A Geant4-based simulation of irradiation system for hadron therapy

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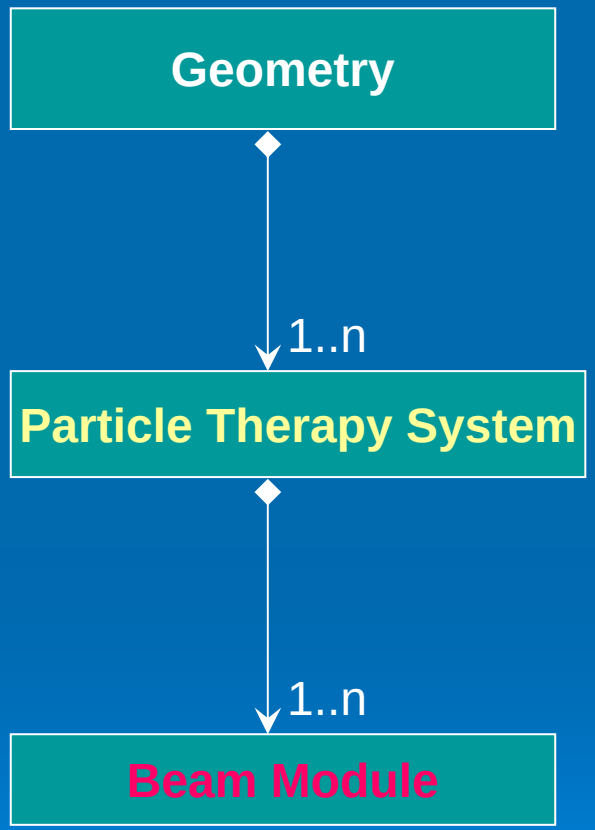
Introduction

- Particle therapy facilities need *"Simulation tools"*.
  - Designing irradiation system according to facility specification.
  - Validation of treatment planning in different configuration.
- The *"Simulation tool"* has to allow users to **setup their own irradiation system** with minimum coding effort.
  - Usually, implementation of complex geometry is one of the issues.
  - Users want to concentrate on evaluation of physics results.
- Our Strategy for addressing to the requirement
  - A software toolkit for *"common software parts"* which is specially dedicated to *particle therapy system*.
    - We provide base/concrete classes for representing irradiation system.
      - **(Reusability)** The beam module classes may be utilized each other, because, in many case, same or similar geometry modules are used at different facilities.
      - **(Extensibility)** Users define their own beam modules on the top of the base class. It gives the user a guarantee that beam modules have basic functionalities.
  - The user can setup his/her own irradiation system geometry by combining those software parts.
  - Comparison of results becomes easier on the common framework using our software toolkit.

Overview of Design concept

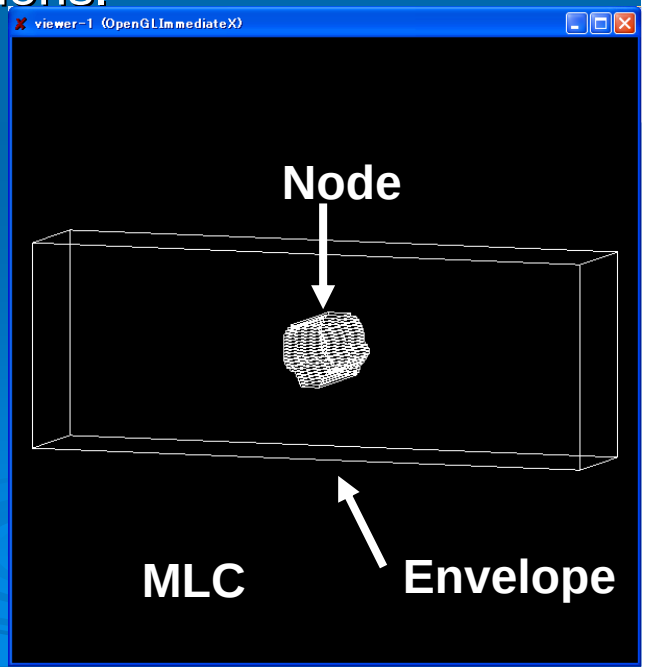
Our simulation toolkit has three layers structure.



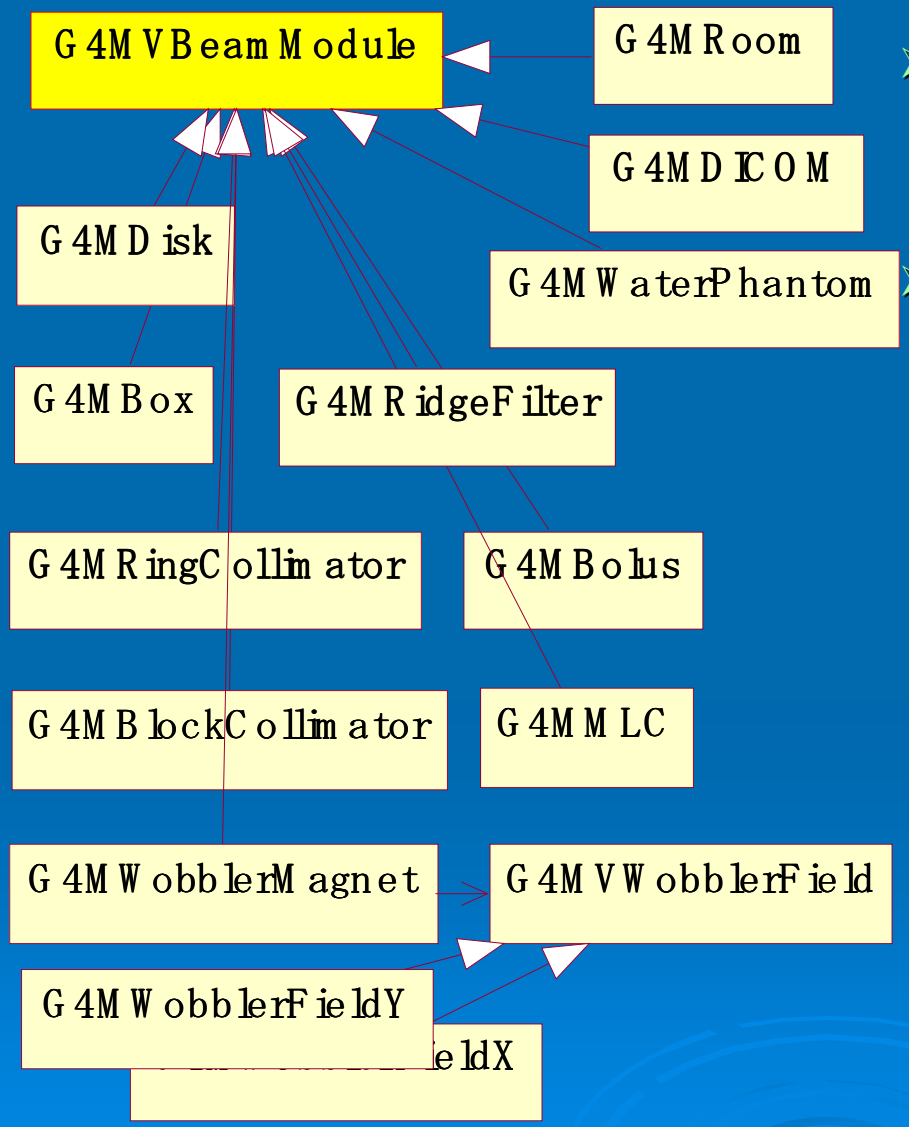
- Geometry represents the world volume of the irradiation system.
  - This is basically identical to G4VUserDetectorConstruction.
- Particle therapy system represents a particular irradiation system. It consists of available beam modules at the facility.
  - i.e. HIBMC Gantry Nozzle, NCC Gantry Nozzle, etc.
- Beam Module represents individual beam module. It involves geometrical information.
  - **i.e. Scatterer, Wobbler magnet etc.**

Beam Module

- Defining Beam Module
  - We introduce the base class ***"G4MVBeamModule"***, where users define their own beam module geometry.
  - This base class is responsible for handling the physical volume of the beam module.
    - Install(uninstall) the module in(from) the beam line.
    - Translate(rotate) the module in the beam line.
  - The user may add new beam module classes on this base class.
    - The user has to implement two virtual functions.
      - ***buildEnvelope()***
      - ***buildNode().***
    - The *"Envelope"* represents a master volume of the beam module, while the *"Node"* represents complex geometries inside the beam module.



Concrete class of Beam Module



- We have already implemented concrete classes of beam modules.

- *These concrete classes are enough for describing*
  - HIBMC gantry nozzle (Hyogo Ion Beam Medical Center)
  - NCC gantry nozzle (National Cancer Center)
  - NIRS experiment port for IHI (National Institute of Radiological Sciences)

Particle Therapy System

- Defining Particle Therapy System
  - We provide a base class ***"G4VParticleTherapySystsm"***.
  - The user has to define their own particle therapy system on this base class. i.e. "HIBMCGantrySetup", "NCCGantrySetup", or "IHIPort" and so on.
  - It mandates to implement three virtual methods.
    - ***Setup()***
      - The user has to register available beam modules in the particle therapy system.
    - ***BuildDefault()***
      - At least, only the treatment room (world volume) has to be installed.
    - ***UpdateEvent()***
      - The user has to describe event by event action.
      - For example, this is a case for wobbling magnetic fields.
- ***G4ParticleTherapySystemMessenger*** for manipulating beam modules.
    - /G4M/Module/install <Module Name>
    - /G4M/Module/uninstall <Module Name>
    - /G4M/Module/select <Module Name>
      - /G4M/Module/translate <X Y Z>
      - /G4M/Module/rotate <Ox Oy Oz>
      - /G4M/Module/typeid < Module's parameter ID>

Geometry Builder

- Geometry builder is responsible for selecting a particle therapy system.
  - We provide the base class ***"G4VGeometryBuilder"***.
  - It has a virtual method "*SystemSelection()*", where the particular particle therapy system is instantiated according to the given name.
  - The current particle therapy system object is obtained by static method, *G4MVGeometryBuilder::GetSystem()*. This is used for accessing functionalities of the particle therapy system and the beam modules.

- *G4MGeometryMessenger*
  - /G4M/System <PTSname> (Pre_init)
  - /G4M/ChangeSystem <PTSname> (Idle)

- At present, our implementation had realized following facilities.
  - HIBMCGantry (Hyogo Ion Beam Medical Center)
  - NCCGantry (National Cancer Center)
  - IHIPort (NIRS experimental port for IHI)

Demonstration

- Contents
  - Particle Therapy System Selection
    - HIBMCGantry , NCCGantry, IHIPort
  - Installing / Uninstalling of Modules
  - Translation / Rotation of Modules

Summary

- We have developed a simulation toolkit for irradiation system of particle therapy.
  - Beam components are modularized as software parts.
  - The toolkit is extended by adding new modules maintaining basic functionalities.
  - Our strategy is successfully applied for three particle therapy systems.
  - The physics validation using this toolkit comes soon.
- We are collecting geometry information of irradiation system.
  - It is welcome to give us your irradiation system geometry.

Parameter modification

- Three type of modification
  - fSystem->GetModule("moduleName")
    - Translation/Rotation
    - More functionality require cast to the module
  - fSystem->ApplyCommand("type");
    - Catalogued parameter is loaded and rebuild the module geometry.
  - fSystem->UpdateEvent();
    - Event by event modification such as wobbler field should be ddescribed.