National Research Centre (NRC)
"Kurchatov Institute"

Big Data Technologies Laboratory
http://bigdatalab.nrcki.ru/

SCIENCE
OF THE FUTURE

Study of ATLAS Transition Radiation Tracker performance with supercomputers and federated data storage system

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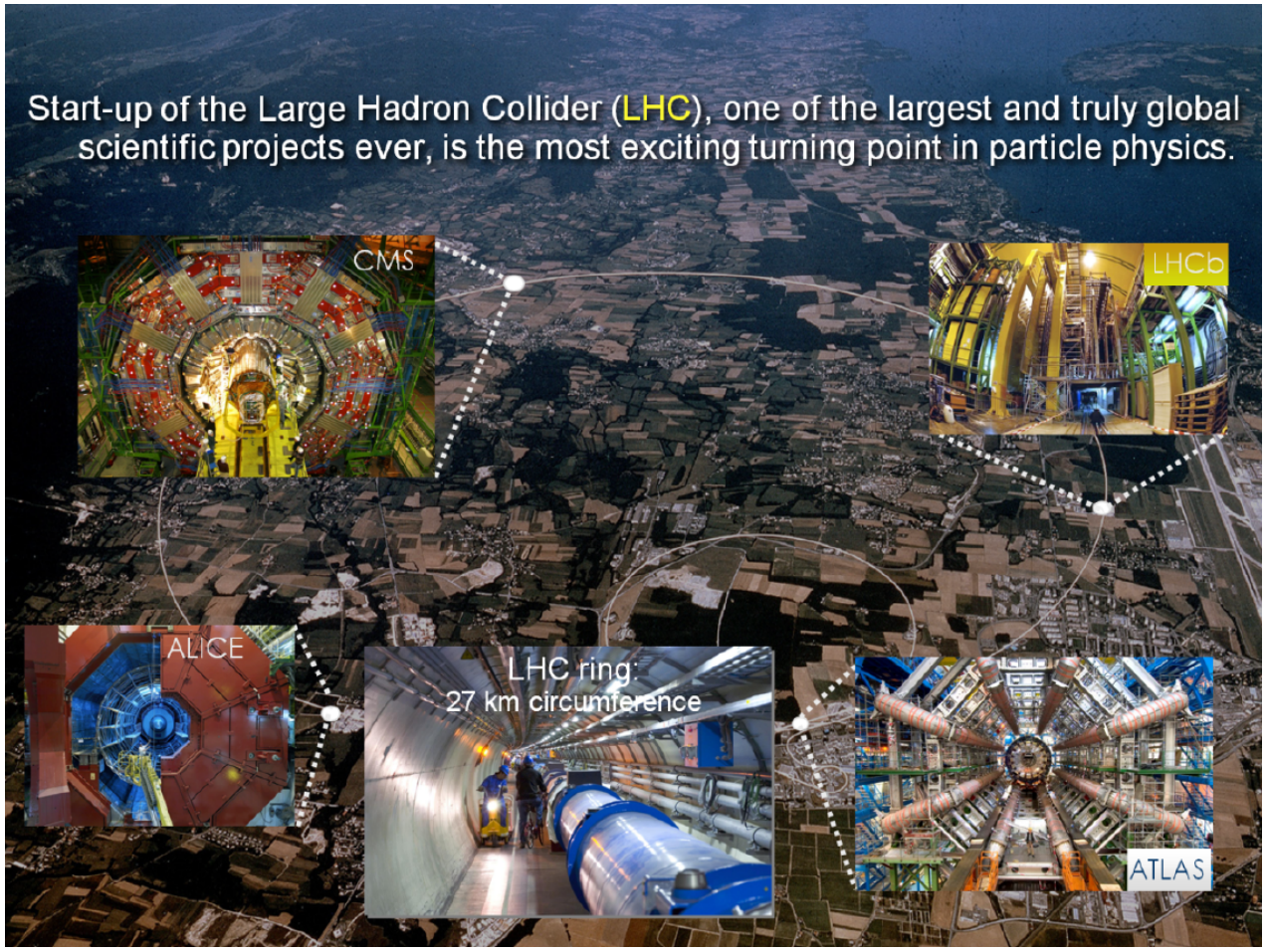
Outline

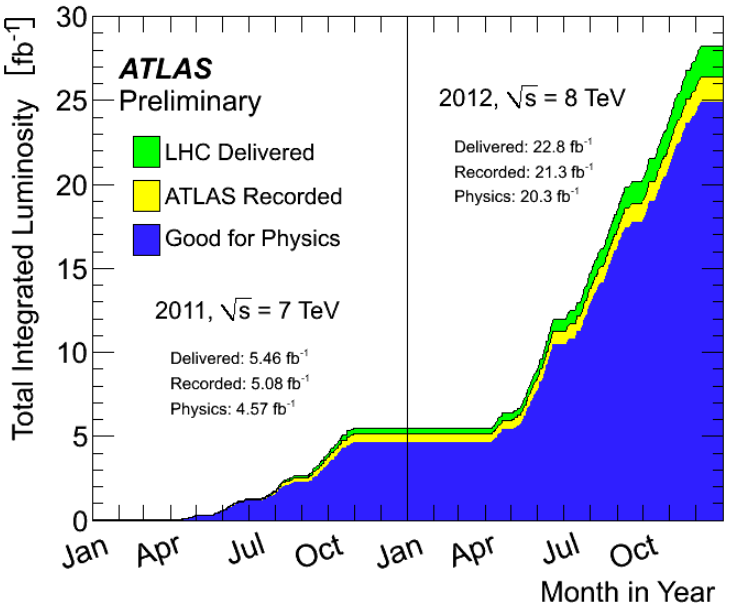
- Motivation
- Transition Radiation Tracker (TRT) in ATLAS experiment
- Physics analysis with supercomputers
  - Distributed computing infrastructure for LHC Experiments
  - High energy physics (HEP) data processing
  - NRC Kurchatov Institute computing facilities
  - Elaboration of CERN GRID and tests on NRC KI supercomputer
- ATLAS tasks on Federated storage system
  - Conception
  - Interpretation
- Summary

- Standard Model
- Higgs boson physics
- Supersymmetry
- Extra dimensions
- Dark matter
- Quark–gluon plasma
- Many many others



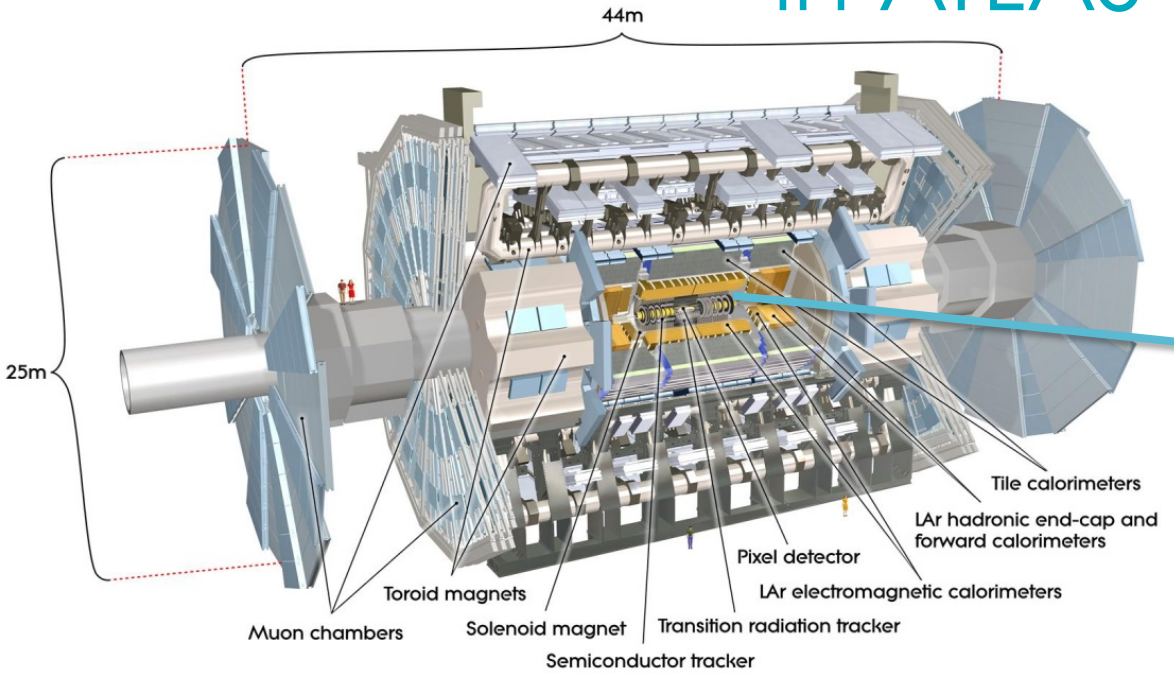
Motivation

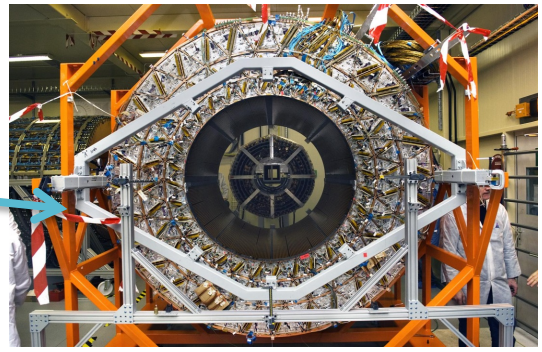
	Run 1 (2011-2013)	Run 2 (2015-2018)
Energy, TeV	7 (8)	13(14)
Luminosity, fb^{-1}	30	100 – 150
Average proton interactions	30	40
Time between interactions, ns	50	25



- Services and facilities should be developed and expanded
- Super computers or high performance clusters (HPC) and federated storage systems linked to CERN GRID system could be a decision (**validation studies are required**)

Transition Radiation Tracker in ATLAS experiment

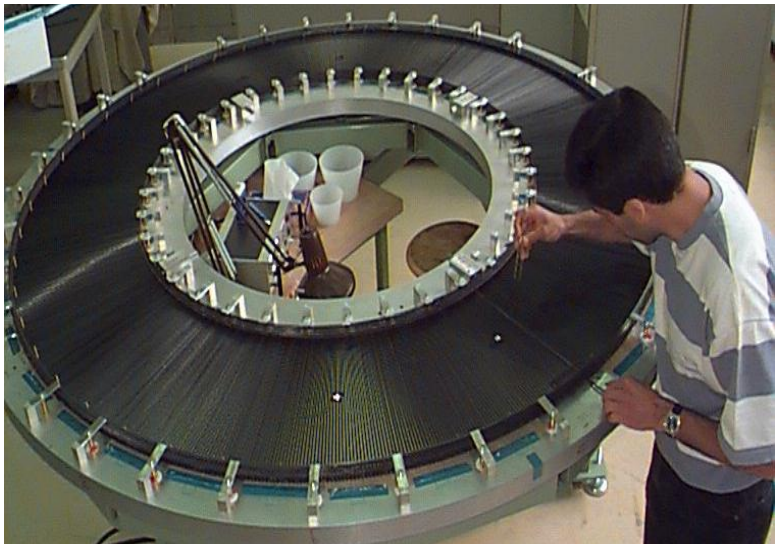




- ATLAS – general purpose experiment united 3000 scientists from 174 institutes in 38 countries
- **Transition radiation tracker (TRT)** is a part of ATLAS tracking system. It eases the tracks pattern recognition with its very large number of close hits (extensions) and contributes to particle identification

Transition radiation tracker (TRT) in ATLAS detector

The first works on transition radiation detectors development have started in National Research Nuclear University MEPhI under prof. B. Dolgoshein's guidance in the early 1970s. MEPhI group proposed a novel concept of transition radiation tracker for experiments at future LHC colliders in 1989, took a leading role in installation into ATLAS detector and continue maintenance of this detector during the whole LHC operation.

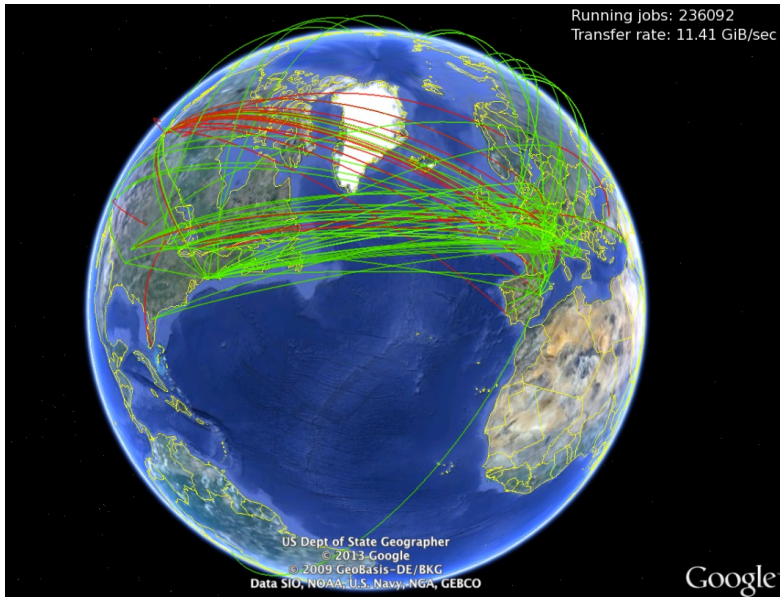


TRT End-cap wheel

- ≈ 0.4 M channels give ≈ 30 two-dimensional spacepoints for charged particles with $|\eta|<2$ and $p_T > 0.5$ GeV
- Single hit resolution: ≈130 μm
- Particle identification (electron-pions separations) by detection of transition radiation
- Provides accurate p_T measurements
- Works at high occupancy conditions
- Stable performance in hard radiation environment

Distributed computing infrastructure for LHC Experiments

- The Worldwide LHC Computing Grid (WLCG) project is a global collaboration of more than 170 computing centers in 42 countries, linking up national and international grid infrastructures.
- The mission of the WLCG project is to provide global computing resources to store, distribute and analyze the ~30 Petabytes (30 million Gigabytes) of data annually generated by the Large Hadron Collider at CERN.



Tasks and data transfers inside CERN GRID system all over the world

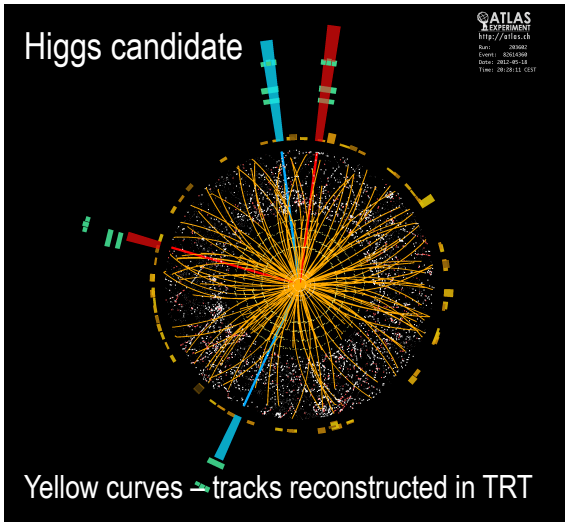
High energy physics data processing

HEP data are organized as events or (particle collisions). Computer power is used for:

- Simulation
- Events reconstruction
- Signal selection

A lot of work in ATLAS TRT collaboration was done using tremendous amount of CPU:

- Study of the TRT performance at high occupancy conditions - great challenge for computers since events reconstruction in TRT require recognition of each hit on tracks
- Tracking inside jets studies in TRT
- Particle identification studies in TRT



NRC computing facilities

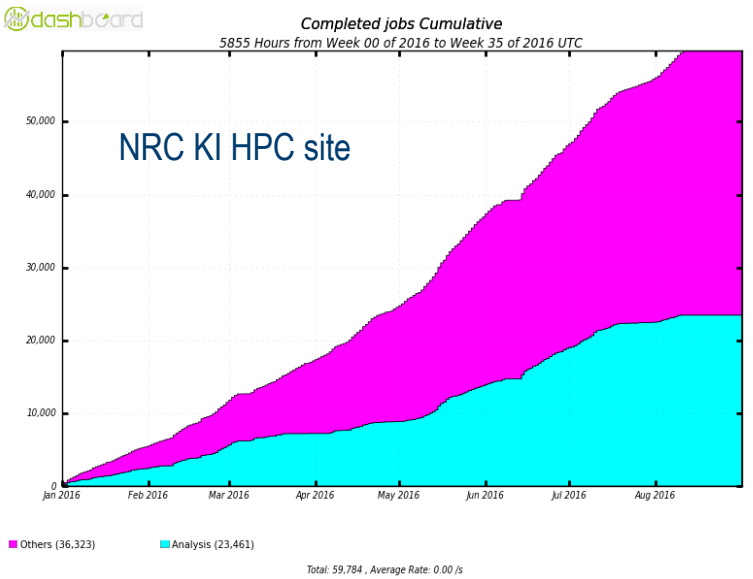
The second generation HPC with peak performance122,9 TFLOPS
#2 in 15-th issue of Russian top50 Supercomputers?

- 10240 CPU cores = 1280 nodes 2x Intel Xeon E5450 3,00GHz 4 core 16 Gb RAM
- User Interface (UI) node allows to run jobs in batch system (SLURM) and compile the code
- 2014 year a new portal combined the NRC KI Tier-1 site and the supercomputer (HPC) into NRC KI Tier-1 center. This center allows starting tasks optionally on CERN GRID and on the supercomputer as well and to collect the results in the common storage.
- For ATLAS analysis tasks new PanDA site "NRC KI HPC" was defined for supercomputer

Elaboration of GRID and supercomputers

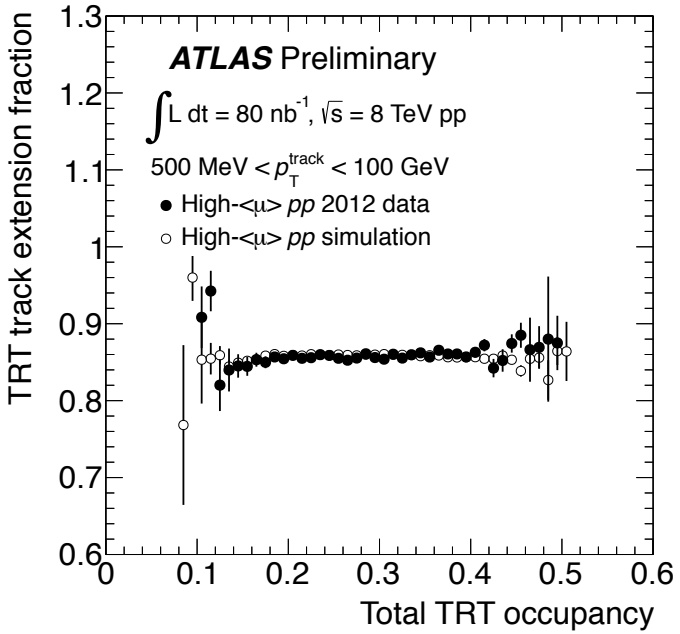
Several initial tests with NRC KI HPC site were done using TRT software studies:

- **Athena validation:** pilot jobs with different basic Athena releases (the Athena framework is an enhanced version of the Gaudi framework and is widely used by LHC experiments to simulate high energy physics (HEP) events and reconstruct LHC data).
- **General test**: comparison of ATLAS reconstruction jobs completed on CERN vs NRC KI (Tier1 and HPC) sites. Up to 100 000 events with 100% agreement.
- **Time test:** reconstruction of 500 simulated events in ATLAS detector. HPC KI CPU performance is on the same level as standard CERN GRID facilities.



Elaboration of GRID and supercomputers

- Complex kinematic distributions were used for **physics validation tests**
- Very important results for TRT collaboration dedicated to detector performance at high occupancy were obtained both on the CERN and NRC KI HPC sites with 100% agreement



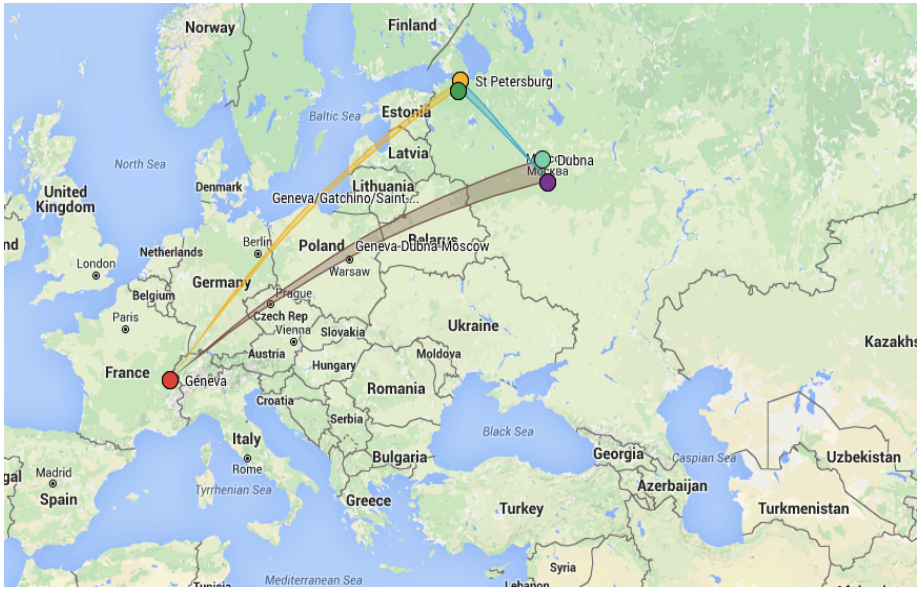
Fraction of tracks reconstructed in ATLAS with TRT extensions vs detector occupancy

"Study of ATLAS TRT performance with GRID and supercomputers"
Physics of Particles and Nuclei Letters, 13(5), 659-664,
DOI:10.1134/S1547477116050307

ATLAS tasks on Federated storage system

Federated storage system is among the best candidates to support high energy experiences in CERN during next intensive data taking periods

- Federating the data centers provides a logical homogeneous and consistent reliable resource for the end users
- Small institutions have no enough people to support fully-fledged software stack.



In this project the set up of distributed storage system in RU region is studied as well as the possibilities of its usage from Grid sites, from HPC, academic and commercial clouds, etc.
Much more details and results will be given in tomorrow talk by Andrey's Z. link

Test conception

Desirable features

- Real and high priority tasks from HEP experiments
- Relatively high CPU requirements
- Large read-in with possibility to store input files on geographically different sites

Test conception

- Standard reconstruction of simulated proton-proton collisions in ATLAS detector: from RDO format files containing currents and voltages to the files with kinematic parameters of particle candidates
- Additionally task contains detailed data processing from the TRT for hundreds of events (1 event in average needs CPU=1500 ms, VMEM=2.5 Gb)
- Each event is reconstructed independently and input RDO files may be divided into several parts

Test interpretation

Test interpretations must be clear and useful.
Tests log file contains:

- **"Rich" output for each reconstructed event**

PerfMonSvc: INFO [evt: 0] cpu=26387.000 ms vmem=2610.117 Mb dvmem= 380.488 Mb alloc= +0 -0
INFO ===>>> done processing event #888108, run #222222 1 events processed so far <<<===

- **Summary output averaged over all events from input file**

Py:PerfMonSvc INFO Events processed: 100
Py:PerfMonSvc INFO Statistics for 'evt': (nbr entries = 99)
Py:PerfMonSvc INFO <cpu>: (2875.354 +/- 394.491) ms
Py:PerfMonSvc INFO <real>: (2994.424 +/- 397.474) ms
Py:PerfMonSvc INFO <vmem>: (2705.933 +/- 2.857) MB

- **And many other useful information about computer resources used during the test**

vmem_peak=2834064 vmem_mean=2769334 rss_mean=1973995
cpu_bmips=5000 cpu_res=10 release=19.1.1.10/x86_64-slc6-gcc48-opt
cpu_model=Intel(R)_Xeon(R)_CPU_E5420_@_2.50GHz/6144_KB?
What else?

Test results

To discuss

Summary

CERN WLCG resources are fully utilized and it is important to integrate opportunistic computing resources such as supercomputers and federated storage systems not to curtail the range and precision of physics studies.

Validation procedure was developed to study the HPC performance with HEP tasks at Kurchatov Institute's Data Processing Center. Validation and verification tests between basic GRID sites and supercomputer demonstrated agreement opening a possibility to integrate supercomputer into standard CERN GRID system.

HEP test was developed based on ATLAS standard reconstruction procedure to examine Federated Storage system performance.

The end
Thank you