LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS

partículas e tecnologia

Portuguese ATLAS Activities

The Portuguese ATLAS team

National group:

LIP (Lisbon, Coimbra, Minho)

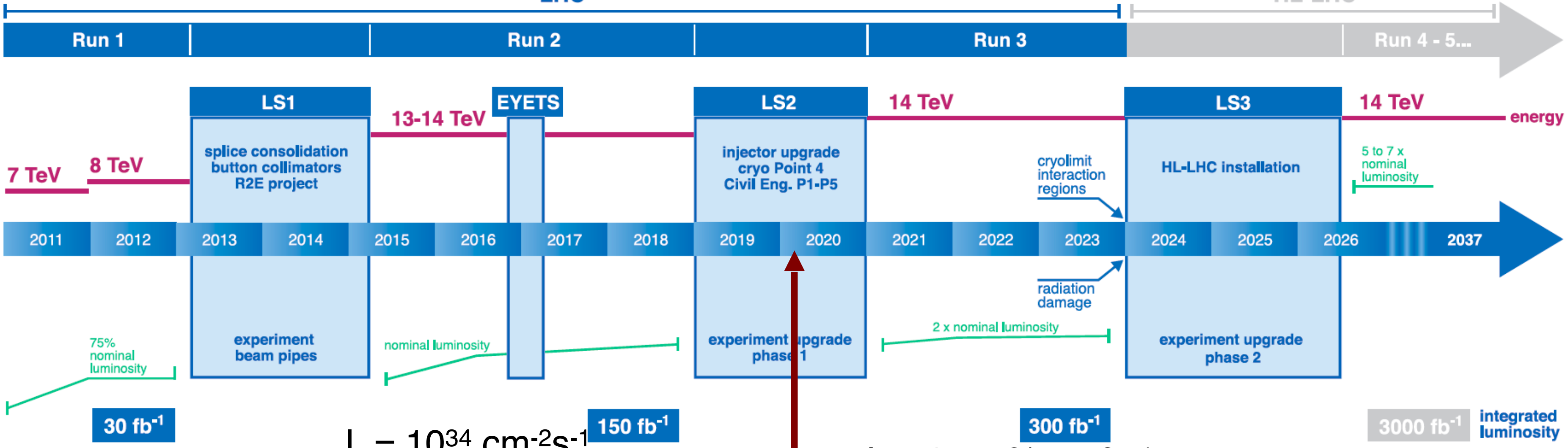
FCUL, FCTUC, U. Minho, CFNUL

CEFITEC/UNL, INESC, CFMC, IBEB

AdI engineers training program

LHC / HL-LHC Plan

Run I   Run II   Run III   Run IV



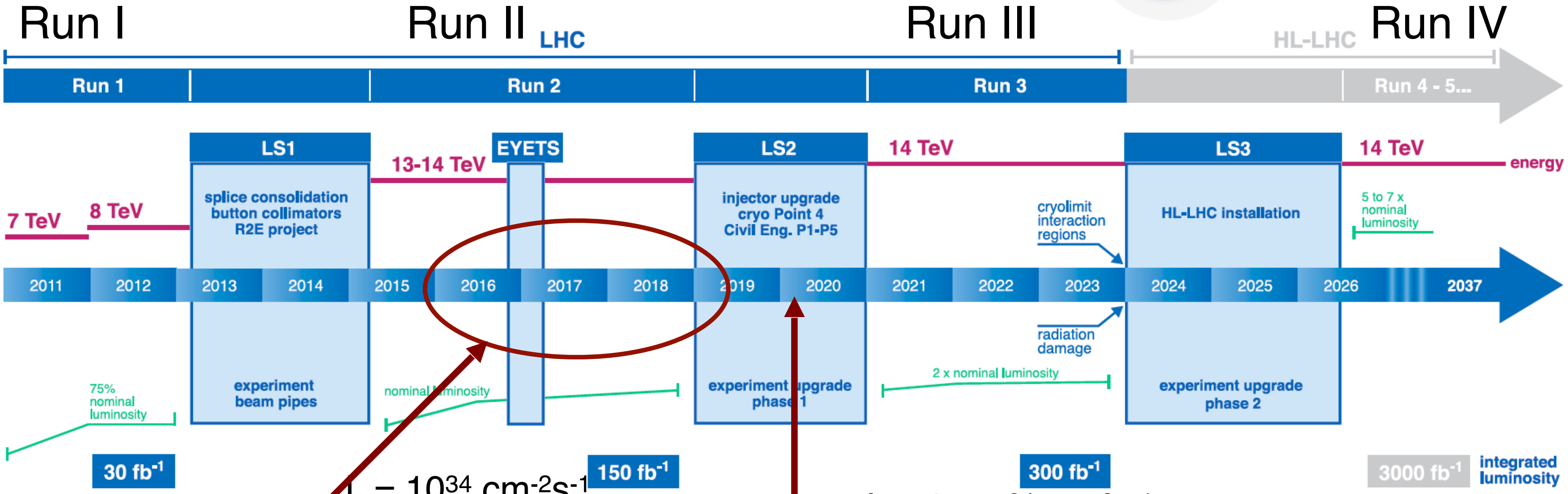
$L = 10^{34}\ cm^{-2}s^{-1}$

$L = 2\times10^{34}\ cm^{-2}s^{-1}$

$L = 5\times10^{34}\ cm^{-2}s^{-1}$

Here we are

LHC / HL-LHC Plan



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Run II Analysis

- Higgs couplings to quarks
- Top quark properties
- Exotic particles searches
- b-jet suppression in HI collisions

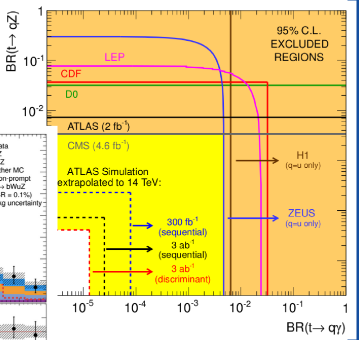
Here we are

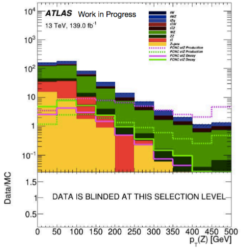
Portuguese contributions
to ATLAS Physics Results

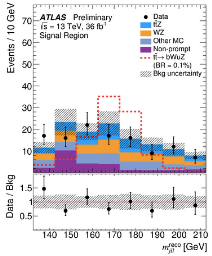
Top quark precision measurements

(F. Veloso, A. Onofre)

Top properties measurements





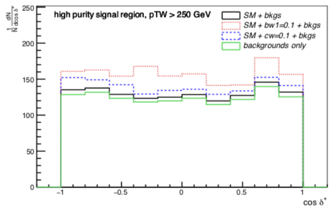


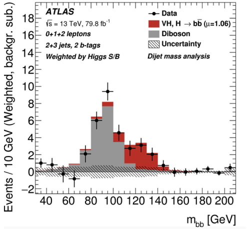
Higgs boson properties

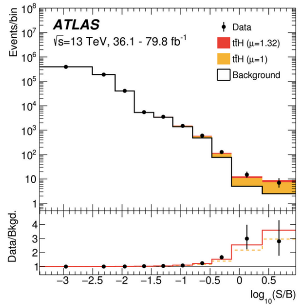
(R. Gonçalo, P. Conde)

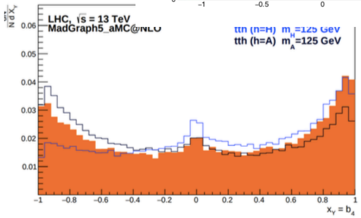
H→WW, H→bb, ttH

Spin/CP properties





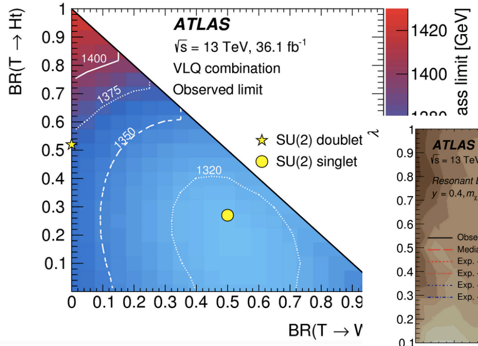


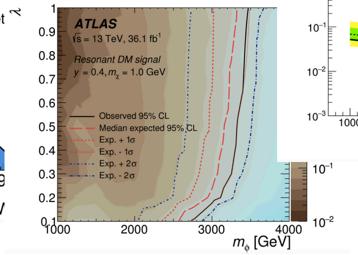


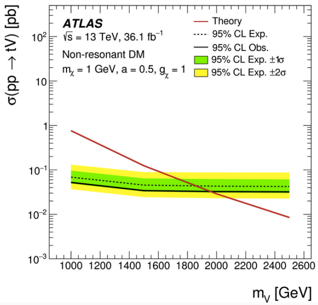
Searches for New Particles & Interactions

(N. Castro) **Vector-like quarks, FCNC, dark matter, ...**

Leading 3 analysis



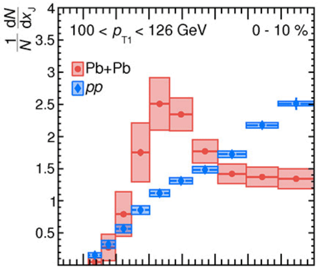


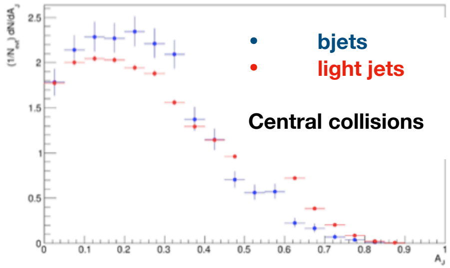


Heavy Ion Physics

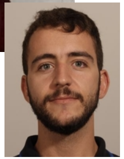
(H. Santos)

QGP jet quenching



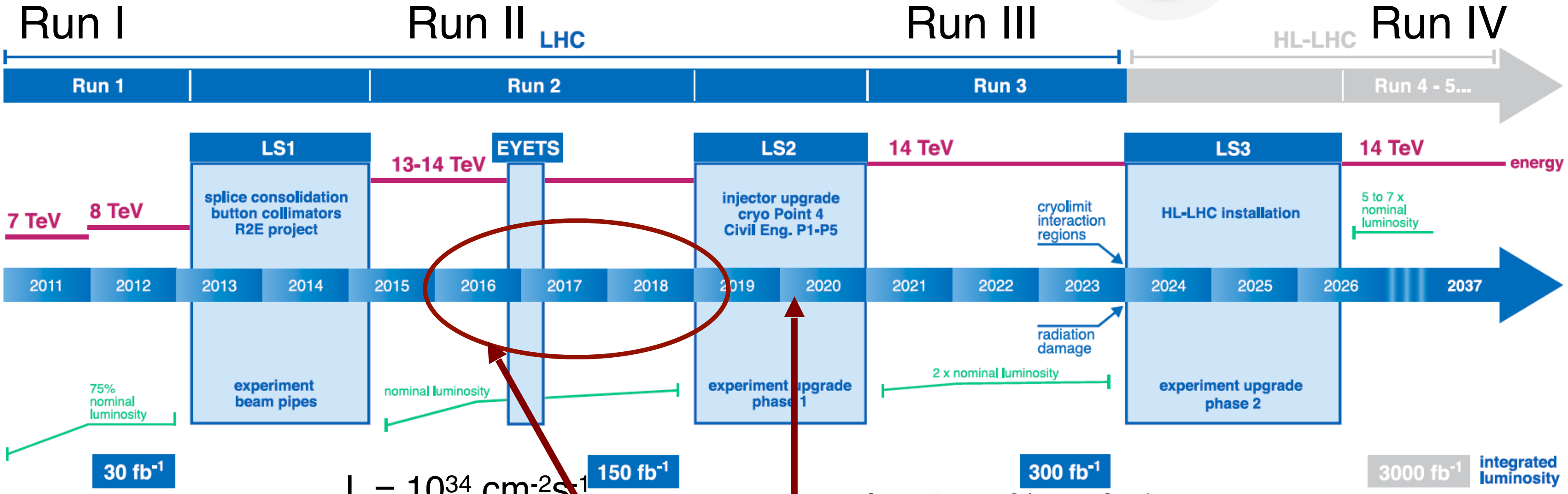


Portuguese contributions to ATLAS Physics Results

- Presentations today:
  - Higgs & Heavy Ions, Emanuel Gouveia 
  - Exotics searches and top properties, Tiago Vale 
- Posters:
  - Sensitivity to anomalous hWW couplings, R. Barrué 
  - Probing the CP nature of the Higgs coupling to top quarks with the ATLAS experiment, E. Gouveia 
  - Search for Flavour Changing Neutral Currents interactions in the tZq vertex with the ATLAS Experiment at 13 TeV, A. Peixoto 
  - Search for vector-like quarks with the ATLAS Experiment, T. Vale 

LHC / HL-LHC Plan

High Luminosity LHC



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Operations and
Phase I Upgrade

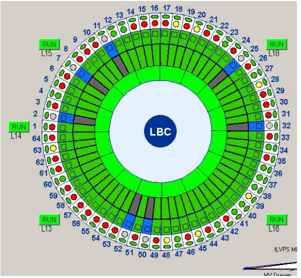
Operations and Phase I Upgrade in ATLAS

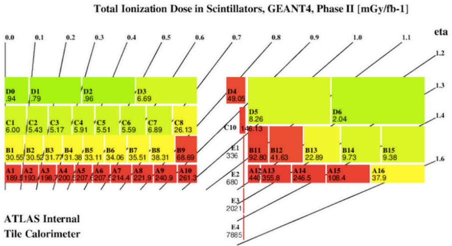
TileCal

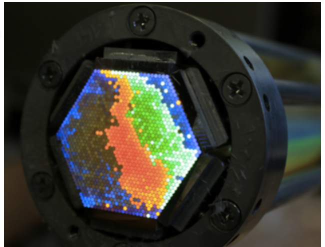
(A. Gomes)

Leading DCS and Calibration

Fibres preparation for Phase I







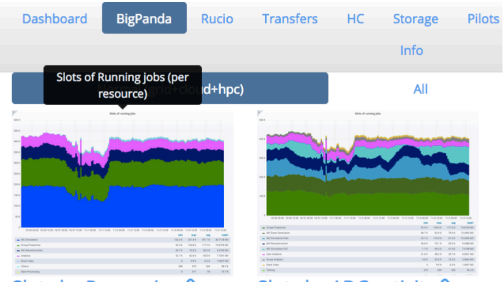
Distributed computing

(H. Wolters)

Iberian cloud coordination

Monitoring tools

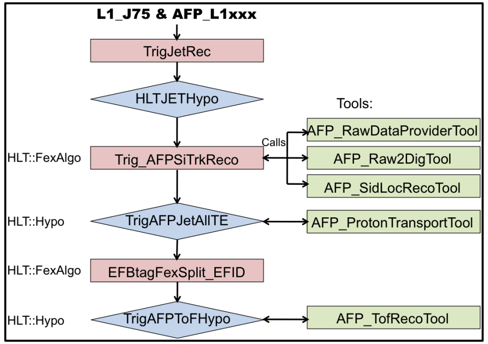
Tier-2 infrastructure responsibility



Jets HLT

(R. Gonçalo)

Operations, validation



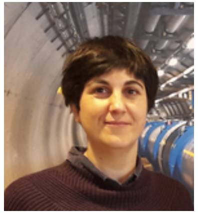
ATLAS Roman Pot Detectors

(P. Conde, N. Castro)

Co-leading DCS

HLT algorithms

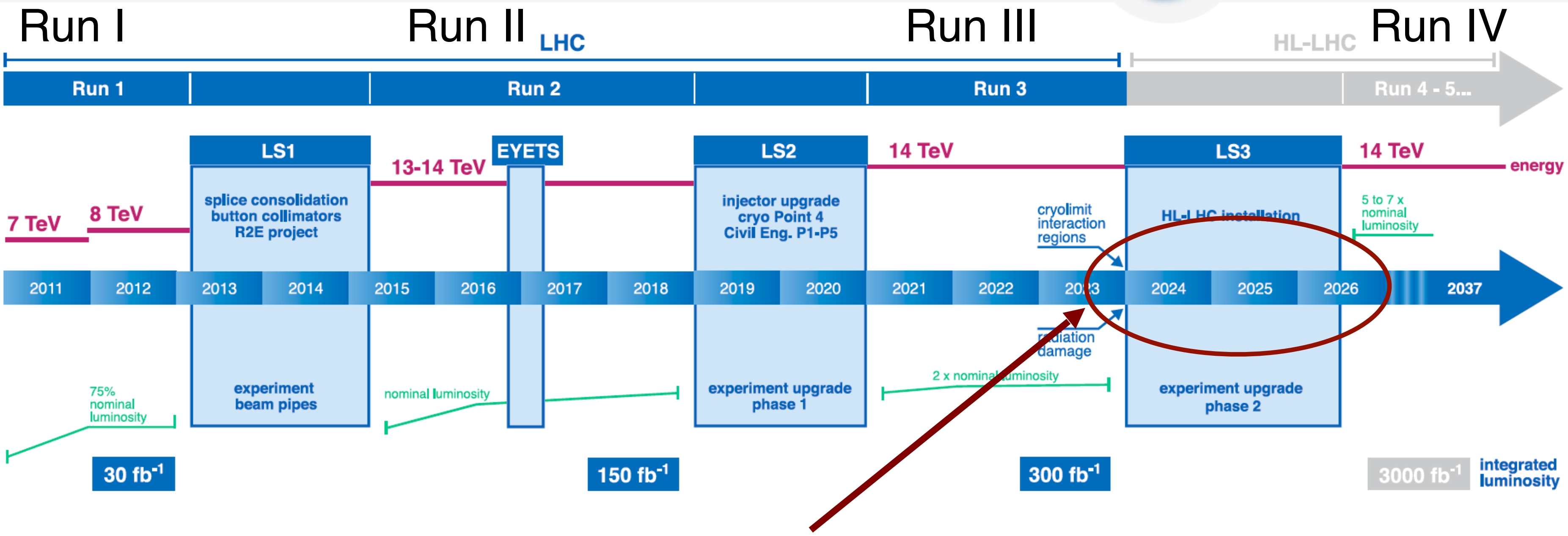
Operations and Phase I Upgrade
in ATLAS



- Presentations today:
  - ATLAS: TileCal Operations, Calibration, Performance and Upgrades, R. Pedro
  - Fibres preparation for the ATLAS MBTS —> LOMAC presentation, J. Gentil

- Posters:
  - TileCal DCS Phase II Upgrade, F. Martins
  - DCS of ATLAS Roman Pots Upgrade for Run 3, L. Seabra

LHC / HL-LHC Plan



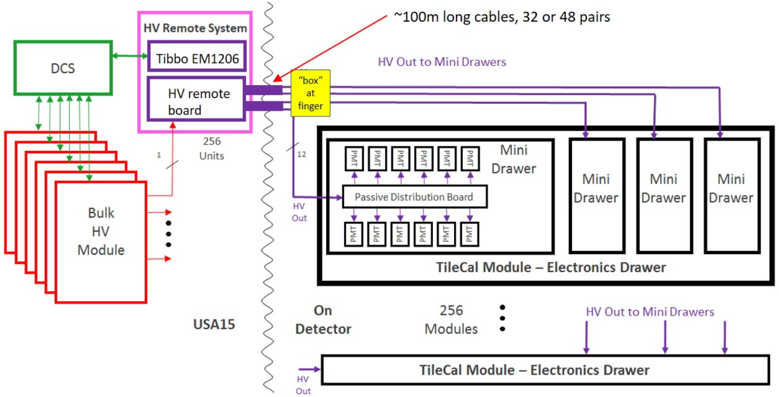
Phase II Upgrade preparations

Current Portuguese Responsibilities
in ATLAS

TileCal Upgrade
(A. Gomes)

Full responsibility on the HV Distribution system

DCS

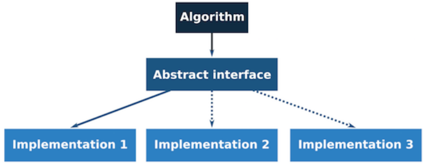


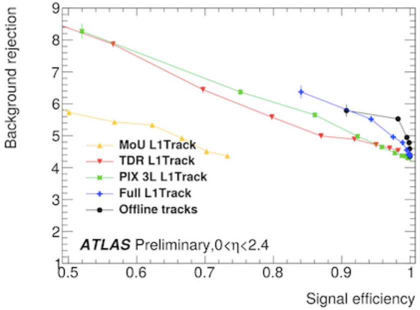
Trigger Upgrade:
(R. Gonçalo, P. Conde Muíño)

Parallel trigger algorithms with GPUs as accelerators

Hardware Track Tricker:

- Fast simulation and performance studies
- Production of a mezzanine board for communications
- DCS





Operations and Phase I Upgrade
in ATLAS

- Presentations today:
  - TileCal HV Distribution system, A. Gomes

- Posters:
  - Power supplies for the high voltage distribution system of the TILECAL in the ATLAS's upgrade, R. Fernandez
  - Software Interface for the TILECAL High Voltage Boards for the ATLAS Phase II Upgrade, F. Cuim
  - The ATLAS Hardware Track Trigger, from simulation to performance, A. L. Carvalho

Responsibilities within collaboration

- P. Conde Muíño, member of the ATLAS Executive Board.
- H. Wolters, coordinator of the Iberian Cloud.
- H. Wolters, responsible for the Portuguese Federated Tier2 in the Iberian Cloud Squad.
- N. Castro, contact person for the effective field theory interpretations of the Top Quark Working Group (since September 2017).
- N. Castro, contact editor for the search for monotop events plus missing energy.
- A. Peixoto, analysis contact for the search for tZ production via FCNC.
- N. Castro, member of the ATLAS Physics Office and coordinator of the gitlab integration team.
- F. Martins, TileCal DCS coordinator.
- L. Seabra, AFP DCS co-coordinator, ALFA DCS responsible.
- P. Conde, member of the Panel for Operation Task Sharing.
- R. Pedro, TileCal Calibration co-coordinator.
- H. Wolters, member of the ATLAS International Computing Board

Thanks!

Acknowledgments

REPÚBLICA PORTUGUESA

FCT Fundação para a Ciência e a Tecnologia

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

ATLAS Group
Higgs + Heavy Ions

Emanuel Gouveia
on behalf of the LIP ATLAS
Higgs and Heavy Ions teams

LIP Jornadas
15th February 2020

Universidade do Minho

IDPASC

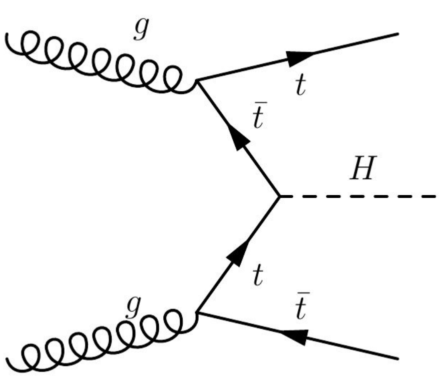
Fundação para a Ciência e a Tecnologia
PD/BD/128231/2016

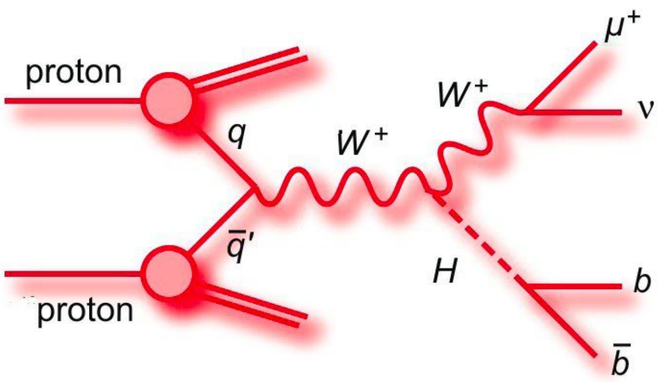
CERN/FIS-PAR/0008/2017
PD/BD/128231/2016

1.
Higgs physics

Motivation

- Studying properties of 125 GeV Higgs boson is a major priority in the LHC programme
- Couplings of Higgs boson to other particles are key to test the EW symmetry breaking mechanism
- **LIP focuses on couplings to 3rd gen quarks and vector bosons**
- Associated production with top quarks (**ttH**) and with W/Z bosons (**VH**). **H⟶bb** decay channel
  - **Direct probes** of the coupling strengths and CP structure





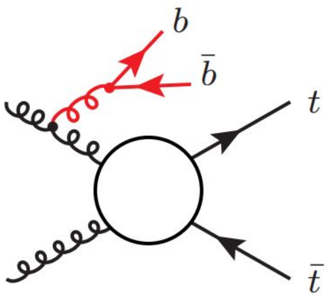
1.1
Higgs physics
ttH

Ana Luísa Carvalho, Patrícia Conde-Muíño, Ricardo Gonçalo,
Emanuel Gouveia, António Onofre

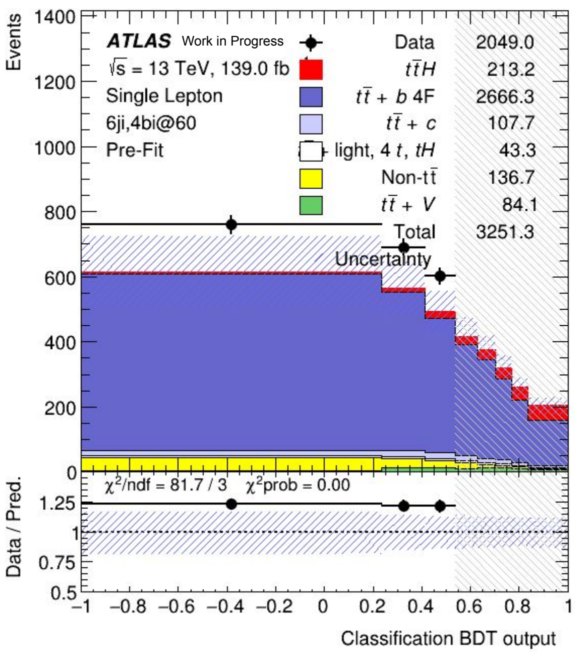
See poster by E.G.

SM tt(H→bb) analysis with leptons Phys. Rev. D 97, 072016 (2018)

- ATLAS observed ttH production in 2018 (Phys. Lett. B 784 (2018) 173)
- New round to improve precision on cross-section, with full Run2 data
- Categories: **dilepton**, **single lepton resolved** and **single lepton boosted**
- Regions with 3 or 4 b-tagged jets, dominated by tt+b background
- Two multivariate discriminants employed:
  - **Reconstruction BDT**
    reconstruct Higgs and top quarks
  - **Classification BDT**
    separate ttH signal from backgrounds
- Profile-likelihood fit to extract signal strength
- Limited by tt+b modeling uncertainties
- Recent improvement: nominal tt+b prediction from tt+bb @NLO

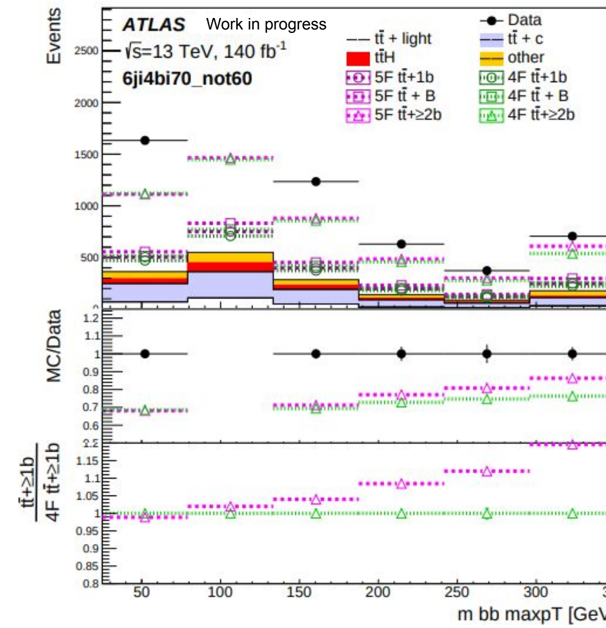


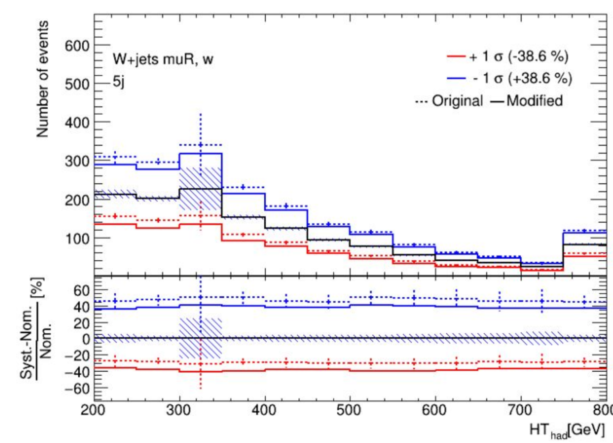
S. Pozzorini



SM tt(H→bb) analysis with leptons

- LIP contributes to analysis of the **single lepton resolved** channel
- Data/MC supporting the change to tt+bb @NLO prediction
- W+jets background
    - Data/MC comparison in control regions
    - Heavy-flavour composition
    - Evaluation of modeling uncertainties
- Studies comparing fit models
    - Expected sensitivities
    - Ability to describe the data
    - Pulls, constraints and correlations
    - Robustness of signal strength when fitting alternative tt+jets model





See posters by E.G. and S. Santos

Measuring CP nature of top-Higgs coupling in tt(H→bb)

$$\mathcal{L}_{tth} = y_t \bar{\psi}_t(\kappa_t + i\gamma_5\tilde{\kappa}_t)\psi_t h$$

- Parametrise signal cross-sections in terms of **κ_t and $\tilde{\kappa}_t$**: $\sigma = \kappa_t^2\sigma_{even} + \tilde{\kappa}_t^2\sigma_{odd}$
- Split regions from the SM analysis based on classification BDT score, to get high signal purity
- Fit distribution of a **CP-BDT**, trained to discriminate CP-even and CP-odd ttH
  - Take advantage of reconstructed Higgs and top quarks
  - Includes variables first introduced in phenomenology work done @ LIP
- Collaborating closely with Manchester group, who focus on the dilepton channel

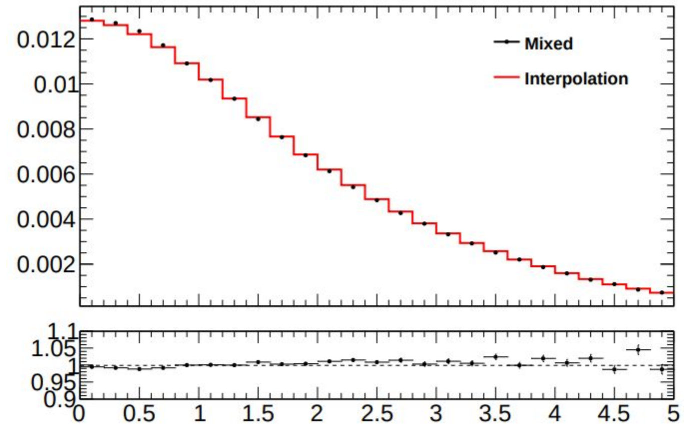
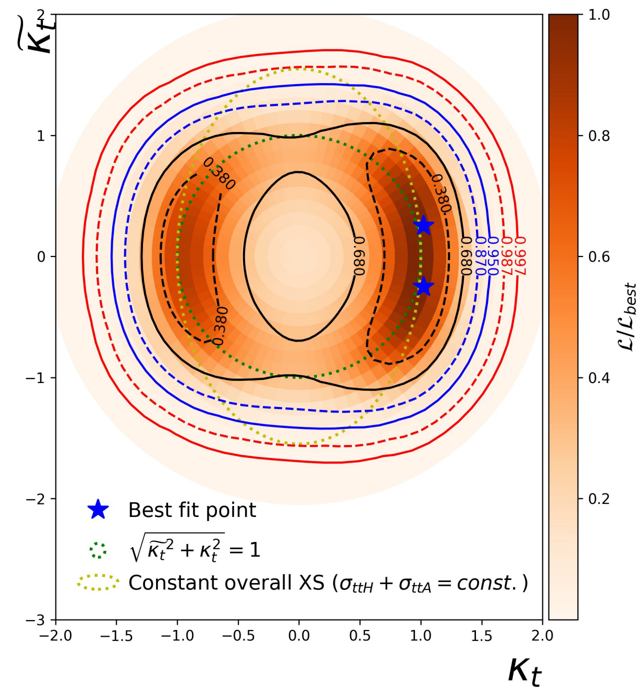


Figure: $\Delta\eta(tlep, thad)$



1.2
Higgs physics
VH

Ricardo Barrué, Patrícia Conde-Muíño,
Ricardo Gonçalo, Rute Pedro

WH/ZH with H→bb search

- In 2018, ATLAS observed
  - H→bb
  - WH/ZH associated production
    (Phys. Lett. B 786 (2018) 59)
- Now what?
- Study anomalous spin/CP components in interaction vertex

Entrar Assine já

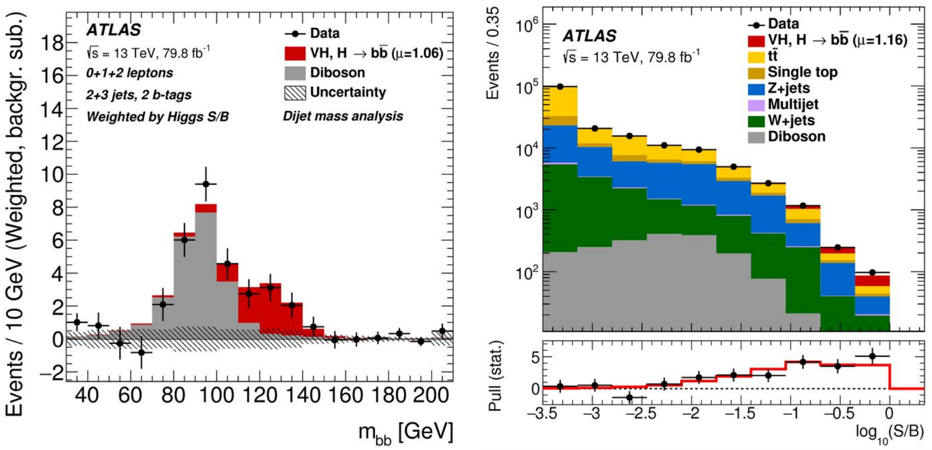
CIÊNCIA › ESPAÇO MEDICINA ECOSFERA

FÍSICA DE PARTÍCULAS

Bosão de Higgs visto (finalmente) a desintegrar-se em quarks *bottom*

Descoberta anunciada no Laboratório Europeu de Física de Partículas (CERN) é um passo fundamental para perceber como o bosão de Higgs faz com que as partículas fundamentais adquiram massa.

PÚBLICO · 28 de Agosto de 2018, 17:47 2295 PARTILHAS



- Combined signal strength

$$\mu_{VH}^{bb} = 1.16^{+0.27}_{-0.25} = 1.16 \pm 0.16(\text{stat.})^{+0.21}_{-0.19}(\text{syst.})$$

See poster by R. Barrué

Spin/CP properties of the hWW vertex

- hWW anomalous couplings
- Affect angular distributions of decay products
- Use angular observables
- Boosted regime enhances the sensitivity
- Working on boosted H→bb search in WH production

$$i\Gamma^{\mu\nu}_{HWW}(k_1,k_2) = i(g_2 m_W)\left[\eta^{\mu\nu}\left(1 + a_W - \frac{b_{W1}}{m_W^2}(k_1\cdot k_2) + \frac{b_{W2}}{m_W^2}(k_1^2+k_2^2)\right) + \frac{b_{W1}}{m_W^2}\,k_1^\nu k_2^\mu - \frac{b_{W2}}{m_W^2}\,(k_1^\mu k_1^\nu + k_2^\mu k_2^\nu) + \frac{c_W}{m_W^2}\epsilon^{\mu\nu\rho\sigma}k_{1_\rho}k_{2_\sigma}\right]$$

- k_1,k_2: gauge boson momenta
- a_W: modifies SM CP coupling
- b_{W1}, b_{W2}: CP-even BSM couplings
- c_W: CP-odd BSM coupling

Boosted H→bb search

- 80 fb-1 @ 13 TeV
- Optimisation of the boosted jet definition
- Proposal of additional selection variable ΔY_{WH}
- Improve significance by 6%
- Expected significance for boosted H→bb: 2.7σ
- Paper under approval

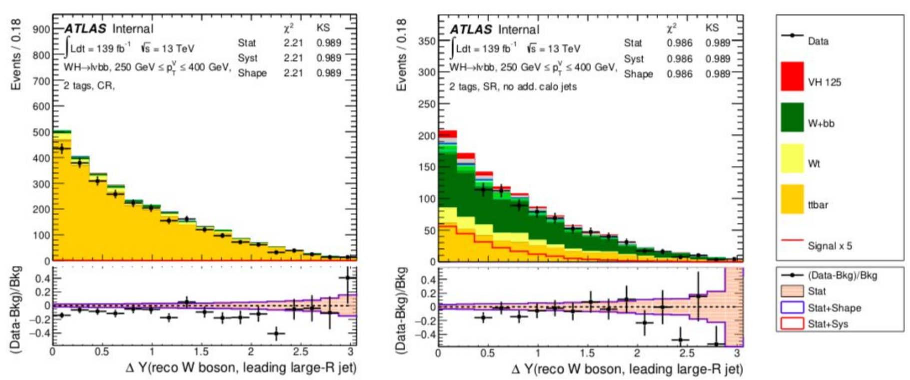
- Fixed radius versus variable radius sub-jet reconstruction

	Signal eff.	ttH rejection	W+jets rejection	Significance
Fixed radius subjets	49.6	100	184	0.86
Variable radius subjets	43.5	143	219	0.90

- b-tagging strategy

	Two leading subjets	All subjets
ϵ (%)	39.1	42.6
$t\bar{t}$ rejection factor	142.9	83.3
W+jets rejection factor	219.5	144.5
Z	0.898	0.766

- Modelling of ΔY_{WH}



(a) $\Delta Y(V,H)$, 250 GeV< p_T^W <400 GeV

2.
Heavy-ion physics

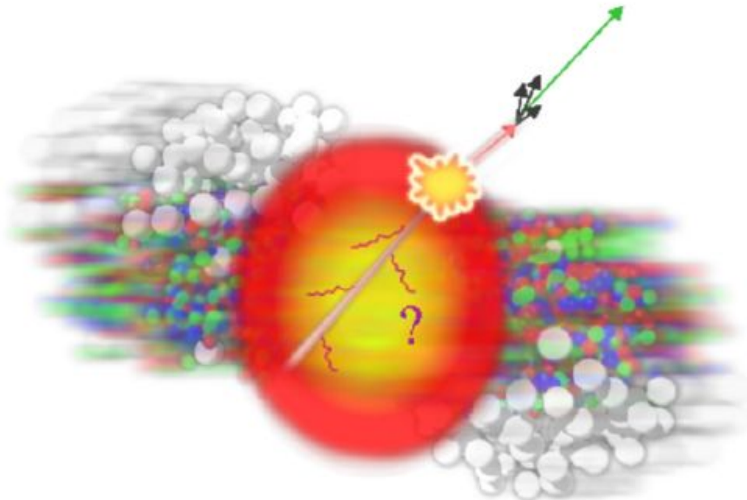
Rodrigo Gazola, Inês Rebanda,
Rui Pereira, Helena Santos

Why study the Quark-Gluon Plasma (QGP)?

The QGP is QCD under extreme conditions of density and/or temperature.
Understanding the QCD phase transition from hadronic matter to a deconfined state of quarks and gluons is a long standing puzzle since the 80's.
(and an ever since hot topic at LIP)

A major goal of the Heavy Ion Program of the LHC is the understanding of the effects of the QGP on heavy flavour jets

Bottom quarks are the earliest to be produced, perceiving the entire evolution of the QGP. They are used as tomographic probes of the QGP.



Dut to the large mass they radiate less gluons, which means they lose less energy compared to other jets.

Understanding the nature of energy loss by the partons that cross the dense medium - either radiative or collisional - allow to infer the properties of the QGP.

First measurements of b-jets in ATLAS using the Pb+Pb data taken in the Fall of 2018

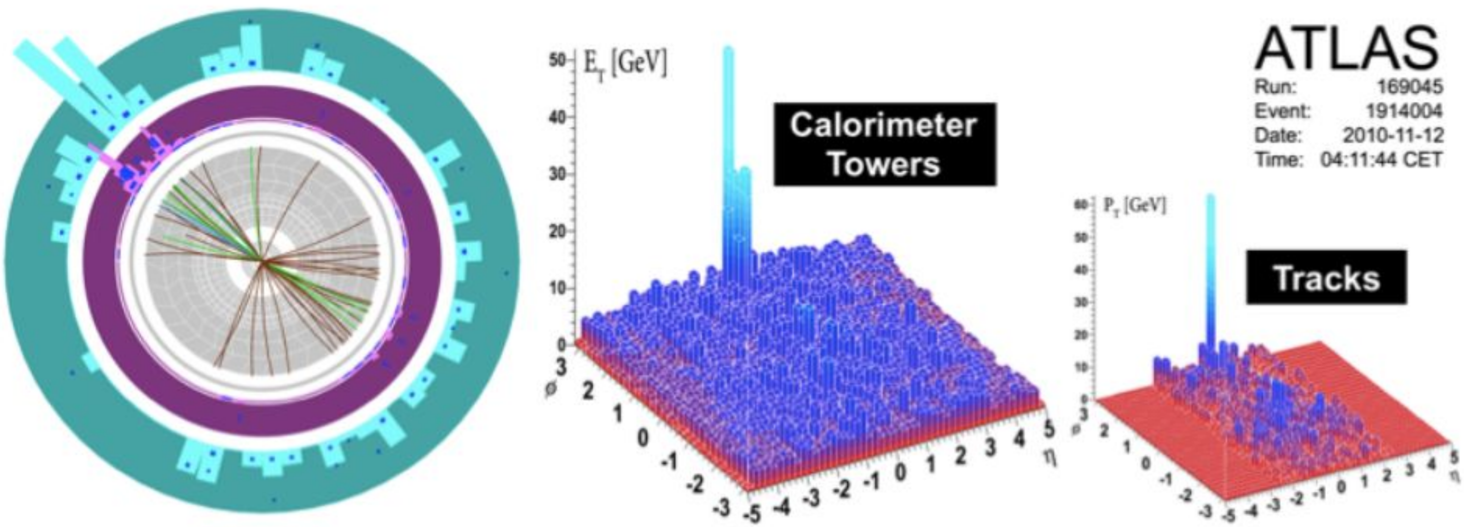
$$A_J = \frac{E_{T1} - E_{T2}}{E_{T1} + E_{T2}}, \Delta\phi > \frac{\pi}{2}$$

The dijet balance in the transverse energy between the leading and sub-leading jets, *A_J*.

A simple, but robust variable - Most of the systematic errors do cancel out in the ratio.

If the two jets emerge from the collisions according to QCD expectations, *A_J*, peaks at 1. It is the case of dijets produced in *pp* collisions

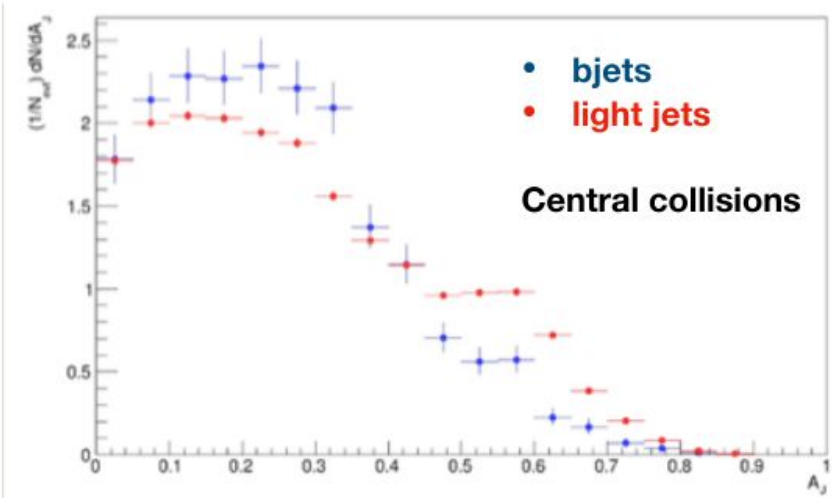
In Pb+Pb collisions we have many dijets as these:

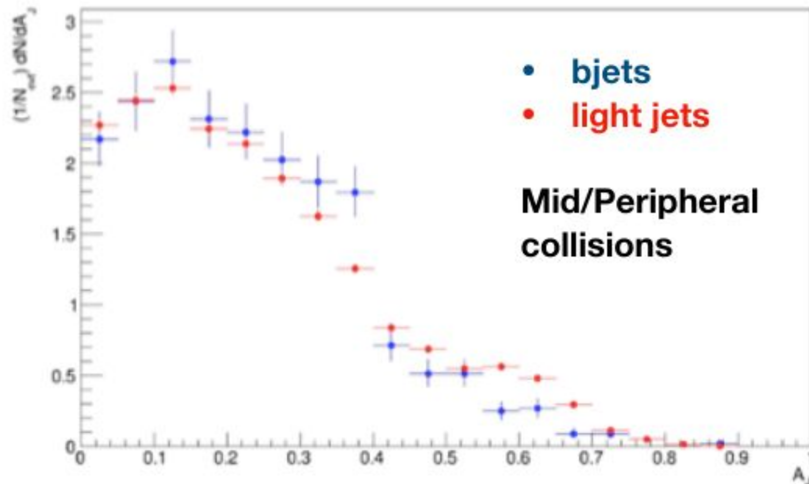


b-dijet asymmetry in Pb+Pb collisions

Inês Rebanda - FCUL
Rebecca Clews - Liverpool U.
Rodrigo Gazola - FCUL

$$A_J = \frac{E_{T1} - E_{T2}}{E_{T1} + E_{T2}}, \Delta\phi > \frac{\pi}{2}$$





Very promising - in central collisions (where the QGP is formed) *b*-dijets are less asymmetric -> they loose less energy as expected by the theory.

These were very good achievements but to move forward we need:

Tag b-jet events in the collisions -> development of the trigger menu and study the performance

How to tag b-jet events with a fast online algorithm and in the dense environment of Pb+Pb collisions?

Look for jets with a muon in the vicinity.

Plots show the b-jet trigger efficiency as a function of jet-pT

Different curves regard different jet thresholds;

Left (right) plots: central (peripheral) collisions

Top (bottom) plots: different pseudorapidity ranges.

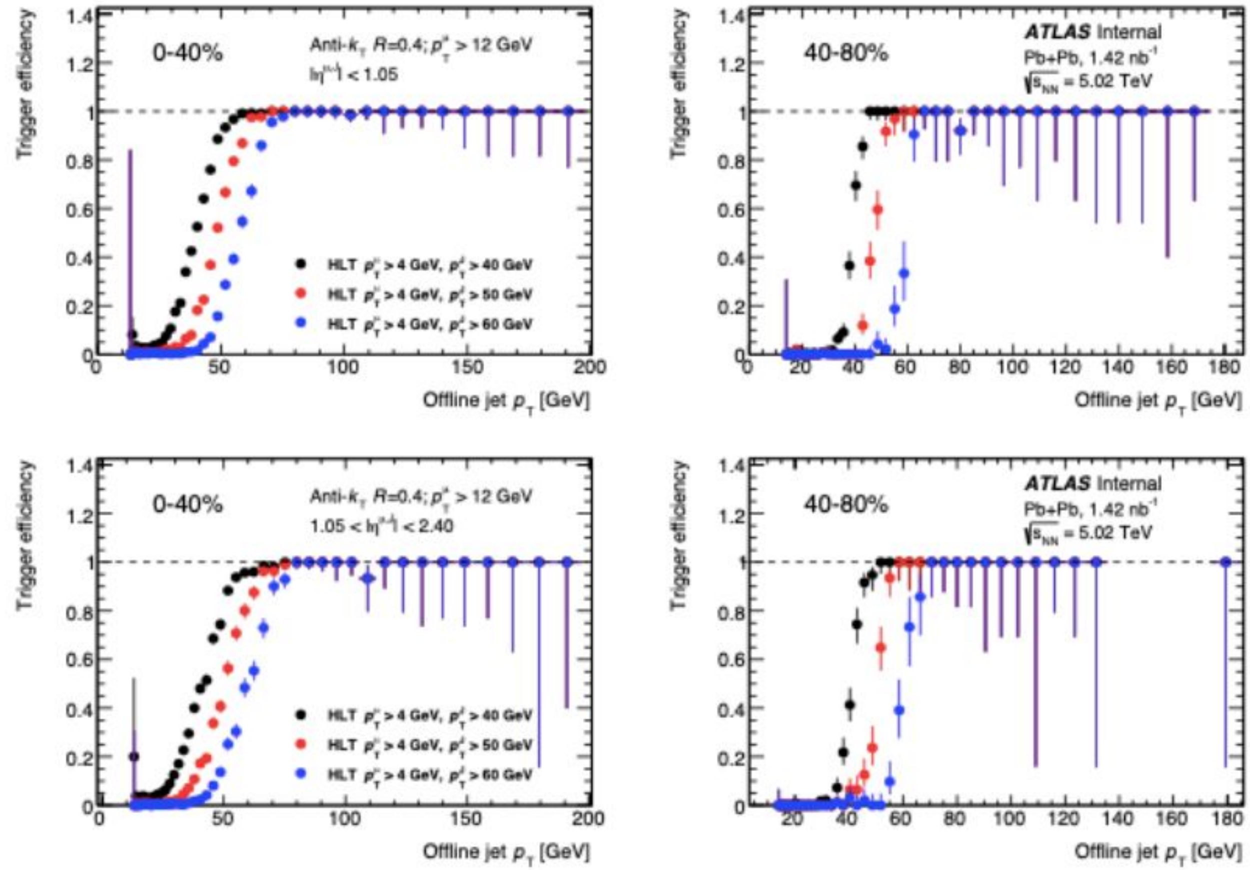


Figure 1: Trigger efficiency as a function of offline jet p_T regarding jets with a muon partener with p_T minimum of 12 GeV. The configuration of the muon-jet combined object requires a muon with $p_T > 4$ GeV and jet p_T thresholds of 40, 50, and 60 GeV. The efficiency is estimated with respect to the single muon trigger with $p_T > 4$ GeV. Top (bottom) panels concern barrel (end-cap) region and left (right) panels concern central (peripheral) collisions.

This work contributes to 2 papers in preparation

Backup

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

ATLAS EXPERIMENT

[Exotics and top in ATLAS]

Nuno Castro, Ana Peixoto, **Tiago Vale**

Jornadas Científicas do LIP
February 15, 2020, Braga

FCT Fundação para a Ciência e a Tecnologia

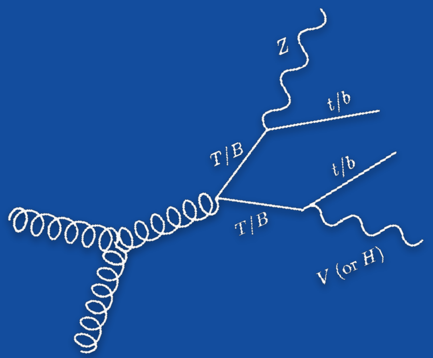
CERN/FIS-PAR/0002/2019,PD/BD/135435/2017, financiado por fundos FCT

Searches for
New Physics

- Search for **new physics** with the ATLAS experiment
  - Look for **new particles** in Exotics
    - ➢ Vector-Like Quarks (VLQ)
  - Look for **new interactions** in Top
    - ➢ Flavor-changing neutral currents (FCNC)
- Been searching since our master thesis (2016)

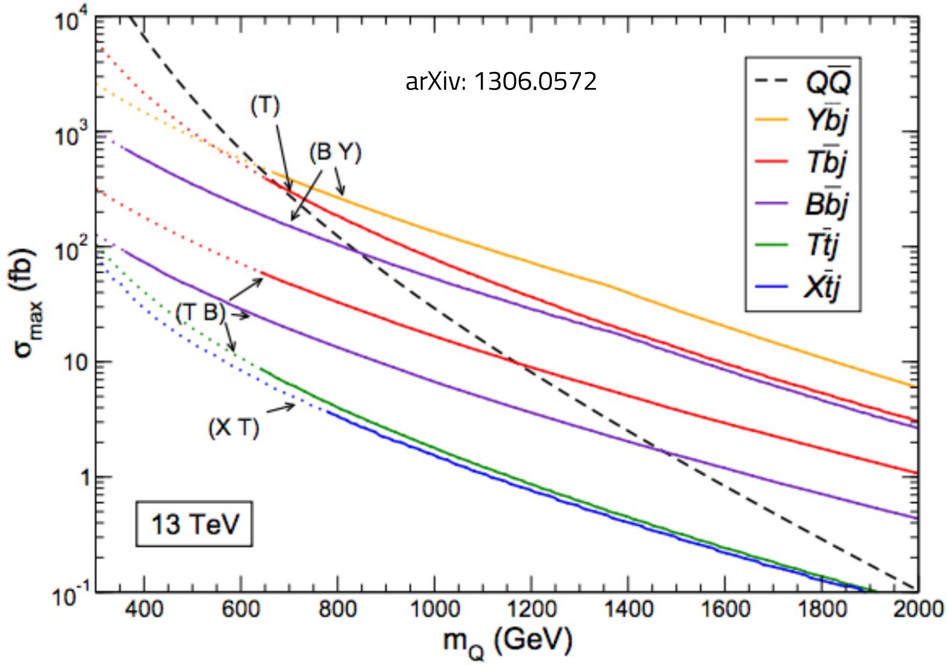
Vector-like quarks

Search for new heavy particles



Phenomenology of
Vector-like quarks

- VLQs have two production mechanisms
  - **Pair** production via QCD
    - ➢ Fairly model independent
  - **Single** production via EW
    - ➢ Bigger model dependency



- SU(2) singlets, doublets or triplets

- SM-like electric charges
  - ⅔ (T) or -⅓ (B)
- Exotic electric charges
  - -4/3 (X) or 5/3 (Y)

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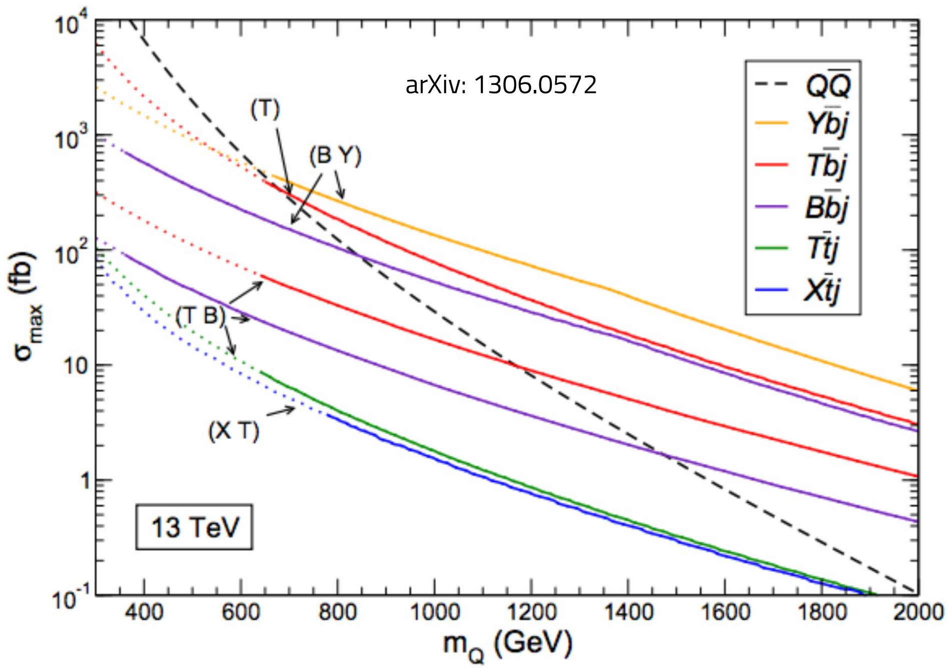

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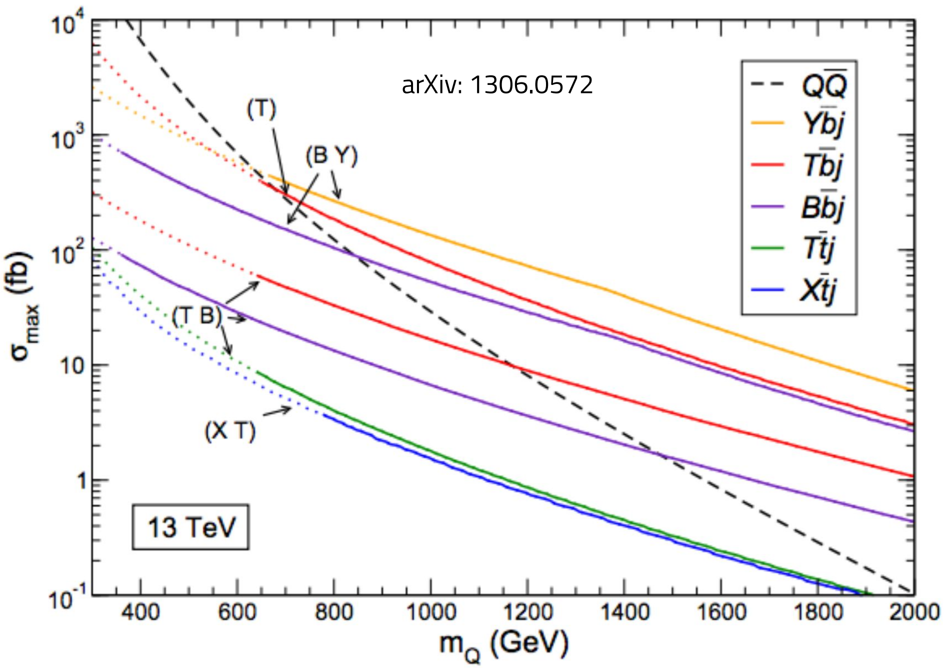

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  - ⅔ (T) or -⅓ (B)

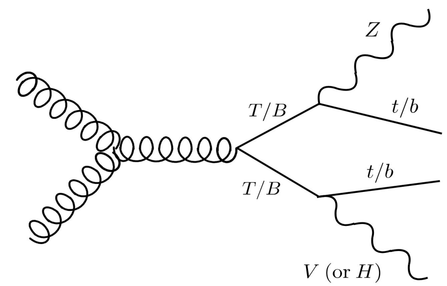
Searched for in this analysis

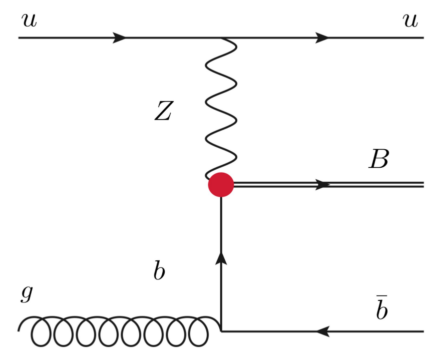
- Exotic electric charges
  - -4/3 (X) or 5/3 (Y)

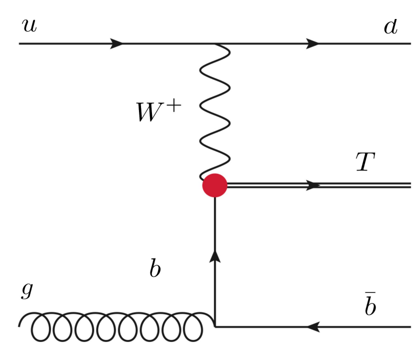
- Predicted in many BSM models that tackle the hierarchy problem
  - Eg: Composite Higgs
    - ➢ See talk by Maria Ramos posters by Maria Ramos and Guilherme Guedes

36 fb^{-1} paper: 10.1103/PhysRevD.98.112010

Analysis Description



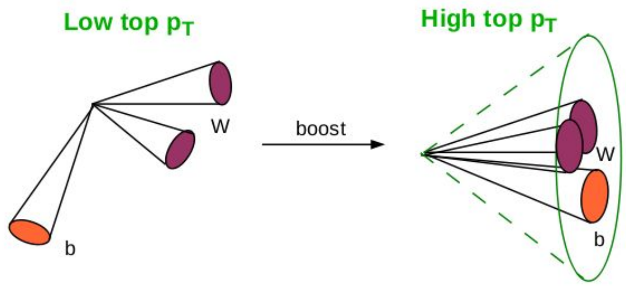




- Search with the **full** ATLAS run 2 dataset (140 fb^{-1})
- With TU **Dortmund** and **Austin** at Texas
- Looking for final states with a reconstructed ***Z*** boson
- Some assumptions were made:
  - Only **SM decays to 3rd generation** (i.e. W/Z/H + t/b)
  - Pair-production is **SM gluon fusion**
  - Singlet and doublet kinematic differences are **negligible**
    - Tested throughout the analysis development

To be revisited

Neural Network
Categorization

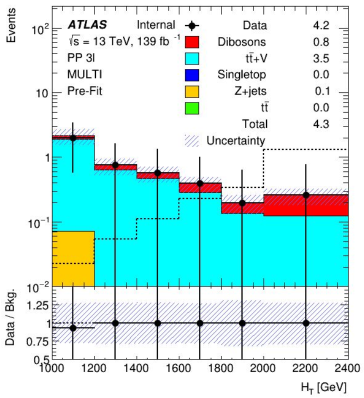


- **Boosted** object tagger to categorize events
  - W/Z
  - H
  - Top

- Deep **Neural Network** that uses reclustered jets for classification

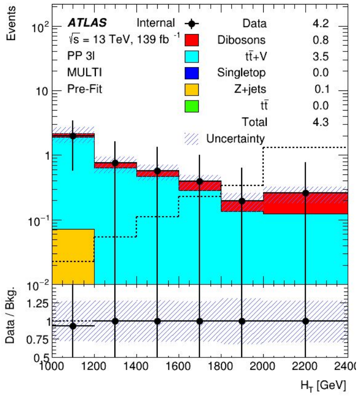
- Split the signal regions based on the presence of these tags

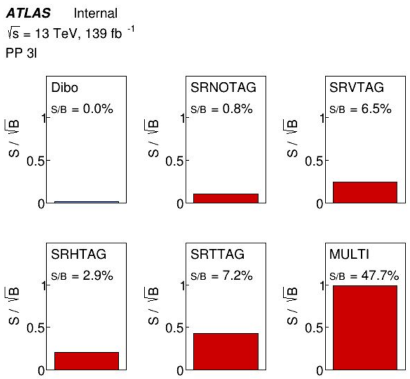
Analysis
Pipeline



- Find a good discriminant variable

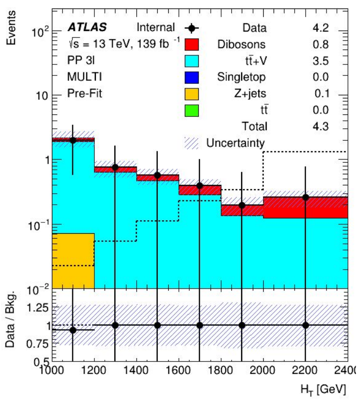
Analysis
Pipeline

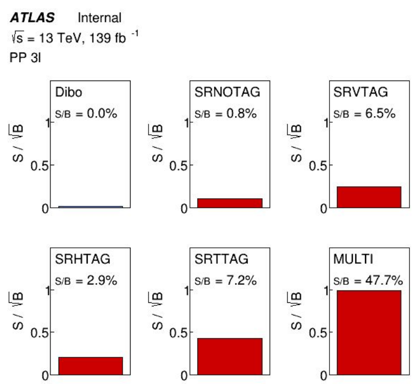


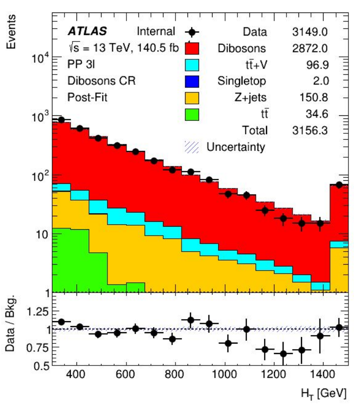


- Split by tagger category

Analysis
Pipeline

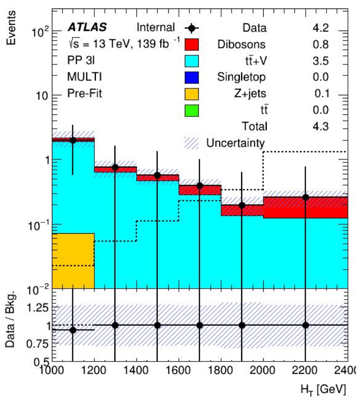


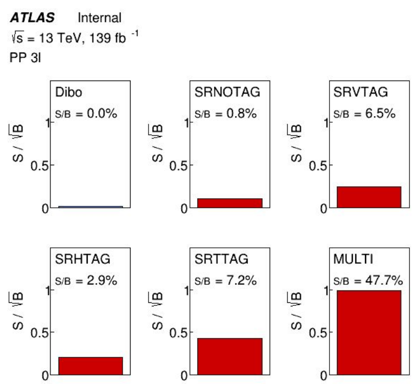


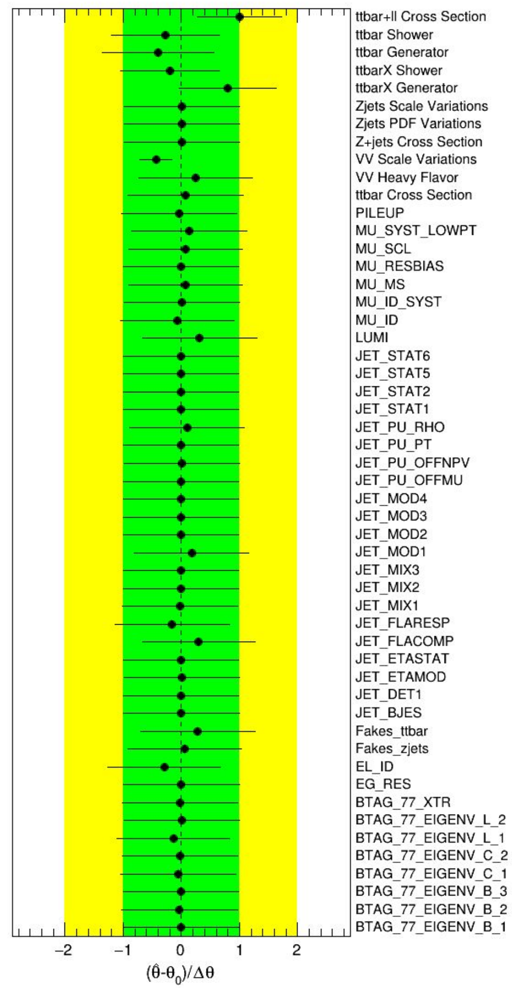


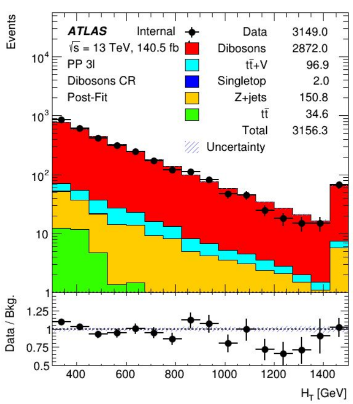
- Control the main backgrounds

Analysis
Pipeline



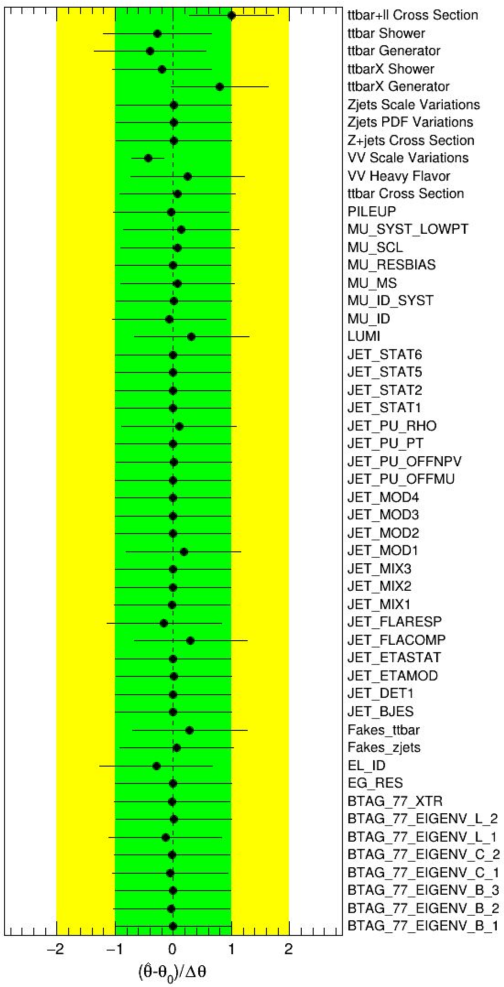






- Perform a fit

Pair-production
Fit

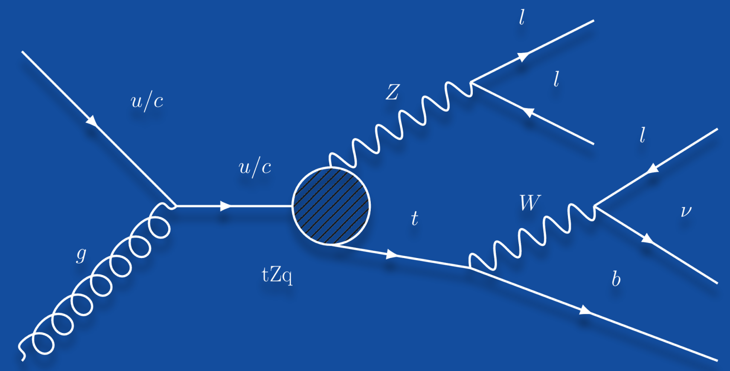


- Fit before combination
- Major backgrounds modelling dominating the fit
- Blinded fit
  - Region split is important because of the different background compositions
  - Unblinding is important for the analysis strategy

	ttbar+ll Cross Section	ttbarX Shower	ttbarX Generator	VV Scale Variations	VV Heavy Flavor	MU_SYST_LOWPT	LUMI	JET_PU_RHO	JET_MOD1	JET_FLARESP	JET_FLACOMP	EL_ID
ttbar+ll Cross Section	100.0	22.4	-32.0	-0.5	-0.5	1.2	-10.6	1.9	0.1	-2.0	0.7	-12.4
ttbarX Shower	22.4	100.0	-15.7	-4.3	-1.2	-0.9	1.9	0.6	3.0	-1.7	3.0	5.6
ttbarX Generator	-32.0	-15.7	100.0	0.2	-1.9	-0.5	-4.7	2.2	3.1	-2.4	3.3	-2.2
VV Scale Variations	-0.5	-4.3	0.2	100.0	-48.3	-29.3	-26.7	-21.7	-22.4	22.4	-44.6	-21.9
VV Heavy Flavor	-0.5	-1.2	-1.9	-48.3	100.0	-1.5	-1.5	-1.1	-1.2	1.2	-2.3	0.3
MU_SYST_LOWPT	1.2	-0.9	-0.5	-29.3	-1.5	100.0	-0.7	-0.7	-0.7	0.8	-1.4	0.4
LUMI	-10.6	1.9	-4.7	-26.7	-1.5	-0.7	100.0	-0.5	-0.7	0.5	-1.2	-1.4
JET_PU_RHO	1.9	0.6	2.2	-21.7	-1.1	-0.7	-0.5	100.0	-0.8	0.7	-1.3	0.3
JET_MOD1	0.1	3.0	3.1	-22.4	-1.2	-0.7	-0.7	-0.8	100.0	1.0	-1.9	0.0
JET_FLARESP	-2.0	-1.7	-2.4	22.4	1.2	0.8	0.5	0.7	1.0	100.0	1.7	-0.4
JET_FLACOMP	0.7	3.0	3.3	-44.6	-2.3	-1.4	-1.2	-1.3	-1.9	1.7	100.0	0.2
EL_ID	-12.4	5.6	-2.2	-21.9	0.3	0.4	-1.4	0.3	0.0	-0.4	0.2	100.0

Final
VLQ Remarks

- Analysis with partial dataset (2015+2016 data) was published
  - https://journals.aps.org/prd/abstract/10.1103/PhysRevD.98.112010
  - Limits above the TeV range
- **Combination** of all ATLAS VLQ analysis with partial dataset was published
  - https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.121.211801
  - PRL editor’s choice
- Analysis with full run-2 dataset is ongoing so stay tuned for news!
- See my **poster** for more details

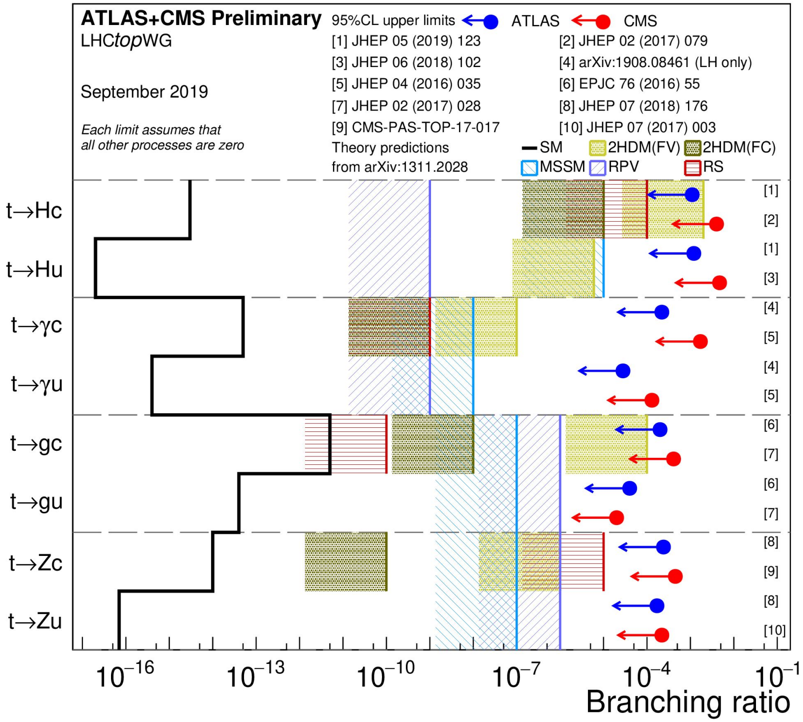


Flavor Changing Neutral Currents

Search for new interactions

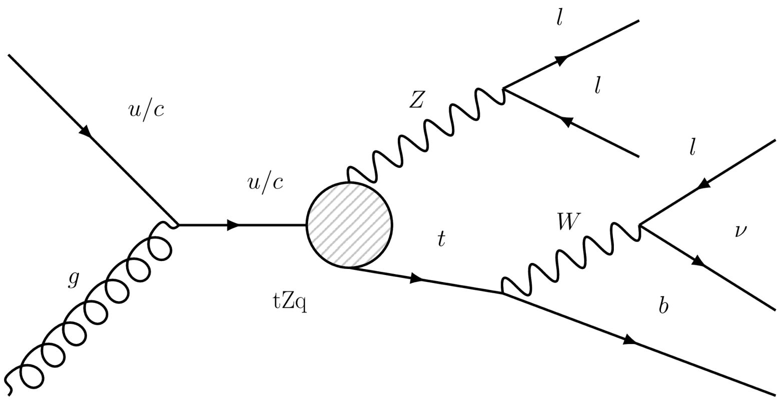
Reminders on **FCNC**

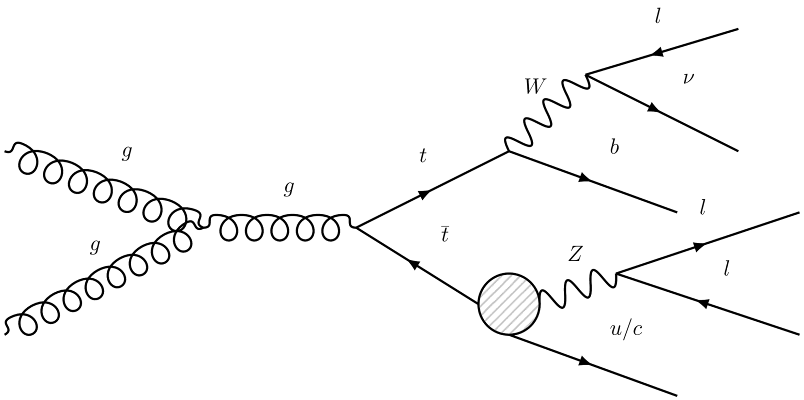
- Fermion changing its **flavor** without changing its charge
- **Forbidden** at tree level and heavily suppressed at **loop level** by GIM mechanism in SM
- Several **BSM models** lead to FCNC contributions, often at tree level
- Top quark decays via FCNC presents a powerful probe of new physics
- Several orders of magnitude of BR to **explore**



Search strategy
FCNC

- FCNC processes possible in two modes
  - In **production**: **t+X** with X = H, Z, g, γ
  - In **decay**: **ttbar (t → qX)** with q = u, c
  - **Interference effects** should be estimated – see arXiv:**1909.08443**





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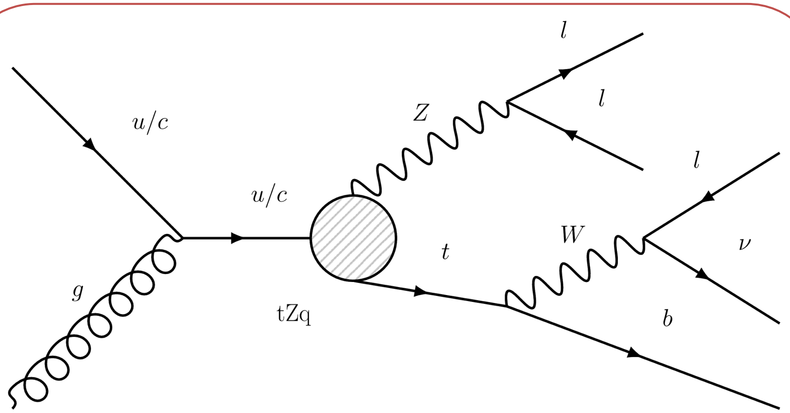

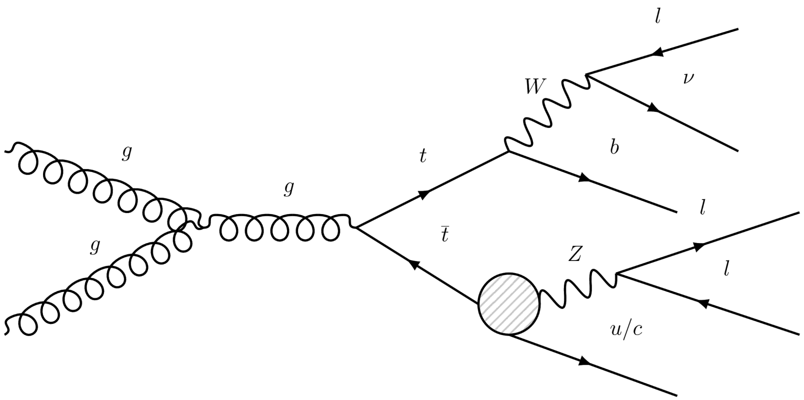

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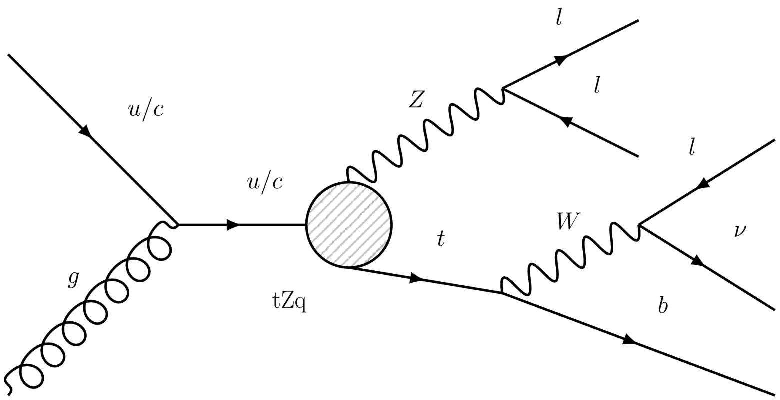

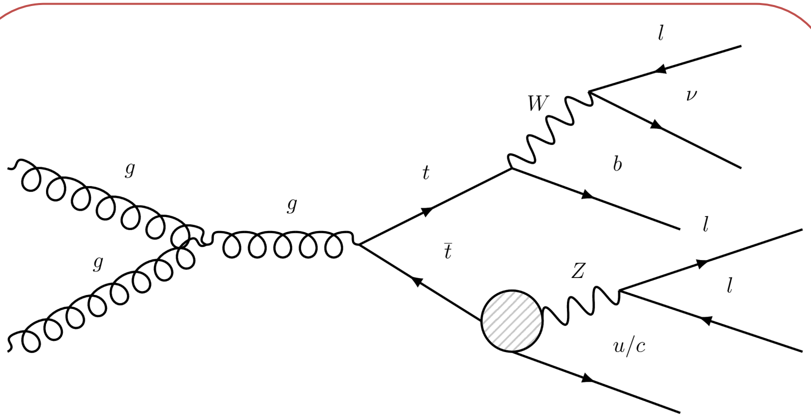

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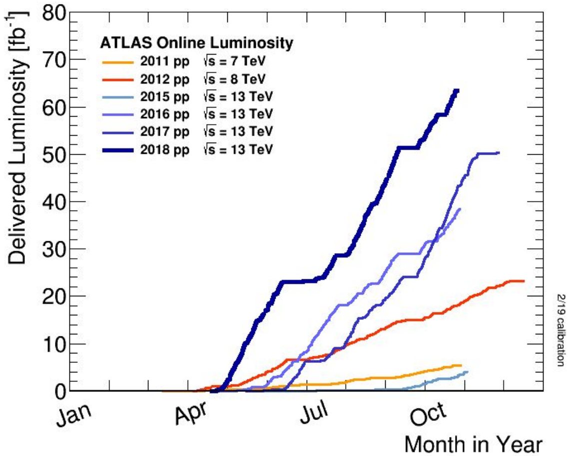
- Analysis with **full** Run-2 ATLAS dataset (140 fb^{-1})
  - Combining **production and decay** modes
  - Collaboration with **Berlin, Tbilisi** and **Roma**
- In **production**: single-top production ⇒ Particularly sensitive to **tZu** coupling



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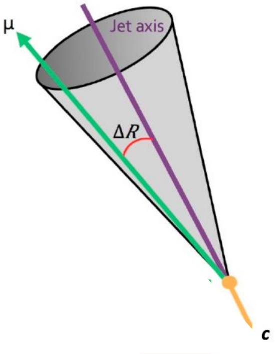

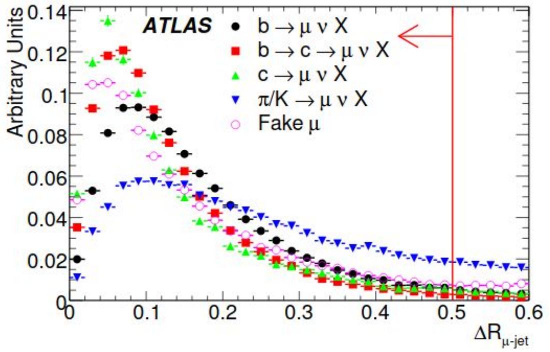

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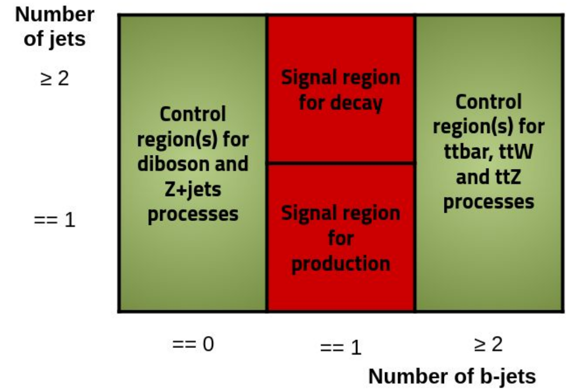

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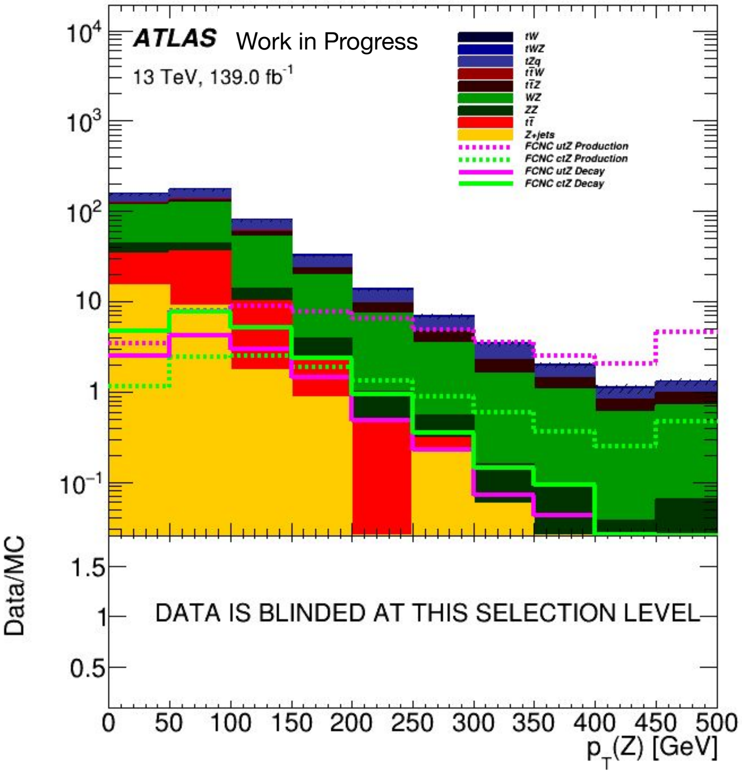
- **Trileptonic** topology: $l^+ l^- + l$ + b-jets + E_T^{Miss}
- **Main backgrounds:** ttbar, ttbar+X, Z+jets and diboson (WZ and ZZ) processes

Event selection
FCNC

- Exploiting expected **boost** of **Z** boson
- **Angular variables** between the Z boson and light quark important in the decay signal regions

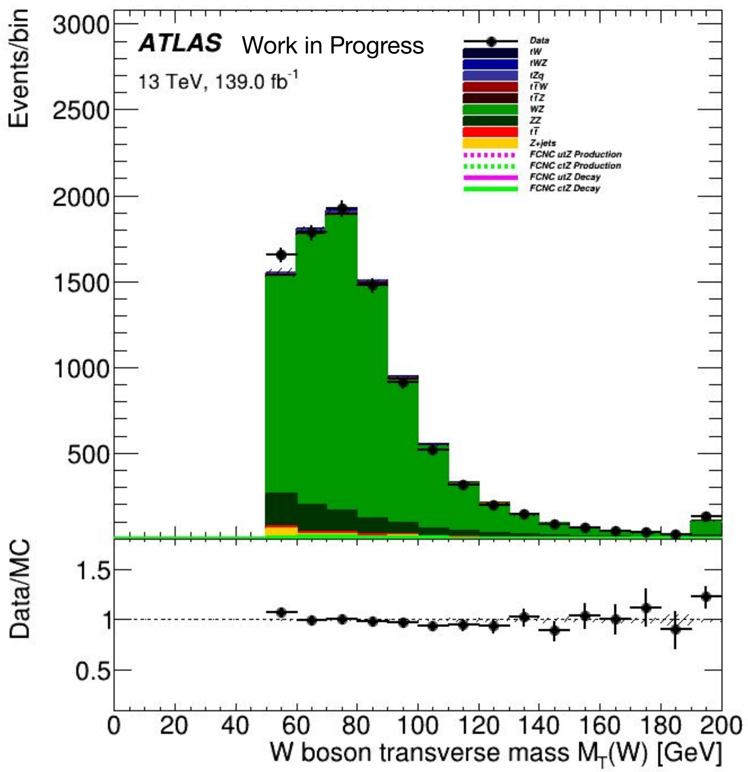
Production signal region



Event selection
FCNC

- Exploiting expected **boost** of **Z** boson
- **Angular variables** between the Z boson and light quark important in the decay signal regions
- **Dominant backgrounds** have dedicated control regions
- Dibosons control region presents a good data and Monte Carlo agreement
- Control regions for **ttbar** with reasonable **isolation**

Diboson control region



Signal and background
Discrimination

- **Boosted Decision Trees with Gradient boosting (BDTG)** method within the TMVA tool used to discriminate signal from background

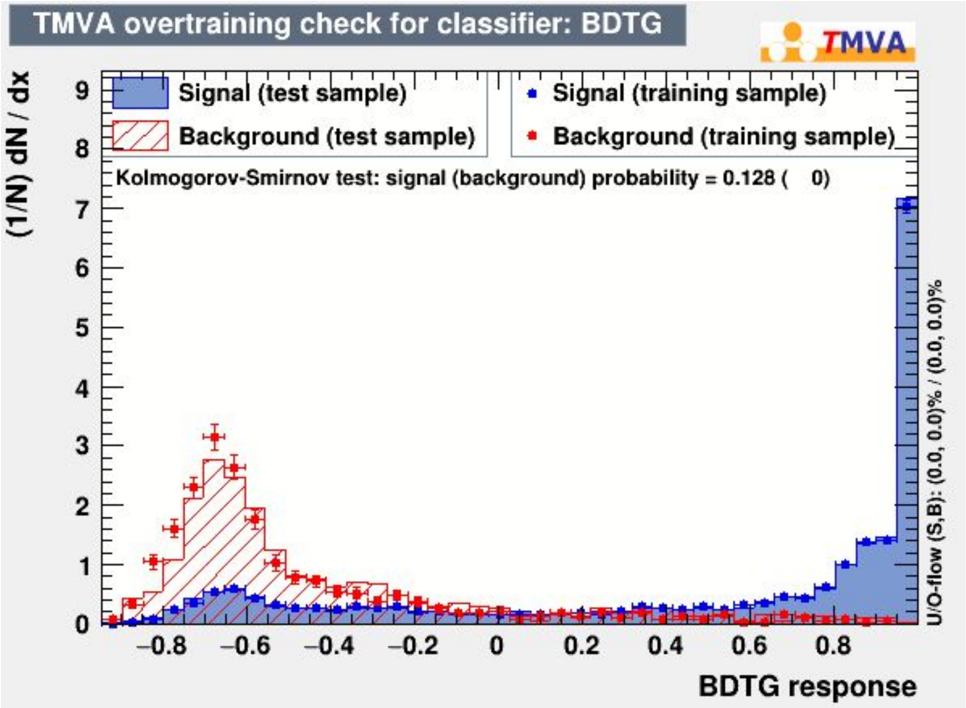
- Promising **variables** considered for each **signal region**:

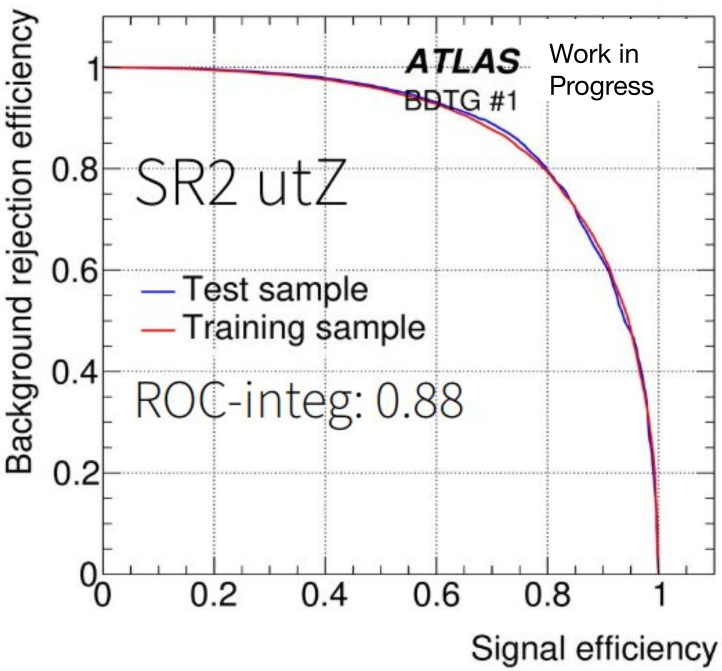
Decay signal region	Production signal region	Decay SMT signal region
M (SM), M(FCNC top quark)	M (SM top quark), M (W boson)	M (SM), M(FCNC top quark)
pT (u/c-quark), pT (b-quark)	pT(Z boson), pT (W boson), pT (b-quark)	pT (u/c-quark), pT (b-quark)
ΔR (SM, FCNC top quark), ΔR (u/c-quark, Z boson)	ΔR (Z boson, b-quark)	ΔR (SM, FCNC top quark), ΔR (u/c-quark, Z boson)
-	-	b/c-quark MV2c10 weight bin

Signal and background
Discrimination

- **Boosted Decision Trees with Gradient boosting (BDTG)** method within the TMVA tool used to discriminate signal from background

- Preliminary **results** of the **production signal region**:





Final
FCNC Remarks

- Search for new physics focusing on the **FCNC processes** via the **tZq vertex**
- Phenomenological studies of **interference effects** between production and decay with **tZq and tγq anomalous couplings** (arXiv:1909.08443)
- First **analysis** focusing on tZq anomalous coupling with **both production and decay modes** profiting from the full Run-2 dataset collected by the ATLAS detector
- **Experimental limits** on branching ratio of $t \rightarrow q\,Z$ with $q=u,c$ obtained using the **BDTG score** from each signal region
- See **Ana**'s **poster** for more details

Final
Remarks

- Different approaches to **new physics** searches are being performed
- All analysis close to **publication**
  - Going through ATLAS internal approval
- If there is no discovery very stringent **limits** will be set
- Both analysis have detailed **posters** so go read and ask questions!

Thanks!

ana.peixoto@cern.ch
tiago.vale@cern.ch

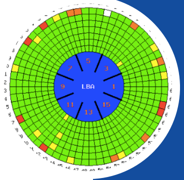
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

[TILECAL *Operations, Calibration, Performance and Upgrades*]

Rute Pedro on behalf of the TileCal/ATLAS PT Team

Jornadas do LIP | Braga | 15th February 2020

Main Activities and Responsibilities



Operations

- Development/maintenance of the Detector Control System (DCS) (F. Martins)
- Coordination of the DCS (F. Martins)
- Data Quality Shifts (most of the team)

Calibration

- Photomultiplier's calibration with the Laser II System (R. Pedro, F. Veloso)
- Coordination of the Calibration (R. Pedro)

Performance

- TileCal Optics Robustness for the HL-LHC Phase (A. Maio, R. Pedro)

Upgrades

- WLS fibres for TileCal crack scintillators replacement in Phase I (LoMAC, talk by J. Gentil)
- R&D and production of the HV distribution system for Phase II (see talk by A. Gomes)

Detector Control System

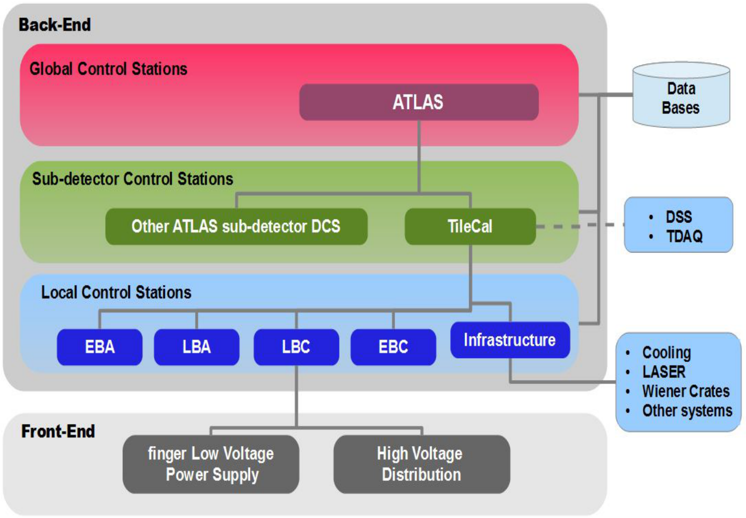
F. Martins

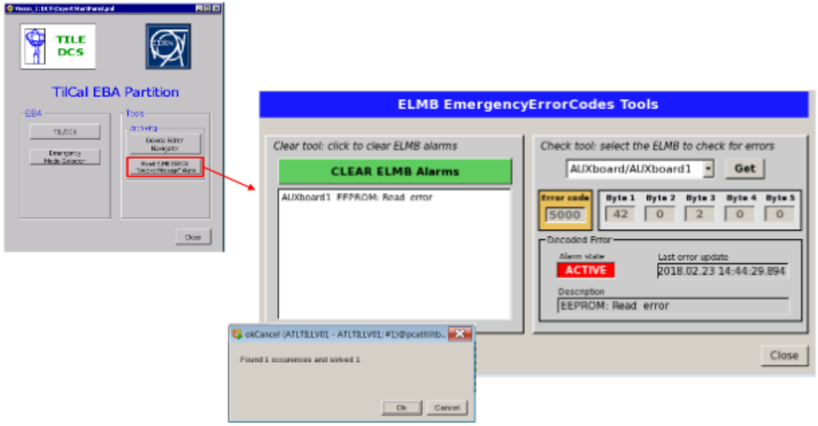
Control and monitor the vital parameters of the detector:

- High/Low voltages, temperature, currents…
- Automatic alarms and safety routines
- Based on Supervision Control and Data Acquisition (SCADA)
- Integrated on the ATLAS DCS hierarchy

New:

- Better user interfaces
- More hardware protection
- Migration of version control to GitLab





More in the poster session!

Data Quality

Access the quality of the data recorded by TileCal

- Prompt analysis of dedicated proton collision data set
- Calibration runs to monitor independently the different components of the detector readout chain
- DQ activities also very helpful during the detector maintenance /refurbishing

2 DQ Leader shifts (1 month at CERN):

H. Santos, R. Pedro

3 DQ Validator shifts (2 weeks, remote):

J. Gentil, H. Santos

Helped keeping good data efficiency at 99.7% for TileCal during Run 2

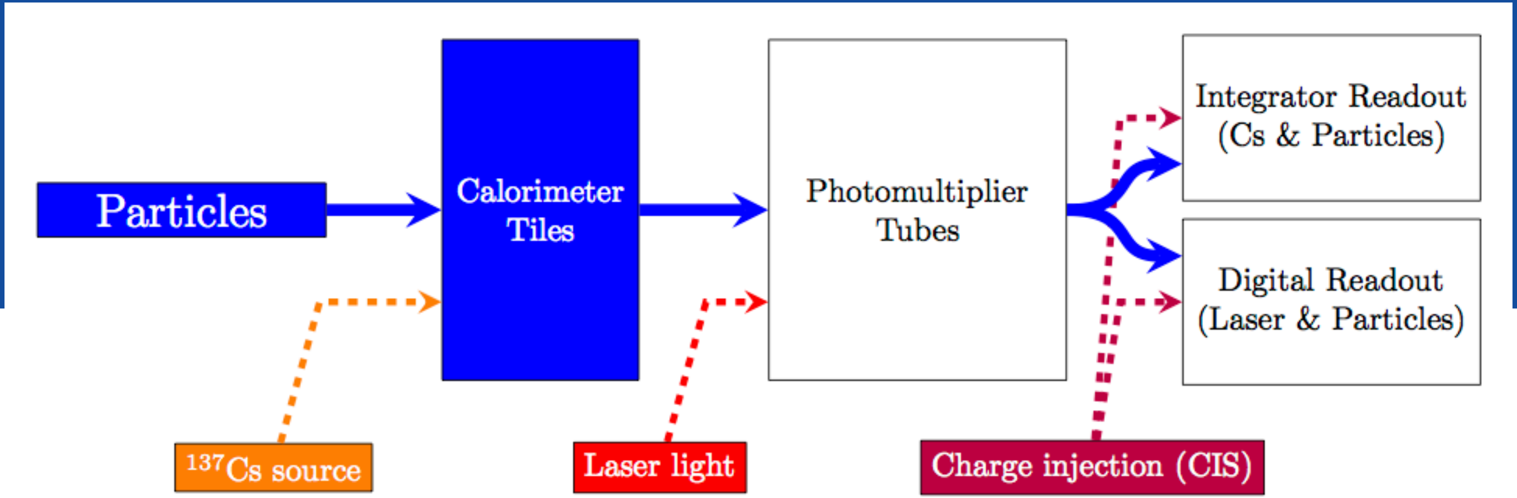
ATLAS pp Run-2: July 2015 – October 2018										
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.5	99.9	99.7	99.6	99.7	99.8	99.6	100	100	99.8	98.8
Good for physics: 95.6% (139 fb^{-1})										

Luminosity weighted relative detector uptime and good data quality efficiencies (in %) during stable beam in pp collision physics runs with 25 ns bunch-spacing at $\sqrt{s}$=13 TeV for the full Run-2 period (between July 2015 – October 2018), corresponding to a delivered integrated luminosity of 153 fb^{-1} and a recorded integrated luminosity of 146 fb^{-1}. Runs with specialized physics goals are not included. Dedicated luminosity calibration activities during LHC fills used 0.6% of recorded data in 2018 and are included in the inefficiency. Trigger-specific data quality problems (0.4% inefficiency at Level-1) are included in the overall inefficiency. When the stable beam flag is raised, the tracking detectors undergo a so-called "warm start", which includes a ramp of the high-voltage and turning on the pre-amplifiers for the Pixel system. The inefficiency due to this, as well as the DAQ inefficiency, are not included in the table above, but accounted for in the ATLAS data taking efficiency.

Calibration

A dedicated system to monitor and calibrate each step of the readout chain

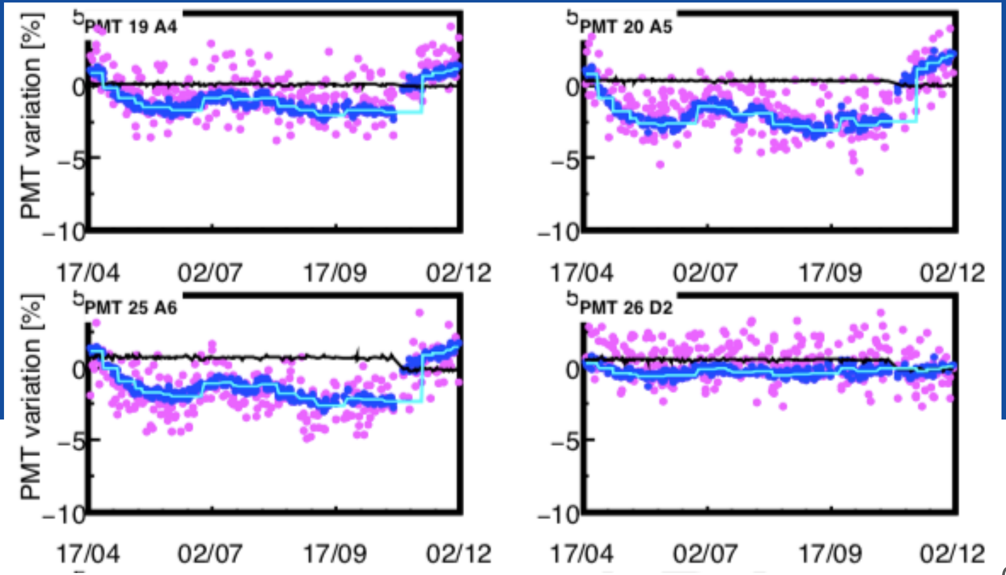
- Cesium-137 radioactive source to calibrate the full readout
- Laser light system to monitor the ~10 k PMTs
- PMT readout and electronics (~20 k channels) is calibrated by charge injection



PMT calibration with Laser

R. Pedro

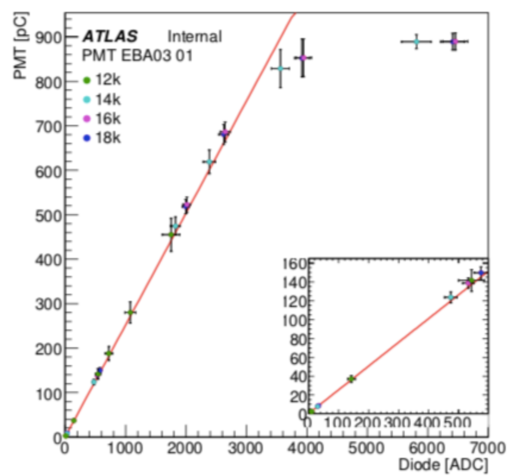
- Optimisation of the algorithm and software of laser data analysis
- Provided the calibration of the PMTs for reprocessing the 2018 collision data
- Public plots with year summary
- Internal note documenting studies, methods, results and operations of Laser calibration in Run 2

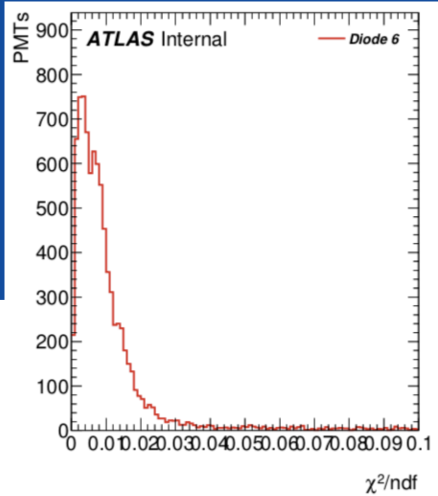


PMT linearity with Laser

F. Veloso

- Ensure that the calibration holds for the full bandwidth of the PMT response
- I.e., Is the PMT response linear?
- Fit the PMT response as a function of a reference laser signal
- Documentation ongoing: internal note on Laser system stability and PMT linearity



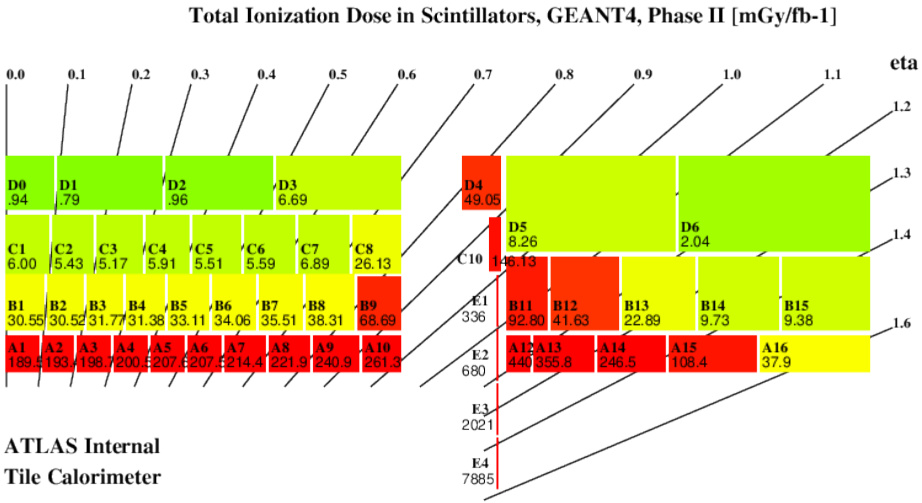


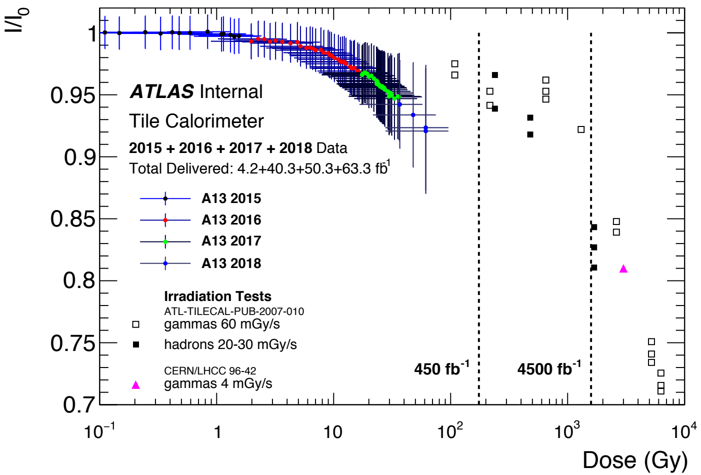
Deviation from Linearity	Fraction of PMTs
1 %	89.9 %
2 %	95.1 %
3 %	98.6 %
4 %	99.6 %
5 %	99.7 %
11 %	99.9 %

Optics Robustness at HL-LHC

A. Maio, R. Pedro

- The HL-LHC will bring additional radiation exposure and damage to the TileCal scintillators and fibres
- Measure light yield with combined analysis of data from all calibration systems
- Disentangle effects not due to optics degradation, eg. PMT/electronics-related
- Long-term goal: modelling of the performance as a function of ionising dose and extrapolation to future conditions at HL-LHC

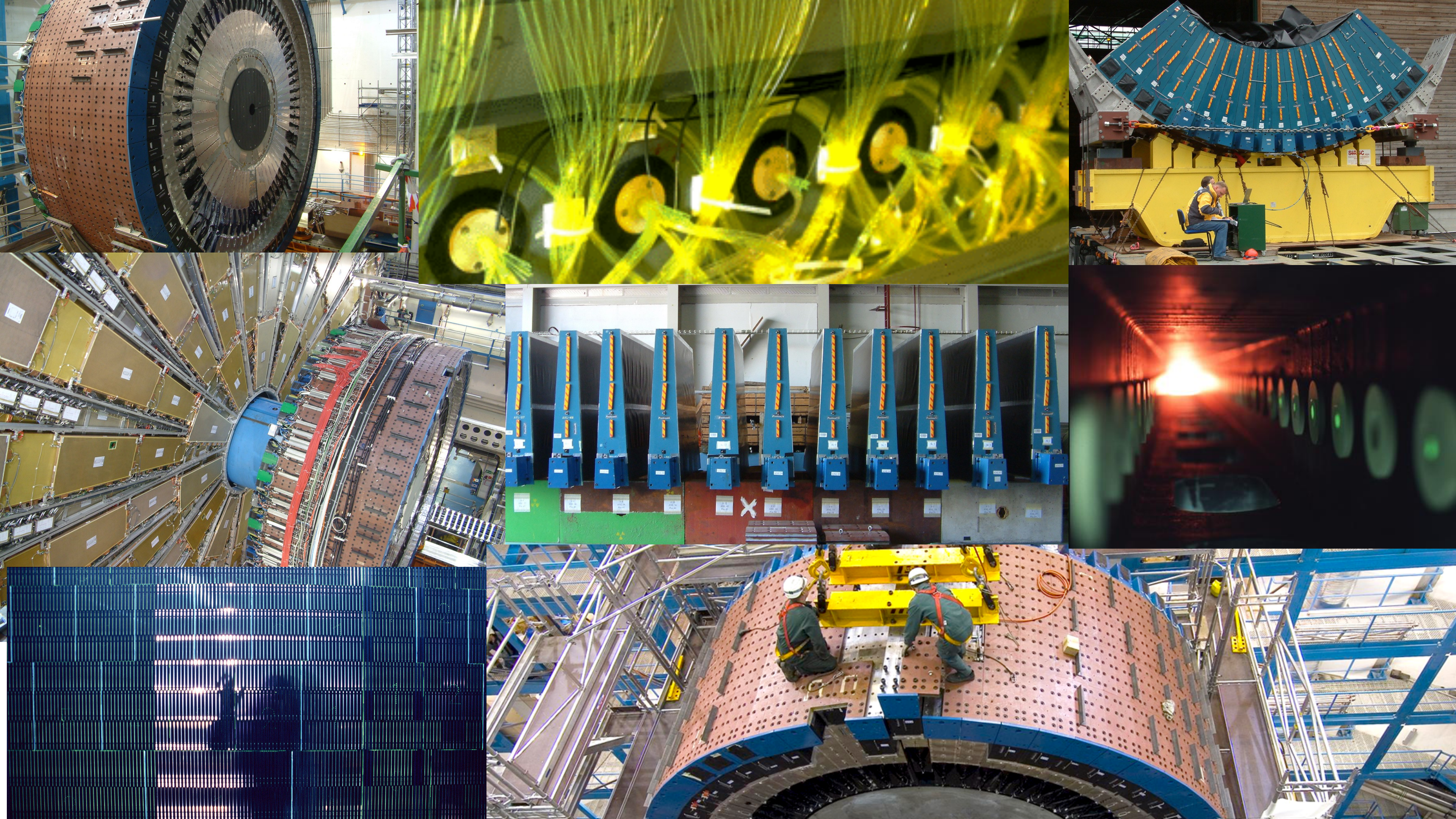




Past two years, next two years

- ATLAS/LIP team had a very strong involvement in many TileCal activities
- Leading contribution to key tasks and studies
  - TileCal DCS fully ensured by ATLAS/LIP
  - Optics robustness studied by ATLAS/LIP

- In the very near-future: contribute to the documentation of Run 2 operation/calibration
- Continue and consolidate our lines of work
- Prepare for a smooth *Operation, Calibration and Performance* of TileCal in Run 3 and for excellent detector *Upgrades*!



ACKNOWLEDGEMENTS

CERN/FIS-PAR/0002/2019

LOMaC

ECR-Lab

High Voltage Distribution System for the Tilecal Upgrade

J. S. Augusto, F. Cuim, G. Evans, R. Fernandez, J. Gentil Saraiva, A. Gomes, L. Gurriana, F. Martins

Jornadas do LIP, Braga, 15th Feb 2020

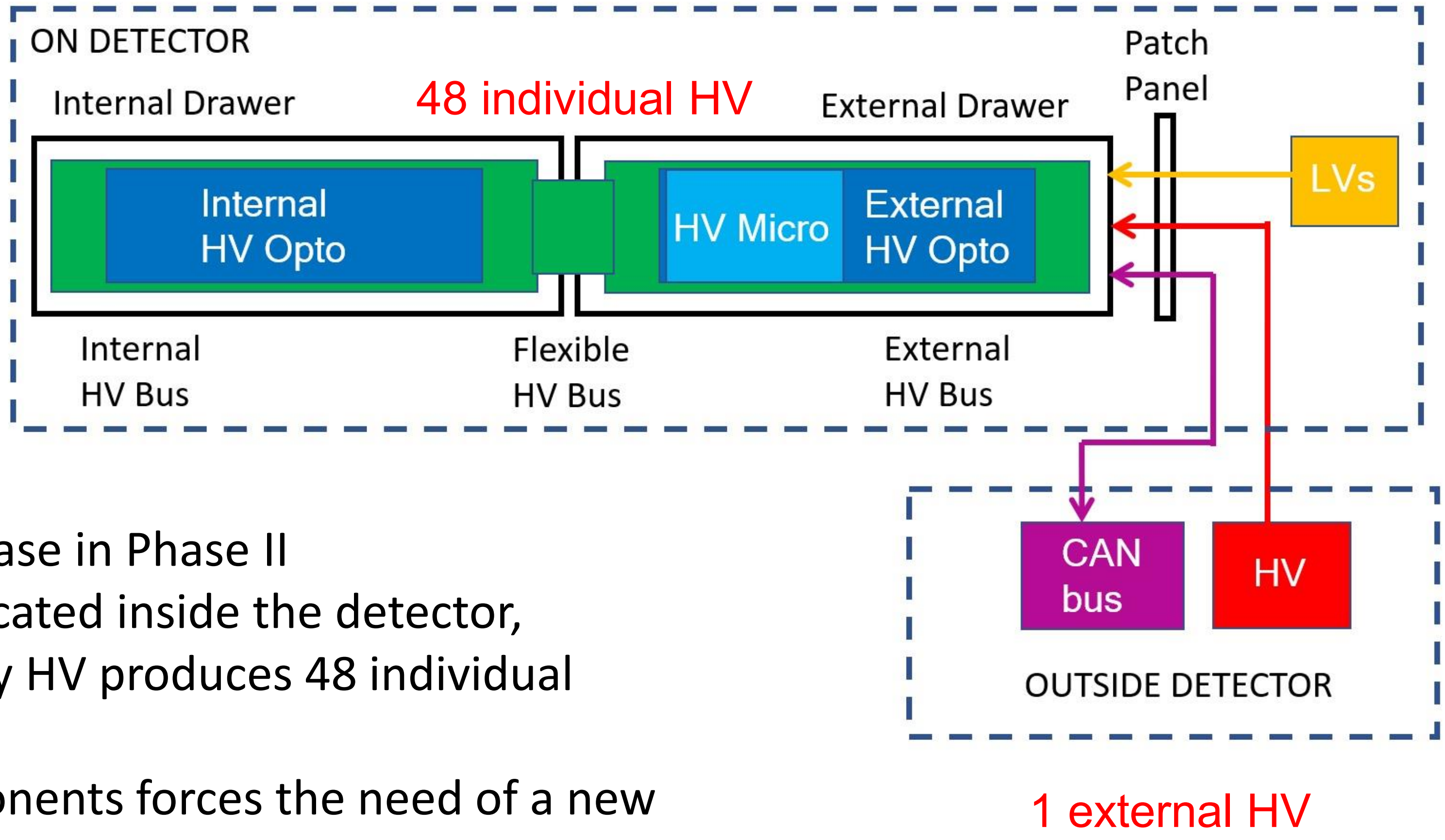
CERN/FIS/PAR/0033/2019

HV upgrade motivation

Main requirements

- Need to provide 9852 voltages in ranges [-470,-830] or [-590,-950] V
- Individual currents < 400 μA
- Voltage stability required: 0.5 V rms
- Hardware precision of setting/reading: 0.25 V
- Achieve the same HV performance of previous LHC runs

Layout of Tilecal current HV system

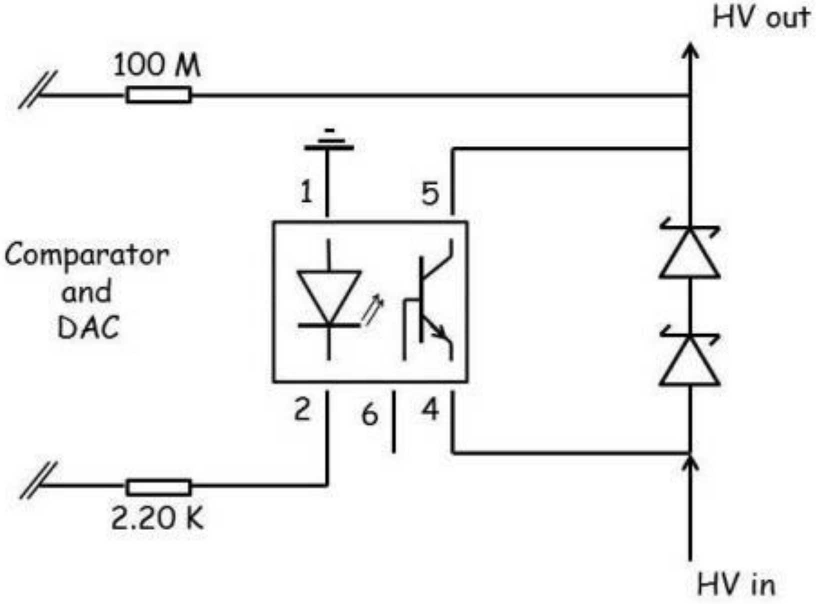


Main motivations for the upgrade

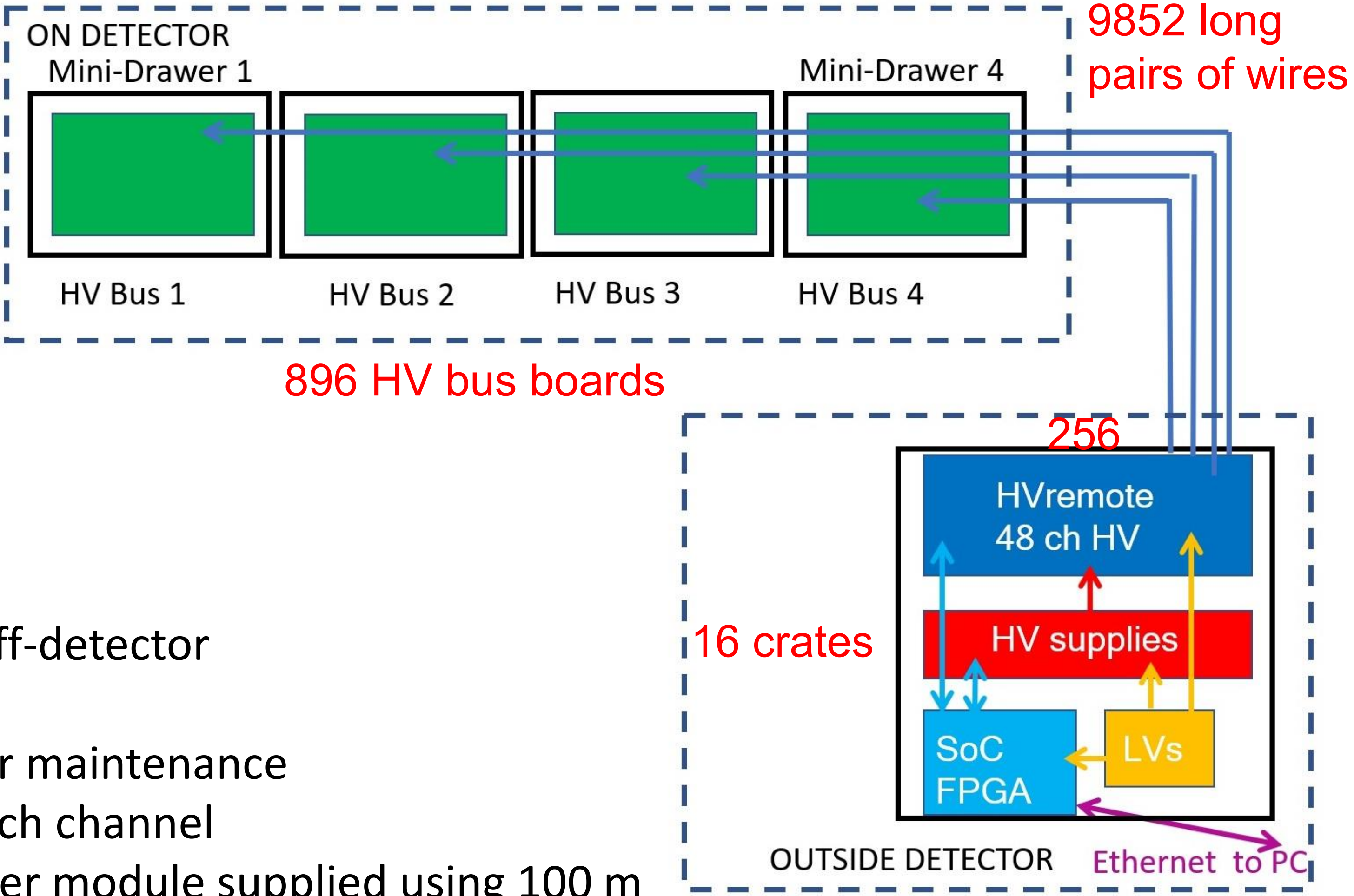
- LHC upgrade aims to a luminosity increase in Phase II
- Current Tilecal HV regulation system located inside the detector, exposed to radiation – 1 external primary HV produces 48 individual HVs in the detector
- Radiation damage and ageing of components forces the need of a new HV system
- Upgraded system should improve the reliability and reduce maintenance needs

New HV system

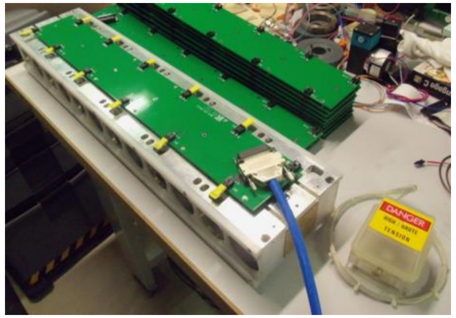
Main part of the regulation loop
in the HVRemote board



Layout of upgrade Tilecal HV system



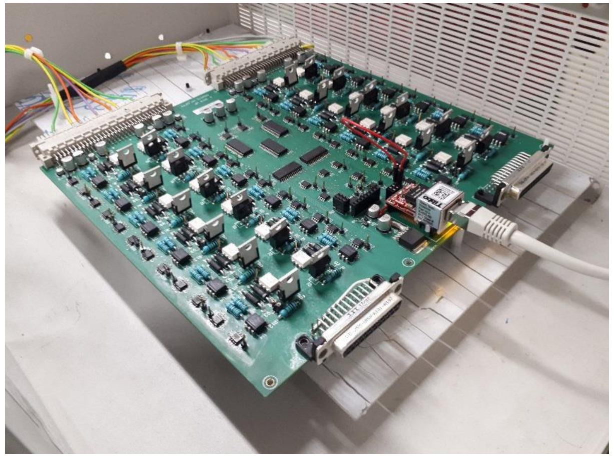
Passive HV bus boards are
the only parts inside detector



- Remote regulation off-detector
- No radiation
- Permanent access for maintenance
- On/off control for each channel
- Up to 48 HV inputs per module supplied using 100 m long multiwire cables
- Communication with DCS using Ethernet

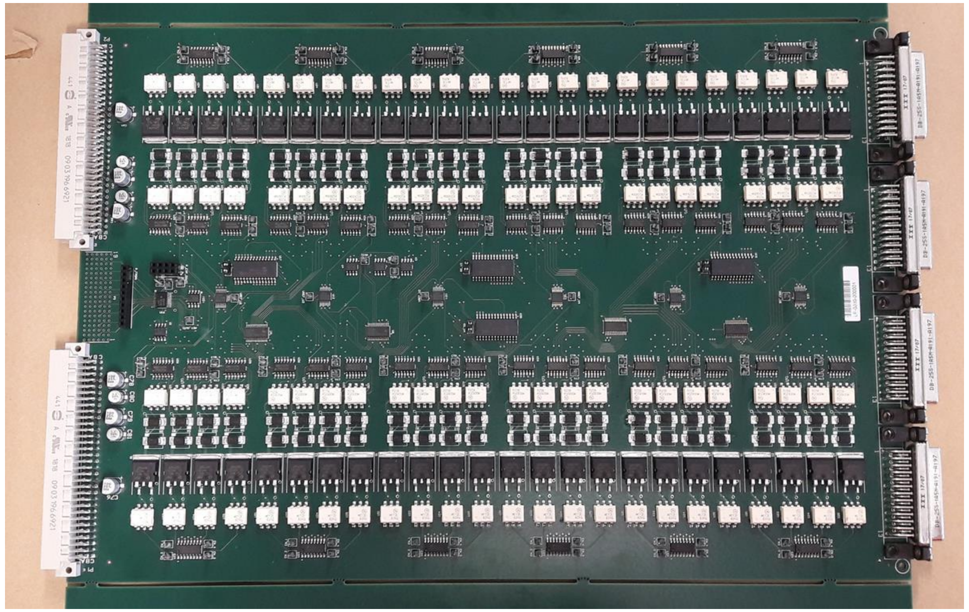
HVRemote Board

- 2 primary HV inputs (10 mA each)
- Regulates up to 48 voltages in a 360 V range
- Output currents < 400 μA
- 256 boards required



24 ch HVRemote prototype

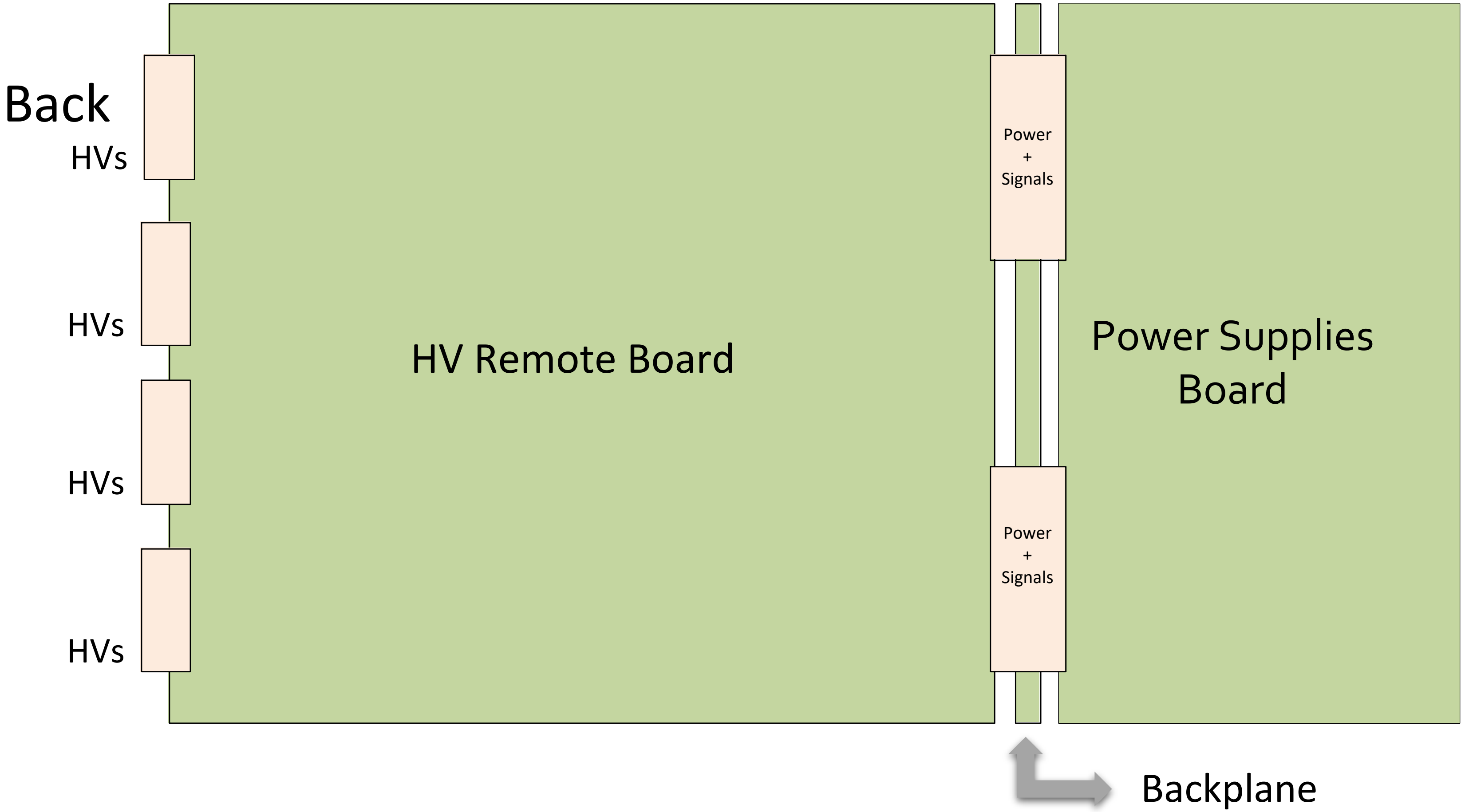
- First prototypes had only 24 ch
- Last year produced prototype with 48 ch
- 23 x 34 cm, 8 layers
- Assembled at Systion
- Control and monitoring being developped with Raspberry Pi (later to be moved to a Zybo Zinq SoC with FPGA)
- Currently in tests



48 ch HVRemote prototype

HV supplies, crate configuration

- Established crate layout proposal configuration with 16 modules per crate + 1 FPGA bus.
- HV remote board connected to HV supply modules as rear modules



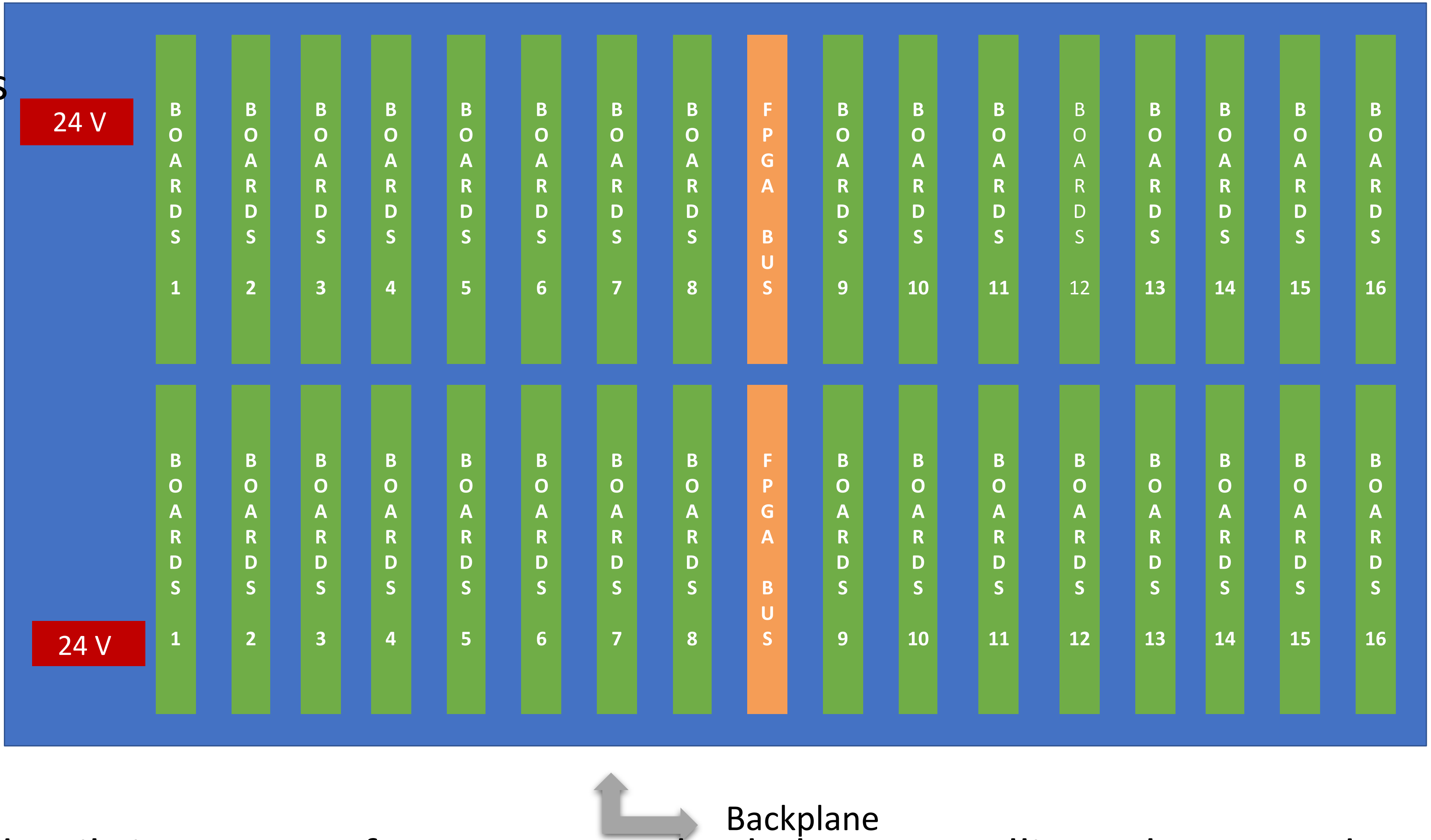
HV DC-DC, hardware switches, LEDs for status and interlock implemented in the front

16 sets per crate, complemented by a SoC board for control and monitoring (Zybo Z7-20 Zinq-7000 ARM replaced by a Raspberry Pi for development for the first prototype)

HV supplies - crate configuration (backplane)

HVremote boards in 6U HV supply. Crates provide primary HV and LV, control, monitoring and communication-

Each HV remote board has an individual supply board but all the power sources are at the crate



Draft design done, details in progress for connectors, backplane, metallic enclosure and bulk LV power supplies – first prototype to be produced soon by Heitec

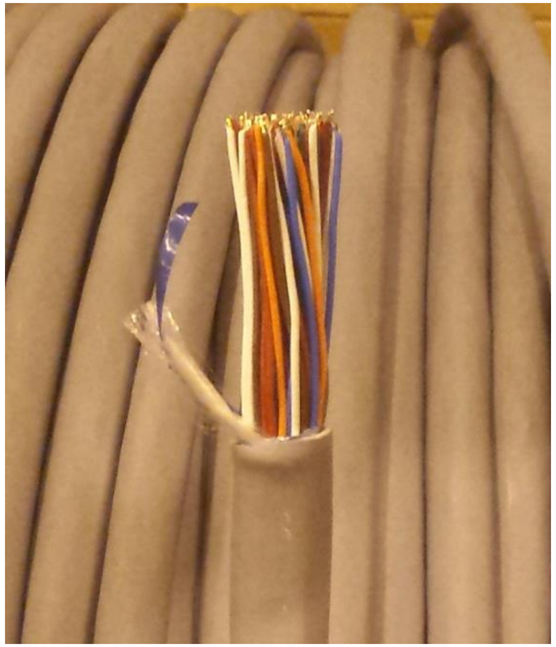
HV supplies – HVsupplies board

- Several changes in the implementation since the first design
- Now all the primary power supplies (20 A @ +24 V, 15 A @ +12V, 25 A @ -12V, 15 A @ +3.3V) are located at the side of the crate
- Two programmable high voltage power supplies (10 mA @ 830 V or 950 V) – Hamamatsu C12446 modules
- Slow ramp up of the high voltage being implemented
- New interlock
- Monitoring of the HVremote currents
- Control circuit with a dedicated SPI bus (similar to the HV Remote)
- Individual switch (on/off) for each power supply

New schematics finished, routing in progress

160x233 mm PCB

HV Cables



Need ~20 000 wires to bring HV from USA15 to the PMTs
located in the mini drawers inside the detector

HV_{max} = 950 V
Max continuous current per wire: 0.4 mA

Main candidate is a cable developed by Cabelte company in Portugal
(suggestion by José Covas from DEP, U. Minho)

Test of cables standalone (3m long cables):
Cabelte cable tested at 3 kV (pairs of wires), ok

Backup cable developed by an Italian company:
Novacavi cable tested at 3 kV (pairs of wires), ok, leakage current < 0,01 μA

Currently testing/certifying cables and connectors

HV remote 48 ch prototypes on test

2 boards were produced

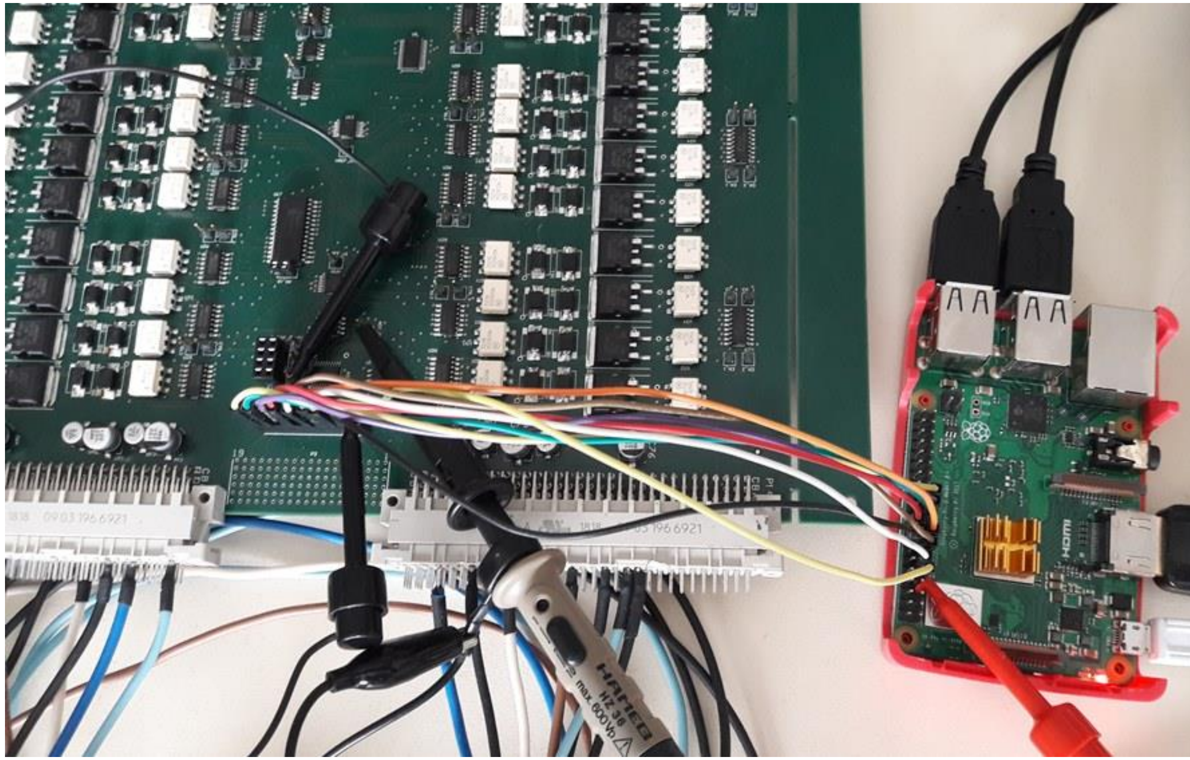
The boards required a few repairs to solve small errors inadvertedly introduced when expanding from the previous 24 ch board

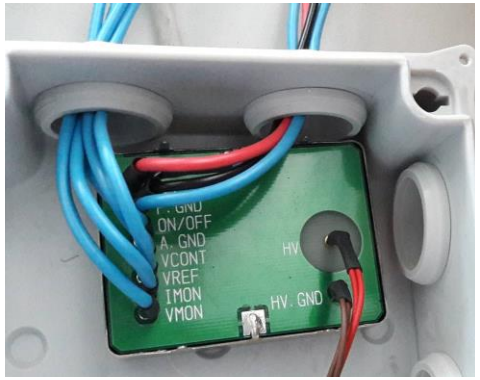
It took a few weeks to debug hardware and software

Control and monitoring is done by a Raspberry Pi

Preliminary status of the boards shows
- no problems in the first board
- 2 ch not yet completely ok at second board

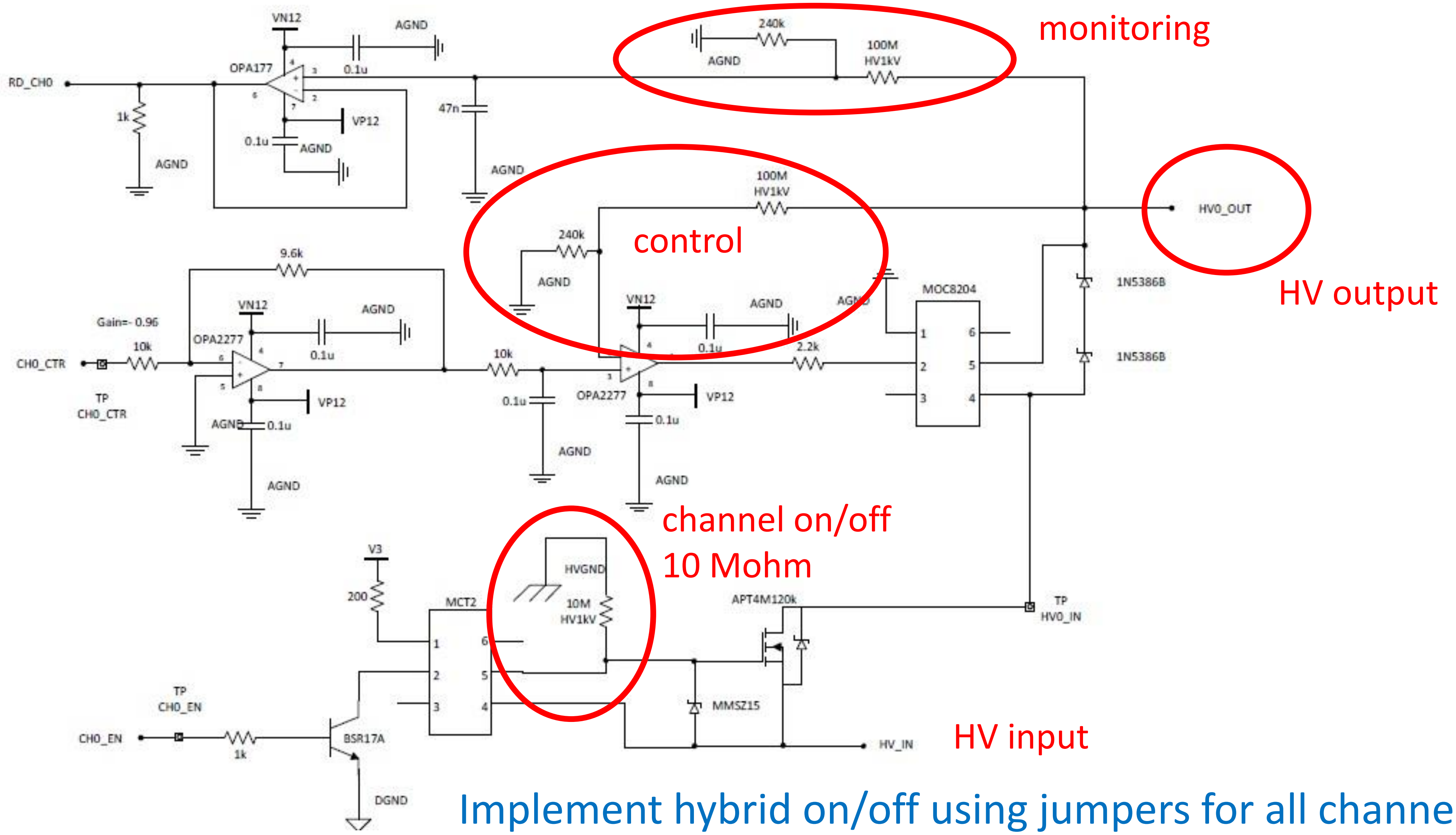
High consumption of HV current in on/off mechanism





HV current available from DC-DC converter for half board is 10 mA

Save HV current



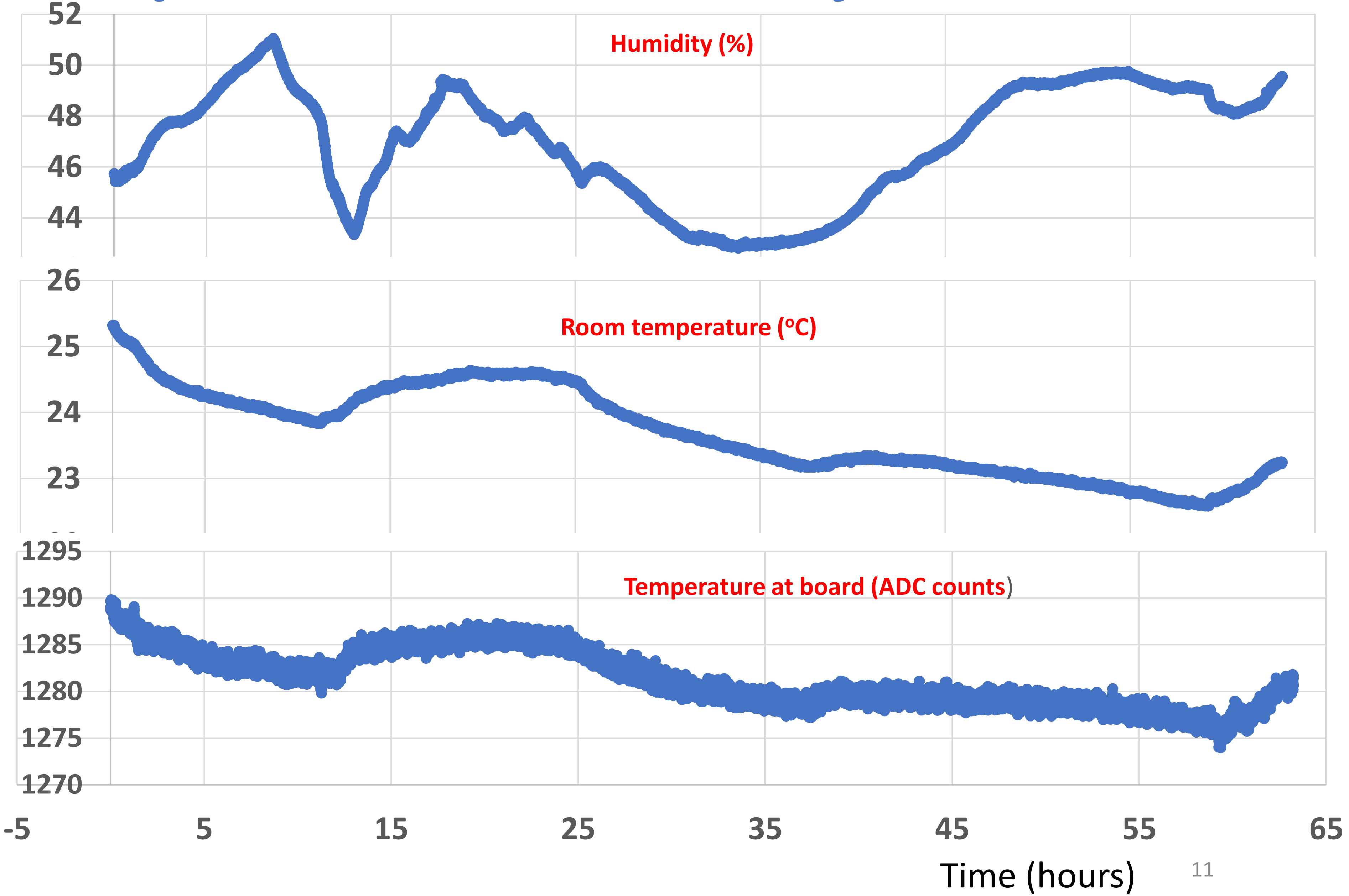
Implement hybrid on/off using jumpers for all channels and 1 opto-coupler for every 2 or 4 channels

Temperature and humidity

Board tested at room temperature

Temperature monitored at the board by monitoring system and near the board by dedicated precison temperature and humidity sensor.

Measurement in the board follows room temperature variations during more than 2.5 days



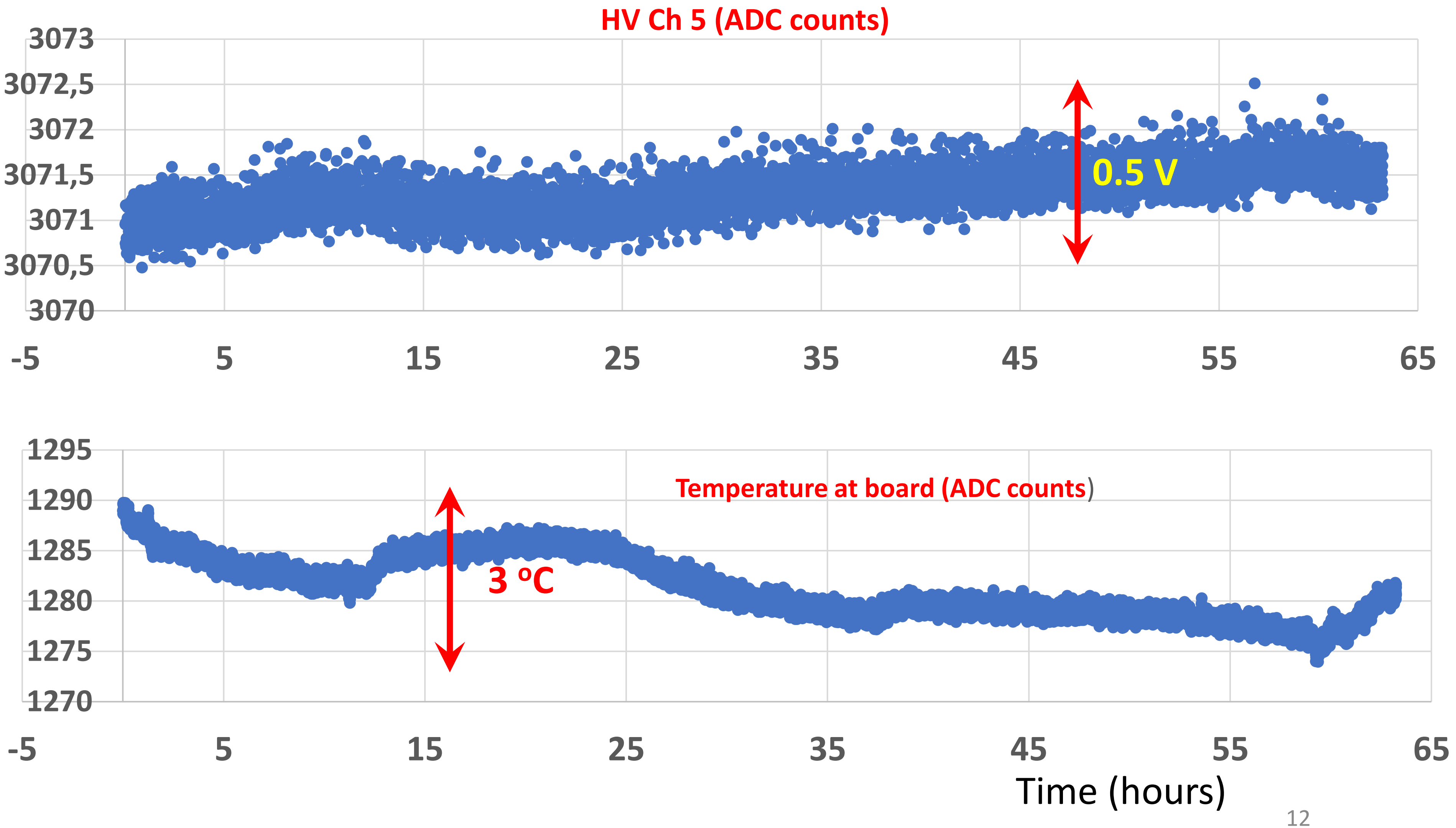
Voltage (reading) stability ch 5 and 6

Recording period is ~2.5 days

0.5V = 2 ADC counts

Ch 5 has an old Tile divider as load and HV = 748 V

Monitoring precision + HV stability less than 0.5V in 2.5 days with 3 ^oC temperature fluctuations



AC noise

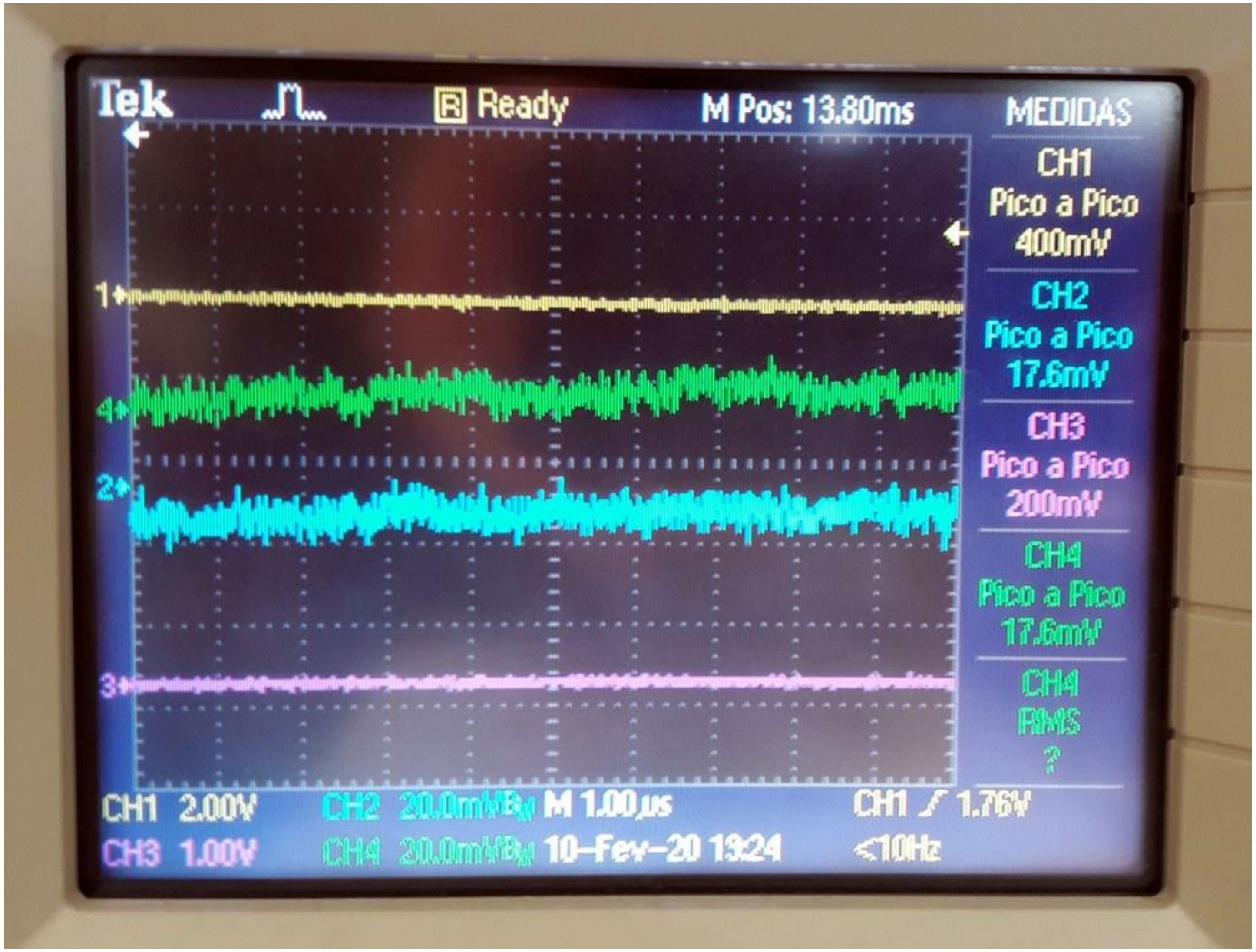
In the old 24 ch prototypes it was seen noise in some channels with oscillations up to a few hundred mV when using resistive load only

The PMT dividers have an RC filter and when they are used the oscillations disappear

Tested HVremote 48ch with old PMT divider

Test with 700V, probes near the end of divider (points with 86V-green ch4- and 286 V – blue ch2)

Peak to peak ~20 mV



Summary

Tilecal HV system for Upgrade Phase II is made in Portugal

Prototypes well advanced, in production for an HV vertical slice test in summer at CERN:

- HVbus final prototype will be produced with new connectors
- HV supplies board will go to production soon
- HVremote boards with a small list of changes will be produced
- Crate and cable
- FPGA board with Zybo SoC for control – not sure if in time for the vertical slice test, Raspberry Pi still in place as replacement

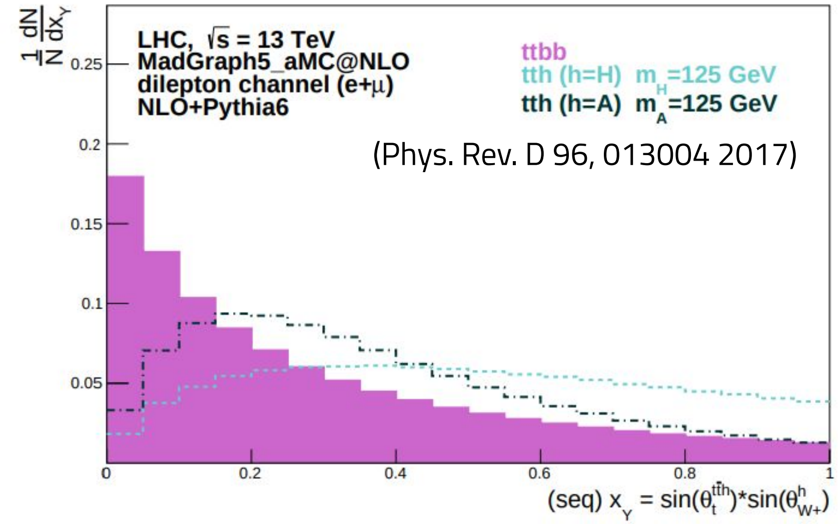
Preliminary lab performance obtained with HVRemote board prototype within specifications (but need to save HV current in the final version).

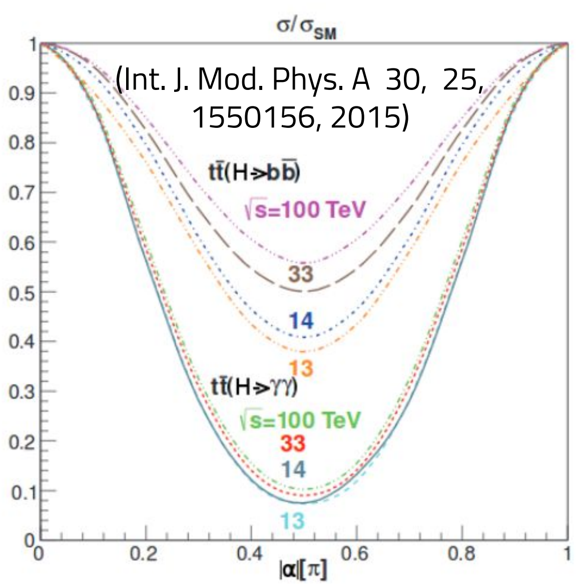
Still missing: long term stability tests (starting now) and tests with PMTs in a Tilecal module (soon at CERN)

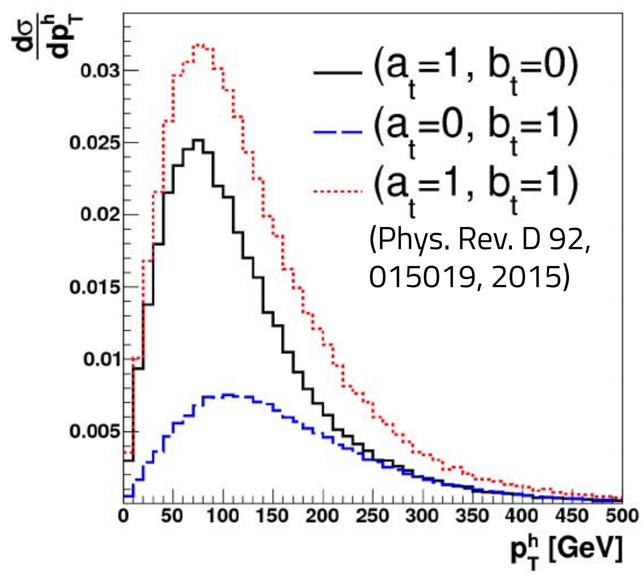
Backup

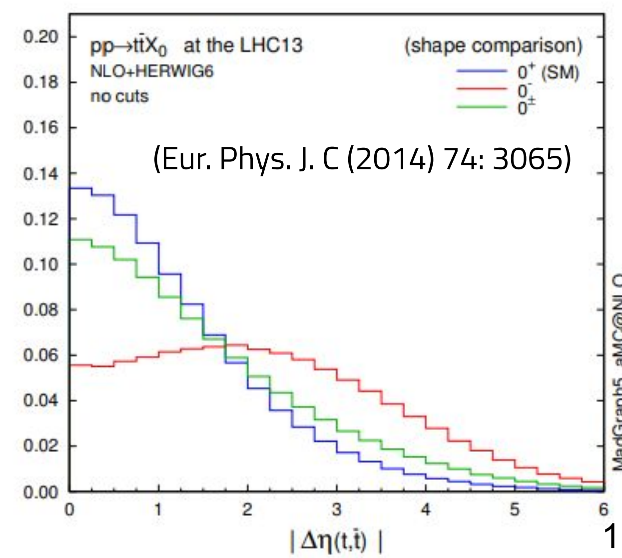
What is different in CP-odd ttH?

- Lower inclusive cross-section
- Higher Higgs p_T
- Top quarks much farther from each other in η and closer in φ
- Different angles measured in boosted rest frames



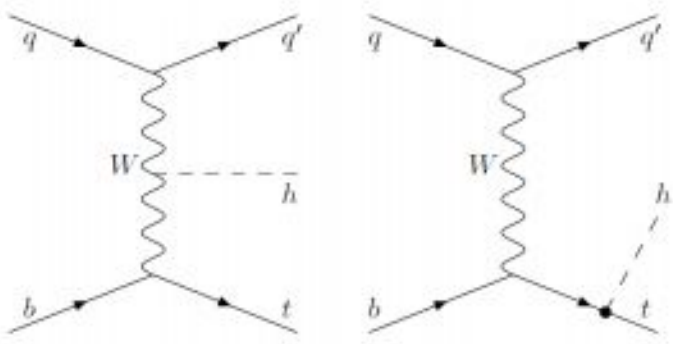


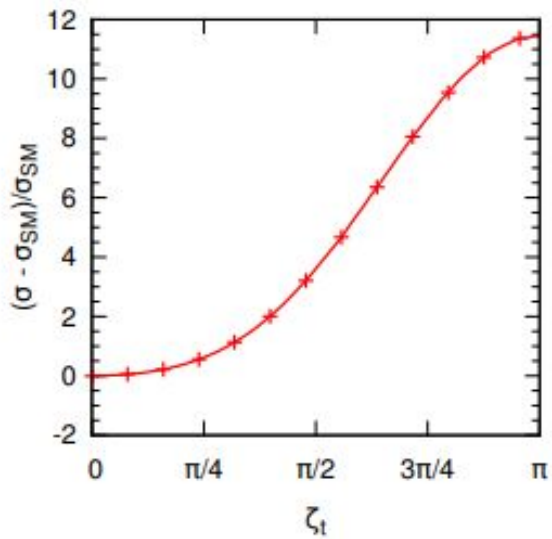




tH and CP-odd ttH coupling

- Large destructive interference in SM
- Great cross-section enhancement as we move through CP-even -> CP-odd -> CP-even negative coupling
- Unlike ttH, for which cross-section decreases
- tH region in ttH(bb) fit could add constraining tension

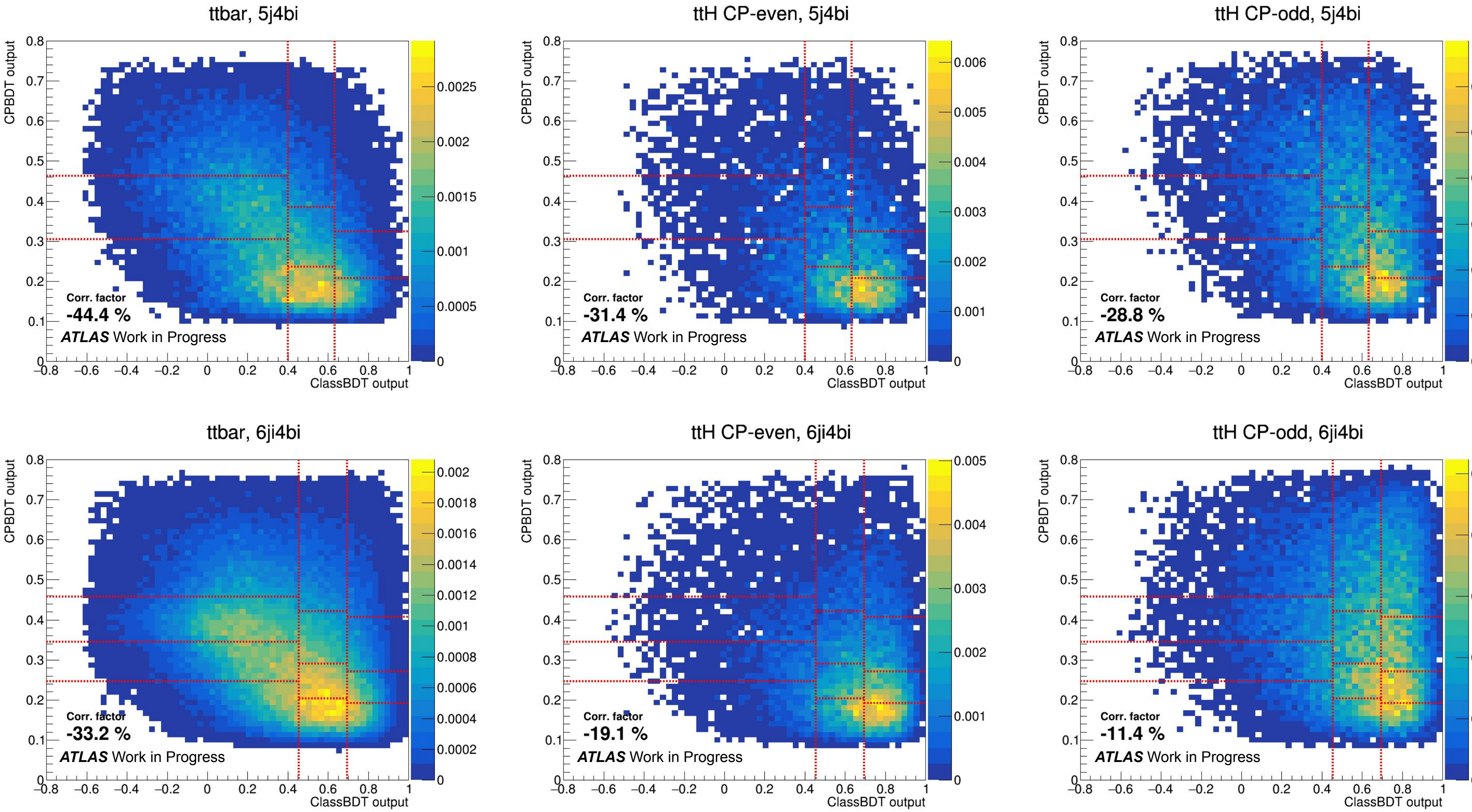




arXiv:1605.03806

CP BDT

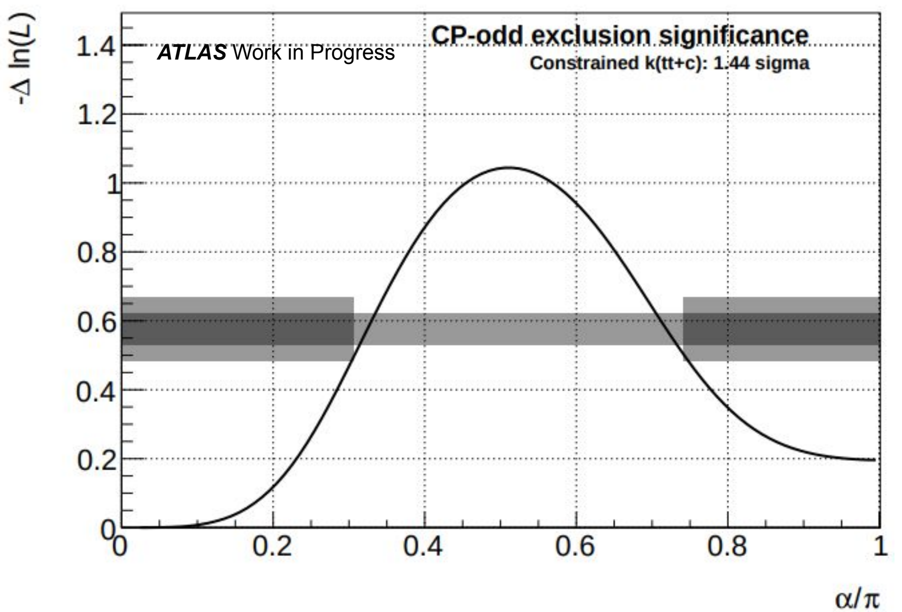
- Trained to classify CP-even and CP-odd ttH signals
- **CP-discriminant used in the fit**



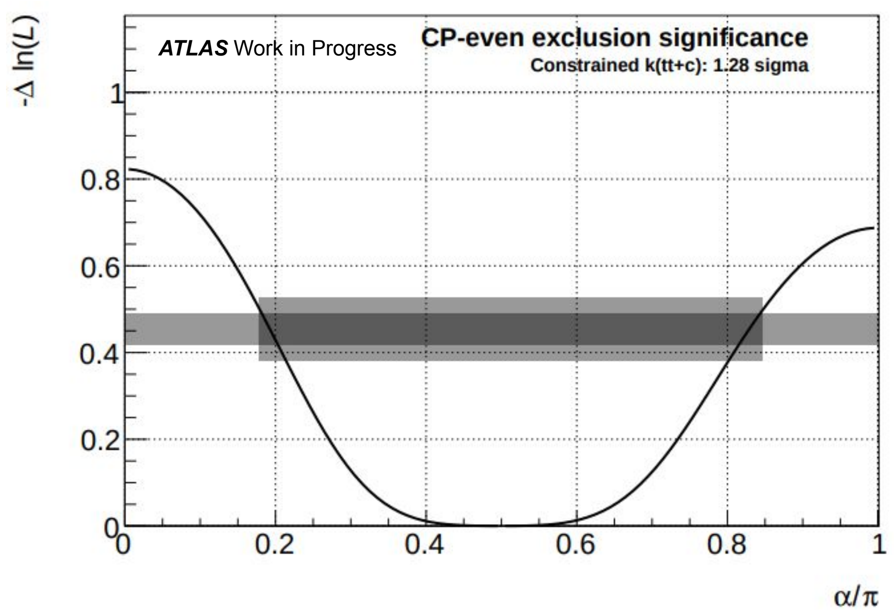
Expected sensitivity - 1D scan

- What range of α can we exclude? With what significance can we exclude a CP-odd coupling in the CP-even scenario (and vice-versa)?

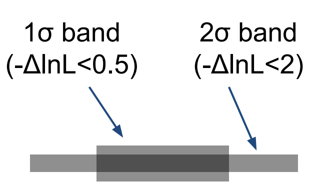
CP-even scenario



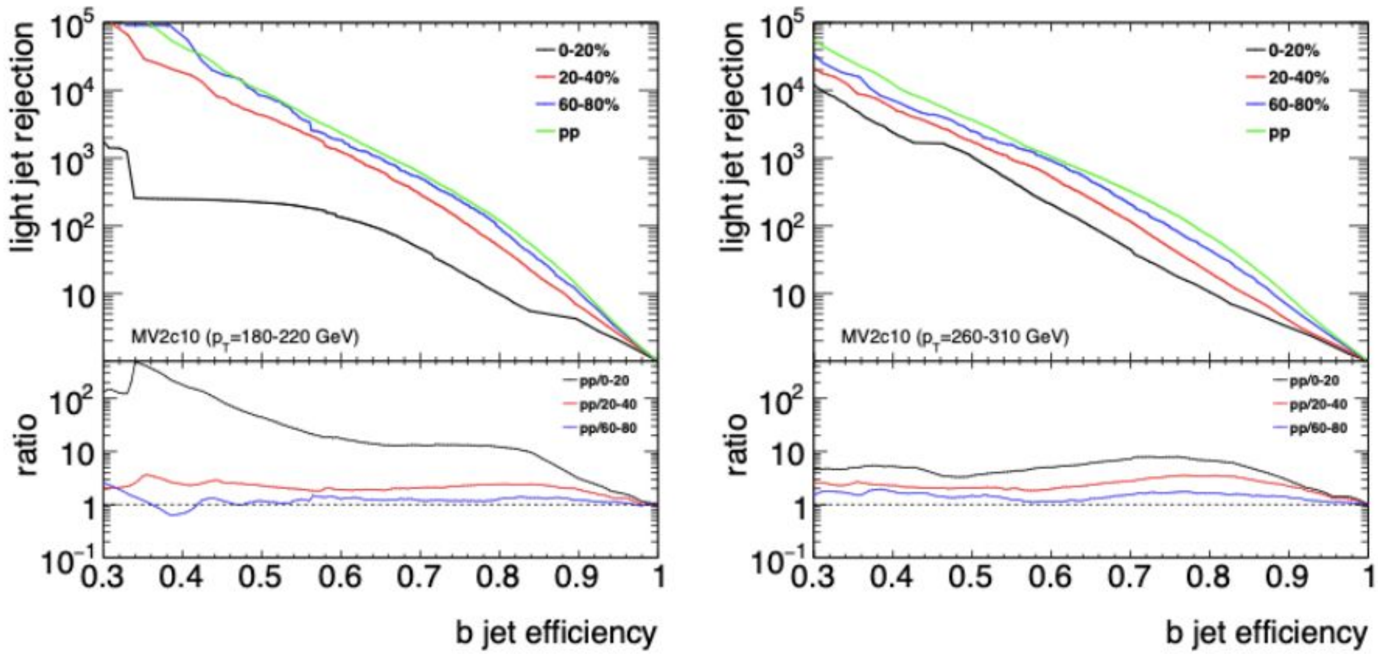
CP-odd scenario



- CP-even Asimov: **1.44 σ** for CP-odd exclusion
- CP-odd Asimov: **1.28 σ** for CP-even exclusion



The *b*-dijet asymmetry measurements were possible by the *b*-tagging developments in Pb+Pb collisions by (exclusively) LIP group, in particular, Rui Pereira.



Different distributions regard different collisions centrality. Peripheral (blue) and Mid (red) performances are similar to the one in pp (green) collisions; central (black) is not.

The ability to tag *b*-jets strongly dependent on the collisions centrality, mainly at lower jet p_T (left plot).

These were very good achievements but to move forward we need:

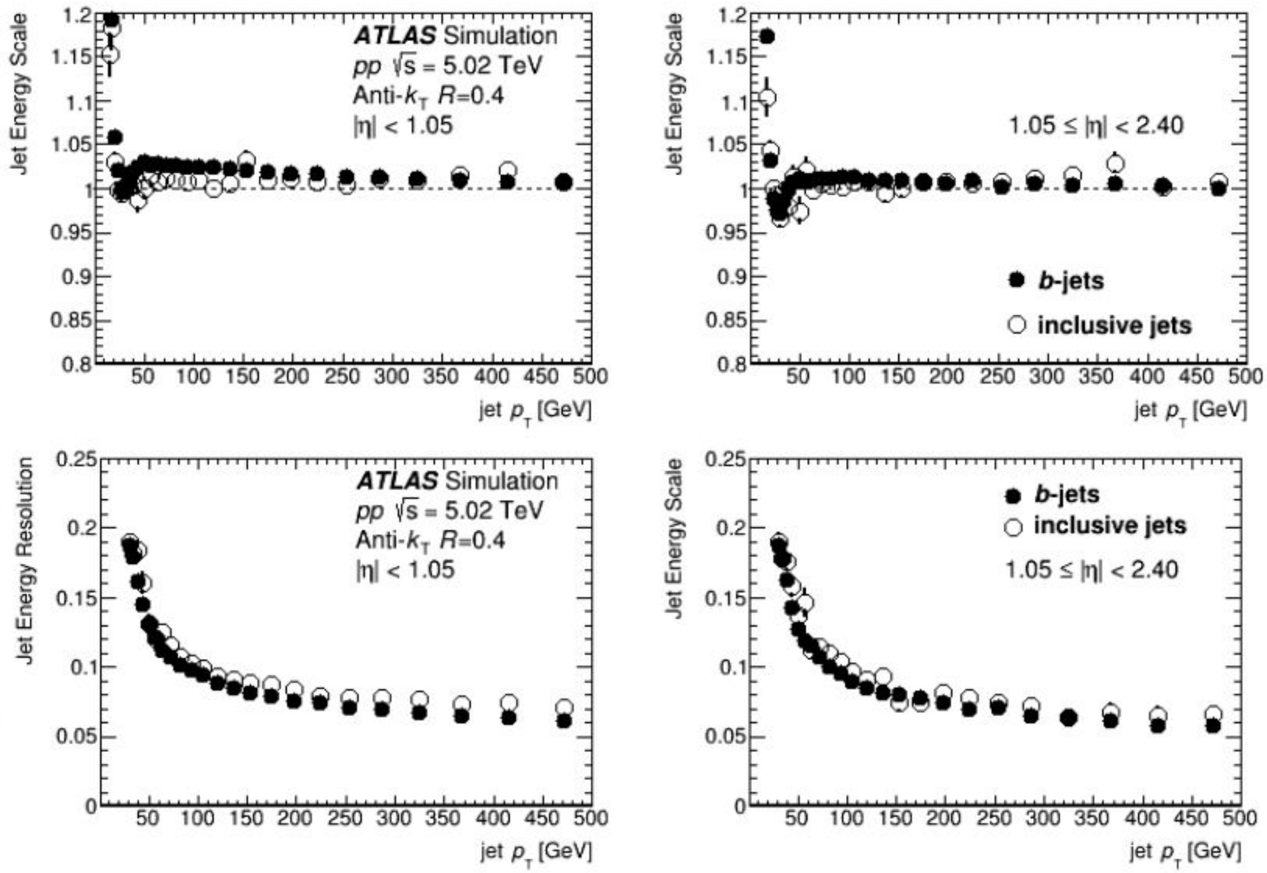
Understand the b-jet reconstruction in Pb+Pb collisions -> study the flavour dependence. Is the detector response the same for b-jets and light jets?

The Jet Energy Scale needs flavour dependent calibrations

The resolution is better for b-jets

The detector response is different for b-jets and light jets.

Coming next:
The same study in Pb+Pb collisions. Need a more complex Monte Carlo, though.

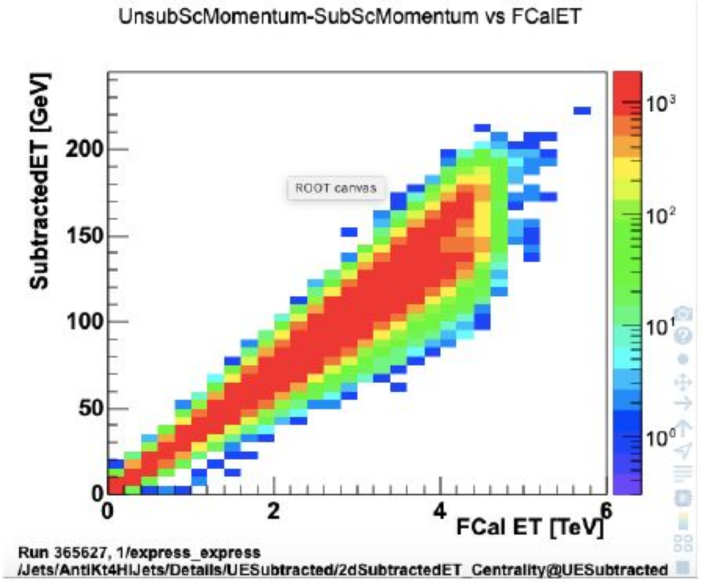


Jet Energy Scale and Resolution are given by the mean and RMS of p_T^{reco}/p_T^{truth} distribution. Here plotted as a function of truth jet pT

More contributions from LIP

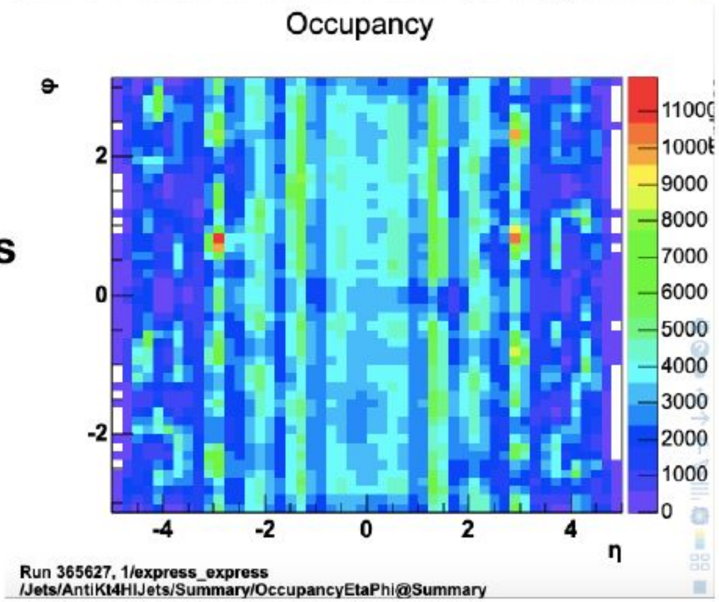
Responsbility of the jet monitoring infrastructure during the Pb+Pb collisions data taking

Energy from the underlying event subtracted to jets as a function of the collisions centrality (strongly correlated to the energy deposited in the forward calorimeters).

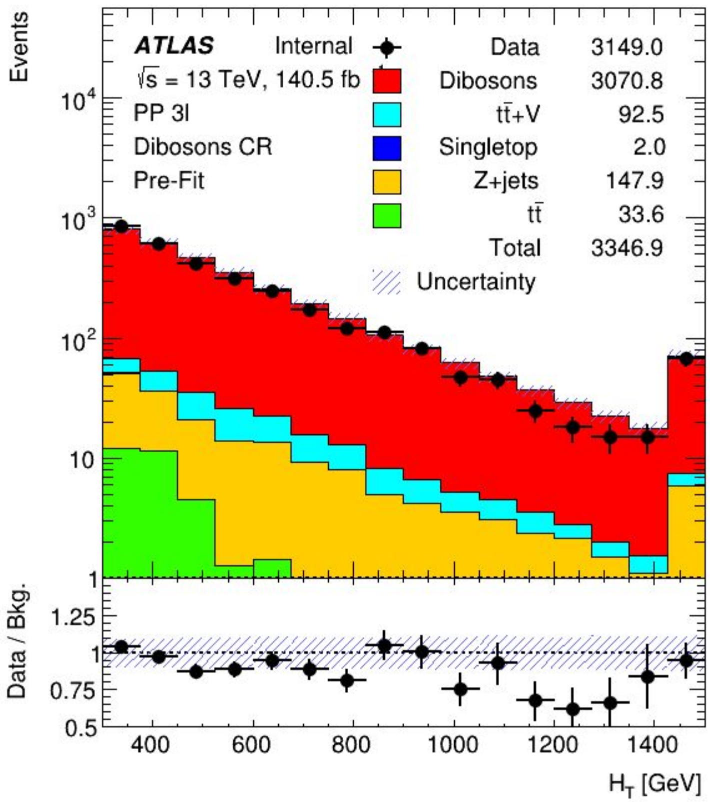


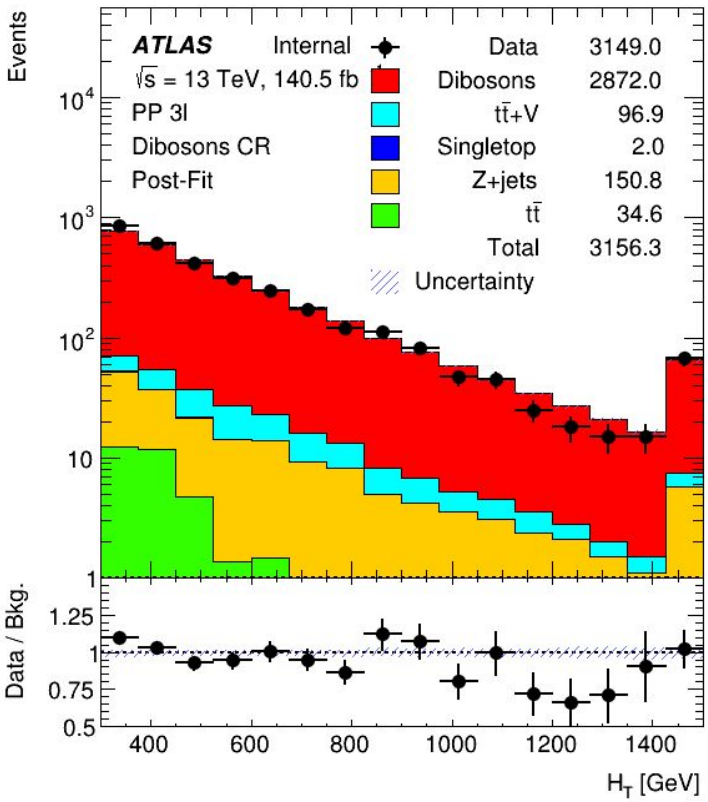
Crucial for correct jet energy measurements

Jet occupancy in the calorimeters



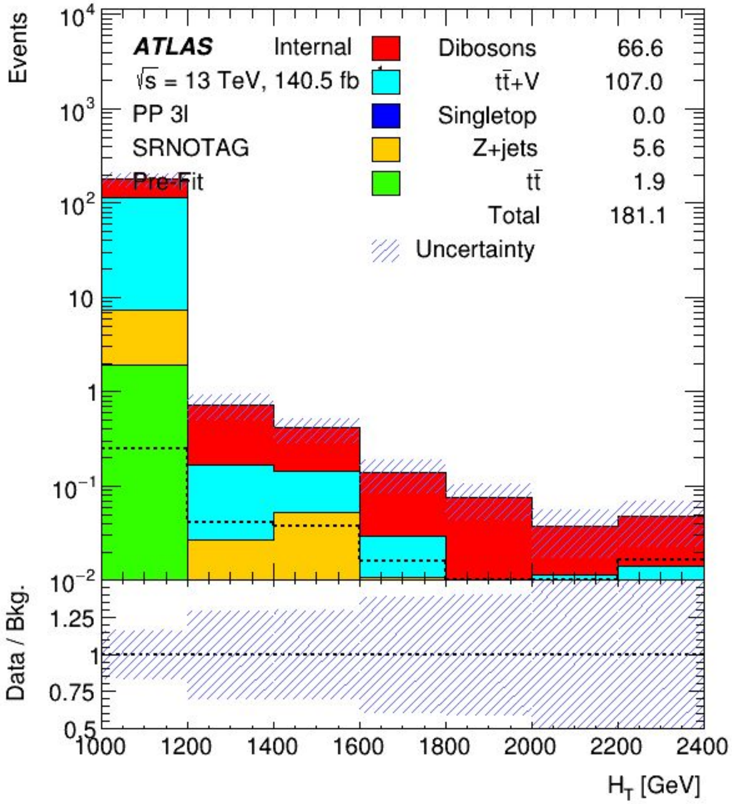
VV Unblinded Region

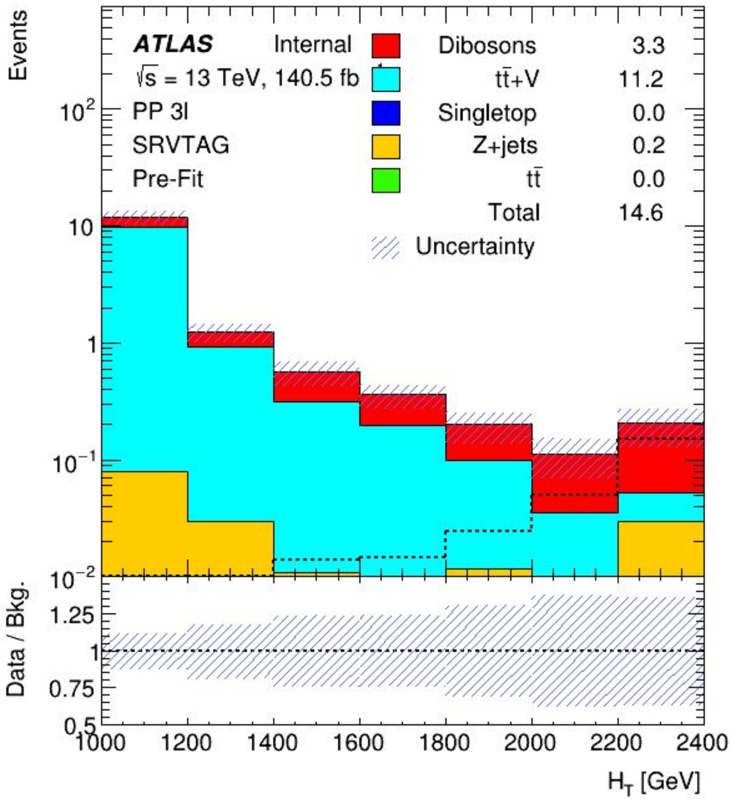




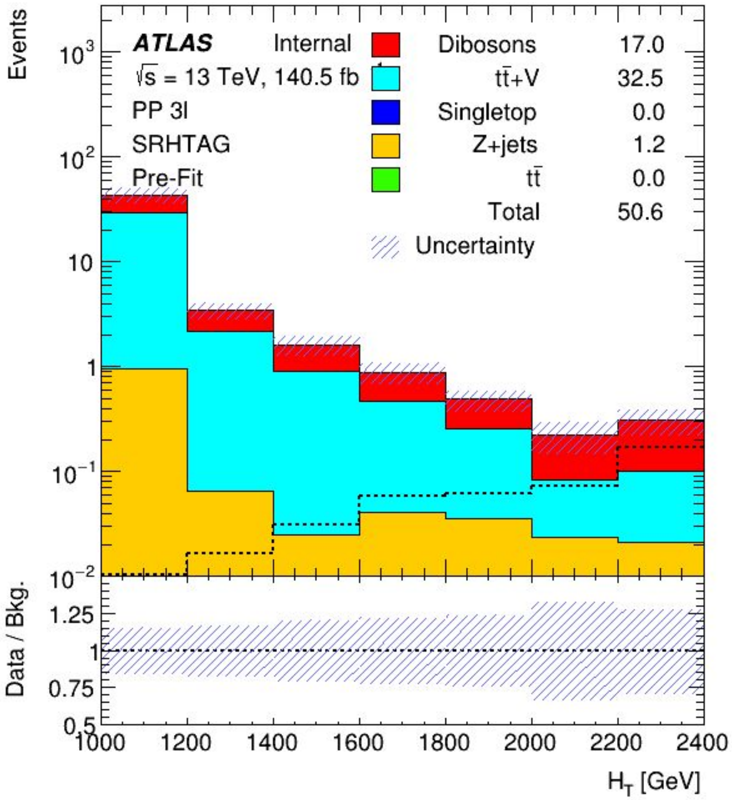
- Good Dibosons isolation (>90%)
- Decent background modeling

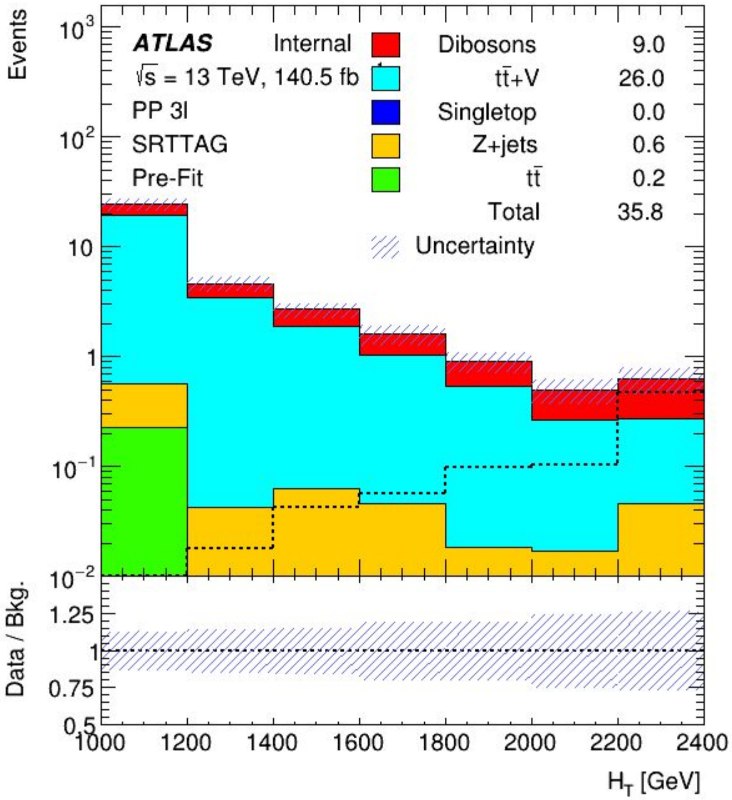
Signal Regions



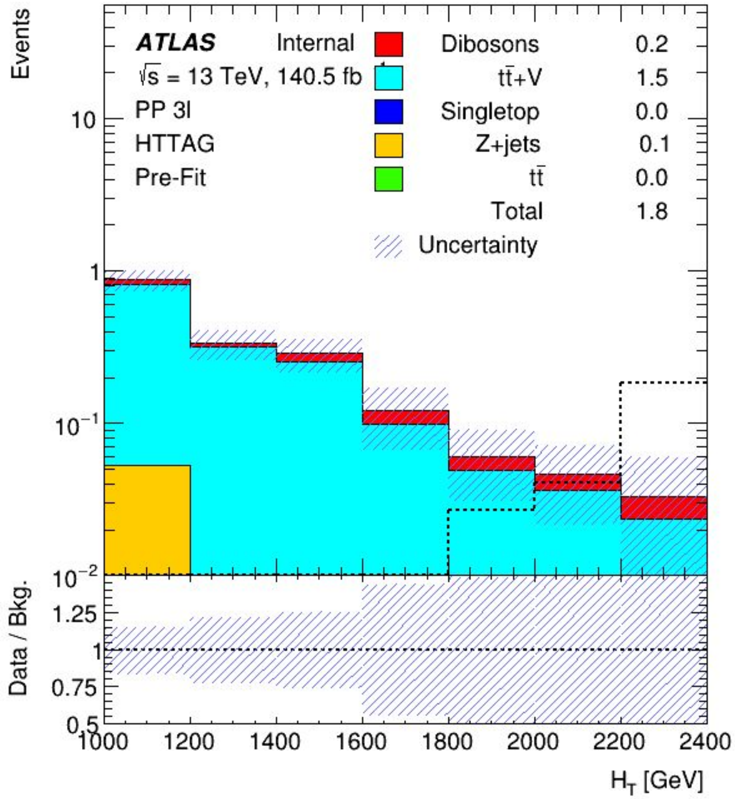


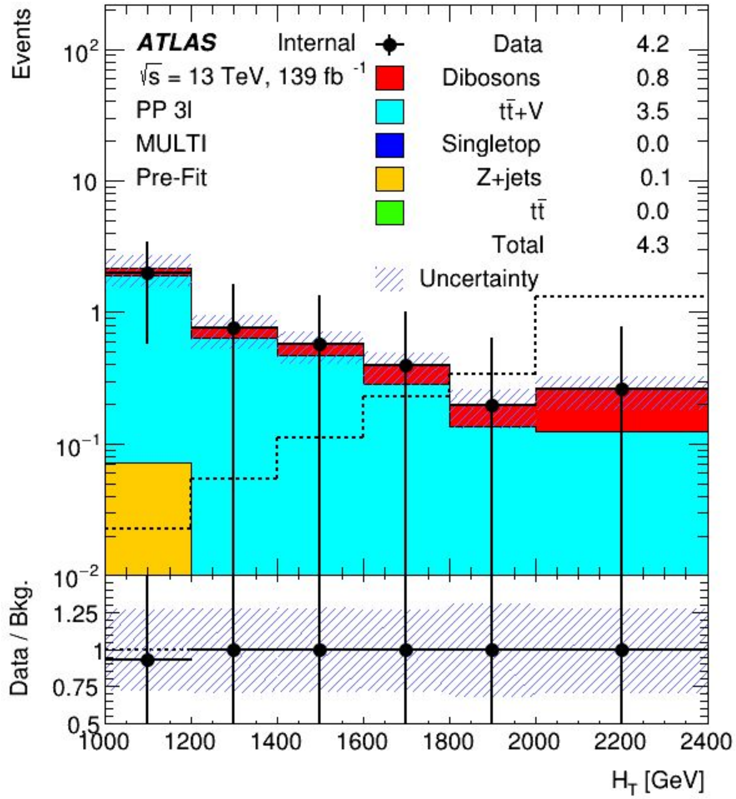
Signal Regions



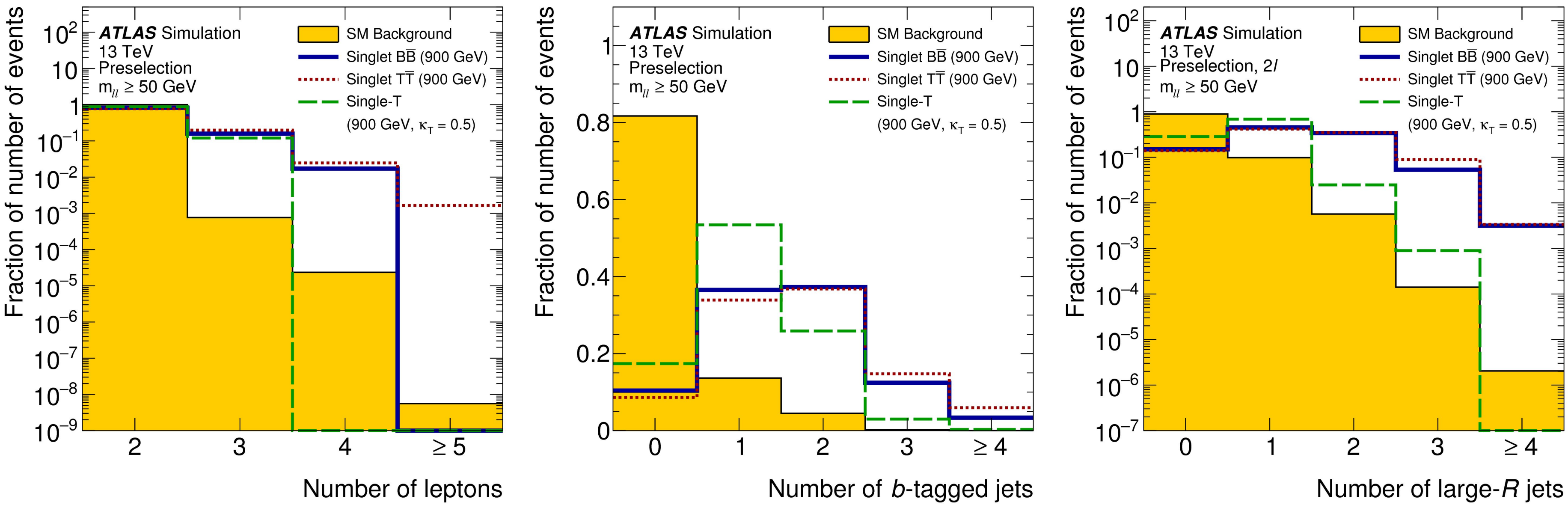


Signal Regions





Basic
Selection



- Object multiplicities vary significantly from signal to background
- Used to define channels:
  - Pair-production:
    - 2 leptons
    - ≥ 3 leptons

  Single Production:
    - 2 leptons
    - ≥ 3 leptons

3l regions
Definition

VV Unblinded Region	Signal Enriched Region
2 central jets with $p_{\mathrm{T}} > 25\,\mathrm{GeV}$	
≥ 3 leptons with $p_{\mathrm{T}} > 28\,\mathrm{GeV}$	
pair of OS-SF leptons with $\lvert m_{\ell\ell} - m_Z \rvert < 10\,\mathrm{GeV}$	
$H_{\mathrm{T}}(\text{jets} + \text{lep.}) > 300\,\mathrm{GeV}$	
$= 0$ b-tagged jets	≥ 1 b-tagged jet
	$p_{\mathrm{T}}(Z) \geq 200\,\mathrm{GeV}$

- Basic selection
  - Select events compatible with a Z boson candidate
  - Look at boosted phase space
  - 0 b-tagged jets region to isolate Dibosons (major background)

Signal regions
Splits

# MCBOT tags	# RC jets	MCBOT categories in b-tag categories	
0	≥ 0	0 tags $\cdot$ $\{1\,b, \geq 2\,b\}$	
1	≥ 1	1V-0H-0top $\cdot$ $\{1\,b, \geq 2\,b\}$ 0V-1H-0top $\cdot$ $\{1\,b, \geq 2\,b\}$ 0V-0H-1top $\cdot$ $\{1\,b, \geq 2\,b\}$	
		$1\,b$	$\geq 2\,b$
2	2	2V-0H-0top + 0V-2H-0top + 1V-0H-1top	1V-1H-0top + 2V-0H-0top + 0V-2H-0top + 0V-0H-2top
2	2	0V-0H-2top + 1V-1H-0top	0V-1H-1top
≥ 3	≥ 3	≥ 3 tags + 1V-1H-0top	≥ 3 tags + 1V-0H-1top

2l categories

# V tags	# H tags	# top tags	Name
0	0	0	NOTAG
≥ 1	0	0	VTAG
0	≥ 1	0	HTAG
0	0	≥ 1	TTAG
≥ 1	≥ 1	0	VHTAG
0	≥ 1	≥ 1	HTTAG
≥ 1	≥ 0	≥ 1	VTTAG_MULTI

3l categories

- Combined fit in the end

Profile
Likelihood

- Used when fitting models with more than one unknown parameter:
  - Parameters of interest (POI, μ). Typical: signal strength
  - Nuisance parameters (NP, θ). Typical: systematic uncertainties

$$\mathcal{L}(\boldsymbol{n}, \boldsymbol{\theta^0} | \boldsymbol{\mu}, \boldsymbol{\theta}) = \prod_R P(n_R | \lambda_R(\boldsymbol{\mu}, \boldsymbol{\theta})) \prod_p C_p(\theta_p^0, \theta_p)$$

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All regions and bins

Profile **Likelihood**

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$$C_p(\theta_p^0, \theta_p) = \frac{1}{\sigma_p \sqrt{2\pi}} \exp\left[-\frac{(\theta_p - \theta_p^0)^2}{2\sigma_p^2} \right]$$

Penalty term

Profile
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All regions and bins

All systematics

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Penalty term

- From histograms of observable X at nominal and ±1 sigma values of nuisance parameter, interpolate and extrapolate for different values

$$\lambda(\mu) = \frac{\mathcal{L}(\mu, \hat{\hat{\theta}}_\mu)}{\mathcal{L}(\hat{\mu}, \hat{\theta})}$$

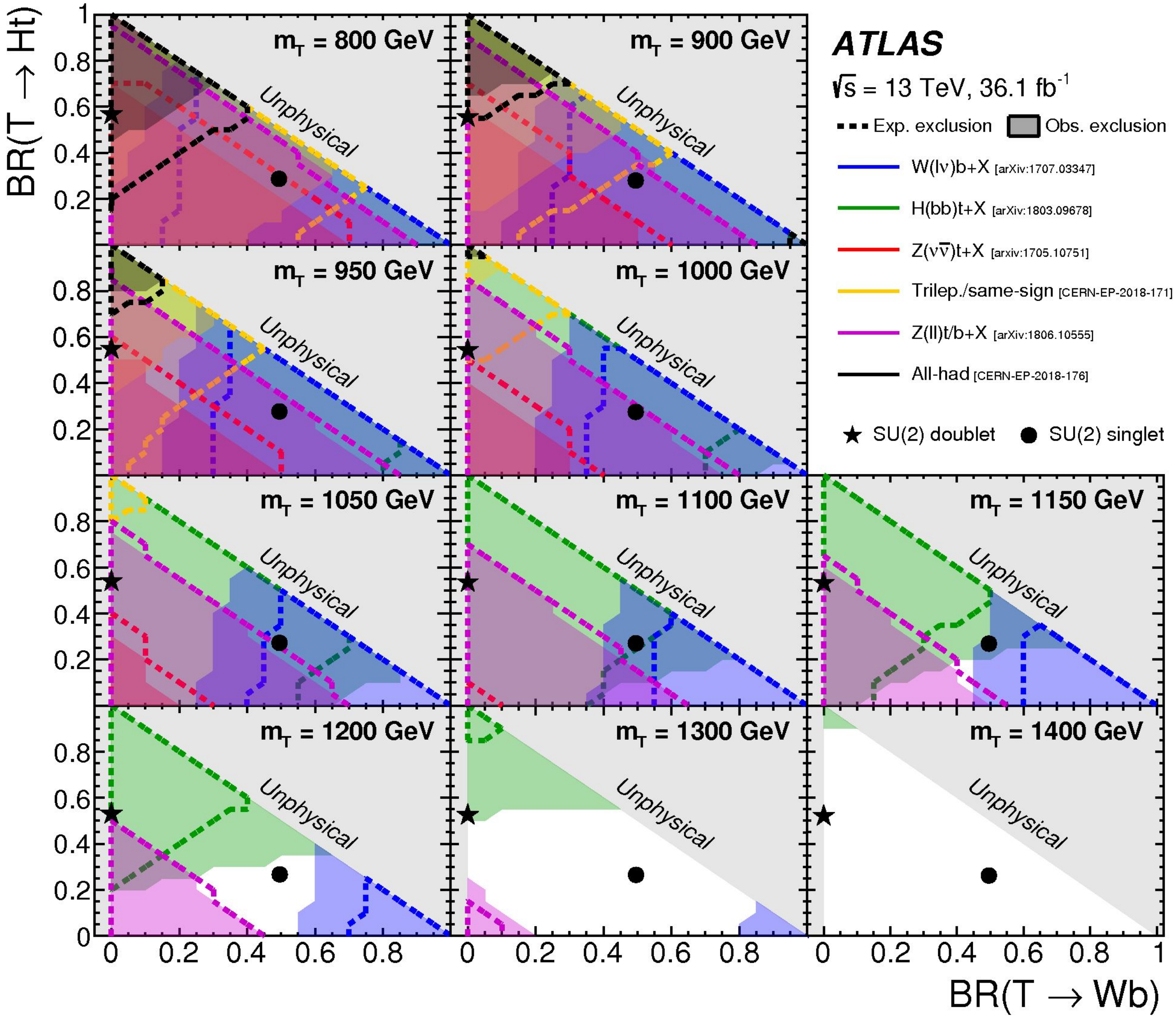
Maximize L for a given μ
'conditional' likelihood

Maximize L
'unconditional' likelihood

10.1103/PhysRevLett.121.211801

Combination
of final states

- Pair-production
- Each analysis gives a contribution to a different BR corner
- Making the most of all analysis optimizations
- Full profit from available statistics



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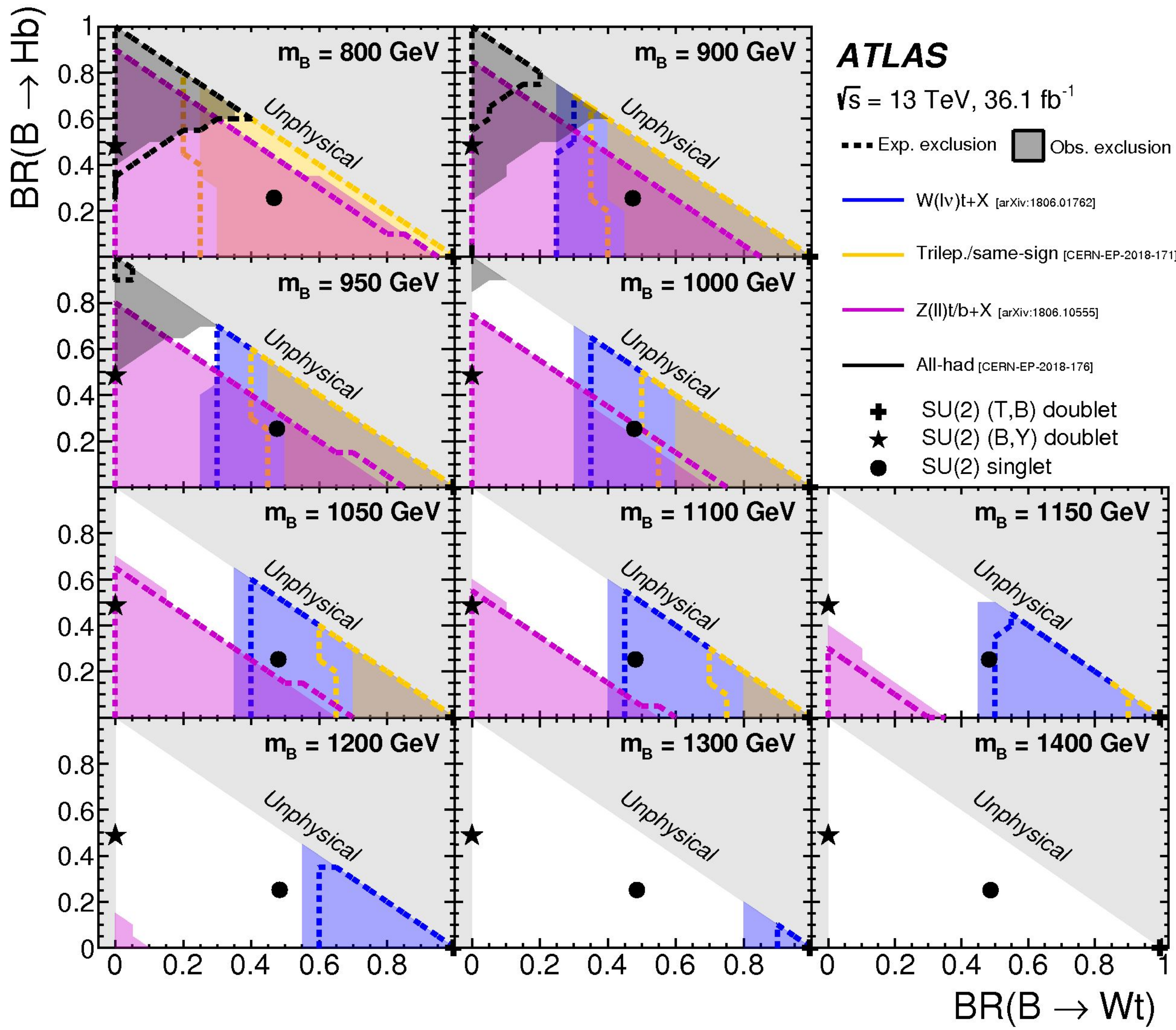
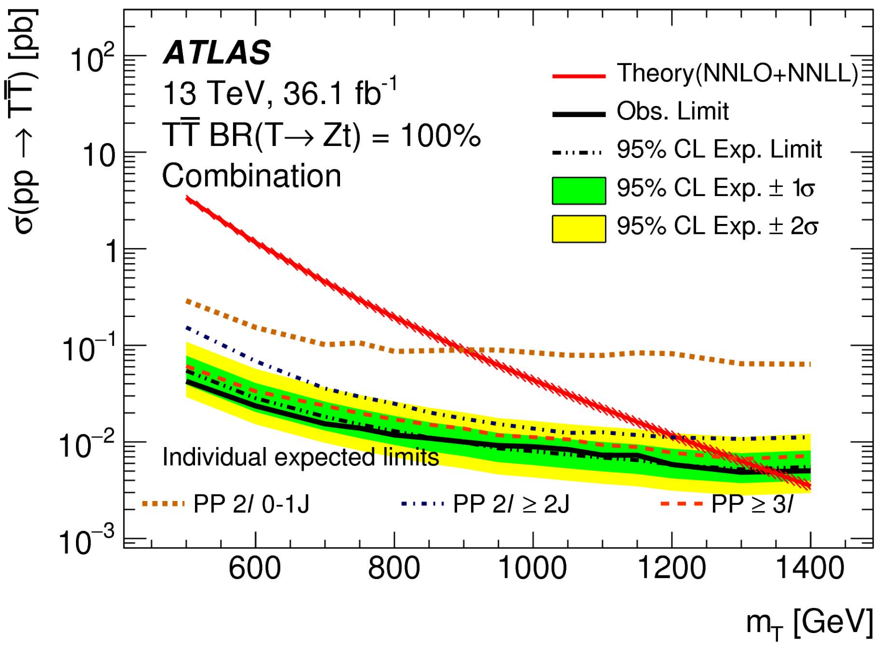
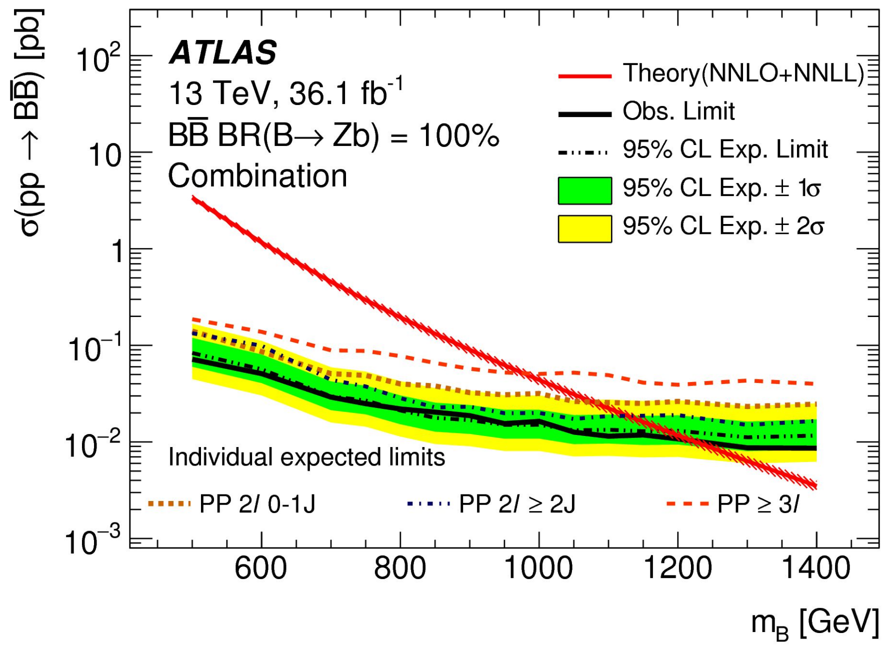


10.1103/PhysRevD.98.112010

Pair-production
Results



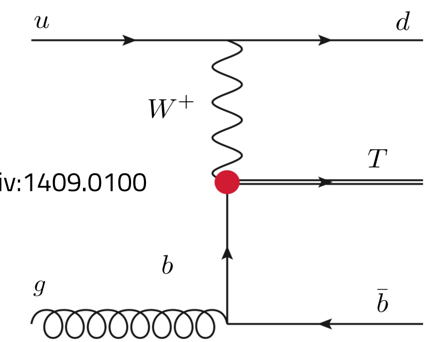


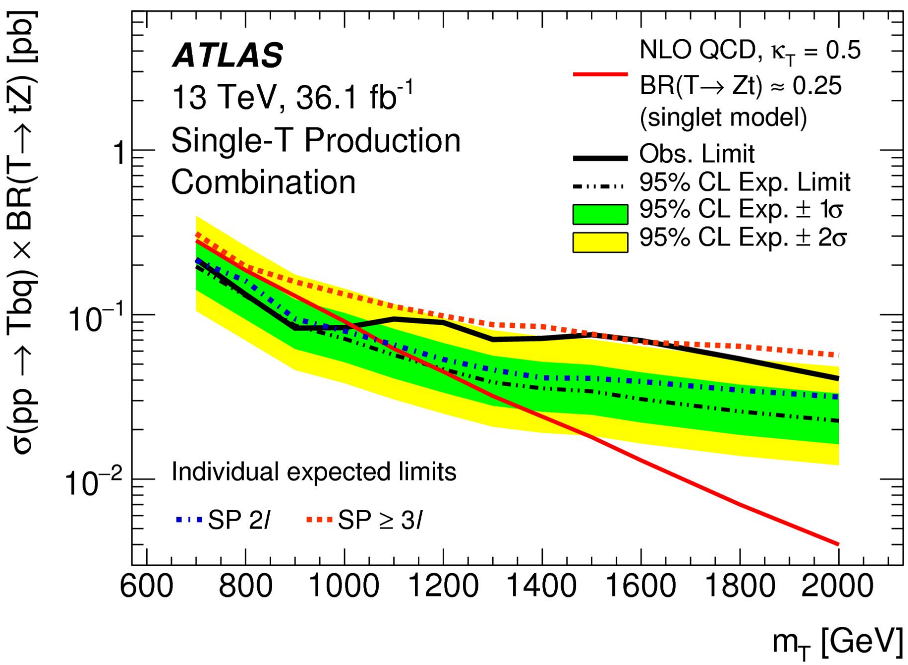
- Excluded up to 1.2 - 1.3 TeV
- **Statistics** as the most limiting factor
  - New data from 2017 and 2018 should boost results

Single-production
Results

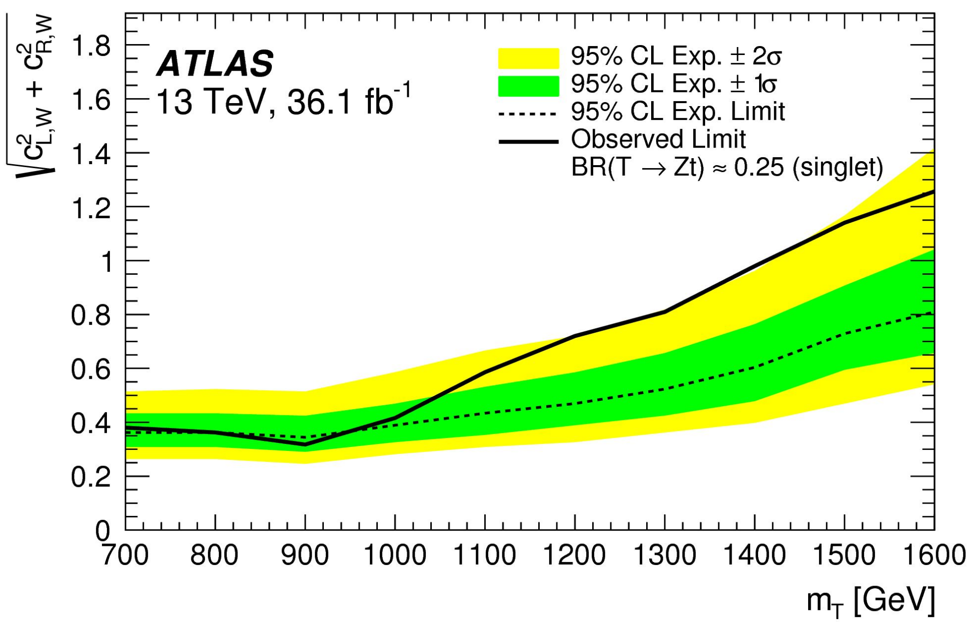
[10.1103/PhysRevD.98.112010](https://doi.org/10.1103/PhysRevD.98.112010)

arXiv:1409.0100





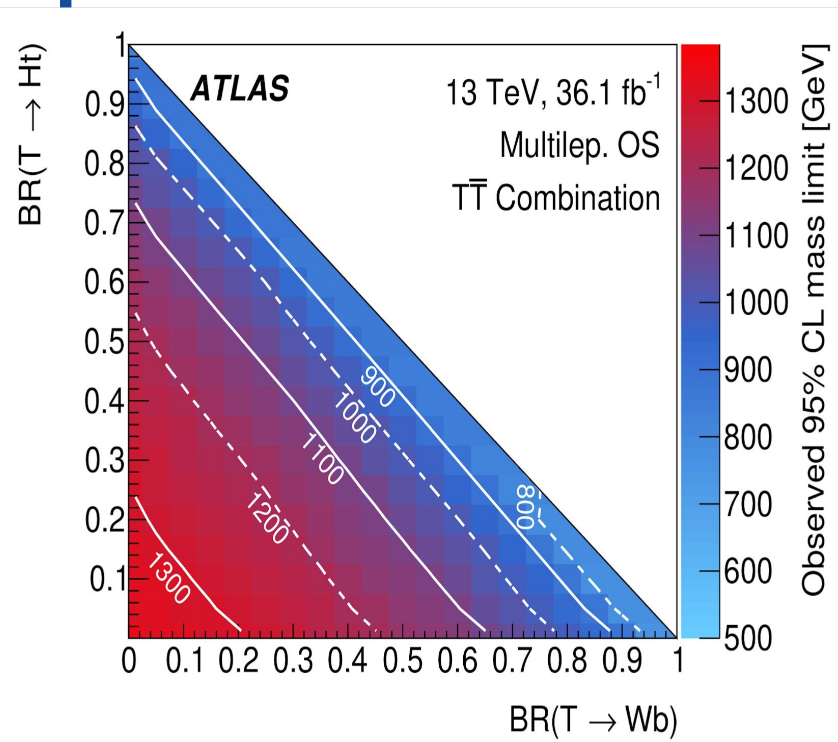
Cross section limit as a function of mass for a fixed coupling

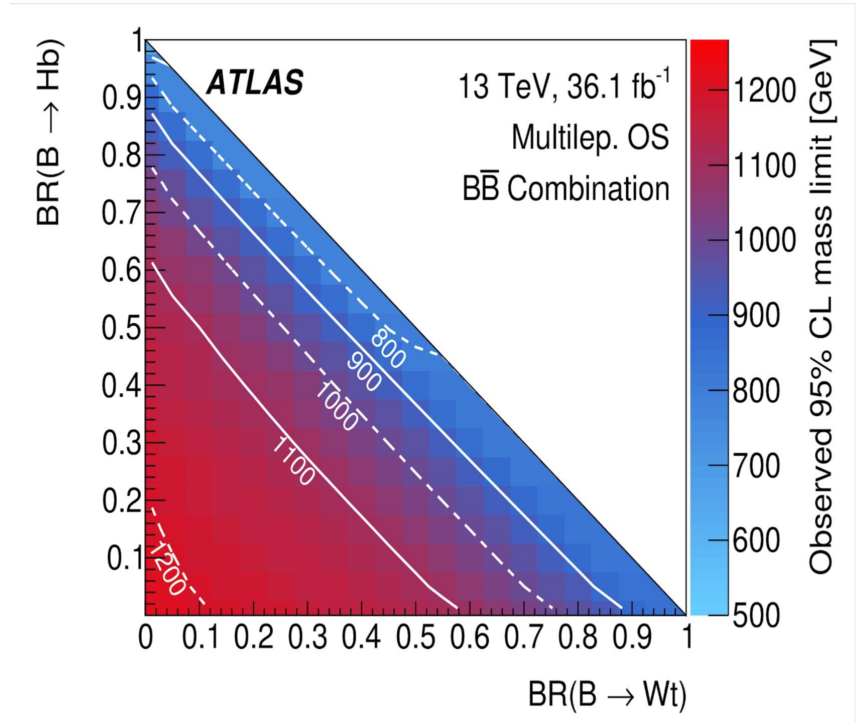


Coupling limits as a function of mass

10.1103/PhysRevD.98.112010

Pair-production limits





Model	Dilepton (0–1 large-R jets)	Dilepton ($\geq$ 2 large-R jets)	Trilepton	Combination
$T\bar{T}$ singlet	740 (720) GeV	950 (930) GeV	950 (1010) GeV	1030 (1060) GeV
$T\bar{T}$ doublet	850 (820) GeV	1100 (1100) GeV	1090 (1150) GeV	1210 (1210) GeV
100% $T \rightarrow Zt$	920 (900) GeV	1210 (1210) GeV	1260 (1290) GeV	1340 (1320) GeV
$B\bar{B}$ singlet	860 (840) GeV	930 (950) GeV	890 (940) GeV	1010 (1030) GeV
$B\bar{B}$ doublet	1040 (1000) GeV	1060 (1070) GeV	820 (880) GeV	1140 (1120) GeV
100% $B \rightarrow Zb$	1110 (1080) GeV	1120 (1130) GeV	930 (980) GeV	1220 (1180) GeV

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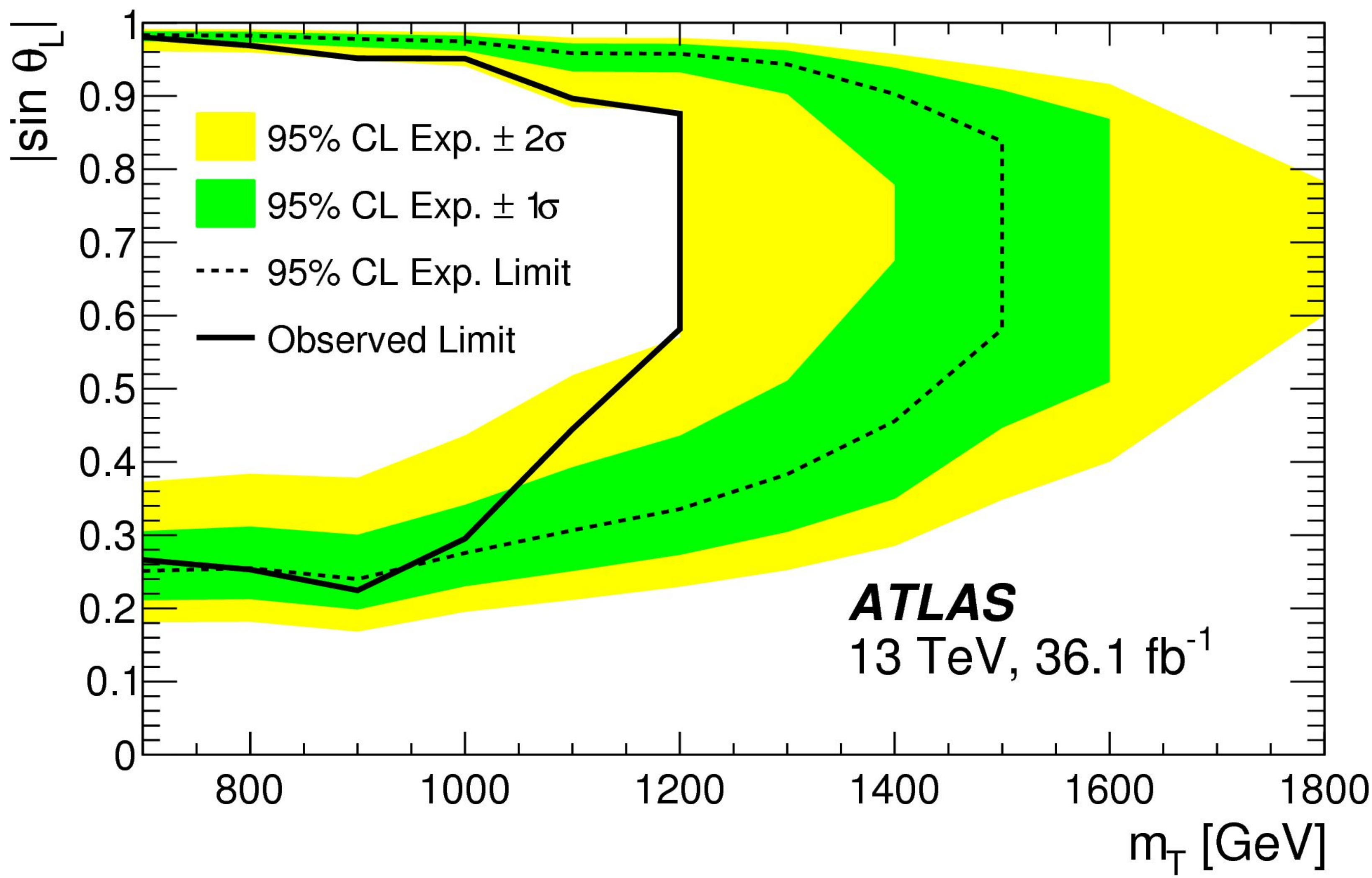
Pair-production **limits**



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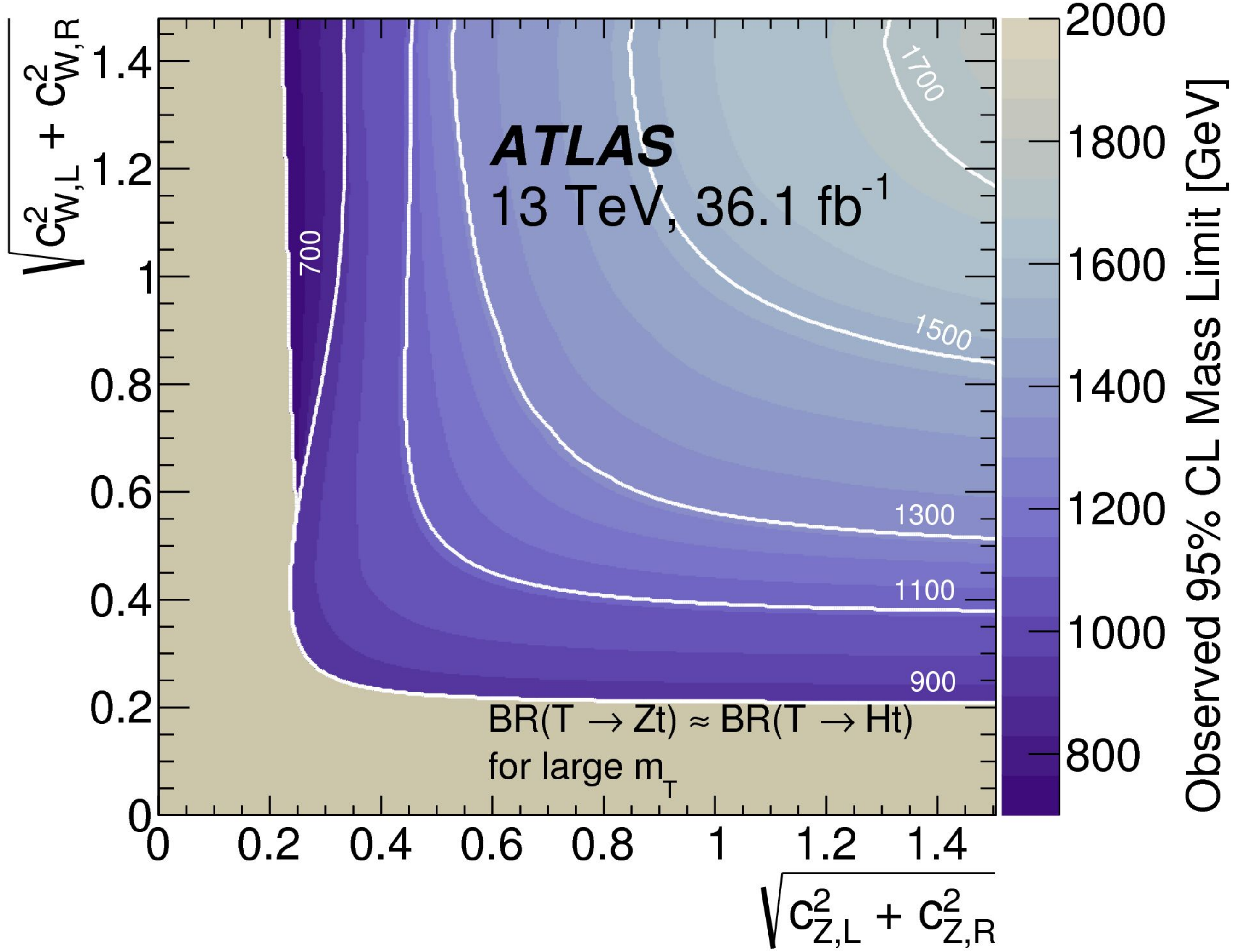
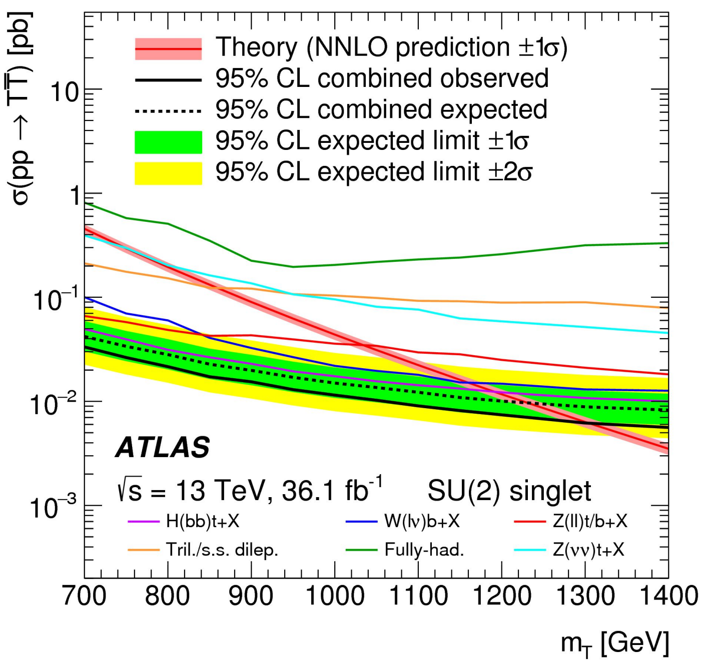
Pair-production **limits**

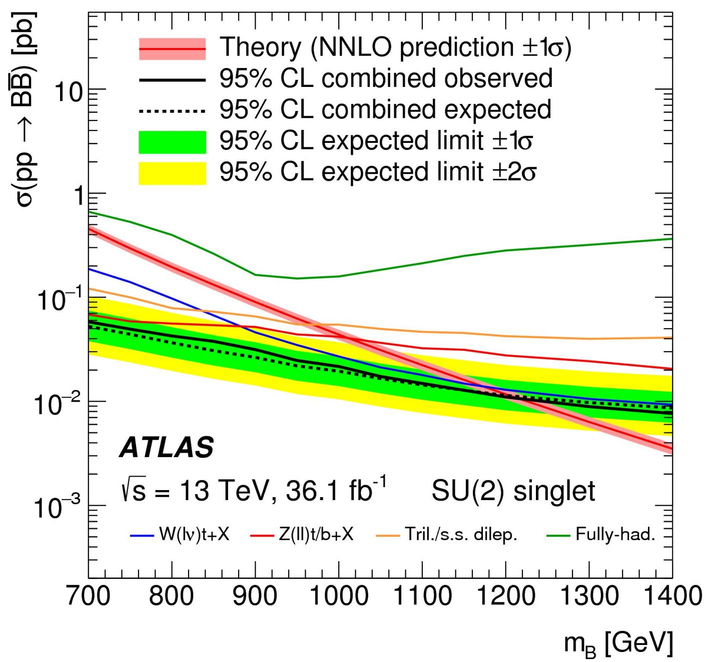


[10.1103/PhysRevLett.121.211801](https://doi.org/10.1103/PhysRevLett.121.211801)

Combination
of final states

- An ATLAS wide combination should bring the best of both worlds
  - Final state specific optimization for each analysis
  - Statistical improvement from combining all analyzed events





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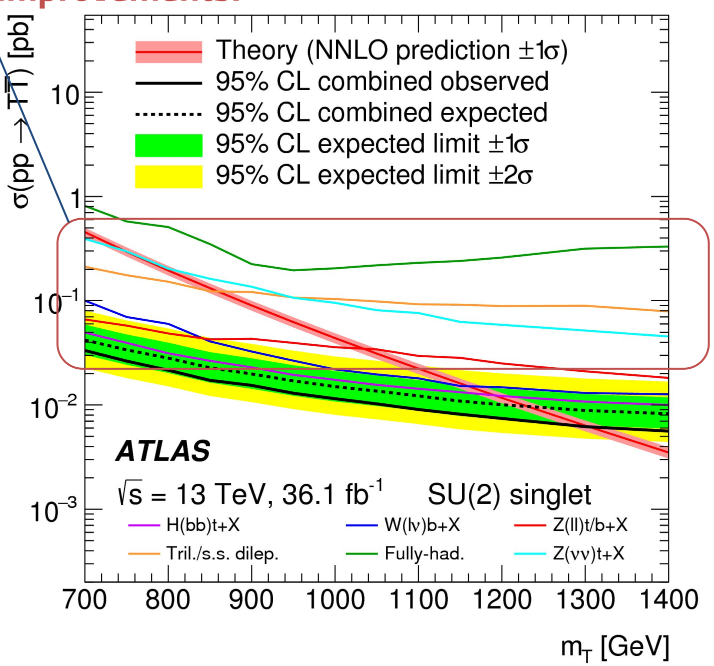
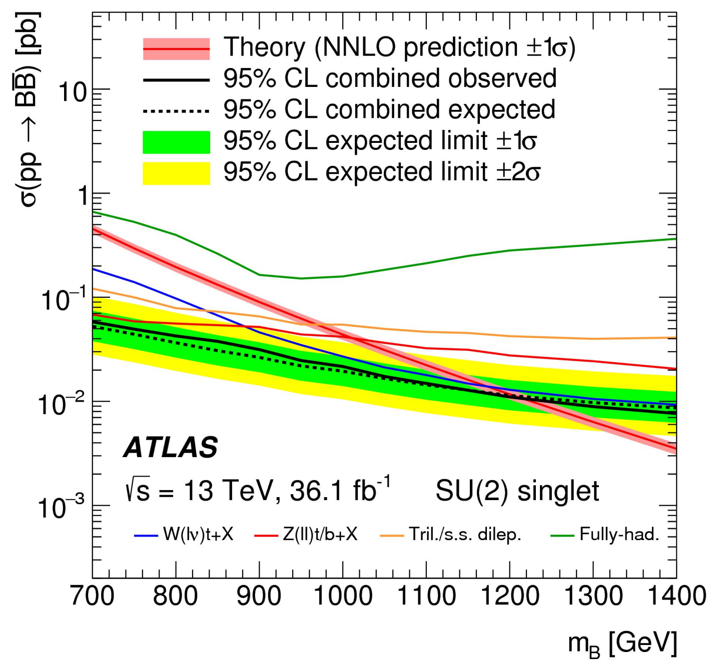
Significant improvements!





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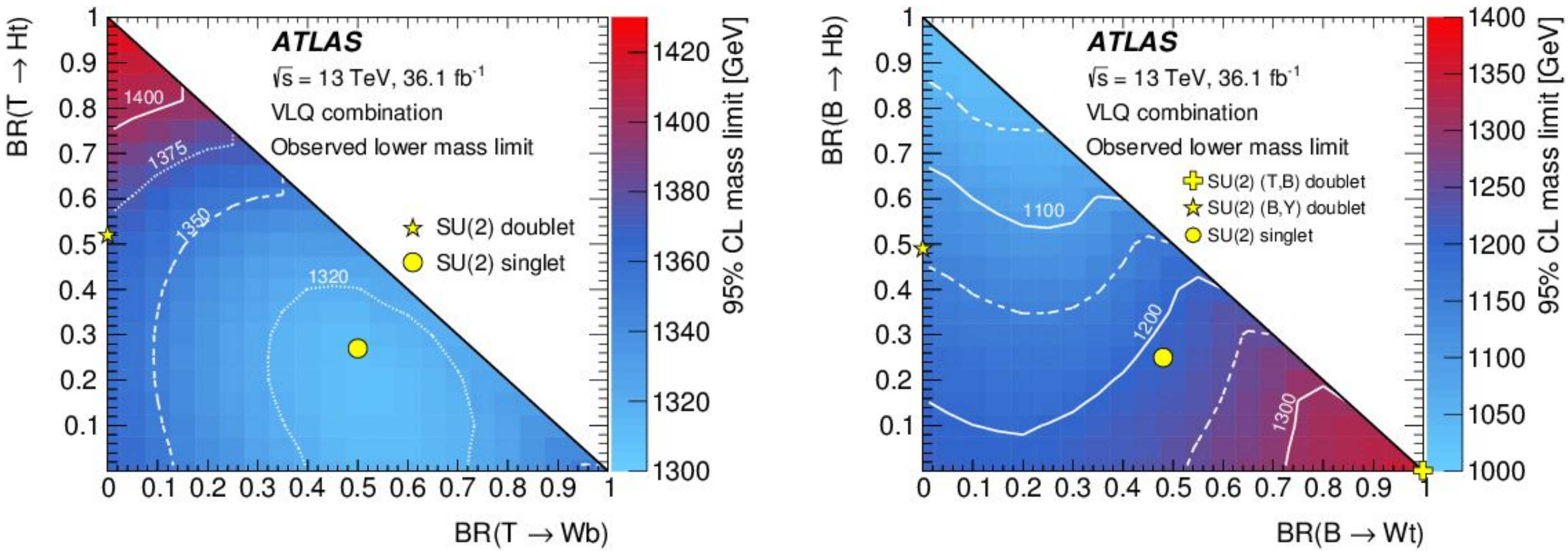
Combination
of searches



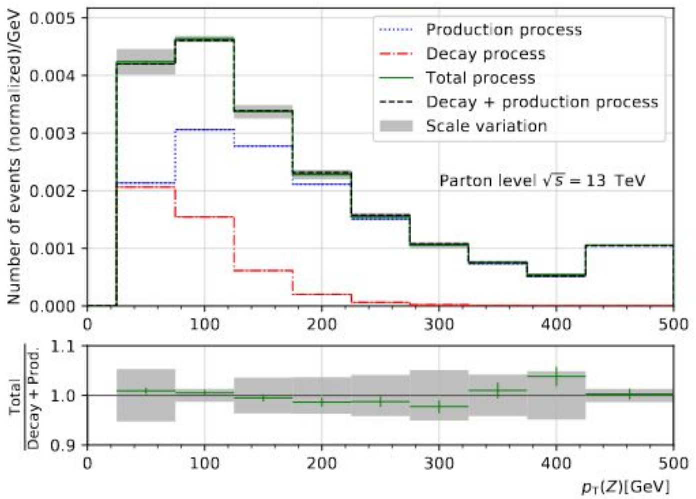
- Combining all ATLAS pair-production searches provides sensitivity across the branching ratio plane

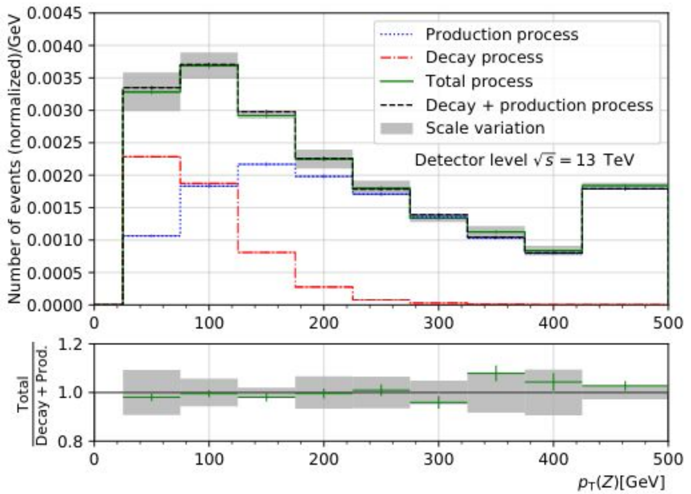
Interference
Production and Decay modes

- **Phenomenological study** (arXiv:1909.08443) for tZq and tγq anomalous couplings (in collaboration with Dortmund University) performed using **MadGraph5 Monte Carlo generator** importing TopFCNC UFO model
- Generation at a **centre-of-mass energy** of **13 TeV** and value of anomalous couplings at the same order of magnitude as the current experimental limits
- Both **parton** and **detector** levels were analyzed
- **Renormalisation** and **factorisation scales** treated as part of the total uncertainty

Interference
Production and Decay modes

- Comparison of the **interference sample** with the **sum of production and decay samples without interference** contribution
- Distribution of the **transverse momentum of the Z/γ boson** presents interference effects at both levels
- Difference covered by **variations of the scales** in the leading-order samples having the **same order** of the expected **modeling uncertainties**





Top quark reconstruction
FCNC tZq

- **Reconstruction of top quark** in FCNC tZ production events with the $\boldsymbol{\chi^2}$ **method** by minimizing the **neutrino $\boldsymbol{p_z}$**:

$$\chi^2 = \frac{(m_{jl\nu}^{\mathrm{reco}} - m_{t_{SM}})^2}{\sigma_{t_{SM}}^2} + \frac{(m_{l\nu}^{\mathrm{reco}} - m_W)^2}{\sigma_W^2}$$

- For the top quark in FCNC ttbar decay events, the $\boldsymbol{\chi^2}$ is minimized with the **neutrino $\boldsymbol{p_z}$** and **jets combination**:

$$\chi^2 = \frac{\left(m_{j_a\ell_a\ell_b}^{\mathrm{reco}} - m_{t_{\mathrm{FCNC}}}\right)^2}{\sigma_{t_{\mathrm{FCNC}}}^2} + \frac{\left(m_{j_b\ell_c\nu}^{\mathrm{reco}} - m_{t_{\mathrm{SM}}}\right)^2}{\sigma_{t_{\mathrm{SM}}}^2} + \frac{\left(m_{\ell_c\nu}^{\mathrm{reco}} - m_W\right)^2}{\sigma_W^2}$$