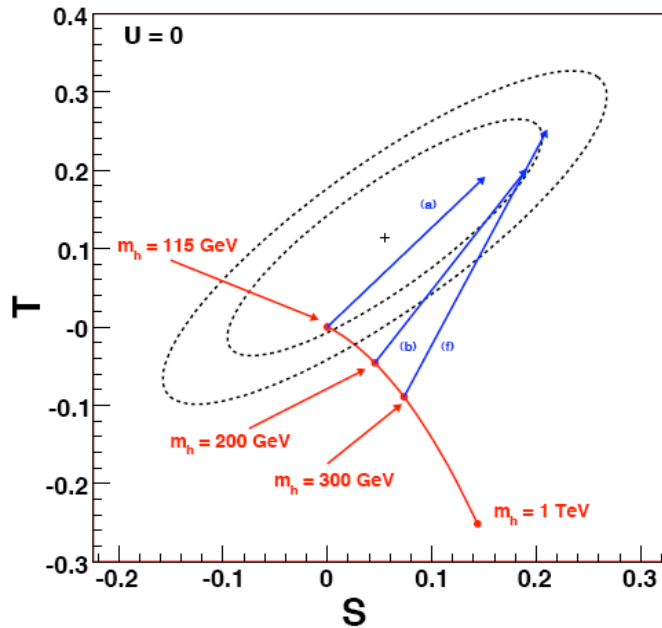
Reduced $H \rightarrow b\bar{b}, \tau\tau$

Enhanced $H \rightarrow gg$



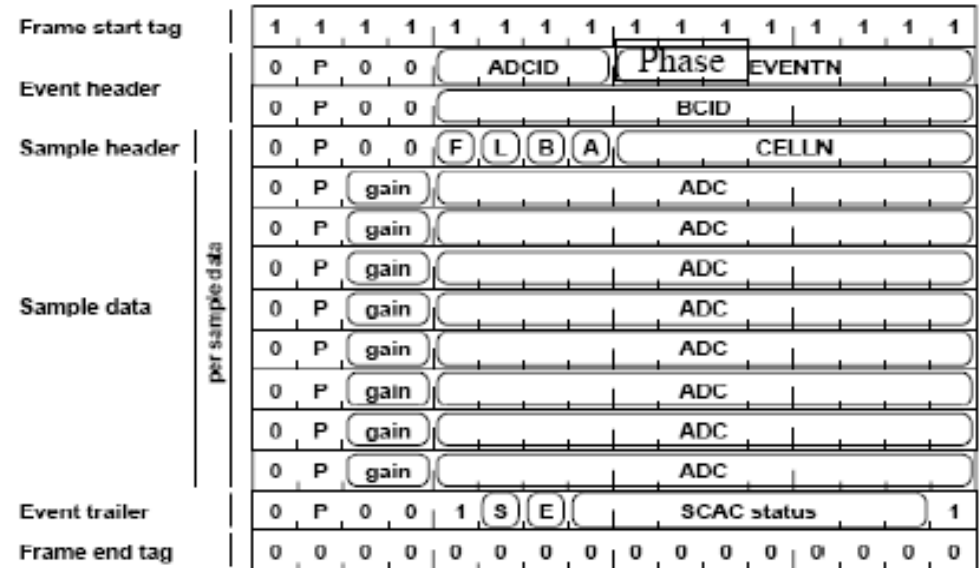
AMPLITUDE $\times 3$
OVER SM

Relieves m_H EW tension



FEB Header Monitor (FEBMon)

- In the data sent from each FEB is information on data quality
 - transmission errors (parity)
 - radiation-induced logic errors (SEU)
 - synchronization between FEBs (same event)
 - synchronization of GSEs within a FEB
 - various other checks that each FEB is behaving as expected
- This information is unpacked by the ByteStreamConverter and available in Athena (after some more interpretation / bitshifting)
- Was run during the full expert-week
 - Found some unexpected behavior (explained on next slide)
- Also run in real-online mode!
 - Tested by Haleh, and Henric

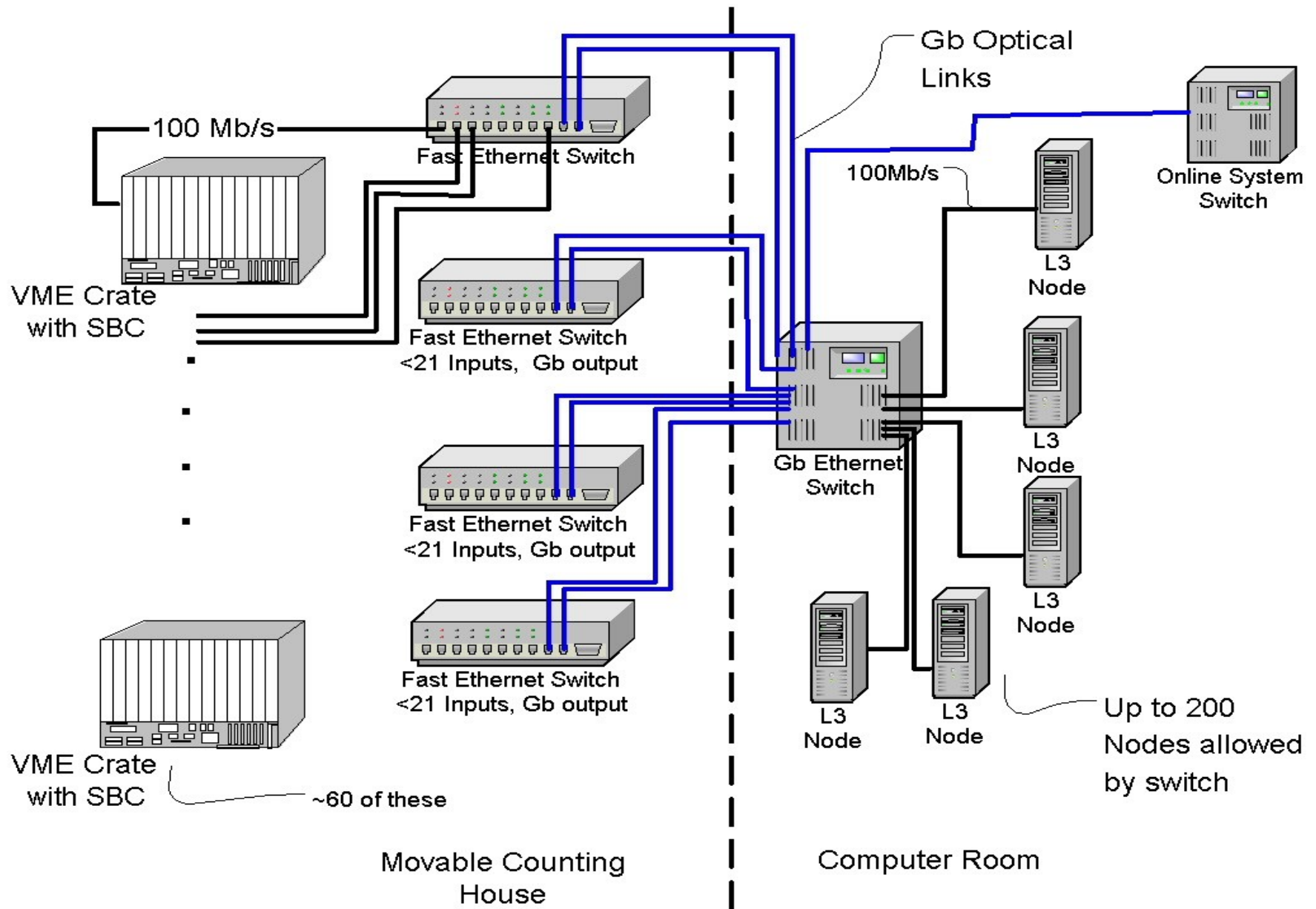


```

// ROD-Header, always present (is part of the FEB-Header)
uint32_t FormatVersion;
uint32_t SourceId;
uint32_t RunNumber;
uint32_t ELVL1Id;
uint32_t BCId;
uint32_t LVL1TigType;
uint32_t DetEventType;

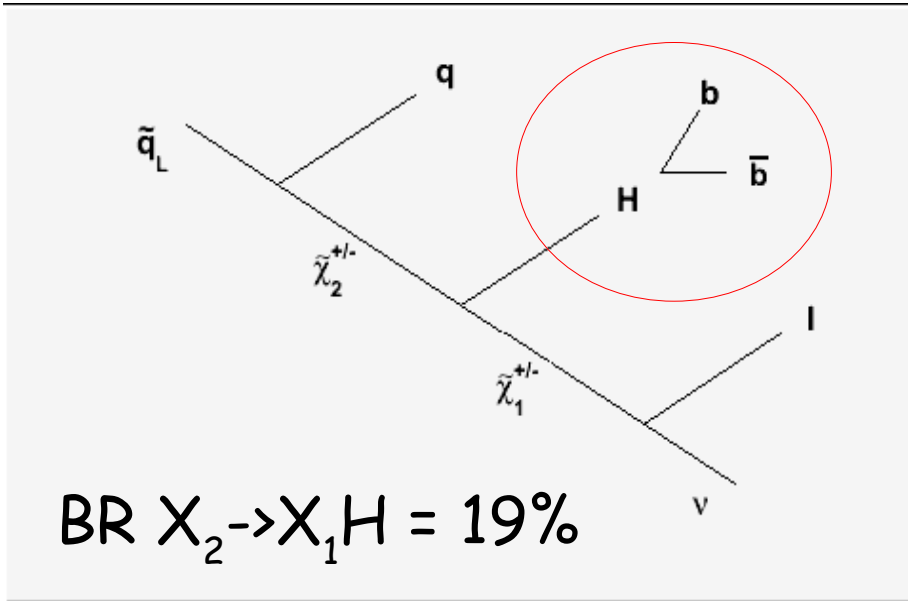
// DSP-Header (most of it is actually in the DSP-Trailer)
uint32_t CodeVersion; // DSP code version
uint32_t EventCounter; // DSP event counter
std::vector<uint16_t> m_SCA; // SCA number for each samples
uint32_t m_ELVL1Id; // FEB EventId
uint32_t m_BCId // FEB BCId
uint32_t ctrl1, ctrl2, ctrl3; // RodStatus / SCAC / etc.;
    
```

DAQ System

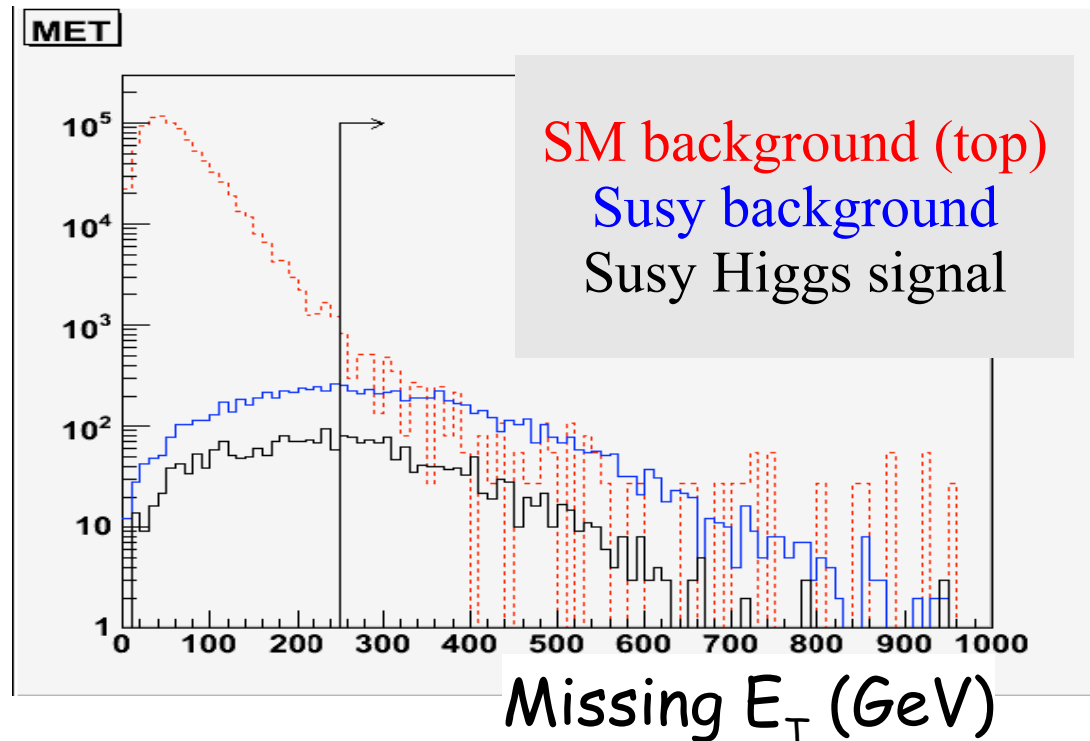


The Higgs in Supersymmetry Decays

Look for Higgs bosons in the *decays* of supersymmetric particles



Require $MET > 250$ GeV to reduce SM background



The Higgs in Supersymmetry Decays

Look for bump from $H \rightarrow bb$ decays

