

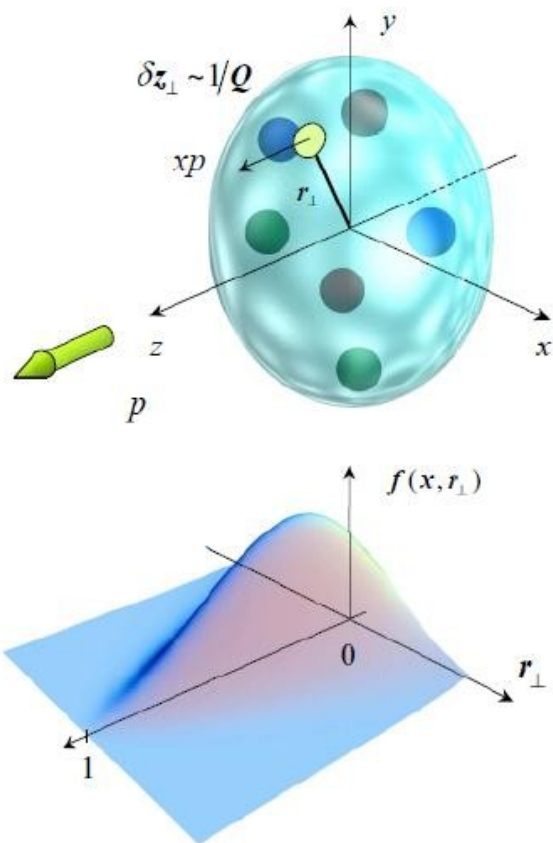
E12-06-144:Deeply Virtual Compton Scattering in Hall A of Jlab: Running Spring 2016

**APS:
18 April 2016**

Mongi Dlamini



Generalized Parton Distributions and 3D Imaging of Nucleons



GPDs → new class of quark and gluon matrix elements

→ GPDs correlate the struck parton's (q/g) transverse spatial distribution with its longitudinal momentum fraction in the nucleon.

→ Nucleon structure described by 4 GPDs:

H, E (no helicity flip), \tilde{H}, \tilde{E} , (helicity flip)

→ First moments of quark GPDs H and E gives elastic form factors and second moments are related to the spin structure of the nucleon.

DVCS is the cleanest way to measure GPDs.

The DVCS process is an essential part of the GPD program with CEBAF at 12 GeV

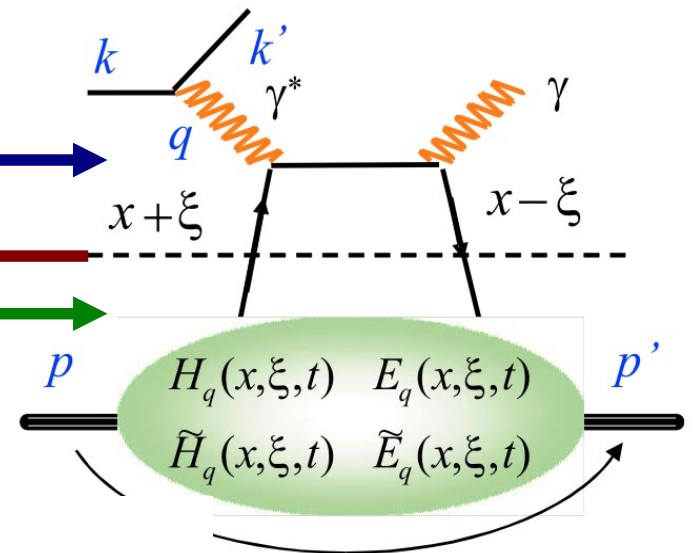
Factorization and GPDs

→ In the Bjorken limit

$$Q^2 = \left. \begin{array}{l} -q^2 \rightarrow \infty \\ \nu \rightarrow \infty \end{array} \right\} x_B = \frac{Q^2}{2M\nu} \text{ fixed}$$

Hard/perturbative part

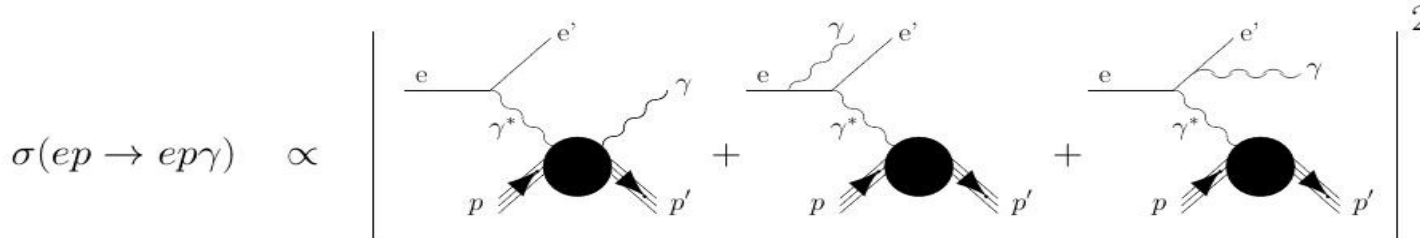
Soft part
Non-perturbative
Parametrized by GPDs



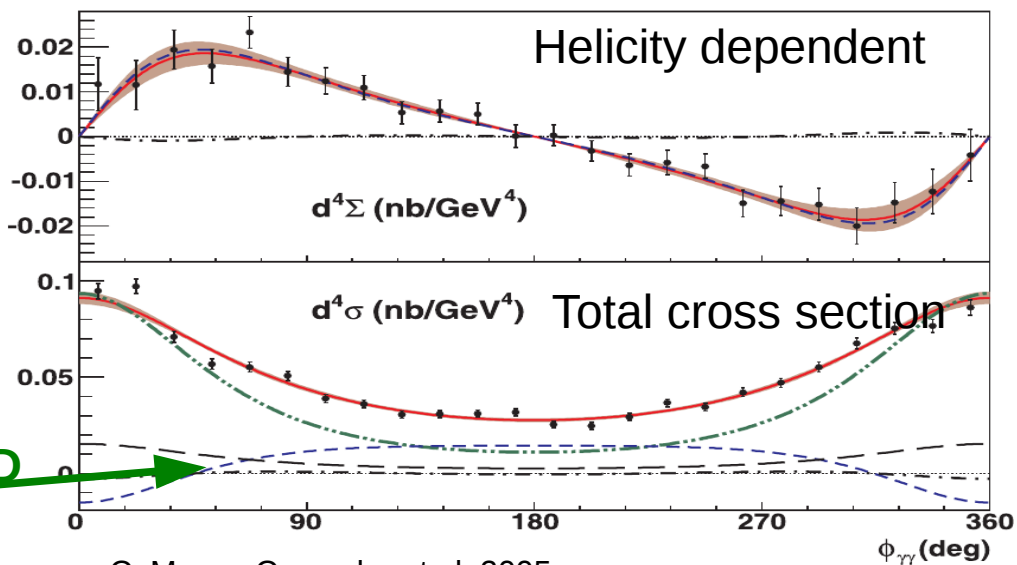
DVCS

BH

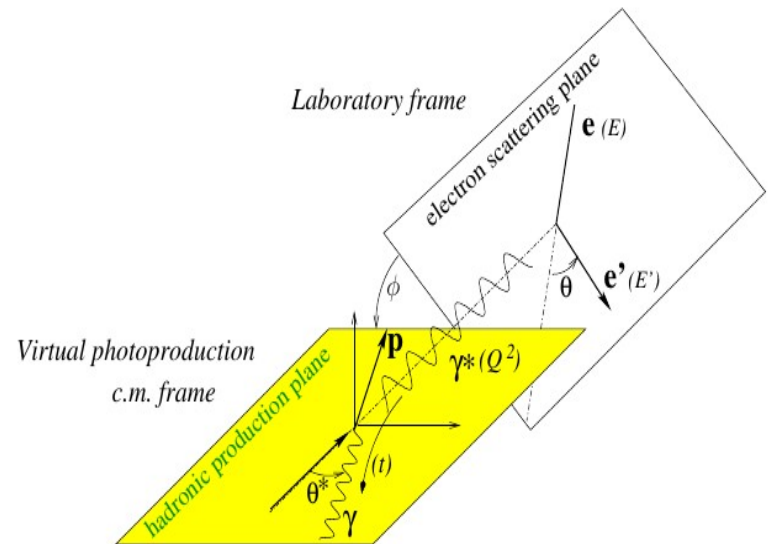
$$t = (p' - p)^2$$



$$|\mathcal{T}|^2 = |\mathcal{T}_{DVCS}|^2 + |\mathcal{T}_{BH}|^2 + \mathcal{I}$$



C. Munoz Camacho et al., 2005



DVCS in Hall A of Jlab:

→ We want to do Q^2 scans at various x_{Bj} to confirm DVCS formalism

→ Separation of Re and Im part of DVCS amplitude (**absolute and helicity dependent cross section**)

$$d^5 \vec{\sigma} - d^5 \overleftarrow{\sigma} = \Im(T^{BH} \cdot T^{DVCS})$$

$$d^5 \vec{\sigma} + d^5 \overleftarrow{\sigma} = |BH|^2 + \Re(T^{BH} \cdot T^{DVCS}) + |DVCS|^2$$

Total = 100 days (88+12 days calibration) approved Proposed scans in Q^2 and x_{Bj}

For these goals, we need:

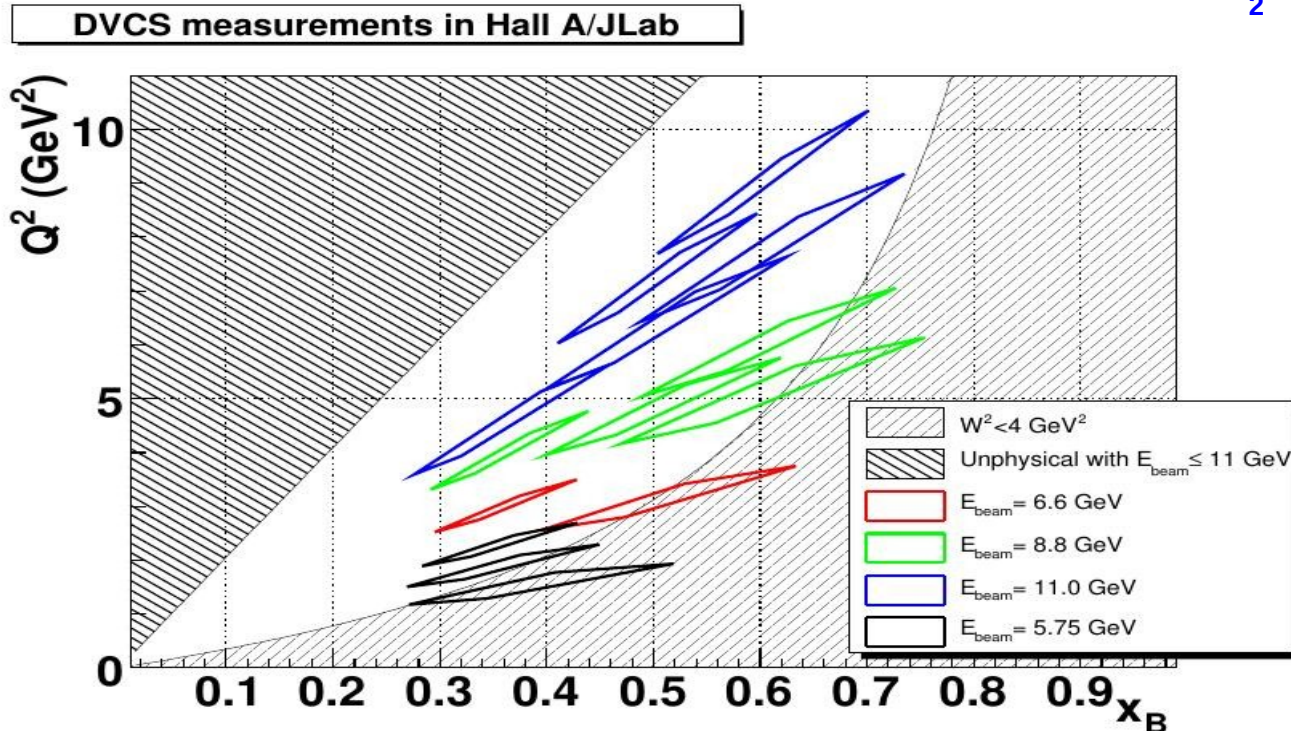
→ High energy beam; **6.6, 8.8 and 11 GeV** hence highest possible HRS momentum

→ longitudinally polarized beam

→ absolute cross section ~4% relative precision

→ beam intensity between 5 – 15 μA

→ LH_2 target



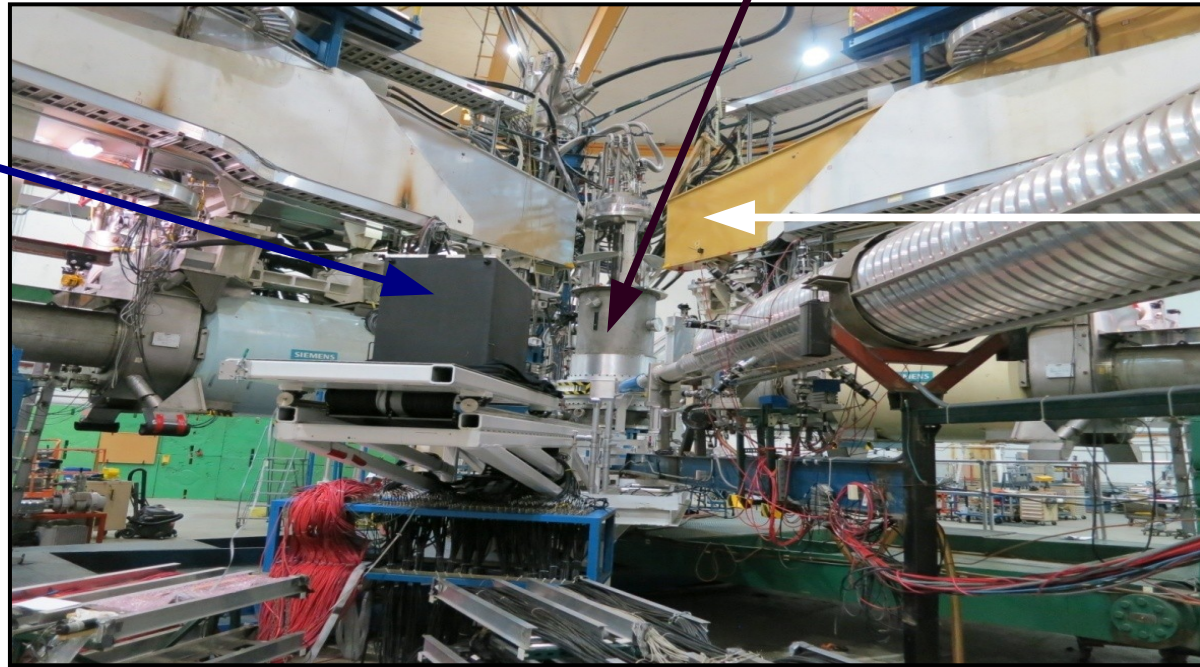
Not available for spring,
But possible in the Fall

$$p(e, e'\gamma)p'$$

TARGET

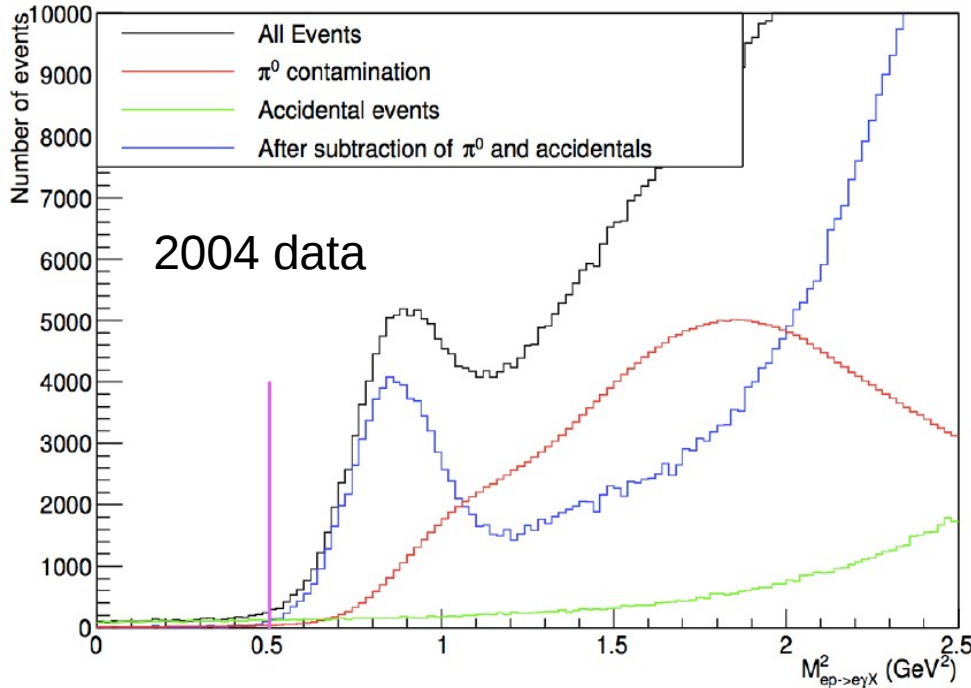
CALORIMETER

- 208 PbF₂ blocks
- $\Delta q/q \sim 3\%$
- Calorimeter energy resolution is our limiting factor in the missing mass reconstruction



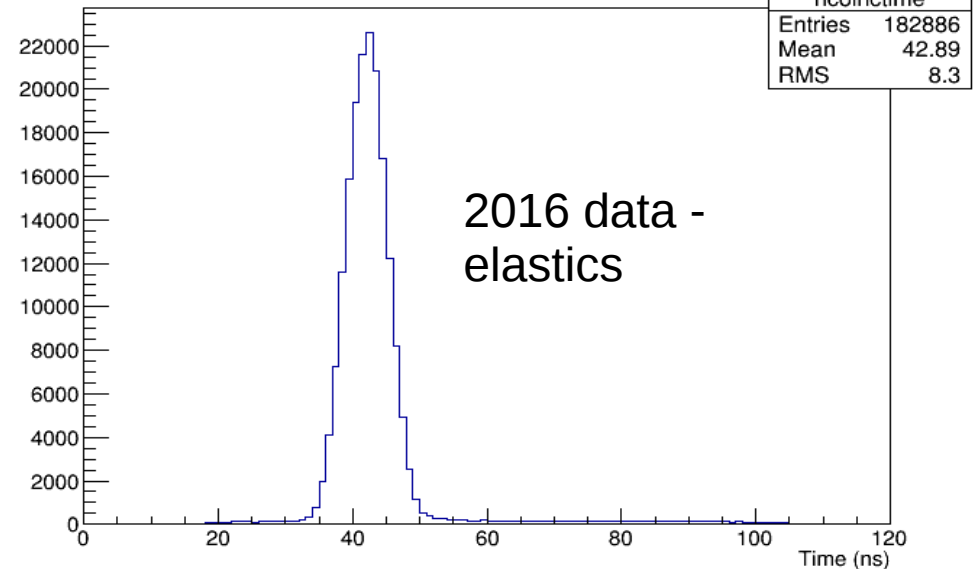
HRS
→ $\delta p/P \sim 10^{-4}$
Excellent!

Missing mass squared cut ensures exclusivity



Raw coincidence time

Calo-HRS Coincidence

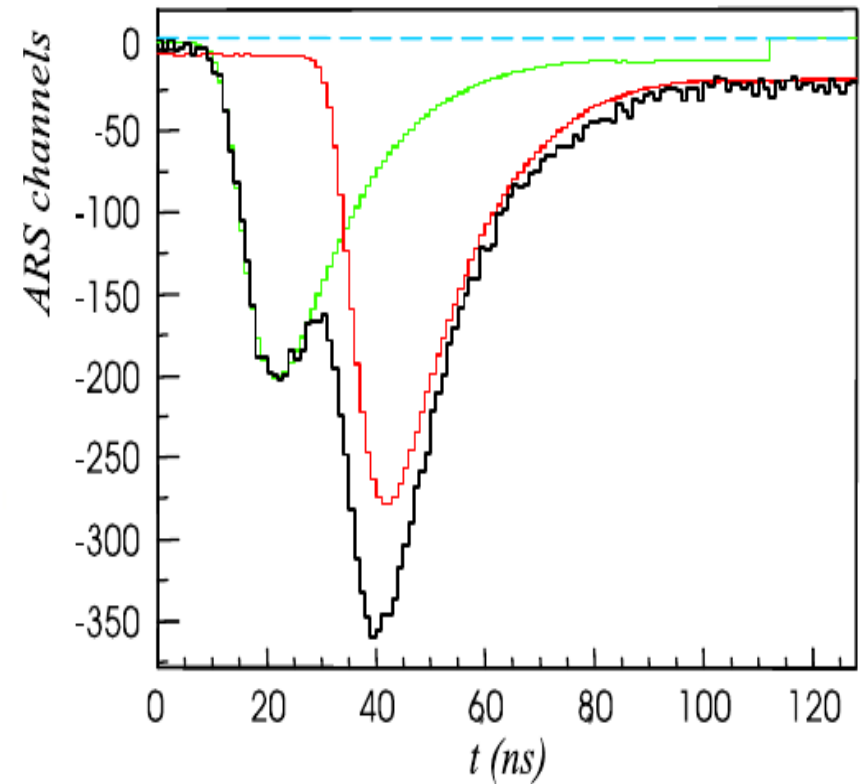


Instrumentation:

DVCS calorimeter

ARS system(for calorimeter signals):

- 1 GHz sampling
- Digitizes PMT signals, allowing off-line pile-up removal
- Readout time = **128 μ s**

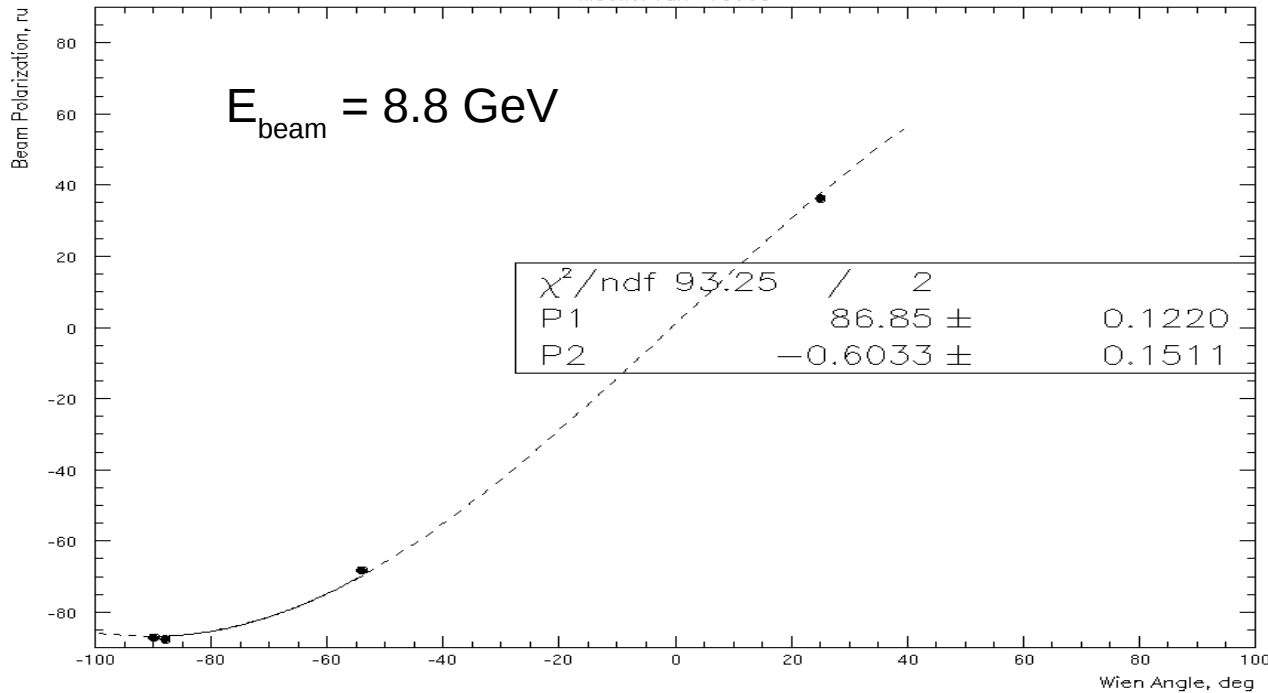


Spring 2016 Running

Moller polarization measurement (Kharkov Institute)
→ done at 4.4 and 8.8 GeV so far, 11 GeV still in plans

Moller results for Spin Dance 02/29/2016

Moeller run=16009

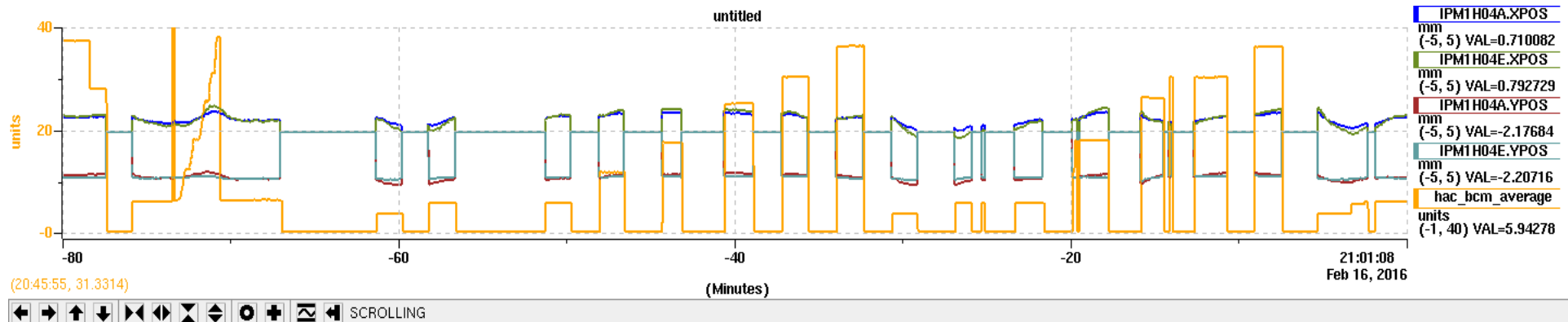


→ We are doing an opportunistic running

→ We have polarized beam at 4.4, 8.8 and 11 GeV

→ Running at various beam currents

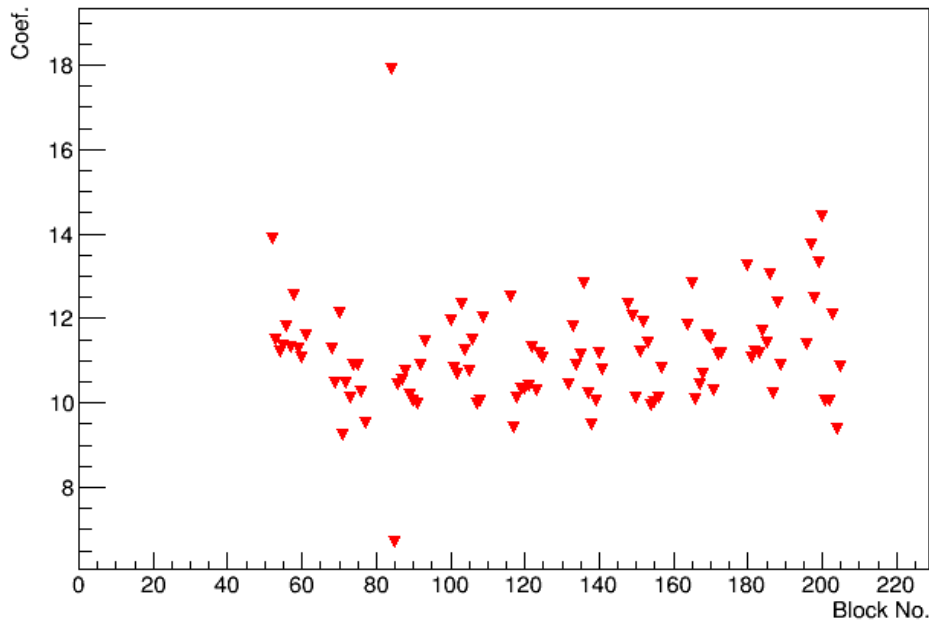
→ Beam energy measurement in hall (D. Higinbotham)



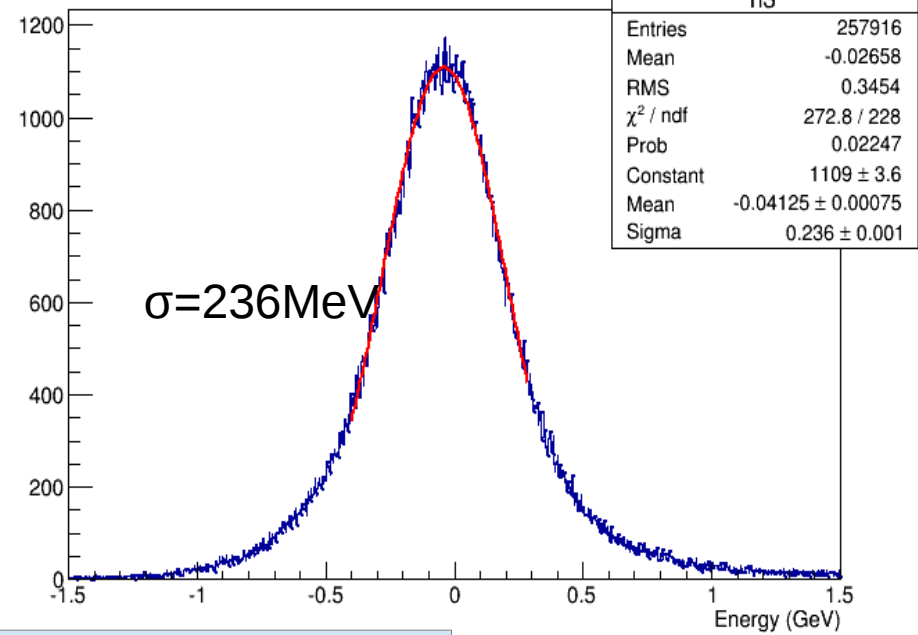
Preliminary Studies Spring 2016

Calorimeter Calibration at $E_{\text{beam}} = 8.8 \text{ GeV}$

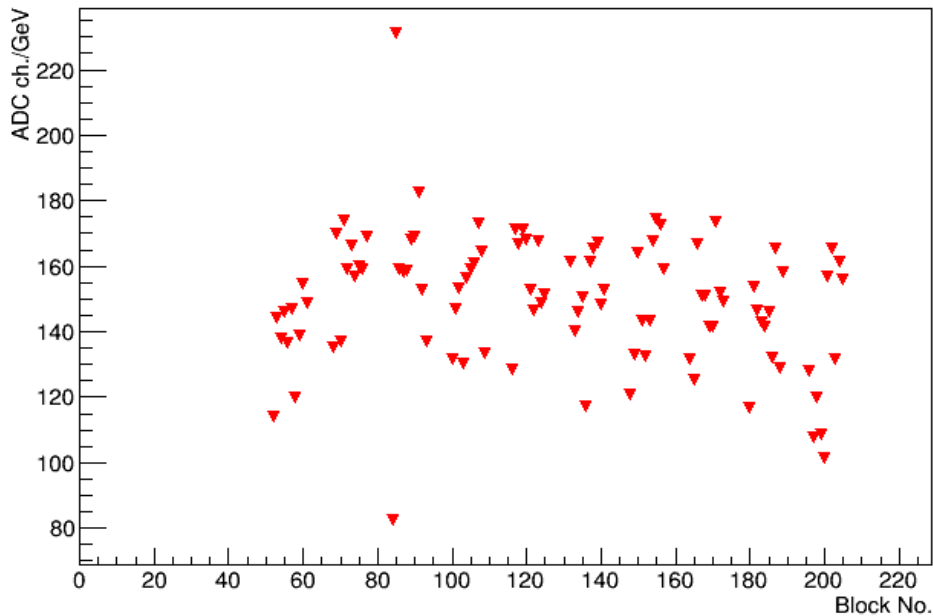
Coefficients (GeV/ARS amplitude)



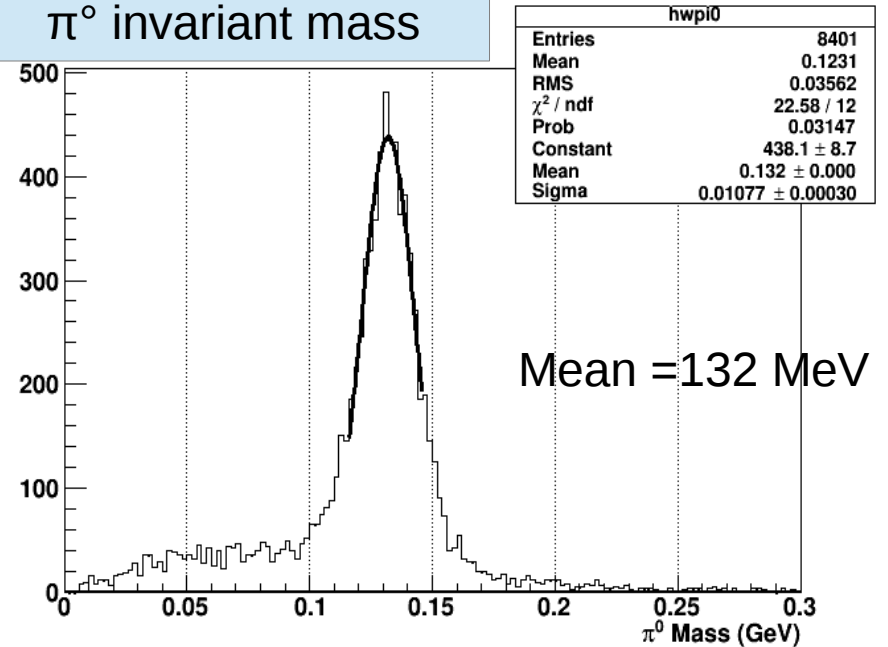
Energy resolution



ADC calibration based on ARS

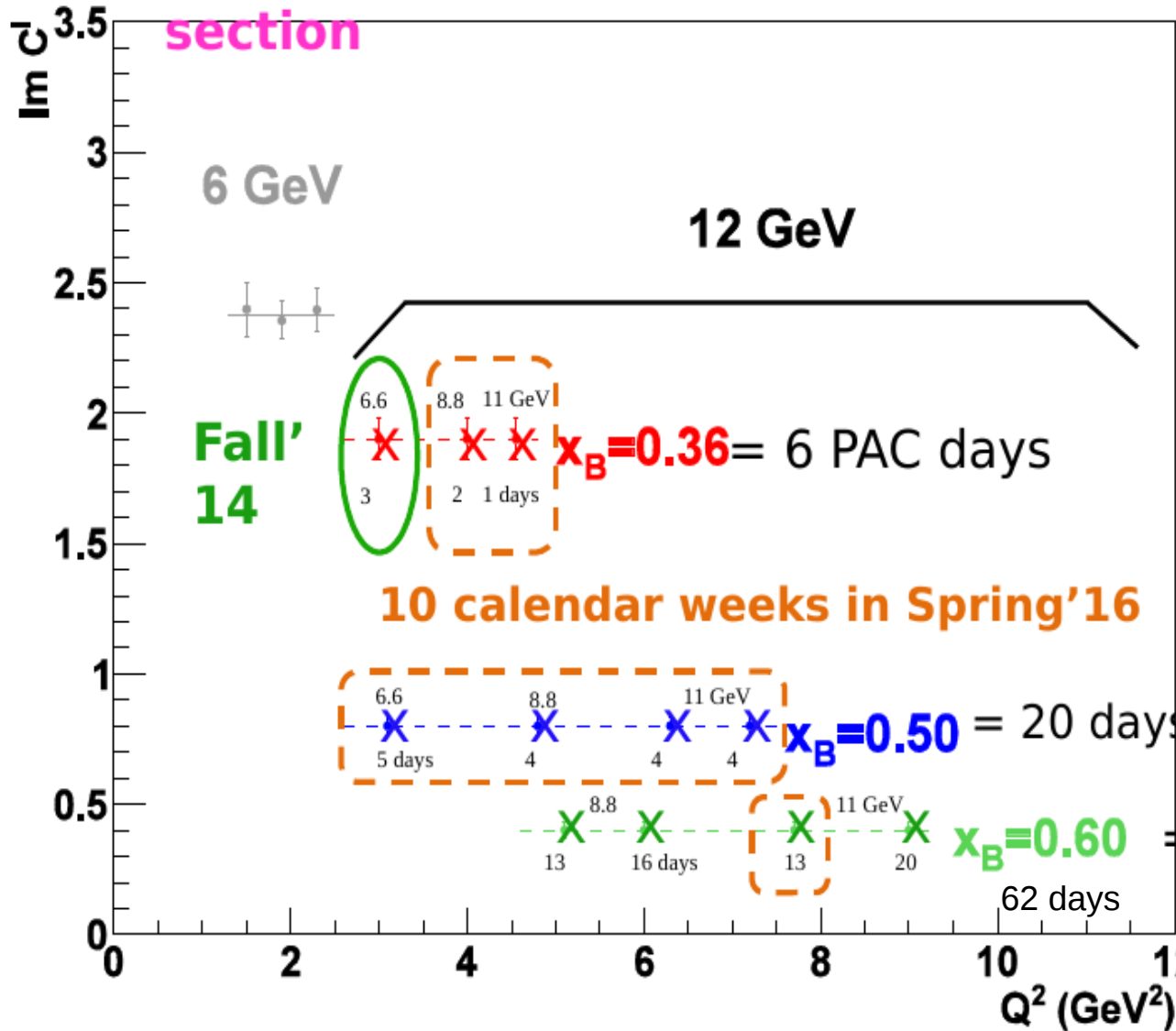


π^0 invariant mass



Statistics so far....

Scaling tests of the DVCS cross section



Kinematic	% of target charge
kin_36_1	100.0
kin_36_2	0.0
kin_36_3	0.0
kin_48_1	95.0
kin_48_2	56.6
kin_48_3	76.4
kin_48_4	51.0
kin_60_1	0.0
kin_60_2	0.0
kin_60_3	0.0
kin_60_4	0.0

Running is in progress

- Running until April 25
- 100 days approved to run the DVCS experiment at JLab Hall A
- Running is already scheduled and will continue Fall 2016
- Scaling test of DVCS cross section for leading order factorization confirmation
- Separation of Real and imaginary parts of DVCS amplitude by measuring absolute and helicity dependent cross section.

Thank you!!!

**Acknowledgments:
Hall A DVCS Collaboration
Hall A Collaboration**

kinematics

DVCS Kinematics													DVCS	9 weeks	
HRS_Acc	6.00E-03	sr												5 Pass	2 days
HRS_delta	0.08	(kMax-kMin)/k0												2 Pass	1 week
Calo_A	0.1386	m^2	208-54'	Crystals	3x3 cm^2									4 pass	3 weeks
HMS_Acc	6.00E-03	sr												5 pass	5 weeks
HMS_delta	0.16	(kMax-kMin)/k0												2 pass	1 week
Calo_C	0.4096	m^2	34x34-4*33'	Crystals	2x2 cm^2										
DeltaT	0.1	GeV^2													
nbarn	1.00E-33	cm^2/mb													
Injector	1.23E-01	1.000	0.123	Injector energy scales with linac											
Linac	2.18E+00	GeV	2.180	GeV											
Hall A															
Name	Kin_36_1	Kin_36_2	Kin_36_3	Kin_48_1	Kin_48_2	Kin_48_3	Kin_48_4	Kin_60_1	Kin_60_2	Kin_60_3	Kin_60_4				
Pass	3	4	5	2	4	4	5	4	4	5	5		Pass		
kBeam	(GeV)	6.663	8.843	11.023	4.483	8.843	8.843	11.023	8.843	8.843	11.023	11.023	kBeam		
Q2	(GeV^2)	3.200	4.000	4.745	2.700	4.365	5.334	6.900	5.541	6.100	8.018	9.000	Q2		
xBj		0.360	0.360	0.360	0.480	0.480	0.480	0.600	0.600	0.600	0.600	0.600	xBj		
MProton	(GeV)	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	0.938	MProton	HRS-L	
nu	(GeV)	4.738	5.923	7.026	2.998	4.847	5.923	7.663	4.923	5.419	7.123	7.996	nu	Window	
kScatt	(GeV)	1.925	2.920	3.997	1.485	3.996	2.920	3.360	3.920	3.424	3.900	3.027	kScatt	47.7	
Q1 detune		1.000	0.856	0.625	1.000	0.626	0.856	0.744						deg max	
Q1 Amp		1462.8	1900.0	1900.0	1128.3	1900.0	1900.0	1900.0							
csThe		0.875	0.923	0.946	0.797	0.938	0.897	0.907	0.920	0.899	0.907	0.865	csThe		
epsilon		0.484	0.560	0.613	0.506	0.711	0.548	0.518	0.691	0.618	0.582	0.460	epsilon		
the	(deg)	28.926	22.698	18.888	37.140	20.244	26.271	24.925	23.062	25.939	24.942	30.101	the		
snThq		0.184	0.180	0.176	0.262	0.262	0.203	0.175	0.281	0.251	0.215	0.178	snThq		
Thq	(deg)	10.592	10.385	10.131	15.198	15.184	11.728	10.069	16.346	14.564	12.388	10.240	Thq		
CaloSetting	(deg)	10.592	10.385	10.131	15.198	15.184	11.728	10.069	16.346	14.564	12.388	10.240	CaloSetting		
pMin	(GeV/c)	0.422	0.422	0.422	0.624	0.624	0.624	0.624	0.890	0.890	0.890	0.890	pMin		
1./ 1-eps)		1.938	2.270	2.585	2.023	3.458	2.212	2.076	3.236	2.621	2.395	1.853	1./ 1-eps)		
qvec	(GeV/c)	5.065	6.251	7.356	3.419	5.278	6.358	8.100	5.457	5.956	7.665	8.540	qvec		
q'	(GeV)	4.651	5.834	6.936	2.827	4.664	5.736	7.471	4.570	5.061	6.752	7.620	q'		
tmin	(GeV^2)	-0.163	-0.166	-0.168	0.321	-0.344	-0.351	-0.359	-0.661	-0.671	-0.697	-0.706	tmin		
sqrt(tmin)	(GeV)	0.404	0.408	0.410	0.567	0.586	0.593	0.599	0.813	0.819	0.835	0.840	sqrt(tmin)		
CaloDist	(m)	1.500	2.000	2.500	1.500	2.000	2.500	2.500	1.500	2.000	2.500	3.000	CaloDist		
DOmega	(sr)	6.16E-02	3.47E-02	2.22E-02	6.16E-02	3.47E-02	2.22E-02	2.22E-02	6.16E-02	3.47E-02	2.22E-02	1.54E-02	DOmega		
Th_gg_max	(rad)	1.24E-01	9.31E-02	7.45E-02	1.24E-01	9.31E-02	7.45E-02	7.45E-02	1.24E-01	9.31E-02	7.45E-02	6.20E-02	Th_gg_max		
q'_min	(GeV)	4.37	5.59	6.71	2.69	4.46	5.54	7.15	4.14	4.76	6.41	7.31	q'_min		
tmax	(GeV^2)	-0.69	-0.63	-0.59	-0.58	-0.72	-0.71	-0.96	-1.47	-1.24	-1.34	-1.28	tmax		
tmin-tmax	(GeV^2)	0.52	0.47	0.42	0.26	0.38	0.36	0.60	0.81	0.57	0.65	0.57	tmin-tmax		
Th_calo_edge	deg	4.86	6.09	6.69	9.47	10.89	8.29	6.63	10.62	10.27	8.95	7.38	Th_calo_edge		
lumi	/cm^2/s	1.86E+37	3.31E+37	5.17E+37	1.86E+37	3.31E+37	5.17E+37	5.17E+37	1.86E+37	3.31E+37	5.17E+37	7.44E+37	lumi		
Beam Curren	(muAmp)	4.9	8.8	13.7	4.9	8.8	13.7	13.7	4.9	8.8	13.7	19.8	muAmp		
d4sig(0deg)	nb/GeV^4	8.21E-02	3.64E-02	1.92E-02	1.24E-03	4.47E-03	2.33E-03	2.38E-03	1.22E-03	9.95E-04	5.06E-04	5.12E-04	OBSOLETE		
d4sig(180)	nb/GeV^4	1.44E-02	7.80E-03	4.69E-03	4.07E-03	1.73E-03	1.01E-03	1.06E-03	5.60E-04	4.68E-04	2.78E-04	2.95E-04	d4sig(180)		
Days		3.00	2	1	5	4	4	7	13	16	13	20	Days		
Charge	Coulomb	1.3	1.5	1.2	2.1	3.0	4.7	8.3	5.6	12.1	15.4	34.2	Coulomb		
Jacob_e	GeV	1.95	3.14	4.52	2.13	7.00	4.18	4.64	8.45	6.70	7.24	5.01	Jacob_e		
counts in DeltaT bin		4.18E+04	5.55E+04	4.61E+04	3.24E+03	4.25E+04	1.75E+04	4.01E+04	2.96E+04	3.68E+04	3.09E+04	3.77E+04	counts in DeltaT bin		
Total Beam Time		Hall A Total = 88 PAC Days											Total Beam Time		