CEPC Software Framework

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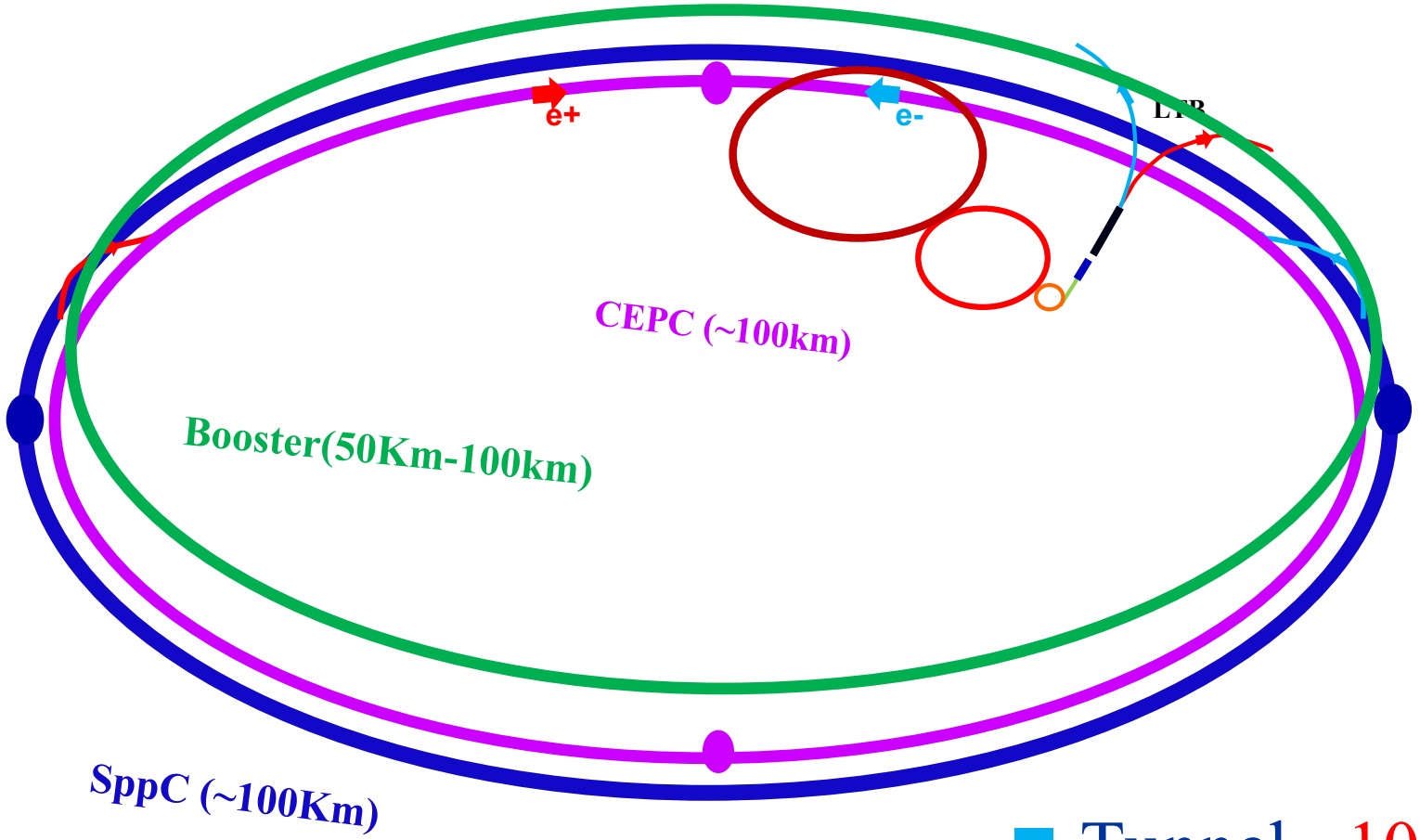
Outline

- About CEPC
- Current CEPC Software System
- Challenges of New Framework
- Design of New Framework
- Investigation and Concerns of Gaudi and Marlin
- Plan of CEPC New Framework Prototype
- Summary

CEPC and SppC

- Circular Electron-Positron Collider (CEPC)
- Supper Proton-Proton Collider (SppC)



- Tunnel~ 100 km

Science at CEPC and SppC

CEPC (90-250 GeV)

⇨ Higgs factory: 1M Higgs boson

- Absolute measurements of Higgs boson width and couplings
- Searching for exotic Higgs decay modes (New Physics)

⇨ Z and W factory: 100B-1T Z boson

- Precision test of the SM
- Rare decay

⇨ Flavor factory: b, c, tau and QCD studies

SppC (~ 100 TeV)

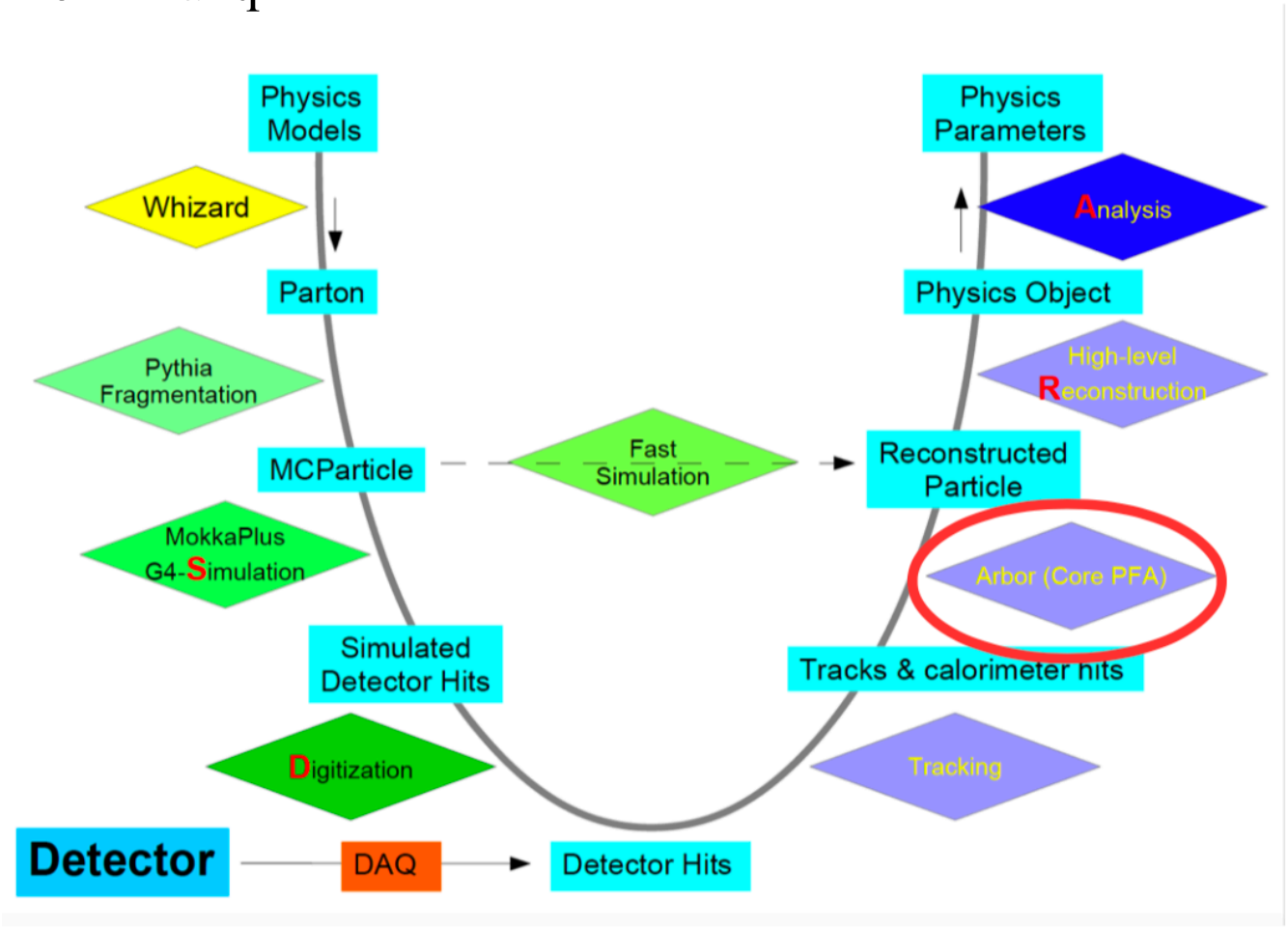
- Direct search for new physics
- Precision test of SM
- Complementary Higgs measurements to CEPC g(HHH), g(Htt)

Huge Data Volume

- Read out in DAQ from CDR
  - ⇨ Maximum event rate: ~100 KHz at Z pole
  - ⇨ Data rate to trigger : ~2 TB/s
- Event Size from simulation
  - ⇨ Size of signal event:
    - ~500 KB/event for Z and ~ 1 MB/event for Higgs
  - ⇨ Signal+background
    - 5~10 MB/event for Z and 10~20 MB/event for Higgs
- Data Storage in disk
  - ⇨ Higgs/W factory
    - ~ 10^8 events for 8 year, 1.5~ 3 PB/year
  - ⇨ Z factory (2 years)
    - 10^{11} ~10^{12} events for 2 years, 0.5~ 5 EB/year

Overview of Current CEPC Software

From Manqi



CEPC-SIMU-2017-001,
CEPC-SIMU-2017-002,
(DocDB id-167, 168, 173)

Generators (Whizard & Pythia)
Data format & management (LCIO & Marlin)
Simulation (MokkaC)
Digitizations
Tracking
PFA (Arbor)
Single Particle Physics Objects Finder (LICH)
Composed object finder (Coral)
Tau finder
Jet Clustering (FastJet)
Jet Flavor Tagging (LCFIPLus)
Event Display (Druid)
General Analysis Framework (FSClasser)
Fast Simulation (Delphes + FSClasser)

General Software | ILCSoft | ILCSoft + Development | Developments

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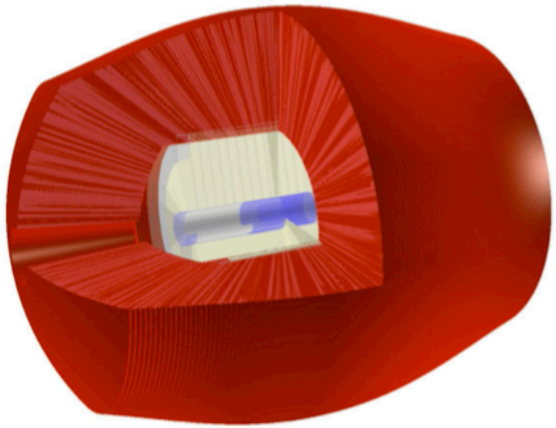
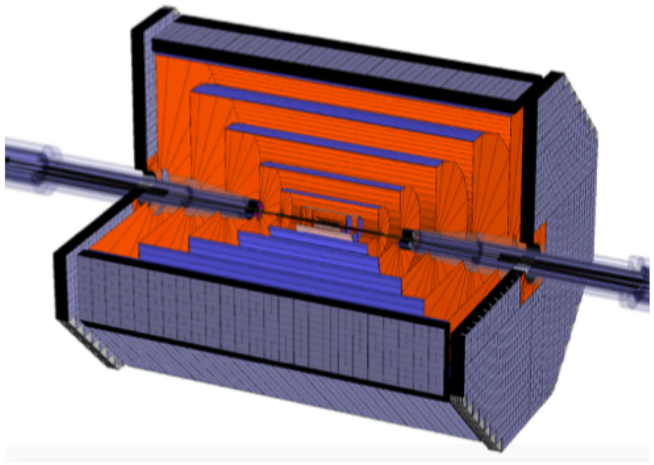
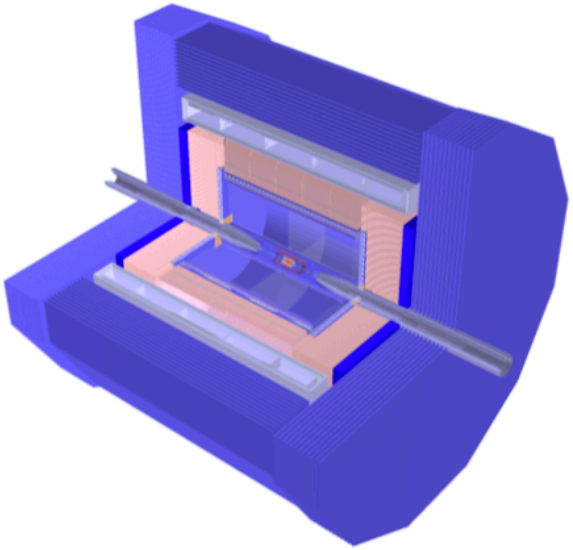
Detector Performance Study

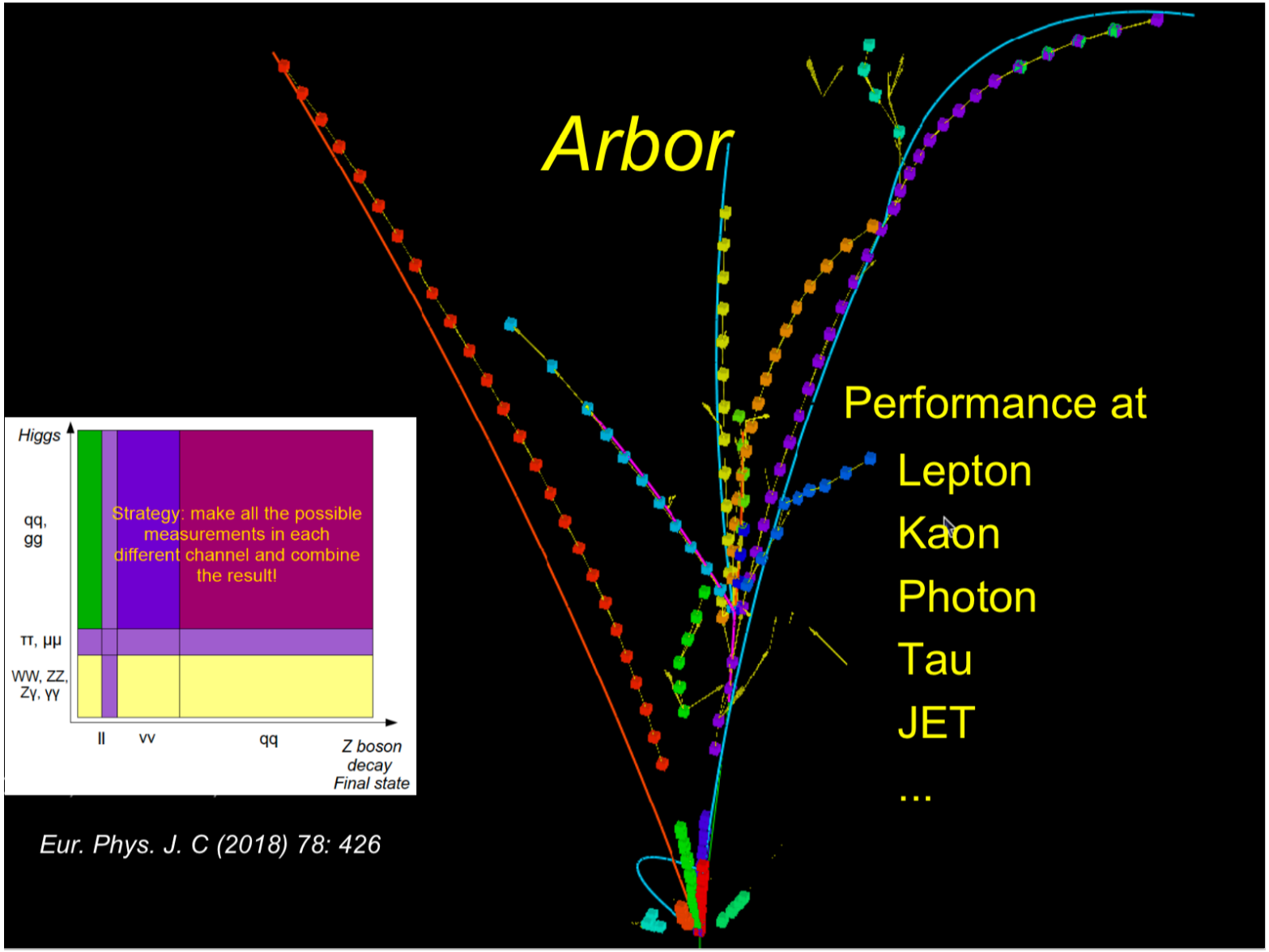






	Geant4-Simulation	Digitization	Reconstruction	Performance-Object	Performance-Benchmark
IDEA					
Full-Silicon					
APODIS					

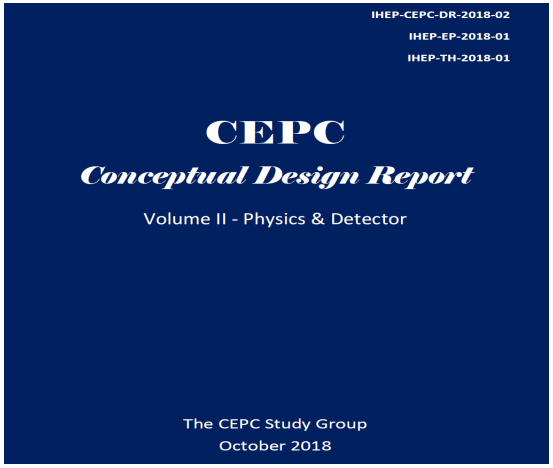
Reconstruction Algorithm Study



Short Summary of Current CEPC Software

- CEPCSW started from ilcsoft (Many Thanks)
  - ⇨ LCIO: ILC event data model and format
  - ⇨ Marlin: data management for reconstruction and analysis
  - ⇨ Some Tracking and flavor-tagging algorithms
- New developments according to CEPC
  - ⇨ MokkaC for detector simulation: Extension on Mokka
  - ⇨ Arbor PFA (Particle Flow Algorithm)
  - ⇨ Some high-level physics object reconstruction….
- The whole M.C. Chain has been setup and played an important role for the entire CDR Study
  - ⇨ Optimize Detector geometry and performance
  - ⇨ Efficiently reconstruct all key physics objects
  - ⇨ Physics potential study

CEPC Timeline



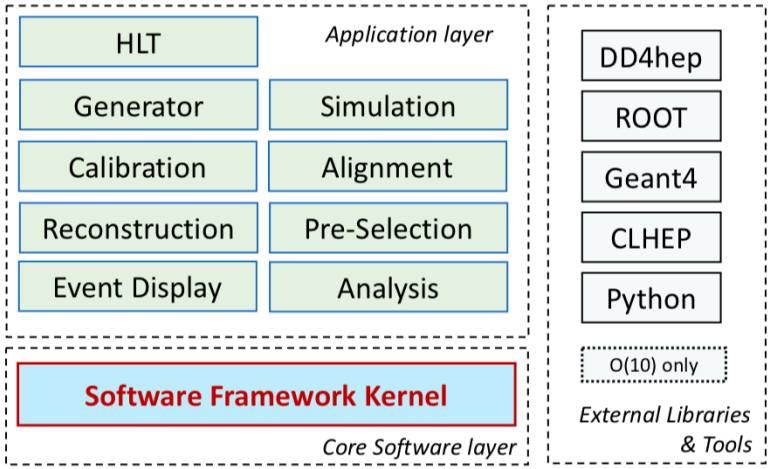
- Finished CDR in Nov, 2018
- Now entering Key Tech. R&D stage
  - ⇨ Accelerator
  - ⇨ Detector
  - ⇨ Software
  - ⇨ ……
- So a new framework for TDR is under investigation!

Challenges of New Framework

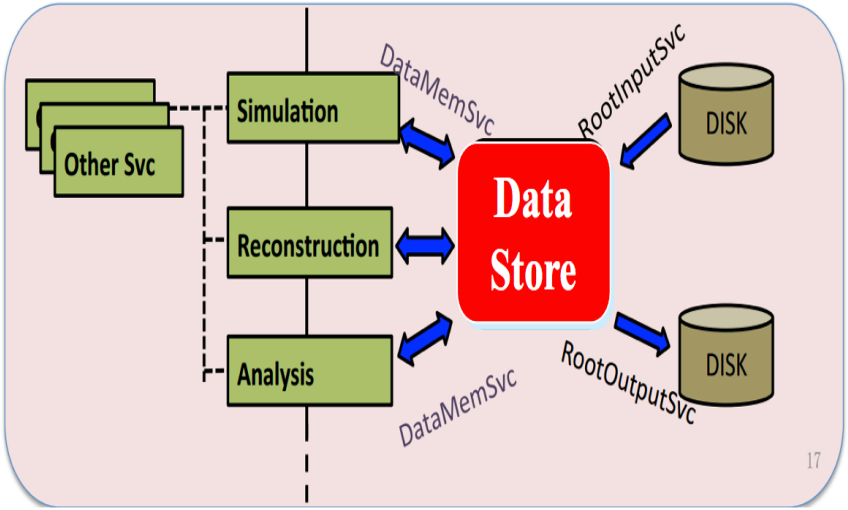
- Huge Data Volume
  - ⇨ O(~EB) for CEPC running at Z pole
  - ⇨ Management of Event Data and even non-Event Data
- Parallelization
  - ⇨ Levels: algorithm, intra-event and inter-event
  - ⇨ Technologies: OpenCL, CUDA, TBB, MPI…
  - ⇨ Re-use of existing and successful serial algorithms
- Heterogeneous Architectures
  - ⇨ CPU,GPU, FPGA, HPC, Cloud…
  - ⇨ Portable and flexible
- Interfaces to novel tools and software
  - ⇨ Application of Machine learning, Deep Learning and Big Data into HEP
- Friendly user interfaces
  - ⇨ Hiding new techniques from physicists
  - ⇨ Support flexible analysis with/without framework , interactive web analysis

Design of New Framework (I)

- Architecture
  - C++ and Python
  - Object-oriented, modular, configurable, load dynamically, easy integration with applications
  - Lightweight, less dependencies and portable on different hardware
  - Easy and good maintance

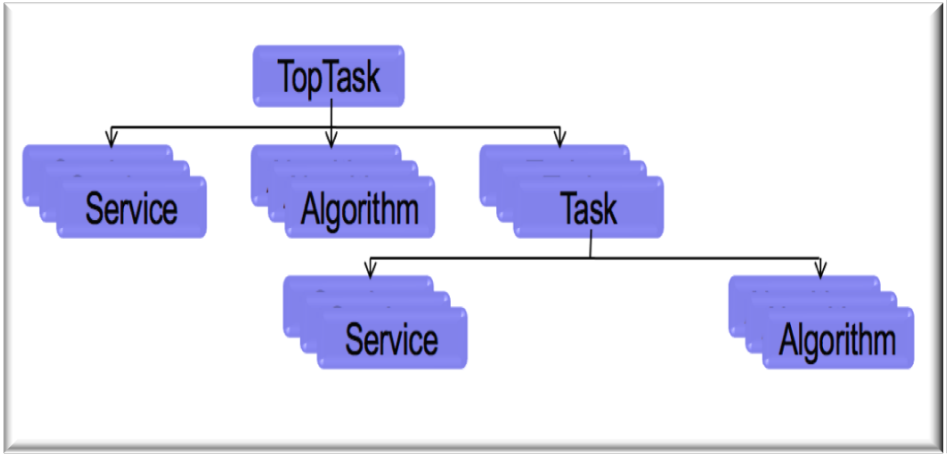


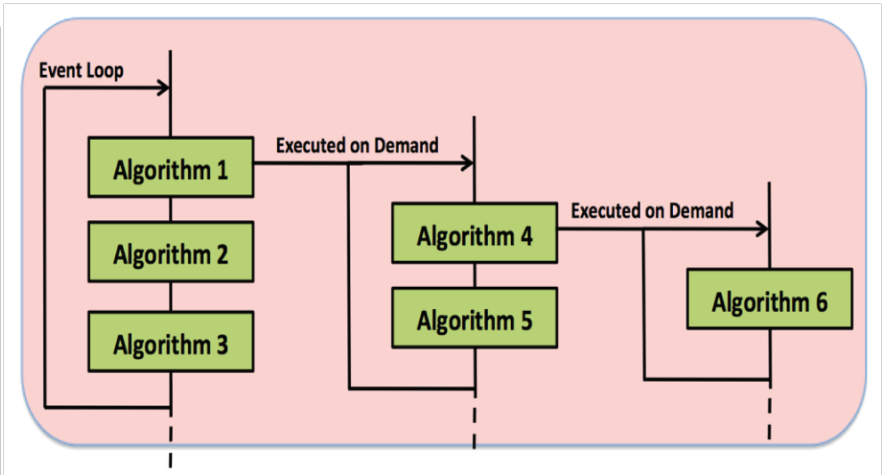
- Event Data Management
  - Data Store serves as the central data management place
  - Objects in Data Store should be generic and flexible
  - Objects in Data Store and access to Objects should be thread-safe
  - Support data from disk, tape and network



Design of New Framework (II)

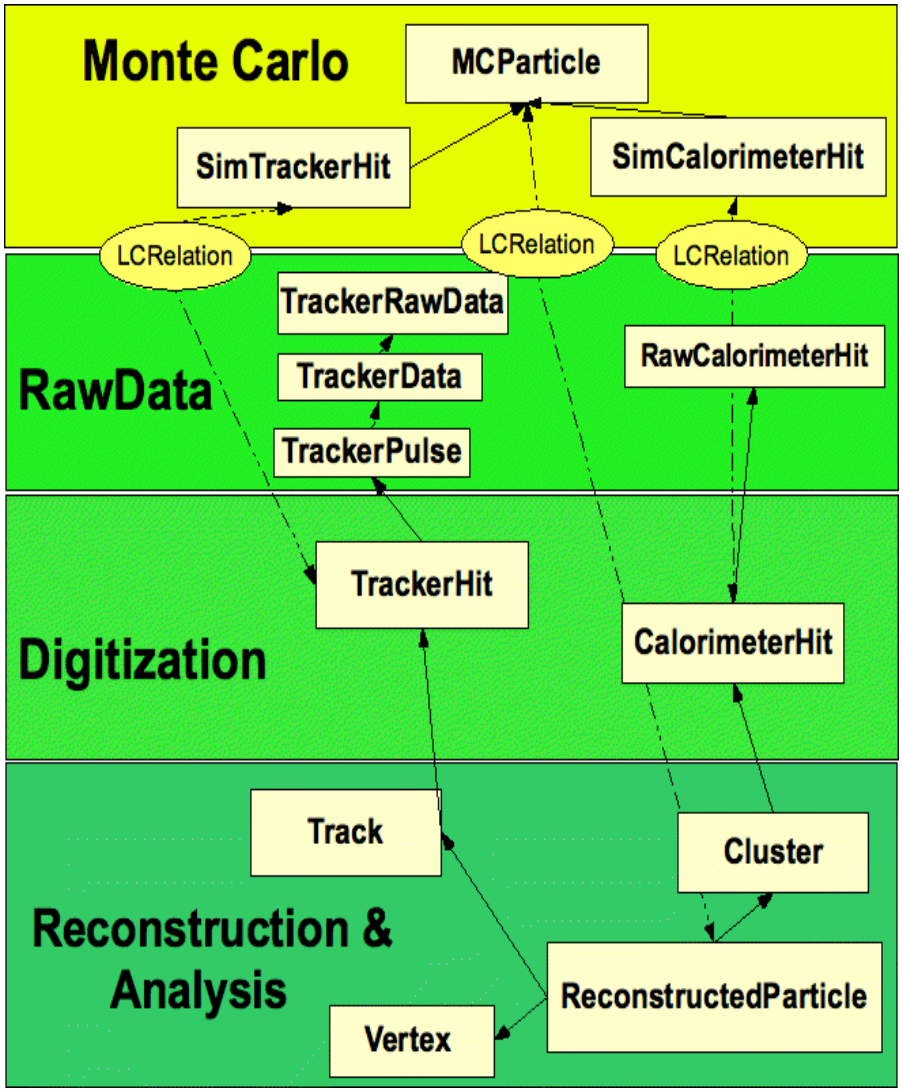
- Data processing
  - ⇨ Flexible workflow management to support event loop & event filter
  - ⇨ Three key components: Algorithm, Service and Task
  - ⇨ Task manages its algorithms, services and subtasks
  - ⇨ Multi-task provides the intrinsic interface for parallelization





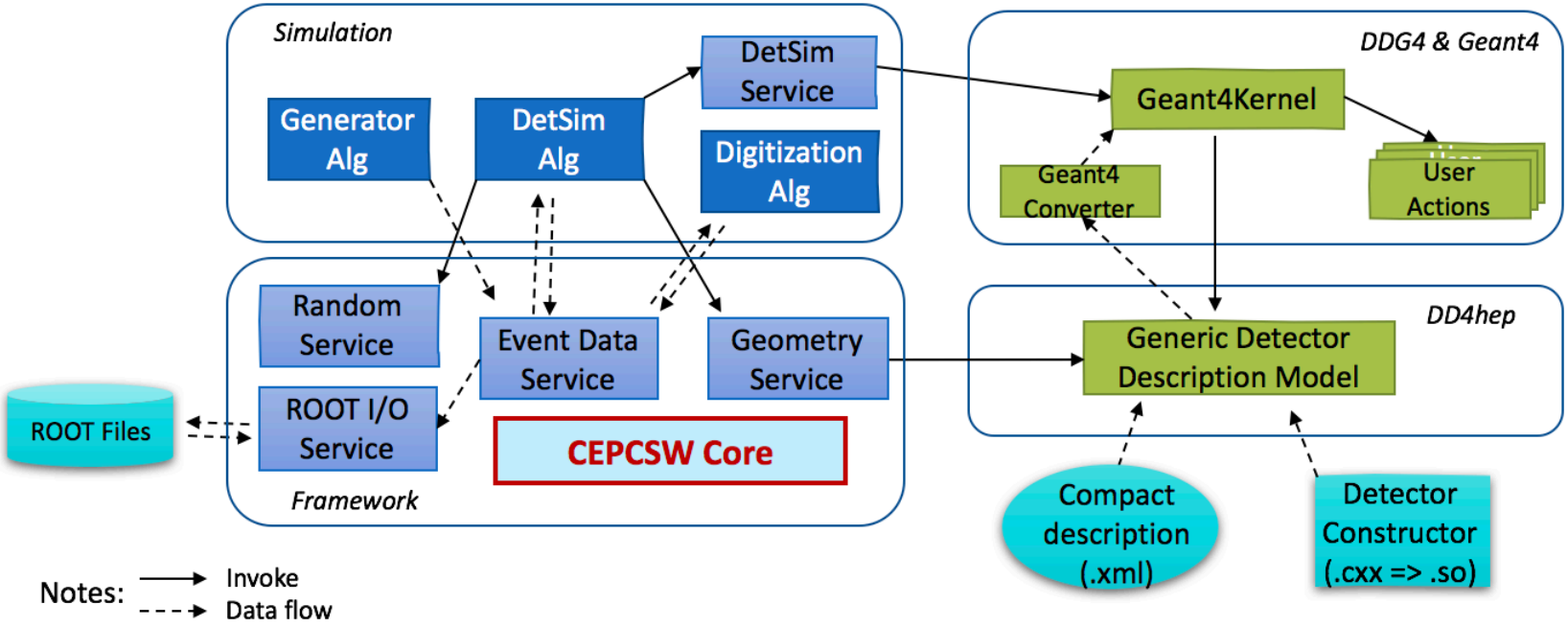
Design of New Framework (III)

- Event Data Model
  - ⇨ LCIO defines a common Event Data Model for Collider Experiments, including
    - Monte Carlo Data, Raw Data
    - Digitization, Reconstruction and Analysis Data
    - Relations between different data objects
  - ⇨ Will be adopted for CEPC with ROOT extension
    - Combine LCIO with ROOT
    - Put LCIO object inheriting from TObject into Data Store
    - Write Data Store objects into ROOT files
    - Convert Data Store objects into other format (such as NumPy for machine learning)



Design of New Framework (IV)

- Detector Simulation
  - ⇨ Integration with generators (for example Whizard and Pythia)
  - ⇨ Adopt DD4hep for detector geometry description
  - ⇨ Integrate DD4hep with framework
  - ⇨ Support running different detector designs and comparison between them.
  - ⇨ Mixing of fast Simulation and full Simulation



Design of New Framework (V)

- Integration of the existing, successful packages and algorithms
  - ⇨ Reconstruction algorithms
    - Tracking, Vertex-finding，Jet-tagging, for example
      - – ACTS (A Common Tracking Software)
      - – Arbor particle Flow Algorithm
  - ⇨ Algorithms developed for physics pre-study
  - ⇨ Algorithms developed in offline could be used online.

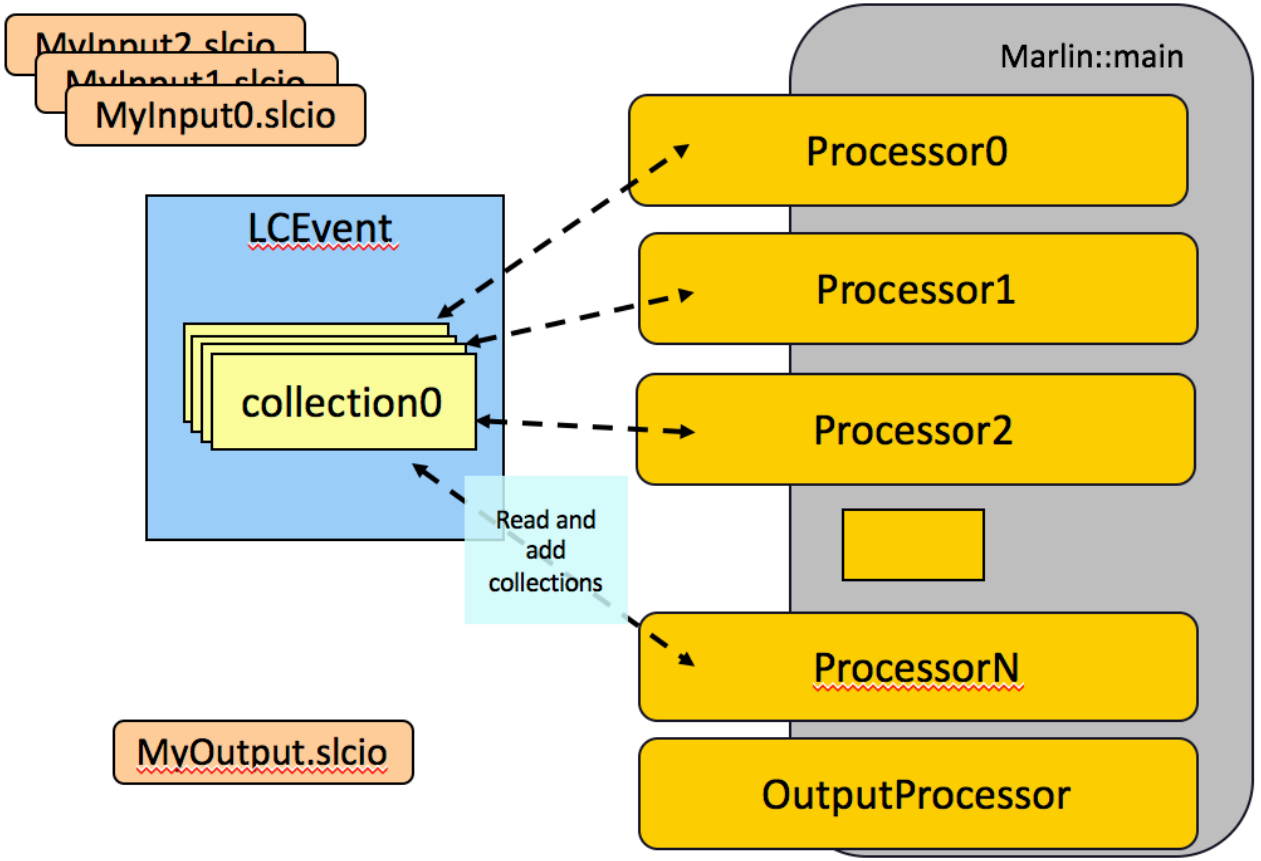
- Integration with New technologies
  - ⇨ Parallel computing: Multithreading, MPI, GPU
  - ⇨ Machine learning: Tesorflow, Blocks, Keras etc.
  - ⇨ Big data techniques: spark and dataframe
  - ⇨ Supercomputers with different computing architectures

CEPC New Framework

- Above are challenges and design consideration for the new Framework
- Honestly speaking, some features and interfaces, especially integration with new technologies, is under study and investigation.
- We urgently hope and need helps/collaborations with the experts from different experiments
- How to do it
  - ⇨ Start from current popular one?
  - ⇨ Start from scratch?

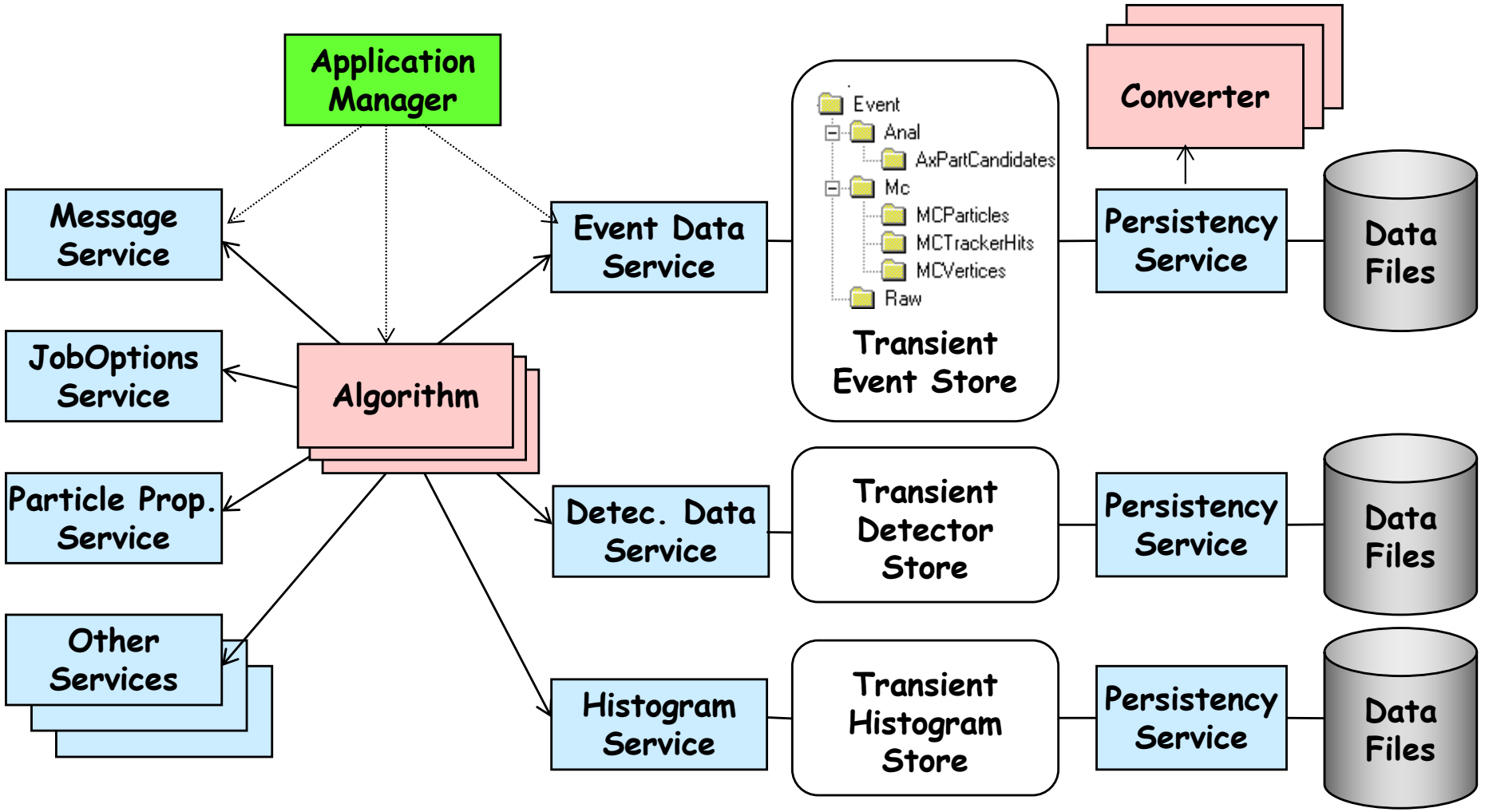
Marlin

- Developed by ILC, used for Reconstruction & Analysis.
- A simple framework based on LCIO
- Used by CEPC-CDR
- Only used in R&D
- Parallelization not yet supported



Gaudi

- Developed by LHCb, became CERN standalone project.
- Already used by BESIII and Daya Bay Experiments
- Good design and very powerful.
- Support Algorithm-level parallelization



Our Concerns with Gaudi

- Less dependencies
  - ⇨ Reduce the number and sizes of external libraries
  - ⇨ Replace inactive and unpopular libraries
  - ⇨ Make it lightweight and convenient to be distributed and deployed
- Be portable on various computing resources
  - ⇨ Cloud, supercomputer, volunteer computing, and etc.
  - ⇨ Non-x86 hosts, such as ARM
- Integration with other software and tools
  - ⇨ General purpose software integration, such as DD4HEP
  - ⇨ Experiment-specific software integration, such as database

Our Concerns with Gaudi

- Event Store and Data I/O services
  - ⇨ Flexible data types other than DataObject in TES
  - ⇨ Unified data structure for transient and persistent data
  - ⇨ Management of condition data

- Parallel Computing
  - ⇨ How to implement a reentrant algorithm
  - ⇨ Migration cost of existing codes
  - ⇨ Smooth switching between parallel and serial mode

Plan of CEPC New Framework Prototype

- Design the kernel part of CEPC new framework prototype
  - ⇨ Based the current one or not?
- Develop ROOT-based Event Data Model & I/O
  - ⇨ Similar interface as LCIO EDM.
- Develop Backward Compatible Input System
  - ⇨ Read existing simulated samples during the migration.
- Develop Unified Geometry System for Sim./Rec./Ana.
  - ⇨ DD4hep
- Integrate and migrate the existing codes into the new framework
  - ⇨ Simulation/Reconstruction/Analysis algorithms
- Design interfaces with new technologies
- Conduct performance testing and give advices for the final CEPC framework

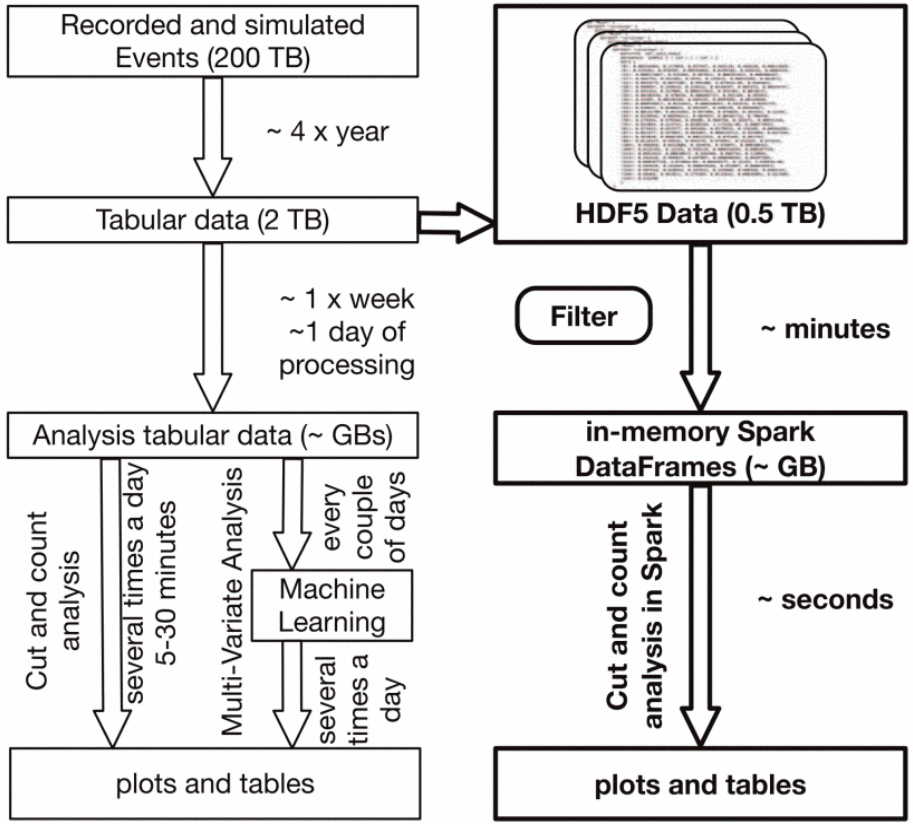
Summary

- Current CEPC Software system played an important role for Detector design, physics benchmarks and CDR.
- A new CEPC framework should be developed in order to meet new challenges
- The prototype of new framework is proposed for software key technology R&D
- We hope to get advices/suggestions/comments from the experts during this meeting
- International collaboration on CEPC framework is mostly welcome
- HSF is the right platform for this kind of collaboration

Thanks a lot!

Interactive Analysis with “Big Data”

- Physics analysis via a web interface with dynamically allocated computing resource.
  - ⇨ Jupyter based web interface.
- “Big data” technology: in-memory analysis
  - ⇨ Read once; Analysis multiple times
  - ⇨ Example: in-memory Spark, DataFrames.
- Challenges: integration with new technologies, such as Spark
  - ⇨ Access event data in different formats.
  - ⇨ Distributed computing with Spark.



Saba Sehrish *et al.*, Spark and HPC for High Energy Physics Data

CEPC Distributed Computing (DC)

- DC will be the main way to organize resources for CEPC
- DIRAC-based DC system has been built up to support CEPC R&D in 2015
  - ⇨ Already integrate resource: Cloud, Cluster, Grid
  - ⇨ Extensible to use more heterogeneous resources
- Several supports for software parallelism in DC are ready
  - ⇨ Multi-core workload scheduling
  - ⇨ Seamless integration of HPC resources
  - ⇨ Singularity supports in pilots