Circular Electron Positron Collider

高能所計算中心
IHEP Computing Center

# Design and Updates CEPC Computing Platform

Xiaowei Jiang
On behalf of CEPC computing team and IHEP-CC
November 10, 2025
The 2025 CEPC International Workshop

# Outline

# Overview

- Resource Estimation
  - With a disk-to-tape storage ratio of 1:1 and a CPU utilization rate of 80%, along with an additional 10% allocated for physics analysis requirements
- Estimation over the five-year period:

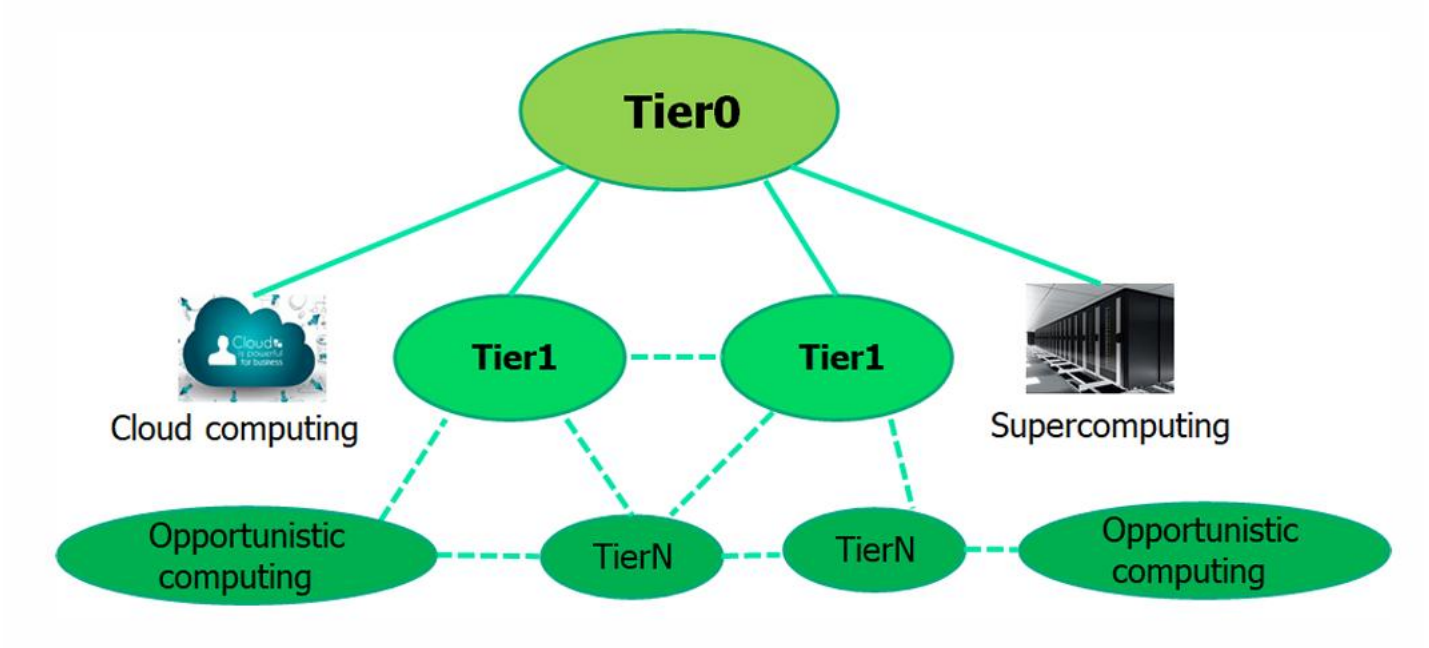
**Table 13.1:** Estimation of computational and storage resources

| Mode | Disk (PB) | Tape (PB) | CPU (kHS23) |
|---|---|---|---|
| Higgs | 40 | 40 | 220 |
| Low-lumi Z | 380 | 380 | 1,760 |
| Total | 420 | 420 | 1,980 |

- Distributed Computing Infrastructure(DCI)
  - Computing Model
  - Workload management system
  - Data management system
  - Opportunistic computing
  - Computing operations
- Open data
- Long term data preservation
- Resource provision
  - Computing
  - Storage
  - Network
  - Smart data center infrastructure

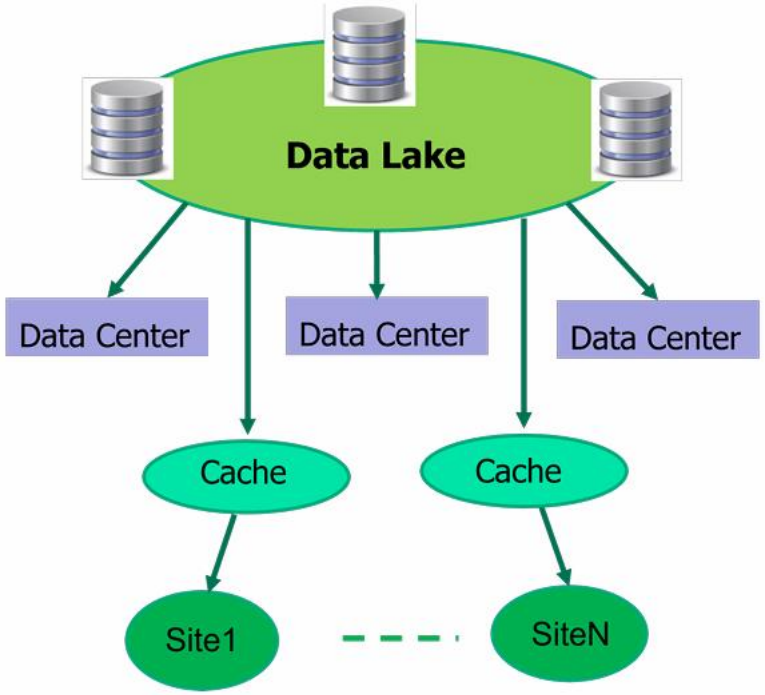
# DCI – Computing Model

- **Distributed computing paradigm and organizes resources in a hierarchy model**
  - **supercomputing centers, commercial cloud platforms, and other opportunistic sources**
  - **resource allocation, dynamic scheduling, job monitoring, and fault tolerance**
- **The example technologies: Dirac and PanDA**



# DCI – Data Model

- A central data storage architecture with a multi-tier caching system
  - Efficiently handle, store, retrieve, and manage large volumes of data across distributed resources
  - The central storage service will be geographically distributed across large data centers
  - Data will be delivered through a multi-tier caching system
- The example technologies: DIRAC DMS and Rucio



# Open Data

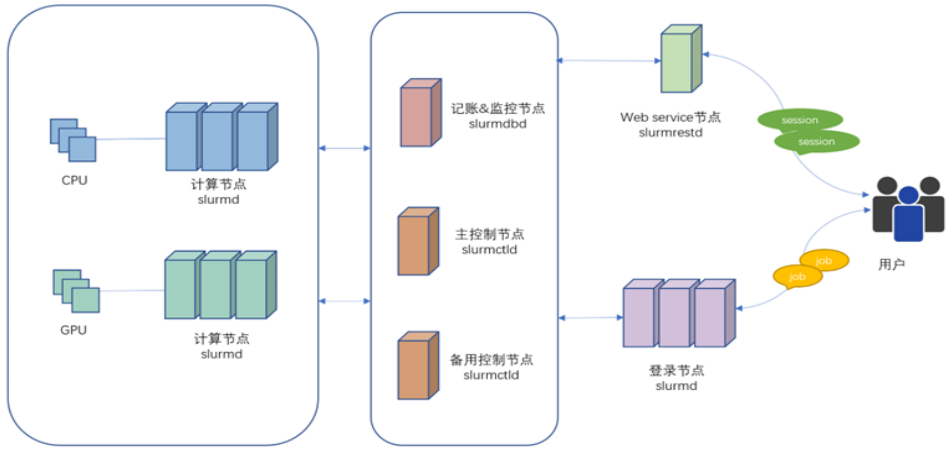
- The purpose of open data is to facilitate multi-tiered data interoperability and transparent knowledge sharing aligned with global open science frameworks
  - Level 1: datasets involved in those published results
    - extended figures/tables for contextual validation
  - Level 2: simplified data formats for outreach and analysis training
    - basic four-vector event-level data
  - Level 3: reconstructed data and simulated data together with analysis-level experiment-specific software
    - allowing to perform complete full scientific analyses using existing reconstruction
  - Level 4: basic raw data
    - allowing the production of new simulated signals or even re-reconstruction of collision and simulated data
- the Data Preservation in HEP (DPHEP):
  - IHEP is a member of DPHEP community

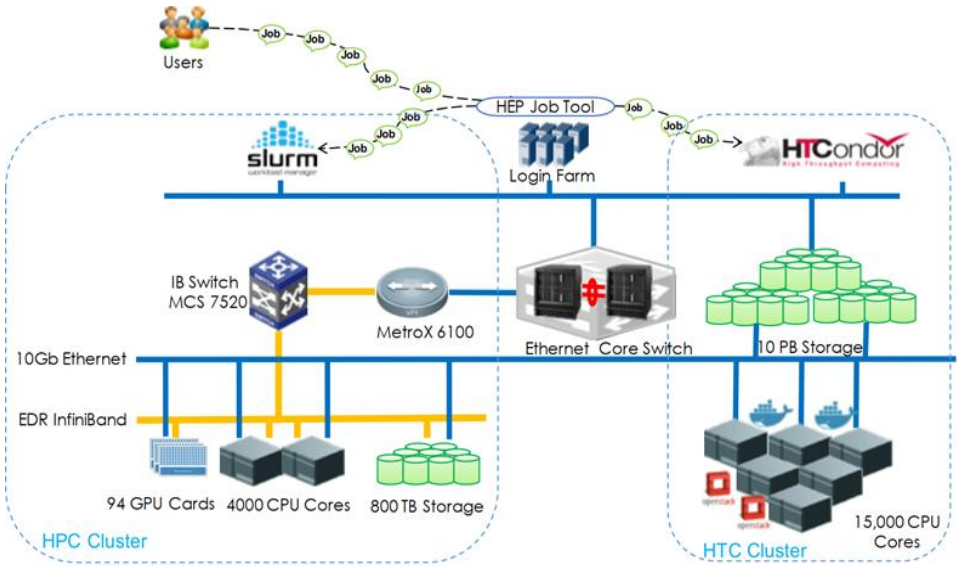
# Long term data preservation

- According to DPHEP, A long-term data preservation model is designed to address data challenges of CEPC
  - it is essential to preserve not only experimental and reconstructed data but also reconstruction and simulation software
  - Multi-layer storage system: disk storage for medium to long-term data preservation, and tape libraries for permanent backup
  - All experimental data, reconstructed data, reconstruction software, and simulation software will be systematically stored and managed
  - it is also necessary to preserve the software and the data processing procedures. The reconstruction software and analysis processes will be preserved in a manner that allows for future execution and modification

# Computing

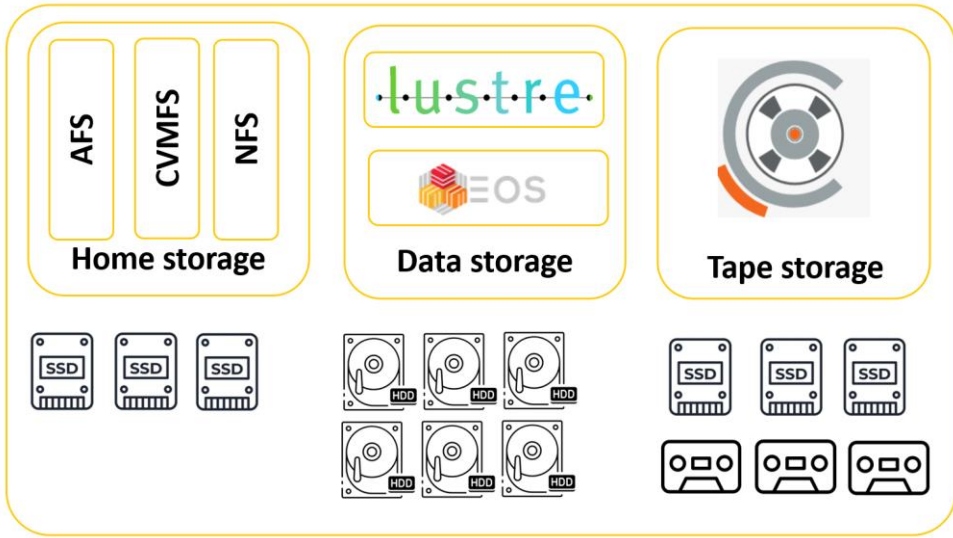
- Type of CEPC computing jobs
  - Single-core job or multi-core job within one node: simulation, reconstruction, analysis
  - Multi-core job on multi nodes or GPU job: part of reconstruction, AI training
- CEPC site computing service is based on HTCondor/Slurm
  - HTC service for single-core job or multi-core job within one node
    - Support 1,000,000 jobs queuing and 100,000 jobs running
  - HPC service for big multi-core job or GPU job
    - Support big-scale parallel job and GPU
- Intelligent scientist workstation service
  - AI support: pre-trained algorithms, curated datasets, and scalable inference services
  - service support: workflow design, parameter optimization, and collaborative analysis



# Data Storage

- User Home Storage Service
  - Based on NVMe SSD and distributed file system architecture
  - Provides high-concurrency, low-latency access for user home directories
- Software Repository Storage
  - Utilizes CVMFS  for efficient software distribution
  - Maintains version consistency with atomic file fetching
- Data Storage
  - Provides exabyte (EB)-level scalable storage capacity
  - Supports multiple access protocols: XRootD, HTTP/HTTPS, FUSE, S3
  - Designed for large-scale scientific computing, AI workloads, and data-intensive experiments
- Tape Storage
  - Offers high-capacity, cost-effective archival storage
  - Suitable for long-term data preservation and multi-site backup



# Network and Cyber Security

- Network system: Unified High-Performance Environment
  - Super High-Bandwidth: Intra- and inter-data center infrastructure for batch processing and cloud computing
  - Lossless Network: Enables large-scale data processing and AI services across geographically dispersed facilities
  - Ultra-Low Latency: Supports the Intelligent Scientist Workstation for interactive computing and real-time IoT operations
- Cybersecurity system: protection against diverse cyber threats for data processing systems, networks, and infrastructure
  - Management System: Establishes security policies, governance protocols, and procedural standard
  - Technical Architecture: Implements logically segmented security domains with layered defenses: Boundary Protection, IDS/IPS, Host Hardening, Vulnerability Management, Log Auditing
  - Security Operations: Features a big data analytics-driven security platform and a cross-facility cybersecurity alliance for joint defense coordination

# Smart Data Center Infrastructure

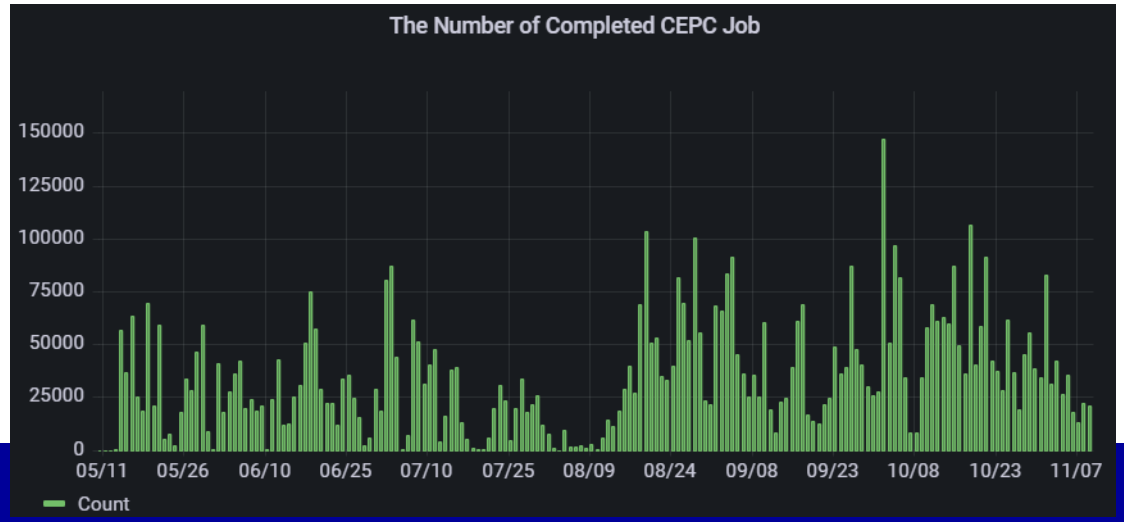
- Green Energy Efficiency and Thermal Management
  - Integrate cold plate and immersion high-efficiency liquid cooling systems, addressing ultra-high rack power densities (exceeding 100 kW)
  - By utilizing free natural cold sources (e.g. outdoor air, lake water) for cooling, cooling-related energy consumption (40–50% of total usage) is reduced
- Transforming data centers from high-carbon units into hubs of energy efficiency and low environmental impact
  - Prioritize adopting renewable energy sources (e.g. photovoltaic, wind power) to replace fossil fuel-based power supply
  - Utilizing heat pump waste heat recovery technology, the data center's waste heat provides district heating and domestic hot water
- AI underpins intelligent data center operations
  - Machine learning models forecast cooling demands and optimize energy allocation

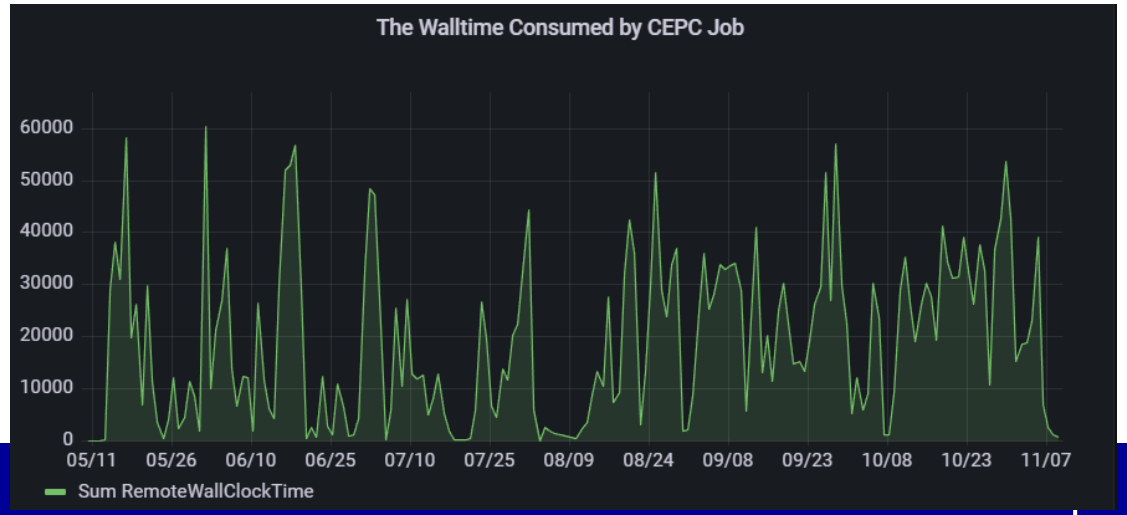
# Current Status

- DIRAC is chosen as distributed computing framework
  - Originally from LHCb, now used for many new experiments: BELLEII, ILC, CTA, SKA…..
- CVMFS for software distribution
  - stratum0 operated @IHEP : /cvmfs/cepc.ihep.ac.cn/, stratum1 @IHEP and @RAL
- VOMS for managing CEPC users (would be reeplaced by IAM)
  - VOMS hosted @IHEP : https://voms.ihep.ac.cn:8443/voms/cepc/
- Lustre for data storage
  - An open source shared file system: /cefs/
- HTCondor and Slurm for local computing resource management

# Current Status

- Resources
  - CPU: ~2000 cores (640 cores shared with ILC in grid)
  - Storage: 3.7 PB, 2.9PB used (81%,should be considered to add more space)
  - Network: a shared network link with 100 Gbps bandwidth between China and Europe
- Jobs (in recent half year)
  - 6,318,503 jobs consumed 3,457,788 CPU hours



# Summary

- CEPC needs large scale of resources for the future requirements
  - Million-core level computing power and EB-level data capacity
- Distributed Idea for computing model and data model
  - Would be consider more types of computing provides
- Resource provision will develop over current mature solutions
  - Computing, storage, network and infrastructure
- CEPC computing platform is supporting the pre-research work
  - Job and data

***Thanks! Q&A***