Status of CEPCSW and consideration on computing

Gang LI

(on behalf of the software team)

ligang@ihep.ac.cn

IHEP

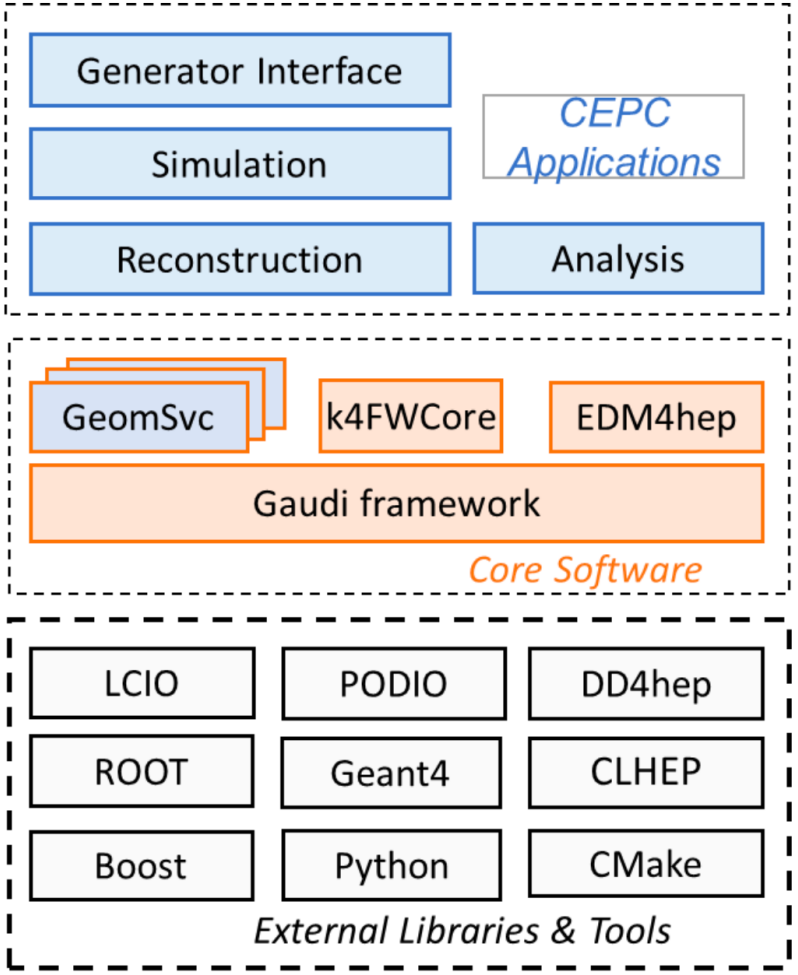
第一届高能物理计算用户研讨会

2024 年5月19-21 日，成都

Outline

- Introduction
- Software
  - Generators
  - Simulation(generator interface)
  - Reconstruction
  - Analysis
- Computing
- Summary

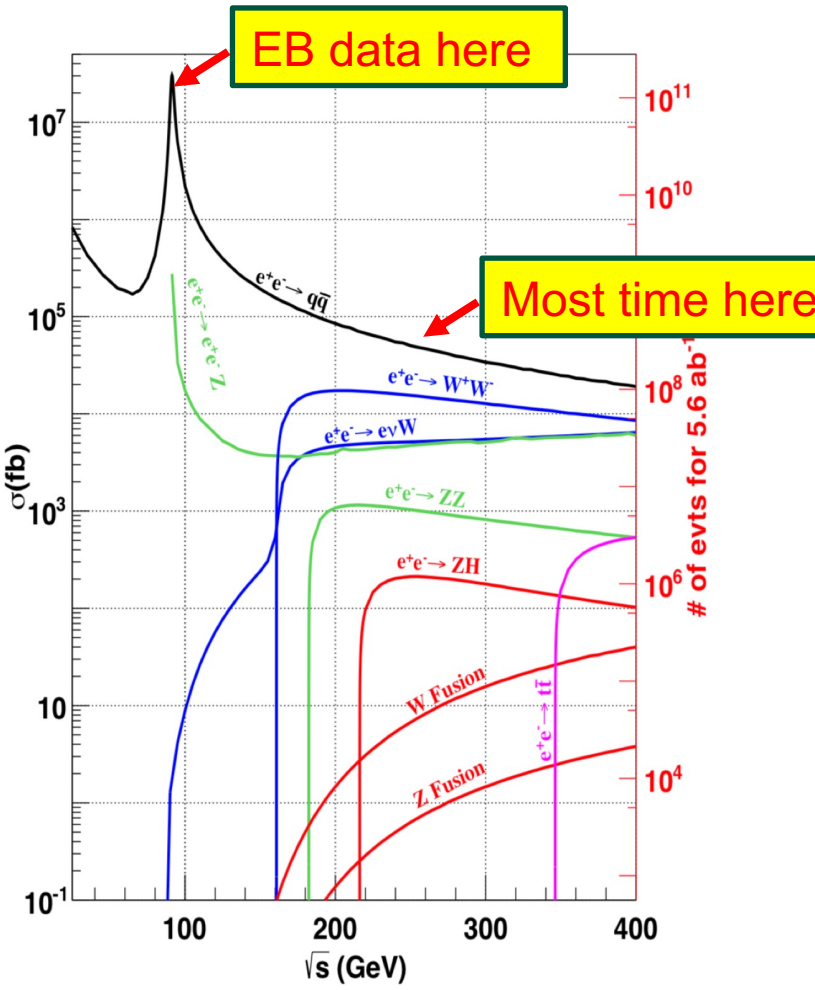
https://github.com/cepc/CEPCSW



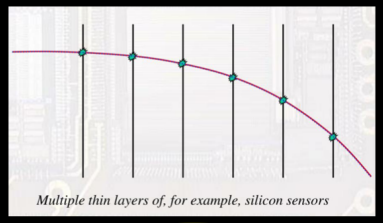
Future Electron Positron Colliders

- Various future electron positron collider experiments proposed, take the CEPC as an example
- Aims to cover a wide energy range: H/Z/W factories
- To run at $\sqrt{s}$ ~ 240 GeV, just above the **ZH** threshold for ~4M Higgs;
- At the **Z** pole for Tera Z (EB);
- Lots of **W^+W^-** pairs, and possible $t\bar{t}$ pairs.
- Higgs, EW, flavor physics & QCD, BSM physics (eg. dark matter, EW phase transition, SUSY, LLP, ….)

http://cepc.ihep.ac.cn/

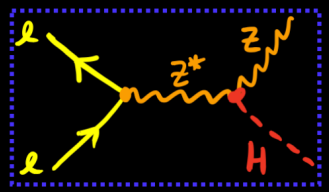


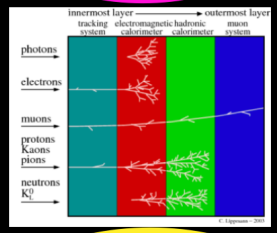
Experiment procedure



Classification of S/B

Nature → Detetor → Reconstruction → Event selection → Statistical inference





Hypothesis testing / Parameter estimation

Event generators → Simulation detector response

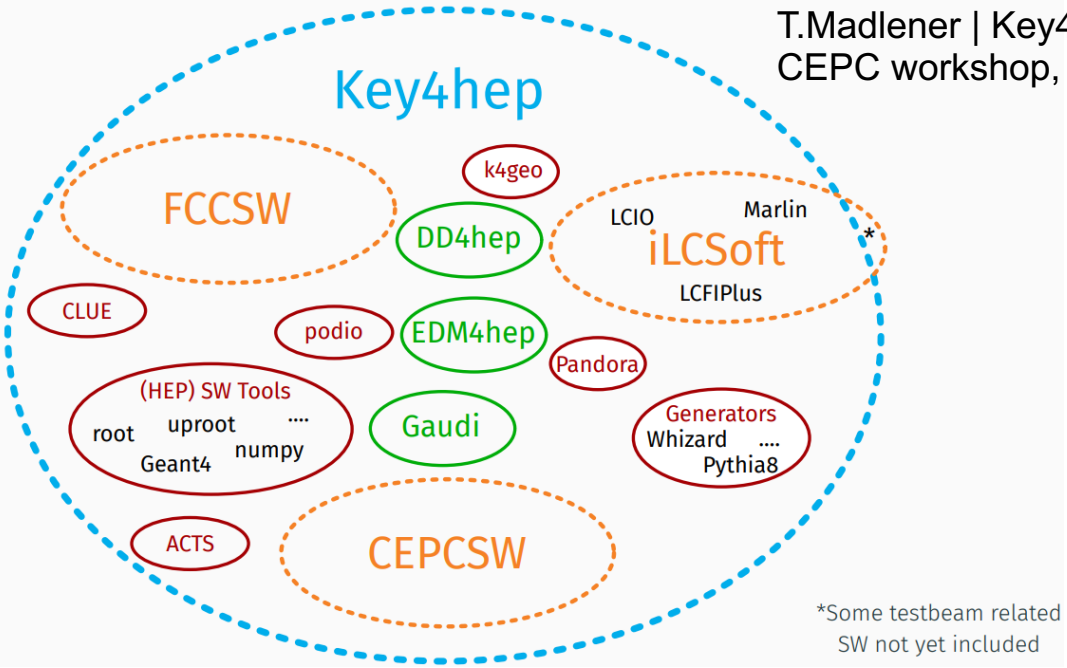
Green loop is the main activity at R&D stage
Yellow ellipses related with software

2024/05/20-22

Introduction

- New CEPC software (CEPCSW) prototype was proposed at the Oxford workshop in April 2019.
- The consensus among CEPC, CLIC, FCC, ILC and other future experiments was reached at the Bologna workshop in June, 2019.
  - Develop a Common Turnkey Software Stack (Key4hep) for future collider experiments

T.Madlener | Key4hep & EDM4hep
CEPC workshop, Edinburgh



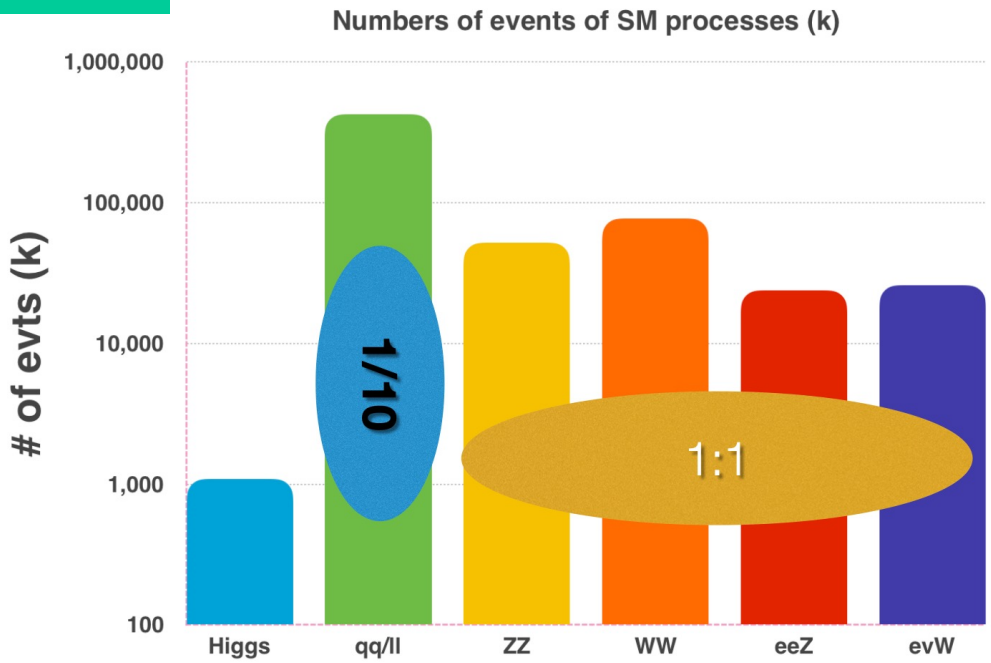
Generators

Generators

- The third part software, not need
  - WHIZARD, MagGraph, Pythia(6&8), TwoGam, …
- Via standard format: HepMC, stdhep, HepEvt, LHE, …

Simulated samples at CDR stage
~200 M events(100 days with 1000 cores)
保证了《概念设计报告》如期发表

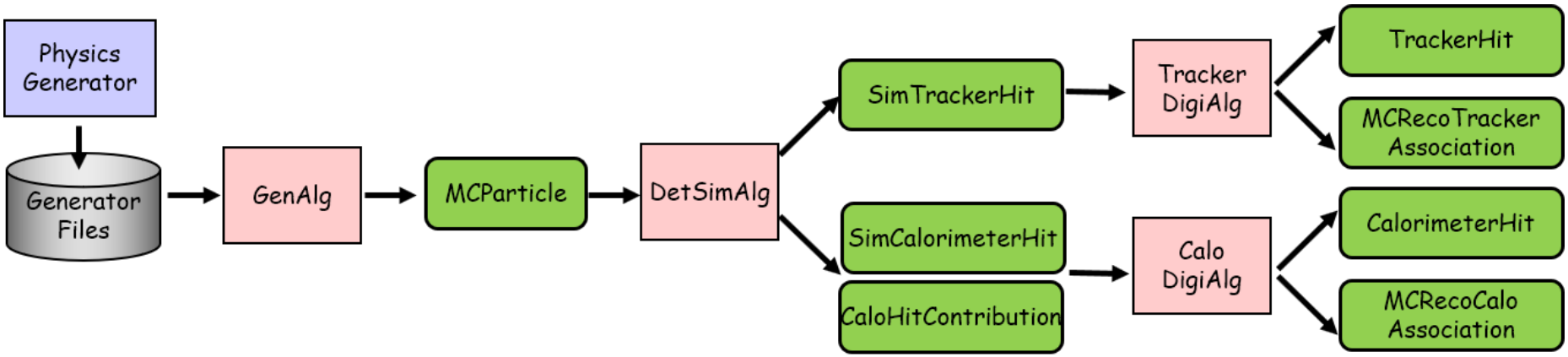
x4 for TDR? + 91 + 360 GeV
Need discussion



Simulation

Simulation in CEPCSW

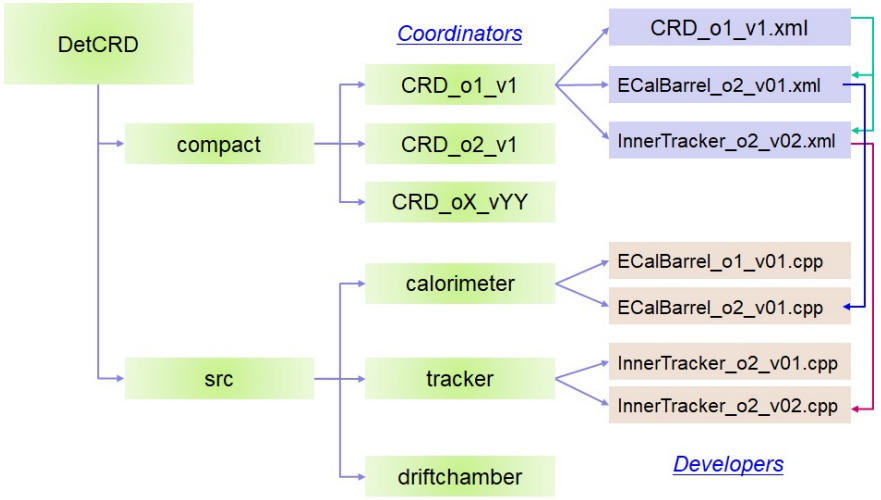
- Complete simulation chain with EDM4hep
  - Physics generator
    - MCParticle
  - Detector Simulation based on Geant4
    - MCParticle (with secondaries), SimTrackerHit, SimCalorimeterHits
  - Digitization
    - TrackerHit, CalorimeterHit



完整的模拟链条

Simulation in CEPCSW

- Geometry management with DD4hep
  - Consists of C++ constructors and XML based compact files
  - https://github.com/cepc/CEPCSW/tree/master/Detector



For the CRD detector models, see README by Chengdong:
https://github.com/cepc/CEPCSW/tree/master/Detector/DetCRD/compact

CRD detector models - Overview

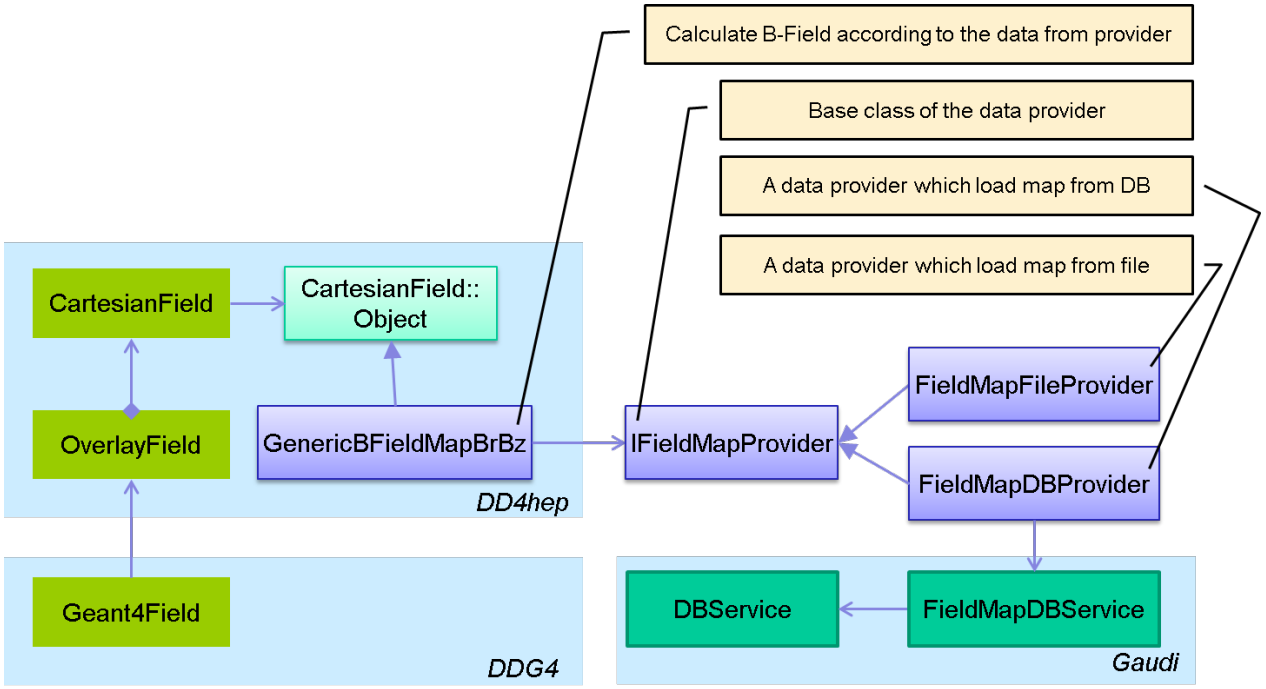
The following CRD detector models are available in CEPCSW

Model	Description	MainTracker	Ecal	Hcal	Status
CRD_o1_v01	coil inside simulation model	SIT+DC+SET	crystal	RPC	developing
CRD_o1_v02	strip SET	SIT+DC+SET	crystal	RPC	developing
CRD_o1_v03	MOST2 vertex	SIT+DC+SET	crystal	RPC	developing
CRD_o1_v04	smaller center beam pipe	SIT+DC+SET	crystal	RPC	developing

模拟的探测器输入和版本管理

Simulation in CEPCSW

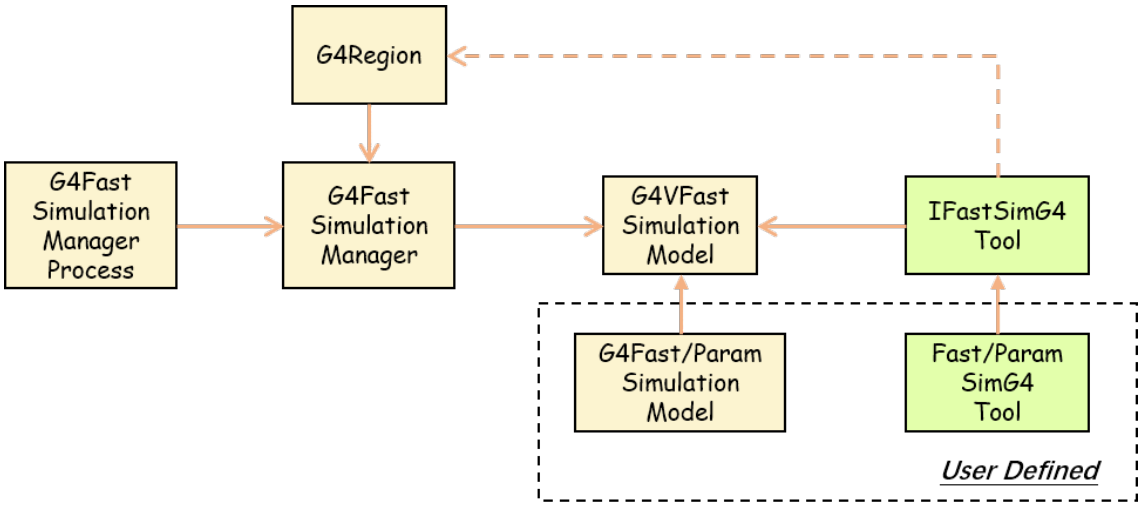
- Non-uniform magnetic fields
  - The Br/Bz csv files are provided by magnetic group.



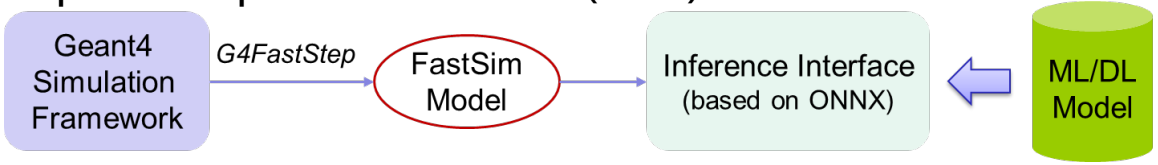
磁场等真实因素的模拟

Simulation in CEPCSW

- Integration with Fast Simulation
  - Region based: when a particle enter a region, fast simulation will be triggered by Geant4.



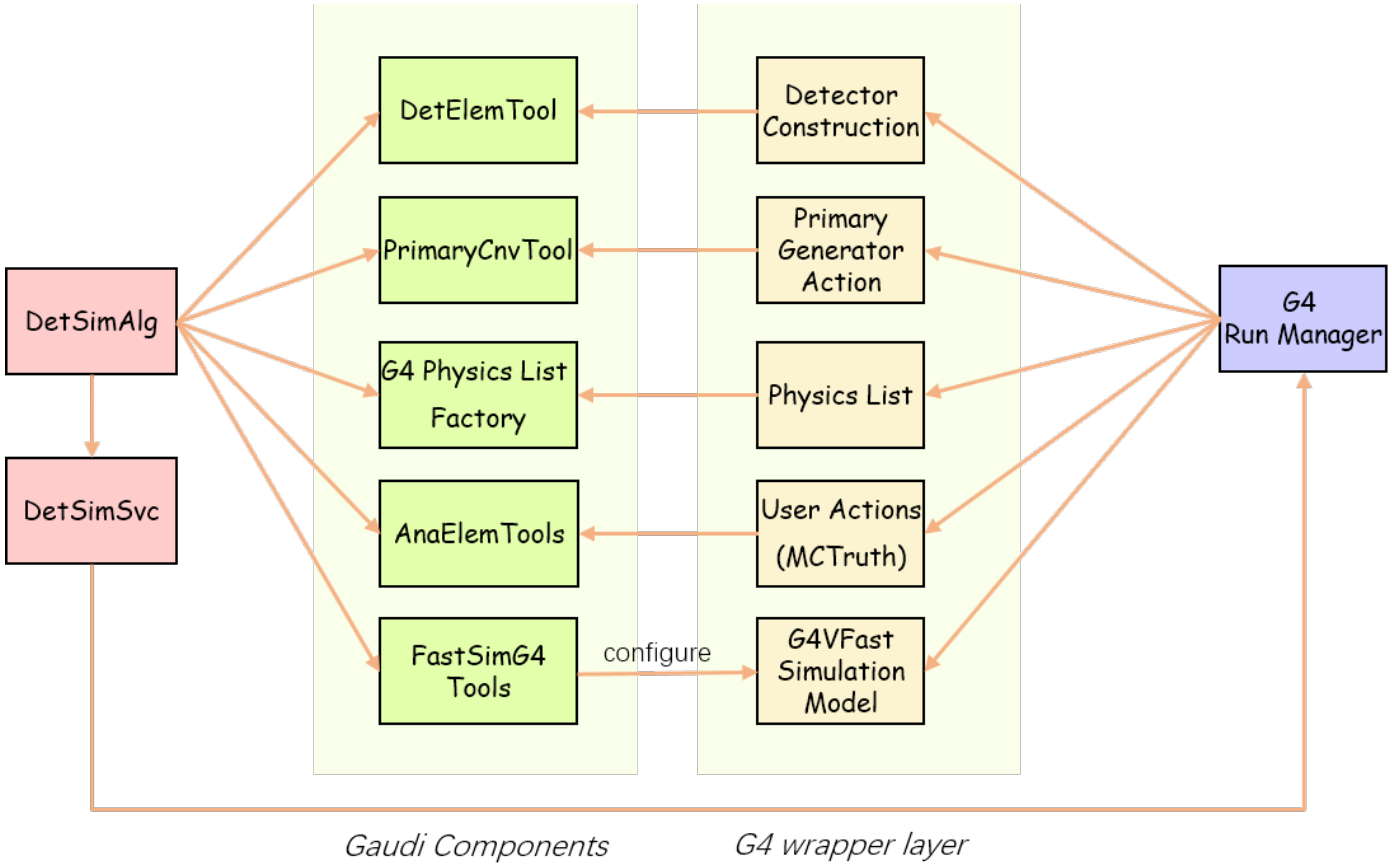
  - Support ML methods via ONNX inference interface.
    - Example: Fast pulse simulation (MLP) in drift chamber done by Wenxing



采用ML 和参数化模拟用来加速

Simulation in CEPCSW

- Integration with Geant4 and Gaudi
  - A thin layer is developed to manage corresponding Geant4 objects.

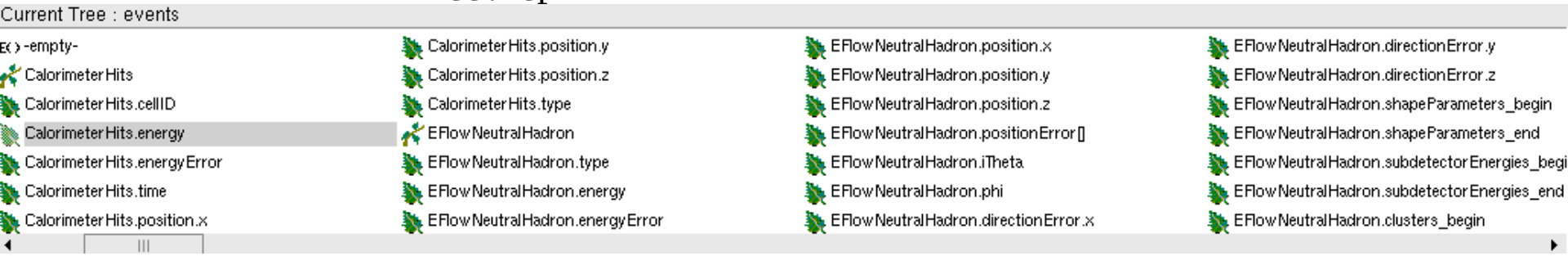


集成到 Gaudi 框架中

Fast simulation with Delphes & k4SimDelphes

- Delphes is also integrated into Key4hep.
  - EDM4hep is one of the supported output formats.
  - k4SimDelphes offers both standalone executables and the integration with framework.
    - https://github.com/key4hep/k4SimDelphes

```
$ DelphesSTDHEP_EDM4HEP \
    delphes/cards/delphes_card_CEPC.tcl \
    k4SimDelphes/edm4hep_output_config.tcl \
    delphes_output_edm4hep.root \
    z ee.hep
```

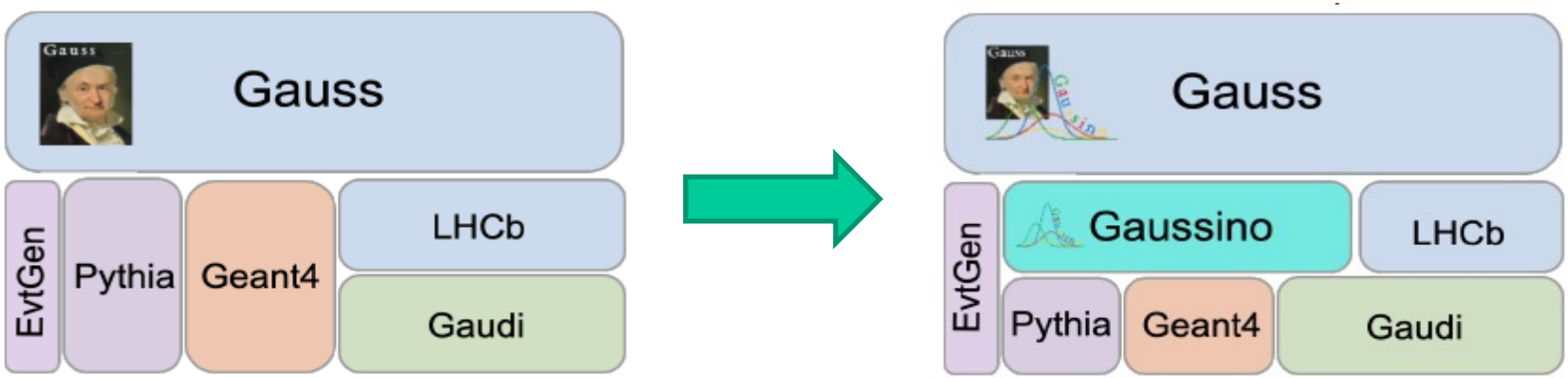


Also see Key4hep-doc:
https://key4hep.github.io/key4hep-doc/k4simdelphes/doc/starterkit/k4SimDelphes/Readme.html

物理研究： 参数化模拟框架

Gaussino-based simulation

- CEPC also works together with Key4hep project members and is re-implementing CEPC detector simulation with Gaussino
- Evolution of the simulation framework from LHCb
  - The underlying framework is moving to Gaudi Functional and Gaudi Hive
  - Better support for multi-threading, machine learning, fast simulation methods
  - Gauss-on-Gaussino is a new version of LHCb simulation framework



- Gaussino is being added to Key4hep by extracting experiment-independent parts from Gauss

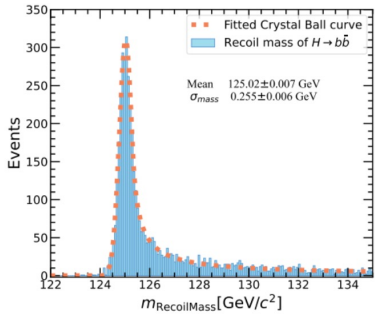
长期：借鉴其它先进模拟方案

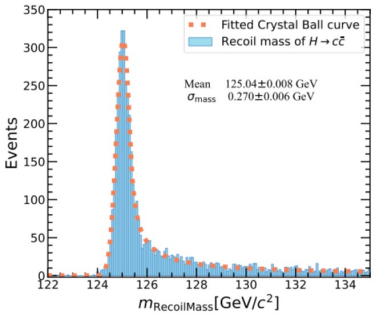
Reconstruction

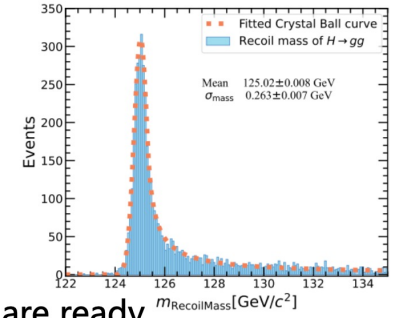
Tracking

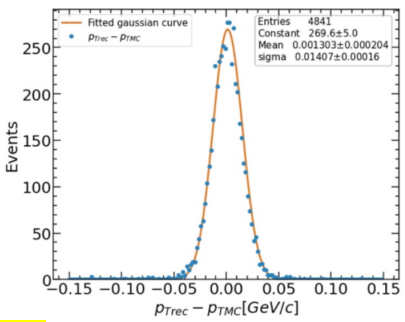
- Physics events:
  - Check the recoil mass of higgs boson
    - $e^+e^- \to \mu^+\mu^- H, H \to b\bar{b}, c\bar{c}, gg$
- Updated DC geometry parameters
  - inner radius: 800mm → 600mm
  - Diameter of field wire: 40μm → 60μm
- DC software be ready and released
  - The compact file of new DC geometery
    - DC_Simple_v01_06.xml
  - CKF algorithm as an external project
  - The codes of simulation and reconstruction are ready
  - good performance and meet requirments

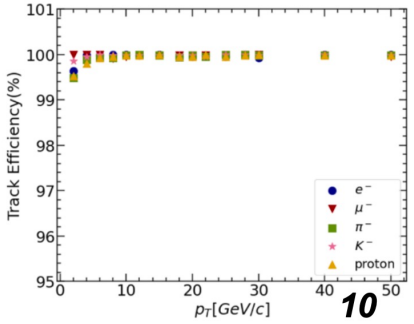
  for tracker
    - $\sigma_{p_T}/p_T \approx 0.14\%$
    - Track efficiency close to 100%
  - To be released new version before 24.04.25











带电粒子重建

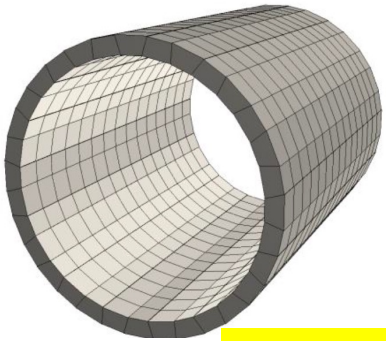
Particle identification

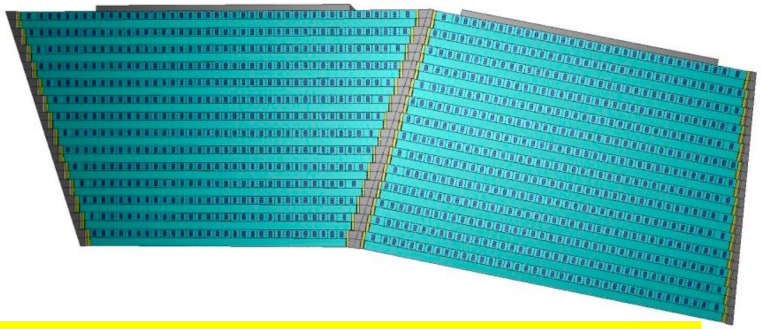
- dN/dx in gaseous detectors
  - Goal: To implement a track-level parameterization model.
  - Status:
    - Drift chamber: Working on a parameterization model with machine learning reconstruction. To make the implementation in CEPCSW.
    - Time projection chamber: Working on the pixel-size optimization.
- Time-of-flight
  - Goal: To implement a track-level parameterization model.
  - Status:
    - There is no datatype related to ToF information in EDM4hep. Will create a new datatype in EDM4hep.

带电粒子种类鉴别

Particle Flow calorimeter

- New geometry for Ref-Det in CEPCSW Rel. tdr24.4.0 (By Weizheng)
  - 32-polygon crystal bar ECAL
    - Inner R = 1900mm, outer R = 2200 mm, Z length = 5900 mm.
    - Dead material in the crack region are considered: total width ~ 20 mm. Including: supporting, electronics, cooling.
  - 16-polygon glass tile HCAL with AHCAL symmetric layout.
    - Glass + steel, totally 48 layers, glass tile size 40 * 40 mm.
  - Still updating with mechanical and electronic design.
- Digitization and reconstruction: migrating to the new geometry and validating the performance.





径迹探测器和量能器的联合

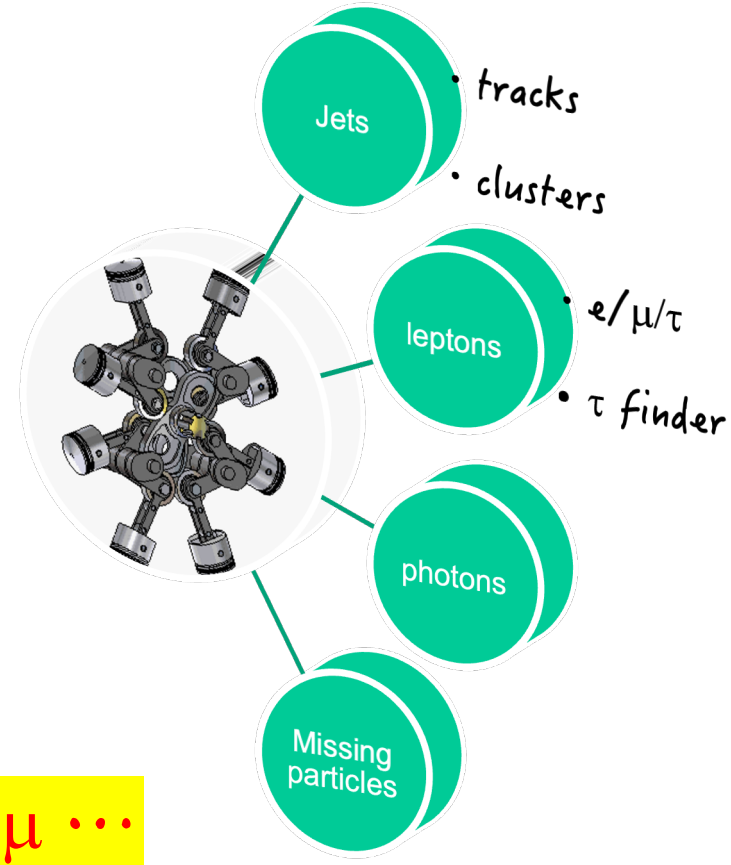
Missing parts

- Unified PID function and interface
- Secondary vertex finding
- Jet clustering
- Jet flavor tagging： interface to ML algorithm

Analysis

Model of data analysis

Feed all types of particle lists to the combination engine for further processing



ee+X, μμ+X, jj+ee, jj+μμ ···

Abstraction

- Class FSParticle → particles & lists
- Class FSinfo → all kinds of combination
- Class NTupleHelper → Ntuple service
- Class MCTruthHelper → MC truth service
- Class FSCut → simple cuts

Example
ee→ μ+μ− Higgs(anything)

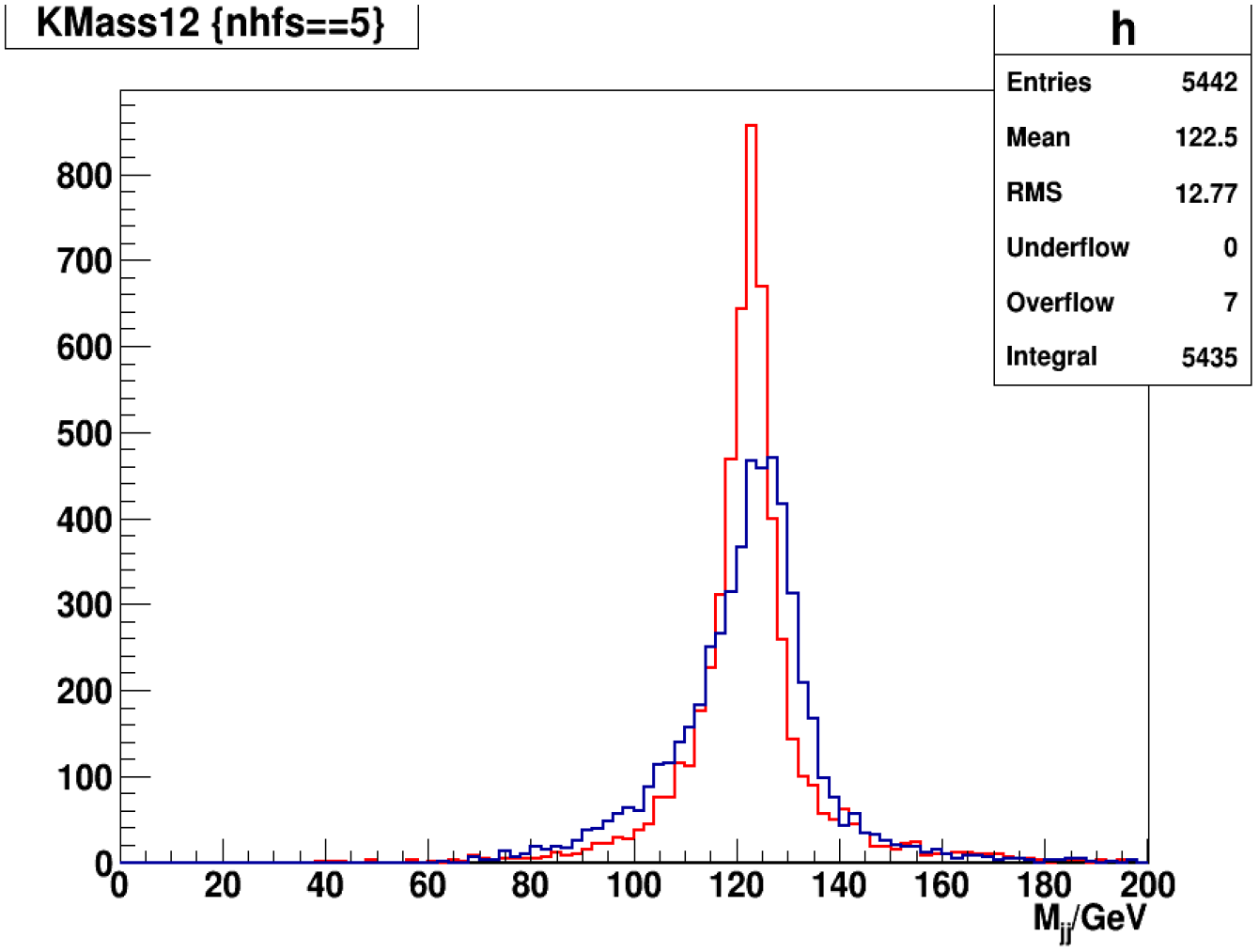
- Tell the FSClasser processor what you want

jet	γ	τ+	τ−	μ+	μ−	e+	e-
INC 0	_	0	0	0	1	1	0	0

8 digits: the numbers of particles your want

Pre-selection cuts, kinematic fit, multi-entry, multiple channels, sufficient information saved, …

Kinematic fit



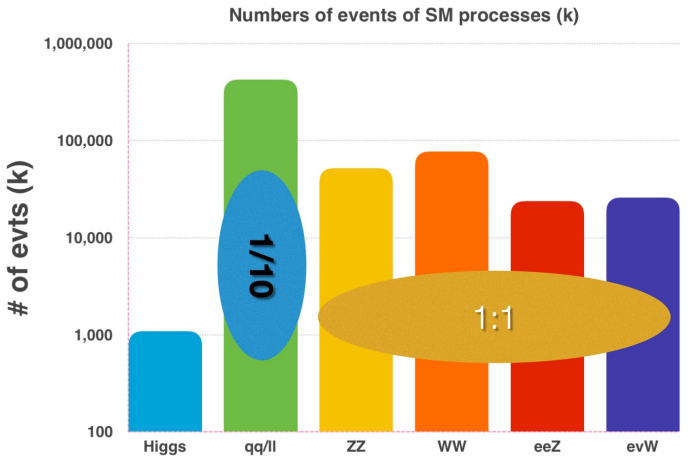
Release plan

- Release tdr24.3 (March 2024)
- Release tdr24.4.0 released
  - Background mixing
  - Silicon detector reconstruction
  - TPC reconstruction
  - Drift Chamber reconstruction
- Release tdr24.5 (May 2024)
  - PID simulation and reconstruction
  - Muon software
- Release tdr24.6 (June 2024)
  - Particle Flow Calorimeter reconstruction

Computing

- Higgs signal
  - Selected backgrounds
  - O(10^7)
- ttbar signals
  - Selected backgrounds
  - O(10^6)
- Z pole (Tera Z: O(10^{12}))
  - Need more discussion
  - Only some selected signal
  - And a "small" background sample O(10^7)

CDRx4 for TDR?
+ 91GeV
+ 360 GeV



工作的常态


车逾之
如果是负载的话，10 点之后很轻松了？
车逾之
Lustre DefaultSegment aggregated load_one last 2hr
240
220
200
180
160
140
120
100
80
60
40
20
0
09:00
09:20
09:40
10:00
10:20
10:40
cefs06.ihep.ac.cn
cefs07.ihep.ac.cn
cefs08.ihep.ac.cn
cefs10.ihep.ac.cn
cefs11.ihep.ac.cn
cefs12.ihep.ac.cn
cefs13.ihep.ac.cn
cefs14.ihep.ac.cn
cefs15.ihep.ac.cn
cefs16.ihep.ac.cn
cefs17.ihep.ac.cn
cefs18.ihep.ac.cn
cemds.ihep.ac.cn
Avg Total: 68.11 Current Total: 0.00
Avg Average: 5.68 Current Average: 0.00
郭方毅
现在确实进得去了
车逾之
但是 10:27 的时候确实在卡
.: 还是卡死的，看起来负载很高...

Summary

- CEPC software is integrated with Key4hep.
  - Adopting a common software makes it easy to share between different experiments, such as k4SimDelphes could be used.
- A complete simulation chain is available in CEPCSW.
  - It is already used for detector software development.
- Reconstruction software under development
  - A complete version will be released on schedule
- Computing for detector study going smoothly
- Computing of mass production for TDR analysis challenging