The first a few fb^{-1} : potential for "observing" SUSY, Higgs

Soshi Tsuno (KEK)

on behalf of the ATLAS and CMS collaborations

Moriond Electroweak 2008

Physics strategy

LHC is the discovery machine.

2008(summer)/09: first 14 TeV physics run, initial L ~$10^{31}cm^{-2}s^{-1}$, L_{int} ~ $1fb^{-1}$
Detector commissioning : alignment, in-situ calibration / trigger menu
First SM measurements : W/Z/top & min.bias/jets & PDF ~$100pb^{-1}$

2009/10 : low luminosity run, instantaneous L ~$2x10^{33}cm^{-2}s^{-1}$, L_{int} ~ $10fb^{-1}$
First B rare decay searches,
First searches : high mass DY(Z'), ADD, BH, **SUSY** ~$1fb^{-1}$
First **Higgs** discovery : H→4leptons, WW, $\gamma\gamma$ & MSSM Higgs

2010/11 : low luminosity run, inst.L ~$2x10^{33}cm^{-2}s^{-1}$, L_{int} ~ $10fb^{-1}$/yr
Light Higgs searches, SUSY measurements (model specific), …

2011/12~ : high luminosity run, inst.L ~$2x10^{34}cm^{-2}s^{-1}$, L ~ $100fb^{-1}$/yr
many, many … toward SLHC…

Selected topics

Focus on early clean discovery :

SUSY searches:

1) Inclusive searches : MET + Jets + leptons
2) Invariant mass edge analysis : opposite sign di-lepton
3) Inclusive w/ Higgs/Z

Remarks : We go in TeV energy region. We don't know how the bkg. (SM) looks like.

- target signal events : excess 100 ~ 1000 events (σ~10pb) at L= 1 fb^{-1}.
- target signal energy : ~1 TeV
- some benchmark scenario : mSugra, etc. (5,6 parameters)

Note that the analysis strategy is NOT equivalent w/ both experiments.
(ex. "inclusive muons" in CMS v.s "exact one muon" in ATLAS etc.)

Higgs searches:

1) SM Higgs : $H \rightarrow \gamma\gamma$, $H \rightarrow ZZ \rightarrow$ 4 leptons , $H \rightarrow WW \rightarrow$ 2 leptons
2) MSSM Higgs : $bbH \rightarrow \tau\tau/\mu\mu$

Remarks : Peak hunting. (this is the most attractive feature.)

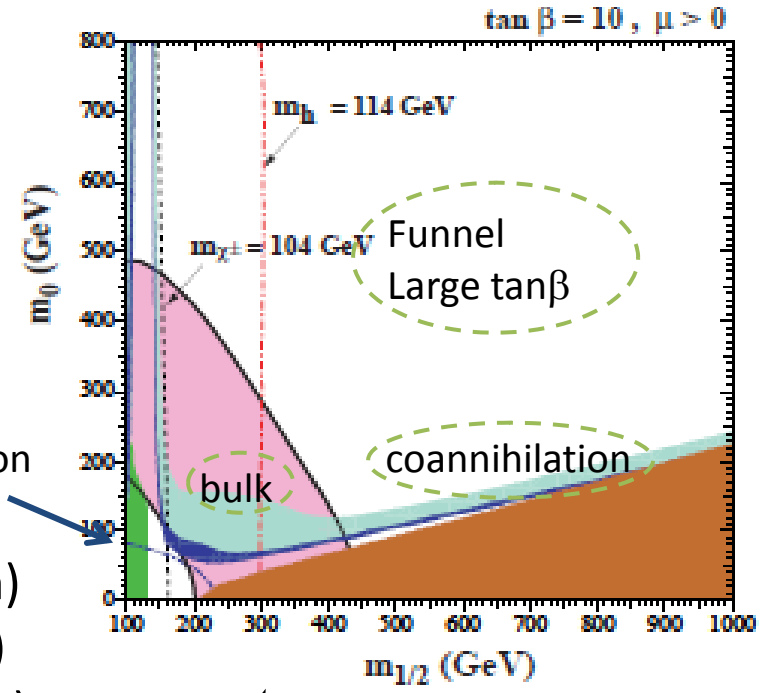
- target signal events : a few ~10 ($H \rightarrow ZZ \rightarrow$ 4 lep.) Mass resolution is ~2GeV.

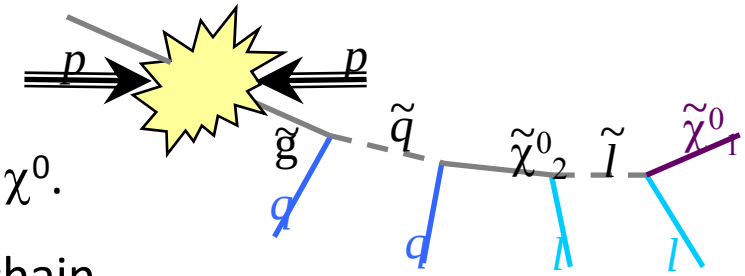
SUSY searches

Goal is to cover ALL characteristics of SUSY scenario .

Set benchmark points. But we don't believe this is the whole story.

- Focus on mSugra.
- R-parity conservation.
- WMAP inspired.
  - bulk region (full coverage of Tevatron)
  - coannihilation point (wino/bino-like)
  - funnel point (enhance 3rd generation)





Event topology has at least two undetected χ^0.

⇒ Large missing Et + cascade decay chain

Important to understand the Missing Et .

Inclusive analysis with MET+Jets

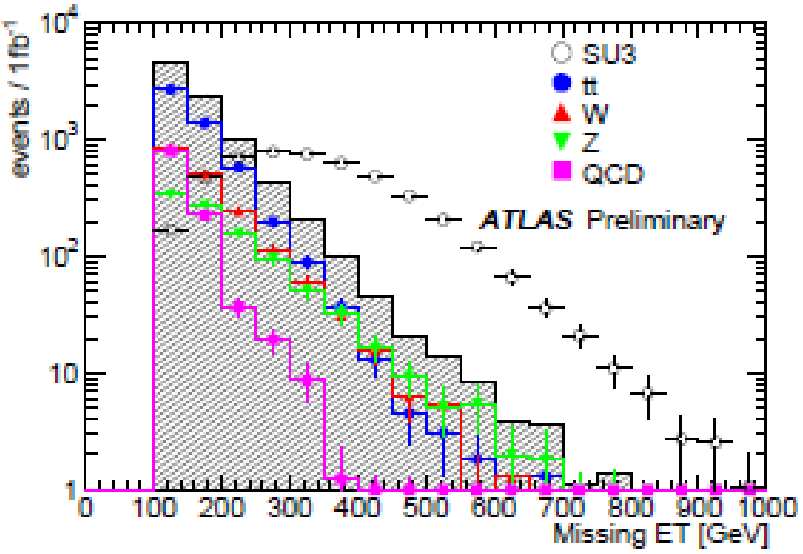
At topology level,

ATLAS baseline selection :

- no lepton

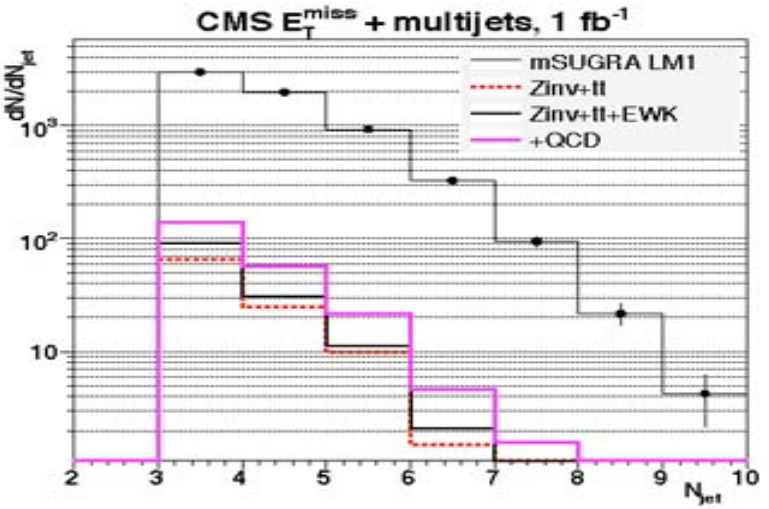
SUSY Cut

- MET > 100 GeV
- leading jet pT > 100 GeV
- at least 4-jets pT>50 GeV
- MET > 0.2 Meff



CMS :

- MET > 200 GeV
- 1st jet pT>180 GeV, 2nd pT>110GeV
- at least 3-jets pT > 30 GeV
- HT > 500 GeV

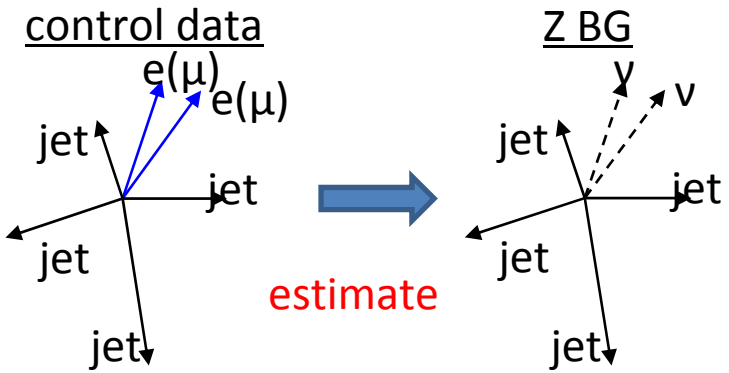


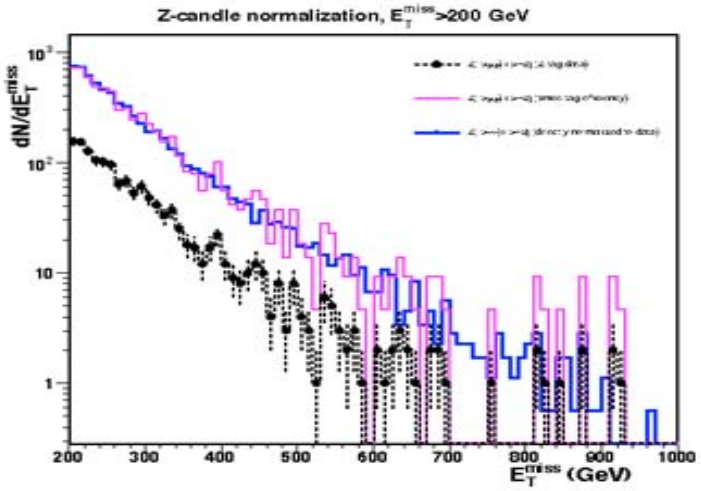
Main backgrounds : QCD jets / W/Z/top

Background estimation: Incl. MET+Jets

Our region of interests are "tail-region".

$Z \rightarrow \nu\nu$ background

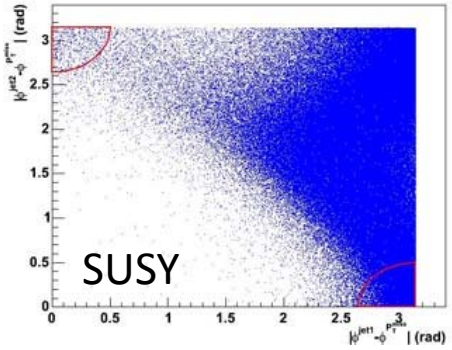


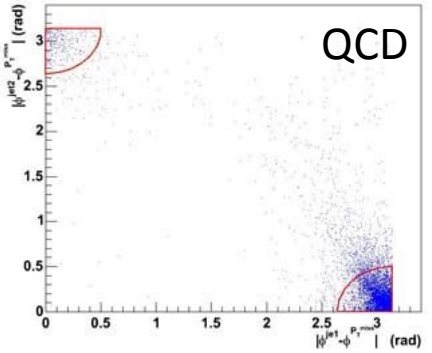


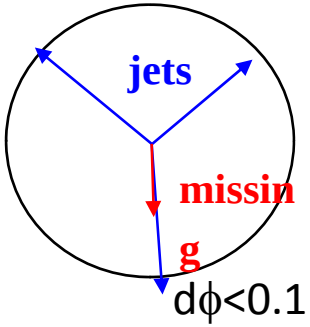
QCD multi-jets

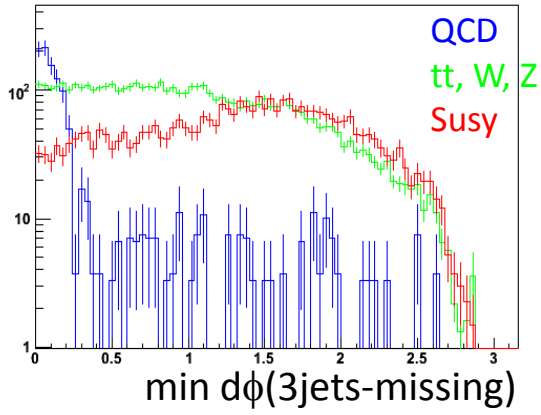
Strong correlation with fake-jet.

Use angle correlation with MET and jets.









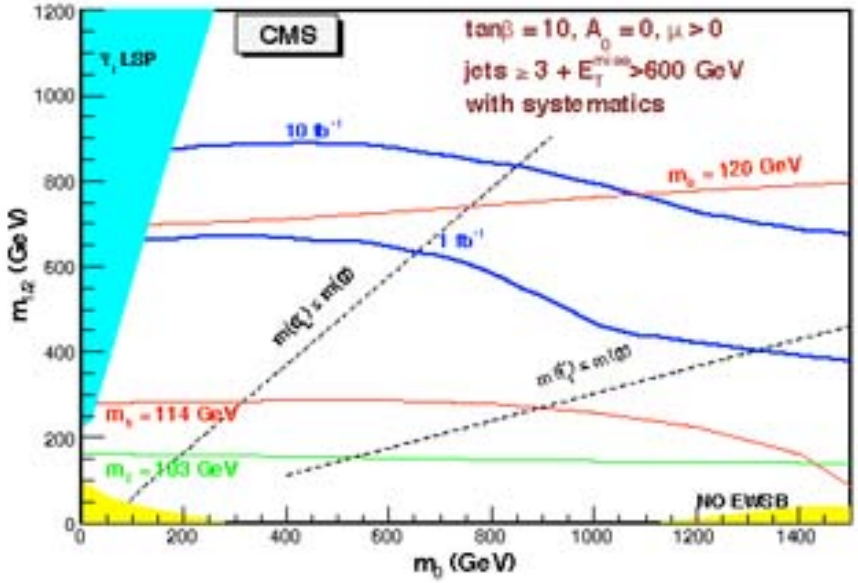
Discovery potential : Incl. MET+Jets

CMS: Signal and SM Background at 1fb^{-1} .

Table 4.3: Selected SUSY and Standard Model background events for 1 fb^{-1}

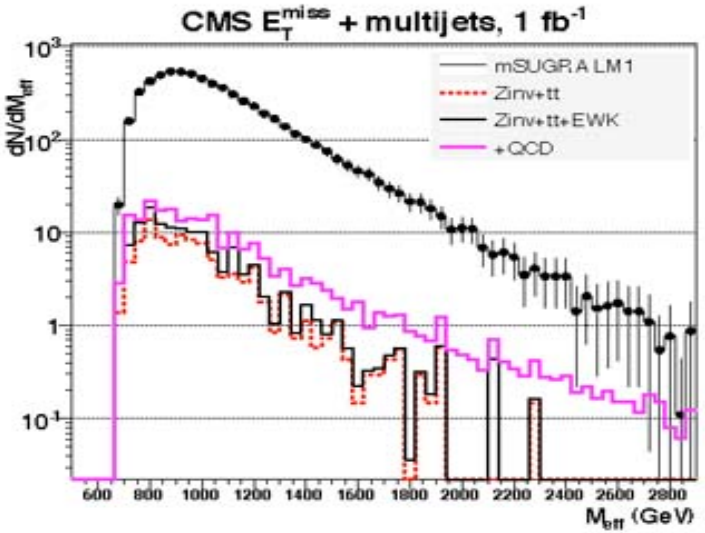
Signal	$t\bar{t}$	single t	$Z(\rightarrow \nu\bar{\nu})$+ jets	$(W/Z,WW/ZZ/ZW)$ + jets	QCD
6319	53.9	2.6	48	33	107

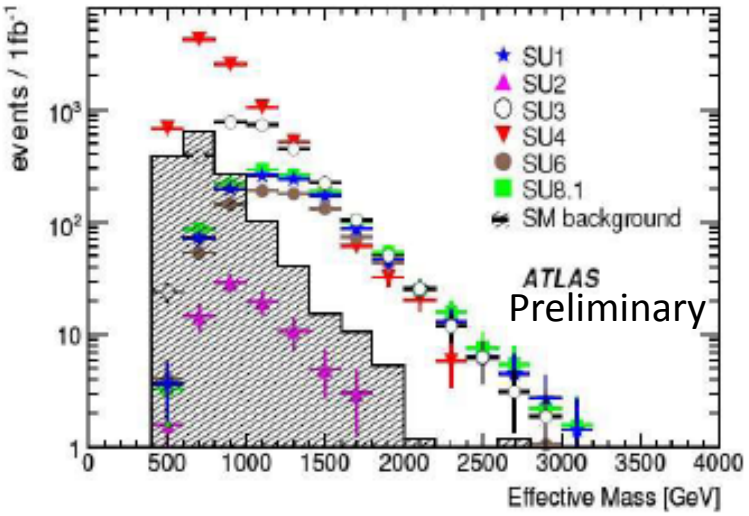
CMS Physics TDR 2006



Dominant systematics : Jet Energy Scale ~22%.

Effective Mass





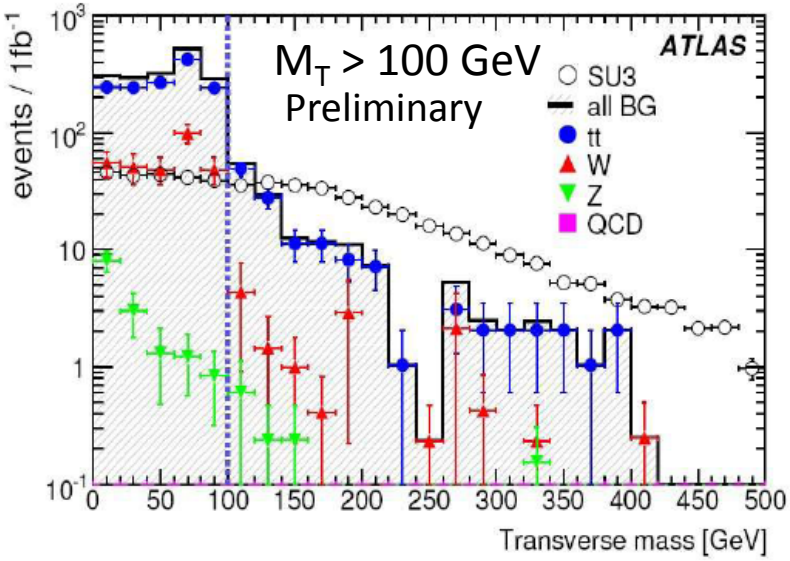
Inclusive analysis with MET+Jets + e or μ

ATLAS :
- Electron pT>25GeV or Muon pT>20GeV
- exact one lepton
+ SUSY cut (same as no-lepton mode)

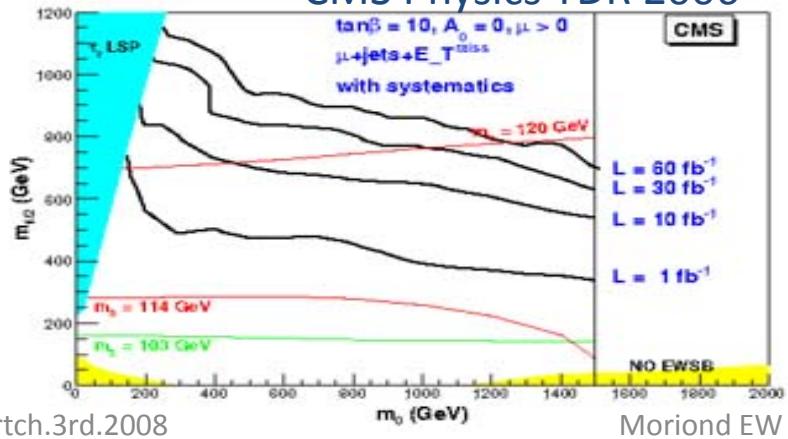
CMS :
- Muon pT > 30GeV, MET>130GeV
- at least one muon
- at least 3-jets, pT > 50 GeV
- 1st and 2nd jet pT > 440 GeV

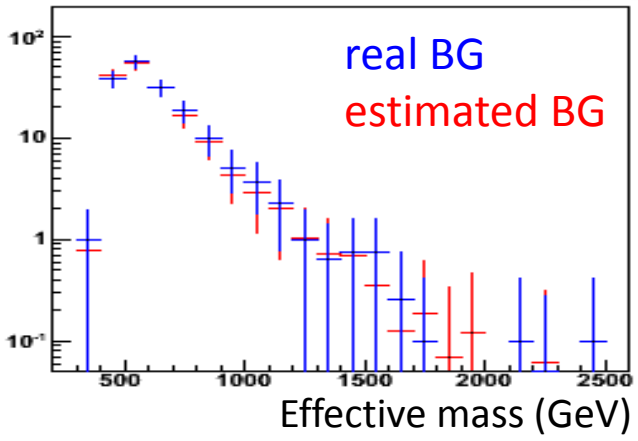
Background Control :
Transverse mass has no correlation.

Control region Signal region



CMS Physics TDR 2006





Inclusive analysis with MET+Jets + e or μ (≥2)

Same charged di-lepton requirement strongly suppresses DY backgrouds.

ATLAS :

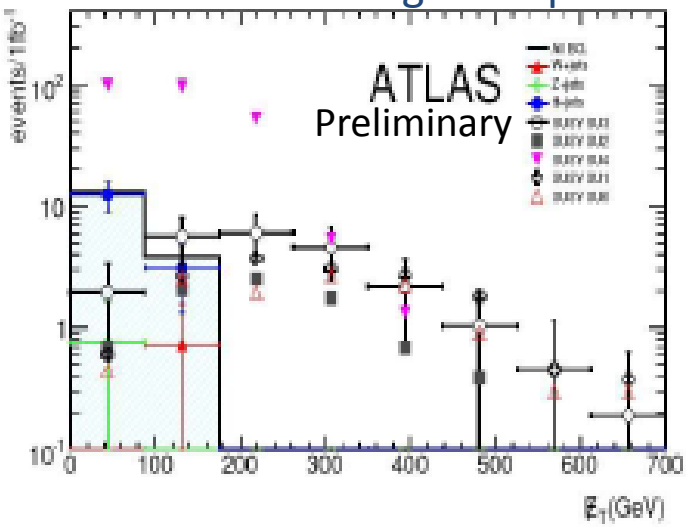
- exact two lepton w/ same signed charge

+ SUSY cut (same as no-lepton mode)

CMS :

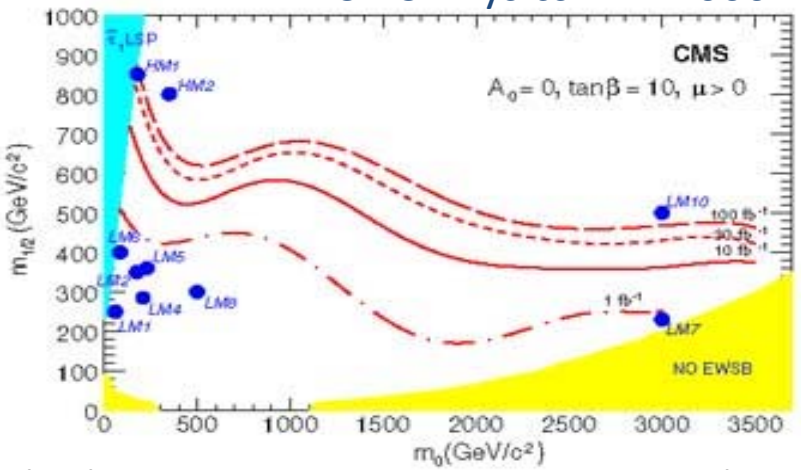
- Two leading muon pT > 10GeV, MET>200GeV
- at least two muon w/ same signed charge
- 1st, 2nd and 3rd jet pT > 175, 130, and 55 GeV

Same sign di-lepton

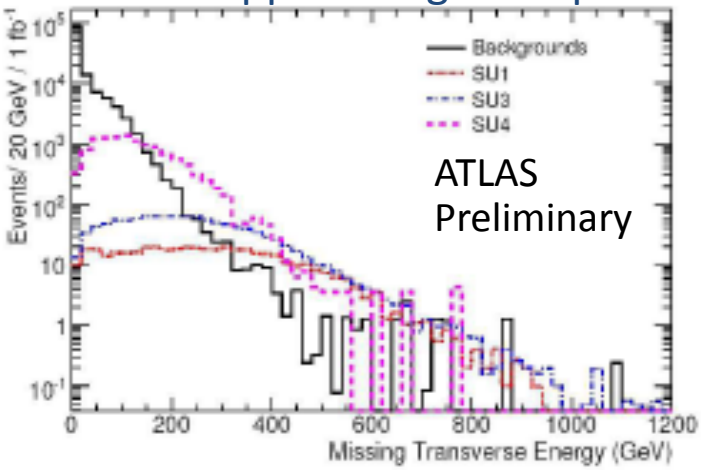


Same sign di-muon

CMS Physics TDR 2006



Opposite sign di-lepton



Di-lepton Edge analysis

The endpoint of mass edge tells us the mass difference.

$$\tilde{q}_L \rightarrow \tilde{\chi}_2^0 q \rightarrow \tilde{\chi}_1^0 l^{\pm} l^{\mp} q$$

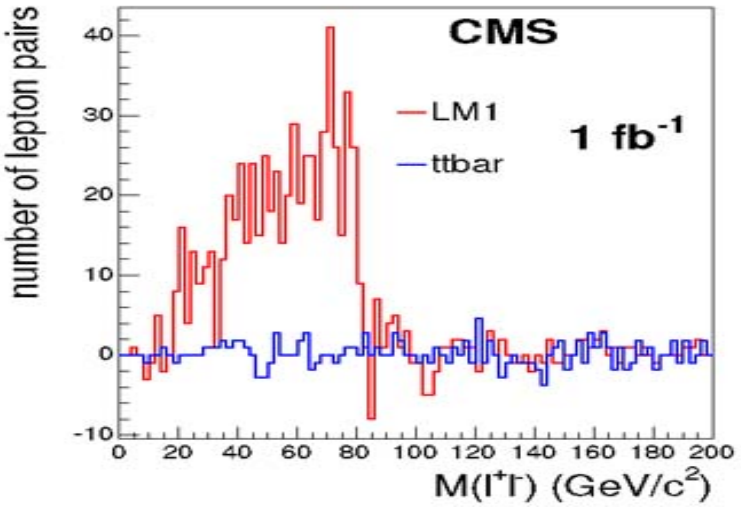
Flavor subtraction method:

SM BG cancels out by taking :

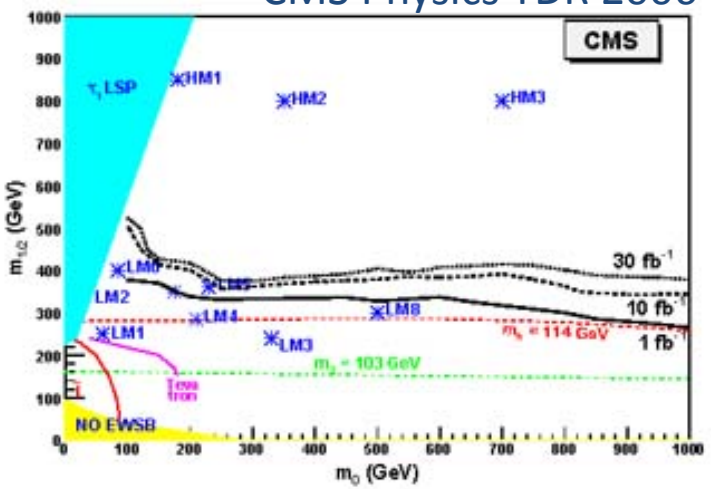
$N(ee) + \beta^2 N(\mu\mu) - \beta N(e\mu)$

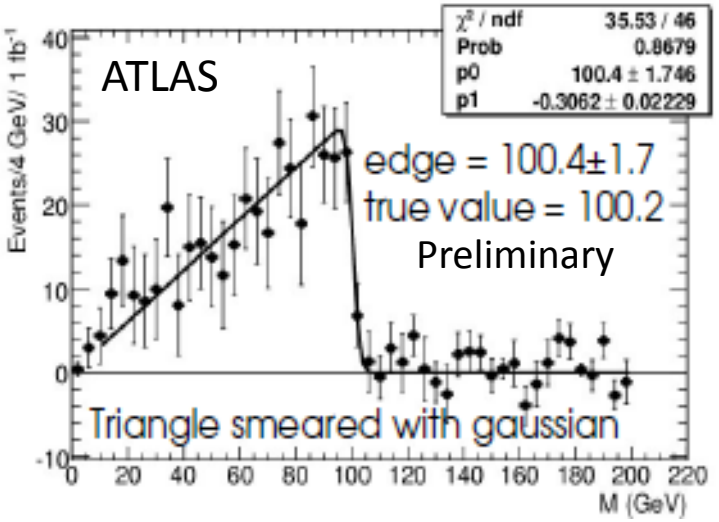
β is efficiency correction.

Subtracted invariant mass



CMS Physics TDR 2006





Inclusive analysis with Higgs/Z

Higgs/Z resonance in SUSY cascade decay chain

Inclusive Higgs :

- $h \rightarrow b\bar{b}$ reconstruction
- large missing pT
- large jet pT's

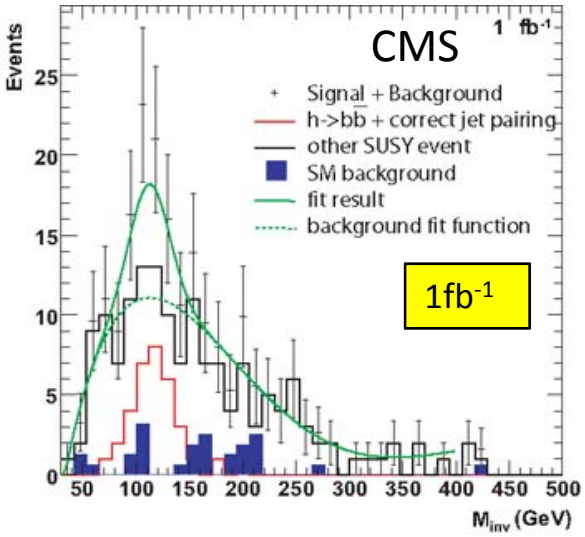
{ >200GeV in CMS
  >100GeV in ATLAS

- other SUSY events rather than SM bkg. (combinatorial bkg.)

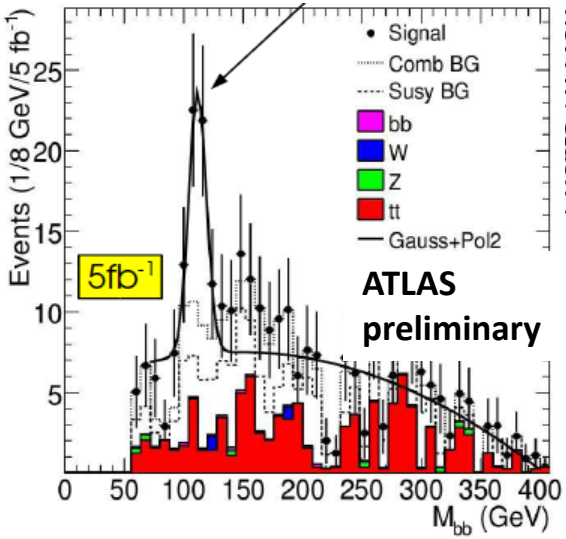
Inclusive Z :

- $Z \rightarrow ee, \mu\mu$
- strict Z mass window cut
- large missing pT

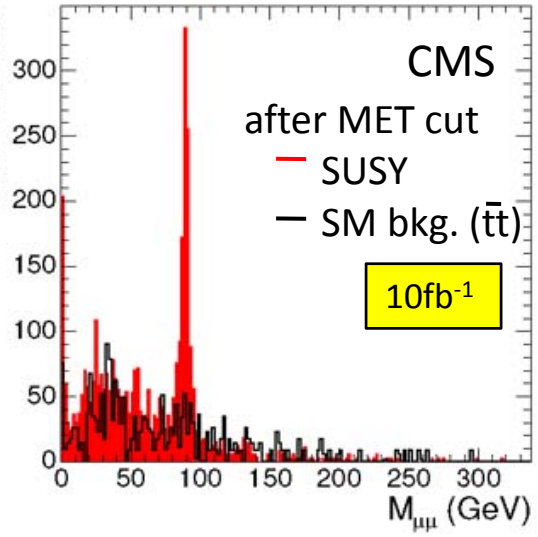
Inclusive Higgs



Inclusive Higgs

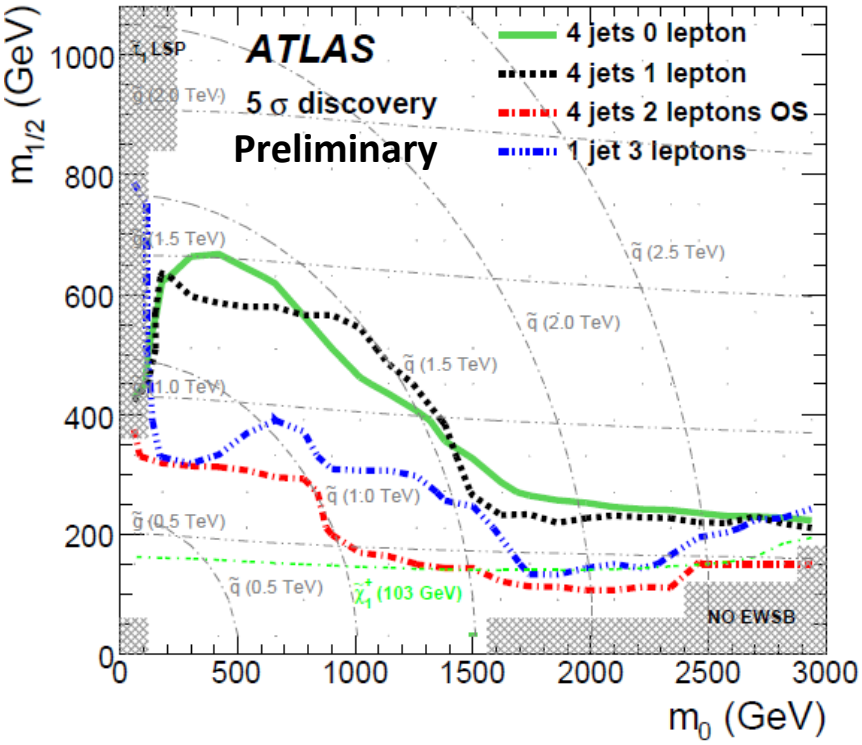


Inclusive Z

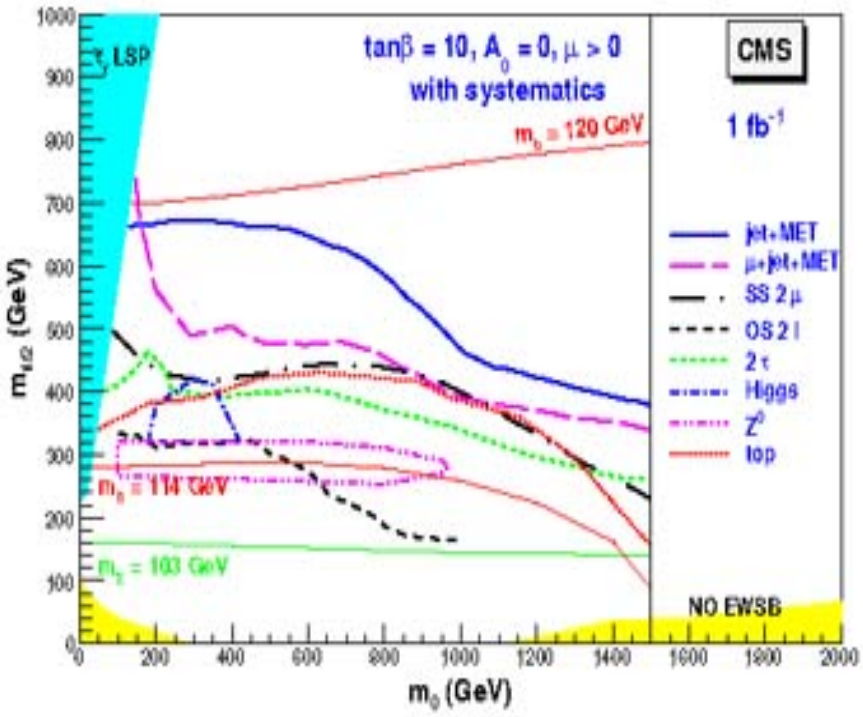


Discovery reach for inclusive analysis

ATLAS CSC 2008



CMS Physics TDR 2006

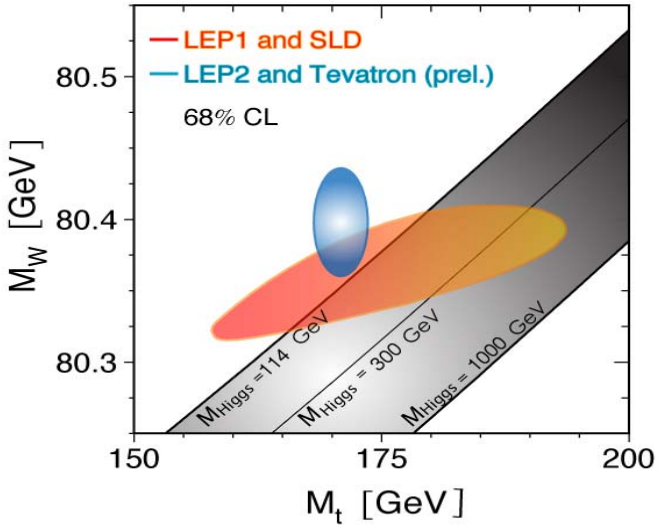


Note: “mode definition” is not same.

Note: CMS only shows “muon channel”.

Higgs searches

Recent Tevatron data suggest to have low mass Higgs.



Golden channels in early discovery :

SM Higgs : (σ ~ a few 10 pb at LHC)

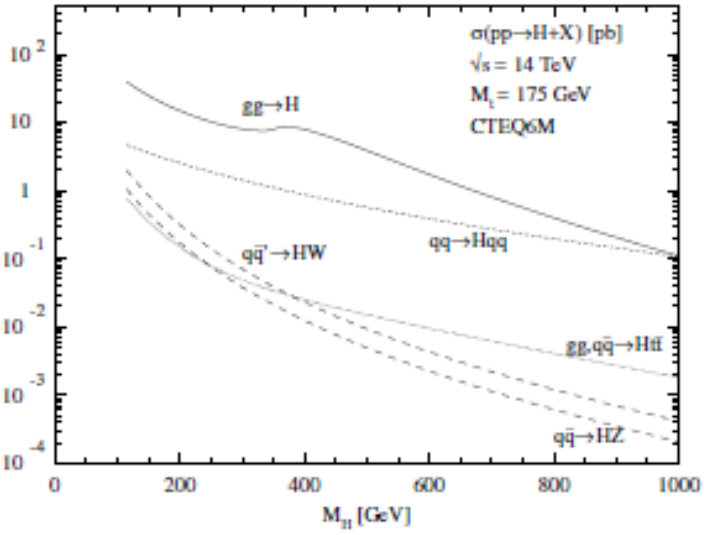
Reconstruct the invariant mass peak.

- $H \rightarrow \gamma\gamma$
- $H \rightarrow ZZ \rightarrow$ 4 leptons

} High resolution ~1~3 GeV

Observe larger event excess than SM.

- $H \rightarrow WW \rightarrow$ 2 leptons



Both searches requires good detector performance.
Object identification is essential.

MSSM Higgs : $A/h/H \rightarrow \tau\tau/\mu\mu$ (large tanβ) , H^+

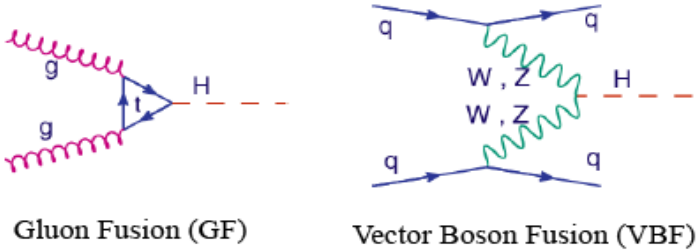
Higgs sector is considered as differently from possible SUSY scenario.

$H \rightarrow \gamma\gamma$

Most promising channel in low mass range.

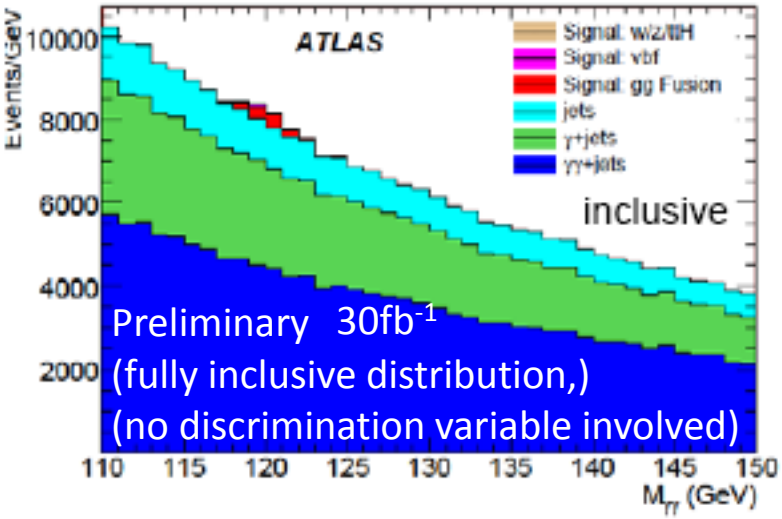
Several production mechanics are analyzed.

Gluon fusion **Vector Boson Fusion (VBF)**



Gluon Fusion (GF) Vector Boson Fusion (VBF)

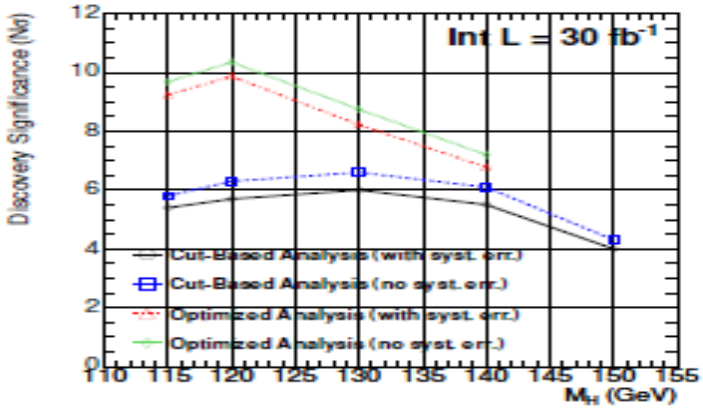
ATLAS CSC 2008

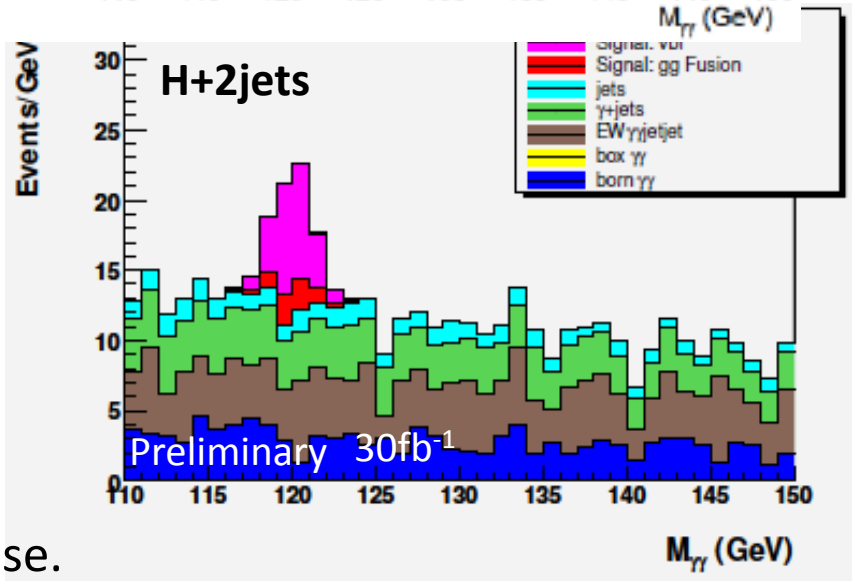


The VBF analysis also looks promising.

CMS Physics TDR 2006

Only inclusive measurement





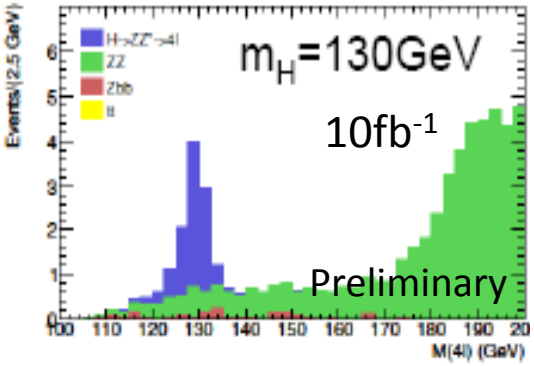
With VBF analysis, significance will increase.

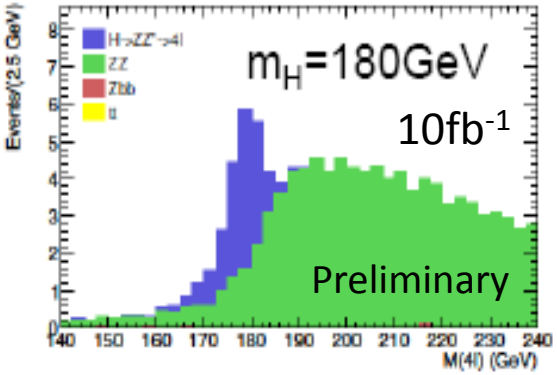
H → ZZ → 4 leptons

Golden discovery channel over wide range.

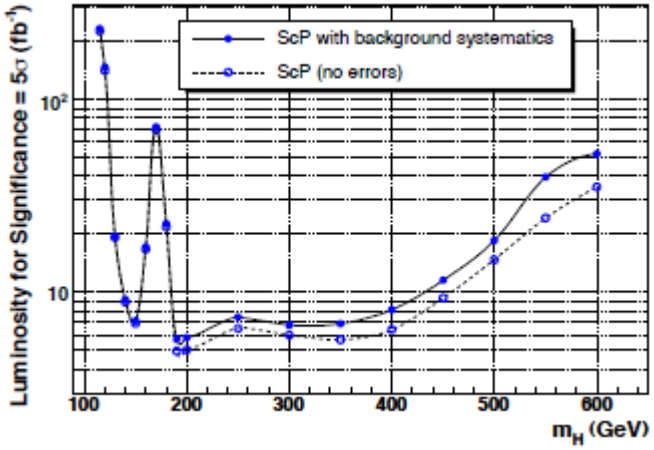
Lepton ID :
- need to achieve high identification/purity.

ATLAS CSC 2008

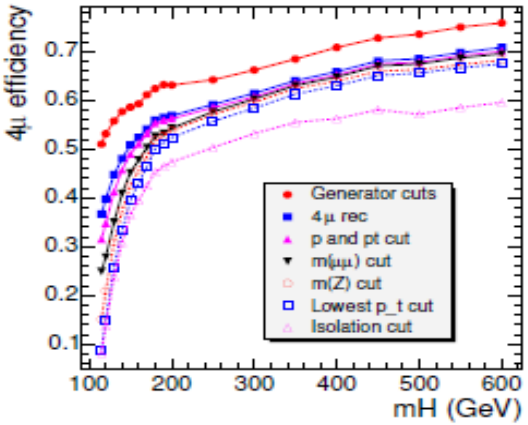




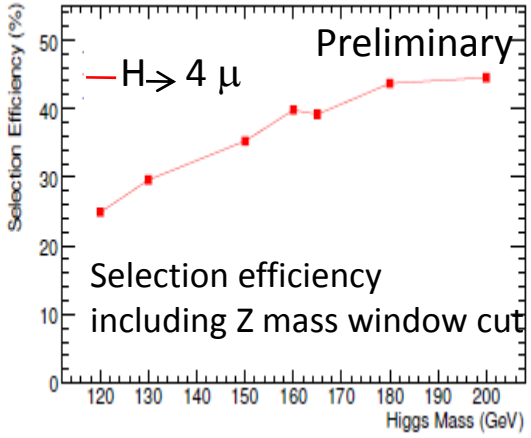
CMS Physics TDR 2006



CMS 4-muon eff.



ATLAS selection eff.



With 10fb^{-1} data, surely, we will find Higgs.

H→WW→2leptons

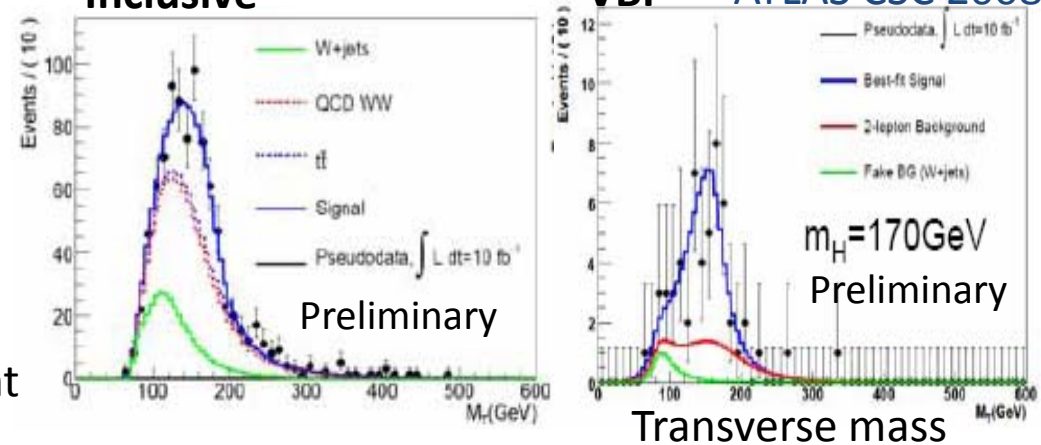
Expects large excess of events.

The VBF analysis is also promising channel.

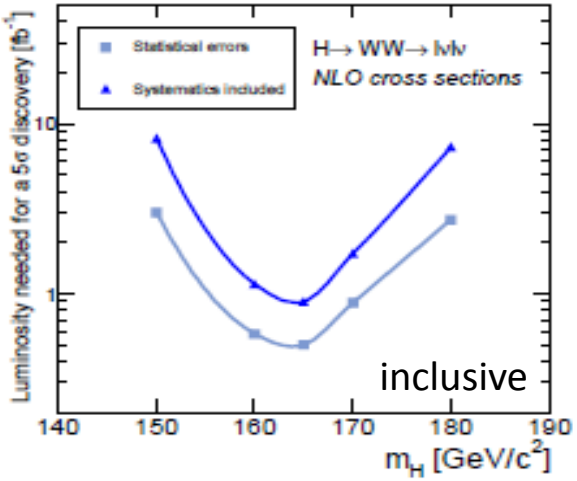
Background normalization by data.

Control region (Normalize WW) (CMS):
all selection except di-lepton invariant mass cut (mll<60GeV).

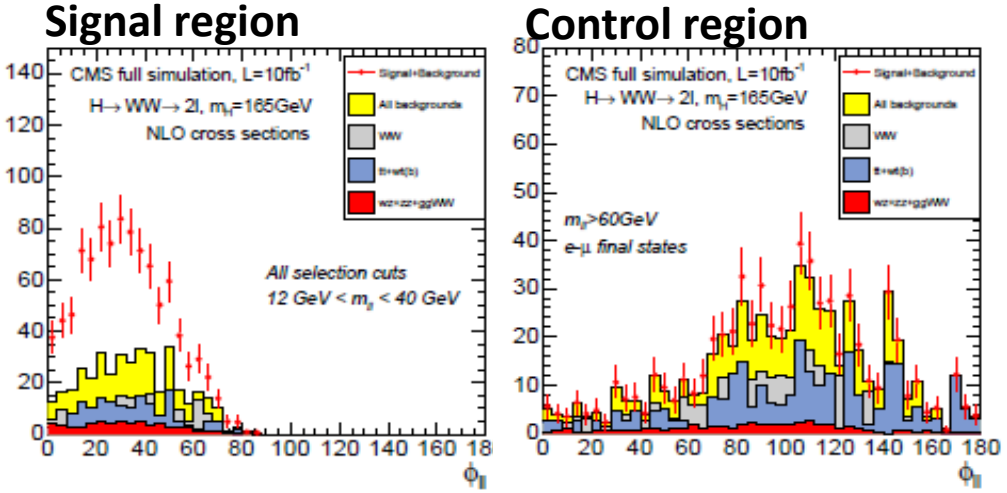
Inclusive **VBF** ATLAS CSC 2008



CMS Physics TDR 2006



Signal region **Control region**



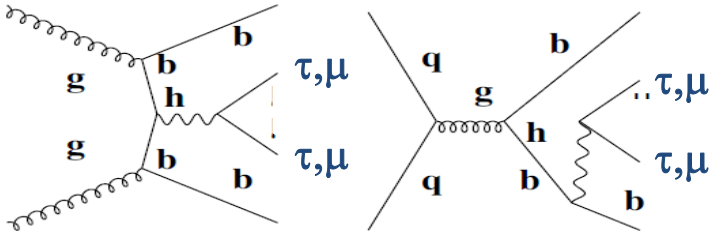
Will observe 5σ excess (160GeV) at 1fb^{-1}.

CMS Physics TDR 2006

MSSM Higgs Associated bbh→ ττ/μμ

Promising channel in large tanβ

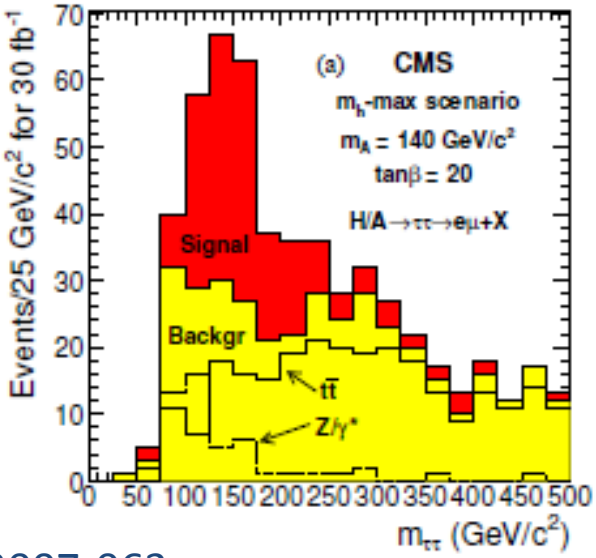
Associate production with b-quark



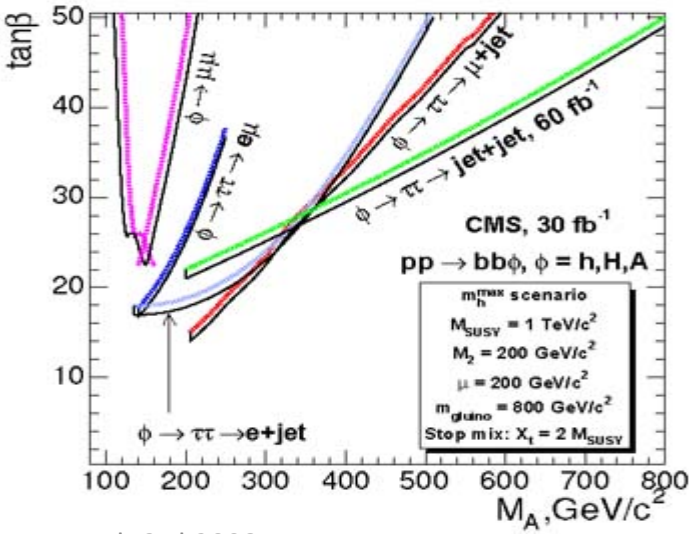
Large coupling or narrow peak (experimental)

(H → ττ) (H → μμ)

CMS Physics TDR 2006



CMS Physics TDR 2006



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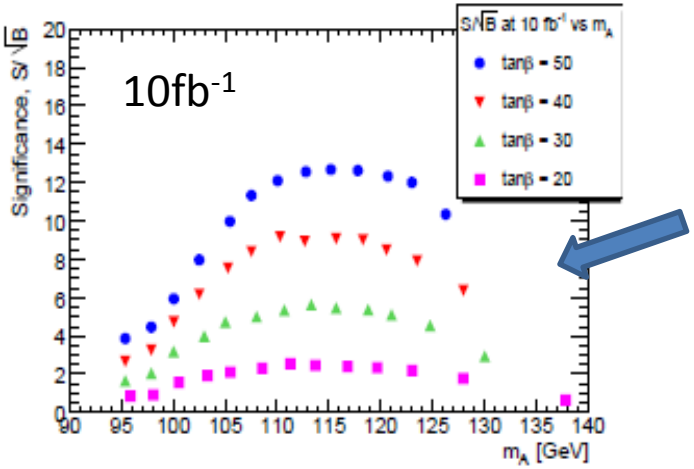


significance for h→ μμ search

Summary

LHC is the discovery machine.

First year (2008/09):

- For sure, detector commissioning.
- Study of min.bias and Standard Candle processes.

2009~

- SUSY will be discovered within the wide range of parameter space at a few fb^{-1} operation.

- Higgs will be also possibly discovered in major channel. Then, promising to find at $10fb^{-1}$.

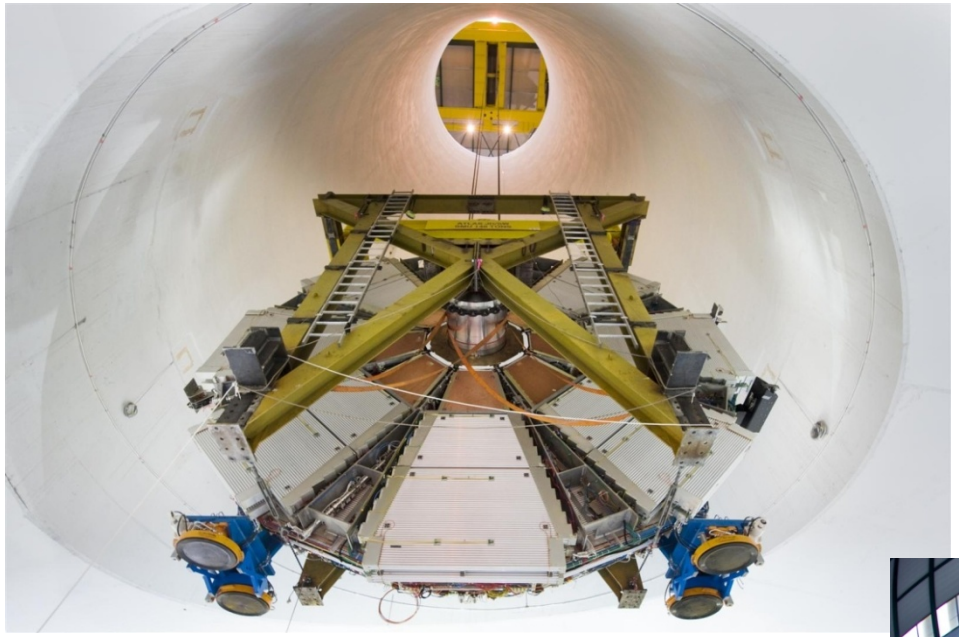
Readiness :

- ATLAS will report on the Physics Readiness Report this spring.

- All CMS/ATLAS detector systems are installed (CMS times Feb.4th, ATLAS Feb.29).

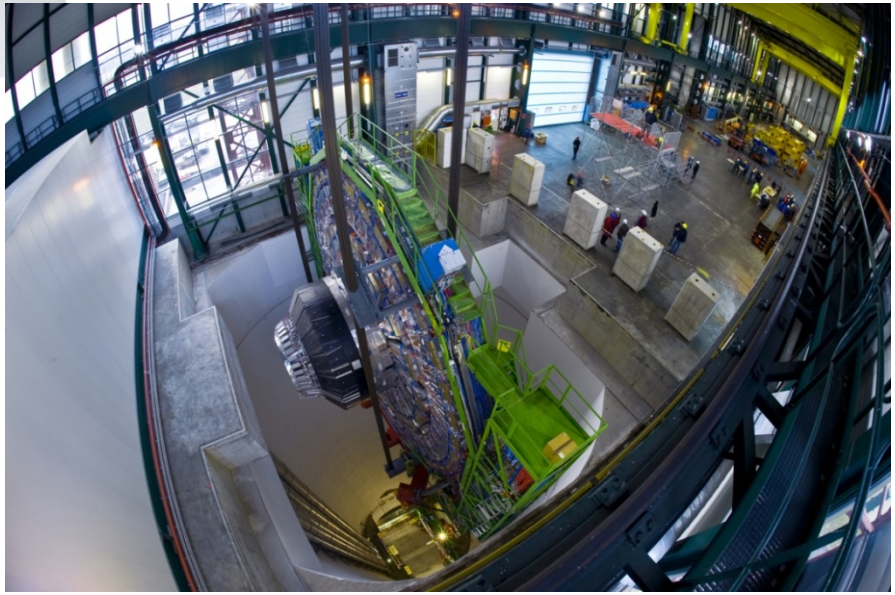
- The first collision : summer, the first result : the next Moriond 09'.

ATLAS / CMS Today



Feb.15.2008

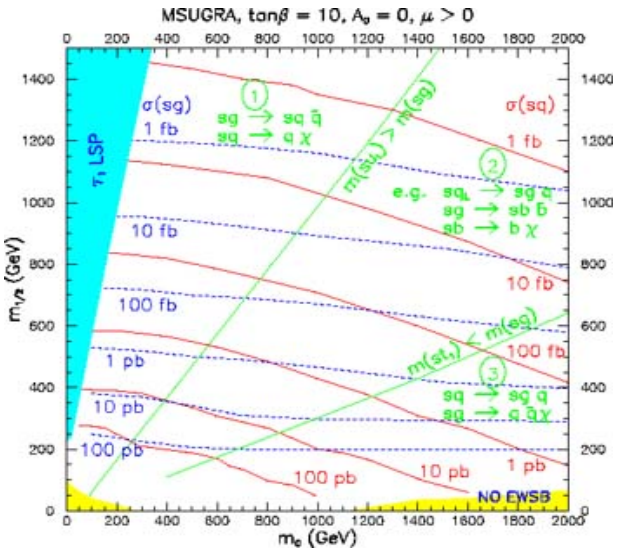
ATLAS muon wheel goes in.
(second last piece)

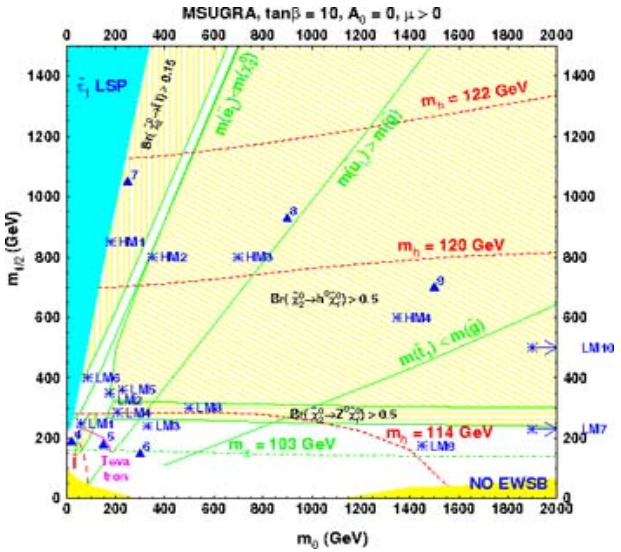


Jan.2008

CMS final elements goes in.

SUSY production cross section and bench mark points





Point	m_0	$m_{1/2}$	$\tan\beta$	sgn(μ)	A_0
LM1	60	250	10	+	0
LM2	185	350	35	+	0
LM3	330	240	20	+	0
LM4	210	285	10	+	0
LM5	230	360	10	+	0
LM6	85	400	10	+	0
LM7	3000	230	10	+	0
LM8	500	300	10	+	-300
LM9	1450	175	50	+	0
LM10	3000	500	10	+	0
HM1	180	850	10	+	0
HM2	350	800	35	+	0
HM3	700	800	10	+	0
HM4	1350	600	10	+	0

Production cross section

CMS benchmark points

Sample		m_0 (GeV)	$m_{1/2}$ (GeV)	A_0 (GeV)	$\tan\beta$	σ^{LO} (pb)
SU1	coannihilation	70	350	0	10	7.43
SU2	focus point	3550	300	0	10	4.86
SU3	bulk	100	300	−300	6	18.59
SU4	low mass	200	160	−400	10	262
SU6	funnel	320	375	0	50	4.48
SU8	coannihilation	210	360	0	40	6.44

ATLAS benchmark points

SM Higgs discovery potential