Top quak mass measurement using m_{T2} at CDF
(dilepton channel)

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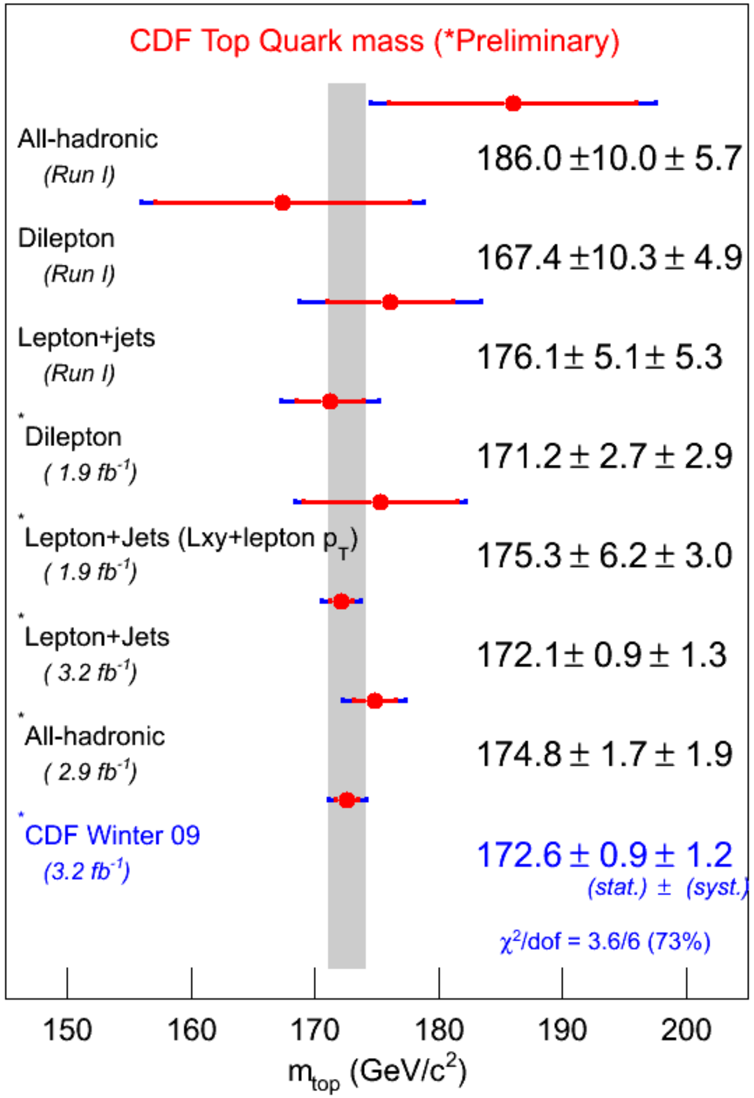
On behalf of the CDF collaboration

Why we measure the top mass in the dilepton channel

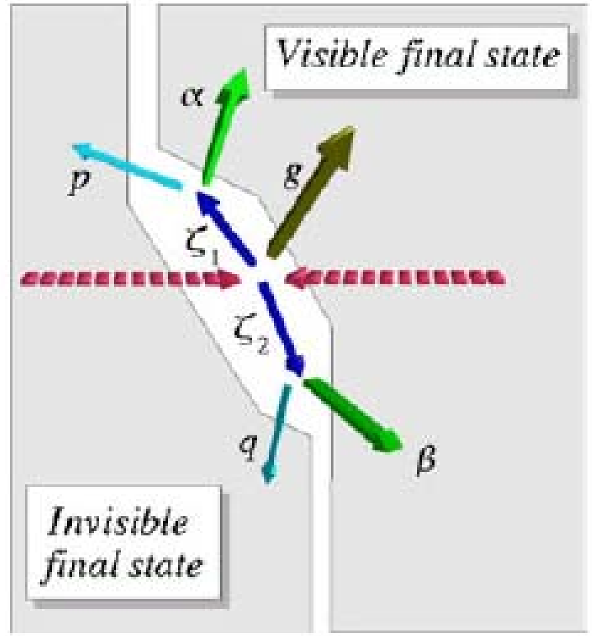


- It is important to check the mass crossing the channels
  - ❖ Is it SM top?
  - ❖ Significant difference indicate the new physics
- This channel can be a standard candle for new physics search
  - ❖ Well known SM process
    - ❑ Signal and background is under control
  - ❖ Similar topology with new physics
    - ❑ Pair produced new particle can have two missing particle final state

Signature of new physics particle and m_{T2}

- New physics predict the candidate of dark matter (WIMP)
  - Ex) Neutralino in the SUSY
- If we consider pair production of new physics particle
  - Two missing particle
  - Visible particle (quark and leptons)
  - Ex) two gluino pair production

$$pp \longrightarrow \tilde{g}\tilde{g} \longrightarrow qq\tilde{\chi}_1^0 \; qq\tilde{\chi}_1^0$$



- We are interesting to determine the mass of new particle
  - m_{T2} was introduced for two missing particle

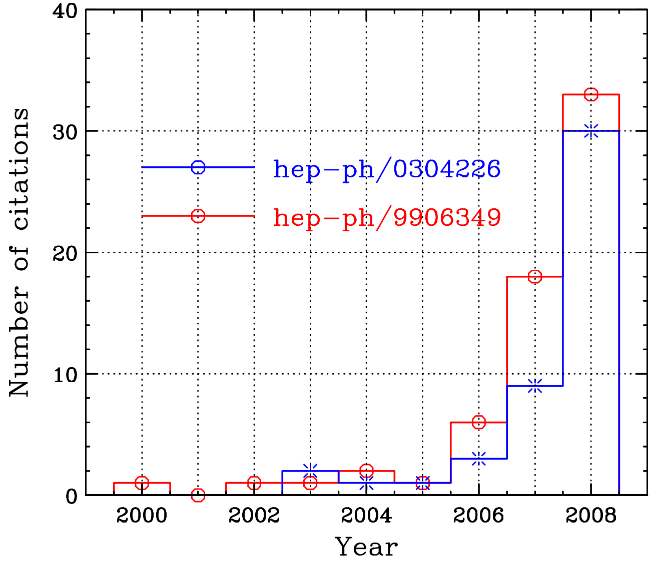
$$m_{T2} = \min[\max(m_{T(1)}, m_{T(2)})]$$

$$q_T + p_T = \text{missing } p_T$$

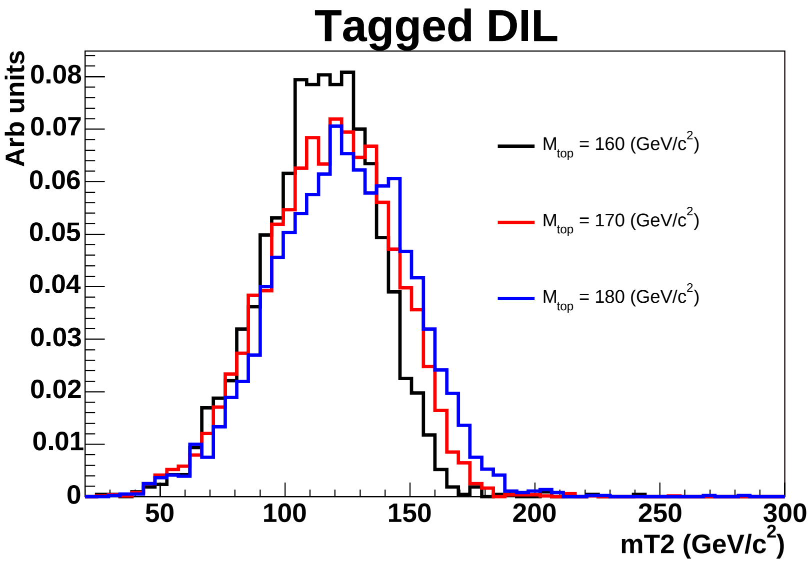
Alan Barr, Christopher Lester and Phil Stephens
J. Phys. G: Nucl. Part. Phys. **29** (2003) 2343–2363

m_{T2}

- Transverse mass of two missing particle system
  - ❖ Similar with m_T for W mass
- Can be useful to determine the mass of new physics particle
  - ❖ One of the most stringent variable

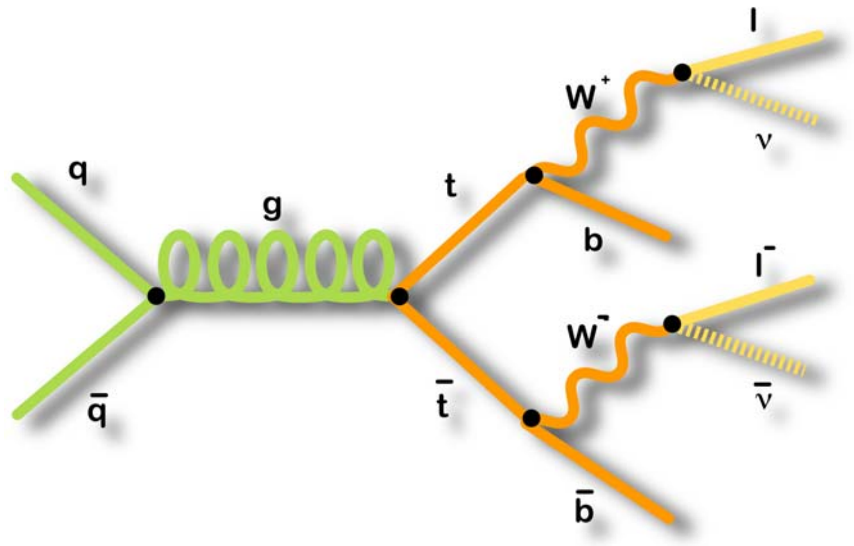


- Top dilepton channel is good example of m_{T2} variable (standard candle)
- We can use real data
  - ❖ First application in the real data



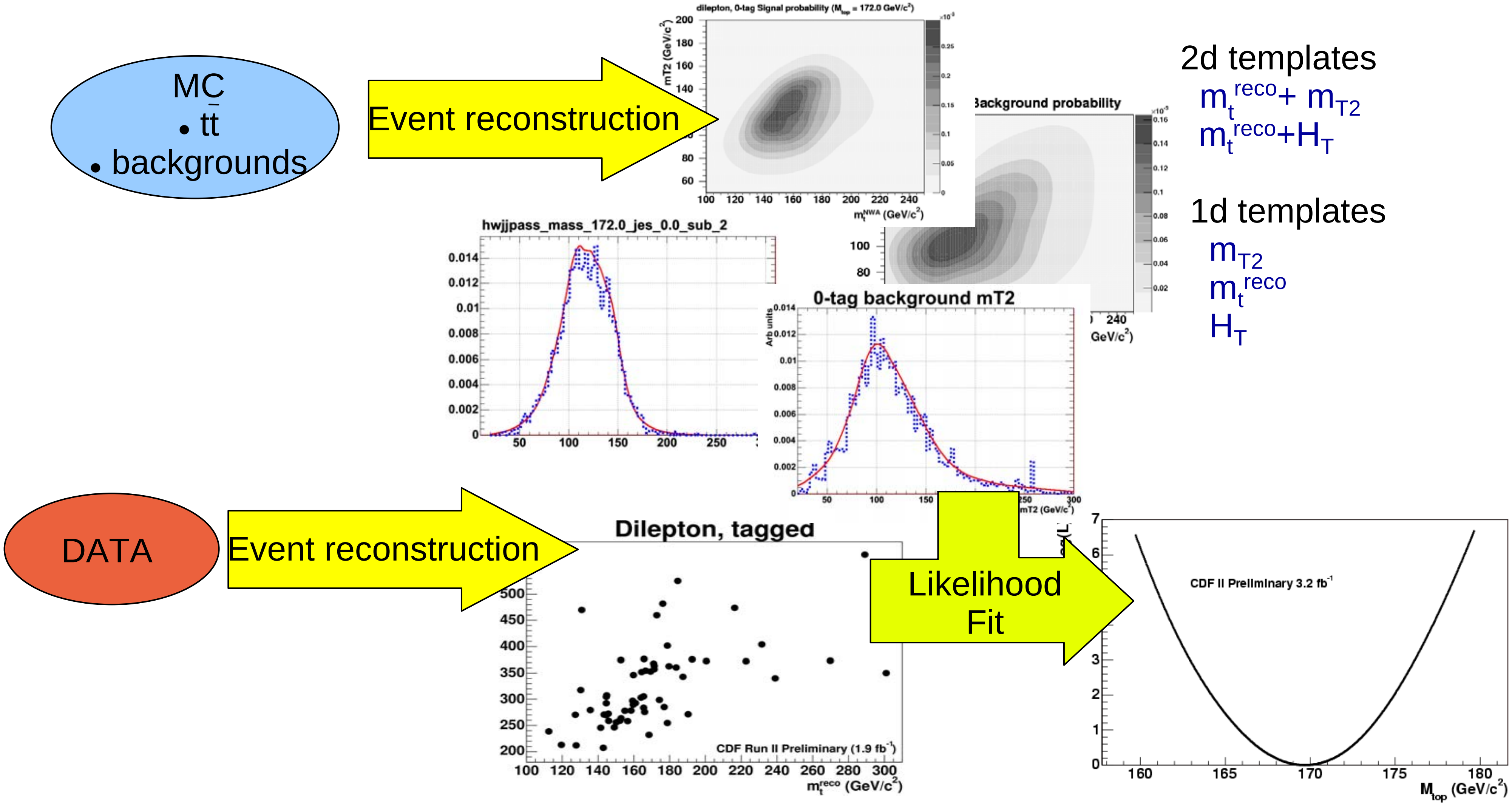
ttbar dilepton channel

- **Dilepton (5% branching ratio, small background)**
  2 high-P_T leptons(e/m),
  2 b-jets, large missing ET
  - **We separate subsample with b tagging**

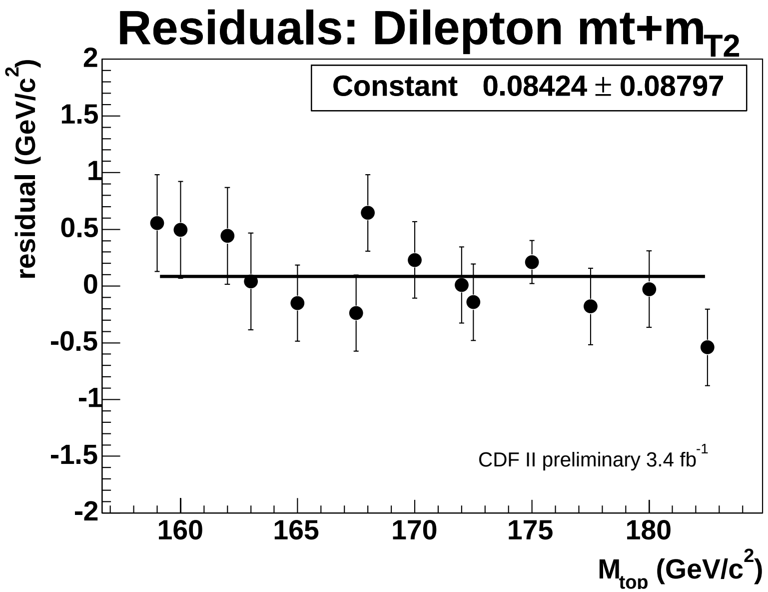


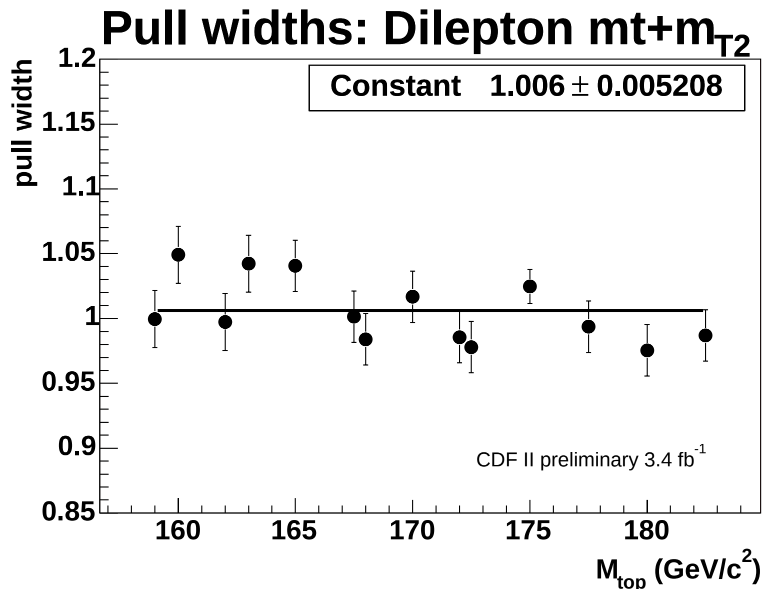
	non-tagged	tagged
Diboson	15.2 ± 2.3	0.6 ± 0.1
Drell-Yan	31.1 ± 3.5	1.7 ± 0.2
Fake	31.2 ± 8.7	4.5 ± 1.3
Total Background	71.3 ± 10.5	6.8 ± 1.3
$t\bar{t}$ (6.7 pb)	68.7 ± 6.8	88.4 ± 8.2
Observed (3.4 fb^{-1})	149	87

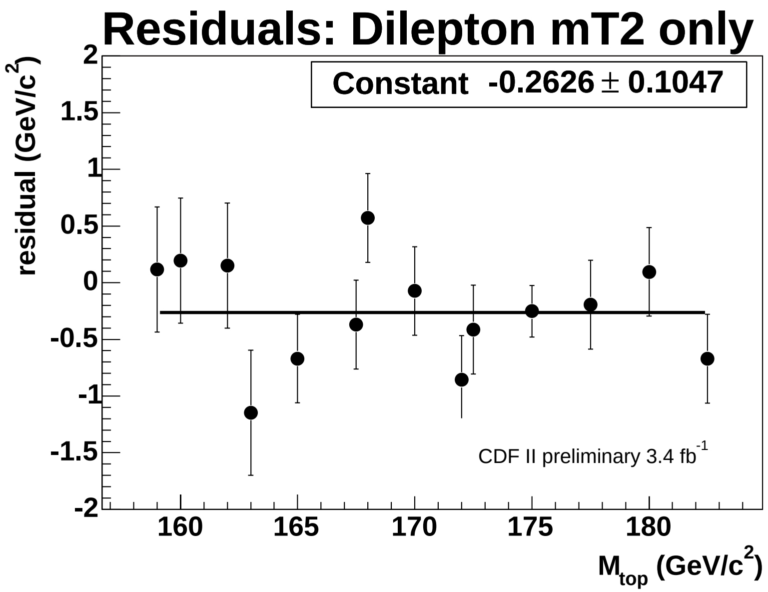
Template method

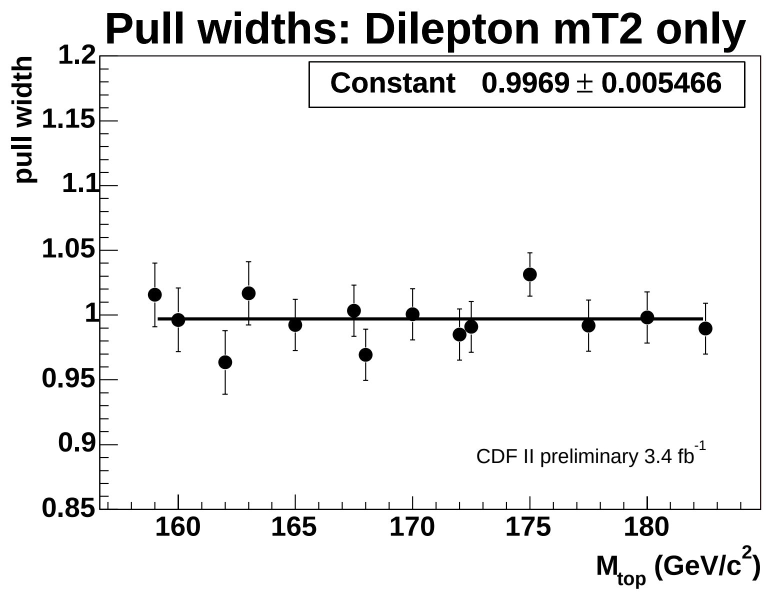


Sanity check

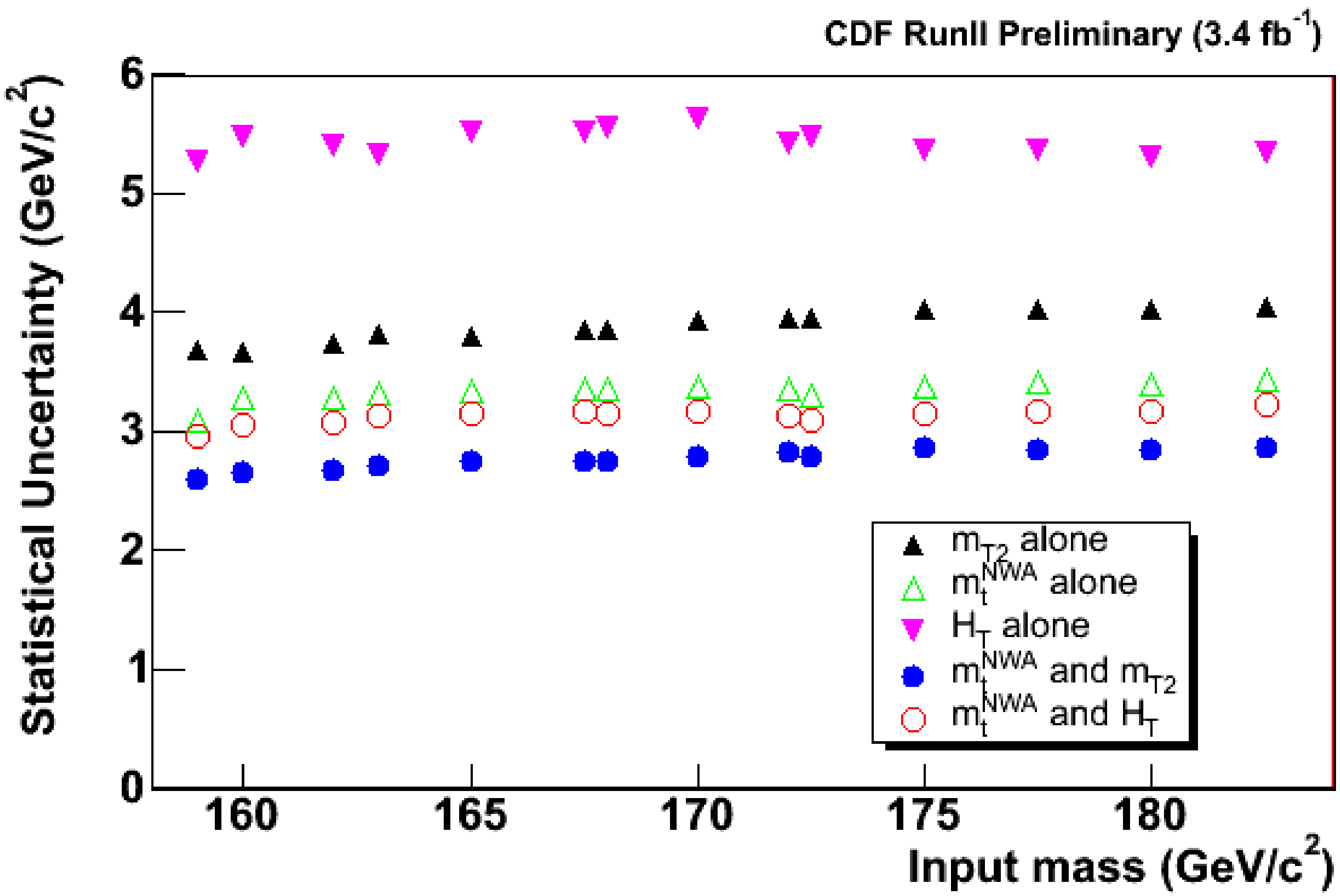








Expected statistical uncertainties



Systematics and total estimated uncertainty

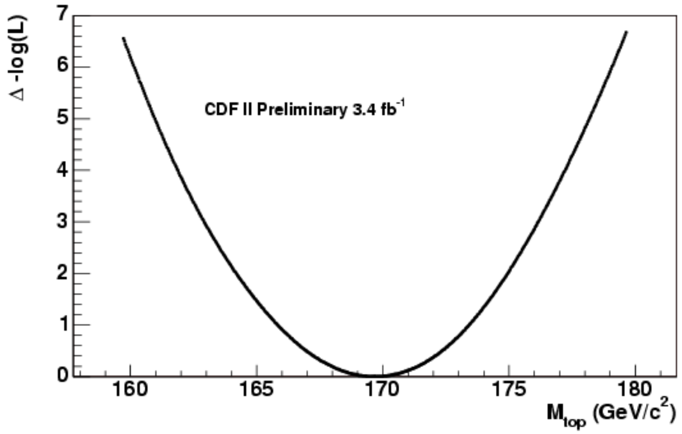
175 GeV/c^2 top mass assumed

Unit (GeV/c^2)		m_{T2}	m_t^{NWA}	H_T	m_t^{NWA} $+m_{T2}$	m_t^{NWA} $+H_T$
Statistical		4.0	3.4	5.4	2.9	3.2
Systematic	Jet Energy Scale	2.6	3.5	3.7	3.0	3.4
	Generator	0.3	1.0	2.6	0.5	1.3
	Parton distribution functions	0.5	0.6	1.8	0.5	0.8
	b-JES	0.2	0.3	0.2	0.2	0.3
	Background shape	0.4	0.3	0.7	0.1	0.3
	Gluon fusion fraction	0.3	0.1	0.3	<0.1	0.1
	Initial and final state radiation	0.6	0.2	0.6	0.3	0.2
	MC statistics	0.3	0.3	0.5	0.3	0.3
	Lepton energy	0.6	0.2	0.7	0.3	0.2
	Multiple Hadron Interaction	0.2	0.3	0.3	0.3	0.3
	Color Reconnection	0.7	0.6	2.5	0.6	0.6
	Total Systematic	2.9	3.8	5.7	3.2	3.8
Total		5.0	5.1	7.8	4.3	5.0

m_{T2} give the best performance
between single observables

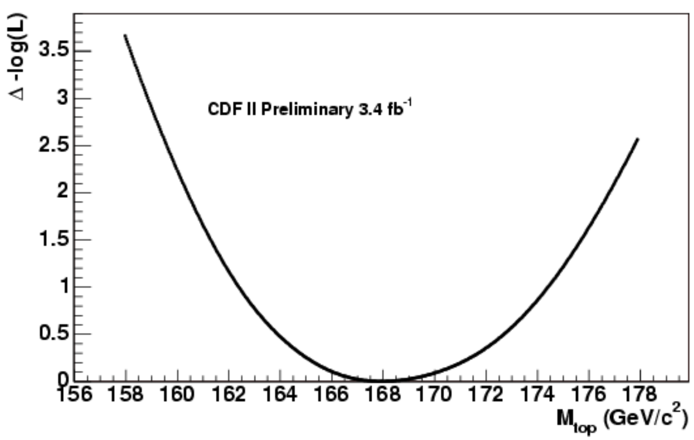
Data fit result

m_{T2} and m_t^{NWA}



169.3 ±2.7 (stat.) ± 3.2 GeV/c^2(syst.)

m_{T2} alone

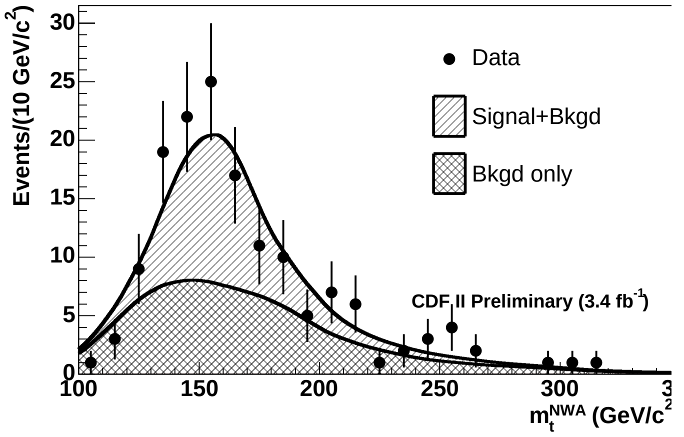


$168.0^{+4.8}_{-4.0}$ (stat.) ± 2.9 GeV/c^2(syst)

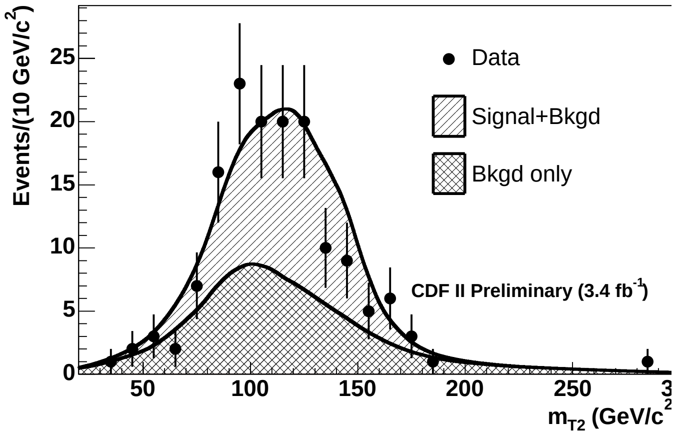
Observables	result (GeV/c^2)	result (GeV/c^2)
m_{T2}	$168.0\ ^{+4.8}_{-4.0}$ (stat.) $\pm$ 2.9 (syst.)	$168.0\ ^{+5.6}_{-5.0}$
m_t^{NWA}	$169.4\ ^{+3.3}_{-3.2}$ (stat.) $\pm$ 3.8 (syst.)	$169.4\ ^{+5.0}_{-5.0}$
H_T	$168.8\ ^{+5.1}_{-6.6}$ (stat.) $\pm$ 5.7 (syst.)	$168.8\ ^{+7.6}_{-8.7}$
m_t^{NWA} and m_{T2}	$169.3\ ^{+2.7}_{-2.7}$ (stat.) $\pm$ 3.2 (syst.)	$169.3\ ^{+4.2}_{-4.2}$
m_t^{NWA} and H_T	$169.6\ ^{+2.8}_{-2.9}$ (stat.) $\pm$ 3.8 (syst.)	$169.6\ ^{+4.7}_{-4.8}$

Data distribution

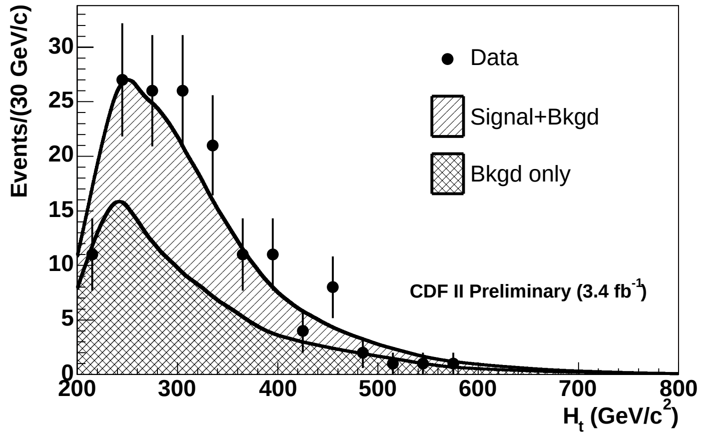
Non-tagged m_t^{NWA}



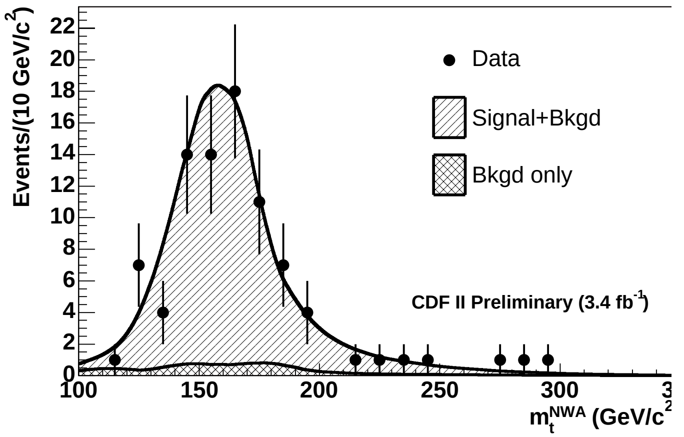
Non-tagged m_{T2}



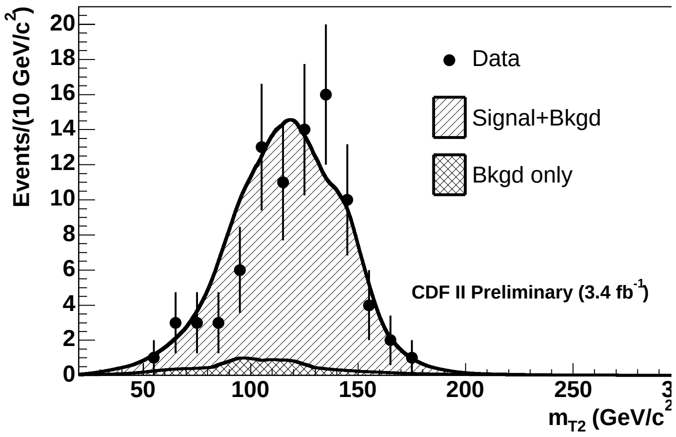
Non-tagged H_T



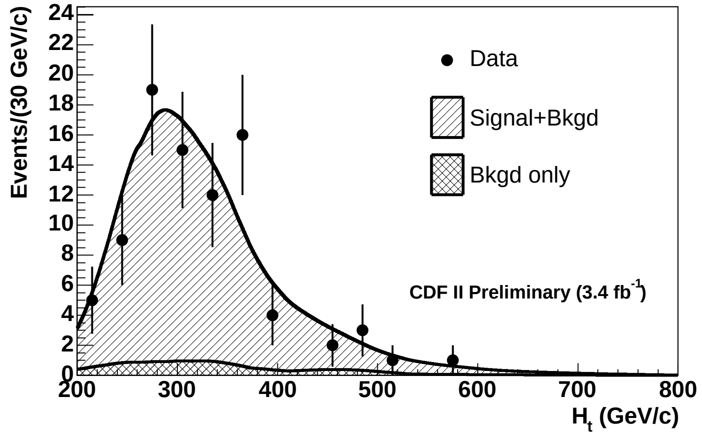
tagged m_t^{NWA}



tagged m_{T2}



tagged H_T



Conclusion

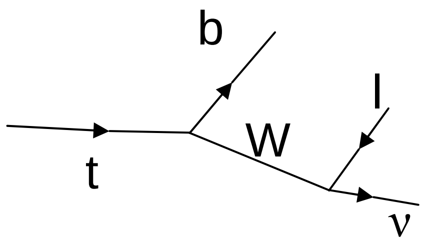
- We measure the top quark mass in the dilepton channel using m_{T2} variable
  - 169.3 ±2.7 (stat.) ± 3.2 GeV/c^2(syst.) with m_t^{NWA} and m_{T2}
  - $168.0^{+4.8}_{-4.0}$ (stat.) ± 2.9 GeV/c2(syst) with m_{T2} alone
  - First application in the real data

- We prove the performance of m_{T2}
  - Best single observable including systematic

- This method can be useful to mass determination of new physics particle

m_t^{NWA}

- Leptonical decay of top
  - t->blv
  - We measure b and lepton but don't know neutrino
    - 4 unknown
  - Known parameter
    - W mass neutrino mass (2 unknown)
  - If we assume the top quark mass and neutrino eta direction, we can measure neutrino x,y momentum
  - Same thing happen for the other leg
- Getting weight using measured missing transverse energy



$$
\begin{aligned}
B &\equiv 2b\nu = m_t^2 - m_W^2 - m_b^2 - 2b\ell \\
L &\equiv 2\ell\nu = m_W^2 - m_\ell^2 - m_\nu^2 \\
&= m_W^2 - m_\ell^2
\end{aligned}
$$

$$
w_i = exp\left(-\frac{(\not{E}_x - P_x^{\nu} - P_x^{\bar{\nu}})^2}{2\sigma_x^2}\right) \cdot exp\left(-\frac{(\not{E}_y - P_y^{\nu} - P_y^{\bar{\nu}})^2}{2\sigma_y^2}\right)
$$

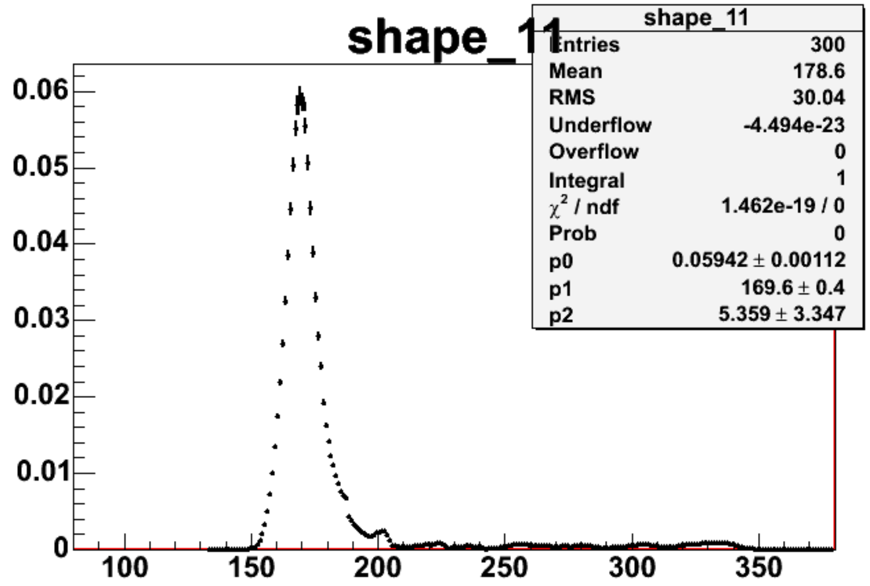
$$
w_i = w_i(m_{top}, \eta_1^{\nu}, \eta_2^{\nu})
$$

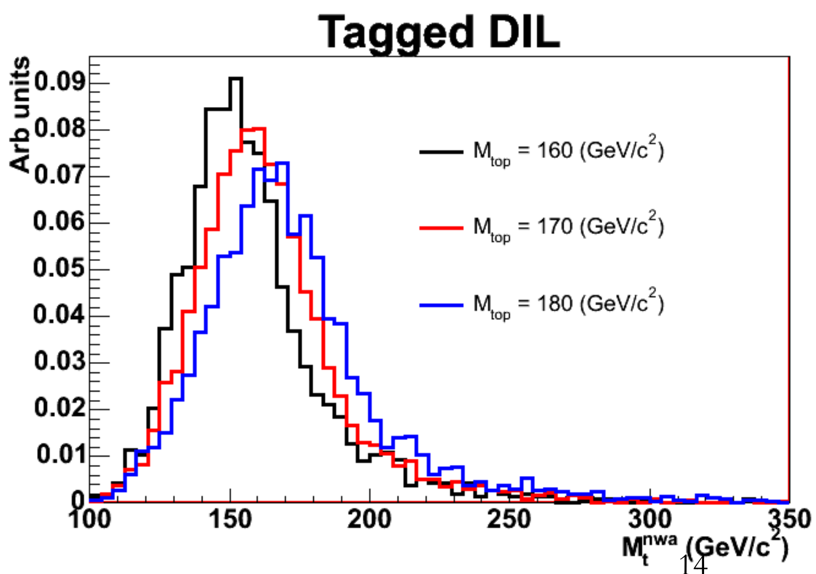
m_t^{NWA}

- Some over neutrino rapidities

$$W(m_t) = \int d\eta_1 \int d\eta_2 P(\eta_1) P(\eta_2) \sum_j \sum_i w(m_t)_{i,j}$$

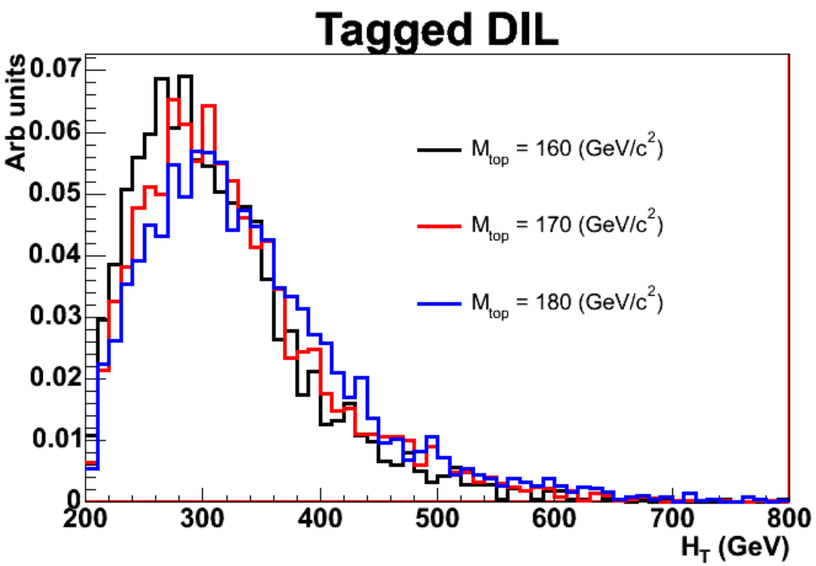
- We have maximum weight m_t as reconstructed mass (m_t^{NWA})
- We scan mt with 3GeV size and then decrease the step size upto 0.15GeV near the peak
- We have gaussian fit in the near of peak to get m_t continuously

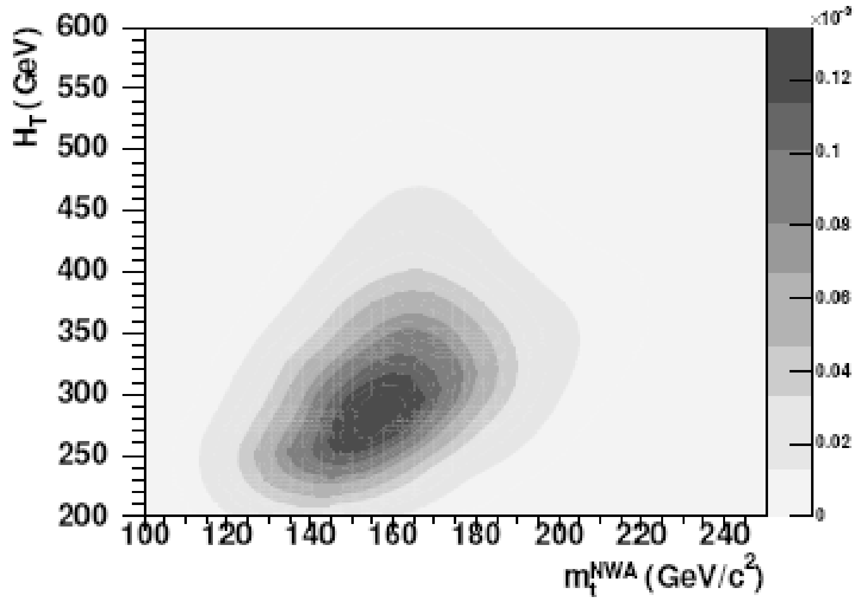




H_t

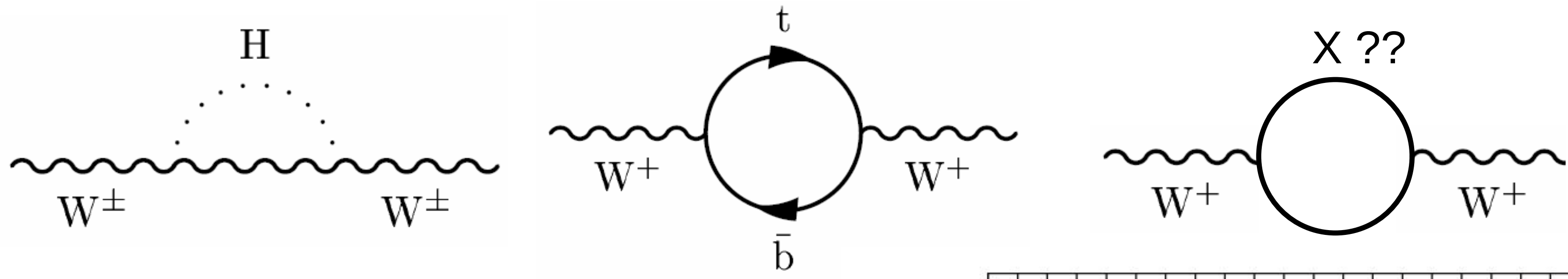
- Linear sum of jets, leptons, and missing Et
- Strong JES correlation and also strong Top Mass correlation (strong correlation with m_t^{NWA})



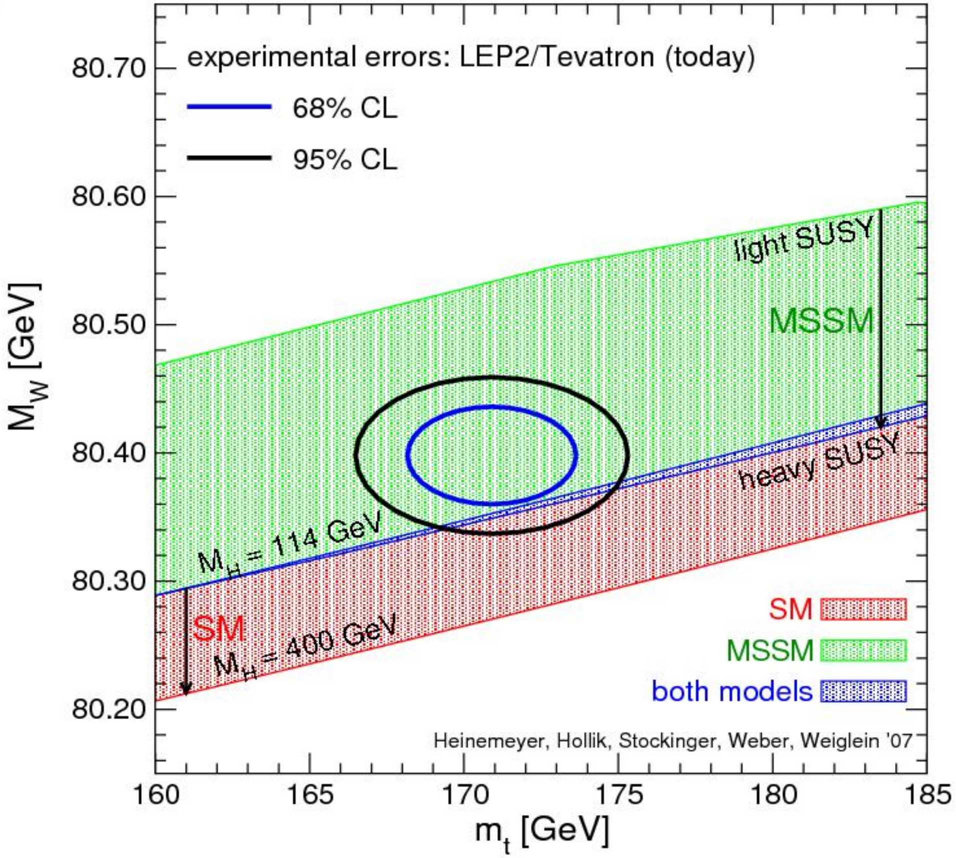


(d) Dilepton tagged

Why we measure top quark mass



- SM Higgs Mass was constrained by M_{top} and M_W through loop correction of W mass



- Precision top quark mass measurement
  - ❖ Predict SM Higgs mass
  - ❖ Constraints for physics beyond standard model