Status of $\bar{p}p \rightarrow h_c \rightarrow \eta_c + \gamma$ analysis

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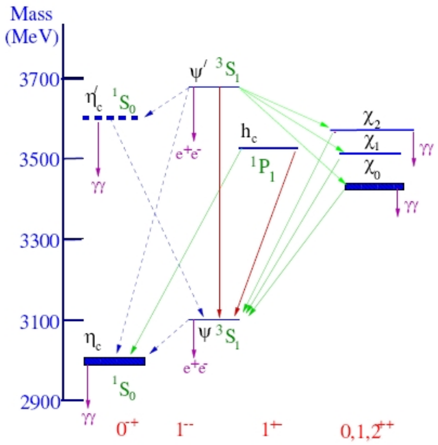
Outline

h_c discovery



- E760 claimed signal in $h_c \to J/\psi + \pi^0$ decay.
- E835 failed to confirm this results but made a hint for $\bar{p}p \to h_c \to \eta_c + \gamma$ decay
- In 2004 CLEO observes h_c in inclusive and exclusive measurements of Ψ' decay.

Motivation to study

Spin-Spin part of potential

$$V_{SS} = \frac{2(\overrightarrow{S}_1 \cdot \overrightarrow{S}_2)}{3m_c^2} \cdot \nabla^2 V_V(r)$$

- For V_V purely from one-gluon exchange V_V (no vector contribution from confining part of potential) $V_V(r) \sim \frac{1}{r}$
- For P-state ($\Psi(r \to 0) \to 0$) no hiper-fine splitting
- Trtplet P-states are split by spin-orbit interaction
- Centre of gravity of triplet state

$$M_{cog} = \frac{M(\chi_0) + 3M(\chi_1) + 5M(\chi_2)}{9}$$

- Small $M_{cog} - M_{h_c}$ results in small vector contribution to confining potential

h_c decay modes

Discovery channel

$$h_c \rightarrow J/\psi + \pi^0$$

Exclusive process

$$\bar{p}p \rightarrow h_c \rightarrow \eta_c + \gamma$$

Neutral channel

$$h_c \rightarrow \gamma + \eta_c \rightarrow \gamma + \gamma + \gamma \quad (BR = 4.3 \cdot 10^{-4})$$

Channels with charged particles

$\eta_c \rightarrow K^0_S K^\pm \pi^\pm \quad (BR = 1.9 \cdot 10^{-2})$

$\eta_c \rightarrow K^0_L K^\pm \pi^\pm \quad (BR = 1.9 \cdot 10^{-2})$

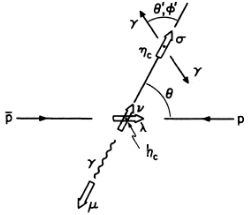
$\eta_c \rightarrow K^+ K^- \pi^+ \pi^- \quad (BR = 1.5 \cdot 10^{-2})$

$\eta_c \rightarrow \pi^+ \pi^- \pi^+ \pi^- \quad (BR = 1.2 \cdot 10^{-2})$

$\eta_c \rightarrow K^+ K^- \pi^0 \quad (BR = 1.5 \cdot 10^{-2})$

$\eta_c \rightarrow \pi^+ \pi^- \eta(\gamma\gamma) \quad (BR = 1.3 \cdot 10^{-2})$

Description of the studied channel



Due to C-parity conservation the helicity-1 state does not enter into h_c production.

$$W(\theta) = W(\pi/2)\sin^2(\theta)$$

$$p\bar{p} \rightarrow h_c \rightarrow \eta_c + \gamma_1 \rightarrow \gamma\gamma\gamma_1,$$

E_γ=503 MeV

$$\eta_c \rightarrow \gamma\gamma,\ BR = 4.3 \cdot 10^{-4}$$

E_{CM}=3526 MeV, p_z=5609 MeV

Cross-sections

$$\sigma_{p\bar{p}\rightarrow h_c\rightarrow\eta_c+\gamma} = 16.8 \pm 2.7pb\ (E835)$$

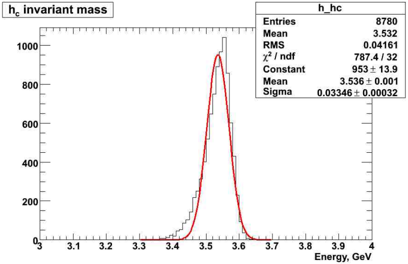
$$\sigma_{\pi^0\pi^0} = 31.4\ nb, E = 3526MeV, |cos(\theta)| < 0.6$$

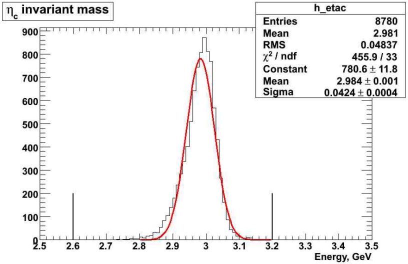
$$\sigma_{\pi^0\gamma} = 1.4\ nb, E = 3526MeV, |cos(\theta)| < 0.6$$

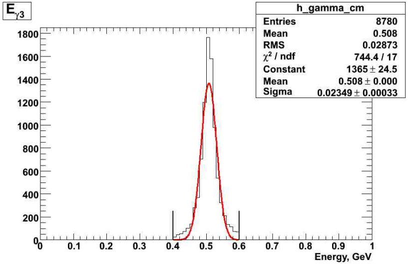
Event selection

- 100 k events $p\bar{p} \rightarrow h_c \rightarrow \eta_c + \gamma, \ (E_{CM} = 3526 MeV)$
- background
  - 1 M $p\bar{p} \rightarrow \pi^0\pi^0$
  - 1 M $p\bar{p} \rightarrow \pi^0\gamma$
- Selection cuts:
  - Only 3 γ in events
  - η_c mass range [2.6:3.2] GeV
  - Difference to beam momentum:
    $|p(\eta_c + \gamma)_z - p_{b,z}| < 0.2 GeV$
    $|p(\eta_c + \gamma)_{x,y}| < 0.2 GeV$
  - $E_{\gamma 3}$ within [0.4:0.6] GeV
  - $|cos(\theta^*_{\gamma 1,2})| < 0.4$
  - $M(\gamma_1 + \gamma_3), M(\gamma_2 + \gamma_3) > 1.0 GeV$

$h_c \rightarrow \eta_c + \gamma$

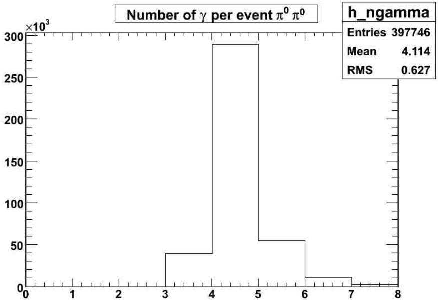


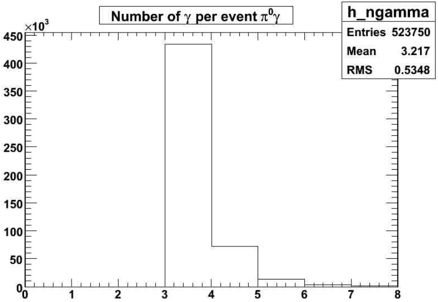




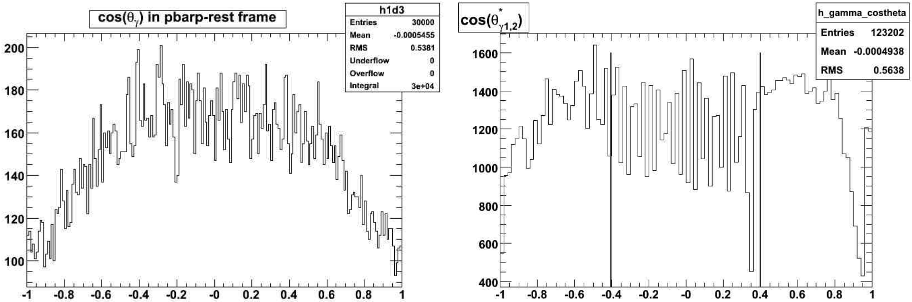
h_c *mass*	86.1%
3γ	67.1%
beam momentum	63.6%
$E_{\gamma 3}$	61.6%
$cos(\theta_{1,2})$	23.5%
$M(\gamma 1+\gamma 3), M(\gamma 2+\gamma 3)$	8.8%

Number of γ in $\pi^0\pi^0$, $\pi^0\gamma$ events

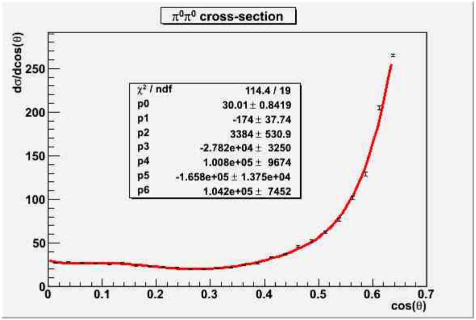


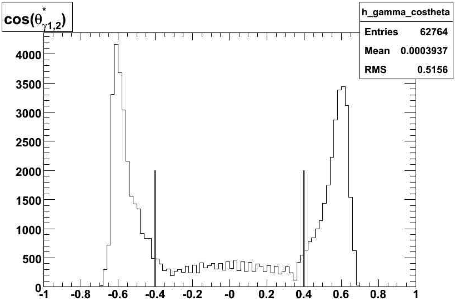


Distribution of $cos(\theta_{\gamma 1,2})$ in h_c events

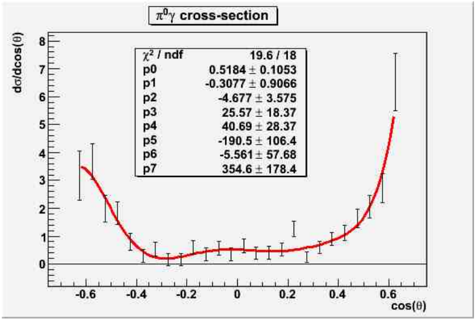


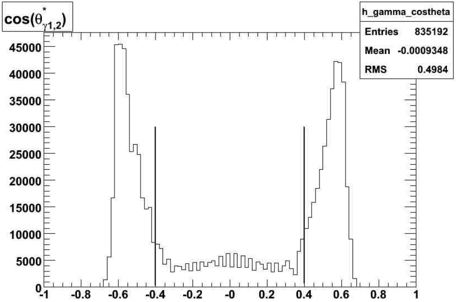
Distribution of $cos(\theta_{\gamma 1,2})$ in $\pi^0\pi^0$ events



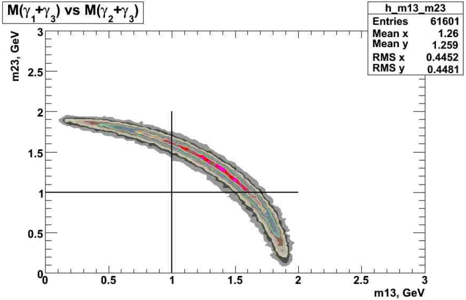


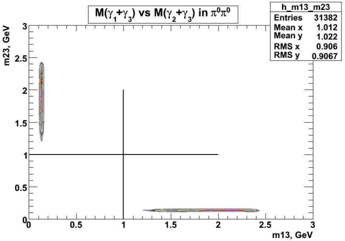
Distribution of $cos(\theta_{\gamma 1,2})$ in $\pi^0\gamma$ events

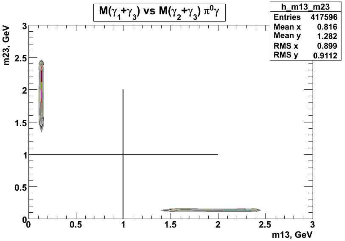




Distribution of $M(\gamma_1 + \gamma_3), M(\gamma_2 + \gamma_3)$







Summary

- With applied tight cuts and available statistics it seems possible to extract signal of interest from background.
- Signal to background ratio $h_c : \pi^0\pi^0 : \pi^0\gamma = 1 :< 0.4 :< 0.02$
- Other background channel with neutral final states should be studied.