Status of separating MAPS and DSSD detector description in the SpdRoot source code

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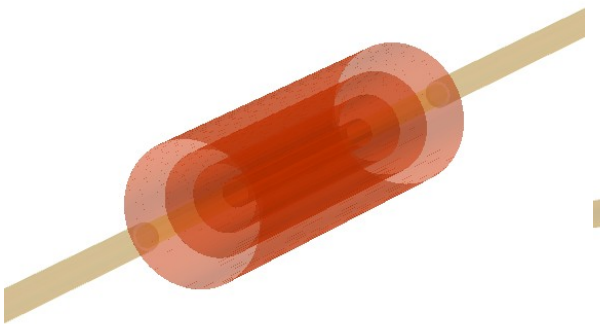
Silicon Vertex detector

- **Silicon vertex detector** (SVD) is responsible for precise determination of the primary interaction point and measurement of the secondary vertices from the decays of short-lived particles.
- SVD is planned to be installed in the second stage of SPD operation.
- It is assumed that it will be based on one of two technologies: MAPS (main) and DSSD (backup).
- Main requirements:
  - Geometry close to 4π;
  - Reconstruction efficiency for muons > 99%
    p_μ < 13 GeV
    η < |2.5|
  - Low material budget;
  - Coordinate resolution $\sigma_{r,\varphi}$ < 50 μm, σ_z < 100 μm;

Previous SVD study reports:

https://indico.jinr.ru/event/4317/#1-prospects-of-d0-tssa-measure
https://indico.jinr.ru/event/4256/#6-vertex-detector-discussion
By Amaresh Datta

MAPS option (main)



DSSD option

SVD in SpdRoot source code (master)

Geometry building:

- <SpdRoot dir>/spdgeometry/its/SpdItsGeoBuilder.cxx/h
- <SpdRoot dir>/spdgeometry/its/SpdItsGeoMapperX.cxx/h
- <SpdRoot dir>/spdgeometry/its/SpdItsVolPars.cxx/h

Subproject for Its detector object:

<SpdRoot dir>/its/

Algorithm for Its hits production:

<SpdRoot dir>/reco/vnt/SpdItsMCHitProducer.cxx/h

Currently, the same classes are used to describe both versions of SVD

+ Code flexibility

- Complicates the code
- Changing the description of one of SVD options may affect the other → complication of further development

The selection of a specific version of the internal detector is made using GeoType flags:

SpdItsGeoMapperX::Instance()->SetGeometryPars(gtype1, gtype2);

layers+ladders parameters
(Ap1) 1 - MAPS 2,3 (default) - DSSD

chip parameters
(Ap1) 1 - MAPS 2,3 (default) - DSSD

For MAPS option one should use:

SpdItsGeoMapperX::Instance()->EnableEndcaps(0);

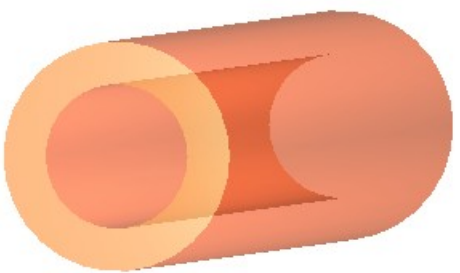
SpdIts: building geometry (1)

Hierarchy of SVD Geometry:

- level1 – layers made of air
- level2 – ladders (staves) made of silicon
- level3 – chips made of silicon

Layer

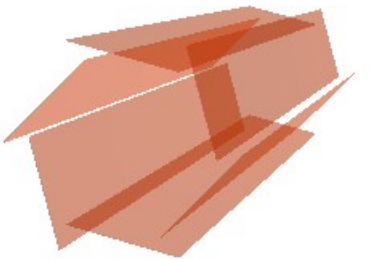
TGeoTube(R_{min}, R_{max}, L_z)



gGeoManager->SetVisLevel(1)

Ladder

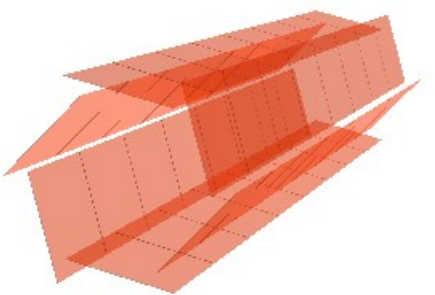
TGeoBox(L_x, L_y, L_z)



gGeoManager->SetVisLevel(2)

Chip

TGeoBox(L_x, L_y, L_z)



gGeoManager->SetVisLevel(3)

SpdIts: building geometry (2)

Creating nodes (positioned volumes) GeoBuilder:

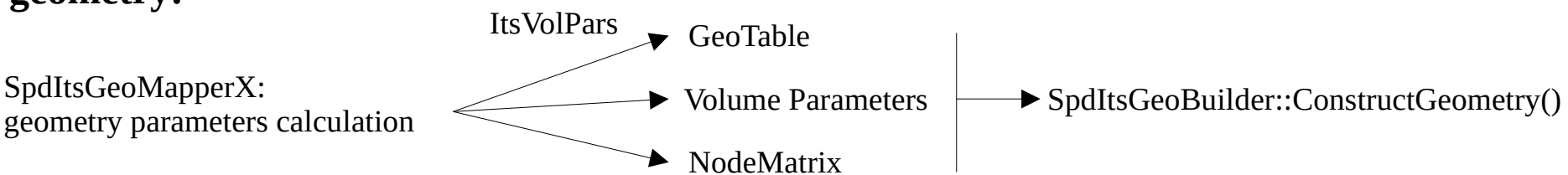
<mother volume>->AddNode(<daughter volume>, ncopy, matrix of geometrical transformation)

TGeoVolume:
- Media (GeoMapper)
- Shape (GeoBuilder)
- Shape parameters (GeoBuilder)

Number of copy of daughter volume

Calculation in ItsVolPars

Building geometry:



Status of MAPS and DSSD separation (1)

branch:
https://git.jinr.ru/avasyukov/spdroot/-/tree/VD_MAPS_DSSD

Geometry building:

- SpdItsGeoBuilder → SpdMapsGeoBuilder + SpdDssdGeoBuilder
- SpdItsGeoMapperX → SpdMapsGeoMapper + SpdDssdGeoMapper

Subprojects for SVD detector objects:

<SpdRoot dir>/its/ → <SpdRoot dir>/maps/ + <SpdRoot dir>/dssd/

Algorithm for Its hits production:

SpdItsMCHitProducer → SpdMapsMCHitProducer + SpdDssdMCHitProducer

- Starting point: Using new classes is identical to using the original ones
- No End-Caps

Status of MAPS and DSSD separation (2)

MAPS

```
SpdIts *its = new SpdIts();
SpdItsGeoMapperX::Instance()->SetGeometryPars(1, 1);
SpdItsGeoMapperX::Instance()→EnableEndcaps(0);
```

```
SpdMaps *its = new SpdMaps();
SpdMapsGeoMapper::Instance()->SetGeometryPars(1);
SpdMapsGeoMapper::Instance()->EnableEndcaps(0);
```

Volume parameters before and after separation see in Ap2

They are identical

DSSD

```
SpdIts *its = new SpdIts();
SpdItsGeoMapperX::Instance()->SetGeometryPars(3, 2);
SpdItsGeoMapperX::Instance()→EnableEndcaps(0);
```

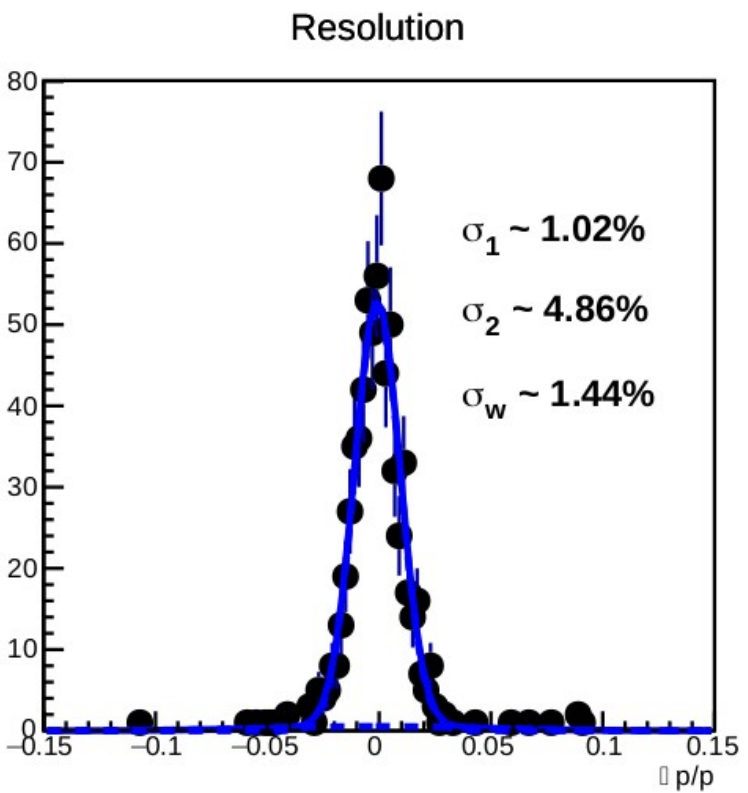
```
SpdDssd *its = new SpdDssd();
SpdDssdGeoMapper::Instance()->SetGeometryPars(1);
SpdDssdGeoMapper::Instance()->EnableEndcaps(0);
```

Volume parameters before and after separation see in Ap3

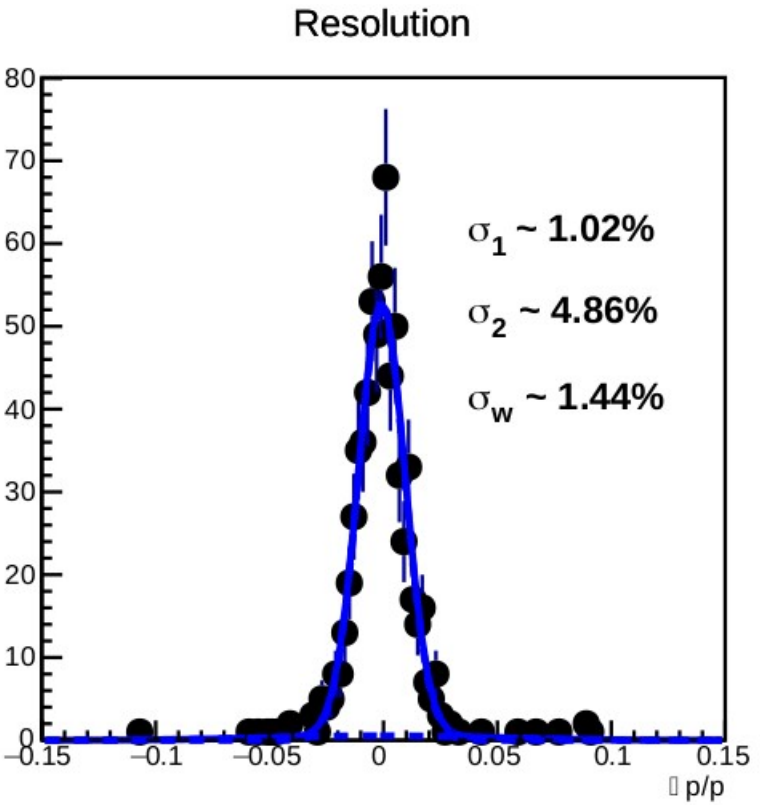
They are identical

Performance tests DSSD

<SpdRoot dir>/macro/performance-tests/track-fitting/dssd-straw
. run.sh

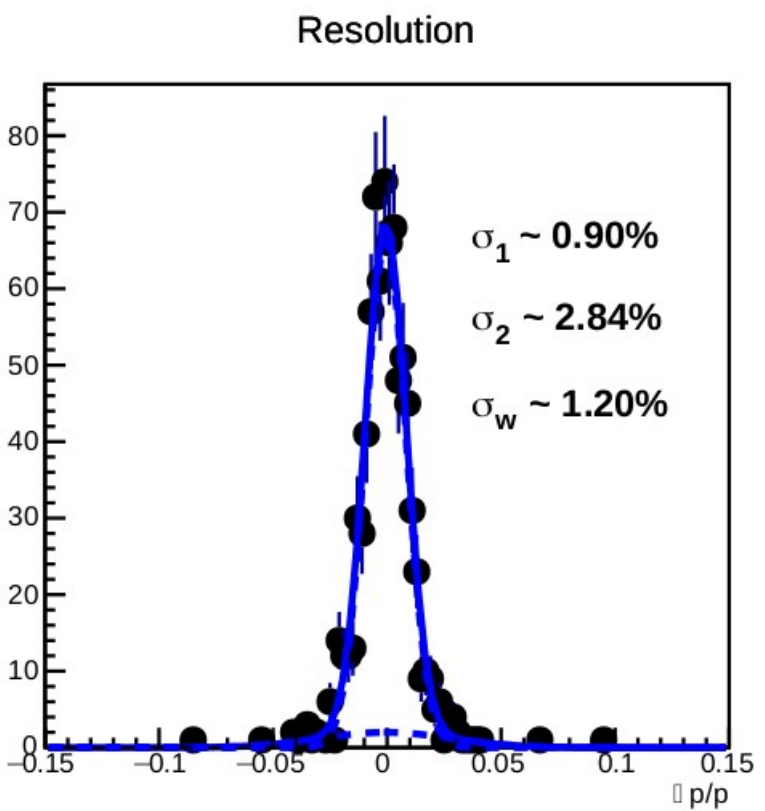


<SpdRoot dir>/macro/performance-tests/track-fitting/dssd-straw_noIts
. run.sh

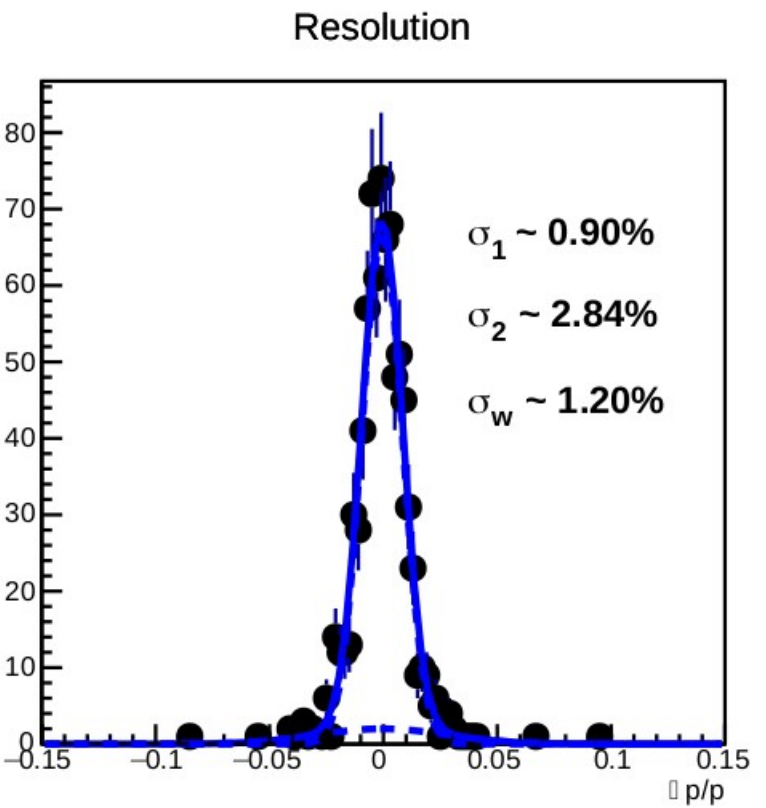


Performance tests MAPS

<SpdRoot dir>/macro/performance-tests/track-fitting/maps-straw
. run.sh



<SpdRoot dir>/macro/performance-tests/track-fitting/maps-straw_noIts
. run.sh

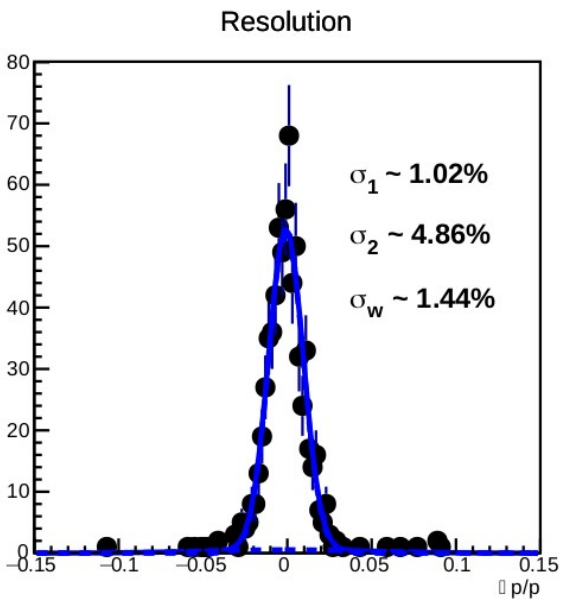


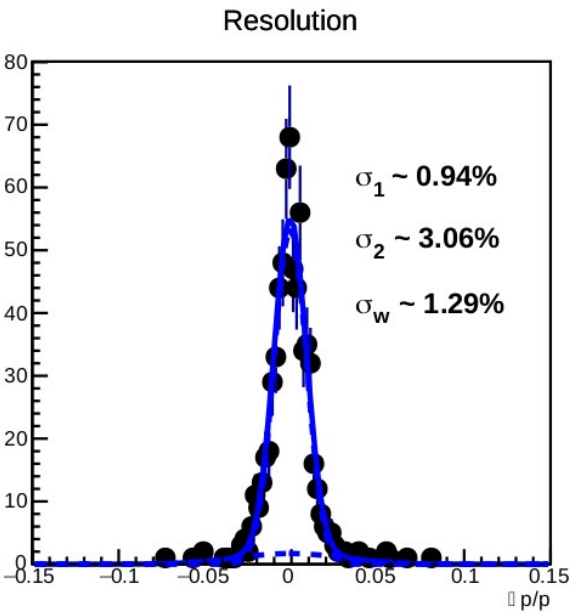
Unpredictable behaviour

The results of track fitting tests depend on R_{min} of layers (media is air).
Transformation matrix from coordinates in the ladder RF to coordinates in the layer RF does not depend on R_{min} (Ap4).

Example:

Rmin of 1st layer is changed: 4.1476 → 4.1





This effect **does not depend** on the choice of the method of describing the SVD (SpdIts or SpdDssd)

Further plans

- Find the reason for the dependence of tracking results on the size of layers
- Adding End-Caps for MAPS and DSSD
- Writing a wiki page
- Code optimization
- Push the changes to the upstream SpdRoot repository

Thank you for your attention!

Appendix

Ap1 SVD parameters

These parameters must be set for each layer:

Layers/ladders parameters:

1. the distance from z axis to ladder center (LAYER radius)
2. ladder size along z axis
3. ladder size along phi axis
4. radial size of ladder
5. local rotation angle for ladder
6. global rotation angle for LAYER
7. number of ladders inside the LAYER

Chip paremeters:

1. chip size along z-axis
2. chip phi-size
3. gap size between chips along z-axis
4. gap size between chips along phi-axis
5. number of chip cells (channels) along z-axis
6. number of chip cells (channels) along phi-axis
7. chip type (0: NO INNER STRUCTURE, 1: MAPS, 2: DSSD, >2: USER DEFINED)

Ap2 Testing separation results (Geometry) MAPS

SpdItsGeoMapperX::Instance()->SetGeometryPars(1, 1);
SpdItsGeoMapperX::Instance()->EnableEndcaps(0);

```
<SpdItsGeoMapperX::PrintVolPars> List of unique volumes (9)
-------------------------------------------------------------------------------------------------------------------------------------------------------
  I   A    NC    NN         Lz    Rmin/Lphi    Rmax/Lr      R/nphi  angle/nz  Class               Name                Media                NN      NV
-------------------------------------------------------------------------------------------------------------------------------------------------------
  0   0     1    17   [  76.2000    4.0121    4.1141] (   4.0286    0.0000) SpdItsLayer         ItsLayer1           air                  17       1
  1   0     1    41   [  88.9000    9.7689    9.8305] (   9.7854    0.0000) SpdItsLayer         ItsLayer2           air                  41       1
  2   0     1    64   [ 101.6000   15.2666   15.3180] (  15.2831    0.0000) SpdItsLayer         ItsLayer3           air                  64       1
  3   0     1    88   [ 127.0000   20.9995   21.0459] (  21.0160    0.0000) SpdItsLayer         ItsLayer4           air                  88       1
  4   0    17    50   [  76.2000    1.5000    0.0330] (         1        50) SpdItsLadder         ItsLadder1          silicon              50       1
  5   0    41    59   [  88.9000    1.5000    0.0330] (         1        59) SpdItsLadder         ItsLadder2          silicon              59       1
  6   0    64    67   [ 101.6000    1.5000    0.0330] (         1        67) SpdItsLadder         ItsLadder3          silicon              67       1
  7   0    88    84   [ 127.0000    1.5000    0.0330] (         1        84) SpdItsLadder         ItsLadder4          silicon              84       1
  8   1   260     0   [   1.4336    1.4336    0.0330] (  MAPS_512x512     ) SpdItsChip           ItsChip1            silicon               0       0
-------------------------------------------------------------------------------------------------------------------------------------------------------
```

SpdMapsGeoMapper::Instance()->SetGeometryPars(1);

```
<SpdMapsGeoMapper::PrintVolPars> List of unique volumes (9)
-------------------------------------------------------------------------------------------------------------------------------------------------------
  0   0     1    17   [  76.2000    4.0121    4.1141] (   4.0286    0.0000) SpdItsLayer         MapsLayer1          air                  17       1
  1   0     1    41   [  88.9000    9.7689    9.8305] (   9.7854    0.0000) SpdItsLayer         MapsLayer2          air                  41       1
  2   0     1    64   [ 101.6000   15.2666   15.3180] (  15.2831    0.0000) SpdItsLayer         MapsLayer3          air                  64       1
  3   0     1    88   [ 127.0000   20.9995   21.0459] (  21.0160    0.0000) SpdItsLayer         MapsLayer4          air                  88       1
  4   0    17    50   [  76.2000    1.5000    0.0330] (         1        50) SpdItsLadder         MapsLadder1         silicon              50       1
  5   0    41    59   [  88.9000    1.5000    0.0330] (         1        59) SpdItsLadder         MapsLadder2         silicon              59       1
  6   0    64    67   [ 101.6000    1.5000    0.0330] (         1        67) SpdItsLadder         MapsLadder3         silicon              67       1
  7   0    88    84   [ 127.0000    1.5000    0.0330] (         1        84) SpdItsLadder         MapsLadder4         silicon              84       1
  8   1   260     0   [   1.4336    1.4336    0.0330] (  MAPS_512x512     ) SpdItsChip           MapsChip1           silicon               0       0
-------------------------------------------------------------------------------------------------------------------------------------------------------
```

Ap3 Testing separation results (Geometry) DSSD

SpdItsGeoMapperX::Instance()->SetGeometryPars(3, 2);
SpdItsGeoMapperX::Instance()->EnableEndcaps(0);

```
<SpdItsGeoMapperX::PrintVolPars> List of unique volumes (5)
-------------------------------------------------------------------------------------------------------------------------------------------------------
  I   A    NC    NN         Lz    Rmin/Lphi    Rmax/Lr      R/nphi   angle/nz  Class              Name               Media              NN     NV
-------------------------------------------------------------------------------------------------------------------------------------------------------
  0   0     1     6   [  73.8000     4.1476     6.6155] (    5.0000    15.0000) SpdItsLayer        ItsLayer1          air                 6      1
  1   0     1    14   [  73.8000    12.1476    14.1916] (   13.0000    15.0000) SpdItsLayer        ItsLayer2          air                14      1
  2   0     1    23   [  73.8000    20.1476    22.0690] (   21.0000    15.0000) SpdItsLayer        ItsLayer3          air                23      1
  3   0    43     8   [  73.8000     6.4000     0.0500] (         1           8) SpdItsLadder       ItsLadder1         silicon             8      1
  4   1     8     0   [   9.2000     6.3000     0.0500] (  DSSD_320x640       ) SpdItsChip         ItsChip1           silicon             0      0
-------------------------------------------------------------------------------------------------------------------------------------------------------
```

SpdDssdGeoMapper::Instance()->SetGeometryPars(1);

```
<SpdDssdGeoMapper::PrintVolPars> List of unique volumes (5)
-------------------------------------------------------------------------------------------------------------------------------------------------------
  0   0     1     6   [  73.8000     4.1476     6.6155] (    5.0000    15.0000) SpdItsLayer        DssdLayer1         air                 6      1
  1   0     1    14   [  73.8000    12.1476    14.1916] (   13.0000    15.0000) SpdItsLayer        DssdLayer2         air                14      1
  2   0     1    23   [  73.8000    20.1476    22.0690] (   21.0000    15.0000) SpdItsLayer        DssdLayer3         air                23      1
  3   0    43     8   [  73.8000     6.4000     0.0500] (         1           8) SpdItsLadder       DssdLadder1        silicon             8      1
  4   1     8     0   [   9.2000     6.3000     0.0500] (  DSSD_320x640       ) SpdItsChip         DssdChip1          silicon             0      0
-------------------------------------------------------------------------------------------------------------------------------------------------------
```

Ap4 Ladder RF→Layer RF transformation matrix

SpdItsVolPars.cxx :

```
TGeoMatrix* SpdItsLayer::MakeNodeMatrix(Int_t nnode) const
{
  if (nnode < 0 || nnode >= fPackingNLadders && fNodesPars.empty()) return 0;

  const std::vector<Double_t>& pars = fNodesPars[0];

  if (pars.empty()) return 0;

  TGeoTranslation trans(0,fPackingLadderRadius,0);

  TGeoRotation rot;
  rot.RotateZ(fPackingLadderAngle);

  TGeoCombiTrans* m = new TGeoCombiTrans(trans,rot);
  m->RotateZ(nnode*360./fPackingNLadders);

  cout << "make_node_matrix_layer\tfPackingLadderRadius\t" << fPackingLadderRadius << endl;

  return m;
}
```