Dirac-based solutions for JUNO production system

Xiaomei Zhang, Xianghu Zhao, Tao Lin
On behalf of the JUNO collaboration
Institute of High Energy Physics
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Jiangmen Underground Neutrino Observatory

- JUNO, a multi-purpose neutrino experiment designed to measure the neutrino mass hierarchy and three neutrino oscillation parameters
  - Started to build in 2015, operational in 2022, located in Guangzhou province
  - Estimated to produce 2 PB data/year for >10 years
  - 20 kt Liquid Scintillator detector, 700 m deep underground
  - Energy resolution 3% @ 1MeV
  - Rich physics opportunities
JUNO distributed computing prototype

- JUNO Distributed Computing system has been built on DIRAC which can easily organize heterogeneous and distributed resources
  - The resources integrated include Cluster, Grid and Cloud
  - Sites joined include IN2P3, IHEP, JINR, Padovana, CNAF
  - Main SE(Storage Element) types: dCache, StoRM

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JUNO computing model

- **Data centers joined**
  - IHEP, CNAF, JINR, MOSCOW, IN2P3

- **IHEP and CNAF (not finally decided)**
  - Hold complete set of data in China and Europe, backup for each other

- **Other centers**
  - Hold just part of data, also for analysis data

- **Small sites**
  - No storage required, access data from the closest data centre

- **MC production will be first considered, and event reconstruction in main data centers**

- **Production system designed can be tuned according to the change of future computing model**
Simulation jobs are distributed by production groups to any centers
- Sim workflow: detsim -> elecsim -> cal -> rec

Sim data produced in other centres will be copied back to IHEP or CNAF, synchronized between IHEP and CNAF
- Dataflow type: move or replication

Raw data would be transferred from onsite to IHEP, then from IHEP to Other Europe data centers
JUNO mass production

- Data processing includes five steps
  - Physics Generator (PhyGen)
  - Detector Simulation (DetSim)
  - Electronics Simulation (EleSim)
  - PMT Reconstruction (PmtRec/Cal)
  - Event Reconstruction (EvtRec)

- Mass production includes large samples of physical processes (IBD*, bkgs, single particles...) with different momenta
  - Each sample includes four data processing interconnected with data
  - Hard to manage all these by hand in distributed environment

*IBD: Inverse Beta Decay
Design of JUNO production system 1

- **Goals**
  - Manage mass workflow and dataflow automatically
  - Provide ways and interface for production groups to manage production tasks

- **JUNO Production System is built on DIRAC transformation system which**
  - Provides a framework to chain production workflow and dataflow in an automatic data-driven way
  - Closely integrates with DIRAC WMS and DMS, and submit jobs and data transfer tasks seamlessly to the related services
Based on DIRAC transformation infrastructure, the role of JUNO production system

- Define production tasks with a steering file
- Provide JUNO job templates for transformations to create final jobs
- **Create transformation modules for each workflow and dataflow**
- **Chain transformation modules with metadata defined**
- Define workflow and dataflow policies according to JUNO computing model
  - eg. Target SEs, Assign tasks to different sites
- Provide a global monitoring and control of workflow and dataflow status in one production task
Each JUNO production task is a chain of workflow and dataflow:
- Workflow: detsim, elecsim, cal, rec
- Dataflow: upload/download, replicate

Each part of workflow is defined as a transformation module:
- Input and output data registered in DFC (Dirac File Catalogue)
- Transformation modules are chained by input metadata query
- Every step is triggered by the output of last step
- Detsim module is an exception, started with number of jobs defined in the steering file
Dataflow is connected to workflow seamlessly with input data query.

The process of dataflow:

- Output data of each modules is uploaded to the closest SE.
- Replication from local SE to final SE is defined as a transfer module.
- Synchronization from IHEP SE to the SE of other data centers (eg. CNAF) can be done immediately if required.

In transformation, each step is triggered by single output of last step, and don’t need to wait for the completeness of last step.
Workflow Implementation

- Transformation and WMS

Data driven task creation
Queue job tasks
Submit jobs to resources
Dataflow Implementation

- Dataflow part has more services and systems joined than Workflow part
  - Advantage: flexible and general, free to choose backends
  - Disadvantage: not easy to track problems and control performance
Steering file to define tasks

- **General parameters**
  - Defines in `[All]`
  - Includes Software version, TargetSE, OutputDir, Sites, ProdName...

- **Special parameters for physics processes required**
  - An example `[Chain]` allows users to generate particles with momenta
    - `Detsim_mode` uses `gun`
    - The particles and momentums info got from `tags`
    - `Tags` allow multi production tasks
  - Other processes support, e.g.
    - `ChainIBD` for signals
    - `ChainDecay` for background
    - `ChainMuon` for Muon simulation

- `[All]`
  - `process = Chain`
  - `softwareVersion = J17v1r1`
  - `prodName = JUNOProdTest`
  - `transGroup = JUNO_prod_test`
  - `OutputDir = production/zhangxm/test001`
  - `outputMode = closest`
  - `TargetSE = IHEP-STORM CNAF-STORM`

- `[Chain]`
  - `seed = 42`
  - `evtmax = 2`
  - `njobs = 10`
  - `tags = e+_0.0MeV e+_1.398MeV e+_4.460MeV`
  - `workDir = Positron01`
  - `position = center`
  - `workflow = detsim elecsim calib rec`
  - `moveType = detsim elecsim`
  - `detsim-mode = gun --particles {particle} --momentums {momentum} --positions 0 0 0`
Usage

❖ Single command to issue production tasks
  ● ihepdirac-juno-make-productions.py –ini <steering file>
  ● Return <production ID>

❖ Monitor and control production tasks with <production ID>
  ● Each production ID linked with the related workflow and dataflow transID
  ● Each transID linked with JobID and RequestID for real jobs and transfers
Tests

- JUNO software version deployed in CVMFS: J17v1r1
- Create samples of positron at different momenta: \(e^+\_0.0\text{ MeV}\), \(e^+\_1.398\text{ MeV}\), \(e^+\_4.460\text{ MeV}\), \(e^+\_6.469\text{ MeV}\)
- For each momentum, 8 transformations are created
  - 4 workflow, 4 replications
  - 100 jobs/each workflow, 1000 events/job
Summary and outlook

- According to requirements of JUNO mass production, the JUNO production system has been designed and implemented based on DIRAC.
  - DIRAC transformation infrastructure makes the work much easier.
- The tests have shown that the system is working.
- Scale tests are in plan to understand more about efficiency and performance.
- Next step GPU and multi-core supports in this framework will be considered to meet challenges of muon simulation with high requirements of CPU and Memory.