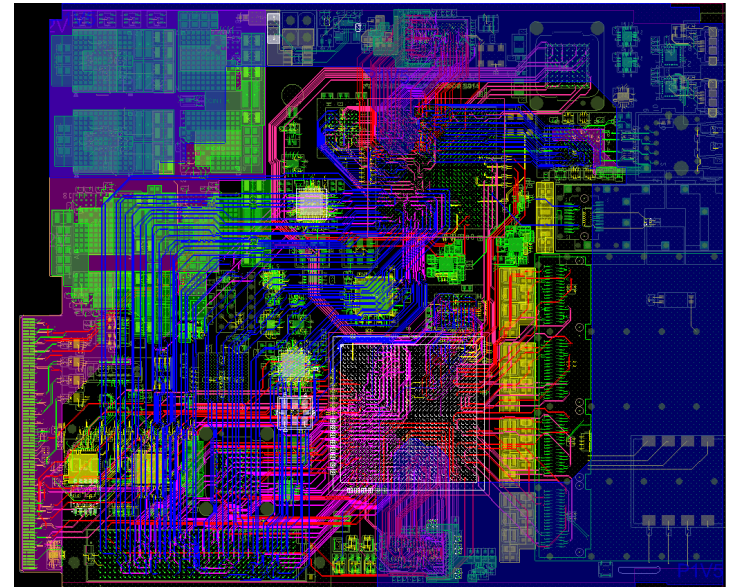
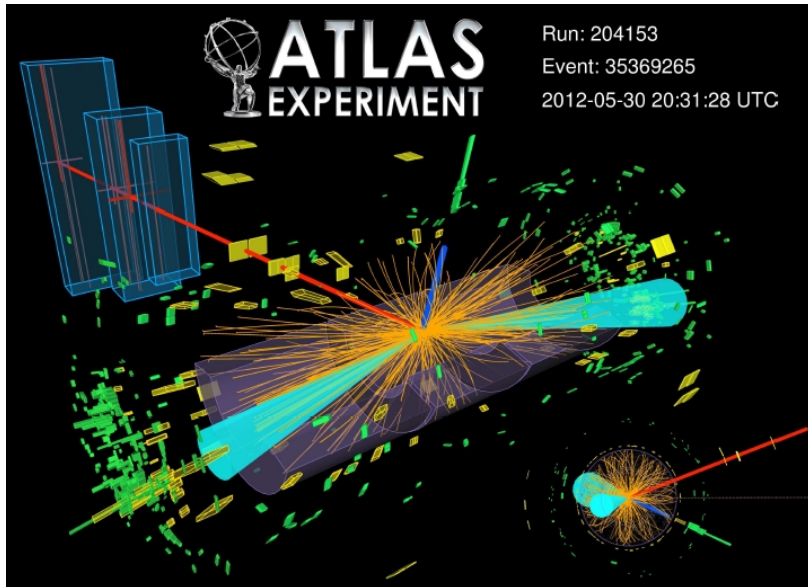


ATLAS Tile Calorimeter Group

Current Project: “Contributions to the Hadronic Tile Calorimeter and Physics programme of the ATLAS experiment at the LHC”, **FPA2015-65652-C4-2-R**
Period: 2016-2018

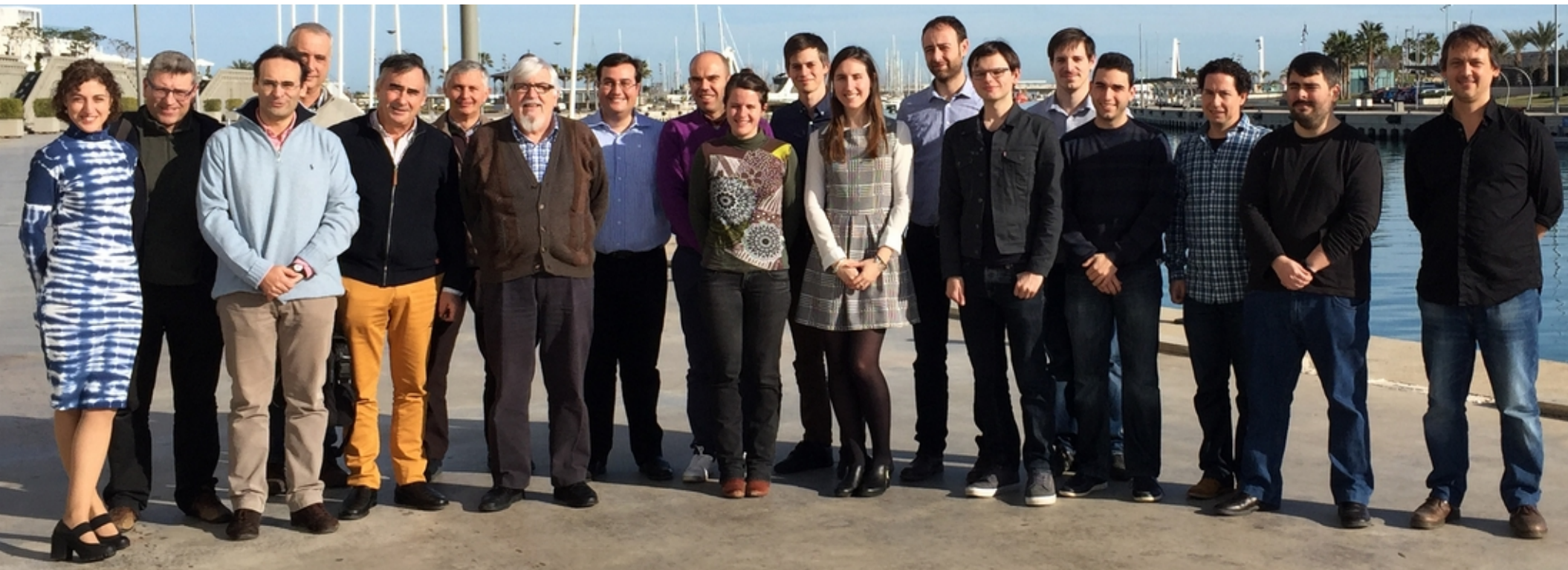


Luca Fiorini

20/01/2017

Group Team

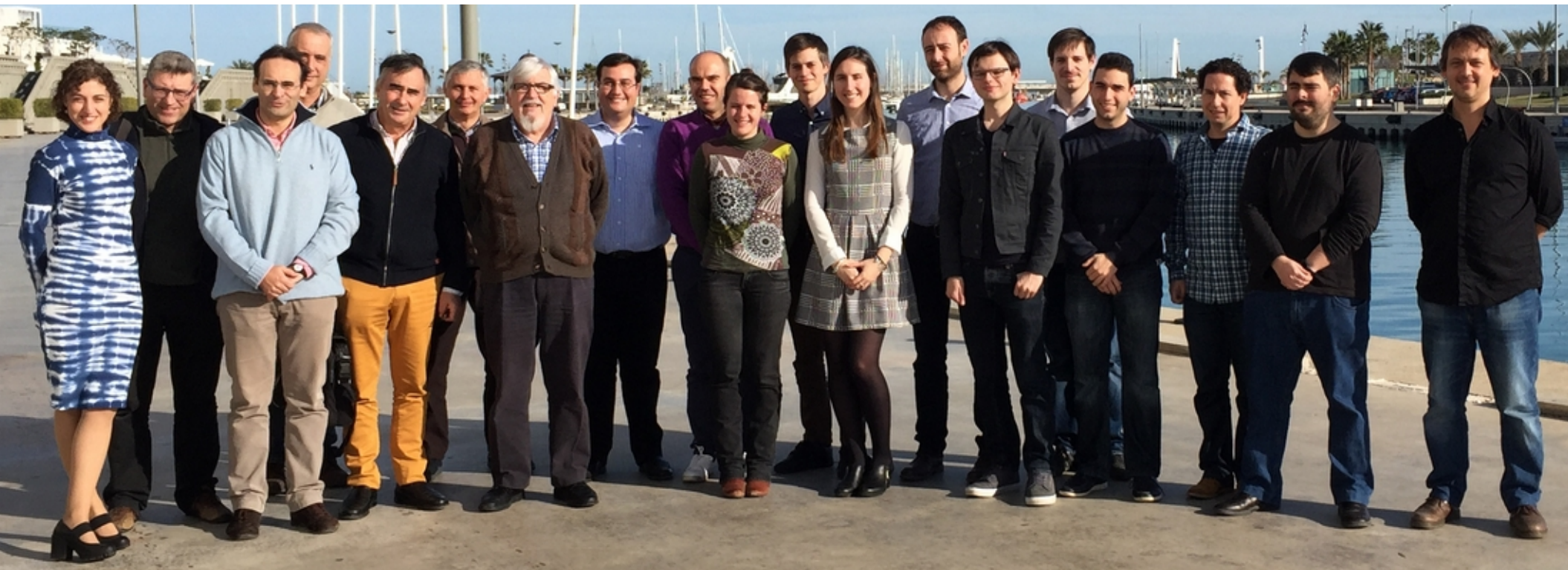
- Physicists
 - L. Fiorini, IP (IFIC- postRyC UV)
 - J. A. Valls, co-IP (IFIC- IC CSIC)
 - A. Ferrer (IFIC- Emeritus UV)
 - E. Higón (IFIC- CU UV)
 - V. Castillo (IFIC- CU UV)
 - A. Bailey (S8A-postdoc)
- Electronic/computing engineers
 - A. Valero (IFIC- TS CSIC)
 - P. Zuccarello (IFIC- VALi+D UV)
 - J. Torres (ETSE- TU UV)
 - R. Garcia (ETSE-PCD UV)
 - J. Soret (ETSE- TU UV)
 - J. Martos (ETSE-TU UV)
 - F. Carrió (IFIC-PTA UV)



Group Team (2)

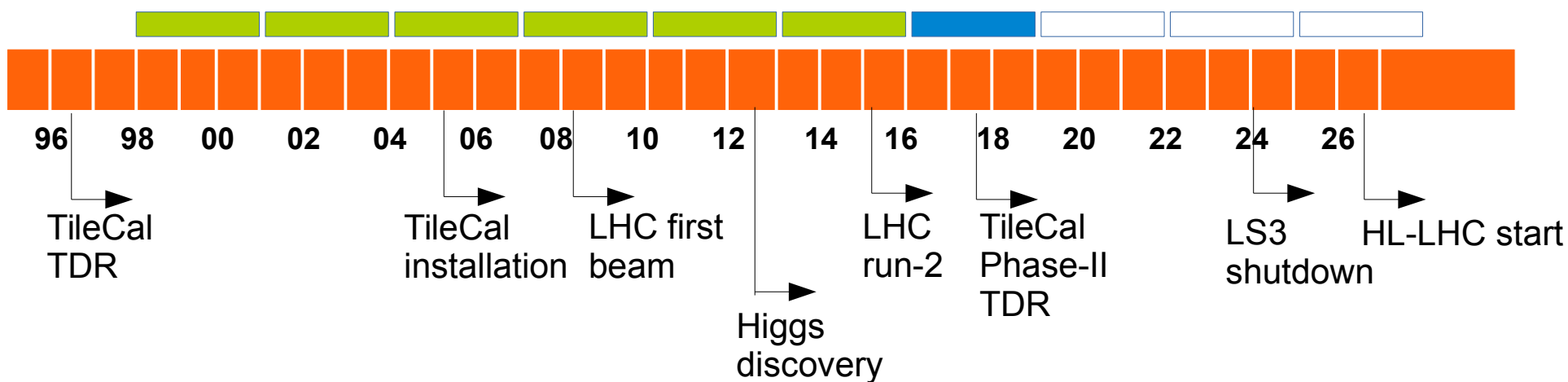
- PhD/Students
 - D. Álvarez (PhD-Fellow)
 - L. Cerdá (PhD-Fellow)
 - S. Rodriguez (FPI S8A)
 - F. García (Eng. student, UV)
 - I. Asensi* (Eng. student, UV)
- Technicians
 - J. M. Lopez (UV)
 - J. R. Ros (UV)
- External collaborators
 - B. Mellado (Fac. Wit)
 - L. March (U. Geneva)
 - X. Ruan (PostDoc Wit)
 - X. Chen (Tchingua)
 - C. Solans (CERN)

*: left end 2016

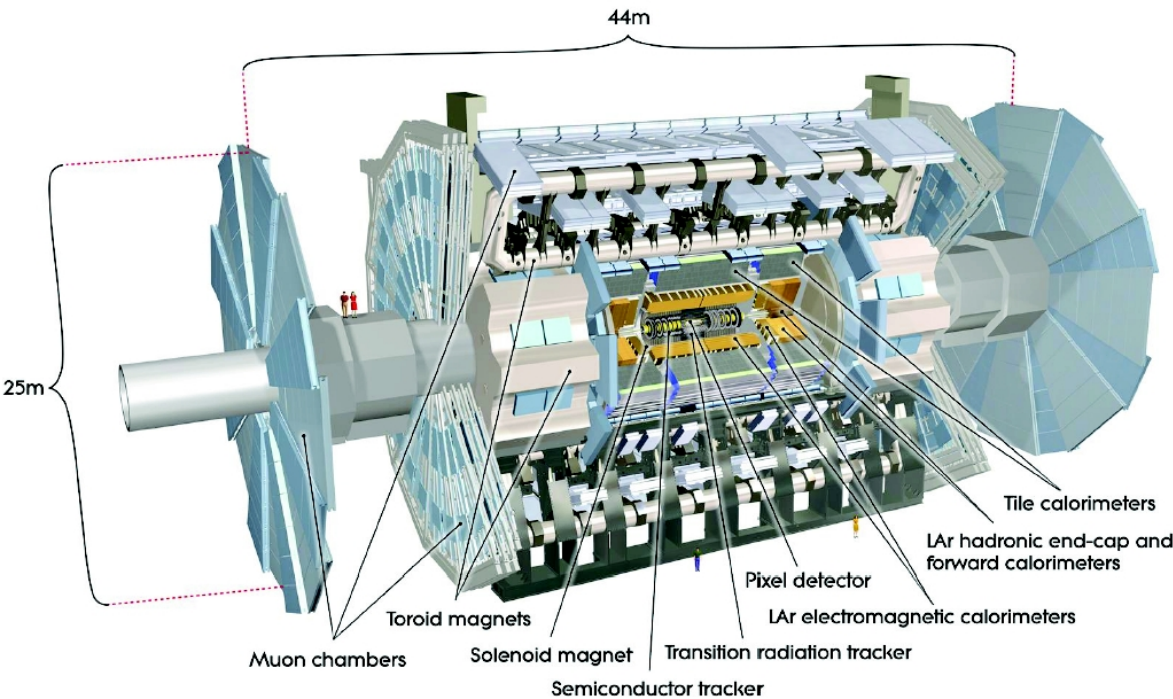


IFIC ATLAS-TileCal Group

- This project part of IFIC-ATLAS coordinated project (Computing excepted).
- It continues and expand our traditional involvement in the construction, operations and upgrade of the ATLAS detector and to the ATLAS physics program. Our research directions are:
 - We have acquired **leadership positions** in the operations and upgrade of the Tile Calorimeter (TileCal) in ATLAS, with a “de facto monopoly” of the **present and future off-detector electronics of TileCal**
 - We believe that the **Higgs sector** is the place to be in the ATLAS Physics programme, and even more now that a Higgs boson has been discovered:
 - If New Physics @ $O(\text{TeV})$, good chances that it is connected to the Higgs sector
 - If no New Physics @ $O(\text{TeV})$, Higgs properties are the most interesting measurements at the Energy Frontier.



ATLAS Detector



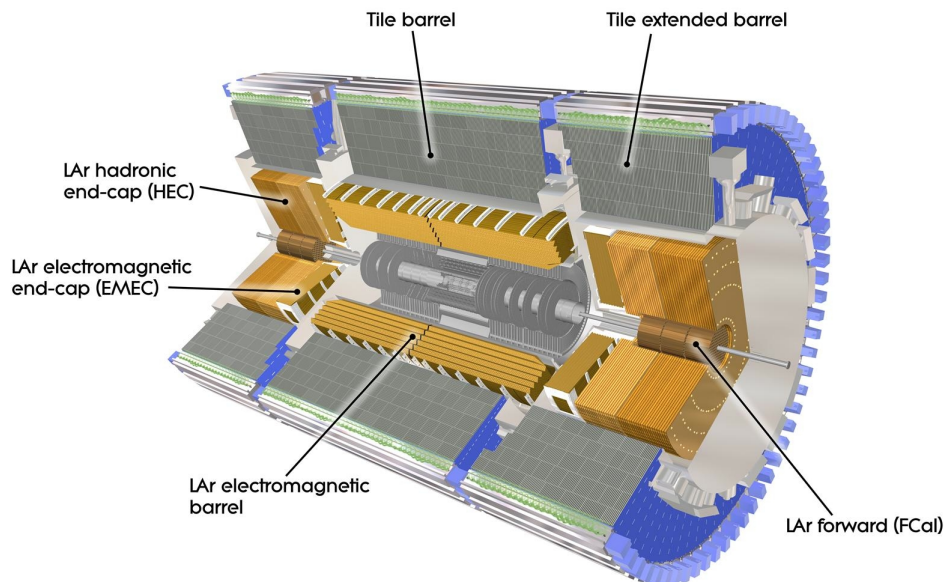
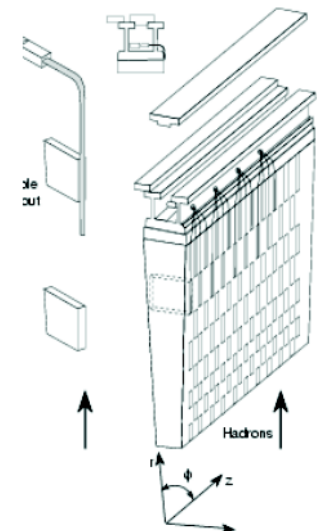
Tile hadronic Calorimeter (TileCal)

- Steel + plastic scintillator tiles
- Coverage: $|\eta| < 1.7$
- 3 longitudinal layers
- 9800 channels (99.5% operational)
- Design resolution:

$$\frac{\Delta E}{E} = \frac{50\%}{\sqrt{E}} \oplus 3\%$$

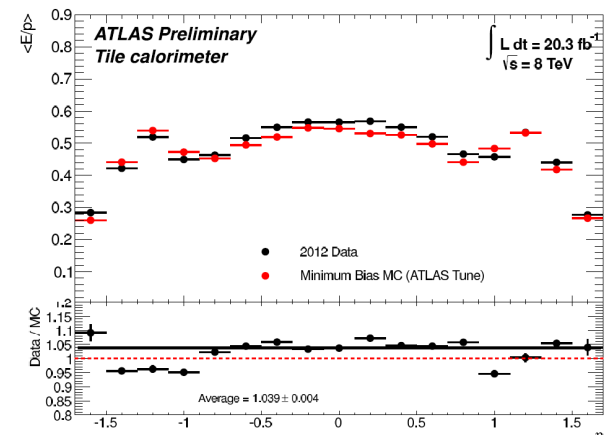
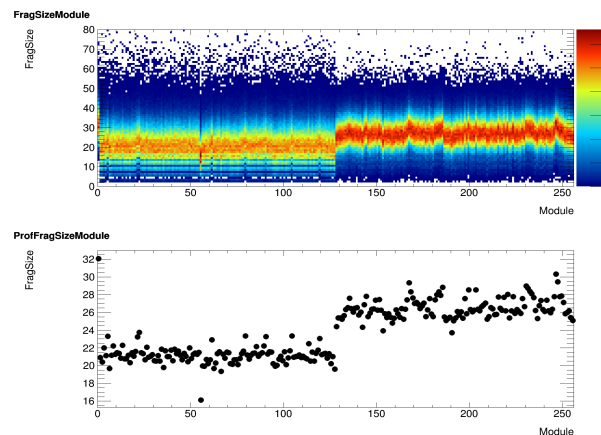
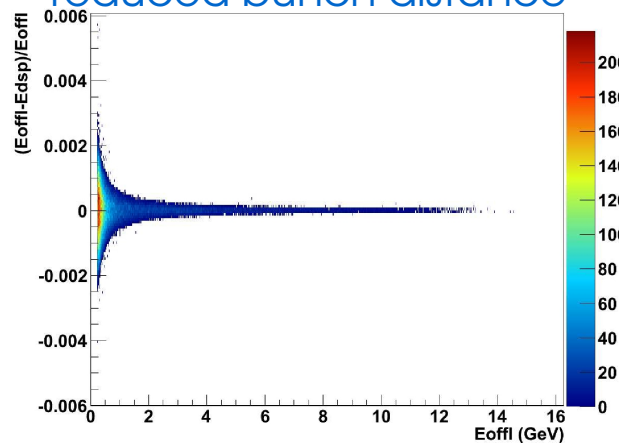
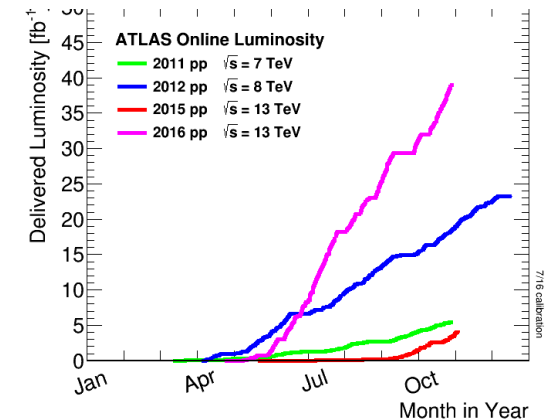
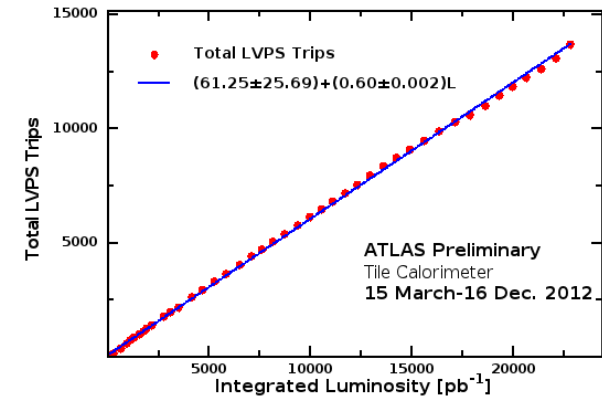
- ~5000 calorimeter cells read-out (in most of the cases) by 2 PMTs: ~10000 channels
- IFIC responsible of the **Tile RODs**, the main off-detector electronics of the calorimeter read-out.

Module + Drawer



ATLAS (& TileCal) Operations

- ATLAS performance was excellent in 2011-2016.
- TileCal > 98% working channels and > 98.5% of the data collected usable for physics.
- Main operational issue for TileCal in run-1:
LVPS trips (SEU) during physics.
 - Tile RODs dynamically filter-out the affected modules & reconf them during data-taking.
- 2016 main issue was high trigger rate joint with unprecedented pile-up, above LHC design!
Achieved L1 rate > 90 kHz with number of interactions per bunch crossing > 40
- The TileCal RODs are performing the signal reconstruction (Ene and Time) for the trigger system and part of offline amplitudes.
- Constant updates to cope with higher pileup and reduced bunch distance

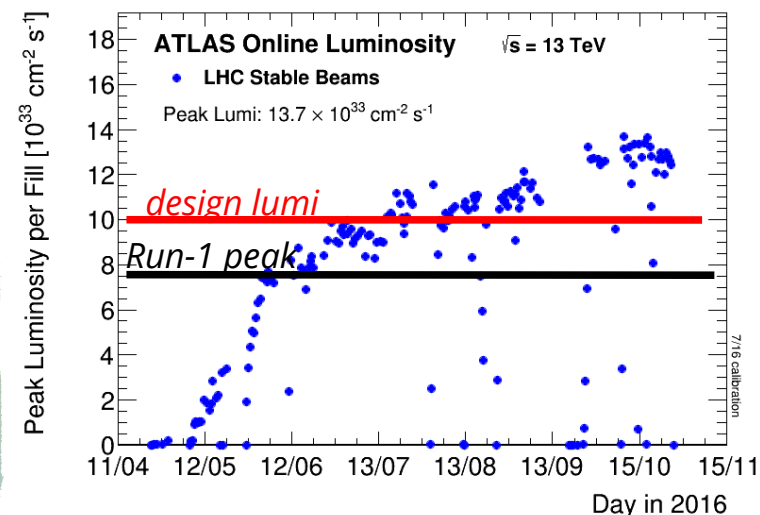
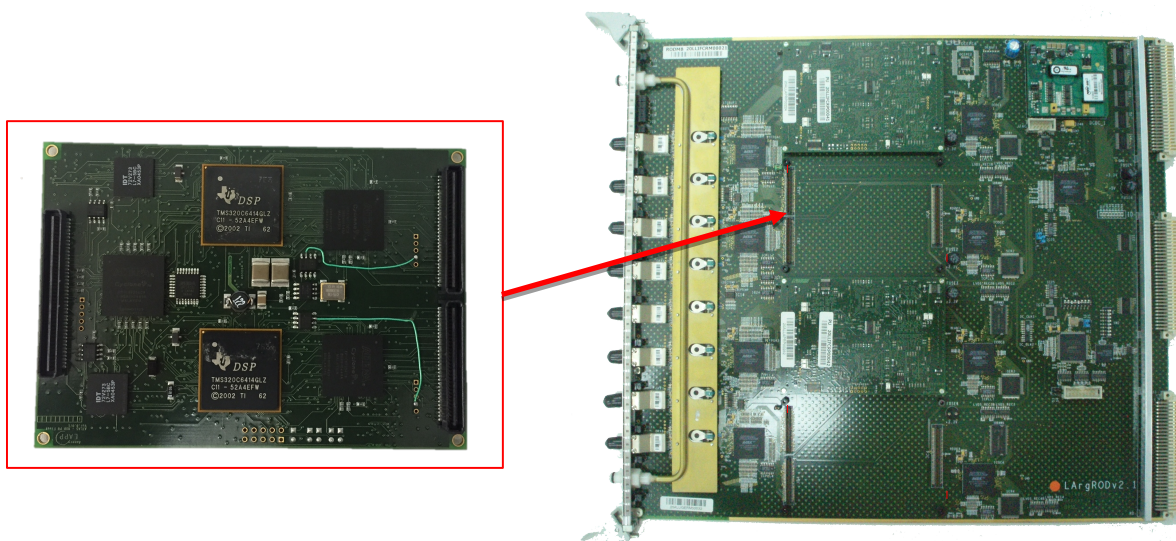
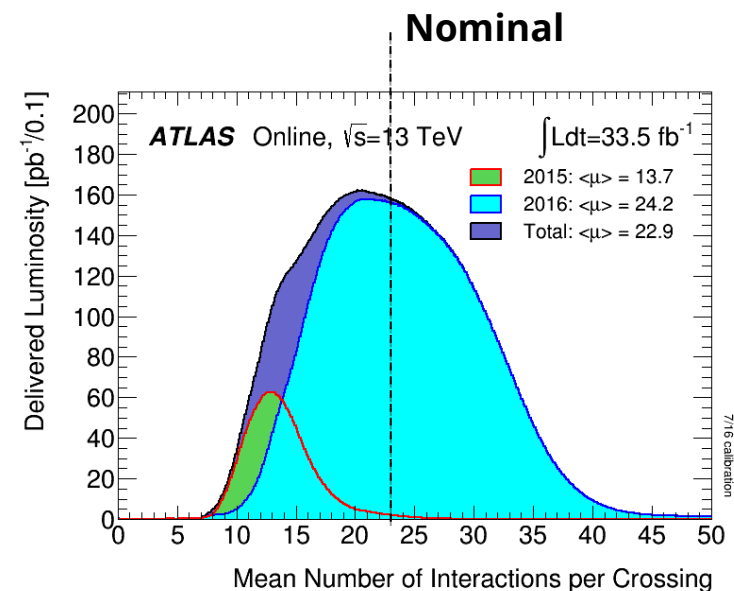


TileCal Operations in 2017-2018

- Constant consolidation of the Tile RODs is required to despite 10 years passed since deployment. Harsher LHC conditions, increased trigger rates, operational issues and more accurate reconstruction at trigger level.

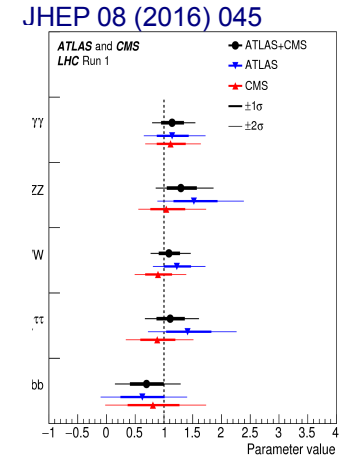
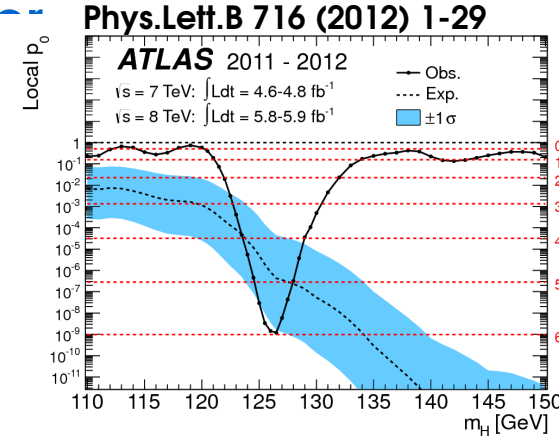
Significant Upgrade of the Tile RODs in 2017 extended shutdown to cope with 100 kHz rate

- Given the concomitant doubling in pileup we plan to:
 - Double the number of DSP Processing Units in the RODs
 - Double the output bandwidth to the event builder
- Production will be done in Spain and validation and qualification at IFIC.
- Firmware and software modifications are ongoing.

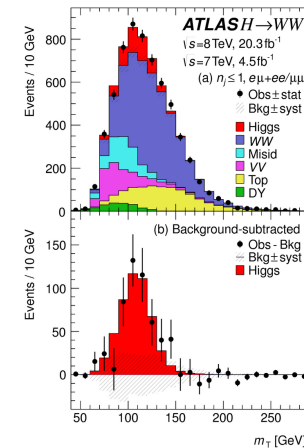


ATLAS Physics Programme

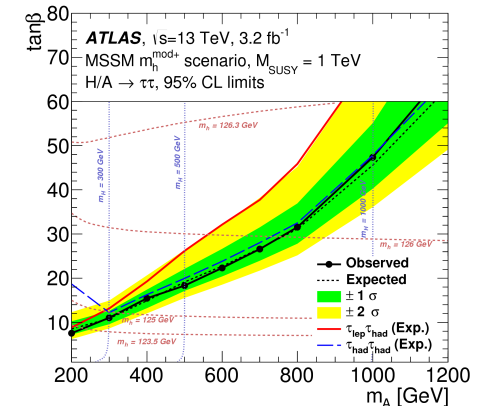
- **Explore and Understand the Higgs sector**
 - High-priority is to explore and understand the Higgs sector (2016-2018):
 - Measure Higgs properties in bosonic and fermionic channels (Indirect search for NP):
 - $H \rightarrow \gamma\gamma$
 - couplings, fiducial cross-section
 - $H \rightarrow \tau\tau$
 - couplings & cross-section,
 - Spin-CP
 - Higgs combination
 - Direct Searches for New Physics related to the Higgs sector:
 - $H/A \rightarrow \tau\tau$
 - $h \rightarrow \tau e / \tau \mu$
 - $H/X \rightarrow hh (bb\gamma\gamma)$



Phys. Rev. D 92, 012006 (2015)



Eur. Phys. J. C 76 (2016) 585



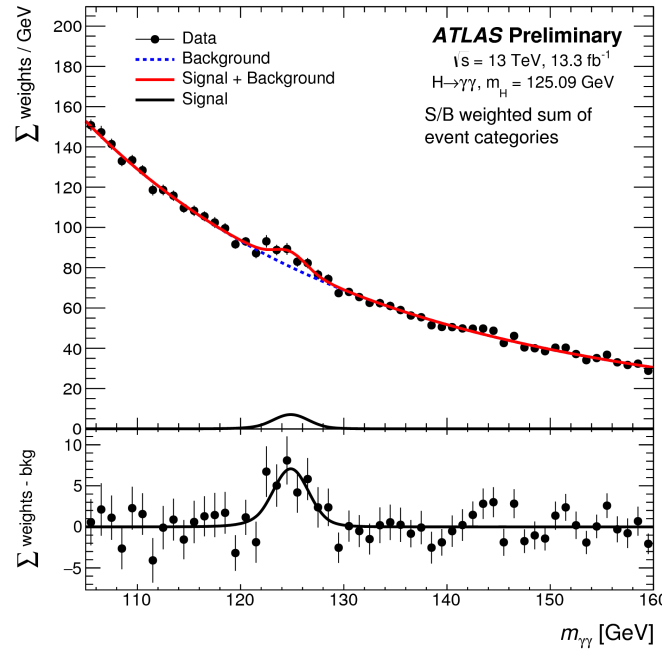
We have acquired experience in Machine Learning in Higgs analyses. Now we'll exploit Deep Learning, new frontier of the Machine Learning to achieve maximal sensitivity with high performance GPU.

	P100 for PCIe-Based Servers
Double-Precision Performance	4.7 TeraFLOPS
Single-Precision Performance	9.3 TeraFLOPS
Half-Precision Performance	18.7 TeraFLOPS
NVIDIA NVLink™ Interconnect Bandwidth	-
PCIe x16 Interconnect Bandwidth	32 GB/s
CoWoS HBM2 Stacked Memory Capacity	16 GB or 12 GB
CoWoS HBM2 Stacked Memory Bandwidth	732 GB/s or 549 GB/s
Enhanced Programmability with Page Migration Engine	✓
ECC Protection for Reliability	✓
Server-Optimized for Data Center Deployment	✓

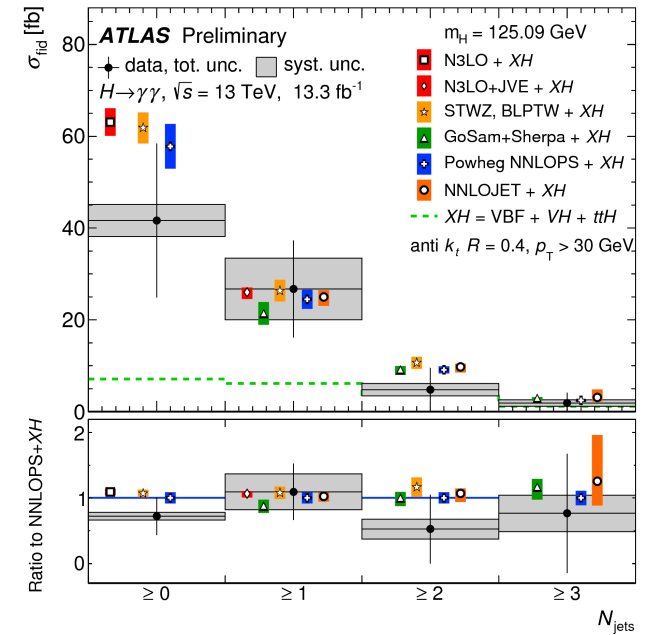
ATLAS $H \rightarrow \gamma\gamma$

- Contribution to first measurement of the Higgs cross-section @ 13 TeV with ATLAS data (2015 data) and subsequent measurement of couplings and differential cross-sections in run-2 (2015+2016) data.
- Measurements of the differential and fiducial cross-section in the $H \rightarrow \gamma\gamma$ final state starts to be precise and comparison
- Particularly interested in this final state given the good mass resolution and fair statistical power.
- Plan to contribute to $H \rightarrow \gamma\gamma$ papers in 2017.

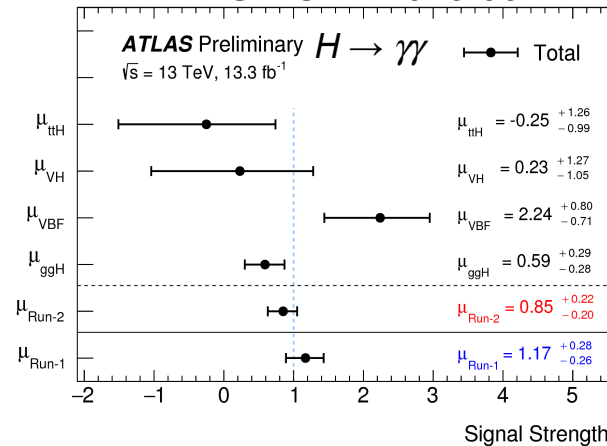
ATLAS-CONF-2016-067



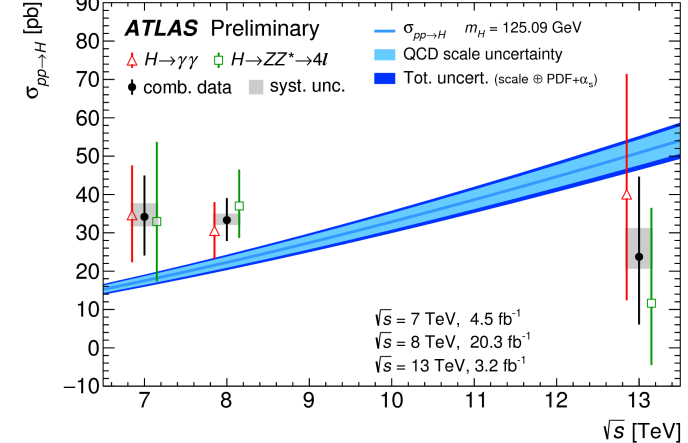
ATLAS-CONF-2016-067



ATLAS-CONF-2016-067



ATLAS-CONF-2015-069



ATLAS $hh \rightarrow bb\gamma\gamma$

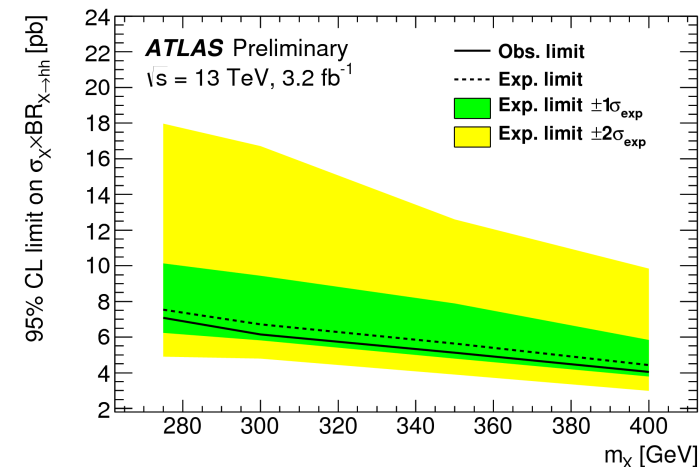
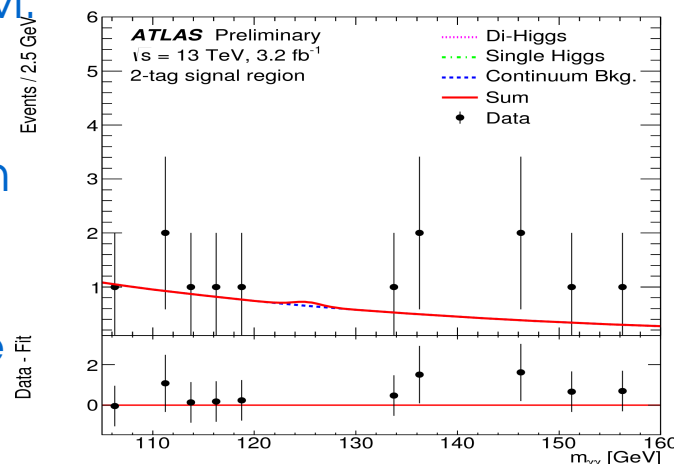
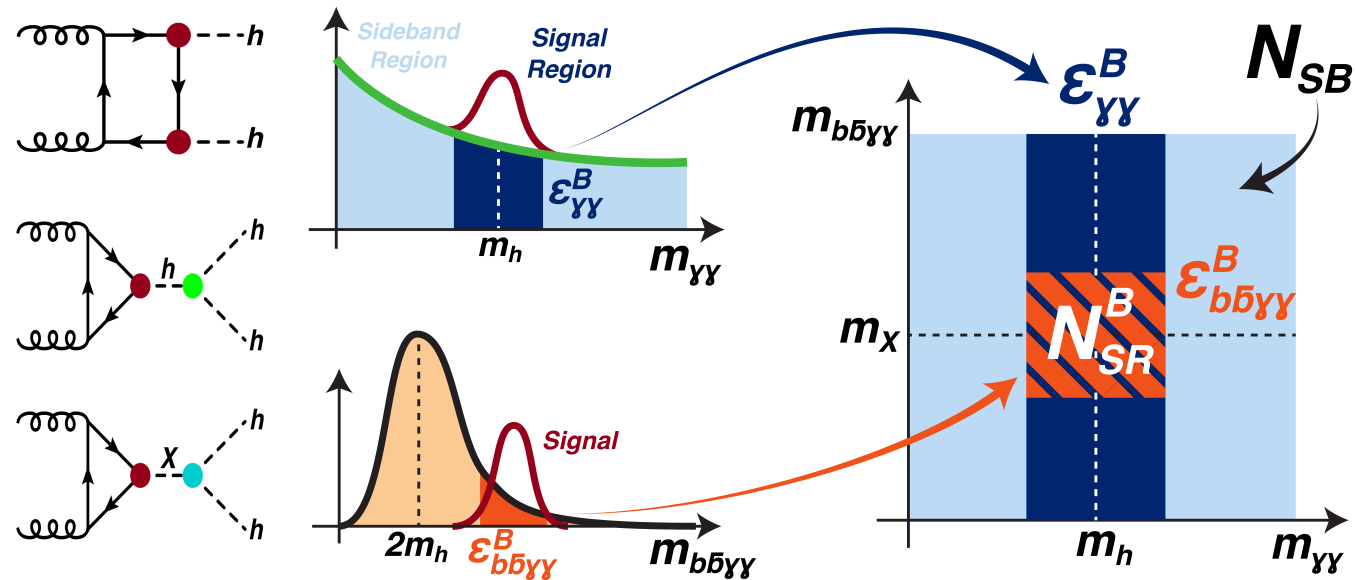
ATLAS-CONF-2016-004

$X \rightarrow hh \rightarrow bb\gamma\gamma$

- Participation in the first $b\bar{b}\gamma\gamma$ searches with 13 TeV data: to confirm excess seen in run-1.

→ $b\bar{b}\gamma\gamma$ analyses:

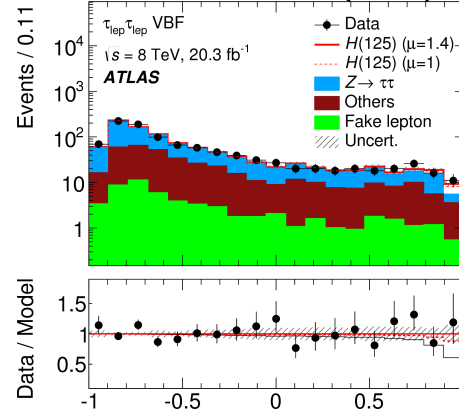
- NP search for heavy resonance decaying to hh
- NP search for non resonant double Higgs production. With current luminosity searching for enhancement above SM.
- Good sensitivity to new physics and synergy with $H \rightarrow \gamma\gamma$ measurements.
- Plan to contribute to the $hh \rightarrow b\bar{b}\gamma\gamma$ papers with run-2 data



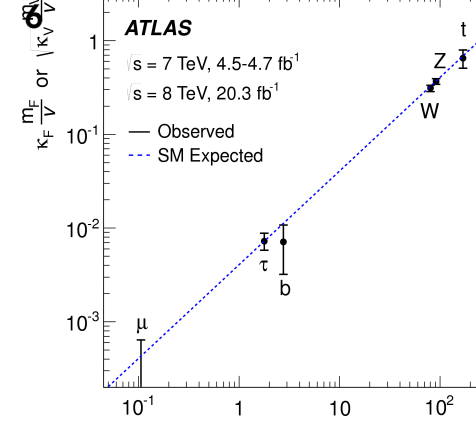
$h(125)$ decays to leptons

- ATLAS obtained Evidence of this decay and recently Observation was achieved combining with CMS.
- It is still the only leptonic channel accessible for a few more years and it is the fermionic channel with best sensitivity.
- $H \rightarrow \tau\tau$ final state has also strong sensitivity to VBF production mode and Higgs CP.
- The search for LFV decays of the Higgs are an interesting door to New Physics, $H \rightarrow \tau\mu, \tau e$
- Excellent synergy with $H \rightarrow \tau\tau$ measurements
- Plan to contribute to $H \rightarrow \tau\tau$ and LFV searches for Run2

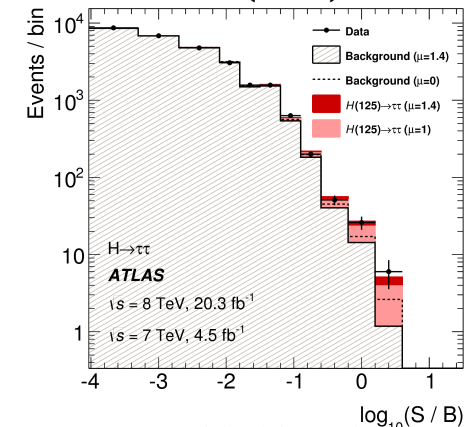
JHEP 1504 (2015) 11



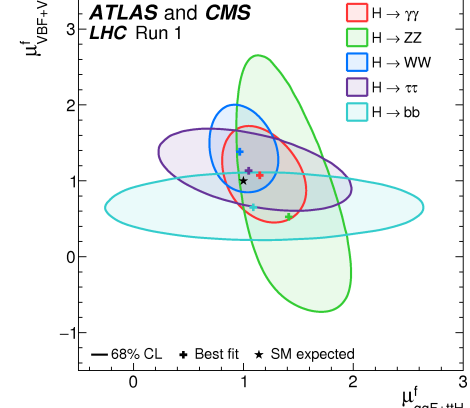
Eur. Phys. J. C76 (2016)



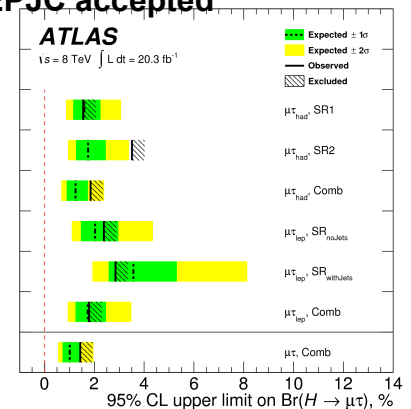
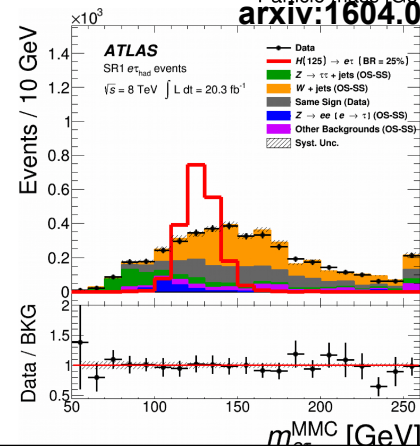
JHEP 1504 (2015) 11



JHEP 1608 (2016) 045

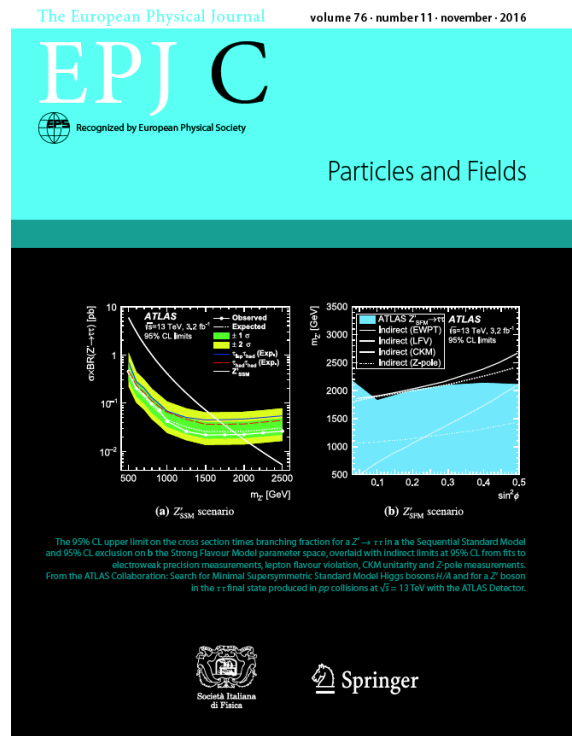
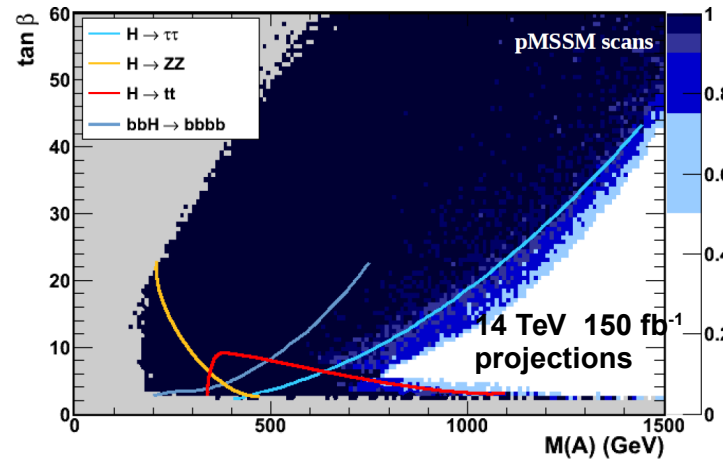


arxiv:1604.07730, EPJC accepted

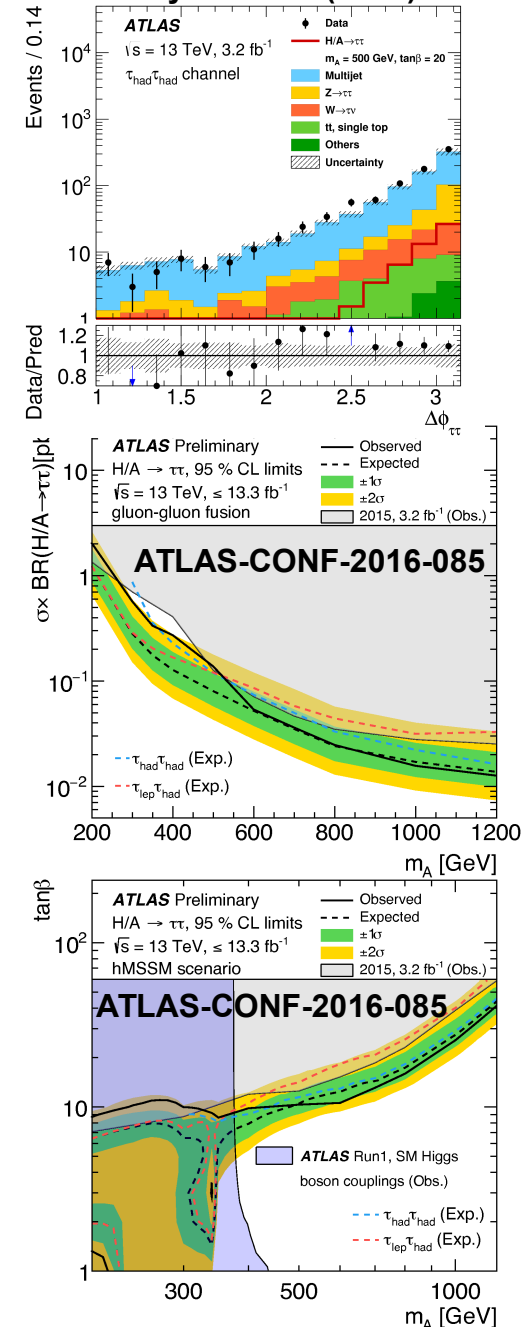


BSM A/H & Z' $\rightarrow \tau\tau$

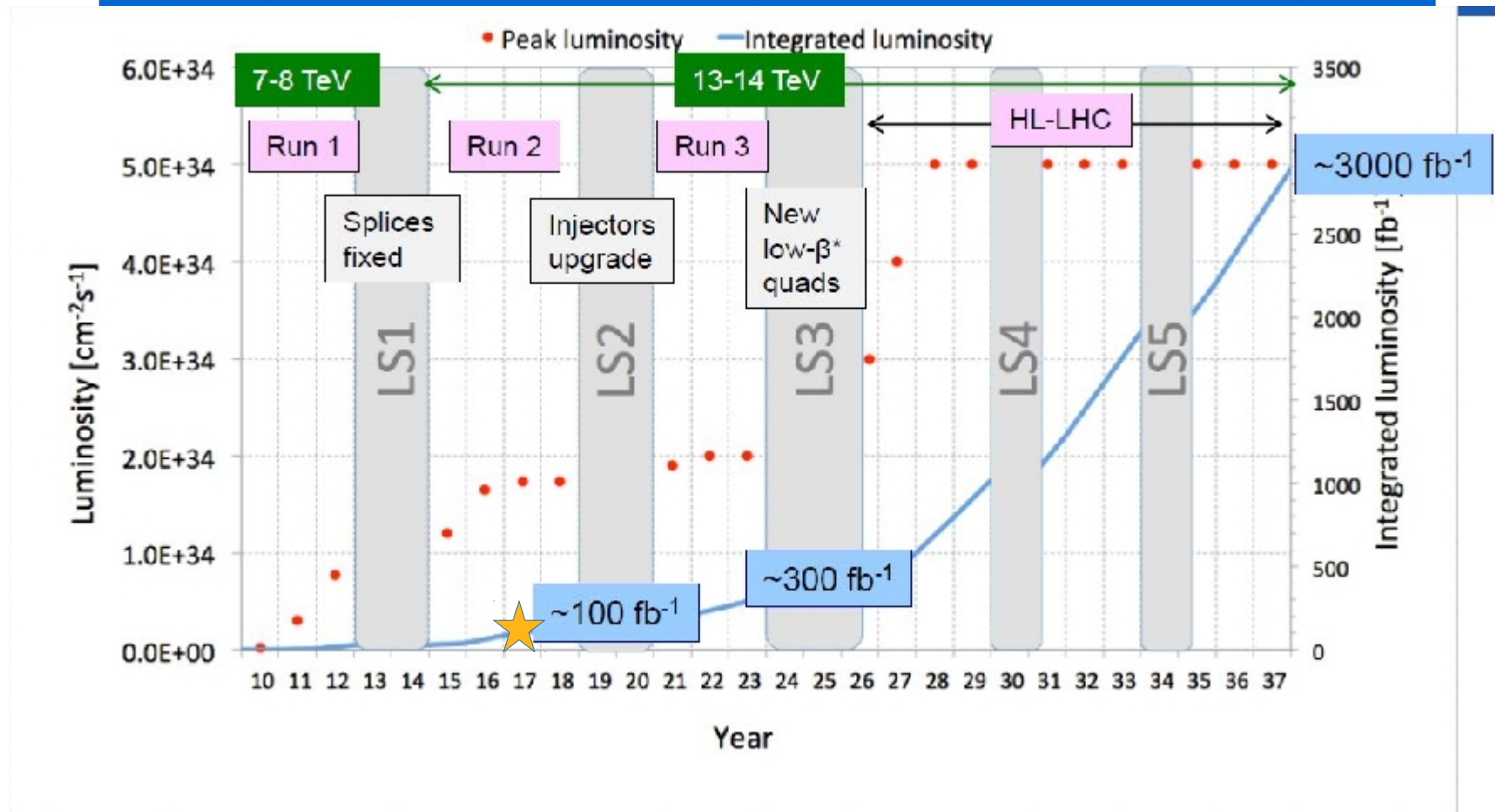
- Focus on early run-2 searches for Heavy bosons contribution, $H/A \rightarrow \tau\tau$
- This final state is very sensitive to a large range of MSSM parameter space and is playing a key role for run-2 MSSM searches.
- 1 paper and 2 CONFs in 2015-2016). The result has been selected for the cover of EPJC vol76 n11 (2016).
- Result is interpreted in model-dependent and independent ways, with and without b-jets in the final states. It is interpreted (with small changes) also in terms of $Z' \rightarrow \tau\tau$ search.
- We plan to keep contributing to this search during the rest of Run-2



Eur. Phys. J. C76 (2016) 585



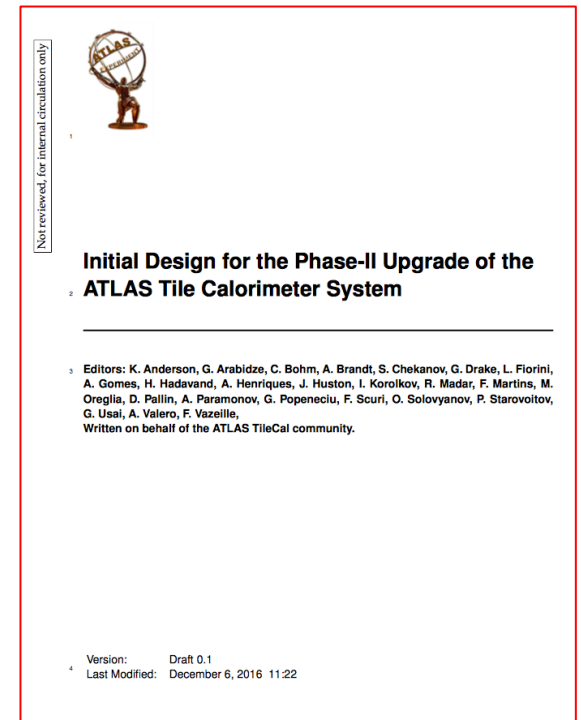
LHC Upgrade Schedule



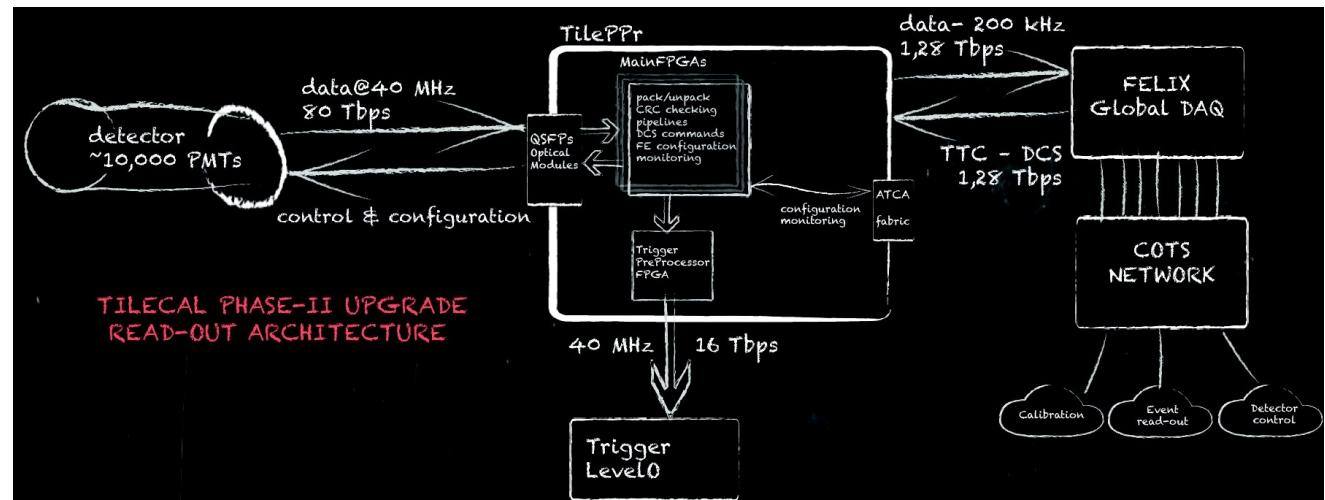
- ATLAS Phase-II Upgrade of the Letter of Intent released in 2012
- HL-LHC part of the European Strategy Forum on Research Infrastructures (2014)
- HL-LHC approved by CERN Council in 2014

HL-LHC TileCal Upgrade

- Complete FE&BE electronics replacement
- **Front-end:** Super-drawer sub-divided of 4 independent Minidrawers to improve redundancy
- **TilePreProcessor (TilePPR)** is the core of the off-detector, it is based on FPGA for high-throughput parallel computation, QSFP optical connectors and based on ATCA transmission architecture.
- Full digitization of data and transmission to **L0 trigger system** at 40 MHz and ≥ 1 MHz accept rate.
- **TileCal Upgrade IDR** release for review in Dec 2016

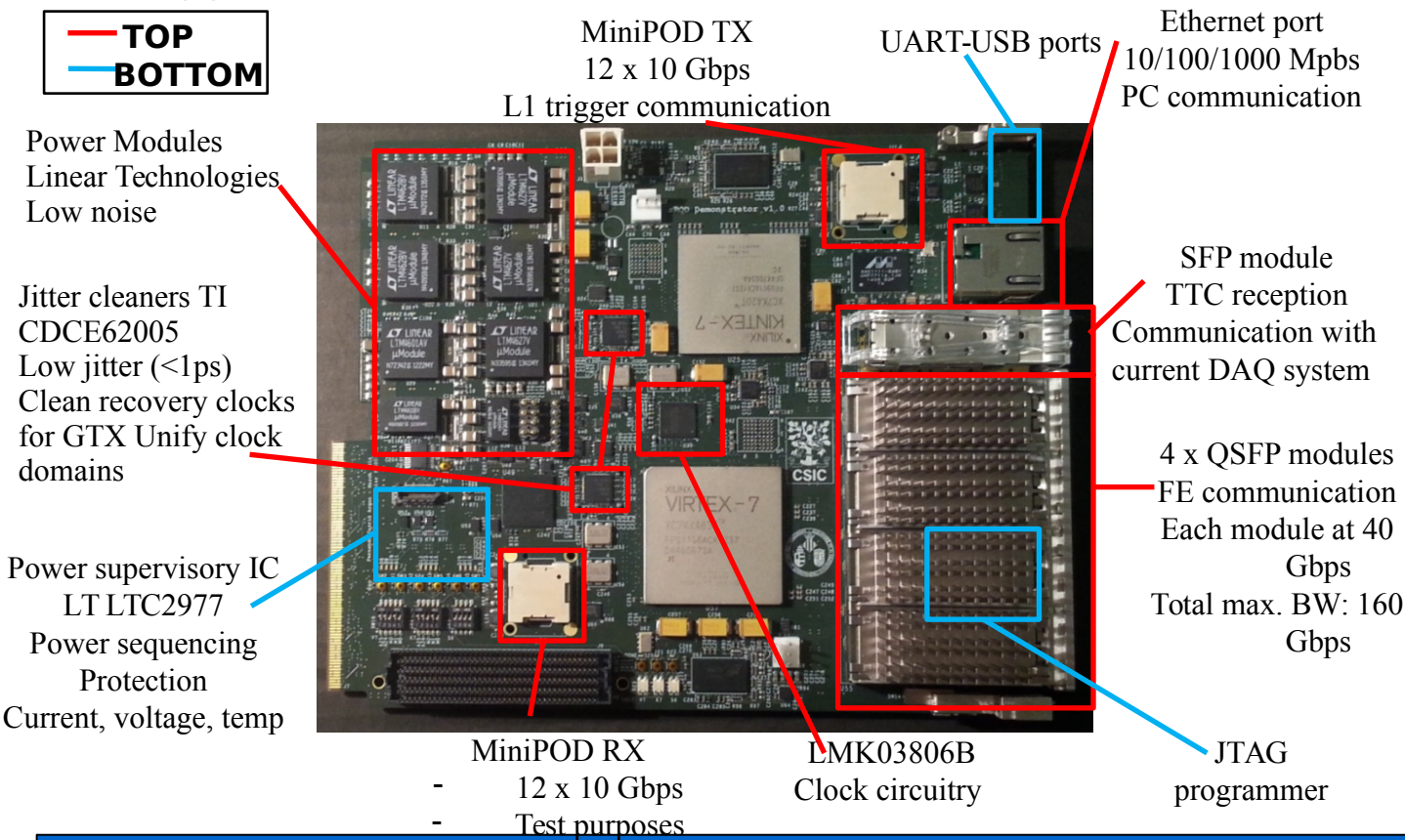
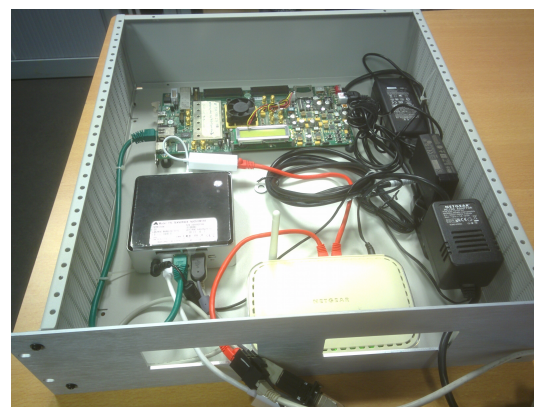
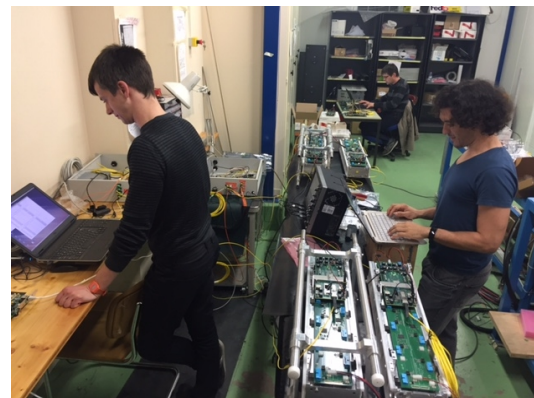
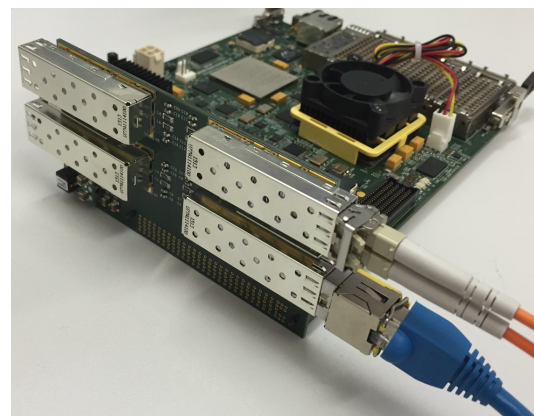


TILECAL READ-OUT SYSTEM		
Up Link only	Present	Upgrade
Total BW	~ 165 Gbps	~80 Tbps
Nb fibers	256	8192
Fiber BW	640 Mbps	10 Gbps
Nb boards	32	32
Nb crates	4 (VME)	4 (ATCA)
In BW/board	5 Gbps	2,5 Tbps
Out BW/board _{DAQ}	2,56 Gbps	40 Gbps
Out BW/board _{L1}	Analog FE	500 Gbps



TilePPR

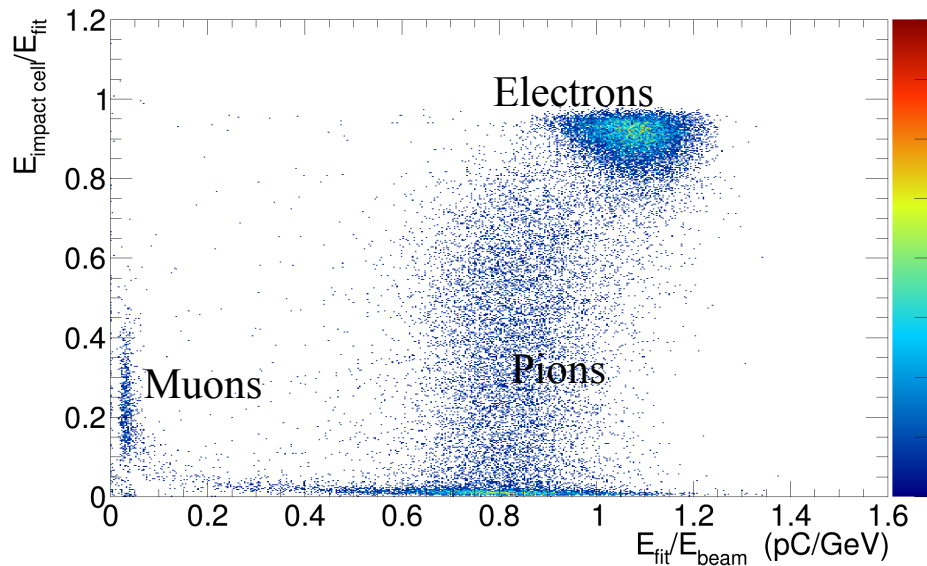
- TileCal-IFIC fully responsible of the **design** of the Trigger PreProcessor (TilePPR), its **firmware** and **DAQ software**
- It represent 1/4 in size of the final Tile-PPR board for the HL-LHC
- First prototype built end 2014 and regularly used
- 5 more prototypes built since then for parallel tests and operations in the lab and at CERN.
- Parallel development of the TilePPR firmware and infrastructure: ATCA crates, Optical Fibres, interface to L0 trigger and Software & assembly of stand-alone test unit



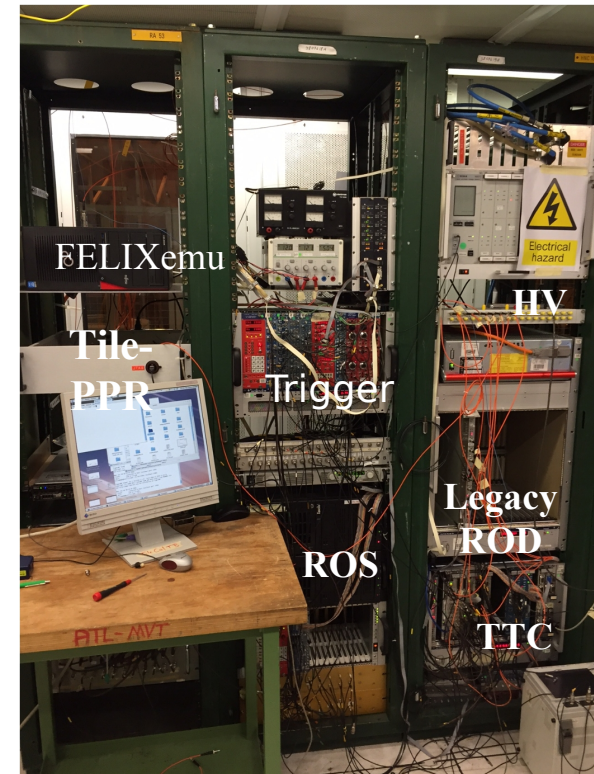
TileCal Test Beam Activities

Testing and Commissioning:

- Regular Expert test weeks at CERN
- Test-beam at CERN
(1 held in 2015, 2 in 2016, 2 foreseen in 2017)
- All three front-end option tested in the test-beam.
- TilePPR used to read-out data in parallel with “legacy” read-out



TileCal test-beam data



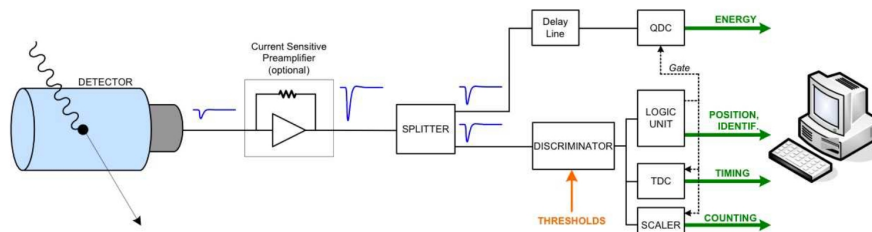
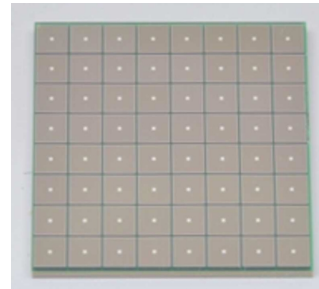
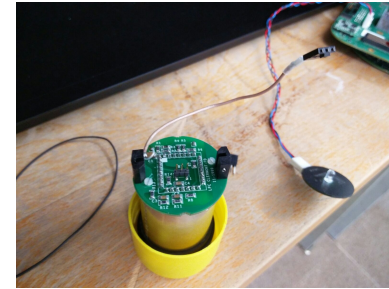
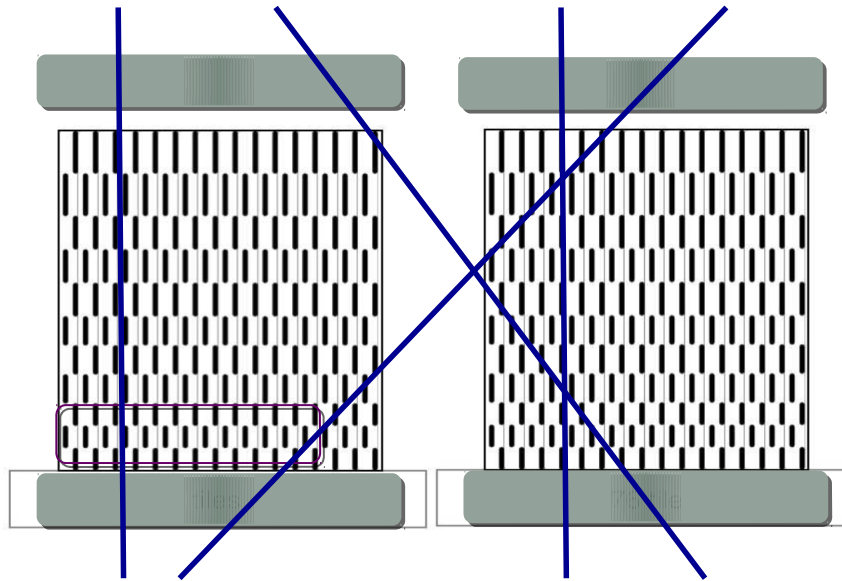
2016 TileCal test-beam read-out crates



PMT Test Bench

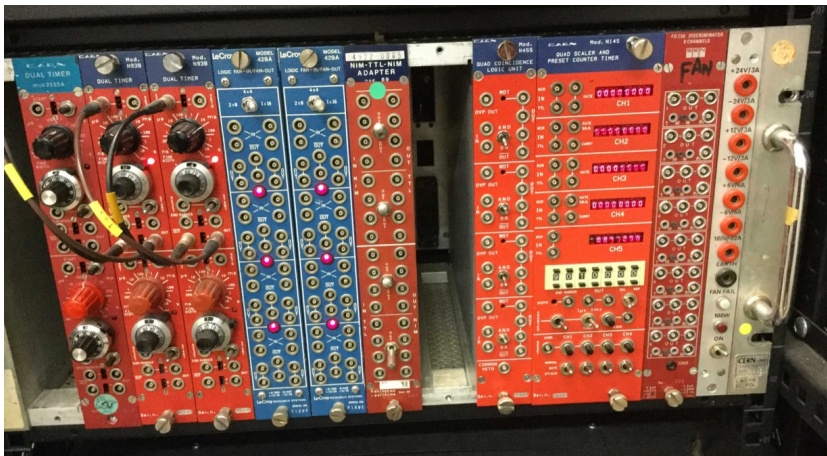
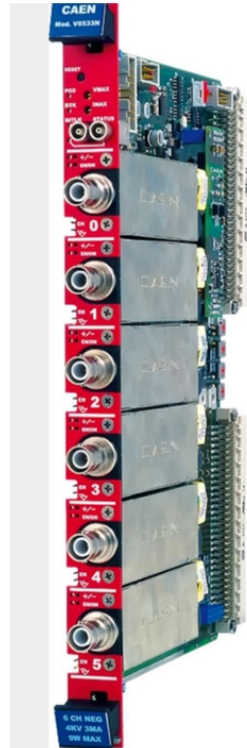
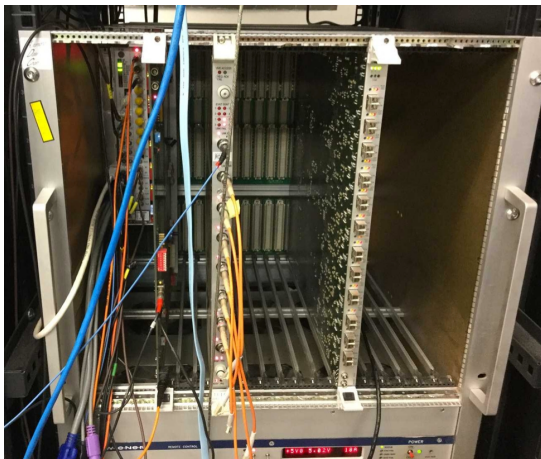
Aim:

- Build a **photodetector test-bench setup** at IFIC-TileCal Lab from where to acquire experience in handling and characterizing new PMT technologies (MA-PMTs & SiPMs) for FCC.
- Use TilePPR to read-out the test-bench → operational setup with physics for the TilePPR
- Build a cosmic ray telescope (external trigger) for light yield measurement of MIPs (muons)
- Estimate, for example, #pe/MIP/tile for different commercially MA-PMTs and SiPMs. Calibrate detectors in terms of pe's
- Reconstruct tracks and study cosmic muon flux as a function of incident angle, etc..



PMT Test Bench

- Reusing electronics available in the IFIC-TileCal lab and expertise in PMT testing.
- Using 9U VME Wiener crate, VME HV board and 1U CAEN NIM crate for discrimination and timing electronics
- New Blackbox for LED irradiation tests and PMT characterization.
- Use existing DELPHI scintillators (NE-110, 3.5 m length) and PMTs to construct an external cosmic trigger



IFIC-TileCal Group

- **Selected Physics and Performance**

- **Responsibilities:**

- ATLAS Tau WG Convener (*L. Fiorini*)
- ATLAS Higgs to Leptons Convener (*L. Fiorini, 2014-2015*)
- LHC Higgs Combination group (*L. Fiorini, 2014-2015*)
- ATLAS Data Preparation Coordination (*L. Fiorini, 2012-2014*)

- **Selected Upgrade/Operations Responsibilities:**

- ATLAS TileCal Upgrade Coordinator (*A. Valero*)
- ATLAS TileCal Run Coordinator (*L. Cerdà*)
- ATLAS TileCal Signal Reconstruction Coordinator (*A. Valero*)
- ATLAS TileCal speaker committee chair (*L. Fiorini*)
- ECFA ATLAS Calorimeter Representative (*A. Valero, 2013-2014*)
- ATLAS TileCal Run Coordinator (*A. Valero, 2013*)

- **Severo Ochoa** (very needed and we are grateful for that):

- 1 post-doc
- 1.3 students

- Typically 10-15 contributions to conferences & Workshops per year.

- **Internationals Conference in 2016:**

- ICHEP 2016 (*L. Cerdà*)
- LHCP 2016 (*L. Fiorini, D. Álvarez*)
- Higgs Hunting 2016 (*L. Fiorini*)
- CHEP2016 (*A. Valero*)
- IEEE NSS/MIC (*P. Zuccarello*)
- IEEE RT2016 (*F. Carrió*)
- ACES (*F. Carrió*)

- **Workshops in 2016:**

- ATLAS Tau+HLeptons Workshop (*L. Fiorini*)
- ATLAS BSM Workshop (*L. Fiorini*)
- ATLAS HH Workshop (*L. Cerdà*)
- ATLAS ML Workshop (*L. Fiorini*)

- **National Meetings in 2016:**

- Winter Meeting (*L. Fiorini, L. Cerdà*)
- TAE 2016 (*S. Rodriguez*)

Summary



Thank You for your attention!



Questions?

Bonus Slides

Conferences in 2016



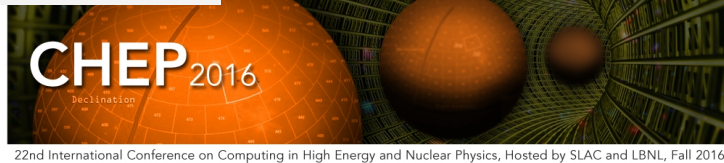
Conferences & Workshops in 2016:

- 4 Talks
- 5 Workshops
- 5 Poster
- 1 PhD School

Contributions+Organization:

ATLAS HH Workshop (Leo)
ATLAS ML Workshop (LF)
ACES (Fernando)
Winter Meeting (LF, Leo)
ATLAS BSM Workshop (LF)
RT2016 (Fernando)
LHCP (LF, Damián)
ICHEP (Leo)
TAE (Sergi)
CHEP (Alberto)
ATLAS Tau+HLeptons Workshop (LF)
Higgs Hunting (LF)
NSS/MIC (Pedro)

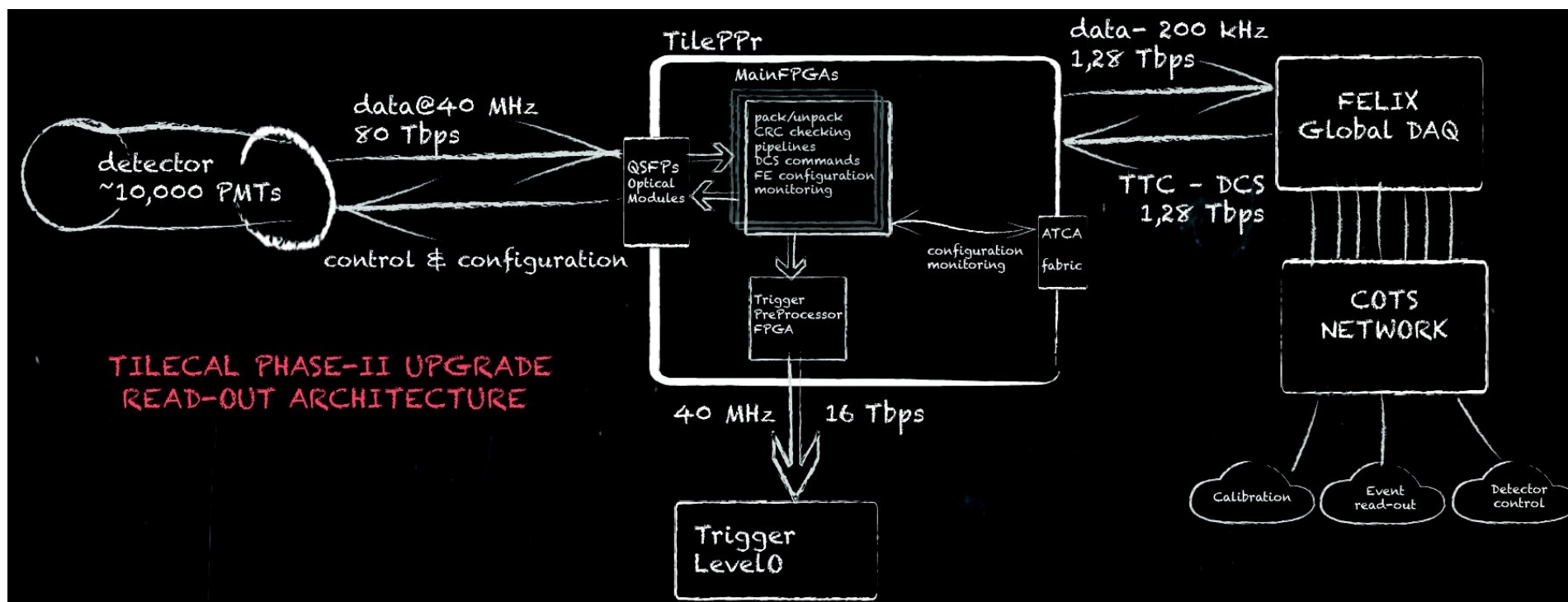
Plenty of contributions this year!

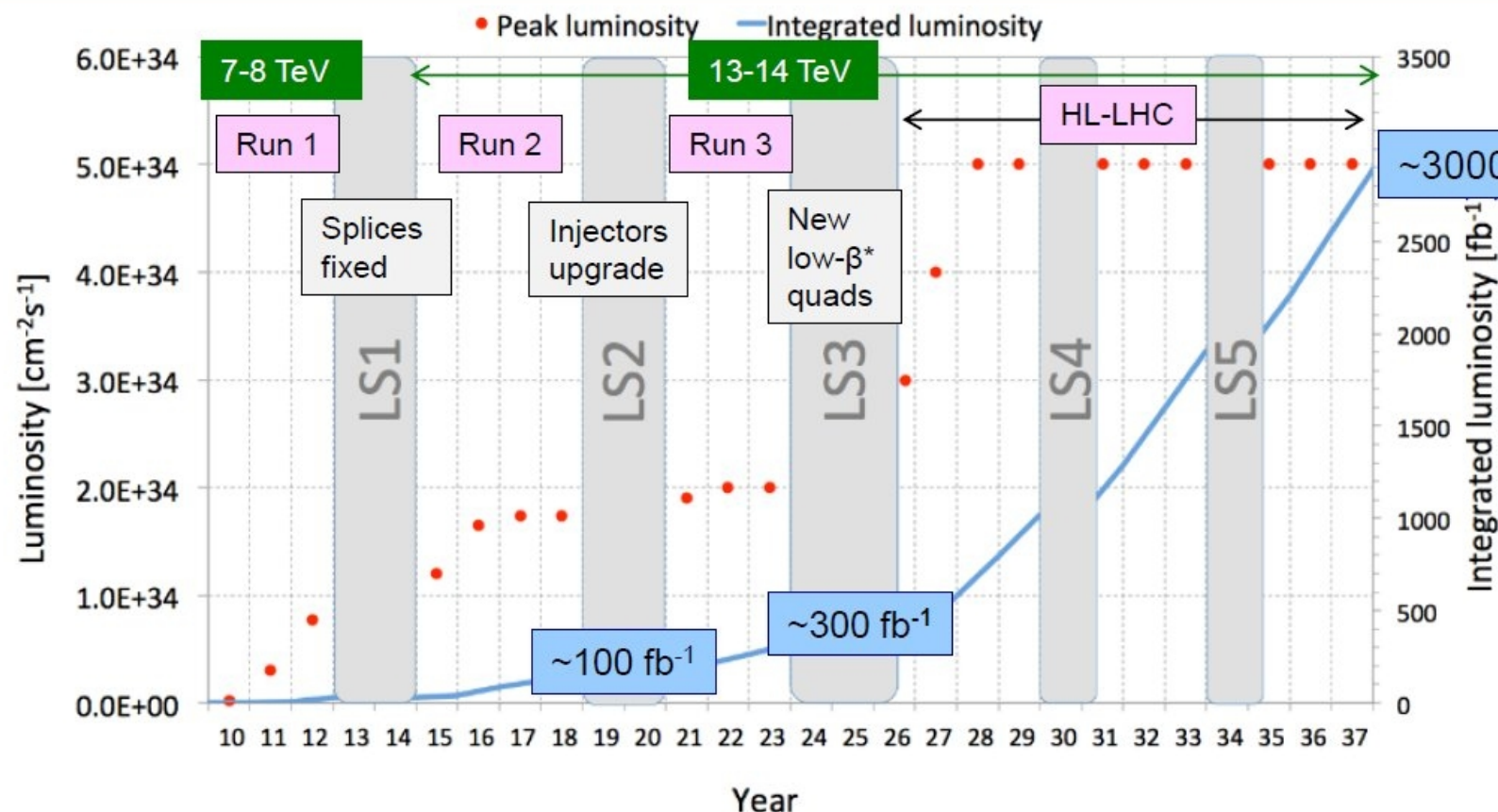


ATLAS TileCal Back-end Upgrade

- **Back-end specific upgrade:**

- Read-Out Devices (ROD) are replaced by Pre-processors (**Tile-PPr**)
- Tile-PPr processes events for each bunch crossing (40 MHz) and send them to the first-level trigger → **Bandwidths: ~80 Tb/s IN, 16+1.28 Tb/s OUT**
- Tile-PPr are also sending the slow-control commands to the detector (DCS).
- Back-plane interface to ATLAS TDAQ (TDAQ-i) separated from the Tile-PPr.





- ❑ LIU/HL-LHC Cost & Schedule reviews in March 2015 and October 2016
- ❑ ATLAS and CMS: “scoping documents” presented to Resources Review Board October 2015
→ scale of funding defined, now proceeding to TDRs
- ❑ ALICE and LHCb: major upgrades under construction for installation in LS2
- ❑ HL-LHC included in ESFRI (European Strategy Forum on Research Infrastructures) roadmap
→ very useful to get funding in the countries