PHOTON CONVERSION EFFICIENCY at CDF

Focusing on:

$D_0^* \to D_0\gamma$

$D_\pm^* \to D_0\pi$

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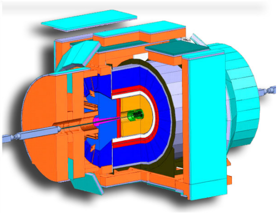
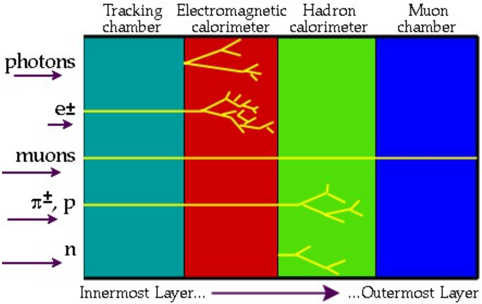
CDF detector

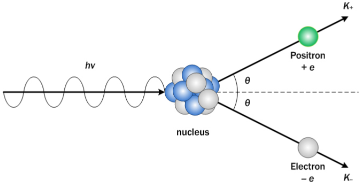
Layers:

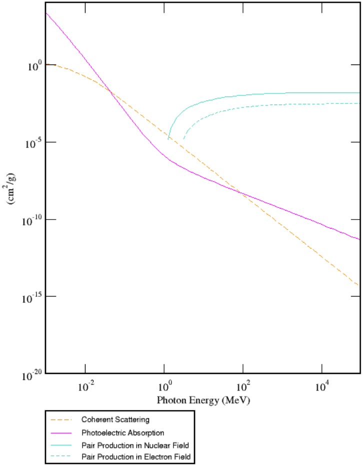
- Silicon Detector
- Central outer tracker
- Electromagnetic Calorimeters
- Hadronic Calorimeters
- Muon Chambers





Conversion Process

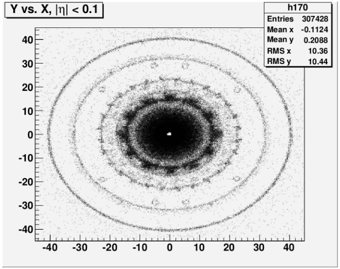


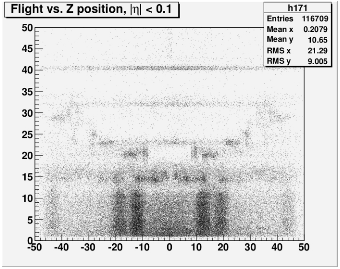


- Pair production when photons interact with matter
- Probability of conversion almost constant at high energy
- Precision of the tracking system for measurement of photon momentum

Why is it important?

- Estimate the distribution and quantity of material in the detector
  - Looking at the conversion point we are able to “xray” the CDF detector





- Application to the $\chi_{c1,2}$ reconstruction:
  - recontruction of the charmonium states through the decay $\chi_{c1,2} \to J/\psi - \gamma$
  - mass resolution sufficient to separate the $\chi_1(3510)$ from the $\chi_2(3555)$.

$D_0^* \to D_0\gamma$ vs $D_\pm^* \to D_0\pi$

D MESONS:

- D lightest particle containing charm quarks:
- D^* is the first exited state: neutral and charged states
- D_0^* and $D_\pm^*$ belong to the same **isospin multiplet**

ISOSPIN SYMMETRY

- Quantum number related to the strong interaction
- Particles affected equally by the strong force but with different charges treated as being different states of the same particle
- **Isospin invariant production**

Main goal of the project:

Understanding whether the following expression can be used to obtain the **conversion efficiency**:

$$1 = \frac{\sigma_{D_0^*}}{\sigma_{D_\pm^*}} = \frac{N_{D_0^*}}{N_{D_\pm^*}} \frac{\epsilon_{D_\pm^*}}{\epsilon_{D_0^*}}$$

- N = number of candidates, from **data**
- ϵ = efficiency, from **simulations**
- **Assumption**: isospin invariant production (cross-sections ratio = 1)

We expect the efficiency to be a strong functions of kinematics variables:

- **Transverse momentum**
  - $p_T(D^*)$ bins (to use equality above)
  - $p_T(\gamma)$ (for each $p_T(D^*)$ bin, neutral case)

Efficiency ratio (from SIM):

The photon efficiency is hidden in the efficiency ratio:

$$\frac{\epsilon_{D^*_\pm}}{\epsilon_{D^*_0}} = \frac{\cancel{\epsilon_{D^0}}}{\cancel{\epsilon_{D_0}}} \quad \frac{\epsilon_\pi}{\epsilon_\gamma} = \frac{N(D^*_\pm \to D_0\pi_{\pm[reco]})}{N(D^*_0 \to D^0\gamma_{[gen]})\epsilon(\gamma)}$$

- $N(D^*_\pm \to D_0\pi_{\pm[reco]})$ = **reconstructed** pions
- $N(D^*_0 \to D_0\gamma_{[gen]})$ = **generated** photons (small sample for $\gamma_{[reco]}$)
- $\epsilon(\gamma) \Rightarrow$ **UNKNOWN PARAMETER!**

Efficiency for PHOTONS

$$\epsilon(\gamma) = \frac{N_{D_0^*}}{N_{D_\pm^*}} \frac{N(D_\pm^* \to D_0 \pi_{\pm[reco]})}{N(D_0^* \to D_0 \gamma_{[gen]})}$$

“Generated Photons” $\rightarrow$ **Definition**:

- $p_T(\gamma) > 1.0 GeV$
- Conversion simulation (we generate the **energy fraction** taken by e^+, e^-, according to Rossi’s treatment for Bethe-Heitler conversion)
- Acceptance simulation: $p_T(e^+, e^-) > 0.4 GeV$
- Efficiency simulation: (π) (CDF Note 8433)

$$\Rightarrow \epsilon(\gamma) = \epsilon_{Reco} * \epsilon_{\textbf{Conv}}$$

Acceptance check:

- **Comparison** (in simulations):
  - Reconstructed photons
  - Generated photons after acceptance and efficiency cuts

$p_T(\gamma)$ GeV	$N(\gamma[FAKE])$	$N(\gamma[RECO])$	$\frac{N(\gamma[RECO])}{N(\gamma[FAKE])}$
$[1.0, 1.3]$	35851 ± 189	3743 ± 61	0.104 ± 0.002
$[1.3, 1.7]$	47676 ± 218	4874 ± 70	0.102 ± 0.002
$[1.7, 2.2]$	48252 ± 220	5144 ± 72	0.107 ± 0.001
$[2.2, 3.0]$	54069 ± 233	5588 ± 75	0.103 ± 0.001
$[3.0, 4.0]$	40603 ± 202	4420 ± 66	0.109 ± 0.002
$[4.0, 5.0]$	23667 ± 154	2620 ± 51	0.111 ± 0.002

Fitting Techniques

DATA and SIMULATIONS

Signal:

- **1 Gaussian**
- **2 Gaussians**

Background:

- **Line**: $a + bx$
- **Modified polynomial**: $aP_0(x) + bP_1(x) + cP_2(x)$

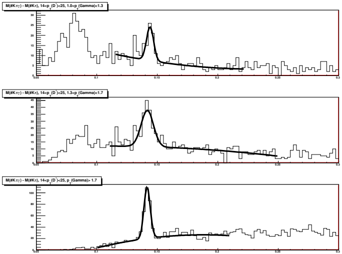


Figure: D_0^*, example

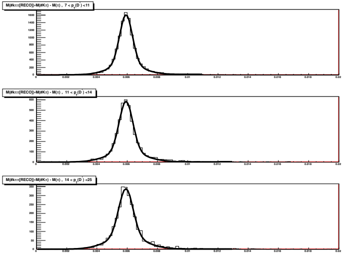


Figure: $D_\pm^*$, example

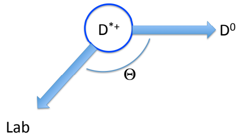
Conversion efficiency: Results

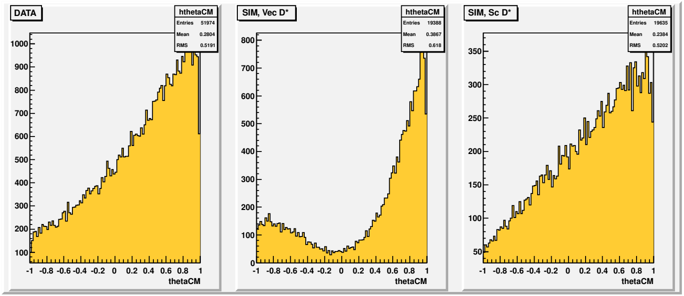
$p_T(\gamma) \diagdown p_T(D^*)$	$[7, 11]$	$[11, 14]$	$[14, 25]$
$[1.0, 1.3]$	0.066 ± 0.007	0.042 ± 0.009	0.037 ± 0.009
$[1.3, 1.7]$	0.13 ± 0.04	0.080 ± 0.009	0.049 ± 0.009
> 1.7	0 ± 0	0.11 ± 0.06	0.072 ± 0.009

- We would expect to see similar results for photons with the same momentum (rows)
- We would expect similar results too for different momentum of the photon (acceptance cuts included)
- Efficiency seems to raise with $p_T(\gamma)$ and to fall with $p_T(D^*)$

Sources of error (1):

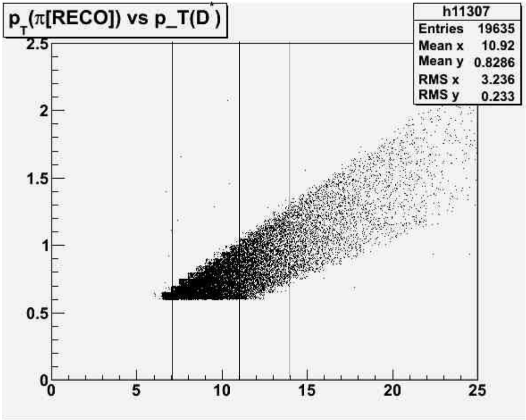
- **Distribution of the decay angle for charged D***:
  - DATA: D^* from different sources
  - SIM: D^* from B decay only





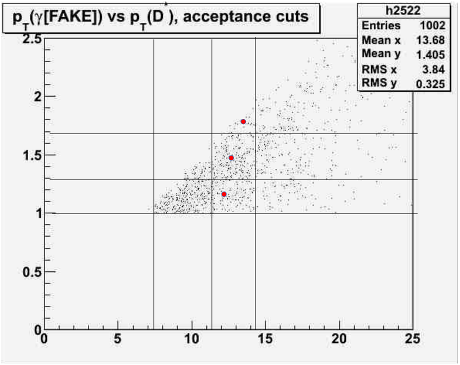
Source of error (1):

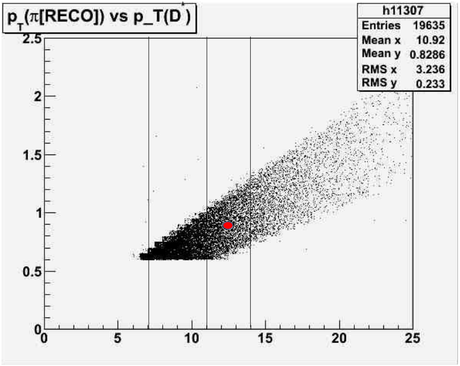
- Important effect : the acceptance strongly depends on $p_T(\pi) \Longleftrightarrow \theta$
- Range of full acceptance: $p_T(D^*_\pm) \in [14, 25] GeV$



Sources of error (2):

- Isospin invariance $\Leftrightarrow \langle p_T(D_0^*)\rangle \sim \langle p_T(D_\pm^*)\rangle$
- Condition NOT satisfied because of correlation between $p_T(\gamma)$, $p_T(D_0^*)$
  $\Rightarrow$ We should have not divided into $p_T(\gamma)$ bins





Final Result for Photon Conversion Efficiency

- **Angular distribution**: Range of full acceptance
- **Isospin invariance**: no binning on $p_T(\gamma)$

$\Rightarrow$ We are left with only one range: $p_{D^*} \in [14, 25] GeV$

$$\Rightarrow \epsilon(\gamma) = 0.057 \pm 0.004$$

Conclusions:

- We know how to reconstruct the **neutral** D^* (~ 1300 events processing only 4 periods)
- We found a **first estimate** for the photon conversion efficiency: $\epsilon(\gamma) = 0.057 \pm 0.004$
- We found out **acceptance issues** that need to be fixed:
  - $D^*_{\pm} \rightarrow \theta$- distribution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BACKUP (1): DATA and SIMULATION SAMPLES

DATA:

- *xbhd0k*, 4 periods out of 38

SIMULATIONS:

- 2 Samples: equal number of events
- Standard Event Generator used for B-decays
- D^* allowed to decay naturally (PDG listings)

$$\begin{array}{lll} B_0 \rightarrow & D^*_- & \pi_+ \\ & \rightarrow & D_0 \pi_- \end{array}$$

$$\begin{array}{lll} B_+ \rightarrow & D^*_0 & \pi_+ \\ & \rightarrow & D_0 \gamma \end{array}$$