Modifying All-Silicon Tracker Prototype in EICroot

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Contents

1 Accessing EICroot image

EICroot and necessary dependencies are already installed in a virtual machine. Install VMware. Double click on the file `vm-eic.vmx`. When the image loads, it will ask for a username (eic) and password (eiceic). This virtual machine was created with the Beast detector geometry. Thus, two files (`vst.C` and `fbst.C`) need to be updated so that the code generates the All-Silicon tracker geometry instead. The original codes I got from Yue Shi Lai are appended at the end of this document.

2 Modifying the geometry

The All-Si tracker geometry is defined in: `Home/eicroot/geometry/`.

2.1 Beampipe

The beam-pipe geometry is defined in:

```
Home/eicroot/geometry/BEAMPIPE/beampipe.C
```

The central part of the beampipe is made of Beryllium and is 800 μm thick. It is 36 mm in diameter, and extends from -400 to 400 mm:

```
BeamPipeElement *ip = new BeamPipeElement("beryllium", 0.800);
ip->AddSection(-400.0, 36.00);
ip->AddSection( 400.0, 36.00);
```

Outside of this range, the beampipe becomes Aluminum and extends from where the Beryllium section ends and up until $\pm$4.5 m. it increases in diameter from 36 mm to 40 mm:

```
BeamPipeElement *p1 = new BeamPipeElement("aluminum", 1.000);
p1->AddSection( 400.0,  36.00);
p1->AddSection(1000.0,  40.00);
p1->AddSection(4500.0,  40.00);
```

This is how the geometry is defined. Then it is assembled as follows:

```
BeamPipeGeoParData *bpipe = new BeamPipeGeoParData();
bpipe->AddElement  (p1, BeamPipeElement::Swap);
bpipe->AddIpElement(ip);
bpipe->AddElement  (p1);
```

Fig. 1 shows a diagram for the beampipe.

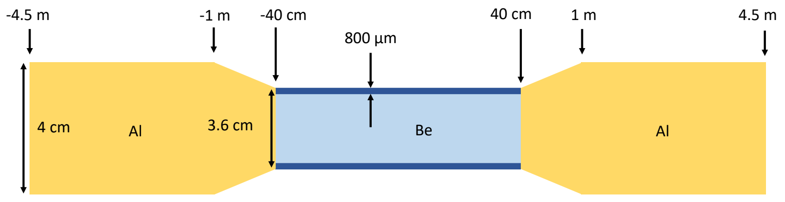


Figure 1: Beampipe schematic (not in scale).

2.2 Mimosa Chips

Mimosa chips are the building blocks for the barrel and disks. The chips are defined with a width of 15 mm and a height of 30 mm in:

```
Home/eicroot/geometry/MAPS/maps-lib.C
```

2.3 Barrel

The barrel details are in:

```
Home/eicroot/geometry/MAPS/vst.C
```

The first step is to define the common cell that will be used to build up the barrel:

```
MapsMimosaAssembly *ibcell = (MapsMimosaAssembly*)ConfigureAliceCell();
```

Then, six layers are assembled, as illustrated below. The variables passed in `AddBarrelLayer` below correspond to: cell assembly type, number of staves in this layer, number of chips in a stave, chip center installation radius, additional stave slope around beam line direction in degrees, layer rotation around beam axis “as a whole” in degrees:

```
vst->AddBarrelLayer(ibcell,   12     ,  9     ,    23.4, 12.0, 0.0);
vst->AddBarrelLayer(ibcell, 2*12     ,  9     ,  2*23.4, 12.0, 0.0);
vst->AddBarrelLayer(ibcell, 6*12     , 14     ,  6*23.4, 14.0, 0.0);
vst->AddBarrelLayer(ibcell, 4*20     , 14     ,  4*39.3, 14.0, 0.0);
vst->AddBarrelLayer(ibcell, 4*20*10/4, 14*10/4, 10*39.3, 14.0, 0.0);
vst->AddBarrelLayer(ibcell, 4*20*11/4, 14*11/4, 11*39.3, 14.0, 0.0);
```

The information in this snippet of code is presented in Table 1. An overall overview of the barrel geometry is shown in Fig. 2 a).

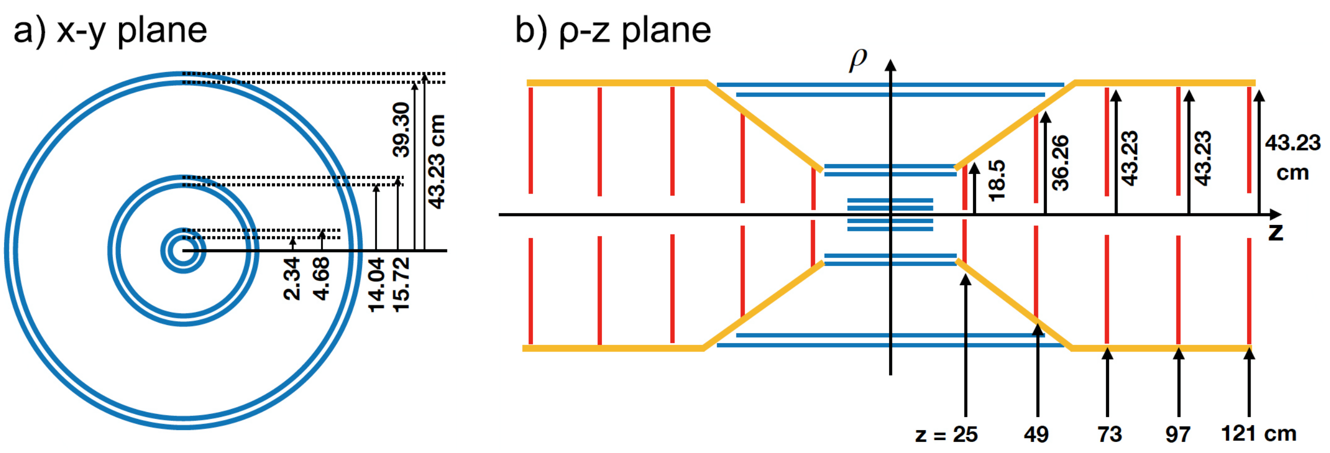


Figure 2: Schematic of the detector geometry. The barrel, disks, and support structure are drawn in blue, red, and yellow respectively. a) barrel as seen in the $x - y$ plane. b) detector as seen in the $\rho - z$ plane. This is a simplified diagram, as the barrel layers and disks are not smooth. The barrel is formed by staves, and the disks have jagged edges.

Table 1: Barrel characteristics

Layer	# staves in layer	# chips in stave	length along z (cm)	chip center installation radius (mm)	stave slope (deg)
1	12	9	27	23.4	12
2	24	9	27	46.8	12
3	72	14	42	140.4	14
4	80	14	42	157.2	14
5	200	35	105	393	14
6	220	38	114	432.3	14

Here, a "chip" refers to a Mimosa chip assembly (see section 2.2). The length of the barrel layers in z is given by the number of chips per stave and corresponds to `(# chips)`×`(chip length)`.

2.4 Disks

The disks are in:

```
Home/eicroot/geometry/MAPS/fbst.C
```

At the top of this code we define the number of disks we will have in each z direction:

```
#define _DISK_NUM_ (5)
```

Then, the positions in z and rotation angle in the $x - y$ plane of these disks are determined as follows:

```
Double_t Z[_DISK_NUM_];
Double_t R[_DISK_NUM_];
for (size)t i = 0; i  < _DISK_NUM_; i++) {
      Z[i] = 250 + i * (1210.0 - 250.0) / (_DISK_NUM_ - 1);
      R[i] = 45.0 * (i % 2);
}
```

This corresponds to the values shown in Table 2 and in Fig. 2 b).

Table 2: Disk characteristics (in the forward direction). To get backward disks multiply the z-position column by -1.

Disk number	z position ("Z") [cm]	axis rotation ("R") [deg]	outer radius [cm]
1	25	0	18.5
2	49	45	36.26
3	73	0	43.23
4	97	45	43.23
5	121	0	43.23

The disks are added the following way:

```
for(unsigned dc=0; dc<_DISK_NUM_; dc++) {
    FstDisc *disc = new FstDisc(ibcell, 18.0, TMath::Min(432.3, 185.0 * Z[dc] / Z[0]), 12.8);
    fbst->AddDisc(disc, (fb ? -1.0 : 1.0)*Z[dc], R[dc]);
}
```

In the first line inside the `for` loop, the parameters passed to create the `FstDisc` disk objects correspond to: the object that will be used as a building block (`ibcell`), the inner radius of the disk, the outer radius of the disk, and the distance between the chips.

2.5 Support structure

Note: EICroot uses millimeters as the standard length unit. All the lengths shown up to this point corresponded to mm. However, the support structure is defined directly using Geant classes, which use cm as the standard length unit. Thus, the lengths in this section are given in cm.

The support structure is also defined in:

```
Home/eicroot/geometry/MAPS/fbst.C
```

The parameters that go into `DefineSection` are: a numeric tag or label, z position, inner radius, and outer radius. The support structure is defined with three sections.

```
TGeoPcon *support = new TGeoPcon("AluStrips_support", 0.0, 360,0, 3);
support->DefineSection(0, (fb ? 1.0 : -1.0) * 20 , 18.5 * 20.0 / 25.0 , 18.5 *  20.0 / 25.0 + 0.5);
support->DefineSection(1, (fb ? 1.0 : -1.0) * 43.23 * 0.1 * Z[0] / 18.5, 43.23, 43.23 + 0.5);
support->DefineSection(2, (fb ? 1.0 : -1.0) * 121, 18.5 * 121.0 / 25.0, 18.5 * 121.0 / 25.0 + 0.5);
TGeoVolume *support_volume = new TGeoVolume("AluStrips_support_volume", support, fbst->GetMedium("aluminum"));
fbst->GetTopVolume()->AddNode(support_volume, 0, new TGeoCombiTrans(0.0, 0.0, 0.0, 0));
```

3 Compiling the geometry into a TGeo file

First of all, run the macros mentioned above. Go to the corresponding directories and run:

- `root -l beampipe.C`
- `root -l vst.C`
- `root -l fbst.C`

This will create root files that contain these pieces of the geometry to be stored in the combined TGeo file. Next, edit the function `void EicDetector::FinishRun()` in code:

```
Home/eicroot/eic/base/EicDetector.cxx
```

to include the following three lines (add as the first three lines of that function):

```
TFile *outfile = TFile::Open("genfitGeom.root","RECREATE");
gGeoManager->Write();
outfile->Close();
```

Afterwards, you have to recompile by `make -C build` or `cd Home/eicroot/eic/build; make`. Run the following root macro to compile the geometry:

```
{
        // Load basic libraries;
        gROOT->Macro("$VMCWORKDIR/gconfig/rootlogon.C");
        // Create simulation run manager; use GEANT3 for tracking excercises here;
        EicRunSim *fRun = new EicRunSim("TGeant3");
        fRun->SetOutputFile("simulation-uds.root");
        // Vertex tracker;
        fRun->AddModule(new EicMaps   ("VST", "/home/eic/eicroot/geometry/MAPS/vst-v01.0-fs.root", qVST));
        fRun->AddModule(new EicMaps   ("FST", "/home/eic/eicroot/geometry/MAPS/fst-v01.0-ns.root", qFST));
        fRun->AddModule(new EicMaps   ("BST", "/home/eic/eicroot/geometry/MAPS/bst-v01.0-ns.root", qBST));
        // Beam pipe; details of IR not known yet -> just a cylinder with thin walls;
        fRun->AddModule(new EicDummyDetector("BEAMPIPE", "BEAMPIPE/beampipe.root"));
        // Initialize and run the simulation; exit at the end;
        fRun->Run(-1);
}
```

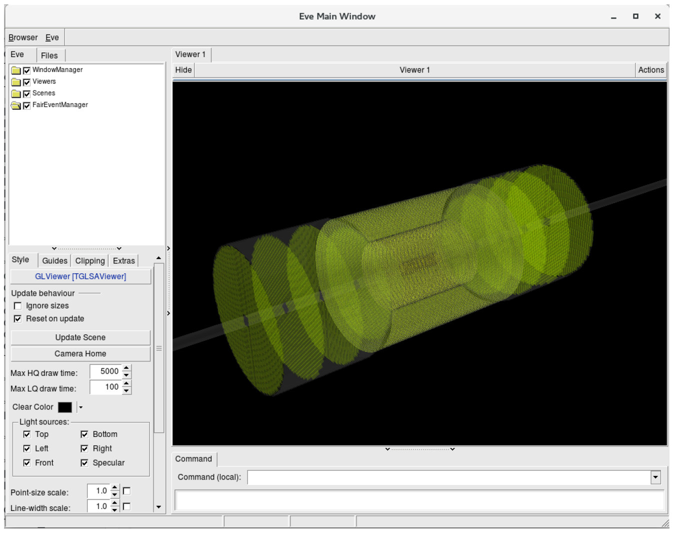
Make sure the lines `AddModule` point to the correct versions of the detector pieces. This will produce two main outputs. The first one is a root file named `genfitGeom.root`, which is the one that will be copied into Fun4All. The second one is named `simulation-uds.root` and will be used in the next section to visualize the geometry in EICroot.

4 Visualizing the geometry

Run the following macro:

```
{
  gROOT->Macro("$VMCWORKDIR/gconfig/rootlogon.C"); // Load basic libraries;
  // Create visualization manager;
  EicEventManager *fMan = new EicEventManager();
  fMan->SetInputFile("simulation-uds.root");
  fMan->Init(); // Initialize and run visualization manager; tune vis.properties a bit;
  fMan->Run();
}
```

This will open a GUI as shown in Fig. 3.



Update behaviour
☐ Ignore sizes
☑ Reset on update
Max HQ draw time: 5000
Max LQ draw time: 100
Clear Color
Light sources:
☑ Top ☑ Bottom
☑ Left ☑ Right
☑ Front ☑ Specular
Point-size scale: 1.0 ☐
Line-width scale: 1.0 ☐

Figure 3: Event-display GUI.

A screenshot of the help menu from the GUI is shown in Appendix A.3. The main commands are listed below:

- `j`, `k`: zoom in and out.
- `e`: change background color between black and white.
- `w`, `r`, `t`: different ways of visualizing the geometry.

5 Detector updates (week of July 13-17, 2020)

5.1 Beampipe updates

This is just a placeholder. A more realistic beampipe is needed.

```
BeamPipeElement *ip = new BeamPipeElement("beryllium", 0.762);
ip->AddSection(-798.0, 62.00);
ip->AddSection( 798.0, 62.00);
BeamPipeElement *pf = new BeamPipeElement("aluminum", 1.000);
pf->AddSection(  798.0, 62.00);
pf->AddSection( 4500.0, 62.00);
bpipe->AddElement  (pf,BeamPipeElement::Swap);
bpipe->AddIpElement(ip);
bpipe->AddElement  (pf);
```

5.2 Barrel updates

Below are two possible updates for the barrel. Tho innermost layers are identical in these two updates, and differ from the original configuration in that their radii and number of staves have been increased to accommodate the beampipe.

Update 1:

This version has the two middle and two outer layers configured such that the triangular staves are back-to-back. See Fig. 4 (center).

```
vst->AddBarrelLayer(ibcell,  17,      10,  32.000,  12.0, 0.0       );
vst->AddBarrelLayer(ibcell,2*13,      10,  40.000,  12.0, 0.0       );
vst->AddBarrelLayer(ibcell,  82,      20, 224.700,   0.5, 0.0       );
vst->AddBarrelLayer(ibcell,  82,      20, 228.980, 179.5, 180/82     );
vst->AddBarrelLayer(ibcell, 151, 14*10/4, 413.985,   0.5,        0.0);
vst->AddBarrelLayer(ibcell, 151, 14*10/4, 419.095, 179.5, 180/151+0.2);
```

Update 2:

This version has the two middle and two outer layers configured such that the silicon part of each stave faces one another. See Fig. 4 (right). This makes the detector more hermetic.

```
vst->AddBarrelLayer(ibcell,  17,      10,  32.000,  12.0, 0.0       );
vst->AddBarrelLayer(ibcell,2*13,      10,  40.000,  12.0, 0.0       );
vst->AddBarrelLayer(ibcell,  82,      20, 224.700,   0.5, 0.0       );
vst->AddBarrelLayer(ibcell,  82,      20, 224.200, 179.5, 180/82     );
vst->AddBarrelLayer(ibcell, 151, 14*10/4, 419.510,   0.5,        0.0);
vst->AddBarrelLayer(ibcell, 151, 14*10/4, 419.095, 179.5, 180/151+0.2);
```

Additionally, with respect to the original barrel, some of the length of the staves in z has been changed to reflect the changes in the rest of the geometry.

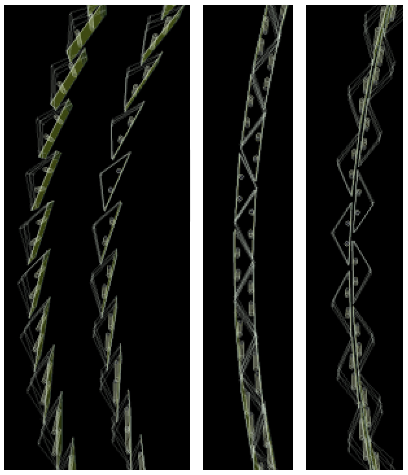


Figure 4: Different configurations for the barrel layers: (left) original, (center) update 1, and (right) update 2.

5.3 Disk updates

There were no changes added to the z position or the outer radii of the disks. Basically, only the inner radii were increased to accommodate the new beampipe. Also, the spacing between staves was increased for reasons listed in the next paragraph. The modified line is shown below:

```
FstDisc *disc = new FstDisc(ibcell, 31.5, TMath::Min(432.3, 185.0 * Z[dc] / Z[0]), 18.);
```

After implementing this, I noticed that a gap appeared between the middle piece and two semi-circles that form the disks, as shown in Fig. 5 (left). I confirmed with Alexander Kiselev that this comes from the fact that exactly three staves are hardcoded for the middle part of the disks.

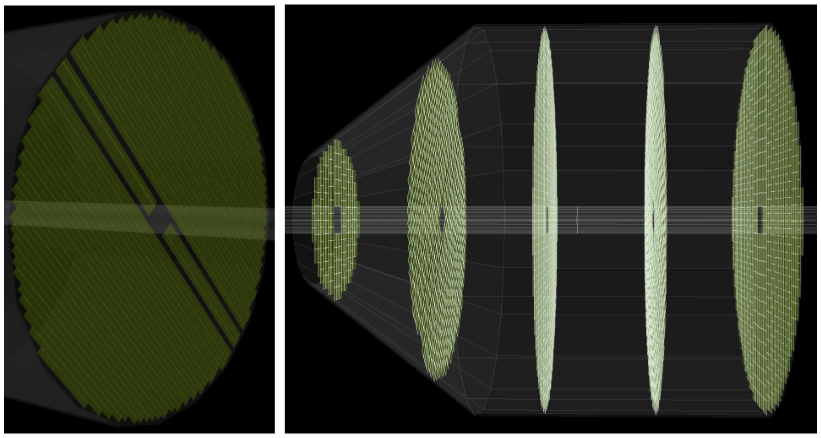


Figure 5: Updates to disks and support structure: (left) gap that appeared between the middle piece and two semi-circles that form the disks after increasing the inner radii. (right) updated disks after increasing Mimosa chip width.

In order to avoid these gaps, a “hack” was implemented. The mimosa chips were extended in width from 15 mm to 25 mm so that the extra horizontal area fills these gaps. Keep in mind that both the barrel (`vst.C`) and disks (`fbst.C`) read from `maps-lib.C` for the definition of the Mimosa chips. However, we only want to change the width of the chips in the disks (not the barrel). To achieve this, I modified the dimensions of the chip in a copy of `maps-lib.C`, and made the disks macro read the chips from this copy. In this copy, the following two lines were modified:

```
ibcell->mChipWidth                  =   25.000;  //15.000;
ibcell->mAssemblyDeadMaterialWidth  =   25.000;  //15.000;
```

Fig. 5 (right) shows what one of the disk regions looks like after implementing these fixes.

5.4 Support structure updates

Previously, we noticed that the "forward"-labeled region of the detector had five disks in the forward direction, and the support structure in the backward direction. Similarly, the "backward"-labeled region of the detector had five disks in the backward direction, and the support structure in the forward direction. I changed the sign in the support structure such that this is corrected.

A Appendices

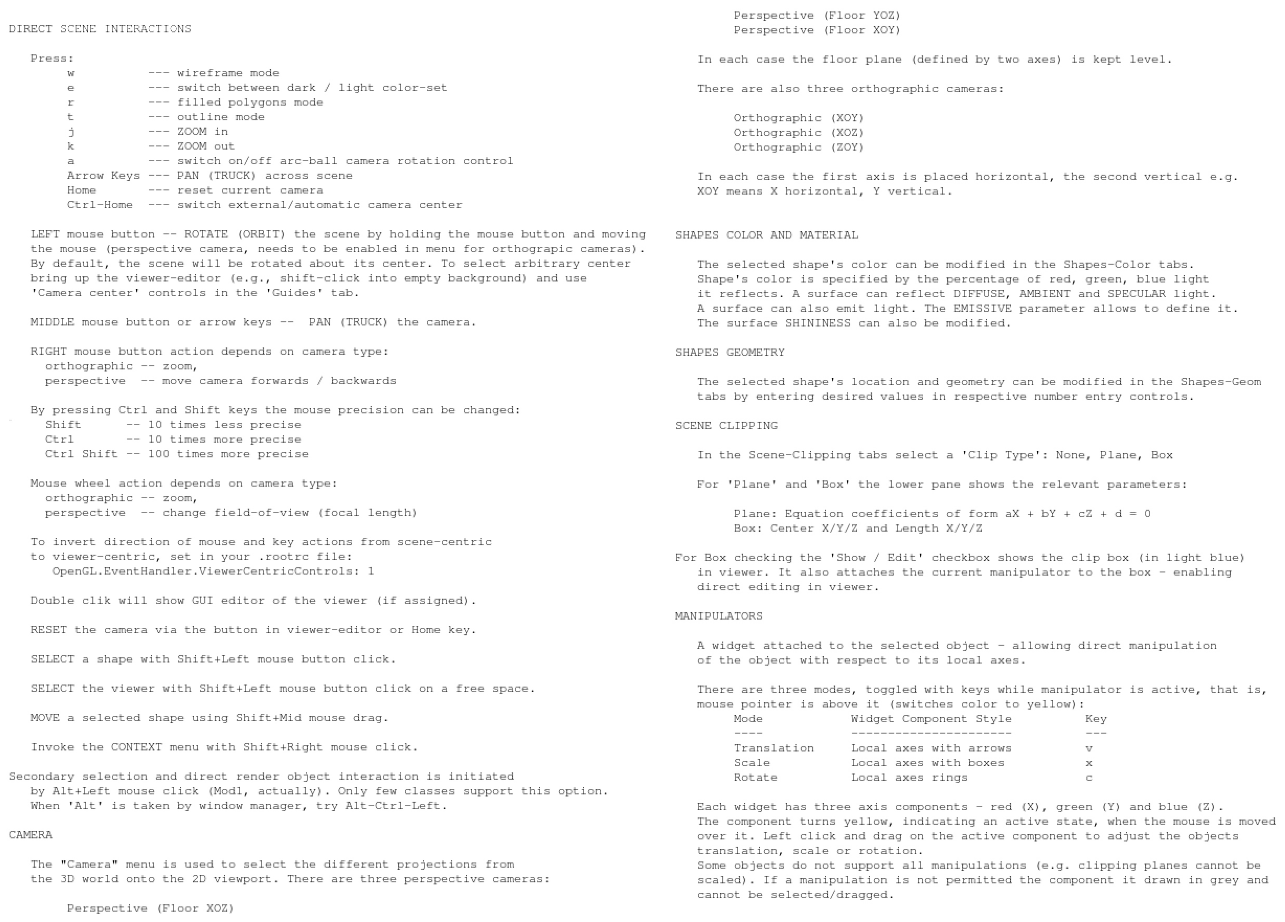
A.1 Original vst.C macro from Yue Shi Lai

```
#define _VERSION_     1
#define _SUBVERSION_  0
//#define _TEST_VERSION_ // Do not want to always overwrite "official" files; place "test" tag into the file name;
// All construction elements are smeared (so chip assembly is uniform in both beam line and asimuthal direction);
//#define _NO_STRUCTURE_GEOMETRY_
// No tricky elements like inclined roof beams; still water pipes, etc are
// created (so chip assembly is uniform in beam line direction only);
//#define _BEAM_LINE_UNIFORM_GEOMETRY_
#define _USE_TRIANGULAR_ASSEMBLIES_ // In case of VST no need to fall back to tricky TGeoCompositeShape cell assemblies;
//#define _WITH_MOUNTING_RINGS_ // Comment out if no mounting rings wanted;
//#define _WITH_ENFORCEMENT_BRACKETS_ // Comment out if no stave enforcement brackets wanted;
//#define _WITH_EXTERNAL_PIPES_ // Comment out if no external water pipe pieces wanted;
#include <geometry/MAPS/maps-lib.C>
vst()
{
  // Load basic libraries;
  gROOT->Macro("$VMCWORKDIR/gconfig/rootlogon.C");
  // Prefer to think in [mm] and convert to [cm] when calling ROOT shape
  // definition routines only;
  VstGeoParData *vst = new VstGeoParData(_VERSION_, _SUBVERSION_);
  // Parse #define statements and make certain configuration calls accordingly;
  // NB: cast to the base MAPS geo class since void* interface used; FIXME!;
  DefinitionParser((MapsGeoParData*)vst);
  // For now assume ALICE Inner Barrel design only (but with more than 9 chips); no problem to introduce similar design with a bit different
  // parameter set later; construction a-la ALICE Outer Barrel looks like an overkill to the moment;
  // No offset per default;
  //vst->SetTopVolumeTransformation(new TGeoTranslation(0.0, 0.0, 0.0));
  // NB: all these numbers are sort of arbitrary; allow to get better visual representation, but do not reflect any reality of the final design;
  // Mounting ring construction; arbitrary numbers, same for all layers;
  if (vst->WithMountingRings()) {
    vst->mMountingRingBeamLineThickness =    5.00;
    vst->mMountingRingRadialThickness   =    5.00;
    vst->mMountingRingRadialOffset      =    3.00;
  } //if
  // Simplify the design -> just a triangular piece with a reasonable volume;
  if (vst->WithEnforcementBrackets())
    vst->mEnforcementBracketThickness   =    1.00;
  // This is something for display purposes mostly;
  if (vst->WithExternalPipes())
    vst->mWaterPipeExtensionLength      =    4.00;
  MapsMimosaAssembly *ibcell = (MapsMimosaAssembly*)ConfigureAliceCell();
  // If (much) longer staves needed, create an enforced configuration;
  //MapsMimosaAssembly *obcell = new MapsMimosaAssembly(ibcell);
  //obcell->mEnforcementBeamDiameter     =    1.00; ... and so on ...
  // Now when basic building blocks are created, compose barrel layers;
  // a dirty part, but perhaps the easiest (and most readable) to do; parameters are:
  //  - cell assembly type;
  //  - number of stoves in this layer;
  //  - number of chips in a stove;
  //  - chip center installation radius;
  //  - additional stove slope around beam line direction; [degree];
  //  - layer rotation around beam axis "as a whole"; [degree];
  //
  vst->AddBarrelLayer(ibcell,   12,  9,   23.4, 12.0, 0.0);
  vst->AddBarrelLayer(ibcell, 2*12,  9, 2*23.4, 12.0, 0.0);
  vst->AddBarrelLayer(ibcell, 6*12, 14, 6*23.4, 14.0, 0.0);
  vst->AddBarrelLayer(ibcell, 4*20, 14, 4*39.3, 14.0, 0.0);
  vst->AddBarrelLayer(ibcell, 4*20*10/4, 14*10/4, 10*39.3, 14.0, 0.0);
  vst->AddBarrelLayer(ibcell, 4*20*11/4, 14*11/4, 11*39.3, 14.0, 0.0);
  vst->AttachSourceFile("vst.C");
  vst->AttachSourceFile("maps-lib.C");
  vst->AttachSourceFile("../../eic/detectors/maps/VstGeoParData.cxx");
  // Specify color preferences; NB: void* interface, sorry;
  SetMapsColors((EicGeoParData*)vst);
  //
  // Fine, at this point structure is completely defined -> code it in ROOT;
  //
  vst->ConstructGeometry();
  // Yes, always exit;
  exit(0);
}
```

A.2 Original fbst.C file from Yue Shi Lai

```
#define _VERSION_     1
#define _SUBVERSION_  0
//#define _TEST_VERSION_ // Do not want to always overwrite "official" files; place "test" tag into the file name;
// All construction elements are smeared (so chip assembly is uniform in both beam line and asimuthal direction);
#define _NO_STRUCTURE_GEOMETRY_
// No tricky elements like inclined roof beams; still water pipes, etc are created (so chip assembly is uniform in beam line direction only);
#define _BEAM_LINE_UNIFORM_GEOMETRY_
// FIXME: does not work; in case of FST/BST will have to fall back to tricky TGeoCompositeShape cell assemblies; also half of the cells should be
// Z-rotated to bring chips close to the beam pipe;
#define _USE_TRIANGULAR_ASSEMBLIES_
//#define _WITH_MOUNTING_RINGS_ // Comment out if no mounting rings wanted;
//#define _WITH_ENFORCEMENT_BRACKETS_ // Comment out if no stave enforcement brackets wanted;
//#define _WITH_EXTERNAL_PIPES_ // Comment out if no external water pipe pieces wanted;
#include <geometry/MAPS/maps-lib.C>
#define _DISK_NUM_  (5)
fbst()
{
  // Load basic libraries;
  gROOT->Macro("$VMCWORKDIR/gconfig/rootlogon.C");
  Double_t Z[_DISK_NUM_];
  Double_t R[_DISK_NUM_];
  for (size_t i = 0; i < _DISK_NUM_; i++) {
     Z[i] = 250 + i * (1210.0 - 250.0) / (_DISK_NUM_ - 1);
     R[i] = 45.0 * (i % 2);
  }
  for(unsigned fb=0; fb<2; fb++) {
    FstGeoParData *fbst = new FstGeoParData(fb ? "BST" : "FST", _VERSION_, _SUBVERSION_);
    // Parse #define statements and make certain configuration calls accordingly;
    // NB: cast to the base MAPS geo class since void* interface used; FIXME!;
    DefinitionParser((MapsGeoParData*)fbst);
    // Prefer to think in [mm] and convert to [cm] when calling ROOT shape definition routines only;
    // Mounting ring construction; arbitrary numbers, same for all layers;
    if (fbst->WithMountingRings()) {
      fbst->mMountingRingBeamLineThickness =    3.00;
      fbst->mMountingRingRadialThickness   =    5.00;
    } //if
    if (fbst->WithEnforcementBrackets()) // Simplify the design -> just a triangular piece with a reasonable volume;
      fbst->mEnforcementBracketThickness   =    1.00;
    // This is something for display purposes mostly;
    if (fbst->WithExternalPipes())
      fbst->mWaterPipeExtensionLength      =    4.00;
    //  For now assume ALICE Inner Barrel design, composed in stoves with varying number of Mimosa chips;
    MapsMimosaAssembly *ibcell = (MapsMimosaAssembly*)ConfigureAliceCell();
    // For now consider a single disc design (all the same); add stoves by hand;
    // Parameters: cell assembly pointer, min available radius, max available radius, default neigboring stave overlap in "X" direction;
    // Declare discs; just put them by hand at hardcoded locations along the beam line;
    for(unsigned dc=0; dc<_DISK_NUM_; dc++) {
      FstDisc *disc = new FstDisc(ibcell, 18.0, TMath::Min(432.3, 185.0 * Z[dc] / Z[0]), 12.8);
      fbst->AddDisc(disc, (fb ? -1.0 : 1.0)*Z[dc], R[dc]);
    }
#if 0
    if (!fb) {
      FstDisc *hdisc = new FstDisc(ibcell, 18.0, 400.0, 12.8);
      fbst->AddDisc(hdisc, 1500.);
    } //if
#endif
    fbst->AttachSourceFile("fbst.C");
    fbst->AttachSourceFile("maps-lib.C");
    fbst->AttachSourceFile("../../eic/detectors/maps/FstGeoParData.cxx");
#if 1
    TGeoPcon *support = new TGeoPcon("AluStrips_support", 0.0, 360.0, 3);
    support->DefineSection(0, (fb ? 1.0 : -1.0) * 20, 18.5 * 20.0 / 25.0, 18.5 * 20.0 / 25.0 + 0.5);
    support->DefineSection(1, (fb ? 1.0 : -1.0) * 43.23 * 0.1 * Z[0] / 18.5, 43.23, 43.23 + 0.5);
    support->DefineSection(2, (fb ? 1.0 : -1.0) * 121, 43.23, 43.23 + 0.5);
    TGeoVolume *support_volume = new TGeoVolume("AluStrips_support_volume", support, fbst->GetMedium("aluminum"));
    fbst->GetTopVolume()->AddNode(support_volume, 0, new TGeoCombiTrans(0.0, 0.0, 0.0, 0));
#endif
    // Specify color preferences; NB: void* interface, sorry;
    SetMapsColors((EicGeoParData*)fbst);
    // Geometry is defined -> build it in ROOT;
    fbst->ConstructGeometry();
  } //for fb
  exit(0);
}
```

A.3 Help menu from event display GUI



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DIRECT SCENE INTERACTIONS

   Press:
        w          --- wireframe mode
        e          --- switch between dark / light color-set
        r          --- filled polygons mode
        t          --- outline mode
        j          --- ZOOM in
        k          --- ZOOM out
        a          --- switch on/off arc-ball camera rotation control
        Arrow Keys --- PAN (TRUCK) across scene
        Home       --- reset current camera
        Ctrl-Home  --- switch external/automatic camera center

   LEFT mouse button -- ROTATE (ORBIT) the scene by holding the mouse button and moving
   the mouse (perspective camera, needs to be enabled in menu for orthograpic cameras).
   By default, the scene will be rotated about its center. To select arbitrary center
   bring up the viewer-editor (e.g., shift-click into empty background) and use
   'Camera center' controls in the 'Guides' tab.

   MIDDLE mouse button or arrow keys --  PAN (TRUCK) the camera.

   RIGHT mouse button action depends on camera type:
     orthographic -- zoom,
     perspective  -- move camera forwards / backwards

   By pressing Ctrl and Shift keys the mouse precision can be changed:
     Shift      -- 10 times less precise
     Ctrl       -- 10 times more precise
     Ctrl Shift -- 100 times more precise

   Mouse wheel action depends on camera type:
     orthographic -- zoom,
     perspective  -- change field-of-view (focal length)

   To invert direction of mouse and key actions from scene-centric
   to viewer-centric, set in your .rootrc file:
      OpenGL.EventHandler.ViewerCentricControls: 1

   Double clik will show GUI editor of the viewer (if assigned).

   RESET the camera via the button in viewer-editor or Home key.

   SELECT a shape with Shift+Left mouse button click.

   SELECT the viewer with Shift+Left mouse button click on a free space.

   MOVE a selected shape using Shift+Mid mouse drag.

   Invoke the CONTEXT menu with Shift+Right mouse click.

Secondary selection and direct render object interaction is initiated
   by Alt+Left mouse click (Mod1, actually). Only few classes support this option.
   When 'Alt' is taken by window manager, try Alt-Ctrl-Left.

CAMERA

   The "Camera" menu is used to select the different projections from
   the 3D world onto the 2D viewport. There are three perspective cameras:

        Perspective (Floor XOZ)
        Perspective (Floor YOZ)
        Perspective (Floor XOY)

   In each case the floor plane (defined by two axes) is kept level.

   There are also three orthographic cameras:

        Orthographic (XOY)
        Orthographic (XOZ)
        Orthographic (ZOY)

   In each case the first axis is placed horizontal, the second vertical e.g.
   XOY means X horizontal, Y vertical.


SHAPES COLOR AND MATERIAL

   The selected shape's color can be modified in the Shapes-Color tabs.
   Shape's color is specified by the percentage of red, green, blue light
   it reflects. A surface can reflect DIFFUSE, AMBIENT and SPECULAR light.
   A surface can also emit light. The EMISSIVE parameter allows to define it.
   The surface SHININESS can also be modified.

SHAPES GEOMETRY

   The selected shape's location and geometry can be modified in the Shapes-Geom
   tabs by entering desired values in respective number entry controls.

SCENE CLIPPING

   In the Scene-Clipping tabs select a 'Clip Type': None, Plane, Box

   For 'Plane' and 'Box' the lower pane shows the relevant parameters:

        Plane: Equation coefficients of form aX + bY + cZ + d = 0
        Box: Center X/Y/Z and Length X/Y/Z

For Box checking the 'Show / Edit' checkbox shows the clip box (in light blue)
   in viewer. It also attaches the current manipulator to the box - enabling
   direct editing in viewer.

MANIPULATORS

   A widget attached to the selected object - allowing direct manipulation
   of the object with respect to its local axes.

   There are three modes, toggled with keys while manipulator is active, that is,
   mouse pointer is above it (switches color to yellow):
        Mode            Widget Component Style          Key
        ----            ----------------------          ---
        Translation     Local axes with arrows          v
        Scale           Local axes with boxes           x
        Rotate          Local axes rings                c

   Each widget has three axis components - red (X), green (Y) and blue (Z).
   The component turns yellow, indicating an active state, when the mouse is moved
   over it. Left click and drag on the active component to adjust the objects
   translation, scale or rotation.
   Some objects do not support all manipulations (e.g. clipping planes cannot be
   scaled). If a manipulation is not permitted the component it drawn in grey and
   cannot be selected/dragged.
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Figure 6: Event-display GUI help menu.