Wide Angle Compton Scattering off A Longitudinal Polarized Proton

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June 6th. 2014

Hall A/C Collabortion Meeting

Outline

- Theory background
- Proposed experiment
  1. Experiment setup
  2. Kinematics
  3. Cuts
  4. Expected result
  5. Beam time
- Summary

Why WACS?

•RCS itself is interesting. It can provide information of nucleon structure.

•RCS works in some kinematics regime where DVCS does not apply.

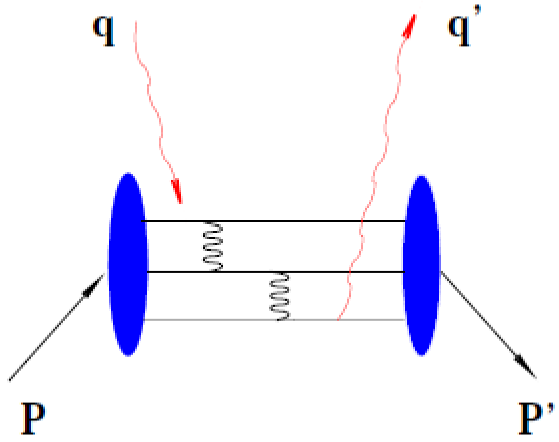
DVCS: small t and large Q2
WRCS: large t and large Q2

•Can help to understand TPE effects.

•Can help to answer the following:

1. What is the nature of the quark which absorbs and emits photons in the RCS process in the wide angle regime? Is it a constituent or a current quark?
2. If the GPD approach is correct, is it indeed true that the RCS reaction proceeds through the interaction of photons with a single quark?
3. What are the constraints on the GPD integrals imposed from the proposed measurement of the A_{LL} observable.

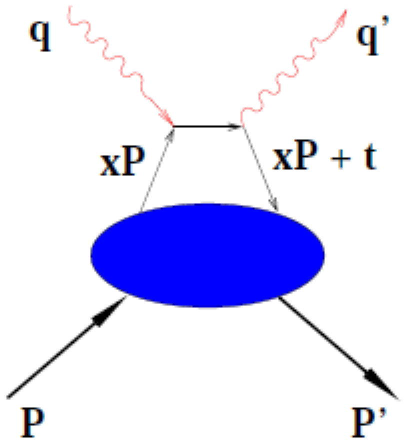
Reaction Mechanism



pQCD:

•3 active quarks
•2 hard gluons
•3-body "form factor"

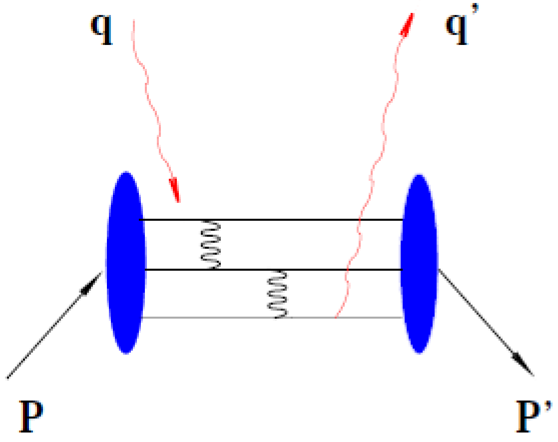
Which one is right?
And in what kinematics range they dominate?



Handbag:

•1 active quark
•0 hard gluons
•1-body "form factor"

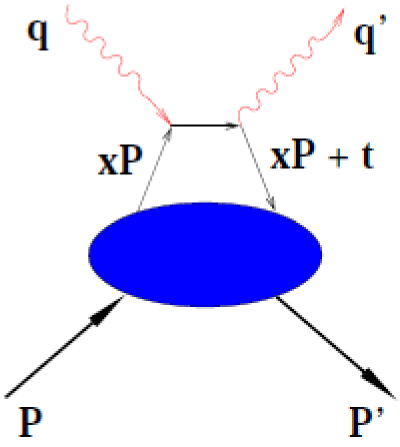
Asymptotic Mechanism (pQCD)



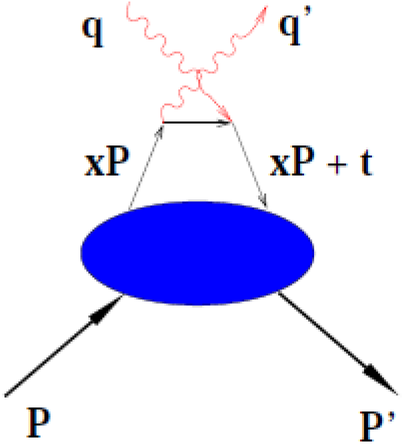
Brodsky/Lepage
Kronfeld, Nizic
Vanderhaeghen, Guichon
Brooks, Dixon, ...

- 2 hard gluons exchange
- 3 valence quarks are active
- constituent scaling: $d\sigma/dt = f(\theta^{CM})/s^6$
- Already proved to dominate at sufficiently high energy
- Predict $K_{LL} = A_{LL}$
- Measured K_{LL} and $d\sigma/dt$ from E99-114 (6GeV) do not agree with pQCD predictions, whcih means pQCD does not apply at this energy. Does it work in 12 GeV range?

Handbag Mechanism (GPD)



Radyushkin
Diehl, Feldman, Jakob, Kroll



- One active quark, no gluon envolved
- Momentum share by soft overlap
- 1-body “form factor”

  $d\sigma/dt = d\sigma^{KN}/dt * f(t)$

Handbag Mechanism (GPD)

$\gamma p \rightarrow \gamma p$ $\qquad\qquad$ $ep \rightarrow ep$

$$R_V(t) = \sum_a e_a^2 \int_{-1}^{1} \frac{dx}{x} H^a(x,0,t), \qquad F_1(t) = \sum_a e_a \int_{-1}^{1} dx\, H^a(x,0,t),$$

$$R_A(t) = \sum_a e_a^2 \int_{-1}^{1} \frac{dx}{x} \mathrm{sign(x)}\, \mathrm{\hat{H}^a(x,0,t)}, \qquad G_A(t) = \sum_a \int_{-1}^{1} dx\, \mathrm{sign(x)}\, \mathrm{\hat{H}^a(x,0,t)},$$

$$R_T(t) = \sum_a e_a^2 \int_{-1}^{1} \frac{dx}{x} E^a(x,0,t), \qquad F_2(t) = \sum_a e_a \int_{-1}^{1} dx\, E^a(x,0,t),$$

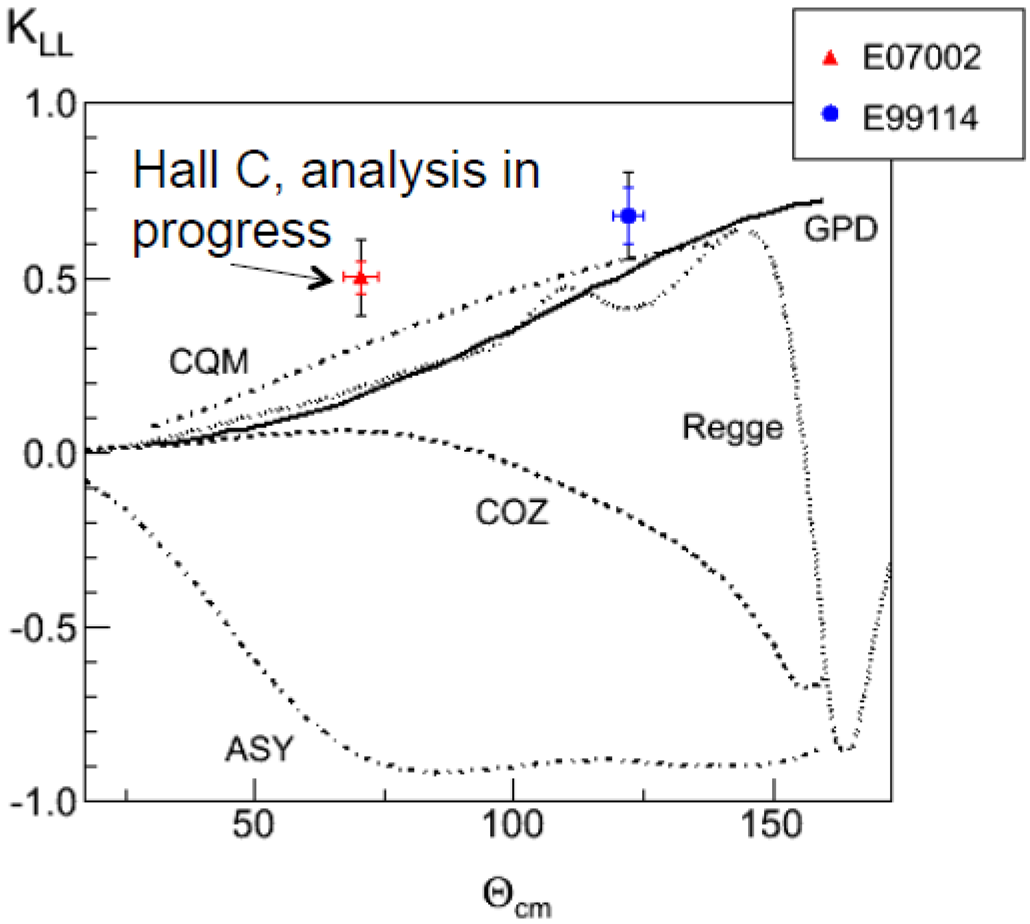
$$\frac{d\sigma}{dt} = \frac{d\sigma}{dt}_{KN} \left\{ \frac{1}{2}\left[R_V^2 + \frac{-t}{4m^2} R_T^2 + R_A^2 \right] - \frac{us}{s^2+u^2}\left[R_V^2 + \frac{-t}{4m^2} R_T^2 - R_A^2 \right] \right\}$$

WACS can help to constrate GPDs at large t and x, due to the fact that RCS contains factors of 1/x and e_a^2 but electromagnetic form factors do not.

Exist Data

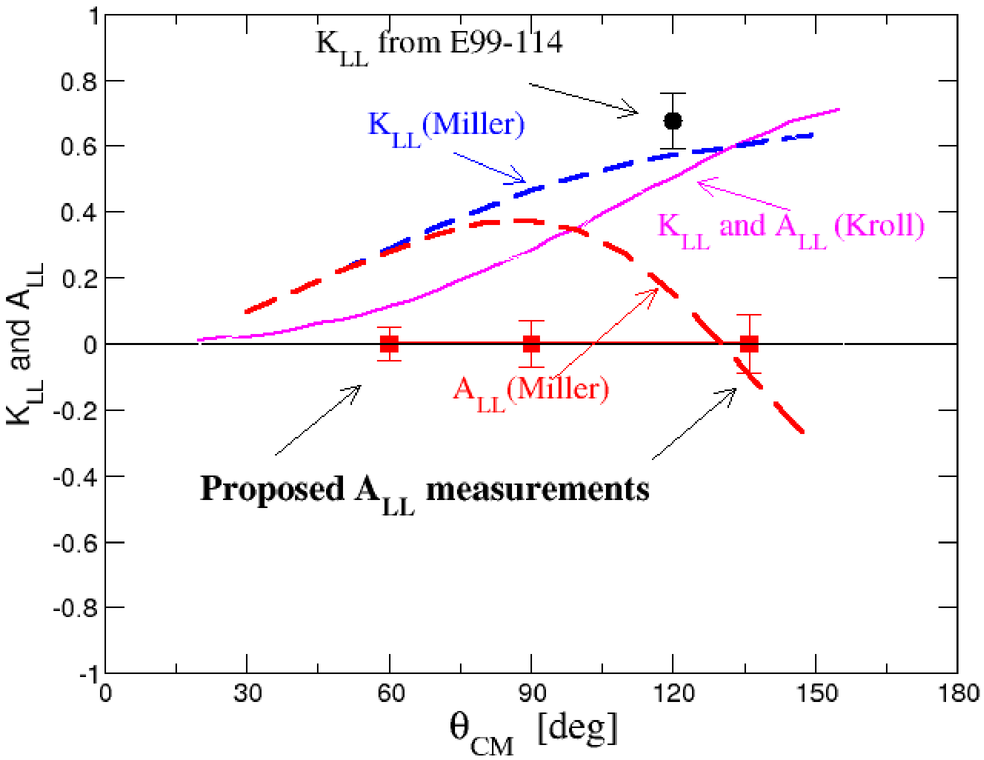
E07-002:
s = 8 GeV^2
t = -2.1 Gev^2

E99-114:
s = 6.9 GeV^2
t = -4.0 Gev^2



K_{LL}: the longitudinal polarization transfer observables, which involves the helicity of the final proton

A_{LL} and K_{LL}



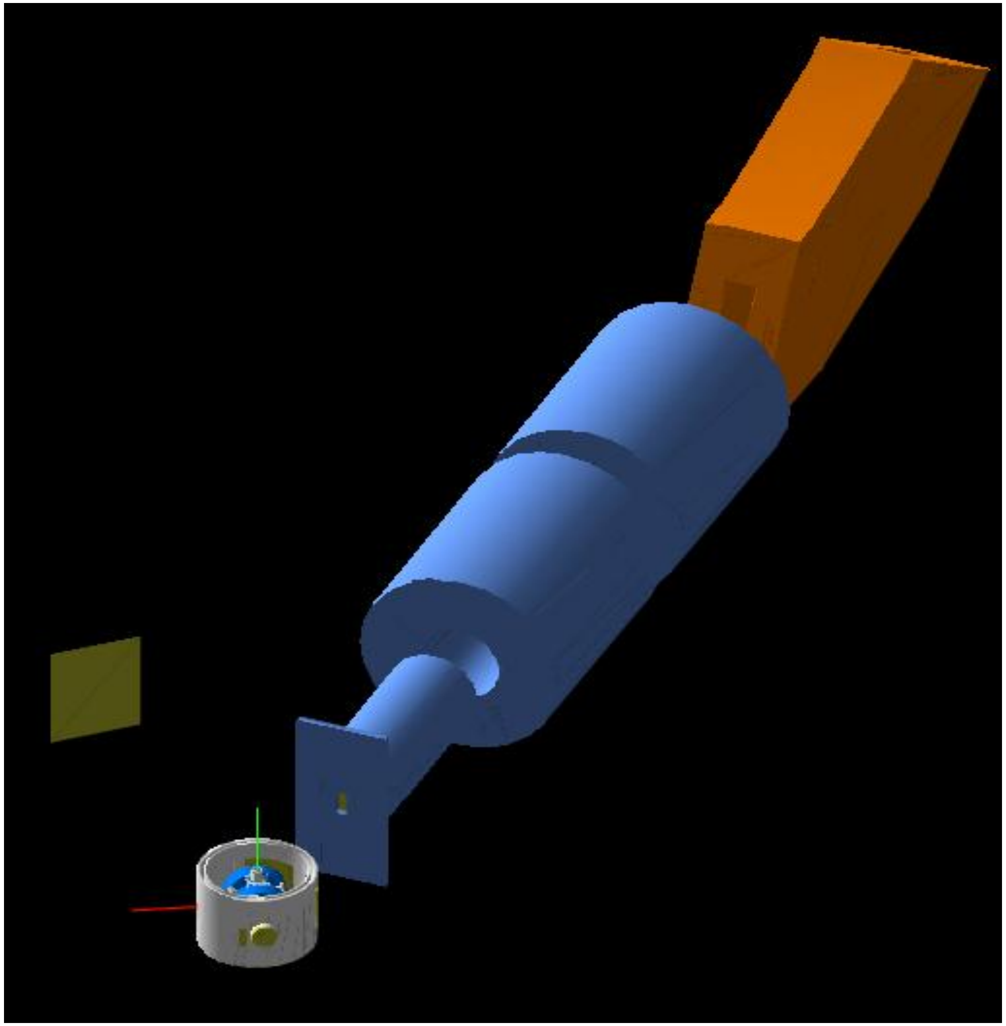
A_{LL}: the initial state helicity correlation observables, which involves the helicity of the initial proton

Kroll: $A_{LL} = K_{LL}$

vs

Miller: A_{LL} != K_{LL}

Experiment Setup: HMS + NPS

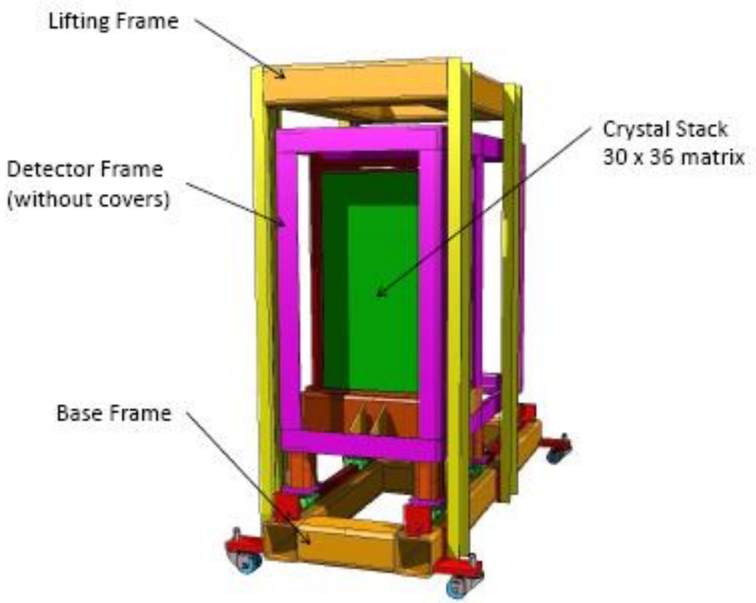


HMS:
About 1.66 m to target
The acceptance is determined by the collimater.
Solid Angle = ~7 msr.
Momentum acceptance: +/-9%
dP/P = 0.2%
dTheta_tr =1 mr , dPhi_tr =1 mr
dY_tg = 1 mm

NPS:
Size = 30” (w) x 36” (h)
dE/E = 3%
Positon = 3 mm

Distance to target and vertical offset depends on kinematics

NPS



Will take 3mm position resolution and 3% energy resolution

Requirements of the experiments

Parameter	DVCS (E12-13-010)	DVCS (pol. 3He)	WACS (PR12-12-009)	DES π^0 (E12-13-010)	SIDIS π^0 (E12-13-007)
Min. dist. From. Tgt. (m)	~3.0-6.0	~3.0-4.0	3.0-5.0	4.0	4.0
Coordinate res. (mm)	3-4	3-4	3-4	2-3	2-3
Photon angl. Res. (mrad)	1-2	1-2	1-2	0.5-0.75	0.5-0.75
Energy res. (%)	$(5\text{-}6)/\sqrt{E}$	$\sim 6/\sqrt{E}$	$\sim 5/\sqrt{E}$	$(2\text{-}3)/\sqrt{E}$	$(2\text{-}3)/\sqrt{E}$

- **Energy resolution** → **high light yield, best achievable crystals**
- **Coordinate resolution** → **fine granularity, small Moller radius, best 2x2 cm^2 or 3x3 cm^2**
- **Angular resolution** → **combine fine granularity with distance from the target**

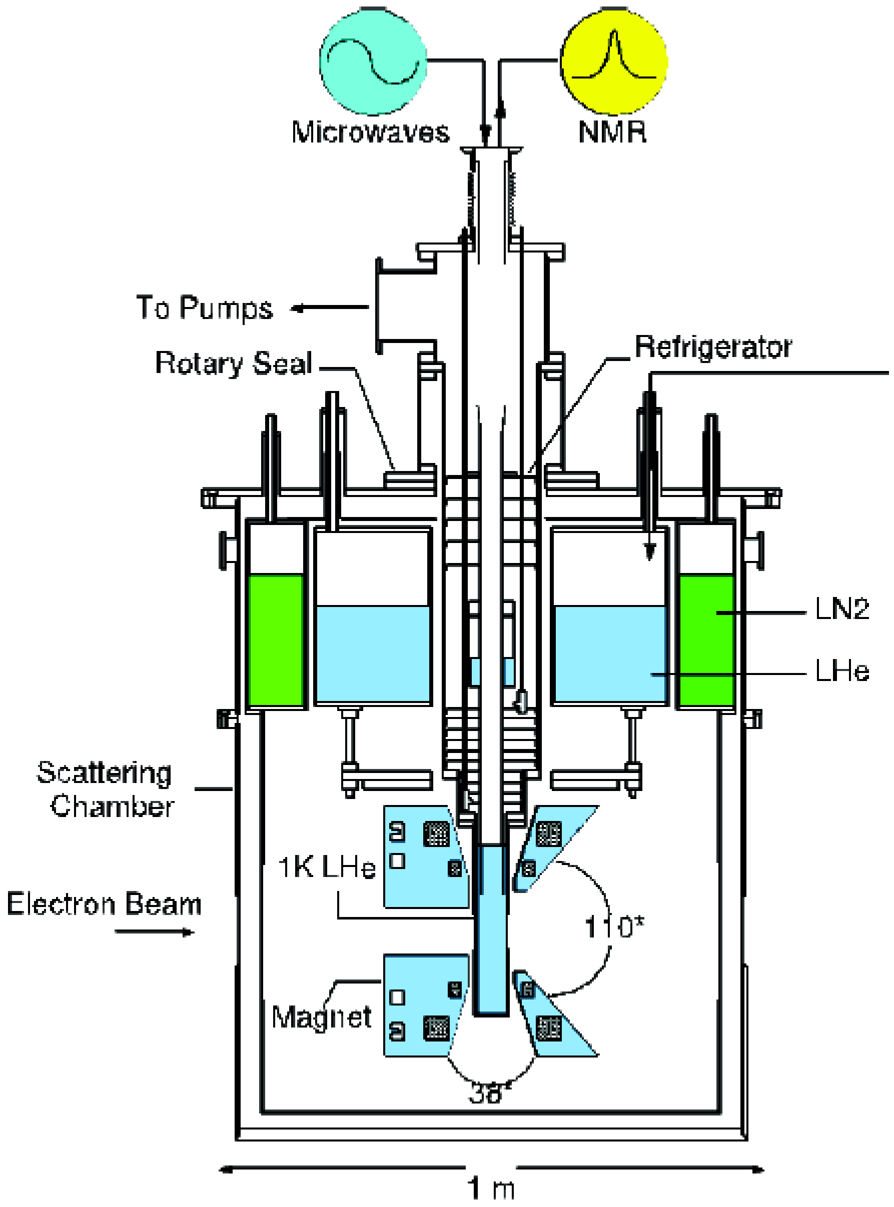
Polarized Target

UVA polarized proton target, NH3|ND3
+/- 55 degrees openning in forward
(But Target Chamber only cover +/-51 deg
+/-19 degrees openning in transverse side
(But Target Chamber only cover +/-18 deg

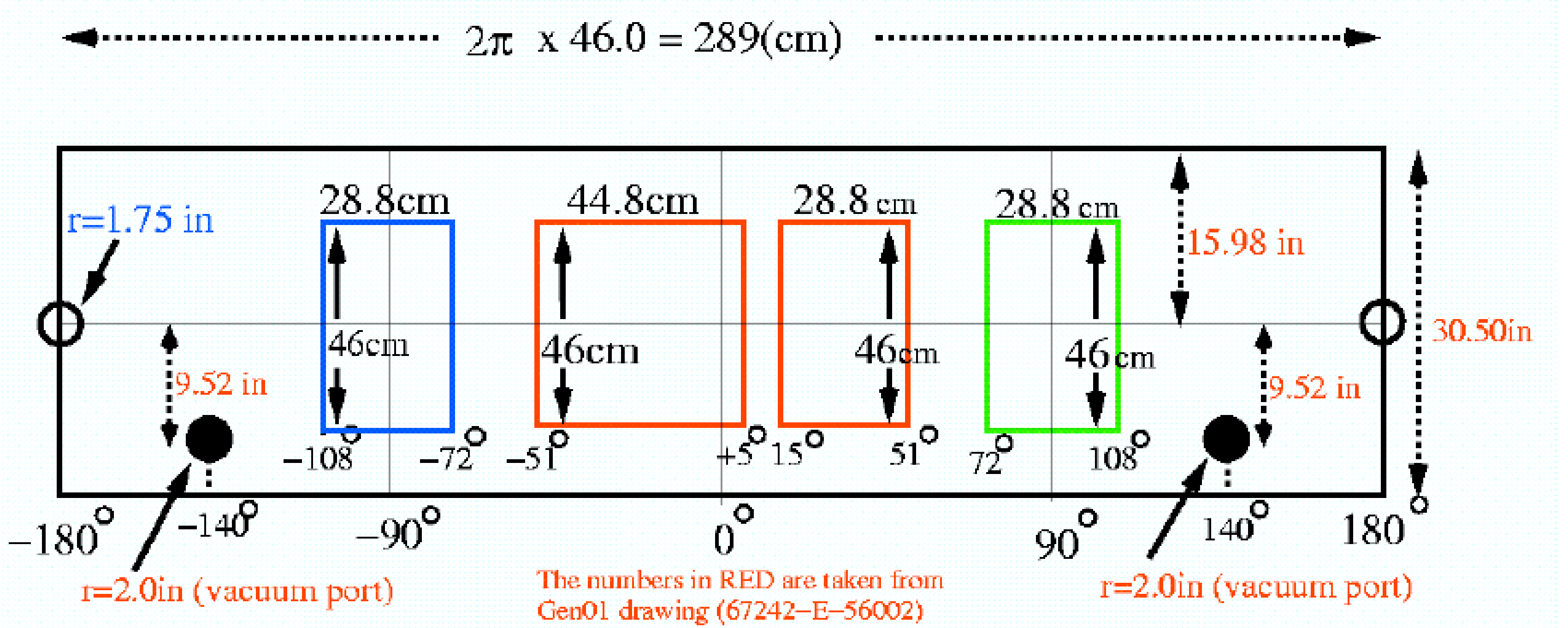
2.82 cm long target cell
55% packing fraction
Target nose diameter is 4.2 cm
Density of solid NH3 = 0.817 g/cm3
Density of liquid Helium = 0.145 g/cm3

Number of 14N = 4.5E22
Number of 1H = 13.45E22
Number of 4He = 5.78E22

Assuming 100 nA beam current,
Lumi_1H = 8.4E34
Lumi_4He = 3.6E34
Lumi_14N = 2.8E34
Lumi_nucleon = 62E34



Target Chamber Opening



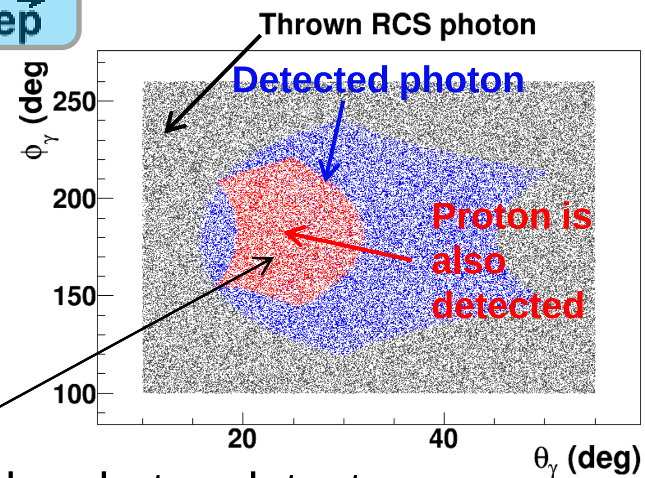
The RCS Event Rate

$$N_{RCS} = \frac{d\sigma_{RCS}}{dt} \frac{(E^f_\gamma)^2}{\pi} \Delta\Omega^{lab}_{\gamma p} \boxed{F_\gamma L_{\vec{ep}}}$$

Photon Flux

$dt/d\Omega_\gamma^{lab}$

From Modified Miller's Model



From Simulation
It is the solid angle of the photon detector where the corresponding proton are also detected by the proton arm

L_{ep} = 8.4E34, assuming 100 nA electron beam scattering off a 55% packing fraction of a 2.82 cm target cell, the same configuration as G2P|GEP.

Totoal nucleon luminosity is 14.8E34

Proposed Kinematics

kin. P#	t, $(\mathrm{GeV}/c)^2$	θ_γ^{lab}, degree	θ_γ^{cm}, degree	θ_p^{lab}, degree	E_γ^{lab}, GeV	p_p, GeV/c	L, cm	H, cm
P1	-1.7	22	60	45	2.87	1.56	785	41.2
P2	-3.3	37	90	30	2.00	2.52	445	21.5
P3	-5.4	78	136	13	0.88	3.55	245	10.0

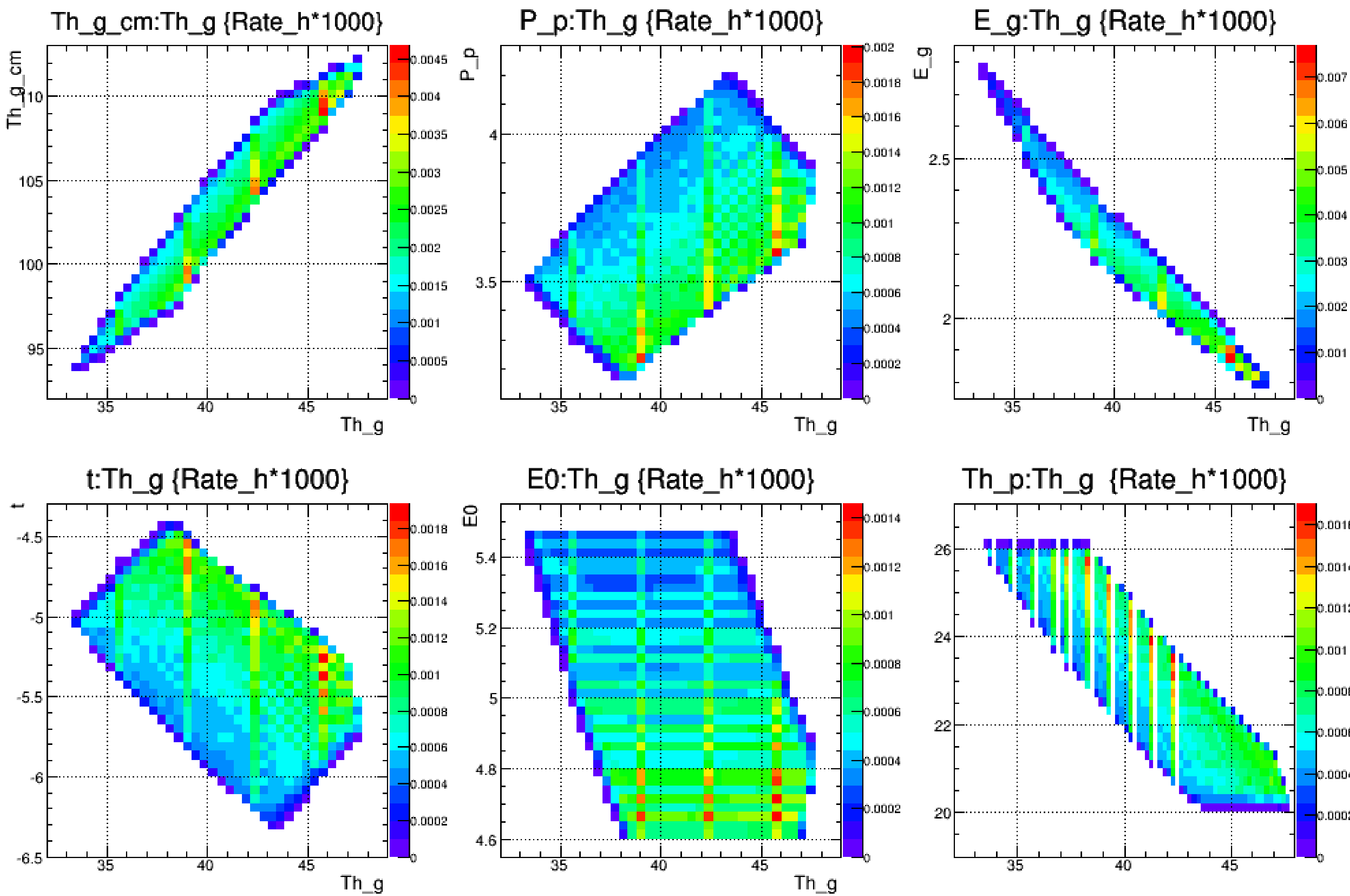
Systematic error:

Source	Systematic
Polarimetry	5%
Packing fraction	3%
Trigger/Tracking efficiency	1.0%
Acceptance	0.5%
Charge Determination	1.0%
Detector resolution and efficiency	1.0%
Background subtraction	4.0%
Total	8%

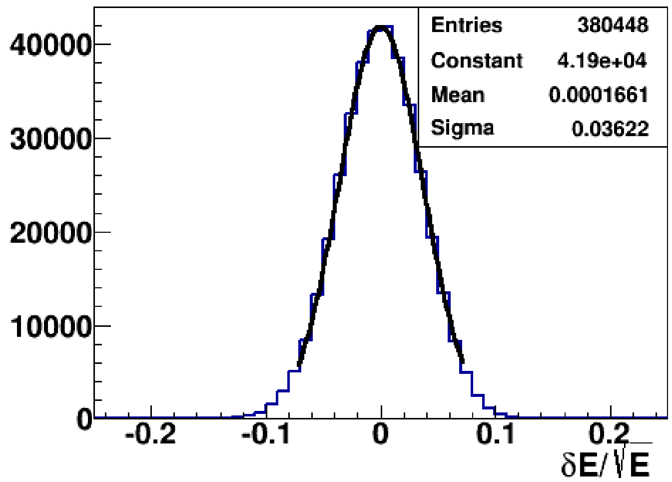
Statistics error:

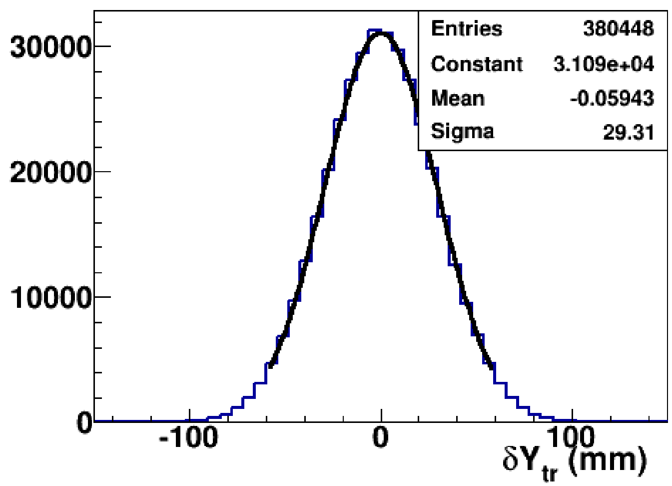
kinematic	P1	P2	P3
N_{RCS}, events	2333	1666	1404
ΔA_{LL}	0.05	0.07	0.09

HMS Kinematics, $\theta_{CM} = 60^o$, P_0=1.56



Cut on dY and dE

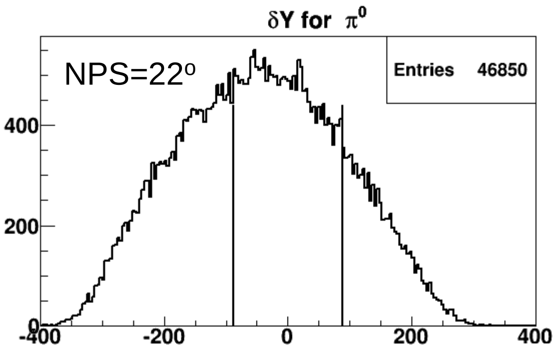


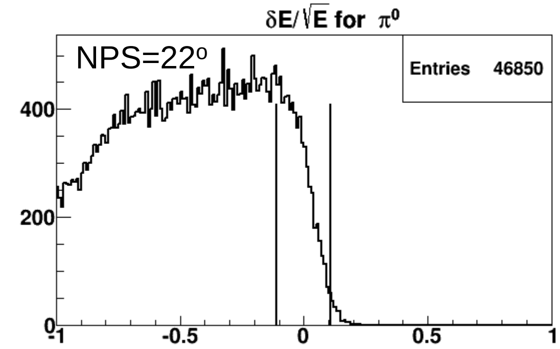


NPS=22 deg

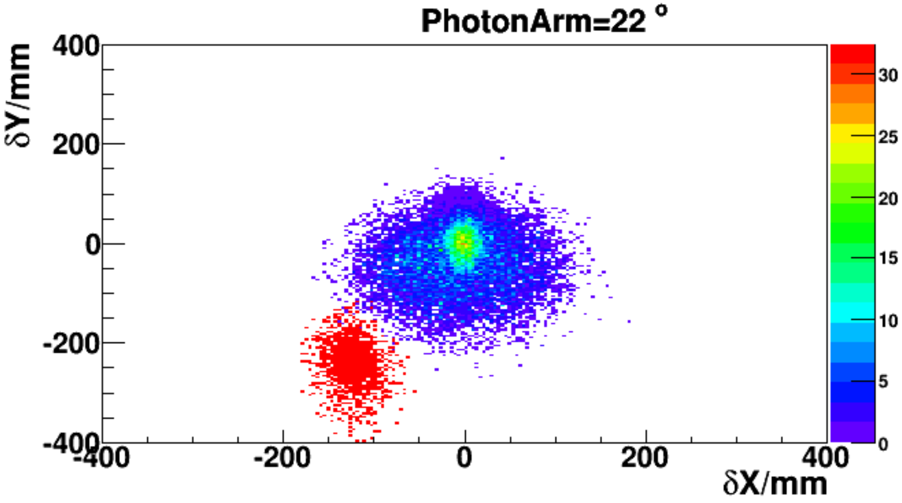
dY: the differece between measured RCS photon hit horizontal position and the inferred horizontal position, which is inferred by the proton.

dE/sqrt(E): the differece between measured RCS photon energy and the inferred energy, which is inferred by the proton.

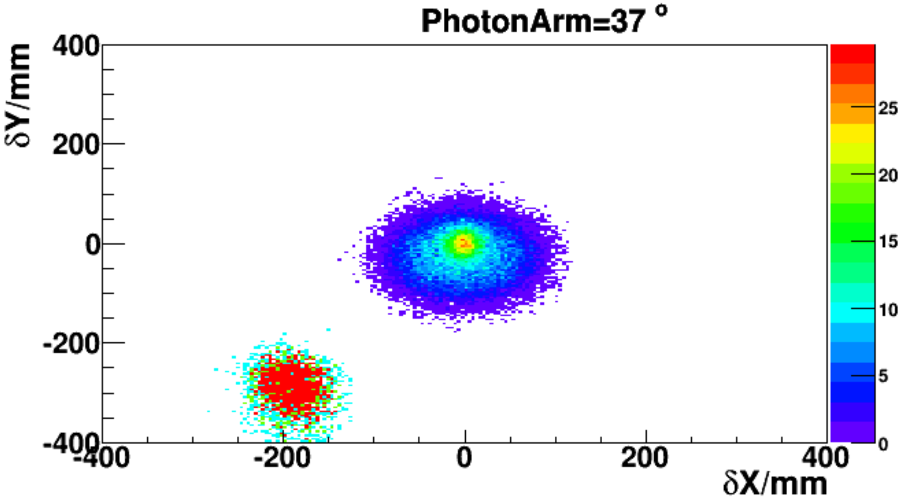


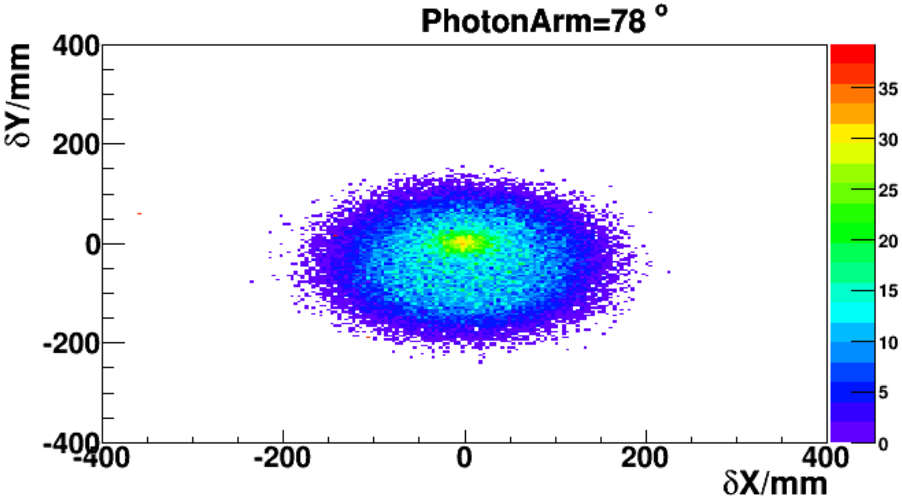


NPS dY vs dX

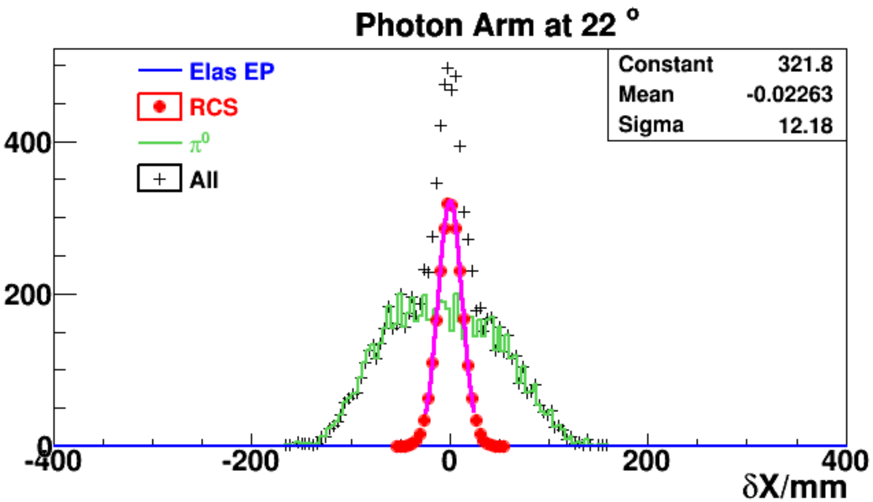


After dE Cut, no dY cut



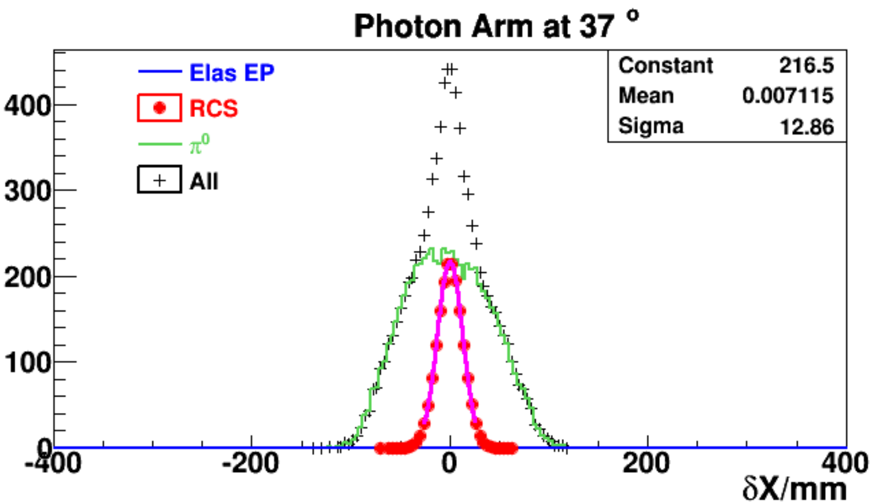


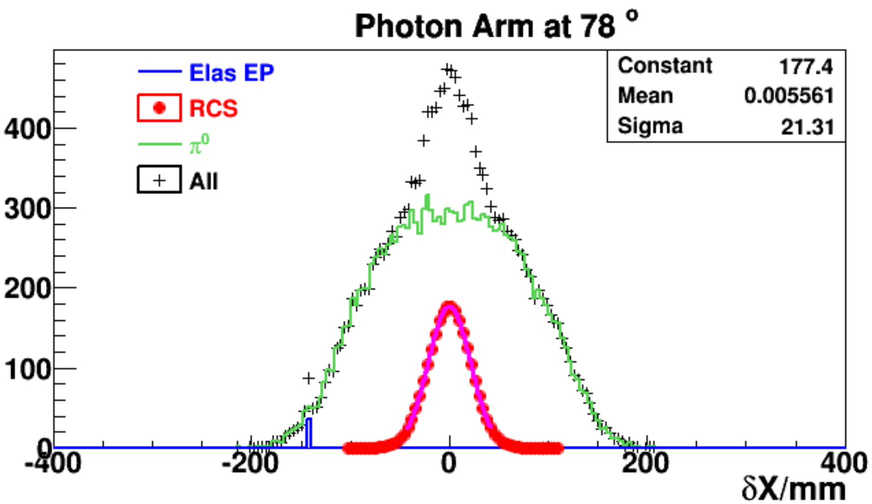
dX



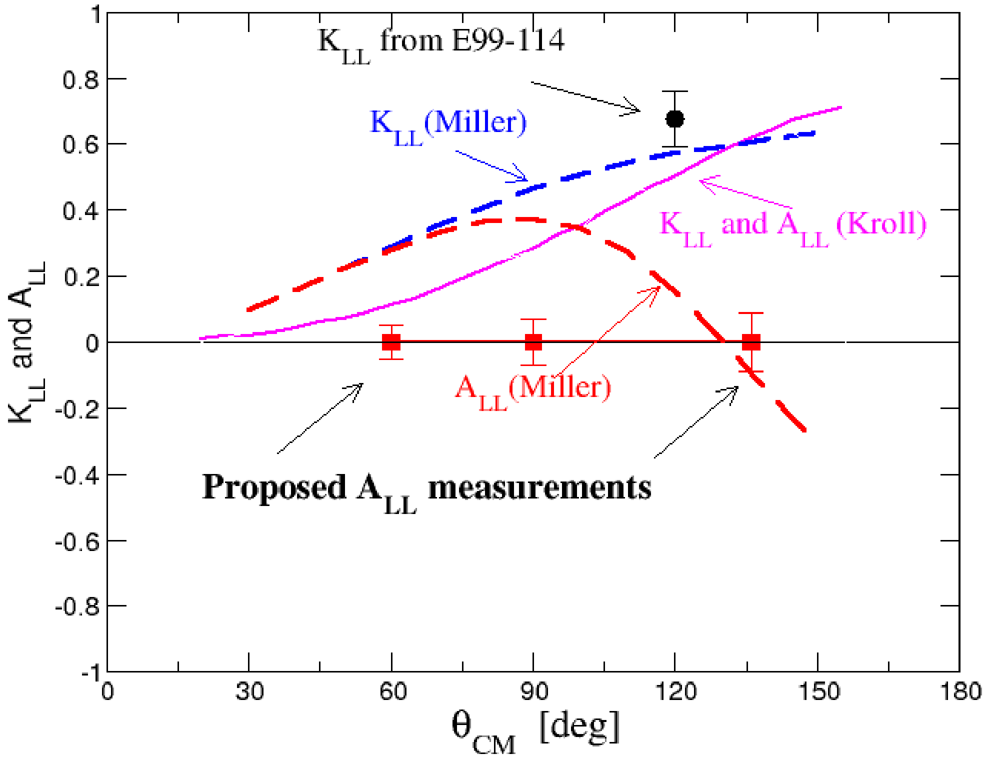
dX: the difference between the measured RCS photon vertical position and the inferred vertical position, which is inferred by the proton.

After both dY and dE cuts





Proposed A_{LL} measurement



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Beam Time

Kin. P#	Procedure	beam, nA	time hours
P1	RCS data taking	90	52
P2	RCS data taking	90	293
P3	RCS data taking	90	185
P1	NPS and HMS calibration	1000	8
P2	NPS and HMS calibration	1000	8
P3	NPS and HMS calibration	1000	8
	Packing Fraction	90	22
	Moller Measurements	200	33
	Beam Time		609
	Target Anneals		55
	Target T.E.		25
	Stick Changes		15
	BCM calibration		13
	Optics		13
	kinematics change		12
	Total Requested Time		742

Summary

- We propose to do a polarized WACS experiment in Hall C using HMS and NPS, with 742 hours of beam time. We will use the UVA|Jlab target, which is longitudinally polarized with 5 T magnetic field. We plan to use 4.4 GeV electron beam at 90 nA with 80% longitudinal polarization
- We will measure A_{LL} at 3 kinematics: θ_{CM} = 60, 90 and 136 degree to the uncertainty of 0.05, 0.07 and 0.09, respectively
- We will put a 6% copper radiator inside the UVA target chamber.
- The expected result will reveal if ALL differ from KLL in large θ_{CM} angle regime. It will provide crutial information to understand GPS and Hand-Bag mechanism in regard of RCS.