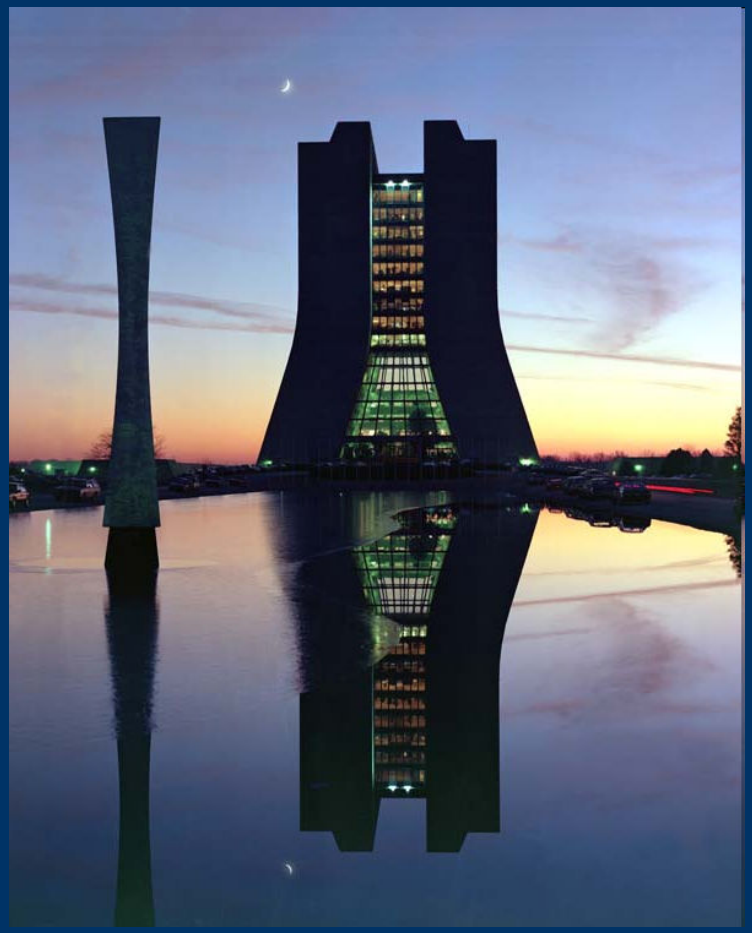
Higgs in CMS

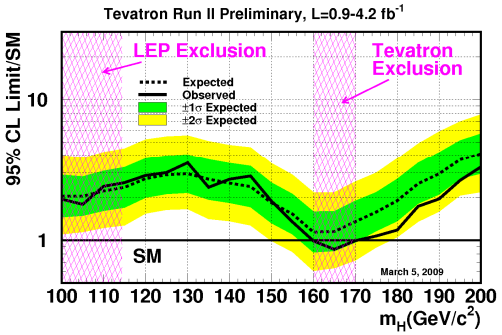
CTEQ and Higgs **Fermilab** **19 November 2009**



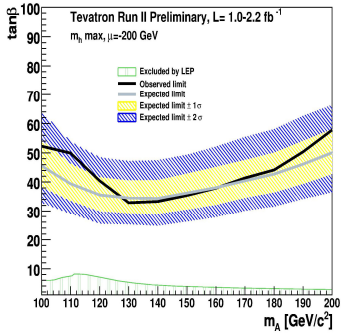
Andrey Korytov, University of Florida, CMS

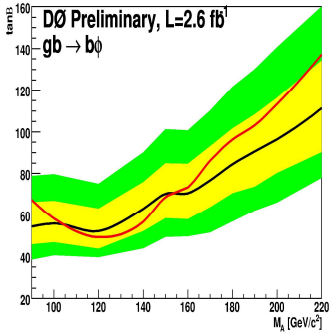
Tevatron Higgs limits (scene for LHC startup)

SM Limits

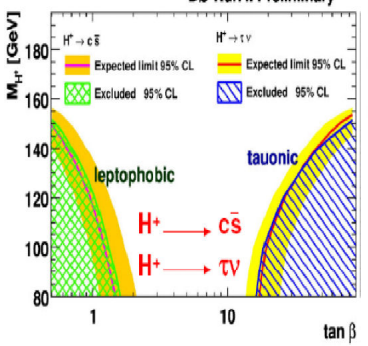


MSSM $\Phi \to \tau\tau$
MSSM $\Phi \to bb$
MSSM $H^{\pm} \to \tau\nu$
MSSM $H^{\pm} \to tb$

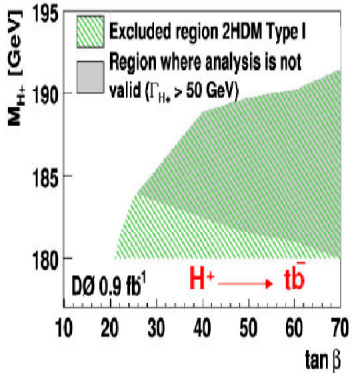




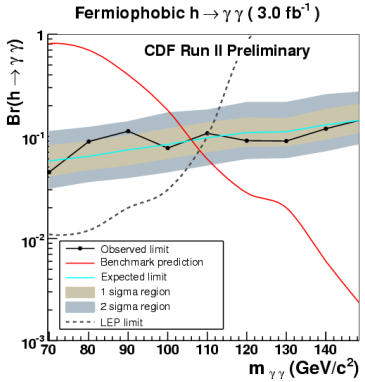
$M_{H^{\pm}} < M_{top}$

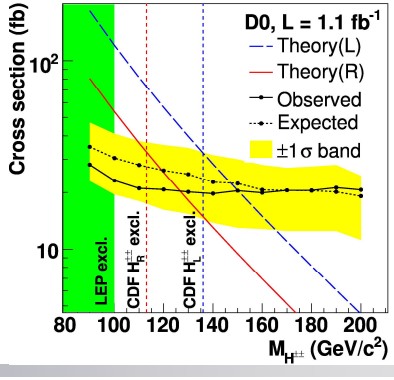


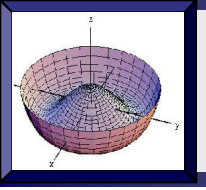
$M_{H^{\pm}} > M_{top}$



Fermiophobic $H \to \gamma\gamma$
Double charged $H^{\pm\pm}$







Can LHC compete next year?

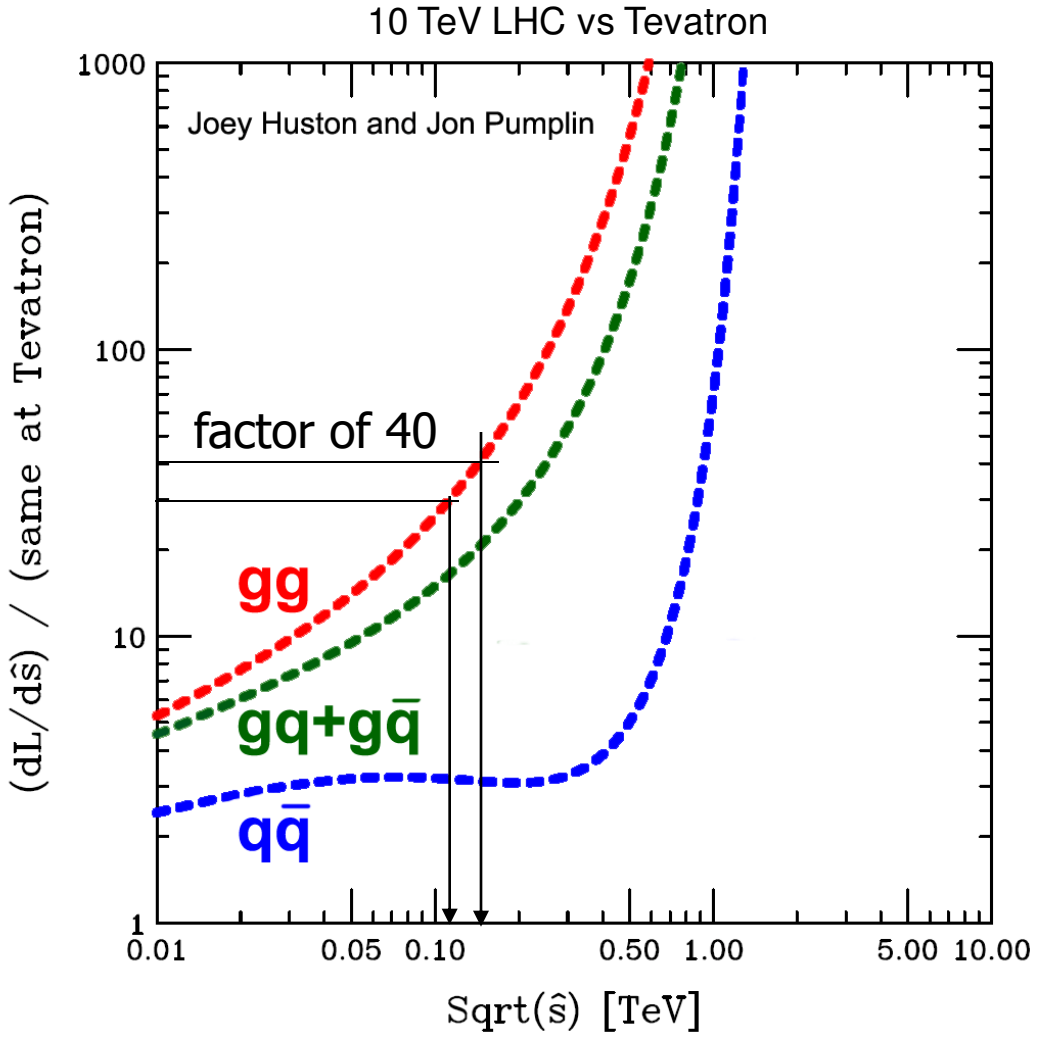
Tevatron: 2 Tev, 8 fb^{-1} per experiment

LHC: 10 TeV, 200 pb^{-1} per experiment *(optimistically)*

To compete, we need to gain a factor of 40 somewhere:

- **larger cross sections at LHC: yes** *(see next slide)*
- **acceptance: not a large factor** *(actually, higher energy reduces acceptance)*
- **reconstruction efficiencies: not a large factor**
- **mass peak resolution:**
  - **$m_{\gamma\gamma}$ resolution at CMS is <1 GeV vs 3 GeV (CDF/D0)**

Parton luminosities

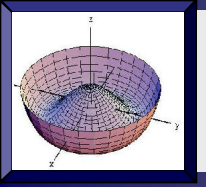


Roughly:

- **gg-induced processes:**
  >30 for m_{inv}>110 GeV
  >40 for m_{inv}>150 GeV

- **qq-induced processes:**
  >40 at m_{inv}>1 TeV…
  but x-sections are minute
  <3 below 0.5 TeV

IMPORTANT NOTE: for some channels, the signal is gg-dominated, while the main bkgd is qq-dominated (e.g. gg→H→WW vs main bkgd qq→WW)



General questions…

… applicable to all Higgs search analyses (individual channels and combinations)

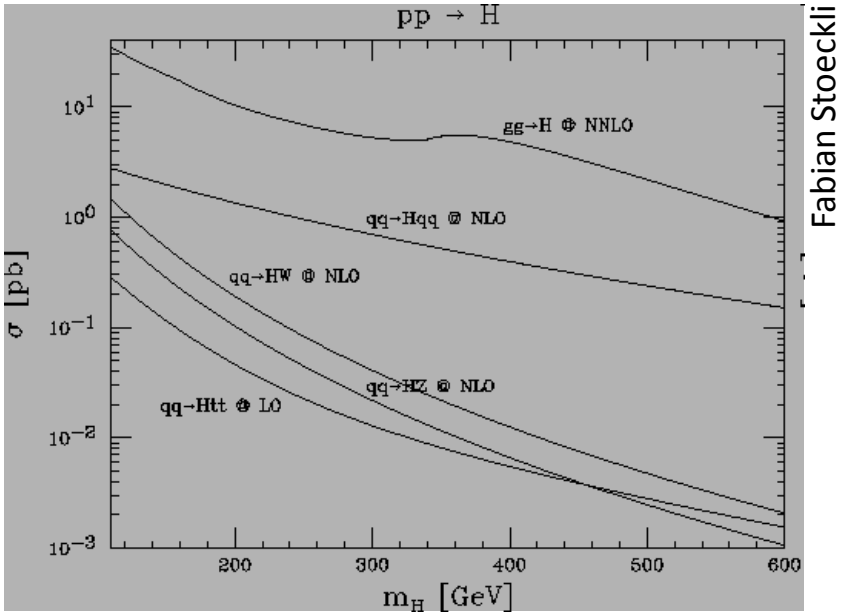
We, LHC and Tevatron, need common defaults at any given time

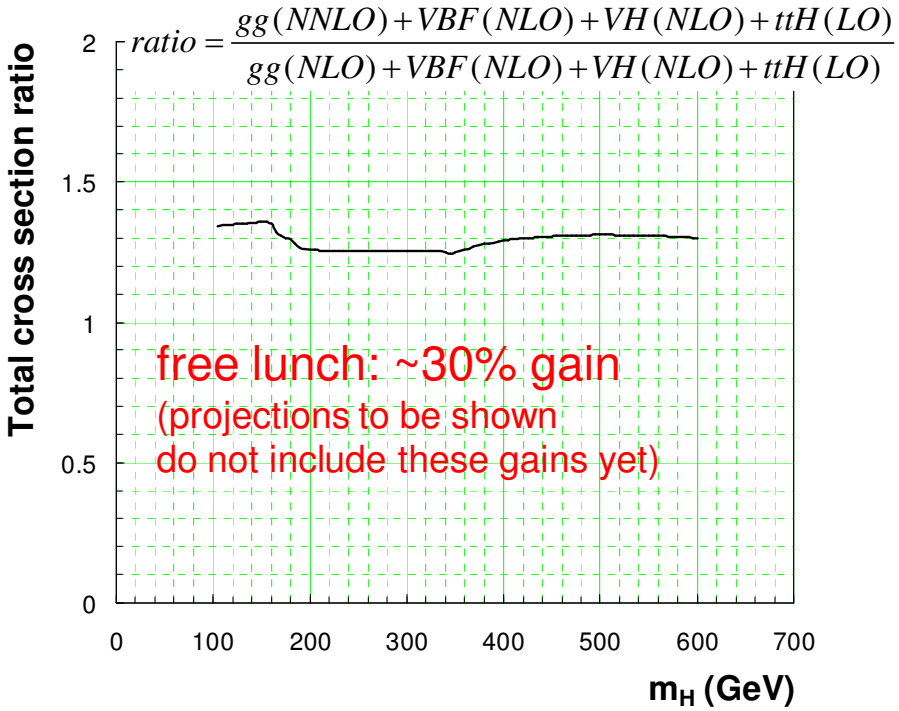
- **Higgs x-sections (each sub-process) and branching ratios**
- **Reference background x-sections**

- **Methods: NNLO, NLO, resummations, EWK corrections**
- **Default settings: renorm/factor scales, pdf's, etc.**
- **dynamic K-factors for using with LO MC**

- **theoretical uncertainties: renorm/factor scales, pdfs**
- **pheno. uncertainties: UE, ISR/FSR (modeling, matching), hadronization**
- **cross-channel correlations of uncertainties (signal, bkgds)**

Current defaults for CMS Higgs analyses

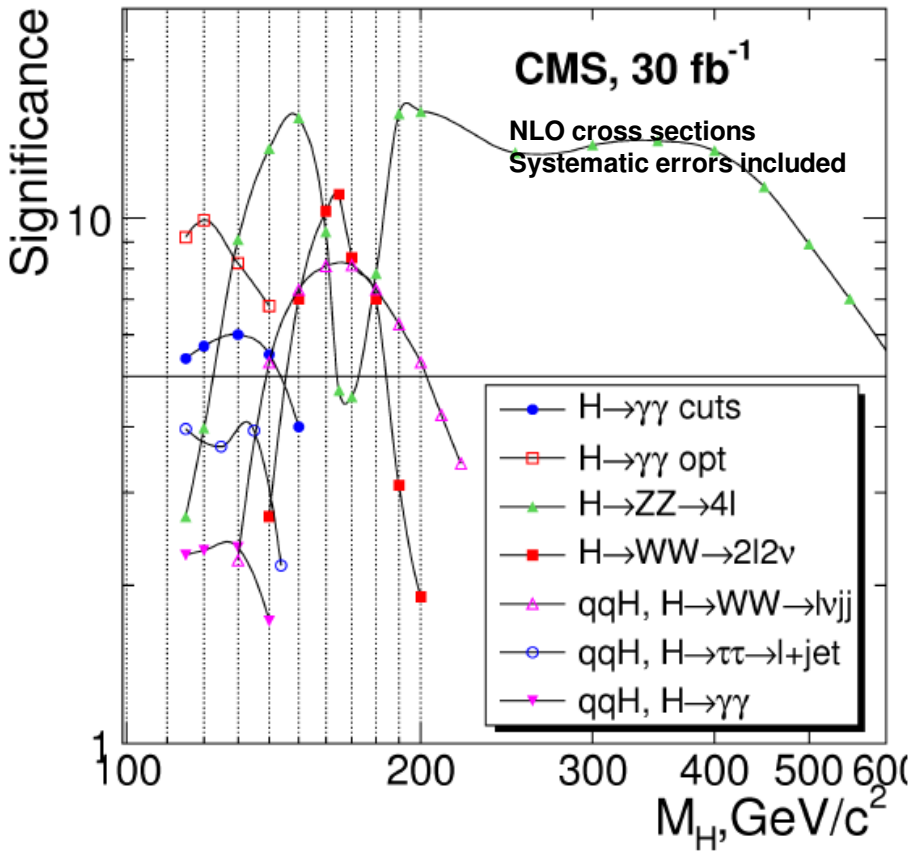




Sub-process	before	now	tools used now
gg fusion	**NLO**	**NNLO**	***HggTotal***
VBF	**NLO**	**NLO**	***VV2H***
VH	**NLO**	**NLO**	***V2HV***
ttH	**LO**	**LO**	***HQQ***

SM Higgs search forerunners at CMS

CMS Physics Technical Design Report 2006



Updates since 2006:

2008

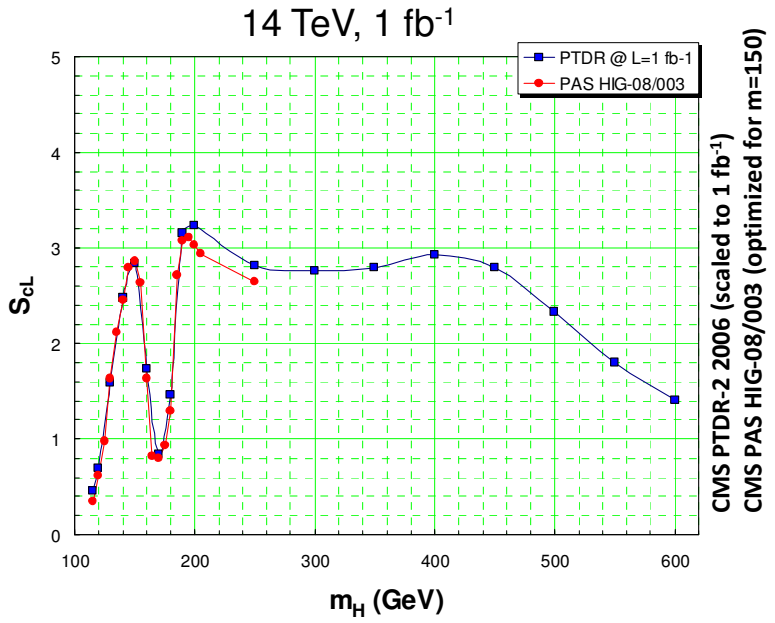
- WW: sensitivity improved wrt 2006
- ZZ: approx no changes in sensitivity
- VBF ττ: approx no changes in sensitivity
- γγ: no official updates
- VBF WW: no official updates

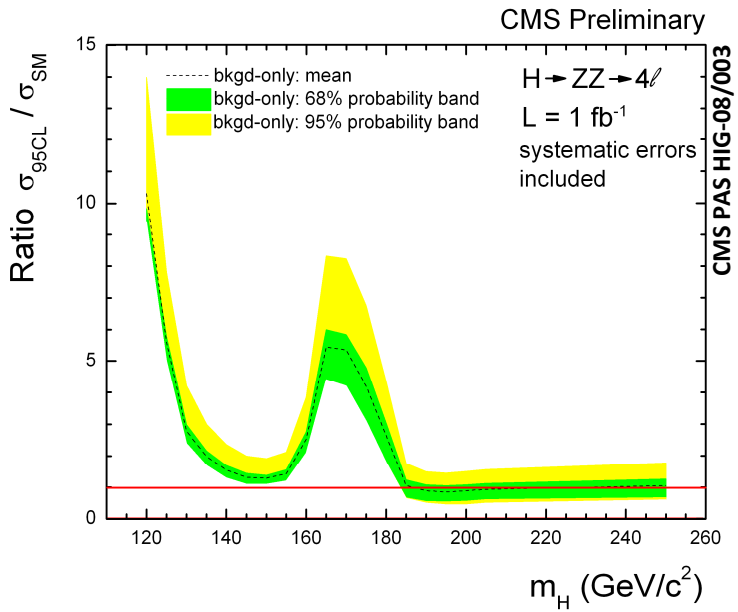
2009

- WW and ZZ scaled down to 10 TeV and 200 pb^{-1} and combined

Bottom line: depending on m_H, forerunners remain the same, i.e. inclusive WW, ZZ, γγ

SM Higgs H→ZZ prospects



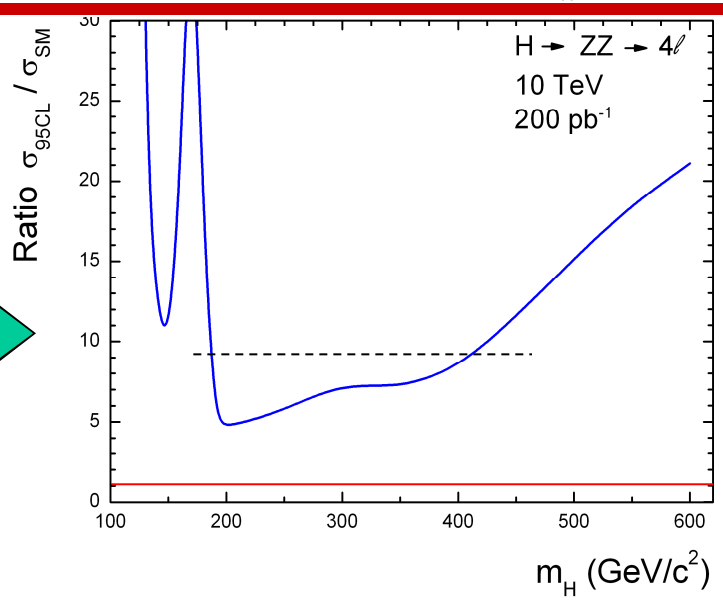


scale down PTDR signal and bkgd events down to 10 TeV and 200 pb^{-1}

- ~3 bkgd events in the full spectrum
- 0.7 signal events for the best m_H~200

Unofficial projected exclusion limits

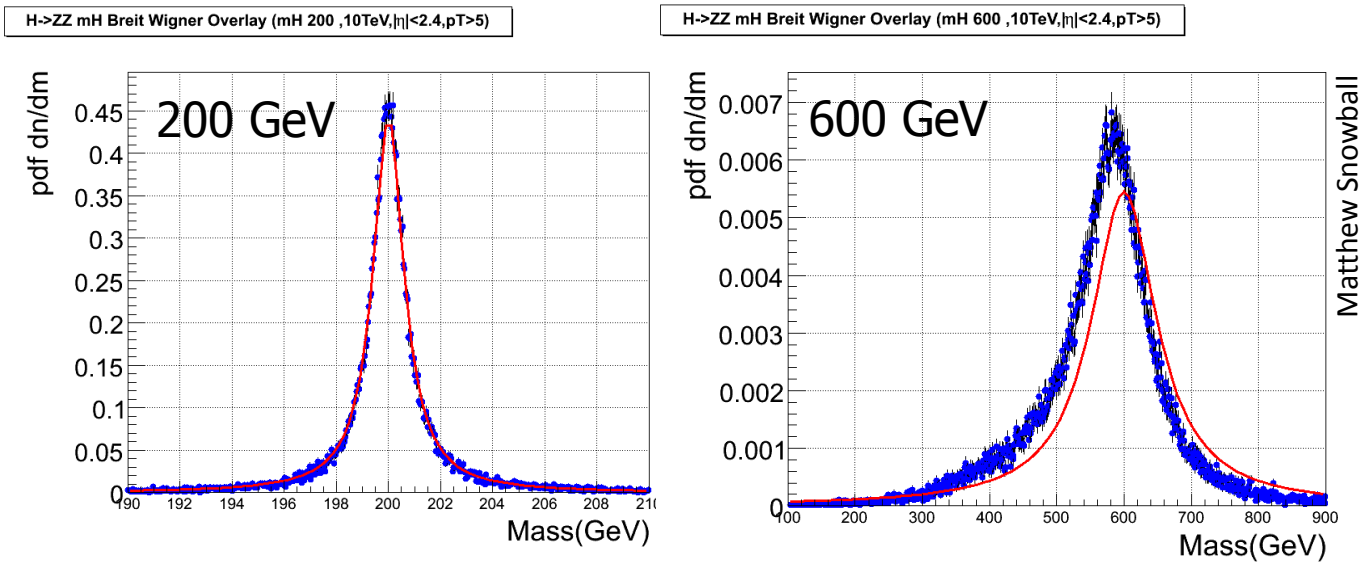
- r<9 in the range 180-400 GeV
- meaningful in the context of 4 generations
- high mass range is better than Tevatron



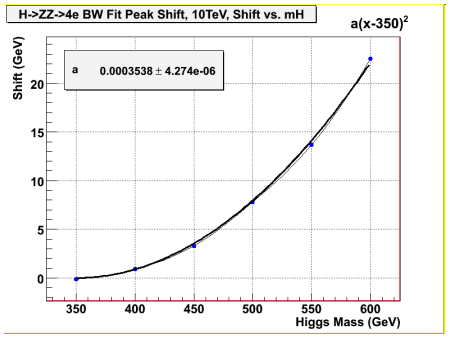
SM H→ZZ questions: signal

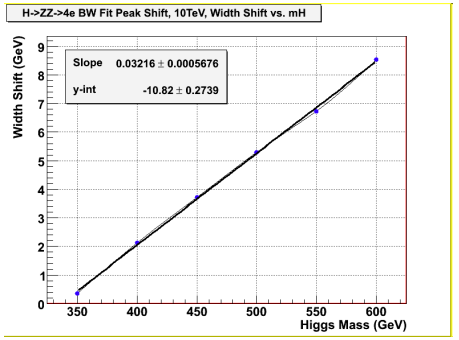
- pp → H → ZZ → 4l
- What is the right m_H^* shape at large Higgs masses?
- What are uncertainties on the shape?

Blue: Pythia m_H^*
Red: Breit-Wigner with $m_0=m_H$ and $\Gamma=\Gamma(m_H)$ from HDECAY



ad hoc offsets





SM H→ZZ questions: background

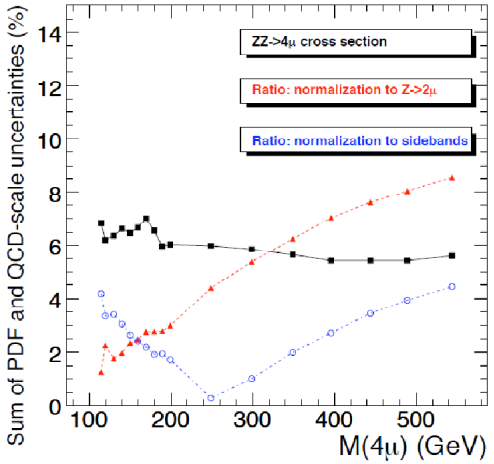
Dominant backgrounds: ZZ and some Zbb

- **qq→ZZ:** **data driven from measuring Z→2l** *(at low lumi, no stat in sidebands)*

$$\frac{dN(m_{4l})}{dm_{4l}} = N(Z \to 2l) \cdot \frac{\frac{d\sigma_{ZZ}(m)}{dm}}{\sigma_Z} \cdot \frac{efficiency(ZZ \to 4l)}{efficiency(Z \to 2l)}$$

ratio of NLO x-sections from MCFM

QCD scale/pdf → ratio uncertainties <10%



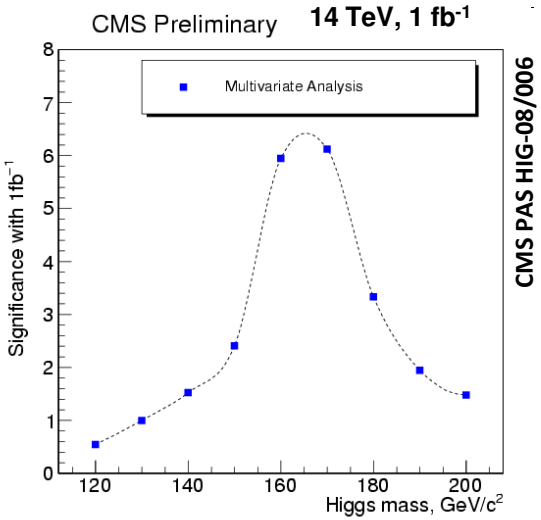
- **gg→ZZ:** **absolute prediction from gg2ZZ**

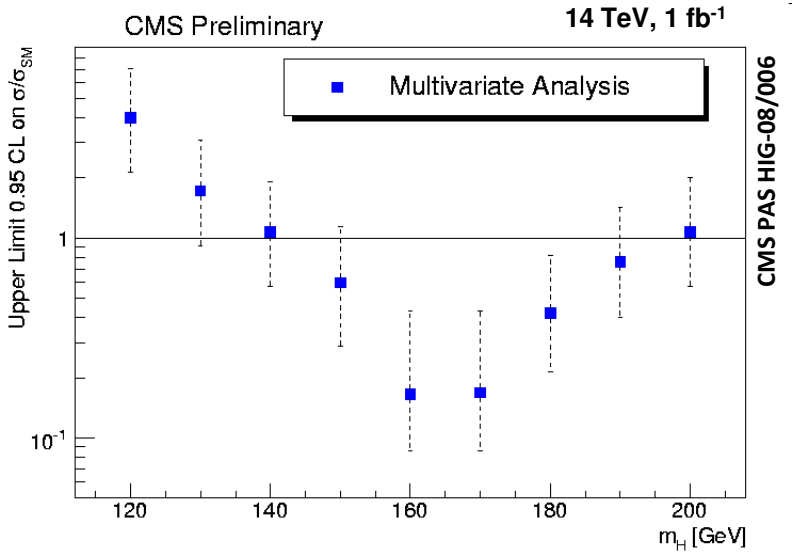
  ~15% contribution, but with large relative uncertainties (~30%)

- **Zbb:** **at low lumi, hard to come up with a fully data-driven method**

  what are theoretical uncertainties? *(note that Wb exp/theory ~ 3)*

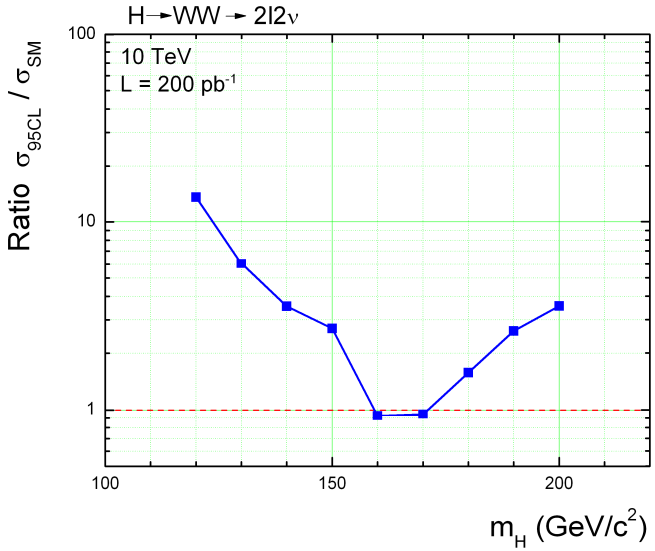
SM Higgs H→WW prospects





scale down PAS HIG-08/006 signal and bkgd events down to 10 TeV and 200 pb^{-1}

- after a cut on the MVA output for mH=160 GeV
- 4 bkgd events
- 7.3 signal events



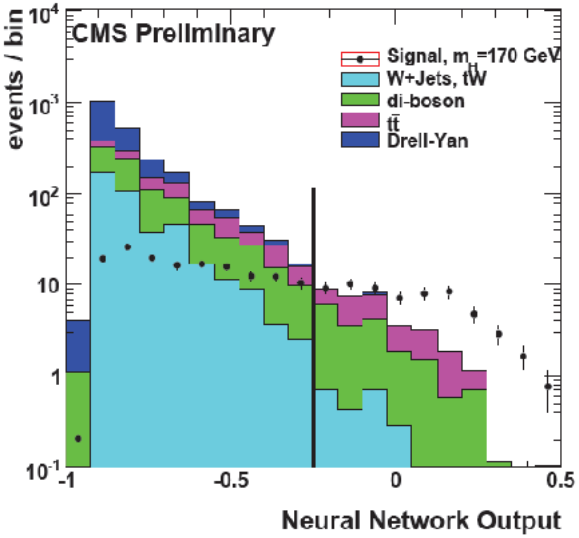
Unofficial projected exclusion limits

- r<1 in the range 160-170 GeV
- r<9: … - 200+ GeV (meaningful in the context of 4 generations)
- comparable to or better than CDF/D0 above 150 GeV

SM H→WW questions: signal

Analysis:

- gg LO MC reweighed by $K_{NLO}(p_T)$, Higgs p_T
- pre-cut on lepton pT, isolation, # of jets, MET
- put lepton kinematics and MET into MVA
- cut on MVA output



Questions:

- large gain in NNLO vs LO x-section due to jets, some of which rather soft

  Cutting on jets in LO MC may seem more efficient than it would be with all soft jets from NNLO—how do we deal with this?

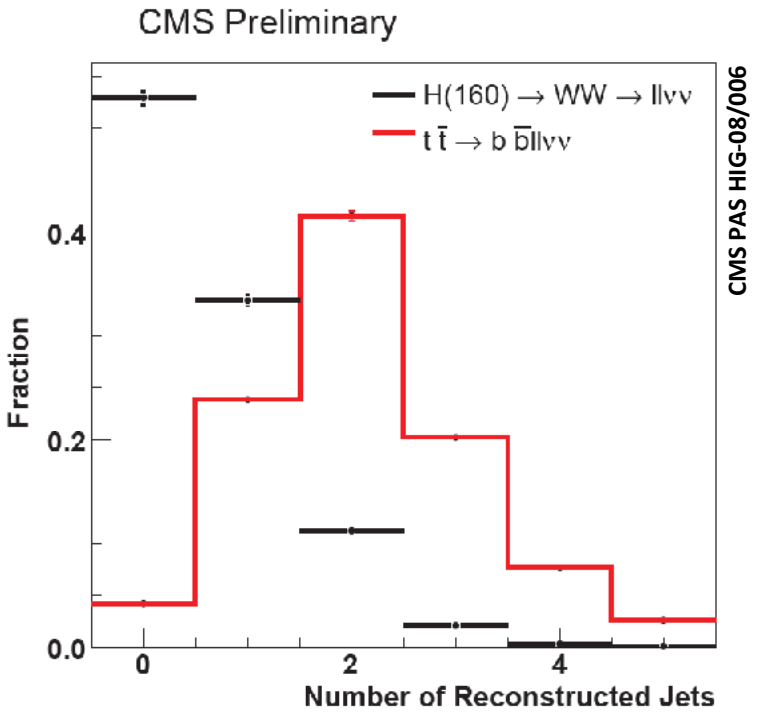
  (We currently try to keep ET threshold relatively high)
- How do we calculate uncertainties on 0-jet and 1-jet bins? Straight out-of-the box NNLO, NLO errors are probably not really applicable

SM H→WW questions: background

Main backgrounds: WW, tt, W+jets, DY

Data-driven methods rely on transitions between different regions of phase space:

- **tt: (0 jets) ←→ (2+ jets)**
- **WW: (low m_{ll}) ←→ (large m_{ll})**
- **must know theoretical and phenomenological uncertainties**



SM Higgs at low mass?

Tevatron:

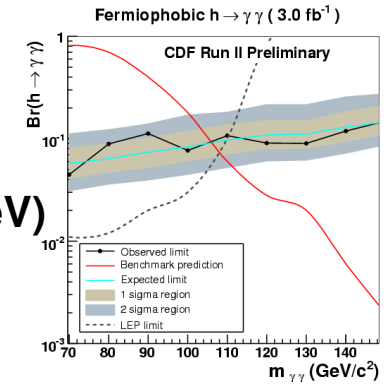
- **qq→VH(bb)**

LHC:

- **same channel: qq luminosity gain is ~3 only;** *hard to compete*
- **Hγγ: at 200 pb^{-1}, we expect exclusion r between 5 and 10 (back-of-envelope extrapolations from PTDR);** *so we need more luminosity to become competitive with Tevatron's VH(bb) low mass limits*

BUT, if Higgs is fermiophobic?

- **SM Higgs limits from Tevatron are not applicable**
  - **high mass: gg-production is gone**
  - **low mass: H→bb decay is gone**
    fermiophobic-specific pp→VH(γγ) opens up
- **LHC:**
  - **VBF at LHC is ~20 times higher than VH at Tevatron**
  - **CMS γγ mass resolution is 3-4 times better than CDF/D0 (3 GeV)**
  - **combined, we effectively gain a factor of 60 or more**



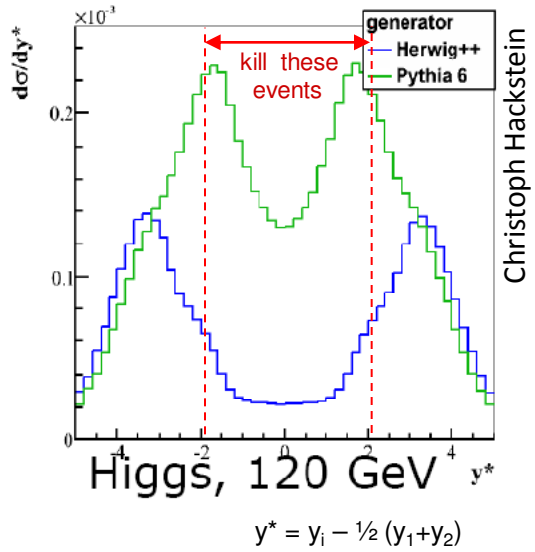
Question: VBF signature

Classical signature:

- **two highest ET jets are in forward-backward directions**
- **large rapidity gap $|\eta_{jet1}-\eta_{jet2}|$**
- **with no jets in between (jet veto)**

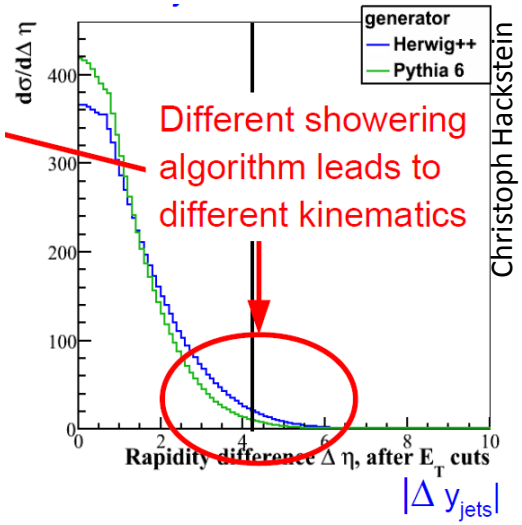
has huge uncertainties for signal and some backgrounds (factor of 2 or so)

Signal:
the problem is relevant for all channels
no standard candles to measure efficiency from data



$y^* = y_i - \frac{1}{2}(y_1+y_2)$

Backgrounds:
γγ: all background rates from sidebands
ττ: Zττ, W+jets, QCD – all data-driven
WW→lνjj: tt-bkgd?

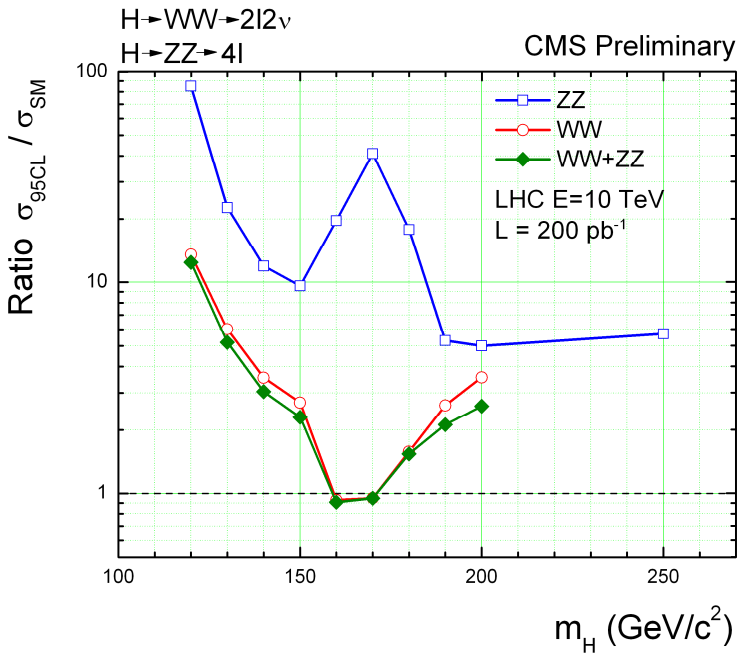


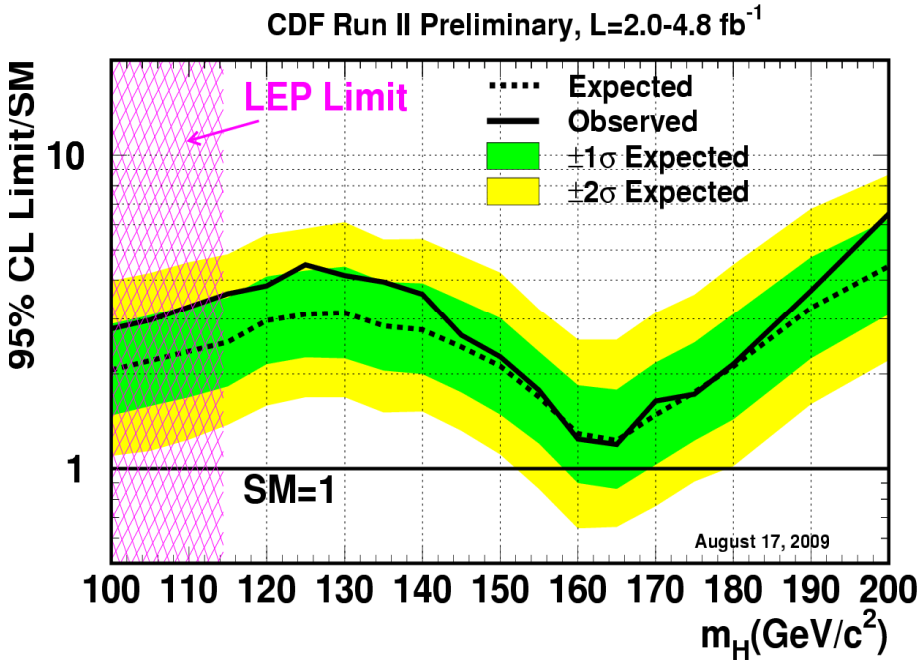
large η-gap between two leading jets

small fraction of events In the tail of distribution, which happens to be sensitive to the choice of a event generator

Combination of early SM Higgs searches

CMS bare minimum: HWW→2l2ν (possibly 0/1jets), HZZ→4l, Hγγ



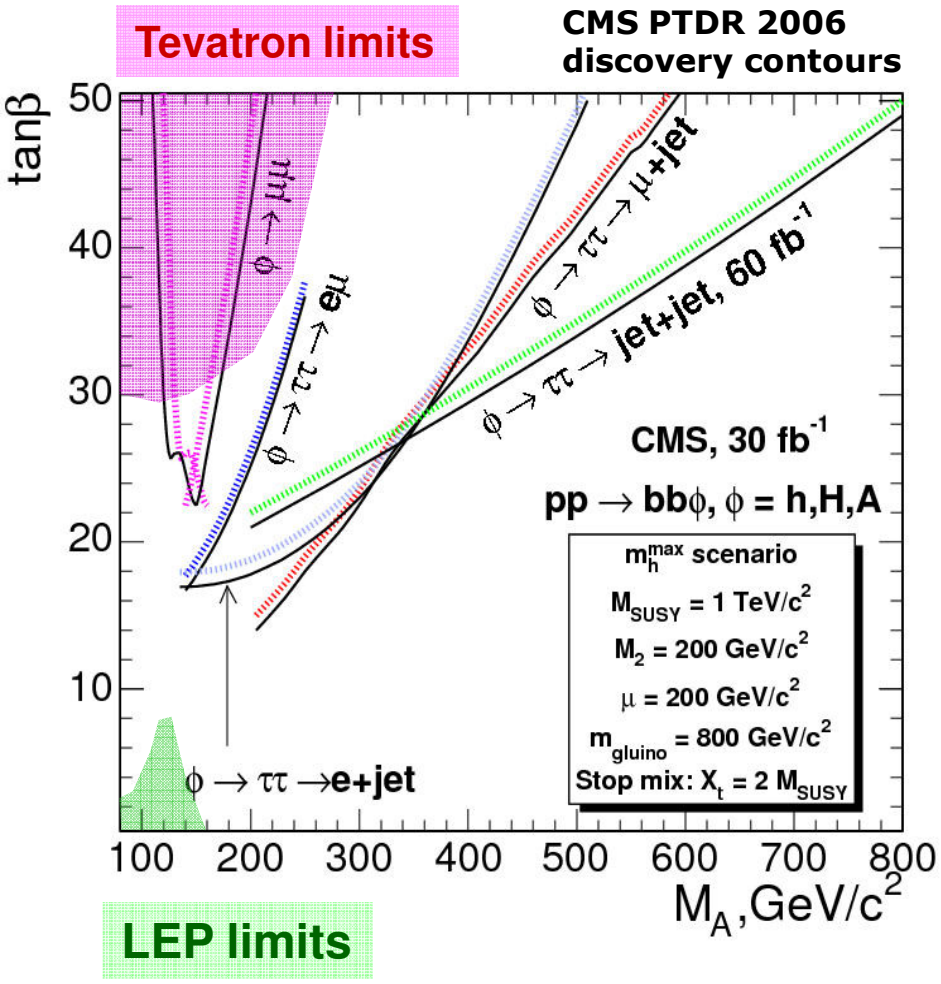


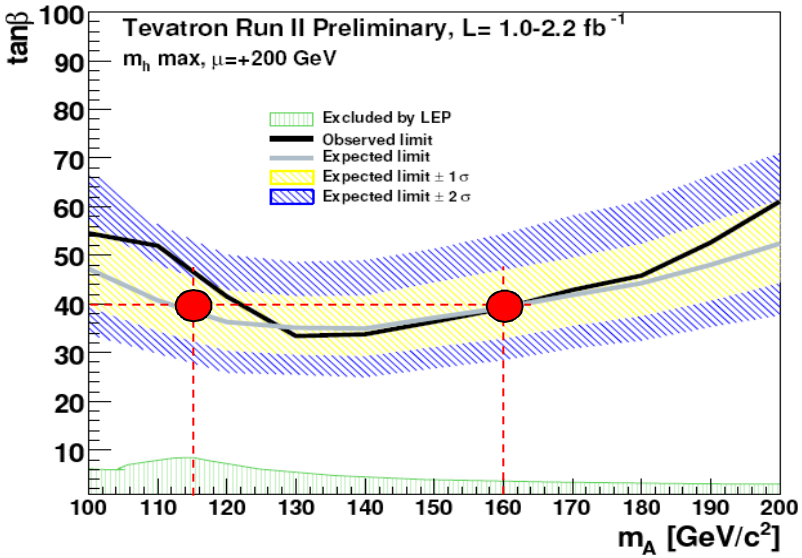
Next step: ATLAS + CMS

Then: LHC + Tevatron (certainly makes sense above 130 GeV)

Must have a common coherent set of x-sections, etc. (see slide 5)

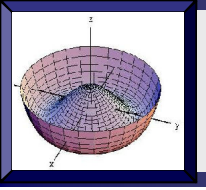
MSSM Hττ prospects





LHC10 : Tevatron ratios		
	m = 115 tanβ=40	m = 160 tanβ=40
signal cross sections	26	43
bkgd cross sections (Z)	8	
luminosities	0.2 : 8	
S/sqrt(B)	1.5	2.5

NOTE: **bbΦ:gg** relative contributions are better at LHC10
45% vs 35% 60% vs 40%



MSSM Hττ questions

Higgs production:

- experimentally, we set limits on or discover and measure σxBR
- thinking in terms of MSSM, production depends on SUSY sector via loops
- strong coupling to b-quarks leads to differences for 4- vs 5-quark pdf's
- are we missing any possibilities of Higgs appearing in cascade decays of SUSY particles?

All main backgrounds are derived from data (no questions)

- Z→tt: by swapping one lepton in Z→2l with tau)
- QCD: same-sign lepton-tau events with relaxed cut on lepton isolation
- W+jets: by measuring W+jets x-section and probability of jet faking tau

MSSM $H^{\pm}$ prospects ($m_H<m_t$)

Higgs production via top-quark decays:

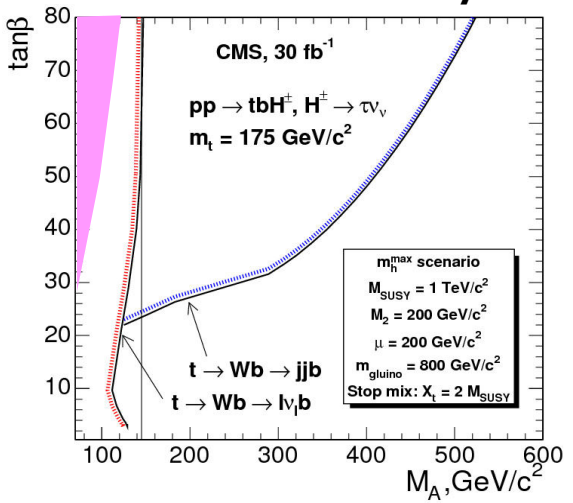
- **pp → tt → (Wb)(Hb) → (lνb)(τνb)**

Main backgrounds:

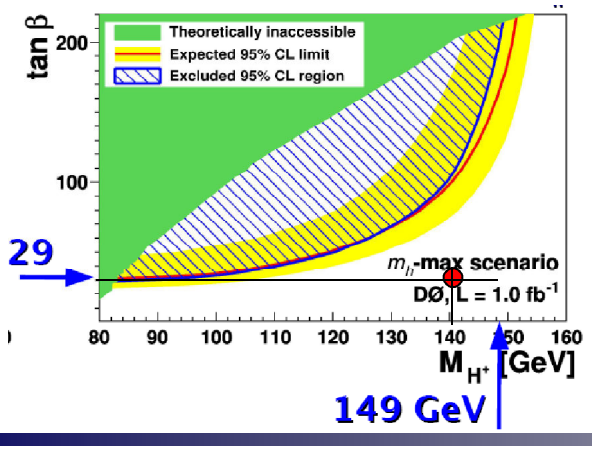
- **tt → (Wb)(Wb) → (lνb)(τνb) ~90%**
  (relatively easy to control)
- **W+3jets → (lν)("b" "b" "τ") ~10%**
  (harder to control, but it is small)

Tevatron limits

CMS PTDR 2006 discovery contours



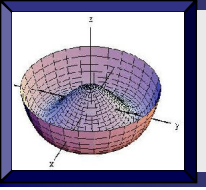
LHC:Tevatron tt x-sections = 400:8 = 50
we should be able to compete



scale down PTDR signal and bkgd events down to 10 TeV and 200 pb^{-1}

- mH=140 GeV, tanβ=30, which gives BR(t→Hb)~10%
- 16 bkgd events
- 12.8 signal events

Unofficial projected exclusion limit r<1



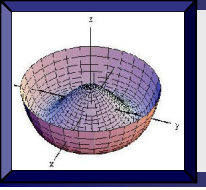
Summing up (1)

Questions where theorists can help:

- Higgs x-sections (each sub-process) and branching ratios
- Reference background x-sections

- Methods: NNLO, NLO, resummations, EWK corrections, etc., etc.
- Default settings: renorm/factor scales, pdf's, etc.
- dynamic K-factors for using with LO MC

- theoretical uncertainties: renorm/factor scales, pdfs
- pheno. uncertainties: UE, ISR/FSR (modeling, matching), hadronization
- cross-channel correlations of uncertainties (signal, bkgds)



Summing up (2)

Questions where theorists can help:

- **VBF signature uncertainties:**
  - **signal (central jet veto in particular)**
  - **tt-bkgd for WW→lνjj**

- **MSSM Higgs: continue with old benchmarks?**
- **MSSM Higgs: 4- vs 5-Flavor Number Scheme?**
- **Are we missing opportunities with SUSY cascade decays?**