Can we measure open charm at GlueX without vertexing and with limited K ID? - material for discussion

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Open charm

- Comparison with J/ψ interesting

- Other theoretical drivers?
  - Input welcome!

- Experimentally challenging
  - Cross section few tens of nb
  - Small branching ratios
  - Identification of the exclusive channel
  - Large backgrounds
  - etc

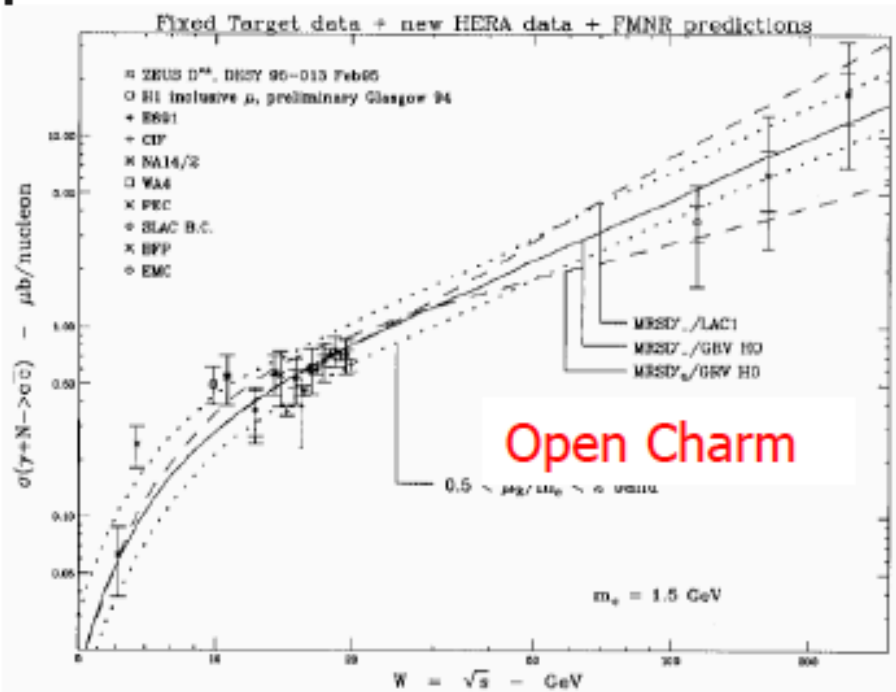
- Often done by displaced vertices and good kaon identification
  - Displaced vertices difficult in fixed target
  - Charged kaon ID is limited in GlueX (TOF, in the future a very forward DIRC)

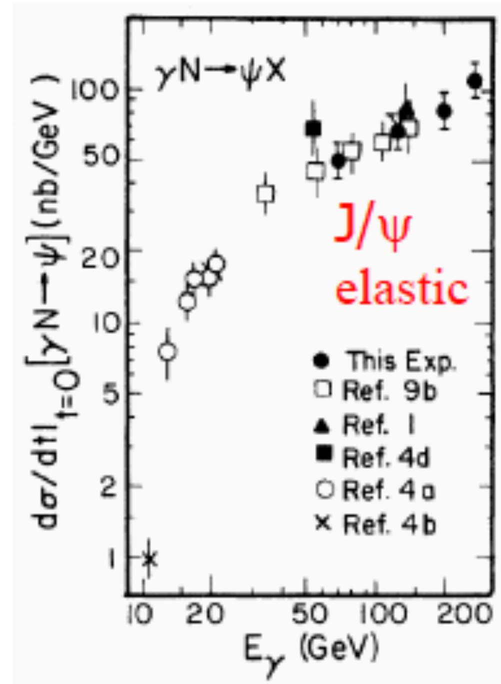
- Can we do something at GlueX now?
  - In the future, can we also do nuclei?

Discussion / Summary

- Exclusive open charm photoproduction is an unexplored field
  - Production cross sections for up to 9 charmed baryons
  - Clues to reaction mechanism - need a real theory
  - Measure $g_{ND\Lambda c}$
- Acceptances quite good if GlueX can detect 5 to 7 charged tracks simultaneously
- Rates are very low: need some tricks to increase yields
- Kaon ID <u>will</u> be needed

Cross Section Comparisons





$$\frac{\sigma(\gamma+N\to c\bar{c})}{\sigma(\gamma+N\to J/\psi)}=\begin{cases}\dfrac{0.55\,\mu b}{.018\,\mu b}=30\pm 9\\[2ex] \dfrac{60\ nb}{5.2\ nb}=11\pm 6\end{cases}$$

at E_γ=150 GeV; W=17 GeV

PNT: Cross section relatively large

Branching ratios and backgrounds?

at E_γ=20 GeV; W=6.1 GeV

We assume a similar ratio all the way down to threshold...

Thresholds & Decay Modes

	W_{th} (GeV)	E^{γ}_{th} (GeV)	(Most) favorable decay modes	Exclusive Branch Fractions
$\gamma p \to p\, J/\psi$	4.04	8.20	$J/\psi \to e^+e^-$	5.94%
$\gamma p \to \Lambda_c^+ \bar{D}^0$	4.15	8.71	$\Lambda_c^+ \to pK^-\pi^+$ $\bar{D}^0 \to K^+\pi^-$	5.0%X3.8%→ 0.19%
$\gamma p \to \begin{cases} \Sigma_c^+ \bar{D}^0 \\ \Sigma_c^{++,0} D^{-,+} \end{cases}$	4.32	9.47	$\Sigma_c \to \Lambda_c^+ \pi$ (~100%)	0.19% 0.47%
$\gamma d \to d\, J/\psi$	4.97	5.75	$J/\psi \to e^+e^-$	5.94%
$\gamma d \to \Lambda_c^+ D^- p$	5.09	5.97	$\Lambda_c^+ \to pK^-\pi^+$ $D^- \to K^+\pi^-\pi^-$	0.47%
$\gamma d \to d\, D^+ D^-$	5.61	7.47	$D^- \to K^+\pi^-\pi^-$	0.90%

An idea:

- Look at $\gamma p \rightarrow D^0 \Lambda_c^+ \rightarrow (K_s^0 + X)_{inclusive} (\Lambda + pions)_{exclusive}$

- K_s^0 and Λ identified from invariant mass in their decays to 2π and $p\pi$, respectively (both charged and neutral branched can be detected)

- Inclusive tagging of a K_s^0 from the D^0 reduces background but retains good branching ratio (BR)

- Both K_s^0 and Λ are very narrow (perhaps a few MeV in the detector), greatly reducing random background

- Additional cuts on the Λ_c invariant mass and missing mass, which whould be selected around the D_0 mass (E_γ obtained from taggeer)

- Lots of particles, but GlueX has very good acceptance and kinematic fitting!

- Can it work? Maybe!?

Branching ratios for D^0 going $K^0 + X$

Inclusive modes

Γ_5	$D^0 \to e^+$ anything	[d]	(6.49 ± 0.11) %	
Γ_6	$D^0 \to \mu^+$ anything		(6.7 ± 0.6) %	
Γ_7	$D^0 \to K^-$ anything		(54.7 ± 2.8) %	S=1.3
Γ_8	$D^0 \to \overline{K}^0$ anything + K^0 anything		(47 ± 4) %	
Γ_9	$D^0 \to K^+$ anything		(3.4 ± 0.4) %	
Γ_{10}	$D^0 \to K^*(892)^-$ anything		(15 ± 9) %	
Γ_{11}	$D^0 \to \overline{K}^*(892)^0$ anything		(9 ± 4) %	
Γ_{12}	$D^0 \to K^*(892)^+$ anything		< 3.6 %	CL=90%
Γ_{13}	$D^0 \to K^*(892)^0$ anything		(2.8 ± 1.3) %	
Γ_{14}	$D^0 \to \eta$ anything		(9.5 ± 0.9) %	
Γ_{15}	$D^0 \to \eta'$ anything		(2.48 ± 0.27) %	
Γ_{16}	$D^0 \to \phi$ anything		(1.05 ± 0.11) %	

- **Large BR for tagging a D^0 with a K^0 (and in particular, K_s^0 decaying into two pions)**

Branching ratios for D^0 to specific $K_s{}^0$ channels small

Hadronic modes with one $\overline{K}$

Γ_{31}	$D^0 \to K^- \pi^+$		(3.88 ± 0.05) %	S=1.1
Γ_{32}	$D^0 \to K^+ \pi^-$		$(1.380 \pm 0.028) \times 10^{-4}$	
Γ_{33}	$D^0 \to K^0_S \pi^0$		(1.19 ± 0.04) %	
Γ_{34}	$D^0 \to K^0_L \pi^0$		$(10.0 \pm 0.7) \times 10^{-3}$	
Γ_{35}	$D^0 \to K^0_S \pi^+ \pi^-$	[e]	(2.83 ± 0.20) %	S=1.1
Γ_{36}	$D^0 \to K^0_S \rho^0$		$(6.3 {}^{+0.7}_{-0.8}) \times 10^{-3}$	
Γ_{37}	$D^0 \to K^0_S \omega,\ \omega \to \pi^+ \pi^-$		$(2.1 \pm 0.6) \times 10^{-4}$	
Γ_{38}	$D^0 \to K^0_S (\pi^+ \pi^-)_{S-\text{wave}}$		$(3.4 \pm 0.8) \times 10^{-3}$	
Γ_{39}	$D^0 \to K^0_S f_0(980),\ f_0(980) \to \pi^+ \pi^-$		$(1.22 {}^{+0.40}_{-0.24}) \times 10^{-3}$	
Γ_{40}	$D^0 \to K^0_S f_0(1370),\ f_0(1370) \to \pi^+ \pi^-$		$(2.8 {}^{+0.9}_{-1.3}) \times 10^{-3}$	
Γ_{41}	$D^0 \to K^0_S f_2(1270),\ f_2(1270) \to \pi^+ \pi^-$		$(9 {}^{+10}_{-6}) \times 10^{-5}$	
Γ_{42}	$D^0 \to K^*(892)^- \pi^+,\ K^*(892)^- \to K^0_S \pi^-$		$(1.66 {}^{+0.15}_{-0.17})$ %	

Branching ratios for Λ_c^+ going to Λ and pions

Hadronic modes with a hyperon: $S = -1$ final states

$\Lambda\pi^+$		(1.07 ± 0.28) %		864
$\Lambda\pi^+\pi^0$		(3.6 ± 1.3) %		844
$\Lambda\rho^+$		< 5 %	CL=95%	636
$\Lambda\pi^+\pi^+\pi^-$		(2.6 ± 0.7) %		807
$\Sigma(1385)^+\pi^+\pi^-$, $\Sigma^{*+} \to \Lambda\pi^+$		$(7 \pm 4) \times 10^{-3}$		688
$\Sigma(1385)^-\pi^+\pi^+$, $\Sigma^{*-} \to \Lambda\pi^-$		$(5.5 \pm 1.7) \times 10^{-3}$		688
$\Lambda\pi^+\rho^0$		(1.1 ± 0.5) %		524
$\Sigma(1385)^+\rho^0$, $\Sigma^{*+} \to \Lambda\pi^+$		$(3.7 \pm 3.1) \times 10^{-3}$		363
$\Lambda\pi^+\pi^+\pi^-$ nonresonant		$< 8 \times 10^{-3}$	CL=90%	807
$\Lambda\pi^+\pi^+\pi^-\pi^0$ total		(1.8 ± 0.8) %		757
$\Lambda\pi^+\eta$	[b]	(1.8 ± 0.6) %		691
$\Sigma(1385)^+\eta$	[b]	$(8.5 \pm 3.3) \times 10^{-3}$		570
$\Lambda\pi^+\omega$	[b]	(1.2 ± 0.5) %		517
$\Lambda\pi^+\pi^+\pi^-\pi^0$, no η or ω		$< 7 \times 10^{-3}$	CL=90%	757

- **About 9% total BR for Λ + 1-4 pions**

Branching ratio for Λ_c^+ going to K^0 (and pions)

Λ_c^+ DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Hadronic modes with a p: $S = -1$ final states				
$p\overline{K}^0$		(2.3 ± 0.6) %		873
$pK^-\pi^+$	[a]	(5.0 ± 1.3) %		823
$p\overline{K}^*(892)^0$	[b]	(1.6 ± 0.5) %		685
$\Delta(1232)^{++}K^-$		$(8.6 \pm 3.0) \times 10^{-3}$		710
$\Lambda(1520)\pi^+$	[b]	(1.8 ± 0.6) %		627
$pK^-\pi^+$ nonresonant		(2.8 ± 0.8) %		823
$p\overline{K}^0\pi^0$		(3.3 ± 1.0) %		823
$p\overline{K}^0\eta$		(1.2 ± 0.4) %		568
$p\overline{K}^0\pi^+\pi^-$		(2.6 ± 0.7) %		754
$pK^-\pi^+\pi^0$		(3.4 ± 1.0) %		759
$pK^*(892)^-\pi^+$	[b]	(1.1 ± 0.5) %		580
$p(K^-\pi^+)_{\text{nonresonant}}\pi^0$		(3.6 ± 1.2) %		759
$\Delta(1232)\overline{K}^*(892)$		seen		419

- **The $p+K_s^0$ could also be an alternative to Λ+pions**

Background

TABLE II. Cross sections presented in this paper. The errors include statistical and systematic errors. The cross sections include strange baryons produced indirectly, e.g., Λ from the decay of Σ^0. K. Abe et al, PRD 32 (1985)

Particle	Unweighted number	$\sigma(\mu b)$
K_S^0	$13\,068 \pm 121$	9.663 ± 0.272
Λ	$7\,315 \pm 93$	5.603 ± 0.180
$\bar{\Lambda}$	375 ± 23	0.389 ± 0.036
Ξ^-	73 ± 9	0.117 ± 0.017
$\bar{\Xi}^-$	9 ± 4	0.010 ± 0.004
Σ^0	29 ± 8	1.65 ± 0.44
$\Sigma^{*+}(1385)$	208 ± 19	0.63 ± 0.06
$\Sigma^{*-}(1385)$	109 ± 15	0.33 ± 0.05
Ω^-	< 7.3 at 90% CL	< 0.017 at 90% CL
$K_S^0 K_S^0$	467 ± 22	0.973 ± 0.040
$K_S^0 \Lambda$	366 ± 19	1.125 ± 0.059
$K_S^0 \bar{\Lambda}$	6 ± 2	0.023 ± 0.009
$\Lambda \bar{\Lambda}$	11 ± 3	0.126 ± 0.038
$\Lambda \Lambda$	4 ± 2	0.028 ± 0.014

- With cuts on the narrow invariant masses of K_s and Λ, the main background comes from the inclusive channel (cross section 1 μb at 20 GeV)
- This is compared with ~10 nb for $D^0 \Lambda_c^+$, or about a factor of 100
- With another factor of 50 from BR, this gives a factor 5000 integrated over *all* Λ_c^+ invariant masses and missing (D^0) masses – a wide 2D phase space
- Would need a study with GlueX resolutions to see background under the peak!

Open charm on nuclear targets?

- Without vertexing and kaon ID even the proton is tricky, but maybe some nuclear measurements of interest could be more inclusive?

- Theory input needed!

Backup