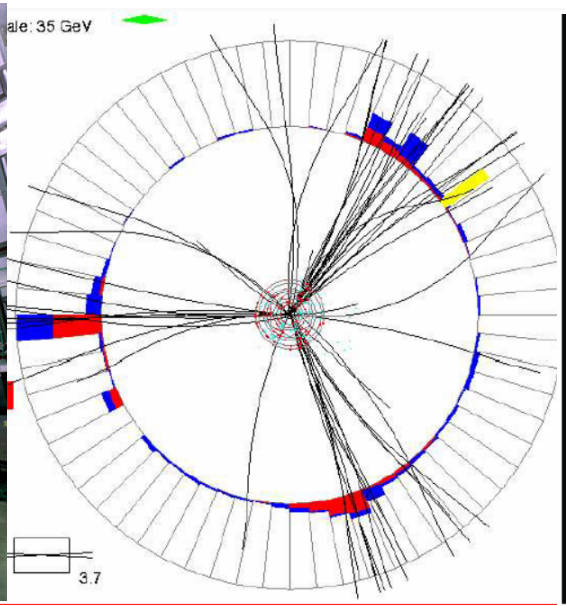
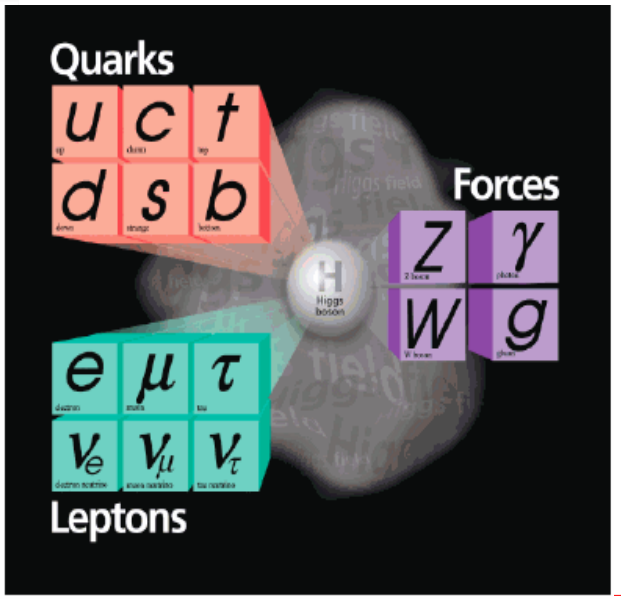
Search for SUSY Higgs bosons at Dzero

Boris Tuchming – Irfu/Spp CEA Saclay

Outline :

- Introduction
- bbb
- ττ



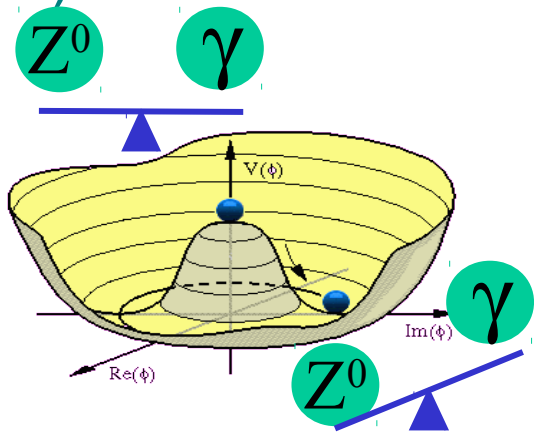


SUSY Higgs

In MSSM 2 Higgs doublets of complex fields (type II)

EW breaking: 2 x 2 x 2 - 3 = 5

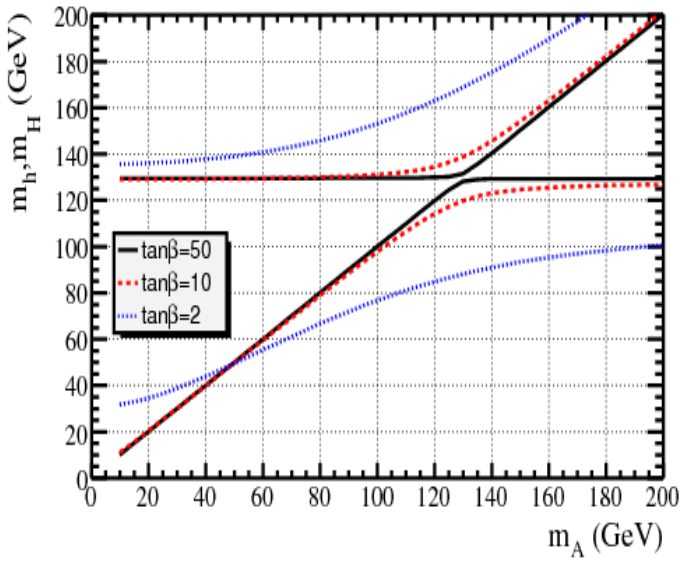
M_Z M_{W^+} M_{W^-}



- 5 Higgs bosons :
  - 3 neutral (h,H,A)
  - 2 charged (H+,H-)

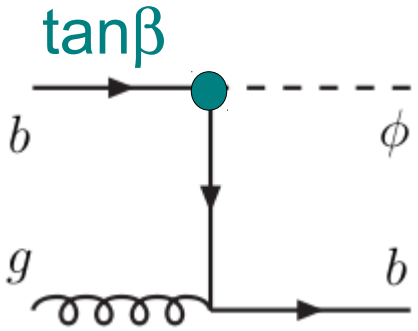
- 2 parameters at tree level : (M_A, tan(β))
  - tanβ= v2/v1 ratio of vev's

- At large tanβ :
  - 2 neutral are ~degenerated in mass
  - Region of particular interest
    tanβ ~ M_t/M_b ~30



SUSY Higgs search at large tan β

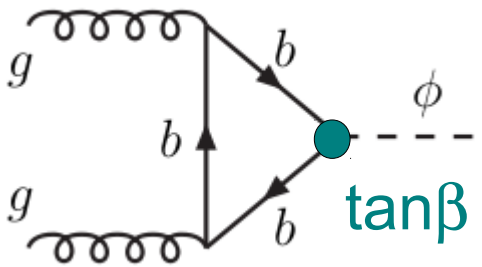
- At large tanβ :
  - 2 neutral are ~degenerated in mass
  - with bbϕ coupling ~tanβ
  - Decays $\phi \rightarrow bb$ (90%), $\phi \rightarrow \tau\tau$ (10%)
- cross-section enhanced by ~ 2 x $\tan^2\beta$ (at leading order) relative to SM. Typically 2000 !!



Search channels at Tevatron

$b\bar{b}b(\bar{b})$

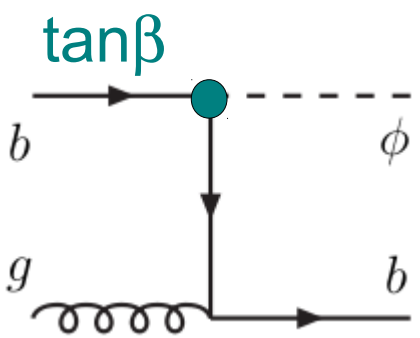
$b\tau^+\tau^-(\bar{b})$



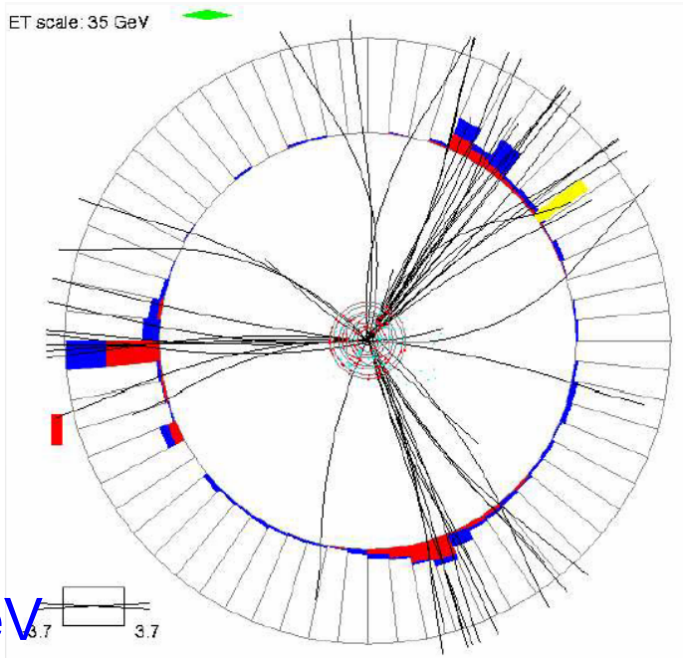
Search channels at Tevatron :

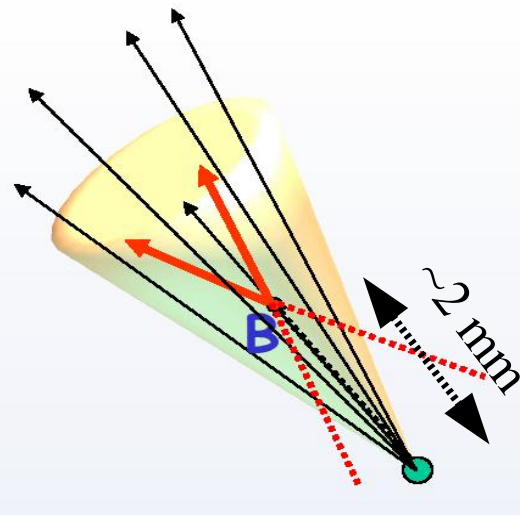
$\tau^+\tau^-$

bbb at large tan β



$\phi \rightarrow bb$





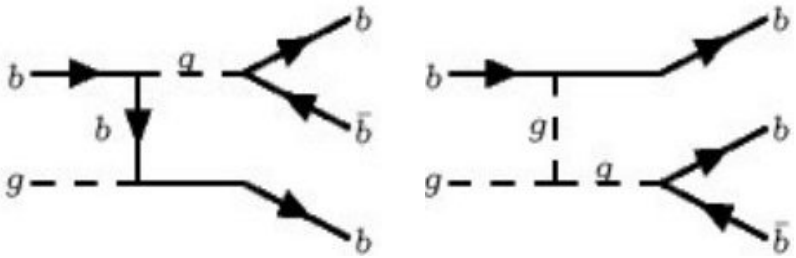
- Multijet signature:
  - ≥3 jets pT>20, 25 GeV
  - 3 b-tags
  - di-jet M_{bb} mass peak
  - multi-jet triggers

Historic:

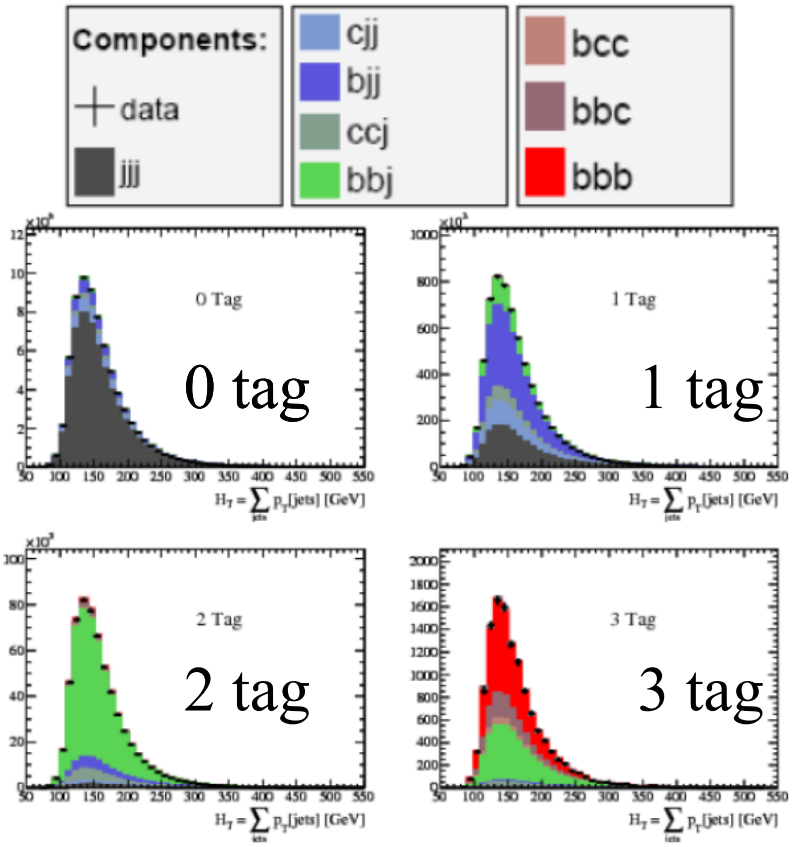
- PRL 95, 151801 (2005) : 260 fb-1
- Large involvement of Saclay group: 2003-2008.
  - PRL 95, 151801 (2005) 1fb-1
  - Infrastructure and code still in use.
- PLB 698, 97 (2011) 5.2fb-1

Challenge: model the multi-jet (HF) background

- Large multi-jet background, hard to understand and model with data.
- backgrounds not only bbj, bbbb BUT ALSO odd number of visible heavy flavor (just like signal) bjj, bbc, bbb,....



- Main background for final selection is found to be bbb very similar to the signal final state.
- backgrounds are not predicted accurately by MC
  - compute DATA/MC correction
  - large systematics



DØ L~5.2 fb^{-1}

background analysis, obtained by fitting data to different tagging efficiency.

3 tag sample:

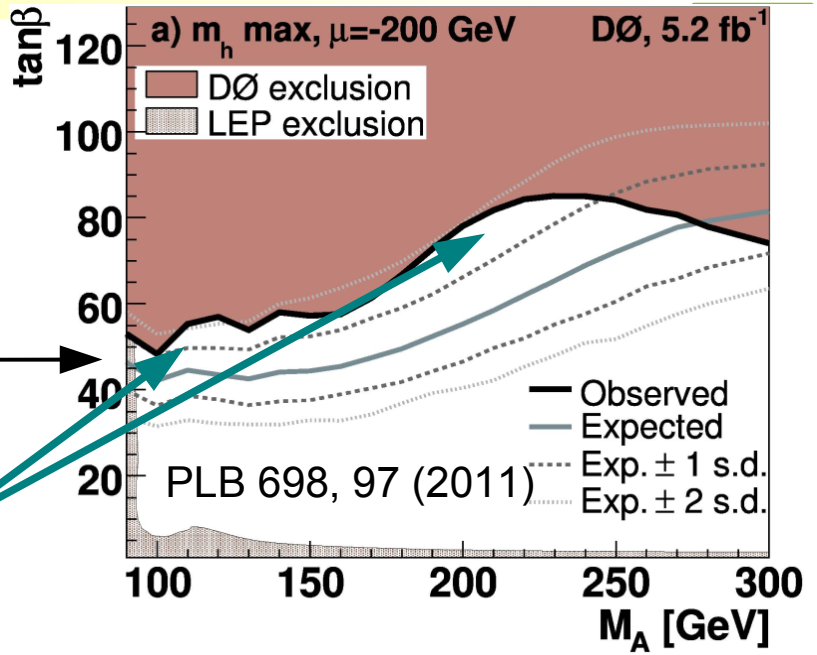
bbb	~47%
bbj	~32%
bbc+bcc	~17%
ccj	~2%
jjx	~2%

Searching for a bbb signal

Strategy

- Build likelihood based on kinematics
- Look for excess in di-jet mass spectrum

sensitivity
around tan β ~45

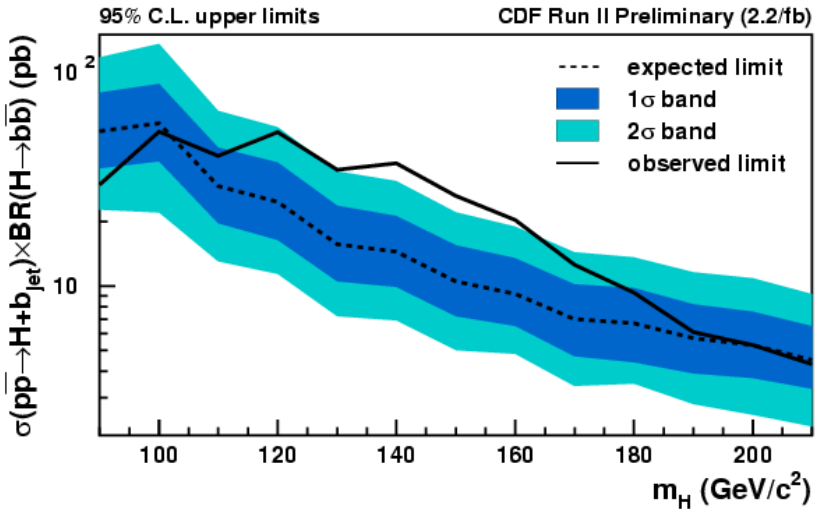


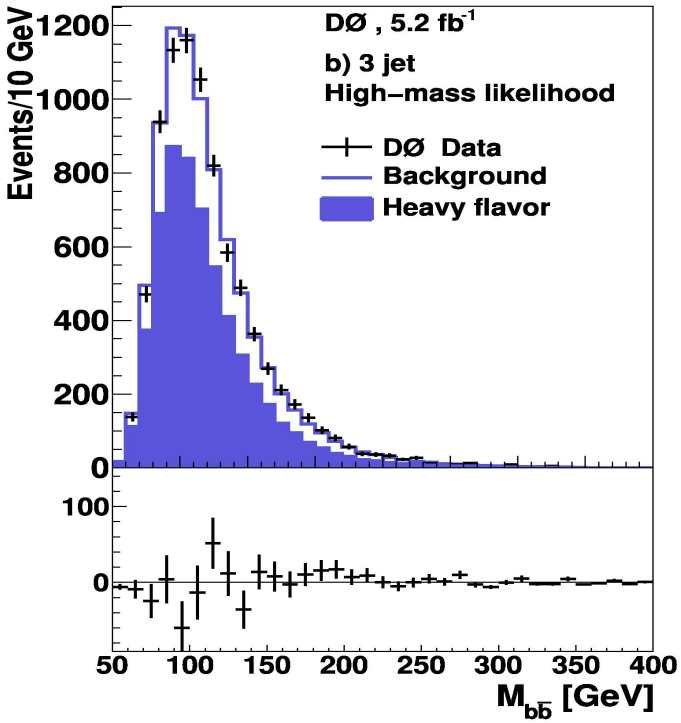
« excess » gave rise to many x-checks

- ~ 2sigma at 120 and 210 GeV

CDF also has excesses @140 GeV

- But not plan for combination yet !!

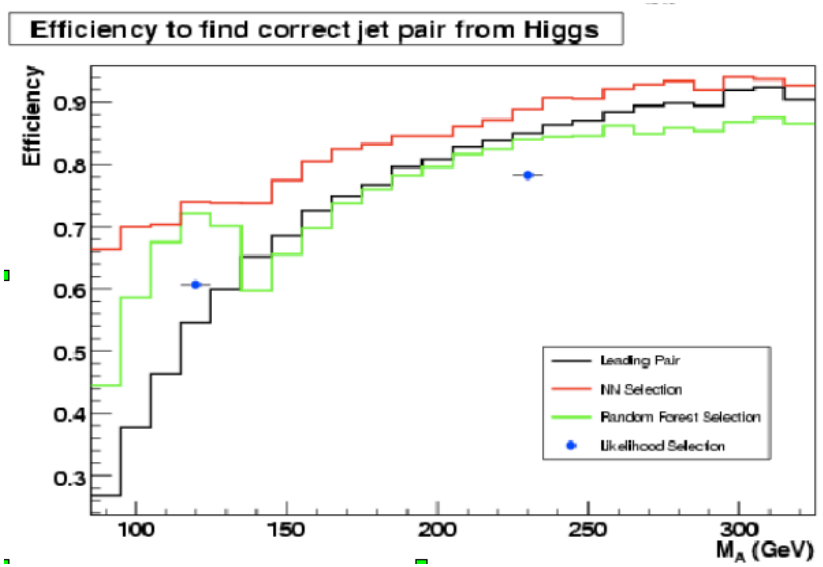




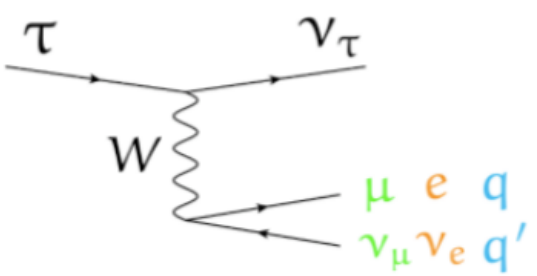
Prospects bbb

- For summer 2011
  - includes more data 5.2 → 7.2 fb-1
  - MVA tagger = +20% signal
  - use NN to pick best jet pairing and enhance mass peak

- Future:
  - would benefit from improved di-jet resolution
  - But systematics are a dominant factor.



tau channel challenges



Relatively soft decay products:

- Energy shared among multiple decay products
- neutrino(s) taking away energy

Large branching ratio to hadrons

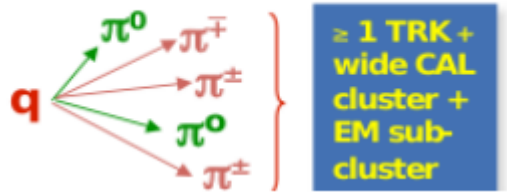
- Need to reconstruct hadronic final states
- Large jet background
- Dedicated energy scale
- Three dedicated NN for τ_h identification
  - typically ε~65% f~2.5%

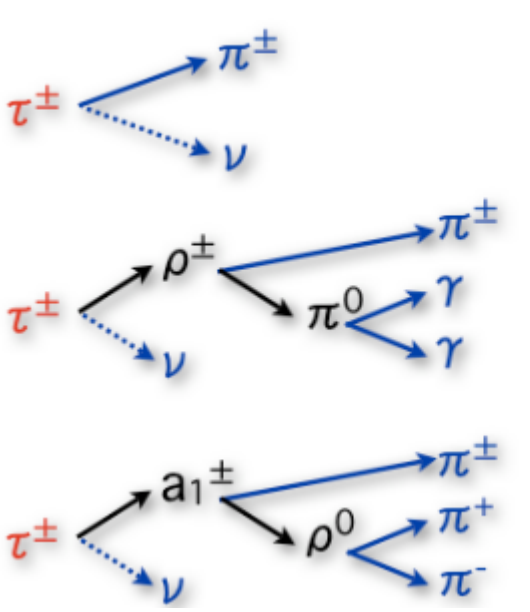
$\tau^+\tau^-$ signatures

- at least one leptonic tau
- « high » pt isolated lepton
- The other is hadronic or leptonic

W+jets, QCD instrumental background

Jet-Background



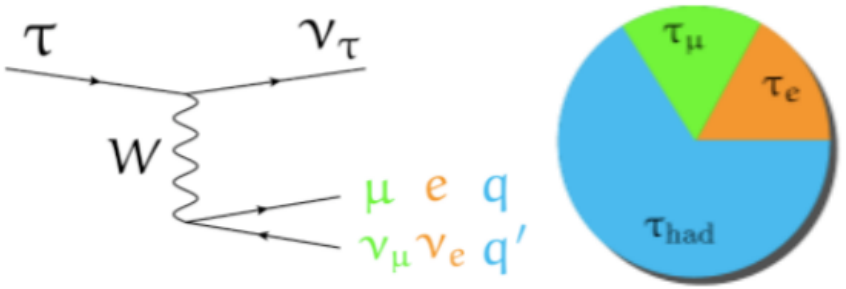


type 1: trk + cal (no EM cluster)

type 2: trk + cal (with EM cluster)

type 3: > 1 trks + cal

tau channel challenges



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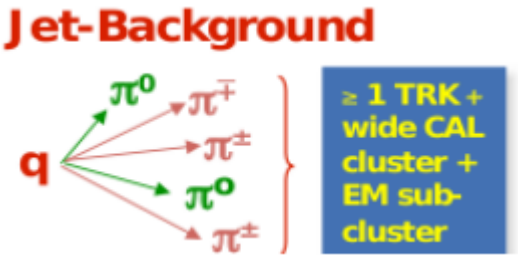
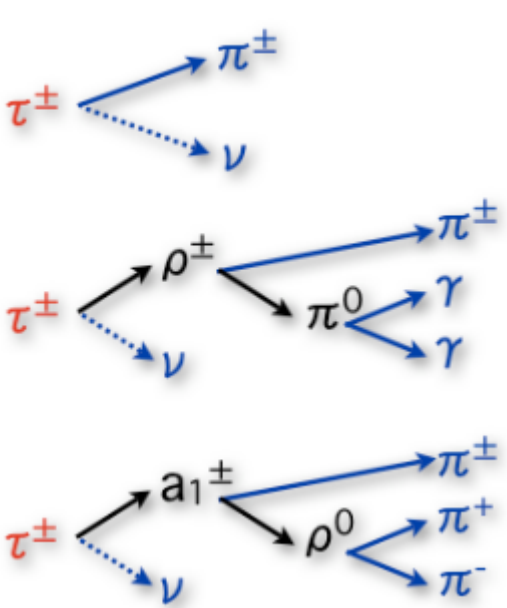


τ+τ- signatures

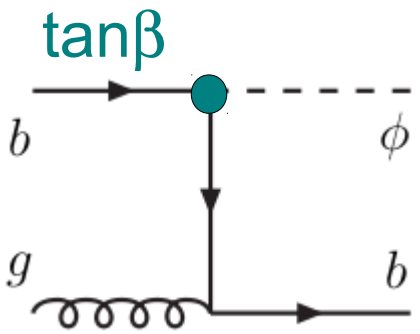
- at least one leptonic tau
  - « high » pt isolated lepton
- The other is hadronic or leptonic

W+jets, QCD instrumental background

- control samples from: same-sign/opposit sign, Isolated/non-isolated, high NNτ/low NNτ, high M_T

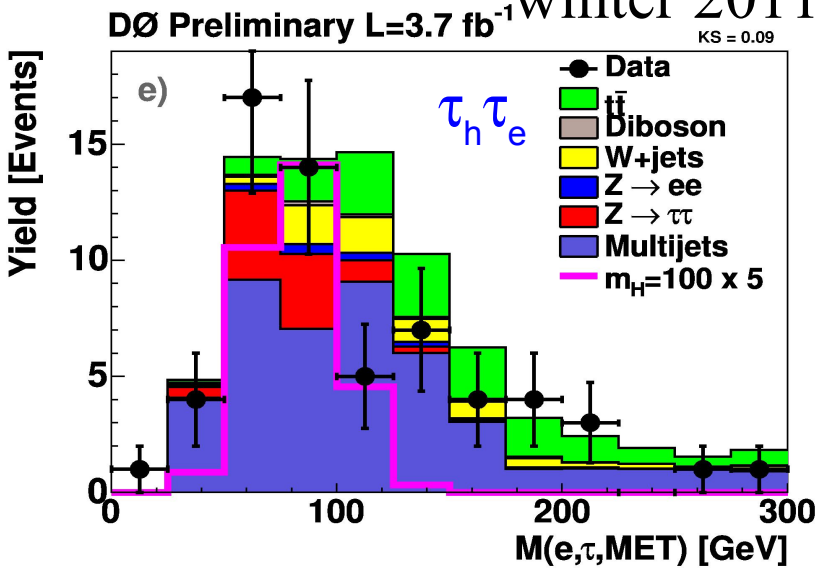


ττ b channels



$\phi \rightarrow \tau^+\tau^-$

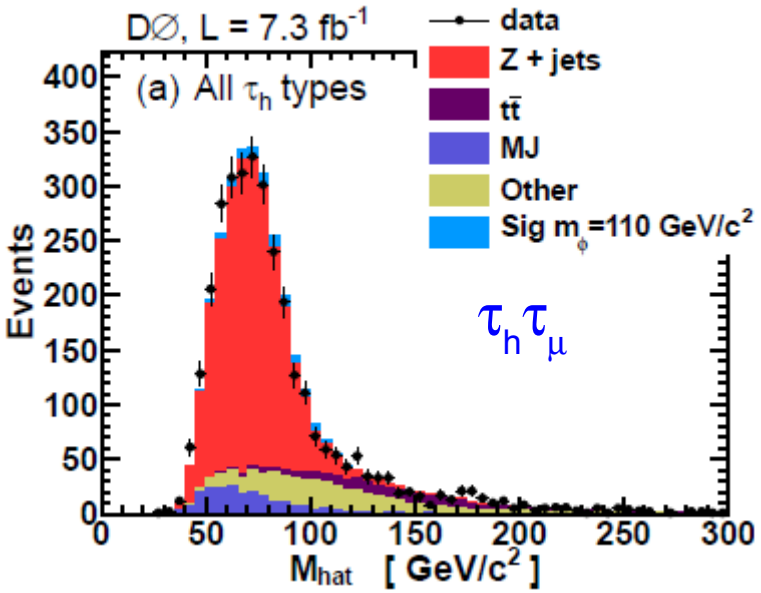
winter 2011 result



Look fo two taus + 1 b-jet

- 2 channels $\tau_h\tau_\mu$, $\tau_h\tau_e$
- Employ multivariate discriminant:
- Main variables : $m_{\rm vis} = \sqrt{(p^{\tau_1} + p^{\tau_2} + \not{E}_{\rm T})^2}$

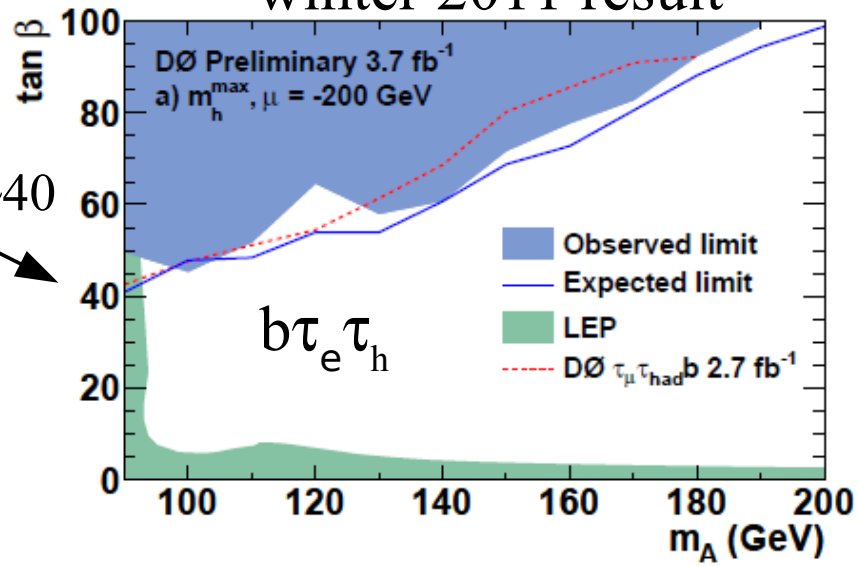
summer 2011



Historic:
Phys. Rev. Lett. 102, 051804 (2009) 0.33 fb^{-1}
Phys. Rev. Lett. 104, 151801 (2010), 2.7 fb^{-1}
Saclay activities:
- b τ_μ τ_h analysis preliminary 5.2 fb^{-1},
- colab review for summer publication 7.2 fb^{-1}

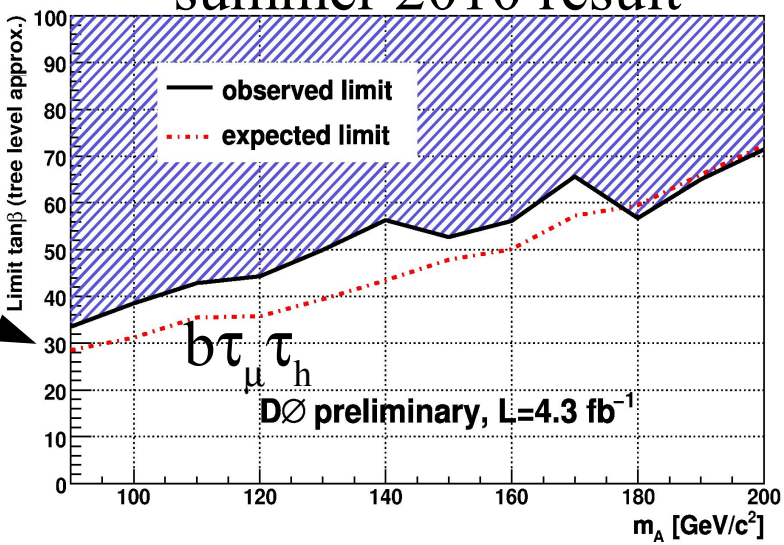
ττ b channels results

winter 2011 result



tanβ ~40

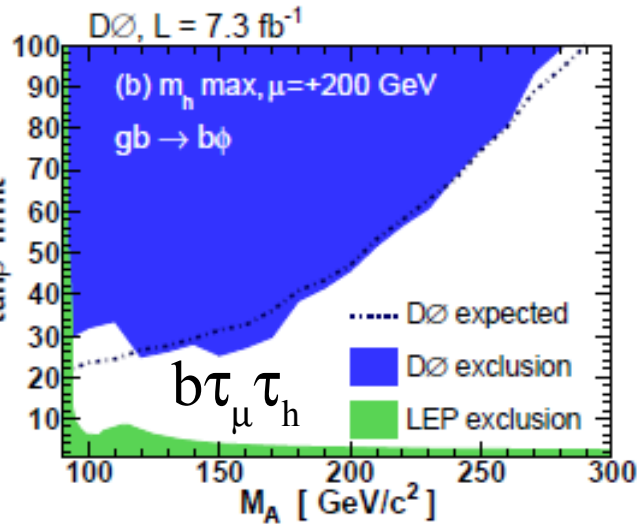
summer 2010 result



tanβ ~30

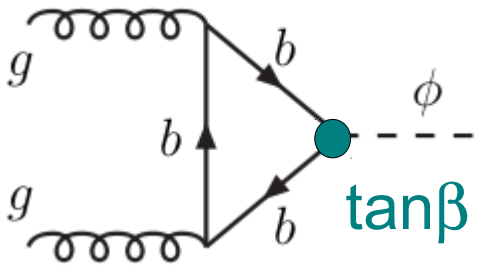
- $\tau_\mu\tau_h$ 7.3 fb^{-1} analysis in collaboration review.
  - Much bigger improvments than just adding more data
    - specific discriminants against different backgrounds
    - inclusive trigger
    - Dominant Z+b background constrained with $Z \rightarrow \mu\mu$ data

summer 2011 result



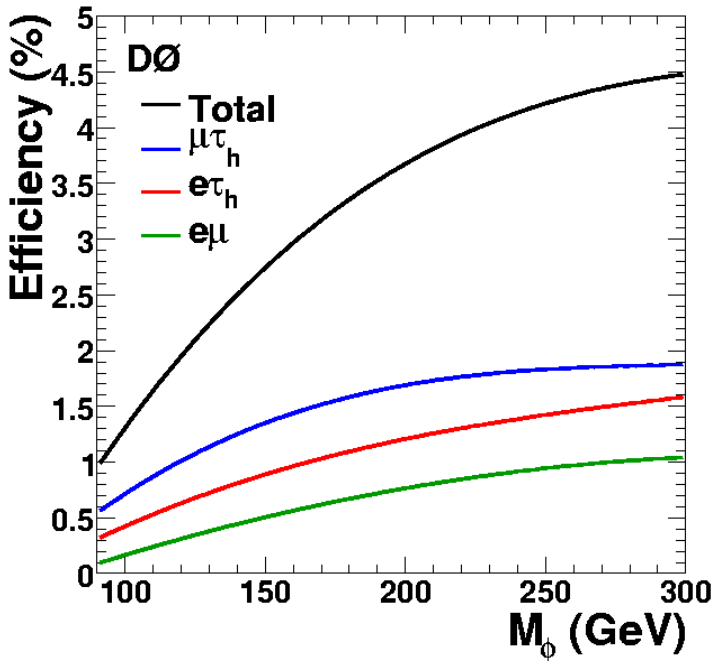
tan β ~20-25

ττ channels

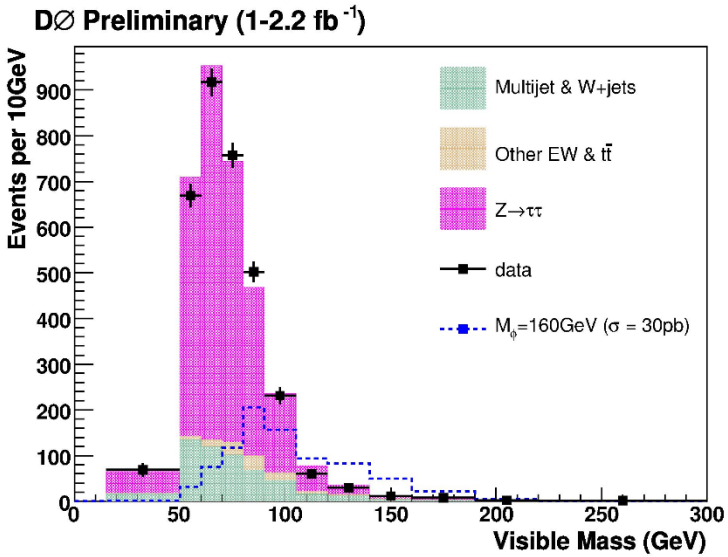


$\phi \rightarrow \tau^+\tau^-$

- Look for τ τ
  - 3 analysis $\tau_e\tau_h$, $\tau_\mu\tau_h$, $\tau_e\tau_\mu$



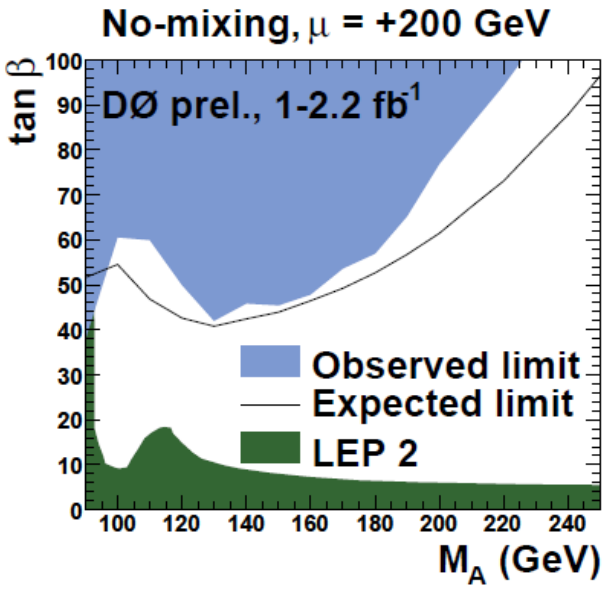
Historic:
Phys. Rev. Lett. 97, 121802 (2006) 0.35 fb^{-1}
Phys. Rev. Lett. 101, 071804 (2008) 1 fb^{-1}
Preliminary : results 1.2-2 fb^{-1} since summer 08



ττ results

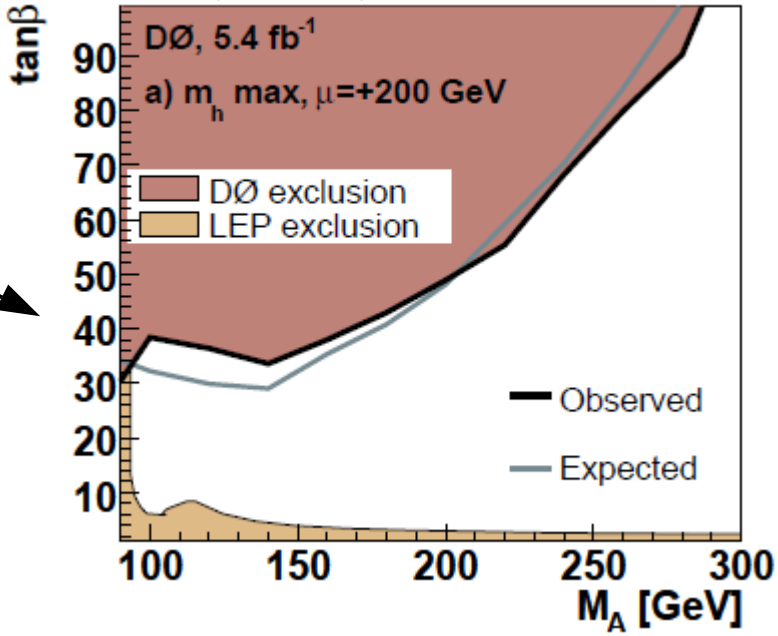
$\tau_e\tau_\mu+\tau_h\tau_\mu+\tau_e\tau_\mu$ summer 2008 result

tanβ ~40

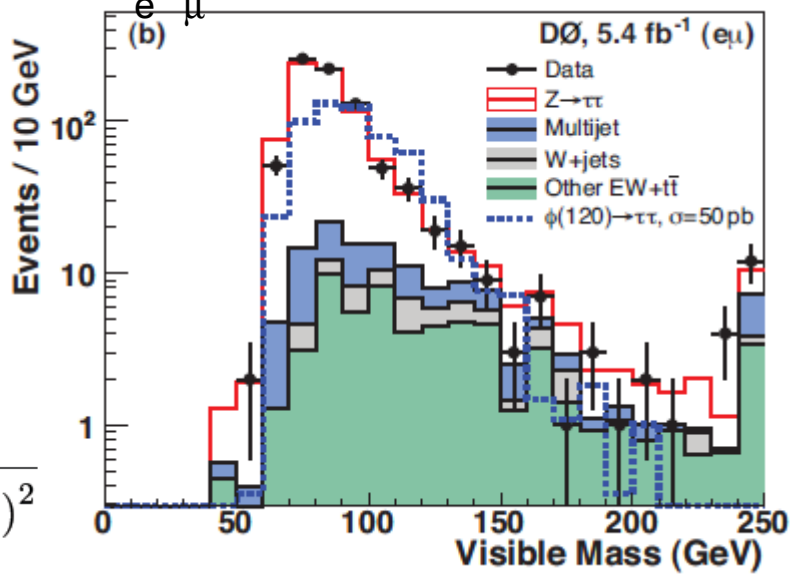


$\tau_h\tau_\mu+\tau_e\tau_\mu$ summer 2011

tanβ ~30



$\tau_e\tau_\mu$ summer 2011



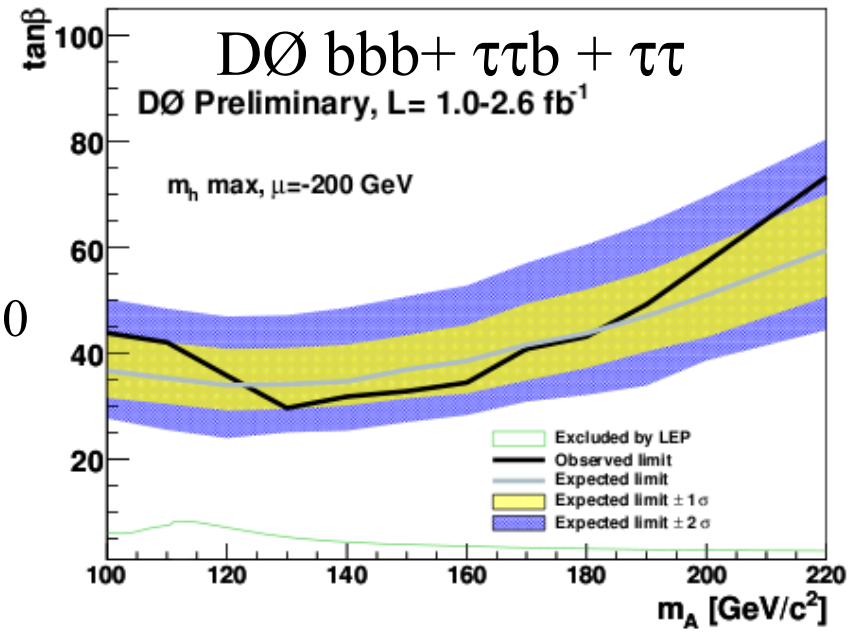
Paper under collaboration review for summer : $\tau_e\tau_\mu+\tau_h\tau_\mu$ 5.4 fb^{-1}

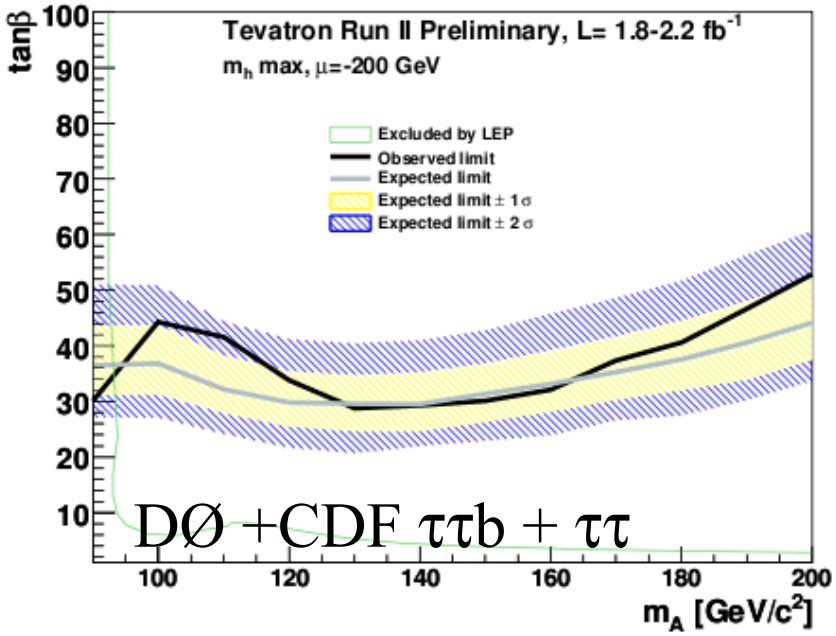
Saclay in charge of $\tau_e\tau_\mu$

$$m_{\text{vis}} = \sqrt{\left(p^{\tau_1} + p^{\tau_2} + \not{E}_{\text{T}}\right)^2}$$

MSSM Constraints market

tanβ ~30





Previous combinations

- sensitive to tanb~30

superseded by new D0 analysis this summer

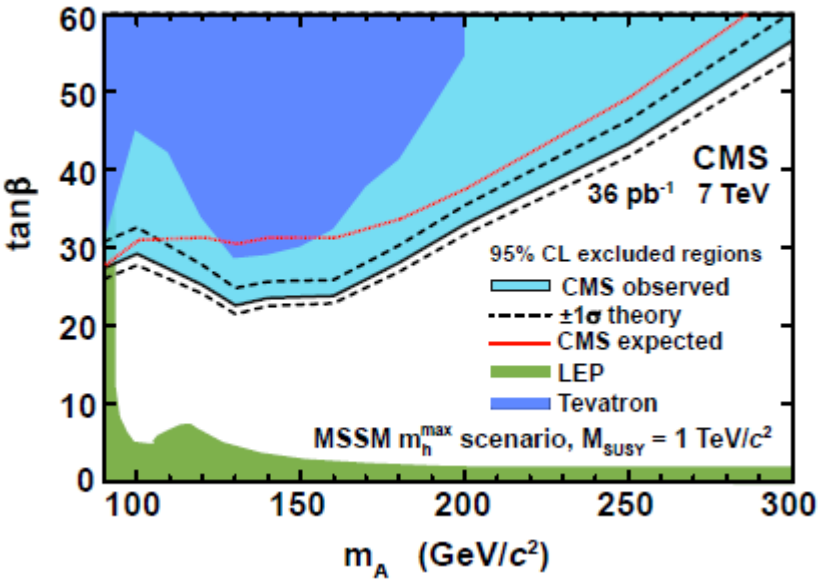
- $b\tau_\mu\tau_h$ (tanβ~20-25)
- $\tau_e\tau_\mu+\tau_h\tau_\mu$ (tanβ~30)

Would be nice to combine these two channels

- But showstopper : need to master overlap, (in particular b-tag jets) but different cafe versions

Conclusion

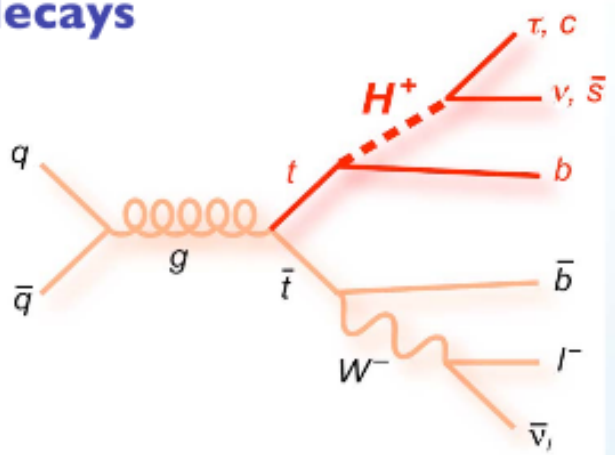
- lot of results from D0 for MSSM Higgs and large contributions from D0 France
  - bbb sensitivity tanβ~45 for 5.2 fb^{-1}
  - ττb sensitivity tanβ~20-25 for 7.3 fb^{-1}
  - ττ sensitivity tanβ~30 for 5.4 fb^{-1}
  - If we combine everything we could reach ~20
- No updates from CDF for a while !
- LHC has a higher cross-sections and much favorable S/B for ττ
  - Already reached tanβ~25 with 36 pb^{-1}
  - We can expect tanβ~15 this summer
- D0 management is considering that after this summer it won't be worthwhile to update tau channels but still worthwhile to do bbb

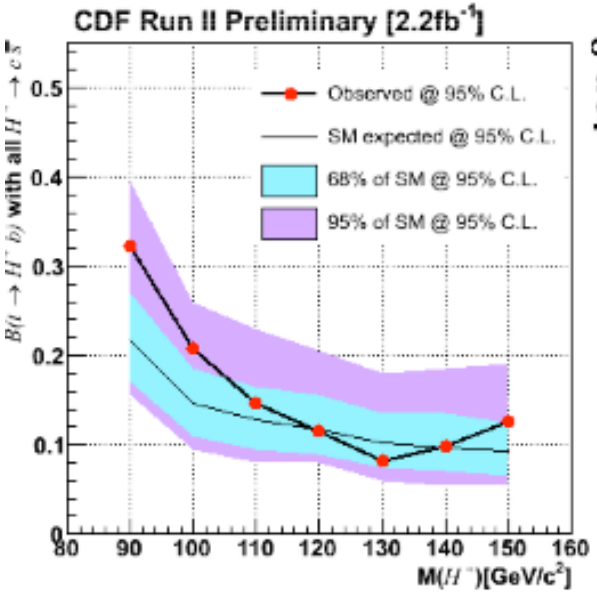


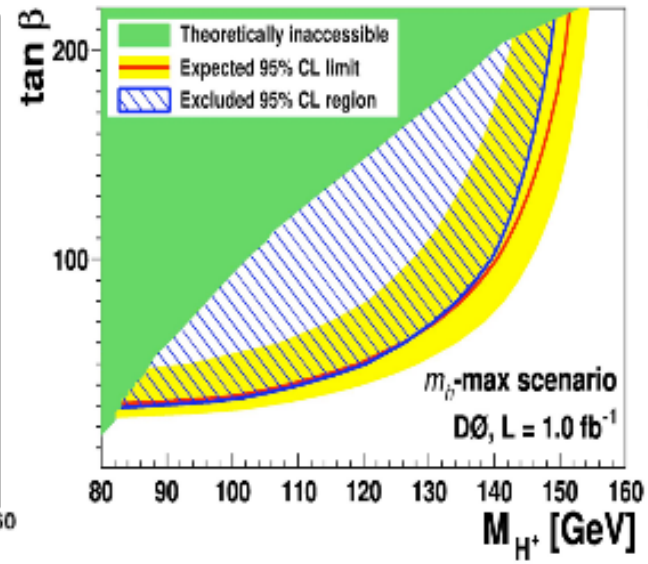
Support slides

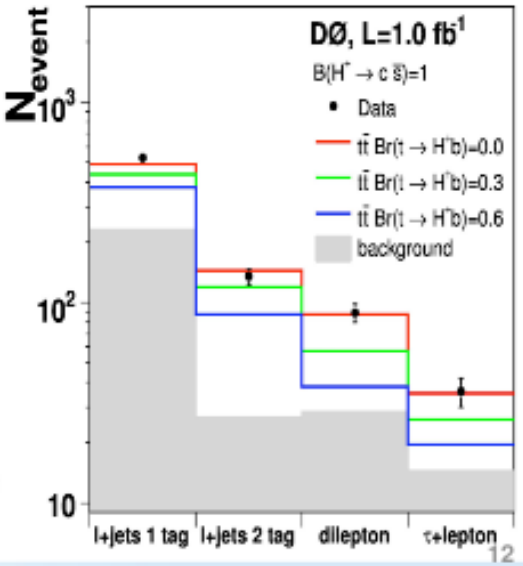
Charged Higgs

- If $m_{H^\pm} < m_{top}$: search in top pair sample for decay to $H^\pm$
- Consider two search modes based on $H^\pm$ decays
  - Tauonic model: $H^\pm \to \tau\nu$ (high tanβ)
  - Leptophobic model: $H^\pm \to c\bar{s}$ (low tanβ)
- Search dilepton, ℓ+jets, $\ell+\tau$ top channels
- Select high-p_T leptons, $\not\!\!E_T$, and b-tag
- 95% CL limits on BR(t→H⁺b)
  - DØ 1.0 fb^{-1}: PLB 682, 278 (2009)
  - CDF 2.2 fb^{-1}: PRL 103, 101803 (2009)









MSSM Benchmark

- 2 parameters, (M_A, tan(β)) to describe SUSY Higgs sector at Leading Order
- hbb vertex receive large corrections from sbottom-gluino and stop-higgsino loop

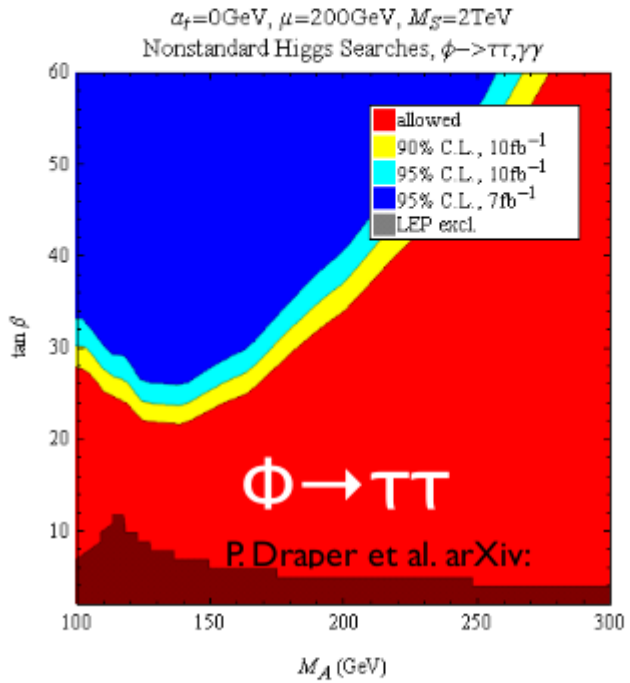
- Five additional parameters due to radiative correction
  - M_{SUSY} (parameterizes squark, gaugino masses)
  - X_t (related to the trilinear coupling $A_t \rightarrow$ stop mixing)
  - M_2 (gaugino mass term)
  - μ (Higgs mass parameter)
  - M_{gluino} (comes in via loops)

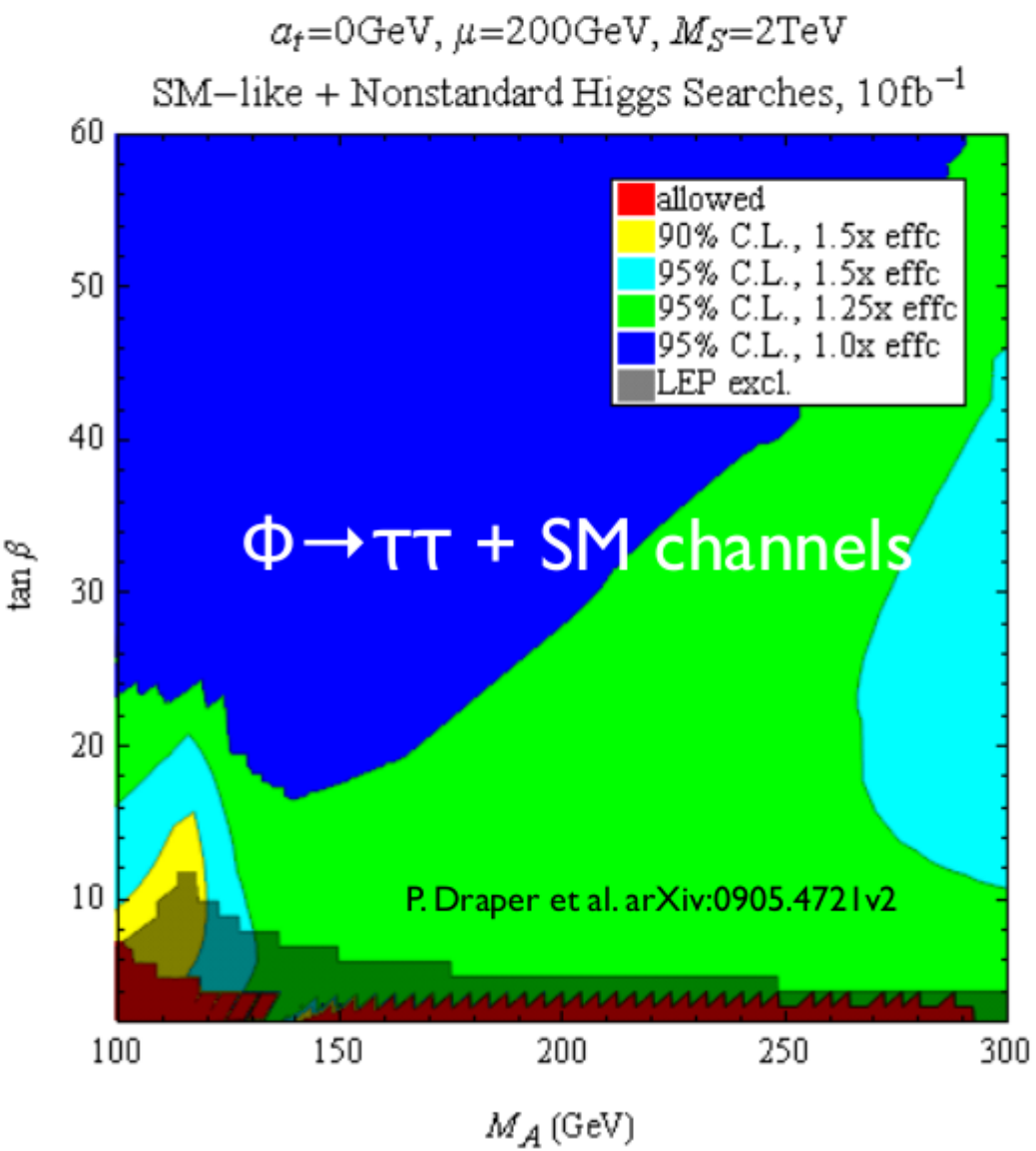
- Two common benchmarks
  - Max-mixing - **Higgs boson mass m_h close to max possible value for a given tanβ**
  - No-mixing - **vanishing mixing in stop sector → small mass for h**

	m_h-max	no-mixing
M_{SUSY}	1 TeV	2 TeV
X_t	2 TeV	0
M_2	200 GeV	200 GeV
μ	±200 GeV	±200 GeV
m_g	800 GeV	1600 GeV

MSSM prospects

Including SM searches

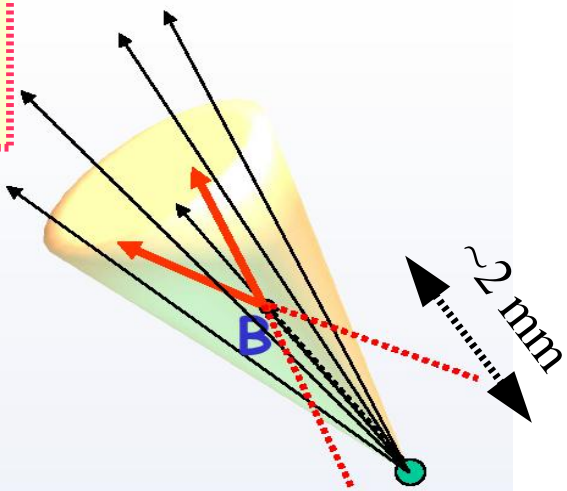


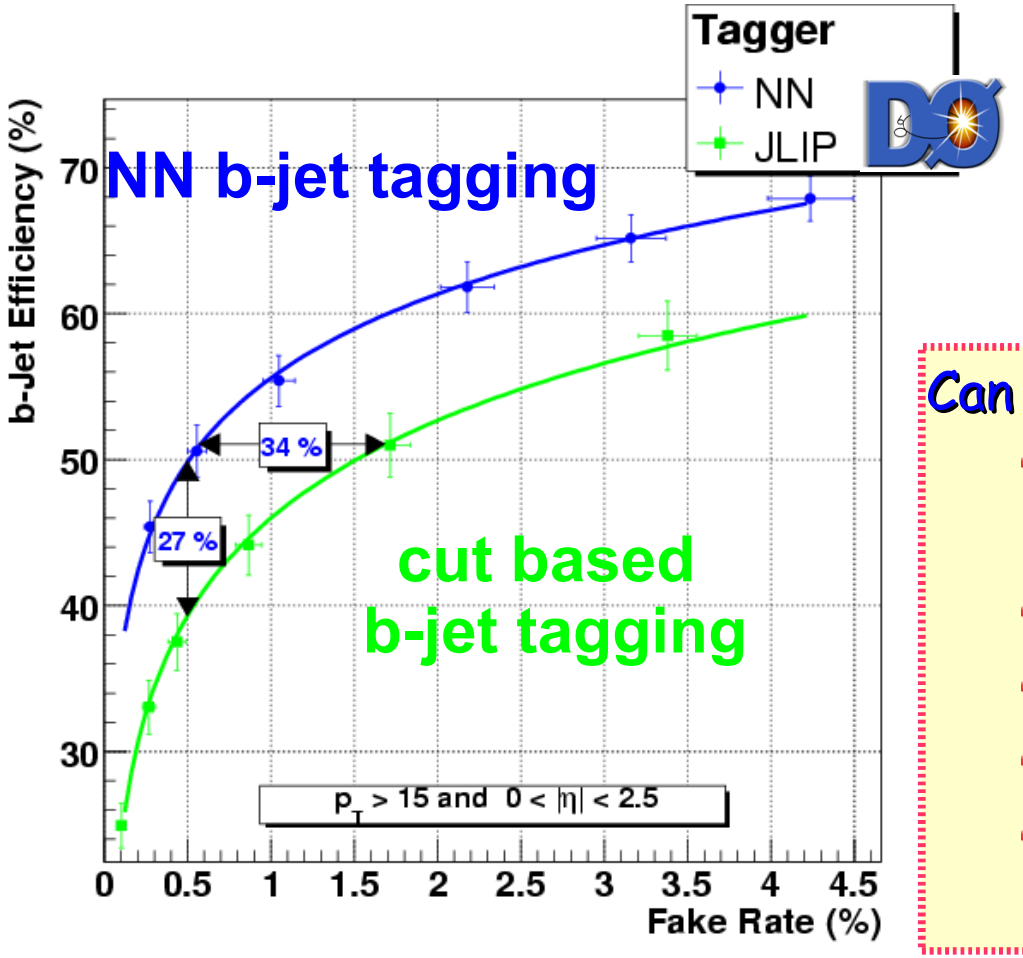


b jets tagging: essential for search at low mass

B-hadrons are long lived particles: $c\tau \sim 0.5$ mm.

B-hadrons can decay semi-leptonically: b->μνc





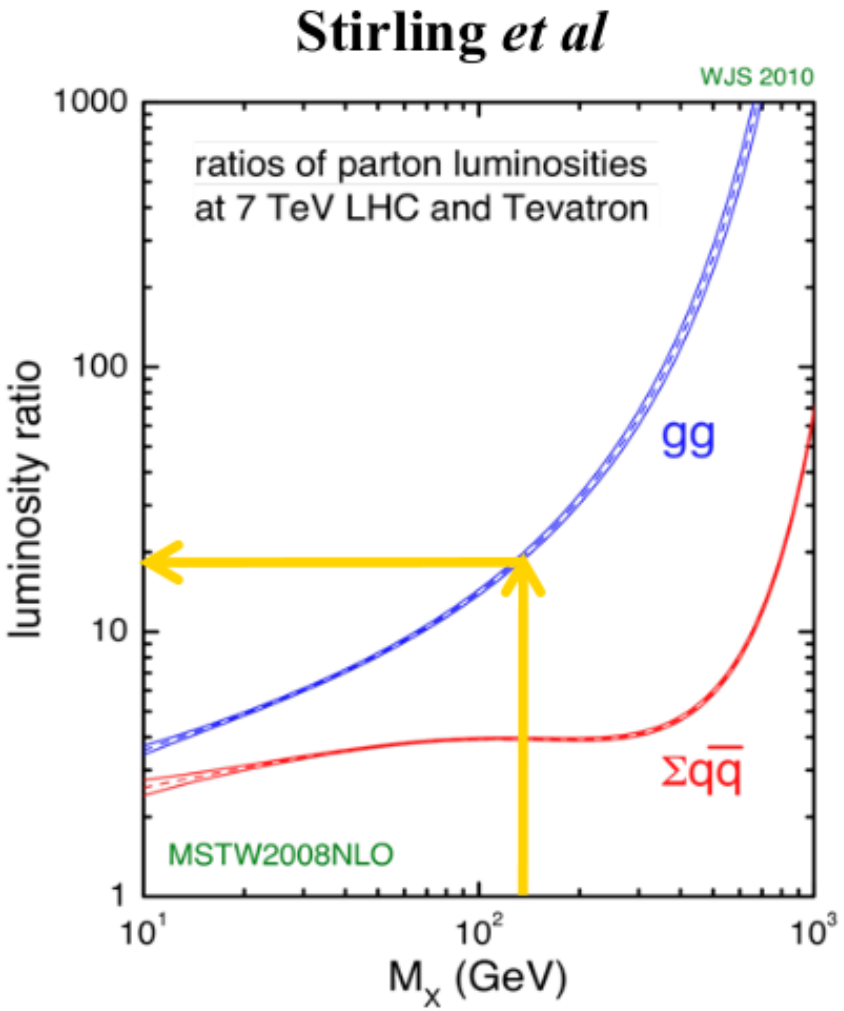
Can make use of:

- High impact parameter of tracks
  ==> light quark Jet Probability
- Secondary vertex reconstruction (SVX)
- Lepton tag
- b-jet kinematics (large B-hadron mass)
- Combination of above with multivariate techniques (eg Neural Network)

Eg: CDF 2rd vtx tag ε=50% for 2% mis-tag at η<1

Eg: D0 NN (2006) ε=60% for 1.5% mis-tag Pt=50 GeV (loose tag)

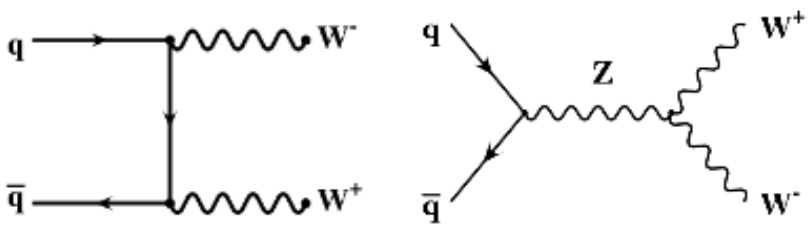
LHC & Tevatron Compared (I)



For M_X > 140 GeV

gg → H cross section at 7 TeV is >15 times that at 2 TeV

Irreducible backgrounds (WW,ZZ) originate from $q\bar{q}$ process which rises relative slowly (pp vs $p\bar{p}$)



⇒ Larger signal, better S/N

3