# Taus and Higgs physics with taus at LHC (CMS)

A. Nikitenko, Imperial College.

Seminar in LIP, 26th May

# CMS Tau roots are from Lisbon !

CMS TN/95 -195
December 14, 1995

## A STUDY OF THE 1ST LEVEL $\tau$ TRIGGER

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ABSTRACT

We present a simulation study of two possible 1st level $\tau$ triggers. It is shown that a trigger efficiency between 50 and 70% can be achieved for $\tau$ jets with $E_t$ above 50 GeV, for a background rate, at $L=10^{33}cm^{-2}s^{-1}$, of 10kHz and 0.3 kHz in the single and double $\tau$ mode, respectively.

**The main motivation was to increase trigger acceptance for SUSY H->$\tau\tau$ and $H^+$->$\tau\nu$**

# Outline

- Tau ($\tau_{had}$) reconstruction and identification
- Expected reach of Higgs boson searches with $\tau$s at 14 TeV with ~ 30 $fb^{-1}$
- Preparation for Higgs discovery and expectations for 7 TeV with 1 $fb^{-1}$

| Decay Mode | Branching ratio(%) |
|---|---|
| $\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$ | 17.4 |
| $\tau^- \to e^- \bar{\nu}_e \nu_\tau$ | 17.9 |
| $\tau^- \to h^- \nu_\tau$ | 11.6 |
| $\tau^- \to h^- \pi^0 \nu_\tau$ | 26.0 |
| $\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$ | 10.8 |
| $\tau^- \to h^- h^+ h^- \nu_\tau$ | 9.8 |
| $\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$ | 4.8 |
| other | 1.7 |

$\tau_{had}$

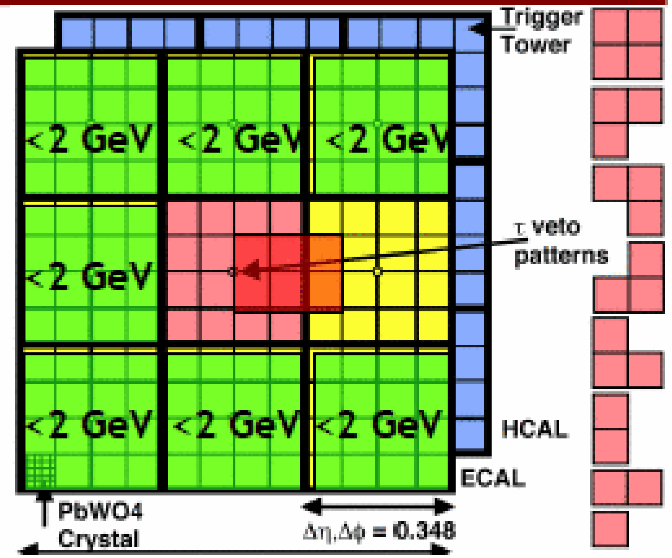
# Tau reconstruction and identification in CMS:

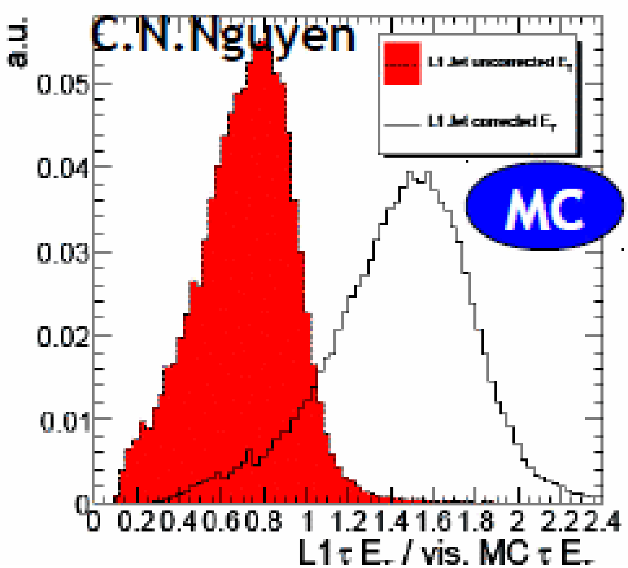
# at Trigger level

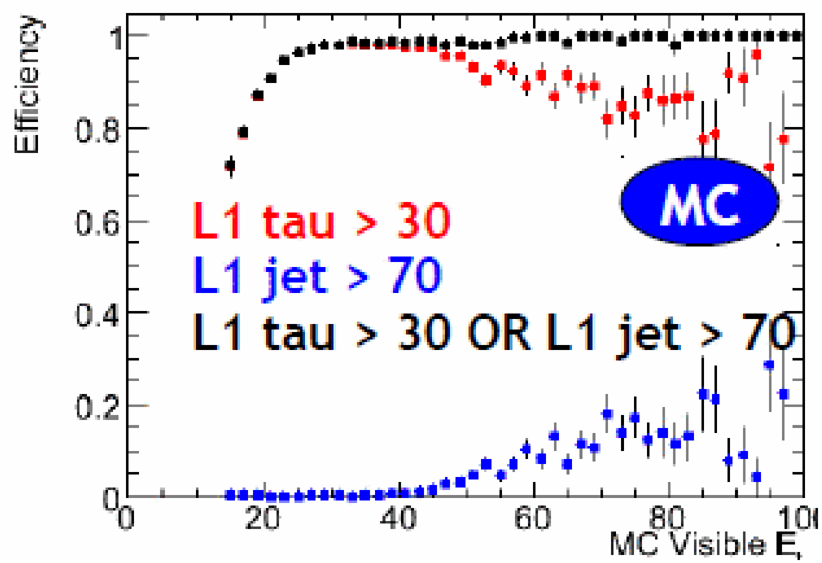
# τ trigger at Level-1

## New L1 Tau Algorithm

- Working on a L1 jet (3x3 regions)
- Requires specific patterns in the central region denoting a narrow jet
- Isolation applied in 7/8 neighbors
  - Latest addition to GCT firmware (Thanks!)
- Jet energy corrections is an issue

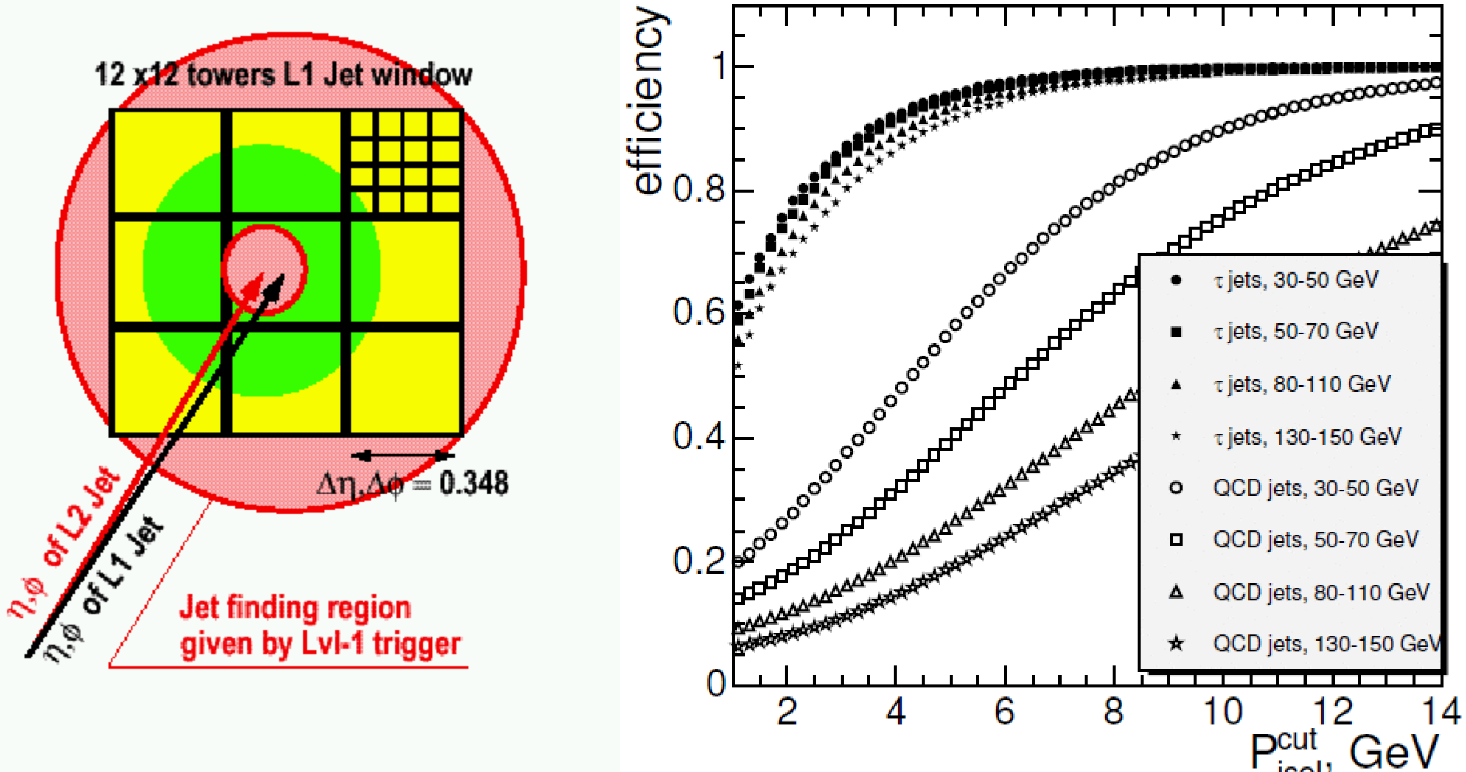


# $\tau$ trigger at HLT: calo part

HLT Tau jet tagging : calo-based $\tau$ -jet id at “Level-2”

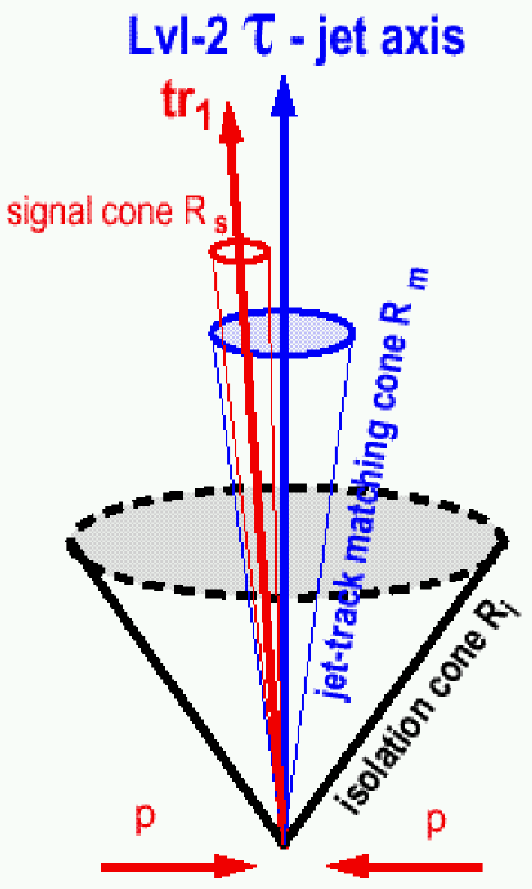



$$P_{isol} = \Sigma\, E_T^{ECAL}(r<0.4) - \Sigma\, E_T^{ECAL}(r<0.13) < cut$$

(CMS PTDR vol.1)

# $\tau$ trigger at HLT: tracker part

## Tau identification at Lvl-3 with Pixels

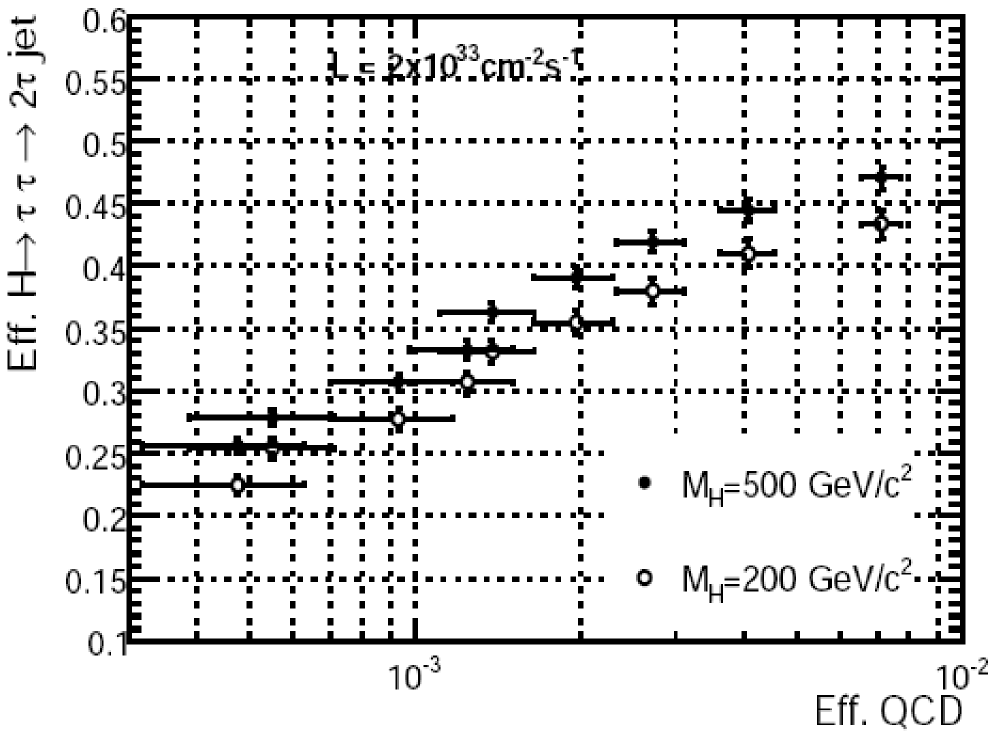


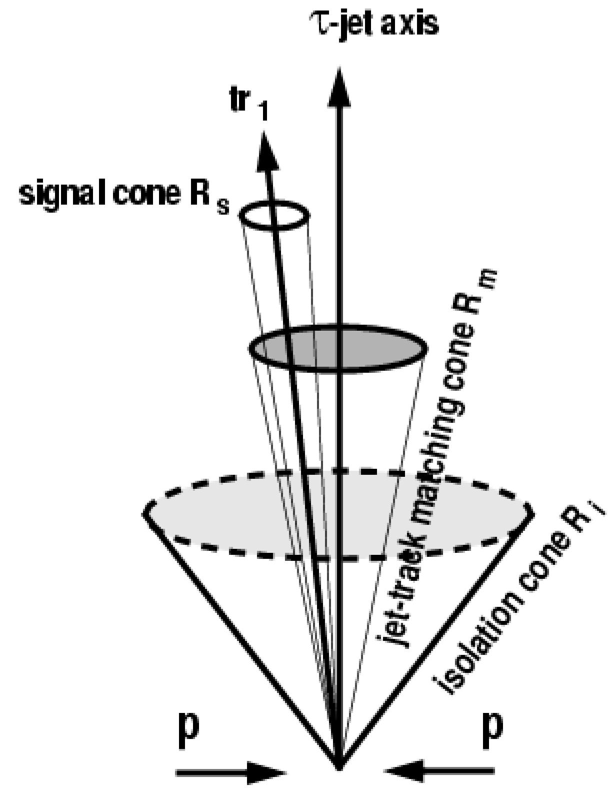

### Algorithm steps

- reconstruct tracks $p_t$ > 1 GeV with pixels only
  resolution : $\sigma(p_t)/p_t=[3.6+1.7p_t(\mathrm{GeV})]\%$
- find primary vertices (histogramming method)
- find highest $p_t$ track with good Lvl-2 jet matching
  $\Delta R(j - tr_1) < R_m$ (~0.1) , $p_t^{tr1} > p_t^m$ (~3 GeV),
  $tr_1$ defines signal primary vertex (PV)
- count number of tracks from PV in the isolation cone and signal cone :
  $N_i$ tracks with $\Delta R(j - tr) < R_i$ (~0.3) ,
  $N_s$ tracks with $\Delta R(tr_1 - tr) < R_s$ (~0.05) ,
  $p_t^{tr} > p_t^i$ (~1 GeV)
- accepts as $\tau$ if tracks found only in signal cone
  $N_s = N_i$

# HLT – double τ tagging, no $E_T$ thresholds on τ-jet candidates: <u>QCD bkg. rejection = $10^3$</u>

*Calo+Pxl Tau trigger; CMS PTDR Vol.1*



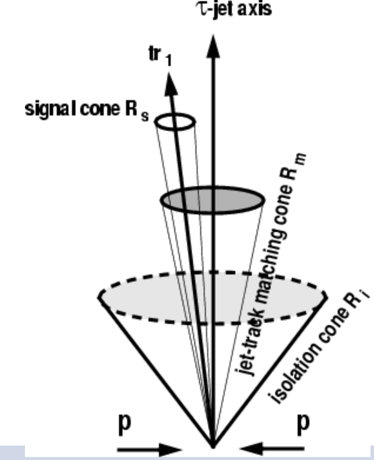




D. Kotlinski et al., CMS Note 2006/028

# Tau reconstruction and identification in CMS:

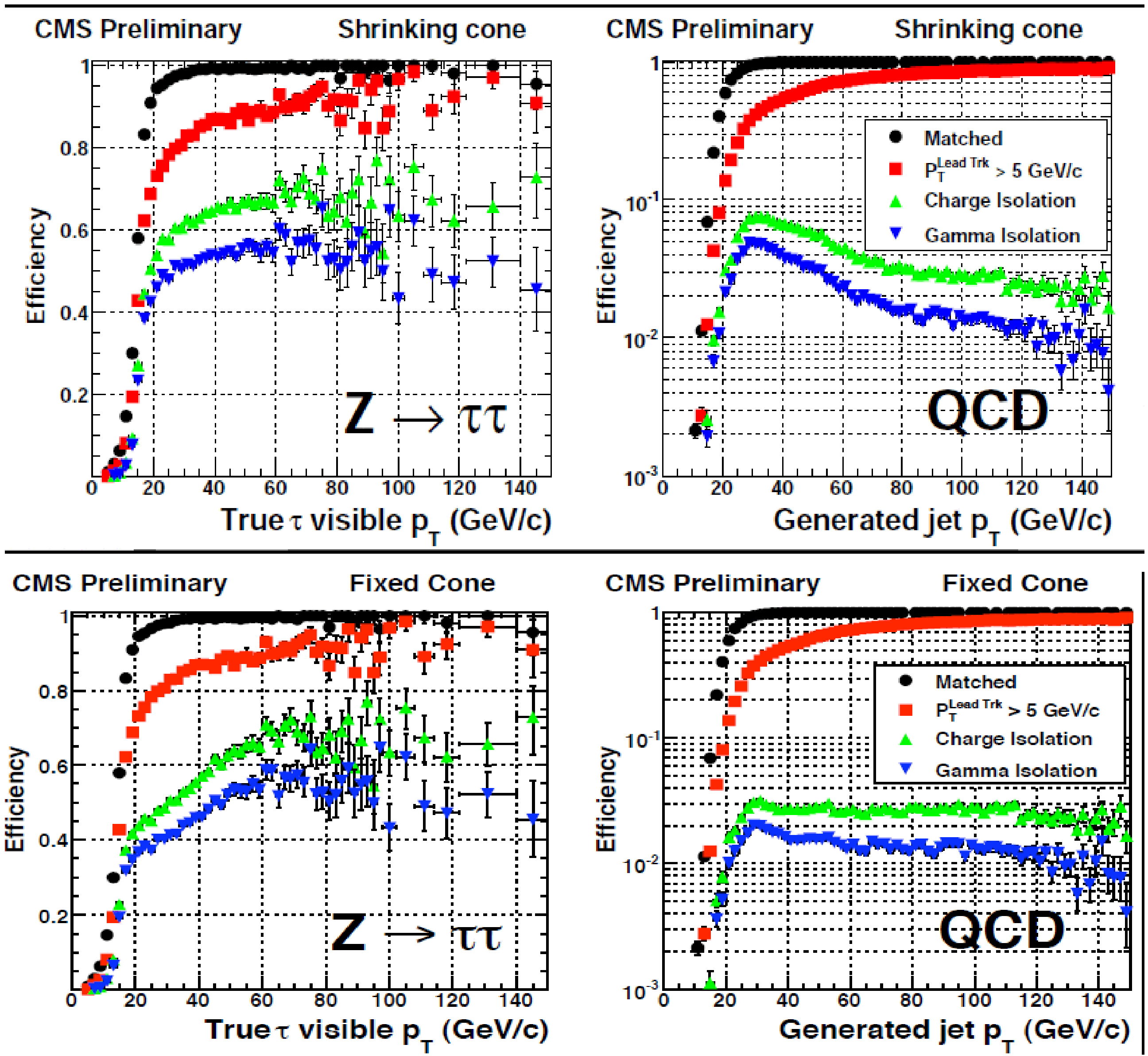
# in off-line analysis

# Basic $\tau$ selections (very similar to HLT)




| Basic Tau ID with PF and tcTau $\tau$s | |
|---|---|
| **PF Tau** | **tcTau** |
| 1. Jet-track matching, $\Delta R(\text{jet-track}) < 0.1$ | |
| *jet build from PF objects* | *calo jet corrected with tracks* |
| 2. Cut on $p_T$ of leading track in signal cone ($R_S$=0.07 or $R_S$=5/$E_T$) | |
| 3. No tracks in annulus between signal and isolation cones | |
| 4. Electromagnetic isolation | |
| *no $\gamma$s in isolation annulus* | *$E_T$ in ECAL isolation annulus < cut* |
| 5. electron and muon vetoes (no $\mu$ veto yet for tcTau) | |

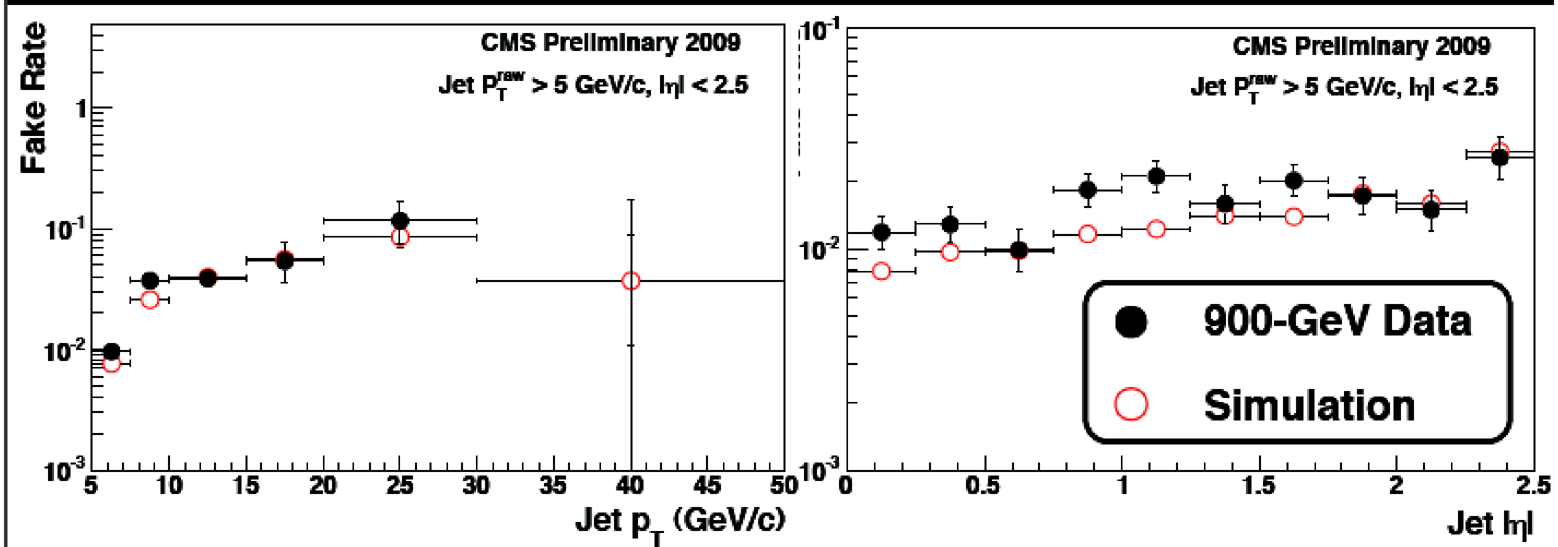
# PF $\tau$ ID efficiency vs $p_T$



# December Data

PFT-10-001

## MinBias fake rate in December data

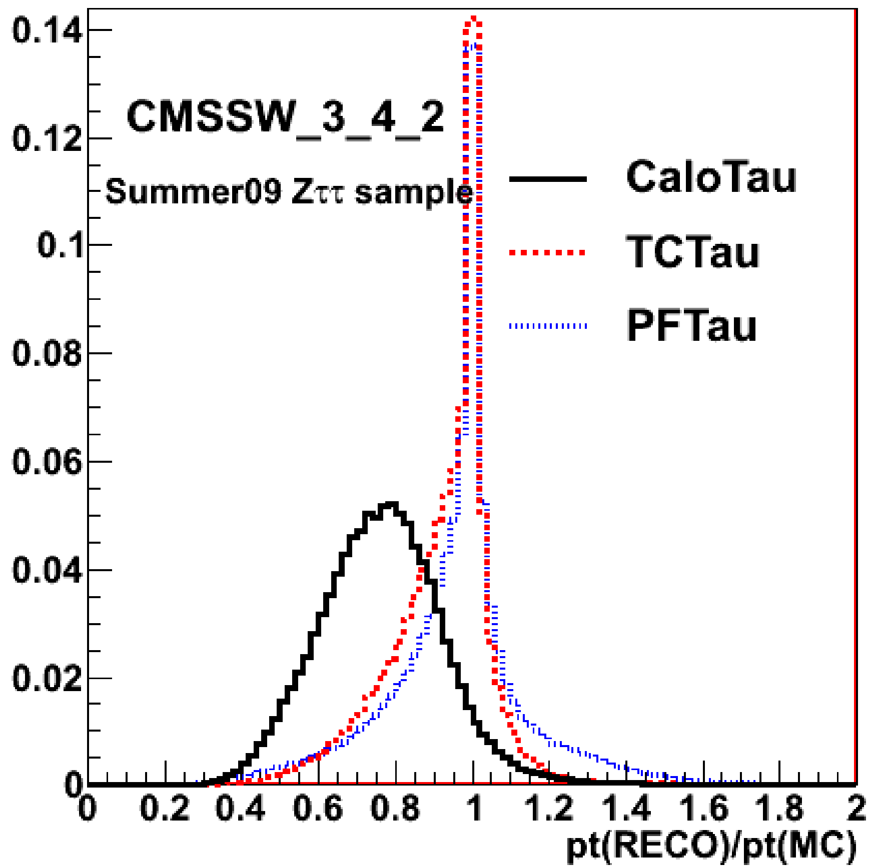


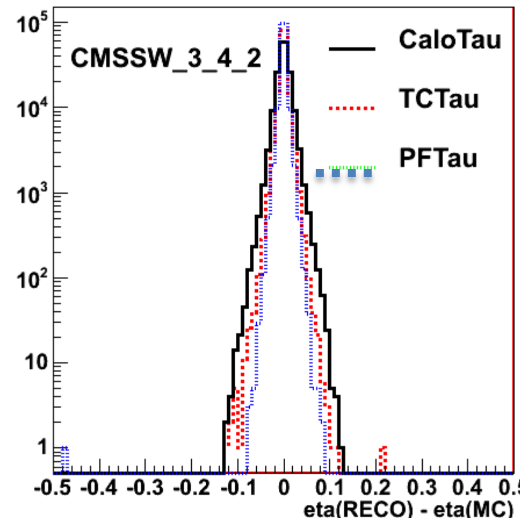

denominator: PFJets with $p_T > 5$, $|\eta| < 2.5$

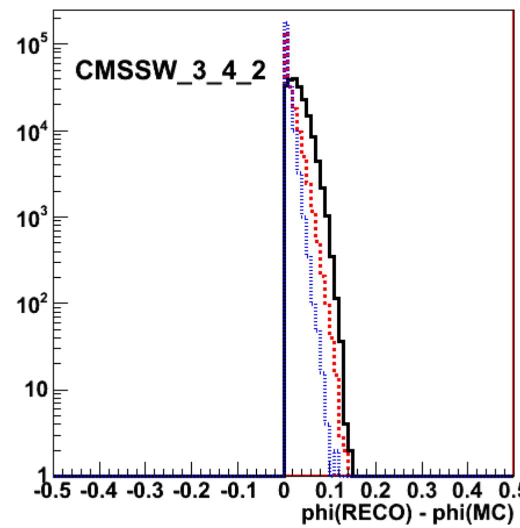
numerator: PFTaus with lead track $p_T > 5$, charged+photon isolation

- **More advanced IDs exploiting $\tau_{had}$ decay modes:**
  - **Tau Neural Classifier (CMS AN-2010/099)**
  - **Hadron Plus Strip Algorithm (CMS AN-2010/082)**

# τ energy / direction reconstruction with PF and tcTau algorithms

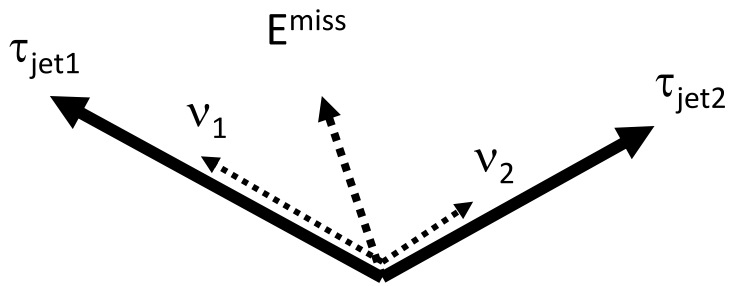


# Full $\phi \to \tau\tau$ mass reconstruction method

**Collinear approximation : $m_\tau \ll p_T^{\ \tau}$ :**

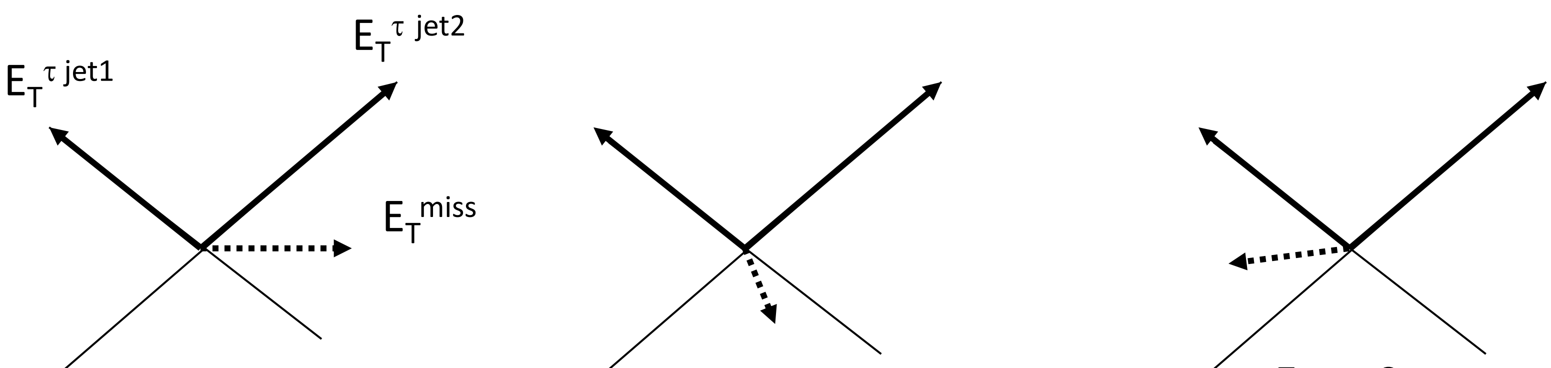



$$E_{\nu 1}\, x_{\tau\ jet1} + E_{\nu 2}\, x_{\tau\ jet2} = E_{TX}^{miss}$$
$$E_{\nu 1}\, y_{\tau\ jet1} + E_{\nu 2}\, y_{\tau\ jet2} = E_{TY}^{miss}$$

$$x_{\tau\ jet} = \sin(\theta_{\tau\ jet})\cos(\phi_{\tau\ jet})$$
$$y_{\tau\ jet} = \sin(\theta_{\tau\ jet})\sin(\phi_{\tau\ jet})$$

$$E_\tau = E_{\tau\ jet} + E_\nu$$

**Negative $E_\nu$ solutions due to $E_T^{miss}$ measurement error :**




$E_{\nu 1} < 0$ $\quad$ $E_{\nu 1}$ & $E_{\nu 2} < 0$ $\quad$ $E_{\nu 2} < 0$

**Higgs boson mass can not be reconstructed if $E_{\tau\ jet} + E\nu < 0$**

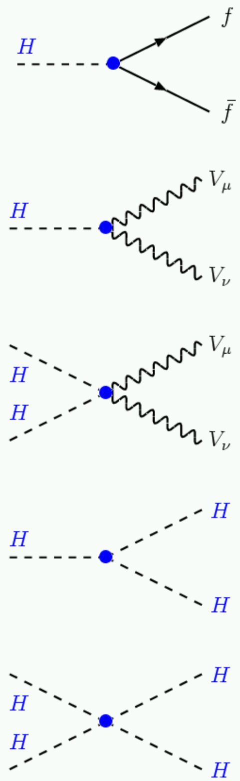
# Higgs boson searches with $\tau$s in the final state

# Higgs boson channels with $\tau$'s studied so far in ATLAS and CMS (PTDRs)

- **qq->qqH, H->$\tau\tau$ (VBF H->$\tau\tau$) in SM and MSSM**
- **MSSM $\phi$->$\tau\tau$ in gg->$\phi$ and gg->bb$\phi$ production**
- **MSSM $H^+$->$\tau$ $\nu$ from tt~(t->$H^+$b) and gb->tb$H^+$**
- ***NMSSM $H_1$->$a_1 a_1$->$\tau\tau\tau\tau$***
  - *arXiv:0805.3505 [hep-ph], arXiv:0801.4321[hep-ph]*
- ***$H^{++}H^{--}$ -> llll (l= $\mu$, $\tau$)***
- ***5D Randall-Sundrum model: $\phi$->hh->$\tau\tau$bb***

# SM Higgs boson couplings and Br. ratios

tree level couplings



$$g_{Hff} = m_f/v = (\sqrt{2}G_\mu)^{1/2}\, m_f \qquad \times\,(i)$$

$$g_{HVV} = 2M_V^2/v = 2(\sqrt{2}G_\mu)^{1/2}\, M_V^2 \qquad \times\,(-ig_{\mu\nu})$$

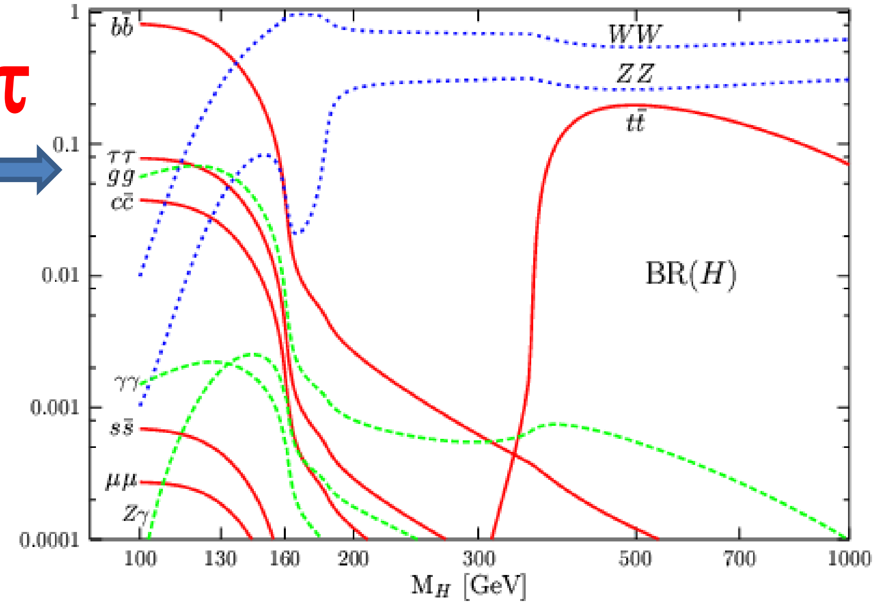
$$g_{HHVV} = 2M_V^2/v^2 = 2\sqrt{2}G_\mu\, M_V^2 \qquad \times\,(-ig_{\mu\nu})$$

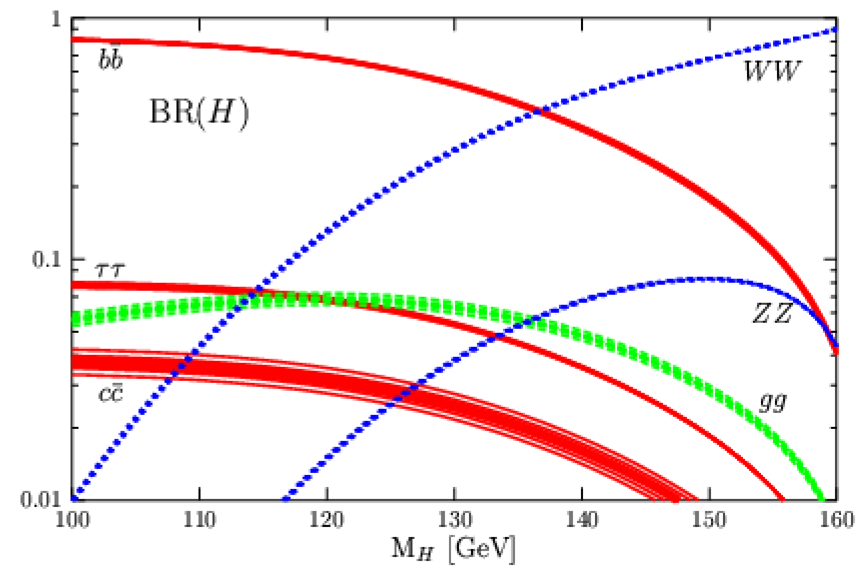
$$g_{HHH} = 3M_H^2/v = 3(\sqrt{2}G_\mu)^{1/2}\, M_H^2 \qquad \times\,(i)$$

$$g_{HHHH} = 3M_H^2/v^2 = 3\sqrt{2}G_\mu\, M_H^2 \qquad \times\,(i)$$

$\tau\tau$

Djouadi, Kalinowski, Spira



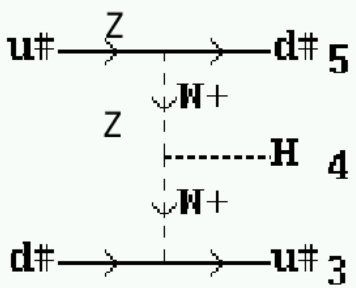




**v is vev of Higgs field = 246 GeV**

Right bottom plot includes uncertainties from the quark masses $m_t$, $m_b$, $m_c$ and $\alpha_s(M_Z)$

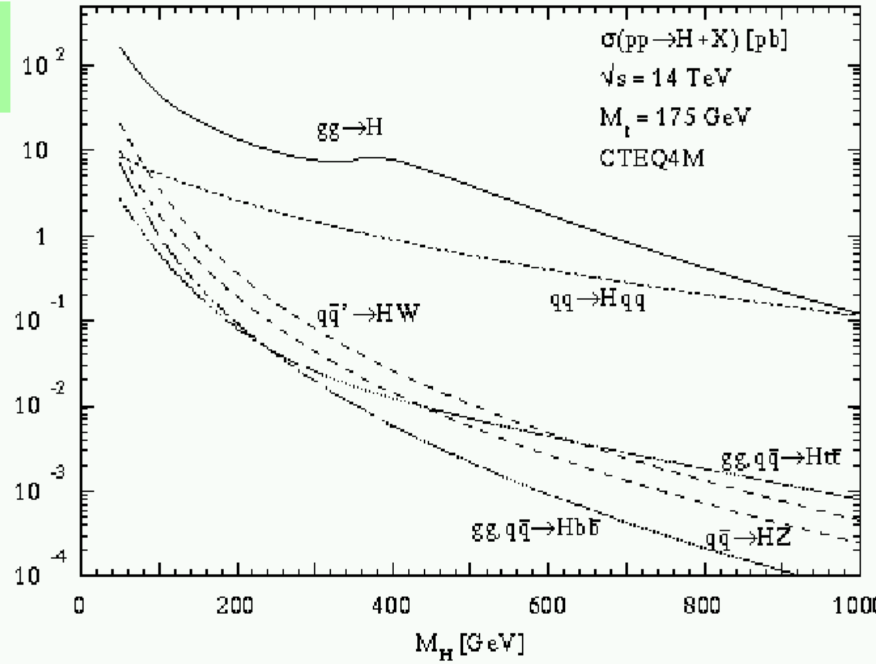
# H->ττ in SM is available only through VBF Higgs production

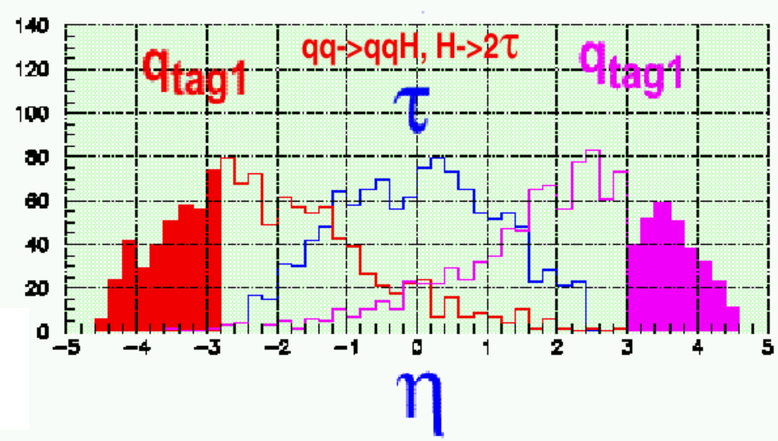
**VBF : qq->qqh process**




- large enough rates
- forward jet tagging and mini-jet veto for low L
- central Higgs decay products to trigger
- not too big bkg, S/B ~ 1

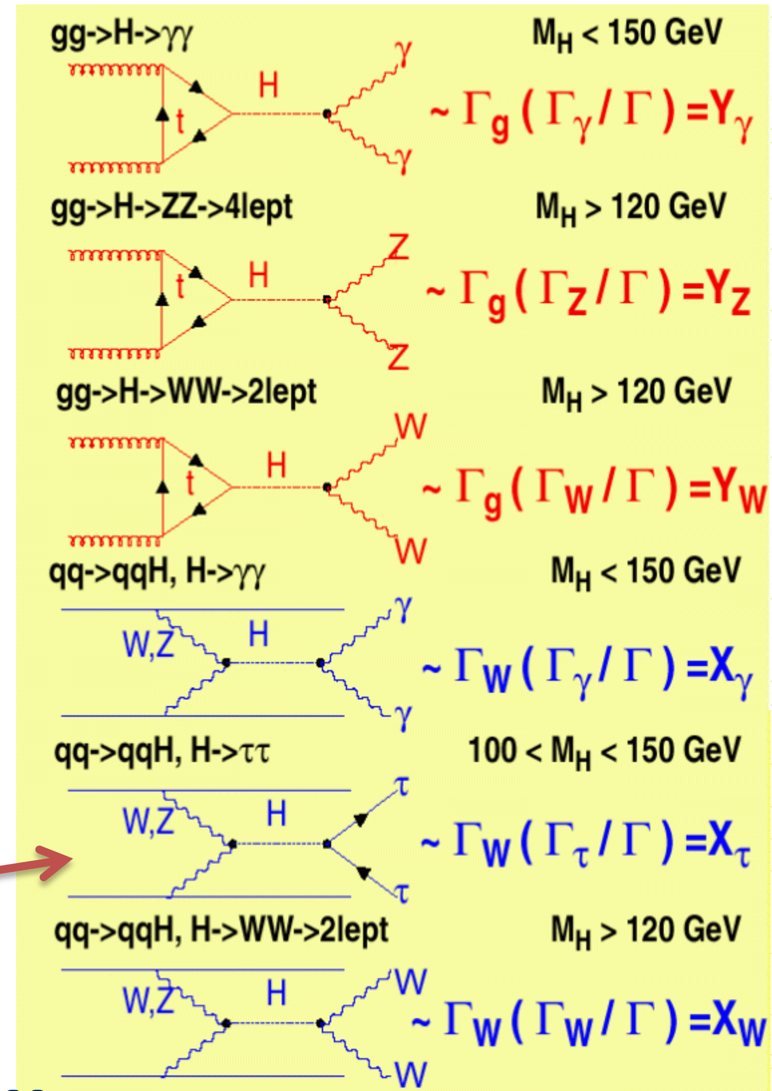
D. Zeppenfeld and collaborators are discussing it since ~ 10 years



# Why VBF channels are very important ?

- Significantly extend the possibility of Higgs coupling measurements
- Provide possibility of the indirect measurement of the light Higgs boson width
  - D. Zeppenfeld, R. Kinnunen, A. Nikitenko and E. Richter-Waz, Phys.Rev. D62 (2000) 013009
  - M. Duehressen et al., Phys.Rev. D70 (2004) 113009




**The only way to measure Higgs coupling to down type fermions; Important in MSSM**

# Selection strategy and bkgs for VBF $H \to \tau\tau \to l$+jet

- **Trigger**
  - with early data (< 1fb$^{-1}$) : single lepton
  - with higher lumi: single lepton plus $l+\tau$
    - Lepton + "VBF jets" is under unvestigation
- **Off-line**
  - a) Lepton counting: only 1 e or 1 $\mu$; b) $p_T^{l} > 15$ GeV
  - $\tau \to$hadrons ($\tau_{jet}$) selection; $E_T > 30$ GeV
  - VBF jet selections: $E_T$>30 GeV, cuts on $\Delta\eta_{j1j2}$, $M_{j1j2}$
  - Central rapidity gap selection
  - upper cut on $m_T(l,E_T^{miss}) < 40$ GeV against Ws
  - Higgs boson mass reconstruction: $l+\tau_{jet}$ or full $\tau\tau$ mass
- **Backgrounds considered:**
  - Z+jets, W+jets, tt~, QCD

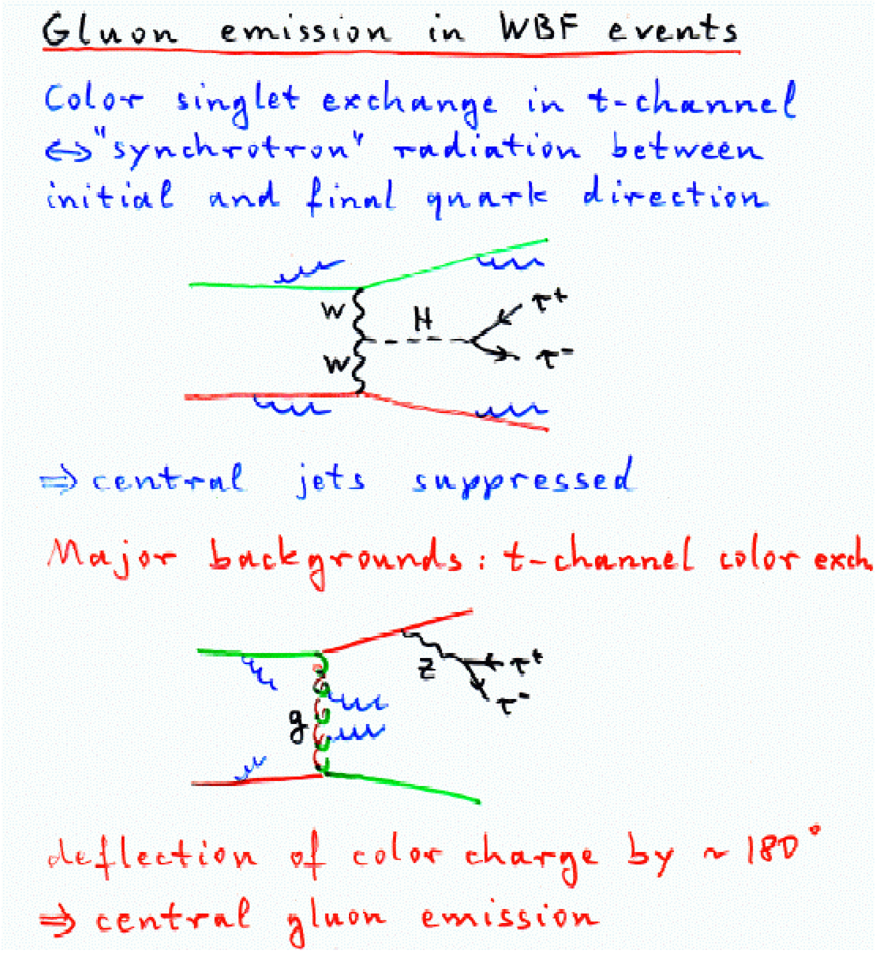
# Rapidity gap in VBF (WW->H) production

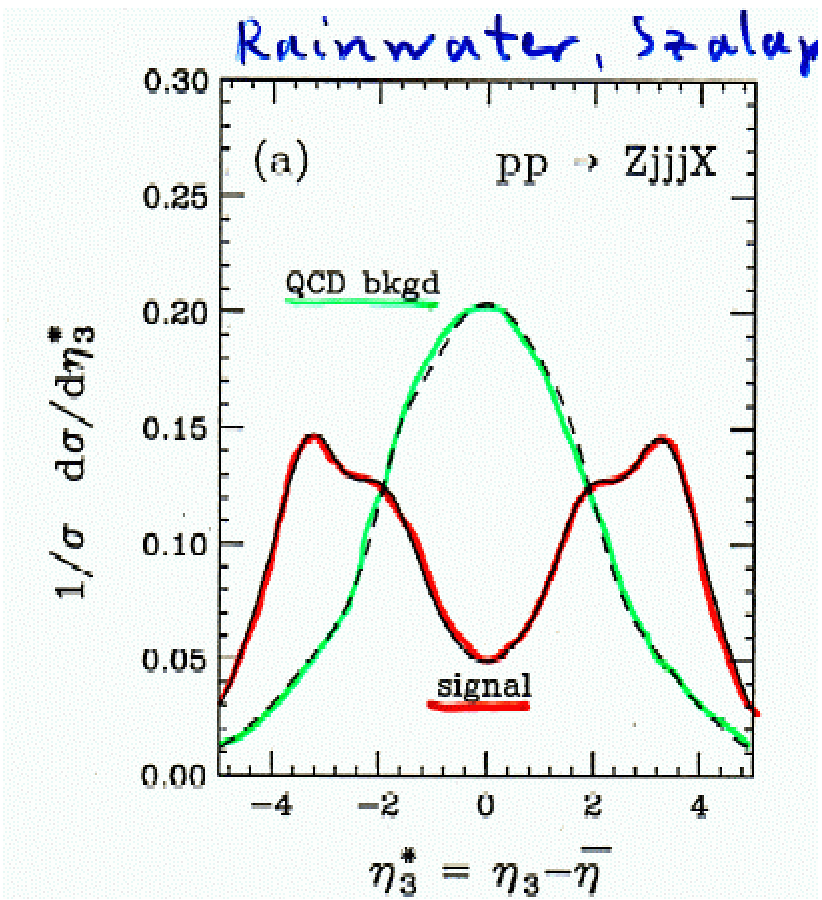
**first discussed in :**

Yu. Dokshitzer, V. Khoze and S. Troyan, Sov.J.Nucl. Phys. 46 (1987) 712

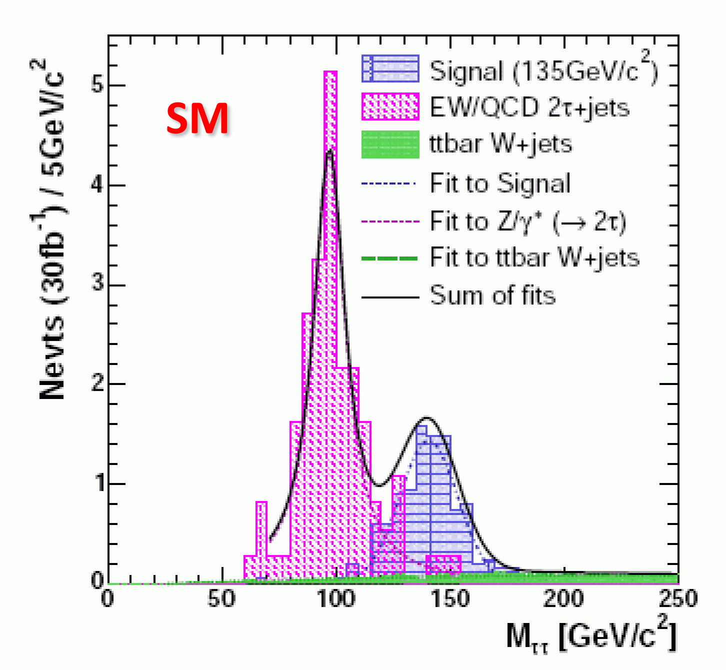
Yu. Dokshitzer, V. Khoze and T. Sjostrand, Phys.Lett., B274 (1992) 116

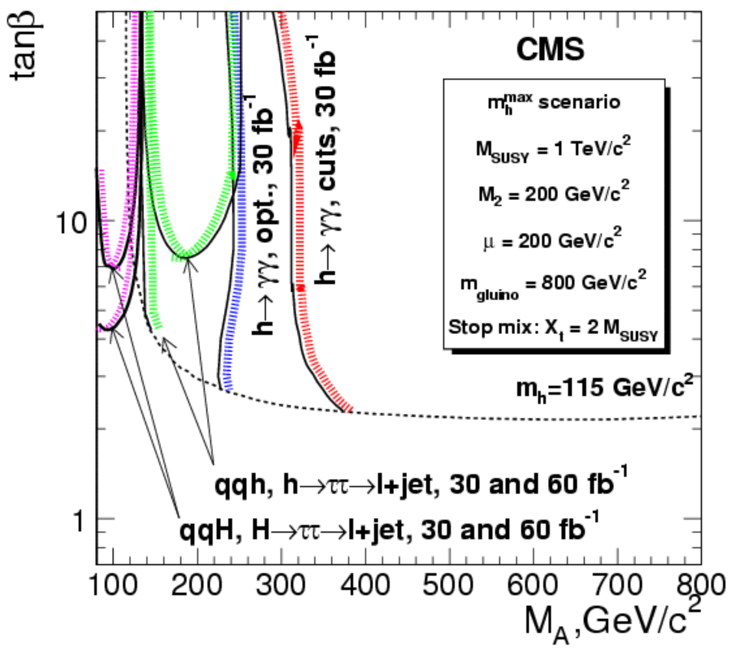
**From D. Zeppenfeld talk on TeV4LHC, 2004**



# Full simulation analysis of qqH, H->ττ->l+jet at LHC 14 TeV




discovery light h in MSSM

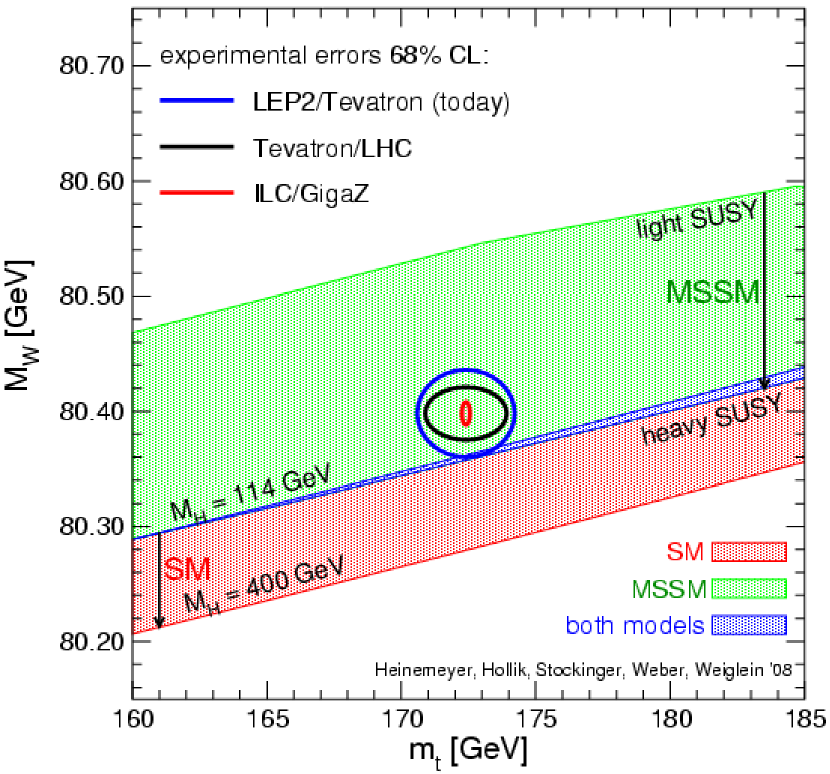
## Discovery in Standard Model

| $M_H$ [ GeV ] | 115 | 125 | 135 | 145 |
|---|---|---|---|---|
| Production $\sigma$ [fb] | $4.65\times10^3$ | $4.30\times10^3$ | $3.98\times10^3$ | $3.70\times10^3$ |
| $\sigma\times$BR($H\to\tau\tau\to lj$) [fb] | 157.3 | 112.9 | 82.38 | 45.37 |
| $N_S$ at 30 fb$^{-1}$ | 10.5 | 7.8 | 7.9 | 3.6 |
| $N_B$ at 30 fb$^{-1}$ | 3.7 | 2.2 | 1.8 | 1.4 |
| Significance at 30 fb$^{-1}$ ($\sigma_B = 7.8\%$) | 3.97 | 3.67 | 3.94 | 2.18 |
| Significance at 60 fb$^{-1}$ ($\sigma_B = 5.9\%$) | 5.67 | 5.26 | 5.64 | 3.19 |

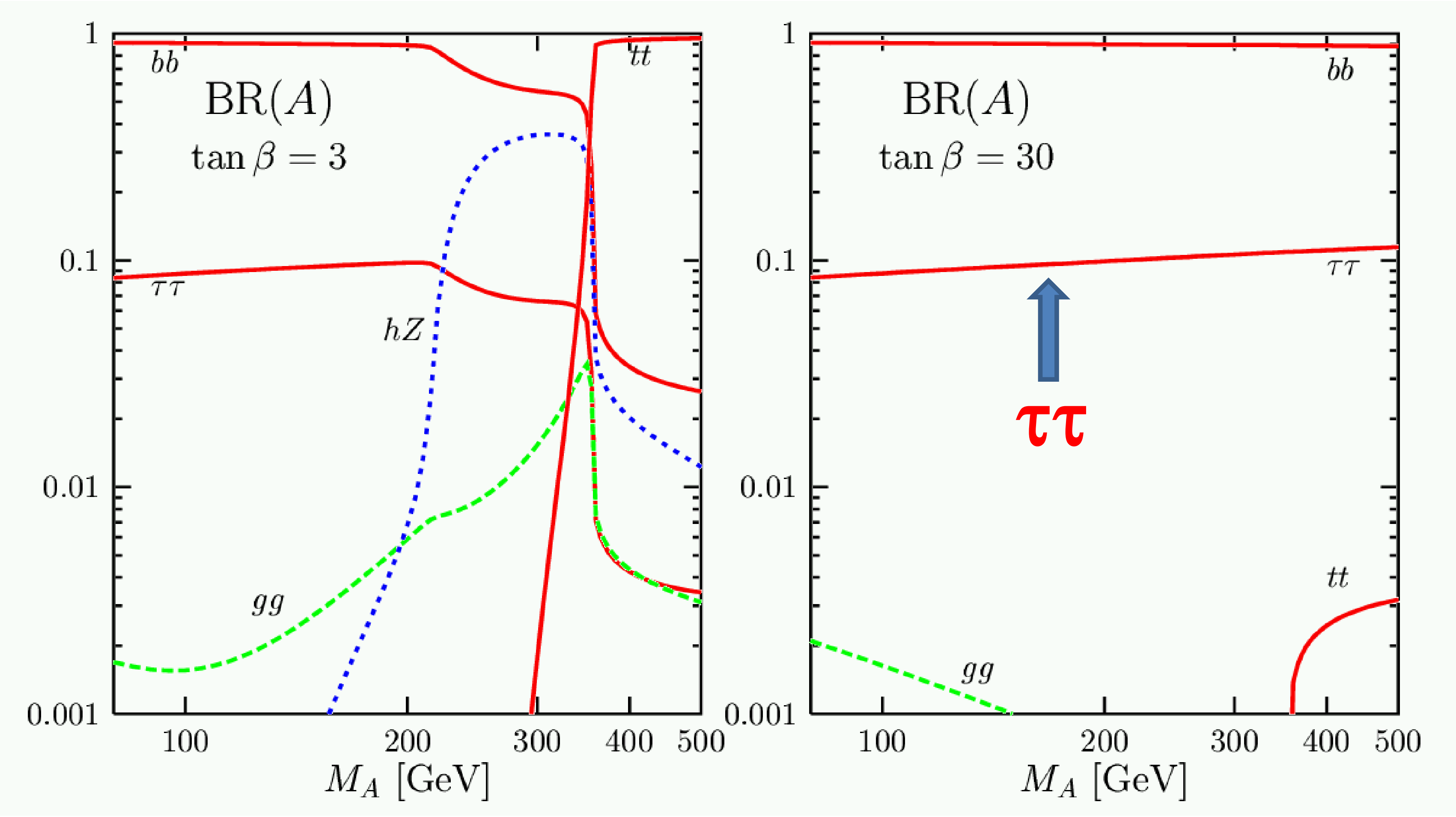
# Exploit 7 TeV data to be prepared for VBF H->$\tau\tau$ analysis at 14 TeV

- **Check the methods of central rapidity gap selection using Z+2 jet events:**
  - *central jet veto*
  - *track counting veto*
    - CMS Analysis Note 2007/035, CMS-PAS-HIG-08-001, arXiv:0803.1154 [hep-ph]
- **Start getting tagging quark jet energy scale using**
  - *W->qq (from tt~)*
    - J.D'Hondt, P. Van Mulders, CMS Analysis Note 2007/029.
  - *Z+jet events*
    - A. Nikitenko, E. Yazgan CMS Analysis Note 2010/044

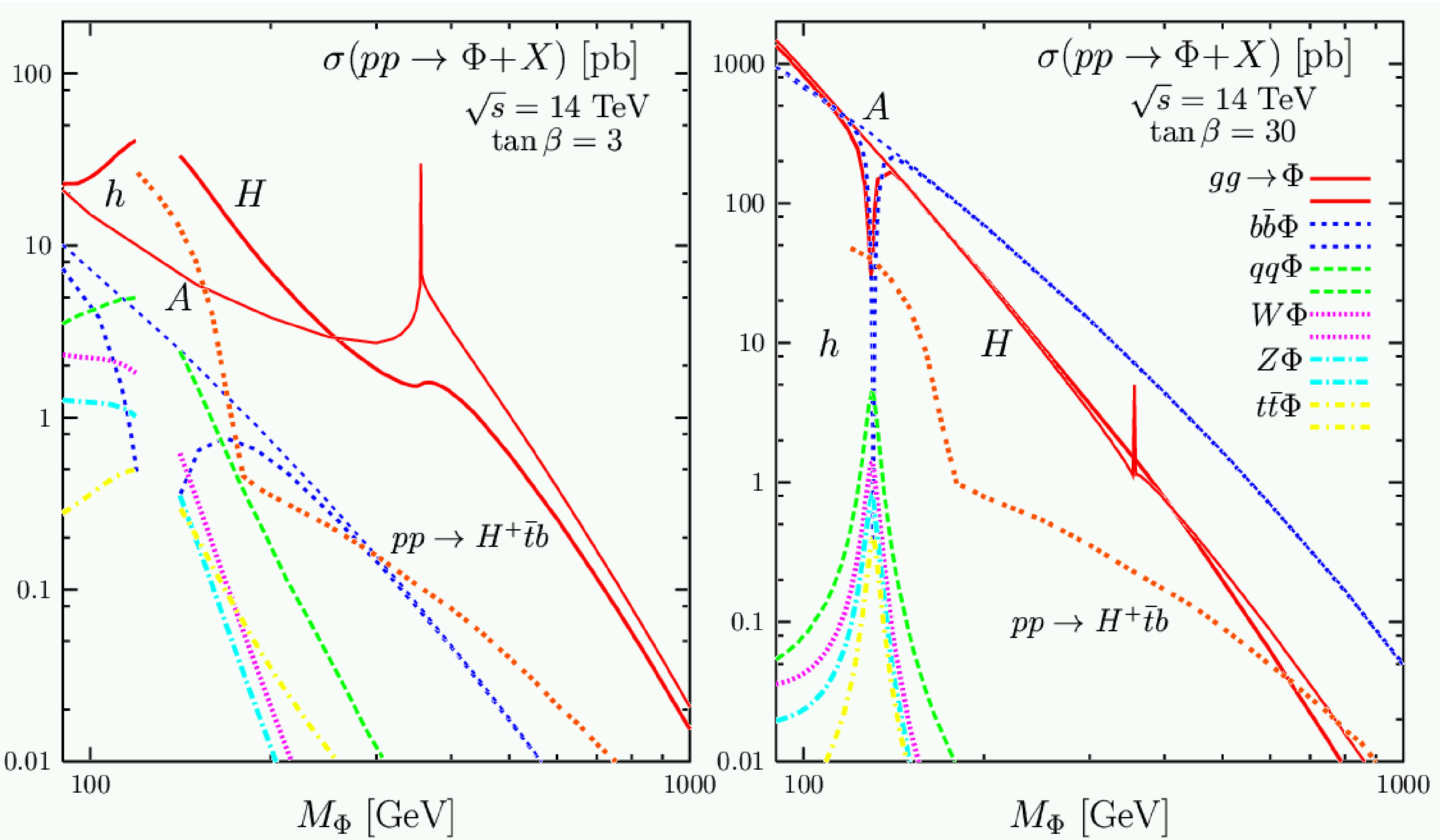
# Searches for MSSM neutral Higgs bosons->$\tau\tau$



# Heavy CP-odd Higgs boson (A) branching ratios

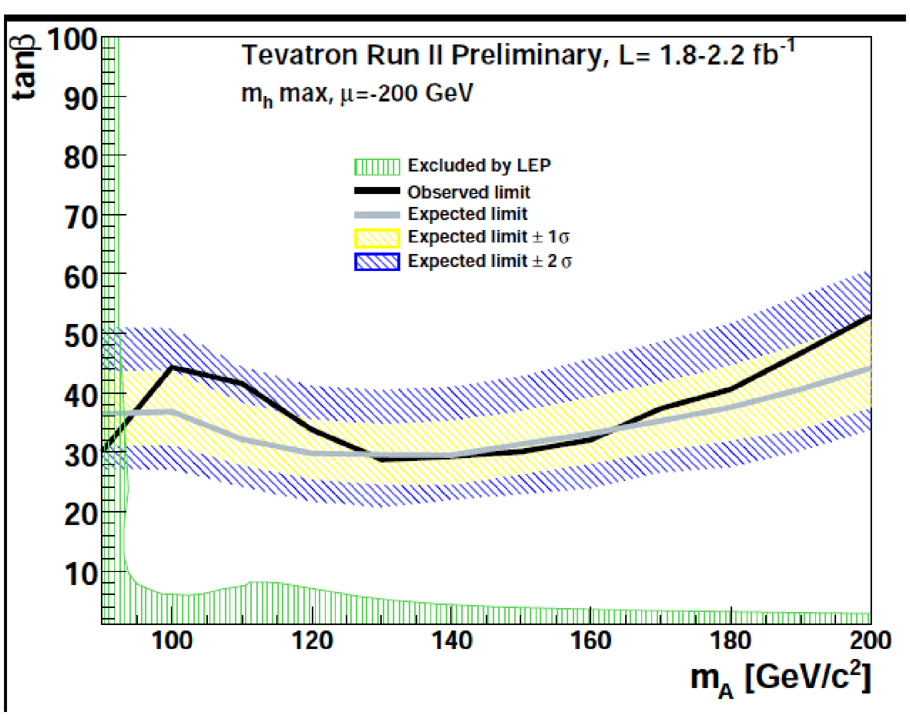


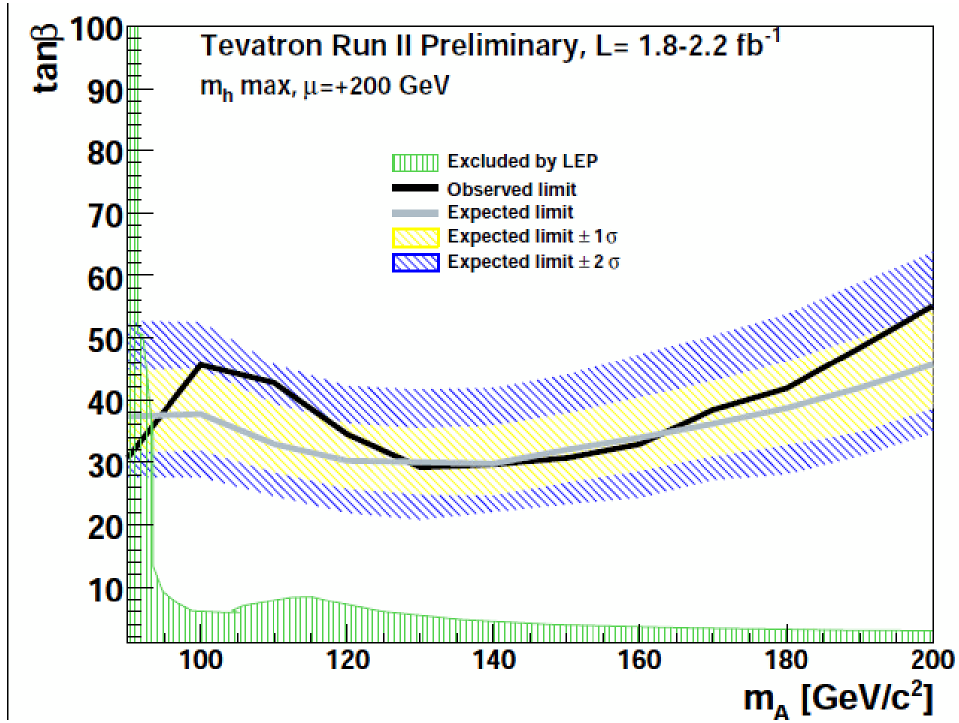
# Cross sections for MSSM Higgs bosons production at LHC for 14 TeV




$X_t=6^{1/2}M_S$ ($m_h^{max}$ scenario), $M_S$=2TeV, $m_t$=178 GeV, $m_b(m_b)$=4.9 GeV;
NLO QCD corrections for all channels, but $tt\Phi$, $bb\Phi$; $\mu_R=\mu_F=1/2(M_\Phi+2m_t)$ for $tt\Phi$ and $¼(M_\Phi+2m_b)$ for $bb\Phi$. NLO MRST set of PDF

# Tevatron: pp->(bb)φ, φ->ττ
# Exclusion limits in $M_A$–tanβ




- High tanβ and $M_A$ = 100-800 Gev is the region for MSSM Higgs searches at LHC with

  pp->(bb)φ, φ->ττ

# CMS: $\phi \to 2\tau$ analyses 2006
## $m_\phi$ > 150-200 GeV with $pp \to bb\phi$

### Final states and background processes

| | |
|---|---|
| $H \to \tau\tau \to e\mu + X$ | $H \to \tau\tau \to ll + X$ |
| Branching ratio BR($\tau\tau \to e\mu$)~6.3% | Branching ratio BR($\tau\tau \to ll$)~12.5% |
| $H \to \tau\tau \to l + jet + X$ | $H \to \tau\tau \to jet + jet + X$ |
| Branching ratio BR($\tau\tau \to lj$)~45.6% | Branching ratio BR($\tau\tau \to jj$)~41.5% |

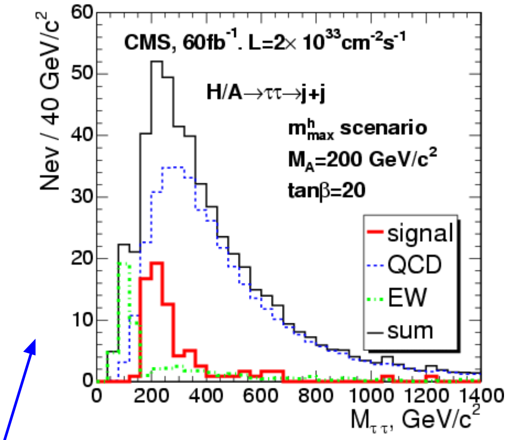
Main backgrounds:

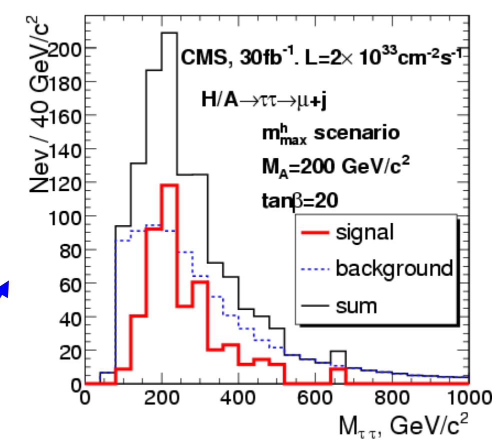
| | |
|---|---|
| $Z,\gamma^* \to \tau\tau$ | (all channels) |
| $Z,\gamma^* \to ll$ | (ll) |
| tt | (all channels) |
| tW | (all channels) |
| bb | (eμ,ll,lj) |
| W+jet | (lj,jj) |
| QCD | (jj) |

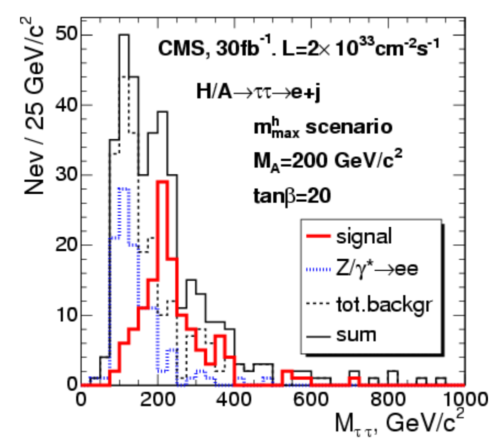
Background suppression after HLT:
- lepton isolation
- τ-jet identification (isol etc.)
- τ-tagging (tau impact param.)
- b-tagging
- jet veto
- positive neutrino energy

**Selections include single b tagging, thus selecting gg->bbA/H production process**

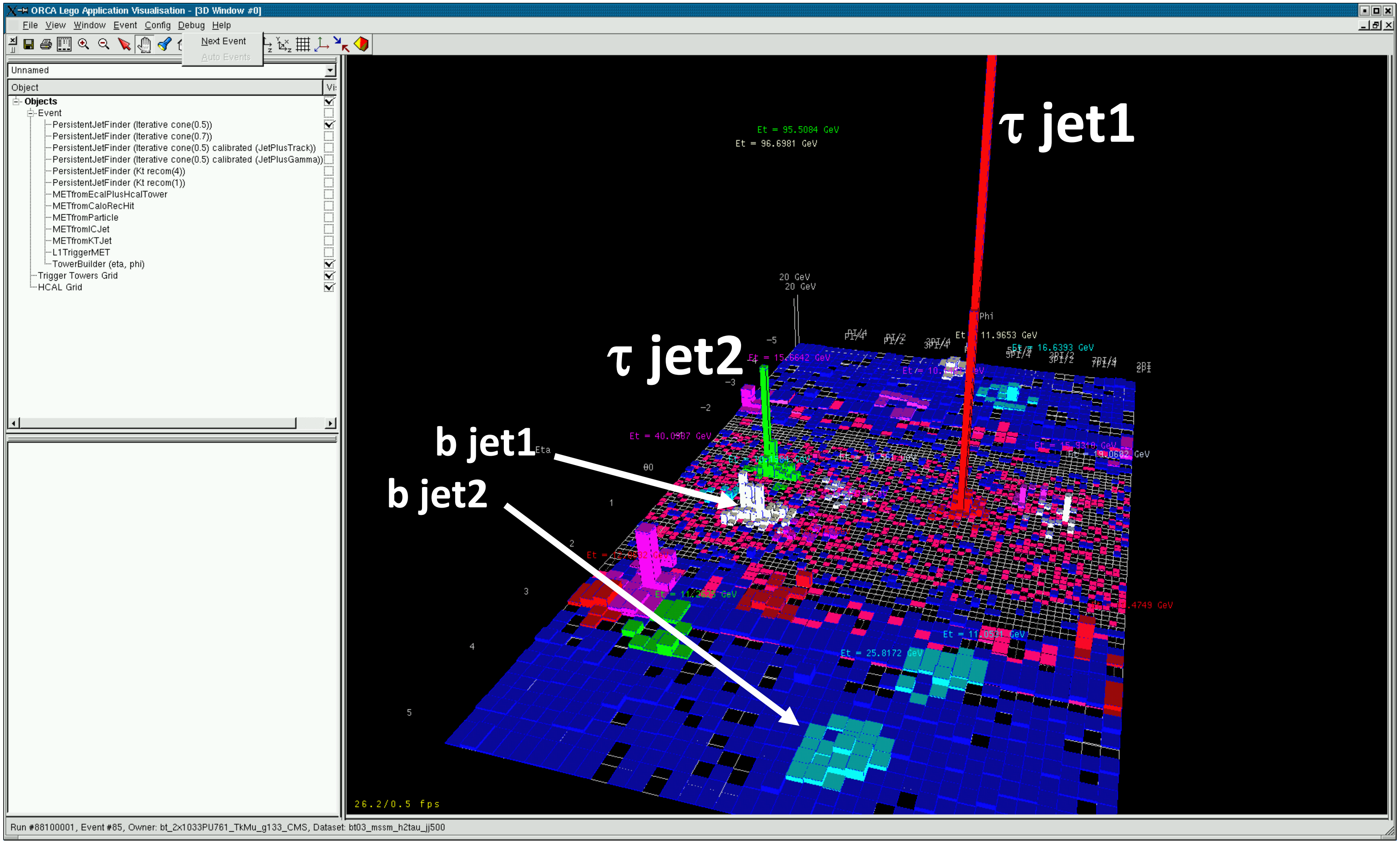
**$m_{\tau\tau}$ with e/μ+j and j+j modes after selections**



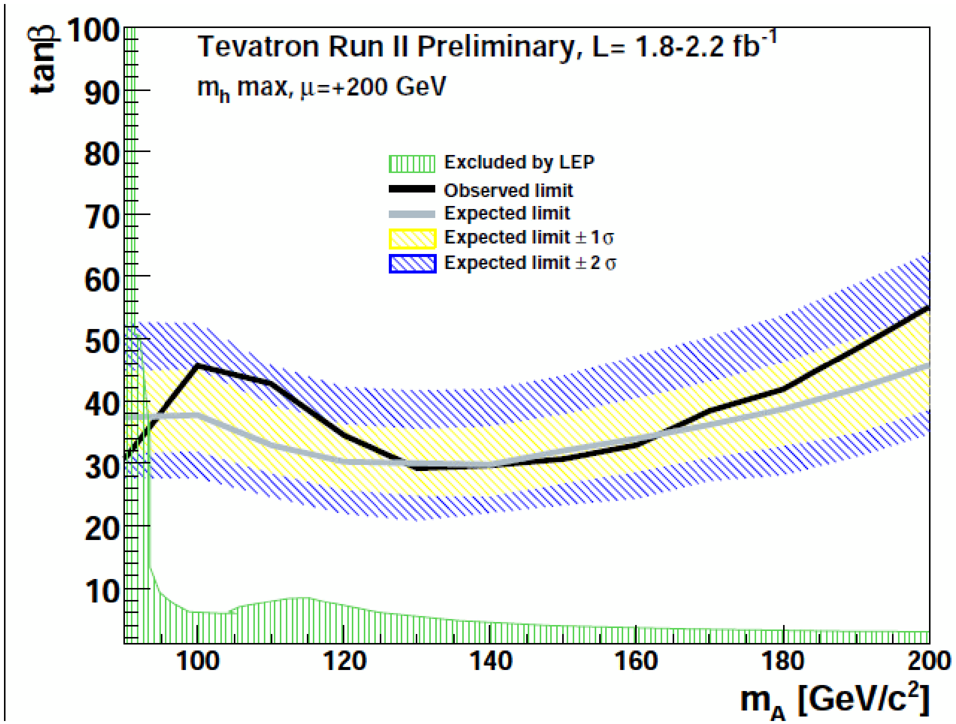



# A->2τ->2jet is most challenging  topology due to multi-jet backgound

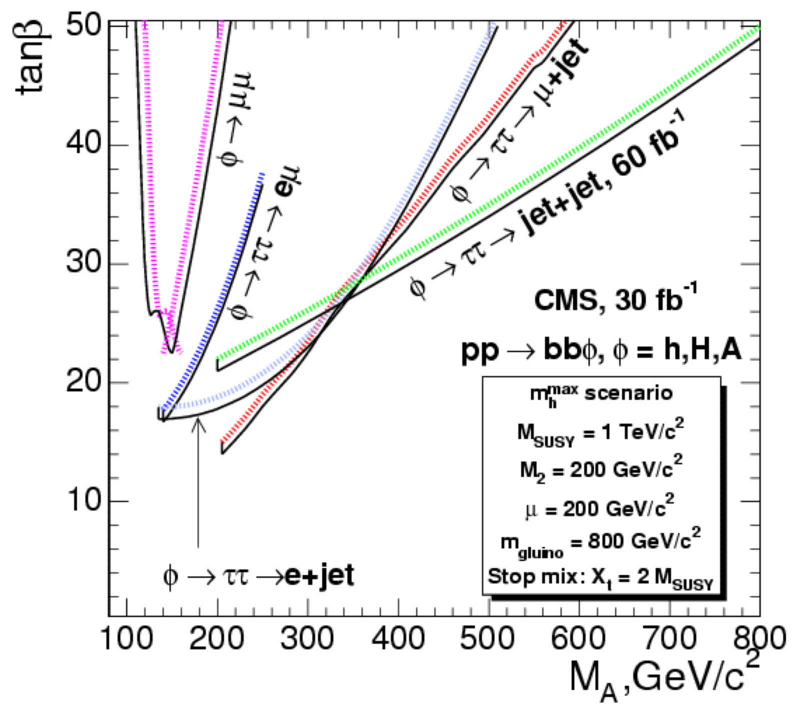


# MSSM neutral Higgs bosons: Teatron vs LHC

## Tevatron exclusion region

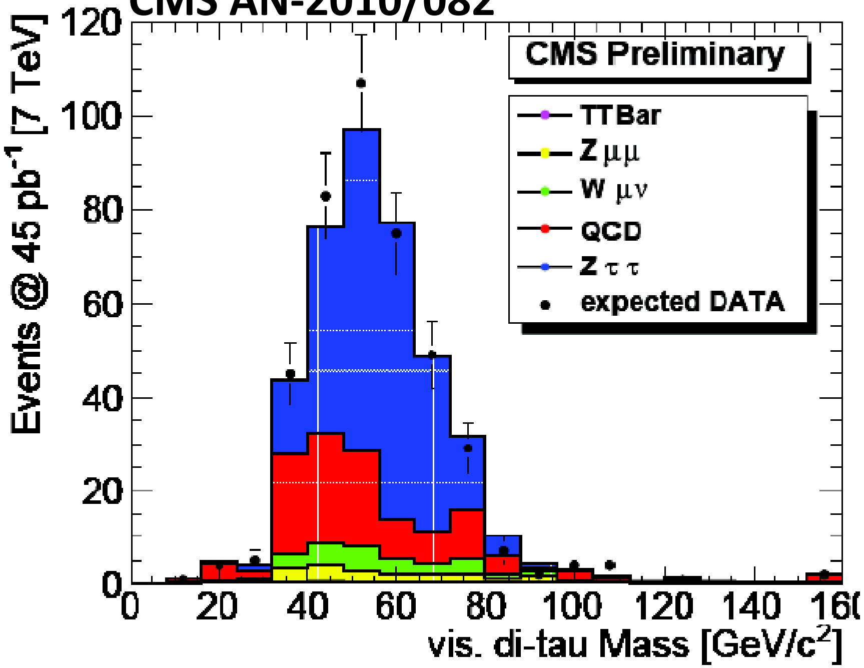


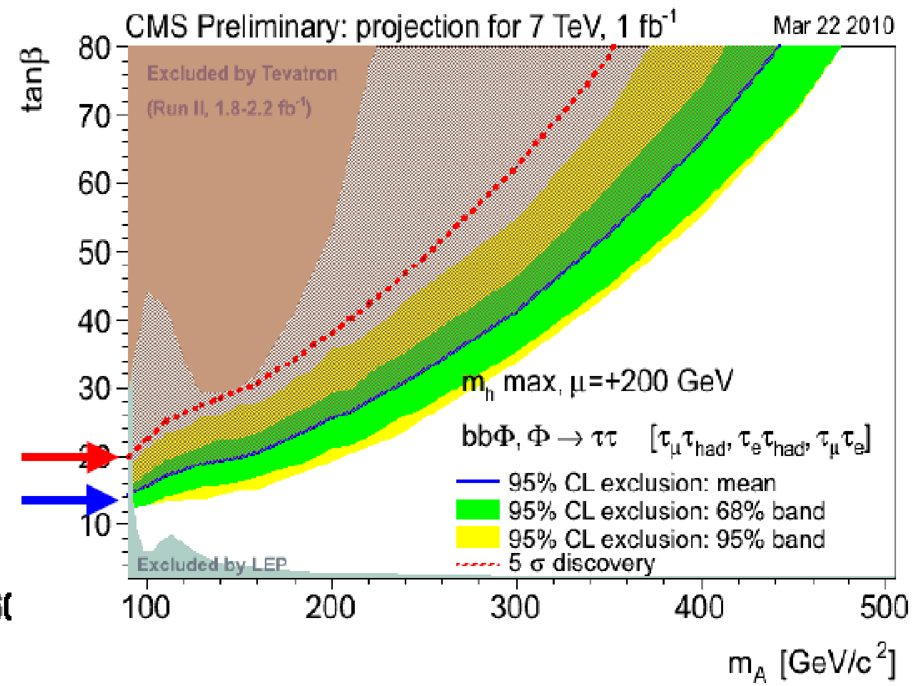

## CMS 5σ discovery region



# Preparation for pp->(bb)$\phi$, $\phi$->$\tau\tau$ discovery with 7 TeV data

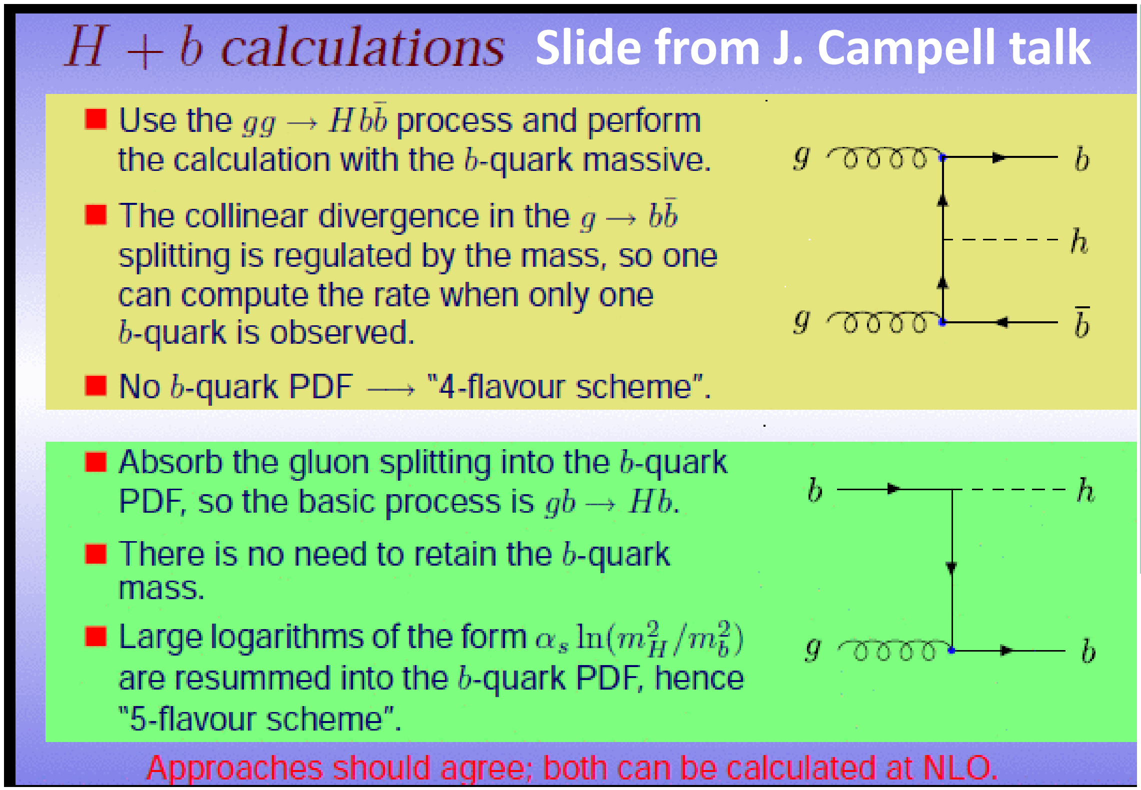
- “discover” Z->$\tau\tau$ => limits in $M_A$-tan$\beta$ for $M_A$ < 200 GeV =>exploit both gg->$\phi$ and bb$\phi$ production

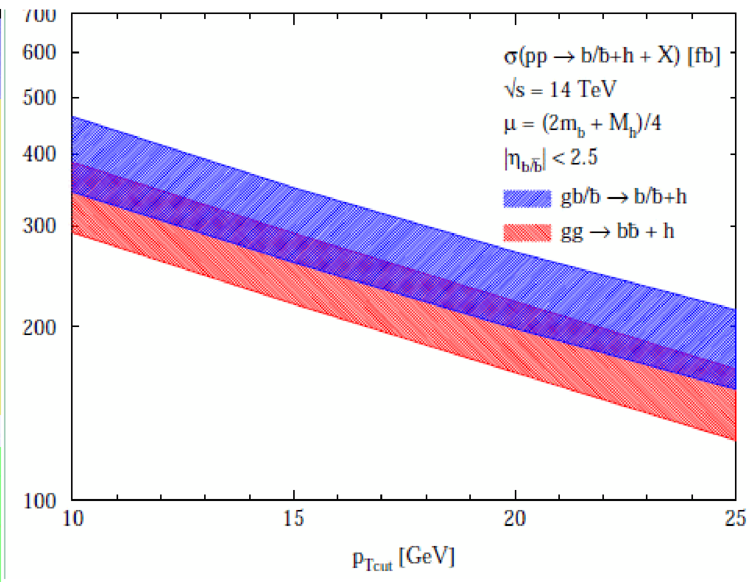



- Measure Z + b as benchmark for H + 1b
- Z->$\tau\tau$ mass shape from Z->$\mu\mu$ data

# H+1 b




**Cut on $p_T^b$, $M_H$=120 GeV**

**Les Houches 2003 (hep-ph/0405302):**

**5F scheme (Campbell, Ellis, Maltoni, Willenbrock);**

**4F scheme (Dittmaier, Kramer, Spira, Dawson, Jackson, Riena, Wackeroth)**

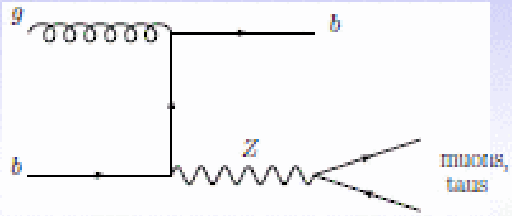
**LHC xs adreed within ~ 20 % uncertainties due to variation of $\mu_F$, $\mu_R$ by factor 2**

# Z+1 b

## $Z + b$ as a test case

**Slide from J. Campbell talk**

- The production of $Z + b$ is very similar to that of $H + b$, even lying in a similar kinematic region for a low mass Higgs.
- Theoretically, the two processes have the same inputs and uncertainties.
  - same initial state, similar $(x, Q^2)$
  - the same $H$ and $Z$ decays




- Test the experimental analysis procedure by re-discovering the $Z$ –

  a) $Z+$ one jet which is b-tagged;

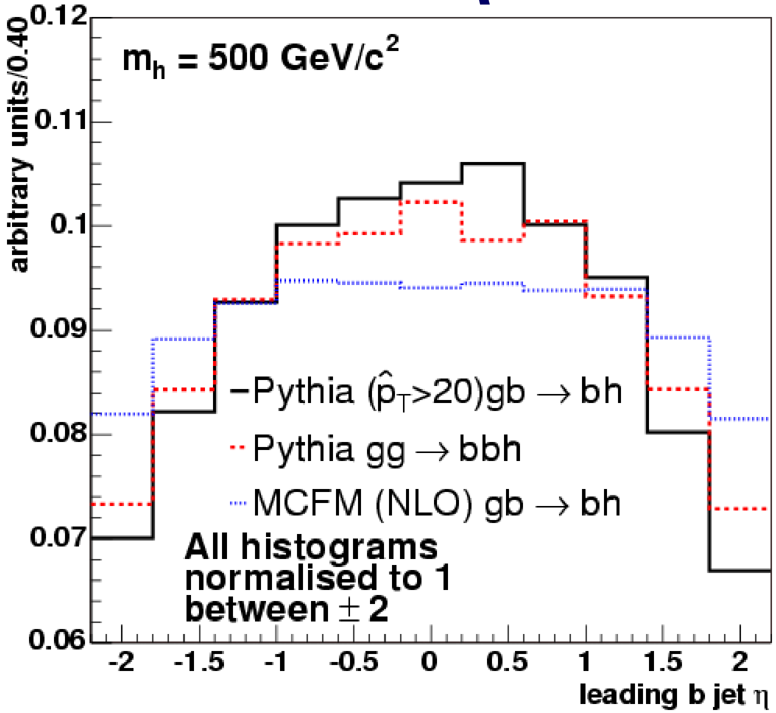
  b) $Z+$ two jets, one or more b-tags.

- Furthermore, for low Higgs masses a significant source of background events could come from the production of a slightly off-shell $Z$ boson and a bottom quark at high $p_T$.

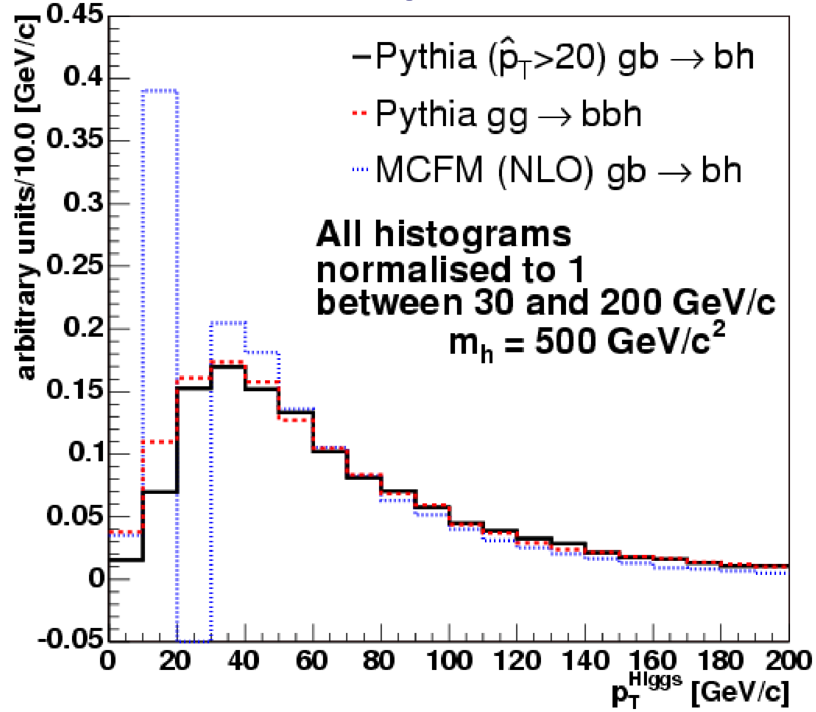
# Different MCs for b(b)H production gives different predictions: => need bbZ data to tune/verify Monte Carlo

Campbell, Kalinowski and Nikitenko; Les Houches 2005 hep-ph/0604120

$\eta^b$




$p_T^H$




PYTHIA gg->bbH describes $p_T^b$ spectra at NLO within 5-10 %;

Kinnunen, Lehti, Moortgat, Nikitenko, Spira. Eur.Phys.J. C40n5:23-32,2005

# want to measure Z + 1(2) b + X

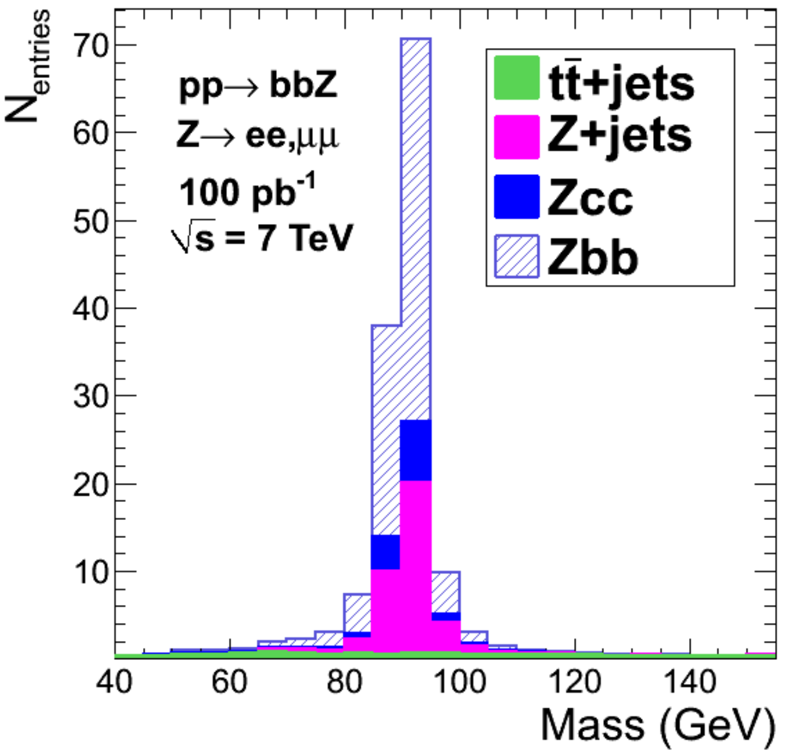
- at least 1 b tagged jet
  - Campbell, Ellis, Maltoni, Willenbrock, McElmurry hep-ph/0312024, hep-ph/0505014. $m_b = 0$
- at least two jets with at least 1 b-tagged jets
  - Campbell, Ellis, Maltoni, Willenbrock hep-ph/0510362, $m_b=0$
- at least two jets with 2 b-tagged
  - Cordero, Reina, Wackeroth arXiv:0906.1923 [hep-ph],massive b
- *MagGraph generator preselections (agreed with F. Maltoni):*
  - *LO gg->bbZ with massive b; $p_T^b$ > 10 GeV for at least one b*
  - *corresponding $\sigma$ NLO needs 4- and 5-flavour merging. L. Rieina, F. Cordero – work in progress*

# CMS expectations for Z+1b at 7 TeV

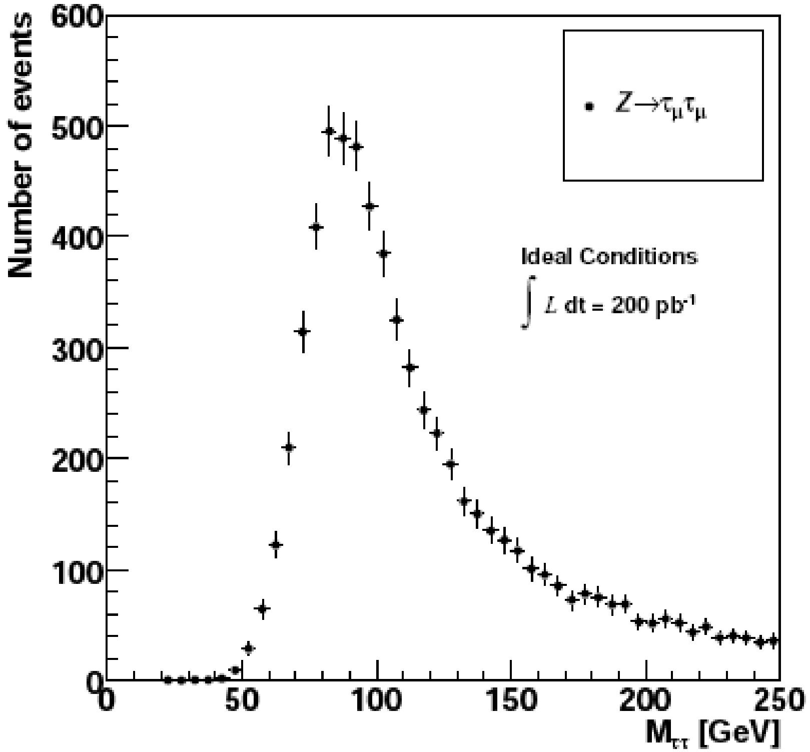
## *(rescaling of 10 TeV result)*

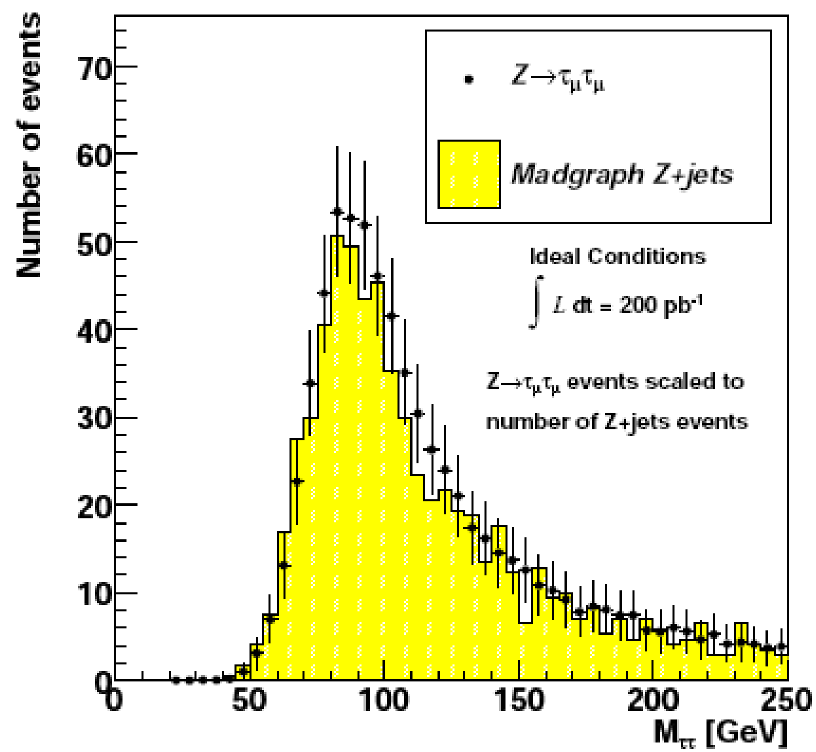
A.M. Magnan, A. Nikitenko . CMS Analysis Note 2010/027
A. Nayak, T. Aziz, A. Nikitenko, CMS Analysis Note 2008/020

- 2 $l$ $p_T$ > 20 GeV, $|\eta|$<2.1
- $E_T^{miss}$ < 40 GeV
- >= 1 b-jet, $E_T$>15 GeV, $|\eta|$< 2.1
- $N_S$ = 84 ev.
- *Background:*
  - *Z+jets: 39 ev.*
  - *Z+cc: 14 ev*
  - *tt~: 15 ev*



- $Z \to \tau\tau$ mass shape from $Z \to \mu\mu$ data
  - replace $\mu$ by generated $\tau$




**Expectation for 200 $pb^{-1}$**

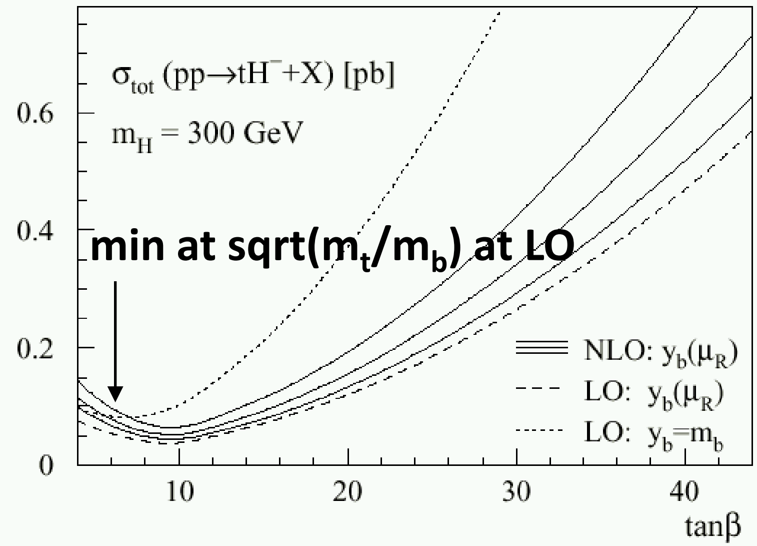
# MSSM charged Higgs boson: $m_{H+} < m_t$ and $m_{H+} > m_t$

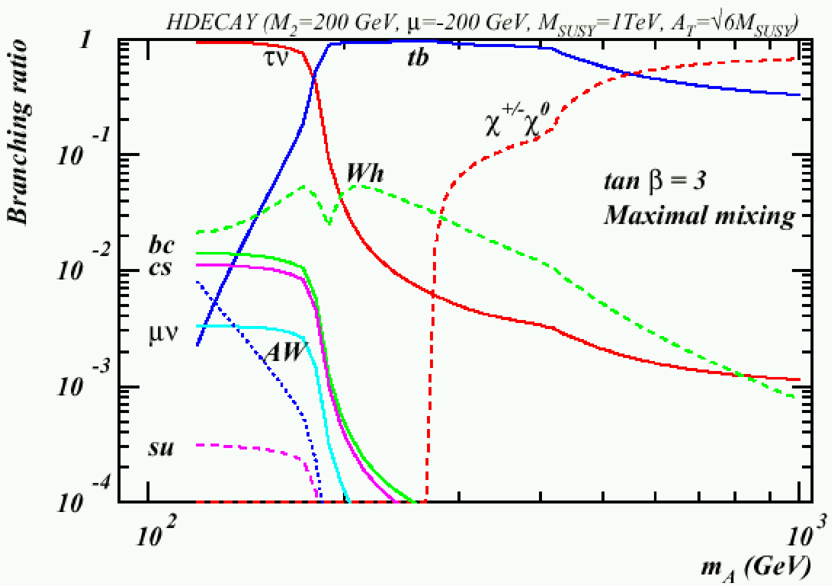
# MSSM charged Higgs boson

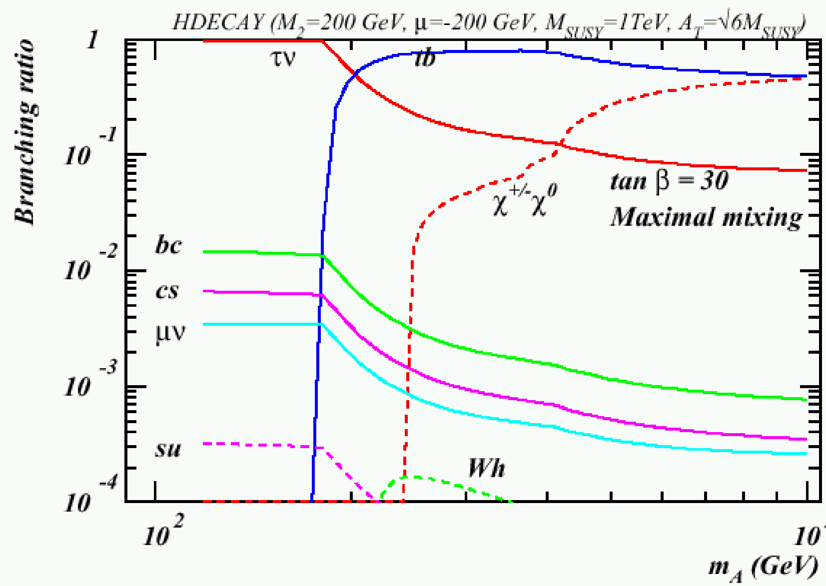
**$m_H > m_t$**

MSSM charged Higgs.
Cross-section and branching ratios

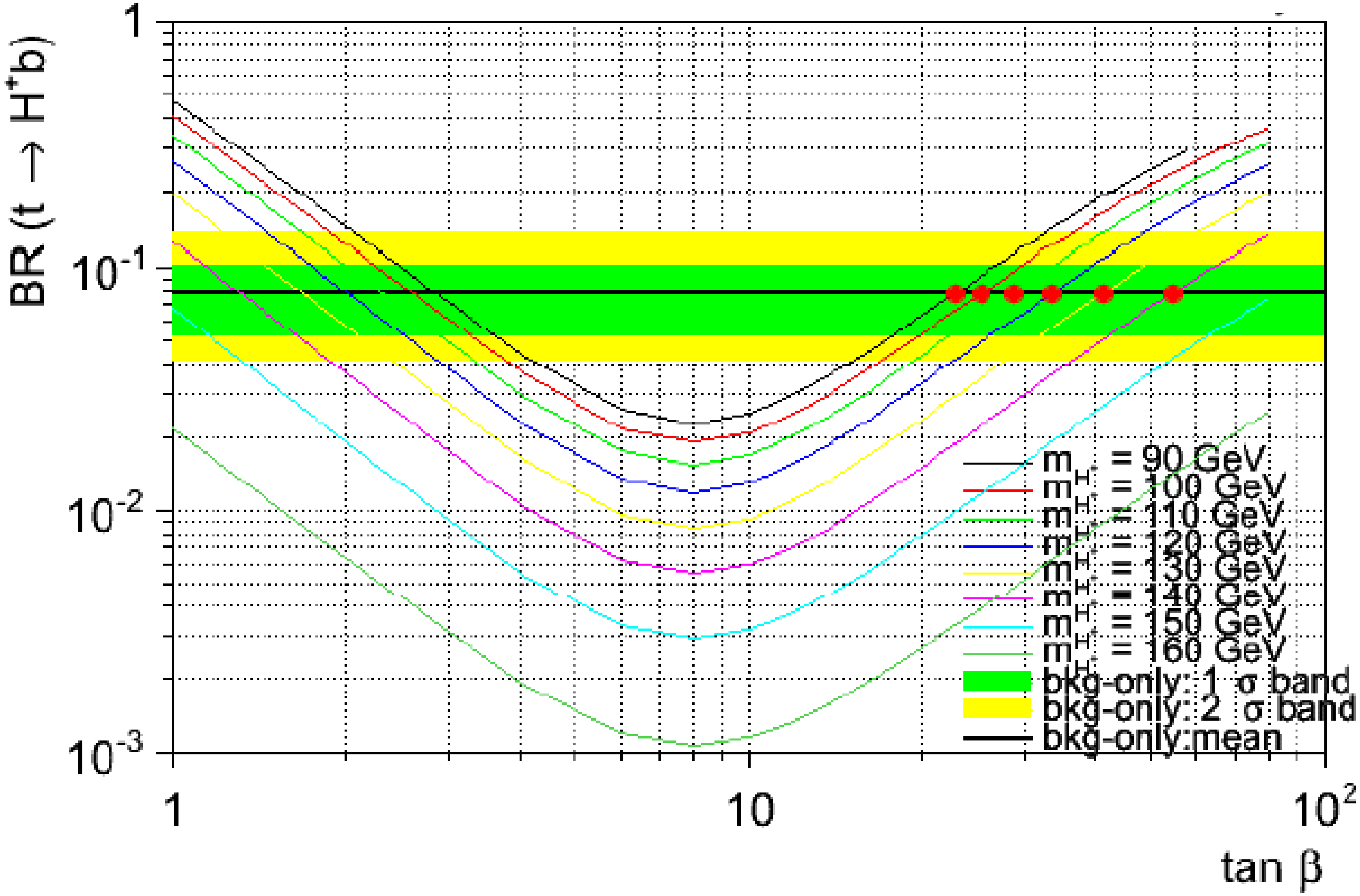
NLO cross-section for gb->tH$^+$
is available (T. Plehn 2003)



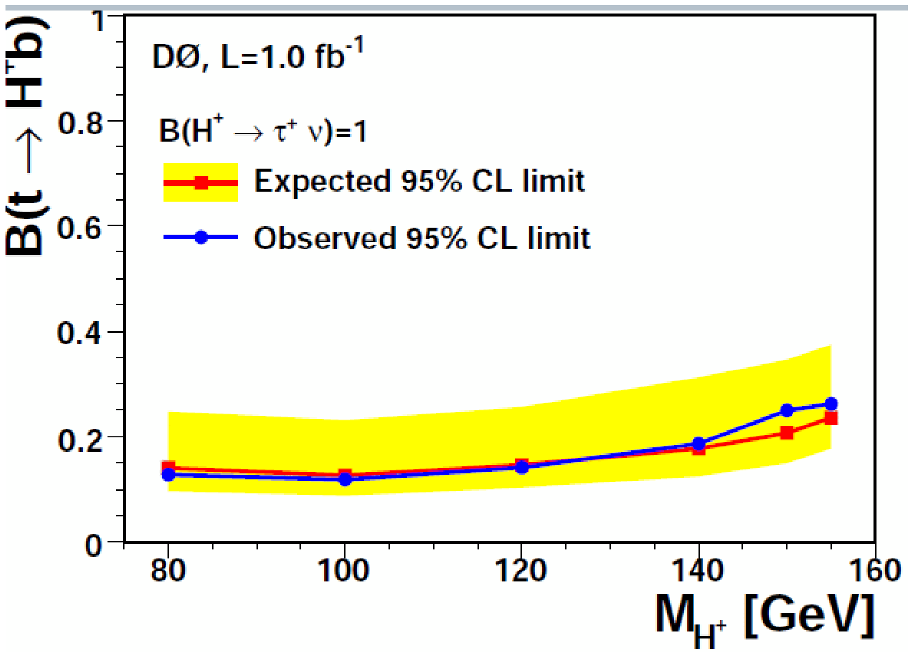



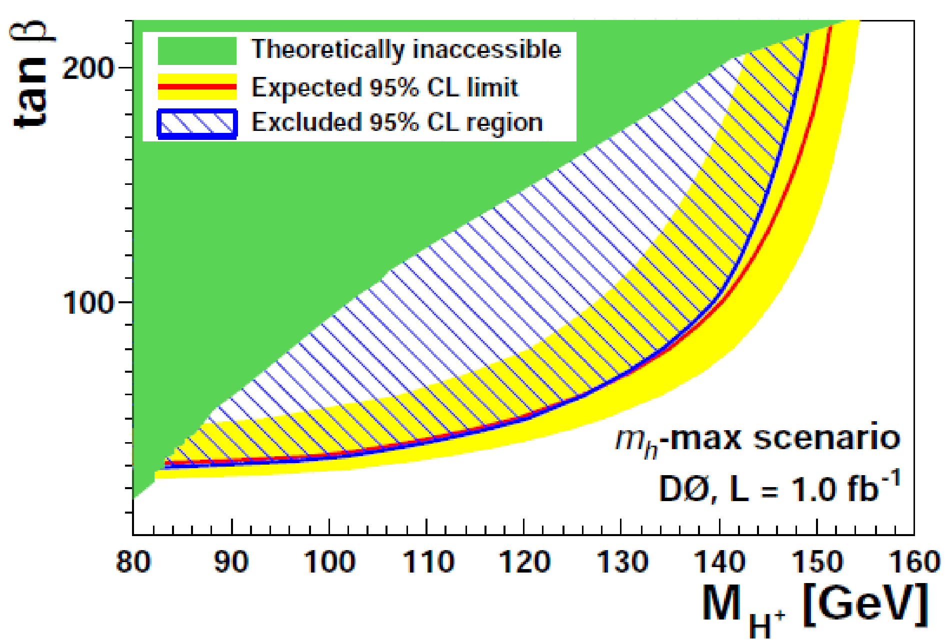



# $M_{H+} < M_t$,   tt->$H^+$bWb
# Br (t->$H^+$b):



# Light charged Higgs: tt->WbH$^+$b: Tevatron limits



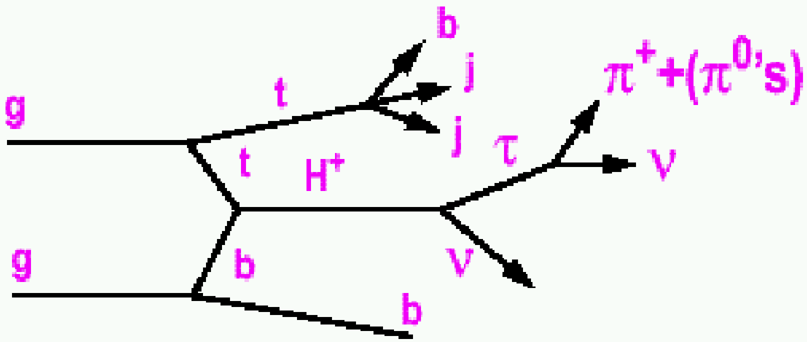



# Search for heavy charged Higgs in pp->tH$^+$, H$^+$->$\tau\nu$

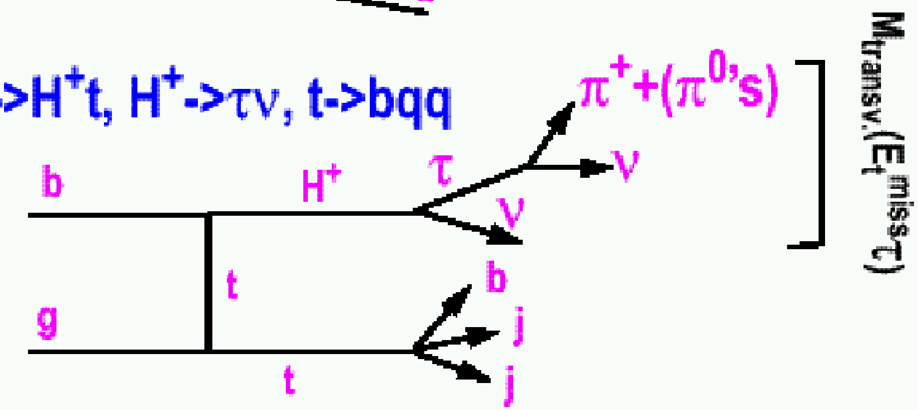
The channel H$^+$->$\tau\nu$ ->h + $E_T^{miss}$+X from pp->tH$^+$, t->qq'b production is potentially the best channel to look at massive H$^+$

**Backgrounds : tt~, Wt, W+jets.**

a) gg->H$^+$tb, H$^+$->$\tau\nu$, t->bqq




b) gb->H$^+$t, H$^+$->$\tau\nu$, t->bqq

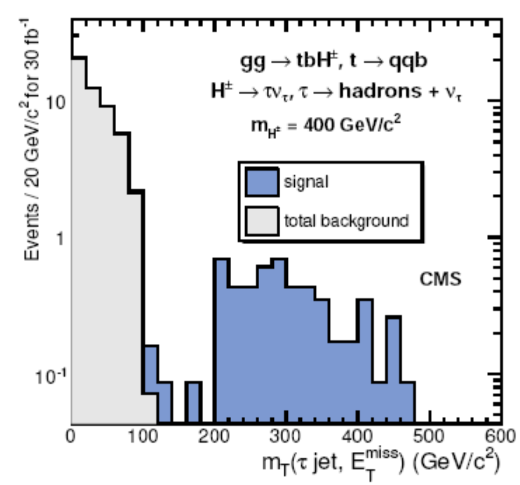



❑ **Method :**

- use t->bjj so that $E_t^{miss}$ gets contribution "only" from Higgs decay
- Jacobian peak

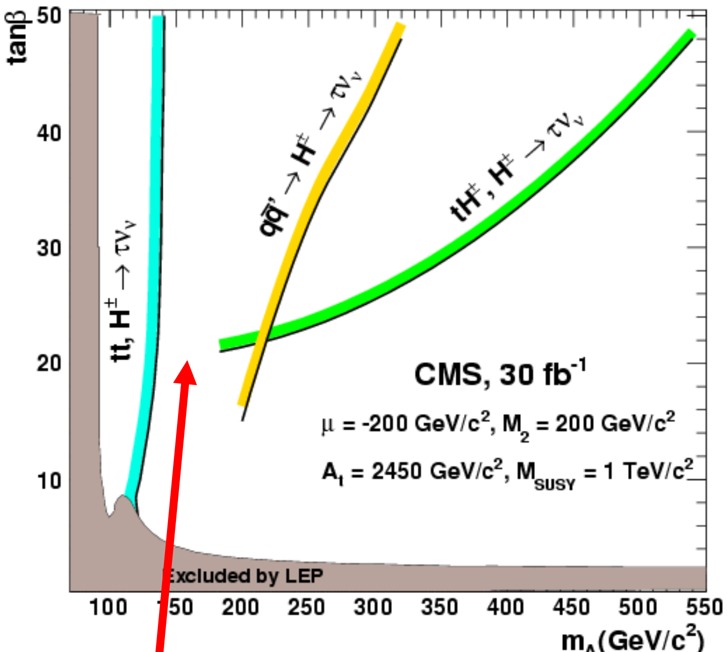
***Selections 2006:***

$E_T^{miss}$ > 100 GeV
$E_T^{\tau\ jet}$ > 100 GeV
$\tau$ polarization:
  $R_\tau = p^{ltr}/E^{\tau\ jet} > 0.8$
$M_{top}$ + b tagging
veto of 4$^{th}$ jet
$E_T^{Higgs}$ > 50 GeV

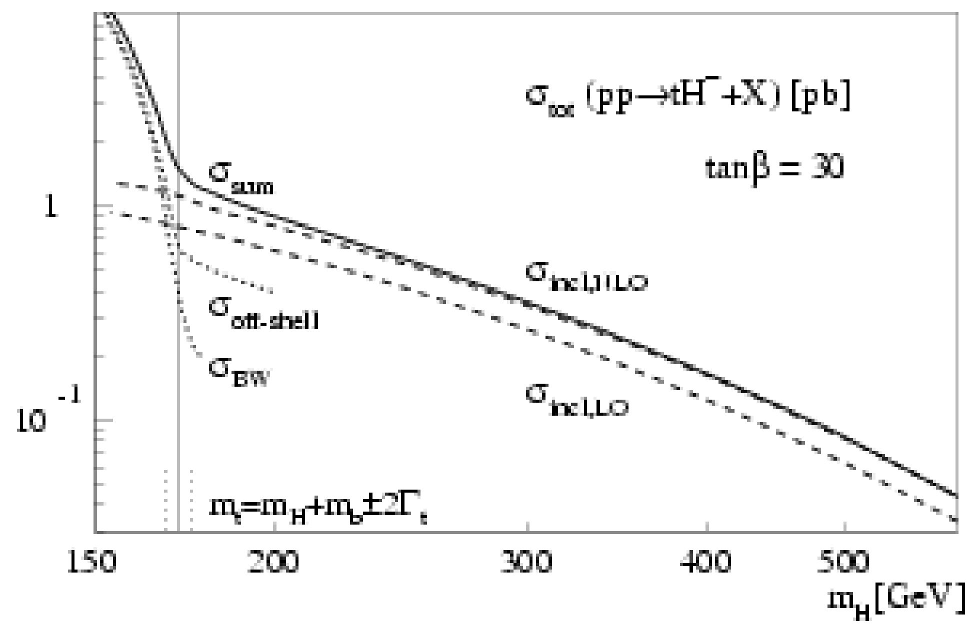


# The 5 $\sigma$ discovery reach of CMS 2003 for MSSM charged Higgs bosons with $m_h^{max}$ scenario.

**CMS Note 2003/033**




**NLO cross section for pp->tH$^-$ +X**




Gap at $M_{H+}$ ~ $M_t$ is artificial due to usage of gg->tt (NWA) cross section

gg->tbH+ process is available in PYTHIA (S. Moretti et al. Les Houches 2003)
NLO cross section (no $\Delta_b$ SUSY corrections) : T. Plehn et al., hep-ph/0312286

# The 5 σ discovery reach of CMS 2006 (PTDR) for MSSM charged Higgs bosons with $m_h^{max}$ scenario.

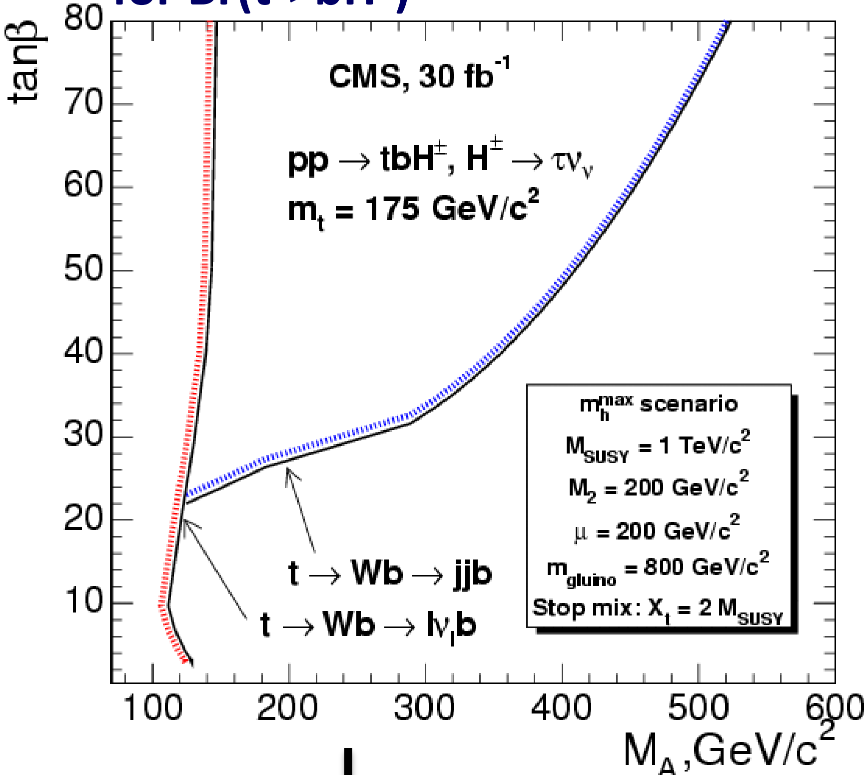
**NLO cross-section, but**

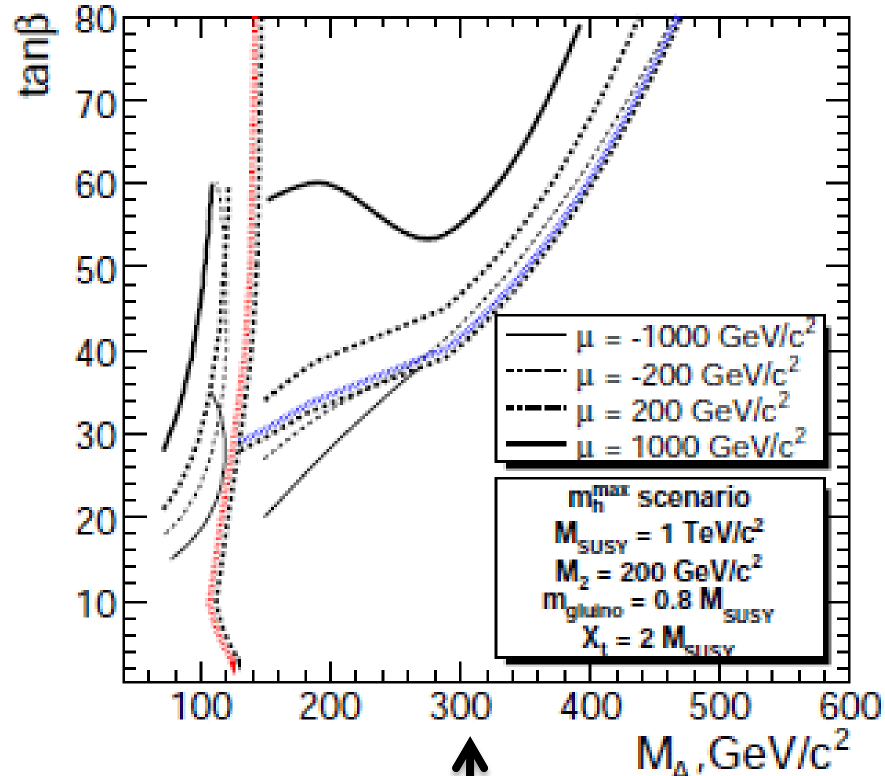
**no $\Delta_b$ SUSY corrections included in PTDR results, no running $m_b$ for Br(t->bH⁺)**

**Post PTDR update**

**M. Hashemi et al.**

**arXiv:0804.1228 [hep-ph]**

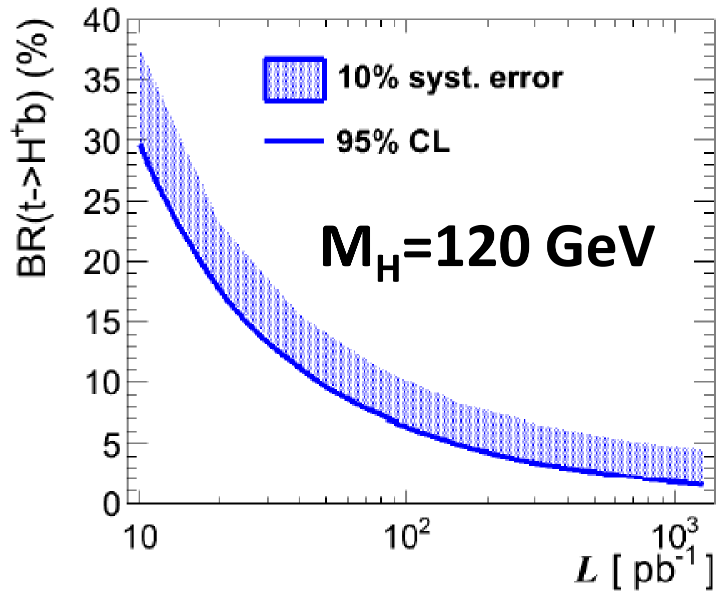


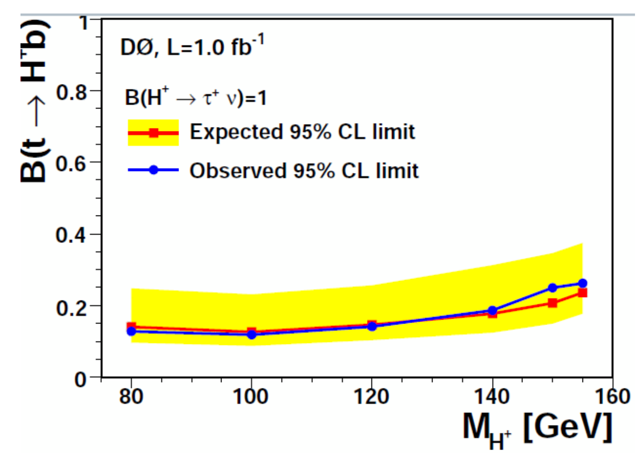




**$\Delta_b$ SUSY corrections and running $m_b$**

# Plan of action for 7 TeV data in tt->bH+Wb-> l$\nu$ $\tau_{had}\nu$ bb analysis (LIP)

- **1-10 pb$^{-1}$:**
  - study $\tau$ fake rate in multi-jet samples
  - lepton/jets/MET
  - validate data-driven bkg method with W+jets
- **10-100 pb$^{-1}$:**
  - estimate fake $\tau$ background
  - look at ttbar events (with/without taus)
- **100-500 pb$^{-1}$:**
  - establish signal/set limits



Very reach program for Higgs physics with $\tau$s !

THE END

# Uncertainties involved in the $\tan(\beta)$ measurement

At large $\tan(\beta)$, $\sigma$ x Br ~ $\tan^2(\beta)_{eff}\, f(M_A)$ at fixed $\mu$, $M_2$, $A_t$, $M_{SUSY}$

$$N_S = \tan^2(\beta)_{eff}\ f(M_A)\ L\ \varepsilon_{sel}$$

$$\tan(\beta) = \tan(\beta)_{mes} +/- \Delta_{stat} +/- \Delta_{syst} +/- \Delta_{MCgen}$$

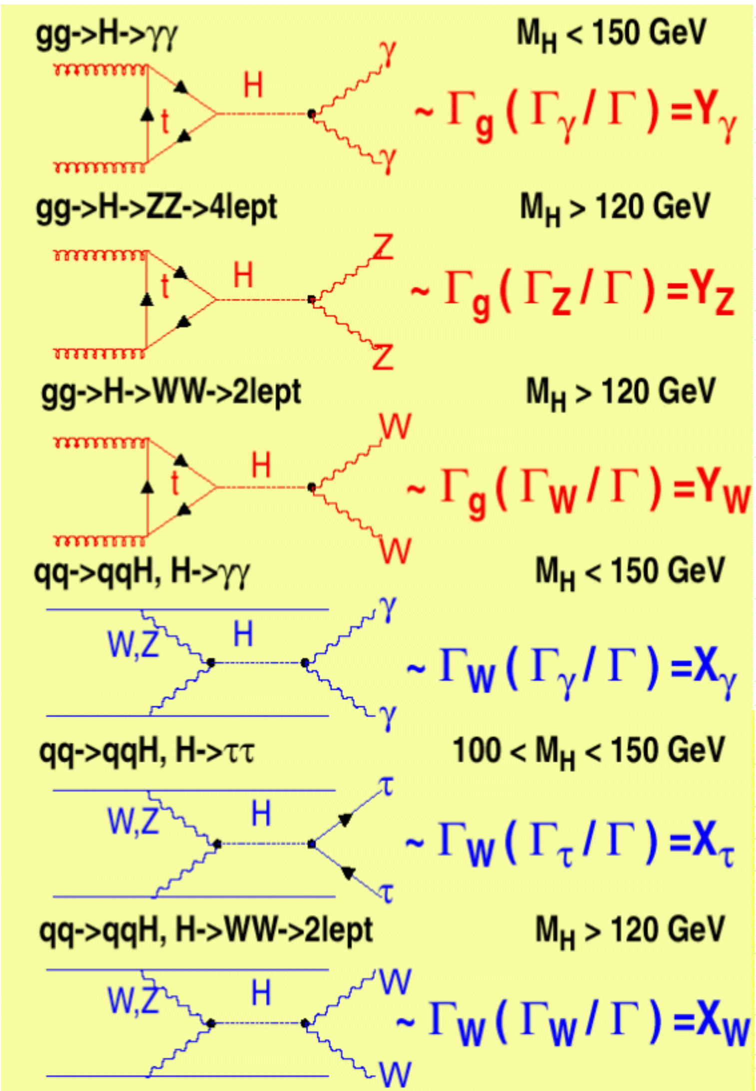
$$\Delta_{syst} = 0.5\ \mathrm{sqrt}(\Delta L^2 + \Delta\sigma_{th}{}^2 + \Delta Br_{th}{}^2 + \Delta\sigma(\Delta M_H)^2 + \Delta\varepsilon_{sel}{}^2 + \Delta B^2)$$

$\Delta\sigma_{th}$ = 20 % due to NLO scale dependence
$\Delta Br_{th}$ = 3 % uncertainties of SM input parameters
$\Delta L$ = 5 % luminosity uncertainty
$\Delta\sigma(\Delta M_H)$ = 10-12 % due to mass measurement at 5$\sigma$ discovery limit
$\Delta B = \Delta N_B / N_S$ = 10 % at 5$\sigma$ discovery limit (preliminary)

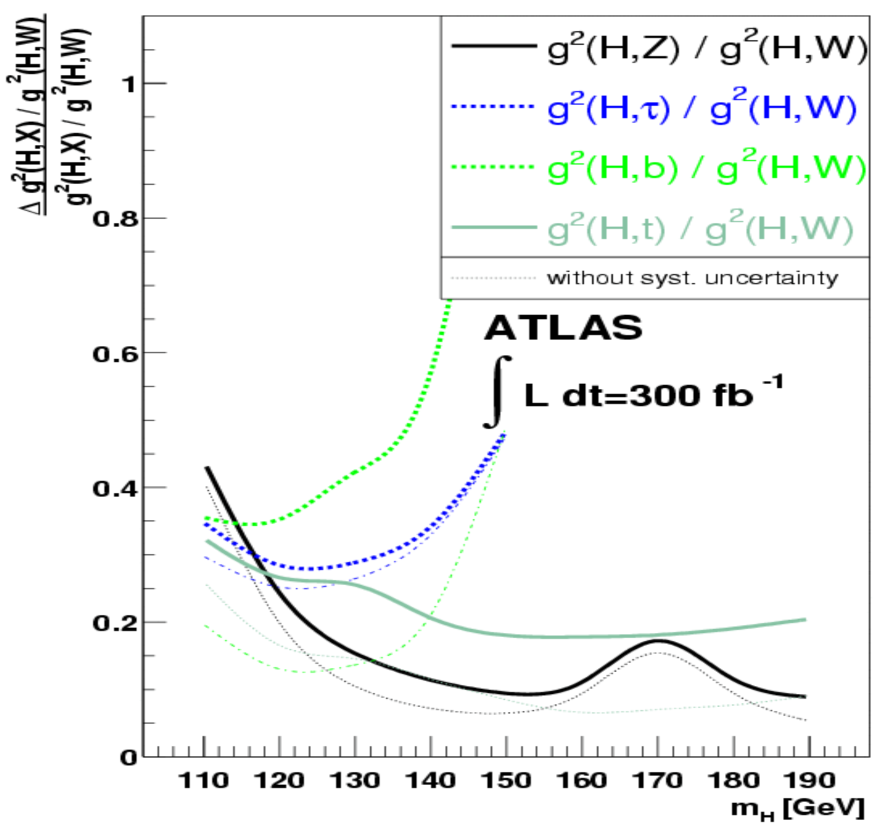
$$\Delta\varepsilon_{sel}{}^2 = \Delta\varepsilon_{calo}{}^2 + \Delta\varepsilon_{b\ tag}{}^2 + \Delta\varepsilon_{\tau\ tag}{}^2$$

**$\Delta\varepsilon_{b\ tag}$ = 2.0 % (preliminary)**
**$\Delta\varepsilon_{\tau\ tag}$ = 2.5 % (preliminary)**
**$\Delta\varepsilon_{calo}$ = 2.9 % (preliminary)**

# Measurement of the SM Higgs boson couplings




ATL-PHYS-PUB-2003/030

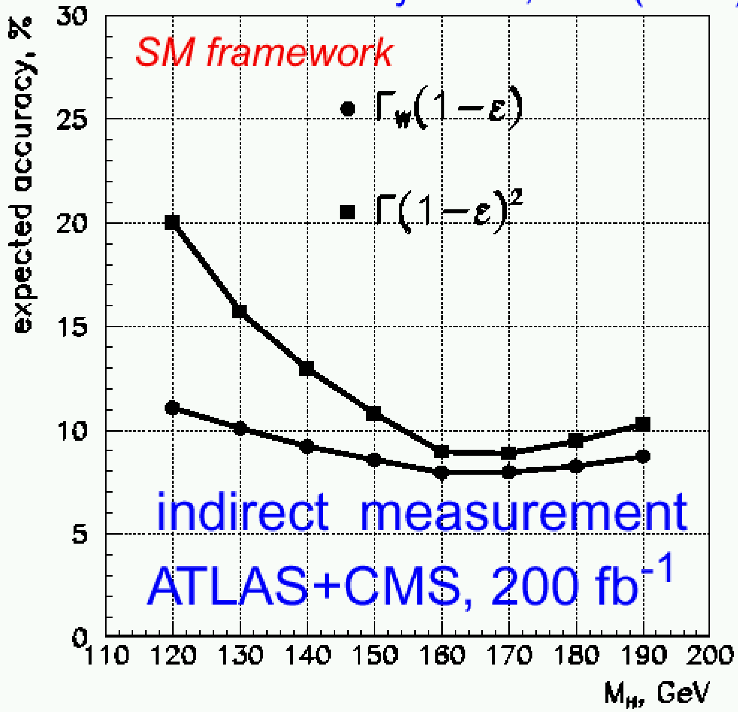


# SM Higgs physics with 100-300 $fb^{-1}$ (II)

- **precise measurement of width**

  qq->qqh. h->2γ,WW$^{(*)}$, 2τ together with gg->WW$^{(*)}$ allows indirect measurement of Higgs width

  D. Zeppenfeld, R. Kinnunen, A. Nikitenko E. Richter-Was. Phys.Rev., D62 (2000)



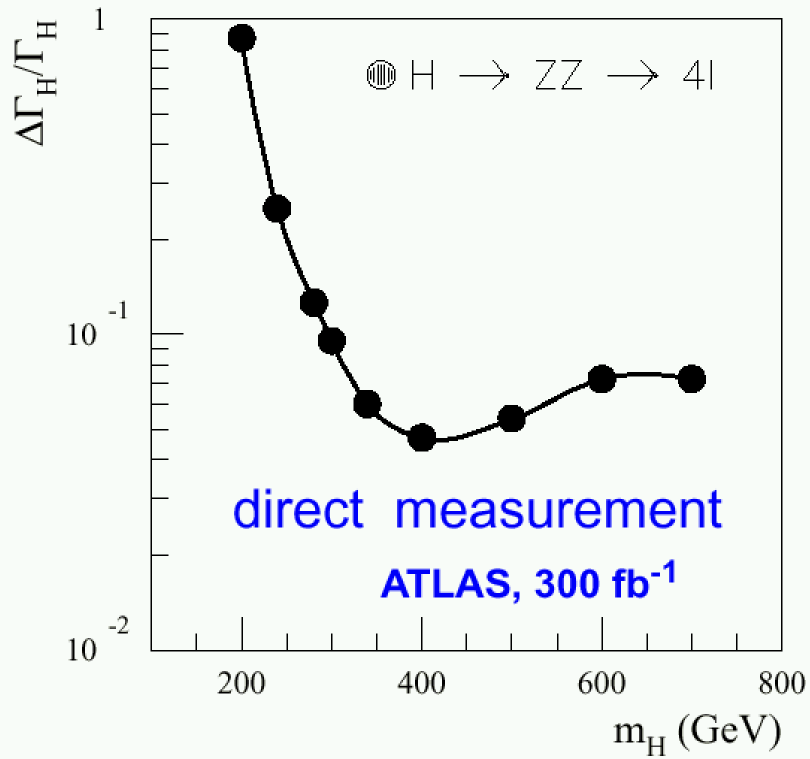

- **observation of other Higgs channels :**

  Wh with h->bb, h->γγ

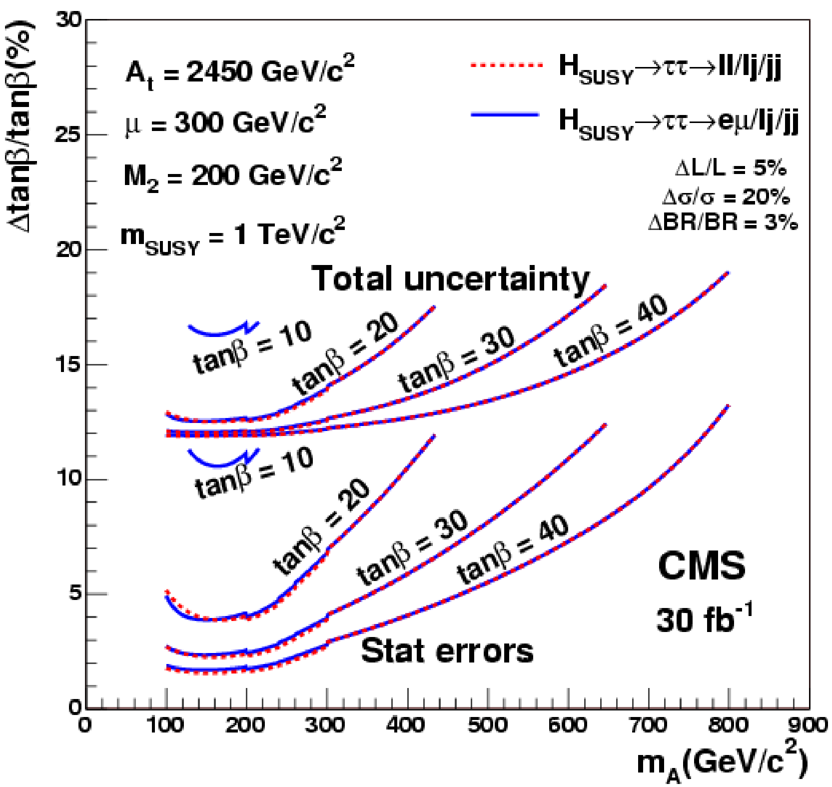
  tth with h->γγ, WW

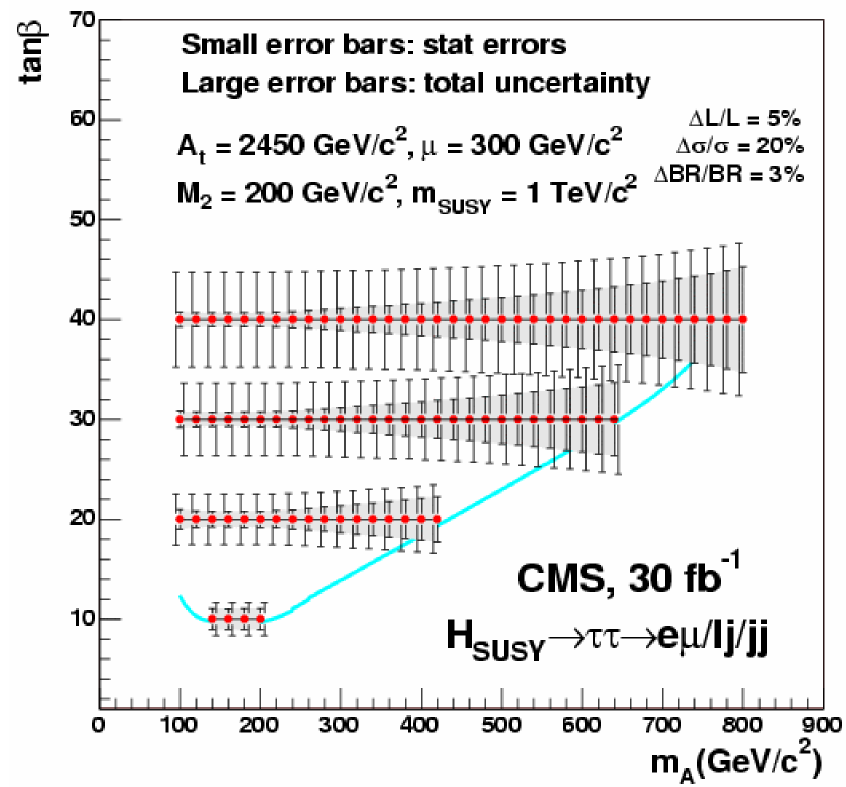
  qqh, with h->μμ (?)

- **self couplings; h->hh (?)**



# MSSM gg->bbA/H, A/H->2τ : accuracy of tan(β) measurement



# tan(β) "measurement" with MSSM bbA

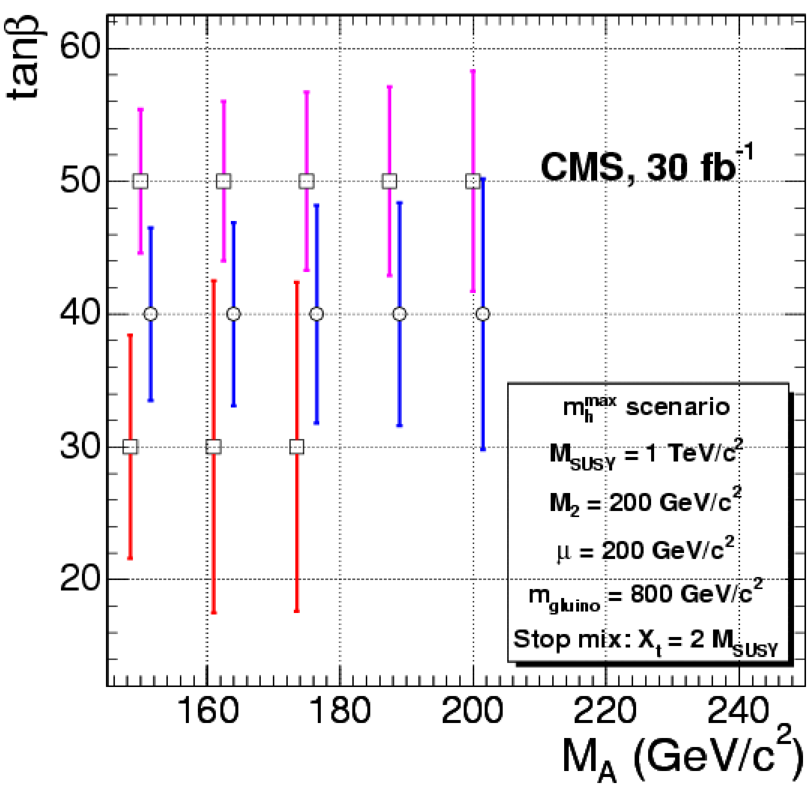
Cross section (and width) exhibits a large sensitivity to tan(β) and thus can add a significant observable to a global fit of the SUSY parameters

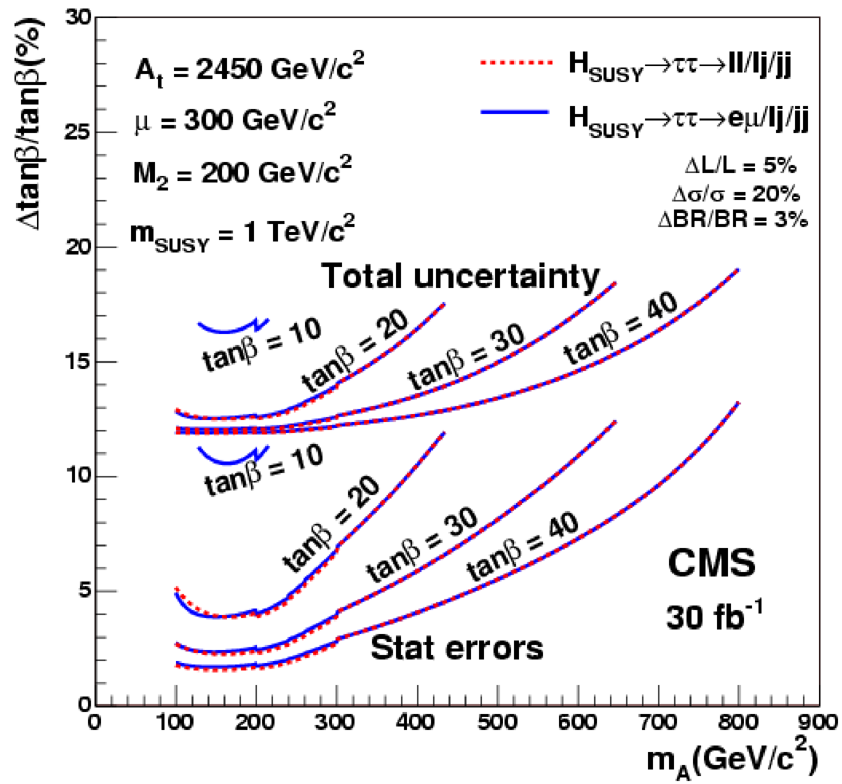
## From width measurement with A->μμ, by G. Masetti, PTDR

## From cross section of A->ττ

R. Kinnunen, S. Lehti, F. Moortgat,
A. Nikitenko, M. Spira. CMS Note 2004/027

Need to be updated for PTDR 2006 results



# PF τ ID efficiency vs η