Implementation of CepC Detector in CEPCSW

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(on behalf of the CEPC software working group)

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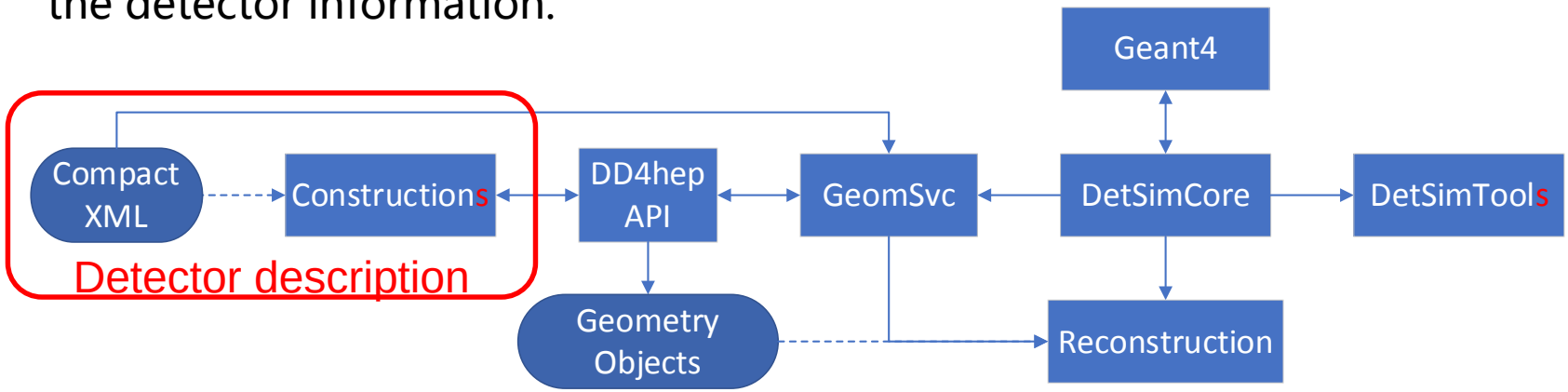
- Implement the baseline detector in CDR
- Implement the reference detector
  - Drift chamber + crystal bar
- Plan and Summary

Introduction

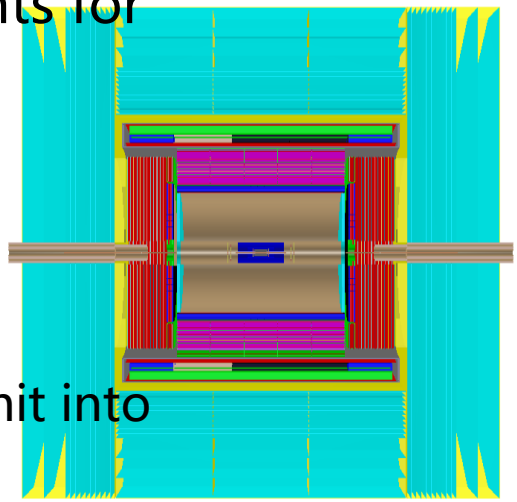
- The DD4hep package is adopted for the detector description, which supports the modeling of complex detectors in a unified way.
- Both the detector simulation and reconstruction share the single source of the detector information.

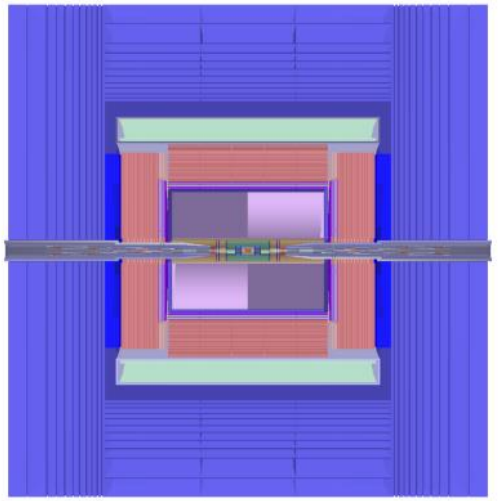


- Many physics analysis have been done based on the baseline detector in CDR, therefore to repeat the results in CEPCSW will help us to understand this new software framework well.
- Reference detector study is ongoing, with new detector modules such as drift chamber and crystal bar calorimeter, require to implement these detectors into CEPCSW to do full simulation.

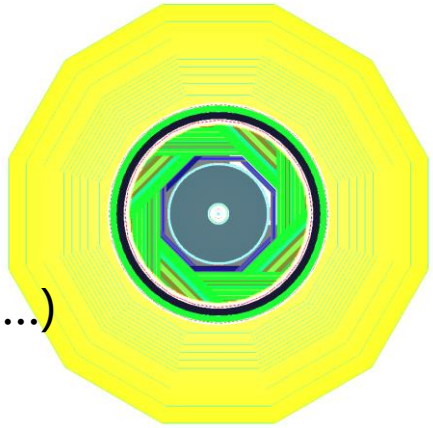
CDR Baseline Detector

- All the detector components for physical study are re-implemented in CEPCSW
- new MDI patch
  - code ready
  - needs new DD4hep commit into Key4hep
  - comment parts of pipe, $\cos\theta<0.99$ ready
- Validation
  - key parameters check
  - material scan (shape, repeat …)
  - hit distributions
  - performance: ongoing together with reconstructions

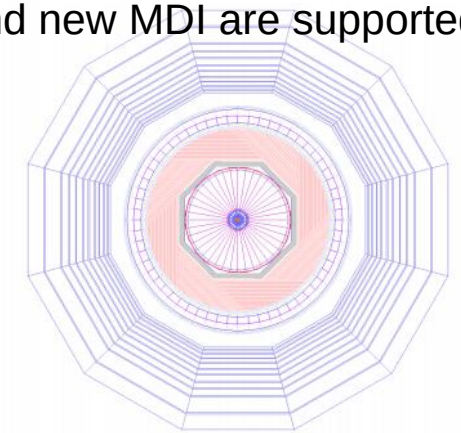




In MokkaC, both old MDI and new MDI are supported



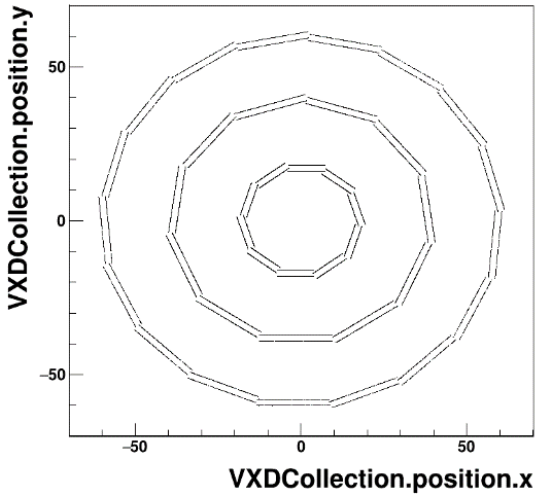
(in CEPCSW)

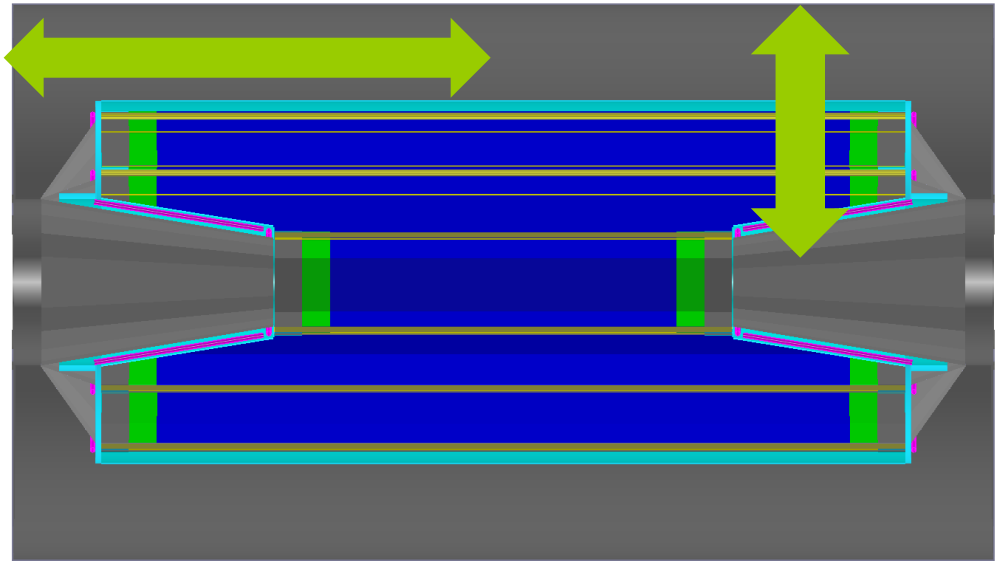


(in MokkaC)

Vertex Detector

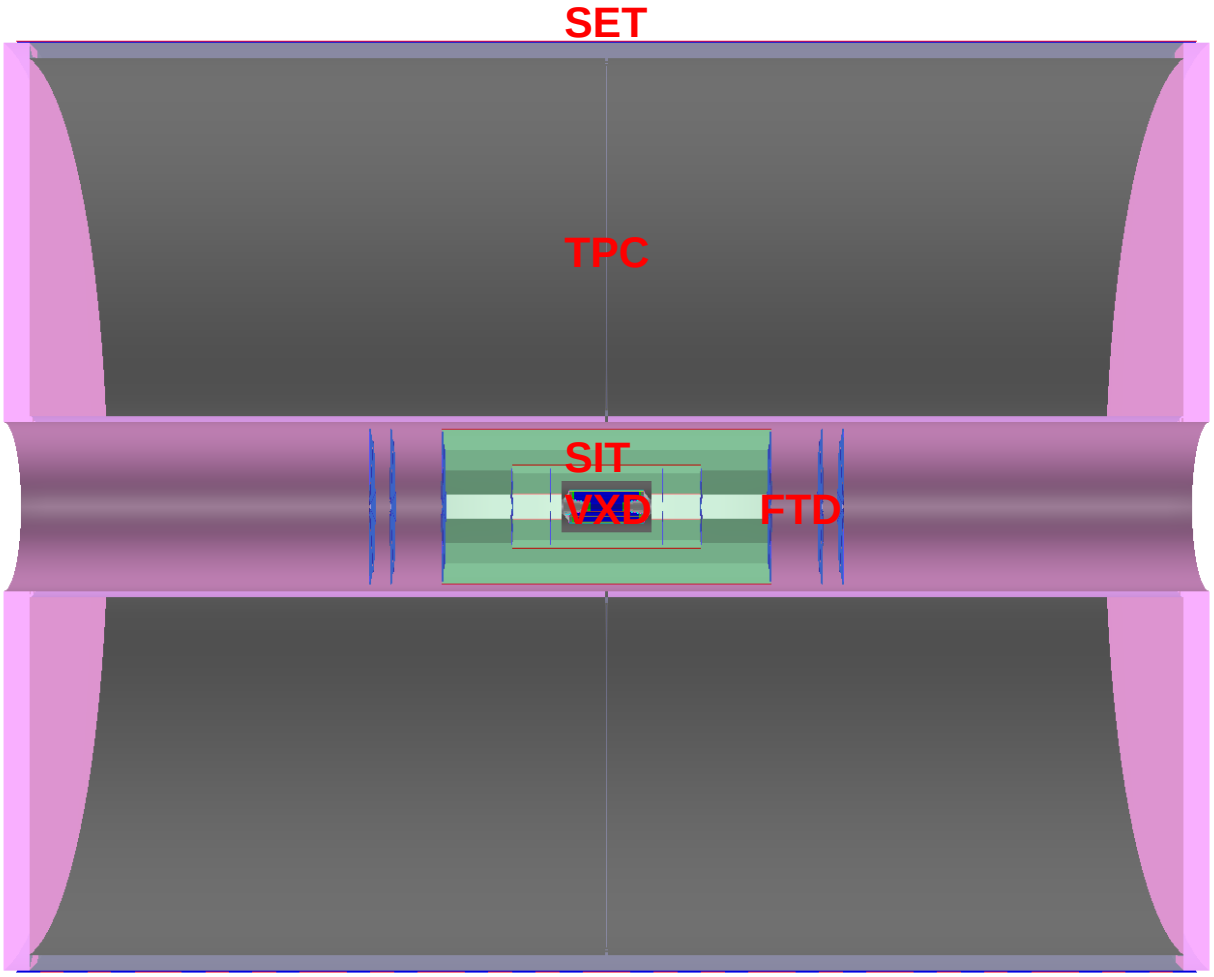
- layer
  - Support (Yellow)
  - Sensor (Blue)
  - electronics side/endplate (Green)
- Support (Cray)
- Cooling pipe (Magenta)
- Cable (Gray)
- Cryostat (Gray)
- Extensibility:
  - radius
  - width
  - Length
  - Material budget

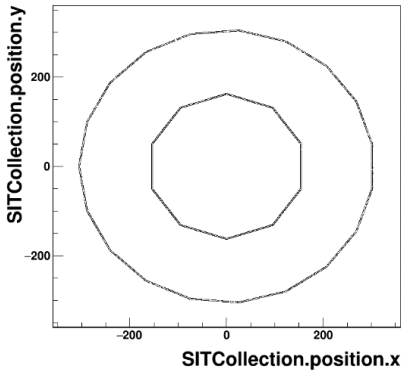


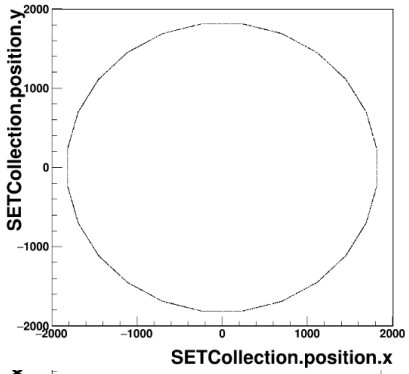


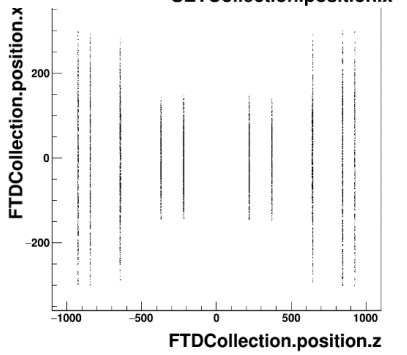
Tracker

- Extensibility: layer number, position, width/length, material



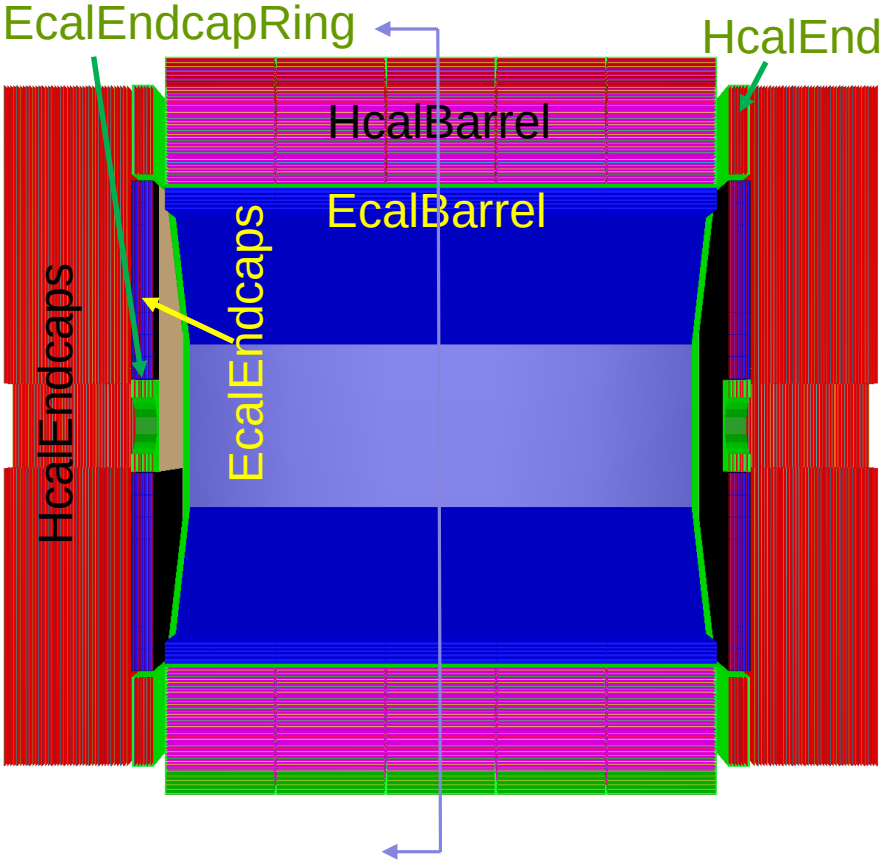


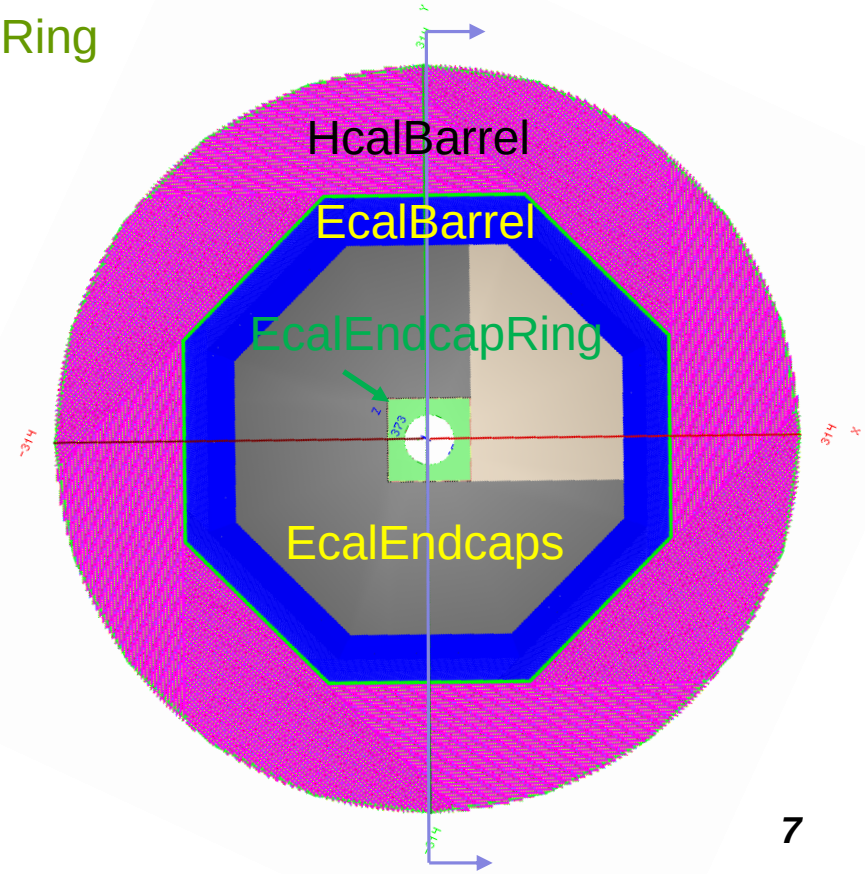




Calorimeters

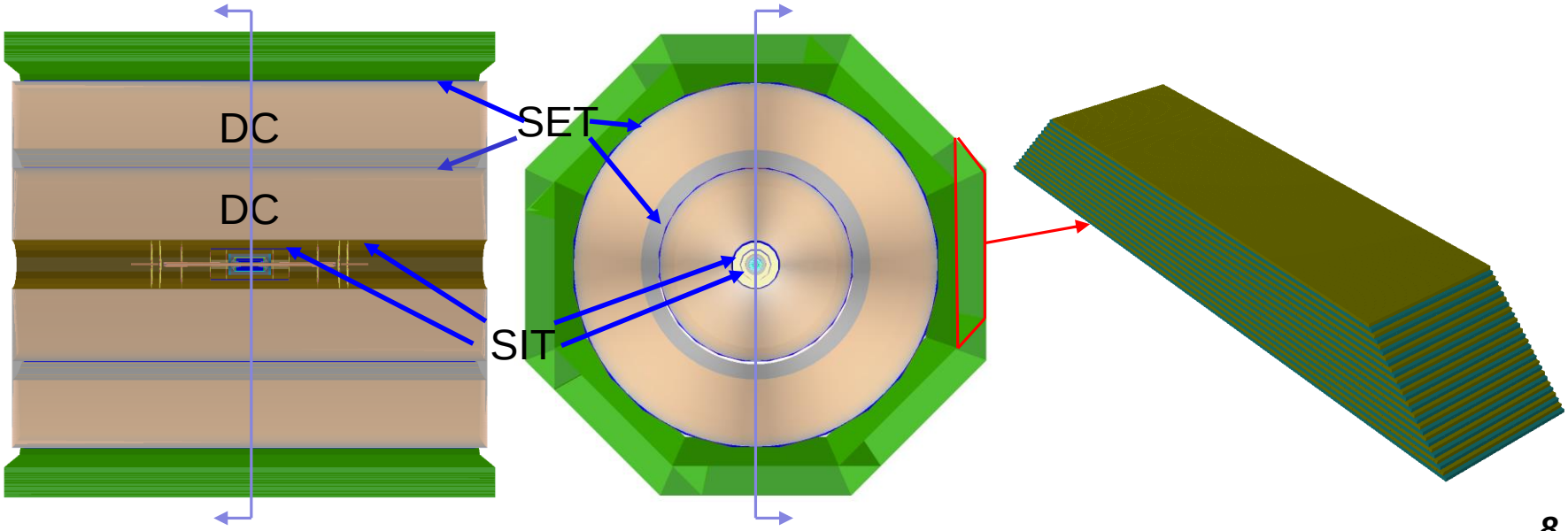
- Si-W Ecal
- RPC-based Hcal (Semi-Digital Hadron Calorimeter)
- Yoke with scintillator Muon Detector
- Extensibility: radius, length, layer/module number, layer structure, symmetry





Reference Detector

- New modules
  - Drift chamber: one or two chambers (optional)
  - Crystal bar Ecal
- CEPC_v4 like modules as preliminary
  - Silicon tracker, EcalEndcap, Hcal, Coil, Yoke/Muon
  - With re-defined dimensions



Geometry Manager

- Version
  - CRD_o1_v01

detector name main version minor version

- Separation of detector construction (via code) and parameters (via XML compact files)
  - current: simulation and reconstruction use same compact files
  - considering:
    - simulated data carry compact file
    - simulated data carry version and save compact file into DB
- Hierarchical structure in the geometry management
  - Main : CRD_o1_v01.xml
  - include:
    - elements.xml and materials.xml
    - CRD_Dimensions_o1_v01.xml
    - Hcal_Rpc_Barrel_v01_01.xml

name type [tag] construction parameter version

    - ...

```
<includes>
  <gdmlFile  ref="${DD4hepINSTALL}/DDDetectors/compact/elements.xml"/>
  <gdmlFile  ref="../CRD_common_v01/materials.xml"/>
</includes>

<define>
  <constant name="world_size" value="25*m"/>
  <constant name="world_x" value="world_size"/>
  <constant name="world_y" value="world_size"/>
  <constant name="world_z" value="world_size"/>

  <include ref="${DD4hepINSTALL}/DDDetectors/compact/detector_types.xml"/>
</define>

<include ref="./CRD_Dimensions_v01_01.xml"/>

<include ref="../CRD_common_v01/Beampipe_v01_01.xml"/>
<include ref="../CRD_common_v01/VXD_v01_01.xml"/>
<include ref="../CRD_common_v01/FTD_SimpleStaggered_v01_01.xml"/>
<include ref="../CRD_common_v01/SIT_SimplePlanar_v01_01.xml"/>
<include ref="../CRD_common_v01/DC_Simple_v01_01.xml"/>
<include ref="../CRD_common_v01/SET_SimplePlanar_v01_01.xml"/>
<include ref="../CRD_common_v01/Ecal_Crystal_Barrel_v01_01.xml"/>
```

Dimensions

- Global dimensions describe in CRD_Dimensions_o1_v01.xml
  - General definitions
    - Sub-detector ID, limits, regions, display
  - General parameters
    - nominal value of magnetic field
    - crossing angle
  - Sub-detector dimensions
    - inner radius and outer radius
    - half length for barrel
    - zmin and zmax for endcap
    - other dimensions

```
name="Yoke_barrel_inner_radius" value="3710*mm"/>
name="Yoke_barrel_outer_radius" value="6951*mm"/>
name="Yoke_barrel_half_length" value="Hcal_endcap_zmax"/>
name="Yoke_barrel_symmetry" value="8"/>
```

easy to locate the edge of every sub-detector, avoiding overlap while updating, quick to modify dimensions to replace with new type of sub-detector

- Module dimensions (optional) describe in sub-detector compact file
  - avoid to fix parameters in construction (hardcode), easy to update

Magnet inside or outside

- Module dimensions
  - calculated by global dimension
  - optional parameters not dependent on global dimensions
    - slice thickness
    - material
    - module gap
    - etc.
- Easy to exchange the positions of two sub-detectors through global dimensions
  - Coil inside
    - Solenoid_inner_radius: Ecal_barrel_outer_radius + Ecal_Coil_gap
    - Hcal_barrel_inner_radius: Solenoid_outer_radius + Hcal_Coil_gap
  - Coil outside
    - Solenoid_inner_radius: Hcal_barrel_outer_radius + Coil_Hcal_gap
    - Hcal_barrel_inner_radius: Ecal_barrel_outer_radius + Ecal_Hcal_gap

Replace sub-detector

- one sub-detector ↔ one or more compact files, forbid to load two sub-detectors in one file
  - Hcal: HcalBarrel, HcalEndcaps, [HcalEndcapRing]
- Add sub-detector by include corresponding compact file
- Remove sub-detector by comment/remove include its compact file

```
<include ref="../CRD_common_v01/Hcal_Rpc_Barrel_v01_01.xml"/>
<include ref="../CRD_common_v01/Hcal_Rpc_Endcaps_v01_01.xml"/>
<!--include ref="../CRD_common_v01/Hcal_Rpc_EndcapRing_v01_01.xml"/-->
```

- To replace a sub-detector with another new sub-detector TPC → DriftChamber

```
<include ref="sit_simple_planar_sensors_01.xml"/>
<include ref="tpc10_01.xml"/>
<include ref="set_simple_planar_sensors_01.xml"/>
```

```
<include ref="../CRD_common_v01/SIT_SimplePlanar_v01_01.xml"/>
<include ref="../CRD_common_v01/DC_Simple_v01_01.xml"/>
<include ref="../CRD_common_v01/SET_SimplePlanar_v01_01.xml"/>
```

Detector Information (README.md)

summary table

SIT: strip→pixel

information for sub-detectors

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	DC	crystal	RPC	developing
CRD_o1_v02	pixel SIT	DC	crystal	RPC	developing
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or frozen …

Details

CRD_o1_v01 (to update)

- coil inside CRD model
- BeamPipe - with center pipe + crotch link to doubly-pipe - Detector/DetCRD/src/Other/CRDBeamPipe_v01_geo.cpp
- Vertex - with silicon ladders (VXD + SIT12) - Detector/DetCEPCv4/src/tracker/VXD04_geo.cpp - Detector/DetCEPCv4/src/tracker/SIT_Simple_Planar_geo.cpp
- MainTracker - with Dirft Chamber + silicon layer between inner and outer chambers (DC + SIT34 + SET) - DC_outer_radius = 1716*mm - Detector/DetDriftChamber/src/driftchamber/DriftChamber.cpp - Detector/DetCEPCv4/src/tracker/SET_Simple_Planar_geo.cpp
- EndcapTracker - with silicon pestals (FTDPixel + FTDStrip) - Detector/DetCEPCv4/src/tracker/FTD_Simple_Staggered_geo.cpp
- Ecal - with crystal - Detector/DetCRD/src/Calorimeter/CRDEcal.cpp - Endcap (TODO)
- Hcal - with RPC readout - creates two sets of hit collections
- Coil - CEPC_v4 like
- Yoke - CEPC_v4 like
- compact files: - ./CRD_o1_v01/CRD_o1_v01.xml

CRD_o1_v02 (to update)

- based on CRD_o1_v01
- SIT: strip -> pixel
- SIT12->SIT1: r = 152.90 -> 140.00 mm (pixel SIT1)

More Modules Implementation

- Beampipe
  - newest MDI design (Chengdong FU following)
- vertex detector
  - layouts and mechanics (Hao ZENG & Kewei WU)
- silicon tracker
  - CMOS module (silicon tracker study group)
- Drift chamber
  - Update (Mengyao LIU, Tao LIN & Yao ZHANG)
- Crystal bar Ecal
  - update (8→12 optional) and Endcaps (Fangyi GUO)
- Hcal
  - Aanalog Hadron Calorimeter (scintillator as) (Chengdong FU implementing first version)
- Coil
  - CEPC_v4 like → new design (from Feipeng NING & Ling ZHAO)
- Yoke
  - CEPC_v4 like → more general layers
  - easy to modify design through parameters (Xiaolong WANG)

Plan

- Current preliminary CRD_o1_v01 and CRD_o1_v02 are been developing, will be frozen in future
  - replace some CEPC_v4 like sub-detectors with new modules
  - mechanics will be added according to study progress
- More versions will be released to support physical study and detector optimization
  - Magnet outside as comparison
  - SDHCAL VS AHCAL
  - Endcap tracker detector (ETD)
  - full silicon tracker
  - magnetic field variation
  - new sub-detectors on requirement (such as TOF, Cherenkov detector etc.)

Summary

- The baseline detector in CDR has been implemented into CEPCSW, and keep almost same as Mokka's, ready for next study.
- There are two versions of reference detectors in developing
  - parts of sub-detectors are CEPC_v4 like
  - available as preliminary, to update
- More implementations of modules and more release detector versions are in plan, together with
  - sub-detector technology study group (base modules)
  - detector optimization group (dimensions)

Thank You !

謝謝