Jiangmen Underground Neutrino Observatory computing requirements and infrastructure

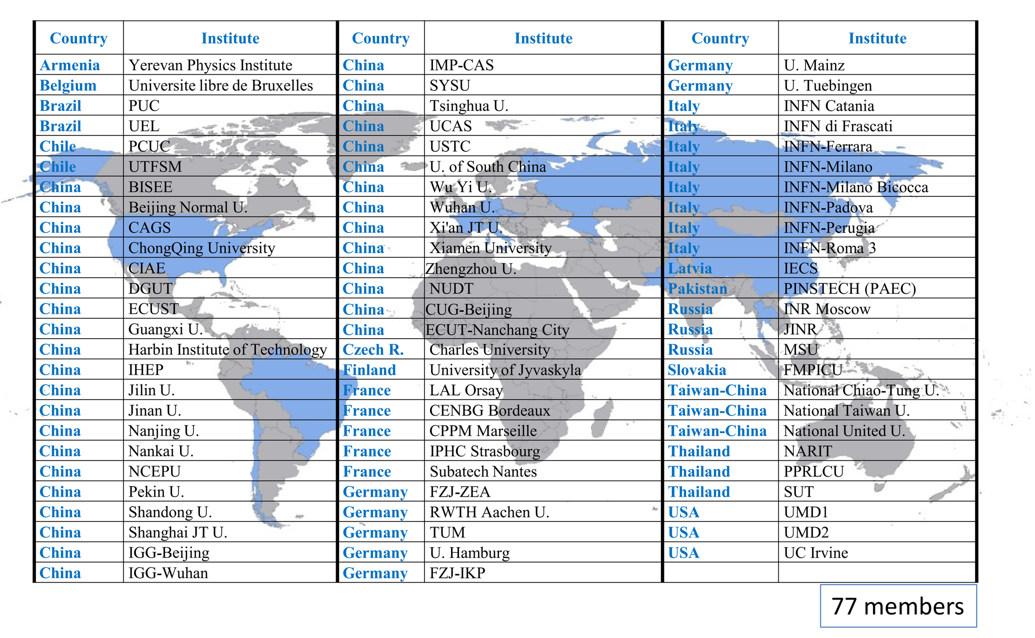
Giuseppe Andronico[1] *, Weidong Li[2] *, Xiaomei Zhang[2]

[1]INFN - Sezione di Catania, IT; [2]IHEP, CN

Correspondence to: giuseppe.andronico@ct.infn.it, liwd@ihep.ac.cn, zhangxm@ihep.ac.cn

The Jiangmen Underground Neutrino Observatory (JUNO) is an underground 20 kton liquid scintillator detector being built in the south of China and expected to start data taking in late 2021. The JUNO physics program is focused on exploring neutrino properties, by means of electron anti-neutrinos emitted from two nuclear power complexes at a baseline of about 53 km. Targeting an unprecedented relative energy resolution of 3% at 1 MeV, JUNO will be able to study neutrino oscillation phenomena and determine neutrino mass ordering with a statistical significance of 3-4 sigma within six years running time. These physics challenges are addressed by a large Collaboration localized in three continents. Different groups of the Collaboration, as simulation and offline groups, have started the evaluation of the requirements of the experiment for computing and the related resources. In this context, key to the success of JUNO will be the realization of a distributed computing infrastructure, which will satisfy its predicted computing needs. Upon its establishment, it is expected to deliver not less than 2 PB of data per year, to be stored in at least four data centers in China and Europe. Data analysis activities will be distributed in a joint effort. This contribution is meant to report how the JUNO computing infrastructure is going to be designed and which will be its main characteristics.

JUNO experiment



Country	Institute	Country	Institute	Country	Institute
Armenia	Yerevan Physics Institute	China	IMP-CAS	Germany	U. Mainz
Belgium	Universite libre de Bruxelles	China	SYSU	Germany	U. Tuebingen
Brazil	PUC	China	Tsinghua U.	Italy	INFN Catania
Brazil	UEL	China	UCAS	Italy	INFN di Frascati
Chile	PCUC	China	USTC	Italy	INFN-Ferrara
Chile	UTFSM	China	U. of South China	Italy	INFN-Milano
China	BISEE	China	Wu Yi U.	Italy	INFN-Milano Bicocca
China	Beijing Normal U.	China	Wuhan U.	Italy	INFN-Padova
China	CAGS	China	Xi'an JT U.	Italy	INFN-Perugia
China	ChongQing University	China	Xiamen University	Italy	INFN-Roma 3
China	CIAE	China	Zhengzhou U.	Latvia	IECS
China	DGUT	China	NUDT	Pakistan	PINSTECH (PAEC)
China	ECUST	China	CUG-Beijing	Russia	INR Moscow
China	Guangxi U.	China	ECUT-Nanchang City	Russia	JINR
China	Harbin Institute of Technology	Czech R.	Charles University	Russia	MSU
China	IHEP	Finland	University of Jyvaskyla	Slovakia	FMPICU
China	Jilin U.	France	LAL Orsay	Taiwan-China	National Chiao-Tung U.
China	Jinan U.	France	CENBG Bordeaux	Taiwan-China	National Taiwan U.
China	Nanjing U.	France	CPPM Marseille	Taiwan-China	National United U.
China	Nankai U.	France	IPHC Strasbourg	Thailand	NARIT
China	NCEPU	France	Subatech Nantes	Thailand	PPRLCU
China	Pekin U.	Germany	FZJ-ZEA	Thailand	SUT
China	Shandong U.	Germany	RWTH Aachen U.	USA	UMD1
China	Shanghai JT U.	Germany	TUM	USA	UMD2
China	IGG-Beijing	Germany	U. Hamburg	USA	UC Irvine
China	IGG-Wuhan	Germany	FZJ-IKP		

Figure 1 JUNO collaboration. Current composition of JUNO collaboration.

The JUNO collaboration is quite large and cover several continents. In Fig. 1 a map of collaboration and a list of institutions participating.

The collaboration is formed from several groups, working on different aspects of the challenging experiment, and interacting between them. In Table 1 a simplified summary, able to put in evidence the components of the experiment producing data to be analyzed.

	Description	Data producer
Central detector	Design, material choice, optimization, deployment	No
Veto detector	Set of detectors to exclude uninteresting signals	No
Liquid scintillator	Design, production and management of liquid scintillator	No
Calibration system	JUNO calibration system, several sources, mechanical part design and implementation	Yes
Large PMT Electronics	Design, test and production of LPMT and electronics Wait trigger signal to write to disk	Yes
Small PMT system	Design, test and production of SPMT and electronics Wait trigger signal to write to disk	Yes
Trigger	Select meaningfull physical events	No
Online event reconstruction	Reconstruct event from data passed trough the firewall and select events to write on disk	No
Offline	Framework, reconstruction, analysis, and all it is offline	No

Table 1 JUNO goups

Computing model

The starting point of our computing model is the amount of data produced from the experiment.

JUNO, as told by its name, is an observatory where several types of physics are studied. The main types of physics and the event rate expected in JUNO are summarized in Figure 2.

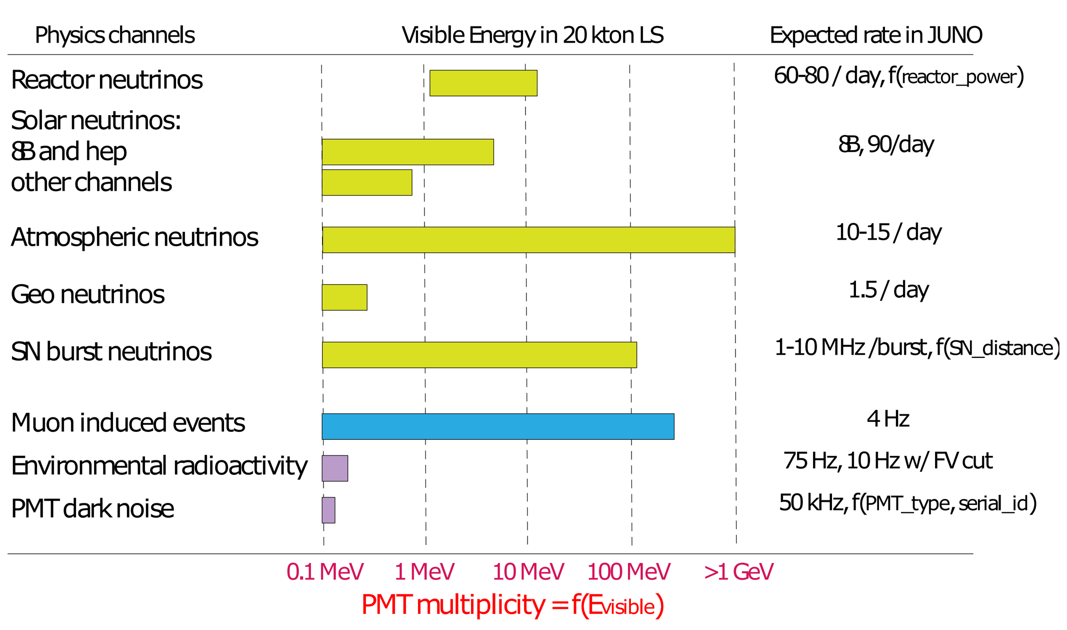


Figure 2 JUNO physics. Event rate for some physics activities. SN burst is just in case of supernova happening.

Correlating the expected events with both the expected JUNO behaviour and studies on reconstruction, it has been possible to estimate the needed data rate, as reported in Table 2.

Event type	Data size MB/s	Note
Vertex and time correlated	3	99.5% IBD, geo-nu, DSNB, ^{9}Li, fast-n, accidentals, etc,
Muon themselves	10?	> 100 MeV nucleon decays
Event following muons in 1 ms	12	Neutrons, accidentals, store fired PMTs
High energy isolated events	3	3.5 – 100 MeV, cosmogenic isotopes, Michel electrons, store fired PMTs
Medium/low energy isolated events 1	8	R < 16 m, 0.75-3.5 MeV, store fired PMTs
Medium/low energy isolated events 2	18	R > 16 m, 0.75-3.5 MeV
Minor energy	3	< 0.75 MeV, only store T/Q pairs
Total	54	No Huffman coding is required

Table 2 Event data rate. Data rate expected from JUNO.

Integrating this number over a period of 1 year, we have a bit less than 2 PB/year of data production. Similar consideration are available for calibration, reconstruction, simulation and analysis, as reported in Figure 3. In total, this means a yearly data production of the order of 3 PB. The estimated computing power to handle this amount of data is about 12,000 cores.

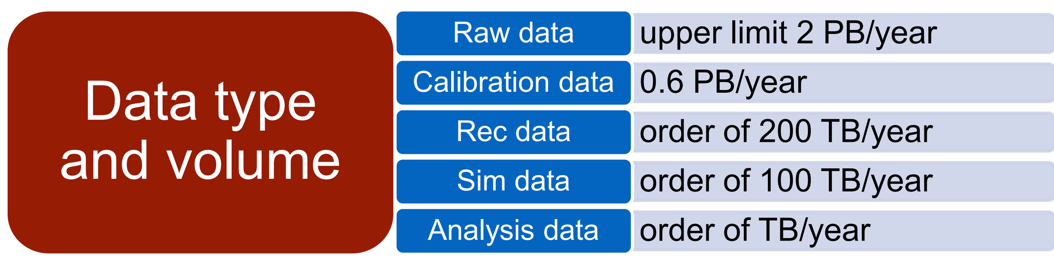


Figure 3 Data volume. Several items contributing to JUNO yearly data volume.

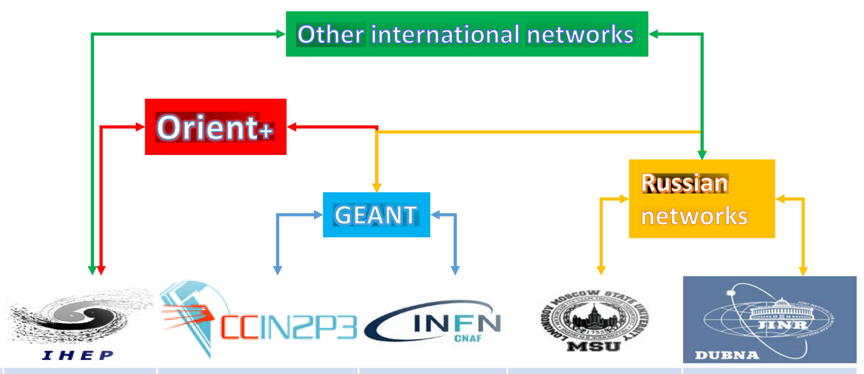
The data will be produced in Kaiping, the JUNO experimental site, transferred through a devoted network connection with 1 Gb/s bandwidth and to IHEP, in Beijing, where they will be stored. To ensure data safety at least a backup is required, and some European partners candidates to host it. Then, making use of international connection between National Research Networks, data are to be copied from IHEP to European data centers. It is required to have a file catalog and a book keeping system to keep trace of files copies.

Simulation, reconstruction and analysis are based on the software framework. The JUNO framework is based on standard libraries as ROOT, Geant4, CLHEP and on SNiPER [7], a software framework developed at IHEP.

Distributed infrastructure

Given the distributed nature of JUNO collaboration, it is quite natural to implement a distribute infrastructure to fulfill computing model. At the moment, the IHEP computing center is a sort of T0 for JUNO experiment, receiving directly the data from Kaiping, the JUNO experimental site.

Other 4 computing centers are available in Europe: CC-IN2P3 from France, INFN-CNAF from Italy, Moscow State University and the computing center at JINR, in Dubna. In Figure 4 are summarized details on the data centers participating.



Kaiping (JUNO)	1 Gb/s				
Generic	10 Gb/s	10 Gb/s	20 Gb/s	10 Gb/s	10 Gb/s
LHCOne	yes	Yes	100 Gb/s	Yes	10 Gb/s
DC Storage (PB)	5+15	70+30	80+33	n.a.	11+12
DC Computing (core)	18,000	38,000	40,000	n.a.	17,000
Storage (disk)	500 TB	8 TB	230 TB	60 TB	25 TB
cores	888	230	250	32	10

Figure 4 Data centers. Data centers participating in JUNO distributed infrastructure. In the table, the row in blue are relative to network, the line in green are relative to all data center, the data in orange are resources devoted to JUNO.

To share these resources and balance the load in order to form a distributed infrastructure, a set of services have to be chosen and a design developed. In Figure 5 a component view description of our design is reported.

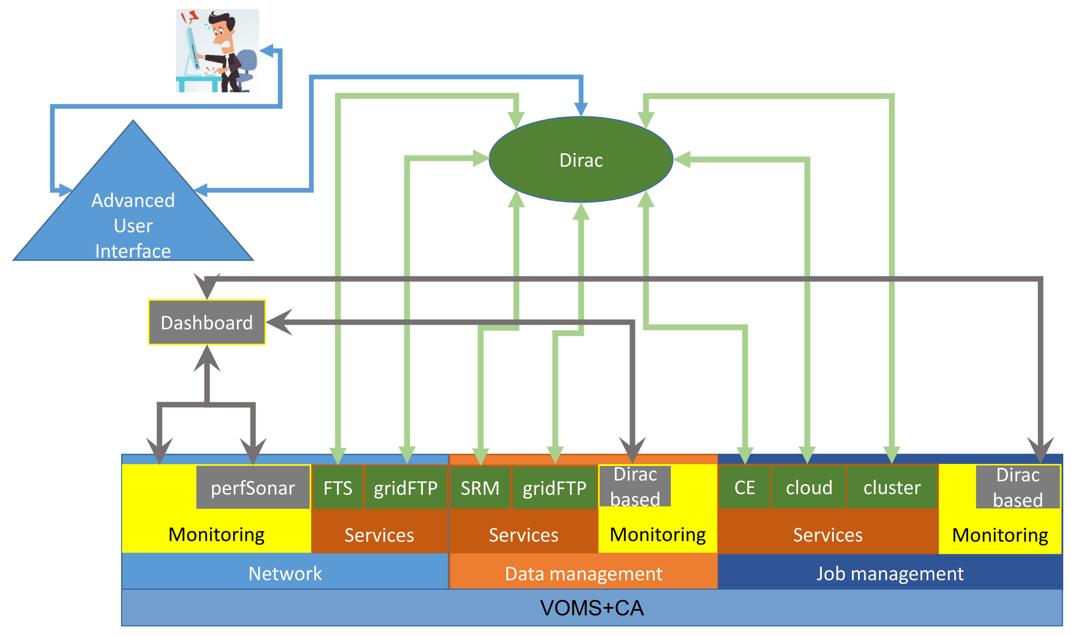


Figure 5 Distributed infrastructure simplified design. A simplified constituent block view of JUNO distributed infrastructure.

The basic requirement is to be able to identify and authorize users. In our design we rely on the standard solution of Virtual Organization (VO) and of Virtual Organization Membership Service (VOMS)[2], that make use of digital certificates issued from trusted Certification Authorities. In VOMS it is possible to define groups and roles to ensure that services and data are accessible only from allowed people.

To ensure that the infrastructure is working properly a monitoring system with a dashboard is needed. Of fundamental importance, to ensure distributed infrastructure is offering what promised, are the network connections between the sites. On top of this we can find the services to replicate and move data around: **1**. gridftp[5] an enhanced version of FTP enabling security and parallel streams; **2**. File Transfer Service (FTS)[3], able to handle file transfer requests and properly schedule them. What we want with the distributed infrastructure is to manage our data, replicate them around and analyze. This is done by means of the other two blocks in the design, Data management and Job management.

To distribute JUNO software the infrastructure relies on **CernVM File System** (CernVM-FS) [1], that provides a scalable, reliable and low-maintenance software distribution service. Data management interacts with the storage resources and implement the services, as the Storage Resource Manager, needed to manage the files, as to locate and retrieve copy of files.

Job management, instead, implements a set of services aimed at submitting jobs, as data analysis, and managing these jobs.

In JUNO design an important role is delegated to **Distributed Infrastructure with Remote Agent Control** (DIRAC) [6, 4], a software framework for distributed computing. In JUNO design, DIRAC provides user interface and both data management service, as File Catalog[1], and job management service.

Distributed infrastructure status

From January 2019, a working group was established. It is composed by JUNO members and representative of data centers involved to work on the distributed infrastructure design and implementation. Till today several parts were installed and tested:

monitoring perfSONAR installed and dashboard operational

VO JUNO VO created, VOMS installed and configurated, VOMS replica deployed

SRM data centers SRM configured for JUNO and some test data transfer already performed

job submission first test successfully performed.

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[1]File Catalog provides interface to locate files and their copies