

Search of Higgs boson on VBF $H \rightarrow \gamma\gamma$

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for ATLAS collaboration

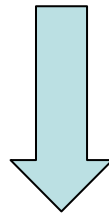
contents

1. LHC experiment
2. ATLAS detector
3. VBF $H \rightarrow \gamma\gamma$ analysis
4. Conclusion

Purpose of LHC experiment

There are two main purposes of the LHC experiment

- ◆ **Discovery of Higgs boson** which is the origin of mass and is expected by the Standard Model
- ◆ **Search of Physics beyond the Standard Model** (Super Symmetric theory)

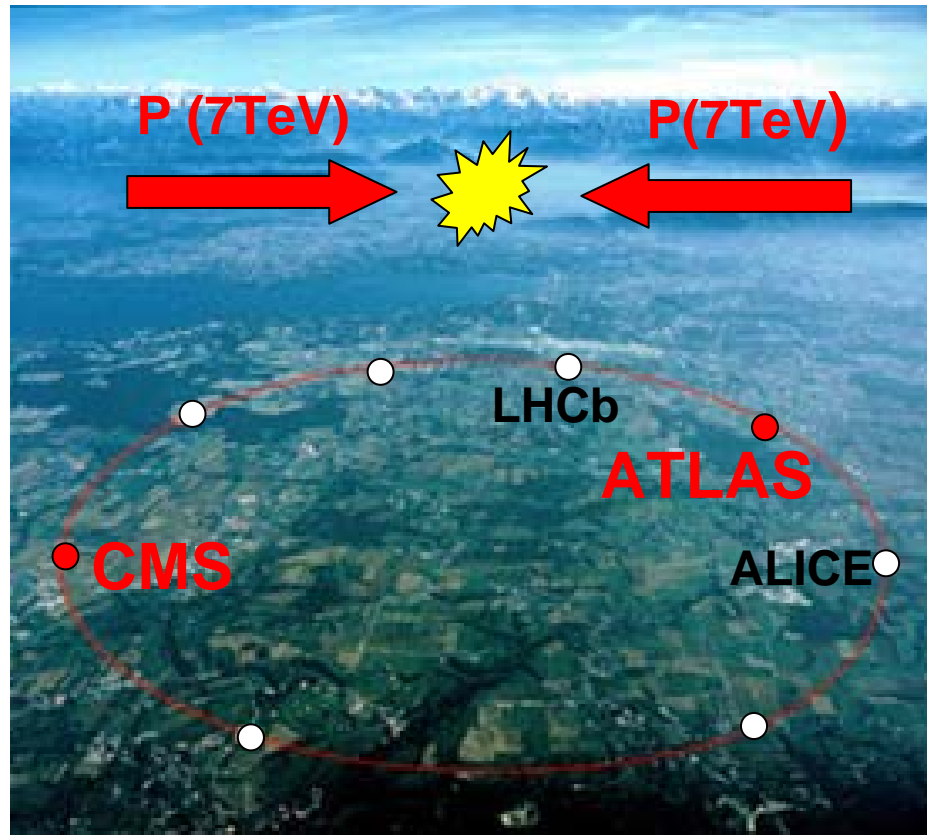


The Large Hadrons Collider (LHC) with the largest energy in the world is used!!

LHC Accelerator

LHC @ Geneva

- Circumference: 27km
- 2 general purpose experiments:
ATLAS, CMS
- Proton-Proton collider
 - Proton energy: 7 TeV
 - center of mass energy in pp: 14TeV
- Start operation in 2007 summer.
 - $L = \sim 100\text{pb}^{-1}$ in 2007
 - $L =$ a few \sim several fb^{-1} in 2008
 - $L = 10 \text{fb}^{-1}$ per year after 2009 (10% of Design luminosity $\sim 10^{34}\text{cm}^{-2}\text{s}^{-1}$)



Construction Status of LHC Accelerator

- LHC Accelerator is composed of 1232 Superconducting Dipole Magnets (SDM). (15m, 8.36T /SD Magnet)
- 75 % of all SDM are assembled.



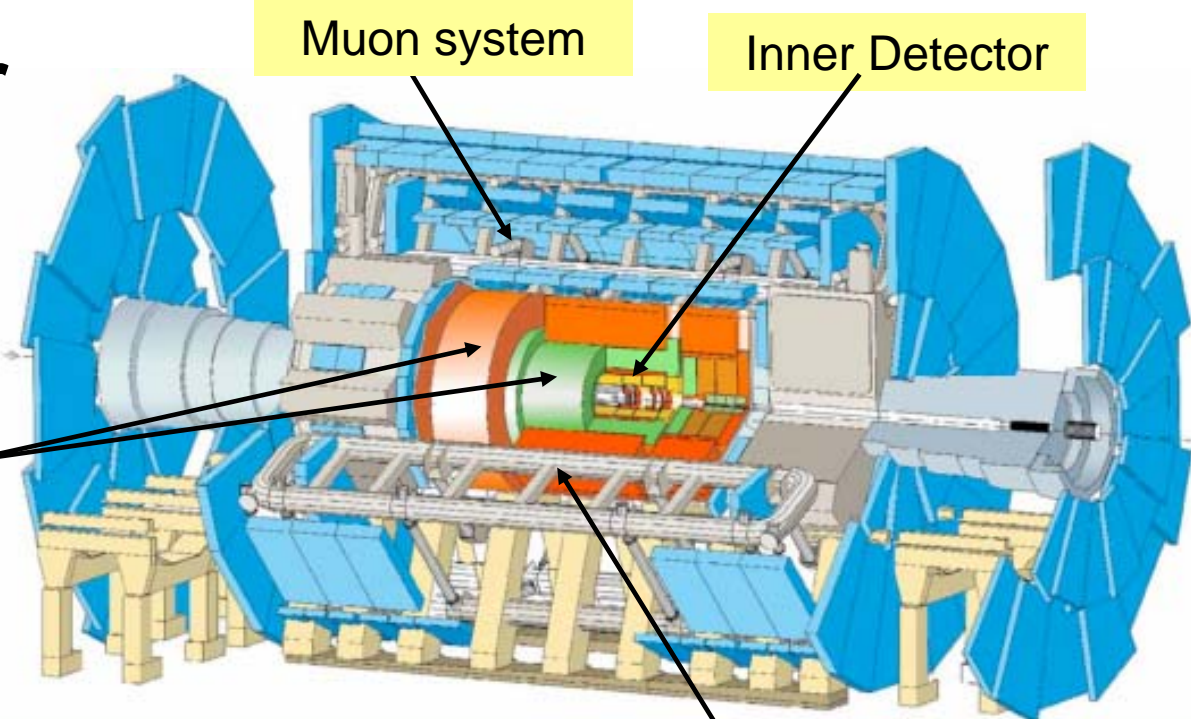
- Presently already 10% among 1232 SDM are installed to the tunnel.
- Installation of all SDM will be complete by the end of 2006.



ATLAS detector

- Huge Detector
Diameter: 25m
total weight: 7000ton

Calorimeter



- Consists of 3 parts.

- Inner Detector with solenoid magnet

(pixel, SCT, TRT) $|\eta| < 2.5$

momentum resolution: $\sim 4\%$ for charged particle $P_t = 100\text{GeV}$

- Calorimeter (LAr Calorimeter, Tile Colorimeter) ($|\eta| < 4.9$)

Energy resolution: 1.5% for electron and photon with $E = 100\text{GeV}$

10% for a hadron jet with $E = 100\text{ GeV}$

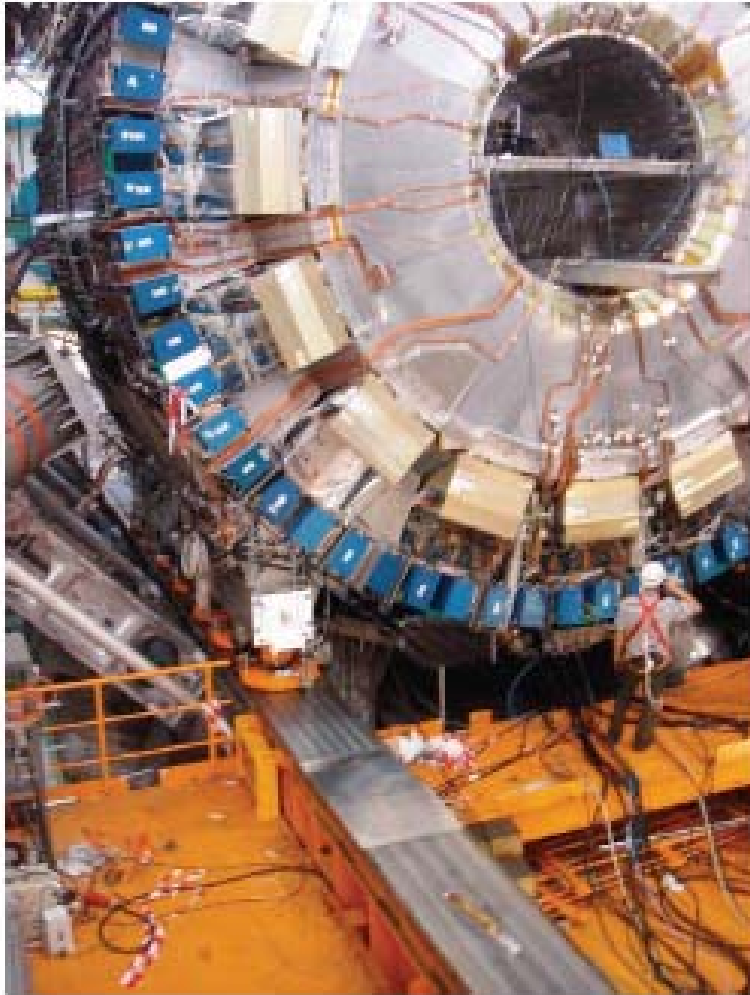
- Muon spectrometer with Toroid Magnets

momentum resolution; 2.0% for $P_t = 100\text{GeV}$

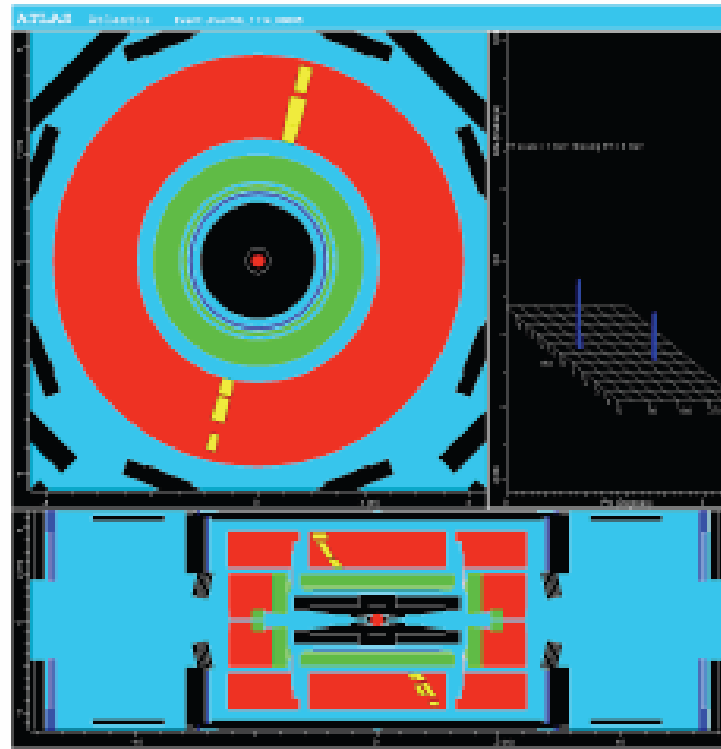
Toroid Magnet

Good performance!!

ATLAS detector construction status



Barrel Calorimeter (04/11/05)



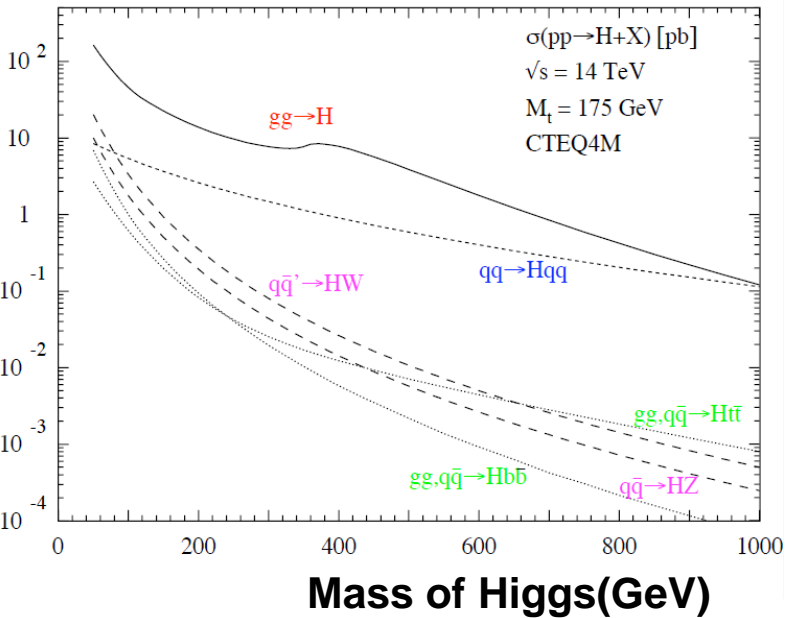
Calorimeter detected cosmic muon clearly

We are making large efforts to prepare the experiment for 2007 summer

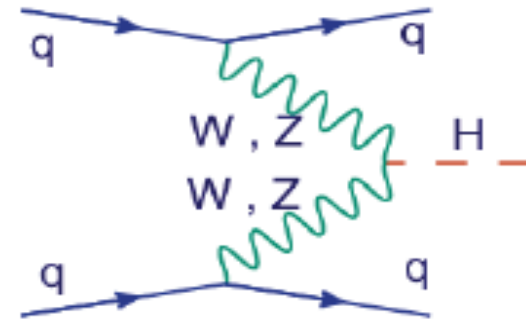
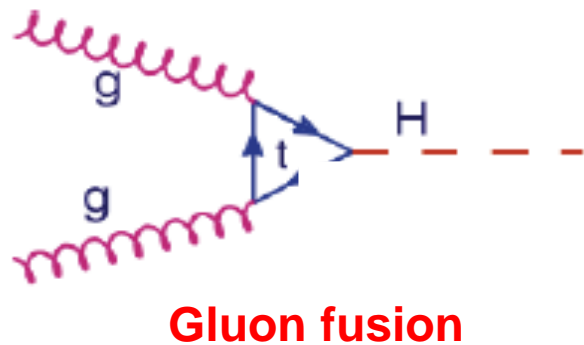
VBF $H \rightarrow \gamma\gamma$ analysis

Higgs production

Production Xsection @LHC



- Higgs boson is produced via 4 processes.
- The dominated cross sections are,
 1. Gluon fusion process with a heavy top quark triangle loop
 2. Vector boson fusion process



Branching fraction of $H \rightarrow \gamma\gamma$ channel

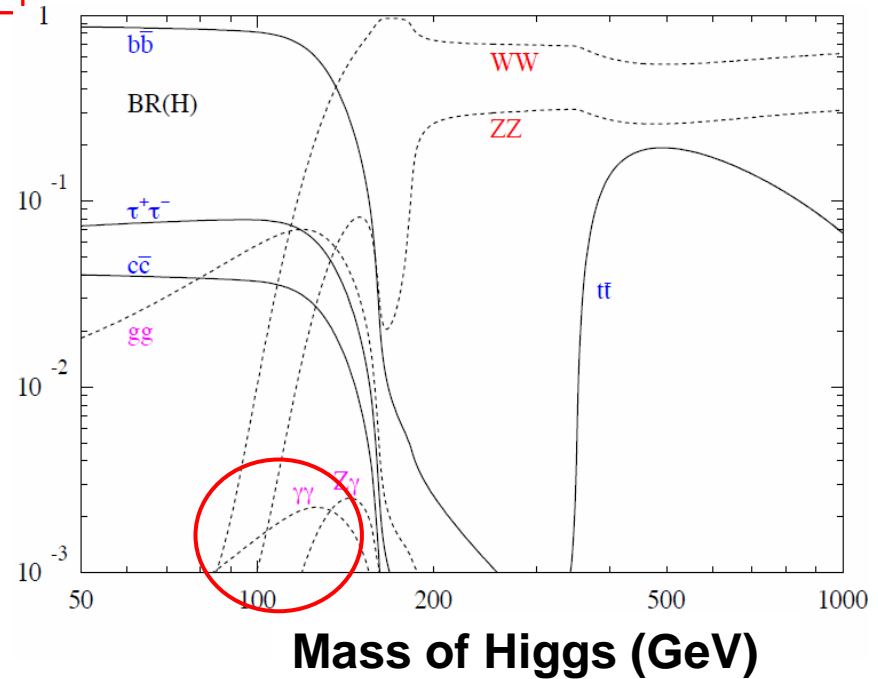
Branching fraction of $H \rightarrow \gamma\gamma$ channel is small ($\sim 10^{-3}$).

However the resolution of both energy and position for photon is excellent at ATLAS.

$\rightarrow \gamma\gamma$ invariant mass can be seen as a clear peak !!

$H \rightarrow \gamma\gamma$ is one of the most promising channel to discover the Higgs boson.

Branching fraction of Higgs



Invariant mass distribution

- ◆ $\gamma\gamma$ invariant mass distribution with "No tagging jets" @ $M_h = 130\text{GeV}$.

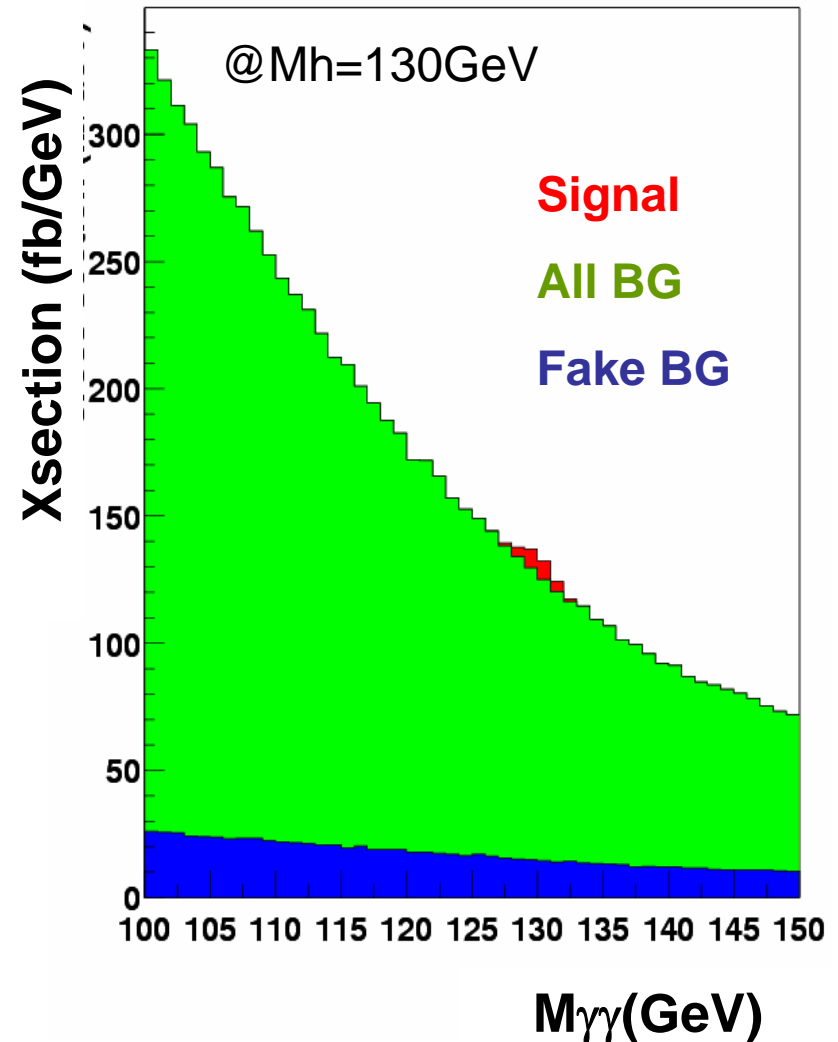
→ Huge background events are seen.

→ About 30 fb^{-1} is necessary for 5 sigma C.L. discovery.

→ It takes a lot of time.

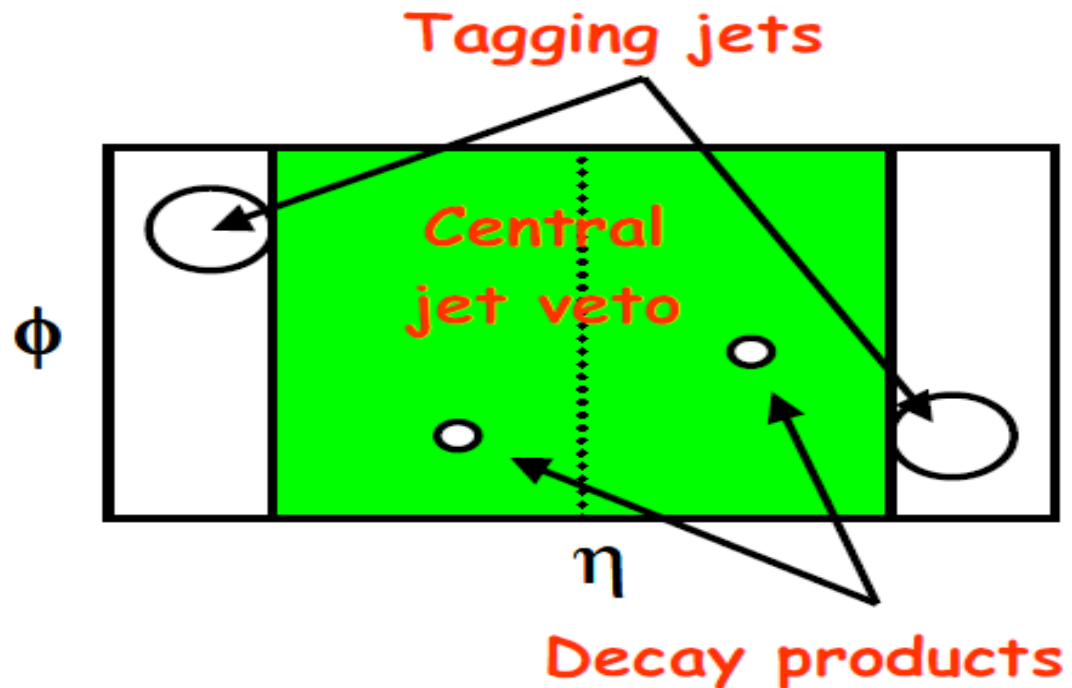
- ◆ We need to improve significance and S/N.

→ Focus on VBF $H \rightarrow \gamma\gamma$.



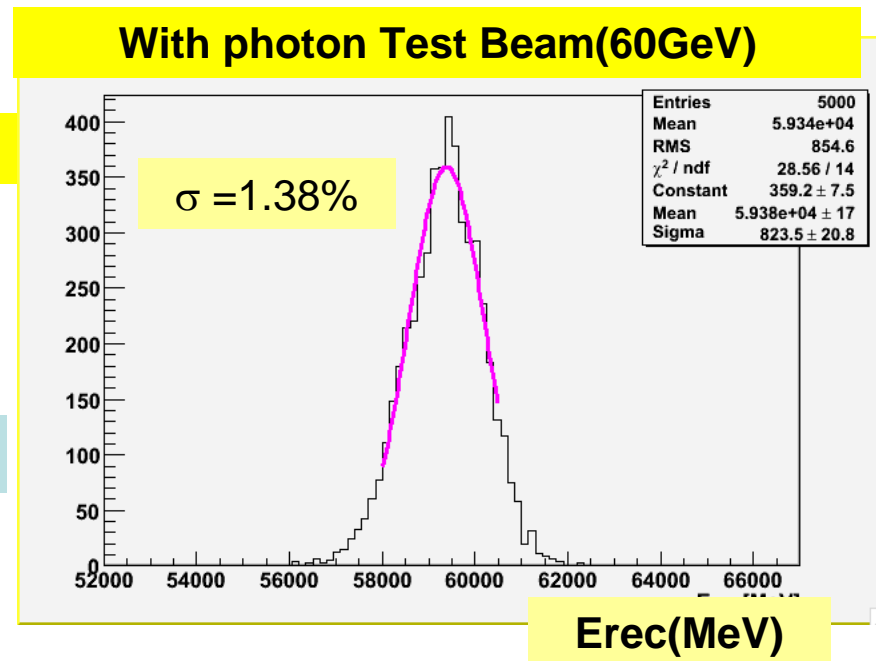
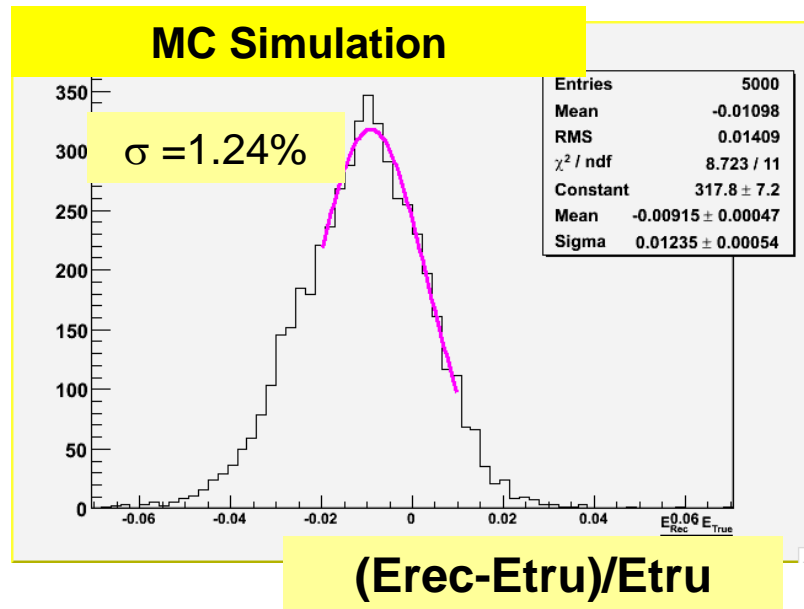
Feature of VBF $H \rightarrow \gamma\gamma$ signal

1. Two forward jets with high P_t in the opposite hemisphere.
2. No colour exchange in the central region. (a large rapidity gap)
→ Two isolated photons from decay of Higgs in the central region.

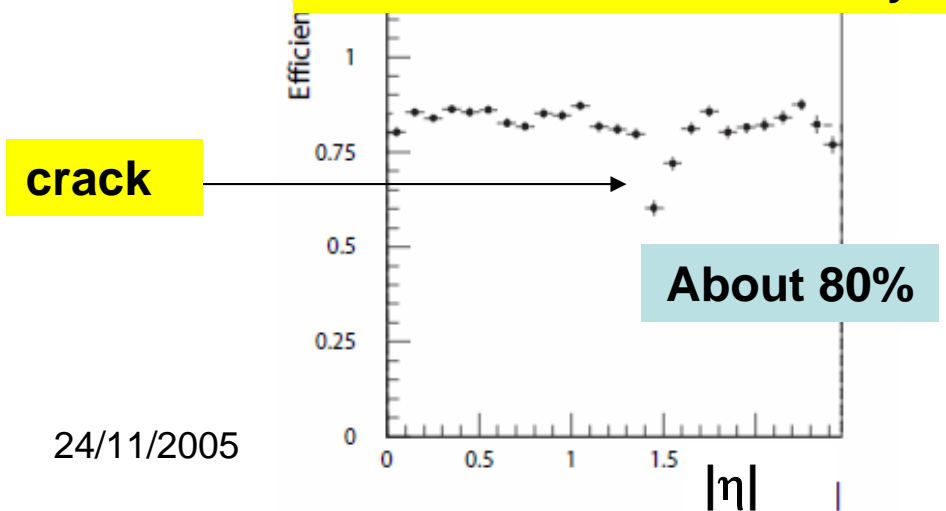


"Isolated photon"

- Invariant mass are obtained using energy and position of photons.
- Energy resolution for 60GeV :
 - MC \rightarrow 1.24 %
 - Data (Test Beam) \rightarrow 1.38%
 - \rightarrow Test-beam is consistent with MC.
- position resolution : ~ 0.9 mrad for 100GeV
- Photon efficiency about 80% in the whole h region.



Photon detection efficiency



Background with Fake photon(s)

"Fake photon"

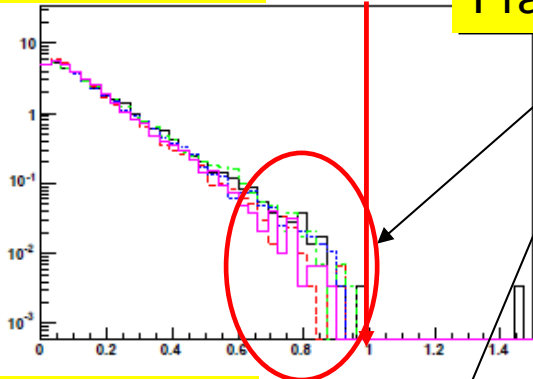
Sometimes Jet is mis-identified as one photon.

In case π^0 in the jet carries almost all of jet energy,

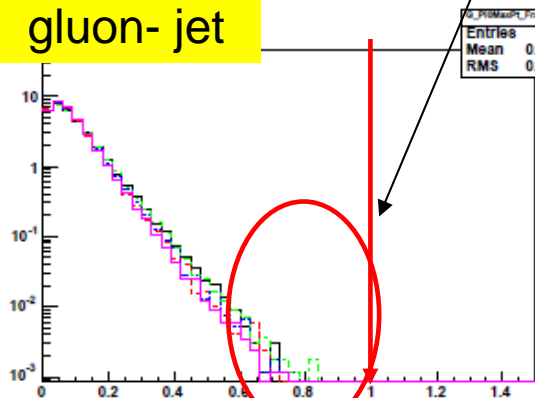
$\rightarrow \pi^0 (\rightarrow \gamma\gamma)$ with high energy looks like one photon.

quark- jet

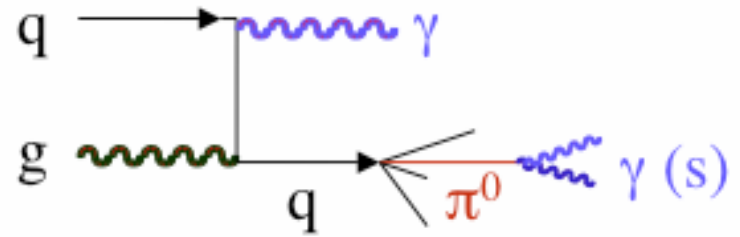
Fraction=1.0



gluon- jet



Energy fraction of π^0



-- π^0 in quark-jet carries more energy than in gluon-jet.

-- estimated "Fake Rate" on Full simulation

\rightarrow Fake Rate gluon jet : 1 / 7800

quark jet: 1 / 2021

} Factor 4

Event Selection Criteria

1. Forward jets requirements (for VBF)

- one jet in each hemisphere
- $P_T(\text{jet1}) > 40\text{GeV}, P_T(\text{jet2}) > 20\text{GeV}$
- $dR_{\text{jetjet}} > 0.7$
- $M_{\text{jetjet}} > 500\text{GeV}$

2. Two Isolated Gamma selection (Higgs products)

- $N_\gamma = 2, |\eta_\gamma| < 2.5$
- $P_T(\gamma1) > 50\text{GeV}, P_T(\gamma2) > 25\text{GeV}$
- gamma should exist between two forward jets in $\eta-\phi$ plane. ($dR(\gamma J) > 0.7$)

3. Additional cuts for no colour exchange.

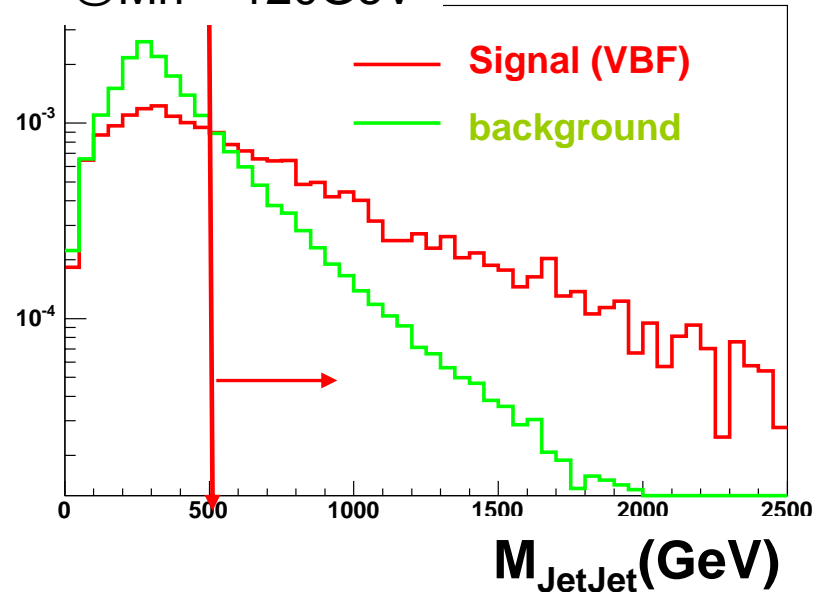
- No Central jet with $P_T > 20\text{GeV}$
- Rapidity Gap requirement
($\eta_{\text{jetmin}} + 0.7 < \eta_{\text{jet}} < \eta_{\text{jetmax}} - 0.7$)
- apply inefficiency of 3.7% due to

minimum bias jets

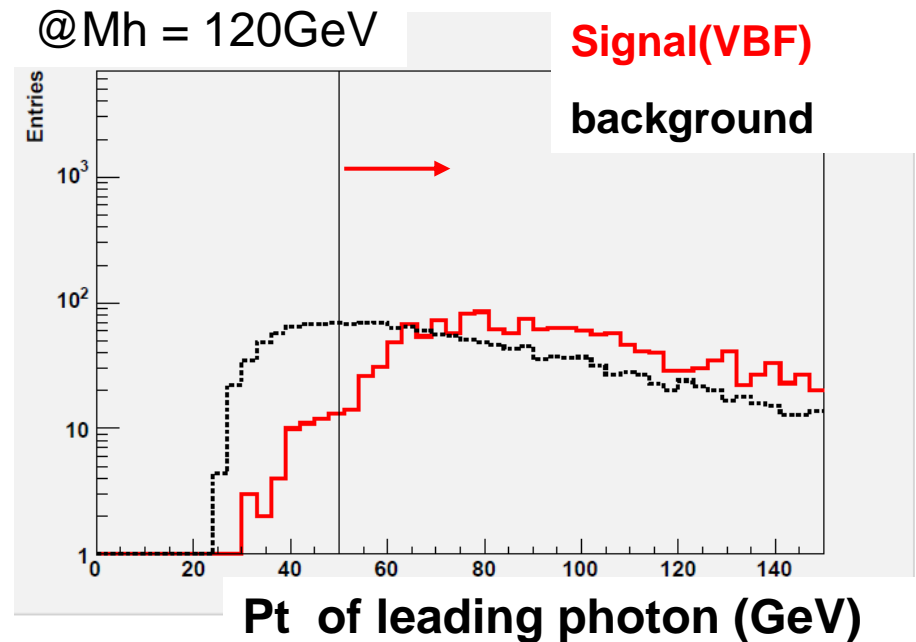
4. Higgs mass window requirement(+ - 2GeV)

- $118 < M_h < 122\text{GeV}$ @ $M_h = 120\text{GeV}$

@ $M_h = 120\text{GeV}$



@ $M_h = 120\text{GeV}$



H → $\gamma\gamma$ on VBF process

- Signal peak can be seen clearly.

Mh = 120GeV, L = 30 fb⁻¹
S = 24.9, B = 19.9
Significance(poisson) = 4.6

“2 jets tagging analysis” on
VBF H → $\gamma\gamma$ is promising !!

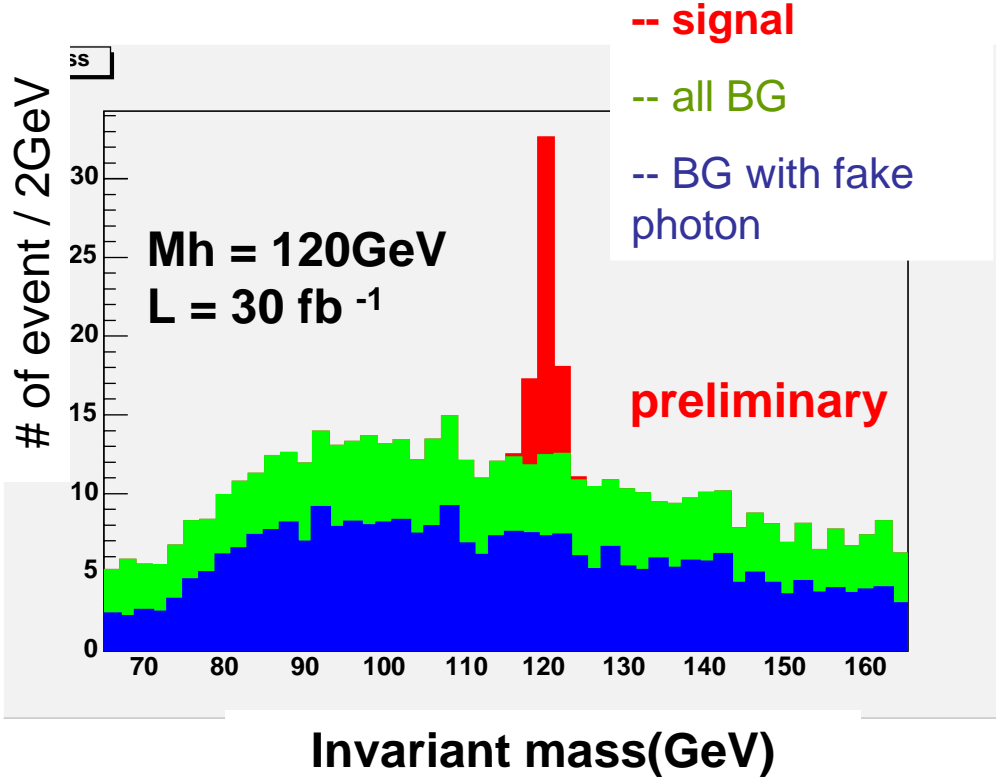
- Most of BG events have fake photon(s).

-4Jets : JJ (JJ)

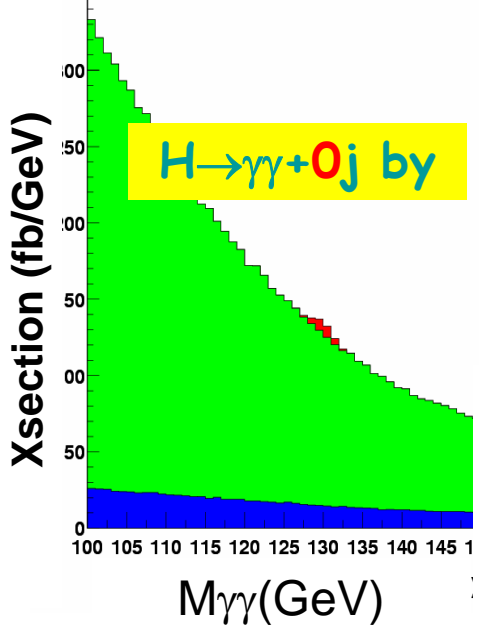
-1 γ + 3Jets : γ JJ (J)

mis-ID

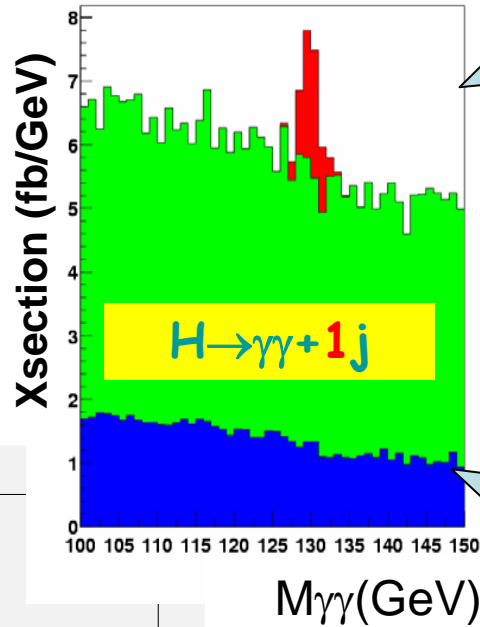
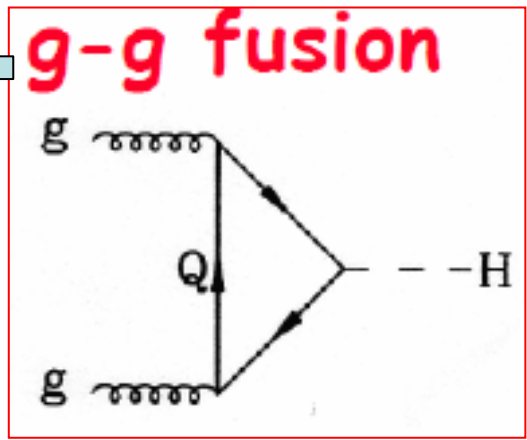
→ Suppression of fake photon is very important



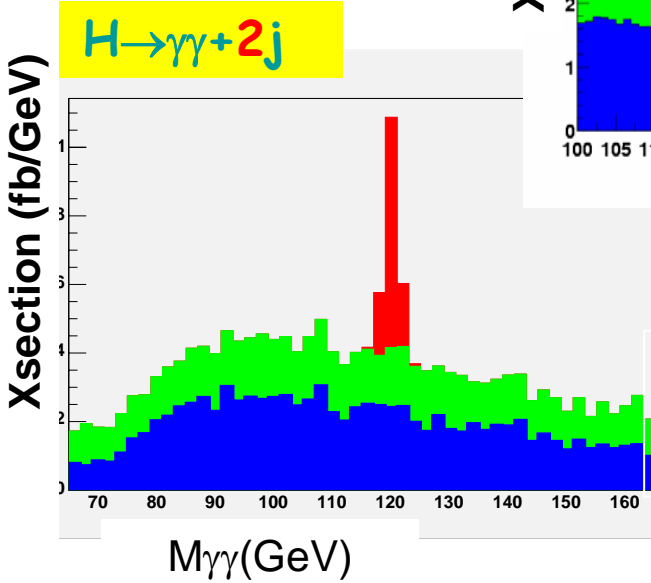
3 analyses on $H \rightarrow \gamma\gamma$ @ATLAS preliminary



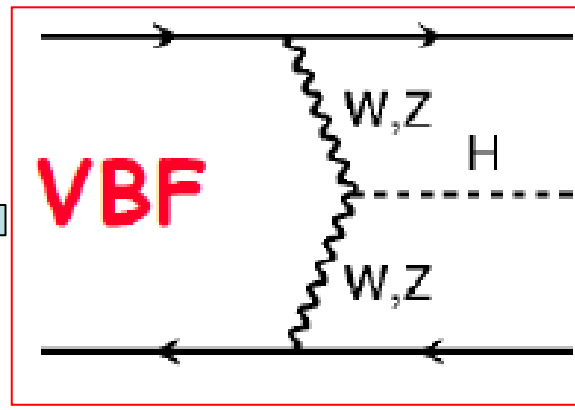
No -jet tagging :
huge BG. S/N $\sim 0.3\%$ \rightarrow S/N is bad



- gg Fusion with additional one jet
 - VBF: one of two forward jets is out of acceptance.
- \rightarrow Statistics of Signal is enough. S/N is not so good ($\sim 10\%$).

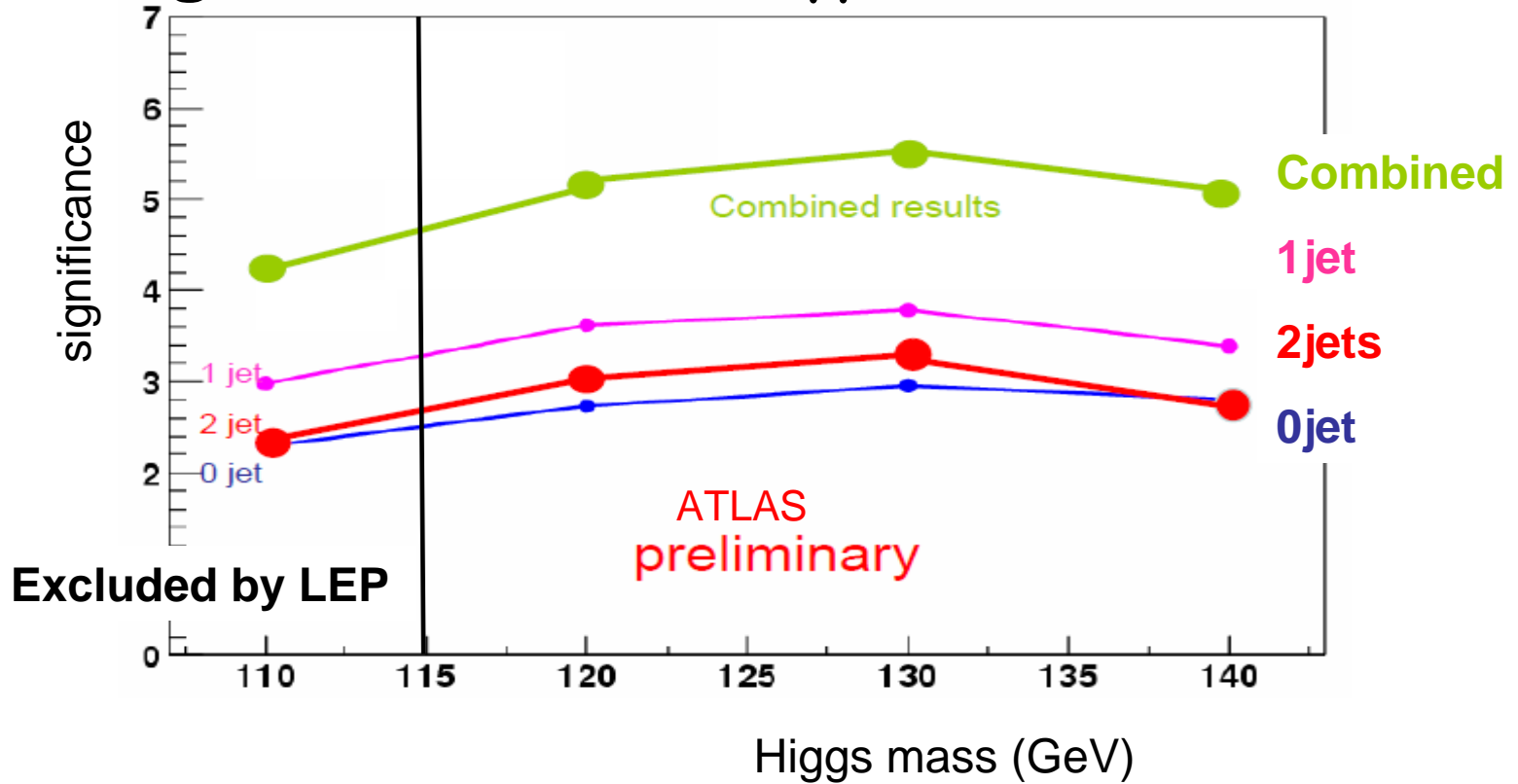


Statistics of Signal is limited.
S/N is good. ($>100\%$)



Important to discover of Higgs at early stage

Significance on $H \rightarrow \gamma\gamma$ @ $L = 10\text{fb}^{-1}$



- Significance on “ 2 tagging jet analysis “ is between 0-jet and 1-jet analyses.
- Higgs boson can be discovered with 5sigma C.L. using $L = 10\text{fb}^{-1}$ (2008-2009) on combined $H \rightarrow \gamma\gamma$ channel analysis.

Future Improvement

- For improvement of the statistics of Signal
 - 30-40% of Photons convert at the material in front of EM calorimeter.
 - Early photon conversion of photon is already performed in this analysis. Late conversion is not yet.
 - studying the late photon conversion.
- Systematics,
 1. Cross section of QCD backgrounds
 2. Estimation of BG with fake photon
 - can evaluate from the side bands.

conclusion

- ◆ LHC will start in 2007 summer.
- ◆ We are making large efforts to prepare the experiment for 2007 summer.
- ◆ “2 tagging analysis” on VBF $H \rightarrow \gamma\gamma$ is very promising.
- ◆ By combined $H \rightarrow \gamma\gamma$ channel analysis (3 approaches), Higgs boson can be discovered with 5sigma C.L on the integrated luminosity of 10 fb^{-1} (by 2009)

Background sample

BG sample with real photon

1. $\gamma\gamma JJ(\text{EW})$: CompHEP + PYTHIA6.221
2. $\gamma\gamma JJ(\text{QCD})$: ALPGEN + PYTHIA6.221

BG sample with fake photon

1. γJJJ : ALPGEN + PYTHIA6.221
2. $JJJJ$: ALPGEN + PYTHIA6.221

PDF : CTEQ5L

P_T ordering is applied to avoid the double counts.

