Dirac-based solutions for JUNO production system

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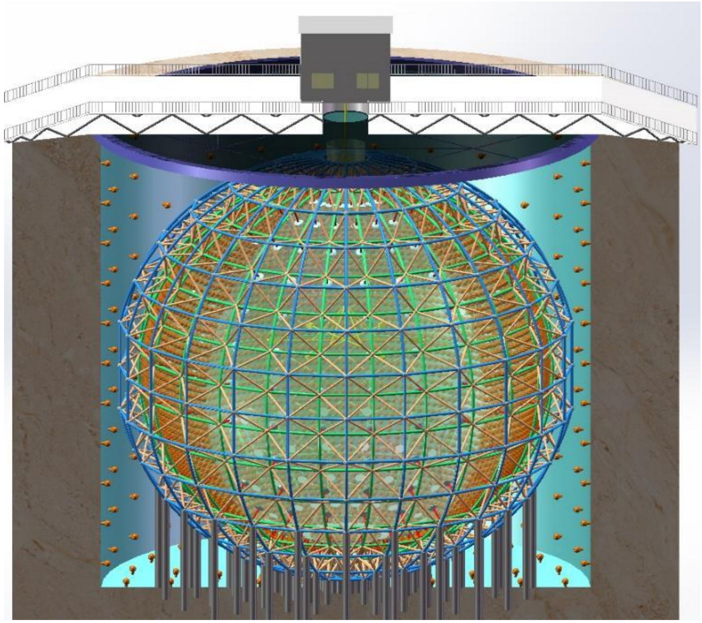
Jiangmen Underground Neutrino Observatory

- 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



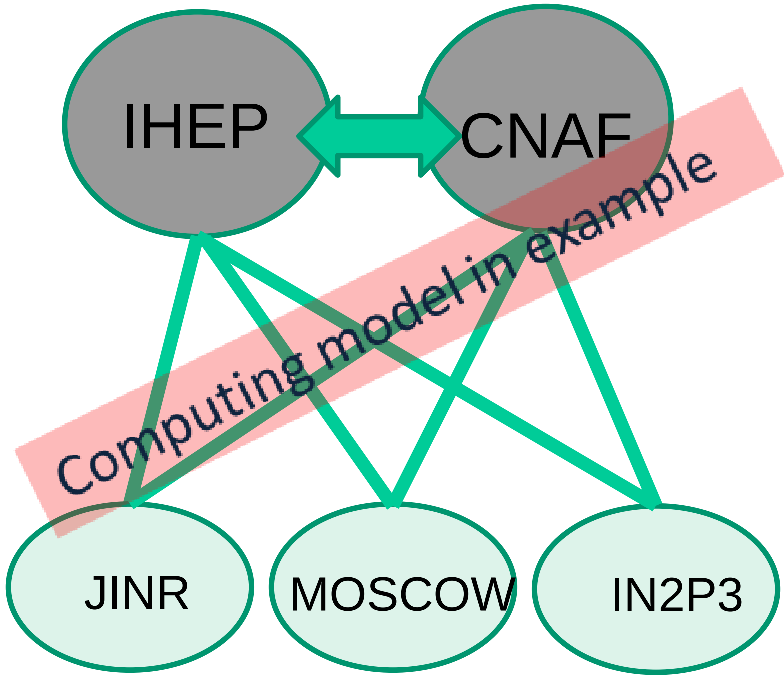
JUNO distributed computing prototype

- 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

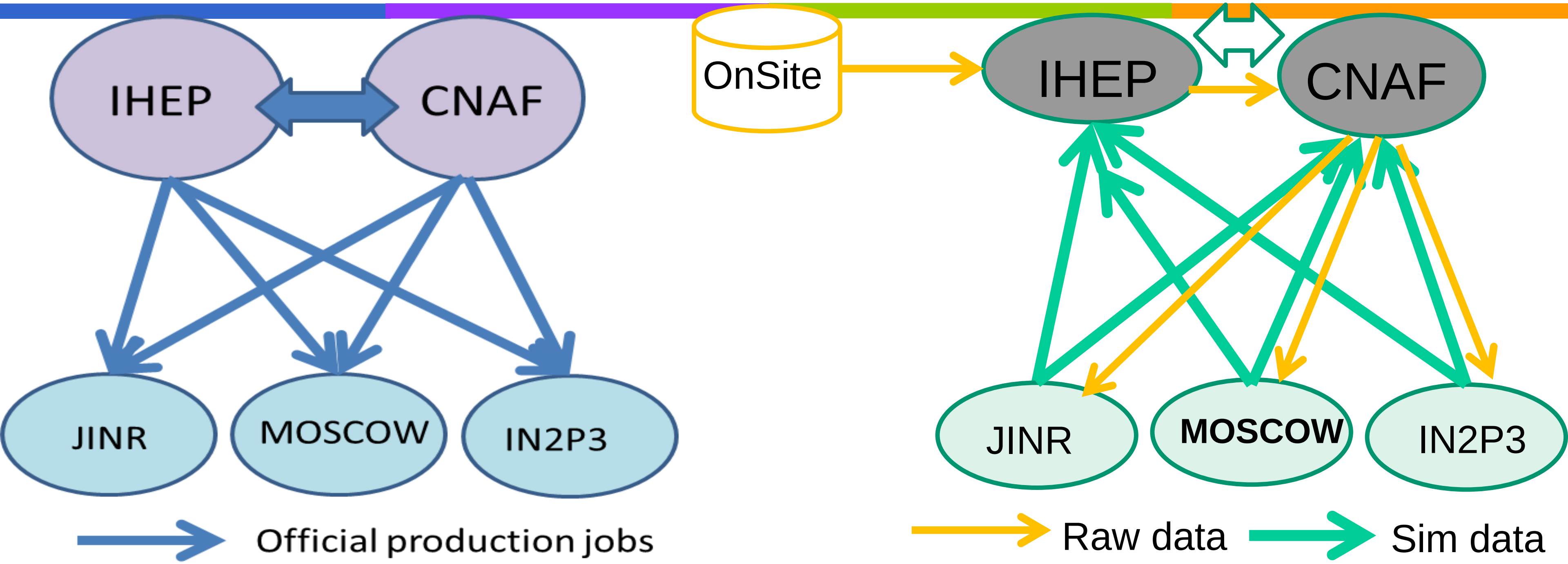
Site	SiteType		MaskStatus	CE-...	SE-...
GRID.IN2P3.fr	GRID		Active	OK	OK
CLUSTER.IHEP-CONDOR.cn	CLUSTER		Active	OK	OK
CLOUD.JINRONE.ru	CLOUD		Active	OK	OK
CLOUD.IHEPCLOUD.cn	CLOUD		Active	OK	OK
CLOUD.INFN-PADOVANA.it	CLOUD		Active	OK	
GRID.INFN-CNAF.it	GRID		Active	OK	OK

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**



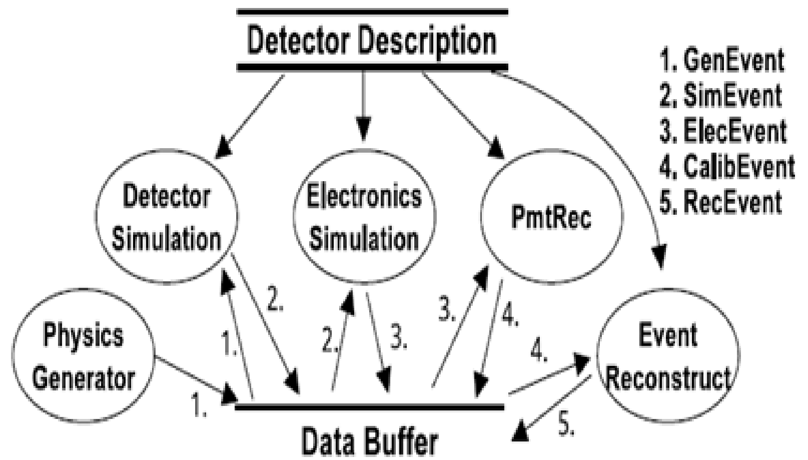
JUNO workflow and dataflow



- 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

a) 100k full OSCILLATED events (➜ is this enough for now? Do you need twice as many or 10x? speak up!)

b) 100k IBD-e+ (➜ is this enough for now? Do you need twice as many or 10x? speak up!)

c) 100k IBD-neutron (➜ is this enough for now? Do you need twice as many or 10x? speak up!)

Positron with different momenta

Energy deposition = 1.022MeV, 3MeV, 5MeV, 7MeV (➜ eliminated 2,4,6 MeV to double stats on existing points: OK?)

a) 100-200k events per energy point, uniform in central detector

b) 100k events for only 1 energy point as reference , at the center of central detector (e.g. 1.022MeV?)

Electron with different momenta

Energy deposition = 1.022MeV, 3MeV, 5MeV, 7MeV (➜ eliminated 2,4,6 MeV to double stats on existing points: OK?)

a) 100-200k events per energy point, uniform in central detector

b) 100k events for only 1 energy point as reference , at the center of central detector (same as positron for comparison)

Radioactivity in CD

a) 100k ^{238}U full chain with GenDecay, Secular Equilibrium

b) 100k ^{232}U full chain with GenDecay, Secular Equilibrium

c) also ^{40}K?

Muons (use those for physics validation)

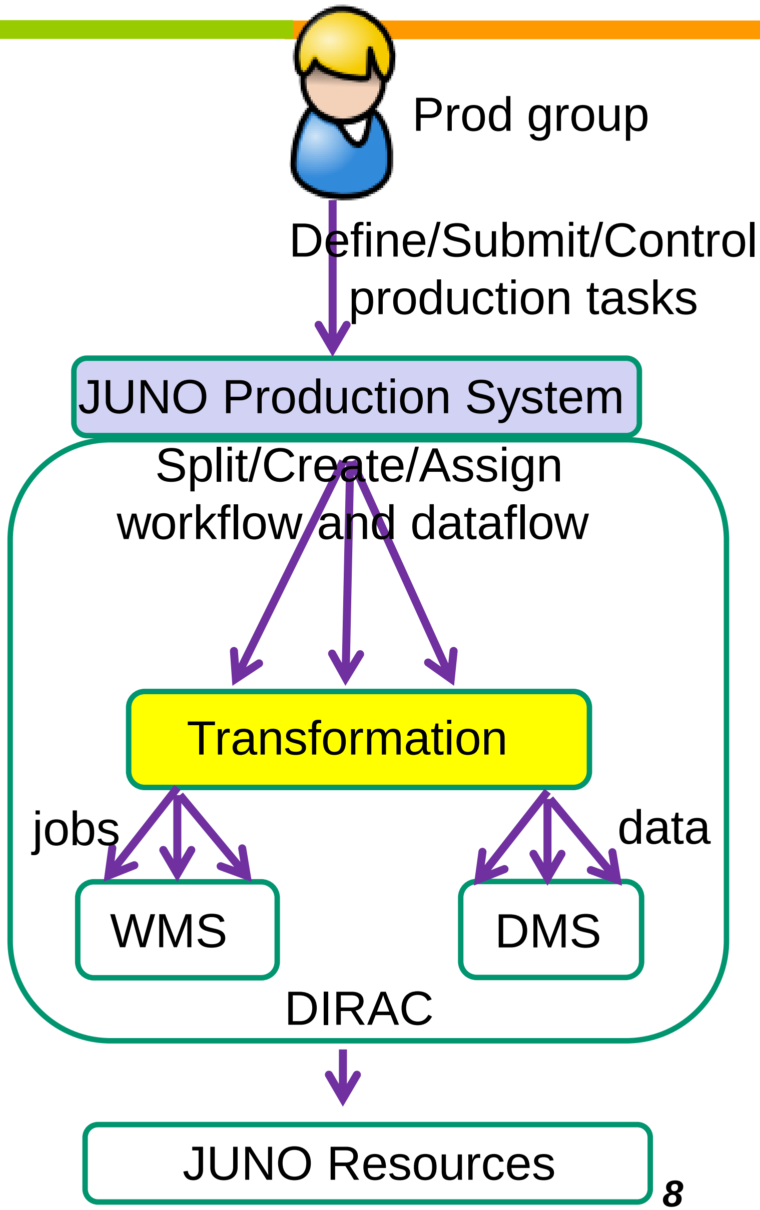
100-500 single muon events, full sim, Energy = 215 GeV -- Different inclinations and impact position:

- θ (incl wrt vertical) = 180° (straight down), 140° (inclined down-going)
- D (dist from centre) = 0, ±4, ±8, ±12, ±16 m

*IBD: Inverse Beta Decay

Design of JUNO production system 1

- Goals
  - Manage mass workflow and dataflow automatically
  - Provide ways and interface for prod 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

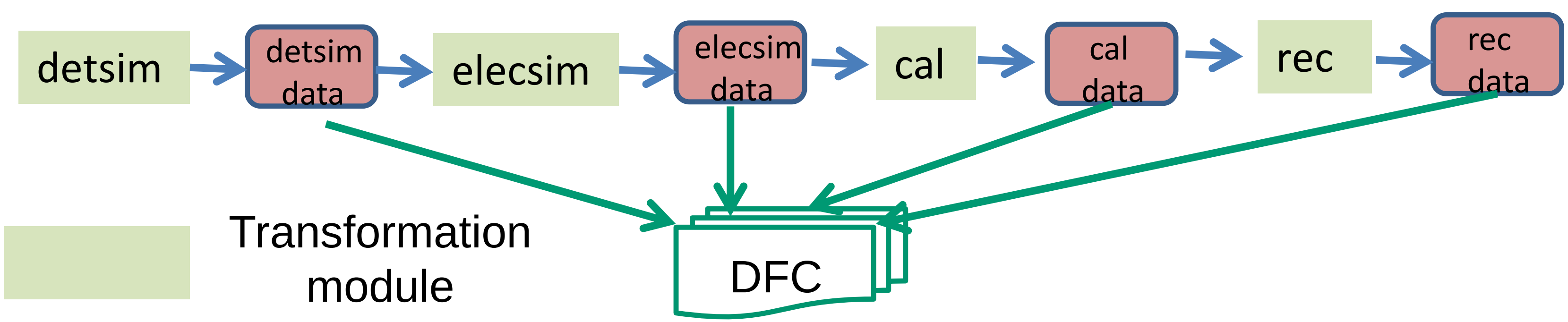


Design of JUNO production system 2

- 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

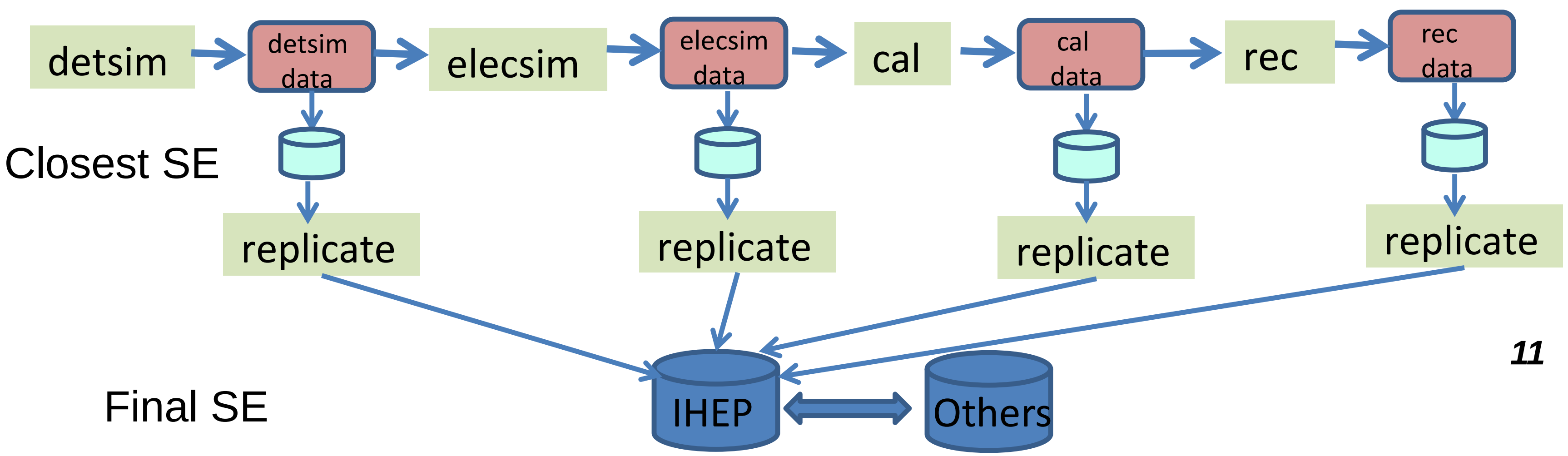
Design of JUNO transformations 1

- 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



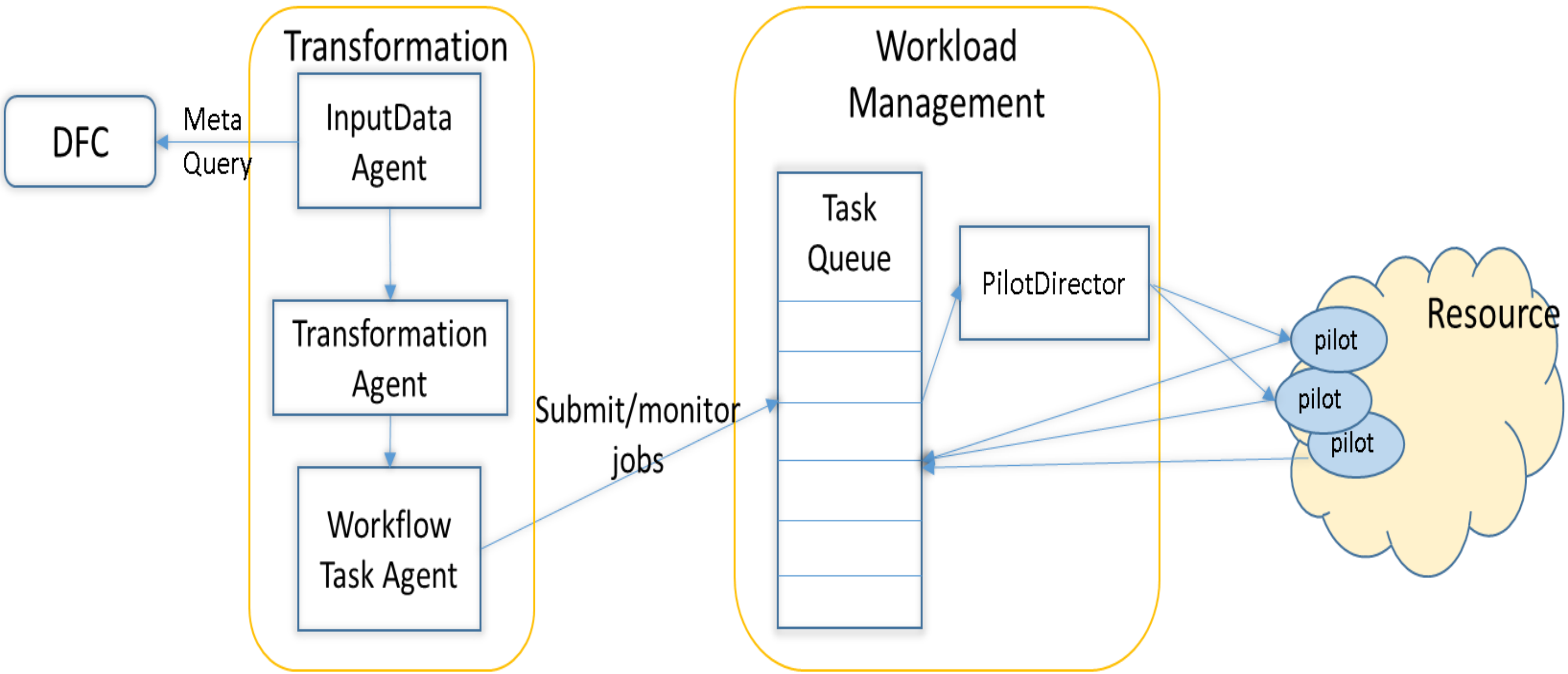
Design of JUNO transformations 2

- 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



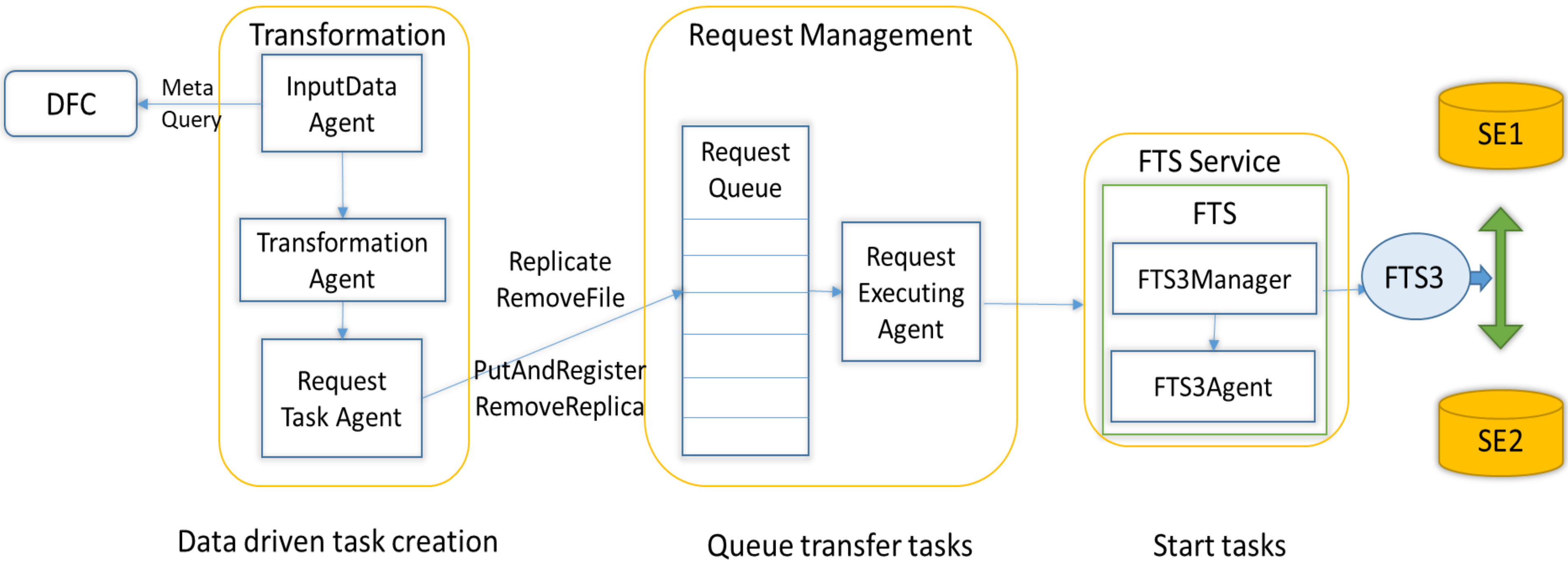
Data driven task creation

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

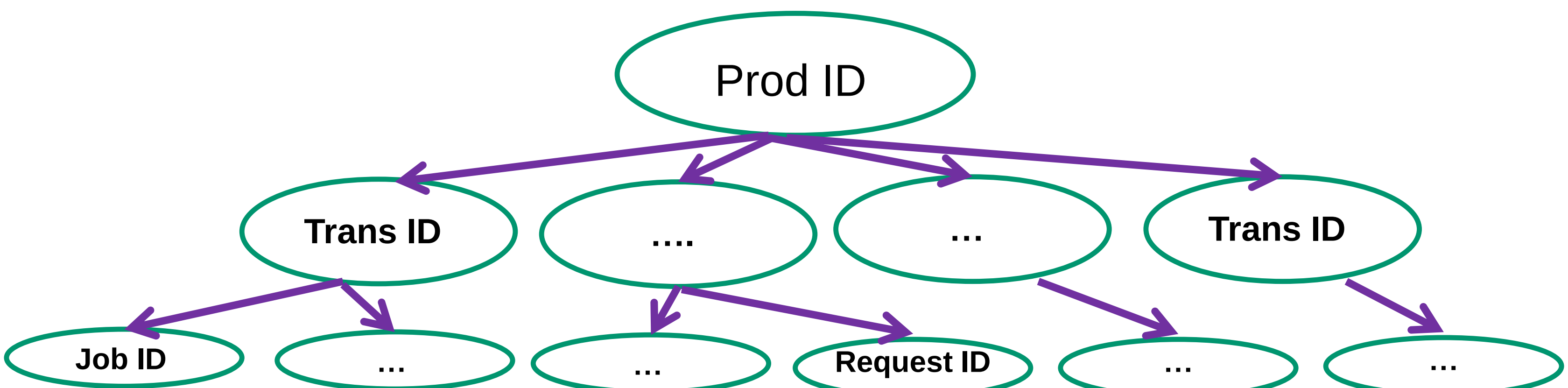
- General parameters
  - Defines in **[All]**
  - Includes Software version, TargetSE, OutputDir, Sites, ProdName…
- Special parameters for physics processes required
  - An example **[Chain]** allows users to generate particles with momenta
    - *Detsim_mode* uses *gun*
    - The particles and momentums info got from *tags*
    - *Tags* allow multi production tasks
  - Other processes support, eg.
    - **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

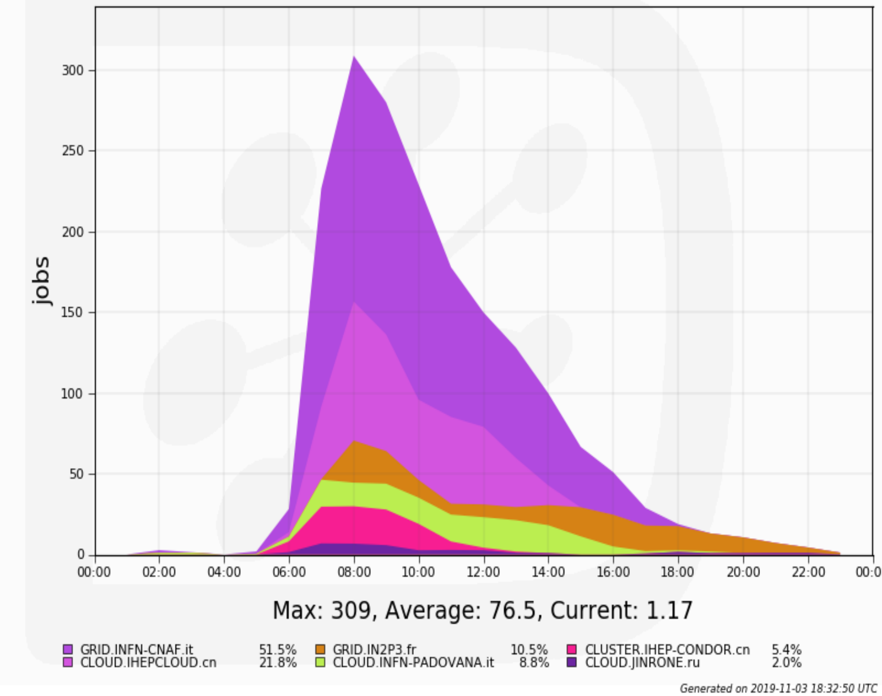
- Single command to issue production tasks
  - ihepdirac-juno-make-productions.py –ini <steering file>
  - Return <production ID>
- Monitor and control production tasks with <production ID>
  - Each production ID linked with the related workflow and dataflow transID
  - Each transID linked with JobID and RequestID for real jobs and transfers

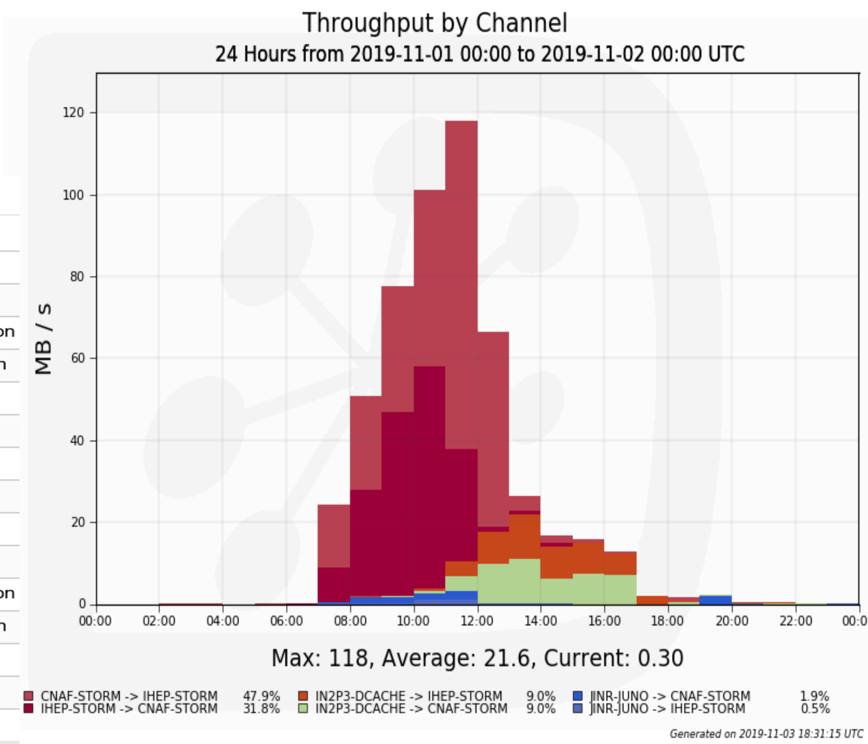


Tests

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

ID		Type	Name
Request: 0			
360		Replication-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_6.469MeV-rec-Replication
359		Replication-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_6.469MeV-calib-Replication
358		Replication-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_6.469MeV-elecsim-Replication
357		Replication-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_6.469MeV-detsim-Replication
356		DataReconstruction-JU…	JUNOProdTest_new-J17v1r1-Positron05-e+_6.469MeV-rec
355		Calibration-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_6.469MeV-calib
354		ElecSimulation-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_6.469MeV-elecsim
353		MCSimulation-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_6.469MeV-detsim
352		Replication-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_4.460MeV-rec-Replication
351		Replication-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_4.460MeV-calib-Replication
350		Replication-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_4.460MeV-elecsim-Replication
349		Replication-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_4.460MeV-detsim-Replication
348		DataReconstruction-JU…	JUNOProdTest_new-J17v1r1-Positron05-e+_4.460MeV-rec
347		Calibration-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_4.460MeV-calib
346		ElecSimulation-JUNO	JUNOProdTest_new-J17v1r1-Positron05-e+_4.460MeV-elecsim





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