Physics & MC meeting
7 July 2021

Reconstruction of D^0 meson in SPD experiment

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Main vertex detector options

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

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

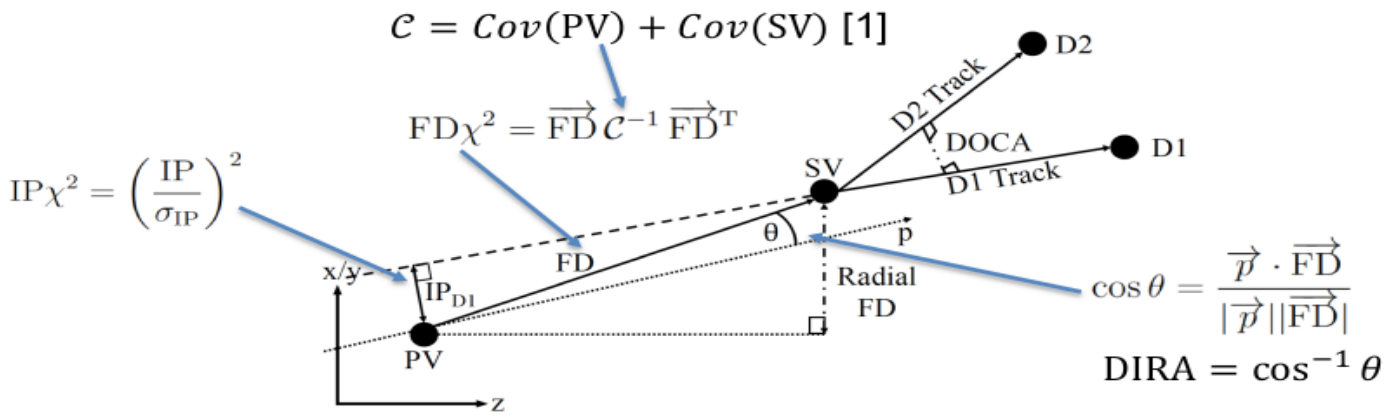
4. Errors
   MAPS: u = v = 4 mkm (effective)
   DSSD: u(z) = 23 mkm, v(x) = 11 mkm (effective)

5. v3 – option was considered in this study with connection of D^0 meson reconstruction

6. SPDroot is used for simulation of vertex and tracker detector response

7. KFParticle – package is used for reconstruction of V0 candidate

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

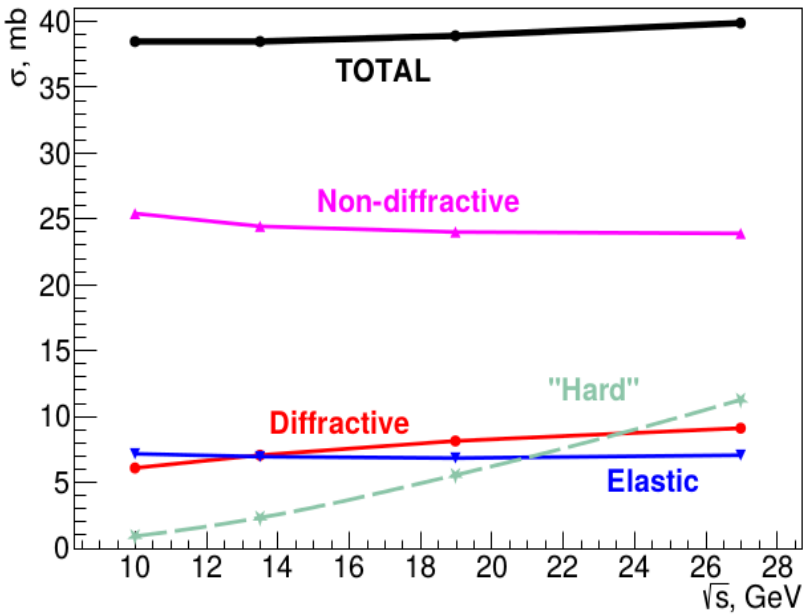
4. θ angle of daughter particle (K^-, pi+)

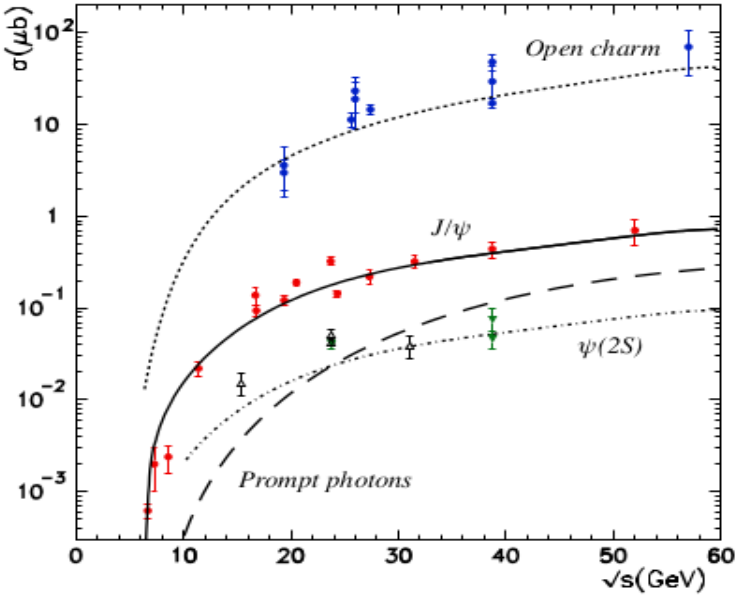
5. angle between V0 candidate and line connected primary and secondary vertex

6. Armenteros-Podolanski plot

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

1. consider $D^0 \to K^- \pi^+$ decay (BR 3.9 %) => cτ = 122.9 μm, M=1864,84 MeV/c²





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

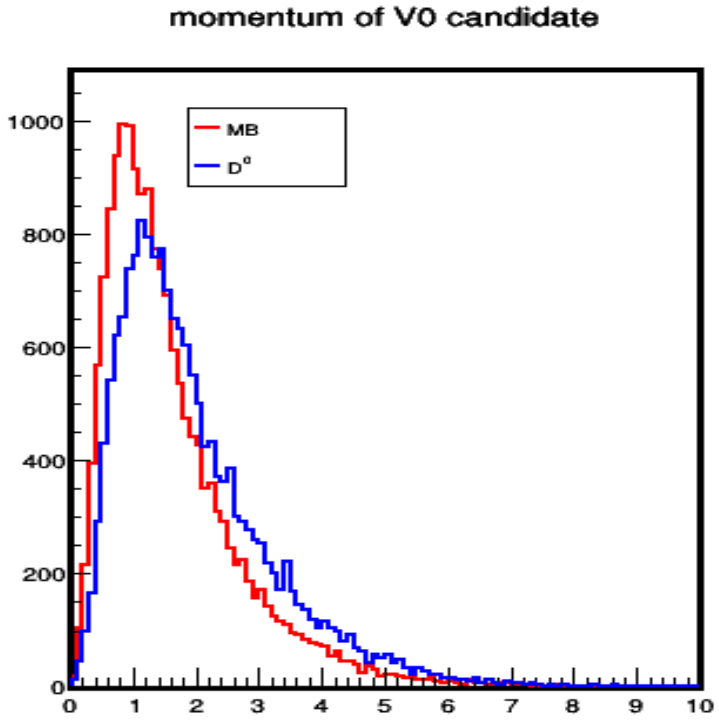
4. ~$6.4*10^4$ MB events and only 1 D^0 event with $D^0 \to K^- \pi^+$ decay mode

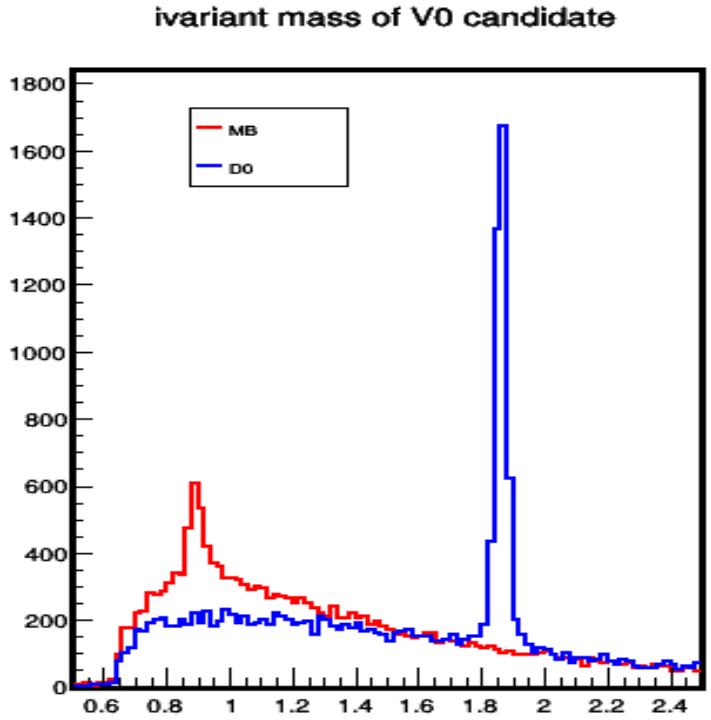
5. events with $|x_F| > 0.2$ are more interesting in our case

Selection cuts for $D^0 \rightarrow K\text{-}pi+$ (1-st step)

1. simulate 6000 D0 and 10000 MB events (without any cuts)

2. select (+-) pair with ideal particle identification (ID) for V0 candidate





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

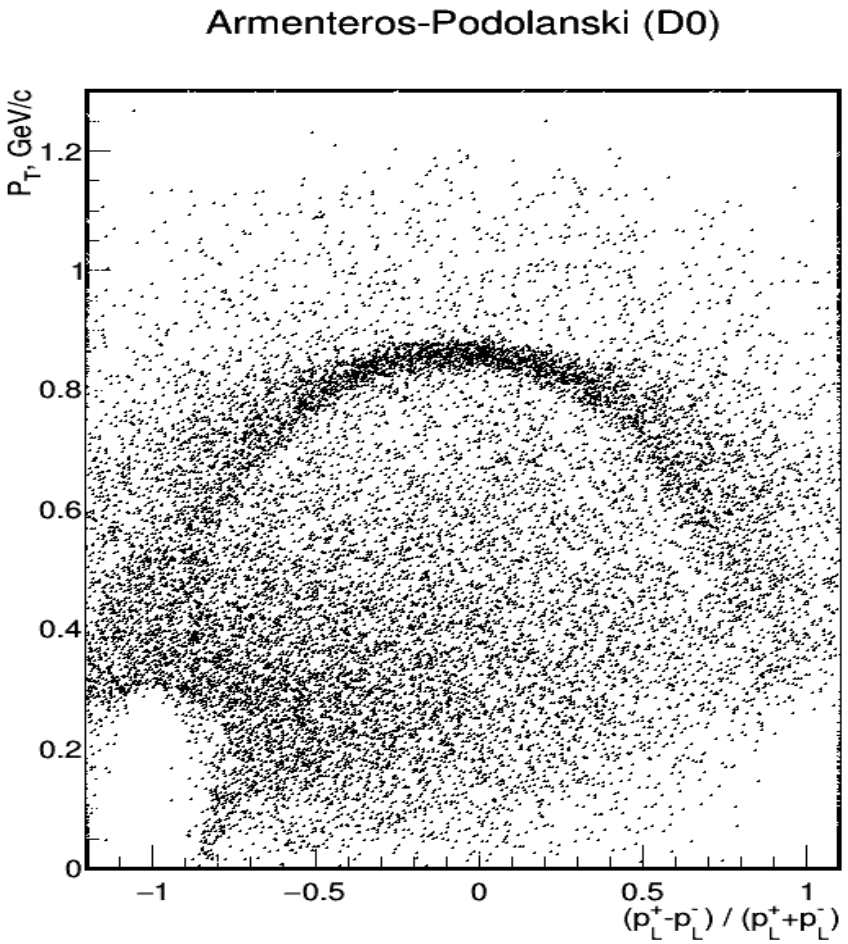
4. Armenteros-Podolanski band cut (cut1 < alfa1 < cut2) => MB (~16.5%) and D0 (~44%)

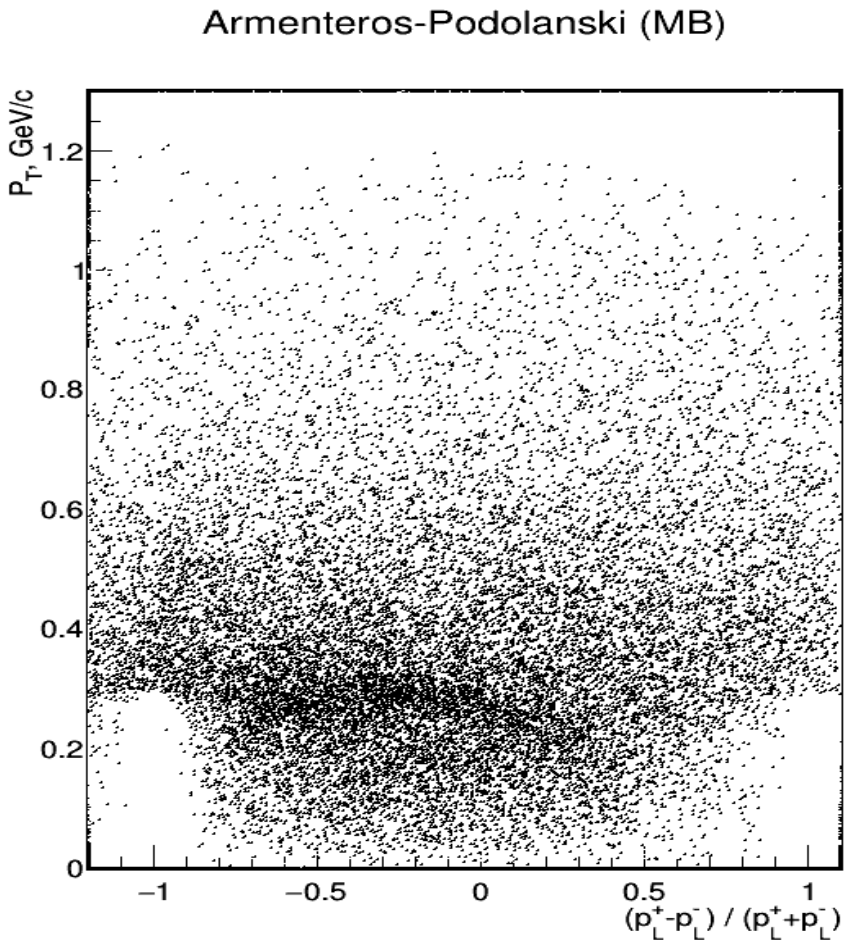
5. Armentros-Podolanski plot, band+range cut (|afa2| < 0.5) => MB (~2.5%) and D0 (~29%)

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

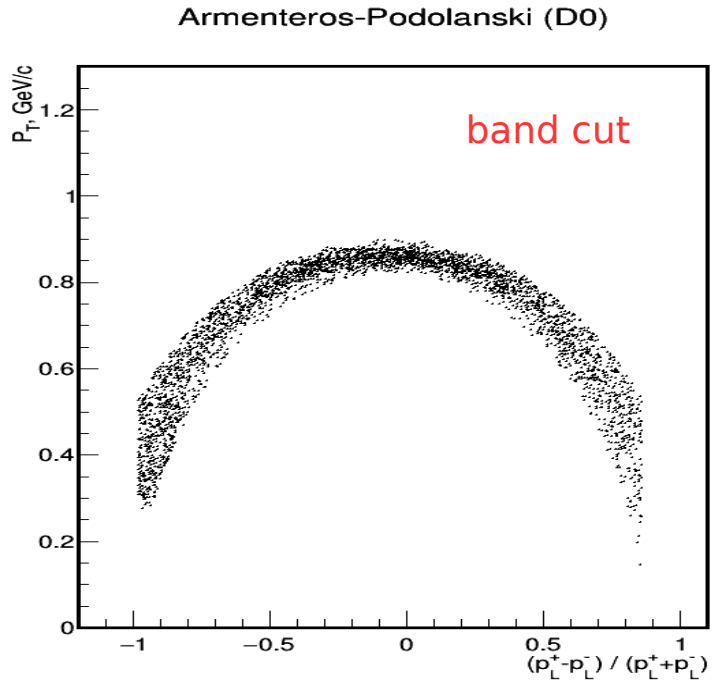
7. need to increase MB statistics essentially

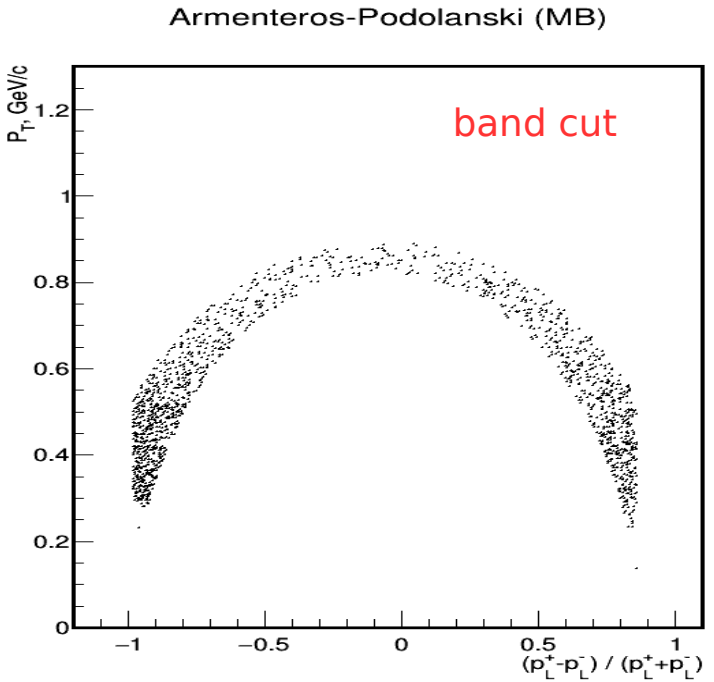
Armenteros-Podolaanski (without cut)

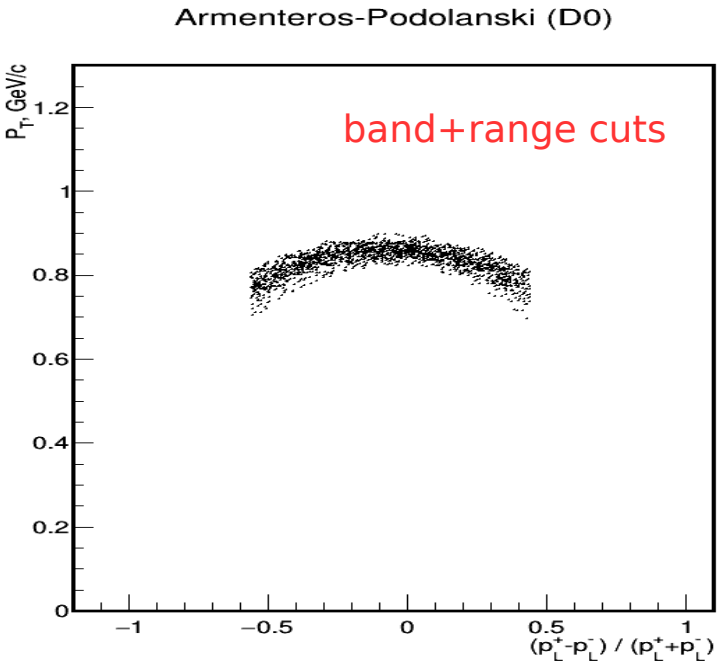


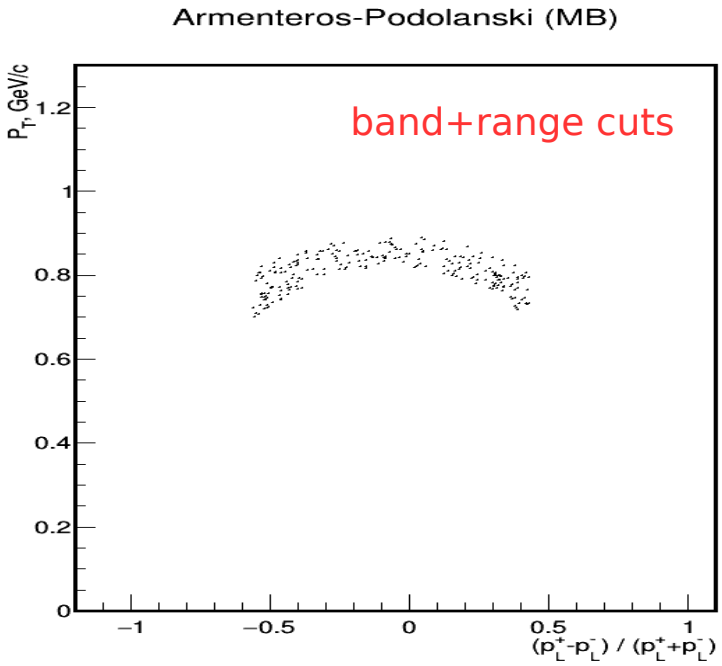


Armenteros-Podolanski plot (with band+range cut)









Next step of simulation

1. add some kinematic cuts on generator level

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

3. for MB sample:

   a) consider all possible (+-) pairs on generator level
   b) if momentum of any (+-) pair > 2.6 GeV/c => go to the step
   c) check band and range Armenteros-Podolanski cuts for each (+-) pair,
      if any of pair takes cuts => take the event
   d) all these selection cuts on generator level increase MB statistics ~95 times

4. 20000 of D^0 mesons and 105000 MB events were simulated

5. effective number of events => ~50000 for D^0 and ~10^7 for MB

6. suggestion: at momentum p <= 2.5 GeV/c there is ideal particle ID, but p > 2.5 GeV/c all negative particles are considered as K- and all positive particle -> pi+

7. after applying V0 momentum cut (p>2.7 GeV/c) + band and range Armeteros-Podolanski cuts + invariant mass cut of V0, inside 3*σ (σ ~ 0.020 GeV/c^2):
   (take cuts: => 4140 events from 10^7 Minimum Bias and 6283 events from 5*10^4 D0 events)

   suppression efficiency =>~4.1*10^{-4} MB and selection efficiency ~12.6% for D0

8. as the result 6.4*10^4 MB vs 1 D^0 => ~27 MB events vs 0.126 D^0 events inside 3*σ cuts
   (S/B ~0.48%)

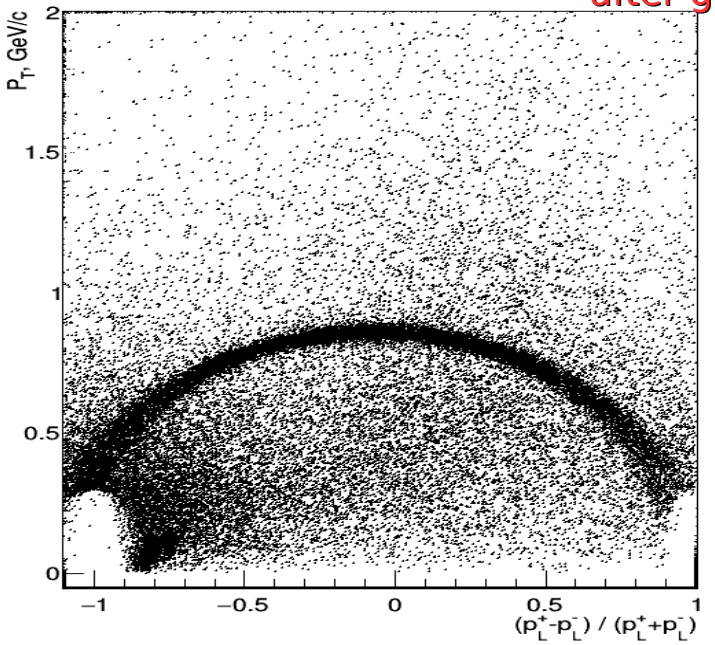
9. need to find additional new cuts

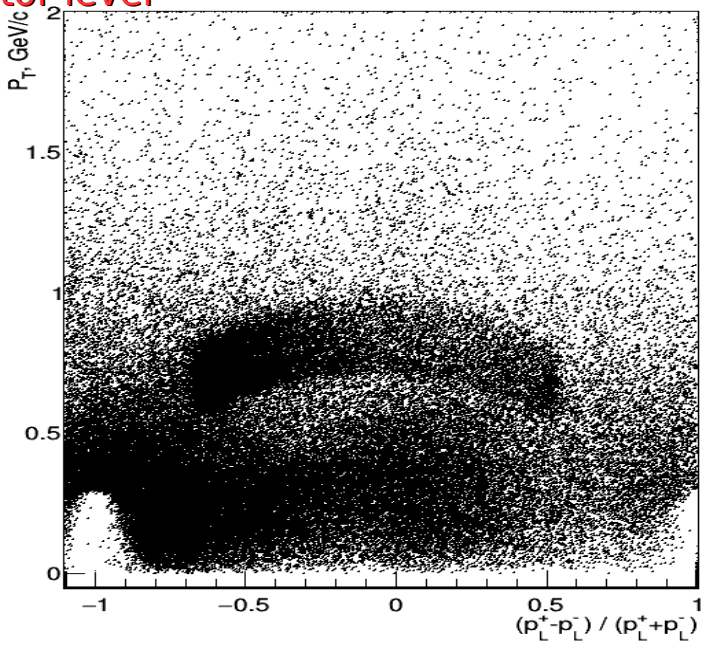
Armenteros-Podolaanski plot for (+-) pair

Armenteros-Podolanski (D0)

Armenteros-Podolanski (MB)

after generator level

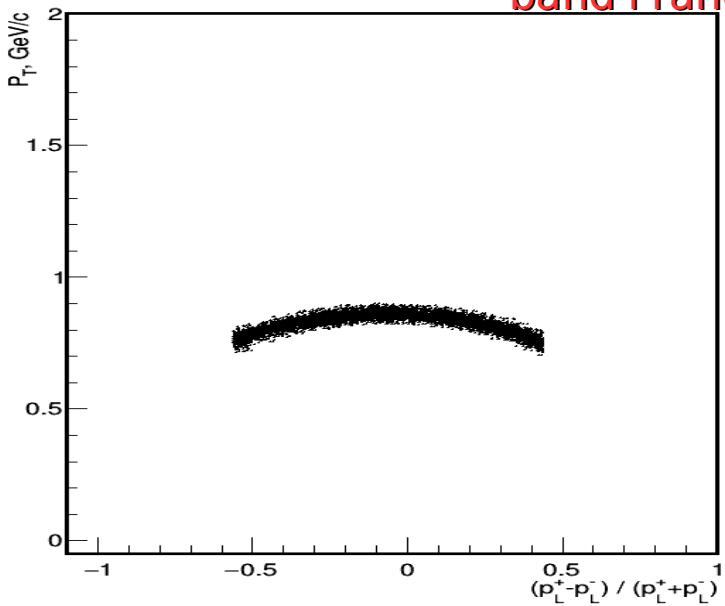


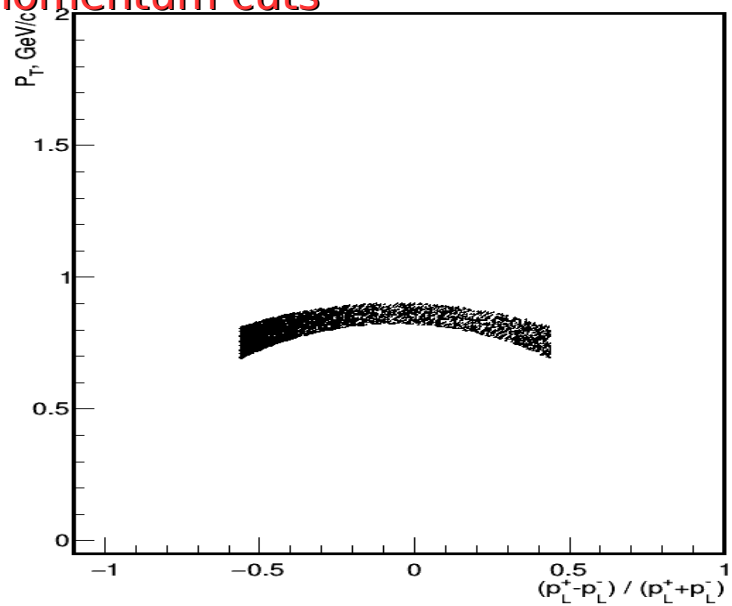


Armenteros-Podolanski (D0)

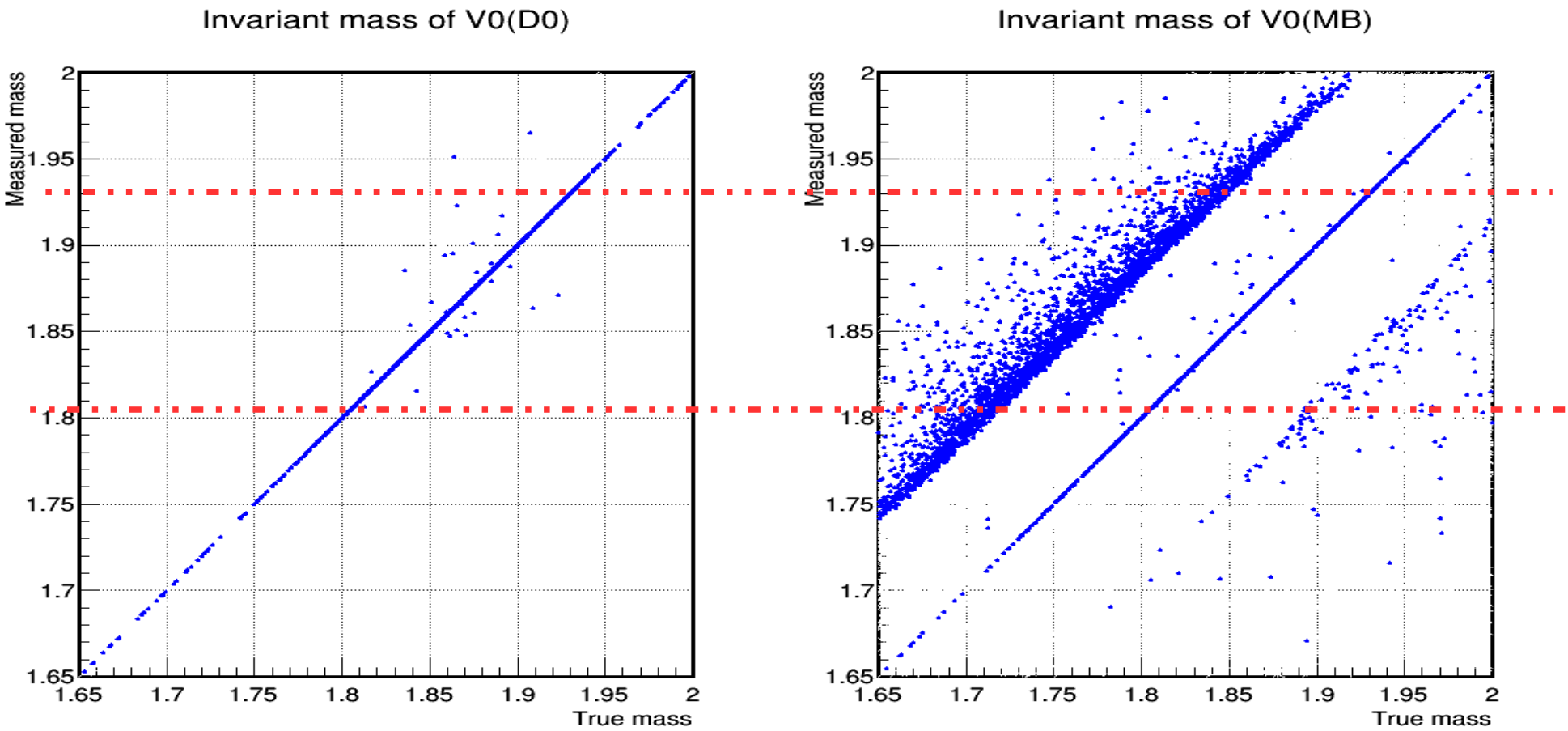
Armenteros-Podolanski (MB)

band+range+momentum cuts





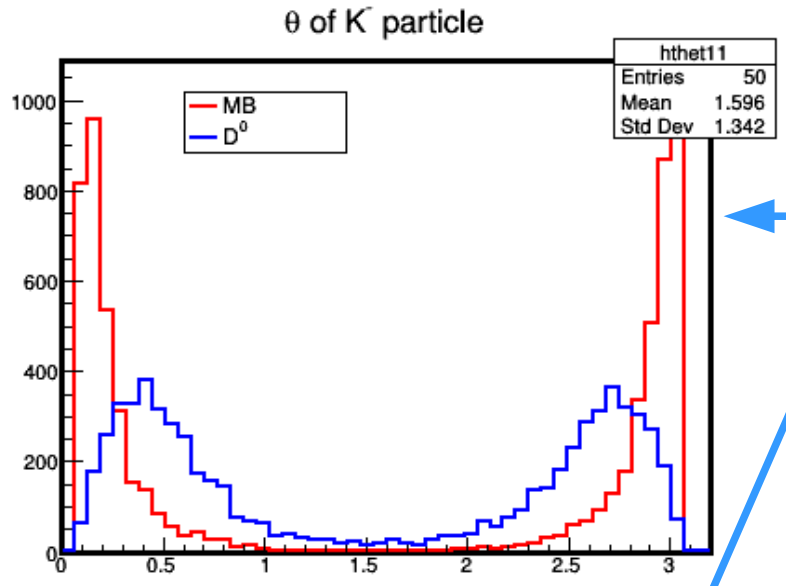
Measured invariant mass vs true mass for (+-) pairs



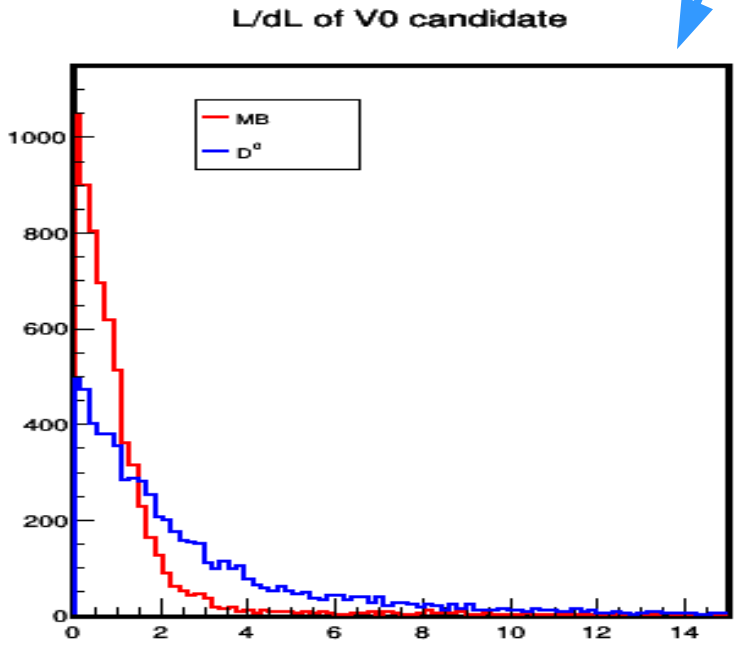
1. measured invariant mass means that all negative particles with p>2.5 GeV/c are considered as K^- and all positive particles with p>2.5 GeV/c are considered as positive pions otherwise used the true mass hypothesis

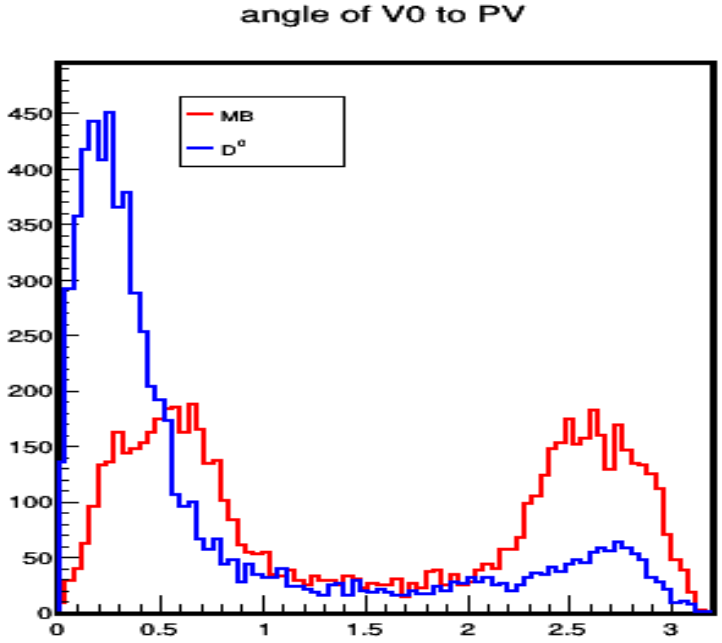
2. red band means 3*σ cuts around nominal D^0 mass

Next important variables for selection (1)

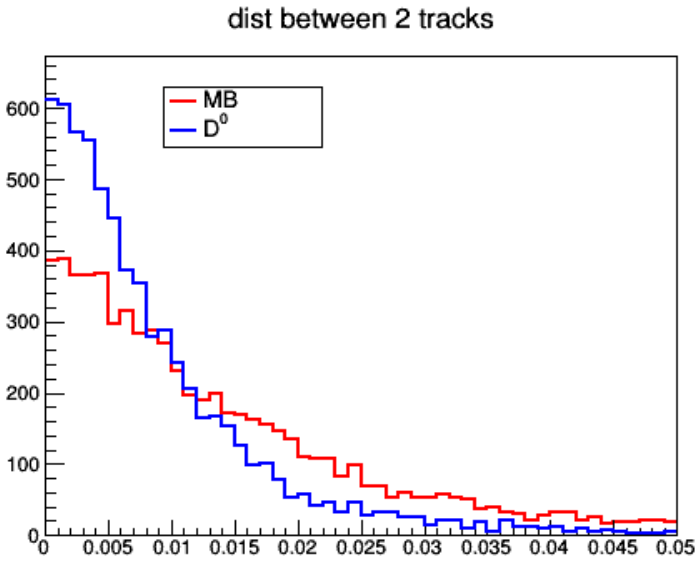


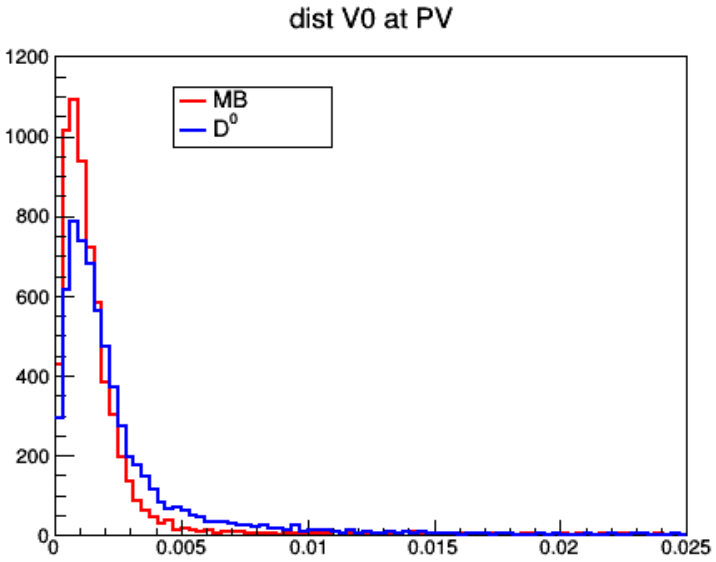
1. θ angle of negative particle (K^-) of V0 candidate
2. normalized decay length (L/dL) of V0 candidate
3. angle of V0 candidate to primary vertex

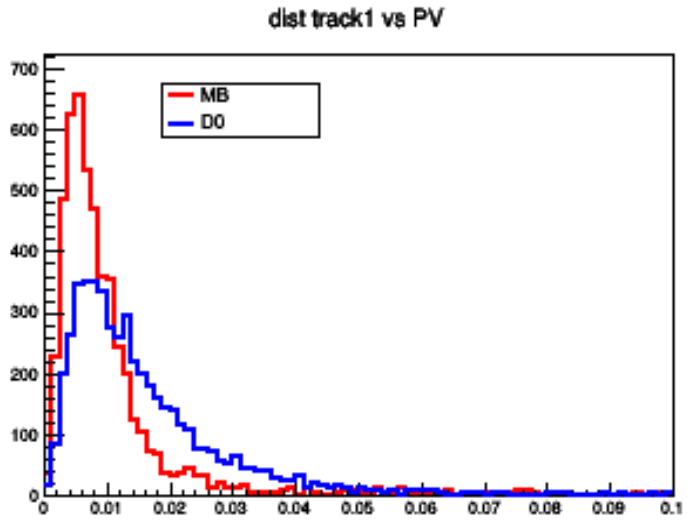


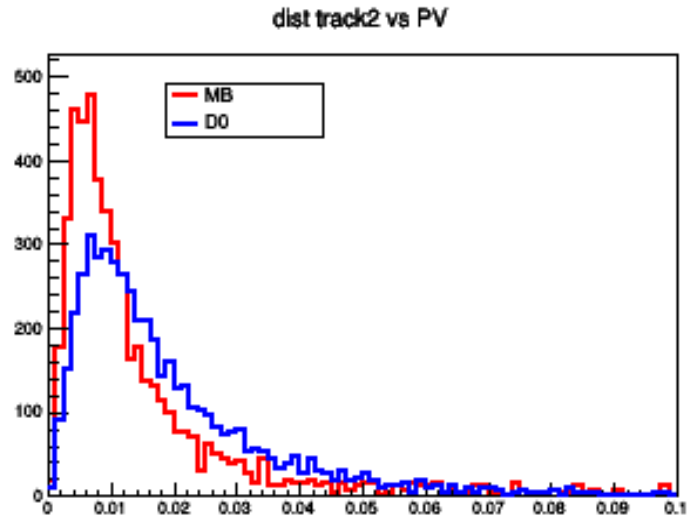


Next important variables for selection (2)









1. minimum distance between secondary tracks in V0 candidate (left-top picture)

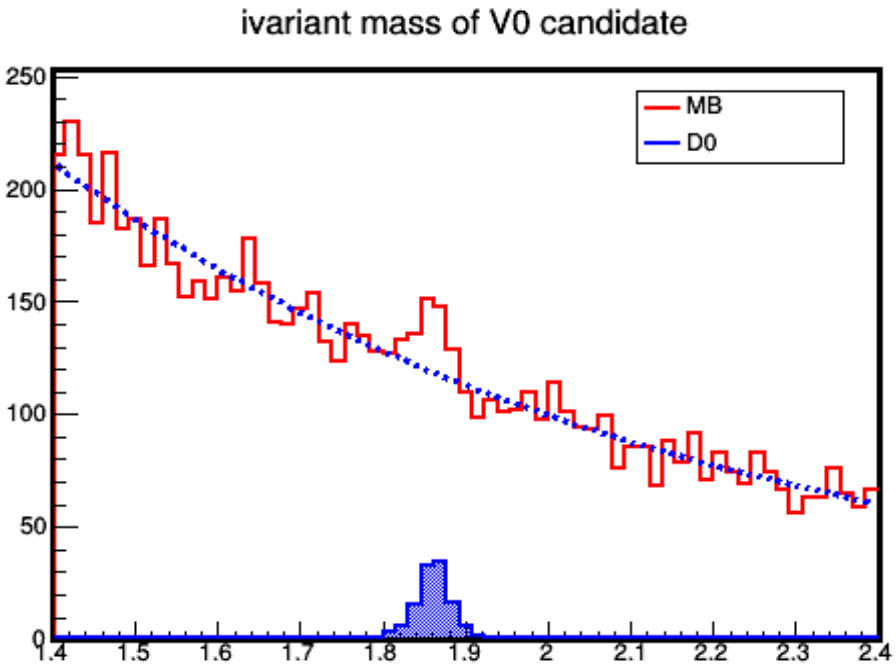
2. minimum distance of secondary tracks to primary vertex (bottom two pictures)

Applying additional selection cuts

1. check additional cuts L/dL >1.5 (>2.0) (>3.0) and cut on angle between V0 candidate and line connected primary vertex (PV) and secondary vertex (SV)

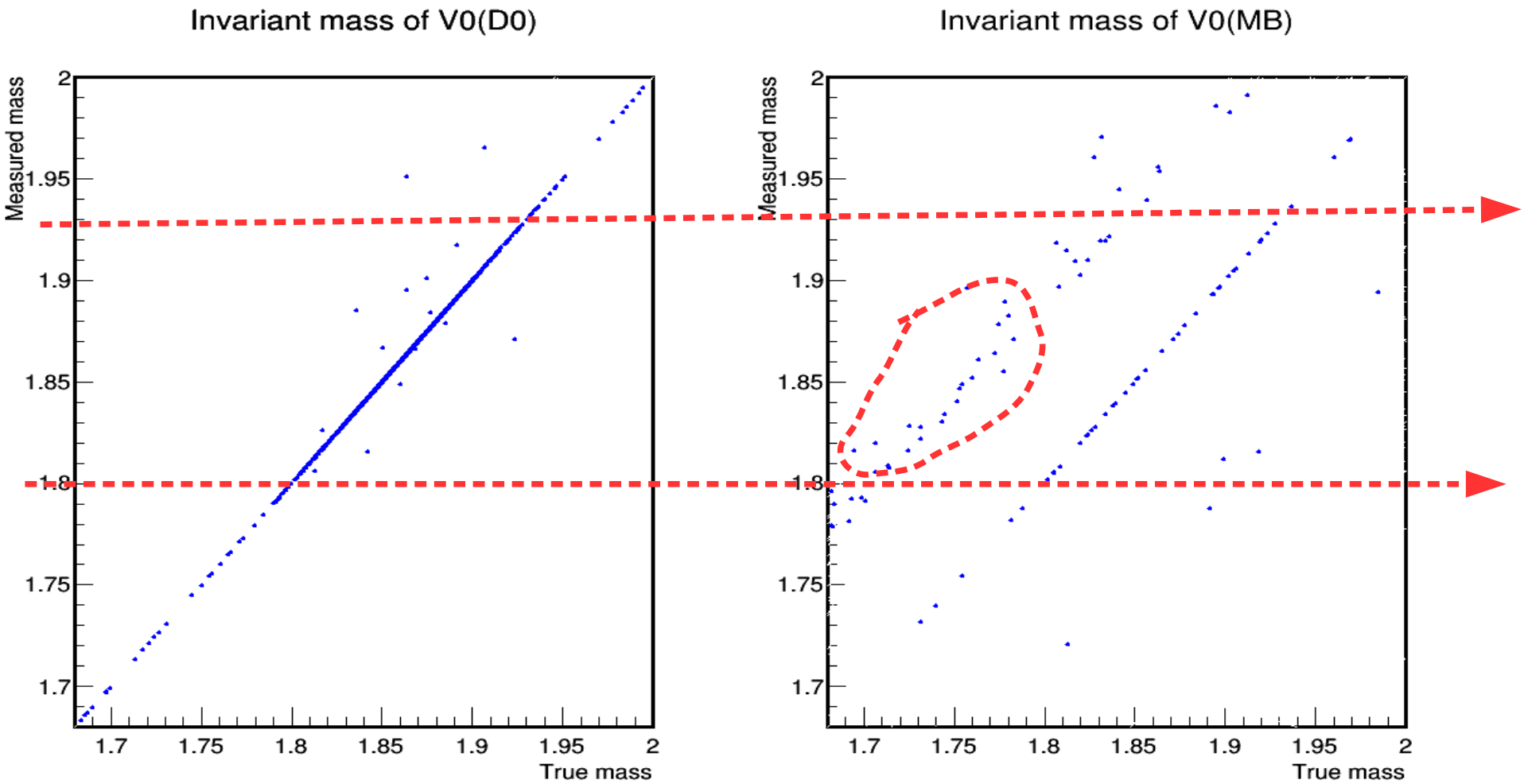
2. we received only 91 (55) (22) Minimum Bias from 10^7 simulated events and 2509 (2060) (1438) D^0 from 50000 simulated events => suppression factor => ~$9.1*10^{-6}$ (~$5.5*10^{-6}$), (~$2.2*10^{-6}$) for MB and selection efficiency ~5.0% (~4.1%), (~2.88%) for D0 mesons

3. result $6.4*10^4$ MB vs 1 D^0 => ~0.58 (~0.35), (~0.14) Minimum Bias events vs ~0.050 (~0.041), (~0.0288) D^0 events => ratio S/B => D^0 / MB ~8.6% (~11.7%), (~20.4%)



S/B => ~10% inside 3*σ range

Measured invariant mass vs true mass for (+-) pairs, after all selection cuts



1. measured invariant mass means that all negative particles with p>2.5 GeV/c are considered as K^- and all positive particles with p>2.5 GeV/c are considered as positive pions otherwise used the true mass hypothesis

2. red band means 3*σ cuts around nominal D^0 mass
3. point inside red area => wrong particle ID (additional input to background)

Applying additional selection cuts (comparison ideal and «real» particle ID)

1. check additional cut L/dL >1.5 (>2.0) (>3.0) and cut on angle between V0 candidate and line connected primary vertex (PV) and secondary vertex (SV)

2. ideal => 60 (40) (20); “real” => 91 (55) (22) MB from 10^7 simulated events

3. ideal =>2511 (2062) (1440); “real” => 2509 (2060) (1438) D^0 from 50000 simulated events

4. suppression factor=>ideal => $6*10^{-6}$ ($4*10^{-6}$) ($2*10^{-6}$);“real”=>~$9.1*10^{-6}$ (~$5.5*10^{-6}$) (~$2.2*10^{-6}$) for MB

5. ratio S/B => D^0 / MB: ideal => ~13% (~16.1%) (~22.5%); “real” => ~8.6% (~11.7%), (~20.4%)

Summary

1. set of cuts are considered for suppression MB events and selection of D0 mesons

2. these cuts provide ~5% (~4.1%) (~2.9%) reconstruction efficiency for D^0 (for L/dL >1.5, 2.0 and 3.0)

3. the signal-to-background ratio (S/B) for D^0 inside 3*σ range is about ~8.6% (~11.7%) (~20.4%) for the MAPS+DSSD configuration (for L/dL > 1.5, 2.0 and 3.0)

3. also, need to take in mind that ~5-8% events in selected D0 sample is from wrong particles combination