Highlight of LHC Physics

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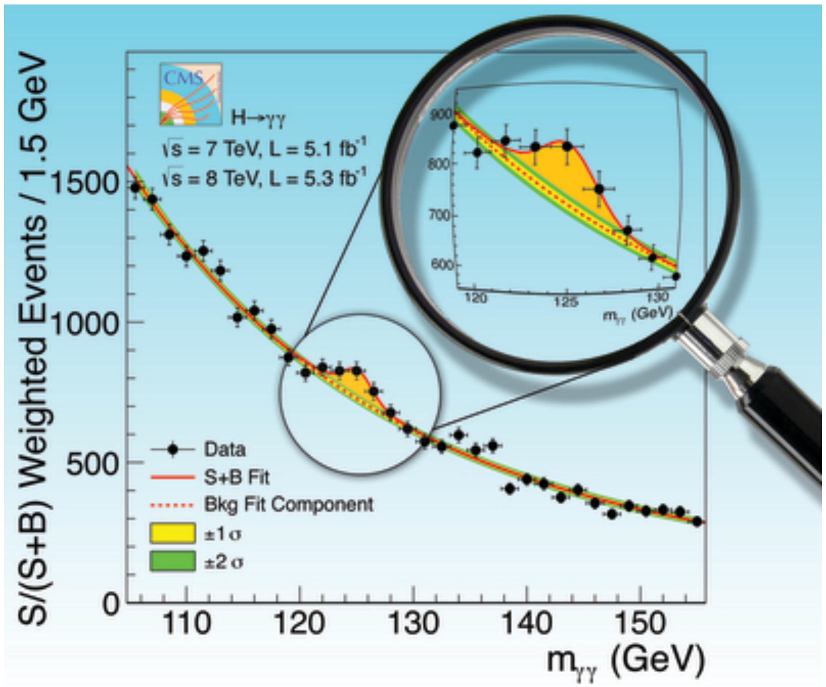


1. Introduction
   (kinematics, Luminosity, detector)
2. Standard Model processes
3. The Higgs(-like) boson

4A. Supersymmetry with mET

4B. Supersymmetry with long-lived particles

5. Extra-dimension
6. Summary & discussion Points

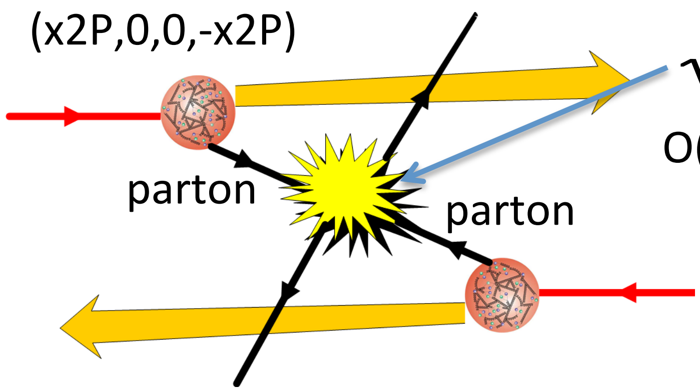
If you have questions even after the school, please send mail to Shoji.Asai@cern.ch

Not Only Scientific results
But also lessons
for experimentalists are listed.
Homework for discussion will be given.

1. Introduction

(1) Kinematics
(2) Luminosity
(3) (Near) Future Plan of LHC
(4) ATLAS / CMS detectors & comparison

Luminosity is essence for Hadron collider



$$\sqrt{\hat{s}} = \sqrt{x_1 x_2}\sqrt{s_{pp}}$$

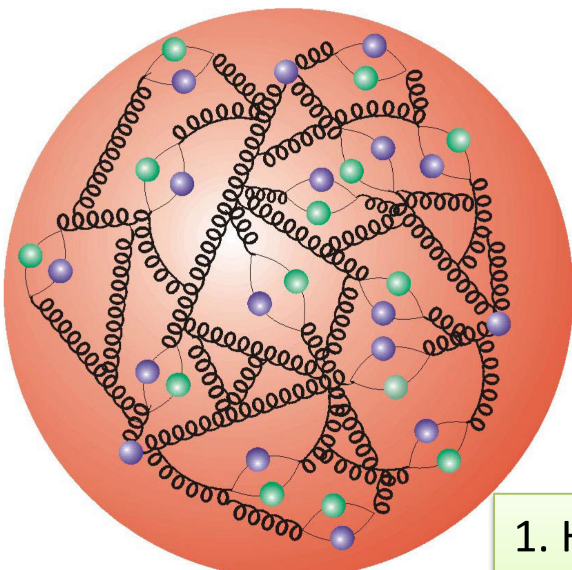
O(TeV)

(8〜14TeV)

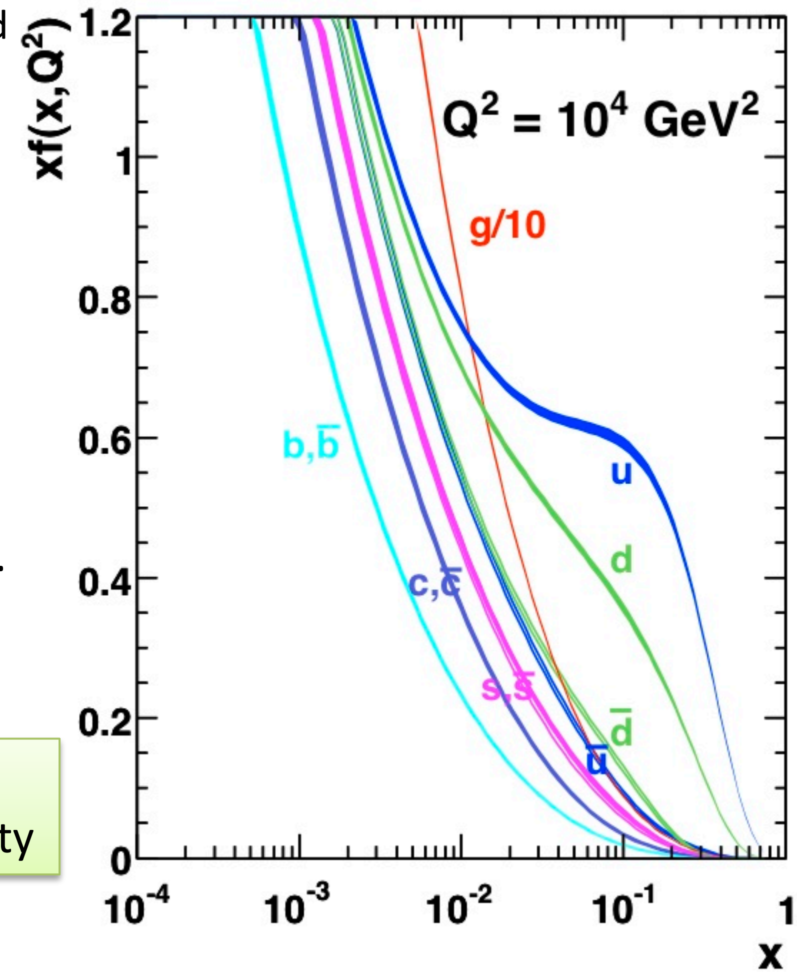
x is ratio of P carried by the parton over P of Proton.

(x1P,0,0,x1P)

For example
1TeV SUSY particles are pair-produced at 8TeV,Only u,d,g can contribute.



Proton is constituted with partons, which contribute directly to interesting elementary processes.



1. High effective CM energy is identical to High Luminosity

2. LHC is a asymmetric collider

Rapidity is useful for asymmetric colliders

CM: $E=(x1+x2)\,P$
$Pz=(x1-x2)\,P$

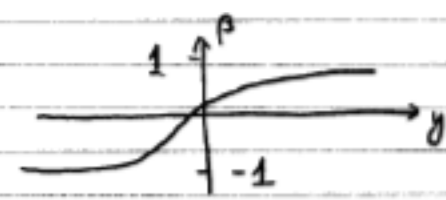
Rapidity y is defined as $y=1/2\ \ln(E+Pz)/(E-Pz)= \ln x1/x2$
$SQRT(S)=sqrt(x1x2)\ 8TeV$

SQRT(S)=2TeV SQRT(x1x2)>0.25 x1,2 > 10 ^-2 |y| < 2.3 Not boosted
heavy particle production is in central region
SQRT(S)=10GeV SQRT(x1x2)>10^-3 x1,x2 > 10^-6 |y| < 6.9 highly boosted
light particle production is in forward region

Why we use rapidity y? β=tanhy β is velocity in natural unit.

Lorentz transfer for β becomes simply (just rotation of complex iy):
adding rapidity y is sequence of Lorentz transfer:

ある系でy βだけ Lorentz 変換



$$\begin{pmatrix} E' \\ P_z' \end{pmatrix} = \begin{pmatrix} \gamma & -\gamma\beta \\ -\gamma\beta & \gamma \end{pmatrix} \begin{pmatrix} E \\ P_z \end{pmatrix}$$

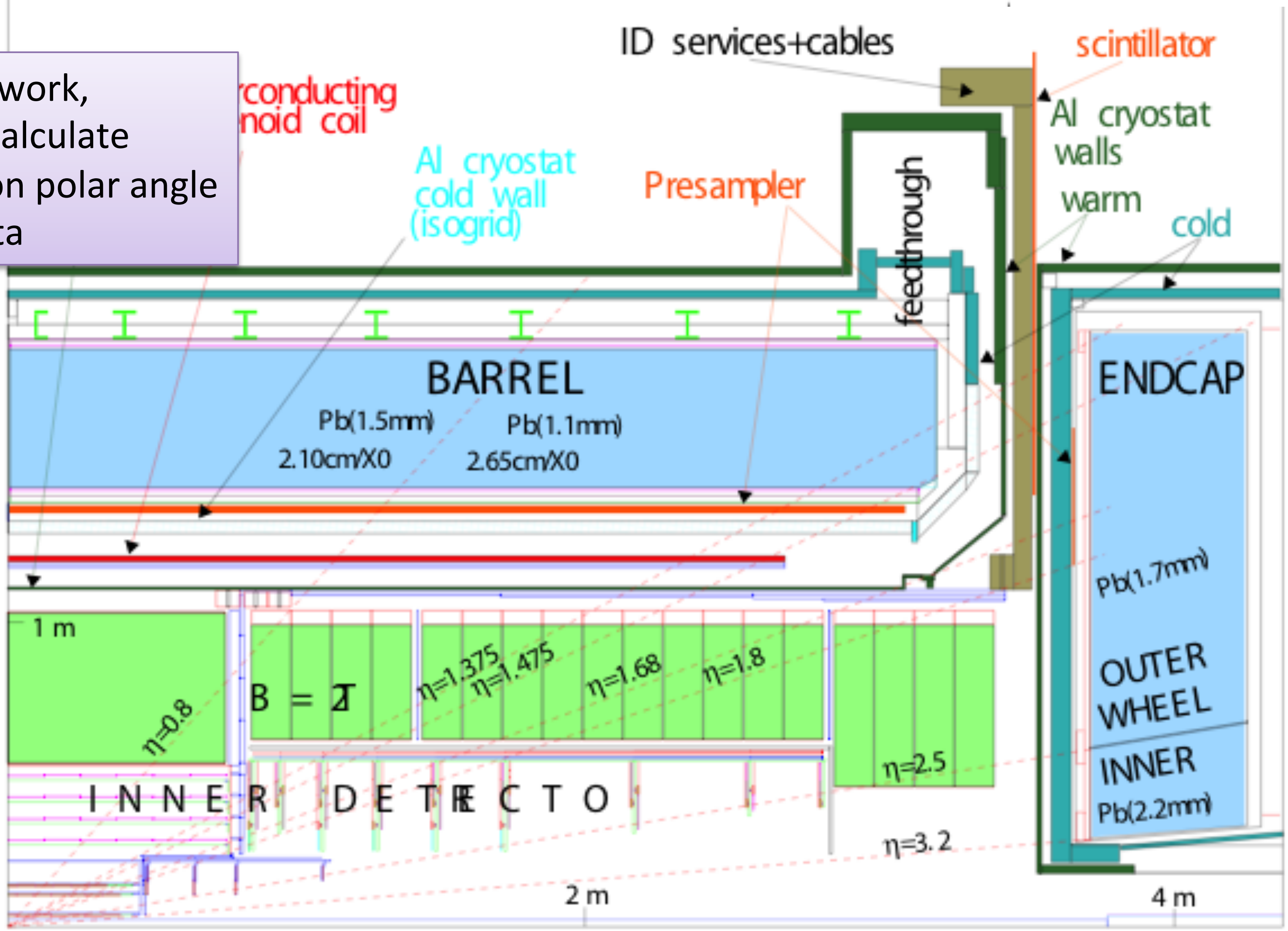
$$y' = \frac{1}{2} \ln\left(\frac{E'+P_z'}{E'-P_z'}\right) = \frac{1}{2} \ln\left(\frac{E+P_z}{E-P_z}\right)\left(\frac{1+\beta}{1-\beta}\right)$$

$$= y + \tanh^{-1}\beta$$

Instead of rapidity
pseudo rapidity η is used:
η is calculated with m=0
$\eta = -\ln(\tan(\theta/2))$ just geometrical

θ	cosθ	η	
45°	0.707	0.88	
10°	0.984	2.44	← tracking
5°	0.996	3.13	← 常識的なカロリメーター
1°	0.9998	4.7	← 前方用のカロリメーター

Homework,
Let's calculate
relation polar angle
cos, eta



Bunch Structure of beam in colliders

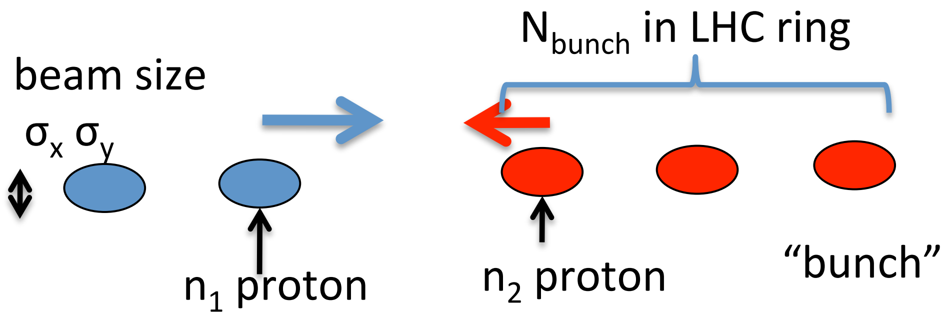
proton beams have the bunch structure.

$$L = \frac{n_1 n_2}{4\pi\sigma_x\sigma_y} f$$

n: number of proton (1.4*10^{11}Proton

σ: beam size (23 μm)

f: frequency of collision (20MHz)



1.4 10^{11} protons
are stored in one bunch
whose size is less than 20μ
length is 6 cm

Today

Nbunch 1380 (20MHz collision)
σ∼ 18 μm
n=1.7E11

Only difference is frequency

Design of LHC

Nbunch 2808 (40MHz collison)
σ~17 μm
n=1.4E11

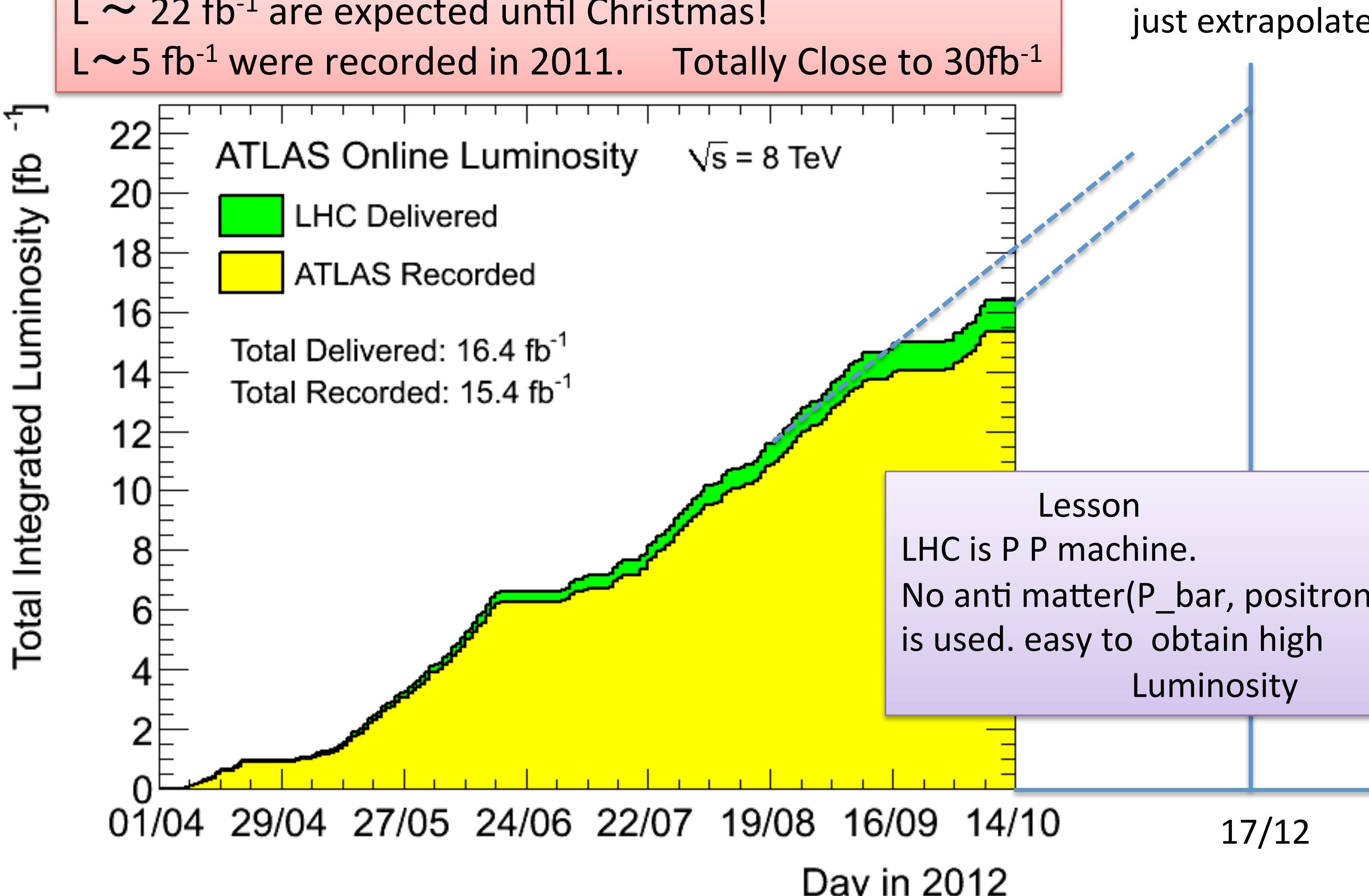
$L=7.7 * 10^{33} cm^{-s} s^{-1}$

$L=1.2 * 10^{34} cm^{-s} s^{-1}$

L>0.25fb-1 / day
L > 25fb^{-1}/year

The same as KEK B/ SLAC-b
Expected Integrated L = 100fb^{-1} / year

L>16 fb^{-1} are recorded by Yesterday(2012) and
L ~ 22 fb^{-1} are expected until Christmas!
L~5 fb^{-1} were recorded in 2011. Totally Close to 30fb^{-1}



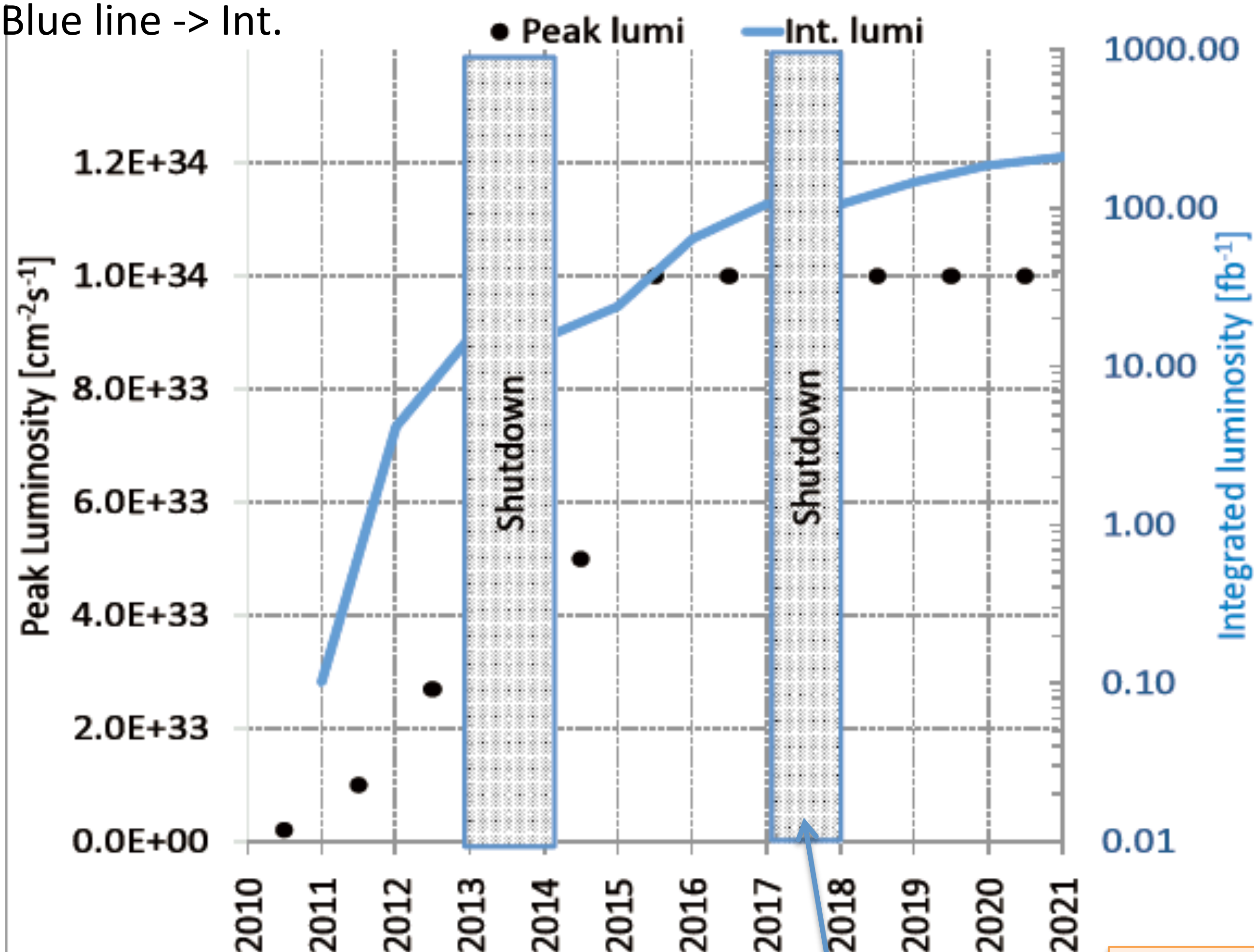
Lesson
LHC is P P machine.
No anti matter(P_bar, positron) is used. easy to obtain high Luminosity

pp collision is assigned until 17th December, We have more 7weeks.
Similar luminosities are obtained both on ATLAS & CMS detectors.

LHC schedule after 2013

2012-2013 Shutdown to repair the bad connections of Cu bar between magnet

Black point -> Peak
Blue line -> Int.



LHC restart from 2014 autumn ～ ECM=13TeV

Similar beam parameters are used

2015-2021
ECM=13-14TeV
L > 300fb^{-1}
Targets are
Higgs coupling
SUSY upto 3TeV

Not solid calendar, But It is approved plan

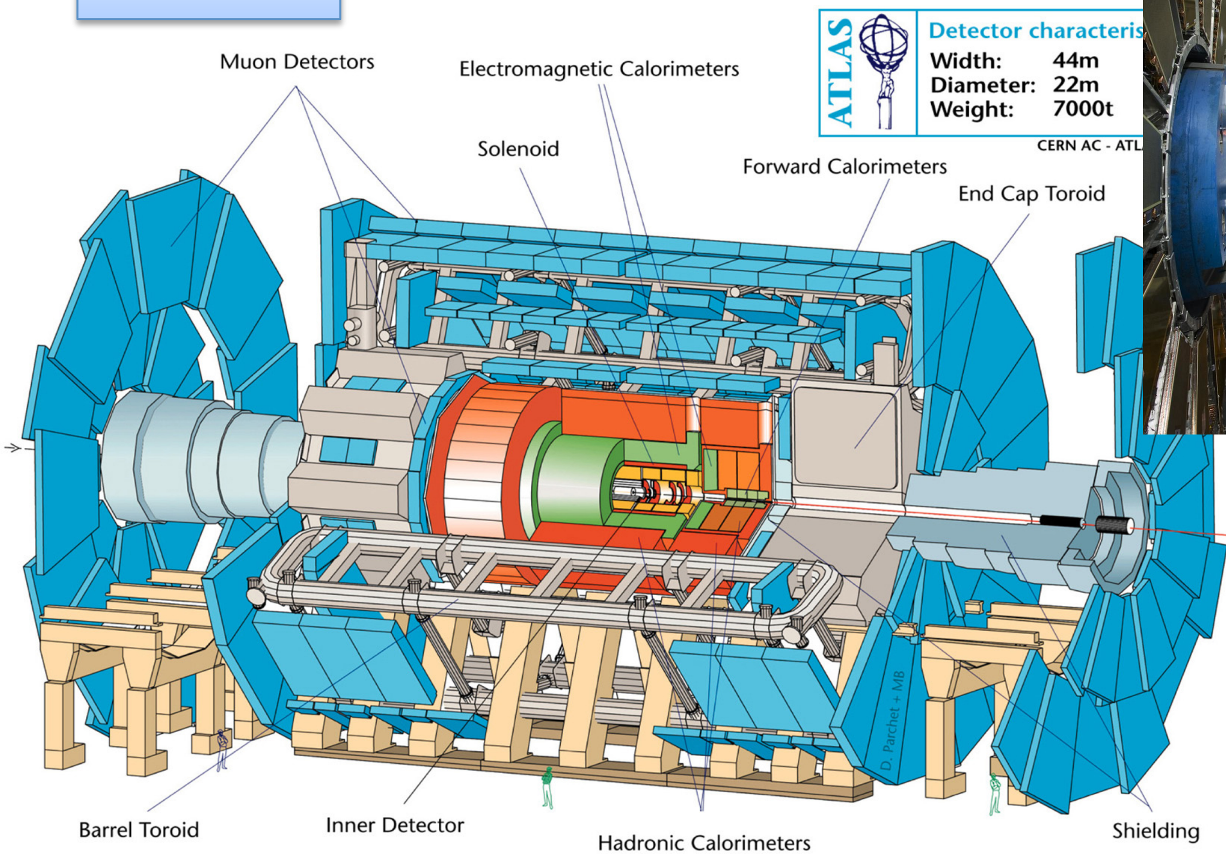
semi-conductor detectors should be replaced

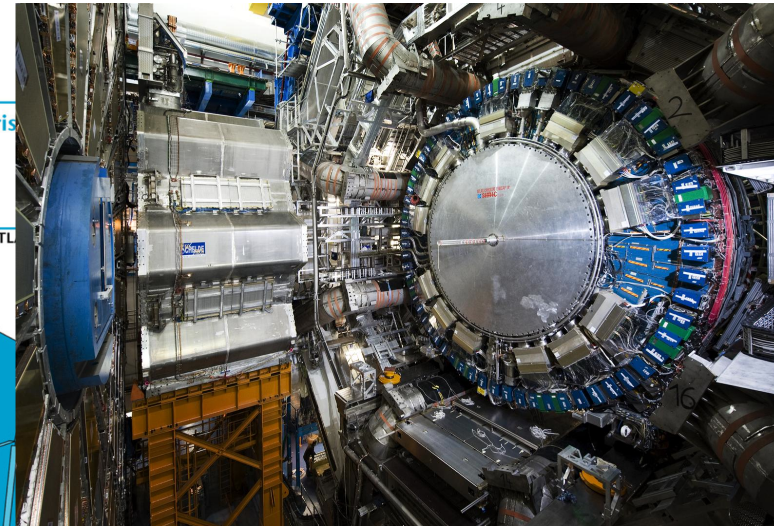
Depends on NF

2023- LH-LHC Self coup. of H
2035- HE-LHC ~40TeV

There are two general purpose detectors:

ATLAS



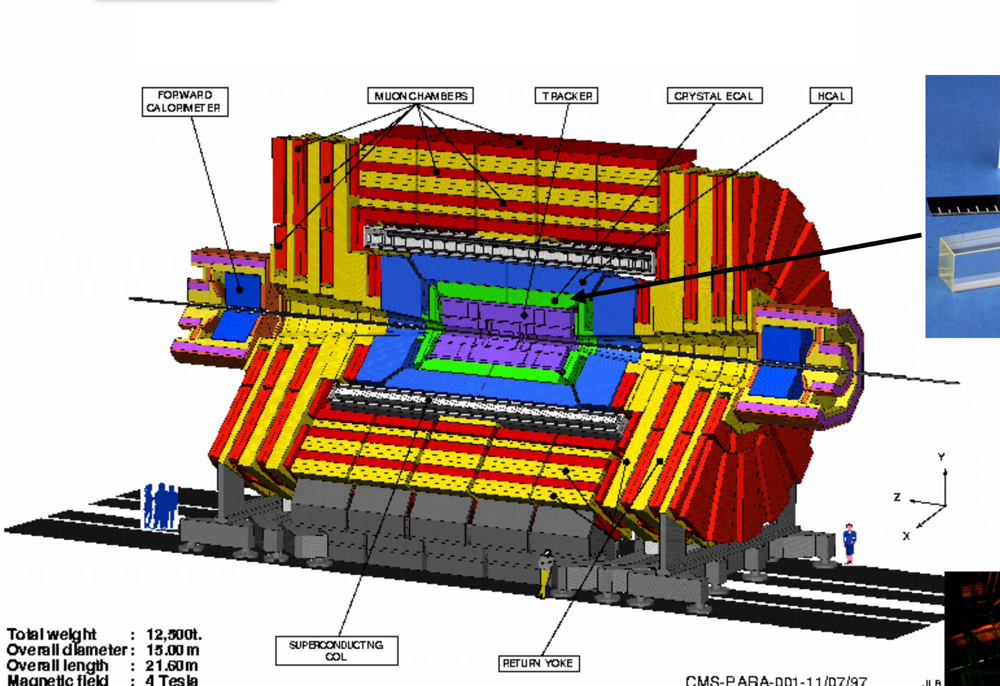


Resolution
(Pt=100GeV)

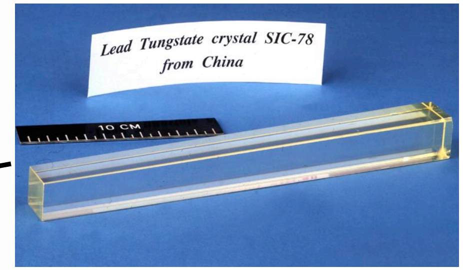
e, γ 1.5%
Muon 2-3%
Jets 8%

- **Large Detectors** since momentum resolution of tracking is $\delta P/P \sim 1/(BL^2)$
- **balance of performance** resolution are good but not specially good for all.
- Accordion Shape of L.Ar calorimeters are used. （**Longitudinal information** & Rad. hard）
- muon system is Large & air-core(less multiple scattering) & toroidal magnet (gain forword)

CMS



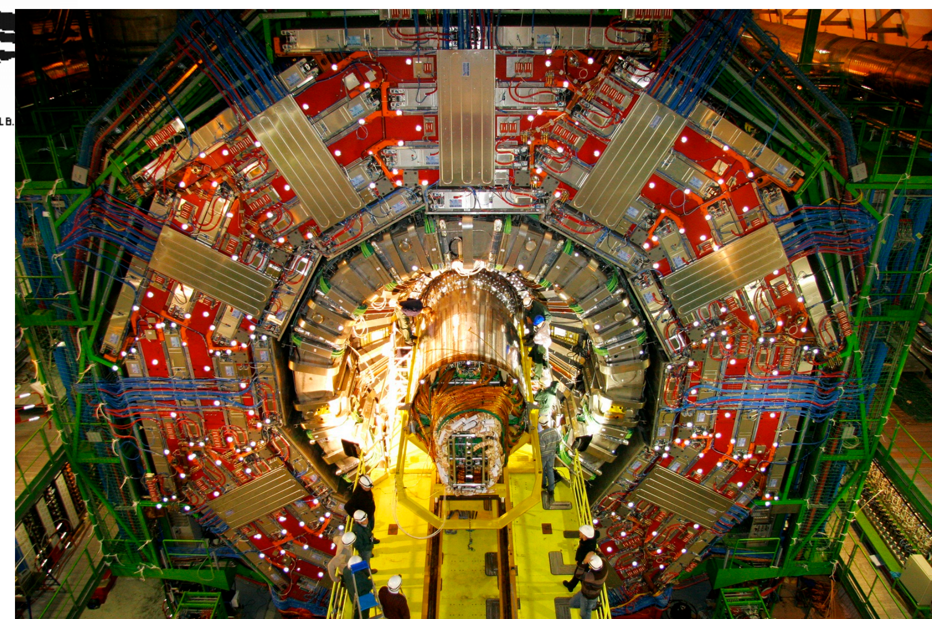
$PbW0_4$



Resolution
(Pt=100GeV)

e, γ 0.9% !!
Muon 2-3%
Jets 12%

- **compact** H=15m L=22m (about half of ATLAS)
  W=12,500ton (twice of ATLAS)
- Unbalanced performance
  $PbWO_4$ scintillator
  excellent energy resolution
- 4T Very strong solenoid magnet
  since momentum resolution of tracking
  $\delta P/P \sim 1/(BL^2)$
- Magnet is outside of calorimeters → thin hadron calorimeter No good jet energy resolution

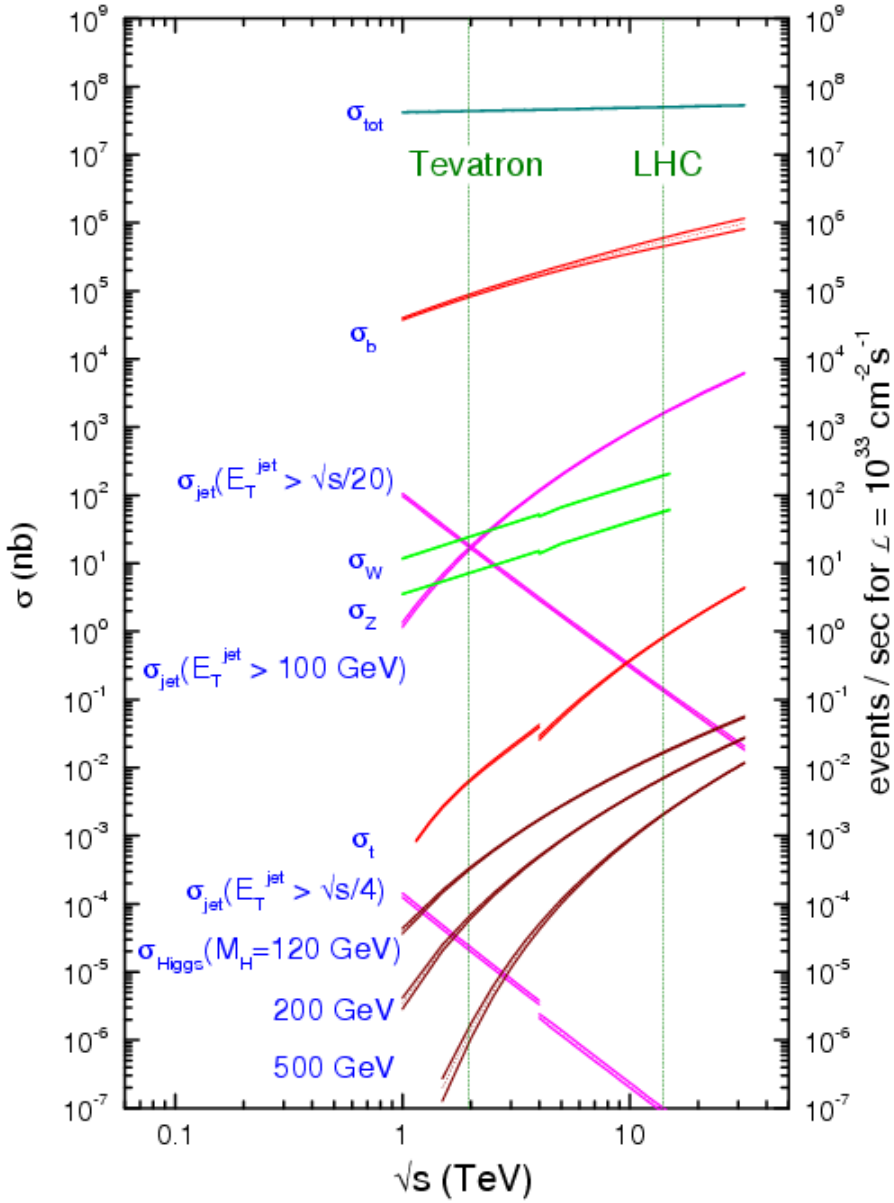


	ATLAS	CMS
characteristic	Accordion-type L.Ar EM cal. Fine segment muon detec. with Toroidal Magnet	PbWO4 EM scintillator has excellent energy resolution 4T Solenoid magnet
Tracker	B=2T Large L -> $\delta \sim 1/BL^2$ TRT continuous (kink, disappear)	B=4T Strong B Only Si (semiconductor)
EM cal.	LAr+Pb 10%/SQRT(E) Fine segment + Layer	Scintillator 3%/SQRT(E) Excellent E not fine segmet
Hadron Cal	Thick Iron + scintillator 50%/SQRT(E)	Thin brass + scintillator 100%/SQRT(E) shower escape
muon	Air core toroidal multiple-scatter is suppressed low PT muon is detectable. complicated magnetic field	Return yoke of solenoid Strong Magnetic field good resolution, multiple scattering
Trigger	3 layer Hard + Local Soft + Full Reconst	2 layer Hard + Full Reconst
Physics	Jet resolution exotic track for LL particles B-physics	e/γ physics simple calibration

2. SM processes

(1) Overview
(2) High Pt 2 jet
(3) top quark σ & mass
(4) W/Z production & diGauge boson

Typical Cross-sections are summarized here



Proton-Proton collision MB O(100mb)
Not parton, nuclear interaction

B-meson O(mb)

High PT jet (>100GeV) O(1μb)

Huge !!

EW (W/Z) O(10nb)

top Pair O(100pb)

has steep distributions since gluon PDF

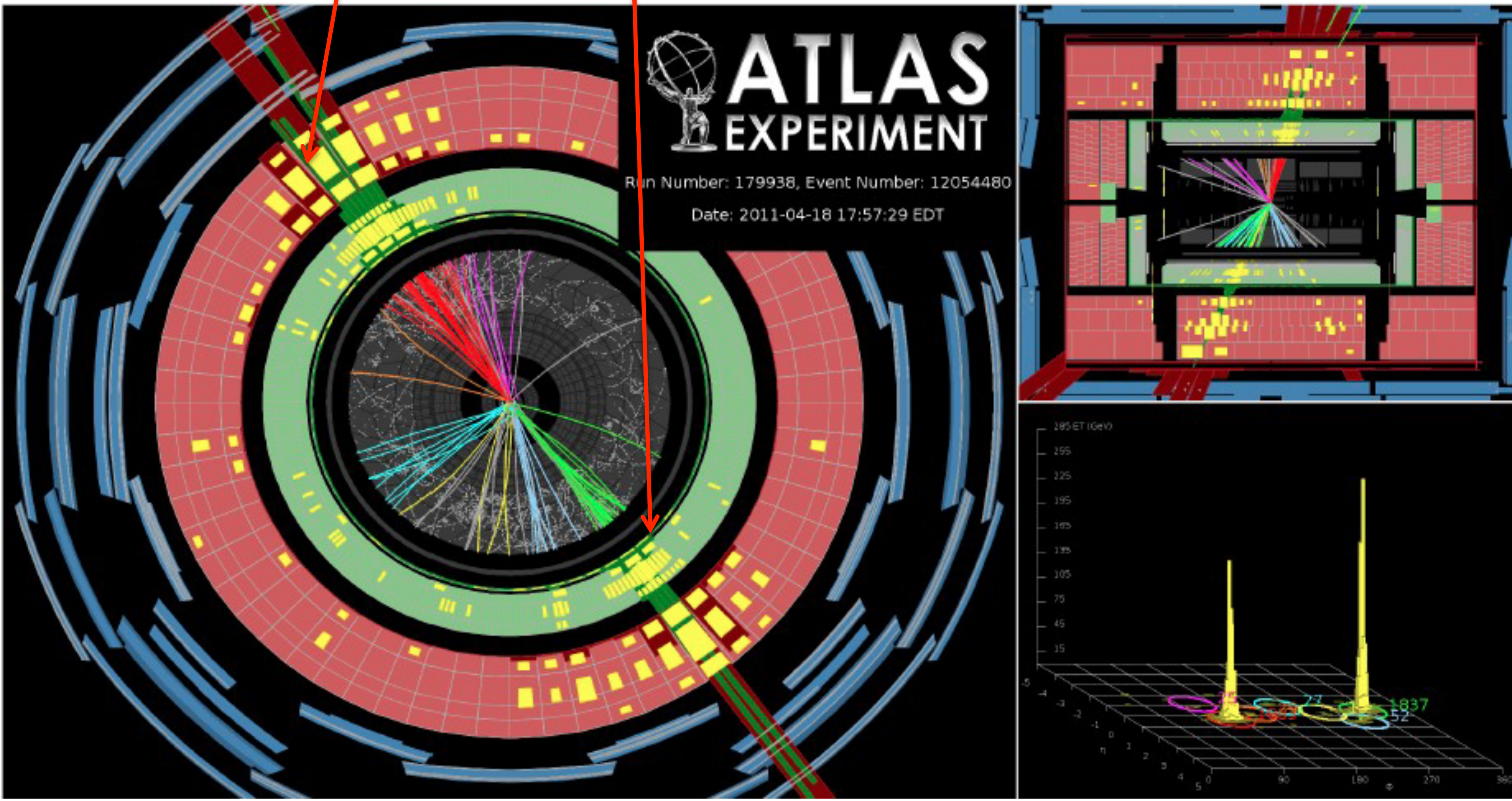
Higgs O(10pb)

Very High PT jet (>1TeV) (1fb)

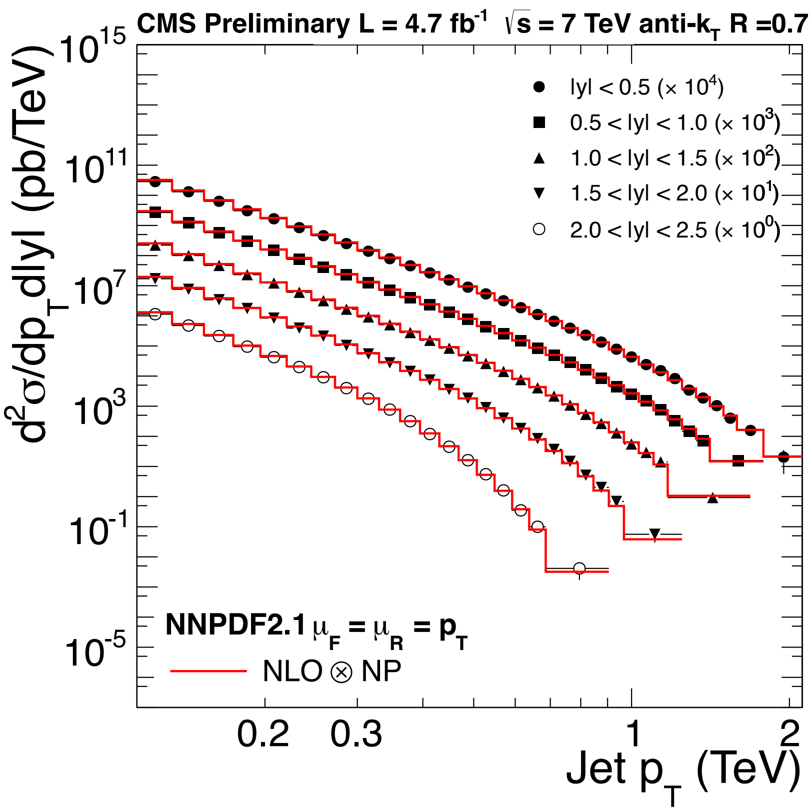
TeV SUSY O(1fb)

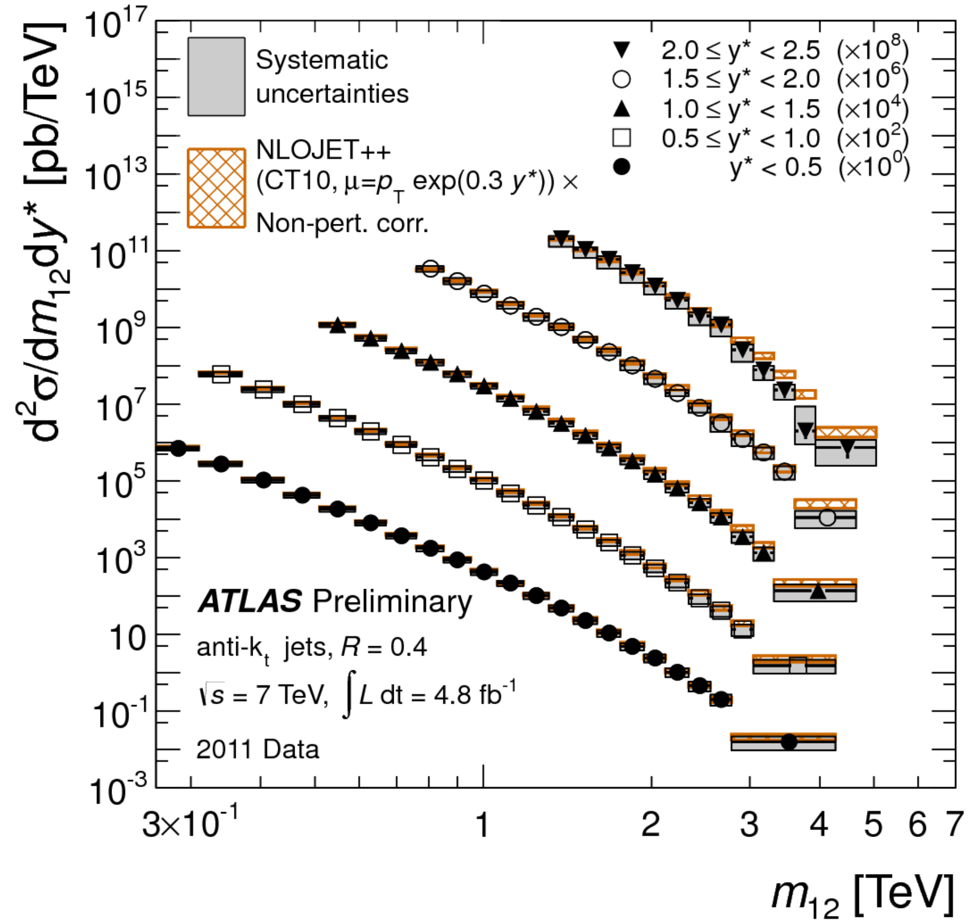
QCD jet   Processes: Most Popular process

PT_1=1.8TeV   PT_2=1.8TeV   Mjj=4TeV   x～0.6



differential σ of QCD Jet



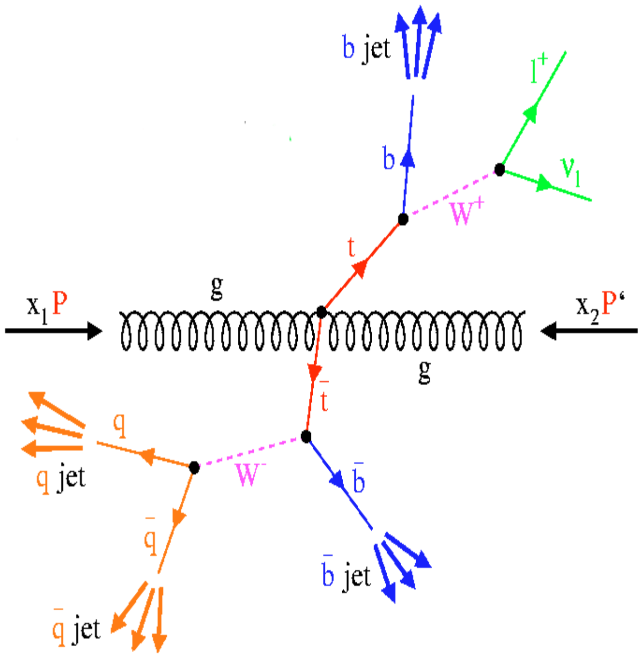


(1) NLO prediction agrees well for 9th order of Magnitude within 10% error
(MPI+Hadronization = NP has been performed with Pythia/Herwig)

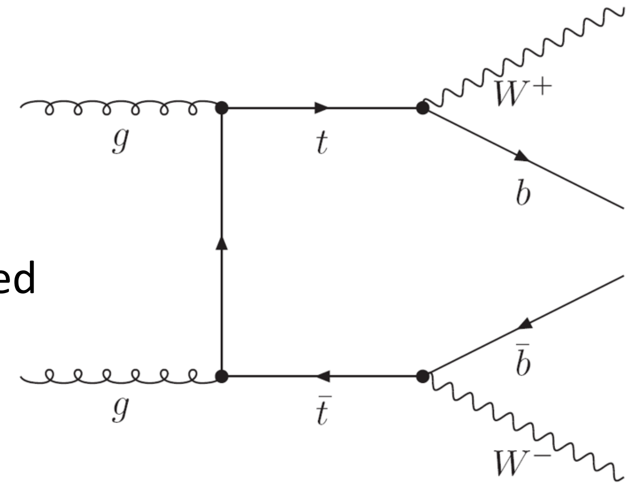
(2) Main experimental systematic error is due to jet energy scale (1-2%)

(3) Dominant theoretical errors are uncertainties in PDF and Renormalization Scale.
We can update PDF using these results

Top quark pair production

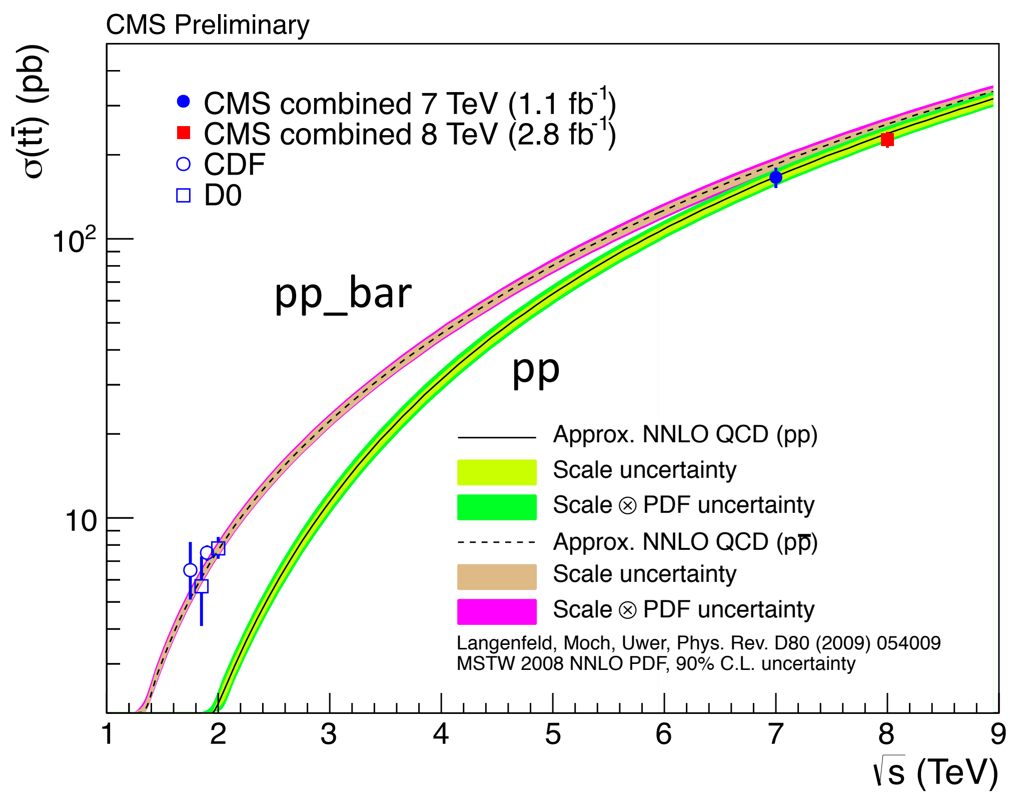


Top pair is produced from gg->tt at LHC



(1) Top -> b W Br=100%
(2) W -> leptonic 30% hadronic 70%

One lepton + mET + Jets + 2b-tagged jet are selected to enhance top sample.

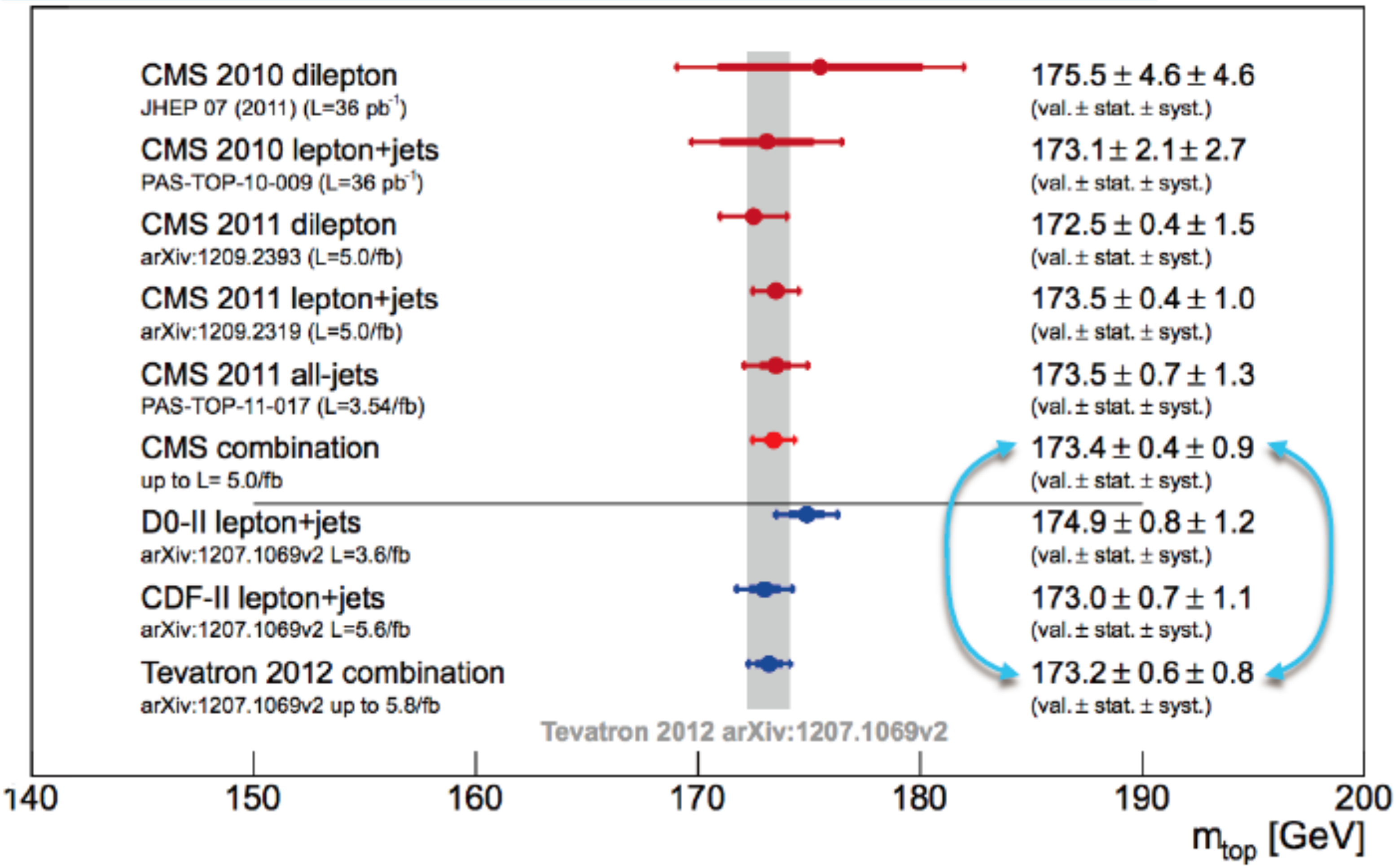


Production cross-section is consistent with SM prediction top mass

LHC result is better than Tevatron Now:
Similar systematic(b-jet energy calib.)
much better stat.

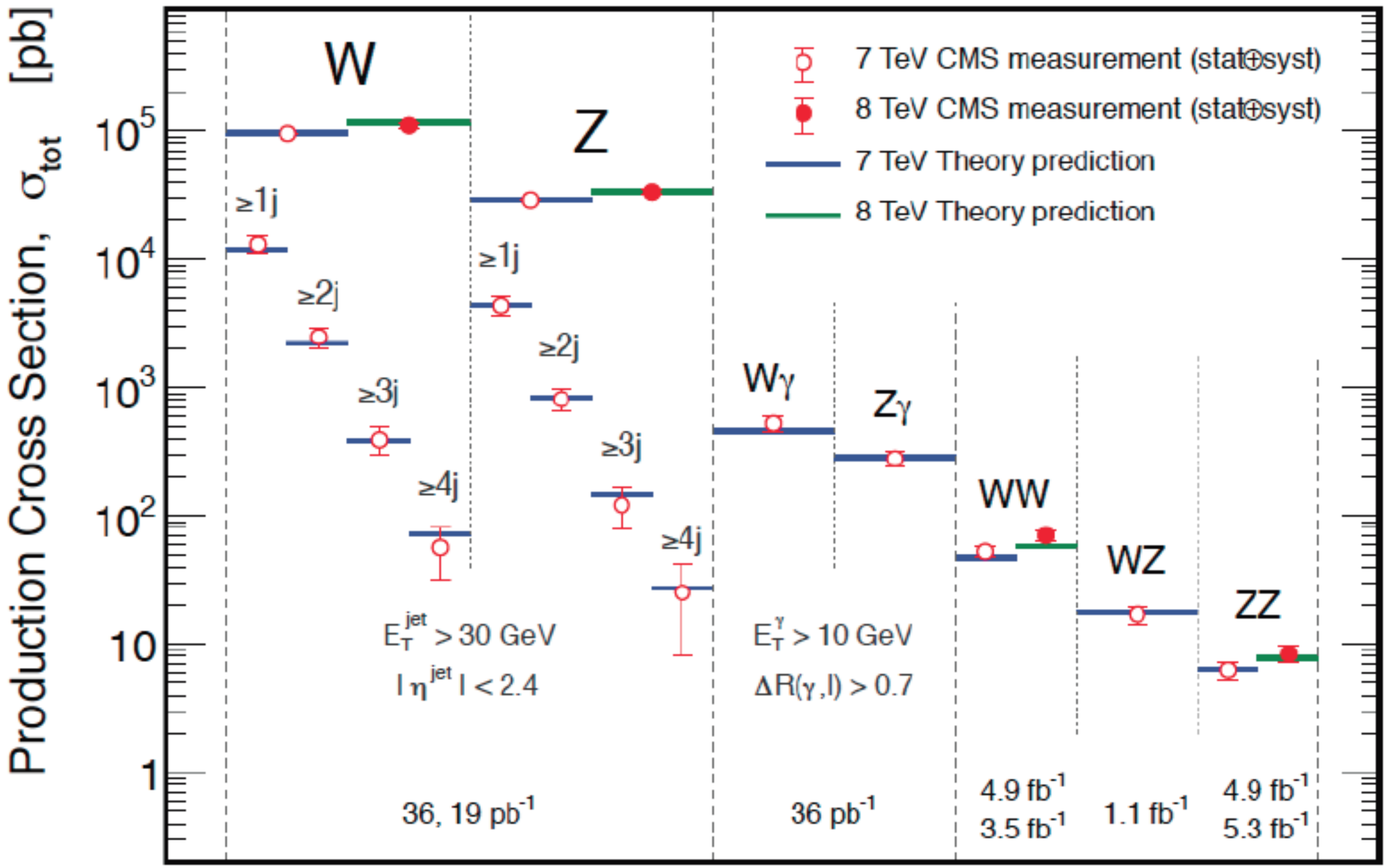
$$m_t = 173.36 \pm 0.38\ (\text{stat.}) \pm 0.91\ (\text{syst.})\ \text{GeV}$$

Excellent work



Gauge Boson Production Processes

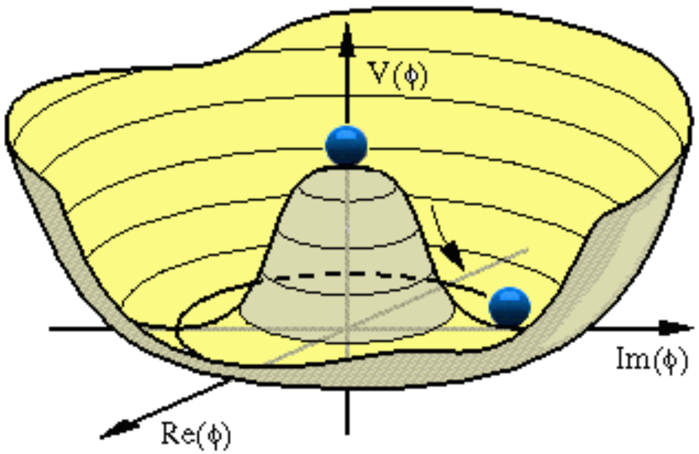
Lesson:
Simulation/calculation is in the new stage



diBoson Processes are well simulated, and V+jets QCD processes are also understood.

3. The Higgs(-like) Boson

Thought Control by CERN council(!!) (for Nobel Prize?) :



Brout-Englert-Higgs Boson

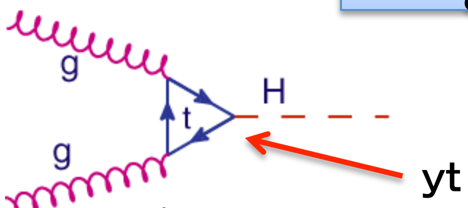
TERMINOLOGY TO BE USED WITH RESPECT TO THE ELECTROWEAK SYMMETRY-BREAKING MECHANISM

The Council agreed that the electroweak symmetry-breaking mechanism should continue to be referred to as **the Brout-Englert-Higgs (or BEH) mechanism** in all official CERN communications, while the boson associated with that mechanism could continue to be called **"the Higgs boson"**, as that term had long since passed into common parlance.

What they are talking at 4th July?

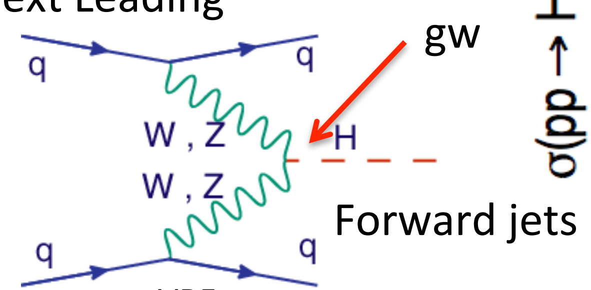
Higgs Production processes @ LHC

Leading

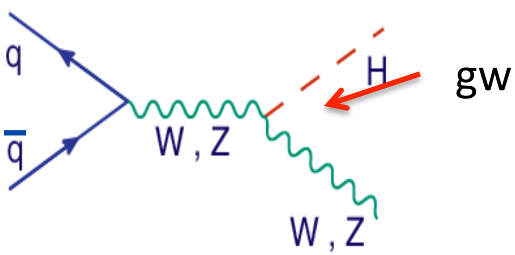


Gluon Fusion

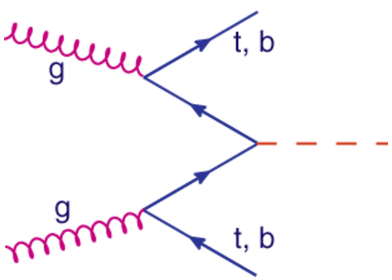
Next Leading



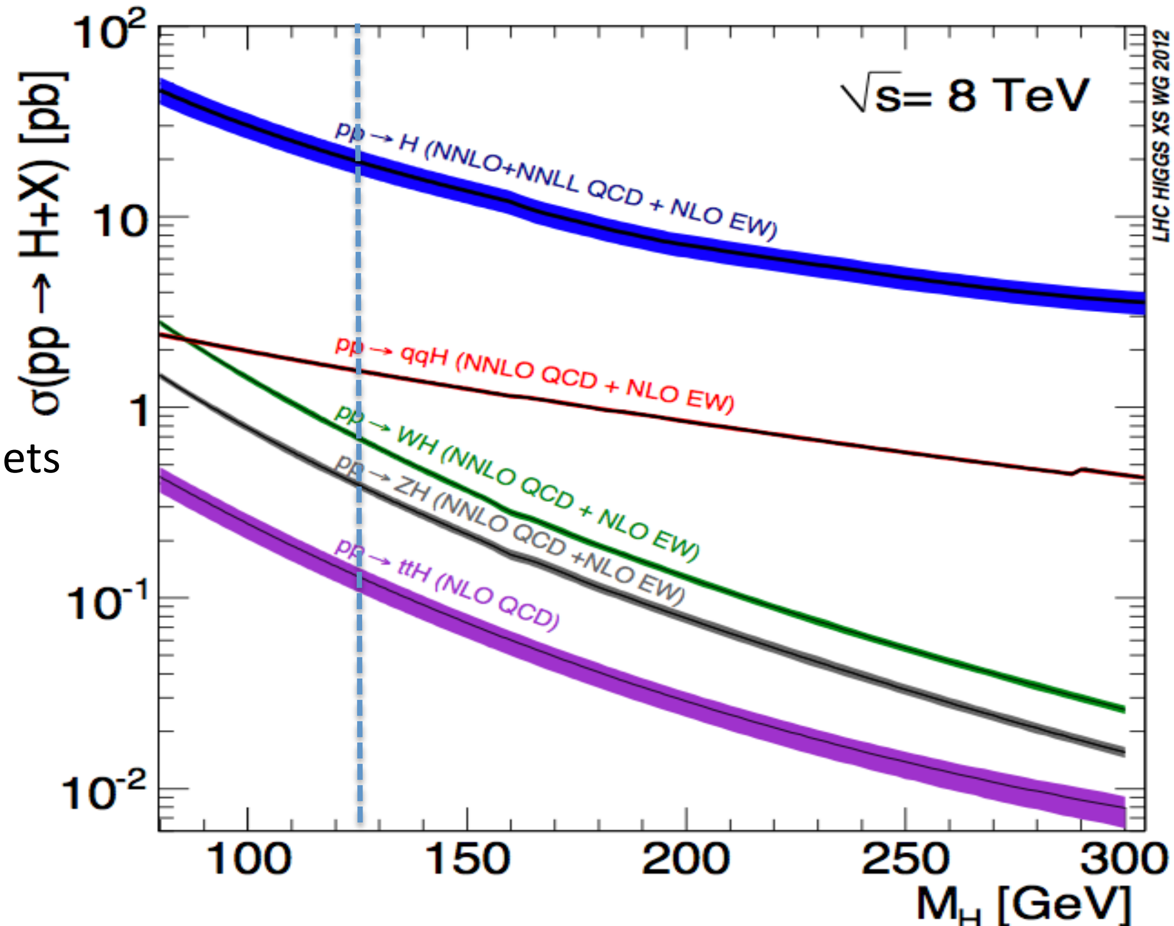
VBF



association production with W・Z



association production with top/b

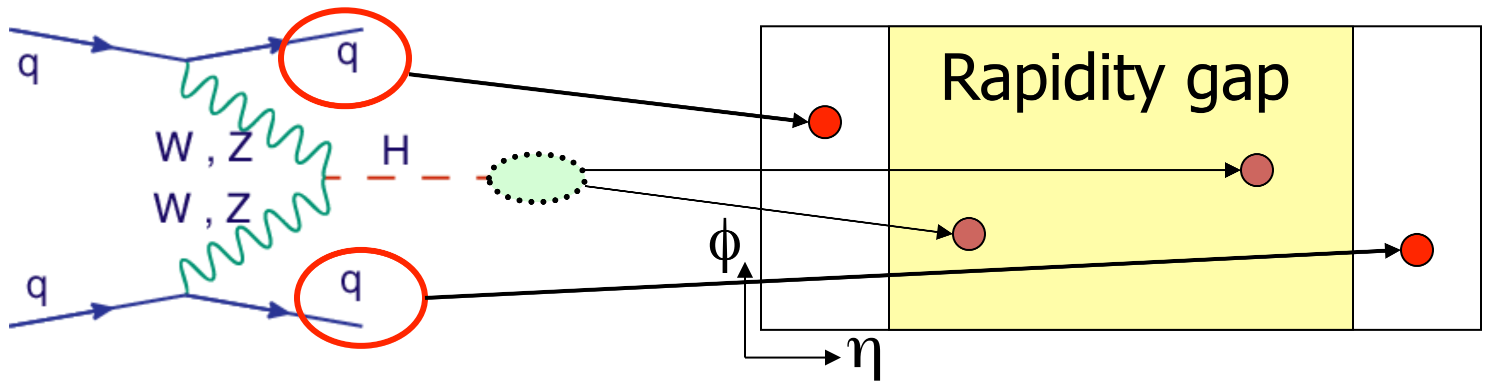


Different couplings contribute for production.
Since Yukawa is NOT inevitable, We have a chance to explore Yukawa.

cross-section (M〜125 GeV)
GF σ〜20 pb
VBF σ〜2 pb
WH+ZH ~1pb

Vector Boson Fusion: Rapidity Gap

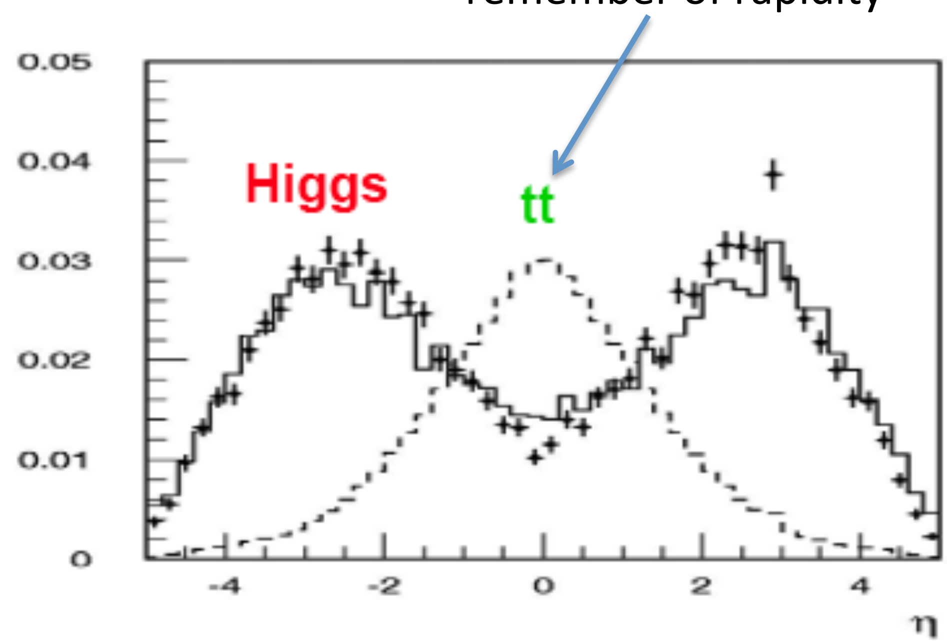
Home work



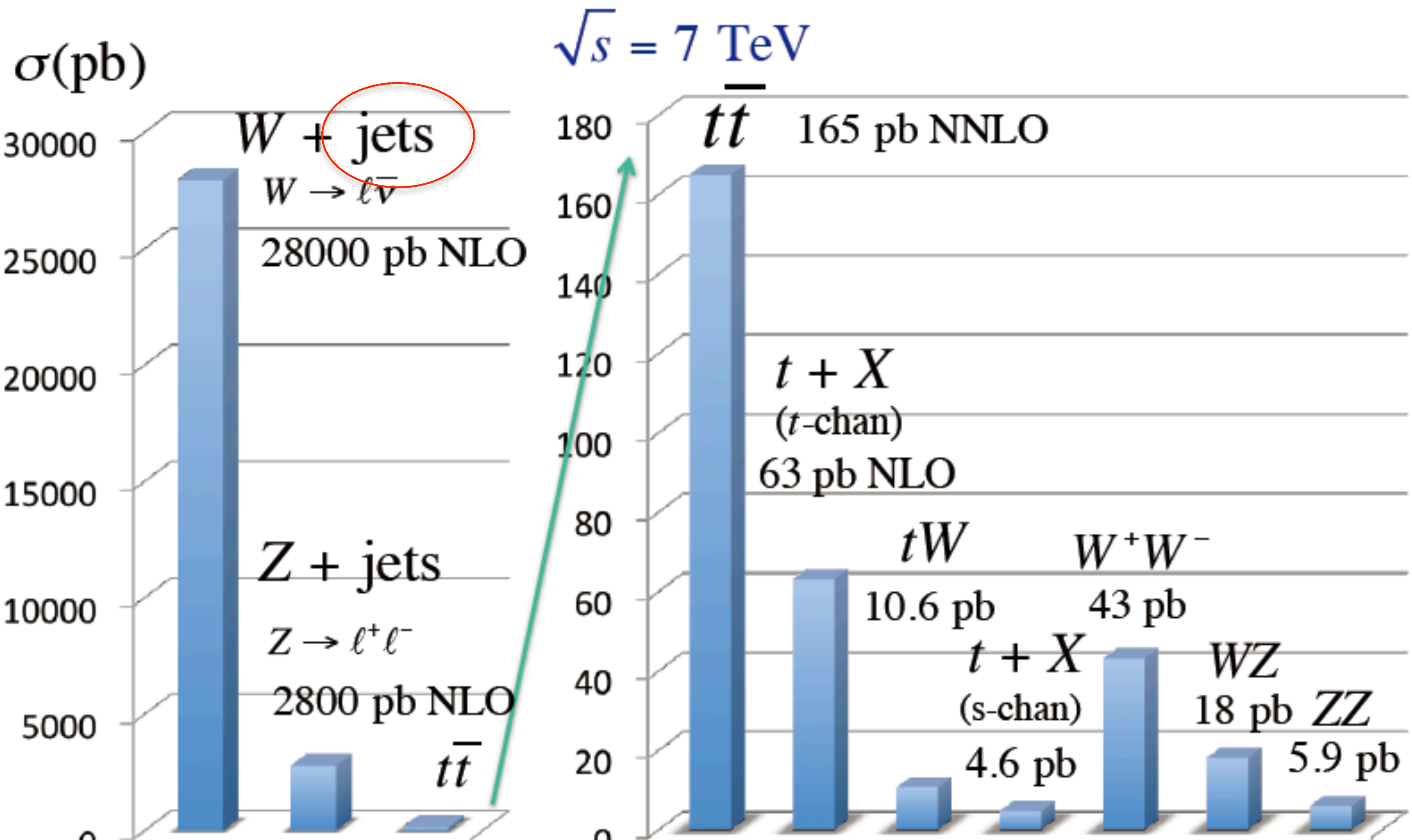
Since no color exchange between two quarks, Rapidity gap will be observed. Only Higgs product is observed

Jet Pt ~ Mw
t-channel
$1/(t-Mw^2)$

Heavy object is in central remember of rapidity



Production σ of the SM background processes



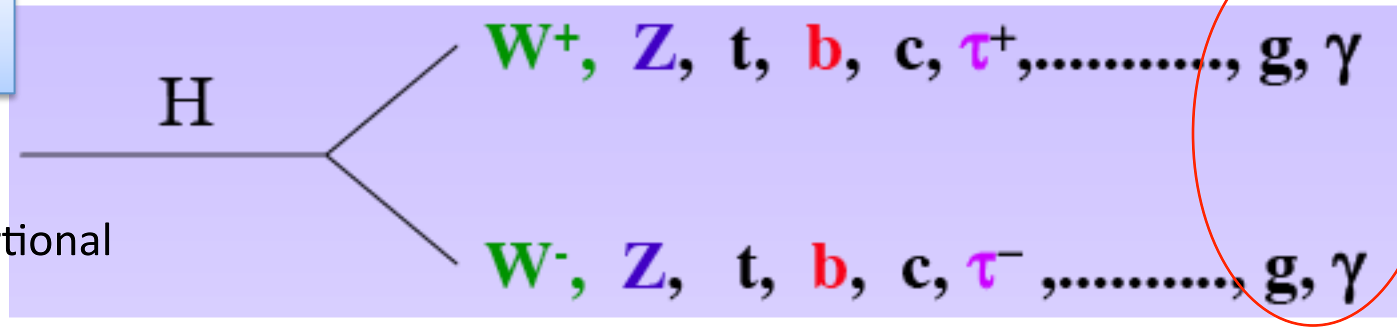
Gauge boson production
factor ~ 10^4

top
factor ~ 100

Di-boson irreducible
factor ~ 10

Fake lepton: Jet is misidentified as lepton (Prob. 10^{-4})

Higgs decay



Coupling is proportional to mass

Massless -> No coupling
Loop

$$WWH = \frac{e}{\sin\theta} m_W$$

$$ZZH = \frac{e}{\sin\theta\cos\vartheta} m_Z$$

$$f\bar{f}H = \frac{\sqrt{2}m_f}{v}$$

$$\int \frac{1}{2m_H} \sum_{spin,color} |M|^2 dLIPS$$

$$dLIPS = (2\pi)^4 \delta^4(q - p_1 - p_2) \frac{d^3 p_1}{(2\pi)^3 2E_1} \frac{d^3 p_2}{(2\pi)^3 2E_2}$$

2body phase space

$$\Gamma(H \to f\bar{f}) = N_f \frac{G_F m_H m_f^2}{4\sqrt{2}\pi} (1 - \frac{4m_f^2}{m_H^2})^{\frac{3}{2}}$$

~ β^3 this is character of Boson

$$\Gamma(H \to WW) = \frac{G_F m^3{}_H}{8\sqrt{2}\pi} (1 - \frac{4m_W^2}{m_H^2})^{\frac{3}{2}}$$

massive Boson Propagator (mH^2/mw^2)

$$\sum_\lambda \varepsilon_\mu^{(\lambda)*} \varepsilon_\nu^{(\lambda)} = -g_{\mu\nu} + \frac{p_\mu p_\nu}{M^2}$$

$$\Gamma(H \to ZZ) \approx \frac{1}{2} \Gamma(H \to WW)$$

Since anti-Z is identical to Z

—> mH^3 instead of $mH\, m^2W$

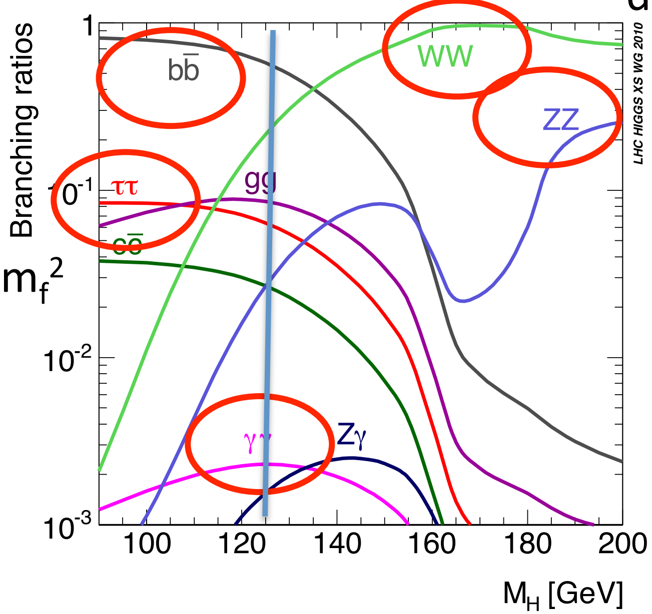
Branching Fraction & Sensitive channels

Higgs decays into heavy particles:
5 important decay channels:

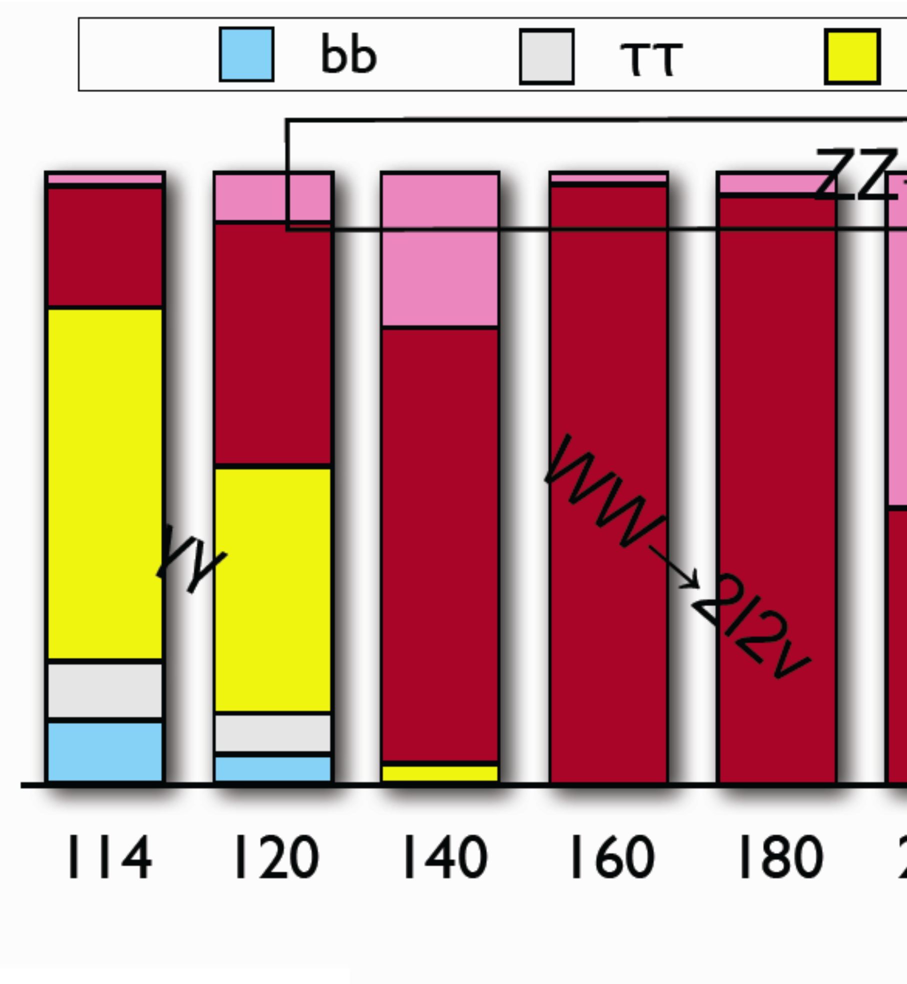
decay width

$\Gamma \sim m_h^3$

$\Gamma \sim m_h m_f^2$



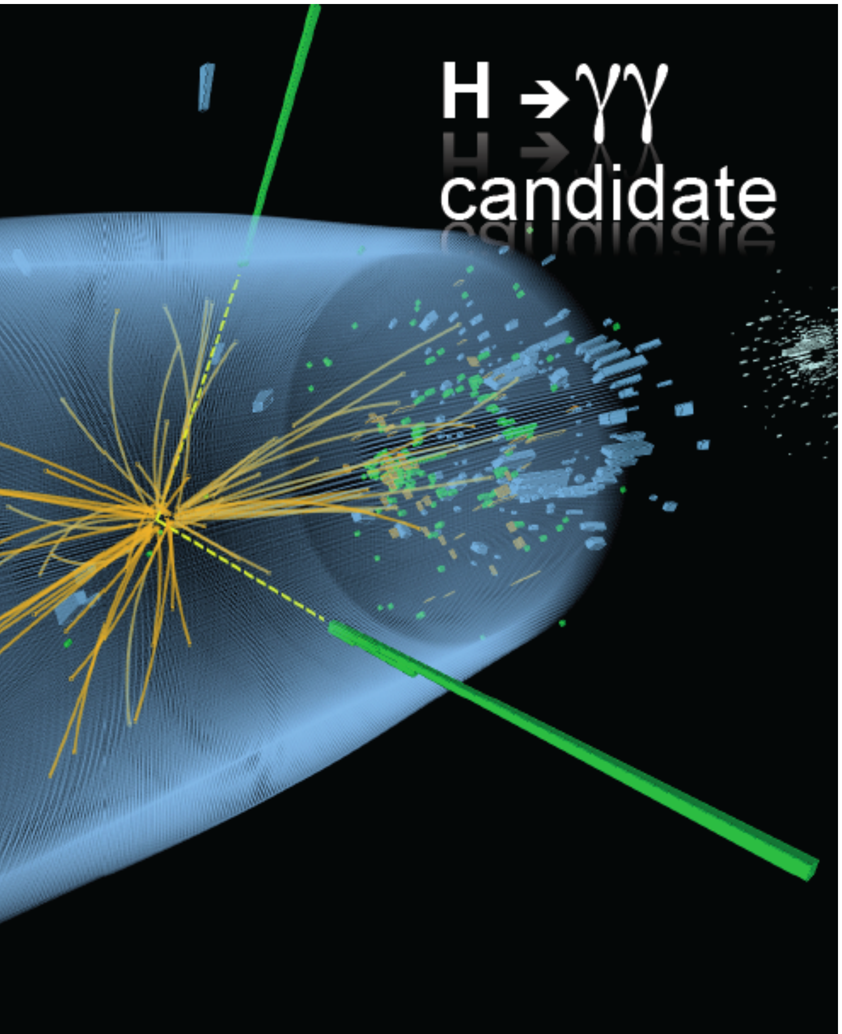
Sensitivity : BG is taken into account
γγ ~ WW(lνlν) > ZZ(4l) > tau > bb

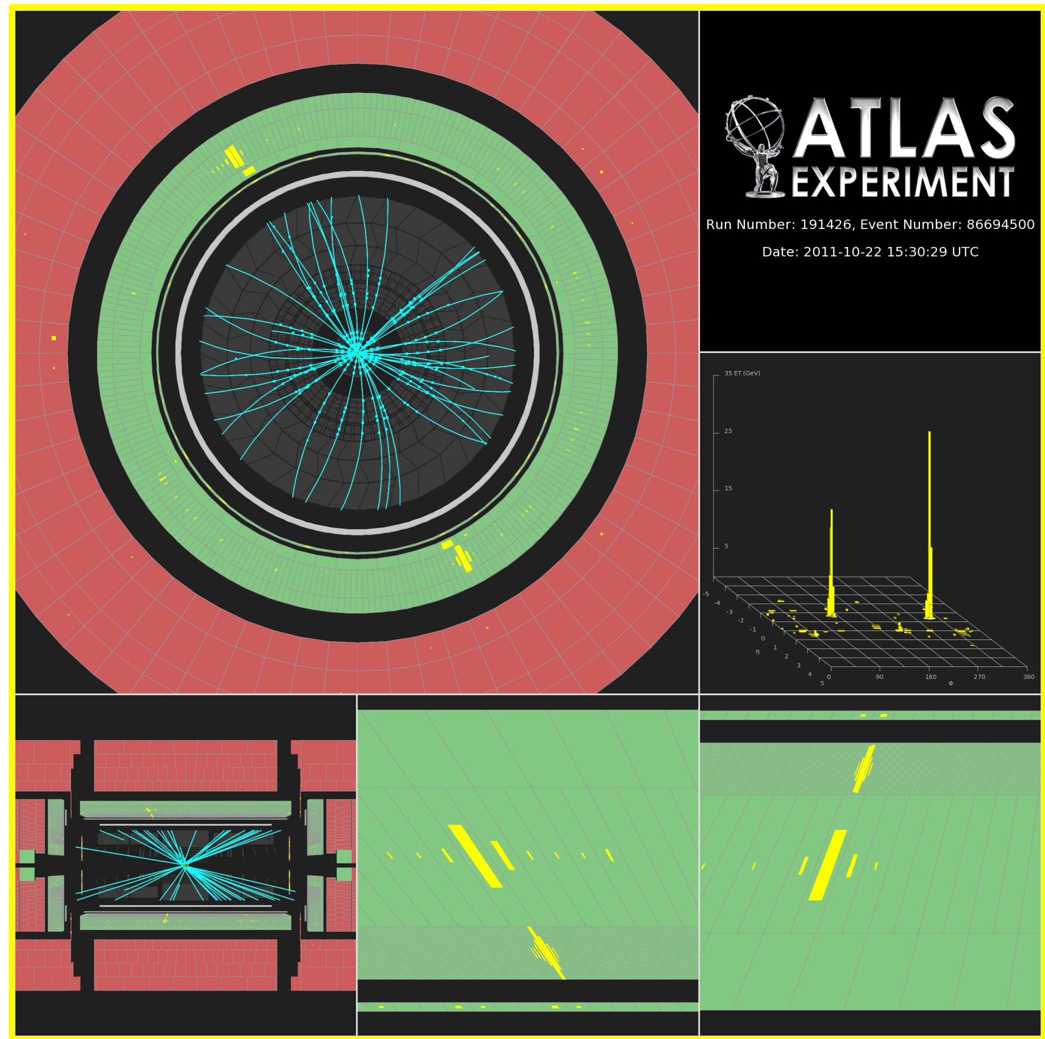


Branching Fraction @ 125GeV
bb ~ 60%
WW ~ 25%
tautau ~ 6%
ZZ ~ 3%
γγ ~ 0.2%

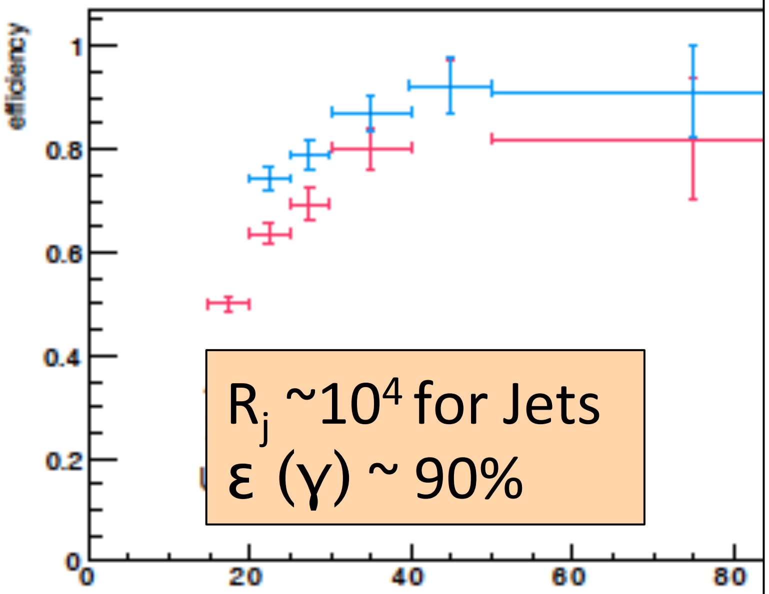
[A] H→ γγ

Let's discuss each channel.
Branching fraction is small (0.2%), but mass resolution is sharp
it is easy to distinguish signal from BG

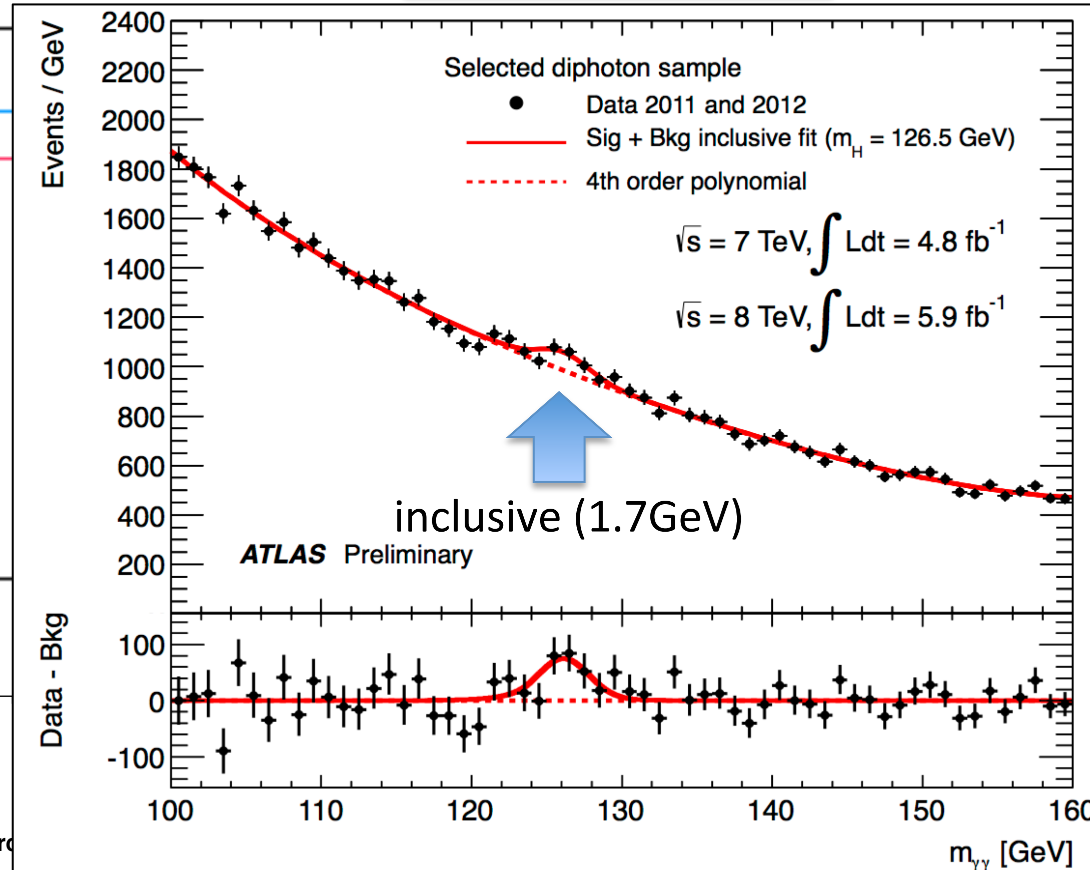


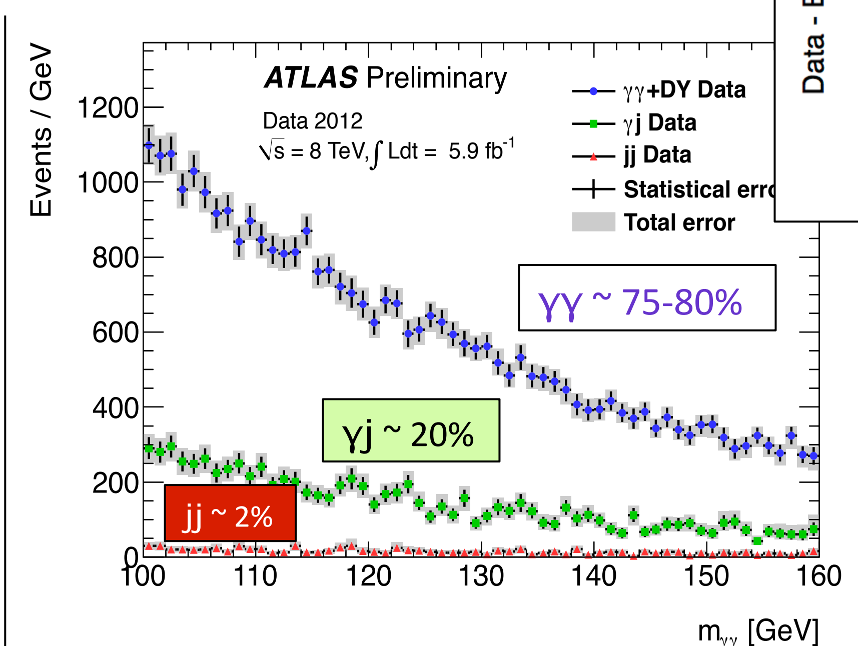


Excellent Photon ID using NN



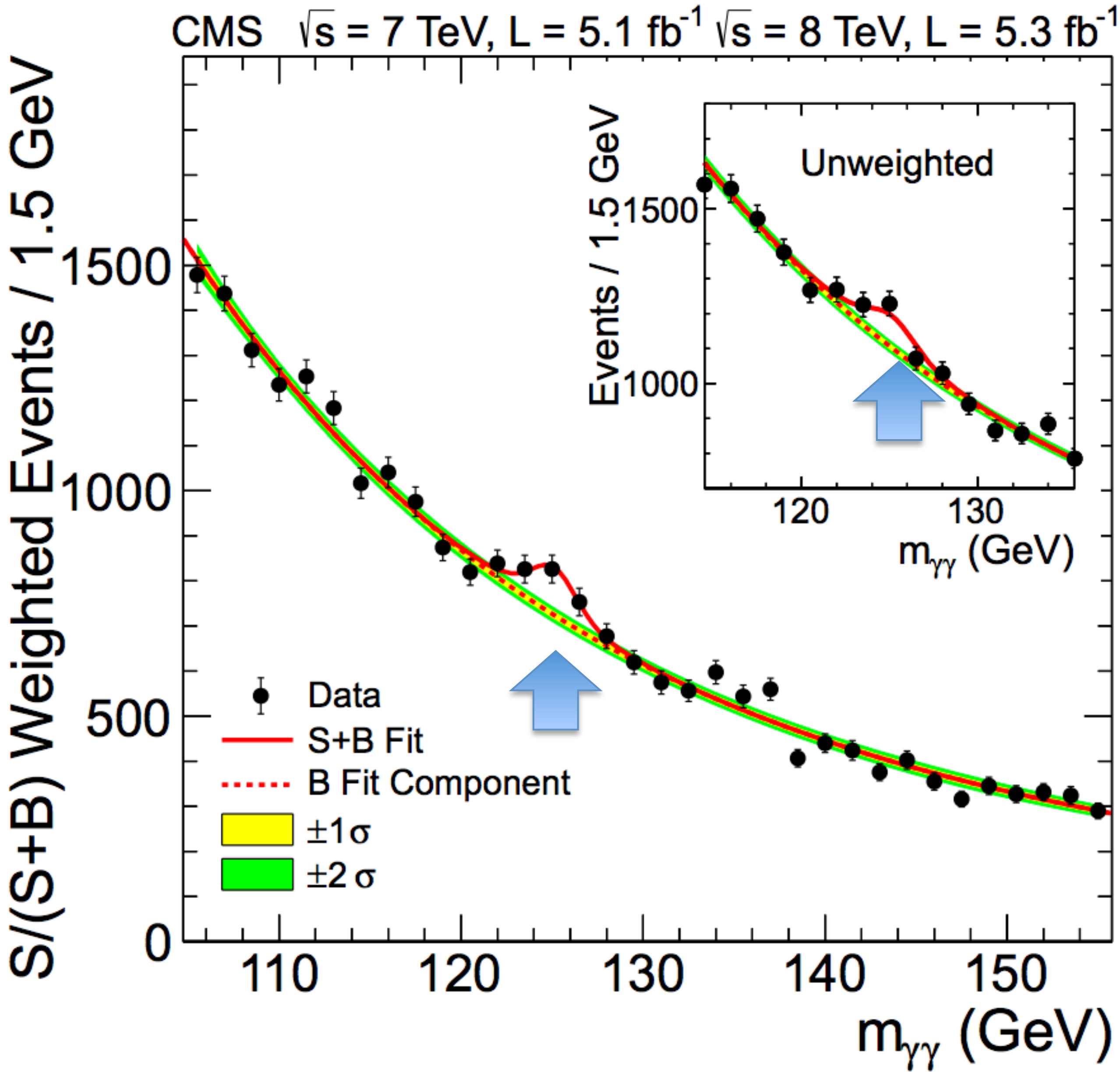
Inclusive study





Even in inclusive study
clear peak（3.5σ）is observed.

Real Photon is real BG:
irreducible background



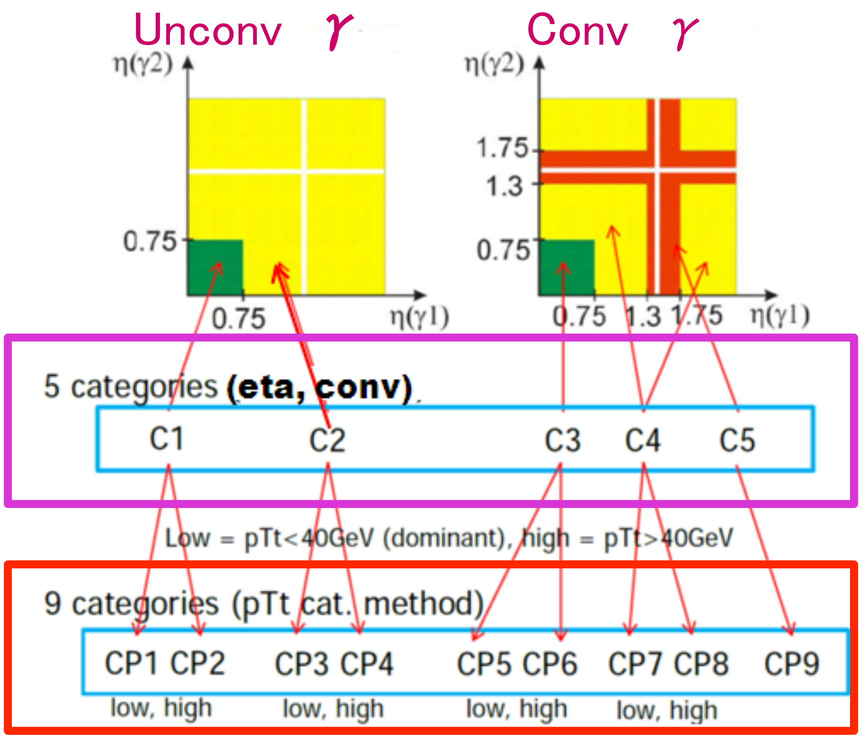
Similar Performance is obtained @ CMS;
This is weighted results.
Event in Good category are weighted;
(Category will be mentioned in next)

Mass resolution
σ=1.4GeV(2011)
σ=1.6GeV(2012)
vs σ=1.7GeV (ATLAS)

Lesson: Resolutions:
PbW04
is very good calorimeter but also careful studies are necessary for energy loss of materials in front of EM:
dE/dx
conversion: 40% of photon is converted
These are reasons why..

Selections are optimized for each category:

(1) Converted Photon or Uncoverted
(2) eta of Photons
-> These affect mass resolution

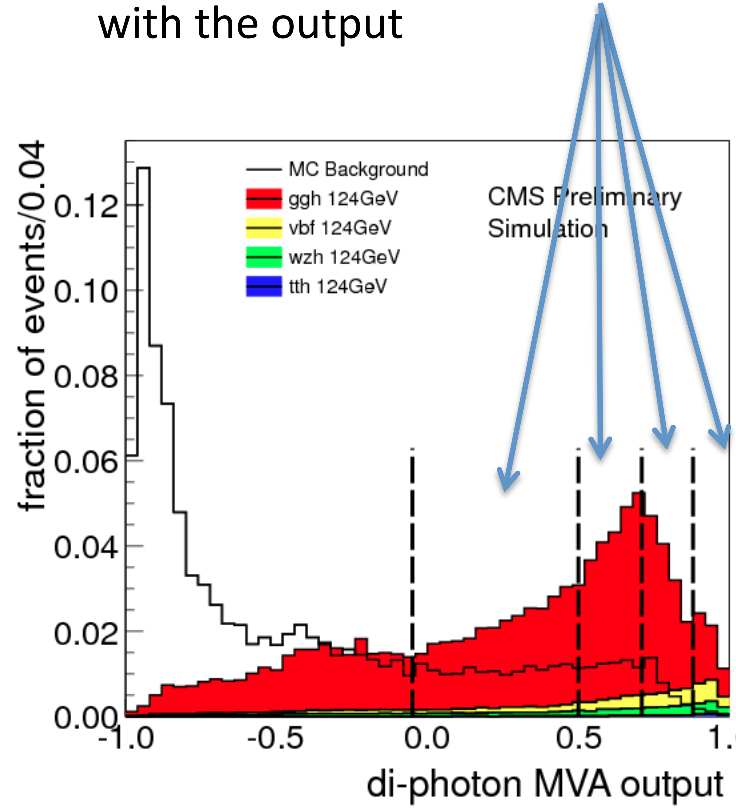


(3) Kinematics
this affect background contributions

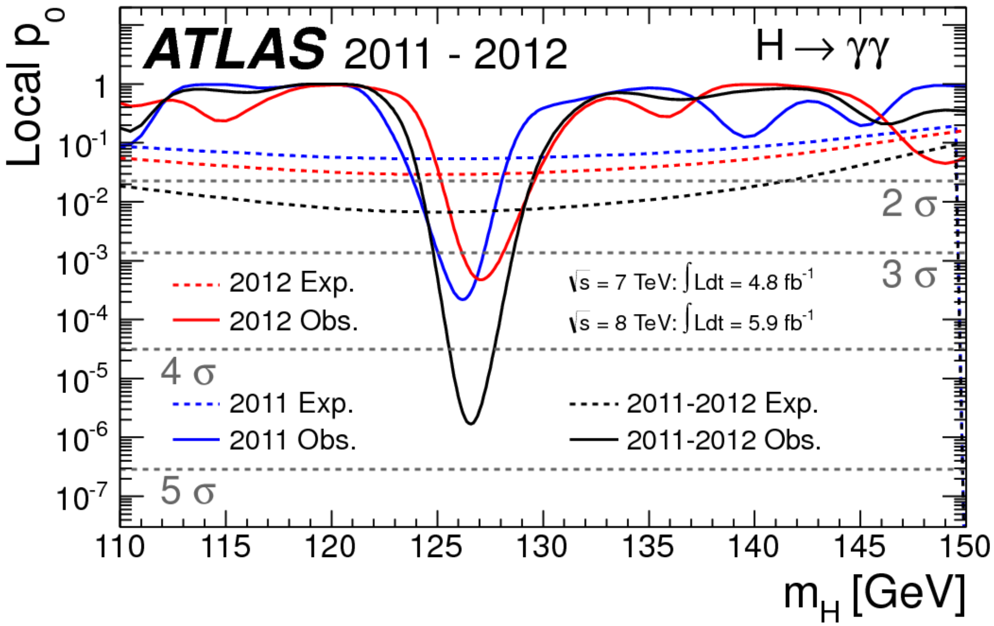
complicated!!!

sophisticated!!

CMS: MVA technique is used (variables are similar to ATLAS)
Distribution of MVA output:
Events are divided into 4 cat with the output



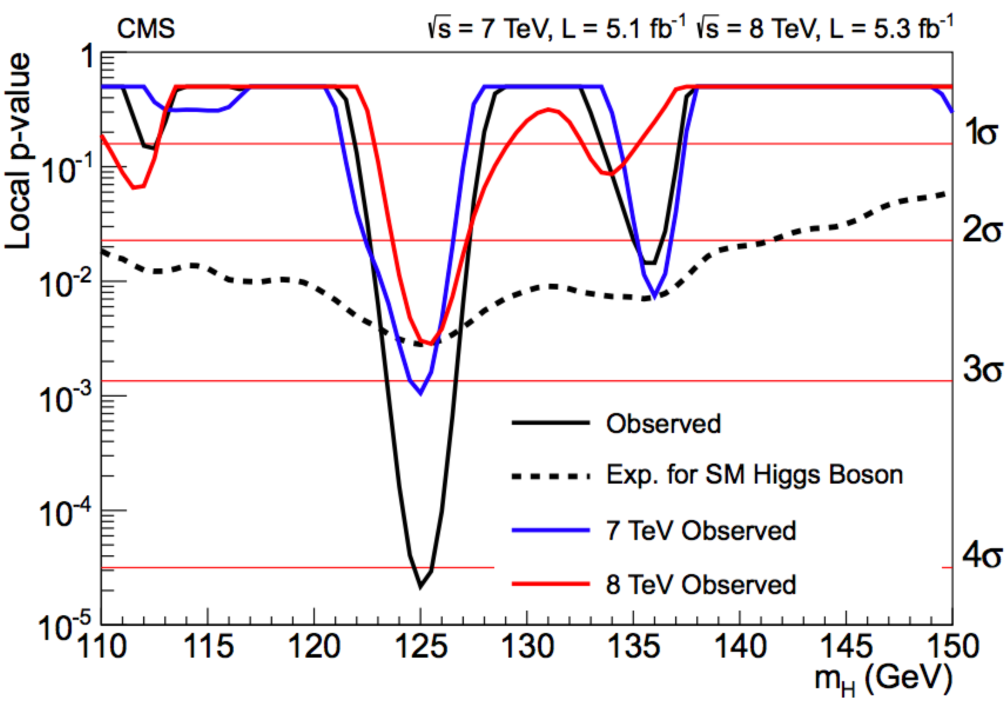
Background is estimated with read data, and significance is calculated in each category, and combined.



These show the p0 values as a function of the Higgs mass.
p0 is probability that the observed events are just background.

Both detectors have observed clear evidence around 125,6GeV

Similar significances are obtained in both detectors and both years.
This is very important point!.



136GeV small excess (**2.2σ**) observed at CMS disappears in 2012.
Just statistical fluctuation.

Lesson (Empirical)
2.7 σ

Dotted line shows the expectation of SM Higgs boson.
As you can see, the observed is higher by about factor 2.
We will discuss later.

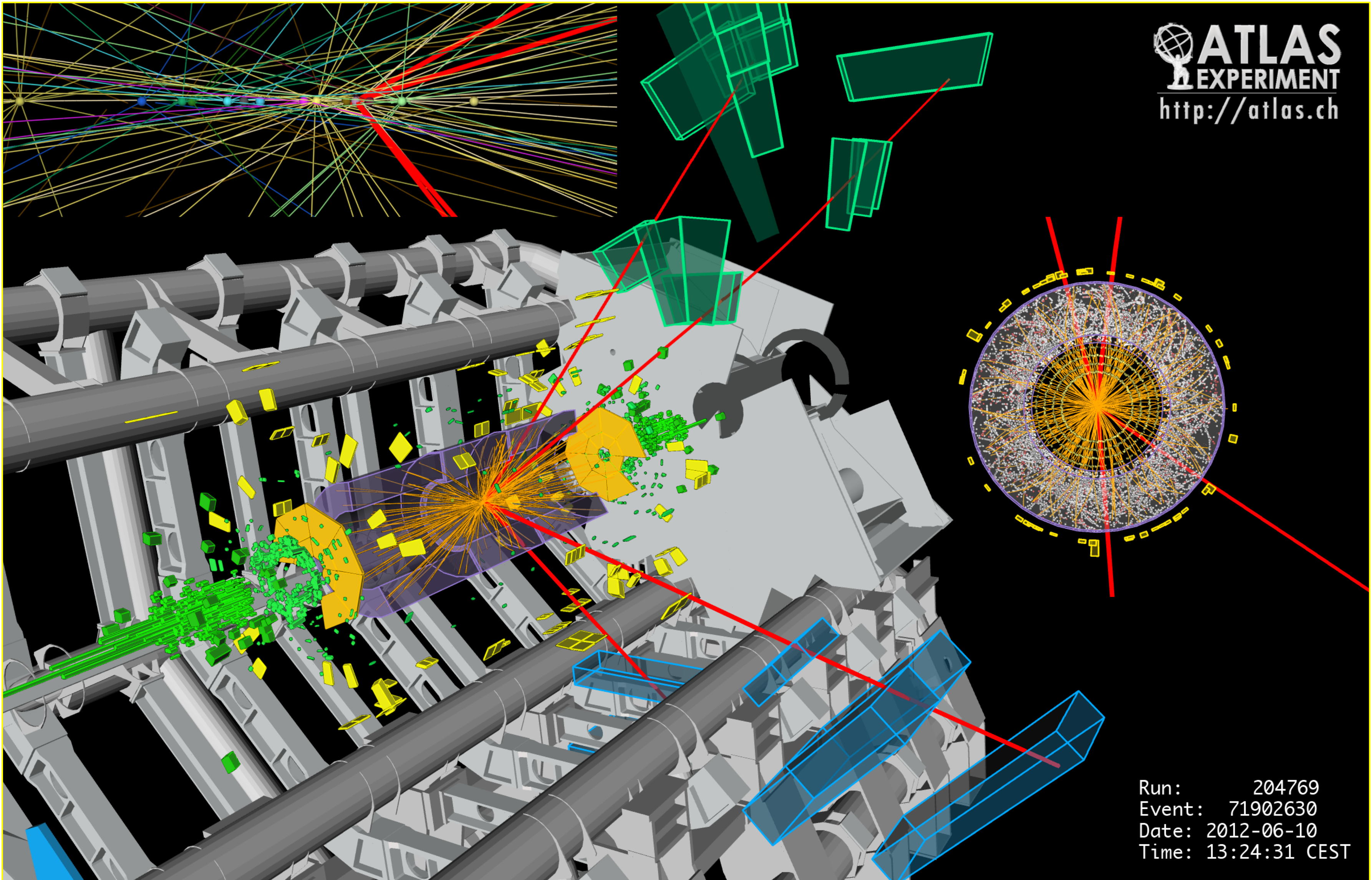
H-> 2γ : some information about spin of H

spin 1, also fermion can not decay into 2γ

It suggest that observed new boson is "scalar"

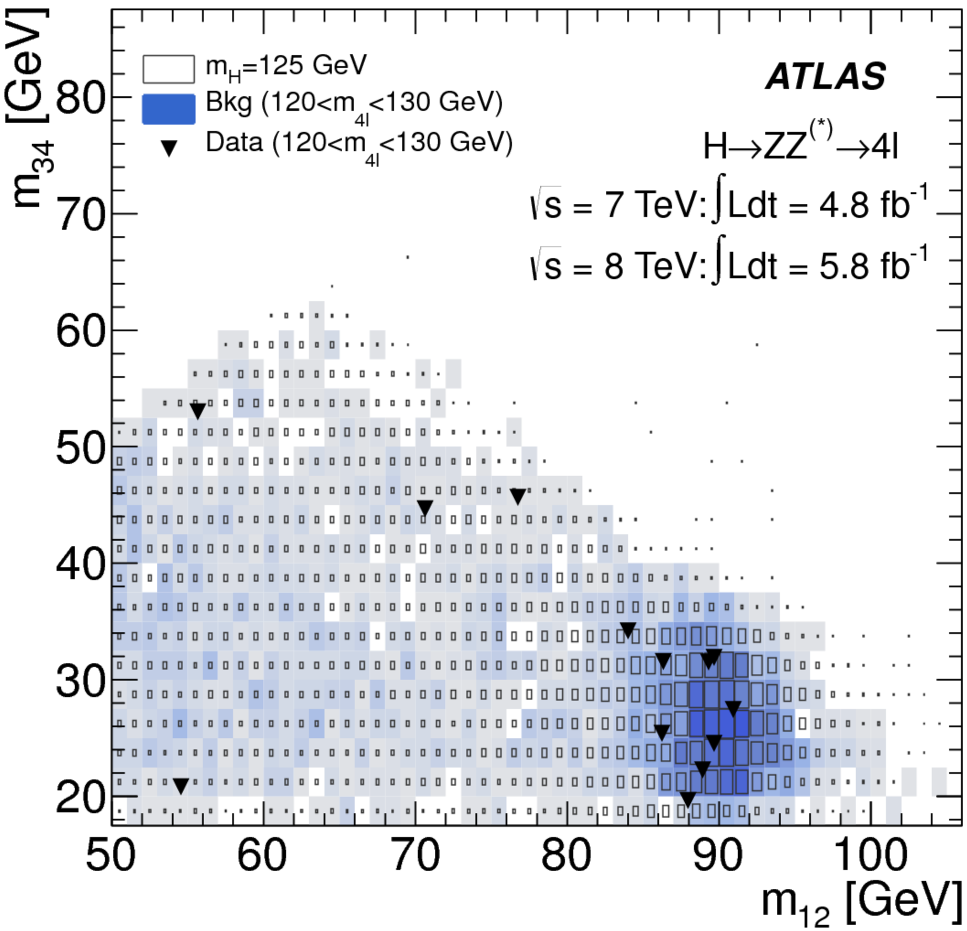
[B] H→ZZ→4lepton

4mu (mass=125GeV) PT=36.1, 47.5, 26.4, 71 .7GeV



H → On shell Z + off Shell Z* :

Breit- Wigner Resonance of Z



$$f(E) = \frac{k}{(E^2 - M^2)^2 + M^2\Gamma^2}.$$

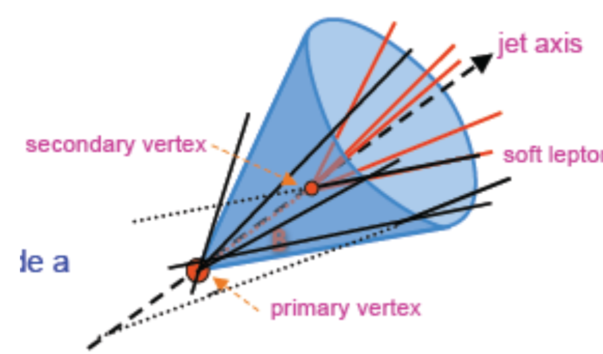
decay width of Z Γ~ 2.5GeV

double suppression on Z*Z*

Homework

Higgs decays into one real Z
|M12-Mz| < 15 GeV

off Shell state mass M34 > 15GeV
to reduce gamma* -> ll

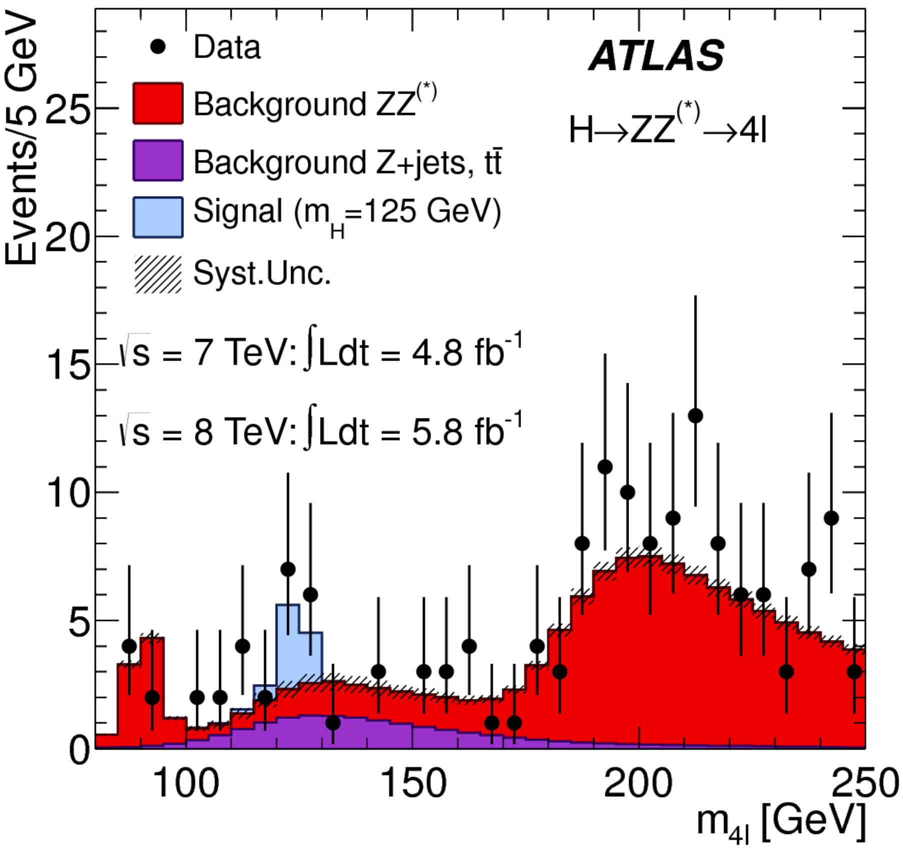


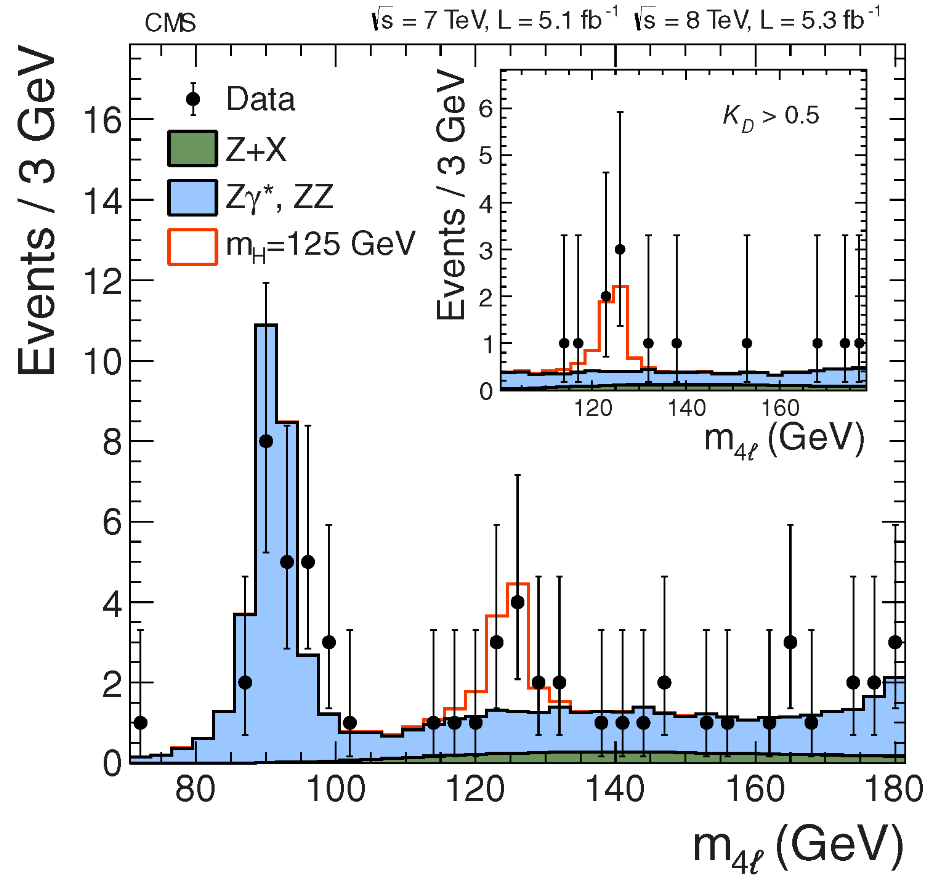
impact parameter of lepton is required to be small to reduce Zbb, tt -> bblnulnu BG

M_{4l} distributions

13 observed
BG about 5 events

12 observed
BG ∼5 events



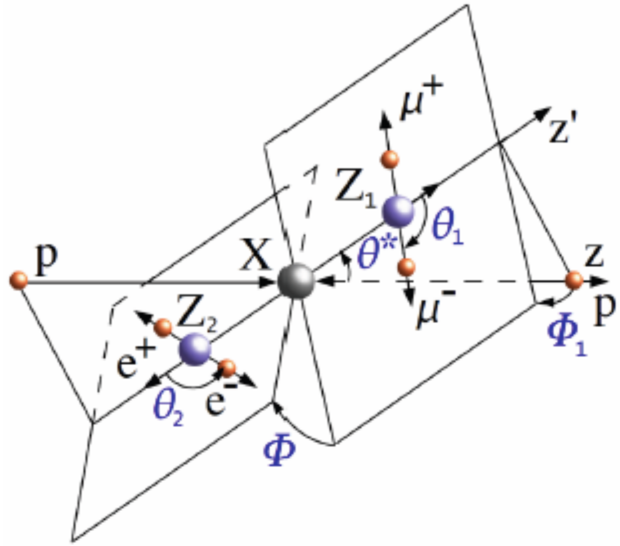


Statistic signal is small, but background contribution is also small; differ from γγ

Lesson : Important points are signal has been checked with different detector components
e,γ ~ EM calorimeter muon ~ muon chember. Careful redundancy is necessary.

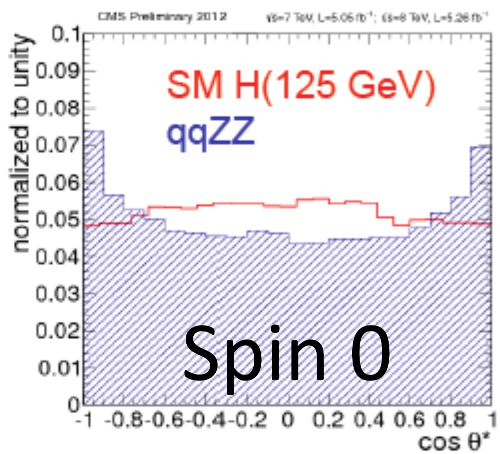
Matrix Element Likelihood Analysis:

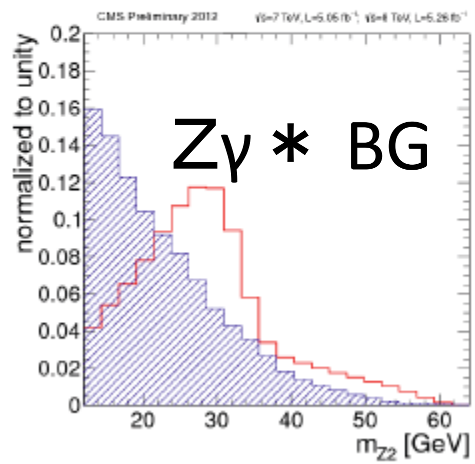
uses kinematic inputs for
signal to background discrimination
$\{m_1, m_2, \theta_1, \theta_2, \theta^*, \Phi, \Phi_1\}$

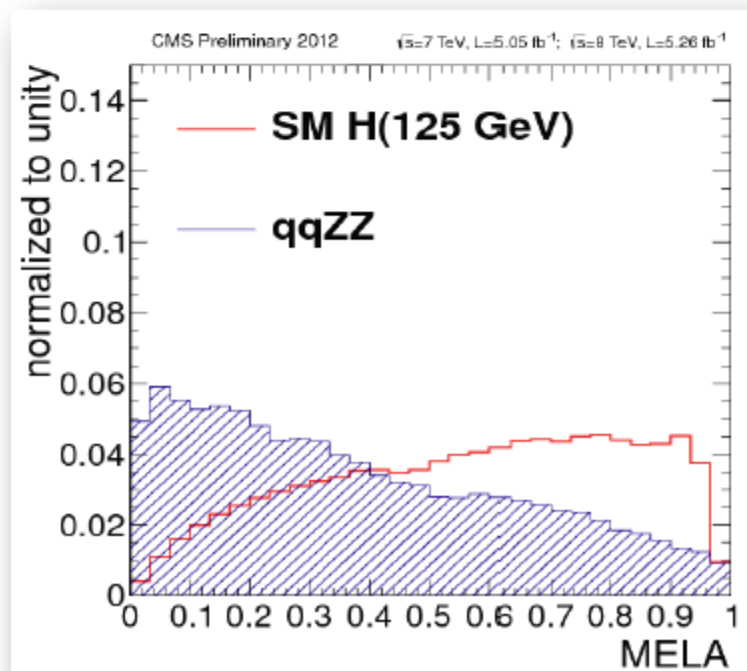


$$\text{MELA} = \left[1 + \frac{\mathcal{P}_{\text{bkg}}(m_1, m_2, \theta_1, \theta_2, \Phi, \theta^*, \Phi_1 | m_{4\ell})}{\mathcal{P}_{\text{sig}}(m_1, m_2, \theta_1, \theta_2, \Phi, \theta^*, \Phi_1 | m_{4\ell})}\right]^{-1}$$

PRD81,075022(2010) http://arxiv.org/abs/1001.3396
PRD82,013003(2010 http://arxiv.org/abs/1001.5300

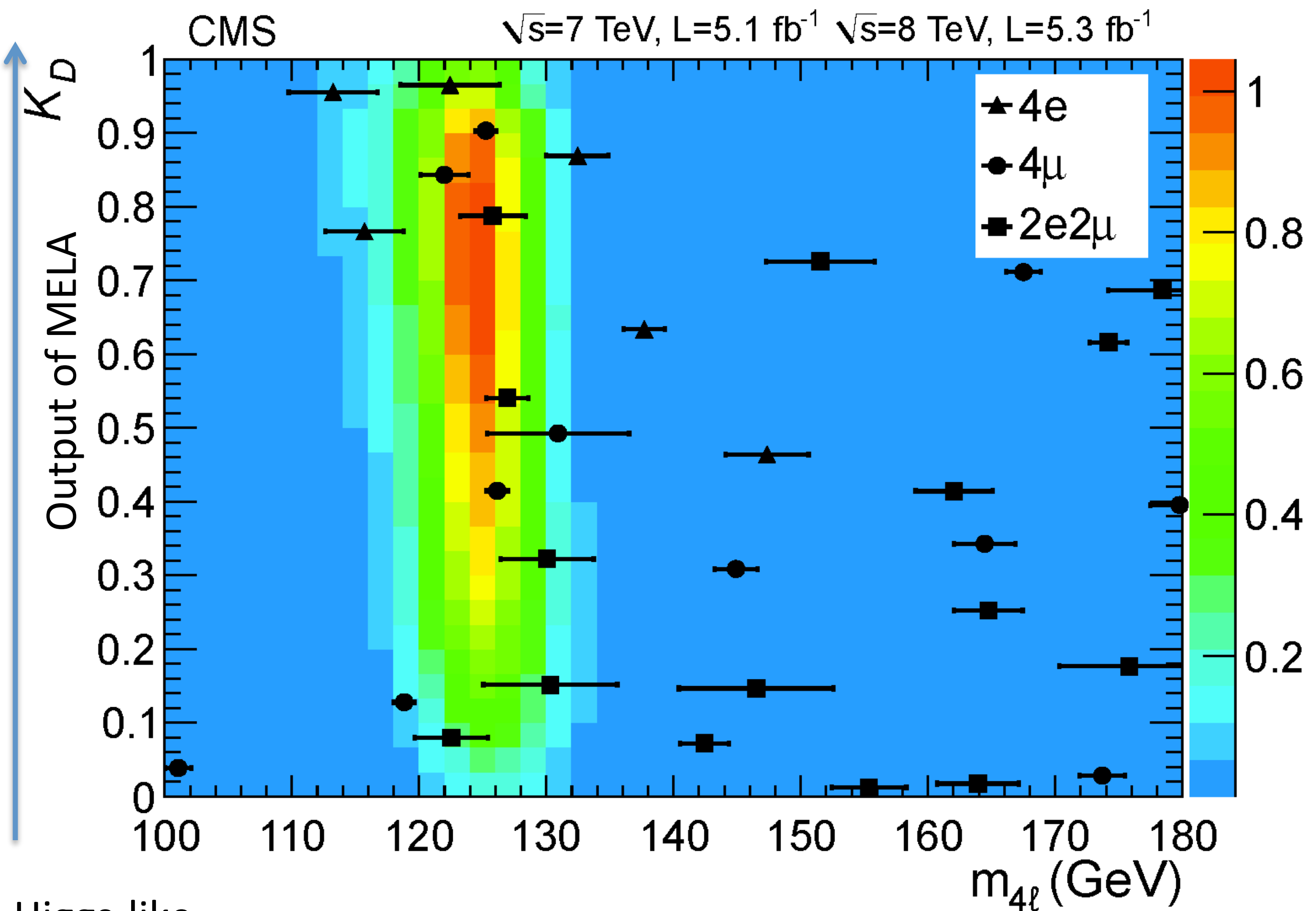






Discrimination with $m_1, m_2, \theta_1, \theta_2, \theta^*, \Phi, \Phi_1$

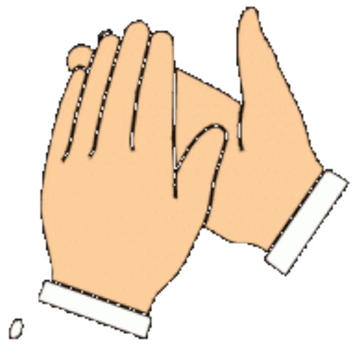
invariant masses of dilepton system, Larger is ~ Mz, softer has different distribution
Higgs is scalar, 2 Z distribution is spherical



Lesson
Lepton can be assigned directly to hard process
We can use them safely:
Jets are different, since we can not say this jet comes from hard-processes or ISR/FSR

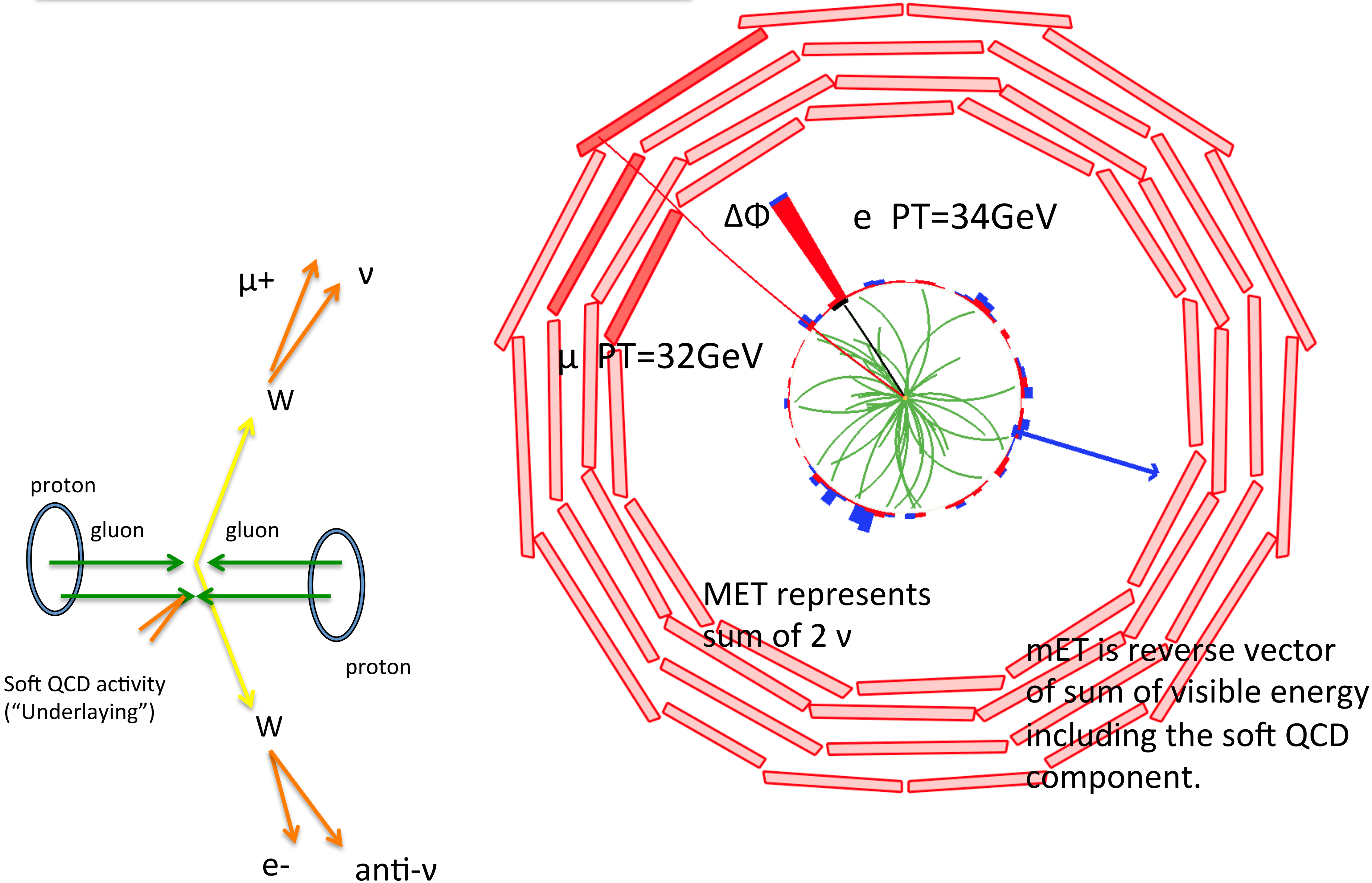
Higgs-like
Events @ 125GeV are enhanced:

Nice Idea !



We can study the property of the new boson (J^P) using this channel / method.

[C] H→WW→lνlν



μ+
ν
W
proton
gluon
gluon
proton
Soft QCD activity
(“Underlaying”)
W
e-
anti-ν
ΔΦ
e PT=34GeV
μ PT=32GeV
MET represents
sum of 2 ν
mET is reverse vector
of sum of visible energy
including the soft QCD
component.

is basic topology

2lepton + mET + (Jets) : Events are categorized with number of the jets: Different production process of H, different BG processes

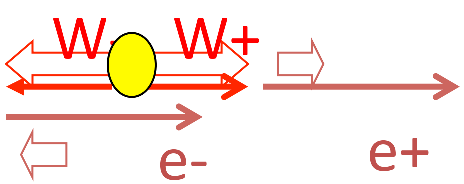
- 0 jet analysis (GF) dominate BG: WW
- 1jet(with b-jet veto) dominate BG: tt, WW (Next page)
- 2jet(VBF) dominant BG: tt

Then two important variables are calculated:

ΔΦ(ll) Azimuthal angle between dilepton

M_T(Transverse mass)

Higgs Spin0



Higgs spin 0
Spin of W is opposite
Since Parity is 100% violated in leptonic decay of W, ΔΦ becomes smaller.

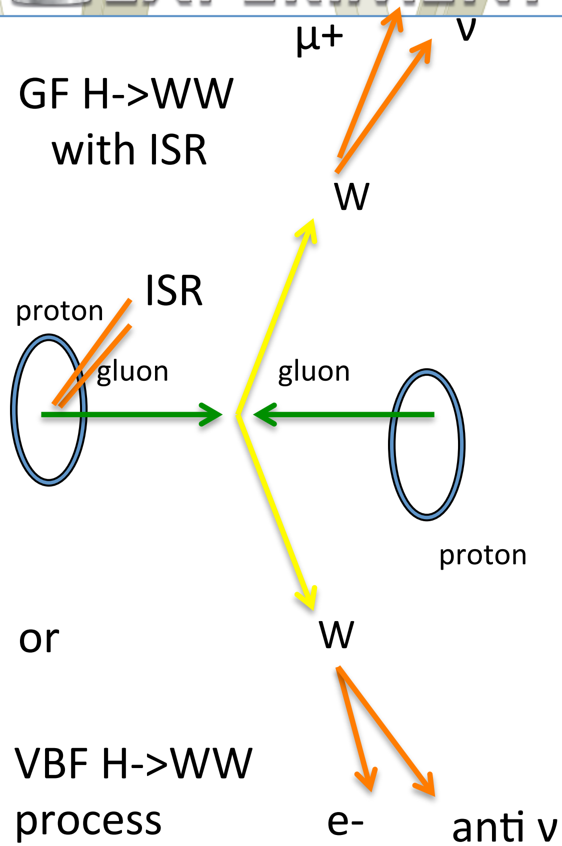
Since We do not have information of Pz of neutrinos, we can not calculate invariant mass:
Transverse mass is analogy of W(->l nu)

$$M_T^2 = (E_T^{ll} + E_T^{missing})^2 - (P_T^{ll} + P_T^{missing})^2$$

$M_T <$ Mhiggs (MT=MH at Pz=0)

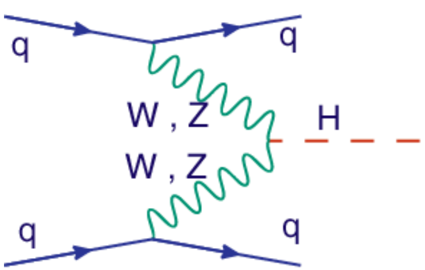
Candidate event in 1 jet category

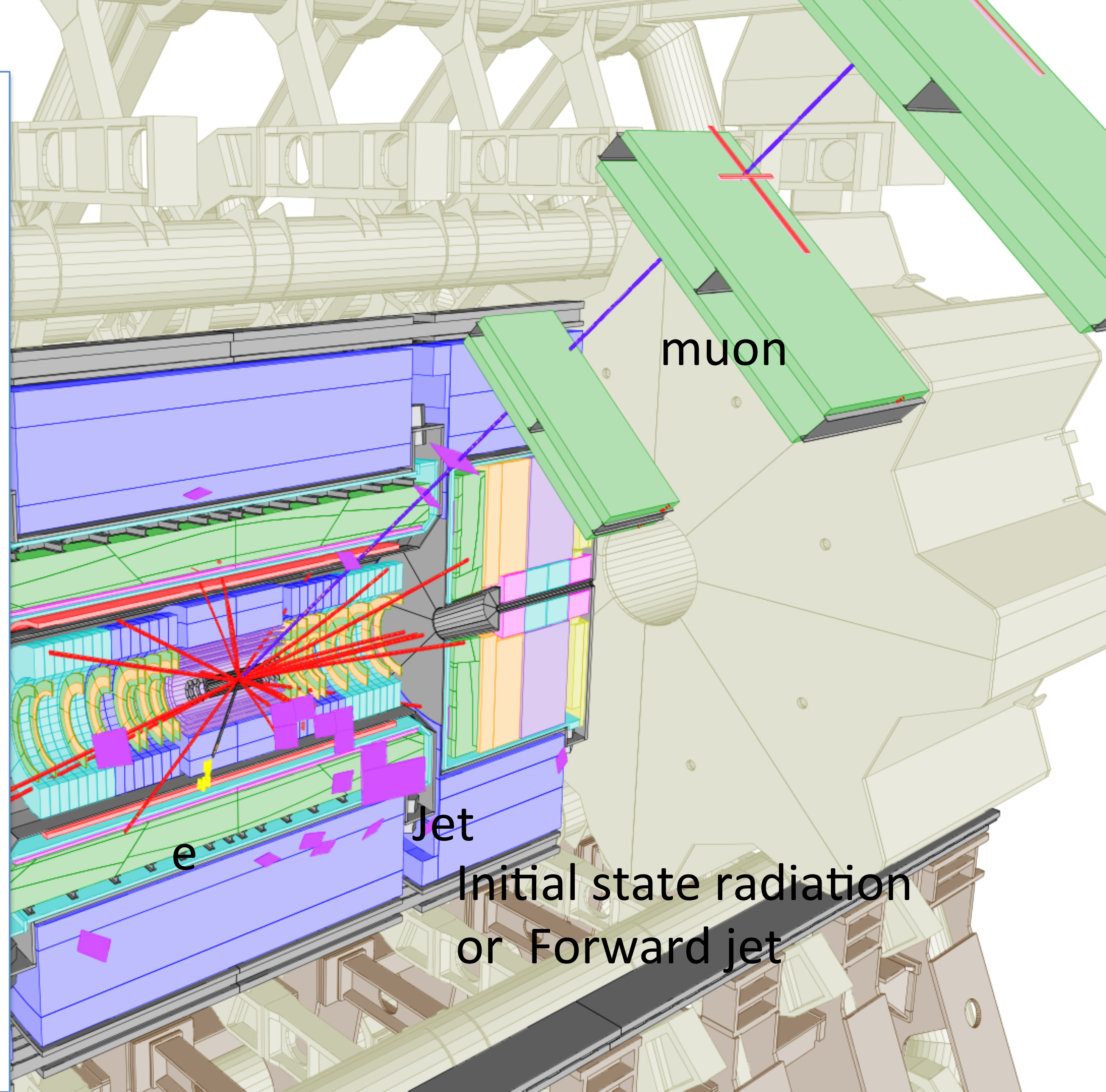
GF H->WW
with ISR



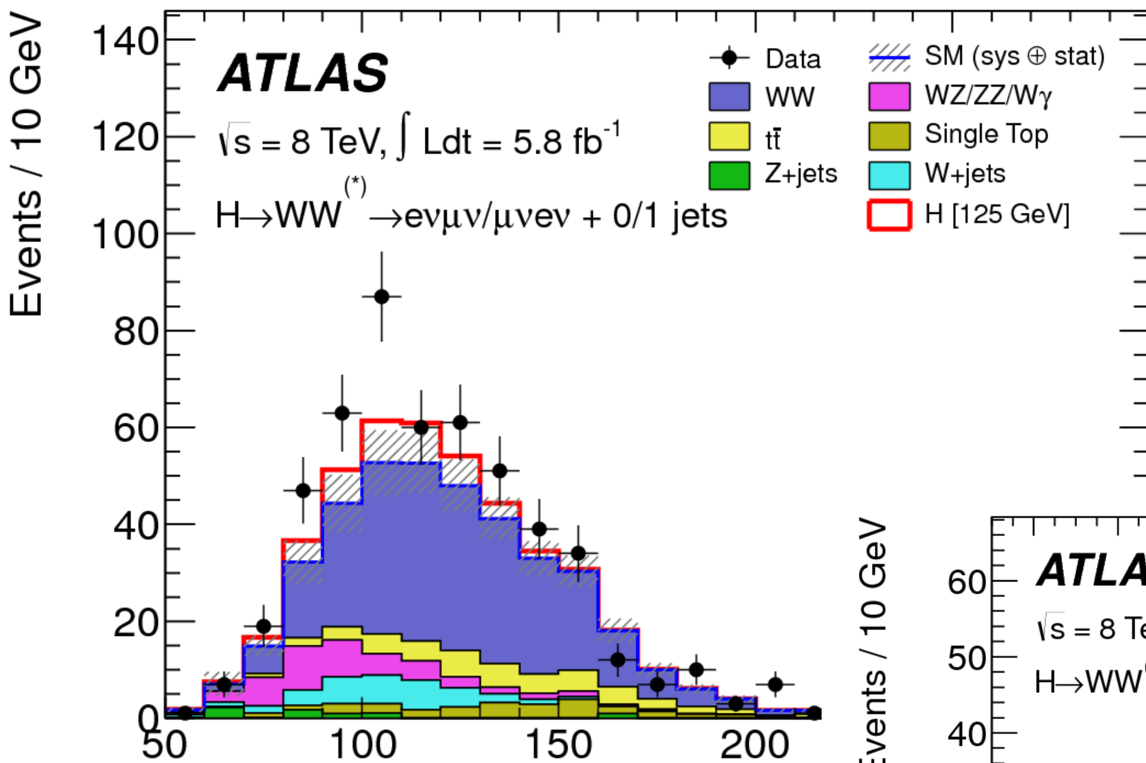
or

VBF H->WW
process
one forward jet missing

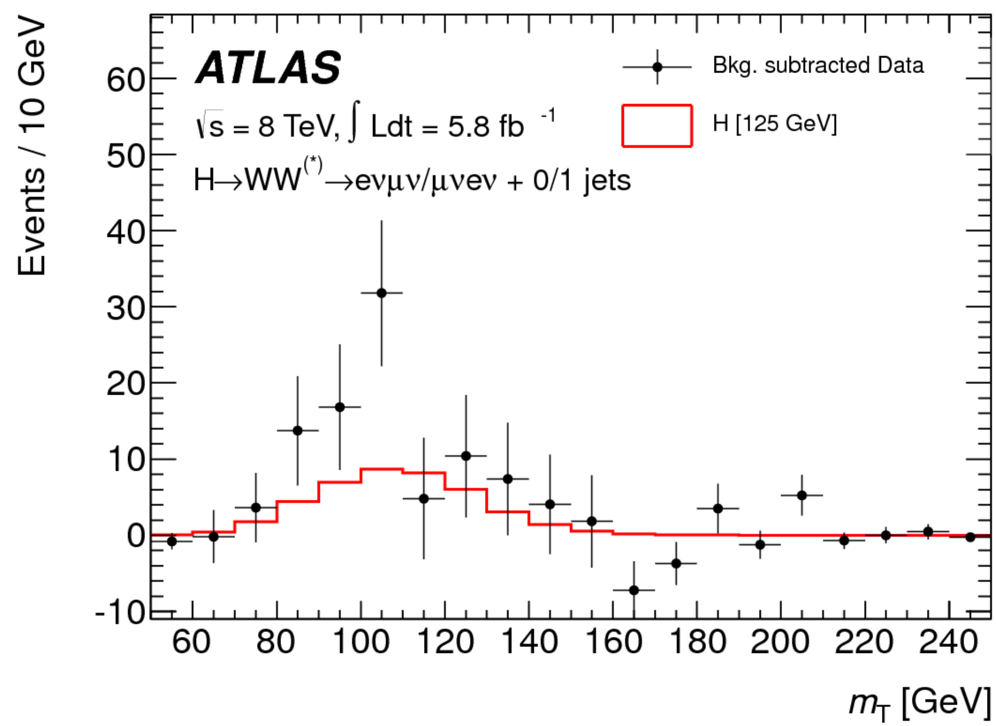




Transverse Mass distributions: 0/1 jets modes, 2 jet mode is still limited in stat.

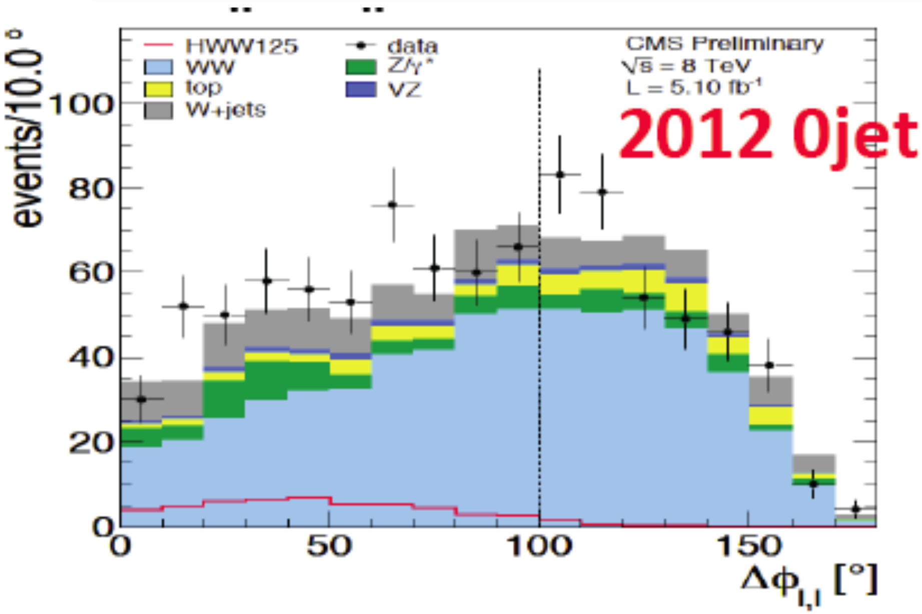


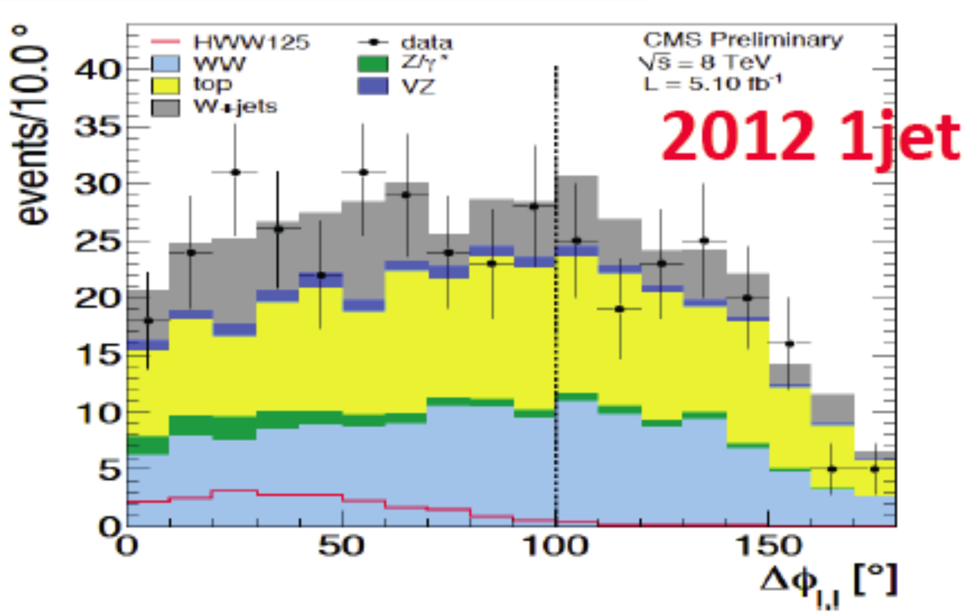
Main BG os WW and top:
These are estimated with MC, but it is normalized with real data.
W+jet also contribute but small, (jet is mis-IDas lepton): This fake lepton BG is estimated with data



BG is subtracted: The rad histogram shows the expected signal:
2.8σexcess is observed
Broad edge is related to Higgs mass
Not good sensitive to Mh

CMS 8TeV Results (Not so easy to add 7+8 TeV since pileup different, ECM different ->)





	H→WW	SM WW	WZ/ZZ/Z+jets	Top	W+jets	Wγ*	All bkg	data
0jet eμ	23.9	87.6	2.2	9.3	19.1	6.0	124.2±12.4	158
0jet ee,μμ	14.9	60.4	37.7	1.9	10.8	4.6	115.5±15.0	123
1jet eμ	10.3	19.5	2.4	22.3	11.7	5.9	61.7	54
1jet ee,μμ	4.4	9.7	8.7	9.5	3.9	1.3	33.1	43

small excess 1.5σ (2012 Only)

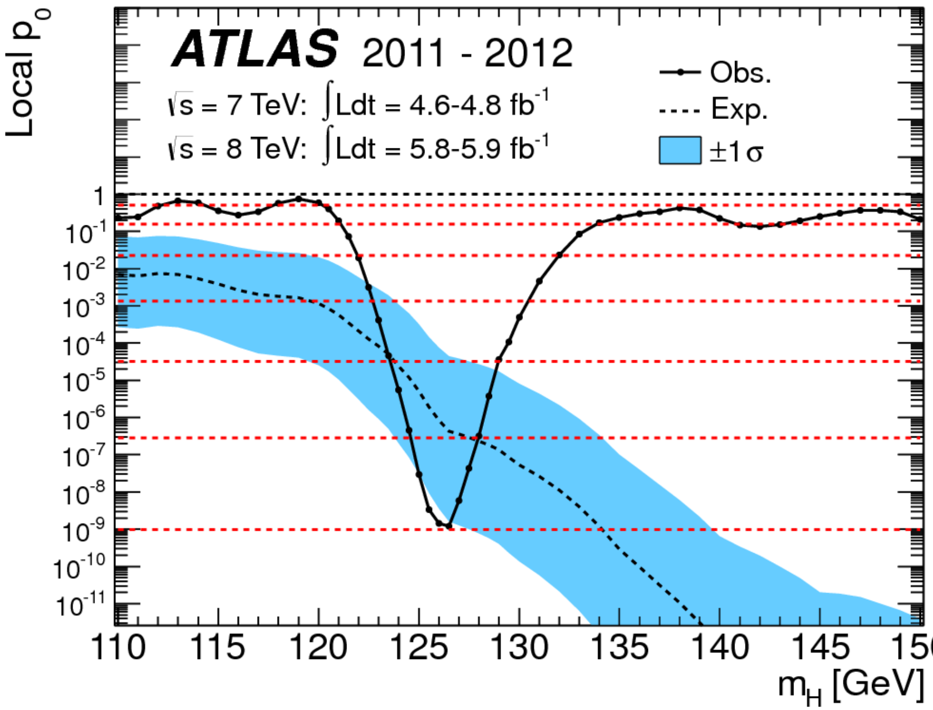
Study Status is summarized here:

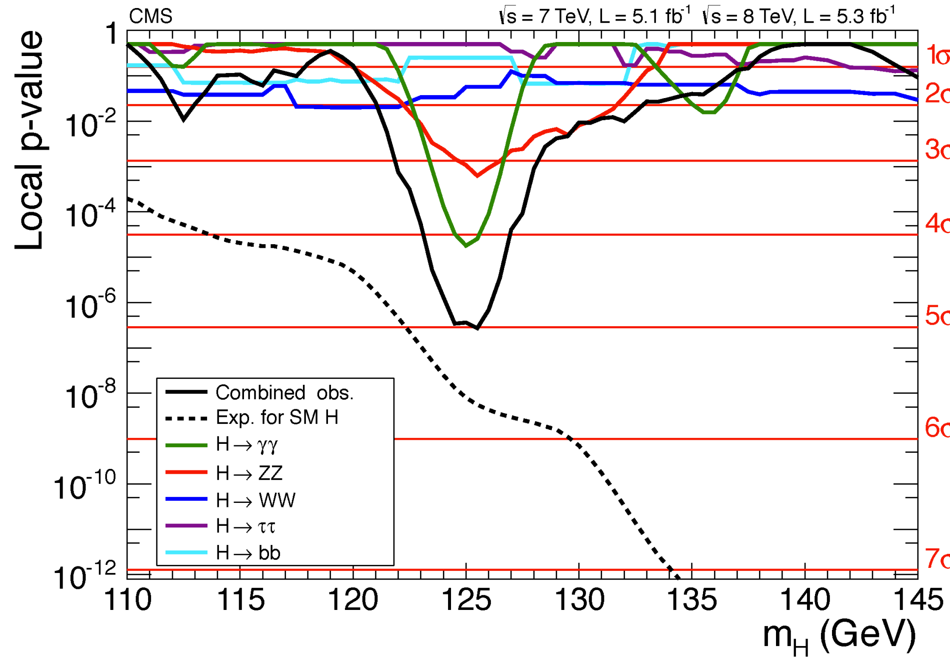
Channel	m_H range (GeV)	L_{2011} (fb^{-1})		L_{2012} (fb^{-1})		ggH		VBF		VH		ttH	
		A	C	A	C	A	C	A	C	A	C	A	C
$H \to \gamma\gamma$	110-150	4.8	5.1	5.9	5.3	√	√	√	√	-	-	-	-
$H \to \tau^+\tau^-$	110-140	4.7	5.1	-	5.0	√	√	√	√	√	√	√	-
$H \to b\bar{b}$	110-130	4.6	5.1	-	5.0	-	-	-	-	√	√	-	√
$H \to ZZ^{(*)} \to \ell^+\ell^-\ell^+\ell^-$	110-600	4.8	5.1	5.8	5.3	√	√	-	-	-	-	-	-
$H \to WW^{(*)} \to \ell^+\nu\ell^-\bar{\nu}$	110-600	4.7	4.7	5.8	5.3	√	√	√	√	-	√	-	-
$H \to ZZ \to \ell^+\ell^-\nu\bar{\nu}$	200-600	4.8	4.7	-	-	√	√	√	√	-	-	-	-
$H \to ZZ \to \ell^+\ell^- q\bar{q}$	130-600	4.8	4.7	-	-	√	√	√	√	-	-	-	-
$H \to WW \to \ell\nu q\bar{q}'$	300-600	4.8	4.7	-	-	√	√	√	√	√	-	-	-

Sensitive channel for discovery

combination

ATLAS	126.0	±0.4 ±0.4	GeV
CMS	125.3	±0.4 ±0.5	GeV





	Obs.	Exp.	Significance
ATLAS	6σ	5σ	
CMS	5σ	5.5σ	

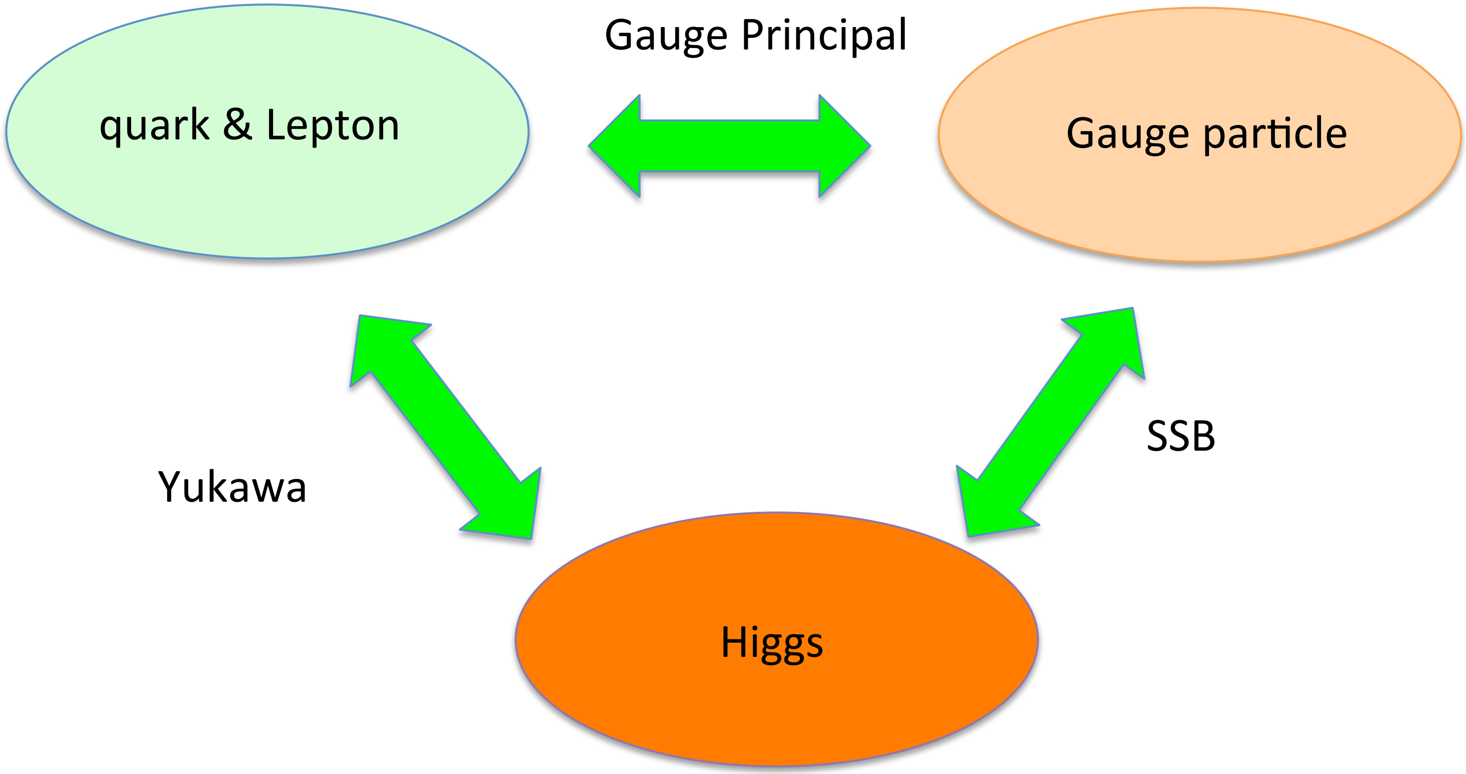
"New Boson is discovered, which is consistent with the SM Higgs boson:

Systematic error on mass is absolute calibration of EM calorimeters. (uncertainties of energy loss in materials)

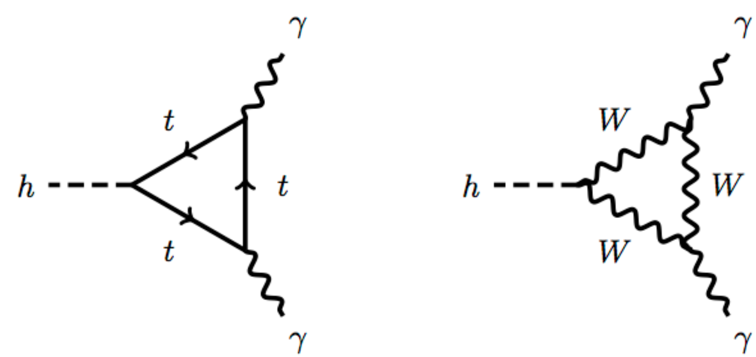
Dramatic !! 4th July

"We have a discovery – we have observed a new particle consistent with a Higgs boson. But which one? **That remains open**.

What we have to do!!!



(1) Different mechanize works & Yukawa coupling is arbitrary
(2) Coupling for down type are suppressed in SUSY with large tanβ
(3) various diagram contributes to H-> γγ
If new particle exists, also contribute



Summary of measurement

SM Higgs boson (H~126GeV)

Decay modes

Production modes

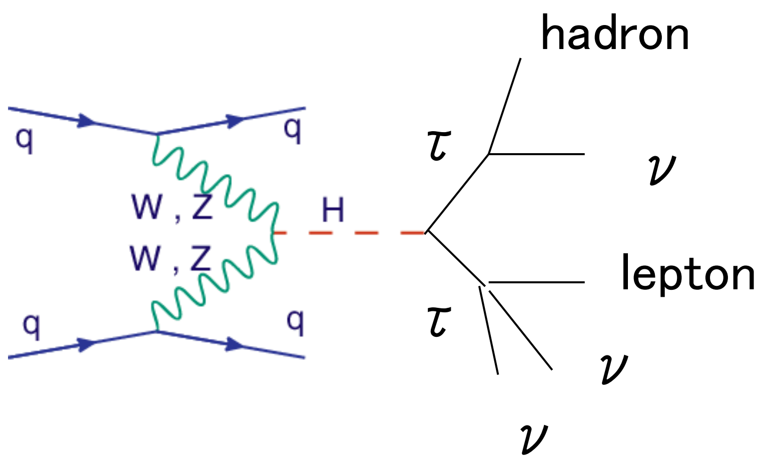
	bb	$\tau\ \tau$	$\gamma\ \gamma$	WW	ZZ
gg→H	×	×	Discovery Mass Yt spin0	Discovery Yt spin 0	Discovery Yt mass spin, CP
VBF	×	Y_τ	Discovery coupling	coupling spin0	mass
ttH	$Y_t\ Y_b$	×	high L	high L	------
WH	Y_b	×	------	------	------

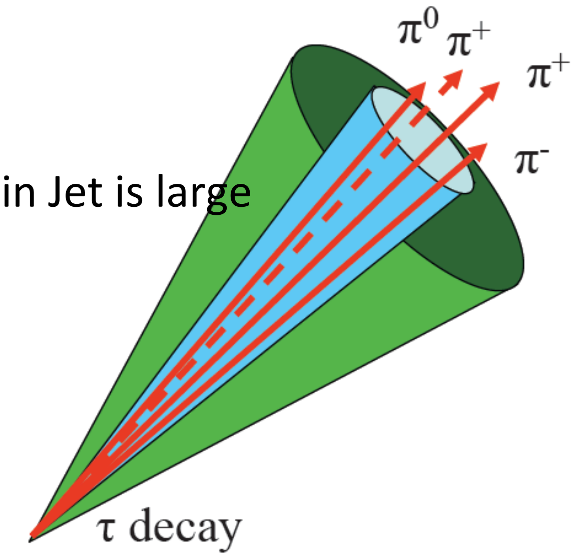
× : BG too high ------: σ ＊ Br too small

we can measure couplings and mass

[D] H→ ττ

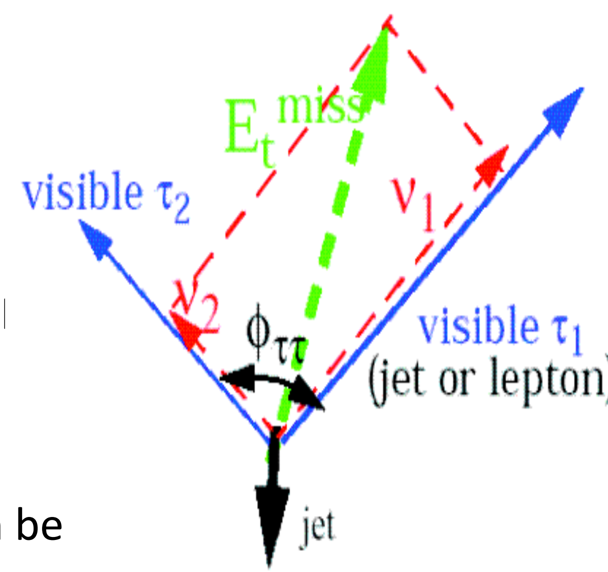
tau-jet
- 1,3 prong
- narrow jet
- EM component in Jet is large since π0→γγ



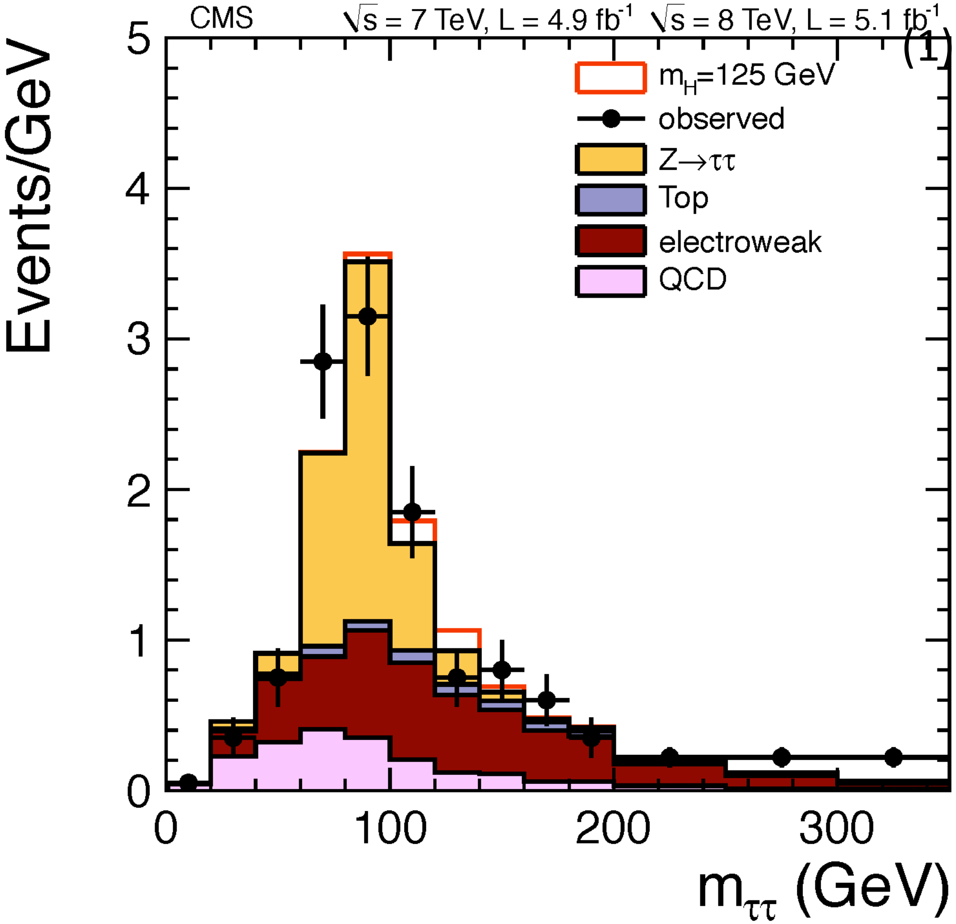


tau 34% leptonic decay

one tau decays hadronic decay HL mode
both leptonic LL mode
both Hadronic is also available with “hadronic tau trigger” H

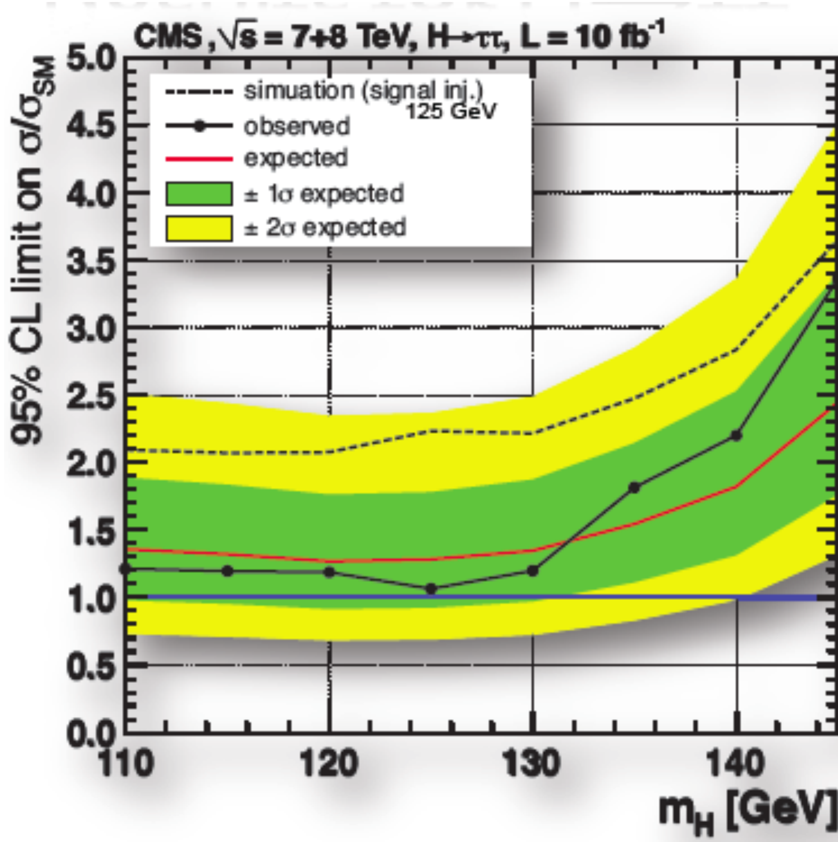


Directions of ν is the same (close to) visible objects,
We can estimate ν momentum with mET -> Higgs mass can be reconstructed



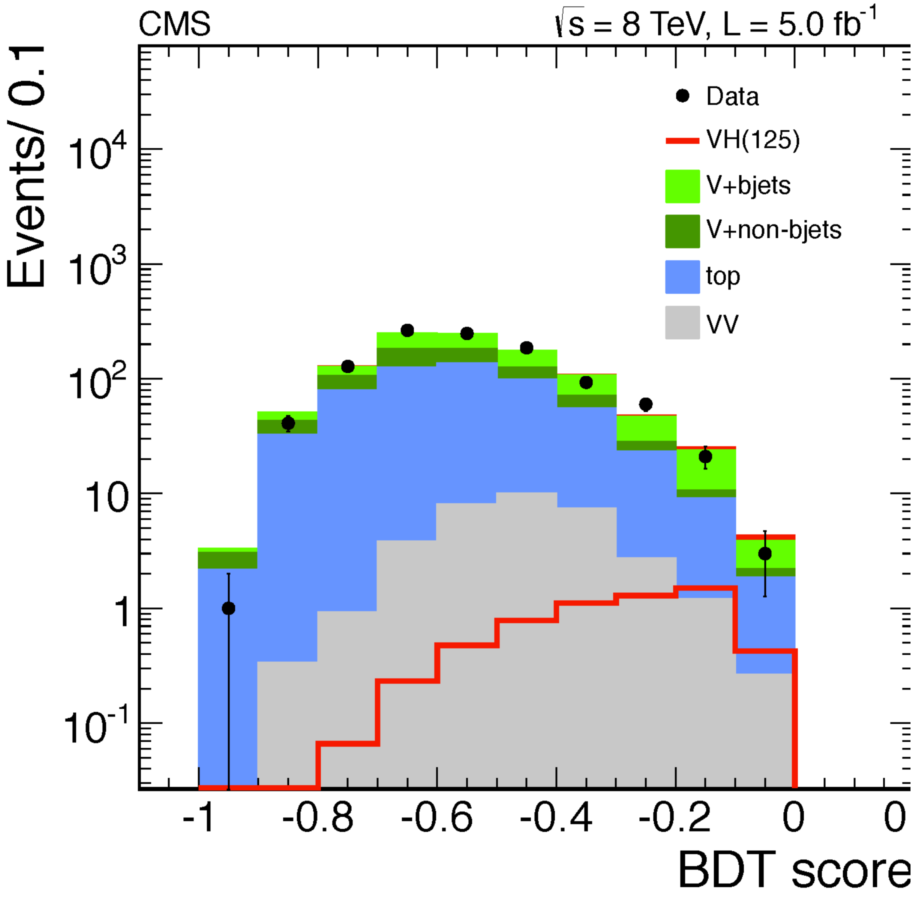
Z->ττ, W+jets(fake tau) are BG

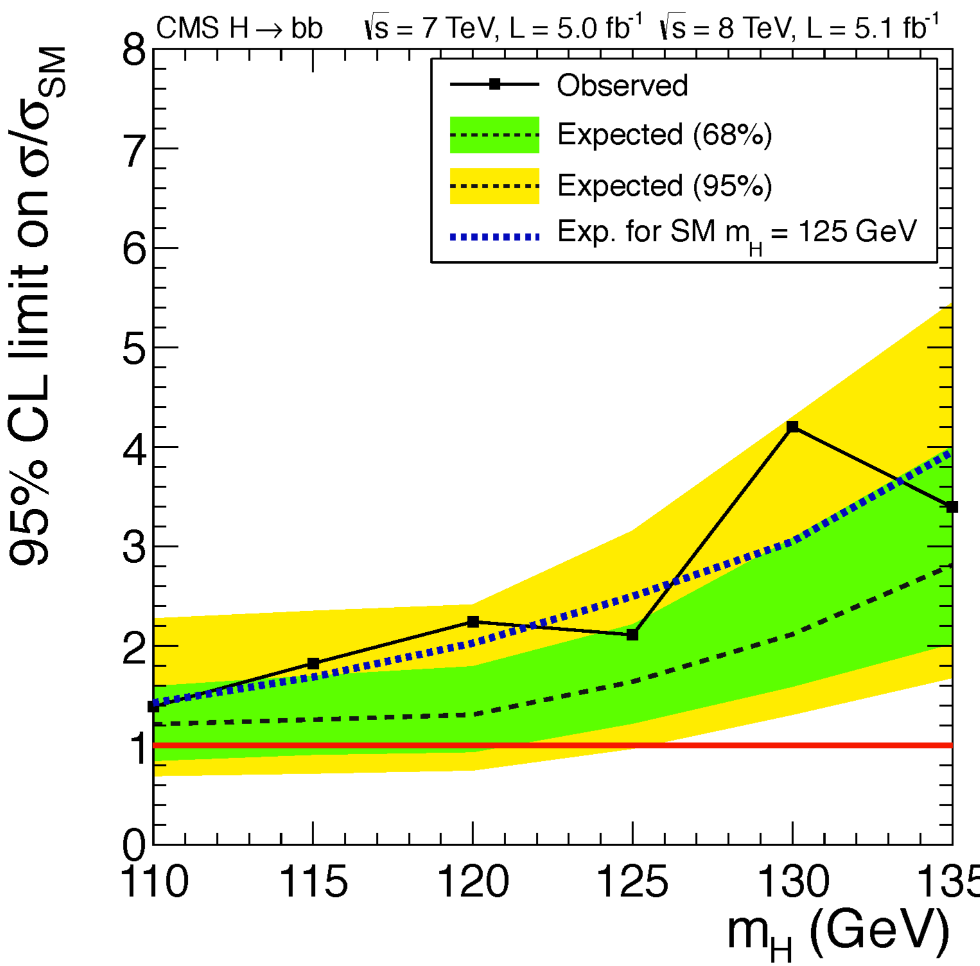
Sensitivity is still not enough
Need luminosity should be checked:
In MSSM (large tanβ case)
This coupling is suppressed

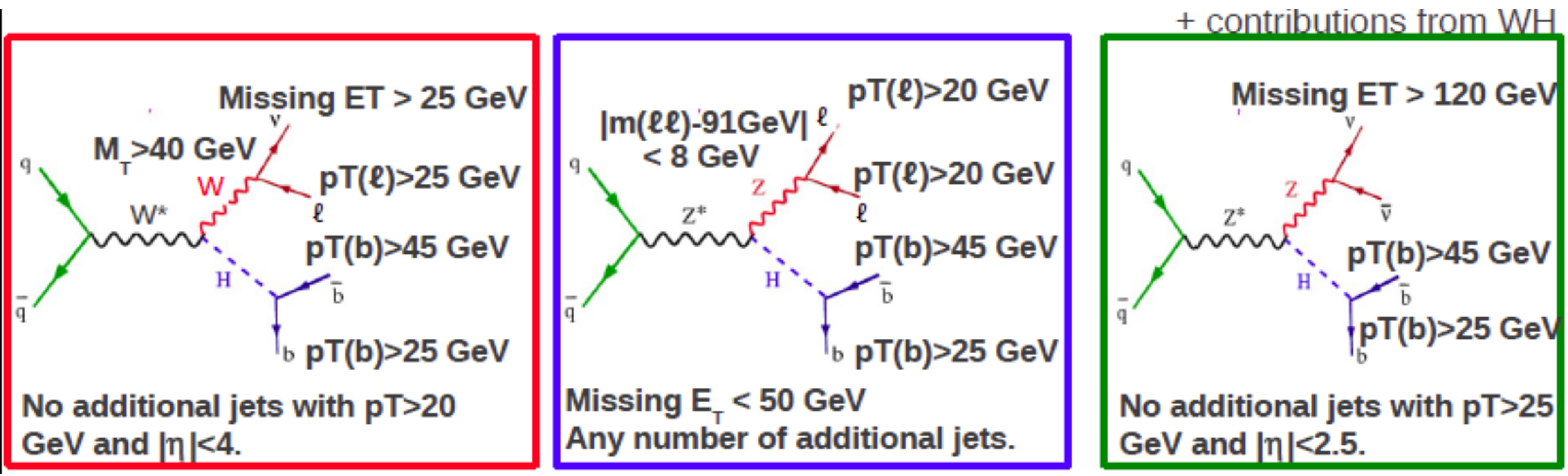


[E] H→bb

(Homework)



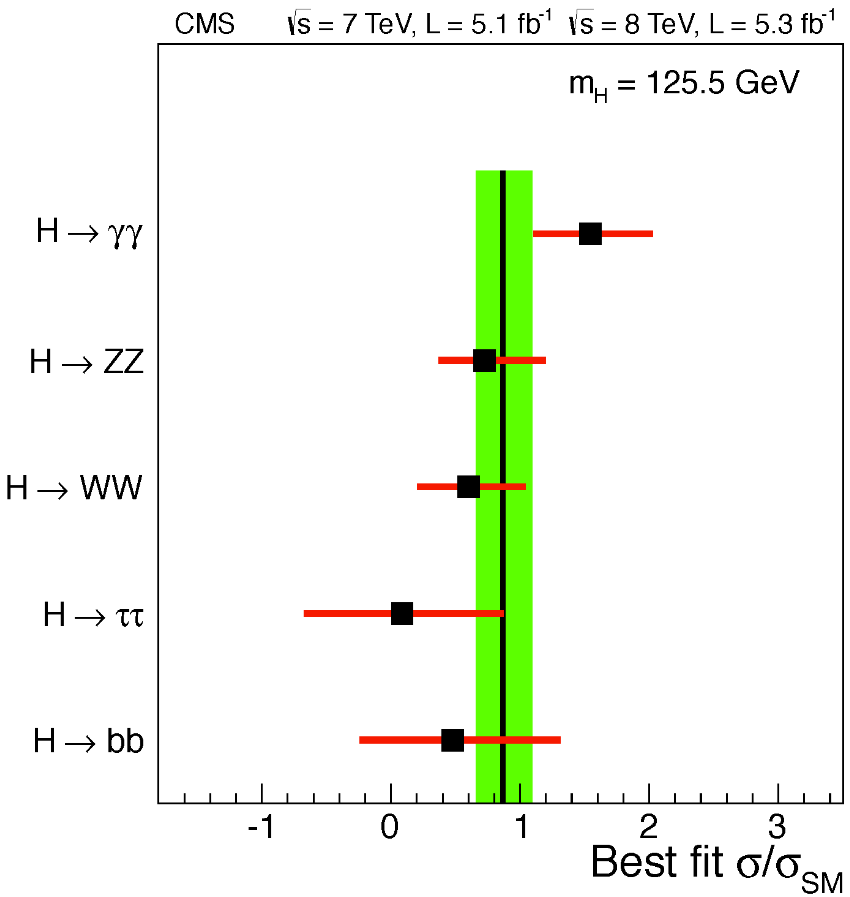


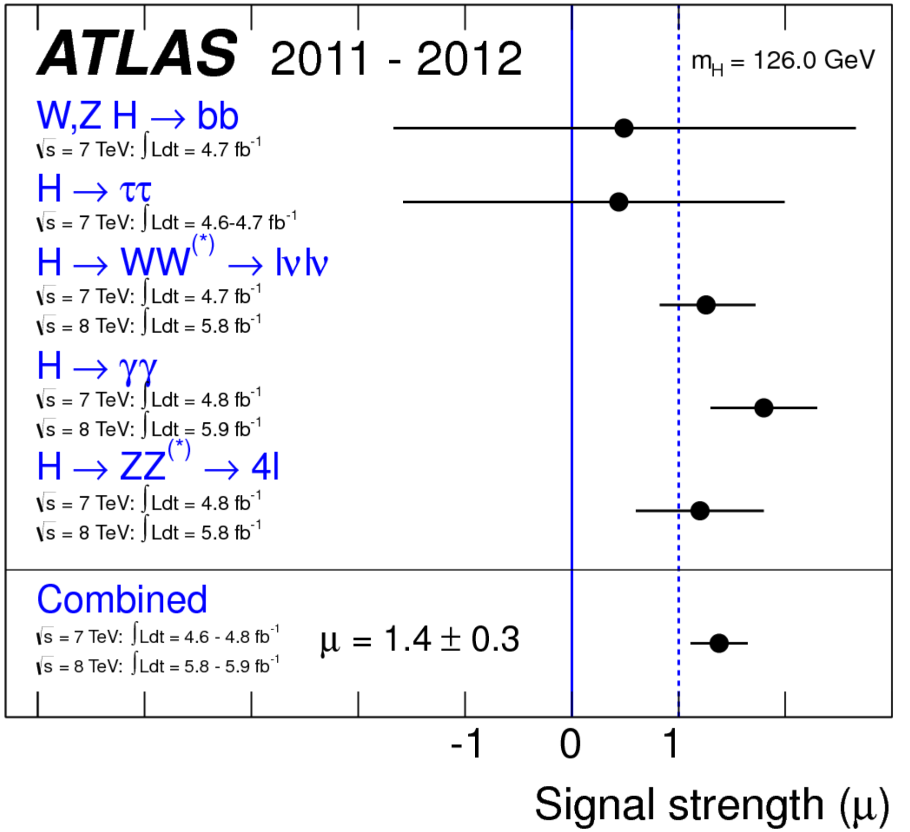


Missing ET > 25 GeV
M_T>40 GeV
W
W*
H
pT(ℓ)>25 GeV
pT(b)>45 GeV
pT(b)>25 GeV
No additional jets with pT>20 GeV and |η|<4.
|m(ℓℓ)-91GeV| < 8 GeV
pT(ℓ)>20 GeV
pT(ℓ)>20 GeV
Z
Z*
H
pT(b)>45 GeV
pT(b)>25 GeV
Missing E_T < 50 GeV
Any number of additional jets.
+ contributions from WH
Missing ET > 120 GeV
Z
Z*
H
pT(b)>45 GeV
pT(b)>25 GeV
No additional jets with pT>25 GeV and |η|<2.5.

[F] H→γγ Still high

This will be updated in HCP2011
Middle of November in Kyoto

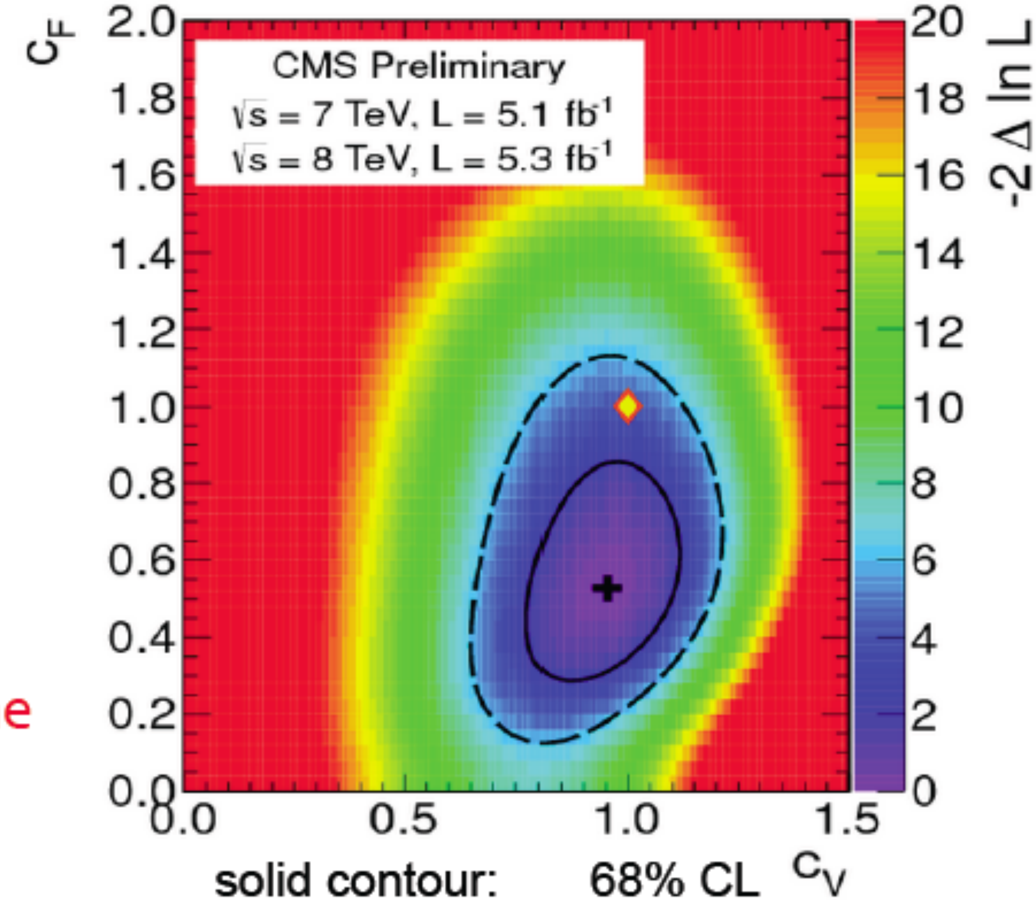




Private roughly combination is SM expectation * 1.7 +- 0.35
interesting but still 2σ (remember 2.7σ rule)

Proparties

(1) Yukawa is Small?



solid contour: 68% CL
dashed contour: 95% CL

:he

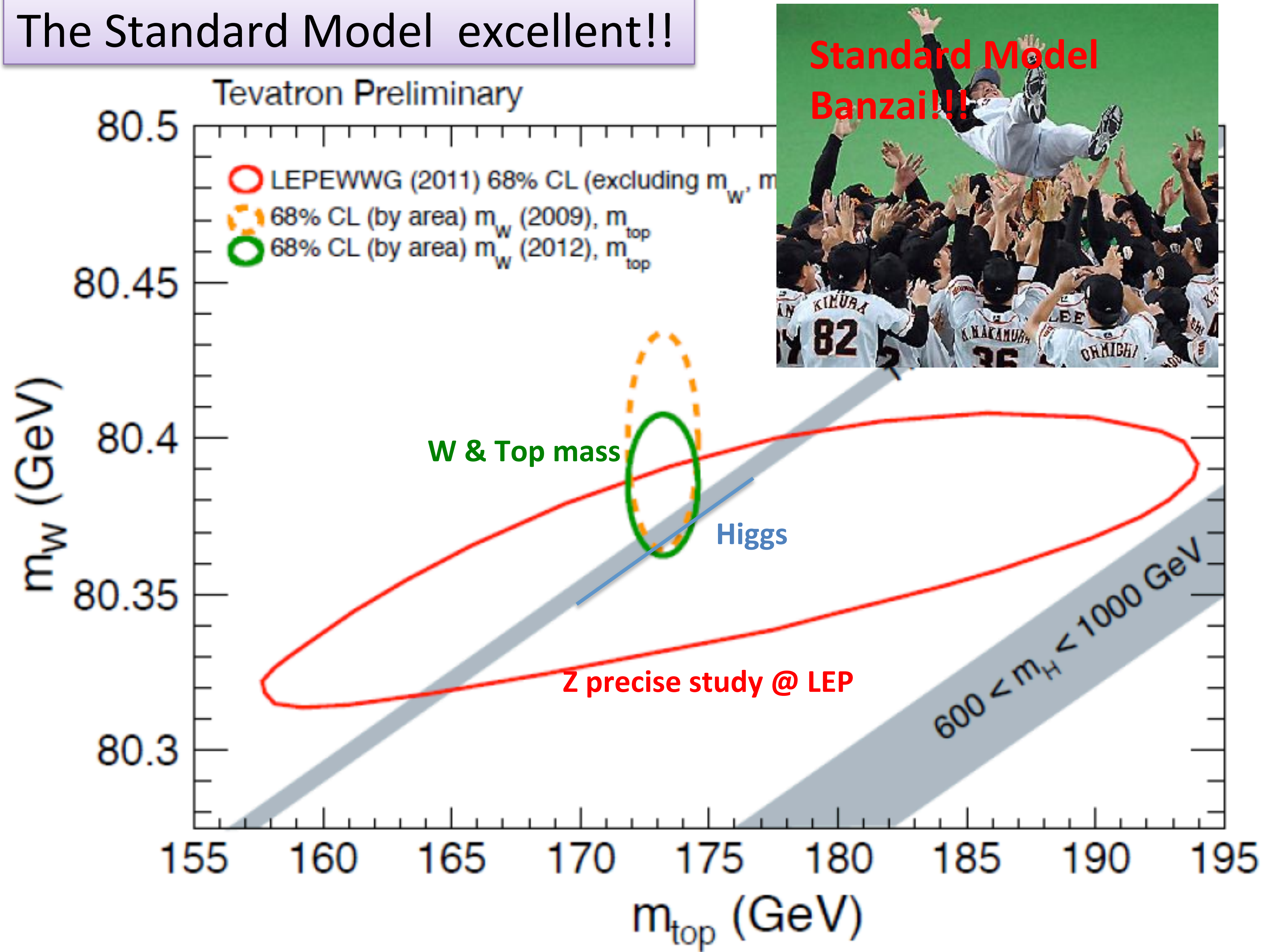
(1) γγ	1.7+-0.35
(2) ZZ	0.9 +- 0.3
(3) WW	0,8 – 1.5 ??
	1.2+- 0.5
(4) bb/tautau Need data	

2）Down Type yukawa is suppressed?

ZZ,WW,gamgam BR will be

gamgam is happy
WW is also acceptable
ZZ is consistent with SM,

The Standard Model excellent!!



Home work / discussion for first course

(1)Calculate psudorapidity as function of polar angle & What type of the detectors are installed in ATLAS/CMS

(2) WW lepton $\Delta\Phi$ distribution

(3) Why high Pt forward jet are expected in VBF

(4) Material in front of Calorimeters in ATLAS & CMS

(5) How to enhance H-> bb against BG (What type of diagram of BG?)

(6) What type of new physics possible? when

(type A) WW,γγ ZZ enhanced bb,tautau suppressed

(type B) all cross-section * Br enhanced (cross-section?)

(Type C) Only γγ enhanced