Brazilian HEP Research at CERN: ATLAS Experiment

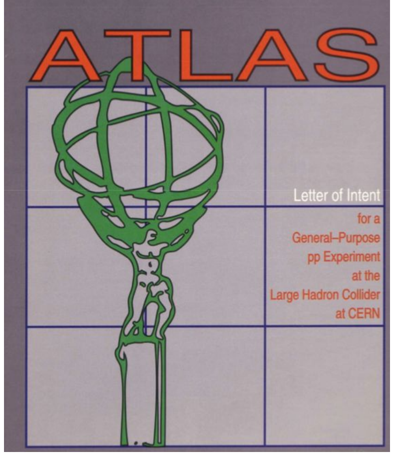
CLAF Symposium - 14 November 2025

CBPF, Rio de Janeiro, Brazil

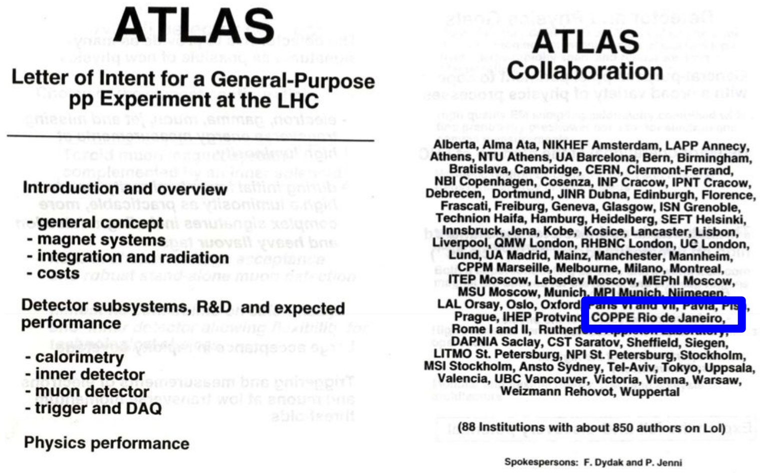
Marisilvia Donadelli, on behalf of the ATLAS Brazil Cluster
Universidade do Estado do Rio de Janeiro (BR)

Brazil in ATLAS

Pioneered by UFRJ (COPPE), Brazil has contributed to ATLAS since its conception in 1988* and is founding member of ATLAS Collaboration.



* The birth of ATLAS
March 1992 – Summer 1992
Merging of ASCOT and EAGLE



ATLAS

Letter of Intent for a General-Purpose pp Experiment at the LHC

Introduction and overview

- general concept
- magnet systems
- integration and radiation
- costs

Detector subsystems, R&D and expected performance

- calorimetry
- inner detector
- muon detector
- trigger and DAQ

Physics performance

ATLAS Collaboration

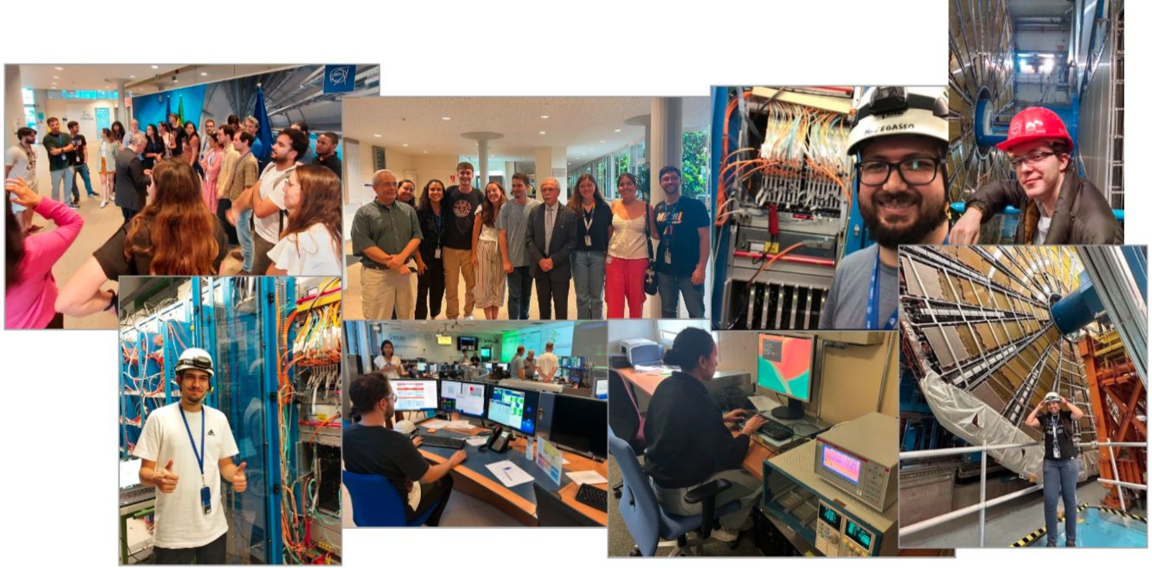
Alberta, Alma Ata, NIKHEF Amsterdam, LAPP Annecy, Athens, NTU Athens, UA Barcelona, Bern, Birmingham, Bratislava, Cambridge, CERN, Clermont-Ferrand, NBI Copenhagen, Cosenza, INP Cracow, IPNT Cracow, Debrecen, Dortmund, JINR Dubna, Edinburgh, Florence, Frascati, Freiburg, Geneva, Glasgow, ISN Grenoble, Technion Haifa, Hamburg, Heidelberg, SEFT Helsinki, Innsbruck, Jena, Kobe, Kosice, Lancaster, Lisbon, Liverpool, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, Mannheim, CPPM Marseille, Melbourne, Milano, Montreal, ITEP Moscow, Lebedev Moscow, MEPhI Moscow, MSU Moscow, Munich, MPI Munich, Nijmegen, LAL Orsay, Oslo, Oxford, Paris VI and VII, Pavia, Pisa, Prague, IHEP Protvino, COPPE Rio de Janeiro, Rome I and II, Rutherf... DAPNIA Saclay, CST Saratov, Sheffield, Siegen, LITMO St. Petersburg, NPI St. Petersburg, Stockholm, MSI Stockholm, Ansto Sydney, Tel-Aviv, Tokyo, Uppsala, Valencia, UBC Vancouver, Victoria, Vienna, Warsaw, Weizmann Rehovot, Wuppertal

(88 Institutions with about 850 authors on LoI)

Spokespersons: F. Dydak and P. Jenni

Cluster of 5 Universities: UFBA, UERJ, UFJF, UFRJ, USP | (collaborating: UFRN and IFBA)

Brazil in ATLAS

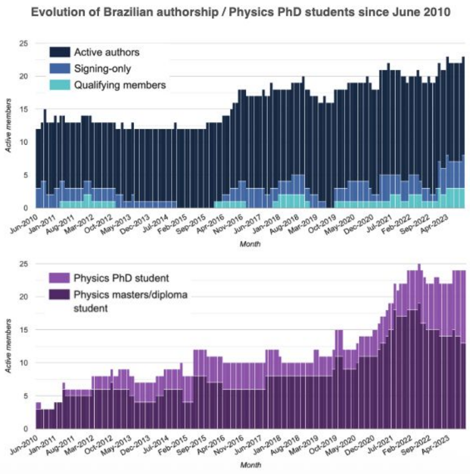


85 members

15 researchers (M&O A)

23 PhD students

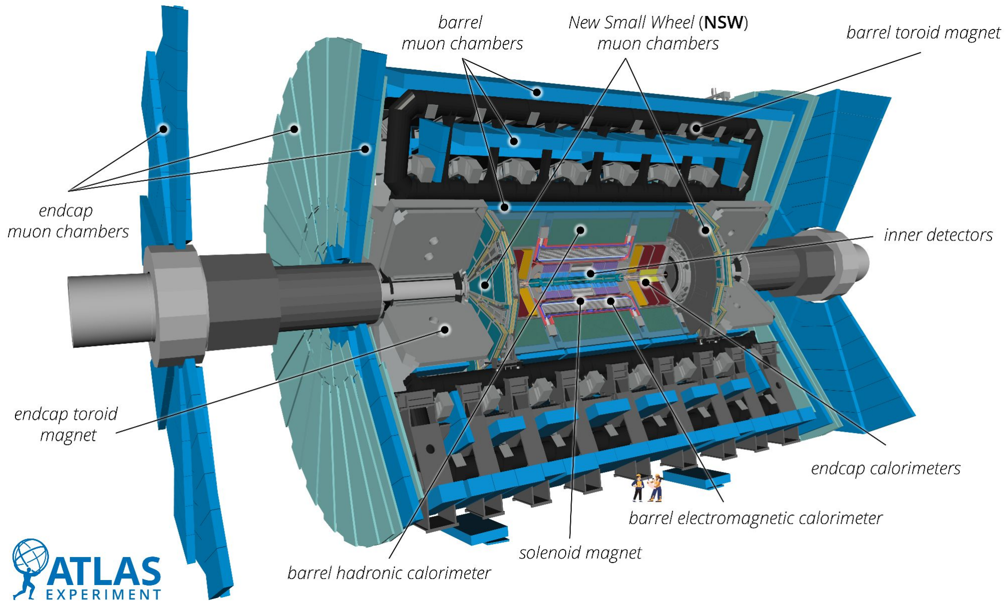
Funding agencies: CAPES, CNPq,FAPESP, FAPERJ,FAPEMIG, FAPESB, FINEP and MCTI



FAPESP FUNDAÇÃO DE AMPARO À PESQUISA DO ESTADO DE SÃO PAULO
CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico
FAPERJ Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro
Finep INOVAÇÃO E PESQUISA EMPRESA PÚBLICA DO MCTI
CAPES
fapesb
FAPEMIG

A Toroidal LHC ApparatuS

Layered detector surrounding the interaction point: central tracker inside of a solenoid, calorimeters and an independent muon spectrometer with superconducting toroids



- fast triggering on interesting signatures
- precise reconstruction of collision vertices
- photons and electrons
- muons
- taus
- jets
- missing transverse momentum
- identification of heavy flavour jets

Brazil in ATLAS: contributions

- Physics analyses (3 ATLAS Physics Working Groups)
- Software and computational algorithm development
- Development of management applications (Glance, Tile DB)
- Big data processing (ATLAS + ALICE SAMPA Tier-2)
- Instrumentation for particle detection and associated systems
- Contributions to detector upgrade and construction projects (Phase-I / Phase-II)
- Science outreach activities

ATLAS Higgs and Di-Higgs Physics Working Group

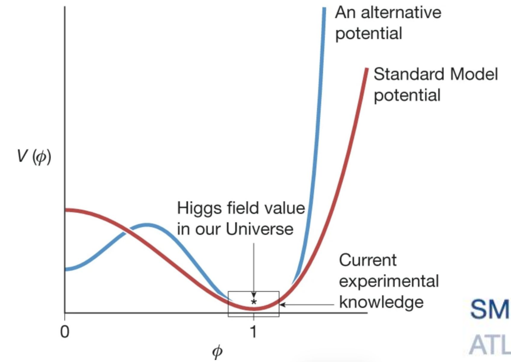
ATLAS Standard Model Working Group

Recent Full Run 2 Physics Results

ATLAS Exotics Working Group

The Higgs potential and Di-Higgs searches

G. Salam's sketch in *Nature* 607,41–47 (2022)



- Potential's shape and origin are experimentally very loosely unconstrained
- Local minimum established since 2012

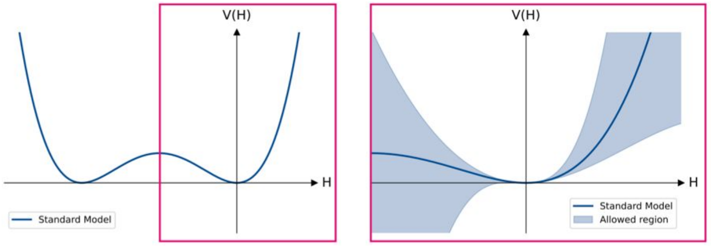
SM λ_{HHH}=$\lambda_{HHHH} \approx \frac{1}{8}$

ATLAS 95% CL

$$V = \frac{m_H^2}{2}H^2 + \lambda_3 v H^3 + \frac{\lambda_4}{4}H^4, \quad \lambda_3 = \lambda_4 = \lambda_{HHH} = \frac{m_H^2}{2v^2}$$

mass term

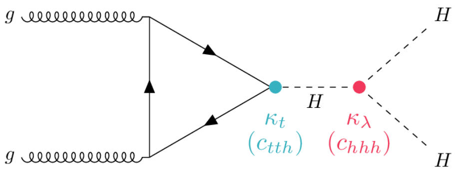
self-coupling term



what the SM predicts

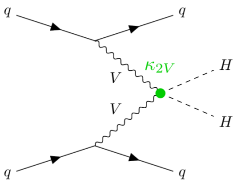
what we know experimentally using current ATLAS limits @95%CL

	bb	WW	ττ	ZZ	γγ
bb	34%				
WW	25%	4.6%			
ττ	7.3%	2.7%	0.39%		
ZZ	3.1%	1.1%	0.33%	0.069%	
γγ	0.26%	0.10%	0.028%	0.012%	0.0005%



$\kappa_\lambda = \lambda_{HHH}/\lambda_{HHH}^{SM}$

SM predicts κ_λ = 1

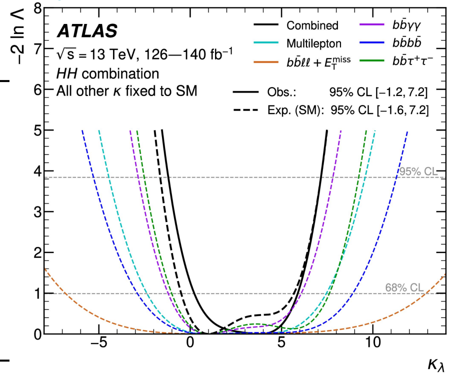


Measure HH to probe the potential shape by determining the **strength** of Higgs boson self-couplings, keeping a compromise between BR and clealingness of the final state

Di-Higgs

ATLAS Higgs and Di-Higgs Physics Working Group

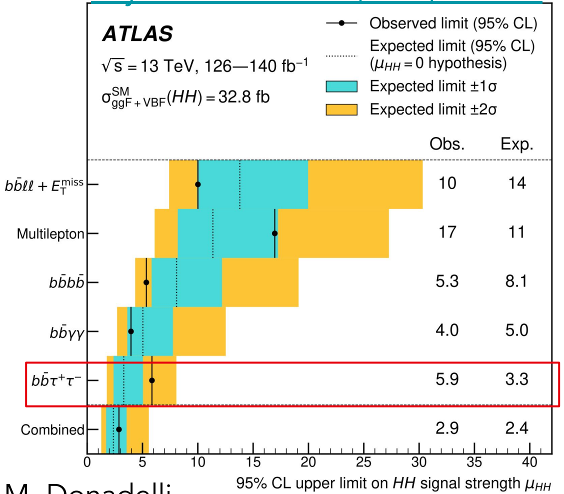
Phys. Rev. Lett. 133 (2024) 101801



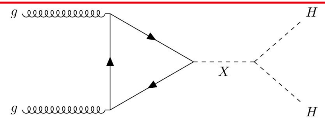
- Flagship LHC analyses
- HH →bb**ττ** amongst the three most sensitive channels
- Contributions in 6 papers (non-resonant, resonant, with partial/full Run 2 datasets and HL-LHC projections since first ECFA 2013 recommendations (ATL-PHYS-PUB-2024-016, CERN Yellow Report and Snowmass)
  - editorial boards, analysis strategy, signal discriminant optimisation, background estimation, statistical analysis

- Expected non-resonant limit driven by HH →bb**ττ**

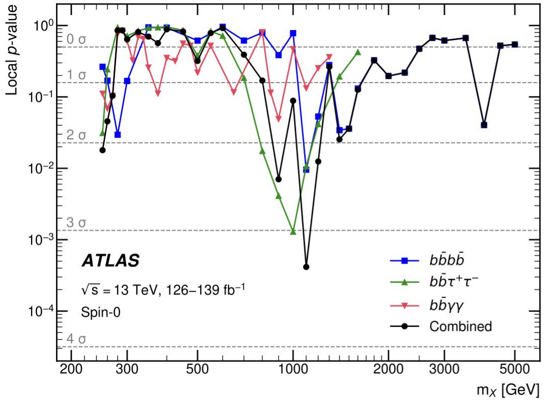
Phys. Rev. Lett. 133 (2024) 101801

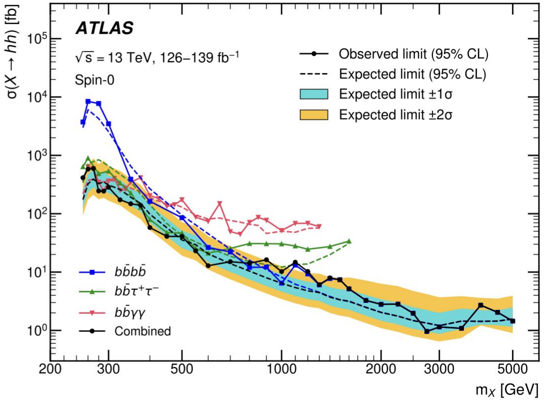


- Resonant: largest deviation observed at 1.1 TeV (3.3 **σ** local) mainly driven by HH →bb**ττ**



Phys. Rev. Lett. 132 (2024) 231801





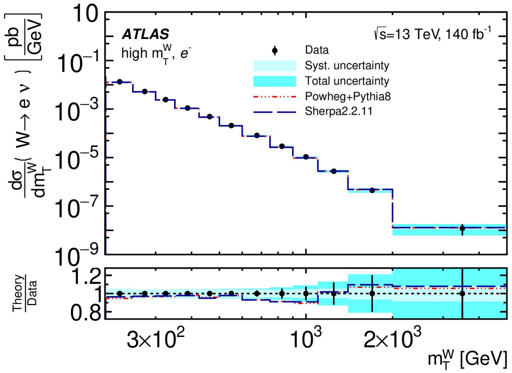
High m_T^W

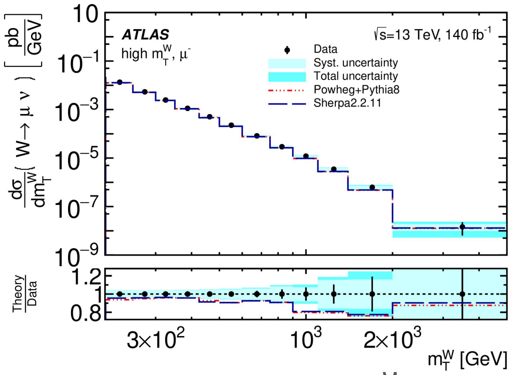
ATLAS Standard Model Working Group

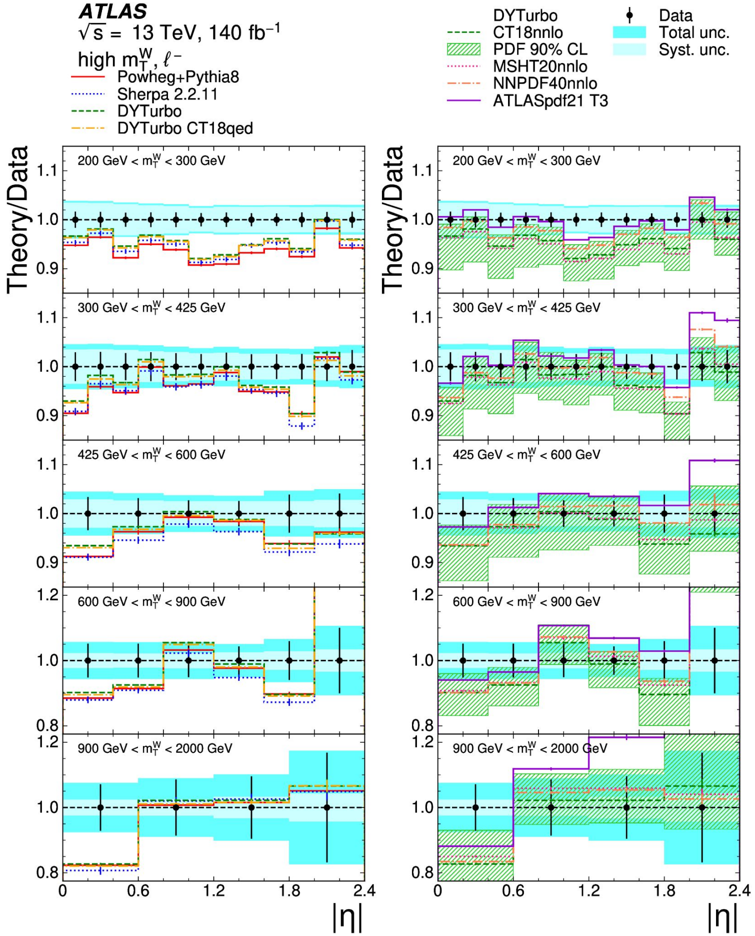
- Fundamental observable of SM, enters global EWK fit
- New particle candidates that couple to the W boson and are lighter than m^W, would open a new decay channel and alter ΓW
- First measurement above resonance region for $m_T^W \in [200, 5000]$ GeV
- Potential of data to constrain different PDFs

Contributions: unfolding, systematic uncertainties

experimental precision of 3% at low m_T^W







JHEP07(2025)026

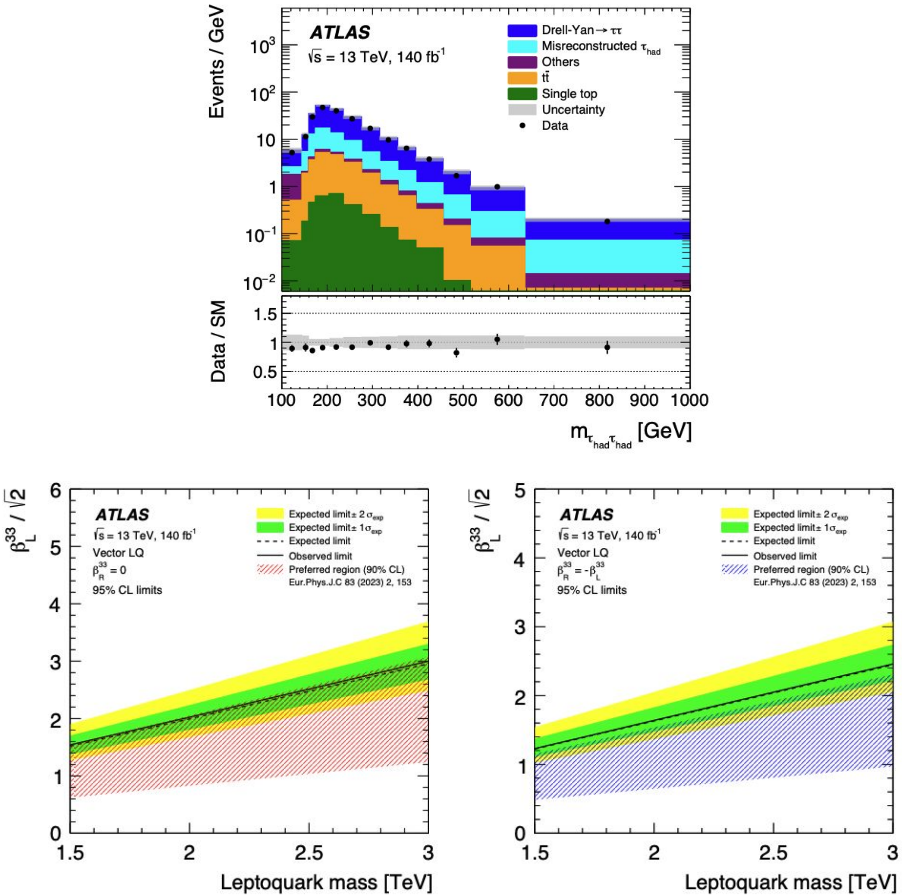
High-mass $\tau\tau$

ATLAS Exotics Working Group

- At high invariant mass, Drell–Yan production probes a variety of possible new interactions including the production or exchange of Z' bosons, leptoquarks and additional Higgs bosons

- First measurement of the inclusive $\tau\bar{\tau}$ fiducial cross-section as a function of visible invariant mass, along with a search for new states through non-resonant interactions

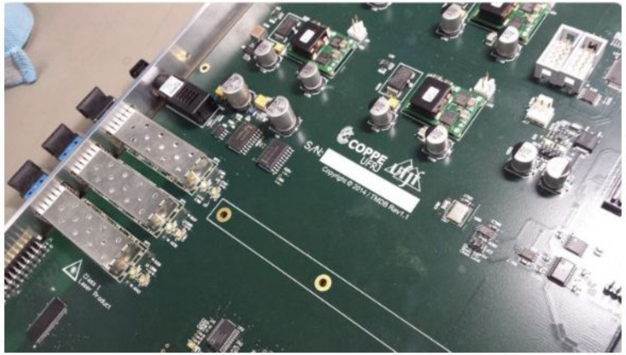
<u>Contributions</u>: $m_{\tau\tau}$ reconstruction studies

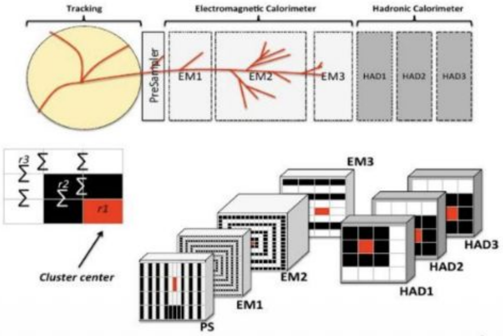


Instrumentation and Trigger for LHC

Main contributions

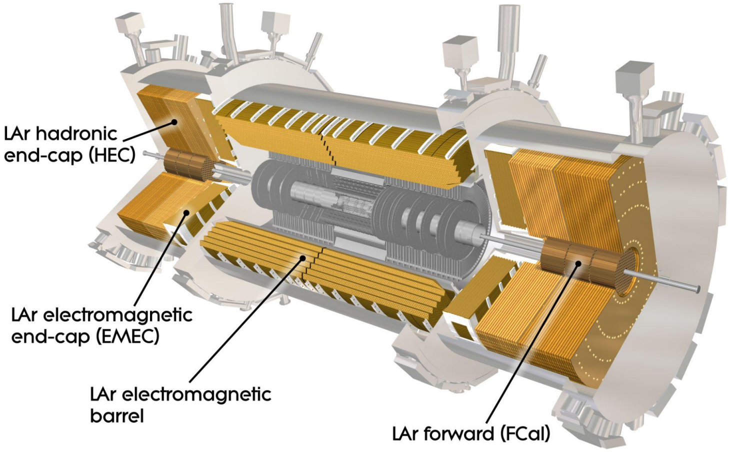
- Hardware that builds the trigger signal for the ATLAS hadronic calorimeter (Tilecal).
- Signal processing methods for energy reconstruction of calorimeter towers.
- First-level muon trigger assisted by calorimetry.
- New feature extraction and Machine Learning topologies for the ATLAS electron and photon identification system.
- Simulation and Signal Processing for Future Developments in High Energy Calorimetry.
- Contributions to mitigating crossTalk effects in the Liquid Argon (LAr) calorimeter.

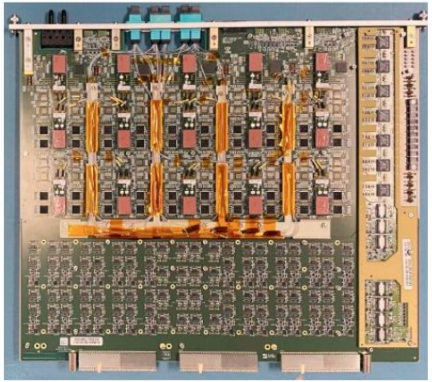




LAr calorimeter

- Contribution to the development of the digital trigger system for the LAr.
  - Radiation testing of the main components in the prototype phase.
  - Especially important knowledge for reading supercells (Run3).
- Development of signal reconstruction methods.
- Contributions to commissioning and operations.

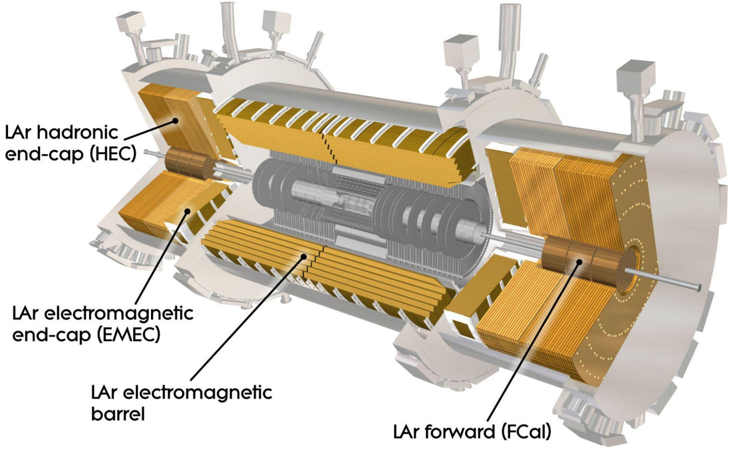


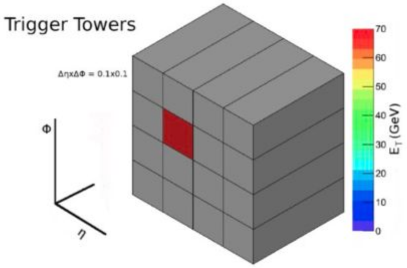


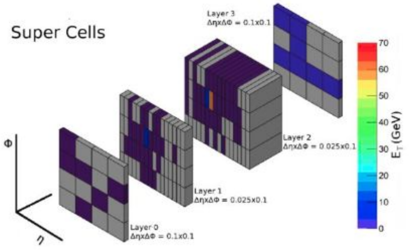
124 boards, each processing 320 channels = ~40,000 channels and 25,000 Gb/s

LAr calorimeter

- Liquid Argon Calorimeter (LAr) Operations
- Phase-I Upgrade Liquid Argon Trigger Digital Board (LTDB)
  - Commissioning Studies.



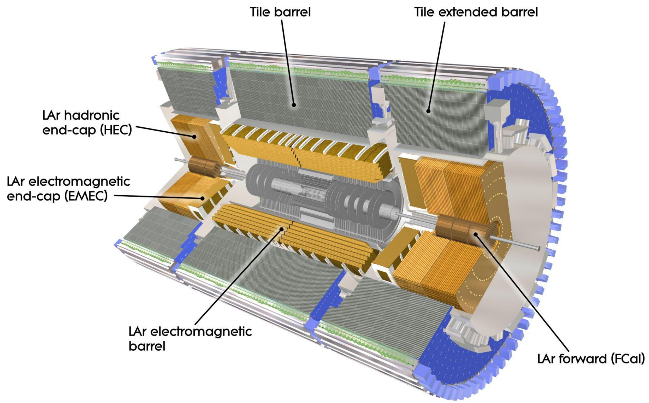




LATOME* boards receive digital data from the calorimeter and perform calculations on transverse energy and timing to send to the next stage of the trigger system

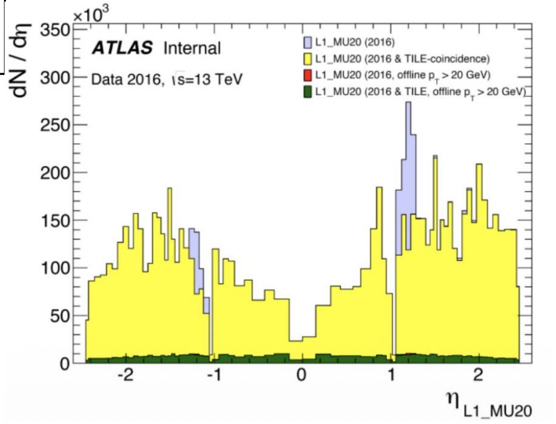
- PhD student work:
  - Baseline - corrections for performance studies of the LATOME* firmware with offline data.
  - Very important for Run 3 2023 ($\langle\mu\rangle$ = 60~70) - developed code being used for validation

Tile Calorimeter

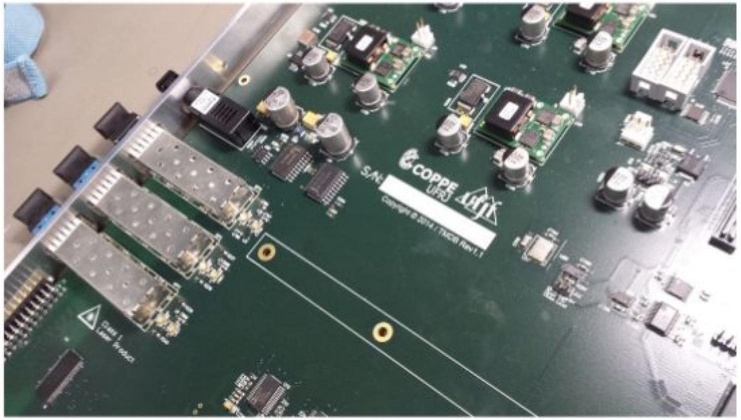


<u>TileCal-assisted Muon Trigger</u>:

- The TMDB electronic module is the main component responsible for merging muon information from TileCal with TGC-Sector Logic.
- With 32 analog-to-digital conversion channels, a TMDB module is capable of digitizing and processing the D5 and D6 cells of 8 modules of the TileCal extended barrel.



TMDB: TileMuon Digitizer Board.

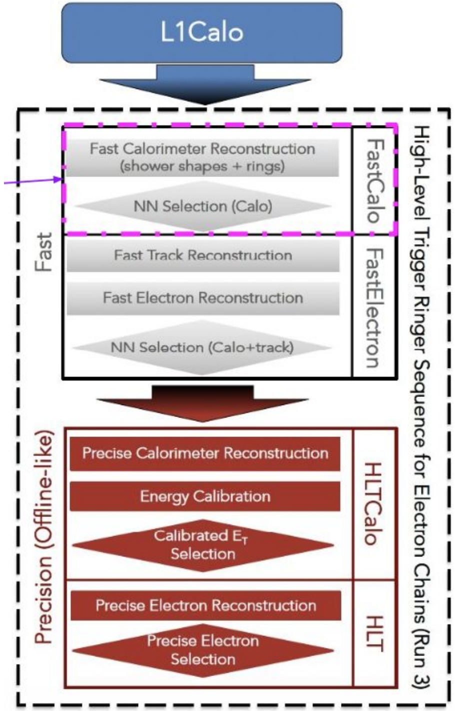


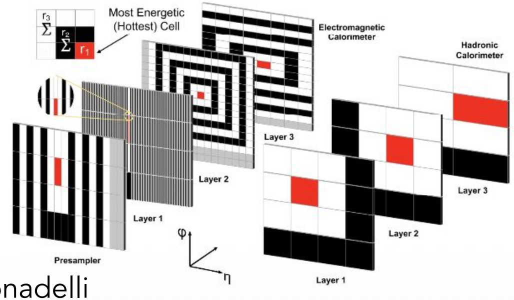
Developed at the end of Run1 and in operation during Run2 and Run3, it was able to efficiently reduce the trigger rate, with improved muon detection efficiency.

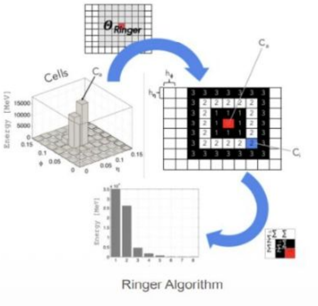
Trigger system

NeuralRinger: Method for online electron identification.

- Algorithm that combines extraction of lateral and longitudinal features of the shower, employing a set of neural networks for electron/photon identification.
- Developed for triggering, enabling high background rejection in the first stage of the HLT.
- Greater resilience to high stacking compared to the cut-based method.
- Standard electron triggering algorithm since 2017 for E_T >15 GeV, and from 2022 covering the entire energy range E_T > 5 GeV.







Ringer algorithm uses as input energy sums of all cells in 100 concentric rings centred around the most energetic cell in each calorimeter sampling layer.

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Trigger system

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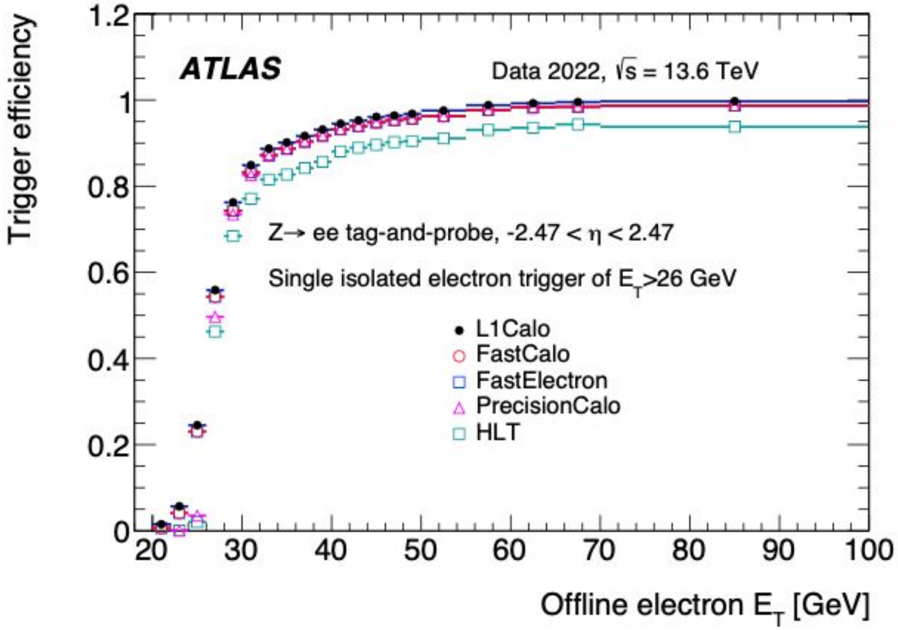
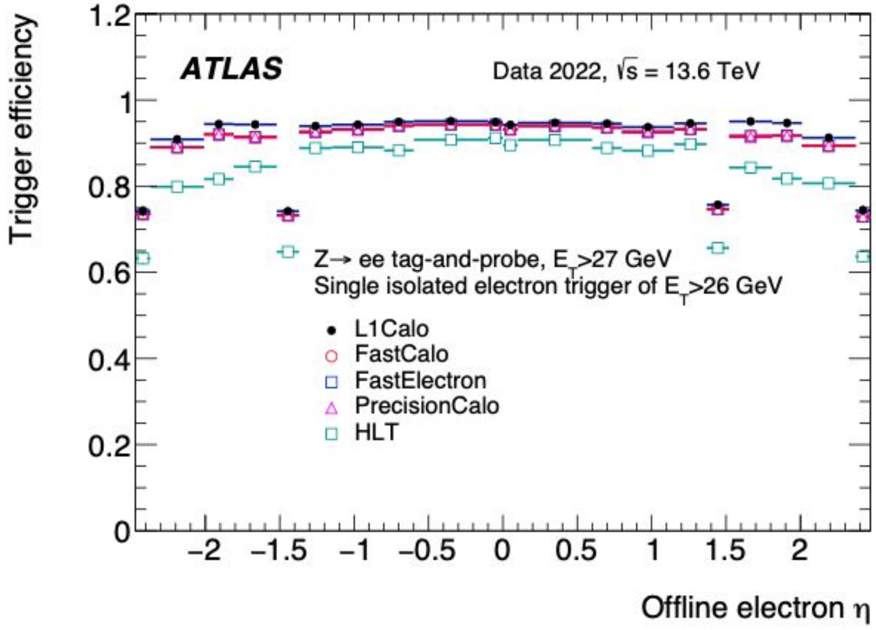
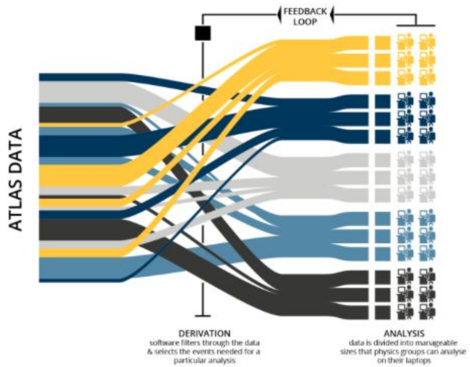




Efficiency of the lowest unprescaled single-electron trigger with respect to offline electron candidates for each step of the online reconstruction.


FEEDBACK LOOP
ATLAS DATA
DERIVATION
software filters through the data & selects the events needed for a particular analysis
ANALYSIS
data is divided into manageable sizes that physics groups can analyse on their laptops

Computing

The Glance Project

- Essential management software tool
- Main objective is to develop and maintain automated web-based solutions that are easy to learn and use and allow collaboration members to perform administrative tasks quickly
- Primarily involves undergraduate students (part-time) - POLI / UFRJ
  - Interns and Scholarship holders
- Two startups whose founders are COPPE alumni with an ATLAS background
- Contributions from other institutes (mainly UDINE / Italy and LIP / Portugal)

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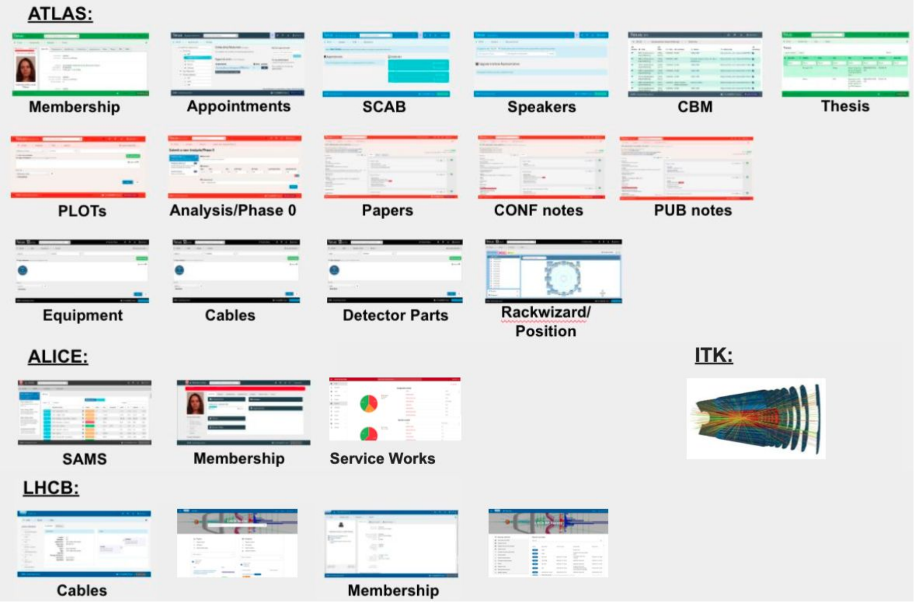
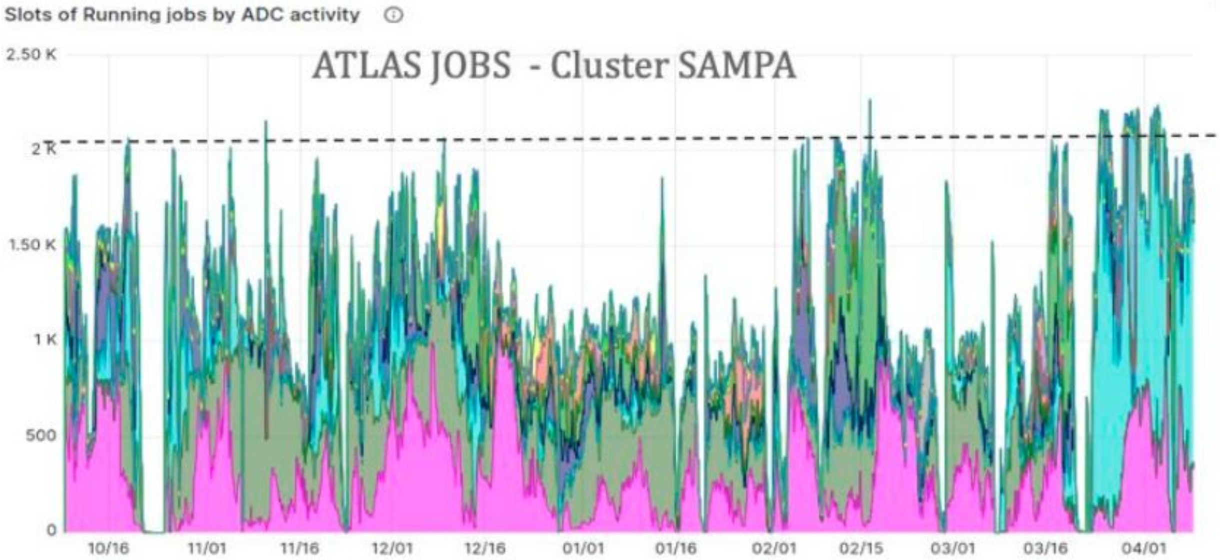
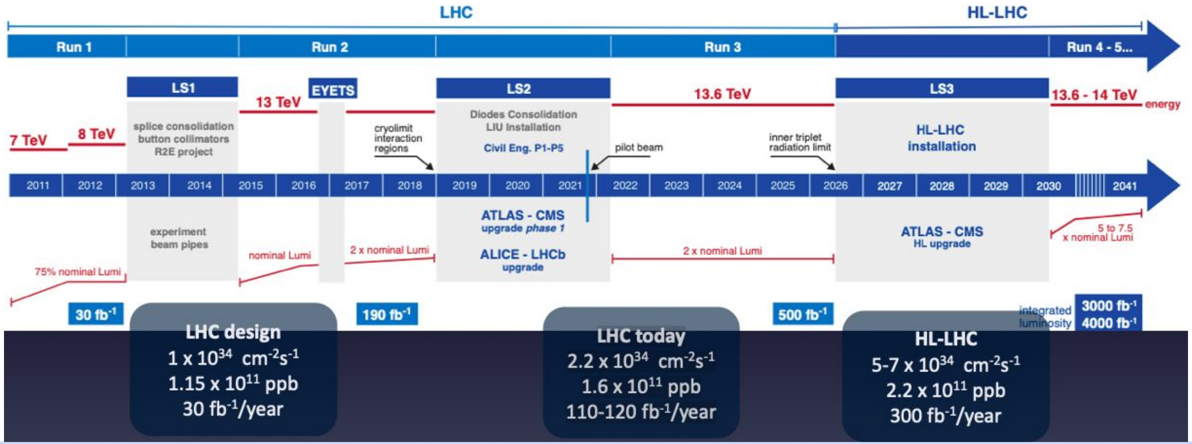


	ATLAS	LHCb	ALICE	ITK
Systems	15	4	3	1
Users	6k	1.5k	1.3k	TBD
Requests per week	10	3	5	TBD

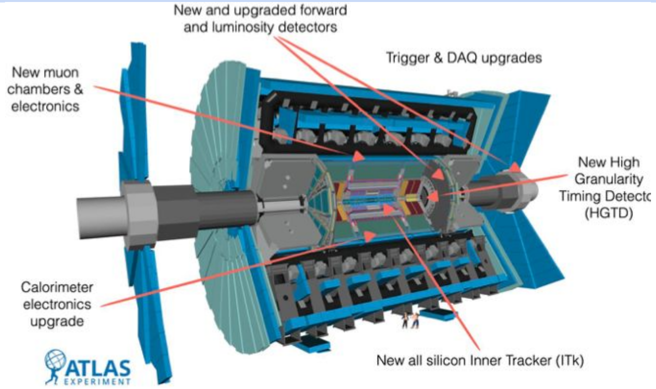
ATLAS Tier-2

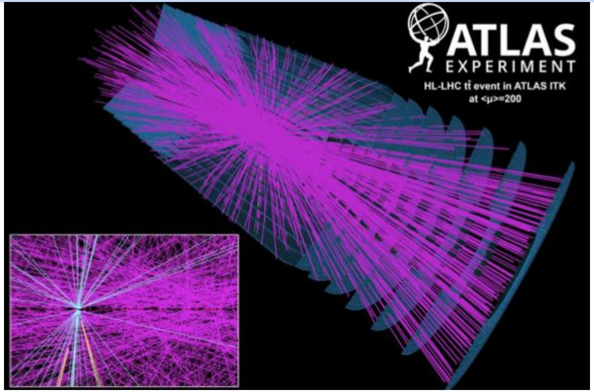
- Hosted by USP (HEPIC)
- Shared between ATLAS and ALICE in the same cluster
  - optimised use of resources
- high efficiency (> 90%)
- in operation in ATLAS since 2022



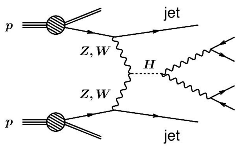


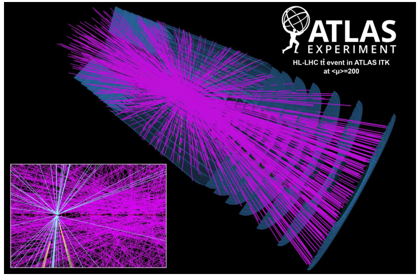
A bright future ahead: HL-LHC





The High Granularity Timing Detector (HGTD)

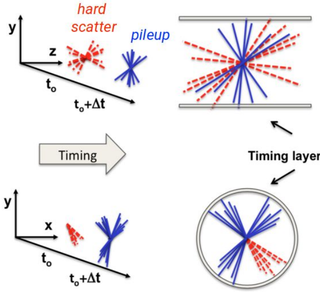




Ultra-fast timing is a key method for exploring HL-LHC physics

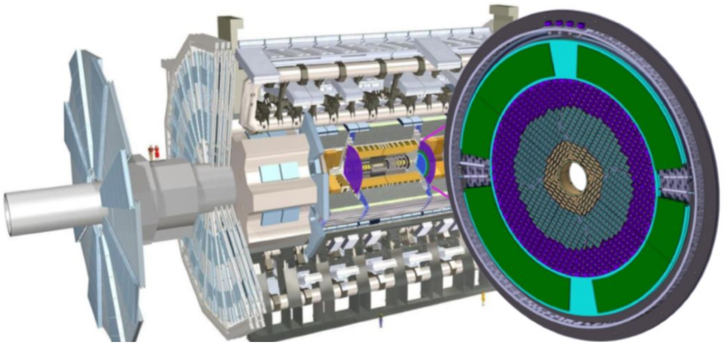
- most of LHC data are expected to come from HL-LHC phase (~4ab^{-1})
- unprecedented 200 simultaneous p+p collisions at every 25 nanoseconds
- pile-up dominated environment
- very challenging track-vertex association during event reconstruction
- impossible for the central semiconductor tracker to achieve the necessary spatial resolution in forward region crucial for the precision measurements in the Higgs sector (e.g.VBF)

- introduce a 4th dimension (time) in the spatial track reconstruction
- must be capable of < 30 picosecond timing resolution
- high segmentation for track association



HGTD

- 8 layers of ultrafast semiconductor sensors
- 16000 15x15 sensor arrays in 3 rings (3.4M channels)
- Total thickness ~ 12cm
- Total radius ~ 1.1m
- very radiation hard
- Needs very thin, very high timing resolution sensors !!



Brazilian contribution to sensors (US$ 172,000 - FAPESP), construction and commissioning

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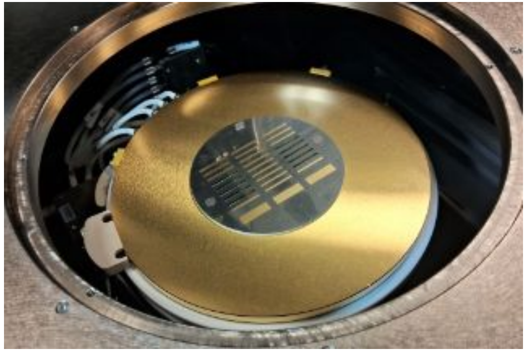
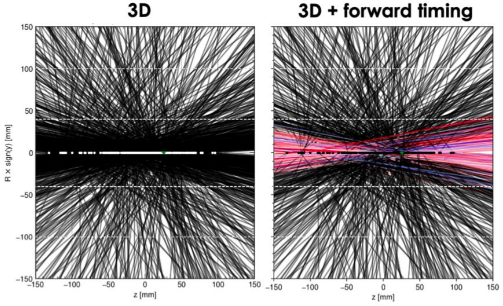
HGTD facility @ USP

- Hosted by USP (HEPIC)
- USP and CERN are the two main institutions for evaluating the performance of sensors produced for the HGTD
- Probe Station MPI TS2000-HP
  - Same as CERN
  - No temperature control, but capable of operation up to 10kV
  - Installed and commissioned
- Already measured 120 test structures from 24 pre-production wafers for HGTD
- HGTD sensors production first delivery as of May 2025

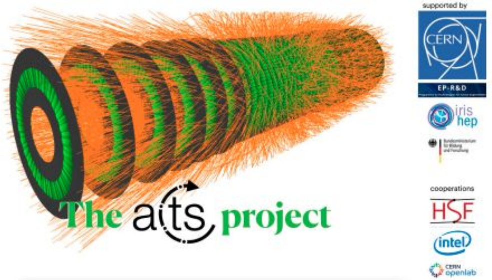


4D tracking for pile up mitigation

- For jets (and many other objects), it is essential to reconstruct the primary vertex position z_0
  - But the high number of interactions increase the z_0 uncertainty
  - Solution: add time information t_0 from HGTD ($2.5 < |\eta| < 4.0$)!
  - z_0 resolution is especially low for tracks that go to the frontal region
  - Still need to devise reconstruction methods that better incorporate the time measurements

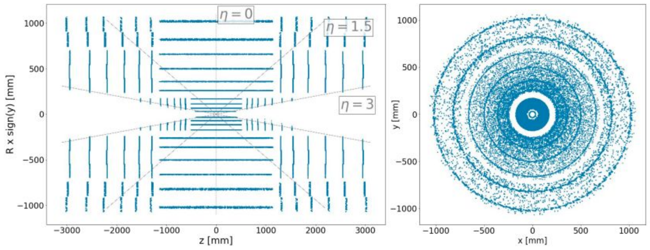


Credits: HSF Seminar - 4D Reconstruction, by Lorenzo de Santi



Graph based Neural Network approach for ATLAS HL-LHC (ITk+HGTD)

- Evaluate using new framework - ACTS with ATLAS geometry
- Exa.trk: HEP advanced tracking algorithms at the Exascale
- Studies with particle gun and ttbar events



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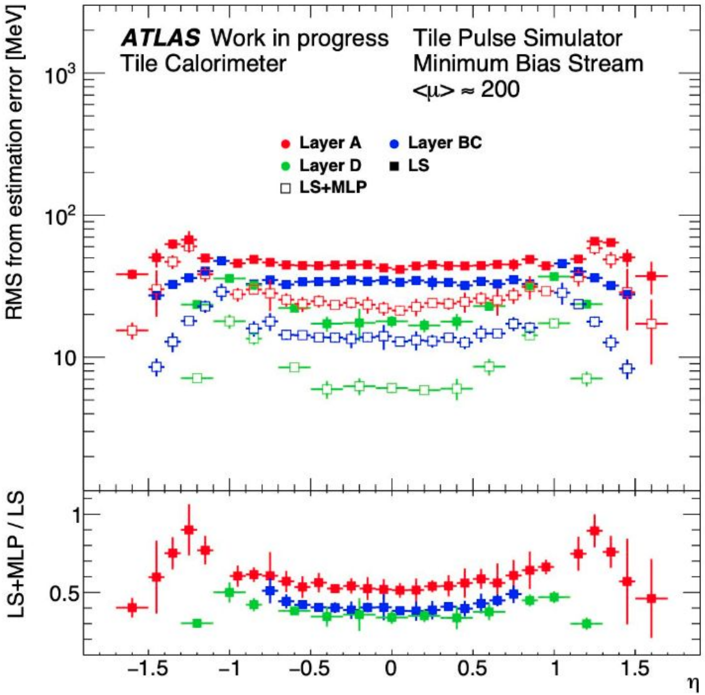
Phase II Tile Calorimeter

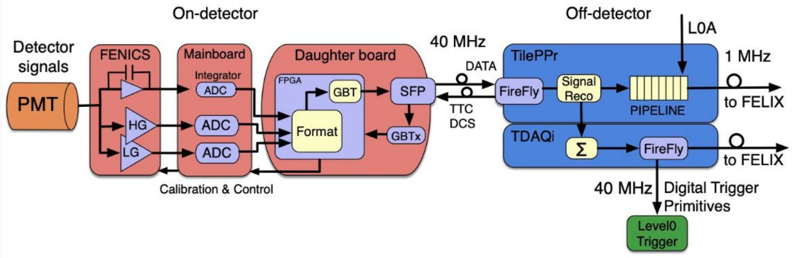
New Energy Reconstruction Methods for Calorimetry:
The new digital event selection system of Phase II of ATLAS requires the calorimeter to estimate energy every 25 ns.

● New strategies proposed by Brazilian groups are being evaluated (linear method with non-linear correction that allows mitigating the stacking effect).

● A linear filter (least squares) was designed and the correction shows a significant improvement in the performance of all calorimeter cells for the operating conditions of the HL-LHC.

● Results show that depending on the channel level occupancy, an improvement of up to 20% can be achieved when the optimized version of the OF method is used.





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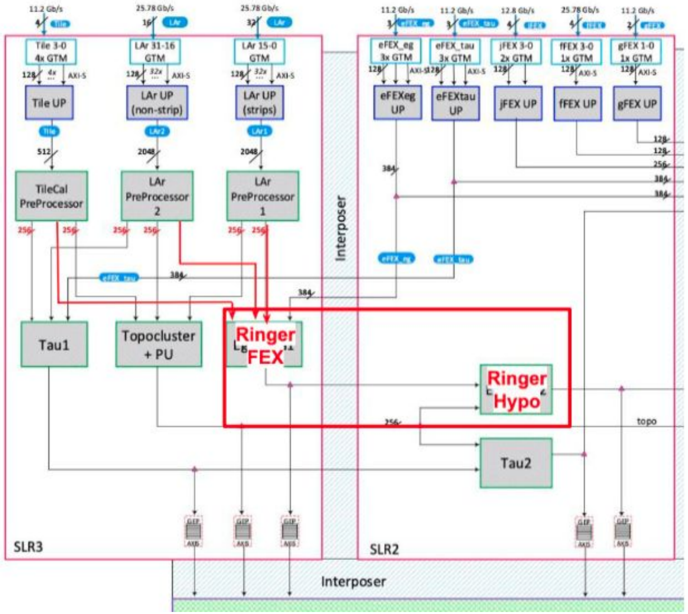
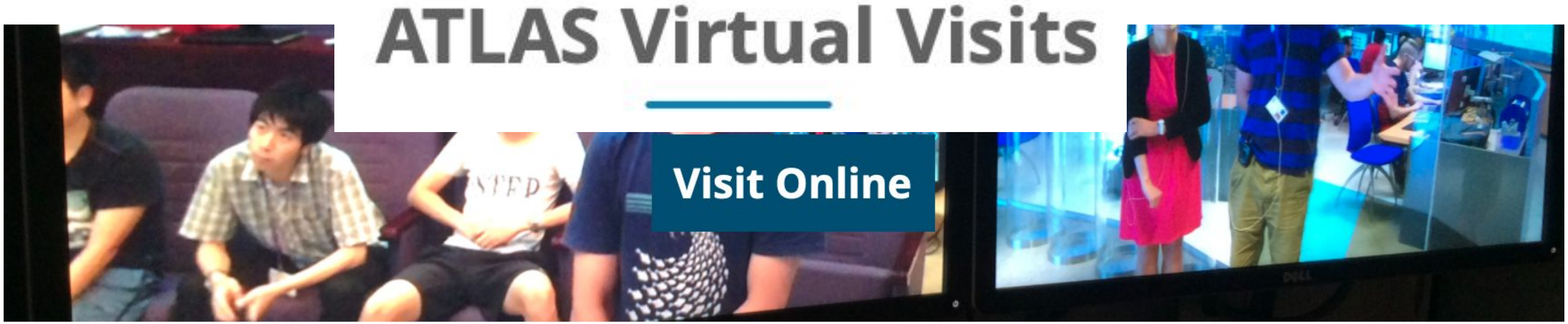
L0 Global EGamma Trigger: NeuralRinger in FPGA

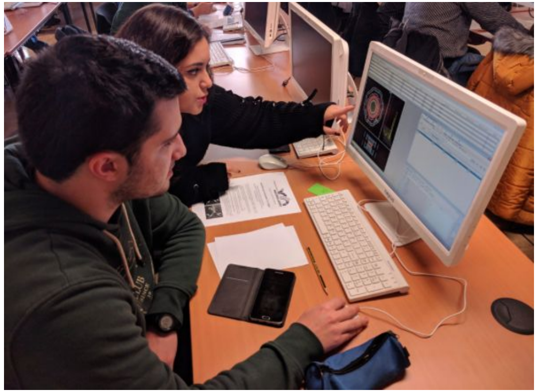
<u>NeuralRinger being developed for operation in FPGA, for the HL-LHC (L0 Global Trigger)</u>

- Qualification Task in progress - UFBA PhD student.
  - Integration and development of firmware in the Global Event Processor (GEP) framework.
  - Development in collaboration with IF-UNLP (La Plata, Argentina).
- Qualification Task completed - UFRJ PhD student.
  - Proof of concept in software with emulation of part of the operating conditions in Run4.
  - Performance of neural network architectures evaluated in software to guide developments in hardware.





Outreach



Particle Physics Masterclasses

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ATLAS - Virtual Visits @ COPPE

Since 2014, virtual visits have been part of the visits made by schools to COPPE-UFRJ.

They take place from 1:30 PM to 5:00 PM.

Schools register at www.espaco.coppe.ufrj.br

Wednesdays ==> public schools

Day to be arranged ==> private schools

COPPE offers a bus (46 seats) to transport students and their teachers from school to COPPE (round trip). Snacks are provided.

"Tent" is a small auditorium with video conference infrastructure dedicated to virtual visits.

Frequency: every 15 days (or less)

ATLAS - Virtual Visits organised by the Cluster

Since 2012, more than 6000 participants and counting!

2024-2025 ATLAS - Masterclasses - Hands on Particle Physics

- Location: State Secretariat of Education, Culture, Sport and Leisure of Rio Grande do Norte State (RN)
- Participants: 27 high school teachers

- Location: UFLA (Lavras - MG)
- Participants: 320 high-school students, 15 teachers, 11 staff members

- Location: USP (São Paulo - SP)
- Participants: 120 high-school students, 2 teachers

CERN Official Masterclasses (once a year):

- UERJ since 2008
- USP since 2015

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Final remarks

- Brazil has contributed to ATLAS since its conception in 1988;
- Our cluster is present in different areas with responsibilities built up throughout Run 1, Run 2 and Run 3 mainly in:
  - Flagship Physics Analysis in the Electroweak Sector;
  - Instrumentation;
  - Trigger and Calorimetry;
  - Computing;
  - Outreach.
- Phase-2 projects for the HL-LHC include:
  - HGTD: dedicated facility for evaluating the performance of sensors;
  - Pile up mitigation studies (ITk+HGTD) using GNNs and new framework;
  - L0 Global EGamma Trigger;
  - New Energy Reconstruction Methods for Calorimetry.

Thanks for your attention!!!