Full G4 Detector Simulation

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Outline

- Status
- Software for full simulation
- Detector geometry implement
- Discussion and Conclusion
Status

- Full simulation is based on Geant4 fully

- History
  - pre-CDR → CDR → TDR → Running
  - Mokka → MokkaC → MokkaC
    \[→ DD4hep → DD4hep \]
    \[→ Another? \]

- MokkaC (a developing version of Mokka at CepC)
  - Updating for TDR as requirement of detector optimization

- DD4hep
  - Developing the geometries
  - Standalone application
  - Implemented into new software framework (Tao Lin’s talk)

Standalone simulation

Generator

- particle gun, gps, stdhep, hepevt, hepmc, pairs, slcio

MokkaC

- slcio+Gear

Reconstruction: Marlin

Detector geometry manager

Database/steering files

xml files
Mokka Interface to Geant4

![Diagram of Mokka Interface to Geant4]
DD4hep Toolkit

- From DD4hep manual
MokkaC VS DD4hep

Geometry manager
- MokkaC: general detector construction with parameters from database or steering file, more readable for Geant4 experts
- DD4hep: organized by models with parameters from xml files, more intuitive for normal users

Physics List
- Both support default Geant4 physics lists: QGSP_BERT, FTFP_BERT, …
- Both easy to change the range cut values

Geant4 version
- 9.6.p02 VS 10.04.p02

Output
- MokkaC → slcio
- DD4hep → slcio/root, support alignment

Development at CepC
- MokkaC: experimental, easy to add new support, such as new generators
- DD4hep: beginning and depending on its development
MC Truth in Simulation

- Use MCParticle class of LCIO
  - Generator status to know stable/decayed particle in generator
  - Simulation status to know whether created in Geant4, back scatter, decayed in tracker, etc.

- Save secondary particles in tracker region, not in calorimeter
  - Cause an issue that those produced in LumiCal also are saved, fix ongoing
Hits and Digitization

- **SimTrackerHit**
  - Cell ID
  - Position
  - Deposited energy
  - Time
  - Path length
  - Link to MCParticle that cause the hit, one hit ↔ one particle

- **SimCalorimeterHit**
  - Cell ID
  - Position
  - Deposited energy
  - Link to MCParticles that cause the hit, one hit ↔ multi particle

- **Digitization of positions**
  - Tracker hit: simple smear according to resolution, completion ongoing
    - processed in Marlin framework before reconstruction
  - Calorimeter hit: cell center

- **Digitization of energy**
  - Not yet
Geometries

- **In Mokka**
  - Driver: general Geant4 detector construction
  - Supper driver: building a temporary database needed by the corresponding driver, based on the parameters from Mokka’s geometry environment (database or steering file), way to change parameters

- **In CDR baseline**
  - Single driver:
    - MDI, SIT/SET, FTD, TPC, Ecal, Hcal, Yoke
  - Driver + supper driver:
    - VXD, Coil, LumiCal

- **In DD4hep**
  - Detector constructors
  - compact description from xml
    - Calculate parameter from others
Vertex Detector

- three double-layers
  - support layer thickness: 0.94 mm SiC foam, 0.05 flex cable, 0.01 metal traces
  - 0.05 mm silicon
  - to TDR
    - 1 mm carbon fiber support, revisable
    - Wider ladder to overlap

- DD4hep can also change them
  - layers_common_parameters

  ```
  flex_cable_material="G4_KAPTON"
  flex_cable_thickness="0.05*mm"
  foam_spacer_material="SiC_foam"
  foam_spacer_thickness="0.94*mm"
  metal_traces_material="G4_Al"
  metal_traces_thickness="0.01*mm"
  ```

- New material in database

Layer parameters etc.
Tracker

- **SIT/SET**
  - SIT: two double-layer strip layers
  - SET: one double-layer strip layers
  - to TDR: possible to add layers through database (MokkaC) or xml (DD4hep)

- **TPC**
  - 222 pad rows, adjusted by radius and pad height, \( N = \frac{\text{Router}_{s-Rinner}_{s}}{\text{Pad Height}} \)

- **FTD**
  - two pixel disks
  - three double-layer strip disks
Ecal option

- Optimized from CEPC_v1 to CEPC_v4, cell size from 5 mm to 10 mm
- 20 layers + 10 layers (optional)
  - 0.5 mm silicon (optional)
  - 2.1 mm (4.2 mm) tungsten (optional)
- Silicon/scintillator as sensitive layer

```c
("Ecal_Aliveolus_Air_Gap");
("Ecal_Slab_shielding");
("Ecal_Slab_copper_thickness");
("Ecal_Slab_PCB_thickness");
("Ecal_Slab_glue_gap");
("Ecal_Slab_ground_thickness");
("Ecal_fiber_thickness");
("Ecal_Si_thickness");
("Ecal_guard_ring_size");
("Ecal_radiator_material");
("Ecal_radiator_layers_set1_thickness");
("Ecal_radiator_layers_set2_thickness");
("Ecal_radiator_layers_set3_thickness"); etc.
```

Default case: 8
Hcal

- Optimized from pre-CDR to CDR, from 48 to 40 layers
  - 6.73 mm RPC chamber
  - 20 mm stainless steel (tungsten)
  - cell size: 10 mm

- optional scintillator readout

Figure 10: The hits in Hcal for 100,000 single muon particles.
Yoke (muon detector) option

- Pre-CDR
  - yoke05 (12 iron layers, 13 RPCs for barrel and 12 RPCs for endcap)

- CDR (driver yoke06 in MokkaC, not official Mokka)
  - /Mokka/init/globalModelParameter YokeUserLayer 1
  - /Mokka/init/globalModelParameter YokeGapThickness 25,40,40,40,40,40,40,40,40,40,40,40
  - /Mokka/init/globalModelParameter YokeIronThickness 80,80,120,120,160,160,200,200,240,540,540
Simple Calorimeter

- Quick geometry implement to simulation (SiCal)
  - Layer: tube
  - SiCalLayerStructure input (chain)
    - (W:2.8, Si:0.5, PCB:2)*30; (W:20, Scintillator:3, PCB:2)*40
  - EcalMaterial
    - Si, BGO, LGO,…
  - HcalMaterial
    - Scintillator, THGEM1, THGEM2, RPC1, RPC2,…

- DD4hep has defined similar detector module
  - CylindricalBarrelCalorimeter
  - CylindricalEndcapCalorimeter
Other detectors

- LumiCal
- ETD (not included in CDR baseline)
- Laser Calibration System of TPC (not included in CDR baseline)
Full Silicon-based Tracker

- Use sub-detector driver
  - /Mokka/init/EditGeometry/newSubDetector SiTracker01 100

- Options
  - ladder/disk number and positions
  - Sensor/support thickness
  - Support material
IDEA Concept

- IDEA group has standalone simulation tool, to implement into CepC software
- Approximated, Geant4 can not work because of too many fiber
- Update Geant4 version for MokkaC is in plan

Simplified method

- Add fiber...
  - Ignore cut
  - 2500 length of fibers: 1mm, 2mm, ..., 2500mm
    - >2500, more memory and less distance
    - <2500, less memory and more distance

This method need only 2500 volumes of class memory. 

Cherenkov fiber

Scintillator fiber

Hyunsuk's

Filled with copper

A little distance < 1mm
Discussion and Conclusion

- Two toys for full simulation to TDR

- Open questions
  - CPU time ↔ Physics list and range cut ↔ Physical results
  - What will be optimized detector

- Ongoing
  - Some fixes
  - Geometry implement for updated detector
  - Complete comparison between MokkaC and DD4hep

- Plan
  - Update Geant4 version
  - Implement DD4hep into new software framework
Thank you!
Material Budget Tools

- Budget plugin in MokkaC
  - Use geantino to scan its past material

- Executable program to scan
  - materialScan CepC_v4.xml 0 0 0 183 0 0
Simple Validation for DD4hep

- As first step, check hits distribution of sub-detectors
- Sample
  - 2000 single electrons, 10GeV
$dE/dx$

![dE/dx in VXD silicon (MeV/mm)](image1)

![dE/dx in TPC gas (MeV/mm)](image2)