ATLAS Higgs Sensitivity for 1fb^{-1} at the LHC running at 7 TeV

Tatsuya Masubuchi
ICEPP, University of Tokyo
on behalf of the ATLAS Collaboration

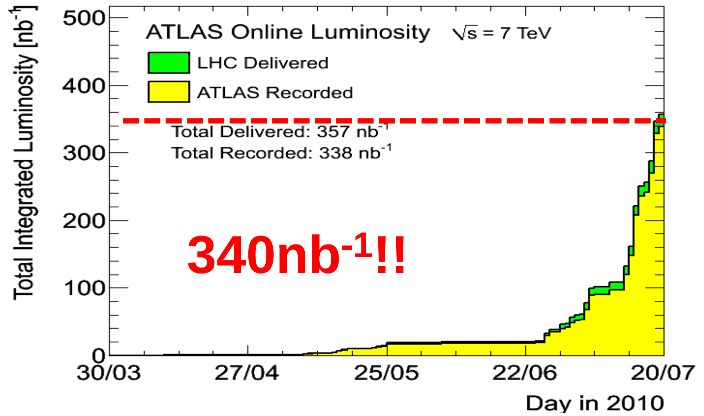
Outline

- Introduction
- Standard Model (SM) Higgs Search
  - $H \rightarrow WW \rightarrow l\nu l\nu$
  - $H \rightarrow ZZ \rightarrow 4l$
  - $H \rightarrow \gamma\gamma$
  - Combined Results and Prospect for $1fb^{-1}$
- Minimal Supersymmetric Standard Model (MSSM) Higgs Search
  - $H^{+} \rightarrow c\bar{s}, \tau\nu$
  - $h/H/A \rightarrow \mu\mu$
- Summary

Introduction

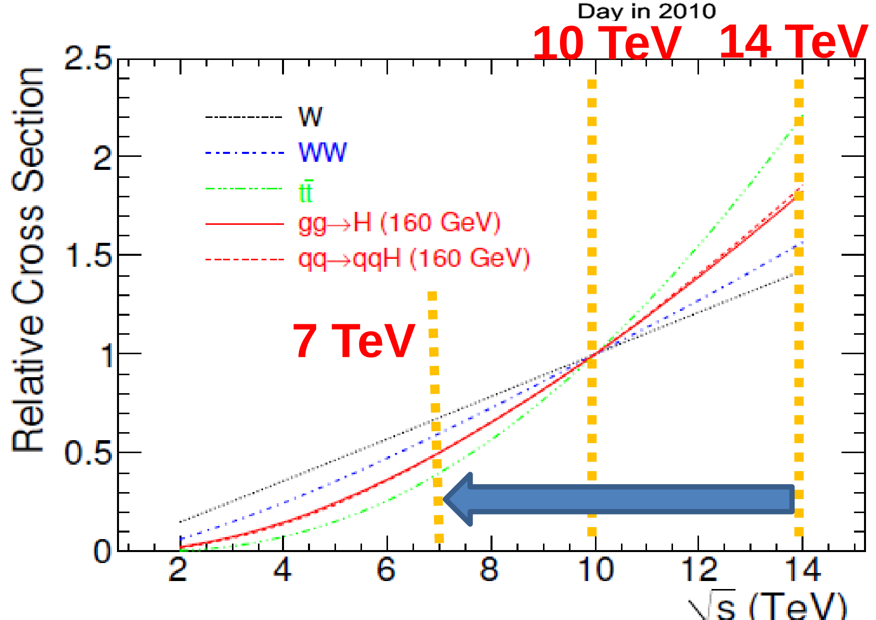
LHC schedule 2010,2011

- ✓ Run in 7 TeV center of mass energy
- ✓ The end of 2010 $O(100pb^{-1})$
- ✓ Expect **1fb^{-1}** by the end of 2011



Impact on cross section from 14 TeV to 7 TeV

- ✓ gg→H (160 GeV) ~ 28%
- ✓ W+jets ~ 48%
- ✓ ttbar ~ 18%
- ✓ WW ~ 38%



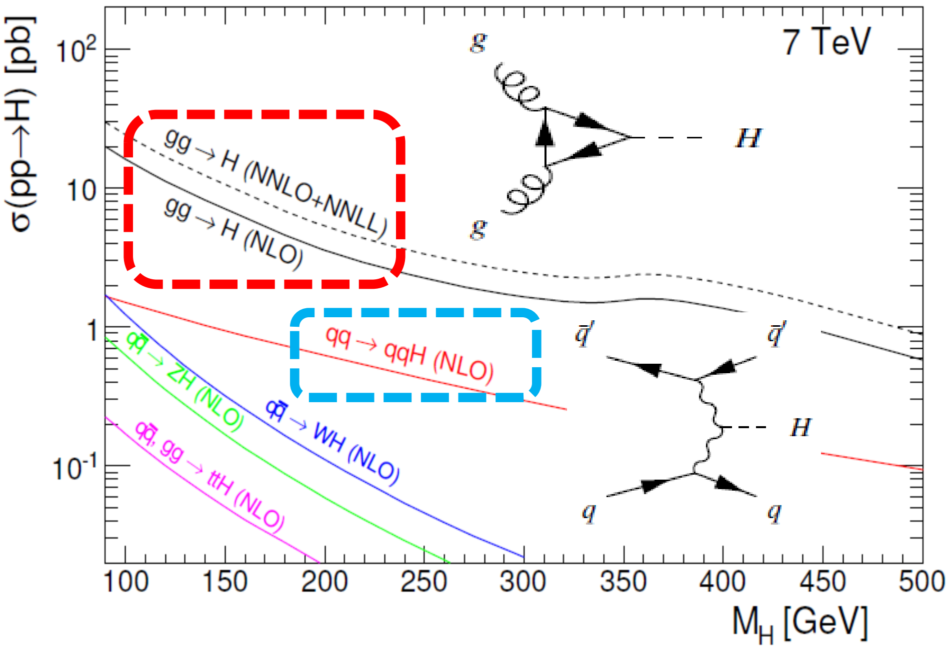
Higgs Sensitivity at 7 TeV at 1fb^{-1} is evaluated by cross section scaling from 10/14 TeV study with full simulation

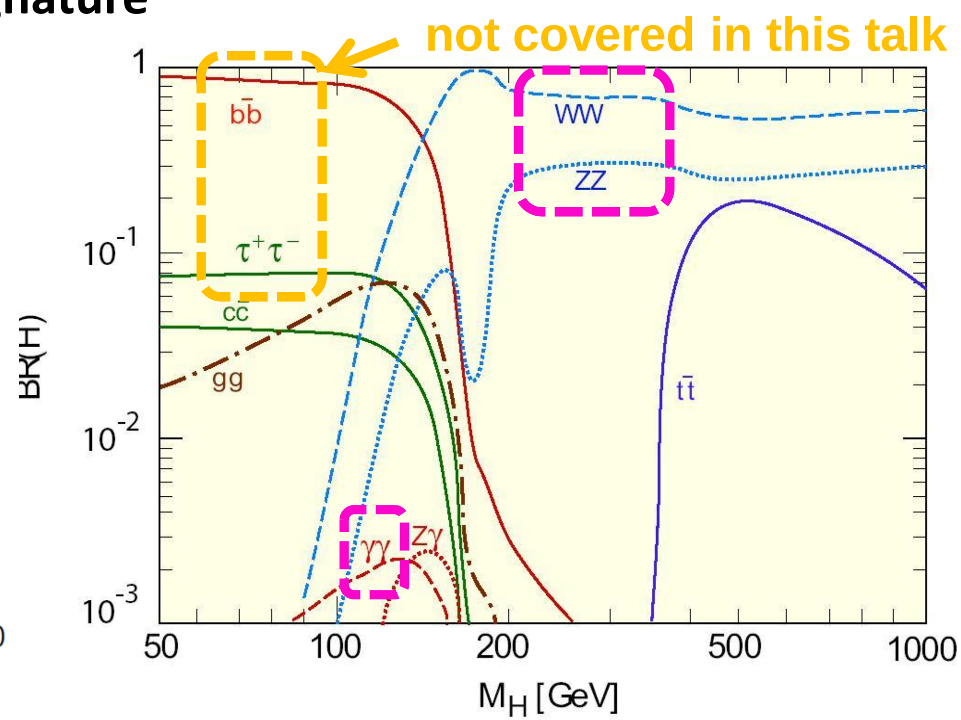
** Cut efficiency difference from 10/14 TeV are verified to be negligible*

Standard Model Higgs

Higgs Production and Decay

- gg→H production is highest cross section at LHC
  - Cross section is about one order higher than Tevatron
  - Need clean signature : diphoton, dilepton, 4 lepton
- VBF qq→qqH production is second highest
  - Forward jets are distinctive signature

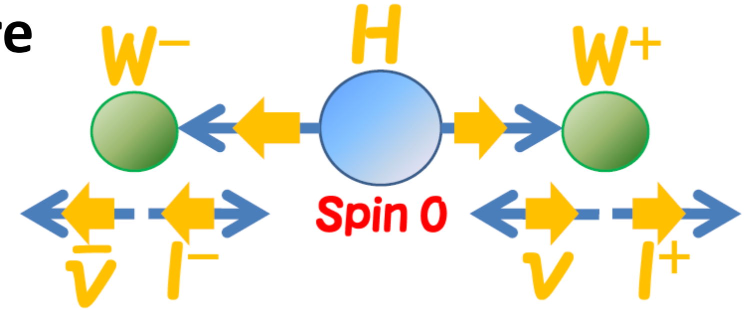




Use NLO cross section for both signals and backgrounds in this study

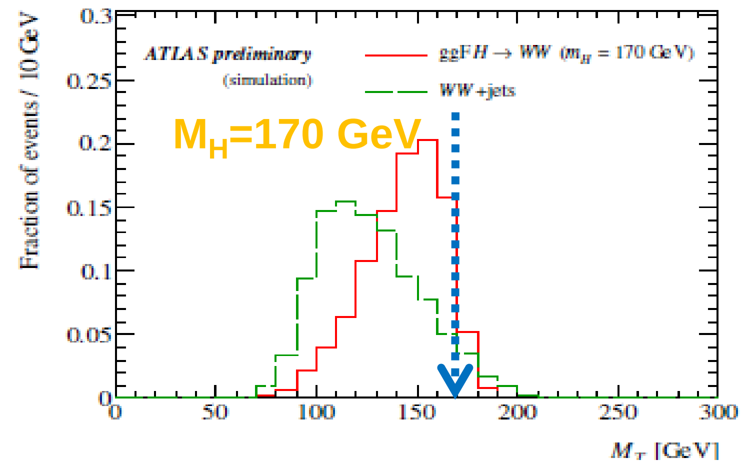
H→WW→lνlν

- **Dilepton (ee,μμ,eμ)+MET+jets signature**
  - **Study 0,1 (GGF) and 2 jets (VBF) separately then combined**
  - **Use spin correlation to reduce background**
    ➔ Small opening angle between dilepton
    ➔ High missing transverse energy
  - **No mass peak is observed due to neutrinos**



$$M_T = \sqrt{(E_T^{ll} + E_T^{miss})^2 - (\mathbf{P_T^{ll}} + \mathbf{E_T^{miss}})^2} < M_H$$

$$E_T^{ll} = \sqrt{(P_T^{ll})^2 + m_{ll}^2}$$



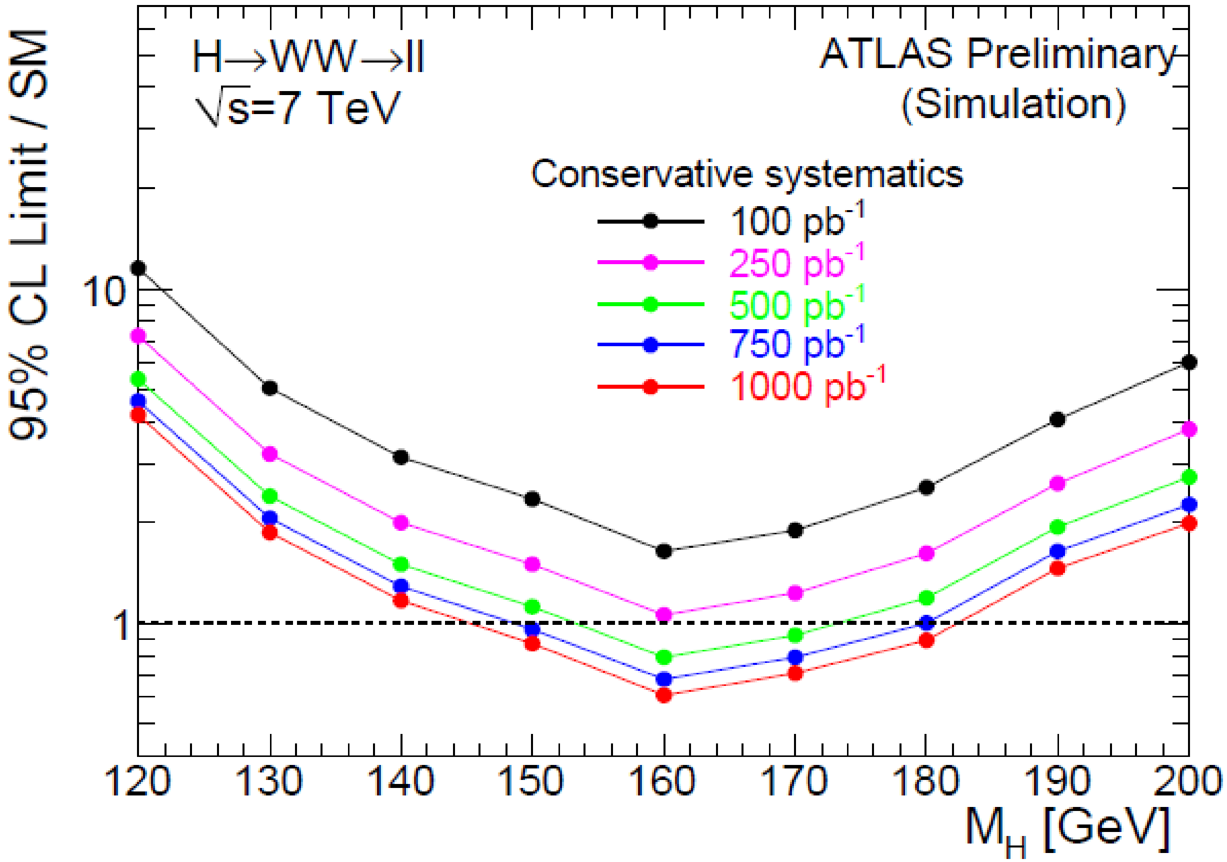
Estimated number of events at 1fb^{-1} after event selection

M_H (GeV)		160
SM WW	0jet/1jet	55.2
top	1jet/2jet	14.0
W+jets	0jet/1jet	5.6
Total background		74.8
Signal		39.5

- **Possible to re-observe in *O*(10pb^{-1})**
- **One fake lepton coming from jets**
- **Data-driven background estimation is on-going**

➔ First measurement is coming soon!!

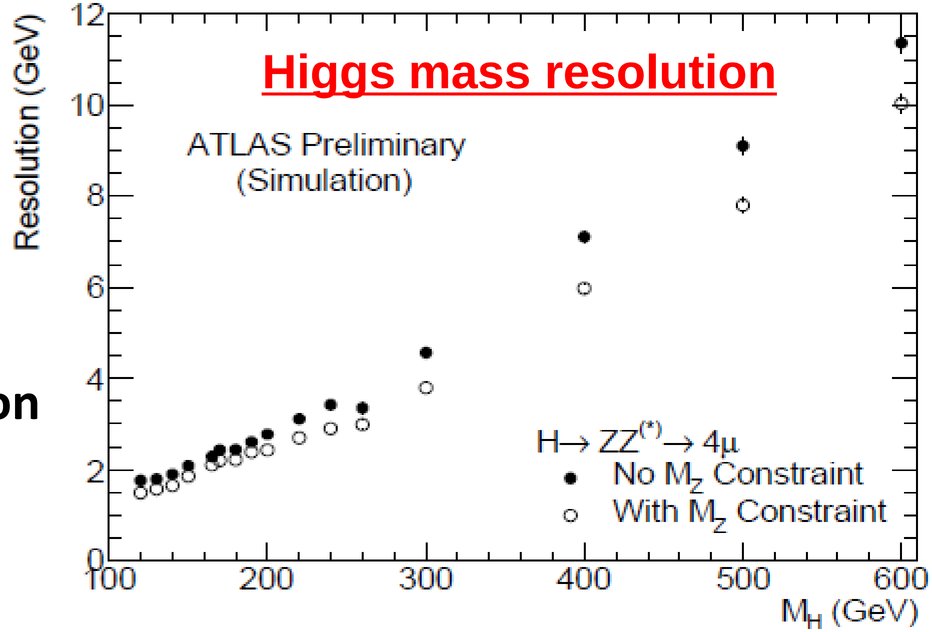
H→WW→lνlν

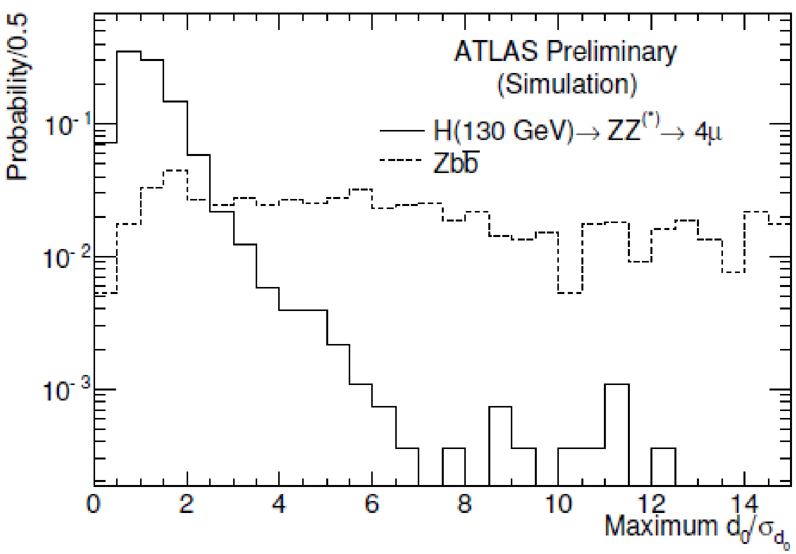


- $250pb^{-1}$: 95 % C.L. upper limit reaches SM cross section in M_H = 160 GeV (comparable to recent CDF,D0 limit)
- $500pb^{-1}$: Expected exclusion mass range is 155-175 GeV
- $1fb^{-1}$: Expected exclusion mass range is 145-183 GeV

H→ZZ→4l

- **4lepton signature (4e,4μ,2e2μ)**
  - **Excellent energy and momentum resolution for reconstructed lepton**
  - **→Narrow Higgs mass peak can be observed**
  - **Mass resolution is crucial : Resolution can be improved by 10-20% with Z mass constraint**



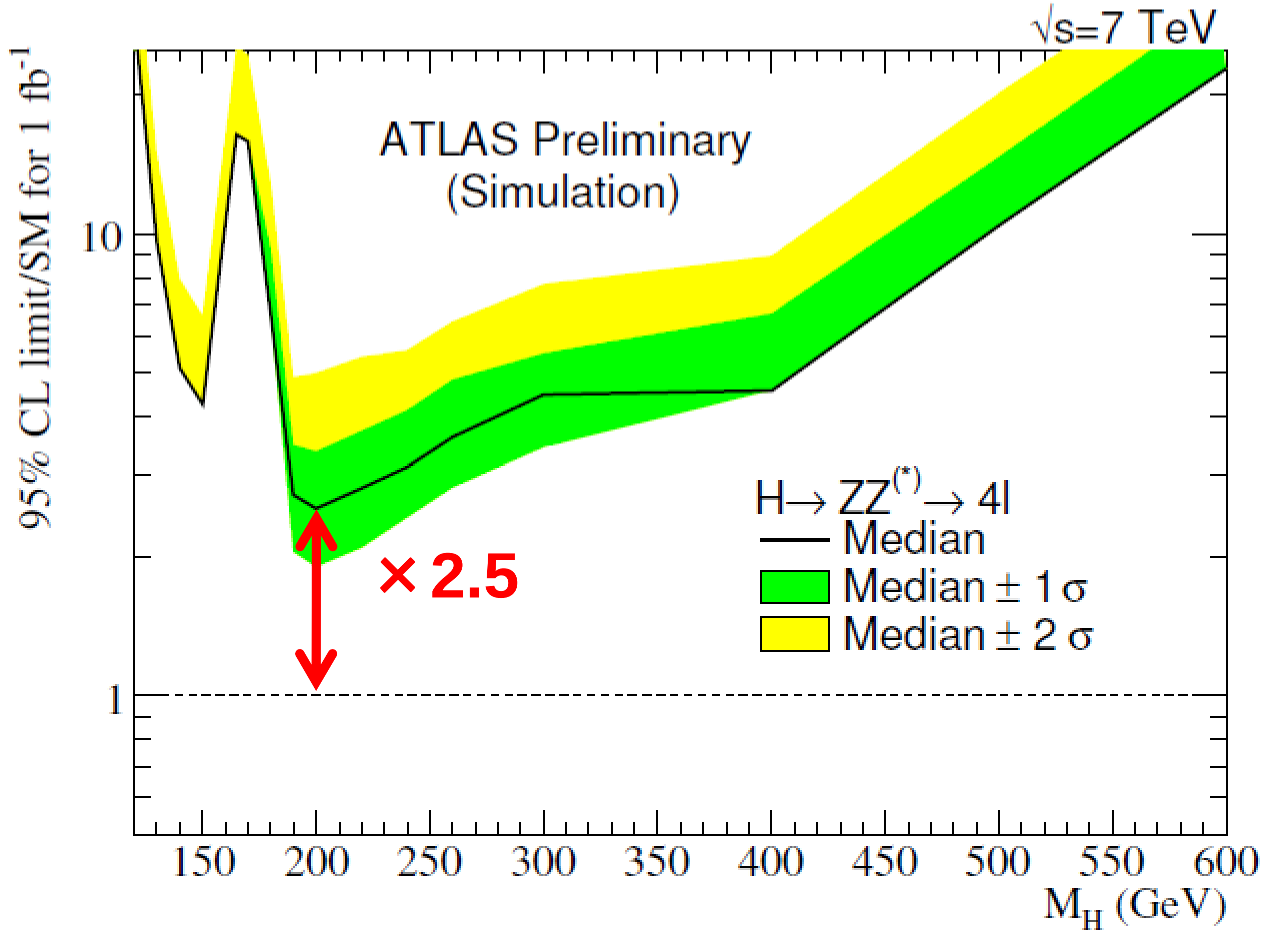


Background

- ✓ **SM ZZ (dominant contribution)**
- ✓ **Z+jets**
- ✓ **top**

- **Impact parameter significance is discriminating variable to reduce $Zb\bar{b}$(→2μ) background in 2μ2μ,2e2μ channel**

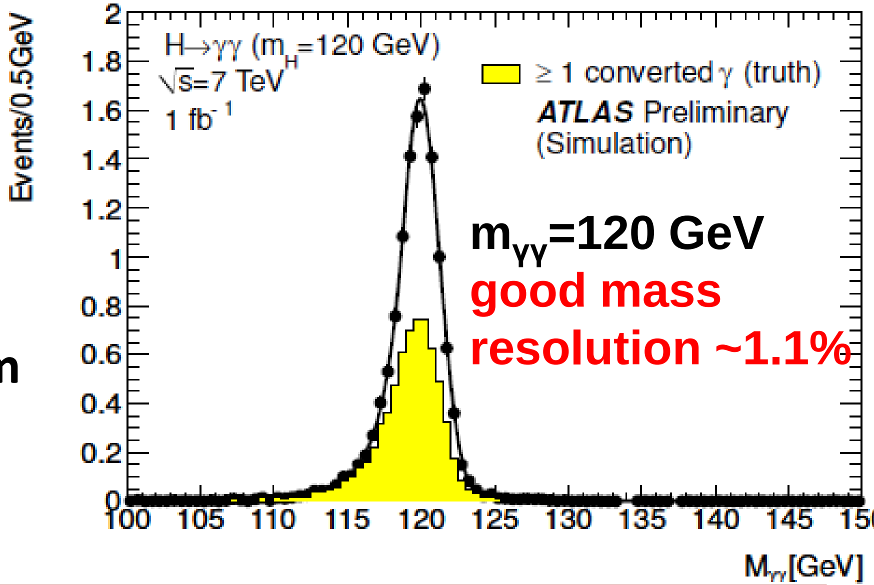
H→ZZ→4l



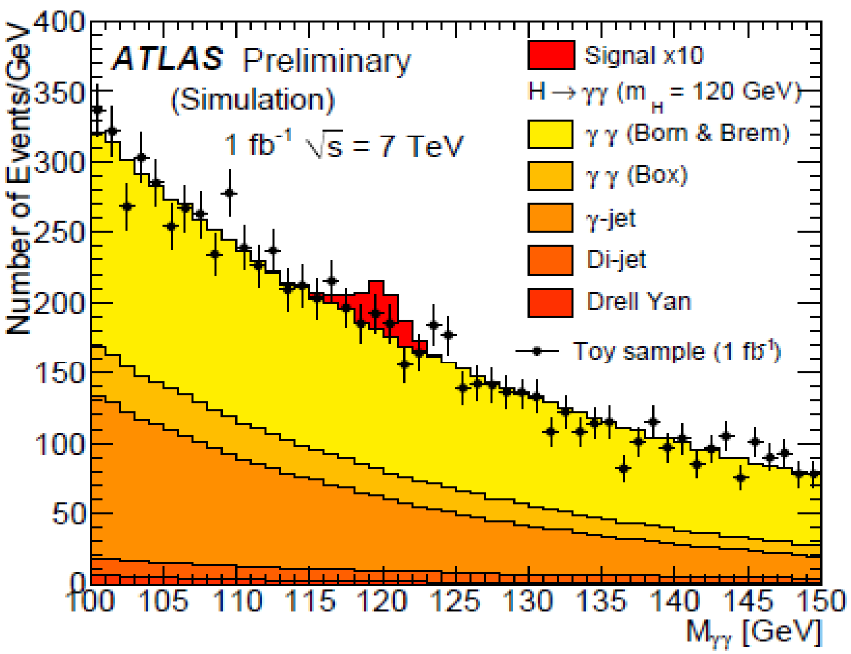
- **Cover large Higgs mass range**
- **Sensitive for around 200 GeV Higgs mass (2.5 times higher than SM cross section)**

H→γγ

- **Perform jet inclusive analysis for early data (GGF dominant)**
- **Narrow diphoton resonance can be observed over smooth background ➔ Background amount is estimated from side-band fitting**



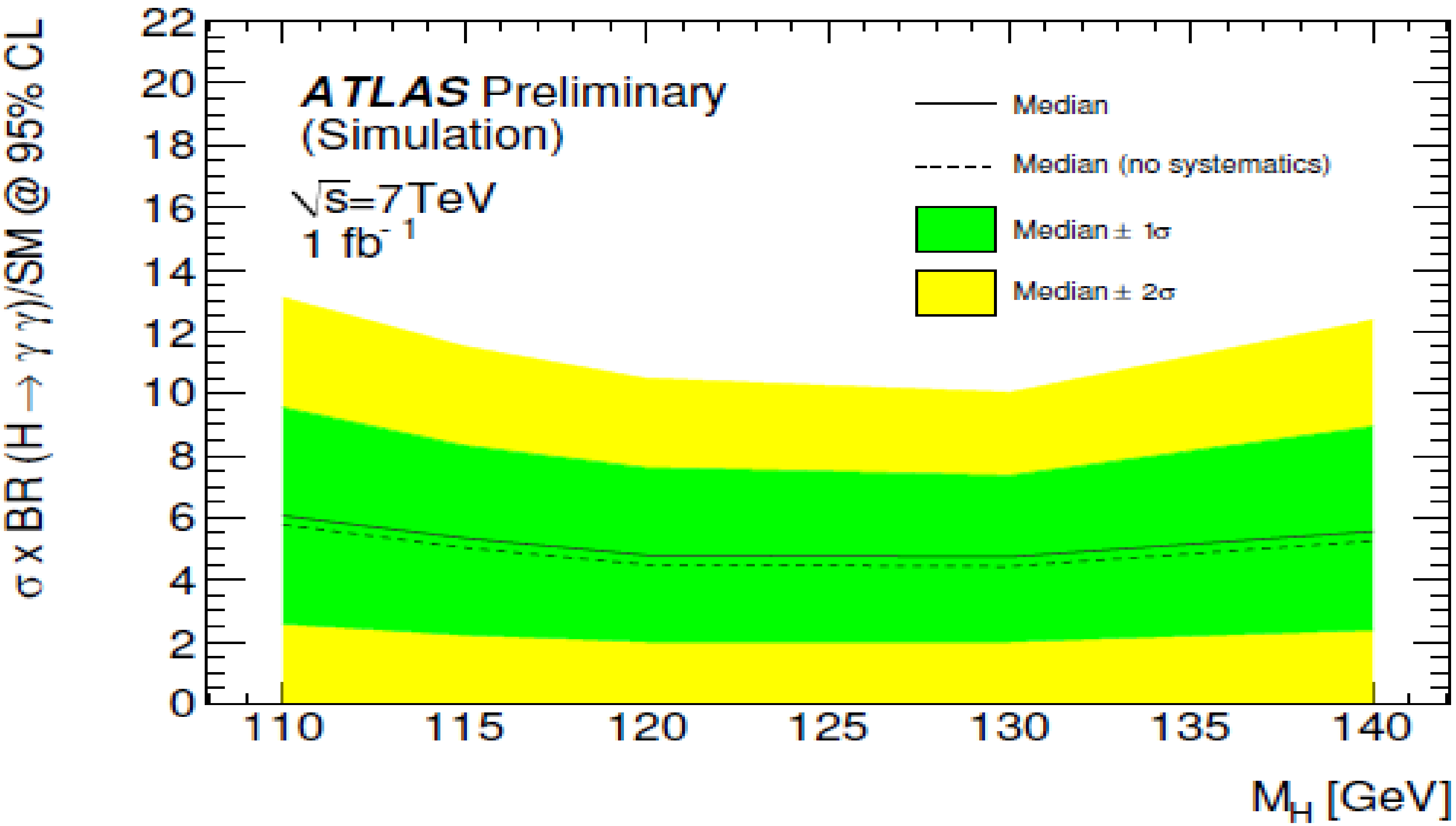
$m_{\gamma\gamma}$=120 GeV
good mass resolution ~1.1%



Expected background @ 1fb^{-1}	
γγ irreducible ~65%	5540
γj reducible ~34%	2500
jj	360
Drell Yan reducible ~1%	90
Total backgrounds	8490
Signal (M_H=120 GeV)	13.0

Use 7 TeV MC simulation for signal

$H \rightarrow \gamma\gamma$



– **Expected upper limit <u>~5 × SM cross section</u> @ $1fb^{-1}$**

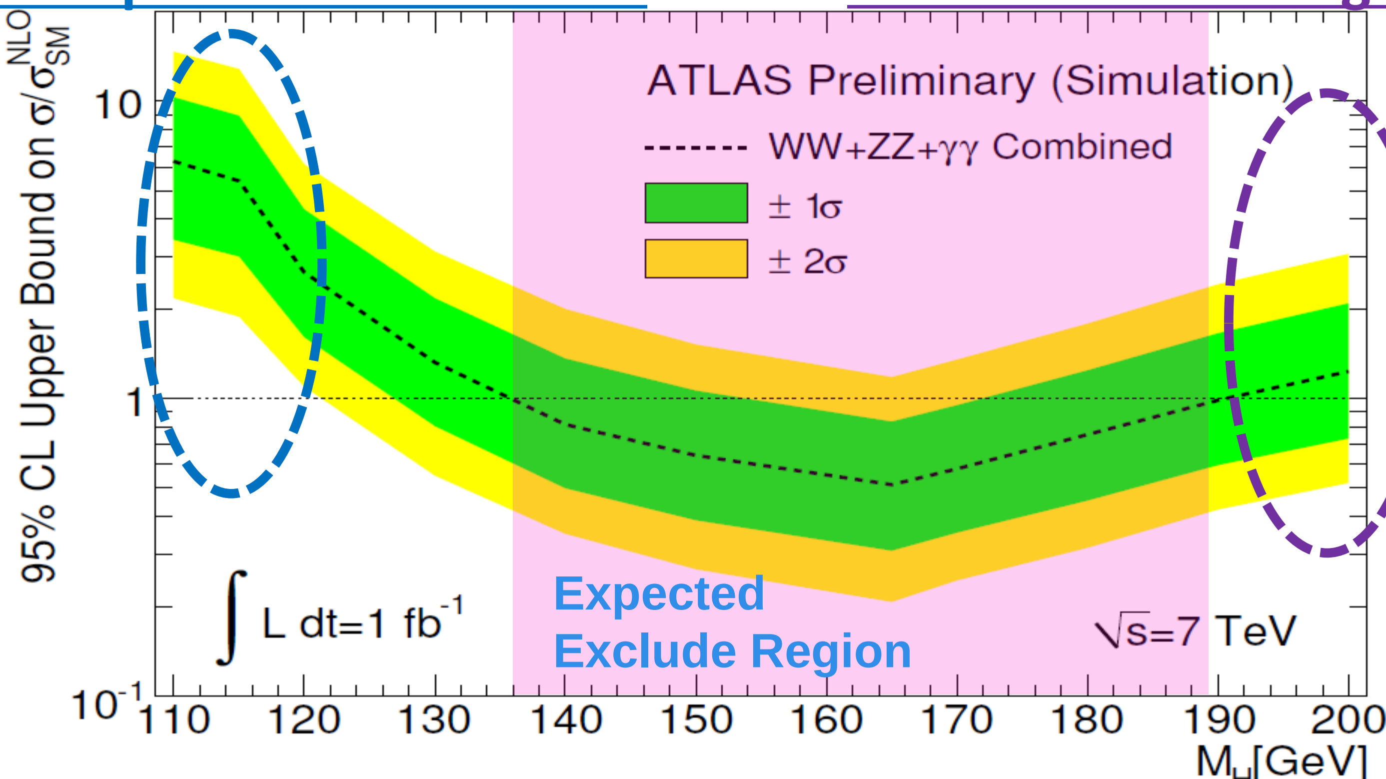
<u>Significantly better than the current Tevatron limit (~20 × SM cross section)</u>

Combined Exclusion Limit

- H→WW→lνlν, ZZ→4l,γγ channels are combined
  - H→WW channel is sensitive in intermediate mass region

γγ is important in low mass

ZZ is sensitive in high mass



Expected 95% C.L. exclusion of SM Higgs is 135-188 GeV @ 1fb^{-1} (end of 2011)

*** $b\bar{b}$,ττ channels help to improve sensitivity in low mass region**

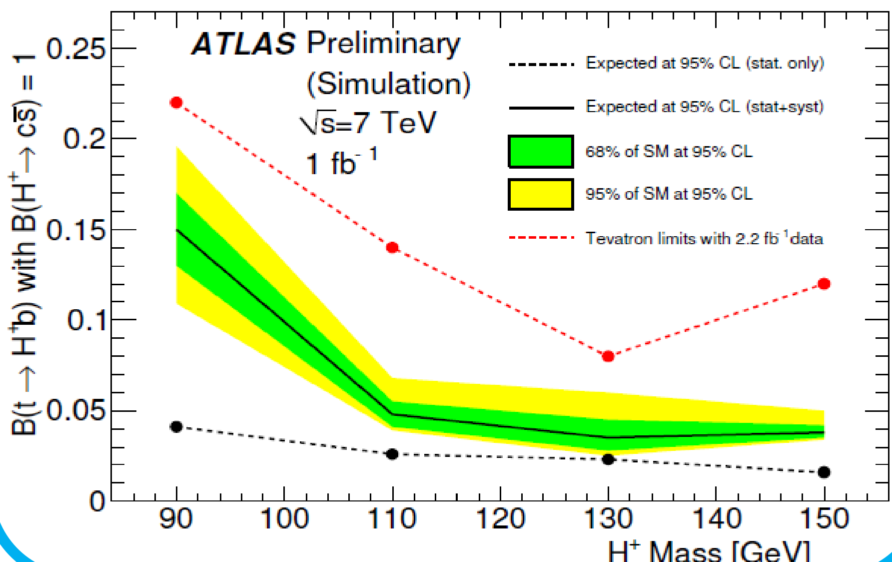
MSSM Higgs

MSSM ($H^+ \rightarrow c\bar{s}, \tau\nu$)

- Light charged higgs ($m_{H+} < m_{top}$) can appear from top quark decay

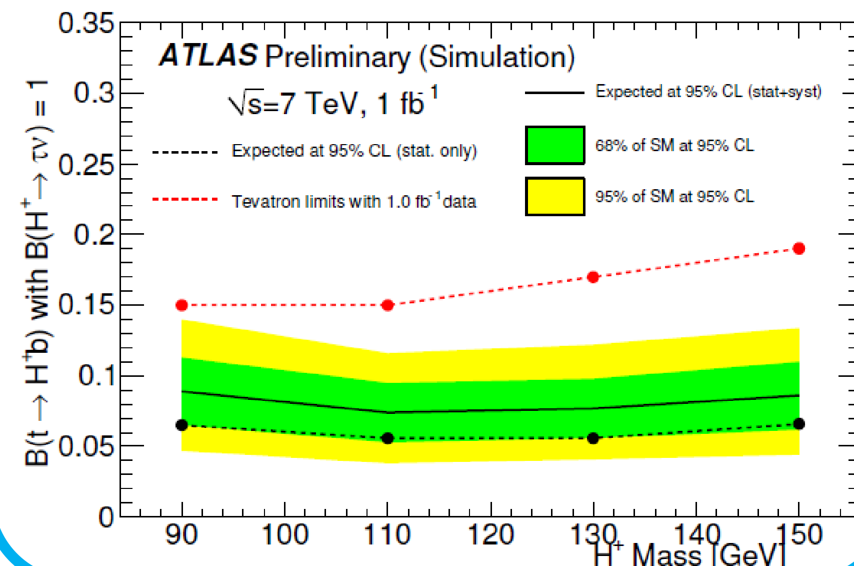
$H^+ \rightarrow c\bar{s}$ in semi-leptonic $t\bar{t}$ events

- lepton + MET + 4jets (with 2 b-tag)
- Reconstruct m_{H+} with 2 untagged jet
- Main background : ttbar (95%)
- Improve dijet mass resolution with leptonic W, top mass constraint



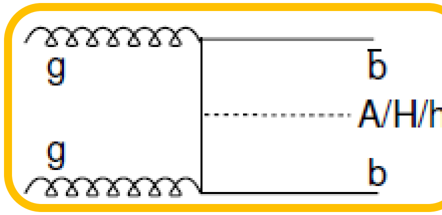
$H^+ \rightarrow \tau\nu$ in di-lepton $t\bar{t}$ events

- Use leptonic tau decay mode
- Two leptons + MET + 2 b-jets
- Main background : ttbar (90%)
- Look for excess close to -1 in helicity angle $\cos\theta_l^*$



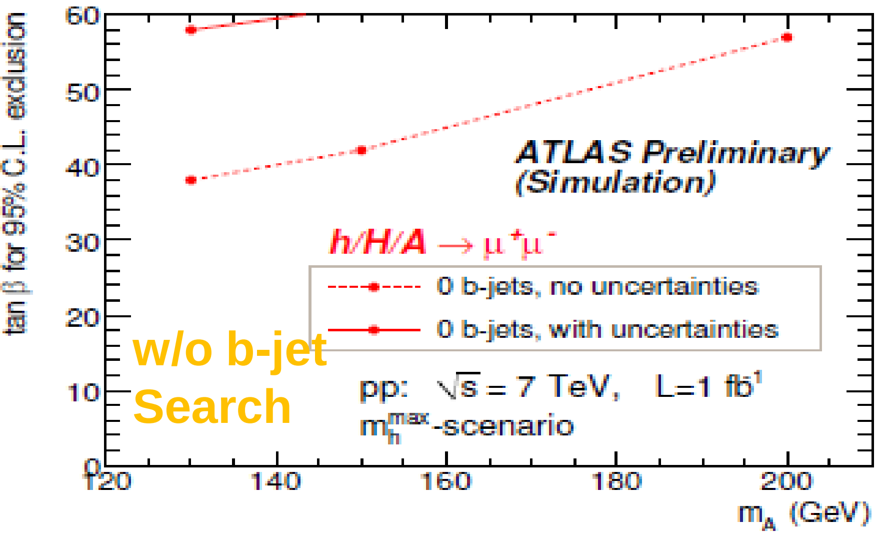
Better upper limit on branching ratio compared to current Tevatron results

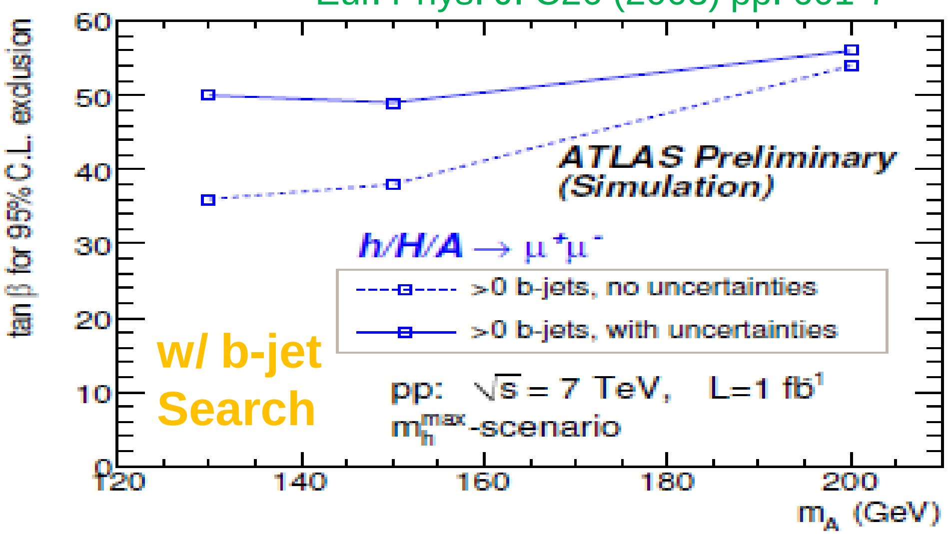
MSSM (h/H/A→μμ)



- Search for high tanβ parameter region (Associated production with b-quark is dominant)
  - Analyze 0 b-jet and at least one b-jet events separately
  - Main background : Z→μμ +jets, ttbar dilepton (important for search w/ b-jet)
  - Results are obtained by simultaneous fitting of $M_{\mu\mu}$ (signal region) and M_{ee} (control region)

m_h max benchmark scenario
Carena, Heinemeyer, Wagner, Weiglein
Eur. Phys. J. C26 (2003) pp. 601-7





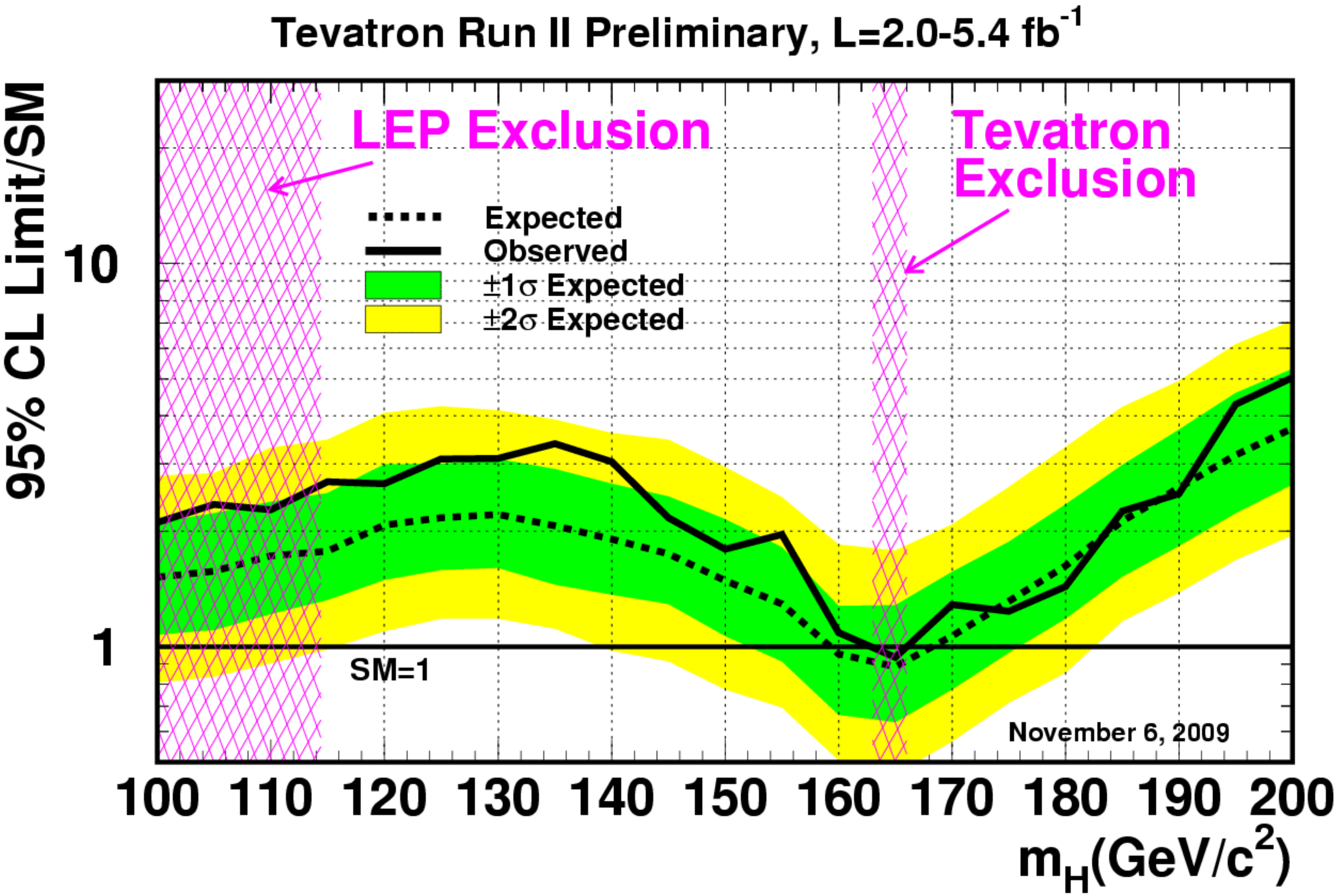
Summary

- **ATLAS Higgs sensitivity prospect has been evaluated at center of mass energy 7 TeV at integrated luminosity $1fb^{-1}$**
  - **Expected exclusion limit on Standard Model Higgs is 135-188 GeV at $1fb^{-1}$($H \to WW \to l\nu l\nu$ contribution is dominant in large mass range)**
  - **$H \to WW$ sensitivity will be comparable with Tevatron at 300-500pb^{-1} (middle of 2011)**
  - **$H \to \gamma\gamma$ sensitivity is also competitive with Tevatron at 2011**
  - **95% C.L. upper limit on $Br(H^+ \to c\bar{s}, \tau\nu)$ is expected below the current Tevatron result at $1fb^{-1}$**
- **Still plenty room for sensitivity improvement ($b\bar{b}$, $\tau\tau$ channels, Multivariate technique for object id and event selection)**
  - **MSSM $H \to \tau\tau$ (one of most sensitive channels) results will come up**

Many interesting results coming soon

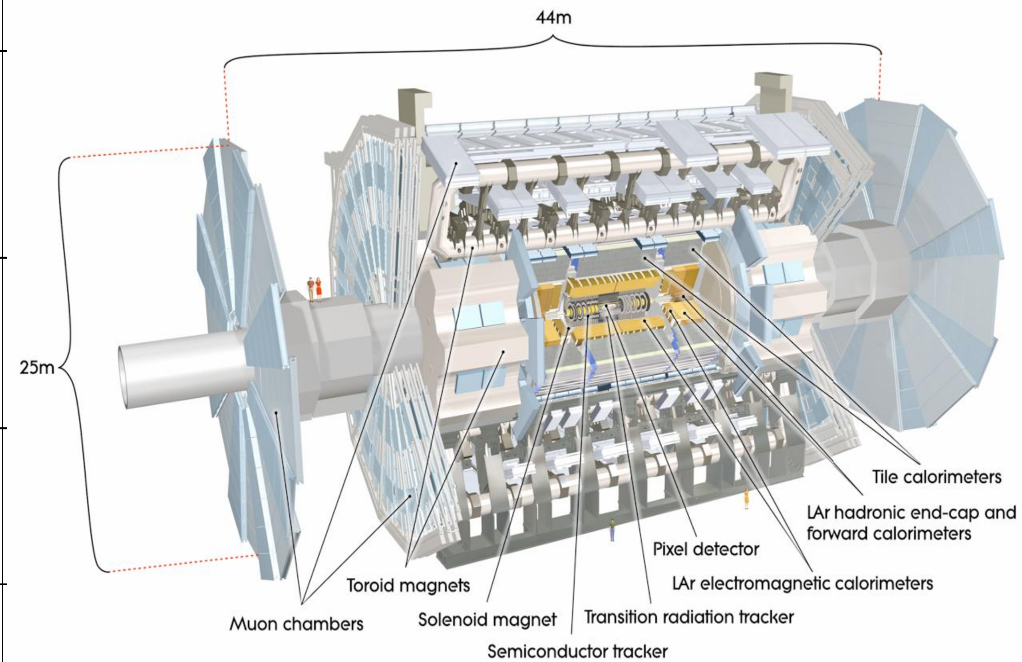
Back up

Recent Tevatron Results



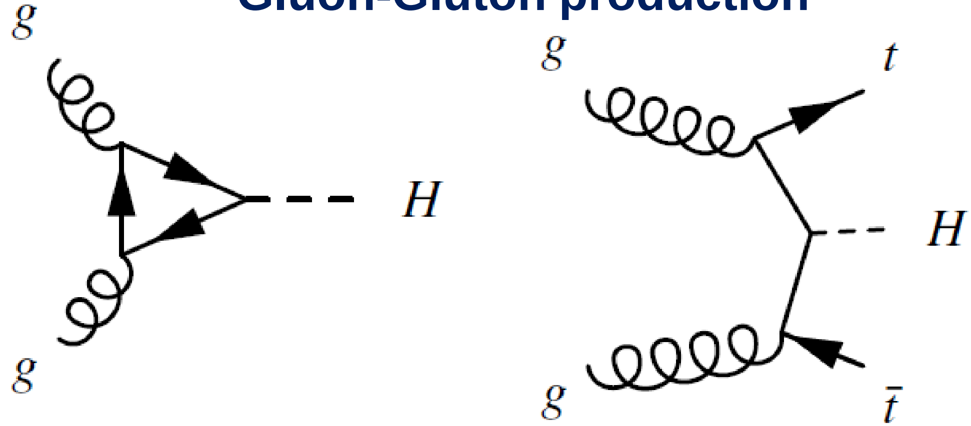
ATLAS detector

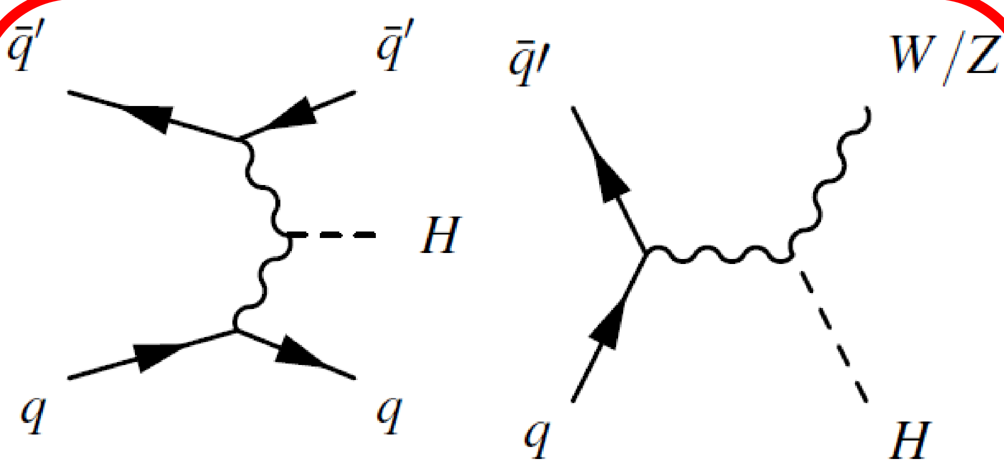
Magnet(s)	Solenoid (within EM Calo) 2T 3 Air-core Toroids
Inner Tracking	Pixels, Si-strips, TRT PID w/ TRT and dE/dx $\sigma_{p_T}/p_T \sim 5 \times 10^{-4} p_T \oplus 0.01$
EM Calorimeter	Lead-Larg Sampling w/ longitudinal segmentation $\sigma_E/E \sim 10\%/\sqrt{E} \oplus 0.007$
Hadronic Calorimeter	Fe-Scint. & Cu-Larg (fwd) $\gtrsim 11\lambda_0$ $\sigma_E/E \sim 50\%/\sqrt{E} \oplus 0.03$
Muon Spectrometer System Acc. ATLAS 2.7 & CMS 2.4	Instrumented Air Core (std. alone) $\sigma_{p_T}/p_T \sim 4\%$ (at 50 GeV) $\sim 11\%$ (at 1 TeV)



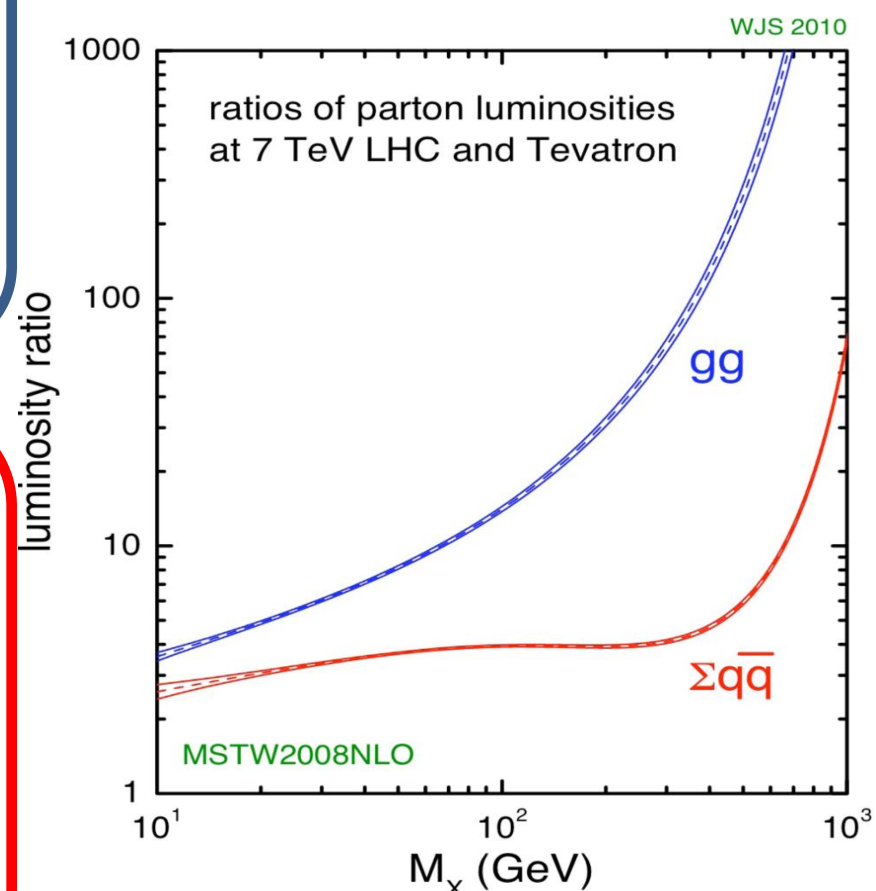
Compare with Tevatron

Gluon-Gluton production





Quark-Quark production



H→WW→lvlv

- **Background understanding is important because of no clear mass peak**

Difficulties of W+jets (fake lepton) background estimation

- Fake lepton modeling from MC is not reliable
- W+jets cross section has large theoretical uncertainty

10 TeV MC Study

Data-driven W+jets Background Estimation

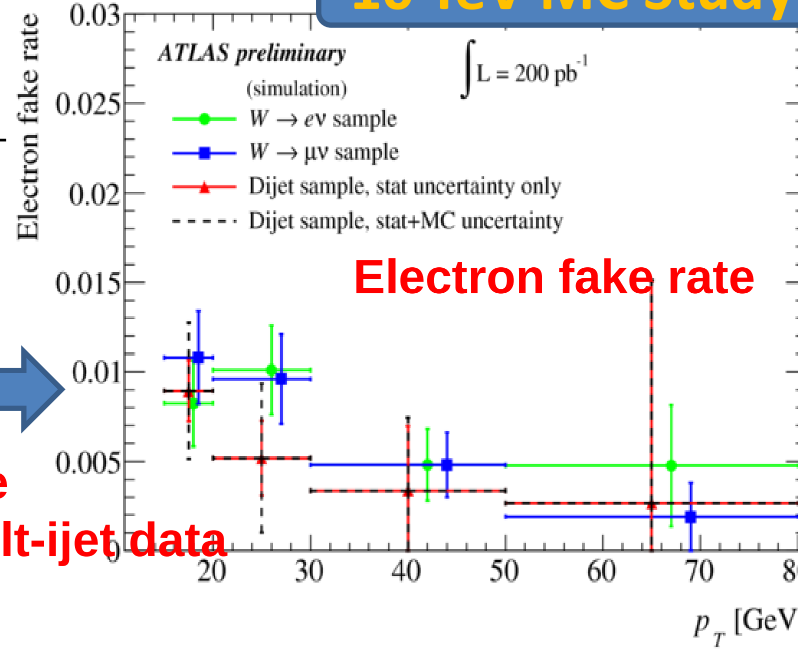
$$N_{W+\text{fake lepton}} = N_{W+\text{loose lepton}} \times \frac{N_{\text{fake lepton}}}{N_{\text{loose lepton}}}$$

W+jets dominant control region

Estimated W+jets background

Determine W+jets normalization from data

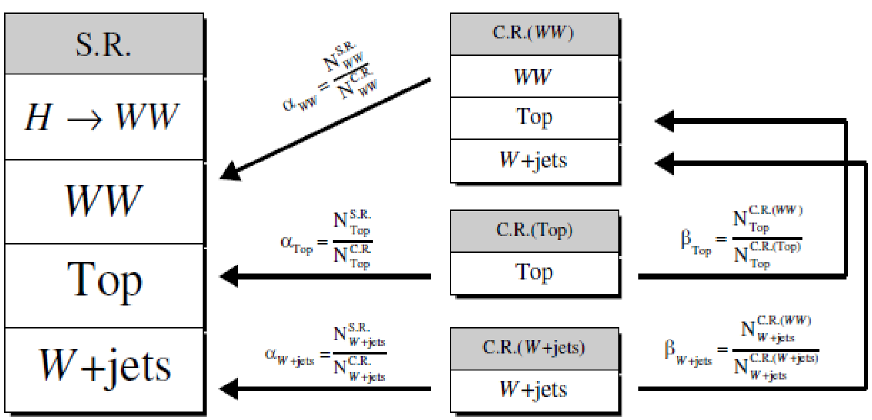
Estimate from mult-ijet data



H→WW Systematic Uncertainties

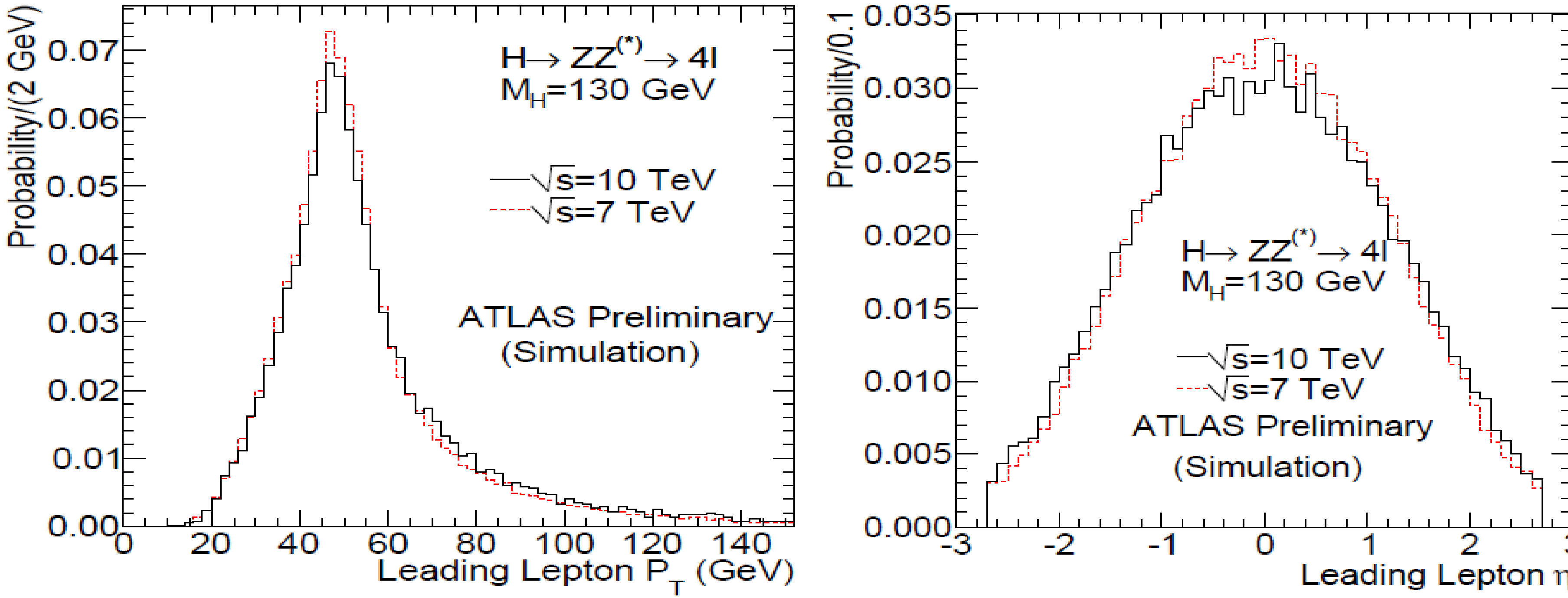
- **Uncertainty on background estimation**
  - Q^2 scale variation : maximum deviation from center value by changing Q^2 scale
  - Jet energy scale and resolution : effect on jet energy and MET by JES shift and smearing energy resolution
  - b-tagging : 10 % uncertainty
  - MC stat : consider limited number of MC sample in SR and CR

	α_{WW}	α_{Top}	α_{W+jets}	β_{Top}	β_{W+jets}
$H+0j$ analysis					
WW MC Q^2 Scale	5.1%	–	–	–	–
Top MC Q^2 Scale	–	27%	–	12%	–
Jet E Scale + Resolution	1.5%	66%	3%	61%	3%
b-tagging eff.	–	4.3%	–	4.3%	–
Wt contribution	–	40%	–	40%	–
MC Statistics	5.3%	71%	100%	8%	100%
Total Uncertainty	7.3%	108%	100%	74%	100%
$H+1j$ analysis					
WW MC Q^2 Scale	11%	–	–	–	–
Top MC Q^2 Scale	–	23%	–	7%	–
Jet E Scale + Resolution	9%	27%	20%	11%	57%
b-tagging eff.	–	34%	–	15%	–
MC Statistics	10.1%	17%	89%	6%	53%
Total Uncertainty	17.2%	52%	91%	20%	78%
$H+2j$ analysis					
WW MC Q^2 Scale	45%	–	–	–	–
Top MC Q^2 Scale	–	38%	–	8%	–
Jet E Scale + Resolution	15%	8%	–	2.5%	–
b-tagging eff.	0.4%	10%	–	16%	–
MC Statistics	27%	17%	–	1.4%	–
Total Uncertainty	54%	43%	–	18%	–



Rescaling Effect on H→ZZ

- **Assume no difference on acceptance in cross section rescaling procedure**
  - **Acceptance of signal and irreducible ZZ background agree to within 2%**

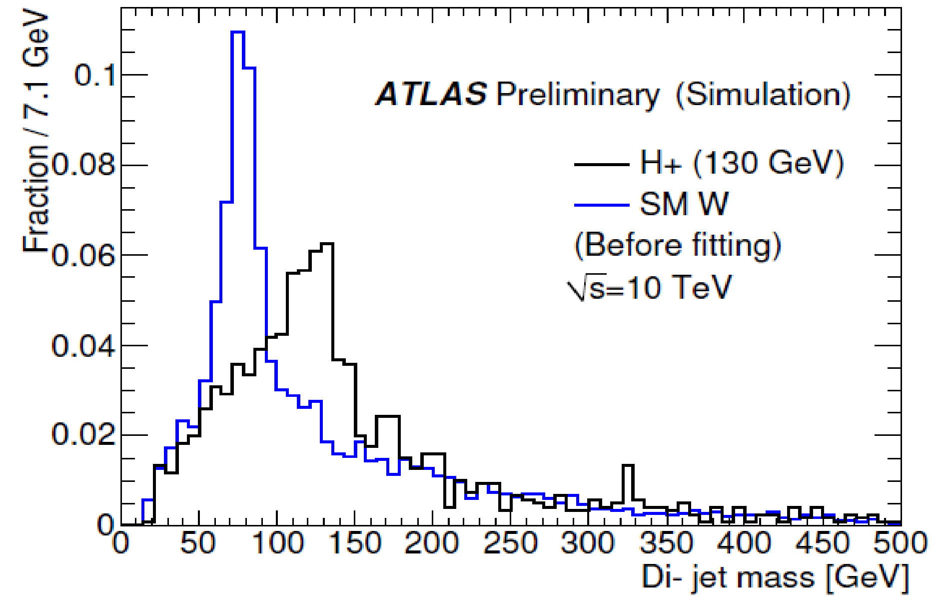


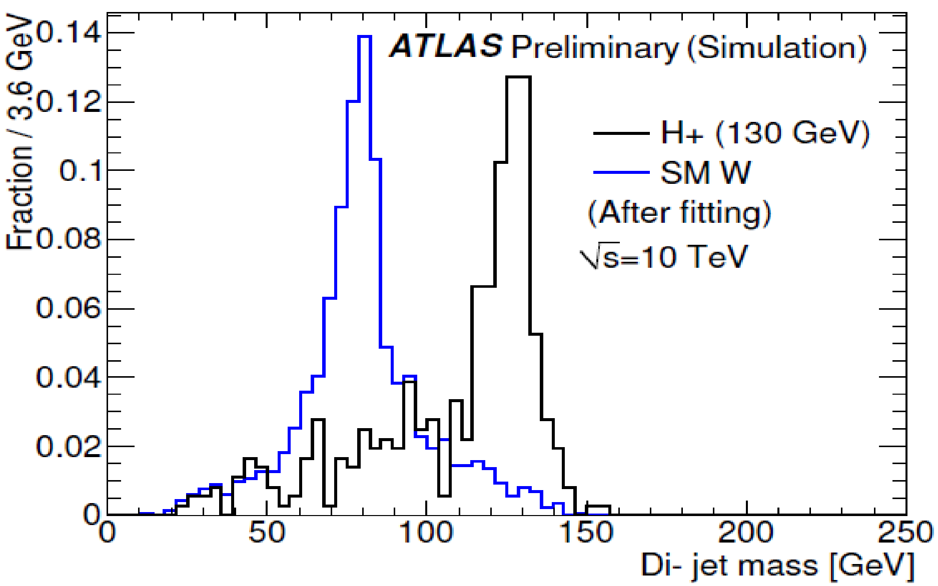
ZZ→4l

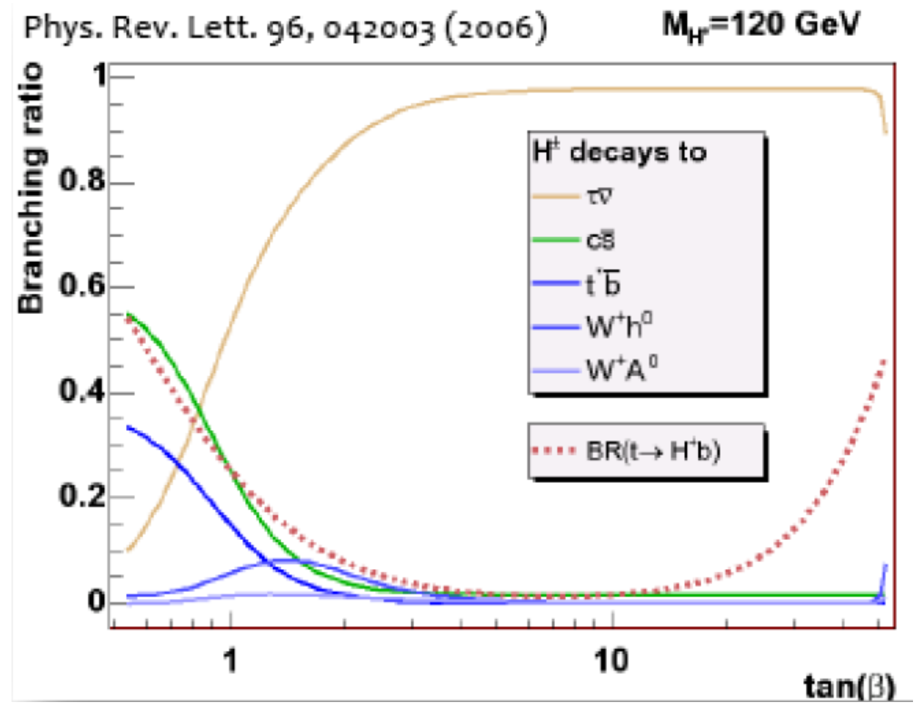
- **Estimated number of events in signal region**

M_H(GeV)	120	130	140	150	165	170	180	190
SM ZZ	0.090	0.094	0.083	0.089	0.121	0.147	0.376	0.981
top & Z+jets	0.005	0.004	0.005	0.004	0.005	0.005	0.003	0.003
Total background	0.095	0.098	0.088	0.093	0.126	0.152	0.379	0.984
Signal	0.105	0.319	0.595	0.713	0.185	0.192	0.458	1.49
M_H(GeV)	200	220	240	260	300	400	500	600
SM ZZ	1.29	1.18	0.92	0.89	0.72	0.48	0.49	0.39
Signal	1.60	1.46	1.25	1.08	0.88	0.67	0.29	0.13

MSSM Charged Higgs

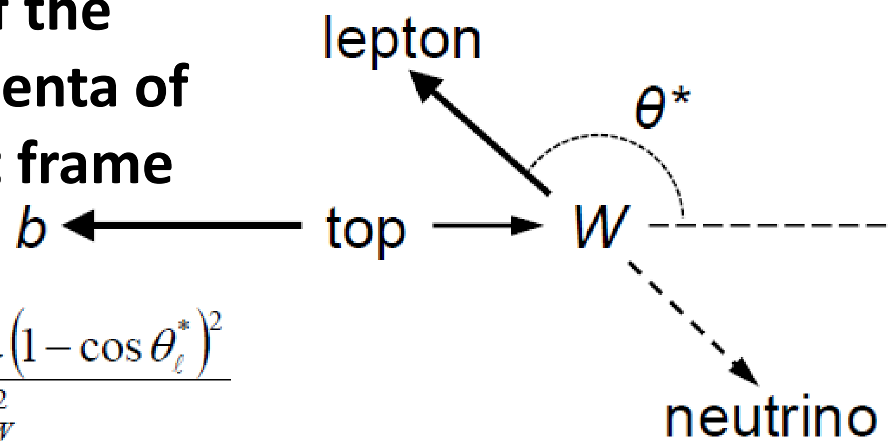






MSSM Charged Higgs

cosθ* is defined by the cosine of the angle between 3-vector momenta of the lepton and b-jet in W rest frame



$$\frac{1}{N}\frac{dN(W \to \ell \nu_\ell)}{d\cos\theta_\ell^*} = \frac{3}{4} \times \frac{m_t^2\left(1-\cos^2\theta_\ell^*\right)+m_W^2\left(1-\cos\theta_\ell^*\right)^2}{m_t^2+2m_W^2}$$

Experimentally, the angle is

$$\cos\theta_\ell^* \cong \frac{4\, p_b \cdot p_\ell}{m_t^2 - m_W^2} - 1$$

In charged higgs decay, the angle has peak close to -1 due to higher charged higgs mass and lower lepton momentum from tau decay