Offline Software Framework for the Super Tau Charm Facility (STCF)

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Outline

- Introduction to STCF
- Overview of STCF Offline Software
- SNiPER framework
- Event Data Model
- Detector Description
- Detector simulation
- Validation System
- Summary

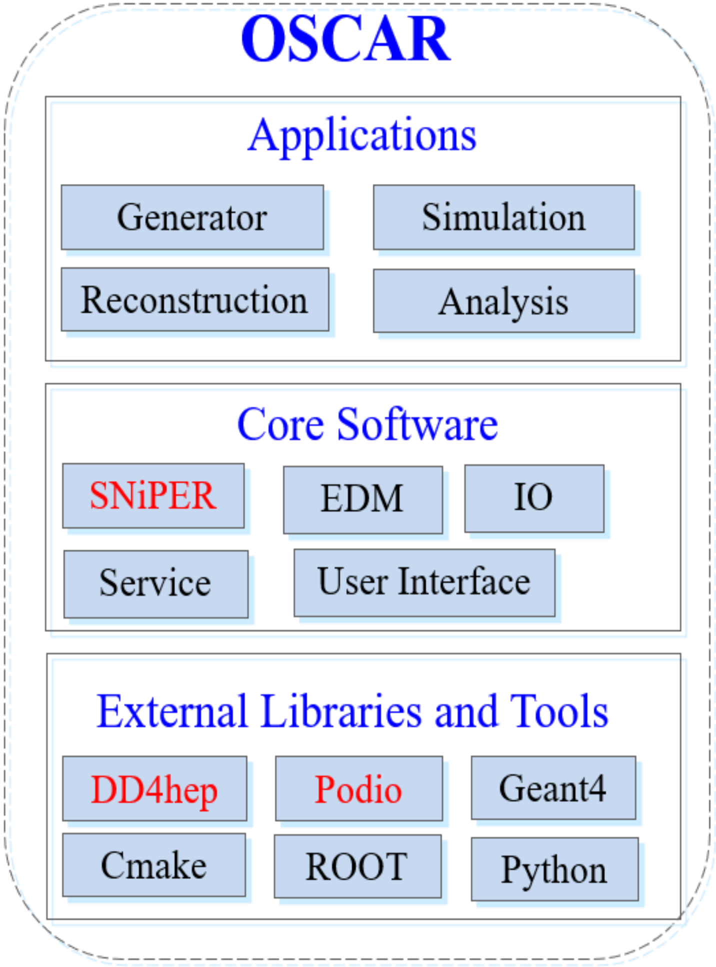
Introduction to STCF

- Tau-Charm factory in China has 30 years history
  - ⇨ From BEPCI/BESI-II to BEPCII/BESIII
  - ⇨ Successful operation, Fruitful physics results
  - ⇨ Pursuing higher and higher center-of-mass energy (CME) and Luminosity

- STCF is proposed for next Tau-Charm factory in China
  - ⇨ CME: $2 - 7\ GeV$
  - ⇨ Luminosity: $> 0.5 \times 10^{35} cm^{-2} s^{-1}$ (100 times of BESIII)
  - ⇨ BESIII-like detector based on new technologies
  - ⇨ Potential to further improve the luminosity and realize polarized beam
  - ⇨ More and higher challenge for offline software system

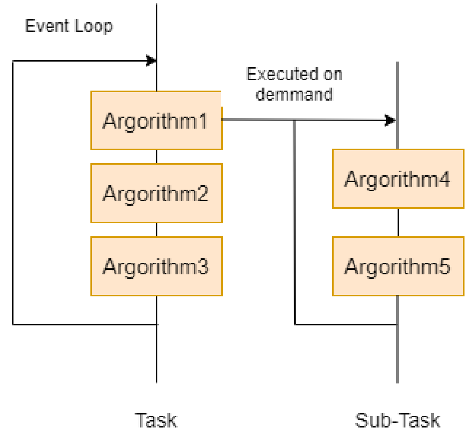
Overview of STCF Software System

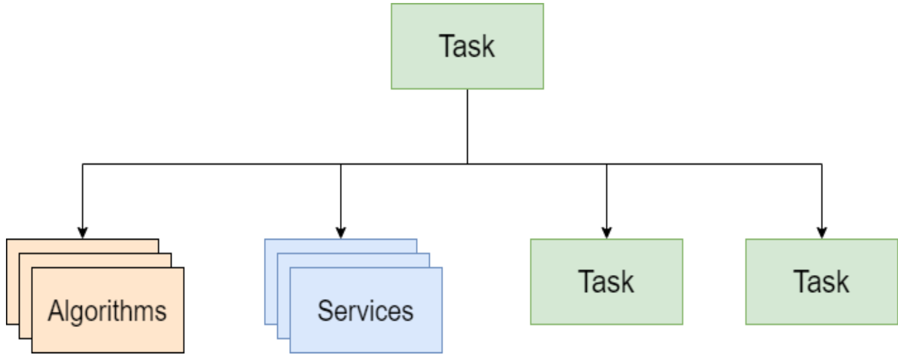
- The Offline Software of Super Tau-Charm Facility(OSCAR) was designed and developed for detector design and optimization as well as M.C data production and physics analysis in future
  - ⇨ Started development based on SNiPER framework from 2018
  - ⇨ Partially based on Key4hep
    - Adopted DD4hep for detector description in 2019
    - Recently move to PODIO for Event Data Model
  - ⇨ Migrated some mature applications from BESIII



SNiPER Framework

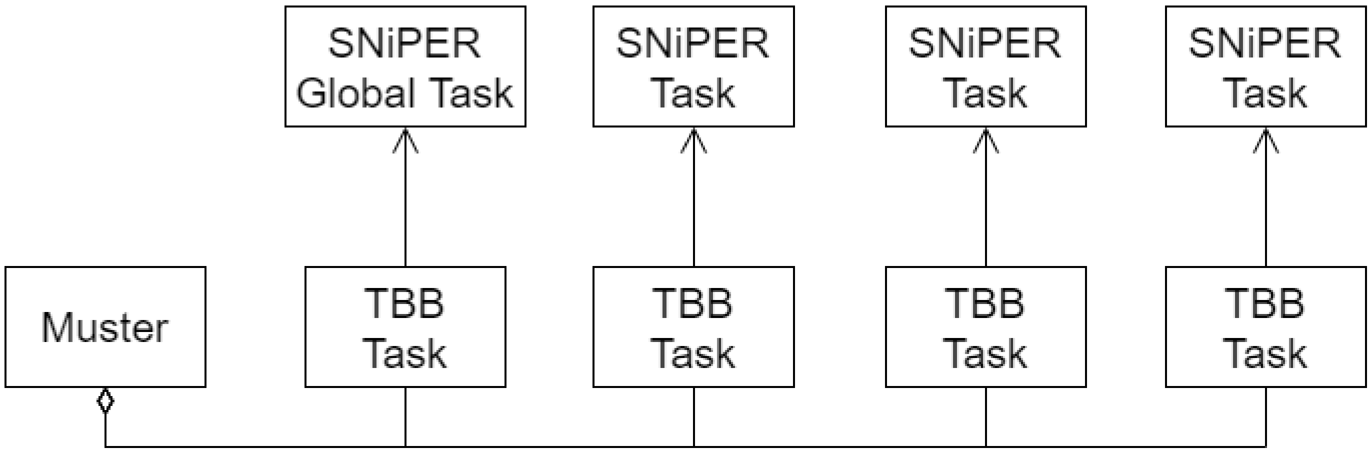
- Developed and optimized for non-collider experiments but also suitable for collider experiments
- It is light-weighted and successfully adopted by JUNO (neutrino), LHAASO (cosmic ray), nEXO (neutrinoless double beta decay) …
- The basic unit of applications is Task
  - ⇨ Application manager
  - ⇨ Event loop automatically
  - ⇨ Usually consist of algorithms, services and sub-tasks
    - Algorithm is the unit of event loop, usually defined by users.
    - Service provides common functions, like data I/O…
    - Sub-tasks have their own algorithms, services and sub-tasks…





Parallelism in SNiPER

- SNiPER Muster (Multiple SNiPER Task Scheduler)
  - ⇨ Based on Intel Threading Building Blocks(TBB).
  - ⇨ Create multiple instances of Task.
  - ⇨ Create TBB-based workers to execute the Task.
    - Each worker would be binded to one thread.
    - One SNiPER Task could be the one on slide5



reference: J. H. Zou et al J. Phys.: Conf. Ser. 664 (2015) 072053

J. H. Zou et al EPJ Web Conf. 214 (2019) 05026

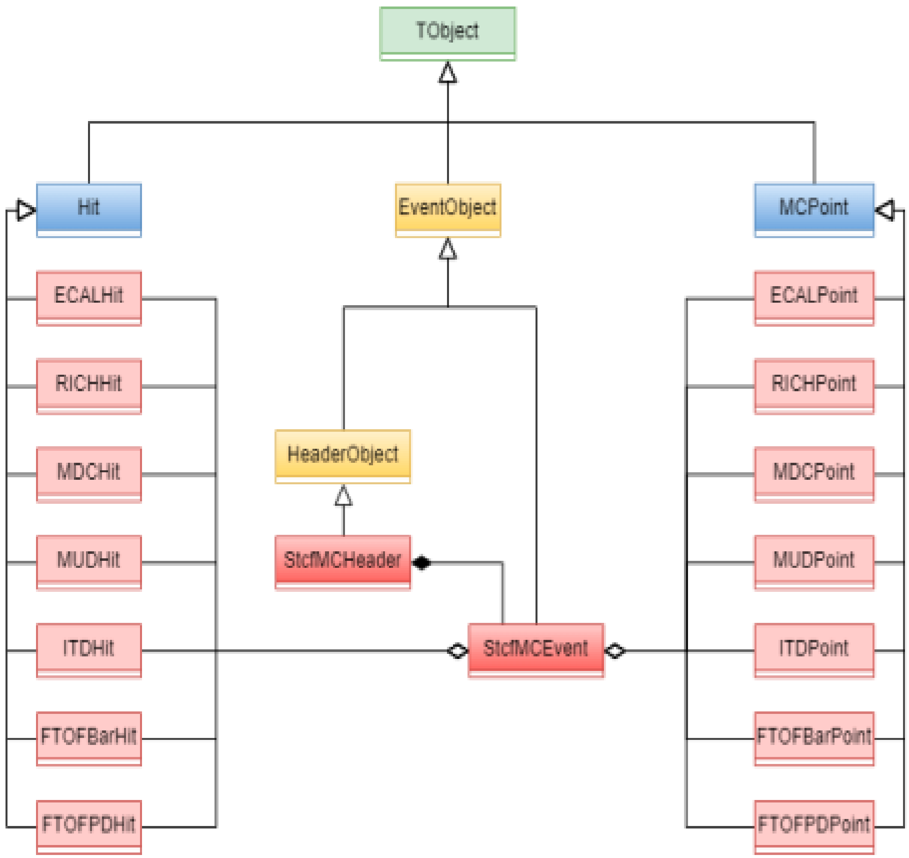
Event Data Model based on ROOT

- Event data model(EDM) is the core of every HEP experiment's software framework.
  - ⇨ Defines interface and communication channels between the different framework components.
  - ⇨ Defines the description of physics event.

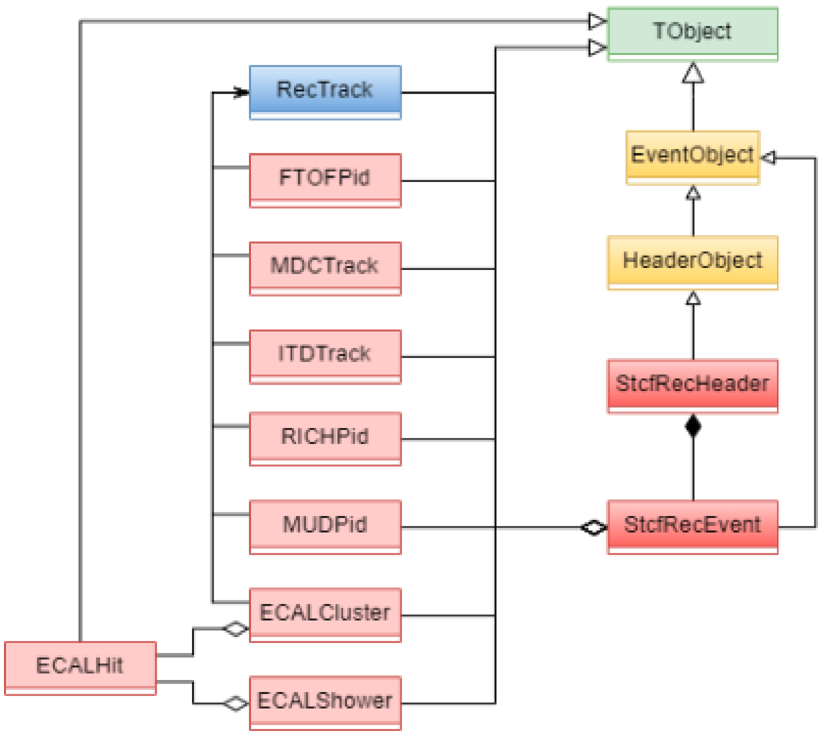
- EDM in OSCAR was defined based on ROOT since 2018.
  - ⇨ EDM for each process and each sub-detector
  - ⇨ Two levels: Event Header and Event
  - ⇨ SmartRef reference class
    - Relationship, associations between files, lazy-loading
  - ⇨ XOD generates C++ codes from xml files.

reference: T Li and X T Huang J. Phys.: Conf. Ser. 762 (2016) 012001

Optimized EDM based on ROOT



MCEvent

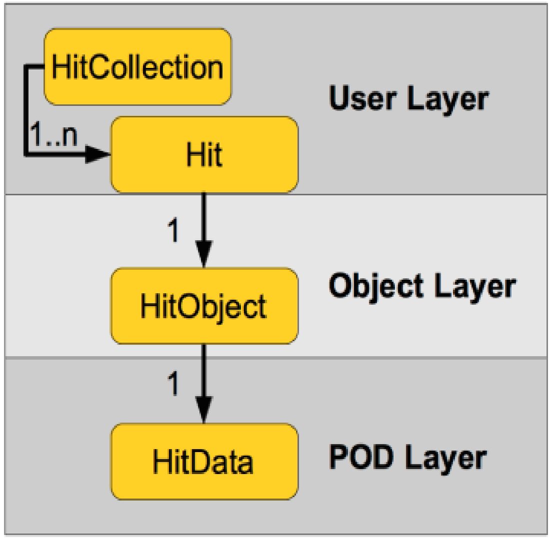


RecEvent

EDM4hep and Podio

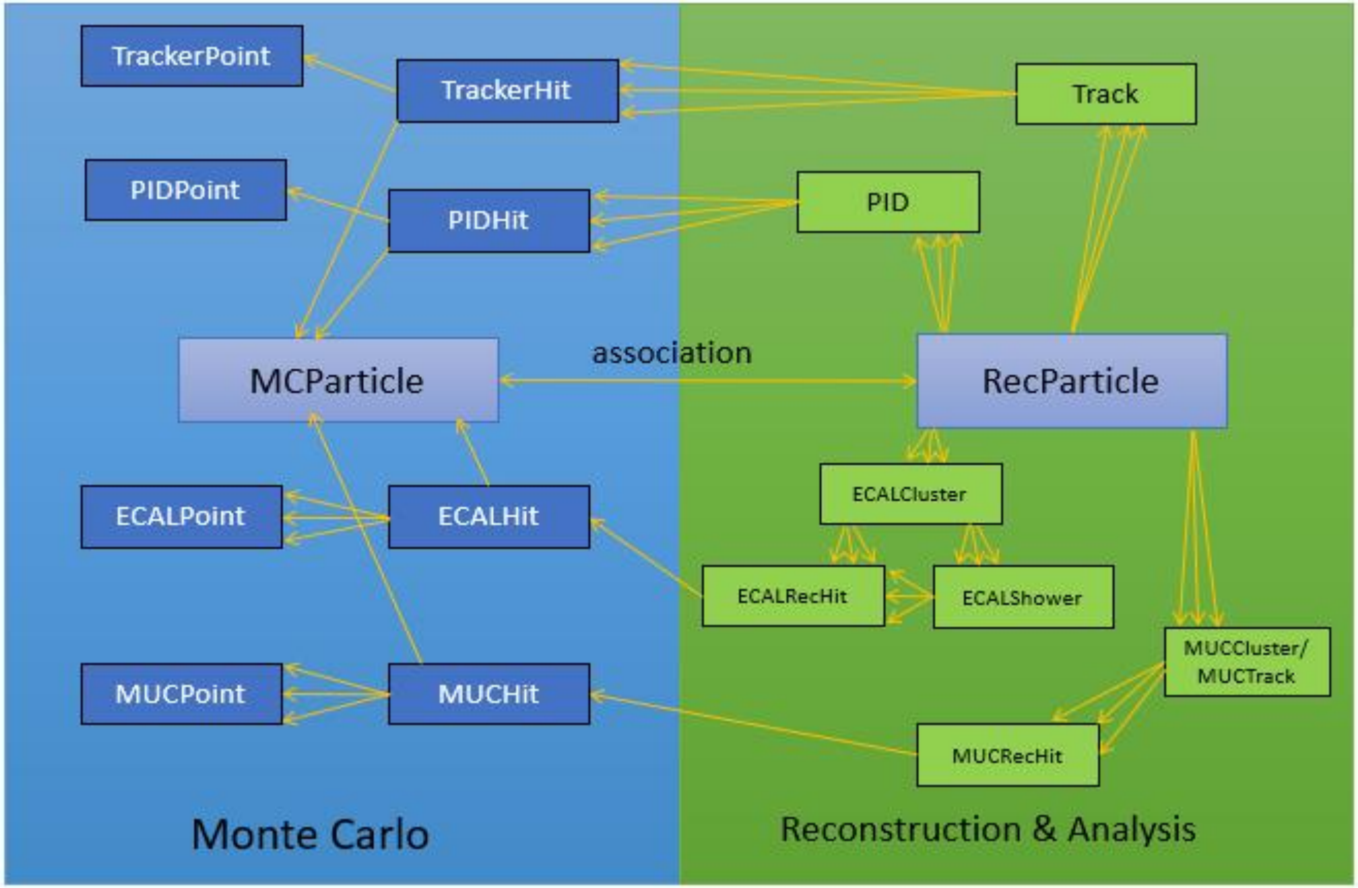
- EDM4hep project
  - ⇨ A common EDM designed for lepton and hadron colliders.
  - ⇨ Handle unique and non-unique relations between objects of arbitrary data types.
  - ⇨ Uses plain-old-data (POD) types wherever possible.(podio)
    - Simple memory model, performant I/O, vectorization…
  - ⇨ Memory management
  - ⇨ Multithread supported
  - ⇨ Automatic code generation.
  - ⇨ Adopted by CEPC, FCC.

https://github.com/AIDASoft/podio



Poster about Key4hep: https://indico.cern.ch/event/855454/contributions/4604989/

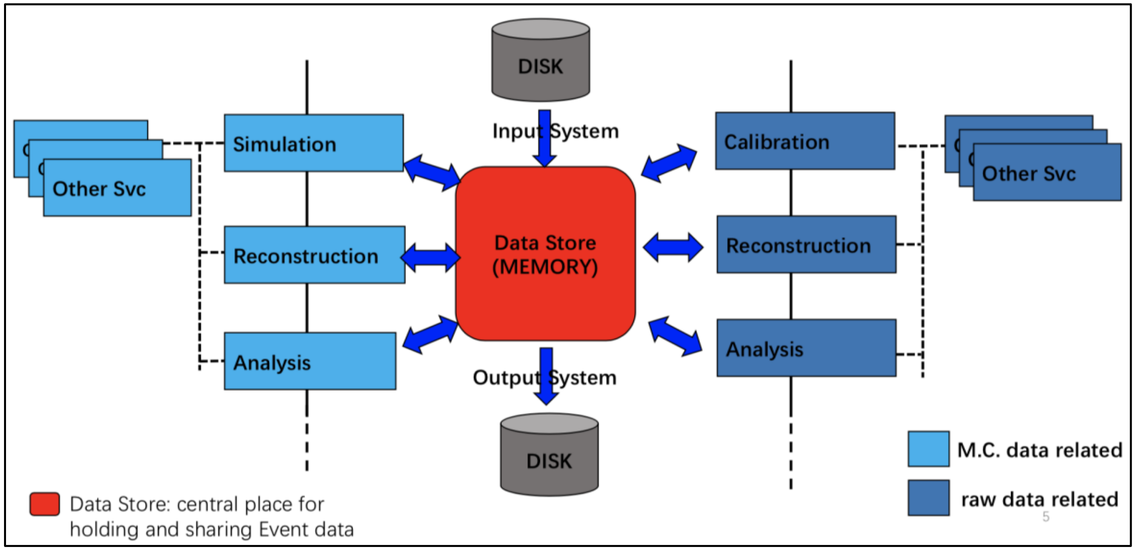
Event Data Model based on Podio



- ⇨ Extended the EDM4hep based on PODIO on demand of STCF
- ⇨ Defined event objects for simulation and reconstruction.
- ⇨ Build relationships between recon. objects and simulated Objects.
- ⇨ Automatically generated c++ codes from yaml files

Integration of Podio into OSCAR

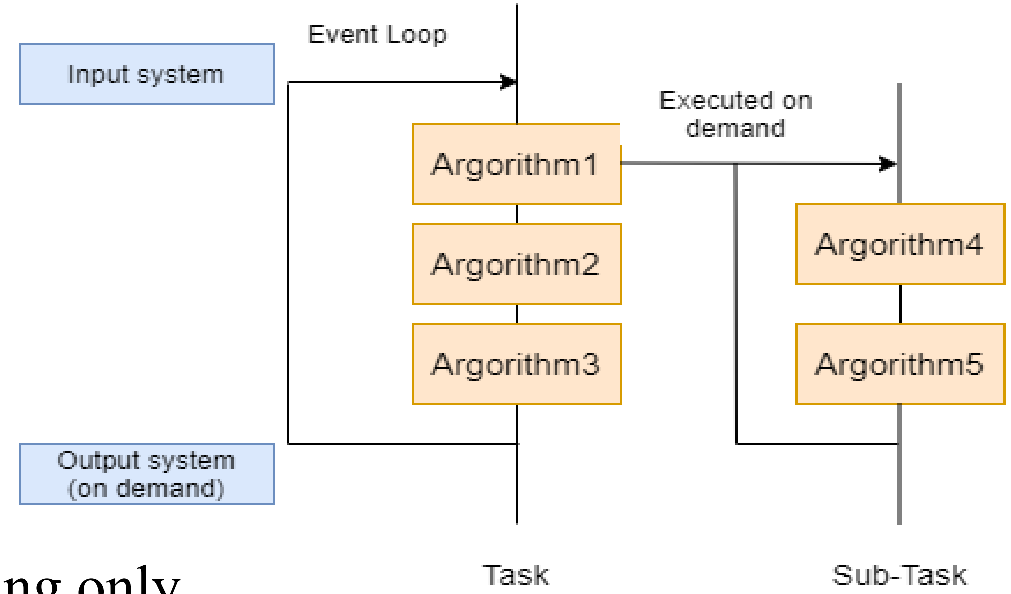
- Podio memory management could be simplified as
  - ⇨ EventStore to handle event data in memory.
  - ⇨ ROOTReader to input data from disk to memory.
  - ⇨ ROOTWriter to output data from memory to disk.
- Similar components in memory management of OSCAR
  - ⇨ DataStore
  - ⇨ Input System
  - ⇨ Output System



Integrated into corresponding components in OSCAR.

Integration of podio into SNiPER

- Input system and Output system are invoked by event loop
  - ⇨ Finish reading at the begin of event loop
  - ⇨ Finish writing at the end of event loop

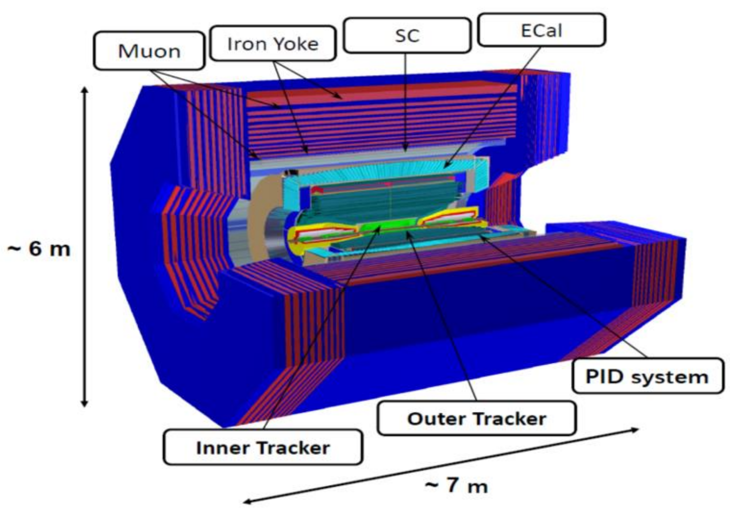


- Provided user interfaces
  - ⇨ getRWColl(…) for Writing only
  - ⇨ getROColl(…) for Reading only

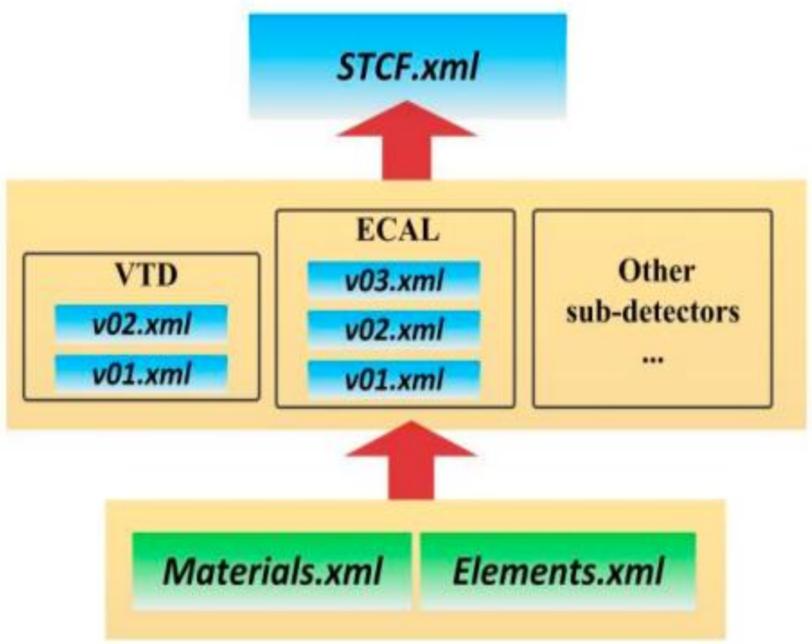
```
ITDHitCollection*    itdhits = getROColl(ITDHitCollection, "ITDHitColl");

ECALHitCollection*   ecalhits = getRWColl(ECALHitCollection, "ECALHitColl");
ECALPointCollection* ecalpoints = getRWColl(ECALPointCollection, "ECALPointColl");
```

Geometry Management System(GMS)

- Detector description based on DD4hep
- Each sub-detector has its geometry description
- Flexible combinations of different scenario and support single/full detector simulation



Detector conceptual design of STCF

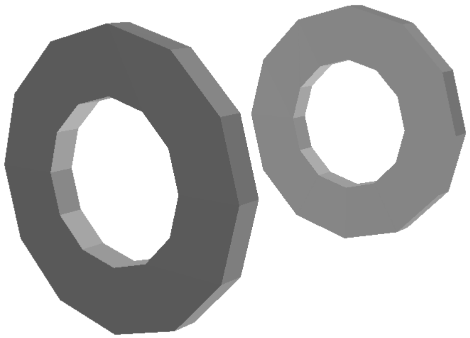


Structure of the geometry parameters repository

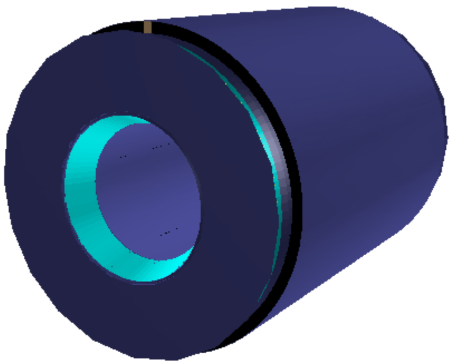
Full detector described by GMS

Poster about GMS: https://indico.cern.ch/event/855454/contributions/4596406/

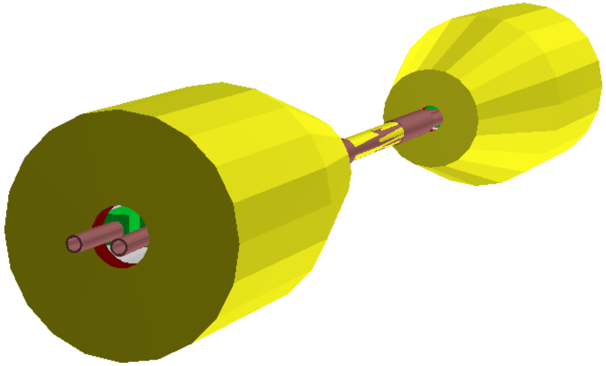
Geometry description of sub-detector



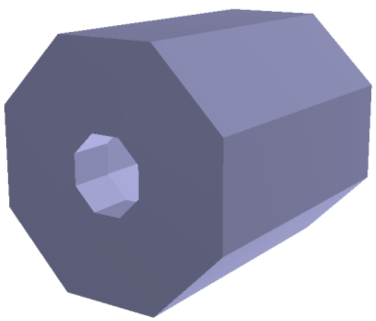
DTOF



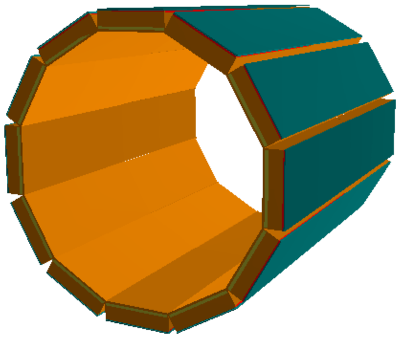
ECAL



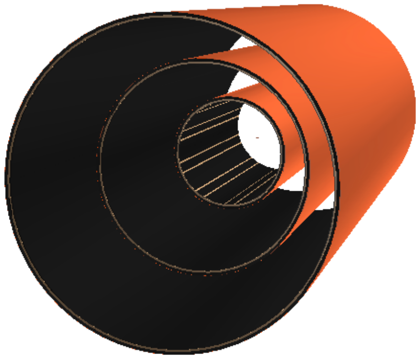
MDI



MUC



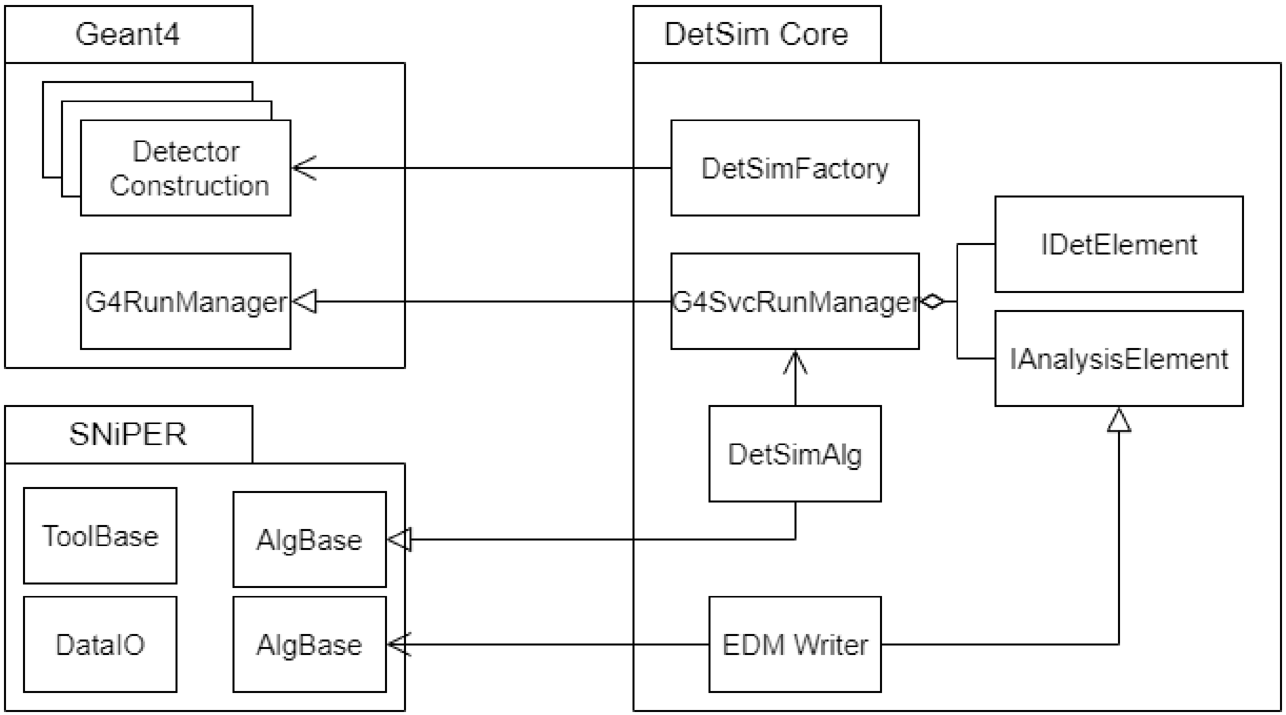
RICH



VTD

Detector Simulation

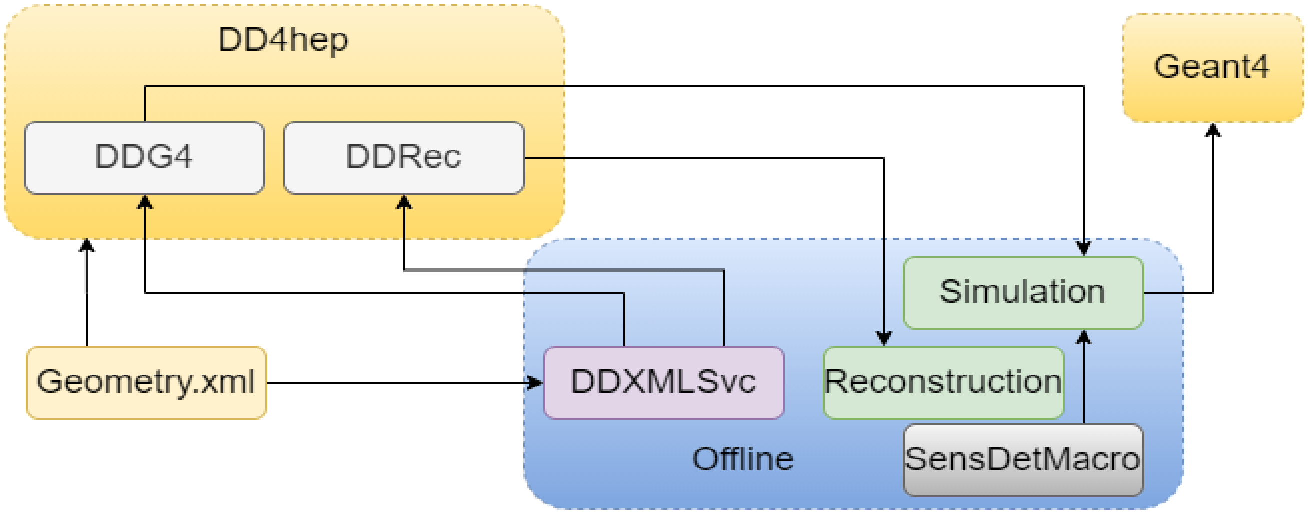
- Design of detector simulation system
  - ⇨ Lightweight, be easily migrated from standalone application



- The component for sub-detector simulation can be easily integrated for full detector simulation
  - ⇨ Detector description, user actions…

Adoption of DD4hep

- DD4hep has been integrated into OSCAR
- Single source of information support detector description, simulation and reconstruction with a same service
  - ⇨ DDG4 for delivering detector geometry to Geant4
  - ⇨ DDRec for delivering detector geometry to reconstruction algorithms
  - ⇨ DDXMLSvc: the unified interface to DD4hep, including DDG4 and DDRec
- OSCAR provides a macro to generate sensitive detector according to string: DECLARE_SENSDET(DetName)



DDXMLSvc for Sim. and Rec.

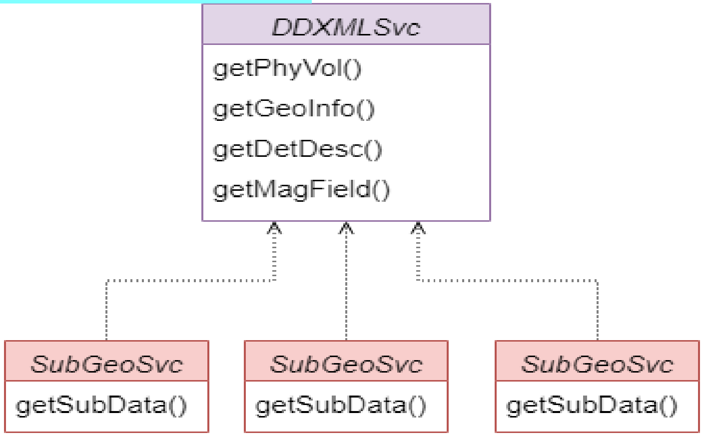
- Most geometry information could be provided

```
SniperPtr<DDXMLSvc> ddsvc(this->getParent(), "DDXMLSvc");   //Get the service

m_PhysicalVolume = ddsvc->getPhyVol();                   //Get physical volume
```

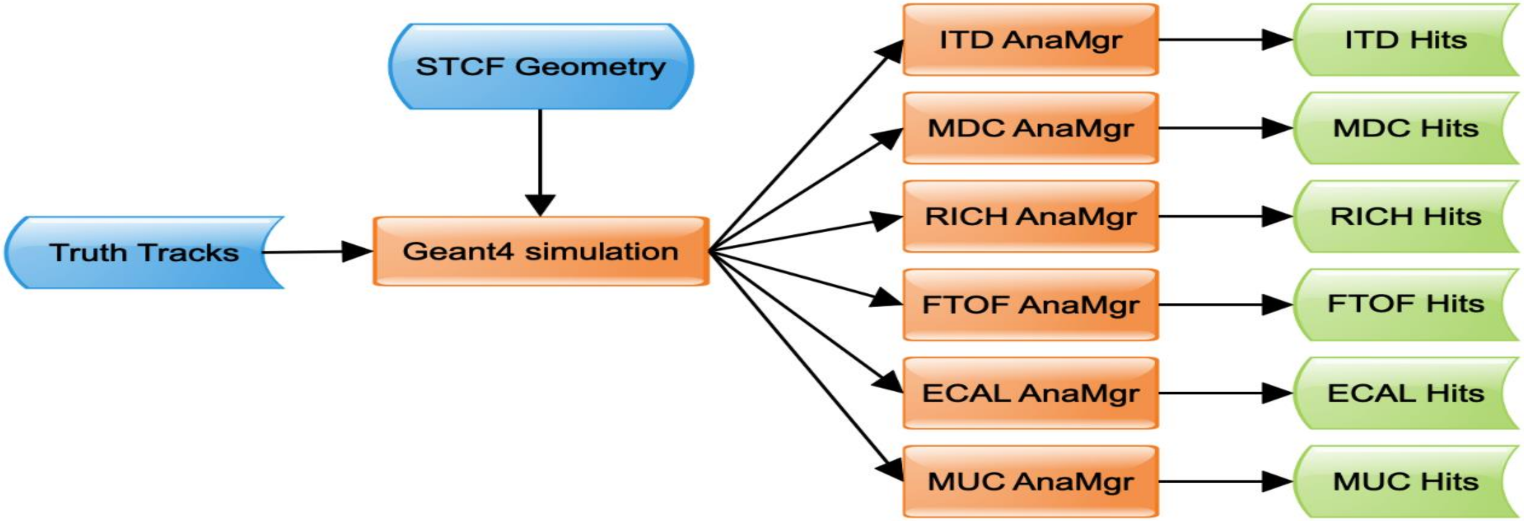
- Developed the GeometrySvc of sub-detector for reconstruction

```
SniperPtr<SubGeoSvc> subsvc(this->getParent(), "SubGeoSvc");

m_subdata = subsvc->getSubData("Detname");
```

- DDXMLSvc provide basic info
  - ⇨ Physical volume, magnatic field…
- SubGeoSvc provide info for specific detector…



Sub-detector and full simulation



- Now every sub-detector has its geometry description
  - ⇨ Run simulation of one sub-detector

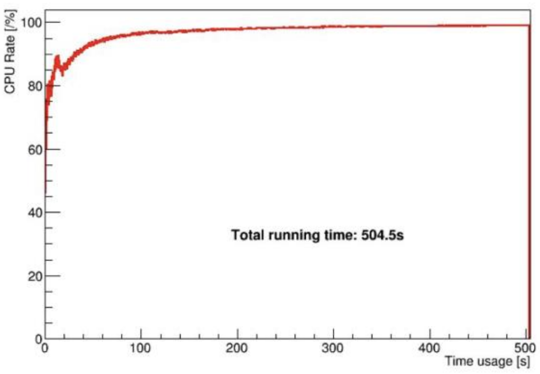
```
factory=task.createSvc("FullSimFactory/FullFactory")
factory.property("AnaMgrList").set(["GeneratorMgr", "ECALAnaMgr"])
```

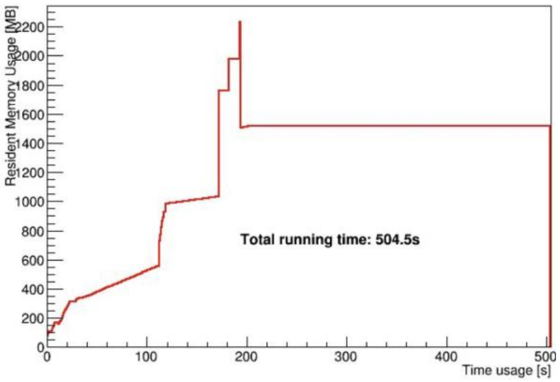
  - ⇨ Run simulation of full detector

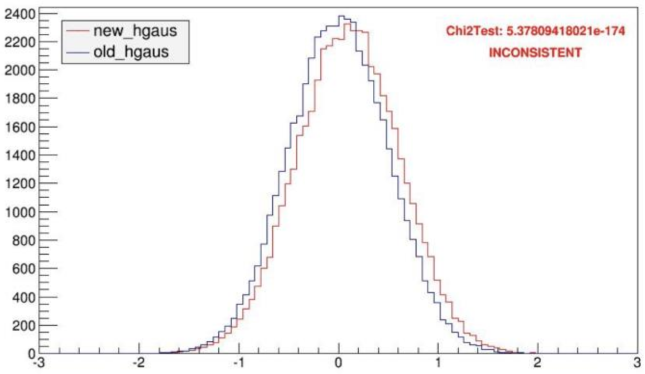
```
factory=task.createSvc("FullSimFactory/FullFactory")
factory.property("AnaMgrList").set(["GeneratorMgr", "ECALAnaMgr", "ITDAnaMgr", "MDCAnaMgr", "FTOFAnaMgr", "RICHAnaMgr", "MUCAnaMgr", ])
```

Automated Validation System

- An automated validation system is being developed for software validation at different levels
  - ⇨ Unit test, integrated test, performance test, physical validation etc.
- A powerful toolkit is developed for building software validation workflow
  - ⇨ Provide interfaces to define and run unit tests
  - ⇨ Support various detectable failures (log errors, memory leaking, ...)
  - ⇨ Support performance profiling
  - ⇨ Support results validation based on statistical methods







Summary

- OSCAR is developed for STCF based on SNiPER framework
- Several state-of-art software and tools in the HEP community are adopted, such as DD4hep,Podio, camke , gitlab
- The detector simulation Chain has been set up for full detector simulation
- Automatically Validation System are under development

Thanks for your attention!

Any questions are welcome!