Detector Geometry in HERDOS

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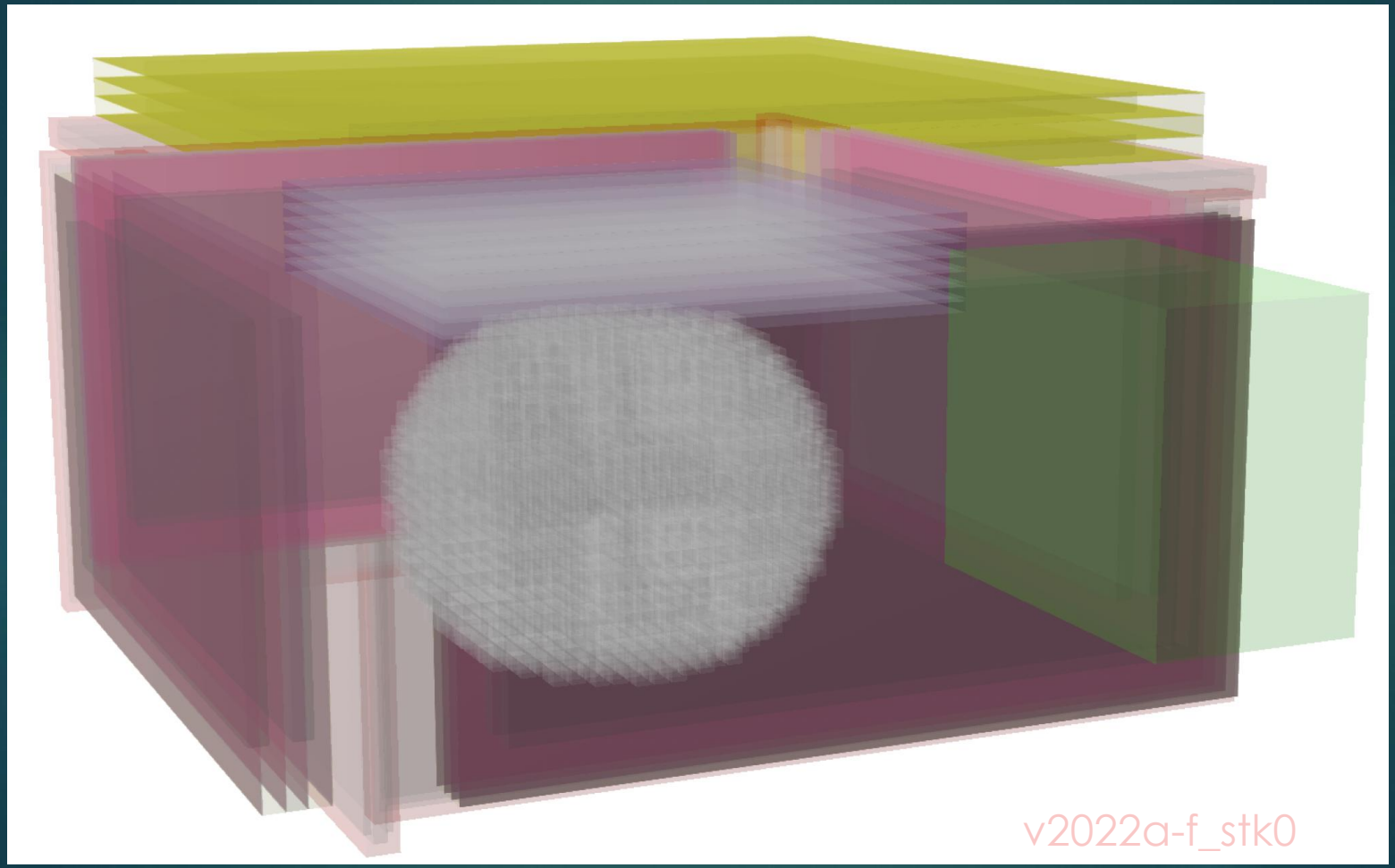
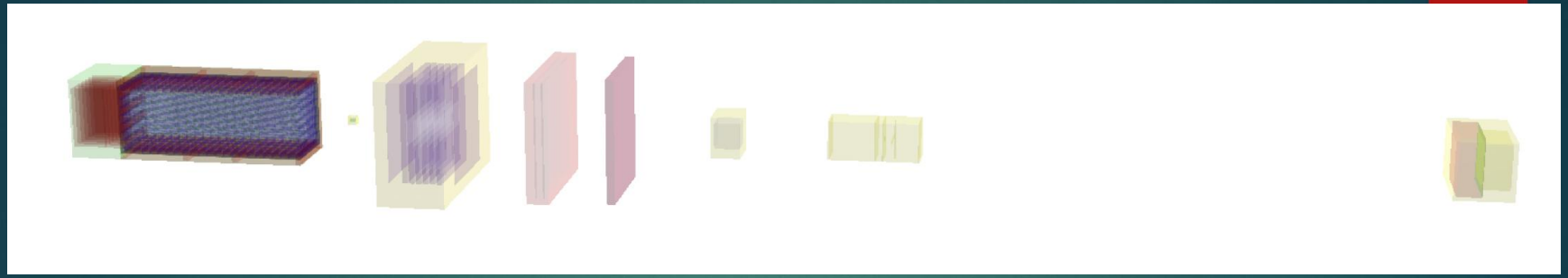
Overview of Detector Geometry

- The description of detector geometry is the **base** of simulation
- Geometry information is also used in reconstruction, calibration, analysis, etc
- The geometry description system provides geometry information **across the whole software**
- A set of rules for **cell ID** and **coordinate** system are carefully designed, in order to simplify the usage
- A **modularized design** is implemented, in order to maintain a flexible geometry for HERD detector
- During detector designing stage, the geometry are changing frequently. A carefully designed **version control** is applied to avoid confusion and miss match of different version of geometry

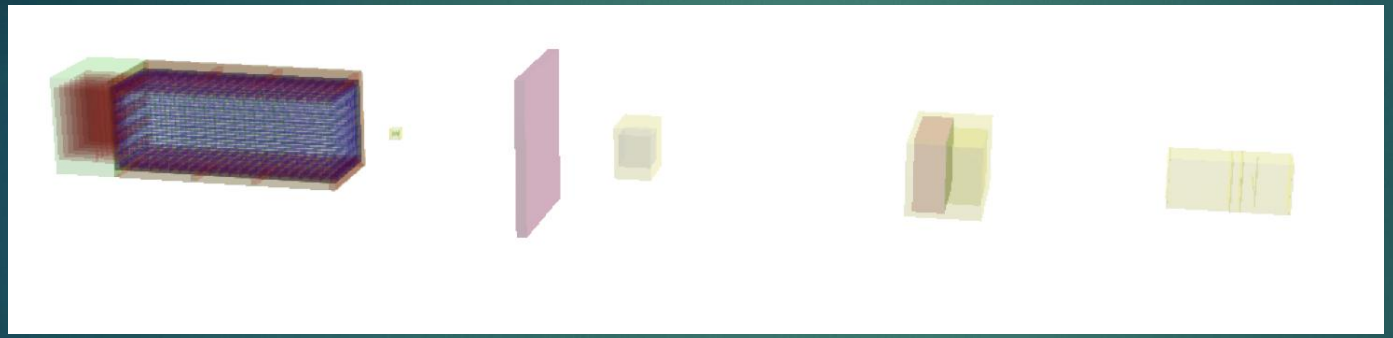
Example of full HERD Geometry



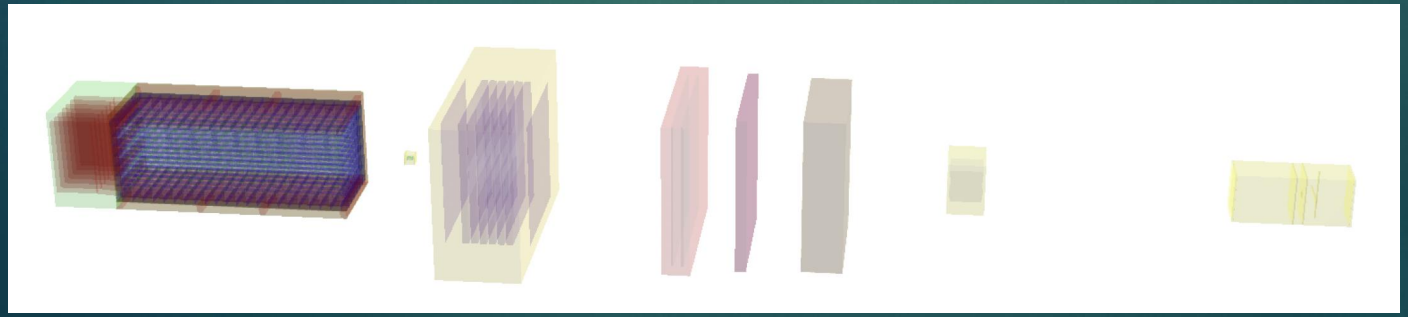
Example of Beamtest Geometry



PS



SPS



SPS Ion

Implementation based on DD4hep

- DD4hep is a software toolkit aimed for geometry description in HEP
- The construction implementation is based on XML files and plugins, making it flexible and compact for large scale detector
- Extra complex supporting structures will be directly imported from CAD models
- The description is provided in Geant4 format during Geant4 based simulation
- Geometry information is obtained in digitization, reconstruction, etc, by either cell ID or iterating of the geometry tree

Design of Geometry System

- Coordinate System

  In geometry construction, it is important to use a universal coordinate system definition rule for all the detector units, to ease the modularization, to avoid inconsistencies between different geometry versions, and to ease the acessing for process like digitization and reconstruction

- Detector Unit Numbering

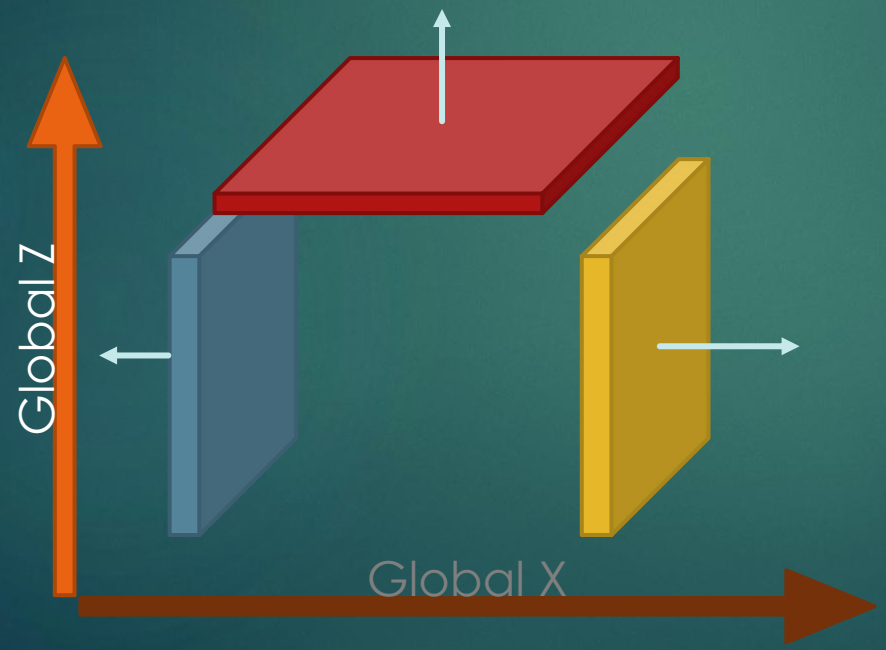
  A unified numbering system is designed in order to ease the identifying of detector geometry concerning the sensitive detector cells which corresponds to detector readout units in actual detector

- Modularized Design and Versioning

  essential for efficient implementation

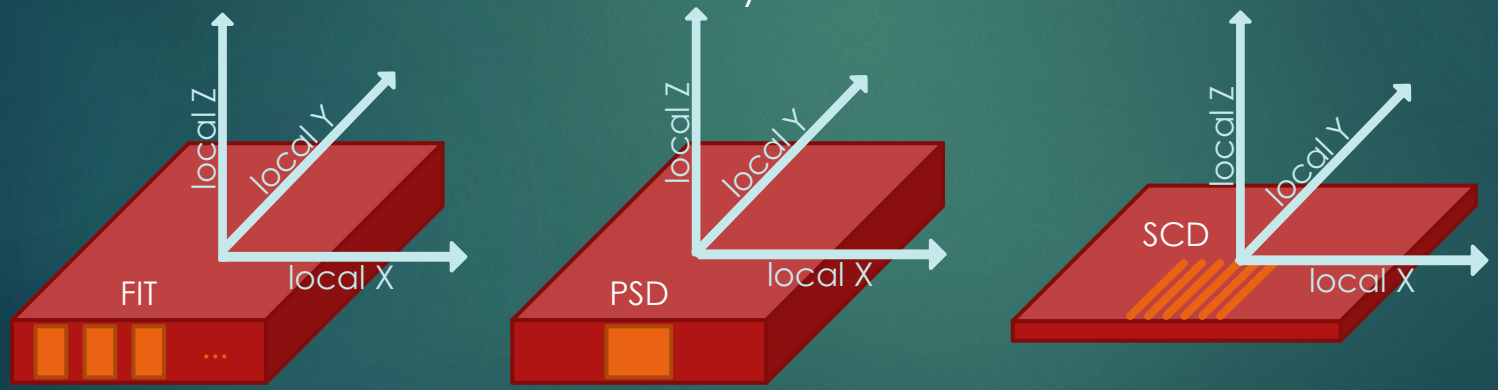
Coordinate System

- The global coordinate system is defined as:
  - X axis point to flying direction (ram)
  - Z axis points to zenith
- For each sector, detector units have different orientation, local coordinate system definition is also needed



Local Coordinate System Definition

- Defined a universal local coordinate system rule for sensitive detector units, or cells, according to the readout of the cell:
  - ✓ Origin point at the cell center
  - ✓ The local Z axis towards the outside of HERD
  - ✓ Readout channels aligned along local X axis, at negative end of local Y axis
    so different readout channel only differ in X coordinate *no matter which sector*

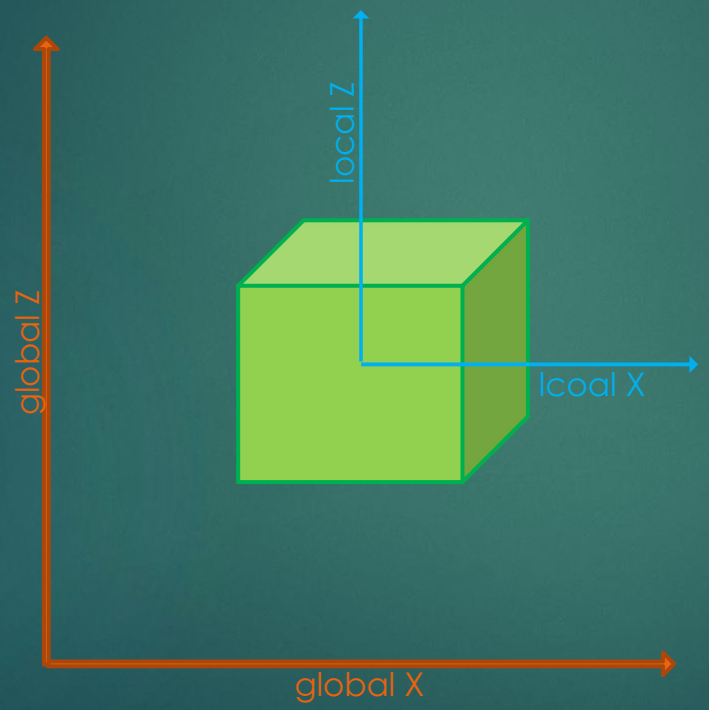


- Ease the acessing processes like digitization and reconstruction,
- Consistent between different geometry versions

e.g. `auto globalpos = geosvc->localToGlobal(localpos, geosvc.SCD, cellcode);`

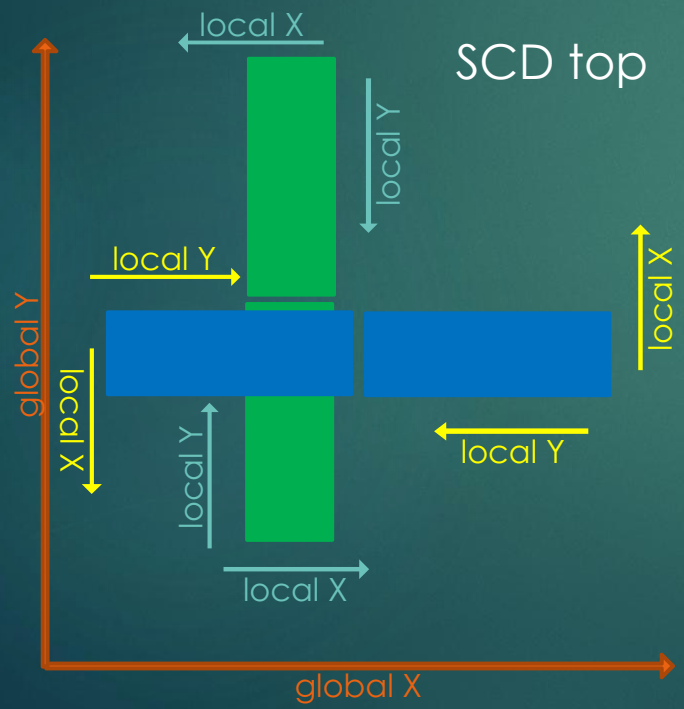
CALO

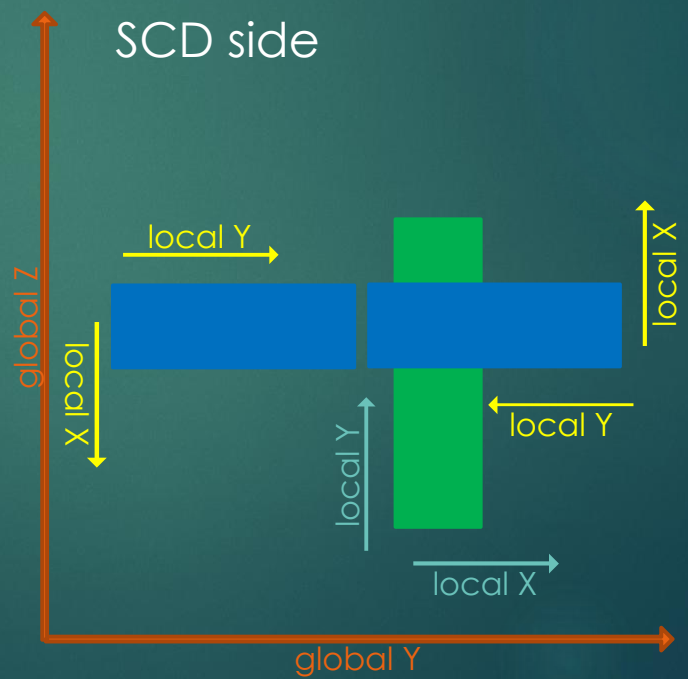
- Same direction for local & global coordinate, only different origin point



SCD (conventional)

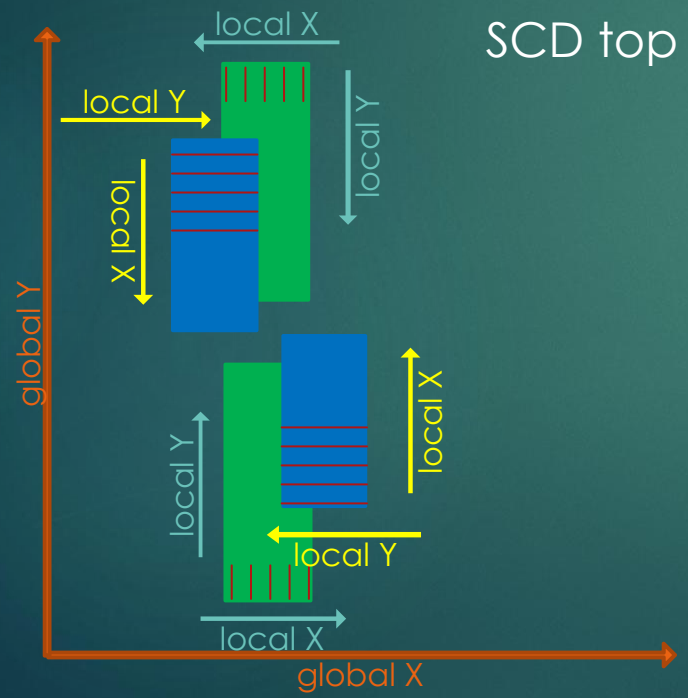
- Might be 2 ladders in a column
- Readout always at the outer end

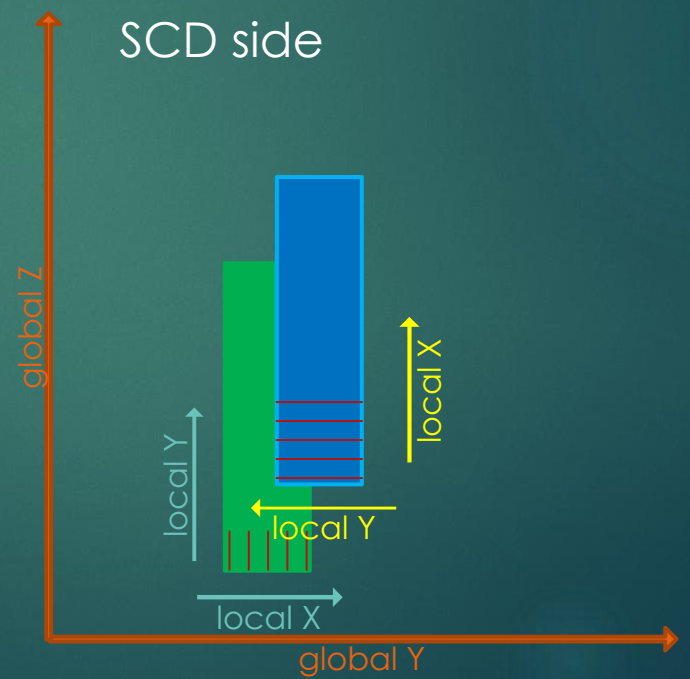




SCD (double layered)

- Might be 2 ladders in a column
- Readout at the outer end for normal ladders at one side for z-shaped ladders

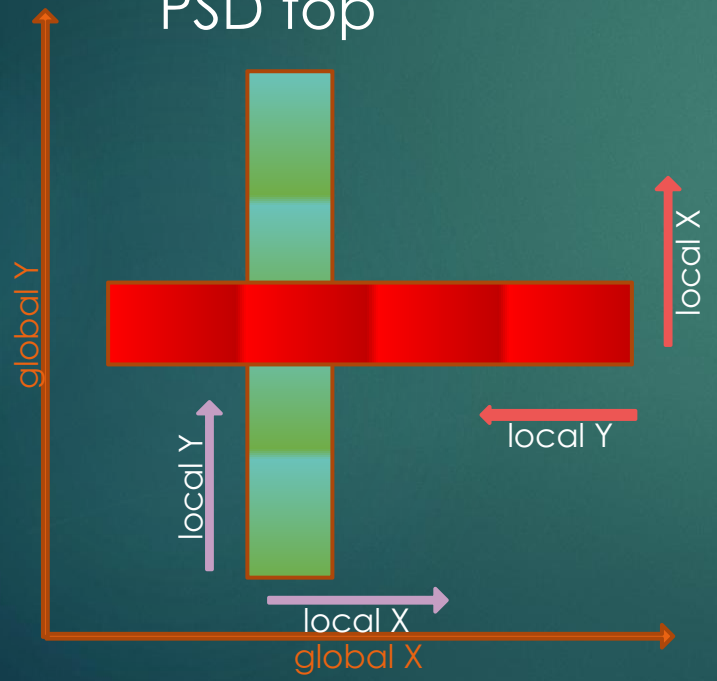




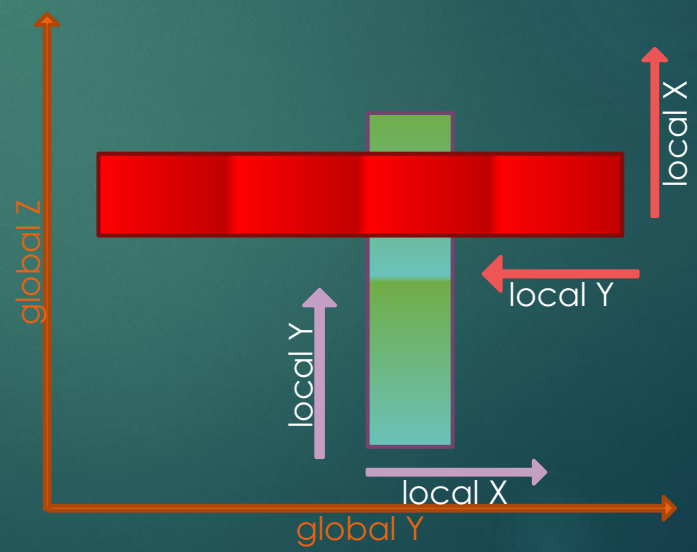
PSD

- Readout of PSD is symmetric, for convenience the same definition is used at top and side

PSD top

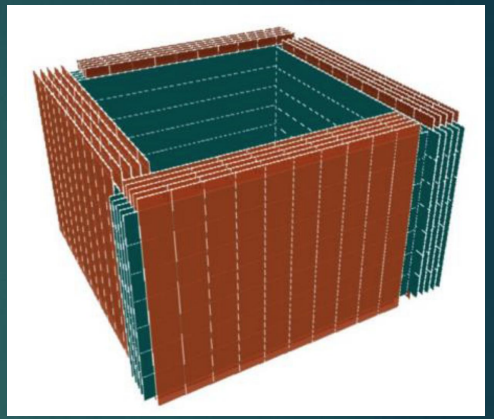


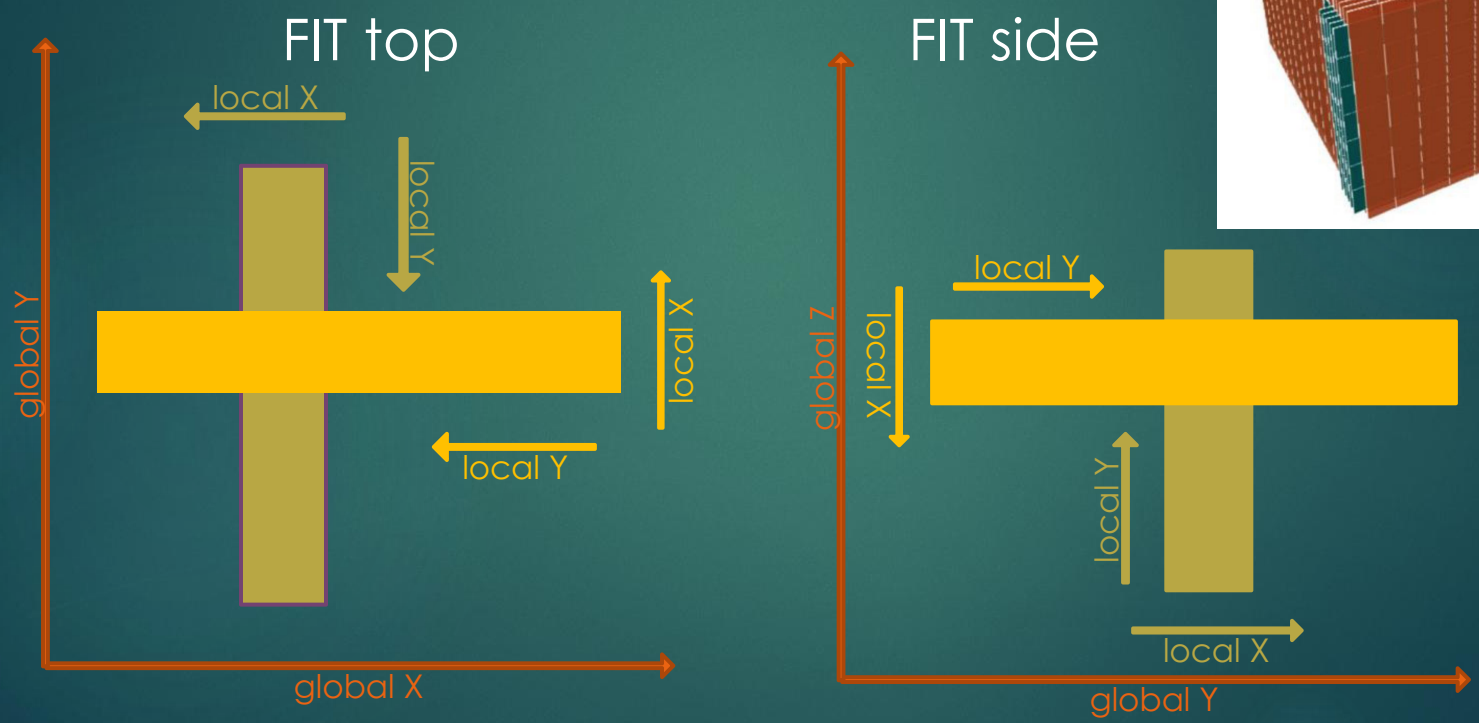
PSD side



FIT

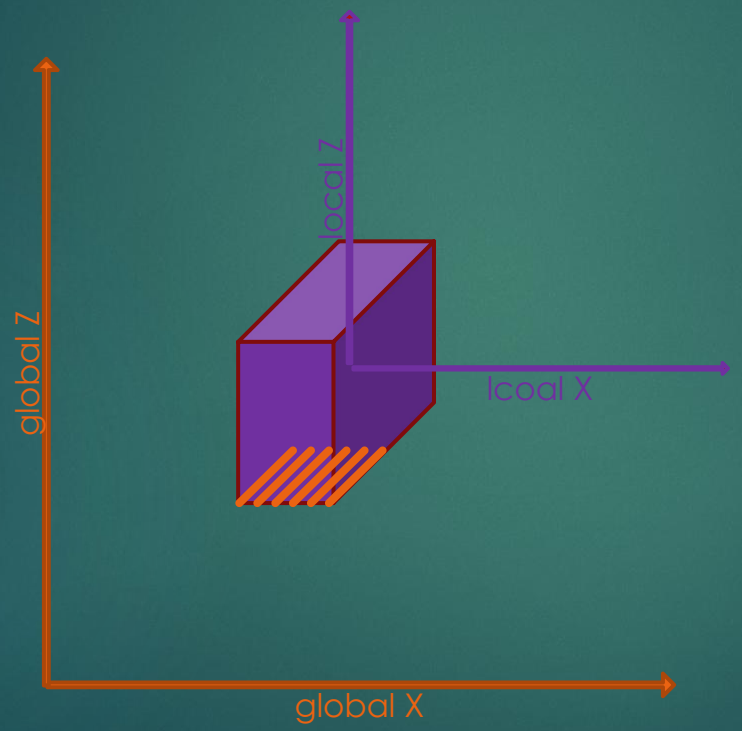
- Readout at top or upper for top sector
- Readout at bottom or left for side sector





TRD

- Same direction for local & global coordinate, different origin point

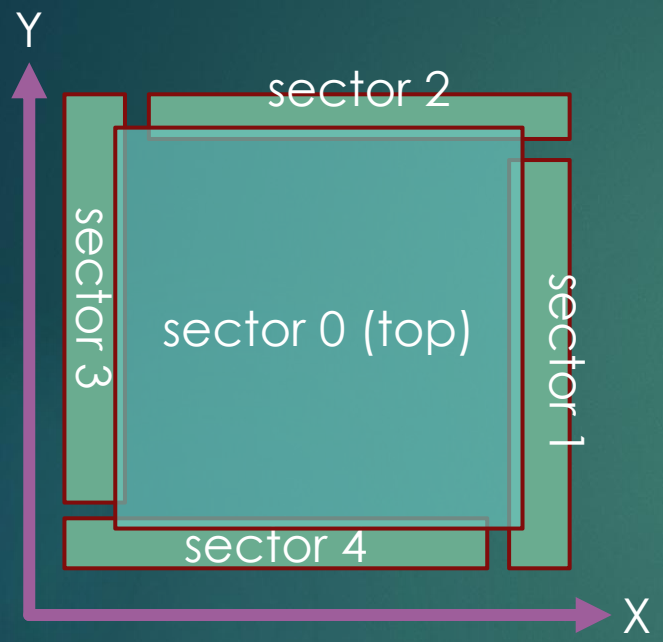


Detector Cell Numbering

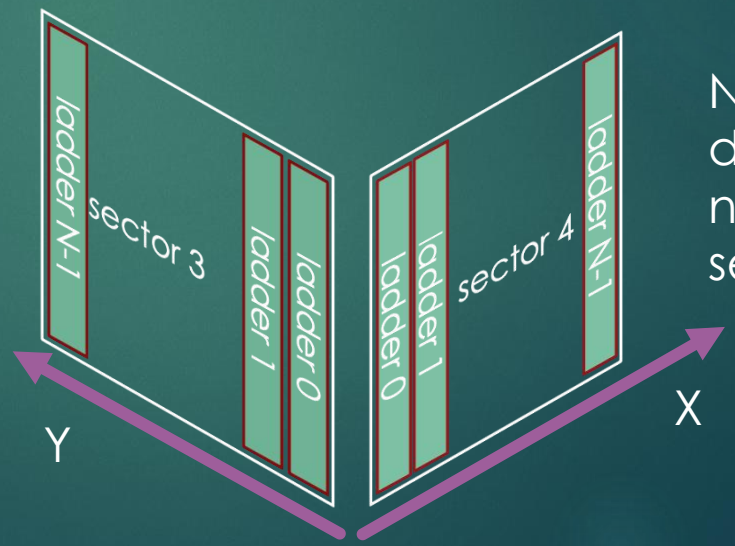
- Firstly ID numbers associated with cells are defined:
  - A **`systemid`** for each type of sub-detector
  - For each detector, a serial of ID numbers for each level of structure, are defined to identify each cell e.g. **`sector`**, **`layer`**, **`ladder`**, **`sensor`** for silicon detector
  - A combined number called **`cellcode`**:
    For storage a single number needed
    For human reading the combining is decimal, e.g. an ID of 1,2,3,4 → **`cellcode`** 01020304
- Then the numbering rule inside each level of structure, e.g. for sensors inside a ladder, are defined
  - Different rule for different layout, but the convention shall be the same.
  - Sectors are numbered as: top sector is 0, side sector at +X is 1, increasing CCW.
  - Layers of outer detectors are numbered <u>starting from the outside</u> of HERD: the outer most layer of each sub-detector is layer 0
  - Other structures, e.g. ladders, mats, sensor, are numbered in a way <u>that larger numbers corresponds to larger values of global coordinate</u>
    Numbering of CALO crystal also follows this rule

Numbering: General

- **systemid**:
  - 0: CALO
  - 1: STK
  - 2: PSD
  - 3: (FIT)
  - 4: SCD
  - 5: TRD



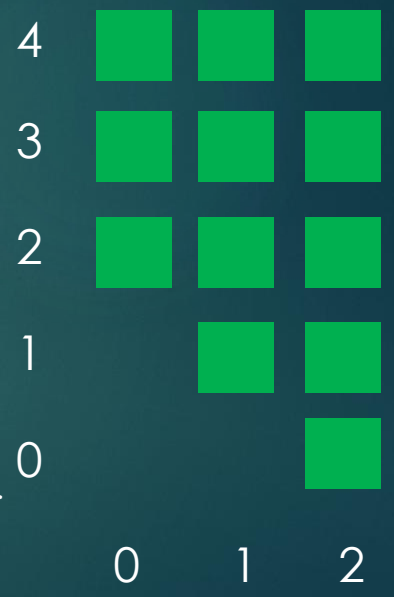
Sector id:
top=0
+X=1
Increasing CCW



Note the difference for neighboring sectors

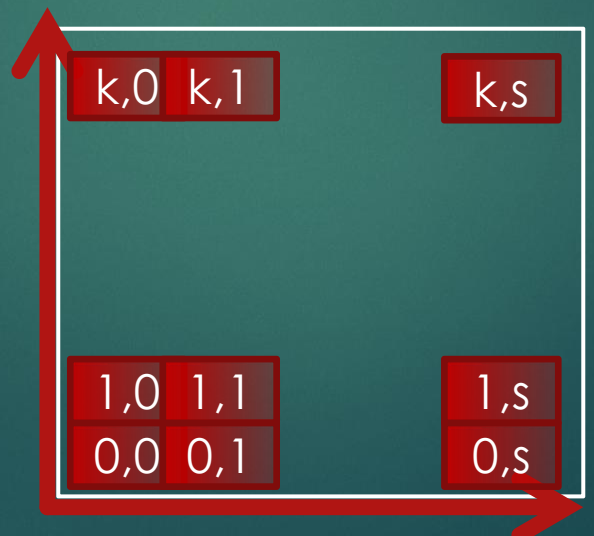
Numbering of CALO

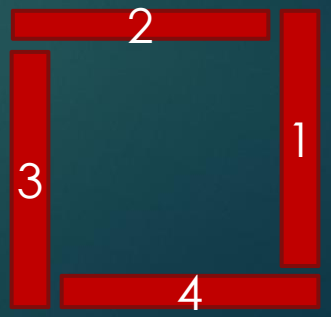
- Cells are numbered according to position in XYZ, increasing with position
- Each cell have ix, iy, iz (0-22, Not all combinations exist)
- cellcode=iz*10000+iy*100+ix
- Index=iz*23^2+iy*23+ix, 0-12167
  - Can be used as array indexes
  - Can be converted bidirectional
- dd4hep readout:
  <id>system:3,index:16,xid:-8,yid:-8,zid:-8,cellcode:20</id>
  - system=0



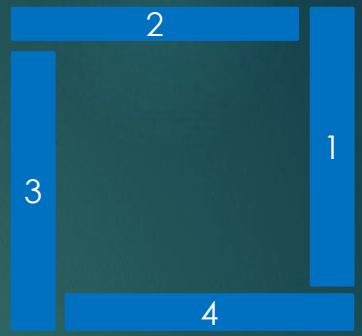
Numbering of PSD

- Numbered according to sector, layer, col, row
- Sector IDs: top=0, +x=1, increasing CCW, Layer id increasing from outside
- Col&row IDs increasing with global position, column along long side of bars
- <id>system:3,type:3,side:3,layer:3,col:7,row:7</id>
  - system=2
  - type of psd geometry: 0: long bar, 1: short bar, 2: tile, ...
- **`cellcode=100000000*type+1000000*sector+10000*layer+100*col+row`**, e.g. **000000300**

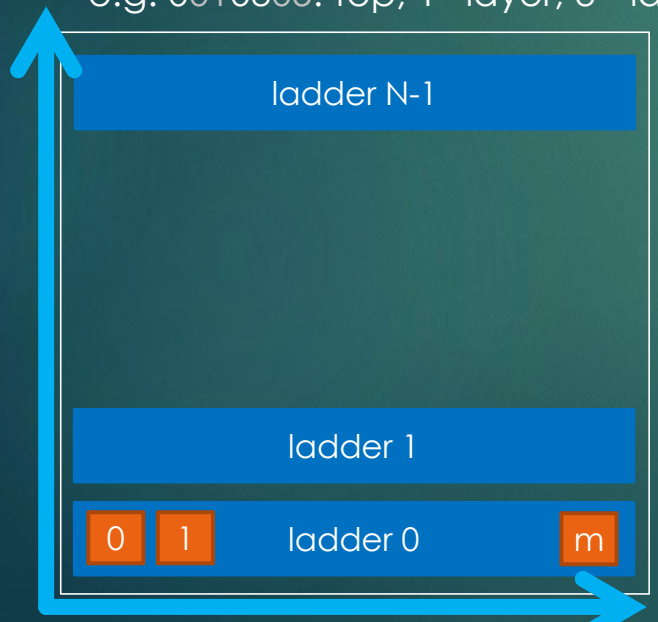


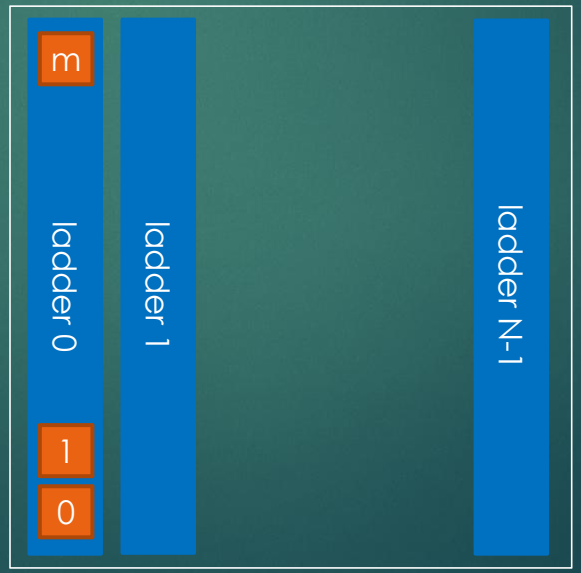


Numbering of SCD/STK



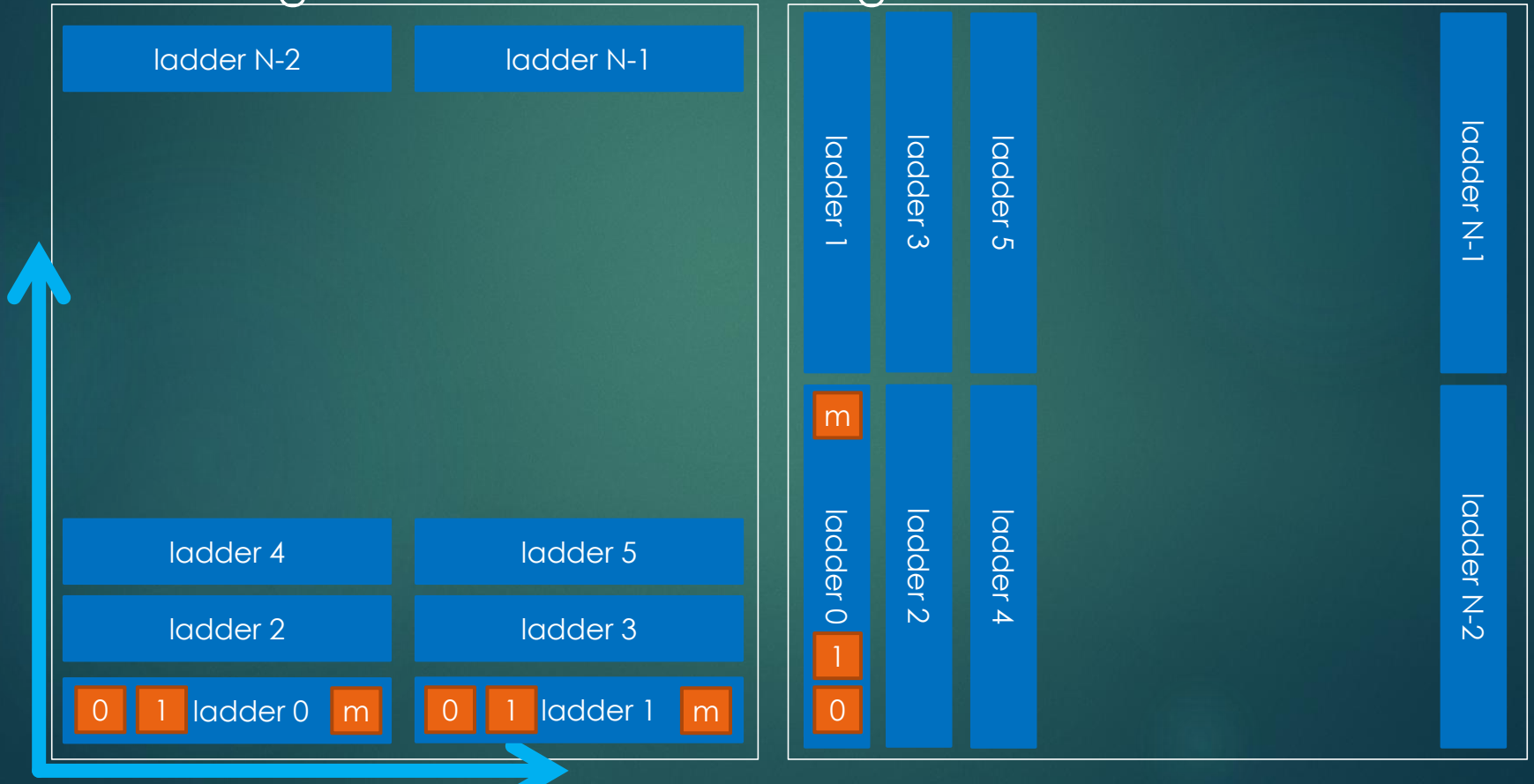
- Numbering as sector, layer, ladder, sensor, strip(reserved)
- Layer IDs increase from outer to inner, starting from 0
- Ladder IDs increase with global coordinate
- Sensor IDs inside a ladder increase with global coordinate
- `<id>system:3,side:3,layer:4,ladder:6,sensor:4,strip:16</id>`
  - system=4 for SCD (1 for STK)
- `cellcode(sensor)=1000000*sector+10000*layer+100*ladder+sensor`, e.g. 0010305: top, 1st layer, 3rd ladder, 5th sensor





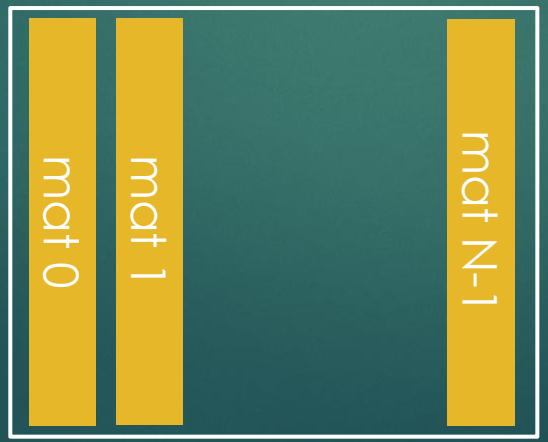
Numbering of SCD/STK

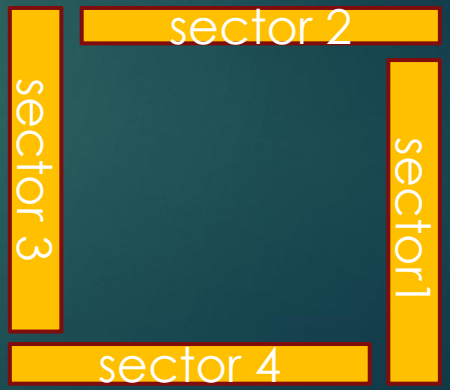
- If there are 2 ladders in a column, the ID increase inside the column, then increase in the next column. The increasing direction matches with global coordinate.



Numbering of FIT

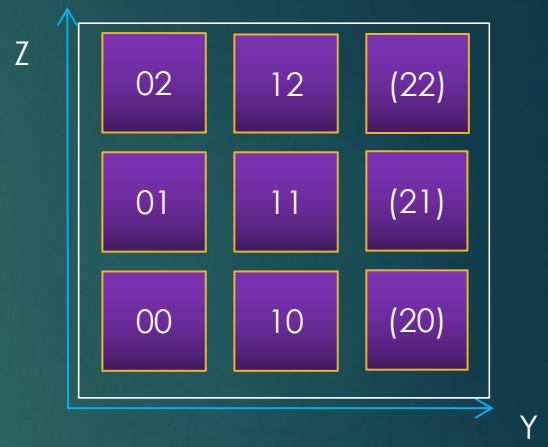
- Numbered according to sector, layer, mat
- Sector IDs: top=0, +X=1, increasing CCW
- Layer IDs increasing from outside
- Mat IDs increasing with global coordinate
- <id>system:3,side:3,layer:4,mat:4,fiber:16,cellcode:16</id>
  - system=3
- cellcode=10000*sector + 100*layer + mat,
  e.g. cellcode=00103: top, layer 1, mat 3

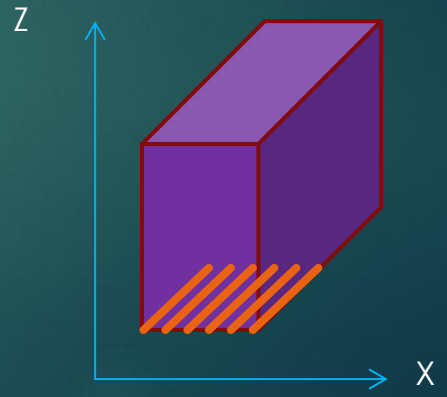




Numbering of TRD

- Numbered according to layer(reserved), module, strip
- Two numbers(col&row) in module IDs increase with position
  - 00, 01, 02, 10, 11, 12, 20, 21, 22
- Readout strip IDs increase from front (+X)
- <id>system:3,layer:2,module:4,strip:8</id>
  - system=5
- cellcode=layer*10000+module*100+strip

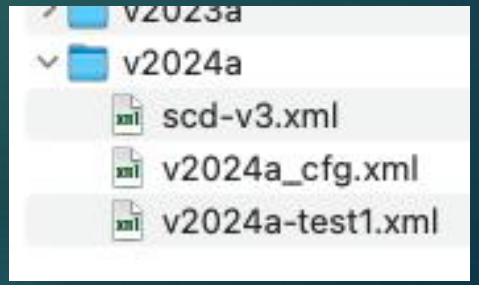




Modularized Design

In the implementation a good file structure will ensure effeciency in development

- A set of similar geometry will be in their own directory
- There will be one or more master XML files as the entrance of geometry
- Definition of commonly used parameters are defined in a central place, i.e. a **_cfg.xml** file, including envelops and center positions of each subdetector
- Each subdetector will be in it's own xml file and being included by a master file. They have to define detailed geometry inside their envelop by adapting common parameters



Version Control

- To ensure the availibility of a specific version of geometry, a proper version control policy is defined
  since the geometry will be used later in recontruction etc
  - Master xml file have a version tag in the name, e.g. v2024a.xml
  - Name of subdetector xml files are also versioned, e.g. scd-v3.xml
- Changes are only allow if compatiable with current one, i.e. no feature changes. if any feature changed a new name (e.g. v3a) should be created and the current one shall be preserved
- very old versions could be removed after disscussion, which makes the corresponding MC samples not useful anymore

Summary

- A carefully designed geometry system is forming the base of simulation, and widely used across the software.
- The coordinate system is defined for all detectors, both globally and locally.
- The numberings of detector units are defined across the whole detector.
- Modulated designing and version controling are taking into account in the implementations.