SUB-THRESHOLD J/ψ PHOTOPRODUCTION
(03-008)

JLab PAC23 Meeting, January, 2003

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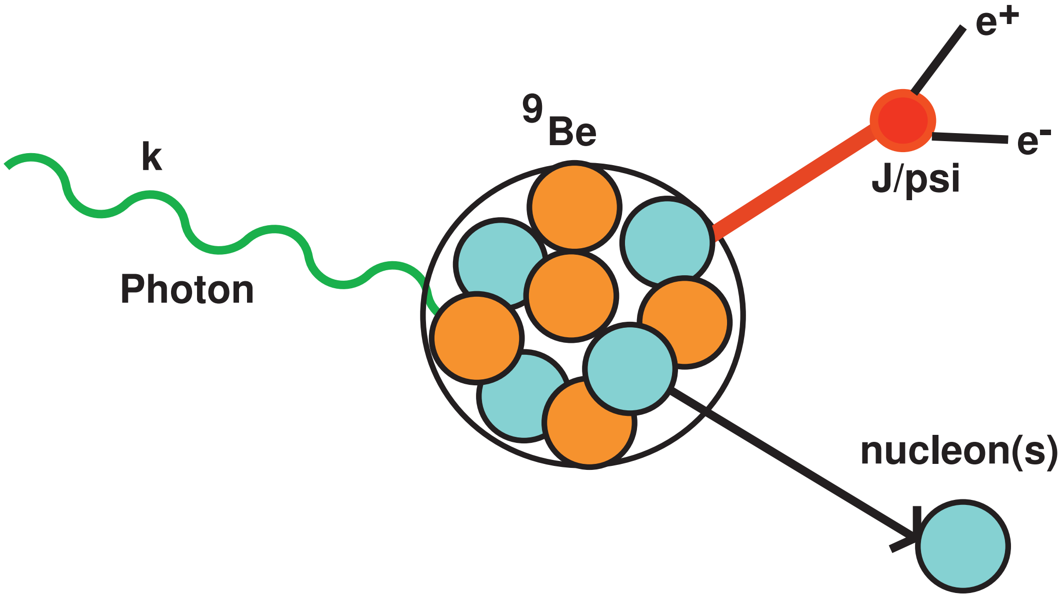
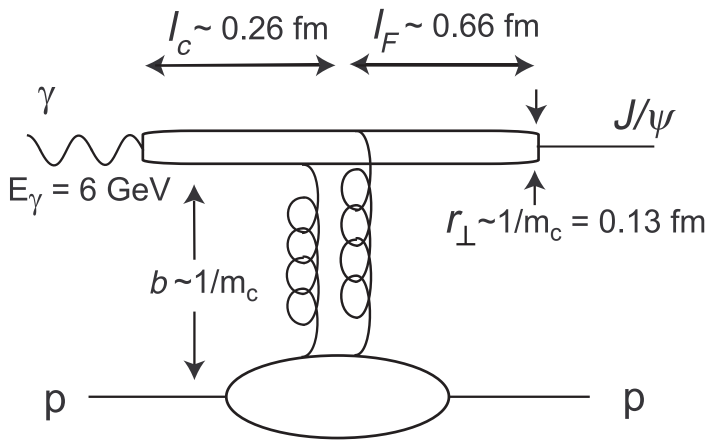
DEFINITIONS



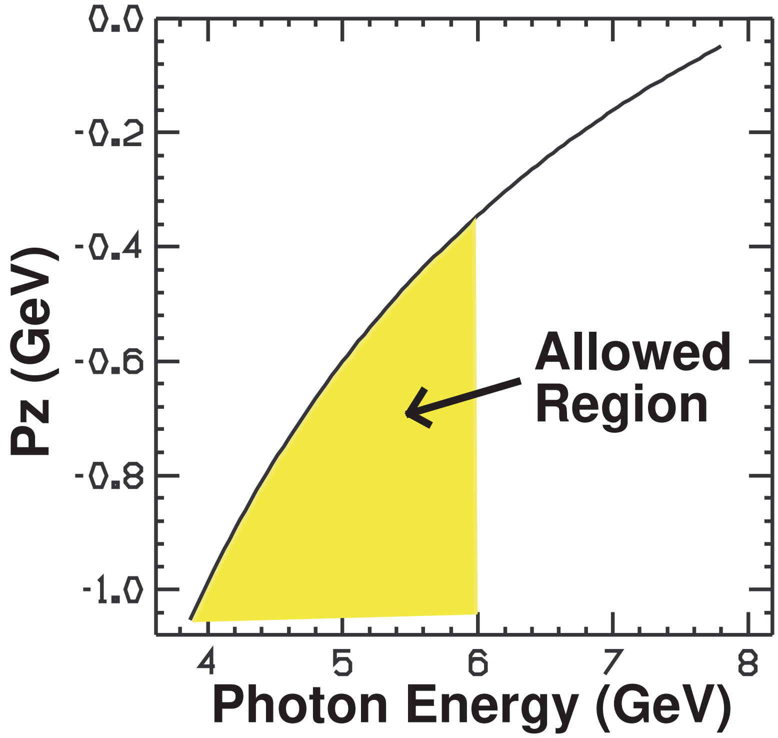
- Threshold for free nucleon is $k = 8.2$ GeV
- Threshold for ^{9}Be is 3.7 GeV
- Thus 6 GeV at JLab is sub-threshold to free nucleon
- Dominated by ^{9}Be breakup to nucleon clusters (requires $>$ 350 MeV/c momentum for bound nucleon)
- Coherent (^{9}Be remains intact) is suppressed by form factor
- Inelastic (additional mesons) is suppressed by phase space

MOTIVATION

- Study how nucleus differs from a loosely bound system of quasi-independent nucleons
- Study short range effects, including hidden color configurations, multi-nucleon correlations.
- Use heavy quarkonium
  - to ensure a hard scale ($m_c^2 > \Lambda_{QCD}^2$)
  - corresponds to small longitudinal coherence length $2k/4m_c^2 \approx 0.3$ fm and small transverse size $1/m_c = 0.13$ fm: picks out small distance scale Fock states.
  - because charm quarks are rare in nucleus so quark exchange mechanism suppressed.



WHY IS 6 GEV OPTIMAL?

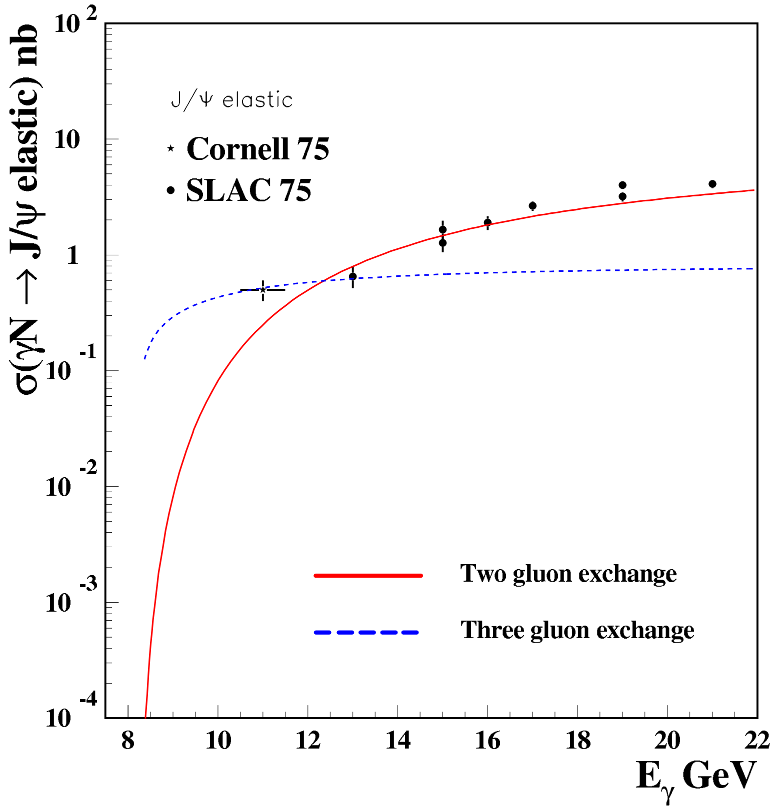


- Minimum nucleon momentum required for quasi-free production decreases with increasing photon energy.
- To emphasize region where short-range effects important, we want $-P_Z > 0.35$ GeV, or $k < 6$ GeV.
- Rates drop very rapidly to zero at threshold of 3.7 GeV, because minimum $-t_{min} \to 1.7$ GeV^2, and form factor (e^{bt}) suppresses cross section.
- Conclude that bremsstrahlung spectrum with endpoint 6 GeV is optimum for this experiment.

CONNECTION TO QGP

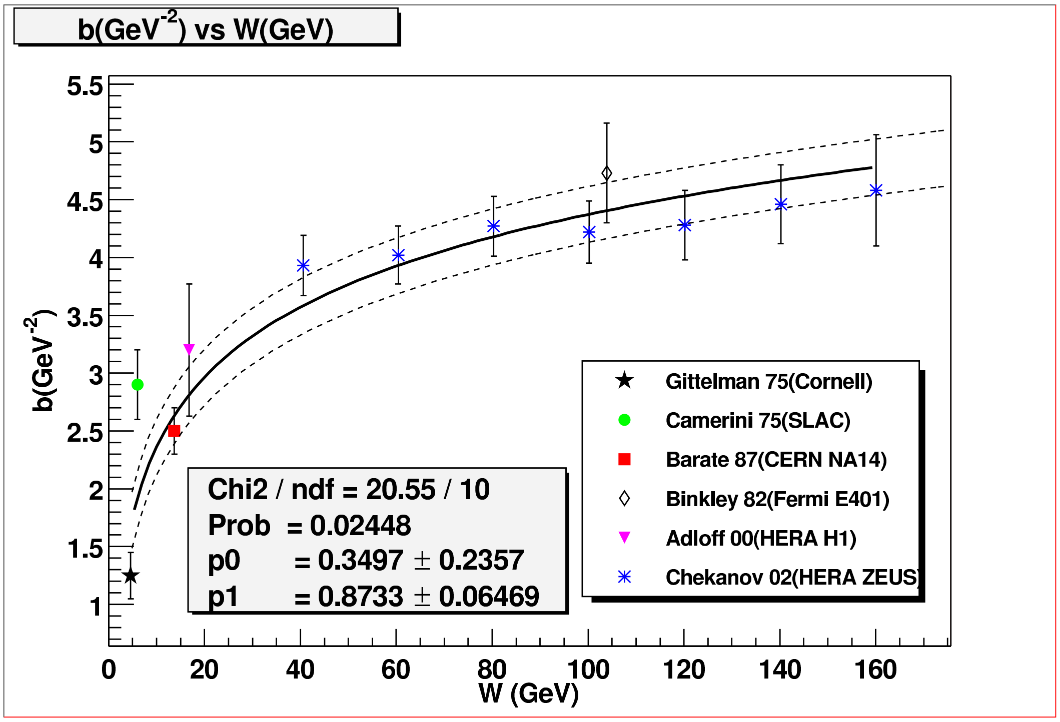
- In quark-gluon plasma search at RHIC J/ψ suppression is one of gold-plated signatures
- Need better understanding of how J/ψ produced and propagate.
- Data with simple photon probe provides test of theories
- Can distinguish between theories in which J/ψ suppression is caused by QGP or by "ordinary" nuclear physics.
- Sub-threshold kinematics ensures high local density, similar to heavy ion collisions.
- In future, use of heavier nuclei can help pin down J/ψ -nucleon cross section.

ABOVE-THRESHOLD CROSS SECTION



- Total cross section small (nb range)
- Cross section flattens out near threshold. Possible explanations are 3-gluon model of Laget, (blue curve in figure), or dipole-like form factor of Strikman.

ABOVE-THRESHOLD CROSS SECTION SLOPE



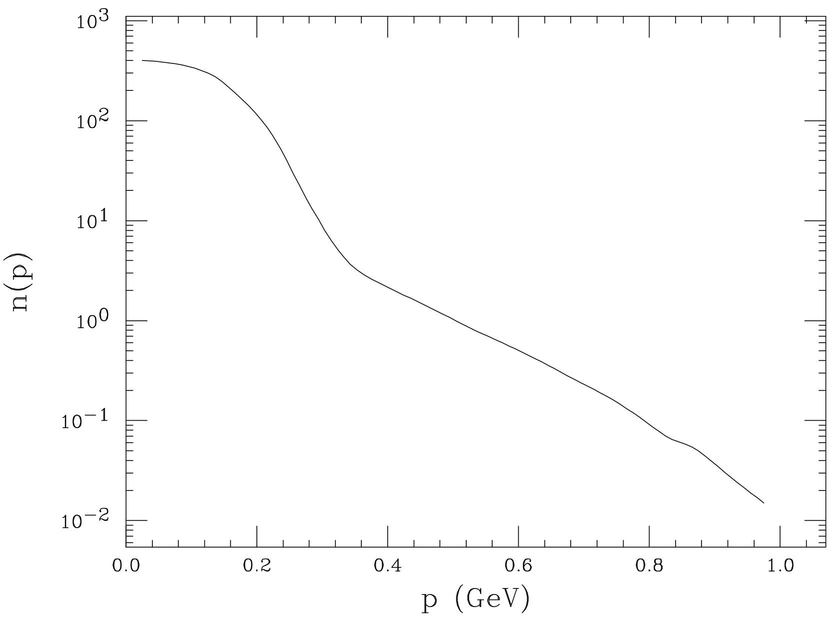
- Experiments fit data as $d\sigma/dt = Ae^{bt}$
- b rises from small values at threshold (highly localized process) to large values at high energy typical of diffractive process.

SUB-THRESHOLD CROSS SECTION ESTIMATES

- **pQCD photon-gluon calculation predicts 2 fb/nucleon at $k = 6$ GeV. This is certainly under-estimate, as same calculation lies well below above-threshold data.**
- **For rough estimates, we used simple Fermi-smearing model**

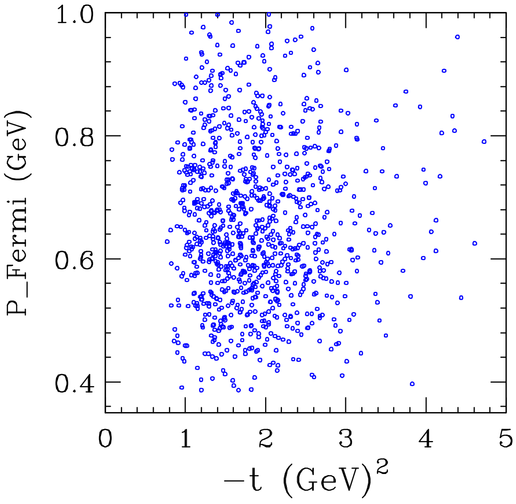
$$d\sigma = \int d\sigma_0/dt(s,t)n(p)d^3p dt \quad (1)$$

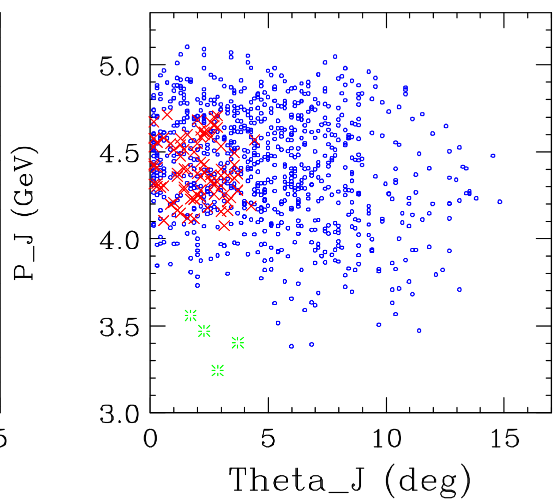
where integral limited to kinematically allowed region, $n(p)$ from $(e, e'p)$ data X. Ji and J. Engel, Phys. Rev. C40, R497 (1989)



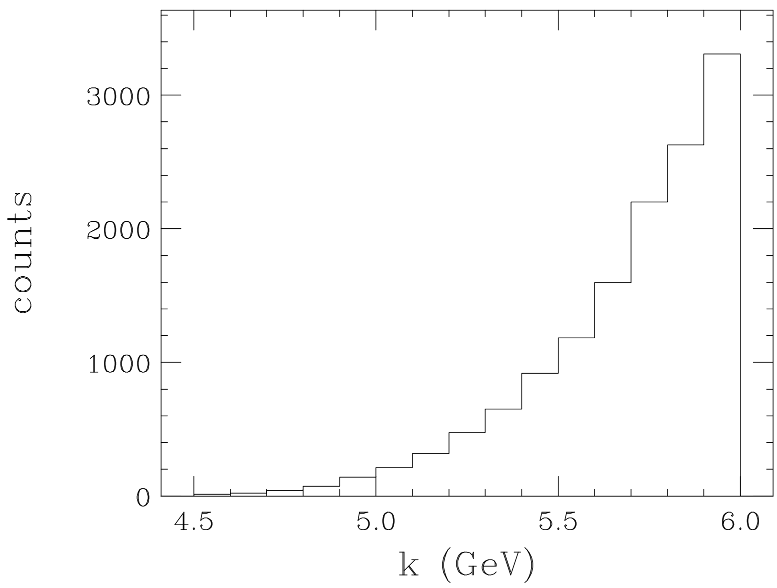
- **Integrated over photon energy k using $1/k$ distribution**
- **Using Cornell fit $d\sigma_0/dt = 1.01e^{1.25t}$ nb/GeV^2, find about 2 pb/nucleon.**
- **Different fits to Cornell data, and different treatments of off-shell effects, result in factors 2 to 4 lower estimates. Will be refined in future.**
- **Estimate from** S.J. Brodsky, E. Chudakov, P. Hoyer, and J.M. Laget, Phys. Lett. B498, 23 (2001) **is possible order of magnitude enhancement due to short range and hidden color effects (or up to 20 pb/nucleon).**

KINEMATICS, RATES





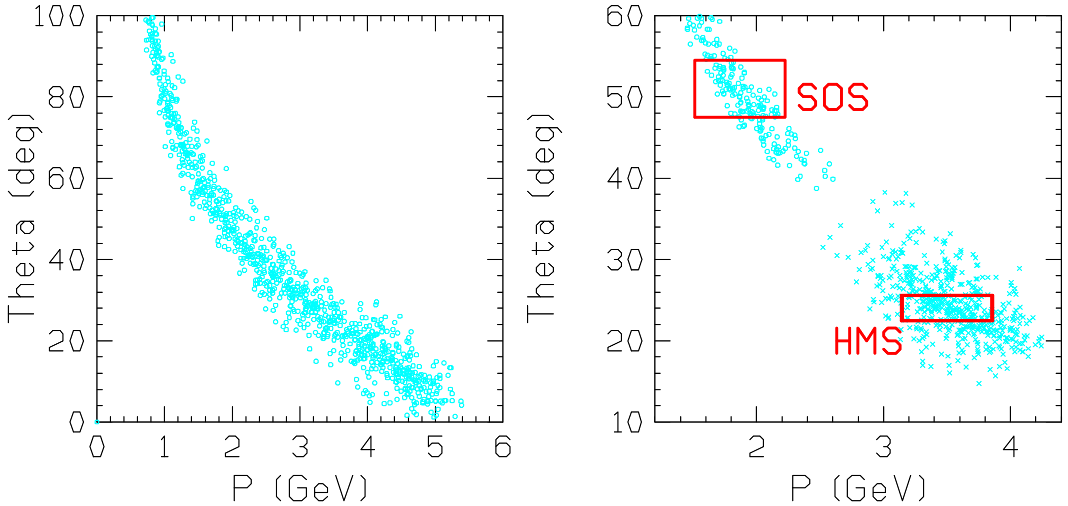
- Large values of z-component of nucleon momentum P_z and momentum transfer $-t$ are probed.
- Typical J/ψ momenta 4 to 5 GeV, typical angles $< 5°$.
- Cross section rise rapidly with k.



EXPERIMENTAL PLAN

- Identify J/ψ from 6% B.R. to each of e^+e^- and $\mu^+\mu^-$
- Since rate and backgrounds uncertain, need good resolution (hence spectrometers) to ensure that J/ψ mass peak is visible above backgrounds.
- Hall C spectrometers factor two more acceptance than Hall A.
- Use 6 GeV, 60 μA electron beam passing through narrow 6.3 gm/cm^2 (3.4 cm, 0.1 r.l.) Be target to generate maximum flux of photons and maximum luminosity.
  Be is both radiator and target (effectively 0.10/2+0.03=0.08 r.l.).
- Could possibly run higher current if additional shielding to reduce radiation.
- Two spectrometer settings to study P_J $(-t)$ dependence (constrains free nucleon fit).

SPECTROMETER SETTINGS



- **Left panel shows all generated lepton pairs.**
- **Right pair shows high J/ψ momentum setting for SOS and HMS acceptance: circles (crosses) are partners of leptons in HMS (SOS).**
- **SOS and HMS settings shifted slightly for low momentum (higher $-t$) J/ψ particles.**

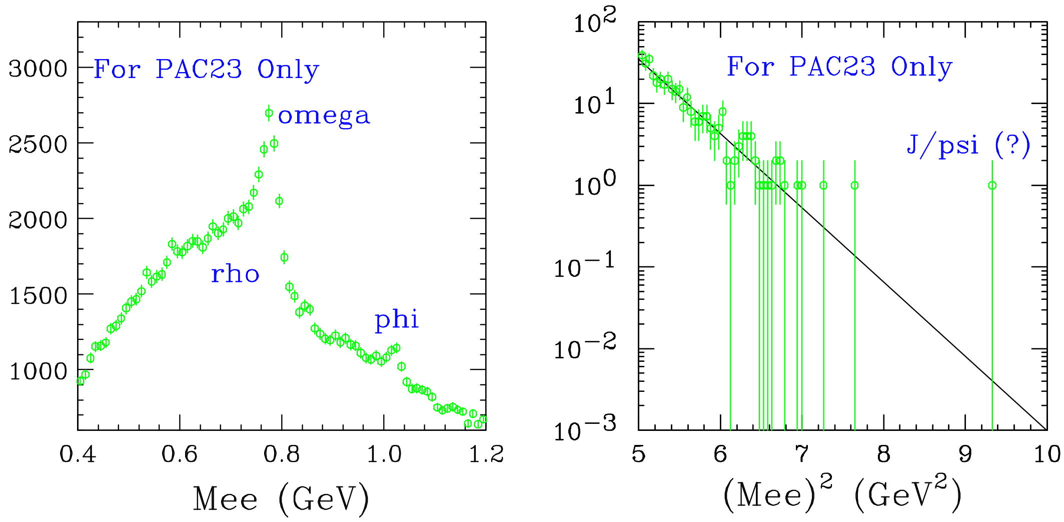
DETECTORS

- Electron pairs use standard SOS, HMS detectors. Expect negligible contamination from $(\pi^+\pi^-)$ or $(e^-\pi^+)$.
- Muons in HMS mainly identified by setting gas Cherenkov threshold to fire for muons, but not pions.
- Muons identified in both SOS and HMS by minimum ionizing signal in all 4 layers of lead glass.
- Additional muon identification from adding scintillator panels behind SOS and HMS lead glass arrays.
- Overall for muons, expect factor 200 rejection of (π^+, π^-) events. Dominated by case where both pions decay to muons before detectors.

COUNT RATES

- In simple Fermi smearing model, expect 25 to 100 counts at high P_J setting in 4 days , 2 to 10 counts at low P_J setting in 3 days.
- If short range effects enhance cross section, could have up to 1000 counts at high P_J, 100 at low P_J.
- Pre-preliminary data from CLAS indicate that even higher rates are unlikely.
- Observation of high rates ($>$ 200 counts at high P_J setting) would be a clear signature of the importance of short range effects, even given present uncertainties in simple Fermi-smearing model. Approval of experiment will spur more sophisticated predictions.

BACKGROUNDS



- **Based on CLAS data (above) and 10x better mass resolution, expect < 0.2 count/day in (e, e) spectrum at J/ψ peak.**
- **Note ω (e^+e^- BR 4.5×10^{-5}) and ϕ (e^+e^- BR 7×10^{-5}) peaks clearly visible, in spite of using electron rather than pure photon beam.**
- **Based on CLAS data, $\pi^+\pi^-$ coincidences about factor 1000 higher than e^+e^- for $M > 2$ GeV. With factor 1000 rejection, expect of order < 0.2 count/day background in $\mu^+\mu^-$ channel.**
- **Accidental rates calculated < 0.01 counts/day for both e^+e^- and $\mu^+\mu^-$**

EXPERIMENTAL PARAMETER SUMMARY

Beam energy	**6 GeV**
Running time	**7 days**
Beam Current	**60 μA**
Target	**3.4 cm Be**
SOS setting I (4 days)	**1.78 GeV, 52.4°**
SOS setting II (3 days)	**1.78 GeV, 56°**
HMS setting I (4 days)	**3.60 GeV, 23°**
HMS setting II (3 days)	**2.82 GeV, 31.5°**
SOS singles rate	**1 kHz**
HMS singles rate	**1 kHz**

COLLABORATION

- **Experienced Hall C users**
- **Experts in all detectors, target**
- **Strong theory support**
- **Large overlap with SLAC E160**

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SUMMARY

- Will be first observation of charm at JLab
- High resolution spectrometers to ensure signal will be seen
- Short, exploratory measurement, sensitive to short range effects in nuclei
- Present JLab energy 6 GeV ideal for this experiment.
- Surprises possible : little known at present. Whatever we find will be both interesting and relevant for fields such the quark-gluon plasma search.