Search of Higgs boson on VBF H→ γγ

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for ATLAS collaboration

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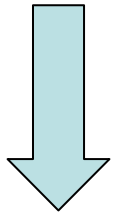
3. **VBF H→ γγ analysis**
4. **Conclusion**

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)

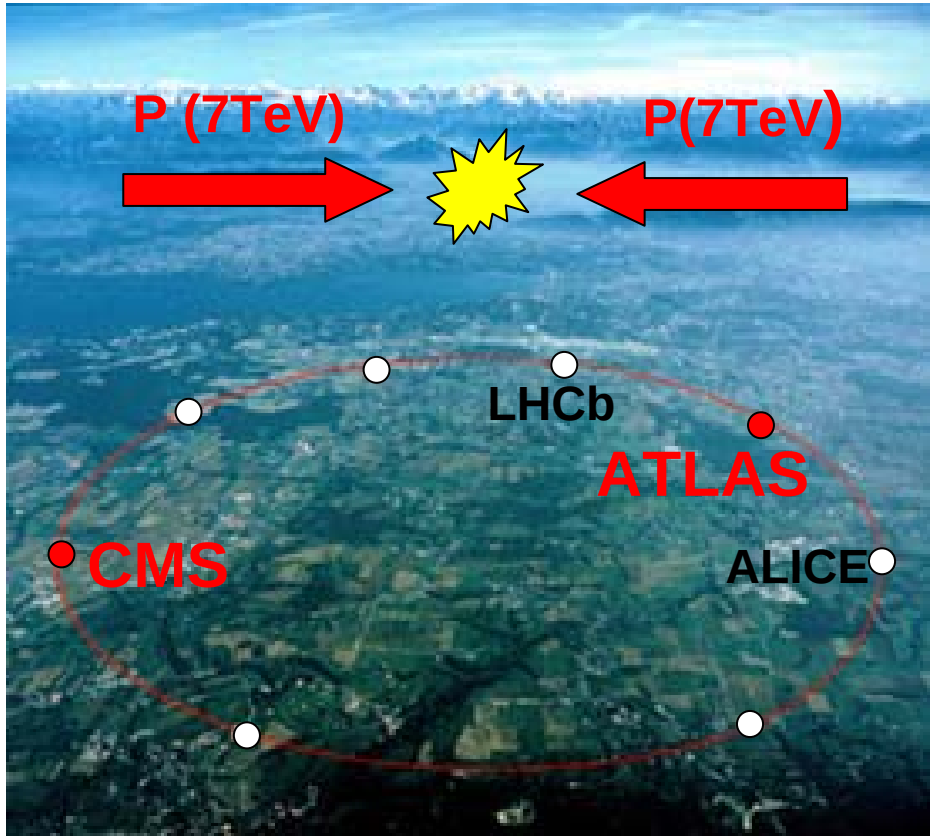


The Large Hadrons Collider (LHC) with the largest energy in the world is used!!

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 = ~ 100pb^{-1} in 2007
  - L = a few ~ several fb^{-1} in 2008
  - L = 10 fb^{-1} per year after 2009 (10% of Design luminosity ~10^{34}cm^{-2}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 Collaboration

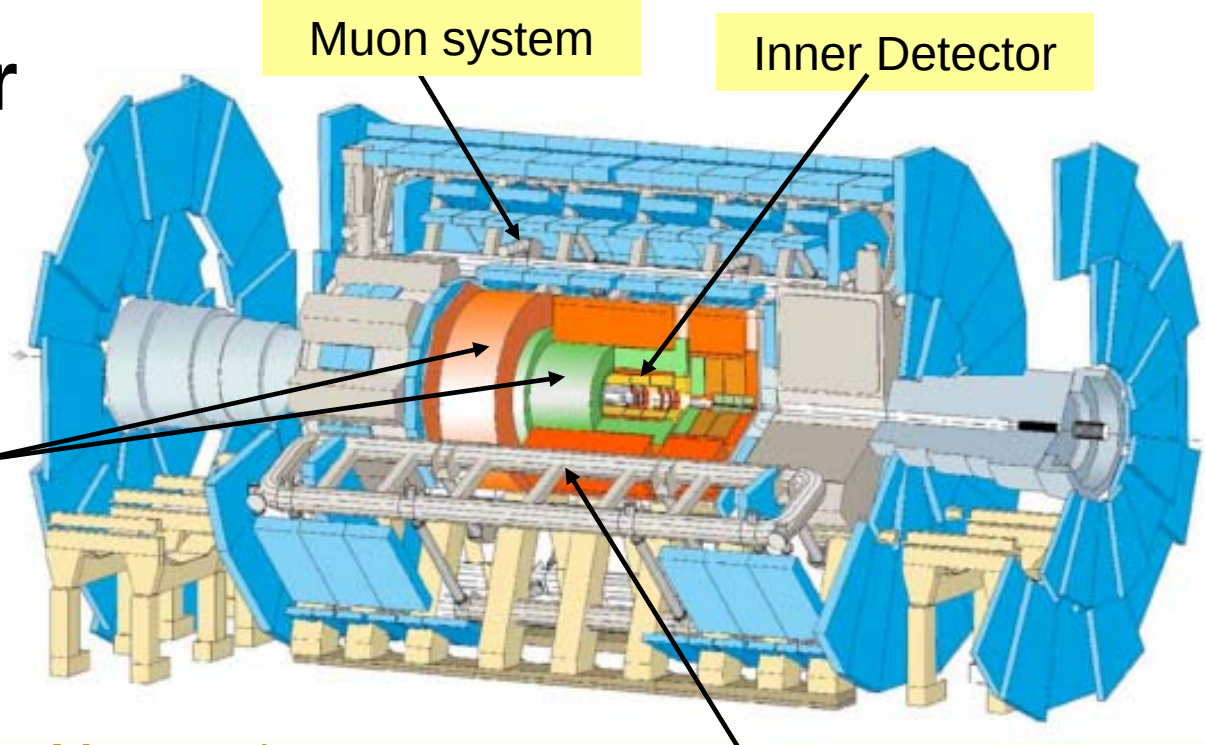
-- ~1800 people join from 154 institutes in 34 countries.

-- 15 institutes (50 people) from Japan.

Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, Bern, Birmingham, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brookhaven NL, Bucharest, Cambridge, Carleton, Casablanca/Rabat, CERN, Chinese Cluster, Chicago, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, INP Cracow, FPNT Cracow, Dortmund, JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Glasgow, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Irvine UC, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, McGill Montreal, UA Madrid, Mainz, Manchester, Mannheim, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Naples, Naruto UE, New Mexico, Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Ritsumeikan, UFRJ Rio de Janeiro, Rochester, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Toronto, TRIUMF, Tsukuba, Tufts, Udine, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, Wisconsin, Wuppertal, Yale, Yerevan

ATLAS detector

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



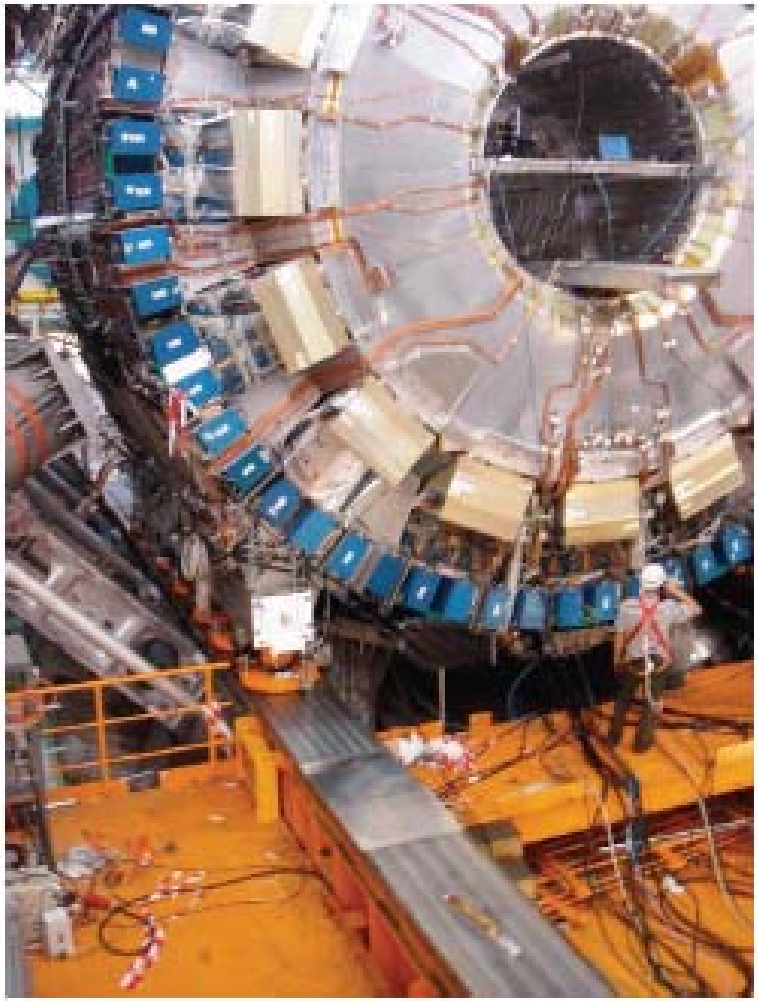
- Consists of 3 parts.
  - Inner Detector with solenoid magnet
    (pixel, SCT, TRT) $|\eta| < 2.5$
    momentum resolution: ~4% for charged particle Pt = 100GeV

  - Calorimeter (LAr Calorimeter, Tile Colorimeter) ($|\eta| < 4.9$)
    Energy resolution: 1.5% for electron and photon with E = 100GeV
    10% for a hadron jet with E=100 GeV

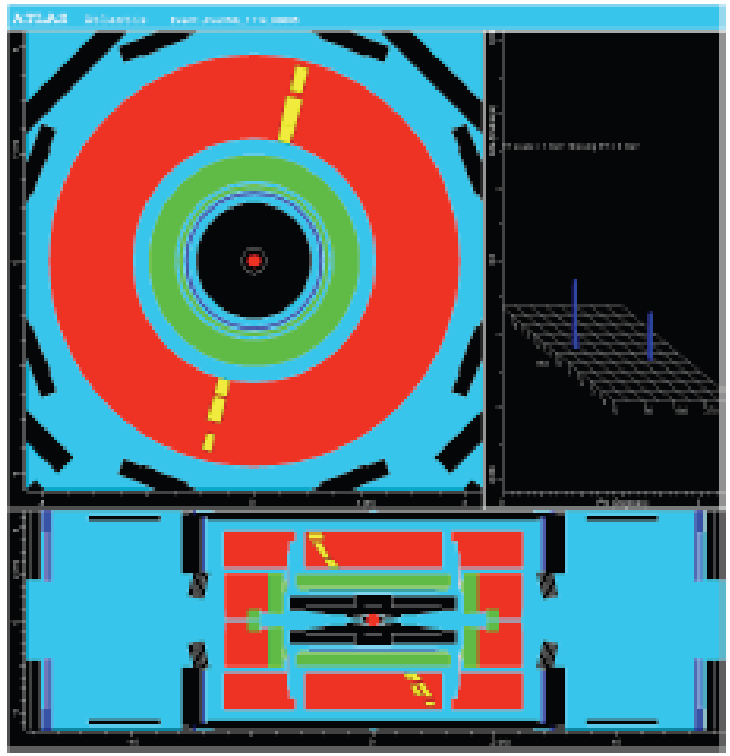
  - Muon spectrometer with Toroid Magnets
    momentum resolusion; 2.0% for Pt = 100GeV

Good performance!!

ATLAS detector construction status



Barrel Calorimeter (04/11/05)



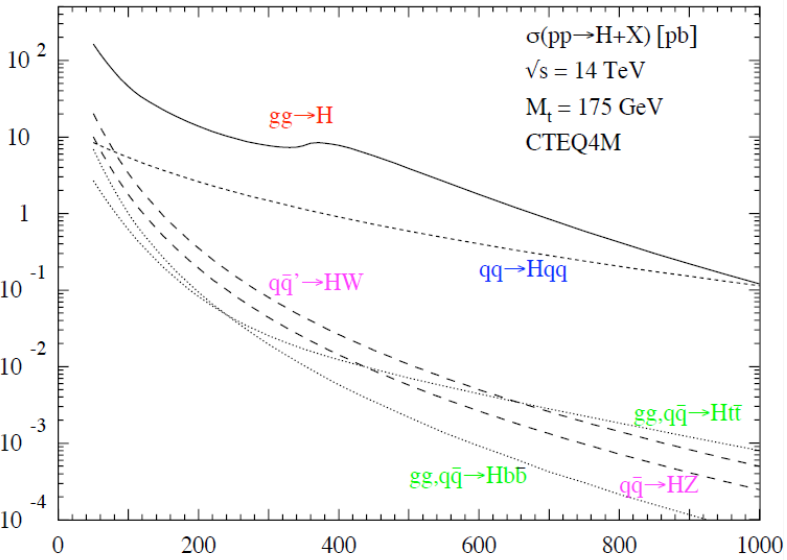
Calorimeter detected cosmic muon clearly

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

VBF H→ $\gamma\gamma$ analysis

Higgs production

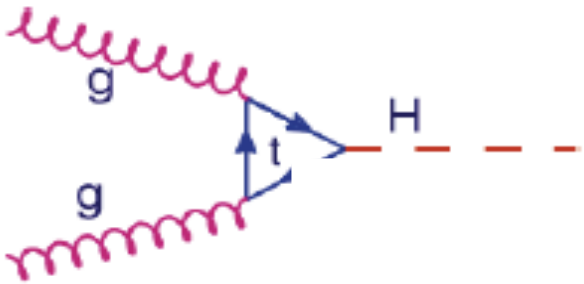
Production Xsection @LHC



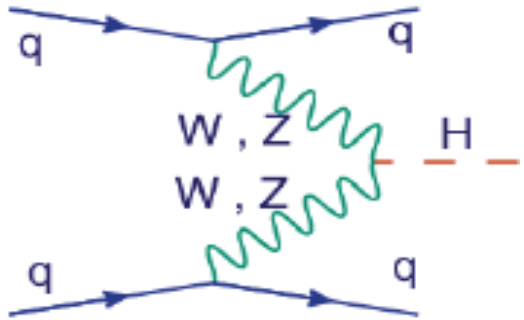
Mass of Higgs(GeV)

- Higgs boson is produced via 4processes.
- The dominated cross sections are,

1. Gluon fusion process with a heavy top quark triangle loop
2. Vector boson fusion process



Gluon fusion



Vector boson fusion

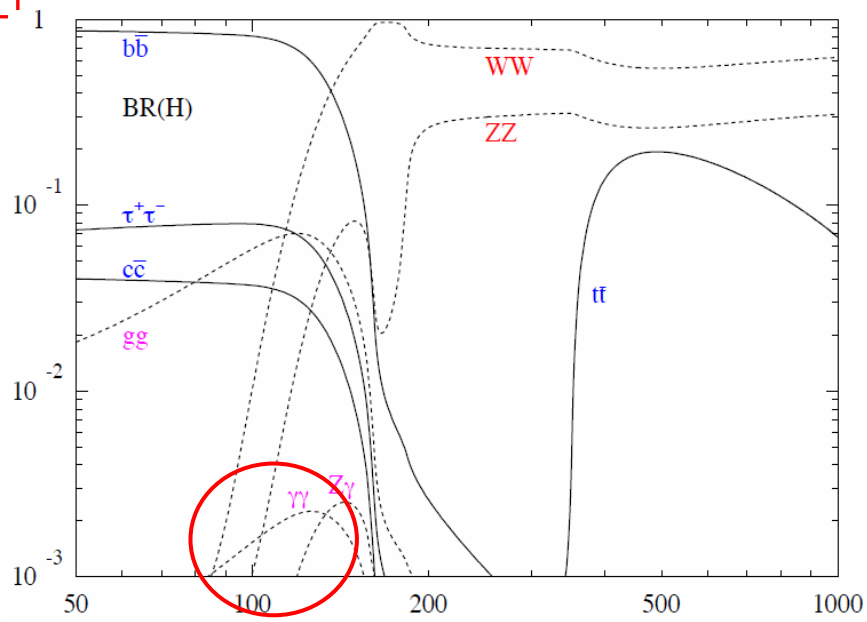
Branching fraction of H→ γγ channel

Branching fraction of H→ γγ channel is small (~10^{-3}).

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

→γγ invariant mass can be seen as a clear peak !!

Branching fraction of Higgs



H→ γγ is one of the most promising channel to discover the Higgs boson.

Invariant mass distribution

- $\gamma\gamma$ invariant mass distribution with "No tagging jets" @ Mh = 130GeV.

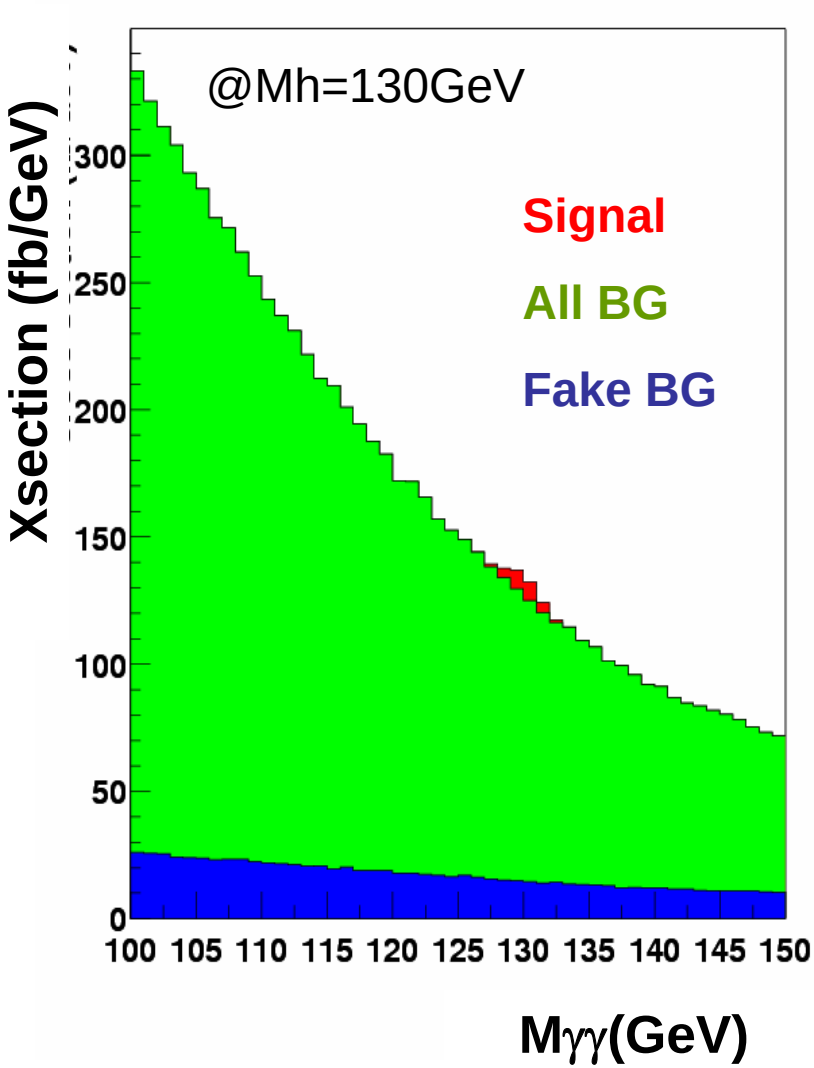
  → Huge background events are seen.

  →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.

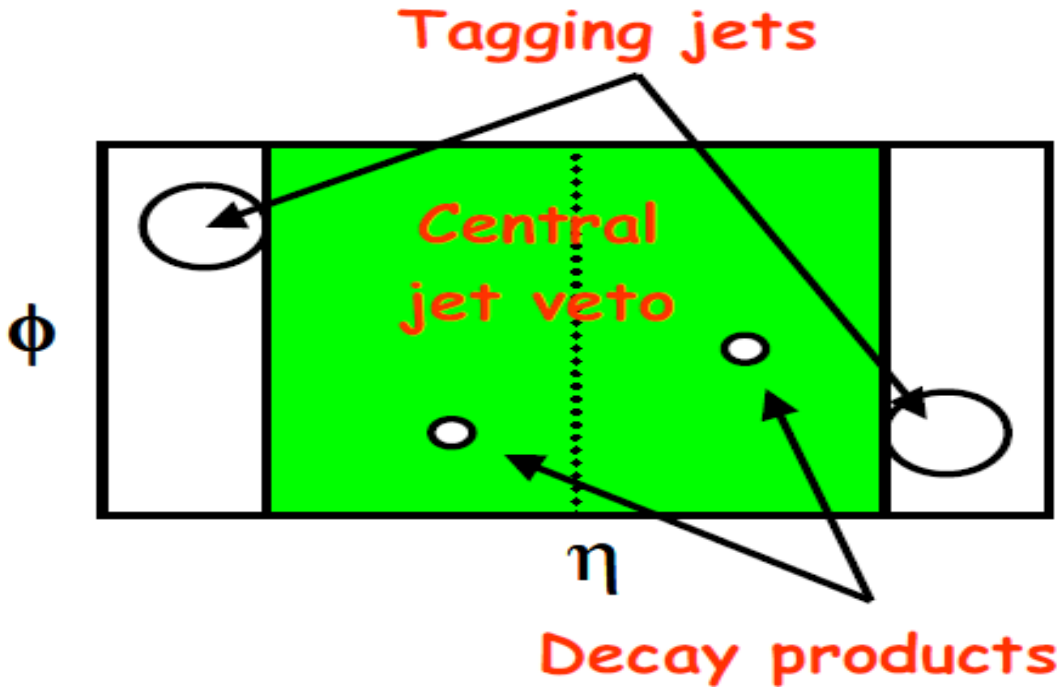
  →Focus on VBF H→ $\gamma\gamma$.



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

1. Two forward jets with high Pt 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 → 1.24 %

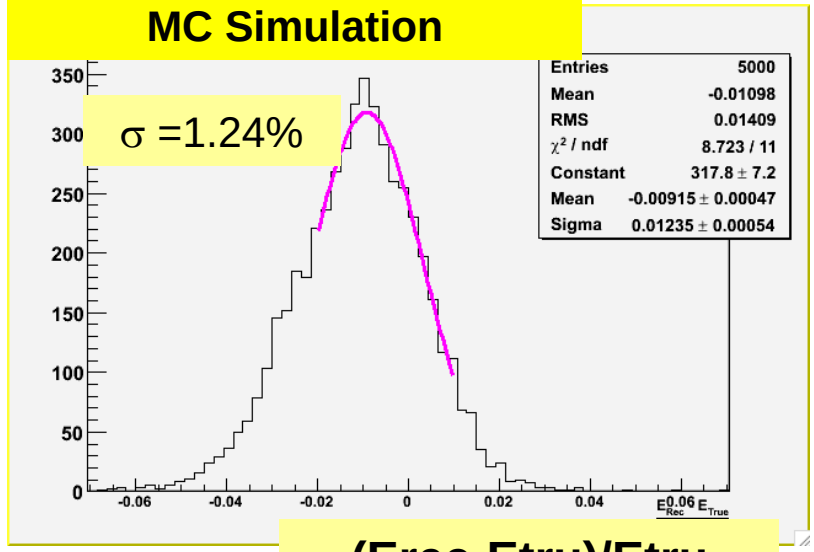
Data (Test Beam)→ 1.38%

→ Test-beam is consistent with MC.

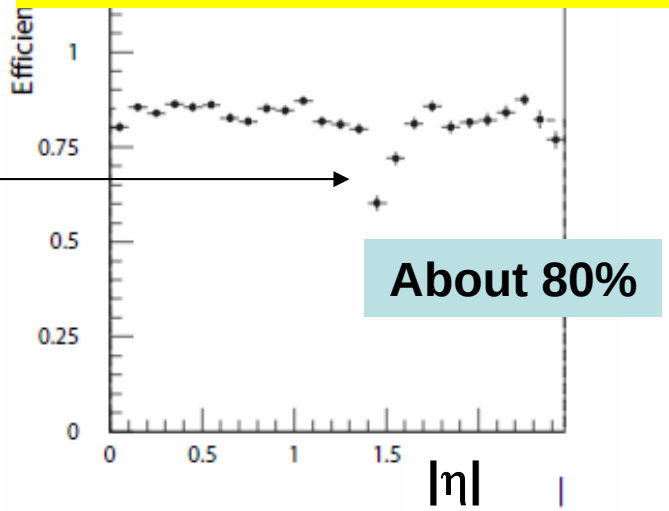
-- position resolution : ~0.9 mrad for 100GeV

-- Photon efficiency about 80% in the whole h region.

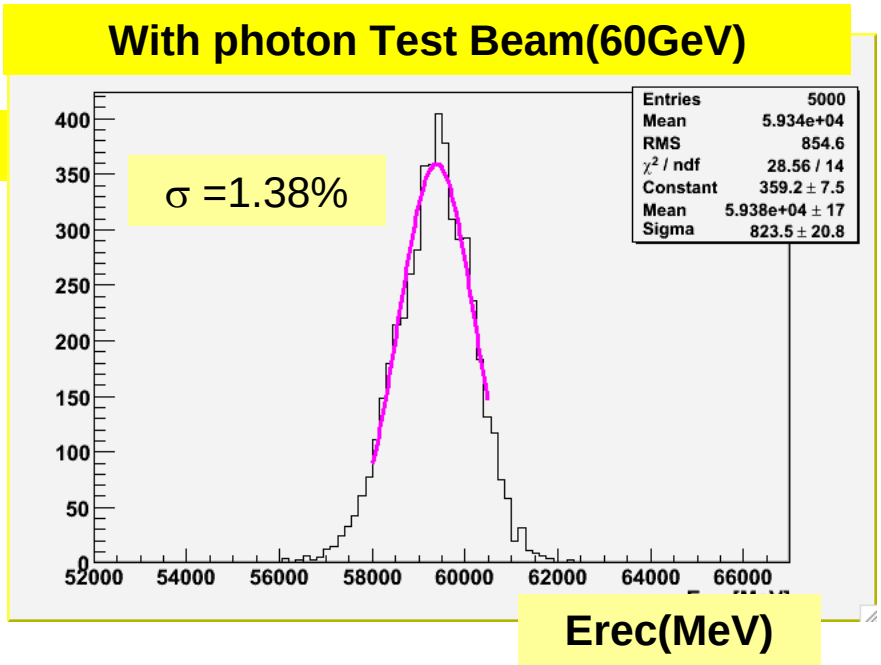
MC Simulation



Photon detection efficiency



With photon Test Beam(60GeV)



Background with Fake photon(s)

"Fake photon"

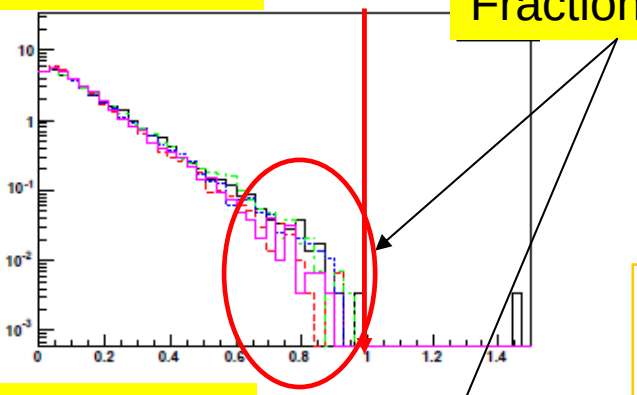
Sometimes Jet is mis-identified as one photon.

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

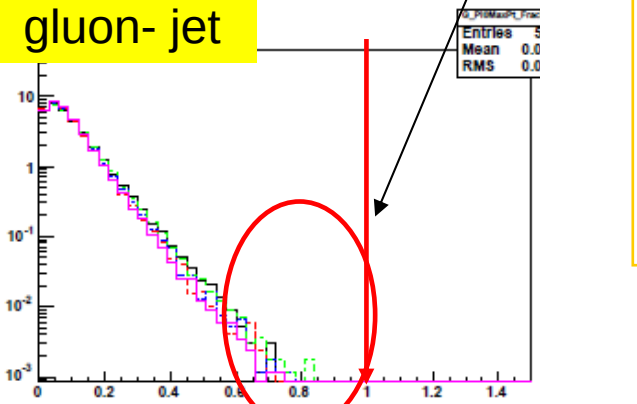
→ π^0 (→$\gamma\gamma$) with high energy looks like one photon.

quark- jet

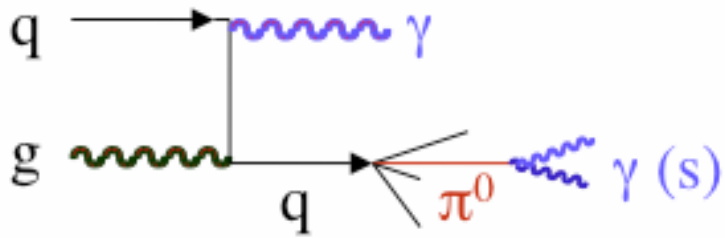
Fraction=1.0



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

→ Fake Rate gluon jet : 1 / 7800

quark jet: 1 / 2021

Factor 4

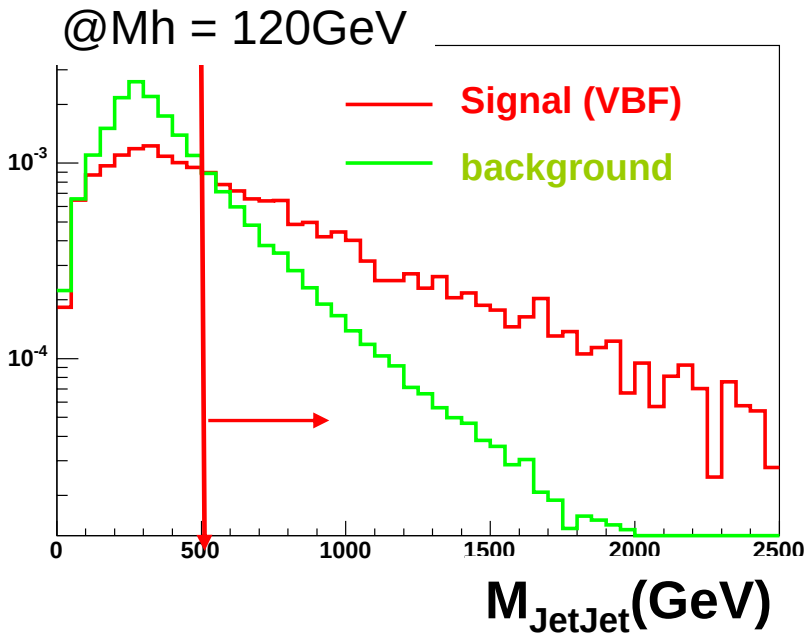
Event Selection Criteria

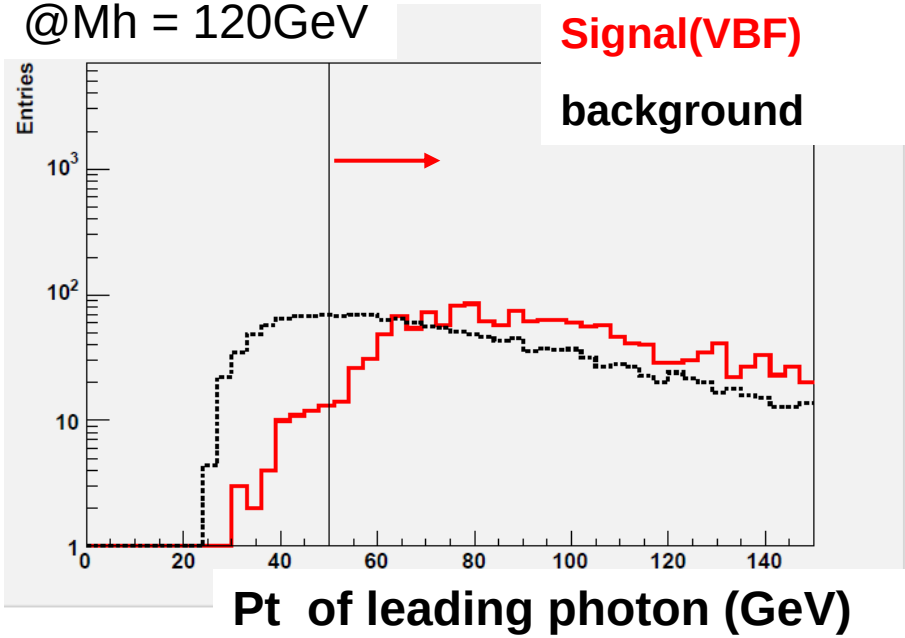
1. Forward jets requirements (for VBF)
   -- one jet in each hemisphere
   -- $P_T(jet1) > 40GeV, P_T(jet2) > 20GeV$
   -- $dR_{jetjet} > 0.7$
   -- $M_{jetjet} > 500GeV$

2. Two Isolated Gamma selection (Higgs products)
   -- $N\gamma = 2$, $|\eta_\gamma| < 2.5$
   -- $P_T(\gamma 1) > 50GeV$, $P_T(\gamma 2) > 25GeV$
   -- gamma should exist between two forward jets in η-ϕ plane. ($dR(\gamma J)>0.7$)

3. Additional cuts for no colour exchange.
   -- No Central jet with $P_T>20GeV$
   -- Rapidity Gap requirement
   ($\eta_{jetmin} + 0.7 < \eta_{jet} < \eta_{jetmax} - 0.7$)
   -- apply inefficiency of 3.7% due to minimum bias jets

4. Higgs mass window requirement(+- 2GeV)
   -- 118 < Mh < 122GeV @Mh = 120GeV





H→ γγ on VBF process

- Signal peak can be seen clearly.

Mh = 120GeV, L = 30 fb $^{-1}$

S =24.9, B = 19.9

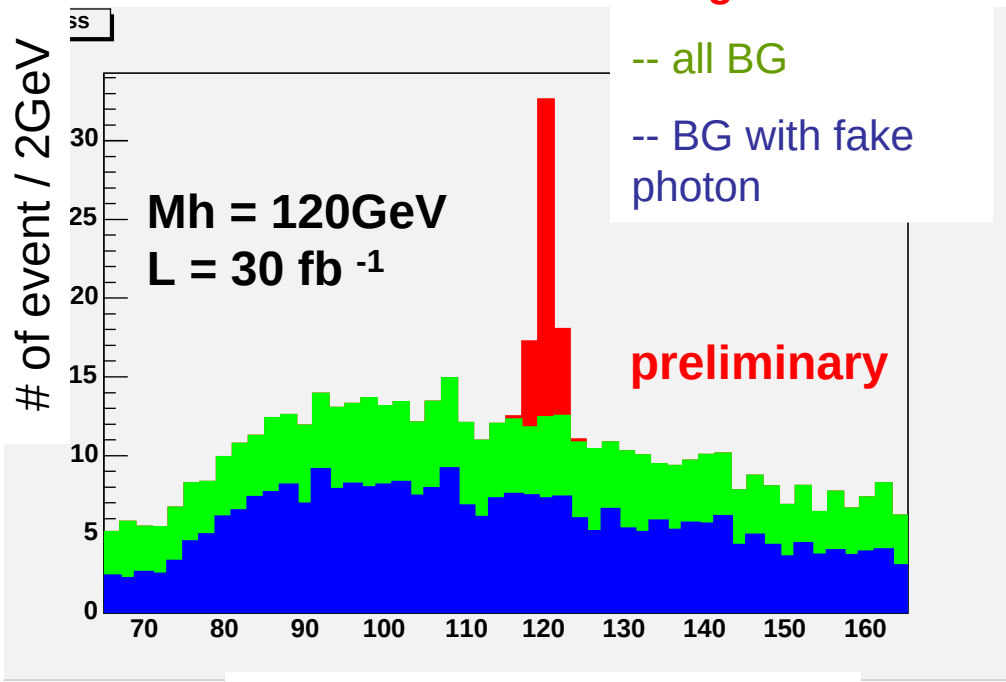
Significance(poisson) = 4.6

"2 jets tagging analysis" on VBF H→ γγ is promising !!

- Most of BG events have fake photon(s).
  - -4Jets : JJ JJ
  - -1γ + 3Jets: γJJ J

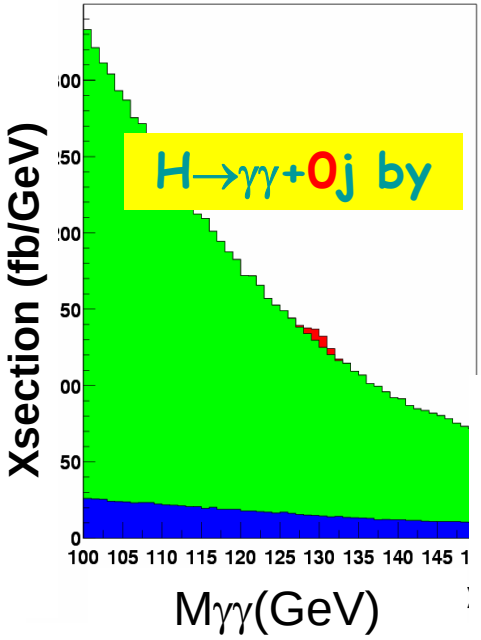
mis-ID

→ Suppression of fake photon is very important



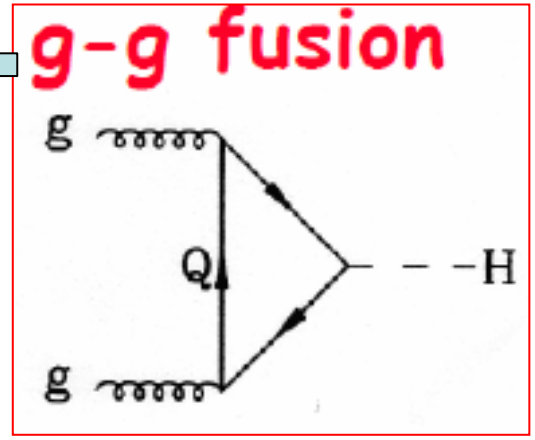
3 analyses on H→ γγ @ATLAS

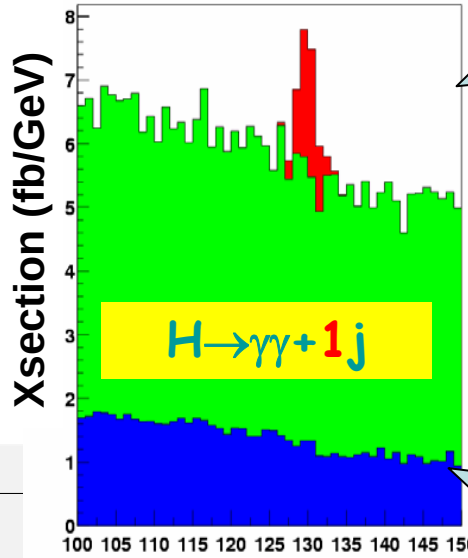
preliminary



No -jet tagging :

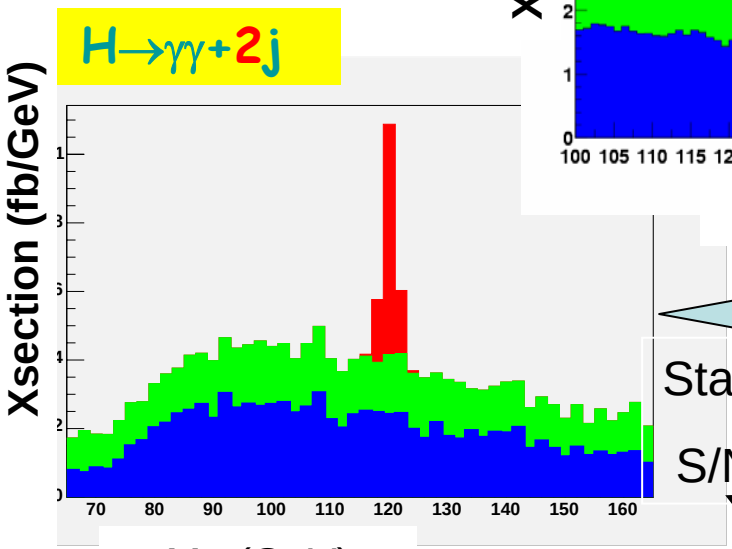
huge BG. S/N ~0.3% → **S/N is bad**





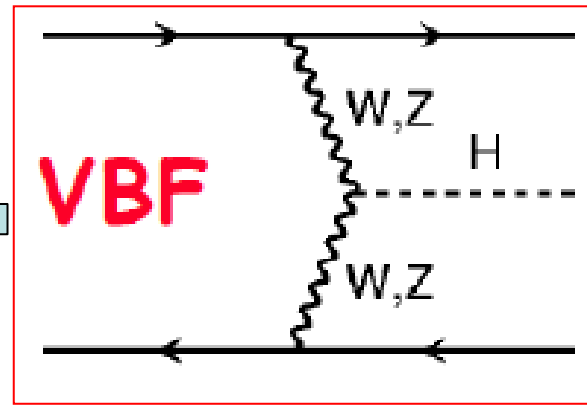
- **gg Fusion with additional one jet**
- **VBF: one of two forward jets is out of acceptance.**

→ **Statistics of Signal is enough. S/N is not so good (~ 10 %).**



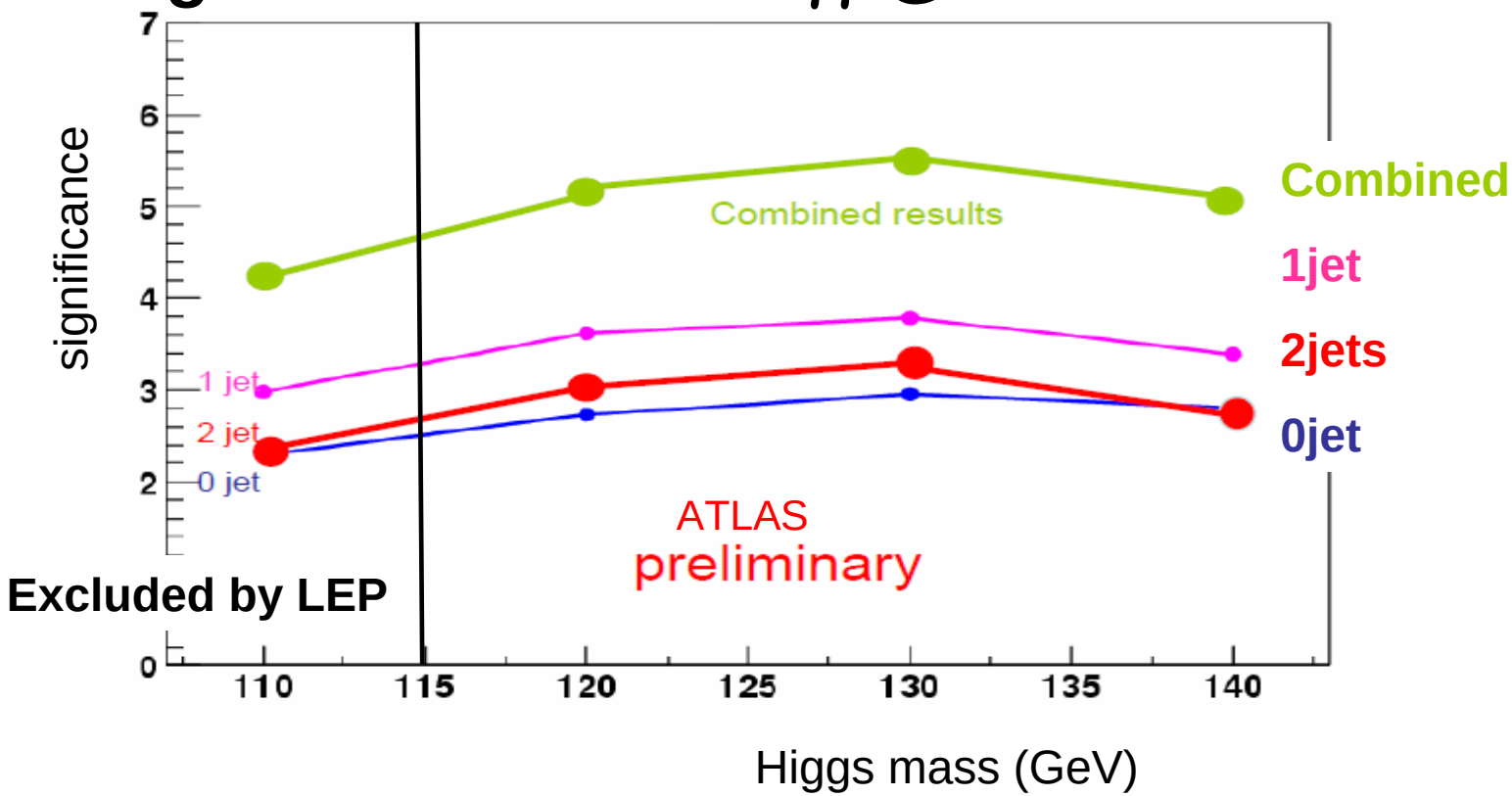
Statistics of Signal is limited.

S/N is good.(>100%)



Important to discover of Higgs at early stage

Significance on H→ γγ @ L = 10fb^{-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 = 10fb^{-1} (2008-2009) on combined H → γγ 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.

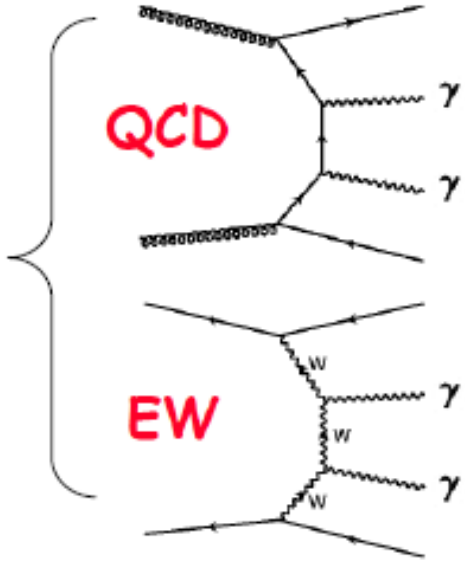
- "2 tagging analysis" on VBF H → $\gamma\gamma$ is very promising.

- By combined H→$\gamma\gamma$ 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(EW) : CompHEP + PYTHIA6.221
2. $\gamma\gamma$JJ(QCD) : ALPGEN + PYTHIA6.221

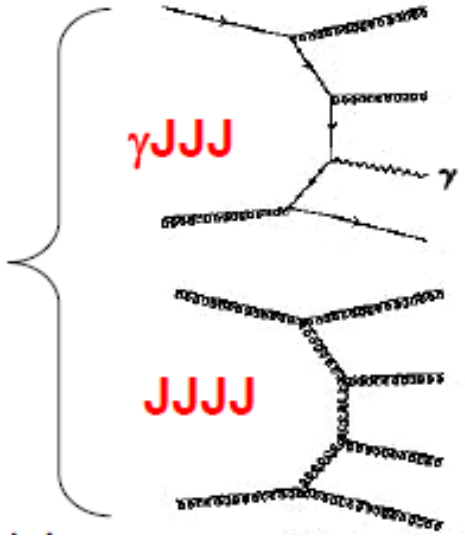


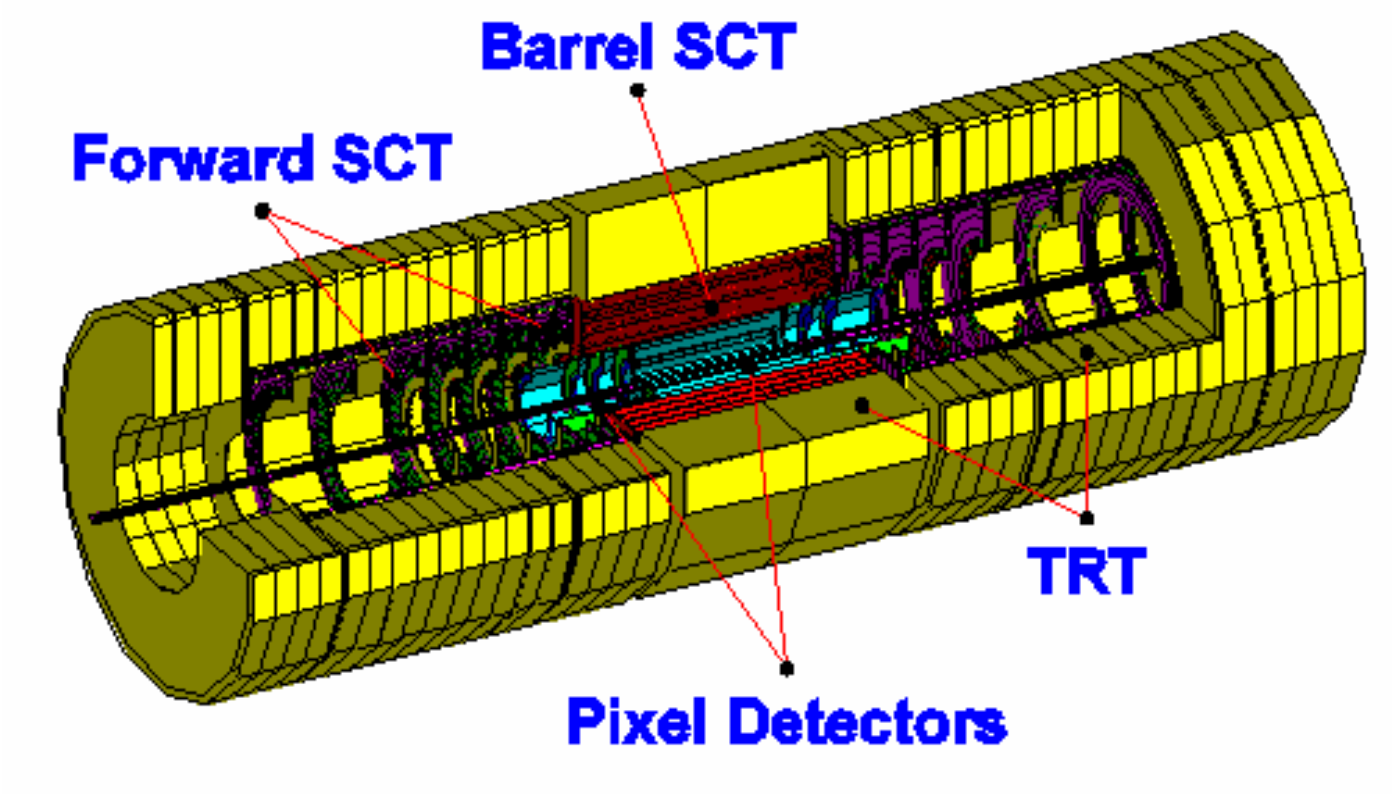
BG sample with fake photon

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

PDF : CTEQ5L

P_T ordering is applied to avoid the double counts.




Barrel SCT
Forward SCT
TRT
Pixel Detectors