I modelli di calcolo degli esperimenti JUNO e LHAASO

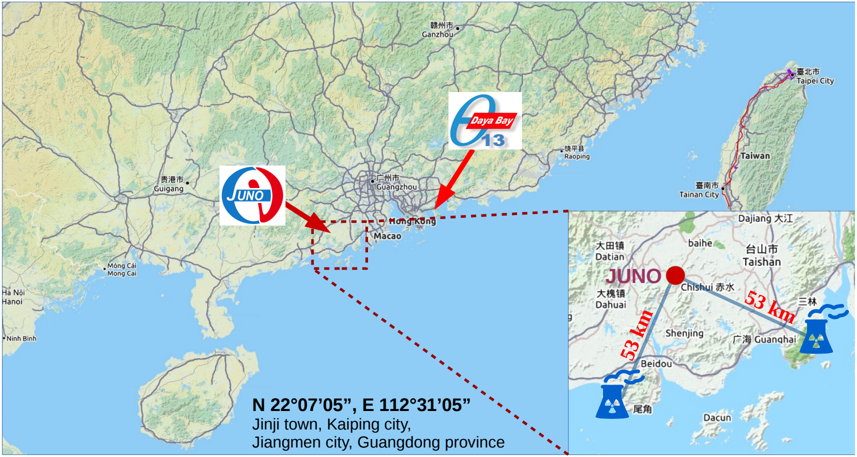
A. Garfagnini

Padova University and INFN

19 Maggio 2016

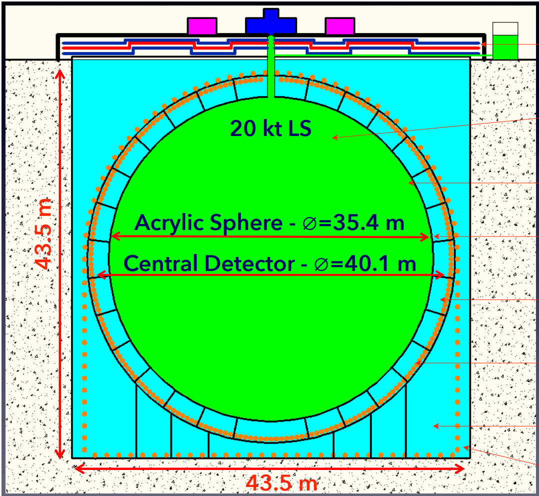
Jiangmen Underground Neutrino Observatory (JUNO)

- JUNO is a medium baseline reactor neutrino experiment
- JUNO will be the largest Liquid Scintillator detector ever built (20 ktons)



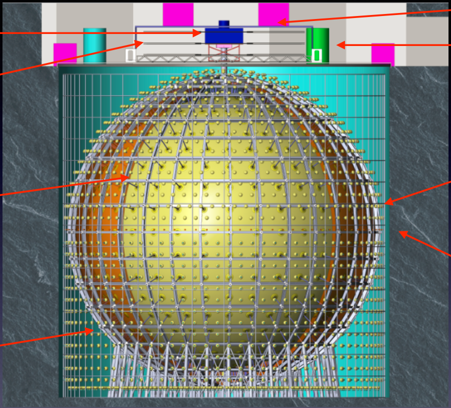
N 22°07’05”, E 112°31’05”
Jinji town, Kaiping city,
Jiangmen city, Guangdong province

JUNO Detector Design



- **Top muon veto:** plastic scintillator strips
- **LS:** 20 kton LAB based
- **LS container:** acrylic. The maximum stress should be <35 MPa.
- **Buffer:** water
- **PMTs:** 17000 20″ PMTs + 34000 3″ PMTS for a ~77.8% coverage
- **Buffer/PMT support:** Stainless steel structure
- **Water Cherenkov veto:** 20 kton water
- **PMTs:** 2000 20″ veto PMTs

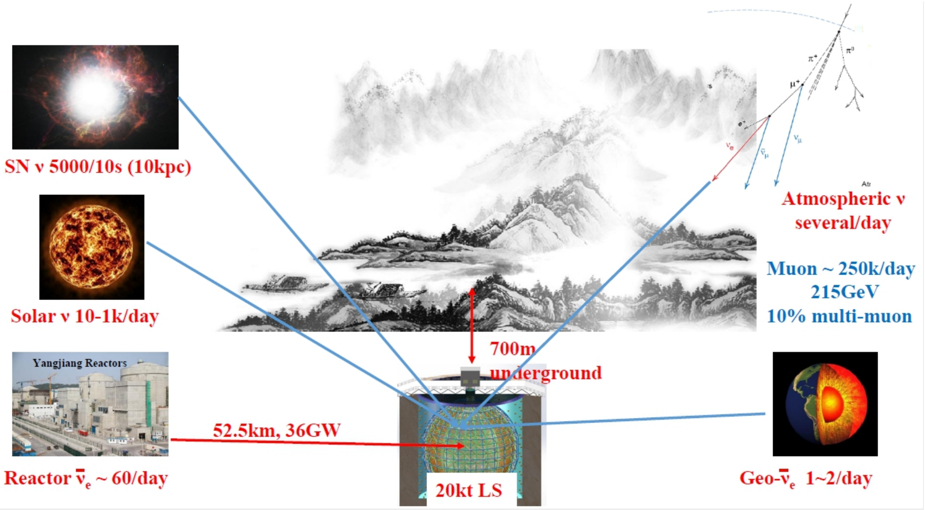
JUNO Detector Challenges



Experiment	Daya Bay	BOREXINO	KamLAND	JUNO
LS mass	20 ton	~300 ton	**~1 kton**	**20 kton**
Coverage	~12%	**~34%**	**~34%**	**~80%**
Energy resolution	~7.5%/√E	**~5%/√E**	~6%/√E	**~3%/√E**
Light yield	~ 160 p.e. / MeV	**~ 500 p.e. / MeV**	~ 250 p.e. / MeV	**~ 1200 p.e. / MeV**

JUNO Detector Physics Data Rates

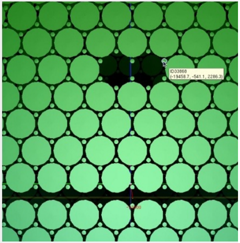
- JUNO has a rich neutrino physics program



JUNO Double Calorimetry Approach

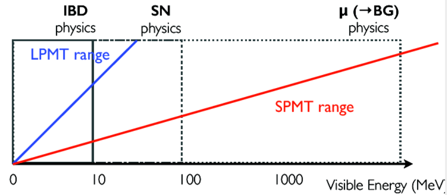
- **Small PMTs (SPMT):**
  → Cheaper, faster in time response (< 1ns), lower noise

- **Idea:**
  → Add 3″SPMTs in the gaps
  → ~ 2 SPMTs for every Large PMT (LPMT): ~ 37000 SPMTs



Why?

- Increase the photocathode coverage
- Improve the muon reconstruction in the central detector
- Pile-up in case of SN
- Increase the dynamic range

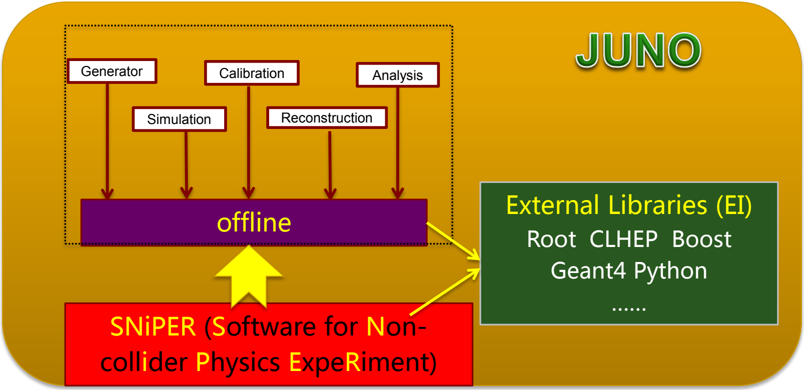


Offline Software Environments

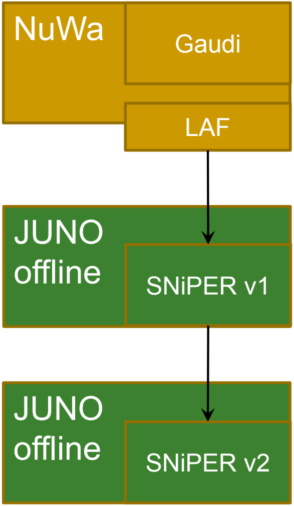
- Programming language: hybrid programming of C++ and Python
  - Very popular in HEP field
  - Most frequently used software is implemented in C++ (ROOT, Geant4 …)
- Job configuration interface: Python
  - Very flexible
  - Easy to glue different tools together (Job scheduling, Monitoring …)
- Packages management tool: CMT(Configuration Management Tool)
  - Help developers to compile packages easily
  - Help users to setup the environment for running the application easily
- Supported Operation System: Linux
  - Official recommendation: Scientific Linux 6
  - Some colleagues compile successfully on Ubuntu, Debian and Mac OS
- Codes Management: SVN
  - Keep the history of code evolution
  - Synchronization and sharing between developers
  - Tag and release

Overview of JUNO Offline Software

- SNiPER: the underlying Framework
- Offline: extension of SNiPER and applications for JUNO
- External Libraries(EI): very frequently used software and tools



The Evolution of JUNO Software



The offline software for Daya Bay Experiment

- NuWa: based on Gaudi (originally for LHCb)
- LAF: a Lightweight Analysis Framework (~ 2012)
  - Released in NuWa, but used as standalone app.
  - Used for physics analysis
  - Optimized for Dayabay Neutrino Experiment

The offline software for JUNO

- JUNO offline: based on SNiPER (~ 2013)
- SNiPER: Software for Non-collider Physics ExpeRiment
  - Plays the role of Gaudi in NuWa
  - v1 is mainly inherited from LAF
  - v2 is extended for specific requirements of JUNO

JUNO Data Rate and Flow

Data volume

– Raw data 2PB/year
– Rec data 200TB/year
– Sim data 20TB/year

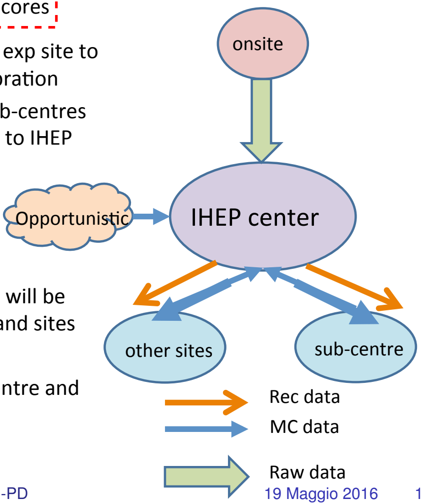
Basic requirements
Storage: 3PB disk
Computing: 12k CPU cores

Raw data transferred from JUNO exp site to IHEP for reconstruction and calibration

Monte Carlo data produced in sub-centres and sites will be transferred back to IHEP for backup

The whole Monte Carlo data sets will be copied and stored in sub-centre and sites

Data will be distributed to sub-centre and sites for analysis



The JUNO Computing Model

Onsite

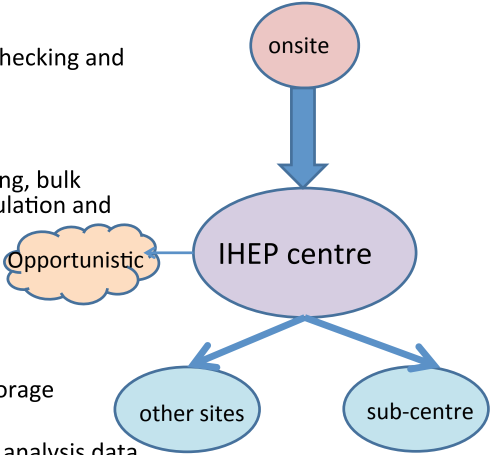
- Fast reconstruction for data quality checking and compression

IHEP as central centre

– Play major role for raw data processing, bulk reconstruction, also take care of simulation and analysis ….
– Hold Central storage for all the data
– Plan 10000 CPU cores, 3PB disk

European sub-centre

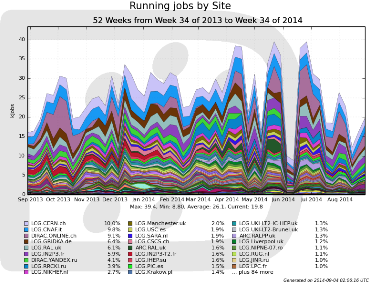
– Could be several sites with shared storage
– Mainly for simulation and analysis
– Hold storage for simulation data and analysis data
– Plan to hold 2000 CPU cores, 500TB disk

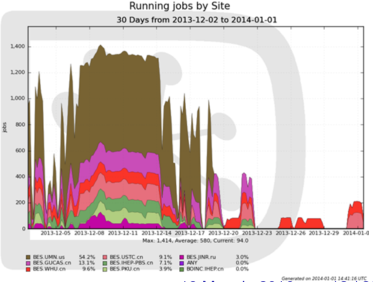


Opportunistic resources for supplement and Redundancy

DIRAC-based framework

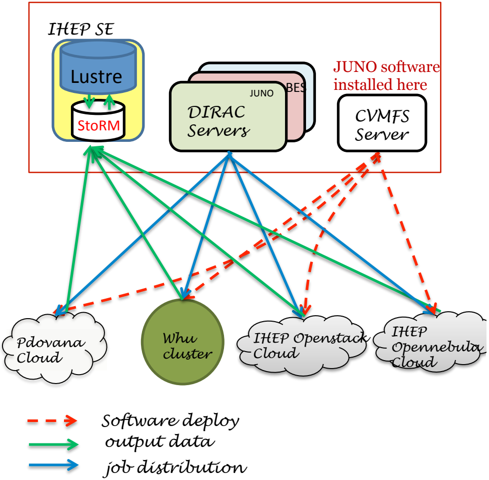
- Dirac is widely used by many HEP experiments
  - LHCb, BelleII, CTA, ILC, BESIII….
- It is proved by LHCb that the framework can deal with 40K jobs at the same time
- Also experience of BESIII distributed computing told us that
  - Easy to setup and customize according to experiment requirements
  - Extensible and reliable
  - Able to integrate various heterogeneous resources





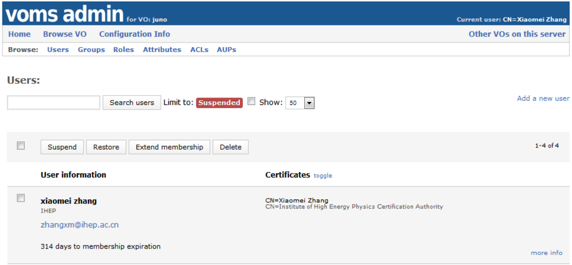
JUNO distributed computing prototype

- Prototype has been set up for JUNO distributed computing , reported during last workshop in Guangzhou
  - Authentication control
  - Software deployment
  - Task submission and management tool
  - Workload management
  - Data management
- Sites involved
  - Padovana **cloud**,
  - Whu **cluster**
  - IHEP **cloud**



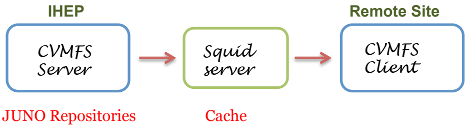
Authentication and Authorization

- Control access to JUNO distributed resources
- Grid certificate and VOMS (Virtual Organization Membership Service)
  - In VOMS, each experiment is mapped to one VO(Virtual Organization)
  - VOMS uses your grid certificate to authenticate you, and to authorize you for VO members
  - Only VO members are allowed to access resources belonged to this VO
- The JUNO VOMS service has been set up in IHEP
- To be a JUNO VO member, get your certificate and join JUNO VO
  - https://voms.ihep.ac.cn:8443/voms/juno



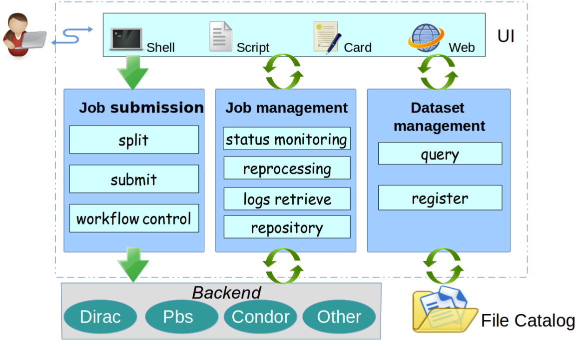
JUNO Software Deployment

- CVMFS: CERN Virtual Machine File System
  - A client-server file system with web servers for caching
  - Greatly simplify processes of remote deployment than tradition way
- Procedure of remote deployment of JUNO software
  - CVMFS server is set up in IHEP
  - JUNO software is installed and published in repositories of CVMFS server
  - CVMFS client is deployed in site work node
  - Local squid server is set up to fasten the same access
  - User in remote sites can find JUNO software in “/cvmfs/juno.ihep.ac.cn/”
  - Software is loaded only on access



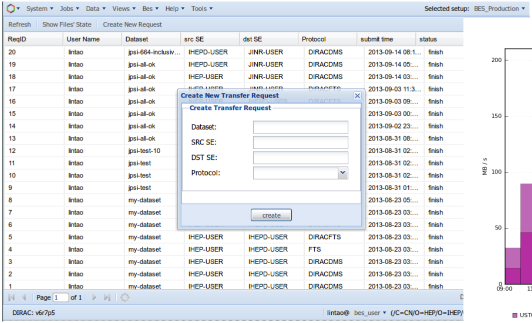
Task submission and management tool

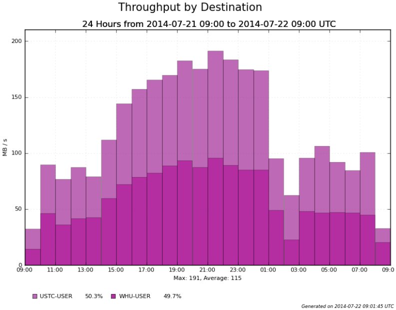
- A user frontend to submit and manage a group of jobs with same properties(Task)
  - Simply physics user experience of using heterogeneous backend
- A task submission and management tool is being developed for JUNO user



JUNO Data Transfer

- Dataset based data transfer system is needed to distribute MonteCarlo and Analysis data around centers and sites
- We has some experiences on data transfer system in BESIII





IHEP→USTC, WHU
@ 10.0 TB/day

Opticks: GPU optical photon simulation

Simon Blyth

- G4+Opticks Sim
  - Take steps info from G4
  - Photon generation & propagation in Opticks

winter 2014 (within *Chroma*)

- integrate G4DAE geometry exports
- generate Cerenkov/Scintillation photons on GPU

spring 2015 (start transition to *Opticks*)

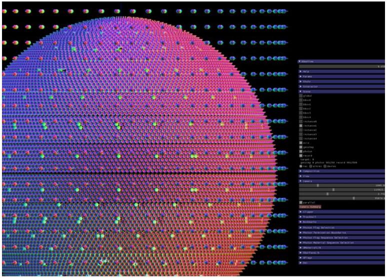
- decide lack of multi-GPU is showstopper for *Chroma*
- discover NVIDIA OptiX ray tracing framework
- create *Opticks* (using OptiX) to replace *Chroma*

summer/autumn 2015 (*Opticks* transition completed)

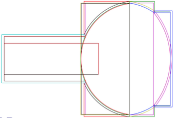
- infrastructure operational, G4 optical physics ported
- large geometry support added using instancing

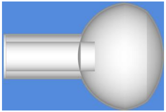
autumn/winter 2015 (Validations begin)

- major tesselation bug avoided with *OpenMesh*
- develop analytic PMT description
- validation machinery created *CfG4*



Geometry Instance Rendering Control



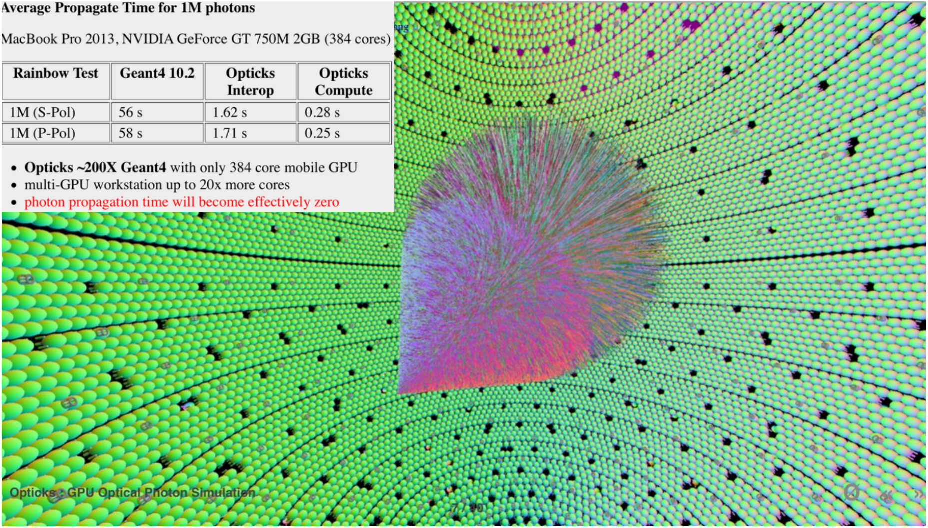


History of GUP optical Sim.

8

Opticks: GPU optical photon simulation

Simon Blyth



Average Propagate Time for 1M photons

MacBook Pro 2013, NVIDIA GeForce GT 750M 2GB (384 cores)

Rainbow Test	Geant4 10.2	Opticks Interop	Opticks Compute
1M (S-Pol)	56 s	1.62 s	0.28 s
1M (P-Pol)	58 s	1.71 s	0.25 s

- **Opticks ~200X Geant4** with only 384 core mobile GPU
- multi-GPU workstation up to 20x more cores
- photon propagation time will become effectively zero

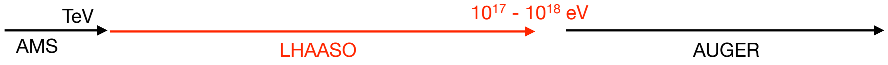
Major progresses have been made. Look forward to really using it in JUNO.

Why LHAASO ?

LHAASO will be the next generation ground-based experiment, capable of acting simultaneously as a Cosmic Ray Detector and a Gamma Ray Telescope.

✤ Cosmic Ray Physics ($10^{12} \rightarrow 10^{18}$ eV): precluded to Cherenkov Telescopes

- CR energy spectrum
- Elemental composition
- Anisotropy



✤ Gamma-Ray Astronomy ($10^{11} \rightarrow 10^{15}$ eV): full sky continuous monitoring

- *Below 20 TeV*: continuous monitoring of the Northern sky at < 0.01 of the Crab flux
→ Sky survey: complementarity with CTA

- *Above 20 TeV*: continuous monitoring of the Northern sky up to PeV with a sensitivity 2000x CTA for sky survey > 70 TeV→ search for PeV CR sources (*Pevatrons)*

The LHAASO experiment

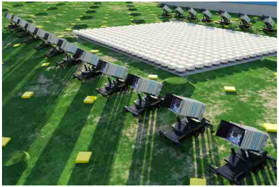
The Large High Altitude Air Shower Observatory (LHAASO) project is a new generation all-sky instrument to investigate the '*cosmic ray connection*' through a combined study of cosmic rays and gamma-rays in the wide energy range 10^{11} -- 10^{17} eV.

The first phase of LHAASO will consist of the following major components:

- 1 km^2 array (LHAASO-KM2A), including 5635 scintillator detectors, with 15 m spacing, for electromagnetic particle detection.
- An overlapping 1 km^2 array of 1221, 36 m^2 underground water Cherenkov tanks, with 30 m spacing, for muon detection (total sensitive area 40,000 m^2).
- A close-packed, surface water Cherenkov detector facility with a total area of 90,000 m^2 (LHAASO-WCDA), four times that of HAWC.
- 24 wide field-of-view air Cherenkov (and fluorescence) telescopes (LHAASO-WFCTA).
- 452 close-packed burst detectors, located near the centre of the array, for detection of high energy secondary particles in the shower core region (LHAASO-SCDA).

LHAASO main components

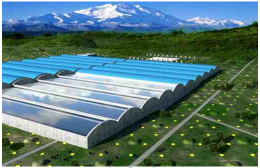
1 KM2A:
5635 EDs
1221 MDs



WFCTA:
24 telescopes
1024 pixels each

Coverage area: 1.3 km^2

WCDA:
3600 cells
90,000 m^2



SCDA:
452 detectors

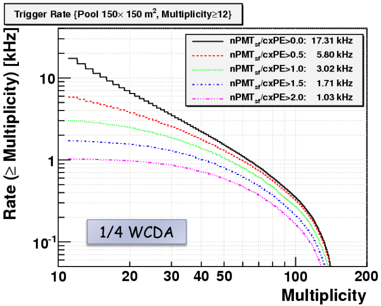
The LHAASO site

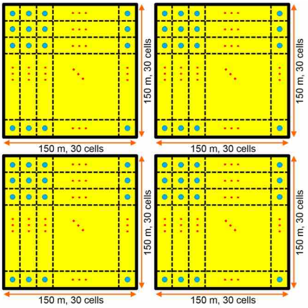
The experiment will be located at 4400 m asl (600 g/cm^2) in the Haizishan (Lakes' Mountain) site, Sichuan province

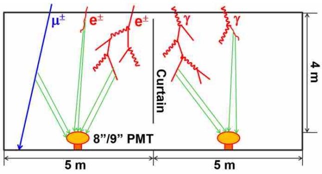
Coordinates: 29° 21' 31'', 100° 08' 15''

700 km to Chengdu
50 km to Daocheng City (3700 m asl, guest house !)
8 km to airport

Trigger Rate & Data Volume





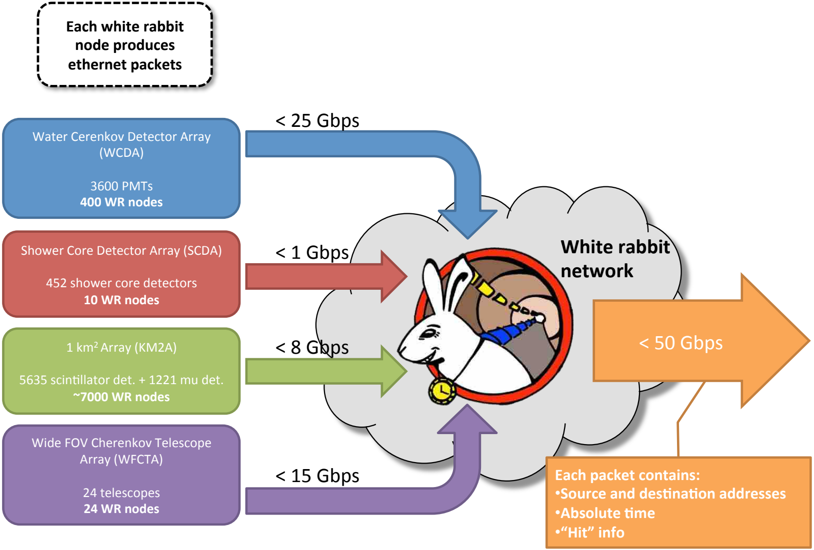


- ✦ Trigger rate:
  17 kHz × 4 ~ 70 kHz.

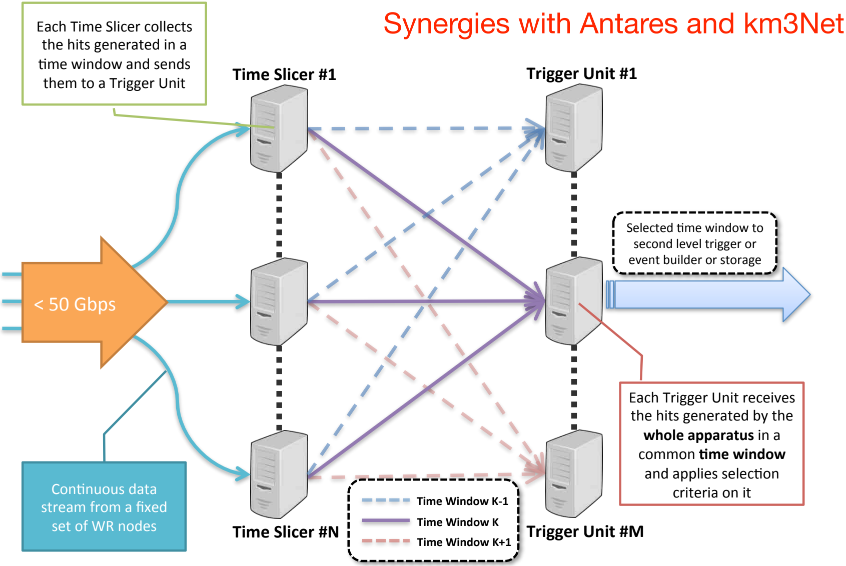
- ✦ DAQ raw input:
  100 bit/hit × 3600 hit × 50 kHz = 18 Gbps ~ 72 PB/yr.

- ✦ Data volume after a possible trigger:
  100 bit/hit × (70 + 50 kHz × 2000 ns × 3600) hit × 70 kHz = 3 Gbps ~ 12 PB/yr.

LHAASO: reference numbers



Time slicing mechanism

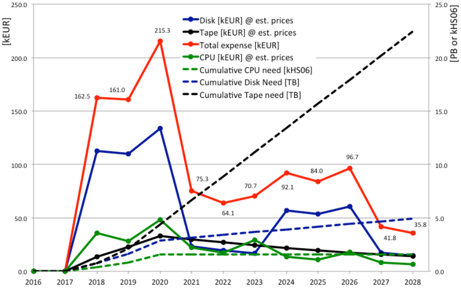


LHAASO Data Transfer Scenarios

✓ Three possible scenarios

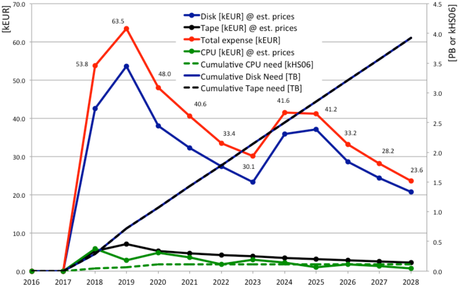
1. full raw data import
2. reconstructed data only import

Scenario 1



Overall requirements			**kEUR**
Disk	4.9	PB	620
Tape	22.5	PB	241
CPU	15.5	kHS06	239
Total			**1100**

Scenario 2 (preferred)



Overall requirements			**kEUR**
Disk	3.9	PB	364
Tape	3.9	PB	44
CPU	1.9	kHS06	29
Total			**437**

Acknowledgements

JUNO

- Weidong Li (IHEP)

LHAASO

- P. Di Sciascio (Roma2)
- P. Vallania (TO)
- S. Bagnasco (TO)