Detection of D-meson decays into $K^0_S X$ (update)

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Minimum-bias events

- pythia8.303 ($p + p$, $\sqrt{s} = 27$ GeV, SoftQCD=on)
- Channels of interest:

  $D^0 \to \pi^+ K^-$ (0.0395 ± 0.0003)

  $D^0 \to K^0_S \pi^+ \pi^-$ (0.028 ± 0.002)

  $K^0_S \to \pi^+ \pi^-$ $(0.6920 \pm 0.0005,\ c\tau \approx 2.7$ cm$)$

  $D^0 \to K^0_S \pi^0$ (0.0085 ± 0.0002)

  $K^0_S \to \pi^+ \pi^-;\ \pi^0 \to 2\gamma$
- Channels of interest:

  $D^+ \to K^- 2\pi^+$ (0.094 ± 0.002)

  $D^+ \to K^0_S \pi^+$ (0.0156 ± 0.0003)

  $K^0_S \to \pi^+ \pi^-$
- $x_F > 0.2$
- Study is focused on data-reduction by the online-filter

Rate of charmed events

Rate of charmed events per 1M pp-collisions at 27 GeV/c

D^+X	24.0	$D^{*+}X$	16.7
D^-X	30.8	$D^{*-}X$	19.9
D^0X	48.5	$D^{*0}X$	16.2
$\bar{D}^0X$	59.2	$\bar{D}^{*0}X$	21.4
D_s^+X	7.2		
D_s^-X	10.4		
Λ_c^+X	22.7		
Λ_c^-X	2.5		

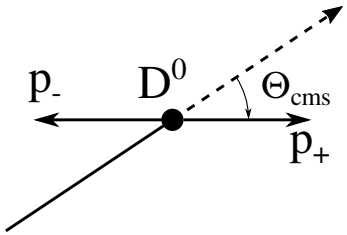
Associated D-meson production:

D^+D^-X	8.5		
$D^+\bar{D}^0X$	12.5		
D^0D^-X	14.3	$\Lambda_c^+D^-X$	5.8
$D^0\bar{D}^0X$	29.2	$\Lambda_c^+\bar{D}^0X$	12.6

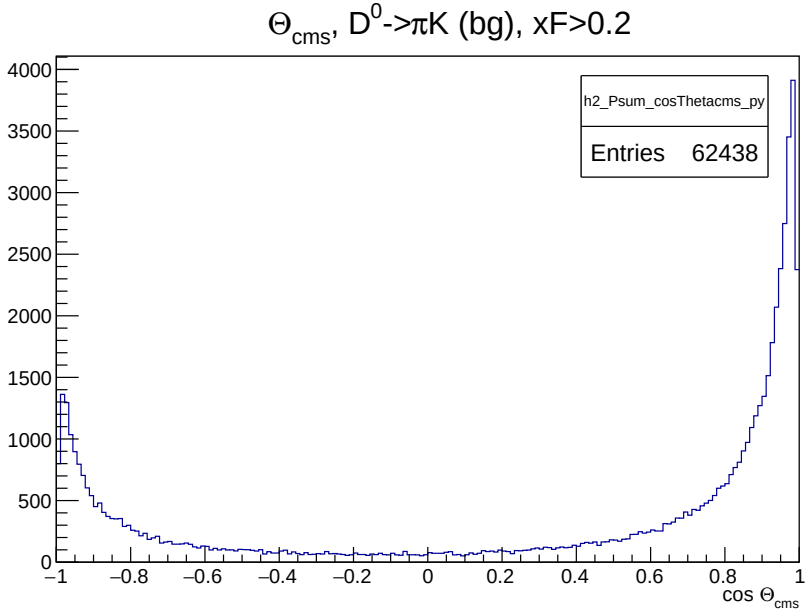
Note: expected rate of inelastic collisions 3 MHz

Selection criteria

- Acceptance: $p > 0.15$ GeV/c, $\frac{p_\perp}{p_z} > 0.1$
- $|M_{\mathrm{inv}} - M_{D0}| < 3\sigma = 150$ MeV/c
  $|M_{\pi^+\pi^-} - M_{K0}| < 3\sigma = 60$ MeV/c
  which correspond to $\frac{\sigma_p}{p} = 0.05$
- CMS kinematics $|\cos\Theta_{\mathrm{cms}}| < 0.68$:



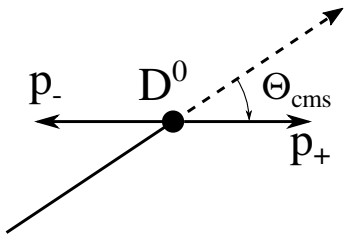
$\sigma(\cos\Theta_{\mathrm{cms}}) \approx 0.02$



- K^0_S vertex
- Ideal particle identification

Selection criteria (CMS kinematics)

D-mesons are pseudoscalars ($J^P = 0^-$)



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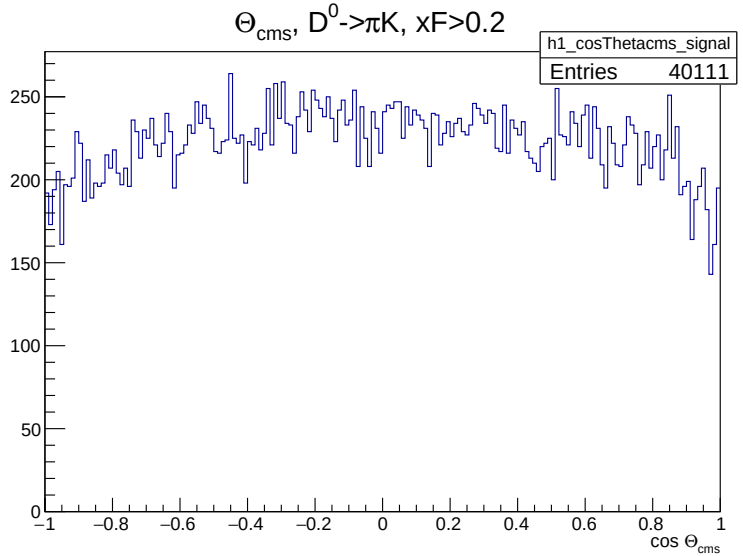


Isotropic distributions:

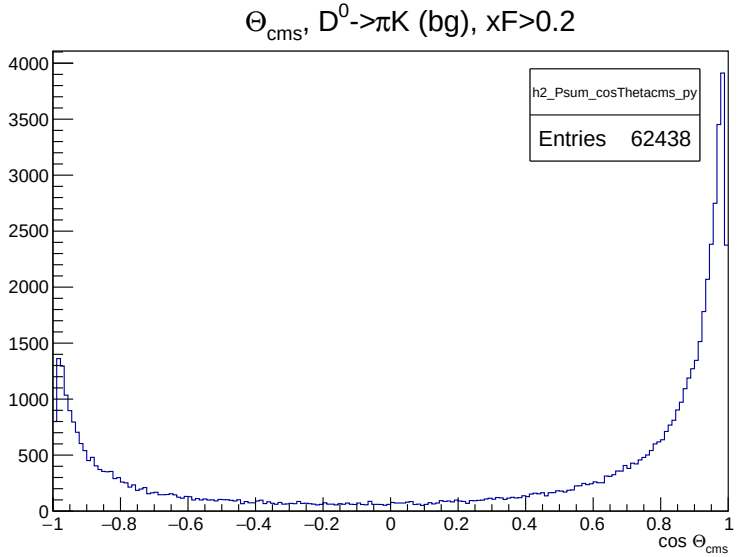
$D^0 \to \pi^+ K^-$: π^+ (or K^-) direction

$D^+ \to 2\pi^+ K^-$: K^- direction

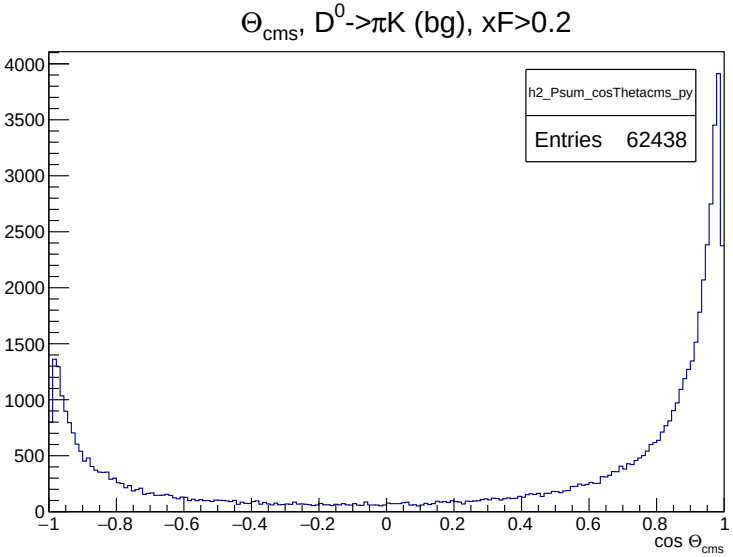
any D-decay: direction of any particular key, e.g. $\max\{p^*\}$ (in CMS)

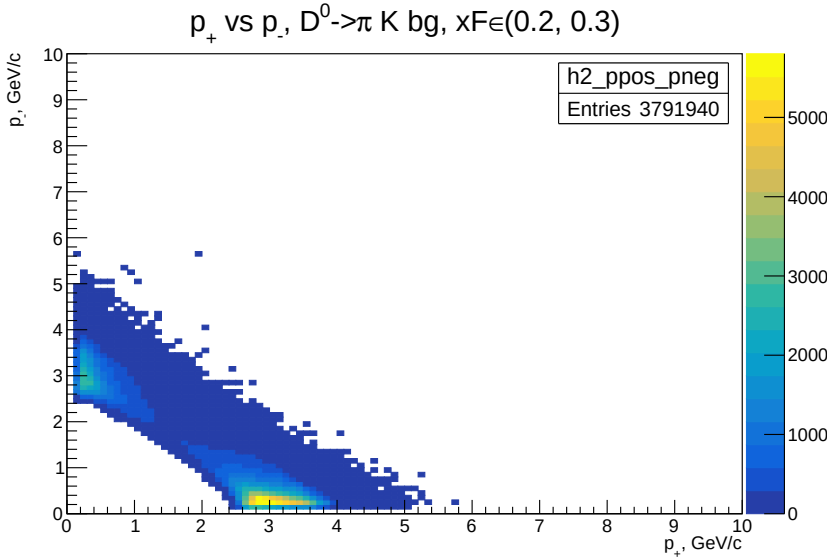
Improves signal-to-bg ratio,

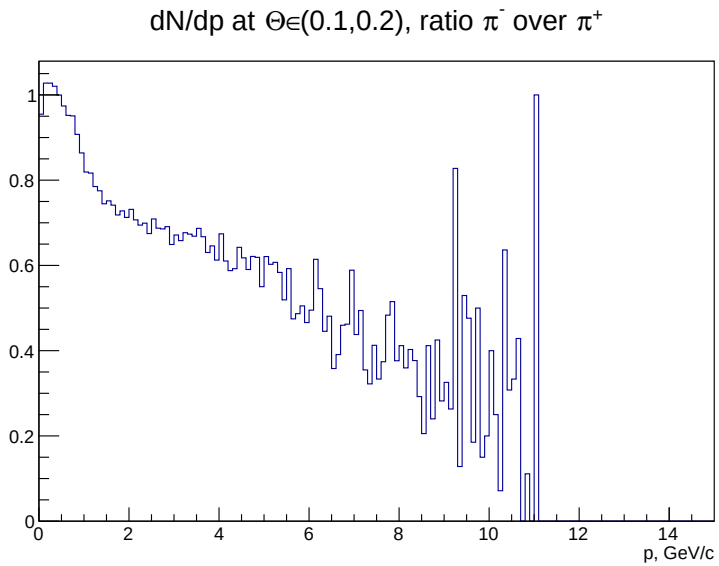
but cuts part of signal!



Asymmetry in bg (CMS kinematics)







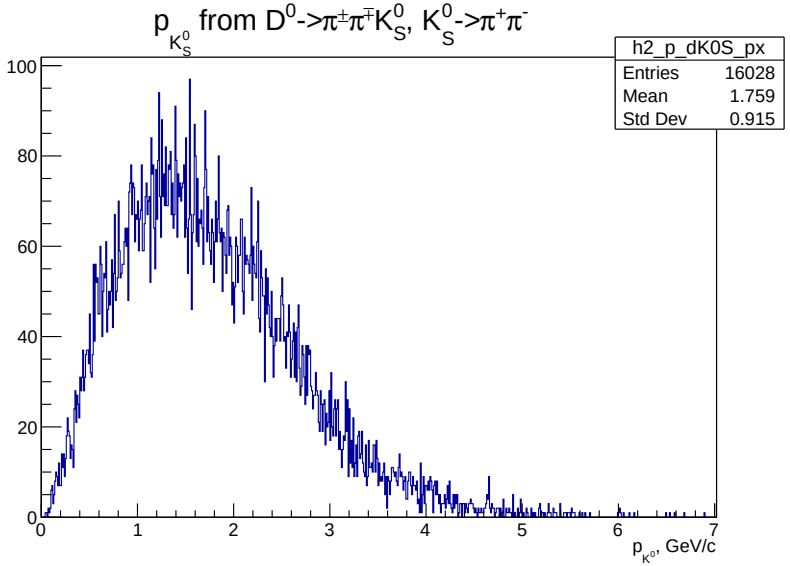
Asymmetry in bg due to:

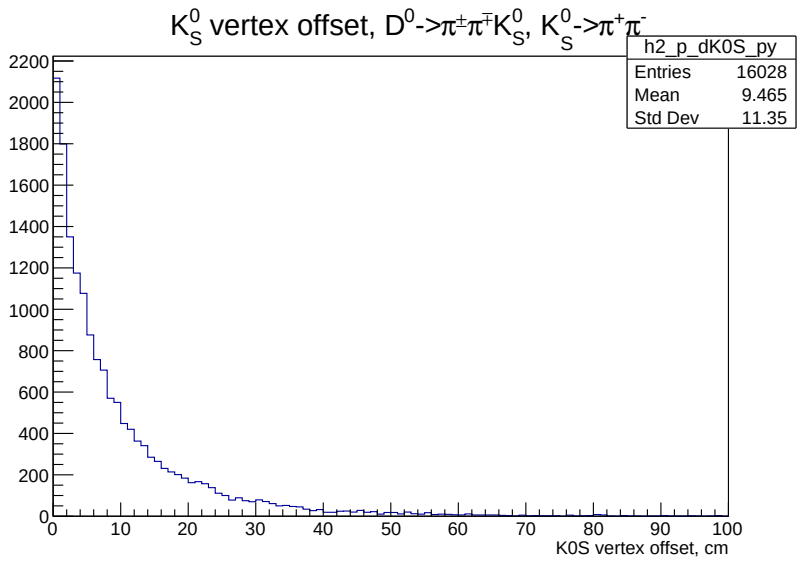
$\rightarrow$ protons

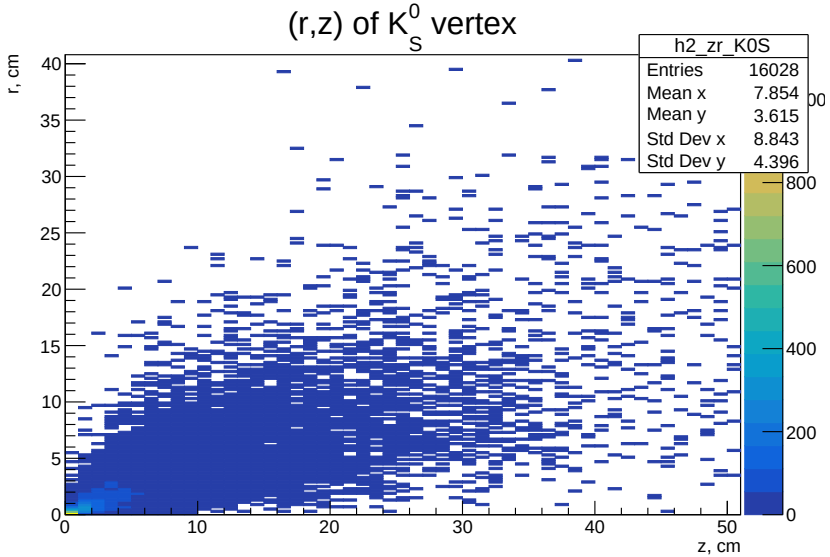
$\rightarrow$ π^+ “faster" than π^-

K^0_S from D^0 decays

$K^0_S \to \pi^+\pi^-$ $(0.6920 \pm 0.0005,\ c\tau \approx 2.7$ cm$)$





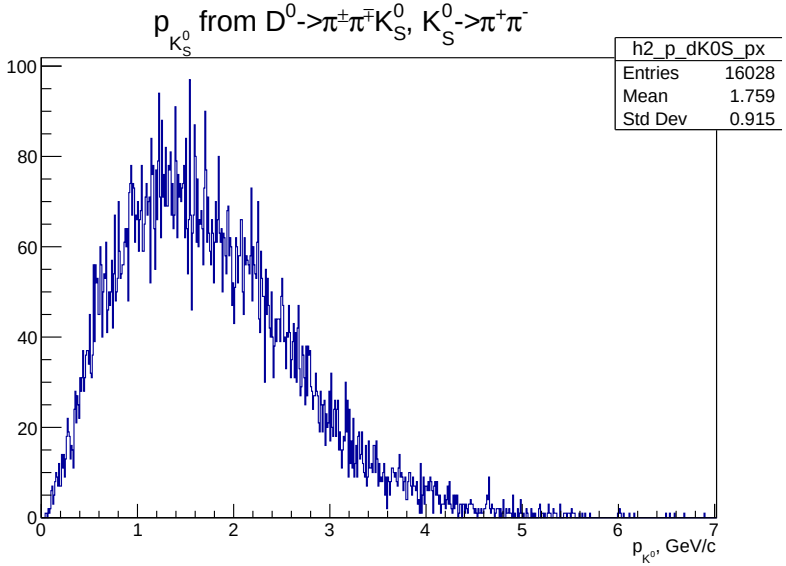


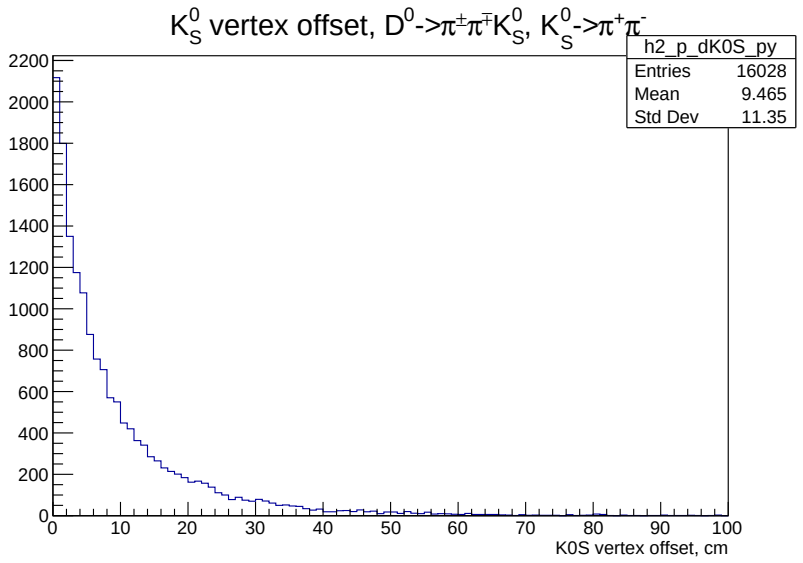
Geometry of $K^0_S \to \pi^+\pi^-$:

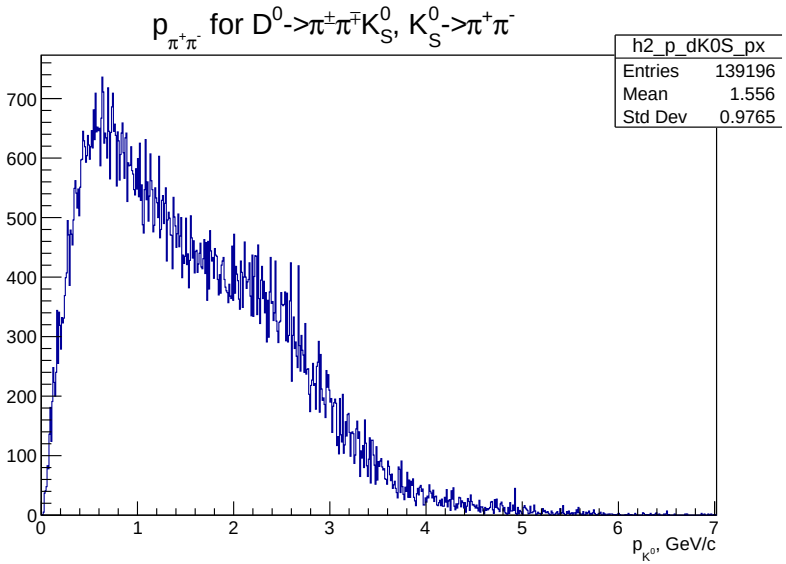
vertex offset (~ 10 cm)

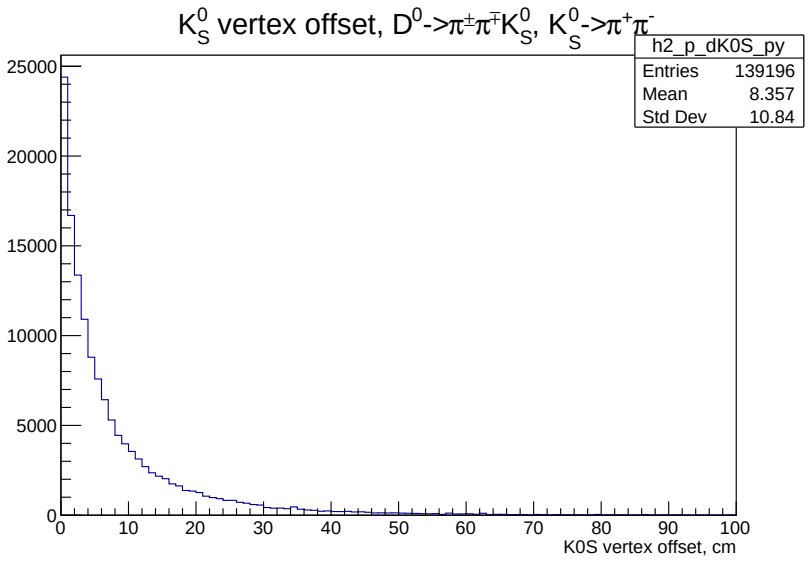
$\vec{p}(\pi^+\pi^-)$ from D^0 vertex

K^0_S from D^0 decays (signal vs bg)









$D^{\pm}$ channels

- Signal (D^+ production):

  $pp \to D^+ X$ $(2.4 \cdot 10^{-5})$

  $pp \to D^- X$ $(3.1 \cdot 10^{-5})$

  $pp \to D^+ D^- X$ $(0.9 \cdot 10^{-5})$

- Signal ($D^{\pm}$ decays):

  $D^+ \to 2\pi^+ K^-$ (0.094)

  $D^+ \to K^0_S \pi^+$; $K^0_S \to \pi^+ \pi^-$ (0.011)

- Background trigger rate ($\Delta m < 3\sigma$, $x_F > 0.2$):

Chn	$m(D^+)$	$\& m(K^0)$	$\& \lvert \cos\Theta^* \rvert < 0.68$	& ideal PID
$2h^+h^-$	0.49	—	0.34	0.035
$K^0_S h^+$	0.019	—	0.007	0.004
(non-K^0_S)h^+	0.46	0.20	0.092	0.041

D^0 channels

- Signal (D^0 production):

  $pp \to \bar{D}^0 X$ $(5.9 \cdot 10^{-5})$

  $pp \to D^0 X$ $(4.9 \cdot 10^{-5})$

  $pp \to D^0 \bar{D}^0 X$ $(2.9 \cdot 10^{-5})$

- Signal (D^0 or $\bar{D}^0$ decay):

  $D^0 \to \pi^+ K^-$ (0.040)

  $D^0 \to K^0_S \pi^+ \pi^-$; $K^0_S \to \pi^+ \pi^-$ (0.019)

  $D^0 \to K^0_S \pi^0$; $K^0_S \to \pi^+ \pi^-$ & $\pi^0 \to 2\gamma$ (0.008)

- Background trigger rate ($\Delta m < 3\sigma$, $x_F > 0.2$):

Chn	$m(D^0)$	$\&m(K^0)$	$\&\lvert\cos\Theta^*\rvert < 0.68$	& ideal PID
h^+h^-	0.29	—	0.084	0.009
$K^0_S h^+ h^-$	0.057	—	0.036	0.031
(non-K^0_S)h^+h^-	0.42	0.34	0.27	0.21
$K^0_S \pi^0$	...			

D^0 channels

- Signal (D^0 or $\bar{D}^0$ decay):

  $D^0 \to \pi^+ K^-$ (0.040)

  $D^0 \to K^0_S \pi^+ \pi^-$; $K^0_S \to \pi^+ \pi^-$ (0.019)

  $D^0 \to K^0_S \pi^0$; $K^0_S \to \pi^+ \pi^-$ & $\pi^0 \to 2\gamma$ (0.008)

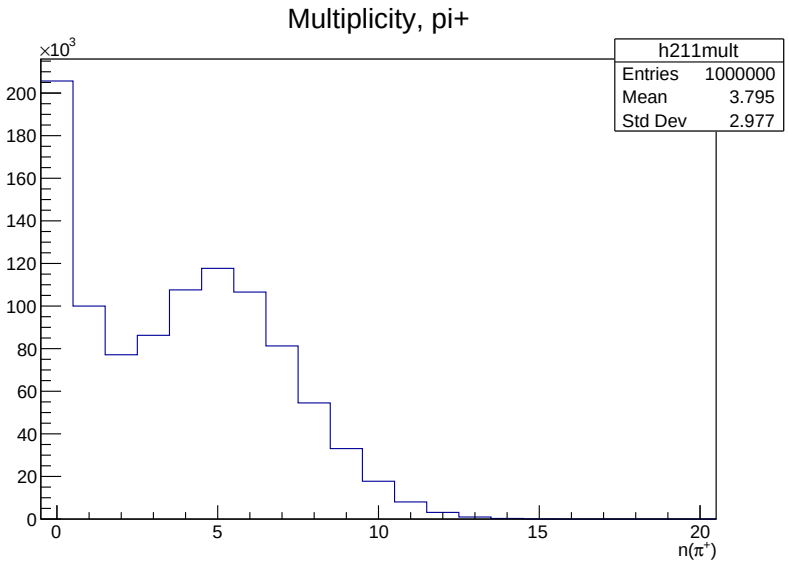
- Background trigger rate ($\Delta m < 3\sigma$, $x_F > 0.2$):

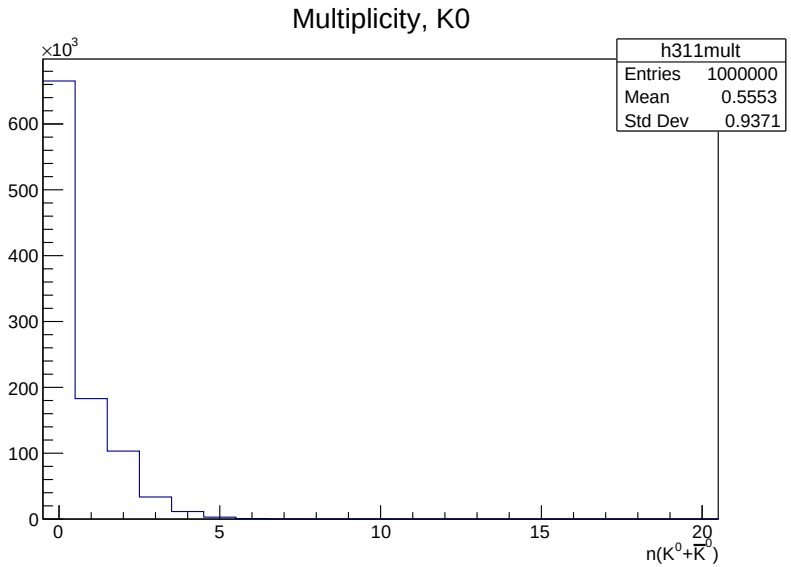
Chn	$m(D^0)$	$\&m(K^0)$	$\&\lvert\cos\Theta^*\rvert < 0.68$	& ideal PID
h^+h^-	0.29	—	0.084	0.009
$K^0_S h^+ h^-$	0.057	—	0.036	0.031
(non-K^0_S)h^+h^-	0.42	0.34	0.27	0.21
$K^0_S \pi^0$	0.006	—	0.002	

- π^0 identification: $\sigma(E) = \frac{0.055}{\sqrt{E\ \text{[in GeV]}}} + 0.025$ (A.Maltsev)

- Bg channels (non-K^0_S)π^0 and (non-K^0_S)(2γ) can be efficiently suppressed

$pp \to K^0_S(\to \pi^+\pi^-)X$





Probability($pp \to K^0_S(\to \pi^+\pi^-)X$) ≈ 0.11

(with both pions within the SPD acceptance)

- Detection of $D^+ \to K^0_S \pi^+$ is favored to $D^+ \to K^- 2\pi^+$
- Detection of $D^0 \to K^0_S \pi^+ \pi^-$ seems to be competitive to $D^0 \to K^- \pi^+$ (unless SPD provides reasonable PID)
- Detection of $D^0 \to K^0_S \pi^0$ is favored to $D^0 \to K^- \pi^+$
- Tuning of the Online-filter to select $pp \to K^0_S (\to \pi^+ \pi^-) X$ events $\to$ the reasonable suppression factor
- Detection efficiency of $K^0_S \to \pi^+ \pi^-$ to be studied within SPDROOT