ANALYSIS REPORT

ATLAS Napoli Meeting 18/10/2018

Analysis Team: S. Auricchio, G. Carlino, F. Cirotto, F.A. Conventi, A. Giannini, M. Lavorgna, L. Merola, E. Rossi

Run-II analyses:

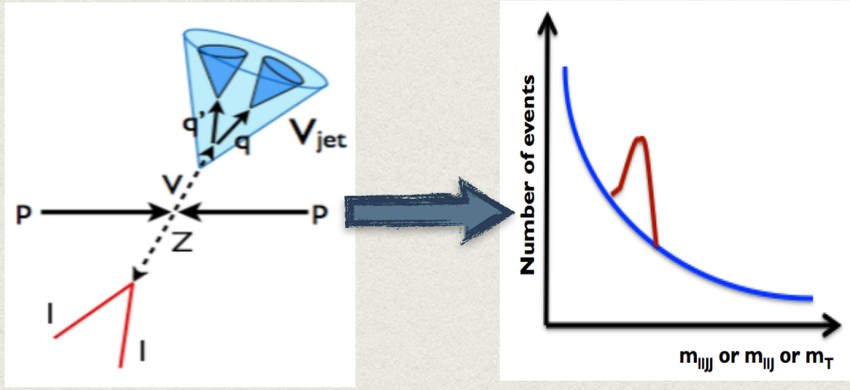
- **BSM Resonances searches in ZV Final States (V=Z,W) (DBL)**
- ***SM Vector Boson Scattering (VBS)***
- ***Searches with Jets and Missing energy in the final states (JDM)***

(S. Auricchio, G. Carlino, F. Conventi, F. Cirotto, A. Giannini, M. Lavorgna, L. Merola, E. Rossi)

DBL analysis goals:

- Look for a peak in the M_{lljj} invariant mass spectrum over a smoothly falling SM background distribution

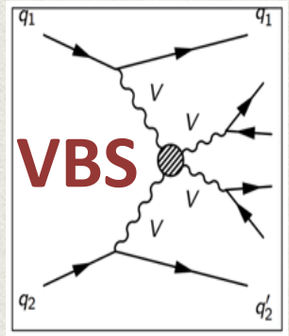
Paper with 2015-1016 Run-II dataset: JHEP, 2018 (3), art. no. 9
Full Run-II paper expected in spring-summer 2019



VBS analysis goals and Physics interpretation:

- Search for anomalous Quartic Gauge Couplings (aQGC)
- Measurement of the VBS VV cross section production

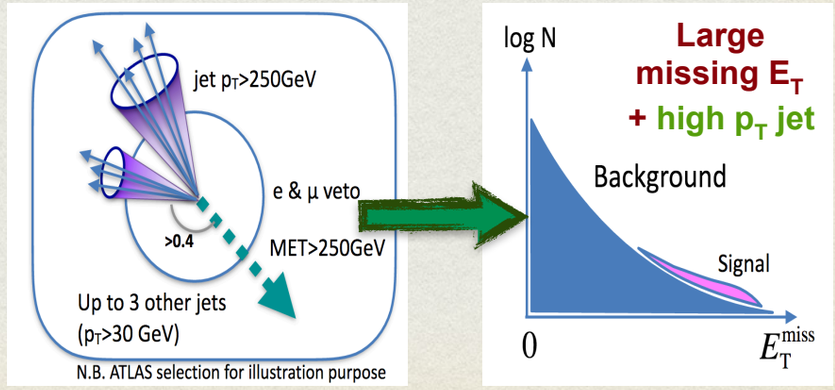
VBS: Paper with 2015-1016 Run-II dataset will be ready soon



JDM analysis goals and Physics interpretation:

- Look for the production of invisible particles recoiling against a high-momentum jet
- Several BSM scenarios: Dark Matter pair production, SUSY in compressed scenarios, Extra spatial dimensions

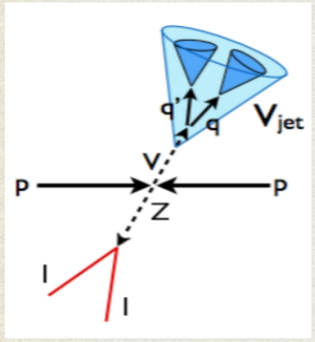
Paper with 2015-1016 Run-II dataset: JHEP, 2018 (1), art. no. 126
Full Run-II paper expected for Moriond 2019

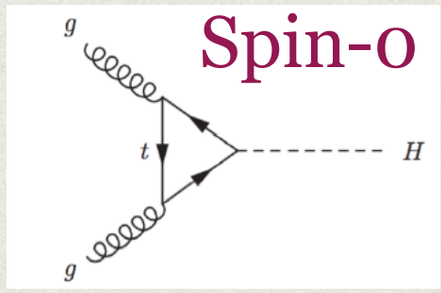


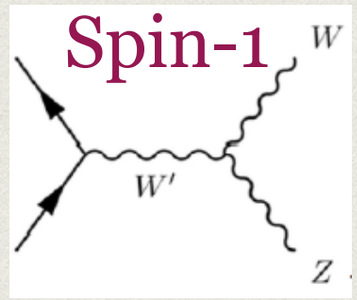
Run-II Diboson analyses (DBL): BSM Resonances searches in ZV Final States X->ZV->llqq (V=Z,W)

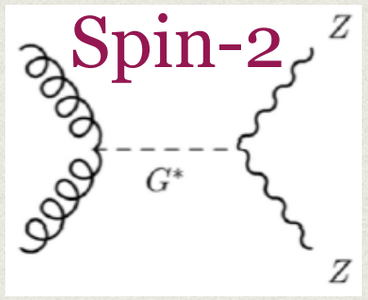
- DBL is now a subgroup of a new dedicated ATLAS Physics group **HDBS**: convener Bill Murray and Viviana Cavaliere
- Collaboration with Lecce's Group: Stefania Spagnolo, Gabriele Chiodini, Dinos Bachas
- ***Cut-based Selection optimisation:***
  - lepton selection: study on the leading and subleading lepton pT
  - pT-Ratio: harmonisation of the variable used for Merged/Resolved Regimes and optimisation of the cut
- ***Machine Learning Approach:***
  - VBF/ggF identification
  - signal/background separation

DBL ANALYSIS: OVERVIEW







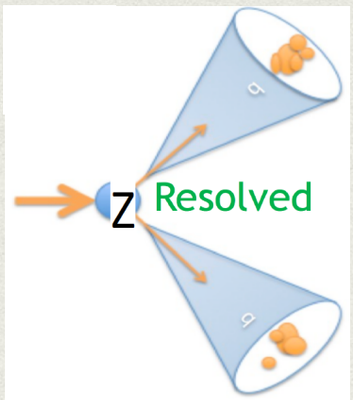


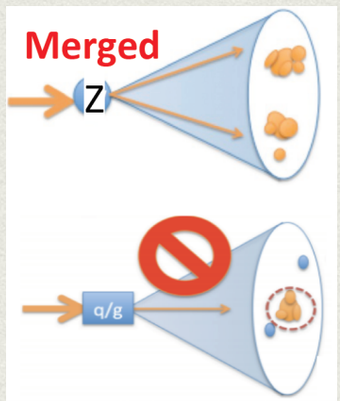
llqq categorization:

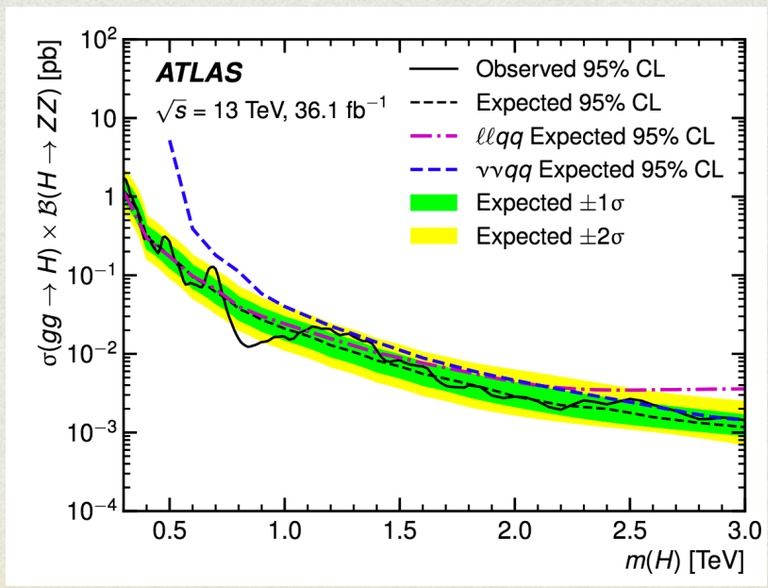
- Merged large−R jet high-purity and low-purity regions
- Resolved 2-jet: tagged (2b-jets) and untagged (<2 b-jets)

vvqq categorization:

- Requires large E_T^{miss}
- Merged large−R jet high-purity and low-purity regions







ATLAS EXPERIMENT

ATLAS Note

ANA-EXOT-2018-10-INT1

17th October 2018

CERN

Draft version 0.1

1

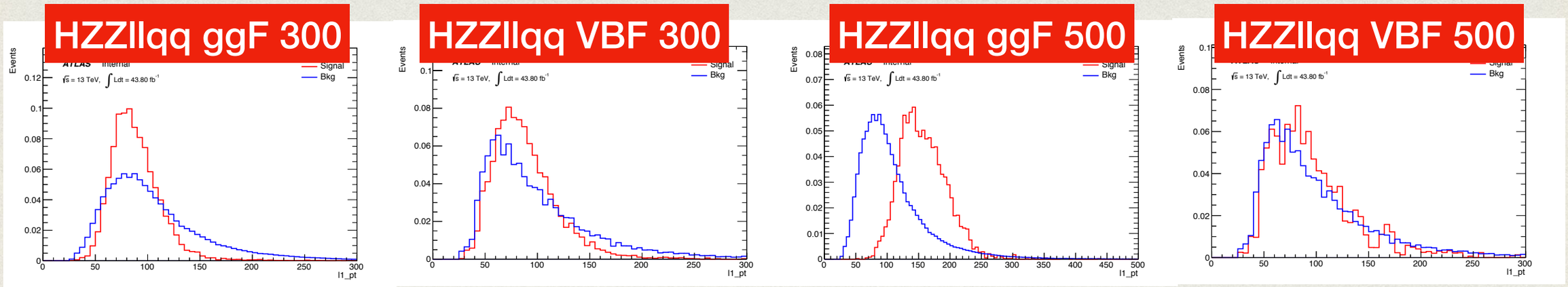
2 **Search for diboson resonance in semi-leptonic final**
3 **states using $\sqrt{s}$ = 13 TeV pp-collision data collected**
4 **with the ATLAS detector**

5 The ATLAS Collaboration[1], Dinos Bachas[a], Adrian Buzatu[n], Gianpaolo
6 Carlino[d], Viviana Cavaliere[b], Chunhui Chen[c], Grabriele Chiodini[a], Francesco
7 Conventi[d], Antonio Giannini[d], Yicheng Guo[e,f], Jonathan Hays[o], David Lack[g],
8 Marco Lavorgna[d], Robert Les[h], Haifeng Li[i], Tong Li[i], Chiao-Ying Lin[j],
9 Lianliang Ma[i], Yanhui Ma[i], Tatsuya Masubuchi[k], Alexey Myagkov[l], Takuya
10 Nobe[k], Alexander Oh[g], Vincent Pascuzzi[h], Jianming Qian[f], Elvira Rossi[d],
11 Stephen Sekula[p], Savanna Shaw[g], Ismet Siral[f], Mario Sousa[i], Stefania
12 Spagnolo[a], Koji Terashi[k], Natasha Woods[m], Lailin Xu[b], Masahiro Yamatani[k],
13 Jie Yu[c], Zhengguo Zhao[e], Bing Zhou[f], Junjie Zhu[f]

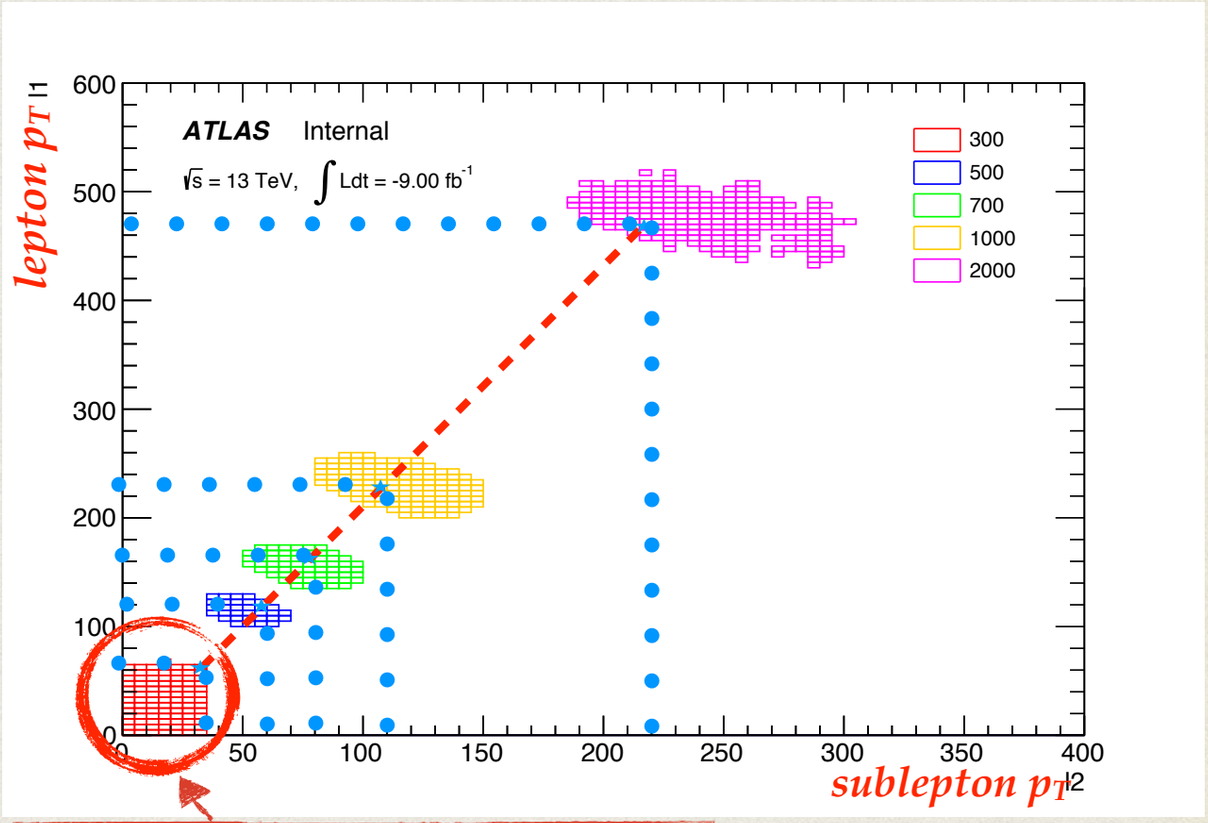
DBL ANALYSIS: CUT-BASED SELECTION OPTIMISATION CONTRIBUTIONS

Lepton selection

- Optimise lepton p_T cut on leading and subleading leptons to enhance discovery significance and improve fake lepton contribution



$l_1 p_T$ > 60 GeV	ggF HP	ggF LP	ggF Untagg	ggF Tagged	Inclusive
300			0,98	0,91	0,97
700	1,04	1,06	1,07	1,21	1,07
1000	1,02	1,05	1,08	1,15	1,08
2000	1,01	1,03			



Optimization of the lepton p_T cuts being

DBL ANALYSIS: CUT-BASED SELECTION OPTIMISATION CONTRIBUTIONS

Lot of work done on analysis harmonization!!

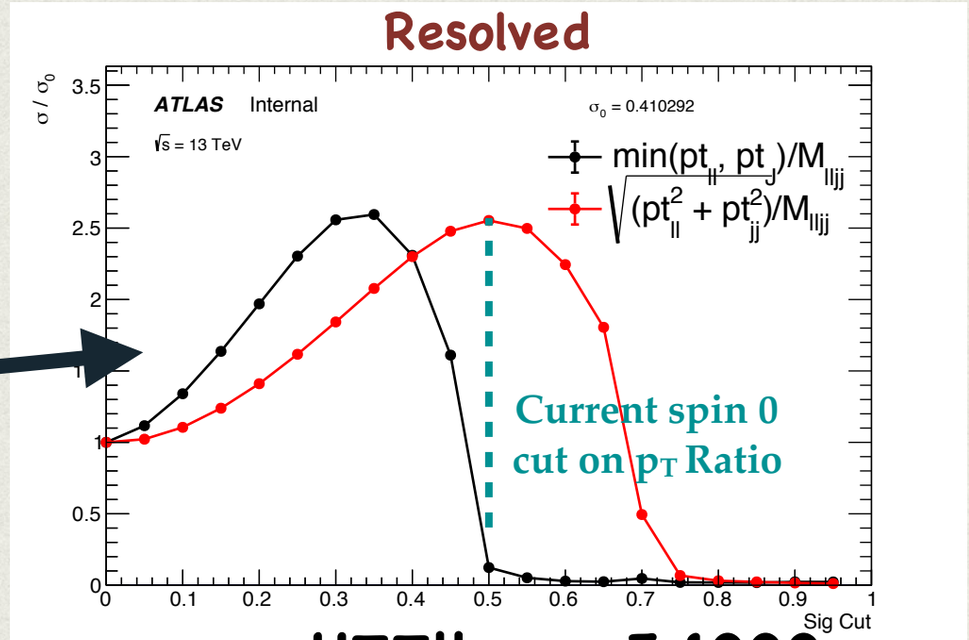
Current spin 0 cut on p_T Ratio

$$\sqrt{p_{Tll}^2 + p_{jj}^2} / M_{lljj} > 0.4$$

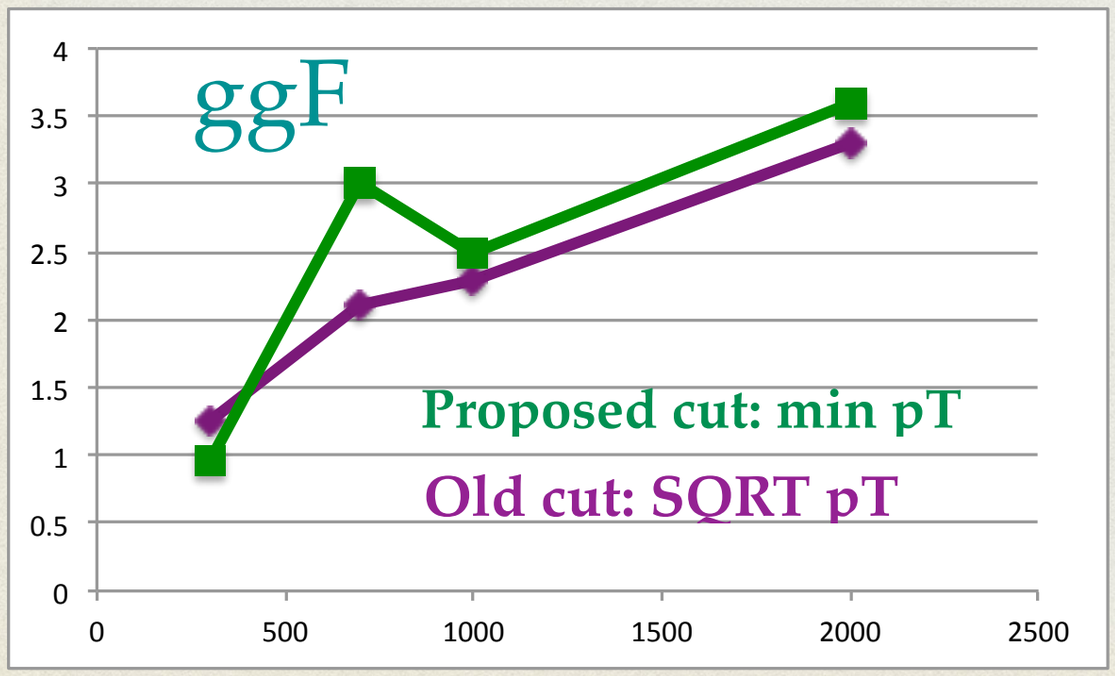
p_T Ratio cut for Resolved Selection

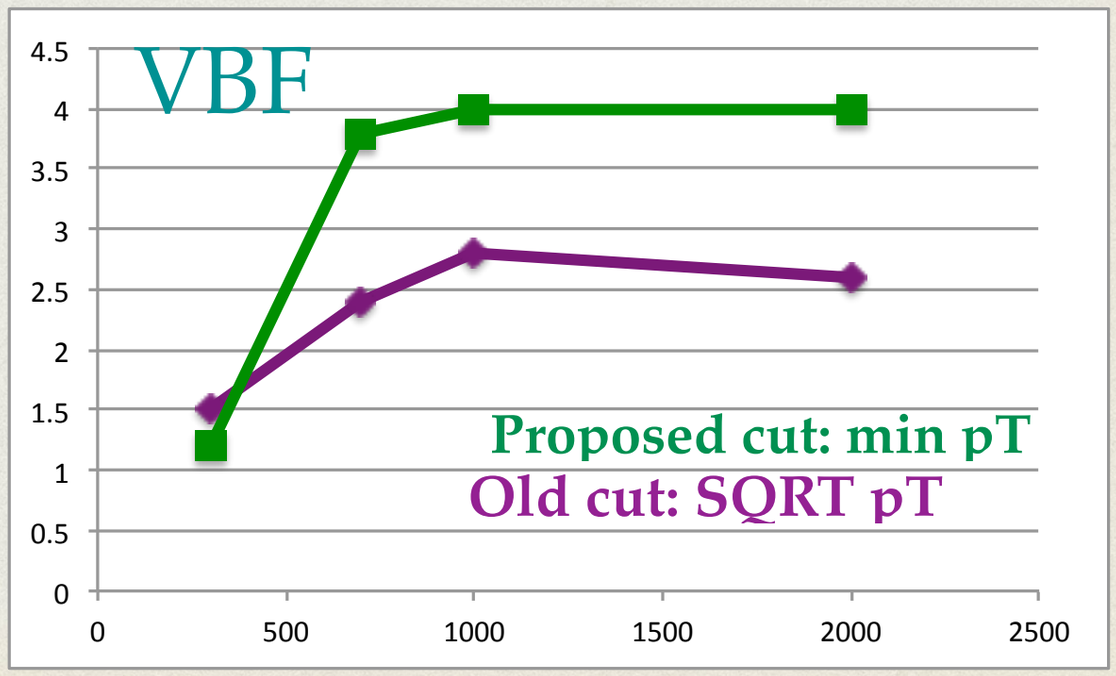
$$\min\left(p_{Tll}, p_{TJ}\right) / M_{llJ} > 0.3$$

p_T Ratio cut for Merged Selection



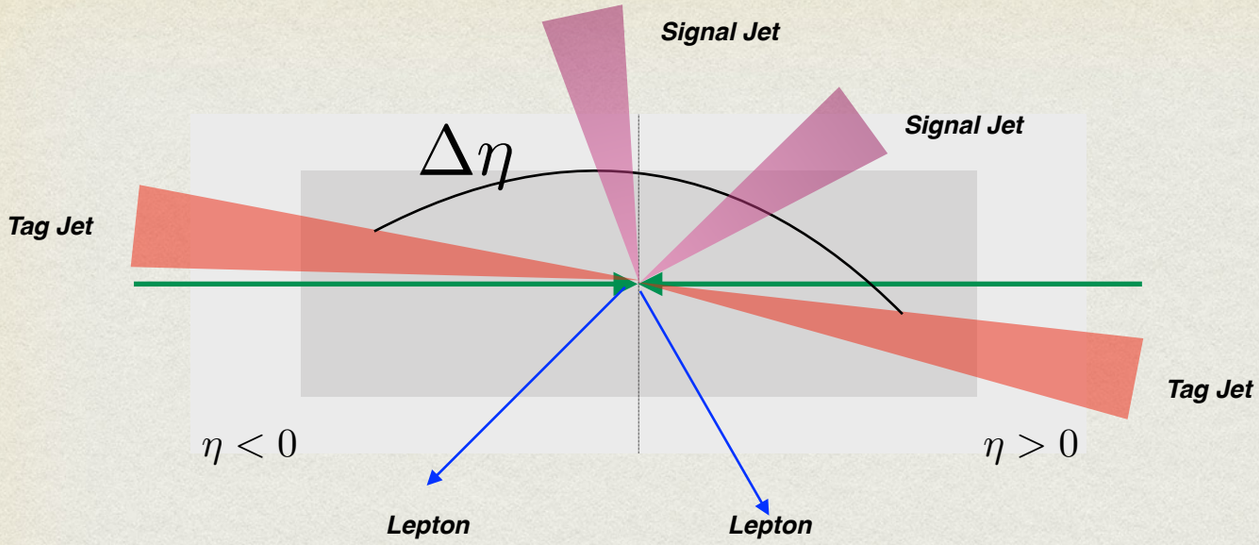
Gain in significance





VBF/GGF CATEGORISATION: HOW?

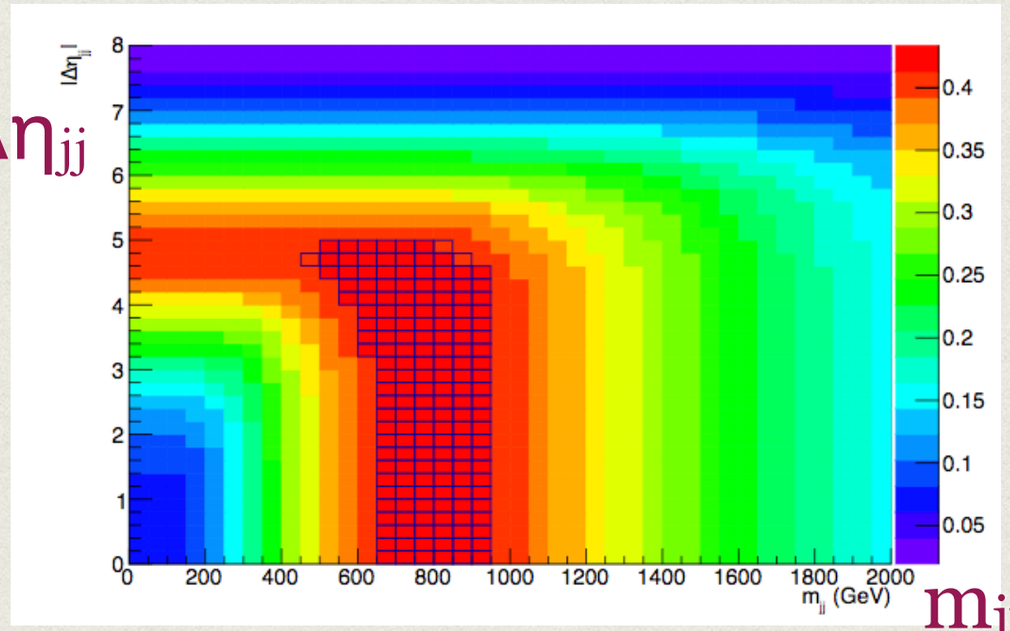
We have been interested in the VBF/ggF categorisation problem inside the X —> ZV—> llqq analysis from some years.

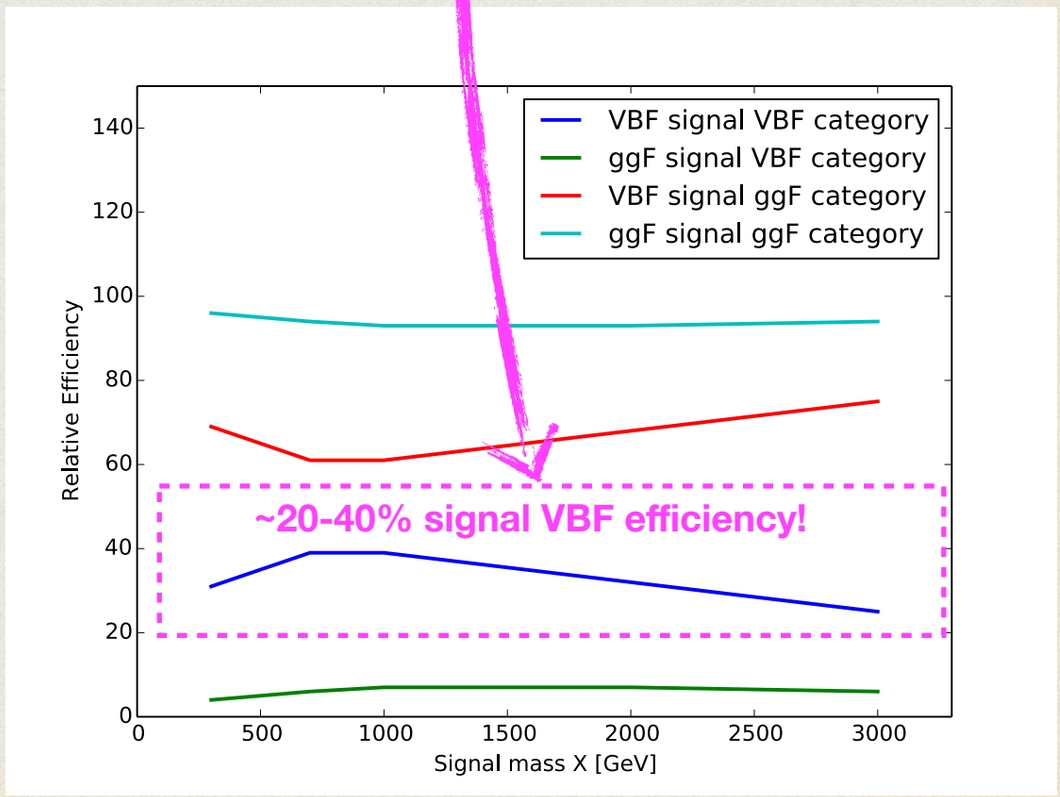


Current Selection

1000 GeV	VBF category	ggF category
VBF Signal	40%	60%
ggF Signal	6%	94%

2015-2016 dataset publication: 2D cut optimization

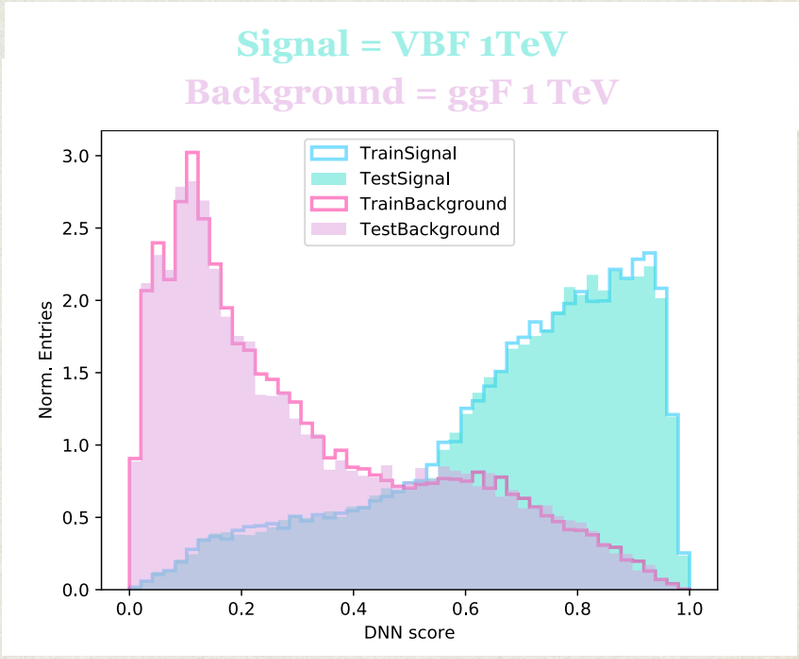




$$\epsilon_{VBF}(1-\epsilon_{ggF})(1-\epsilon_{Bkg})$$

MACHINE LEARNING APPROACH: DNN CLASSIFICATION

- First attempt to use a Machine Learning Approach to Classification problem (not ROOT based).
- Collaboration with the Lecce group.
- Current implementation: **Deep Neural Network (DNN)** —> updates to **Recursvie Neural Network (RNN)** very soon



What we have learned up to now:

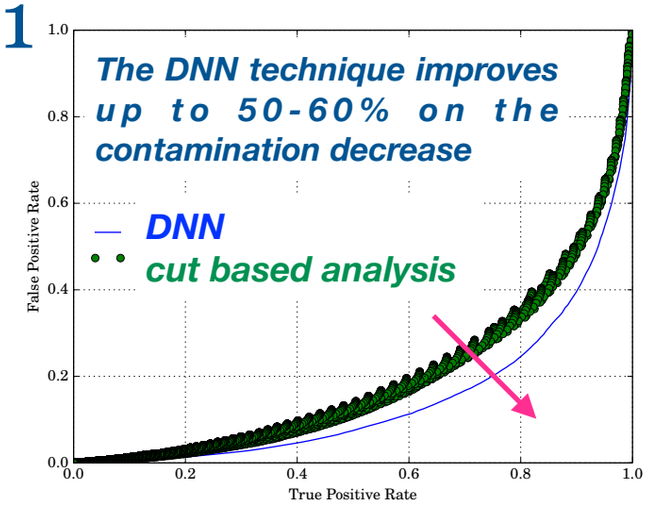
1.DNN improve the 2D cuts significance as expected

2.Low level variables (jets 4-momenta) over perform high level variables

3.The DNN performances improve for higher mass signals —> implementation ongoing of the parametrised NN (10.1140/epjc/s10052-016-4099-4)

4.See next slides…

1



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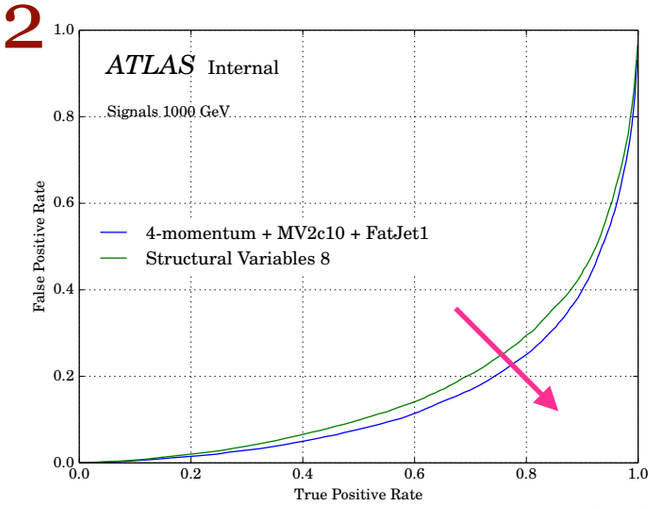

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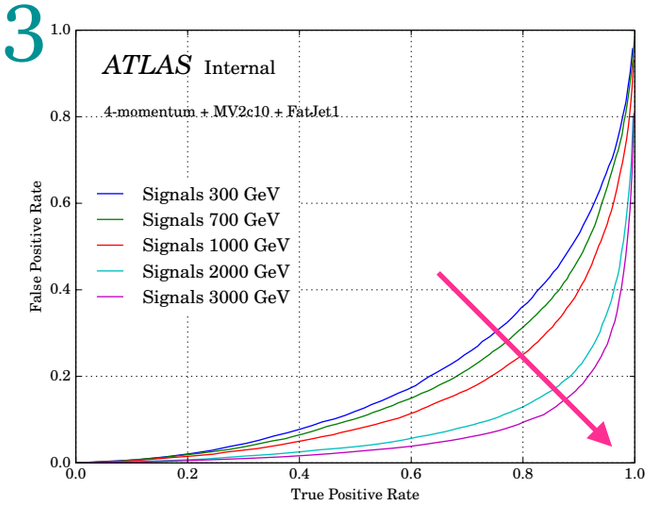
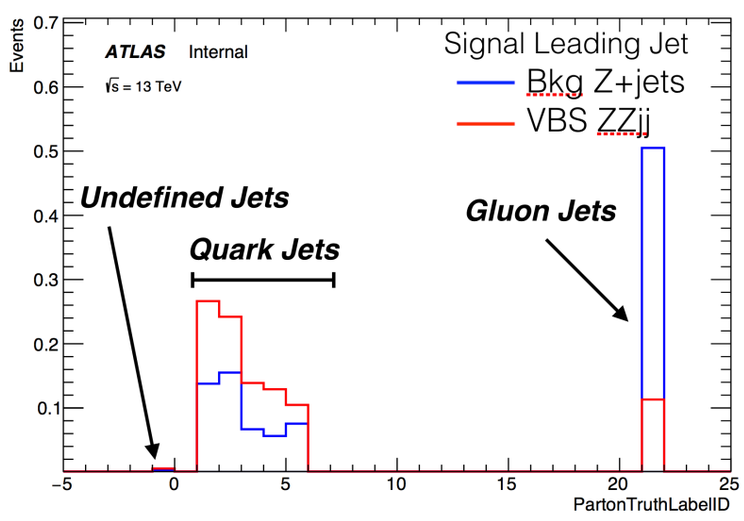


QUARK/GLUON TAGGING: NTRACKS CUT BASED TAGGER

Gluon jets are expected to have more tracks multiplicity than the Quark jets —> The official tagger uses the number of tracks inside the small-R jets.

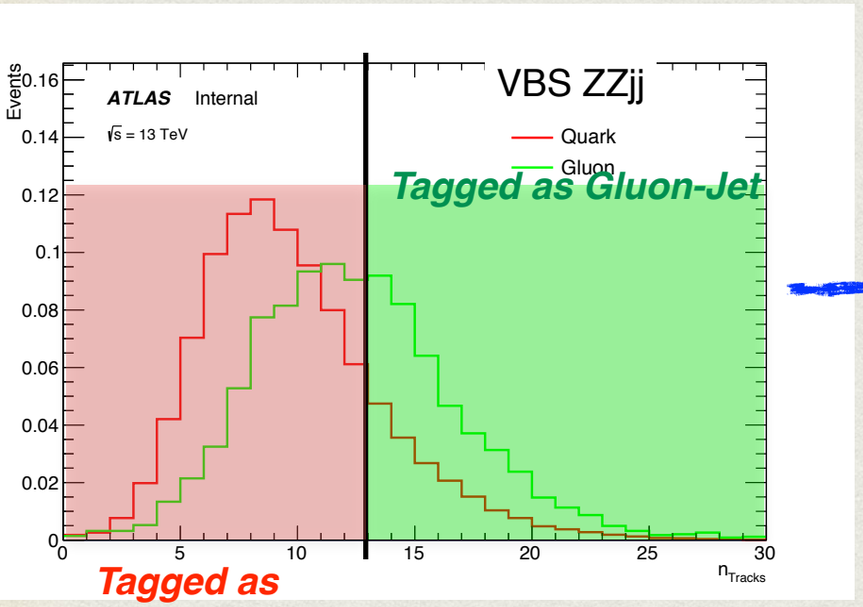
Removing gluon jets considering the truth flavour.

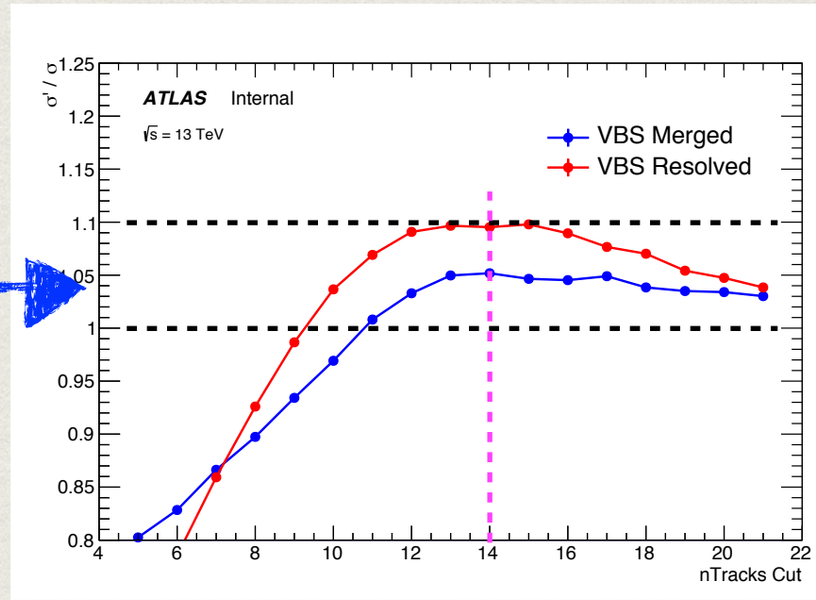


	Quark	Gluon
VBS ZZjj	88%	12%
Bkg Z+jets	49%	51%

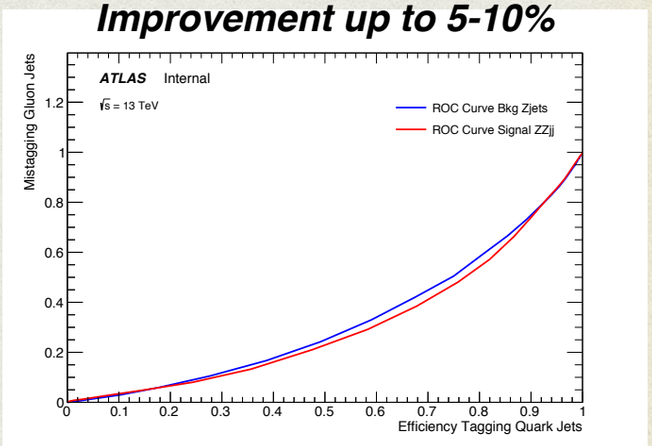
MC truth

Tagging gluon jets using the nTracks variable





Improvement up to 5-10%

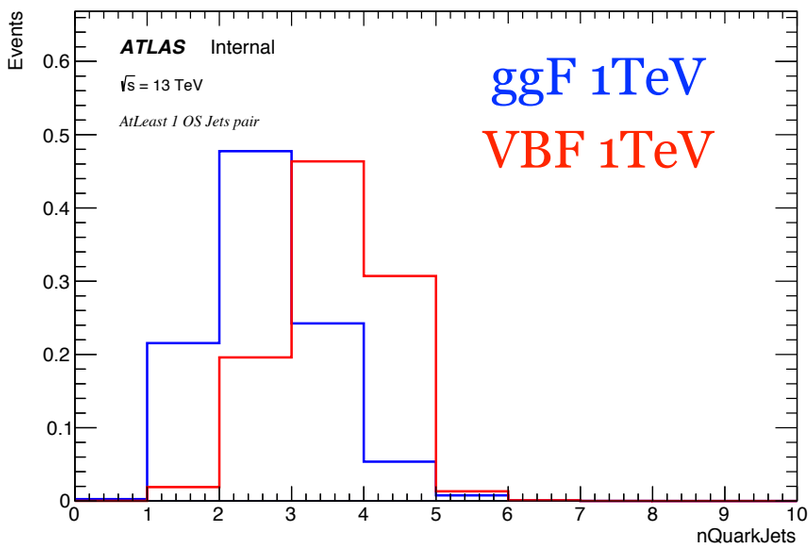


https://indico.cern.ch/event/663471/contributions/2755449/attachments/1541177/2416925/VBSMeeting_16oct2017.pdf

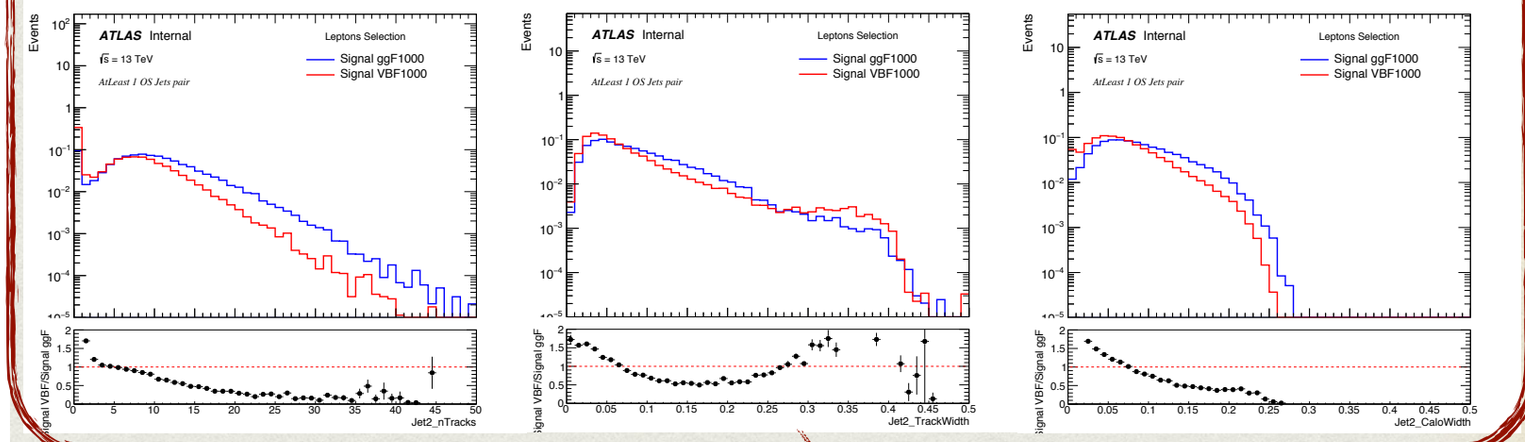
QUARK/GLUON TAGGING: IMPLEMENTATION IN DNN

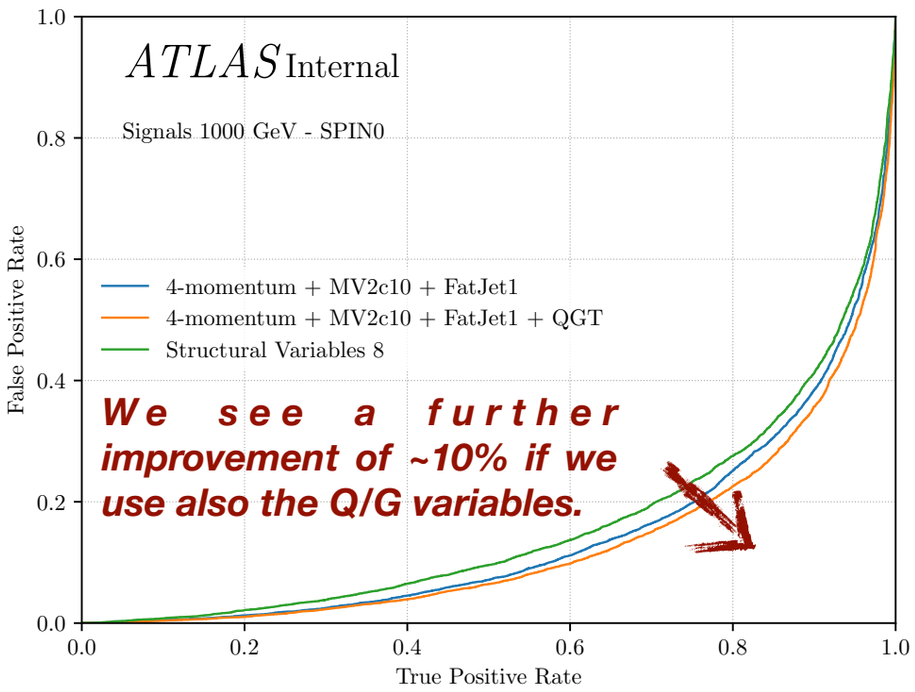
According to the event topology, the **VBF process** is expected to have **2 additional QUARK jets**.

Number of Quark Jets



number of tracks ***tracks width*** ***calo width***





What we are learning from DNN:

4. **Quark/Gluon informations play also an important role in the VBF/ggF discrimination (more than expected!)**

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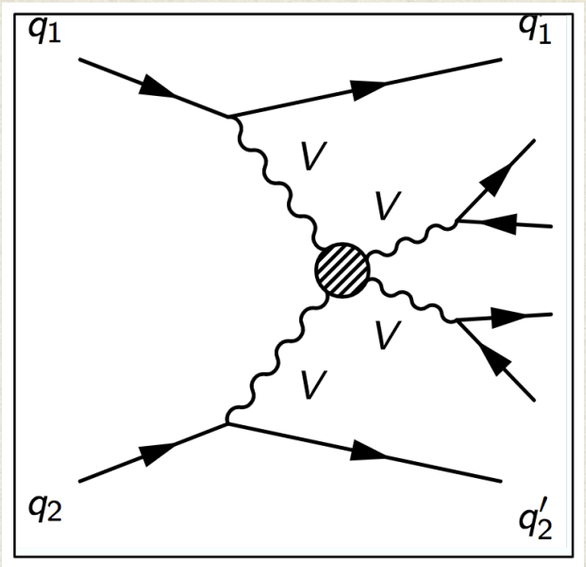
- https://indico.cern.ch/event/741959/contributions/3122767/attachments/1708103/2752732/DBLAnalysis_meeting_30ago18.pdf

VECTORBOSONSCATTERING



***Analysis motivation*:**

a unique way to probe Electroweak Symmetry Breaking

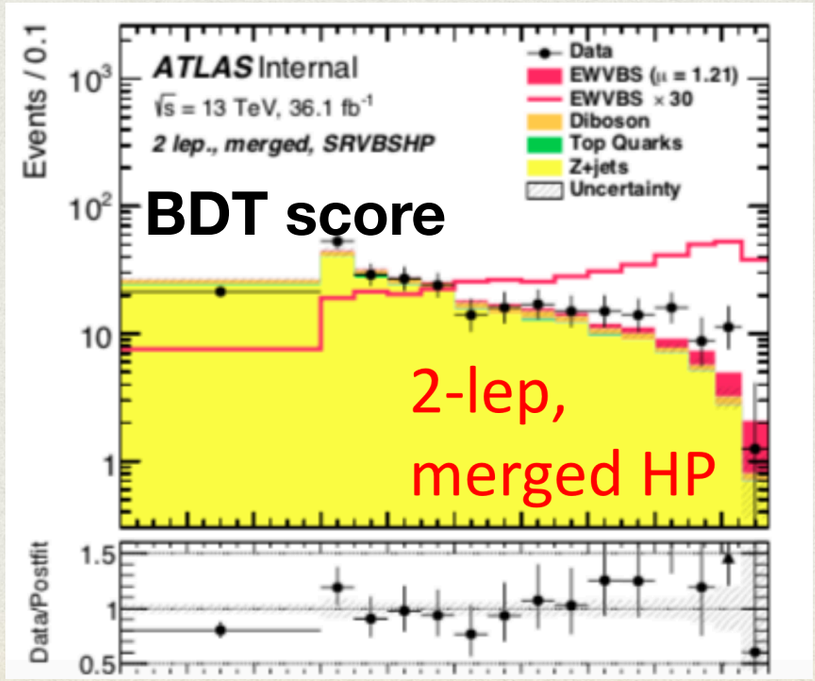
- Current measurement: VBS VV cross section measurement; (Paper with 2015+2016 data, under **EB approval**)
- Next —> Anomalous quartic gauge coupling (aQGC) indicate scale of new physics
- (aiming for PUB with full Run-II dataset—> end of 2019)

Analysis selection —> **ll/lv/vv + qq + 2 tag jets**
(similar to resonant searches in DBL);

Analysis strategy:

- Main backgrounds, V+jets (~92%), top (~5%), diboson (~3%).
- Various data control regions are defined to constrain the modelling of the major backgrounds: V+jets and tt-bar.

- **Simultaneous fit in all regions using the BDT score as discriminant variable**



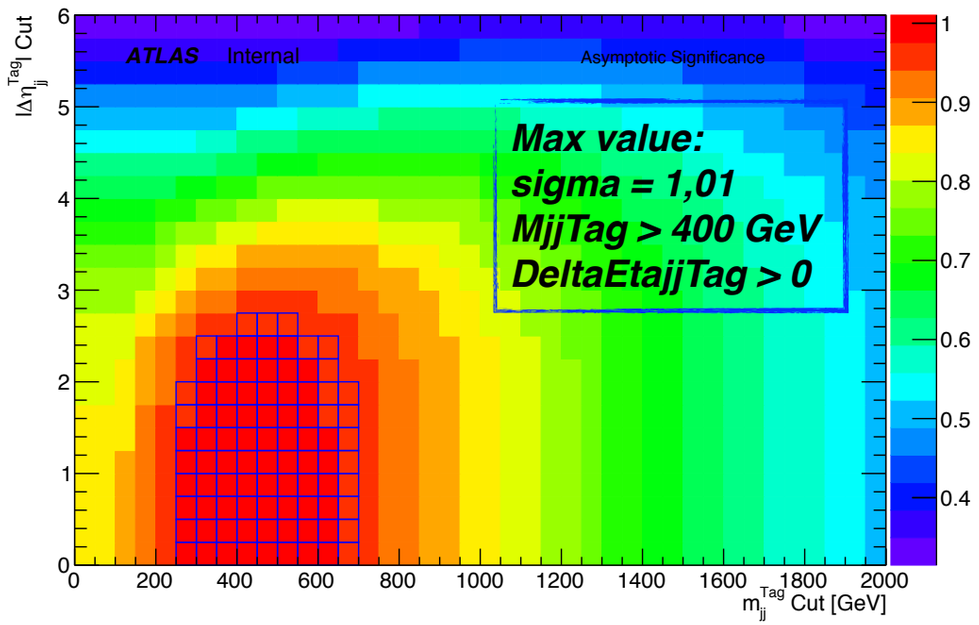
Q/G related variables in BDT

Variable	0-lepton	1-lepton	2-lepton
$M_{tag\ jets}$	✓	–	✓
E_T^{miss}	✓	–	–
$\Delta\eta(tag\ jet_1, tag\ jet_2)$	–	–	✓
$\Delta\eta(j_1, j_2)$	✓	✓	✓
$p_T^{sig\ j_1}$	✓	–	–
$p_T^{sig\ j_2}$	✓	✓	✓
$\eta(\ell)$	–	✓	–
$\Delta R(\ell, \nu)$	–	✓	–
$width(sig\ jet_1)$	✓	✓	✓
$width(sig\ jet_2)$	✓	✓	✓
$N_{trk}(sig\ jet_1)$	✓	✓	✓
$N_{trk}(sig\ jet_2)$	–	✓	–
$p_T^{tag\ jet_1}$	✓	✓	–
$p_T^{tag\ jet_2}$	✓	✓	✓
$width(tag\ jet_1)$	✓	✓	✓
$width(tag\ jet_2)$	✓	✓	✓
$N_{trk}(tag\ jet_1)$	✓	✓	✓
$N_{trk}(tag\ jet_2)$	–	✓	✓
$N(track\ jets)$	✓	✓	✓
$N(additional\ jets)$	✓	–	–
M_{VV}	–	–	✓
$M_{VVj^{tag}j^{tag}}$	–	✓	–
ζ_V	–	✓	✓

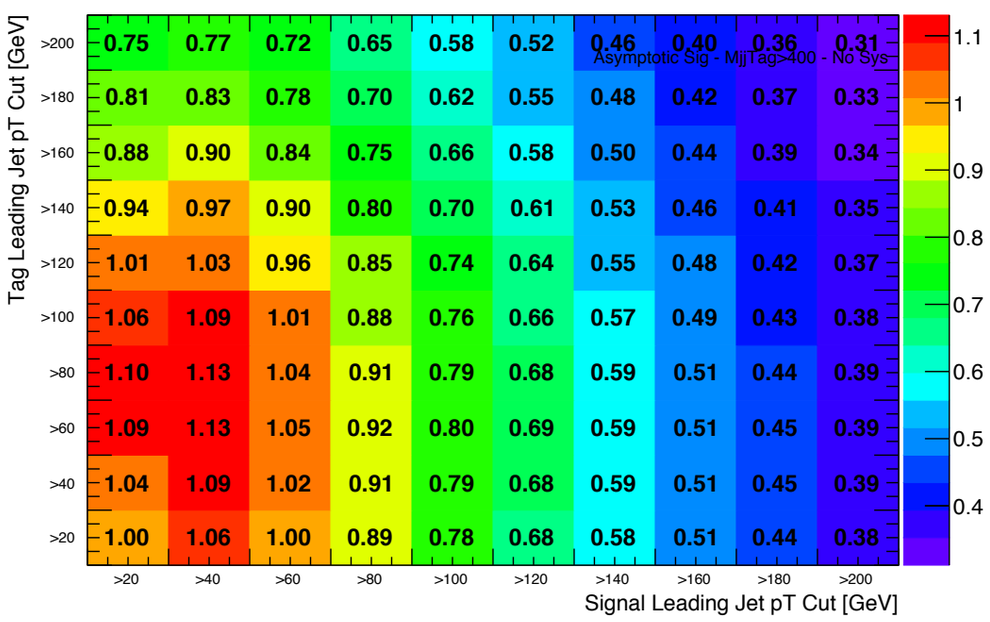
VBS ANALYSIS: CONTRIBUTIONS

For the VBS analysis we contributed also on some analysis optimisation:

m_{jj}^{Tag} and $|\Delta\eta_{jj}^{Tag}|$ cut optimisation



pT cut of the 2 Signal jets coming from the V



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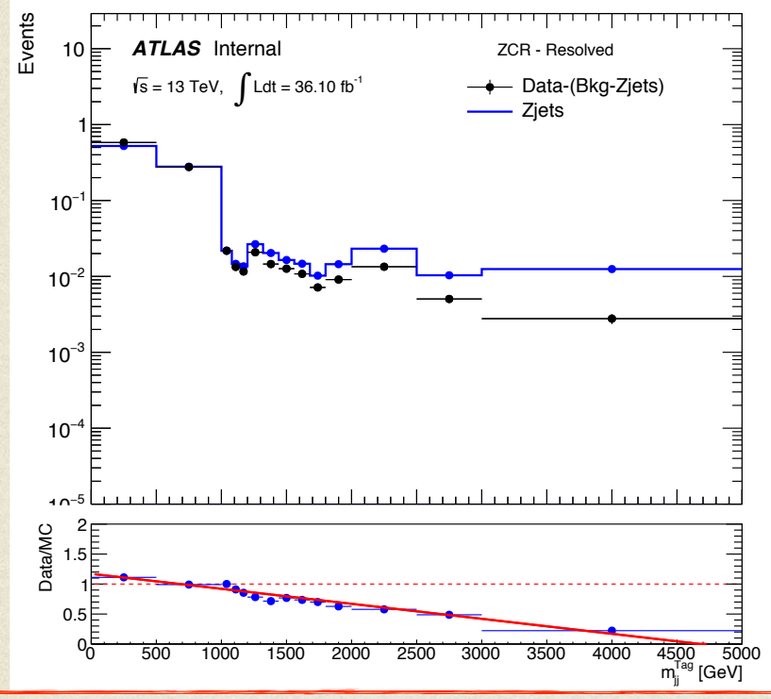
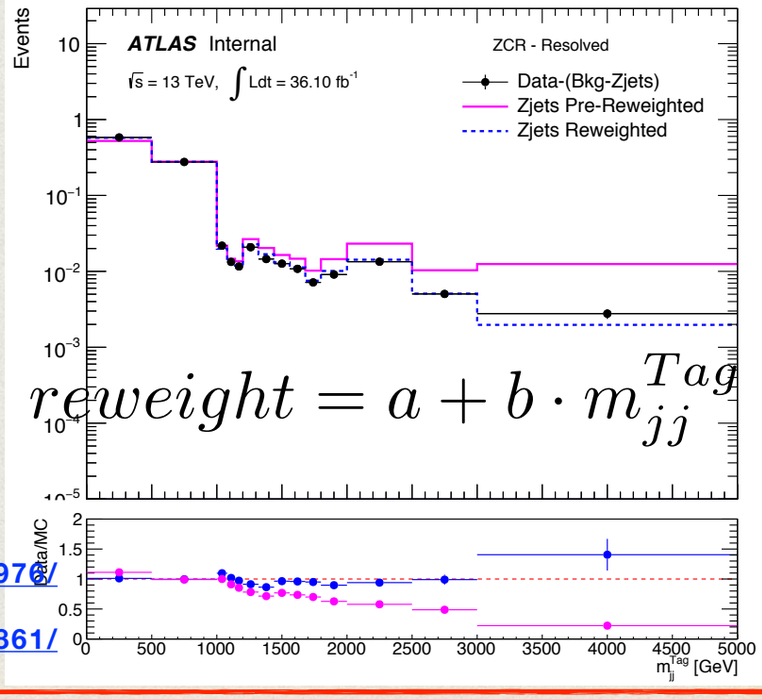
- https://indico.cern.ch/event/680525/contributions/2885352/attachments/1595050/2525918/VBSMeeting_5feb18.pdf



MjjTag reweighting for Z+jets

after re-weighting

The Sherpa MC is affected by some mis-modelling of the Mjj variable;



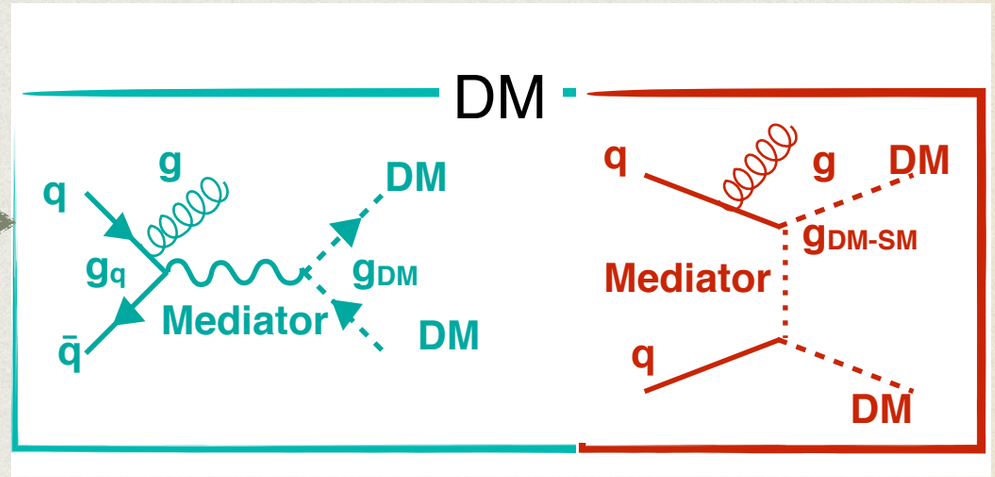
$$reweight = a + b \cdot m_{jj}^{Tag}$$

- https://indico.cern.ch/event/680531/contributions/2939976/attachments/1619394/2575454/VBSMeeting_19mar18.pdf
- https://indico.cern.ch/event/680533/contributions/2957861/attachments/1627006/2591358/VBSMeeting_4apr18.pdf

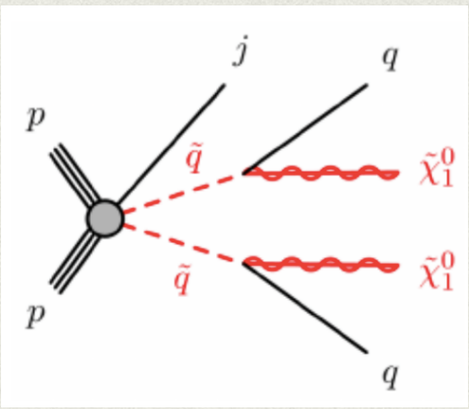
JDM:SEARCHES WITH JETS AND MISSING ENERGY IN THE FINAL STATE - MONOJET ANALYSIS

Search for Dark Matter particles

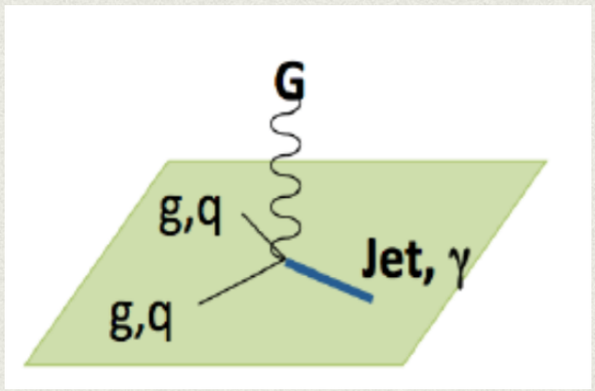
- **Dark Matter**: simplified models describing interaction between DM and SM particles through a mediator M (4 parameters: DM and Mediator masses, couplings)



- **SUSY compressed scenario**: a model where the sparticle mass difference is small. The particle decay products lead to a monojet signature

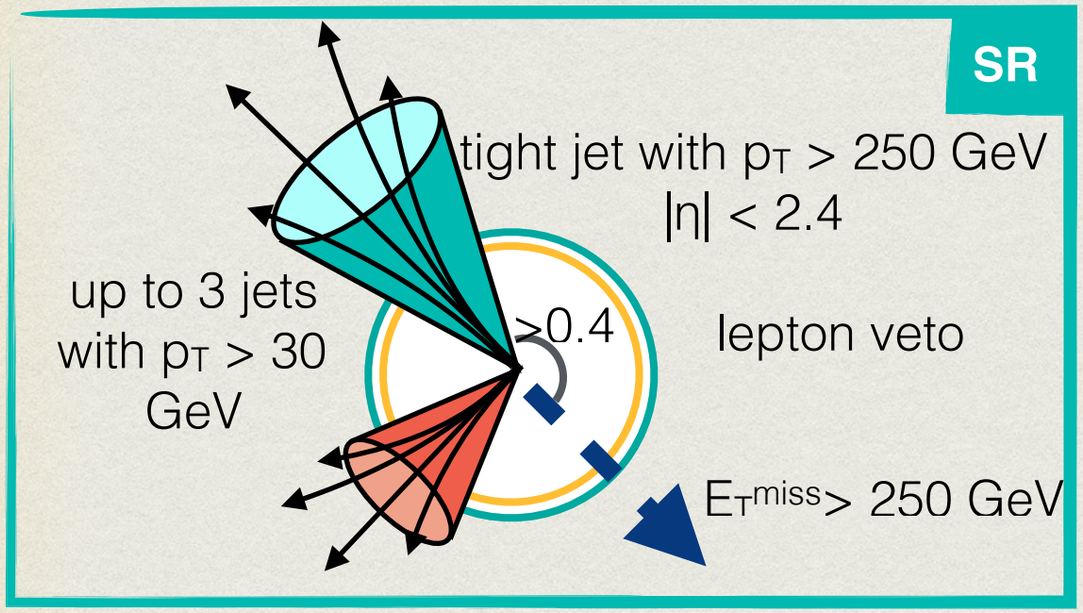


- **Large extra dimension**: graviton produced in association with a jet. The graviton escape detection leading to missing energy in the detector

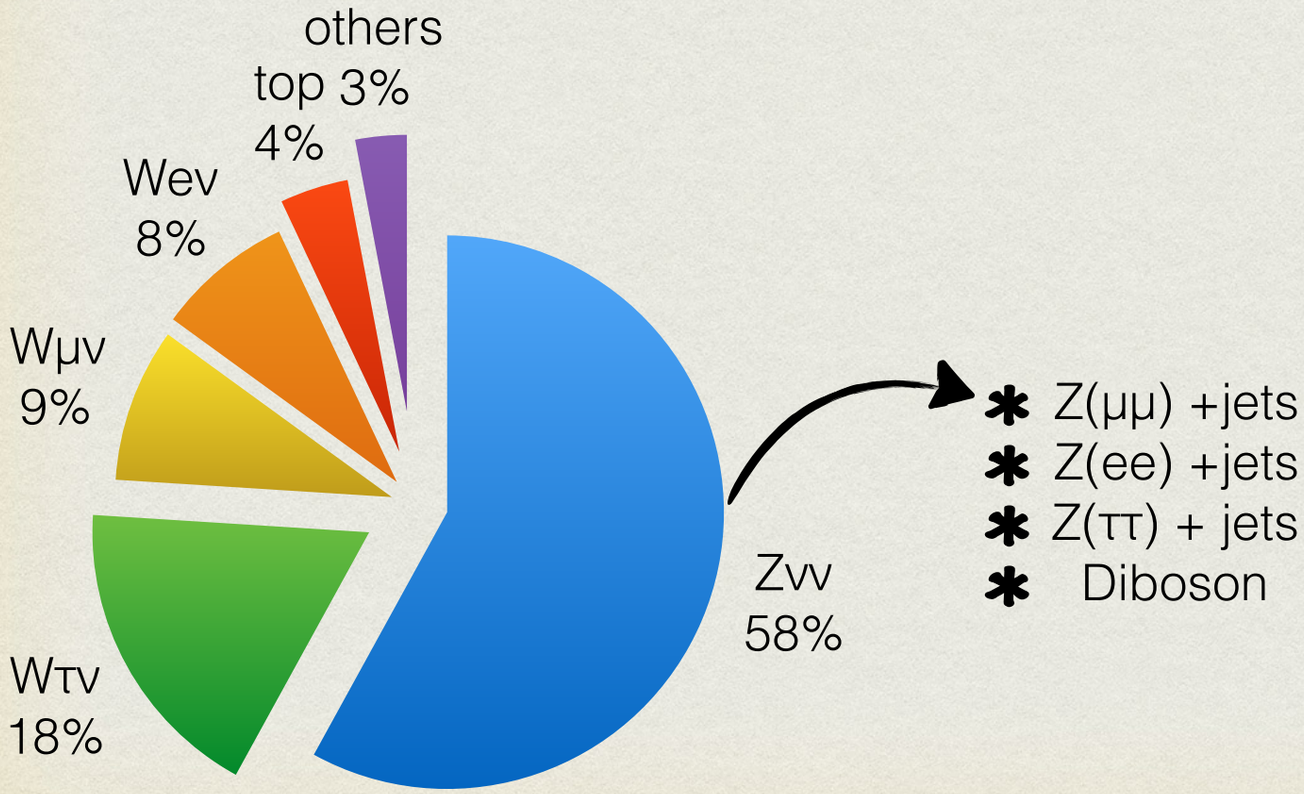


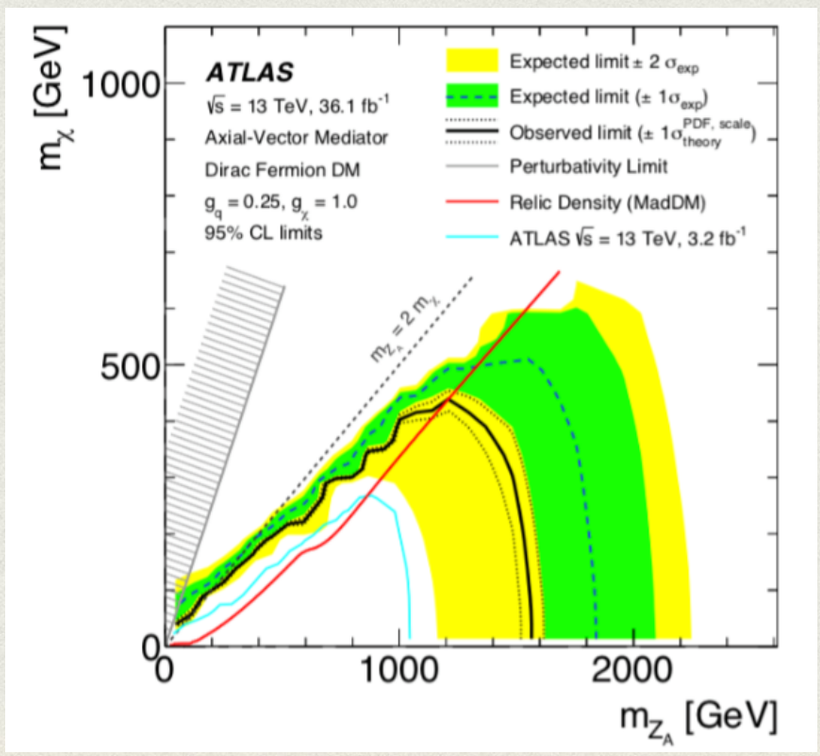
best channel if tagging object comes from ISR

JDM:SEARCHES WITH JETS AND MISSING ENERGY IN THE FINAL STATE - MONOJET ANALYSIS



- Dominant backgrounds (Z+jets, W+jets, top) estimated with a semi data-driven approach
  - ↪4 CRs defined inverting lepton veto criteria and with a kinematic as close as possible to SR
  - ↪Simultaneous fit, exploiting E_T^{miss} shape information (Precision on the background estimate: 2-7%)
- Model dependent/independent interpretation
  - ↪Set limits on model, on DM and mediator masses





JDM:SEARCHES WITH JETS AND MISSING ENERGY IN THE FINAL STATE - MONOJET ANALYSIS

Papers:

Search for dark matter produced in association with bottom or top quarks in √s=13 TeV pp collisions with the ATLAS detector (2018) European Physical Journal C, 78 (1), art. no. 18.

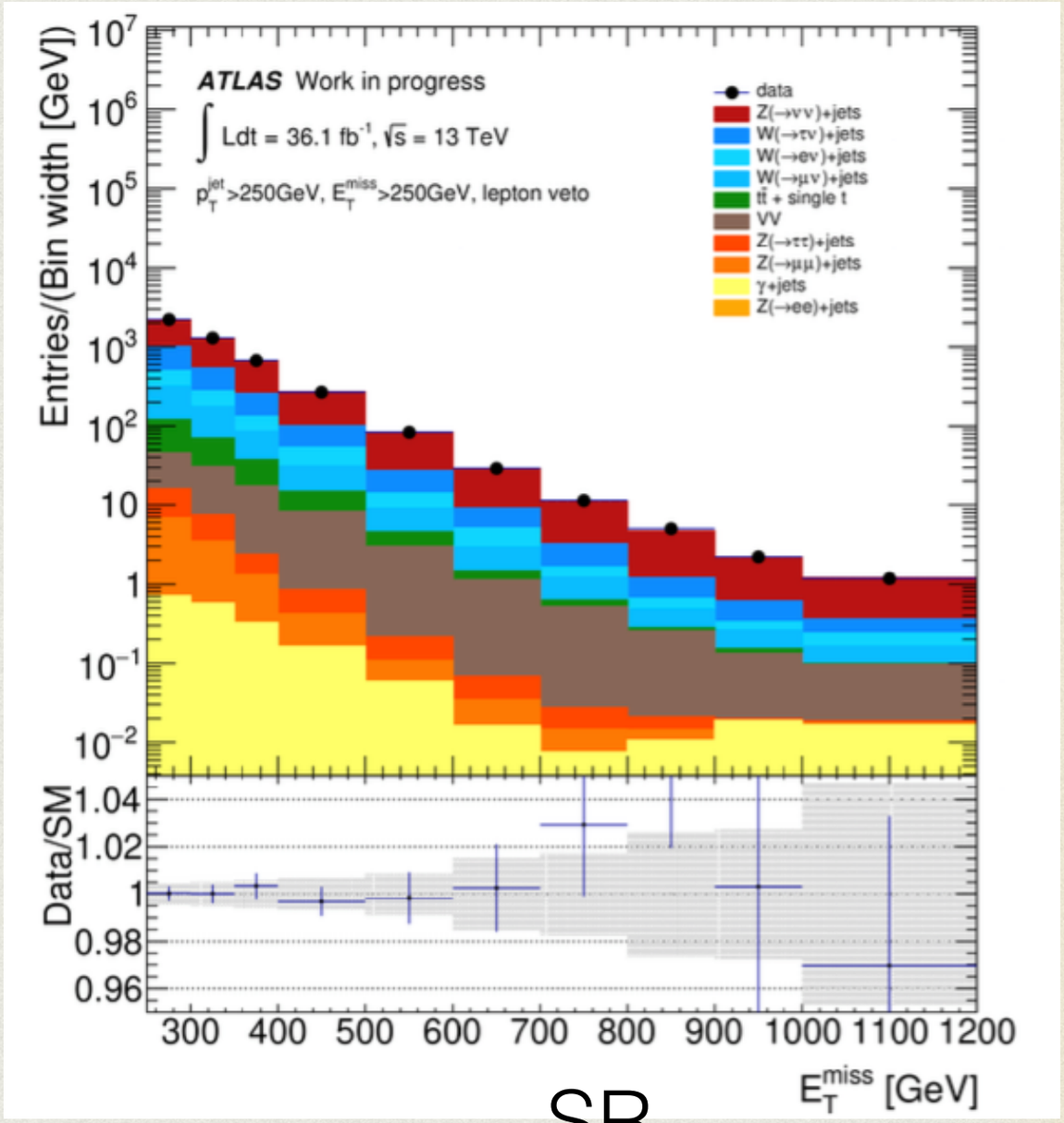
Search for dark matter and other new phenomena in events with an energetic jet and large missing transverse momentum using the ATLAS detector (2018) Journal of High Energy Physics, 2018 (1), art. no. 126.

Napoli's contribution

- Code development
  - ↪ Developed all MJ analysis code within R21 framework
- Data/MC
- Background estimation
- Interpretation

Ongoing work

- Software implemented
  - ↪ Now working with JDM contact person to implement a common interface for future recasting
- Working on the definition of a photon CR
  - ↪ Check the impact on background estimations —> Seems not very helpful
- Look at 2018 data sample
- Moving to most updated MC derivations
- Lowering MET threshold (trigger studies)
  - ↪ Study impact of QCD
- **Aim to have a paper for Moriond 2019**



SR

RESPONSIBILITIES IN SERVICE TASKS WITH OTP CREDITS

- Marco Exotic MC Manager —> Responsible for the MC production for the Exotic Group

- Antonio —> Coordinator of the Derivation production for DBL group —> data format used in DBL analyses

- Antonio —> is part of the CP Jet group and he is one of the developer of QG Tagger Tool in Derivation Framework in rel21