



LPNHE ATLAS Physics Analysis at LHC run 2

B. Laforge on behalf of the LPNHE ATLAS group

15/04/2019 – Biennale 2019 du LPNHE

Human forces (1/04/2019)

Enseignants-Chercheurs :

7 – 5 HDR

5 UPD/P7 – 2 SU/P6

5 MdC – 2 PR

- T. Beau (MdC P7)
- M. Bomben (MdC P7)
- B. Laforge (PR SU)
- I. Nikolic (MdC P7)
- J. Ocariz (PR P7)
- M. Ridet (MdC P7)
- S. Trincaz-Duvoid (MdC SU)

Chercheurs :

9 – 7 HDR

3 CR – 6 DR

- G. Bernardi (DR)
- R. Camacho Toro (CR)
- G. Calderini (DR)
- F. Derue (DR)
- W. Krasny (DR)
- D. Lacour (DR)
- B. Malaescu (CR)
- G. Marchiori (CR)
- L. Roos (DR 20%, DAS IN2P3)

Doctorants : 9 (since last biennale)

- L. D'Eramo (2016)
 - L. Pascual Dominguez (2017)
 - R. Hankache (2016)
 - A. Leopold (2017)
 - I. Luise (2016)
 - A. Tarek (2016)
 - R. Taibah (2018)
 - Y. Wang (2017)
 - J. Zahreddine (2017)
- + Marton Sandes dos Santos (2019 - 1 year)

Postdocs : 3

- W. Spolidoro Freund, COFECUB 01/09/2018 - 31/08/2019
- K. Liu, ANR prolongation, 01/09/2018 - 31/08/2019
- I. Nomidis, ANR 02/2018 - 01/2020

6 Defended Theses since last Biennale

- Y. Yapp (01/2017) (High mass diphoton resonance search)
- A. Lopez Sollis (09/2017) (DM in mono-Higgs ($\gamma\gamma$))
- S. Manzoni (12/2017) (SUSY in $\gamma\gamma$ + MET) – ATLAS Thesis Award
- D. Portillo (10/2018) (mono-Higgs b - $b\bar{b}$, DM)
- A. Ducourtial (10/2018) ($H \rightarrow b$ - $b\bar{b}$)
- C. Li (11/2018) (Observation $H \rightarrow b$ - $b\bar{b}$)

Departures

- Departure of S. Laplace mid-2018
- Departure of R. Wang Dec. 2018 (ILP)
- Departure Paolo Francavilla 2017 (ILP)
- Departure Sandro de Cecco 2017 (U. Roma)

Analysis Strategy

Our group is involved in :

- **Establishing the validity of the Standard Model:**
 - Study of the Higgs sector :
 - Spin, mass, couplings, Branching Ratios, production modes, cross-section
 - Top quark mass measurement
 - Jet physics (sub-structure, mass, boosted topologies...)
- **Searching for new physics :**
 - Resonance searches (dijets, diphoton)
 - Search for Dark Matter at the LHC (mono-Higgs, SUSY)
 - Quantifying the residual open space for new physics (Effective Field Theories)

Those activities are coming **with important contributions to performance studies** (e/gamma, jets/MET, b-tagging,...) and **computing (Grid, Tier 2, Computing ATLAS France)**

Activities acknowledged by several convenerships :

ATLAS groups : S. Laplace (e/y), B. Malaescu (Statistical forum, SM)

ATLAS subgroups : G. Marchiori (Higgs yy, Photon ID), B. Malaescu (SM Jet/y),
R. Camacho (Exotics DBL pre-LPNHE), B. Laforge (DQ calo combined)

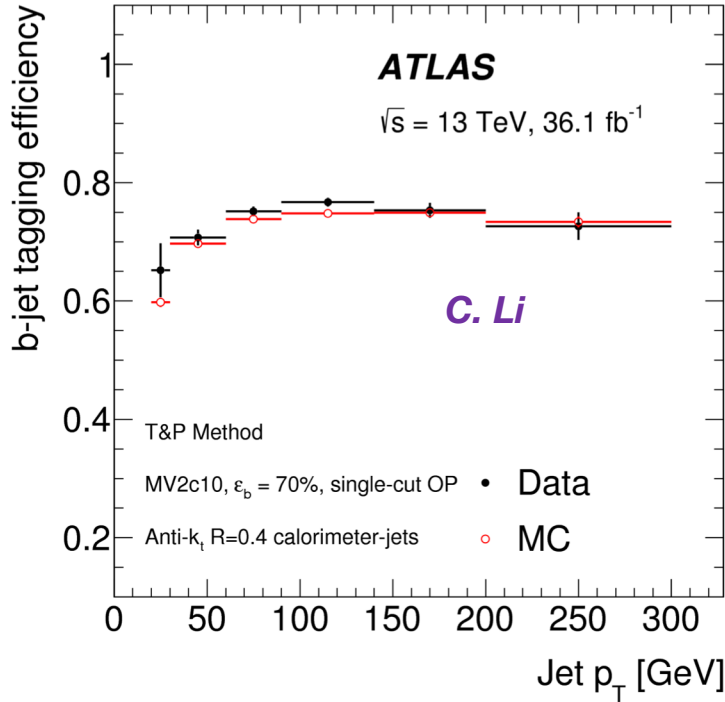
Analysis contacts (today) : B. Laforge, R. Wang (Hyy+MET), K. Liu (SM VHbb), L. Roos,
I. Nomidis (resonance yy), R. Camacho (z(bb)+y)

Performance studies (I)

JINST 14 (2019) P03017,
JHEP 08 (2018) 89

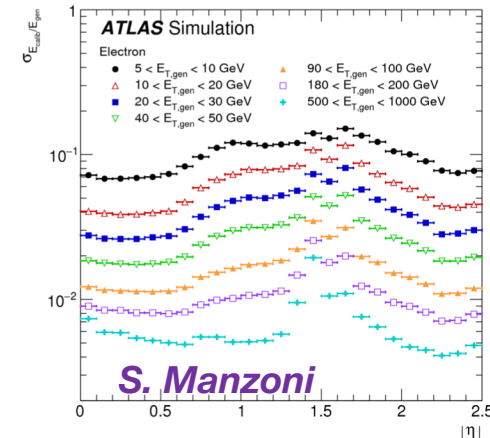
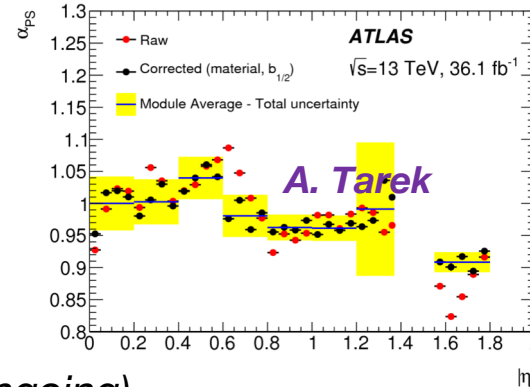
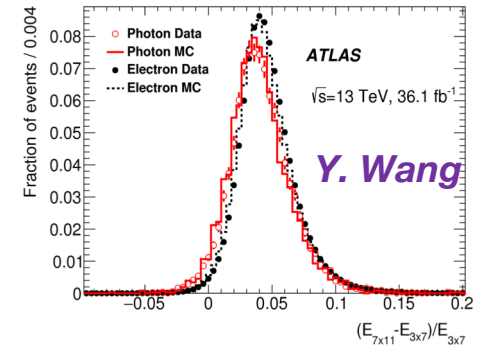
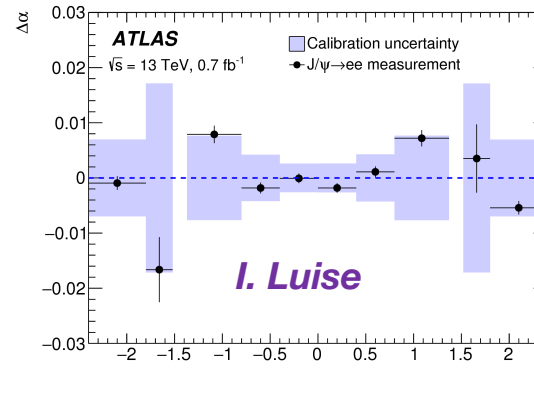
- b*-tagging efficiency calibration

Thesis **C. Li**
for *VH*, *H*->*bb* analysis



- Electron/photon energy calibration

Theses **S. Manzoni, I. Luise, A. Tarek, Y. Wang**
Important for e.g Higgs mass measurement in *H*->*yy*, *4l* and resonance searches



- Electron/photon energy calibration (ongoing)

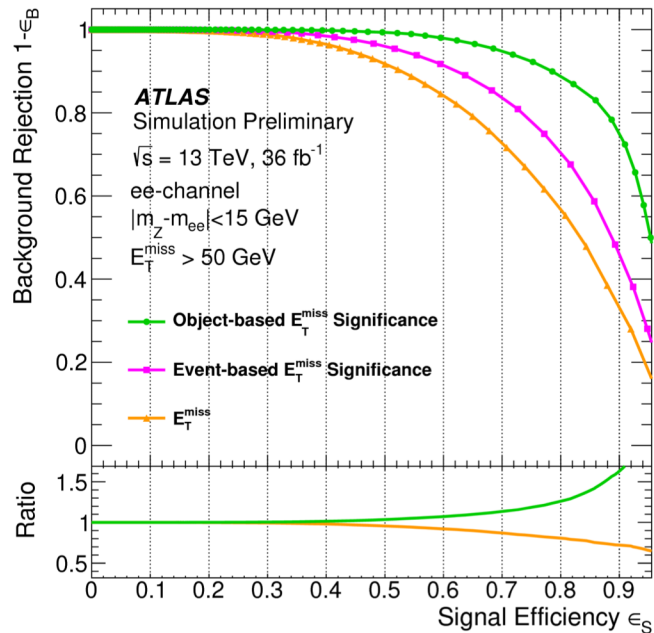
Thesis **M. Sandes Dos Santos**
Xtalk corrections using data

W. Freund, A. Leopold, B. Laforge
ML for calibration (Ringer, Shower Asymmetries)

Performance studies (II)

- *ETmiss* significance calculation

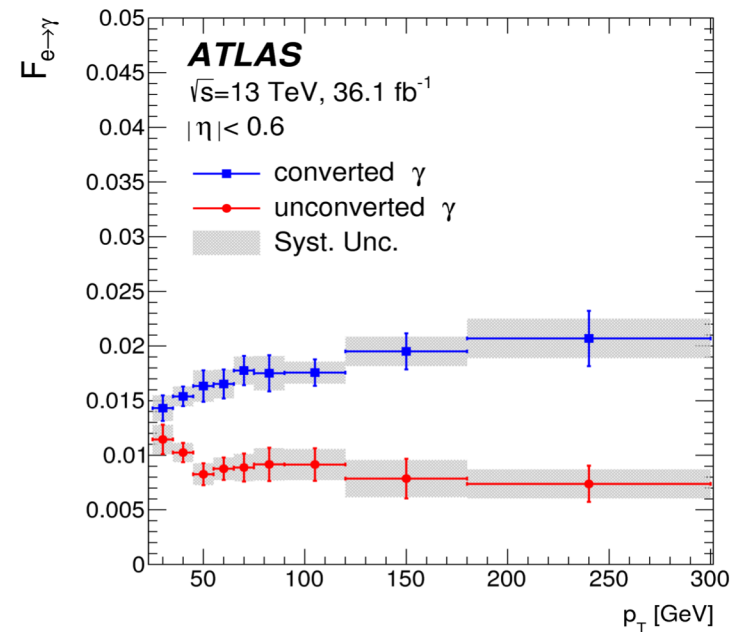
Thesis D. Portillo, P. Francavilla (ILP), S. de Cecco
for e.g DM search in $H \rightarrow bb + ET_{miss}$



Thesis A. Lopez Solis, A. Leopold, B. Laforge
Validation of *Etmiss* calculation in Hyy framework
for e.g DM search in $H \rightarrow yy + ET_{miss}$
Study of Xtalks in LAR calorimeter

- photon identification efficiency

Thesis S. Manzoni
for e.g. SUSY search in $yy + ET_{miss}$

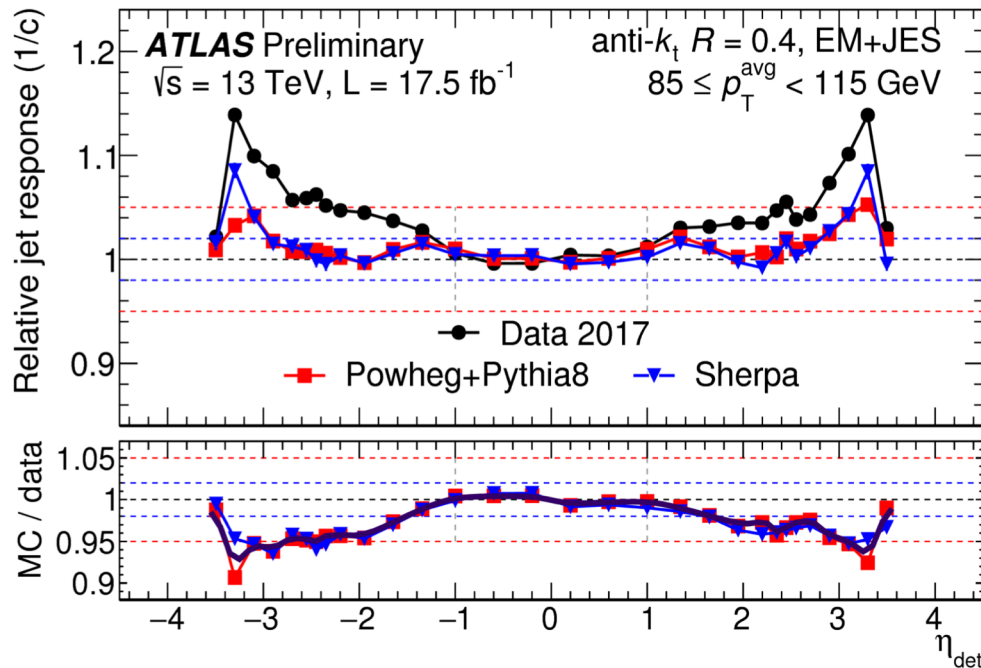


Thesis Luis Pascual Dominguez, J. Ocariz
Study of pileup rejection in isolation variables

Performance studies (III) **Jet physics**

B. Malaescu, thesis Robert Hankache, M. Ridet, R. Camacho

Inter calibration en énergie des jets en fonction de eta



Réponse relative des jets en fonction de eta pour les données et deux simulations, publication en préparation

Identification of resonance in a boosted b-bbar topology

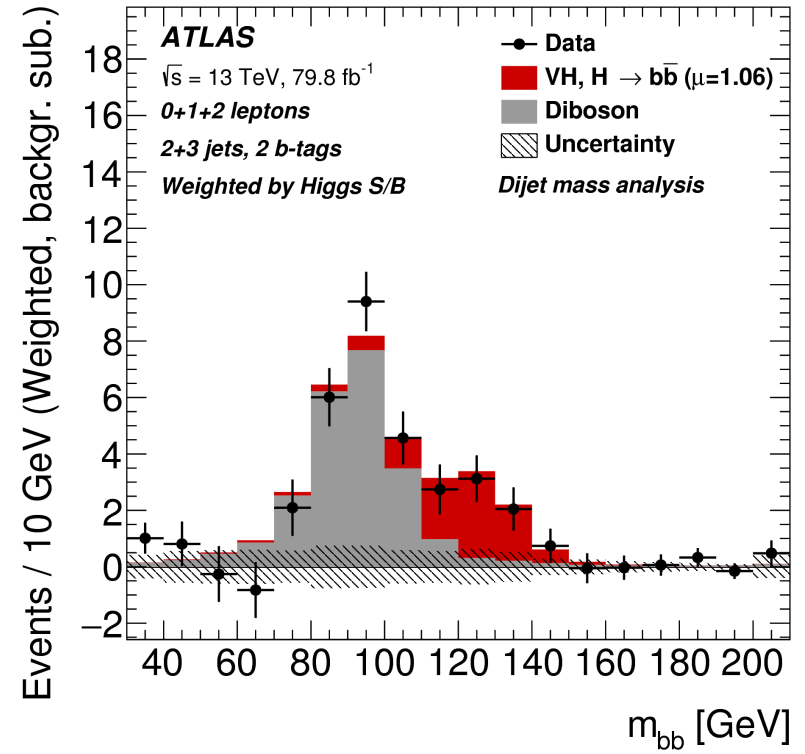
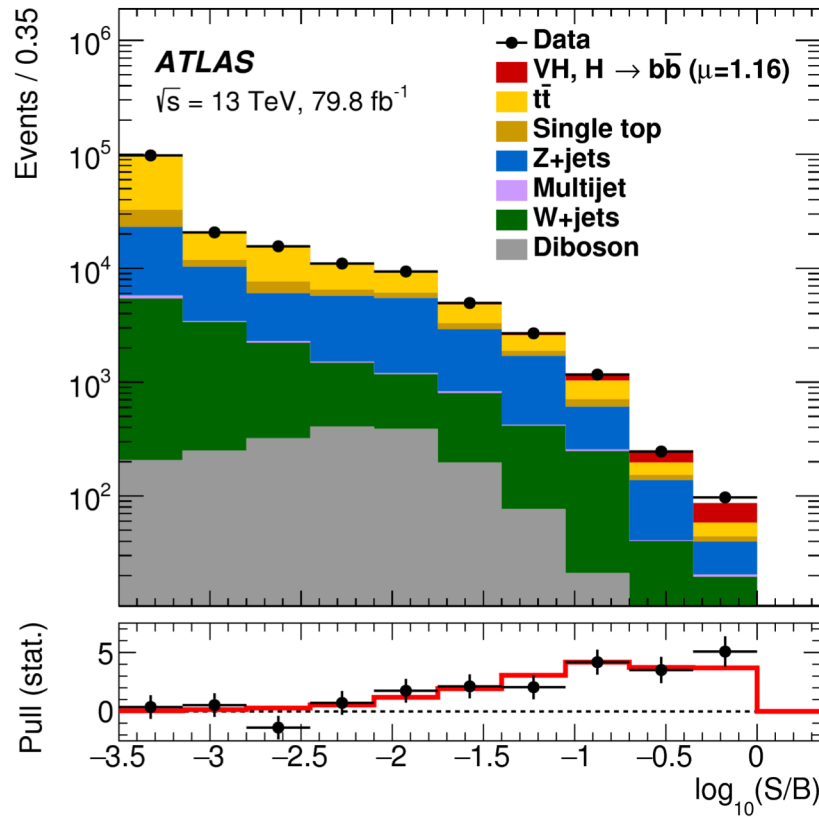
Validation with Z(bb)+y (Publication being finalised), will provide a SM measurement too.

This technique using jet substructure will be used in the future searches with full run 2 data to reconstruct the resonance mass using the jet mass,

Goal : Use to identify Higgs to b-bbar too.

Standard Model Physics

Higgs: observation of $H \rightarrow b\bar{b}$



Signal strength	Signal strength	p_0		Significance	
		Exp.	Obs.	Exp.	Obs.
0-lepton	$1.04^{+0.34}_{-0.32}$	$9.5 \cdot 10^{-4}$	$5.1 \cdot 10^{-4}$	3.1	3.3
1-lepton	$1.09^{+0.46}_{-0.42}$	$8.7 \cdot 10^{-3}$	$4.9 \cdot 10^{-3}$	2.4	2.6
2-lepton	$1.38^{+0.46}_{-0.42}$	$4.0 \cdot 10^{-3}$	$3.3 \cdot 10^{-4}$	2.6	3.4
VH, H $\rightarrow b\bar{b}$ combination	$1.16^{+0.27}_{-0.25}$	$7.3 \cdot 10^{-6}$	$5.3 \cdot 10^{-7}$	4.3	4.9

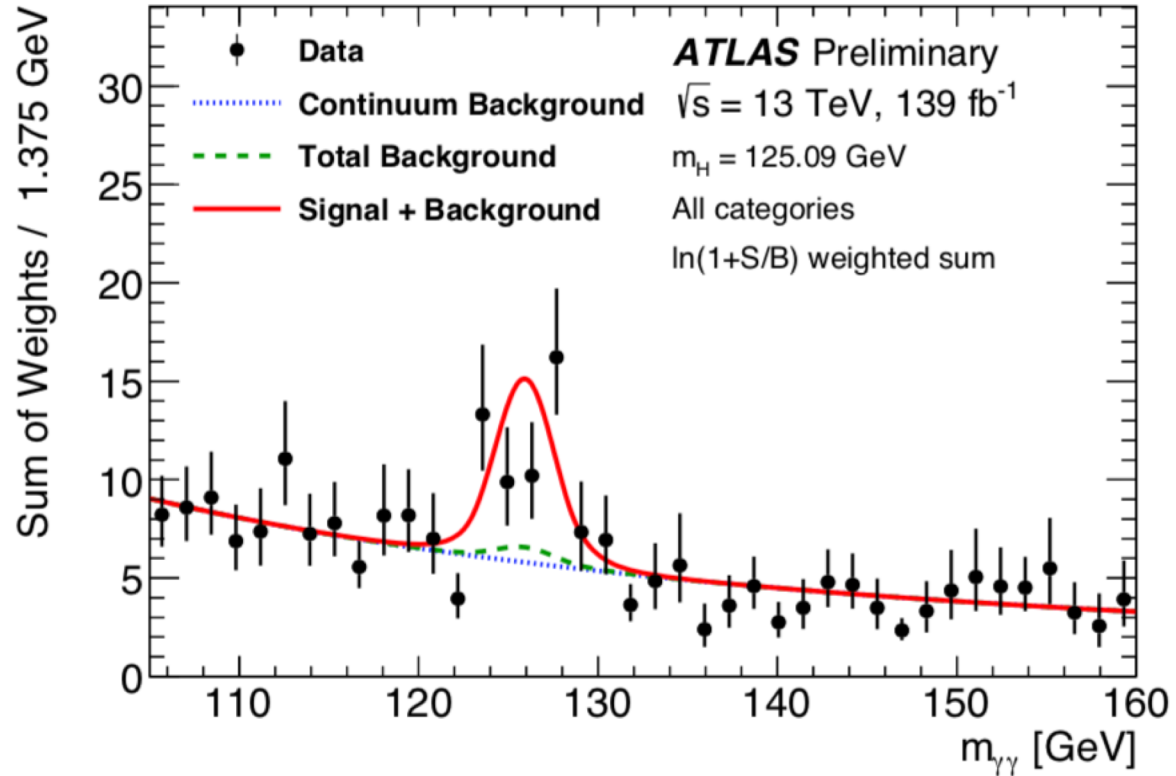
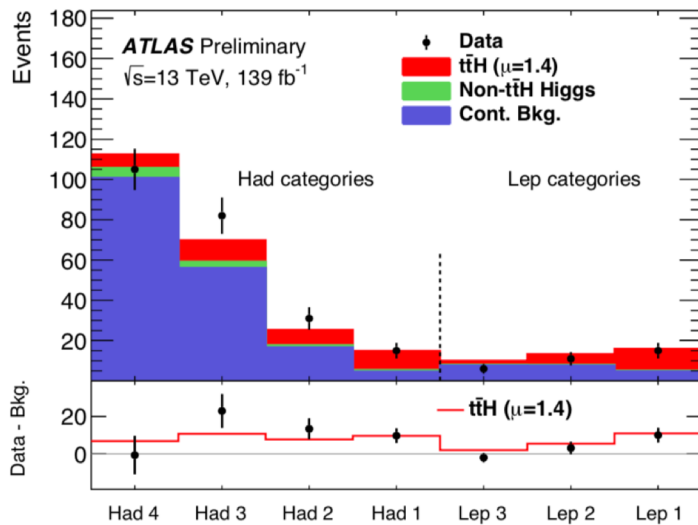
Channel	Significance	
	Exp.	Obs.
VBF+ggF	0.9	1.5
$t\bar{t}H$	1.9	1.9
VH	5.1	4.9
H $\rightarrow b\bar{b}$ combination	5.5	5.4

Theses C. Li, L. D'Eramo, I. Luise,
Post-doc K. Liu

Higgs: observation of $t\bar{t}H(\gamma\gamma)$

ATLAS-CONF-2019-004

Use both hadronic and leptonic decay of the tops

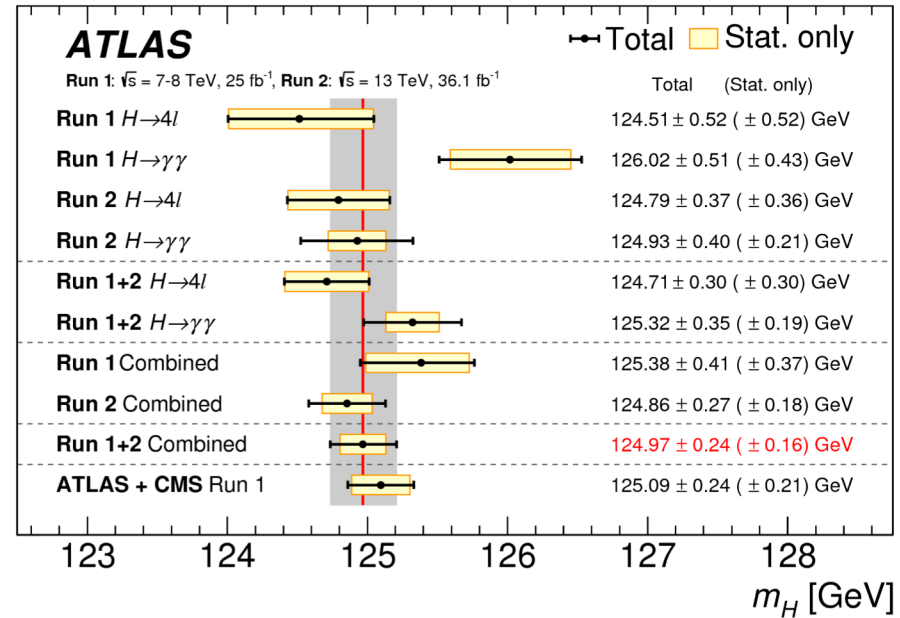
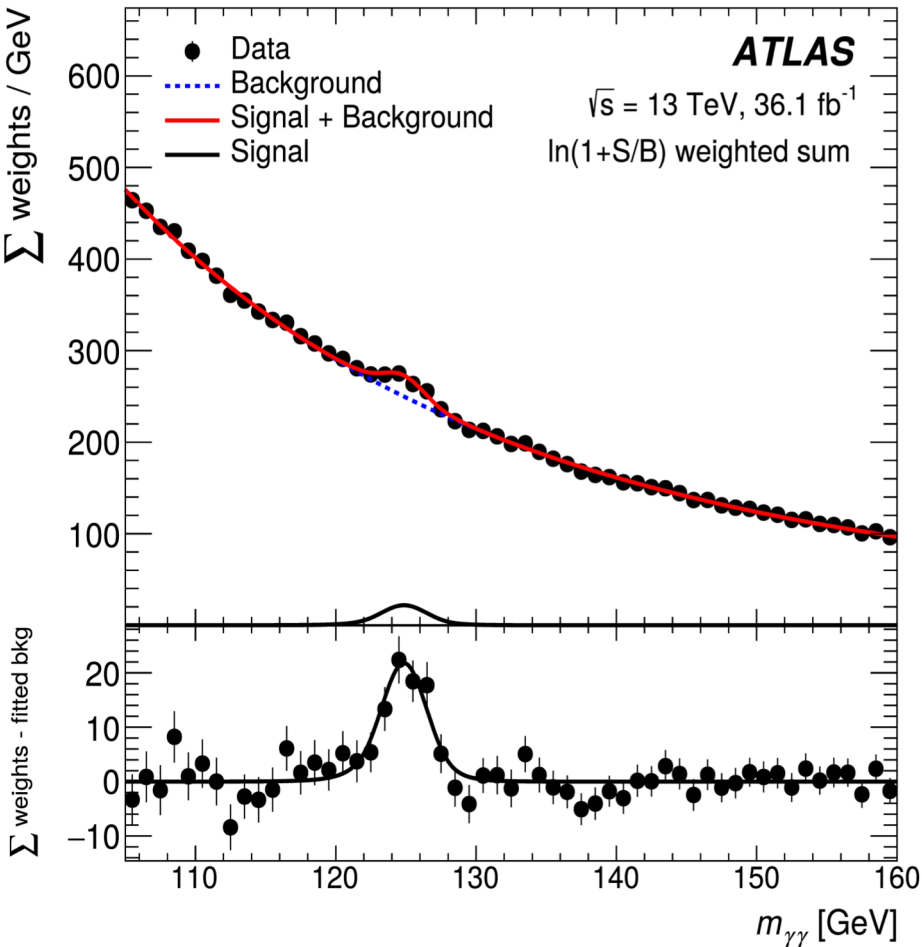


$$\sigma_{t\bar{t}H} \times B_{\gamma\gamma} = 1.59^{+0.43}_{-0.39} \text{ fb} = 1.59^{+0.38}_{-0.36} \text{ (stat.) } ^{+0.15}_{-0.12} \text{ (exp.) } ^{+0.15}_{-0.11} \text{ (theo.) fb.}$$

$$\mu_{t\bar{t}H} = 1.38^{+0.41}_{-0.36} = 1.38^{+0.33}_{-0.31} \text{ (stat.) } ^{+0.13}_{-0.11} \text{ (exp.) } ^{+0.22}_{-0.14} \text{ (theo.)}$$

The combined observed significance is 4.9σ , while the expected significance is 4.2σ .

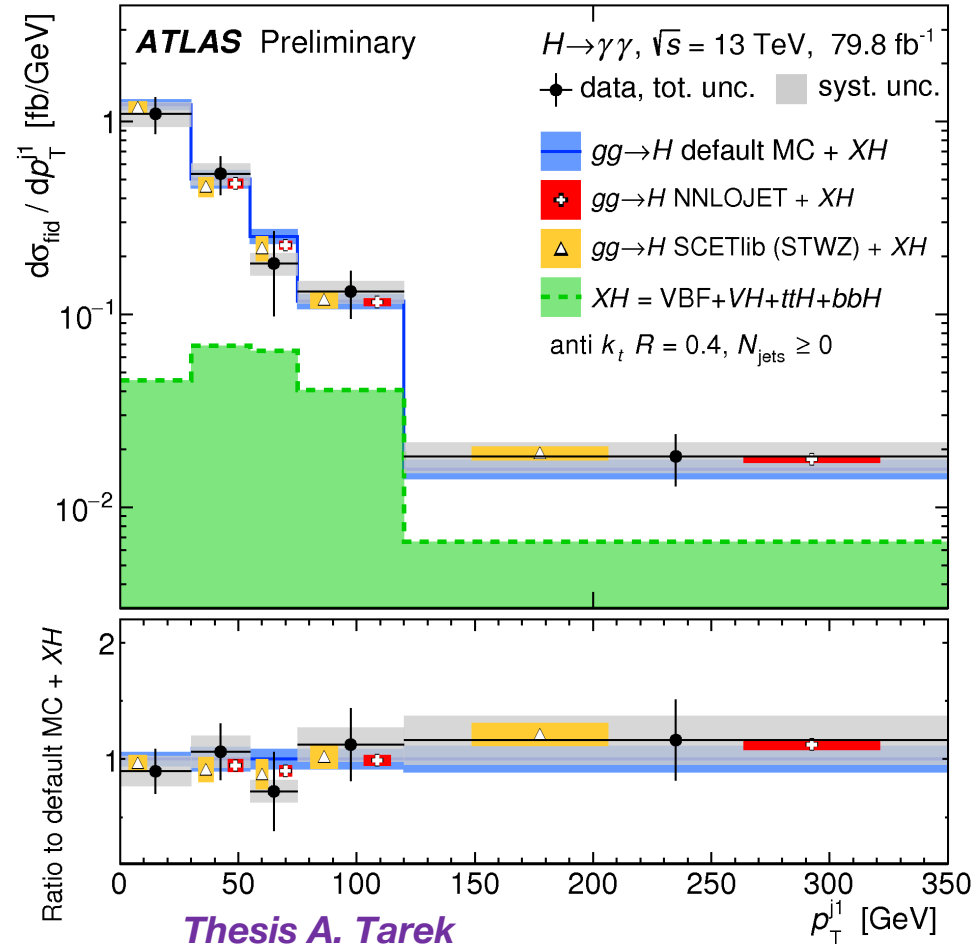
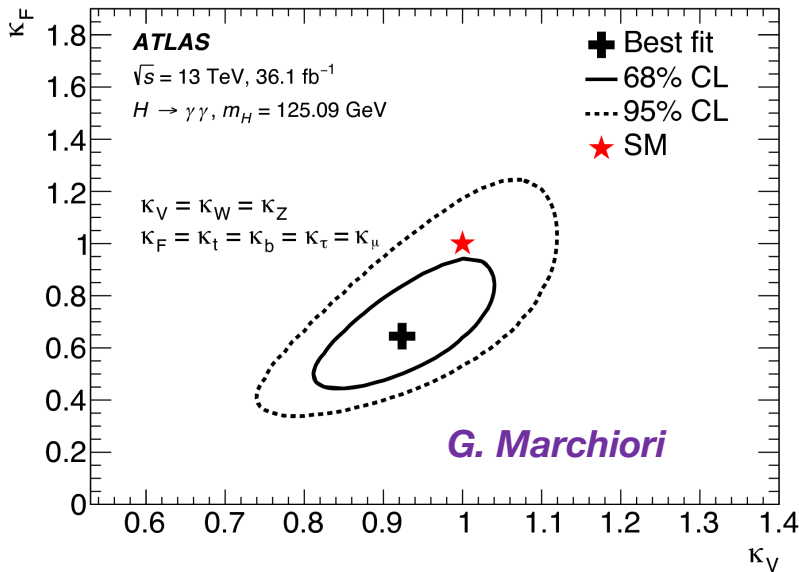
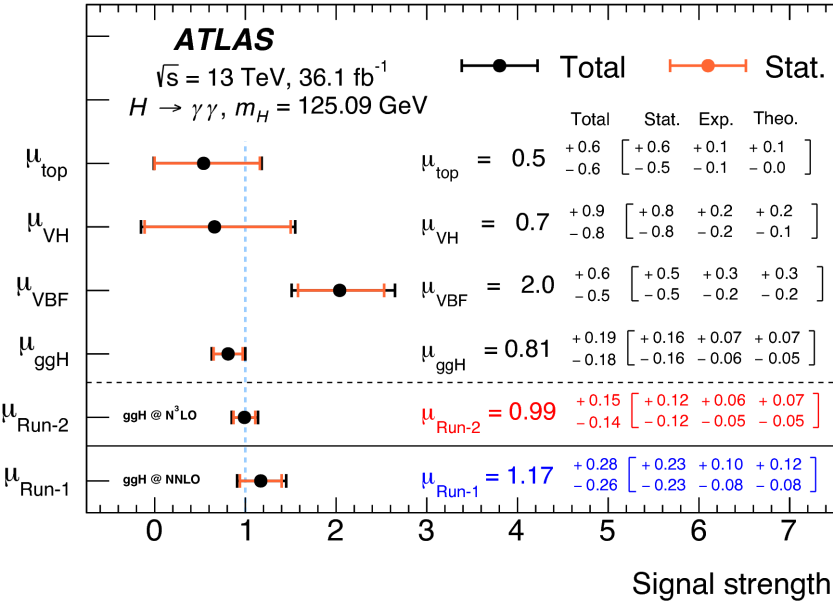
Higgs: mass



Thesis S. Manzoni

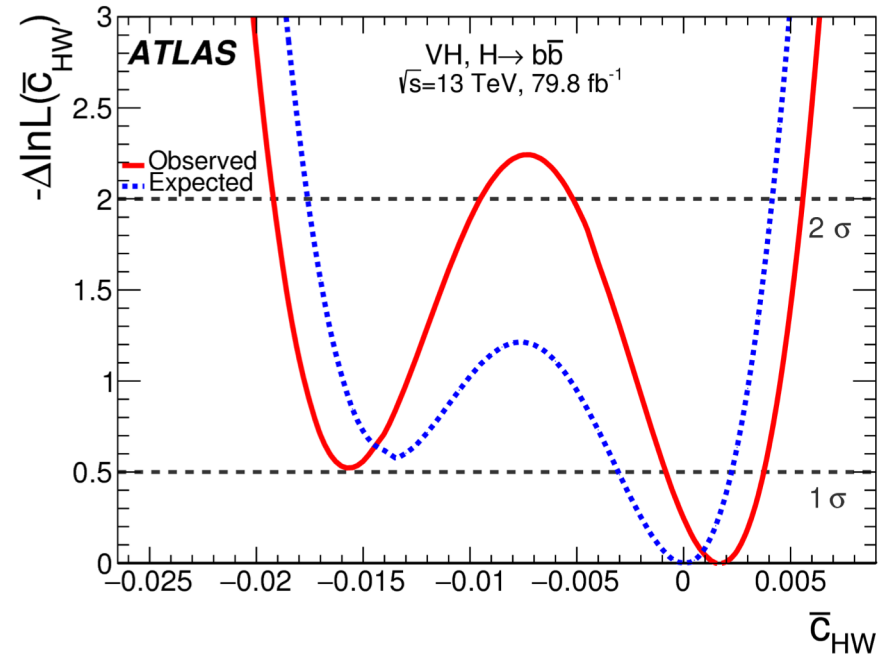
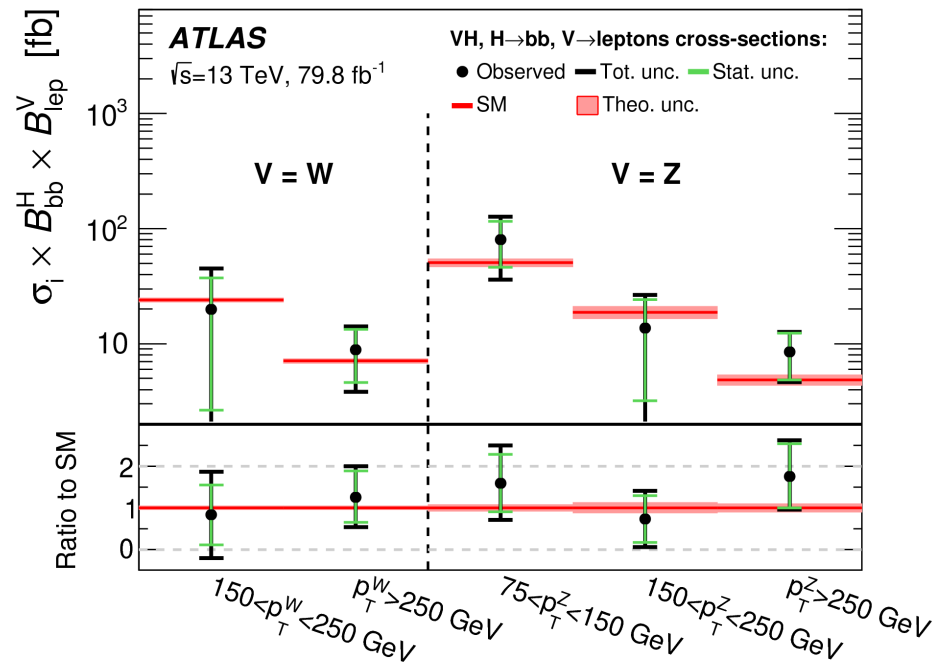
Source	Systematic uncertainty on $m_H^{\gamma\gamma}$ [MeV]
LAr cell non-linearity	± 200
LAr layer calibration	± 190
Non-ID material	± 120
Lateral shower shape	± 110
ID material	± 110
Conversion reconstruction	± 50
$Z \rightarrow ee$ calibration	± 50
Background model	± 50
Primary vertex effect on mass scale	± 40
Resolution	$^{+20}_{-30}$
Signal model	$^{+20}_{-0}$

Higgs: couplings/xsections ($\gamma\gamma$)



Higgs: measurement of $H \rightarrow b\bar{b}$ xsections

ATLAS-CONF-2017-046
[arXiv:1903.04618](https://arxiv.org/abs/1903.04618), submitted to JHEP



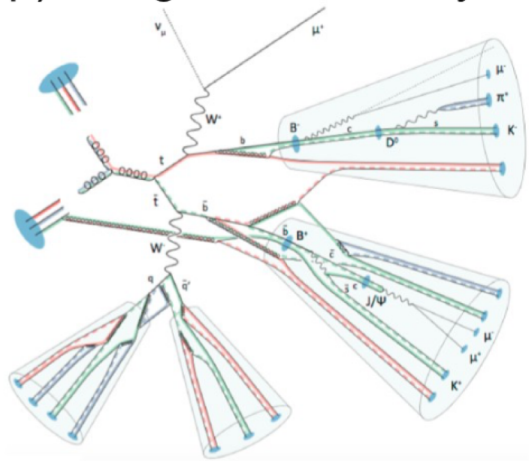
Thesis C. Li



Study of $t\bar{t}$ pairs with a B-hadron decaying in $J/\psi \rightarrow \mu\mu$ or D mesons offers alternative methods to measure $m(\text{top})$ using the sensitivity of $m(IJ/\psi)$, $m(ID)$ to $m(\text{top})$

Low statistics channel :

- $\text{BR}(b \rightarrow J/\psi \rightarrow \mu\mu) \sim 7 \times 10^{-4}$
- $\text{BR}(b \rightarrow \mu D^0 \rightarrow \mu K\pi) \sim 5.9 \times 10^{-3}$
- $\text{BR}(b \rightarrow D^{*}(2010)^+ \rightarrow D^0 \pi) \sim 2.2 \times 10^{-2}$



PhD of Jad Zahreddine (\rightarrow July 2020)

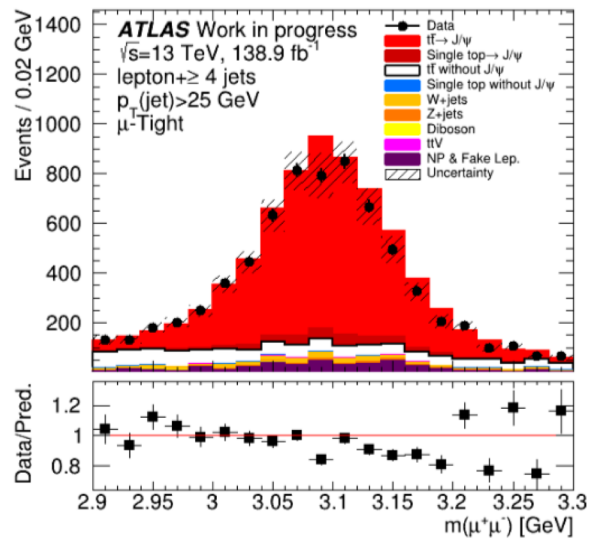
Full Run 2 analysis 140 fb^{-1} (ongoing)

Motivation for $m(\text{top})$

- $m(H)$, $m(W)$ and $m(\text{top})$ within SM
- sensitivity to vacuum fluctuations

Motivations for these channels

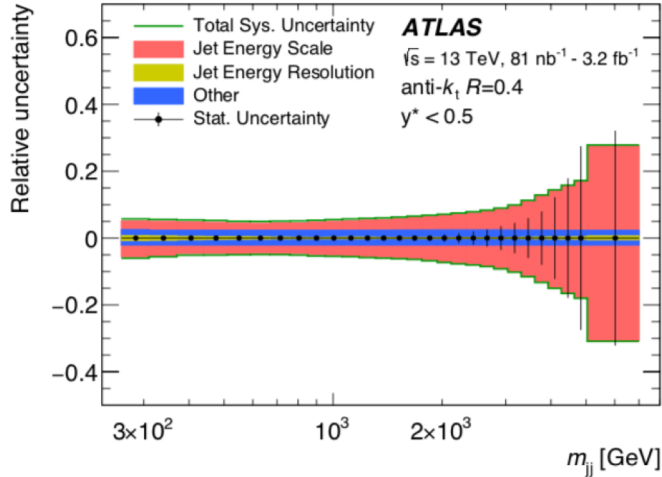
- purely leptonic/tracking observables less sensitive to Jet Energy Scale than the ones from jet reconstruction
- still sensitive to parton shower, hadronization, b-fragmentation effects...
- will help to reduce the final uncertainty in combination of all measurements



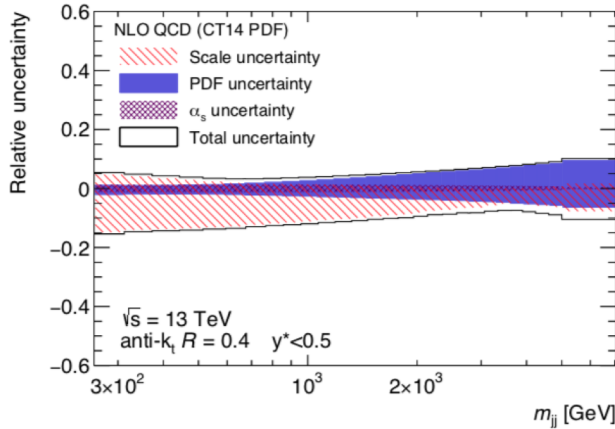
Prospects for HL-LHC 3000 fb^{-1}

- part of CERN Yellow Report
- $\sigma(\text{stat}) \sim 0.14 \text{ GeV}$
- $\sigma(\text{syst}) \sim 0.5 \text{ GeV}$ dominated by $t\bar{t}$ modelling (b-production and b-fragmentation)

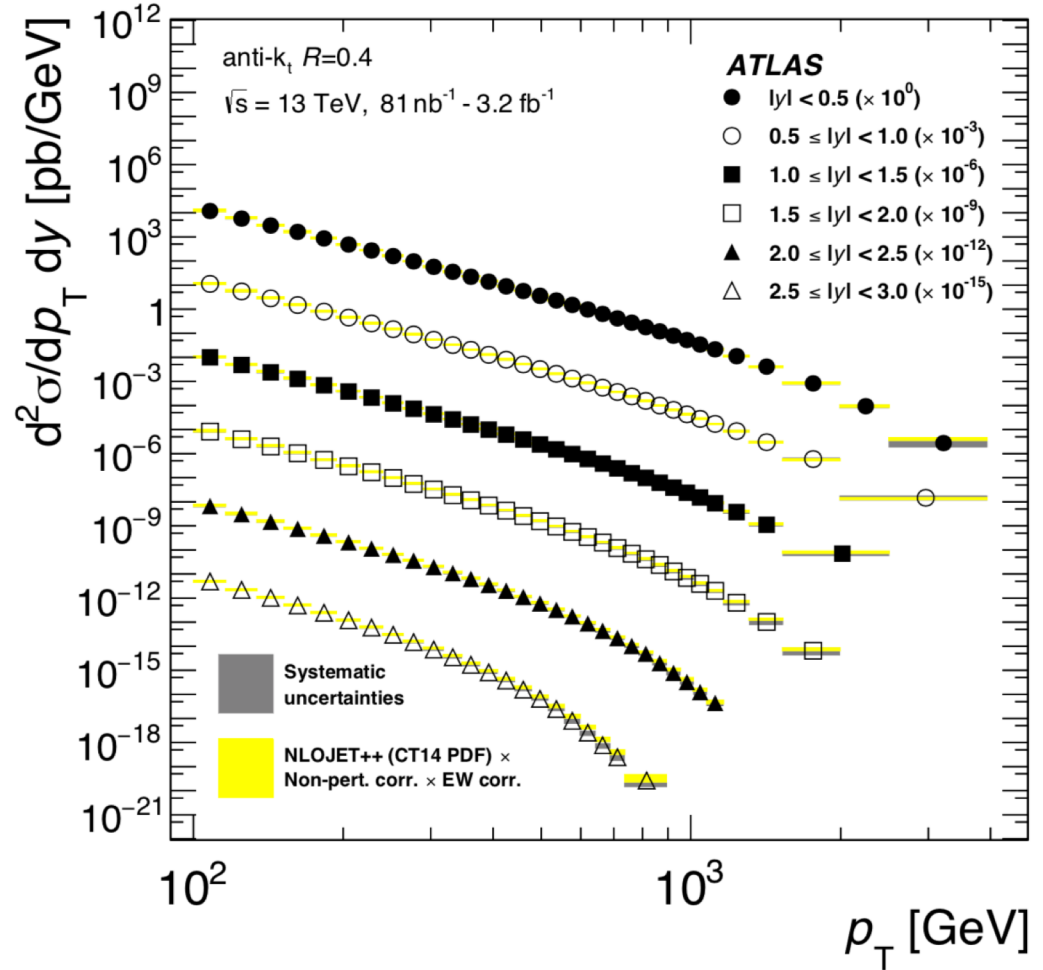
Jet XS measurements (1,2-jets)



(c) dijet



(c) dijet



arXiv:1711.02692

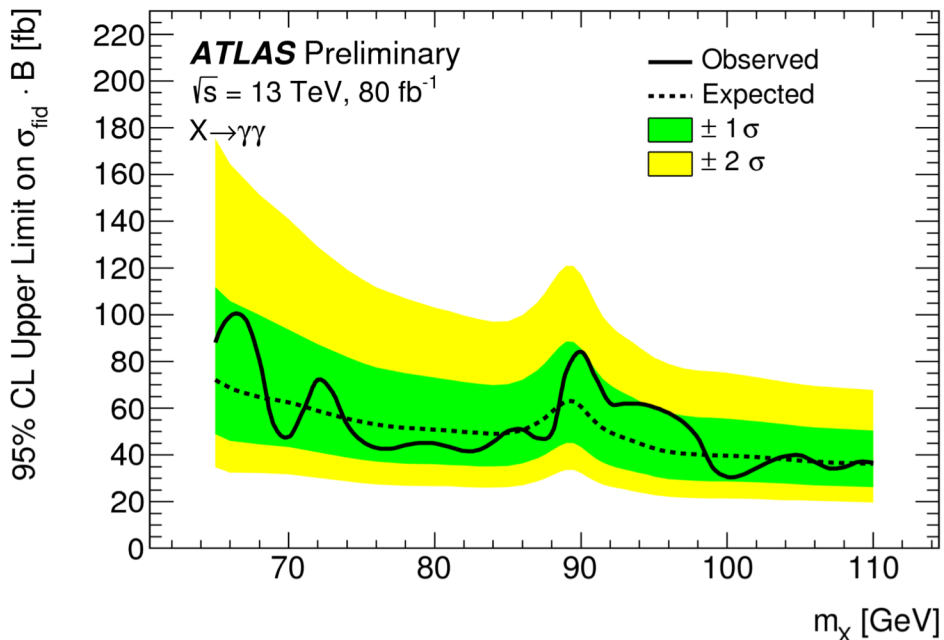
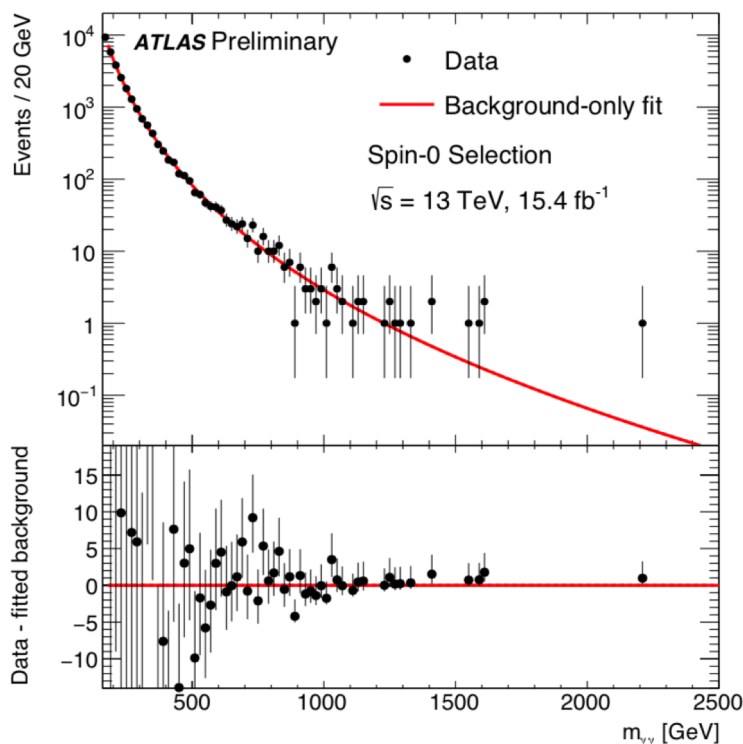
Beyond Standard Model Physics

Diphoton resonance search

After the ATLAS + CMS excess observation in 2015, things are back to null result, up to now...

2018: search for low mass diphoton resonance, [ATLAS-CONF-2018-025](#)

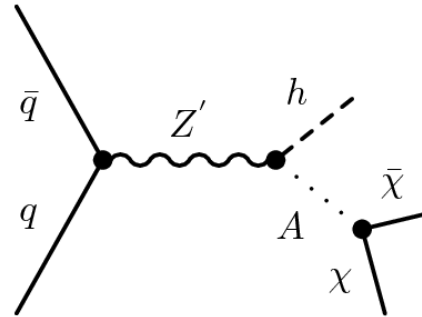
2015 + 2016



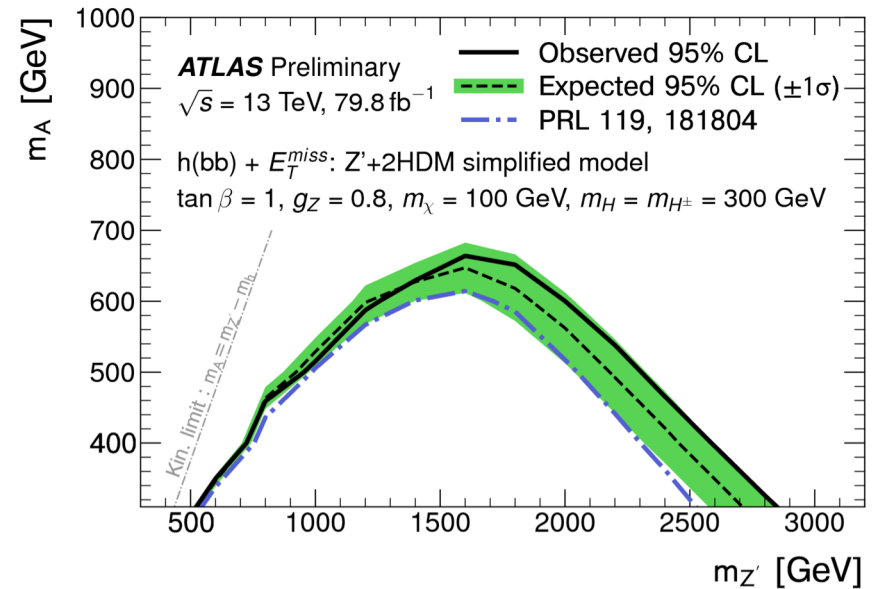
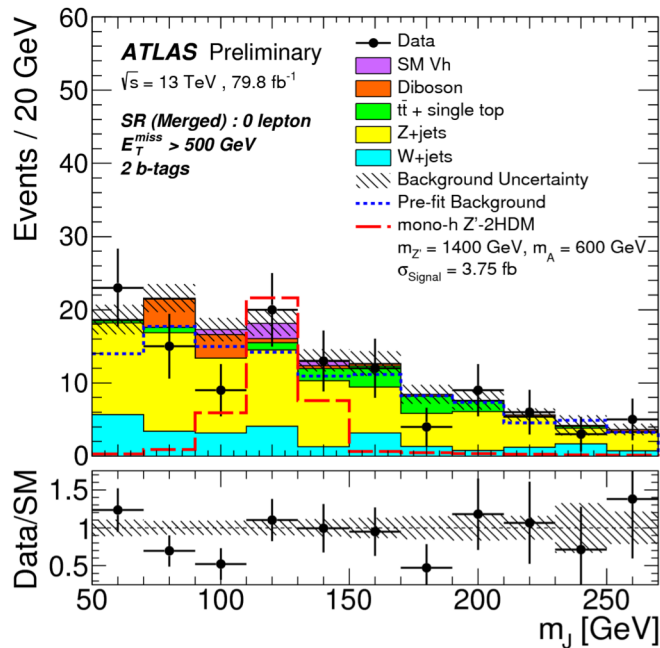
Selection optimization, SM Higgs background, SM continuum background (Yufeng, Ioannis)

Involvement of L. Pascual, J. Ocariz to go to lower mass (boosted topology)

Dark matter search with mono-H (bb)



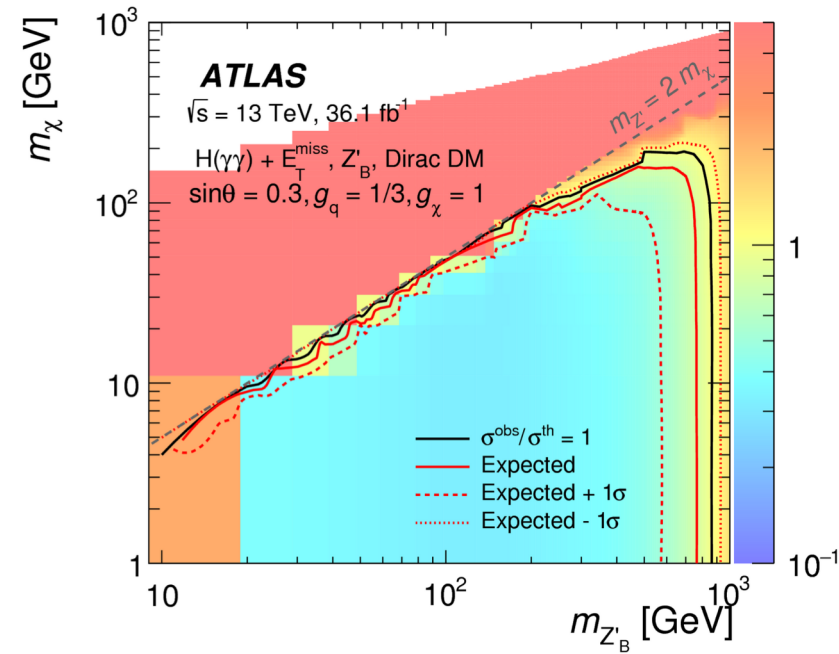
ATLAS-CONF-2018-025
Phys. Rev. Lett. 119 (2017) 181804



Thesis D. Portillo

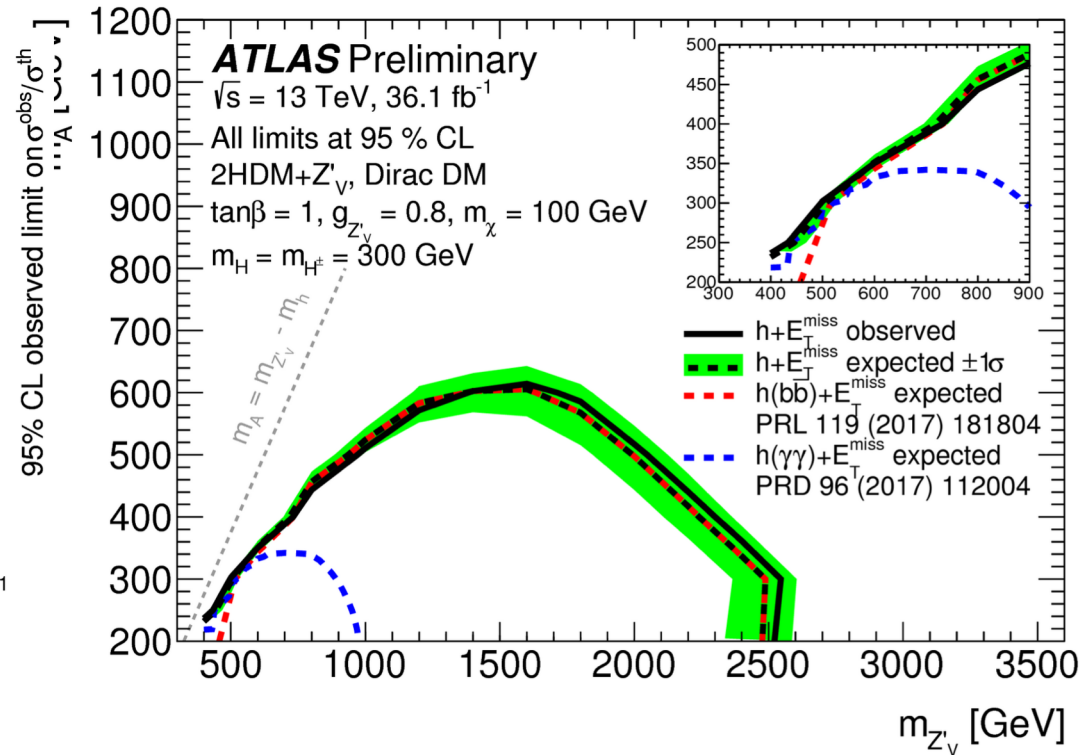
Dark Matter search with mono-H ($\gamma\gamma$)

2016 - 2018 Recherche de Matière Noire produite en association avec un boson de Higgs



Analyse du canal $H(\gamma\gamma) + \text{MET}$
 (CONF note ICHEP 2016, puis
 papier en 2017

[Phys. Rev. D 96 \(2017\) 112004](#)

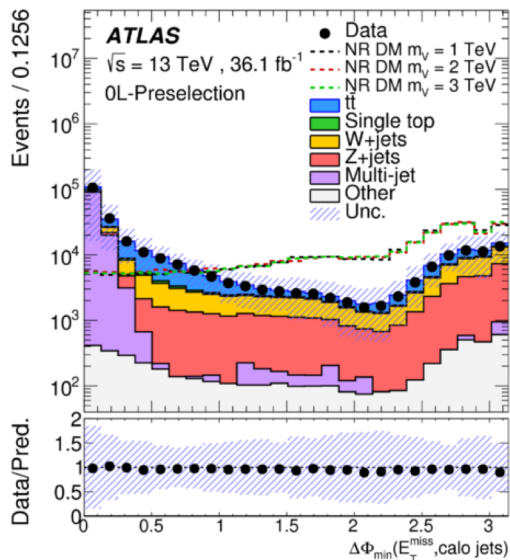
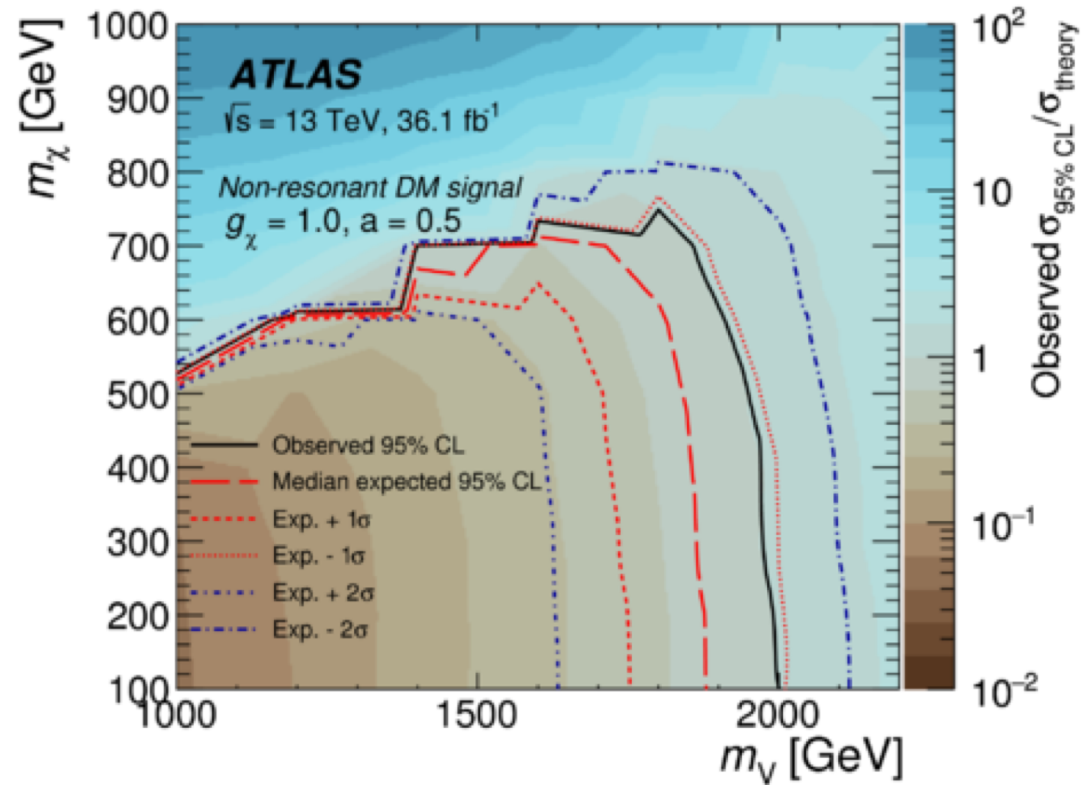
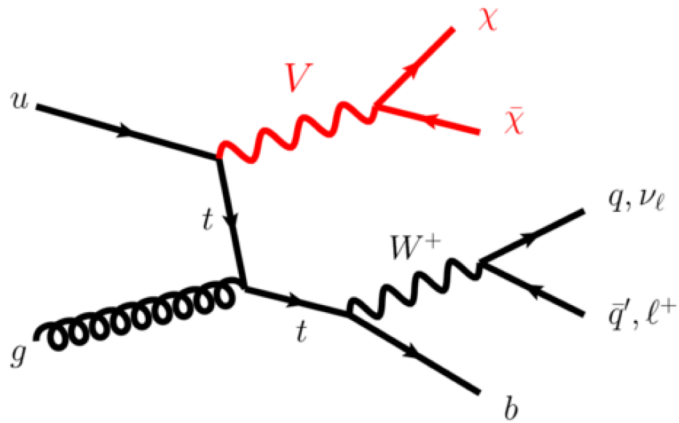


Participation au papier de combinaison
 des différentes recherches de DM
 (2018)

*Thesis A. Lopez-Sollis (2017), A. Leopold (2020, with full run 2 dataset)
 R. Wang, B. Laforge*

Dark Matter search with mono-top ($\gamma\gamma$)

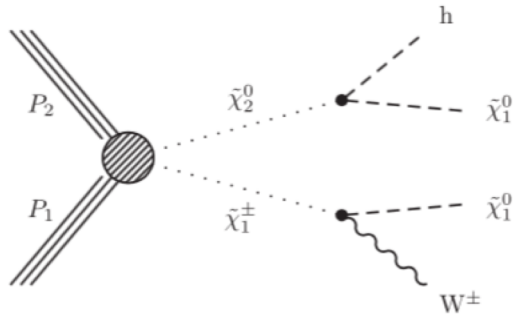
R. Wang



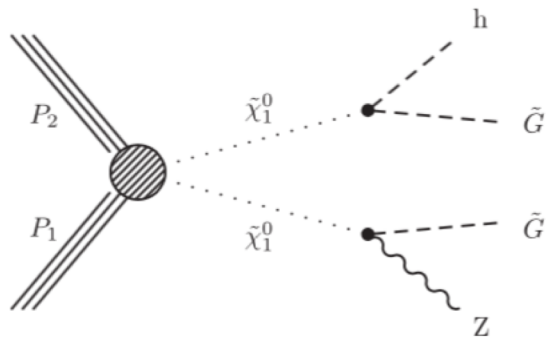
Submitted to JHEP

[arXiv:1812.09743](https://arxiv.org/abs/1812.09743)

Search for GMSB SUSY with Wh as a by product of H(yy) +MET



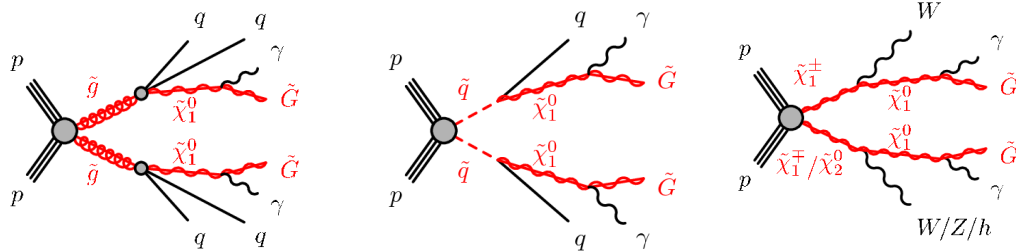
Search for chargino and neutralino production in final states with a Higgs boson and missing transverse momentum at $\sqrt{s}=13$ TeV with the ATLAS detector



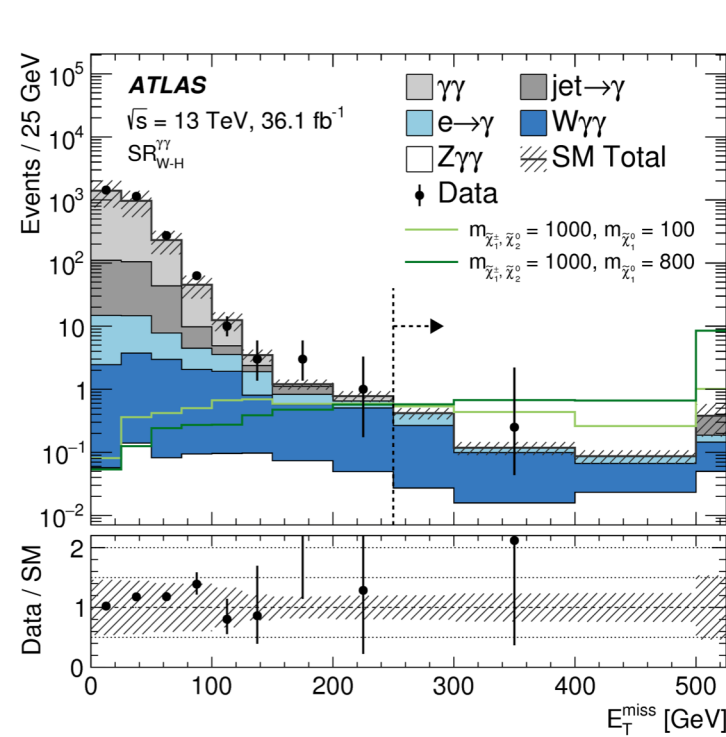
Extension of the 36/fb dataset analysis with hadronic reco of W and h→yy.

Paper in preparation with full integration of the W (leptonic and hadronic channel) using the full run 2 data

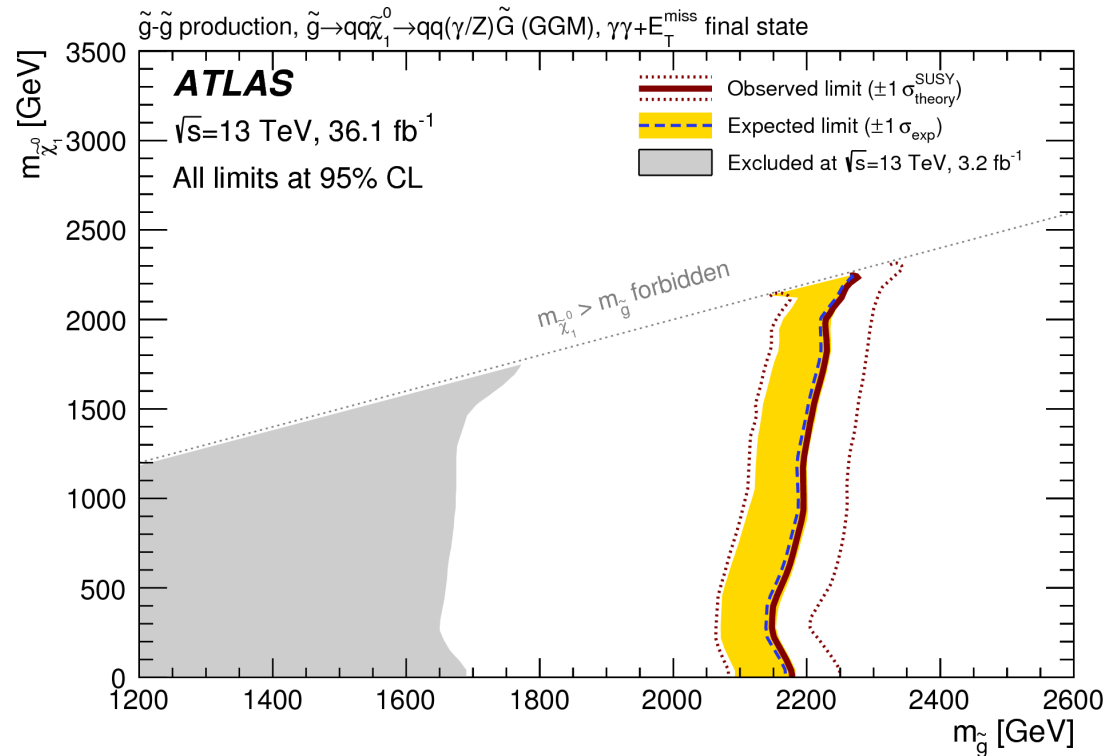
Search for GMSB SUSY with $\gamma\gamma$ +MET



Phys. Rev. D 97 (2018) 092006
Eur. Phys. J. C 76 (2016) 517

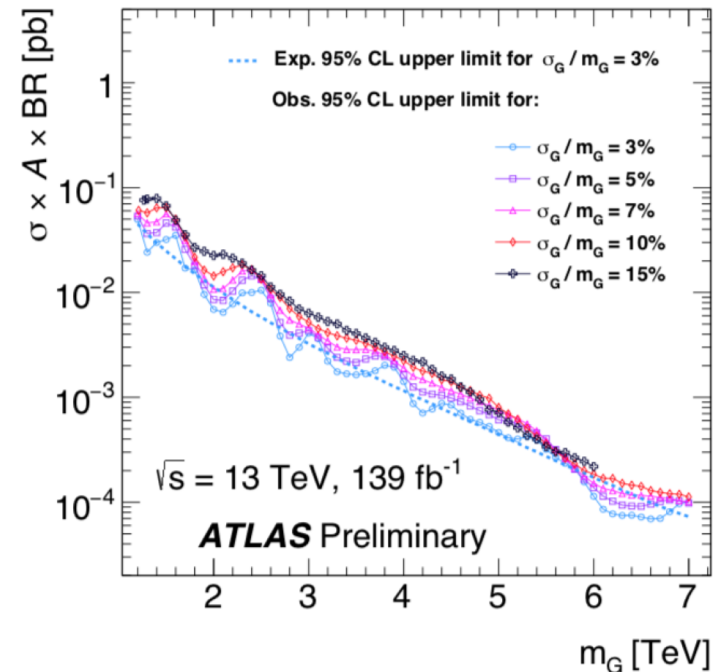
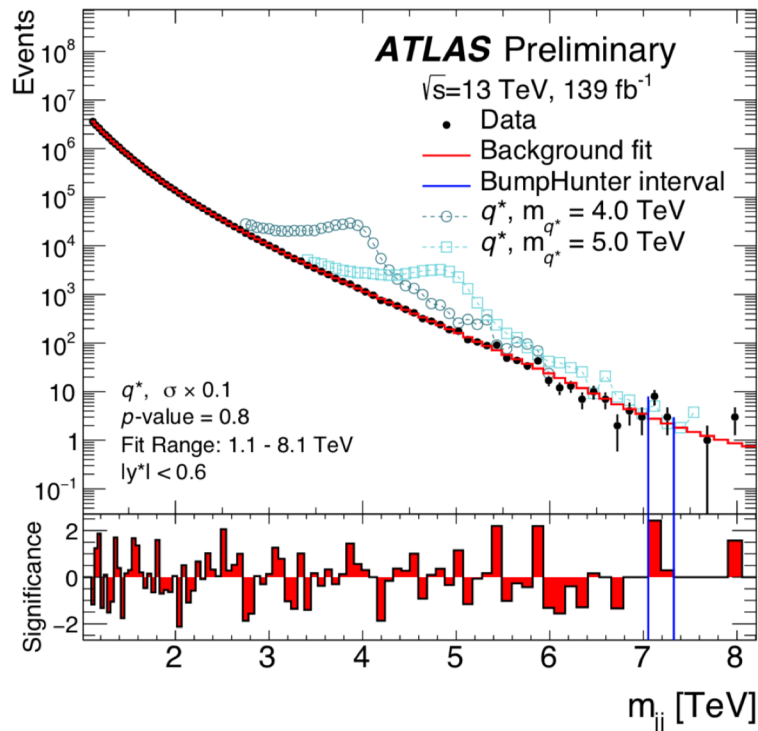


Thesis S. Manzoni



Search for di-jet resonance

Recherche de nouvelle physique dans les événements dijets



(b) Gaussian peak

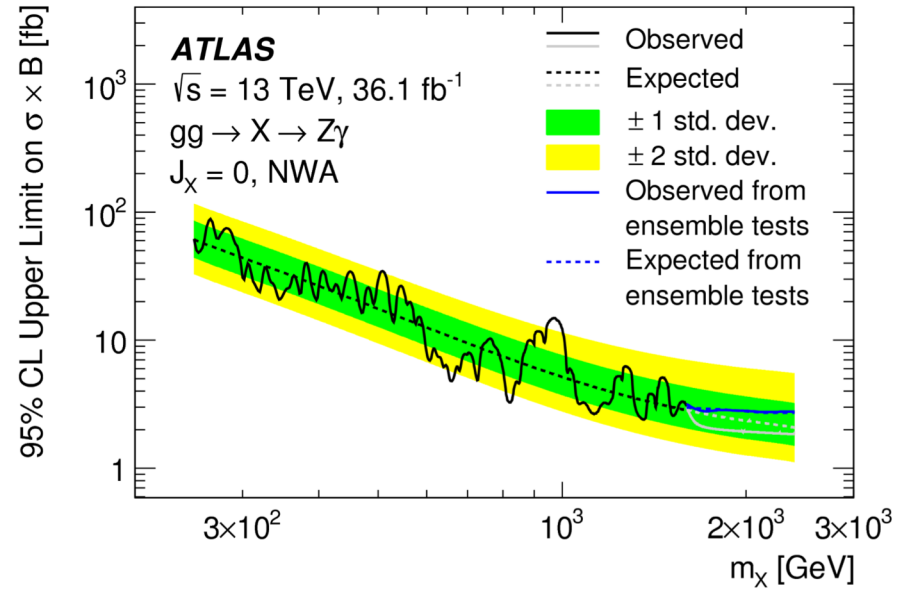
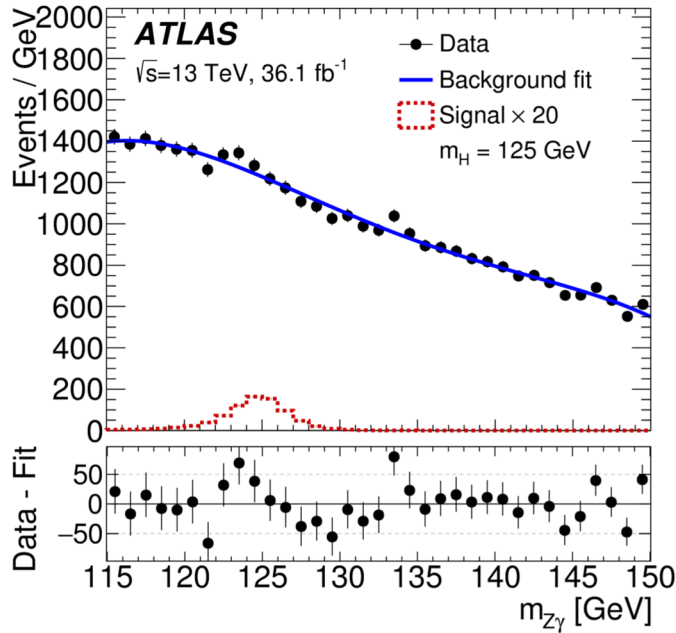
Distribution de la masse des di-jets: données
prédiction du bruit de fond et exemple de
résonance

Limites supérieures obtenues pour différents
signaux de nouvelles physiques

B. Malaescu, thesis Robert Hankache, M. Ridel

ATLAS-CONF-2019-007

$$H/X \rightarrow Z\gamma$$



Obs (exp) 95% CL upper limit on
 $\text{Sigma} \cdot \text{BR} < 6.6$ (6.2) $\cdot \text{SM}$ for
 $m_H = 125.09$ GeV

G. Marchiori

Backup

Publications 2017-2019

2019

1. ATLAS Collaboration, "Measurements of VH , $H \rightarrow bb$ production as a function of the vector boson transverse momentum in 13 TeV pp collisions with the ATLAS detector", submitted to JHEP, [arXiv:1903.04618](https://arxiv.org/abs/1903.04618)
2. ATLAS Collaboration, "Electron and photon energy calibration with the ATLAS detector using 2015-2016 LHC proton-proton collision data", JINST 14 (2019) P03017
3. ATLAS Collaboration, "Measurement of the photon identification efficiencies with the ATLAS detector using LHC Run 2 data collected in 2015 and 2016", Eur. Phys. J. C 79 (2019) 205
4. "In situ calibration of large-R jet energy and mass in 13 TeV proton-proton collisions with the ATLAS detector", the ATLAS Collaboration, Eur.Phys.J. C79 (2019) no.2, 135, arxiv:1807.09477.

2018

1. ATLAS Collaboration, "Observation of $H \rightarrow bb$ decays and VH production with the ATLAS detector", Phys. Lett. B 786 (2018) 59
2. ATLAS Collaboration, "Measurement of the Higgs boson mass in the $H \rightarrow ZZ^* \rightarrow 4\ell$ and $H \rightarrow \gamma\gamma$ channels with $\sqrt{s}=13$ TeV pp collisions using the ATLAS detector", Phys. Lett. B 784 (2018) 345
3. ATLAS Collaboration, "Measurements of b -jet tagging efficiency with the ATLAS detector using tt events at $\sqrt{s}=13$ TeV", JHEP 08 (2018) 89
4. ATLAS Collaboration, "Measurements of Higgs boson properties in the diphoton decay channel with 36 fb^{-1} of pp collision data at $\sqrt{s}=13$ TeV with the ATLAS detector", Phys. Rev. D98, 052005 (2018)
5. ATLAS Collaboration, "Search for photonic signatures of gauge-mediated supersymmetry in 13 TeV pp collisions with the ATLAS detector", Phys. Rev. D 97 (2018) 092006
6. "Search for low-mass dijet resonances using trigger-level jets with the ATLAS detector in pp collisions at $\sqrt{s}=13$ TeV", the ATLAS Collaboration, Phys.Rev.Lett. 121 (2018) no.8, 081801, arxiv:1804.03496. 3
7. "Measurement of inclusive jet and dijet cross-sections in proton-proton collisions at $\sqrt{s}=13$ TeV with the ATLAS detector", the ATLAS Collaboration, JHEP 1805 (2018) 195, arxiv:1711.02692. 16 cit.(*)

Publications 2017-2019

2017

1. ATLAS Collaboration, "Evidence for the $H \rightarrow b\bar{b}$ decay with the ATLAS detector," (2017), JHEP 12 (2017) 024, arXiv:1708.03299 [hep-ex]
2. ATLAS Collaboration, "Search for heavy resonances decaying to a Z boson and a photon in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector," Phys. Lett. B764, 11–30 (2017), arXiv:1607.06363 [hep-ex]
3. ATLAS Collaboration, "Searches for the $Z\gamma$ decay mode of the Higgs boson and for new high-mass resonances in pp collisions at $\sqrt{s}=13$ TeV with the ATLAS detector", JHEP 10 (2017) 112, arXiv:1708.00212 [hep-ex]
4. ATLAS Collaboration, "Search for new phenomena in high-mass diphoton final states using 37 fb⁻¹ of proton-proton collisions collected at $\sqrt{s}=13$ TeV with the ATLAS detector", Phys. Lett. B 775 (2017) 105
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