The $\gamma\gamma$ contribution to the Higgs discovery with the ATLAS detector
(a personal overview)

HiggsDiscovery@10
Birmingham, June 30 and July 1, 2022

L. Carminati (Universita' Degli Studi and INFN, Milano)

.... and many others (N. Berger, M. Delmastro, M. Escalier, L. Fayard, J. Schaarschmidt, , K. Tackmann, J. Tanaka, H. Torres, H. Wang)

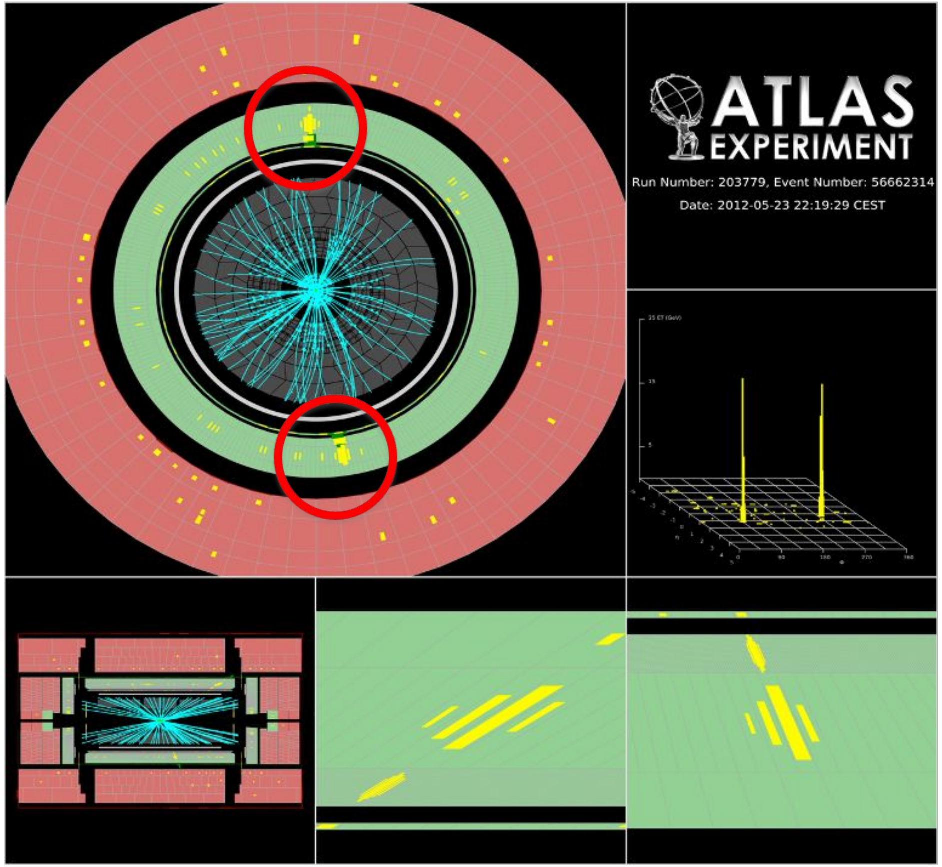
To make a long story...longer

From ATLAS Detector, Physics and Performance TDR back in 1999

19.2.2 $H \to \gamma\gamma$

The decay $H \to \gamma\gamma$ is a rare decay mode, only observable over a limited Higgs boson mass region, where the production cross-section and the decay branching ratio are both relatively large. It is a promising channel for Higgs searches in the mass range $100 < m_H < 150$ GeV and places severe requirements on the performance of the EM Calorimeter. Excellent energy and angular resolution are needed to observe the narrow mass peak above the irreducible prompt $\gamma\gamma$ continuum. Powerful particle identification capability is also required to reject the large QCD jet background as well as the potentially dangerous resonant background from $Z \to ee$ decays, in the case where $m_H \approx m_Z$.

To make a long story...longer



In principle the analysis itself is quite simple : look for two high p_T photons

- ❑ Trigger: two clusters with $E_T^{\gamma 1} > 20(35)$ $E_T^{\gamma 1} > 20(25)$ compatible with showers initiated by a photon (loose selection)
- ❑ Both photons with $|\eta|<2.37$ ($1.37<|\eta|<1.56$ excluded)
- ❑ Both photon candidates are calibrated: $E_T^{\gamma 1} > 40$ GeV (leading) and $E_T^{\gamma 2} > 30$ GeV (subleading)
- ❑ Both photon candidates are required to fulfill identification criteria (tight selection)
- ❑ Both photon candidates are required to be isolated (low hadronic activity around the candidate)
- ❑ Select a discriminating variable (invariant mass)

$$m_{\gamma\gamma} = \sqrt{2E^{\gamma 1}E^{\gamma 2}[1 - \cos(\theta(\gamma_1, \gamma_2))]}$$

- ❑ Categorisation of the events
- ❑ Model signal and background invariant mass distributions with functional forms in each category
- ❑ Fit to data !

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1-Excellent energy resolution

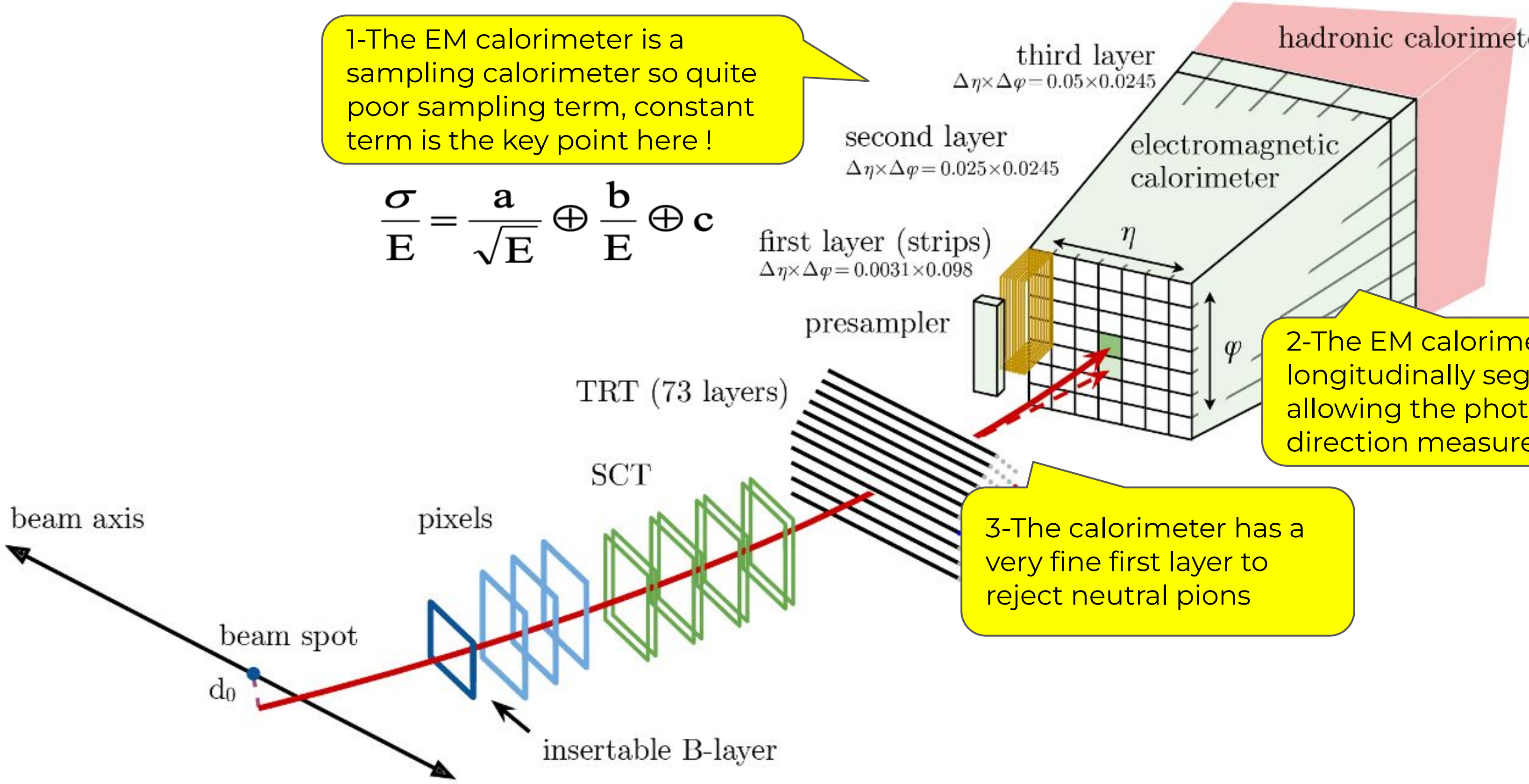
2-Excellent angular resolution

3-Powerful particle identification capability

To make a long story...longer

1-The EM calorimeter is a sampling calorimeter so quite poor sampling term, constant term is the key point here !

$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$



2-The EM calorimeter is longitudinally segmented allowing the photon direction measurement

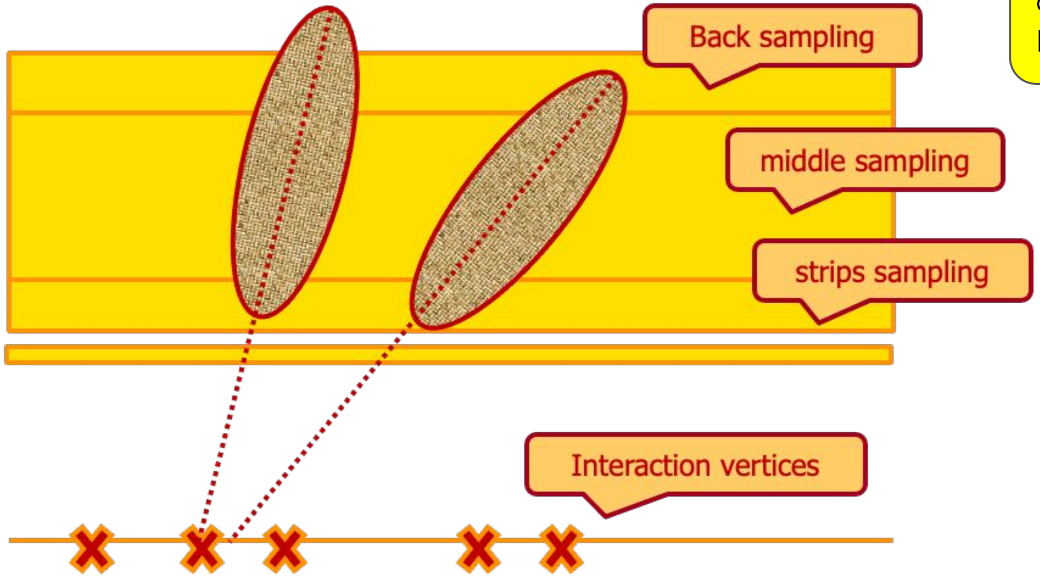
3-The calorimeter has a very fine first layer to reject neutral pions

1-calorimeter energy resolution

Constant term requirements met only through a maniacal characterization of each single component and assembly

2-direction resolution

The determination of the interaction vertex is crucial for the invariant mass calculation : for di-photon events (especially in high pileup conditions) might not be a good idea to rely on tracking



Interaction vertex from the EM Calo alone by a common vertex fit of the two photons + beam-spot constraint : z = 0, σz = 5.6 cm.

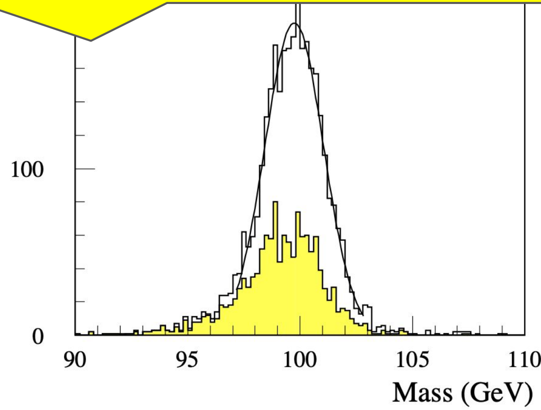


Figure 7-48 Two-photon invariant mass reconstructed in the EM Calorimeter for $H \rightarrow \gamma\gamma$ events with m_H = 100 GeV at high luminosity. The open histogram is for all events; the shaded histogram, for events containing at least one converted photon. The fitted curve is a Gaussian with a width of 1.31 GeV.

3-photon identification, background rejection

Photon identification through criteria on variables quantifying the shower development in the calorimeter (shower shapes)

These rejection factors have been realistically evaluated by using large samples of fully simulated two-jet events, as described in Section 7.6. The rejection factors were then applied to estimate the cross-sections for the reducible jet-jet and γ-jet backgrounds relative to the irreducible γγ-background. The results are shown in Figure 19-2 as a function of the two-photon invariant mass $m_{\gamma\gamma}$. After applying the full photon identification cuts from the calorimeter and the Inner Detector, the residual jet-jet and γ-jet backgrounds are found to be at the level of approximately 15% and 20%, respectively, of the irreducible γγ background over the mass range relevant to the $H \to \gamma\gamma$ search.

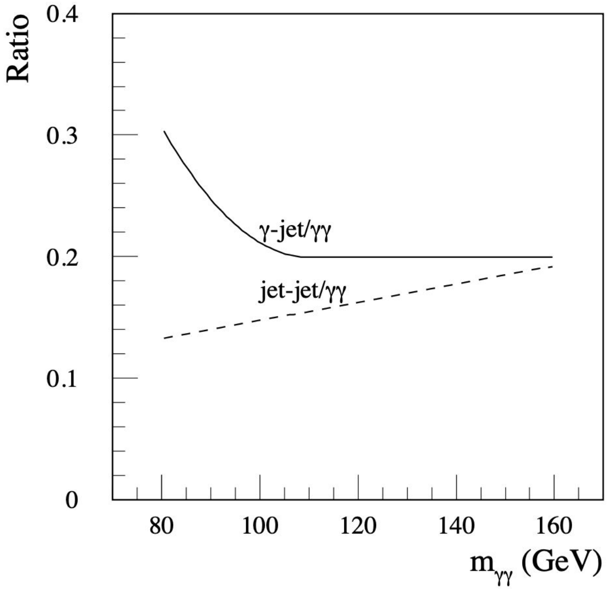


Figure 19-2 Expected ratios of the residual reducible jet-jet and γ-jet backgrounds to the irreducible γγ-continuum background as a function of the invariant mass of the pair of photon candidates at high luminosity.

To make a long story...longer

Table 19-2 Observability of the $H \to \gamma\gamma$ signal (direct and associated production) for $80 < m_H < 150$ GeV. The expected numbers of signal and background events in the mass window, chosen to be $m_H \pm 1.4\sigma$, are given for an integrated luminosity of 100 fb^{-1}. The signal significances are given for integrated luminosities of 100 fb^{-1} (high luminosity) and 30 fb^{-1} (low luminosity).

Higgs mass (GeV)	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**
Signal events (direct production)	502	655	947	1110	1190	1110	915	617
Signal events (WH, ZH, $t\bar{t}H$ production)	85	76	98	97	93	76	58	35
$\gamma\gamma$ background	41 700	41 000	41 400	35 000	29 000	24 700	20 600	16 900
Jet-jet background	5400	5600	5950	5300	4600	4100	3550	3050
γ-jet background	12500	10600	9100	7000	5800	4900	4100	3400
$Z \to ee$ background	-	< 70	-	-	-	-	-	
Stat. significance for 100 fb^{-1}	2.4	3.1	4.4	5.6	6.5	6.5	5.8	4.3
Stat. significance for 30 fb^{-1}	1.5	1.9	2.7	3.4	3.9	4.0	3.5	2.6

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$Z \rightarrow ee$ background	-	< 70	-	-	-	-	-	
Stat. significance for 100 fb^{-1}	2.4	3.1	4.4	5.6	6.5	6.5	5.8	4.3
Stat. significance for 30 fb^{-1}	1.5	1.9	2.7	3.4	3.9	4.0	3.5	2.6

For an integrated luminosity of 100 fb^{-1}, a Standard Model Higgs boson in the mass range between 105 GeV and 145 GeV can be observed with a significance of more than 5σ by using the $H \rightarrow \gamma\gamma$ channel alone. Table 19-2 also contains the estimated significances of the $H \rightarrow \gamma\gamma$ channel for an integrated luminosity of 30 fb^{-1}, corresponding to the first three years of LHC operation. The significances at low luminosity have been evaluated by taking the resulting improvements in mass resolution and background rejection into account. A signal in the $\gamma\gamma$ channel can only be seen in this case with a significance of $\sim 4\sigma$ over a narrow mass range between 120 and 130 GeV.

A long and hard road : testbeams !

Long testbeam campaign to understand and improve the the detector performance

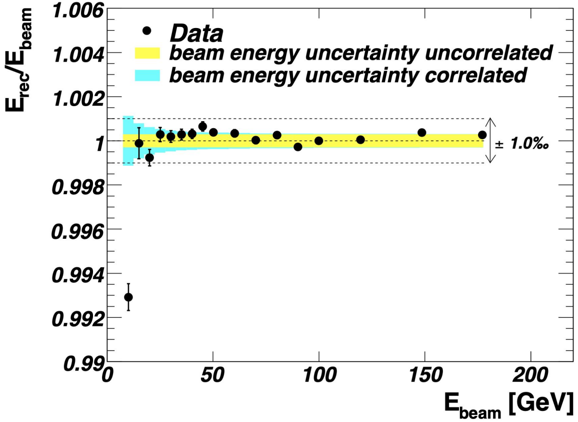


Fig. 16. Ratio of the reconstructed electron energy to the beam energy as a function of the beam energy. All points are normalised to the value measured at $E = 100$ GeV. The inner band illustrates the uncorrelated uncertainty of the beam energy measurement; in the outer band the correlated uncertainty is added in quadrature to the inner band.

'local' performance

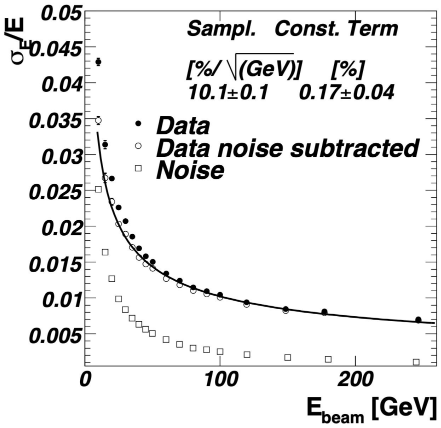


Fig. 19. Fractional energy resolution as a function of the beam energy. Shown are the data before (closed circles) and after (open circle) the gain dependent noise subtraction. Overlayed as a line is a parameterisation of the resolution based on eq. 8 obtained from a fit. The open squares indicate the subtracted noise contribution.

'global' performance

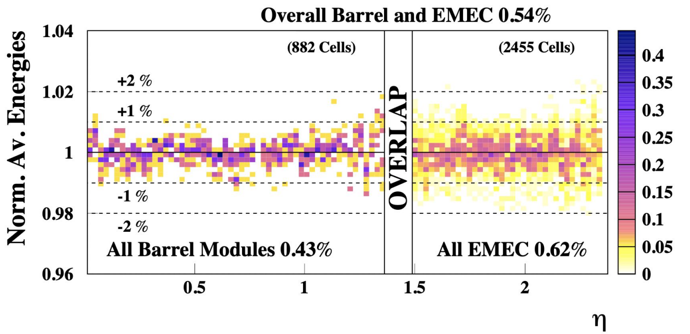


Fig. 26. *Two dimensional histogram of the average energies measured in all cells of all tested modules normalized to the mean energy of the modules. In the barrel the energies were ∼245 GeV and ∼120 GeV in the EMEC. The distributions are normalized to the number of middle cells scanned in* ϕ *for each value of* η.

A long and hard road : testbeams !

Measurement of pi0 rejection capability on testbeam data : create pseudo-pi0s from single photons showers

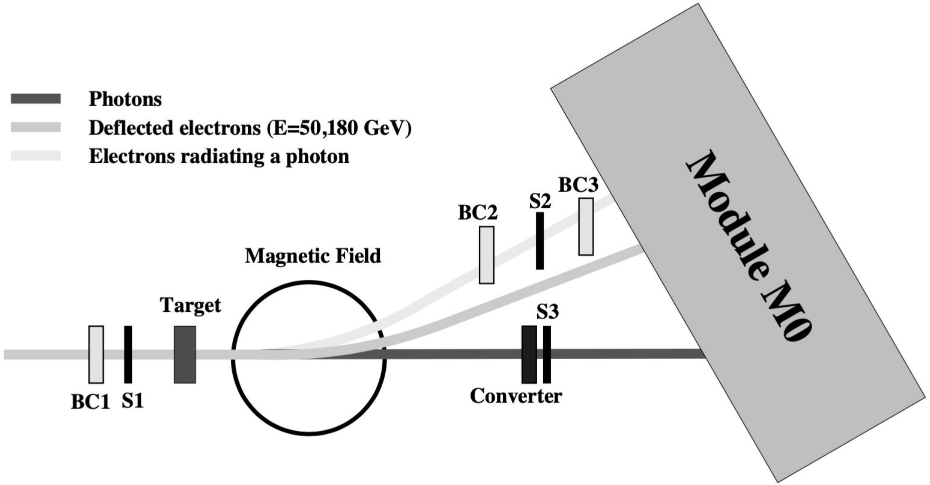
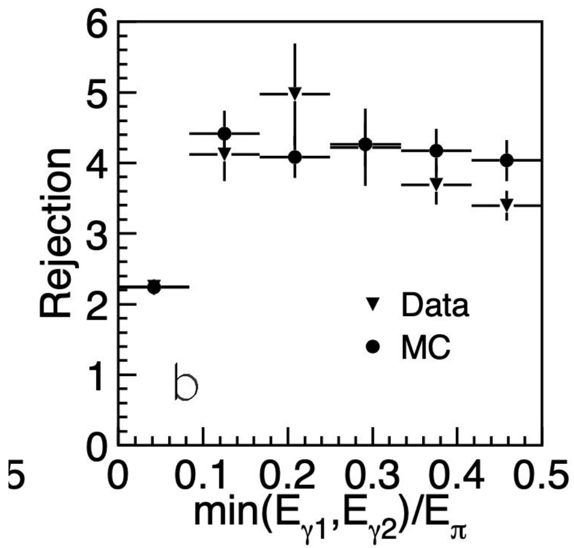


Fig. 2. Photon beamline setup.

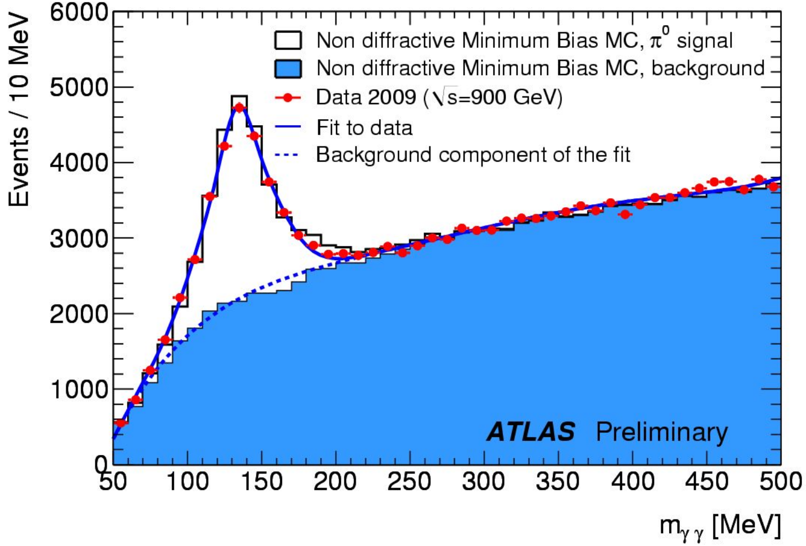


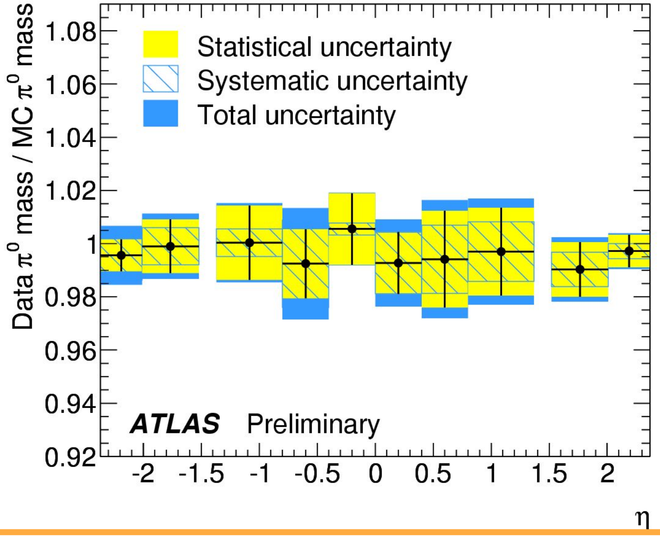
Teastbeam measurements paper

First data 900 GeV : the first di-photon resonance

ATLAS-CONF-2010-006

The analysis is based on a data sample collected at √s = 900 GeV. The sample requires good data quality for the electromagnetic calorimeter and hadronic calorimeters. The solenoidal field is required to be at its nominal value. The data sample consists of 493,683 collision candidates which corresponds to an integrated luminosity of approximately 11.5 μb−1.

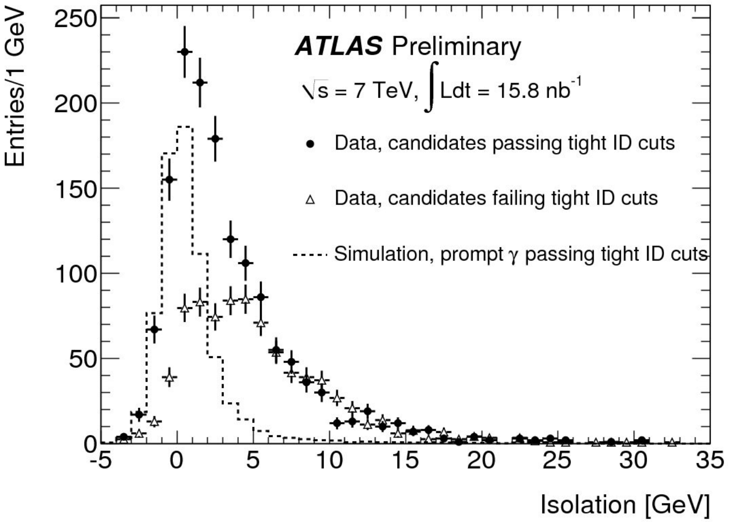


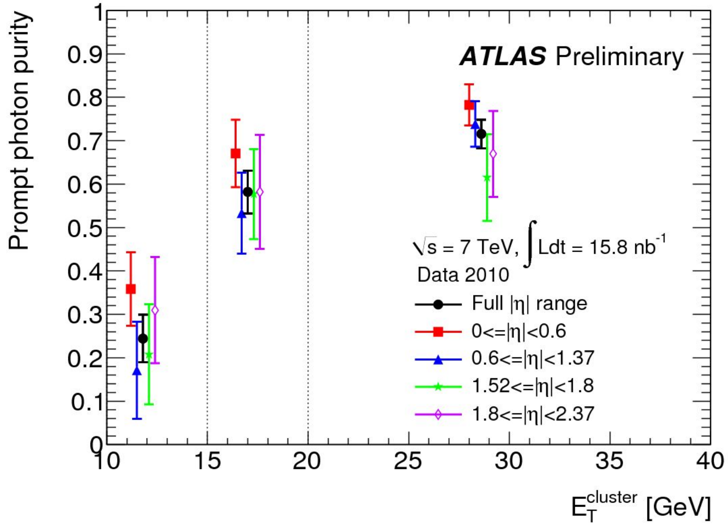


The good agreement between data and Monte Carlo for low-energy photons gives confidence that the nominal performance expected for the EM calorimeter at higher energy can be achieved.

The first evidence of prompt photon production

ATLAS-CONF-2010-077

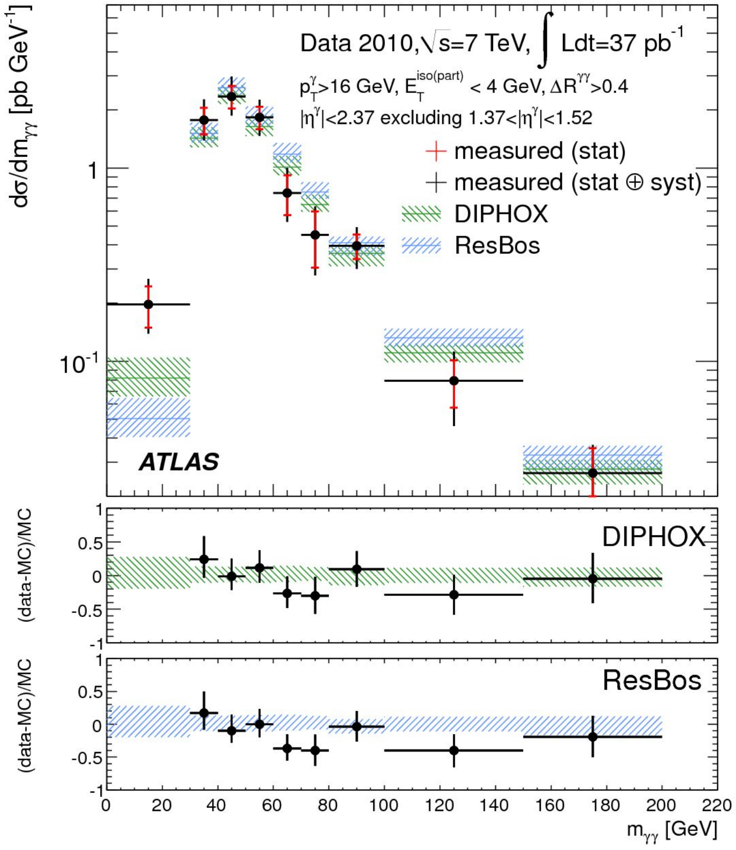




A signal of prompt photon production has been extracted from a small set of 7 TeV *pp* collision data collected at the LHC with the ATLAS detector. After tight identification cuts, a statistically significant prompt photon yield above 15 GeV is found, as well as a prompt photon purity which increases as a function of the photon transverse energy. For transverse energies above 20 GeV a signal yield of (618 ± 72) prompt photons with a purity of $(72 \pm 7)\%$ is measured, including statistical and systematic uncertainties. Together with the first estimates of the photon efficiency measurement, this gives confidence that a measurement of the prompt photon production cross section will soon be possible and that physics studies with photons in the final state are promising.

First measurement of prompt di-photon production

First diphoton paper



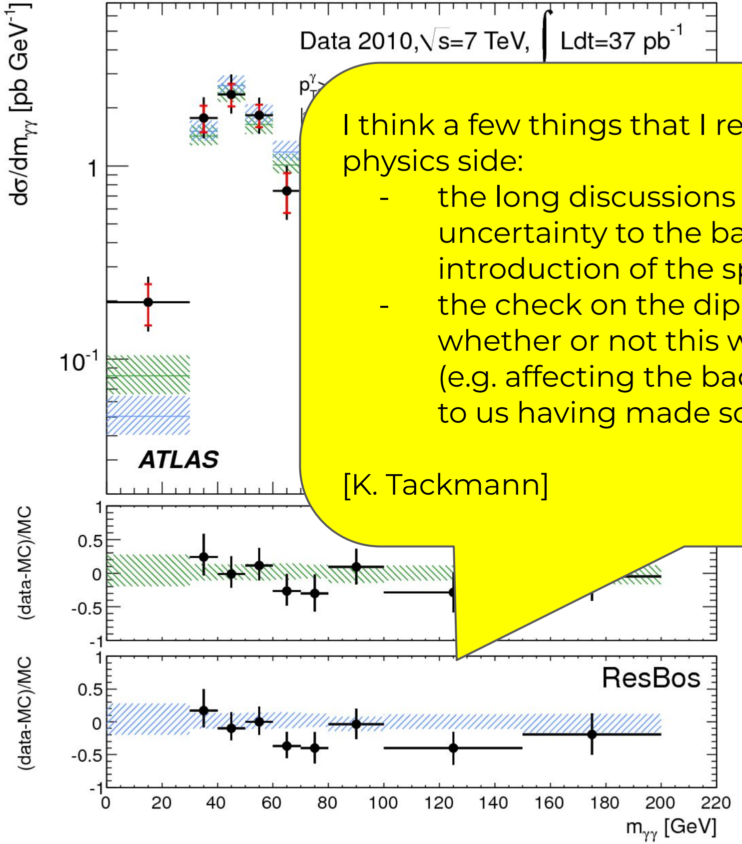
This paper describes the measurement of the production cross-section of isolated di-photon final states in proton-proton collisions, at a centre-of-mass energy $\sqrt{s} = 7$ TeV, with the ATLAS experiment. The full data sample collected in 2010, corresponding to an integrated luminosity of 37.2 ± 1.3 pb^{-1}, has been analysed.

From the evaluation of the background yields ($N^{\mathbf{TITI}}_{\gamma j} + N^{\mathbf{TITI}}_{j\gamma}$ and $N^{\mathbf{TITI}}_{jj}$), the average fractions of photon-jet and di-jet events in the **TITI** sample are $\sim 26\%$ and $\sim 9\%$ respectively.

predictions. The distribution of $d\sigma/dm_{\gamma\gamma}$ is in good agreement with both the DIPHOX and ResBos predictions, apart from the low mass region. The result for

First measurement of prompt di-photon production

First diphoton paper



I think a few things that I remember particularly on the physics side:

- the long discussions how to assign a proper uncertainty to the background model choice and introduction of the spurious signal uncertainty
- the check on the dip just left of the peak, and whether or not this was indicating some problem (e.g. affecting the background shape, or pointing to us having made some mistake)

[K. Tackmann]

… the measurement of the pro- … solated di-photon final states … s, at a centre-of-mass energy … LAS experiment. The full data … corresponding to an integrated … b^{-1}, has been analysed.

… he background yields ($N_{\gamma j}^{TITI}$ + … average fractions of photon-jet … **TITI** sample are ~ 26% and ~ 9% respectively.

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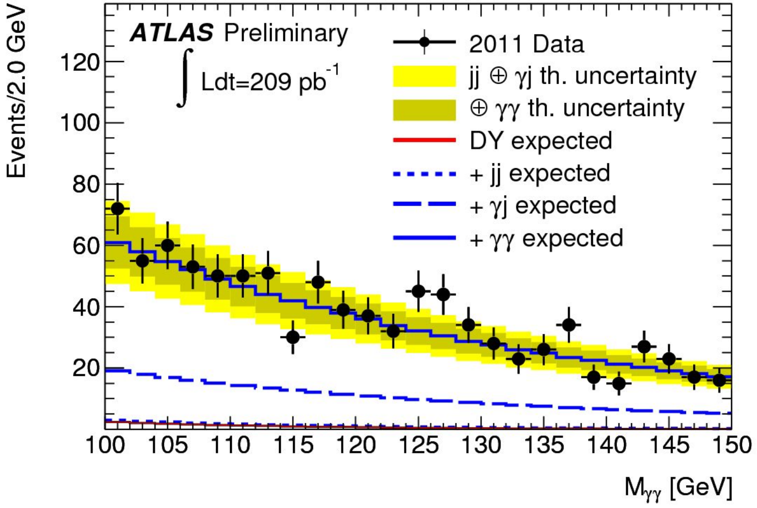
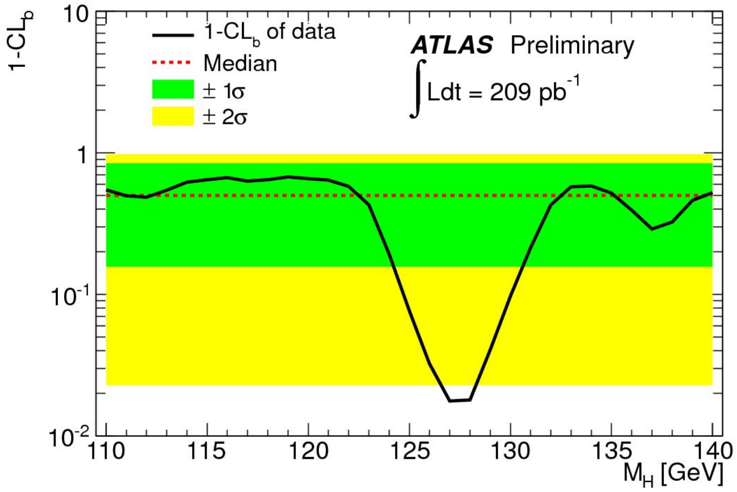
Higgs search is on : June 2011, 0.209 fb^{-1}

PLHC results

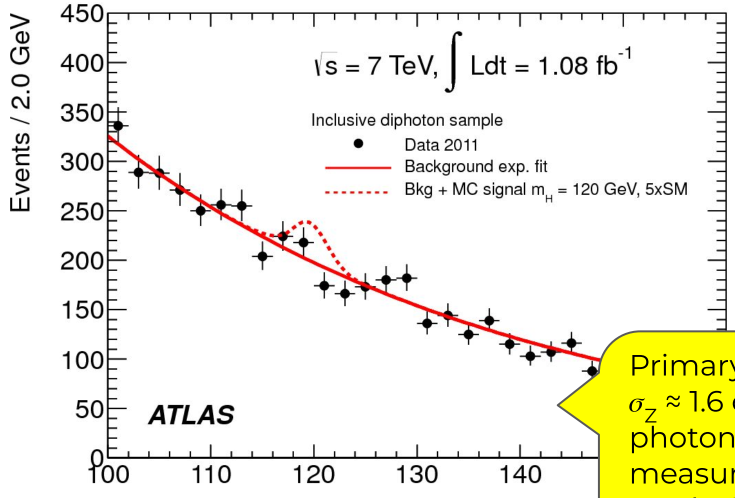


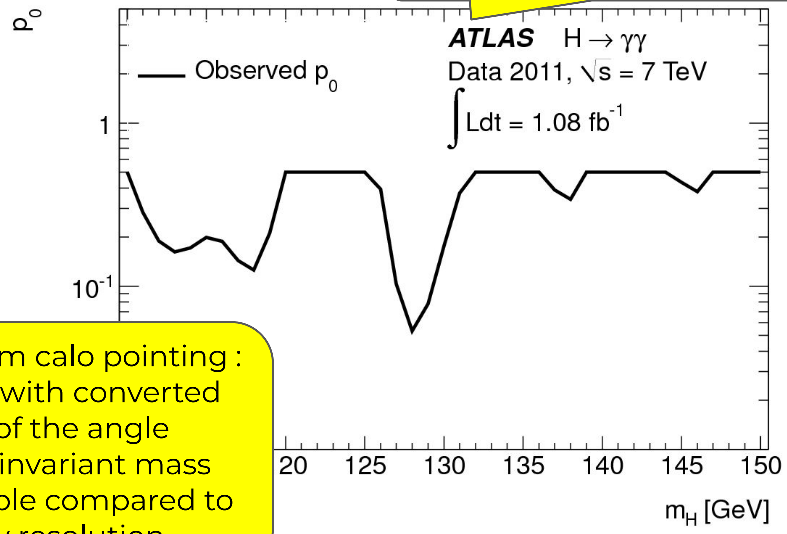


The compatibility of the selected events with the background-only hypothesis is quantified by the $1-CL_b$ (the probability to observe an excess larger than that observed in the data in the background-only hypothesis) shown in Figure 3 (a) and reported in Table 2. A slight excess is observed at a diphoton invariant mass of $\sim$ 127 GeV. The $1-CL_b$ or corresponding p-value of the excess is $\sim 2\%$. The probability for such an excess to occur anywhere in the 110–140 GeV mass range is approximately 30%.

Higgs search is on : August 2011, 1.08 fb^{-1}

'EPS 2011' paper





Primary vertex from calo pointing : $\sigma_Z \approx$ 1.6 cm (better with converted photons). Impact of the angle measurement on invariant mass resolution negligible compared to the photon energy resolution

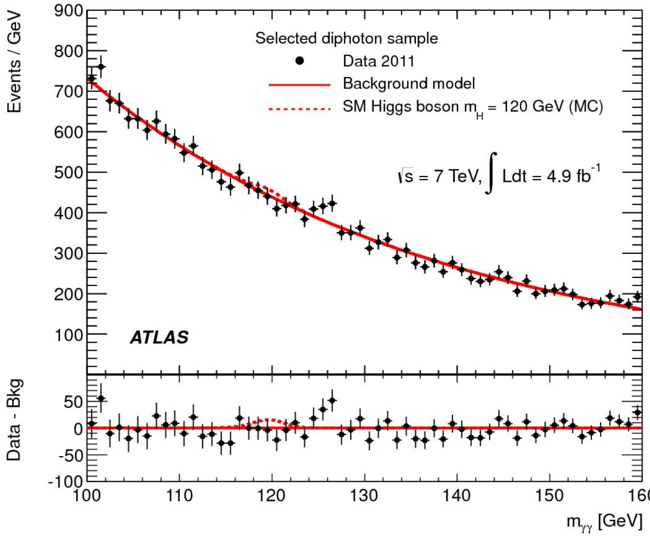
Table 1: Cross-section times branching ratio and expected signal events after all cuts (total and per category), for various Higgs boson masses and for an integrated luminosity of 1.08 fb^{-1}.

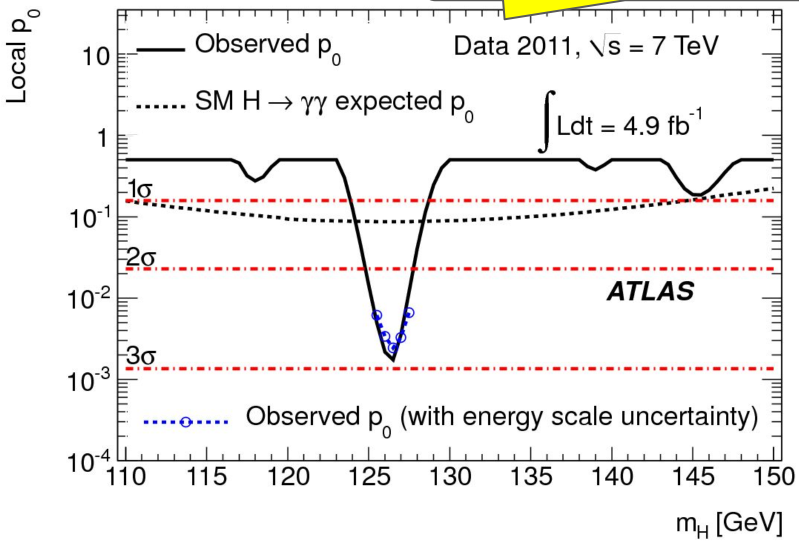
m_H [GeV]	110	120	130	140	150
$\sigma\times$BR [fb]	45	43	37	27	16
Signal yield	17.0	17.6	15.8	12.1	7.7
Unconverted central	2.6	2.6	2.3	1.7	1.1
Unconverted rest	4.6	4.7	4.2	3.4	2.1
Converted central	2.0	2.0	1.7	1.3	0.8
Converted transition	2.3	2.2	2.1	1.5	1.0
Converted rest	5.6	6.0	5.6	4.2	2.7

A search for the Standard Model Higgs boson in the $H \rightarrow \gamma\gamma$ decay mode has been performed using an integrated luminosity of 1.08 fb^{-1} recorded by the ATLAS experiment in 2011. A high purity diphoton sample is selected. No excess is found in the diphoton invariant mass distribution in the mass range of 110-150 GeV.

Higgs search is on : December 2011, 4.9 fb^{-1}

'Council" paper





Category	σ_{CB}	FWHM	N_S	N_D	S/B
Unconverted central, low p_{Tt}	1.4	3.4	9.1	1763	0.05
Unconverted central, high p_{Tt}	1.4	3.3	2.6	235	0.11
Unconverted rest, low p_{Tt}	1.7	4.0	17.7	6234	0.02
Unconverted rest, high p_{Tt}	1.6	3.9	4.7	1006	0.04
Converted central, low p_{Tt}	1.6	3.9	6.0	1318	0.03
Converted central, high p_{Tt}	1.5	3.6	1.7	184	0.08
Converted rest, low p_{Tt}	2.0	4.7	17.0	7311	0.01
Converted rest, high p_{Tt}	1.9	4.5	4.8	1072	0.03
Converted transition	2.3	5.9	8.5	3366	0.01
All categories	1.7	4.1	72.1	22489	0.02

Before considering the uncertainty on the signal mass position, the largest excess with respect to the background-only hypothesis in the mass range 110–150 GeV is observed at 126.5 GeV with a local significance of 2.9 standard deviations. The uncertainty on the mass position (±0.7 GeV) due to the imperfect knowledge of the photon energy scale has a small effect on the significance. When this uncertainty is taken into account, the significance is 2.8 standard deviations; this becomes 1.5 standard deviations when the look elsewhere effect [42] for the mass range 110–150 GeV is included. The median expected

Eagerly waiting for new data

Frenetic activity on several fronts in the first half of 2012 :

ICHEP Plans

- Improved analysis of the 2011 data
  - ⋆ Optimized photon p_T selection
  - ⋆ Photon identification with neural net
  - ⋆ Topological cluster-based isolation
  - ⋆ Additional VBF category and reoptimized categorization

Almost completed

- Analysis of the 2012 data
  - ⋆ Include as much of the 2012 data as possible
  - ⋆ Profit from work done with 2011 since January and also additional improvments

Just started

- Final result from statistical combination of the two analyses

Will mostly focus on plans for $\mathbf{8}$ $\mathbf{TeV}$ analysis here

Kerstin Tackmann (DESY) | HSG1 report, 2012 strategy internal note | May 10, 2012 | 3 / 26

- ❏ Optimised pt selection
- ❏ Robust photonID menu to reduce the impact of pileup
- ❏ Topological cluster based isolation
- ❏ Improved conversion reconstruction
- ❏ Primary vertex selection combining calo pointing and Sumpt2
- ❏ New “VBF” category
- ❏ Background modelling and uncertainty

Kerstin Tackmann, Hyy meeting, May 10, 2012

Towards unblinding

- My plan/mind on "unblind" looks to be changed weekly since the situation is changed day-by-day. Sorry for that.

- The date of our Higgs approval was fixed;
  - June 6th(Wed) 16:00-

- We have two possibilities on the date of "unblind".

  [Case 1] $m_{\gamma\gamma}$ and p0-value/limits on this Thursday (then update them before the Higgs approval by using the latest GRL.)

  [Case 2] $m_{\gamma\gamma}$ on this Thursday and p0-value/limits on the next Tuesday

[Case 1]

- Pros … Start it soon. Can have a backup and have a time to do x-check etc
- Cons … Two results before the Higgs approval

[Case 2]

- Pros … only one result with the largest dataset (before the Higgs approval)
- Cons … Very very tight schedule.

29 May, 2012 HSG1 meeting 2

Junichi Tanaka (convener), Hyy meeting introduction, May 29, 2012

Towards unblinding

News

- 8TeV data
  - **~3.5 fb-1 data** has been recorded. (~2.7 fb-1 on the last Thursday)

- H->aa->4photons conf note/paper
  - We had the 1st EB meeting and got several suggestions/questions, in particular, difference between the signal (a->$\gamma\gamma$) and π^0(->$\gamma\gamma$).
  - Hard to show this result in ICHEP.

- We'll open 8TeV data of 1.7fb-1 today!
  - "Don't circulate/distribute our results!"
    - Even if people understand that the present stat does not say anything(?), our results could become easily a rumor. ("...an excess again or the excess is gone...")
    - Even if we did so-called limit challenge, we need x-check until the Higgs approval.

The decision was taken !

Junichi Tanaka (convener), Hyy meeting introduction, May 31, 2012

31 May, 2012 HSG1 meeting 2

Towards unblinding

News

- 8TeV data
  - **~3.5 fb-1 data** has been recorded. (~2.7 fb-1 on the last Thursday)

Hi,
I thought it's worth a note that we unblinded the Higgs to gamma gamma analysis with part of 2012 data ten years ago today. At that time, we had processed only 1.68 fb-1 data from 2012, and there was a 1.93 sigma excess at 126.5 GeV in the 2012 data. That and the 2011 data combined, gave us 3.94 sigma. That was when many of us knew the signal was there.
Best,
Haichen

unichi Tanaka,
Hyy convener

- Even if people understand that the present stat does not say anything(?), our results could become easily a rumor. ("…an excess again or the excess is gone…")
- Even if we did so-called limit challenge, we need x-check until the Higgs approval.

31 May, 2012 HSG1 meeting 2

Checks, checks, checks

To be honest, as a convener of HSG1, I definitely needed to avoid making a false "discovery", so I also spent much time for x-checks of data...

[J. Tanaka]

Conclusion

Different kind of variables have been tested for both sidebands (pileup, met, number of jets, kinematic va[…] calorimeter regions, OQ, z_{vtx}, RunNumber/Period, …)

- No clear evidence of a systematic problem in the signal region.

July 4, 45 pages presentation

I think the thoughts were all about "what if we have a bug somewhere", or "what if we missed something", "what if this isn't real" etc. In fact, I think we performed checks all the way until the night before the discovery. Well, I'm glad we weren't wrong.

[J. Schaarschmidt]

conclusion

July 4, 65 pages presentation

- no abnormal excess and hot spot can be found

The last mile

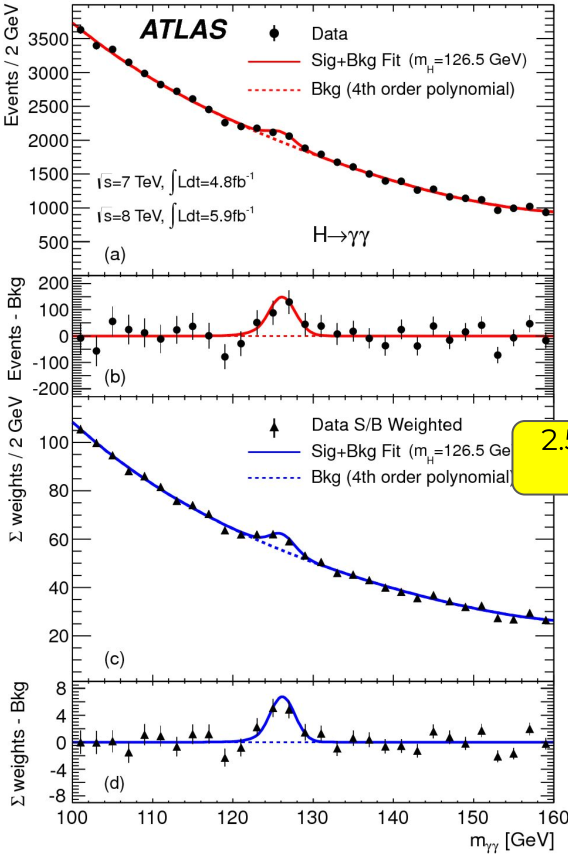
Schedule for Seminar/ICHEP

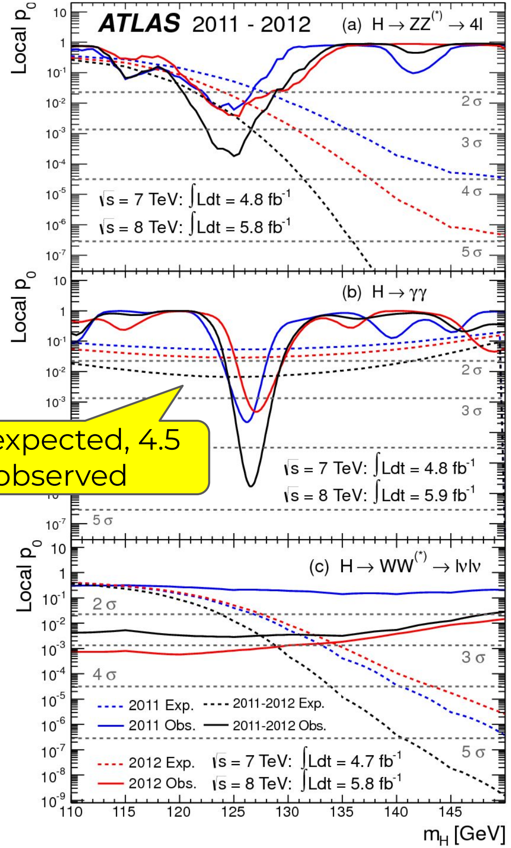
- **TODAY** 26 June … HSG1 meeting for results with the Final GRL
- 27 June … EB meeting
- **28 June … ATLAS approval with the full dataset (13:00~) by Heberth**
- 29 June … ATLAS approval of the combination with the full dataset
- 4 July … CERN seminar (9:00~)
- 7 July … ICHEP parallel session => Kerstin will give a talk on H->$\gamma\gamma$ results
- 9 July … ICHEP plenary session => Richard will give a talk on the combination.

26 June, 2012 HSG1 meeting 3

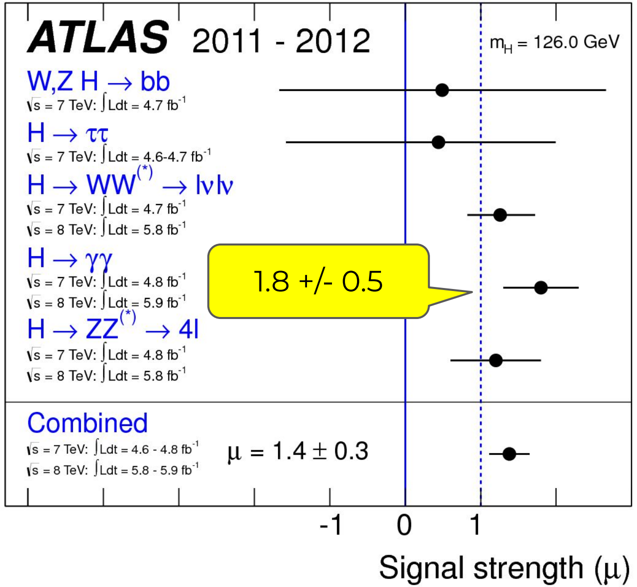
Junichi Tanaka (convener), Hyy meeting introduction, June 26, 2012

The big day





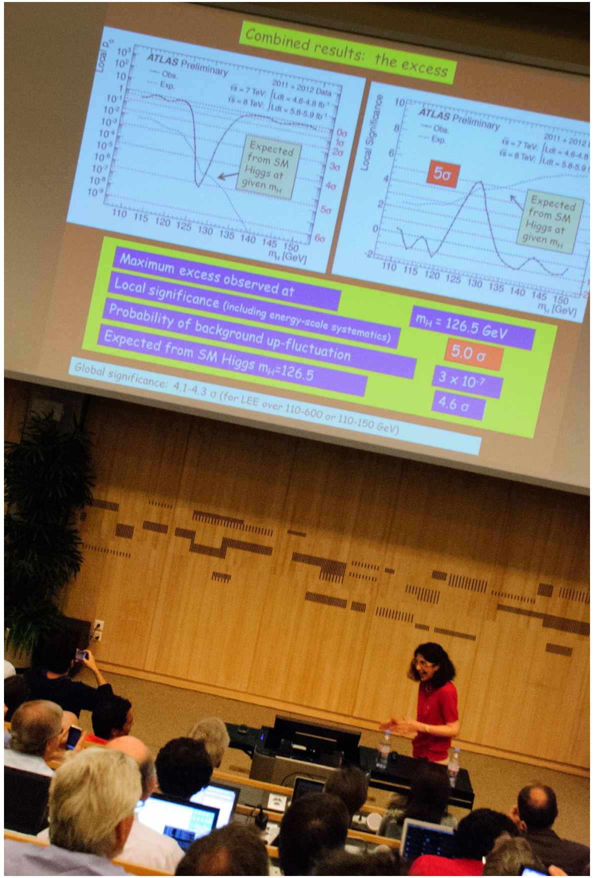
2.5 expected, 4.5 observed



1.8 +/- 0.5

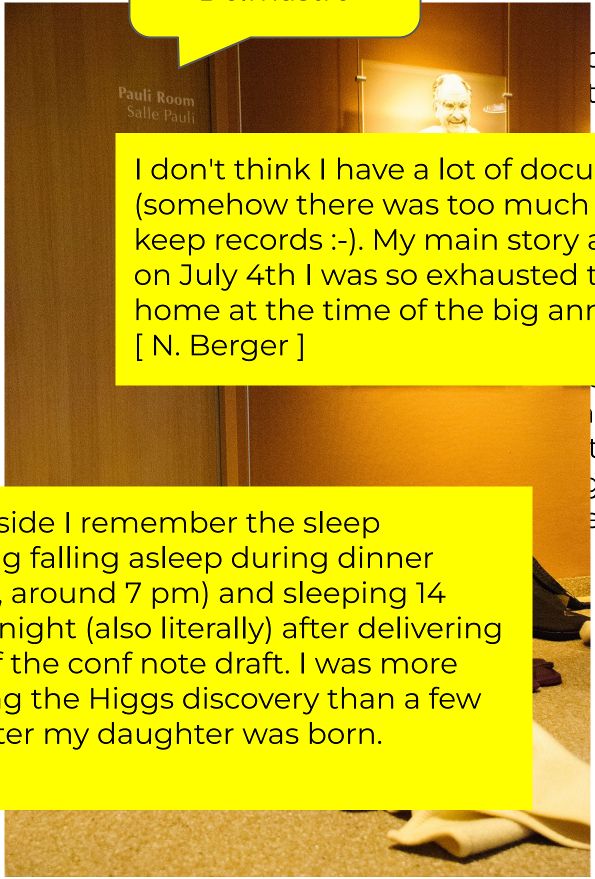
The seminar

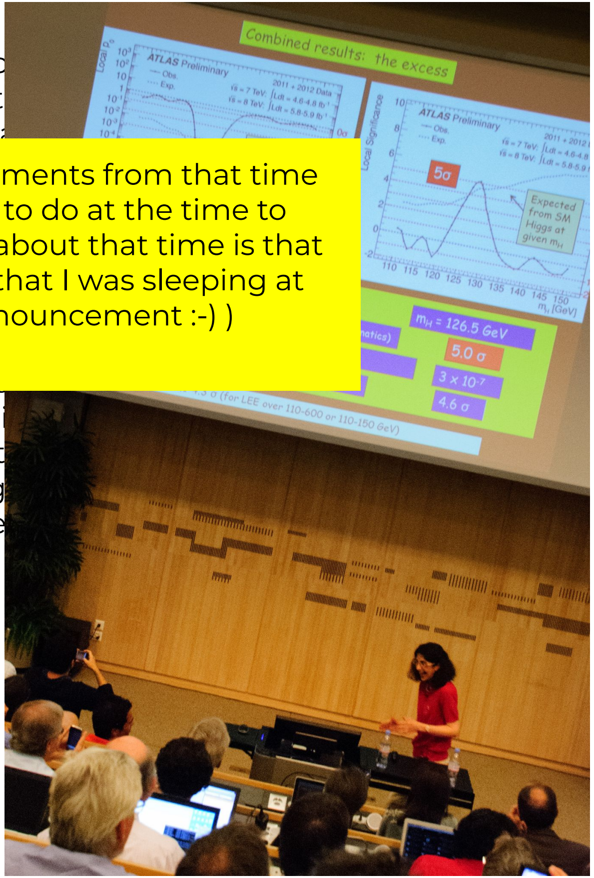
Courtesy of M. Delmastro



The big day

Courtesy of M. Delmastro



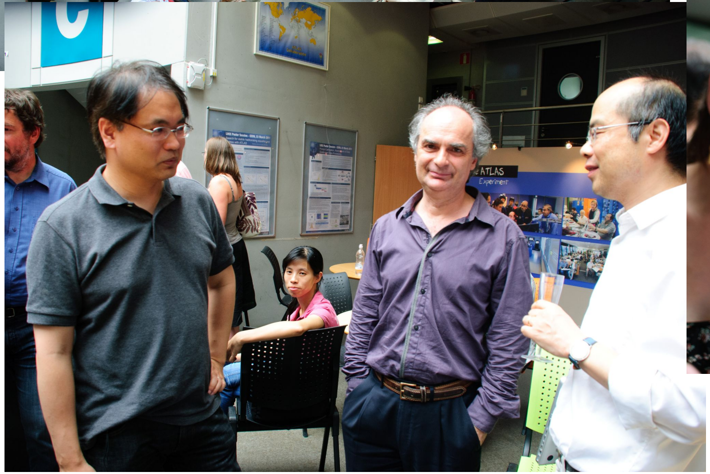


I don't think I have a lot of documents from that time (somehow there was too much to do at the time to keep records :-). My main story about that time is that on July 4th I was so exhausted that I was sleeping at home at the time of the big announcement :-))
[N. Berger]

On the non-physics side I remember the sleep deprivation, including falling asleep during dinner (literally, at the table, around 7 pm) and sleeping 14 hours non-stop one night (also literally) after delivering some new version of the conf note draft. I was more sleep deprived during the Higgs discovery than a few months ago right after my daughter was born.
[K. Tackmann]

Celebrations

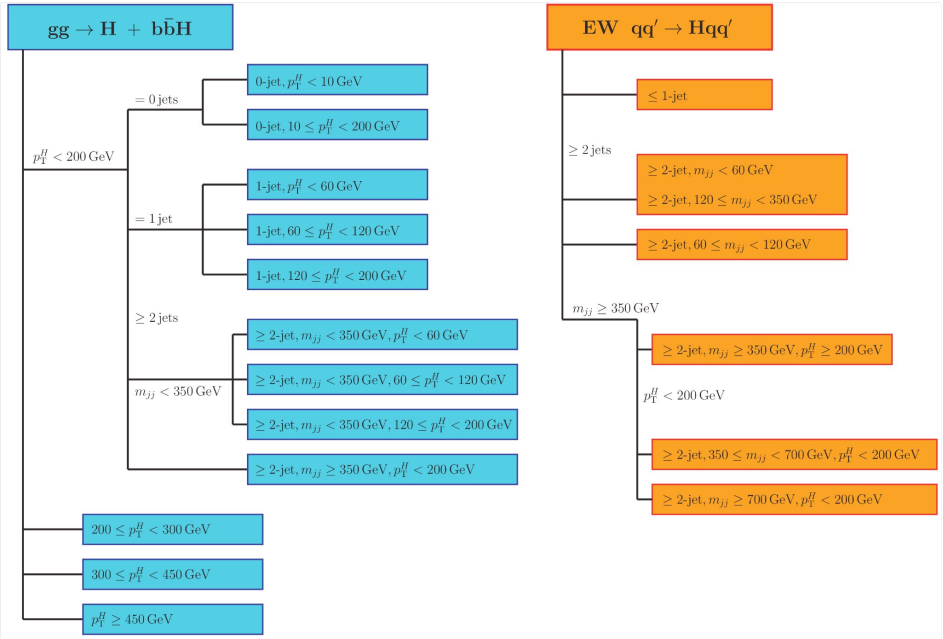
Courtesy of M. Delmastro

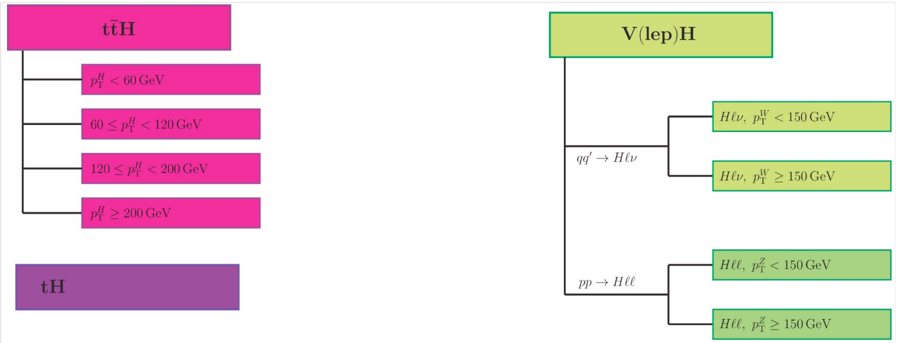


Conclusions

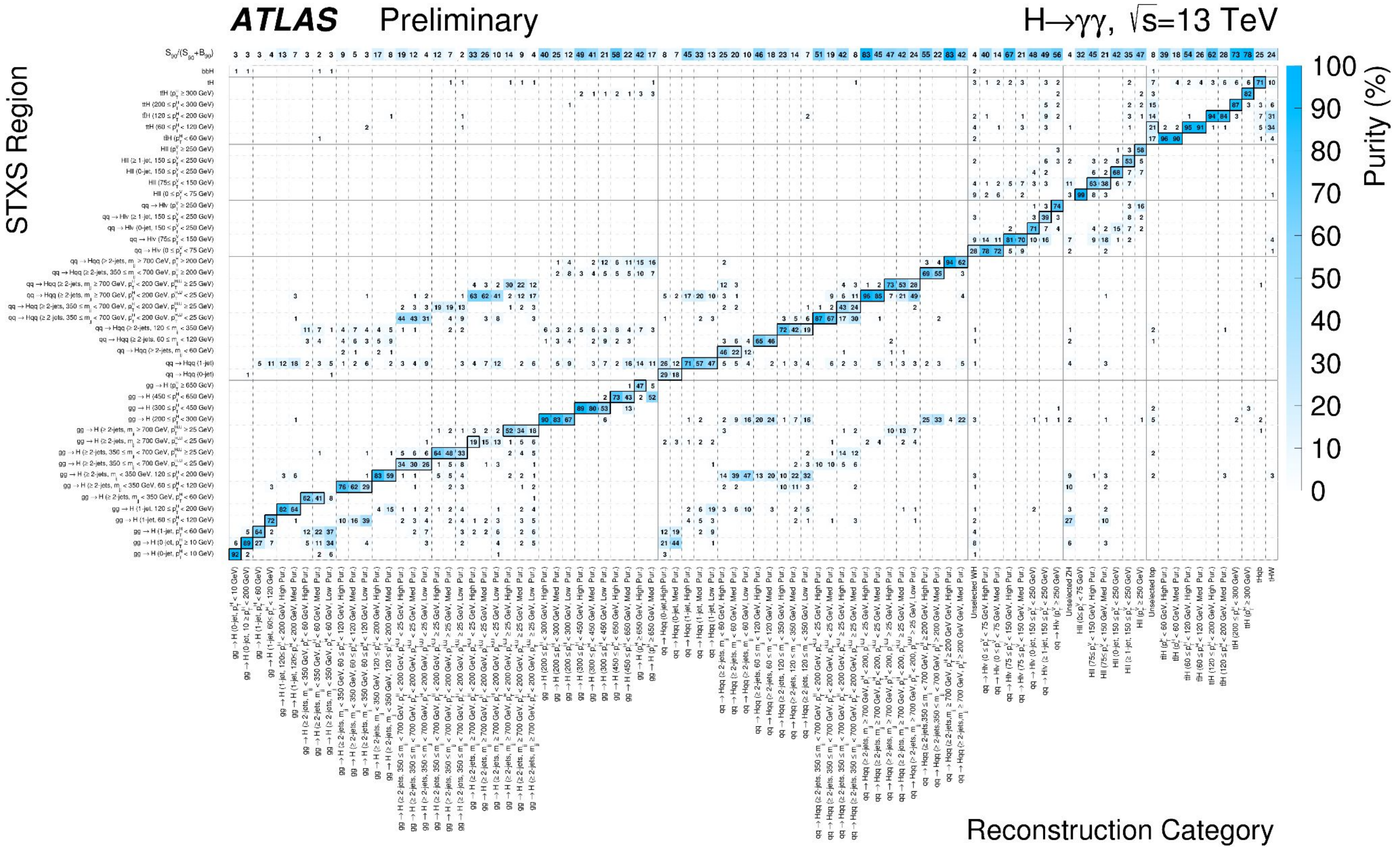
- The discovery of the Higgs boson was a real groundbreaking milestone in HEP, it was fantastic for me to be part of this
- Higgs to diphoton channel was expected to be important since the beginning although with large uncertainties. Basically the real bet was on the detector performance : the detectors have maintained their promises !
- This giant effort only possible through a worldwide collaboration based on respect, information exchange, discussions inside a team of dedicated and passionate physicists, engineers, technicians, computing experts.
- Personal comment: I was lucky enough to have see the electromagnetic calorimeter parts on a table, follow the assembling, test-beams and the fist physics analyses. I'm honored for the opportunity I had to work within this environment, I certainly learned from my colleagues much more than I gave back !

What are we measuring now

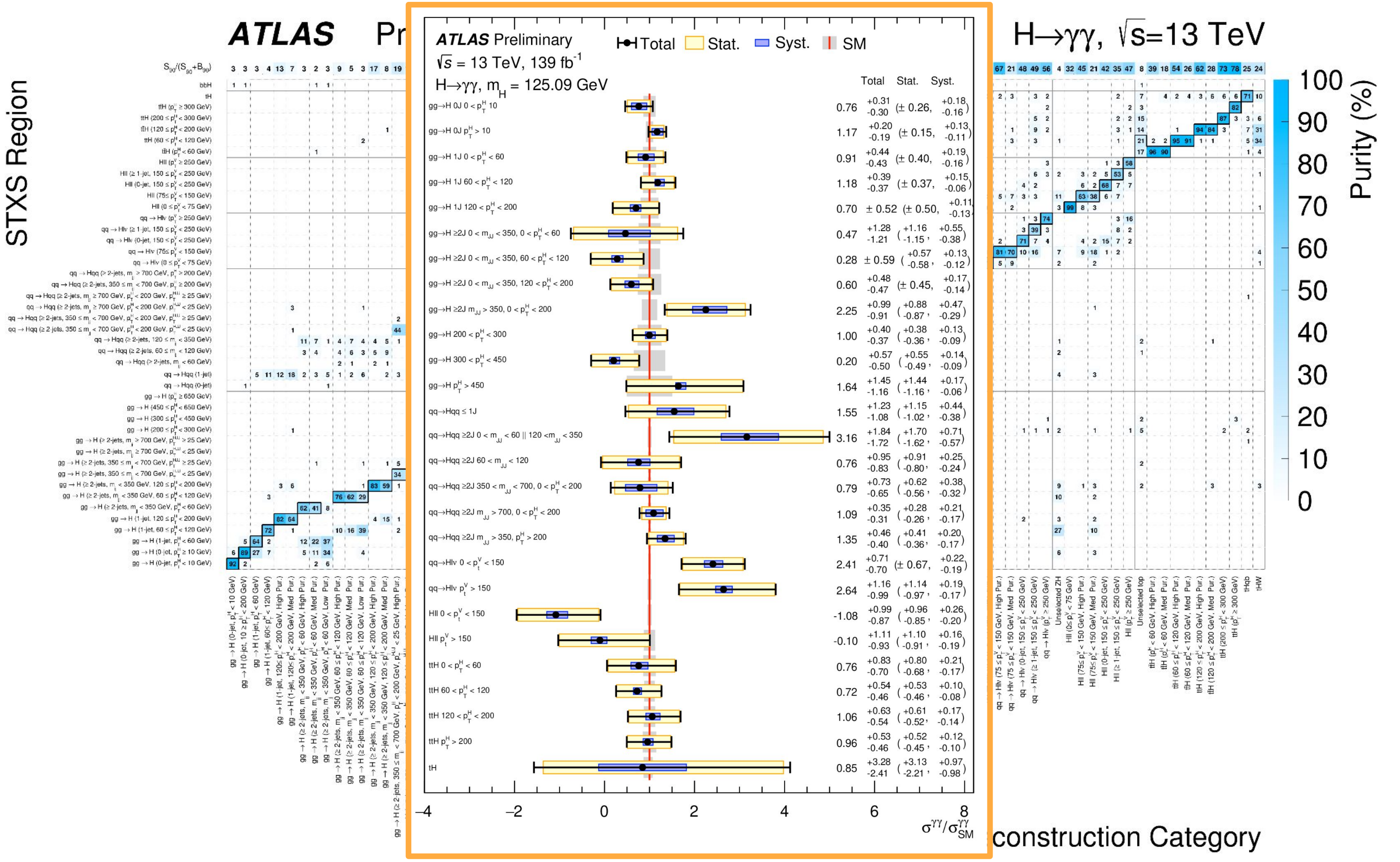




What are we measuring now



What are we measuring now



To make a long story...longer

Letter of intent, 1992

Table 8.1: *Observability of H → γγ (direct and associated H production). The event numbers include the losses due to photon efficiency and bin width.*

	$H \to \gamma\gamma$ direct production					WH, $t\bar{t}$ H $\to \ell\gamma\gamma$+X			
Higgs mass (GeV)	80	90	110	130	150	80 WH	80 $t\bar{t}$ H	110 WH	110 $t\bar{t}$ H
$\sigma \times$BR (fb)	51	57	68	70	35	0.82	0.80	0.74	0.71
Acceptance (%)	23	30	41	46	51	15	21	23	32
Mass resolution (%)	1.45	1.40	1.22	1.19	1.12	1.45		1.22	
N_S (signal in mass bin)	600	876	1430	1650	915	14		18	
N_B (bgd in mass bin)	36000	34000	25000	20000	13500	11		7	
Stat. significance	3.2	4.8	9.0	11.7	7.9	4.2		6.8	

To make a long story...longer

Technical proposal, 1994

Table 11.2: Observability of the direct $H \to \gamma\gamma$ signal for $80 < m_H < 150$ GeV. The mass bin chosen to compute the signal and background rates was $m_H \pm 1.2\sigma_m$. The overall photon efficiency was taken to be 80%, including triggering and identification cuts. For $m_H = 90$ GeV, it was reduced to 72% as a result of applying the electron veto procedure to eliminate the resonant background from $Z \to ee$ decays (see text).

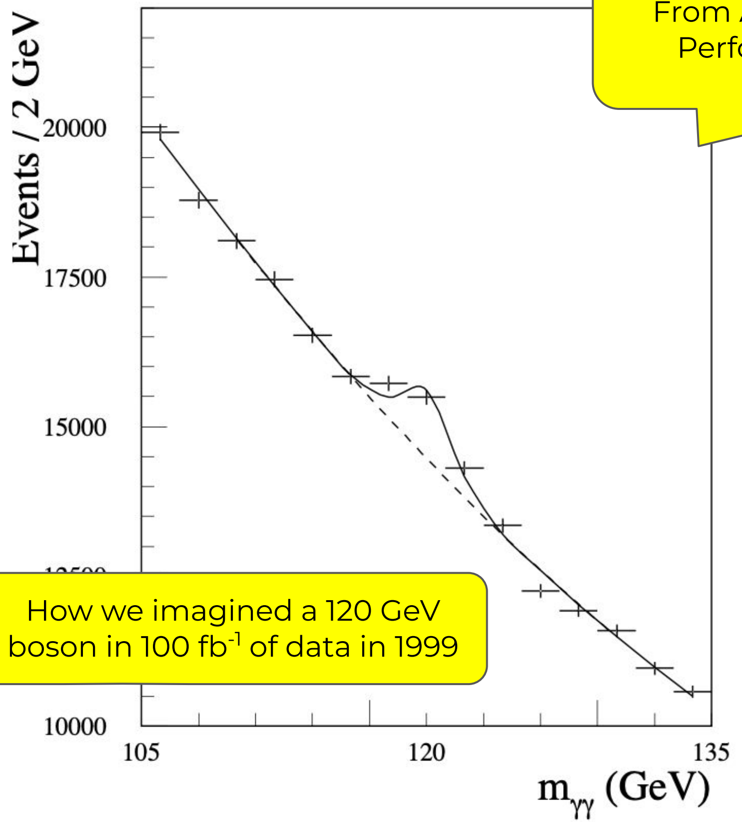
Higgs mass (GeV)	80	90	100	110	120	130	150
$\sigma \times$ BR (fb)	36	40	44	48	51	45	24
Acceptance $\times$ efficiency	19%	19%	27%	28%	29%	30%	33%
Mass resolution σ_m (GeV)	1.2	1.3	1.4	1.4	1.5	1.6	1.7
Signal events in mass bin	480	550	840	950	1040	950	560
$\gamma\gamma$ background events in mass bin	41 600	40 700	40 700	29 900	26 300	22 600	15 300
Jet–jet background events in mass bin	1700	1600	1700	1300	1200	1200	900
γ–jet background events in mass bin	6300	5300	5000	3600	3200	2700	1800
$Z \to ee$ background events in mass bin	–	< 70	–	–	–	–	–
Statistical significance for 10^5 pb^{-1}	2.2	2.5	3.9	5.1	5.9	5.8	4.2
Number of LHC years to reach 5σ	5.4	3.9	1.7	1.0	0.7	0.7	1.4

To make a long story...longer

From ATLAS Detector, Physics and Performance TDR back in 1999

19.2.2 $H \to \gamma\gamma$

The decay $H \to \gamma\gamma$ is a ra… …ted Higgs boson mass re-
gion, where the producti… …o are both relatively large.
It is a promising channel… …$m_H < 150$ GeV and places
severe requirements on t… …ellent energy and angular
resolution are needed to … …educible prompt $\gamma\gamma$ contin-
uum. Powerful particle i… …ect the large QCD jet back-
ground as well as the p… …om $Z \to ee$ decays, in the
case where $m_H \approx m_Z$.



How we imagined a 120 GeV boson in 100 fb[-1] of data in 1999

A long and hard road : testbeams !

Teastbeam measurements paper

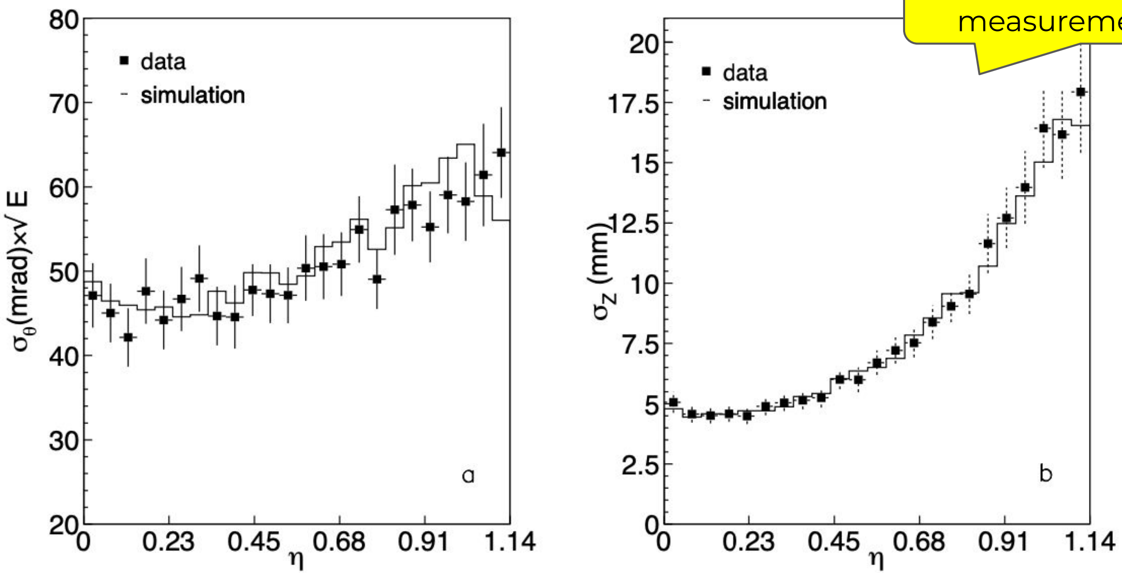


Fig. 13. Angular resolution in θ times the square root of the beam energy (a) and z_{vertex} resolution (b) as function of η for barrel module P13, obtained using information from the front and middle compartments at $\phi = 0.26$ rad, at $E = 245$ GeV.

Towards unblinding

News

"I needed a kind of x-check by Kostas but I remember that Kostas told me like "...ask H->gamgam to discover the Higgs..." (but I don't remember the exact phrase...) because around May (?) or June (?) 2012, there was no clear evidence in the 4l-channel...
To be honest, I could not enjoy the discovery so much before July 4th. (As you know, H->gamgam has many BG, so the peak is not relatively clear comparing to 4l. We have to rely on p0-value in a sense.
Of course, a clear peak of the 4l-channel reassured me.)

{(If Kostas does not remember or I'm wrong, please let me know. I need to update my memory...)}"

[J. Tanaka]

ticular,

ning(?), our results could become easily a rumor. ("...an excess again or the excess is gone...")

- Even if we did so-called limit challenge, we need x-check until the Higgs approval.

31 May, 2012 HSG1 meeting 2

To make a long story...longer

CSC notes, 2008

Table 18: Signal significances (expressed in terms of Gaussian sigmas) for a Standard Model Higgs boson as a function of the mass (in GeV) using the different analyses reported in Sections 5.1-5.3 for 10 fb^{-1} of integrated luminosity. Results are reported in terms of the signal significance based on event counting, $\sigma(S,B)$, and a fit-based signal significance, σ_{1D}^{Fix} and σ_{1D}^{Float} (see text).

	Inclusive (with K-factors)			$H+1$jet (no K-factors)			$H+2$jet (no K-factors)			Combined
m_H	$\sigma(S,B)$	σ_{1D}^{Fix}	σ_{1D}^{Float}	$\sigma(S,B)$	σ_{1D}^{Fix}	σ_{1D}^{Float}	$\sigma(S,B)$	σ_{1D}^{Fix}	σ_{1D}^{Float}	$\sigma(S,B)$
120	2.6	2.4	1.5	1.8	1.8	1.3	1.9	2.0	1.1	3.3
130	2.8	2.7	1.8	2.0	2.1	1.6	2.1	2.1	1.2	3.5
140	2.5	2.2	1.3	1.8	1.7	1.2	1.7	2.0	1.0	3.0