Recent Physics Results from LHC experiments

status of data taking in 2011

Higgs search

2012 & beyond

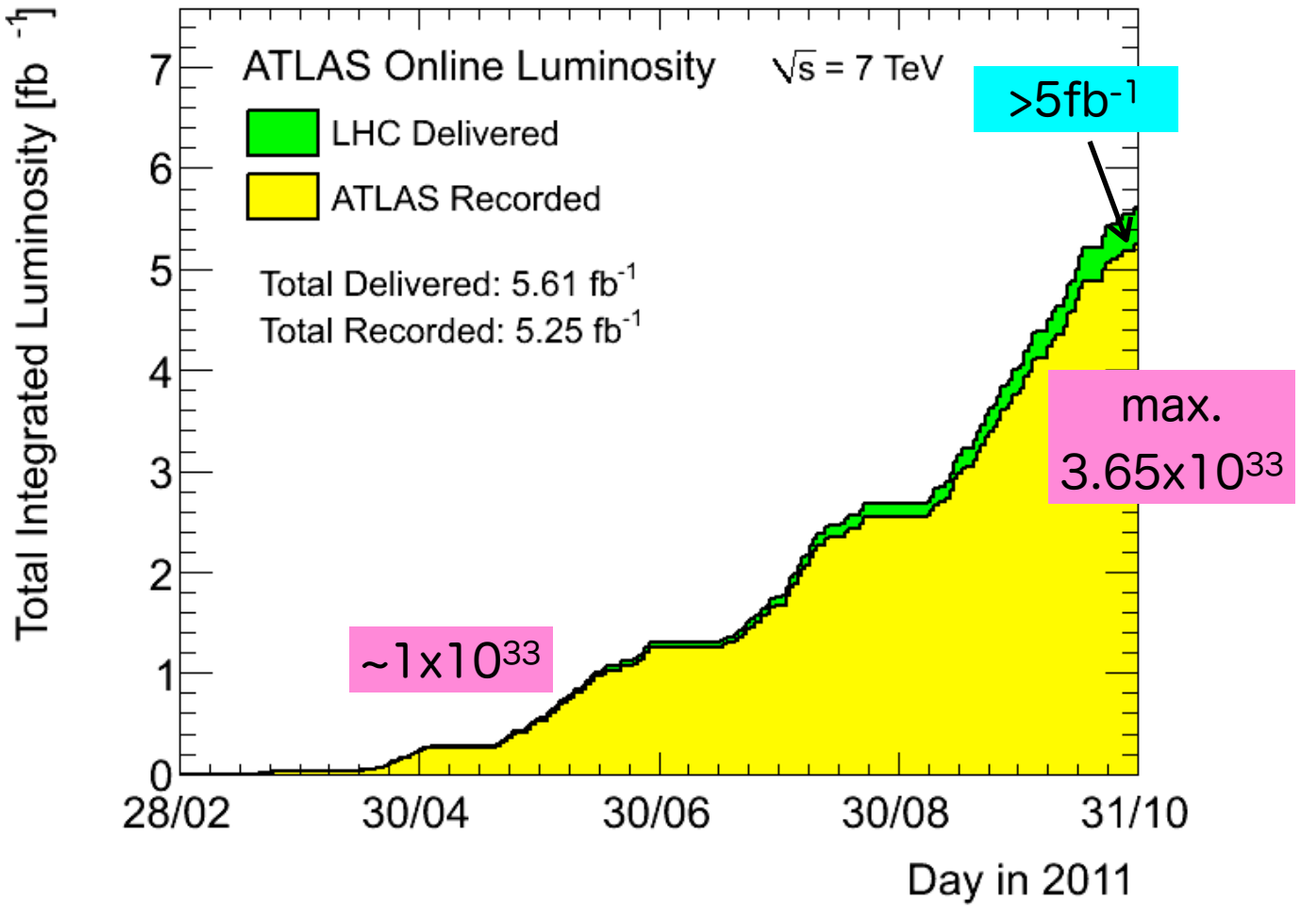
to study so-called “hierarchy problem”, an experimental input about “Higgs Boson” may be important !?

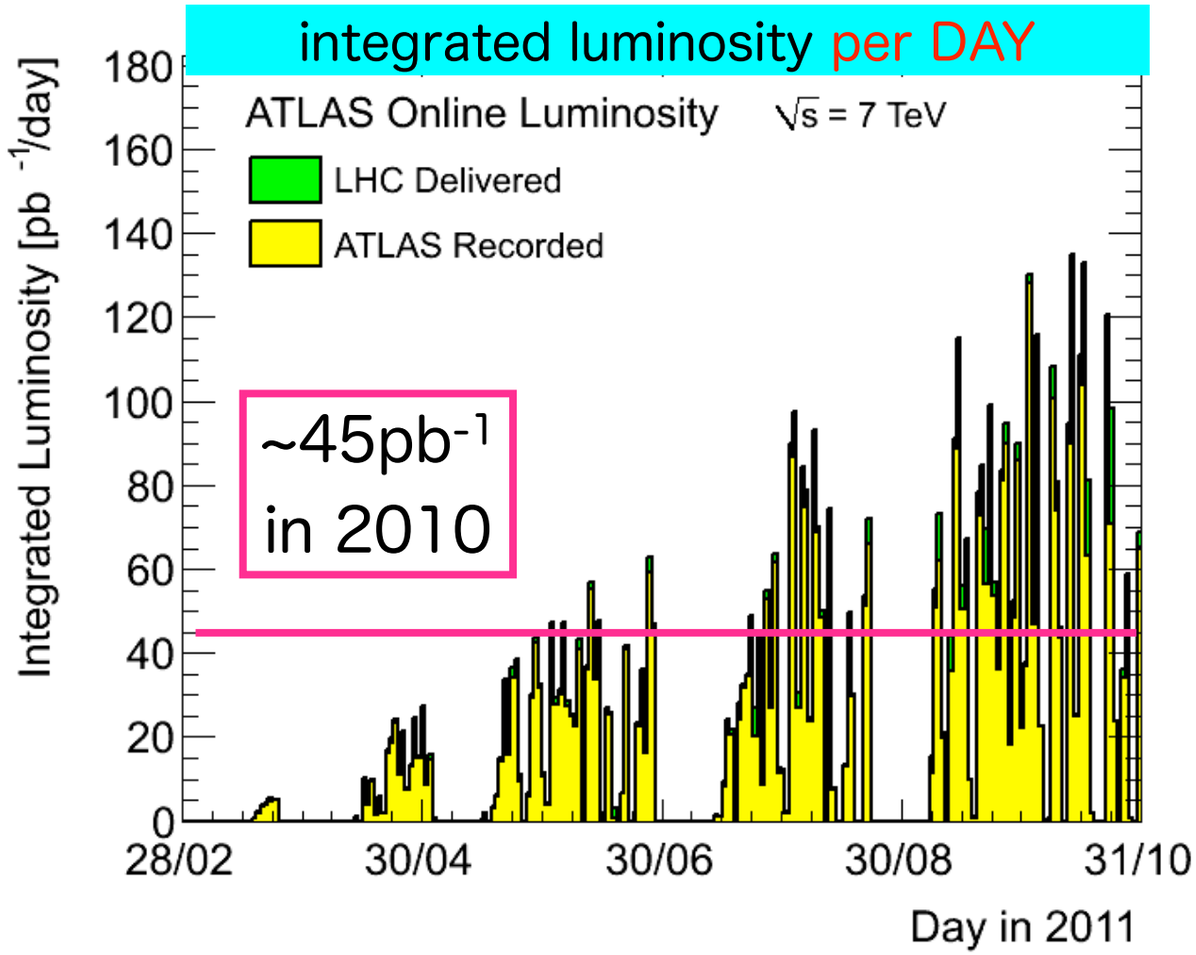
LINKS among Hierarchies ...
Weak scale ~ TeV ~ Plank

ISHINO Masaya (Kyoto Univ.) 2012.02.15

- 8.3T Super-conducting magnet x 1232
- 7TeV (= 3.5TeV x2) in 2010 / 2011
- 8TeV in 2012
- 13 or 14TeV (= 7.0TeV x2) from 2015

delivered luminosities by LHC





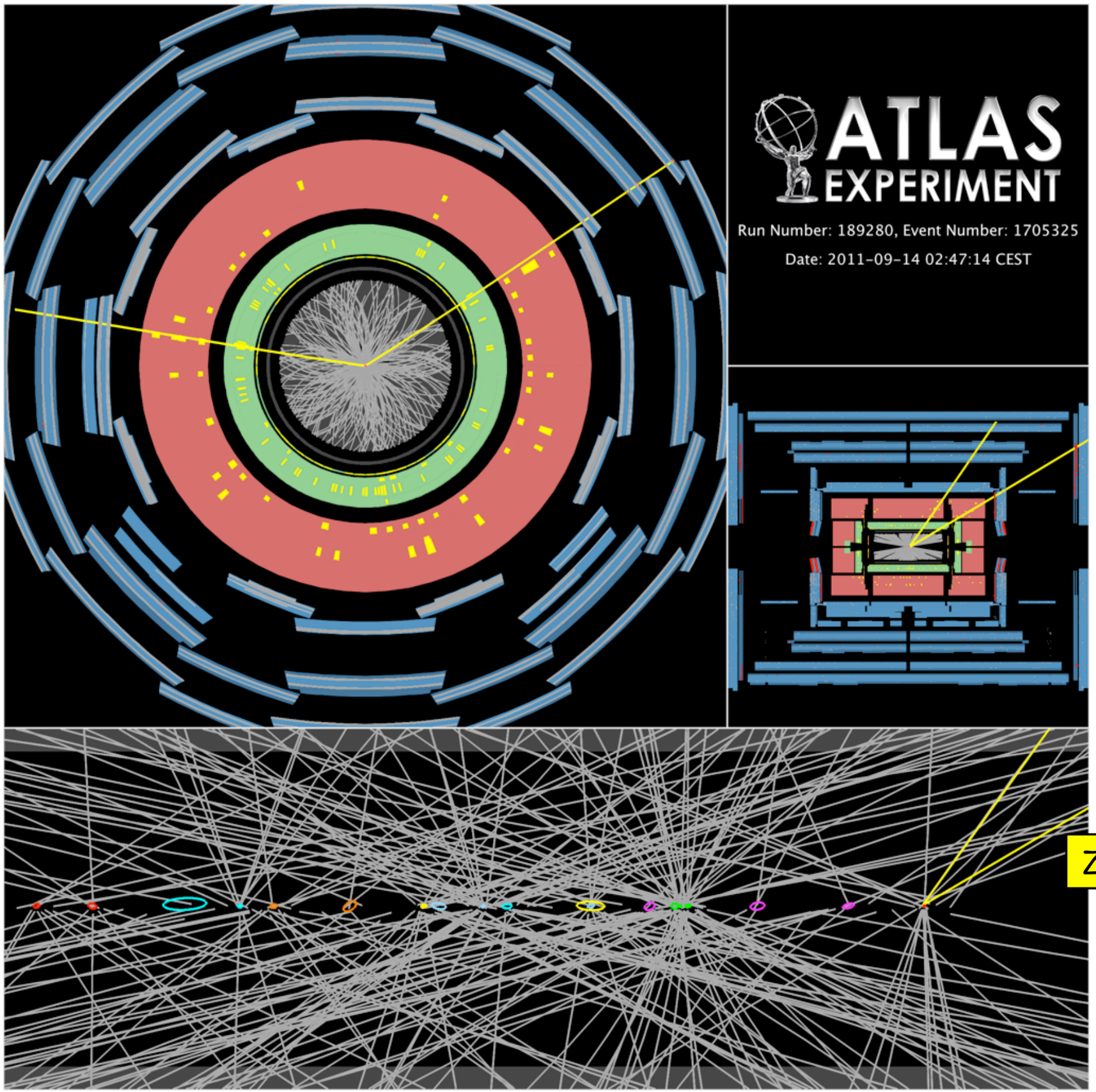
the difference of Green & Yellow

-> Data Taking efficiency : ~ 93.5%

Detector : working well (97.5% ~ 100%) : ATLAS & CMS

Inner Tracking Detectors			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.8	99.6	99.2	97.5	99.2	99.5	99.2	99.4	98.8	99.4	99.1	99.8	99.3

Z -> $\mu^+\mu^-$ with 20 reco. vertices



tracks P_T>400MeV

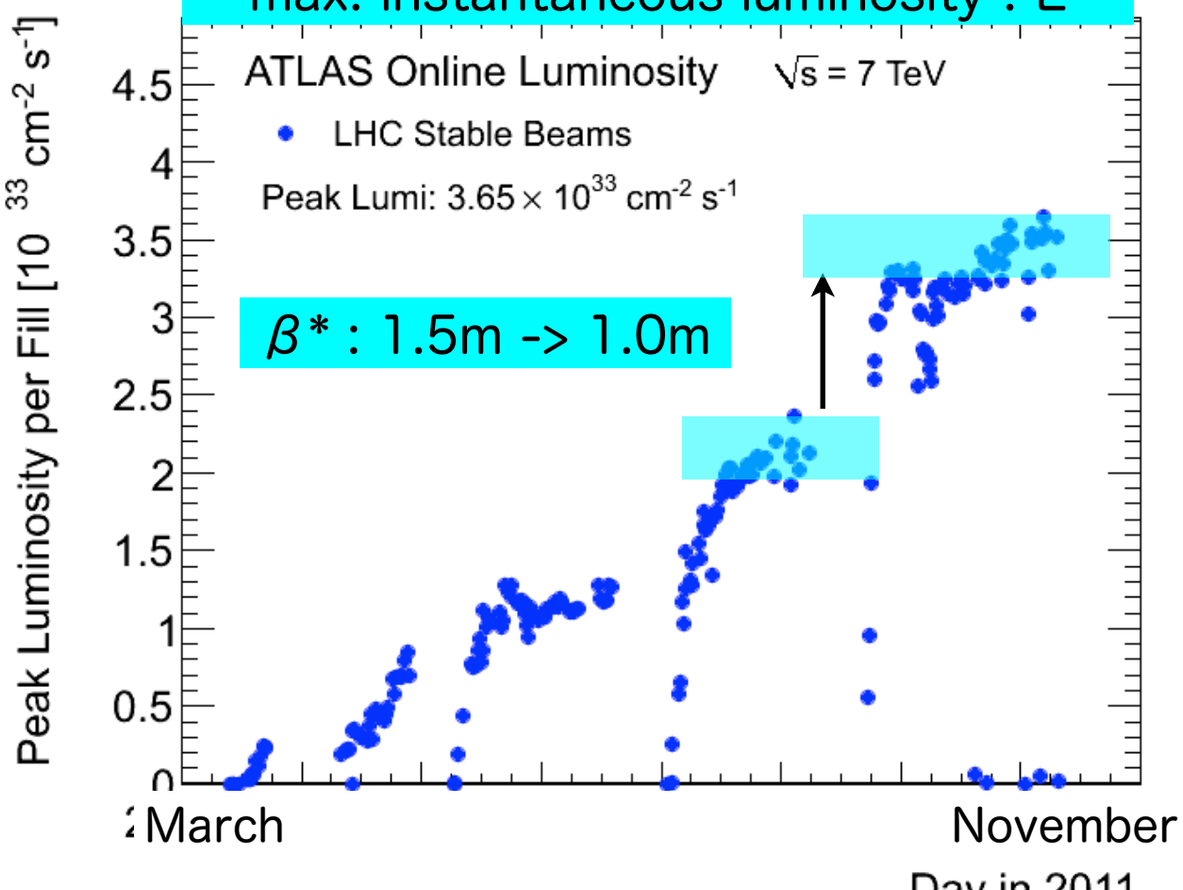
Z→ μμ

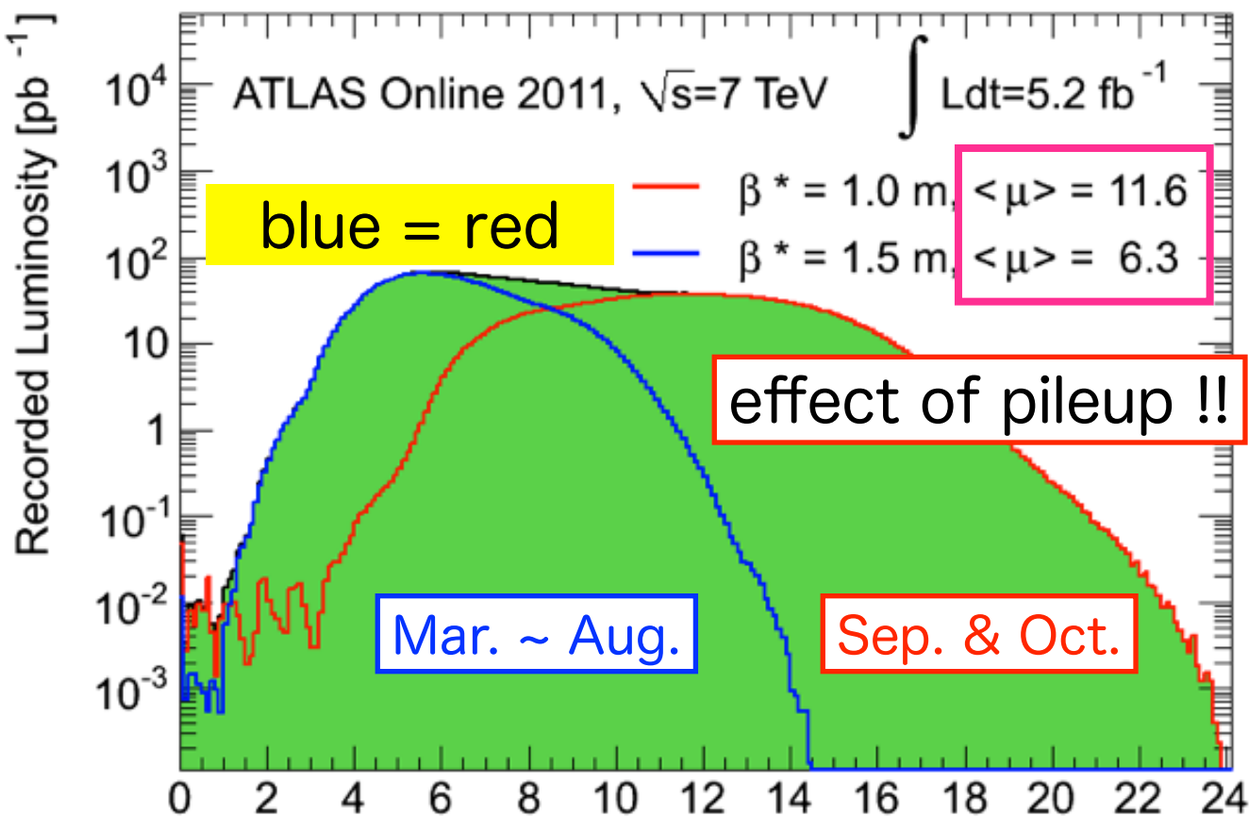
ellipse : uncertainty of vertex (magnified by 20 times to make visible)

event pileup

of interactions per crossing

max. instantaneous luminosity : L





revolution frequency 11253Hz

# of bunches

# of protons per bunch

$$L = \frac{f_{rev} \cdot n_b \cdot N_b^2 \cdot \gamma_r}{4\pi \cdot \epsilon_n \cdot \beta^*} \cdot F$$

(F ~ 0.941)

emittance

squeezing

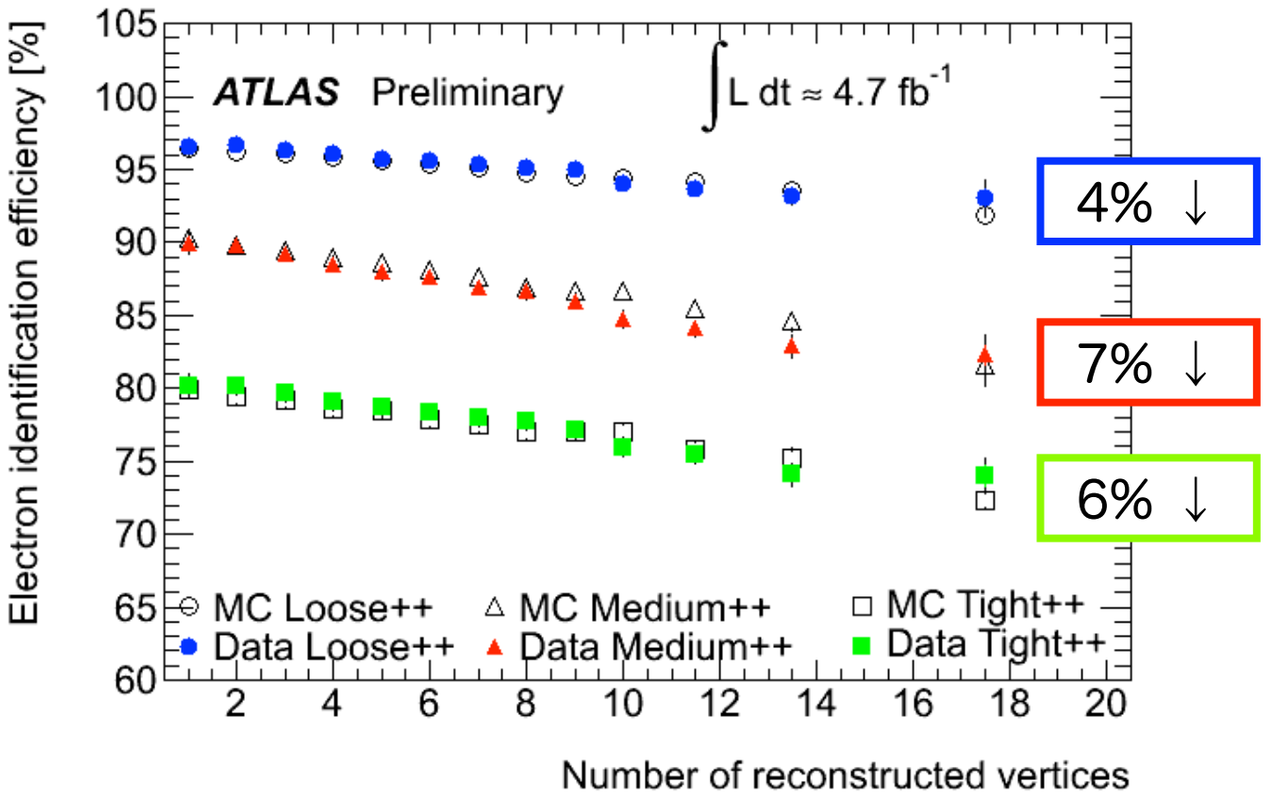
Mean Number of Interactions per Crossing

parameter	2011	design	
# of protons per bunch	1.5x10^11	1.15x10^11	x 1.7
emittance [μm rad]	1.9~2.3	3.75	x ~2
β*	1m (-> 0.6m in 2012)	0.55m	
# of bunches	1380	2808	
L [cm^-2 s^-1]	3.6x10^33	1x10^34	

pileup effect on lepton ID

H -> ZZ -> 4L

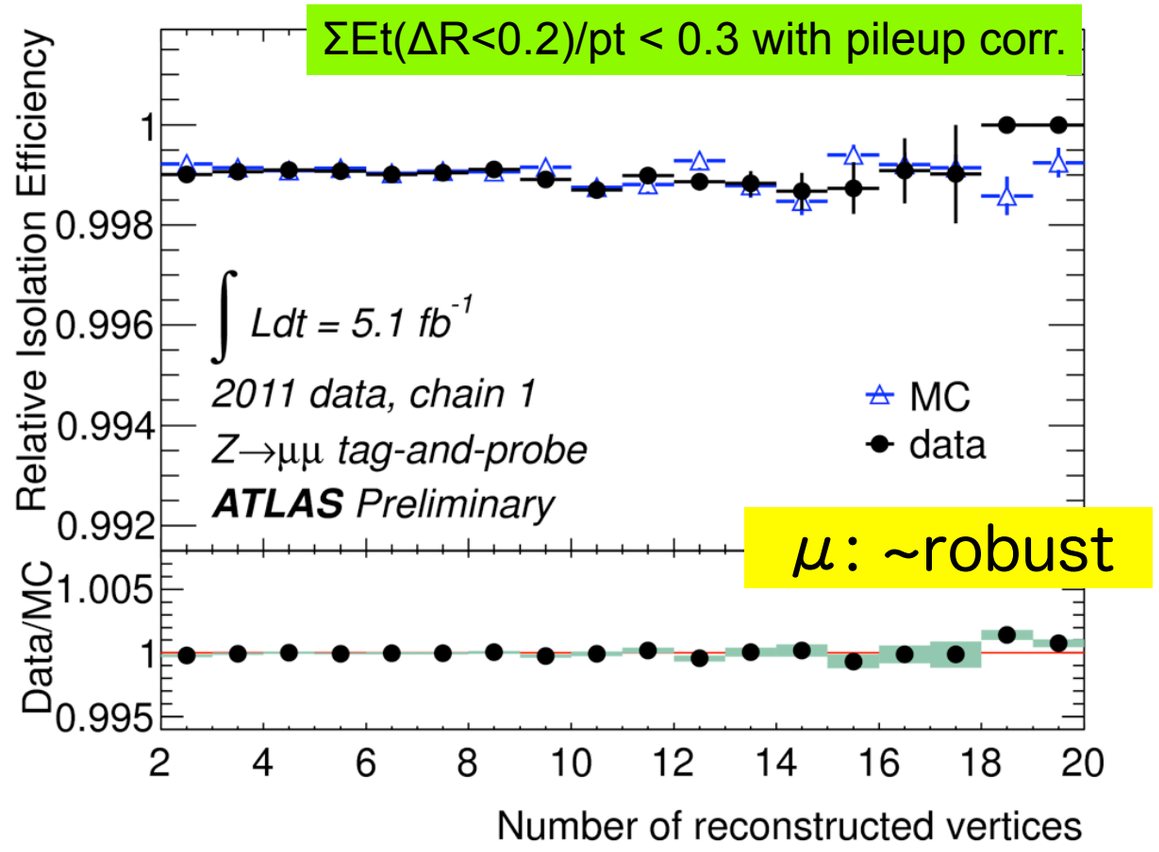
electron ID efficiency : Z -> ee

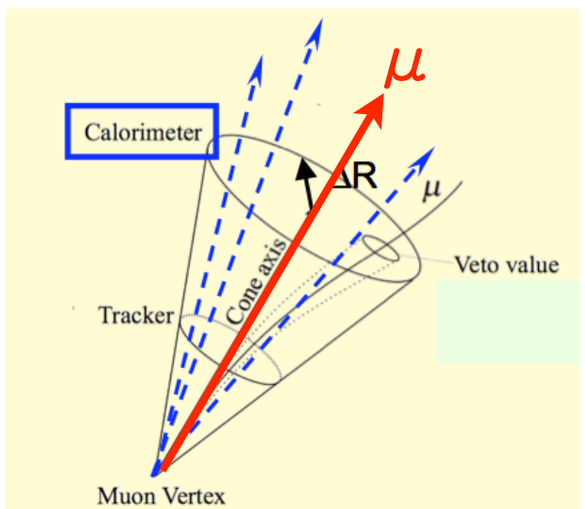


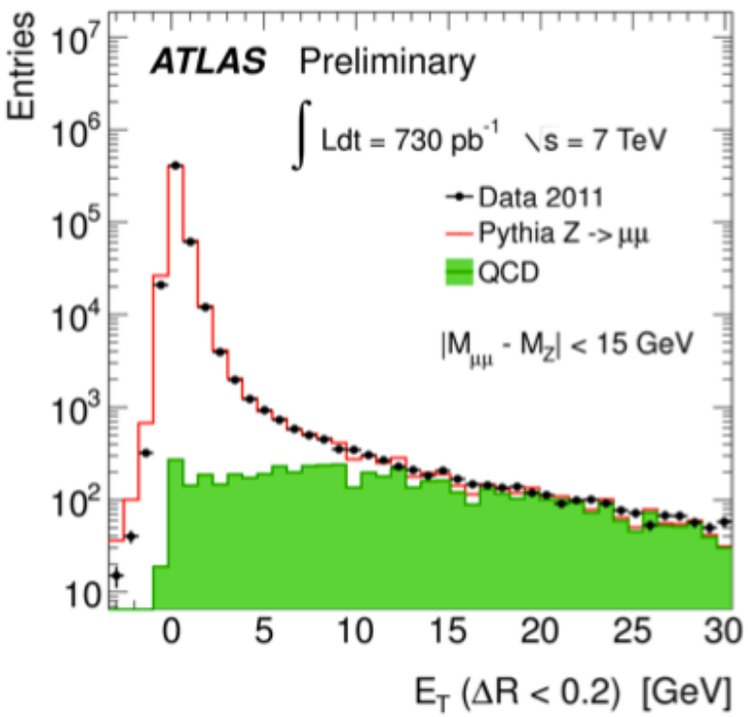
hadron tracks from different vertex is overlapped to Calorimeter-cluster -> eff. loss

(* room for improvement)

μ (calorimetric) isolation eff. Z -> μ μ





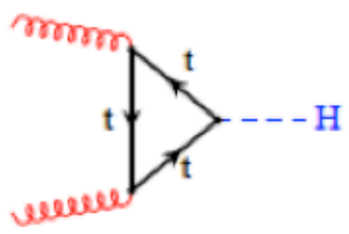


Higgs

Higgs Boson Production

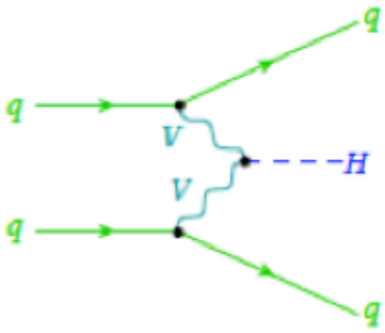
Higgs production @ LHC

cross section @ m_H=125GeV



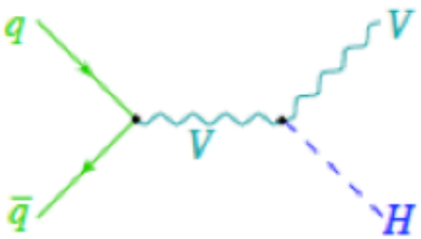
Gluon Fusion (GF) — 15.3pb

Δσ ~ 20%

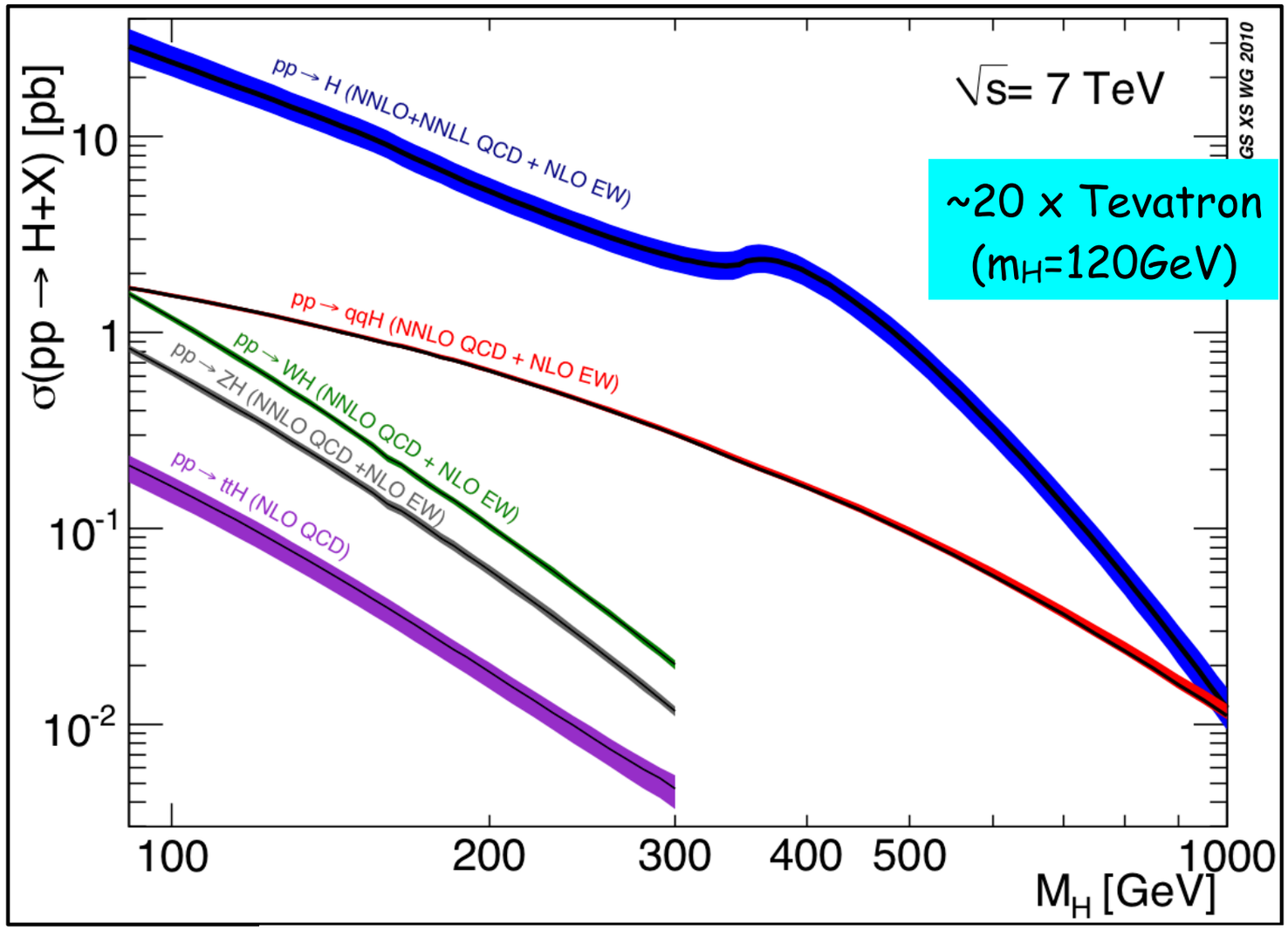


Vector boson fusion (VBF) — 1.2pb

tt associated production (ttH) — 0.09pb



WH/ZH associated production (VH) — 0.3pb



~20 x Tevatron (m_H=120GeV)

LHC Higgs cross section working group, 2010, arXiv: 1101.0593

cross section @ NNLO (for GF, VBF and VH)

error : GF : < 20% , (VBF : 3~9% , VH : ~ 5%)

16.9pb x $6\times10^{33}cm^{-2}s^{-1}$ ~ 0.1Hz

16.9pb x $5fb^{-1}$ ~ 84.5k

Higgs production x Branching Fraction (σ x Branch)

moreover ...
x Acceptance x eff.
-> yield

@ 5fb^{-1}

5,000

500

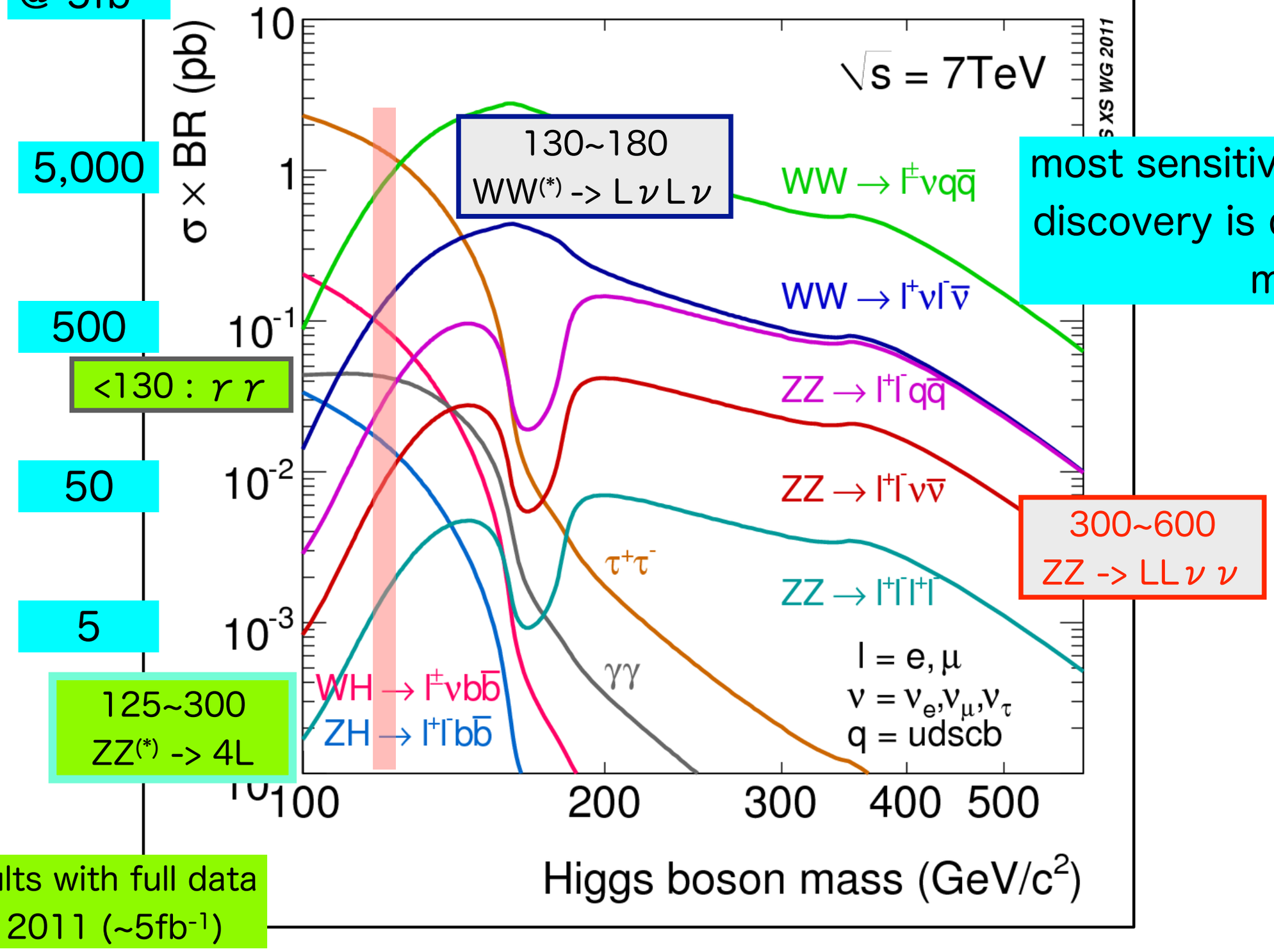
<130 : $\gamma\gamma$

50

5

125~300
$ZZ^{(*)}$ -> 4L

results with full data in 2011 (~5fb^{-1})



most sensitive channel for discovery is different with m_H

Higgs -> $\gamma\gamma$

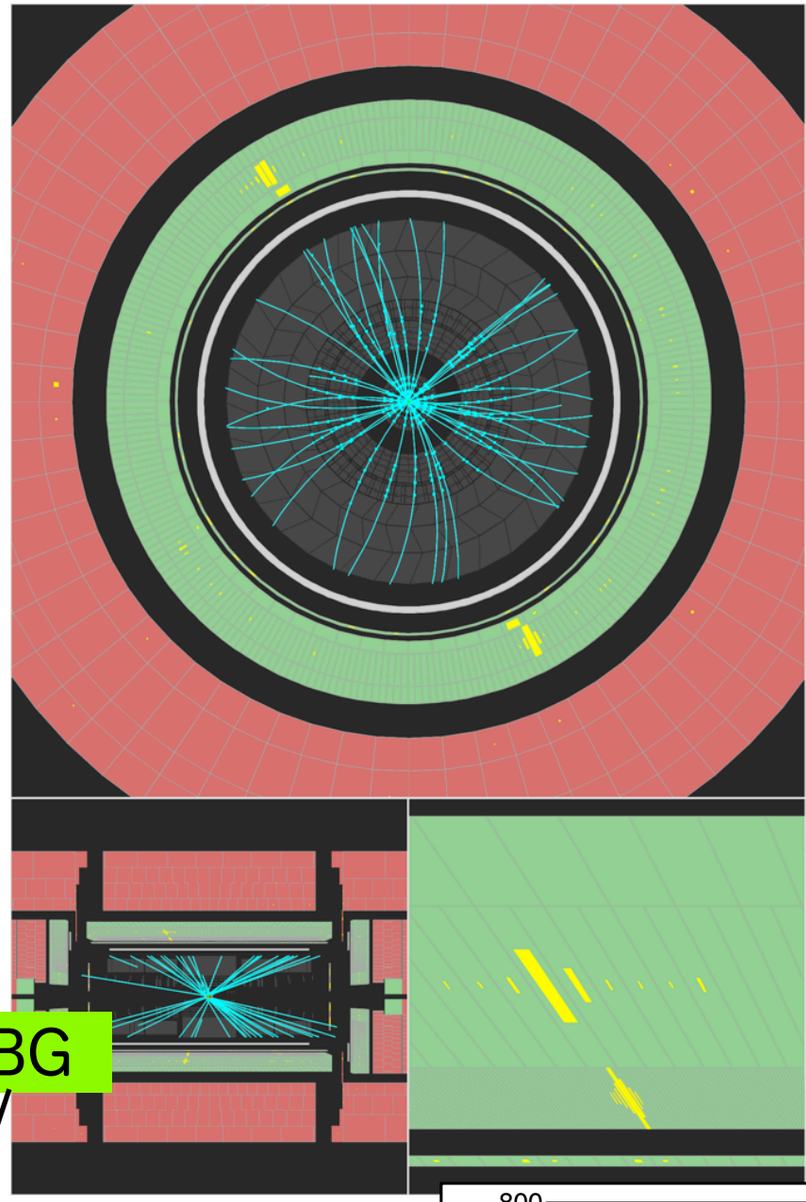
- $\sigma \cdot Br \sim 40fb$
- 2 x isolated-γ (simple !)
  - ✓ $E_T(\gamma_1, \gamma_2) > 40, 25GeV$
  - ✓ including $\gamma \to e^+e^-$ (material > $2X_0$)

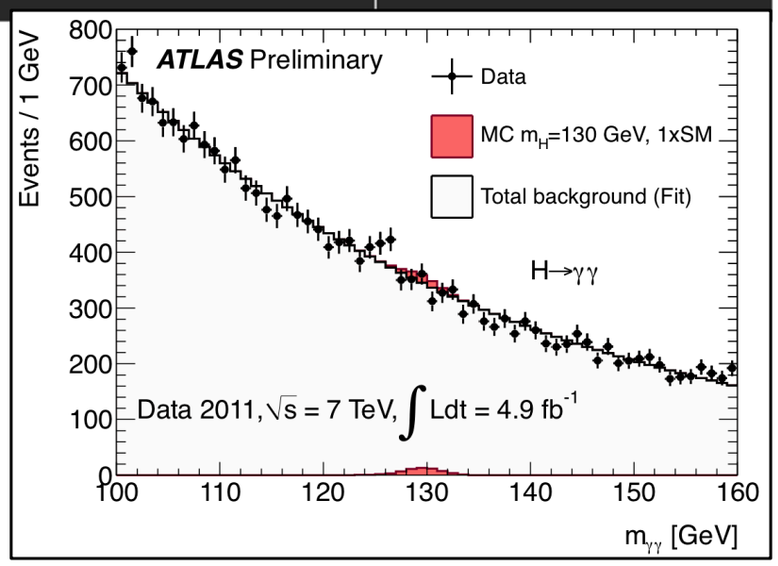
- S/B : ~ 0.02 , many backgrounds !
  - ✓ S~70 / B~ 3,000 @ $4.9fb^{-1}$ (m_H~125GeV)

find a shoulder on $\gamma\gamma$ continuum / smooth BG

(i) mass resolution of $\gamma\gamma$: important !!

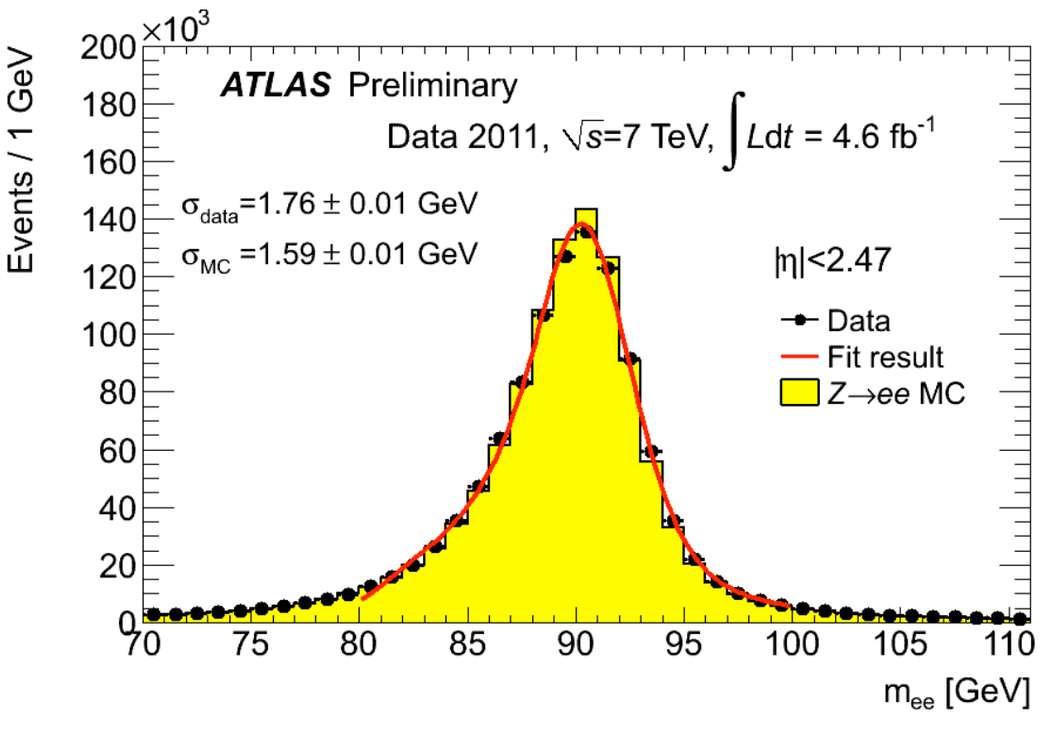
(ii) to suppress γj , jj BG, π^0/γ separation : important

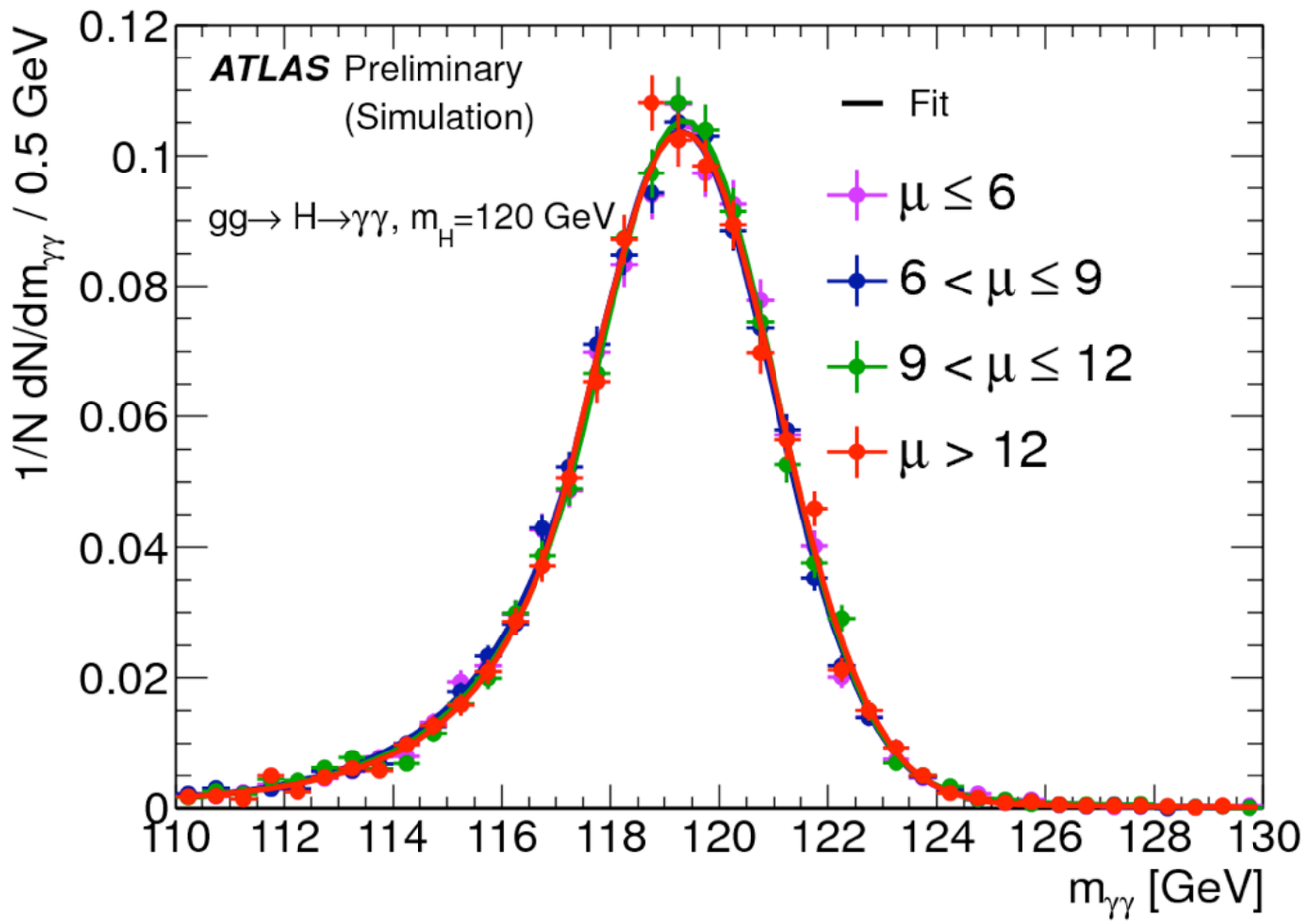




(i-1) mass resolution ~ Energy measurement

$m^2_{\gamma\gamma} = 2 E_1 E_2 (1-\cos\alpha)$





Z->ee (Data)

e -> γ extrapolate via MC

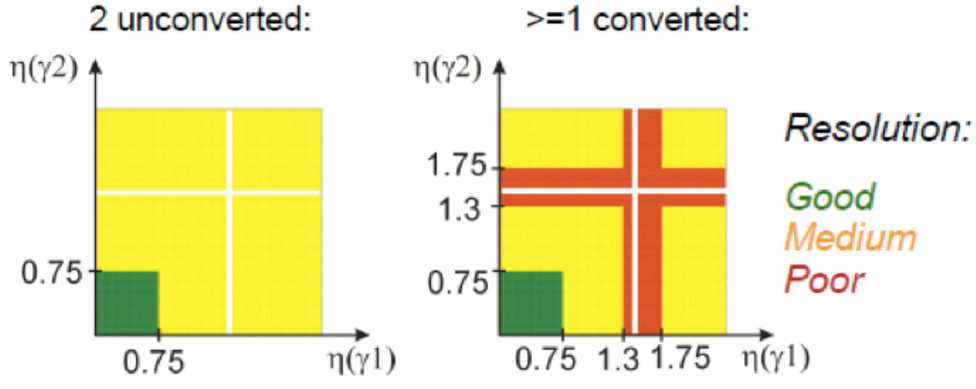
- energy scale : 0.5% @ M_Z
- Linearity : < 1% (a few GeV ~ n x 100 GeV)
- Uniformity : 1% Barrel / 1.7% Endcap

robust against event pileup

mH=120GeV

$\sigma(m_{\gamma\gamma})$: 1.4 (best) ~ 2.3 GeV (worst)

[all : 1.7GeV]



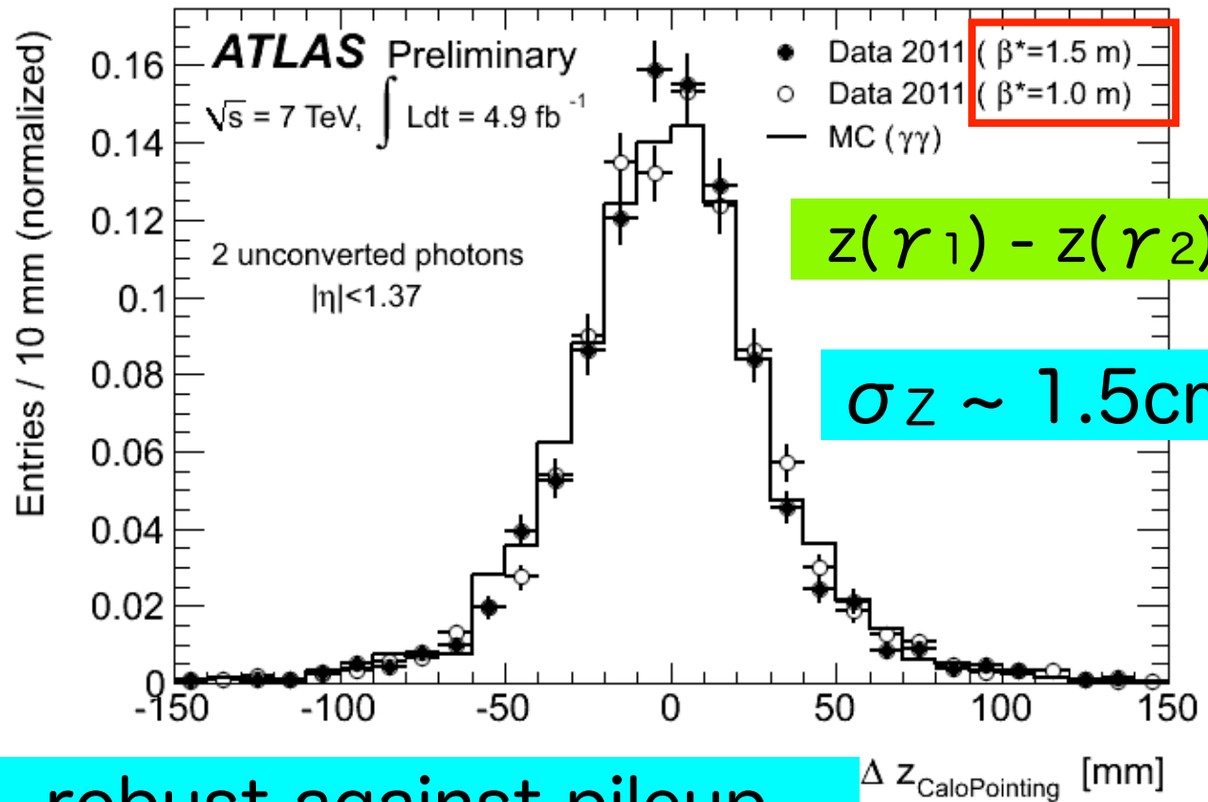
(i-2) mass resolution [α : angle 2γ]

$m^2_{\gamma\gamma} = 2\,E_1\,E_2\,(1-\cos\alpha)$

$$\frac{\Delta m_H}{m_H} = \frac{1}{2}\left(\frac{\Delta E_1}{E_1} \oplus \frac{\Delta E_2}{E_2} \oplus \frac{\Delta\alpha}{\tan(\alpha/2)}\right)$$

negligible

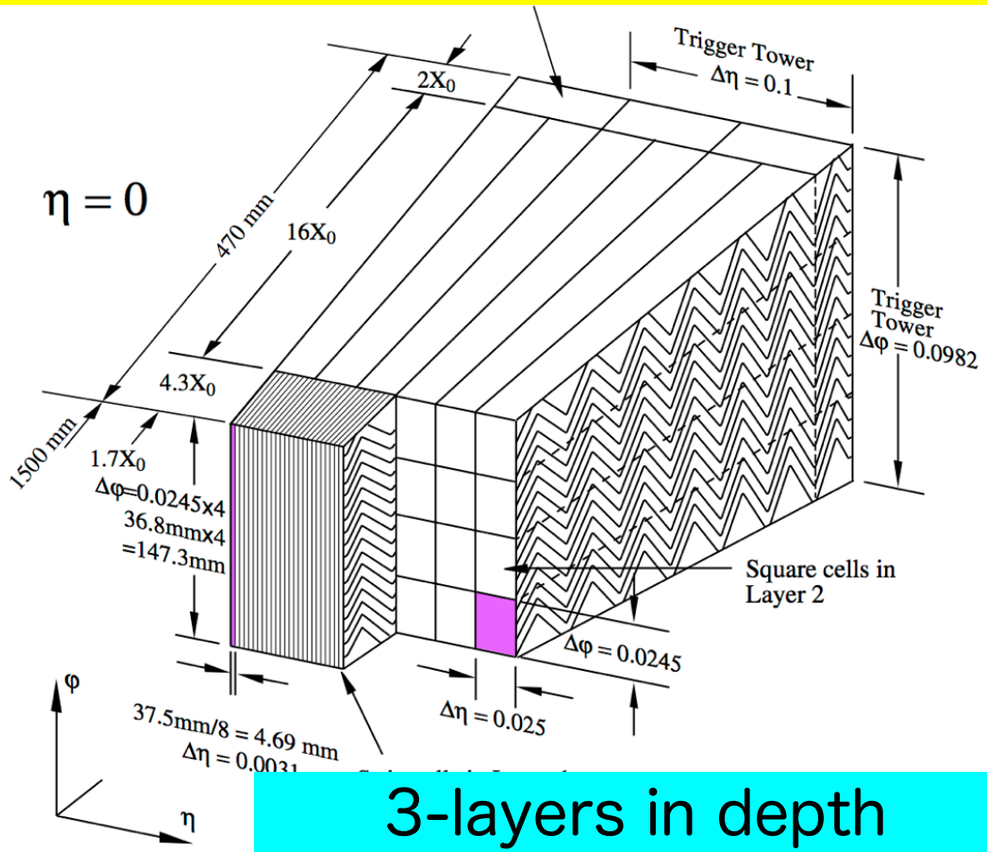
Z-Vertex resolution [mm] (on beam-axis)



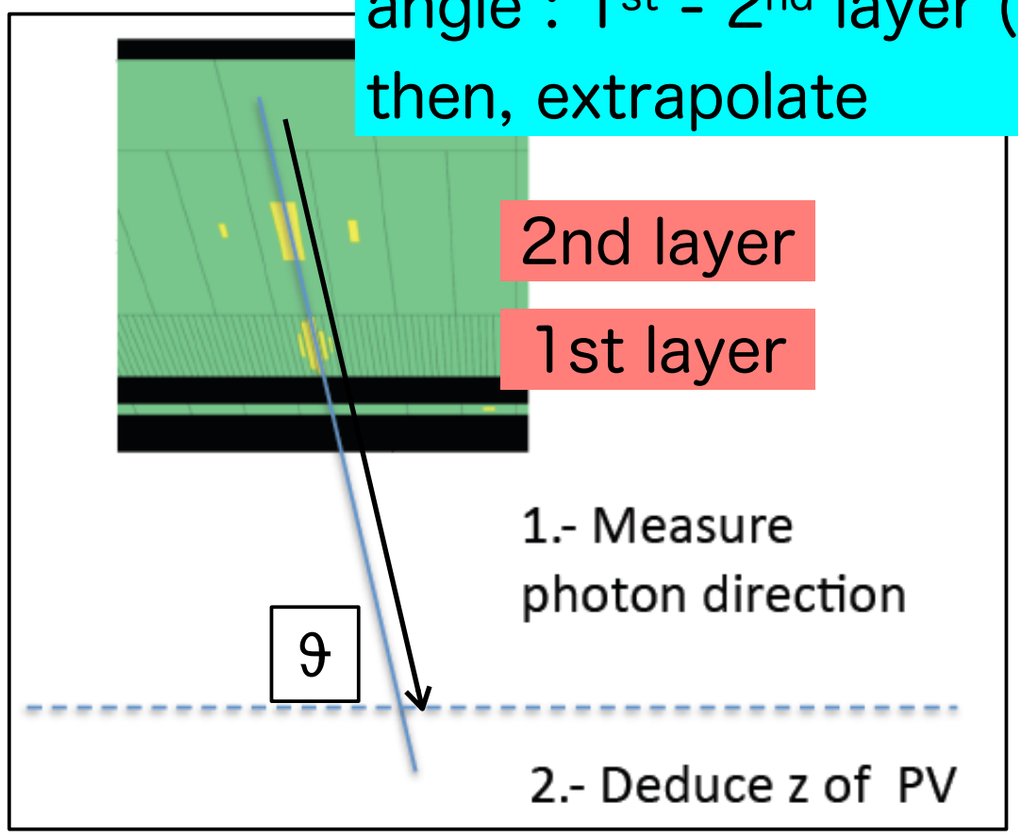
$z(\gamma_1) - z(\gamma_2)$

$\sigma_z \sim 1.5$cm

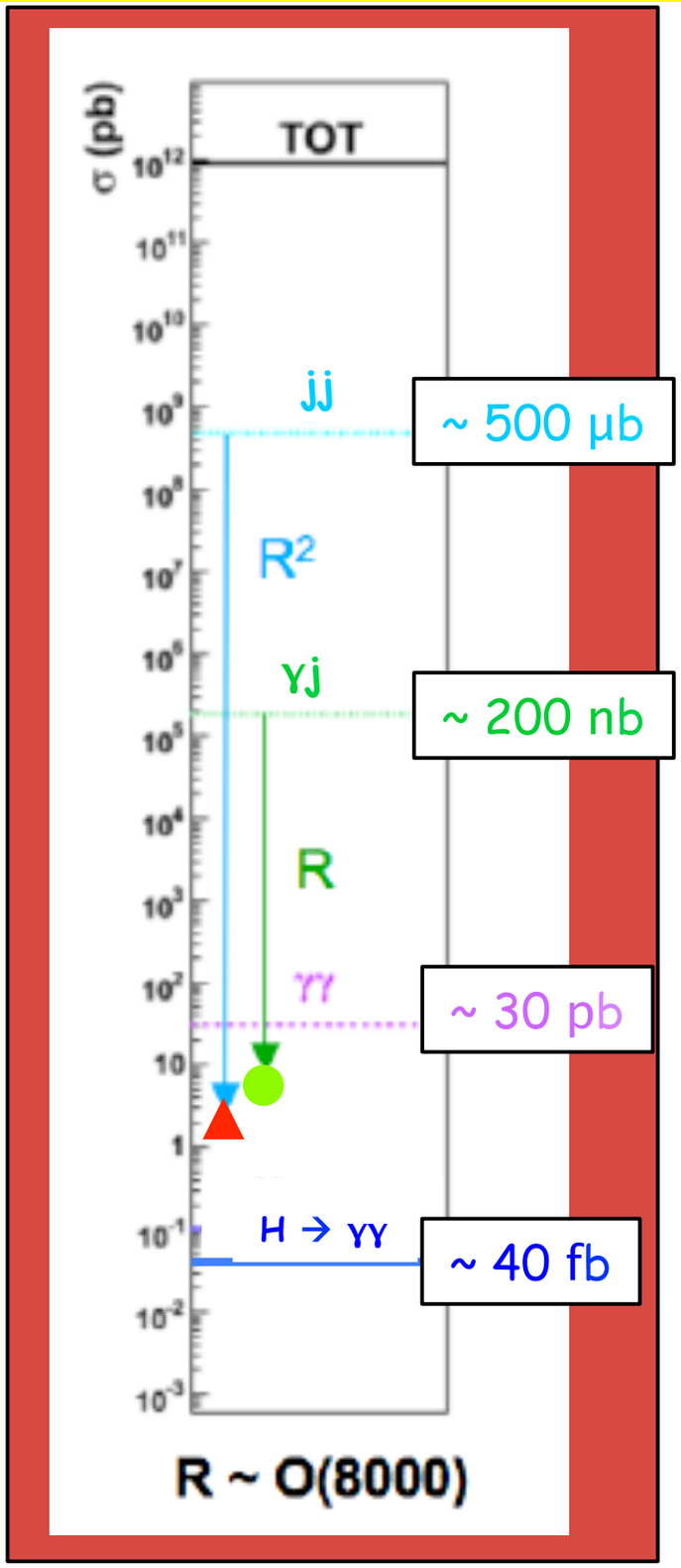
robust against pileup

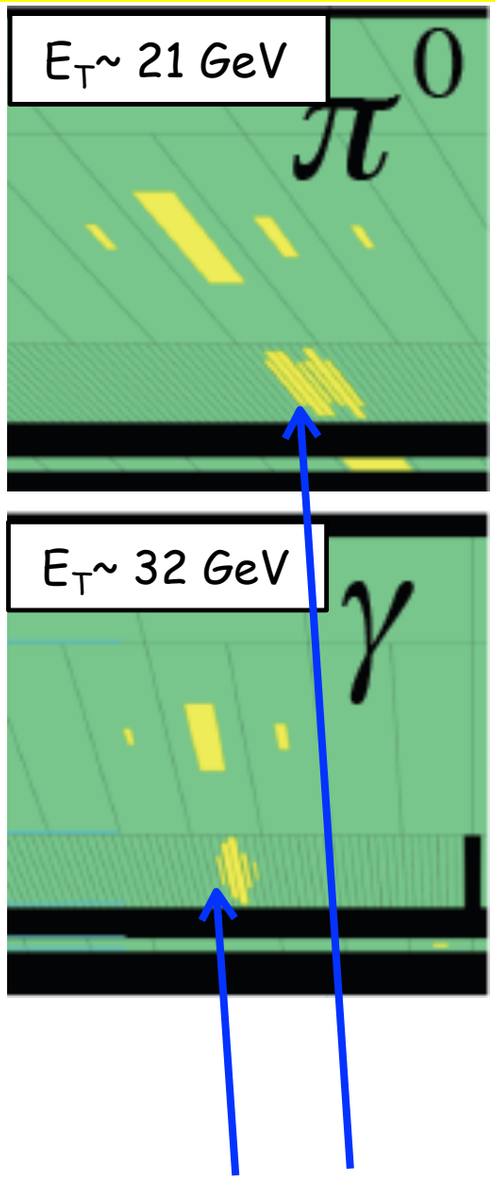


3-layers in depth
angle : 1st - 2nd layer (η)
then, extrapolate

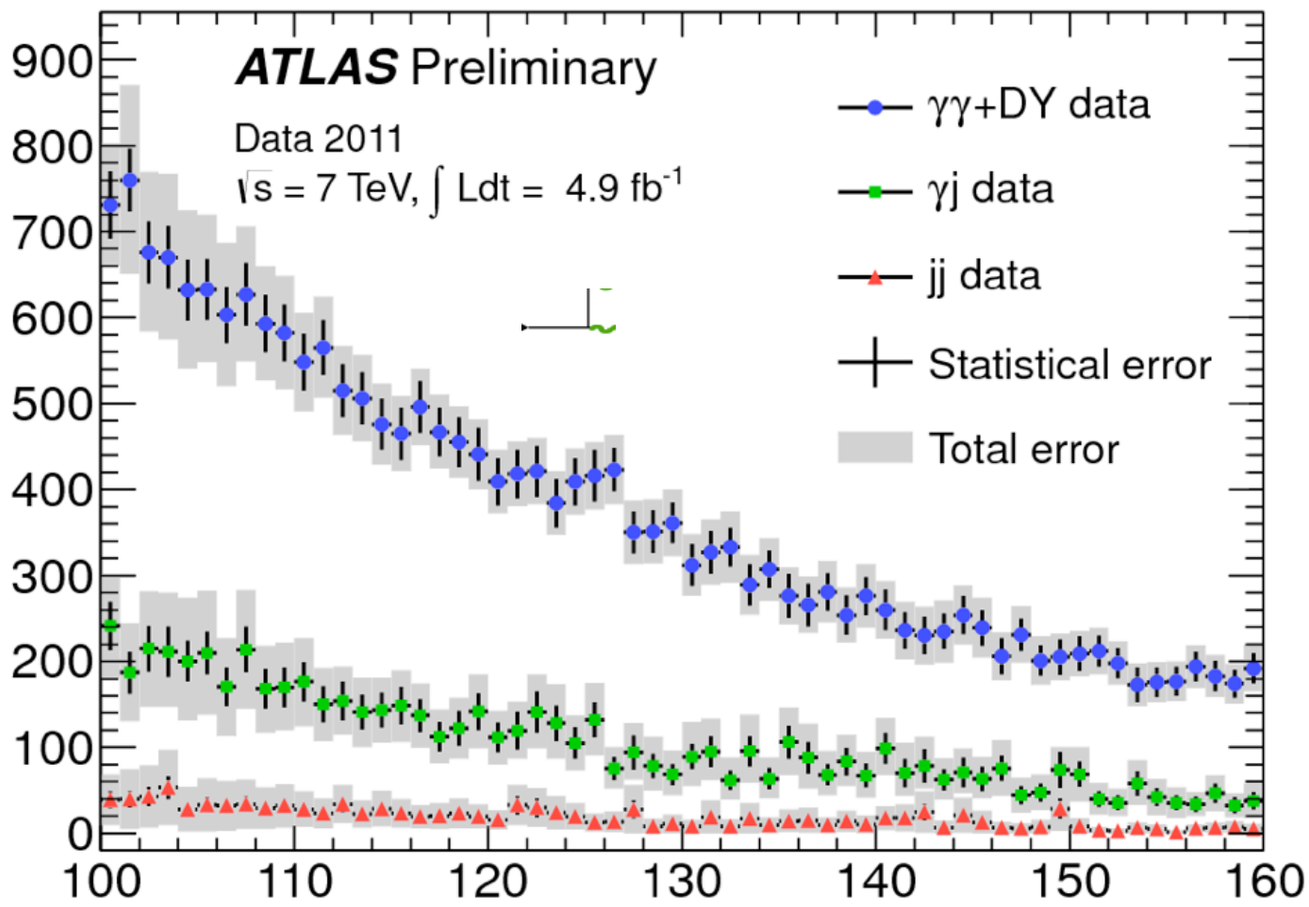


(ii) Background : jj , γj ~ π^0/γ





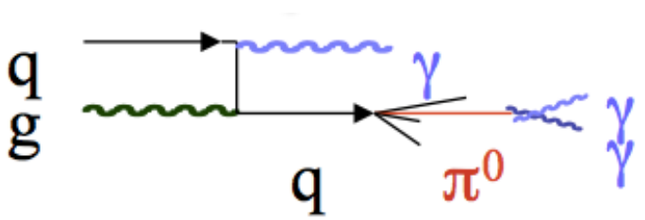
1st layer strip (η)
4mm pitch



	Number of events	Fraction
γγ	16000 ± 1120	71 ±5 %
γj	5230 ± 890	23 ±4 %
jj	1130 ± 600	5 ±3 %
DY/Z	165 ± 8	0.7 ±0.1 %

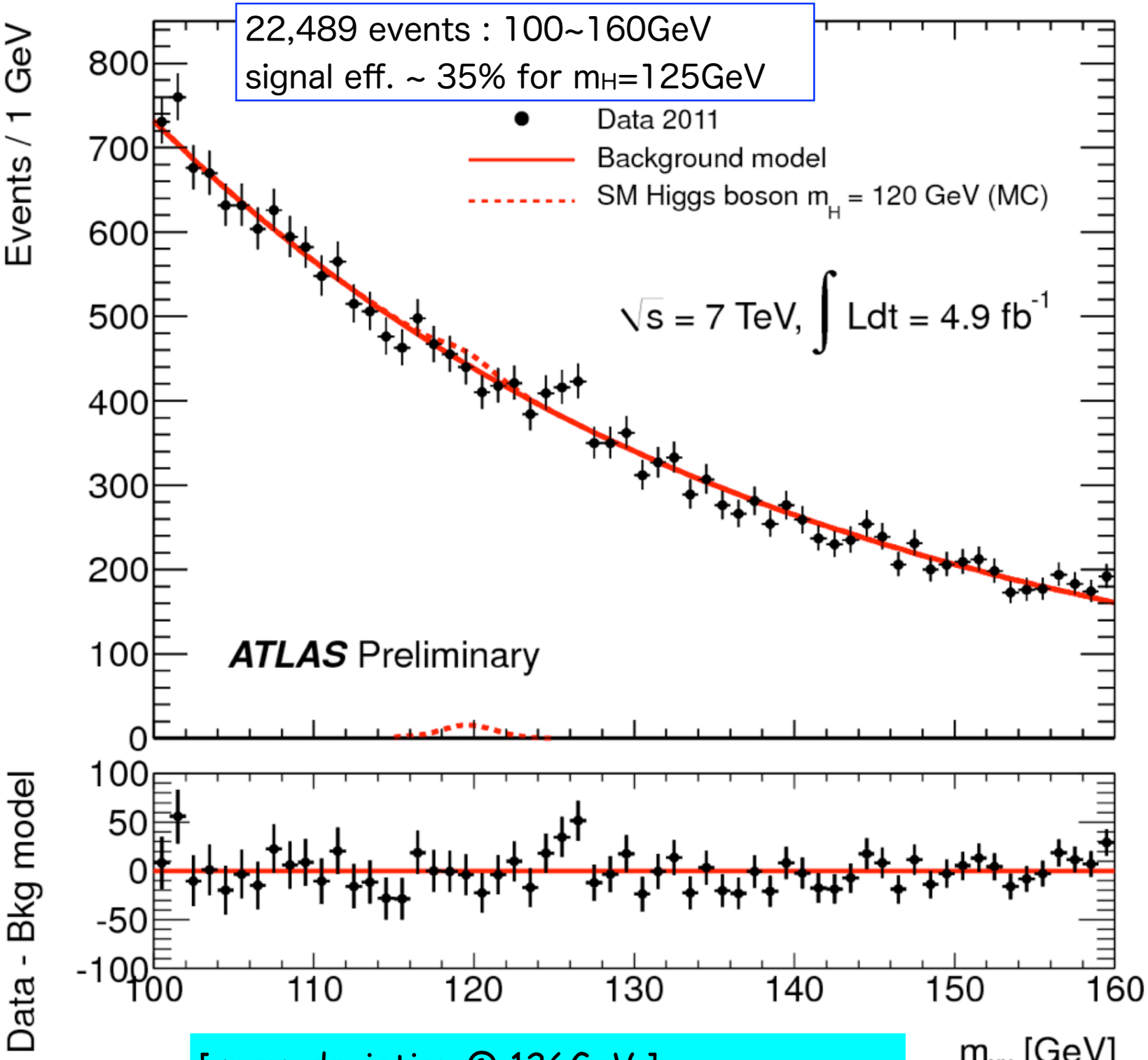
lateral shower shape -> π^0->2γ rejection (miss ID as 1γ) : suppress γj & jj

R ~ 4 order !!



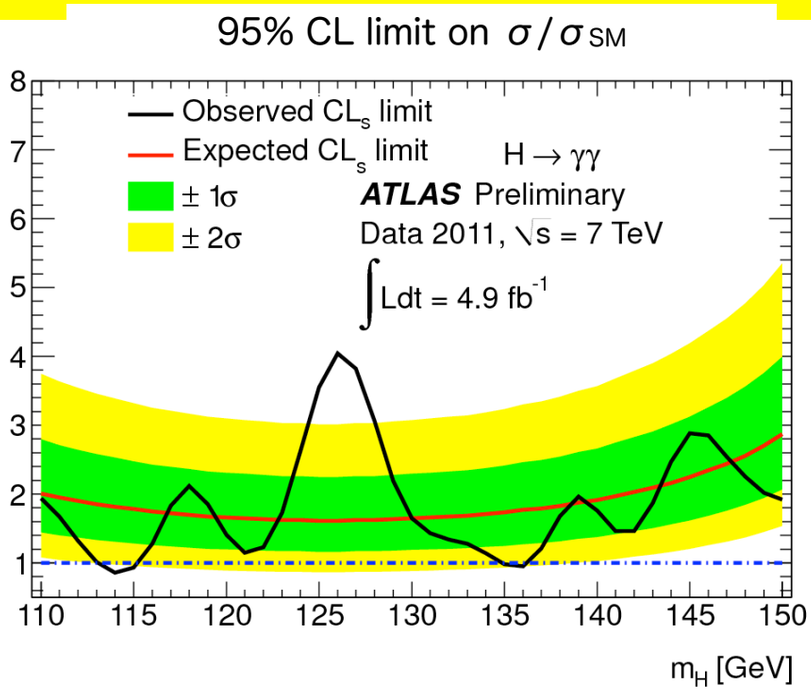
$\gamma\gamma$ invariant mass

22,489 events : 100~160GeV
signal eff. ~ 35% for m_H=125GeV

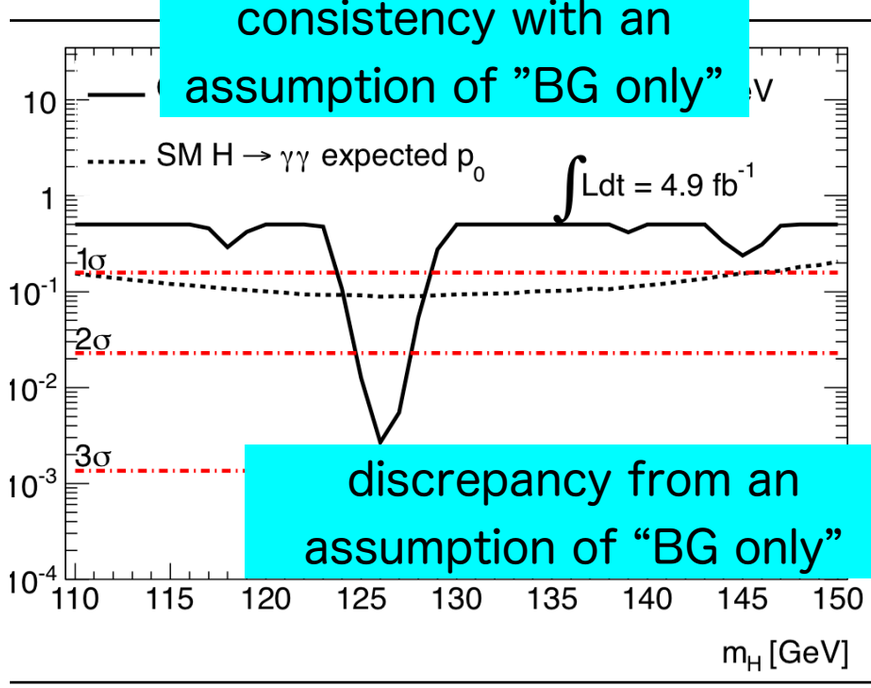


[max. deviation @ 126GeV]
- local-P_0 : 0.27% (2.8σ) -> 1.5σ (LEE)
- expect SM : 1.4σ

too much ...



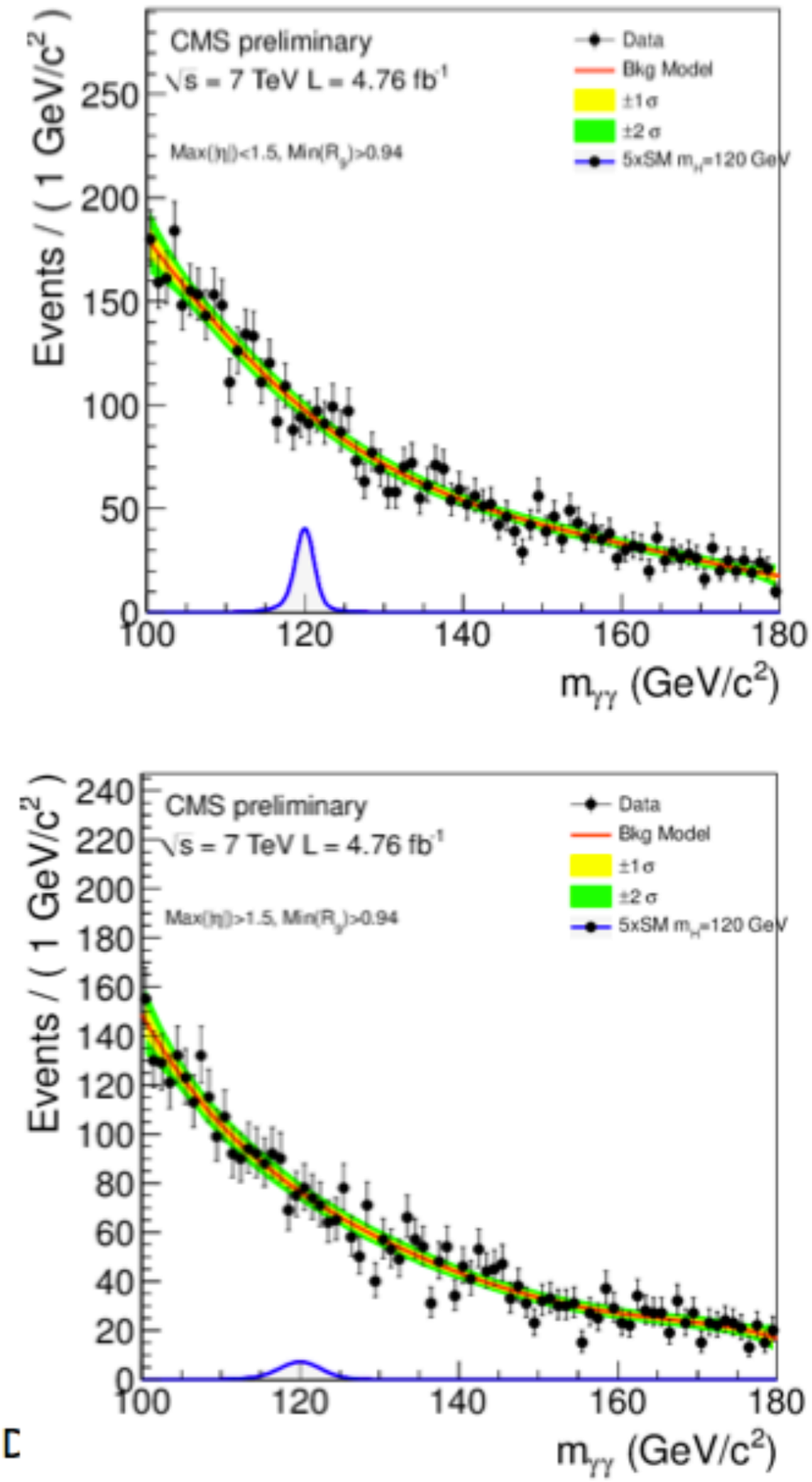
consistency with an assumption of "BG only"

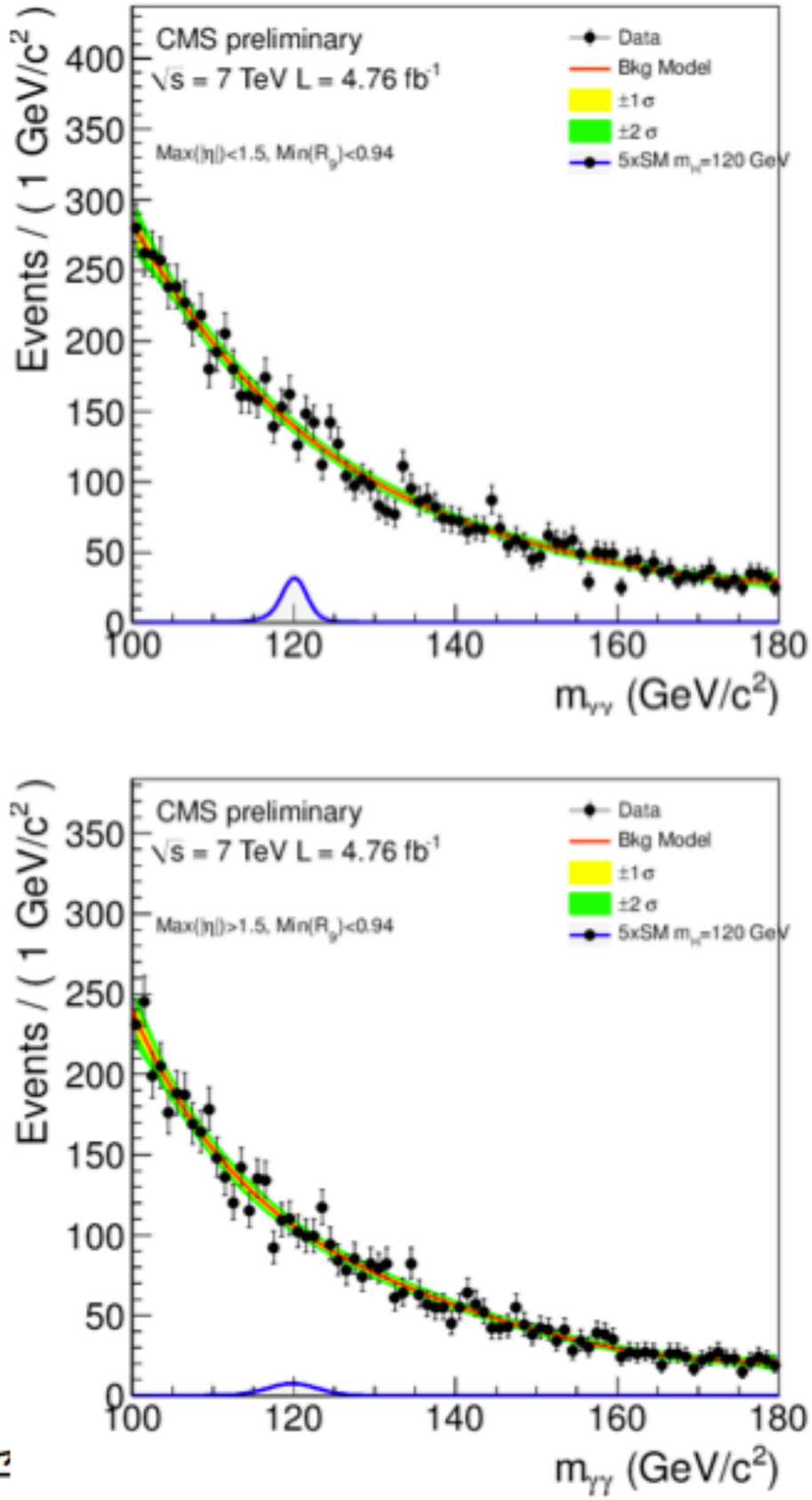


discrepancy from an assumption of "BG only"

systematic error	
Expected signal yield	: ~ 20%
H -> γγ mass resolution	: ~ 14%
H -> γγ p_T modeling	: ~ 8%
Background modeling	: ±0.1-5.6 evts

CMS : $m_{\gamma\gamma}$





H -> ZZ(*) -> 4L (4e, 4μ, 2e 2μ)

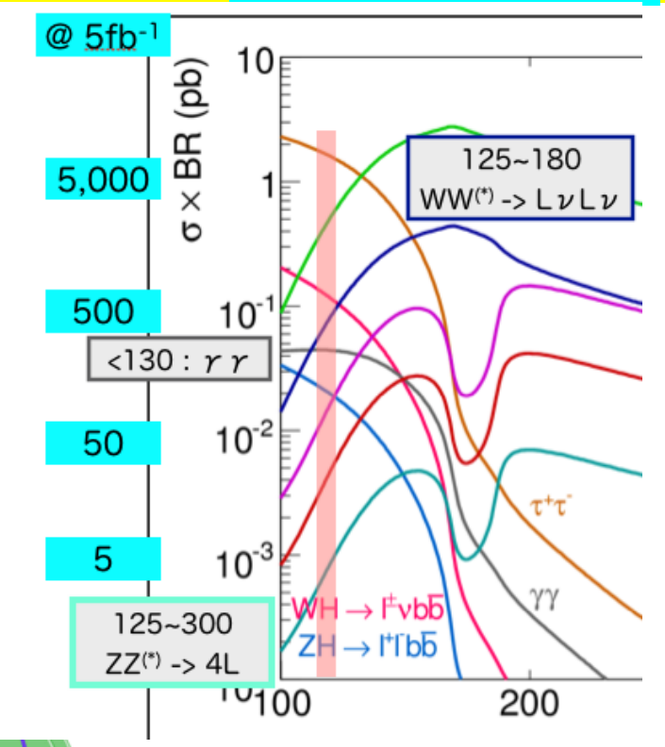
110~600GeV
4.8fb-1

・low mass (120GeV) σ・Br is one order smaller than 2γ

nevertheless ...

・4L inv. mass -> resolution !!

・S/N ~ 1 : very clean !!



0. single Lepton trigger, mu18 , e22(20)

1. 4L : $p_T^{1,2,3,4}$ > 20, 20, 7, 7 GeV

low P_T lepton (e)

✓$m_{12} = m_Z \pm 15$ GeV

✓m_{34} > 15~60 GeV

$m_{4\ell}$ (GeV)	≤120	130	140	150	160
threshold (GeV)	15	20	25	30	30

・Main backgrounds:

✓SM_ZZ(*) (irreducible)

✓2L from b(q)-jets , Zbb , Z+j , tt

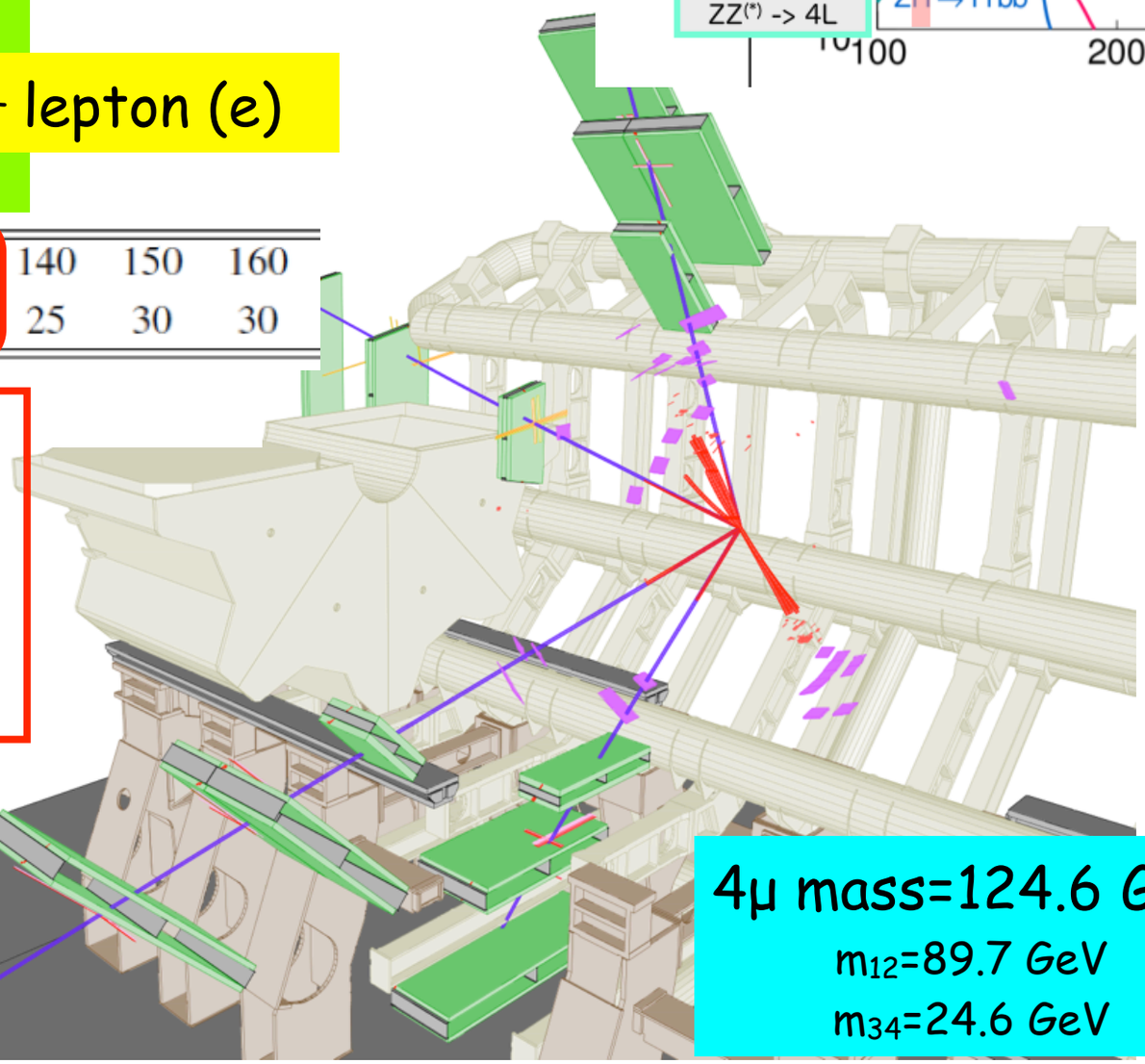
($m_H < 2m_Z$)

・lepton isolation cut

・impact parameter cut

pileup sensitive

-> b-veto for m_{34} leptons



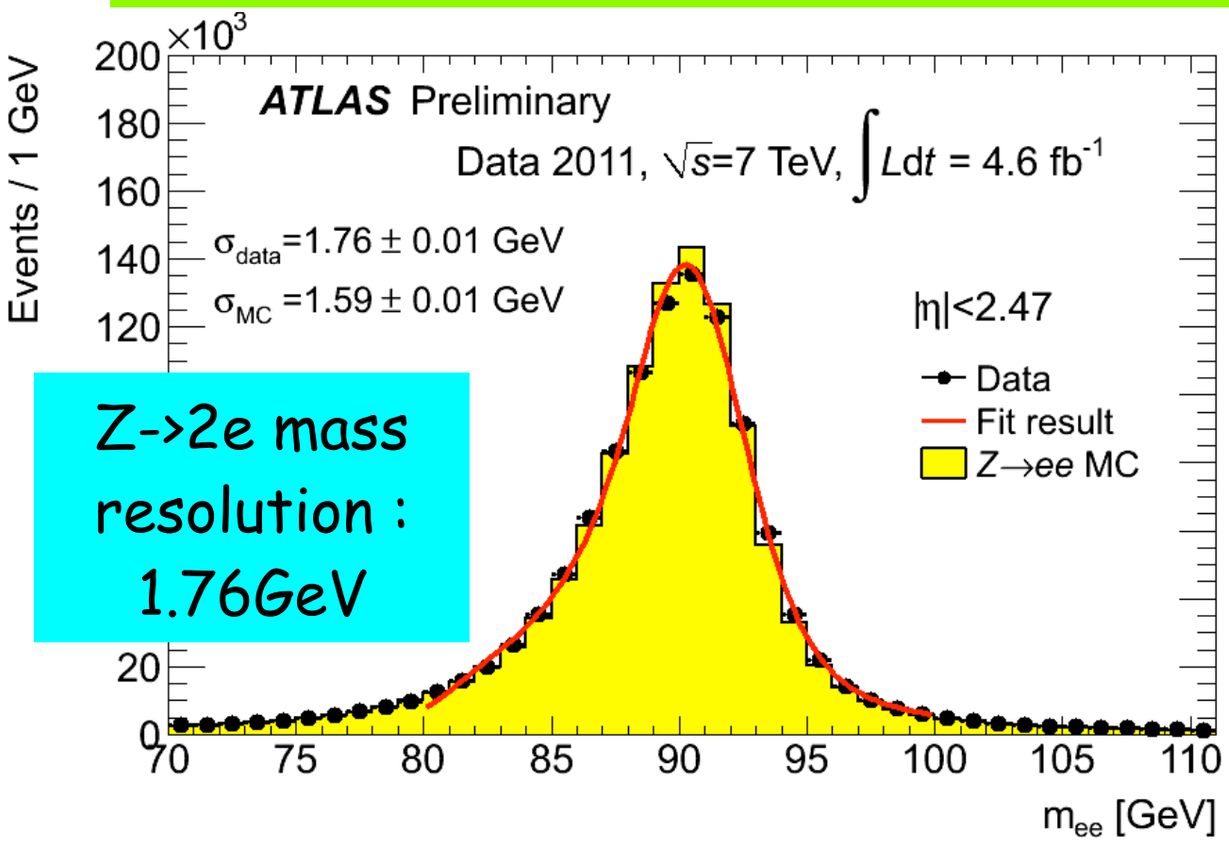
4μ mass=124.6 GeV

m_{12}=89.7 GeV

m_{34}=24.6 GeV

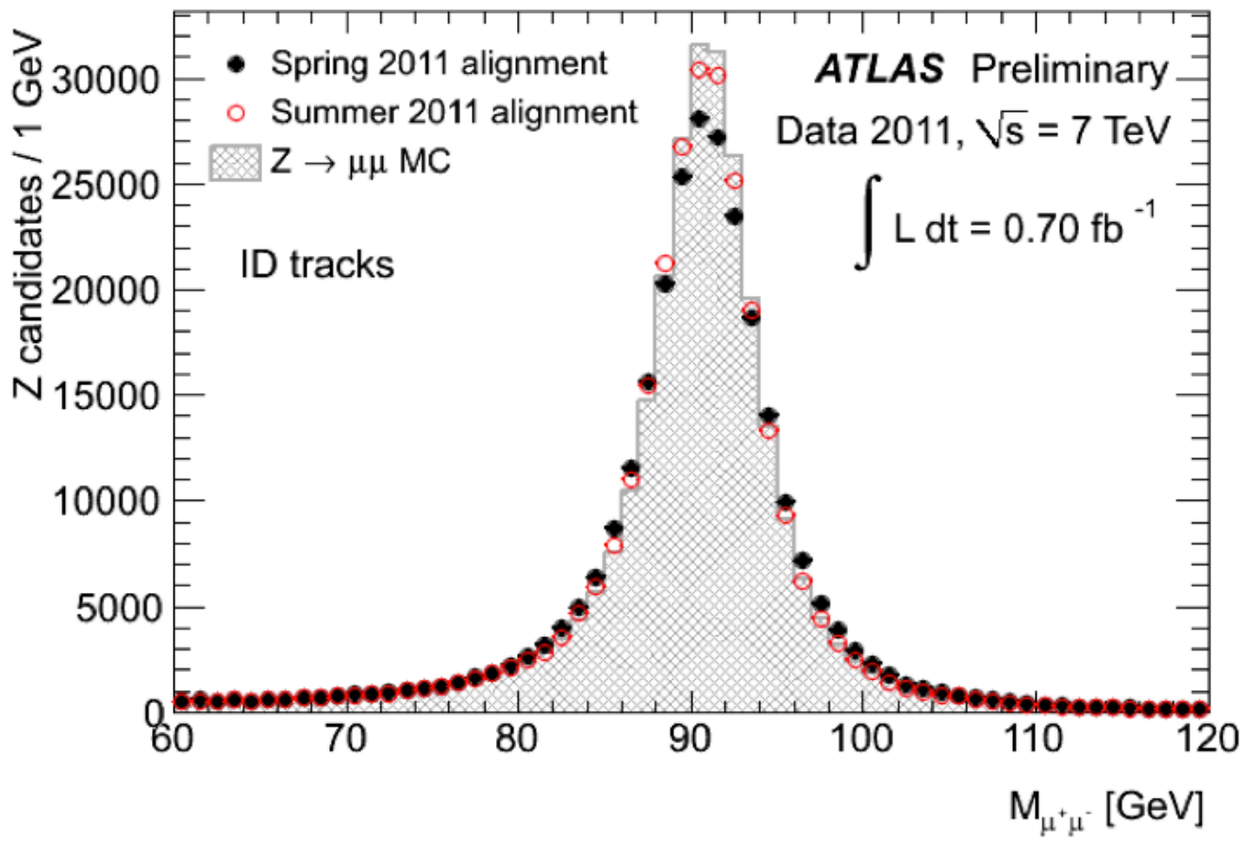
electron / μ performance

Z -> ee : mass resolution



Z->2e mass resolution : 1.76GeV

Z -> $\mu\mu$: inv. mass resolution

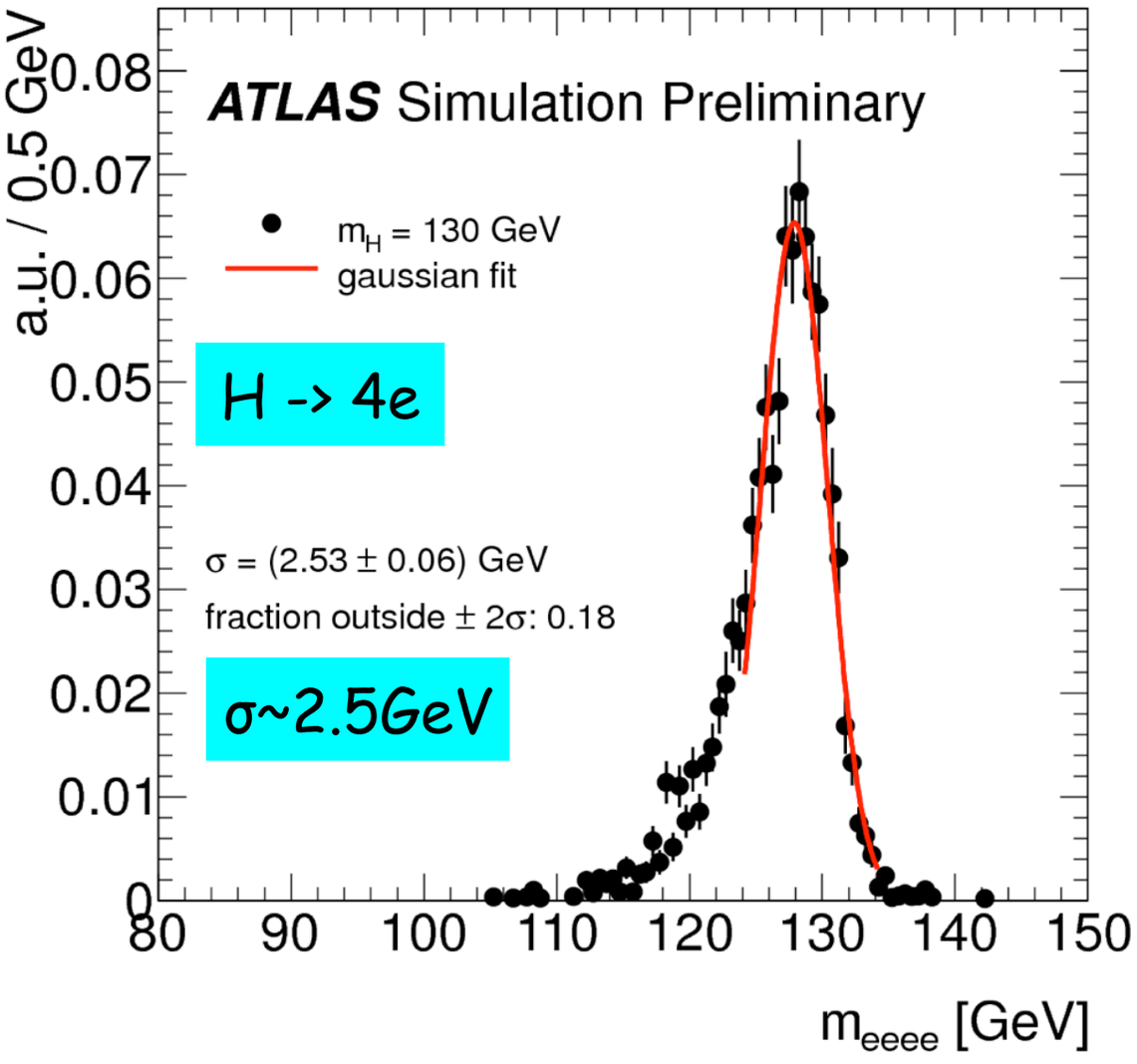


MC (perfect):	2.31 GeV
Data Spring 2011 :	2.89 GeV
Data Summer 2011:	2.45 GeV

accuracy of detector alignment is approaching to the ideal situation
(MC : ~30μm)

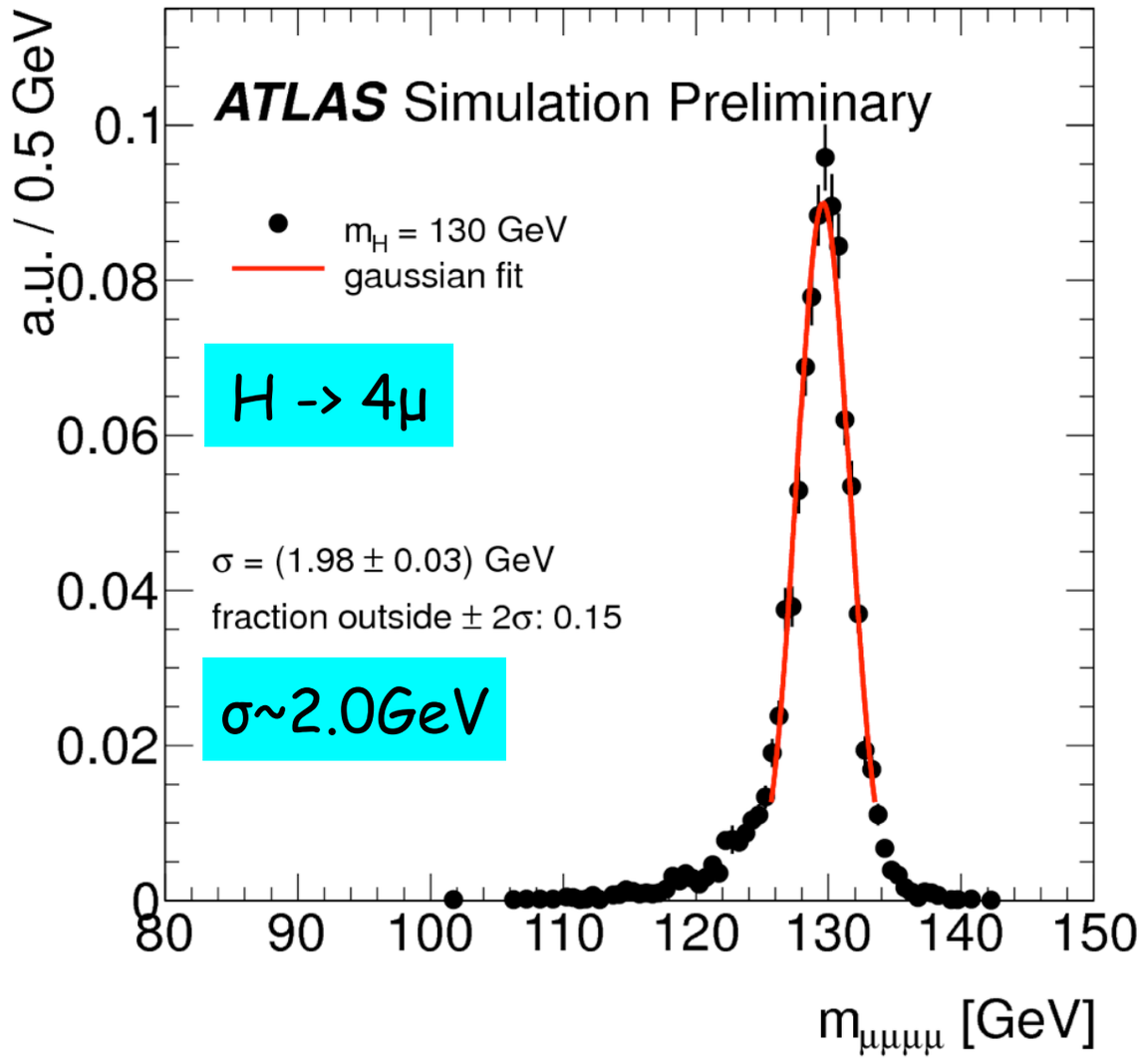
H(130GeV) -> 4Lepton inv. mass (MC)

MC : H(130) -> ZZ -> 4e



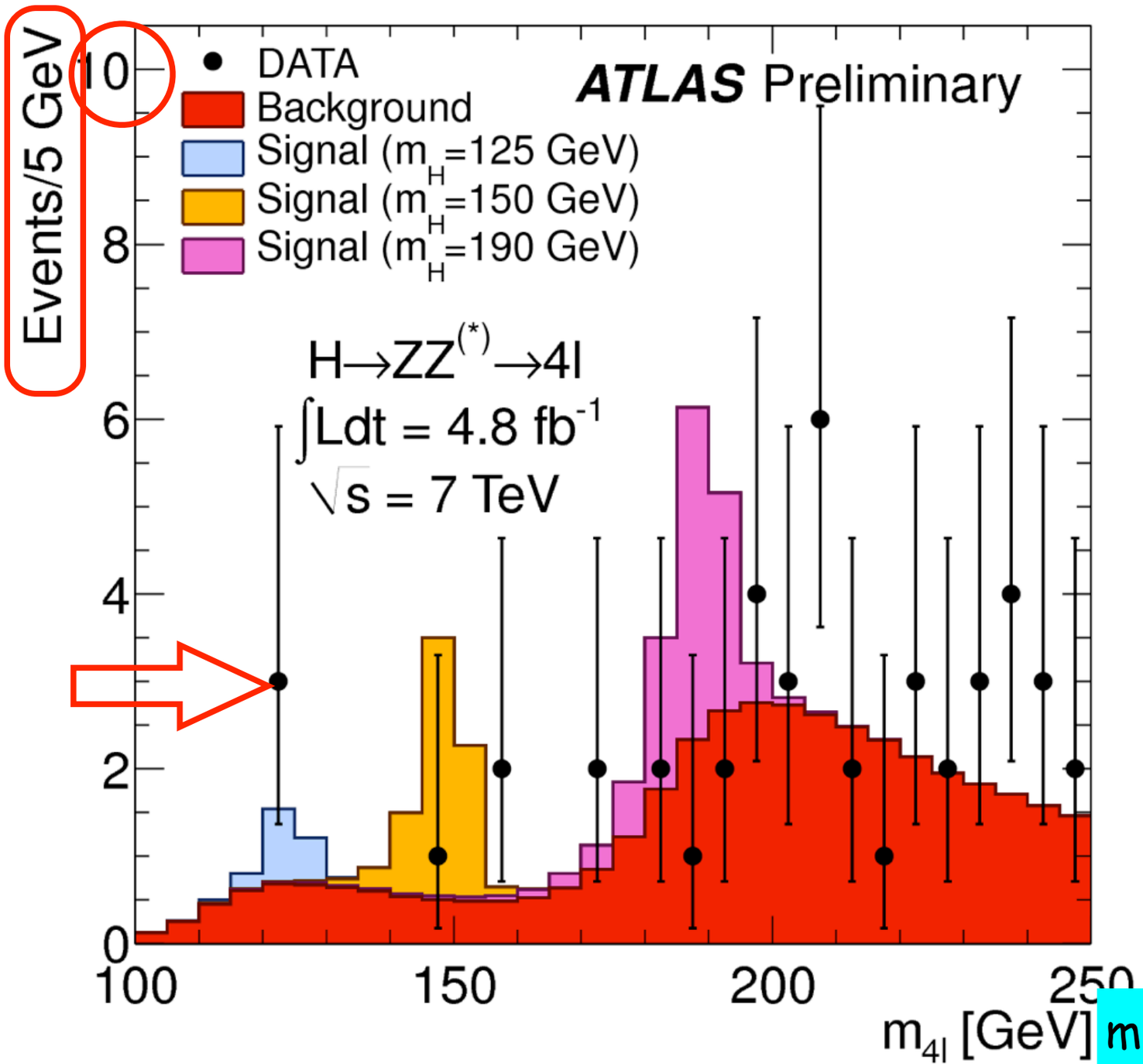
82% in ±2σ (i.e. 82% in **10GeV**)

MC : H(130) -> ZZ -> 4μ



85% in ±2σ (i.e. 85% in **8GeV**)

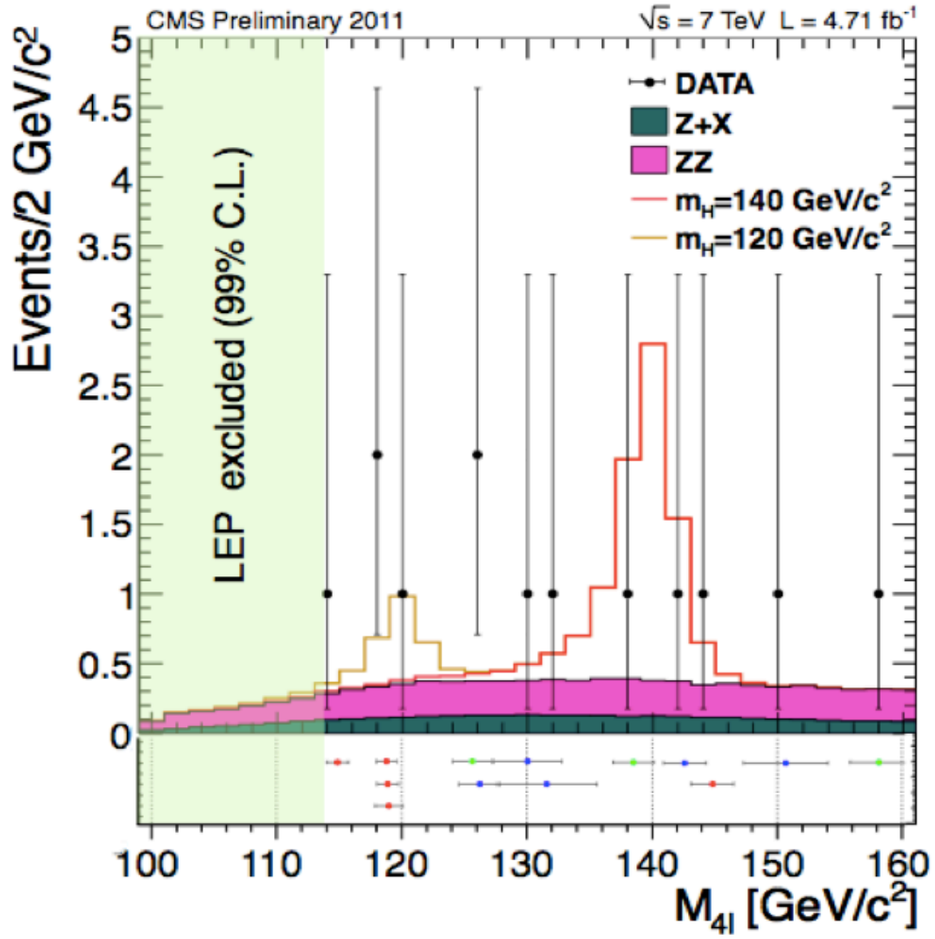
4Lepton invariant mass distribution



3events in 1bin (10GeV) ...

124.6 (4μ), 124.3 (2e2μ), 123.6 (2e2μ)

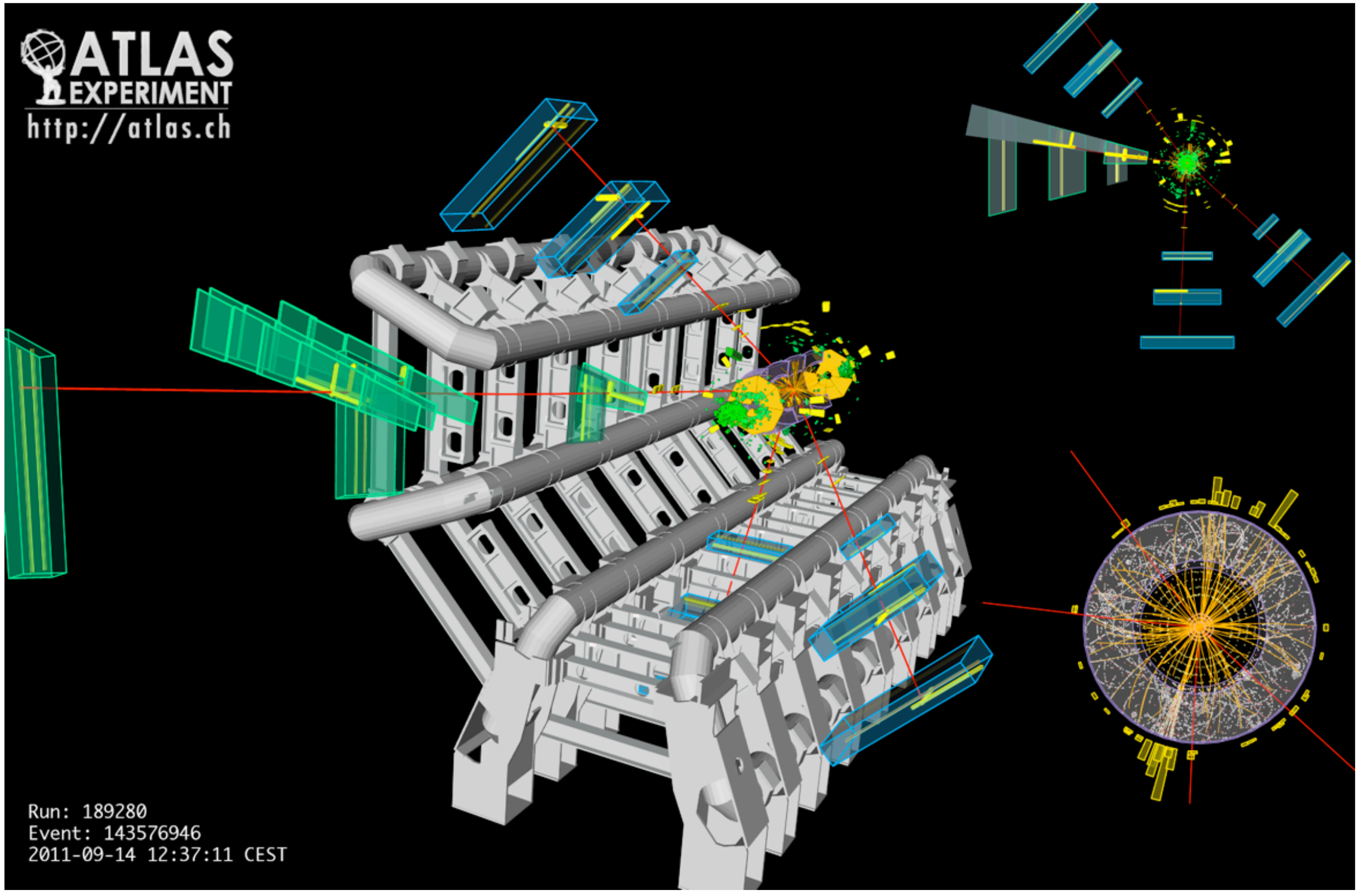
CMS : ZZ -> 4L



m(4L) < 180 GeV
Observed: 8 events:
[3 (4μ) + 3 (2e2μ) + 2 (4e)]
Expected from background: 9.3 ± 1.5

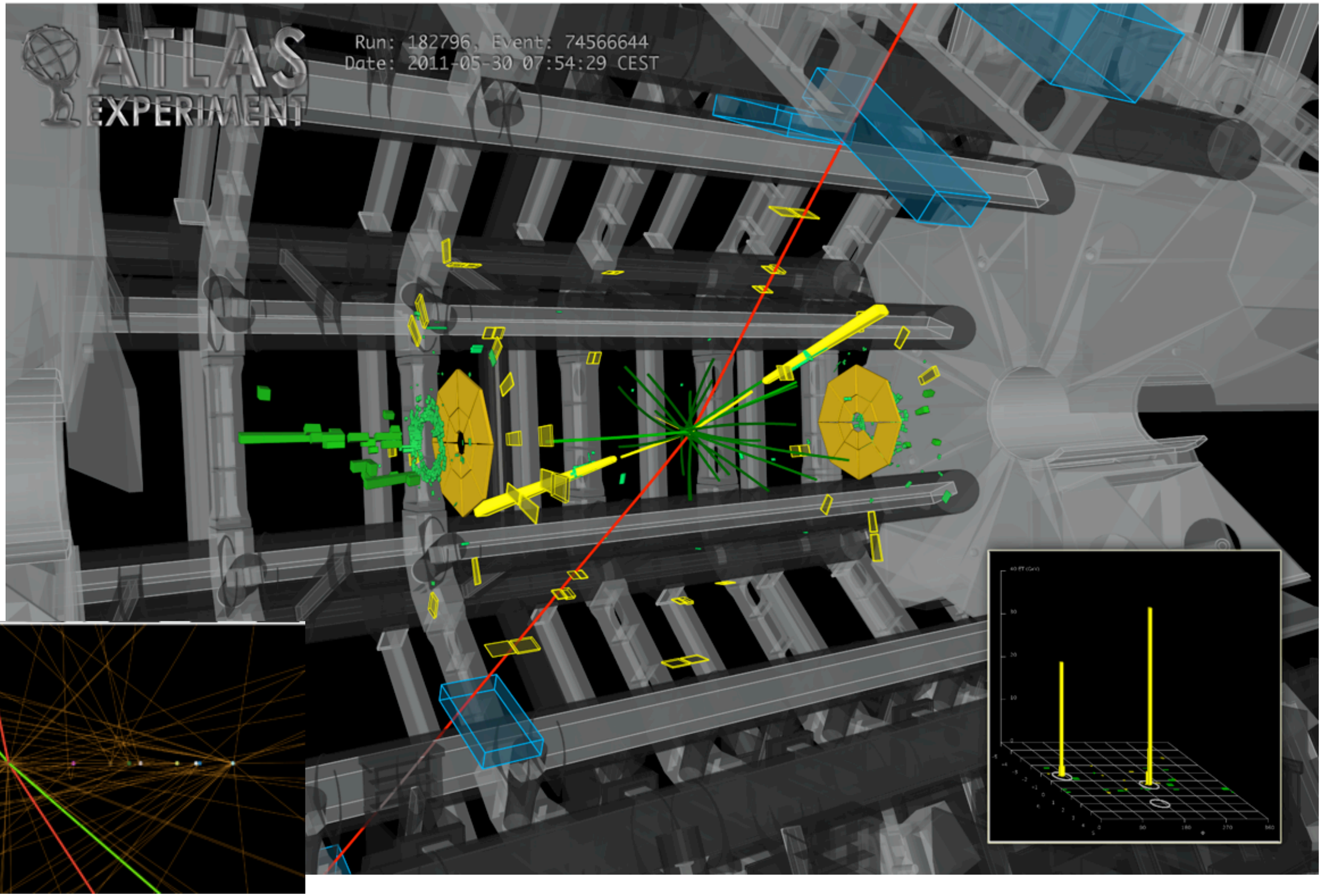
$m_{4\mu}$ = 124.6 GeV

p_T (μ^-, μ^+, μ^+, μ^-)= 61.2, 33.1, 17.8, 11.6 GeV
m_{12}= 89.7 GeV , m_{34}= 24.6 GeV

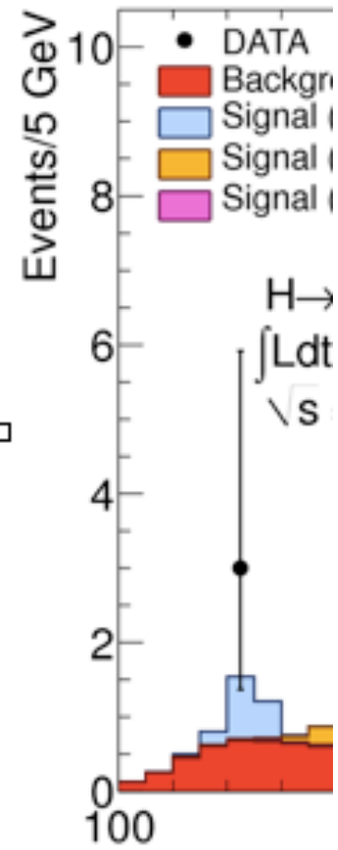


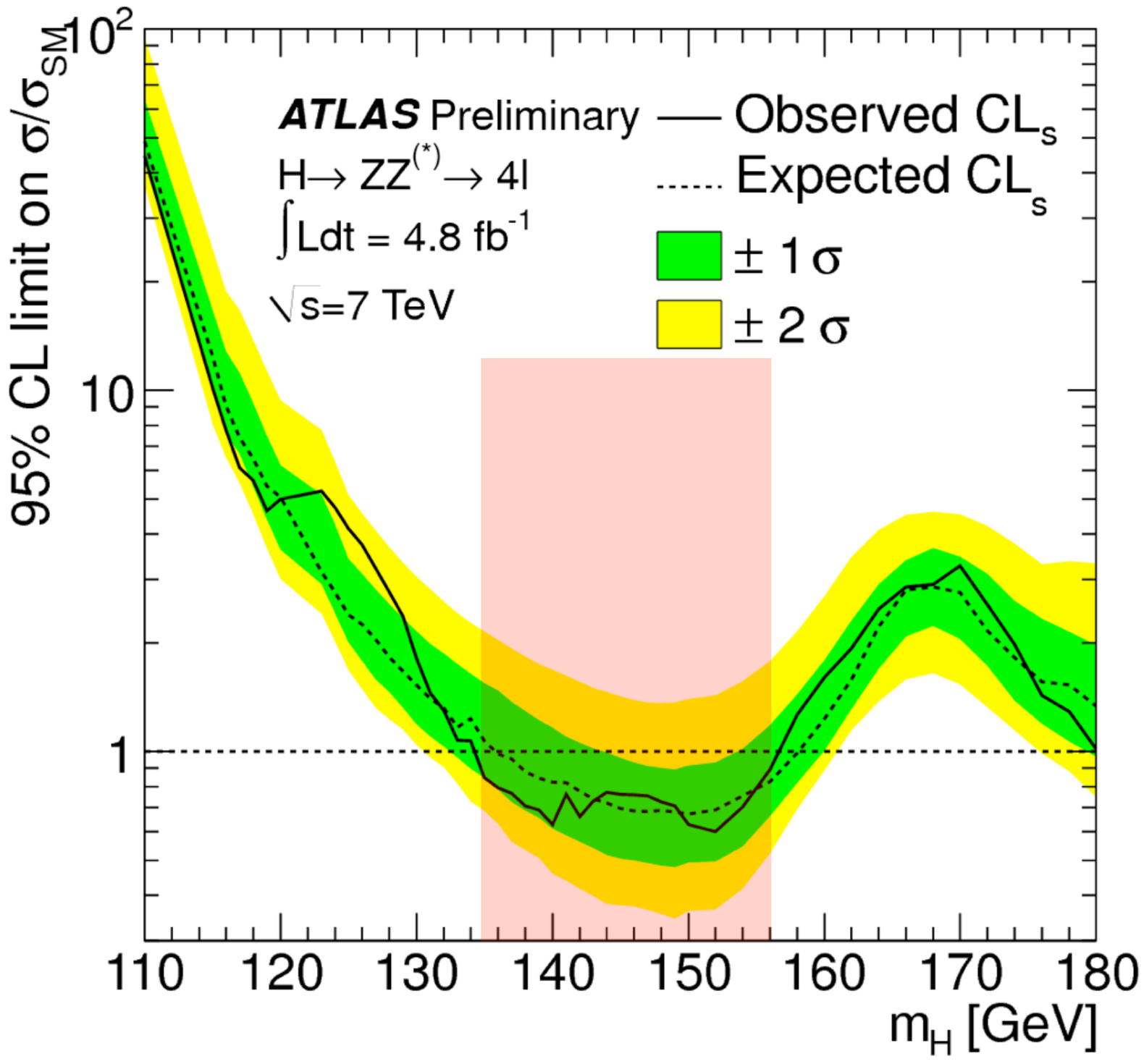
$m_{2e2\mu}$ = 124.3 GeV

p_T (e^+, e^-, μ^-, μ^+)= 41.5, 26.5, 24.7, 18.3 GeV
m (e^+e^-)= 76.8 GeV , m($\mu^+\mu^-$) = 45.7 GeV



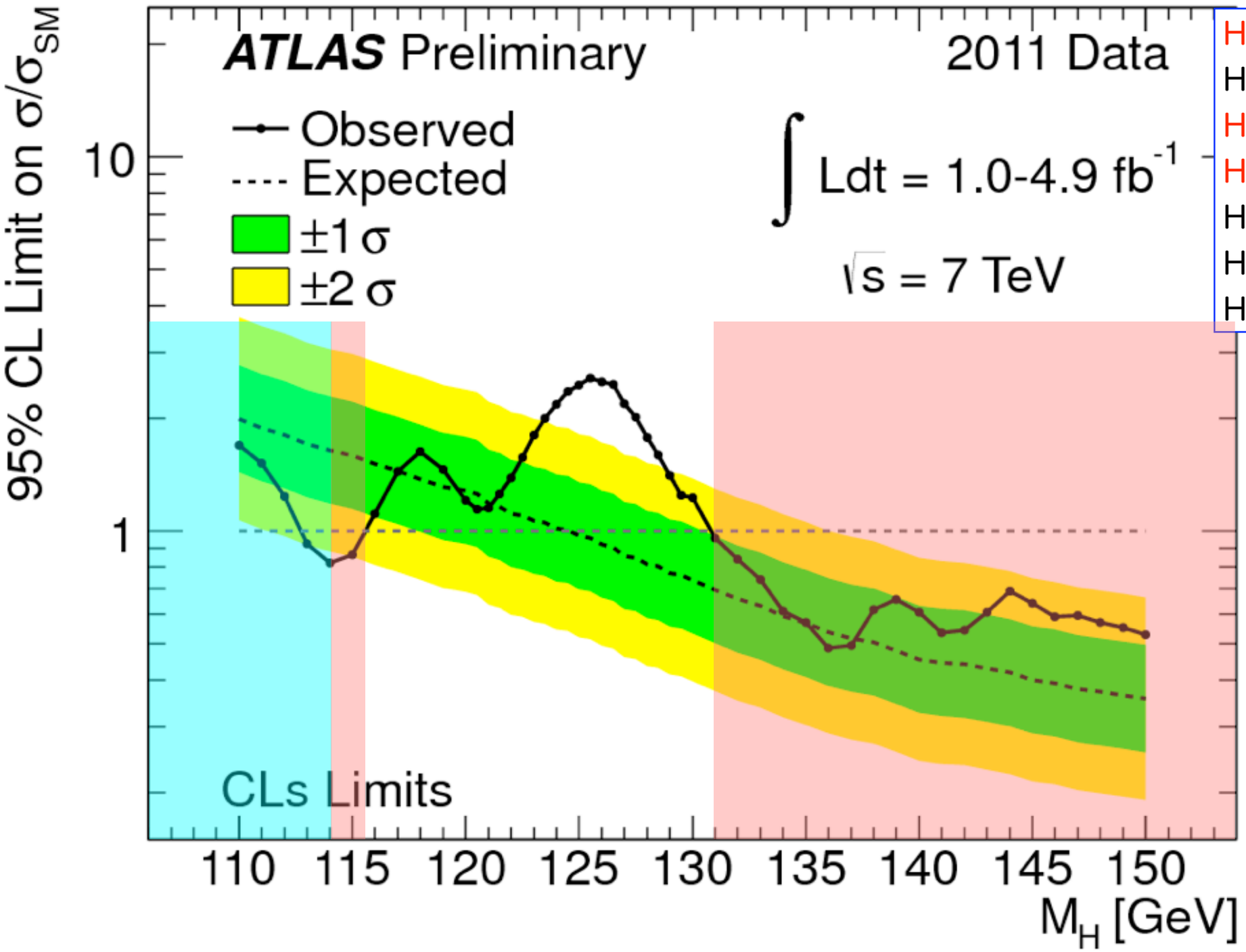
H -> ZZ -> 4L : sensitivity & exclusion





Excluded (95% CL): **135 < m_H < 156 GeV** and 181 < m_H < 415 GeV
Expected (95% CL): 137 < m_H < 158 GeV and 185 < m_H < 400 GeV

ATLAS Higgs Combined (i)



H->γ γ	(4.9fb^{-1})
H->τ τ	(1.06fb^{-1})
H->WW$^{(*)}$ -> L ν L ν	(2.05fb^{-1})
H-> ZZ$^{(*)}$ -> 4L	(4.8fb^{-1})
H-> ZZ-> ll ν ν	(2.05fb^{-1})
H-> ZZ -> llqq	(2.05fb^{-1})
H-> WW -> l ν qq	(1.04fb^{-1})

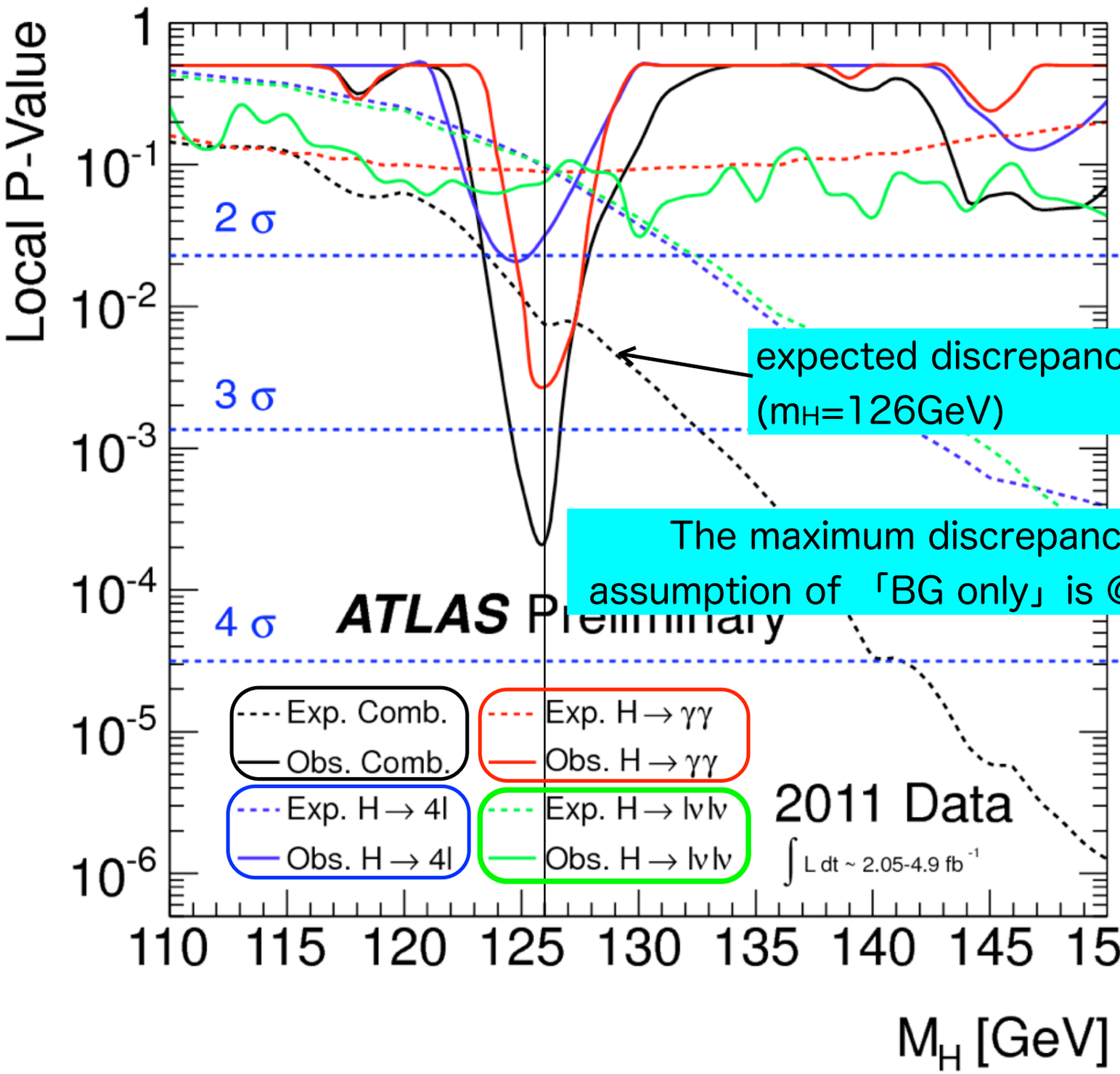
Excluded at 95% CL Limit

- 112.7 < m_H < 115.5 GeV
- 131 < m_H < 453 GeV (除 : 237-251GeV)

Expected , if no signal

- 124.6 < m_H < 520 GeV

ATLAS Higgs combined (ii)



expected discrepancy, if there is a SM Higgs (m_H=126GeV)

The maximum discrepancy from an assumption of 「BG only」 is @ m_H=126GeV

local P_0-value: 1.9×10^{-4} (3.6σ)

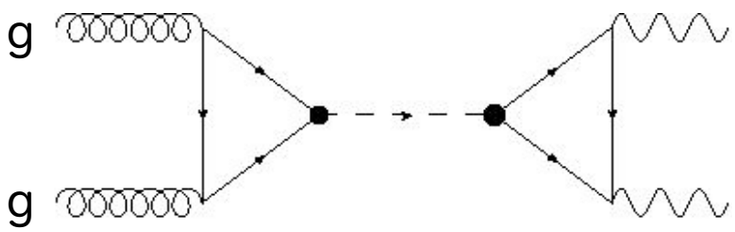
- ~2.8σ(γγ)
- ~2.1σ(4L)
- ~1.4σ(Lν Lν)

expected SM_Higgs ~2.4σ

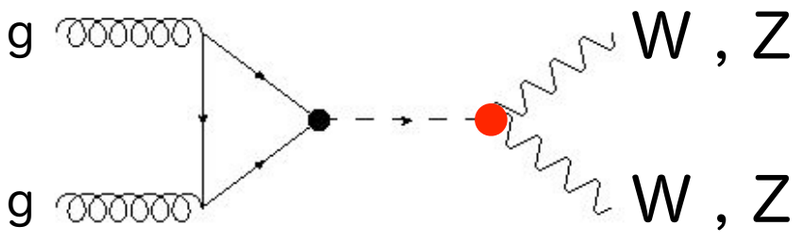
2012

・7TeV -> 8TeV : σ x 1.3
・~15fb^{-1}

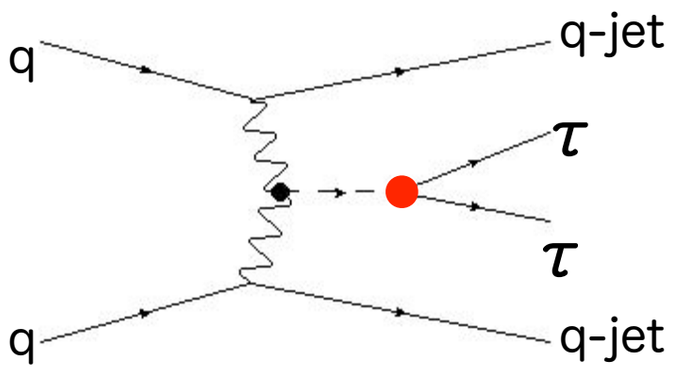
・m_H : 120~130GeV -> 5 σ discovery , if there is ...



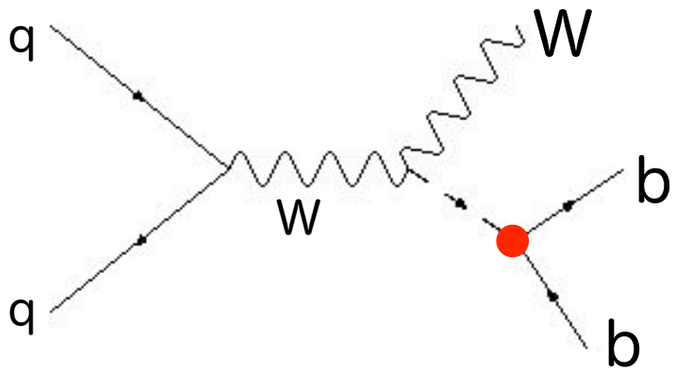
indirect
Y_t



g_{ZZH} , g_{WWH}

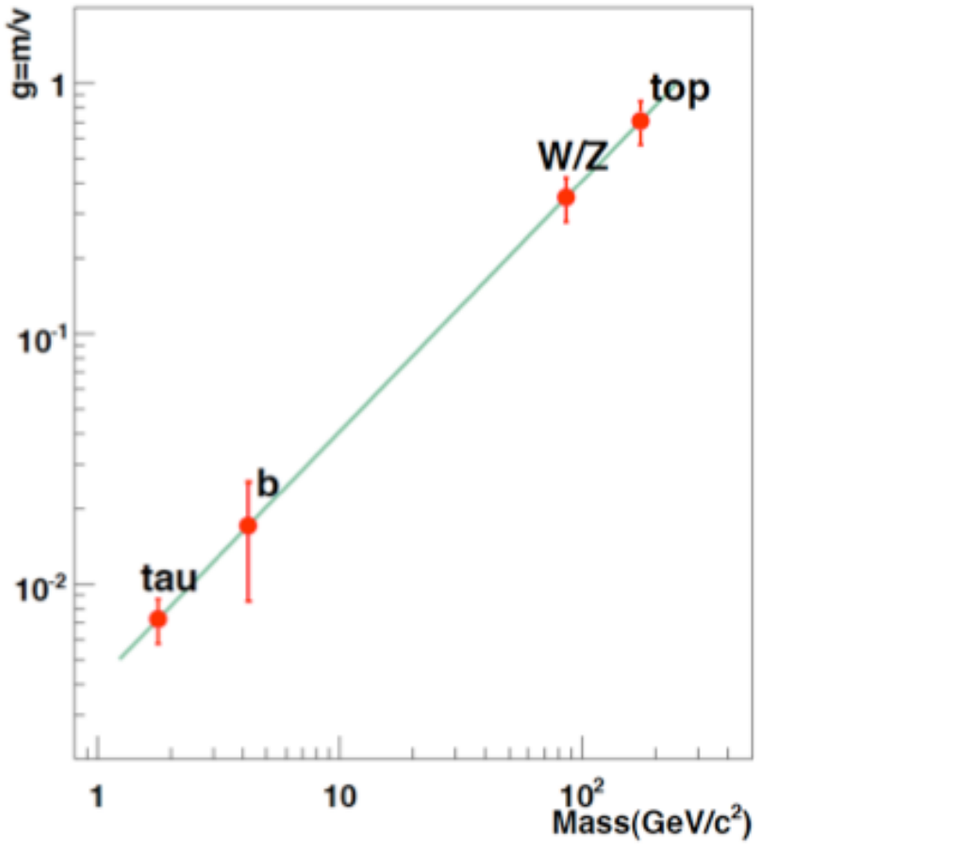


Y_τ (tau)



Y_b

measurements of Higgs coupling
(gauge , lepton , quark)
-> HHH self-coupling important



7->14TeV , 300fb^{-1} , 3,000fb^{-1}
more luminosity , more event pileup (140 ?)

LHC : phase-0 , 1 , 2 upgrade

draft :
10yr calendar