Measurement of electron efficiency using $W \rightarrow e\nu$ decays. Study of the Higgs production in association with tt quarks

Ana Elena Dumitriu (CPPM, IFIN-HH)

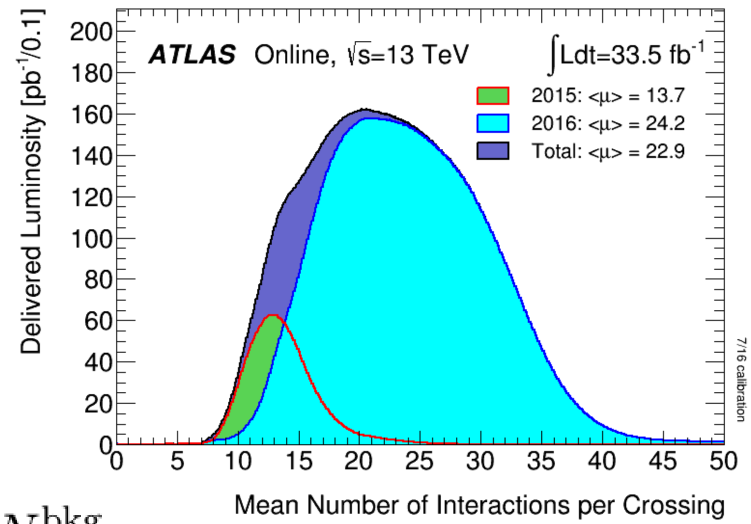
Few words about myself

- **2015-2018 co-PhD between CPPM and IFIN-HH, University of Bucharest/Aix Marseille University**
  - Electron efficiency measurements with the ATLAS detector using the Run 2 LHC proton-proton collision data at cme of 13 TeV
    - Tag and Probe method in $W \rightarrow e\nu$ decay channel
    - Efficiency measurement using isolation method, systematic studies
    - Trigger analysis → trigger emulation, proposal of new set of configuration for 2016/2017 data taking
  - Study of the Higgs production in association with tt quarks
    - Study of top Yukawa coupling and properties of Higgs boson

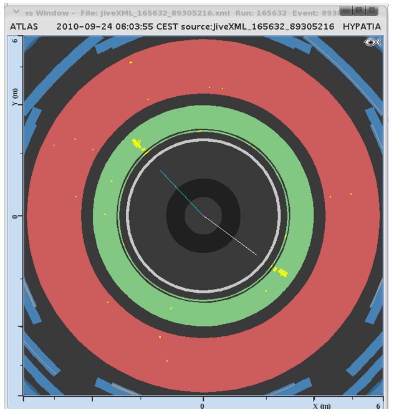
Outline of the presentation:

- ATLAS experiment and detector
- Introduction to electron efficiency studies
- Introduction to Tag and Probe Method
- Tag and Probe Method applied on $W \rightarrow e\nu$ decay
- Introduction to ttH analysis
- Conclusions

Introduction to efficiency studies



The production cross-section times branching-ratio



$$\sigma_{W/Z} \times BR(W/Z \to e\nu/ee) = \frac{N^{\text{data}} - N^{\text{bkg}}}{A_{W/Z} \cdot C_{W/Z} \cdot L_{\text{int}}}$$

the correction factors to account for the efficiency of the event being reconstructed in the detector

correction factors to account for the geometrical and kinematic acceptance of the detector

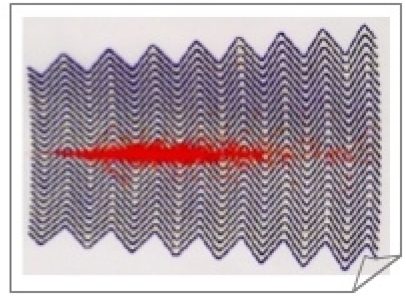
$$C_W = \varepsilon_{\text{event}} \cdot \alpha_{\text{reco}} \cdot \varepsilon_{\text{ID}} \cdot \varepsilon_{\text{trig}} \cdot \varepsilon_{\text{iso}}$$

- ε_{event} : efficiency of the signal events passing the event preselection cuts
- α_{reco} accounts for the differences between applying the geometrical and kinematic selection at generator or reconstruction level, i.e. the reconstruction efficiency;
- ε_{ID} : efficiency of an e/ν passing the identification criteria
- ε_{trig} is the efficiency of an event being triggered;
- ε_{iso} is the efficiency of possible isolation cuts.

Precise knowledge of the electron identification efficiency is an essential ingredient for many physics analysis

Electron identification

- Starts in the high granularity Lar sampling EM calorimeter



Shower Shape Variables

$\mathbf{R_{had}}$ → E_T (hadronic cal)/E_T (EM cal)
$\mathbf{R_\eta}$ → Ratio In η of cell energies in 3x7 vs 7x7 cels
$\mathbf{R_\Phi}$ → Ratio In Φ of cell energies in 3X3/7X7
$\mathbf{W_{stos}}$ → Total shower width.
TQ (Track quality): Number of hits in the pixel detector ≥ 1+ Nb of hits in the pixels and SCT ≥ 7

- Loose : uses EM shower shape information and discriminant variables from hadronic calorimeters
- Medium: full info from EM + some from inner tracking detector (ID) (track quality variables + cluster-track matching variables)
- Tight: full electron identification:

Showe shapes

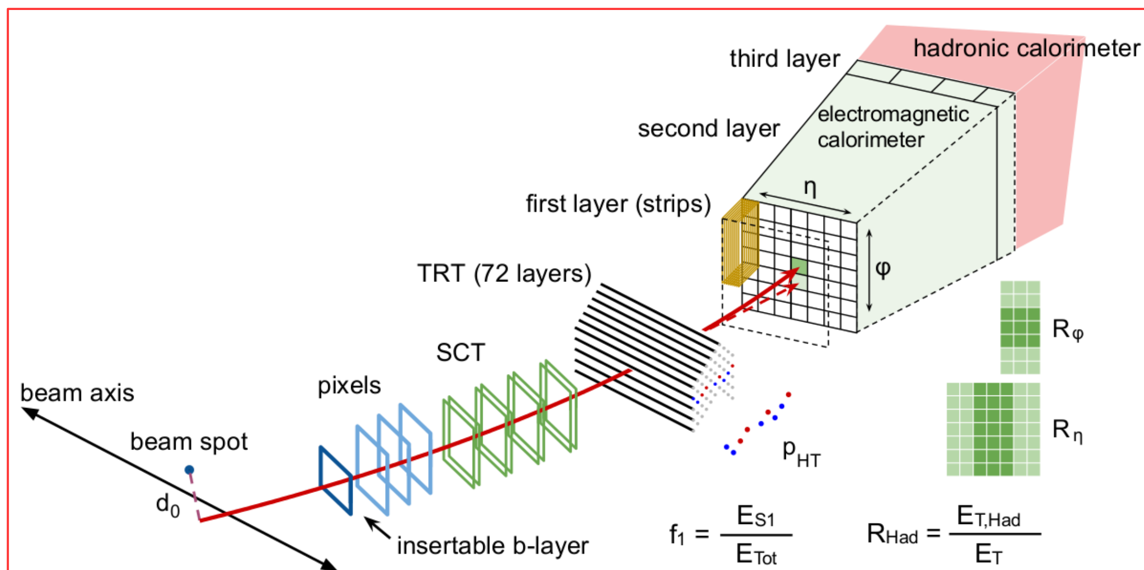
Ratio of energy deposited in the hadronic to EM cal

Inner-detector track quality

Track-to-showe matching

Ratio of calorimeter energy measurement to track momentum

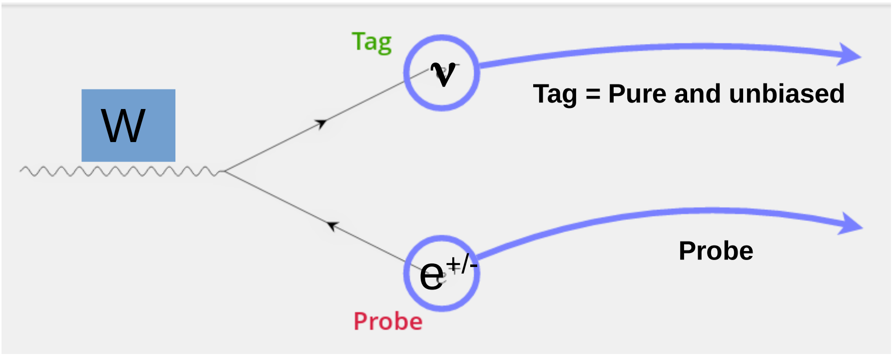
Transition radiation in the straw tube tracker



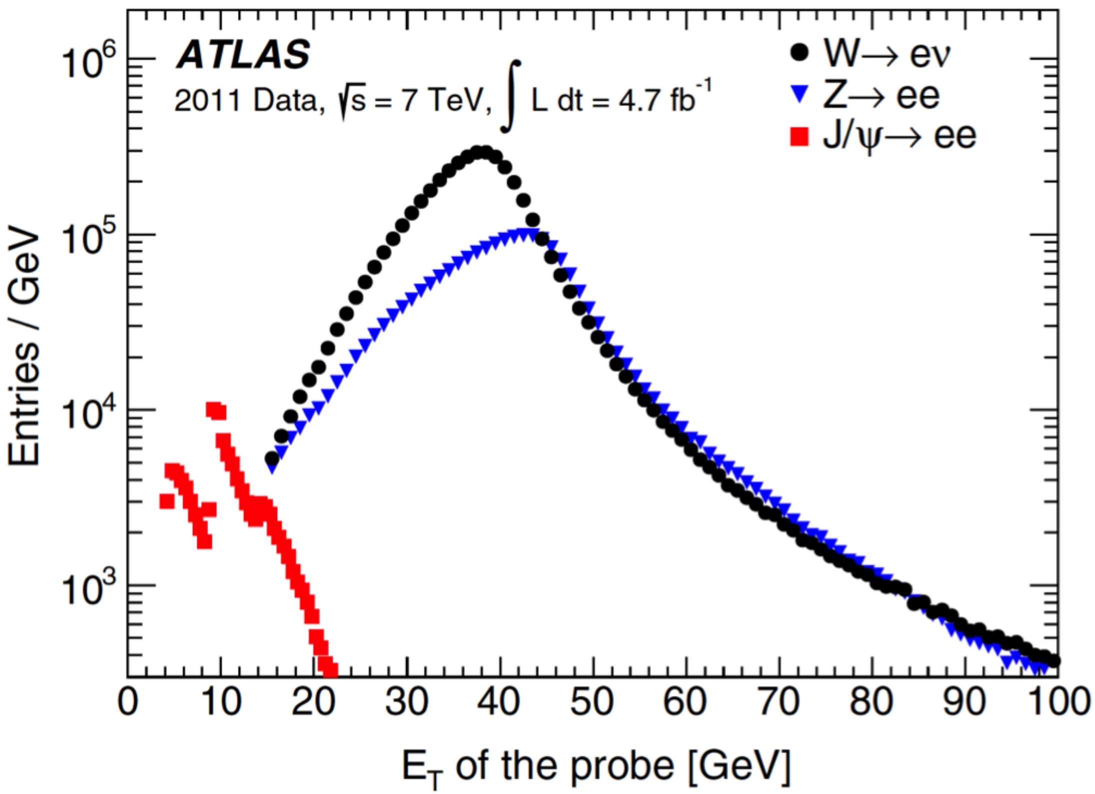
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ElectronGammaPublicCollisionResults

The Tag & Probe Method

- The **tag** object: strict requirements to enhance the purity of the sample
- The other particle serves as a **probe** for the measurement.



- The efficiency: $\frac{N\ selected}{N\ probe}$

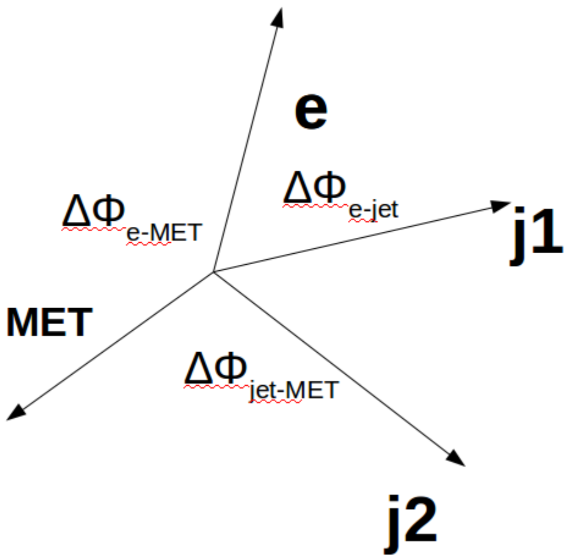


Numerous advantages in using W events:

- The measurements with W and Z bosons cover both a large kinematic range;
- The J/ψ channel completes the measurement at low pT.
- W provides additional statistics for the low Et range (15-25 GeV) and offers interesting experimental signatures due to its large statistics
- Different systematics from Z

W → eν analysis

W events topology



Selection

- Triggers WTP (prescaled)
- MET > 25 (TST)
- $|\eta| < 2.47$
- $m_T > 40$ GeV

Probe

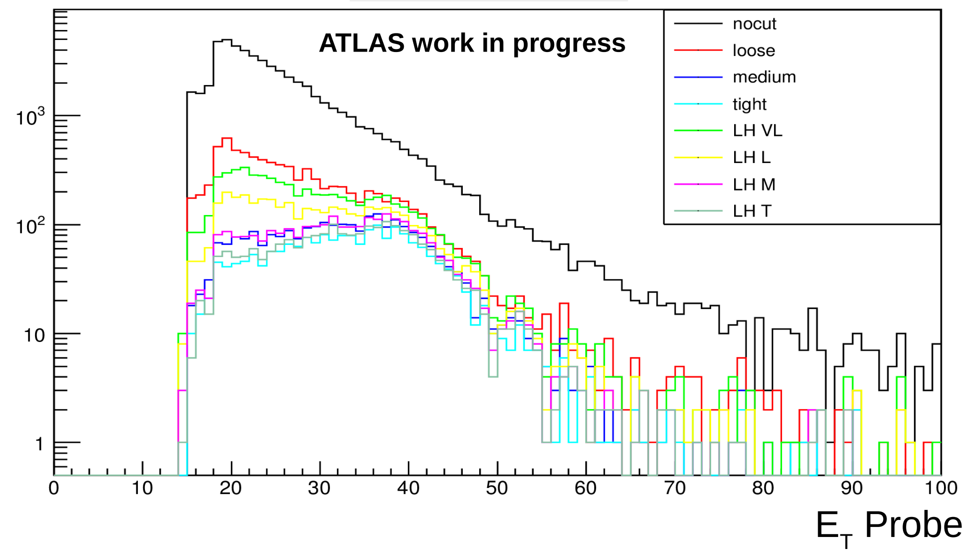
- rHad and TQ + $w_{stos} < 4$, $R_\eta > 0.7$, $R_\Phi > 0.7$
- $p_T > 15$ GeV

- In oder to reduce the background, we test the angular distribution in the transverse plane
- Jets with p_T>15,10,5 GeV tested
  - Only first 2 leading jets are used && ΔR (e-jet)>0.2

$$\Delta R = \sqrt{\Delta\phi^2(\text{jet} - \text{electron}) + \Delta\eta^2(\text{jet} - \text{electron})}.$$

All details in backup about the cleaning procedure by using the W topology

E_T vs e^- menu



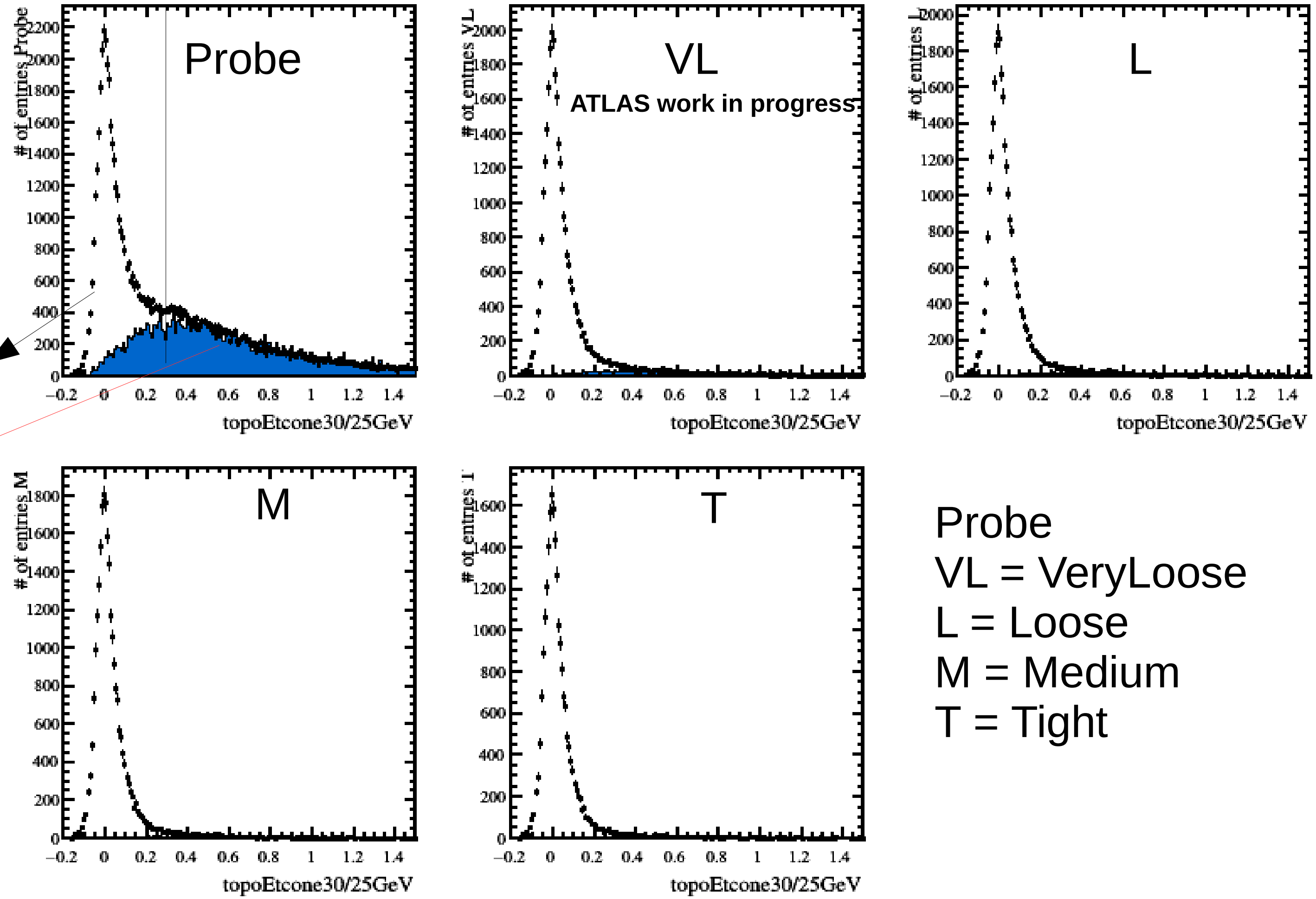
The large suppression by the tight ID algorithm indicate large backgrounds at low PT

Efficiency measurement method

Example for HLT_xe70 Cone30,20<E_T<25 GeV

signal

background

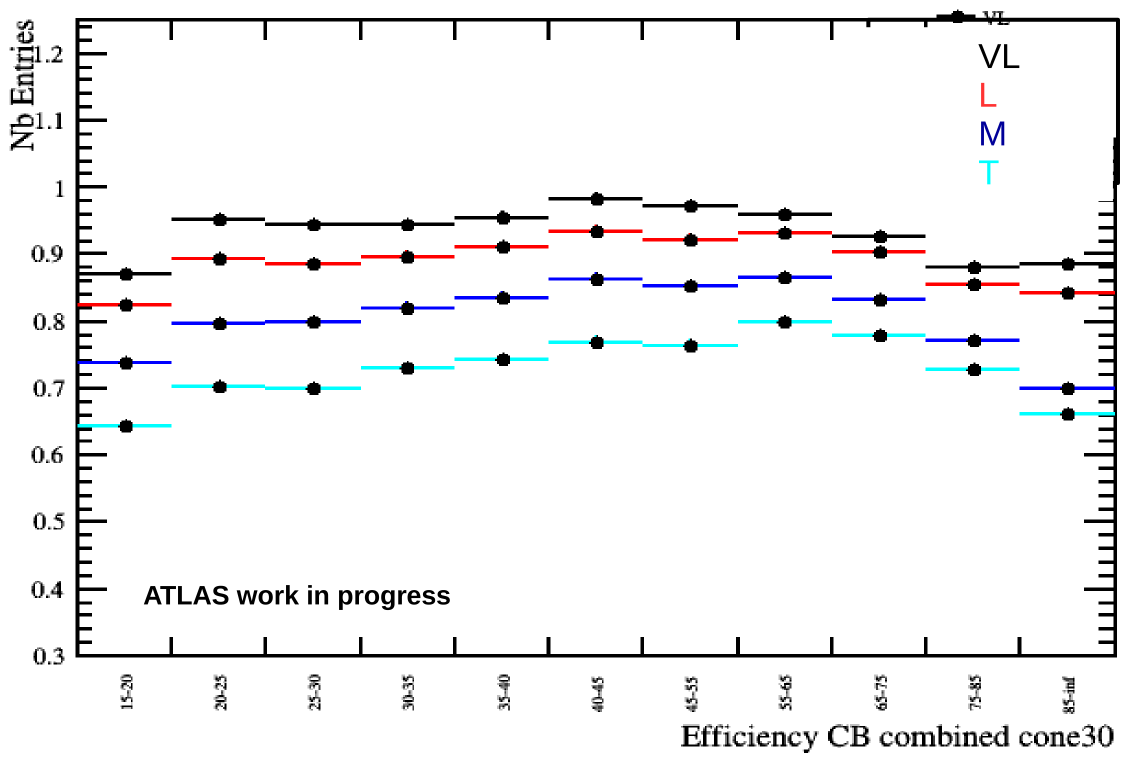


Probe
VL = VeryLoose
L = Loose
M = Medium
T = Tight

Efficiency for each identification algorithm extracted from the ratio of signal electrons

$\varepsilon_{Level}=N_{Level}/N_{probe}$ (Level=VL,L,M,T)

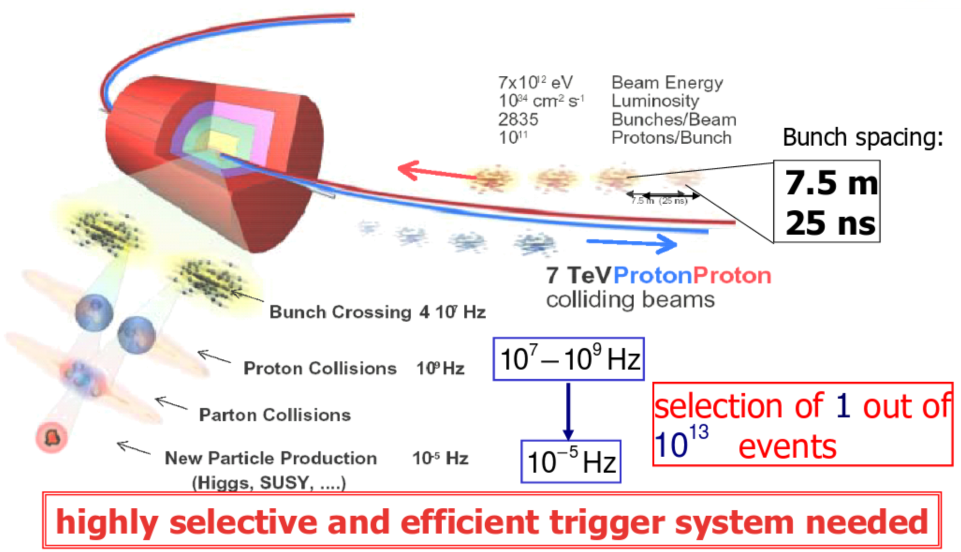
Efficiency results example



VL = VeryLoose
L = Loose
M = Medium
T = Tight

- **Systematics of the efficiency measurements to be studied (various bckg template, triggers, subtraction methods, cone size, trigger matching effect, topology dependency etc.)**
- **New trigger proposed for 2016 will collect much more statistics with better background conditions**

The ATLAS Trigger System



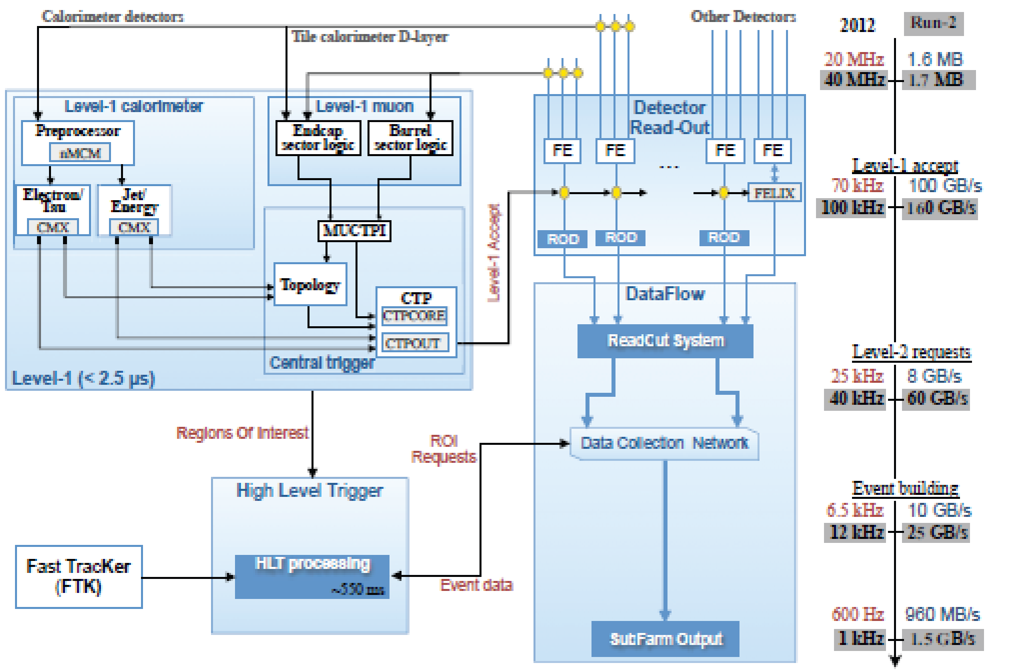


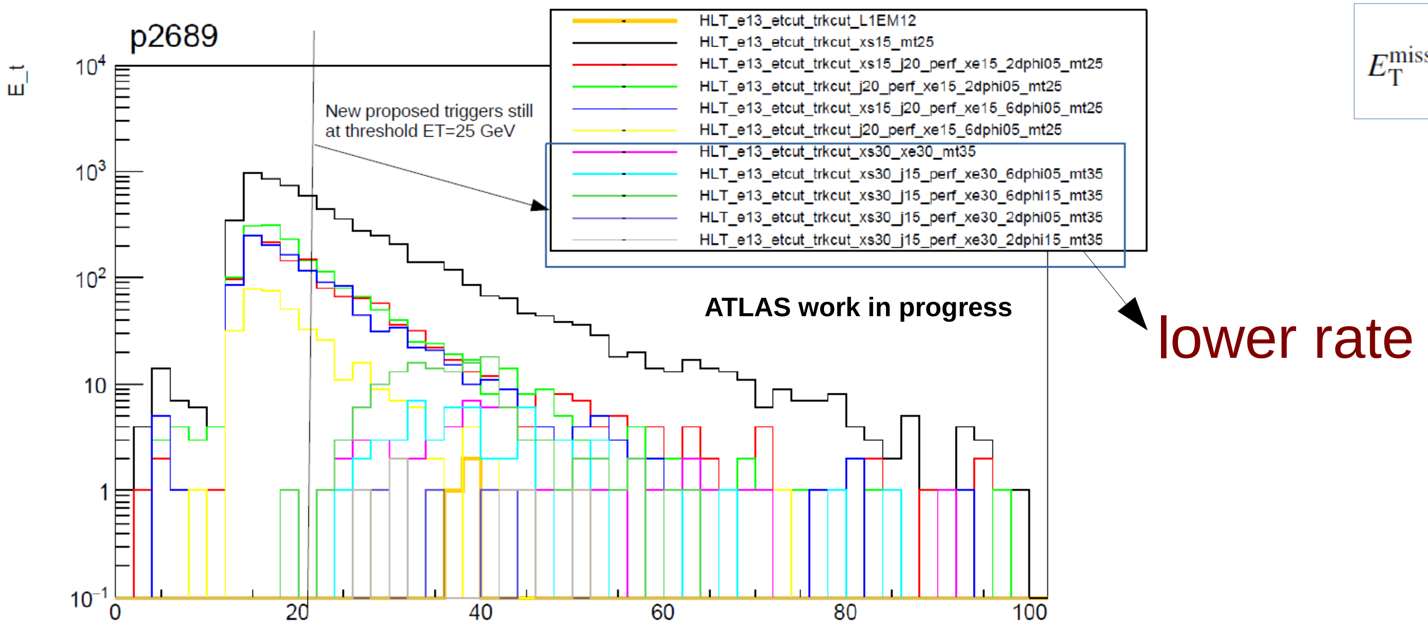
Figure 1. Schematic overview of the Run-2 configuration of the Trigger and DAQ system.

http://atlasexperiment.org/trigger.html

- The trigger system consists of:
  - hardware Level-1 (L1) : L1 calorimeter trigger system (L1Calo), the L1 muon trigger system (L1Muon), new L1 topological trigger modules (L1Topo) and the Central Trigger Processors (CTP)
  - a single software-based high-level trigger (HLT): fast algorithms accessing data from an RoI (Region of Interest), or offline-like algorithms using the full-event information
- This new two-stage system will reduce the event rate from the bunch-crossing rate of 40 MHz to 100 kHz at L1 and to an average recording rate of 1 kHz at the HLT

Trigger tunning in Run II

- ATLAS trigger organized in Level1 + HighLevelTrigger (HLT)
  - Use topological variables to reduce the background, use track requirements (trkcut) , use MET (xe) and MET significance (xs)

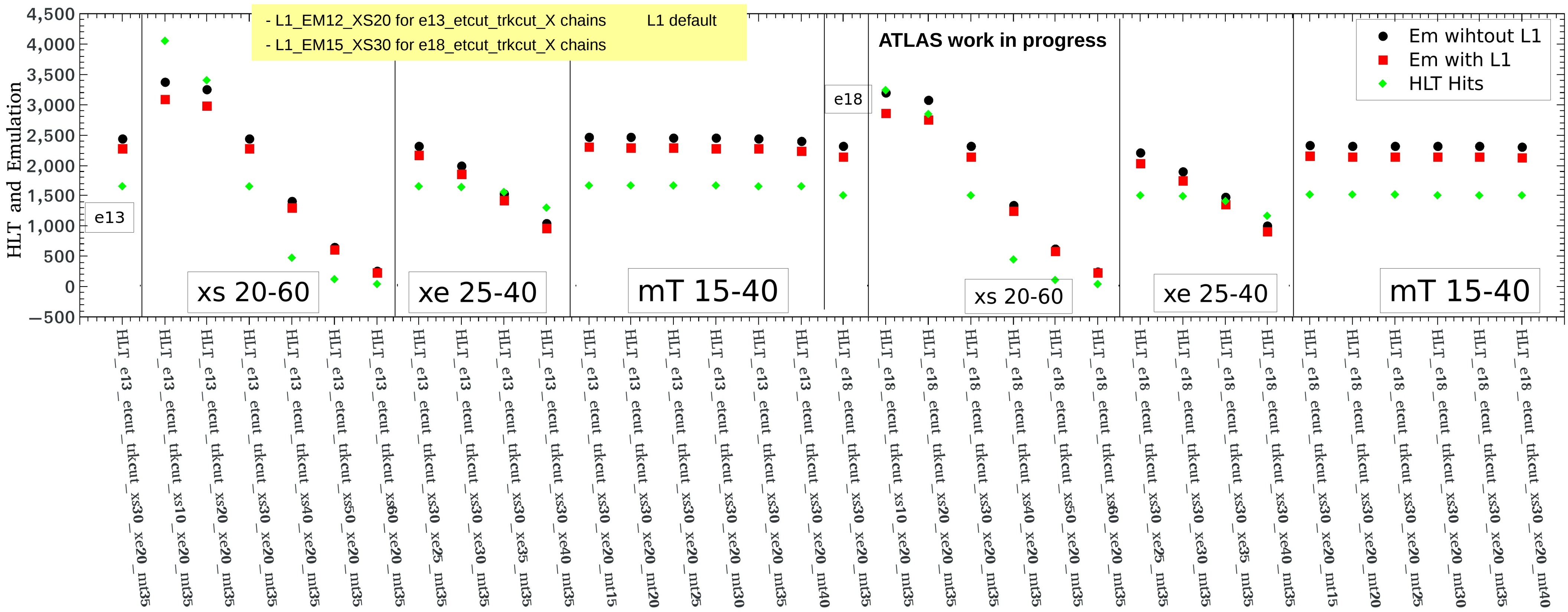


$$E_{\mathrm{T}}^{\mathrm{miss}}\,\mathrm{significance} = xs = \frac{E_{\mathrm{T}}^{\mathrm{miss}}}{0.5 \times \sqrt{\sum E_T}}$$

- Topological variables tuned to reduce trigger rates: tuning at HLT and L1. Recently, algorithms implemented in a new system L1TOPO.

Trigger menu tuning in offline and online emulation

- **Trigger rates reproduced in emulation: rates can be reduced with modest cost in efficiency**

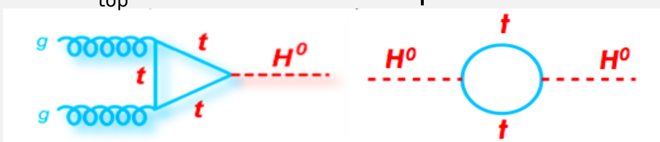


- Similar efficiency in HLT compared to Emulation with L1 topo.
  - **New trigger proposal includes xs,xe,m_T cuts + topological cuts for different E_T threshold**

Motivation for studying top quarks

Heaviest fundamental particle in the Standard Model

Larger mass → Larger coupling to SM Higgs
+ m_{top} is a fundamental parameter in SM



Allows for Self-Consistency Checks of SM Post Higgs Discovery

Processes including top are backgrounds for new physics

e.g. $H \to b\bar{b}$

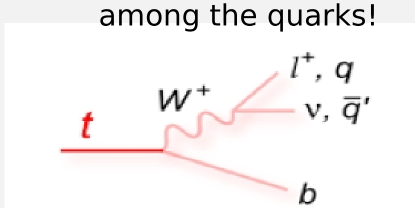
$H \to WW$

+ *Exotics and SUSY*

Good Understanding → Improvements in Searches

Short Lifetime(~10^{-25} s)

Reconstruction before hadronization – Unique among the quarks!



Access to Polarization and Spin Correlations

Hints of new BSM/physics?

Exotic Particles Could Decay Preferentially to Top Quarks

The top quark may serve as a window to New Physics related to the electroweak symmetry breaking:

Yukawa coupling ~ 1

$$M_t = \frac{1}{\sqrt{2}} \lambda_t v$$

$$\Rightarrow \lambda_t = \frac{M_t}{173.9\ \mathrm{GeV}/c^2}$$

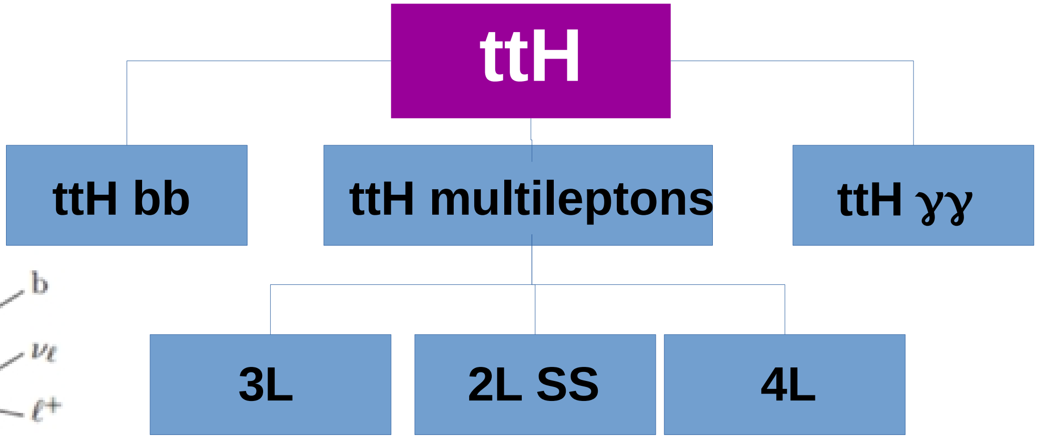
ttH channel:

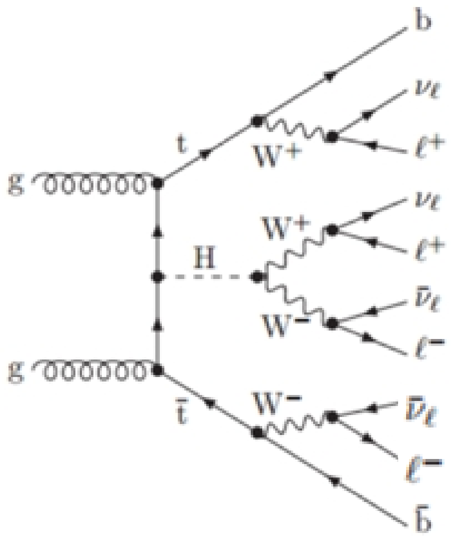
1% of Higgs production

Direct measurement of Yukawa coupling!

Introduction to 4l channel

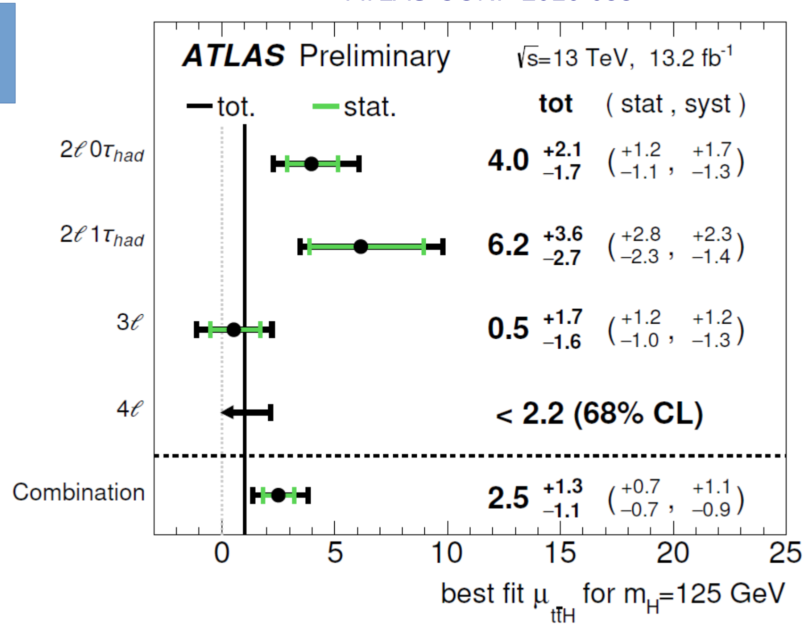
- My analysis is based on a 4l final state → ttH to 4L affected by a small branching ratio, but benefit from low background





L = 13.2 fb^{-1}
Now full stat in our hands !

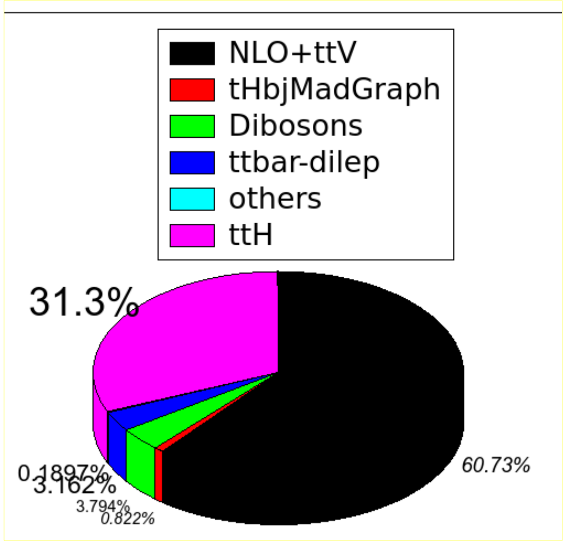
ATLAS-CONF-2016-058



4L SR selection:

- **4 Tight leptons, |charge|=0**
- **Pass isolation gradient selection → suppress ttbar background**
- **M_{l+l-} >12 GeV and $|M_{l+l-}$ - 91.2 GeV| > 10GeV for all SameFlavorOppositeSign (SFOS) pairs → remove controbution from dilep and Z events**
- **N jets ≥2 and N bjets ≥2 → suppress ttbar, ttV and VV**

How to handle a data analysis



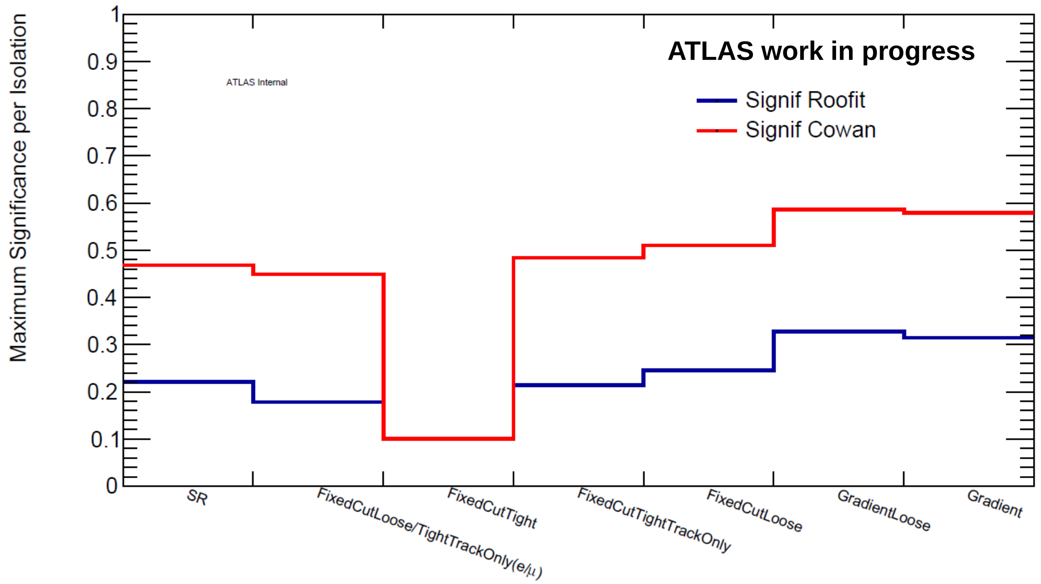
Background composition

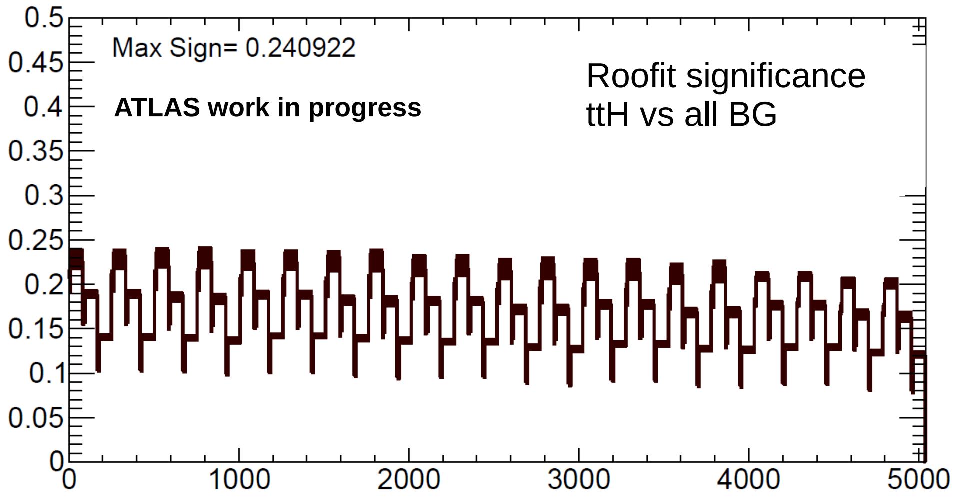
- Low statistics → need clean signal
  - Optimization cut based
  - Optimization MVA
- Need to reduce the uncertainty → look at background composition
- Background processes can be sorted :
  - Events with a non prompt or a fake lepton selected as prompt lepton.
    - main backgrounds of this sort are: tt(+jets), Z+jets and W^+W^- .
    - Data-driven techniques are used to control this category of events.
  - Events which can lead to the same final state as the signal.
    - main background of this category are: ttV (V=Z,W), tZ, $W^\pm Z$ and $W^\pm W^\pm$.
    - Modelled using the Monte Carlo simulations and checked in data control regions (if enough statistics available).

Optimization studies → cut based method

- Study options to reduce the background (in particular ttbar) contribution:
  - Different Isolation WP
    - Fixed Signal Region and Kinematics cuts optimization
  - Different Event Topologies
    - As a function of bjet multiplicity (and algorithm)
    - As a function of lepton charge/flavor (SFOS)

- In order to test the nominal cuts, we varied 5 variables:
  - MET > {10,20,25,30,35,45,50,55}
  - |Mll – 91| > Zveto {-1, 10, 13, 15}
  - M4l> {100, 120, 150};
  - M4l< {300,350,400,450,500, 600, 10000}
  - Pt_lep_0 > {25, 30, 35}
  - Pt_lep_1 > {13, 15, 18, 20}





Kinematic cuts variations

The main reduction of the background with a small signal loss is provided by IsolationGradient

Further optimization using BDT in 4L SR

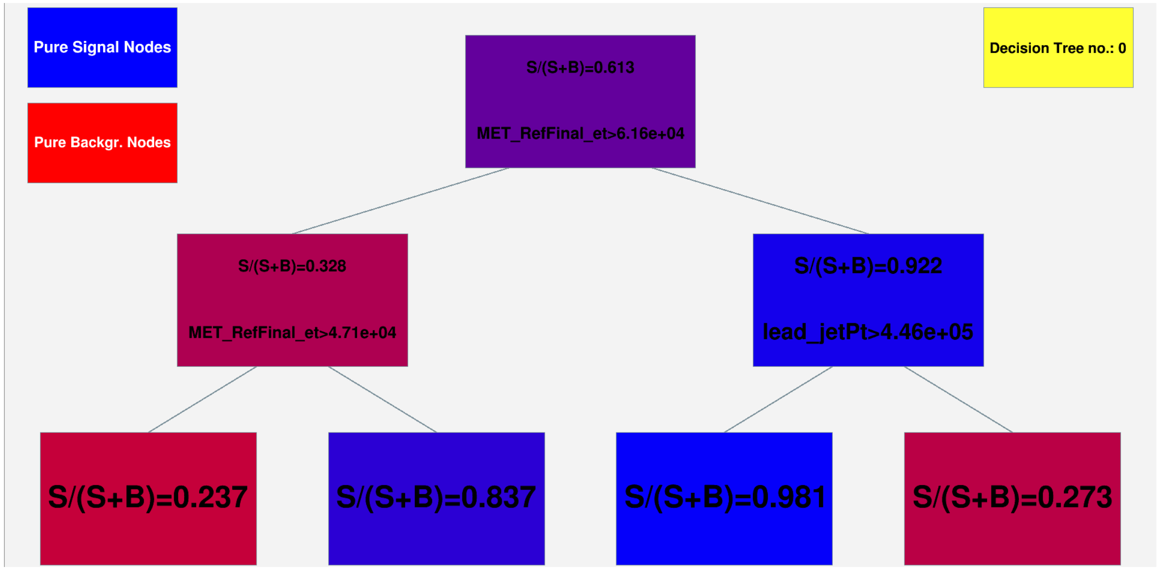
- Most HEP analysis require discrimination of signal from background

http://tmva.sourceforge.net/

Decision trees

Out of all the input variables, find the one for which with a single cut gives best improvement in signal purity:

$$P = \frac{\sum_{\text{signal}} w_i}{\sum_{\text{signal}} w_i + \sum_{\text{background}} w_i}$$



where w_i. is the weight of the *i*th event.

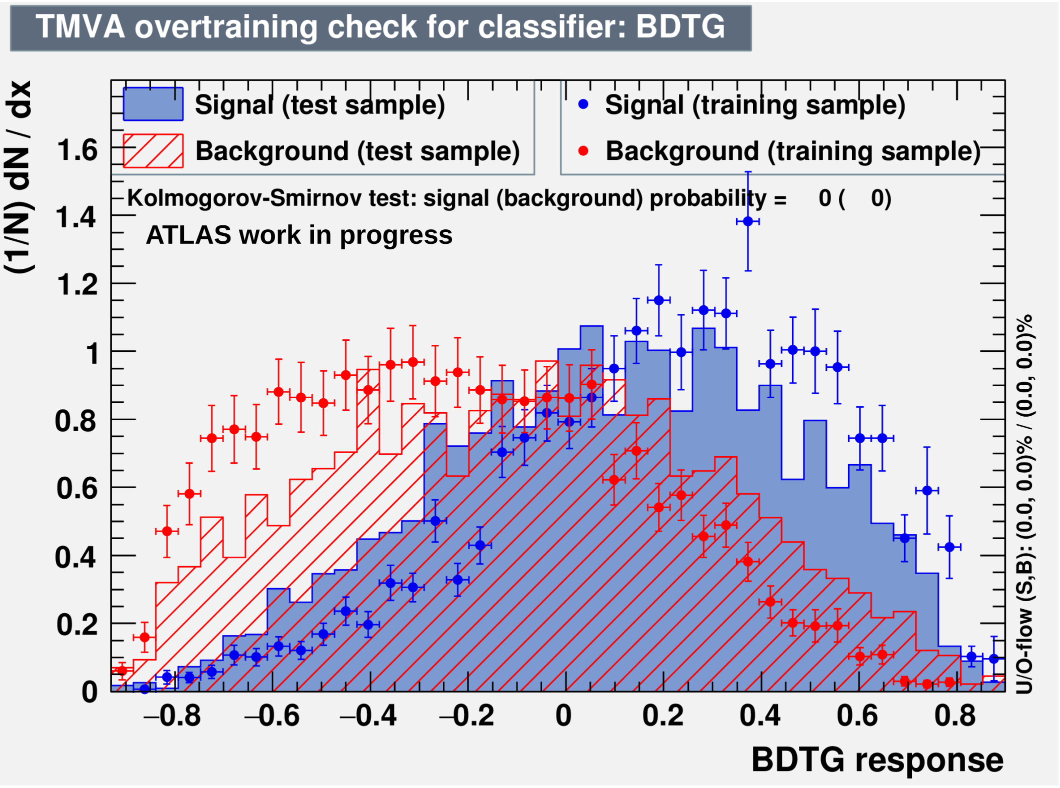
Resulting nodes classified:

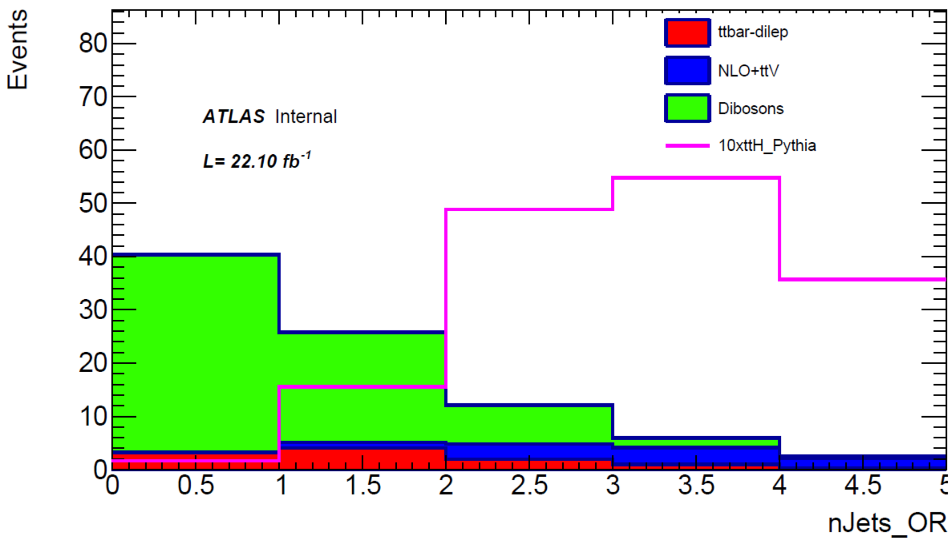
- signal/background.

Iterate until stop criterion reached based on e.g. purity or minimum number of events in a node.
The set of cuts defines the decision boundary.

ttH_Pythia against ttV: TMVA BDTG output

- Procedure: select discriminating variables (ex number of jets) and train the BDT with ½ events, test the training on the other ½ of the events
- Use the BDT ouput in the analysis as a cut





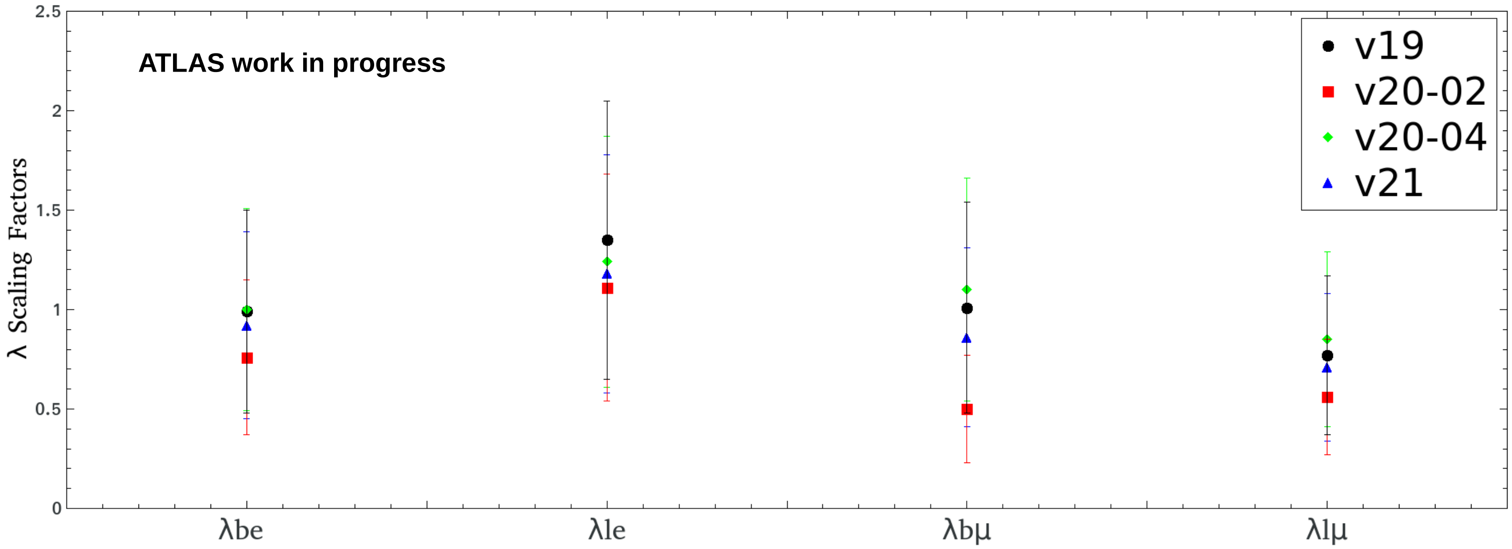
- Cuts applied before training:4L + isoGrad + Zveto + dilep veto+ njet>=2 + nbjet>=1

- Problems → low statistics, need to look at CR; list of variables limited

Fakes analysis: The Scaling Factor

- **Principles:**
  - **2 categories of fake source:**
    - **Z-like: fake leptons (mostly) coming from light-jets**
    - **top-like: fake leptons (mostly) coming from b-jets**
- **The fundamental idea: select a control sample (CR) of events enriched in the background being estimated, and then use an extrapolation factor to relate these events to the background in the signal region (SR).**
- **In this talk explore the influence of a b-jet requirement on the Scaling factors determination**

$$N_{\mathrm{data}}^{f,CR} - N_{\mathrm{others}}^{f,CR} = \lambda^{f}_{\mathrm{b}} \cdot N_{t\bar{t}}^{f,CR} + \lambda^{f}_{\mathrm{l}} \cdot N_{Z+\mathrm{jets}}^{f,CR}$$



Scaling Factor method is robust between different MC and data versions

Fakes studies: Data driven method

- Study the fake contributions in SR' and 3 CR enriched in $t\bar{t}$ and Z+jets:
  - CR1: 2 tight leptons + 2 anti-tight electrons
  - CR2: 2 tight leptons + 2 anti-tight muons
  - CR3: 2 tight leptons + 1 anti-tight electron + 1 anti-tight muon

ATLAS work in progress

V20/04 (13.2 fb^{-1}):	4T	CR1	CR2	CR3
Data	12	9	5	11
prompt	17.60+-1.53	3.50+-0.62	0.81+-0.31	1.87+-0.47
ttbar-dilep	0.02+-0.02	3.95+-0.64	3.68+-0.68	8.66+-1.01
ttH_Herwig	0.69+-0.04	0.08+-0.01	0.10+-0.03	0.12+-0.03

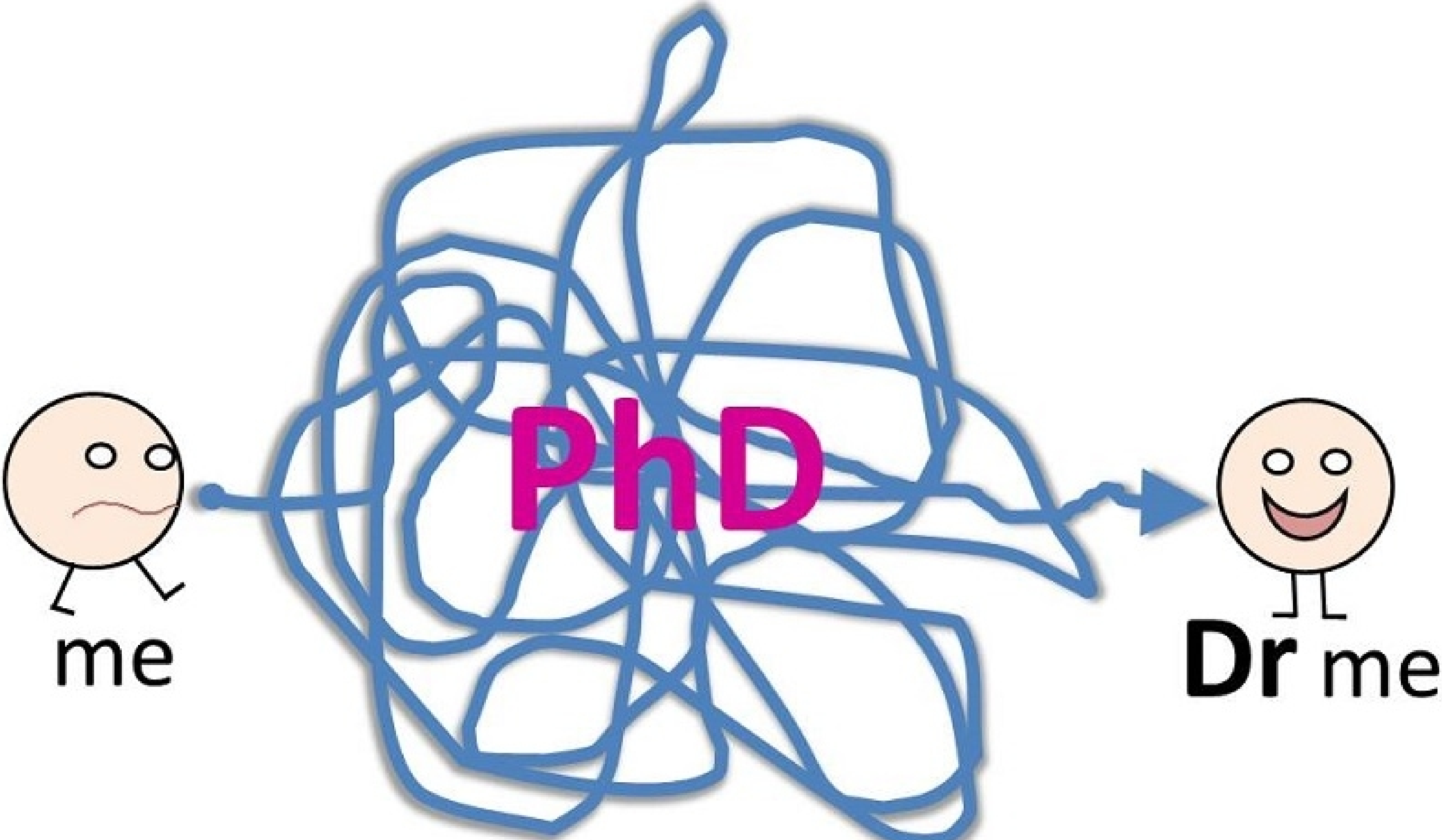
Robust data-driven method, but statistics is poor so far; it will become feasible with more data

Conclusions

- Electron identification efficiency measured using W T&P
- Tuning the analysis in 2015/2016, new triggers implemented in 2016
- In work: Performance publication including W T&P analysis → for Moriond 2017

- Main analyst of ttH->4L for ICHEP2016
- Signal selection optimization, fake leptons studies
- In work: refined analysis using MVA, publication with full stat by summer 2017

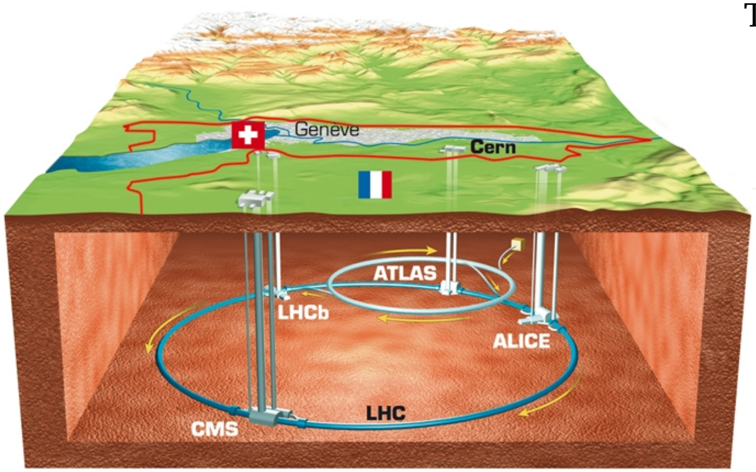
Special thanks to my supervisors:
Cristinel Diaconu (CPPM), Emmanuel Monnier (CPPM), Alexa Calin (IFIN-HH)



Thank you for your attention!

Backup Slides

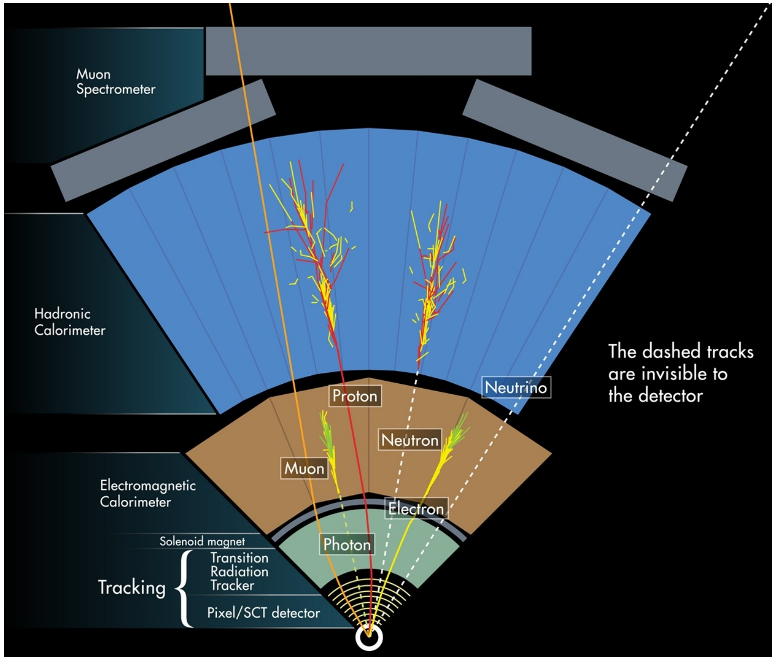
ATLAS experiment and detector



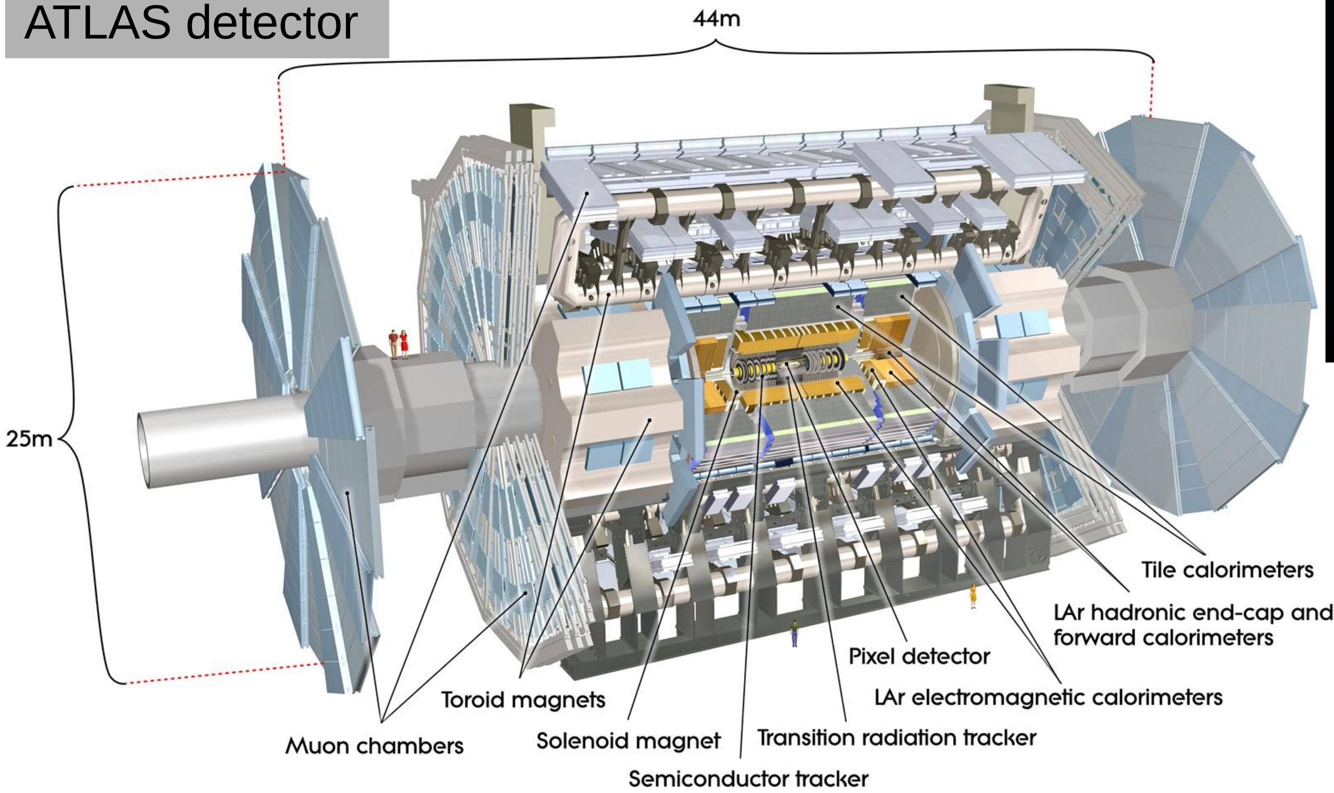
The LHC is the world's largest and highest-energy particle accelerator. The collider is contained in a circular tunnel, with a circumference of 27 kilometers underground.

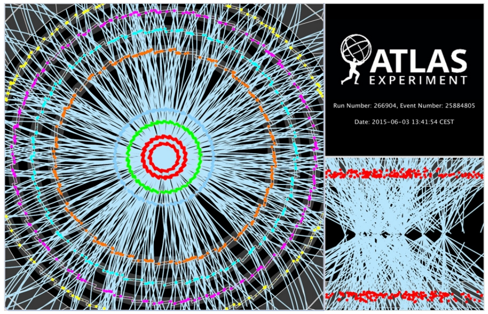
ATLAS: One of two general purpose detectors (CMS), used to look for signs of new physics, including the origins of mass and extra dimensions.

Not keep if introduced before



ATLAS detector



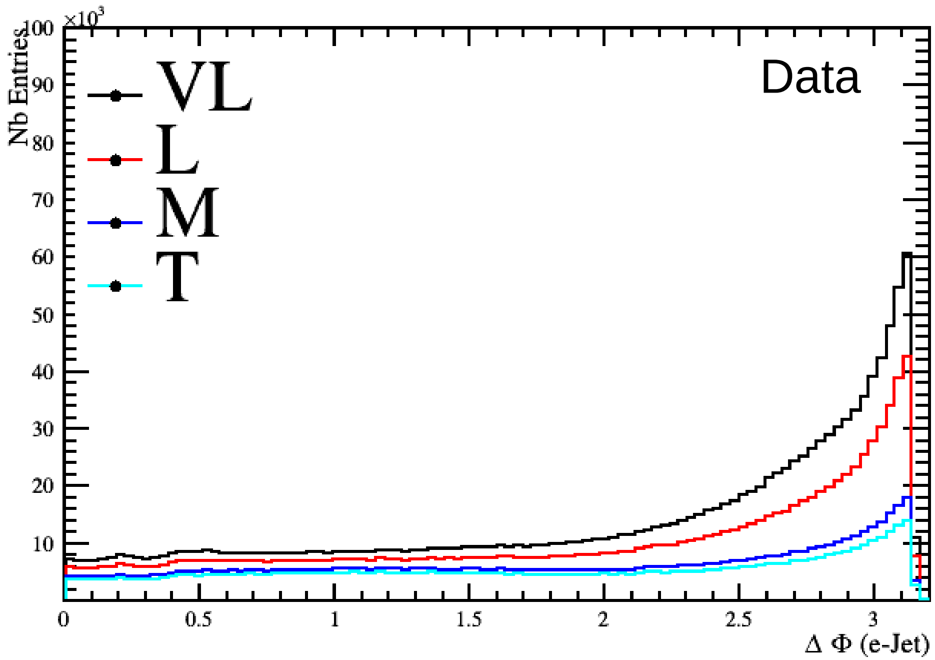


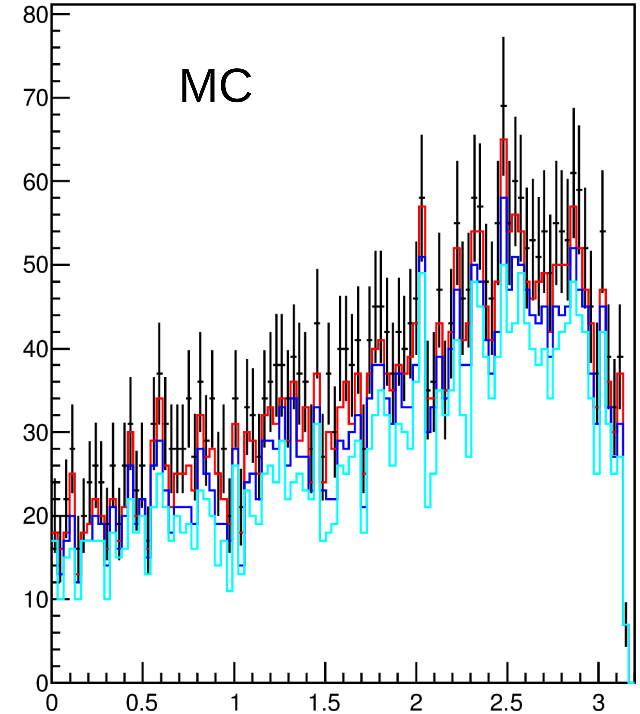
Display of a proton-proton collision event recorded by ATLAS on 3 June 2015, with the first LHC stable beams at a collision energy of 13 TeV.

$\Delta\phi$ distributions for Jets p_T>15

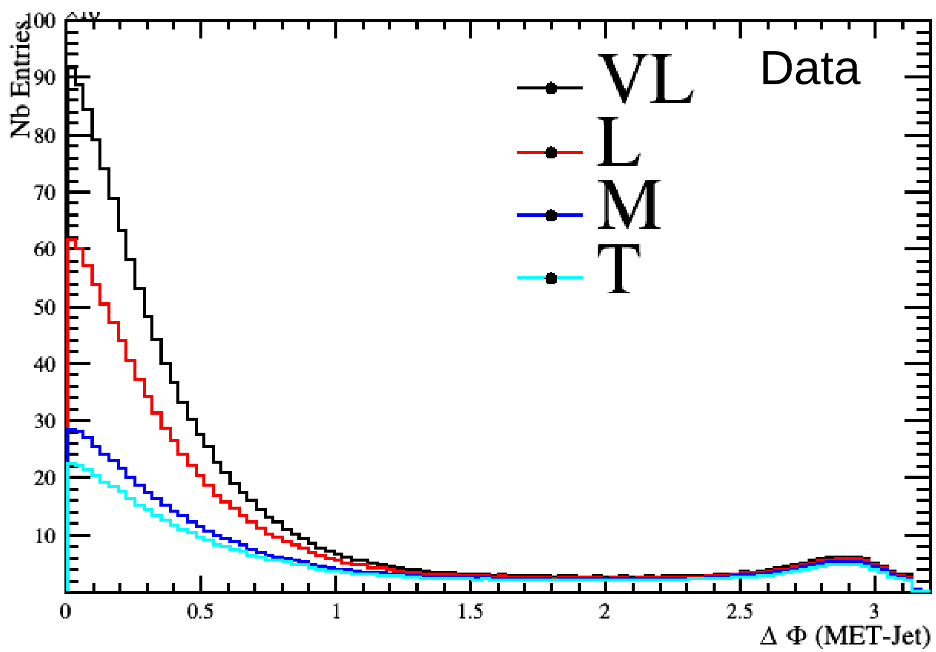
ATLAS work in progress

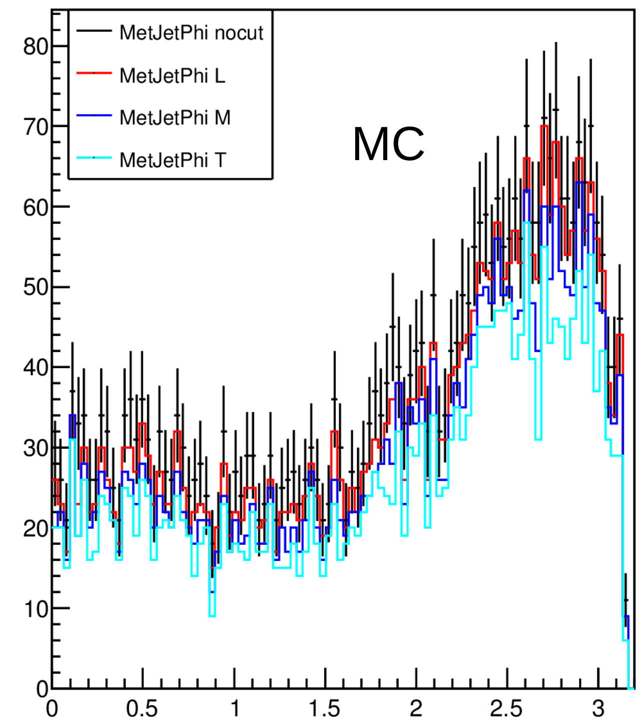
$\Delta\Phi_{e\text{-jet}}$





$\Delta\Phi_{jet\text{-}MET}$



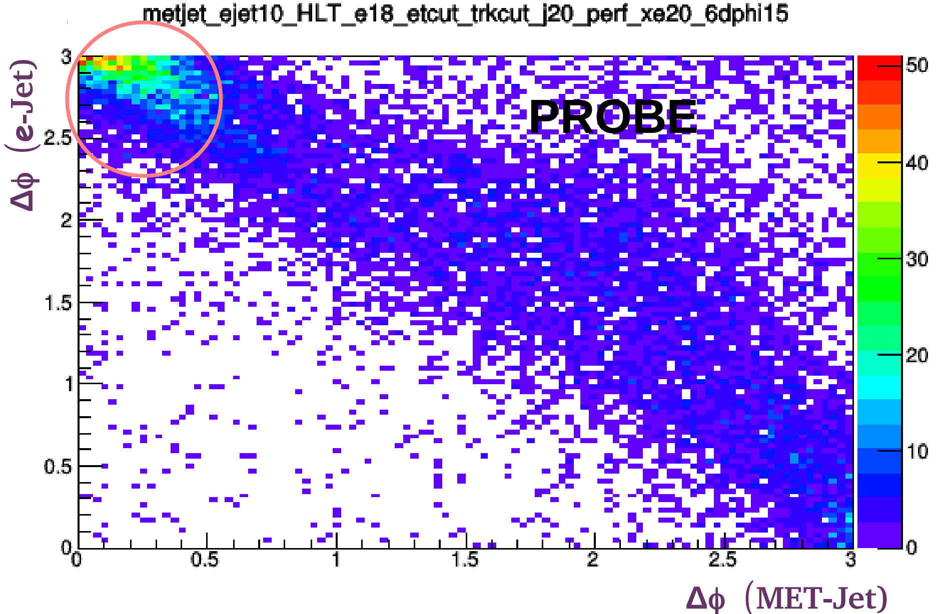


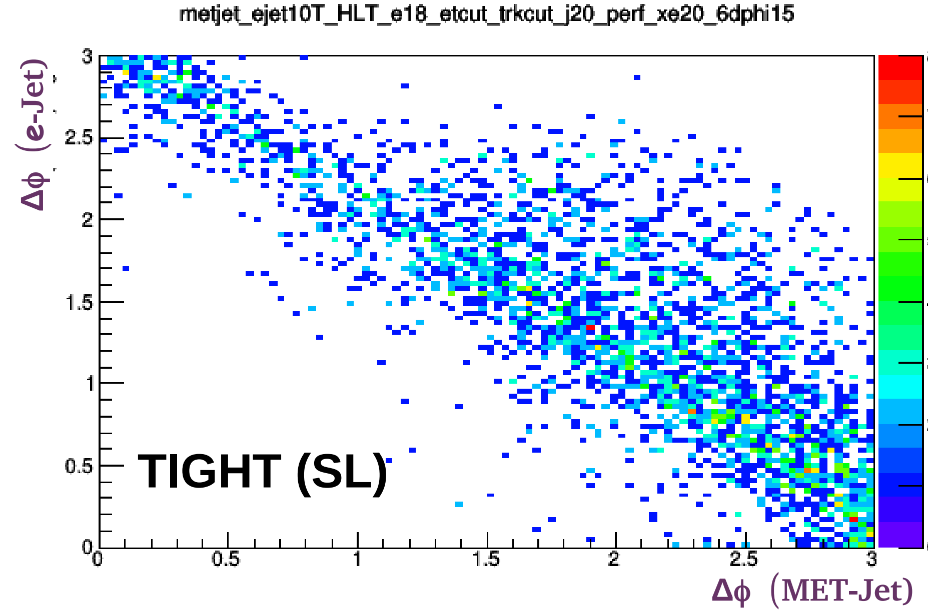
Final cuts applied on angular variables:

- $\Delta\Phi_{e\text{-jet}}<2.5$ && $\Delta\Phi_{MET\text{-jet}}>0.7$

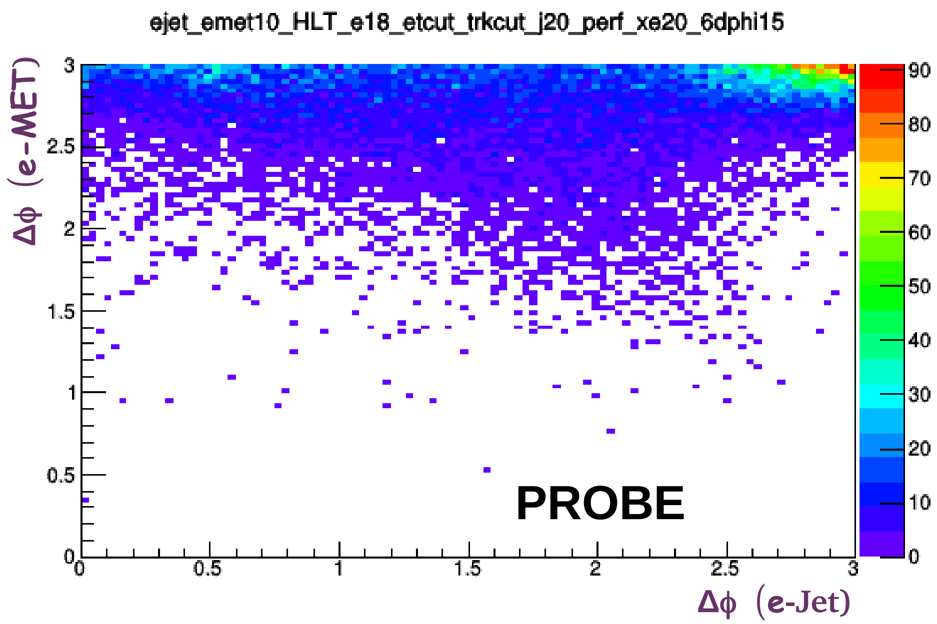
All other kinematic distributions in

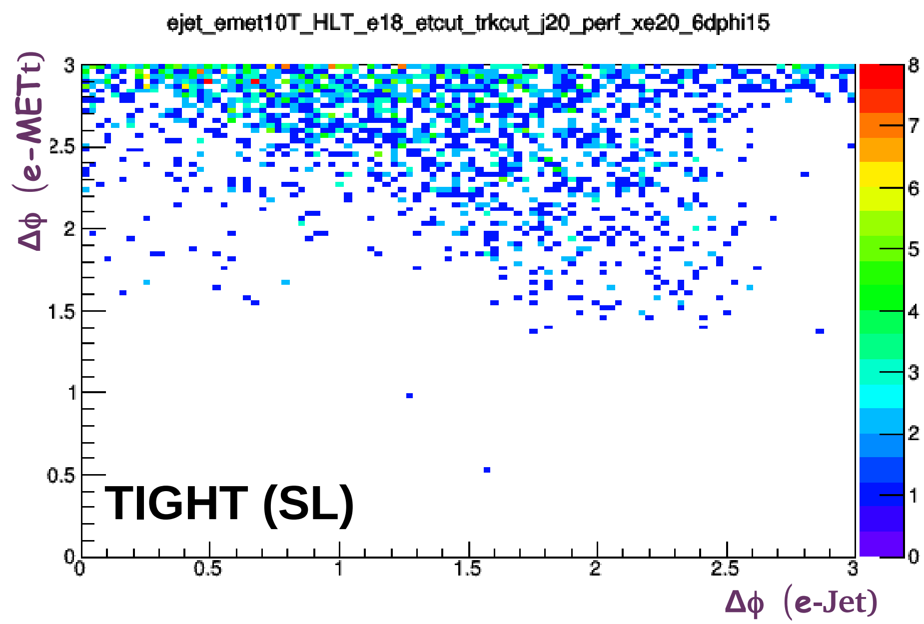
Δφ (MET-Jet e-Jet) correlation between for Jets with pT>10





Δφ (eJet e-MET) correlation between for Jets with pT>10



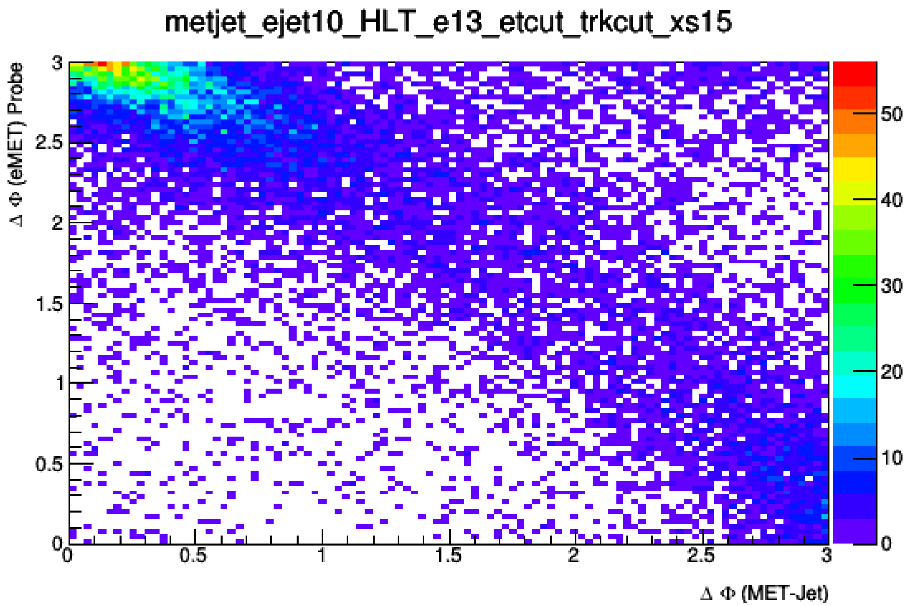


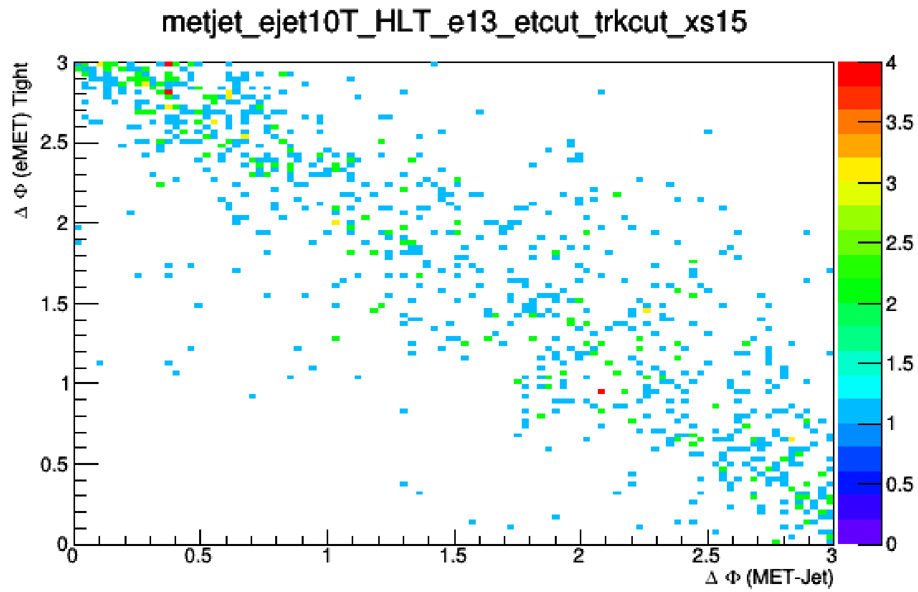
e18a

- **Most of the statistics at trigger level is in background region.**
- **Further cuts on angular variable to reduce the background won't affect the signal (as seen in Tight = Signal Like distribution)**

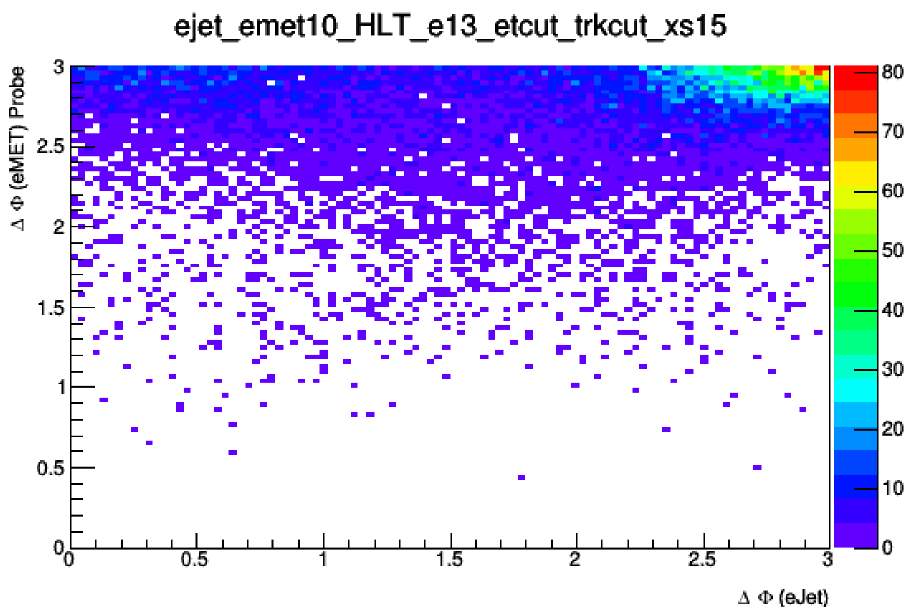
ATLAS work in progress

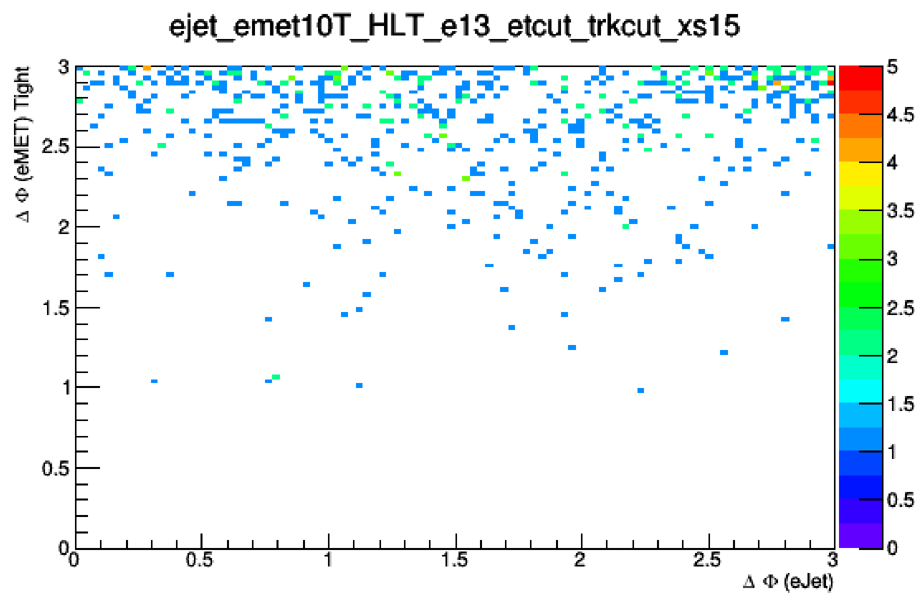
Δϕ（MET-Jet e-Jet) correlation between for Jets with pT>10





Δϕ（eJet e-MET) correlation between for Jets with pT>10





e13

Top quark polarization and spin correlation

The scope of my PhD thesis is to explore the potential of the spin-correlation properties in the associated Higgs top-pair production at the LHC as a possible tool to improve the separation of the signal from the $t\bar{t}H$ irreducible backgrounds.

- spin correlations could help in disentangling the SM scalar component from a pseudoscalar contribution in the top-Higgs coupling
- by reconstructing the individual top systems, the top-quark spin properties can be accessed by measuring angular distributions of the final decay products

- Observables in the laboratory frame and in different top quark spin quantization bases are explored, used to measure the coefficient fSM , which is related to the number of events where the t and $\bar{t}$ spins are correlated as predicted by the SM,
- The measured value of fSM is translated into the spin correlation strength A , which is a measure for the number of events where the top quark and top antiquark spins are parallel minus the number of events where they are antiparallel with respect to a spin quantization axis, divided by the total number of events:

$$A = \frac{N_{\text{like}} - N_{\text{unlike}}}{N_{\text{like}} + N_{\text{unlike}}} = \frac{N(\uparrow\uparrow) + N(\downarrow\downarrow) - N(\uparrow\downarrow) - N(\downarrow\uparrow)}{N(\uparrow\uparrow) + N(\downarrow\downarrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow)} ,$$

The strength of the spin correlation is:

$$C = -A\,\alpha_+\alpha_- \,.$$

$$C = -9\,\langle\cos(\theta_+)\cos(\theta_-)\rangle.$$

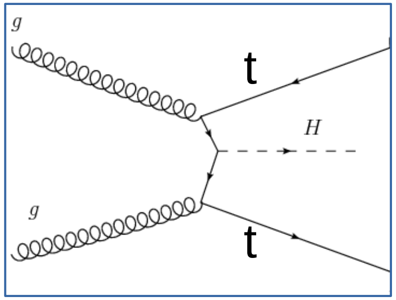
The factor α_i is the spin-analyzing power, which must be between -1 and 1.

As shown in JHEP07(2014)020, spin-correlation features in the $t\bar{t}H$ production are quite promising for enhancing the signal sensitivity over the irreducible background.
Similar studies will be performed on 2015 data.

PhD topic : $t\bar{t}H$ spin correlations at LHC

The goal of my PhD thesis is to explore the potential of the spin-correlation properties in the associated Higgs top-pair production at the LHC as a possible tool to improve the separation of the signal from the $t\bar{t}H$ irreducible backgrounds.

- spin correlations could help in disentangling the SM scalar component from a pseudoscalar contribution in the top-Higgs coupling
- by reconstructing the individual top systems, the top-quark spin properties can be accessed by measuring angular distributions of the final decay products



As shown in JHEP07(2014)020, spin-correlation features in the $t\bar{t}H$ production are quite promising for enhancing the signal sensitivity over the irreducible background. Similar studies will be performed on 2015 data.

→ in the chiral limit of vanishing top-quark mass (mtt ≫ mt) t and $\bar{t}$ spins are highly correlated and parallel to each other along the tt production axis. Top pairs are hence produced in the LR + RL helicity configurations.

→ **when the $t\bar{t}$ is produced in association with a Higgs boson**, the top quark and antiquark helicities are also correlated, but Higgs-boson emission from the top-quark final states via Yukawa interactions induces a **chirality flip** in the top-quark polarization → LL+RR helicity configuration, (LR+RL configuration suppressed by terms of order $O(m^2_t/m^2_{tt})$.

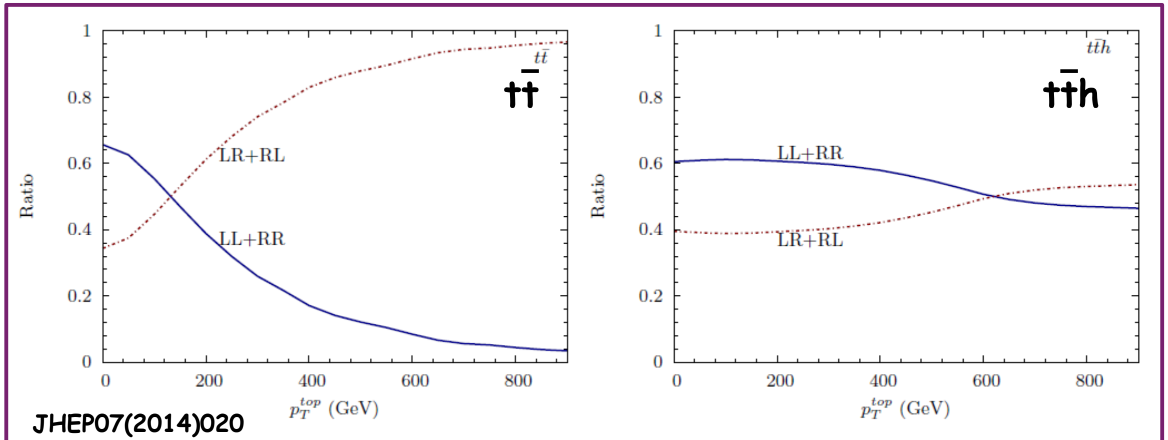
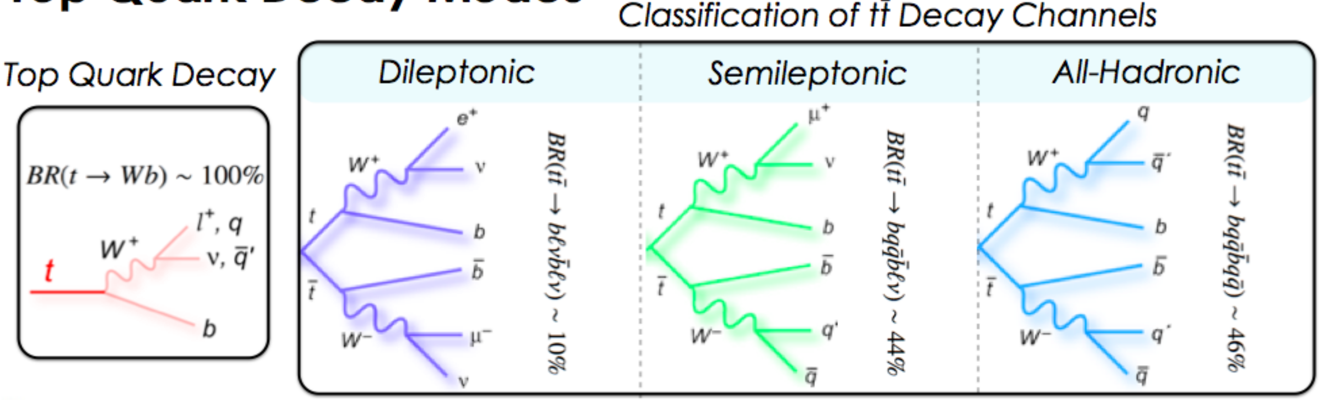


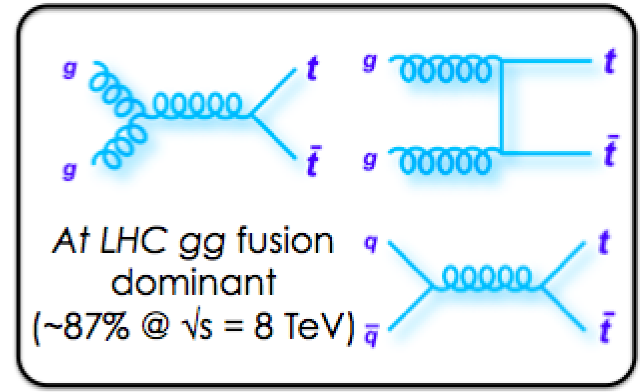
Figure 1. Integrated p_T distributions for the like-helicity top pairs ($t_L\bar{t}_L + t_R\bar{t}_R$) and unlike-helicity top pairs ($t_L\bar{t}_R + t_R\bar{t}_L$) in unpolarised $t\bar{t}$ (left plot) and $t\bar{t}h$ (right plot) samples, versus the hardest-top p_T cut at c.m. energy of 14 TeV, in the Lab frame.

Top quark physics

Top Quark Decay Modes

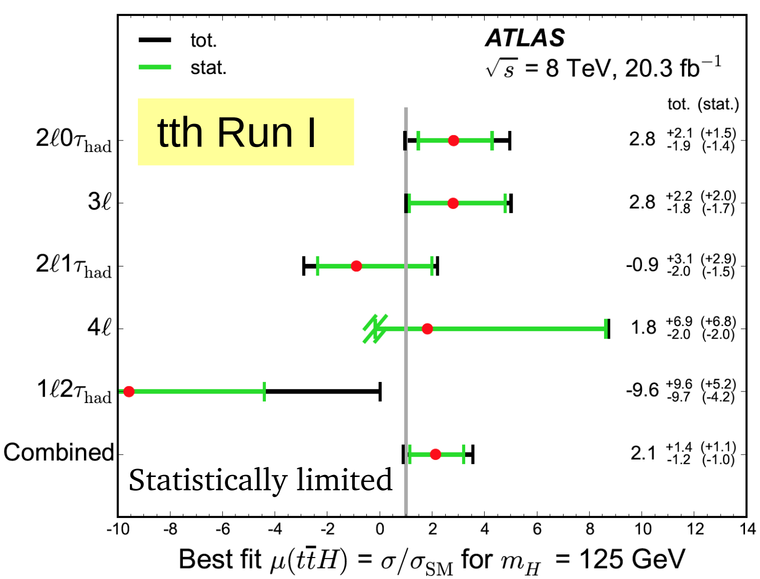


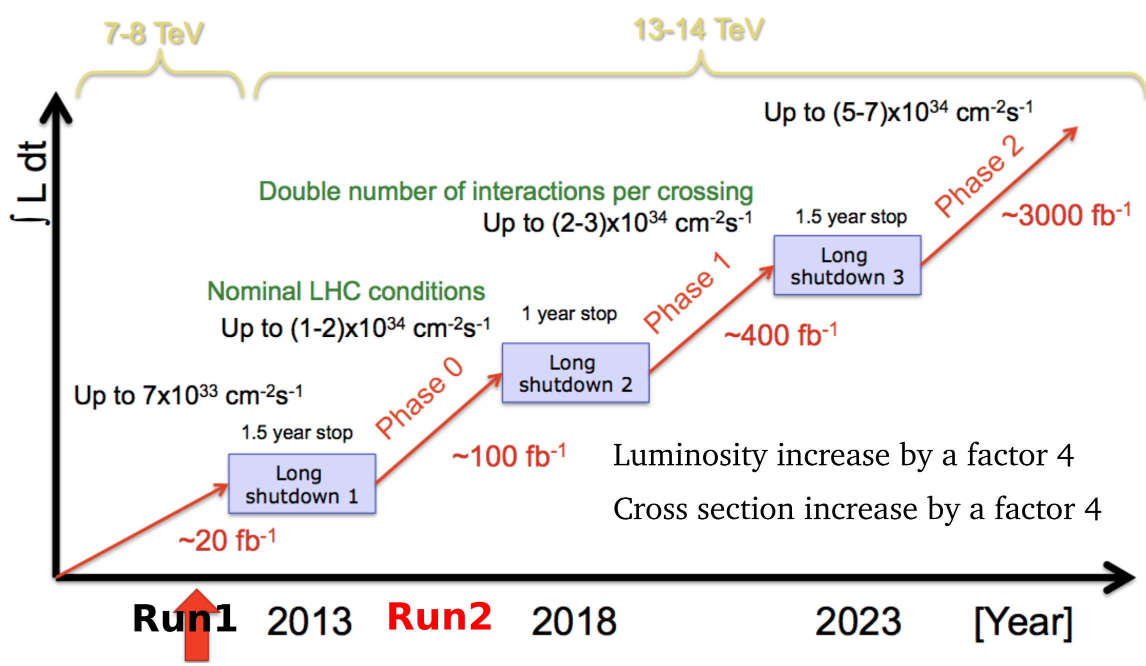
LO tt̄ Production Modes



Decay products of the top quark: correlated with its spin → the direct coupling of top quark with W^+ opens the window for a direct measurement of the CKM element $|V_{tb}|$ + one can also predict the Standard Model (SM) allowed helicity states of the produced W^+ and check experimentally beyond the SM predictions (new top quark supersymmetric decay modes can be tested, as well as other aspects of the SM limits)

- ttH is a major goal at LHC in the next period, new properties can be studied with higher statistics





Test a custom cut on isolation using cone 0.2

ATLAS work in progress

	SR Nominal entries + MET>10 GeV + topo20ET/pt <0.06 for lep0 and lep1	Optimization of SR + MET>10 GeV + topo20ET/pt <0.06 for lep0 and lep1	*SR + IsoGrad=4 for nbjet=1* + MET>10 GeV + topo20ET/pt <0.06 for lep0 and lep1	*SR + IsoGrad=4 for (SFOS=2 || SFOS=0)* + MET>10 GeV + topo20ET/pt <0.06 for lep0 and lep1
ttH	0.873+-0.111	0.895+-0.111	0.781+-0.097	0.784+-0.106
BG_ALL	1.925+-0.300	2.193+-0.382	1.085+-0.066	0.985+-0.054
ttbar	0.328+-0.255	0.564+-0.347	0+-0	0+-0
Significance	0.272	0.256	0.339	0.365
	MET>35 Zveto_13 100<M4l<10000 PT0>25 PT1>20	MET>35 Zveto_13 100<M4l<10000 PT0>25 PT1>20	MET>10 Zveto_13 100<M4l<500 PT0>30 PT1>13	MET>10 Zveto_13 100<M4l<500 PT0>25 PT1>13

Backup

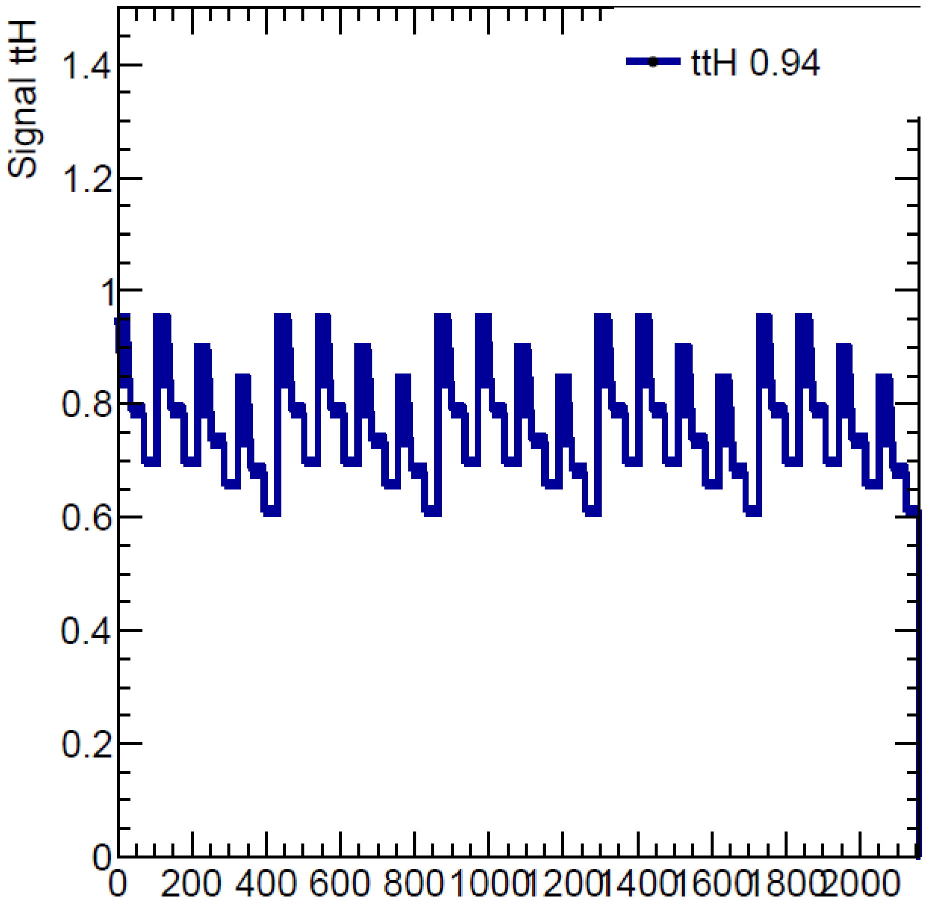
SG optimization+Isolation

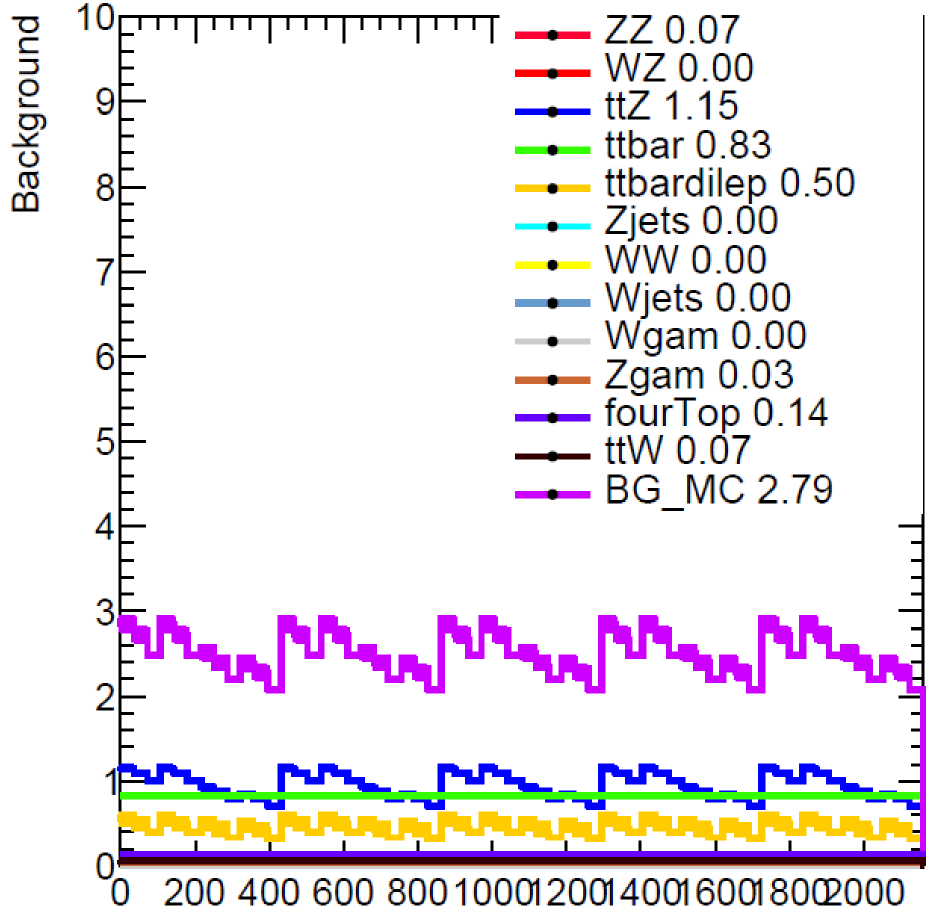
ATLAS work in progress

	Baseline Selection fixed	Optimized SR	+isoGrad
ttHSG	0.954+-0.114	0.884+-0.110	0.713+-0.092
ttZ	1.165+-0.031	0.821+-0.026	0.602+-0.022
ZZ	0.070+-0.024	0.029+-0.013	0.028+-0.013
ttbar	0.828+-0.436	0.828+-0.436	0+-0
ttbardilep	0.6556+-0.182	0.444+-0.148	0+-0
BG_MC	2.964+-0.47	2.312+-0.464	0.732+-0.045
Signif	0.220	0.238	0.372
		Zveto_13 100<M4l<400 PT0>25 PT1>20	Zveto_13 100<M4l<350 PT0>30 PT1>13

Signal and Bakcground samples in optimized SR

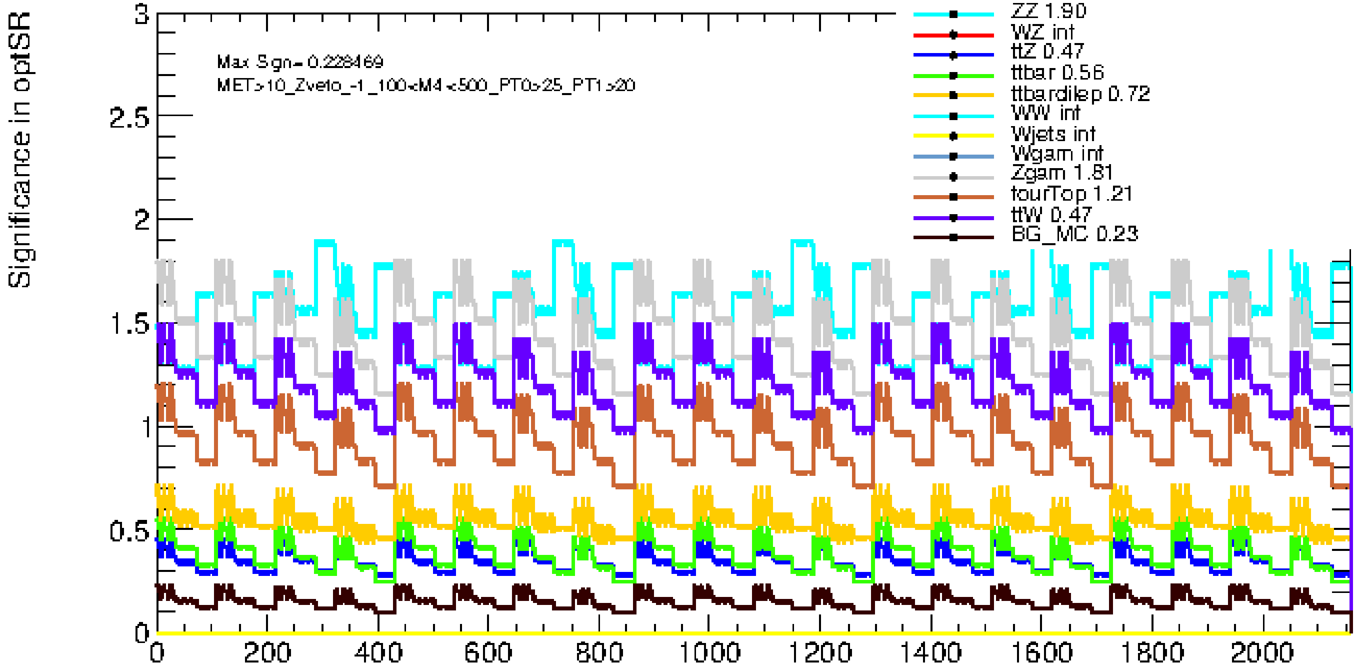
ATLAS work in progress





Significance in optimized SR

ATLAS work in progress



Lambda propagation models

- M1
  - An event with at least a fake lepton is a fake event
  - FSFs are applied according to the nature of the fake event (“light” or “heavy” environment) and the flavour of the leptons
  - Events with N expected fakes will be reweighted by $\prod_{i=1}^{N} FSF_i$
- M2:
  - Method 1 applied only if is NotIsolated type lepton
  - Factorize if more than 1 fake lepton
- M3: use lep_isFake to separate fakes FSF applied the same as in Method 1
- Option: apply lambda deduced at high b-jet multiplicity

Summary on the 4l fake estimation v21

Backup

ATLAS work in progress

ttH(herwg)	M1	M2	M3
Total_Brut	1.031	1.031	1.031
Prompt	0.908	0.908	0.927
Fakes	0.12	0.12	0.1
Fakes_Scaled	0.11	0.11	0.09
Total_Corrected	1.016	1.013	1.016
Fakes_Scaled bjet>0	0.12	0.18	0.16
Total_Corrected bjet>0	1.031	1.092	1.083
TOTAL_BG	M1	M2	M3
Total_Brut	2.197	2.197	2.197
Prompt	1.834	1.834	1.870
Fakes	0.36	0.36	0.33
Fakes_Scaled	0.4	0.36	0.32
Total_Corrected	2.236	2.192	2.187
Fakes_Scaled bjet>0	0.8	0.49	0.39
Total_Corrected bjet>0	2.630	2.329	2.255

The fake rates with various methods vary within 13-14%

4l Yields in the 4T and CR v21

	4T	CR1	CR2	CR3
Data	19	7	5	7
prompt	27.15+-2.05	4.80+-0.82	0.80+-0.33	2.04+-0.59
ttbar-dilep	0.05+-0.05	3.28+-0.61	1.50+-0.40	5.75+-0.87
ttH_Herwig	1.09+-0.06	0.10+-0.02	0.05+-0.02	0.08+-0.03

4l Yields in the 4T and CR v20/04

Compatible with Run1

	4T	CR1	CR2	CR3
Data	12	9	5	11
prompt	17.60+-1.53	3.50+-0.62	0.81+-0.31	1.87+-0.47
ttbar-dilep	0.02+-0.02	3.95+-0.64	3.68+-0.68	8.66+-1.01
ttH_Herwig	0.69+-0.04	0.08+-0.01	0.10+-0.03	0.12+-0.03

Run1 results (20.3 fb^{-1}):

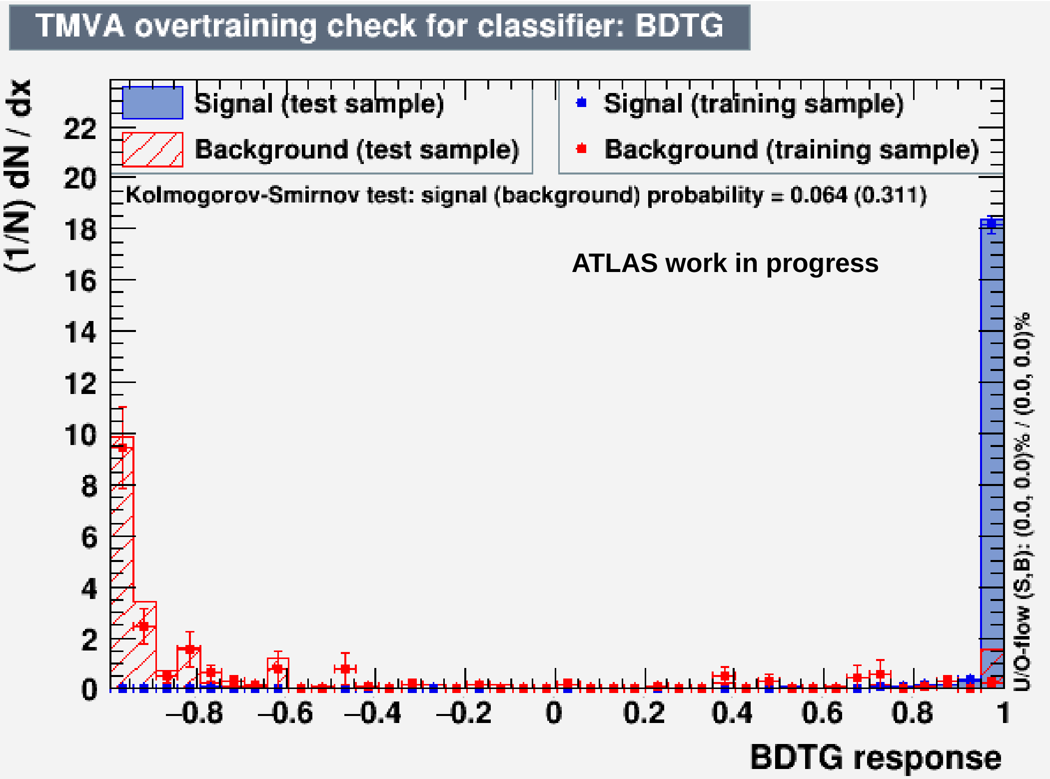
CR	prompt	WZ	$t\bar{t}/t + X$	Z+jet	Sum Bkg.	Data
2T+2L(ee)	0.52 ± 0.27	0.00 ± 0.00	1.87 ± 0.17	0.00 ± 0.00	2.39 ± 0.21	7
2T+2L($\mu\mu$)	0.25 ± 0.25	0.00 ± 0.00	6.62 ± 0.31	0.64 ± 0.49	7.45 ± 0.58	7
2T+2L($e\mu$)	0.57 ± 0.57	0.00 ± 0.00	8.23 ± 0.38	0.30 ± 0.30	9.03 ± 0.49	15

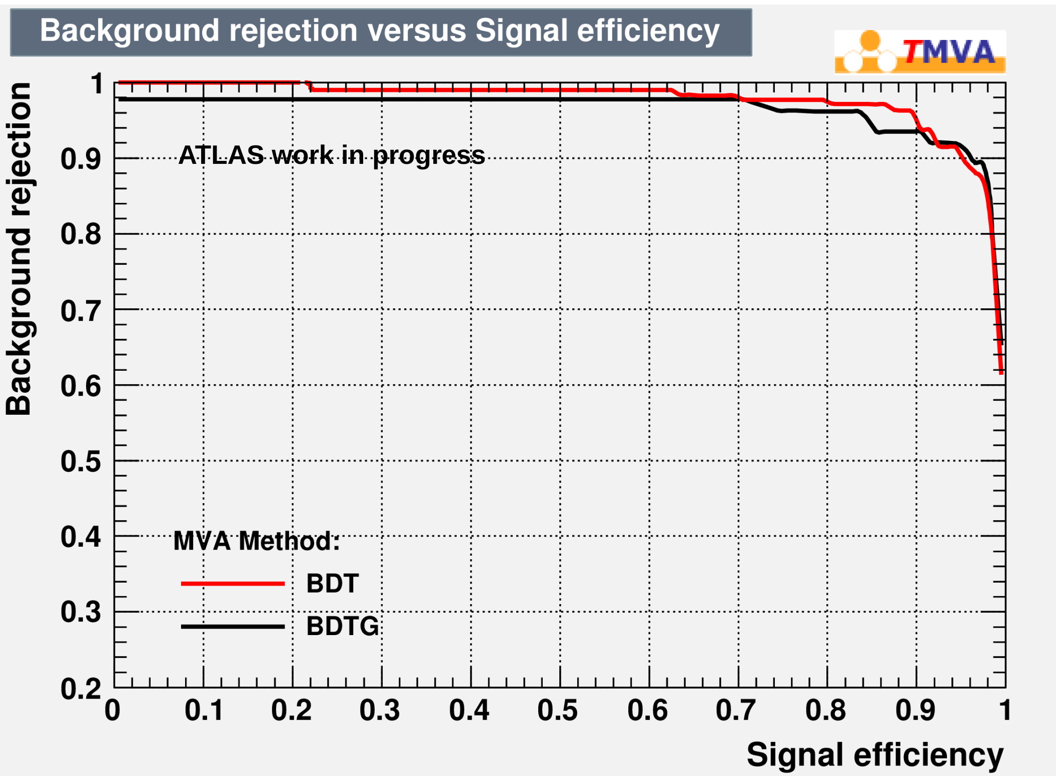
prompt = tZ_bis + tttt_ttWW + W+gamma + tribosons + tWZ + VH + tHbjMadGraph+Herwig + W+jetsSherpaNNPDF30NNLO + NLO+ttV + Dibosons

ttH_Pythia against VV: TMVA BDTG output

ATLAS work in progress

- Cuts applied before training:4L + Zveto + njet>=2





	Signal (efficiency)	Background (efficiency)
Total entries	15756	64855
Nb events passed	10737 (0.671)	1358 (0.022)

All weights taken into computation!