Detection of D-meson decays into K_S^0X (update)

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- 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)

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

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

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

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

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

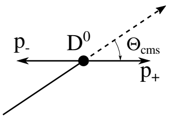
  $\quad K^0_S \to \pi^+ \pi^-$
- $x_F > 0.2$
- Study is focused on data-reduction by the online-filter

Selection criteria

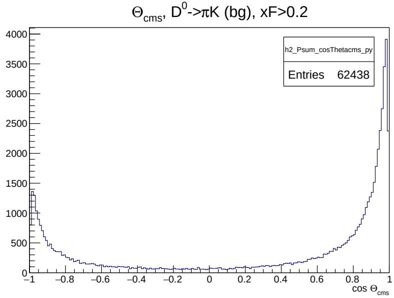
- Acceptance: $p > 0.15$ GeV$/c$, $\frac{p_\perp}{p_z} > 0.1$
- $|M_{\text{inv}} - M_{D^0}| < 3\sigma = 150$ MeV$/c$

  $|M_{\pi^+\pi^-} - M_{K^0}| < 3\sigma = 60$ MeV$/c$

  which correspond to $\frac{\sigma_p}{p} = 0.05$
- CMS kinematics $|\cos\Theta_{\text{cms}}| < 0.68$:



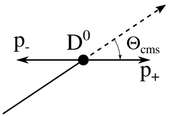
$\sigma(\cos\Theta_{\text{cms}}) \approx 0.02$



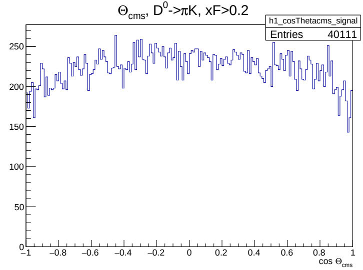
- K^0_S vertex
- Ideal particle identification

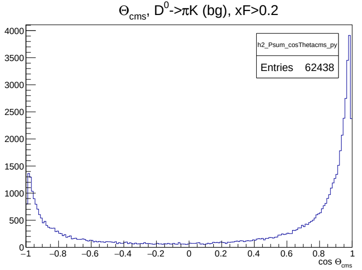
Selection criteria (CMS kinematics)

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



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





Isotropic distributions:

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

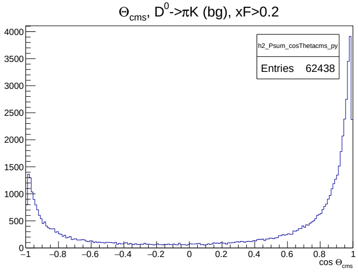
$D^+ \to 2\pi^+ K^-$: K^- direction

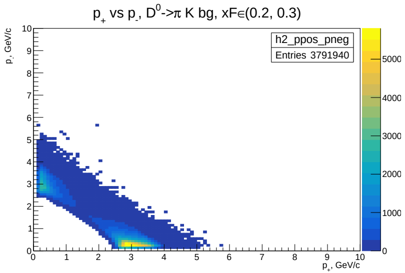
any D-decay: direction of any particular key, e.g. $\max\{p^*\}$ (in CMS)

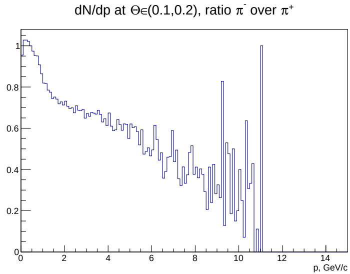
Improves signal-to-bg ratio,

but cuts part of signal!

Asymmetry in bg (CMS kinematics)







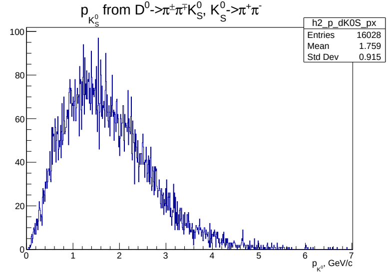
Asymmetry in bg due to:

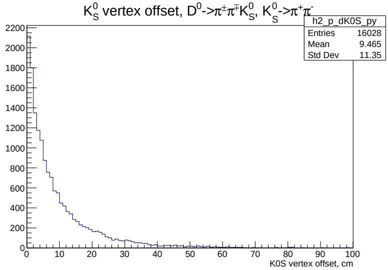
→ protons

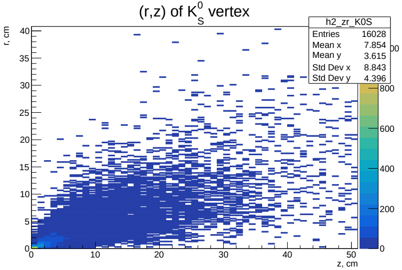
→ π^+ “faster" than π^-

K_S^0 from D^0 decays

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





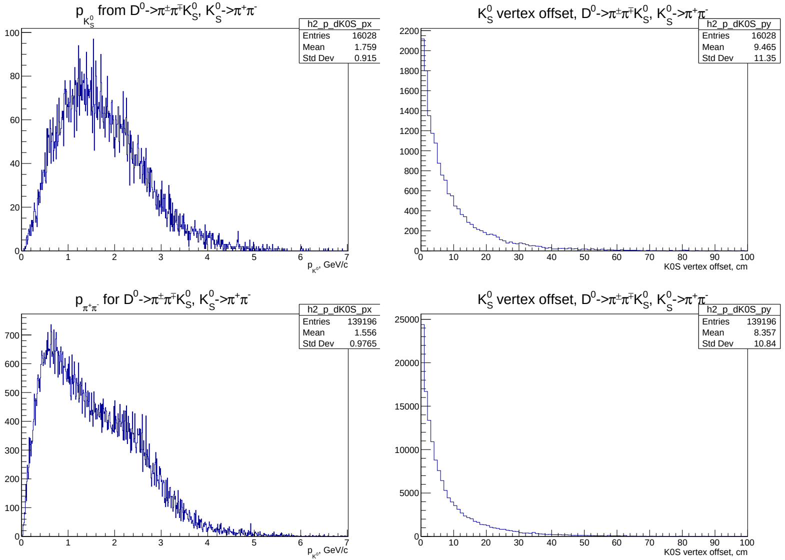


Geometry of $K_S^0 \to \pi^+\pi^-$:

vertex offset (~ 10 cm)

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

K_S^0 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
$h^+h^+h^-$	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
$K^0_S \pi^0$	...			

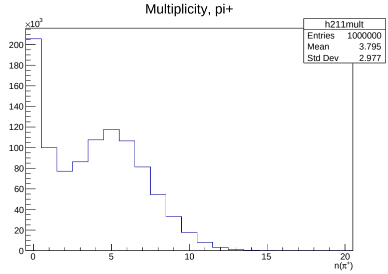
D^0 channels

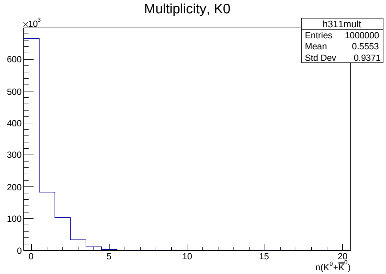
- Signal (D^0 or $\bar{D}^0$ decay):
  $D^0 \to \pi^+ K^-$ (0.040)
  $D^0 \to K^0_S \pi^+\pi^-$; $K^0_S \to \pi^+\pi^-$ (0.019)
  $D^0 \to K^0_S \pi^0$; $K^0_S \to \pi^+\pi^-$ & $\pi^0 \to 2\gamma$ (0.008)
- Background trigger rate ($\Delta m < 3\sigma$, $x_F > 0.2$):

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

(with both pions within the SPD acceptance)

D^0: better resolution

D^0 candidates. Bg trigger rate ($\frac{\sigma_p}{p} = 0.05$, $\Delta m < 3\sigma$, $x_F > 0.2$)

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
$K^0_S \pi^0$	0.006	—	0.002	

D^0 candidates. Bg trigger rate ($\frac{\sigma_p}{p} = 0.02$, $\Delta m < 3\sigma$, $x_F > 0.2$)

Chn	$m(D^0)$	$\&m(K^0)$	$\&\lvert\cos\Theta^*\rvert < 0.68$	& ideal PID
h^+h^-	0.18	—	0.044	0.004
$K^0_S h^+h^-$	0.034	—	0.020	0.017
$K^0_S \pi^0$	0.003	—	0.0008	

$D^{\pm}$: better resolution

$D^{\pm}$ candidates. Bg trigger rate ($\frac{\sigma_p}{p} = 0.05$, $\Delta m < 3\sigma$, $x_F > 0.2$)

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

$D^{\pm}$ candidates. Bg trigger rate ($\frac{\sigma_p}{p} = 0.02$, $\Delta m < 3\sigma$, $x_F > 0.2$)

Chn	$m(D^+)$	$\&m(K^0)$	$\&\lvert\cos\Theta^*\rvert < 0.68$	& ideal PID
$h^+h^+h^-$	0.39	—	0.23	0.017
$K^0_S h^+$	0.009	—	0.0030	0.0018

Accumulated statistics

S/B ratio for several channels, $N_{pp} = 3 \cdot 10^{14}$

	S, 10^{-6}	B	S/B, 10^{-5}	$S/\sqrt{B}$, 100 days	$\frac{S/\sqrt{B}}{(S/\sqrt{B})_{\mathbf{ref}}}$
π^+K^- or π^-K^+	0.77	0.084	0.92	46	1.0
$K_S^0(\to \pi^+\pi^-)\pi^+\pi^-$	0.31	0.036	0.87	28.7	0.62
$\pi^+\pi^+K^-$ or $\pi^-\pi^-K^+$	1.00	0.34	0.29	29.8	1.0
$K_S^0(\to \pi^+\pi^-)\pi^+$ or c.c.	0.098	0.007	1.40	20.3	0.68

Summary

- Reference decay channels ($D^0 \to K^-\pi^+$ and $D^+ \to K^-\pi^+\pi^+$) provide better sensitivity
- Detection of $D^+ \to K_S^0(\to \pi^+\pi^-)\pi^+$ has a reasonable sensitivity and small bg rate
- Tuning of the Online-filter to select $pp \to K_S^0(\to \pi^+\pi^-)X$ events $\to$ the reasonable suppression factor