Data taking with the LAr Demonstrator for the Phase-I trigger readout electronics upgrade of the ATLAS experiment and studies on associated Higgs boson production with top quark pair

CPPM PhD day 2016

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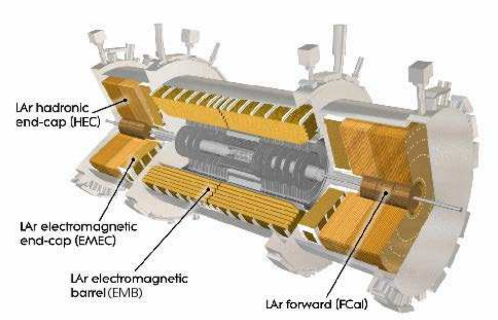
Aix*Marseille université ATLAS EXPERIMENT cnrs IN2P3 Les deux infinis CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE CPPM

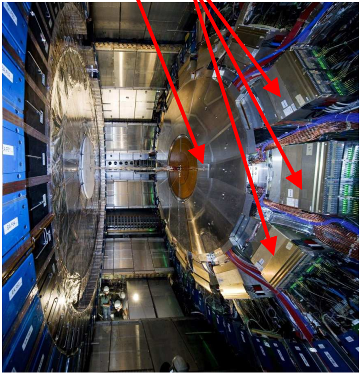
The ATLAS Liquid Argon (LAr) Calorimeter



- **LAr calorimeter : 182k channels**
- **Front End : 1600 Front End Boards**
- **Back End : 200 Readout Out Driver boards**

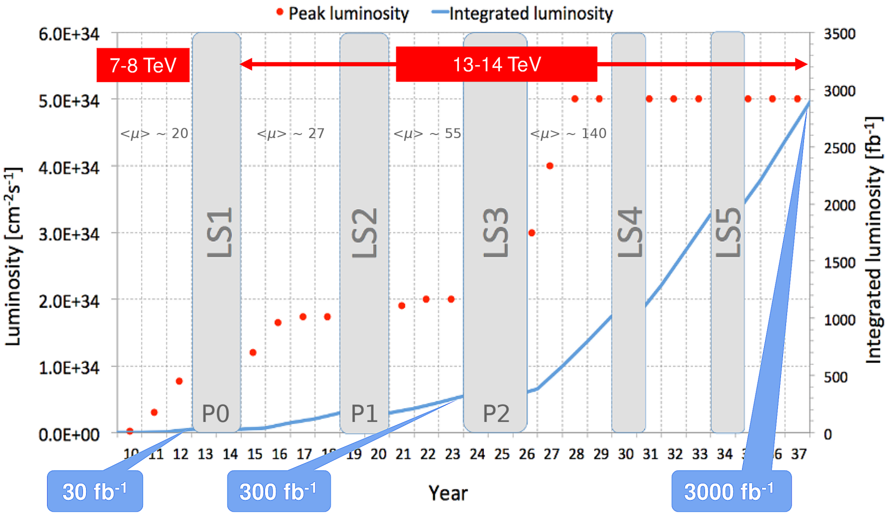
Front End Crates

Calorimeter



Between Electromagnetic barrel and end-cap

The LHC Forecast



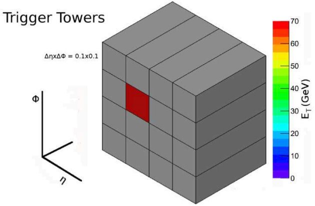
- high particle flux through detectors, limited trigger rate

→ trigger improvements, e. g. use higher granularity

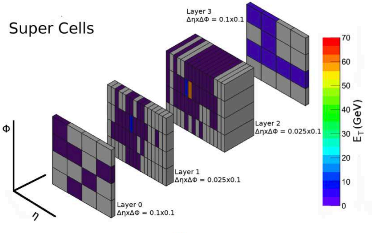
Phase-I upgrade of the ATLAS LAr Calorimeter readout

Purpose :
providing higher-granularity, higher-resolution, and longitudinal shower information from the calorimeter to the Level-1 trigger processors

Strategy :
increasing granularity 10 times by changing from **Trigger Tower** to **Super Cell** readout (will be done during 2018)



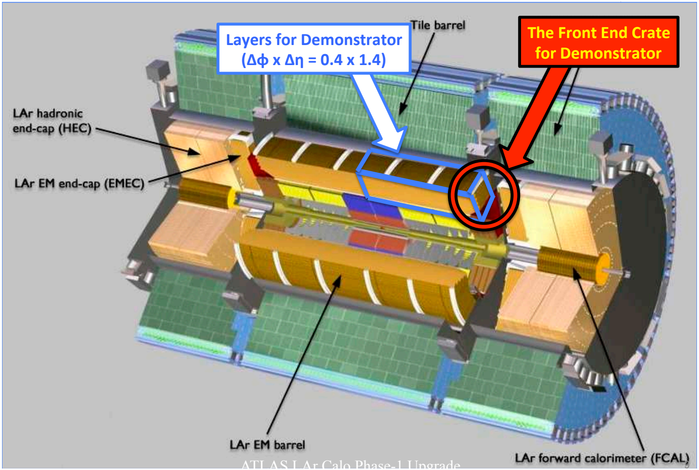
Upgrade



Trigger Tower :
sums the energy deposition across the longitudinal layers of the calorimeters in an area of $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$

Super Cell :
provides information for each calorimeter layer for the full η range of the calorimeter, and finer segmentation ($\Delta\eta \times \Delta\varphi = 0.025 \times 0.1$) in the front and middle layers

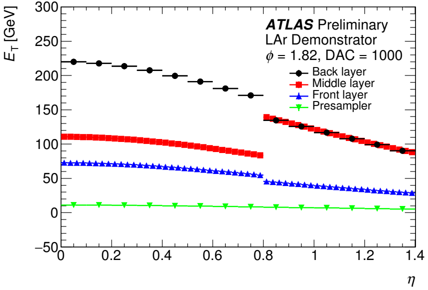
The LAr Demonstrator



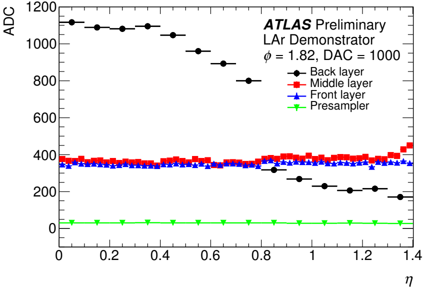
- June 2014: new concept installed, covering a small area of the detector
  - → part of the calorimeter covered: $1.767 < \phi < 2.160$, $0 < \eta < 1.4$
  - → no disturbance of current system
    - 2 ABBA boards: wait for TTC trigger (L1) for readout of super cells
  - → need specific trigger for spy data taking: Level 1 trigger type 0x90

Calibration studies at LAr Demonstrator

predicted energy for the super cells

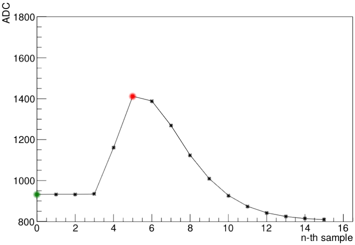


measured pulse heights



- pulses and noise in calibration have been measured
- ADC differences by estimation:

$$\mathrm{ADC} = \mathrm{ADC}_{\mathrm{max}} - \mathrm{ADC}_{\mathrm{pedestal}}$$



- from calibration studies energies

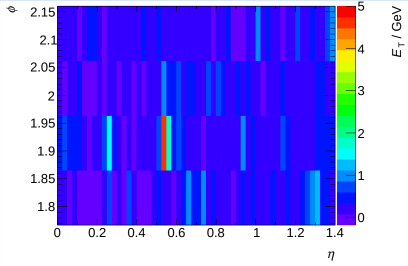
$$E_{\mathrm{T}} = \mathrm{const} \cdot \mathrm{ADC}$$

- plan: extract energies on-the-fly from optimal filtering constants

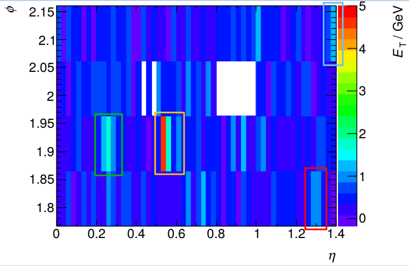
Data taking with the LAr Demonstrator since 2015

- data taking with proton-proton and heavy-ion collisions since 2015
- require Level 1 trigger type 0x90
- compare LAr Demonstrator readout and ATLAS main readout
  - matching of events uses L1ID, BCID and trigger type
  - nearly unique identifiers ($\sim$ 1 pair in 10k events)
- check comparison in event signature (E_{T} distribution):

ATLAS main readout



LAr Demonstrator readout

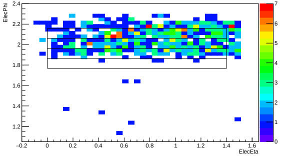


- matched reconstructed objects in corresponding ATLAS event:
  - electrons (11.0, 5.6, 6.7 GeV)
  - photons (6.3, 4.8 GeV)

Detector coverage of trigger type 0x90

- LAr Demonstrator trigger type was not always covering full demonstrator region
- Finally fixed by L1Topo (trigger) developers. Electrons in ATLAS main readout ($x = \eta, y = \phi$):

2015



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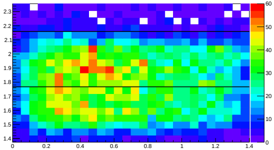

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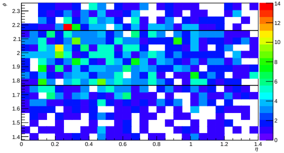
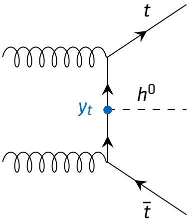


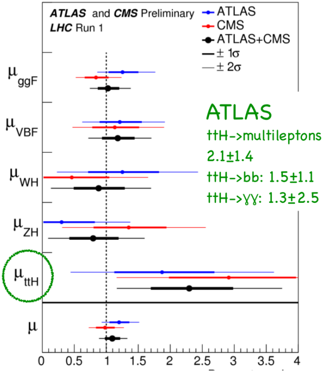
- I contributed to LAr calorimeter operation in data quality shifts @CERN.

$t\bar{t}H$ with multileptons final state

- direct measurement of top Yukawa coupling to Higgs boson (y_t) via associated Higgs production with top quark pair
  - any deviation might be hint for new physics
- four main channels for final state targeting $H \to WW^*/ZZ^*/\tau\tau$ decays:
  - 2 same-sign light leptons, τ veto (2ℓ**ss**)
  - 2 same-sign light leptons $+$ 1 opposite-sign τ (2ℓ**ss**$+1\tau$)
  - 3 light leptons with total charge ±1 (3ℓ)
  - 4 light leptons with total charge 0 (4ℓ)
- cross sections increase from $\sqrt{s} = 8$ to 13 TeV

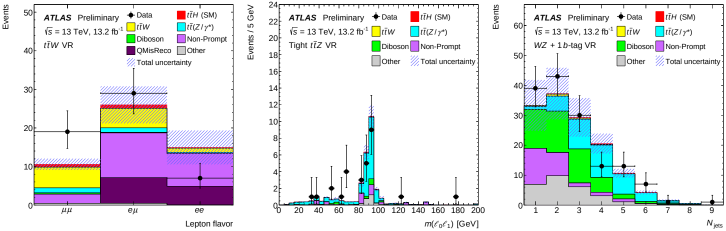
	$t\bar{t}h^0$	VV	$t\bar{t}W$	$t\bar{t}Z$	$t\bar{t}$
$\sigma^{8\ \mathrm{TeV}}$	130 fb	8220 fb	232 fb	206 fb	253 pb
$\sigma^{13\ \mathrm{TeV}}$	507 fb	14200 fb	601 fb	839 fb	831 pb
$f_{\sqrt{s}}$	3.9	1.7	2.6	4.1	3.3





$t\bar{t}H$ with multileptons final state – my contributions

- group ntuple production (input for the analysis)
  - code development and job submission before ICHEP conference
- validation of ntuples:
  - signal and validation region plots for ICHEP conference note



- contribution and validation of final fit
  - understanding and development of TtHFitter framework
  - proper treatment of systematic uncertainties

Systematic uncertainties on cross sections (theoretical)

- $t\bar{t}H$ cross section at $\sqrt{s}$ =13 TeV [fb]:

Theoretical calculation	NLO QCD+EW
CERN Yellow Report 4	$507.1^{+5.8\%}_{-9.2\%}{}^{+3.6\%}_{-3.6\%}$ (PDF incl. α_S)

- $t\bar{t}V$ cross sections at $\sqrt{s}$ =13 TeV [fb] (from CERN Yellow Report 4):

Process	Cross section @NLO
$t\bar{t}W^{\pm}$	600.8 $^{+12.9\%}_{-11.5\%}$ $\pm$ 2.7%
$t\bar{t}Z$	839.3 $^{+9.6\%}_{-11.3\%}$ $\pm$ 2.8

- Acceptance systematics for scale, PDF and shower variations from variations between 2μ and $\mu/2$ around nominal μ
- 50 % normalisation uncertainty on VV and rare processes

Experimental systematic uncertainties

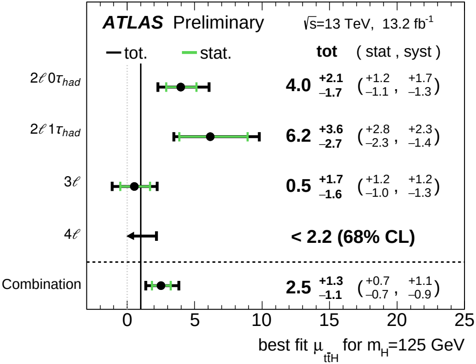
- 4 % on luminosity
- pileup reweighting
- JVT event weight
- trigger scale factors
- lepton reconstruction and isolation scale factors
- hadronic tau reco. BDT-ID & electron veto SF
- Jet Energy Scale (19 nuisance parameters)
- B-tagging MV2c10 (24 NP)
- uncertainties on fake and charge mis-reconstruction estimates

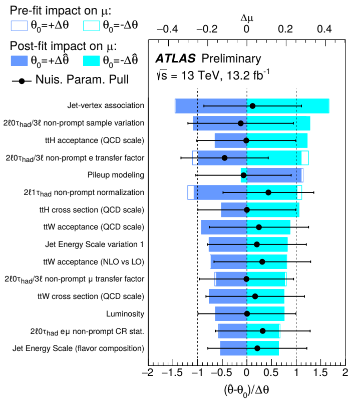
Uncertainties [%]		Channels			
		$2\ell \geq 5$ jets			3ℓ
		$e^{\pm}e^{\pm}$	$\mu^{\pm}\mu^{\pm}$	$e^{\pm}\mu^{\pm}$	
Statistical	$\Delta\theta_e^{\text{stat}}$	30.247	–	24.066	16.671
	$\Delta\theta_\mu^{\text{stat}}$	–	23.733	4.8496	10.652
	$\Delta N_{\ell\ell}(CR \geq 5\text{ jets})(\text{stat})$	26.279	34.196	28.148	21.047
Systematics	$\Delta\theta_e^{\text{syst}}$ (closure)	31.343	–	24.939	17.278
	$\Delta\theta_\mu^{\text{syst}}$ (closure)	–	11.921	2.4359	5.350
	$\Delta\theta^{\text{syst}}$ (other fakes)	19	19	15.608	13.506
	MC Q Mis Id ($\ell\ell$)	17.623	–	6.996	9.715
Total		**57.091**	**47.283**	**48.119**	**37.925**
Correlated Systematics	Q Mis Id ($\ell\ell$)	29.30	–	23.29	16.139

- $\sim$ 50 % systematic uncertainties on fakes in 4ℓ, largely correlated, in particular within "light" and "heavy" categories
- 73 % uncertainty on fakes in 2ℓ**ss**$+1\tau$ channel

Fit in $t\bar{t}H$ to multileptons

- profile likelihood ratio fit using TtHFitter, interfaced with Histfactory
- parameter of interest (POI): signal strength $\mu = \frac{\text{data}}{\text{SM with } H \text{ prediction}}$
- nuisance parameters (NPs): theoretical and experimental systematics, systematics on data-driven fake estimates

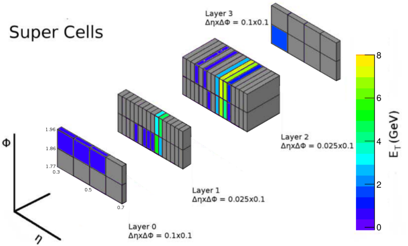




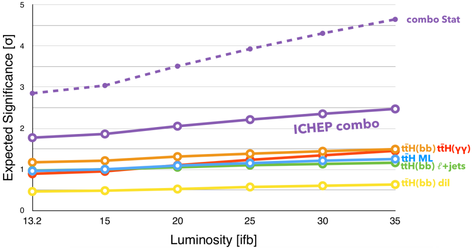
- fakes uncertainties dominate uncertainty on signal strength

Conclusions and outlook

- successful data taking with Liquid Argon demonstrator in collisions of 2015 and 2016
  - plan to continue studying performance of future system
  - apply optimal filtering coefficients on physics pulses



- successful $t\bar{t}H \rightarrow$ multileptons analysis with published ICHEP conference note
  - improve fakes and charge mis-reconstruction measurements (MM, MVA)
  - MVA for event selection
  - shape fits?, signal region splitting?, control regions?
  - planned paper in summer 2017 with full 2015+2016 dataset



- Huge effort to find evidence for $t\bar{t}H$ production (in combination)

Backup slides