Jinagmen Undeground Neutrino Observatory

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JUNO & INFN – Catania

ISGC 2024

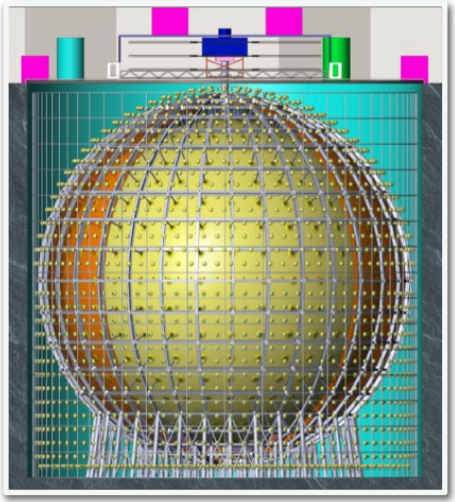
Taipei, March 27°, 2024

A large LS spherical detector

- **LS large volume:** ➔ **for statistics**
- **High Light yield and transparency** ➔ **for energy resolution 1200 pe/MeV**

Steel Truss
Holding PMTS
~20000 x 20”
~25000 x 3”

Acrylic Sphere
filled with 20 kton
of liquid scintillator



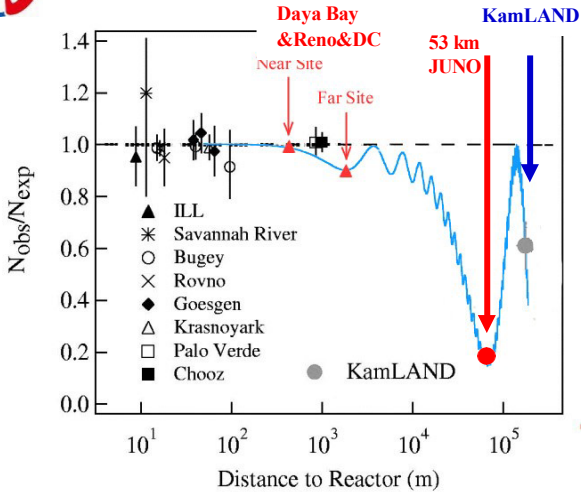
JUNO has been approved in February 2013

Approved funding from several countries:

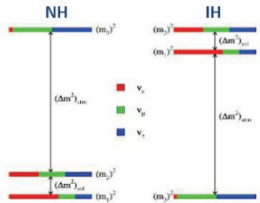
- Armenia
- Belgium
- Brazil
- Chile
- Czech Republic
- Finland
- France
- Germany
- Italy
- Pakistan
- People’s Republic of China
- Russia
- Slovakia
- Taiwan
- Thailand
- USA

74 institutes
> 700 collaborators

JUNO physics summary



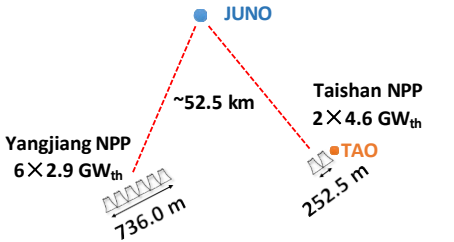
- **20 kton LS detector**
- **~3 % energy resolution-the greatest challenge for MH**
- Rich physics possibilities-neutrino oscillation and astroparticle program
  - ⇨ **Mass hierarchy**
  - ⇨ **Precision measurement of 3 mixing parameters Δm^2_{atm} Δm^2_{sol} θ_{12}**
  - ⇨ **Supernova neutrinos**
  - ⇨ **Diffuse supernova background**
  - ⇨ **Geo-neutrinos**
  - ⇨ **Solar neutrinos**
  - ⇨ **Atmospheric neutrinos**
  - ⇨ **Nucleon Decay**
  - ⇨ **Exotic searches**

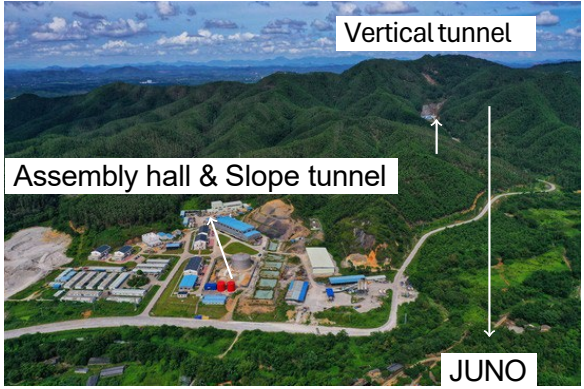


Background challenge especially for solar neutrinos - target range 10^{-15} (minimum requirement) 10^{-17} (ideal) g/g of U and Th

Neutrino Physics with JUNO, J. Phys. G 43, 030401 (2016)
JUNO physics and detector, Progress in Particle and Nuclear Physics 123, 103927 (2022)

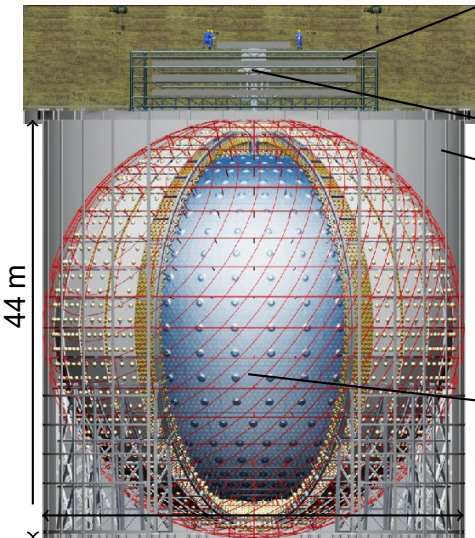
JUNO geometry and site





- **Civil construction finished: 12/2021**

The JUNO detector



Top Tracker (TT)

- Precise μ tracker
- 3 layers of plastic scintillator
- $\sim$ 60% of area above WCD

Calibration House

Water Cherenkov Detector (WCD)

- 35 kton ultra-pure water
- 2.4k 20” PMTs
- High μ detection efficiency
- Protects CD from external radioactivity & neutrons from cosmic-rays

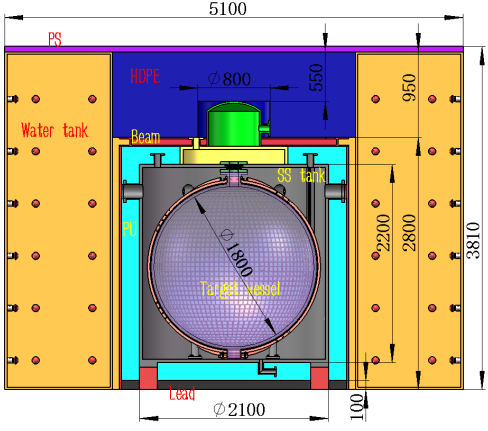
Central Detector (CD) $\bar{\nu}$ target

- Acrylic sphere with 20 kton liquid scint.
- 17.6k 20” PMTs + 25.6k 3” PMTs
- 3% energy resolution @ 1 MeV

JUNO-Tao

To measure the reactor neutrino spectrum as a reference to JUNO

- Sensitive to fine structure, reference spectrum with less uncertainties
- Improvement for nuclear databases
- Sterile neutrino searches



Idea: Gd-loaded LS @-50°C + SiPM

- 700k/year@44m from the core(4.6 GW), with 10% bkg.
- Energy resolution: ~1.5%/√E, 4500 p.e./MeV
- 10 m^2 SiPM (>94% coverage) w/ PDE > 50%
- Operating at -50 °C to reduce the SiPM dark rate by 10^3 to 100 Hz/mm^2
- 2.8 ton(1t fiducial volume) new type of Gd-LS for -50 °C

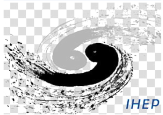
Component production mostly completed

Data volumes, computational requirements

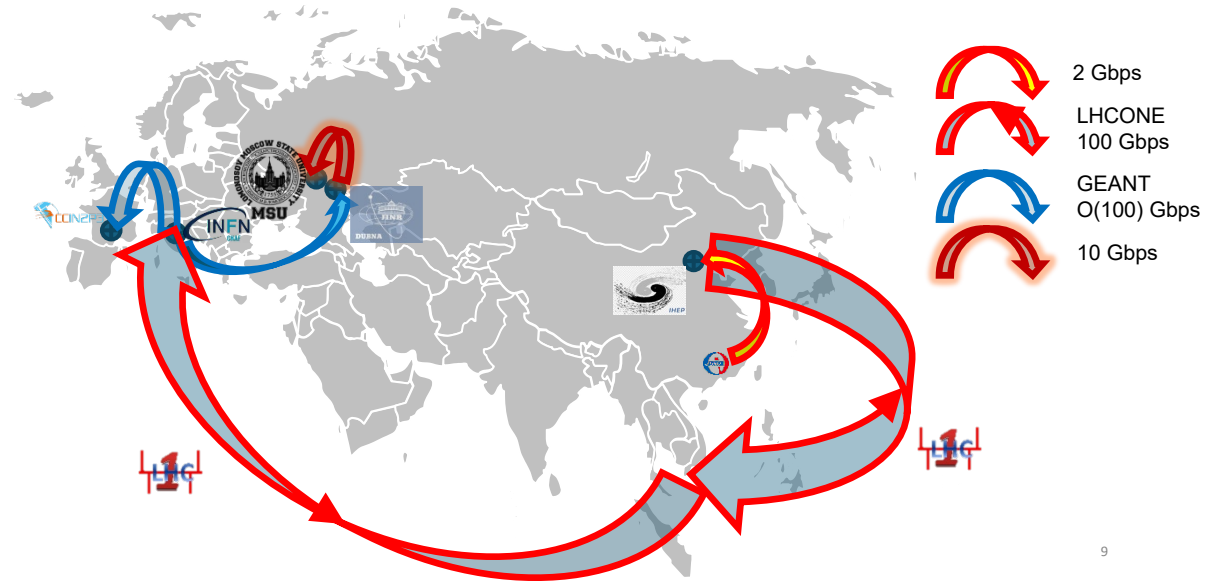
Estimated Raw data production	60 MB/s ↔ 2PB/year
Estimated other data (reconstructed, calibration, analysed)	1.0 PB/year
Bandwidth required to copy 3 PB in 1 year	0.8 Gbps

- 1 event reconstruction goal: 5s with a 18 HS06 core
- Rate: 1kHz
- Reconstruct 1 year data in 1 year then requires about 120 kHS06, or about 155 kHS23.

JUNO Data Centres

	Role	Foreseen in 2024		
		CPU (kHS06)	Disk (PB)	Tape (TB)
	T0: next to JUNO site, collect all data, DQM, first reconstruction	180	8.0	4.0
	T1: 1/3 of data, computing power	15	0.2	2.0
	T1: full data, computing power	20	3.0	1.0
	T1: full data, computing power	120	10.0	10.0
	T2: no data, computing power; not yet on line			
Totals		335	21.2	17.0

International networks



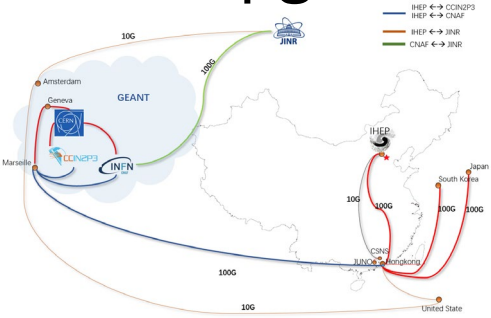
IHEP International Network Upgraded

The international link of IHEP has been upgraded to 100Gbps from 20Gbps since 22nd Sept, 2023

- Shared with other organizations
- IHEP is the main user of the link

Network Test

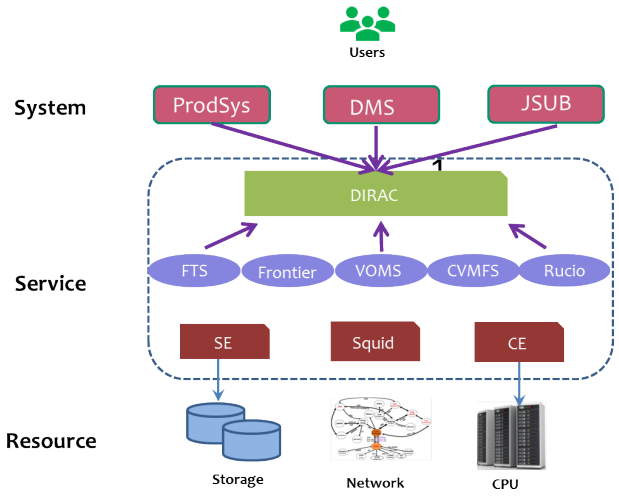
- The network connections among IHEP, CCIN2P3, CNAF are good
  - Test shows the both performance and latency are satisfied
- The network bandwidth from IHEP to JINR keeps 10Gbps
  - IHEP connects with JINR via 100G link is not supported
  - The solution of data transfer with better performance from IHEP to JINR is still under discussion



International Network Connection of IHEP

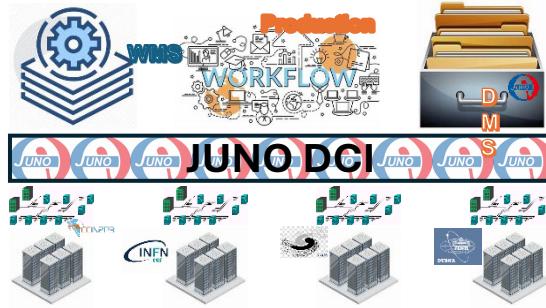
Traffic of the International Network Test

DCI Architecture



JUNO Distributed Computing Infrastructure

- JUNO DCI is made up of data network, data centres, with their local services, and some global services. Based on WLCG



Grid services at sites

- Batch system (HTCondor)
- Storage system and Storage Element
  - IHEP, JINR: EOS
  - CC-IN2P3: dCache
  - CNAF: STORM
- Tape systems
- Local monitoring

Specific tools

- JSUB: users' submit tool
- ProdSys: production submit tool

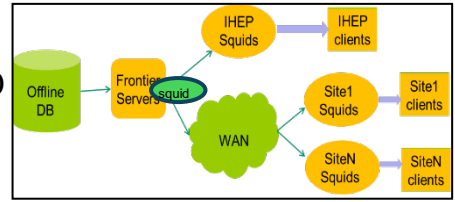
Grid global services

- VOMS, IAM
- CVMFS
- DIRAC (DMS, WMS, monitoring, accounting, ...)
- FTS
- System support

Other features

- Multi threading jobs
- IPv6 ready

Access Condition DB with Frontier/Squid 1/2



- Frontier/Squid is used for access to JUNO offline Condition DB
  - Multi-layer squids to cache DB query results
  - Avoid high load to central DB in case of massive parallel access
- Frontier server deployed in IHEP and squids spread in every data center
  - Frontier server holds frontier and central squid
  - Each site has one or several squids and info is collected in DIRAC
  - Jobs access Condition data through site squids which request to Frontier server only when no hits

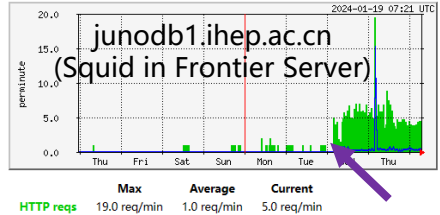
Access Condition DB with Frontier/Squid 2/2

In recent offline data challenges, squid monitoring show 99% traffic reduced to the central DB

- Central squid: junodb1.ihep.ac.cn
  - <5 req/min to frontier server during tests
- Site squid: junosquid01.ihep.ac.cn
  - Average 13 req/min to central squids
  - Average 700 req/min from clients

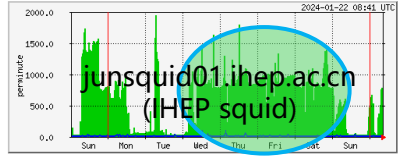
- HTTP reqs means the requests from clients to squid.
- HTTP fetches means from squid to frontier.

`Weekly' Graph (30 Minute Average)



	Max	Average	Current
HTTP reqs	19.0 req/min	1.0 req/min	5.0 req/min
HTTP fetches	15.0 req/min	0.0 req/min	0.0 req/min

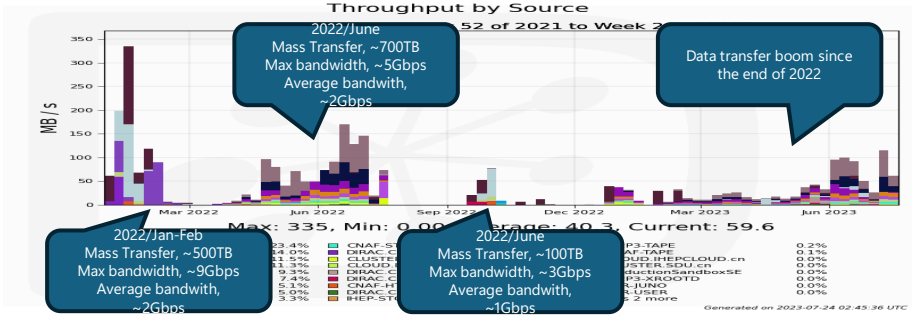
`Weekly' Graph (30 Minute Average)



	Max	Average	Current
HTTP reqs	1941.0 req/min	623.0 req/min	694.0 req/min
HTTP fetches	97.0 req/min	13.0 req/min	12.0 req/min

Challenge History

- 2 formal data challenges before bandwidth upgrades (August 2023)
  - Mar 2022, the 1st round, Dec 2023, the 2nd round
- Data challenge with upgraded bandwidth and new monitoring after bandwidth upgrades.
  - Jan-Feb 2024.
- Several informal data transfers before 2023



Challenge Methodology

Network bandwidth test

- Tools: Iperf3.
- Between each 2 sites among [IHEP, CNAF, IN2P3, JINR].
- Aim to realize the network connection status between each sites.

Mimic DCI data transfer

- Tools: Gfal2, FTS3, DIRAC-DMS.
- In first 2 rounds, between each 2 sites among [IHEP, CNAF, IN2P3, JINR] with 10 Gbps bandwidth.
- In 2024 data challenge, between IHEP and [CNAF, IN2P3, JINR] with improved bandwidth.

Data injection tools development,

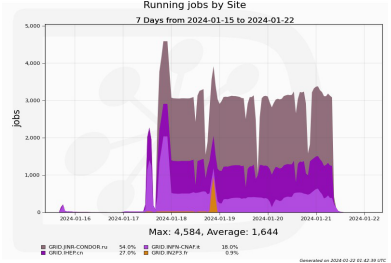
- Developed for data challenge in Feb 2024.

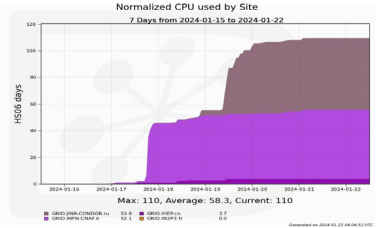
Monitoring and visualization

- Before 2024, monitoring based on FTS3 and DIRAC-DMS monitoring tools,
- New monitoring system based on Grafana developed since 2024.

DC-1 – large scale test

- The test started from Jan 17 (4 days) when all the data is ready in DCI
  - JUNO SW version: J23.1.0-rc8.dc1
  - Input data: {"Type":"RTRAW"}, ~100K files
- The re-reco system generated and assigned jobs to sites with input data
  - fulfill site available CPU resource
- Total ~100K jobs, 110HS06 days
  - Average cores used: 3200
    - JINR: ~1900 cores
    - IHEP: ~900 cores
    - CNAF: ~400 cores （ peak:1800)
    - CC-IN2P3: too few jobs due to only partial data stored there
  - Peak cores can reach 4584





DC-1 – large scale test

- Total success rate is 99.9%
  - 0.1% failed mainly because of memory congestion
  - Success rate in the same level as what was in local cluster
  - failed jobs can be completed after rescheduled
- All output data is successfully transferred to target SEs (25TB)
  - One copy in CNAF, JINR, IHEP SE

```
FC:/juno/data/rec/dc1-100K-01>size -l
directory: /juno/data/rec/dc1-100K-01
Logical Size: 12,788,078,767,816 Files: 100800 Directories: 16

   StorageElement Size                Replicas
================================================
 1 CNAF-STORM     12,787,005,175,330   100791
 2 IN2P3-DCACHE      105,748,910,641      841
 3 JINR-EOS       12,787,415,728,441   100794
 4 IHEP-JUNOEOS   12,786,452,456,446   100786
   Total          38,466,622,270,858   303212
------------------------------------------------
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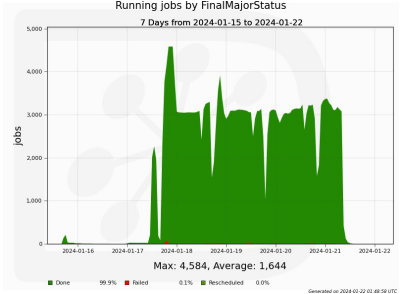
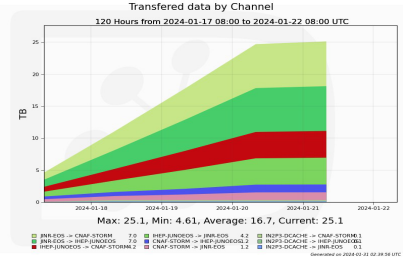
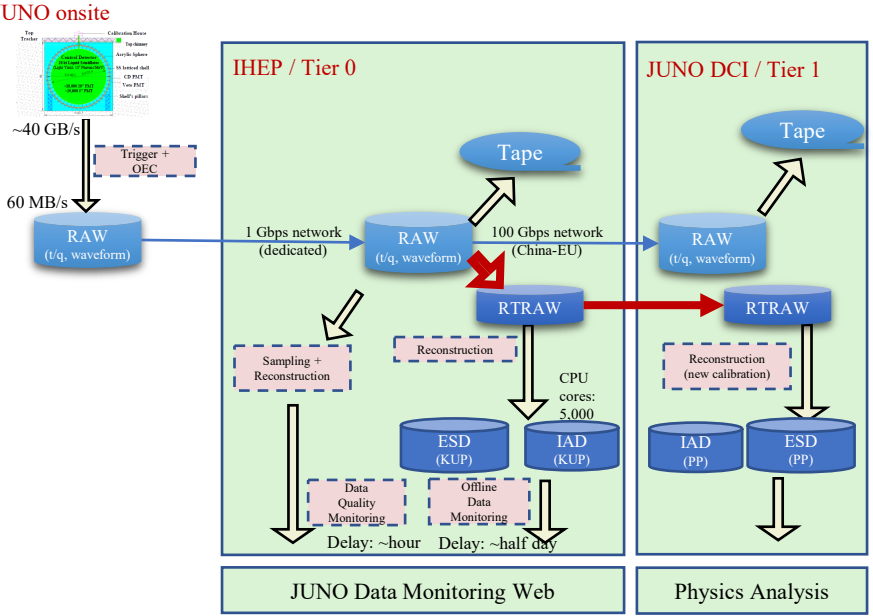


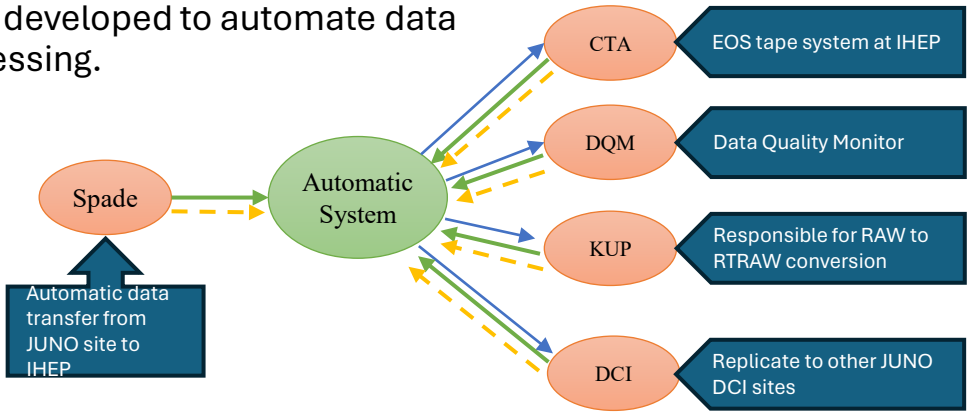


Data flow


JUNO onsite
~40 GB/s
Trigger + OEC
60 MB/s
RAW
(t/q, waveform)
IHEP / Tier 0
1 Gbps network
(dedicated)
RAW
(t/q, waveform)
Tape
100 Gbps network
(China-EU)
RTRAW
Sampling + Reconstruction
Reconstruction
CPU cores: 5,000
ESD
(KUP)
IAD
(KUP)
Data Quality Monitoring
Offline Data Monitoring
Delay: ~hour
Delay: ~half day
JUNO DCI / Tier 1
Tape
RAW
(t/q, waveform)
RTRAW
Reconstruction
(new calibration)
IAD
(PP)
ESD
(PP)
JUNO Data Monitoring Web
Physics Analysis

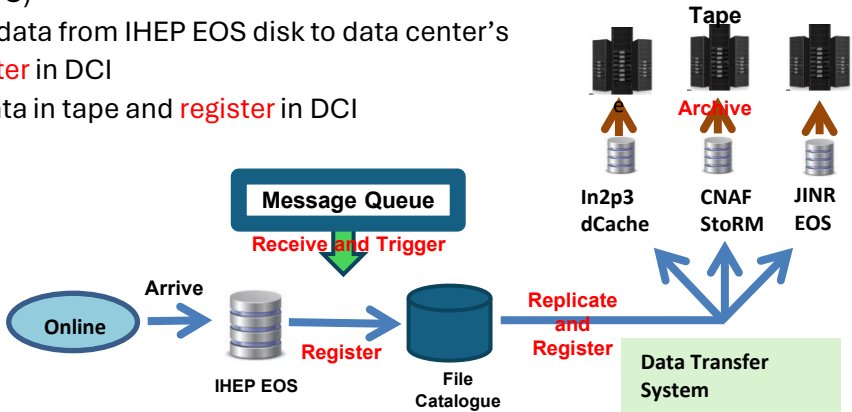
Automated Data Processing Pipeline

Kafka-based message system had been developed to automate data processing.



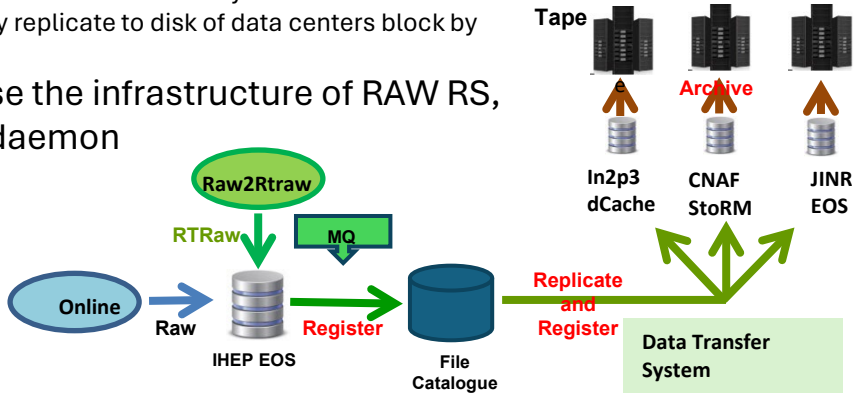
Raw data flow in DCI

- Receive **RAW** and **RTRAW** from Message Queue when data arriving at EOS which trigger the DCI transfer process
- Register data from IHEP EOS disk in DCI File Catalogue (DFC)
- Replicate data from IHEP EOS disk to data center's disk and register in DCI
- Archive data in tape and register in DCI



RTRAW Replication System (RS)

- Replicate RTRAW to three data centers
  - Accept RTRAW file info from MQ when RTRAW is produced from data production group
  - Register files into DFC and classify them into blocks
  - Automatically replicate to disk of data centers block by block
- RTRAW RS reuse the infrastructure of RAW RS, but in different daemon



IAM

- INDIGO IDENTITY and ACCESS MANAGEMENT service, developed and maintained at CNAF
- JUNO IAM instance up and running
- Both storage (davs) and computing resources (HTCondor) can be contacted using tokens…
- … but DIRAC is not yet fully supporting tokens
- Enabled VOMS on IAM, working on periodic usage of VOMS importer migration script, to use IAM as VOMS in a smooth transition to tokens
- Preparing to switch to tokens once DIRAC fully support them

Summary

- JUNO is a challenging experiment, gong to take data next year
- Data volume requires to make use of distributed computing
- JUNO Distributed Computing Infrastructure (DCI) is up and running, based on consolidated technologies already in use in HEP