Open Charm Photoproduction at GlueX

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Introduction

- Motivation
  - J/ψ elastic and inelastic
  - Exclusive open charm photoproduction
- Experimental considerations
  - Reaction channels
  - Cross section estimates
- Simple parametric Monte Carlo study:
  - Acceptances
  - Resolutions
- Rate estimates

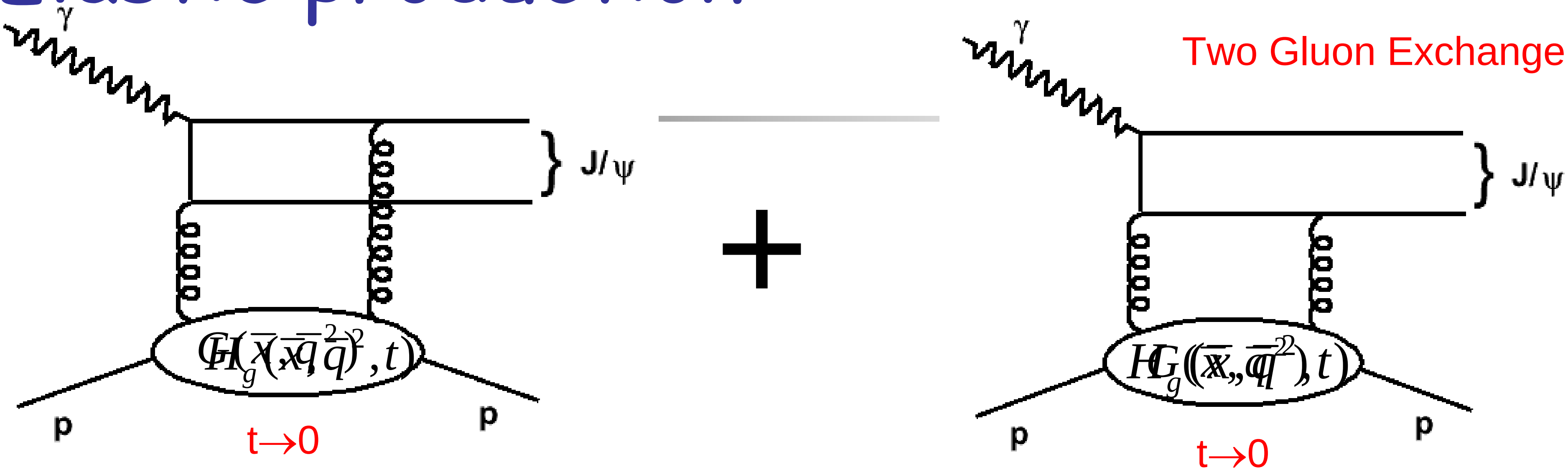
Motivation

- J/ψ elastic and inelastic production*
  - Multi-gluon exchange near threshold: higher-twist dominance
  - Off deuteron: search for hidden color in w.f.
  - Look for intrinsic charm ← contribution to spin crisis solution
  - *Access to gluon GPD's*
- Open charm: $\bar{D}^0$ Λ_c^+ , $D^{+,-,0}$ $\Sigma_c^{0,++,+}$, D^+D^-p
  - Nearly nothing is known, experimentally
  - Exclusive charmed baryon photoproduction
  - Larger cross sections than J/ψ ... but smaller branching fractions

* S. Brodsky, E. Chudakov, P. Hoyer, J. M . Laget, Phys Lett. B 498 23 (2001)

Elastic production

(slide from M. Osipenko / R. De Vita)



Factorization for heavy meson exclusive photoproduction: D. Ivanov et al, EPJ C34 (04)

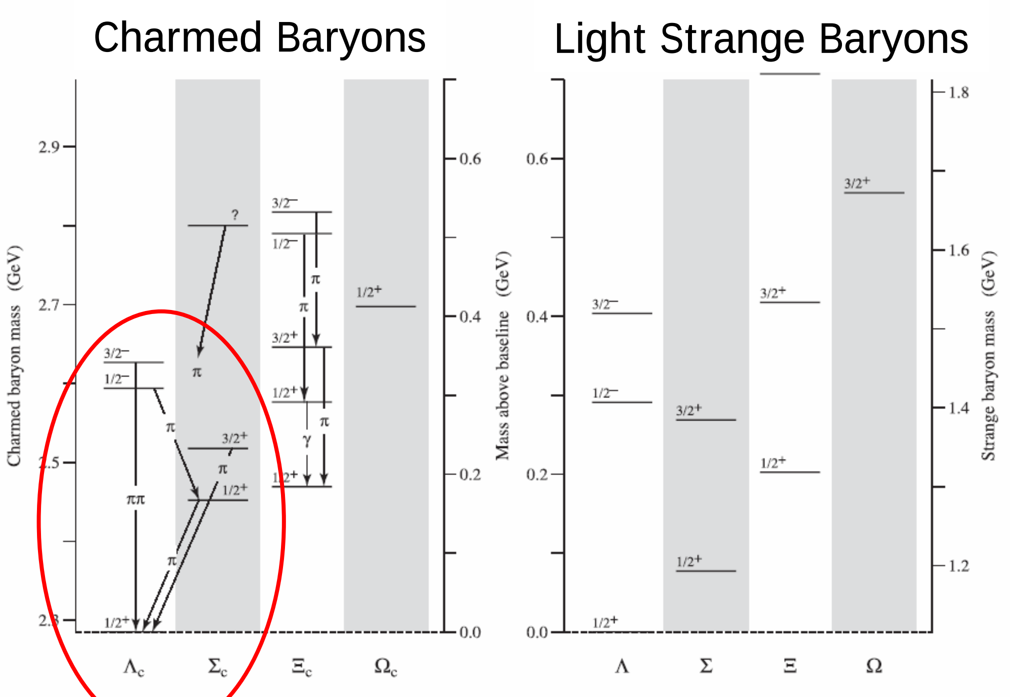
gluon GPD $$\frac{d\sigma_T}{dt} \sim H_g(\bar{x}, \bar{q}^2, t)$$ $$xg(x) = H_g(x, \xi = 0, t = 0)$$

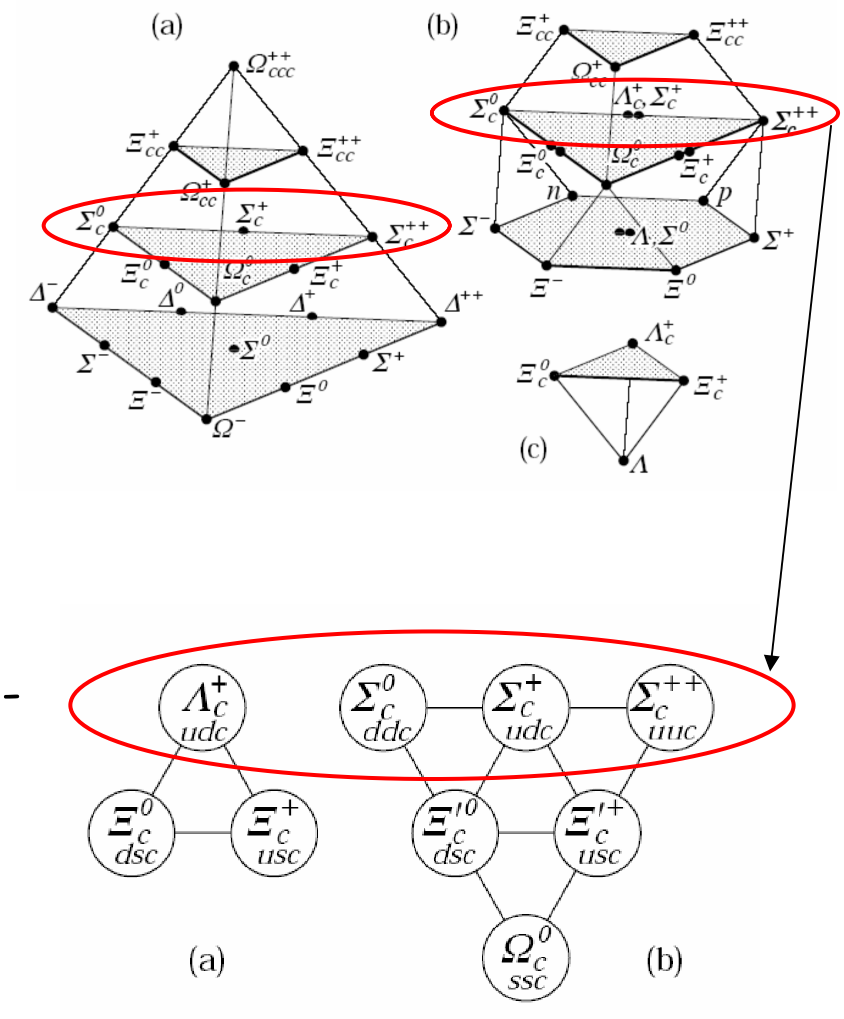
4-momentum fraction carried by gluon: $$\bar{x} = \frac{Q^2 + M_{J/\psi}^2 + p_T^2}{W^2}$$

Hard scale: $$\bar{q}^2 = \frac{Q^2 + M_{J/\psi}^2 + p_T^2}{4}$$

In t→0 limit gives Gluon Distribution in the proton: $$\left.\frac{d\sigma_T}{dt}\right|_{t\to 0} \sim \left[\bar{x}g(\bar{x}, \bar{q}^2)\right]^2$$

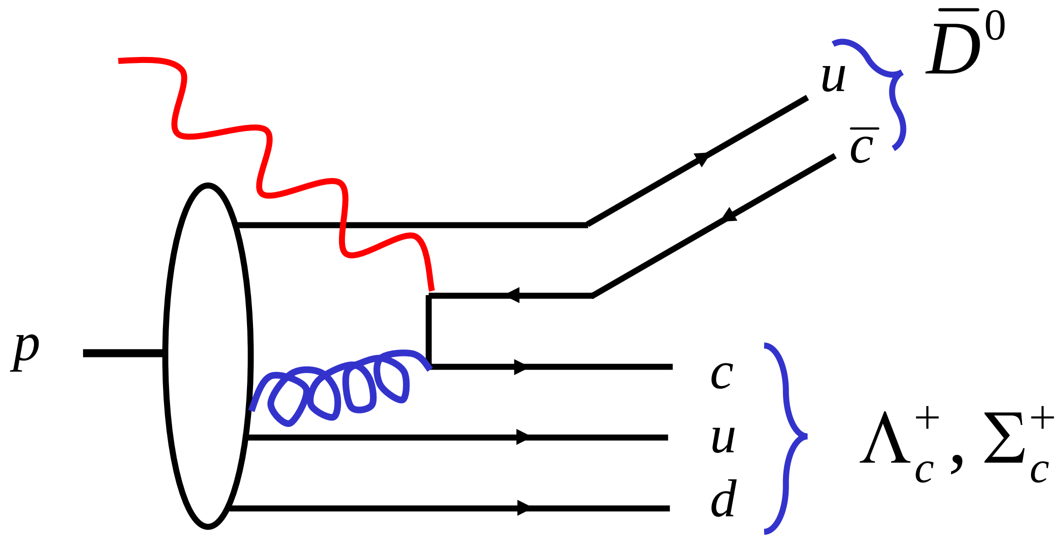
The Charmed Baryon States





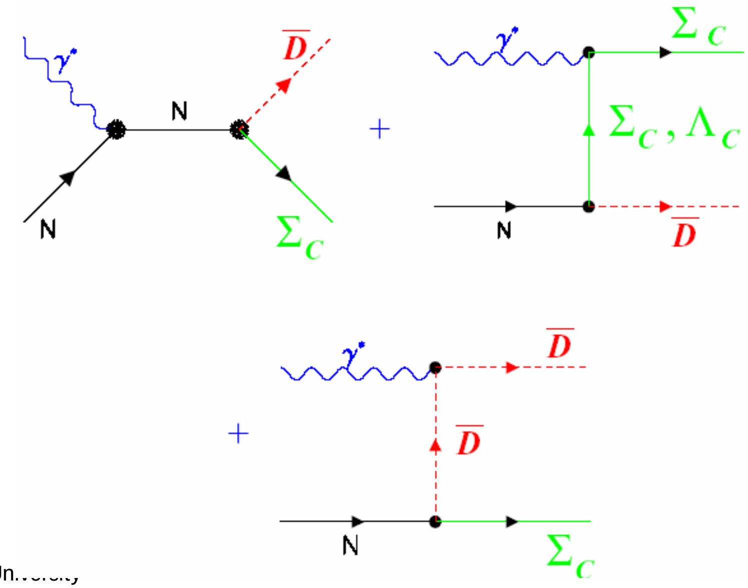
- 12 GeV: over threshold for ~9 charmed non-strange baryons
- Most have *** status
- Photoproduction cross sections near threshold are unmeasured.
- Neither J's nor P's of excited states are measured.

Dynamical Ansatzes



Photon-gluon fusion "inside" the nucleon

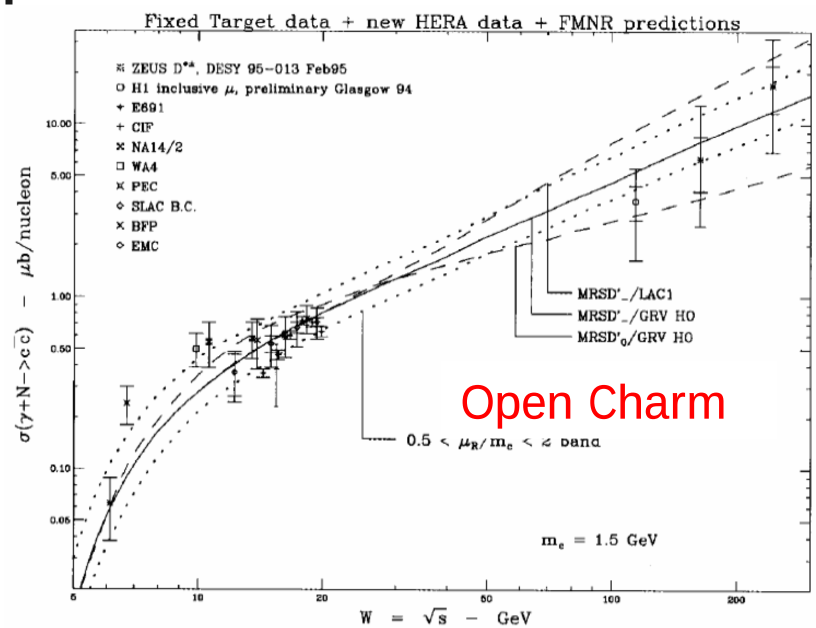
Feynman propagator approach

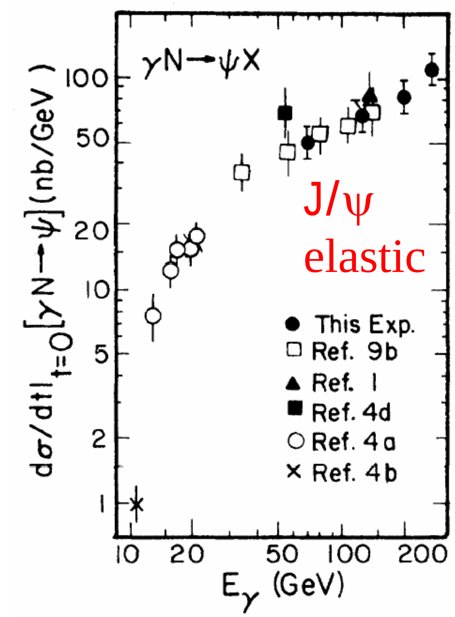


Thresholds & Decay Modes

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

Cross Section Comparisons





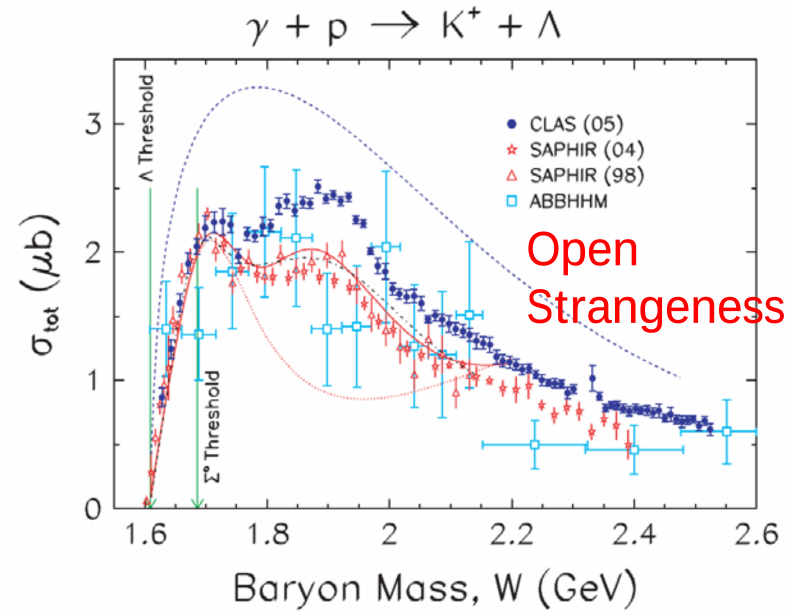
$$\frac{\sigma(\gamma+N\rightarrow c\overline{c})}{\sigma(\gamma+N\rightarrow J/\psi)}=\begin{cases}\dfrac{0.55\mu b}{.018\mu b}=30\pm 9 & \text{at } E_\gamma=150\text{ GeV; } W=17\text{ GeV}\\[2ex] \dfrac{60\ nb}{5.2\ nb}=11\pm 6 & \text{at } E_\gamma=20\text{ GeV; } W=6.1\text{ GeV}\end{cases}$$

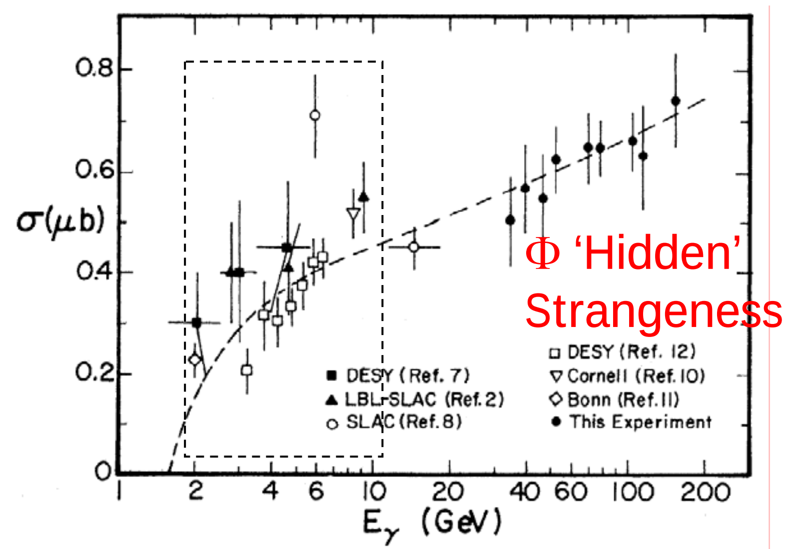
We assume a similar ratio all the way down to threshold...

P. Garbincius, FNAL-Conf-95/041

M. Binkley et al.(FNAL), PRL 48, 73 (82)

Estimate via strangeness production





$$\frac{\sigma(\gamma+N\to c\bar{c})}{\sigma(\gamma+N\to J/\psi)} \approx \frac{\sigma(\gamma+N\to KY)}{\sigma(\gamma+N\to \phi)} = \frac{4.2\mu b}{.4\mu b} \simeq 10\pm 4$$

Valid near-ish the threshold, from E_γ=2 to 12 GeV

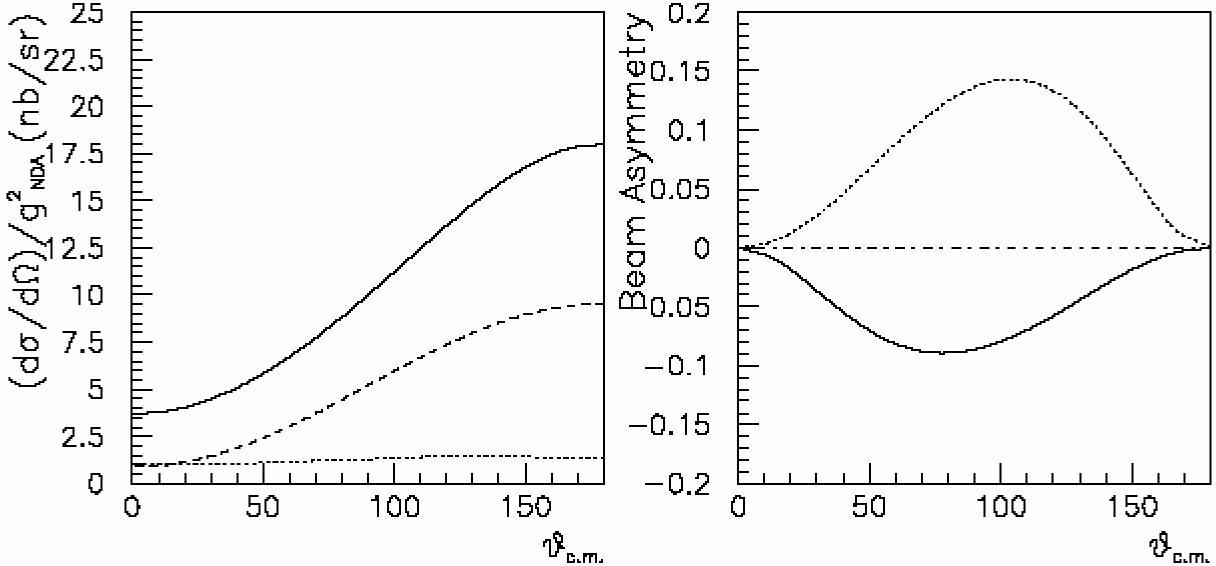
Included contributions from KΛ, $K^{+0}\Sigma^{0+}$, $K^+\Lambda(1520)$, $K^*\Sigma$

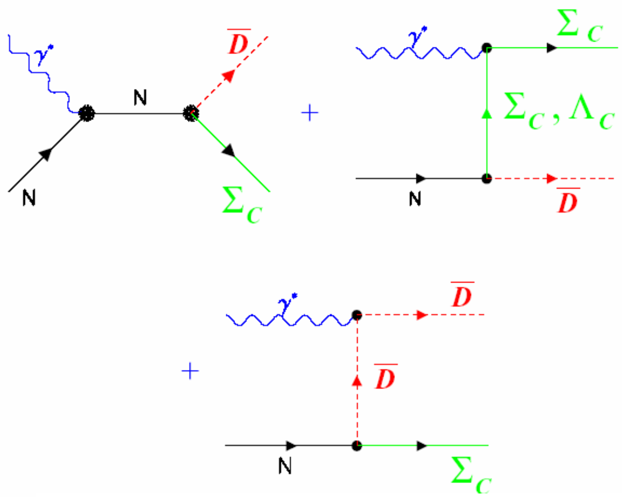
Consistent with previous charm production ratio estimate.

 R.Bradford et al.(CLAS), PRC 73, 035202 (06) R.M.Egloff et al.(FNAL), PRL 43, 657 (79)

Theory estimate of open charm production

$$\gamma\ p \rightarrow \Lambda_c^+\ \bar{D}^0$$





- See Egle Tomasi-Gustafsson, (JLAB at 12 GeV Workshop (2000))
- Basic s- and u-channel Feynman propagator approach
- Coupling $g_{ND\Lambda}$ is unknown
- Predicts σ_{TOT} ~ 10 - 100 nb at 11 GeV
- Predicts backward-peaked production of D^0.

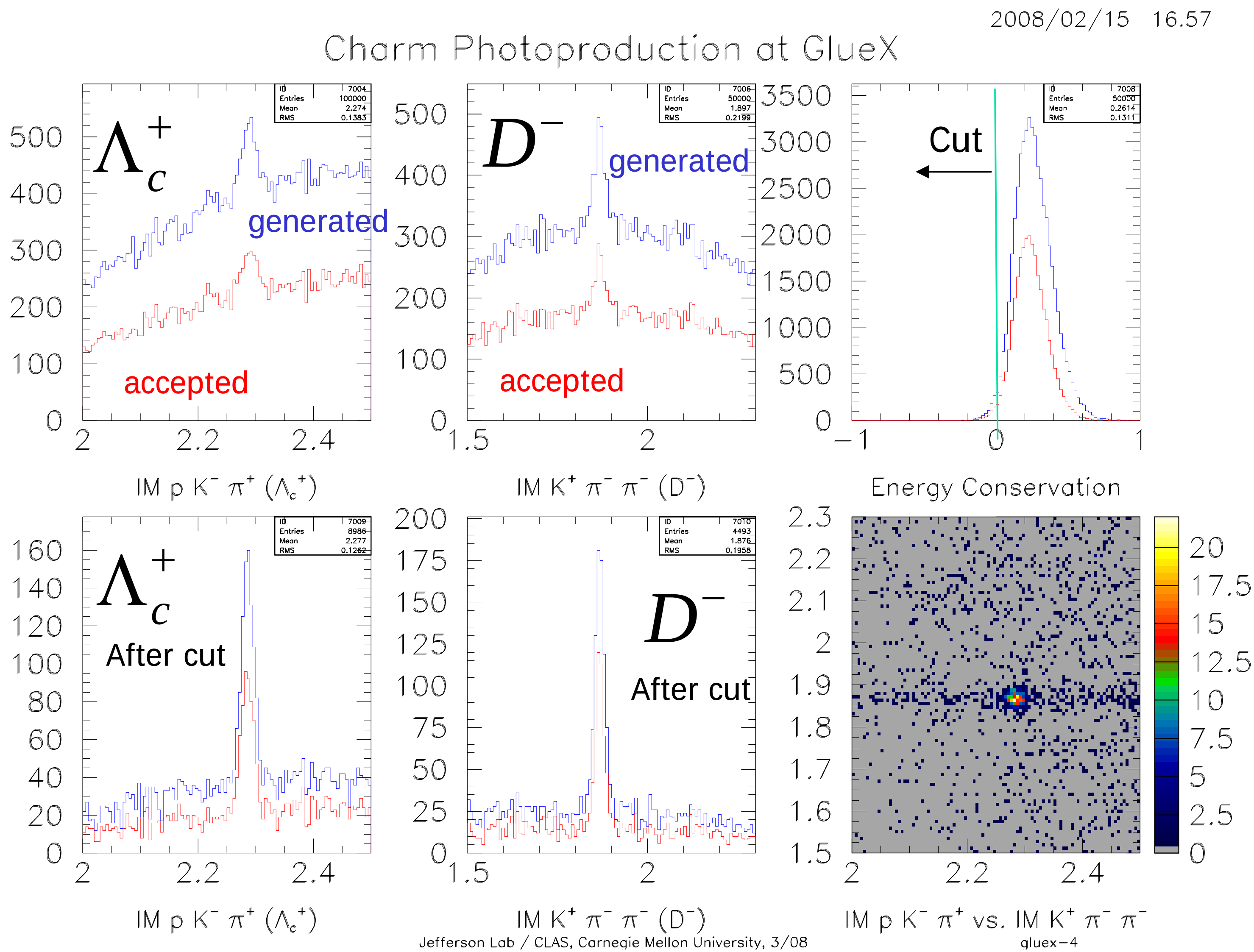
Experimental Considerations

- Consider $\gamma d \rightarrow \Lambda_c^+ D^- (p)$
- Take advantage of the "narrowness" of charm states
- Suppose we require exclusive detection (nothing missing) to permit energy conservation enforcement

Monte Carlo Simulations

- Parametric MC $\gamma d \rightarrow \Lambda_c^+ D^- p$
  - Resolution roughly mimics D. Lawrence's GlueX-doc-761
  - Acceptance: "geometric" & > 0.2 GeV/c cut on momentum of charged tracks
- Use 8 to 9 GeV photons (6 GeV threshold)
- Multi-pion background : Signal = 99:1
  - 2p $3\pi^+$ $2\pi^-$
- Assume proton identified, but no K/π separation, no kinematic fit, but enforce energy conservation

Monte Carlo $\gamma d \rightarrow \Lambda_c^+ D^- p$



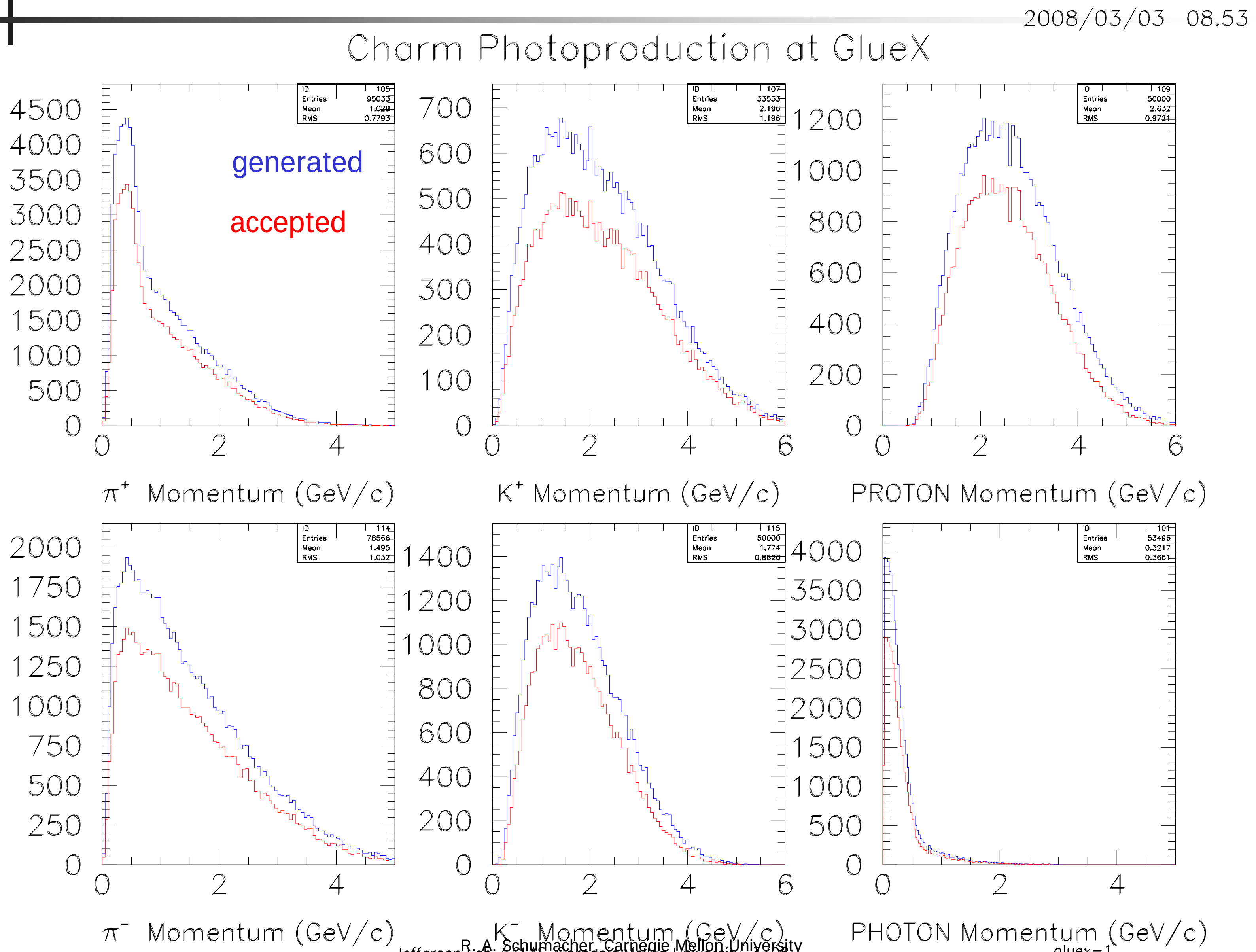
Observations

- Exclusive kinematics can be used to separate signal/background in face of x100 background w/o without π/K PID
- Λ_c^+ resolution is ~12 MeV (σ)
- D^- resolution is ~15 MeV (σ)

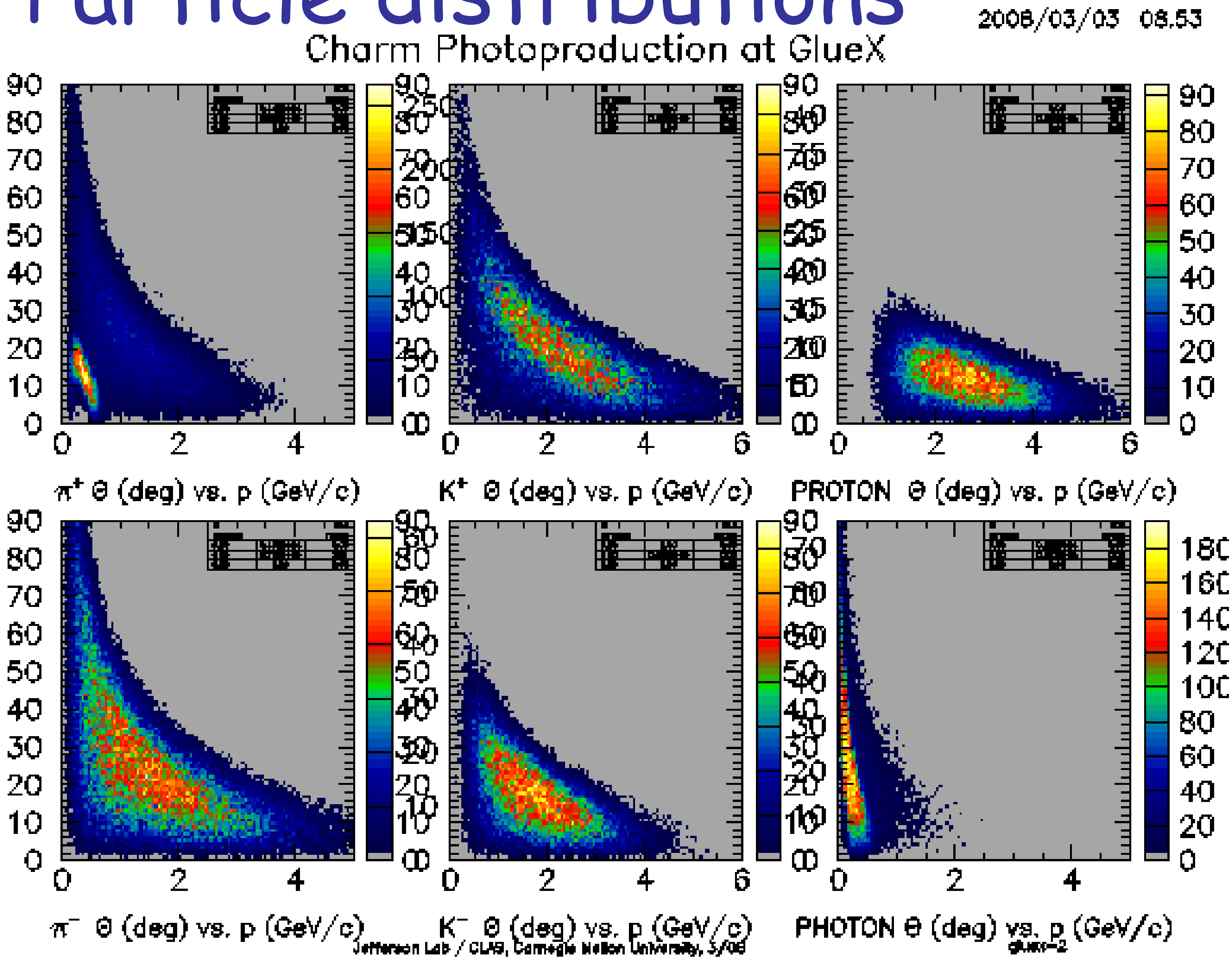
Monte Carlo Simulations

- Parametric MC $\gamma\ p \rightarrow \Lambda_c^+\ \bar{D}^0, \Sigma_c^+\ \bar{D}^0, \Sigma_c^{++}\ D^-$
  - Resolution roughly mimics D. Lawrence's GlueX-doc-761
  - Acceptance: "geometric" & > 0.2 GeV/c cut on momentum of charged tracks
- Use 9.5 to 10.5 GeV photons
- No background in simulation
  - Phase space production model
- Assume proton identified, but no K/π separation, & no kinematic fit

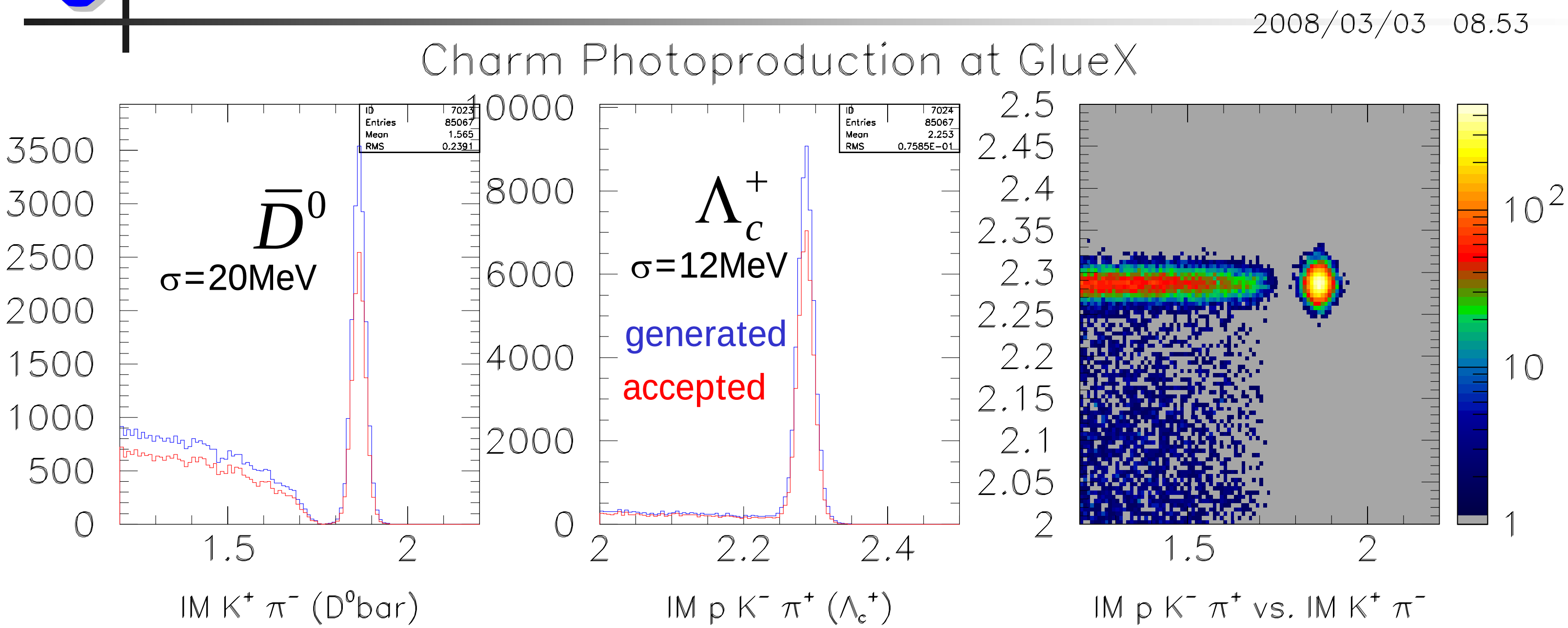
Particle distributions



Particle distributions

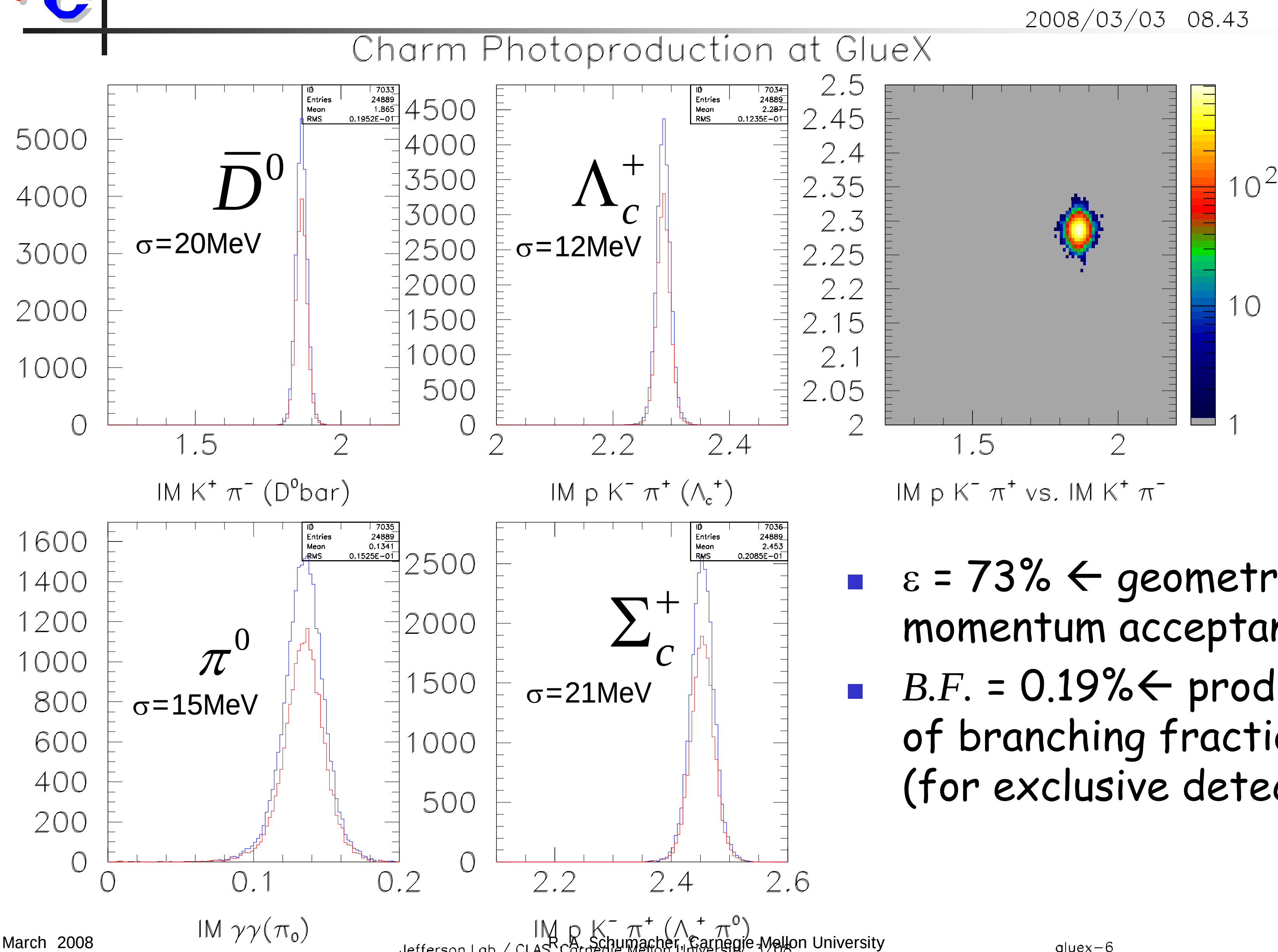


Channel: $\gamma\, p \rightarrow \Lambda_c^+\, \bar{D}^0$



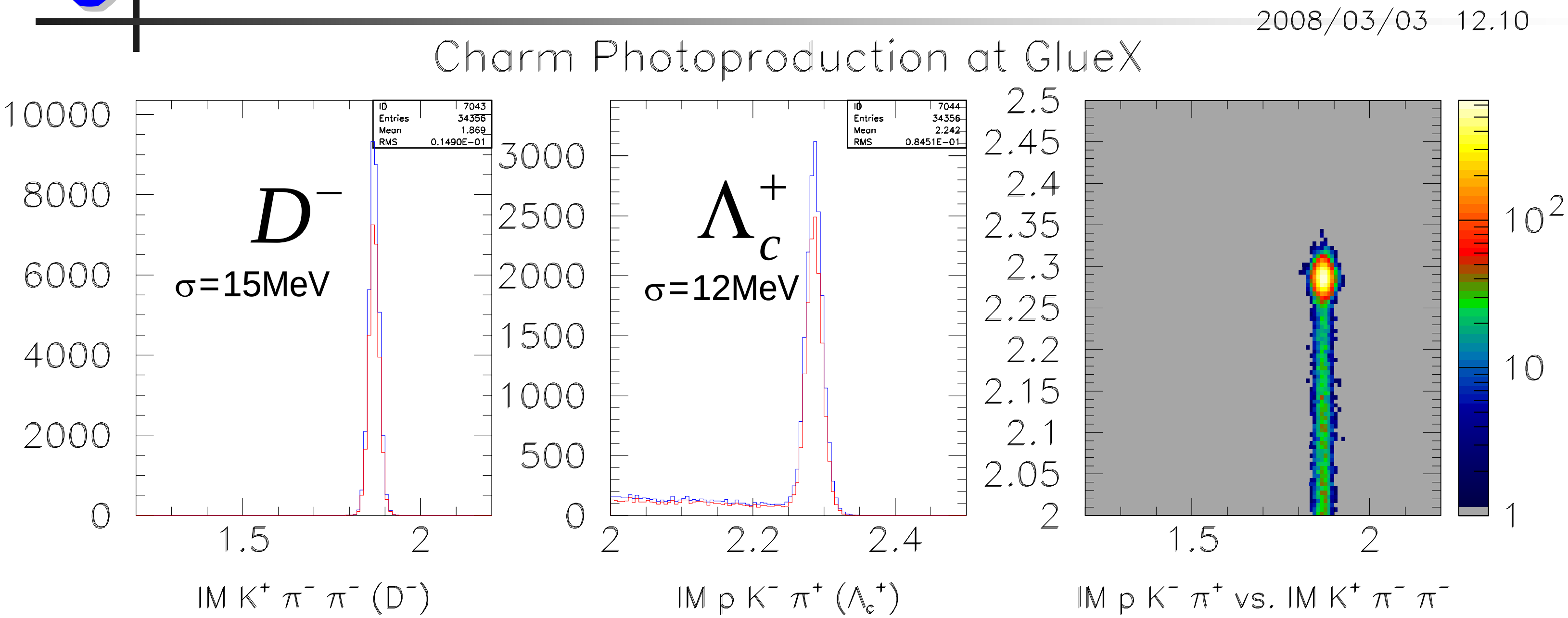
- ε = 68% ← geometric & momentum acceptance
- *B.F.* = 0.19%← product of branching fractions (for exclusive detection)

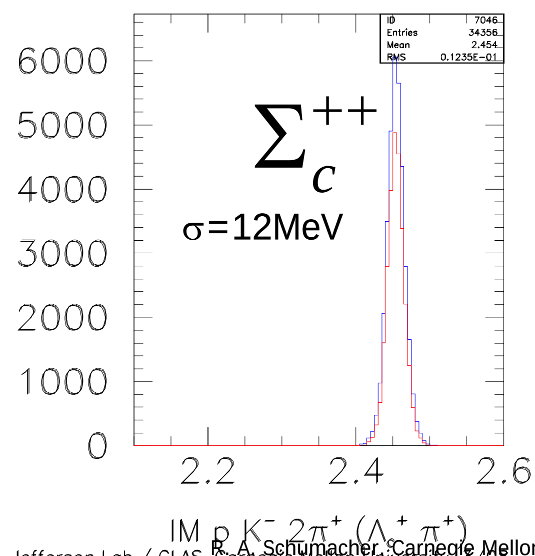
Channel: $\gamma\, p \rightarrow \Sigma_c^+\, \bar{D}^0$



- ε = 73% ← geometric & momentum acceptance
- *B.F.* = 0.19%← product of branching fractions (for exclusive detection)

Channel: $\gamma\ p \rightarrow \Sigma_c^{++}\ D^-$





- ε = 78% ← geometric & momentum acceptance
- *B.F.* = 0.48%← product of branching fractions (for exclusive detection)

Rate Estimates

$$N_{detect} = N_{\gamma}\sigma_{tot}\left(\frac{l\rho t N_A}{A}\right)(B.F.)\varepsilon\kappa$$

- Use $N_{\gamma}=10^8$/s ; target length = 30 cm
- Use kaon decay factor of $\kappa \approx 0.5$
- Get N_{detect}/σ_{tot} = (451 events/hr/nb)x$B.F.$x$\varepsilon\kappa$
- .29 events/hr/nb $\gamma\, p \rightarrow \Lambda_c^+\, \bar{D}^0$
- .31 events/hr/nb $\gamma\, p \rightarrow \Sigma_c^+\, \bar{D}^0$
- .86 events/hr/nb $\gamma\, p \rightarrow \Sigma_c^{++}\, D^-$

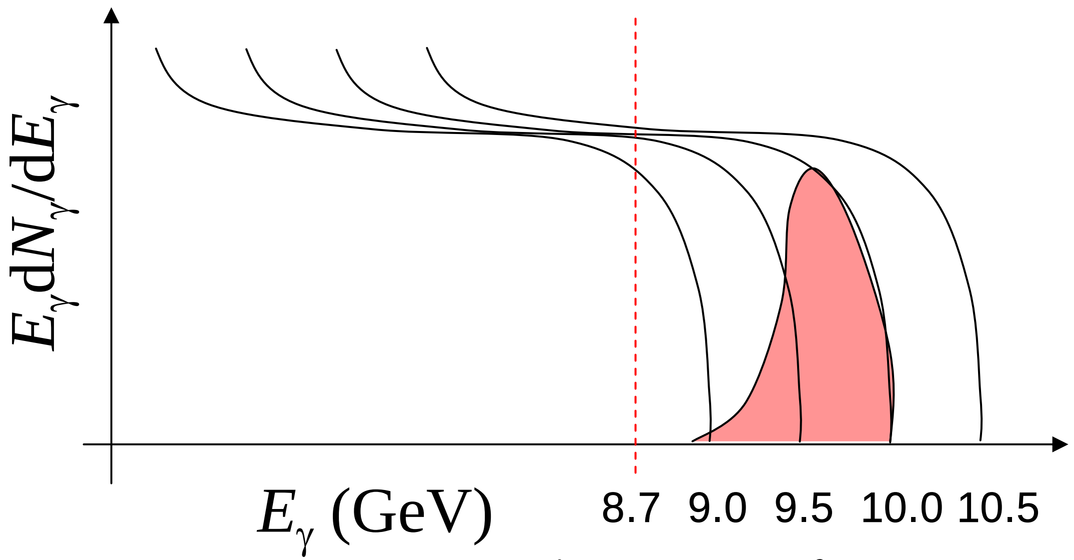
Rate Estimates – "Background"

	σ (μb)	Tagged event rate near 9 GeV (s^{-1})	Total untagged rate (s^{-1})
Total	124	15.5k	200k (?)
7 prong	7	0.88k	?
Visible Strange	9.8	1.2k	~20k (?)
Charm	~0.010	1.2	1.2

A. Dzierba, GlueX-doc-856-v1 ← Rate estimates from data and from Pythia

Possible ways to increase rate

- (Untagged) bremsstrahlung difference method



- Restrictive trigger: $N_{track} > 4$
  - $(\sigma_{5prong} + \sigma_{7prong})/\sigma_{TOT} \sim 1/3$
  - Raise beam intensity to singles rate limit (where is it?)
- Use thicker nuclear target

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

BACKUP SLIDES…