Search for Heavy Top at CDF

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CDF Collaboration

DPF+JPS Meeting
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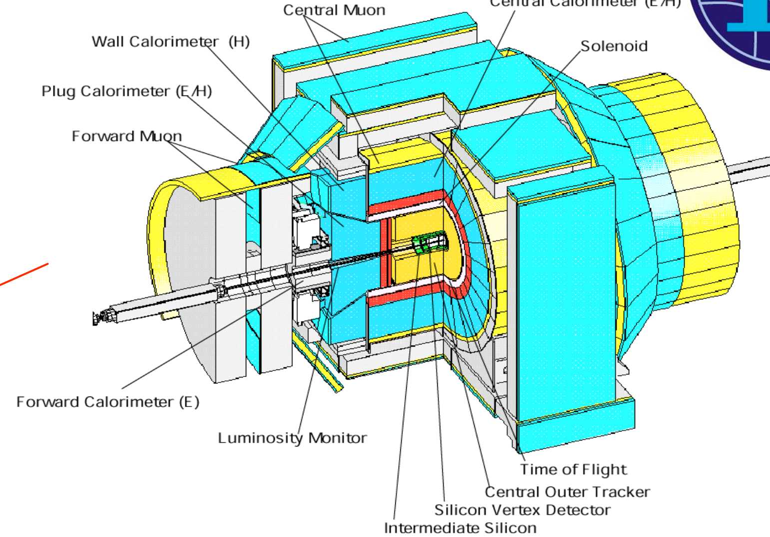
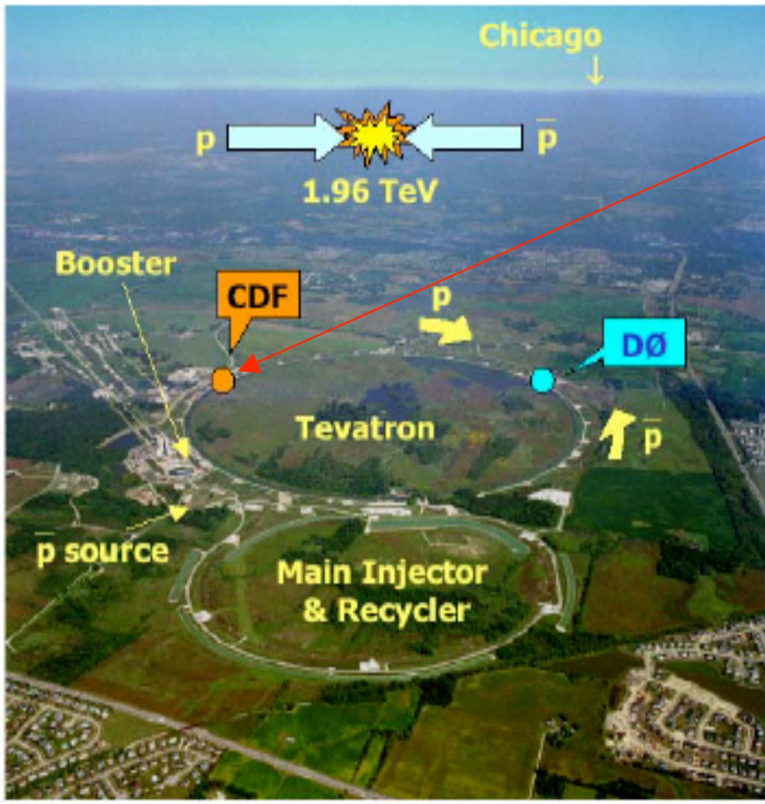
Tevatron and CDF detector





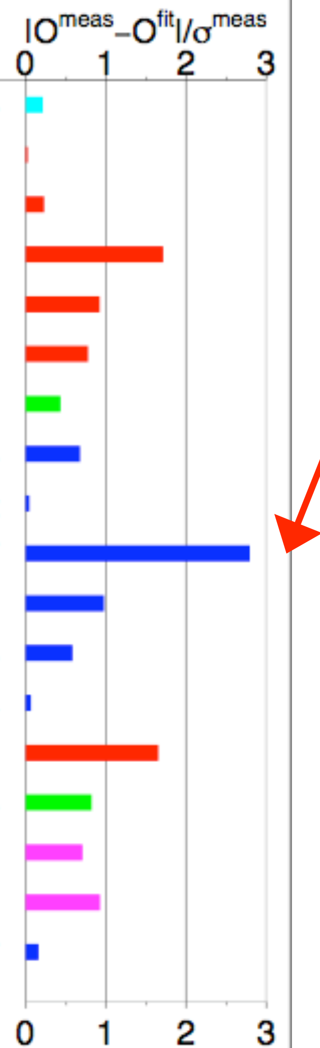
- ~ 1.4 fb^{-1} delivered
- Expect to collect 6–8 fb^{-1} by 2009
- New heavy particle discovery reach up to masses of ~ 1 TeV
- This analysis uses 760 pb^{-1}

Theoretical Motivations

- **Heavy Top** appears in many theories
- Usually too heavy for Tevatron
  - e. g. Little Higgs (heavy Top with mass ~1-2 TeV)
    - (hep-ph/0310039,0402037,0520225)
- **Possible 4-th generation quark** with mass of few hundreds GeV
  - Consistent with EWK data
  - Oblique corrections drive Higgs Mass to ~ 500 GeV
    - (C.He et al, hep-ph/0102144)
  - Almost degenerate b´ and t´ masses: M(t´) – M(b´) < M(W)
  - Decays as top! t´ -> Wq (q=d,c,b)
- **New mirror quarks** with not necessarily same properties as first three generations
  - "Beautiful Mirrors": new heavy quarks decaying into Wb
  - Motivated by data
  - (C. Wagner, hep-ph/0109097)

EWK precision data

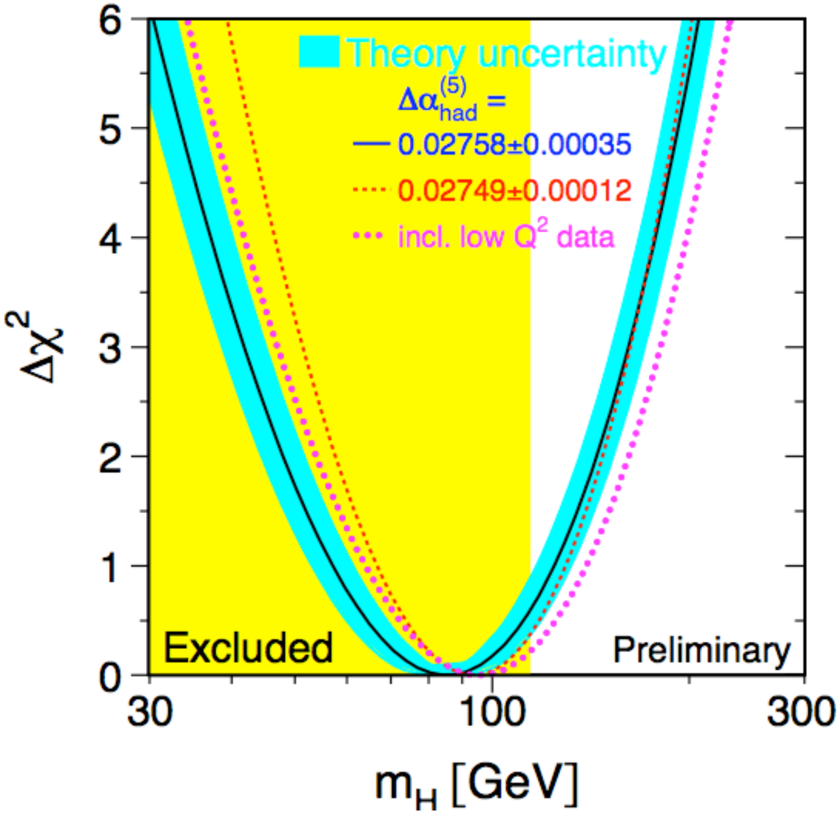
	Measurement	Fit
$\Delta\alpha_{had}^{(5)}(m_Z)$	0.02758 ± 0.00035	0.02766
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4957
σ_{had}^0 [nb]	41.540 ± 0.037	41.477
R_l	20.767 ± 0.025	20.744
$A_{fb}^{0,l}$	0.01714 ± 0.00095	0.01640
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1479
R_b	0.21629 ± 0.00066	0.21585
R_c	0.1721 ± 0.0030	0.1722
$A_{fb}^{0,b}$	0.0992 ± 0.0016	0.1037
$A_{fb}^{0,c}$	0.0707 ± 0.0035	0.0741
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1479
$\sin^2\theta_{eff}^{lept}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.392 ± 0.029	80.371
Γ_W [GeV]	2.147 ± 0.060	2.091
m_t [GeV]	171.4 ± 2.1	171.7



- Precision data is not consistent with SM!
- $A_{FB}{}^b$ – b-quark forward-backward assymetry ~2.9 σ away
- Not a big deal?
- $\sin\theta_W$ leptonic is ~3.6 σ away from $\sin\theta_W$ hadronic
- Suppose $A_{FB}{}^b$ measurement has larger uncertainty or systematically off, and we force:

$$\sin\theta_{W,\,had} = \sin\theta_{W\,,\,lep}$$

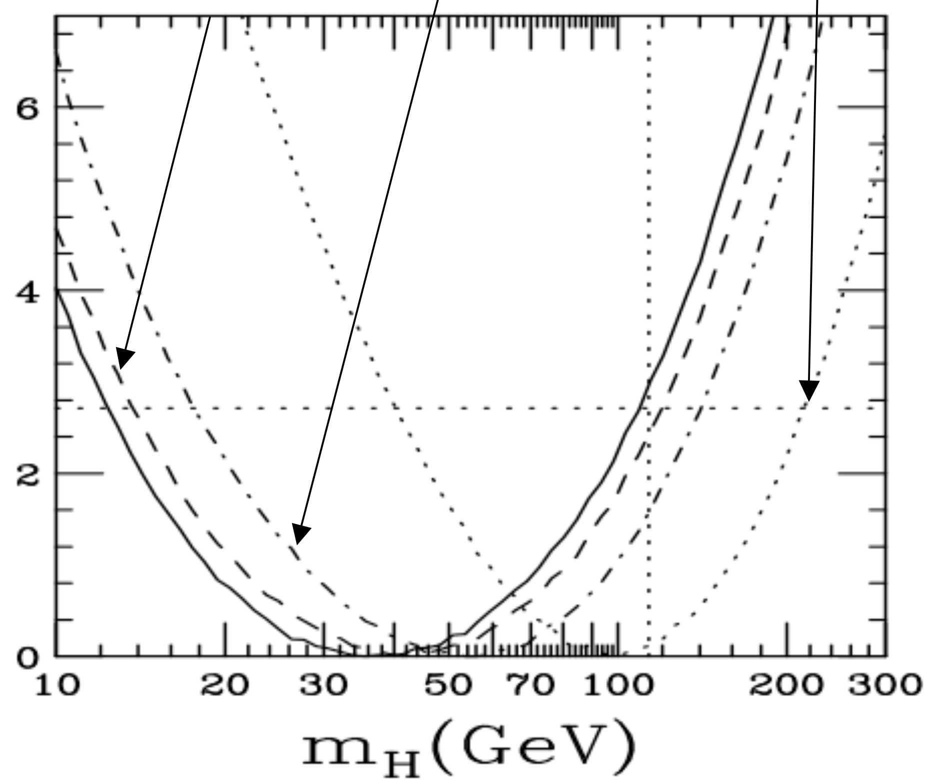
Higgs Mass fit



Fits to leptonic data

$+A^c_{FB}$

$+A^b_{FB}$

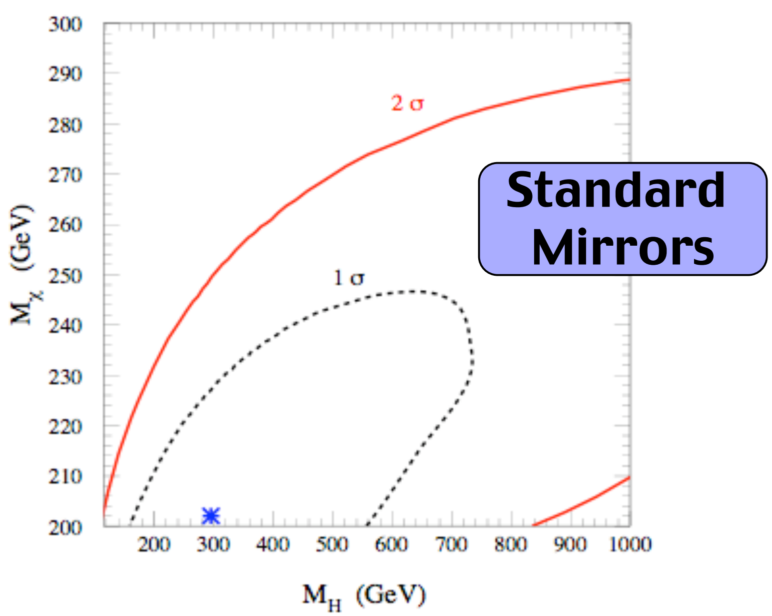


Higgs would be already discovered!

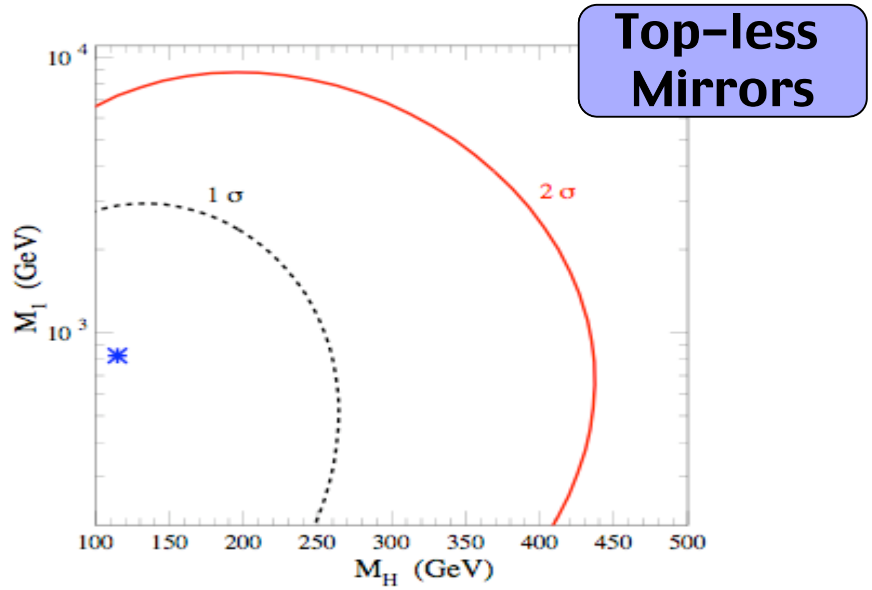
M. Chanowitz, hep-ph/0104024

Beautiful mirror quarks

- New physics in Z->bb? Different coupling of the b-quark to Z?
  - (C. Wagner, hep-ph/0109097)
- Mirror quarks of b-quarks improve the fit
  - couple to b's and less to d's or c's
- Two scenarios: with and without top mirror quarks



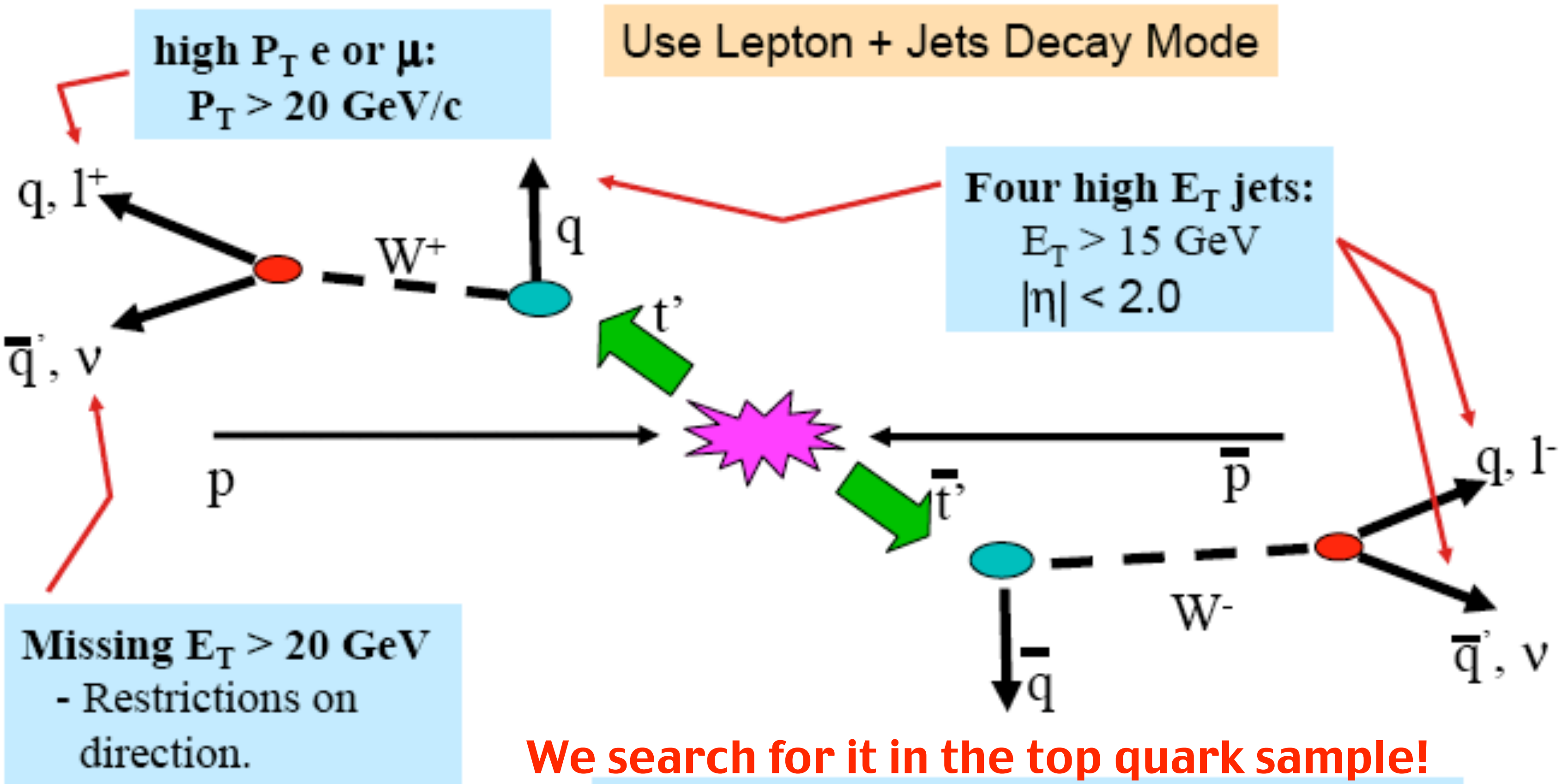
Perfect for Tevatron searches



Might have to wait for LHC

t´ Decay and Event Selection

Decays as top only heavier!



We search for it in the top quark sample!

Same event selection as for top, no b-tagging requirement

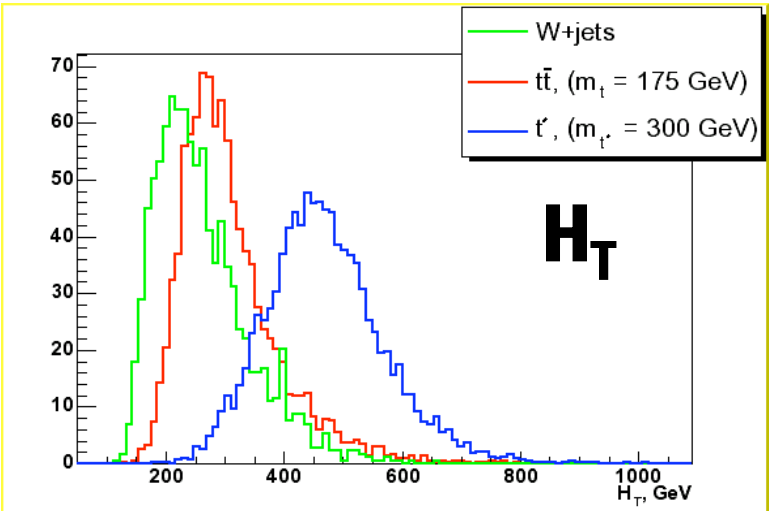
Analysis Strategy

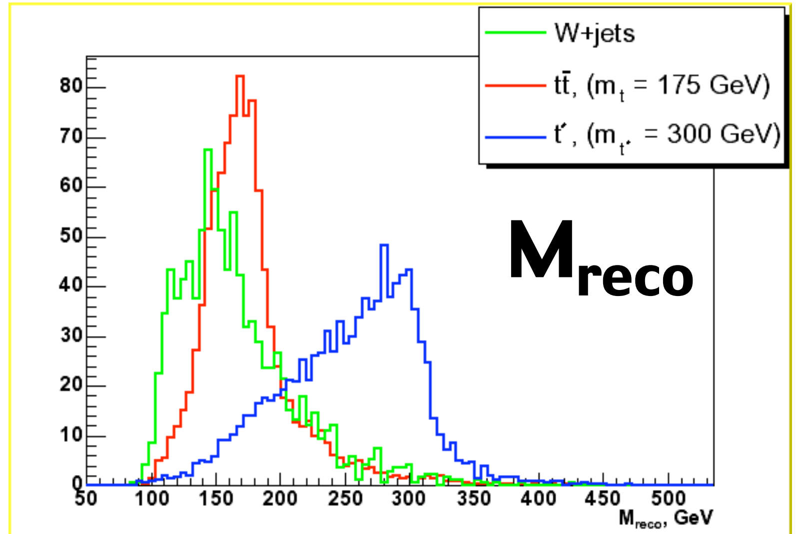
- **Main backgrounds: W+jets and ttbar**
- Others: QCD, EWK (WZ,WW,Z+jets,single top) ~ 8%
- Assume top mass = 175 GeV and constrain ttbar(Pythia) to theoretical cross section 6.7+– 0.9 pb
- Allow W+jets normalization float freely and perform kinematic fit
- Use the following kinematic quantities

1. $H_T = \sum E_{T,\,jets} + E_{T,\,lepton} + \not{E}_T$
2. M_{reco} – reconstructed mass as in Top Mass Fitter:

$$\chi^2 = \Sigma_{i=\ell,4jets} \frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i} + \Sigma_{j=x,y} \frac{(p_j^{UE,fit} - p_j^{UE,meas})^2}{\sigma_j} + \frac{(M_{jj} - M_W)^2}{\Gamma_W^2} + \frac{(M_{\ell\nu} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj} - M_t)^2}{\Gamma_t^2} + \frac{(M_{b\ell\nu} - M_t)^2}{\Gamma_t^2}.$$

Analysis Strategy (cont.)





- Quasi model-independent variables retain sensitivity to other possible beyond SM events
- Perform a binned Likelihood Fit
- Scan Likelihood as a function of t´ cross section
- Include systematic effects as nuisance parameters (σ_{tt}, Luminosity, lepton ID efficiencies, MC/data scale factors, Jet Energy Scale, Q2 scale, initial/final state radiation, PDF)
- Maximize Likelihood with respect to all them – profiling method

observed

$$L(\sigma_{t'}) = \prod_i P(n_i \mid \mu_i)$$

$$\mu_i = \sum_j L_j \sigma_j \varepsilon_{ij}$$

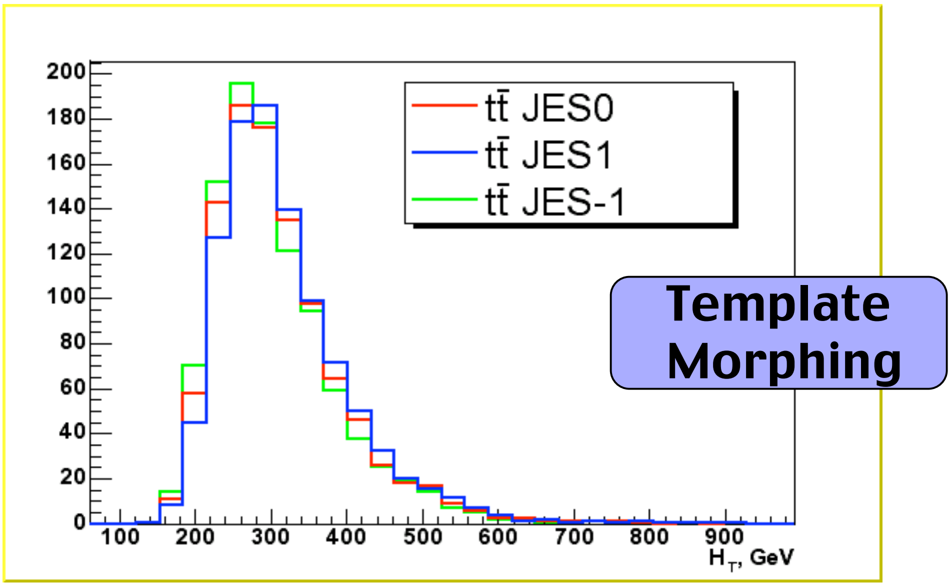
expected

Handling Systematics

$$\mathcal{L}(\sigma_{t'}|n_i) = \prod_{i,k} P(n_i|\mu_i) \times G(\nu_k|\tilde{\nu}_k, \sigma_{\nu_k})$$

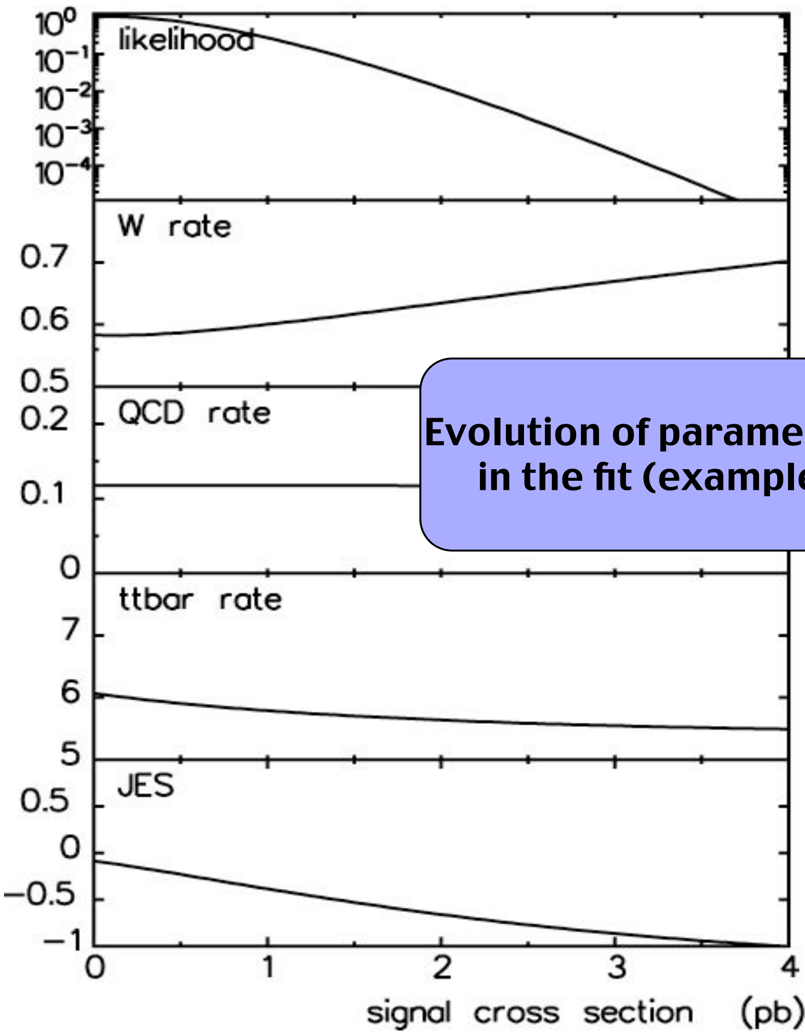
Nuisance parameters

- Effects evaluated based on measuring how the $\sigma_{t'}$ changed given t´ existed
- The shifts measured by drawing "pseudo-experiments" from shifted templates and fitted to nominal



- Jet Energy Scale (JES):
  - Obtain JES +−1σ shifted templates by shifting JES upward and downward
  - Include the shape transformation due to variation of ν_{JES} into the fit

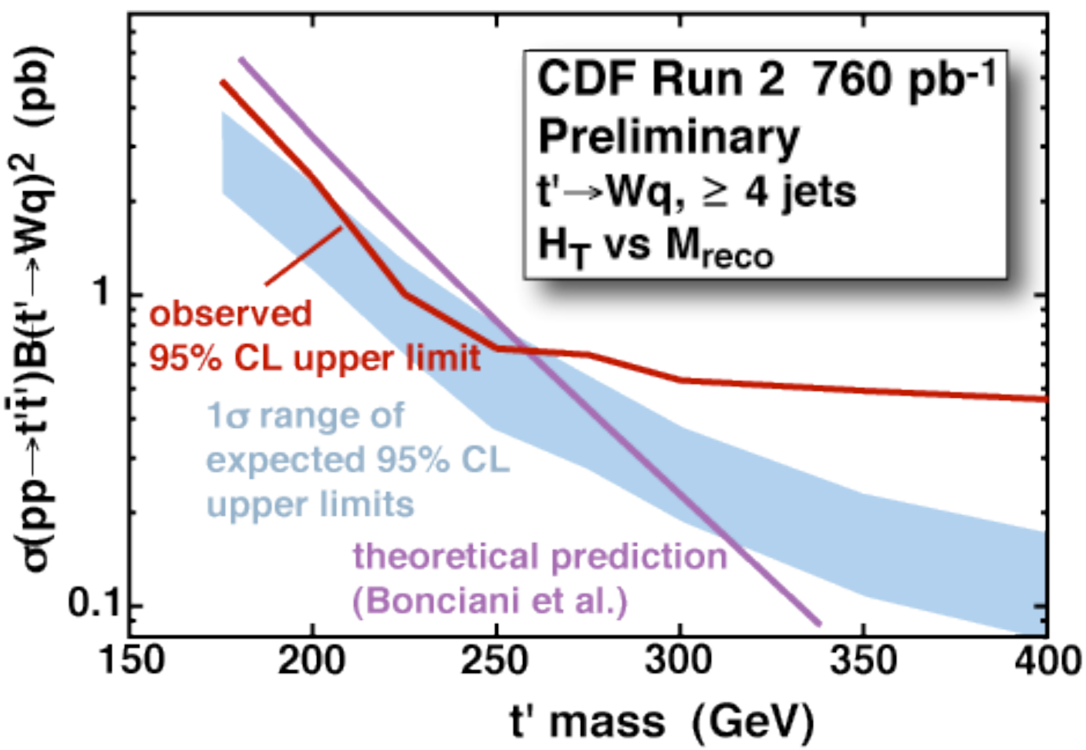
Systematic Effects



Evolution of parameters in the fit (example)

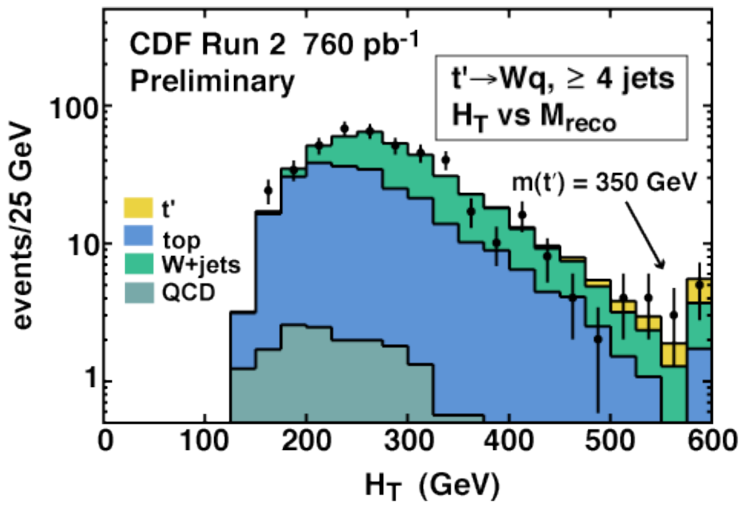
Effect	Error
Jet Energy Scale	Template Morphing
Q^2 Scale	$\delta\sigma_{t'}$ < 1.25 pb
Lepton Isolation	2%
Lepton ID	0.7%
ISR/FSR	$\delta\sigma_{t'}$=0.2 pb
Luminosity	5.8%
QCD Background	negligible
PDF	1.0%
Theory	10%

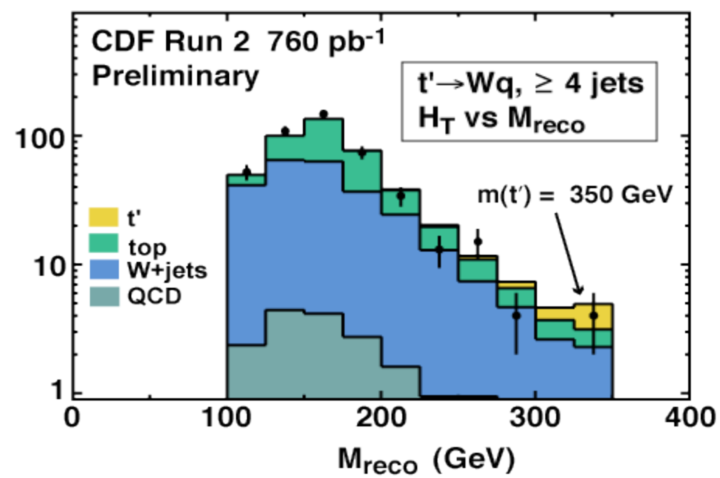
Looking at the data: 95% CL Limits

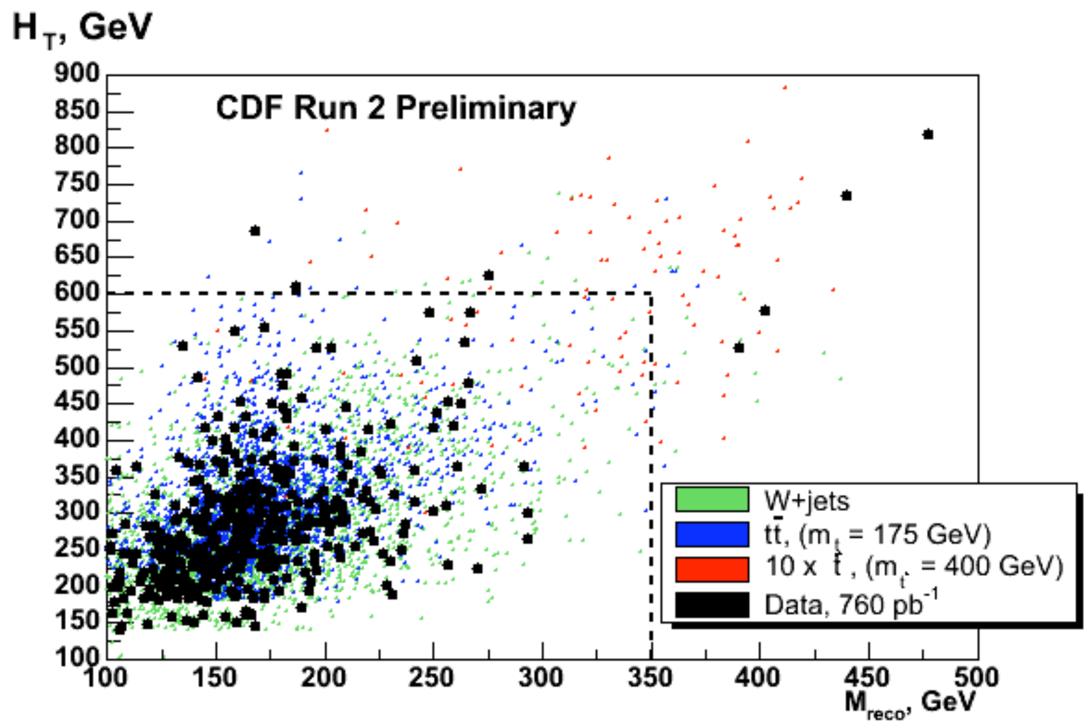


- Theory curve from
  - Bonciani et al. hep-ph/9801375
  - Mangano et al. hep-ph/0303085
- Expected limits obtained using pseudo-data
- Exclude with 95%CL region of t´ masses below 258 GeV

Data Fit for m $_{t'}$ =350 / 400 GeV

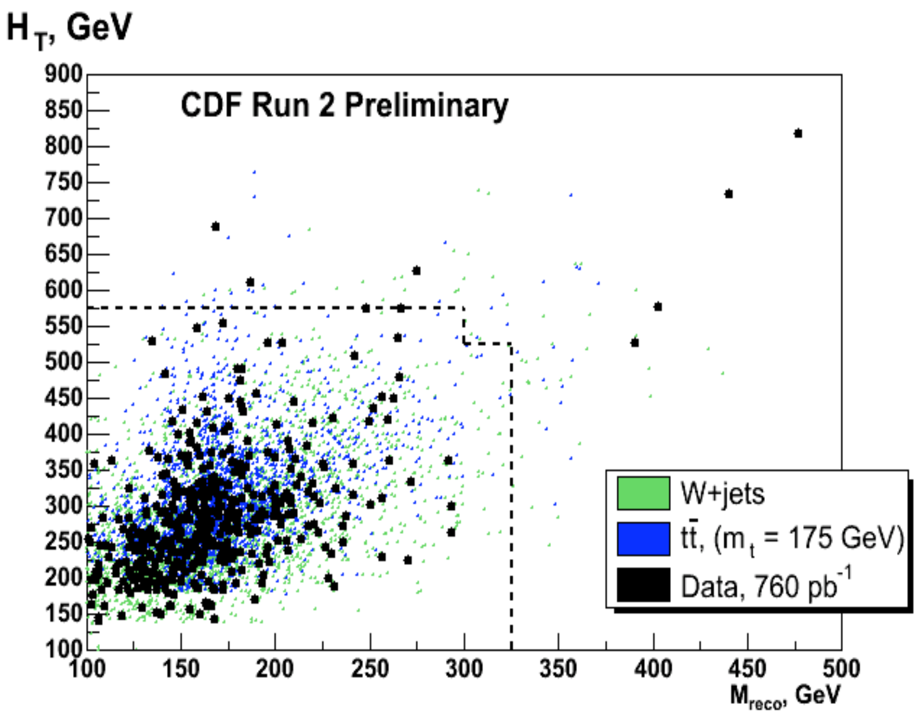






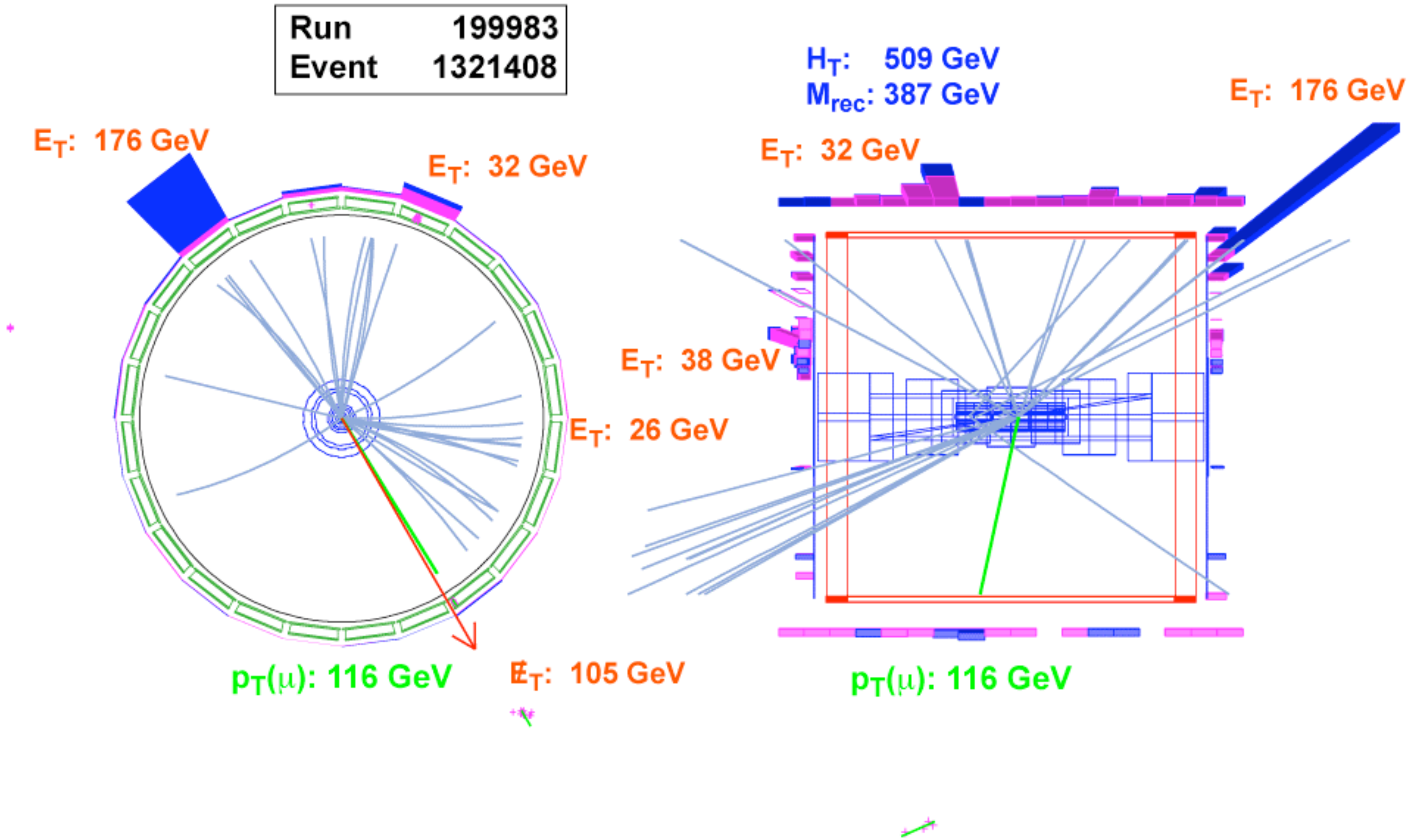
- **Expect ≈ 1.3 events for m(t′) = 400 GeV at 760 pb^{-1} luminosity**

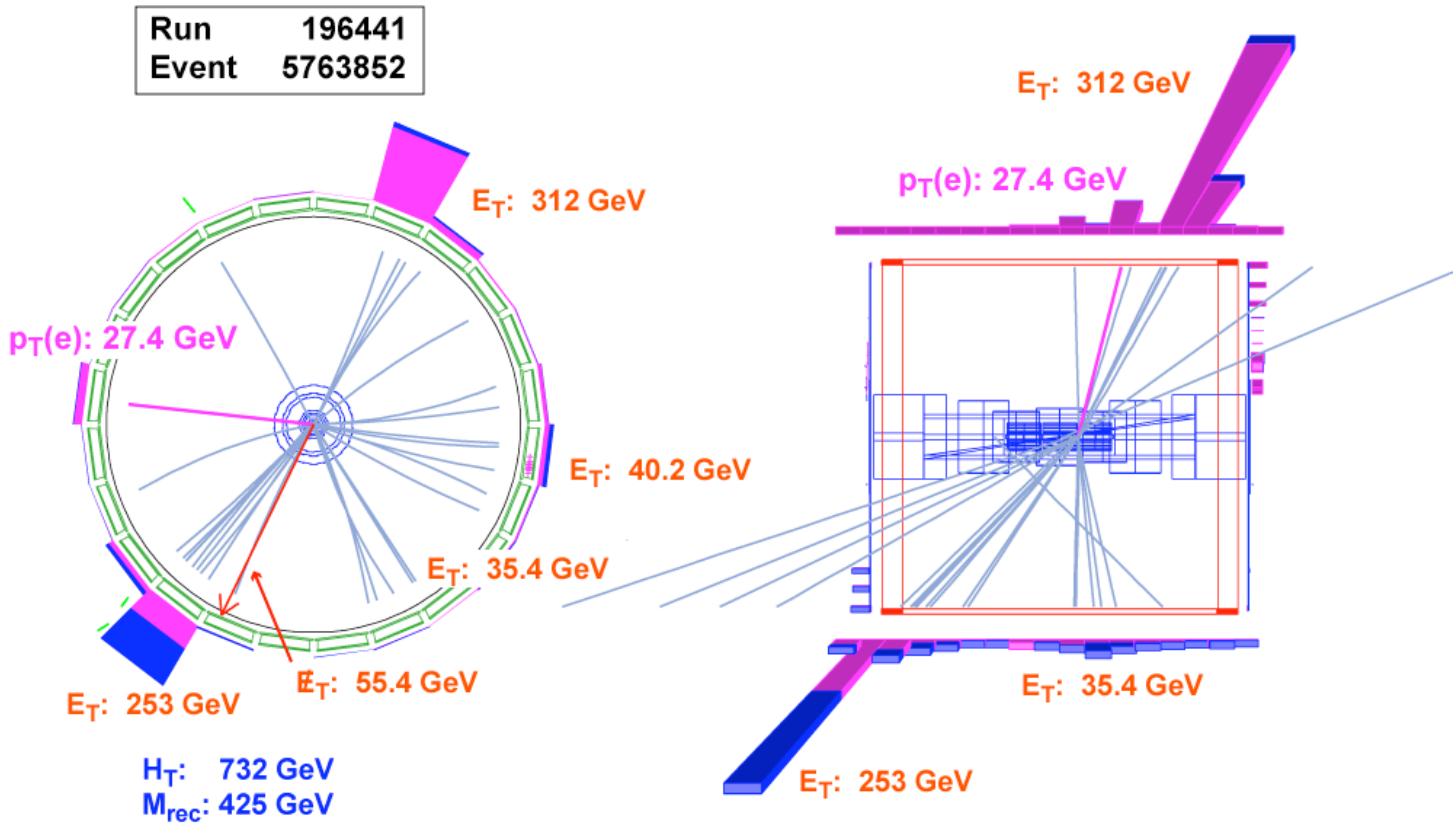
Significance of an Excess

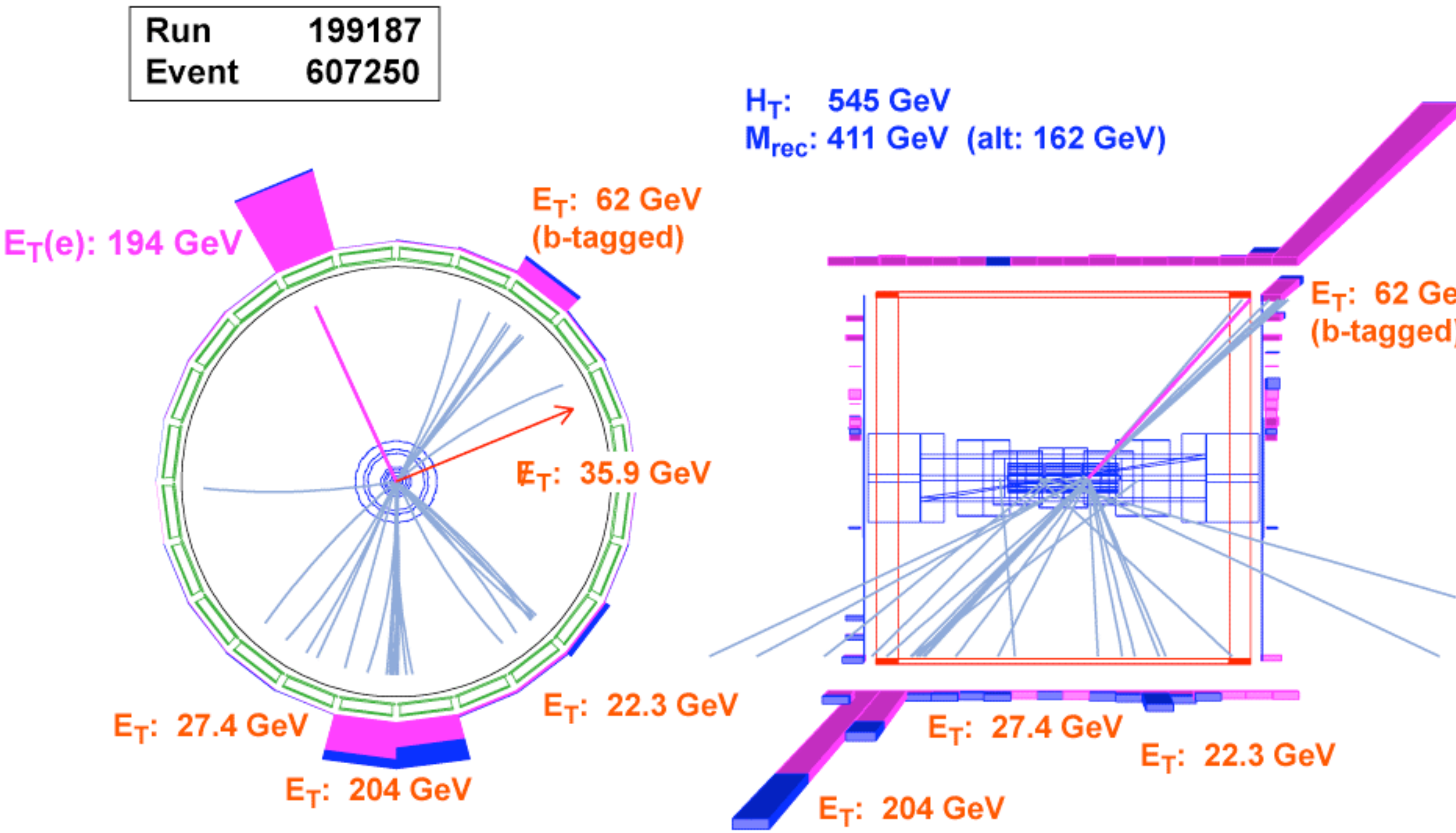


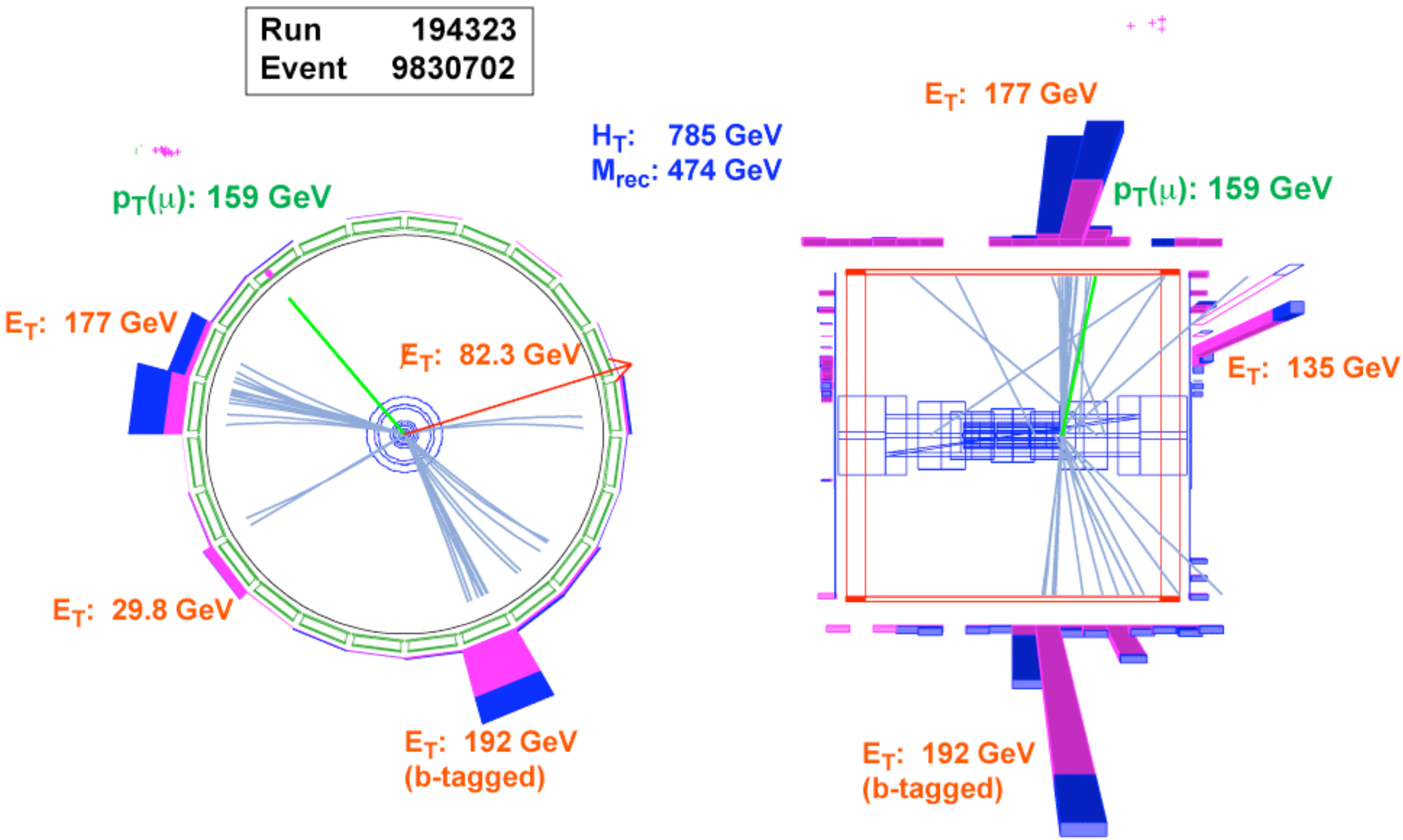
- A priori chose high-H_T, M_{reco} signal region with ~1 % of SM events
  - All overflow bins + 2 high H_T, M_{reco} bins
- Expect 6.8 events– observe 7 events

Event Displays of 4 events at the high Mass tail


Run 199983
Event 1321408
E_T: 176 GeV
E_T: 32 GeV
H_T: 509 GeV
M_{rec}: 387 GeV
E_T: 176 GeV
E_T: 32 GeV
E_T: 38 GeV
E_T: 26 GeV
$p_T(\mu)$: 116 GeV
$\not{E}_T$: 105 GeV
$p_T(\mu)$: 116 GeV

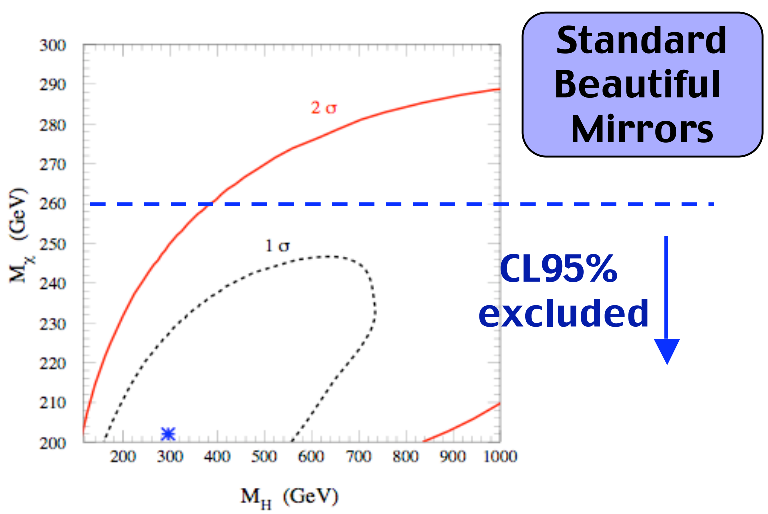

Run 196441
Event 5763852
E_T: 312 GeV
$p_T(e)$: 27.4 GeV
E_T: 40.2 GeV
E_T: 35.4 GeV
$\not{E}_T$: 55.4 GeV
E_T: 253 GeV
H_T: 732 GeV
M_{rec}: 425 GeV
E_T: 312 GeV
$p_T(e)$: 27.4 GeV
E_T: 35.4 GeV
E_T: 253 GeV


Run 199187
Event 607250
H_T: 545 GeV
M_{rec}: 411 GeV (alt: 162 GeV)
$E_T(e)$: 194 GeV
E_T: 62 GeV
(b-tagged)
$\not{E}_T$: 35.9 GeV
E_T: 27.4 GeV
E_T: 22.3 GeV
E_T: 204 GeV
E_T: 62 GeV
(b-tagged)
E_T: 27.4 GeV
E_T: 22.3 GeV
E_T: 204 GeV


Run 194323
Event 9830702
H_T: 785 GeV
M_{rec}: 474 GeV
$p_T(\mu)$: 159 GeV
E_T: 177 GeV
$\not{E}_T$: 82.3 GeV
E_T: 29.8 GeV
E_T: 192 GeV
(b-tagged)
E_T: 177 GeV
$p_T(\mu)$: 159 GeV
E_T: 135 GeV
E_T: 192 GeV
(b-tagged)

Final Remarks

- The analysis is based on 760 pb−1of integrated luminosity
- CDF is currently analyzing 1.2 fb−1 of data
- See new results at winter conferences



Backup Slides

Results

Mass (GeV)	Expected Limit (pb)	Actual Limit (pb)
175	$2.93 \pm^{1.05}_{0.66}$	4.86
200	$1.70 \pm^{0.57}_{0.44}$	2.36
225	$0.92 \pm^{0.40}_{0.27}$	1.01
250	$0.54 \pm^{0.24}_{0.14}$	0.68
275	$0.40 \pm^{0.15}_{0.12}$	0.64
300	$0.28 \pm^{0.12}_{0.08}$	0.54
350	$0.18 \pm^{0.07}_{0.05}$	0.50
400	$0.13 \pm^{0.06}_{0.04}$	0.46