Search for a beyond the standard model resonance decaying to top quark pair in the dilepton final state with the ATLAS experiment

Maurizio De Santis

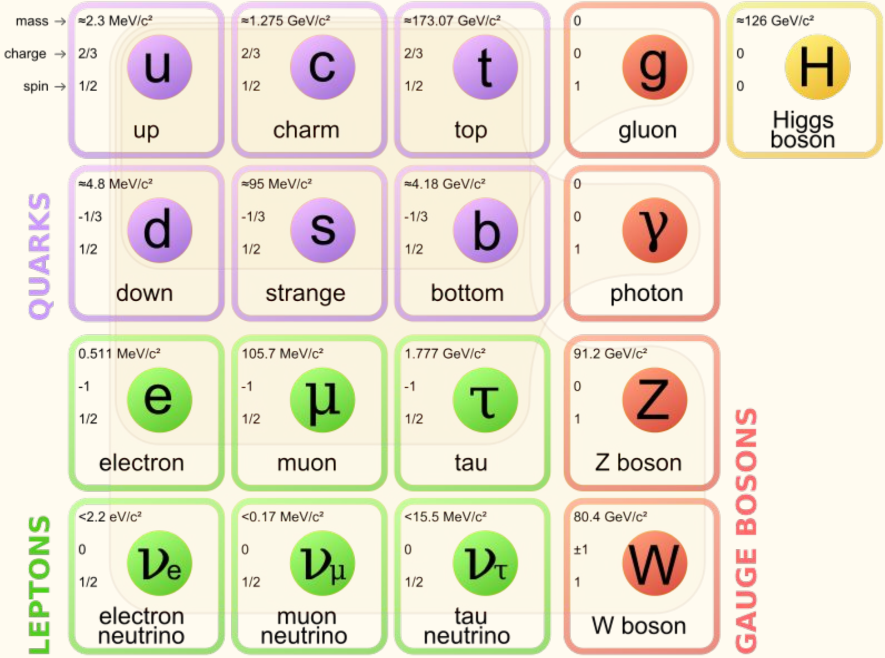
Final Exam A.A. 2018/2019

05/20/2020

Overview

- The Standard Model of particle physics;
- The LHC collider and the ATLAS experiment;
- QT: Reconstruction efficiency for muons close to jets;
- Studies about electron isolation and Overlap Removal extension;
- Search for a broad resonance in the dilepton channel with full Run 2 data sample.

Introduction: the Standard Model of particle physics



Particles divided into: fermions (half spin, i.e. quarks and leptons) and bosons (integer spin).
Fermions are divided in three families.

3 fundamental forces:

- Electromagnetic force (γ)
- Weak nuclear force (W,Z)
- Strong nuclear force (g)

Electroweak force

There are still several open question, for example **Gravity** and the **Hierarchy** problems → BSM

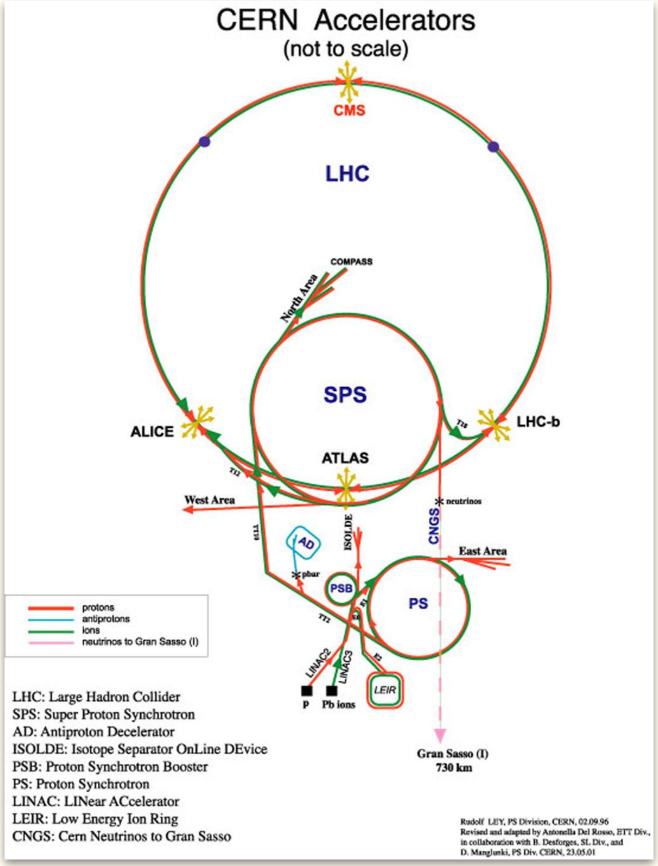
The LHC accelerator at CERN

The Large Hadron Collider (LHC) is the largest energy particle accelerator ever built.

- Circumference of 27 km located at CERN;
- proton-proton (and heavy ions) collider where two beams of high-energy particles (6.5 TeV for each beam).

The main experiments are:

- ATLAS (A Toroidal LHC ApparatuS);
- CMS (Compact Muon Solenoid);
- LHCb (Large Hadron Collider beauty);
- ALICE (A Large Ion Collider Experiment).

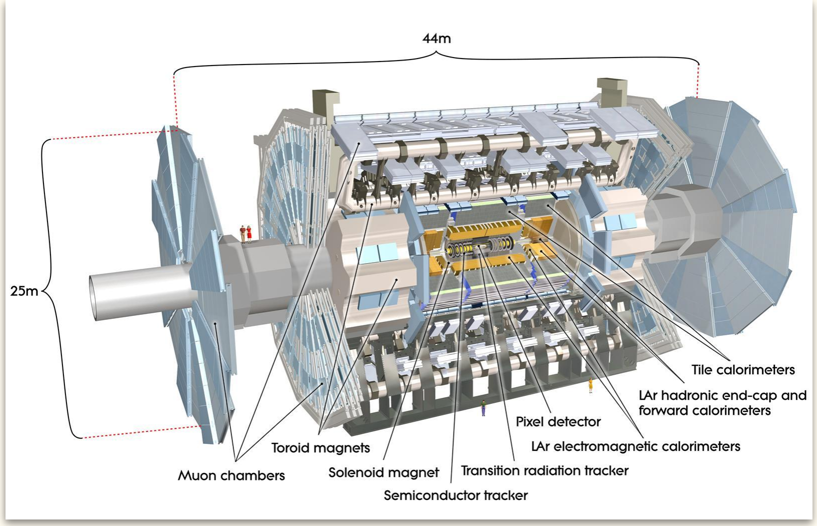


The ATLAS experiment

The ATLAS detector is 25 meters high and 44 meters long and has an onion-like structure.

Multi-purpose experiment.
It can be divided into five main parts:

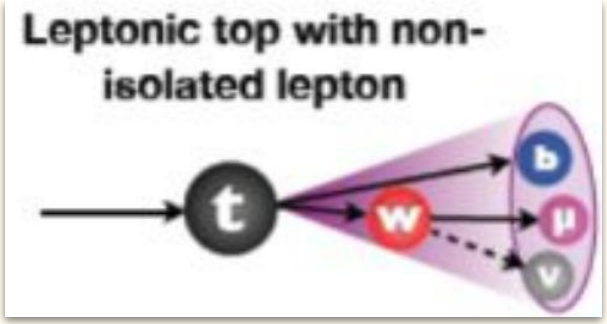
- Magnet System;
- Inner Detector (ID);
- Electromagnetic calorimeter (ECAL);
- Hadronic calorimeter (HCAL);
- Muon Spectrometer (MS).



Luminosity (10^{34} $cm^{-2}s^{-1}$) 2015: 0.5 → 2018: 2.0

Pileup: when particle detector is affected by several collision events at the same time.

QT: Reconstruction efficiency for muons close to jets I



- The reconstruction efficiencies are computed using the Tag&Probe method in J/Ψ events → useful for soft-muons analysis (i.e. Soft Muon Tagging analysis).
- The method is based on the selection of an almost pure muon sample from J/Ψ → μμ events, requiring one leg of the decay (tag) to be identified as a muon that fires the trigger and the second leg (probe) to be reconstructed by a system independent of the one being studied.

This study was performed within the ATLAS Muon Combined Performance (MCP) group.

Reconstruction efficiency for muons close to jets II

Tag selection:

- $p_T > 4$ GeV;
- $|\eta| < 2.5$;
- matched with the trigger;
- Quality type "Medium";
- Iso WP: FCTightTrackOnly.

Probe selection:

- $p_T > 4$ GeV;
- $|\eta| < 2.5$;
- $2.7 < m(\mu_{tag}\mu_{probe}) < 3.5$ GeV;
- $\Delta R(\text{jet}, \mu_{probe}) < 0.4$.

In order to have the reconstruction efficiency for non-isolated muons, three different non-isolated regions are used:

p_T : ptvarcone30/pt > 0.06

E_T : topoetcone20/pt > 0.06

ΔR(jet, probe) : $0 < \Delta R < 0.2$ and $0.2 < \Delta R < 0.4$

- ptvarcone30: Σ_{track} Pt($\Delta R = 0.3$) excluding the muon track itself.
- topoetcone20: Σ_{track} Et($\Delta R = 0.2$) excluding the energy deposit of the muon itself.
- $\Delta R = \text{sqrt}(\Delta\eta^2 + \Delta\varphi^2)$.

2016 data and Monte Carlo referred to this dataset are used.

Reconstruction efficiency for muons close to jets III

T&P: Tag muon → match with the trigger; Probe muon → match between two tracks in different detector (i.e. ID and MS).

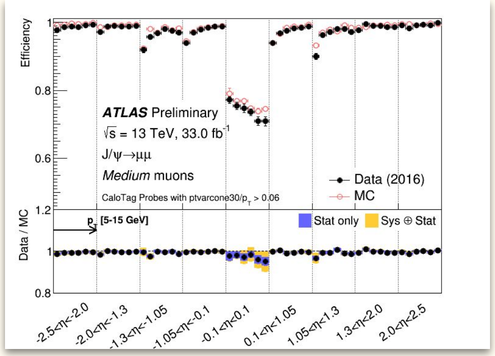
Total reconstruction efficiency for muons with “Medium” quality is defined as:

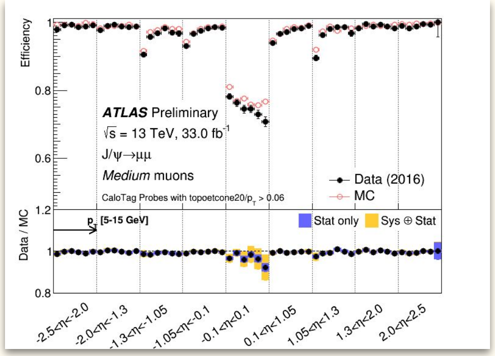
ε(Medium) = ε(Medium|CP) * ε(ID|MS) Labeled as “CaloTag probes”

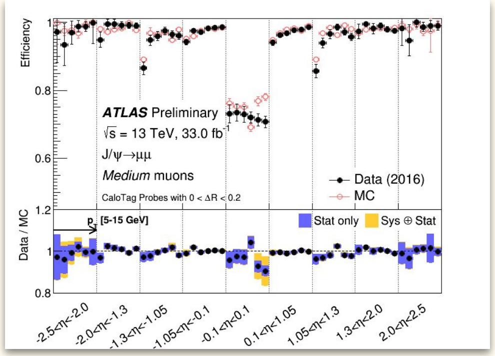
Where “Medium” is a kind of muon selection that minimises the systematic uncertainties associated with muon reconstruction and calibration; CP (Calo Probes) are the Inner Detector (ID) tracks tagged as muons by the calorimeter deposit; MS are the probe muons in the Muon Spectrometer.

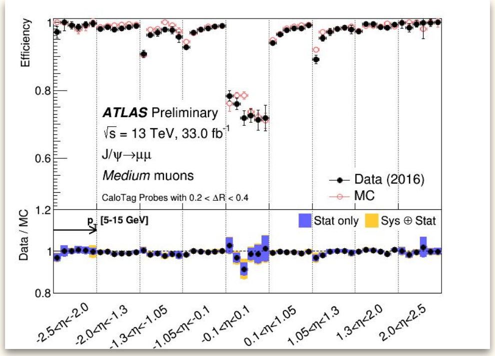
The efficiencies are then measured in the three different non-isolated regions.

Reconstruction efficiency for muons close to jets IV









Total P(χ^2) comparison → reco. efficiencies compatible with the isolated muons in MCP recommendations.

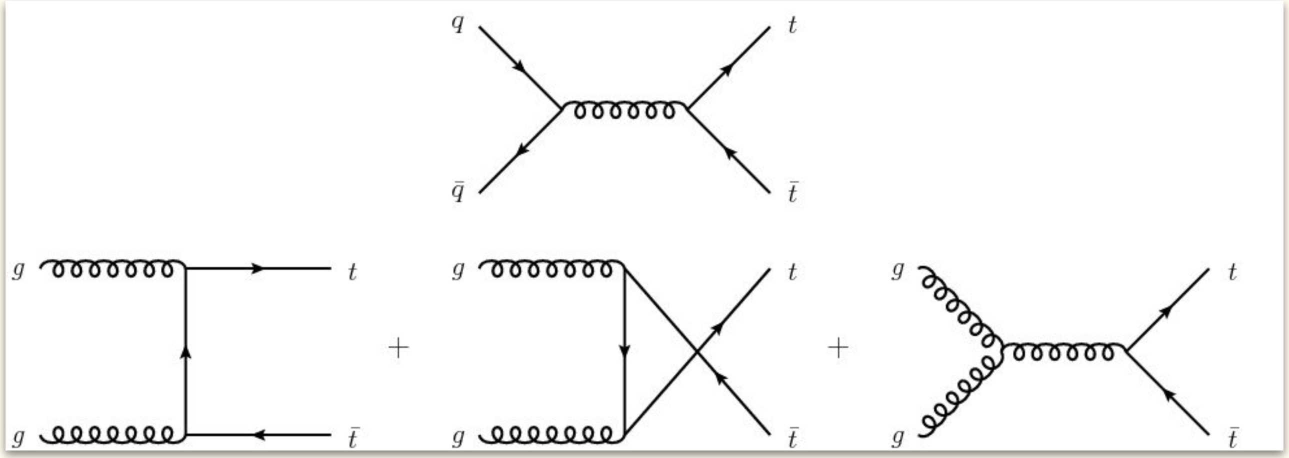
The analysis

The protagonist: the top quark

The heaviest particle in the SM (m = 173.34±0.76 GeV [world comb. 2014]). Several properties:

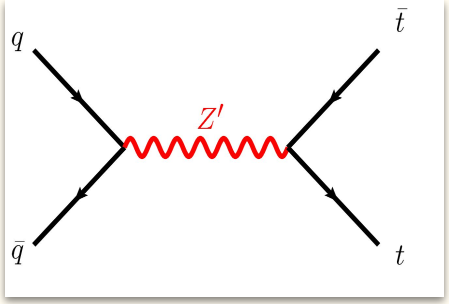
- Decay before hadronisation;
- Decay almost exclusively into a W boson and a bottom quark b (t→Wb);
- Coupling close to 1 with the SM Higgs via Yukawa mechanism.

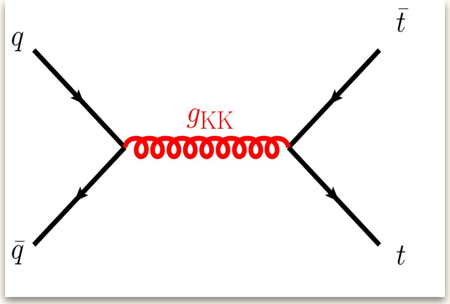
Special role in the Standard Model. An accurate knowledge of its properties → information about new physics?

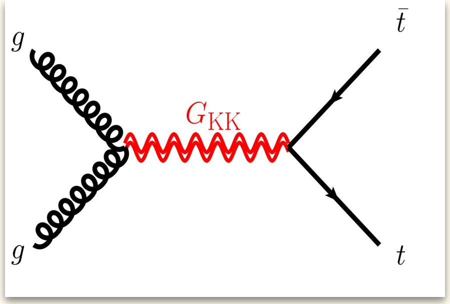


ttbar production mechanisms at hadron colliders

Beyond the Standard Model (BSM)







Three BSM models under study:

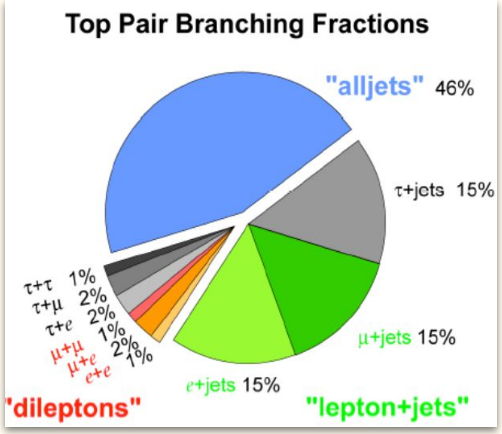
- **SSM TC2 Z’**;
- **Kaluza-Klein gluon**;
- **Randall-Sundrum graviton**.

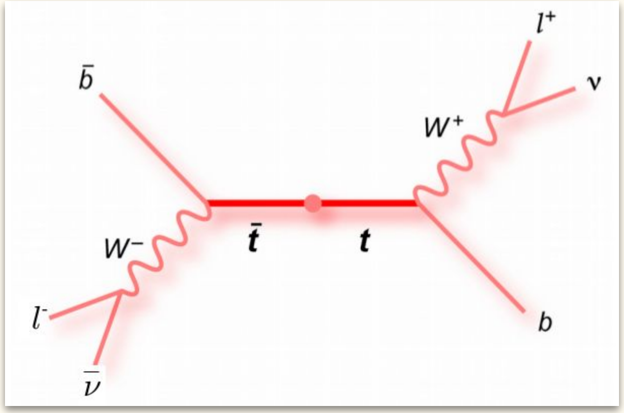
All of these models want to resolve the hierarchy problem in the Standard Model.

Search for a BSM resonance: Introduction

Search for a BSM ttbar resonance in dilepton channel.

~7% of the total Branching Ratio (BR). Low statistic (with respect to all channels) → Low background.





The resonance study is useful to search BSM phenomena.

- Dilepton channel is more sensitive to variations of spin correlation.
- Various signal of new physics change the spin correlation near the resonance (i.e. broad resonances).

Combine the invariant mass of the top-antitop system and the spin-sensitive variable ($\Delta\varphi(\ell\ell)$).

Study about the electron isolation and OR extension

In order to have the best setup available for my analysis, a previous work is done. This work involved detailed studies on the electron isolation efficiency and the Overlap Removal (OR) procedure.

The main motivation for this work is similar to the muon case: the request of electron isolation and how the choice can be improved are very useful if I want to get a very sensitive measurement for the BSM signals.

The standard configuration $\Delta R_{(\mathrm{el,jet})} > 0.4 \rightarrow$ I need a different requirement.

The overlap removal studies for electrons → dilepton-channel analysis.
Also for muons → to confirm lepton+jet measurement.

Study about the electron isolation I

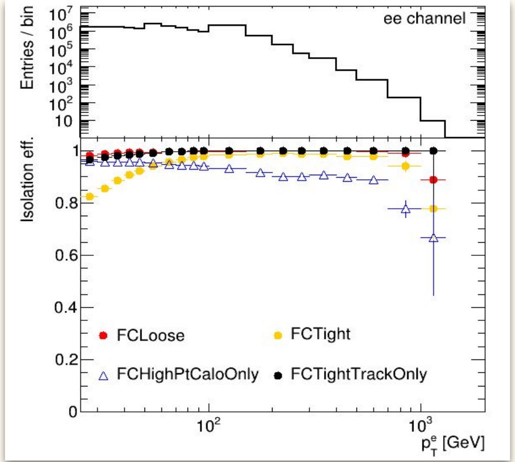
Only Monte Carlo simulated samples referred to 2015+2016 dataset (36.1 fb^{-1}) are used.
Main background SM $t\bar{t}$ dilepton and Z' m = 3 TeV.

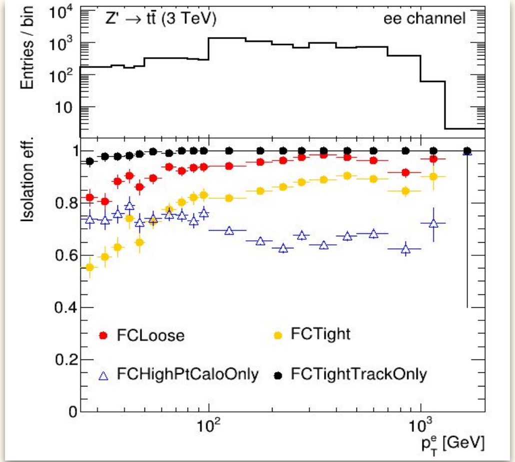
The electron criteria are:

- $p_T > 25$ GeV;
- $|\eta| < 2.5$ (excluded $1.37 \leq |\eta| \leq 1.52$);
- Tight quality selection.

Isolation efficiency vs p_T of the leading electron in the ee-channel.

FCTightTrackOnly working point
→ isolation efficiency ~ 99% .





Study about the electron isolation II

Some WP → no recommendation yet.

NO isolation working point (for the time being) → better than standard “Gradient” woking point.

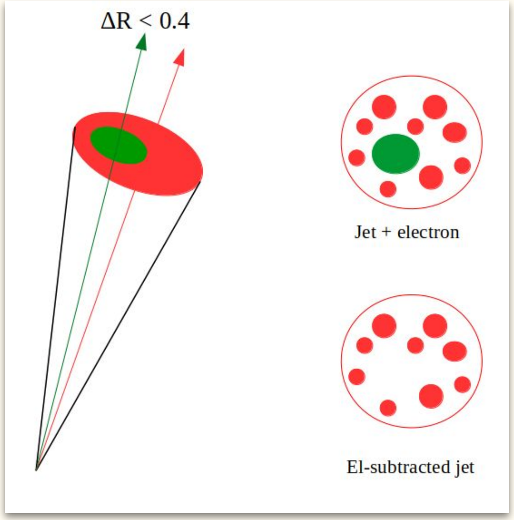
	Gradient	*No − isolation*
$t\bar{t}$ background	504411	568199
Z’ (3 TeV)	661	950
$\frac{S}{\sqrt{S+B}}$	0.93	1.26

The Overlap Removal (OR) procedure

An electron-jet overlap removal procedure is used to prevent the double counting of electrons as jets as well as to remove non-prompt electrons, to reduce the rate of events with mis-reconstructed or non-prompt electrons. The main variable used to achieve this is the angular distance $\Delta R(\text{el, jet})$, measured for all electron-jet combinations in each event.
The procedure depends on the type of particle:

- Jets are removed if the angular distance is $\Delta R < 0.2$;
- Electrons are removed if the angular distance is $0.2 < \Delta R < 0.4$.

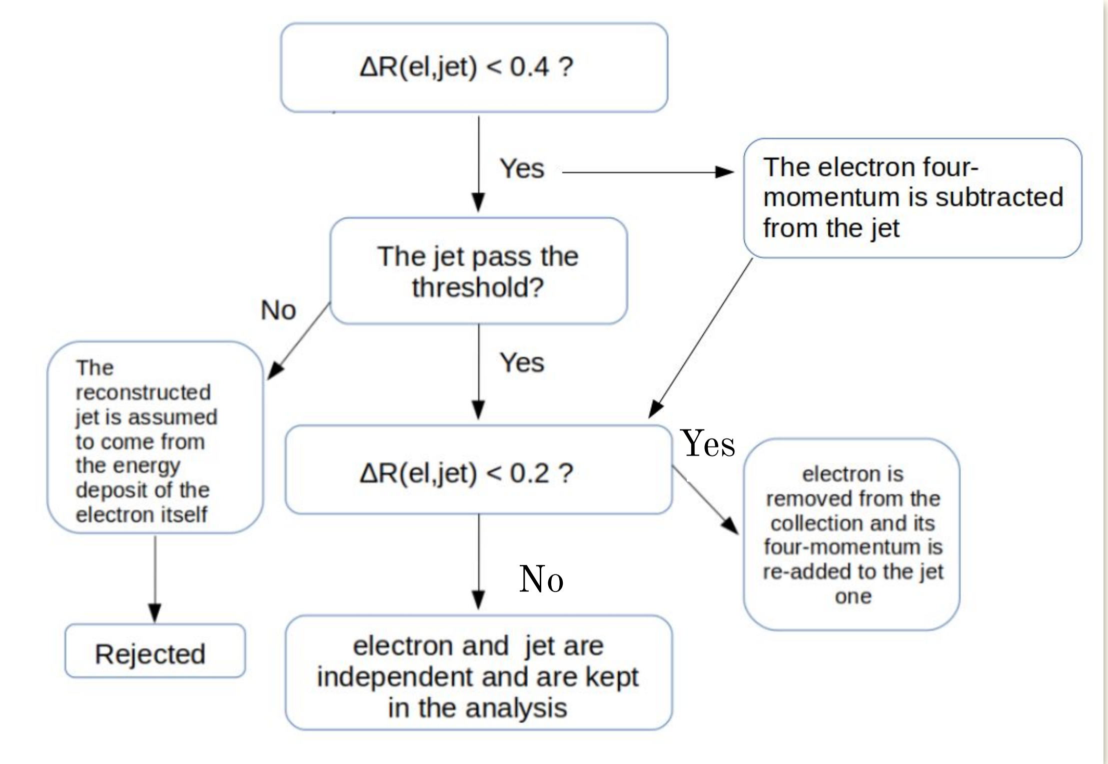
As a consequence, the electron and the b-jet from a leptonic top or antitop decay are both kept in the event only if $\Delta R > 0.4$.



Extension of the Overlap Removal (OR) procedure I

The standard configuration $\Delta R_{(el,jet)} > 0.4$
$\rightarrow$ I need a different requirement.

$$0.2 < \Delta R_{(el,jet)} < 0.4$$



Extension of the Overlap Removal (OR) procedure II

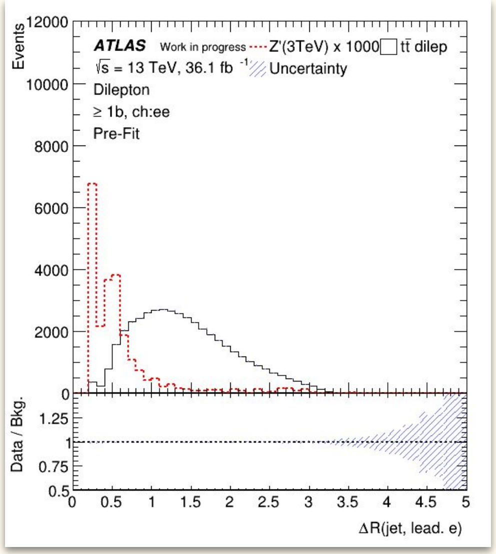
Only Monte Carlo simulated samples referred to 2015+2016 dataset (36.1 fb^{-1}) are used: the $t\bar{t}$ dilepton sample as the main background, Z' with a mass of 3 TeV as simulated signal and fake events.

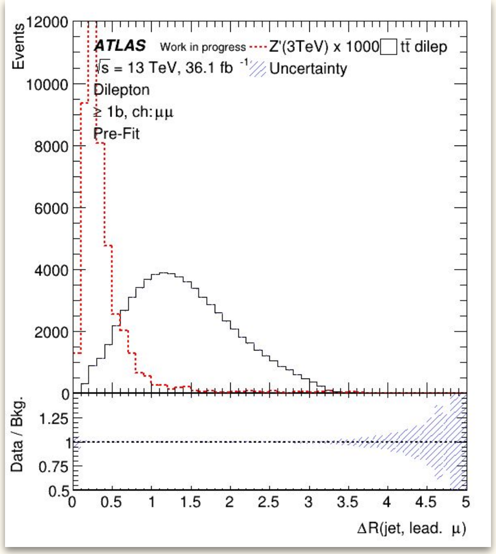
Electrons:

- $p_T > 25$ GeV;
- $|\eta| < 2.5$ (excluded $1.37 \leq |\eta| \leq 1.52$);
- Tight quality selection;
- No isolation (for the time being).

Muons:

- $p_T > 25$ GeV;
- $|\eta| < 2.5$;
- Medium quality selection;
- FCTightTrackOnly isolation.





Extension of the Overlap Removal (OR) procedure III

Channel:	Z' events	$t\bar{t}$	Fake	$\frac{S}{\sqrt{S+B}}$
$ee-channel$	$m_{Z'} = 3$ TeV			
Default OR	777	2082918	594265	0.47
Dilepton OR	1277	2349108	697985	0.73
$e\mu-channel$	$m_{Z'} = 3$ TeV	$t\bar{t}$	Fake	$\frac{S}{\sqrt{S+B}}$
Default OR	1113	4634558	1317518	0.45
Dilepton OR	3435	5503025	1614445	1.29
$\mu\mu-channel$	$m_{Z'} = 3$ TeV	$t\bar{t}$	Fake	$\frac{S}{\sqrt{S+B}}$
Default OR	416	2538907	720284	0.23
Dilepton OR	2325	3192341	926846	1.15

All these studies, shown in the table, assert that this configuration is the best choice for the subsequent steps regarding the measurement of invariant masses and signal limits.

Event selection

Full Run2 data (139 fb^{-1}) and MC referred to this full dataset.
Signals: SSM leptophobic Z', Randall-Sundrum Graviton and Kaluza-Klein Gluon.

Electron selection:

- $p_T > 25$ GeV
- $|\eta| < 2.5$ excluding $1.37 < |\eta| < 1.52$
- No isolation (for the time being)

Muon selection:

- $p_T > 25$ GeV
- $|\eta| < 2.5$
- FCTightTrackOnly

Jet selection:

- $p_T > 25$ GeV
- $|\eta| < 2.5$
- EM-topo, anti-kt $R = 0.4$

Other selection:

- Single lepton trigger
- leading lepton $p_T > 27$ GeV
- 2 charged leptons ($ee/\mu\mu/e\mu$)
- ≥ 2 jets
- ≥ 1 b-jet (using mv2c10 @77%)
- $m\ell\ell > 15$ GeV & $80 < m\ell\ell < 100$ GeV veto for ee and $\mu\mu$

Overlap Removal (non standard):

- Muon: **BoostedSlidingDrMu**
- Electron: **EleInJetSubtraction**

Search for a BSM resonance

In this analysis the backgrounds are:
- **SM $t\bar{t}$ dilepton**: this is an irreducible background and it is simulated using POWHEG+PYTHIA8.
- **Z+jets**: it is simulated using SHERPA2.2.1 NLO.
- **Diboson** (ZZ,WW,ZW): it is simulated using SHERPA2.2.1 NLO.
- **Single-top**: it is simulated using POWHEG+PYTHIA8.
- **$t\bar{t}$+V** ($t\bar{t}Z$, $t\bar{t}W$, tZ and tWZ): they are simulated using MADGRAPH5_aMC@NLO+PYTHIA8.
- **Fakes**: events with only one prompt charged lepton (from a W or Z decay) with a non-prompt lepton that pass the dilepton event selection.

channel	$ee \geq 1$ b [x10^3]	$e\mu \geq 1$ b [x10^3]	$\mu\mu \geq 1$ b [x10^3]
$t\bar{t}$ dilep.	190 ± 50	480 ± 70	287 ± 9
Single top	8.9 ± 2.7	22 ± 7	13 ± 4
Z+jets	60 ± 18	0.76 ± 0.23	100 ± 30
Diboson	2.6 ± 1.3	1.8 ± 0.9	3.9 ± 2.0
$t\bar{t} + V$	1.11 ± 0.33	1.07 ± 0.32	1.5 ± 0.5
Fakes	2.8 ± 0.8	3.8 ± 1.1	0.86 ± 0.26
Total	270 ± 50	510 ± 70	406 ± 32

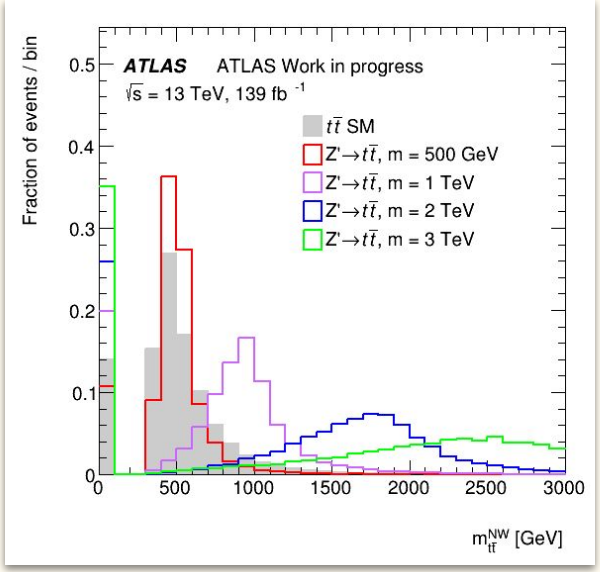
Top pair invariant mass reconstruction

Two invariant mass variables are used:

- $m_{\ell\ell bb}$: the invariant mass of the system built using the two charged leptons and the two highest-p_T b-tagged jets, ordered in p_T;

$$m^2_{\ell\ell bb} = (E_{\ell_1} + E_{\ell_2} + E_{b_1} + E_{b_2})^2 - (\overrightarrow{p}_{\ell_1} + \overrightarrow{p}_{\ell_2} + \overrightarrow{p}_{b_1} + \overrightarrow{p}_{b_2})^2$$

- m_{tt} using the Neutrino Weighting (NW):
  Constraints (m_W and m_t) → weights for neutrino p_x and p_y.
  Mis-measurement increasing with high invariant masses.

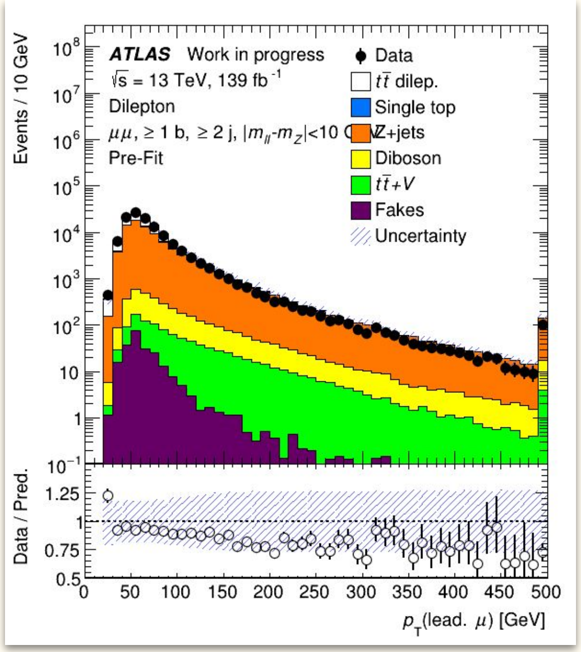


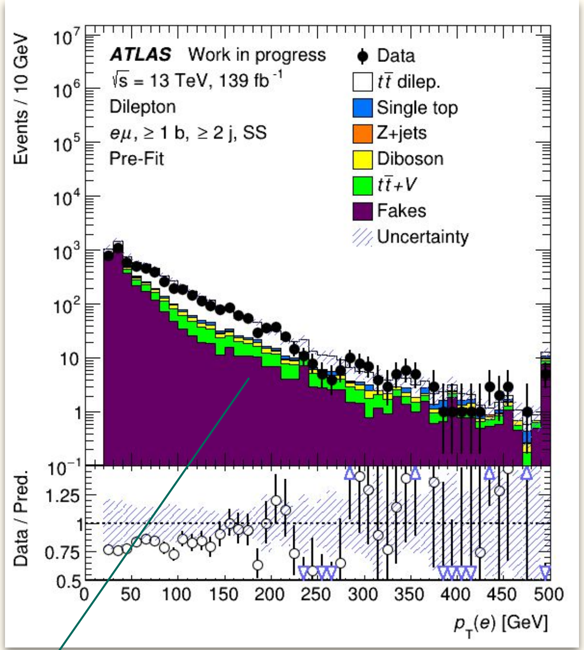
Search for a BSM resonance: Control Regions

Z+jets background CR: obtained by selecting the ee and μμ events and inverting the Z-mass window cut, i.e. requiring $80 < m\ell\ell < 100$ GeV and MET > 45 GeV

Fake background CR: obtained by inverting the opposite-sign requirement on the electric charges of the selected leptons, i.e. requiring same-sign dilepton events.

The CRs are used only to validate the background estimation. For the future, the plan is to add them to the fit.



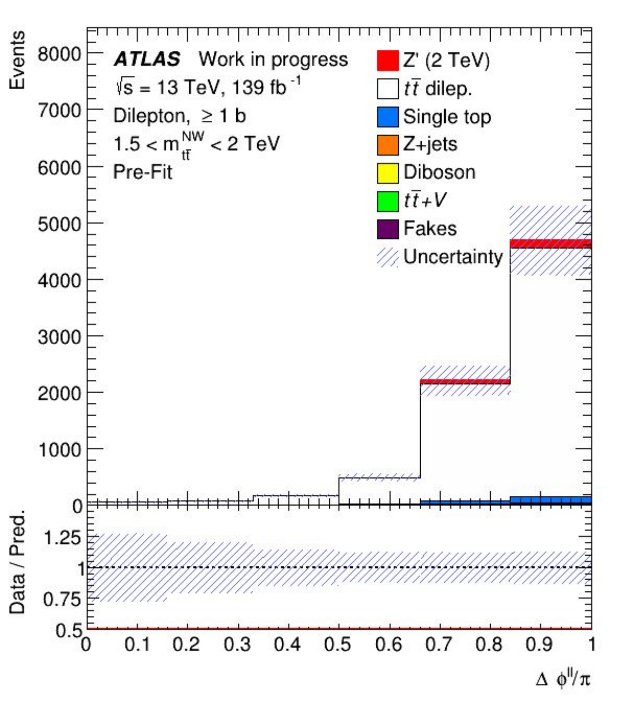


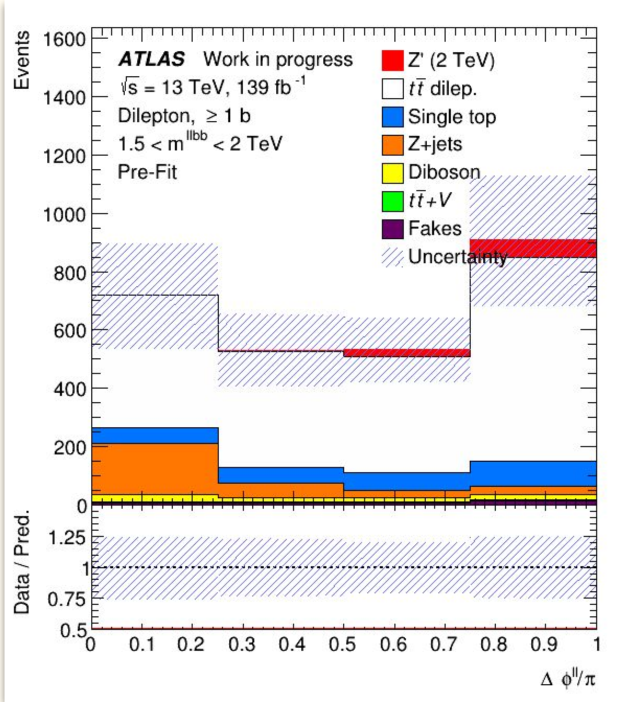
Agreement not very good but is $< 1\%$

Search for a BSM resonance: Signal Regions

A signal region is defined for each bin of the mass variable, $m_{t\bar{t}}$(NW) or $m_{\ell\ell bb}$, and in each of these regions the spin-sensitive variable $\Delta\varphi(\ell\ell)/\pi$ is considered. In these SRs the signal sensitivity increases in the region of $\Delta\varphi(\ell\ell)/\pi > 0.5$. The number of bins chosen is based on the simulated statistics we have.

Variable	Bins [TeV]
$m_{\ell\ell bb}$	0-0.3
	0.3-0.4
	0.4-0.5
	0.5-0.75
	0.75-1
	1-1.25
	1.25-1.5
	1.5-2
	2-2.5
	$>$ 2.5
$m_{t\bar{t}}$	0.3-0.5
	0.5-0.75
	0.75-1
	1-1.25
	1.25-1.5
	1.5-2
	2-2.5
	2.5-3
	3-4
	$>$ 4





Search for a BSM resonance: Fit

2-Dim fit: the two dimensions are the invariant mass variable and the Δφ. The mass variable is split in bins and the Δφ distribution in each bin is evaluated; finally, I fit all distributions simultaneously.

The general likelihood function is written as a product of Poisson measurements in all considered bins plus a probability density function (G) for each of the nuisance parameters and it is defined as:

$$L(n, \theta_0|\mu, \theta) = \prod_{i \in bins} P(n_i|\mu, S_i(\theta) + B_i(\theta)) \cdot \prod_{j \in n.p.} G(\theta_j^0|\theta_j)$$

Such a likelihood is built with all the bins Δφ in all the mass regions.

A simultaneous binned max-likelihood fit for SRs is performed (MC for signal and background).
Templates → binned distributions of Δφ. Asimov dataset is used.

Search for a BSM resonance: Systematics uncertainties I

The systematics used in this analysis are only for the SM $t\bar{t}$ background → not the complete set.

Modelling uncertainties (MC):

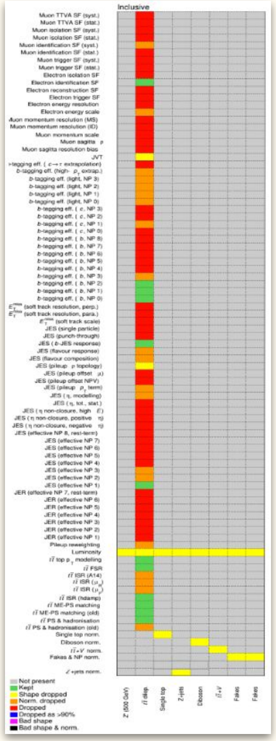
- Initial State Radiation;
- Final State Radiation;
- Parton Shower;
- Matrix Element

  ...

Instrumental uncertainties:

- Jet Energy Scale;
- Jet Energy Resolution;
- b-tagging;
- Luminosity

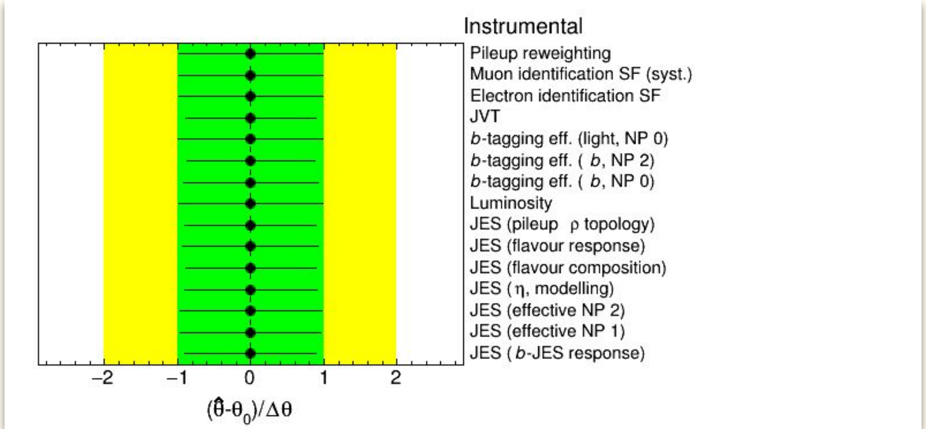
  ...

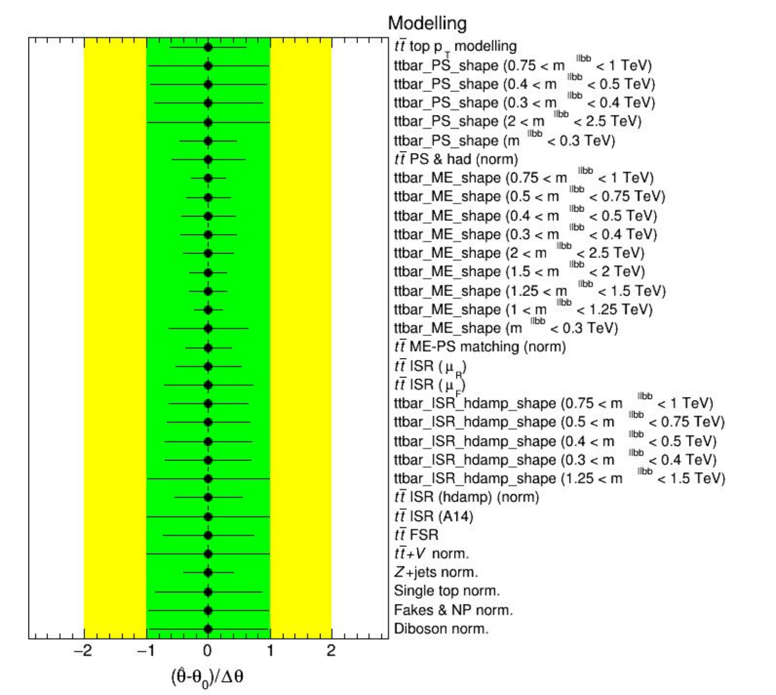


In order to minimise numerical instabilities of the fit procedure, a pruning of 0.5% is used.

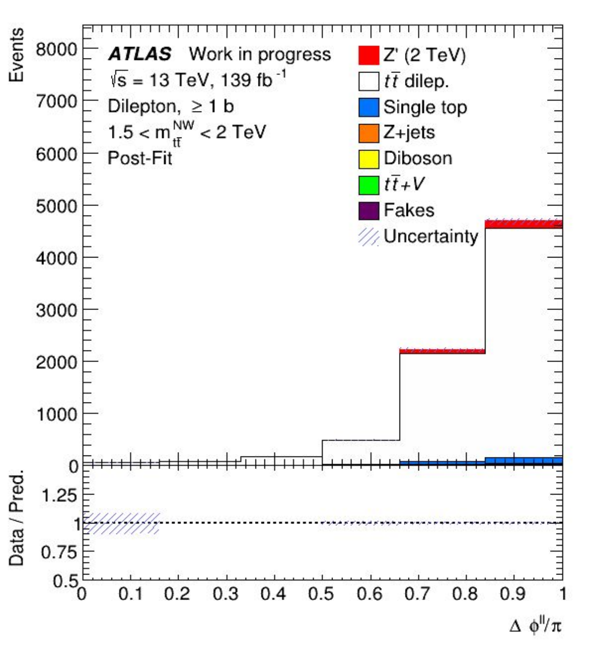
Some uncertainties show constraints. In order to relax → splitted the normalisation and shape components and then I de-correlated the shape component for each mass bin used in the fit. The normalisation of the $t\bar{t}$ background is left free floating in the fit.

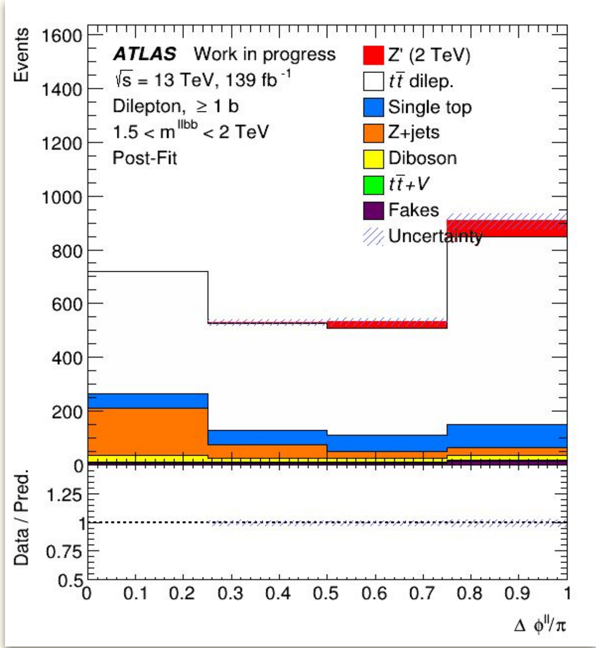
Search for a BSM resonance: Systematics uncertainties II





SRs after the fit

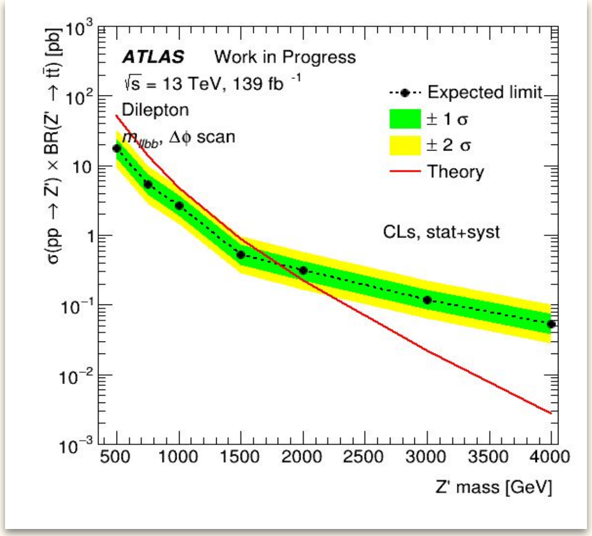


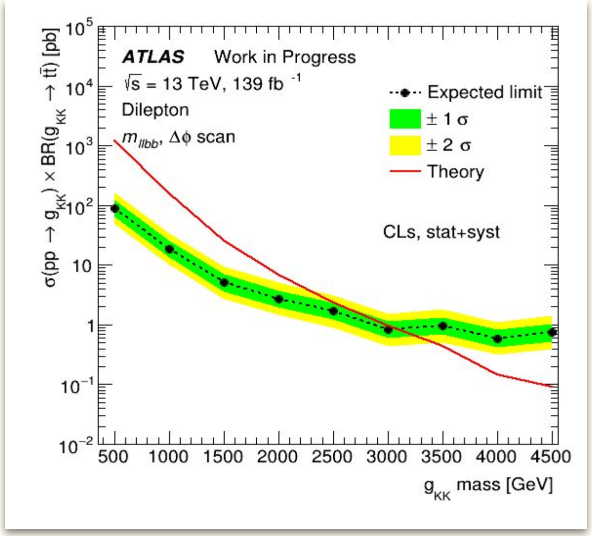


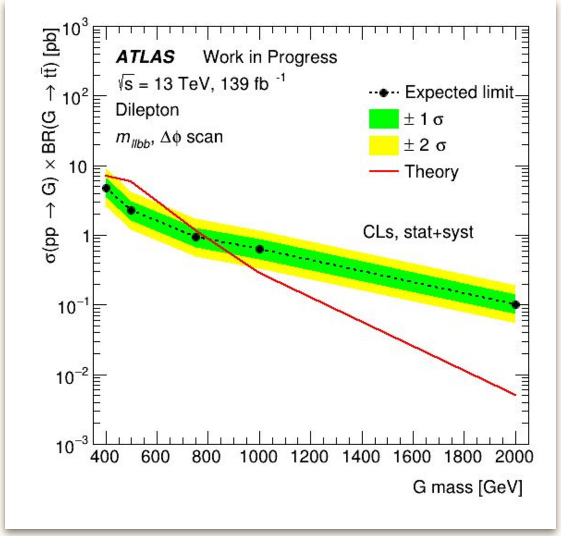
The post-fit plots show that the systematic constraints led a great reduction of the error bands in the SRs.

Search for a BSM resonance: Expected limits I

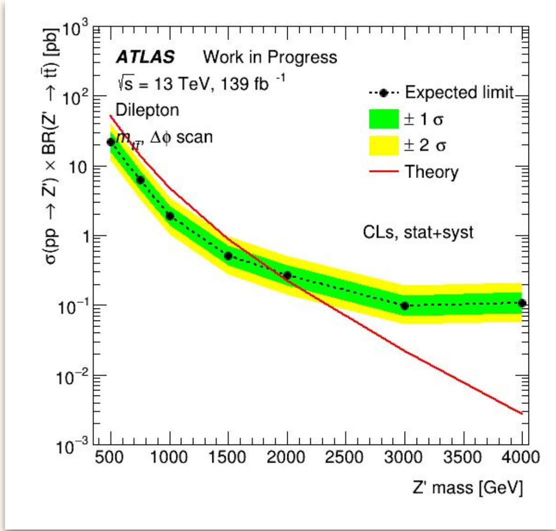
To improve the signal sensitivity, the three final states (ee, μμ and eμ) are combined together in each of the two mass variables ($m_{\ell\ell bb}$ and $m_{t\bar{t}}$(NW)) considered in this analysis.

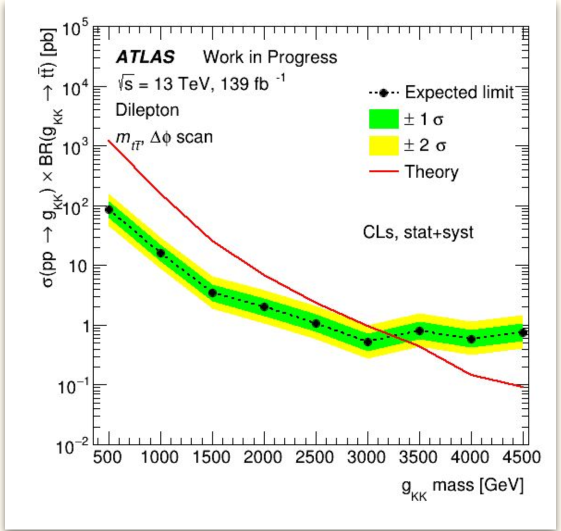


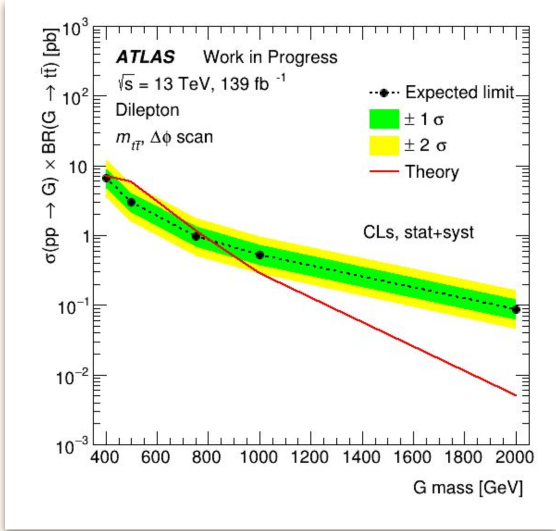




Search for a BSM resonance: Expected limits II







Search for a BSM resonance: Expected limits III

The expected limits are quit same for both the two mass variable.

Variable	Z' [TeV]	g_{KK} [TeV]	G [TeV]
$m_{\ell\ell bb}$	1.8	3.1	0.8
$m_{t\bar{t}}^{NW}$	1.85	3.25	0.8

These limits can be compared with the most recent analyses.

Analysis, CoM, Int. Lumi.	Z' [TeV]	g_{KK} [TeV]	G [TeV]
ATLAS $l + jets$, 13 TeV, 36.1 fb^{-1} [29]	2.6	3.2	0.65
ATLAS *Dilepton*, 7 TeV, 1.04 fb^{-1} [31]		0.84	
CMS $All - channels$, 13 TeV, 35.9 fb^{-1} [25]	(Γ/m 1%) 3.8 (Γ/m 10%) 5.25 (Γ/m 30%) 6.65	4.55	

Conclusions

- The eff. measured for muon close to jets are compatible to the default MCP eff. measured for isolated muons.
- Good setup for my analysis: no isolation working point and extension of the Overlap Removal procedure for electrons close to jets.
- The 95% C.L. expected limits on the cross section times branching ratio versus the mass of the signal samples are produced.

The analysis is still work in progress and it is still blinded, but in future I can compare the simulation with the real data collected from ATLAS. An improvement of the systematics and setup will increase the sensitivity. All of these studies will be describe in a public note.

Schools and outreach

In addition to the PhD studies, during these three years:

- Outreach events during 2016-2019 (“Notte dei ricercatori” and masterclasses);
- Schools:
  - XIX LNF Spring School “Bruno Touschek” (Frascati INFN);
  - ESHEP2019 (St. Petersburg).
- Proceedings and posters:
  - IFAE 2017 - XVI Incontri di Fisica delle Alte Energie, “Top quark mass measurement with soft muons from b-hadron decay”;
  - XIX LNF Spring School “Bruno Touschek” in Nuclear, Subnuclear and Astroparticle Physics, “Preliminary study for ttbar resonance search in dilepton channel and performance of muon reconstruction close to jets in ATLAS”;
  - 133 rd LHCC Conference, “Muon identification performance of the ATLAS experiment”;
  - EUROPEAN SCHOOL of HIGH ENERGY PHYSICS 2019 (ESHEP2019), “Beyond Standard Model top-antitop resonance in dilepton channel”.

Thanks!

Backup

- **Dark matter** and **Dark energy**: only 5% of the Universe composition is made of SM particles. The remaining part is composed of dark matter (~25%) and dark energy (~70%);
- **Neutrino masses**: in the SM the neutrinos do not have masses, but we know from experiments of neutrino oscillation ($\nu_e \rightarrow \nu_\mu$ or $\nu_\mu \rightarrow \nu_\tau$) that these particles have a mass, though very small;
- **Matter — antimatter asymmetry**: the universe is composed almost exclusively of matter, but it is reasonable to think that in its first moments of life, the quantity of matter and antimatter was the same.
- **Number of the parameters**: the Standard Model is based on 19 numerical parameters known from the experiments, but whose theoretical origins are still unknown.

Reconstruction efficiency for muons close to jets V

Region	$P(\chi^2)$
$p_T^{varcone30}/p_T(probe) > 0.06$	0.74
$E_T^{topocone20}/p_T(probe) > 0.06$	0.32
$0 < \Delta R < 0.2$	0.36
$0.2 < \Delta R < 0.4$	0.83

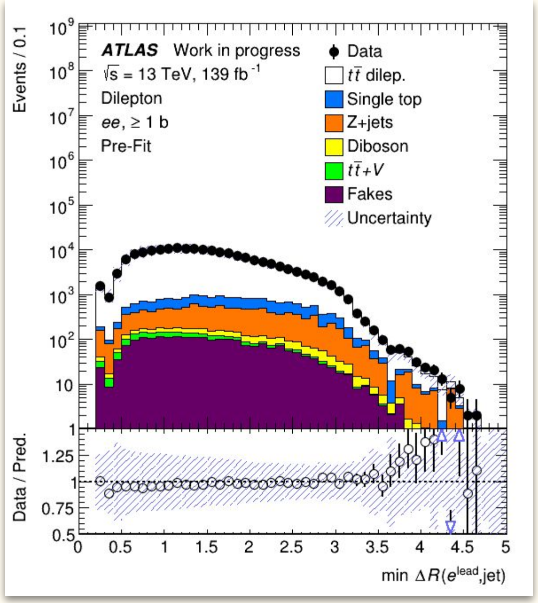
channel	ee $\geq$ 1 b [%]	eμ $\geq$ 1 b [%]	$\mu\mu$ $\geq$ 1 b [%]
$t\bar{t}$ dilep.	~39.4	~94	~37.2
Single top	~1.8	~4.2	~1.7
Z+jets	~56.5	~0.2	~59.3
Diboson	~1.4	~0.3	~1.4
$t\bar{t}+V$	~0.3	~0.2	~0.2
Fakes	~0.6	~0.8	~0.1

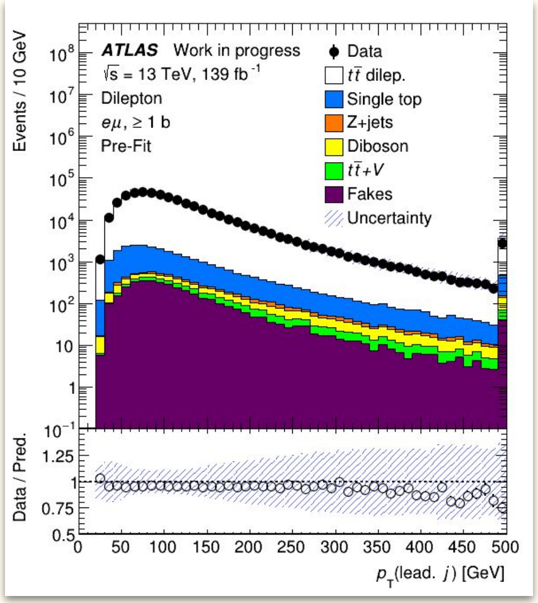
Search for a BSM resonance: Background estimation

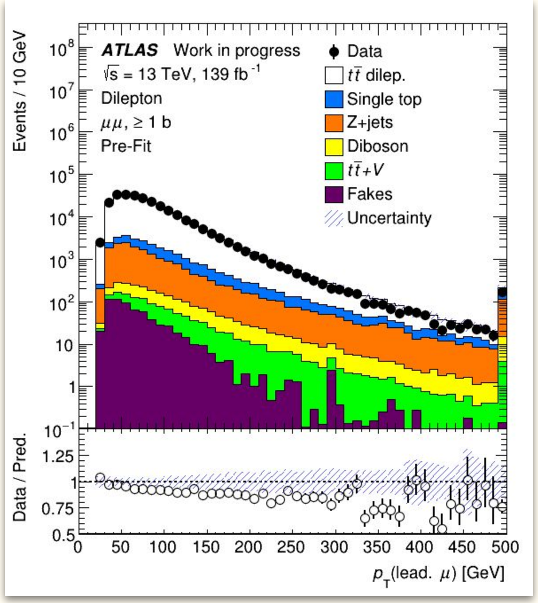
First study: agreement data/MC in the kinematics plots to assert the goodness of the predictions.
Main backgrounds:

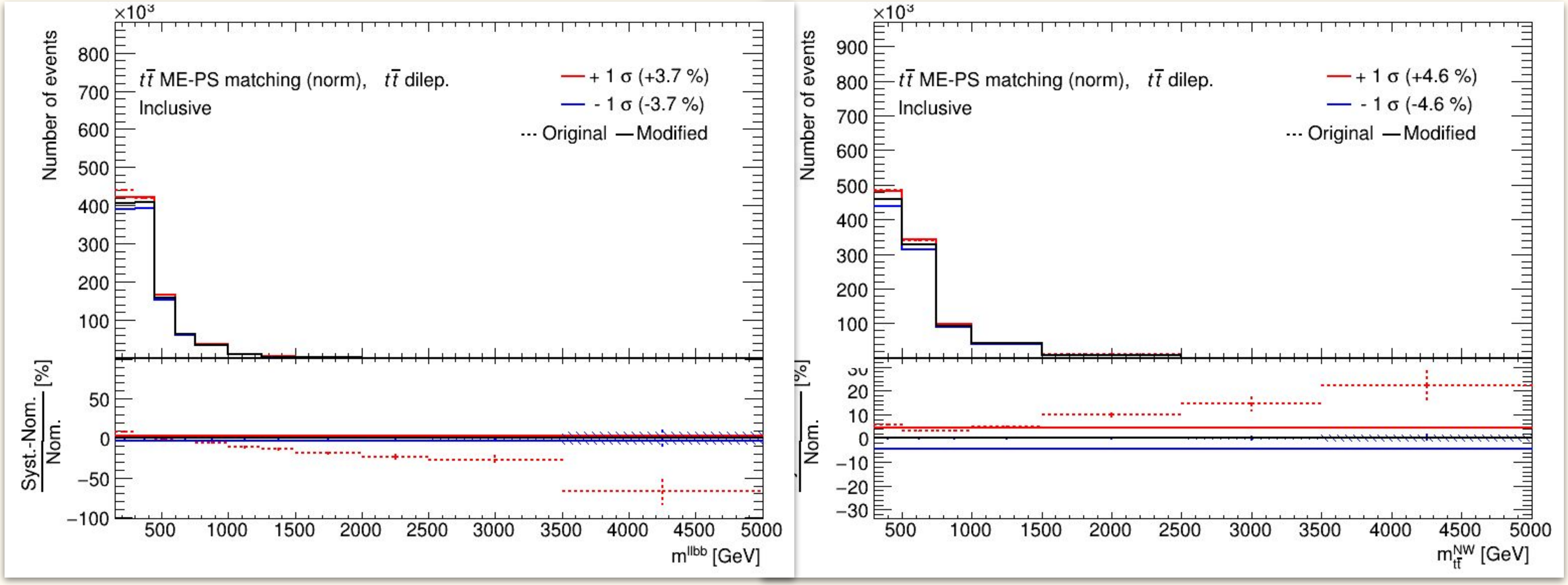
SM ttbar → irreducible bkg → top Pt reweight (NNLO in QCD, including NLO EW)

Z+Jets → reducible bkg → veto around Z boson mass ($80 < m\ell\ell < 100$ GeV) and MET > 45 GeV







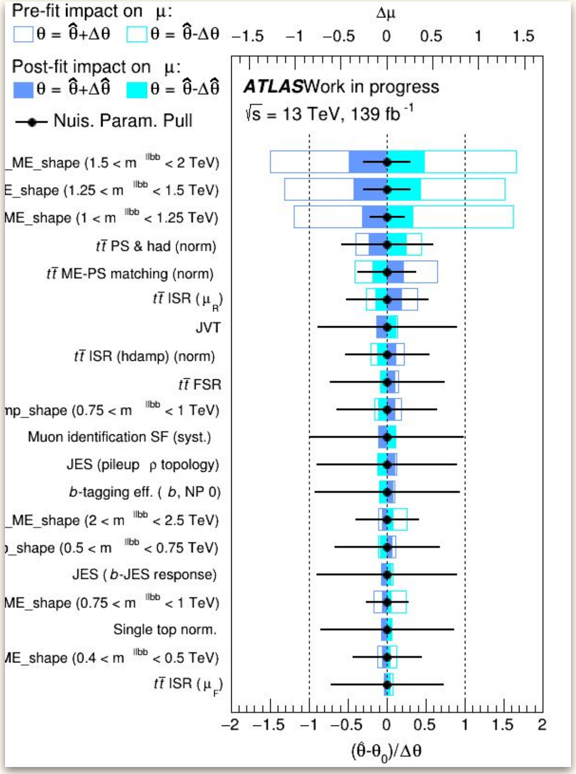


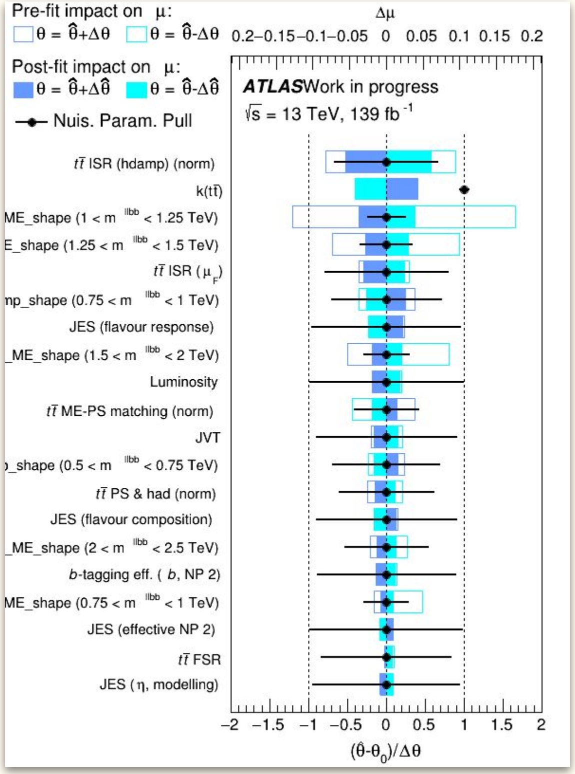
×10³
Number of events
$t\bar{t}$ ME-PS matching (norm), $t\bar{t}$ dilep.
Inclusive
+ 1 σ (+3.7 %)
- 1 σ (-3.7 %)
Original
Modified
Syst.-Nom. / Nom. [%]
m^llbb [GeV]
×10³
Number of events
$t\bar{t}$ ME-PS matching (norm), $t\bar{t}$ dilep.
Inclusive
+ 1 σ (+4.6 %)
- 1 σ (-4.6 %)
Original
Modified
$m_{t\bar{t}}^{NW}$ [GeV]

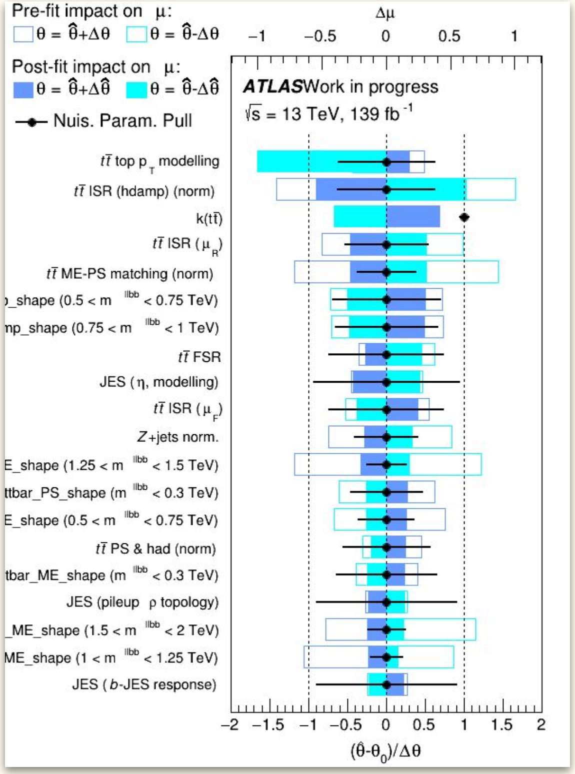
Z’ 2 TeV

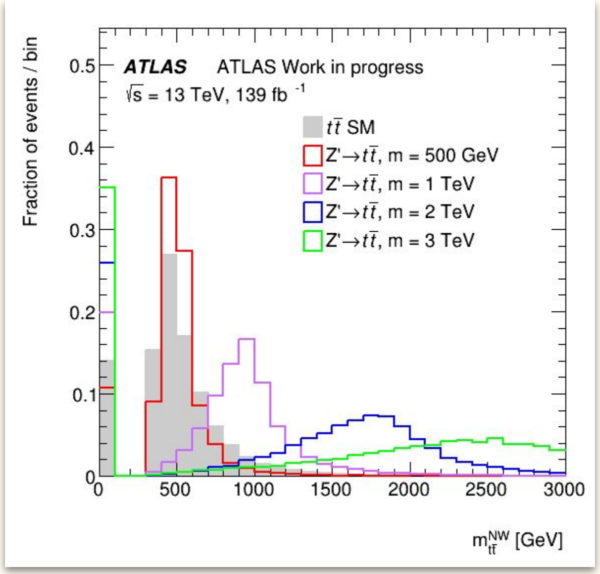
KK-g 1.5 TeV

G 1 TeV

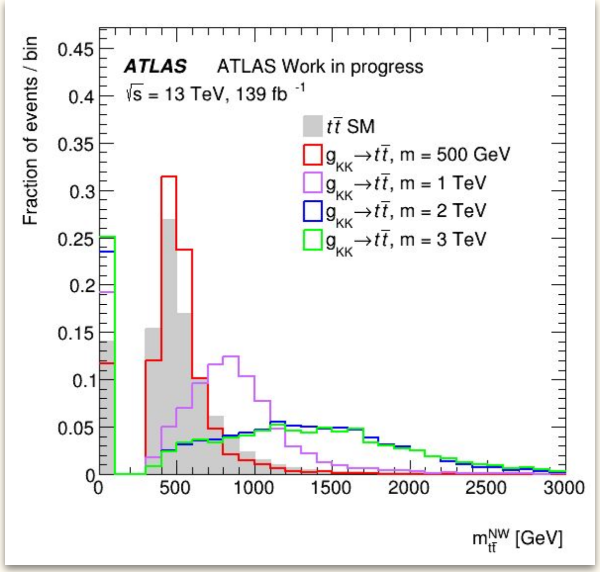




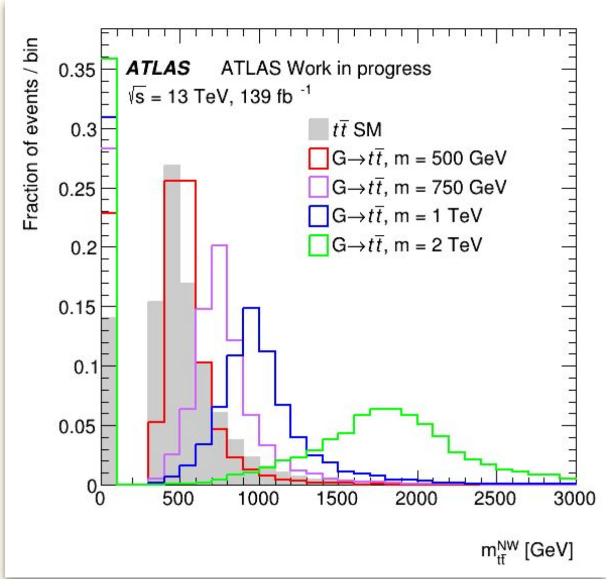




ATLAS ATLAS Work in progress
√s = 13 TeV, 139 fb -1
$t\bar{t}$ SM
Z'→$t\bar{t}$, m = 500 GeV
Z'→$t\bar{t}$, m = 1 TeV
Z'→$t\bar{t}$, m = 2 TeV
Z'→$t\bar{t}$, m = 3 TeV
Fraction of events / bin
$m_{t\bar{t}}^{NW}$ [GeV]



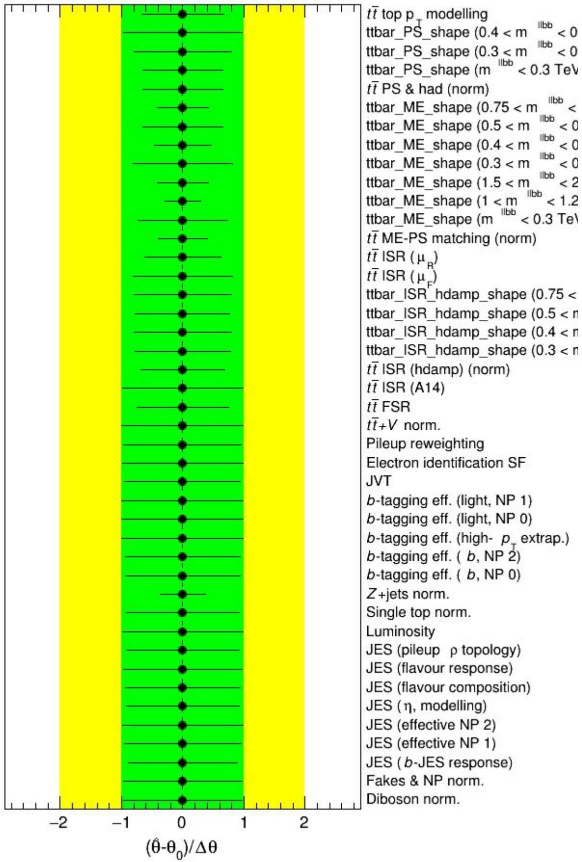
ATLAS ATLAS Work in progress
√s = 13 TeV, 139 fb -1
$t\bar{t}$ SM
g_{KK}→$t\bar{t}$, m = 500 GeV
g_{KK}→$t\bar{t}$, m = 1 TeV
g_{KK}→$t\bar{t}$, m = 2 TeV
g_{KK}→$t\bar{t}$, m = 3 TeV
Fraction of events / bin
$m_{t\bar{t}}^{NW}$ [GeV]



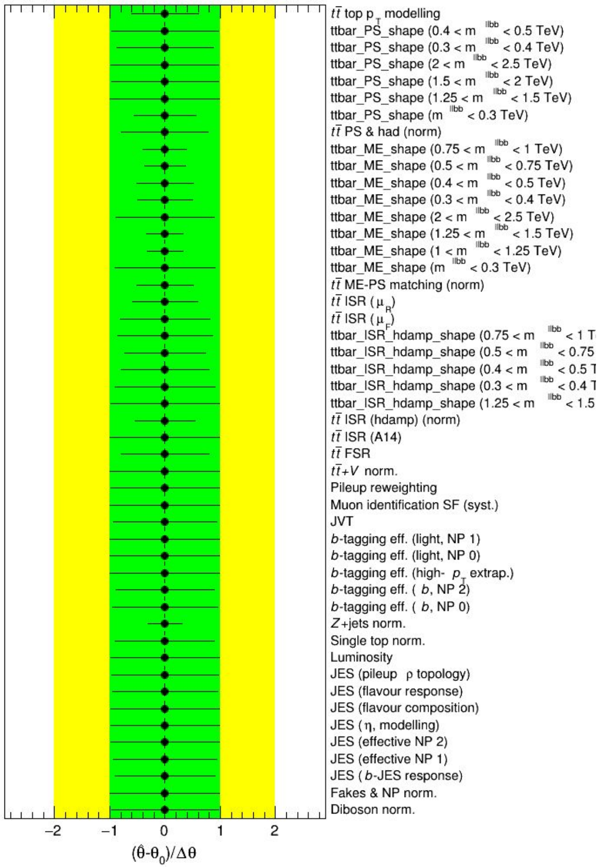
ATLAS ATLAS Work in progress
√s = 13 TeV, 139 fb -1
$t\bar{t}$ SM
G→$t\bar{t}$, m = 500 GeV
G→$t\bar{t}$, m = 750 GeV
G→$t\bar{t}$, m = 1 TeV
G→$t\bar{t}$, m = 2 TeV
Fraction of events / bin
$m_{t\bar{t}}^{NW}$ [GeV]

NP Z' 2 TeV

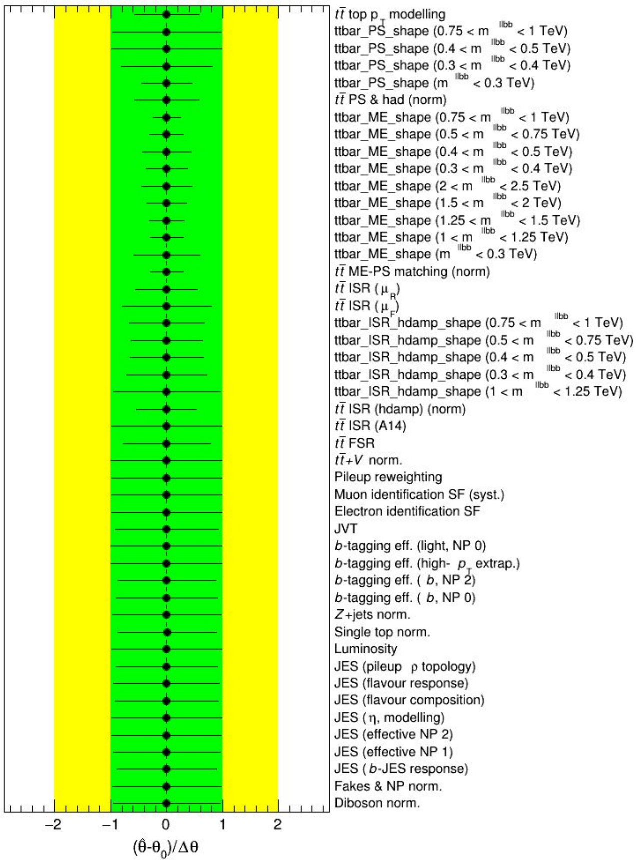
ee

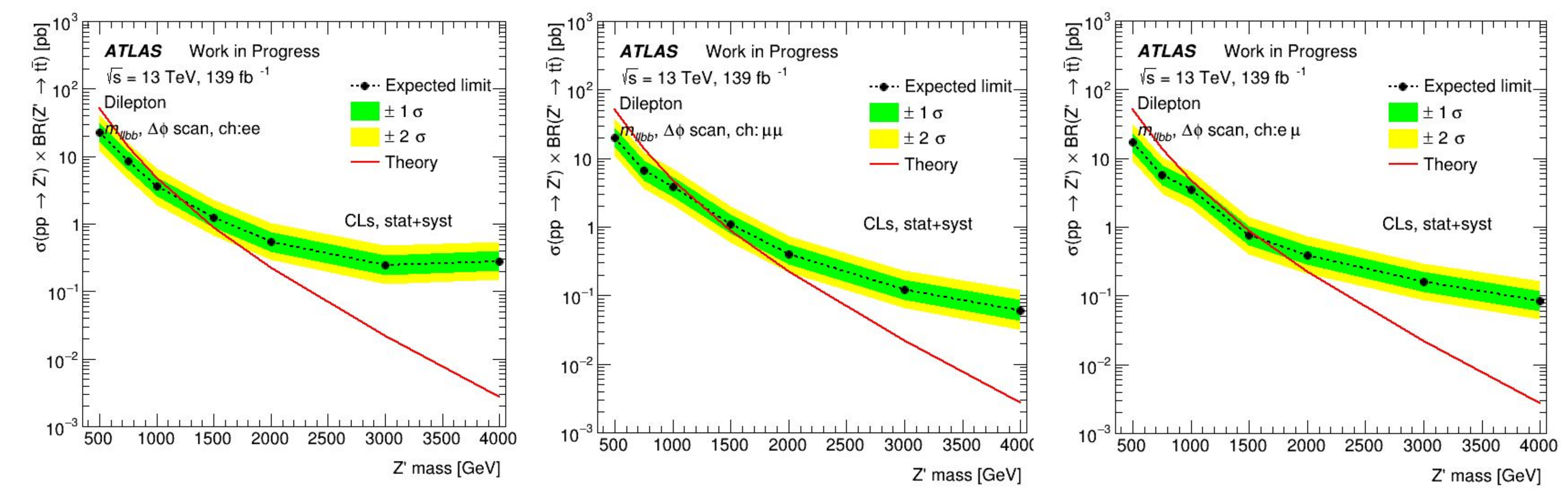


μμ



eμ





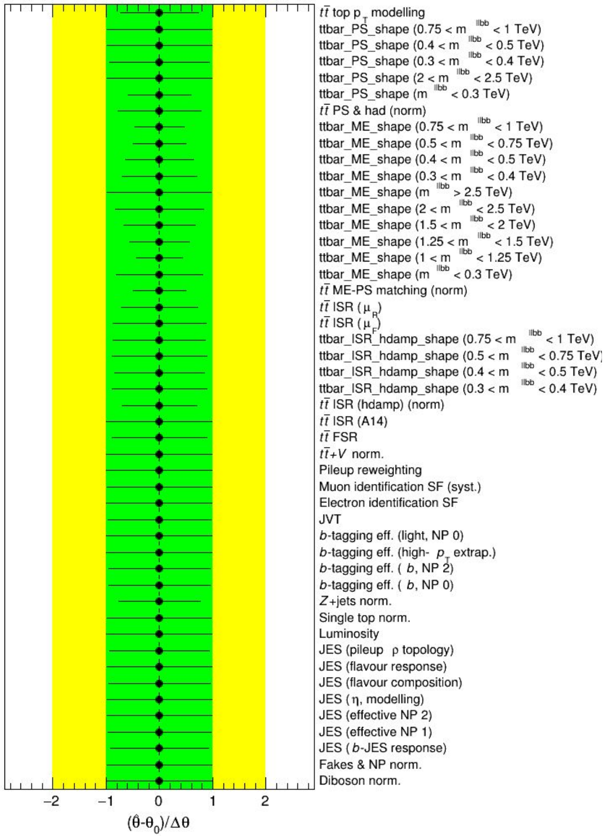
Splitting into the dilepton sub-channels it is possible to see that the eμ channel is more sensitive w.r.t. the other channels.

The fake component is present mainly in the ee channel.

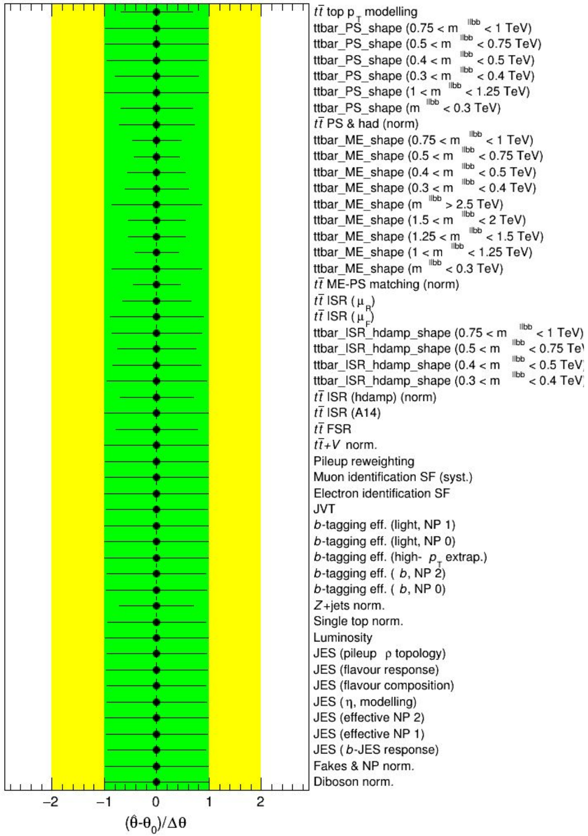
The constraints are a bit more relaxed w.r.t. the combined results in the thesis.

NP Z’ 2 TeV

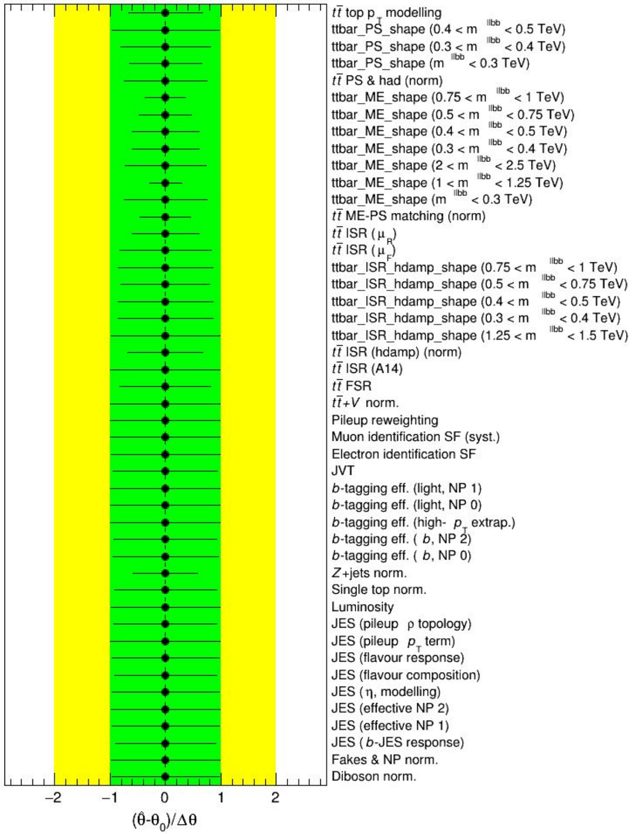
mc16a

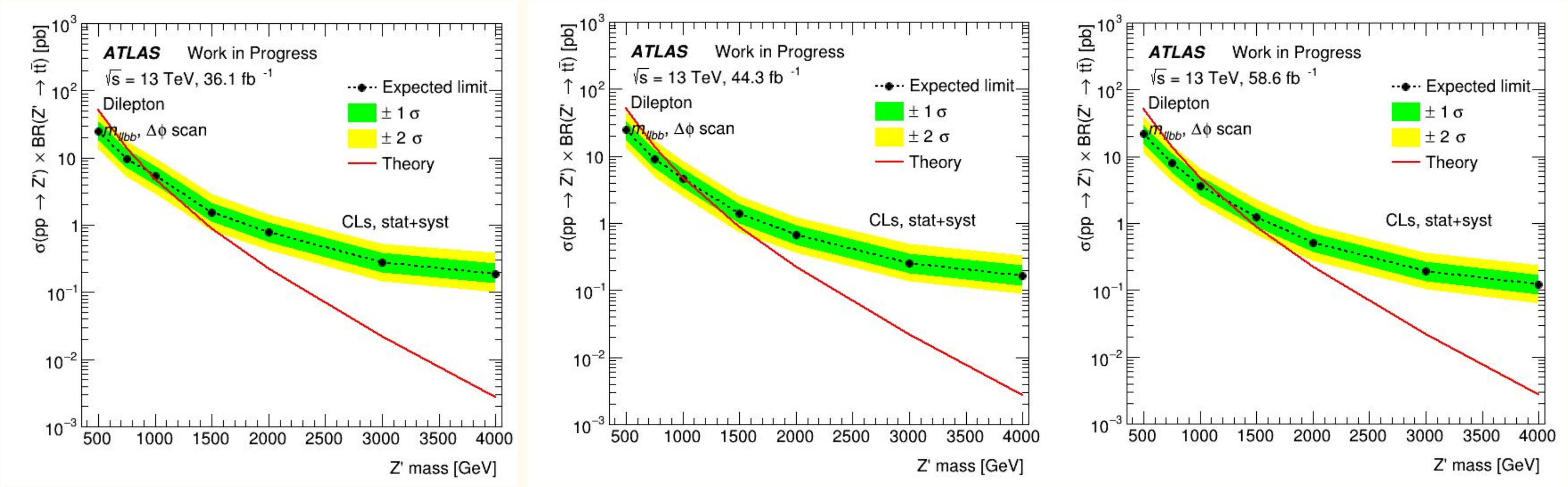


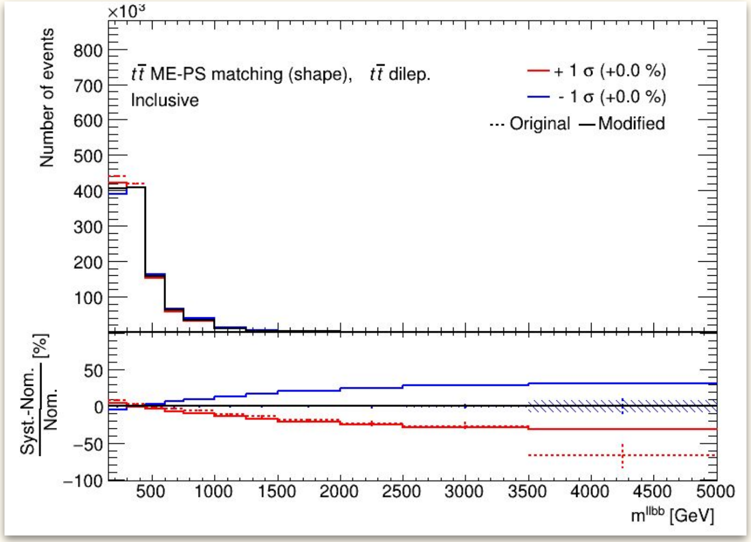
mc16d

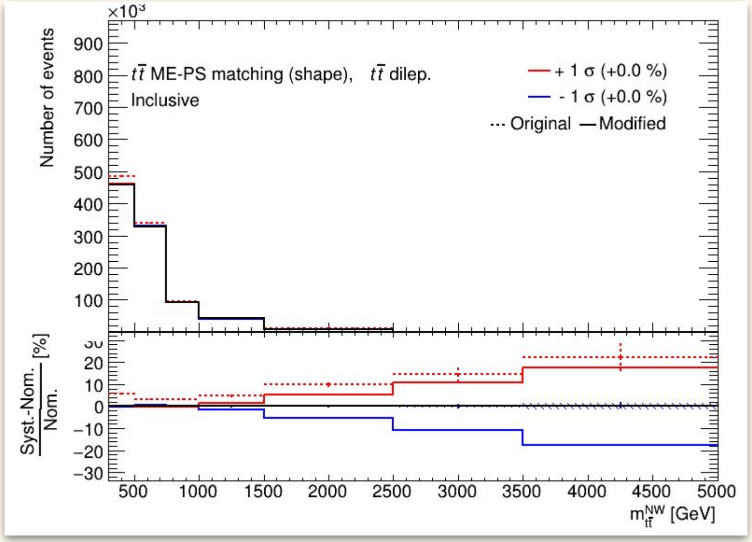


mc16e




ATLAS Work in Progress
√s = 13 TeV, 36.1 fb -1
Dilepton
m_llbb, Δφ scan
Expected limit
± 1 σ
± 2 σ
Theory
CLs, stat+syst
σ(pp → Z') × BR(Z' → tt̄) [pb]
Z' mass [GeV]
ATLAS Work in Progress
√s = 13 TeV, 44.3 fb -1
Dilepton
m_llbb, Δφ scan
Expected limit
± 1 σ
± 2 σ
Theory
CLs, stat+syst
σ(pp → Z') × BR(Z' → tt̄) [pb]
Z' mass [GeV]
ATLAS Work in Progress
√s = 13 TeV, 58.6 fb -1
Dilepton
m_llbb, Δφ scan
Expected limit
± 1 σ
± 2 σ
Theory
CLs, stat+syst
σ(pp → Z') × BR(Z' → tt̄) [pb]
Z' mass [GeV]





The black line is the shape of the nominal sample and in red (blue) is the $+1\%$ (—1%) of deviation standard from it, the dashed lines are before the symmetrization and smoothing and the continuous lines are after these.

The Standard Model: open questions

The SM of particle physics has been extremely successful in predicting and explaining particle physics phenomenology so far. Nonetheless, it presents several limitations and some of the phenomena not described by Standard Model are (relative to this analysis):

- **Gravity**: the SM does not explain the gravitational force, one of the four known fundamental interactions;

- **Hierarchy problem**: the SM introduces the particle mass through the BEH mechanism; but loop corrections to the Higgs mass would lead to values of its mass depending on the Planck scale → If no New Physics is found a fine tuning is needed to keep the Higgs mass close to the EW scale;

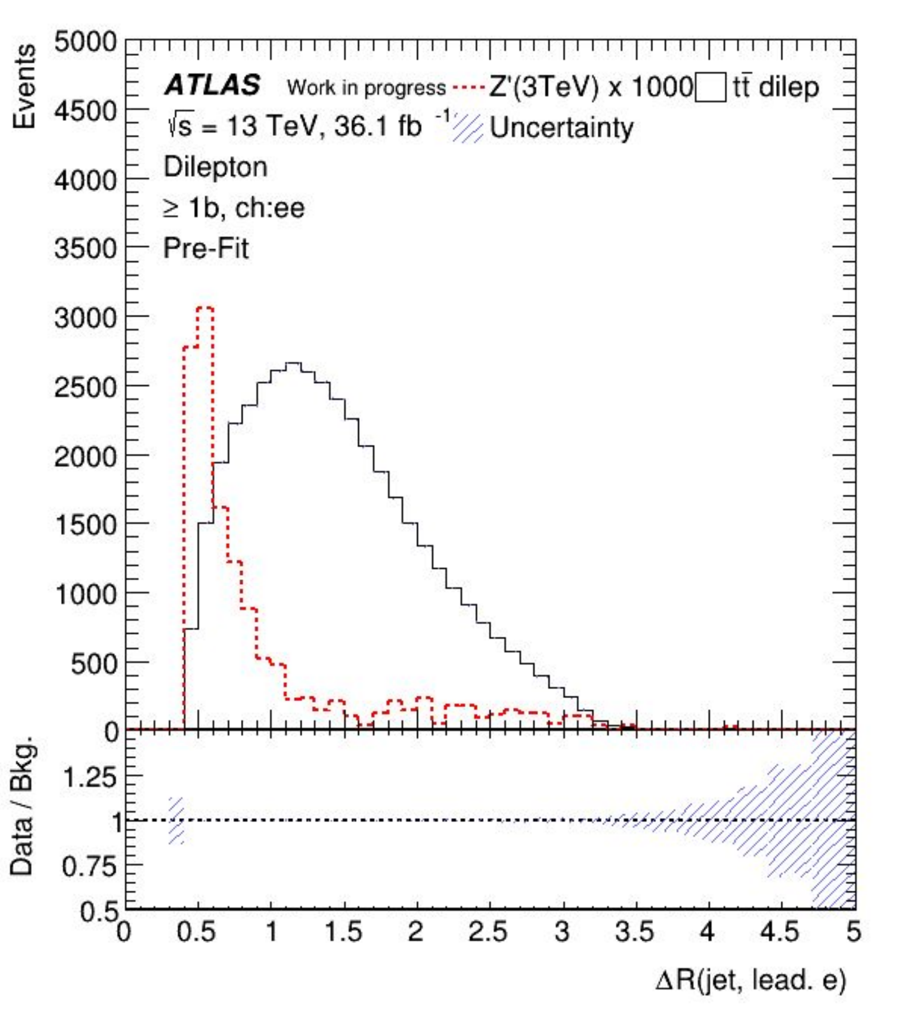
Working Point	Calo. Isolation	Track Isolation
Gradient	$\epsilon = 0.1143$ x p_T + 92.14%	$\epsilon = 0.1143$ x p_T + 92.14%
GradientLoose	$\epsilon = 0.057$ x p_T + 95.57%	$\epsilon = 0.057$ x p_T + 95.57%
FCHighPtCaloOnly	$E_T^{cone20} <$ max(0.015 x p_T,3.5GeV)	-
FCLoose	$E_T^{cone20}/p_T < 0.2$	$p_T^{varcone20}/p_T < 0.15$
FCTight	$E_T^{cone20}/p_T < 0.06$	$p_T^{varcone20}/p_T < 0.06$
FCTightTrackOnly	-	$p_T^{varcone20}/p_T < 0.06$

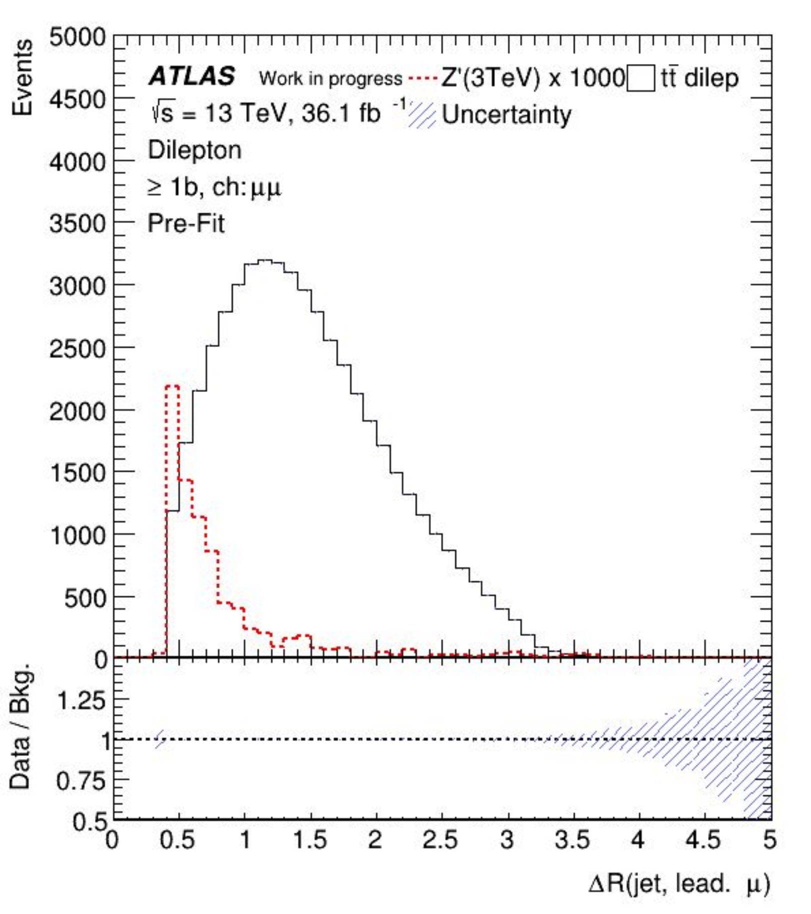
Tab shows definition of the main electron isolation working points (WP). These WPs depend on calorimeter isolation and/or track isolation variables.

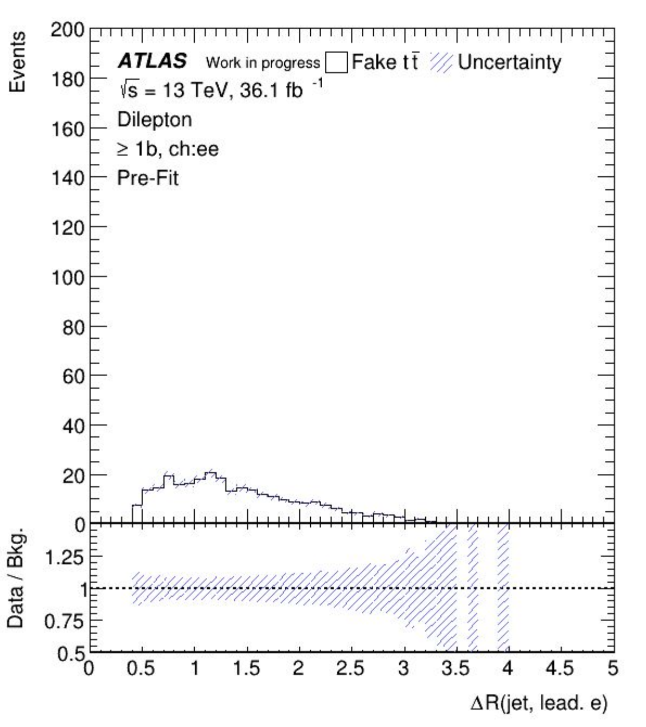
The Overlap Removal (OR) procedure II

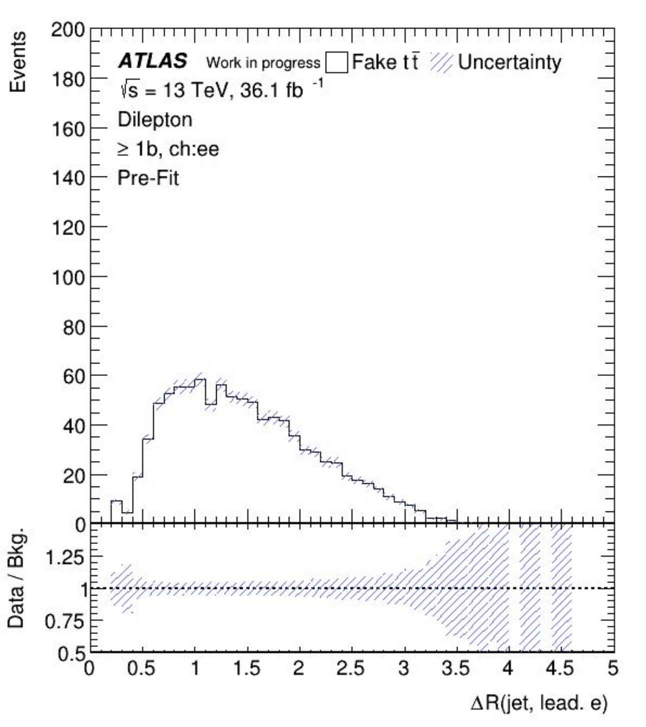
The standard configuration in the top pair measurements rejects electrons close to jets ($\Delta R_{(el,jet)} < 0.4$), but for this analysis I need a different requirement because in the high pT-region the electrons tend to be close to jets and I want to keep electrons information.

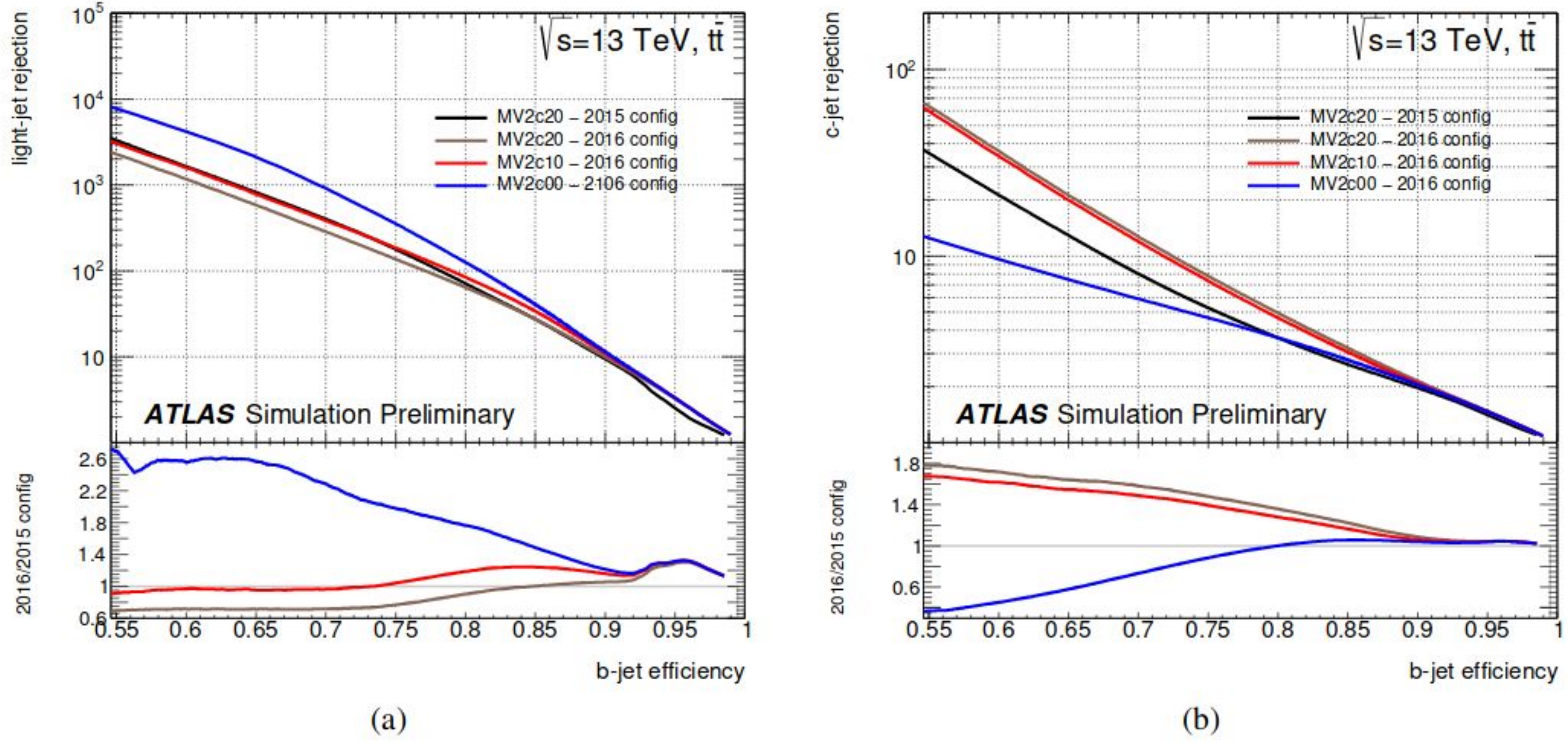
The overlap removal studies for electrons have been carried on specifically in the dilepton-channel analysis context, while in the case of muons the outcomes of previous studies performed for the lepton + jet channel analysis have been considered and applied.


ATLAS Work in progress
Z'(3TeV) x 1000
$t\bar{t}$ dilep
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
Uncertainty
Dilepton
≥ 1b, ch:ee
Pre-Fit
Events
Data / Bkg.
ΔR(jet, lead. e)


ATLAS Work in progress
Z'(3TeV) x 1000
$t\bar{t}$ dilep
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
Uncertainty
Dilepton
≥ 1b, ch:μμ
Pre-Fit
Events
Data / Bkg.
ΔR(jet, lead. μ)


Events
ATLAS Work in progress
Fake $t\bar{t}$
Uncertainty
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
Dilepton
≥ 1b, ch:ee
Pre-Fit
Data / Bkg.
ΔR(jet, lead. e)


Events
ATLAS Work in progress
Fake $t\bar{t}$
Uncertainty
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
Dilepton
≥ 1b, ch:ee
Pre-Fit
Data / Bkg.
ΔR(jet, lead. e)


light-jet rejection
√s=13 TeV, tt̄
MV2c20 – 2015 config
MV2c20 – 2016 config
MV2c10 – 2016 config
MV2c00 – 2106 config
ATLAS Simulation Preliminary
2016/2015 config
b-jet efficiency
(a)
c-jet rejection
√s=13 TeV, tt̄
MV2c20 – 2015 config
MV2c20 – 2016 config
MV2c10 – 2016 config
MV2c00 – 2016 config
ATLAS Simulation Preliminary
2016/2015 config
b-jet efficiency
(b)