SEARCH FOR SM HIGGS WH→ lvbb WITH MATRIX ELEMENT TECHNIQUE AT CDF

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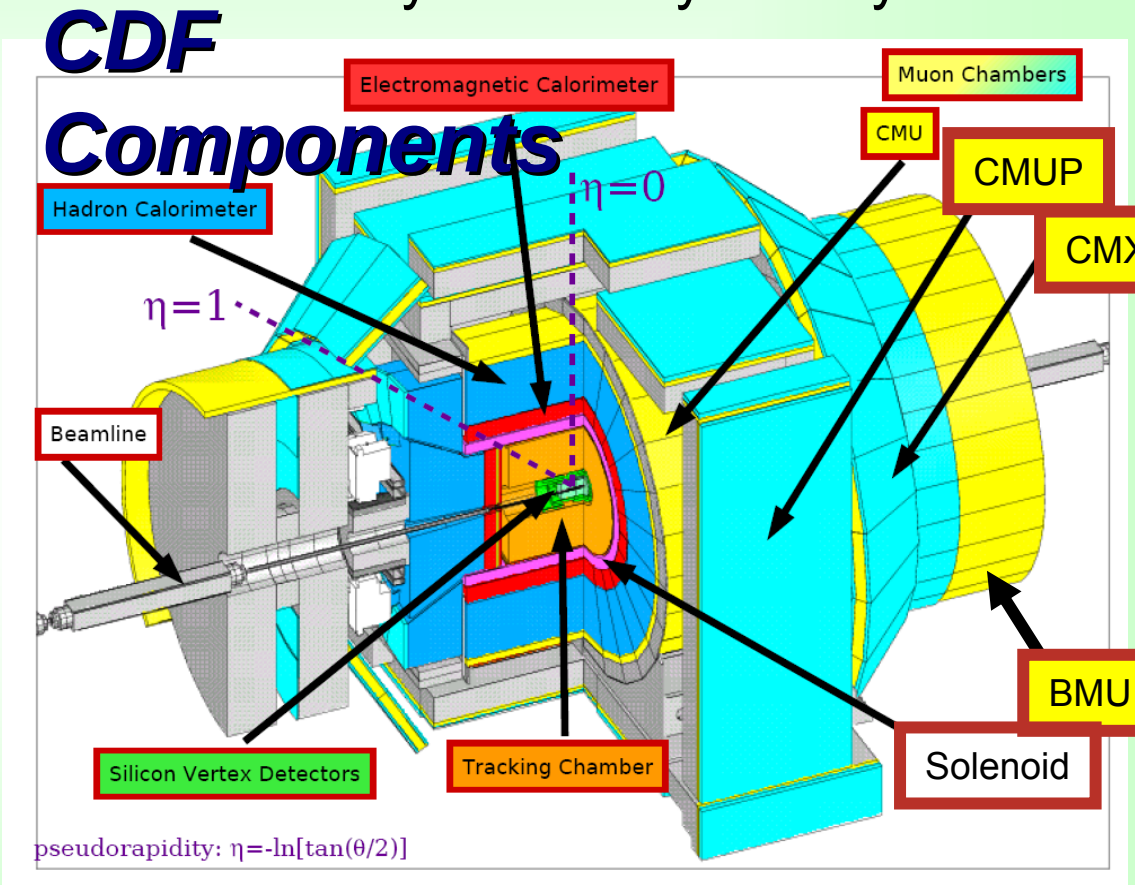
APS April Meeting 2008, St. Louis (Missouri)

THE CDF EXPERIMENT

- General purpose particle detector with cylindrical symmetry.

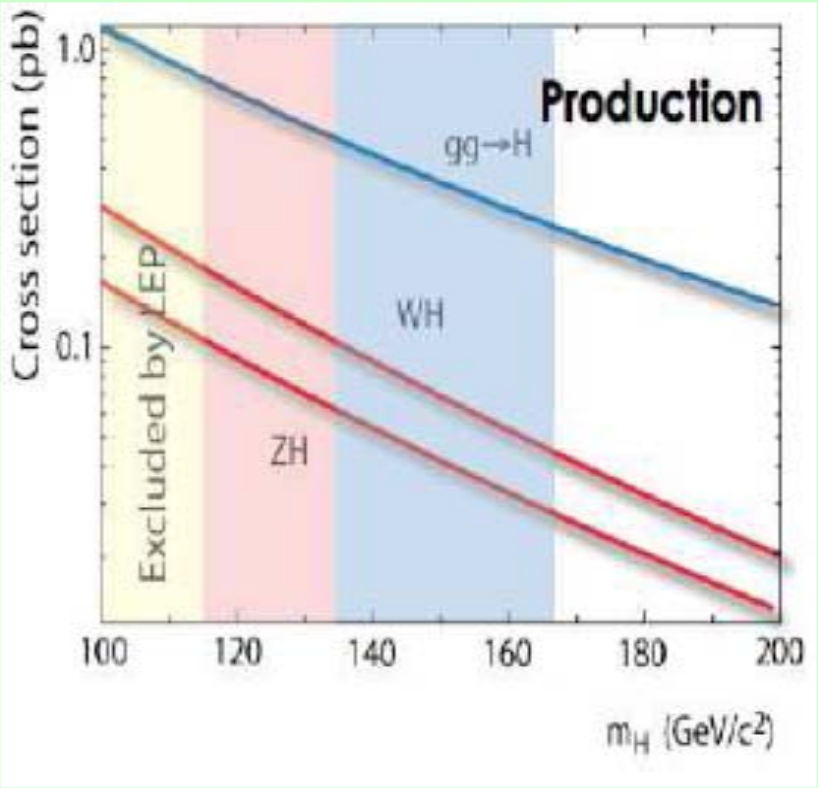
- Tracking (inside a 1.4 T solenoidal magnetic field) calorimetry and muon systems.



For Higgs physics the *full detector* is needed.

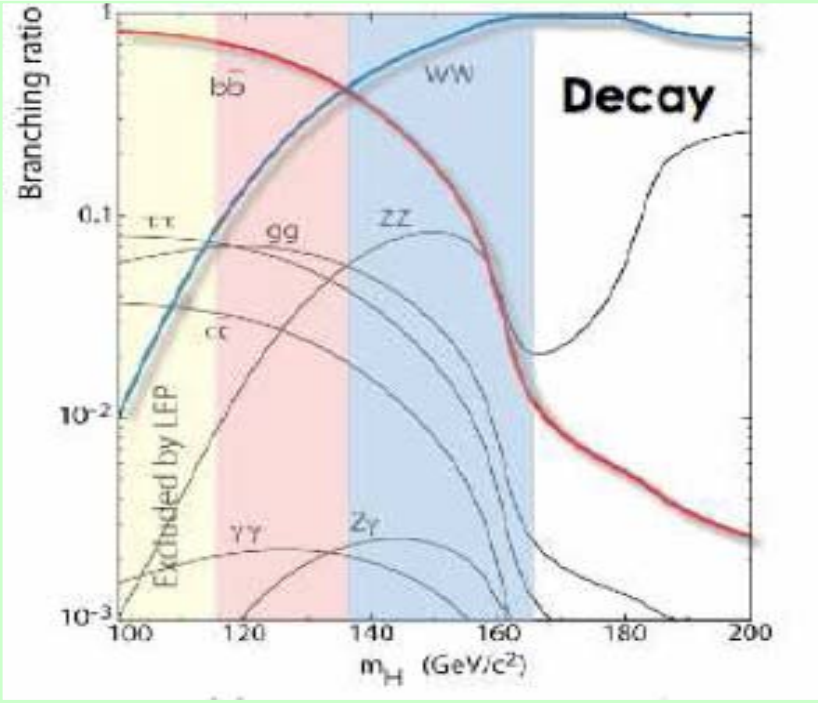
For a CDF virtual tour go to: http://www-cdf.fnal.gov/virtualtour/

SM HIGGS PHYSICS



Low mass m_H < 135 GeV

- The most relevant production mechanism at Tevatron is the one associated with a vector boson (W or Z).



- Use leptons from W decay to trigger.

- The largest branching ratio decay channel is: H→bb

WH EVENT SELECTION

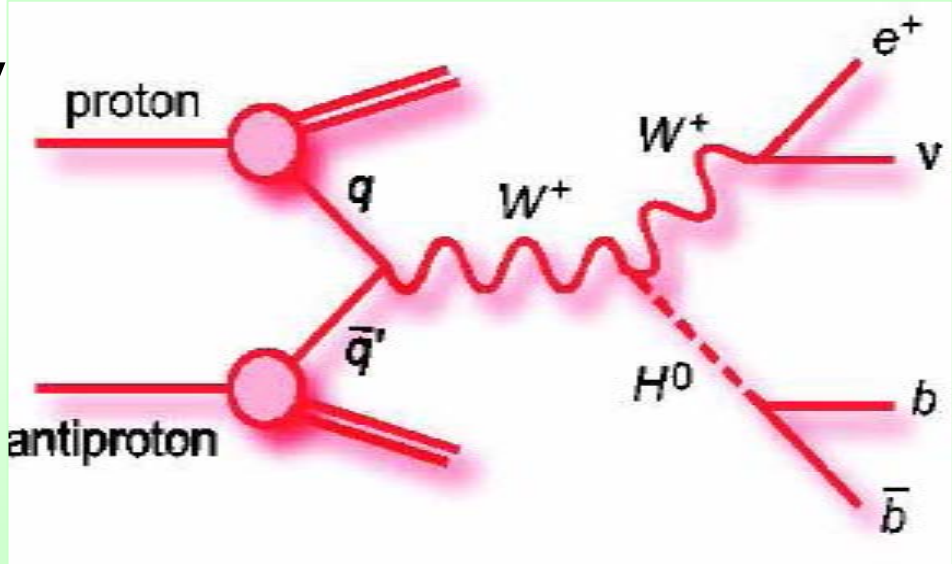
- High p_T isolated lepton (e/muon): p_T > 20 GeV.
  Adding new muon types increase the acceptance ~25%.

- High missing transverse energy: MET > 25 GeV.

$\eta = -\ln(\tan(\theta/2))$

- Two energetic jets with:
  Transverse energy: E_T > 20 GeV
  Pseudorapidity: $|\eta| < 2.8$

- At least one jet identified as b-jet.



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BACKGROUND ESTIMATION

Top/EWK (WW/WZ/Z→ττ, ttbar)

- MC normalized to theoretical cross-section

Non-*W (QCD)*

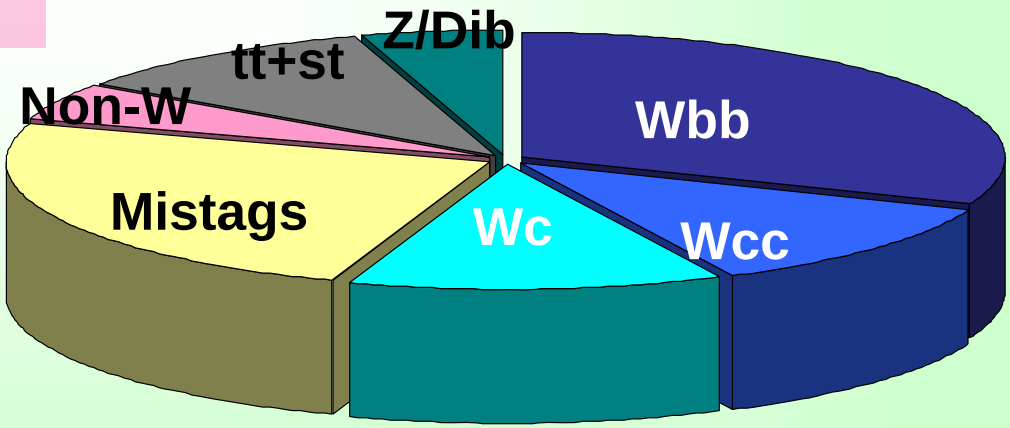
- Predominantly, due to multijet events with semileptonic *b*-decay
- Fit low MET data and extrapolate into signal region

W+HF jets (Wbb/Wcc/Wc)

- Calibrated using W+1jet data

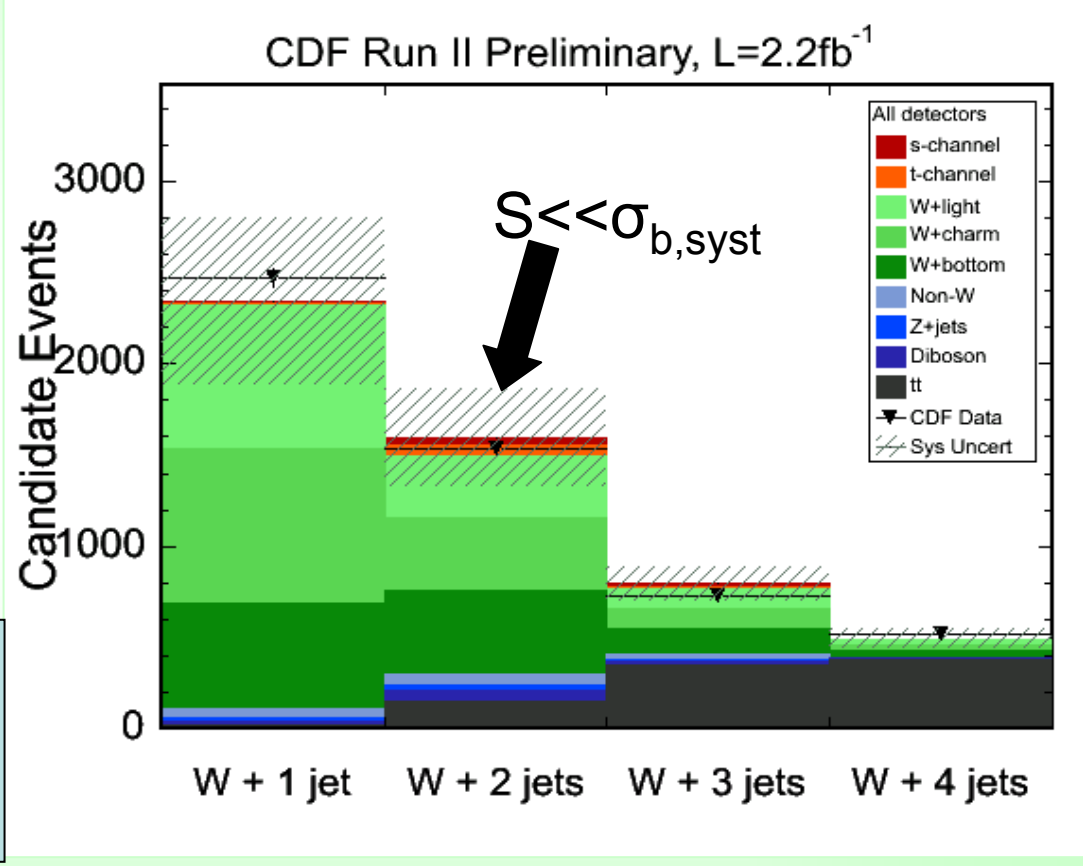
Mistags (W+2jets)

- Falsely tagged light quark or gluon jets
- Mistag probability parameterization obtained from inclusive jet data



SOPHISTICATED TOOLS NEEDED

- Signal is much smaller than background.
- Counting experiment is not possible -> need sophisticated tools to isolate regions with high signal purity.



For a Higgs mass of 115 GeV:
4.6±0.3 expected events (single tag)
1.4±0.2 expected events (double tag)

- **We use a Matrix Element (ME) Technique to calculate event probabilities for the signal and the background (bkg) hypothesis.**

MATRIX ELEMENT METHOD

- The probability of an event of being signal is proportional to the differential cross section of a given process:

$$P(x) = \frac{d\sigma}{\sigma}$$

- Fermi's Golden Rule tells us the differential cross section for a given scattering process:

$$d\sigma = \frac{1}{2E_1 E_2 |v_1 - v_2|} \prod_i \left(\frac{d^3 p_i}{(2\pi)^3 2E_i} \right) |\mathcal{M}|^2 (2\pi)^4 \delta^{(4)} \left(p_1 + p_2 - \sum_i p_i \right)$$

EVENT PROBABILITIES

- Calculate probability density of an event resulting from a given process:

$$P(p_l^\mu, p_{j1}^\mu, p_{j2}^\mu) = \frac{1}{\sigma}\int d\rho_{j1} d\rho_{j2} dp_\nu^z \sum_{comb} \phi_4 \, |M(p_i^\mu)|^2 \frac{f(q_1) f(q_2)}{|q_1||q_2|} W_{jet}(E_{jet}, E_{part})$$

Phase Space Factor

Matrix Elements

Parton Distribution Functions

Transfer Functions

Inputs:
lepton and jet 4-vectors – no other information needed!

❖ **TRANSFER FUNCTIONS (TFs):**
We parameterize the Ep – Ej distribution as a sum of two Gaussian functions.

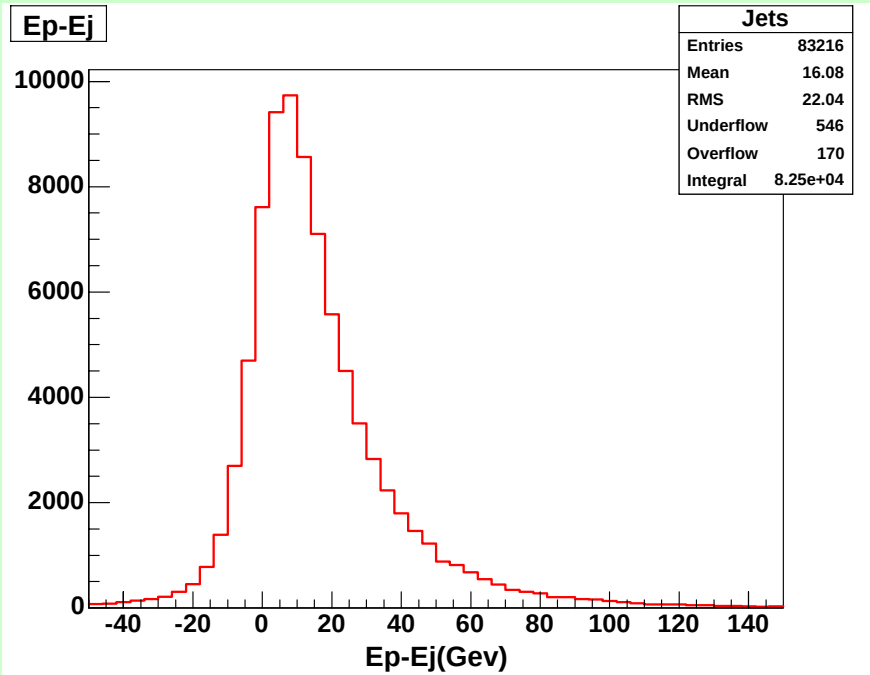
TRANSFER FUNCTIONS

- TFs parameterize parton energy as a function of measured energy.

- Ep – Ej parameterize as a sum of two gaussians:

  - ➢ One to account for the peak.
  - ➢ The other for the asymmetric tail.

- Different TFs for heavy quarks (b and c), light quarks and gluons.



$$W_{jet}\left(E_{jet}, E_{parton}\right) = \frac{1}{\sqrt{2\pi}\left(p_1 + p_2 p_5\right)}\left(e^{\frac{-\left(\delta_E - p_1\right)^2}{2p_2^2}} + p_3 e^{\frac{-\left(\delta_E - p_4\right)^2}{2p_5^2}}\right)$$

$$p_i = a_i + b_i E_{parton}$$

$$\delta E = \left(E_{parton} - E_{jet}\right)$$

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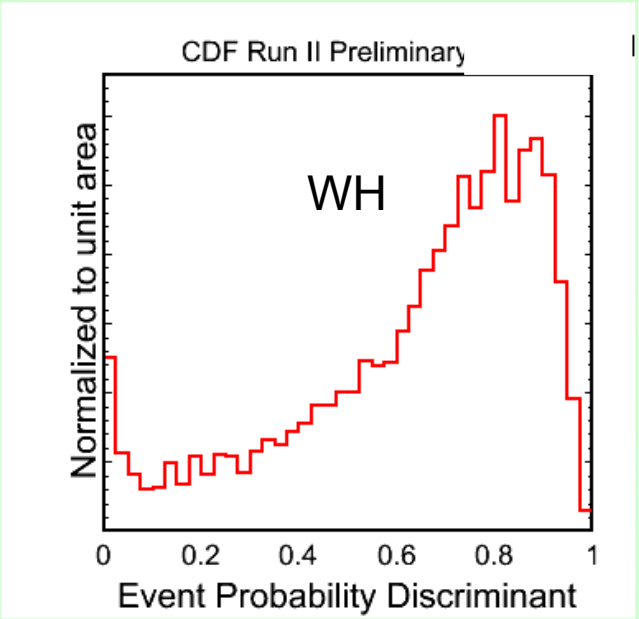
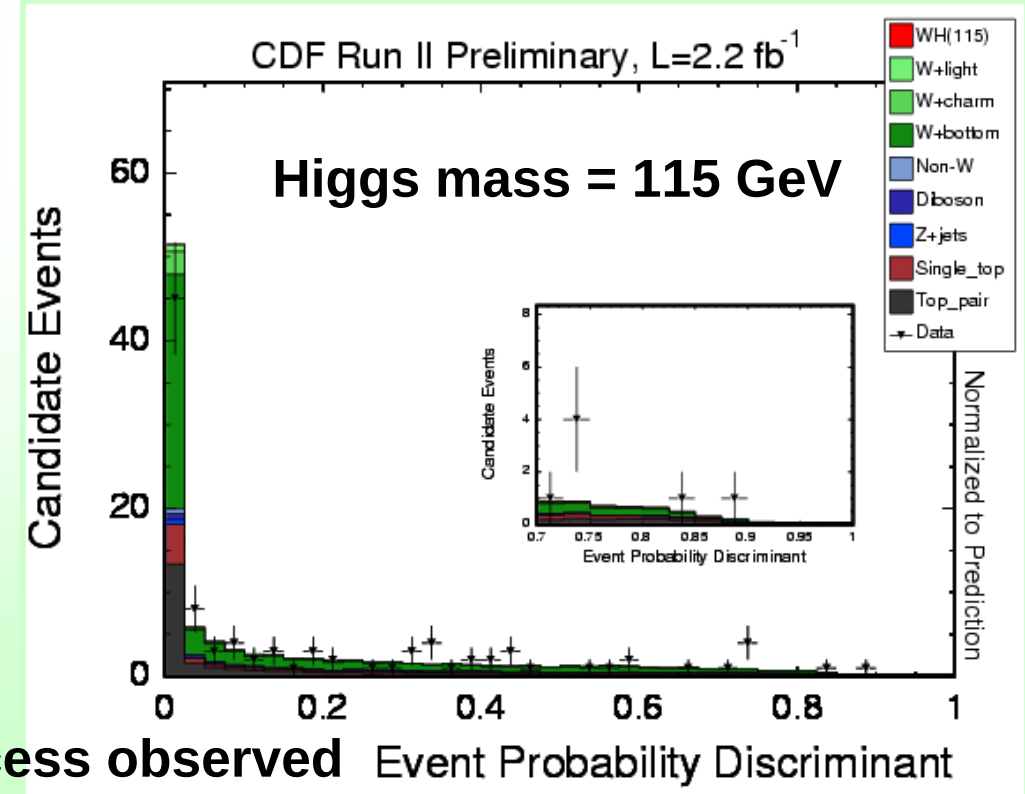
DISCRIMINANT

- **E**vent **P**robability **D**iscriminant (EPD) definition:

$$EPD = P_{signal} / (P_{signal} + P_{background})$$

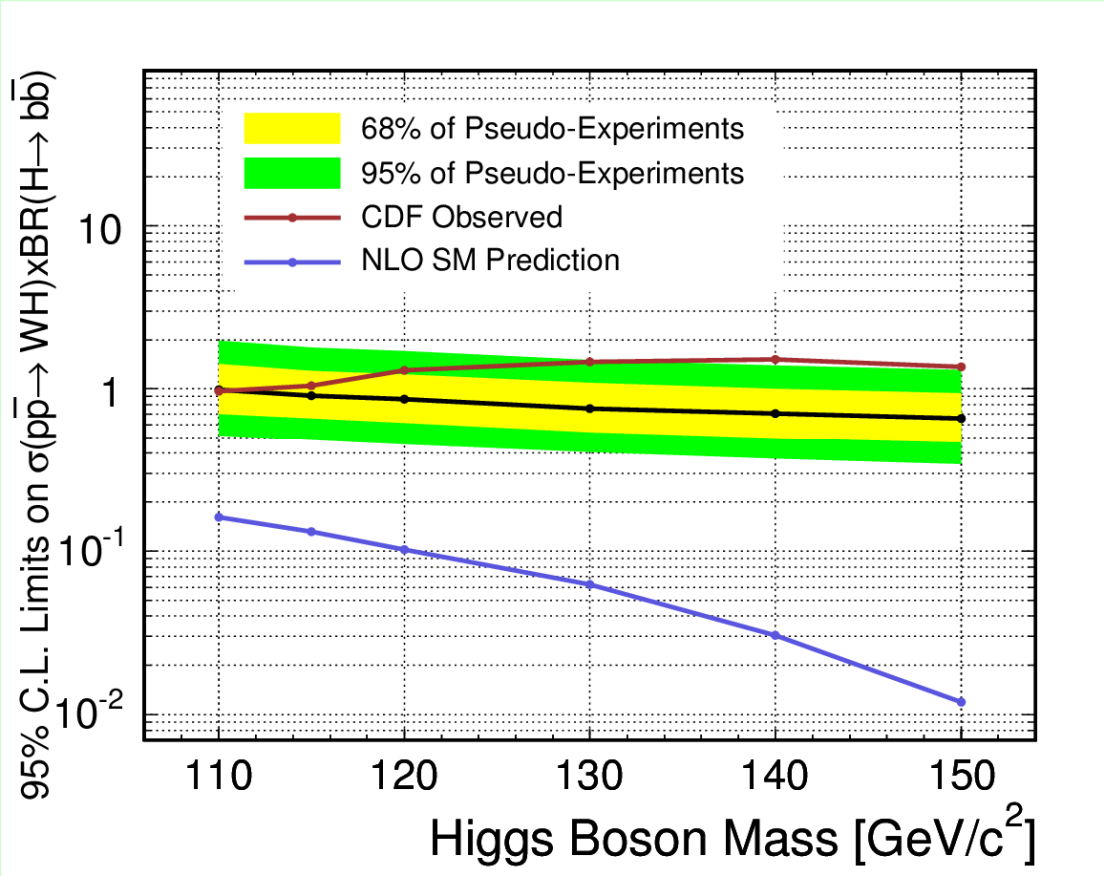
- Backgrounds peak in cero and signal peaks higher.





No significant excess observed

95 % C. L. LIMITS



- For a Higgs mass of 115 GeV:

✓ Expected limit is 0.91 pb (6.9x SM).

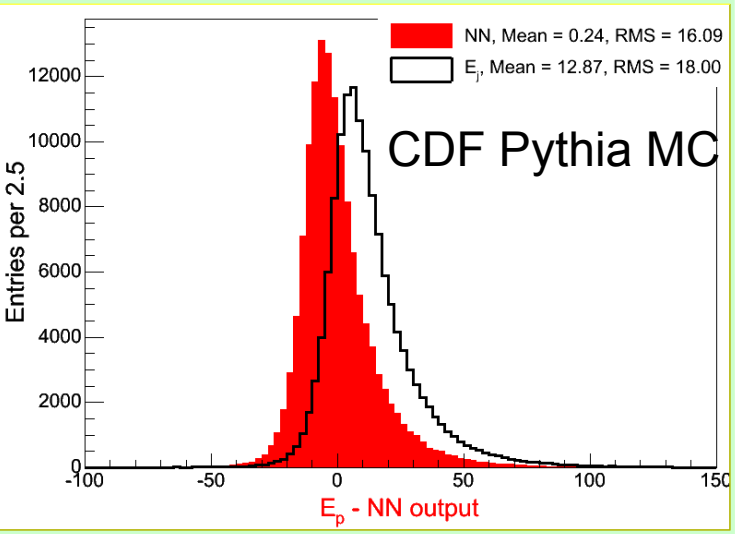
✓ Observed limit is 1.05 pb (8.0x SM).

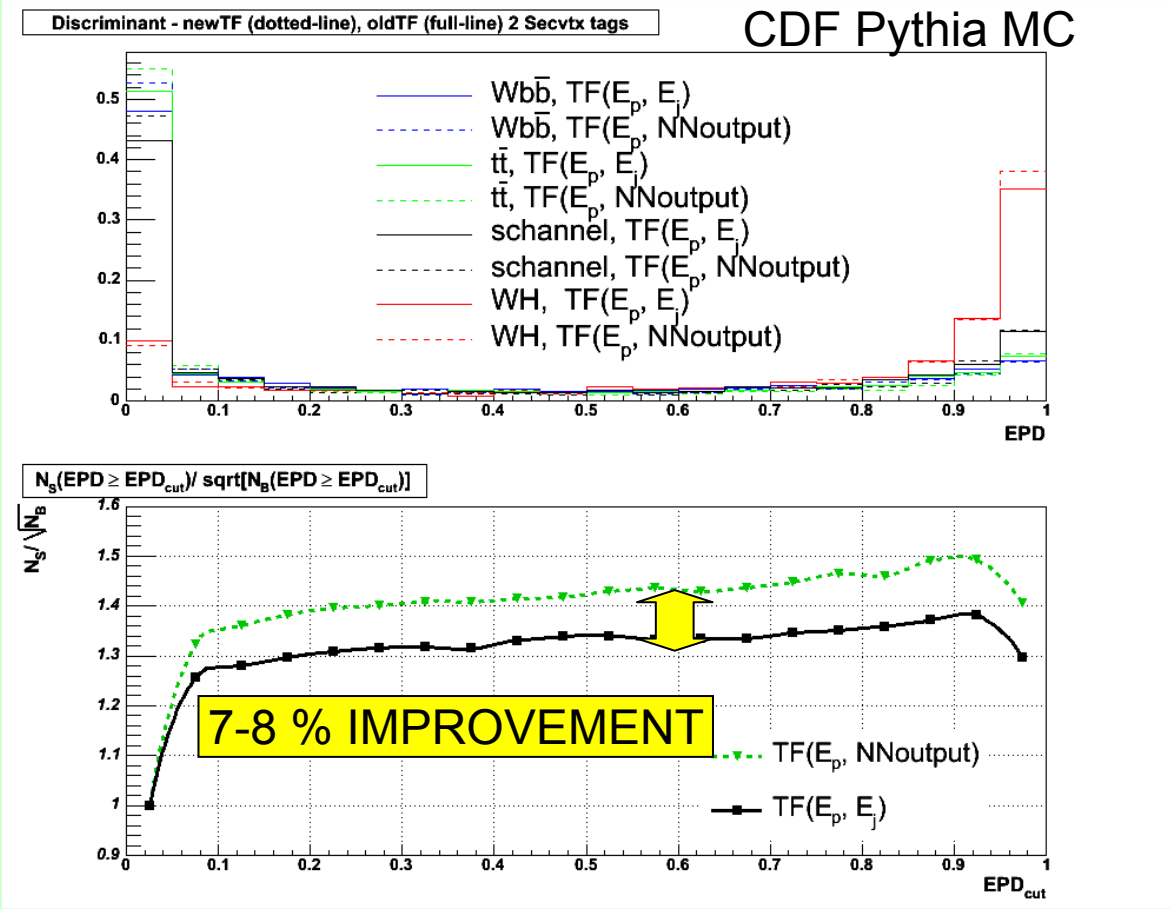
The most sensitive single Tevatron low mass Higgs search to date!!

FUTURE IMPROVEMENTS

- Use a Neural Network to better reproduce the parton energy.
- 9 input variables: E_{jet}, SumE, p_T, NTracks, EMF, RawE, η_{jet}, Φ_{jet}, cone 07 E_{jet}.

- New transfer function using the output of the NN.





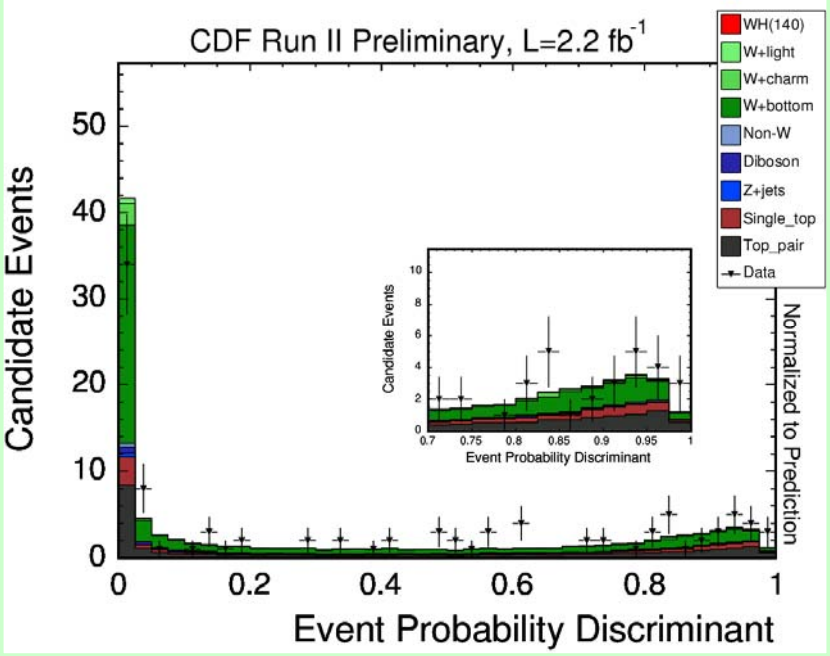
NNoutput improves the Jet resolution.

SUMMARY

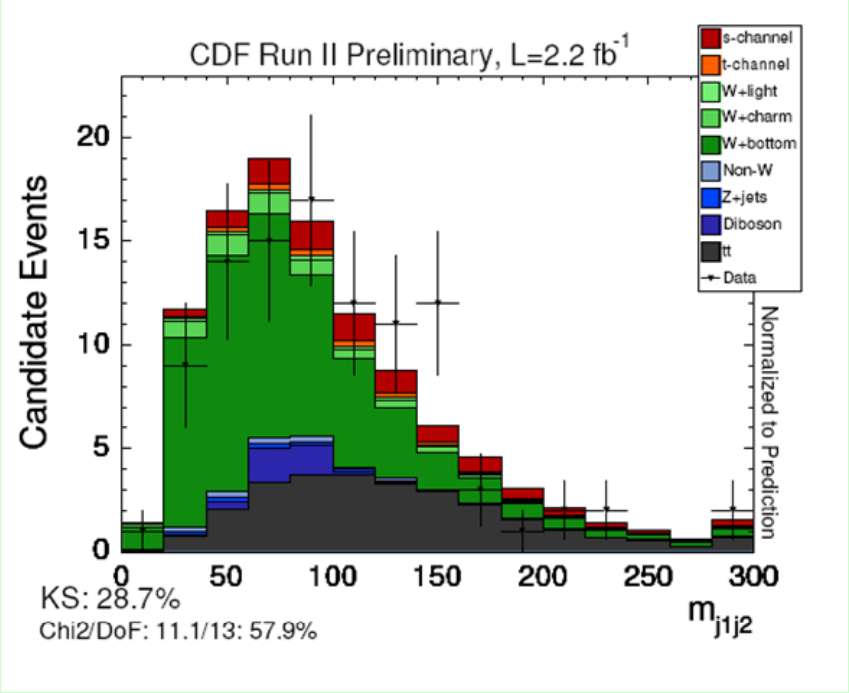
- SM Higgs search with ME technique has been performed with 2.2 fb^{-1} of data.
- Our 95% C. L. expected upper limit is ~0.9 pb (6 - 8x SM for low mass).
- Observed limit of 0.96 -1.3 (6 - 12x SM for low mass).
- The most sensitive single Tevatron low mass Higgs search to date!
- Working on improvements that will be crucial for gaining some Higgs sensitivity.

THANK YOU FOR YOUR ATTENTION!

BACK UP SLIDES

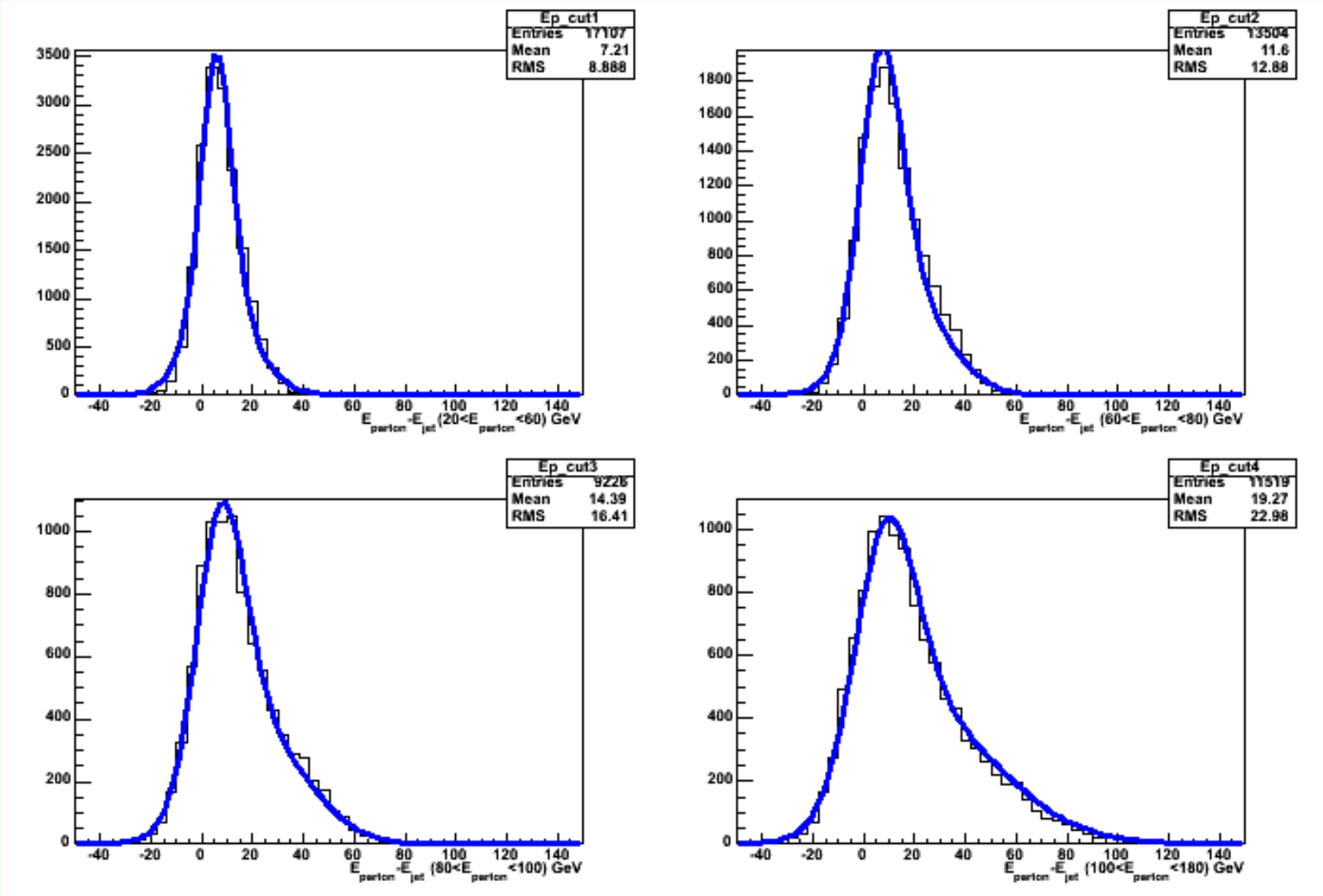


- Clear excess at high discriminant in 2-tags.
- Statistically consistent with background still.

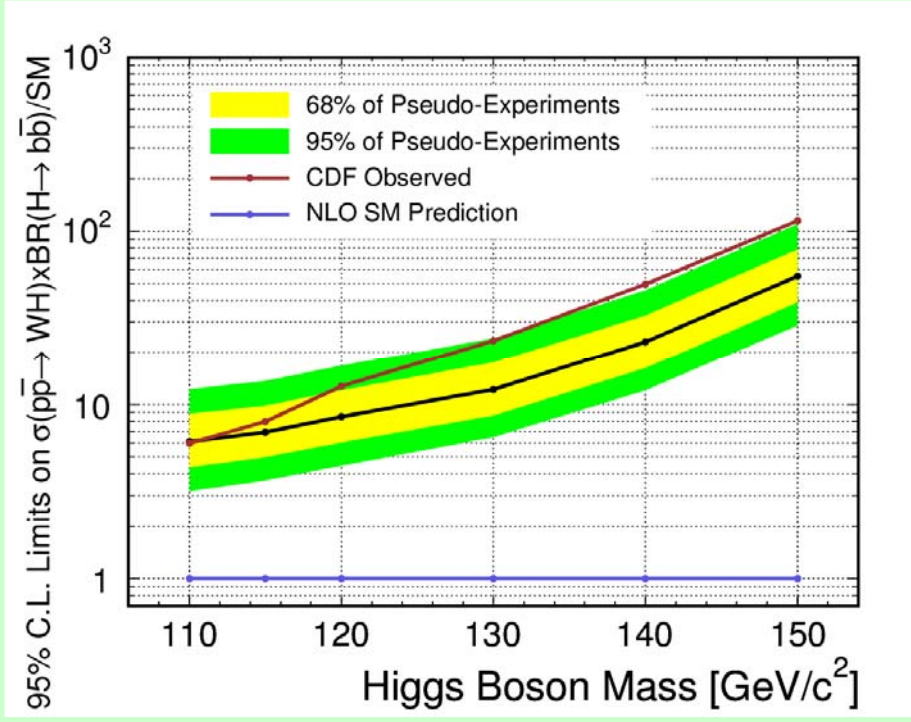


- Dijet mass is high at 140 -150 GeV.

TESTING THE TFs



95 % C. L. LIMITS



EXPECTED

Mass	Limit (pb)	X SM
110	0.99	6.1
115	0.91	6.9
120	0.87	8.5
130	0.76	12.2
140	0.70	23.0
150	0.66	55.1

OBSERVED

Mass	Limit (pb)	X SM
110	0.96	6.0
115	1.05	8.0
120	1.30	12.7
130	1.46	23.4
140	1.51	49.5
150	1.37	114.9