Plans to measure J/ψ photoproduction on the proton with CLAS12

Pawel Nadel-Turonski

Jefferson Lab

Nuclear Photoproduction with GlueX,
April 28-29, 2016, JLab

Outline

Introduction

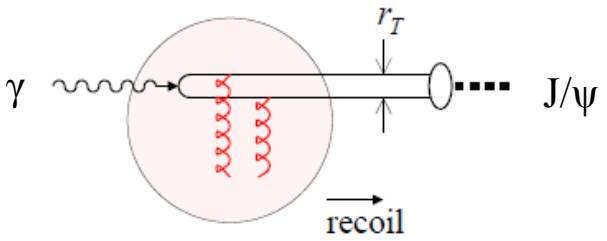
J/ψ on the proton in CLAS12

Opportunities for nuclear targets

Charmonium is a probe of the nucleon's color field

At high Q^2 $c\bar{c}$ is produced in small-size configurations

- *c.f.* color transparency
- Local probe of color field



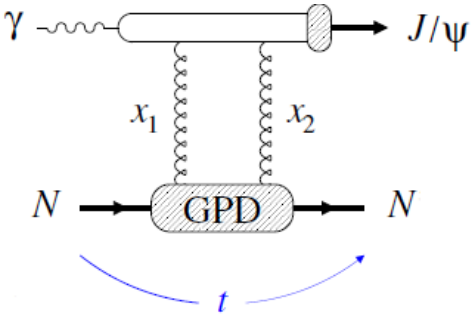
J/ψ photoproduction

- Probes distances $\approx 1/\sqrt{Q^2 + M_{J/\psi}^2} \approx 1/M_{J/\psi}$
- J/ψ radius still smaller than nucleon: $r_{J/\psi} \sim 0.2 - 0.3$ fm $<< 1$ fm

J/ψ production at high vs. low W (= √s)

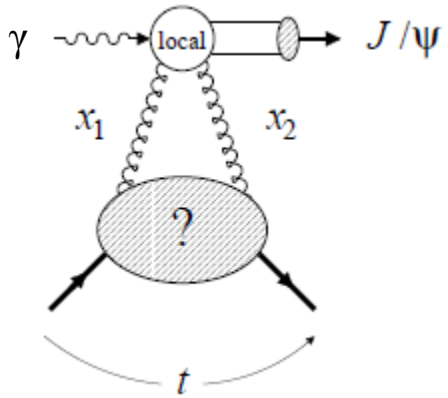
J/ψ production at high W

- Access to nucleon's gluon GPD at small x
  - t_{min} and ζ small, well understood diffractive process
  - Measurements at EIC, HERA, COMPASS, FNAL



J/ψ production near threshold

- t_{min} and ζ large, implies large skewness x_1 - x_2
- Natural interpretation in terms of a gluonic form factor sensitive to non-perturbative gluon field
  - analogous to high-t elastic eN scattering
- Amplitude constant, but cross section near threshold suppressed by large t_{min}

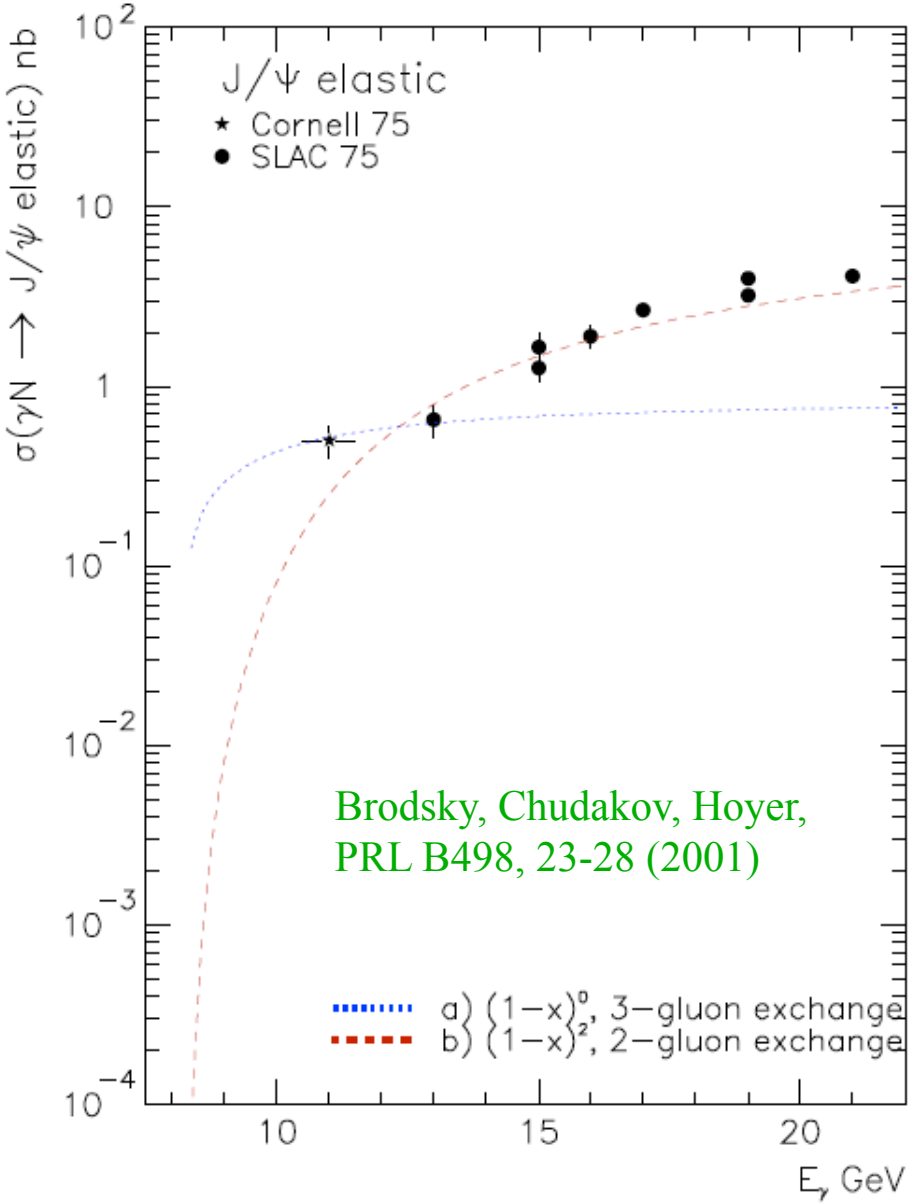


$$A(\gamma + p \to J/\psi + p) \propto F_{2g}(t)$$

gluonic form factor

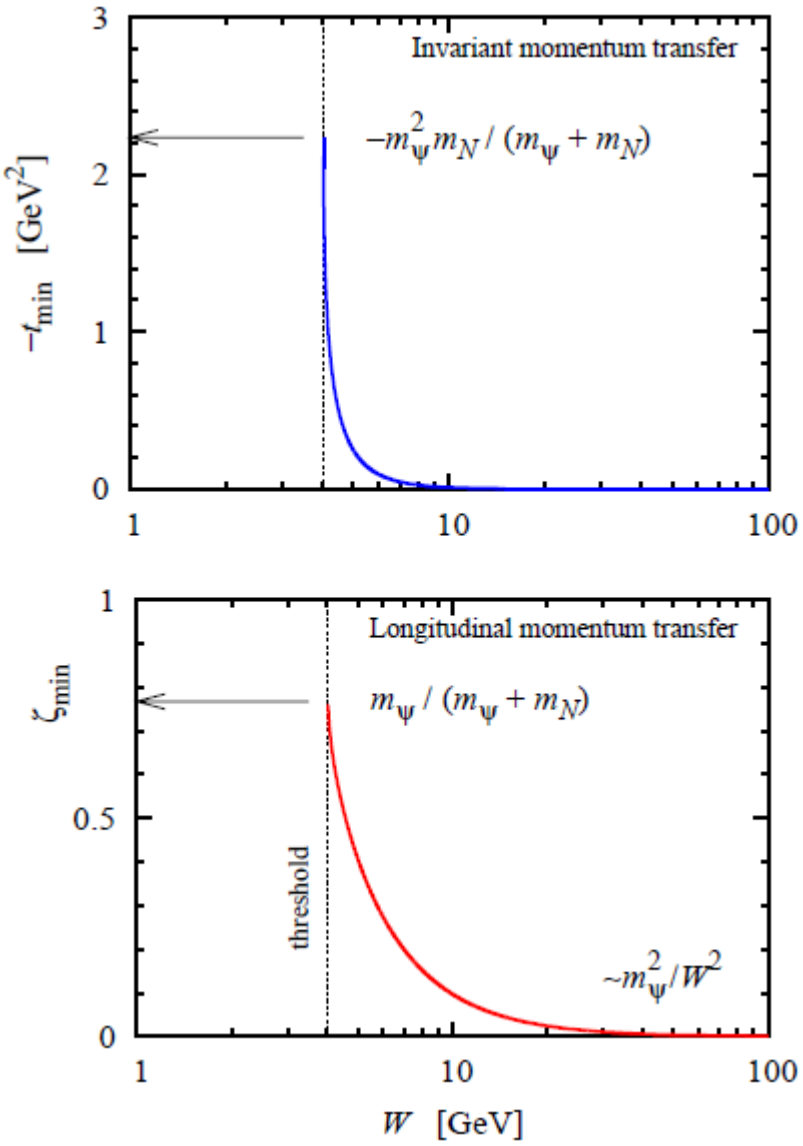
Weiss, Strikman

Enhancement instead of suppression near threshold?



- But should we expect an enhancement instead, despite the impact of a large t_{min}?
- Need theory input for interpretation of data, which will soon be here!
- Also need theory predictions for nuclear targets (both coherent and incoherent case)

Exclusive J/ψ kinematics near threshold



Four-momentum transfer to the nucleon

$$t = -(\zeta^2 m_N^2 + \Delta_T^2)/(1-\zeta)$$

- ζ is the „plus“ momentum transfer
  - light cone variables
- Δ_T is the transverse momentum transfer
- t_{min} at threshold is 2.2 GeV^2

C. Weiss, Non-perturbative forces in QCD, Temple U., 26-28 March 2012

Approved CLAS12 experiments

Proposal	Physics	Contact	Rating	Days	Group	New equipment	Energy	Run Group	Target
E12-06-108	Hard exclusive electro-production of π^0, η	Stoler	B	80	139	RICH (1 sector) Forward tagger	11	A F. Sabatié	liquid H_2
E12-06-112	Proton's quark dynamics in SIDIS pion production	Avakian	A	60					
E12-06-119	Deeply Virtual Compton Scattering	Sabatie	A	80					
E12-09-003	Excitation of nucleon resonances at high Q^2	Gothe	B+	40					
E12-11-005	Hadron spectroscopy with forward tagger	Battaglieri	A-	119					
E12-12-001	Timelike Compton Scatt. & J/ψ production in e+e-	Nadel-Turonski	A-	120					
E12-12-007	Exclusive φ meson electroproduction with CLAS12	Stoler, Weiss	B+	60					
PR12-12-008	Photoproduction of the very strangest baryon	Guo	--	80					
E12-07-104	Neutron magnetic form factor	Gilfoyle	A-	30	90	Neutron detector RICH (1 sector) Forward tagger	11	B K. Hafidi	liquid D_2 target
PR12-11-109 (a)	Dihadron DIS production	Avakian	-	-					
E12-09-007a	Study of partonic distributions in SIDIS kaon production	Hafidi	A-	56					
E12-09-008	Boer-Mulders asymmetry in K SIDIS w/ H and D targets	Contalbrigo	A-	TBA					
E12-11-003	DVCS on neutron target	Niccolai	A	90					
E12-06-109	Longitudinal Spin Structure of the Nucleon	Kuhn	A	80	170	Polarized target RICH (1 sector) Forward tagger	11	C S. Kuhn	NH_3 ND_3
E12-06- 119(b)	DVCS on longitudinally polarized proton target	Sabatie	A	120					
E12-07-107	Spin-Orbit Correl. with Longitudinally polarized target	Avakian	A-	103					
PR12-11-109 (b)	Dihadron studies on long. polarized target	Avakian	-	-					
E12-09-007(b)	Study of partonic distributions using SIDIS K production	Hafidi	A-	110					
E12-09-009	Spin-Orbit correlations in K production w/ pol. targets	Avakian	B+	103					
E12-06-106	Color transparency in exclusive vector meson production	Hafidi	B+	60	60		11	D	Nuclear
E12-06-117	Quark propagation and hadron formation	Brooks	A-	60	60		11	E	Nuclear
E12-10-102	Free Neutron structure at large x	Buetlman	A	40	40	Radial TPC	11	F	Gas D_2
TOTAL approved run time (PAC days)				1491	559				

E12-12-001

Approved for 100 PAC days as part of Run Group A, plus an additional 20 days with reverse torus polarity

Jefferson Lab PAC 39 Proposal

Timelike Compton Scattering and J/ψ photoproduction on the proton in e^+e^- pair production with CLAS12 at 11 GeV

I. Albayrak,[1] V. Burkert,[2] E. Chudakov,[2] N. Dashyan,[3] C. Desnault,[4] N. Gevorgyan,[3] Y. Ghandilyan,[3] B. Guegan,[4] M. Guidal*,[4] V. Guzey,[2,5] K. Hicks,[6] T. Horn*,[1] C. Hyde,[7] Y. Ilieva,[8] H.-S. Jo,[4] P. Khetarpal,[9] F.J. Klein,[1] V. Kubarovsky,[2] A. Marti,[4] C. Munoz Camacho,[4] P. Nadel-Turonski*†,[2] S. Niccolai,[4] R. Paremuzyan*,[4,3] B. Pire,[10] F. Sabatié,[11] C. Salgado,[12] P. Schweitzer,[13] A. Simonyan,[3] D. Sokhan,[4] S. Stepanyan*,[2] L. Szymanowski,[14] H. Voskanyan,[3] E. Voutier,[15] J. Wagner,[14] C. Weiss,[2] N. Zachariou,[8] and the CLAS Collaboration.

[1] *Catholic University of America, Washington, D.C. 20064*

[2] *Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23606*

[3] *Yerevan Physics Institute, 375036 Yerevan, Armenia*

[4] *Institut de Physique Nucleaire d'Orsay, IN2P3, BP 1, 91406 Orsay, France*

[5] *Hampton University, Hampton, Virginia 23668*

[6] *Ohio University, Athens, Ohio 45701*

[7] *Old Dominion University, Norfolk, Virginia 23529*

[8] *University of South Carolina, Columbia, South Carolina 29208*

[9] *Florida International University, Miami, Florida 33199*

[10] *CPhT, École Polytechnique, 91128 Palaiseau, France*

[11] *CEA, Centre de Saclay, Irfu/Service de Physique Nucléaire, 91191 Gif-sur-Yvette, France*

[12] *Norfolk State University, Norfolk, Virginia 23504*

[13] *University of Connecticut, Storrs, Connecticut 06269*

[14] *National Center for Nuclear Research (NCBJ), Warsaw, Poland*

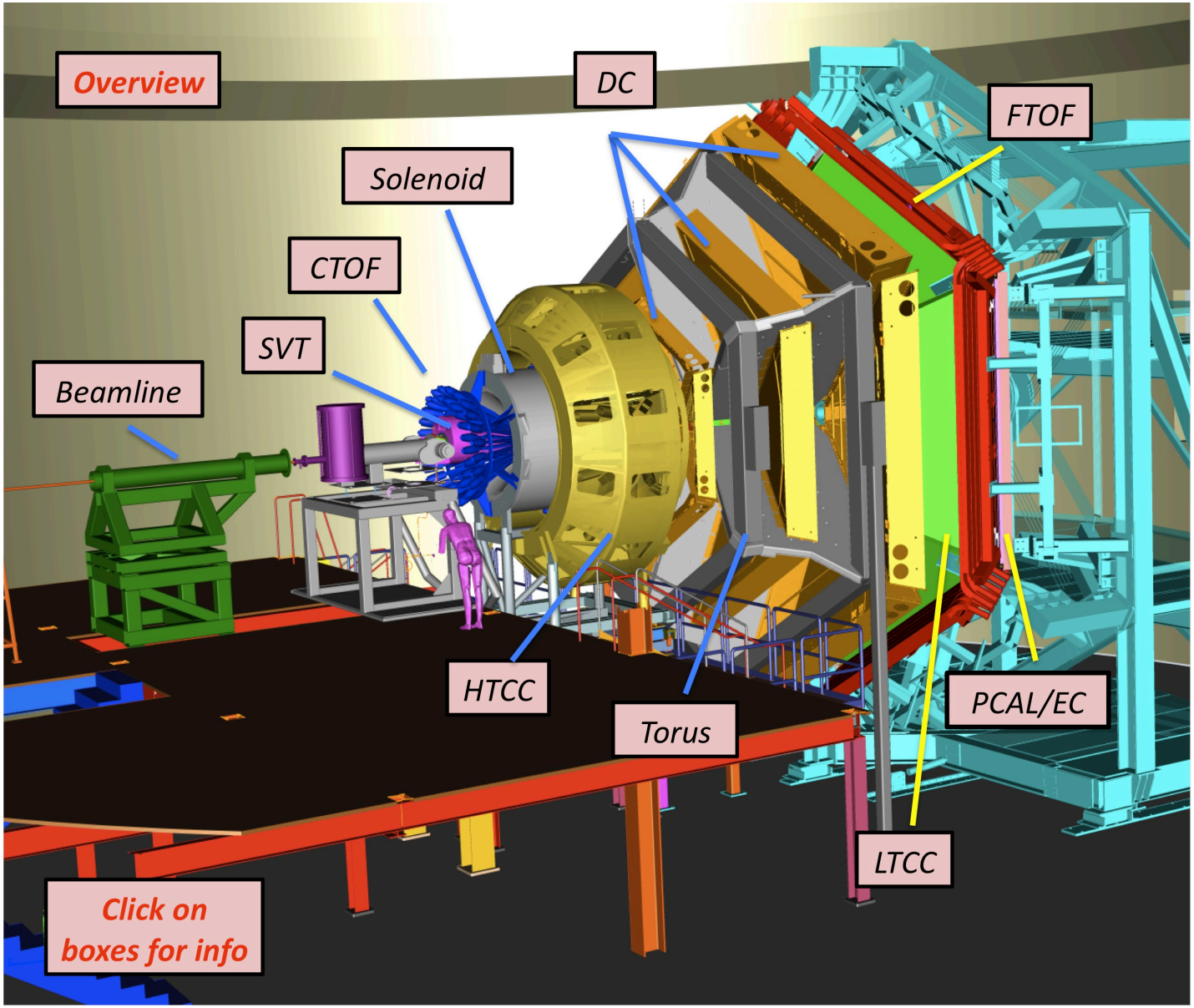
[15] *LPSC Grenoble, 38000 Grenoble, France*

(Dated: May 4, 2012)

*Co-spokesperson

†Contact person: turonski@jlab.org

The CLAS12 detector



The CLAS12 detector

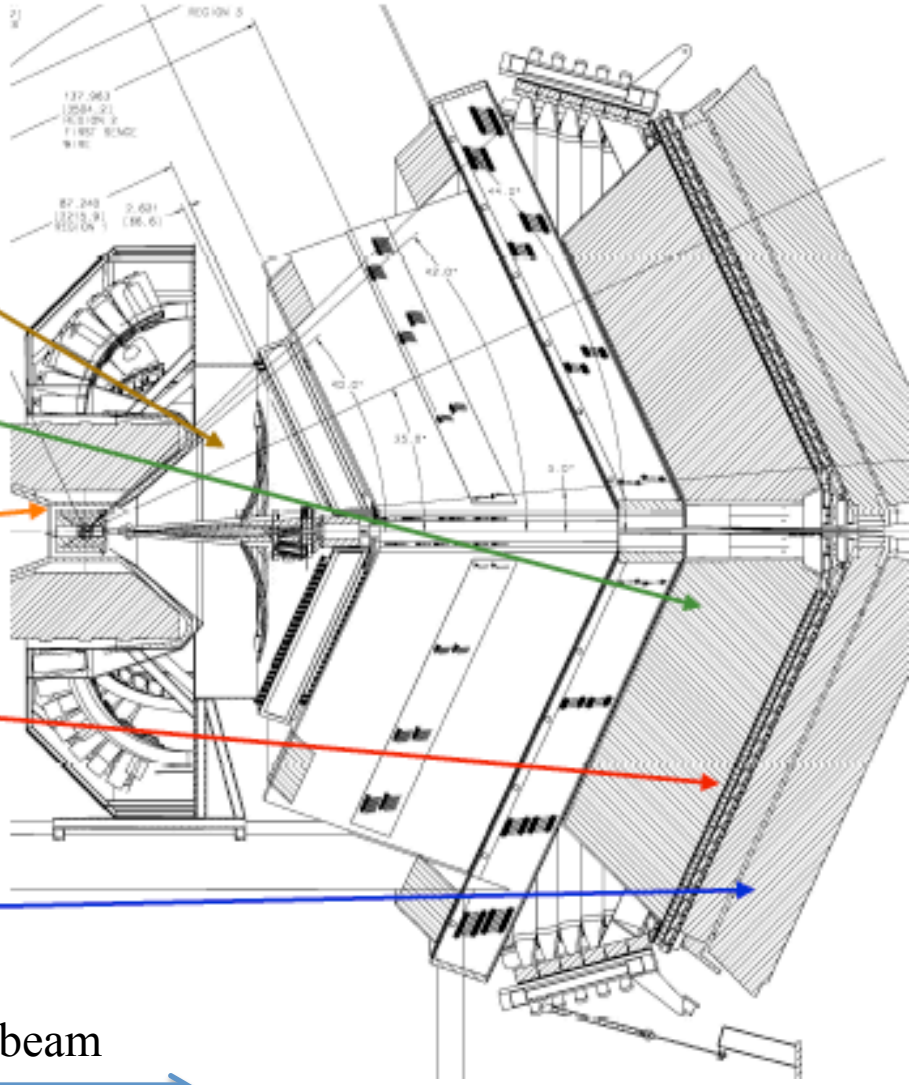
High Threshold Cherenkov Counter (HTCC) for e/π separation, $P_{th}^{\pi} > 4.7\ GeV/c$

Low Threshold Cherenkov Counter (LTCC) for e/π separation, $P_{th}^{\pi} > 2.7\ GeV/c$

Scintillator counters (cTOF) @ 50 cm from the target, time resolution of 60ps

Scintillator counters (fTOF) @ ~650cm from the target, time resolution of 80ps

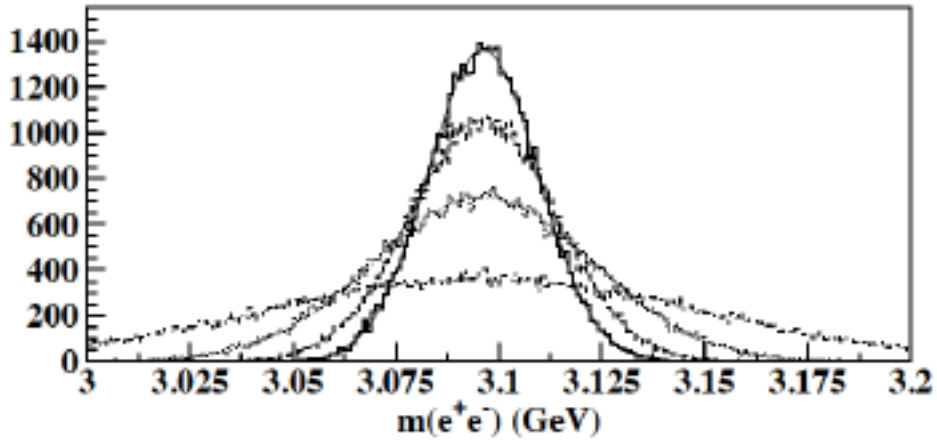
Electromagnetic calorimeters (PCAL&EC), 54 layers of lead and scintillators, 22 r.l.

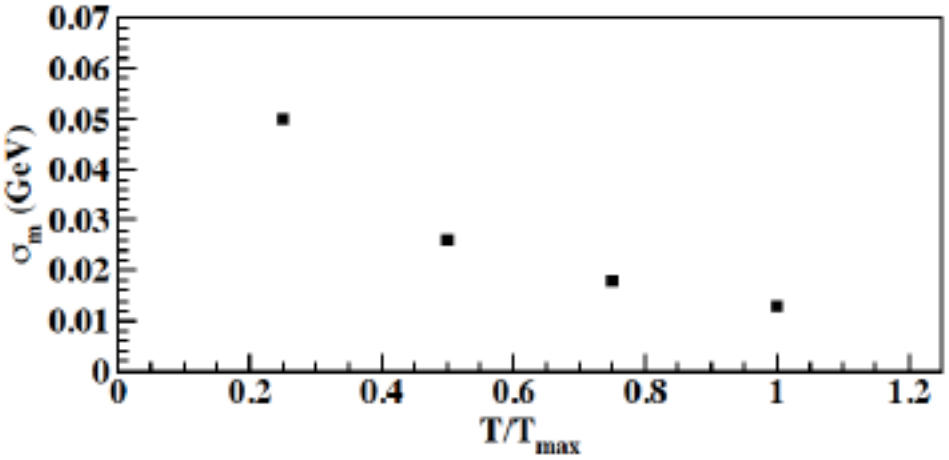


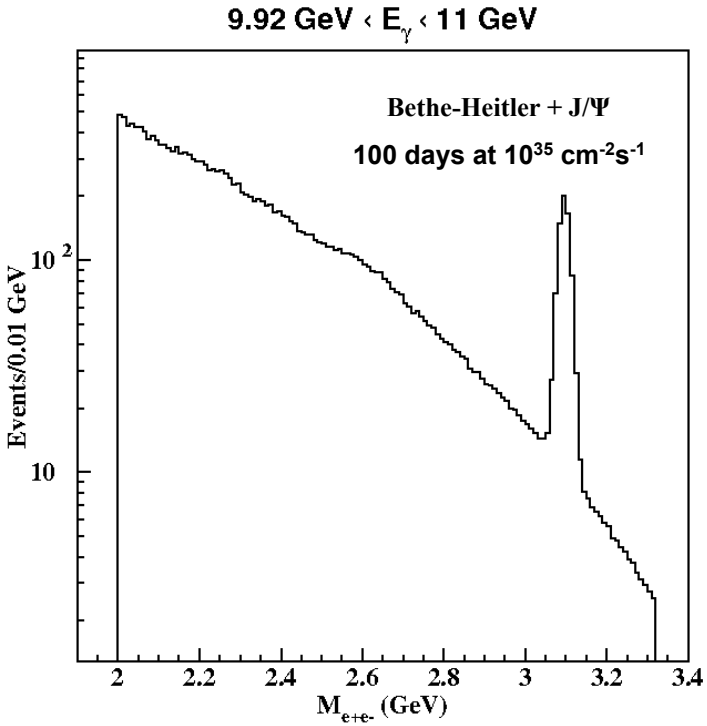
CLAS12 parameters (at max torus field)

Parameters	Forward Detector	Central Detector
Charged tracks:		
polar angular range (θ)	5° to 35°	35° to 125°
resolution:		
polar angle ($\delta\theta$)	< 1 mr	< 10 mr to 20 mr
azimuthal angle ($\delta\phi$)	< 4 mr	< 5 mr
momentum (δp/p)	$< 1\%$ at 5 GeV/c	$< 5\%$ at 1.5 GeV/c
Neutral particles:		
angular range (θ)	5° to 40°	40° to 125° (neutrons)
angular resolution ($\delta\theta$)	< 4 mr	< 10 mr
Energy resolution	$< 0.1/\sqrt{(E)}$	$< 5\%$
PID:		
e/π	full momentum range	NA
π/p	full momentum range	< 1.25 GeV/c
K/π	< 3 GeV/c	< 0.65 GeV/c
K/p	< 4 GeV/c	< 1 GeV/c

J/ψ mass resolution in CLAS12



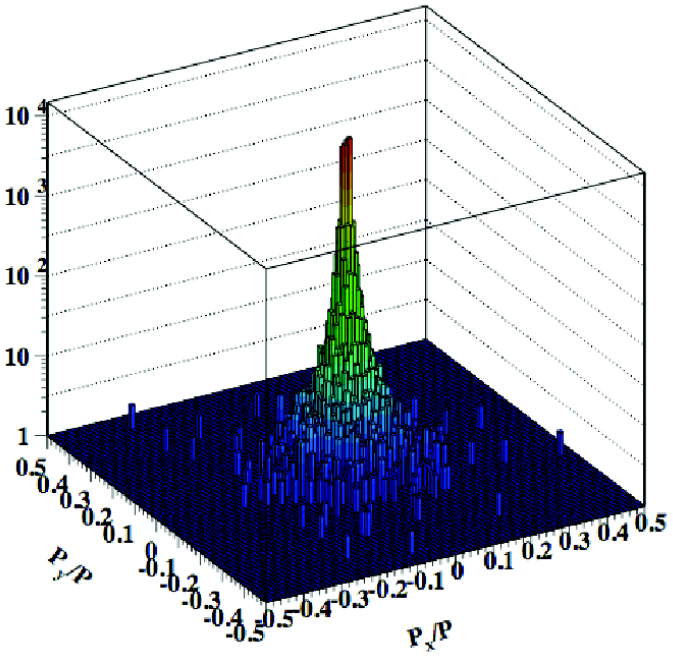


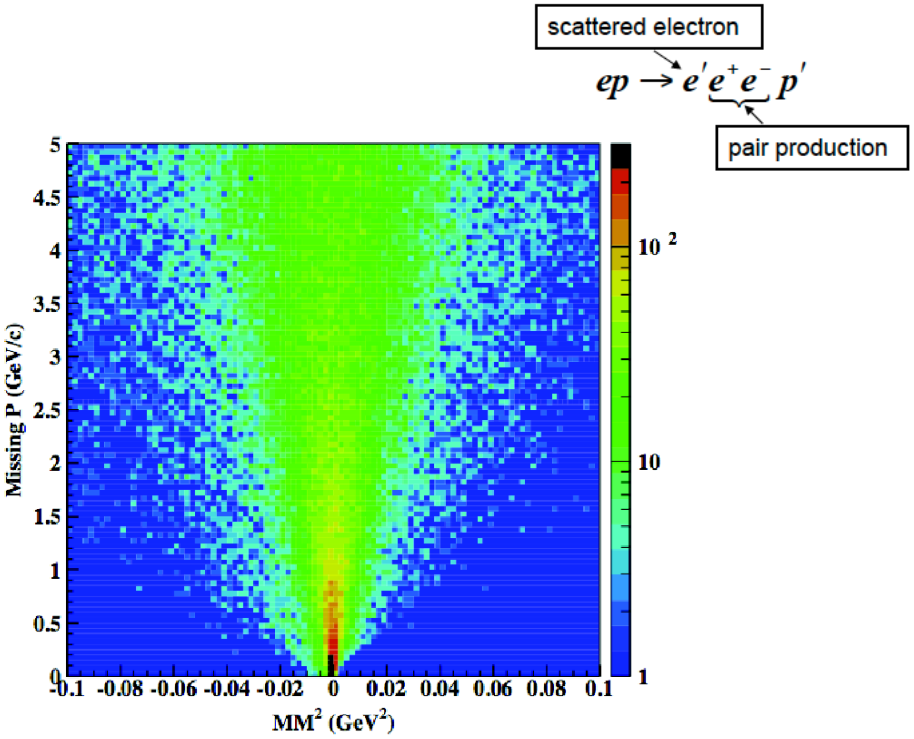


- J/ψ + Bethe-Heitler at max field

- The CLAS12 resolution is good for J/ψ for fields at half field or above.

Exclusive quasi-real photoproduction in CLAS12

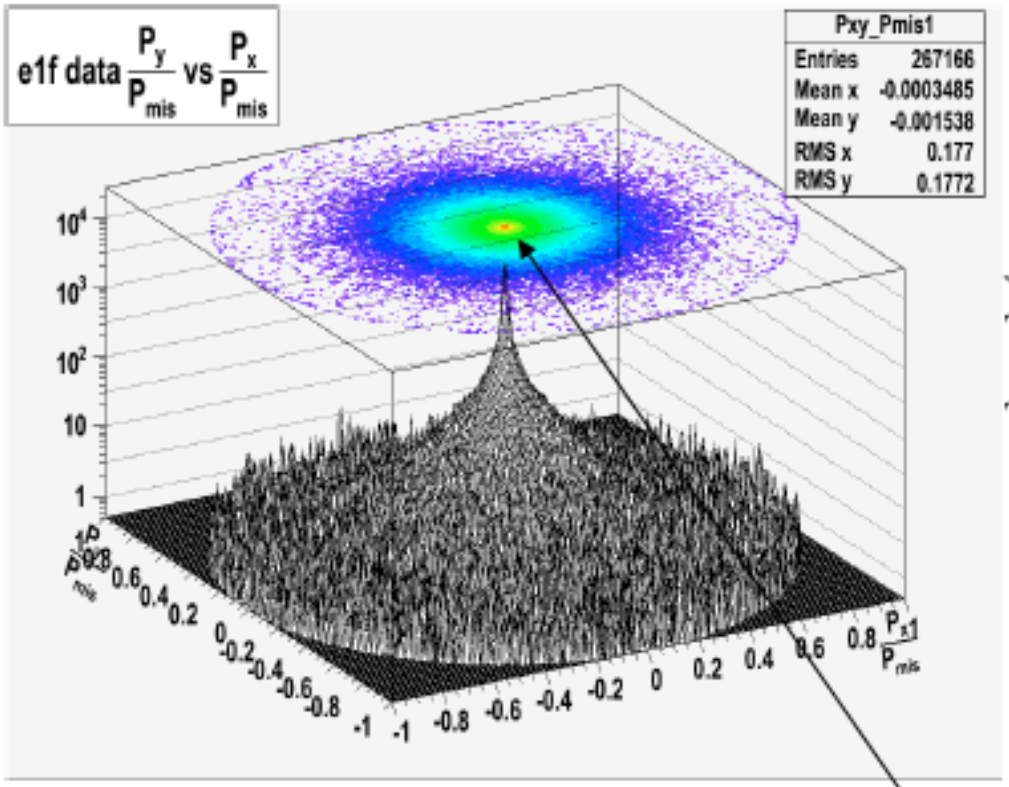


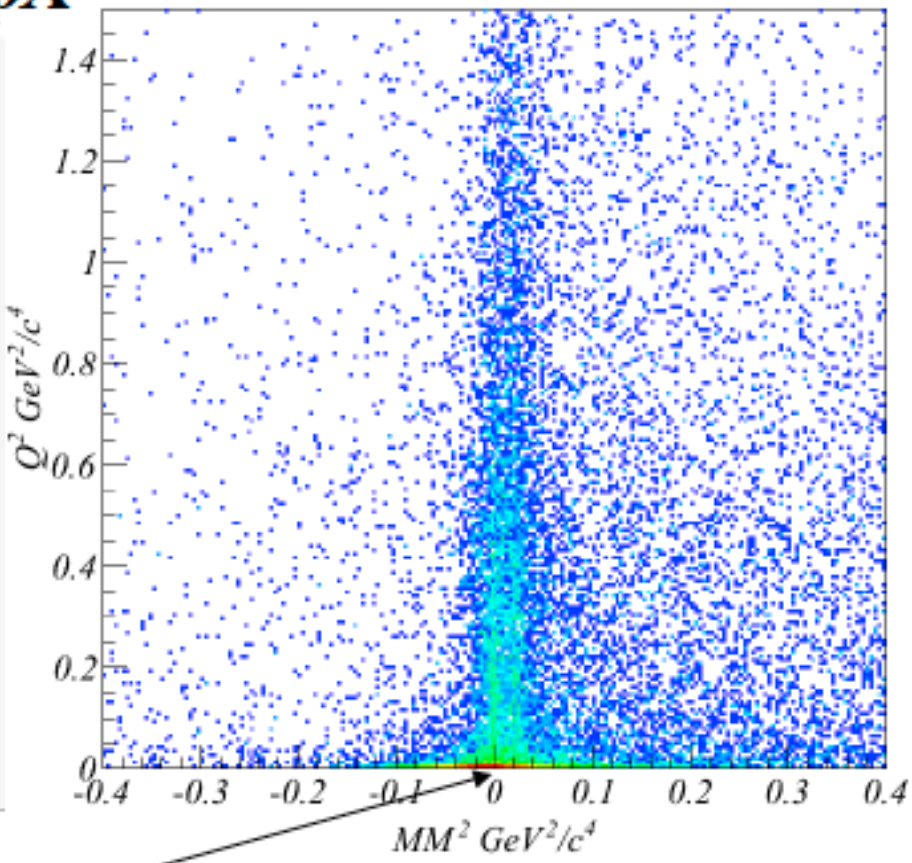


- Low-Q^2 events are reconstructed by applying cuts on the transverse momentum of the missing beam electron.
- Exclusivity is ensured by detection of all produced final-state particles, and application of an additional missing mass cut.

Exclusive quasi-real photoproduction in CLAS (data)

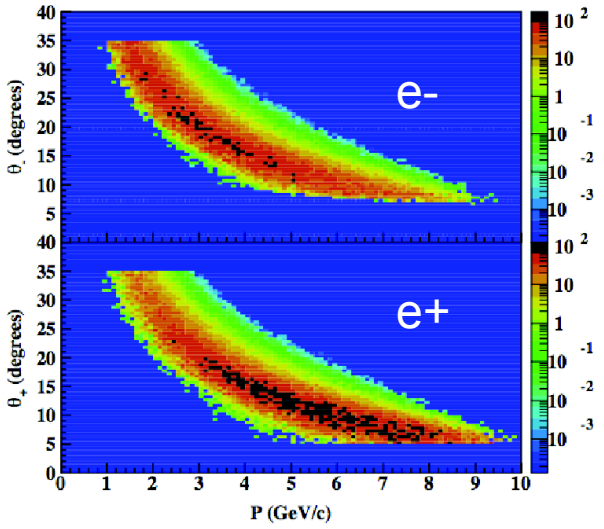
$$ep \rightarrow e^+e^-pX$$

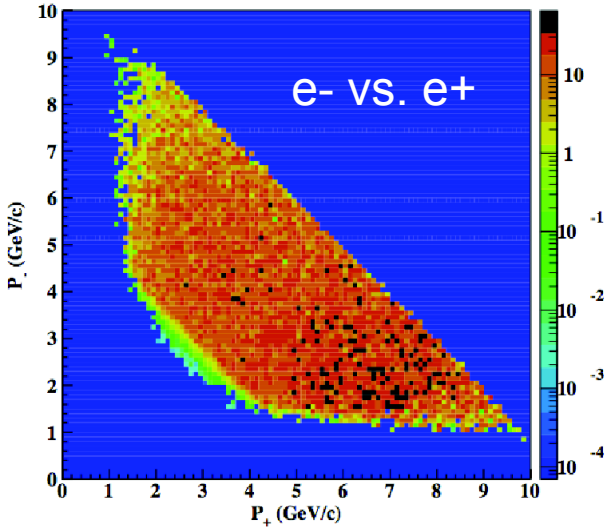


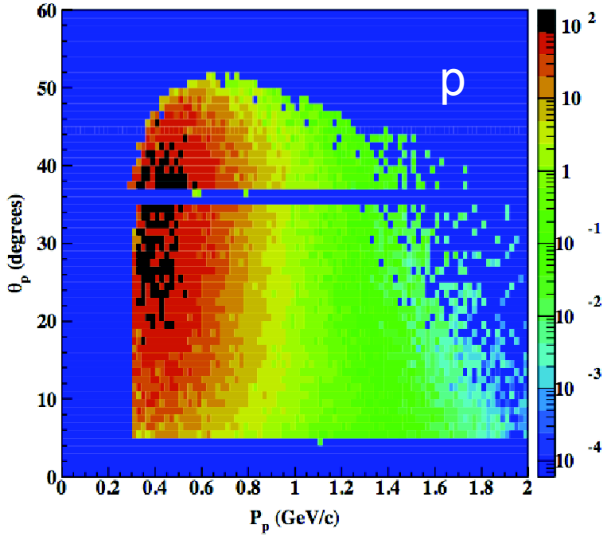


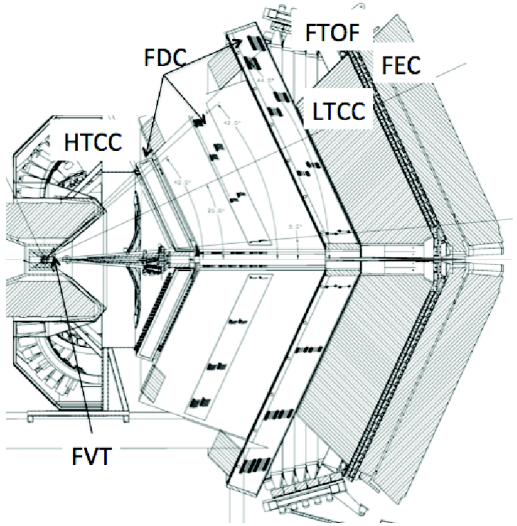
X – is identified as an electron scattered at 0 degrees, Q^2<0.01 (GeV/c)^2 and $|M_X^2|$<0.1 (GeV)^2

Detection of the exclusive final state in CLAS12



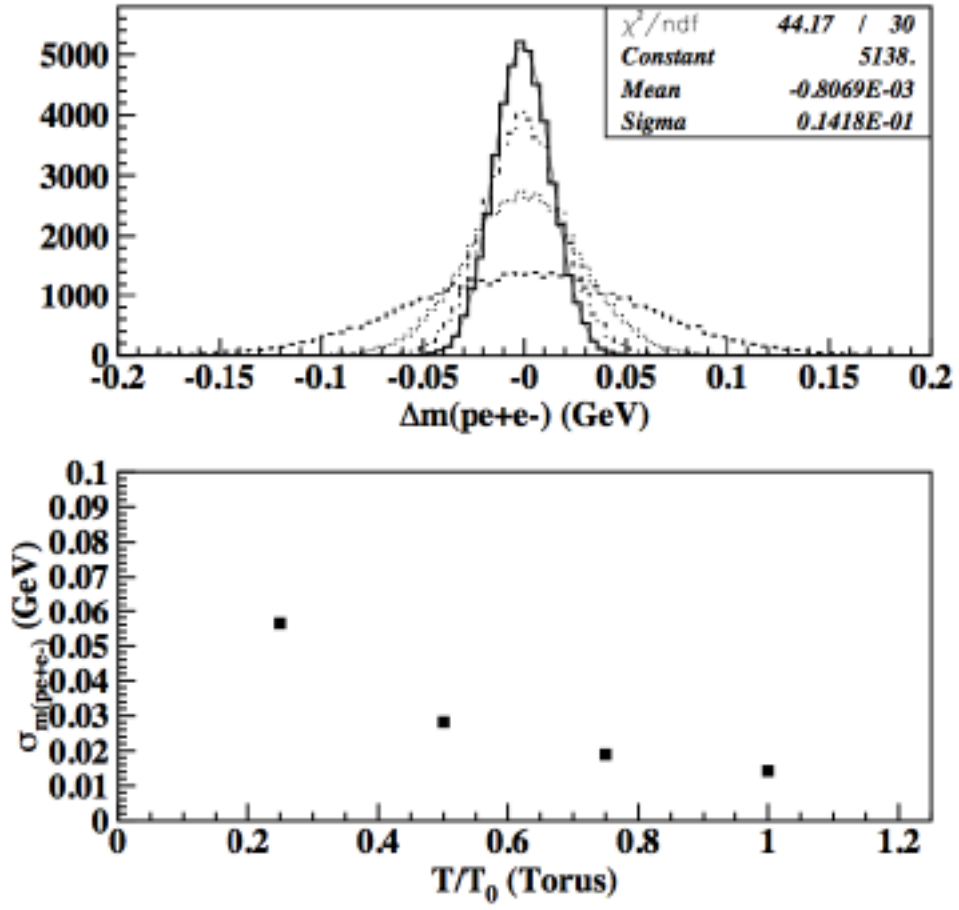






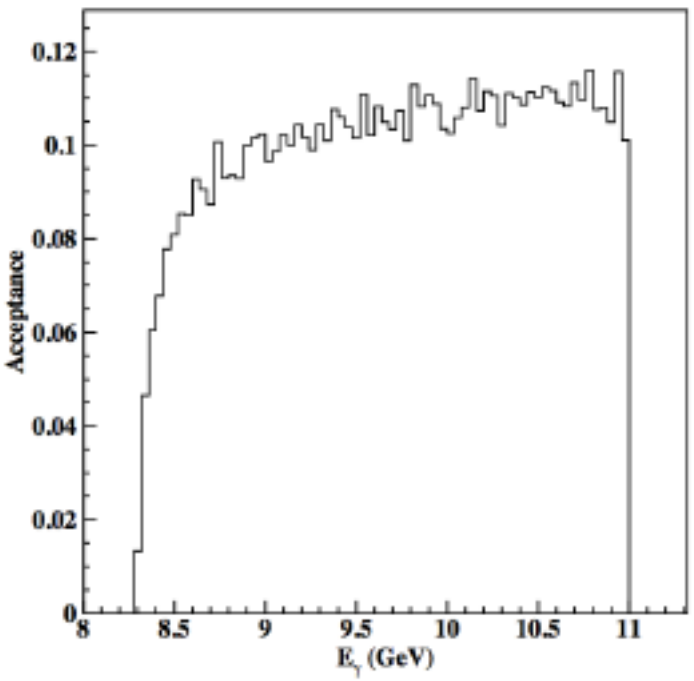
- The leptons pairs are detected and identified using the High-Threshold Cherenkov Counter (HTCC) and the Forward Electromagnetic Calorimeter (FEC).
- Pairs with one lepton below the HTCC pion threshold of 4.9 GeV/c will have a pion pair rejection factor of $2 \cdot 10^7$.
- Proton kinematics and acceptance are shown on the right.

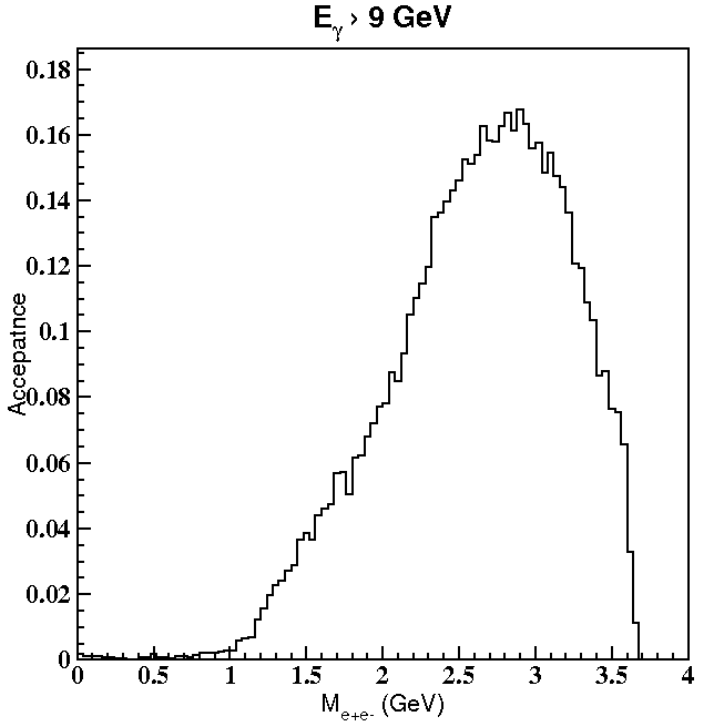
CLAS12 mass resolution as a function of the torus field



- Mass resolution of the detected "p-J/ψ" system

CLAS12 acceptance for pe^+e^-



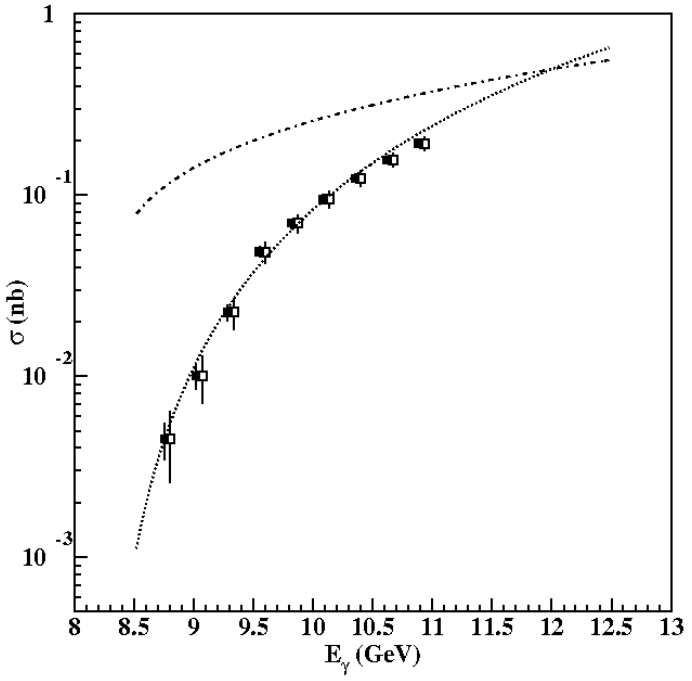


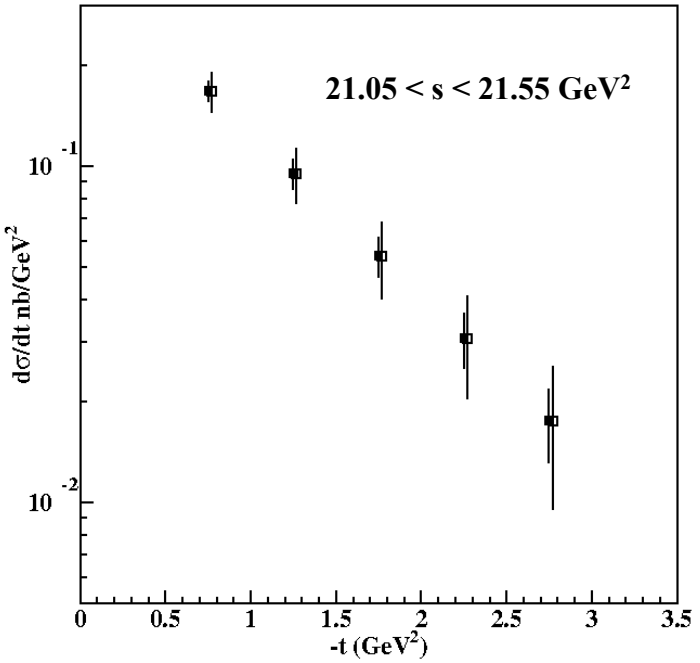
- CLAS12 has excellent acceptance for photoproduction of lepton pairs with a large invariant mass over a wide range of photon energies.

Projected results – "inclusive" J/ψ production (no p)

Statistical uncertainties at a luminosity of 10^{35} $cm^{-2}s^{-1}$

Filled squares: 100 days Open squares: 30 days

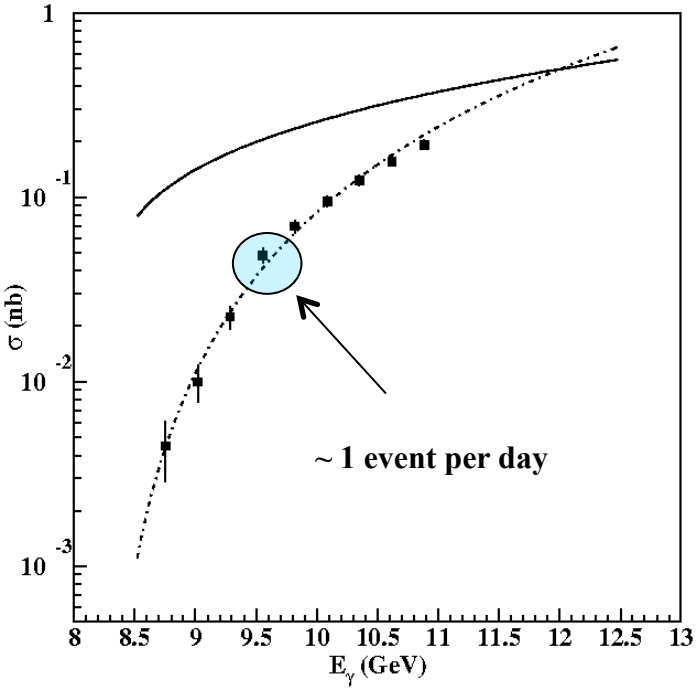


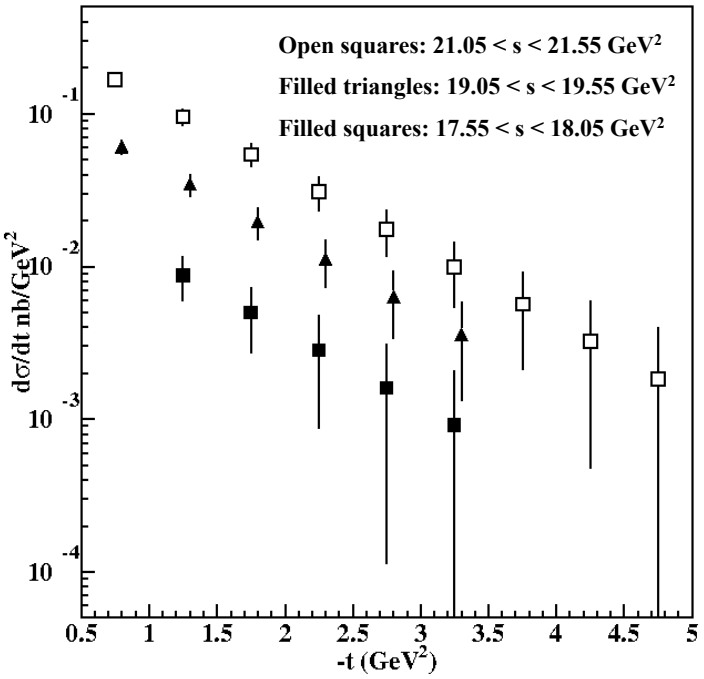


- Excellent benchmark for studies of detector efficiency
  - Nominal acceptance for e^+ e^- final state identical for both torus polarities

Projected results – exclusive J/ψ production

Statistical uncertainties for 100 days at a luminosity of 10^{35} $cm^{-2}s^{-1}$



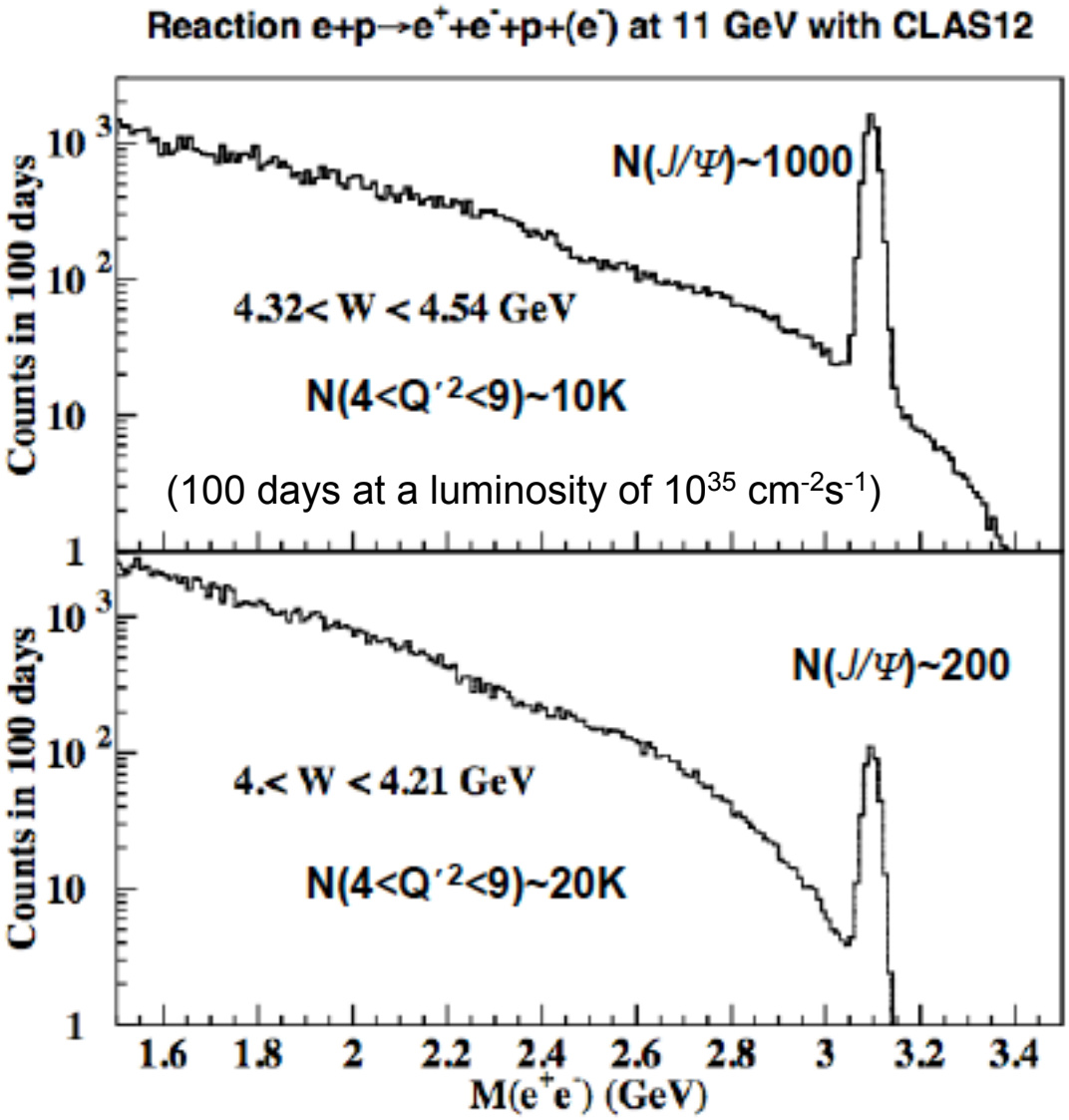


Uncertainties for the total cross section assuming the most conservative prediction

(smaller than point side except for the three lowest points)

t-dependence in narrow bins of *s* for a total cross section given by the lower curve on the left

Conservative J/ψ yield projections in two sample bins



Complementarity between CLAS12 and GlueX

CLAS12

- Good invariant-mass resolution and electron ID
  - Clean J/ψ signal
- High luminosity for quasi-real photoproduction and > 10% acceptance for pe^+e^-
  - Good for a proton target and coherent production on nuclei, but tricky to reconstruct Eγ if not all final-state particles detected
- Small-angle (low-Q2) electron tagger available, but lower rate
  - ~2° minimum electron angle
  - May not always be available

GlueX

- High photon energy
  - 12 vs 11 GeV in CLAS12
- Good and uniform acceptance
  - Great for complex final states
- Good E_γ resolution (from tagger)
  - Does not need to detect all nuclear fragments

Approved beam time for nuclear targets in CLAS12

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TOTAL approved run time (PAC days)				1491	559				

J/ψ from nuclear targets in CLAS12

- Significant beam time already approved for nuclear targets:
  - Unpolarized deuterium (90+40 days)
  - Ammonia from polarized targets (170 days)
  - Heavier nuclear targets (60+60 days)

- Run group proposals for nuclear J/ψ will be submitted!

- But heavier nuclei may not be scheduled in CLAS12 for quite a long time

- Together with limitations in quasi-real photoproduction in CLAS12 for nuclei where all particles in the final state are not detected and a good accepance in GlueX, this creates an opportunity for complementary program for J/ψ production on nuclear targets in GlueX!

Summary

CLAS12 experiment E12-12-001 will measure J/ψ on the proton

- Also Timelike Compton Scattering
- A LOI will be submitted to this PAC for J/ψ with muons

Extensions to J/ψ production on nuclei natural

- Lot of beam time already approved – can submit run group proposals
- Need theory guidance!

Nuclear J/ψ program has natural complementarity with GlueX!

Backup

CLAS12 baseline PID