Using CAD files in the HERD simulation

A software-side perspective

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HERD mechanics engineering meeting - 22nd April 2021

Introduction

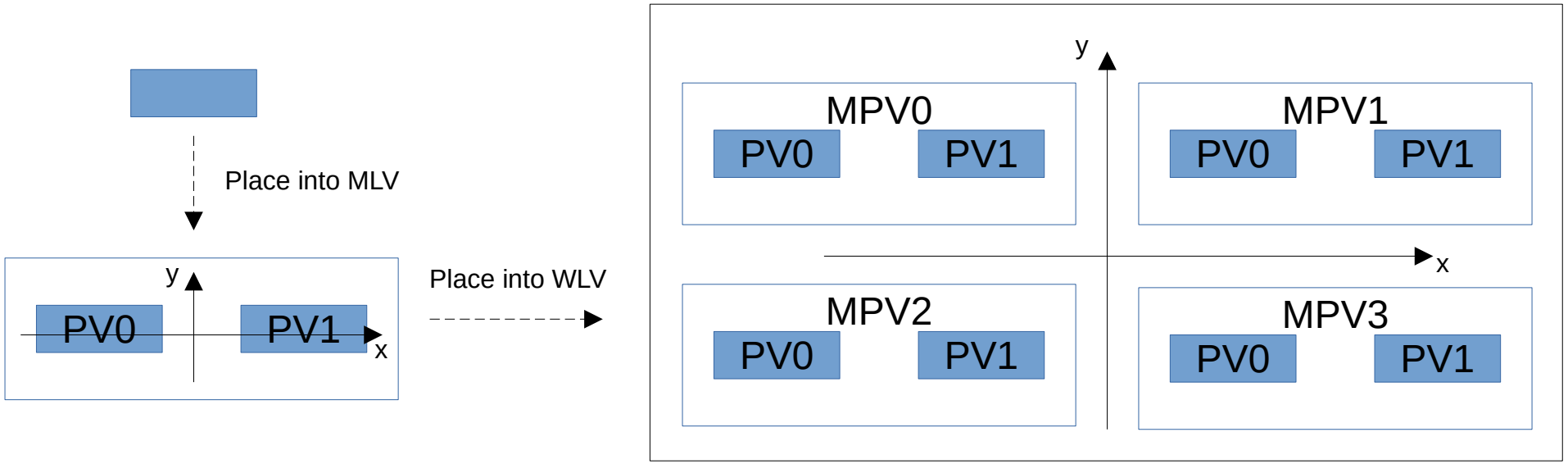
- List of significant details to ease the transfer from engineering design to Monte Carlo physics simulation based on Geant4 (G4)
- Based on the G4 geometry model and HERD software design assumptions

G4 geometry model

- Three-level description:
  - Solids: shapes in 3D space
    - Box, cone, sphere, …
  - Logical volume (LV): solid + material
    - “A cube made of LYSO”
  - Physical volume (PV): LV + placement
    - “A cube made of LYSO placed at coordinates (x,y,z)”
  - The same LV can be shared between multiple PV
    - “A set of identical cubes made of LYSO at coordinates (x_0,y_0,z_0), (x_1,y_1,z_1), (x_2,y_2,z_2), …”

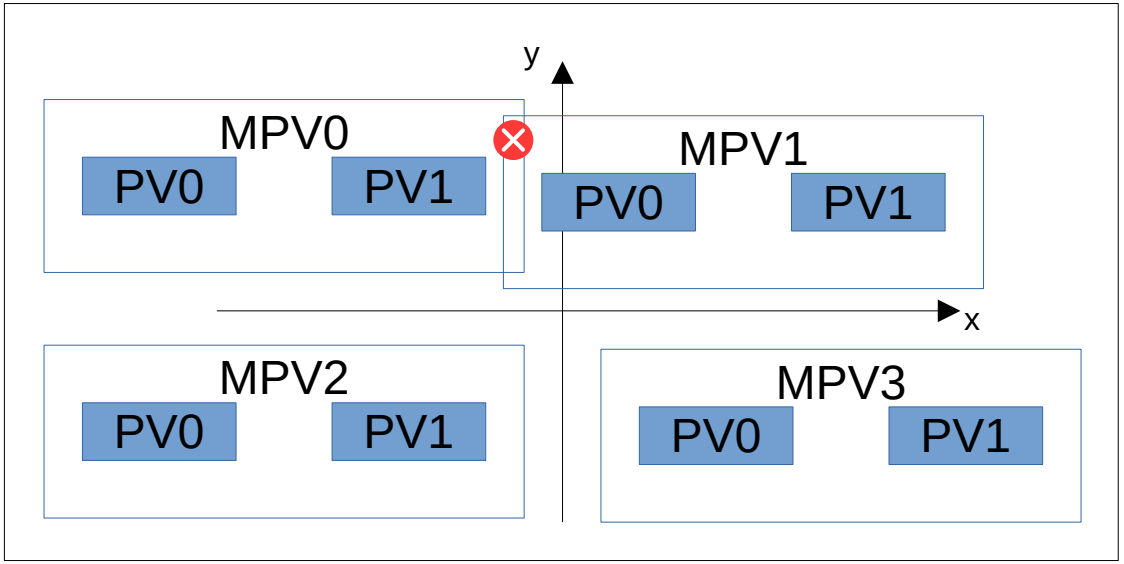
G4 geometry model

- Nested placement:
  - Each PV is placed inside a mother LV (MLV)
    - The MLV material fills all the MLV space not occupied by daughter volumes
  - Each mother PV will contain replicas of all the daughter Pvs
  - Multi-level structure
  - Top level: world logical volume (WLV)

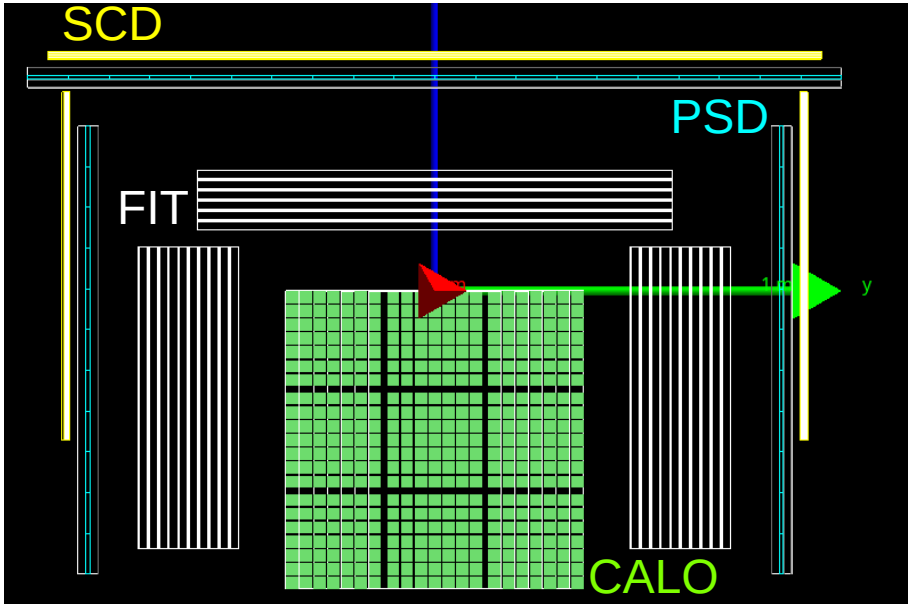


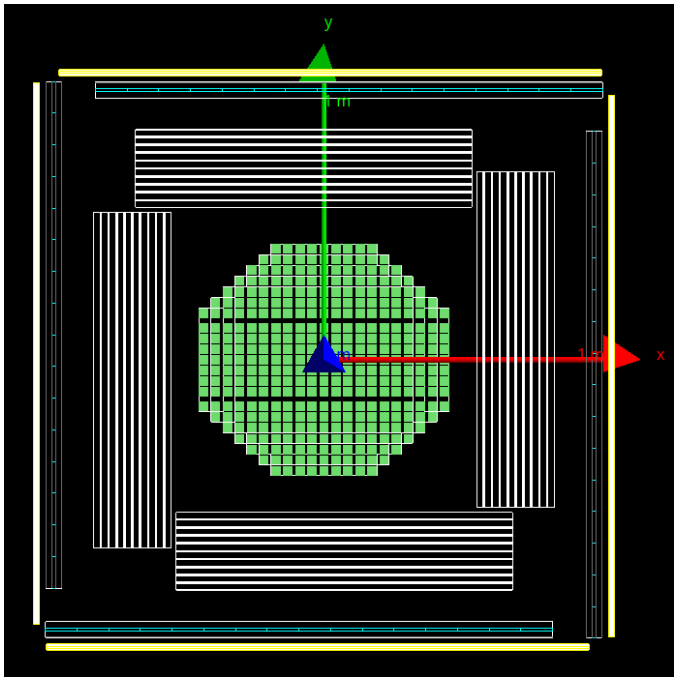
G4 geometry model

- PVs at the same depth in the volumes tree (i.e. inside the same MLV) must not overlap



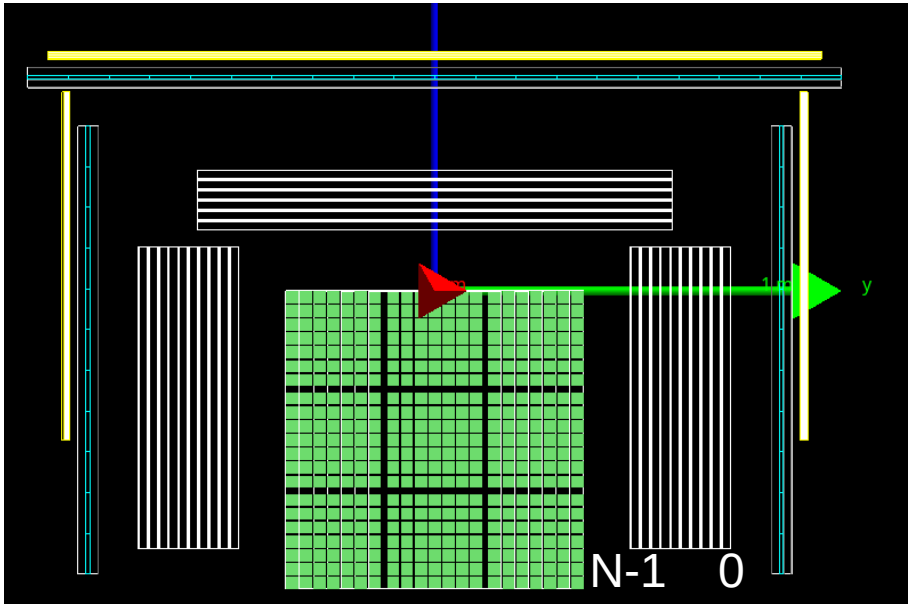
The HERD G4 geometry





- Global (world) reference frame as in the picture
  - z=0 → top surface of top CALO cubes
- Sub-detectors are built by filling MLVs (envelopes) with elements
  - Active volumes (Si wafers, scintillating tiles etc.)
  - Simplified support structures
- Place the detector envelopes
  - 1x for top detectors
  - 4x (with rotations) for side detectors
- (Almost) fully-parametric geometry
  - Distances between sub-detectors on the same side
  - Positions along X-Y (top) and H-V (sides)
  - Number of layers
  - Size of elements
  - . . .

The HERD G4 geometry



- Layer numbering: from outmost to innermost
  - Independent on each side
  - Not used in MC simulation
- Sensitive element (e.g. LYSO cubes, Si wafers) numbering: different conventions
  - Technical constraints from simulation SW
    - e.g. different ID sets for even and odd SCD layers
  - Unique element ID:
    - for top
    - for the set of 4 lateral sides

- Sensitive elements (segmentation):
  - CALO: single LYSO cube
  - FIT: single fiber layer
    - A monolithic slab of plastic
    - No fibers
  - PSD: single bar or tile
  - SCD: single Si wafer
    - No strips

- Sensitive elements: identified by LV name
  - CALO:
    - Crystal
  - FIT:
    - topFitMatCore, sideFitMatCore
  - PSD:
    - bartopPSD, barsidePSDH, barsidePSDV
    - tiletopPSD, tilesidePSD
  - SCD:
    - scdSiWaferTop, scdSiWaferSideH, scdSiWaferSideV

Towards realistic detector simulations

- Need to implement design details for robust performance evaluation
  - Support/dead materials, realistic dimensions
- Detailed CAD projects usually available at a certain experiment stage
- Model the MC geometry after CAD design

CAD → MC state-of-the-art

- The old way: create a MC geometry from CAD files manually
  - Highly adjustable/customizable
  - Time consuming, error-prone, hard to iterate for different versions
- The smart way: automatic conversion from CAD format to MC format
  - e.g. STEP → GDML
  - Needs a working conversion tool, common CAD-MC conventions and manual tuning

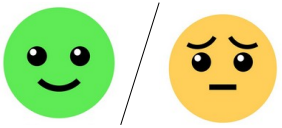
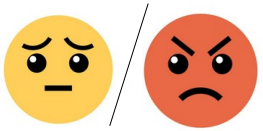
CAD → MC state-of-the-art

- "Automatic" CAD → MC succeeded for:
  - small experiments (e.g. HEPD/Limadou): limited workforce but simple geometry
  - large experiment (e.g. ATLAS): extreme detector complexity but powerful workforce
- HERD sits ~ in the middle…
  - Too complex for our limited workforce?

CAD → MC state-of-the-art

- Main hurdle: manual tuning due to complex design and to different conventions between engineers and physicists
- Proposal: try to establish from the very beginning a common ground to minimize the need for manual tuning → ease the process → (hopefully) make it feasible for HERD
- Goal 0: assess the feasibility of plugging HERD CAD projects into the simulation program (to some extent)

CAD → MC tentative strategy

- Produce STEP files 
- Simplify STEP files 
- Convert to GDML 
- Adjust the GDML 
- Make the necessary modifications in MC software 

Engineers

Physicists

Wishlist

- A set of matching features for the engineering design and current MC geometry model
- Would simplify the usage of CAD models in the MC simulation
- Not strictly necessary but really helpful
- Can be discussed/detailed in dedicated meetings

Wishlist

- Names of sensitive LVs
- ID of sensitive elements
- Detector segmentation
  - e.g. single, monolithic FIT planes
- Materials
- Separate design of each sub-detector
- Reference frame(s)