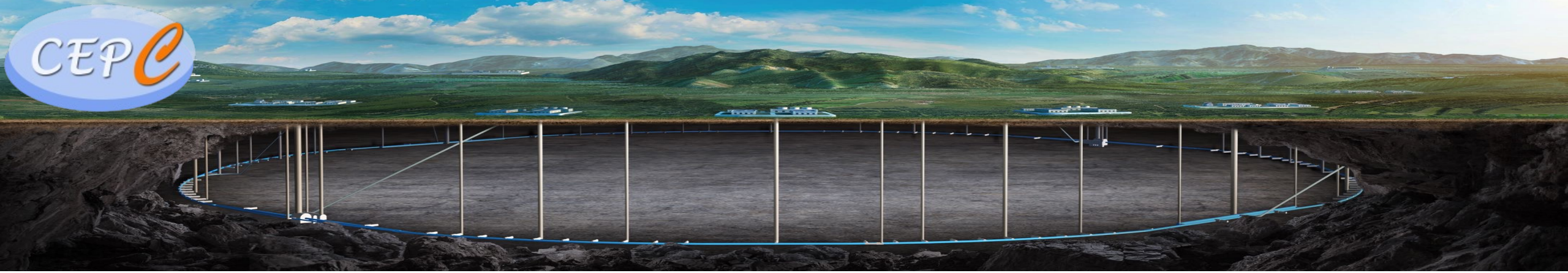

CEPC Industrialization Preparation and DeepC Documentation System

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(For CEPC study group)

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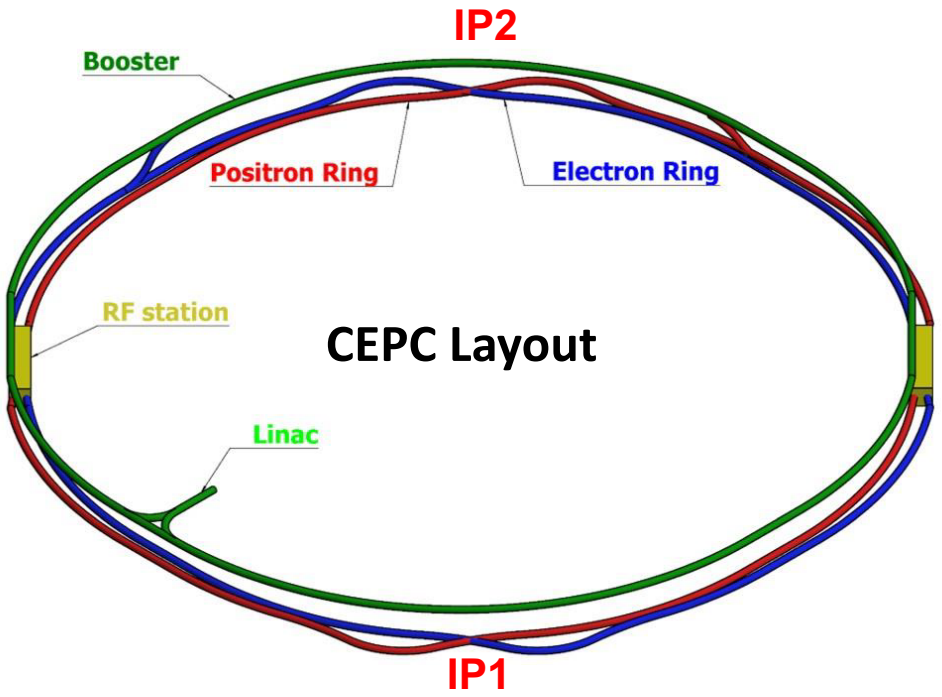
Chinese Academy of Sciences

Content

1. Introduction
2. Status of industrialization preparation and plan
3. Documentation system, DeepC
4. Summary

1. Introduction

- CEPC is one of most advanced future colliders with a large-scale accelerator complex.
  - A 1.8 km 30GeV Linac
  - Two 100 km circular accelerators, booster and collider
  - A dozen of subjects
    - magnet and power supply, vacuum and mechanics,
    - SRF, RF power, cryogenics, instrument, control,
    - survey and alignment, radiation protection, sources, etc.
  - A large amount of devices or components
    - ~40,000 magnets; ~38,000 magnet power supplies;
    - ~80,000 mechanical supporters; ~300 km vacuum system;
    - ~300 superconducting RF cavities; ~200 klystron; etc.;



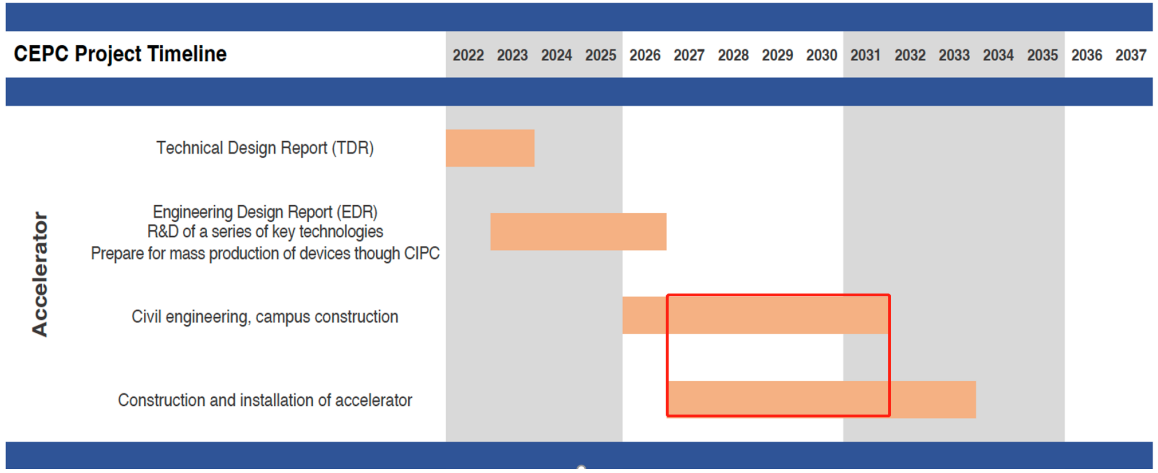
- A project the size of CEPC will rely heavily on industry to provide cost-effective production.

Two important characteristics

- **The one is for magnet similar components.**
  - Non-standard products;
  - High requirements of fabrication accuracy;
  - But an amazing huge number since they will fill most the 100 km tunnels;
- **The other is for SRF cavities similar components.**
  - Few vendors or may no final performance guarantees by vendors;
  - Complicated technologies support, e.g. SRF Cavity, electron-beam welding, fine controlled electro-chemical polishing, mid-T baking , high- pressure pure water rinsing, RF tuning, the assembly;
  - All in clean or semi-clean room environments, e.g. especially the cavity clean assembly requires well defined procedures and rigorous training;

Challenges we might face*

- Technology maturity level;
  - e.g. magnet and magnet power, vacuum pipe, mechanical supporters, etc.
- Technology transfer: some may be completely new for companies:
  - e.g. high performance SRF cavities, high efficiency klystron, superconducting magnets, etc.
- The cost versus time factor
  - ***We also need do more detailed analyses for the scheduling, such as increasing overlap of various periods.***

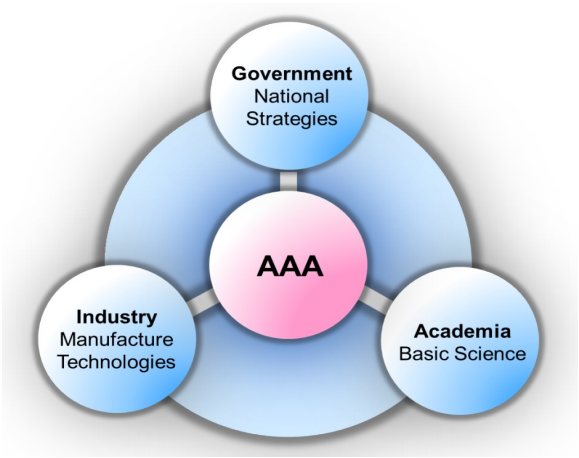


Accelerator system	Specification	Prototype
Magnets	√	
Vacuum	√	
RF power		√
Mechanics	√	
Magnet power supplies	√	
SRF	√	
Cryogenics	√	
Linac and sources	√	
Instrumentation	√	
Control		√
Survey and alignment		√
Radiation protection	√	
SC magnets		√
Damping ring	√	

* Isabel Bejar Alonso, HL-LHC industrialization and procurement. Lessons learnt, ICHEP2018, Seoul, Korea, 5-11 July 2018

Much can be learnt from the former works

- LHC also has large number of magnet, especially the High-Luminosity LHC project **summarized several key factors**.
- European XFEL: ~80 cryomodules (~640 cavities), the largest deployment of SRF technology even today.
- ILC made a lot of efforts, such as establishing of AAA, proposed **Project Implementation Plan (PIP)**
- Recent years, several conferences added industrialization session such as LCWS, IPAC, as well as CEPCWS, etc..



Advanced Accelerator Association
Promoting Science and Technology

Main Content

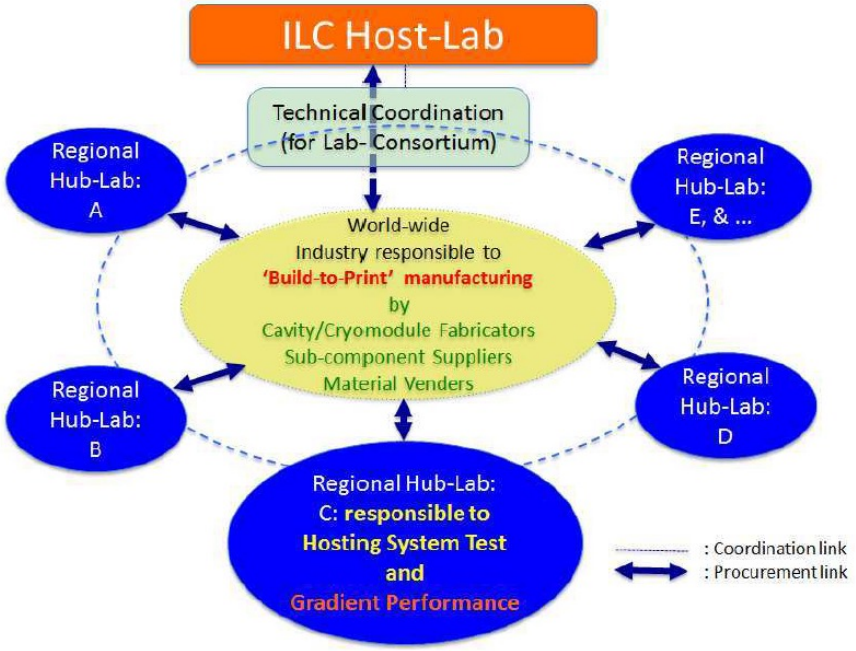
- This report is mainly about industrialization preparation status and some plan for EDR to face those challenges.
- The primary goal is the reduction of the unit cost and avoid risks.
- It relates to the "charge letter" parts of item 8 and 9.

8. Will the CEPC accelerator be ready for construction, after the completion of the outlined R&D program, and industrial and engineering preparation, as well as issues identified in item 7 above be properly addressed in due time?
9. Any other issues you notice or any improvements you may suggest.

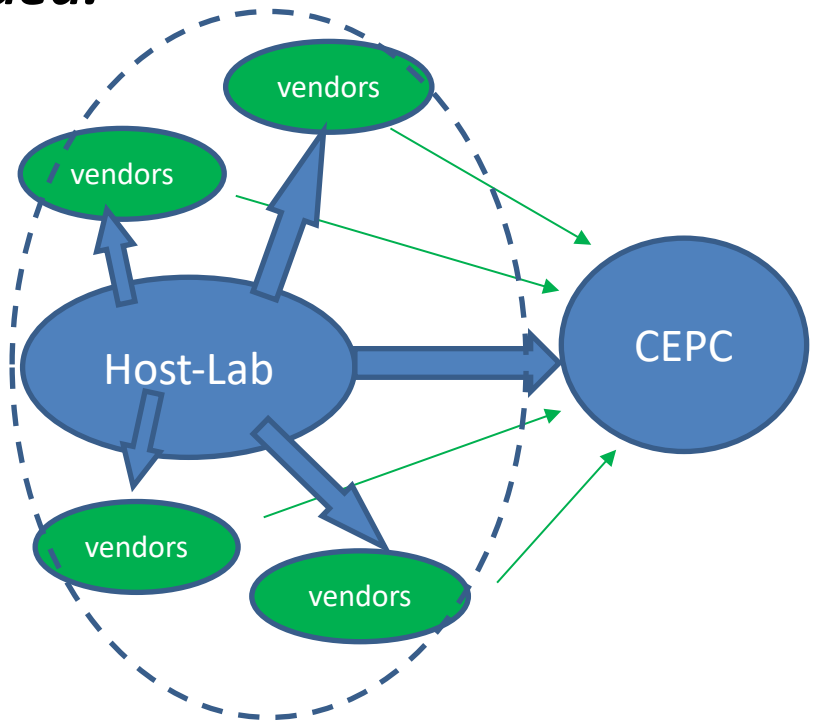
2. Industrialization Preparation

Organization model consideration.

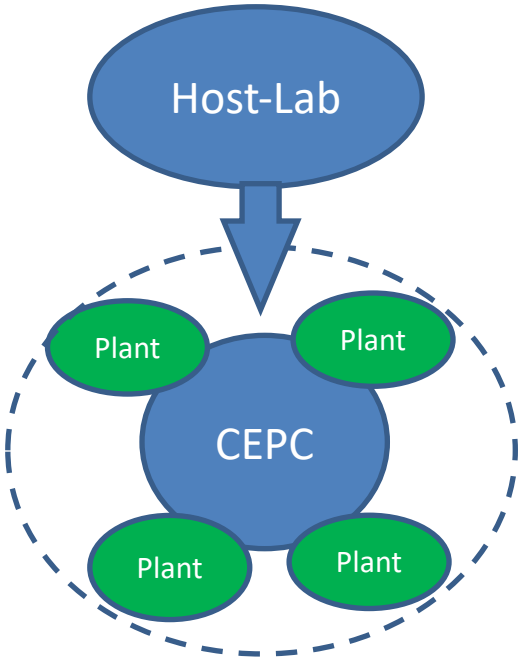
- *Model 2 or 3 might be preferred.*
- ***Further detailed study is still needed.***



Model1. A globally distributed model based on the "hub laboratory" from ILC PIP



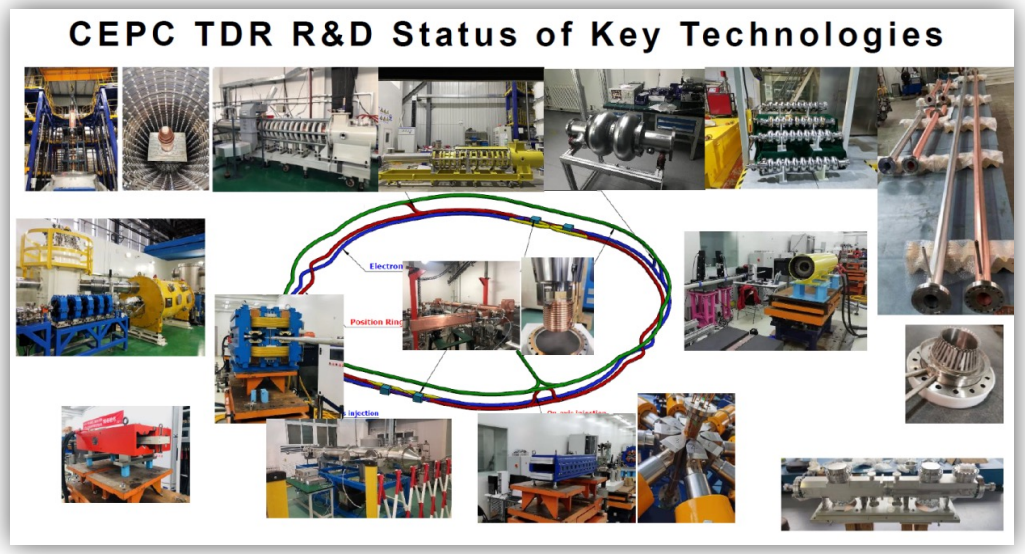
Model 2. Centralize as far possible the procurement

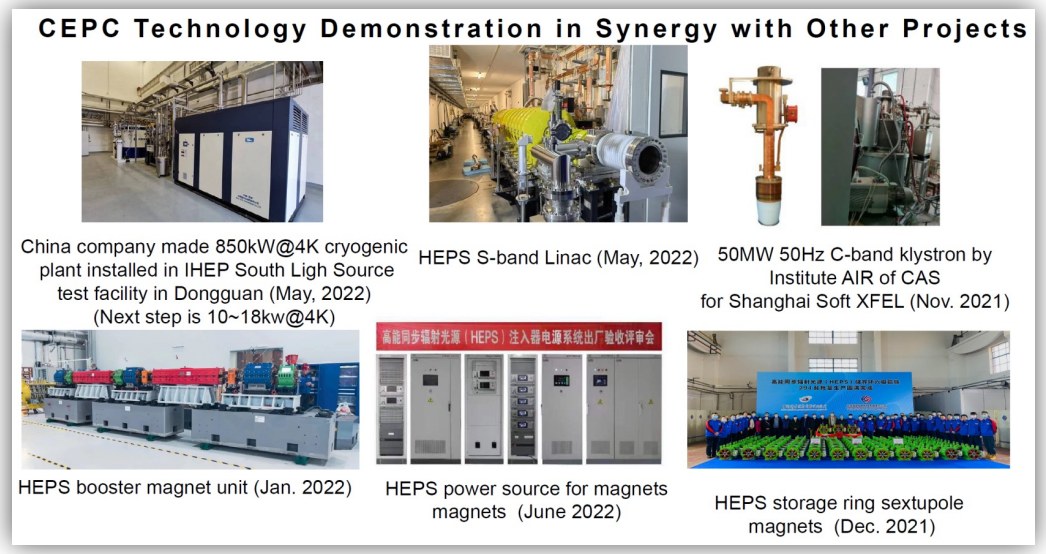


Model 3. The variant of model 2, centralized several large production plant.

“Make or buy process”

- According to the experience of HL-LHC, it is useful to do a analysis whether we could push the products to a high Technology Readiness Level (TRL) in a suitable time. It called “Make or buy”.
- Actually, plenty of information were obtained in TDR.
  - Parts from development on prototypes like some types of magnets, vacuum components, klystron, SRF cavities and so on
  - Parts are based on other projects such as HEPS, PAPS, etc., like magnet power, control, instrumentation and so on.
- ***However, the detailed and specialized assessment should continue in EDR periods.***





An example of the effort to push the "make" to "buy"

- "Buy" usually can bring more competition and reduce the cost.
- We collaborate with IHEP factory He Racing to transfer the technology of 1.3GHz SRF cavities.
  - Detailed procedures are made; Workers are trained.
  - Recently, the company obtain the cavity order from SHINE projects though the surface treatment is not needed.
  - Experiences of the technology transfer should be helpful in the future mass-production preparation.
- ***Similar works might be needed in EDR.***

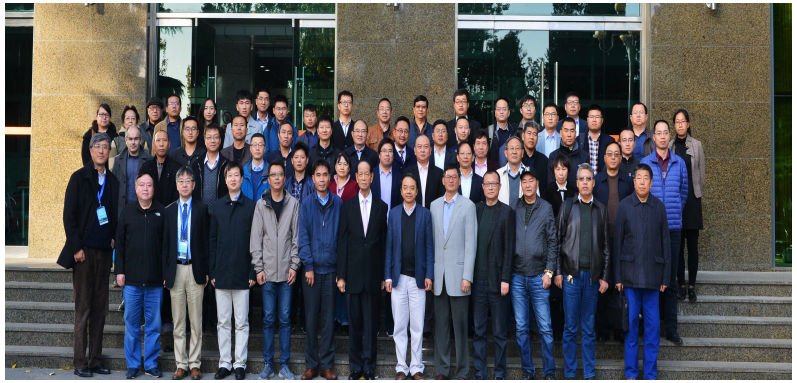
Infrastructures

- Clear vision of what could never be produced in industry is important, such as testing infrastructures or more efficient internal production.
- This strategy may save the project of delays.
  - In TDR period, one of most infrastructures is Platform of Advanced Photon Source (PAPS) around 4500m^2 which could support test or treatment on magnet test, alignment, cryogenics, SRF cavities mass production.
- ***Further analyses might be still needed in EDR for mass production.***



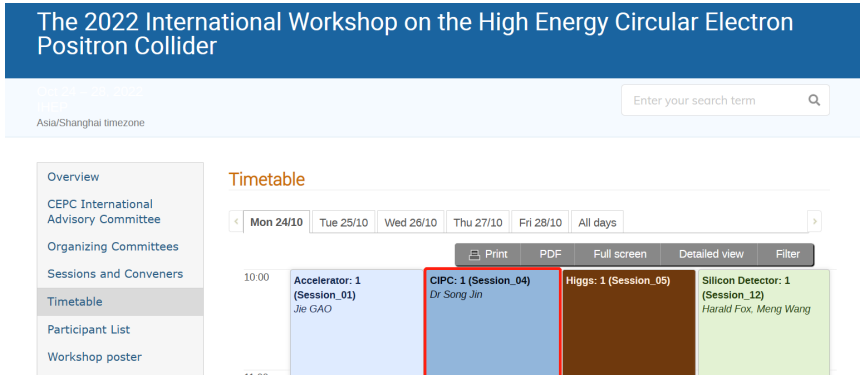

Working with industry

- The earliest involvement will be helpful to make industrialization clear and lower the cost.
- We established CEPC Industrial Promotion Consortium (CIPC) in 2017. A lot of works in TDR finished by working with industry.
- CIPC also helps the companies know each other by annual meeting during CPECWS and some collaborations are also done on some interfaces of works.
  - For example, for development of a SRF cavity electro polishing facility, the machine company, chemistry company, pure water company, civil company worked together.
- In EDR, the working with industry will continue.



CIPC established in Nov. 7 , 2017

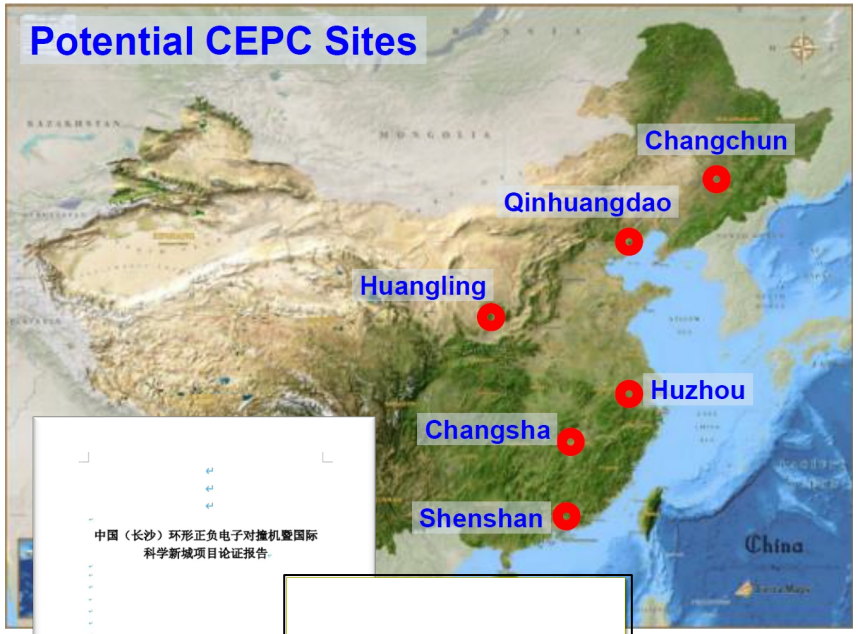
The plate for CIPC member

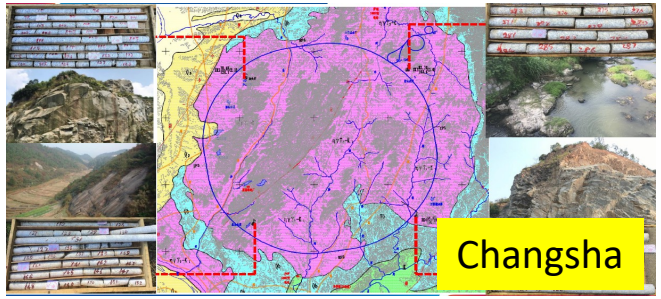


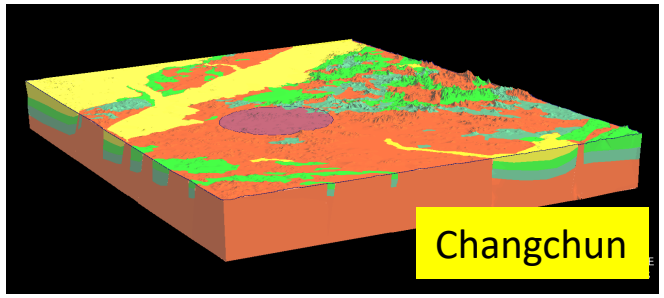
CIPC will have meeting in CEPCWS each year

Site selection

- We worked with Huanghe, Huadong, and Zhongnan Engineering Company.

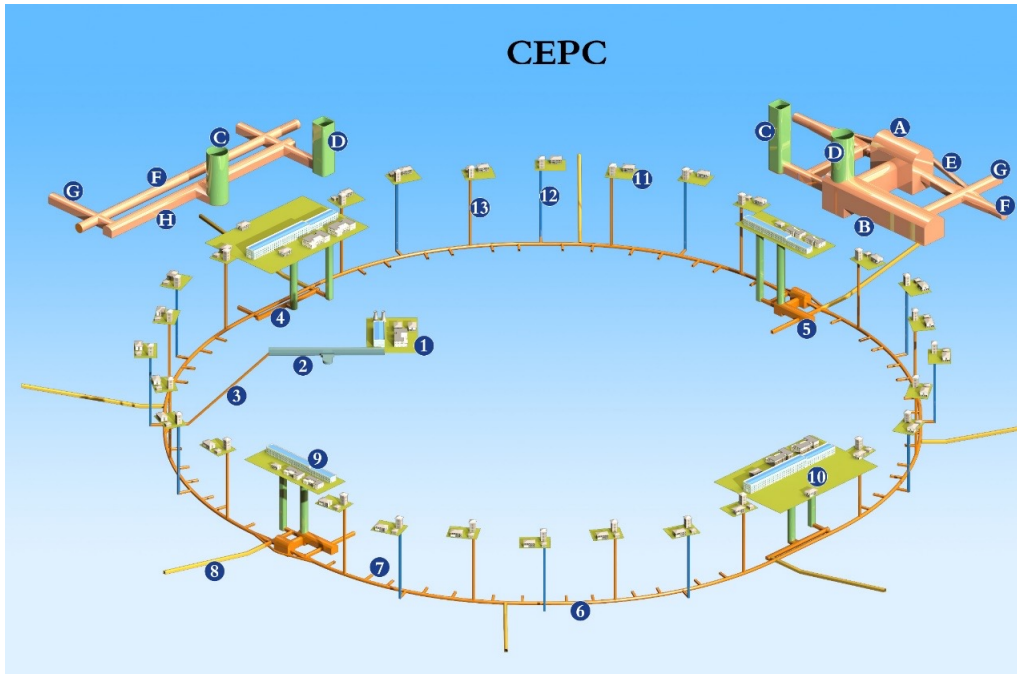




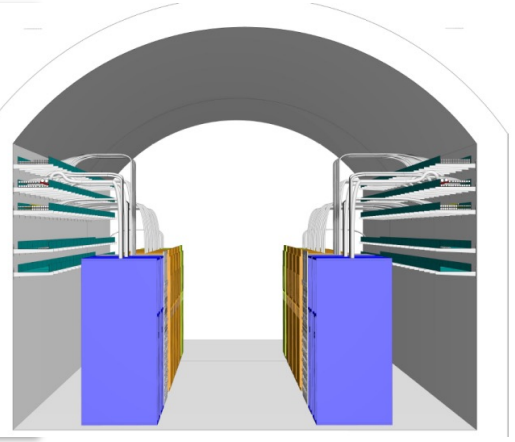


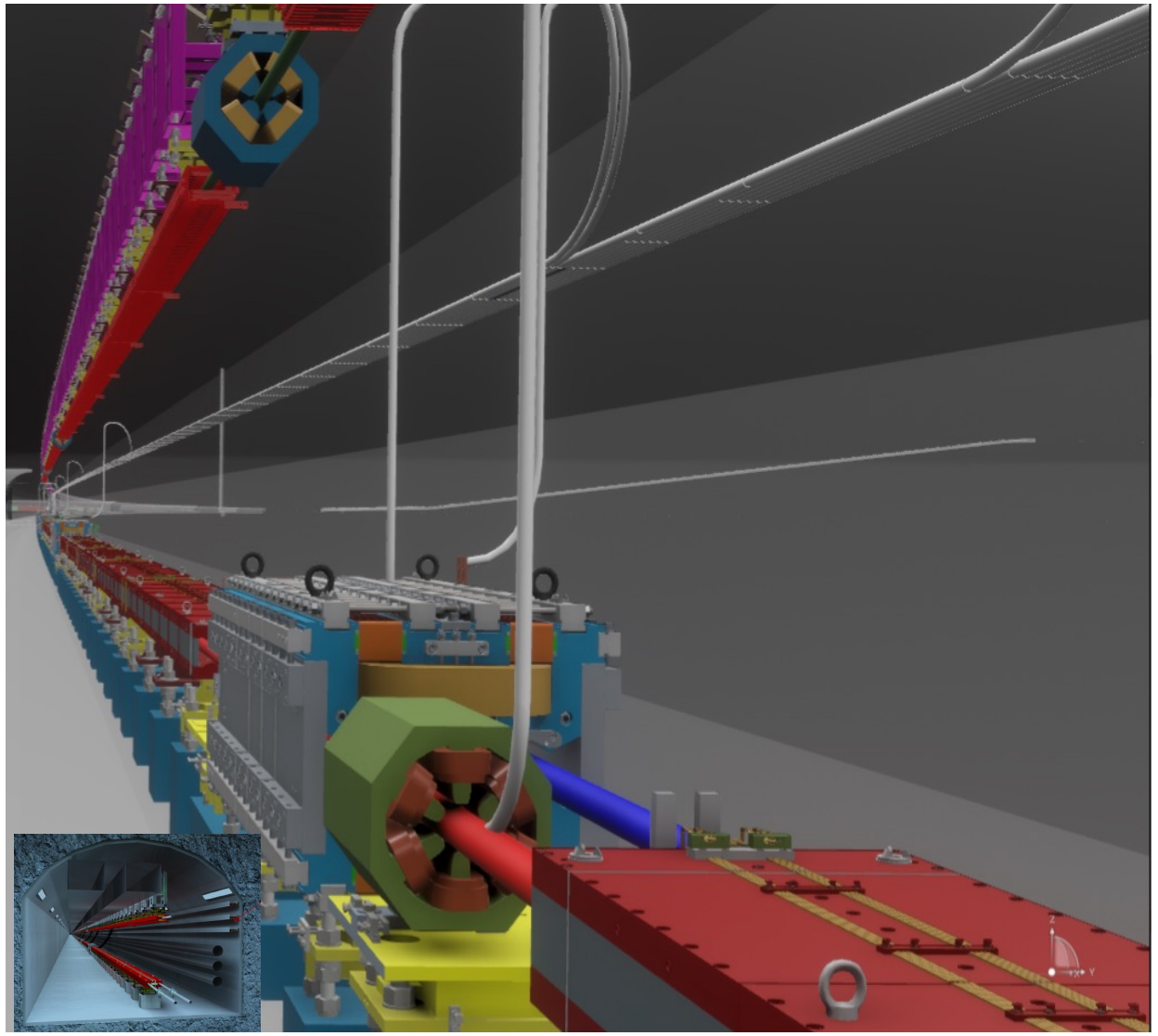
CEPC Sites Engineering Geologies for Qinhuangdao, Huzhou, Changsha

Tunnel design



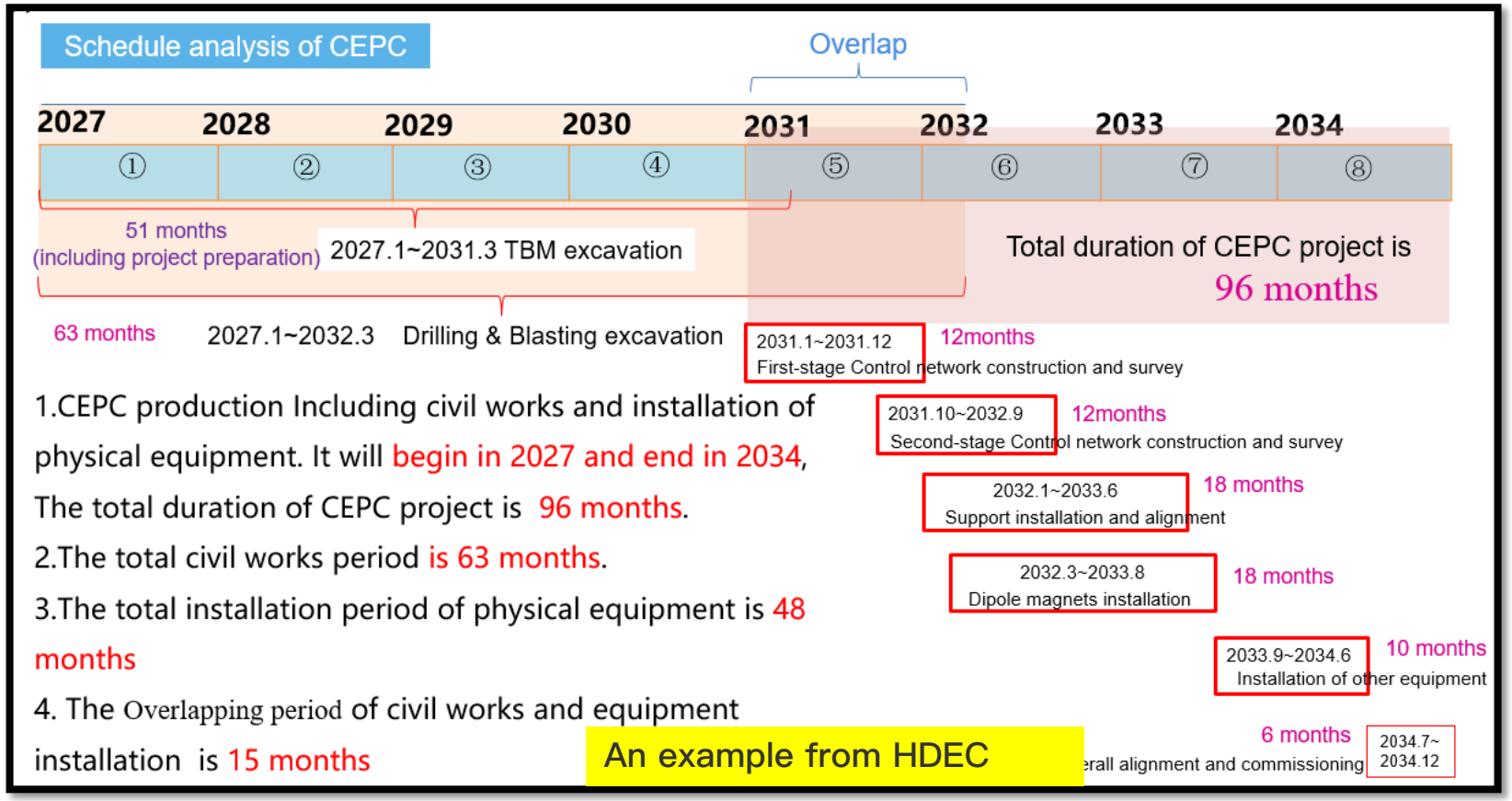
Logistics warehousing





Strategy study on the installation plan

- Working with CIPC member of Huadong Engineering Company
- Other two strategies of installation were anlysed by Huanghe and Huanan Company



The table summarized working with companies from CIPC.

	Companies/ Acc. systems	Magnet	Power supplier	Vacuum	Mechanics	RF Power	SRF/ RF	Cryogenics	Radiation protection
1	Beijing HE Racing	Participate					Participate		
2	Xingxia OCIT						Participate		
3	**Kunshan Guoli**					Participate			
4	Huadong Guangdian						Participate		
5	Huiyu Vacuum			Participate	Participate				
6	Hefei Keye	Participate		Participate	Participate				
7	Wuxi Creative Tech.						Participate		
8	Beijing Zhongkefuhai							Participate	
9	Jiangsu Cryote							Participate	
10	Anhui Wangrui							Participate	
11	SCSC(Shanghai Kechuang)	Participate							
12	Beijing Gaoneng Tech.								Participate
13	Jiangsu Chenxin								Participate
14	Hefei Juneng	Participate		Participate			Participate		

The table summarized working with companies.

	Companies/ Acc. systems	Magnet	Power supplier	Vacuum	Mechanics	RF Power	SRF/ RF	Cryogenics	Survey and alignment	Radiation protection	Civil
15	Huaqiao University										Participate
16	Beijing Puda Ditai								Participate		
17	Chengdu Puda Ditai								Participate		
18	Wuhan University								Participate		
19	Shanghai Kelin	Participate									
20	Suzhou Superconducting tech.	Participate									
21	Shanghai Superconducting tech.	Participate									
22	Yellow river Corp.										Participate
23	Huadong Corp.										Participate
24	Zhongnan Corp.										Participate

Sources

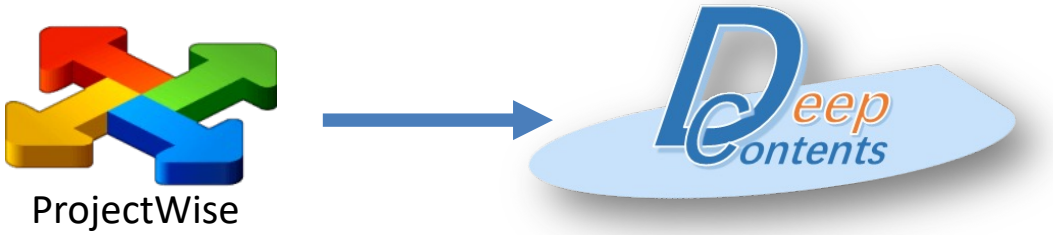
- It is the key to identify new suppliers so to avoid single supplier tenders and reduce cost;
- There are about 70 Chinese domestic vendors in CIPC.
- A preliminary survey for international vendors was just carried on.
- *But in my opinion, survey might not be difficult, but persuade them to establish essential collaboration is not easy.* ***More works and deep survey are still needed in EDR.***

(Many thanks to colleagues for recommendation and nice discussion)

Discussion with Kyma, Cosylab

Tools to ensure the follow-up

- Tools should be of paramount importance when we procure and produce components for a large-scale project.
  - Trace the components from their design to manufacturing steps and any non-conformity, or test result can be retrieved in a simple and long-term way.
  - Manage documents and quickly prepare the production folders and to transfer easily in house development to the industry.
  - Provide the documents or materials of components for maintained or repaired in machine lifetime.
- CEPC also made several attempts from a commercial tool of ProjectWise commonly used in traditional large project to a new specially developed tool for scientific projects called Deep Content (DeepC).

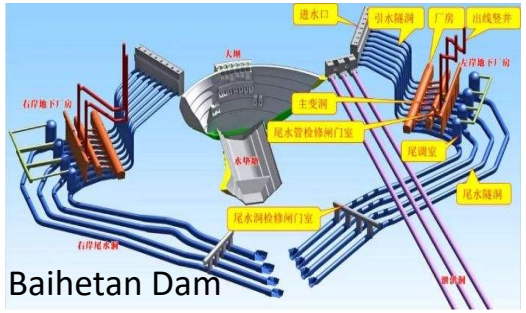


3. Documentation System, DeepC

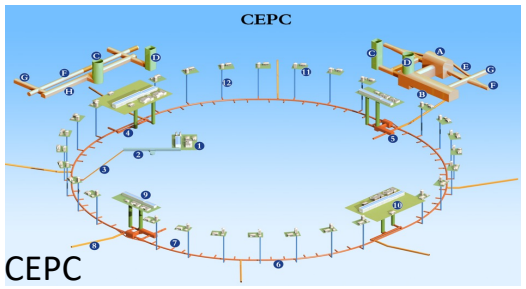
A brief background

- DeepC is a documentation system developed by HDEC company, one of important CIPC members.
- Main works of HDEC are on traditional project such as hydropower stations, some similar as CEPC.
- Besides construction, HDEC also has a team to provide a all life-time customized digital software.

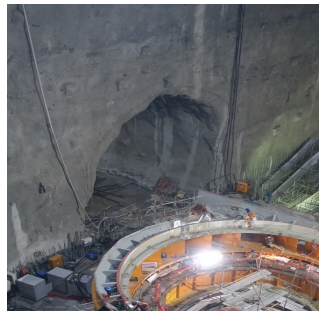

Baihetan Dam, ~178 Billion RMB

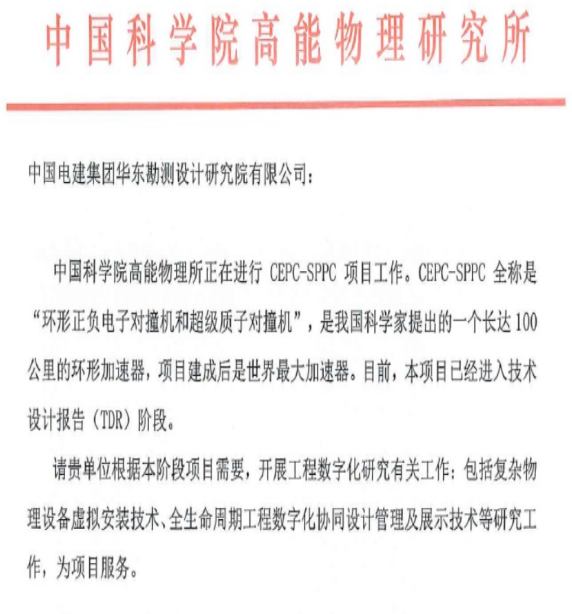


Baihetan Dam



CEPC




中国科学院高能物理研究所

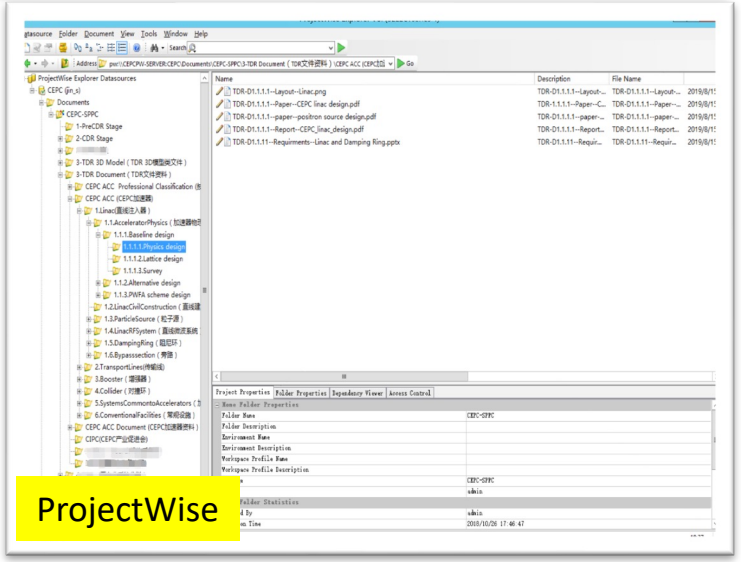
中国电建集团华东勘测设计研究院有限公司：

中国科学院高能物理所正在进行 CEPC-SPPC 项目工作。CEPC-SPPC 全称是“环形正负电子对撞机和超级质子对撞机”，是我国科学家提出的一个长达 100 公里的环形加速器，项目建成后是世界最大加速器。目前，本项目已经进入技术设计报告（TDR）阶段。

请贵单位根据本阶段项目需要，开展工程数字化研究有关工作：包括复杂物理设备虚拟安装技术、全生命周期工程数字化协同设计管理及展示技术等研究工作，为项目服务。

Why we develop new software

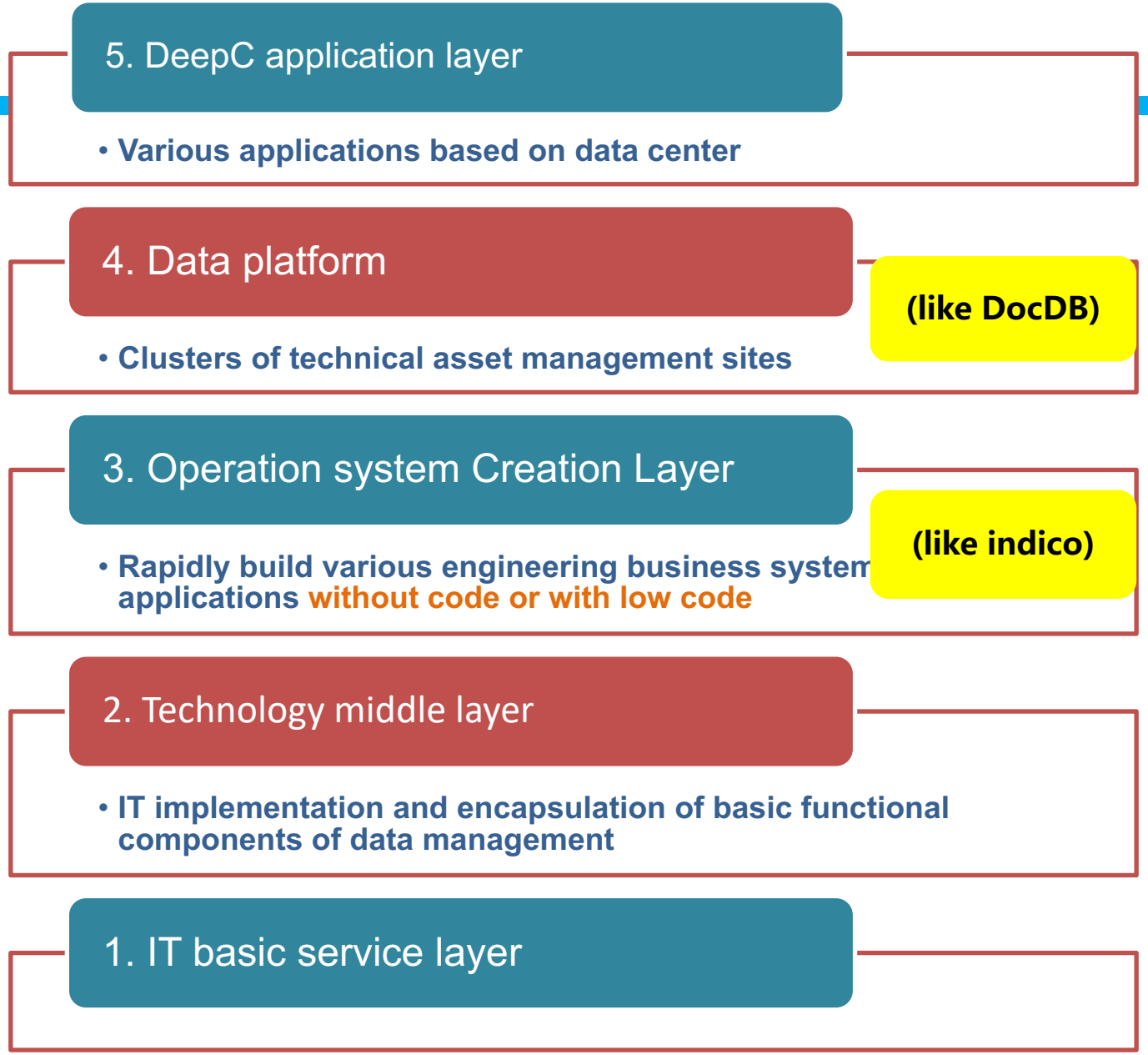
Comparison of different kinds projects	
Traditional projects (such as hydropower station)	**CEPC similar scientific projects**
Mainly for a single company and standard products	More collaboration and non-standard products
Can be strictly decomposed into multiple engineering stages, and the process of each stage is relatively fixed	Relative long project time span and high degree of process freedom
Usually single management core is adopted, requiring more full-time project management personnel who are familiar with the details of project management	The project structure is complex and professional. It is difficult for one person to cover every discipline. Multi-center will be better.



What is the DeepC

Hierarchical structure of DeepC

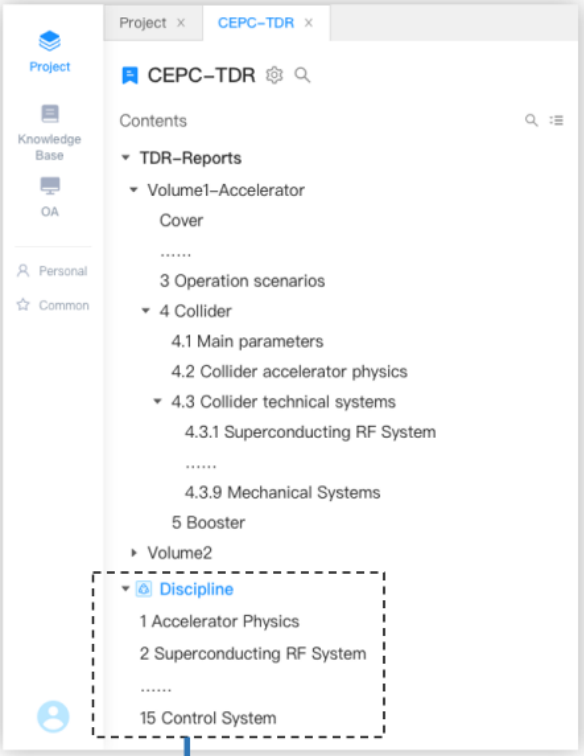
DeepC is a set of open data management function components, which can realize codeless construction of different business scenario **data management**.

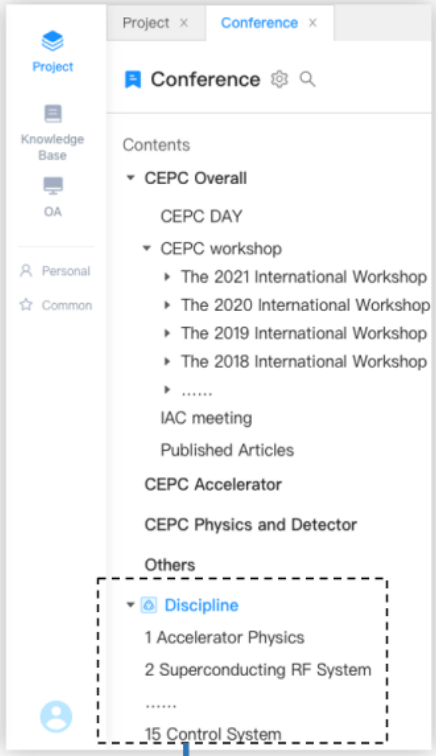


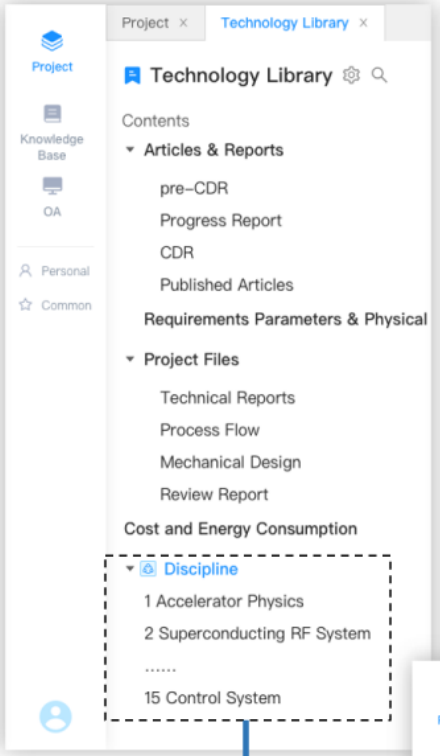
Main functions

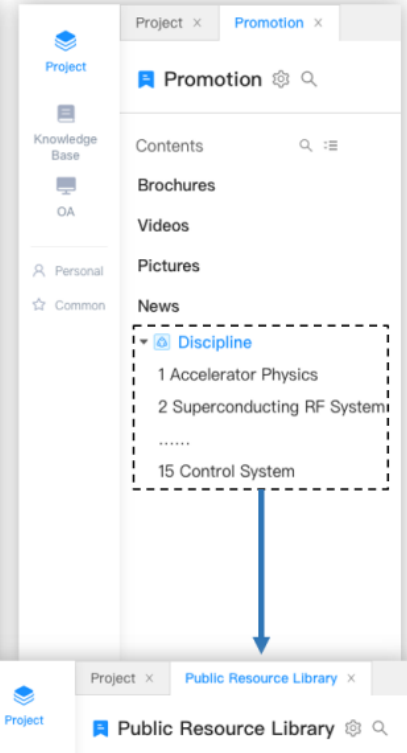
- **Phase 1: *Multiple sites document system (2019-2021.12)***

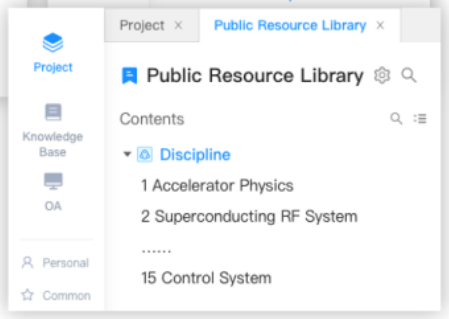
Interconnection between sites

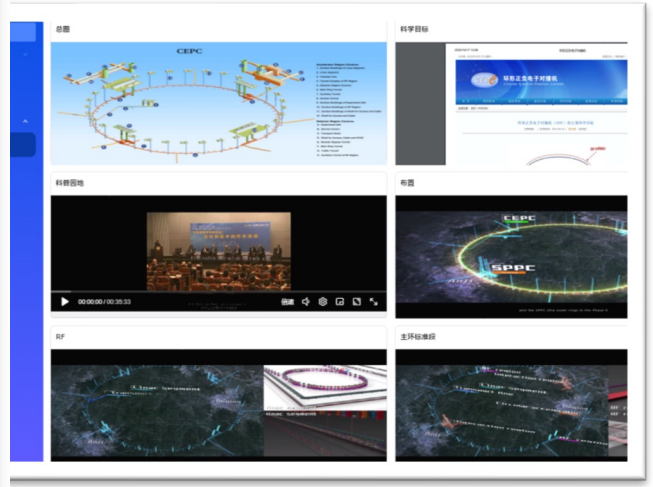






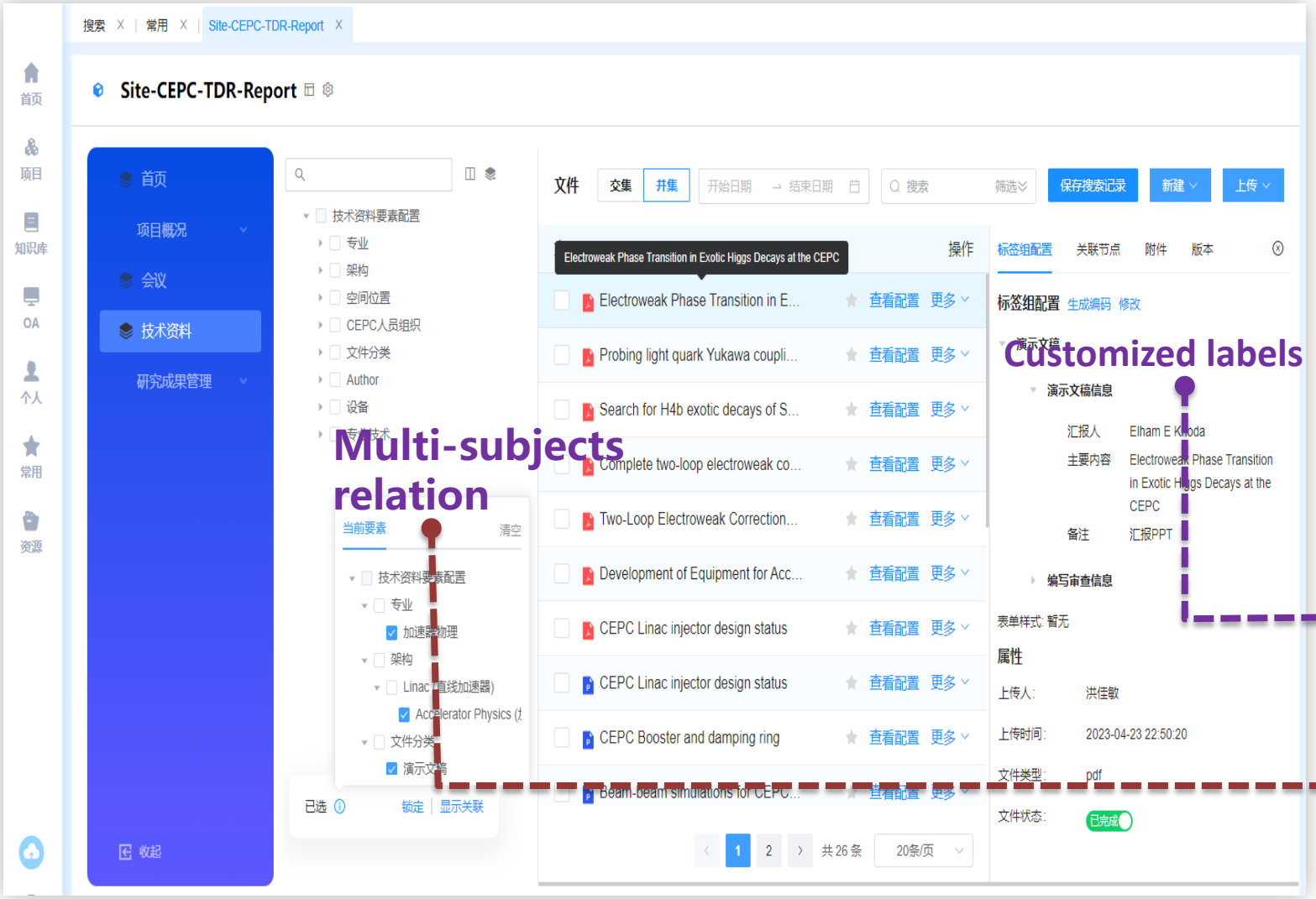


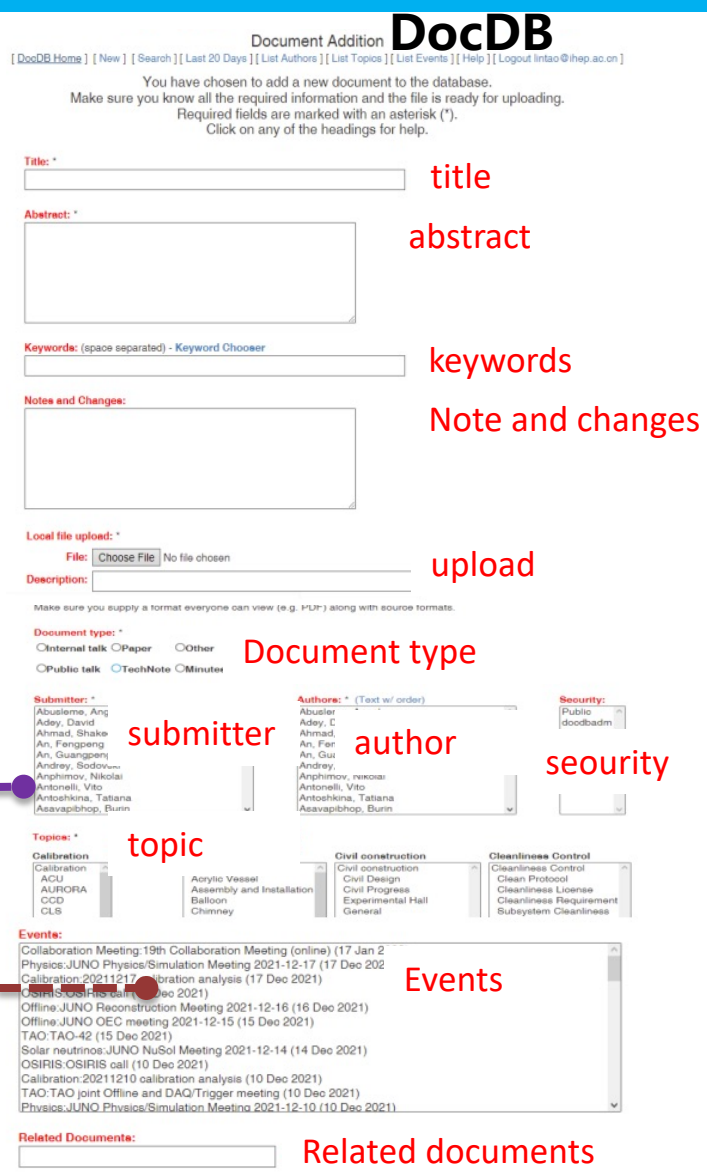




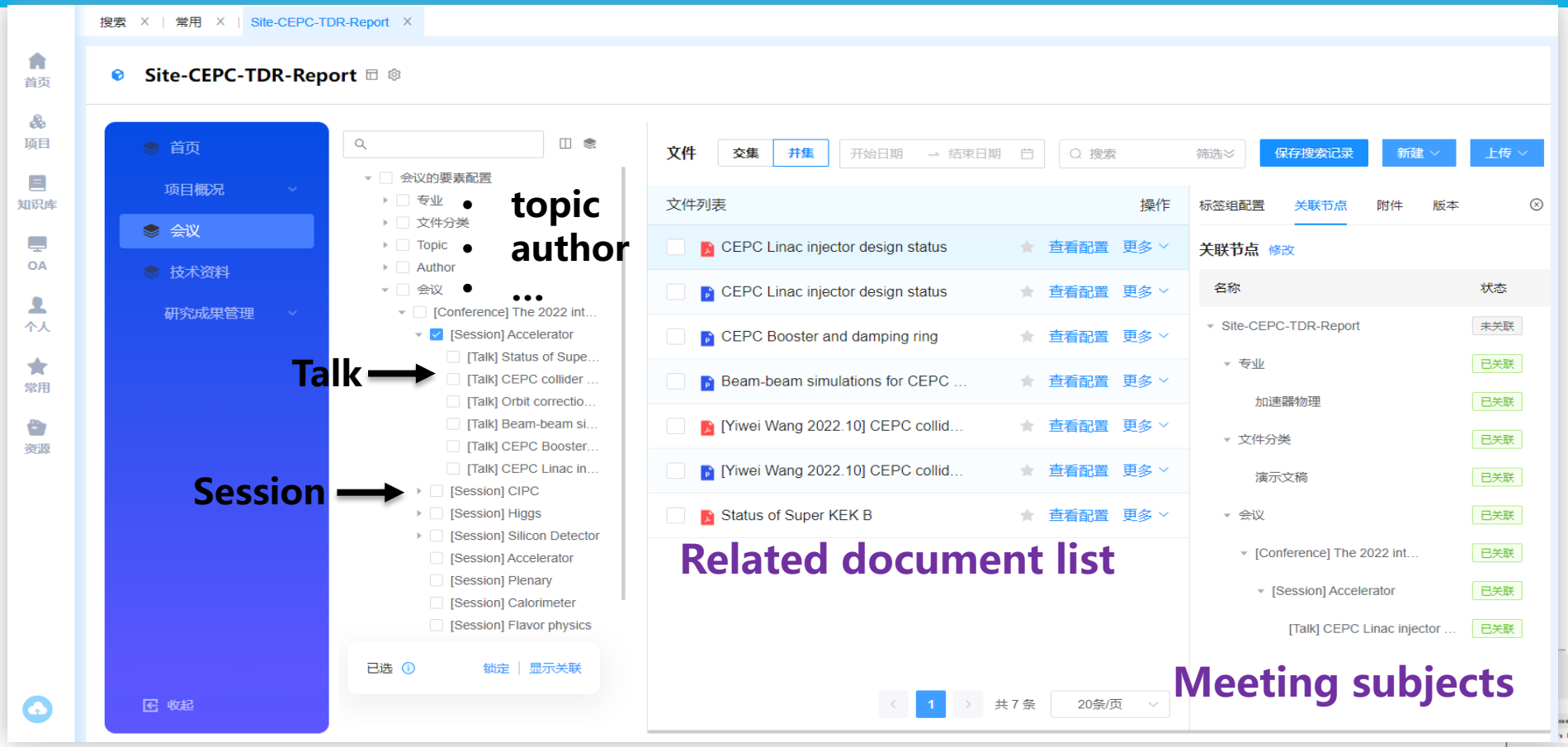
4 Sites: TDR Preparation; Conference; Technology Library; Promotion

One site shown (interface like DocDB)





An other application for conference (indico)

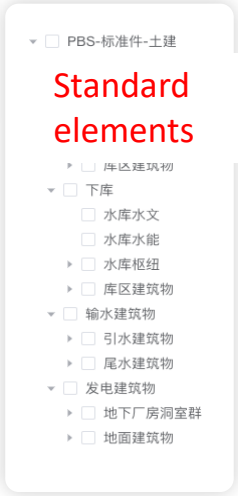


- Meeting information management
- Meeting document management
- Search
- ...

Phase 2. Structured data management (2021 to 2022.12, formal funding support)

Feature configuration

Create feature configurations based on use cases



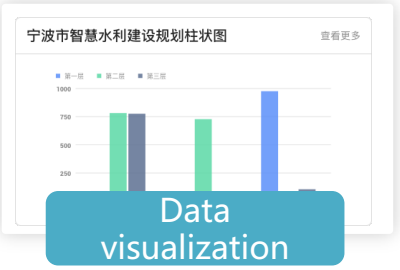
Data sources

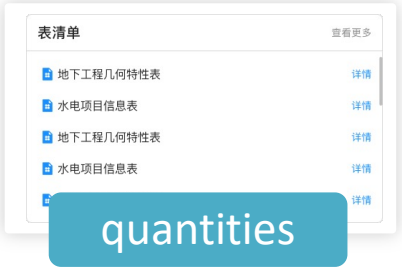
Targeted linking of internal data sources

- document
- Search history
- Search list
- Template upload
- Structured data
- Search inventory
- Single table search record
- Tag group
- Element association
- Element configuration
- Element reference

Data application

Generate a custom dataset

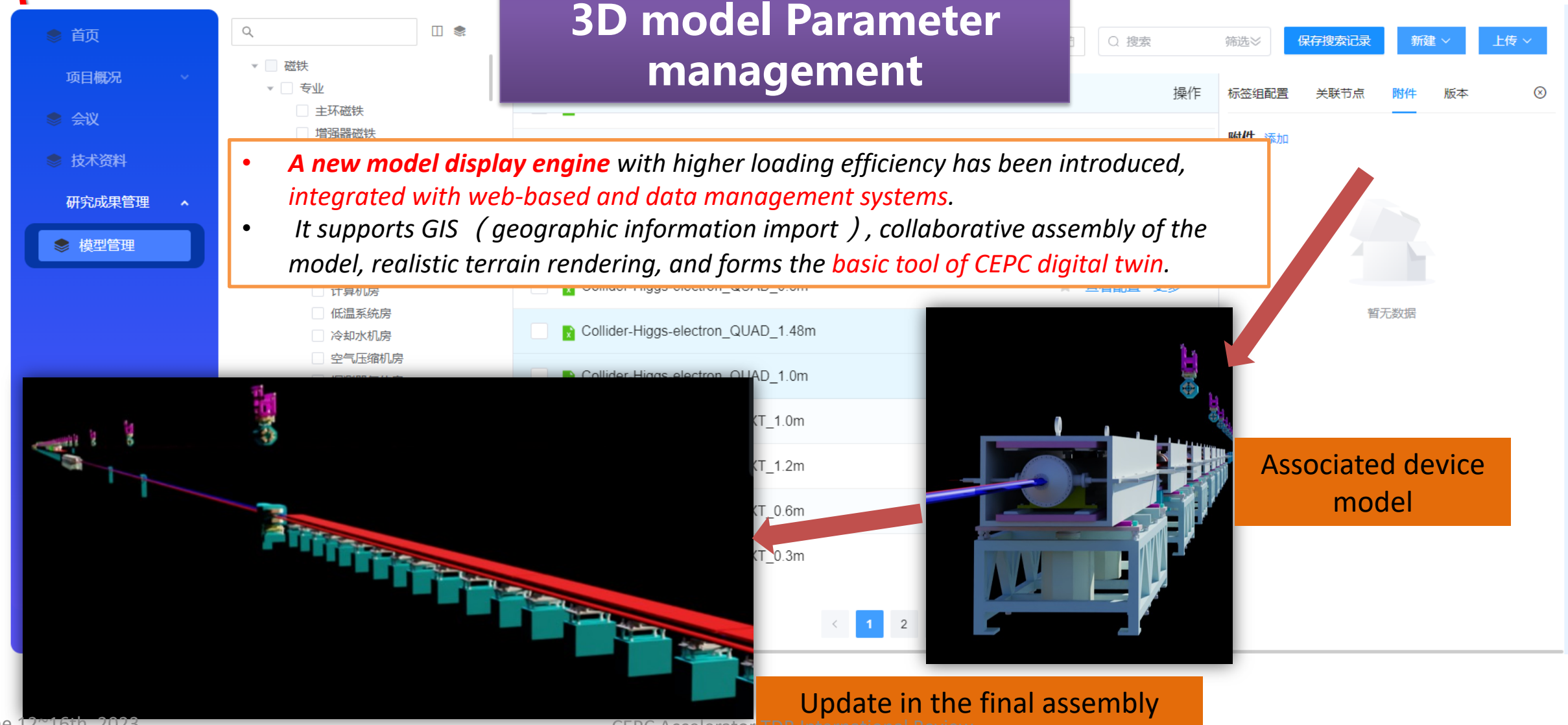




Phase 3: Relevant with 3D models *(a funding about 10 million RMB obtained)*

3D model Parameter management

- ***A new model display engine*** *with higher loading efficiency has been introduced, integrated with web-based and data management systems.*
- *It supports GIS（geographic information import）, collaborative assembly of the model, realistic terrain rendering, and forms the basic tool of CEPC digital twin.*



Phase 3 (2): Seamless integration of knowledge graph (AI)

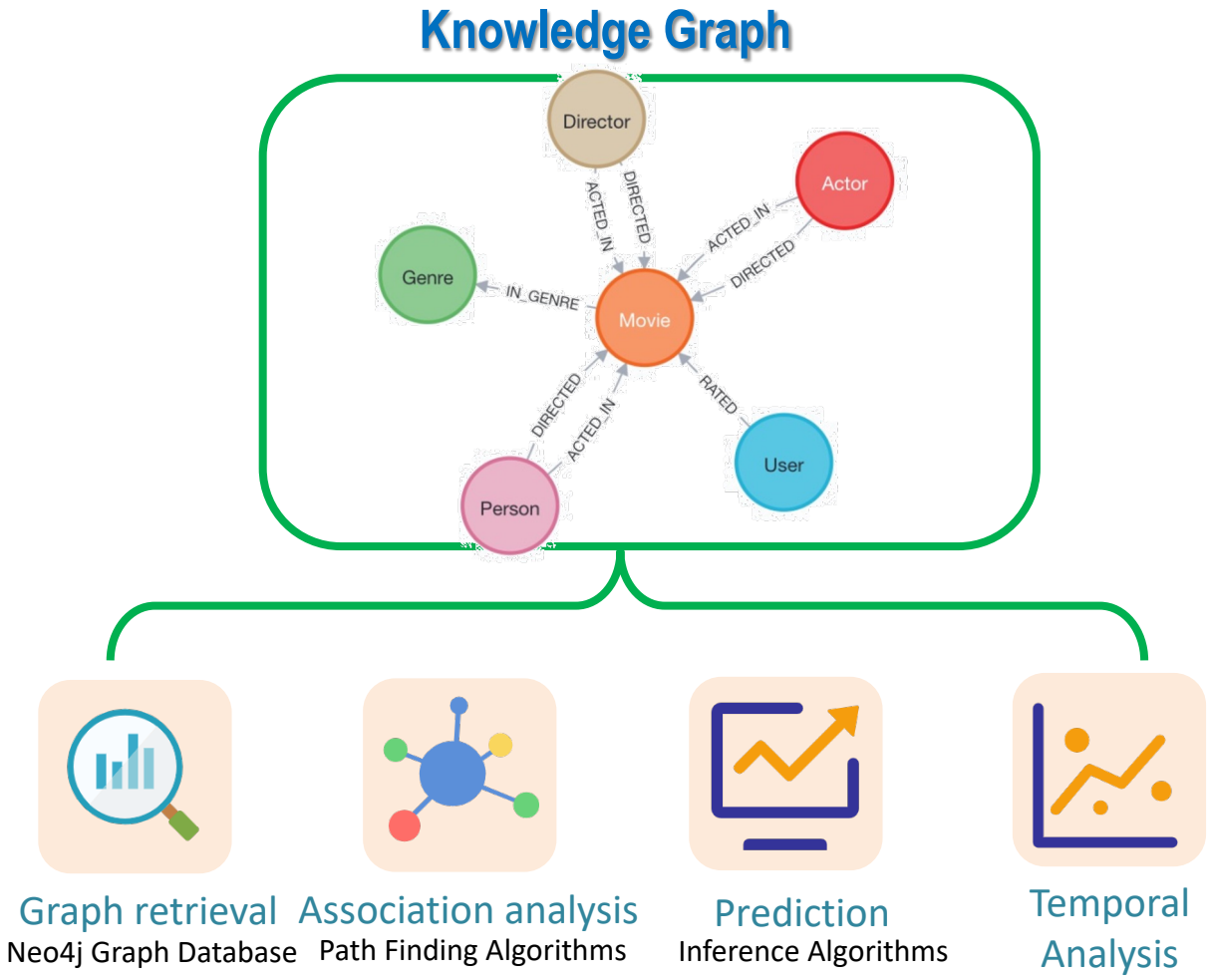
DeepC Structured Data Management

- Achieve a seamless integration with the knowledge graph, including ontology mapping, entity mapping, relationship mapping, and attribute mapping.
- Intelligent recommendations and associative retrieval can be achieved.
- It also serves as the foundational platform for deep learning on existing data.

✓ This step should take long time for maturity.

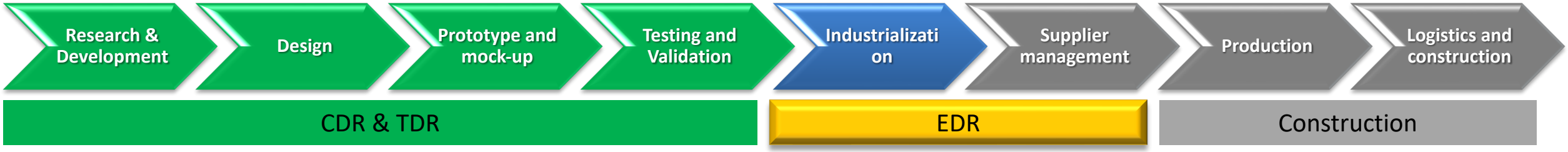
✓ The feedbacks of applications are very important.

✓ We hope it can be grown well together with CEPC.



4. Summary

- To a so large scientific project of CEPC, challenges might be a common problem to face for industrialization and mass-production. Former experience will be important to help build resilience to adverse events.
- The primary goal of any approach is reduction of the unit cost and avoid risk**.**
- Many works have been done in TDR. **However, further works are still needed in EDR period.**
- The documentation system DeepC is under developing, and hope it can become an good tool to lubricate the industrialization process or even more.



Thanks!

The engineering data sea waiting for us to explore.