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

Santiago González de la Hoz

IFIC – Valencia (Spain)

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

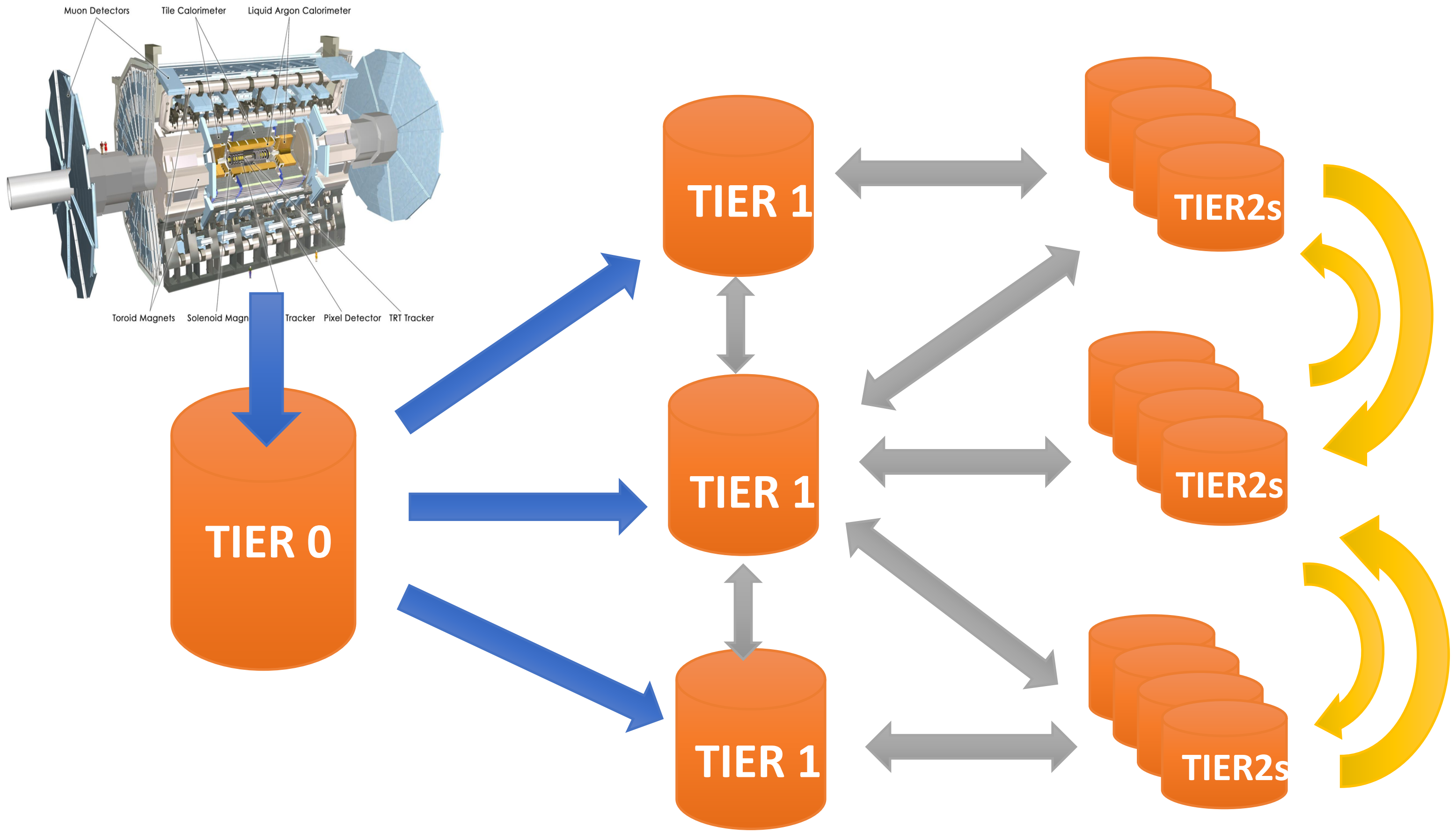
24th CHEP conference, 4-8 November 2019. Adelaide, Australia

PIC port d'informació científica · IFAE Institut de Física d'Altes Energies · IFIC Institut de Física Corpuscular · Excelencia Severo Ochoa · CSIC Consejo Superior de Investigaciones Científicas · Vniversitat de València · Universidad Autónoma de Madrid

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)

Spanish Cloud Facilities

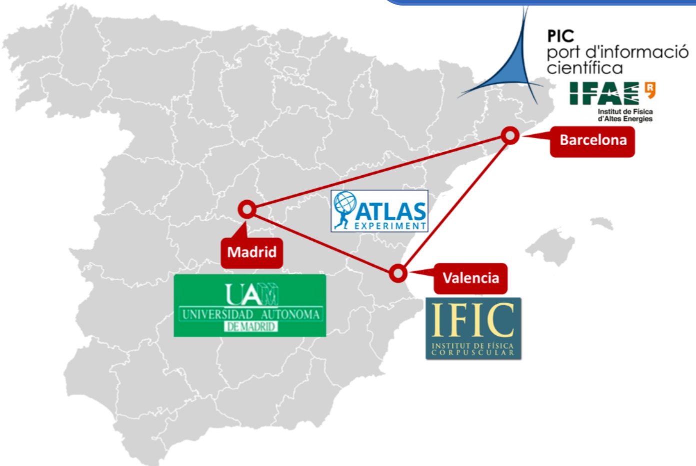
(October 2019)

At the top of availability and reliability ranks

Site	CPU (HEP-SPEC06)	DISK (TB)	TAPES (PB)	Availability (2018)	Reliability (2018)
PIC-Tier1	42300	3500	8.8	98.76%	99.60%
IFIC-Valencia	26751	2600		97.93%	98.33%
IFAE-Barcelona	10420	980		99.22%	99.59%
UAM-Madrid	10358	1220		99.05%	99.66%
NCG-Lisbon	4000	220		91.00%	92.42%

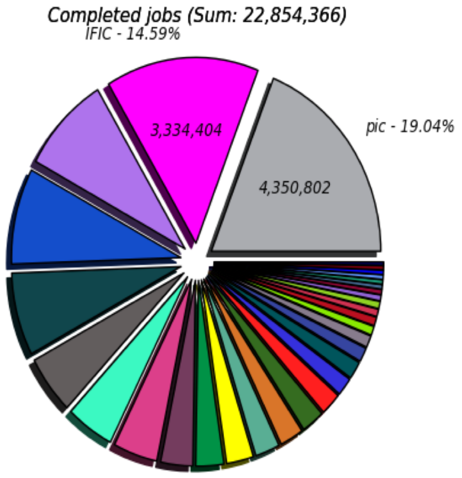
PIC New tape library (IBM TS4500)

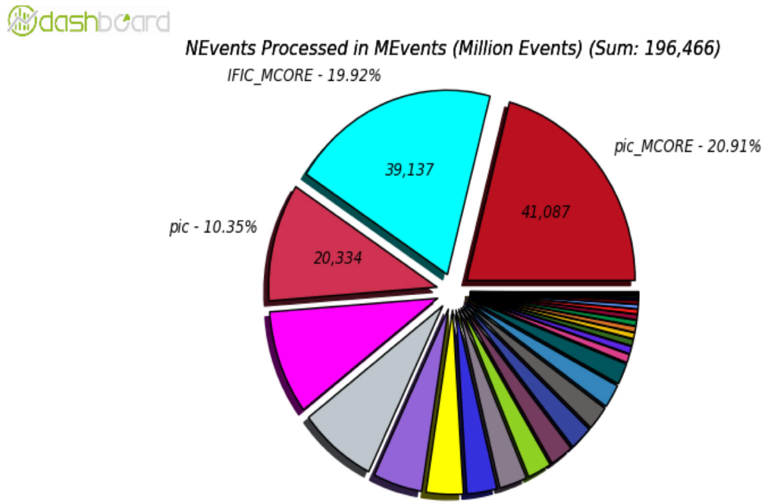
On average (regular machine): 12 cores (2100 clock time) → 1 HEP-SPEC06



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

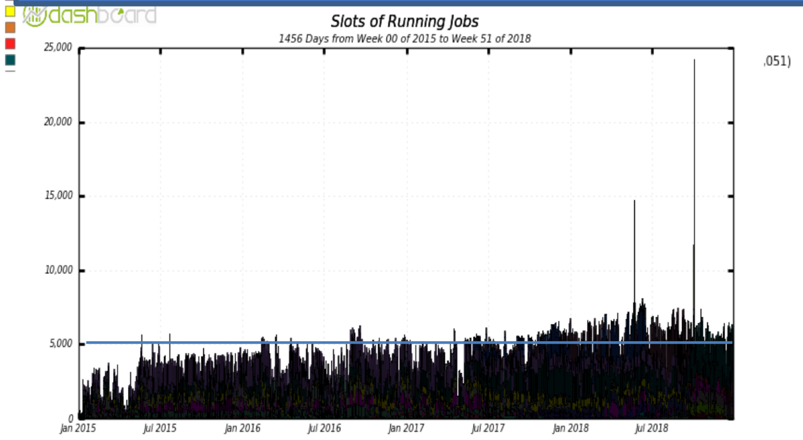
Spanish Cloud performance in Run II

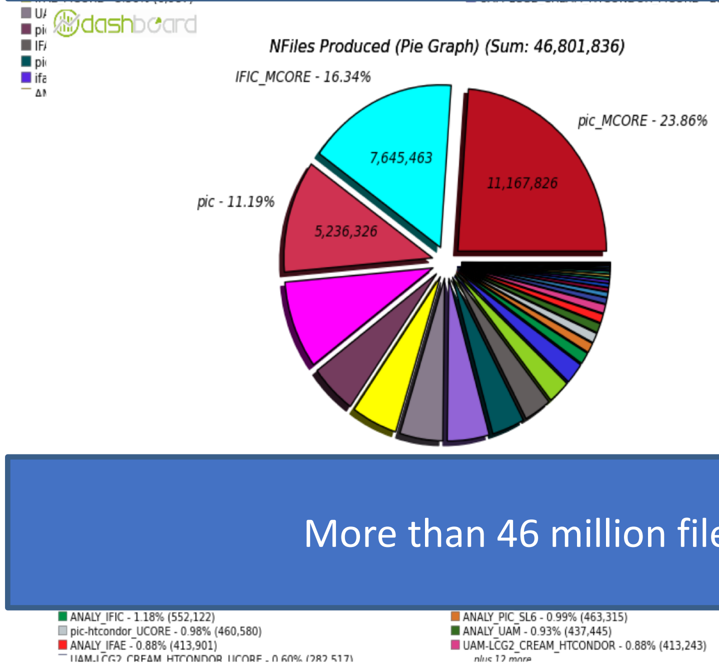




More than 22 million finished jobs

More than 196 million events proccessed





On average, 5000 slots occupied by running jobs daily

More than 46 million files produced

ADC development Activities in ES groups

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

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.

- **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.

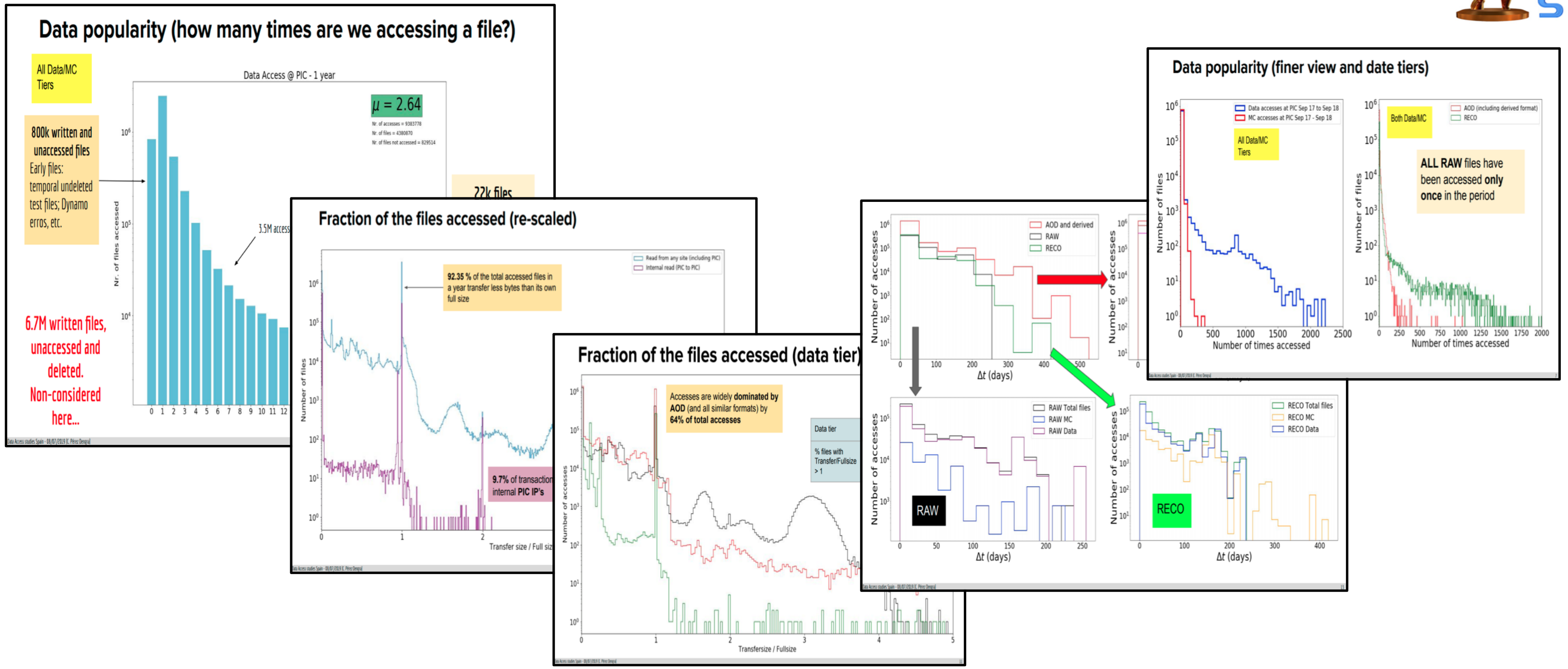
- **Event Index Project**
  - provide a **catalogue of data of all events in all processing stages** needed to meet multiple use cases and search criteria.
  - Billion of events have been indexed so far (PetaBytes)!

- **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**

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

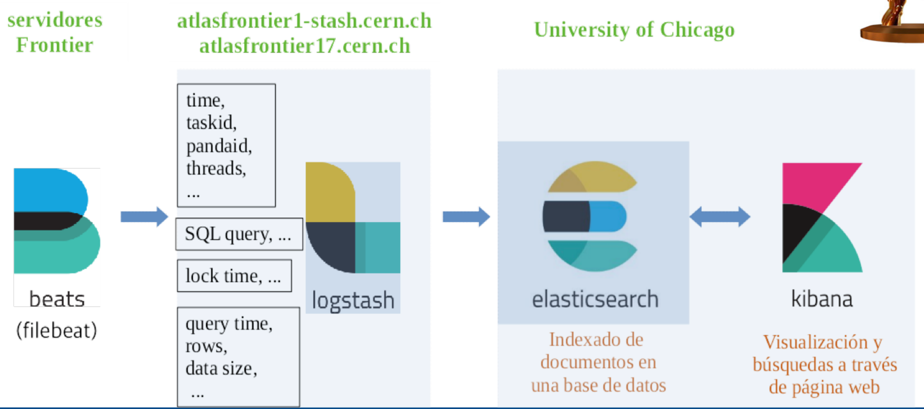


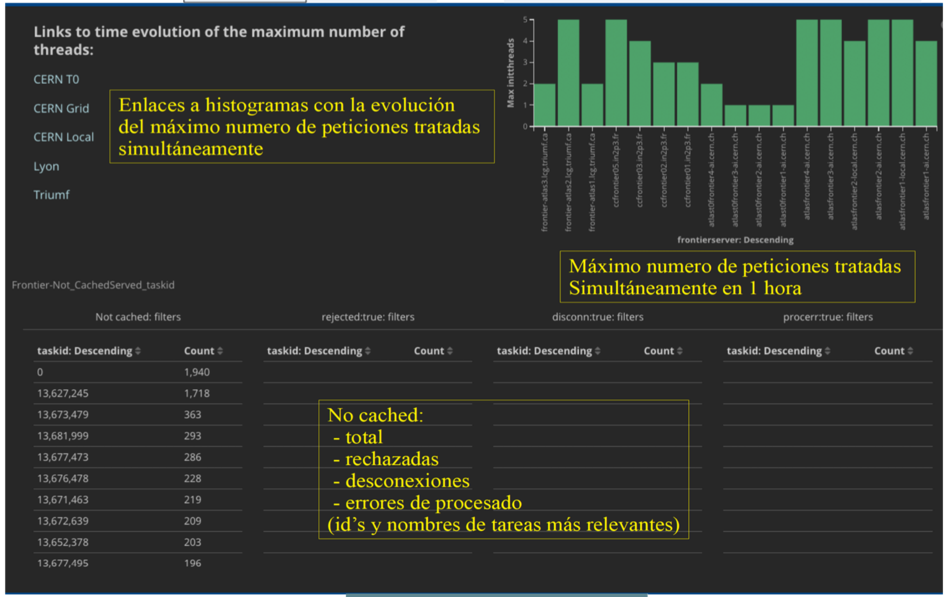
Including **CIEMAT Tier-2** and **CERN Tier-0** (collab. with CERN-IT) to draw conclusions at all Tier levels

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



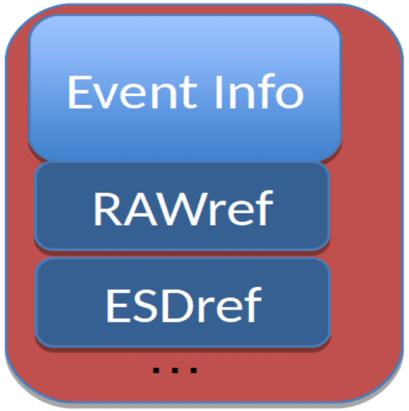


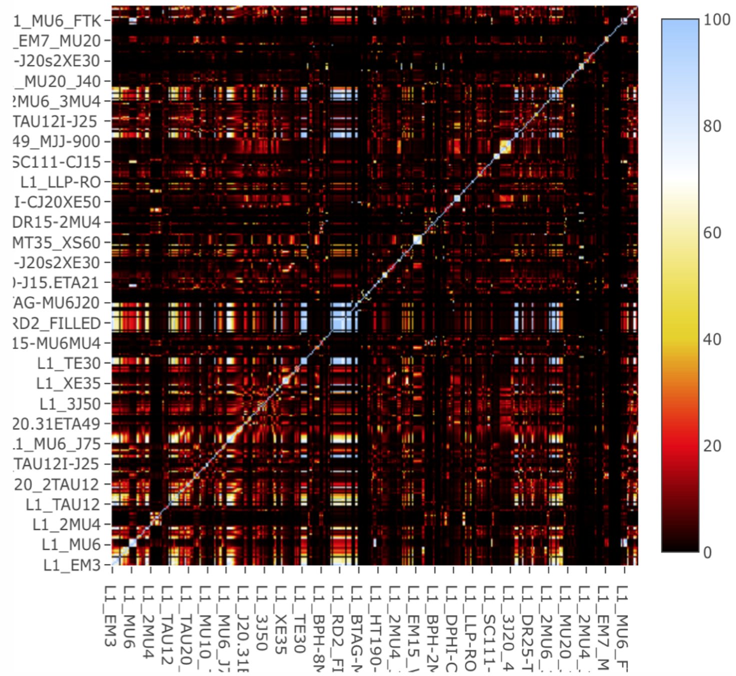
Event Index Project

- 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**

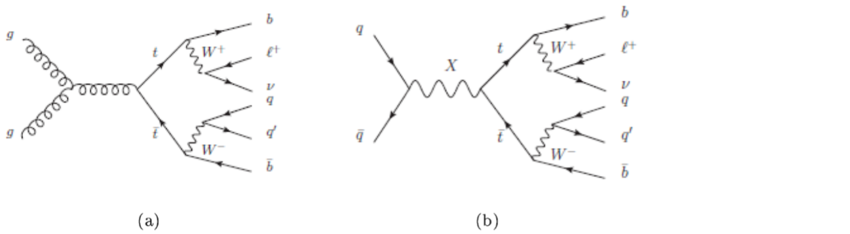




Summary: ML @ T2-ATLAS-IFIC project

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

21 low-level (kinematic variables) + 5 high-level (Invariant masses)



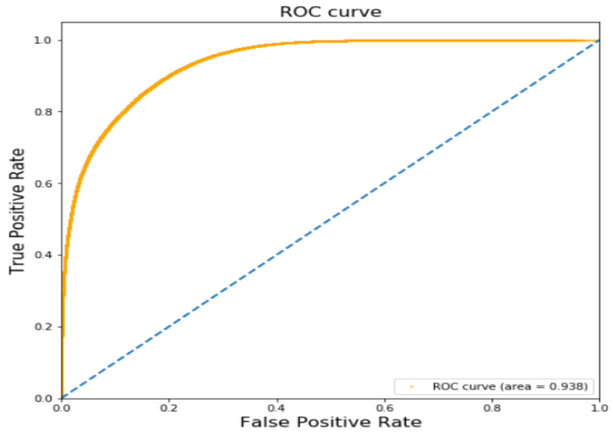
a) Diagrama de Feynman del modelo SM (Fondo). b) Diagrama de Feynman del modelo BSM (Señal).

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. Logisitic Regression

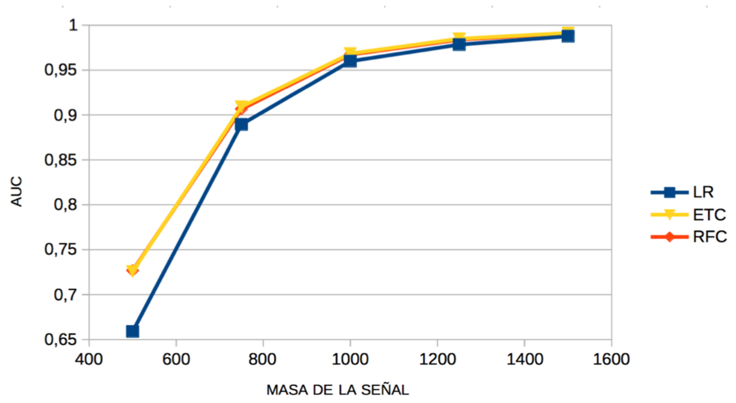
ML methods applied

26 variables related with the process



AUC vs mass of the signal (ttbar resonance)

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



AUC curves generated

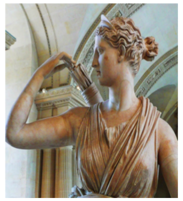
AUC

Dataset	NN_MLP	NN_Shallow	NN_keras	NN-sklearn	R.F.	R. LIN	R. LOG
500000	0.931	0.924	---	0.935	0.934	0.909	0.909
730000	0.938	0.937	0.939	-----	-----	0.910	0.910

Summary: ML @ T2-ATLAS-IFIC project

- **<u>Physics Case</u> 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:



The design and deployment of novel analysis facilities using 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

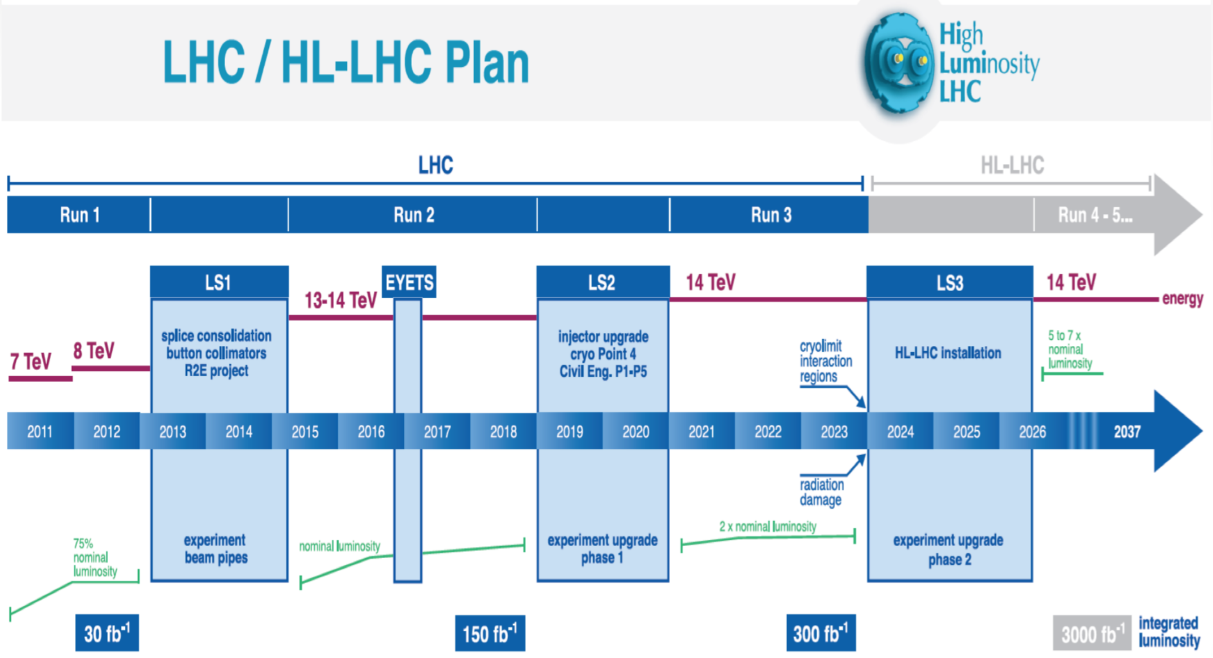
✓It will be used to find the optimal configuration of each ML algorithm (more computing intensive calculations)

✓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)



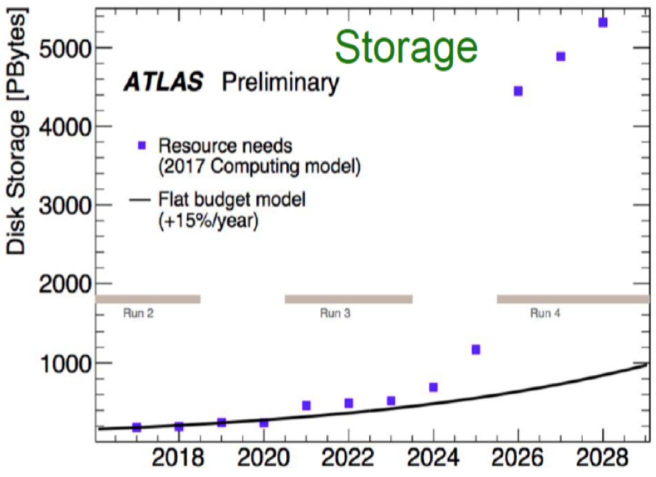
CPU, disk storage and bandwidth requirements prediction:

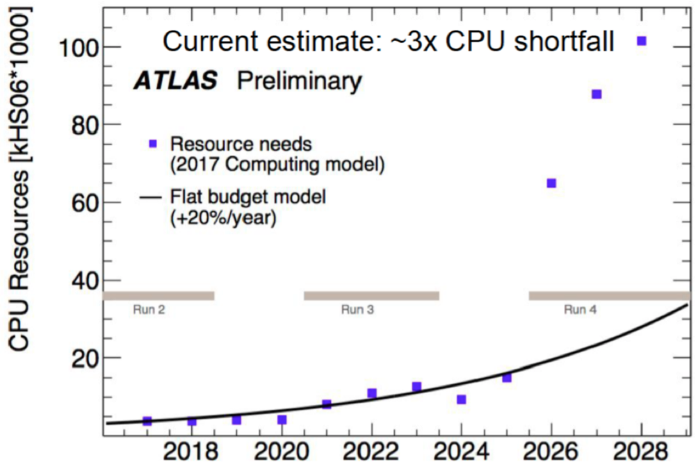
- HL-LHC CPU estimations showed a ~3x shortfall with respect to the flat budget model
- ~6x shortfall by today's estimate in Storage on Disk. Storage shortfall is our biggest problem
- HL-LHC will require to increase the network bandwidth by a factor 10

Higher luminosity is equivalent to higher data flow.

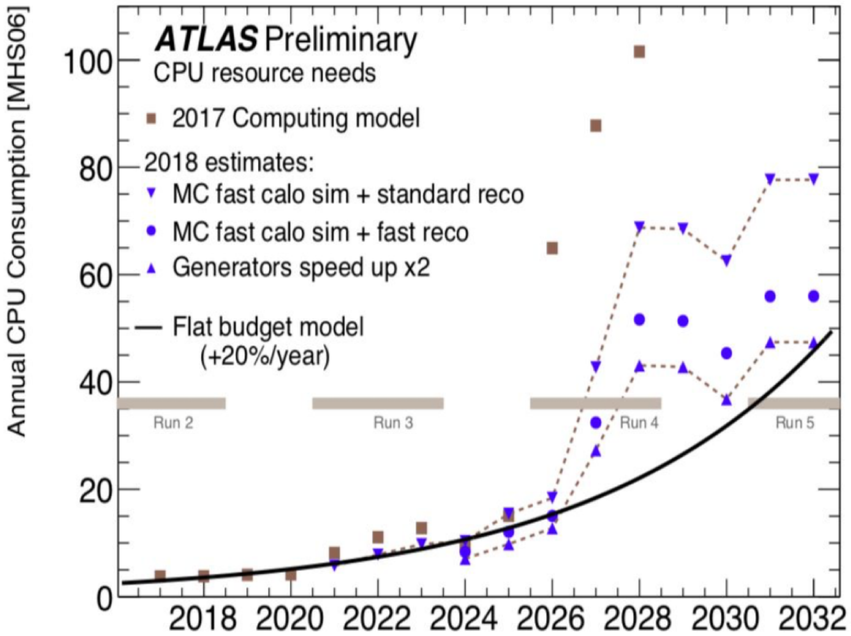
So there is an increase of one order of magnitude on the horizon!

Challenges on storage, network bandwidth and processing power.



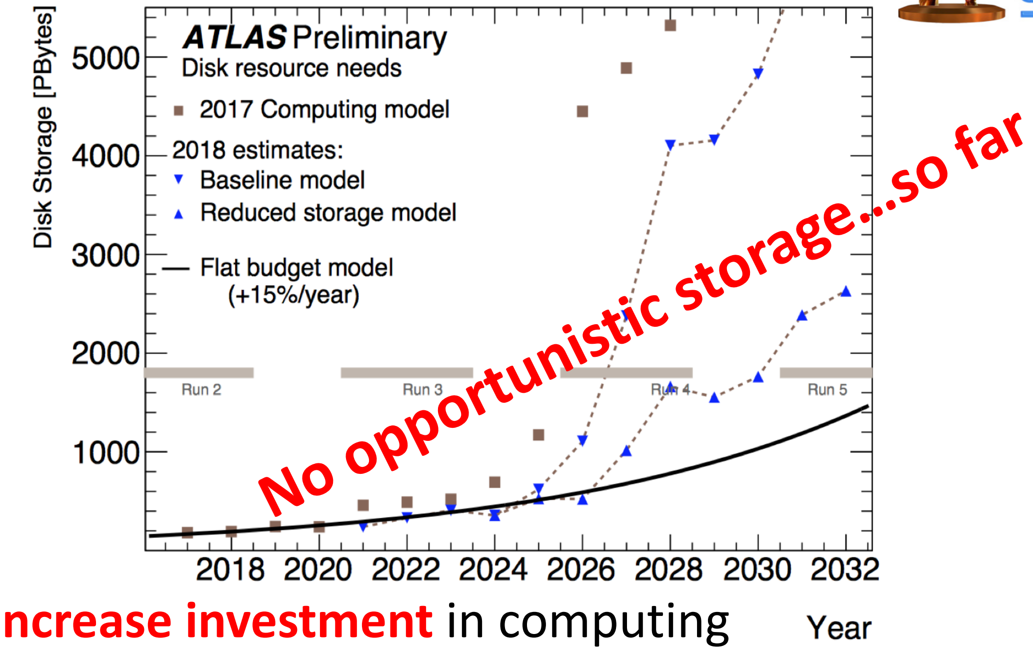


Approaches to solve CPU shortfall



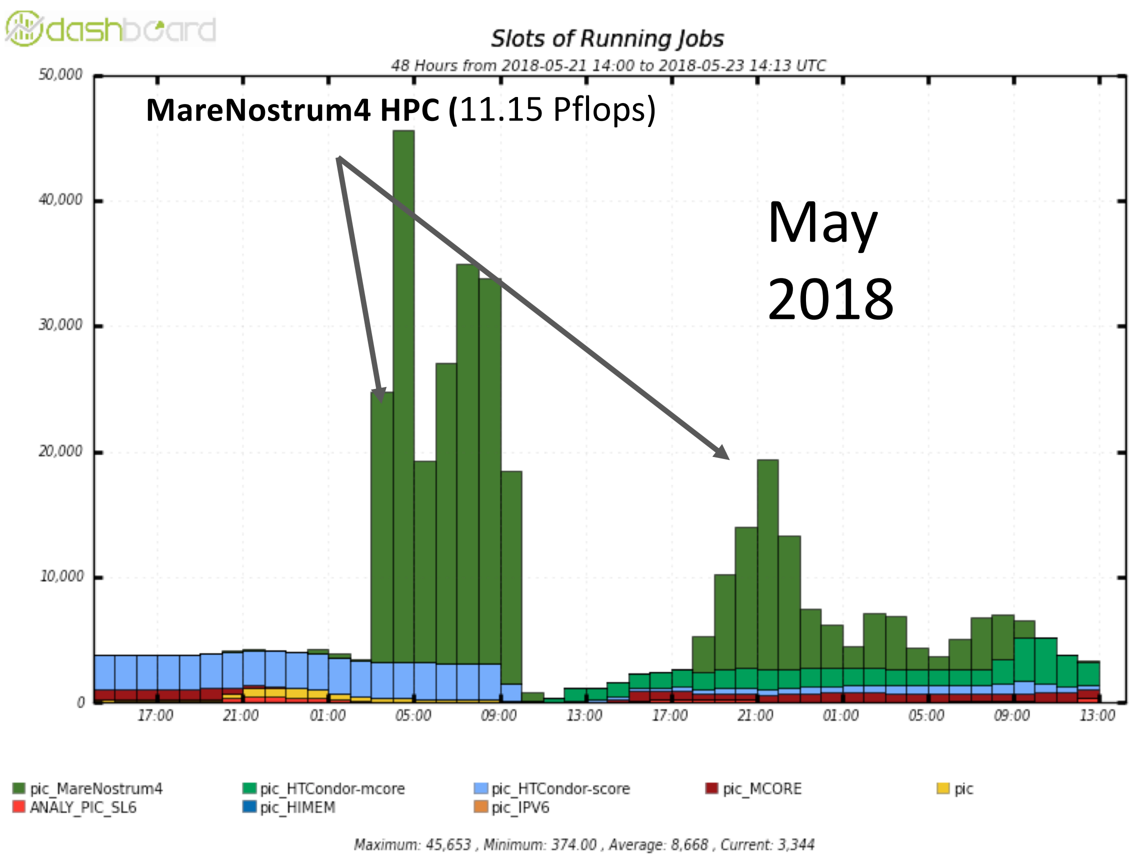
- There are a few options to face this challenge: **HPC's, cloud computing and High Level Trigger Farm.**
- Further options: use **fast simulation** instead of full one. And **speed up the MC generators** by a factor two.
- **Running on GPU's** is also feasible, but needs significantly time and effort 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**

Integration of HPC resources [ATLAS]



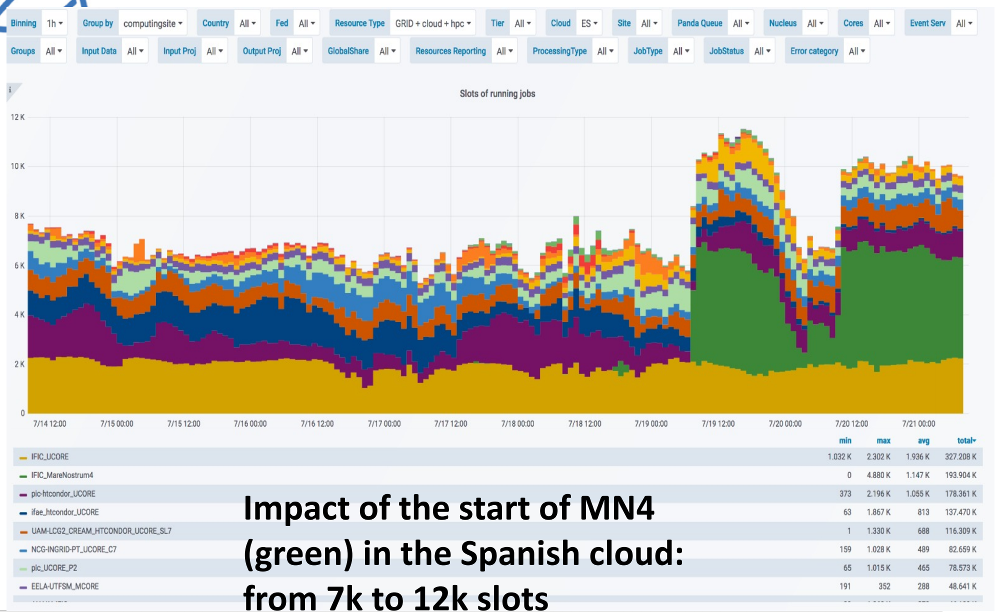
- Tests on the **MareNostrum HPC** integration in the ATLAS production system **started in April 2018** in joint collaboration between IFIC and PIC centers.
- Since then, we have received hours to exploit Spanish HPC's (**RES** and **PRACE**):
In 2019, both centers were granted **4 million hours in the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

- Two types of payload submission:

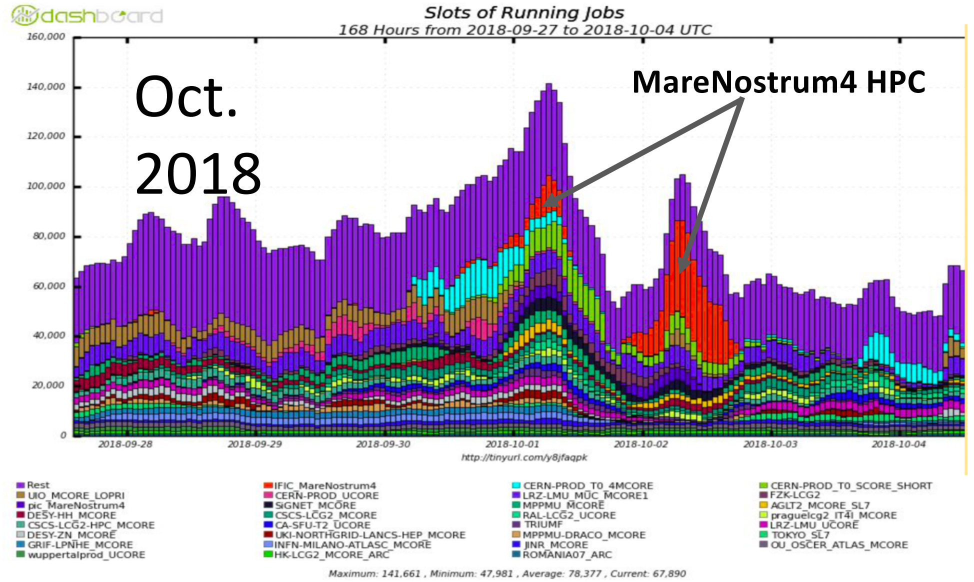
  - 1 job = 1 full node (48 cores)
  - 1 job = 50 nodes using MPI/Yoda (2400 cores)

- 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]



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

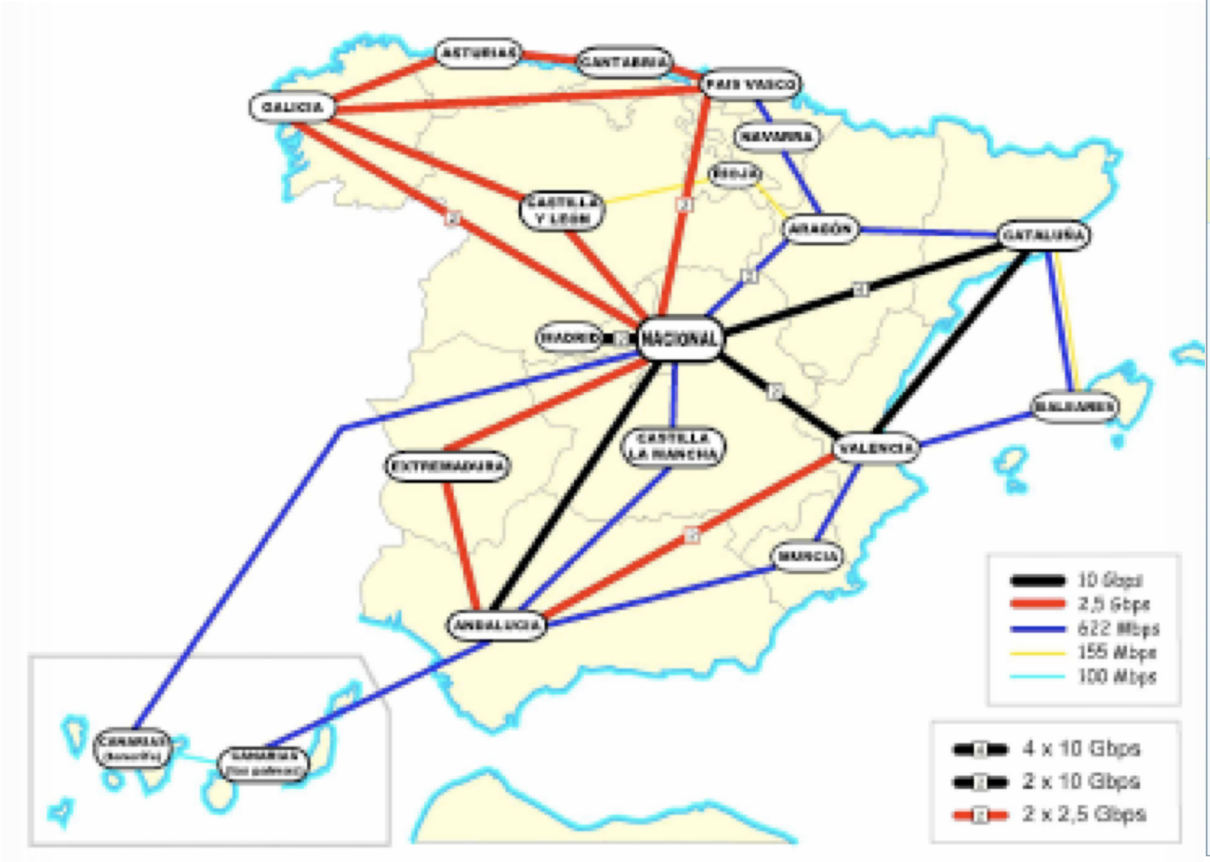


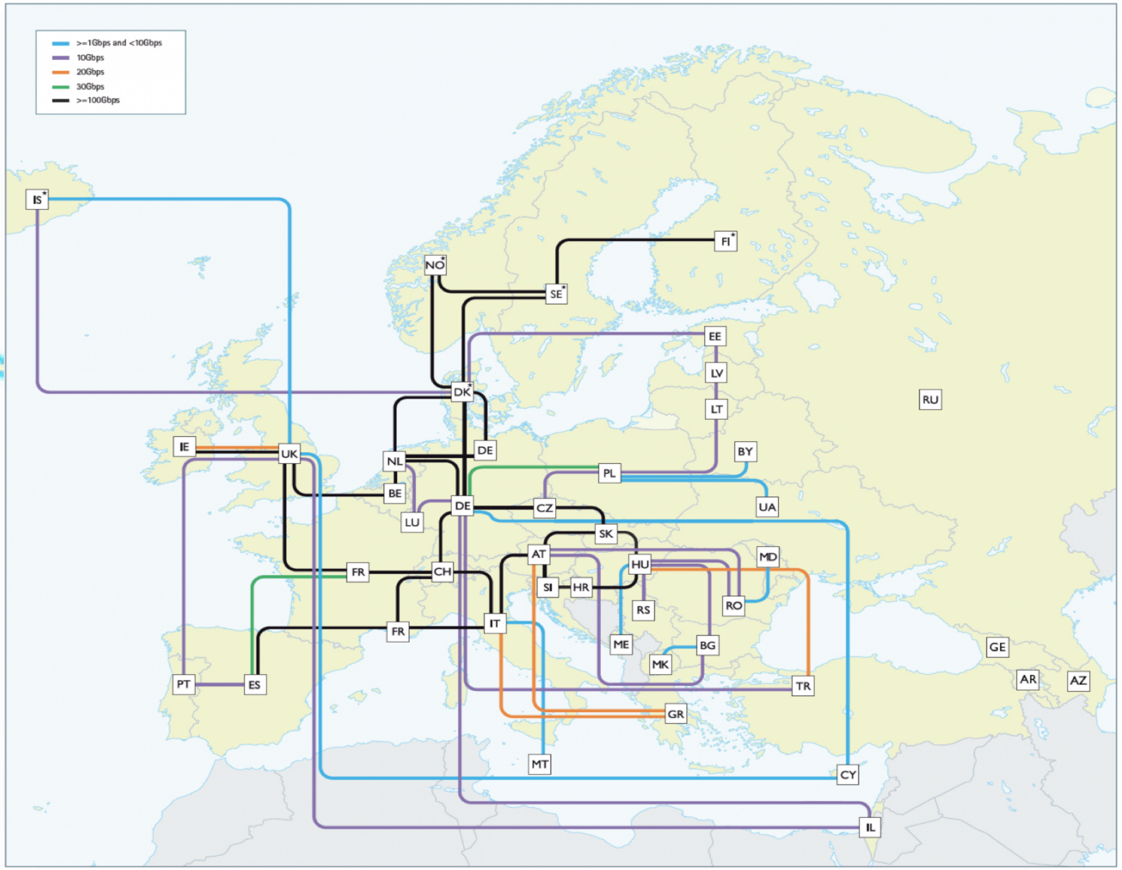
- - **Opportunistic resources** turn out to be a meaningful way to face the future HL-LHC challenges in terms of CPU requirements
- - High Performance Centers (**HPC's**) have been tested recently. **Further work is required to use these resources** since they aren't available from the ATLAS GRID.

- **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)

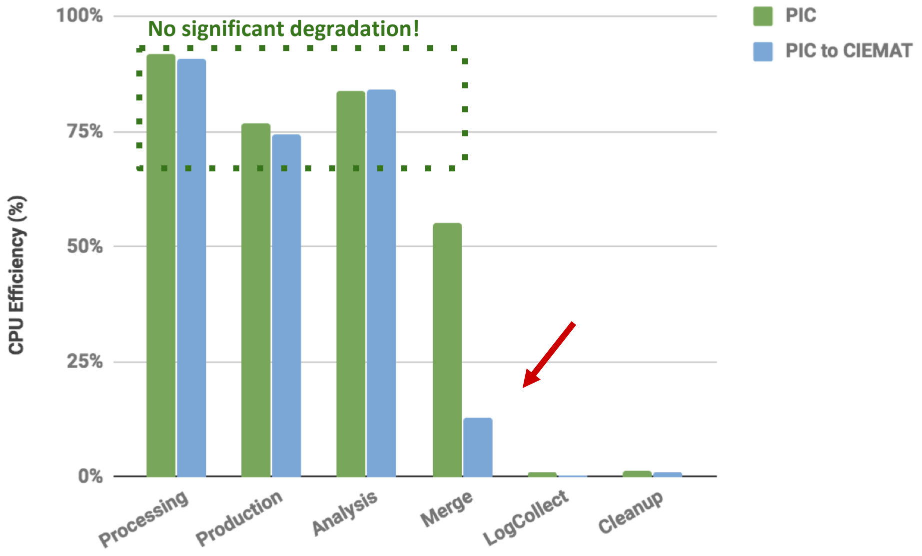
While ago CMS enabled **overflow** of analysis jobs from PIC (Barcelona) to CIEMAT (Madrid) and vice versa, and we **deployed a regional XRootD re-director** in HA (High Availability)

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

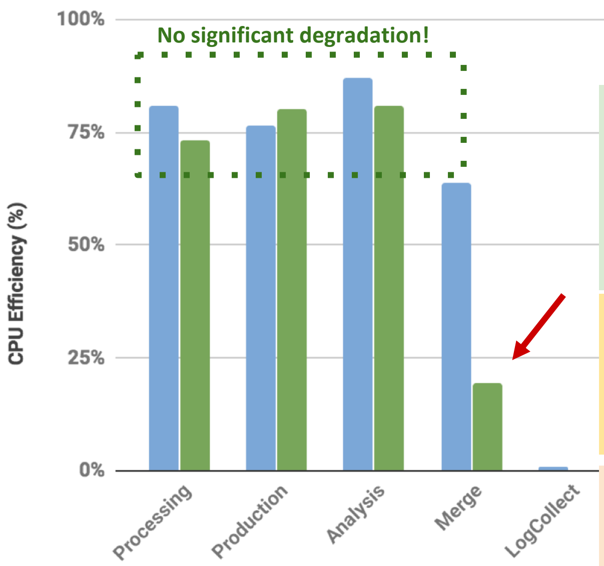
Regional input file reads are preserved, since we have regional XRootD re-director deployed - hence we can study job degradations when running remotely

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

InputFiles Onsite



2.8 % of CIEMAT jobs executed in PIC

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)!

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

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

Conclusions

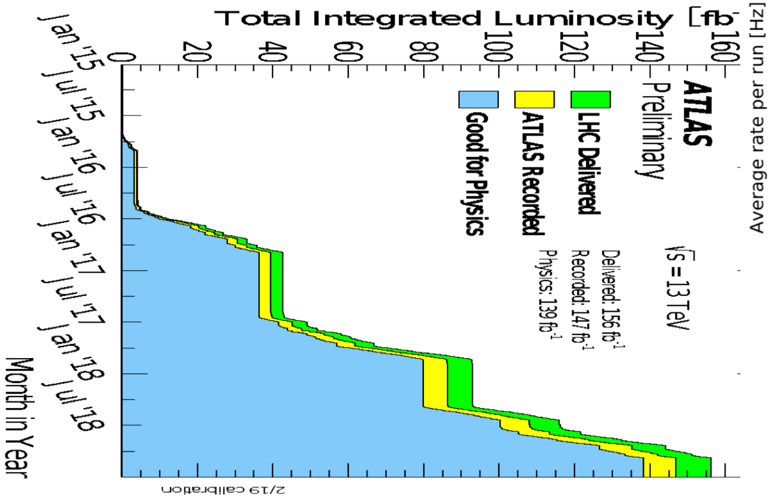
- The Spanish Cloud (ES) contributes around 5% of the total resources deployed in Tier-1 and 2 sites.
- Spanish Tier-2 has the so-called “nucleus” status in ATLAS. Major responsibilities and larger work volume!
- Not only deployment of CPU and storage resources for the ATLAS experiment but also several 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

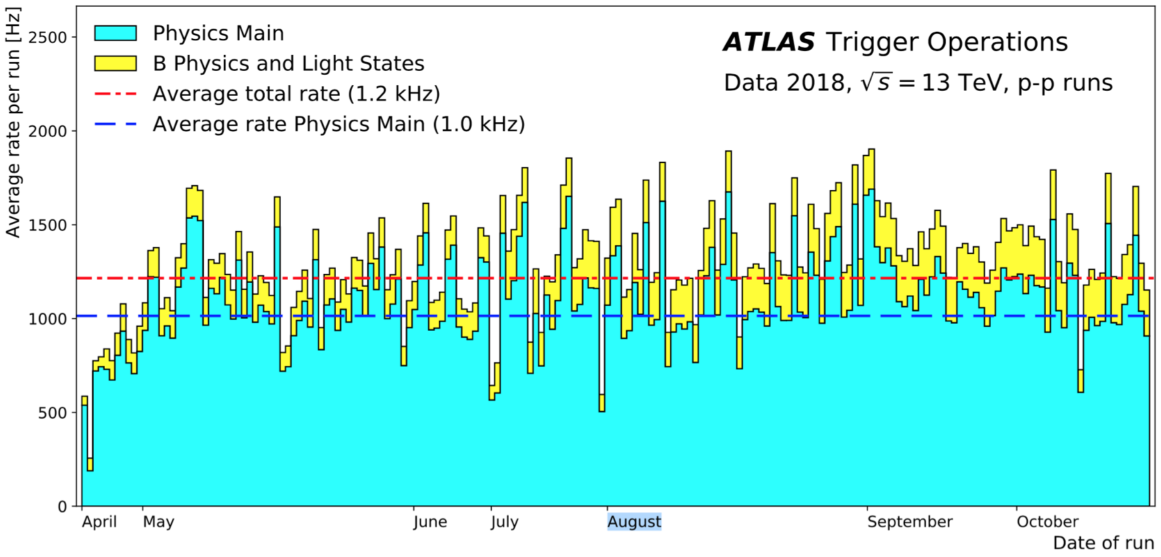
Thanks for your attention!

Santiago González de la Hoz (IFIC)
Carlos Acosta-Silva (IFAE,PIC)
Javier Aparisi Pozo (IFIC)
Jose Del Peso (UAM)
Álvaro Fernández Casani (IFIC)
José Flix Molina (PIC,CIEMAT)
Esteban Fullana Torregrosa (IFIC)
Carlos García Montoro (IFIC)
Julio Lozano Bahilo (IFIC)
Gonzalo Merino (CIEMAT,PIC)
Almudena del Rocio Montiel (UAM)
Andreu Pacheco Pages (IFAE,PIC)
Javier Sánchez Martínez (IFIC)
José Salt (IFIC)
Aresh Vedaee (IFAE,PIC)

BACKUPs

ATLAS event recording performance





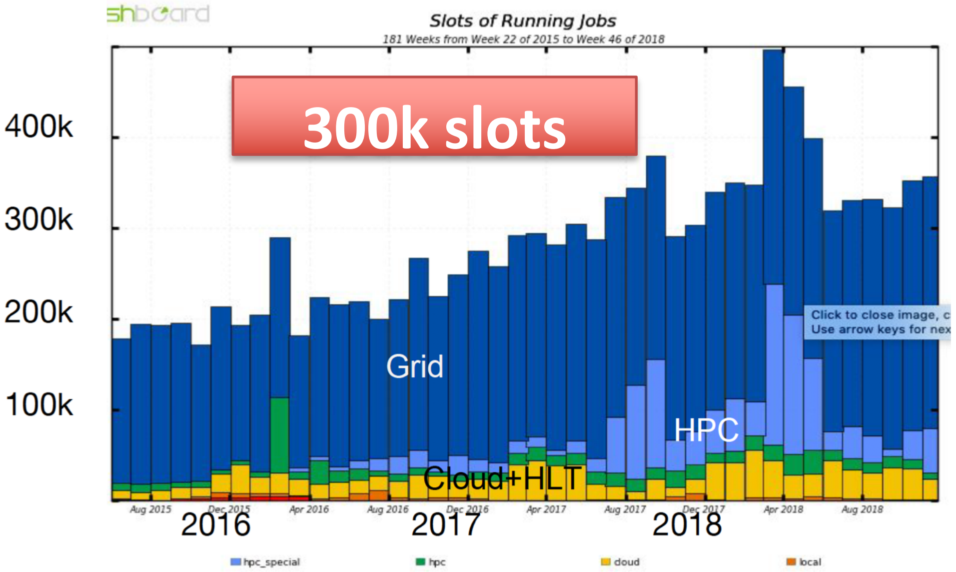
94% of the luminosity delivered by LHC is collected!!

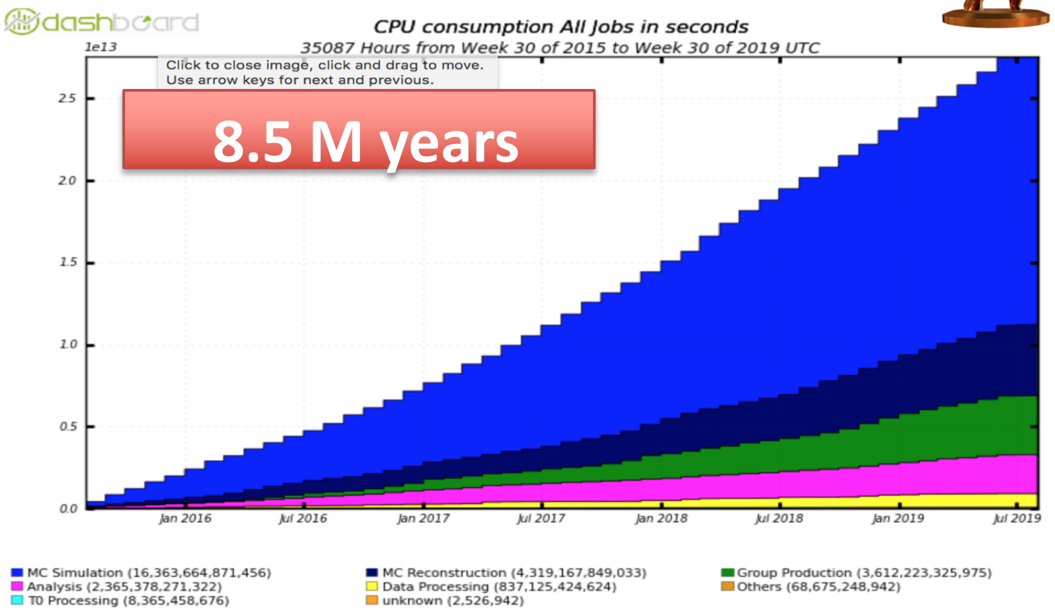
Event Rate in Run I (HLT readout): 300 Hz

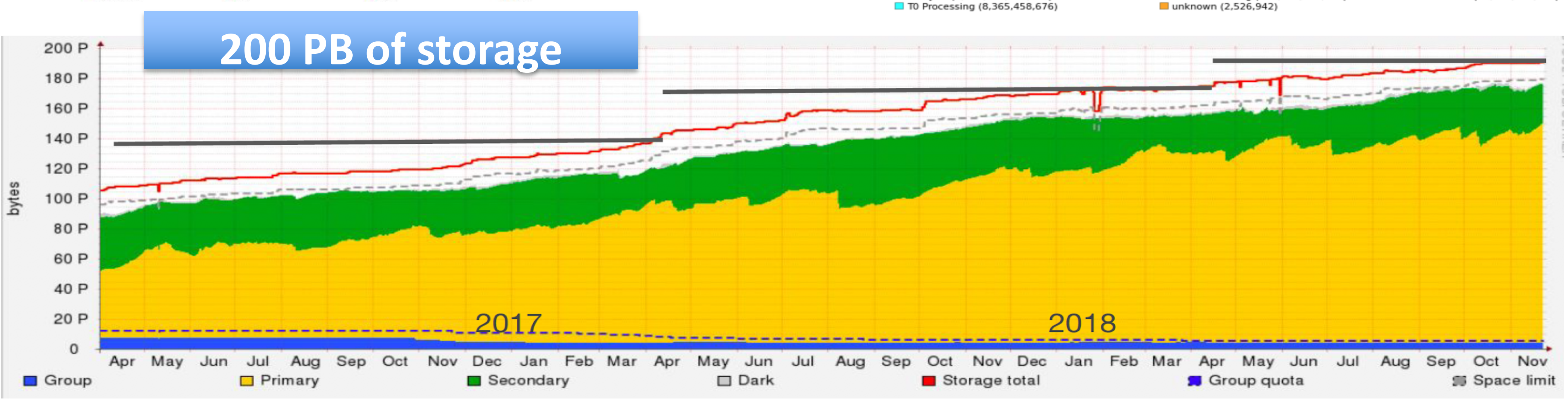
Event Rate in Run II (HLT readout): 1.2 kHz

Expected Event Rate in Run III (HLT readout): 5-10 kHz

ATLAS GRID performance







HPC Usage 2019

PIC:

MareNostrum	Scheduled (kHours)	Used (kHours)	%	
RES FI-2019-1-0035	700	822.08	117	completed
RES FI-2019-2-0030	2000	703.55	35	grant valid until end of October
PRACE 2010PA5027	50	54.18	108	completed

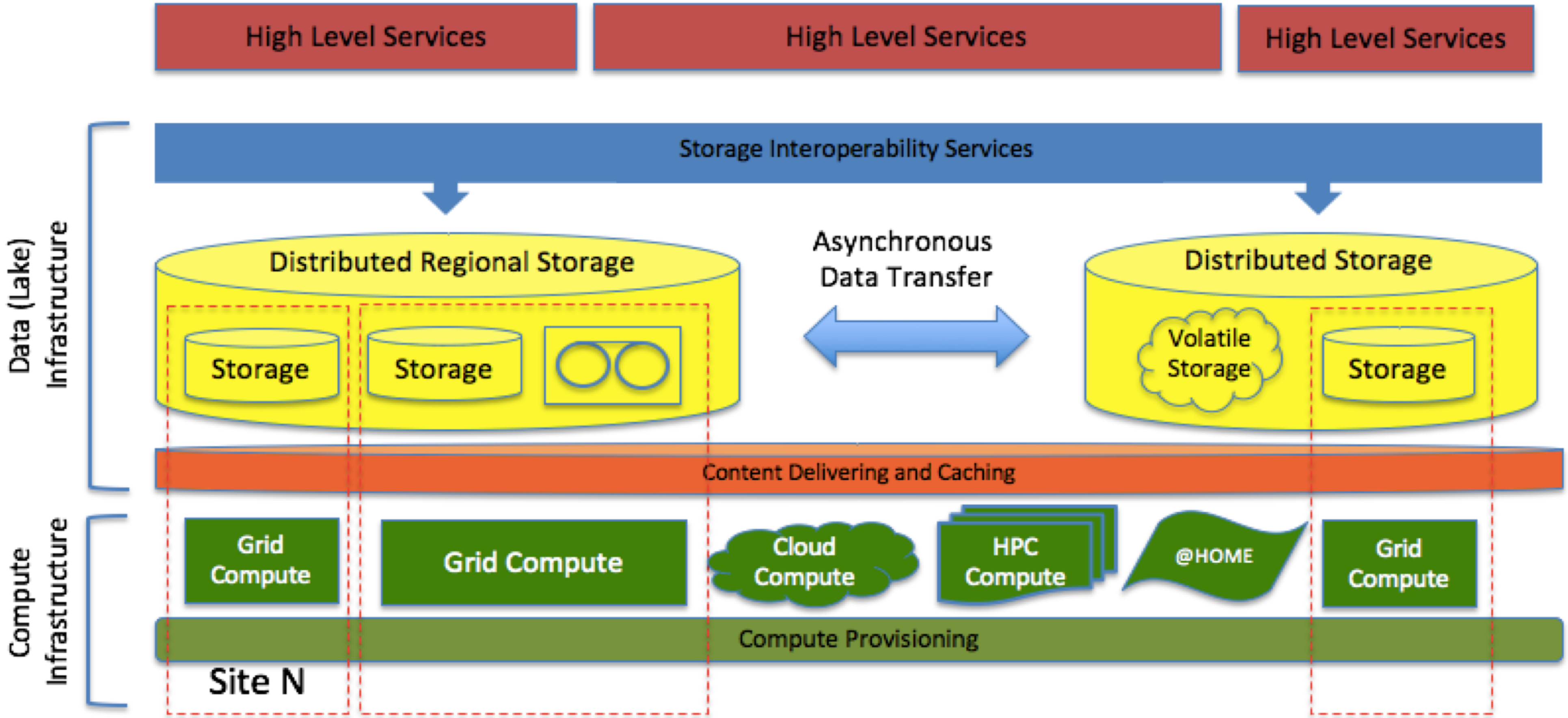
Around 2.75 Mhours with 1.2 Mhours granted to IFIC gives 4 millions hours granted in MareNostrum4 this year.

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

Data delivery "data lake (cloud)"



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

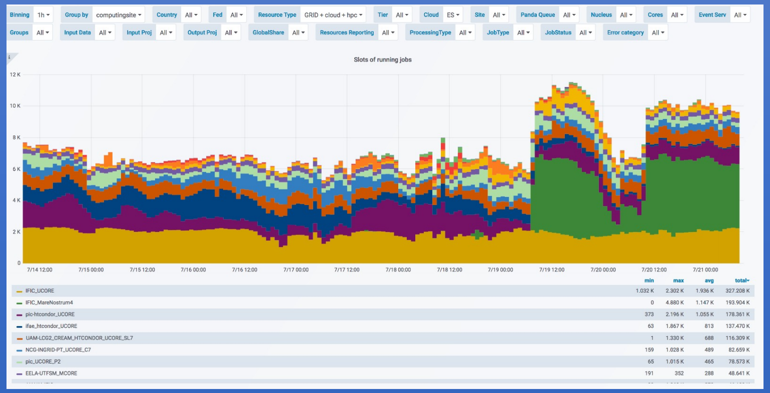
Located in Extremadura-SPAIN

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 1st to june 30th 2019, 95% efficiency to use them
- 50 million event simulated
- 55k jobs ended successfully (90% of the total)

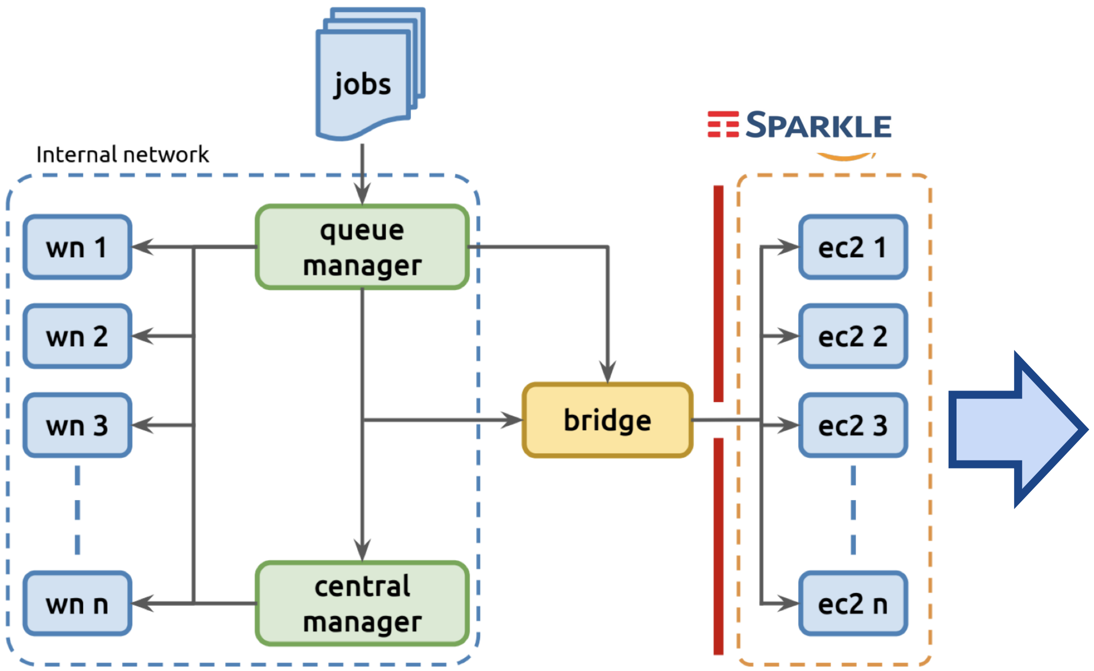
Mare Nostrum 4 - 11.15 Pflops
3,456 servers each with two **Intel Xeon Platinum** chips, with 24 processors each

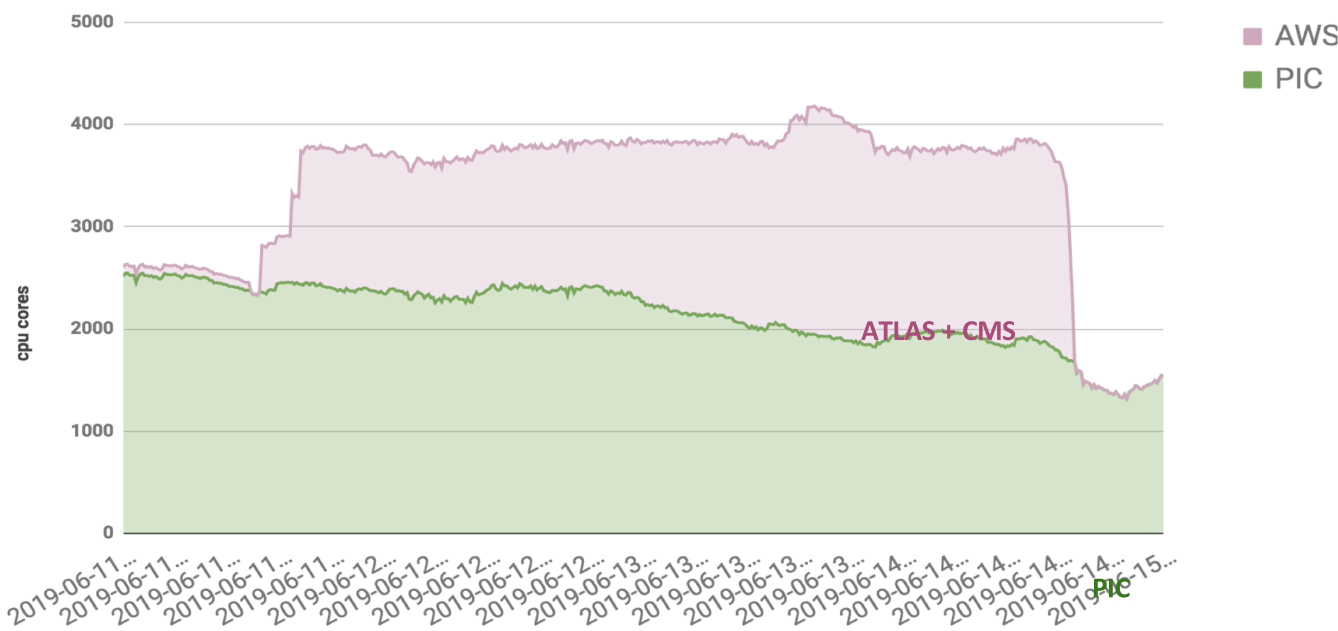
- Got CPU 1200kh to be used from july 1st to october 31st 2019, 100% efficiency to use them
- 11.76 million event simulated
- 12k jobs ended successfully



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

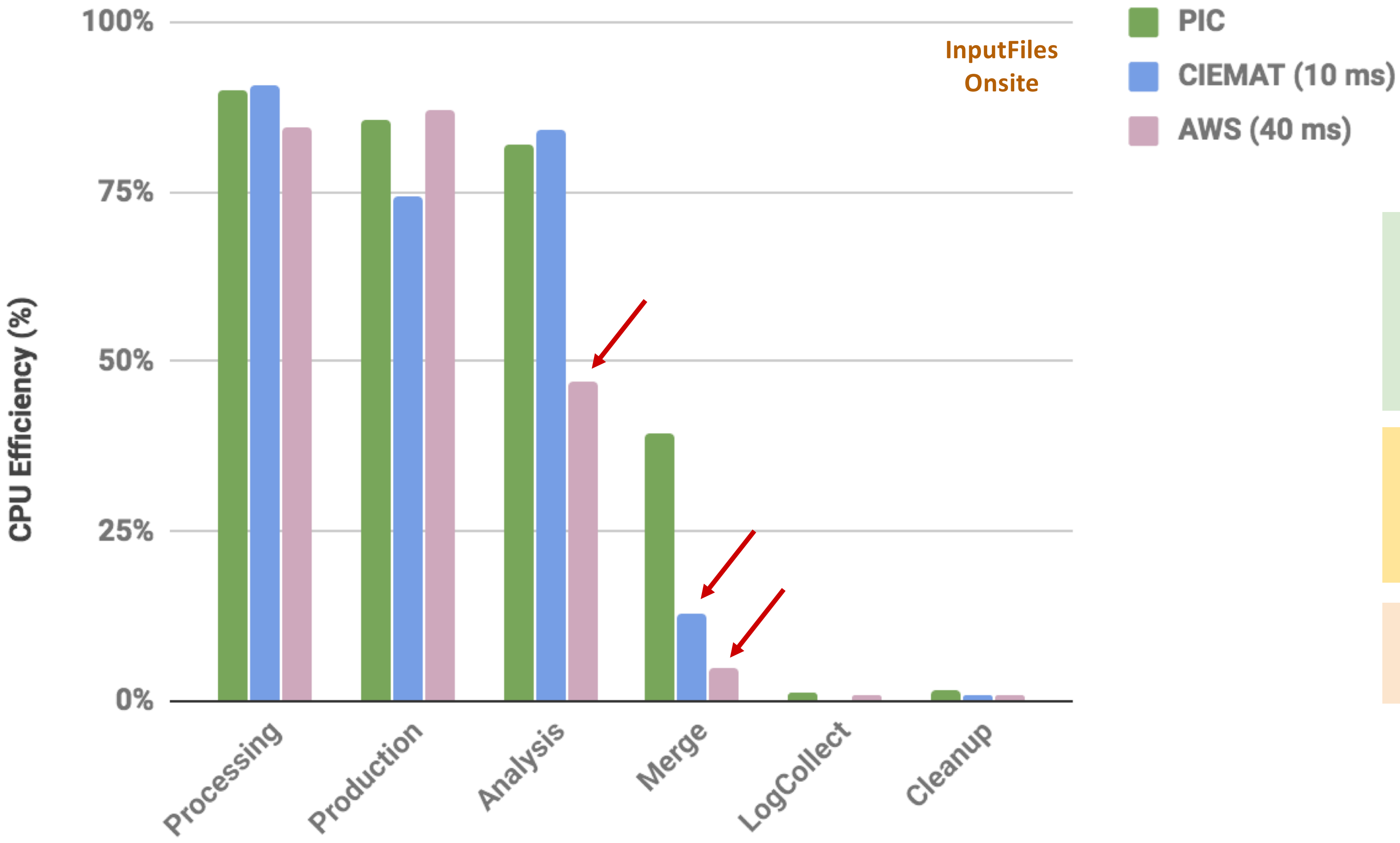
Custom **WN image** deployed in AWS servers, + CVMFS, + access to Squids

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]

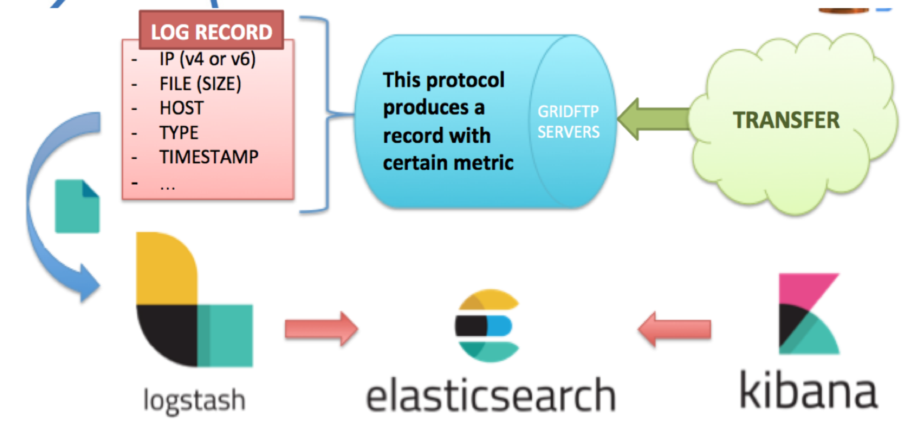


This tells us that within the region, PIC could run jobs either at PIC or CIEMAT (reading files from PIC), except merge (which should run locally always)!

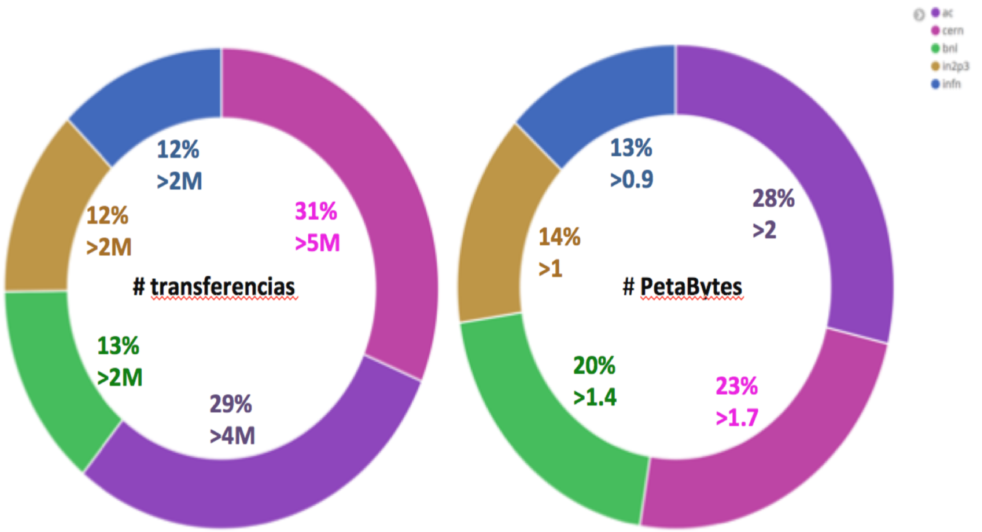
This of course would cause an increase of PIC exports (stressing both for network and storage system… how much?)

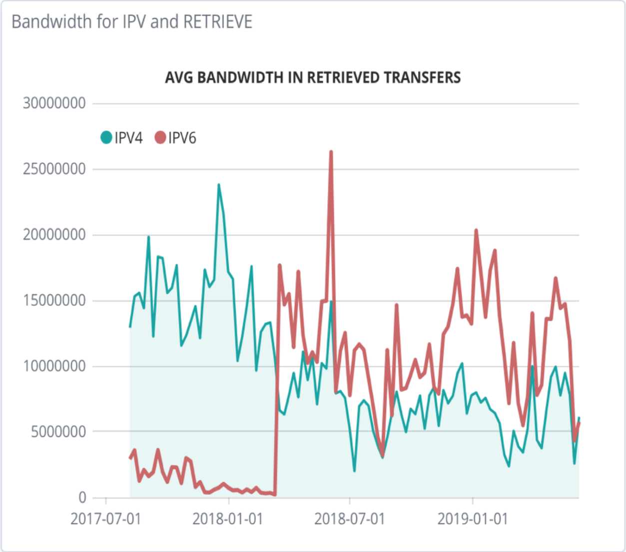
At higher latencies (40 ms), analysis starts to be degraded

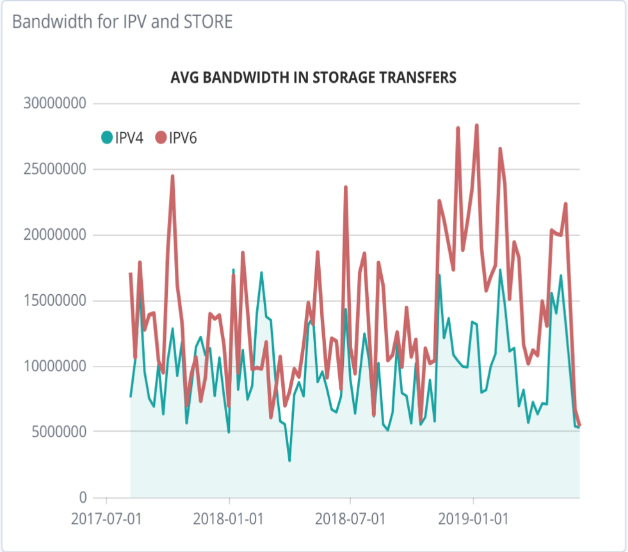
IFIC transfers monitoring



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



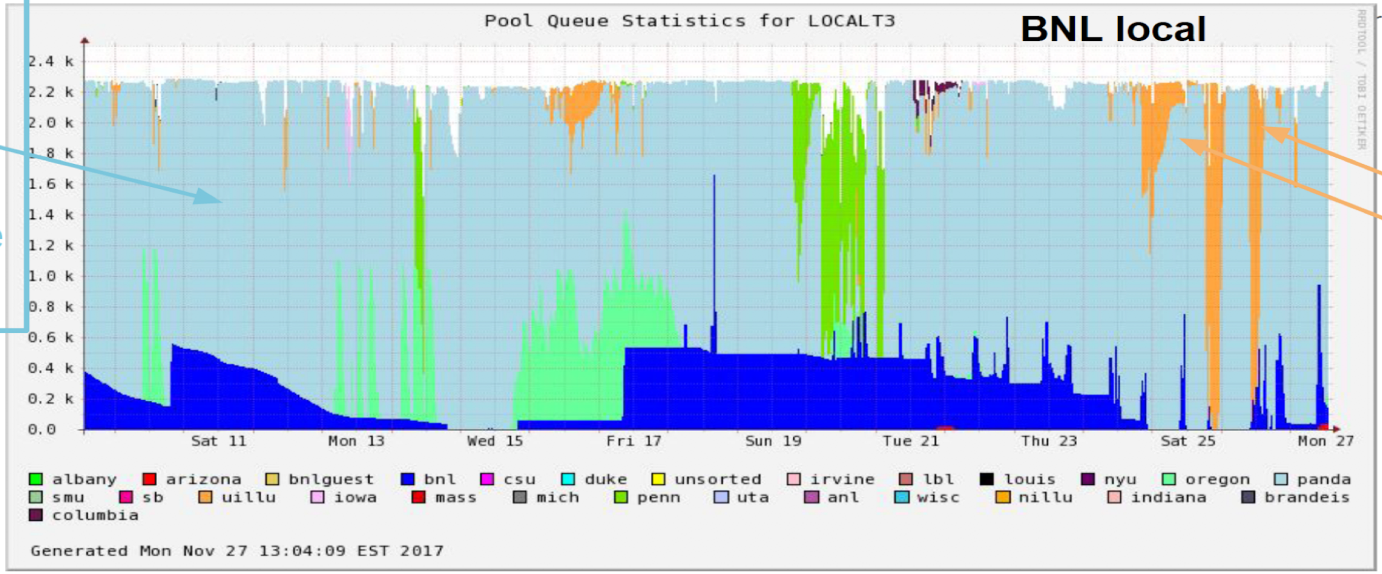




Event Service

- 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



[See other example by Rod]