SPD S&C meeting,
22 June 2021

Primary vertex reconstruction and D^0 selection in SPD experiment (update)

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Main vertex detector options

There are some questions of SPD DAC connected with the options of vertex detector and possibility to improve separation of D^0 meson

1. 2 configurations of silicon vertex detector were considered in SPD CDR

2. DSSD (c.t. = 300 mkm, 5 layers) => option = v0;

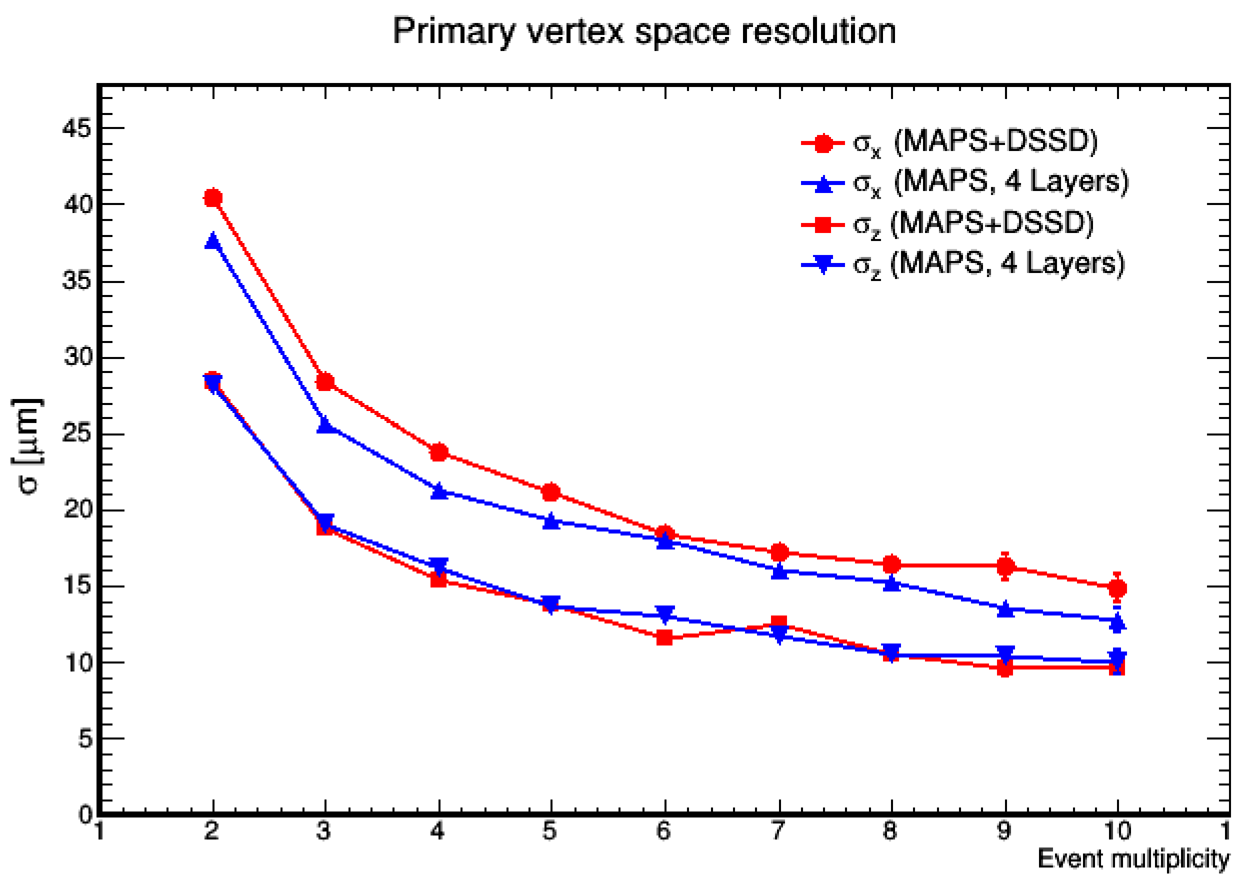
3. MAPS (c.t. = 50 mkm, 1,2,3 layers) + DSSD (c.t. = 300 mkm, 4,5 – layers) => option=v3

4. MAPS (c.t. = 50 mkm, 4 layers) => option=v4 (new configuration was proposed by SPD DAC and is considered in this study, thank to Artur for quick providing of new version)

5. Errors
   MAPS: u = v = 4 mkm (effective)
   DSSD: u(z) = 23 mkm, v(x) = 11 mkm (effective)

6. **Question => is there any difference between option v3 and v4 of vertex detector ?**

Primary vertex resolution (vtx+straw)

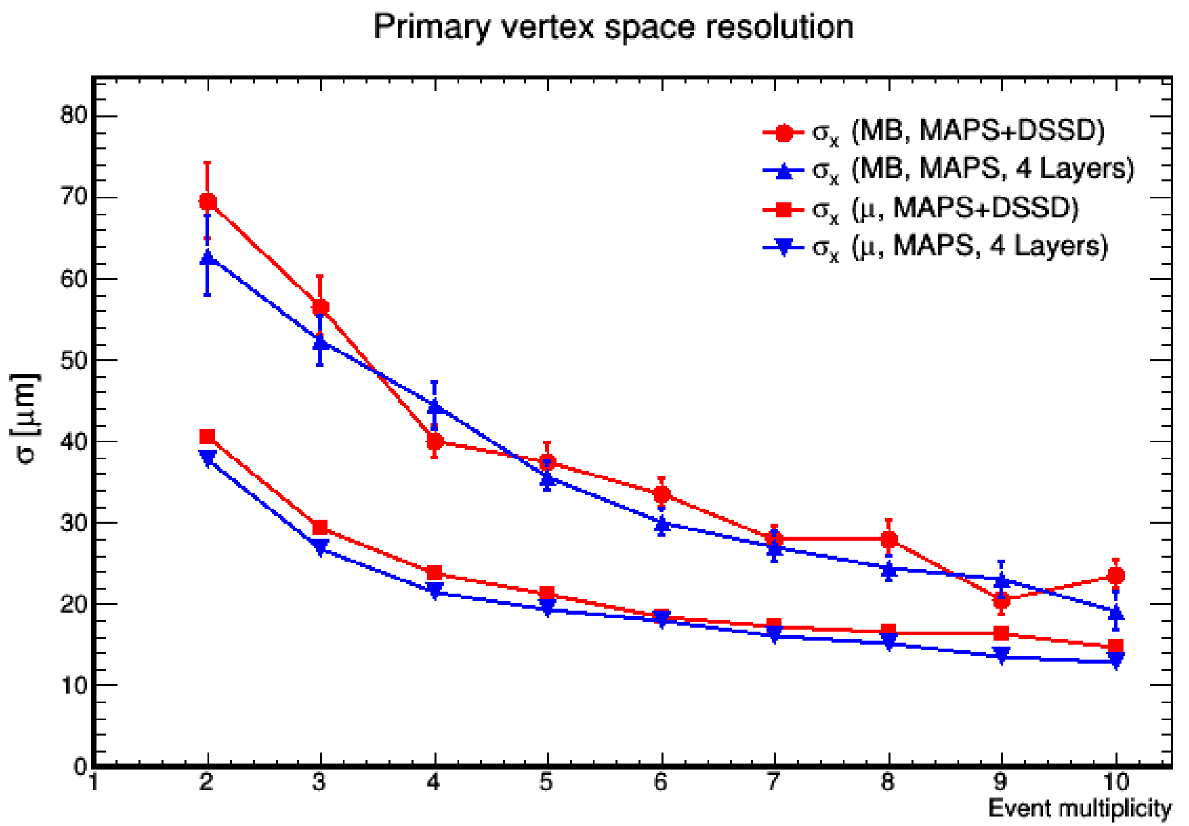


1. samples with 10 muons ($\mu^+ \mu$-) are simulated for MAPS+DSSD and MAPS (4 layers) options

2. presence of 5 hits in VD for MAPS+DSSD and 4 hits in VD for pure MAPS (4 layers) options is required

3. then primary vertex was reconstructed

Primary vertex resolution (MB and muons)



1. samples with 10 muons (μ^{+} μ-) are simulated for MAPS+DSSD and MAPS (4 layers) options
2. samples with Minimum Bias (MB) events are simulated for MAPS+DSSD and MAPS (4 layers)
3. presence of 5 hits in VD for MAPS+DSSD and 4 hitts in VD for pure MAPS (4 layers) options is required
4. new vertex detector configuration shows the similar precision for primary vertex resolution as MAPS+DSSD options

Track fit precision for 2 options of vertex detector

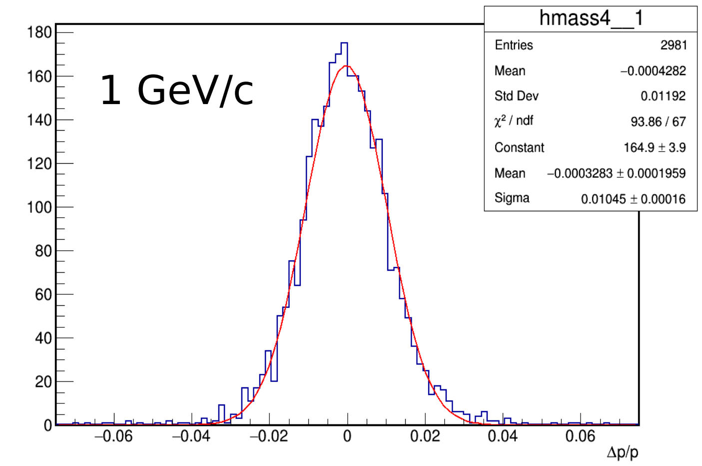
1. samples with uniform distribution of pions inside θ and φ angles are simulated

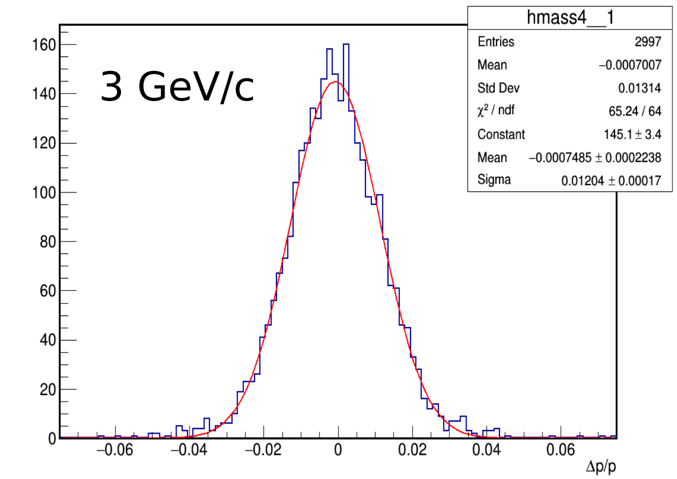
2. then standard track fit for 2 options of vertex detector MAPS+DSSD and MAPS (4 layers) is performed

3. select track with 5 hits in VD for MAPS+DSSD and 4 hits in VD for MAPS (4 layers)

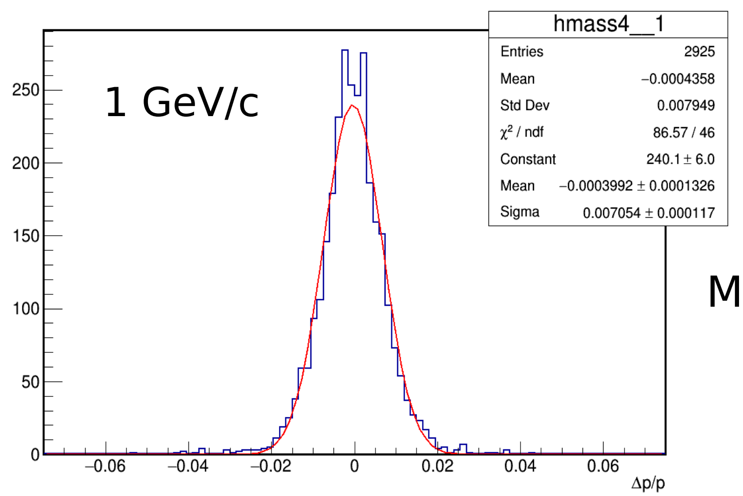
4. select only pions inside barrel part of vertex detector

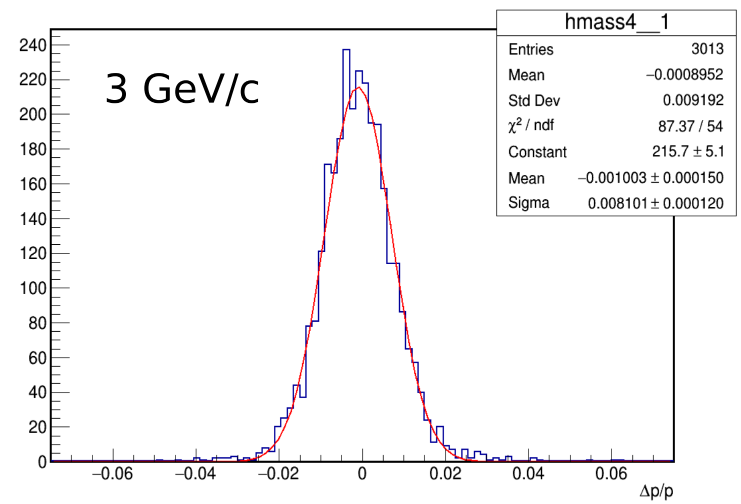
Track fit precision (vtx+straw)





MAPS+DSSD



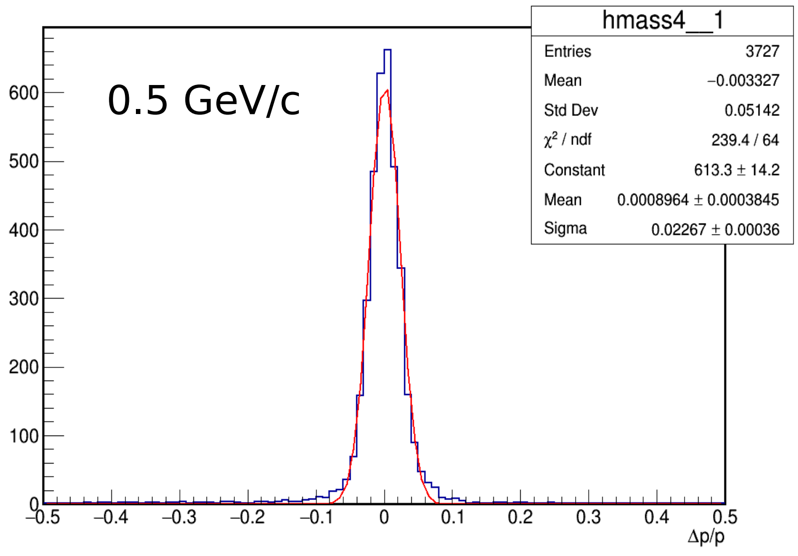


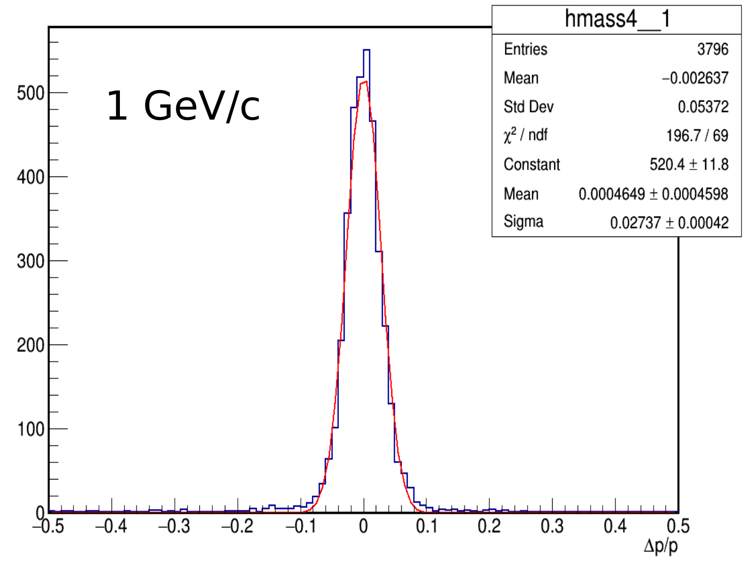
MAPS, 4 layers

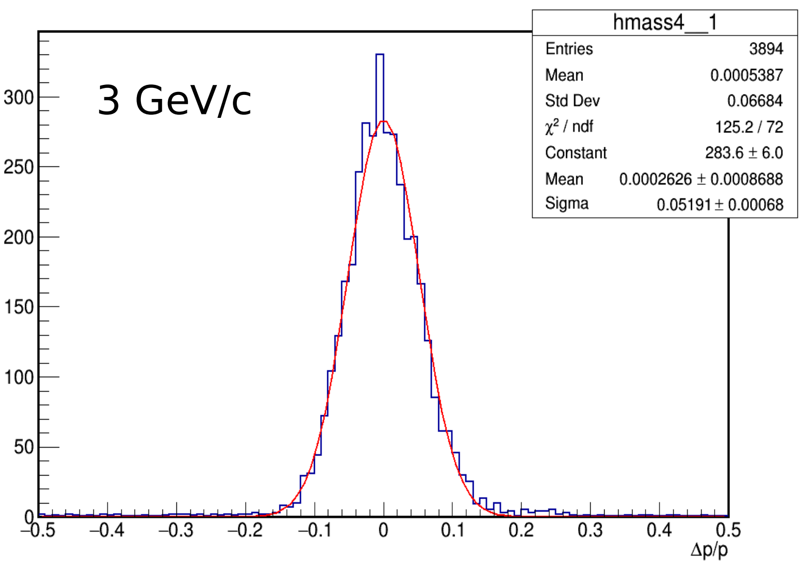
Resolution: 0.5 GeV/c => ~1.0% (MAPS+DSSD) and ~0.6% (MAPS, 4 layers)
1.0 GeV/c => ~1.0% (MAPS+DSSD) and ~0.7% (MAPS, 4 ayers)
3.0 GeV/c => ~1.2% (MAPS+DSSD) and ~0.8% (MAPS, 4 layers)

Vertex detector option with 4 MAPS layers provides ~1.5 better track momentum resolution (!)

Track fit precision (only straw)



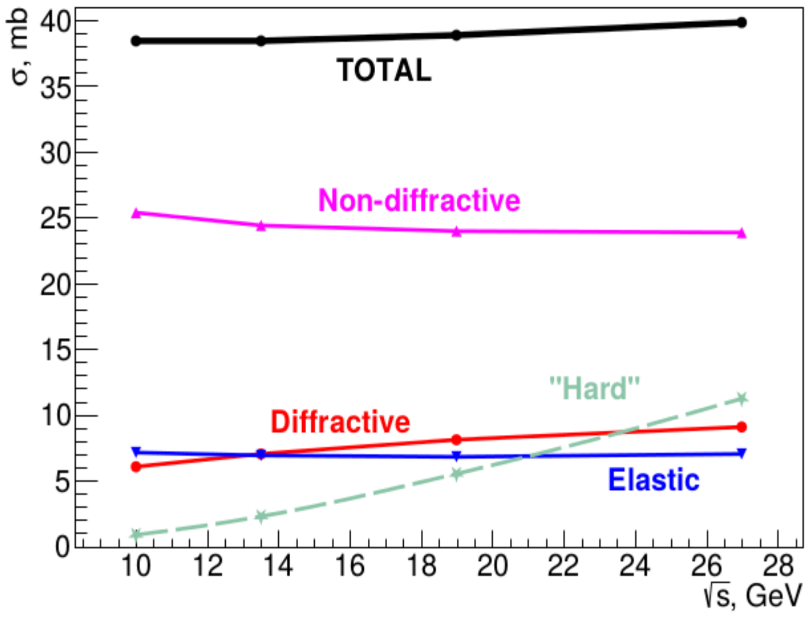


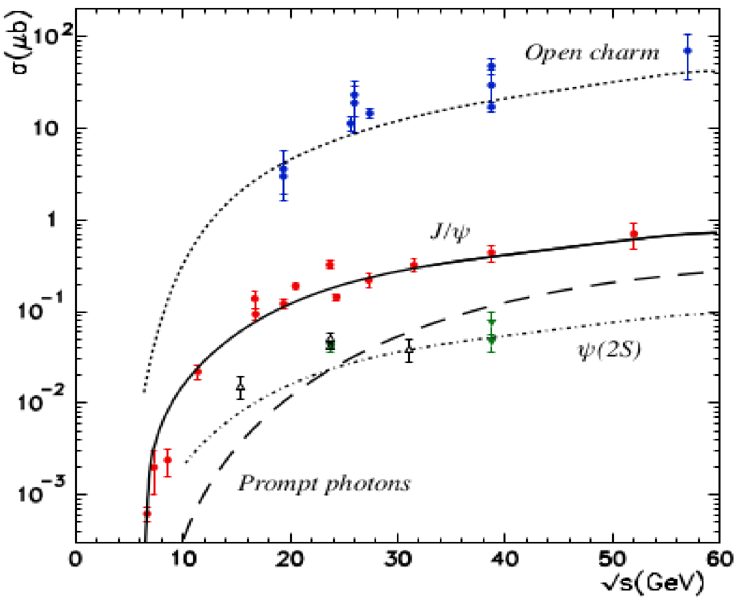


Resolution: 0.5 GeV/c => ~2.3% ; 1.0 GeV/c => ~2.7% ; 3.0 GeV/c => ~5.2%

Open charm selection ($D^0 \rightarrow K^- \pi^+$)

1. consider $D^0 \rightarrow K^- \pi^+$ decay (BR 3.9 %) => cτ = 122.9 μm, M=1864,84 MeV/c^2





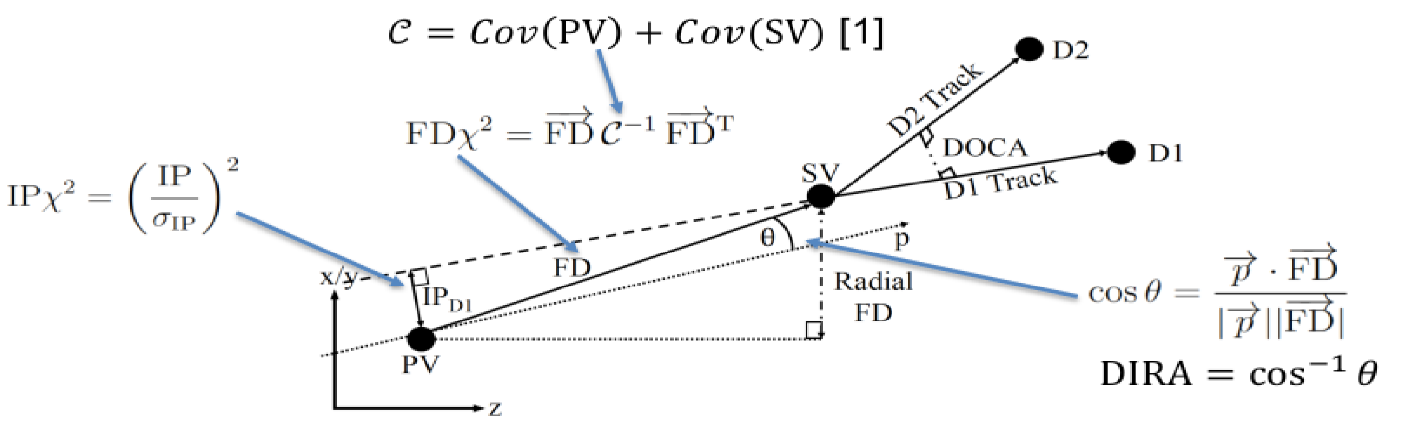
2. cross-section MB ~35 mb (without elastic) and D^0 production ~14 μb

3. ~2.5*10^3 MB events and only 1 D^0 event

4. ~6.4*10^4 MB events and only 1 D^0 event with $D^0 \rightarrow K^- \pi^+$ decay mode

5. events with | x_F | > 0.2 are more interesting

Selection cuts for $D^0 \to K^- \pi^+$



1. distance between 2 daughter particles (DOCA)

2. select tracks on the base of chi2 of track and primary reconstructed vertex

$$\chi^2_{prim} = \Delta\mathbf{r}^T (C_{track} + C_{PV})^{-1} \Delta\mathbf{r},$$

where Δr – distance between track and the primary vertex position, C_{track} is a covariance matrix of a track and C_{PV} is a covariance matrix of primary vertex

3. check L / dL - decay length normalized on the error

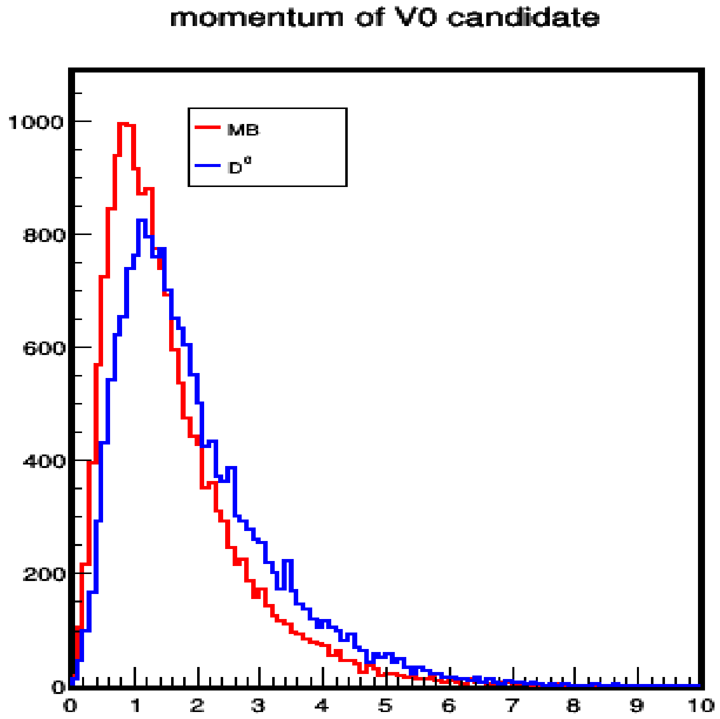
4. θ angle of daughter particle (pi+)

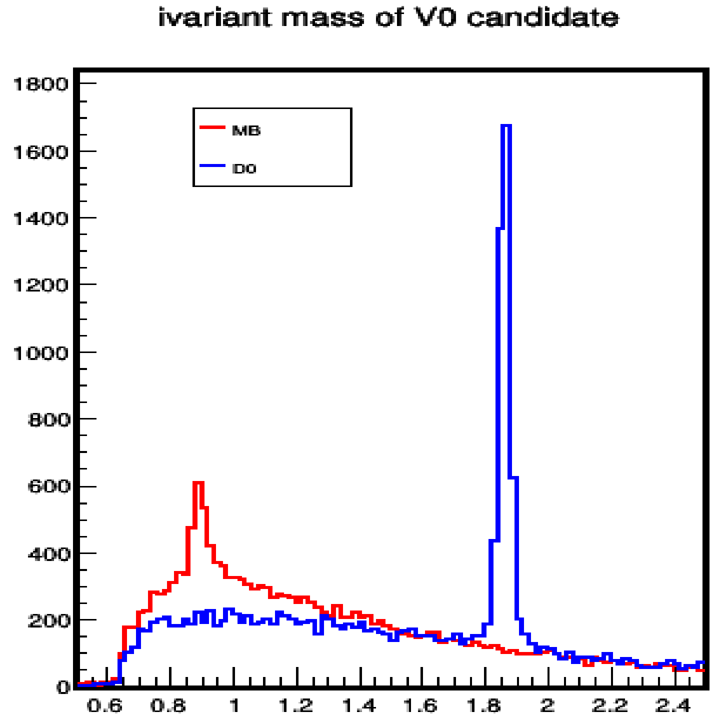
5. angle of V0 candidate and primary vertex (cosθ)

6. use Armenteros-Podolanski plot

Selection cuts for $D^0 \rightarrow K^- \pi^+$

1. => simulate 6000 D0 and 10000 MB events (without any selection)





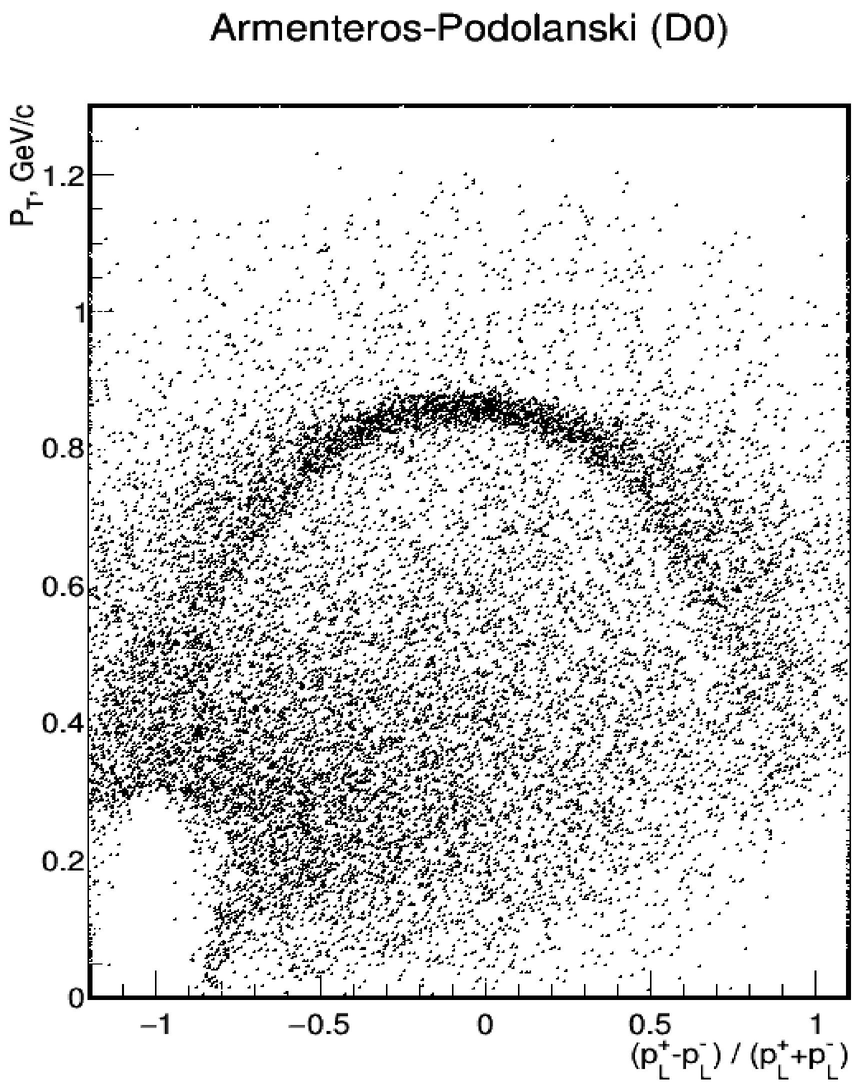
2. cut V0 candidate momentum (p > 2.7 GeV/c) => MB (~33%) and D0 (~26%, with ~70% of D0 reconstruction efficiency)

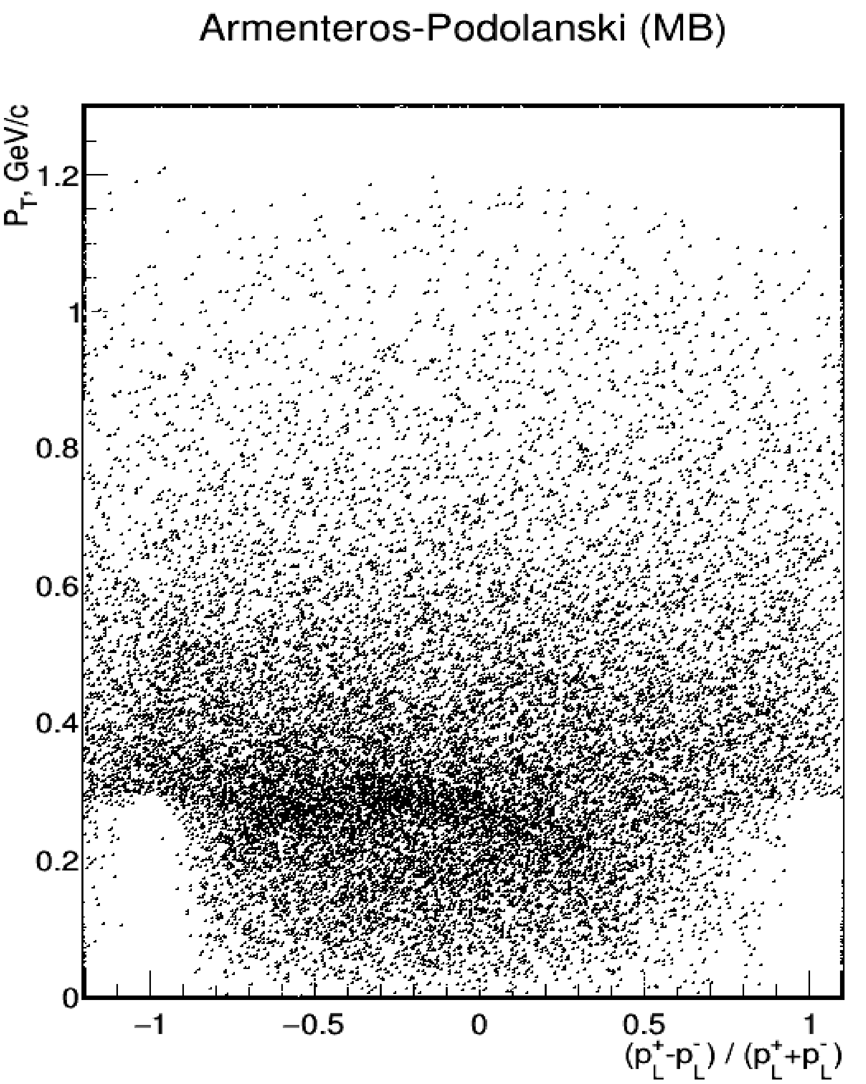
3. Armenteros-Podolanski band cut (cut1 < alfa1 < cut2) => MB (~16.5%) and D0 (~44%)

4. Armentros-Podolanski plot, band+range cut (|afa2| < 0.5) => MB (~2.5%) and D0 (~29%)

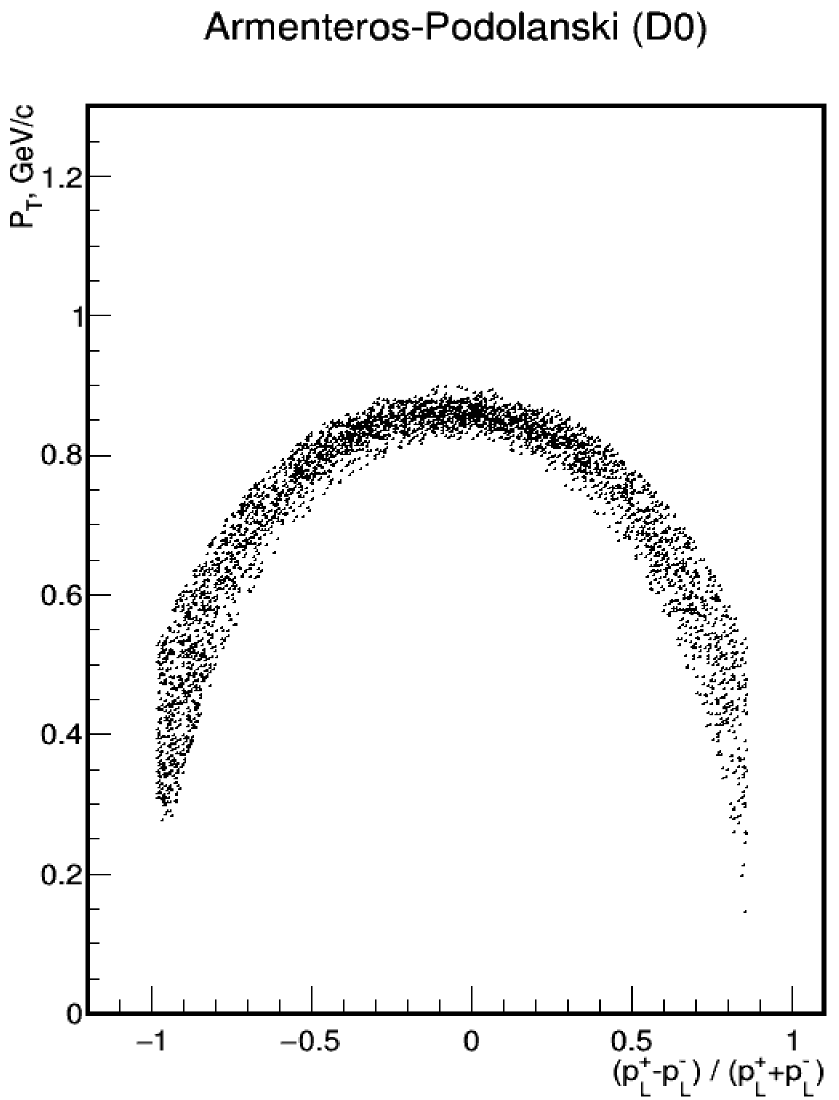
5. Armenteros-Podoanski plot cuts + momentum => MB (~0.4%) and D0 (~13.5%)

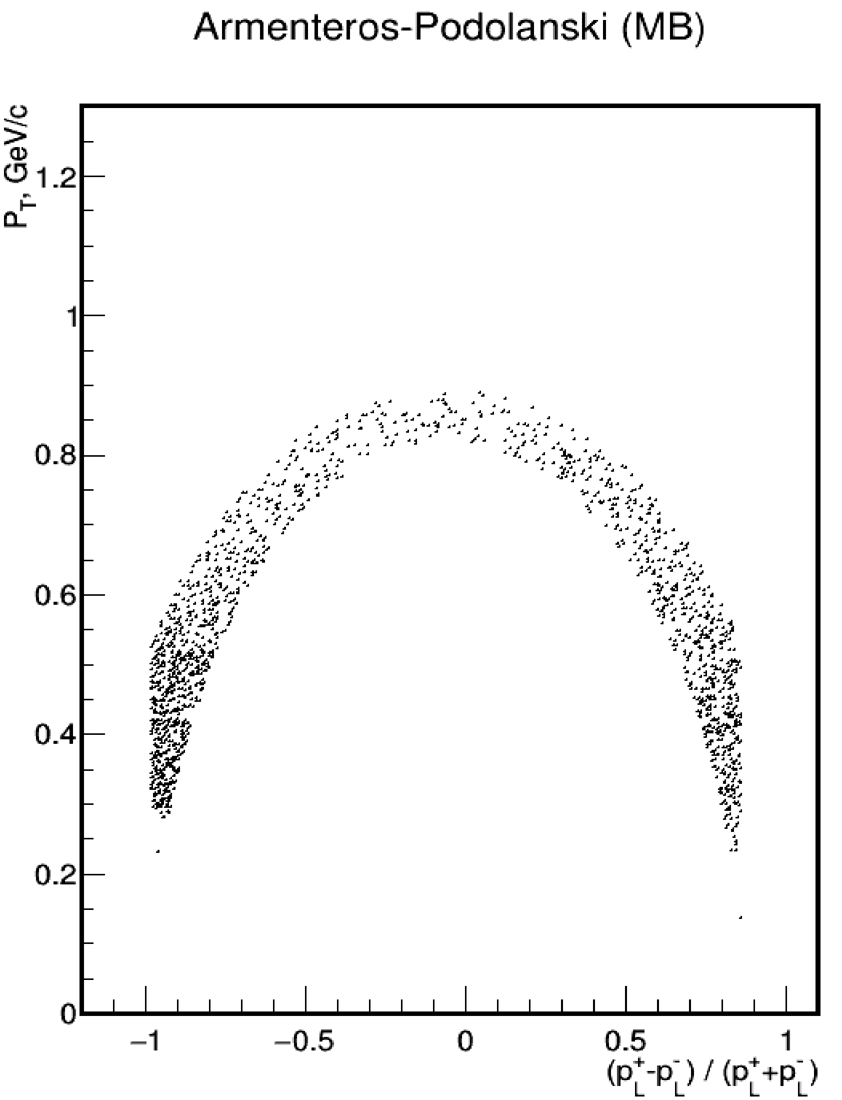
Armenteros-Podolaanski (without cut)



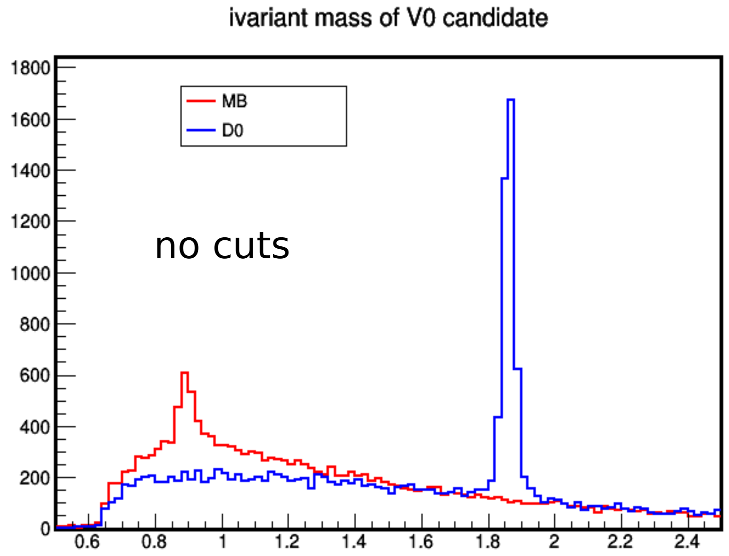


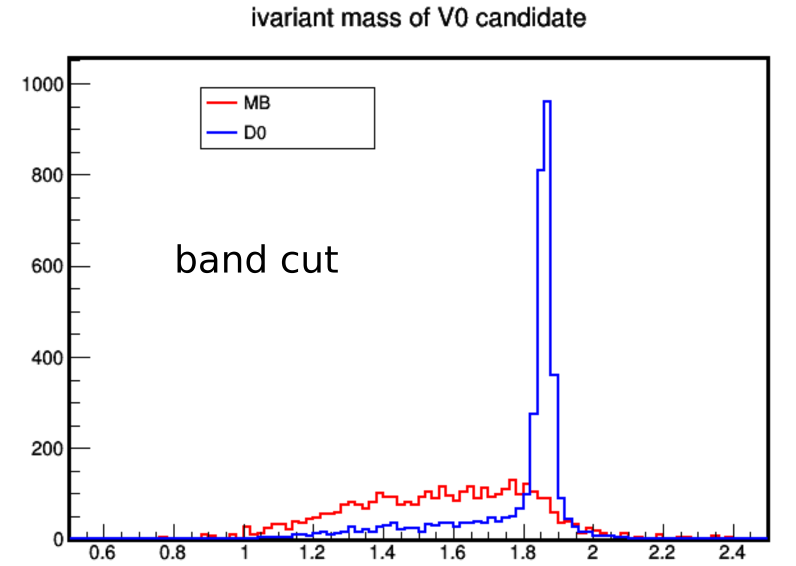
Armenteros-Podolanski plot (with band cut)

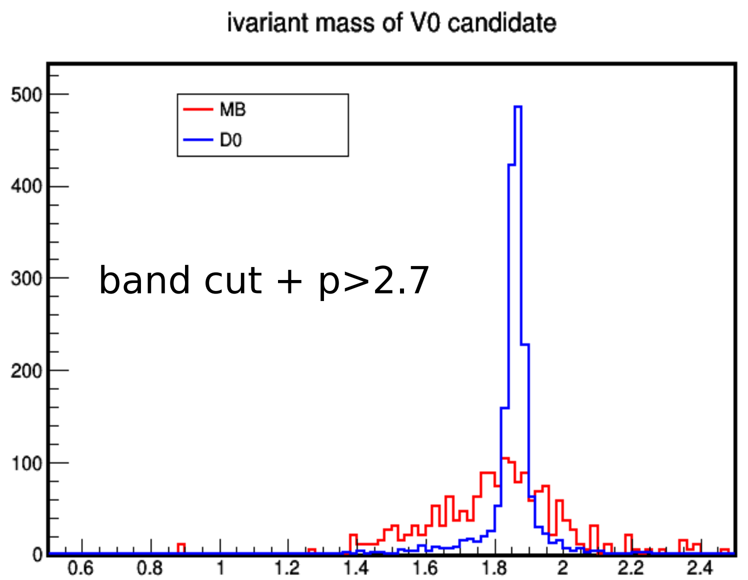


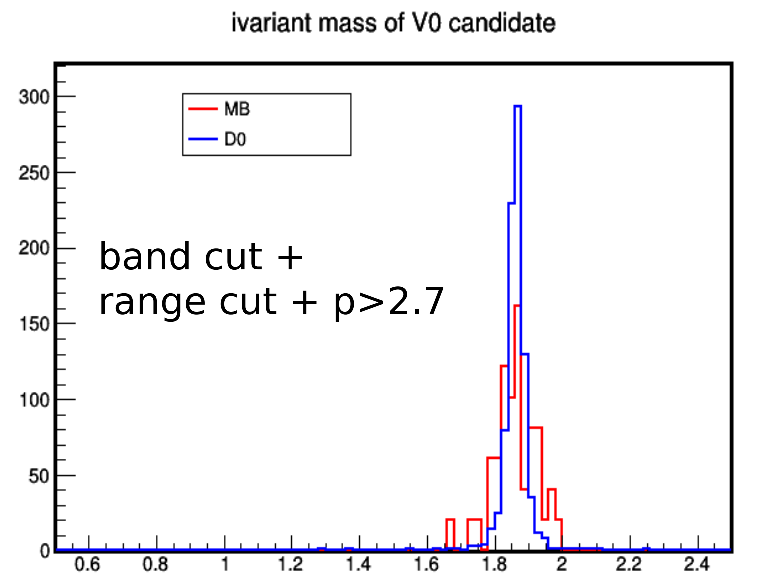


Selection cuts for $D^0 \rightarrow K^- \pi^+$









1. selection efficiency => ~0.4% (MB) and ~13.5% (D0) with ~70% D0 reconstruction efficiency

2. result $6.4 \cdot 10^4$ MB vs 1 D^0 => ~256 MB events vs ~0.135 D^0 events

Next step of simulation

1. add some kinematic cuts on generator level

2. for D^0 meson sample => momentum of D^0 > 2.6 GeV/c => ~2.5 times increasing statistic

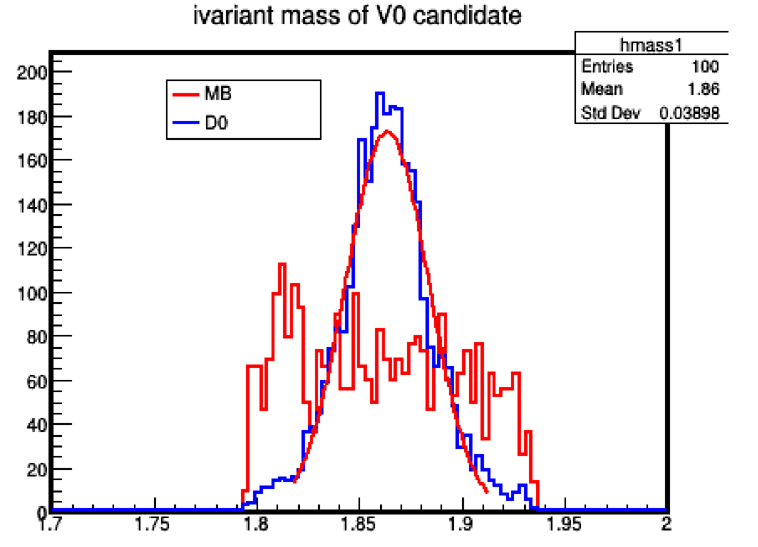
3. for MB sample:

   a) presence K^- meson in events
   b) invariant mass of ($K^- \pi^+$) pair 1.665 < m < 2.065
   c) momentum of ($K^- \pi^+$) pair > 2.6 GeV/c

   d) all these selection cuts increase MB statistic ~40 times

4. 10000 of D^0 mesons and 30000 MB events were simulated

5. effective number events => 25000 for D^0 and $1.2*10^6$ for MB

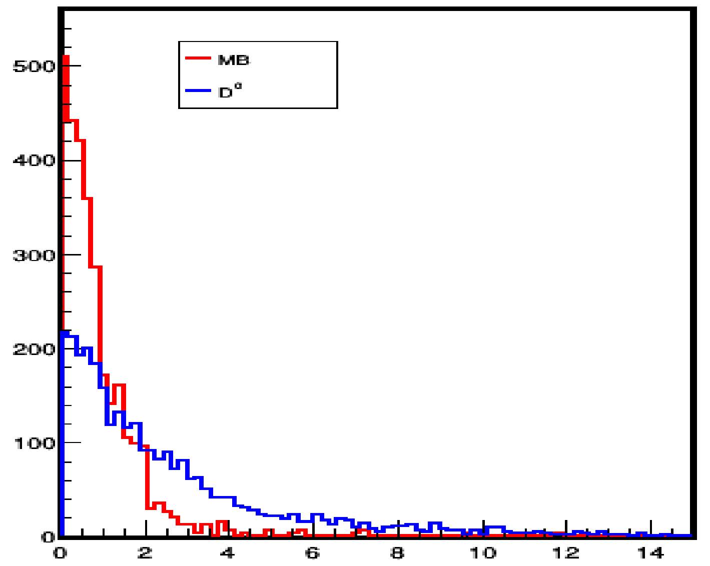


6. after applying p>2.7 GeV/c, invariant mass |m-1.865|<0.070, band and range Armeteros-Podolanski cuts: selection efficiency =>$7.8*10^{-4}$ MB and ~12.2% for D0

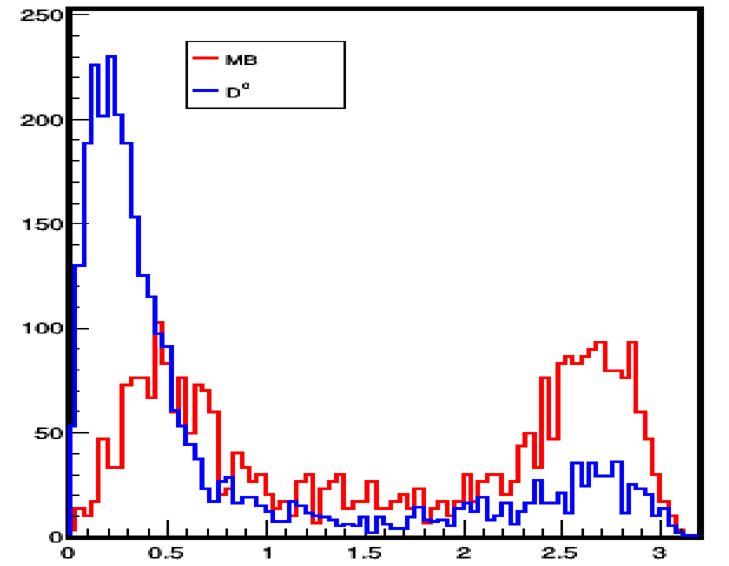
7. result $6.4*10^4$ MB vs 1 D^0 => ~50 MB events vs 0.122 D^0 events (S/B ~0.24%)

Next variables for selection
(after applying Armenteros-Podolanski)

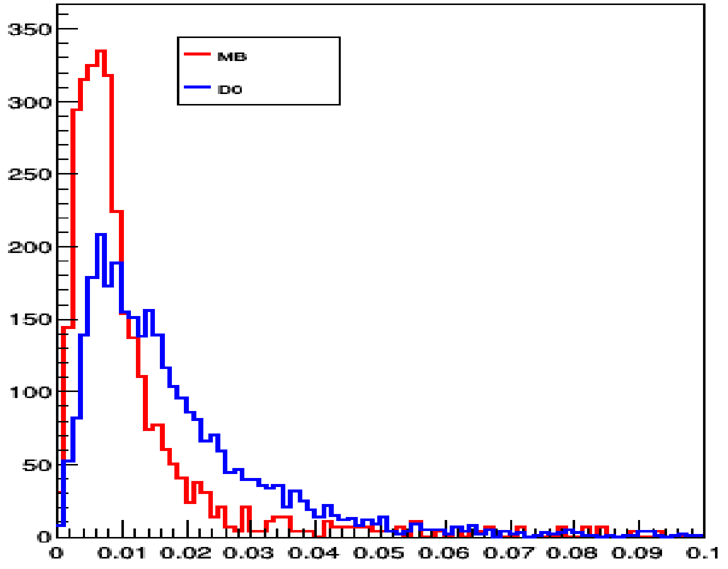
L/dL of V0 candidate



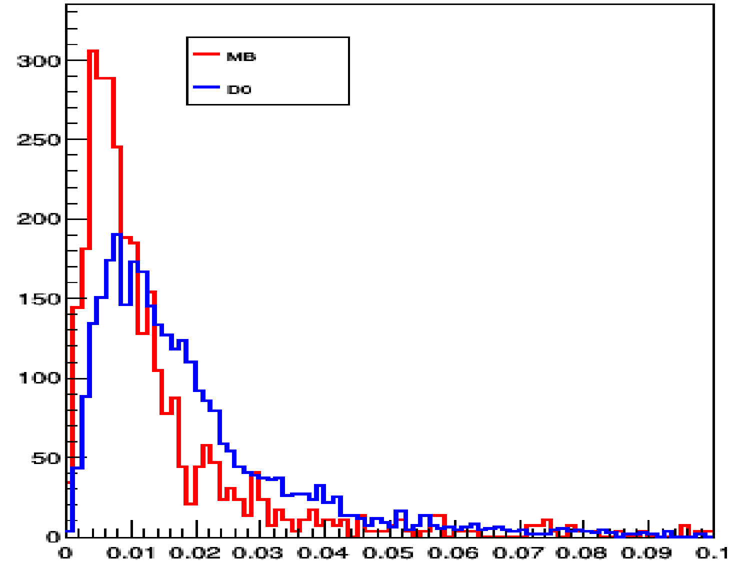
angle of V0 to PV



dist track1 vs PV



dist track2 vs PV



New selection cuts

1. add L/dL cut (>2.0) and angle between V0 candidate and line connected primary vertex and Secondary vertex

2. selection efficiency => ~$2.5*10^{-5}$ for Minimum Bias events and ~4.9% for D0 mesons

3. result $6.4*10^{4}$ MB vs 1 D^0 => ~1.6 Minimum Bias events vs ~0.049 D^0 events => ratio D^0 / MB ~3.0%

From SPD CDR:

“Figure 9.24 (a) presents the $K^- \pi^+$ invariant mass spectrum obtained as the result of such a selection for the D^0 -signal in the kinematic range $|x_F| > 0.2$ as an example for both variants of the VD after one year of data taking. About 96% of the $D^0 \to K - \pi +$ events were lost, while the combinatorial background under the D-meson peak was suppressed by 3 orders of magnitude. The signal-to-background ratio for D^0 is about 1.3% for the DSSD configuration and about 3.9% for the DSSD+MAPS one.”

Summary

1. new vertex detector options with 4 MAPS layers shows the same precision in vertex reconstruction as MAPS+DSSD configuration

2. new vertex detector options (MAPS, 4 layers) also provides better track momentum resolution

3. considered selection cuts give ~5% reconstruction efficiency for D^0 and provide the signal-to-background ratio for D^0 is about 3.0% for the MAPS+DSSD configuration

4. Plans:

   a) tune cuts on generator level and increase statistics (~10 times)

   b) optimize L/dL and angle cuts

   c) check additional cuts (track distance to PV)