Charm Studies at JLAB at 12GeV

E.Chudakov, JLAB

Charm has been studies for 25 years. There were important impacts on the particle physics:

- Fact of existence
- Spectra of charmonia $\Rightarrow$ development/tuning of QCD
- Decays, lifetimes $\Rightarrow$ weak interactions

Charm photo and hadro-production:

- A good probe for gluon densities
- $\mathrm{m}_C \approx 1.5\ GeV/c^2 \gg \Lambda_{QCD}$ $\Rightarrow$ pQCD is meaningful

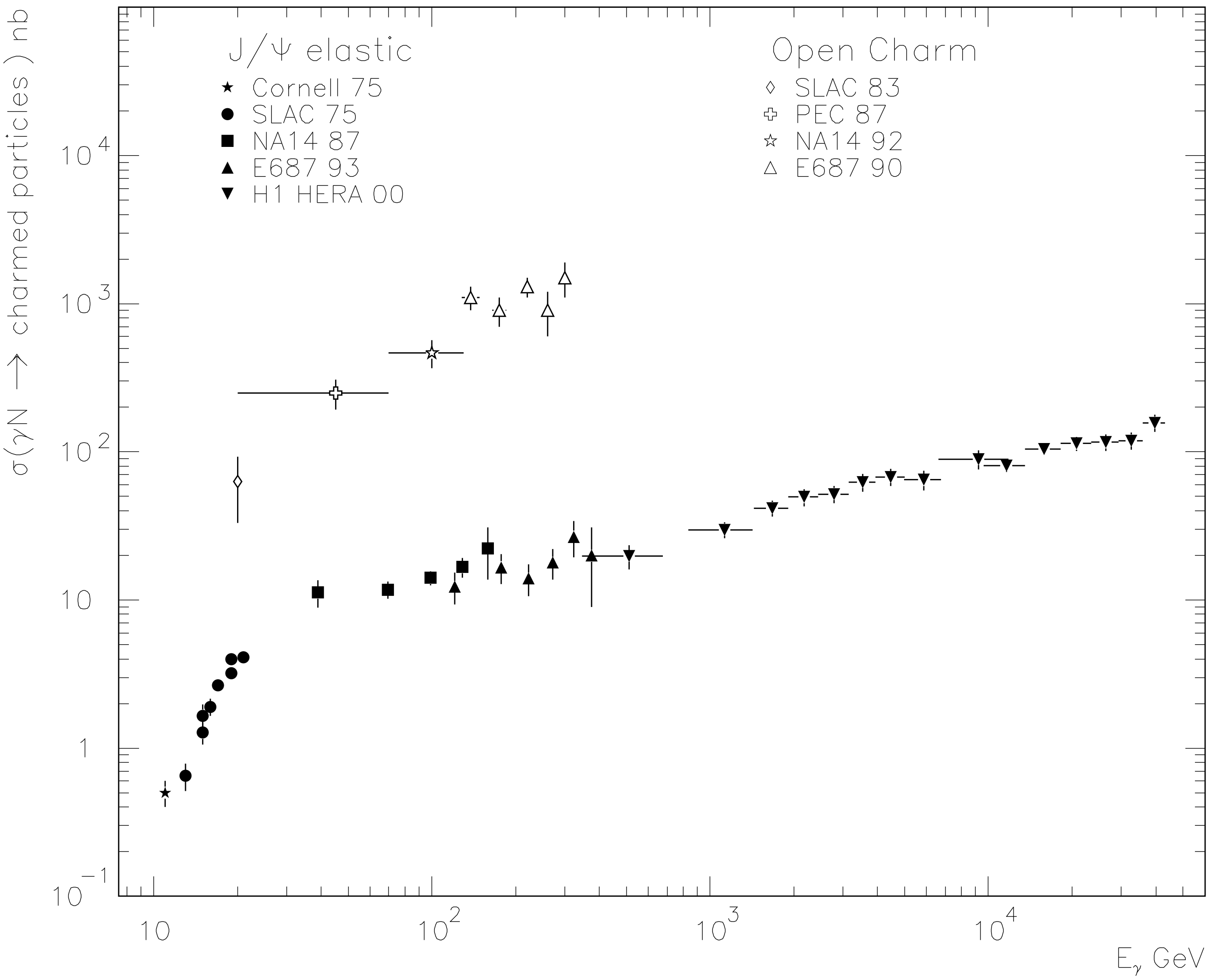
In this talk:

- Short overview of charm photoproduction: data and theory
- Threshold charm photoproduction: existing data
- Threshold charm photoproduction at JLAB
  - Physics motivation for new measurements
  - Capabilities of the existing/planned facilities
  - Proposal for a dedicated experiment
  - Summary of the experimental options

Existing Data on Charm Photoproduction

γp $\rightarrow$J/ψ(1S)p was measured at E$_\gamma > 11$ GeV

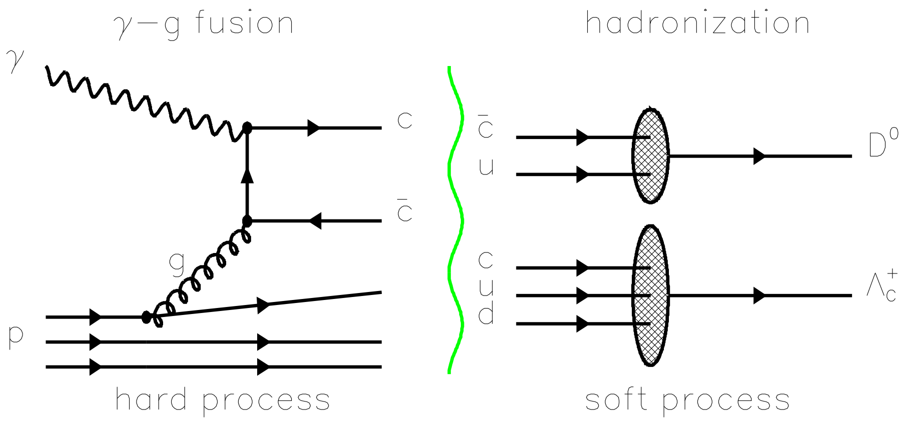
γp $\rightarrow c\bar{c}$+X was measured at E$_\gamma > 20$ GeV



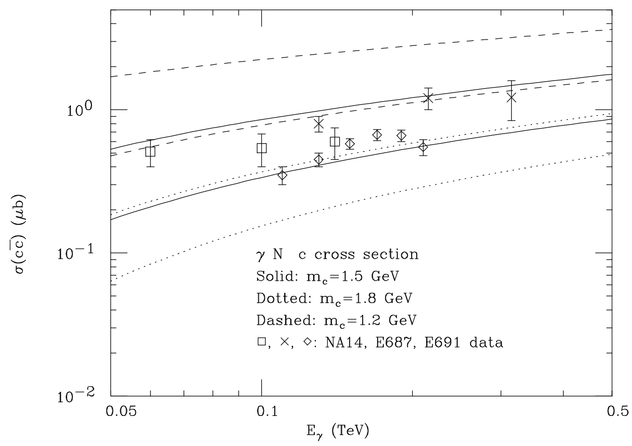
*Only a part of the experimental results are presented

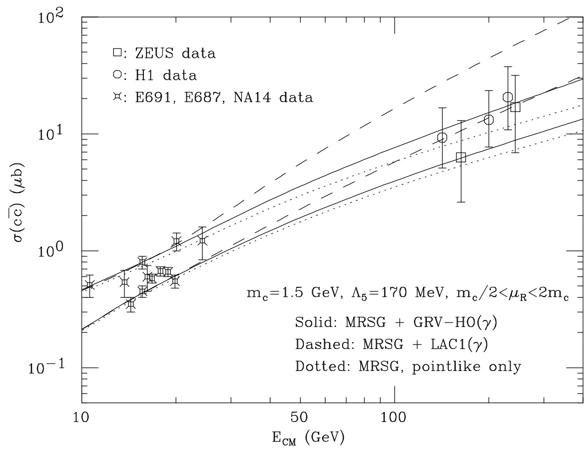
Theory: Open Charm Photoproduction

Factorization



Calculated in LO and NLO	Full inclusive charm:
Main parameters:	– hadronization ignored
– m_C: 1.2-1.8GeV	Exclusive production:
– renormalization scale	– use fragmentation functions from e^+e^-
– gluon PDF	– final state interaction





S.Frixione,M.Mangano,P.Nason,G.Ridolfi, CERN-TH/97-16

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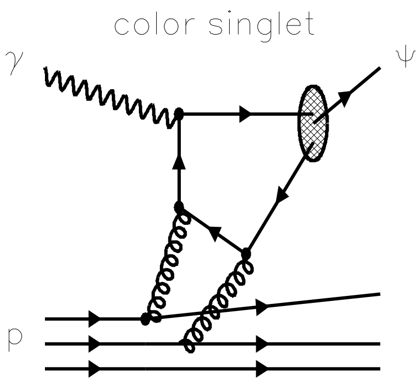
Theory: Charmonium Photoproduction

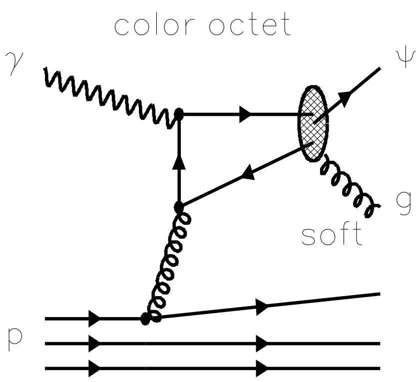
$c\bar{c}$ should combine into a colorless state. Are only hard processes involved?



Color Singlet

– everything is calculable

– Underestimates the Tevatron data by $\times 100$



Color Octet

– The soft part: phenomenology

– Good description of cross-sections

– Problems with polarization

Color Evaporation

In order to verify the models:

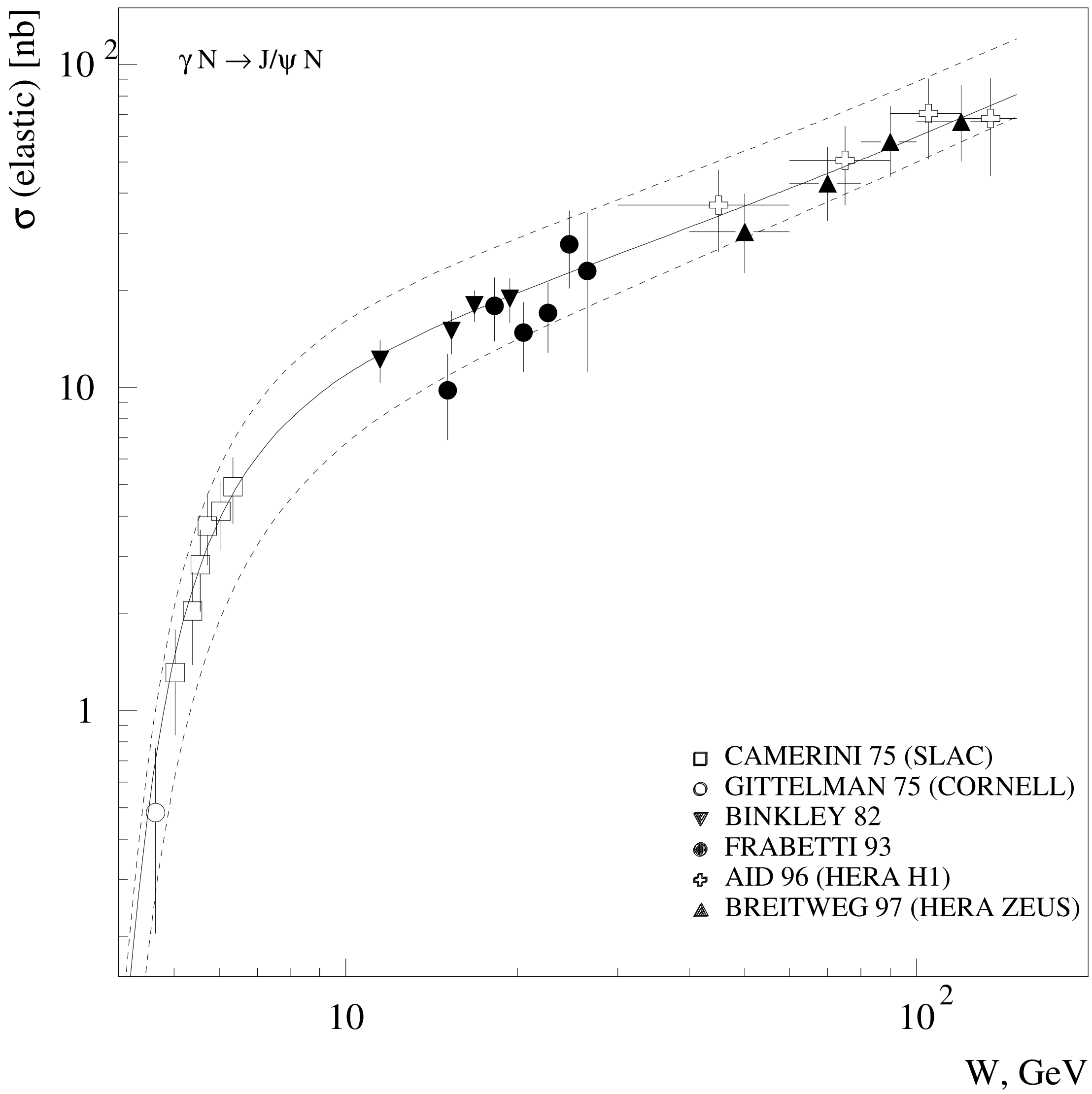
– Cross-sections

– Polarization

Measuring Singlet/Octet is important in order to extract ΔG in Ψ production at RHIC

Calculation of ΨN$\rightarrow$ ΨN and Ψ Photoproduction

(From: D.Kharzeev et al Eur.Phys.J. C 9,459 (1999))

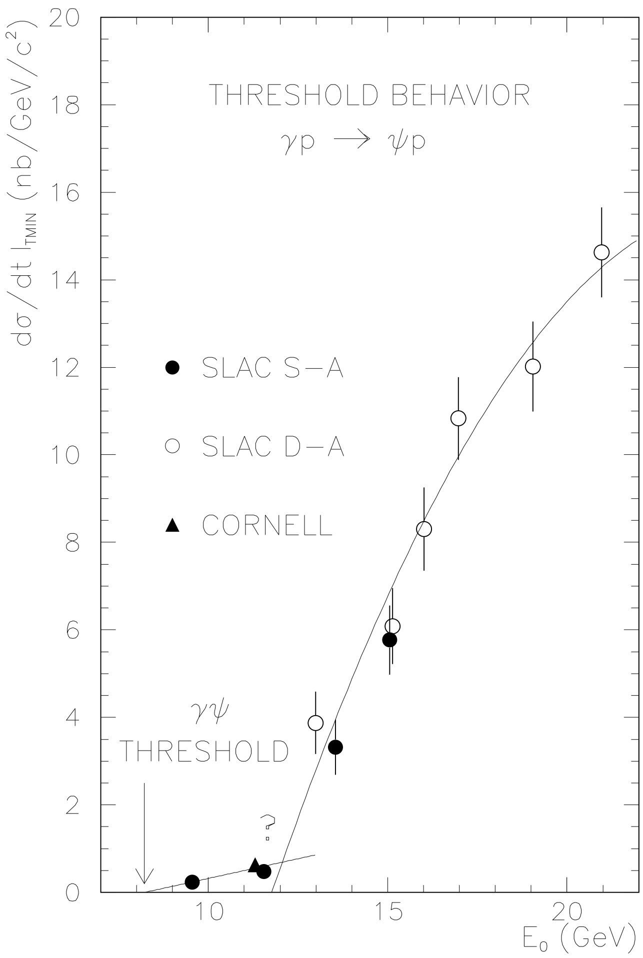


- Calculation of ΨN$\rightarrow$ ΨN using gluon PDF
- Link to photoproduction using VDM, optical theorem and dispersion relations

Applicable at E_γ >25 GeV : $\ell_{coherence} = \frac{2E_\gamma}{M_\Psi^2} > 1\ fm$

Experiment: Low Energy Photoproduction

Cornell
SLAC:
Double arm measurements: low background
Single arm measurements: BH background subtracted



Double Arm: published

Single arm: unpublished, very large errors below 12 GeV

At 20GeV
$\frac{d\sigma}{dt} = A \cdot \exp Bt$,
where
A=10.8 ± 1.1 nb/GeV^2,
B=2.9 ± 0.3 GeV^2

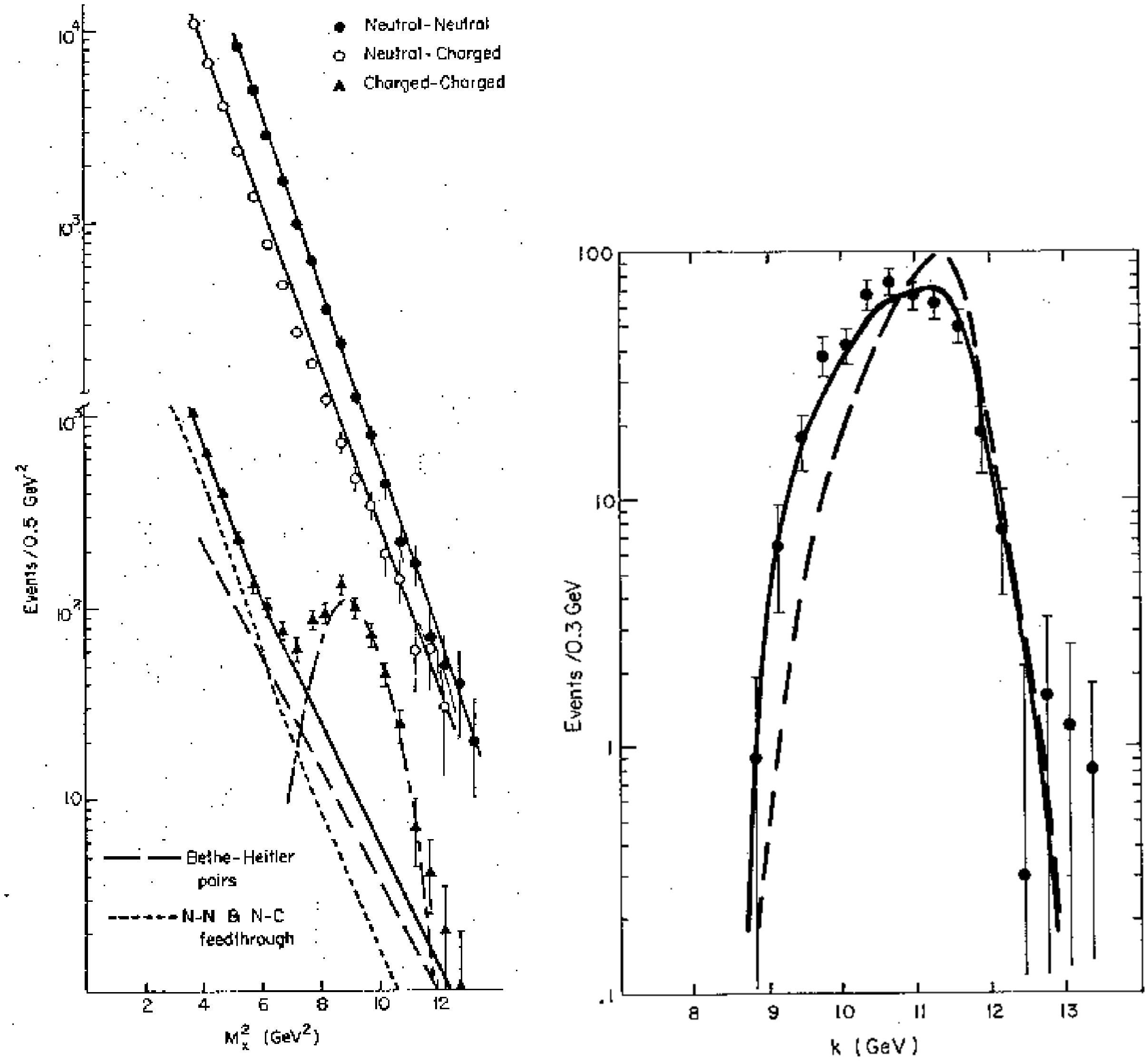
This indication of the behavior close to threshold is not published by SLAC

Experiments on Low Energy Charm Photoproduction

γp $\rightarrow J/\psi(1S)$p at low energies was detected:

- SLAC, at 19 GeV on ^{1}H and 13-21 GeV on ^{2}H.
  - 5% radiator and 30 cm target.
  - Standard spectrometers (20 and 8 GeV) used.
  - $J/\psi(1S) \rightarrow e^+e^-$, $\mu^+\mu^-$ detected.
  - Signals: 1200 $J/\psi(1S)$ and 13 $\psi(3770)$.
  - Results: in γp: $\frac{d\sigma}{dt} \mid_{tmin} = 10.8 \pm 1.1$ nb/GeV^2.
- SLAC, at E_0=19 GeV on Be and Ta.
  - Single 20 GeV spectrometer detecting μ^- at high P_T.
  - High statistics and high background.
  - Results: $\sigma(Be)/\sigma(Ta) = 1.21 \pm 0.7 \Rightarrow$
    $\sigma_{\psi N}$ $=3.5 \pm 0.8$ mb.
- Cornell, at E_0=11.8 GeV on Be.
  - $J/\psi(1S) \rightarrow e^+e^-$ detected with lead-glass calorimeters.
  - Average photon flux $1{\cdot}10^9$/s for 8.5<$E_\gamma < 11.8$ GeV, duty cycle=7%, Be target 2.9g/cm^2
  - Signal/background $\sim$470/70
  - Results: $\frac{d\sigma}{dt} = A \cdot \exp Bt$, where
    A=0.9 ± 0.1 nb/GeV^2, B=1.13 ± 0.18 GeV^2.

Cornell Results at 11.8 GeV



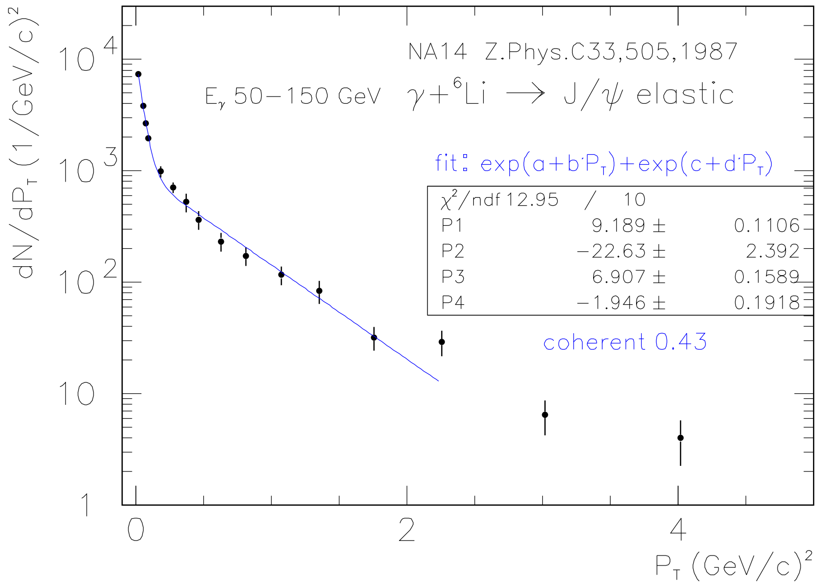
Calorimeter resolution: $\sigma E/E = 0.16/\sqrt{E}$

Background: neutrals $\times 10$ charged

BH describes the charged background

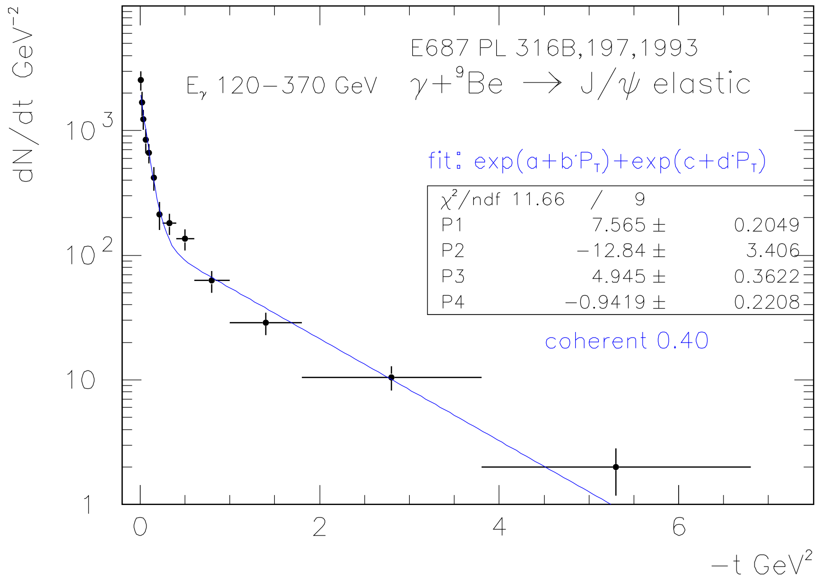
No dependence of cross-section on E_γ observed!

$J/\psi(1S)$ Production on Nuclei



^6Li NA14

vertex detector



^9Be E687

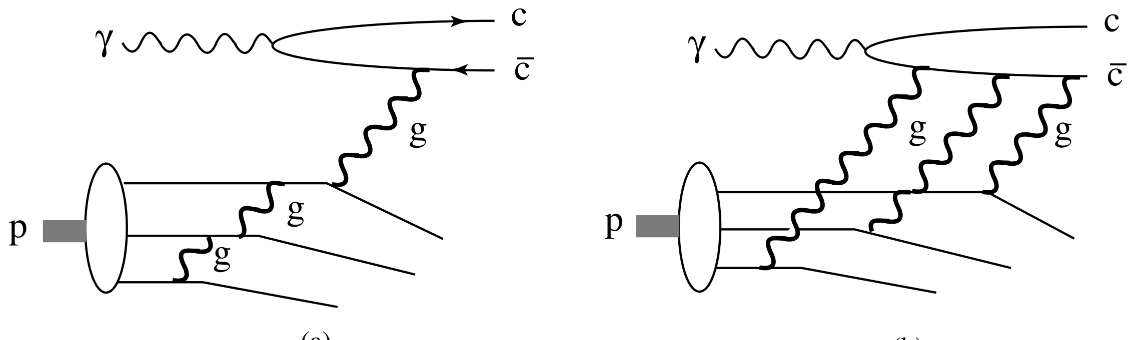
vertex detector

- A large coherent production: ≈40%
- "Coherent" slopes: NA14 and E687 are inconsistent
- NA14 and E687 - good t resolution, recoil undetected
- full cross-section A-dependence $\approx A^1$
- Potential interest: measuring Im A/Re A

Physics of the Production at Threshold

What is interesting in the charm photoproduction close to the threshold?

- Small size of the e^+e^- fluctuation, longitudinal: $\ell_{coh} = \frac{2E_\gamma}{4m_c^2} \approx 0.4\ fm$, transverse: $\sim \frac{1}{m_c} = 0.13\ fm$. Small impact parameter: all quarks involved must be in the same small volume
- Nucleon targets: 3 gluon exchange may be dominant: probes correlations between the valence quarks



(a) (b)

- Nuclear targets: $\ell_F \cong \frac{2}{m_{\psi'} - m_{J/\psi}} \left[\frac{E_{J/\psi}}{2m_c}\right] \cong 0.11 E_\gamma$ about 1 fm. One can study the $\Psi N \rightarrow \Psi N$ interactions.
- Nuclear targets: search for "hidden color"
- Nuclear targets: search for charm bound states

A Model for the Cross-Section near Threshold

A draft of the proposal for charm studies, by J.-M.Laget:

http://www.jlab.org/ gen/charm/meeting.html

Model of S.Brodsky: exchange of 1,2 or 3 gluons imposes factors of $(1-x)^{2n_s}$, where:

n_s is the number of spectator quarks, $=$ 0/1/2 for 3,2 and 1-gluon exchanges

$x = \frac{s_{thresh}-m_p^2}{s-m_p^2}$.

This approach is applicable at $x \sim 1 \Rightarrow E_\gamma < 12-15GeV$.

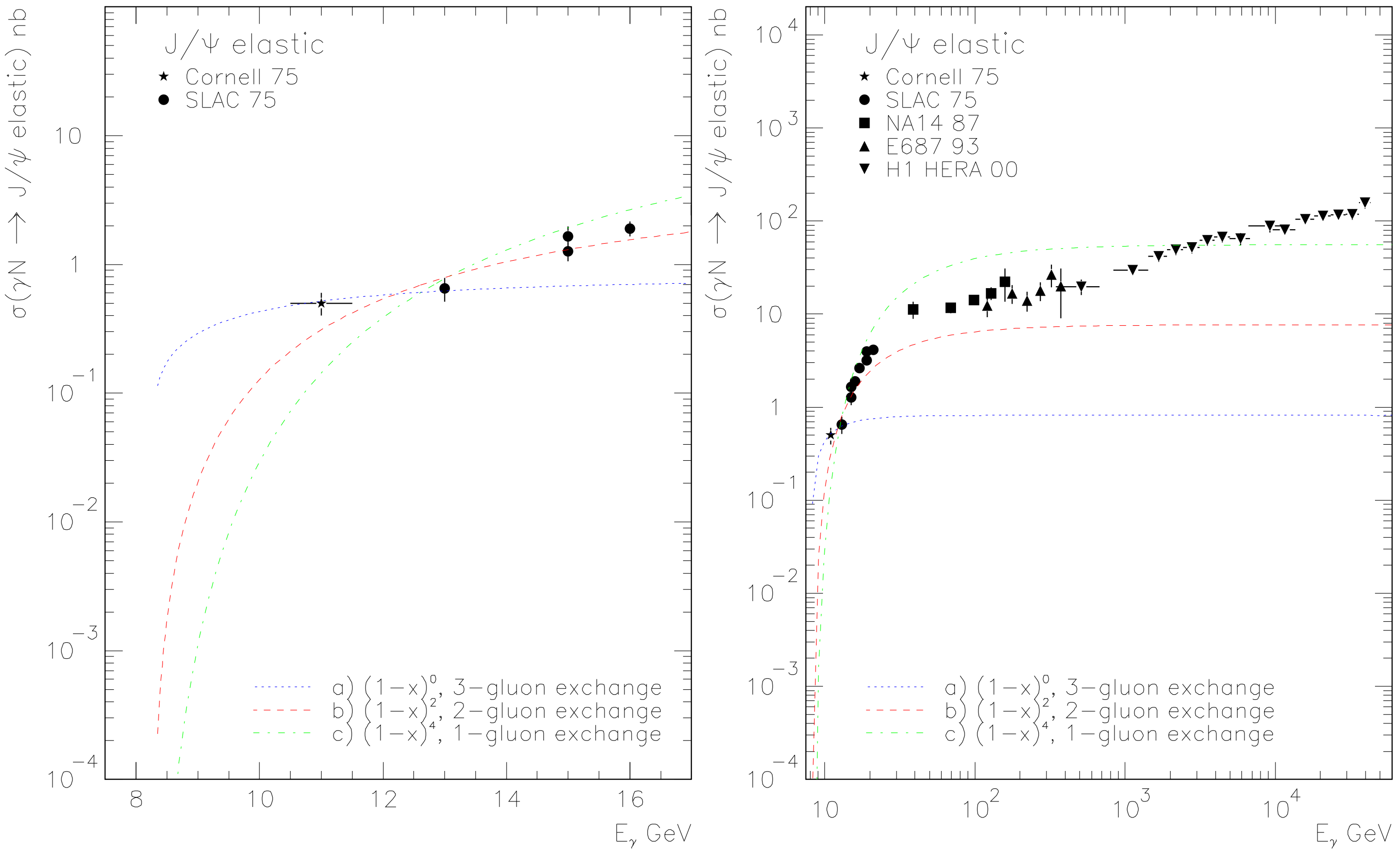
The cross-section:

$\frac{d\sigma}{dt} = \frac{1}{16\pi(s-m_p^2)^2} \cdot |\mathcal{A}(s,t)|^2$, or

$\frac{d\sigma}{dt} = C(n_s) \cdot (1-x)^{2n_s} \frac{1}{16\pi} \cdot e^{\beta t}$

The factors $C(n_s)$ have not been calculated so far. They should be obtained experimentally.

World Data and Predictions for Low Energies



- Fit to the two lowest energy points (from Cornell and SLAC).
- The curves are only applicable at $E_\gamma < 15\mathrm{GeV}$

Charm at JLab

reaction	E_γ threshold
γp $\to \eta_c(1S)$p	7.7 GeV
γp $\to J/\psi(1S)$p	8.2 GeV
γp $\to \Lambda_c^+ \overline{D}^0$	8.7 GeV
γp $\to \Sigma_c^+ \overline{D}^0$	9.5 GeV
γp $\to \chi_{c1}(1P)$p	10.1 GeV
γp $\to \psi(3770)$p	11.0 GeV
γp $\to D^0 \overline{D}^0$ p	11.1 GeV

These reactions are within the reach at 12 GeV.
At 7-8 GeV: subthreshold production on nuclei?

Detecting charm is difficult:

- Low cross-section: $\approx$1nb.
- Low branching ratios, for ex. $J/\psi(1S) \to e^+e^-$ 6%.

Illustration:
the yield $J/\psi(1S) \to e^+e^-$ to $\phi(1020) \to K^+K^- \sim 10^{-4}$.

Nevertheless: charm detection at low energies is *possible*.

Charm Identification

Effective mass reconstruction:

- Small (or zero) particle width.
- Large free energy ⇒ low background.

2-body decays provide the lowest background:

particle	mass MeV/c^2	E_γ thr GeV	decay	BR	P_{CM} MeV/c^2	Exp*
$\eta_c(1S)$	2980	7.7	$\gamma\gamma$	0.03%	1490	no
			$p\bar{p}$	0.12%	1157	no
$J/\psi(1S)$	3100	8.2	e^+e^-	6.0%	1548	yes
			$\mu^+\mu^-$	6.0%	1545	yes
$\overline{D}^0$	1865	8.7	$K^+\pi^-$	4.0%	861	yes
$\chi_{c1}(1P)$	3510	10.1	$J/\psi(1S)\gamma$	27.0%	389	no
$\psi(3770)$	3690	11.0	e^+e^-	0.8%	1843	yes
			$\mu^+\mu^-$	0.8%	1840	yes

(∗) Observed in photoproduction at E_γ <25 GeV

Open charm production may provide other signatures:

- Decay path 0.01 - 1 cm ⇒ vertex detector
- Decays of the associated particle ⇒large acceptance

Charm Studies at JLAB at 12GeV

What can be done at JLab?

#	reaction	measured	impact
1	γp $\to$J/ψ(1S)p $\psi \to$e$^+$e$^-$,$\mu^+\mu^-$	$\frac{d\sigma}{dt}$ (E$_\gamma$)	Production mechanisms Models: gluon PDF Models: $\sigma_{\psi N}$
2	γA $\to$J/ψ(1S)X $\psi \to$e$^+$e$^-$,$\mu^+\mu^-$	$\frac{d\sigma}{dt}$ (A)	Models: $\sigma_{\psi N}$
3	γp $\to\Lambda_c^+\overline{\mathrm{D}}^0$ $\overline{\mathrm{D}}^0\to\mathrm{K}^+\pi^-$	$\frac{d\sigma}{dt}$ (E$_\gamma$)	Production mechanisms Models: gluon PDF
4	γA $\to\psi(3770)$X $\psi \to$e$^+$e$^-$,$\mu^+\mu^-$	$\frac{d\sigma}{dt}$ (A)	Models: $\sigma_{\psi N}/\sigma_{\psi' N}$
5	γA $\to\chi_{c1}$(1P)X χ_{c1}(1P)$\to$J/ψ(1S)γ	$\frac{d\sigma}{dt}$	Production mechanisms
6	γp $\to\eta_c$(1S)p η_c(1S)$\to\gamma\gamma$	$\frac{d\sigma}{dt}$	Production mechanisms

Improvements with respect to the old experiments:

- 1-3 Higher statistics ($\times 500$), better systematics
- 1 Recoil detection (inelastic $\sim 30\%$)
- 4-6 Possible observation

Charm Studies at JLAB at 12GeV

JLab standard spectrometers

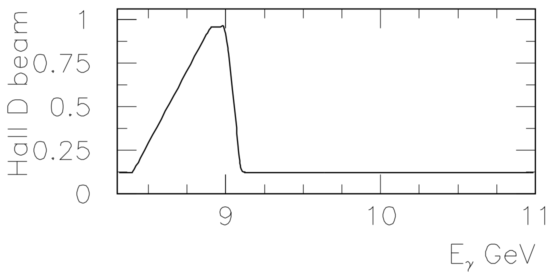
hall	beam μA	setup	$\Delta\Omega$ ster	P_{max} GeV	$\frac{\Delta P}{P}$ %	$\frac{\sigma P}{P}$ %	$\sigma\theta_{in}$ mrad	$\sigma\theta_{out}$ mrad
Hall A	100	HRS	0.006	4.0	9	0.01	0.6	2.0
		HRS	0.006	3.2	9	0.01	0.6	2.0
		MAD*	0.030	6.0	15	0.3	1.0	2.0
Hall C	100	HMS	0.006	7.5	18	0.1	0.8	0.8
		SOS	0.009	1.8	40	0.1	1.0	1.0
		SHMS	0.003	12.	18	0.1	1.0	1.0
Hall B	0.01	CLAS	$\sim 2\pi$	-	-	0.5		
Hall D	γ		$\sim 4\pi$	-	-	$<1.$		

$(*)$ Proposed for structure functions measurements

Possible photon flux:

- Halls A,C: $40\mu A$ at 6% RL radiator: $1.2 \cdot 10^{12}\gamma$/s/GeV
- Halls B: in $0.2 < \frac{E_\gamma}{E_0} < 0.95$: $< 10^7/10^8$ tagged/untagged
- Halls D, tagged:

  $\sim 2 \cdot 10^7/s$ in $8.4 < E_\gamma < 9.1$GeV coherent
  $\sim 2 \cdot 10^7/s$ in $8.4 < E_\gamma < 11.$GeV incoherent



Measuring the photon energy

Measuring $\frac{d\sigma}{dt}(E_\gamma)$: ~ 6 bins of ~ 0.4GeV in E_γ.
E_γ should be measured to about 1%.

- Hall D tagger: $\sigma E_\gamma / E_\gamma < 0.1\%$
- Hall A,C - no tagging:
  - 2-body decay of $\mathrm{J}/\psi(1\mathrm{S})$ or $\overline{\mathrm{D}}^0$, (assuming the 2-body "elastic" reaction!) $\sigma E_\gamma / E_\gamma \approx 0.2\%$
  - Since the recoil particle is not detected, one can not be sure that the reaction is indeed defined, apart from a narrow energy band - just above the threshold.
  - Subtraction method: measuring several (~ 6) end-points.
    - Time/measurement selected to equalize the errors at different energies
    - Direct (no subtraction) measurement at low energy, example: γp $\rightarrow\overline{\mathrm{D}}^0$ X in an range 8.7-9.4 GeV, is limited to the $\Lambda_c^+\overline{\mathrm{D}}^0$ final state.

Charm Studies at JLAB at 12GeV

Simulation

γp $\rightarrow$J/ψ(1S)p

- 2-body reaction, $t = (p_\psi - p_\gamma)^2$, $\frac{d\sigma}{dt}$~e$^{1.0\cdot t}$
- Decay e$^+$e$^-$ $\sim (1 + cos^2\theta^*)$

γp $\rightarrow\Lambda_c^+\overline{\mathrm{D}}^0$

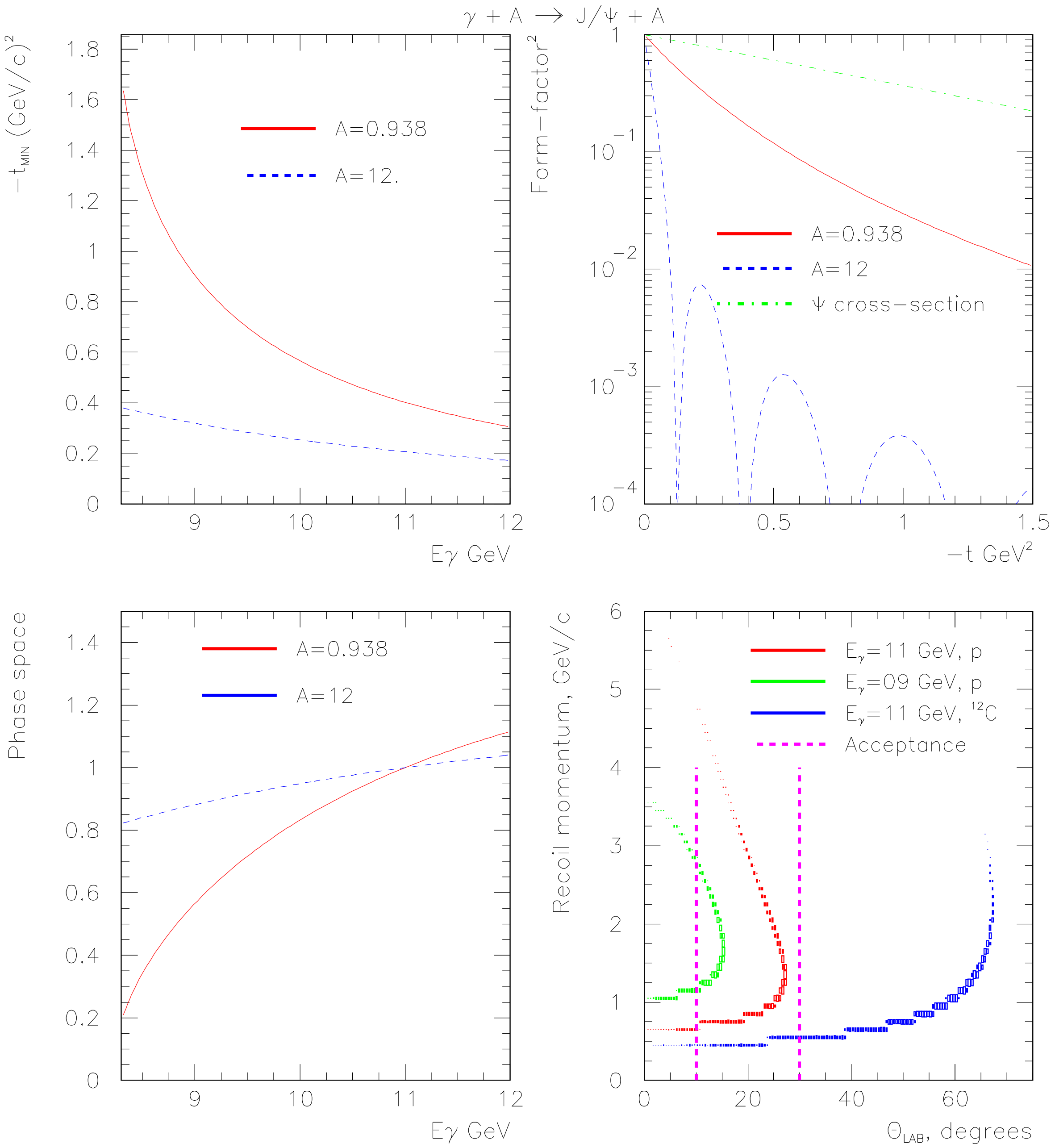
- 2-body reaction, $t = (p_D - p_\gamma)^2$, $\frac{d\sigma}{dt}$~e$^{1.0\cdot t}$
- Decay $\overline{\mathrm{D}}^0 \rightarrow \mathrm{K}^+\pi^-$ is isotropic

Other conditions:

- Targets A>1: Fermi motion
- GEANT-based simulation of tracking
- Acceptance and mass resolution are calculated.
- Efficiency of 0.5 (trigger, dead time etc)
- For K^+: not decayed at 15 m (MAD, SHMS): 0.5
- Beam delivery efficiency 0.7

Charm Studies at JLAB at 12GeV

γ+A$\rightarrow$ J/Ψ+A Kinematics



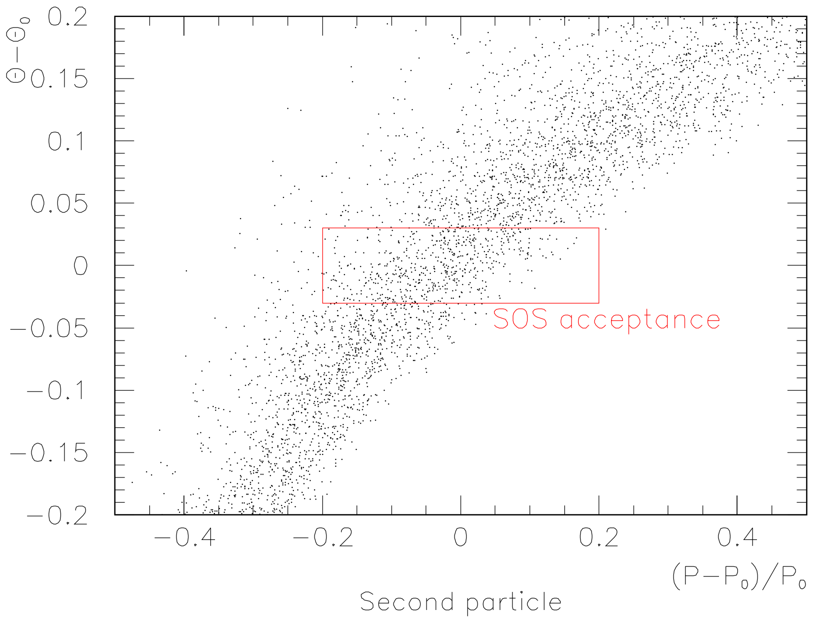
Elastic production on nuclei is strongly suppressed by the formfactor.

Charm Studies at JLAB at 12GeV

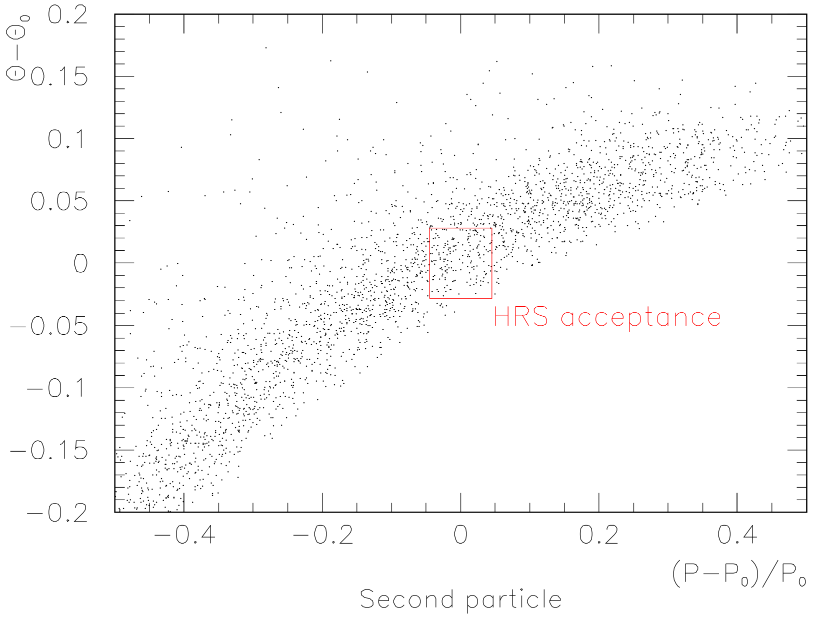
HRS,HMS acceptance

One spectrometer is hit:

$\gamma p \rightarrow J/\psi(1S)p$



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



Standard spectrometers

Assumed cross-section:

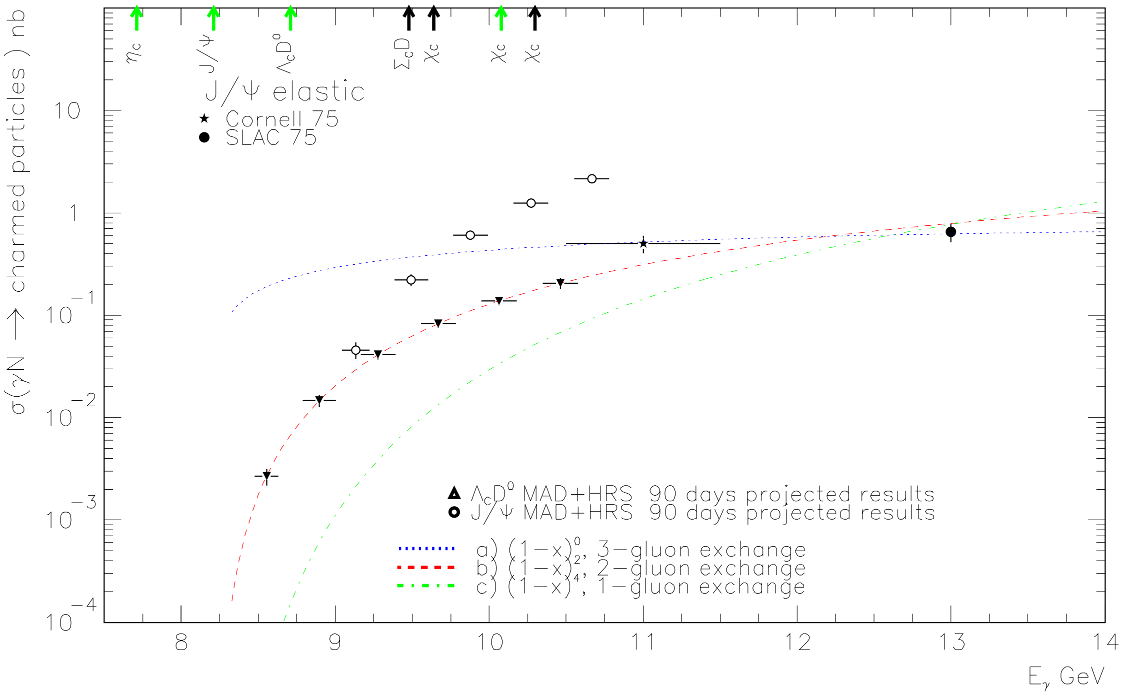
- $J/\psi(1S)$: $\frac{d\sigma}{dt} = c \cdot (1-x)^2 \cdot e^{1.1t}$, normalized that: $\sigma = 0.32$nb at E_γ=11 GeV.
- Open charm: $\times 10$ of $J/\psi(1S)$
  The photon energy is split in 0.4GeV bins.

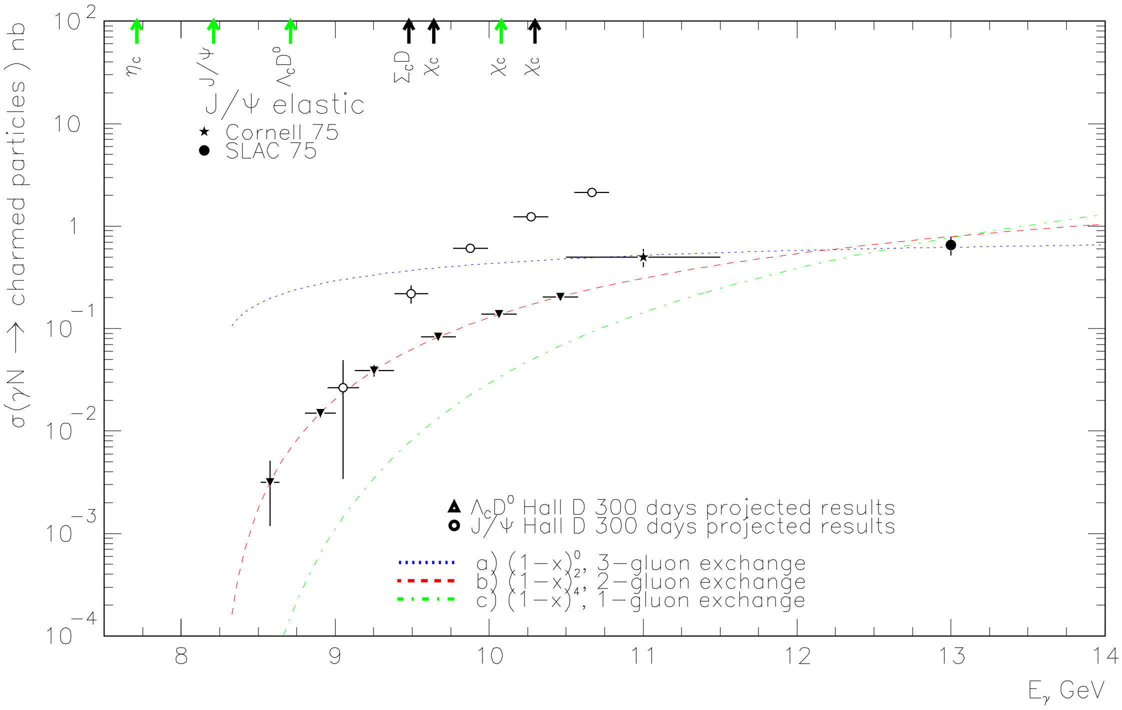
meaning	Hall D	HRS+HRS	HRS+MAD	HMS+SOS	HMS+SHMS
tagged γ	yes				
target LH	30 cm	15 cm	15 cm	4 cm	15 cm
$J/\psi(1S) \to e^+e^-, \mu^+\mu^-$					
$E_\gamma range$ GeV	8.3-11.	8.3-11.	8.3-11.	8.3-9.5	8.3-11.
decay angle CM	-	-	100^o	51^o	90^o
Acceptance %	~ 40	-	0.027	0.026	0.009
$\sigma M/M$	$\sim 1\%$	-	0.24%	0.2%	0.2%
events/90days	270	-	4100	180	1400
days required*	510	-	150	-	450
$\overline{D}^0 \to K^+\pi^-$					
$E_\gamma range$ GeV	8.7-9.3	8.7-11.	8.7-11.	8.7-10.	8.7-11.
decay angle CM	-	90^o	100^o	66^o	80^o
Acceptance %	~ 40	0.003	0.022	0.026	0.008
$\sigma M/M$	$\sim 1\%$	0.17%	0.2%	0.2%	0.2%
events/90days	590	930	6800	400	2500
days required*	1200	-	150	-	400

$*$ – Condition: the accuracy at $E_\gamma - E_{thresh} > 0.4GeV$ is $< 10\%$

Charm Studies at JLAB at 12GeV

Expected Results





Summary on the standard spectrometers

The possibilities of the "standard" spectrometers of JLab are as follows:

- $J/\psi(1S)$ studies:
  - Halls A/C (mainly HRS+MAD)
    - Enough statistics for $\sigma >\sim 0.01\mathrm{nb}$
    - The recoil particle is not detected
    - The decay angular distribution not measured
  - Hall D has some advantages
    - The recoil and other particle are detected
    - The angular distribution is measured
    - No end point tunes
    - About 2 years running is needed
    - Running parallel with the other programs
- Open charm studies:
  - Results are dependent on the level of background (no experimental data exists on this matter)
  - Halls A (HRS+MAD) has a statistical advantage over Hall D and needs 3-5 months to make a useful measurement

Conclusion: the existing equipment should be enough for a cross-section measurement on one target (Hydrogen) for both $J/\psi(1S)$ and open charm. It would not be possible to measure effects like hidden color, various nuclear effects etc. Also it is not enough for looking for $\chi_{c1}(1P)$ or $\eta_c(1S)$

A Dedicated Experiment for $J/\psi(1S)$

It would be difficult to improve considerably the prospects for open charm studies at JLab. However it is possible to make a major improvement of $J/\psi(1S)$ studies, building a dedicated detectors, which:

- Capable to work at a luminosity of $\mathcal{L} \sim 10^{36}$
- Has a high acceptance of >0.2
- Detects Ψ and the recoil proton
- Detects a wide range of the decay angles: $-0.5 < cos(\theta_{CM}) < 0.5$

Recoil's momentum and angle ranges are similar to those of e^+e^-, but its direction is not correlated with e^+e^-. Let us consider an open detector consisting of:

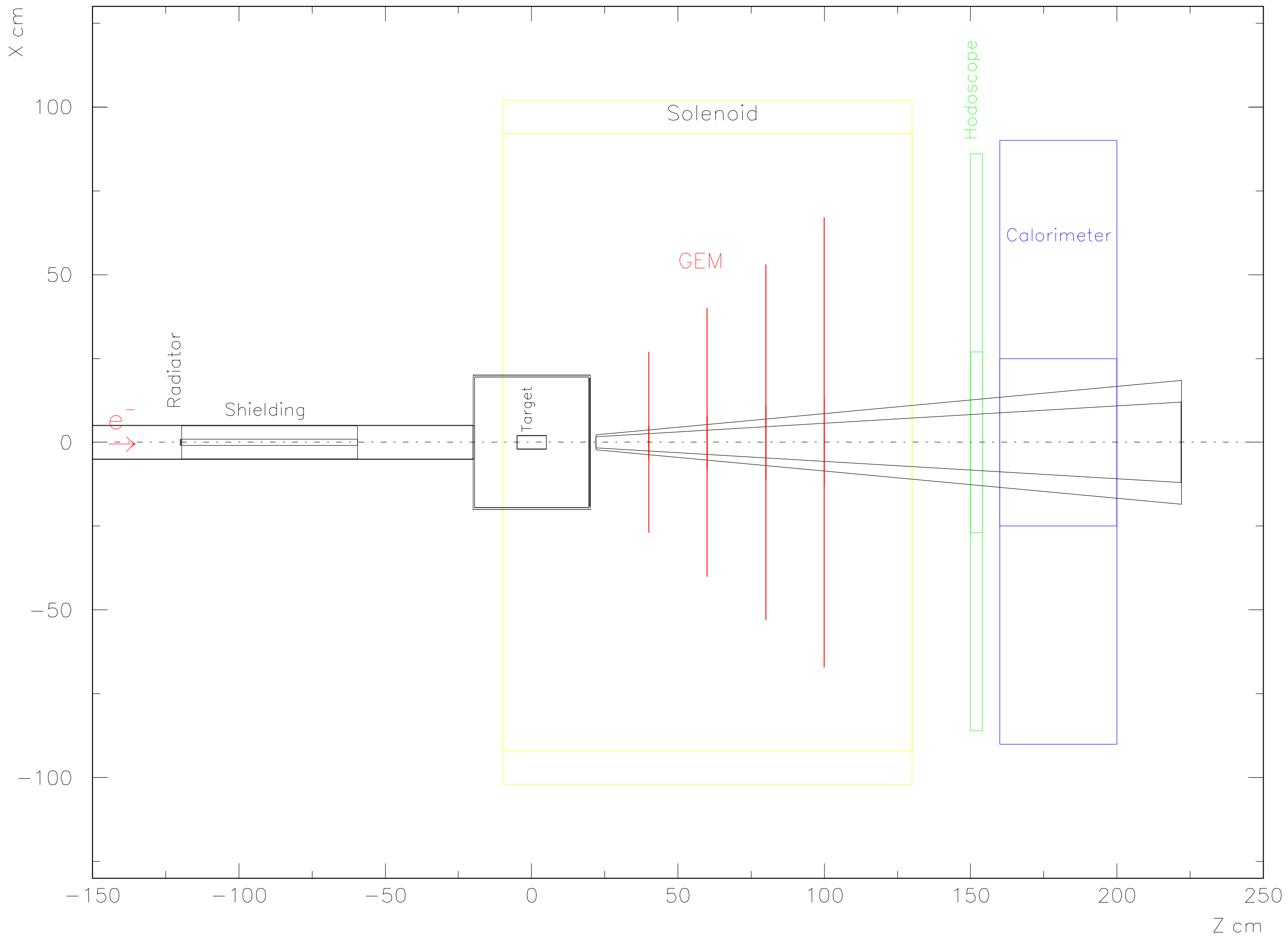
- Calorimeter for detecting e^+e^-: the energy and the coordinates are measured.
- A scintillator (lucite?) hodoscope in front of the calorimeter
- Protons are detected/identifies using the calorimeter and a scintillator detector behind
- Tracking would be of a big help in order to reduce the accidental rate (in a long target) and backgrounds

Limitations for "Open Detector" experiments

High rate of electromagnetic background in e^- and γ beams. The limitations on the possible luminosity are driven by:

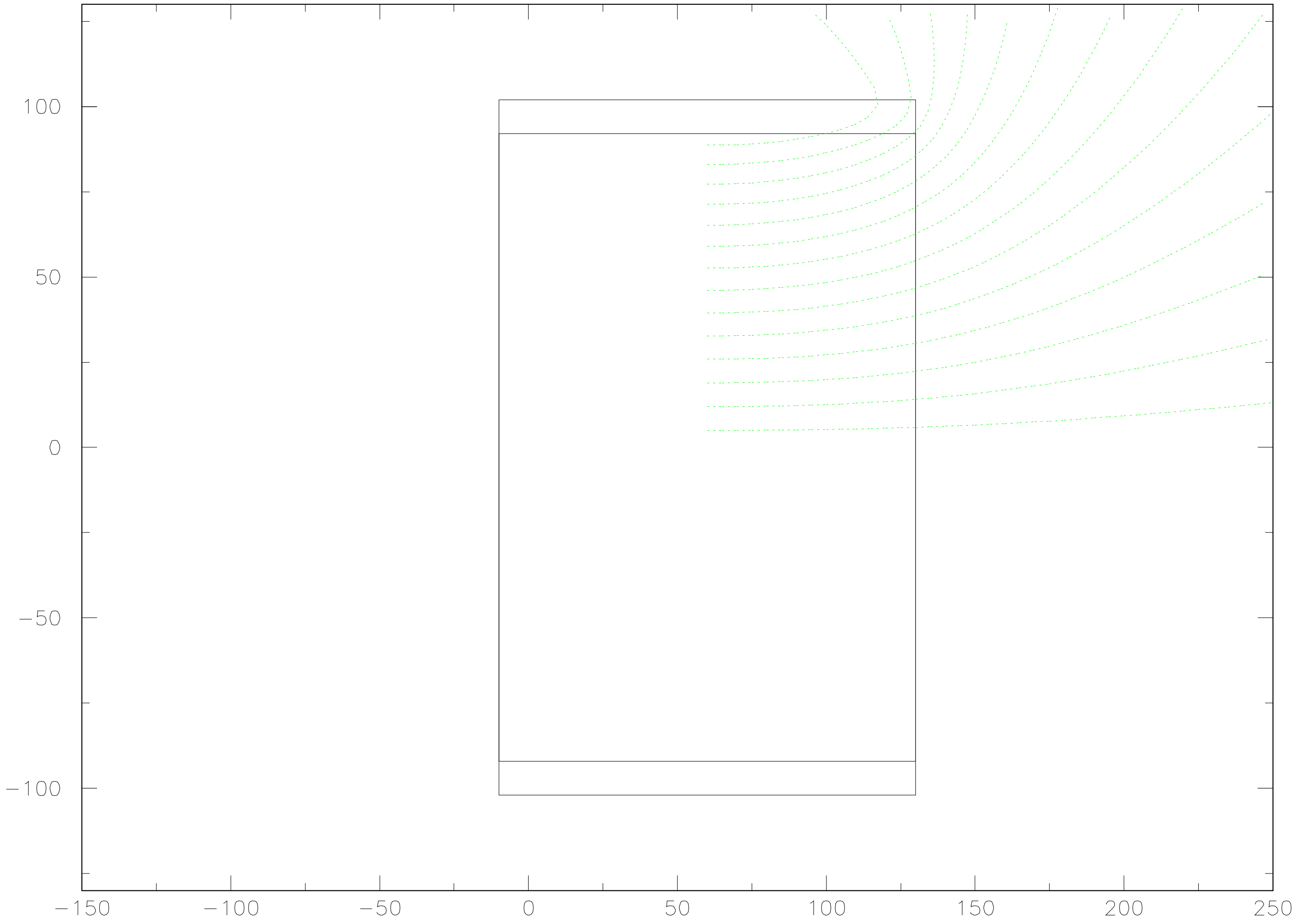
- Detectors:
  - Calorimeters: energy flow/s/module ($< 2 \cdot 10^5$GeV - from RCS tests);
  - Track detectors: charged particle flow/s/cm^2 ($< 10^7$ for GEM, HERA-B: $< 0.25 \times 10^7$);
  - Scintillator: charged particle flow/s/module ($< 3 \times 10^6$);
- Trigger rate: ($< 2 \cdot 10^4$/s)
- Accidental coincidence
  - CEBAF: resolution time of 2ns;
  - Track reconstruction with an extended target: a factor of $>$10 improvement;

Proposed Calorimeter Setup

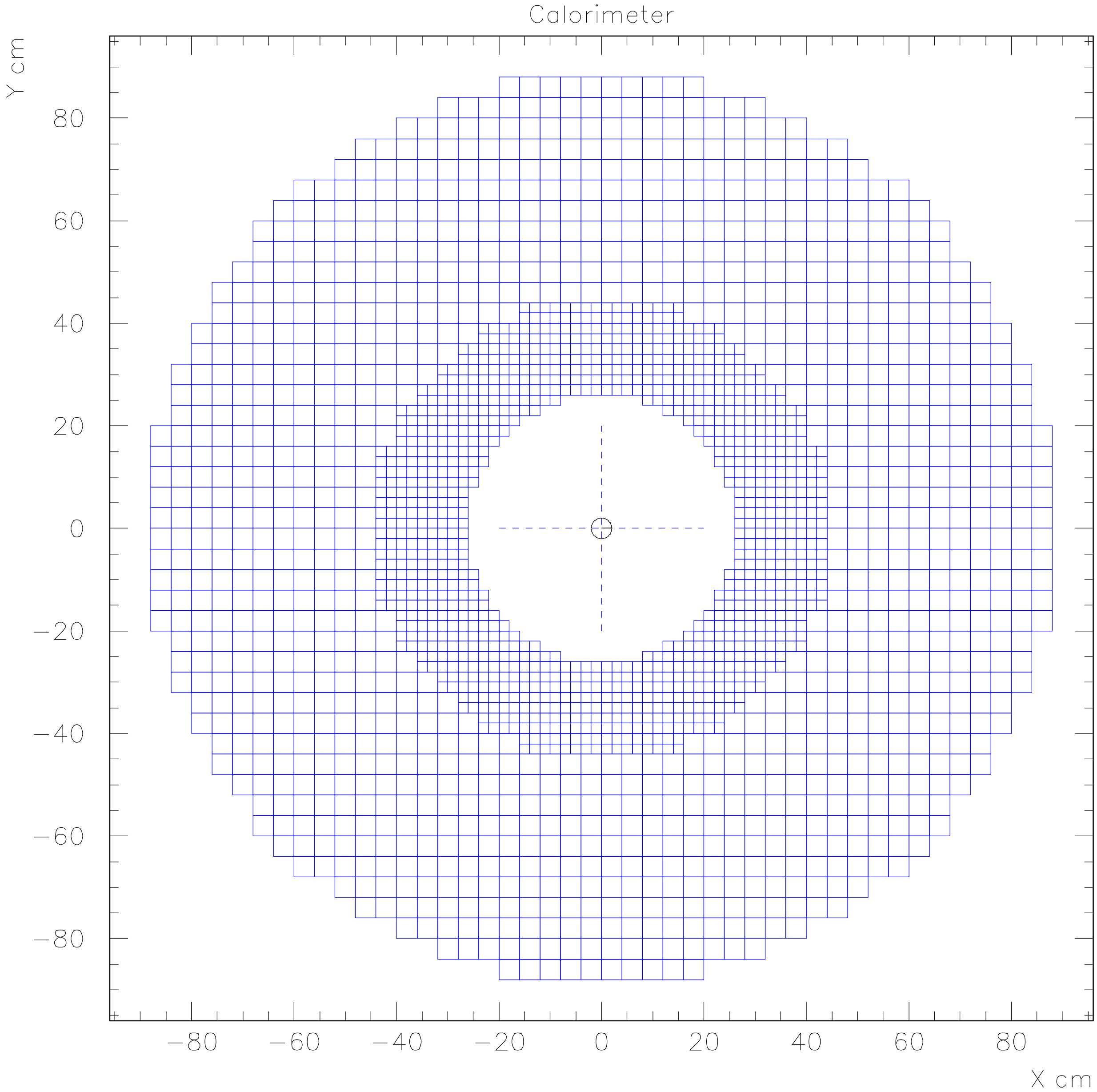


Charm Studies at JLAB at 12GeV

Solenoidal field

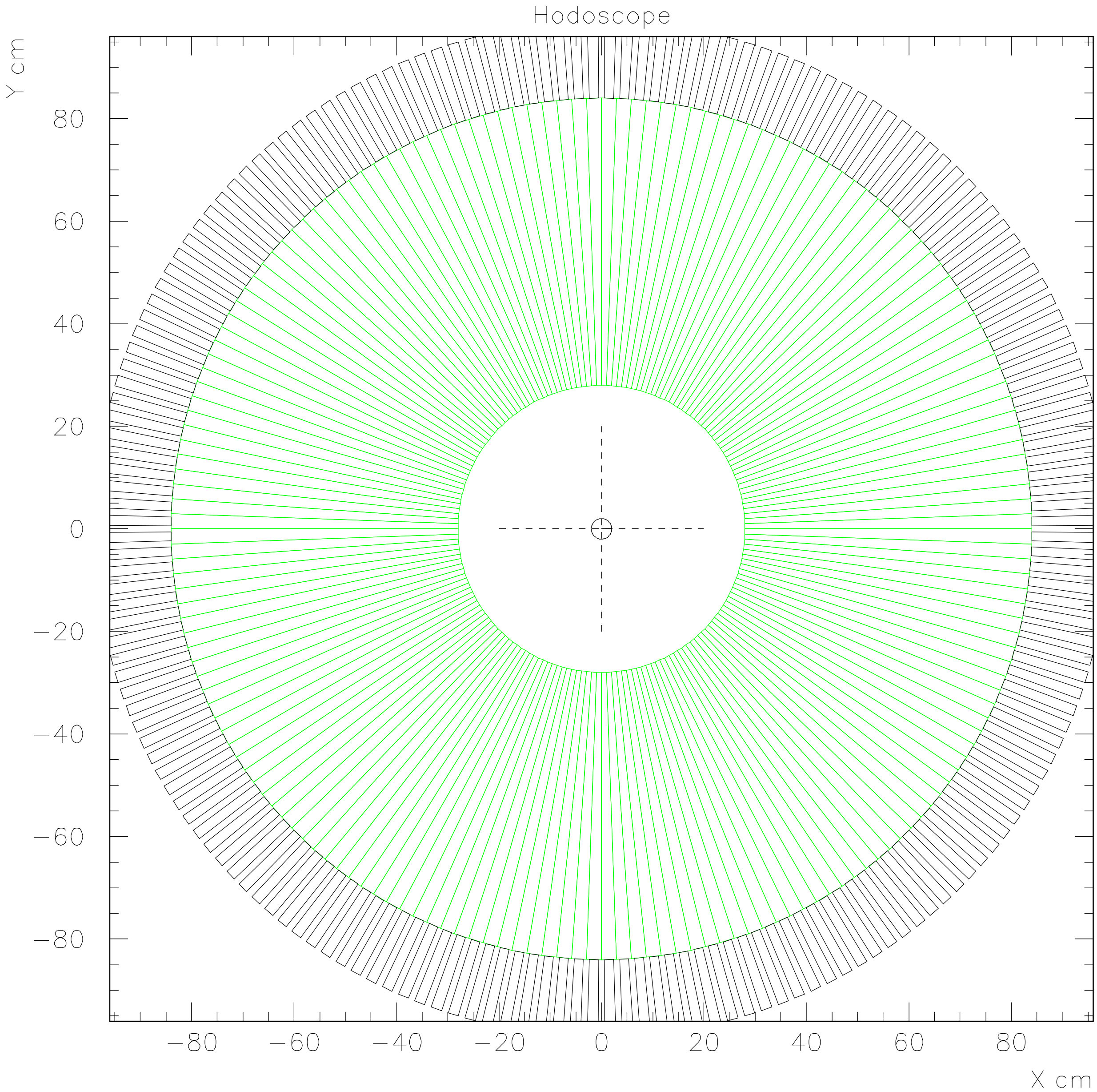


Proposed Detectors: Calorimeter



Number of modules: 1136 of $4 \times 4\text{cm}^2$ lead-glass and 1028 of $2 \times 2\text{cm}^2$ PbW crystals.

Proposed Detectors: Hodoscope



Number of modules: 180 of lucite.

Proposed Detectors: Tracking (GEM)

Solenoidal field: $R(cm) = 300 \times P_T/B(T)$.
Typically $P_T \approx 1$GeV/c and $R \approx 150cm$ at $B = 2T$.
The only candidate for the moment is GEM:

- Highest particle density $< 10^7/cm^2/s$
- A very good resolution $\approx 40 - 60\mu m$
- Complex detector shapes
- Thin in RL (0.1%)

Development for COMPASS and HERA-B:
$30 \times 30cm^2$, 2-coordinate, 2 GEMs, the anode is a printed circuit board.
Simulation: 5-6 planes (rings) (4 points/track), positioned at distances 40 - 120 cm from the target center. Nearly radial stripes (10° stereo angle). Resolution: $40\mu m$ normally to the stripe at R=10cm.

P GeV/c	θ	$\sigma P/P$
2.	30°	1.3%
5.	20°	3.3%
9.5	10°	6.7%

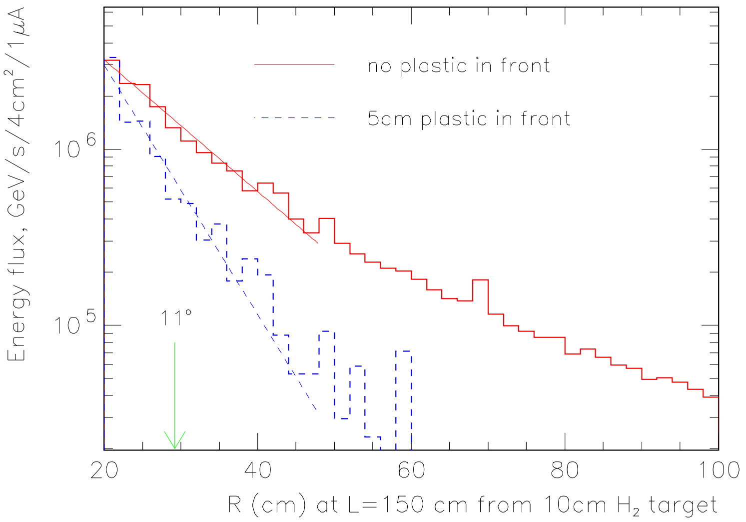
In total 3.5m^2 of GEM detectors and 20k channels are needed. Further optimization should be done.

Normalization of MC results

How well does GEANT simulate the background particle flux?

Tests in Hall A used LG modules 4×4cm^2 at 10m from the 15cm H_2 target. There $\approx$5cm of plastic in front of LG.

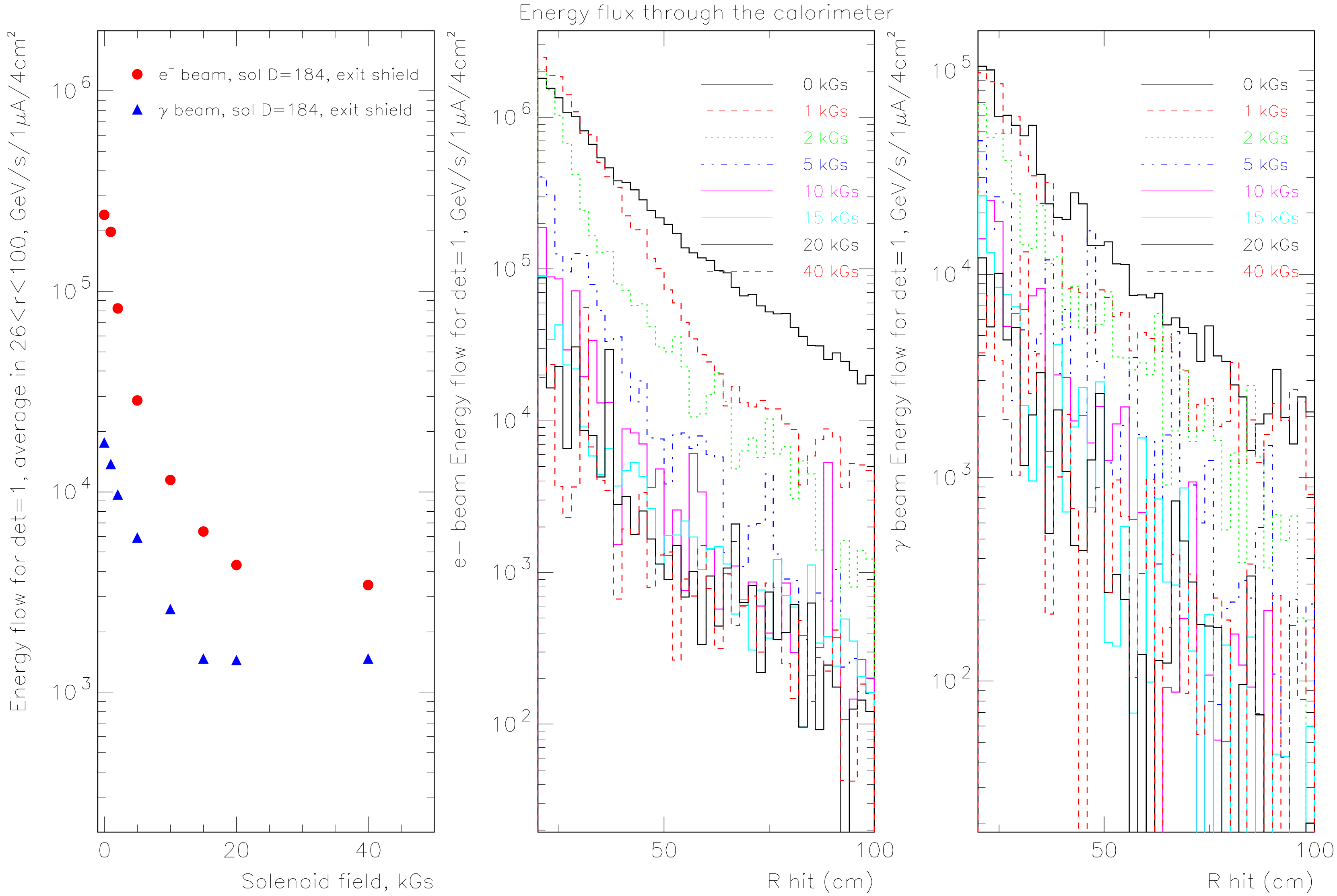
E_b GeV	μA	θ	pedestal shift	Energy flux GeV/s/block	MC flux GeV/s/block
1.833	23	11^o	14 cha	$1.1 \pm 0.2 \cdot 10^6$	$1.5 \cdot 10^6$
1.833	1	11^o	$\approx$1 cha		



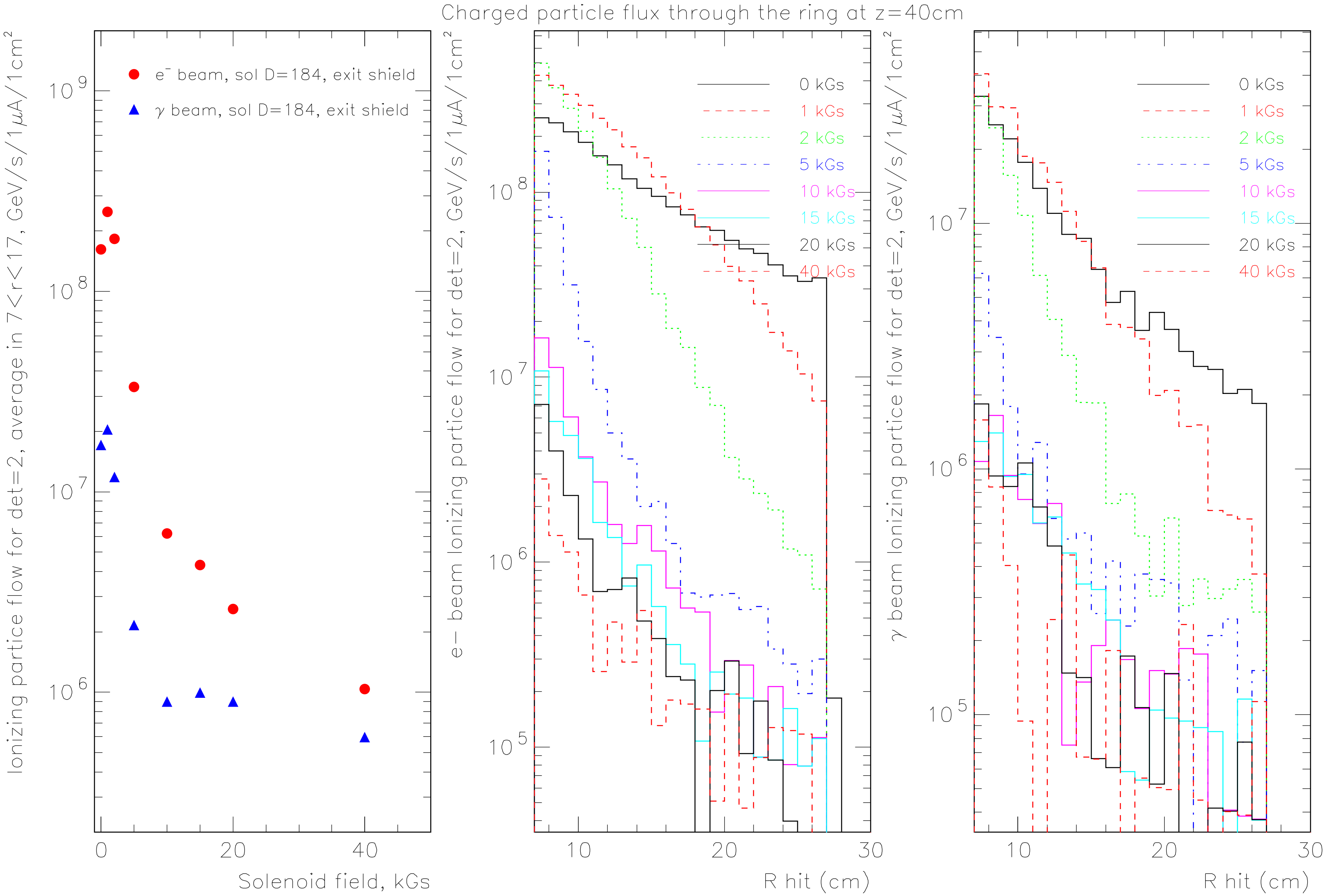
Mainly from e^- at low angles.

Result: GEANT provides a sufficiently good agreement with the measurements.

Background MC Simulation: Calorimeter

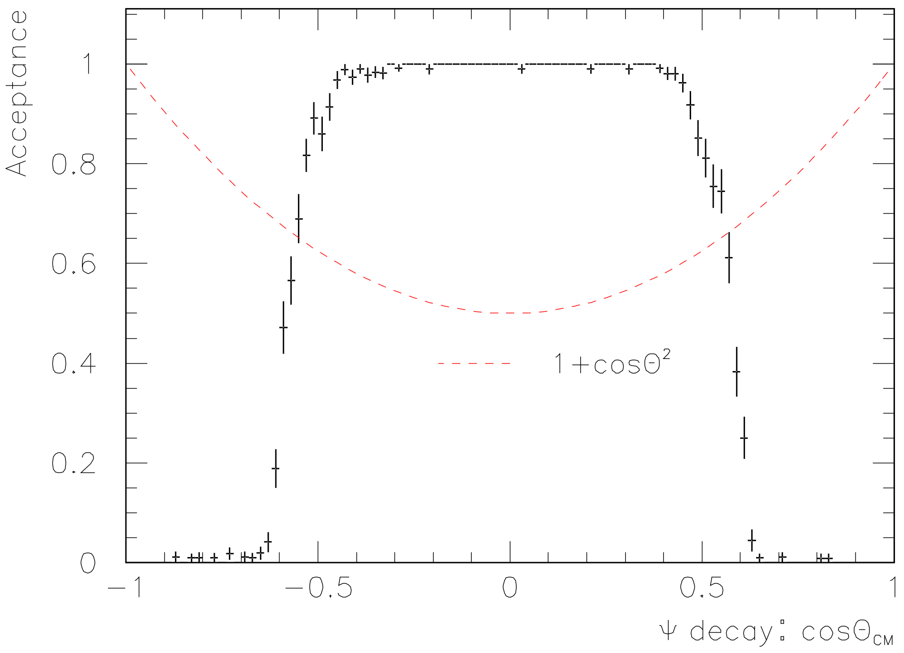


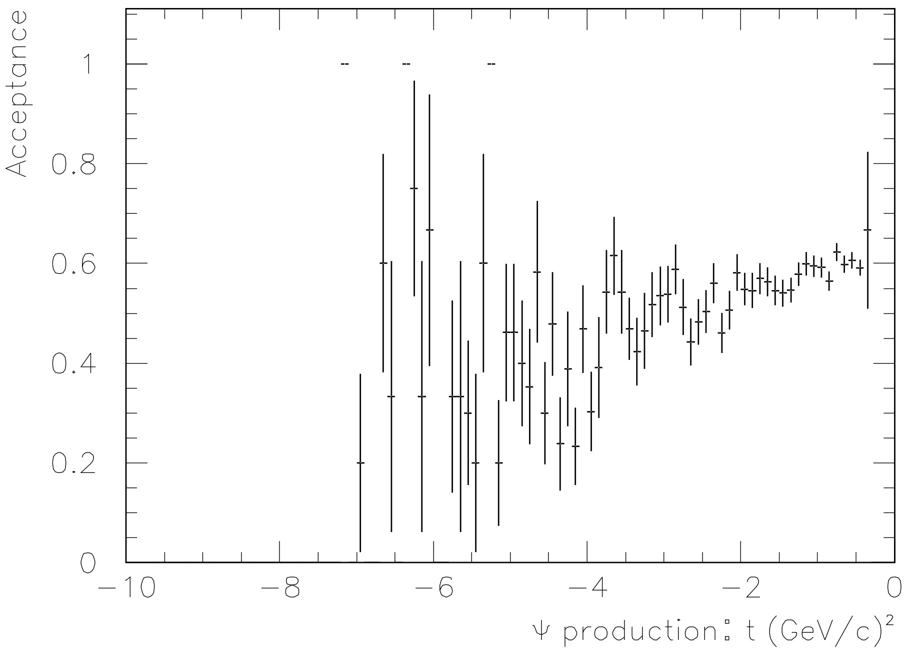
Background MC Simulation: Coordinate detectors



Acceptance

$J/\psi(1S)p$ detected with EM calorimeter





Comparison: Cornell - JLab proposal

meaning	Cornell, 1975	JLab proposal
Duty cycle	0.07	1.
End point, GeV	11.8	11.
E_γ range, GeV	9-11.8	8.5-11.
Beam, current	γ	e^-
e^- beam current	-	1μA
Radiator	-	0.05
N_γ, in spill, E range	$1.4 \cdot 10^{10}$/s	$6.2 \cdot 10^{10}$/s
Target	2.9 g/cm^2 Be	0.7 g/cm^2 LH
$\mathcal{L}$, γp, in spill, cm^{-2}s^{-1}	2.5×10^{34}	2.6×10^{34}
Magnetic field	0.85kGs·m dipole	20kGs solenoid
Days of running	14	90*0.7=63
$\int \mathcal{L} \cdot$ dt, cm^{-2}	2.1×10^{39}	1.4×10^{41}
Acceptance	≈ 0.03	≈ 0.3
$J/\psi(1S)$ / BG	500/100	$\times 670$
expected statistics	-	$3 - 5 \cdot 10^5$
Recoil detected?	no	yes
Mass resolution	-	$\times 0.3$
Full kinematics	no	yes

Charm Studies at JLAB at 12GeV

Feasibility

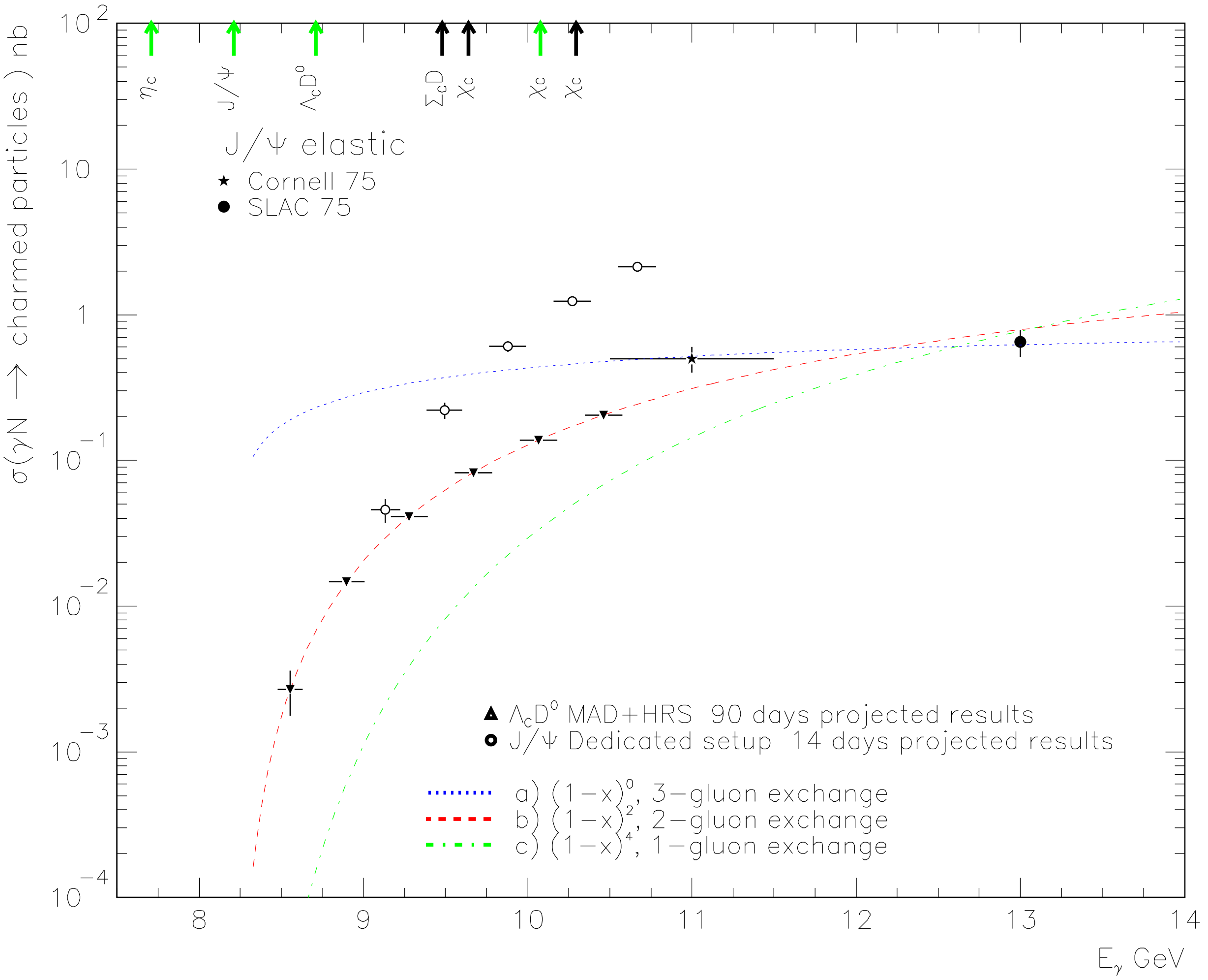
The experiment is feasible, since:

- The luminosity for the photon component of the beam is the same as at the Cornell experiment in-spill
- The e^- beam produces additionally about $5 \cdot 10^4$/s scattered e^- at E>1.5GeV in $10^\circ < \theta < 30^\circ$. The accidental coincidence rate should be still under control.
- The pion rate from the e^- beam should be about 2 times higher than in Cornell experiment, where it made no visible contribution to the background.

Advantages with respect to the Cornell experiment:

- Higher statistics (about $\times 700$)
- The better energy and mass resolution ($\times 3$) and also the full kinematic information on the event should reduce the background from BH.
- The full kinematic information should exclude the inelastic processes, which could contribute about 30% to the Cornell sample.
- The γ energy can be reconstructed with a resolution of about 1% - at least 2 times better than at Cornell.

Expected results with the dedicated setup



The "open geometry" dedicated set-up is capable of:

- Reaching the statistical accuracy of Hall D at 1% of the running time
- Detecting the proton recoil and additional tracks and photons
- In a 3-month running period use ∼5 various targets
- Search for $\chi_{c1}(1P)$ and $\eta_c(1S)$
- Search for exotic effects, like the hidden color

Detecting γA $\to J/\psi(1S)$X

Options:

- Similar to γp $\to J/\psi(1S)$p, no nucleus recoil detected
- With the option of detecting a nucleus recoil
  - Thin target $\approx$ 20mg/cm^2
  - Beam $\approx 40\mu$A
  - Low pressure chamber for detecting nuclear recoils

Summary of the options

Resolution, obtained using the $J/\psi(1S)$ mass in the fit or the tagger:

setup	$\sigma M/M$	$\sigma E_\Psi/E_\Psi$	$\sigma E_\gamma/E_\gamma$	$\sigma t(GeV/c)^2$
ECAL	0.035	0.007	0.01	0.11
HRS+MAD	0.002	0.001	0.002	0.014
Hall B,D no tag	0.010	0.004	0.001	0.03

The statistical accuracy is estimated assuming the charm cross-section as: $\frac{d\sigma}{dt} = c \cdot (1-x)^2 \cdot e^{1.1t}$, normalized that: $\sigma = 0.32$nb at E_γ=11 GeV.

process	setup	recoil	BG/sig*	days needed**
$\gamma p \rightarrow J/\psi(1S)p$				
$\rightarrow e^+e^-$	ECAL	yes	0.10	5
$\rightarrow e^+e^-, \mu^+\mu^-$	A, HRS+MAD	no	<0.02	150
$\rightarrow e^+e^-, \mu^+\mu^-$	D tag	yes	0.07	500
$\gamma p \rightarrow \Lambda_c^+ \overline{D}^0$				
$\rightarrow K^+\pi^-$	A, HRS+MAD	no	0.05	150
$\rightarrow K^+\pi^-$	D tag	yes	0.25	1200

$*$ – at about 11 GeV

$**$ – to reach at least 10% accuracy in the energy range $> thresh + 0.4$GeV

Conclusion

A program for charm studies at 12GeV JLab:

1 Measurements of $\frac{d\sigma}{dt}(E_\gamma)$ of $\mathrm{J}/\psi(1\mathrm{S})$ and open charm in the energy range from the threshold to 11GeV. This should provide a unique information on the gluon fields and correlations in proton.

2 Measurements of Ψ-Nucleon cross-section - an important parameter in heavy ion physics

3 Search for rare effects like hidden color

Experimental possibilities:

- The part 1 on $\mathrm{J}/\psi(1\mathrm{S})$ - Hall D in 2 years.
- The part 1 on open charm: Hall A (HRS+MAD) in 3-5 months
- The part 2: Hall A (limited possibilities)
- The parts 2-3: a dedicated experiment is needed. The outlines of the experiment proposed are:
  - Open geometry
  - Beam of 1μA on a 6% radiator
  - Solenoid R>80cm, 2T
  - Calorimeter: ≈1100 of 4×4cm^2 lead-glass and 1028 of 2×2cm^2 PbW crystals.
  - GEM ≈3.5m^2
  - Hodoscope ≈200 modules