Study of ATLAS TRT performance with GRID and supercomputers

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Outline

- ATLAS detector
  - Inner tracking system
    - Transition radiation tracker (TRT)
- High energy physics data and data processing
  - ATLAS data
  - TRT Software
  - Elaboration of distributed computing infrastructure for LHC Experiments (GRID)
  - Kurchatov institute computing facilities
  - GRID and supercomputers
LHC experiments

Start-up of the Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever, is the most exciting turning point in particle physics.
ATLAS detector

- general-purpose detector
- 3000 scientists from 174 institutes in 38 countries work on the ATLAS

Pixel detector mainly contribute to the accurate measurement of vertices

Semiconductor (SCT) measures precisely the particle momenta

**Transition radiation tracker (TRT)** eases the pattern recognition with its very large number of close hits (extensions) and contributes to electron identification.
Transition radiation tracker

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 in Moscow. 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.

Facts:

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

Combining two major ATLAS inner detector components. The semiconductor tracker is inserted into the transition radiation tracker.
The TRT consists of three parts: barrel and two end-caps (A and C wheels)

- **Barrel**
  - $|\eta| < 1$
  - 52544 straws (105088 readout channels)
  - 1.44 m in length are oriented parallel to beam axis

- **Endcaps**
  - $1 < |\eta| < 2$
  - 122880 straws (122880 readout channels) 39 cm in length radially aligned to the beam axis
Transition radiation appears at the environments boundary with different dielectric constants \((P \sim \alpha = 1/137)\)

- During one collision particle loses about 100 eV energy (4 electrons are formed)
- Transition photon emission angle \(\sim 1/\gamma\) (almost all photons are very close to particle tracks)
- Transition radiations has a threshold nature and is used for particles identification
- Gas amplification is used to enhance the signal
Principles of Operation

The r-t relation is used to translate drift time into a measured drift-radius.

The TRT measures the spatial position of tracks using drift-time measurements provided by recording the time at which the ionization signal exceeds the low level threshold.
ATLAS data processing

- High energy physics data are organized as **Events** (particle collisions).

Computer power is used for:

- Simulation
- Reconstruction
- Signal selection  \[ \text{event by event} \]

ATLAS has collected already incredible amount of data

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

- Study of TRT performance at high occupancy
  - Events reconstruction with high number of interactions “<mu>” per event (great challenge for computers since events reconstruction in TRT require reconstruction of each hit on track)
  - Signal events selection for tracking inside jets studies

- Particle identification in TRT
Why is it important?
Proper understanding of TRT performance at high occupancy is important for:
• different ongoing physics analyses (good operation of the TRT detector will decrease tracking uncertainty)
• future work of TRT detector with higher energies and <\mu> (Run 2 2015)

What were the methods?
• TRT occupancy vs <\mu> study (study is done to estimate rough TRT occupancy during Run 2)

TRT occupancy=Fired straws/All straws

Run 2 ➔ \mu [25-40] ➔ TRT occupancy < 25%

It is expected that there is no significant performance loss in this pile-up range

Good simulation vs data agreement
Physical task
The main goal of PID in matter of TRT is to separate electrons from pions. Methods are based on counting the ration between the Low Level and High Level hits in TRT and take into account the ratio as function of many TRT variables (Straw layer, Z/R position and so on).

A lot of Monte Carlo samples were produced for PID studies to tune it up and predict the effects we may use to improve the PID. CERN computing facilities were used for the following purposes:

- to run small jobs (low statistics) and get a first look on the things;
- to generate huge sets of Monte-Carlo samples with stable parameters;
- to simulate detailed response of the ATLAS detector for the MC-Data comparisons.
Elaboration of distributed computing infrastructure for LHC Experiments (GRID)

LHC Physics Run 1
- Energy = 7 (8) TeV
- Luminosity ~ 30 fb-1
- ~1400 bunches total
- \( \mu \sim 30 \) (ATLAS, CMS)
- 50ns bunch spacing

Factor \( \approx 2 \)

LHC Physics Run 2
- Energy = 13 (14) TeV
- Luminosity ~ 100 – 150 fb-1 (factor 5 for storage memory)
- ~2500 – 2800 bunches total
- \( \mu \sim 40 \) (ATLAS, CMS)
- 25 ns bunch spacing

Computer power

Services and facilities should be developed and expanded
Super computers or high performance clusters (HPC) linked to GRID system could be a decision (Cross checks are needed)

<table>
<thead>
<tr>
<th>Physical CPU</th>
<th>Logical CPU</th>
<th>HEPSPEC06</th>
<th>CPU Pledge</th>
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<tbody>
<tr>
<td>179,625</td>
<td>532,910</td>
<td>5,716,182</td>
<td>3,083,512</td>
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</table>

<table>
<thead>
<tr>
<th>Total Online Storage, Gb</th>
<th>Disk Pledge, Gb</th>
<th>Total Nearline Storage, Gb</th>
<th>Tape Pledge, Gb</th>
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</thead>
<tbody>
<tr>
<td>325,934,747</td>
<td>249,432,000</td>
<td>240,447,948</td>
<td>274,592,000</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Dedicated to ATLAS:</th>
<th>CPU, HEPSPEC06</th>
<th>Disk, Tbytes</th>
<th>Tape, Tbytes</th>
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</thead>
<tbody>
<tr>
<td>Required</td>
<td>1175000</td>
<td>103000</td>
<td>98000</td>
</tr>
<tr>
<td>Provided</td>
<td>1275226</td>
<td>110293</td>
<td>103190</td>
</tr>
<tr>
<td>% from total</td>
<td>22</td>
<td>34</td>
<td>43</td>
</tr>
</tbody>
</table>
Kurchatov institute computing facilities

The second generation HPC with peak performance 122,9 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
- Shared FS Lustre for Worker Node’s (WN’s) and UI
- WN’s has an access to WAN
- CVMFS connected to WN’s
- Broadband to Tier-1 Storage Element (ANALY_RRC-KI GRID site)
• In 2014 the new portal combined the Kurchatov Institute’s Tier-1 site and the supercomputer HPC2 into Kurchatov Institute’s Tier-1 center. This center allows starting tasks optionally not only on GRID but on the supercomputer as well and to collect the results in the common storage.

• For ATLAS analysis tasks new PanDA site “ANALY_RRC-KI-HPC” within ATLAS Tier-1 site of National Research Center “Kurchatov Institute” was defined for supercomputer.

• System was successfully tested using ATLAS tasks and biological applications.
Several tests with Kurchatov Institute (KI) site were done using TRT SW 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 ATLAS experiment to simulate HEP events and reconstruct LHC data.

General test: comparison of ATLAS reconstruction jobs on CERN and KI (Tier1 and HPC) sites. Up to 100 000 events with 100% agreement.
Validation and verification KI computers

- Time test: reconstruction of 500 Monte-Carlo events in ATLAS detector including detailed TRT reconstruction (for each TRT hit):

<table>
<thead>
<tr>
<th>site</th>
<th>ANALY_RRC-KI-T1</th>
<th>ANALY_CERN_SLC6</th>
<th>ANALY_RRC-KI-HPC (super computer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time statistics</td>
<td>&lt;cpu/real&gt;: 30145 / 30548 ms</td>
<td>&lt;cpu/real&gt;: 31906 / 32337 ms</td>
<td>&lt;cpu/real&gt;: 23054 / 23332 ms</td>
</tr>
</tbody>
</table>

≈25% time gain with supercomputer

- Physical test: track kinematic distributions demonstrate 100% agreement in output data from CERN and KI sites

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NEC 2015, Montenegro  
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Summary

- A proper understanding of the ATLAS inner detectors performance at high occupancy conditions is important for many on-going physics analyses. The ATLAS Transition Radiation Tracker contributes significantly to the resolution for high-pT tracks in the ID providing excellent particle identification capabilities and electron-pion separation.

- ATLAS experiment is using Worldwide LHC Computing CRID. WLCG resources are fully utilized and it is important to integrate opportunistic computing resources such as supercomputers, commercial and academic clouds not to curtail the range and precision of physics studies.

- One of the most important studies dedicated to be solved on a supercomputer is reconstruction of proton-proton events with large number of interactions in Transition Radiation Tracker. It becomes clear that high-performance computing contributions become important and valuable. An example of very successful approach is Kurchatov Institute’s Data Processing Center including Tier-1 grid site and supercomputer.

- Validation and verification tests between basic GRID sites and super computer demonstrate total agreement in physics and around 25% time gain on supercomputers.
The end.
Thank you!