Status of vertex detector simulation

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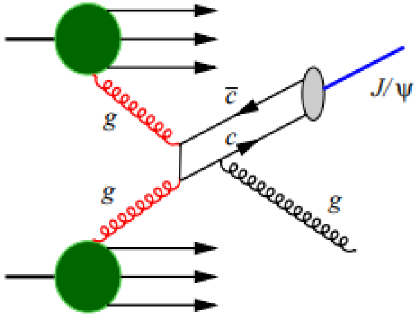
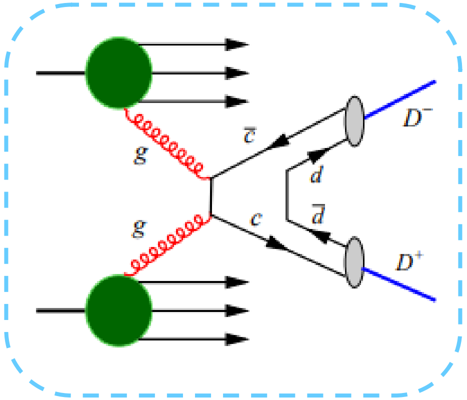
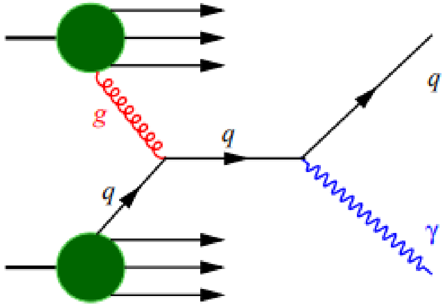
Introduction

- **Vertex detector** is responsible for precise determination of the primary interaction point and measurement of the secondary vertices from the decays of short-lived particles.







- On 1st stage Micromegas-based Central tracker will be installed;
- On 2d stage SVD (DSSD or MAPS) is planned to be installed;
- D^0 decay length 123 μm => secondary vertex resolution ~50-80μm is required;
- Only ST shows unsatisfactory performance in the recoconstruction of position of secondary vertex (see Ap. 1);
- Reconstructions of tracks from high pseudorapidity region is important for D-meson TSSA measurements;

Overview of VD options

Stage 1 of SPD operation

- MicroMegas-based central tracker: 1 barrel (super)layer;
  - With electronic modules (types#1,#2);
  - Without electronic modules;

Stage 2 of SPD operation

- DSSD TDR config: 3 barrel layers (~0.53% X_0 per layer) + 3 EC layers;
- MAPS-based detector with following configs:
  - **#1** 4 layers in barrel only (~0.8%X_0 per layer), z-length 150 cm **gtype = 3**; (TDR config)
  - **#2** 2+2 layers in barrel only **gtype = 2**:
    - (~0.35%X_0 per layer), z-length 74 cm;
    - (~0.8%X_0 per layer), z-length 150 cm;
  - **#3** 4 layers in barrel (~0.35%X_0 per layer), z-length 74 cm + 4 EC layers (~0.3%X_0 per layer) **gtype = 1**; (DSSD-like config)

VD option | Micromegas-based Central Tracker

- The idea of the Micromegas-based Central Tracker (MCT) is to improve the momentum resolution and tracking efficiency of the main tracking system during the first period of data taking (see Ap. 4);
- 1 super layer;
- Barrel layer length: 90 cm (TDR) vs 80 cm (D. Dedovich talk);
- FEE modules were simulated;
- FEE location: 15 cm from MCT active area;

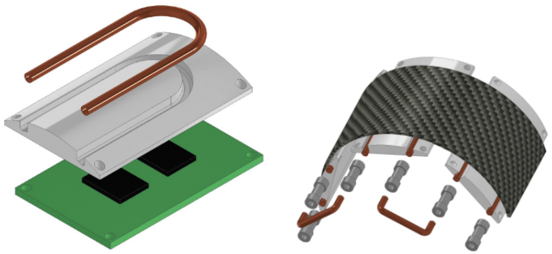
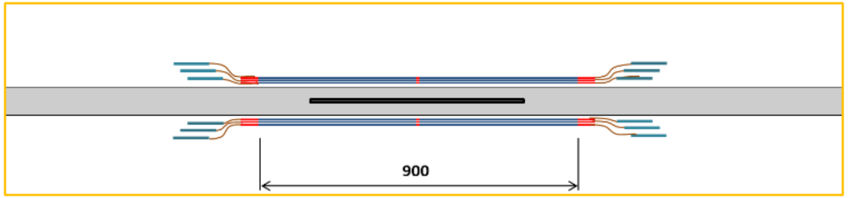
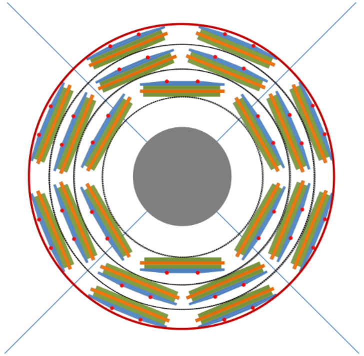
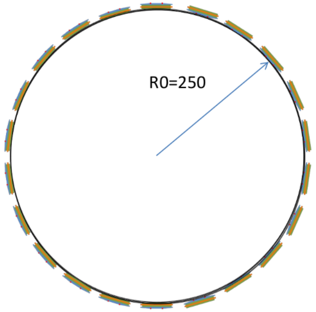


Figure 12.12: (a) Exploded-view diagram of a single cooling plate with the FE board. (b) Schematic view of the carbon fiber support structure with cooling plates fixed to it.

TDR

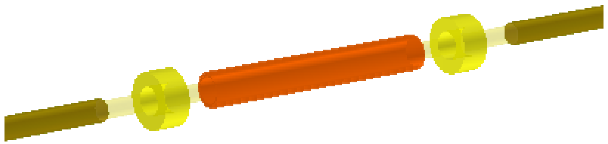




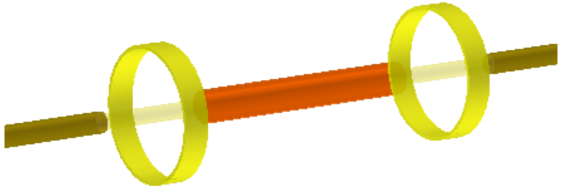


MCT + no Electronics

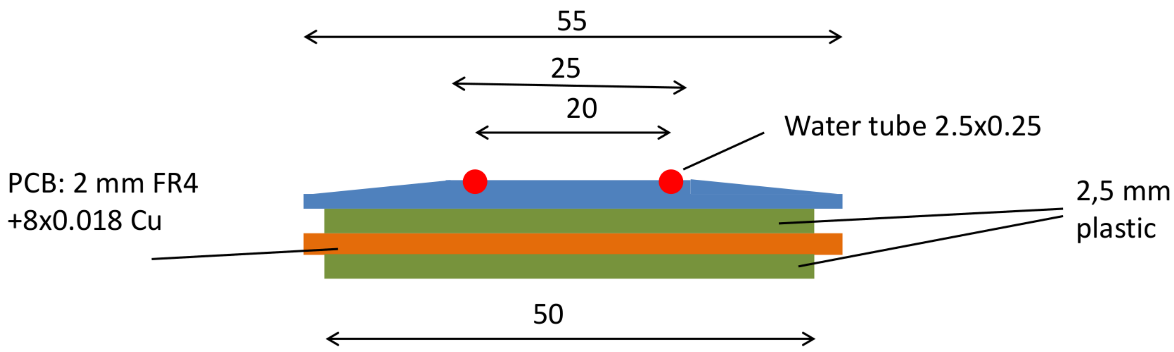
MCT + Electronics#1

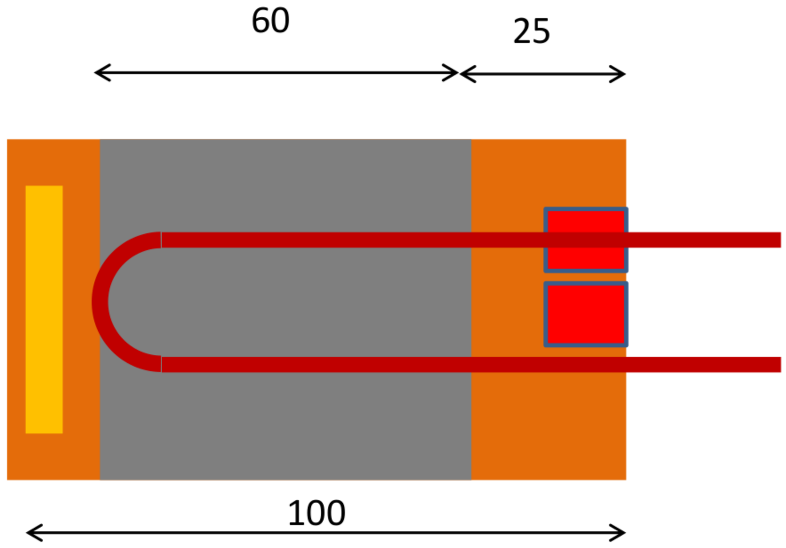


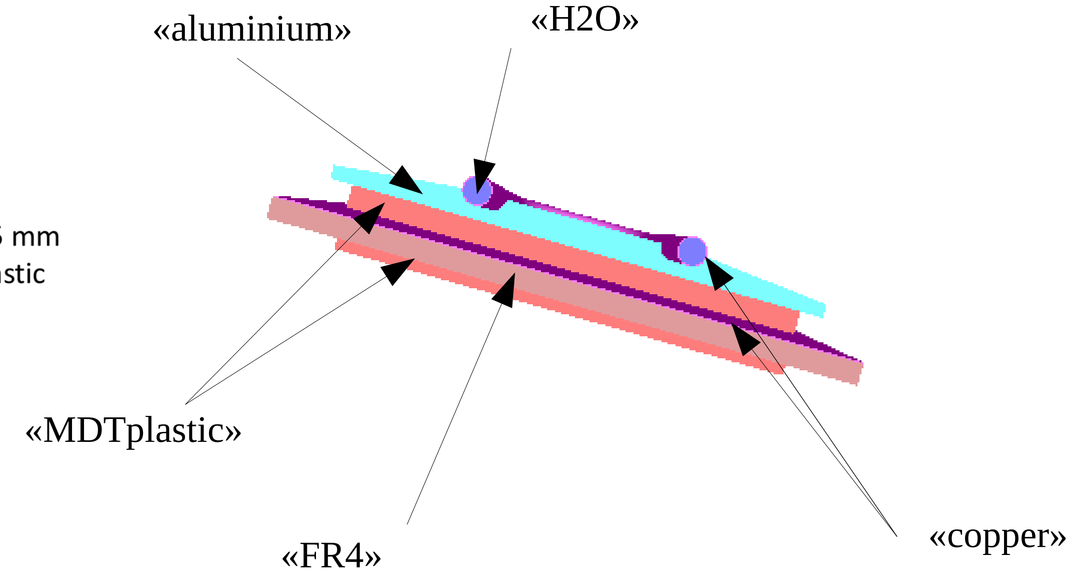
MCT + Electronics#2



VD option | Micromegas-based Central Tracker | FEE







Material budget per 1 module: ~ 2.57-6.86%X_0

Main sources:
- Copper;
- Aluminium;

Performance tests description | momentum resolution

Muon momentum resolution

- Isotopic production of 1.5 GeV muons at (0, 0, 0) point (no PV smearing);
- For MCT FEE performance tests the phase space is limited by the range of angles at which the tracks enter the electronics (see slides 7-8);
- SpdMCTrackFinder default settings:
    - Minimum number of ITS hits = 1, exception: ST only config (min ITS hits = 0) Ap. 4;
    - Minimum number of TS hits = 0;

Detector setup:

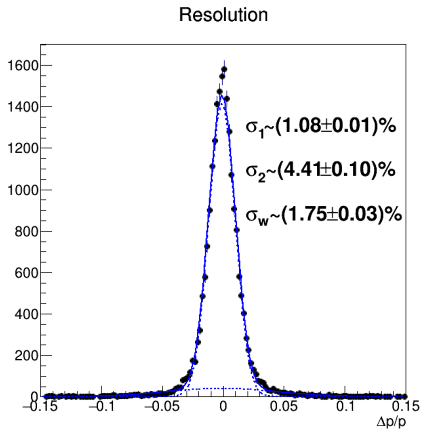
- Aluminium pipe — for stage1 VD;
- Berrylium pipe — for stage2 VD;
- Magnetic field;
- Vertex detector + Straw tracker;

- Each $\Delta(p_{reco} - p_{gen})/p_{gen}$ distribution is fitted with two gaussians;
- σ is weighted average of two gaussians;

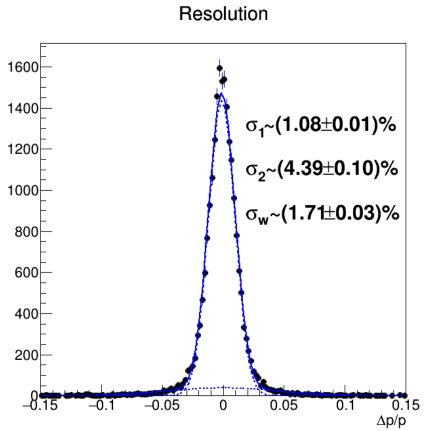
VD performance | MCT with electrics#1

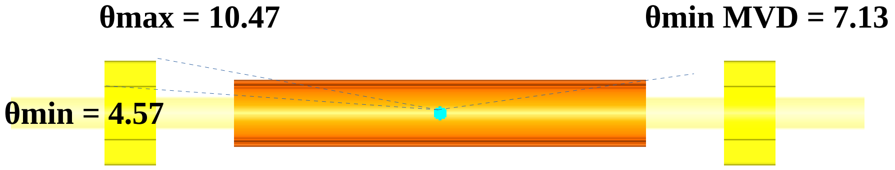
MCT customize geometry: CustomMvd(3);
Barrel length: 80 cm.

Without FE Modules



With FE Modules



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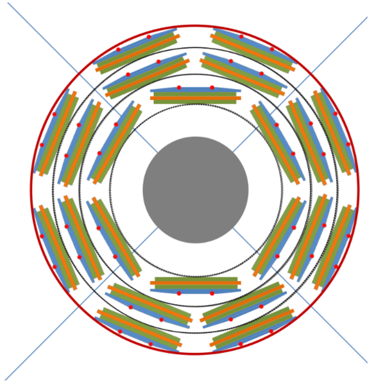
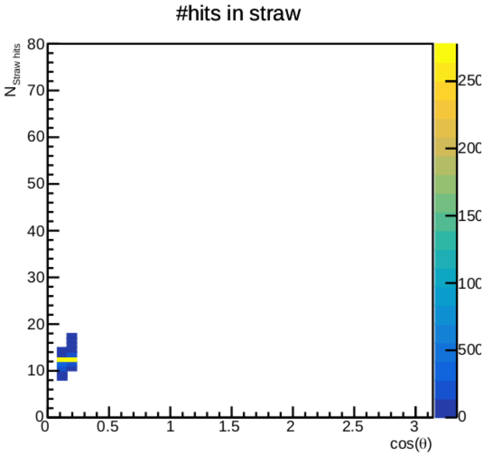
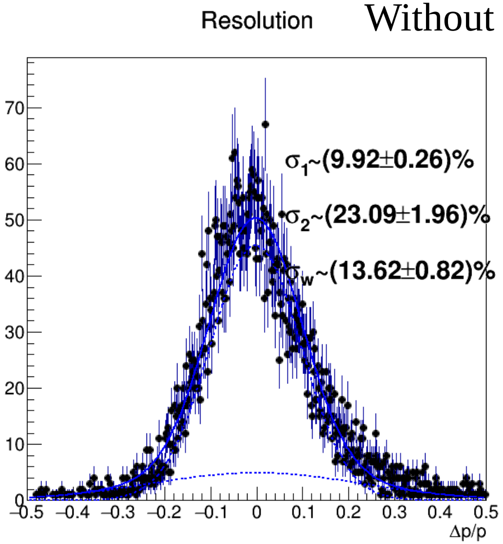
primGen->SetBeam(0., 0., 0., 0.);
primGen->SetTarget(0., 0.);
```

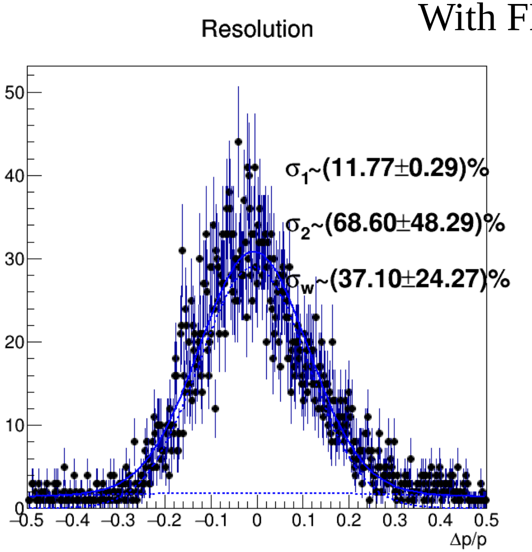




Without FE



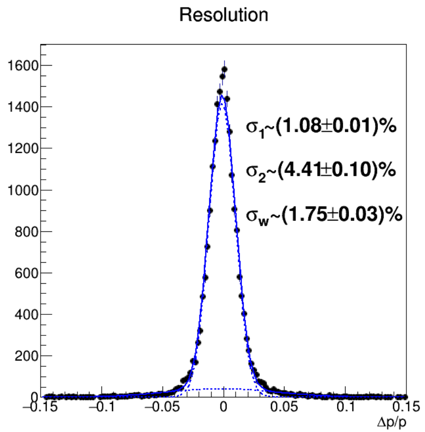
With FE



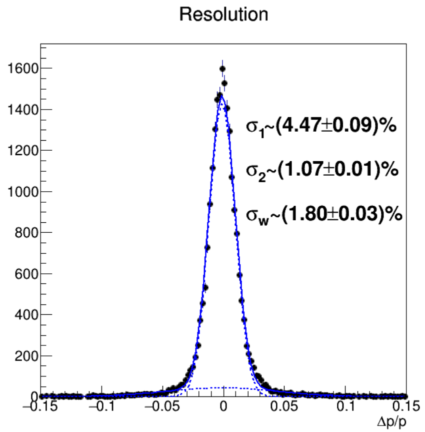
VD performance | MCT with electrics#2

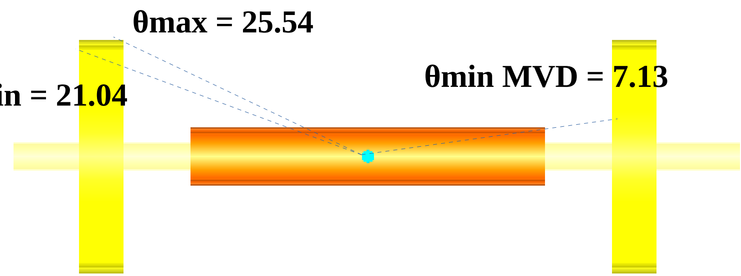
MCT customize geometry: CustomMvd(3);
Barrel length: 80 cm.

Without FE Modules



With FE Modules





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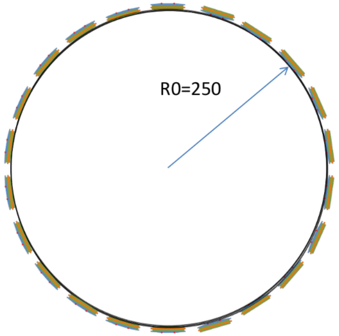
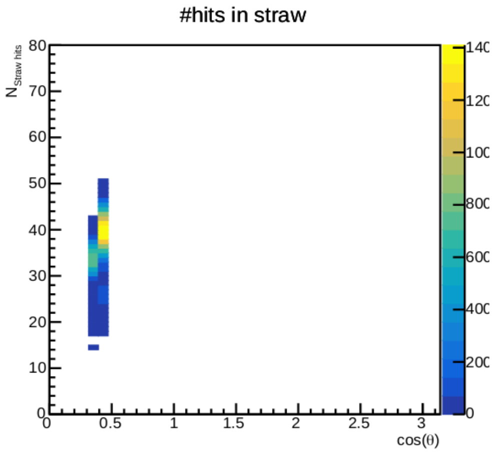
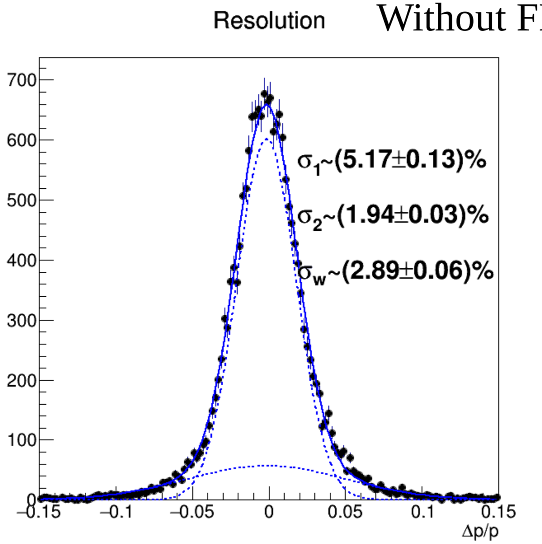
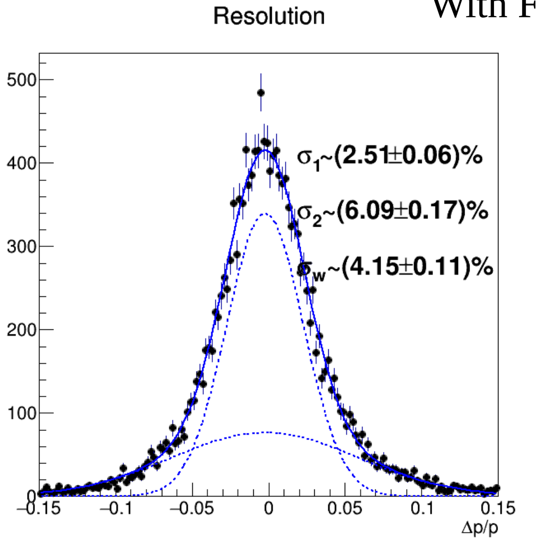




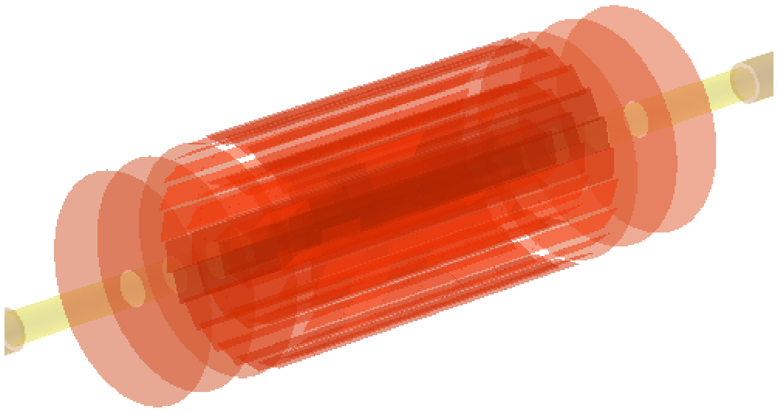
Without FE



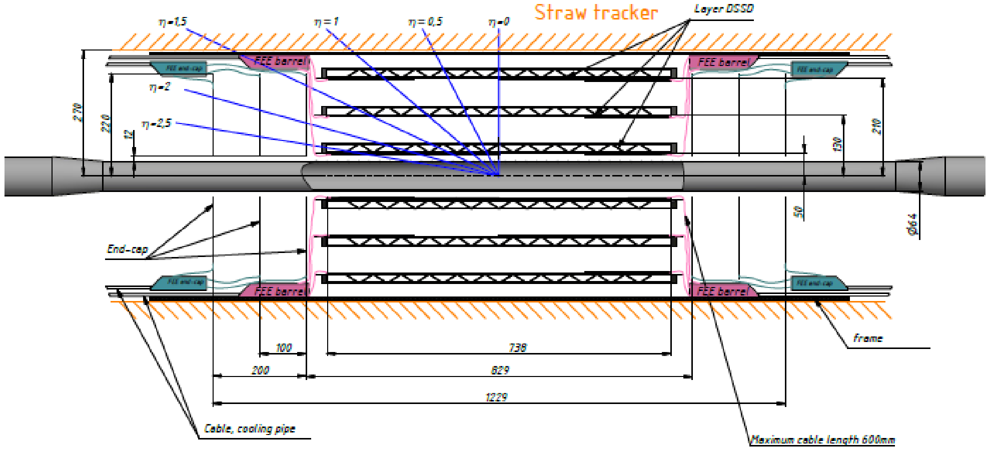
With FE



VD option | DSSD-based SVD

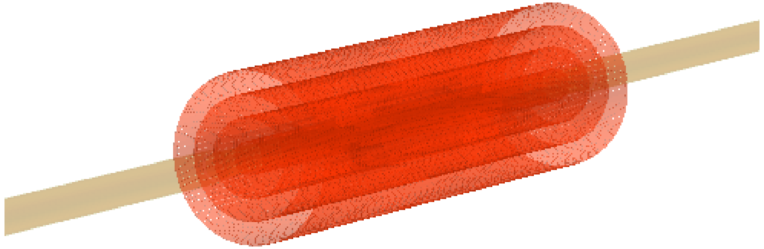


TDR

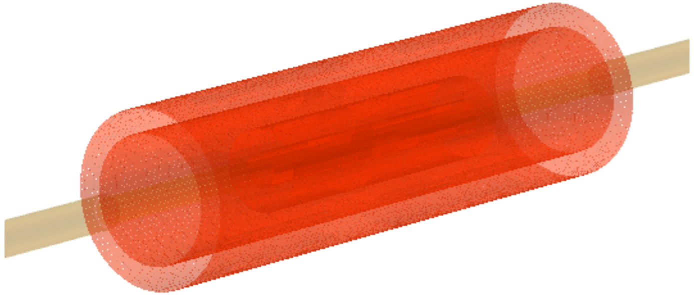


- 3 barrel layers;
- Barrel layer length: 74 cm;
- Barrel layer thickness: 500 µm (0.53% X_0);
- 3 End-Cap disks: width — 300µm, Rmin: 3.5 mm, Rmax: 22 cm;
- Positions of DSSD end-caps:
  - ± 41.45 cm; (TDR)
  - ± 51.45 cm; (TDR)
  - ± 61.45 cm; (TDR)

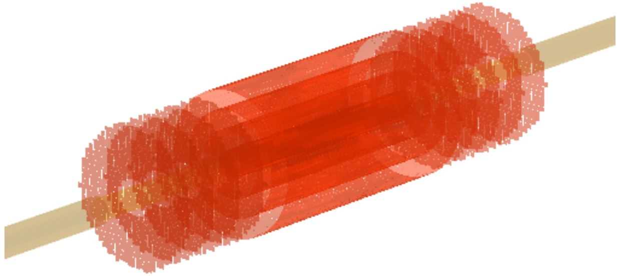
VD option | MAPS-based SVD



- 4 barrel layers;
- Barrel layer length: 150 cm;
- Barrel layer thickness: 750 μm (0.80% X_0);
- No End-Cap disks;



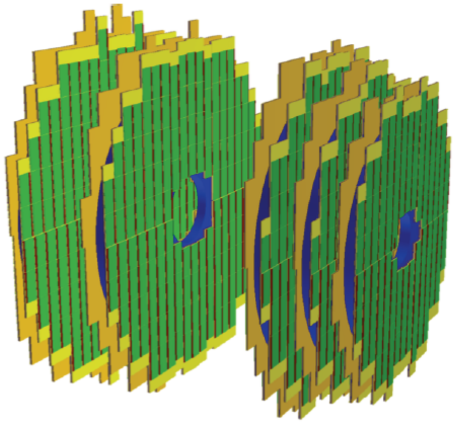
- 4 barrel layers;
- #1, #2 barrel layers length: 74 cm;
- #3, #4 barrel layers length: 150 cm;
- #1, #2 barrel layers thickness: 330 μm (0.35% X_0);
- #3, #4 barrel layers thickness: 750 μm (0.80% X_0);
- No End-Caps;

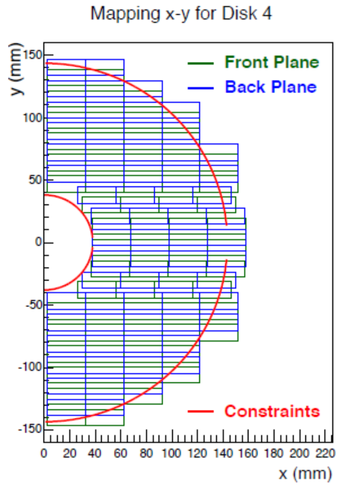


- 4 barrel layers;
- Barrel layers length: 74 cm;
- Barrel layers thickness: 330 μm (0.35% X_0);
- 4 End-Cap disks:
- $|Z_{pos}|$ = 45, 55, 65, 75 cm;
- EC disks thickness: 290 μm (0.3% X_0)

VD option | MAPS-based SVD | End-caps

Role model: Muon Forward Tracker (ALICE experiment)
TDR: https://cds.cern.ch/record/1981898
Detector web page:
https://alice-collaboration.web.cern.ch/menu_proj_items/MFT





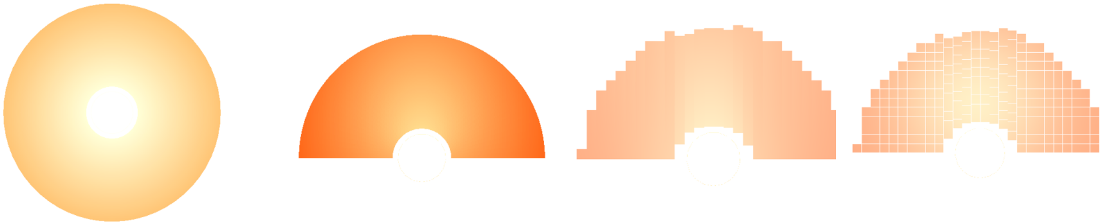
- It is based on Alpide chip architecture;
- Five disks, each one has 2 detection planes;
- The overlap between sensors of the back and front plane ensures the hermeticity of the half-disk;
- Material budget: 0.6% X_0 per disk

SpdRoot source code:

- EC Ladder thickness: 290 μm (0.3%X_0)
- EC Layer material budget: 290 + 290 μm of silicon

0.6%X_0 MFT Alice TDR;

- Distance between sensitive planes: 20 mm**;**
- Rmin: 5cm;
- Rmax: 21 cm (as for Barrel);



Level 1	Level 2	Level 3	Level 4
MapsECLayer	MapsECHalfCone	MapsECLadder	MapsECChip
air	air	silicon	silicon
TGeoTube	TGeoTubs	TGeoBox	TGeoBox
kFALSE	kFALSE	kFALSE	kTRUE

- To reduce material budget EC Layer for MAPS#3 config contains 2 half cones instead of 4;

Performance tests description | SV reconstruction

- Pythia 8 + SpdRoot (SpdD0Generator)
- Open-charm process, $D^0 \rightarrow \pi^+ K^-$ forced;
- Event vertex Z: Gaussian profile with σ_Z = 30 cm;
- Event vertex X, Y: Gaussian profile with $\sigma_{X,Y}$ = 0.1 cm;
- KFParticle to reconstruct secondary vertex (D^0);
- SpdMCTrackFinder settings:
  - Minimum number of ITS hits = 2 (SVD), 1 (MVD);
  - Minimum number of TS hits = 6;
- Resolution obtained from the distribution of (Reco — MC True) secondary vertex positions;
- Only ST config shows unsatisfactory performance in the recoconstruction of position of secondary vertex (see Ap. 1);

SpdD0Generator was developed by Amaresh Datta:

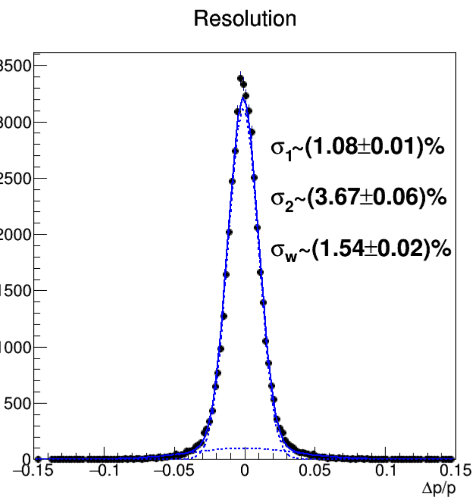
- D^0 partical gun with proper P_T distribution for pp collisions $\sqrt{s}$ = 27 GeV;
- The PDF is presented as a two-dimensional histogram (p — θ);
- Hit-and-miss method is used;

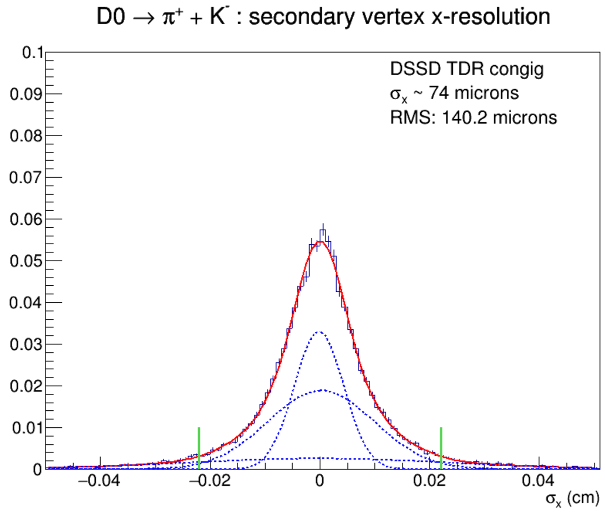
Detector setup:

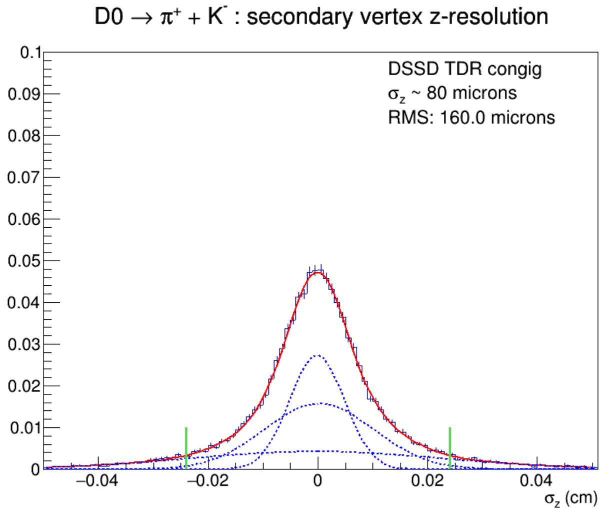
- Aluminium pipe — for stage1 VD;
- Berrylium pipe — for stage2 VD;
- Magnetic field;
- Vertex detector + Straw tracker;

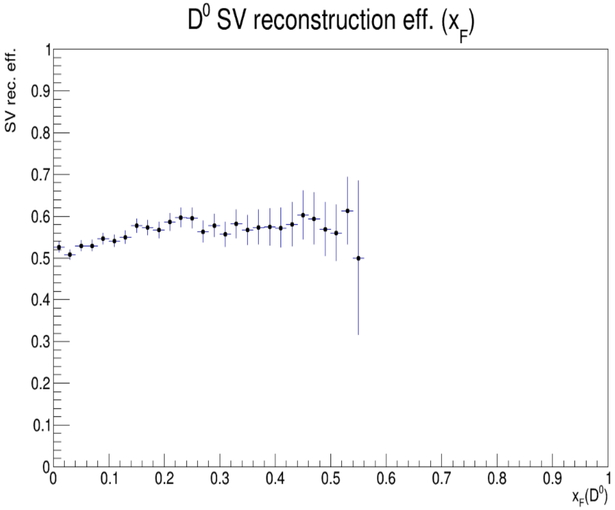
- Each normalized distribution is fitted with three gaussians;
- σ is weighted average of two narrow ones within ~3σ range;
- Range shown with **green** lines;
- Third one ignored as it`s almost flat in most cases;
- As an additional characteristic of the distribution, RMS is also presented;

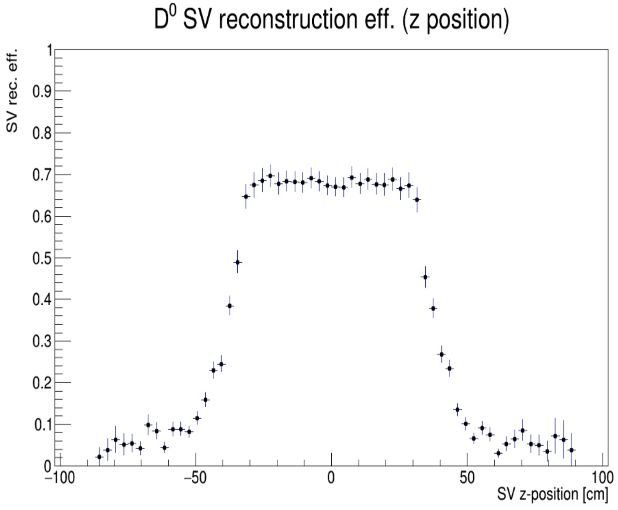
D^0 vertex resolution | DSSD configuration TDR

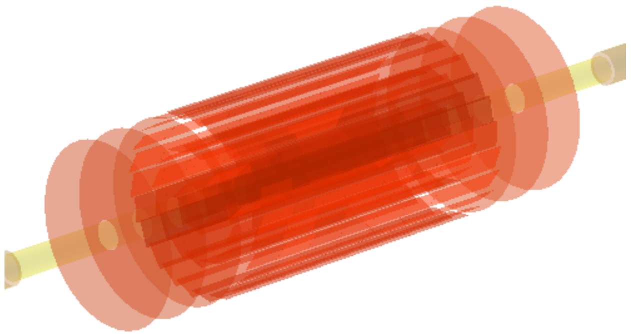




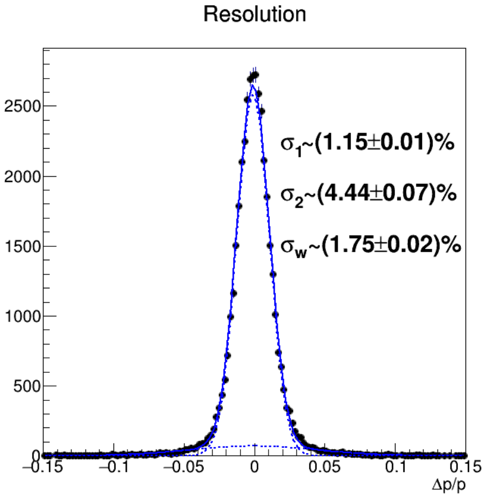


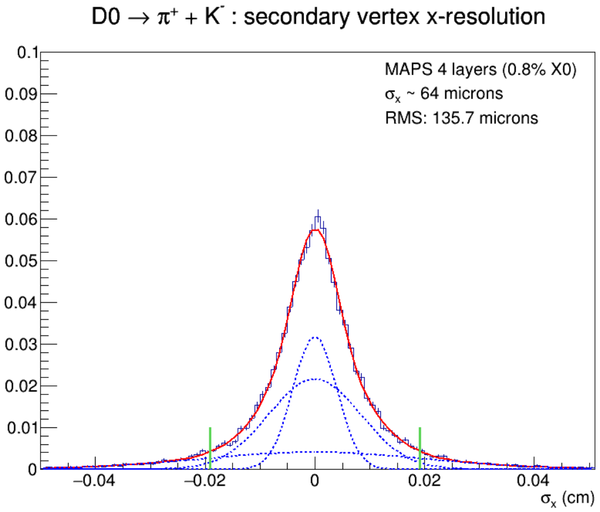


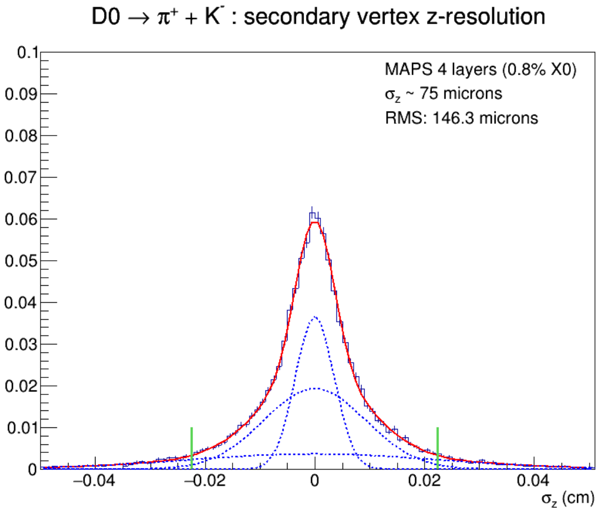


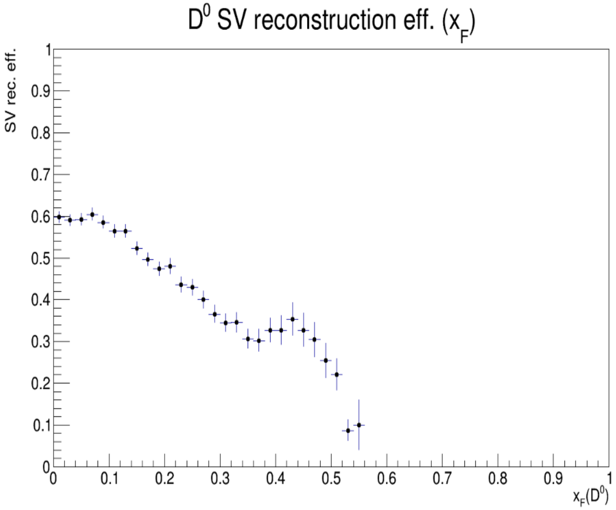


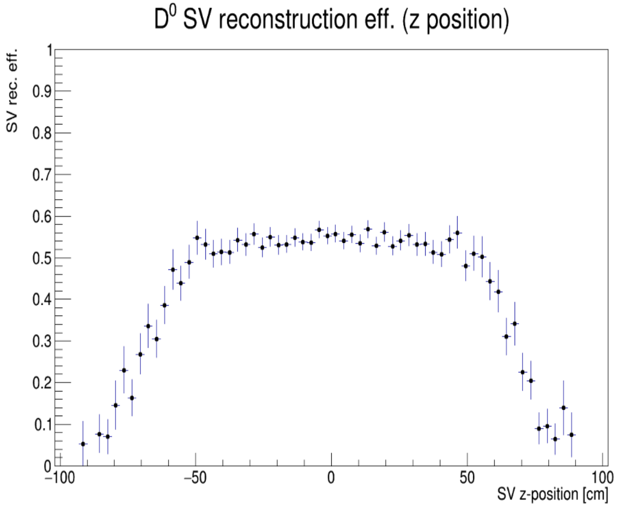
D^0 vertex resolution | MAPS configuration #1

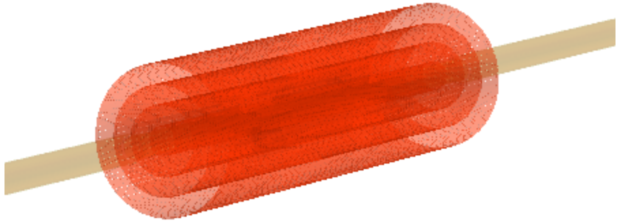




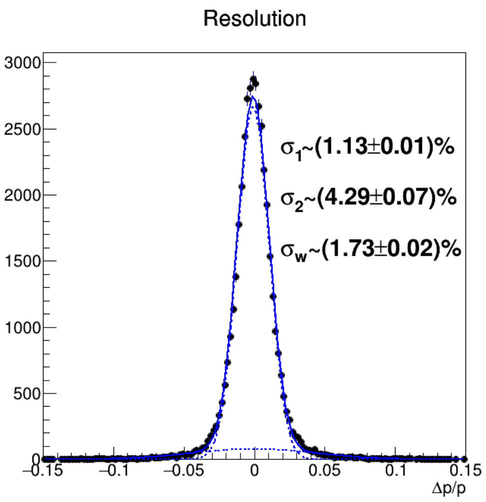


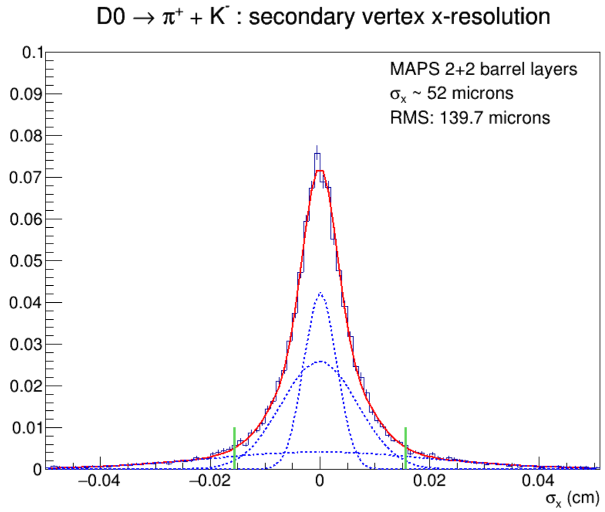


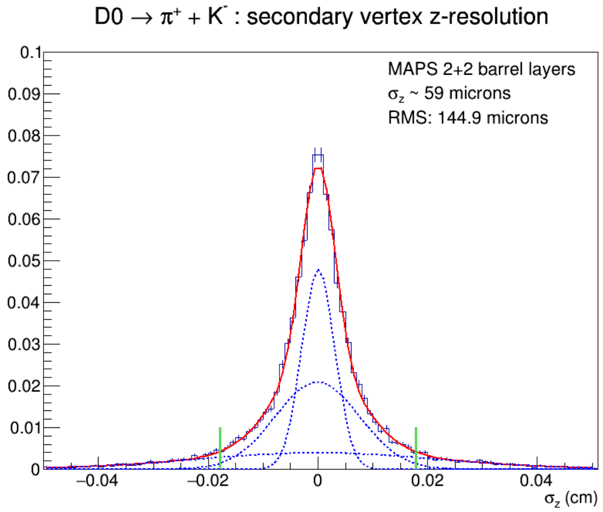


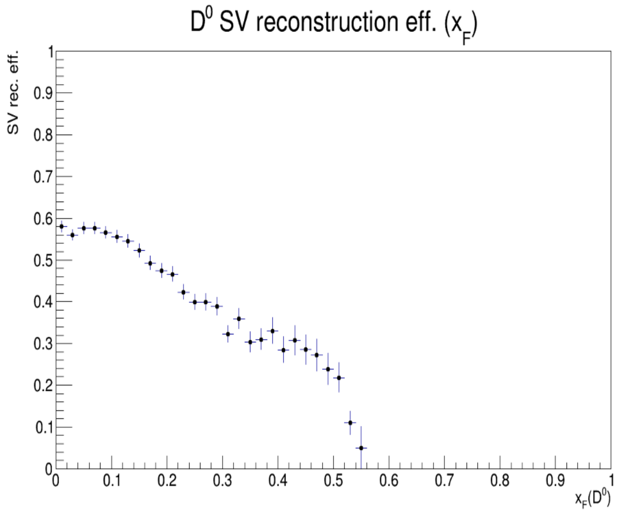


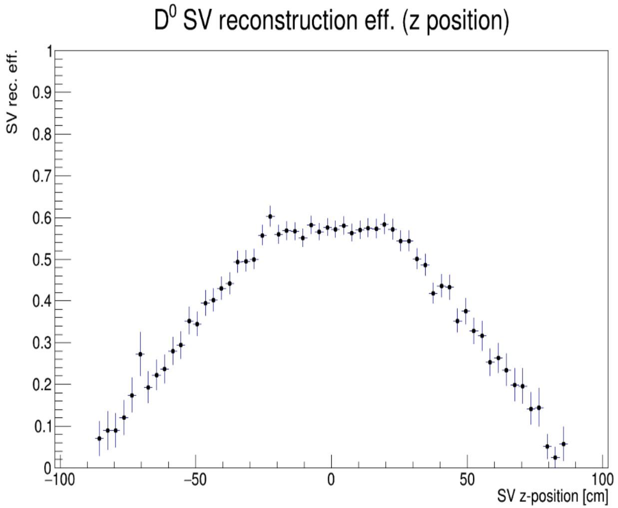
D^0 vertex resolution | MAPS configuration #2

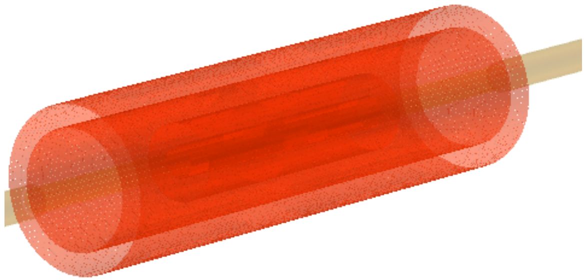




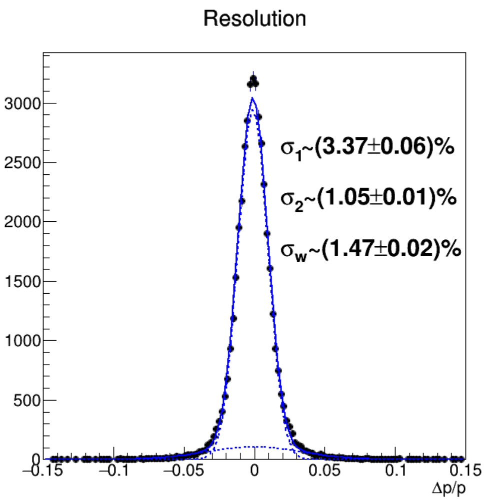


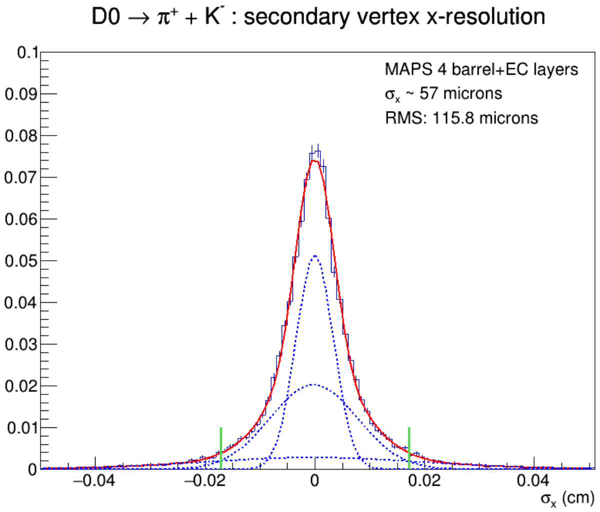


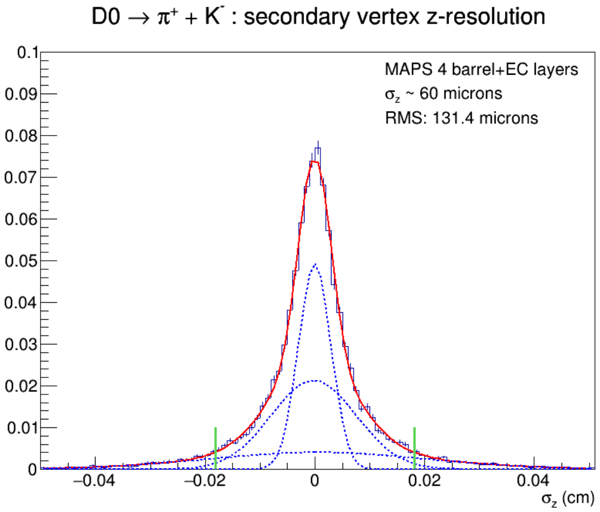


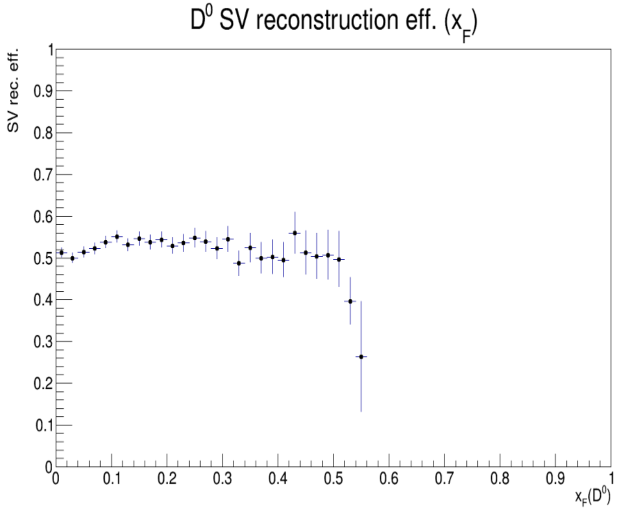


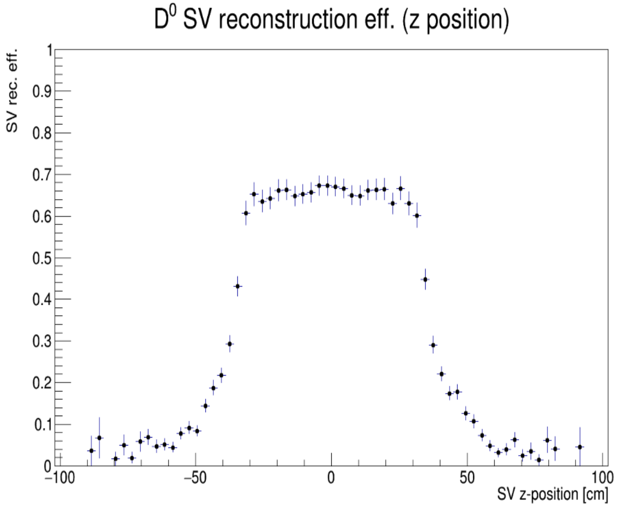
D^0 vertex resolution | MAPS configuration #3

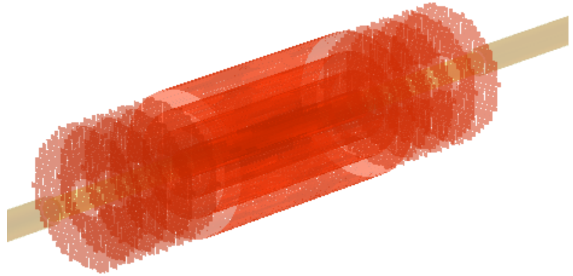




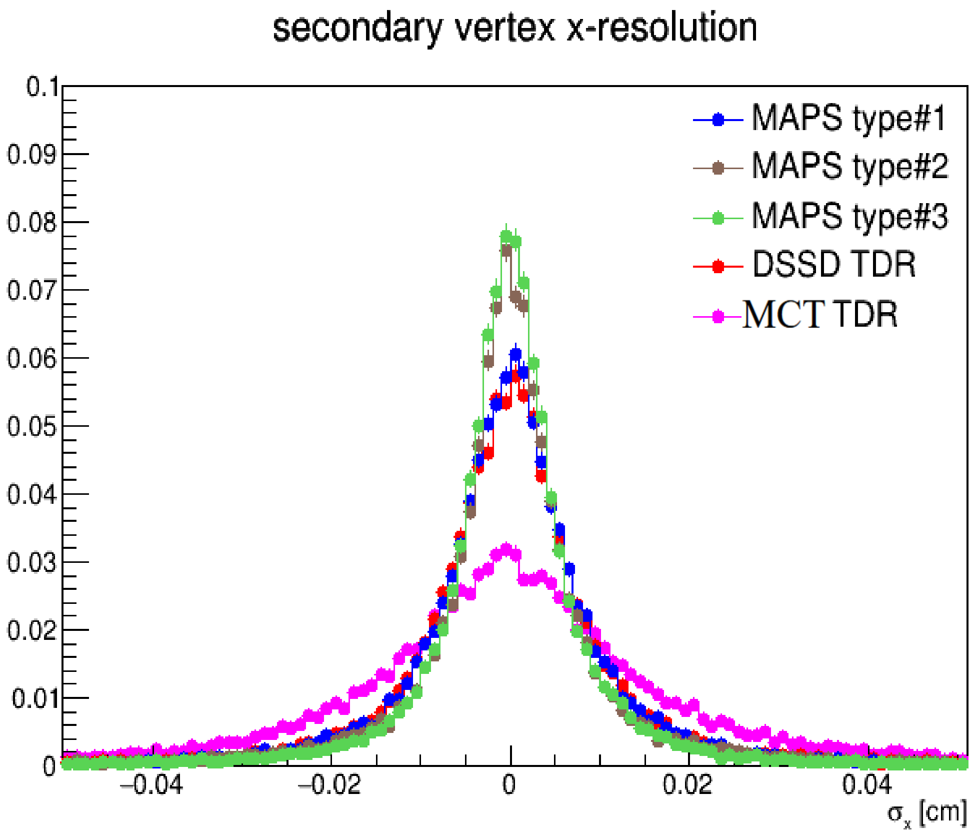


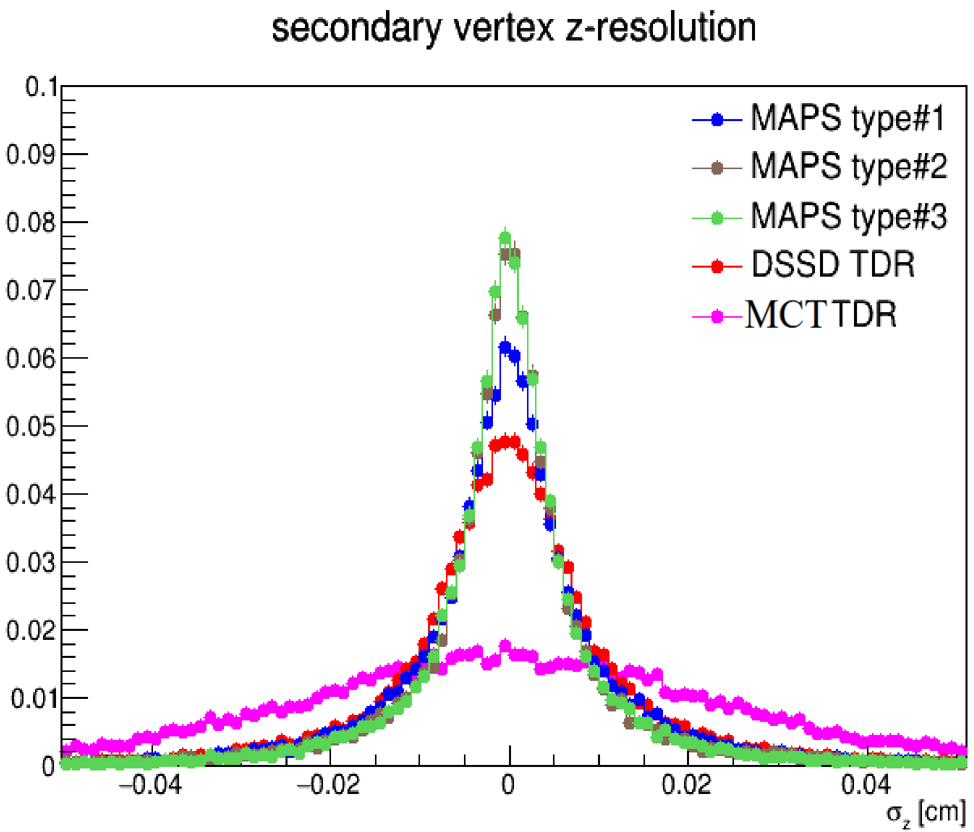




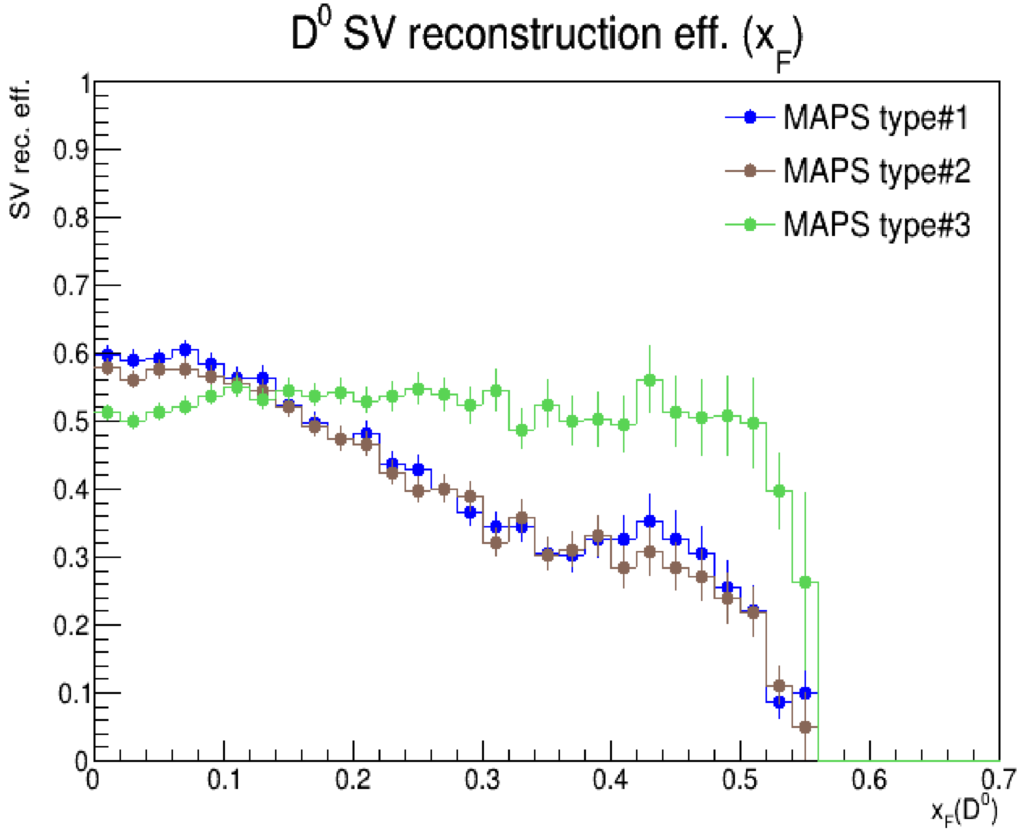


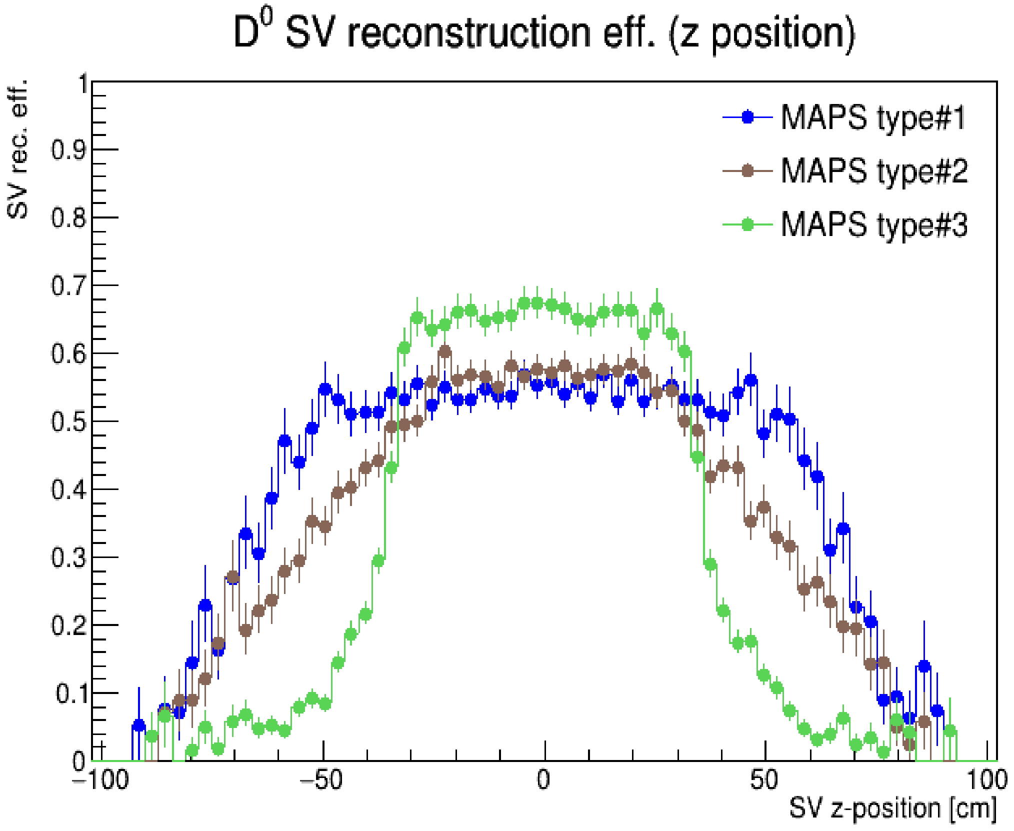
D^0 vertex resolution | Different options for VD





Different options for MAPS-based SVD





Recommendation of using SVD in simulation

- You can **use prepared** configurations:
  - DSSD TDR: SpdDssdGeoMapper::Instance()->SetGeometryPars(1)
  - MAPS#1: SpdMapsGeoMapper::Instance()->SetGeometryPars(3)
  - MAPS#2: SpdMapsGeoMapper::Instance()->SetGeometryPars(2)
  - MAPS#3: SpdMapsGeoMapper::Instance()->SetGeometryPars(1)

- **Default** gtype parameters:
  - DSSD: 1
  - MAPS: 1

- It is possible to make **user custom** config (SetGeometryPars should not be used in that case). Useful methods:
  - Both MAPS & DSSD (see Ap. 6 for parameters description):
    - <GeoMapper>::SetDefaultLadderPars(Int_t nlayer, Int_t npar, Double_t value); // to change the list of default layer/ladder parameters
    - <GeoMapper>::SetDefaultChipPars(Int_t nlayer, Int_t npar, Double_t value); // to change the list of default chip parameters
    - <GeoMapper>::SetNLayers(Int_t nlayers); // force number of layers
  - Only MAPS:
    - SpdMapsGeoMapper::SetECLayerPosZ(Int_t nlayer, Double_t PosZ); // Position of layer along Z radius
    - SpdMapsGeoMapper::SetECLayerRmin(Int_t nlayer, Double_t Rmin); // min radius of EC layer
    - SpdMapsGeoMapper::SetECLayerRmax(Int_t nlayer, Double_t Rmax); // max radius of EC layer
    - SpdMapsGeoMapper::SetECLayerDz(Int_t nlayer, Double_t Dz); // distance between sensor planes
    - SpdMapsGeoMapper::SetECLayerNhalfCones(Int_t nlayer, Double_t NHalfCones); // number of half cones inside layer (4 - 2 sensor planes, 2 - 1 sensor plane)
    - SpdMapsGeoMapper::SetNECLayers(Int_t nlayers); // force number of EC layers

Conclusion

- FEE modules for MCT detectors were simulated;

- FEE modules do not affect the overall performance of the MCT detector, however, they significantly deteriorate the resolution for tracks that pass directly through the electronics;

- SVD is needed to achieve the required secondary vertex position resolution resolution;

- MAPS is still better than DSSD:
  - At least ~10% (σ_z & RMS) better resolution in beam direction for MAPS#1;
  - ~30% σ_z & ~25% RMS better resolution in beam direction for MAPS#3;

- End-caps significantly improve reconstruction of SV of D0 decays efficiency for events with high x_F^{D0} values;

ToDo

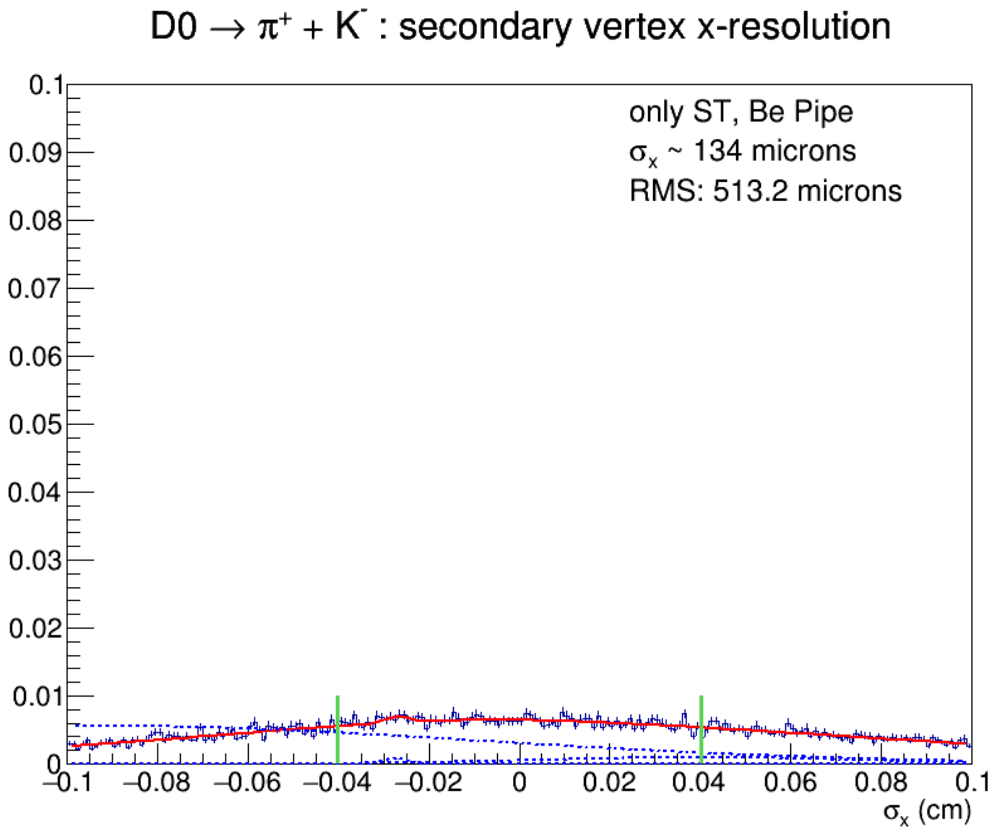
- Push MCT Electrics class to SpdRoot development branch;

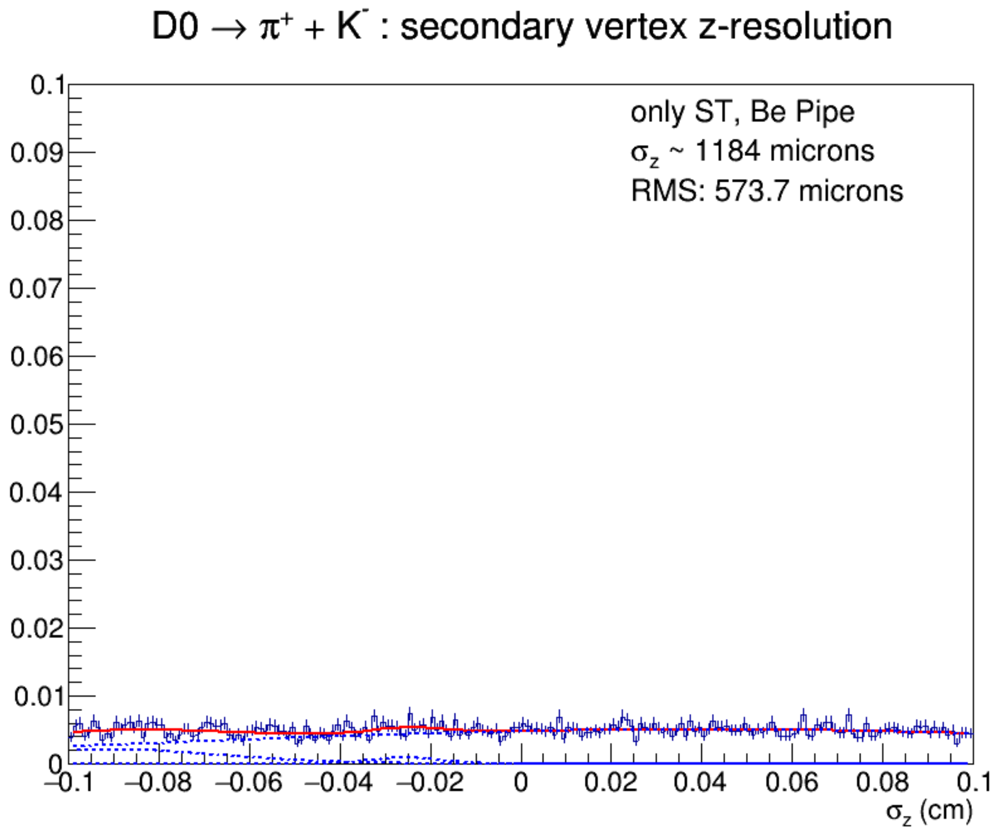
- End-caps for Micromegas-based central tracker (see A.Datta talk);

- Writing a Wiki page containing information about the geometric model of SVD and instructions for its use for simulation;

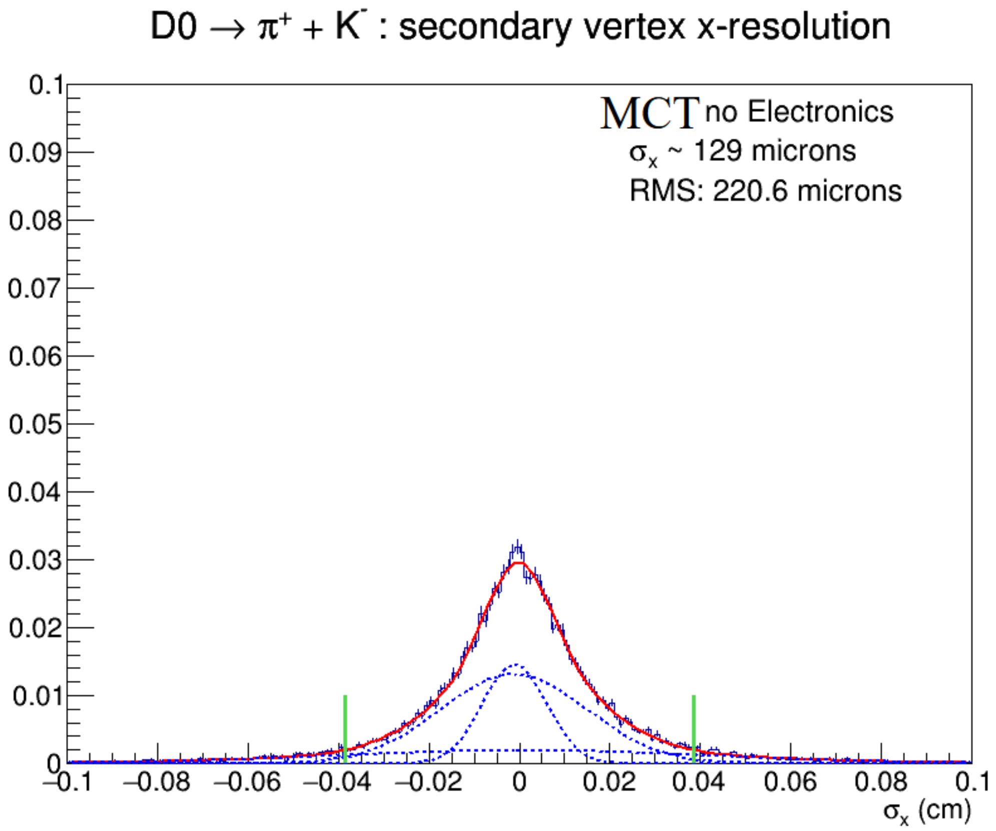
Thank you for your attention!

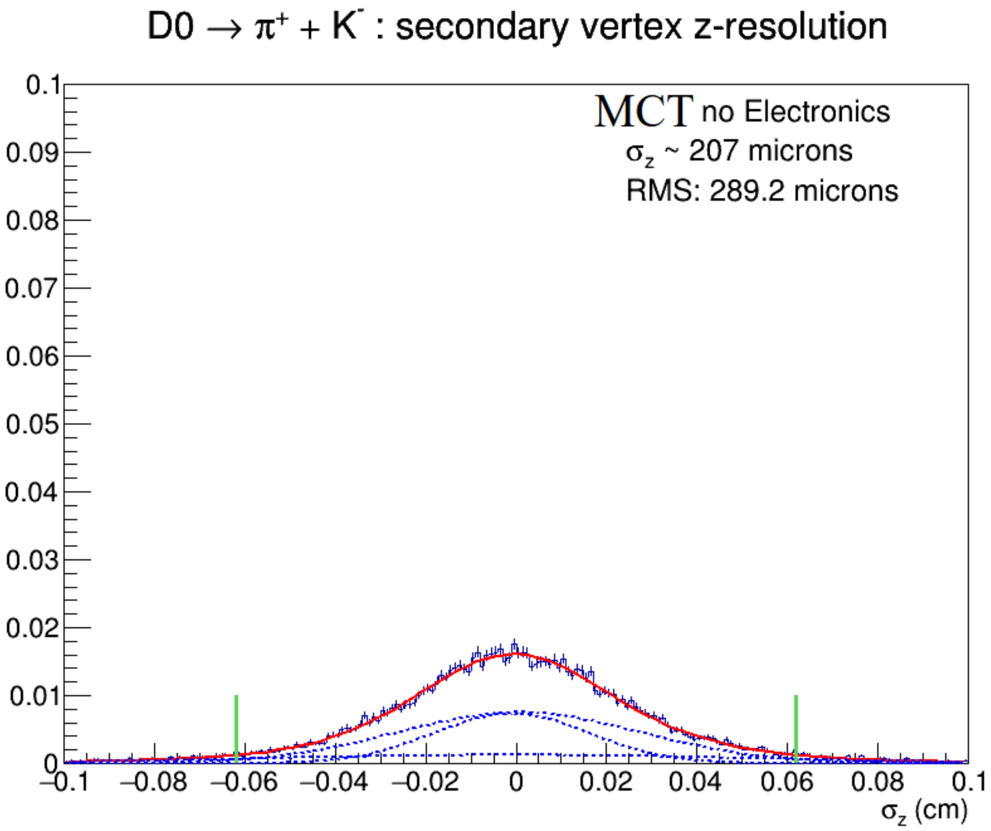
Ap. 1 | SV reconstruction with only ST config.



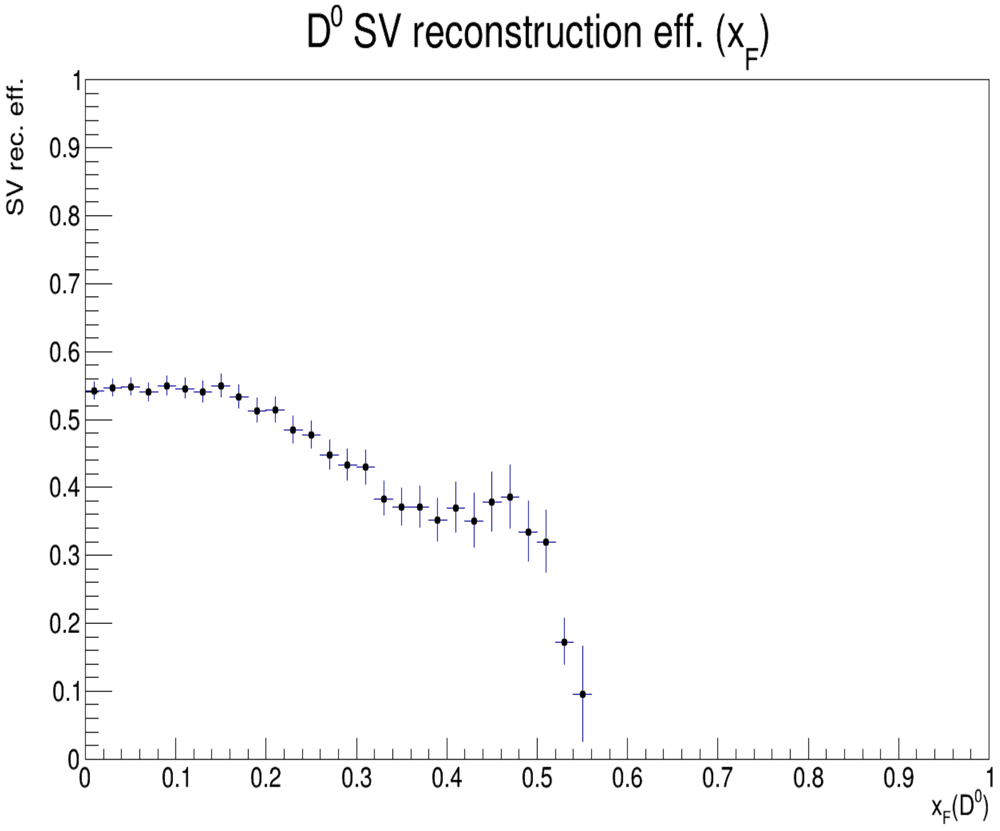


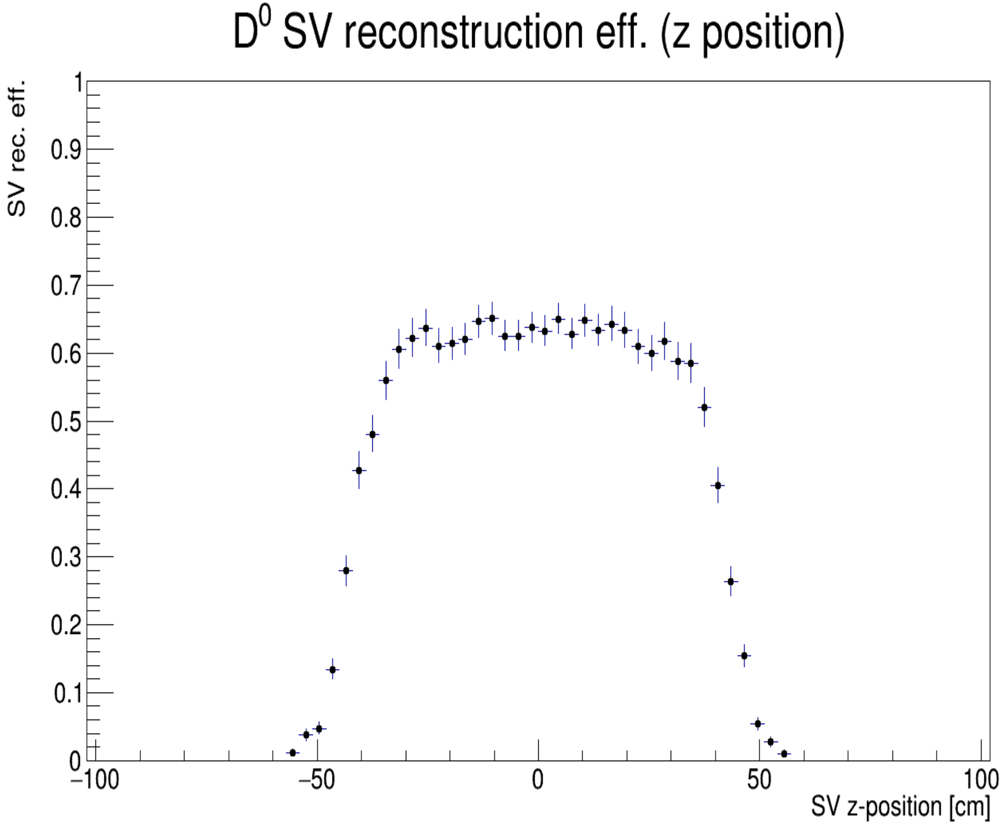
Ap. 2 | SV reconstruction with MCT (1)





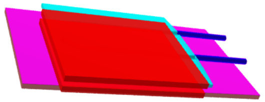
Ap. 2 | SV reconstruction with MCT (2)



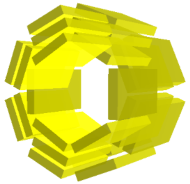


Ap. 3 | FEE for MCT

Module



ElTube



MvdBarrel

Current solution:

```
// Check that master volume contains MVD barrel

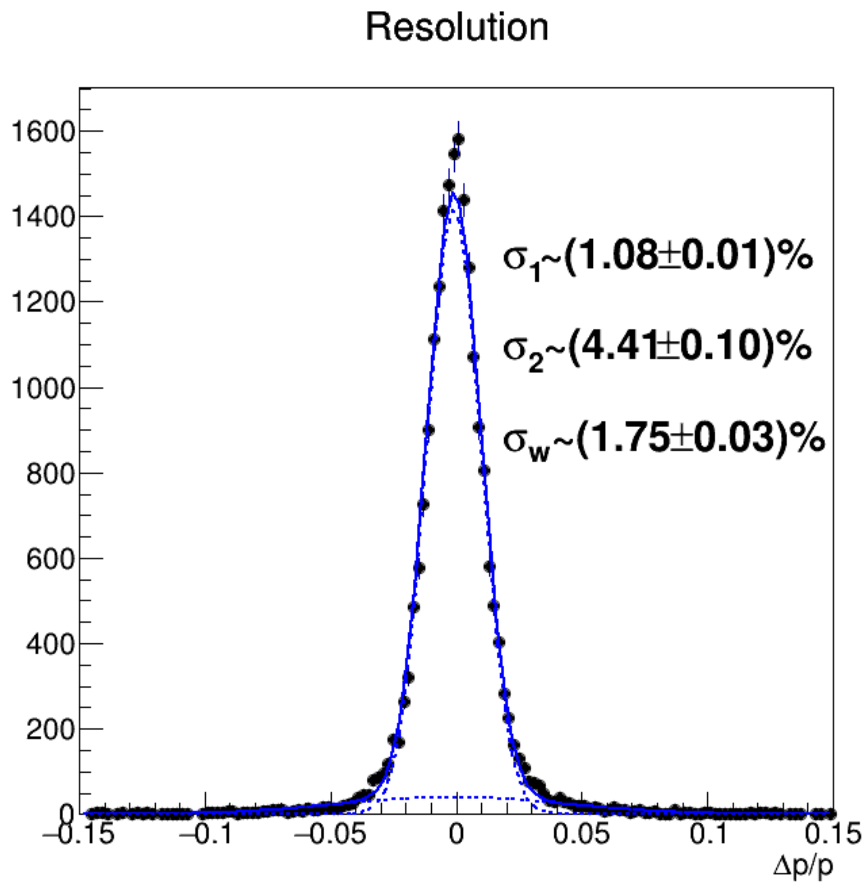
if (!fMasterVolume->GetNode("MvdBarrel_1"))
{ cout << "-E- <SpdMvdElectrics::ConstructGeometry> No Mvd Barrel " << endl; return; }
TGeoVolume *mvd_barrel = fMasterVolume->FindNode("MvdBarrel_1")->GetVolume();

// Put electrics module into MVD barrel

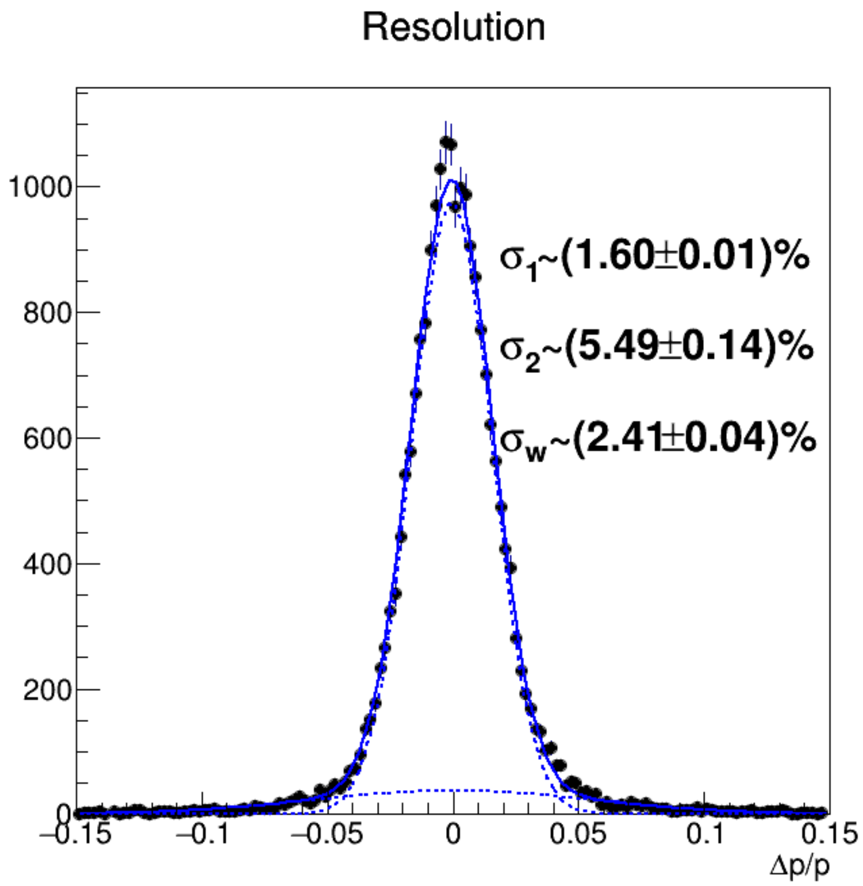
mvd_barrel->AddNode(fElTube, 1, new TGeoTranslation(0., 0., -fZshift));
mvd_barrel->AddNode(fElTube, 2, new TGeoCombiTrans(0., 0., fZshift, new TGeoRotation("fElTubeRot", 0.,
180., 0.)));
```

Ap. 4 | Comparing momentum resolution: MVD vs ST only

ST + MVD



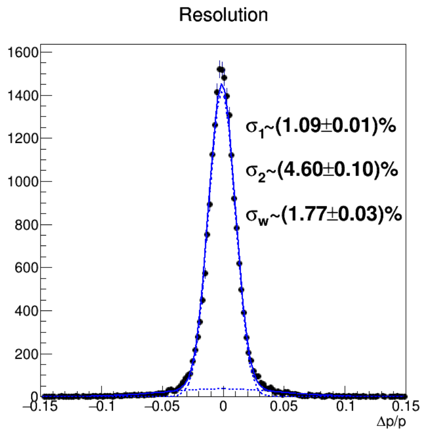
ST only



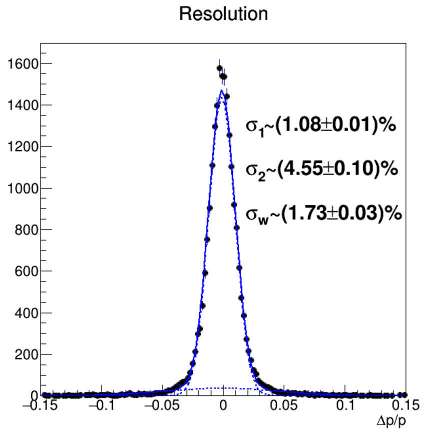
Ap. 5 | VD performance | MVD with electrics#1

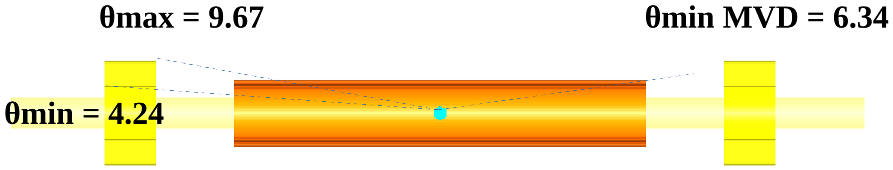
Mvd customize geometry: CustomMvd(3);
Barrel length: 90 cm.

Without FE Modules

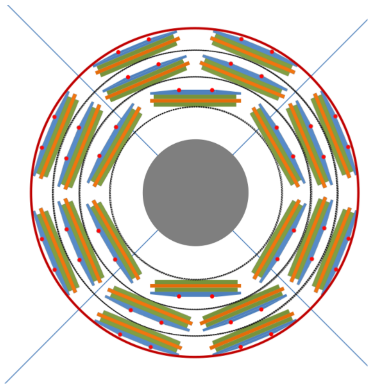


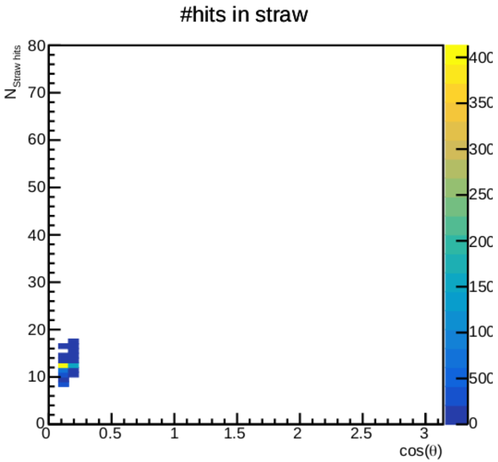
With FE Modules



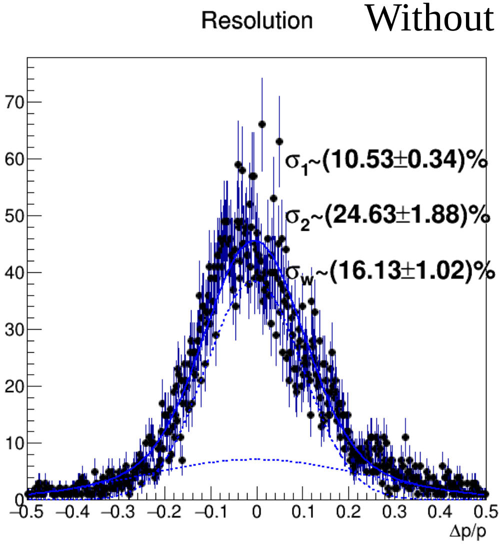


IGen->SetSpherical(4.2484545, 9.6666064, 0., 360.);
primGen->SetBeam(0., 0., 0., 0.);
primGen->SetTarget(0., 0.);

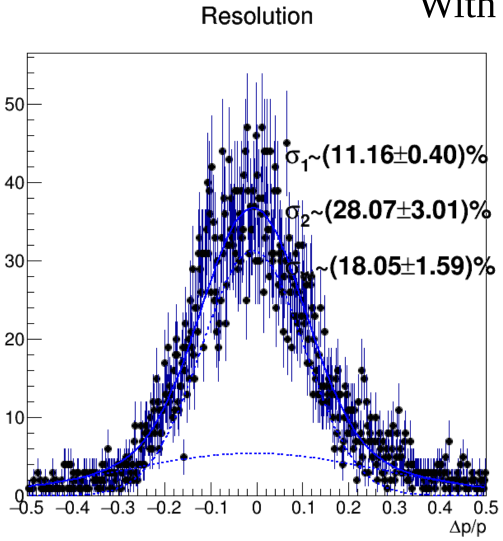




Without FE



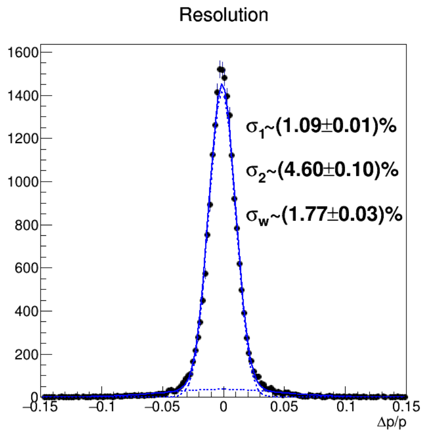
With FE



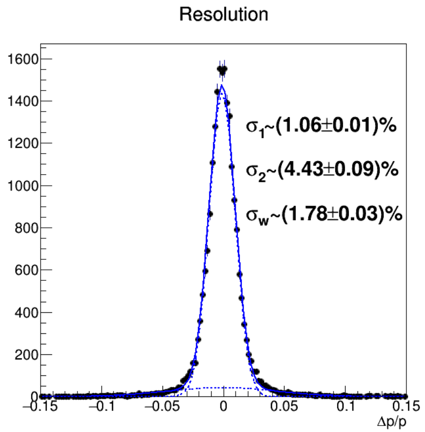
Ap. 5 | VD performance | MVD with electrics#2

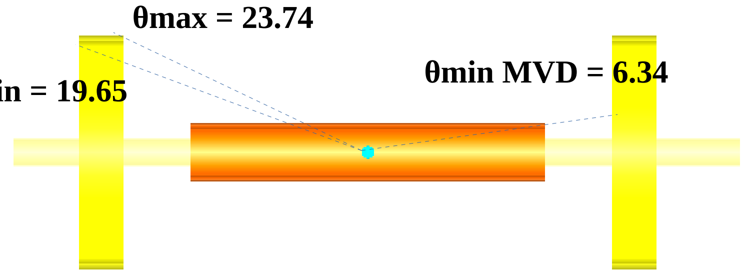
Mvd customize geometry: CustomMvd(3);
Barrel length: 90 cm.

Without FE Modules

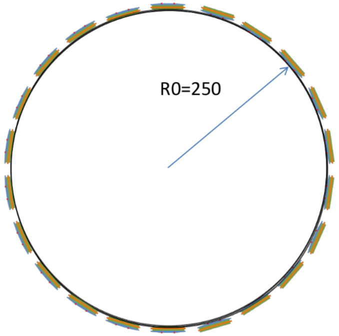


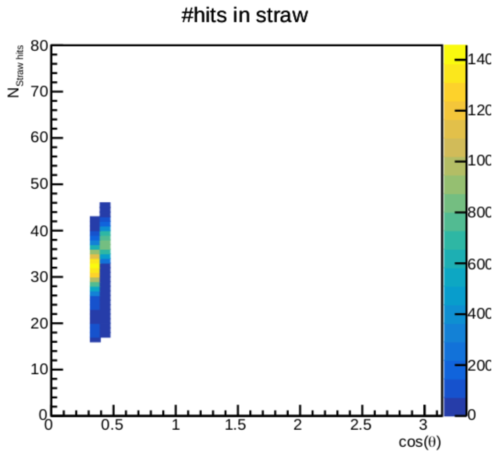
With FE Modules



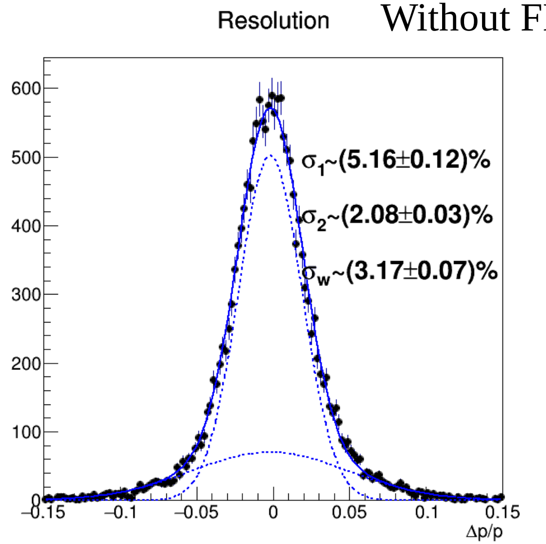


IGen->SetSpherical(19.653824, 23.736453, 0., 360.);
primGen->SetBeam(0., 0., 0., 0.);
primGen->SetTarget(0., 0.);

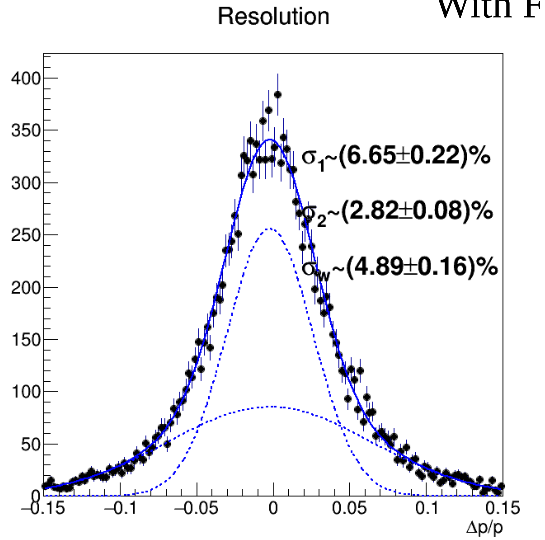




Without FE



With FE



Ap. 6 | SVD parameters

SetDefaultLadderPars

(1) Rlayer : the distance from z-axis to ladder center (LAYER radius)
(2) Lz : ladder size along z axis
(3) Lphi : ladder size along phi axis
(4) Lr : radial size of ladder
(5) angle : local rotation angle for ladder
(6) Phi : global rotation angle for LAYER
(7) Nladders : number of ladders inside the LAYER (it will be calculated automatically for g = 1,2)

SetDefaultChipPars

(1) lz : chip size along z-axis
(2) lphi : chip phi-size
(3) dlz : gap size between chips along z-axis
(4) dlphi : gap size between chips along phi-axis
(5) ncz : number of chip cells (channels) along z-axis
(6) ncphi : number of chip cells (channels) along phi-axis
(7) type : chip type (1: MAPS, 2: DSSD) // legacy (to be fixed)

(1) PozZ : Position of layer along Z radius
(2) dz : distance between sensor planes
(3) Lz : layer size along z axis
(4) Rmin : min radius of EC layer
(5) Rmax : max radius of EC layer
(3) LzC : HalfCone size along z axis
(4) RminC : min radius of EC HalfCone
(5) RmaxC : max radius of EC HalfCone
(9) Lx : ladder size along x axis (analog of Lphi for barrel)
(10) Lymin : min ladder size along y axis (Lz for barrel)
(11) nHalfCones : number of half cones inside layer (4 - 2 sensor planes, 2 - 1 sensor plane)

Ap. 7 | D0 vertex reconstructions efficiency

Source tracks for analysis:

- track->GetIsFitted() == true;

Conditions for the existence of a reconstructed SV D^0 vertex in the event:

- Reconstructed vertex exists;
- Mass of «mother» particle lies in the range:
  (1.7, 2.0) GeV;