Overview of the LHC-D Higgs workshop at Karlsruhe (March 7-8, 2006)

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MPI ATLAS meeting, March 20, 2006

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Outline

Topics of the workshop

Experimentalist talks

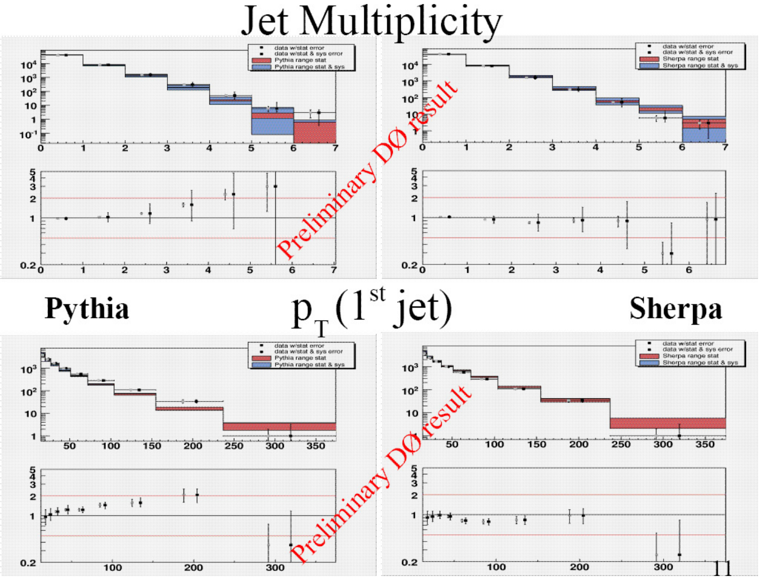
- sorted by collaboration
  - ATLAS (7 talks)
  - CMS (3 talks)
  - D0 (2 talks)
- sorted by Higgs channel
  - SM Higgs
    - $H \to \tau\tau$ (ATLAS,D0)
    - $H \to WW$ (ATLAS,CMS)
    - $H \to \gamma\gamma$ (CMS)
    - $H \to ZZ^* \to 4l$ (ATLAS)
    - $H \to ZZ \to 2l2j$ (CMS)
  - MSSM Higgs
    - $A/H \to \mu\mu, \tau\tau$ (ATLAS)
    - $A/H \to t\bar{t}$ (ATLAS)
    - $A/H \to \tilde{\chi}_2^0\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\tilde{\chi}_1^0 4l$ (ATLAS)

Theoretician talks

- SM Higgs (2 talks)
  - EW corrections to $H \to 4l$
  - QCD corrections to $H \to WW$
- MSSM Higgs (5 talks)
  - NLO calculations for MSSM gluon fusion production mode
  - Associated MSSM Higgs production with heavy quarks
  - MSSM neutral Higgs + Jet production
  - Anomalous couplings in VBF
  - QCD corrections to h^0 mass

Outline

Comparison of D0 data vs Sherpa/Pythia MC in $Z(\to ee) + jets$ (H. Nilsen, Freiburg)



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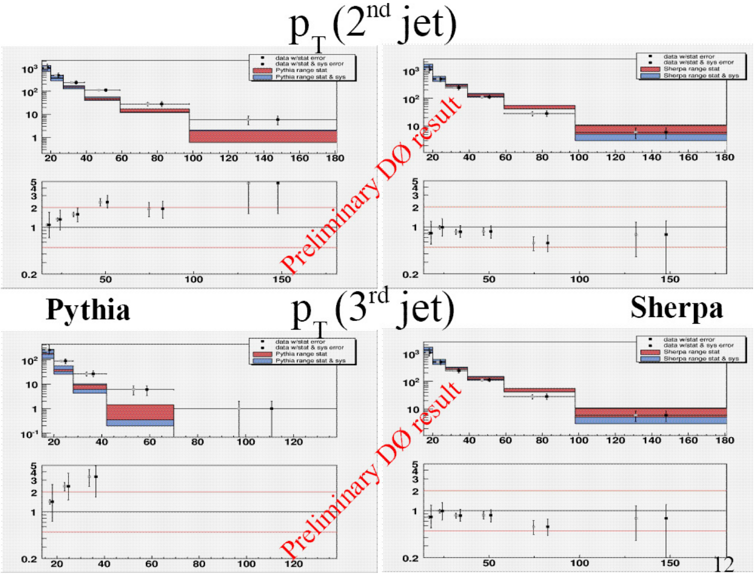

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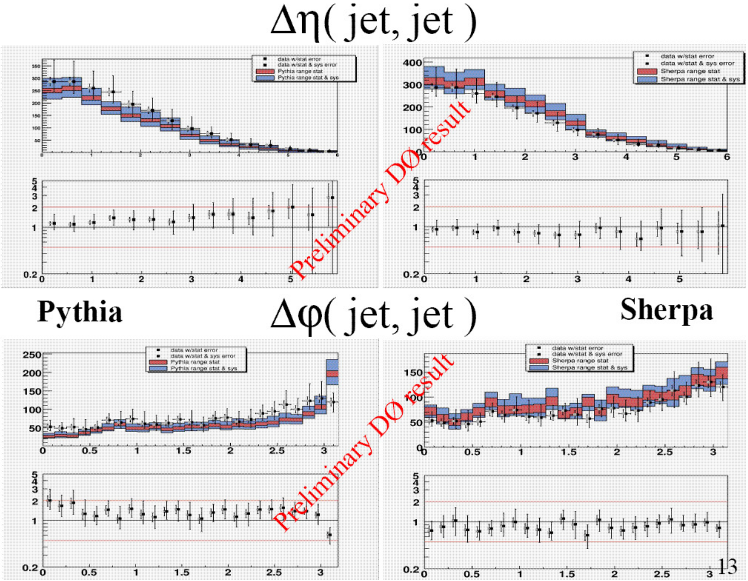
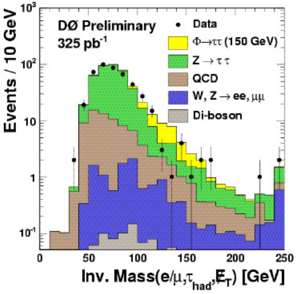
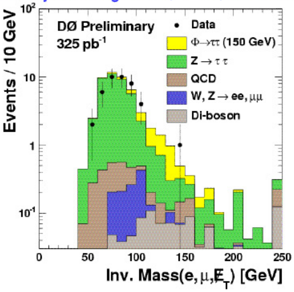


- Observed data events and expected BGND events at the end of the selection: (statistical and systematic uncertainties are added in quadrature)

	Data	Sum BGND	QCD	$Z \to \tau\tau$	$Z \to \mu\mu / ee$	W	Di-Boson	tt(bar)
$e+\tau_h$	484	427.3 ± 55.3	199.5 ± 26.0	202.7 ± 26.3	10.2 ± 1.4	14.0 ± 1.9	0.54 ± 0.09	0.35 ± 0.05
$\mu+\tau_h$	575	576.3 ± 61.5	62.2 ± 6.6	491.7 ± 52.6	4.6 ± 1.1	13.5 ± 1.6	3.05 ± 0.33	1.22 ± 0.14
$e+\mu$	42	43.5 ± 5.3	2.1 ± 0.4	39.1 ± 5.0	0.63 ± 0.12	0.30 ± 0.20	0.99 ± 0.14	0.06 ± 0.02

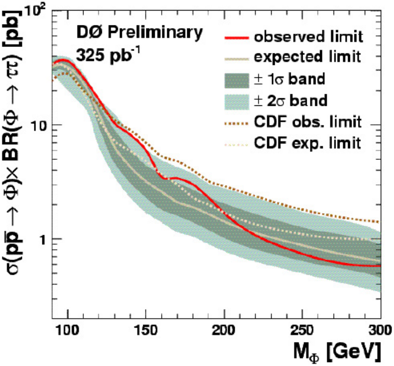
- Major systematic uncertainties: normalization of multi-jet background, τ-ID, Jet-Energy-Scale





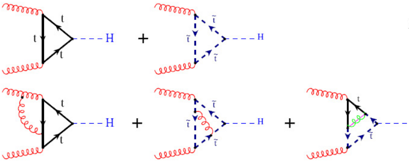
Search for $h/H/A \to \tau\tau$ with D0 data (I. Torchiani, Freiburg)

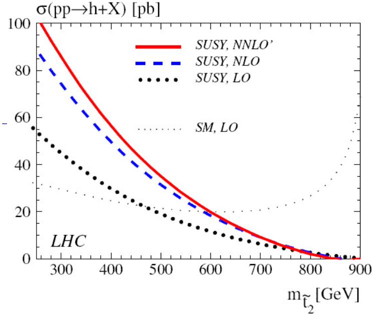
- A search for Neutral Higgs Bosons in τ final states as been performed using 325 pb^{-1} data taken by DØ in Run II
  - ⇨ No indication for a signal has been found
  - ⇨ Upper limits were derived at 95% CL
- τ results are comparable with CDF



Outline

SUSY-QCD effects in gluon fusion Higgs production (M. Steinhauser, Karlsruhe)



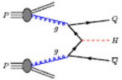


- $gg \to H$: most important production mechanism at LHC
- SM: NNLO predictions available (+ NNNLO-soft)
- MSSM: NLO top squark effects known (Computer code: `evalcsusy`; uses `SLHA`)
- $K^{\rm MSSM} \sim K^{\rm SM}$
- Interesting: gluophobic Higgs
- $gg \to A$ known to NLO

Associated MSSM Higgs production with heavy quarks (M. Krämer, Aachen)

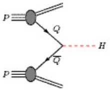
Inclusive $b\bar{b}H$ production: two calculational schemes

4-flavour scheme



- $+$ exact $g \to b\bar{b}$ splitting & mass effects
- $-$ no summation of $\ln(M_H/M_b)$ terms

5-flavour scheme

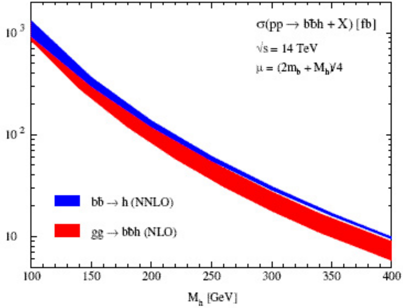


- $+$ summation of $\ln(M_H/M_b)$ terms
- $-$ LL approximation to $g \to b\bar{b}$ splitting

- Status
  - $gg \to h/H + Q\bar{Q}$: QCD corrections, full SUSY-QCD in progress [Peng, Wen-Gan, Hong-Sheng, Ren-You, Liang, Yi, unpublished; Dittmaier, Häfliger, MK, Spira, in preparation]
  - $gg \to A + Q\bar{Q}$: QCD corrections [Dittmaier, MK, Spira, preliminary]
  - $gg \to H^\pm + Q\bar{Q}'$: (SUSY)-QCD corrections [Peng, Wen-Gan, Ren-You, Yi, Liang, Lei; Dittmaier, Spira, MK, Walcher, in preparation]
  - $b\bar{b} \to h/H/A$: NNLO QCD corrections [Harlander, Kilgore]
    MSSM EW corrections [Dittmaier, MK, Mück, preliminary]
  - $bg \to h/H/A + b$, $bg \to H^\pm + t$: NLO (SUSY-)QCD corrections [Plehn, Zhu, Berger, Han, Jiang Plehn, Alves, Plehn,...]

$\Rightarrow$ Lots of activity and ongoing calculations...

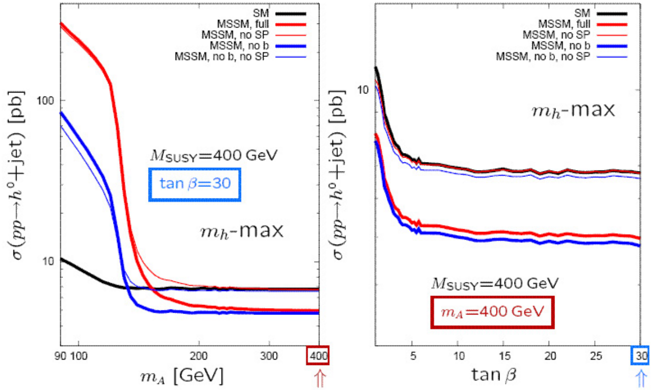
[Harlander, Kilgore; Dittmaier, MK, Spira]



Production of $h/H/A + jet$ in MSSM (O. Brein, Durham)

[MSSM Results]

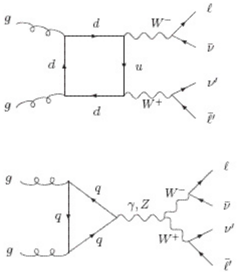
– m_A- and $\tan\beta$-dependence (cuts: $p_{T\,\mathrm{jet}} \geq 30$ GeV , $|\eta_{\mathrm{jet}}| \leq 4.5$)



- SM simulations show: Higgs + high-p_T jet production is a promising alternative to the inclusive production.

- LO MSSM prediction shows large effects due to virtual squarks. (processes loop-induced)
  - sizeable differences between SM and MSSM expectations can occur
  - angular distributions are changed at the ≈ 5% level

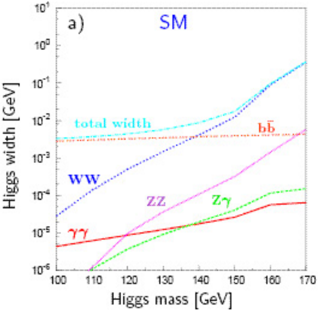
Gluon-induced WW background in $H \to WW$ (N. Kauser, Würzburg)

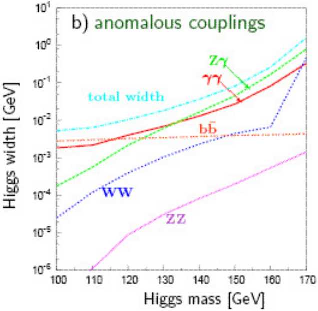


	$\sigma(pp \to W^*W^* \to \ell\bar{\nu}\bar{\ell}'\nu')$ [fb]					
	gg	$\frac{\sigma_{gg,3gen}}{\sigma_{gg,2gen}}$	$q\bar{q}$ LO	$q\bar{q}$ NLO	$\frac{\sigma_{NLO}}{\sigma_{LO}}$	$\frac{\sigma_{NLO+gg}}{\sigma_{NLO}}$
σ_{tot}	$60.12(7)$ $53.61(2)^{+14.0}_{-10.8}$	1.12	$875.8(1)^{+54.9}_{-67.5}$	$1373(1)^{+71}_{-79}$	1.57	1.04 1.04
σ_{std}	$29.79(2)$ $25.89(1)^{+6.85}_{-5.29}$	1.15	$270.5(1)^{+20.0}_{-23.8}$	$491.8(1)^{+27.5}_{-32.7}$	1.82	1.06 1.05
σ_{bkg}	$1.416(3)$ $1.385(1)^{+0.40}_{-0.31}$	1.02	$4.583(2)^{+0.42}_{-0.48}$	$4.79(3)^{+0.01}_{-0.13}$	1.05	1.30 1.29

- calculation for loop-induced $gg \to W^*W^* \to \ell\bar{\nu}\bar{\ell}'\nu'$
- including loops with finite quark masses (t, b)
- including full spin correlations, off-shell & interference effects
- important background to $H \to WW$ searches at LHC
- $\mathcal{O}(\alpha_s^2)$, but enhanced by Higgs search cuts and g $\mathcal{L}$
- without cuts only 5% correction to known WW background
- but up to $\sim$ 30% with realistic experimental cuts
- GG2WW event generator available

VBF with anomalous couplings (V. Hankele, Karlsruhe)





- Decay $H \to \gamma\gamma$ and $H \to Z\gamma$ only at one-loop-level
- Dominant decay channel $H \to b\bar{b}$ for small Higgs masses and $H \to WW$ for larger Higgs masses

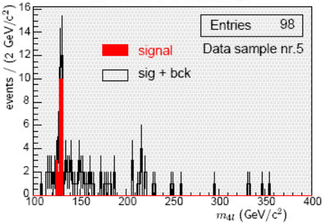
- $H \to b\bar{b}$ is dominant decay channel only for very small Higgs masses.
- Partial decay widths of $H \to \gamma\gamma$ and $H \to Z\gamma$ can be enhanced by several orders of magnitude. Dominant decay channels above 120 GeV.

Outline

Study of $H \to ZZ^* \to 4l$ with full simulation (S. Horvat, MPI)

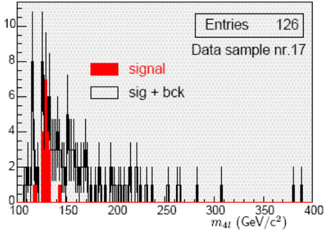
- actual data at 30 fb^{-1} will look more like this (for 130 GeV/c^2):

if we're lucky



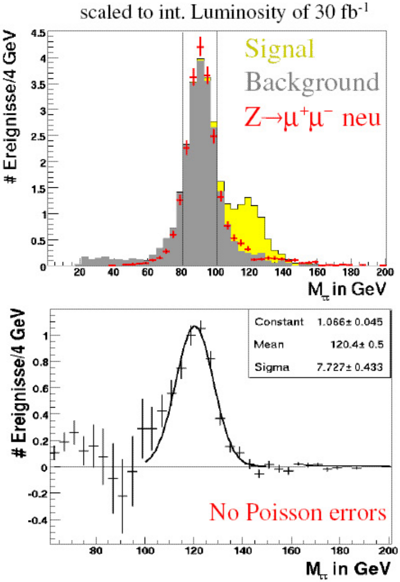
(2 independent data subsets)

if we're not so lucky



	m_H =130 GeV/c^2	m_H =180 GeV/c^2	m_H =280 GeV/c^2
N_{signal}	19.7±0.1	23.4±0.3	53.0±0.1
N_{ZZ}	12.0±0.3	31.8±0.5	35.2±0.6
$N_{Zb\bar{b}}$	4±2	1±1	0±2
$N_{t\bar{t}}$	0.7±0.4	0.5±0.4	0.4±0.4
Significance	4.0±0.3	3.5±0.2	7.3±0.4
TDR study	4.8	11.2	14.5

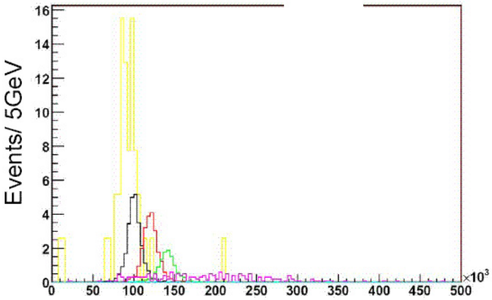
Estimating $Z \to \tau\tau$ background in VBF $H \to \tau\tau$ with $Z \to \mu\mu$ data (M. Shmitz, Bonn)



Procedure:

- Select $Z \to \mu^+\mu^-$ events
- Change μ-energy
- Recalculate $p\!\!\!/_{T,miss}$
- Calculate $M_{\tau\tau}$ distribution
- Normalise to $H \to \tau^+\tau^- \to \mu^+\mu^-$ data
  - → 81 GeV < $M_{\tau\tau}$ < 101 GeV
- Subtract of the background
- Measure M_H

Study of $H \to \tau\tau$ with fast simulation (C. Valderanis, MPI)

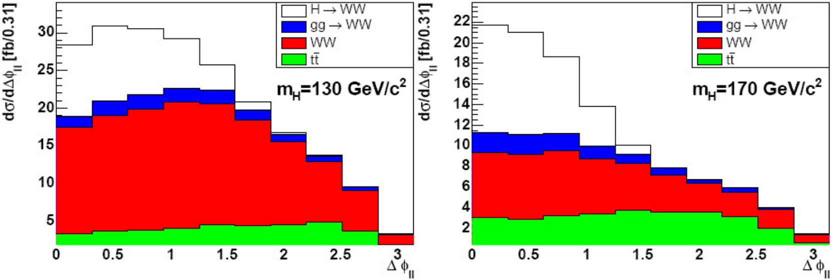


	Mass window	N_{signal}	N_{back}	$s/\sqrt{(s+b)}$
H(100)	[90,115]	22	57	2.4
H(120)	[110,135]	19	8	3.6
H(140)	[130,155]	9	6	2.3

Background normalization in $H \to WW$ (M. Dührssen, Freiburg)

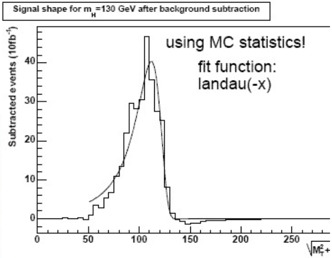
Background normalization :

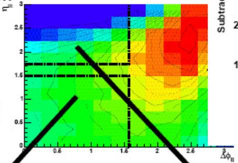
- tt : get shape and absolute size from control sample with 2 b-tagged jets
- qq $\longrightarrow$ WW :
  - shape from MC : PDF and renormalization/ factorization scale variation gives uncertainty $<$5%
  - absolute size : normalization from data at $\Delta\phi_{ll} > 2$
- gg $\longrightarrow$ WW : shape and absolute size from MC !

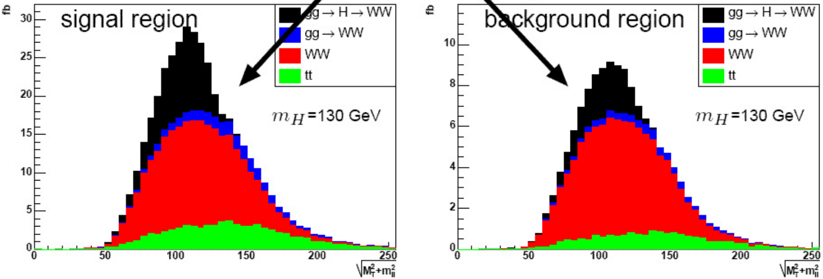


- experimental and theoretical uncertainties still under evaluation

- Measure M'_T in signal and background region, take the difference...
- Not optimal solution : subtracts also a lot of signal !!!
- relative normalization
  - from MC
  - from sideband $M'_T > m_H$



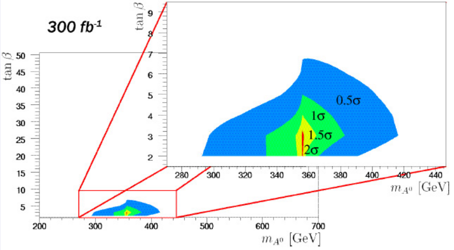




Study of $A/H \to \tilde{\chi}_2^0\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\tilde{\chi}_1^0 4l$ with fast simulation (N. Möser, Bonn)

m_h max scenario

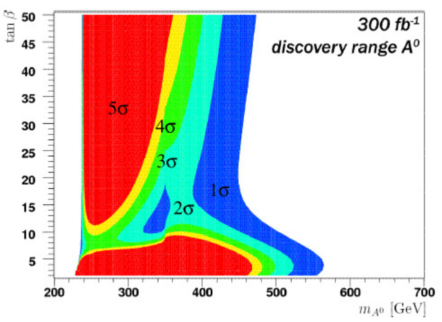
masses of squarks and sleptons $\sim$ 1 TeV



max signal $\sim$ 20, background $\sim$ 110 (most SUSY)

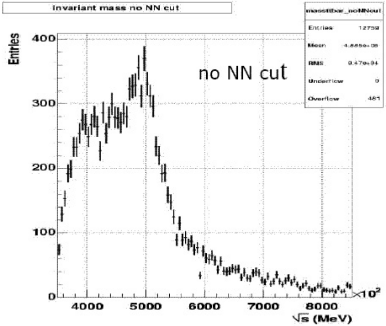
light sleptons scenario

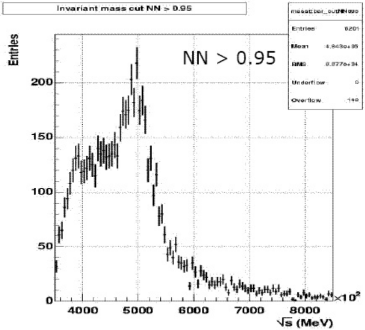
masses of sleptons $\sim$ 250 GeV



max signal $\sim$ 3600, background $\sim$ 220

Study of $A/H \to t\bar{t}$ with fast simulation (A. Siebel, Wuppertal)

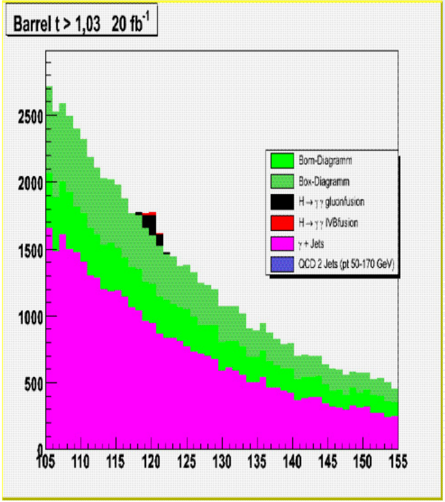




- MSSM $H^0/A^0 \to t\bar{t}$ studied
- Interference term introduced in MC
- Mass reconstruction using KINFIT
- χ^2 procedure recognises Higgs and discriminate QCD $t\bar{t}$ for “true” jets
- Better selection for light jets required
- **First indications: “fully hadronic” $t\bar{t}$ can be used to find resonances!**

Outline

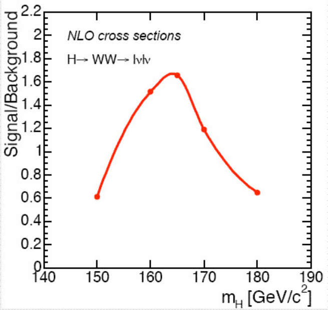
Study of $H \to \gamma\gamma$ with full simulation (T. Bosse, Aachen)

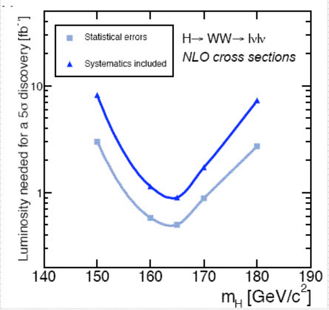


- Choose a mass-window of ΔM = 2 GeV with center at Higgs Boson mass
  - $\frac{N_S}{\sqrt{N_B}} \approx 1{,}15$ for 1 fb^{-1}
- This equals about 18 fb^{-1} for a significance $\frac{N_S}{\sqrt{N_B}} = 5$

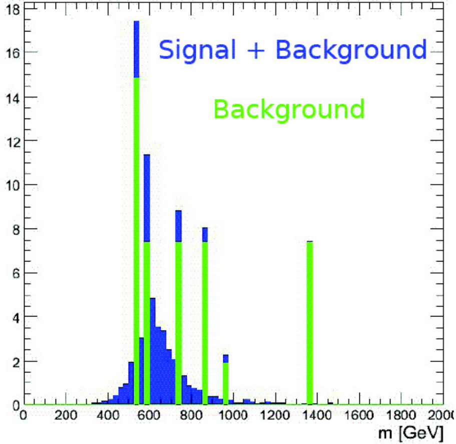
Study of $H \to \tau\tau$ with full simulation (G. Davatz, Zurich)

Reaction $pp \to X$	$\sigma_{NLO} \times BR$	L1+HLT	2 leptons	All cuts
$\ell = e, \mu, \tau$	pb	Expected event rate in fb		
$H \to WW \to \ell\ell$, $m_H = 160$ GeV	2.34	1353 (58%)	359 (27%)	42 (12%)
$H \to WW \to \ell\ell$, $m_H = 165$ GeV	2.36	1390 (59%)	393 (28%)	46 (12%)
$H \to WW \to \ell\ell$, $m_H = 170$ GeV	2.26	1350 (60%)	376 (28%)	33 (8.8%)
$qq \to WW \to \ell\ell$	11.7	6040 (52%)	1400 (23%)	12 (0.9%)
$gg \to WW \to \ell\ell$	0.48	286 (60%)	73 (26%)	3.7 (5.1%)
$tt \to WWbb \to \ell\ell$	86.2	57400 (67%)	15700 (27%)	9.8 (0.06%)
$tWb \to WWb(b) \to \ell\ell$	3.4	2320 (68%)	676 (29%)	1.4 (0.2%)
$ZW \to \ell\ell\ell$	1.6	1062 (66%)	247 (23%)	0.50 (0.2%)
$ZZ \to \ell\ell, \nu\nu$	1.5	485 (32%)	163 (34%)	0.35 (0.2%)
Sum backgrounds	105	67600 (64%)	18300 (27%)	28 (0.2%)





Study of $H \to ZZ \to 2l2j$ with full simulation (U. Felzmann, Karlsruhe)



Reconstructed invariant *lljj* mass, $m_{Higgs} = 700$ GeV

Very preliminary Plot

NLO, $\int L dt = 60\ fb^{-1}$
low luminosity, $L = 2x10^{33} s^{-1} cm^{-2}$

Dataset	σ [fb]	Events expected	after selection
qqH700	7.43	446	41
TTbar_inclusive	840,000	50,400,000	0
ZZjets_inclusive	15,300	918,000	2
Zjets_400_700	2,224	133,447	44

Outline

Summary

- there were no “big news” or “considerable improvements” talks – mostly “current status” and “analysis optimization” talks
- main question asked by experimentalists: When NLO calculations of background processes $WWjj$, $ZZjj$, $t\bar{t}jj$ will be done? – Answer: It takes about 2 years to calculated one of those, so don’t expect it too soon.
- general tendency: the closer the LHC start-up date, the lower expected signal significances (more realistic detector simulations)