Review of Higgs in CMS

- Where we are
- What is missing or must be updated for Phys. TDR
- Some new studies since 2003

A. Nikitenko, Imperial College;   LHC Days in Split

SM Higgs boson searches: status and plans for PTDR

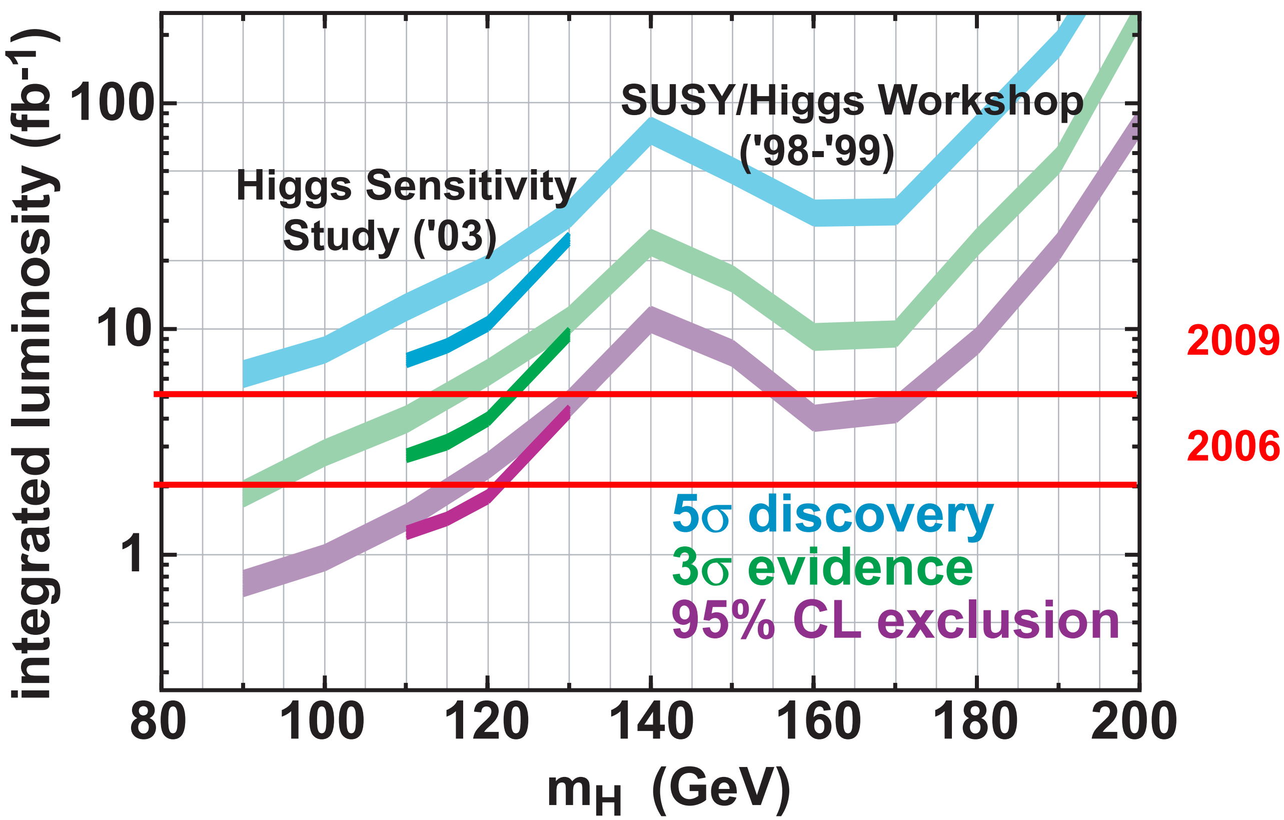
Prospects for Tevatron

SM Higgs at 120 GeV/c^2

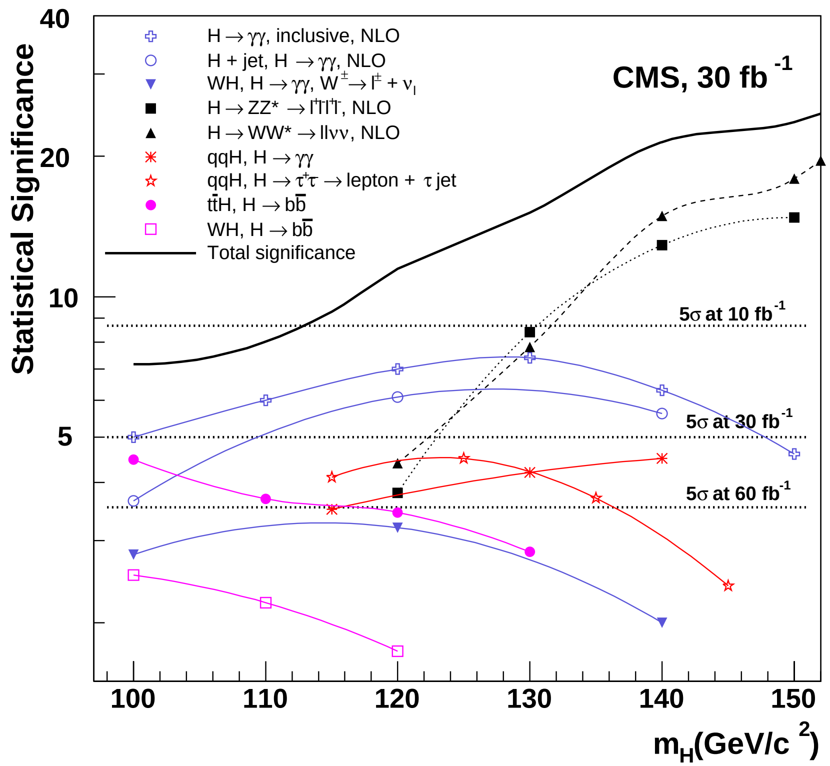
- exclude at 95 % C.L. in 2006

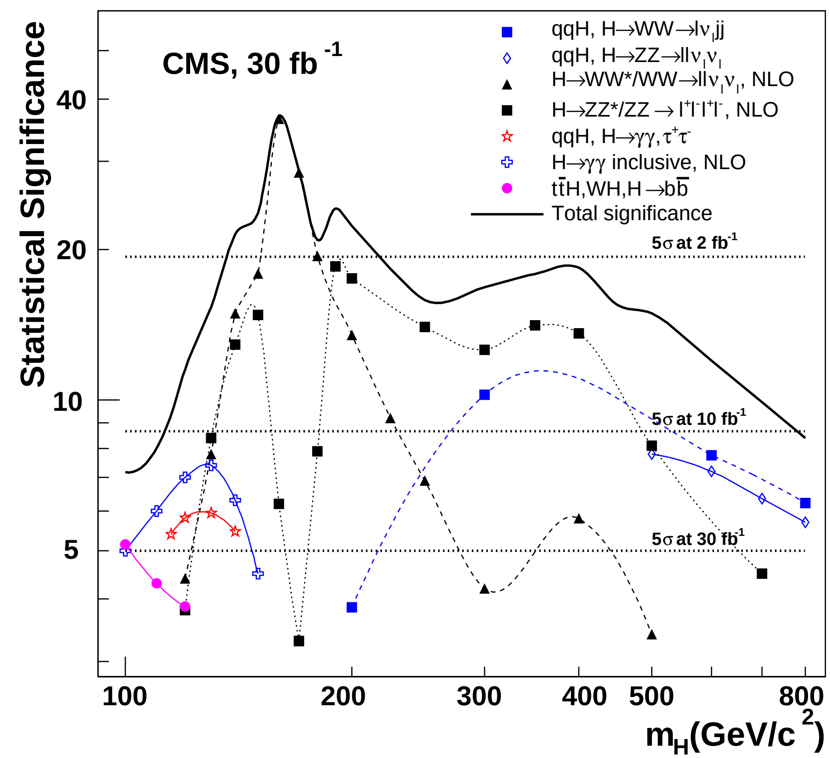
- 3 σ evidence in 2009

B. Heinemann. talk on UK Forum, April 2004



SM Higgs boson discovery potential in CMS. Summary of 2003. (CMS Note 2003/033)





- NLO cross sections for gg->H and related backgrounds
- no systematic uncertainties;
- 10 fb^{-1}: the 5 σ discovery for M_H > 114 GeV/c^2 combining all channels

Possible conservative roadmap in SM Higgs searches

- **10 fb^{-1}:**
  - The 5σ discovery of the Higgs boson with inclusive H->$ZZ^{(*)}$->4*l* and H->$WW^{(*)}$->*ll*
- **30-60 fb^{-1} at low luminosity:**
  - the 5σ observation of the other channels: H->γγ, ttH(H->bb), VBF Higgs channels (qq->qqH)
  - first estimates of the couplings, mass
- **100-300 fb^{-1} at high luminosity:**
  - the 5σ observation of “rare” Higgs channels: WH (H->bb, γγ), ZH (H->γγ), ttH (H->γγ, WW), H->HH, . . .
  - precise measurement of the couplings, width, mass
  - measurement of spin, CP

W/Z/tt~ rates at LHC

Z, W, tt cross sections and expected number of events after trigger in CMS with 10 fb^{-1}

channel, NLO σ x Br	Level-1 + HLT efficiency	events for10 fb^{-1}
W->e ν, 20.3 nb	0.25	5.1 x 10^7
W->μν, 20.3 nb	0.35	7.1 x 10^7
Z->ee, 1.87 nb	0.53	1.0 x 10^7
Z->μμ, 1.87 nb	0.65	1.2 x 10^7
tt~->μ+X, 187 pb	0.62	1.2 x 10^6

Very important to understand Z+nj, W+nj, tt~ as background for Higgs (and SUSY) searches

MC tuning at Tevatron (ME+PS)

J. Campbell, R.K. Ellis, D. Rainwater
hep-ph/0308195

W/Z+nJ+X NLO predictions at LHC with cuts (pb) :

$p_T^l > 15$ GeV
$|\eta^l| < 2.4$
$p_T^j > 20$ GeV
$|\eta^j| < 4.5$
$\Delta R_{lj} > 0.4$
$\Delta R_{ll} > 0.2$

process	σ_{LO}	σ_{NLO}
$e^+\nu_e + X$	5670	6780^{+290}_{-130}
$e^-\bar{\nu}_e + X$	3970	4830^{+210}_{-90}
$e^+e^- + X$	803	915 ± 31
$e^+\nu_e j + X$	1660	1880^{+60}_{-50}
$e^-\bar{\nu}_e j + X$	1220	1420 ± 40
$e^+e^- j + X$	248	288^{+8}_{-7}
$e^+\nu_e jj + X$	773	669^{+0}_{-18}
$e^-\bar{\nu}_e jj + X$	558	491^{+0}_{-7}
$e^+e^- jj + X$	116	105^{+1}_{-5}

W/Z bb + X

$|\eta^b| < 2.5$

process	σ_{LO}	σ_{NLO}
$e^+\nu_e b\bar{b} + X$	$1.30^{+0.21}_{-0.18}$	$3.06^{+0.62}_{-0.54}$
$e^-\nu_e b\bar{b} + X$	$0.90^{+0.14}_{-0.12}$	$2.11^{+0.46}_{-0.37}$
$e^+e^- b\bar{b} + X$	$1.80^{+0.60}_{-0.40}$	$2.28^{+0.32}_{-0.29}$

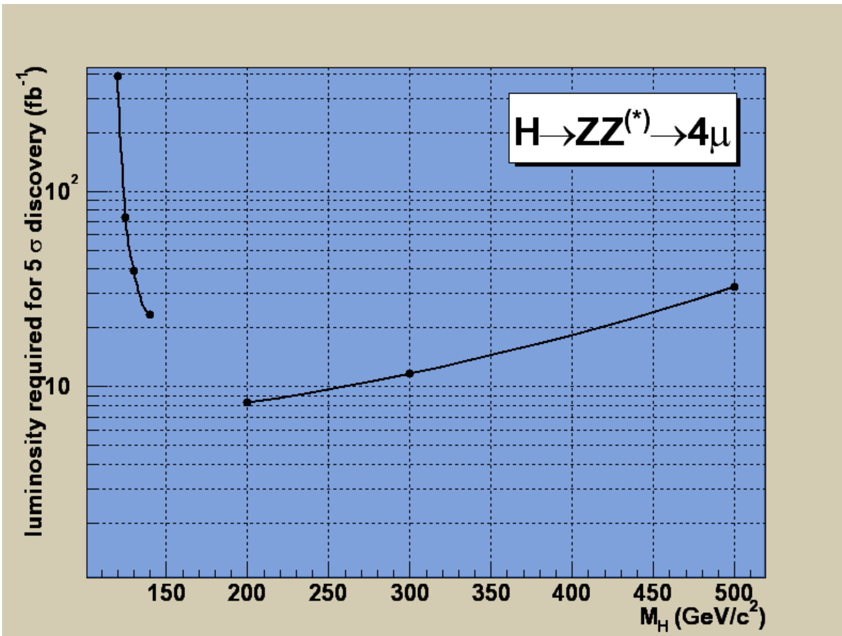
W/Z+nJets as background for Higgs at LHC

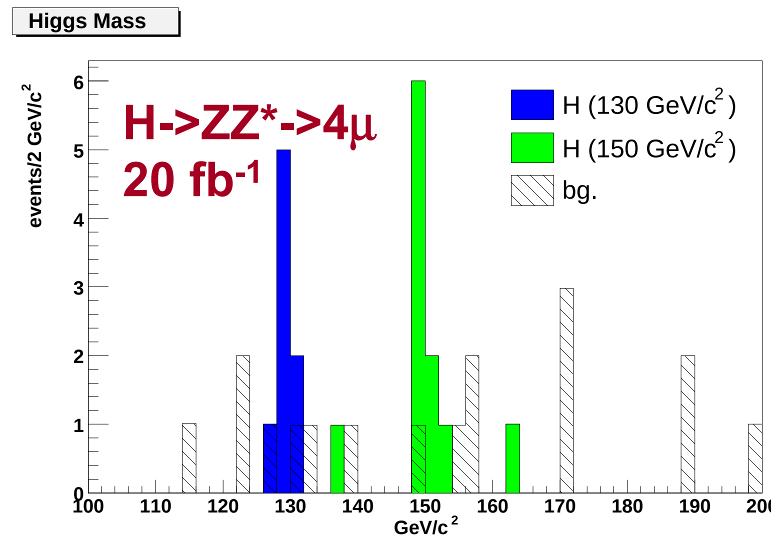
topology	Background for Higgs channel (one example)
W+1j+X	gg->WW*->2l (?)
W+2j+X	MSSM gg->bbH, H->ττ->*l*+jet (one b-tag)
W+3j+X	VBF qq->qqh, h->ττ->*l*+jet + 2 tag. jets
W+4j+X	VBF qq->qqh, h->WW->*l*νjj + 2 tag jets
Z+1j+X	MSSM gg->bbH, H->ττ->l+jet (one b-tag)
Z+2j+X	VBF qq->qqh, h->ττ->*l*+jet + 2 tag jets
Z+4j+X	VBF qq->qqh, h->ZZ->*ll*jj + 2 tag jets

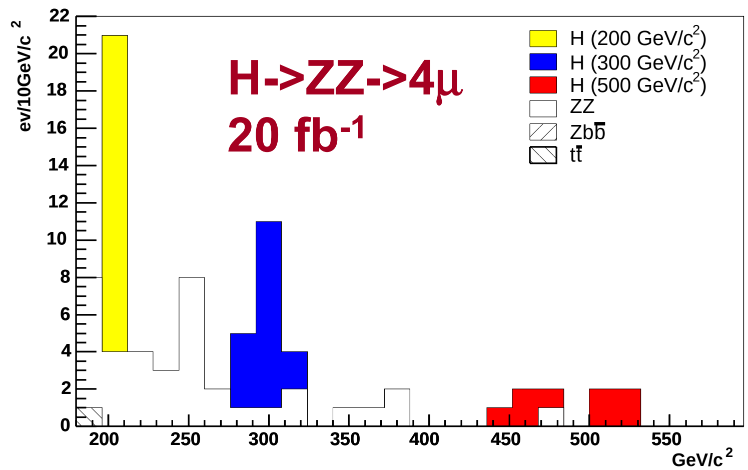
Zbb,Zcc, Wbb, Wcc (W/Z+QQ+nj) are as important as W/Z+nj

The 5σ Higgs boson discovery with 10 fb^{-1}

$H \to ZZ^{(*)} \to 4\mu$ (New results by M. Sani, V. Bartsch et al., 2003)



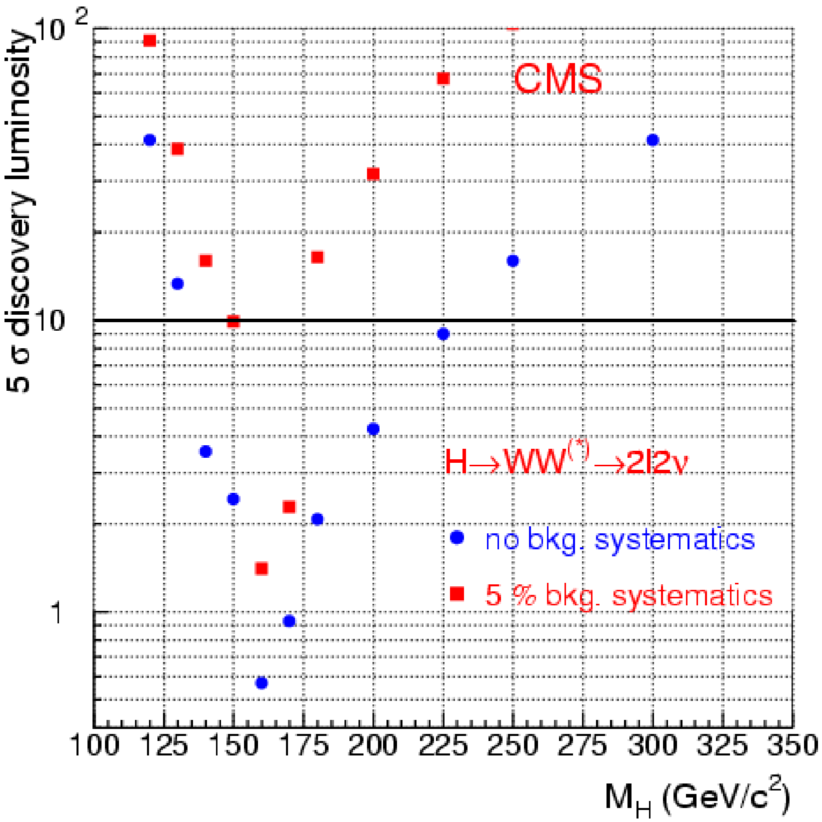




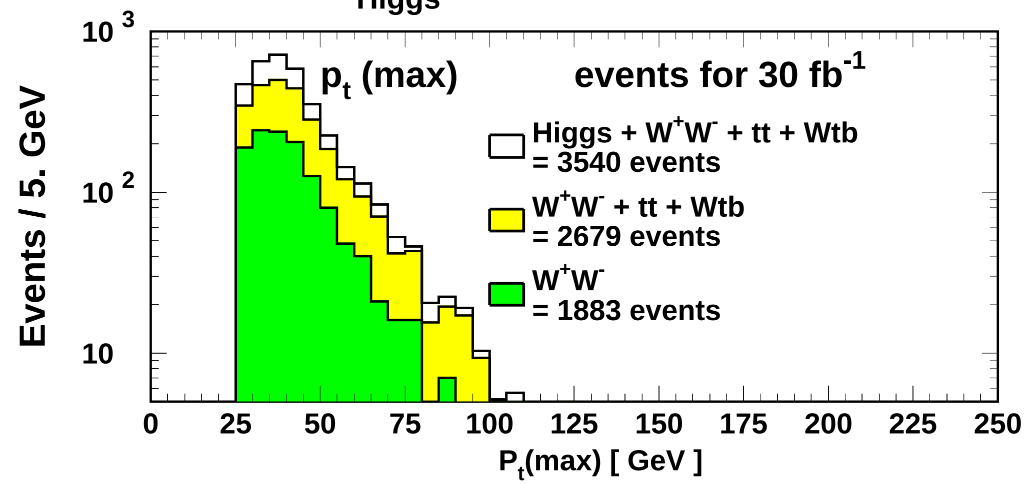
The 5σ discovery for
M_H > 130 GeV/c^2 with $ZZ^* \to 4l$

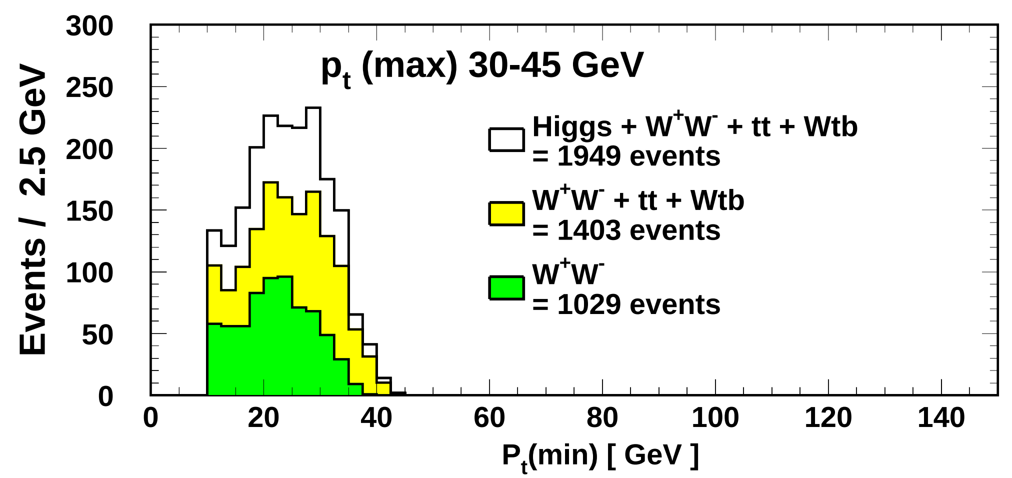
The 5σ Higgs boson discovery with 10 fb^{-1}

H->WW$^{(*)}$->2l (M. Dittmar, H. Dreiner *, 1997)



M_{Higgs}= 140 GeV





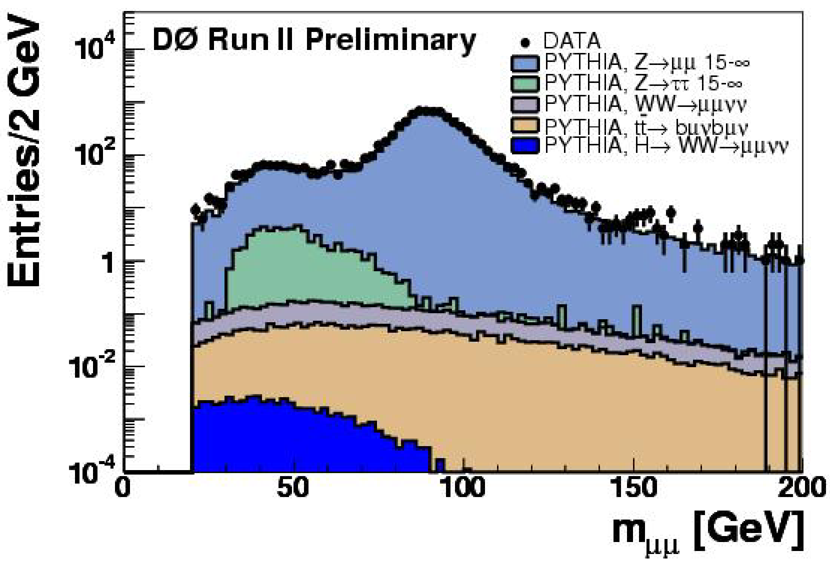
The 5σ discovery for M_H > 140-150 GeV/c^2 with WW*->ll

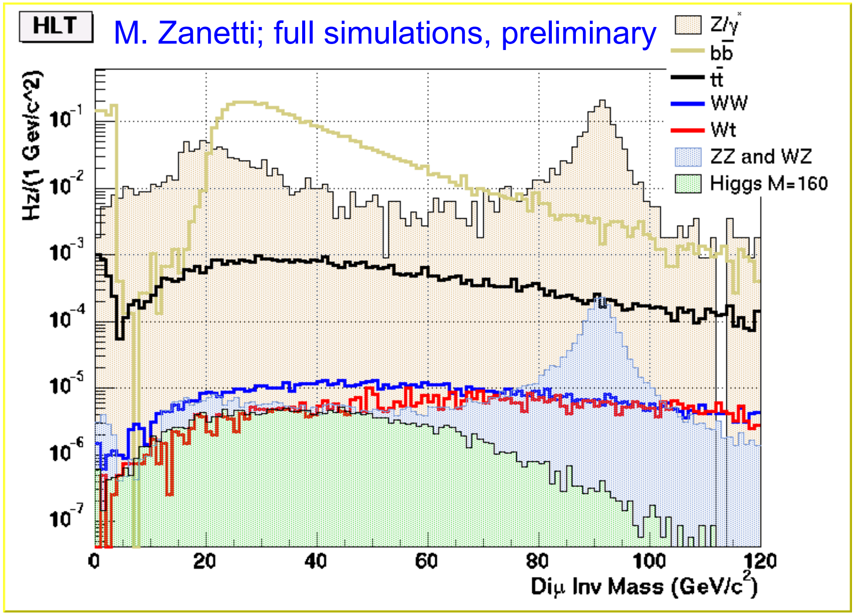
*** 5% bkg. systematic was added by A.N. as S= N_S/sqrt(N_B^2+ΔN_B^2)**

H->WW->2l analysis at TeV and LHC (I)

Tevatron data and MC (PYTHIA) **LHC (CMS) Monte Carlo (PYTHIA)**

M_H=160 GeV





<u>**Very similar event selections:**</u>

- cuts on lepton p_T
- cut on miss E_T, Z resonance veto
- jet veto against tt~
- $\Delta\phi$(ll) cut is particularly important; exploit spin correlations

Tevatron results

Number of events after selections

	ee	eμ	μμ
Observed	2	2	5
Expected	2.7±0.4	3.1±0.3	5.3±0.6

0.11 ev Higgs
Expected in SM

Dominant bkg. in eμ sample

WW	W+jets	WZ	tt
2.51±0.05	0.34±0.02	0.11±0.01	0.13±0.01

LHC "results" (tab. from old M. Dittmar, H. Dreiner analysis; 30 fb^{-1})

Higgs	WW	tt~	Wtb
879	376	64	146

From ATLAS analysis of K. Jakobs and T. Trefzger

W+jets / WW < 2 % !

WZ+ZZ / WW = 2 %

W+Jet background in H->WW->2l

Ratio of W+jets and WW backgrounds in Tevatron analysis is much bigger than in LHC analysis (CMS did not take into account W+jet)

It can not be explained by difference in cross sections at TeV and LHC :

σ, pb	W	WW	WW / W
LHC	1.65×10^{5}	74	4.5×10^{-4}
TeV	1.80×10^{4}	8.4	4.7×10^{-4}

Calculated by E. Boos, CompHEP (LO); $Q^2 = M_W^2$, CTEQ6l1

We should check W+jets bkg. with realistic simulation of jet->e miss id.

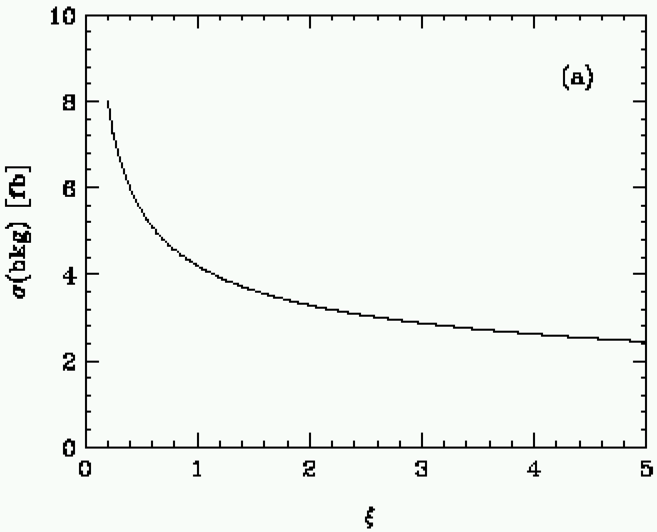
Possible way to estimate WbWb background for h->WW->2l at LHC:

prospects for tt~ bkg. uncertainty in h->ww->2l; extrapolation method

N. Kauer. hep-ph/0404045: ATLAS/CMS cuts (parton level) + $\varepsilon_{b\text{-}tag}$

method (D. Zeppenfeld, N. Kauer) : $N_{bkg} = (\sigma_{bkg}\,\varepsilon_{bkg} / \sigma_{ref}\,\varepsilon_{ref})\; N_{ref}$

WbWb scale uncertainties (LO):
$\mu_F = \mu_R = \xi\, m_t$

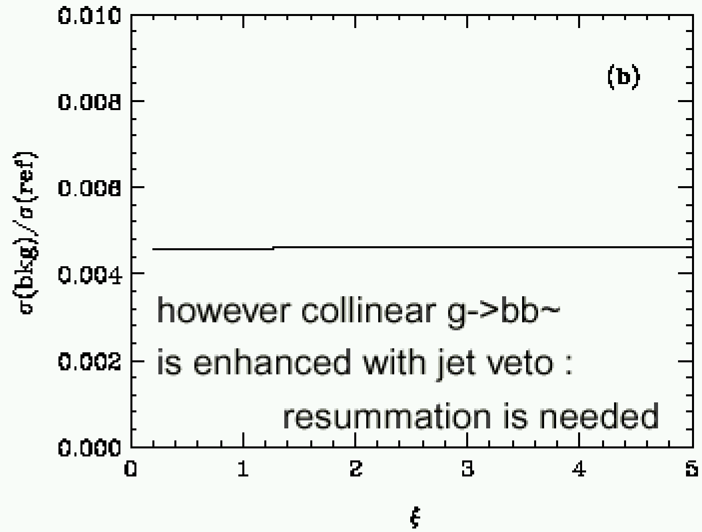


- stat error (N_{ref}) ~ < 1 % (> 10 fb^{-1})
- $\sigma_{bkg} / \sigma_{ref}$ (scale) < 1 %
- $\sigma_{bkg} / \sigma_{ref}$ (pdf) ~ 3 %

$\sigma_{bkg} / \sigma_{ref}$ scale uncertainties (LO):

reference selections :

- no jet veto E_T > 20 GeV, η < 3
- at least one b jet
- the rest select. are the same



What are our systematic uncertainties ?
Learn what Tevatron is doing.

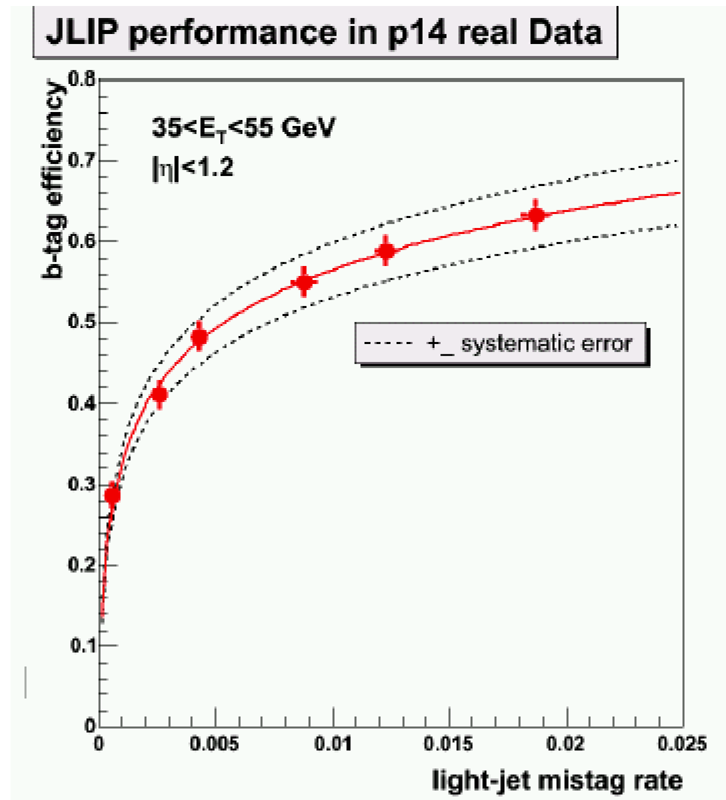
Summary of Run I uncertainties for tt~ study (talk A.-S. Nicollerat; Binn 2003)

Uncertainties on $\sigma_{t\bar{t}}$ (CDF, DØ)

$t\bar{t} \rightarrow WWbb \rightarrow \ell\nu +$ 4jets

	CDF	DØ	
statistical error	26%	25%	
luminosity	~4%	~4%	
tagging	10%	10%	
mainly statistical; CDF:SVX,SLT; DØ:TOPO,SLT			
"MC"	7%	10-20%	
gluon radiation, modeling of $t\bar{t}$ prod.			
backgrounds	~5%	~10%	
jet energy scale	~5%	~4%	
use incl. Z,γ			
trigger	~0 (e)	~5%	(e+jets)
simulated	~10% (μ)	~5%	(E_t^{miss}+jets)
lepton ID use Z peak			
electrons	2.5%	1.8-3.5%	
muons	3.2%	13-15%	

b-tagging efficiency and uncertainty from Run II (talk of R. Demina; TeV4LHC, 16 Oct. 2004)



H->WW->2l: generator uncertainty of jet veto

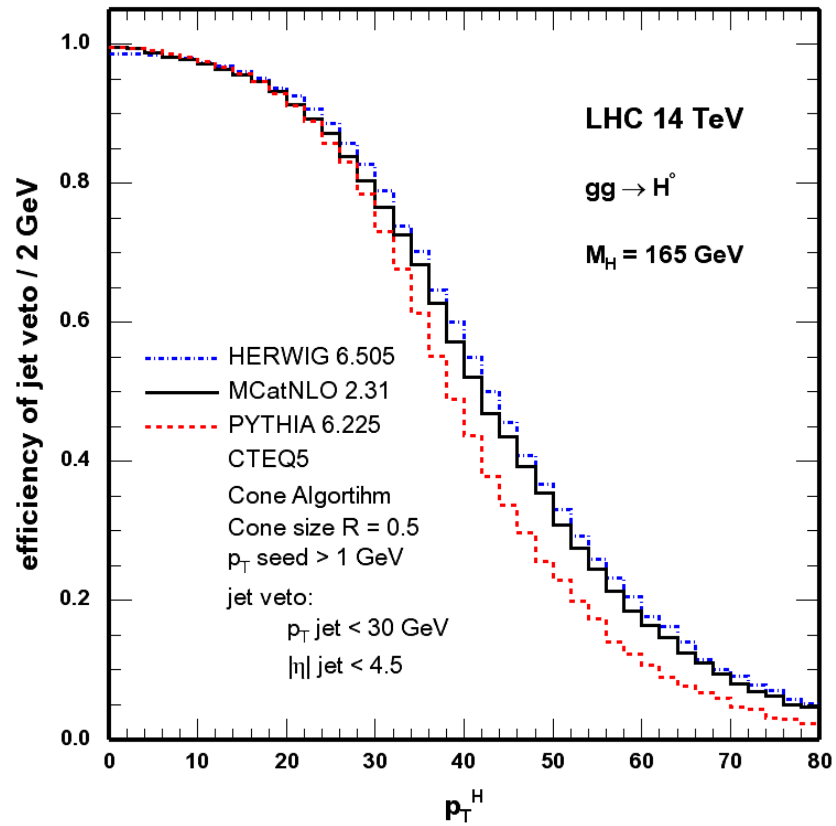
Giovanna Davatz (ETH)

For cross section measurement signal systematic becomes as important as background one.

Monte Carlo systematic may be significant due to Jet Veto

This plot shows efficiency of Jet Veto as a function of Higgs p_T for different generators WITHOUT multiple interactions.

Uncertainty is ~ 5 %



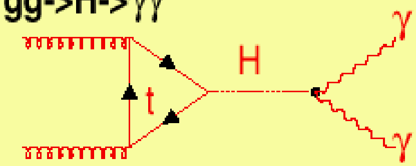
<u>**Some points on top background for h->WW->analysis at LHC :**</u>

- both on-shell and off-shell contributions to top production are important after jet veto
- **σ_{NWA}(tt~) + σ_{NWA}(Wtb)** after cuts leads to large double counting

N.Kauer and D. Zeppenfeld arXiv:hep-ph/0107181

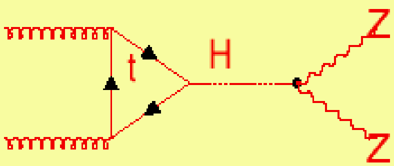
SM Higgs physics with 30 - 60 fb^{-1}

gg->H->γγ $M_H < 150$ GeV



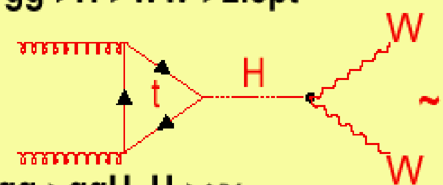
$\sim \Gamma_g(\Gamma_\gamma/\Gamma) = Y_\gamma$

gg->H->ZZ->4lept $M_H > 120$ GeV



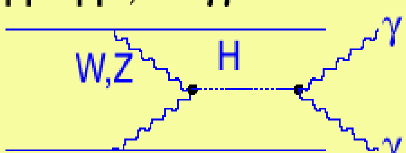
$\sim \Gamma_g(\Gamma_Z/\Gamma) = Y_Z$

gg->H->WW->2lept $M_H > 120$ GeV



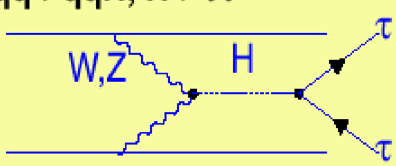
$\sim \Gamma_g(\Gamma_W/\Gamma) = Y_W$

qq->qqH, H->γγ $M_H < 150$ GeV



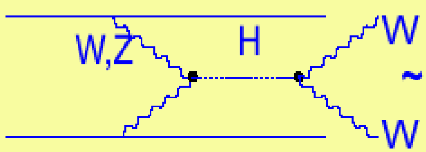
$\sim \Gamma_W(\Gamma_\gamma/\Gamma) = X_\gamma$

qq->qqH, H->ττ $100 < M_H < 150$ GeV

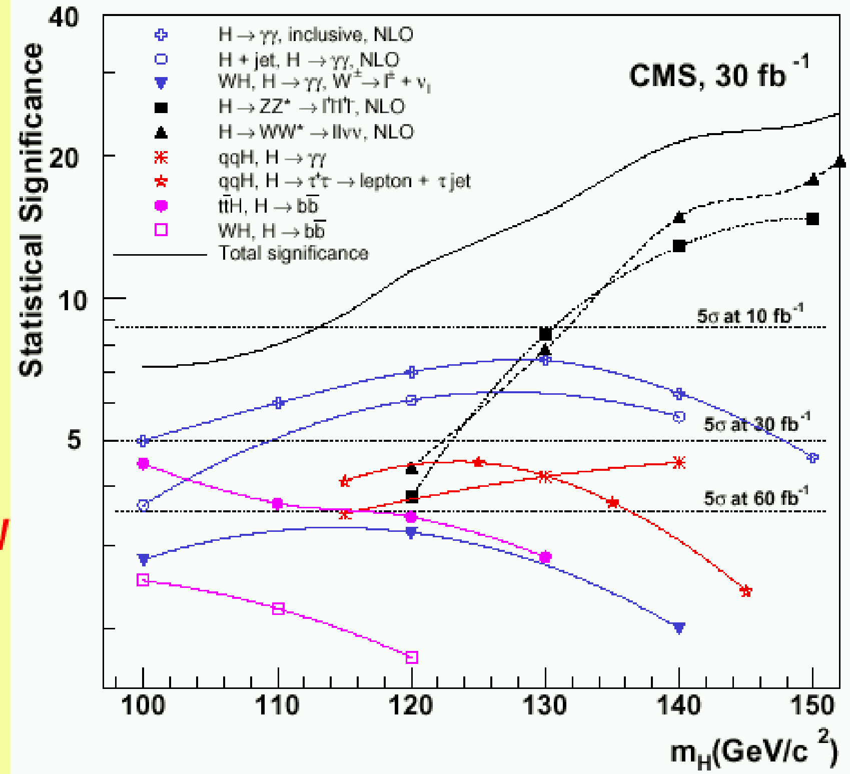


$\sim \Gamma_W(\Gamma_\tau/\Gamma) = X_\tau$

qq->qqH, H->WW->2lept $M_H > 120$ GeV



$\sim \Gamma_W(\Gamma_W/\Gamma) = X_W$



- ❑ observ. of incl. h-> γγ, tth (h->bb)
- ❑ observation of Higgs in VBF production (qq->qqh)
- ❑ first measurement of Higgs couplings using qqh & gg->h

Inclusive h->2γ (from ECAL TDR. 1997)

Full simulation of the signal ;

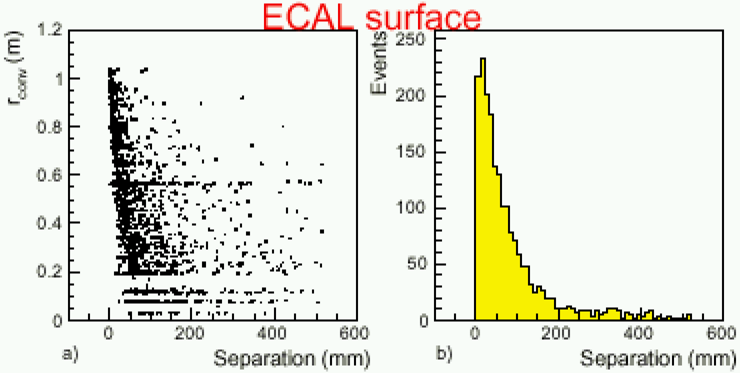
PYTHIA/fast simulation of the background :

- *born process - quark annihilation*
- *box diagram - gluon fusion*
- *γ+q with isolated bremsstrahlung*

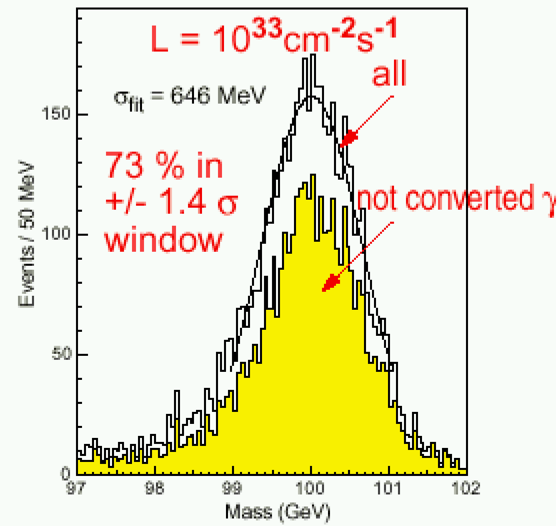
single photon reconstruction efficiency

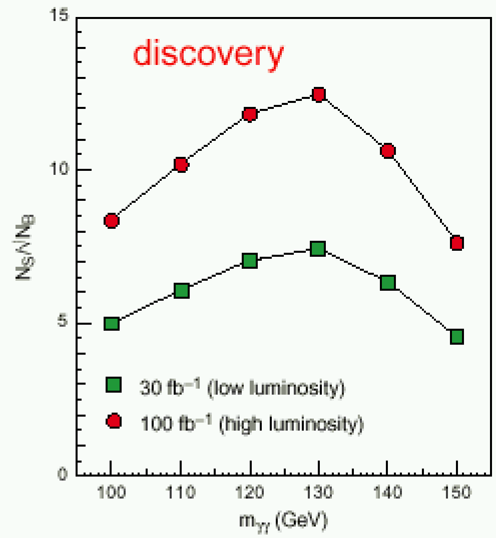
Fiducial area cuts within $\|\eta\| < 2.5$	92.5%
Unrecoverable conversions	94%
Isolation cuts	95%
π^0 rejection algorithms	90%
Total reconstruction efficiency	**74.5%**

γ conversions in the tracker :e^+e^- separation on ECAL surface



usage of tracks to find the Higgs vertex

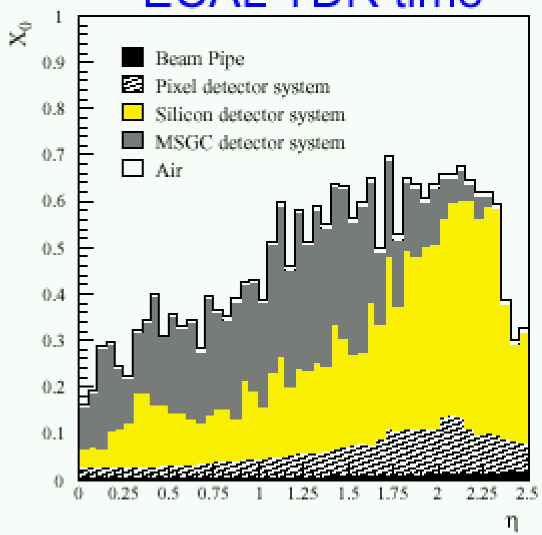




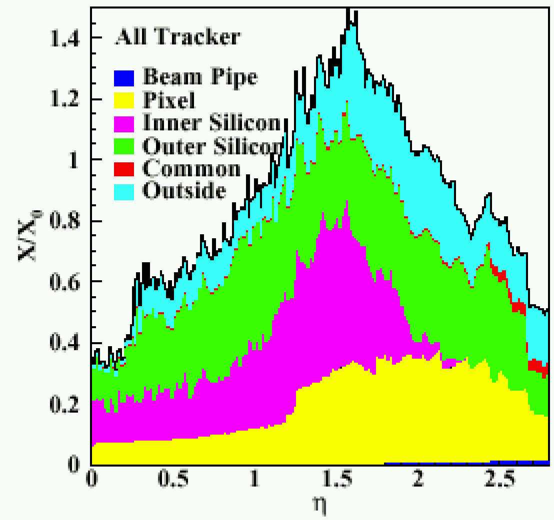
expected updates for h->2γ due to : new tracker design

tracker material budget

ECAL TDR time



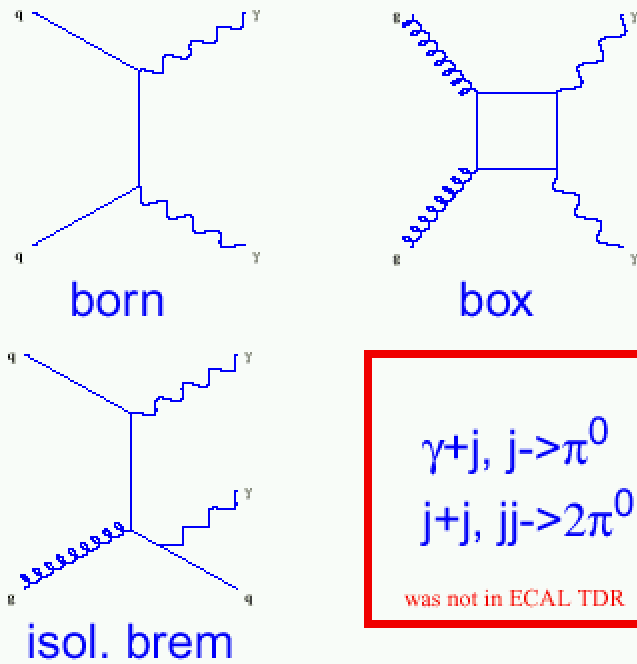
current design



fraction of photons converting before ECAL

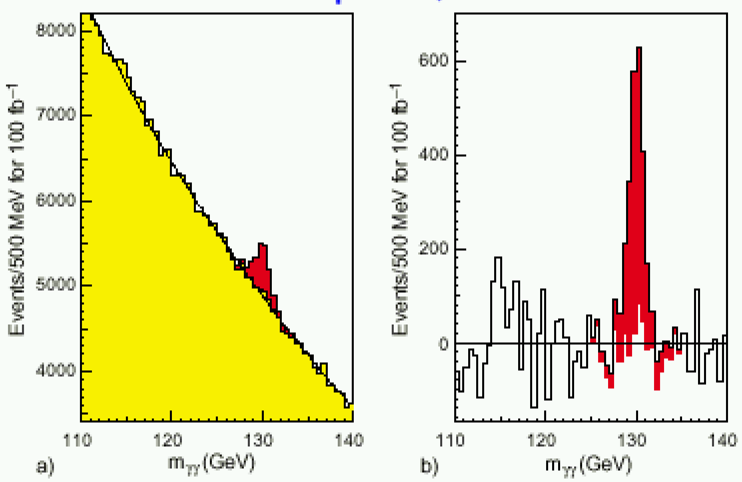
	Unconverted	Converted (Invisible)	Converted (Visible)
Barrel (ECAL TDR)	76.2 %	5.0 %	18.8 %
Barrel (present)	58.0 %	10.7 %	31.3 %
EndCap (ECAL TDR)	65.1 %	8.7 %	26.2 %
EndCap (present)	40.5 %	14.4 %	45.1 %

expected updates for h->2γ due to : additional backgrounds and new k factors



γ+j, j->π^0
j+j, jj->2π^0
was not in ECAL TDR

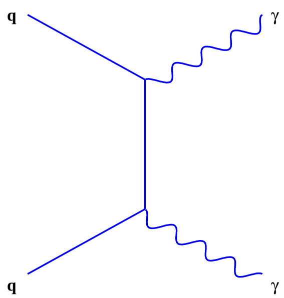
ECAL TDR plots, L=$10^{34}cm^{-2}s^{-1}$

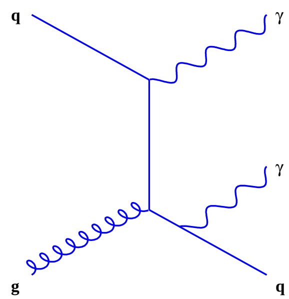


	ECAL TDR K factors	current K factors: DIPHOX(NLO) / PYTHIA
born	1	1.50 , uncertainty 10-20 %
box	1.85	1.20, uncertainty 10-20 % (Dixon et al)
isolated brem	1	1.72, uncertainty 20-30 %
γ+j, j->π^0	not simulated	1.00, uncertainty 30-40 %
j+j, jj->2π^0	not simulated	unknown; work in progress

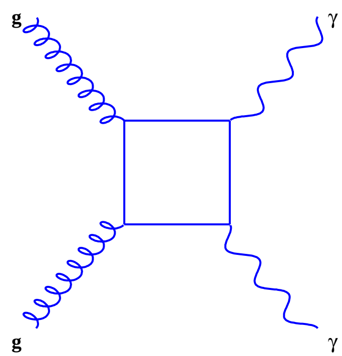
Mγγ at Tevatron: data comparison with PYTHIA and DIPHOX

In CMS we use K factors obtained from comparison of PYTHIA with DIPHOX after "experimental" selections for different backgrounds:

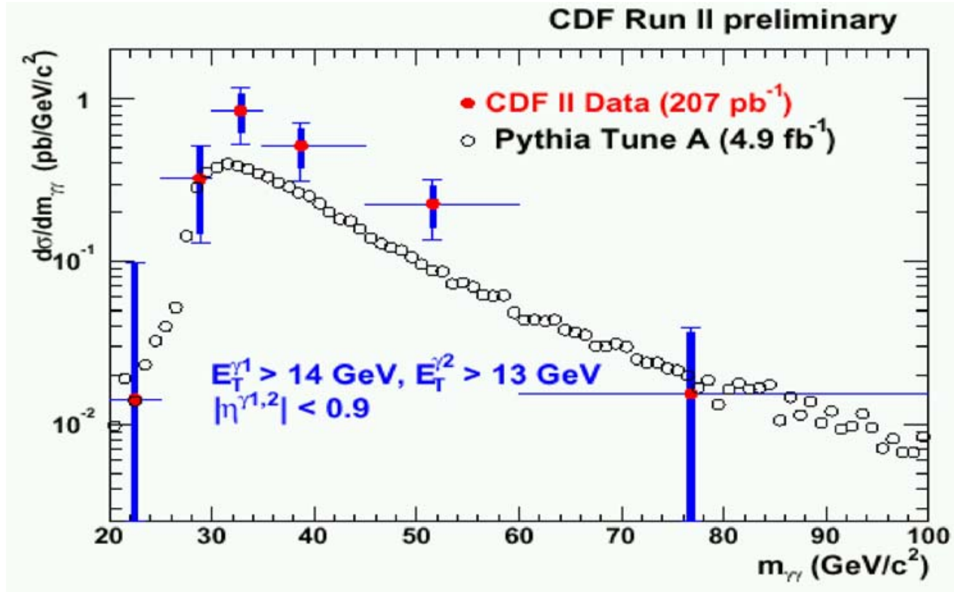


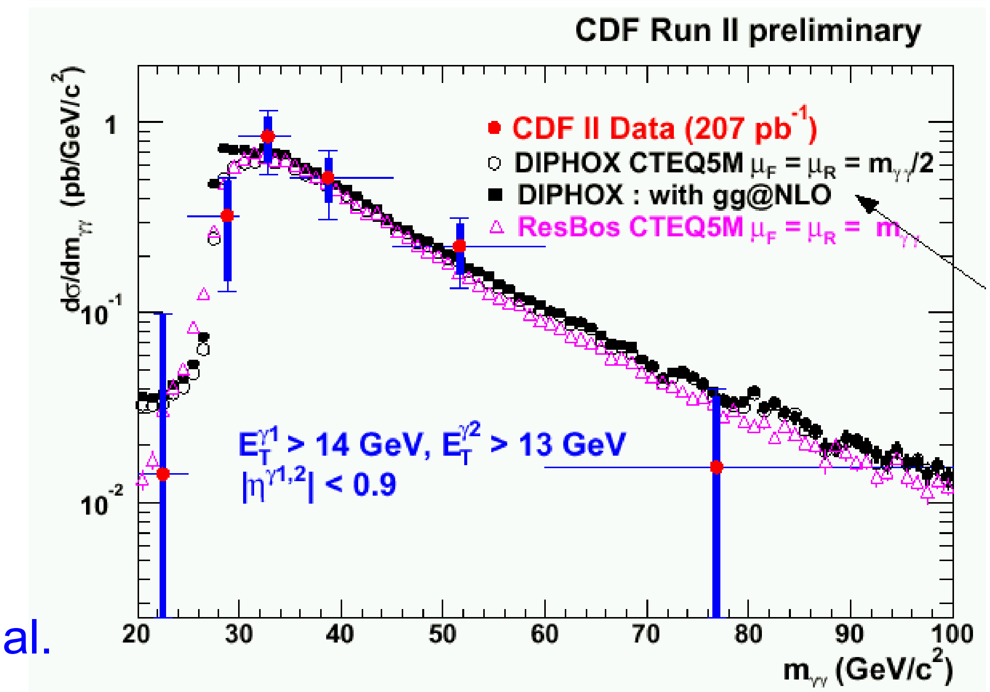


pp->γ"π⁰"
pp->"π⁰π⁰"



Box: K from Dixon et al.





Composition of the background for CMS : full simulation study by S. Shevchenko, T. Lee, V. Litvin, H. Newman (preliminary). PYTHIA K factors from:

T. Binoth et al., Les Houches 2001; hep/ph-0203316

T. Binoth, K. Lassila-Perini (CMS), Les Houches 2003; hep-ph/0403100

Z. Bern, L. Dixon, C. Schmidt, Phys. Rev. **D 66** (2002) 074018

Table 6: Remaining background in fb/(GeV/c^2) at different mases. The recently calculated next-to-leading order corrections to background cross sections are included. The numbers, shown in brackets, do not include the next-to leading order corrections. The γ + jets background is splitted into two parts: i) the part of the background, which contains two real photon in the final state and ii) the part of the background, which contains one real photon and one fake photon in the final state.

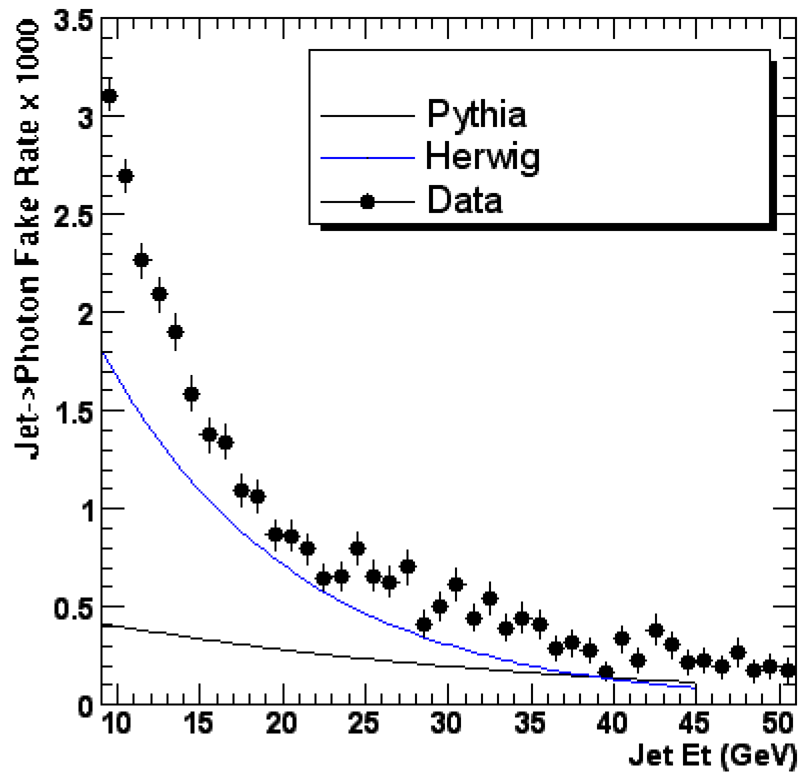
Background	110 GeV/c^2	120 GeV/c^2	130 GeV/c^2	140 GeV/c^2	150 GeV/c^2
QCD pp->jj	35.6 (35.6)	40.9 (40.9)	32.0 (32.0)	21.4 (21.4)	14.2 (14.2)
γ + jets two real photons	67.1 (40.4)	51.6 (31.1)	36.3 (21.8)	27.9 (16.8)	13.9 (8.4)
γ + jets one real + one fake photons	60.6 (60.6)	46.6 (46.6)	32.8 (32.8)	25.2 (25.2)	12.6 (12.6)
Gluon fusion	43.4 (36.2)	32.5 (27.1)	24.0 (20.0)	17.3 (14.4)	11.3 (9.4)
Quark annihilation	55.1 (36.7)	45.6 (30.4)	37.1 (24.7)	30.0 (20.0)	21.0 (14.0)
Total	262	217	162	122	73

Photon Fake Rate from data

- Rate of jets with leading meson (pi0, eta) which cannot be distinguished from prompt photons: Depends on
  - detector capabilities, e.g. granularity of calorimeter
  - Cuts!
- Systematic error about 30-80% depending on Et
- Data higher than Pythia and Herwig
- Pythia describes data better than Herwig

B. Heinemann. UK Forume, April 2004

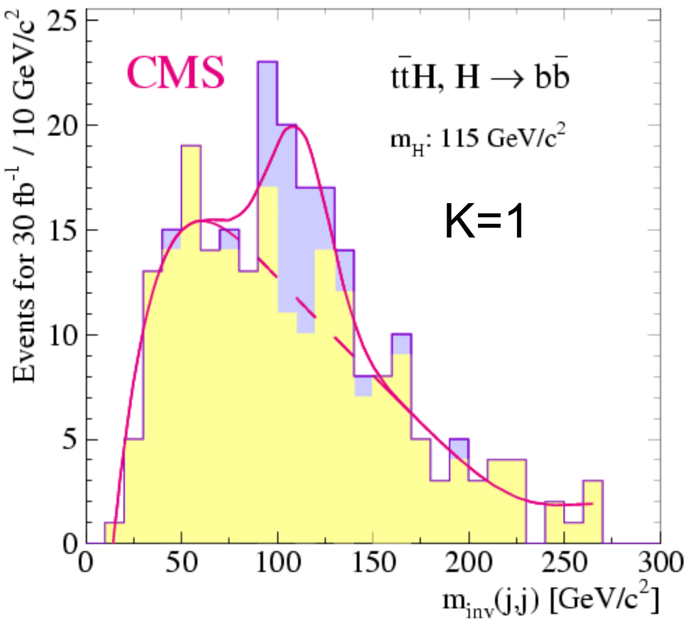
CDF (preliminary result)



At TeV Jet->γ miss ID is obtained from γ+jet data.
We should evaluate how does it work with CMS detector

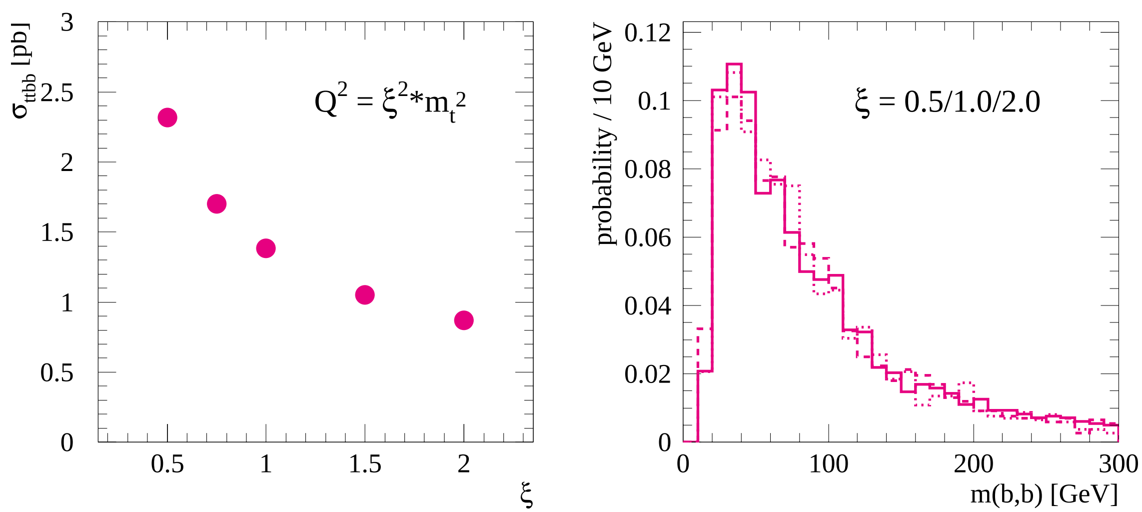
"Difficult channel": tth, h->bb

NLO tth from M. Spira et al., hep-ph/0107081



Backgrounds:
ttb, ttjj, Ztt from LO CompHEP
ttbb is dominant after selections

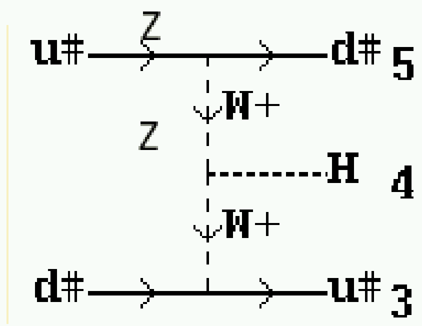
ttbb (and ttjj) predictions at LO has very big scale uncertainties ~ factor 2.
V. Drollinger , Les Houches 2003; ALPGEN
$Q^2=m_t^2$, CTQ5L, $p_T(b)>25$ GeV, $|\eta|< 2.4$, $\Delta R(bb) > 0.4$



ttbb shape is not affected by scale change, BUT additional jets (at NLO) can give different combinatorics which could change the shape

NLO predictions for ttbb and ttj(j) is very desirable;
NLO ttj(j) can be verified by Tevatron data

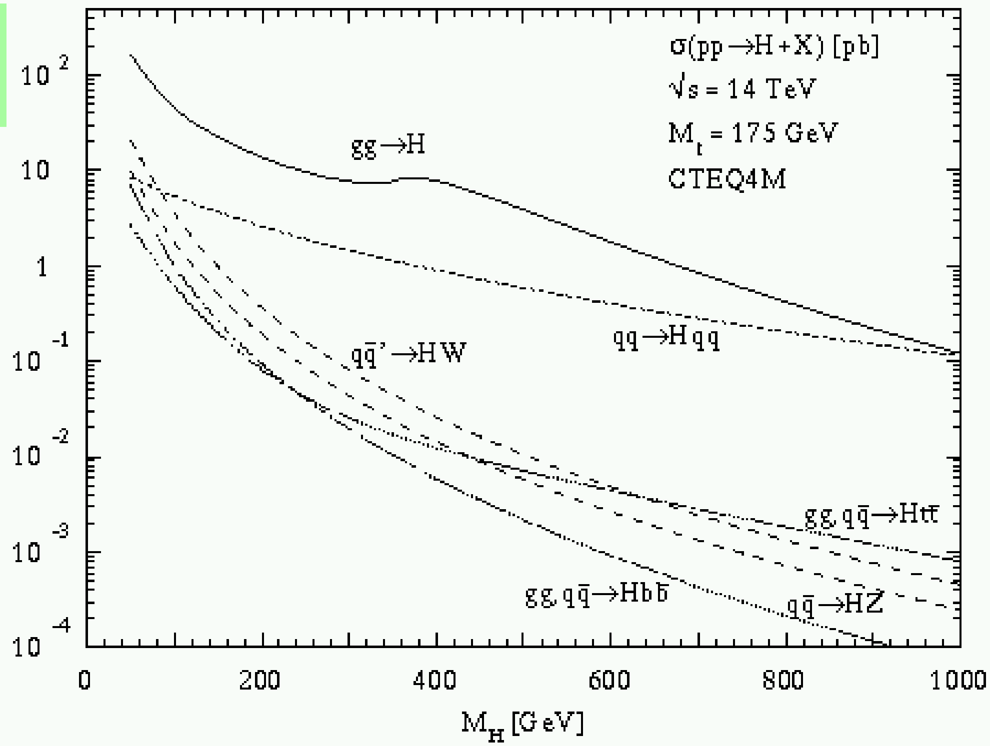
VBF : qq->qqh process

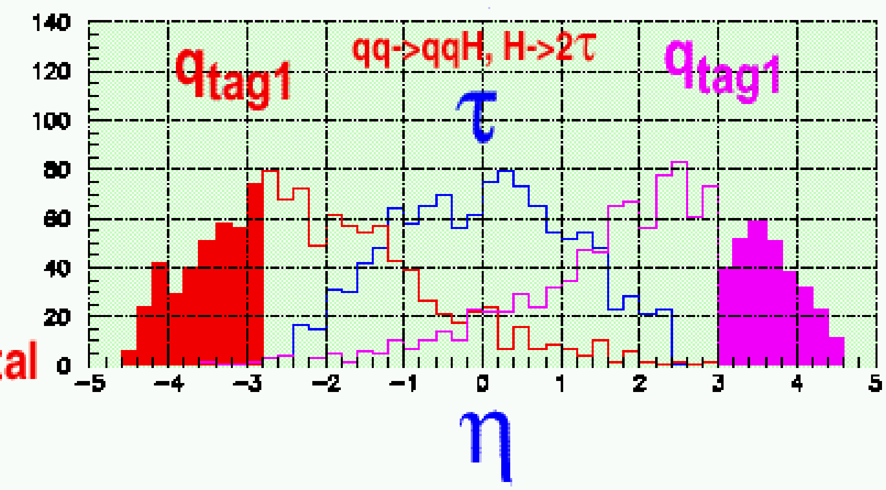


- large enough rates
- forward jet tagging and mini-jet veto for low L
- central Higgs decay products to trigger
- not too big bkg, S/B ~ 1

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

BUT detailed simulations / experimental analysis is needed !



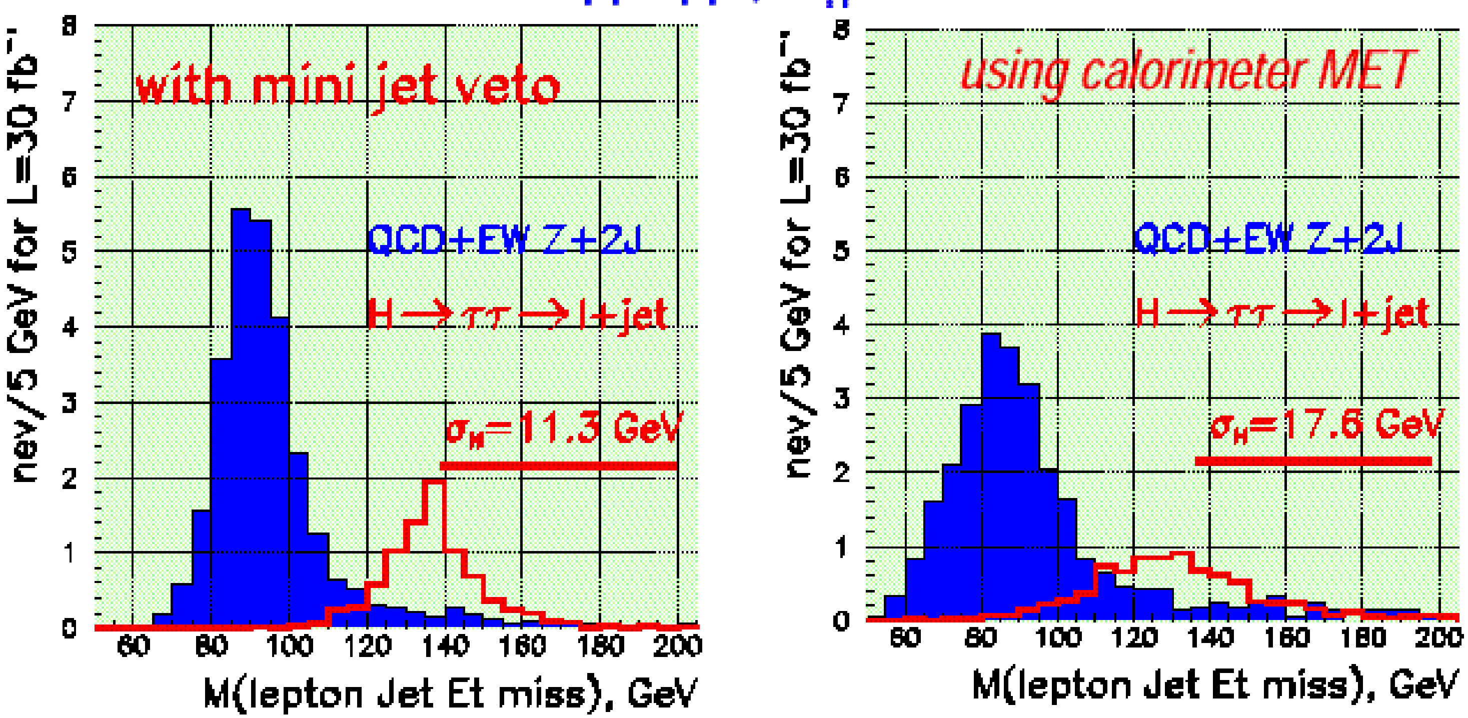


Going to full simulation: challenge I

***improve calo missing E_T**: one of the most suffering Higgs channels is light Higgs in qq->qqH, H->2τ->lepton + jet*

CMSJET fast simulation | **full simulation and OO/c++ reco**

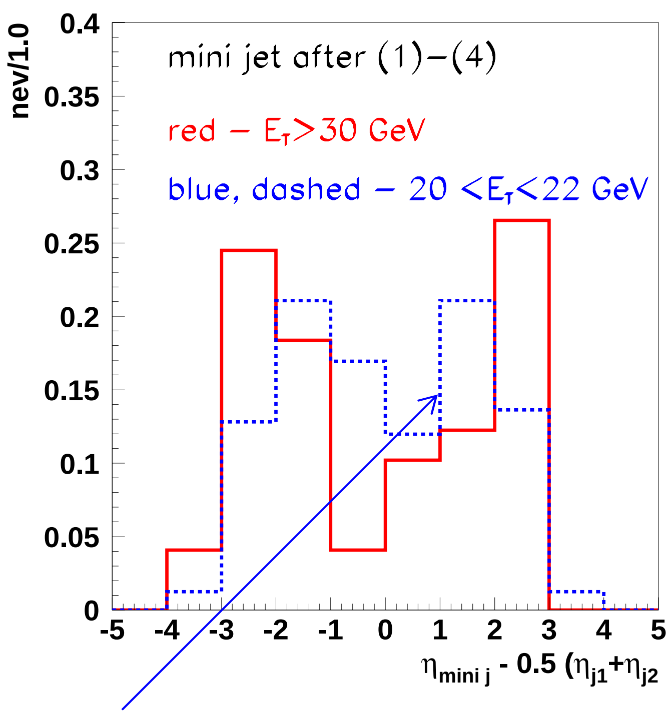
qq->qqH, M_H = 135 GeV *A. Nikitenko*



First try in 2002. ORCA_?

Going to full simulation: challenge II

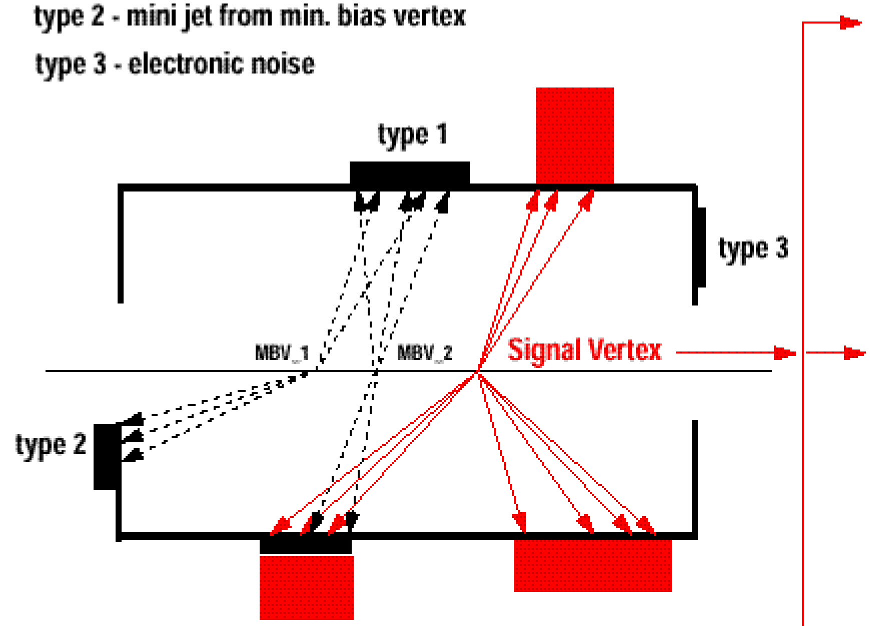
Rapidity of the central jet in Higgs events;
CMS; full simulation, L=2x10^{33}cm^{-2}s^{-1}. A.N.



"bkg. like" behaviour for soft jets;
fake jets: pile up+UE+detector

Calo false jets due to :

type 1 - overlap from different min.bias vertices
type 2 - mini jet from min. bias vertex
type 3 - electronic noise



False jets

Most probably false jet problem will be solved using tracks

Very promising algorithm to suppress false jets :

$\alpha_{jet} = \Sigma P_T^{track} / E_T^{JET}$; using tracks from PV and within cone around jet direction at PV

take jet as real one if $\alpha_{jet} > \alpha_{cut}$

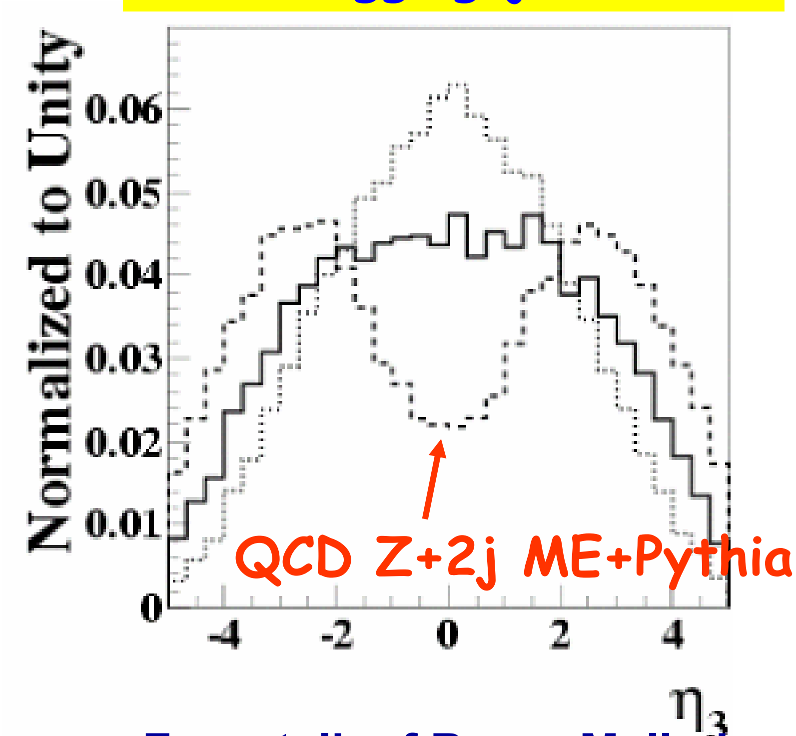
N. Ilina, A. Krokhotin, V. Gavrilov. preliminary

	Efficiency of 3rd jet veto after VBF selections (preliminary)	
	Without algo	With algorithm
Efficiency of jet veto; Et > 20 GeV	24 %	88 %
Efficiency of jet veto; Et > 30 GeV	70 %	96 %

challenge III : generation

Proper generation of 3^rd^ jet for jet veto in Z+JJ

η_3 after requiring two tagging jets



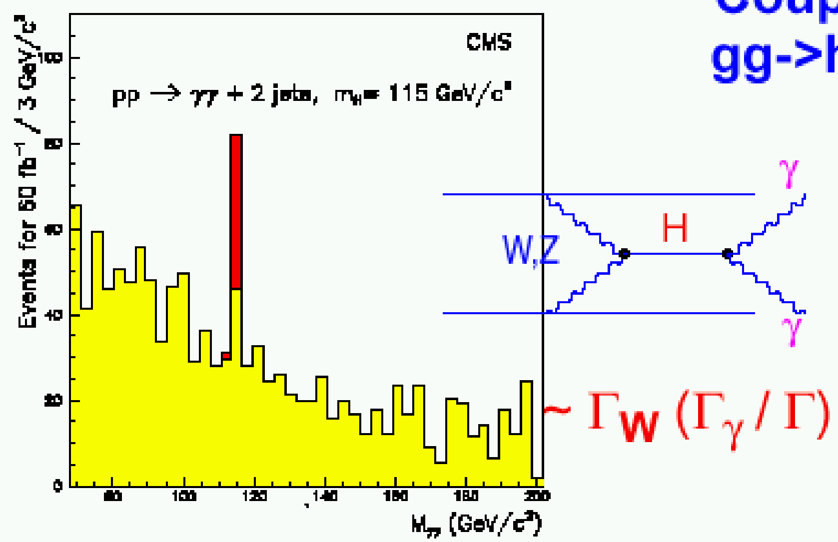
From talk of Bruce Mellado. CERN MC Workshop 2003

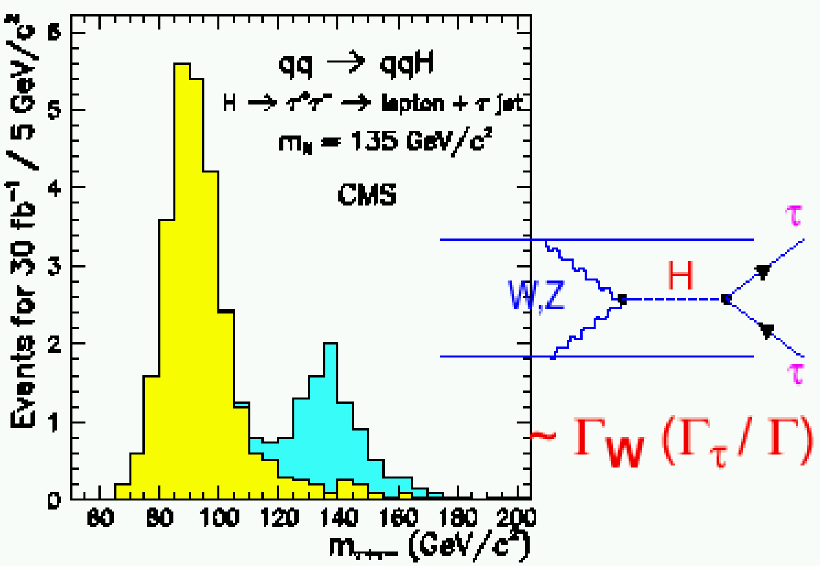
ME Z+JJ + PYTHIA or HERWIG does not provide correct eta for 3rd jet (this statement should be re-checked, however)

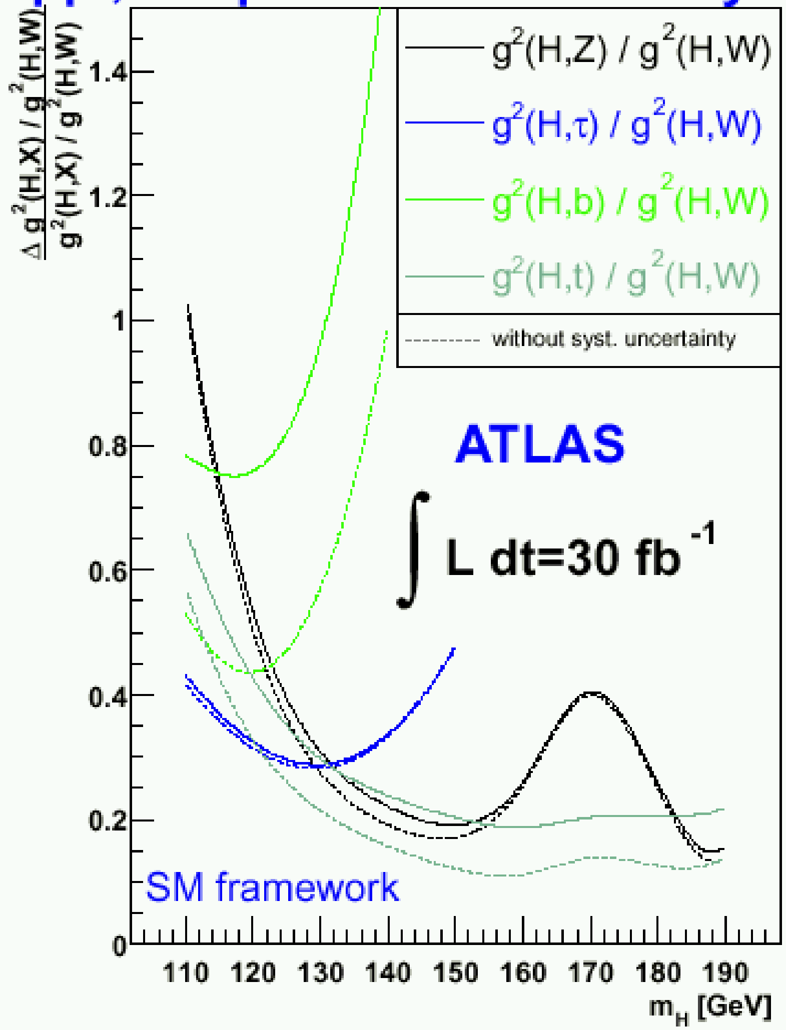
Looks like ME + PS matching with Z+2J and Z+3J may be good solution (message from Dave Rainwater; we will try this way as well)

first measurement of Higgs couplings with 30-60 fb^{-1} (II)

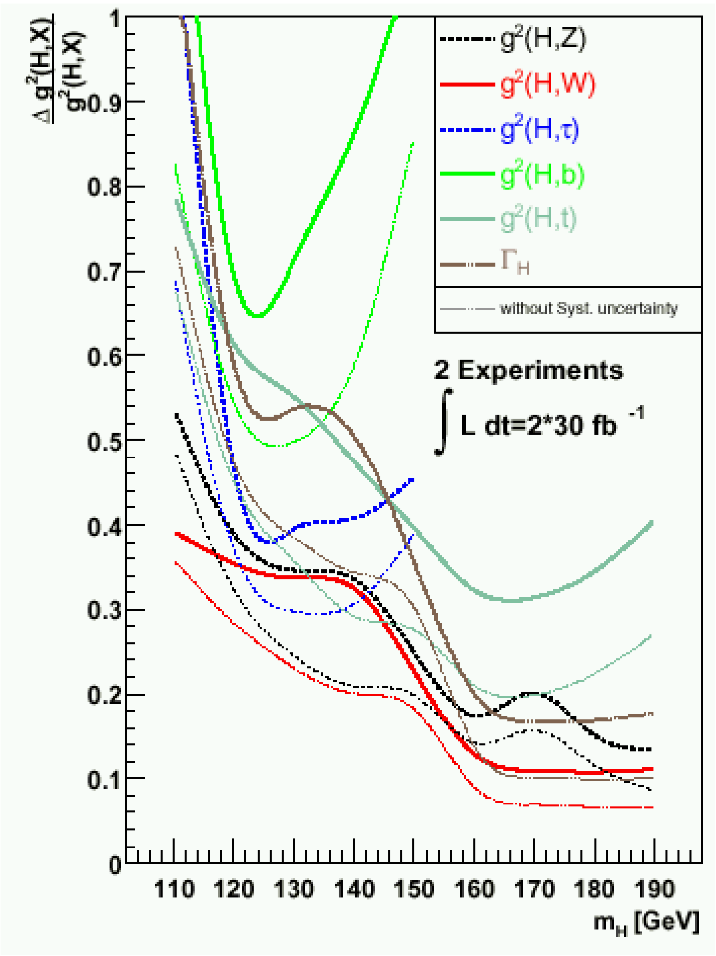
Coupling measurements combining gg->h, qqh, tth prod. and diff. decays







Higgs boson coupling measurement $2 \times 30\ fb^{-1}$



M. Duhrssen, S. Heinemeyer, H. Logan, D. Rainwater, G. Weiglein and D. Zeppenfeld; hep-ph/0406323

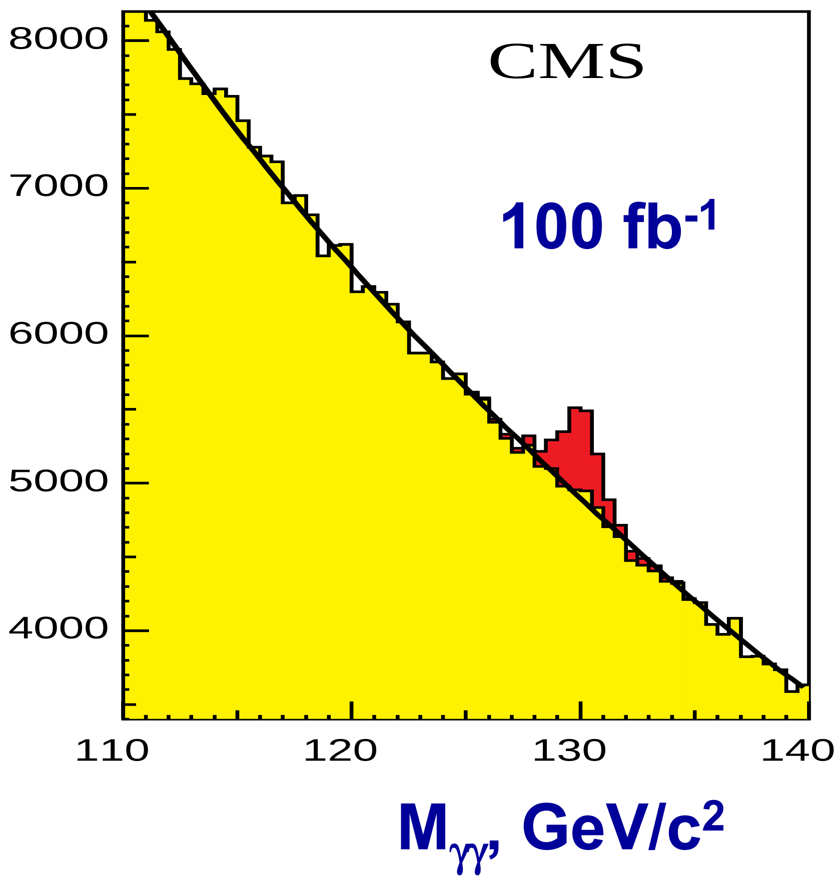
no SM assumptions; general multi-Higgs doublet model)

ATLAS experimental systematic uncertainties are taken (ATL-PHYS-2003-30)

L	5%	Measurement of luminosity
ϵ_D	2%	Detector efficiency
ϵ_L	2%	Lepton reconstruction efficiency
ϵ_γ	2%	Photon reconstruction efficiency
ϵ_b	3%	b-tagging efficiency
ϵ_τ	3%	hadronic τ-tagging efficiency
$\epsilon_{\rm Tag}$	5%	WBF tag-jets / jet-veto efficiency
$\epsilon_{\rm Iso}$	3%	Lepton isolation ($H \to ZZ \to 4\ell$)

SM Higgs boson physics with 100-300 fb^{-1} (I)

Precise measurement of Higgs boson mass

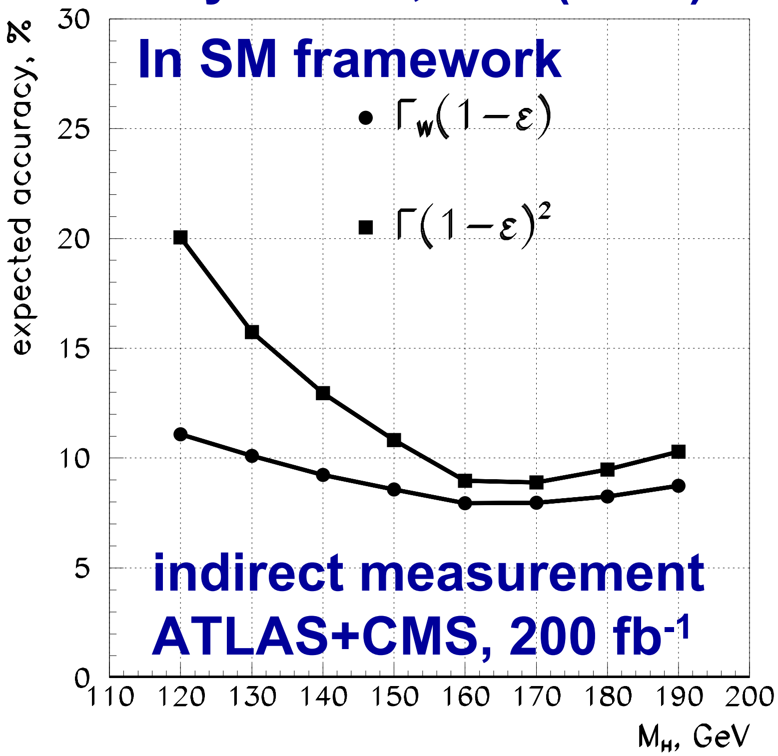


ATLAS, 300 fb^{-1}

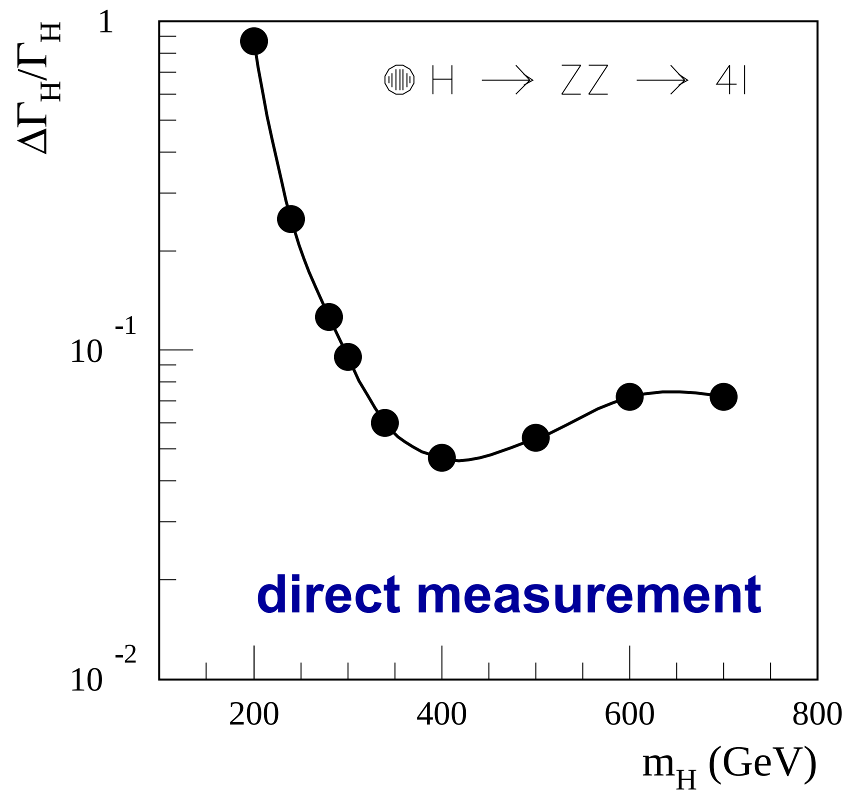
SM Higgs boson physics with 100-300 fb^{-1} (II)

Measurement of Higgs boson width

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

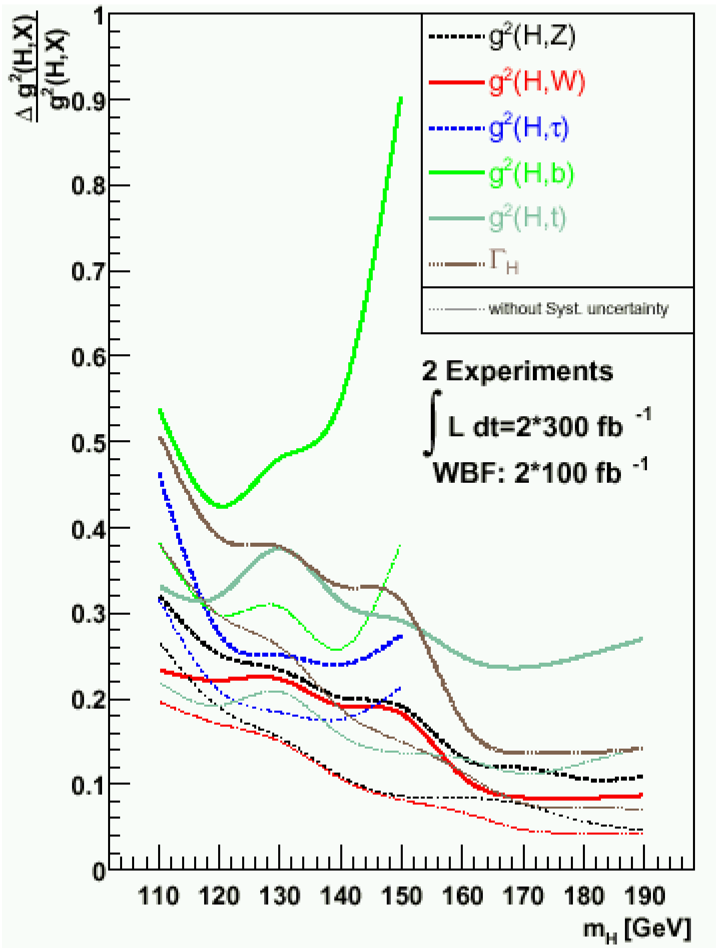


ATLAS, 300 fb^{-1}

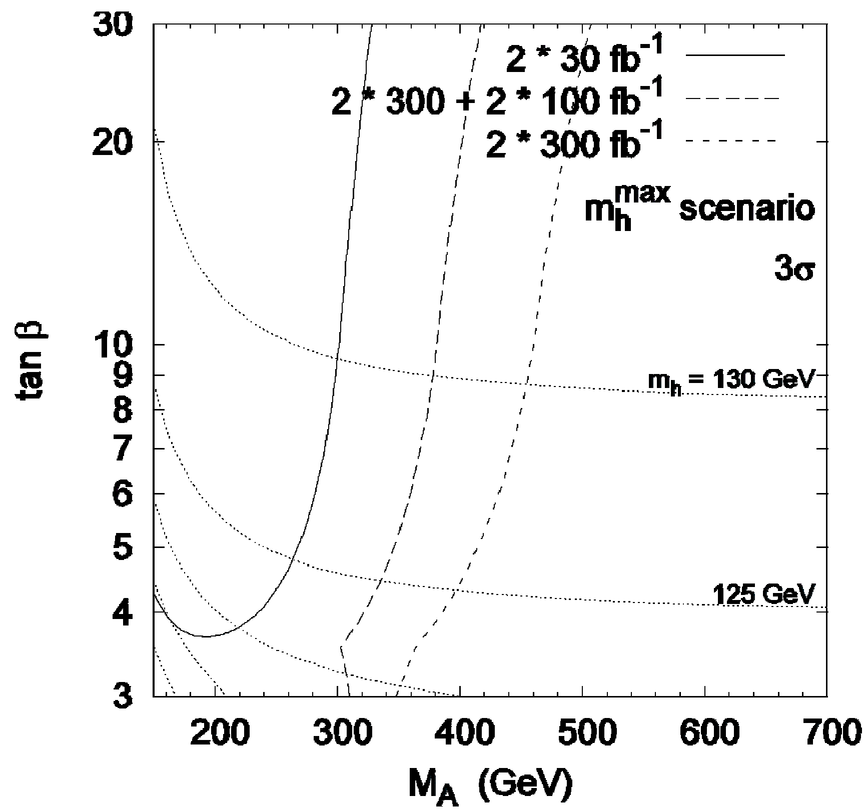


"SM" Higgs boson physics with 100-300 fb^{-1} (III)

Discovery of "rare" Higgs boson channels; coupling measurement; discrepancy from the SM for light h



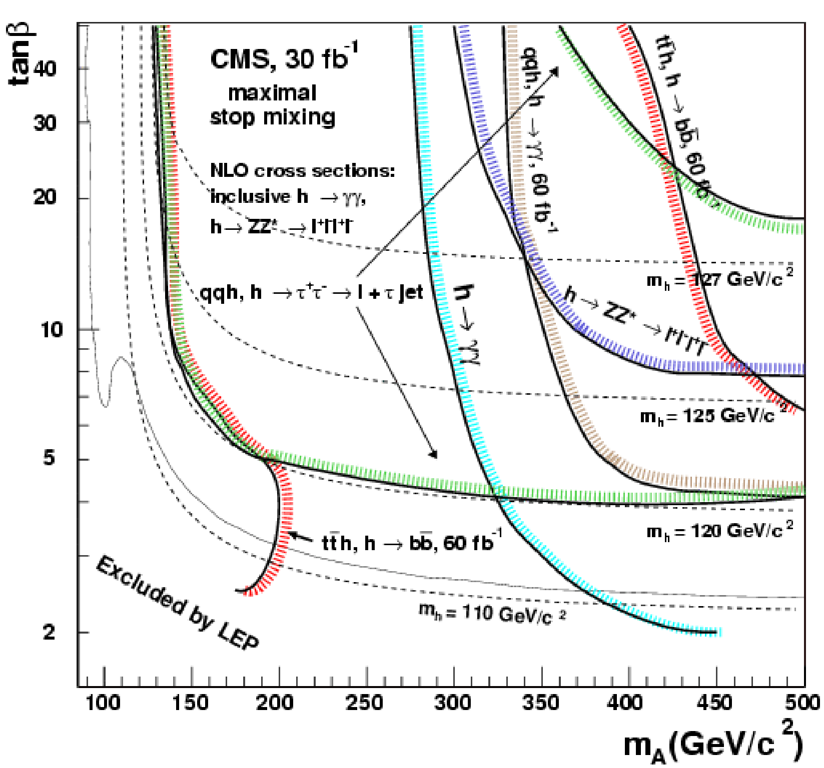
hep-ph/04063232

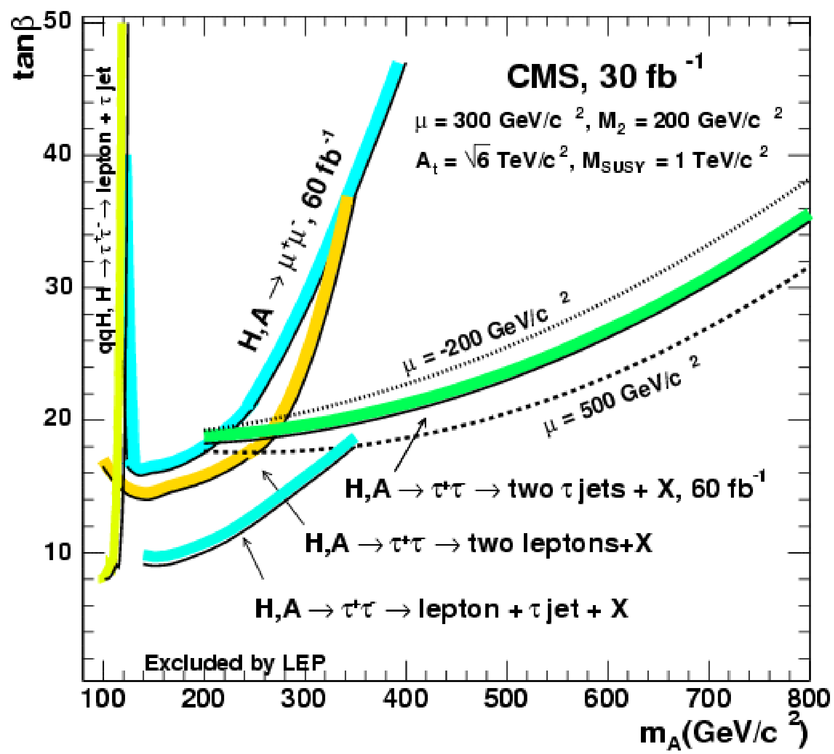


MSSM and beyong MSSM Higgs boson searches: status and plans for PTDR

The 5 σ discovery reach of CMS for MSSM neutral Higgs bosons with m_h^{max} scenario. Decays to sparticles are ON (m_h^{max} scenario see in M. Carena et al., hep-ph/0202167)

h **CMS, December 2003** **H, A**



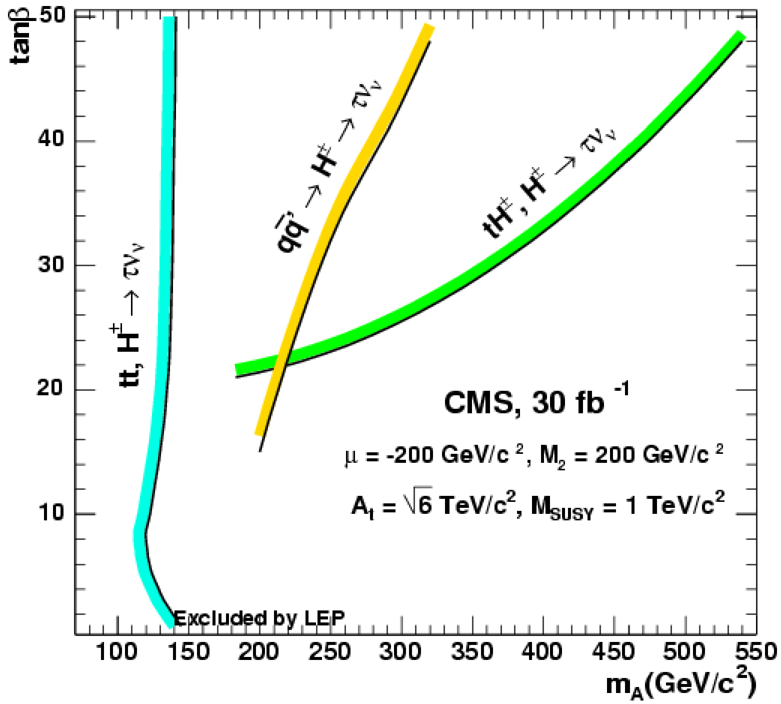


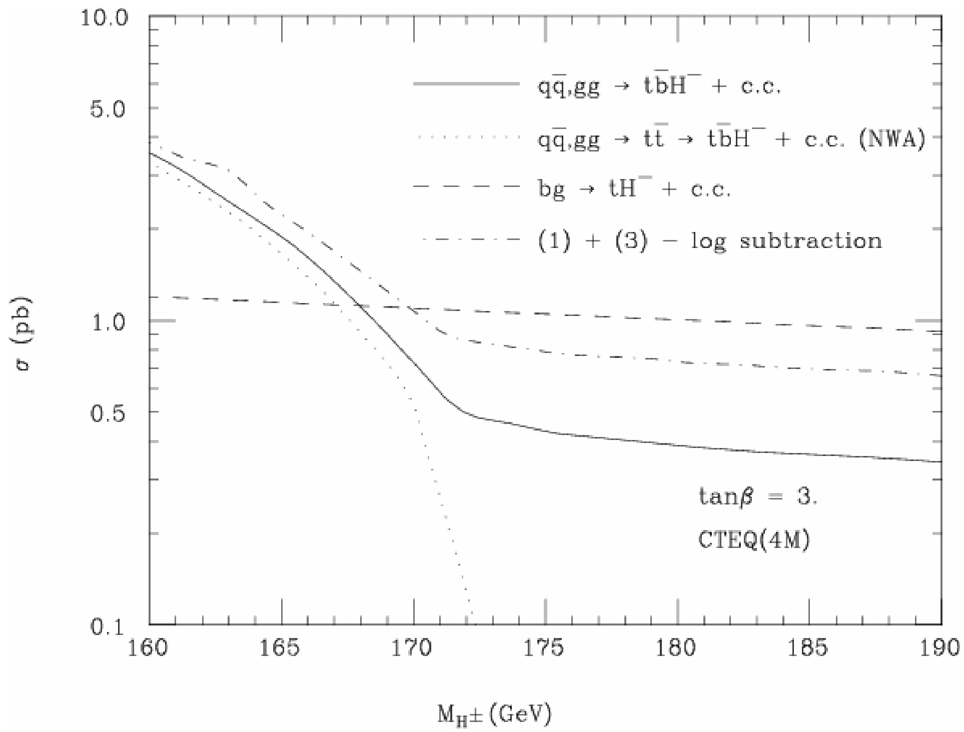
No systematic uncertainties are included
Poisson statistics

The 5 σ discovery reach of CMS for MSSM charged Higgs bosons with m_h^{max} scenario. Decays to sparticles are ON.

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

LO cross sections S. Moretti & M. Guchait, 2002



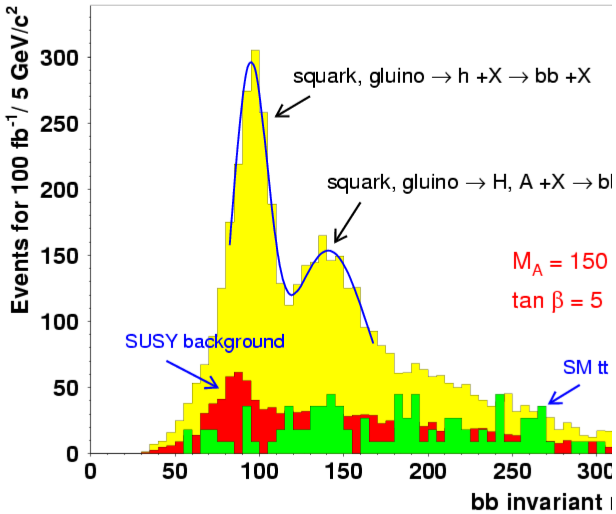


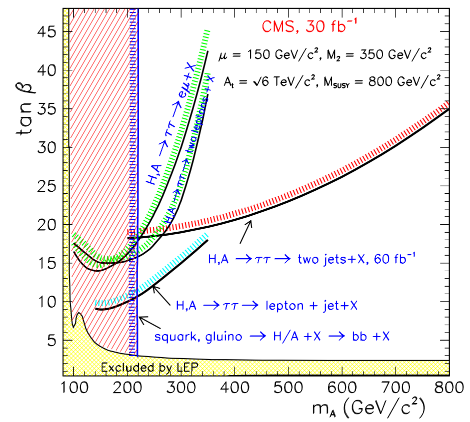
gg->tbH⁺ process is available in PYTHIA (S. Moretti et al. Les Houches 2003)
NLO cross section is available. (T. Plehn et al., hep-ph/0312286)

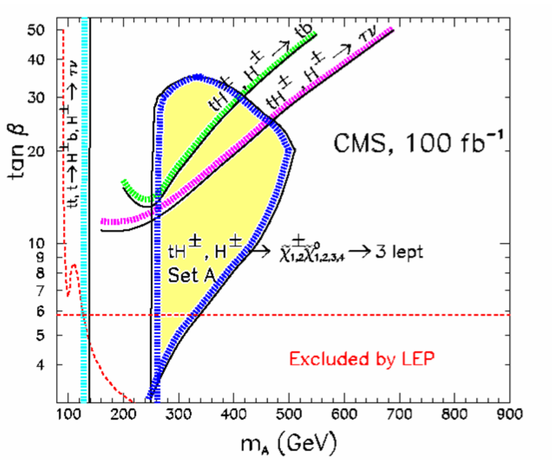
Gap should be closed with the future simulations for PTDR

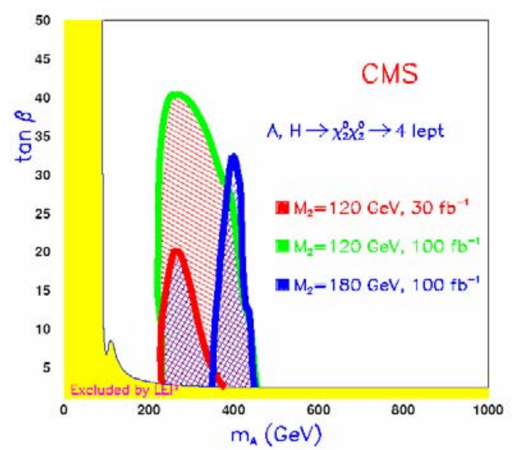
Observation of Higgs boson to sparticles decays and Higgs boson from SUSY cascades.

F. Moortgat and collaborators







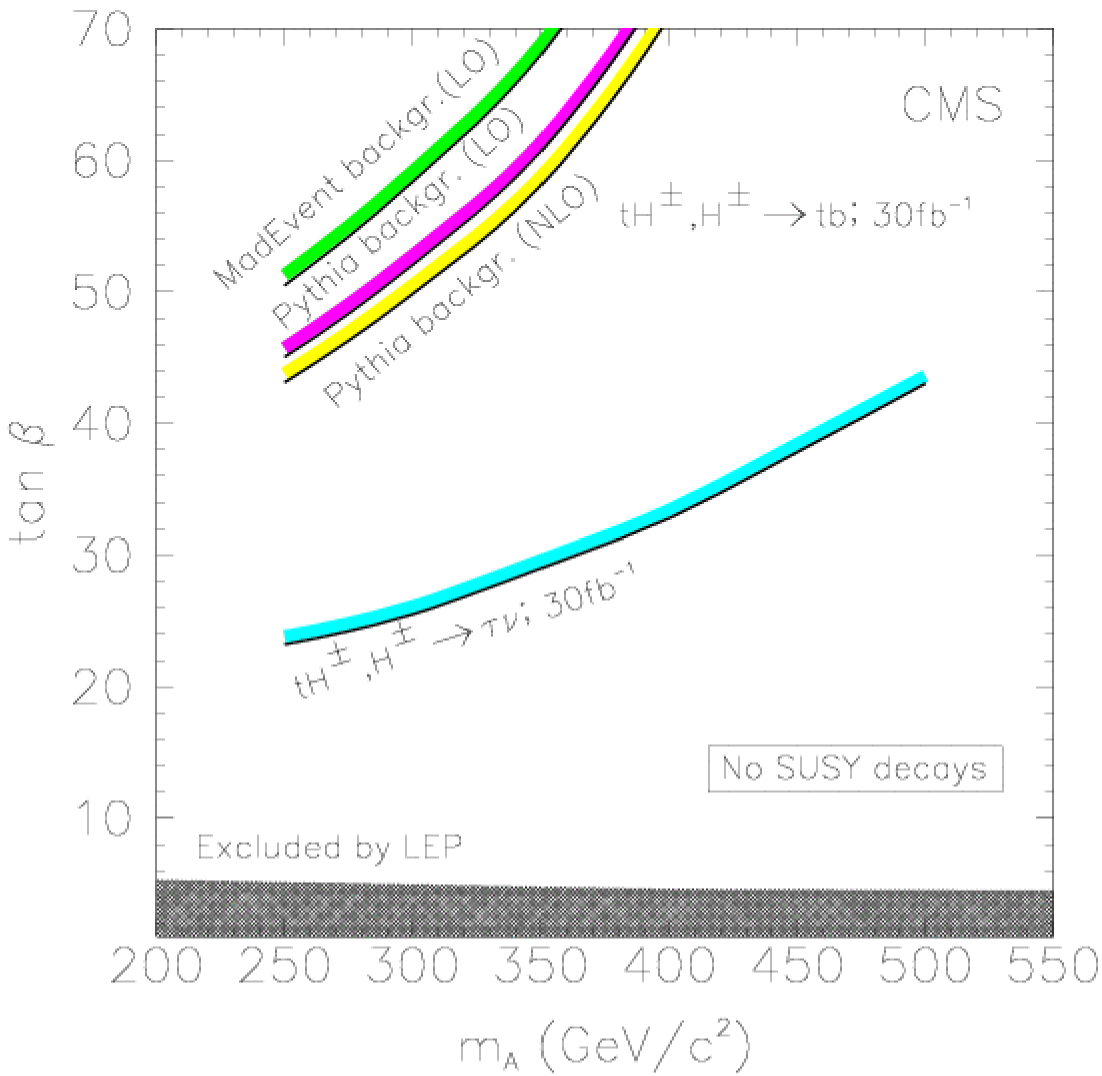


New approved results since 2003

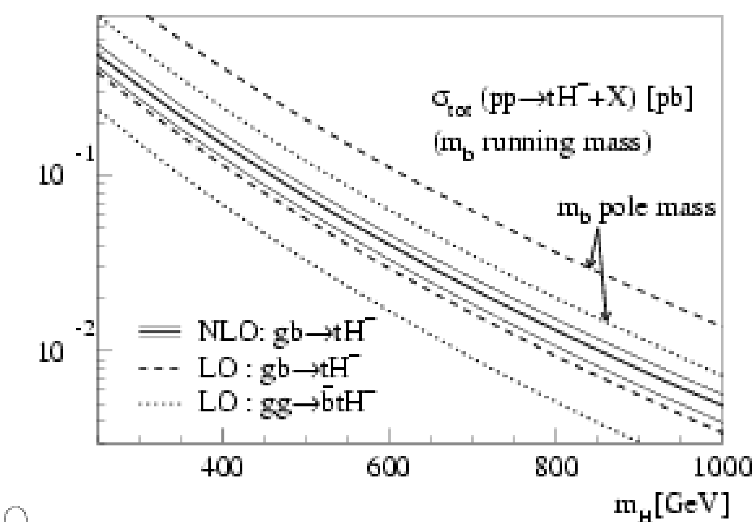
H^+->tb with new cross sections and MadGraph background

S. Lowette, P. Vanlaer, J. Heyninck. CMS Note 2004/017

Reach in M_A-tan(β) is dramatically reduced



New LO and NLO cross sections from Tilman Plehn are used



tan(β) measurement with MSSM bbH, H->2τ

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

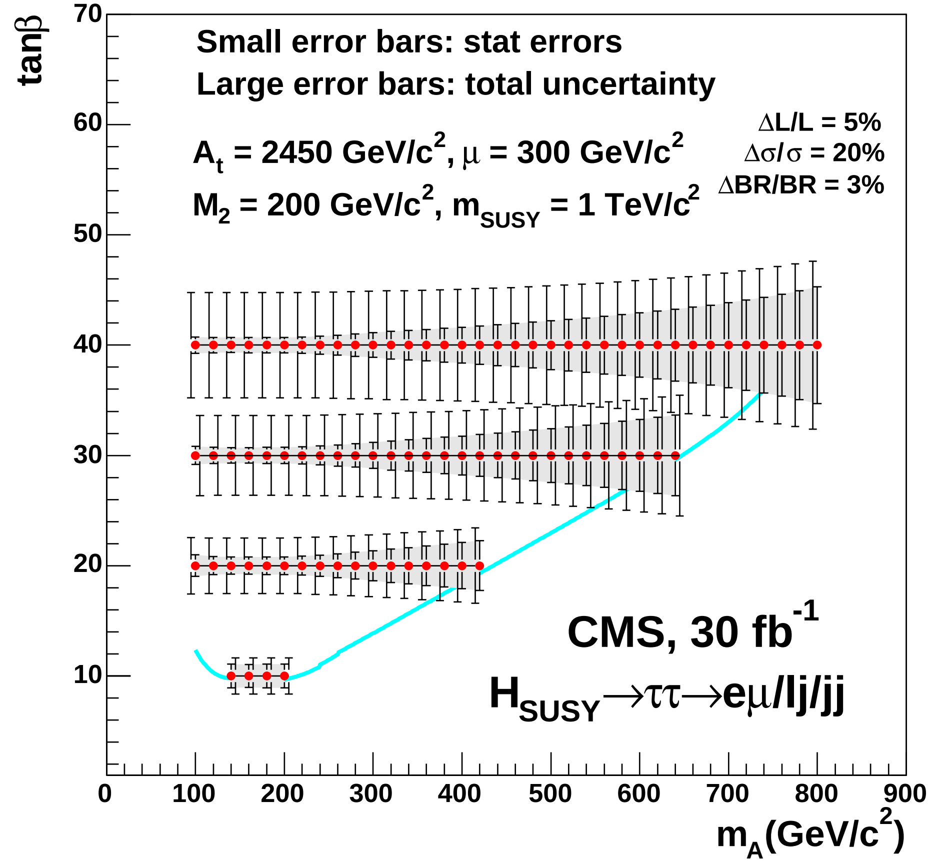
R. Kinnunen, S. Lehti, F. Moortgat, A. Nikitenko, M. Spira
CMS Note under CMS EB processing.

Uncertainty of NLO calculations
~ 20 % for 1b tag
[S. Willenbrock, M. Spira et al.]
is bigger than stat. uncertainty.

However systematic due to event selections in this analysis:

τ tagging
b tagging (1 b tag)
jet veto (2nd b veto)
calo scale

should be more understood



Uncertainties involved in the tan(β) measurement

At large tan(β), $\sigma \times Br \sim \tan^2(\beta)_{eff}\, f(M_A)$ at fixed μ, M_2, A_t, M_{SUSY}
$N_S = \tan^2(\beta)_{eff}\;\; f(M_A)\;\; L\;\; \varepsilon_{sel}$

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

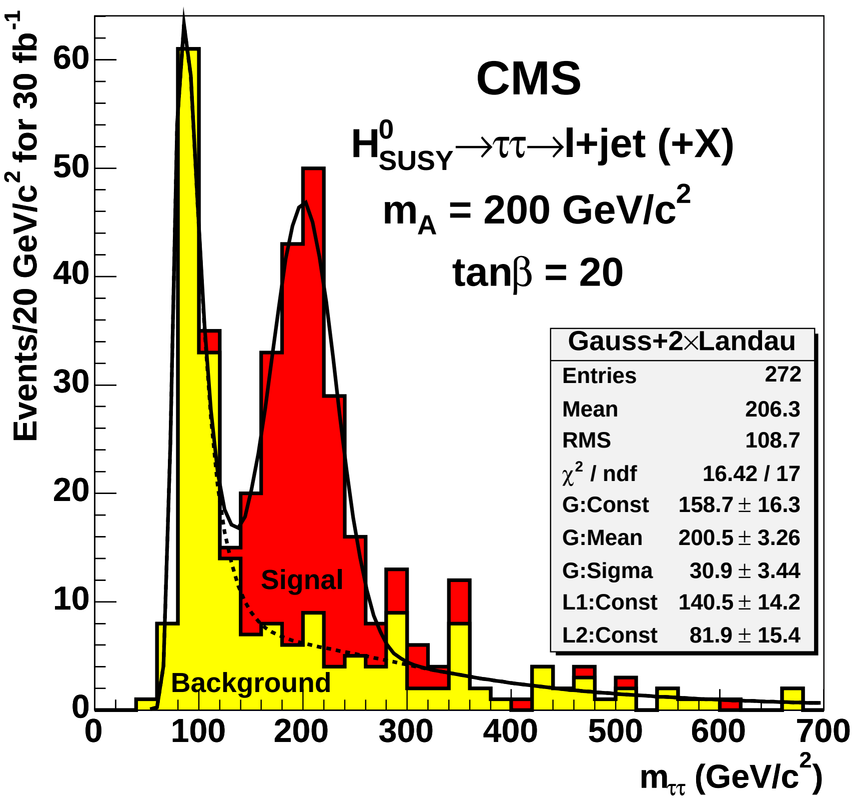
$$\Delta_{syst} = 0.5\, \mathrm{sqrt}(\Delta L^2 + \Delta\sigma_{th}^2 + \Delta Br_{th}^2 + \Delta\sigma(\Delta M_H)^2 + \Delta\varepsilon_{sel}^2 + \Delta B^2)$$

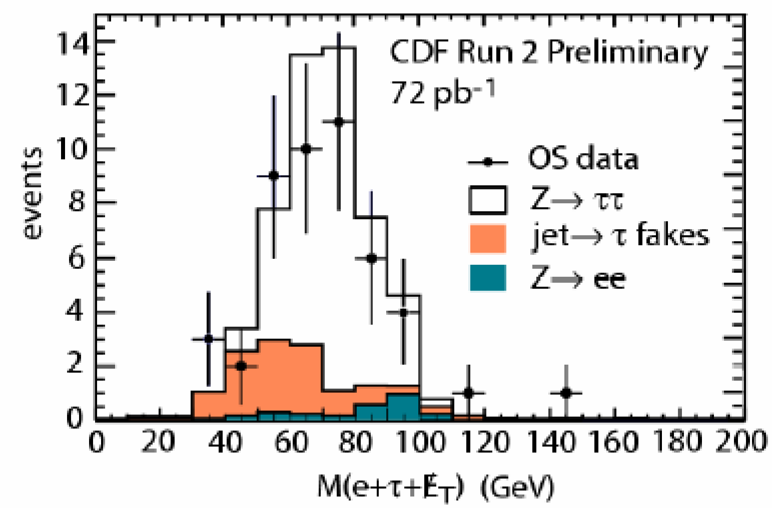
$\Delta\sigma_{th}$ = 20 % due to NLO scale dependence
ΔBr_{th} = 3 % uncertainties of SM input parameters
ΔL = 5 % luminosity uncertainty
$\Delta\sigma(\Delta M_H)$ = 10-12 % due to mass measurement at 5σ discovery limit
$\Delta B = \Delta N_B / N_S$ = 10 % at 5σ discovery limit (preliminary)

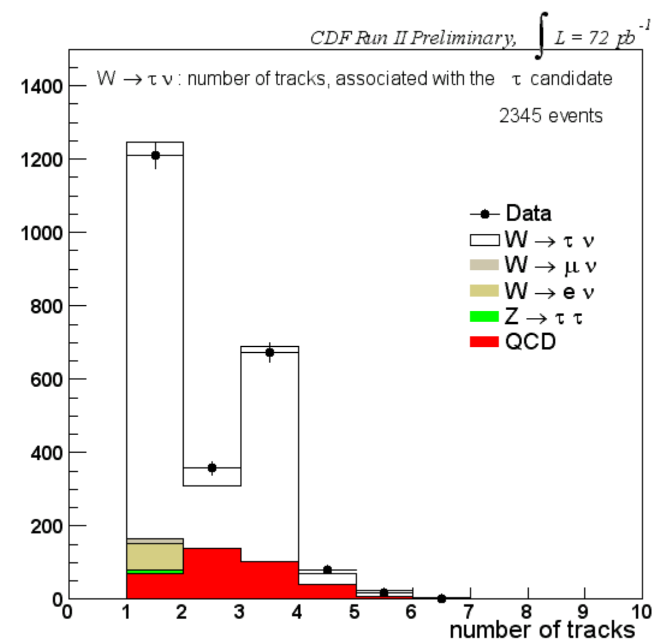
$$\Delta\varepsilon_{sel}^2 = \Delta\varepsilon_{calo}^2 + \Delta\varepsilon_{b\,tag}^2 + \Delta\varepsilon_{\tau\,tag}^2$$

$\Delta\varepsilon_{b\,tag}$ = 2.0 % (prelim.)
$\Delta\varepsilon_{\tau\,tag}$ = 2.5 % (prelim.)
$\Delta\varepsilon_{calo}$ = 2.9 % (prelim.)

Exploiting TeV Z →τ+τ– and W->τν







- How TeV evaluates τ id efficiency from the data, what we can learn ?
- How evaluate fake τ jet rate ?
  will be studies for PTDR

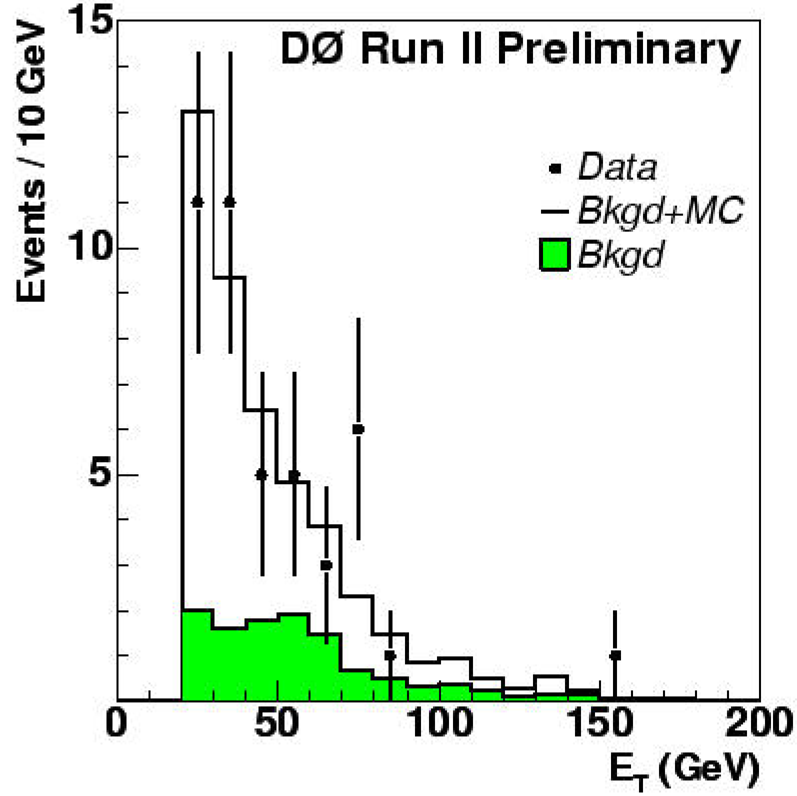
Z+b at TeV as benchmark for gb->bh (gg->bbh)

Z+b can be used as a benchmark for gb->hb at LHC: test N(N)LO predictions and Monte Carlo.

However, be careful:
at Teatron both contributions gb->Zb and qq~->Zbb are important while only gb->Zb is dominant at LHC and thus relevant to gb->hb
[J. Campbell et all hep-ph/0312024]

N(N)LO calculations are available for bb->h, gb->hb and gg->bbh and compared in J. Campbell et al, arXiv:hep-ph/0405302

184 pb^{-1} for e^+e^-
152 pb^{-1} for $\mu^+\mu^-$



Comparison of p_T^b between PYTHIA and NLO gb->hb, gg->bbh was presented in A.N. talk on HERA-LHC Workshop meeting 27 March, 2004

MSSM bbH, H->bb at high tanβ.

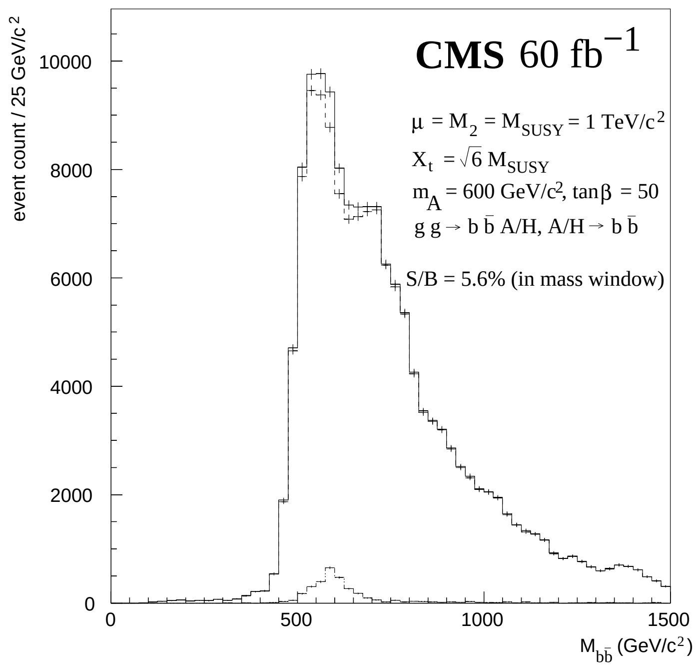
P. Gras

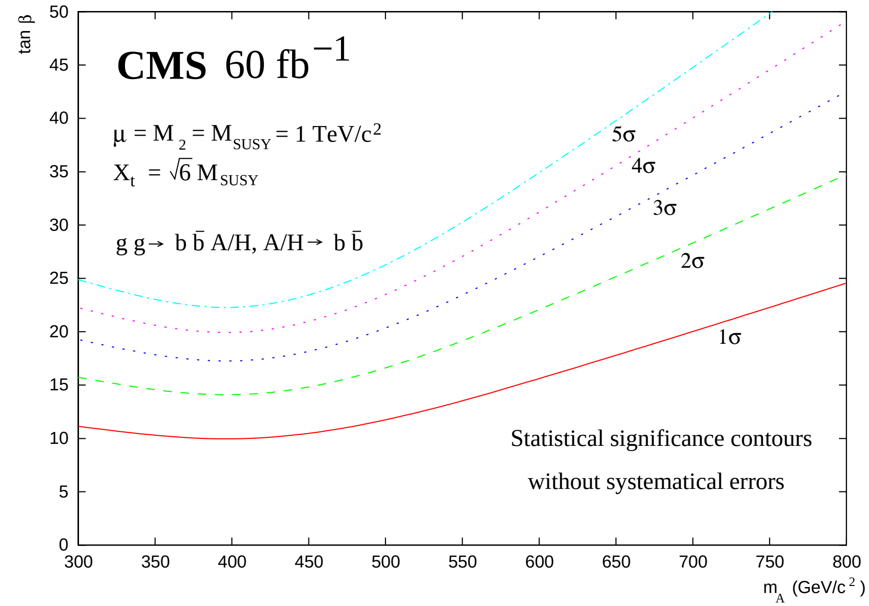
Level 1 multi-jet trigger : 1J or 3J or 4J ; thresholds 177, 86, 70 (95% eff) => 3 kHz

HLT – single b tagging for next-to-leading jet E_T > 160 GeV => 5 Hz

Off-line selections are similar to D0 : two hard jets (E_T > 220 GeV for M_H=600 GeV)
two soft jets E_T > 20 GeV
>= 3 b tagged jets

PYTHIA simulations

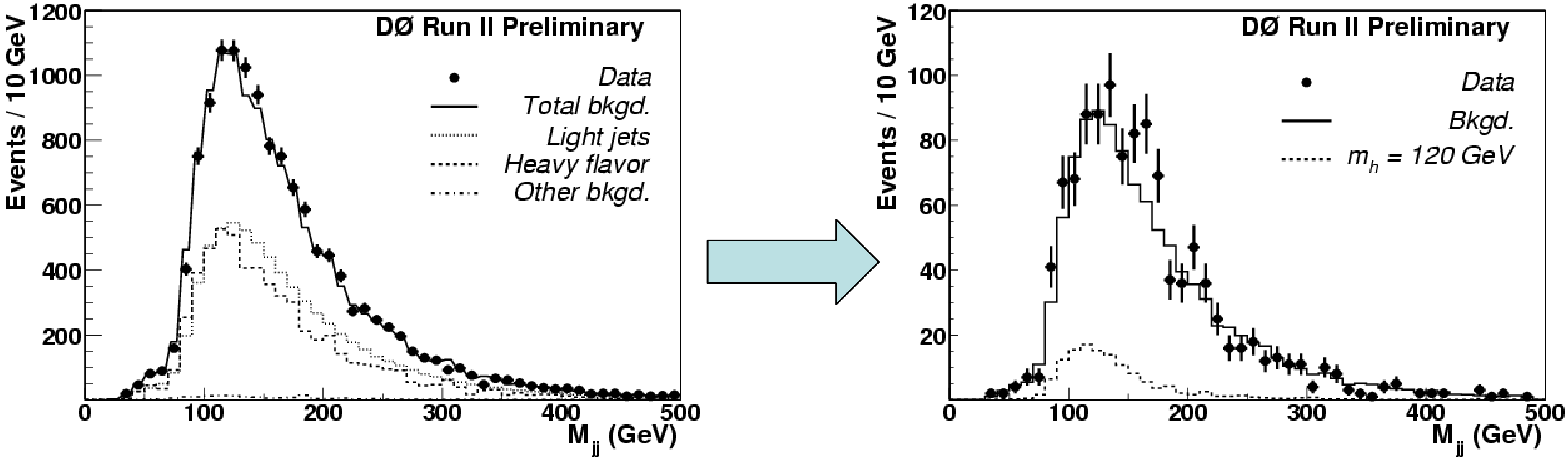




Common question : how to evaluate background shape ?
Will be addressed in details in the next iteration for PTDR

… learning D0 way …

From the double b-tagged data to triple b-tagged data background



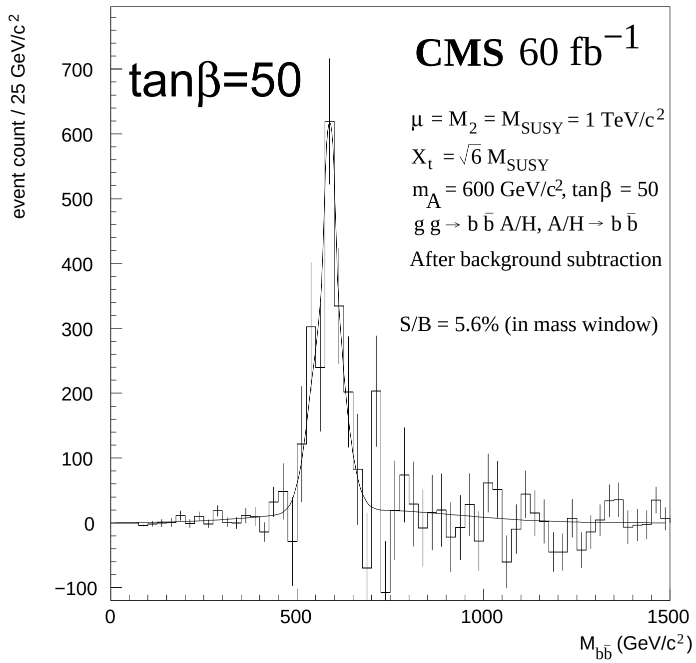
"The shape of the triple b-tagged data was estimated from double b-tagged data and extrapolated using a **tag-rate-function** derived on the multi-jet data sample. This background was then normalized to the triple b-tagged data outside 1 σ signal mass window" from the D0 Higgs results page

Can it be applied at LHC ? Background composition should be different at LHC

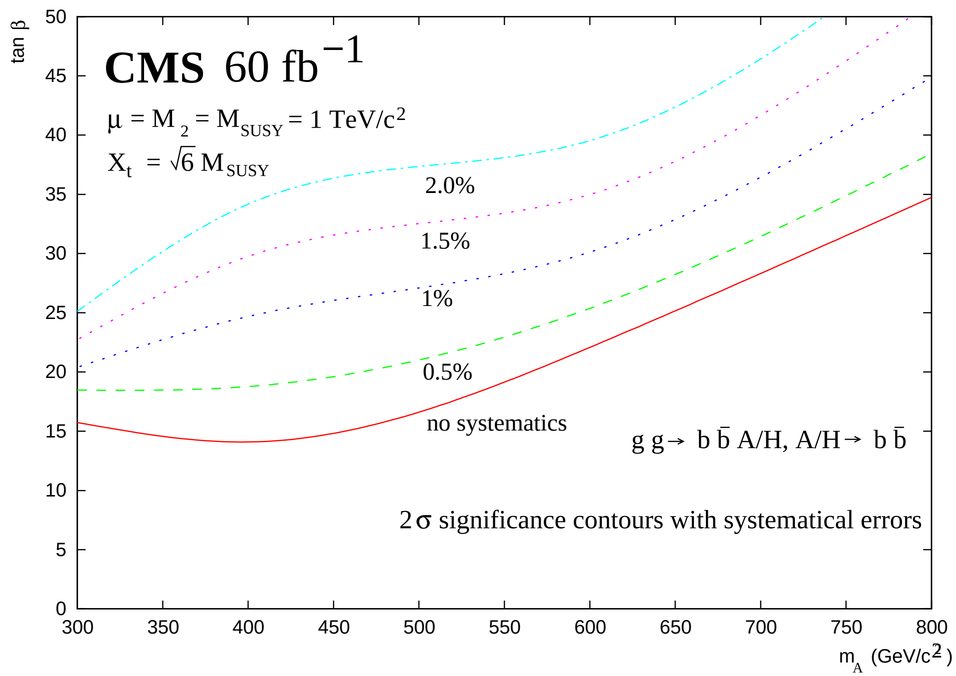
- triple b-tagged background with two of three real b jets is dominant (~ 72%)
- the main contribution come from gg->gg, gb->gb with g->bb~

Current CMS results on bbH, H->bb

Higgs mass after bkg. subtraction with known bkg. shape



The 2 σ discovery reach with different assumptions on the level of systematic



Beyond MSSM :

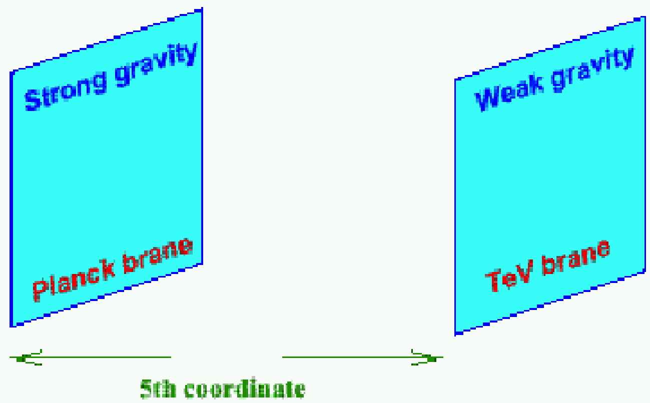
Radion -> hh -> $\gamma\gamma$bb, $\tau\tau$bb, bbbb

**D. Dominici, G. Dewhirst, S. Gennai, L. Fano,
A. Nikitenko; CMS Note under referees processing**

Extra dimensions : alternative to SUSY the solution of the hierarhy problem

Do we live on the brane?

We generally assume that we live on a brane, but it may not be the brane on which gravity is concentrated. Suppose that gravity is highly concentrated near what I'll call the Planck brane. So gravity is concentrated on one brane, the Planck brane, and we live on a second brane, not precisely on top of the first brane but a little apart. Gravity on our second brane would appear to be weak. And that's precisely what we wanted to explain: why gravity appears to be so weak. That's the hierarchy problem-why gravity is so weak. (Lisa Randall)



The Scalar Sector of the 5D Randall-Sundrum Model includes Higgs (h) and radion (ϕ)

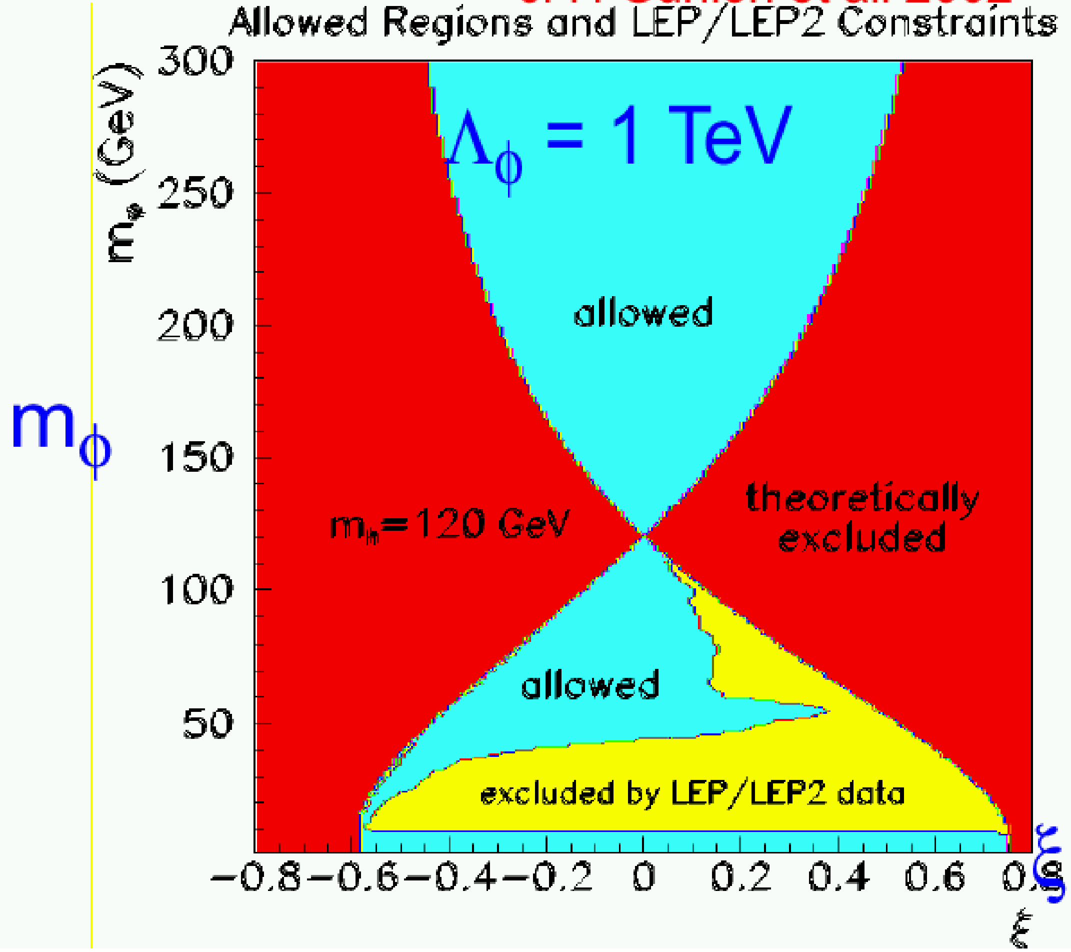
radion (ϕ) is a graviscalar which corresponds to fluctuations in the size of the extra dimension

The Randall-Sundrum Model : parameters and exp. constraints

4 independent parameter of the theory:

- Λ_ϕ - vacuum expectation value of the radion field (order of TeV)
- ξ - mixing parameter; affects mixing between Higgs and radion fields
- m_ϕ - radion mass, m_h - Higgs mass

J. F. Gunion et all 2002

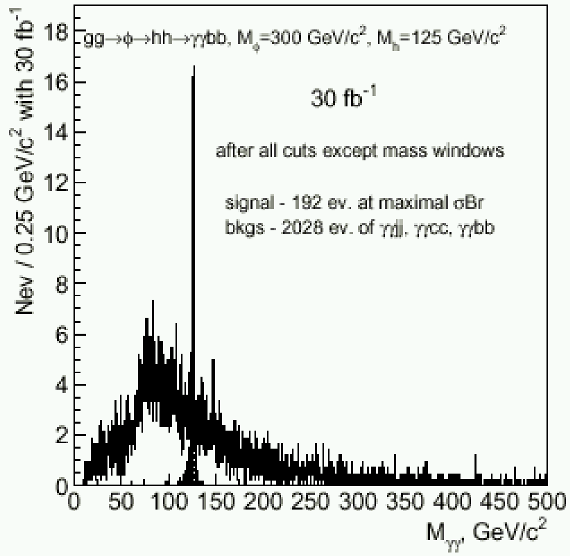


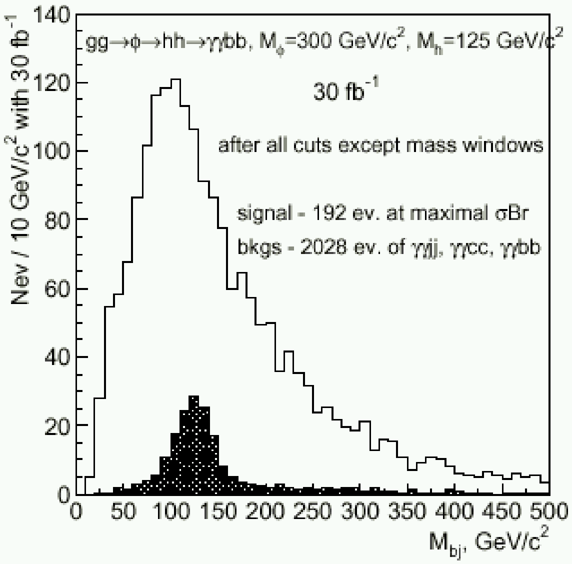
CMS : study on observability of radion -> hh, m_ϕ=300 GeV/c^2, m_h=125 GeV/c^2 (I)

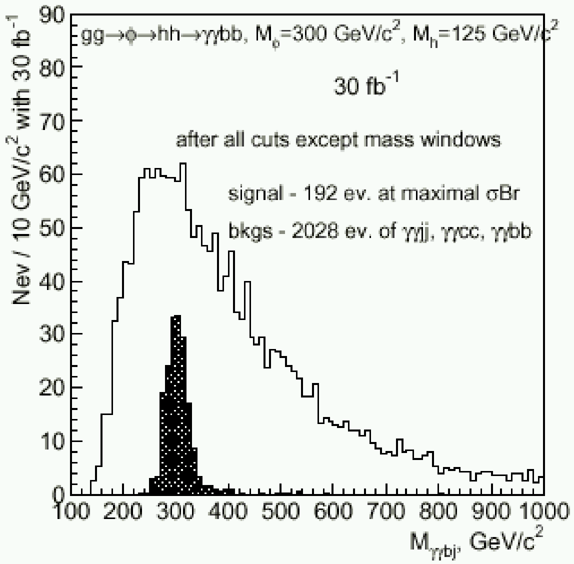
radion -> hh -> 2γ 2b

Background : γγjj, γγcc, γγbb + expected 40 % of reducible γ+3j, γ+bbj, ... (from inclusive h->γγ study)

$m_{\gamma\gamma}$, m_{bj} and $m_{\gamma\gamma bj}$ after selection of two isolated photons, two jets E_T > 30 GeV an single b tagging, but before mass cuts.







CMS : study on observability of radion -> hh, m_ϕ=300 GeV/c^2, m_h=125 GeV/c^2 (II)

Reconstructed radion mass after all selections for

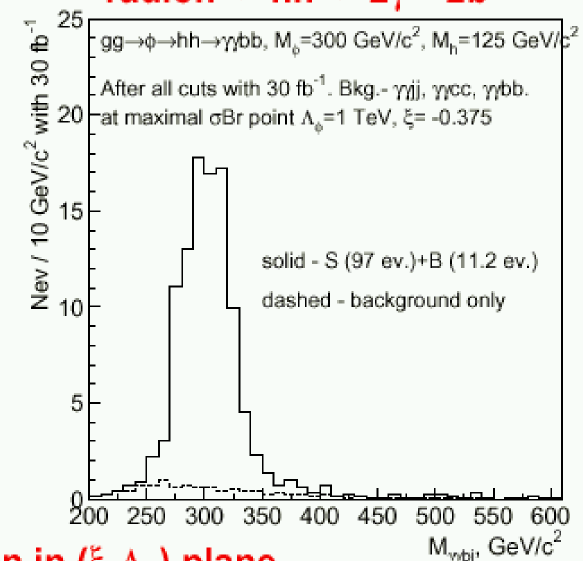
radion -> hh -> 2γ + 2b

radion -> hh -> 2τ (l + τ jet) + 2b

radion -> hh -> 2b + 2b

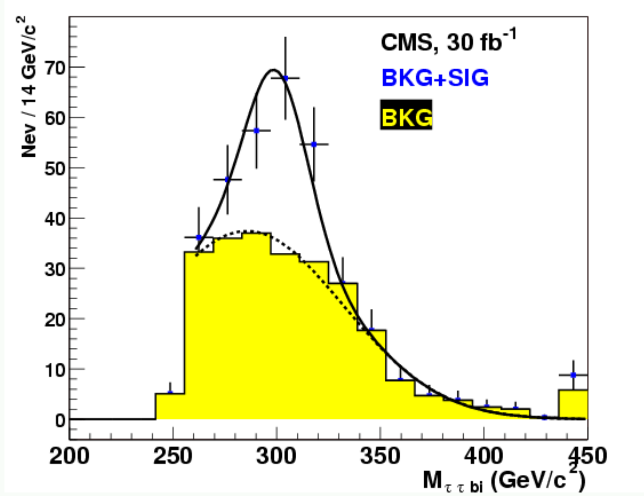
with 30 fb_{-1}

radion -> hh -> 2γ + 2b

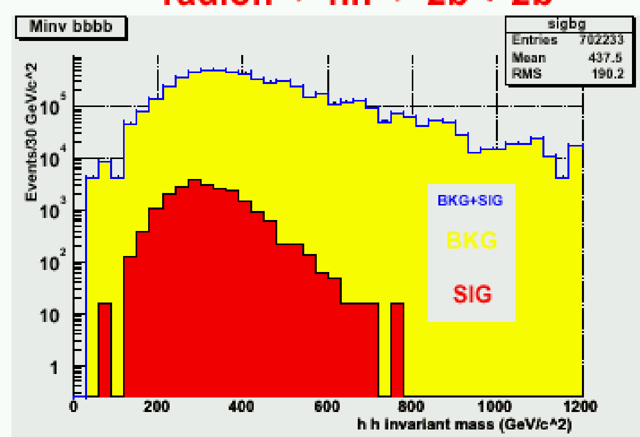


Maximal radion production cross section is taken in (ξ-Λ_ϕ) plane

radion->hh->ττbb

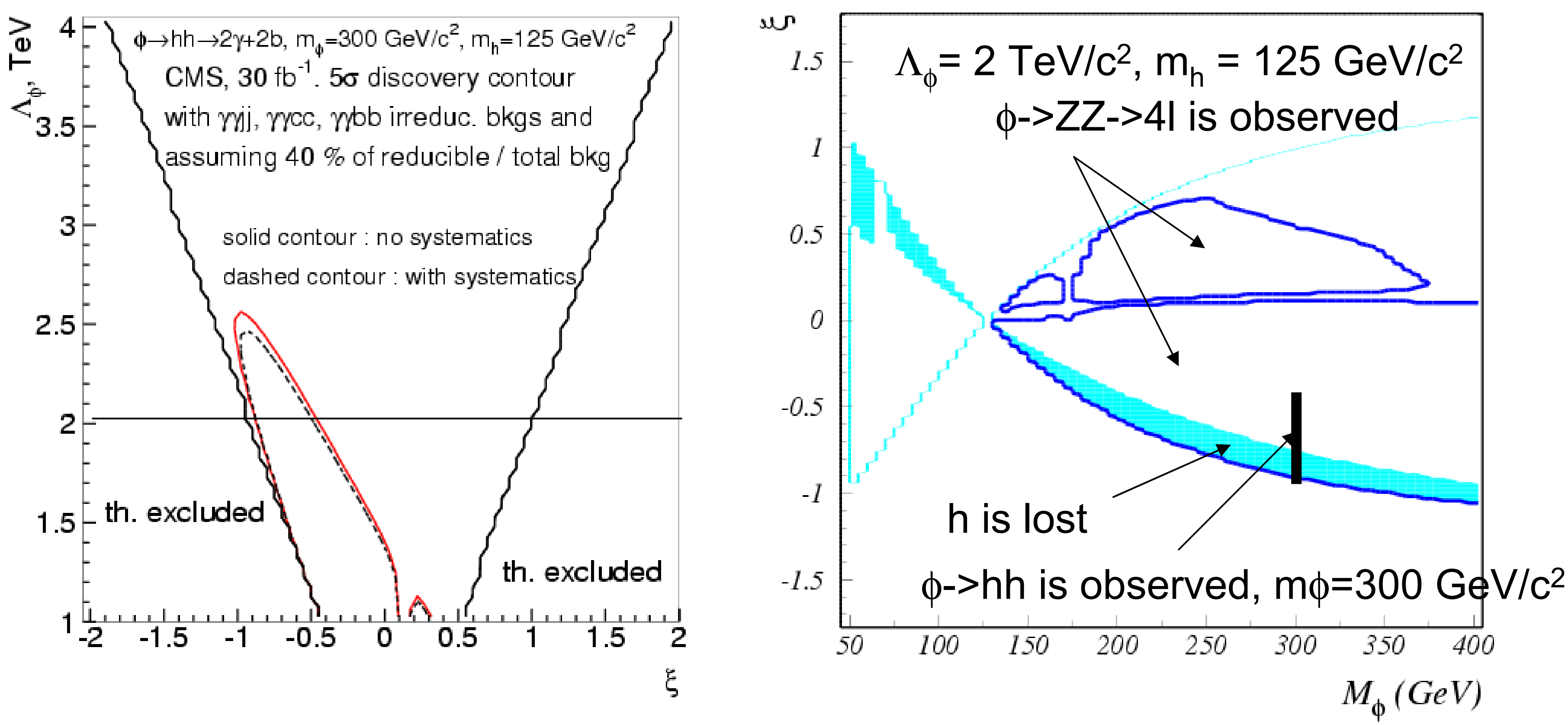


radion -> hh -> 2b + 2b



Radion->hh->γγbb, ττbb, bbbb observability

Scan in (Λ_ϕ, ξ) plane for m_ϕ=300 GeV/c², m_h=125 GeV/c²



Most probably will be re-done for MSSM pp->hh->γγbb case for PTDR

The next iteration of Higgs searches for Phys.TDR 2005 should include

- Updated trigger table and HLT algorithms
- Updated simulation and reconstruction software
- Experimental and theoretical systematic uncertainties for discovery and measurement; understanding of the generator uncertainties
- Understanding on how to measure background from the data
- Production of the official analysis code

THE END

1. Search for the Standard Model Higgs boson

(detector PRS channels are not included: incl. h->2γ, tth(h->bb),
qqh(h->WW(*)->2l 2ν, lν+jj), strong VV scattering)

1.1. Introduction; 1.2. Channels

1.2.1. inclusive H->ZZ$^{(*)}$->4l

1.2.2. inclusive H->WW$^{(*)}$->2l 2ν

1.2.3. VBF (qq->qqH) H->2γ

1.2.4. VBF (qq->qqH) H->2τ

1.2.5. ttH; H->2γ

1.2.6. WH, ZH; H->2γ

1.2.7. ttH, WH; H->WW$^{(*)}$->2l

2. Search for the MSSM Higgs bosons

2.1. Introduction; 2.2. Channels

(detector PRS channels are not included: bbH, H->2τ with l+τ jet, 2 jet)

2.2.1. bbH, H->$\tau\tau$->2l

2.2.2. bbH, H->2μ

including "intensive coupling regime" in collaboration with theorists: A. Djouadi (Montpellier) + E.Boos (MSU)

2.2.3. bbH, H->bb

2.2.4. gg->tbH$^+$, H$^+$->$\tau\nu$->τ jet

$M_{H+} < M_t$, lepton trigger

$M_{H+} < M_t$, fully hadronic topology

$M_{H+} > M_t$, fully hadronic topology

2.2.5. Specific SUSY searches

2.2.5.1. H->invisible ($\chi_1\chi_1$) in qqH mode

2.2.5.2. $H \to \chi_2\chi_2 \to 4l$, $H^+ \to \chi_{2,3}\,\chi^+_{1,2} \to 3l$

2.2.5.3. stop stop Higgs, $H \to bb$

Low tan(β)

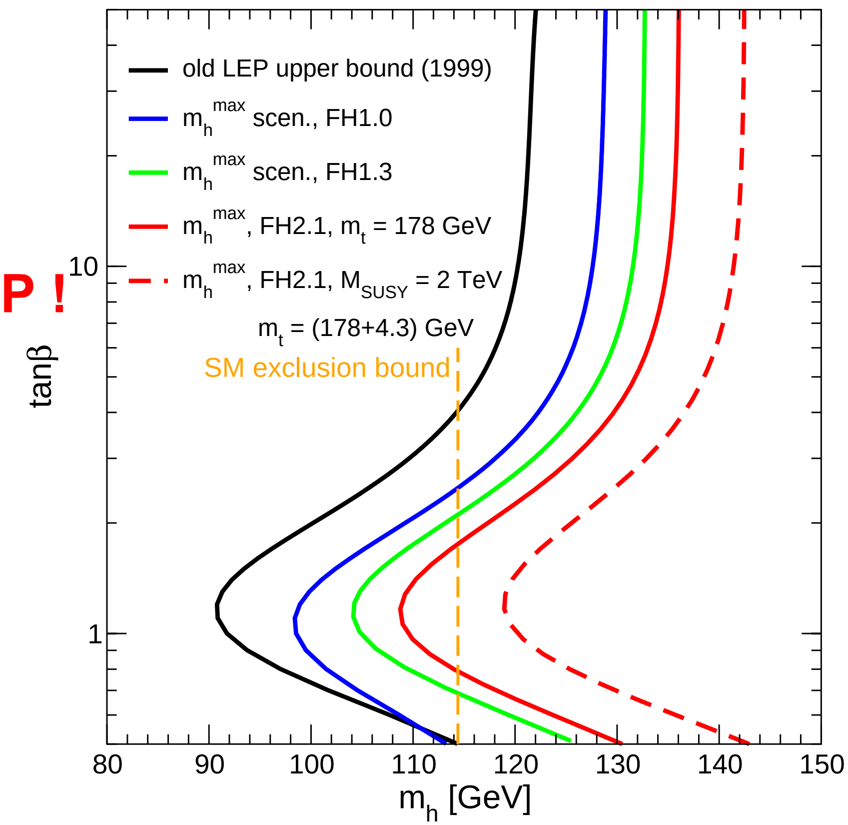
S. Heinemeyer, G. Weiglein, 04

No tan(β) exclusion for

$m_t \to m_t + \sigma_{mt}$

M_{SUSY}=1 TeV->2 TeV

Low tan(β) not fully excluded by LEP !



We should not forget "low tan(β) channels" :

A->Zh (Z->ll, h->bb)

A->tt

A->2γ

H->hh->2γ 2b

2.3. Discovery reach and measurement of MSSM parameters

2.2.1. discovery reach in the Benchmark scenarios

M. Carena et al., hep-ph/0202167

- see in the talk of G. Weiglein at Higgs meeting 11.05.2004.
- FeynHiggs input for considered scenarios can be found in

http://cmsdoc.cern.ch/~anikiten/cms-higgs/feynhiggs_bmscenarious/
(thanks to Sven Heinemeyer)

2.2.2. mass and width measurement

2.2.3. tan(β) measurement

- cross section of gg->bbH (H->2τ, 2μ), gb->tH^+,H^+->$\tau\nu$; as an input in the global fit of SUSY parameters;
- from Higgs width with A/H->$\mu\mu$ at high tan(β)

3. Search for Higgs bosons in other models

3.1. Scalar sector of 5D Randal-Sundrum Model

3.1.1. ϕ->hh->$\gamma\gamma$+bb
3.1.2. ϕ->hh->$\tau\tau$+bb
3.1.3. ϕ->hh->bb+bb
3.1.4. Complementarity of Higgs and radion searches

For every analysis:

1. Level 1 and HLT path
2. Optimized off-line selections
3. How to evaluate background from the data to maximum possible extend
4. Systematic uncertainties: exp. + theoretical