Higgs to $\tau\tau$ at CDF

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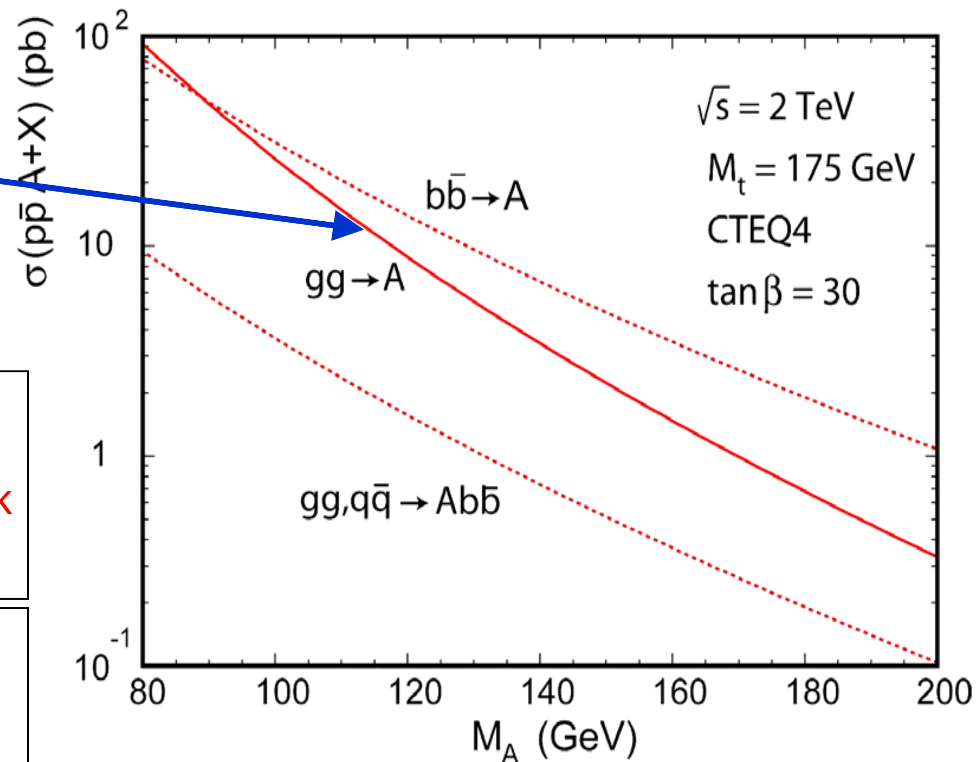
MSSM Higgs Production

- MSSM Higgs
  is produced copiously!
  (at reasonably large tanβ)



- Two main channels:

-$b\bar{b}$ → A

NLO from Maltoni, Sullivan, Willenbrock
NNLO from Harlander, Kilgore

-gg → A

HIGLU (NLO) program from M. Spira

Do the math: **For M_A=120 GeV/c², tanβ=30:**

σ(bb→A) = (8.9e-3)(30)² = 8.0 pb
σ(gg→A) = 5.2 pb

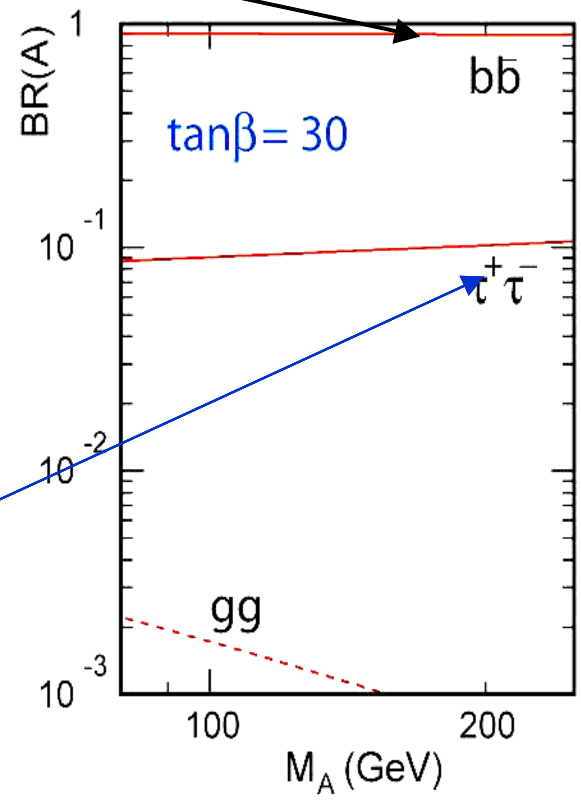
σ = 13.2 pb

~2500 A produced with 200 pb^{-1} !
(x2 more if you consider h as well)

Higgs Decays

Higgs decays primarily to bb (~ 90%)

- HUGE background from strongly produced bb.



So what can we do?

1) Look for ***associated*** production

- associated with W, Z *Yoshio Ishizawa's talk*
- with a 3rd, 4th b-quark.

Avto Kharchilava's talk

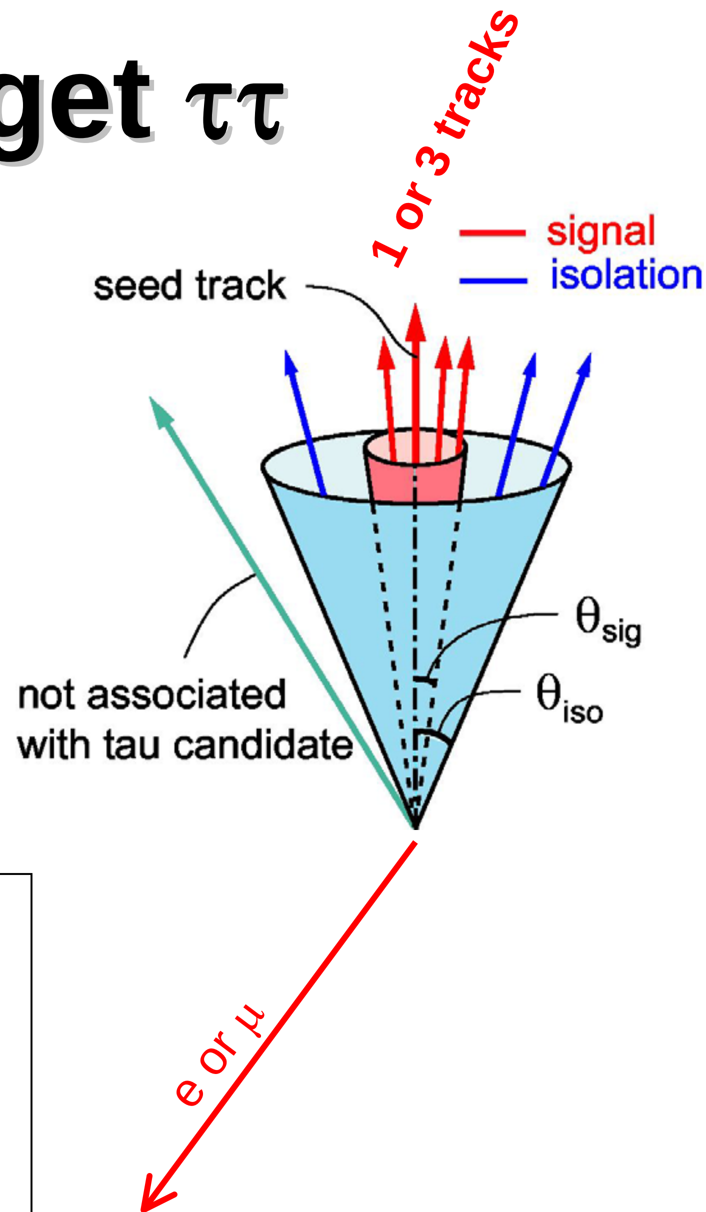
2) Look for other higgs decays:

- **ττ is promising**
  (down by x10, but only Weak bgs)
- γγ *Sungwon Lee's talk*

How to get ττ

- Trigger on isolated "pencil jets" hadronic τ decays (τ_h)
- Ask for an e, μ, [or 2nd (τ_h)] in event.

1st time at hadron collider!
(to be added to higgs search)



τ decays

$\tau \to e\nu_e\nu_\tau$, $\tau \to \mu\nu_\mu\nu_\tau$: **leptonic decays (~36%).**

$\tau \to \pi\nu_\tau$, $\tau \to \pi\pi^0\nu_\tau$, $\tau \to \pi\pi\pi\nu_\tau$, … : **hadronic decays (~ 64%).**

The Trouble with τ

- QCD jets! They can look like τ_h
- Fight with: energy, isolation.

Triggered τ_h object:
- cluster-matched track with $p_T > 4.5$ GeV.
- no tracks w/ $p_T > 1.5$ Gev in 10-30^0 iso. annulus.

-Electron + τ_h

→ central electron ($E_T > 8$ GeV) + τ_h object (~30nb at L3)

-Muon + τ_h

→ central muon ($p_T > 8$ GeV) + τ_h object (~30nb at L3)

-τ_h + τ_h

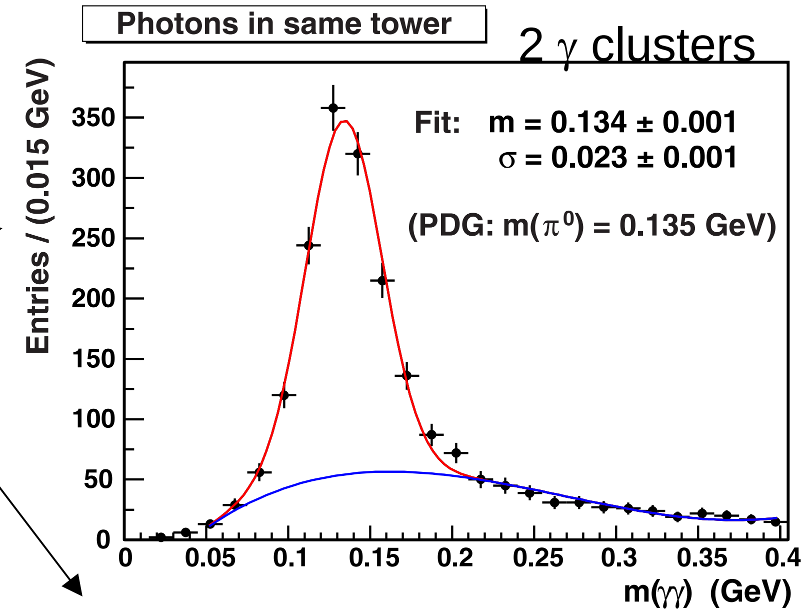
→ two τ_h objects, with extra L2 isolation (~13nb at L3)

Not yet included in MSSM higgs search.

LHC take note! constant trigger rate battles!

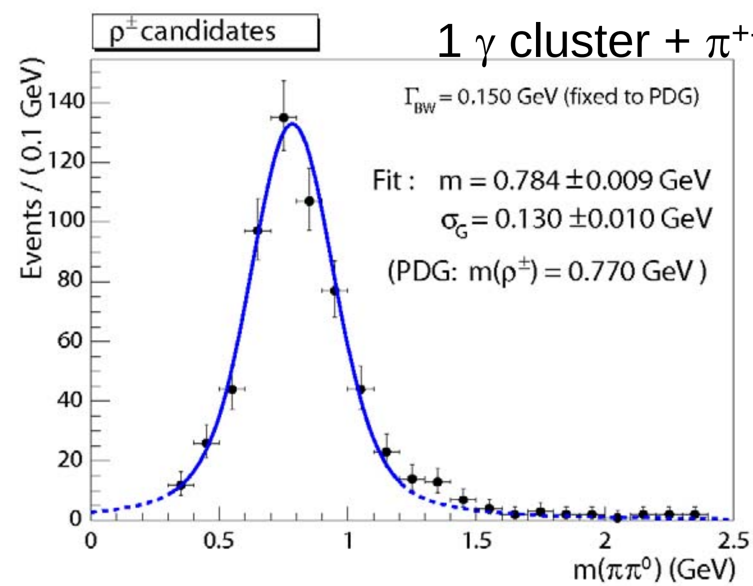
Reconstructing τ_h

- Tighten isolation.
- **Reconstruct π^0.**
  - use EM calorimeter for γ energy.
  - use ShowerMax for γ position.

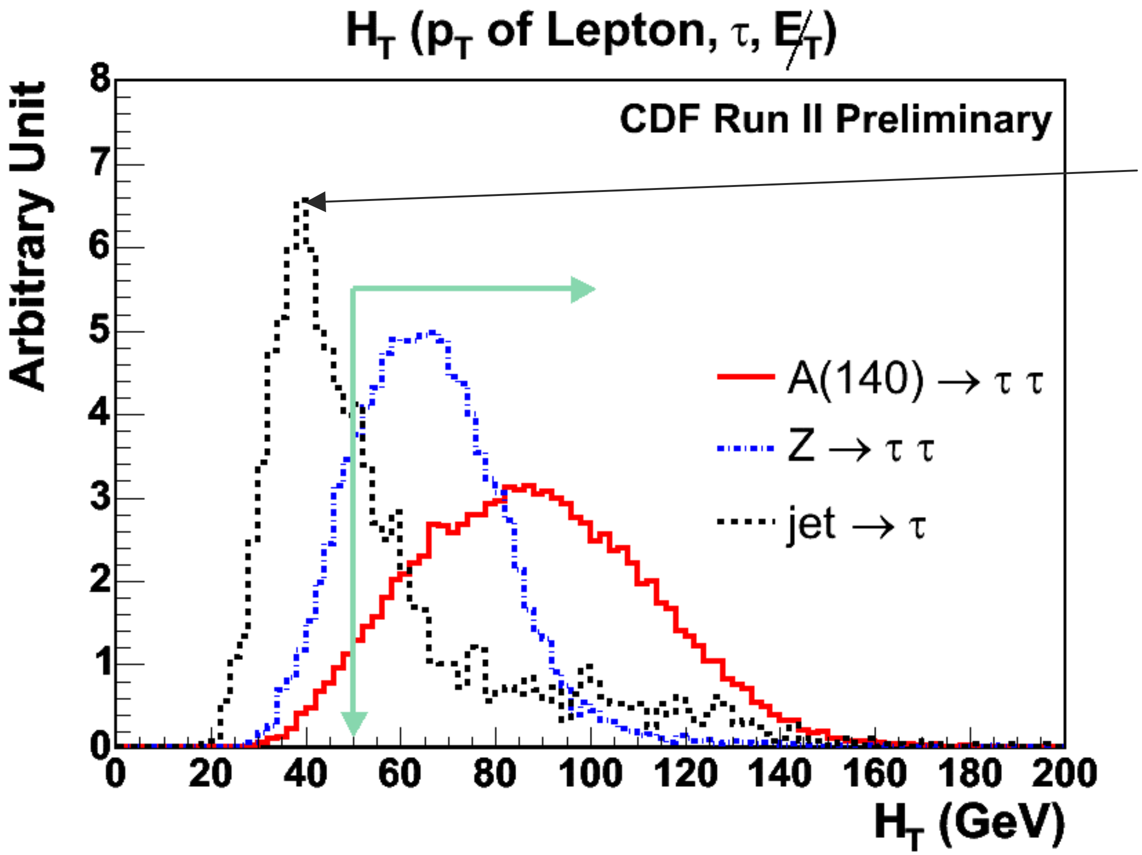


- Remove electron candidates.
- $m_{trks+\pi^0} < 1.8$
- **Look for characteristic 1, 3 track enhancement.**

Signature of hadronic tau decay!



Background Removal



Jets tend to be soft.

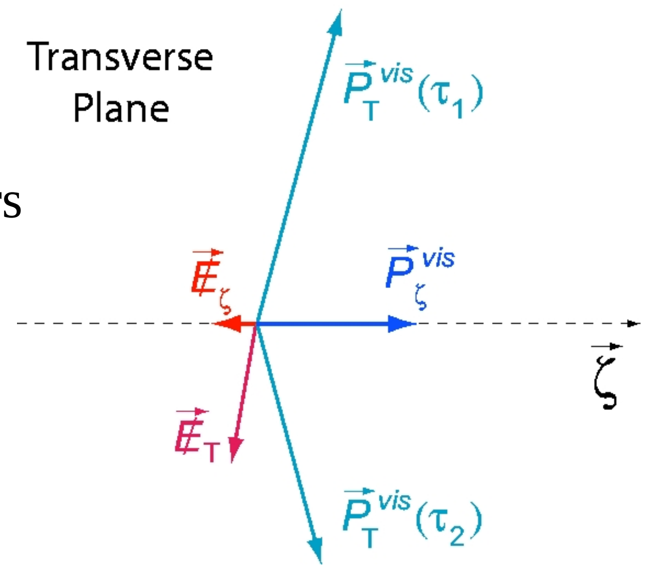
Requiring **scalar sum of energy of objects** in event > 50 GeV further reduces backgrounds.

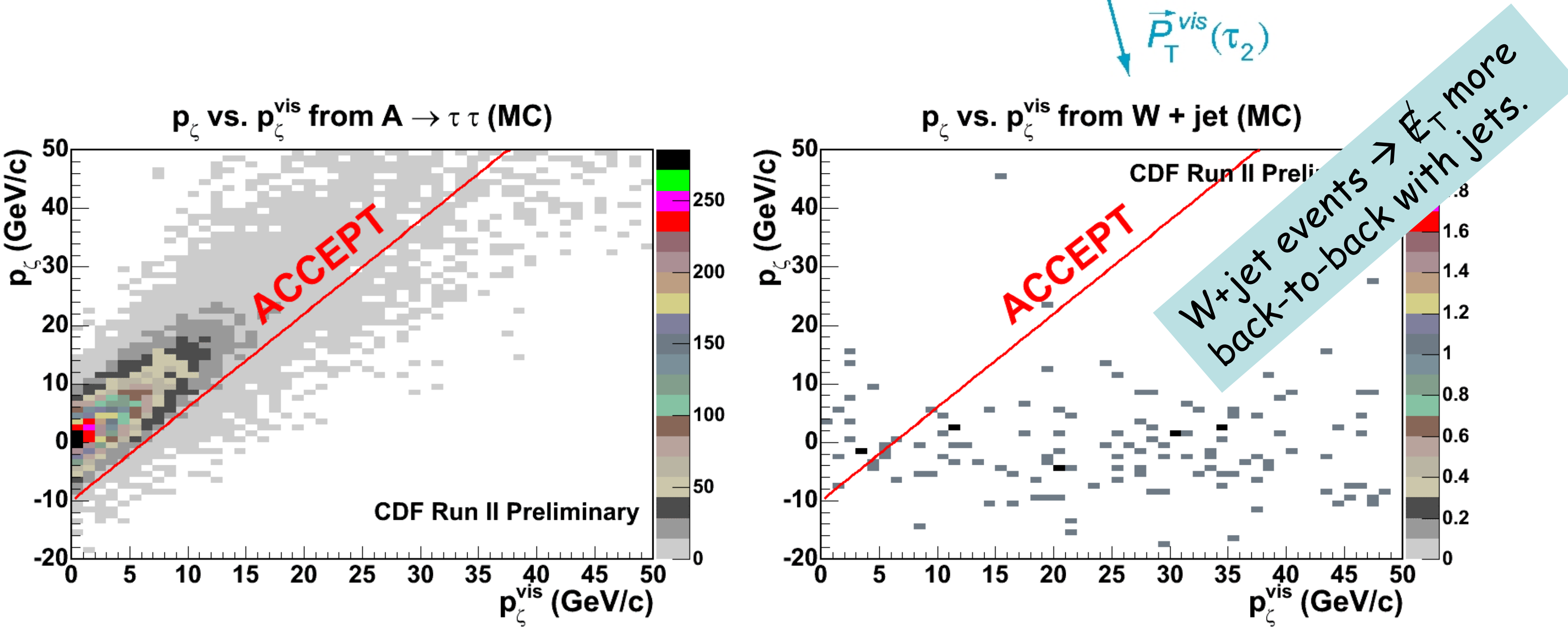
$$|P_T^{\tau 1}| + |P_T^{\tau 2}| + |\not{E}_T| > 50 \text{ GeV}$$

W associated backgrounds

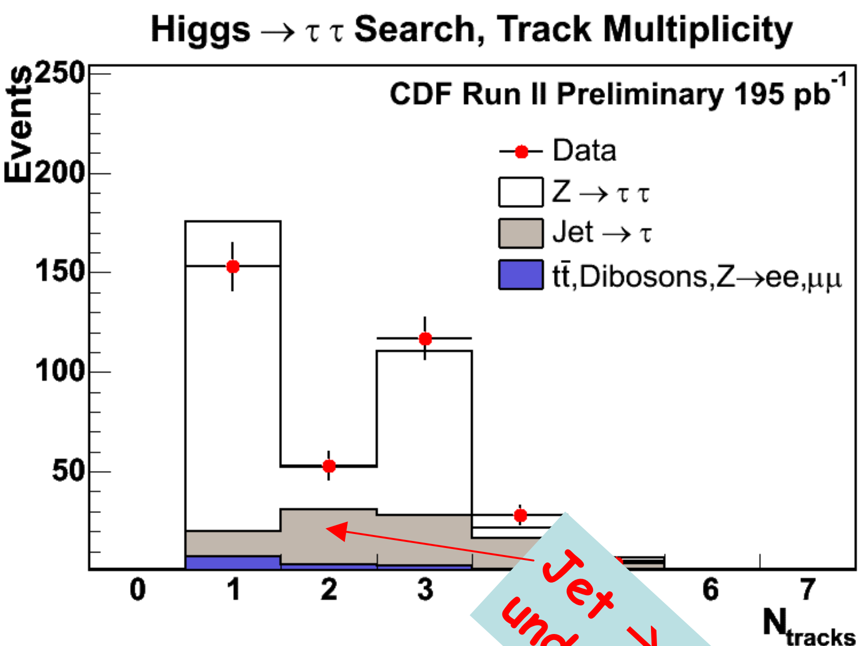
- **Define:** ζ–vector: Bisector of visible τ dirs

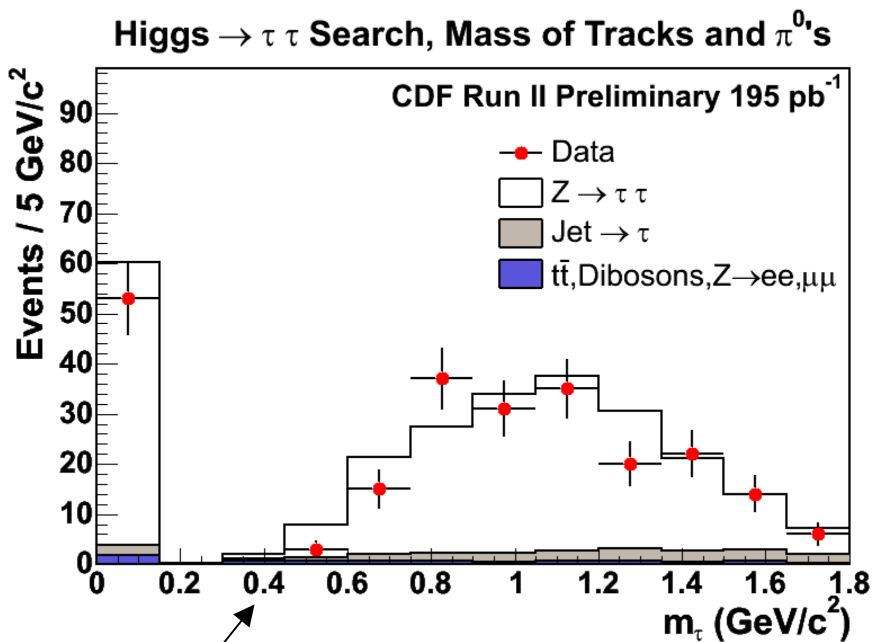
- P^{vis}_{ζ} = project VISIBLE τ's onto ζ
- $P_{\zeta} = P^{vis}_{\zeta} + \not{E}_T \cdot \zeta$





Hadronic τ signature



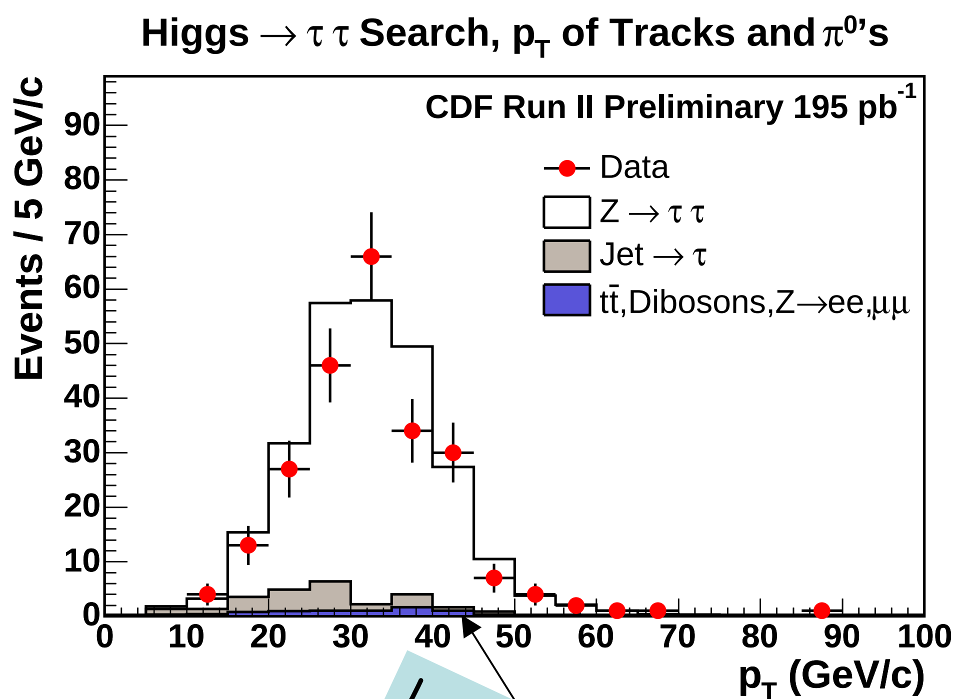


Jet → τ fakes under good control!

Nice 1, 3
track enhancement.

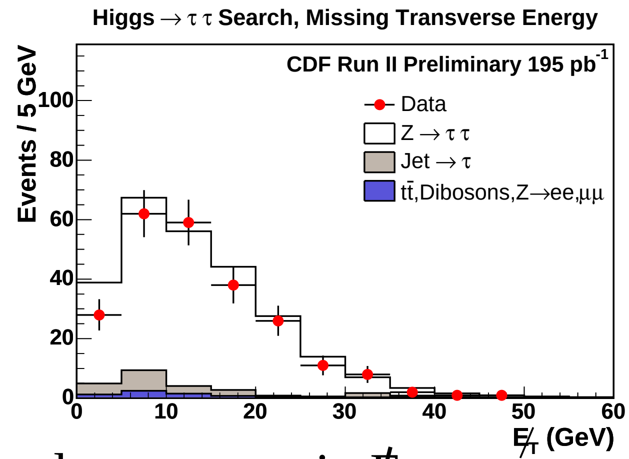
Only 1,3 track events.
Only events with τ_h ,
e/μ opp. Charge.

Hadronic τ distributions

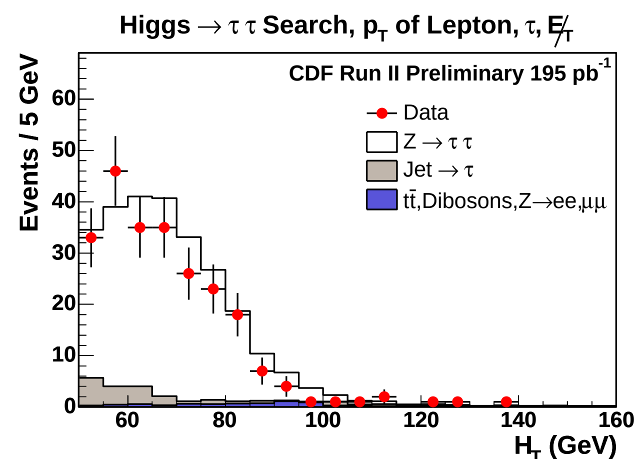


Low levels of jet→τ fakes (~0.1% at higher p_T)

Fakes **well** understood.
Long-standing discrepancies between jet samples resolved.
(Run 1 → fakes ~ 1%)



Good agreement in $\not{E}_T$



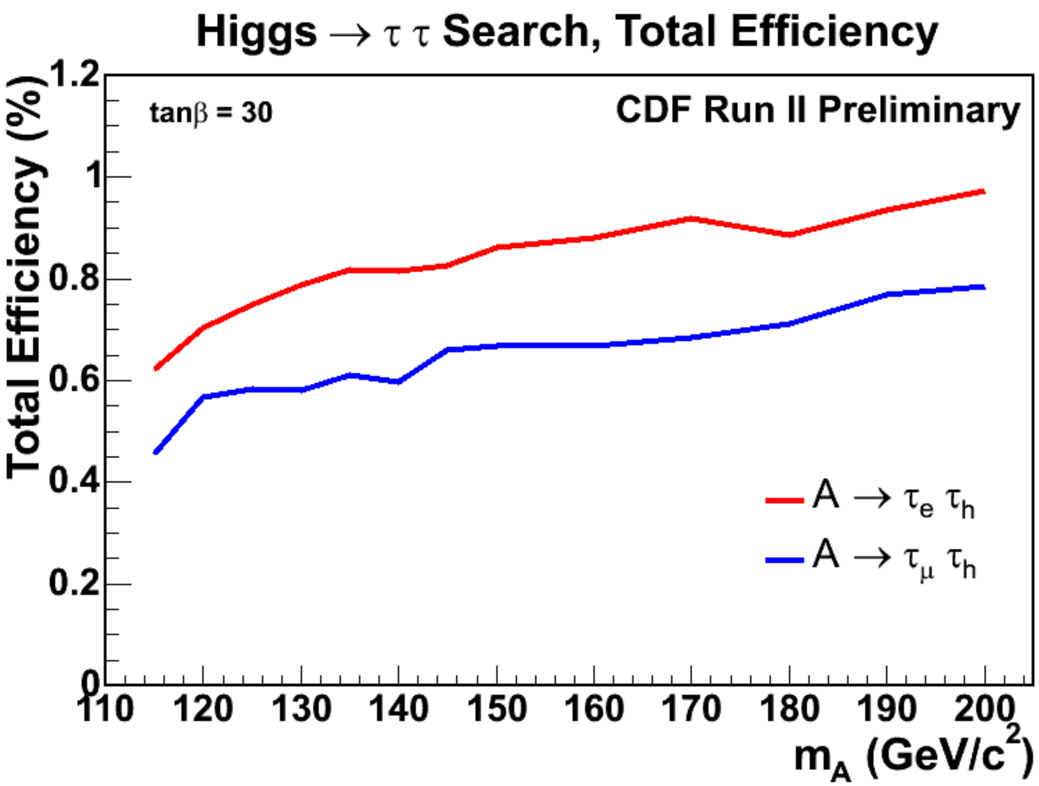
H_T above cut of 50 GeV

Predicted vs. Observed Events

CDF Run 2 Preliminary (195 pb^{-1})

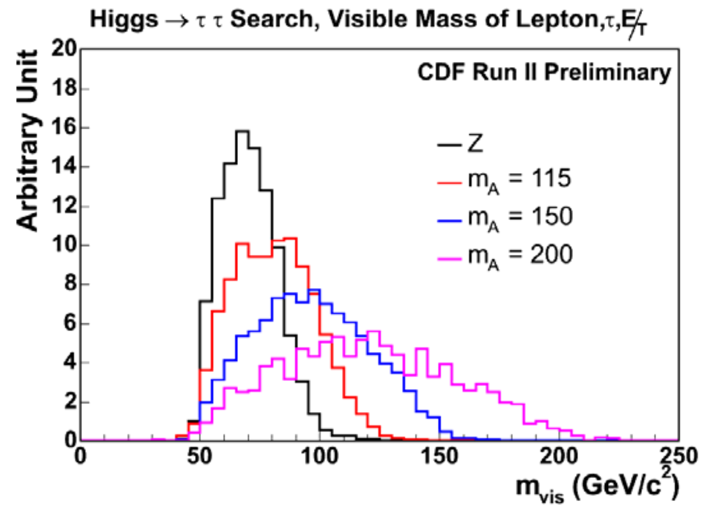
source	$\tau_e\tau_h$	$\tau_\mu\tau_h$	combined
$Z/\gamma^* \rightarrow \tau\tau$	132.3 ± 17.1	104.1 ± 13.3	236.4 ± 29.5
$Z/\gamma^* \rightarrow ee, \mu\mu$	1.8 ± 0.2	4.9 ± 0.4	6.7 ± 0.6
VV, tt	0.7 ± 0.1	0.8 ± 0.1	1.5 ± 0.1
Jet $\rightarrow \tau$ fakes	12.0 ± 3.6	7.0 ± 2.1	19.0 ± 5.7
Total predicted BG	146.8 ± 17.5	116.8 ± 13.5	263.6 ± 30.1
Observed	133	103	236

MSSM Higgs Signal



Pseudo scalar MSSM Higgs generated

with tanβ=30 used as acceptance model.

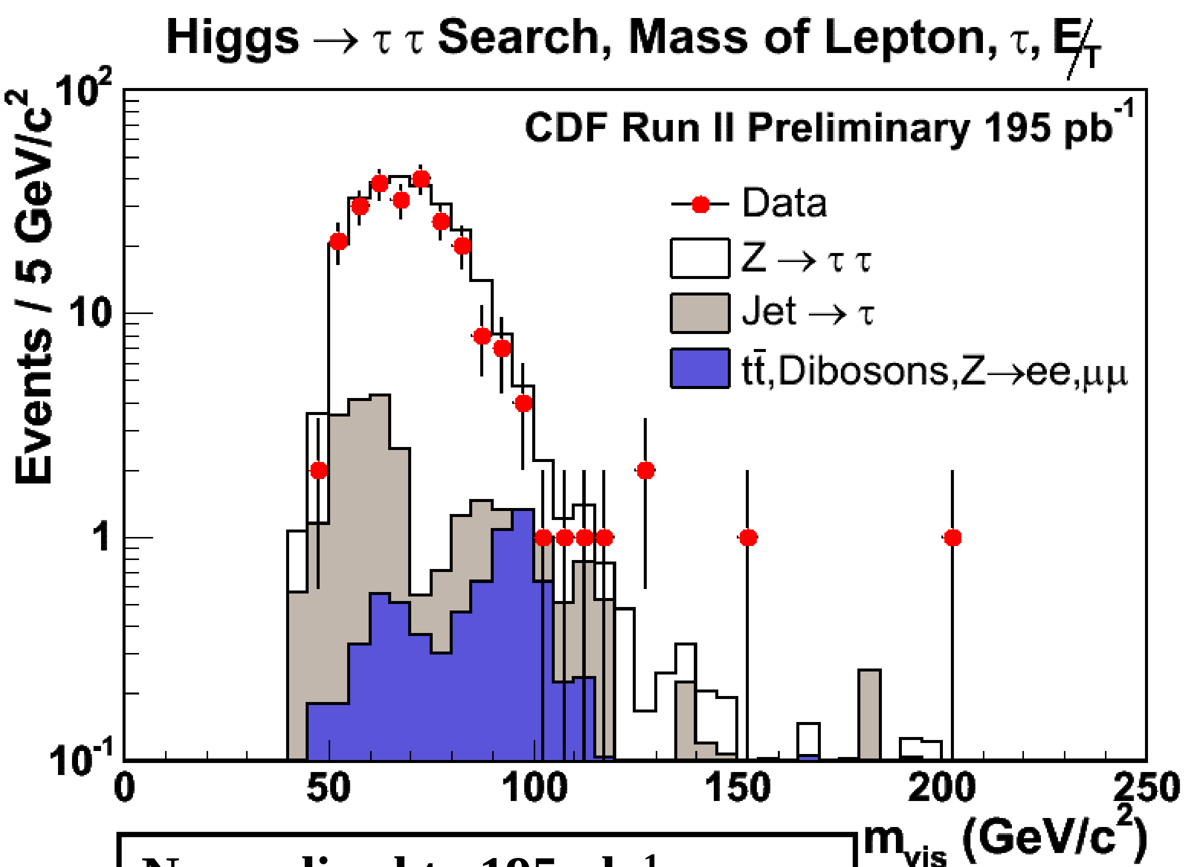


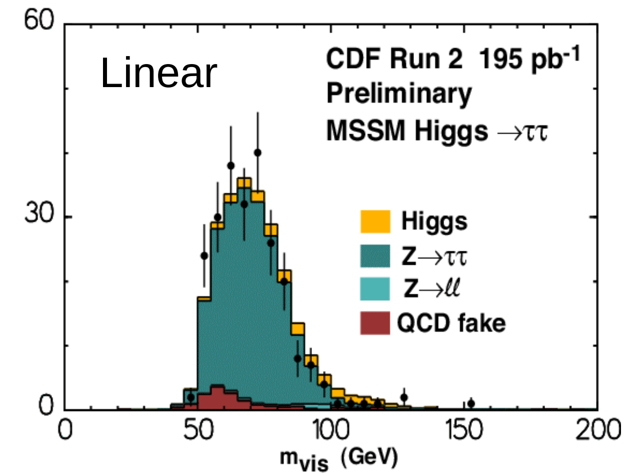
Define m_{vis} =

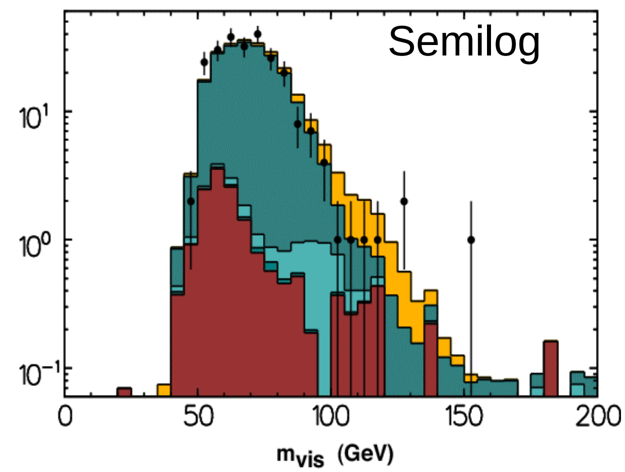
$$m(p(\tau_1) + p(\tau_2) + p(E_T))$$

Where $p(\not{E}_T) = (\not{E}_X, \not{E}_Y, 0, \not{E}_T)$

Z/Higgs Separation







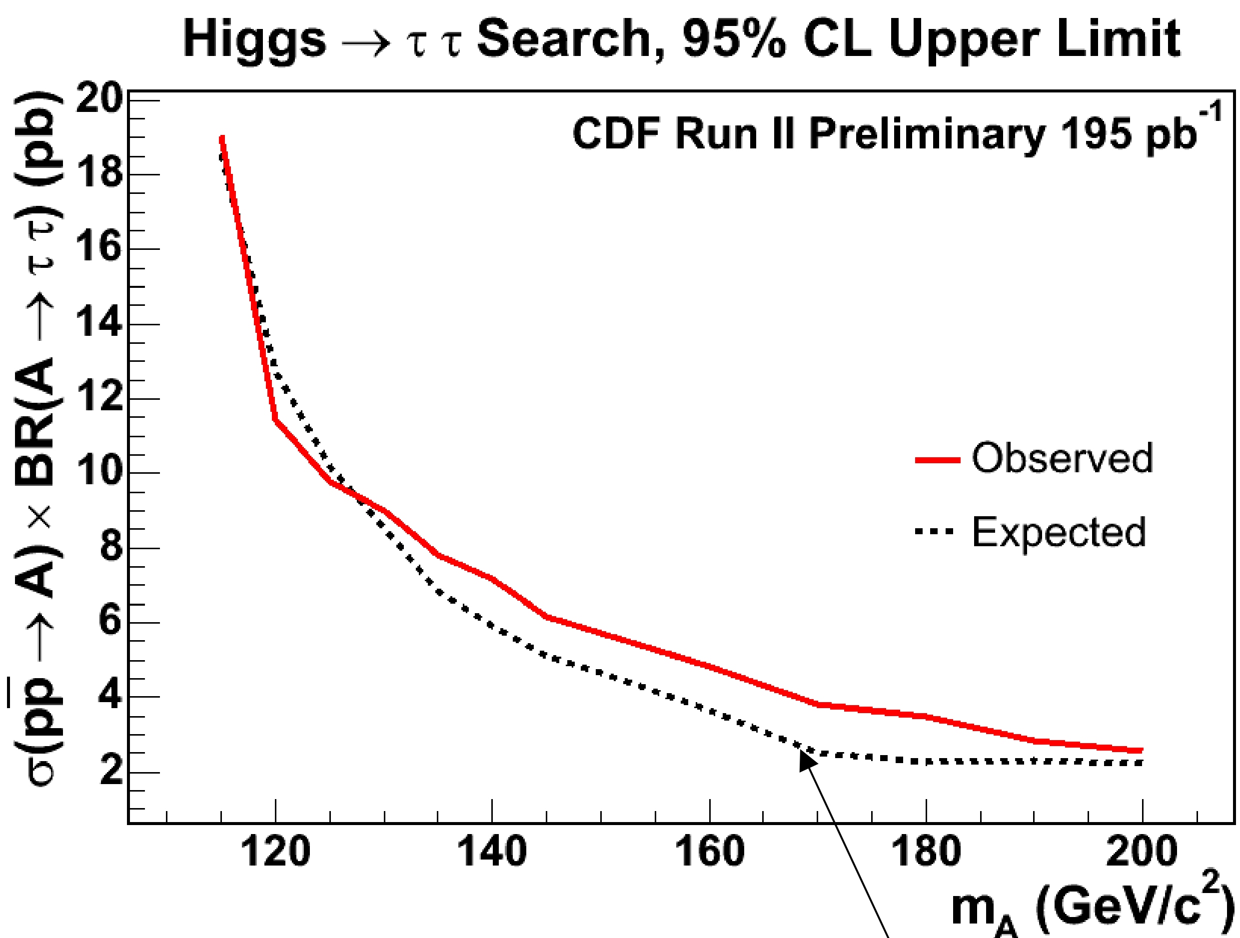
Normalized to 195 pb^{-1}

No Higgs component

Lum, Z-xscn, bg, all fixed w/in errors.

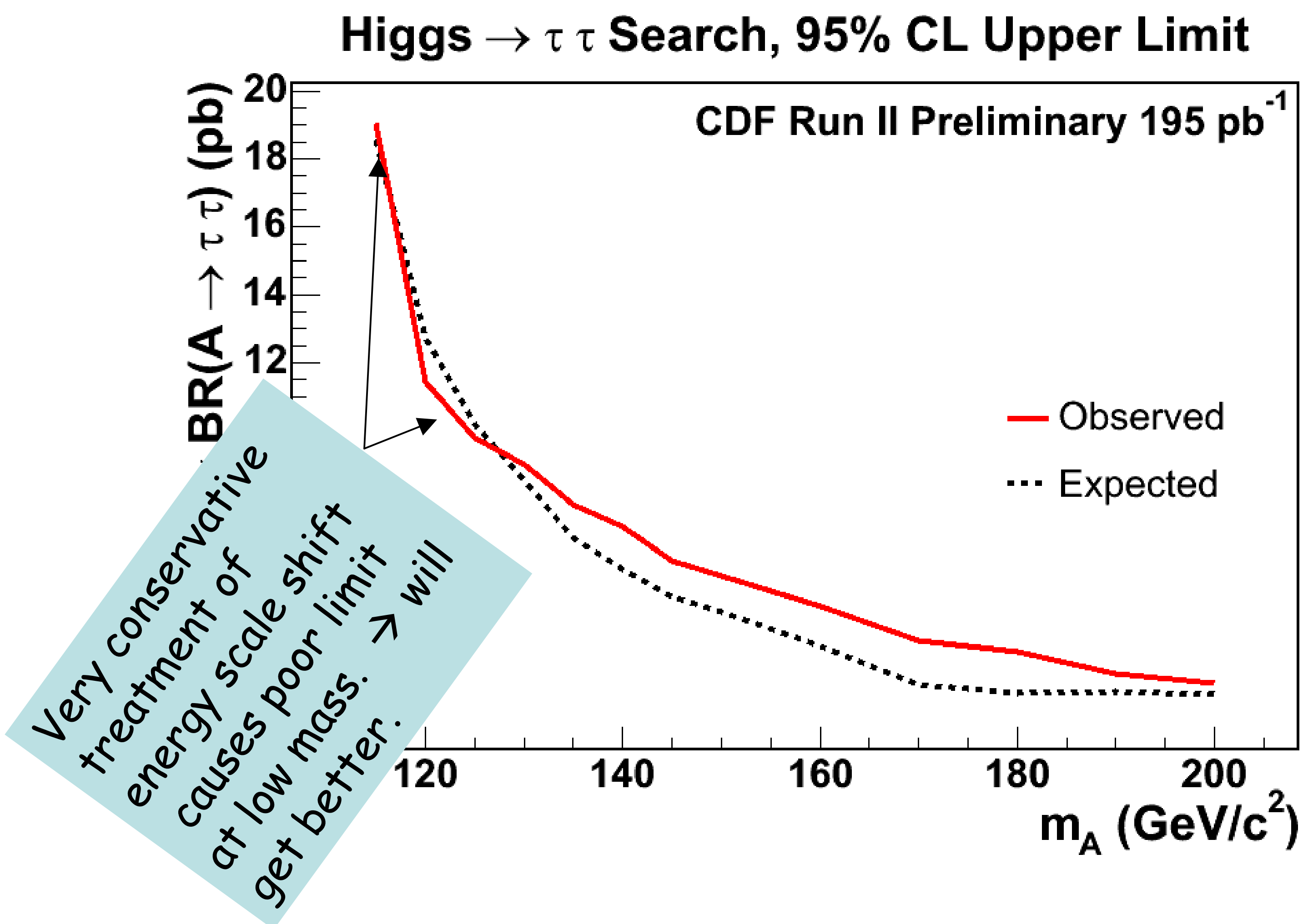
Binned likelihood fit shown with m_A = 130 GeV component in yellow

Fit Results



From pseudoexperiments

Fit Results



Higgs → τ τ Search, 95% CL Upper Limit
CDF Run II Preliminary 195 pb⁻¹
BR(A → τ τ) (pb)
20
18
16
14
12
120
140
160
180
200
m_A (GeV/c²)
Observed
Expected
Very conservative treatment of energy scale shift causes poor limit at low mass. → will get better.

Limit Table

MSSM Higgs $\rightarrow \tau\tau$ Search, 95% CL Upper Limits

m_A (GeV)	Observed (pb)	Expected (pb)
115	19.03	18.58
120	11.43	12.73
125	9.76	10.18
130	9.00	8.53
135	7.83	6.84
140	7.19	5.91
145	6.15	5.12
150	5.71	4.65
160	4.84	3.65
170	3.80	2.50
180	3.48	2.26
190	2.84	2.30
200	2.55	2.25

CDF Run II Preliminary

Need NLO calculation of higgs production to get exclusion in M, tanb plane.

What's Next?

- Have > x2 luminosity on tape already.
- Understand energy scale better, limits (esp. at lower mass) will get better.
- Will add $\tau_h \tau_h$ (ditau), $\tau_e \tau_\mu$ channels
  - Ditau adds stats similar to $\tau_e \tau_h$ channel.
  - $\tau_e \tau_m$ small, but very clean.
- Also looking at:
  - Additional jet with b-tag.
  - Extending acceptance into plug region.
  - Neural nets for reconstruction.

First time at hadronic collider.

Conclusion

- Direct Search for A → $\tau\tau$ performed at CDF
- Didn't find evidence of higgs, but…
  - achieved excellent acceptance
  - lower than expected jet → τ fake rates

- CDF expects ~ 4 fb^{-1} of data by end of Run 2
  - if MSSM higgs exists (at higher tanβ)

    we will see it!