Porting LHAASO WFCTA simulation job to ARM computing cluster

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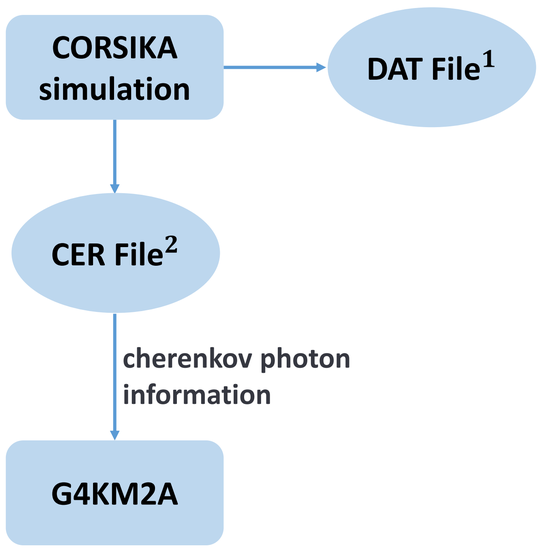
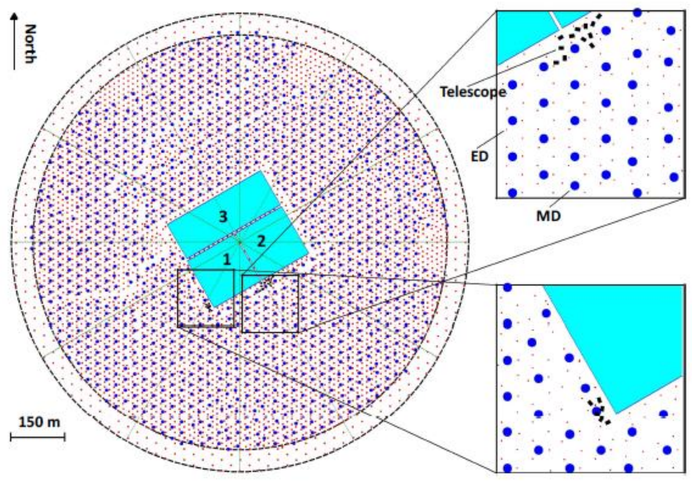
1. Introduction

The Wide Field-of-View Cerenkov Telescope Array (WFCTA) is a crucial component of the Large High Altitude Air Shower Observatory (LHAASO) that aims to measure the energy spectra of cosmic rays individually from ~30 TeV to a couple of EeV.
However, due to limited CPU resources, only 25% of the first stage planned data could be produced on the Intel X86 cluster in 2020.
In 2021, an ARM computing cluster with 10,000 CPU cores was established in Dongguan, Guangdong province, China. We have built an application ecosystem based on the ARM architecture on top of this infrastructure to support the offline data processing work of WFCTA.
Our main works include: porting WFCTA offline software to run on ARM machine, formulating data transmission and job scheduling strategies for ARM cluster, and evaluating the performance and power consumption at both Intel X86 and ARM cluster.

2. Simulation task of LHAASO WFCTA

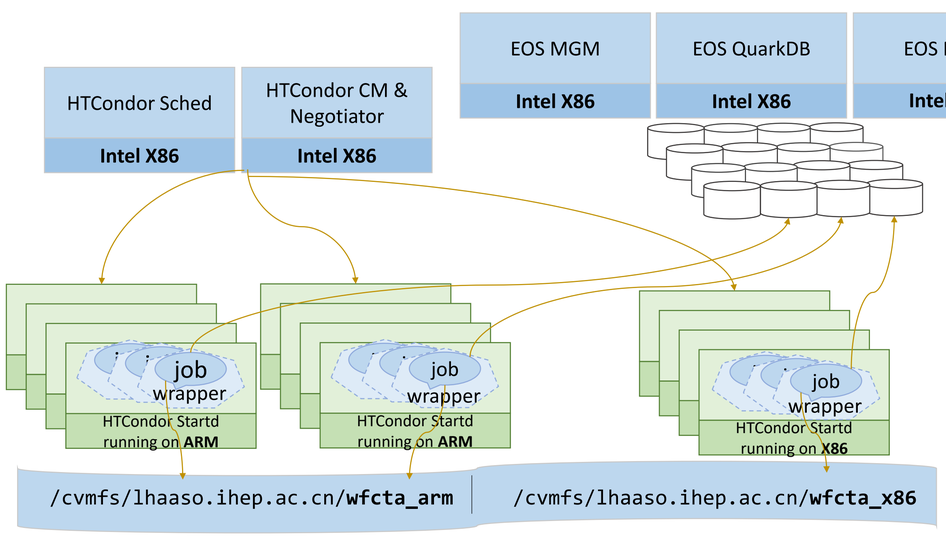
- The Monte Carlo simulation includes two parts.
  - Part 1. The simulation of extensive air showers produced by primary particles in the atmosphere is done by CORSIKA.
  - Part 2. Simulating the WFCTA detector using G4KM2A.
- CORSIKA: The main simulation processes include simulation of electromagnetic components, simulation of high and low energy hadronic interactions, and propagation of Cherenkov photons.
- G4KM2A: WFCTA detector simulates the processes of photon reflection on the focal plane, light collector absorption, and SiPM response.





LHAASO Array Schematic Diagram

1. The file that stores secondary particle information.
2. The file that stores cherenkov photon information.



3. Job scheduling strategies for the cluster

- HTCondor servers, EOS servers, cvmfs server : Intel X86
- Worker nodes : Arm and Intel X86
- WFCTA software version: Intel X86 version and ARM version
  - Stored at separated directories at cvmfs
- User does not to care about what kind of worker node will run the job
- Job wrapper coded in bash and deployed to every workernode
  - User job script is wrapped by the job wrapper
  - Wrapper choose the suitable wfcta software version based on the detected architecture
- The Scheduler strategies decides WFCTA simulation job could be scheduled to both Intel86 and ARM worker node

4. Porting to ARM

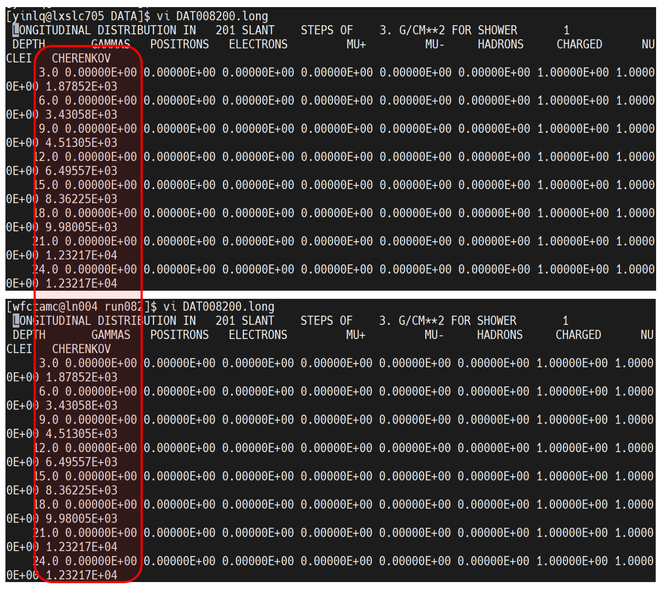
- ARM Computing Cluster
  - KunPeng 920 CPU: aarch64 ARM v8.2
  - Taishan 200K server: 96cores/node & 256 GB Memory
- CORSIKA
  - Version: V77420
  - Fluka: Fluka-CERN
- G4KM2A
  - Version: 10.1
  - Geant4 Version: 10.4.2
- System Software
  - HTCondor: 9.1.0
  - EOS: 4.7.7
  - CVMFS: 2.5.2

Advantages of ARM

- At the same performance, ARM chip has smaller size, lower power consumption and higher integration than x86
- More CPU cores have better concurrency performance
- 64-bit RISC, higher compatibility for Applications

5. Result and performance of CORSIKA at both Intel X86 and ARM cluster

- Using CORSIKA version V77420 and GHEISHA model with the same options, the running results of Beijing and Dongguan are completely consistent.
- For 5000 Corsika simulation jobs
  - ARM : Kunpeng 920@2.6 GHz, 48 cores
  - X86 : Intel 6240R@2.4 GHz, 24 cores



```
[yinlq@lxslc705 DATA]$ vi DAT008200.long
 LONGITUDINAL DISTRIBUTION IN   201 SLANT    STEPS OF    3. G/CM**2 FOR SHOWER      1
 DEPTH      GAMMAS   POSITRONS   ELECTRONS         MU+         MU-     HADRONS     CHARGED      NU
CLEI    CHERENKOV
     3.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 1.87852E+03
     6.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 3.43058E+03
     9.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 4.51305E+03
    12.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 6.49557E+03
    15.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 8.36225E+03
    18.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 9.98005E+03
    21.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 1.23217E+04
    24.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 1.23217E+04
```

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[wfctamc@ln004 run082]$ vi DAT008200.long
 LONGITUDINAL DISTRIBUTION IN   201 SLANT    STEPS OF    3. G/CM**2 FOR SHOWER      1
 DEPTH      GAMMAS   POSITRONS   ELECTRONS         MU+         MU-     HADRONS     CHARGED      NU
CLEI    CHERENKOV
     3.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 1.87852E+03
     6.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 3.43058E+03
     9.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 4.51305E+03
    12.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 6.49557E+03
    15.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
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    18.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
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0E+00 1.23217E+04
    24.0 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.0000
0E+00 1.23217E+04
```

Node Type	Num. of Jobs	Num. of nodes	Job Run Time (s)
X86	5000	209	982.073
ARM	5000	105	1661.432

- Single-core performance, X86 is 169% than ARM
- Entire server performance, ARM is 118% than X86