# Beyond SM Higgs Boson Search at DØ

**July 29, 2010**
**Higgs Hunting Workshop**
**Orsay, France**

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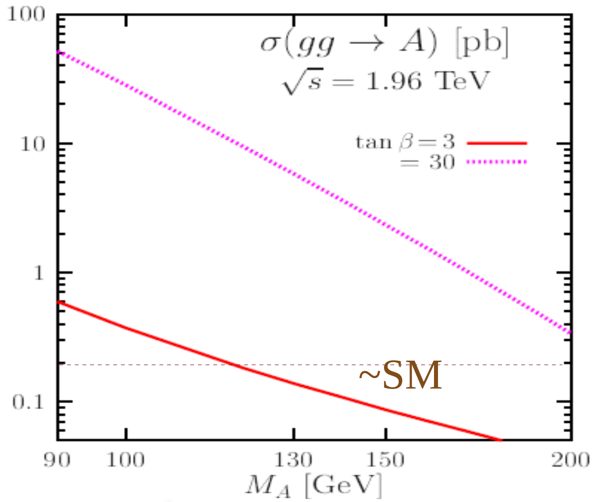
***(for the DØ Collaboration)***
**The University of Manchester**

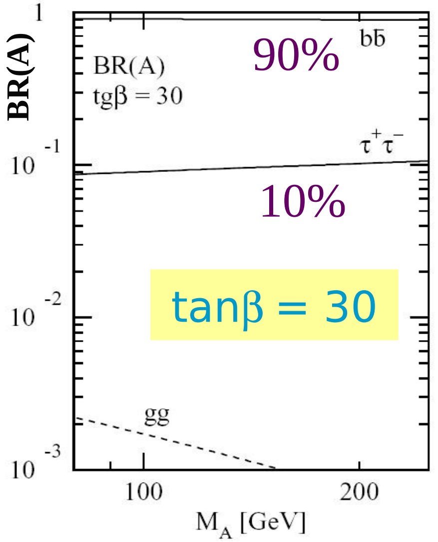
# Outline



- **Neutral MSSM Higgs Search**
  - * 3 physical neutral Higgs bosons after EWSB
    - two neutral CP-even : h,H
    - one neutral CP-odd: A

    (h/H/A are denoted as $\phi$)
  - * tanβ: ratio of two v.e.v
  - * Production cross section is enhanced ~ $\tan\beta^2$
  - * Three search channels: $\phi\to\tau^+\tau^-$, $\phi b\to b\tau^+\tau$, $\phi b\to b\bar{b}b$



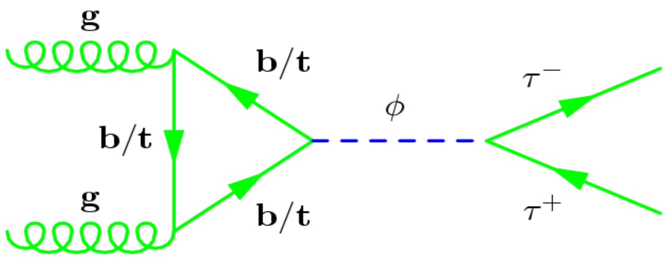



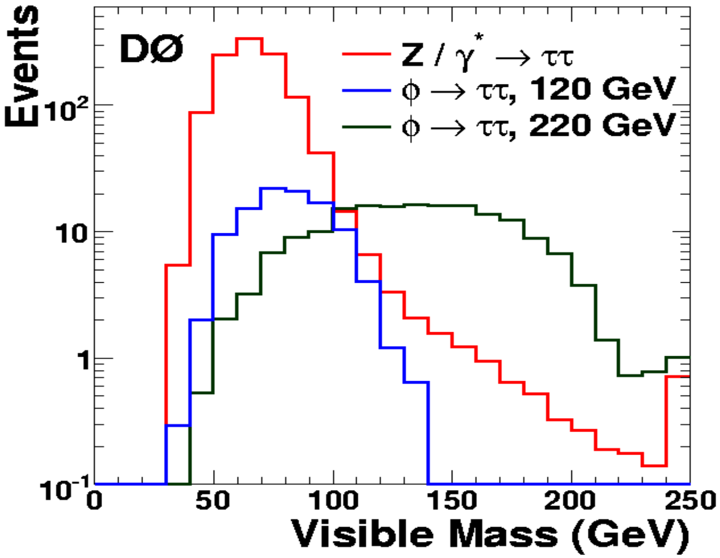

- **MSSM Combination**

**Other BSM Searches not covered in this talk:**
Fermiophobic Higgs Search, MSSM charged Higgs $H^\pm$

# Inclusive Search (1-2.2 $fb^{-1}$ )





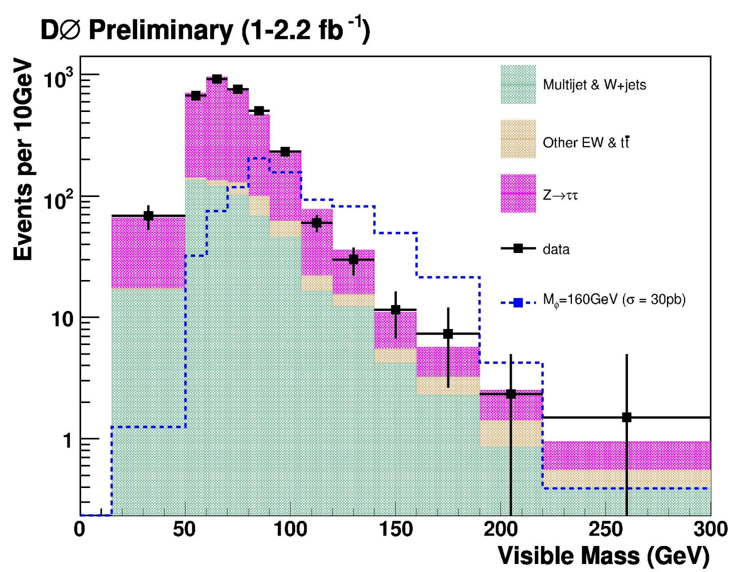




**Search in three decay channels:**

$\phi \rightarrow \tau^+\tau^- \rightarrow \mu\tau_h$ (2.2 $fb^{-1}$)

$e\tau_h$ (1.0 $fb^{-1}$)

$e\mu$ (1.0 $fb^{-1}$)

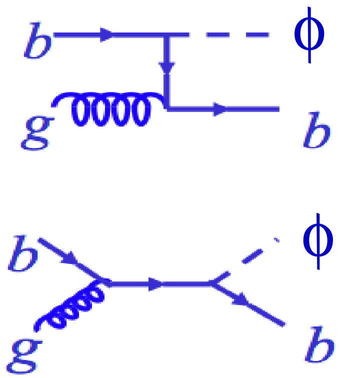



- **Distinguish signal from background mainly by mass.**
- **Presence of neutrinos, not possible to reconstruct full mass.**

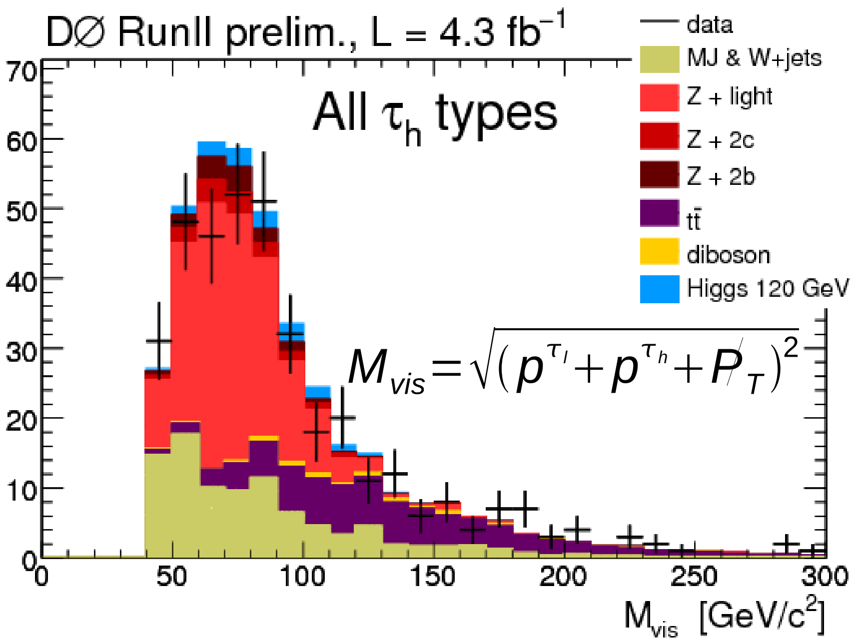
$$M_{vis} = \sqrt{(p^{\tau_l} + p^{\tau_h} + \not{P}_T)^2}$$

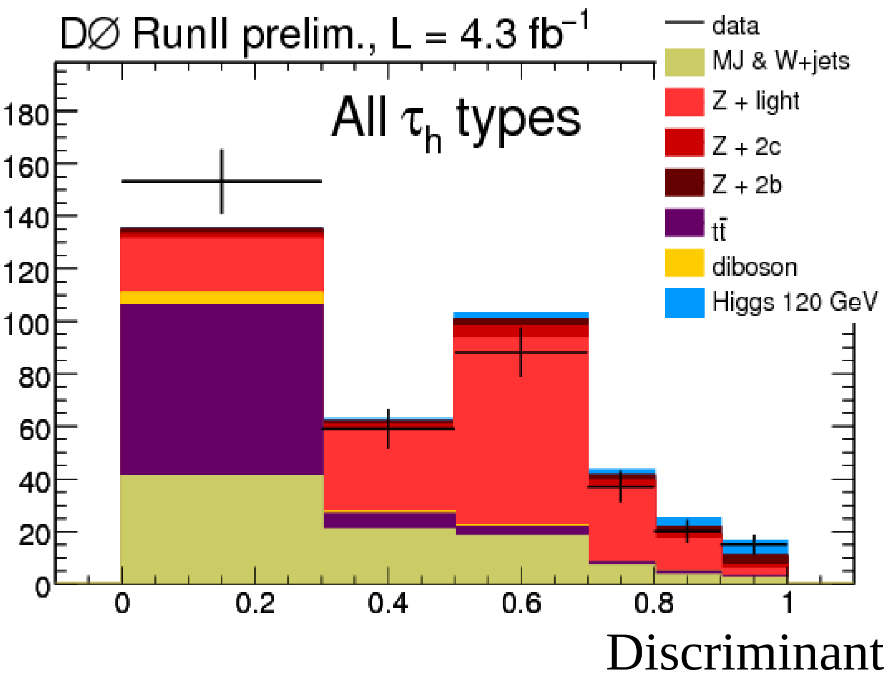
# $\phi b \rightarrow b\tau_\mu\tau_h$ (4.3 $fb^{-1}$ )






- **Select b-tagged jets to suppress large contribution from $Z\rightarrow\tau\tau$ source.**
- **Build final discriminant based on b-tagging and other kinematics.**



# $\phi b \rightarrow b\bar{b}b$ (2.6 fb$^{-1}$)

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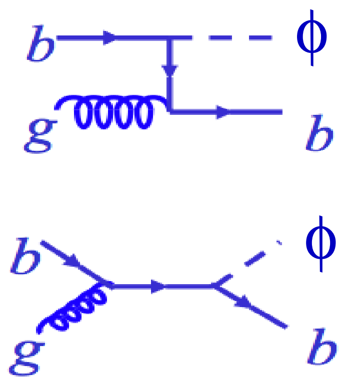
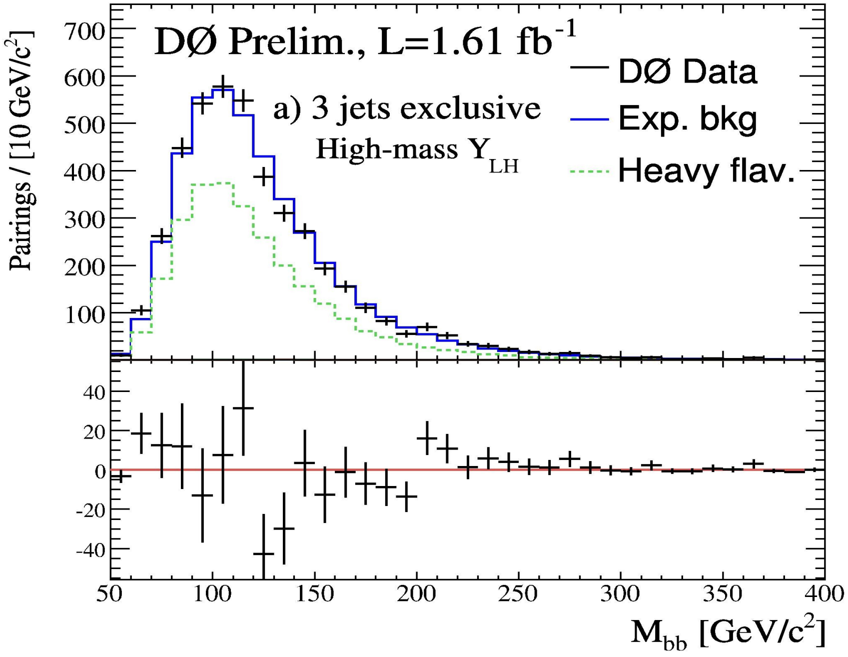
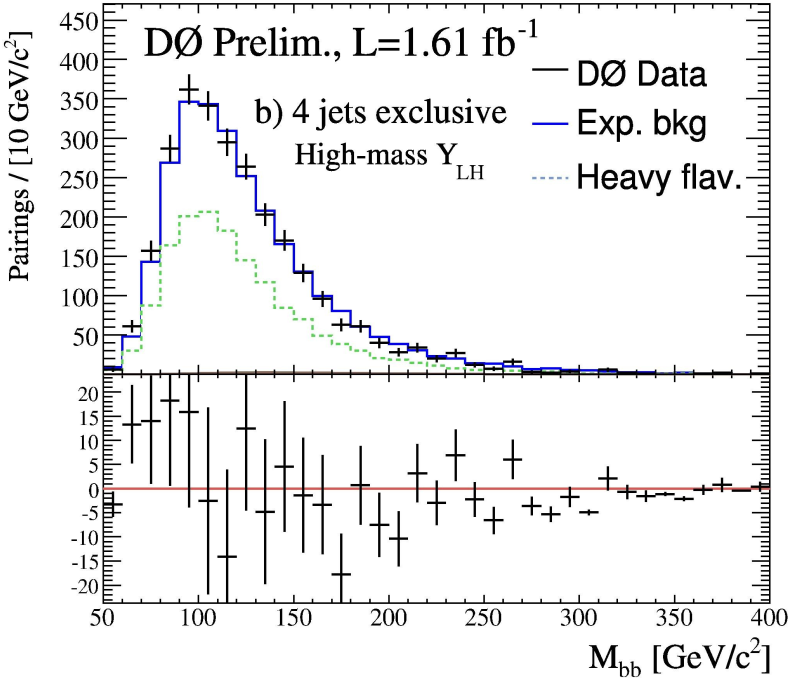



- **Large multi-jet background can be suppressed efficiently by btagging 3 jets.**
- **Split in exclusive 3 and 4-jet bins to improve sensitivity.**
- **There is no significant deviation observed.**

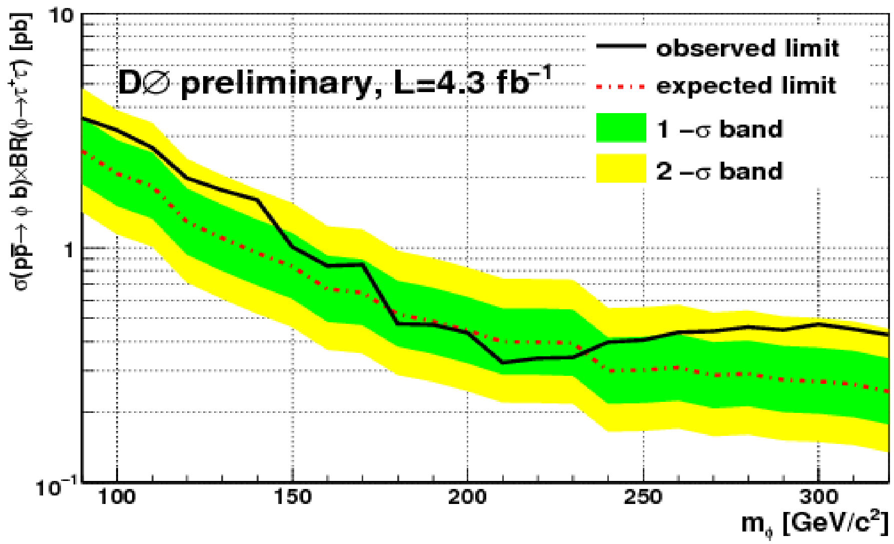


# Limits

**95% C.L. mass-dependent limits calculated for σ X BR**

## Example on bϕ→bττ




Translate into MSSM exclusions in tanβ-$M_A$ space:

* **$M_h^{max}$ (max-mixing):** Relatively conservative.

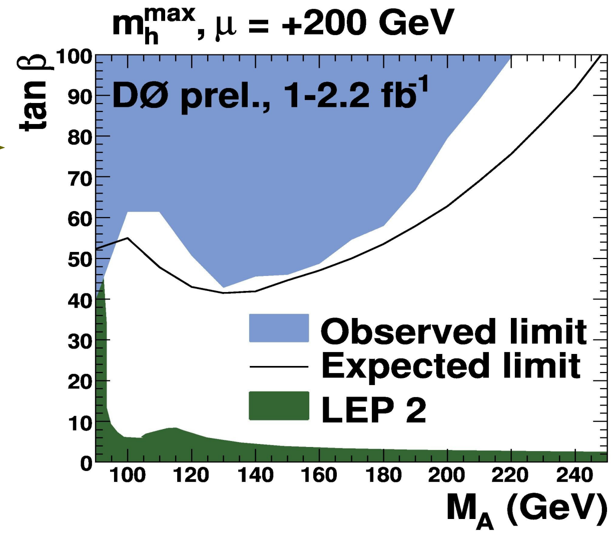
* **No-mixing:** Small $m_h$.

* Both with two given value of Higgs mass parameter μ.

# Limits (cont.)

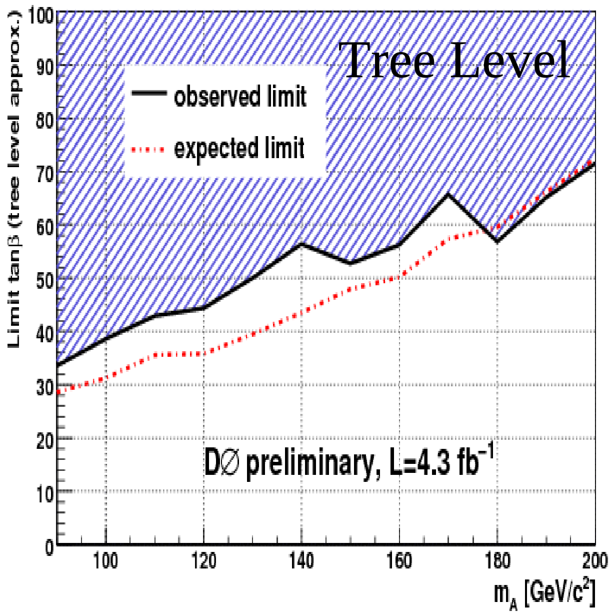
**$\phi \to \tau\tau$**

Larger statistics and not sensitive to μ. Provides a good probe at higher masses



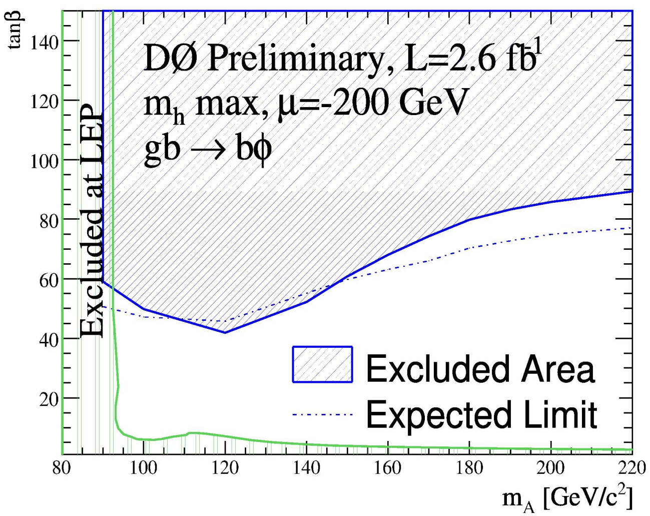

**$b\phi \to b\tau\tau$**

Most stringent to date results from a single channel for direct MSSM Higgs search and reaches tanβ~35 at 90 GeV.




**$b\phi \to bb\bar{b}$**

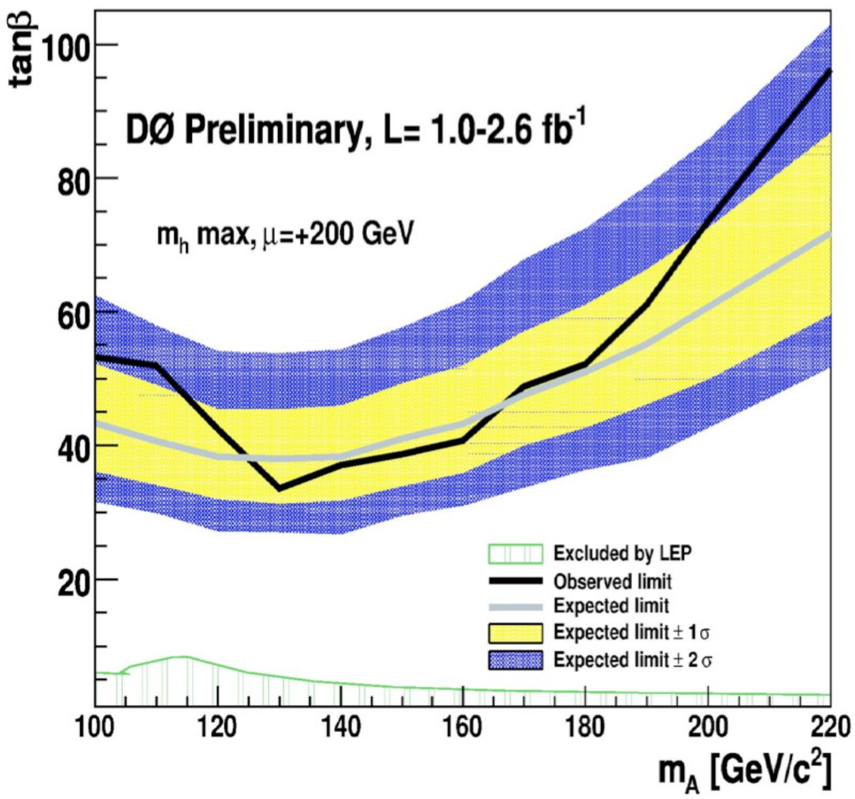
This channel gives strong limits with μ<0. Radiative corrections give large sensitivity to μ and its negative sign gives enhanced production.

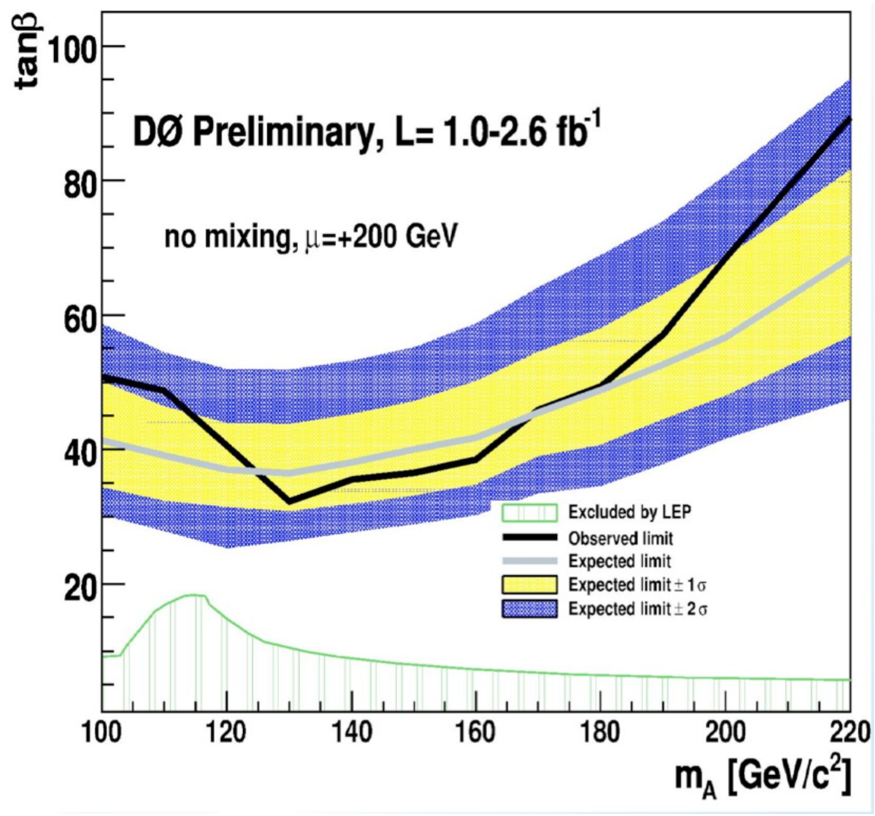


# DØ MSSM Combination



- Combine:
  $\phi\to\tau\tau$ (1.0-2.2 fb$^{-1}$), $\phi b\to b\tau\tau$ (1.2 fb$^{-1}$), and $\phi b\to bbb$ (2.6 fb$^{-1}$)
- Latest $\phi b\to b\tau\tau$ (4.3 fb$^{-1}$) is not included,
- Similar sensitivity as Tevatron combination on $\tau\tau$ searches.



# Conclusion and Outlook



- No signal observed in data over expected backgrounds.
- Upper limits set for σ × BR and subsequently translated into 95% CL exclusions in MSSM parameter space.
- MSSM projections show (with full 2011 dataset): if no Higgs boson observed, exclusions reach tanβ~ 20 for $M_A$ ~ 120-160 GeV
- More than 8 $fb^{-1}$ of data has been recorded by the DØ detector, and more is coming!

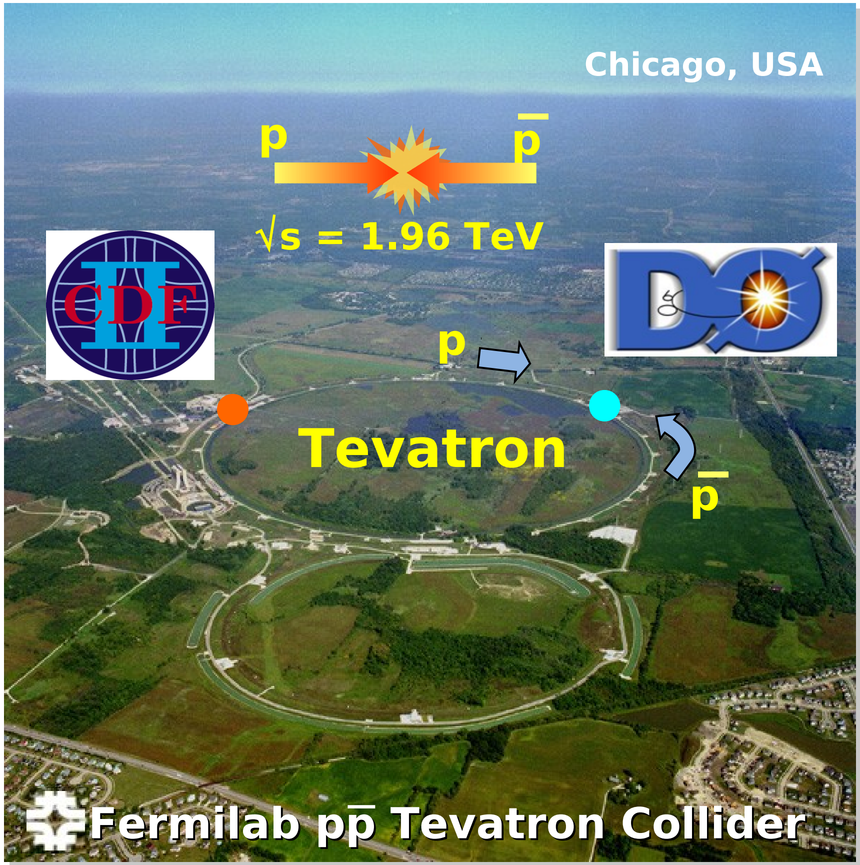
Very exciting time! Please keep an eye on the future updates.

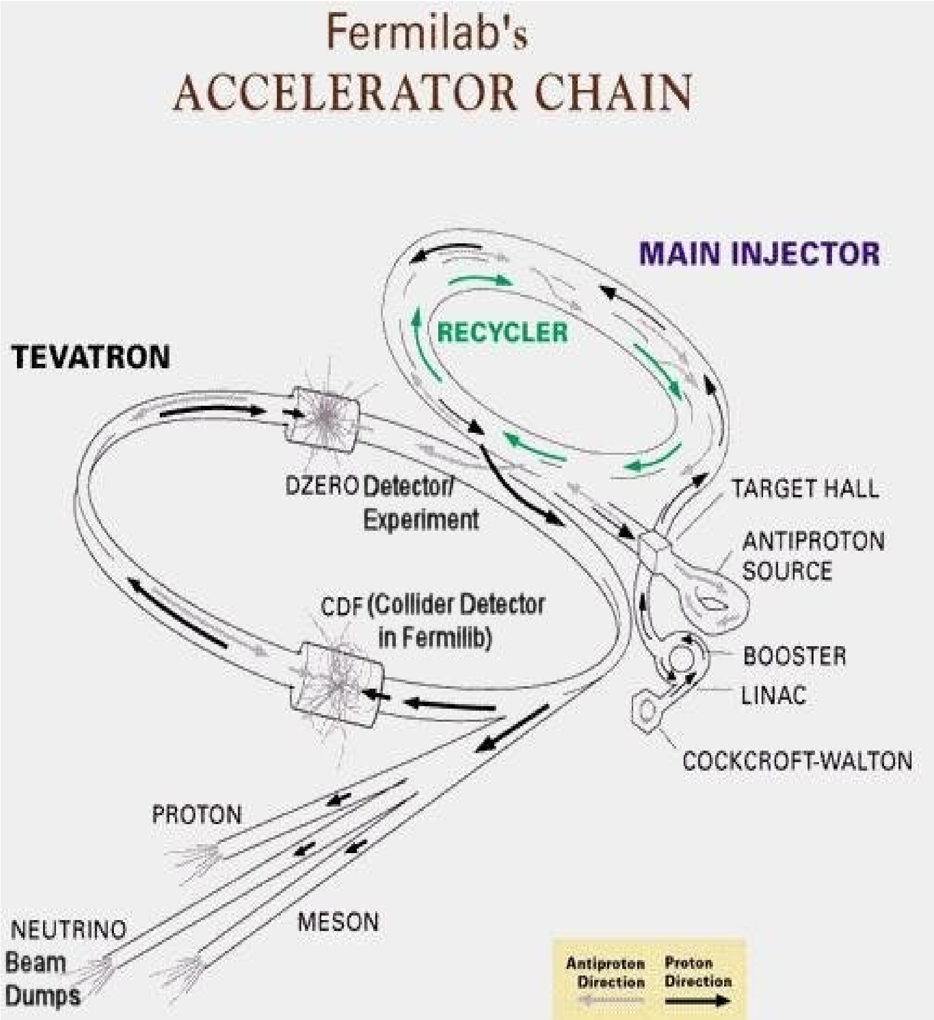
# Reference Slides

# Tevatron



Collide p-$\bar{p}$ at $\sqrt{s}$ = 1.96 TeV
Two general purpose detectors
CDF and D0

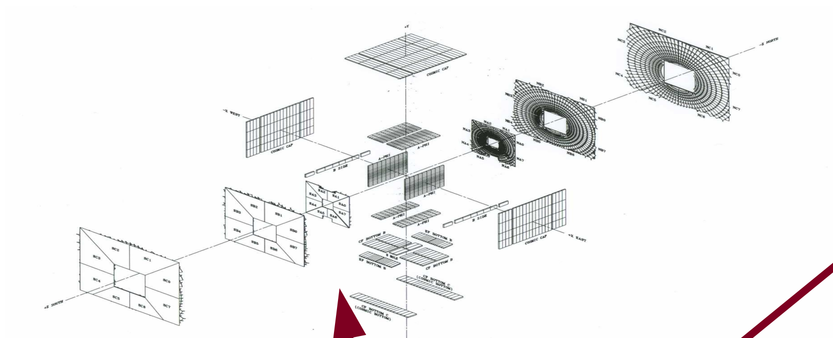


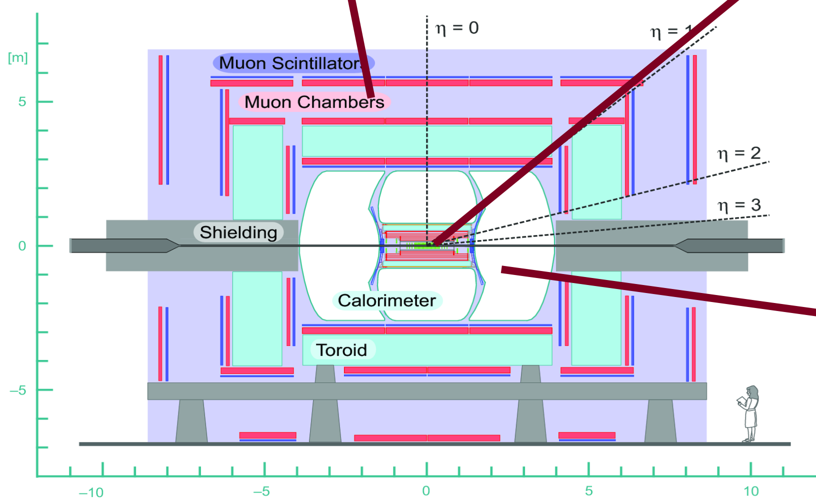



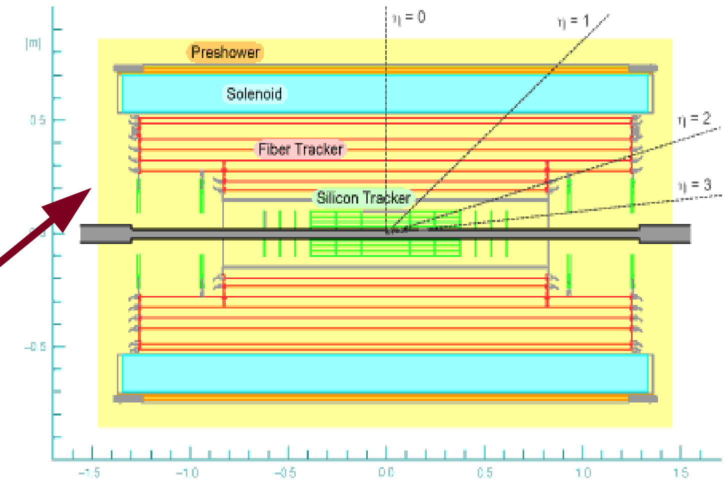
# DØ Detector

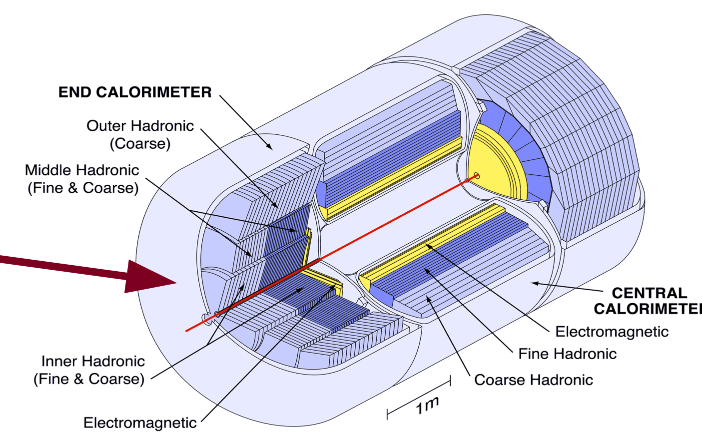
## Main Features:

- Silicon tracker and scintillating fiber tracker in 2.0T field.
- Liquid argon/uranium calorimeters.
- Muon system covers up to |η|=2.0.



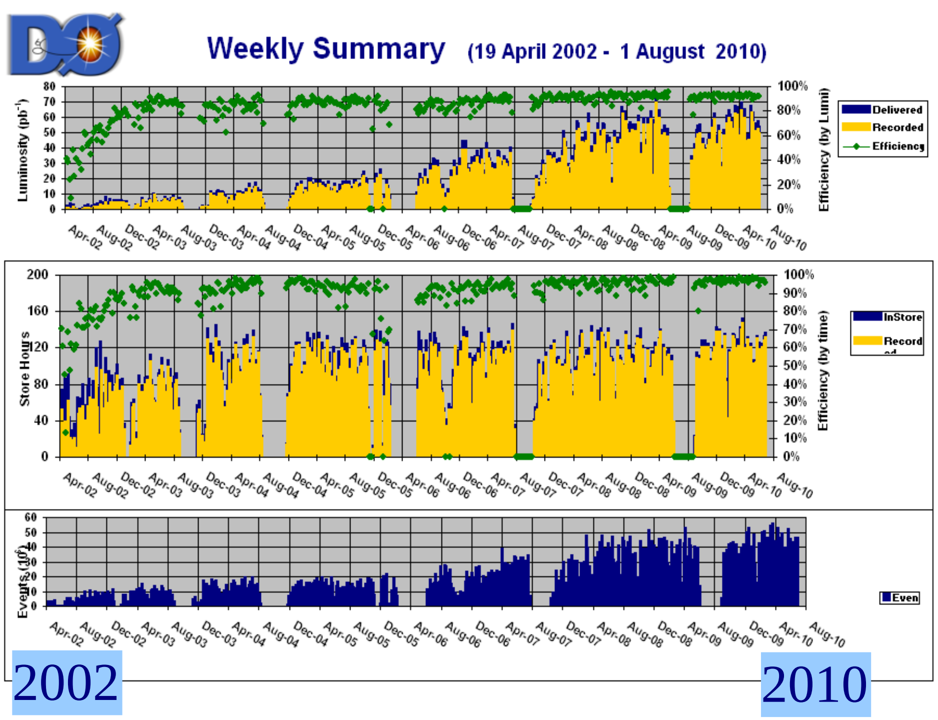


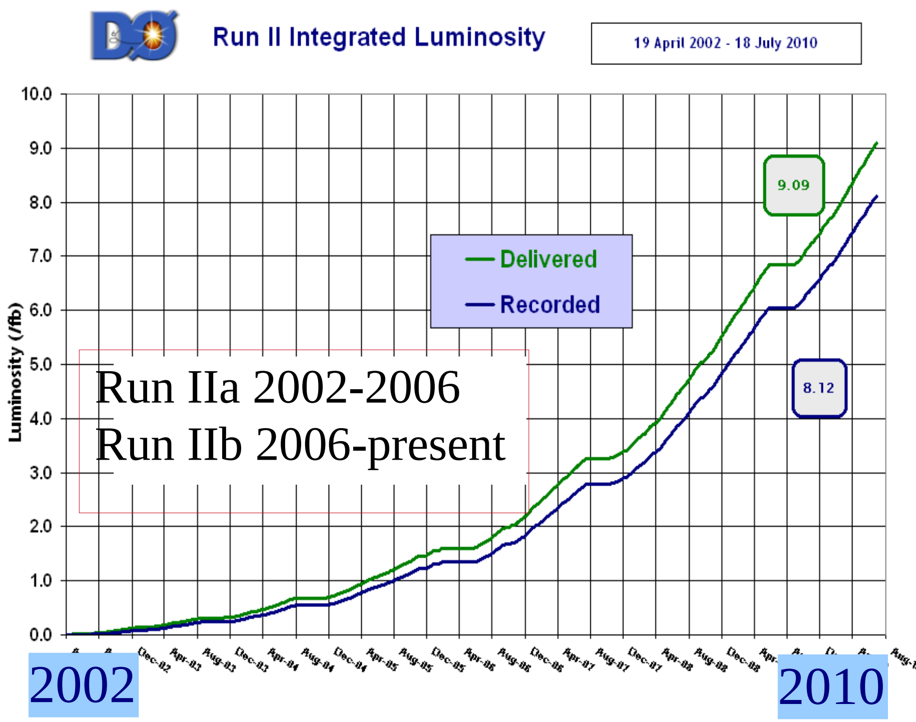



# DØ Data Collection

- D∅ also performs very well and records high quality physics data smoothly.
- The average data taken efficiency ~ 90%.
- Typically, over 55 $pb^{-1}$ recorded in a week, ~8.1 recorded in RunII.
- Analysis at D0 use up to 6.3$fb^{-1}$ data.



# Supersymmetry

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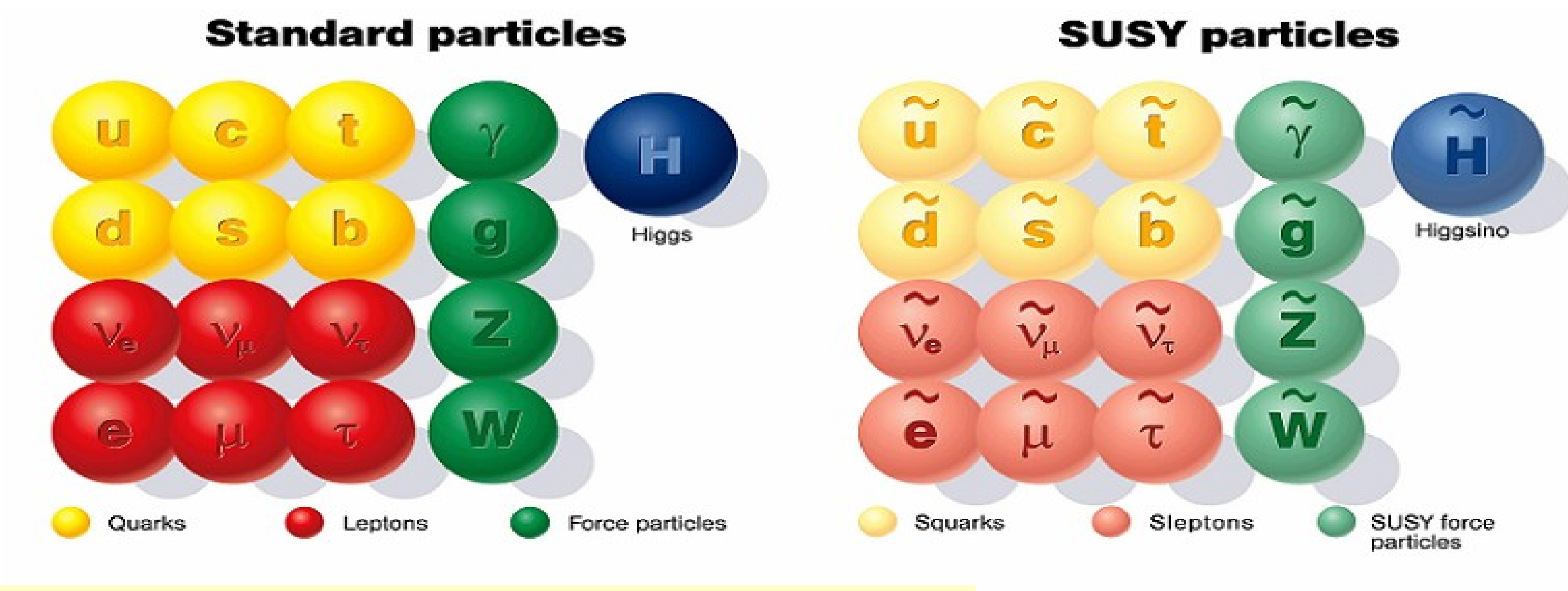
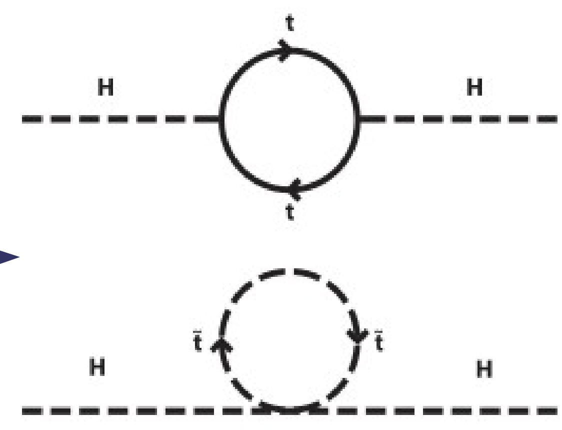


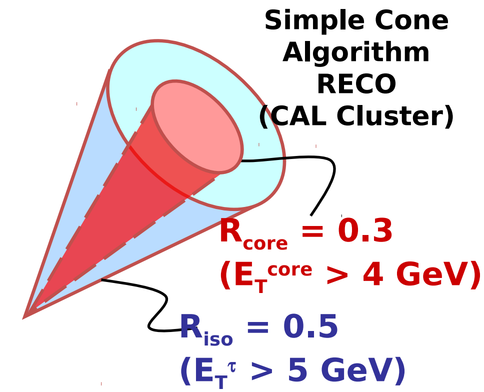

- One of the most popular solutions for those open questions in the SM is the Supersymmetry (SUSY).
- In SUSY, every elementary particle has a super-partner differs by ½ spin.
- This provides a natural solution for the Hierarchy problem of the SM.
- The minimal extension of the SM is called Minimal Supersymmetric Standard Model (MSSM)



# Hadronic Tau($\tau_{had}$)Identification at DØ - (1)



- $\tau$ lepton properties:
  - Mass: 1.78 GeV ; Short lifetime: O($10^{-13}$s)
  - Decay prior to reaching any detector component.
- Main decay channels:



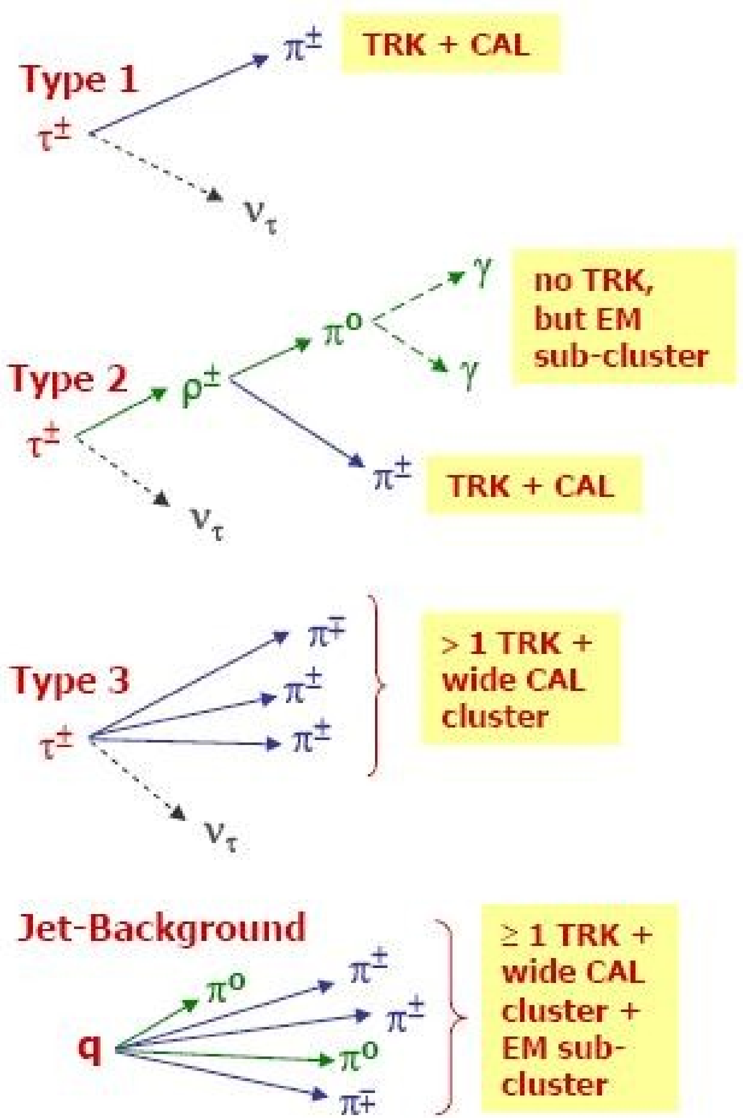

| Decay products | BR (%) | Decay Type | |
|---|---|---|---|
| $e + \upsilon_e + \upsilon_\tau$ | 17.8 | Leptonic (35.2%) | e |
| $\mu + \upsilon_\mu + \upsilon_\tau$ | 17.4 | | μ |
| $\pi^{\pm}$(/K)+$\upsilon_\tau$ | 11.8 | 1-prong (48.7%) | $\tau_h$ |
| $\pi^{\pm}$(/K)+$\geq 1\pi^0+\upsilon_\tau$ | 36.9 | | |
| $\pi^{\pm}\pi^{\pm}\pi^{\pm}+\geq 0\pi^0+\upsilon_\tau$ | 13.9 | 3-prong | |

Detect using standard e/μ ID algorithms

Need dedicated tau ID to measure narrow , low multiplicity jet object

- $\tau$ identification at DØ begins with calorimeter cluster using single cone algorithm.
- Search for the associate EM sub-cluster.

# Hadronic Tau($\tau_{had}$)Identification at DØ - (2)




**Type 1:**
**Single track plus cal. cluster, no electromagnetic (EM) subcluster.**
**Type 2:**
**Single track plus cal. cluster + EM subclusters.**
**Type 3:**
**Wide calorimeter cluster and more than one track.**

- For each tau type, a separate Neural Network is trained to separate hadronic taus from jets.
- For type 2 taus, an additional NN is trained (NNe) to further discriminate type 2 taus and electrons.

# Interpretation within MSSM



- At tree level, Higgs sector is described by tanβ and $M_A$.
- Higher order corrections introduce dependency on additional SUSY parameters.
- Cross-sections taken from FeynHiggs v.2.6.4

**Five additional, relevant parameters:**

$M_{SUSY}$ Common Scalar mass
$X_t$ Mixing Parameter
$M_2$ SU(2) gaugino mass term
$\mu$ Higgs mass parameter
$m_g$ gluino mass

**Two common benchmarks:**

$M_h^{max}$ (max-mixing):
Higgs boson mass, $m_h$, close to maximum possible value for a given tanβ.

No-mixing:
vanishing mixing in stop sector, small Higgs boson mass, $m_h$