
SPD Physics & MC meeting
22 March 2023

# Reconstruction of $D^0$ meson in SPD experiment

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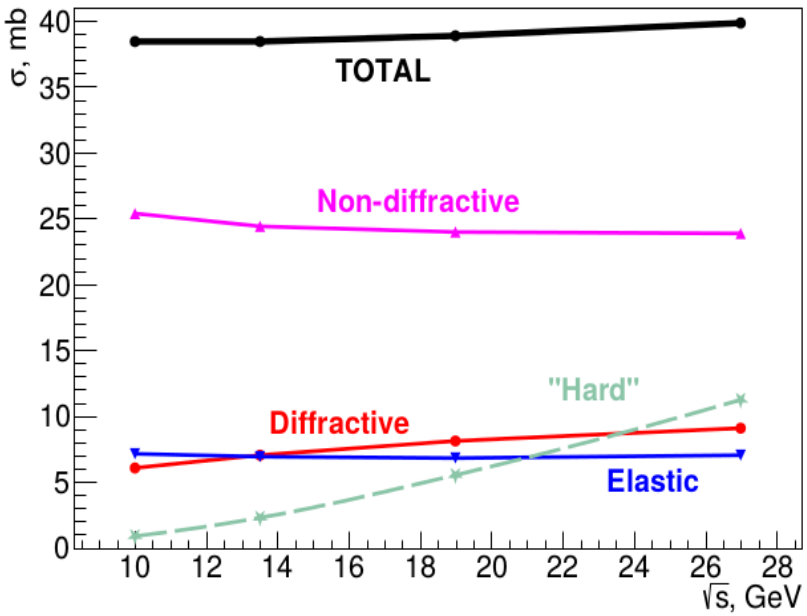
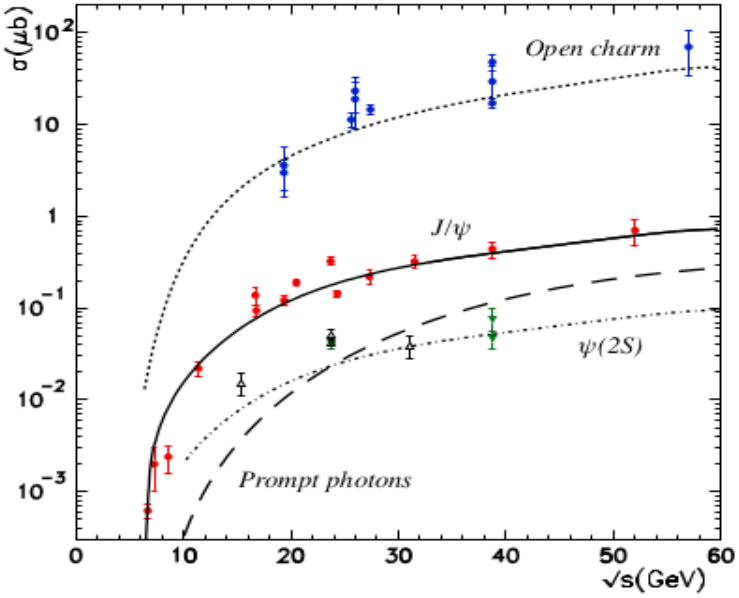
# Vertex detector configuration

1. MAPS – 4 layers (c.t. = 300 μm thickness for one layer) => default option
2. Errors – MAPS => default option
3. PYTHIA8 – is used for generation MB and open charm production
4. SPDroot is used for simulation of vertex and tracker detector response
5. KFParticle – package is used for reconstruction of V0 candidate

# 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 open charm production ~14 μb

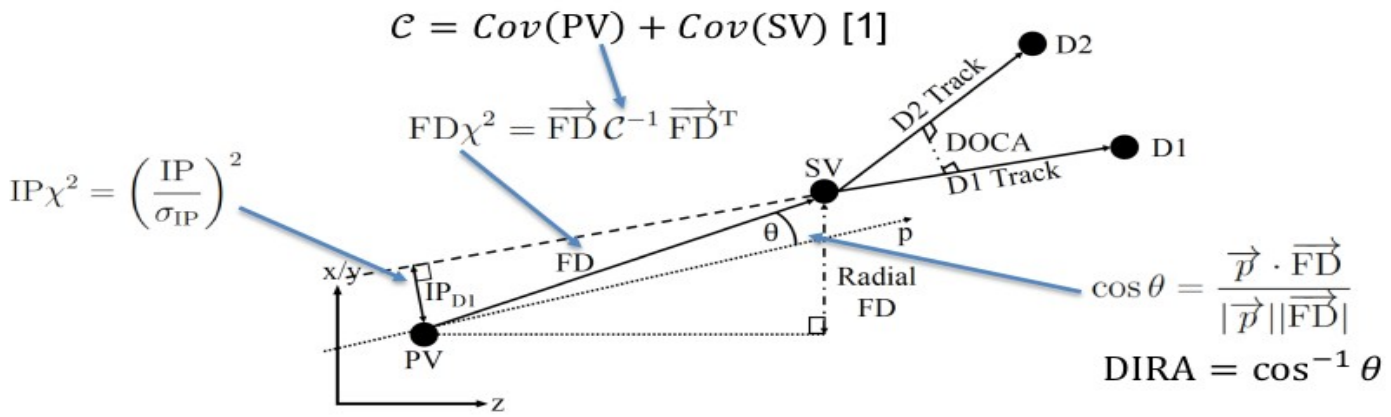
3. ~2.5*10³ MB events and only 1 $D^0$ event

4. ~6.4*10⁴ MB events and only 1 $D^0$ event with taking into account BR (3.9 %, for $D^0 \to K^- \pi^+$ )

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

6. and events inside ~3*σ cuts around $D^0$ mass value, 1.765 GeV/c² < $M_{V0}$ < 1.965 GeV/c²

# Possible selection cuts for $D^0 \to K^- \pi^+$




1. distance between 2 daughter particles (DCA – distance of closest approach)

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. L – decay length of V0 candidate

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

5. θ angle between daughter particles ($K^-$, pi+)

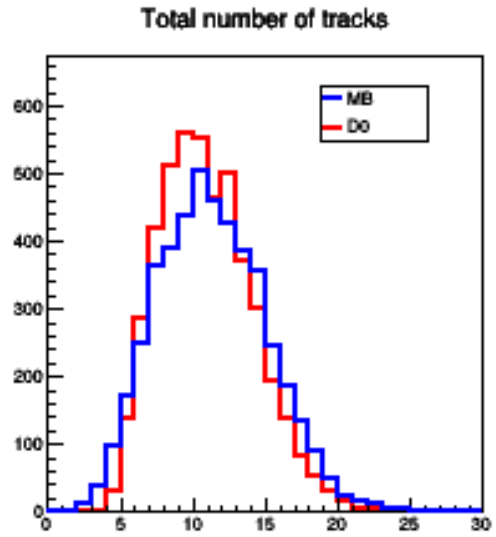
6. angle between V0 candidate and line connected primary and secondary vertex

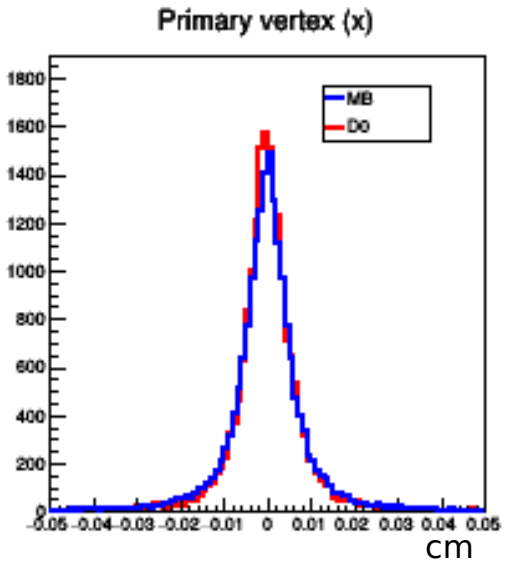
7. DCA of V0 and daughter particles to PV

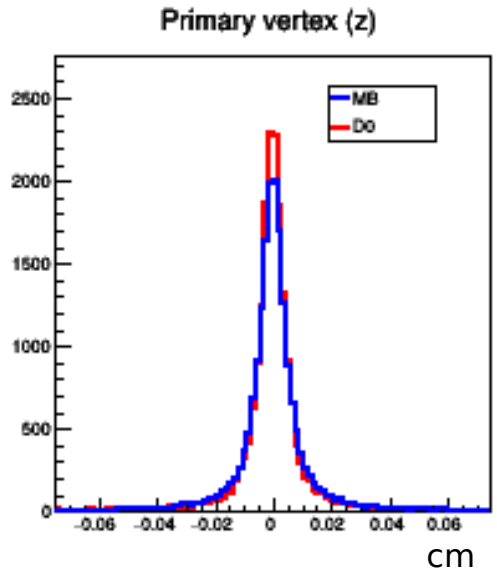
# General view MB and $D^0$ (1)

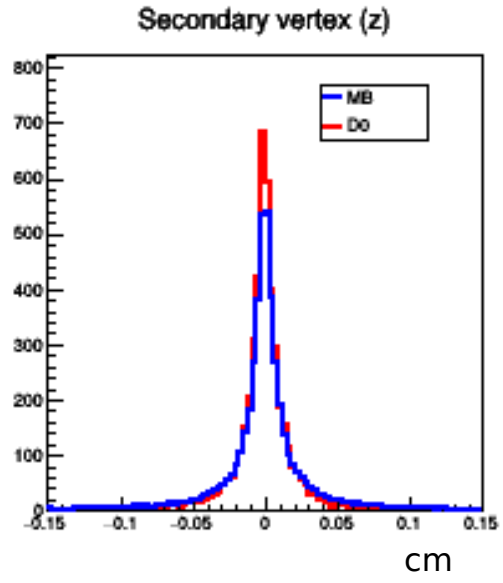
1. simulate 20000 D0 and 80000 MB events (without any cuts)

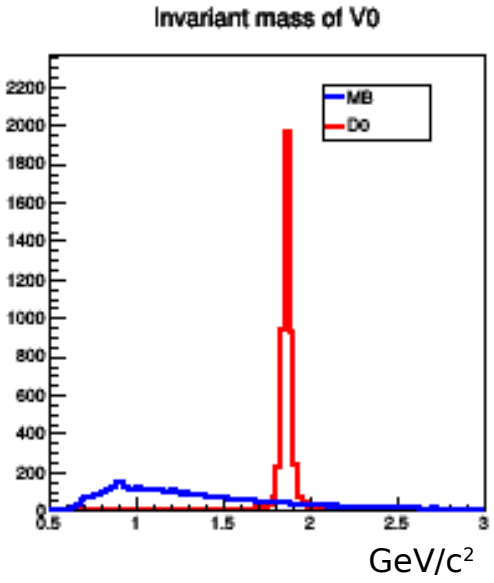
2. select (K- pi+) pairs with ideal particle identification (ID) for V0 candidate

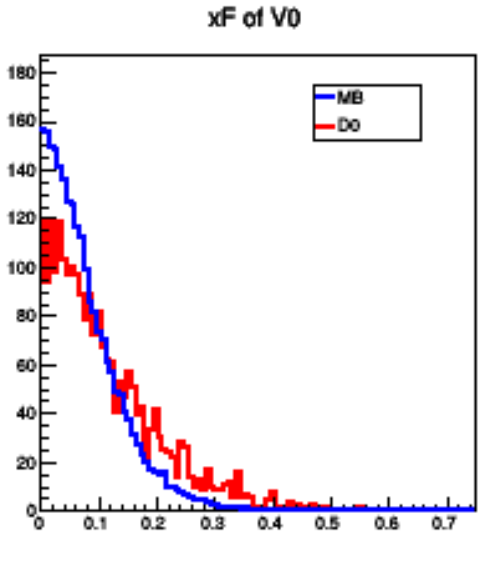


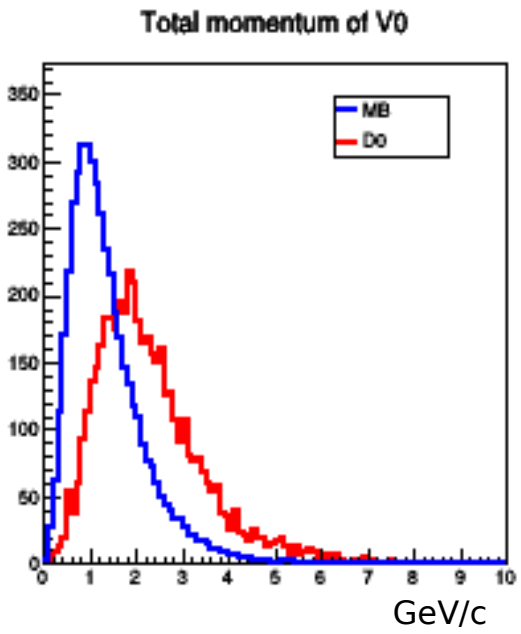



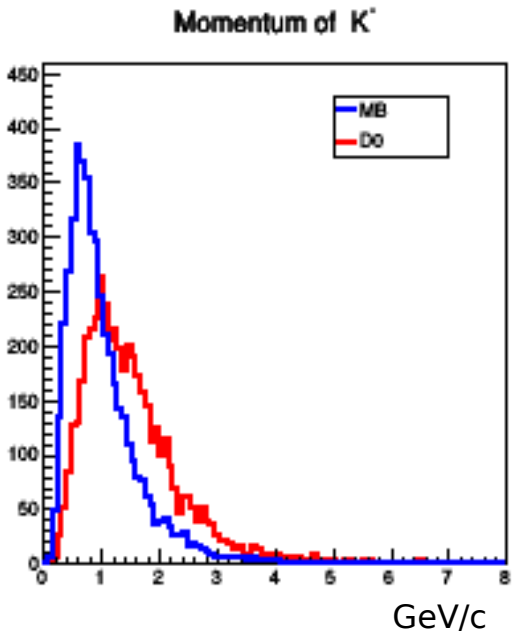



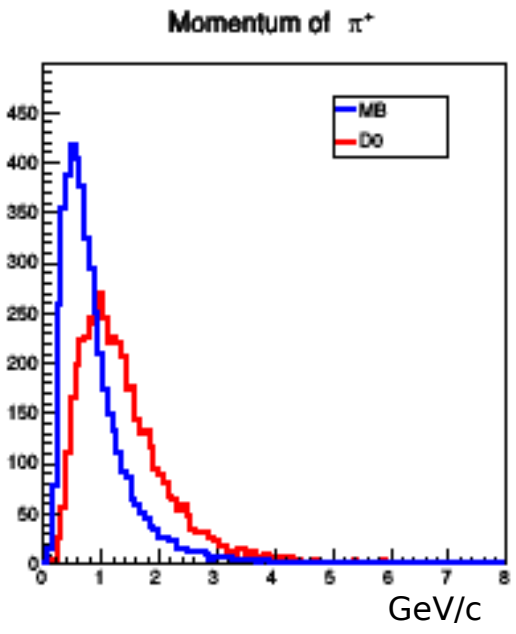



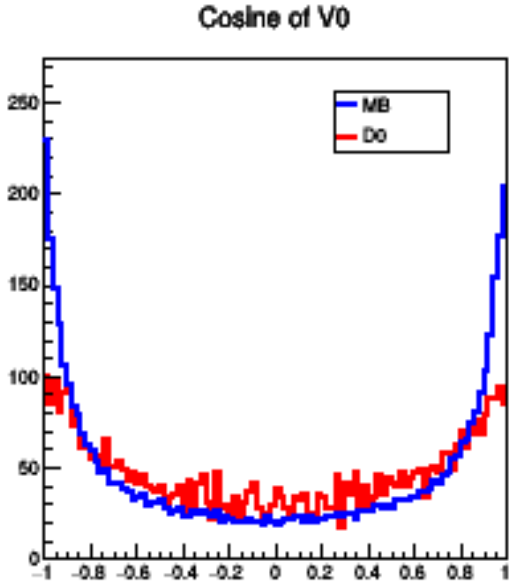



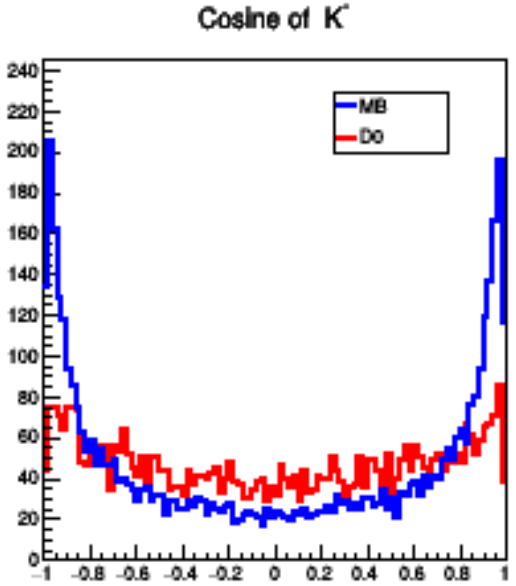
# General view, MB and $D^0$ (2)

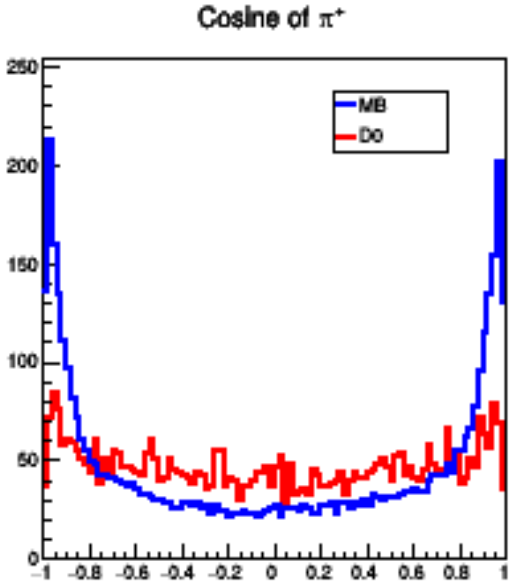


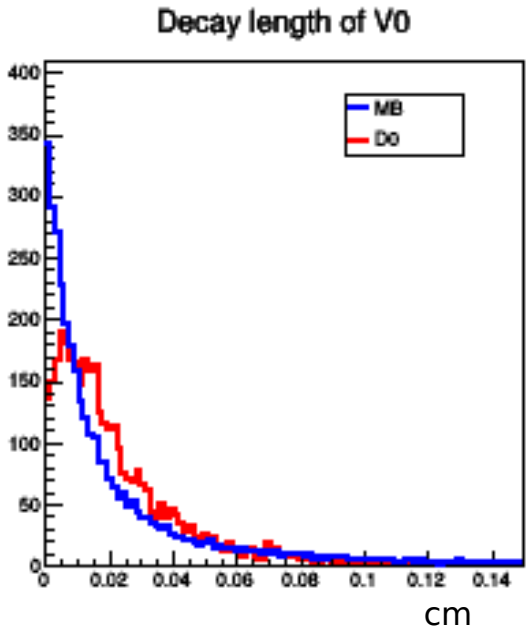



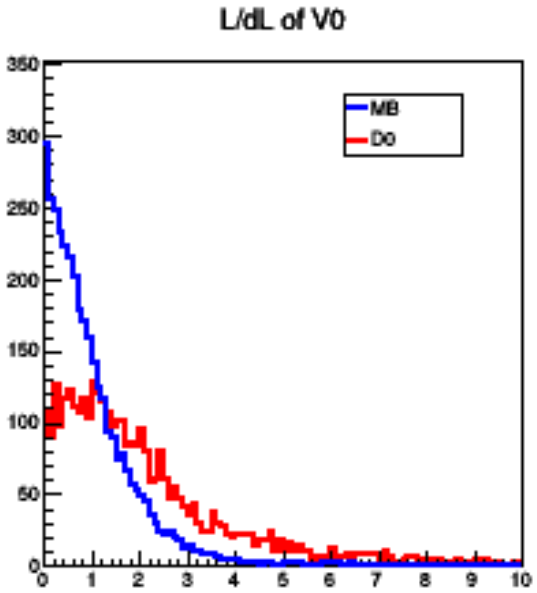



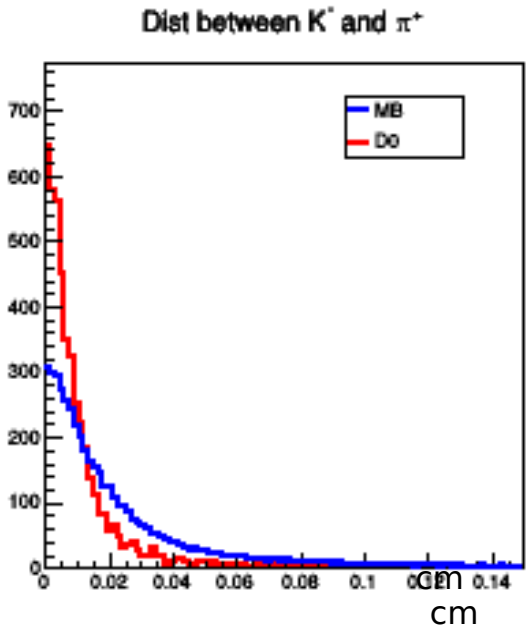



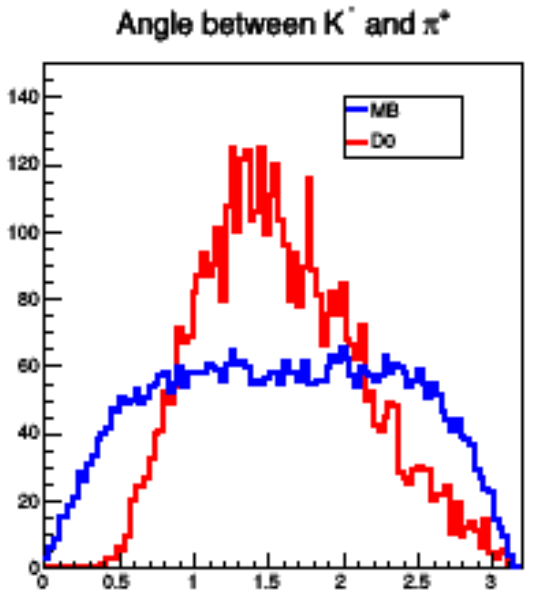



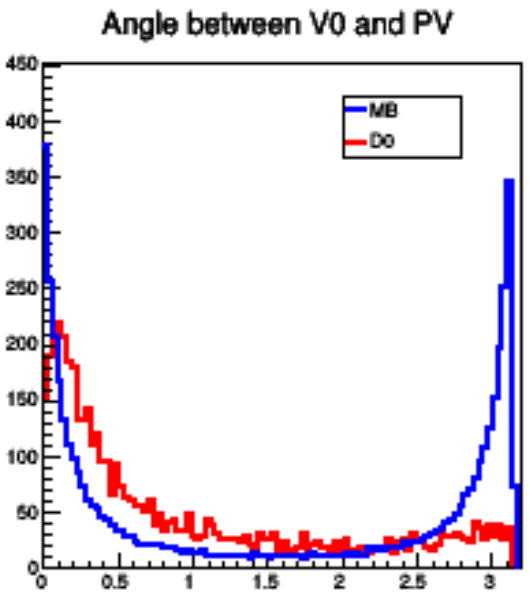
# General view, MB and $D^0$ (3)



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

1. simulate 20000 D0 and 80000 MB events (without cuts)

2. after reconstruction procedure:
MB => 44602 (K- pi+) pairs => ~55.8 %
D0 =>  4653 (K- pi+) pairs => ~23.3 %

3. apply Δm and xF cuts:

MB => 185 (K- pi+) pairs => $2.3*10^{-3}$ ( ~0.23%)
D0 =>  673 (K- pi+) pairs => $3.4*10^{-2}$ ( ~3.4 %)

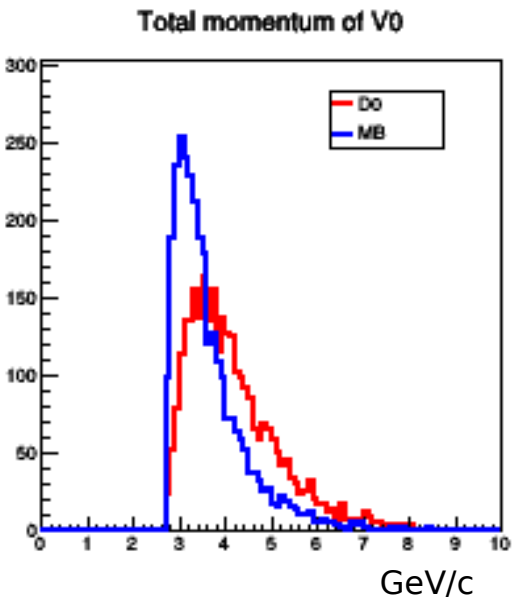
4. need more statistics

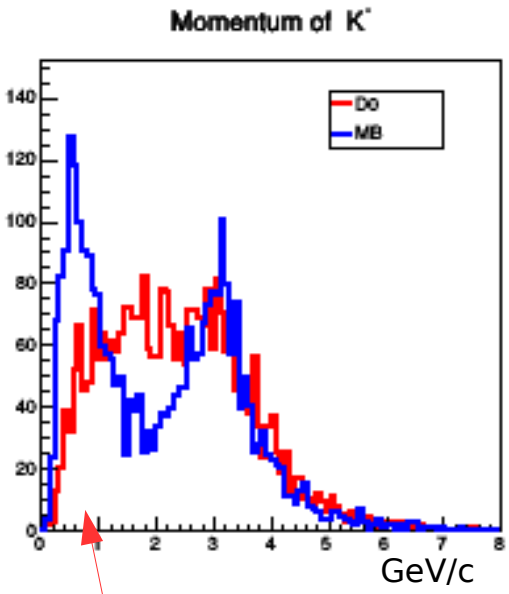
5. next step => apply cuts on generator level:
   a) MB – generation:
      - loop over particles and find $K^-$ or pi+ ;
      - then loop over others particles and find $\pi^+$ or $K^-$ ;
      - construct V0 particle from (K- pi+) pair;
      - check invariant mass => 1.70 < M < 2.0;
      - check | xF | > 0.18;
      - these cuts give => ~25 increasing statistics;
      - were generated 80000 MB events => ~ 1978242 effective MB events
   b) D0 – generation:
      - check | xF | > 0.18;
      - this gives => ~4.4 increasing statistics;
      - were generated 20000 D0 events => ~87216 effective D0 events

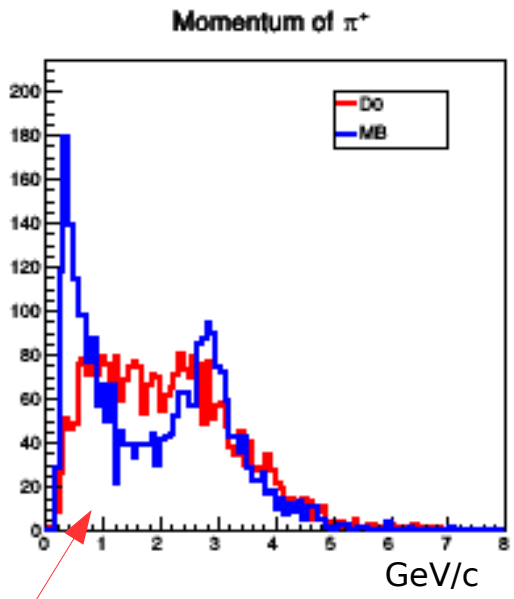
6. apply Δm and xF cuts:

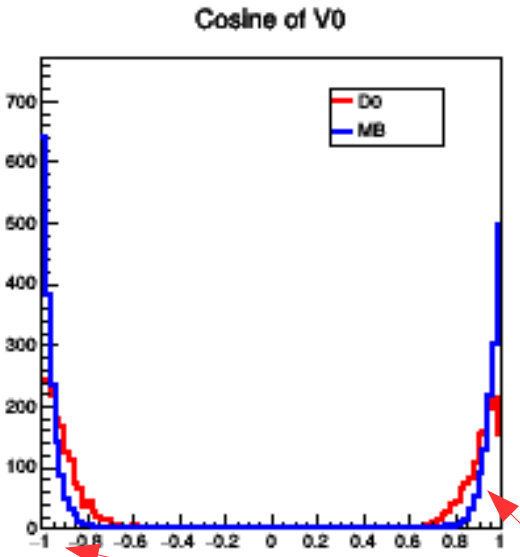
MB => 3376 (K- pi+) pairs => ~ $1.7*10^{-3}$ ( 0.17 %)
D0 =>  2960 (K- pi+) pairs => ~$3.4*10^{-2}$ ( 3.4 % )

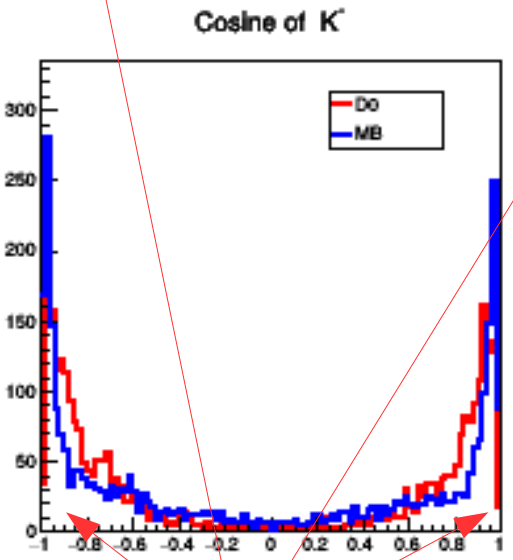
# Selection cuts for $D^0 \rightarrow K^- \pi^+$ (2)

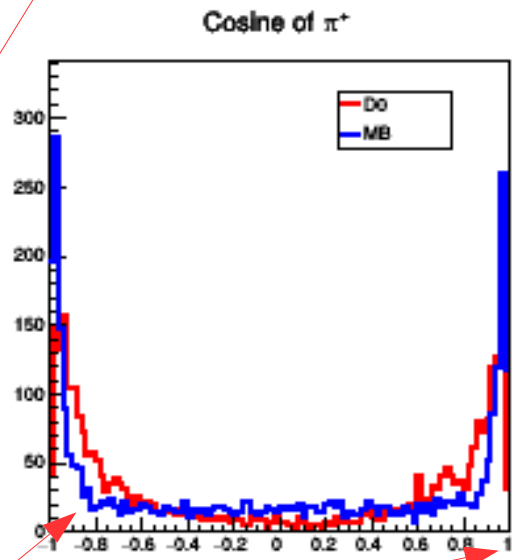


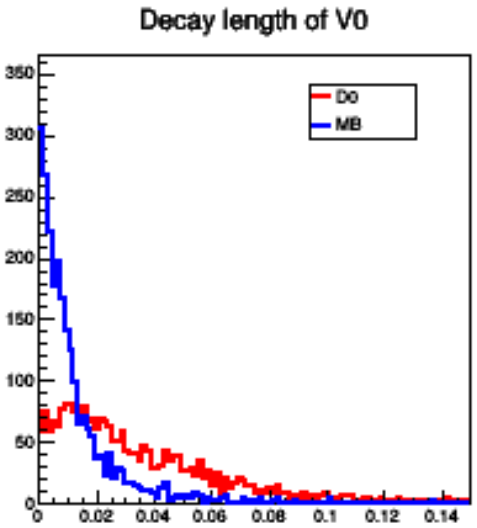



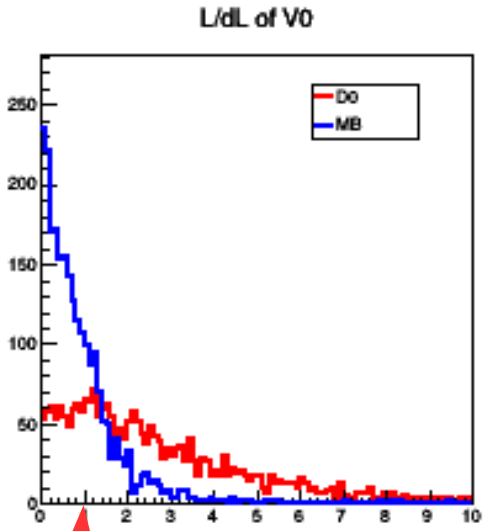



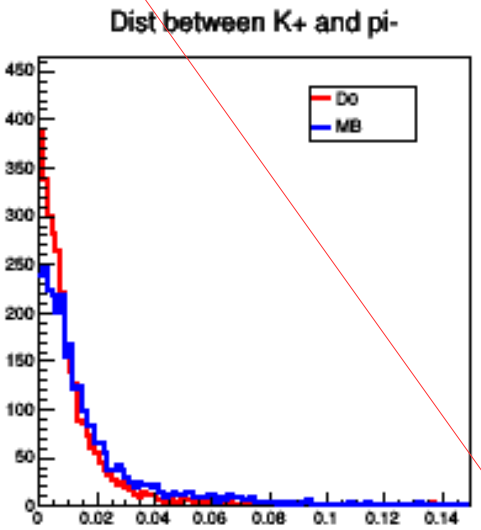



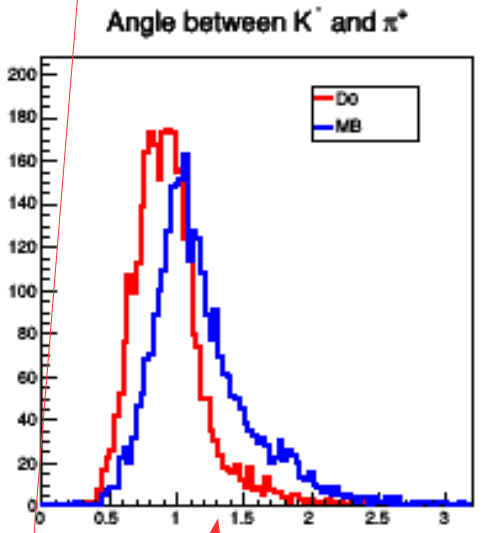

possible useful cuts

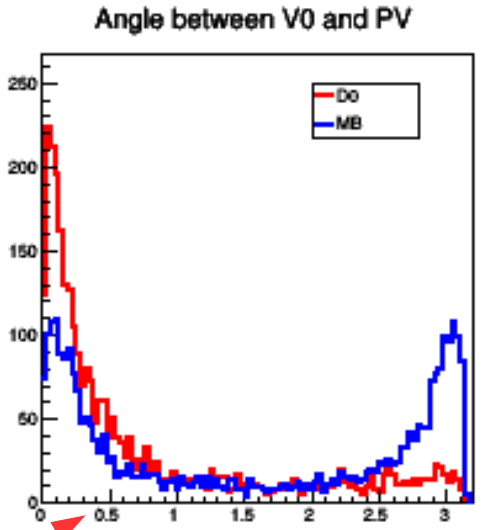
# Selection cuts for $D^0 \rightarrow K^-\pi^+$ (3)



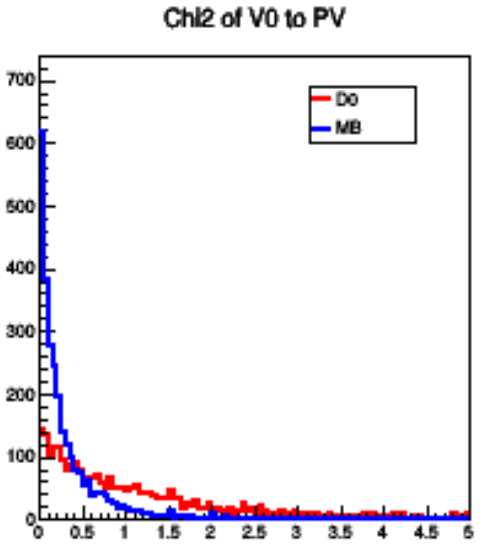



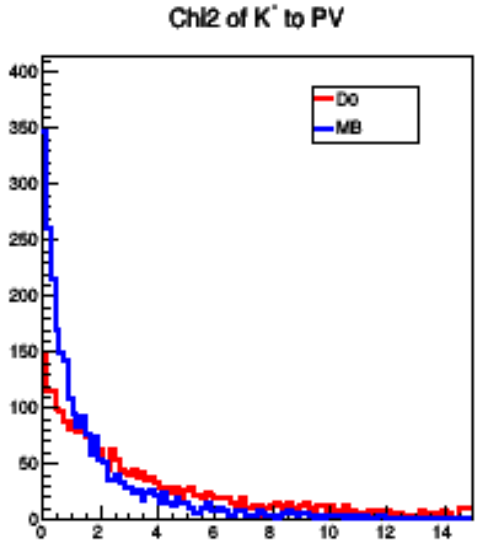



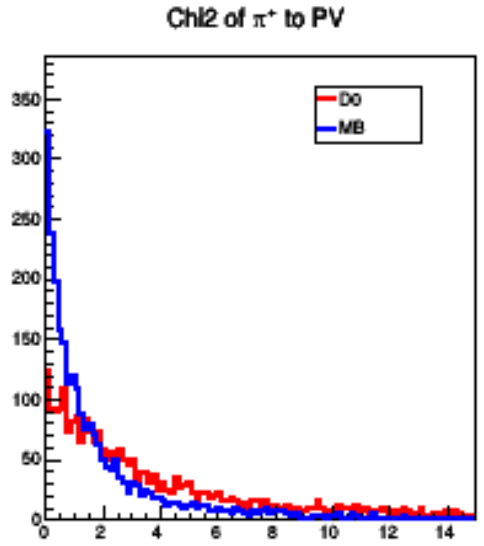



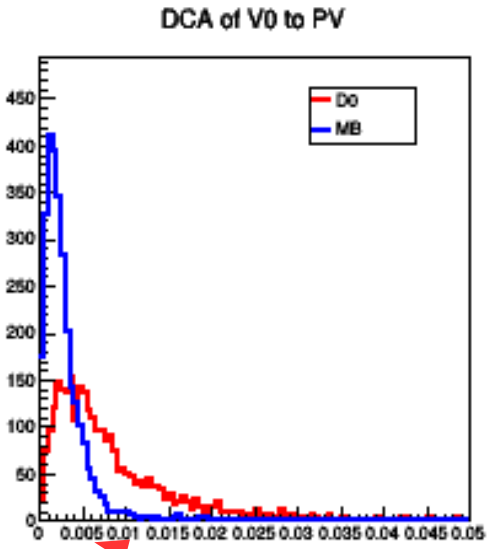

Possible useful cuts

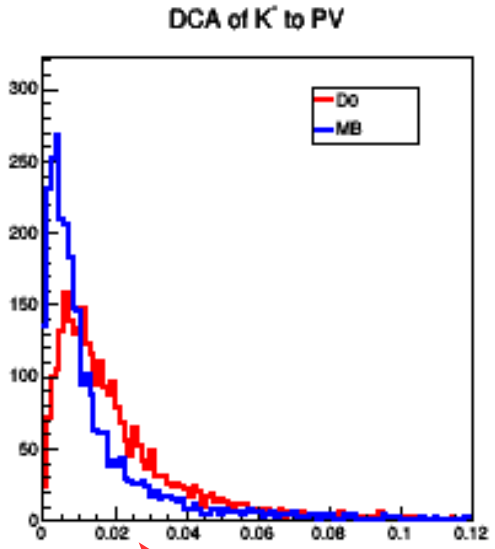
# Selection cuts for $D^0 \rightarrow K^-\pi^+$ (4)

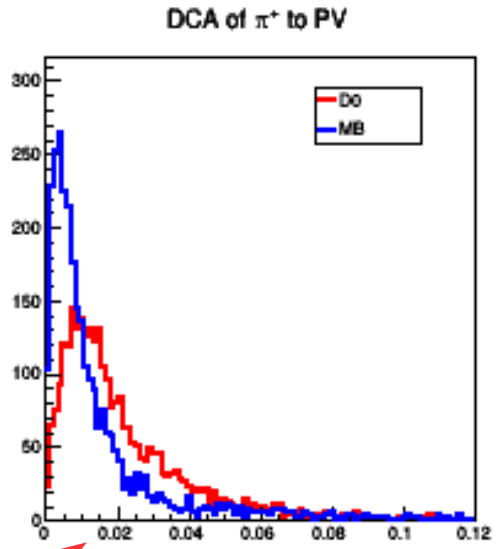



Possible useful cuts

# First pleliminary results

1. add some kinematic cuts on generator level

2. were generated 80000 MB events => ~ 1978242 effective MB events

3. were generated 20000 D0 events => ~ 87216 effective D0 events

4. apply Δm and xF cuts:

   MB => 3376 ($K^-$ pi+) pairs => $1.7*10^{-3}$ ( ~0.17 %)
   D0 => 2960 ($K^-$ pi+) pairs => $3.4*10^{-2}$ ( ~3.4 %)

5. add the next additional cuts:

   a) cosine of V0, $K^-$ and pi+ should be $|\cos\theta| < 0.95$
   b) open angle between $K^-$ and pi+ => $0.6 < \Omega < 1.5$
   c) momentum of $K^-$ => $p > 0.5$ GeV/c
   d) DCA of V0 to PV => DCA > 0.003 cm

6. all these cuts give the next suppression factors:

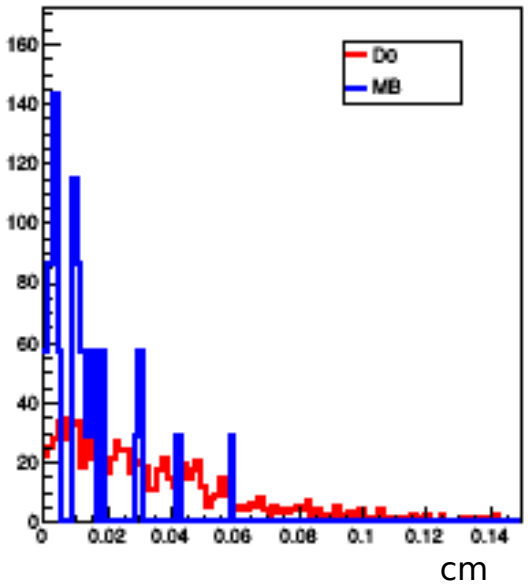
   MB => 65 ($K^-$ pi+) pairs => ~$3.0*10^{-5}$
   D0 => 1052 ($K^-$ pi+) pairs => ~$1.2*10^{-2}$ ( 1.2 % )

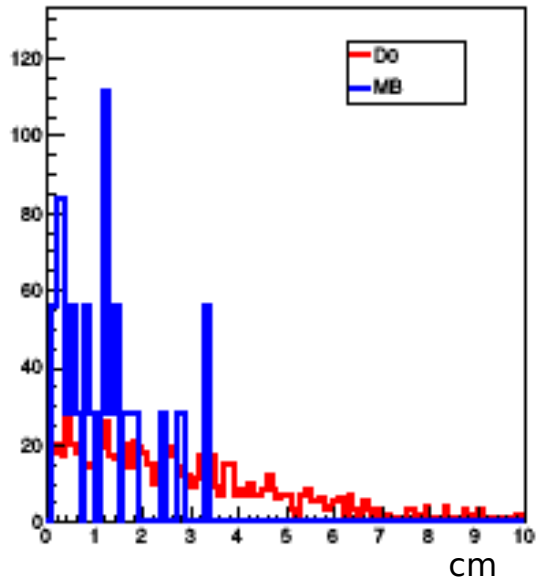
7. ~$6.4*10^4$ MB events and only 1 $D^0$ event with taking into account BR (3.9 %)

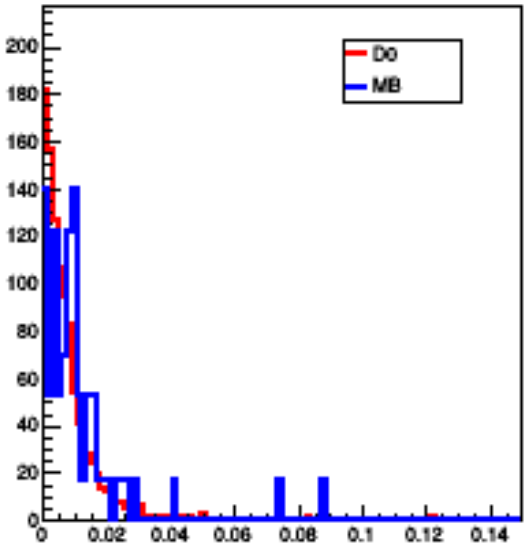
   ~160 MB and only 1 D0 event

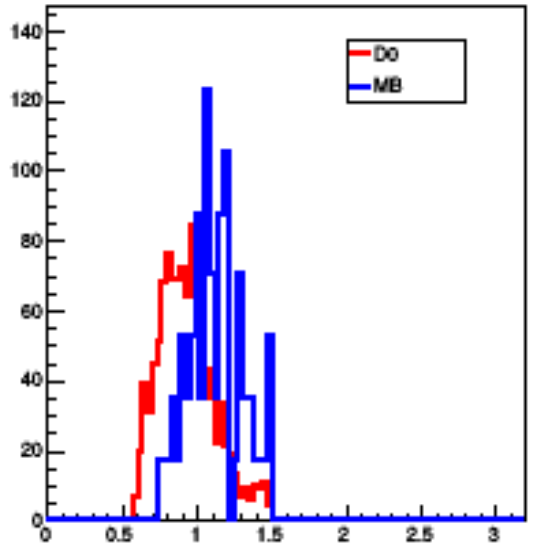
8. need more statistics

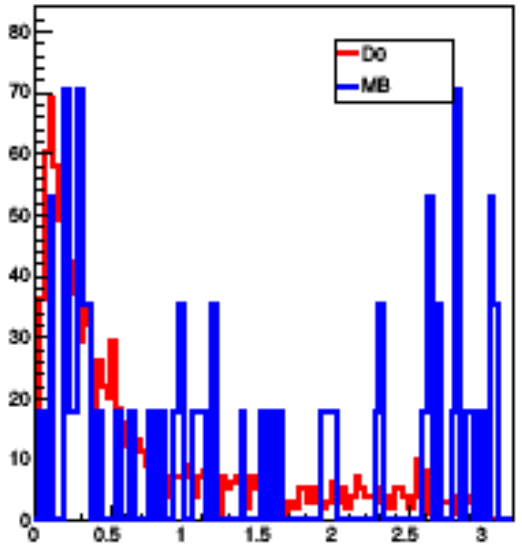
# First pleliminary results (2)



# Next step of simulation

1. increase statistics with some additional kinematic cuts on generator level

2. were generated 125000 MB events => ~ 32 M effective MB events

3. were generated 38000 D0 events => ~ 250000 effective D0 events

4. add next cuts:

   a) apply Δm and xF cuts
   b) cosine of V0, $K^-$ and pi+ should be | cos θ | < 0.95
   c) open angle between $K^-$ and pi+ => 0.6 < Ω < 1.5
   d) momentum of $K^-$ => p > 0.5 GeV/c
   e) DCA of V0 to PV => DCA > 0.003 cm

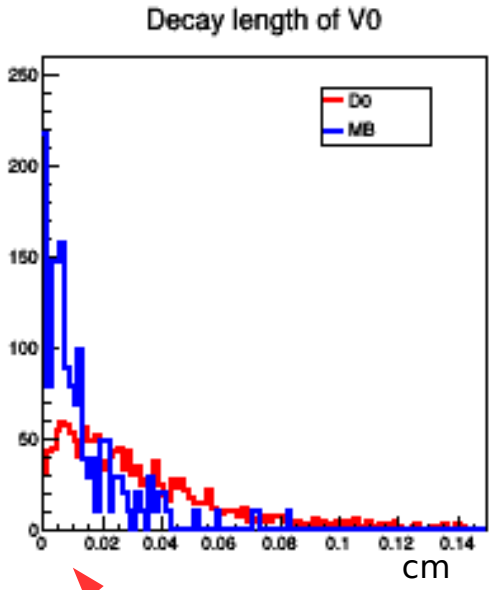
5. all these cuts give the next suppression factors:

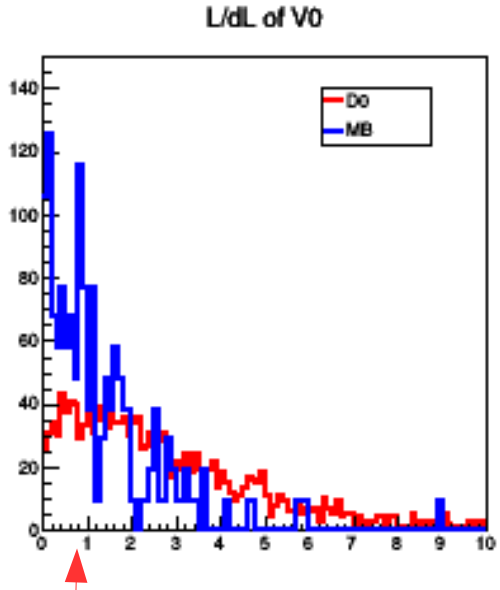
   MB => 640 ($K^-$ pi+) pairs => ~$2.0*10^{-5}$
   D0 => 2221 ($K^-$ pi+) pairs => ~$1.2*10^{-2}$

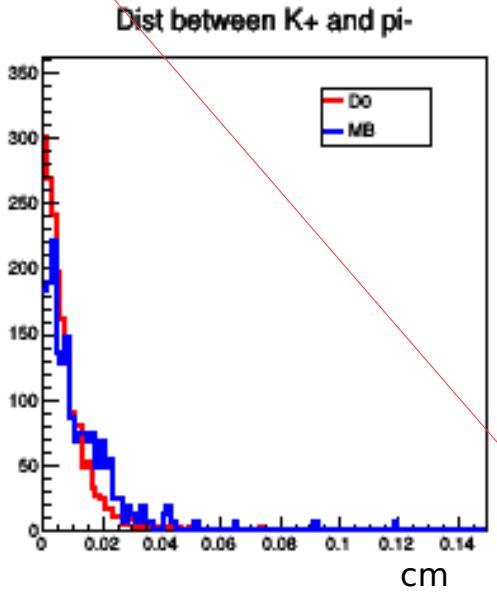
6. ~$6.4*10^4$ MB events and only 1 $D^0$ event with taking into account BR (3.9 %)

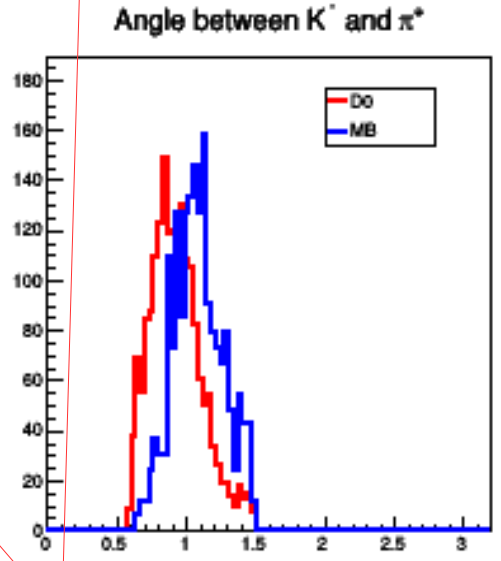
   ~107 MB and only 1 D0 events

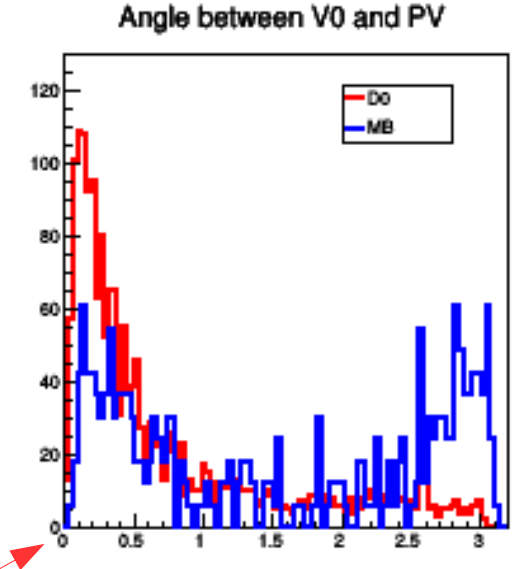
# Next step of simulation (2)



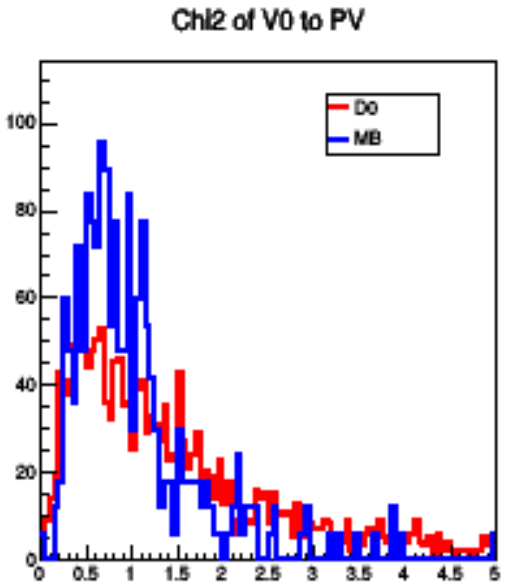



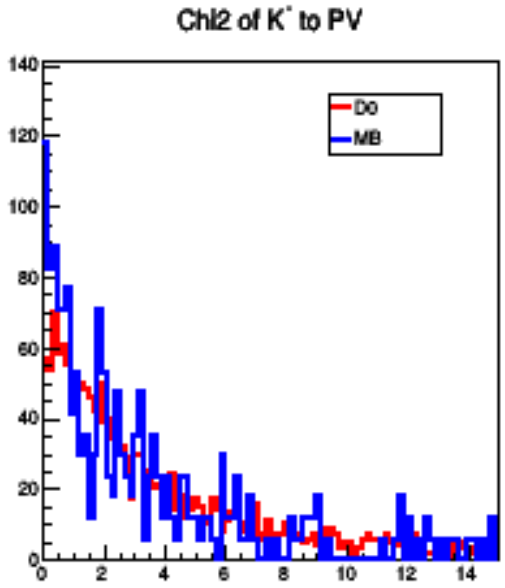



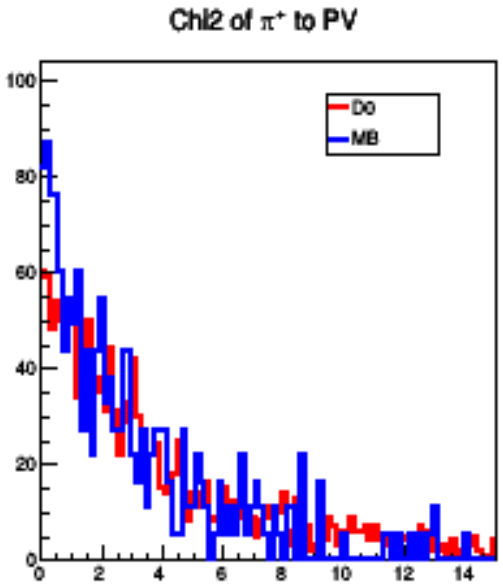



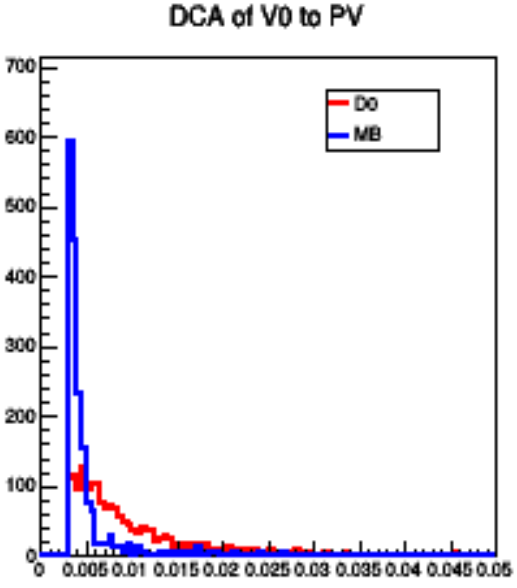

Possible useful cuts

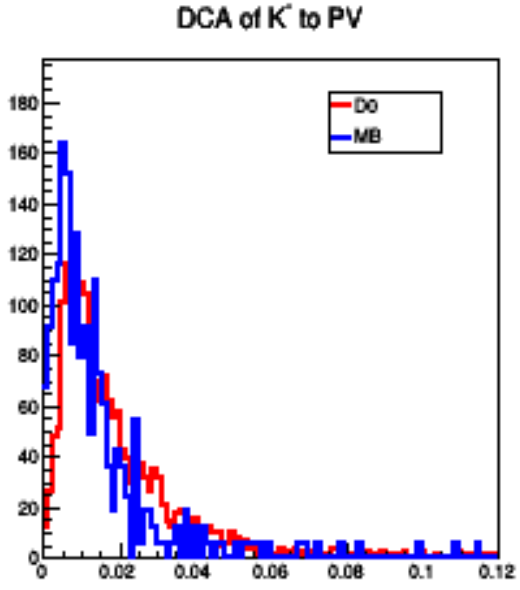
# Next step of simulation (3)

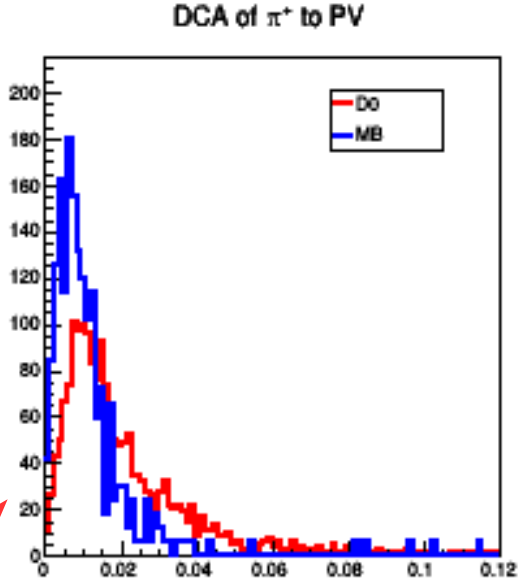



Possible useful cuts

# Final results

1. add some additional kinematic cuts on generator level

2. were generated 125000 MB events => ~ 32 M effective MB events

3. were generated 38000 D0 events => ~250000 effective D0 events

4. add next cuts:

   a) apply Δm and xF cuts
   b) cosine of V0, $K^-$ and pi+ should be $|\cos\theta| < 0.95$
   c) open angle between $K^-$ and pi+ => $0.6 < \Omega < 1.5$
   d) momentum of $K^-$ => $p > 0.5$ GeV/c
   e) DCA of V0 to PV => DCA > 0.003 cm

5. all these cuts give the next suppression factor:

   MB => 640 (K- pi+) pairs => ~$2.0*10^{-5}$
   D0 => 2221 (K- pi+) pairs => ~$1.2*10^{-2}$

6. ~$6.4*10^4$ MB events and only 1 $D^0$ event with taking into account BR (3.9 %)

   ~107 MB and only 1 D0 events

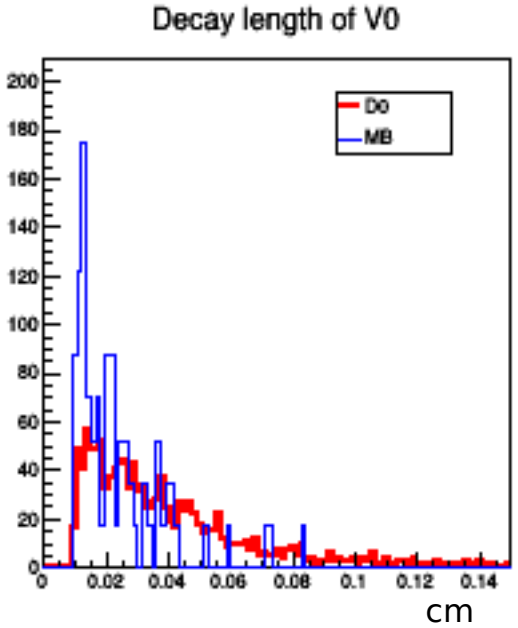
7. add new cut => decay length > 0.01 cm, DCA K- and pi+ > 0.01 cm:

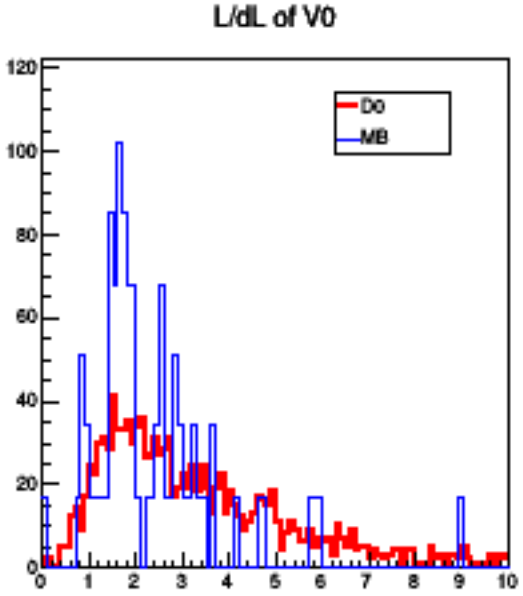
   MB => 26 (K- pi+) pairs => ~$8.2*10^{-7}$
   D0 => 1075 (K- pi+) pairs => ~$4.3*10^{-3}$

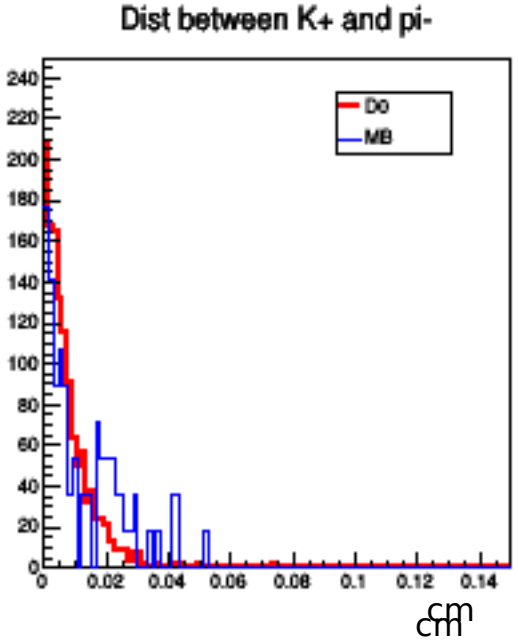
8. ~$6.4*10^4$ MB events and only 1 $D^0$ event with taking into account BR (3.9 %)

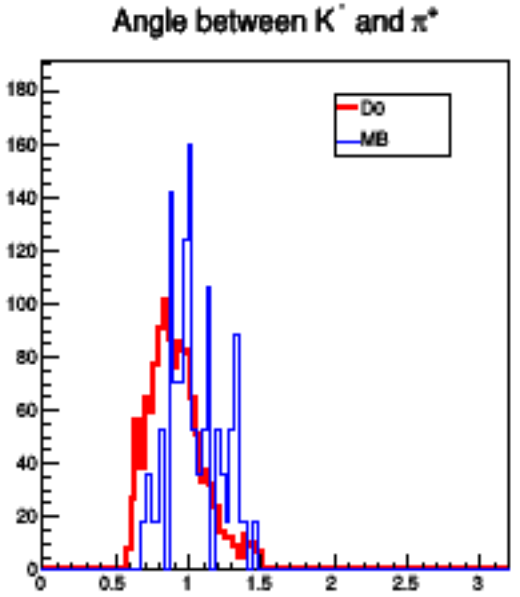
   ~ 12 MB and only 1 D0 events or with another cuts configuration => ~8 MB and 1 D0 events

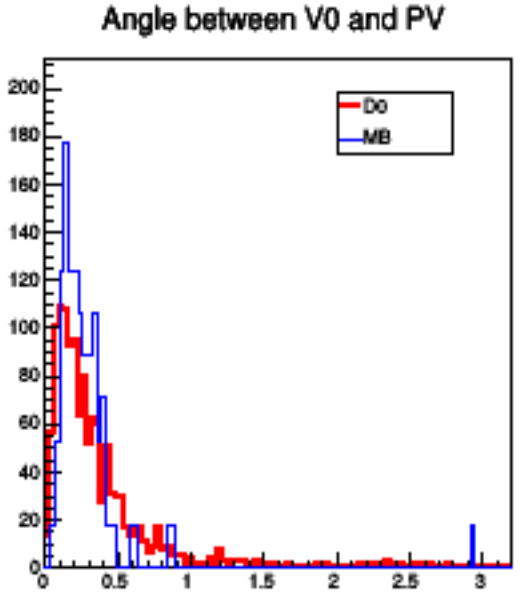
# Final results (2)



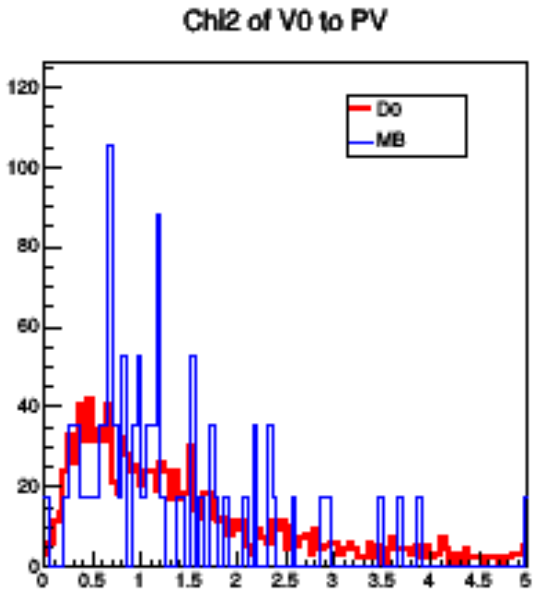



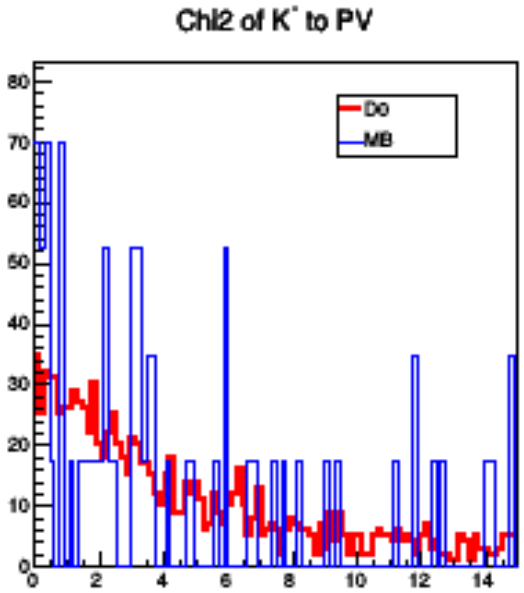



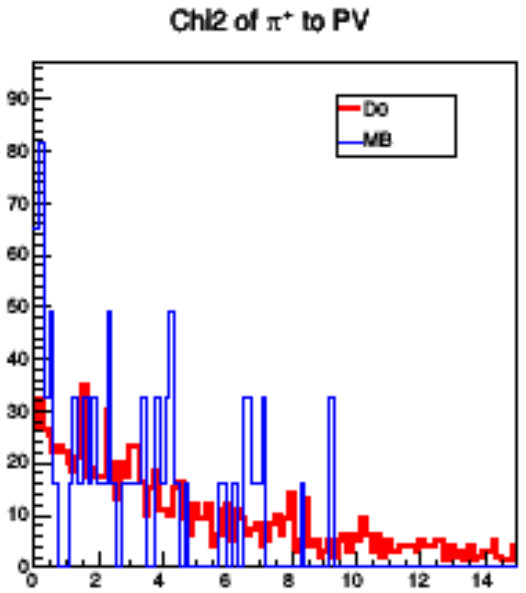



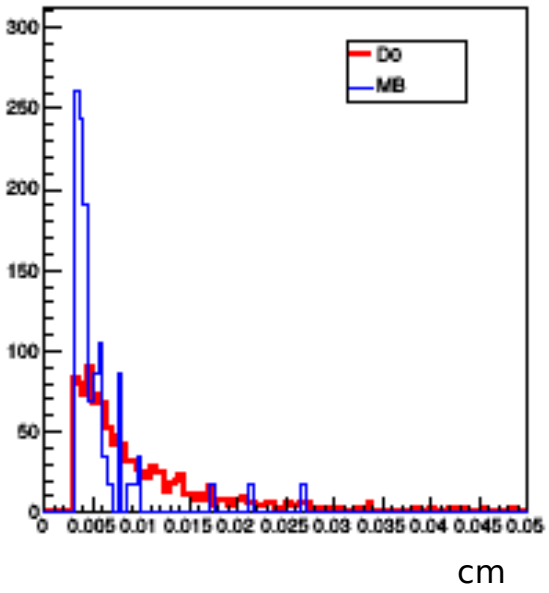



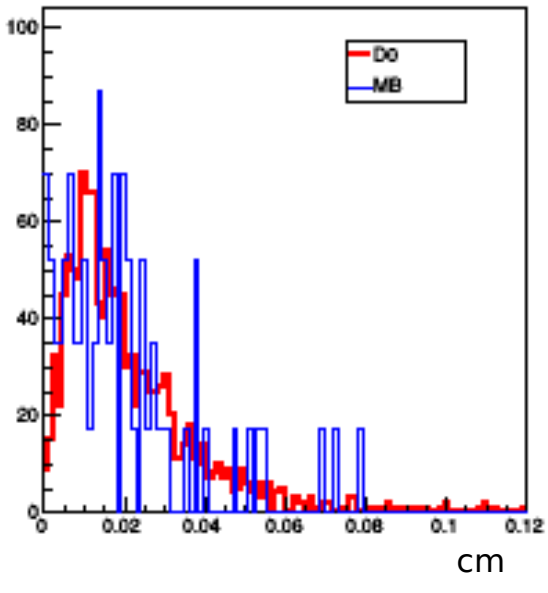
# Final results (3)

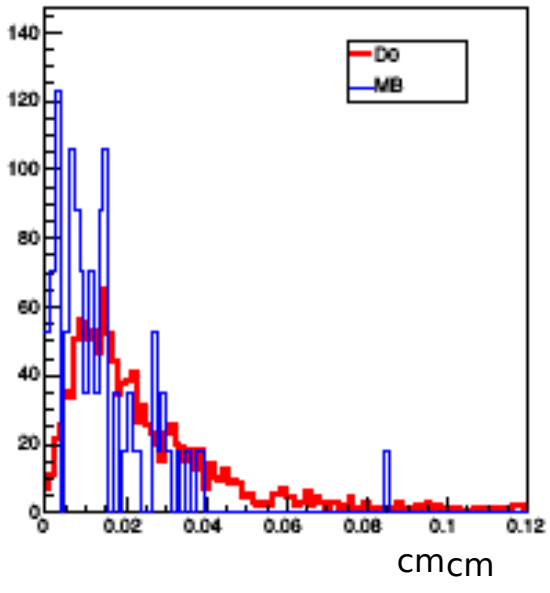


# Summary

1. there we simulated ~250000 D0 and ~32000000 MB effective events

2. selected cuts provide suppression factor ~$8.2*10^{-7}$ for MB and ~$4.3*10^{-3}$ for D0 events

3. with these cuts S/B ratio => 1/12 — 1/8 ( ~8.3 % - 12.5) S/B can be reached

4. need more statistics

5. also need provide some optimization procedure for cuts selection as some cuts are strongly correlated