Computing Activities at the Spanish Tier-1 and Tier-2s for the ATLAS experiment towards the LHC Run3 and High Luminosity (HL-LHC periods)

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On behalf of the Spanish Tier-1 and Tier-2s team and ATLAS Collaboration

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Overview

• ATLAS Computing Model (Mesh Model)
• Spanish Tier-1 and Tier-2s inside ATLAS
• Development Activities for ATLAS Distributed Computing (ADC)
• Challenges for Run3 and High Luminosity (HL-LHC)
• Conclusions
ATLAS Computing Model in Run2 and for Run3

Original ATLAS Computing Model

- Tier1 has associated Tier2s that are close to it in terms of network connectivity, and they form the “cloud”.
- All data flow to and from Tier2s goes via its Tier1

More and more Tier2s have very good worldwide network connections and could exchange data directly between them.

This leads to the

Nucleus ↔ Satellite Model

- Tier2s with a big amount of storage and very good network connection get elected “Nucleus”, passing job production on to smaller Tier2s (Satellites) in any cloud, exchanging data directly.
- The Spanish Federated Tier2 is a Nucleus.

Note: “Cloud” in ATLAS means a regional setup of one Tier1 and its Tier2s in a certain geographical area!
Spanish Tier-1 and Tier-2s inside ATLAS

Clouds:
- CERN, CA, DE, ES, FR, IT, ND, NL, RU, TW, UK, US

The Iberian Cloud (ES) inside ATLAS:
- Tier1: PIC Barcelona
  - Provides 5% of Tier1 data processing of CERN's LHC detectors ATLAS, CMS and LHCb
- Tier2s:
  - Federated Spanish Tier2
    - IFIC Valencia (60%)
    - IFAE Barcelona (25%)
    - UAM Madrid (15%)
  - LIP Lisbon, Portugal
  - UTFSM Santiago, Chile
  - UNLP La Paz, Argentina (inactive)

ES-ATLAS-T2 y Tier-1:
- Integrated in the WCLG project (World Wide LHC Computing GRID) and strictly following the ATLAS computing model
- We represent the 4% of the total Tier-2s resources and the 5% of the Tier-1s ones

Spanish Cloud Facilities (October 2019)

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PIC New tape library (IBM TS4500)

On average (regular machine): 12 cores (2100 clock time) → 1 HEP-SPEC06

At the top of availability and reliability ranks

On average (regular machine): 12 cores (2100 clock time) → 1 HEP-SPEC06
Spanish Cloud performance in Run II

More than 22 million finished jobs

On average, 5000 slots occupied by running jobs daily

More than 196 million events processed

More than 46 million files produced
ADC development Activities in ES groups

Summary of R&D activities where Spanish sites are contributing:

• Monitoring
  • Monitoring frontier-servers
  • IFIC Transfer monitoring
  • Site and Cloud support tools
  • ADC Live Page

• Participation in the DOMA-TPC tests and storage system performance studies (for the implementation of the tape carousel) led by ATLAS. All of them are addressing the HL-LHC challenges.

• Event Index Project
  • Provide a catalogue of data of all events in all processing stages needed to meet multiple use cases and search criteria.
  • Billion of events have been indexed so far (PetaBytes)!

• Event Service
  • Main goal: allow a more flexible and efficient usage of CPUs available when running simulation ATLAS jobs

• Physics Case:
  • Selection of events with t tbar resonances (BSM) from the SM events (background) in collisions pp in the ATLAS Experiment using Machine Learning methods and GPUs

The sites are already actively participating in, and even coordinating, emerging R&D computing activities developing the new computing models needed in the LHC Run3 and HL-LHC periods.
Data access studies/storage performance

- How are the **storage systems** utilized in PIC Tier-1 and Tier-2s for ATLAS/CMS? Are we working in the most optimal point?

- ~3% of data blocks are replicated both at PIC_Disk and CIEMAT, not an issue

- Which data is susceptible to be **cached** and what could be the **benefits**? (we can simulate based on real data accesses)

- PIC and CIEMAT are close enough (10ms) - shall we aim for a **data federation** or **consolidation** of storage in the region?
  - **In depth data access and performance studies**, for both PIC and CIEMAT

  Including **CIEMAT Tier-2** and **CERN Tier-0** (collab. with CERN-IT) to draw conclusions at all Tier levels

These studies can be done easily at any site running dCache (since it gets data from the billingDB)
Monitoring frontier-servers

- **Frontier servers** optimize the access to the so-called “Conditions database” (variables of the ATLAS detector), needed to run simulation or production jobs.
  - A **squid server** provides *caching* of data
  - A Tomcat **servlet** connects to the Oracle database when needed

- The monitoring system collects information about the *queries* from ‘log’ files:

- System operates in a steady and stable way processing **12M of queries daily on average in data taking period**

- Allows the visualization of meaningful information by means of **Dashboard. Namely, summary tables and histograms**

- Incorporates Alarm&Alert to send e-mail warning when a site performance deteriorates

- Thanks to its versatility and the close relation between ATLAS and CMS on this project, all CMS servers are monitored as well
Event Index Project

• The EventIndex Project aims to provide a catalogue of real and simulated data of all events in all processing stages needed to meet multiple use cases and search criteria.

• Billion of events have been indexed so far (PetaBytes) since 2015

• Some use cases:
  1. Event picking
  2. Duplicate event checking
  3. Overlap
  4. Trigger checks and event skimming
  5. Trigger Counter
Summary: ML @ T2-ATLAS-IFIC project

- **Physics Case 1:** Selection of events with $t\bar{t}$ resonances (BSM) from the SM events (background) in pp collisions in the ATLAS Experiment using ML methods

21 low-level + 5 high-level

(kinematic variables) (Invariant masses)

- $NN_{MLP}$: Neural Network – Multilayer perceptron
- $NN_{sklearn}$: Neural Network (sklearn)
- $NN_{Shallow}$: Neural Network - Shallow
- R.F.: Random Forest
- $NN_{Keras}$: Neural Network (Keras)
- R.LIN: Linear Regression
- R. LOG: Logistic Regression

AUC vs mass of the signal ($ttbar$ resonance)

- LR: Logistic regression
- ETC: Extra Trees classifiers
- RFC: Random Forest classifiers

<table>
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<th>AUC</th>
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<th>$NN_{MLP}$</th>
<th>$NN_{Shallow}$</th>
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<th>R.F.</th>
<th>R. LIN</th>
<th>R. LOG</th>
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Summary: ML @ T2-ATLAS-IFIC project

- **Physics Case 2:** Searching for DM in the ATLAS experiment by applying ML methods to detect Outliers
  - just starting

ARTEMISA (ARTificial Environment for ML and Innovation in Scientific Advanced computing) facility based on GPUs:

- Hardware: Worker nodes composed of several Intel Xeon Platinum CPUs and Tesla Volta GPUs
- Project “Application of ML methods for studies on New Physics in ATLAS”
  - Use Case: ttbar resonances
- It will be used to find the optimal configuration of each ML algorithm (more computing intensive calculations)
- Code implemented in Python has been tested and first results obtained with this facility in batch mode
- Studies of performance gain will be carried out
- Simplistic MC data to be replaced with ATLAS real and simulated data
Challenges for Run3 and High Luminosity (HL-LHC)

Higher luminosity is equivalent to higher data flow.

So there is an increase of one order of magnitude on the horizon!

Challenges on storage, network bandwidth and processing power.

CPU, disk storage and bandwidth requirements prediction:

- HL-LHC CPU estimations showed a ~3x shortfall with respect to the flat budget model
- ~6x shortfall by today’s estimate in Storage on Disk. Storage shortfall is our biggest problem
- HL-LHC will require to increase the network bandwidth by a factor 10
Approaches to solve CPU shortfall

There are a few options to face this challenge: HPC’s, cloud computing and High Level Trigger Farm.

Further options: use fast simulation instead of full one. And speed up the MC generators by a factor two.

Running on GPU’s is also feasible, but needs significantly time and effort to adapt our software to new architecture.

Approaches to solve Storage shortfall

- Increase investment in computing
- New file formats (to reduce filesize, many data formats for physics analysis)
- “Less data”
- Use of tapes. But this option slows down the workflow
- Data Lakes / DOMA

No opportunistic storage...so far
Integration of HPC resources [ATLAS]

- Tests on the MareNostrum HPC integration in the ATLAS production system started in April 2018 in joint collaboration between IFIC and PIC centers.
- Since then, we have received hours to exploit Spanish HPC’s (RES and PRACE):
In 2019, both centers were granted 4 million hours in the MareNostrum 4 HPC

- Two types of payload submission:
  - 1 job = 1 full node (48 cores)
  - 1 job = 50 nodes using MPI/Yoda (2400 cores)

- Data async. transferred to PIC and registered into ATLAS Rucio system
- Tested transfer mode using `globus-url-copy` with ssh as authentication (no certificates) which is standard for HPC sites
Integration of HPC resources [ATLAS]

- **Opportunistic resources** turn out to be a meaningful way to face the future HL-LHC challenges in terms of CPU requirements.
- High Performance Centers (HPC’s) have been tested recently. **Further work is required to use these resources** since they aren’t available from the ATLAS GRID.

- IFIC/IFAE-PIC led ATLAS simulation when profiting of opportunistic HPC resources
- More than 60 millions of events simulated
- More than 90% of jobs ended successfully
Increasing bandwidth

- Barcelona, Madrid and Valencia have their own dedicated connection.
- Current network bandwidth is around 20 Gbits/s → up to 100 Gbits/s expected next year thanks to REDIRIS (Spanish Academic network provider) → RedIRIS-Nova at 100 Gbps
  - PIC/Tier1 would increase it WAN connectivity to 100 Gbps by mid-2020
- All this makes Spanish cloud one of the most efficient and powerful over all ATLAS grid sites for the RUN3 and HL-LHC.
Toward a regional federation (Tier1-Tier2)

While ago CMS enabled overflow of analysis jobs from PIC (Barcelona) to CIEMAT (Madrid) and vice versa, and we deployed a regional XRootD re-director in HA (High Availability)

Since May 2019, we are flocking CMS pilot jobs from PIC to CIEMAT and vice versa, since we have HTCondor BS in both sites → 80 cpu-cores available at each site [dedicated machines, for the moment - 10 ms latency]

From 2019-06-07 to 2019-07-07

Regional input file reads are preserved, since we have regional XRootD re-director deployed - hence we can study job degradations when running remotely

How does latency affect the CMS workloads? This is important to understand the effects of federating the resources at a national level

5.6 % of PIC jobs executed in CIEMAT

2.8 % of CIEMAT jobs executed in PIC
Conclusions

• The Spanish Cloud (ES) contributes around 5% of the total resources deployed in Tier-1 and 2 sites.
• Spanish Tier-2 has the so-called “nucleus” status in ATLAS. Major responsibilities and larger work volume!
• Not only deployment of CPU and storage resources for the ATLAS experiment but also several researching activities are carried out by the teams in the ES Cloud.
• Run-3 and HL-LHC defy the current ATLAS computing model. CPU resources, disk storage and bandwidth shortfalls have to be assessed and faced asap.
  • Usage of opportunistic resources (HPC)
  • Data format, data processing and storage..
  • Bandwidth requirements seem to be satisfied in time
Thanks for your attention!

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Jose Del Peso (UAM)
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Almudena del Rocio Montiel (UAM)
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Javier Sánchez Martínez (IFIC)
José Salt (IFIC)
Aresh Vedaee (IFAE,PIC)
BACKUPs
ATLAS event recording performance

94% of the luminosity delivered by LHC is collected!!

Event Rate in Run I (HLT readout): 300 Hz
Event Rate in Run II (HLT readout): 1.2 kHz
Expected Event Rate in Run III (HLT readout): 5-10 kHz
ATLAS GRID performance

- **300k slots**
- **8.5 M years**
- **200 PB of storage**
HPC Usage 2019

**PIC:**

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<th>MareNostrum</th>
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<th>Used (kHours)</th>
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Around 2.75 Mhours with 1.2 Mhours granted to IFIC gives 4 millions hours granted in MareNostrum4 this year.

**IFIC:** this year 1.2 Mhours in **MareNostrum**, and 2 Mhours in **Lusitania** both of them already consumed

**UAM:** **Cibeles** in Madrid, opportunistic

**LIP:** **BOB** (Minho), planned, opportunistic
Idea is to localize bulk data in a cloud service (Tier 1’s ➔ data lake): minimize replication, assure availability

Serve data to remote (or local) compute – grid, cloud, HPC, ???

Simple caching is all that is needed at compute site (or none, if fast network)

Federate data at national, regional, global scales
Spanish HPCs for ATLAS-IFIC-Valencia

Céntis Lusitania

Located in Extremadura-SPAIN

40 servers Fujitsu Primergy CX2550 with 2 processors Intel Xeon E5-2660v3, of 10 cores each, working at 2,6GHz

• Got CPU 2000kh to be used from march 1<sup>st</sup> to june 30<sup>th</sup> 2019, 95% efficiency to use them
• 50 million event simulated
• 55k jobs ended successfully (90% of the total)

Mare Nostrum 4 - 11.15 Pflops

3,456 servers each with two Intel Xeon Platinum chips, with 24 processors each

• Got CPU 1200kh to be used from july 1<sup>st</sup> to october 31<sup>st</sup> 2019, 100% efficiency to use them
• 11.76 million event simulated
• 12k jobs ended successfully

Impact of the start of MN4 (green) in the Spanish cloud: from 7k to 12k slots
Amazon - cloud bursting tests

We tested **AWS** for a week (June 2019), doubling PIC compute power

- Integration of a cloud environment with the local batch system - sporadic increase of resources
- Special interest in a spot instance based scenario

Data center in Frankfurt (~40 ms) - used Condor_Annex

Set up HTCondor Connection Brokering (CCB)

- **Bridge** server to connect the local system to the outside nodes

HTCondor-CE routing modified so only **ATLAS** and **CMS** send jobs to AWS

Custom **WN image** deployed in AWS servers, + CVMFS, + access to Squids

**Good option** to increase computing resources sporadically

**Flexible and easy** to deploy through HTCondor

**Not very good for data intensive** jobs
Towards a regional federation [CMS]

This tells us that within the region, PIC could run jobs either at PIC or CIEMAT (reading files from PIC), except merge (which should run locally always)!

At higher latencies (40 ms), analysis starts to be degraded.

This of course would cause an increase of PIC exports (stressing both for network and storage system... how much?)
IFIC transfers monitoring

By means of ELK stack, we can filter, store, analyze and display huge amount of information of the transfers made from and to our Tier-2 center.
Event Service

• Main goal: a more flexible and efficient usage of the CPU available when running simulation ATLAS jobs. Improving performance in HPC’s
  1. Splitting event bunch in GRID jobs: from 1000 to 1!!!
  2. In tier-3 facilities, when no user analysis are running, ES uses this CPU

Efficiently and flexibly exploit any CPUs available
  • Efficient use of opportunistic and volatile resources
    Dynamically making use of available CPUs as they appear

When CPU is not used by local users, EventService can use it
See other example by Rod

ES jobs killed, restarted, re-killed, etc...