Progress on $B_s^0 \to D^0[K^-\pi^+\pi^0]\varphi$

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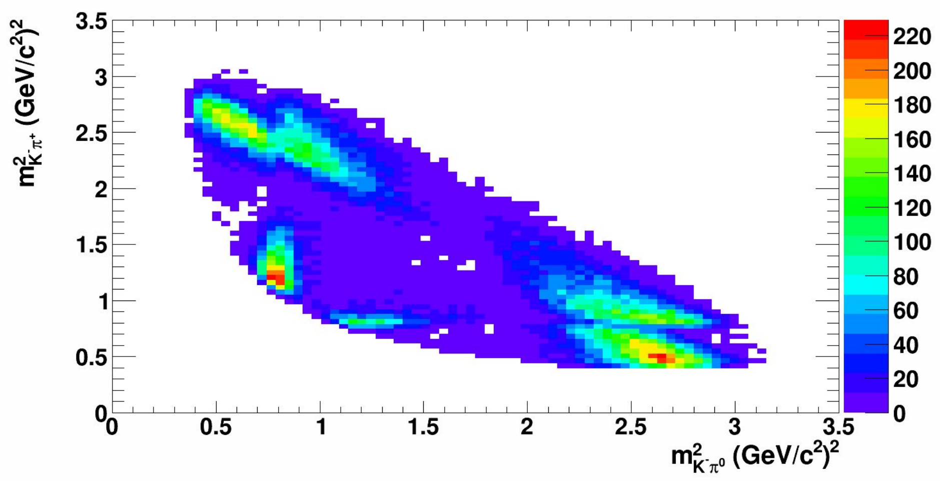
Data include run 1 and run 2 except 2018 data

Selection of $D^0 \longrightarrow K\pi\pi^0$: Three body decay

Dalitz plot $(m^2(K^-\pi^+)\ , m^2(K^-\pi^0))$ in MC simulation amplitude model from the E691 experiment:



D^0 decays toward $K\pi\pi^0$ involving Spin-1 resonant particle.

$Br(D^0 \longrightarrow K\pi\pi^0) = (14.2 \pm 0.5)\%$

- ❖ $Br(D^0 \longrightarrow K^{*0}\pi^0) = (1.93 \pm 0.24)\%$
- ❖ $Br(D^0 \longrightarrow K^{*-}\pi^+) = (2.27^{+0.40}_{-0.20})\%$
- ❖ $Br(D^0 \longrightarrow K^-\rho^+) = (11.1 \pm 0.7)\%$

Background event are uniformly distributed in the plane whereas signal event are gather around resonants particles.

The Dalitz weight.

The probability of phase space $(m^2(K^-\pi^+)$,$m^2(K^-\pi^0))$ occupation is given by:

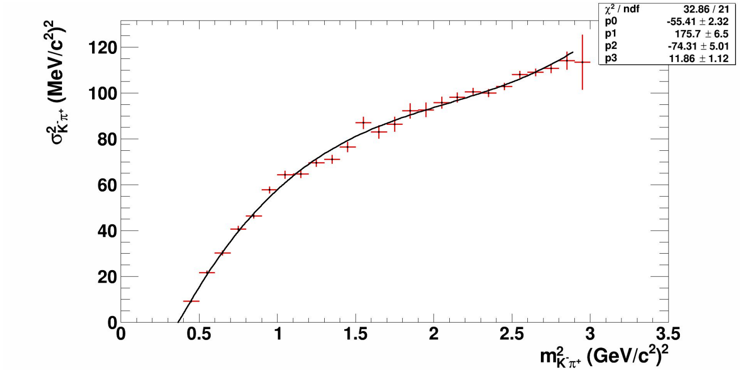
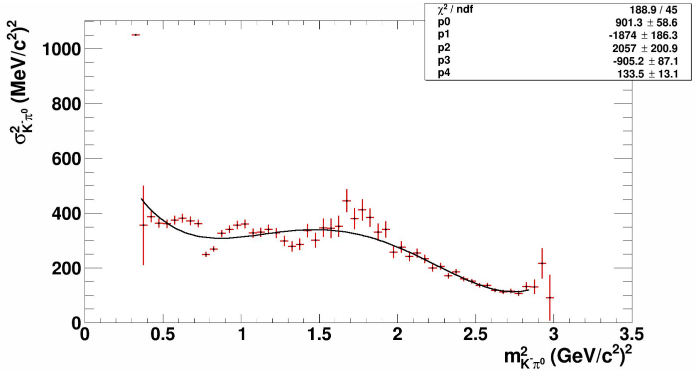
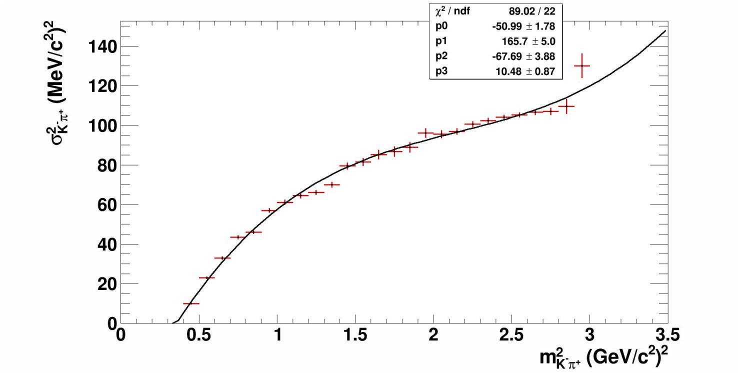
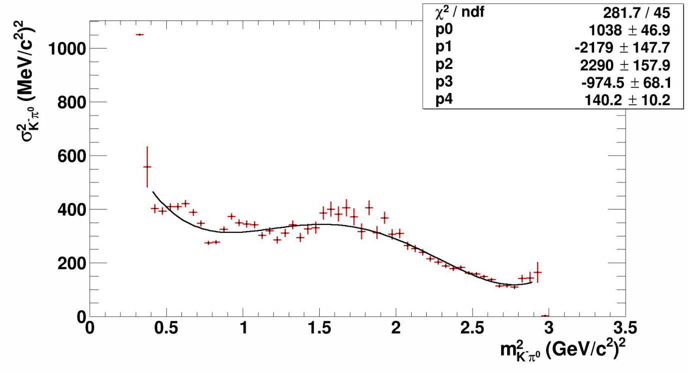
$$P_{D^0\to K^-\pi^+\pi^0}(m^2_{K^-\pi^+};m^2_{K^-\pi^0}) = |A_0 + A_{\overline{K}^{*0}} + A_{K^{*-}} + A_{\rho^+}|^2 \quad \text{with} \quad A_R = \frac{C_R e^{i\frac{\phi_R \pi}{180}}\sqrt{\frac{\Gamma_R}{2\pi}}\cos\theta^*_{ij}}{m_R - m_{ij} - i\frac{\Gamma}{2}}$$

The above probability is convoluted with two gaussians which represents the experimental precision of $m^2(K^-\pi^+)$ and $m^2(K^-\pi^0)$:

$$\begin{aligned} DW(m^2(K^+\pi^+, m^2(K^-\pi^0)) &= (\mathcal{G}_1 \times \mathcal{G}_2) \otimes P_{D^0\to K^-\pi^+\pi^0}(x,y) \\ &= \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \mathrm{dxdy}\frac{1}{\sqrt{2\pi\sigma^2_{m^2(K^-\pi^+)}}}\exp\frac{(x-m^2(K^-\pi^+))^2}{2\sigma^2_{m^2(K^-\pi^+)}} \times \frac{1}{\sqrt{2\pi\sigma^2_{m^2(K^-\pi^0)}}}\exp\frac{(x-m^2(K^-\pi^0))^2}{2\sigma^2_{m^2(K^-\pi^0)}} \times P_{D^0\to K^-\pi^+\pi^0}(x,y) \end{aligned}$$

Need to calibrate the resolution of the two gaussian $\sigma^2_{m^2(K^-\pi^+)}$, and $\sigma^2_{m^2(K^-\pi^0)}$ in Monte-Carlo simulation.

Resolution of the two gaussians.

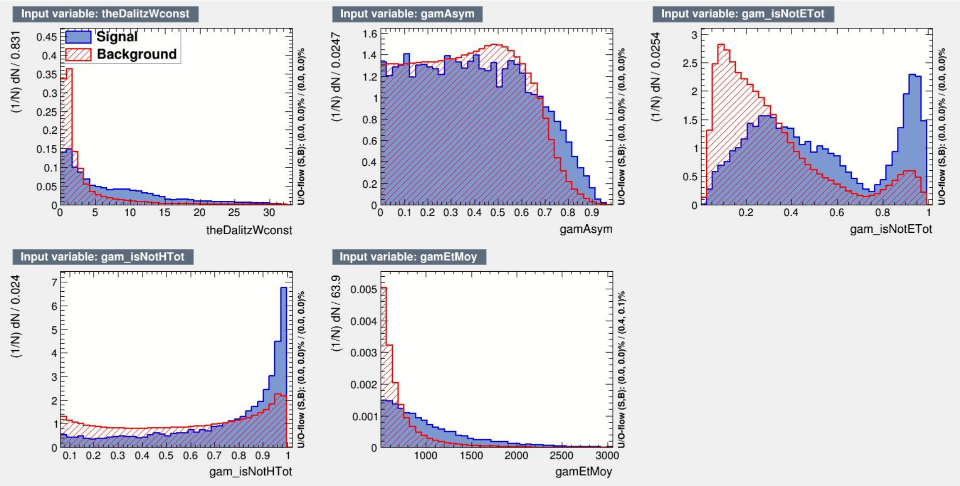
	Resolution of $m^2(K^-\pi^+)$	Resolution of $m^2(K^-\pi^0)$
Run 1		
Run 2		

MVA method:BDTD.

Selection of the π^0 in the $D^0 \rightarrow K^- \pi^+ \pi^0$ using a MVA method.

Five variables used:

- Log(Dalitz weight)
- gamAsym: $(E_{\gamma 1}-E_{\gamma 2})/(E_{\gamma 1}+E_{\gamma 2})$
- gam_isNotETot: probability of the two γ of not being an electron
- gam_isNotHTot: probability of the two γ of not being a hadron
- gamEtMoy: $(E^T_{\gamma 1}+E^T_{\gamma 2})/2$

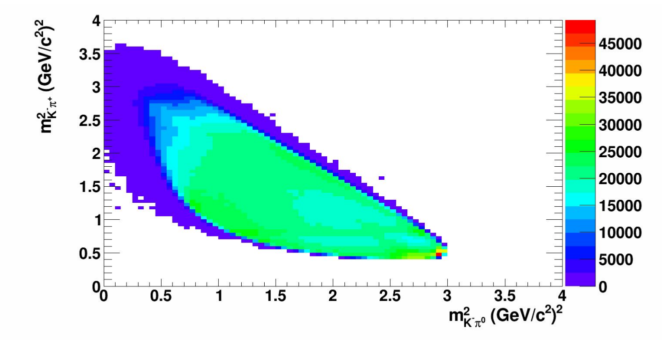


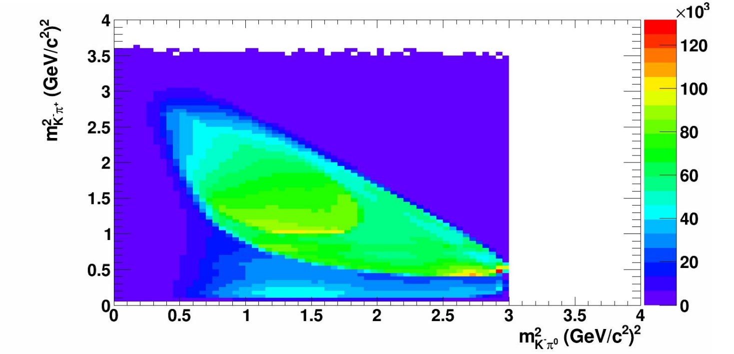
MVA method:BDTD.

Dalitz plot of Run 1

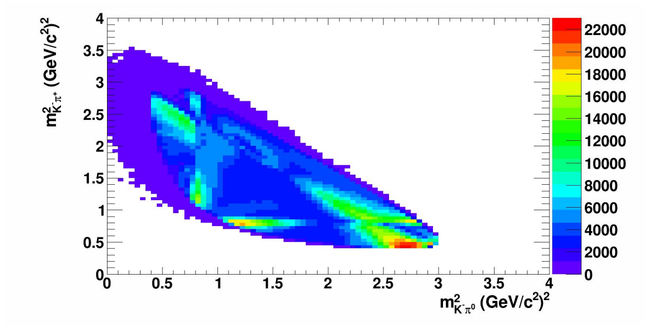
Dalitz plot of Run 2

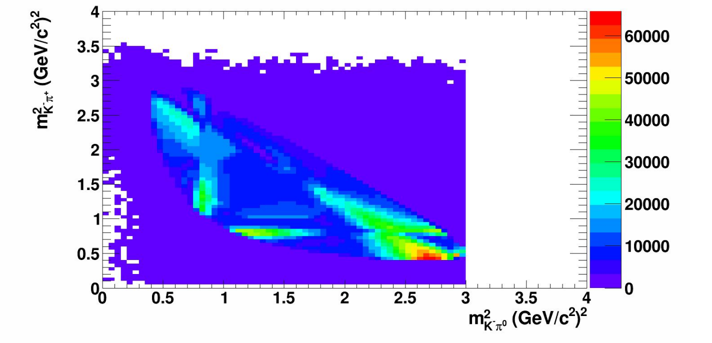
Before the cut





After the cut



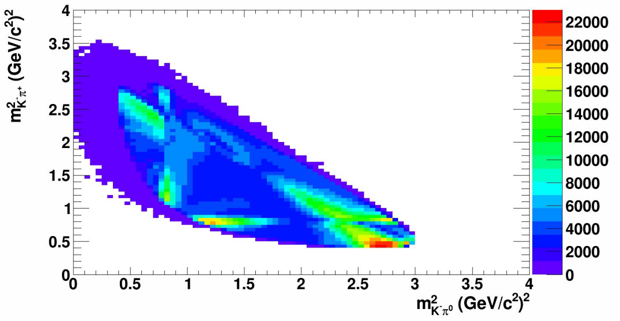
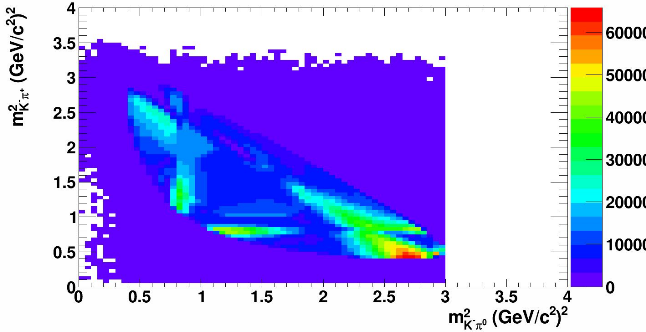
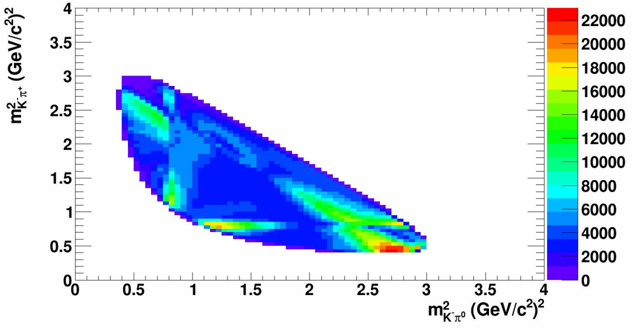
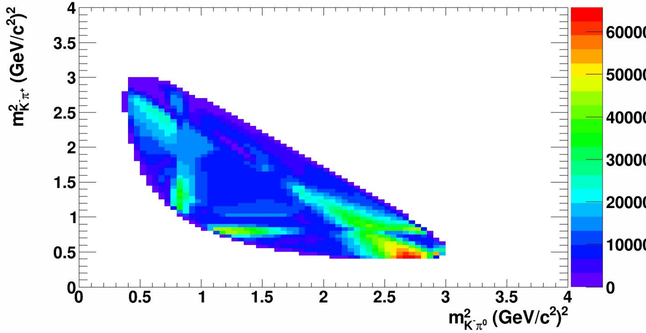


Efficiency

6 909 650 / 27 140 350 = 25.46%
(80.55% for MC signal)

19 531 700 / 99 979 120 = 19.06%
(79.95% for MC signal)

Cut on the Dalitz shape

	Dalitz plot of Run 1	Dalitz plot of Run 2
Before the cut		
After the cut		
Efficiency	6 820 958 / 6 909 650 = 98.72% (99.61% for MC signal)	18 227 500 / 19 531 700 = 93.32% (99.76% for MC signal)

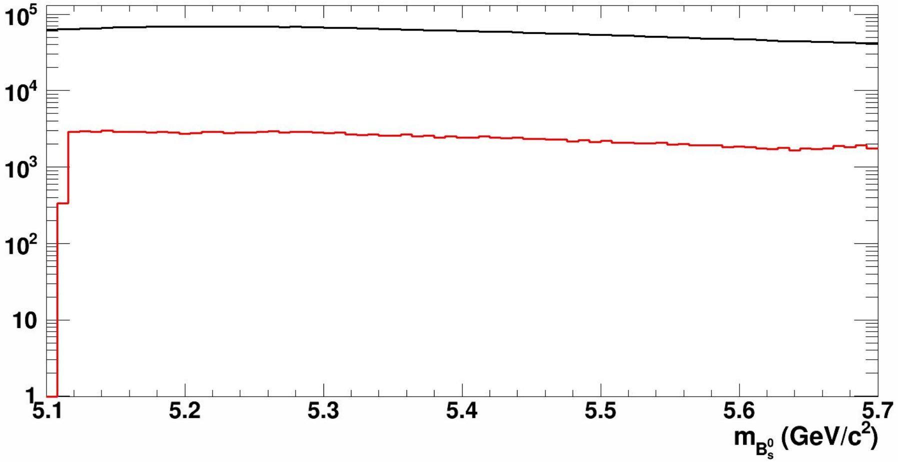
Reproduce the same cut as $B^0 \to D^0 \pi^+ \pi^-$

Preliminary cut: cluster ten cuts on discriminating variables.

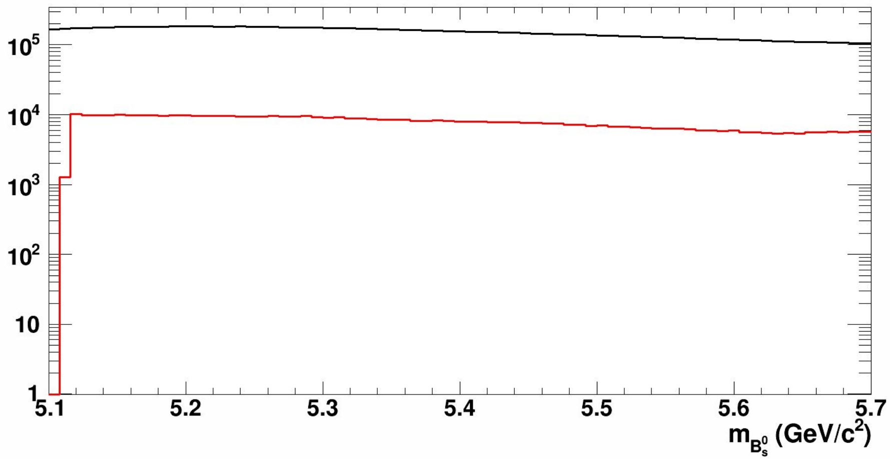
- **B_s^0 mass candidate:** [5.1 ; 6.0] GeV
- **π^0 mass candidate:** [117.0 ; 155.0] MeV
- **RICHs identification**
  - **Probability of the D^0 daughters of being a kaon:** 2%
  - **Probability of the D^0 daughters of being a kaon:** 0.2%
- **D^0 mass candidate:** [1795.7 ; 1932.3] MeV
- **χ^2/nDoF of the D^0 vertex:** <6
- **χ^2 of the D^0 impact parameters:** >16
- **Difference of the D^0 and B_s^0 vertex position z:** >3
- **χ^2/nDoF of the B_s^0 vertex:** <4
- **Cos(Θ_D),** Θ_D being the angle between the direction of the trajectory of the B_s^0 and the direction defined by (primary vertex; B_s^0 vertex): >0.99995
- **χ^2 of the B_s^0 impact parameters:** >4

Effect on B_s^0 mass.

Run 1



Run 2



221 633 / 6 820 958 = 3.25%

Monte Carlo signal: 45.76%

717 876 / 17 647 130 = 4.06%

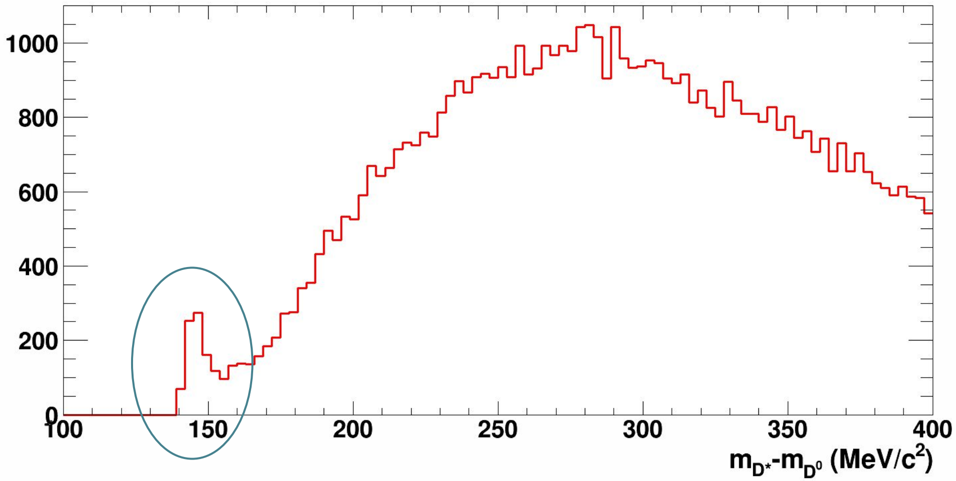
Monte Carlo signal: 42.70%

Veto D^{0*}

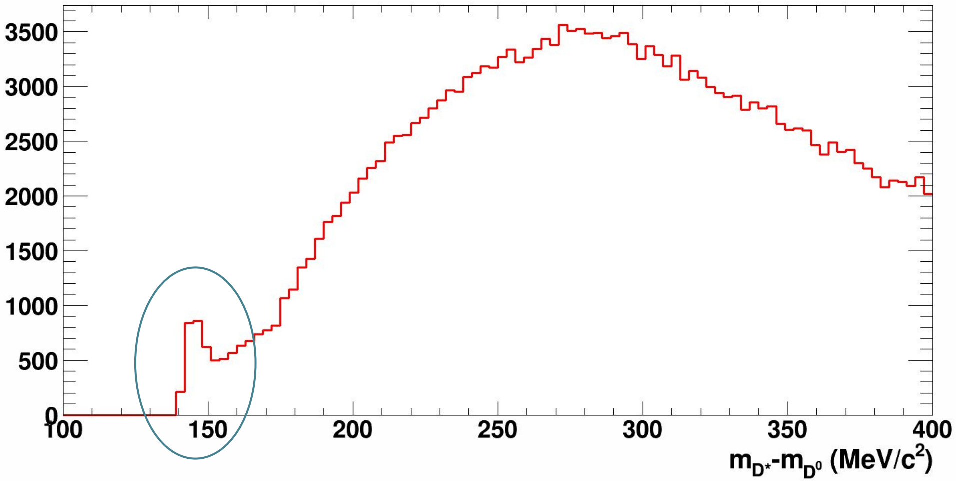
Difference m(D^{0*})-m(D^0).

$B^0 \rightarrow D^{*-}[D^0\pi^-]\pi^+$ have a strong contribution to the signal so the D* event must be reject.
Difference compute with the D^0 constrain to the π^0 mass and to the primary vertex.
m(D^{0*})-m(D^0)=145.4257±0.0017 MeV/c² (PDG)

Run 1



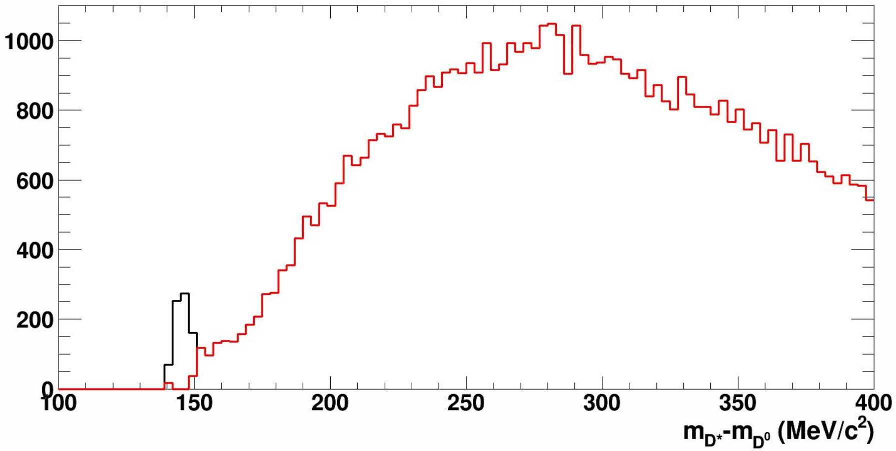
Run 2



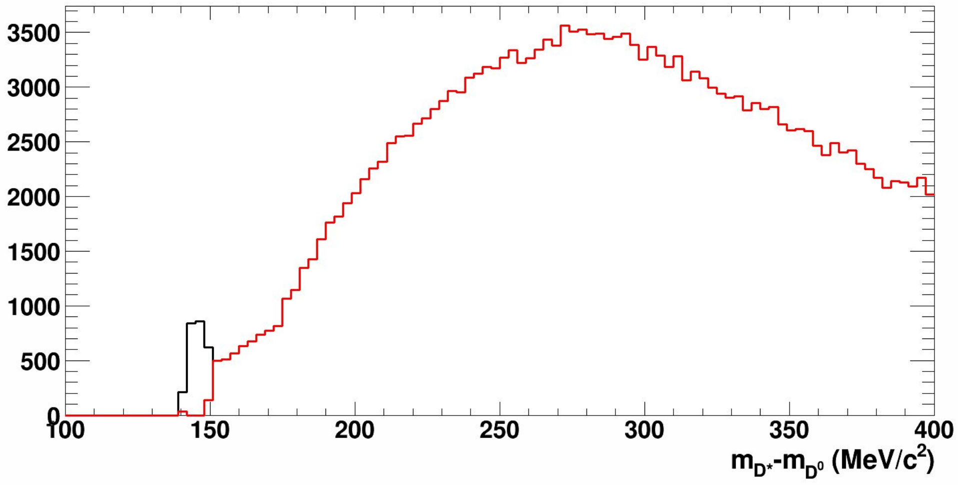
Cut on the difference $m(D^{0*})-m(D^0)$.

Resolution of this mass difference in LHCb: 0.8MeV/c^2.
Reject event ∈ [140.621, 150.221] GeV i.e. 6σ of the resolution

Run 1

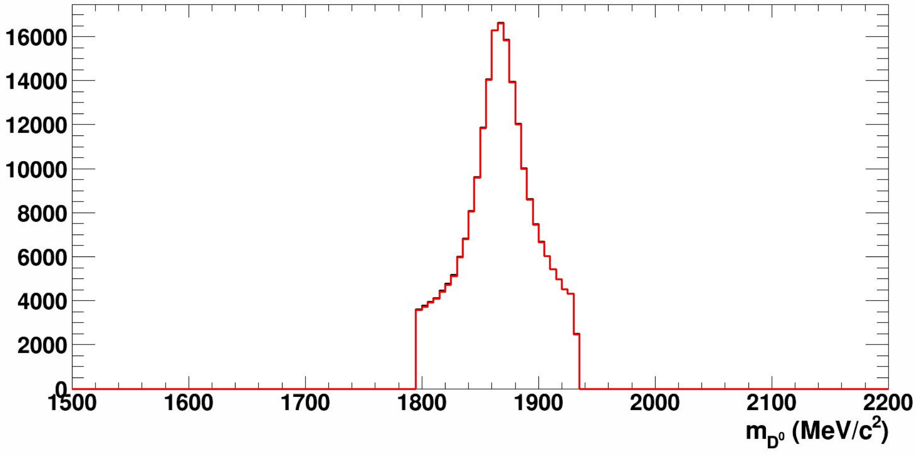


Run 2

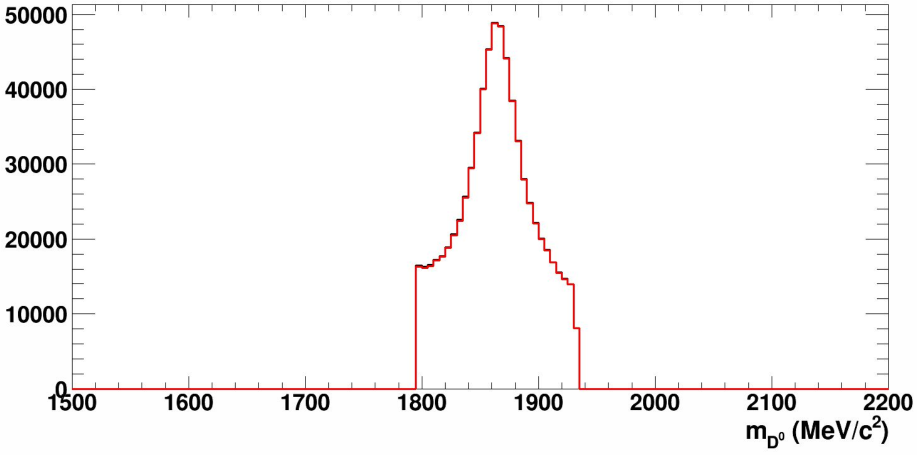


Effect on D^0 mass.

Run 1



Run 2



220 932 / 221 633 = 99.68%

Monte Carlo signal: 99.96%

714 876 / 717 876 = 99.67%

Monte Carlo signal: 99.98%

MVA: Fisher analysis $B^0 \to D^0 \pi^+ \pi^-$

Selection with M.V.A method.

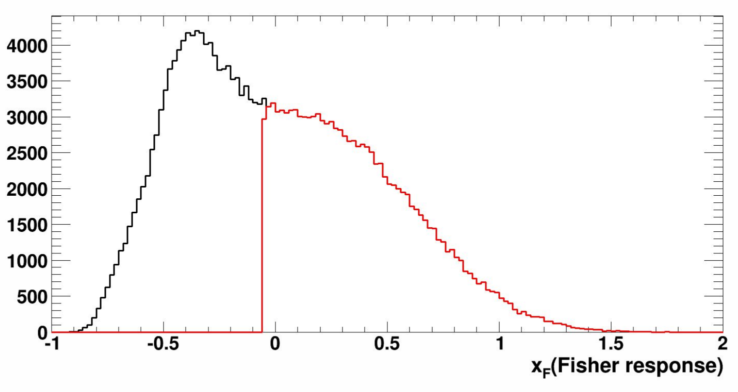
Optimised for D^0KK

Five variables used:

- Min(BdauChi2IP)
  - The reconstruction quality of the B daughters h^+ and h^-. To avoid correlation, the minimum is taken instead of the two variables.
- Min(BdauPT)
  - The transverse momentum of the B daughters h^+ and h^-. To avoid correlation, the minimum is taken instead of the two variables.
- CHI2_BFlightDistance
  - The χ^2 of the B^0 flight distance.
- D0CHI2IP
  - The χ^2 of the impact parameters of the D^0.
- Tvar
  - Cosinus of the angle between the transverse momentum of the D^0 and of the transverse momentum of each of the B^0 daughters. To avoid correlation, the minimum is taken instead of the two variables.

Fisher response cut at -0.0581.

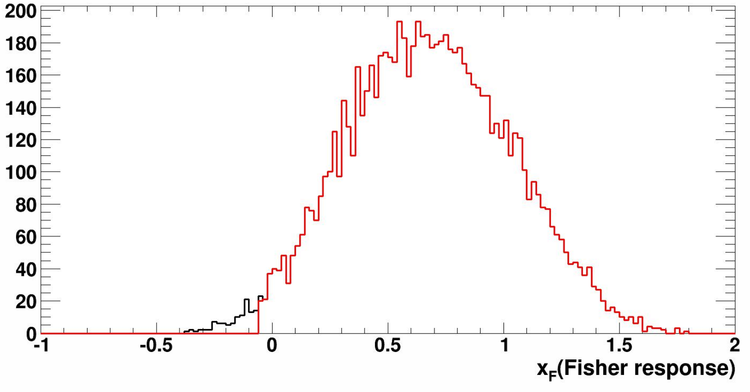
Run 1



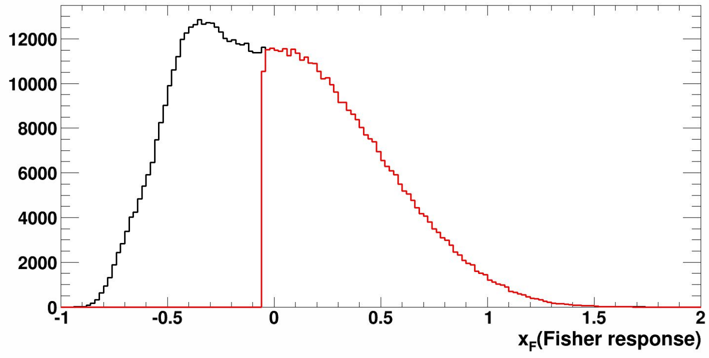
115 309 / 220 932 = 52.19%

Monte Carlo signal: 98.69%

MC Run 1



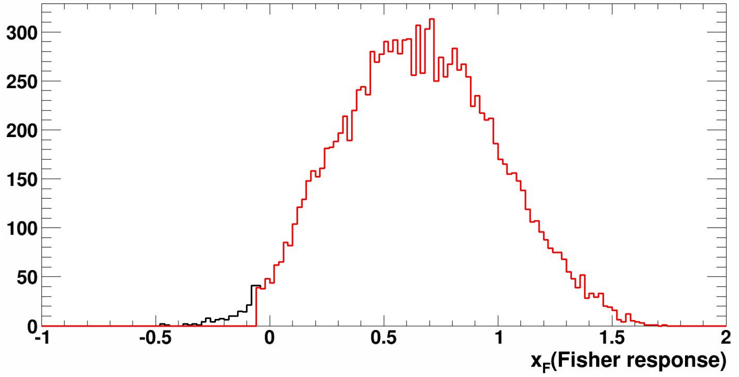
Run 2



381 695 / 714 876= 53.39%

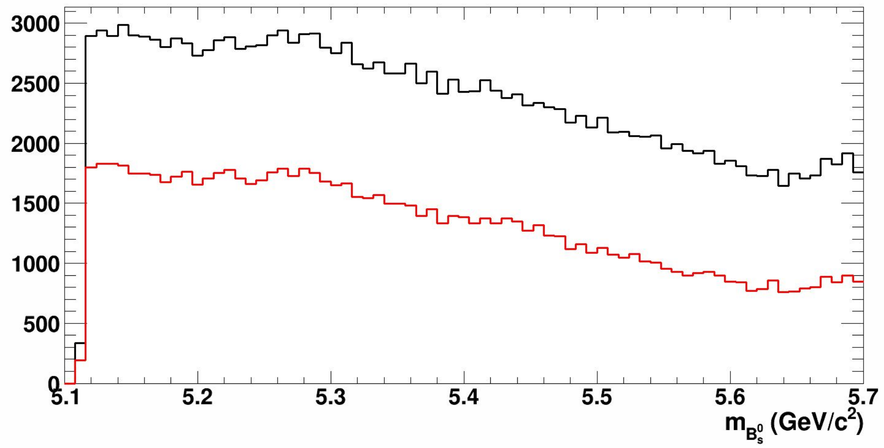
Monte Carlo signal: 98.81%

MC Run 2

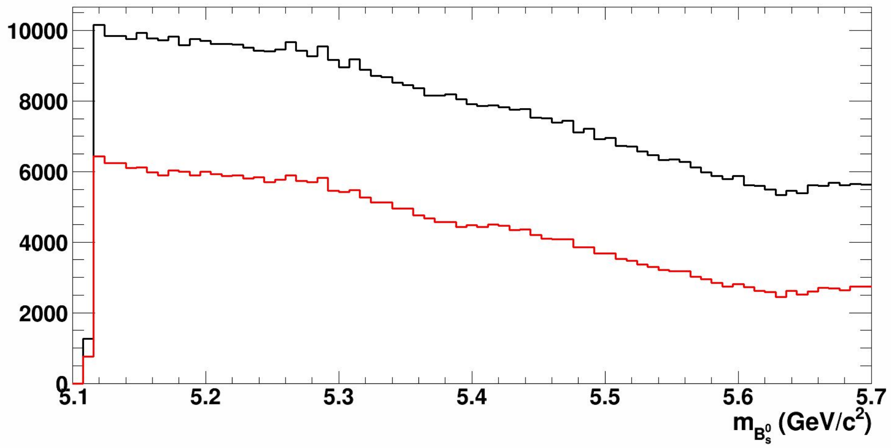


Effect on B_s^0 mass.

Run 1



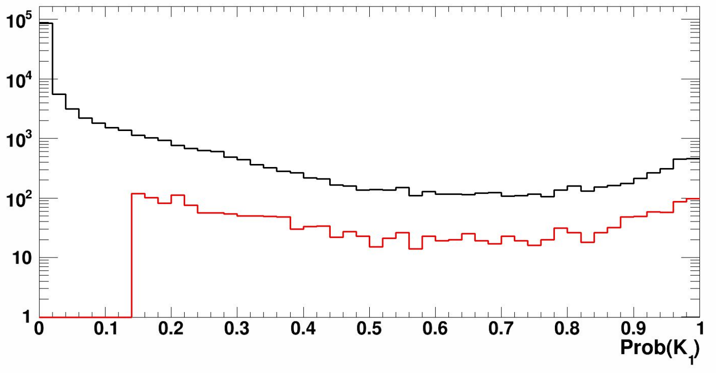
Run 2



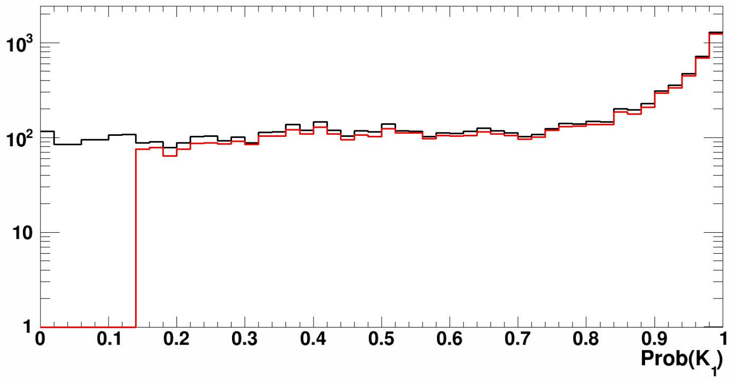
PID B_s^0 daughter

PID daughter h1>14%

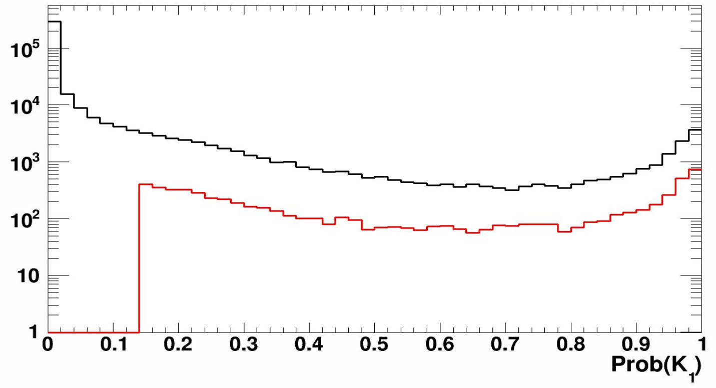
Run 1



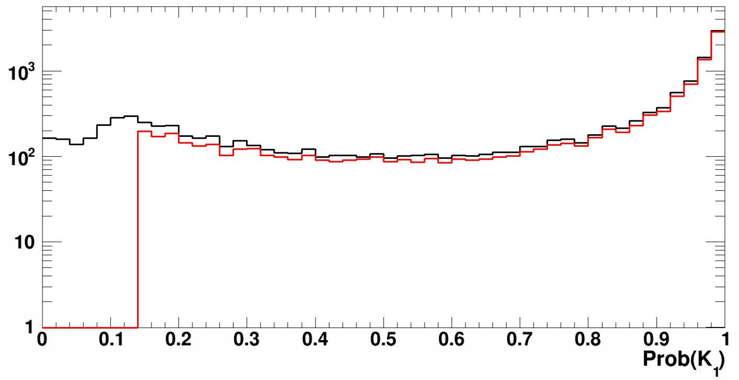
MC Run 1



Run 2

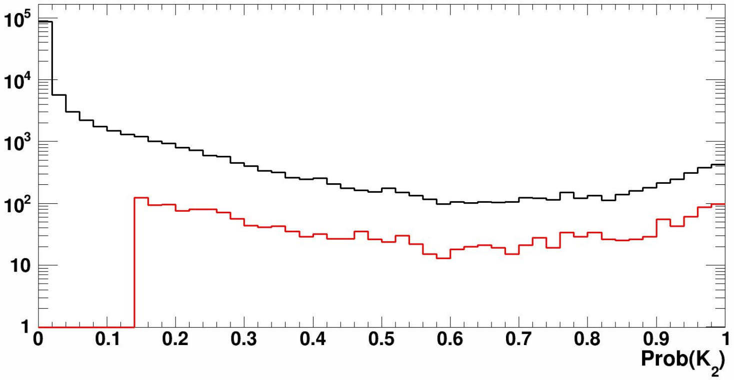


MC Run 2

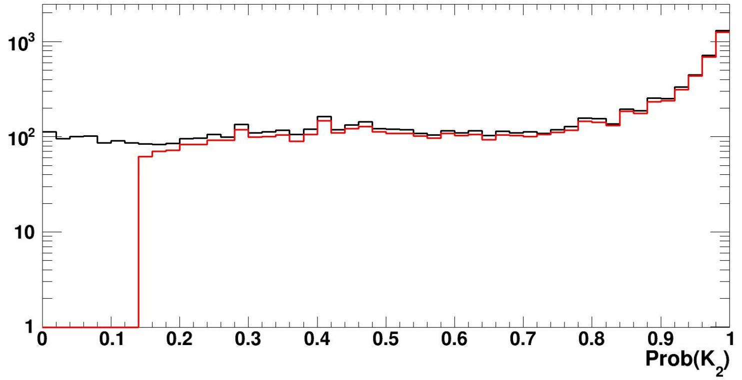


PID daughter h2>14%

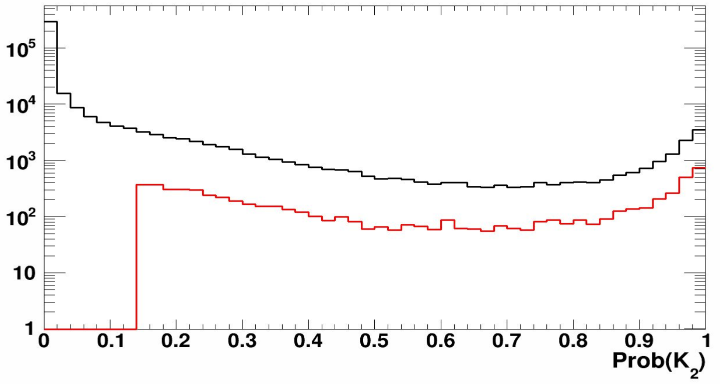
Run 1



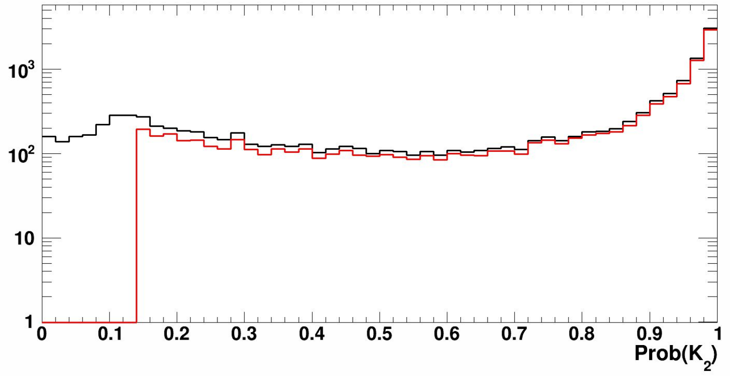
MC Run 1



Run 2

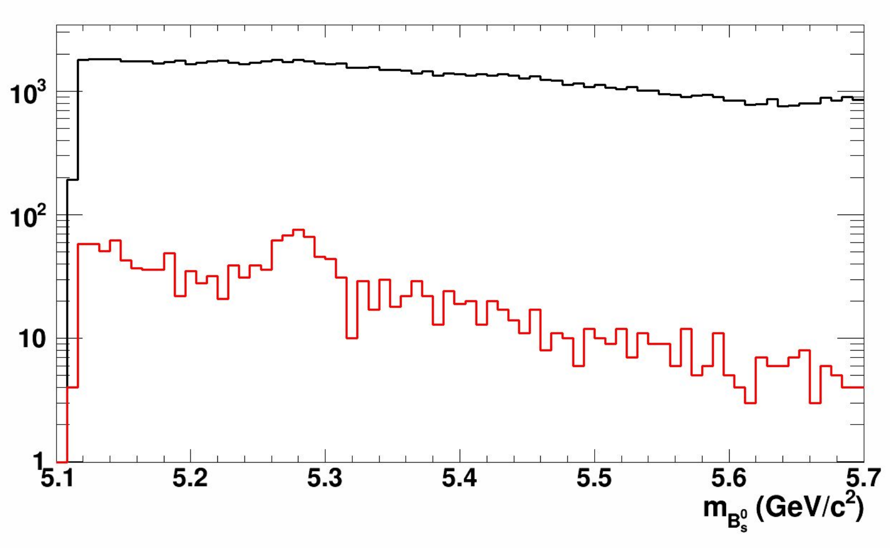


MC Run 2



Effect on B_s^0 mass.

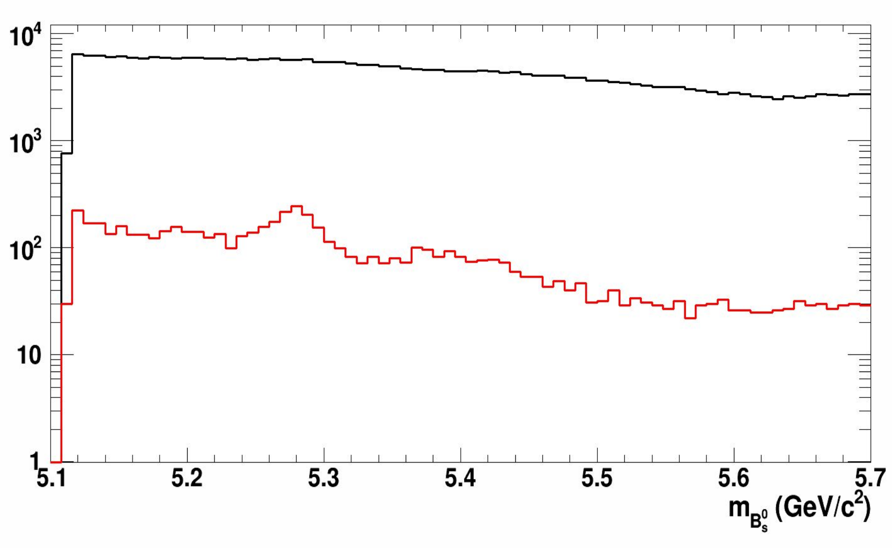
Run 1



1 826 / 115 309 = 1.58%

Monte Carlo signal: 85.53%

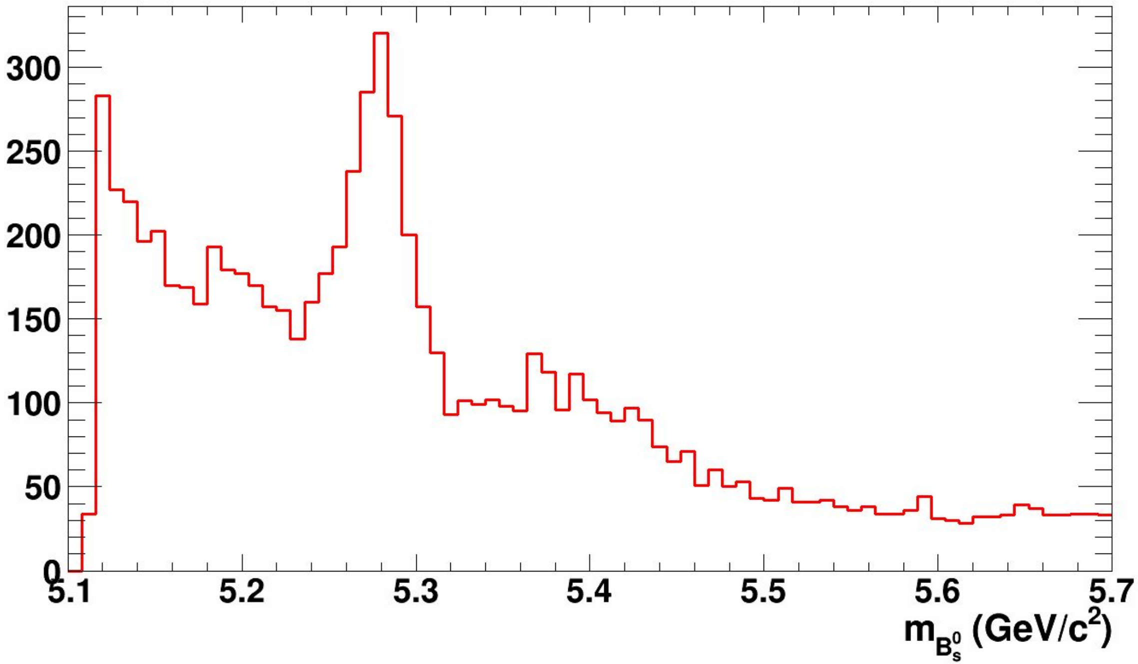
Run 2



6 828 / 381 695 = 1.79%

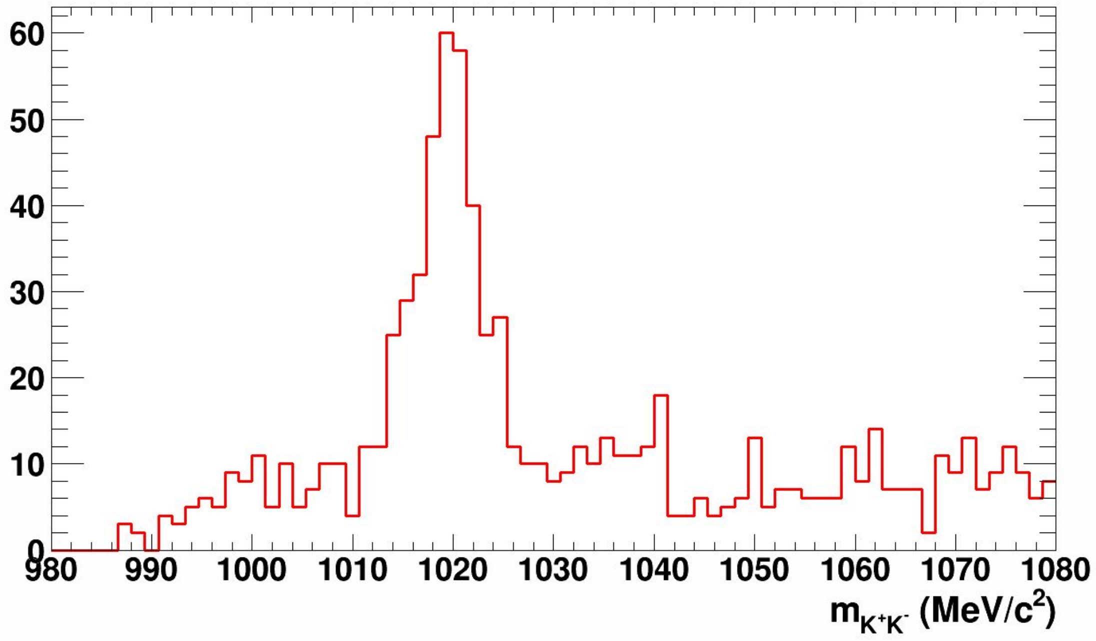
Monte Carlo signal: 81.12%

B_s^0 mass, sum of run 1+2

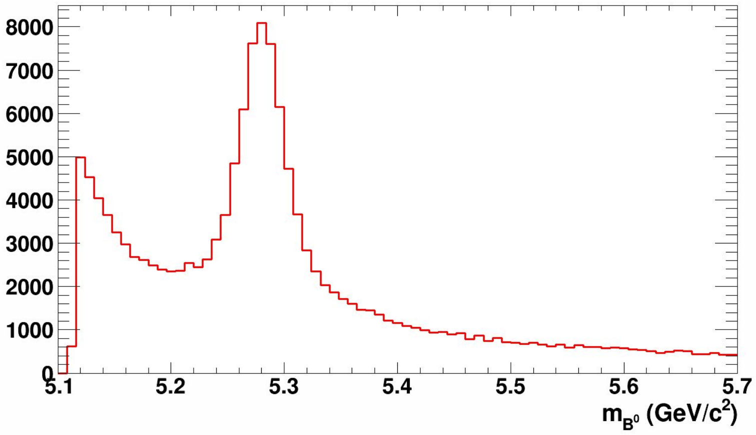


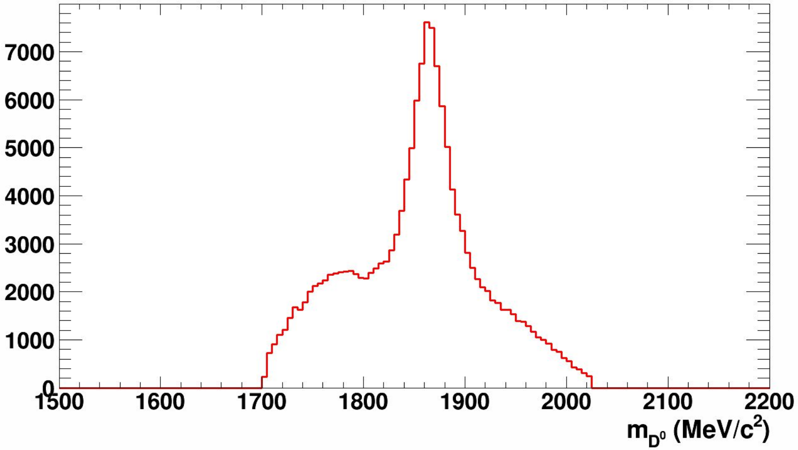
8 654 events

KK candidate, sum of run 1+2



$B^0 \to D^0 \pi^+ \pi^-$ mass, sum of run 1+2

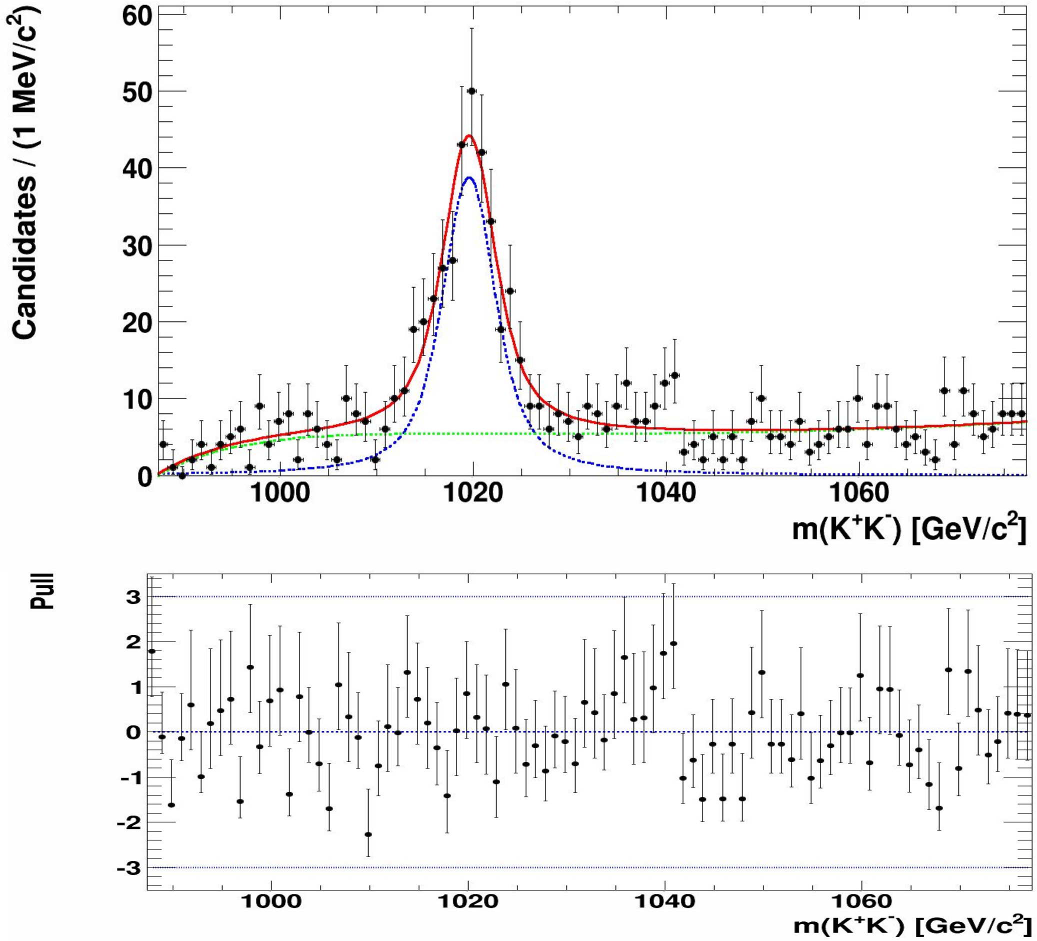




The constraints on the mass cut have been released

Fit, sPlot method

Fit of the mass of the KK candidate



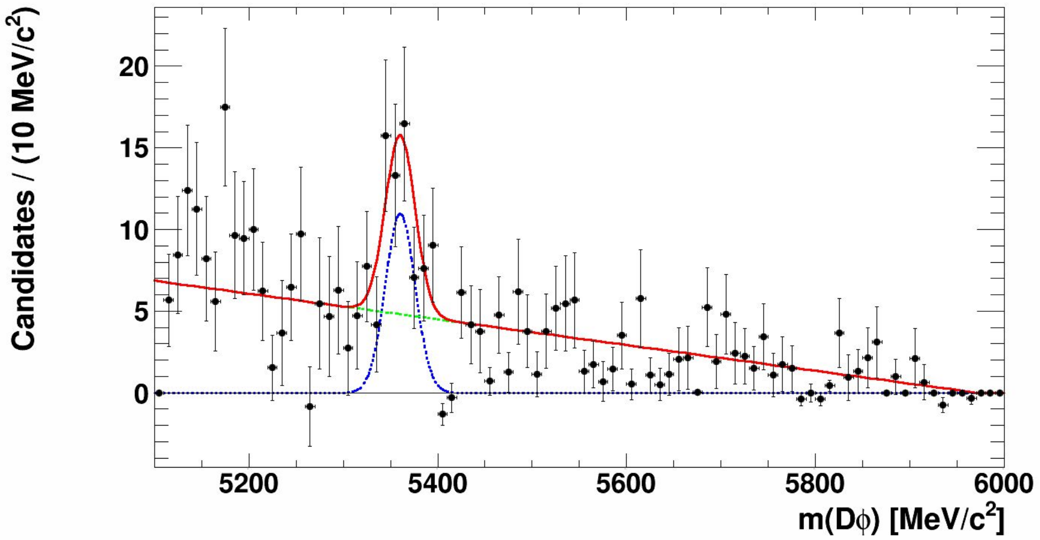
Number of φ:

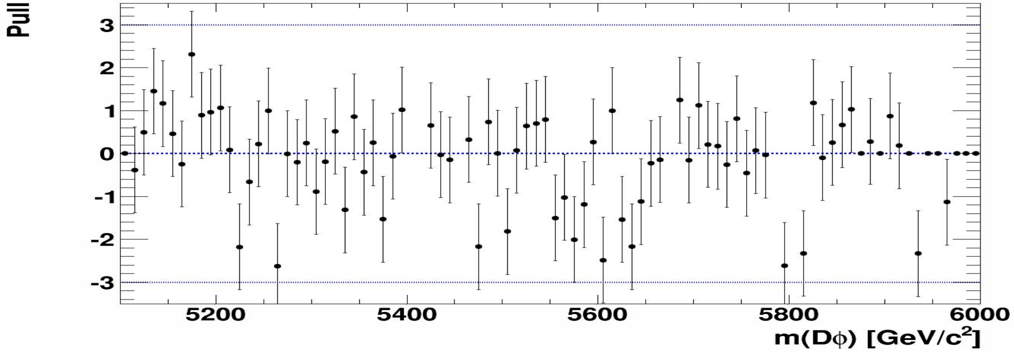
341.7 ± 31.2 event

Number Background event:

475.3 ± 34.0 events

Fit of the mass of the B_s^0 candidate



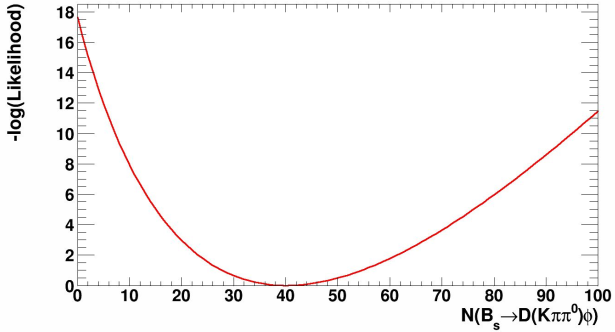


Number of $B_s^0 \to D^0[K^-\pi^+\pi^0]\varphi$:

43.6 ± 8.7 events

Number of background events:

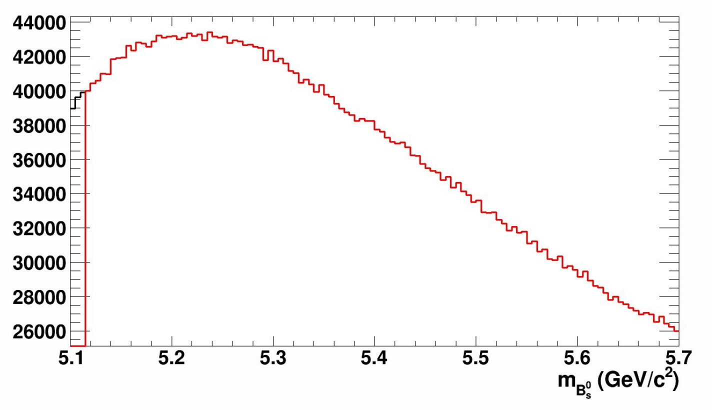
300.7 ± 16.1 events



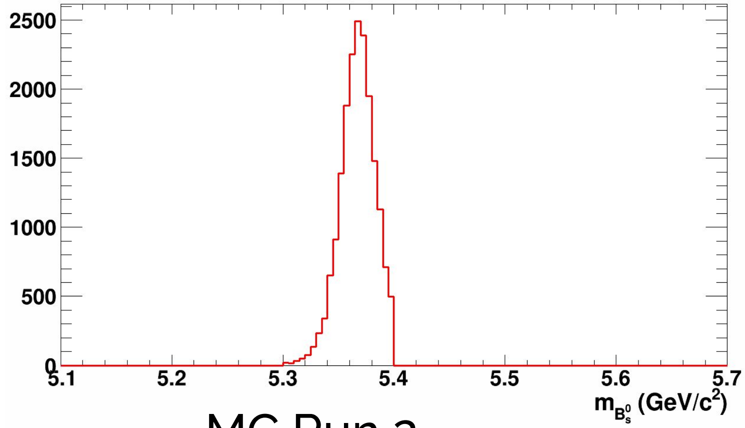
Backupe slide

B^0_s mass range $\in [5.115, 6.]$ GeV.

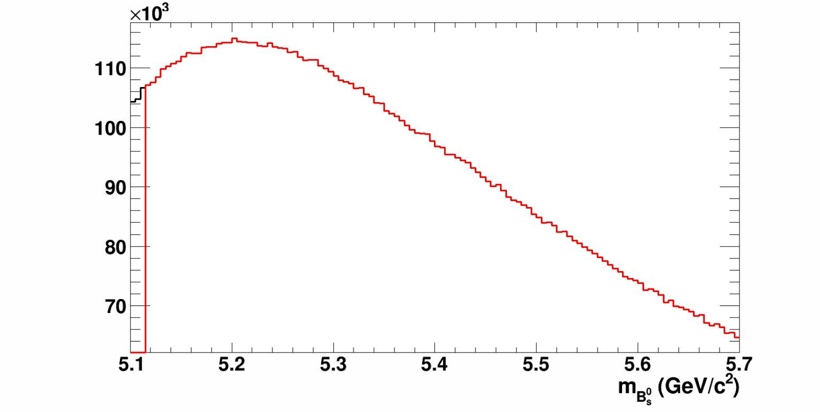
Run 1



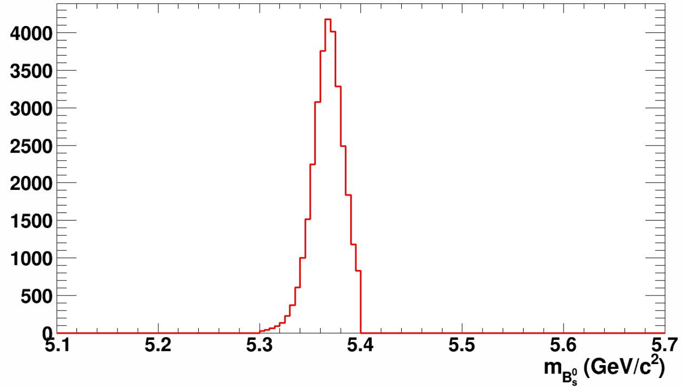
MC Run 1



Run 2

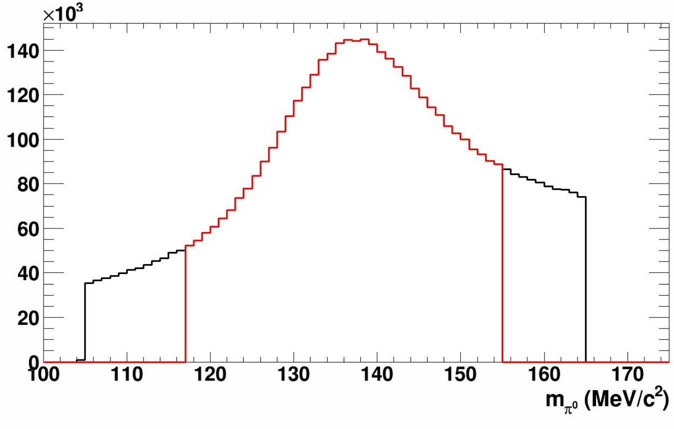


MC Run 2

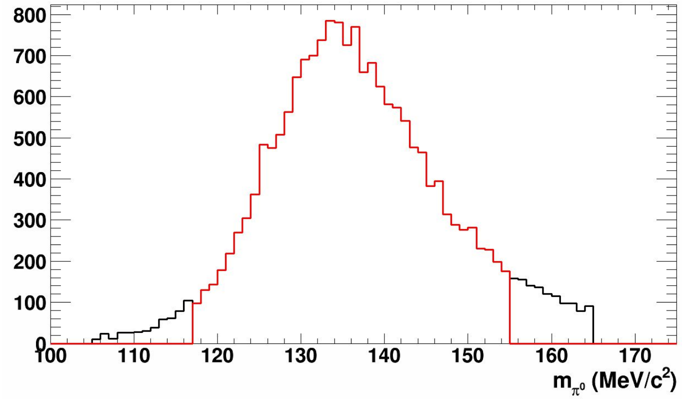


π^0 mass range $\in$ [117., 155.] MeV.

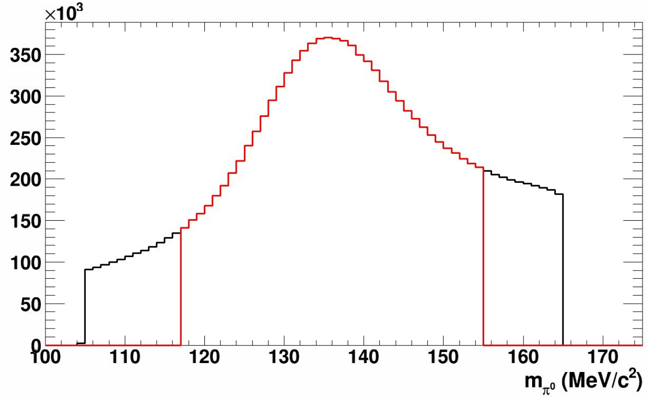
Run 1



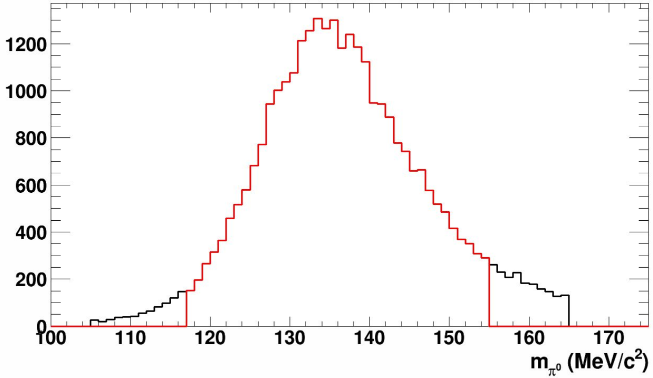
MC Run 1



Run 2

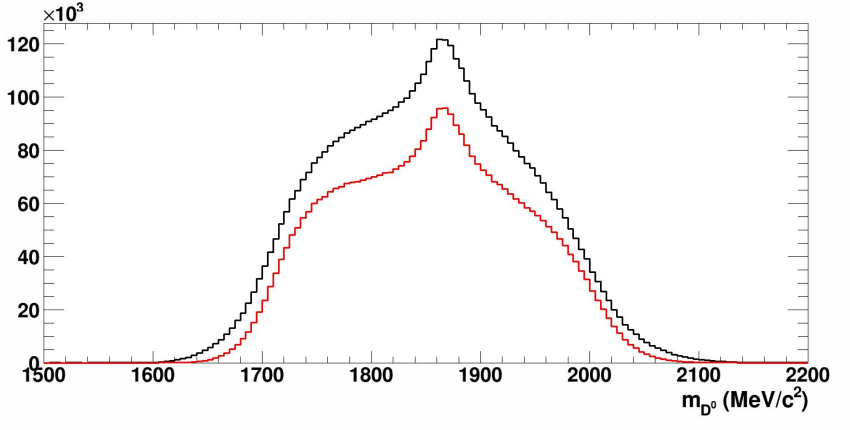


MC Run 2

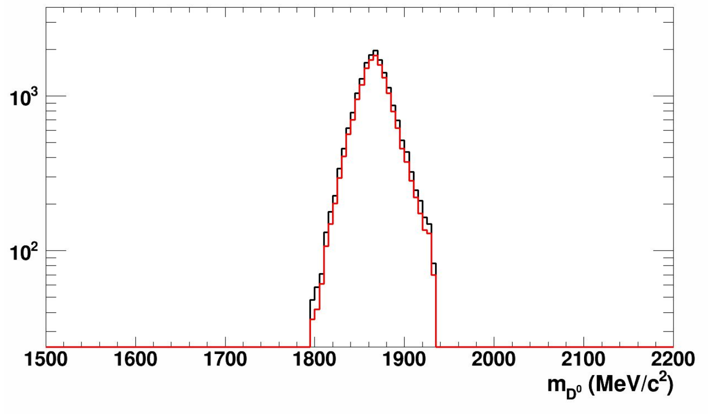


π^0 mass range: effect on D0 mass

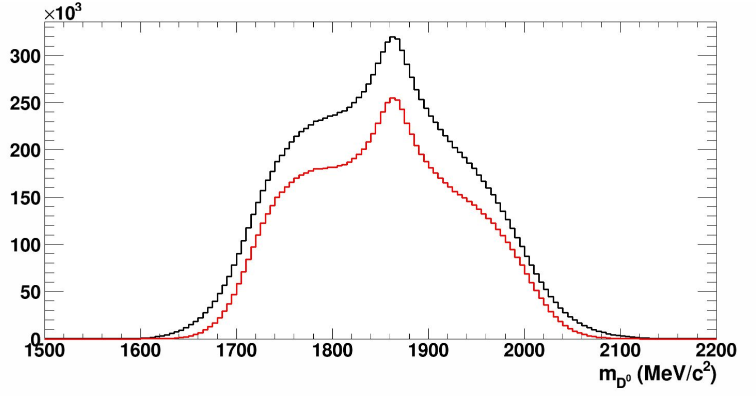
Run 1



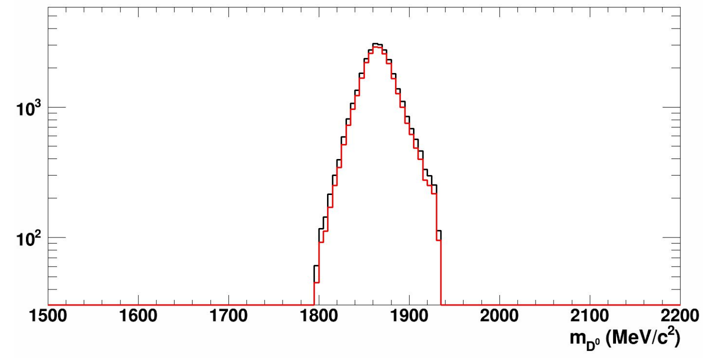
MC Run 1



Run 2

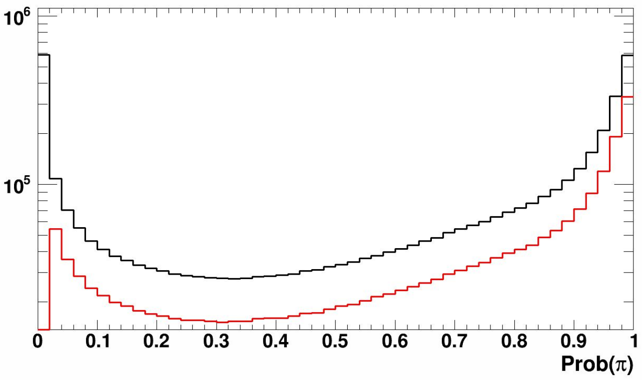


MC Run 2

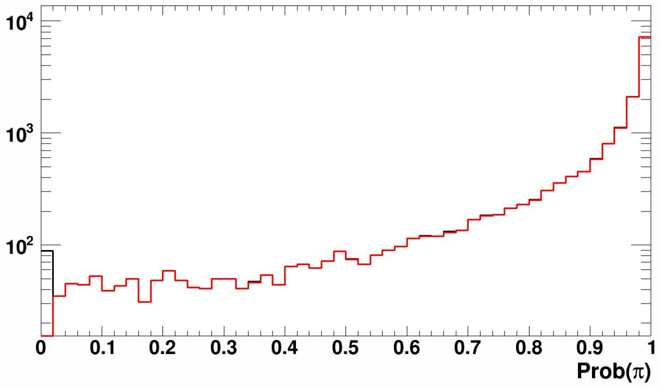


PID of D^0 daughter (pion>0.2%)

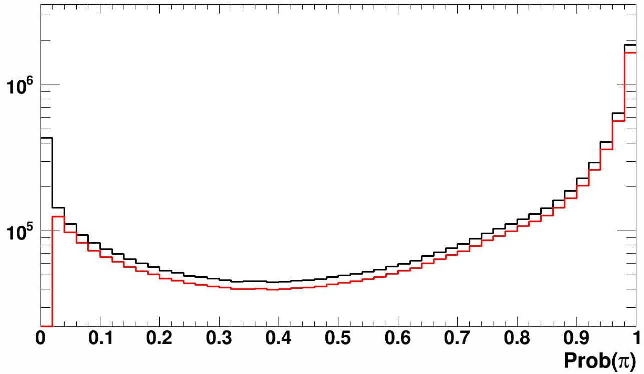
Run 1



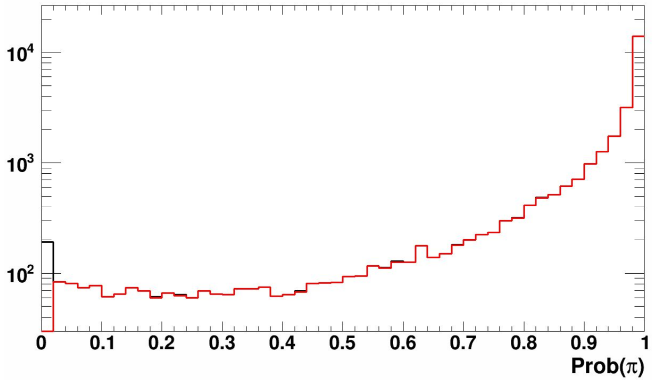
MC Run 1



Run 2

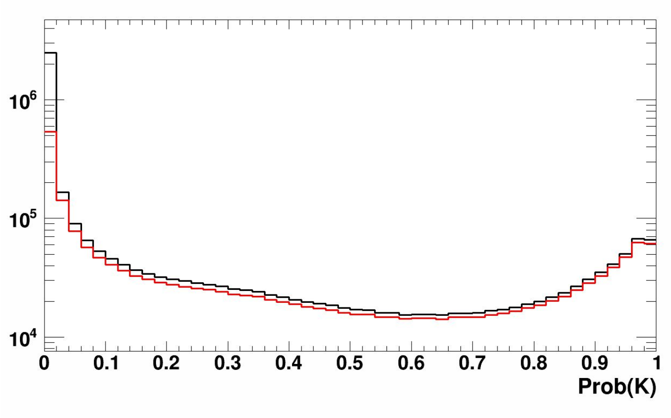


MC Run 2

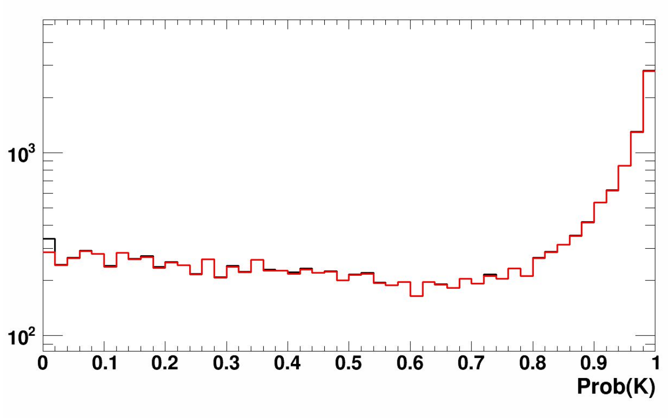


PID of D^0 daughter (kaon>2%)

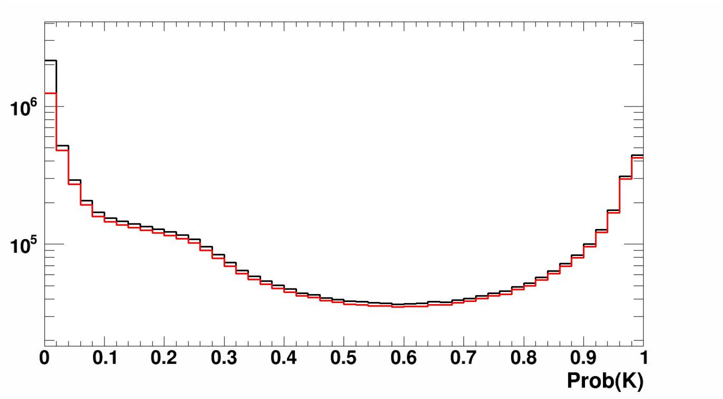
Run 1



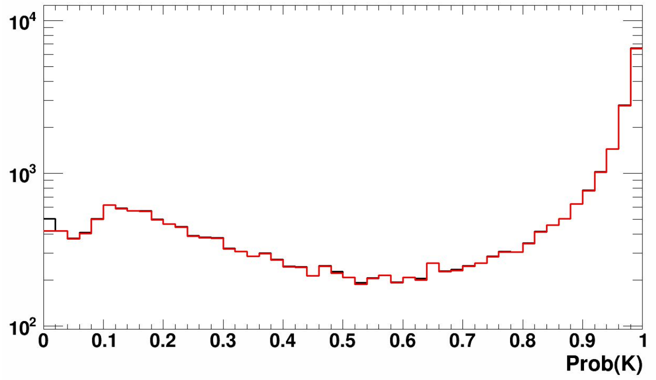
MC Run 1



Run 2

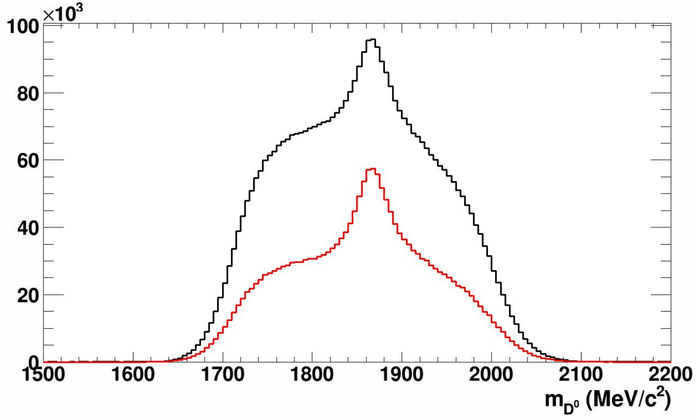


MC Run 2

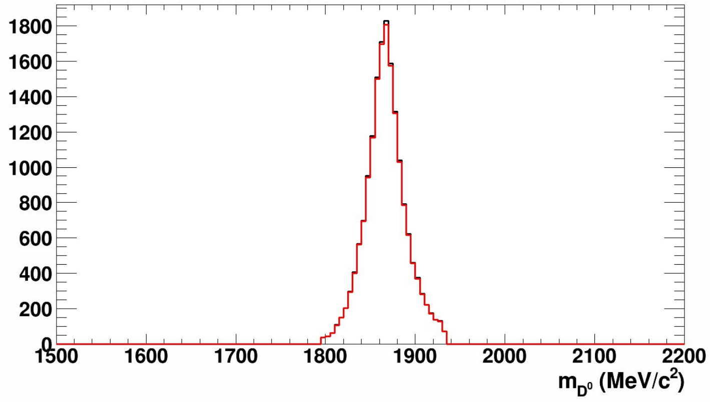


PID of D^0 daughter: effect on D^0 mass

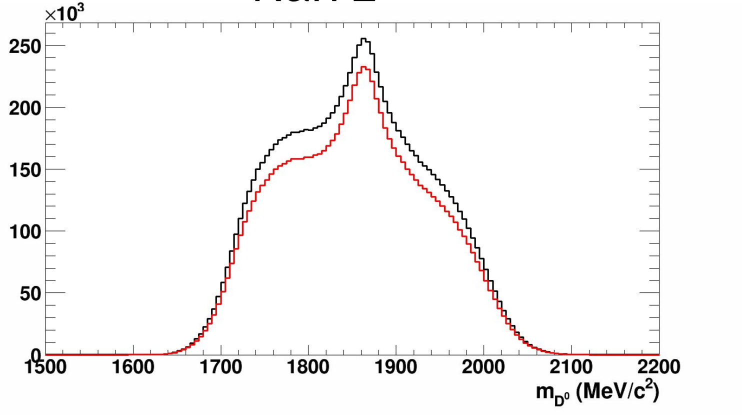
Run 1



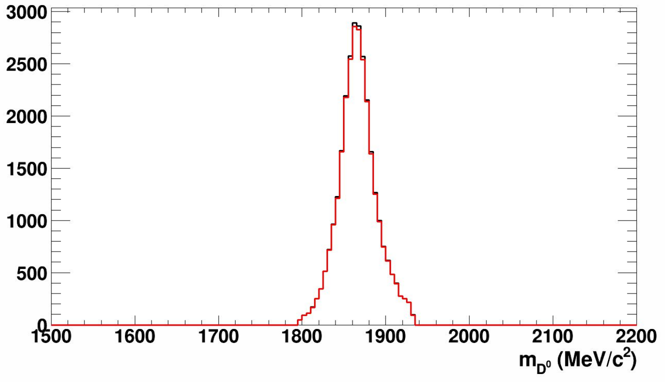
MC Run 1



Run 2

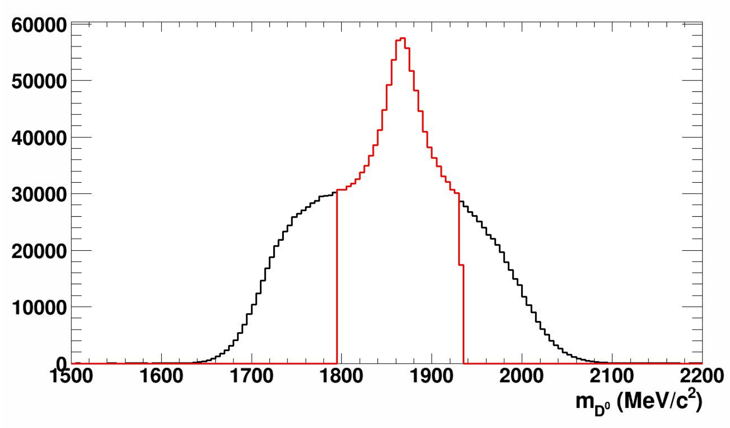


MC Run 2

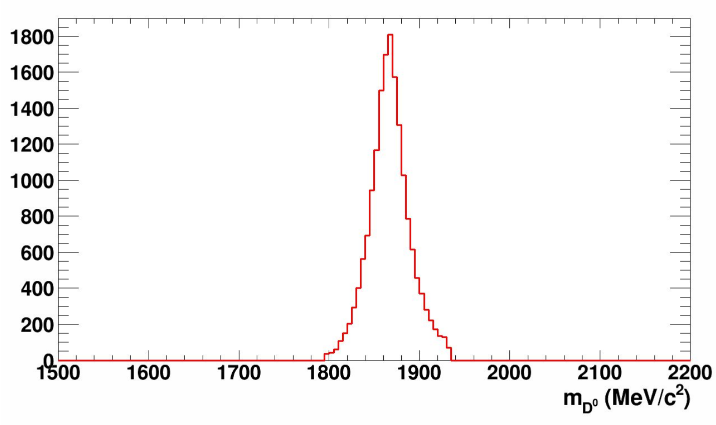


D^0 mass range $\in$ [1795.7, 1932.3] MeV

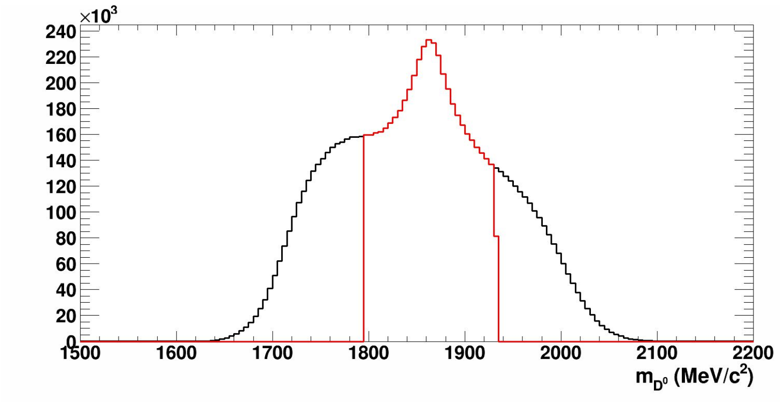
Run 1



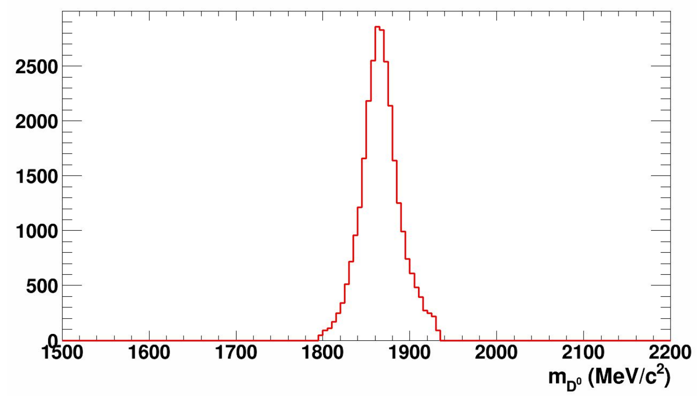
MC Run 1



Run 2

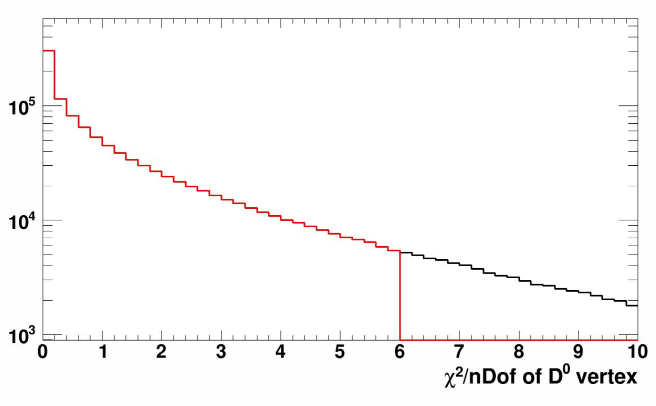


MC Run 2

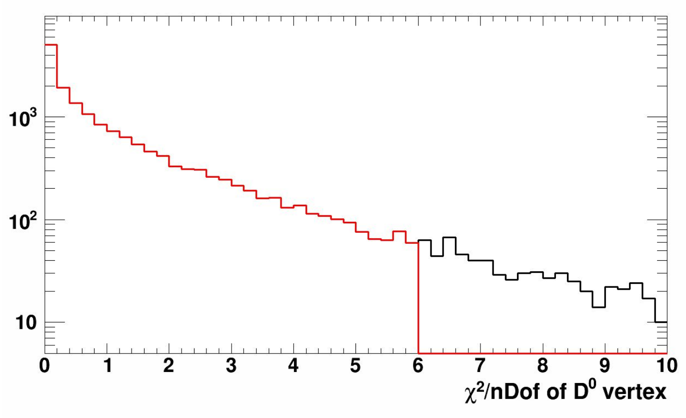


χ2/nDof of the D0 vertex>6

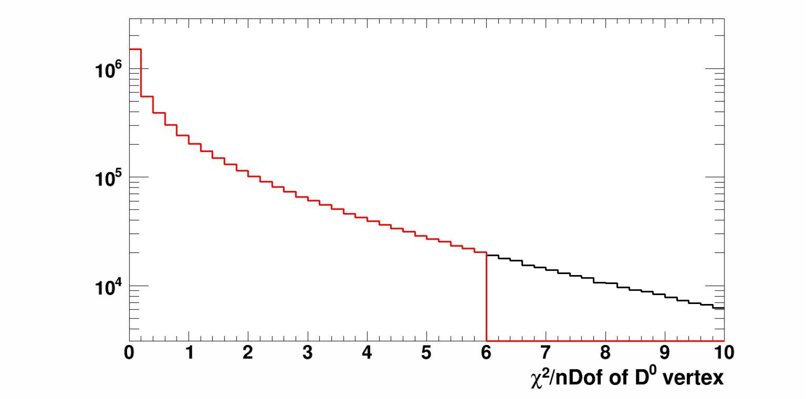
Run 1



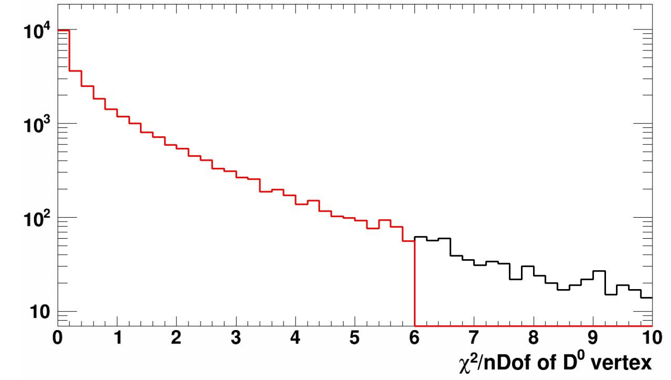
MC Run 1



Run 2

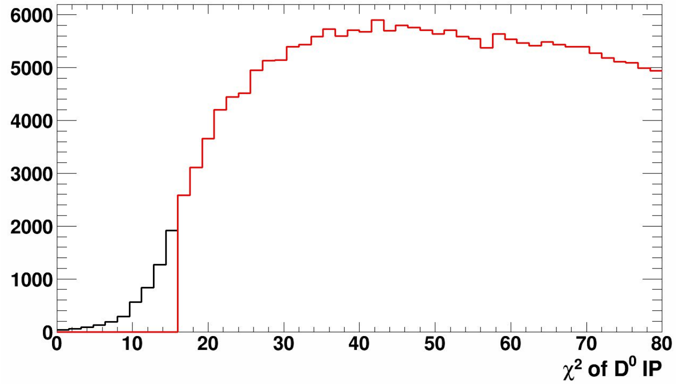


MC Run 2

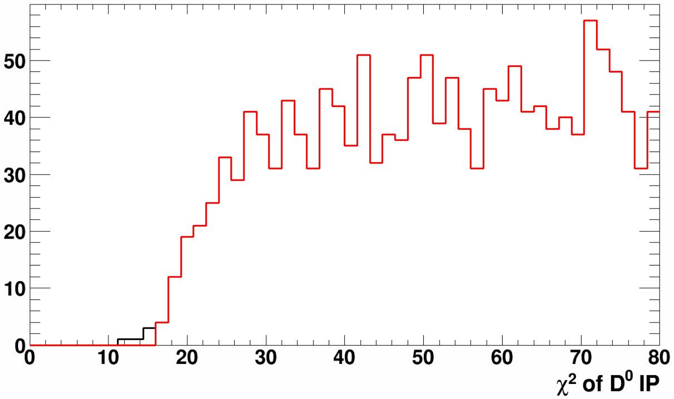


χ2 of the D0 IP>16

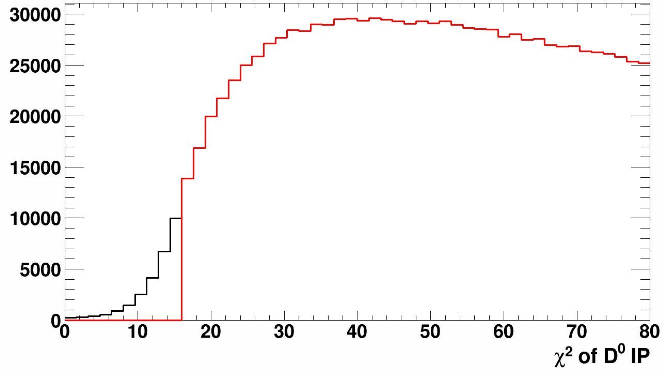
Run 1



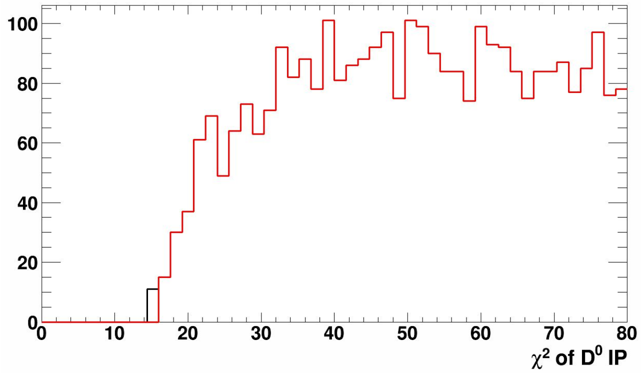
MC Run 1



Run 2

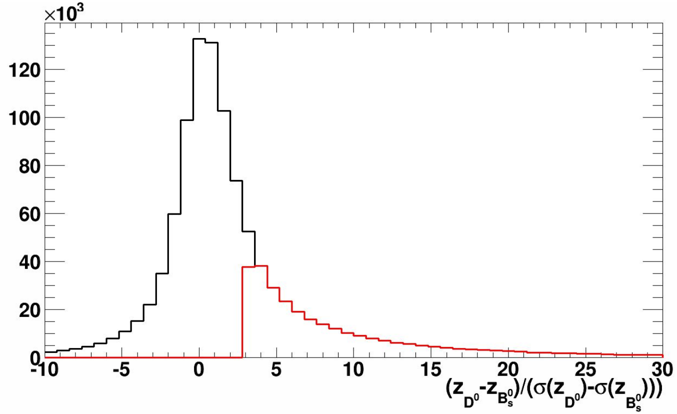


MC Run 2

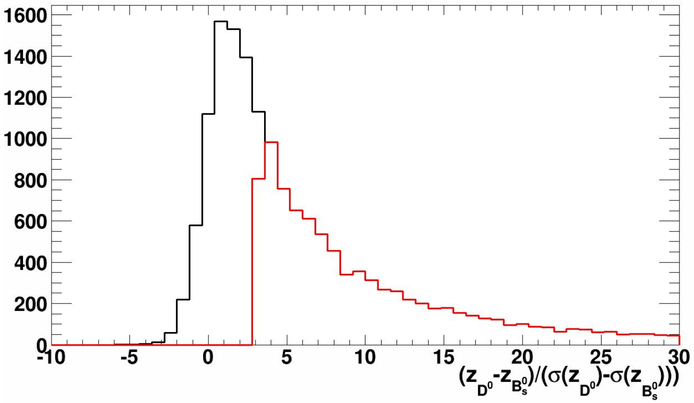


Difference of the D0 and B0 vertex z position>3

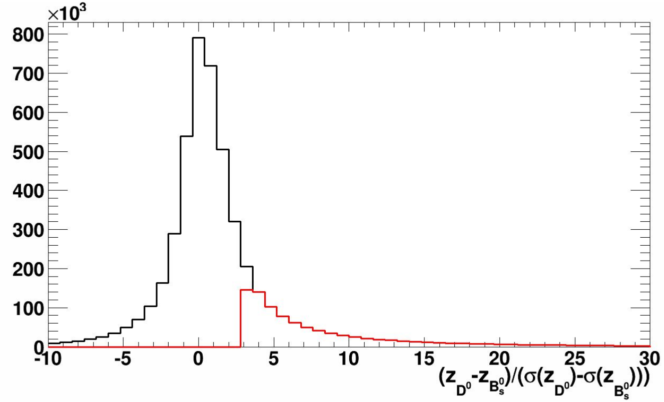
Run 1



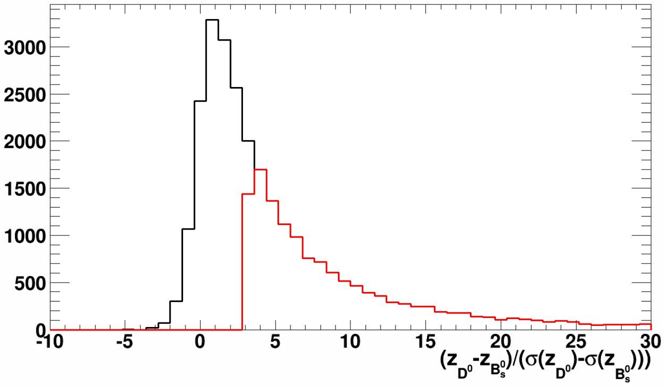
MC Run 1



Run 2

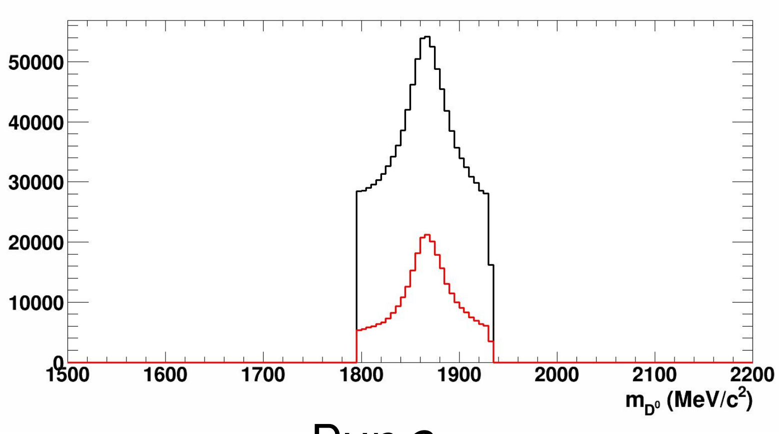


MC Run 2

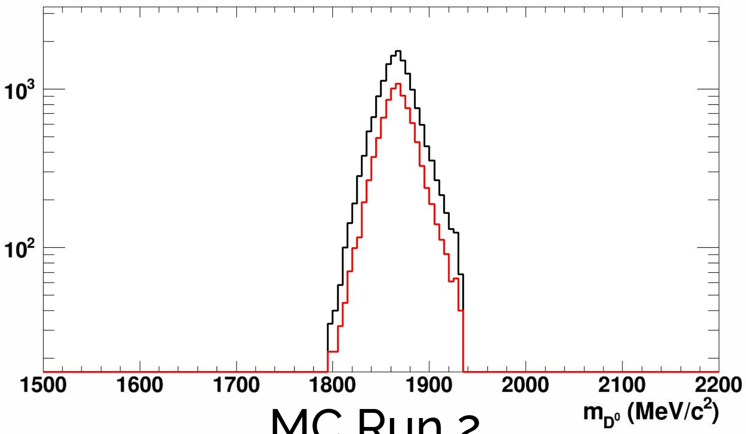


Effect on D^0 mass

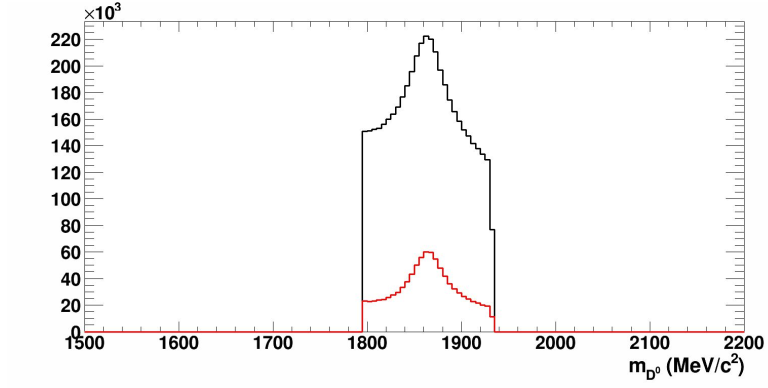
Run 1



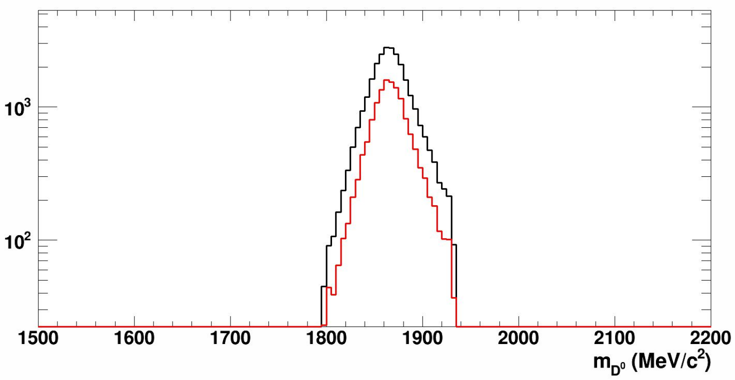
MC Run 1



Run 2

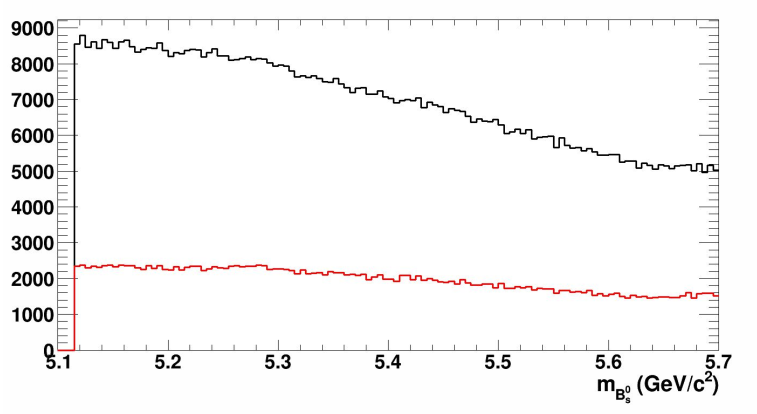


MC Run 2

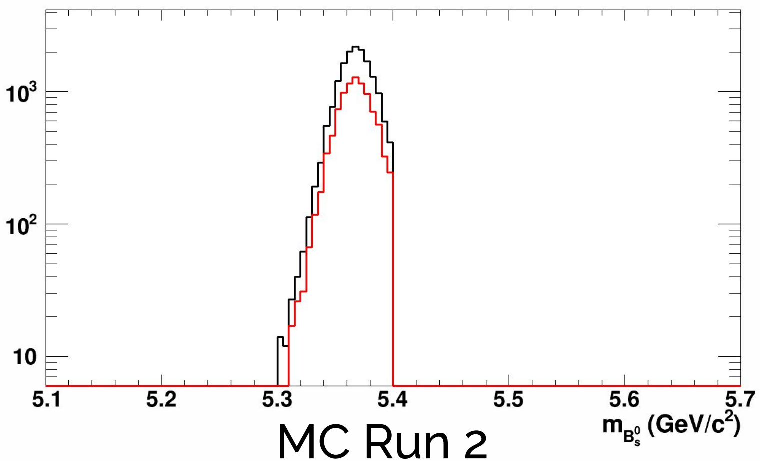


Effect on B mass

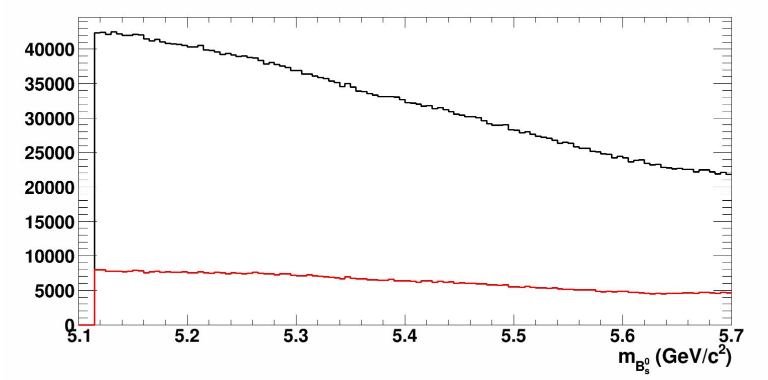
Run 1



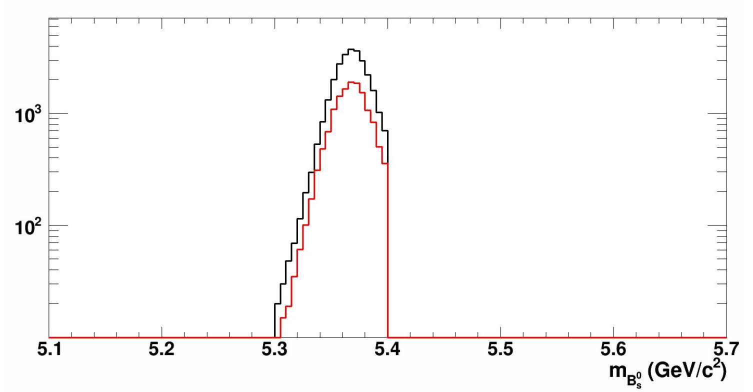
MC Run 1



Run 2

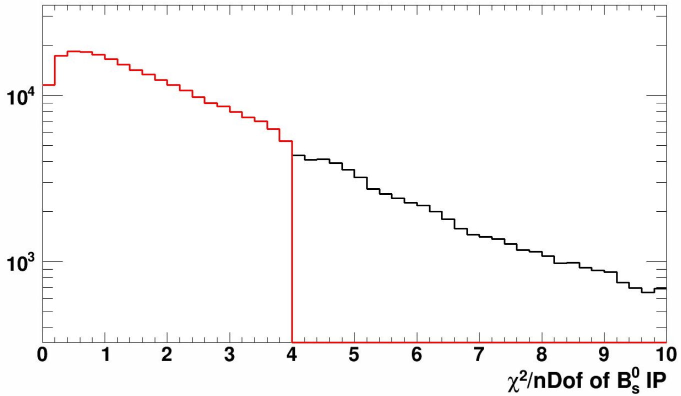


MC Run 2

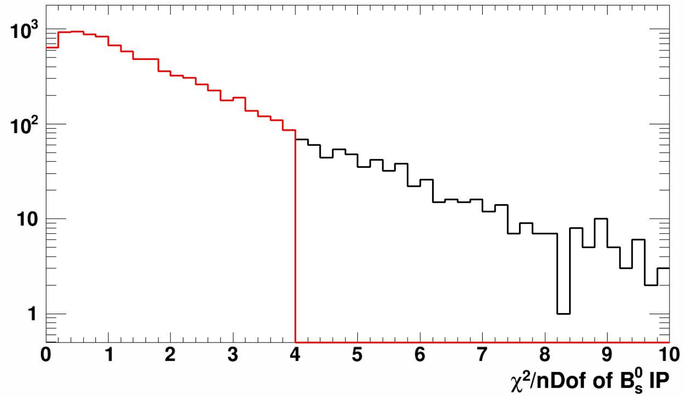


χ2/nDof of the B0 vertex>4

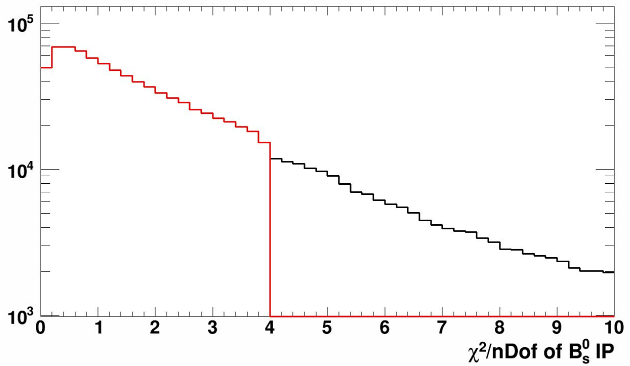
Run 1



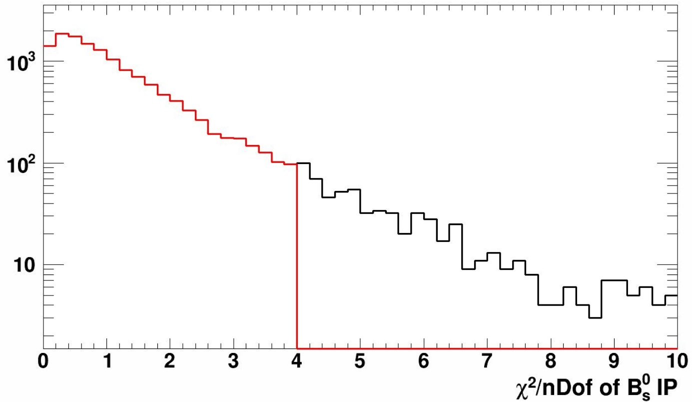
MC Run 1



Run 2

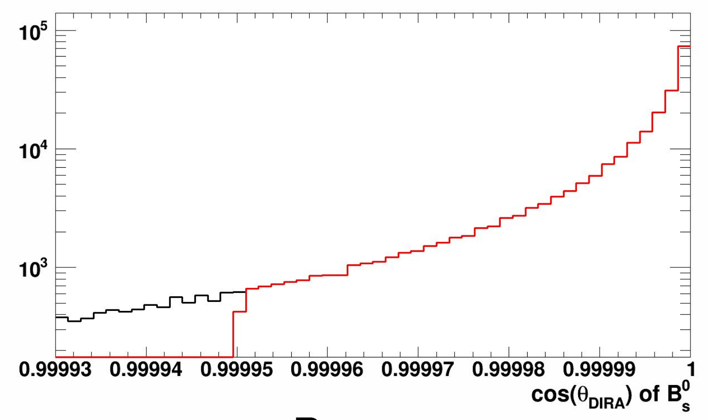


MC Run 2

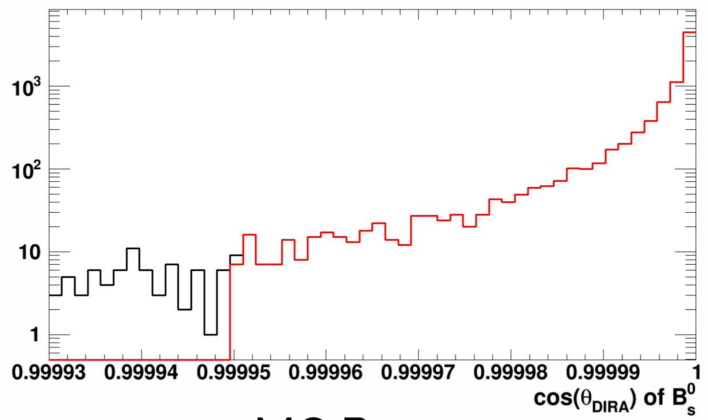


cos(ΘDIRA) of B0>0.99995

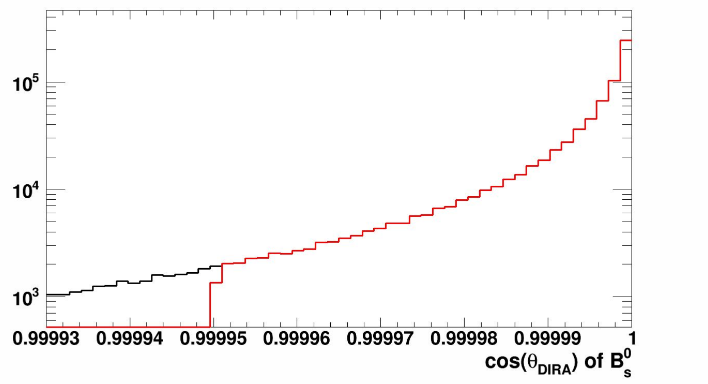
Run 1



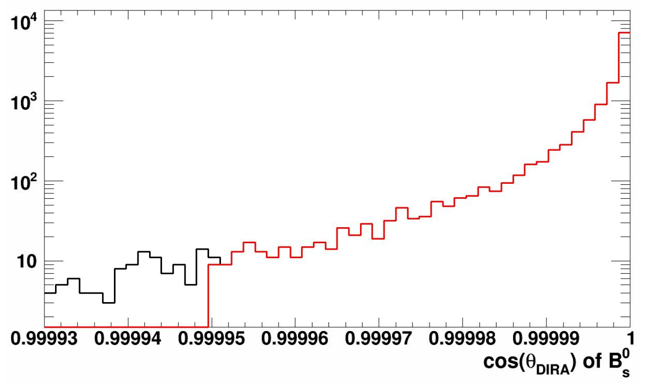
MC Run 1



Run 2

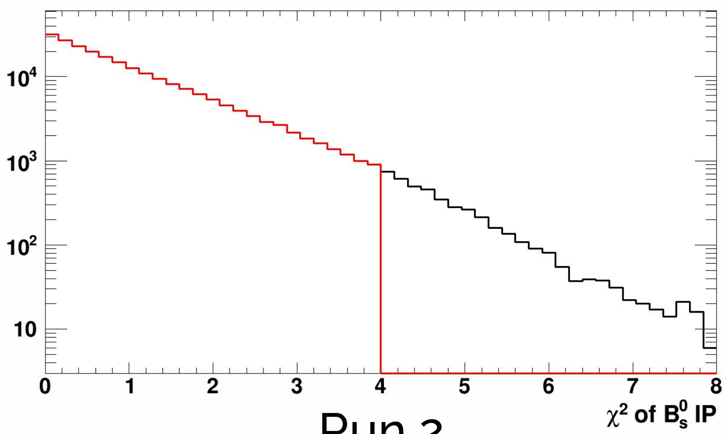


MC Run 2

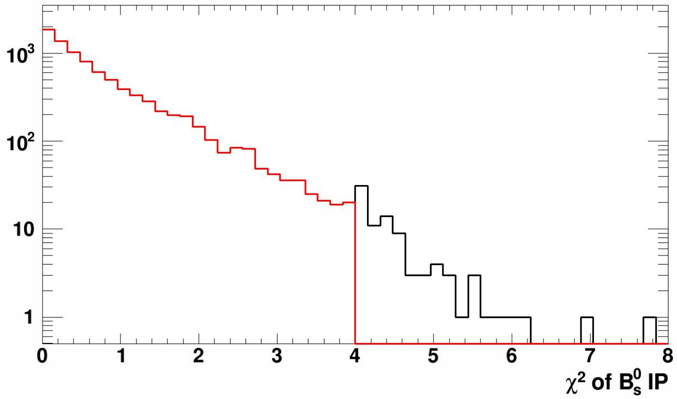


χ2 of B0 IP>4

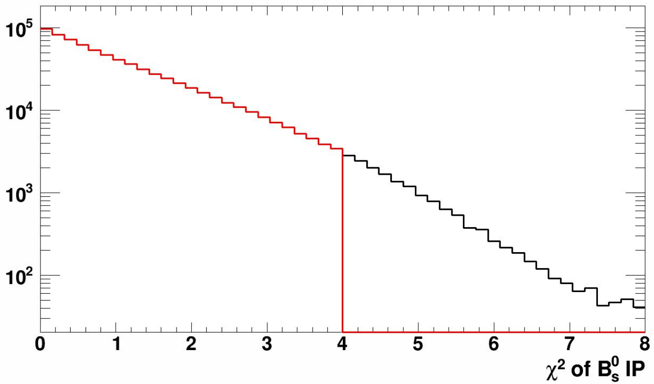
Run 1



MC Run 1



Run 2



MC Run 2