Longitudinal and Transverse Target Correlation Asymmetries in WACS

PR12-16-009

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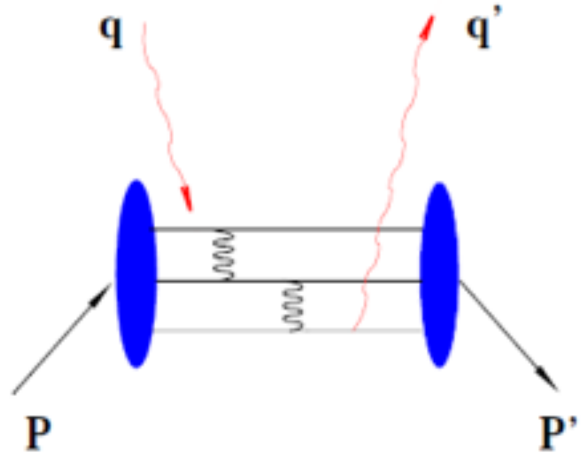
Outline

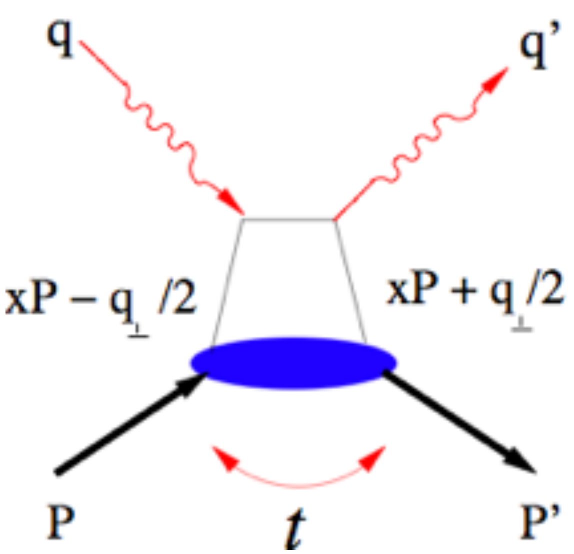
- Background
- Theoretical Context
  - pQCD
  - Handbag GPDs
  - SCET
- Proposed Experiment
  - Experiment setup
    - Pure Photon Source
  - Kinematics and Analysis
  - Expected results
- Summary

Framework and Mechanisms

- pQCD (two gluon exchange)
- 3 active quarks
- 2 hard gluons
- 3-body form factor
- Constituent scaling
  - Dominant at high energy



- Handbag Approach (GPD's)
- 1 active quark
- no hard gluons
  - 1-body form factor
- Amplitude a convolution of hard and of overlap of Φ_i and Φ_f wf describing the coupling of active quarks



- Constituent Quark Model

- Soft collinear effective theory (SCET)
- universal form factor
- systematic QCD factorization
- description of soft-spectator contribution

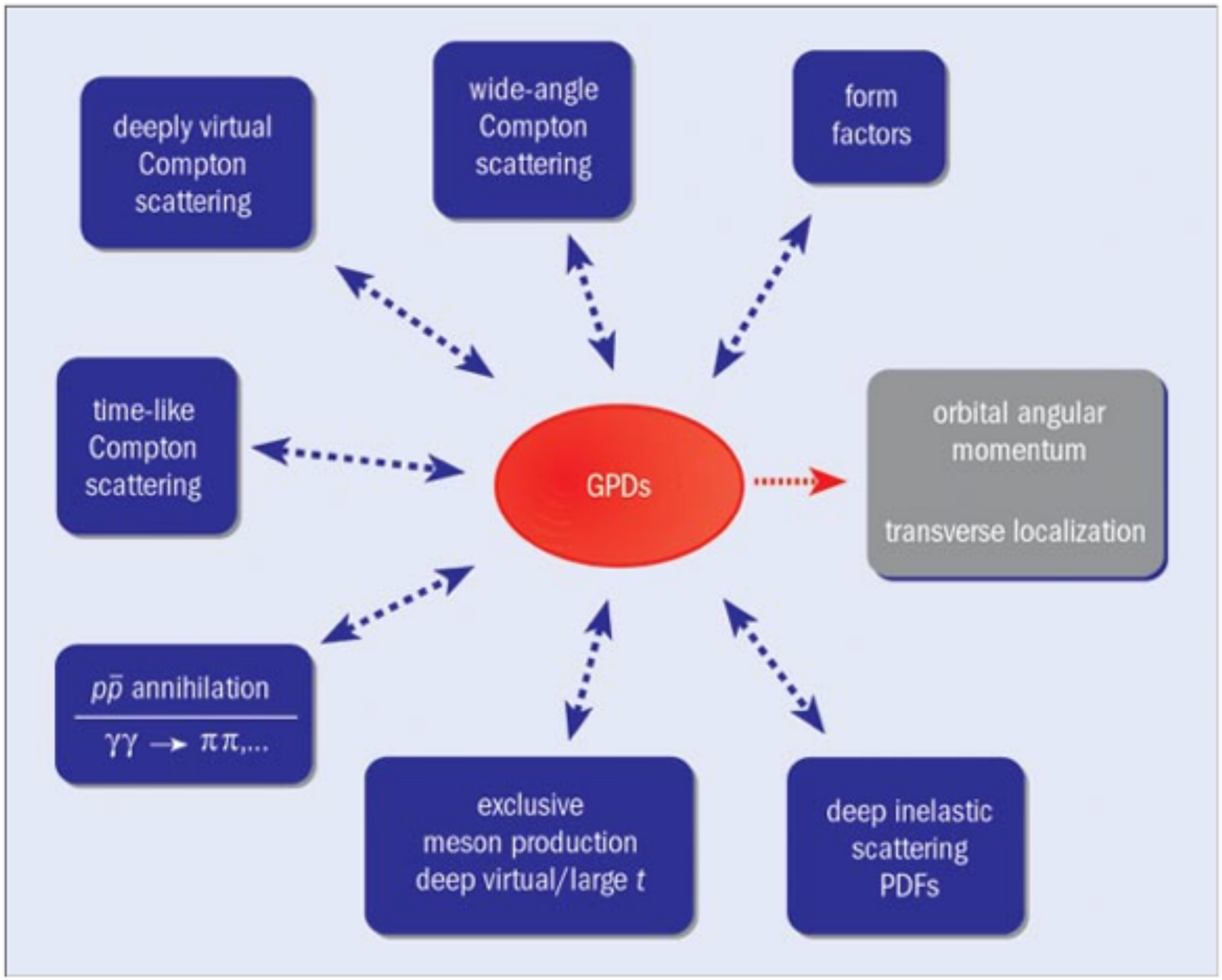
$64000 Question: which and how much of each at JLAB energies?

Wide Angle Compton Scattering

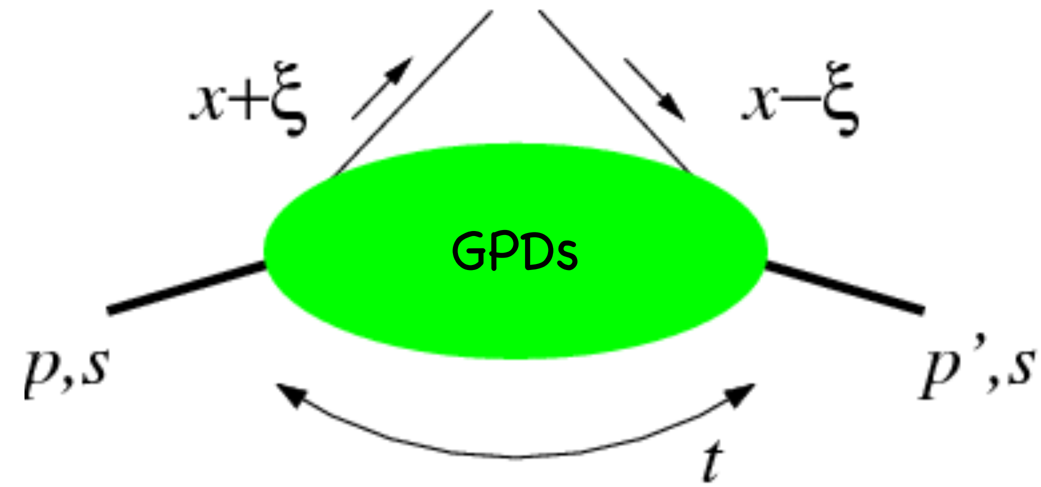
- One of the most fundamental processes yet it is still not well understood at medium energy
- For wide angle kinematics (s,-t,-u >> M^2) there is consequential untapped information on nucleon structure
- WACS provides complimentary information to elastic FF at high Q^2 and DVCS, TCS, DDVCS, DVMP
  - Common thread: large energy scale leading to factorization of scattering amplitude into a hard perturbative kernel and a factor expressing soft non-perturbative WF
- Polarized observables can provide access to information not otherwise available

GPDs

Study of hard exclusive processes leads to GPD's, providing most complete description of the nucleon



Generalized parton distributions (GPDs) provide a unique framework for describing many different hard processes and accessing new fundamental observables such as quark orbital angular momentum. (Marc Vanderhaeghen, Mainz.)



Correlation between transverse position and longitudinal momentum fraction of quark in nucleon

Form Factors: Transverse distribution of quarks in space coordinate

$$F(t) = \int dx\, GPD(x, \xi, t)$$

PDFs: Quark longitudinal momentum fraction in the nucleon

$$q(x) = GPD(x, \xi = 0, t = 0)$$

GPD Approach

$\gamma p \rightarrow \gamma p$

$ep \rightarrow ep$

Compton form factors

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

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

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

Elastic form factors

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

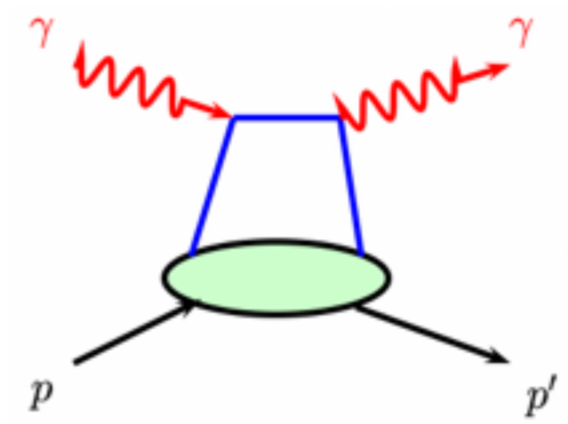
$$G_A(t) = \sum_a \int_{-1}^{1} dx \, \mathrm{sign}(x) \, \hat{H}^a(x,0,t)$$

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

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

WACS is unique compared to elastic form factors:

- vary s and t independently
- can help to constrain GPDs through:
  - e_a^2 (charge) weighting
  - independent integral of GPD's, x^{-1} weighting
  - $\xi=0$ so momentum absorbed by quarks purely transverse
- Lead to constraints on GPD at large -t and x which differ from electromagnetic form factors



Polarization observables: WACS in GPDs handbag calculations

$$K_{LL}\frac{d\sigma}{dt} \equiv \frac{1}{2}\left[\frac{d\sigma(\uparrow\uparrow)}{dt} - \frac{d\sigma((\downarrow\uparrow)}{dt}\right] \qquad K_{LS}\frac{d\sigma}{dt} \equiv \frac{1}{2}\left[\frac{d\sigma(\uparrow\rightarrow)}{dt} - \frac{d\sigma(\downarrow\rightarrow)}{dt}\right]$$

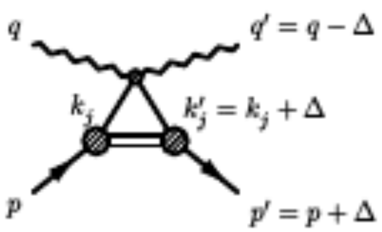
$$K_{LL}^{KN} = \frac{s^2 - u^2}{s^2 + u^2}$$

KN, structureless Dirac particle

$$\frac{K_{LL}}{K_{LL}^{KN}} = \frac{R_A}{R_V}\left[1 - \frac{t^2}{2(s^2+u^2)}\left(1 - \frac{R_A^2}{R_V^2}\right)\right]$$

$$\frac{K_{LS}}{K_{LL}} \approx \kappa(t)\,\frac{1+\beta\kappa^{-1}(t)}{1-\beta\kappa(t)} \qquad \beta = \frac{2m}{\sqrt{s}}\,\frac{\sqrt{-t}}{\sqrt{s}+\sqrt{-u}} \qquad \kappa(t) = \frac{\sqrt{-t}}{2m}\,\frac{R_T(t)}{R_V(t)}$$

K_{LL} measured to be large and > 0, in contradiction to pQCD where it is posited to be small and negative. Does this suggest, with Compton dσ/dΩ data, that pQCD at 5-10 GeV in exclusive processes is not to be applied?



Helicity Amplitudes of WACS

Kroll's approach

Justification to show how K_{LL} and A_{LL} are related, much approximated, cont on next slide

μ(ν), μ'(ν') are light-cone helicity of in and out photons (proton)

$$\mathcal{M}_{\mu'+,\mu+}(s,t) = 2\pi\alpha_{\text{em}}\left[\mathcal{H}_{\mu'+,\mu+}(s,t)\left(R_V(t)+R_A(t)\right) + \mathcal{H}_{\mu'-,\mu-}(s,t)\left(R_V(t)-R_A(t)\right)\right]$$

$$\mathcal{M}_{\mu'-,\mu+}(s,t) = -\pi\alpha_{\text{em}}\frac{\sqrt{-t}}{m}\left[\mathcal{H}_{\mu'+,\mu+}(s,t) + \mathcal{H}_{\mu'-,\mu-}(s,t)\right] R_T(t)$$

Symmetric frame helicity amplitudes in terms of contribution subprocess amplitudes and Compton form factors

+, - on M, T are helicity of in and out proton and quark

$$\Phi_{\mu'\nu',\mu\nu} = \mathcal{M}_{\mu'\nu',\mu\nu} + \beta/2\left[(-1)^{1/2-\mu'}\mathcal{M}_{\mu'-\nu',\mu\nu} + (-1)^{1/2+\mu}\mathcal{M}_{\mu'\nu',\mu-\nu}\right] + \mathcal{O}\left(\Lambda^2/t\right)$$

Ordinary photon-proton cm helicity basis

Generic notation for six independent helicity amplitudes

$$\Phi_1 = \Phi_{++++},\ \Phi_3 = \Phi_{-+++},\ \Phi_5 = \Phi_{+-+-},$$
$$\Phi_2 = \Phi_{--++},\ \Phi_4 = \Phi_{+-++},\ \Phi_6 = \Phi_{-++-}.$$

$$\Phi_2 = -\Phi_6 + \mathcal{O}\left(\Lambda^2/t\right)$$

$$K_{LL}\frac{d\sigma}{dt} = \frac{1}{32\pi(s-m^2)^2}\left[|\Phi_1|^2 - |\Phi_2|^2 - |\Phi_5|^2 + |\Phi_6|^2\right]$$

Correlation between the helicity of incoming photon and outgoing proton

Relating Polarized Observables

$$A_{LL}\frac{d\sigma}{dt} = \frac{1}{32\pi(s-m^2)^2}\left[|\Phi_1|^2+|\Phi_2|^2-|\Phi_5|^2-|\Phi_6|^2\right]$$

Correlation of the photon and target proton in the initial state

$$= \frac{\pi\alpha_{em}^2}{2(s-m^2)^2}R_A\Big\{R_V\left[1-\beta_K\right]\left[|\mathcal{H}_{++++}|^2-|\mathcal{H}_{+-+-}|^2\right]$$
$$+R_V^g\left(\mathcal{H}_{++++}^{LO}-\mathcal{H}_{+-+-}^{LO}\right)\mathrm{Re}\left(\mathcal{H}_{++++}^g+\mathcal{H}_{+-+-}^g\right)\Big\}.$$

$$K_{LL}\frac{d\sigma}{dt} = \frac{1}{32\pi(s-m^2)^2}\left[|\Phi_1|^2-|\Phi_2|^2-|\Phi_5|^2+|\Phi_6|^2\right],$$

since $\Phi_2=-\Phi_6$ in the handbag approach

$$A_{LL}=K_{LL}$$

Spin averaged $\frac{d\sigma}{dt}$ factorizes into product of $\frac{d\sigma}{dt}_{KN}$ and $\sum R_i(t)$

Relating Polarized Observables

Similarly for the correlation between the helicity of the incoming photon and sideways target polarization

$$A_{LS}\frac{d\sigma}{dt} = \frac{1}{2}\left[\frac{d\sigma(\uparrow\rightarrow)}{dt} - \frac{d\sigma(\downarrow\rightarrow)}{dt}\right]$$

$$= \frac{1}{16\pi(s-m^2)^2} Re\left[(\Phi_1 - \Phi_5)\Phi_4^* - (\Phi_2 + \Phi_6)\Phi_3^*\right]$$

$$= -\frac{\pi\alpha_{em}^2}{2(s-m^2)^2} R_A \left\{ \frac{\sqrt{-t}}{2m} R_T \left[1 + \beta_K^- 1\right]\left[|\mathcal{H}_{++++}|^2 - |\mathcal{H}_{+-+-}|^2\right] + \beta R_V^g \left(\mathcal{H}_{++++}^{LO} - \mathcal{H}_{+-+-}^{LO}\right) Re\left(\mathcal{H}_{++++}^g + \mathcal{H}_{+-+-}^g\right)\right\}$$

$$K_{LS}\frac{d\sigma}{dt} = \frac{1}{16\pi(s-m^2)^2} Re\left[(\Phi_1 - \Phi_5)\Phi_4^* + (\Phi_2 + \Phi_6)\Phi_3^*\right].$$

And the correlation between the helicity of the incoming photon and the sideway polarization of the outgoing proton

$$|A_{LS}| = |K_{LS}|$$

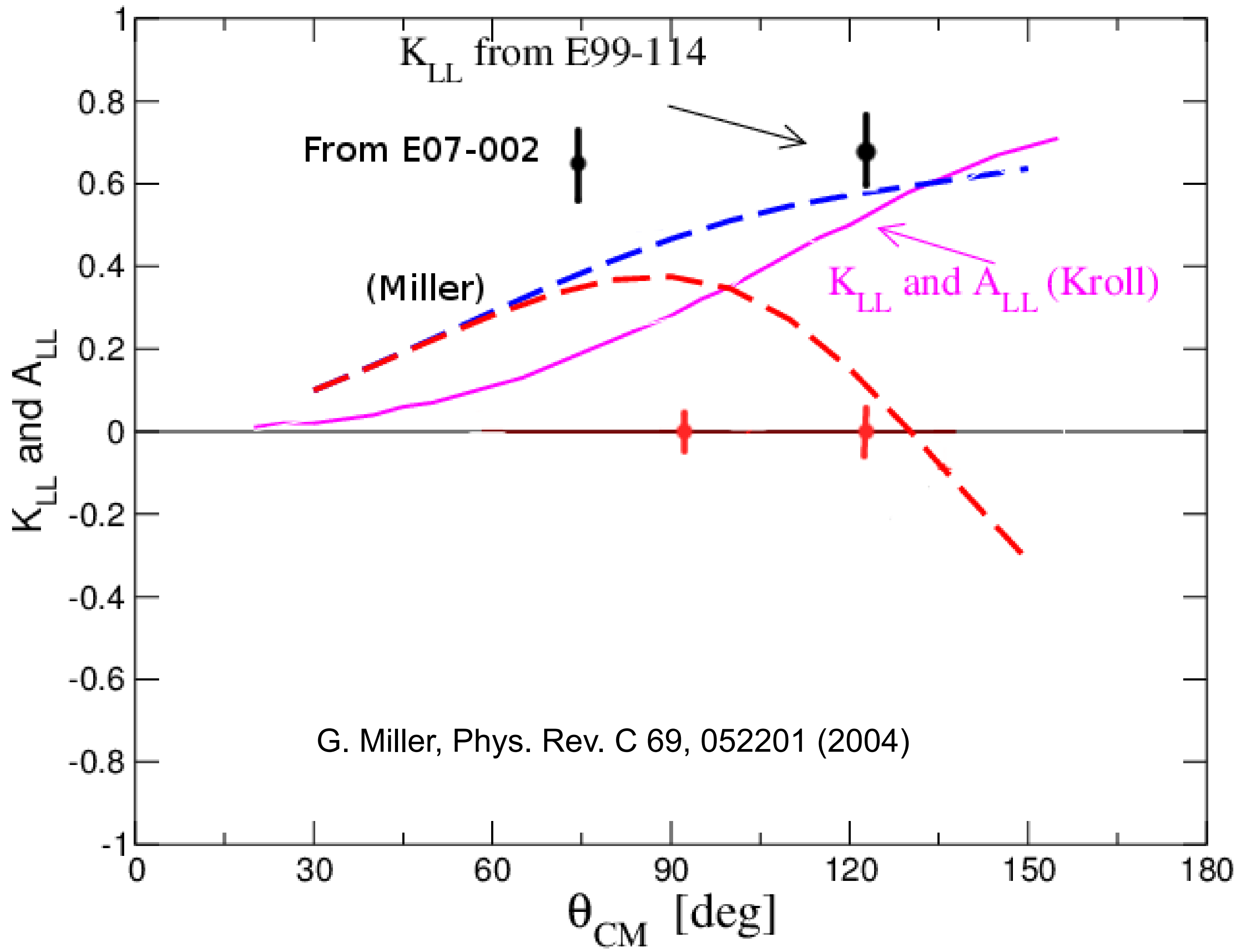
K_{LS} measured in agreement pQCD and handbag suggesting proton helicity flip in reaction. Our measurement of A_{LS} will confirm this equality and the weak s-dependence.

Constituent Quark Model

$A_{LL} \neq K_{LL}$

Millers Approach

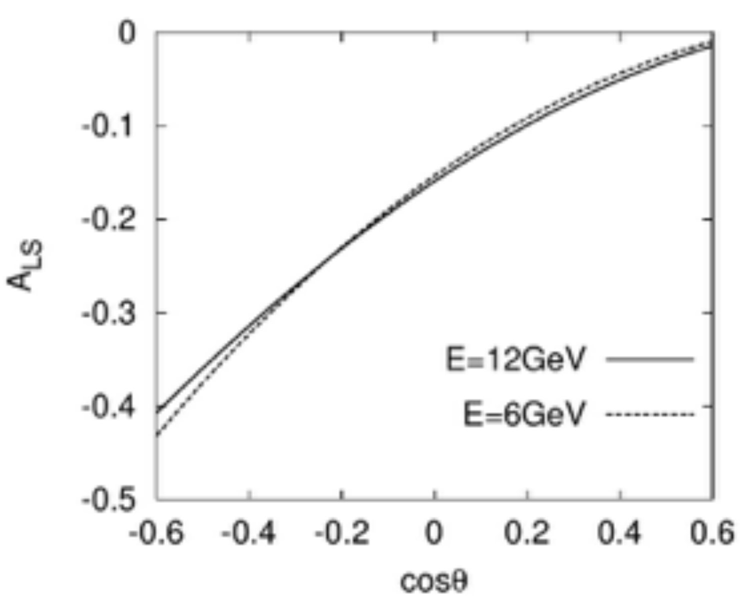
- still handbag
- quark mass contribution
- wave function ~ E/M FF
- Non-conservation of p-helicity
- Agreement with cross section
- Model only - need data to determine whether proton helicity conservation holds in WACS at a given energy



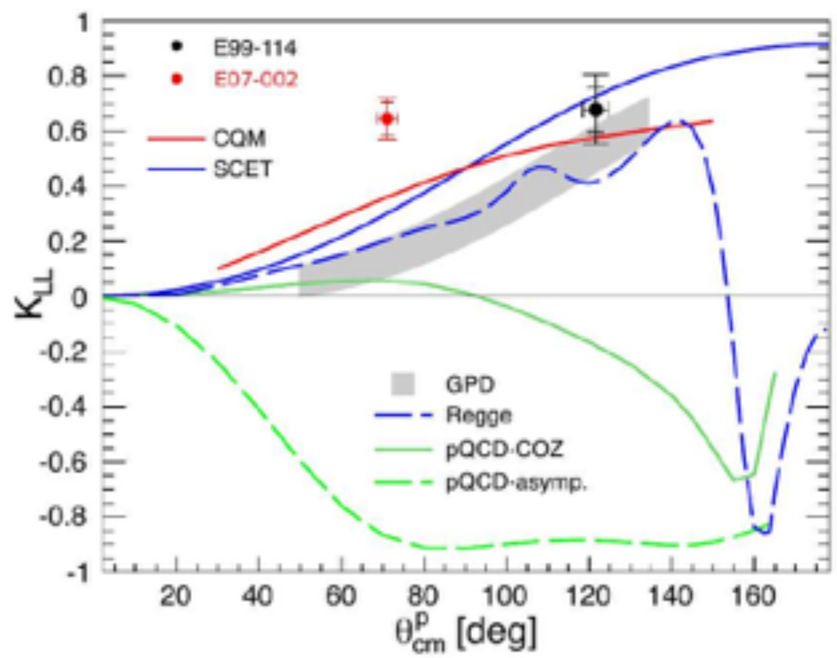
Impulse approximation evaluation of the handbag diagram using proton wave functions constrained by measured form factor and incorporate quark transverse and orbital-angular momentum leads very different values for A_{LL} and K_{LL}

Polarization Transfer in WACS

Experiment	(s,-t,-u)	K_{LL}	K_{LS}	
E07-002	(7.8,2.1,4.0)	0.645 (0.059)(0.048)	-0.089 (0.059)(0.040)	Θ_{cm}=70°
E99-114	(6.9,4.0,1.1)	0.678(0.083)(0.04)	0.114 (0.078)(0.040)	Θ_{cm}=120°



GPD: Huang and Kroll
CQM: Miller's K_{LL}
ASY: Brooks and Dixon
COZ: Chernyak-Ogloblin-Zhitnitsky
Regge: Cano and Laget (A_{LL})



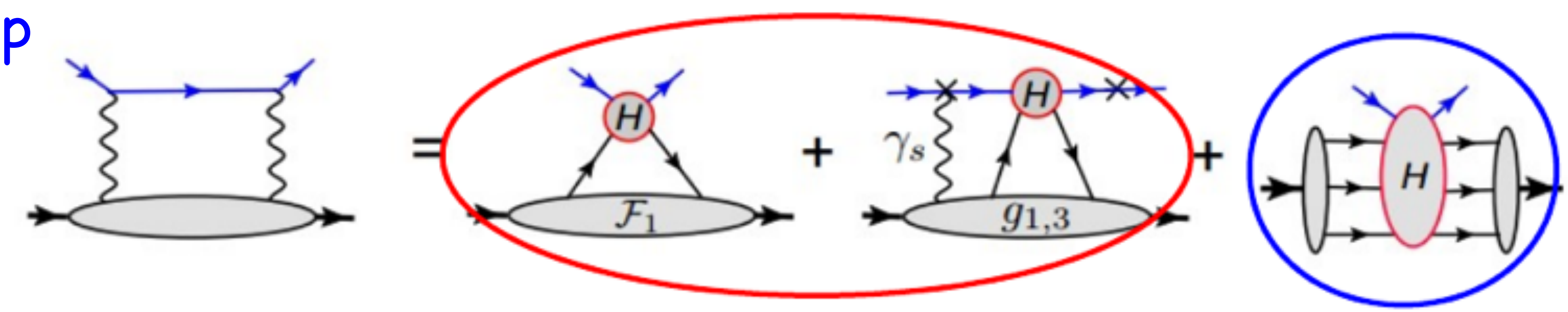
- The K_{LS} is in agreement within errors with calculations for both leading-quark and pQCD (evidence for proton helicity flip)
- The K_{LL} in E07-002 (Θ_{cm}=70°) is larger than all the available predictions (non=collinear effects, parton correlations, ...?)

Data from E07-002 is within the error bars of initial K_{LL} measurement

Soft Collinear Effective Theory

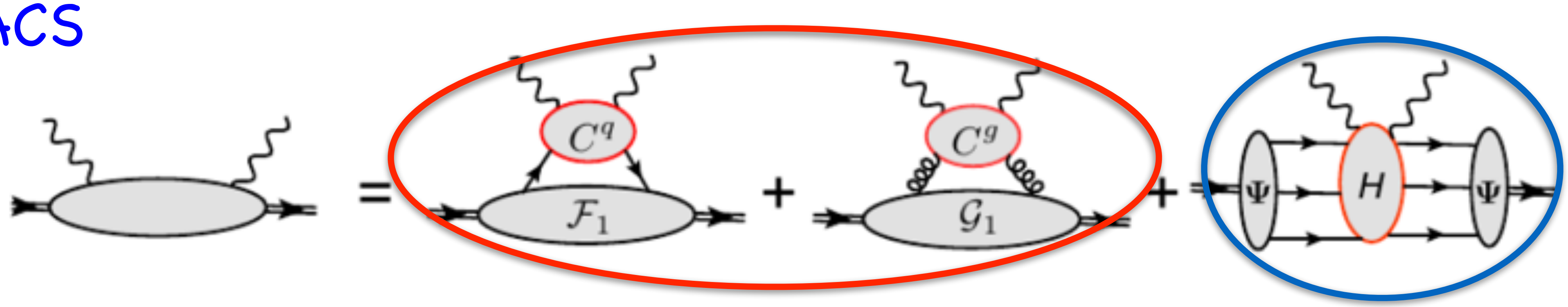
SCET is an effective theory for highly energetic quarks interacting with collinear or soft gluons
- The TPE corrections are calculated for large momentum scales relative to the soft hadronic scale
- QCD factorization formulated in SCET with soft-spectator scattering contribution need for the scale
- A complete factorization for TPE at leading power with logarithmic accuracy
- Same form factors arise for WACS

Elastic e-p



Soft spectator scattering contribution: Hard spectator scattering contribution:

WACS



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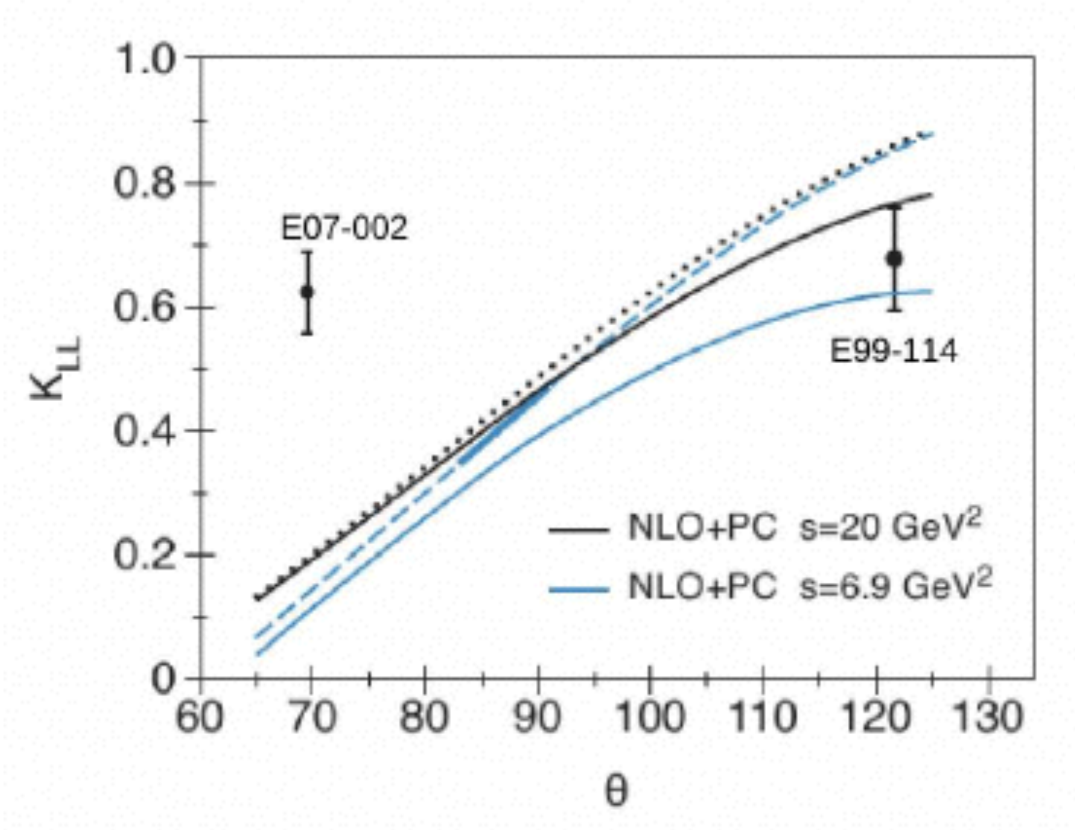
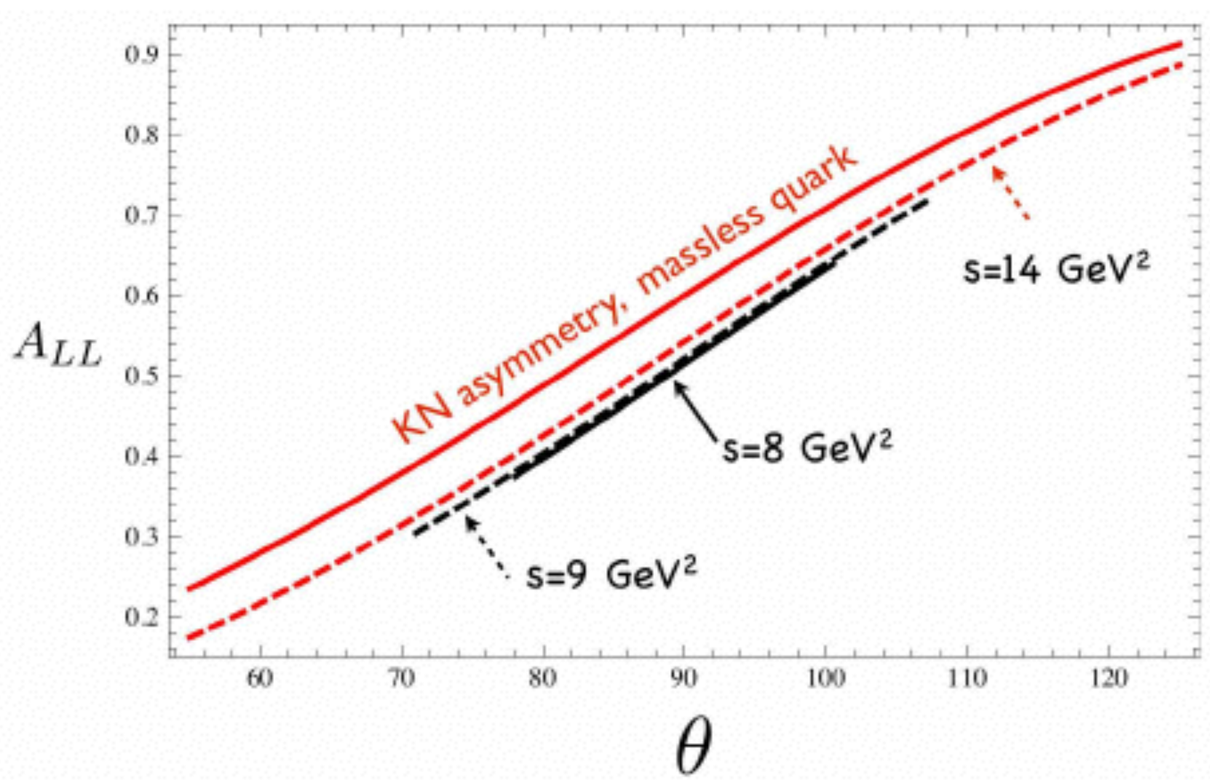
Soft Collinear Effective Theory

- The SCET approach is very relevant two-photon exchange in elastic ep as well as WACS
- In SCET $A_{LL}=K_{LL}$ to all orders in α_s
- SCET helicity flip amplitudes LO in α_s introduce 3 new non-perturbative matrix elements which require data to fix
- No substantive contribution from helicity flip effects
- s-dependence needs extreme values to provide constraints
- Uncertainty comes from power corrections
- Important to make measurement of K_{LL} and A_{LL} at same angle





Updates to the Handbag Approach

Kroll, private communication

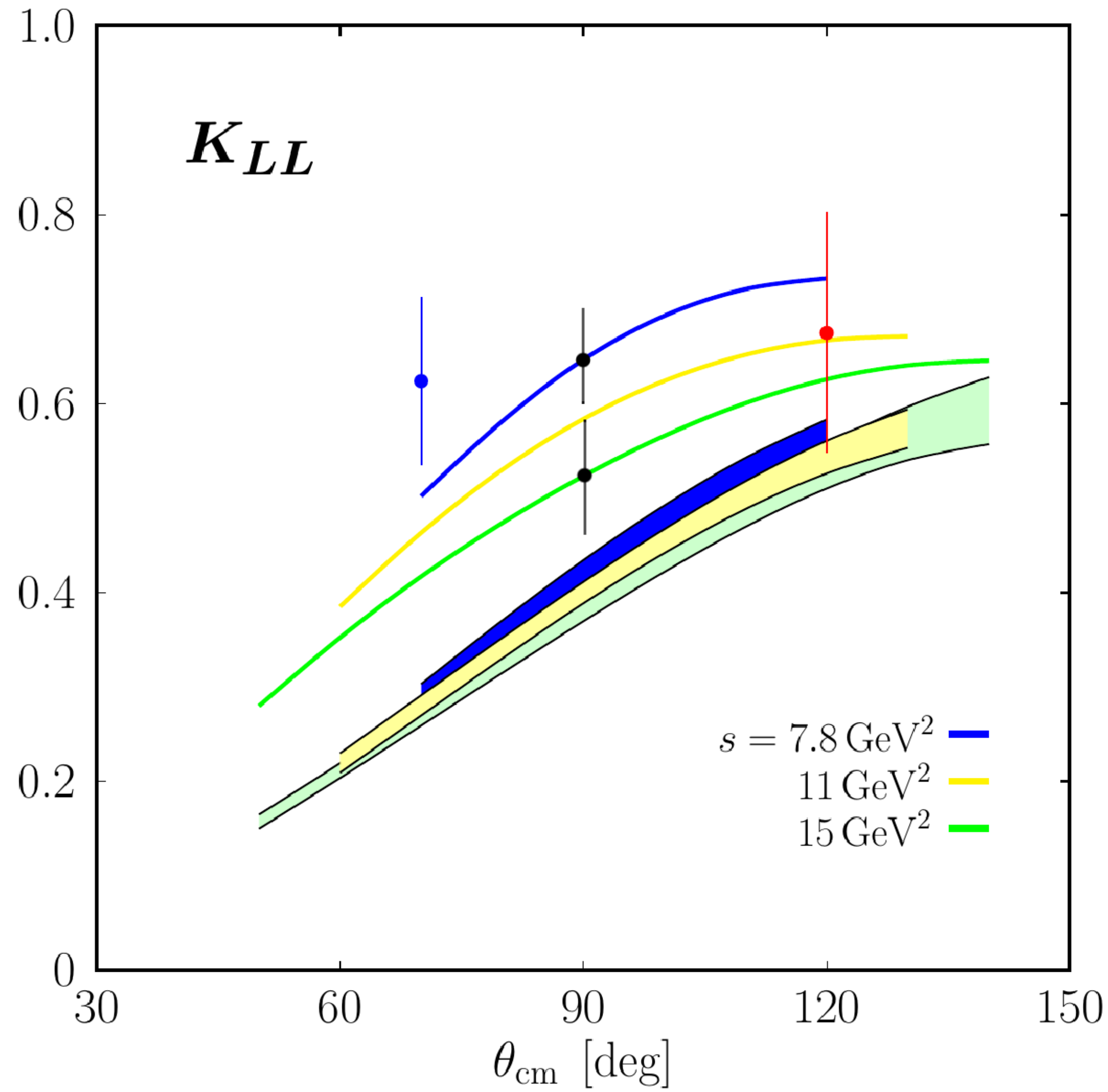


Figure 9: An example fit used in the hangbag approach to the data on the axial form factor and the two K_{LL} measured data points. The new results are indicated by the lines and the old predictions are indicated by the bands [13]. The results of the K_{LL} measurment from E02-007 are shown as the blue point and from E99-114 as the red point. Our proposed measurements at θ_{γ}^{cm}=90° are shown as the black points for 4.4 GeV and 8.8 GeV electron beam energy.

Preliminary Model (Kroll) based on the axial form factor and the polarization observables so far available. New results are lines.

Extracting Information

Measurements of K_{LL} and K_{LS}/K_{LL} are directly related to R_A/R_V and R_T/R_V

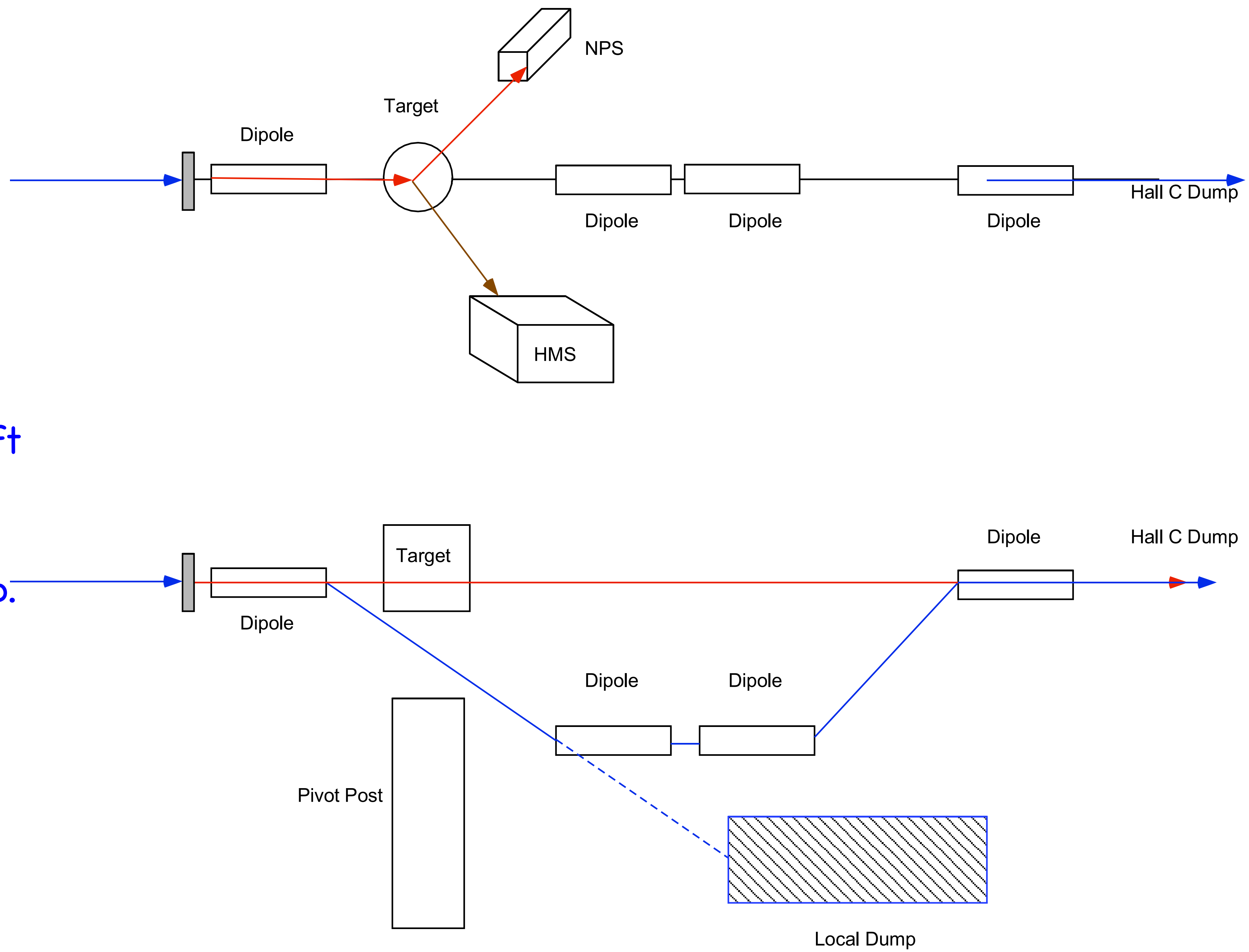
There is expected to be a close relationship between R_T/R_V and F_2/F_1 and R_A/R_V with $\Delta q^a(x)/q^a(x)$

Measurements of A_{LL} and A_{LS} tell us the same things if $A_{LL} = K_{LL}$ and $A_{LS} = K_{LS}$ and give essential phenomenology if not!

This would not only provide a crucial test of the handbag approach but at the same time may also help in improving the parametrization of the corresponding GPDs $\tilde{H}$ and E

Experiment Setup: PR12-16-009

1) Use Pure Photon Beam
2) 10% radiator
3) 3 uA beam current
4) FZ dipoles chicane
5) Electron beam goes under the target chamber, then either drift to a local dump in the hall or transported to the standard Hall C dump.
6) Target Field at (0, 0, 5° for longitudinal and 275° transverse

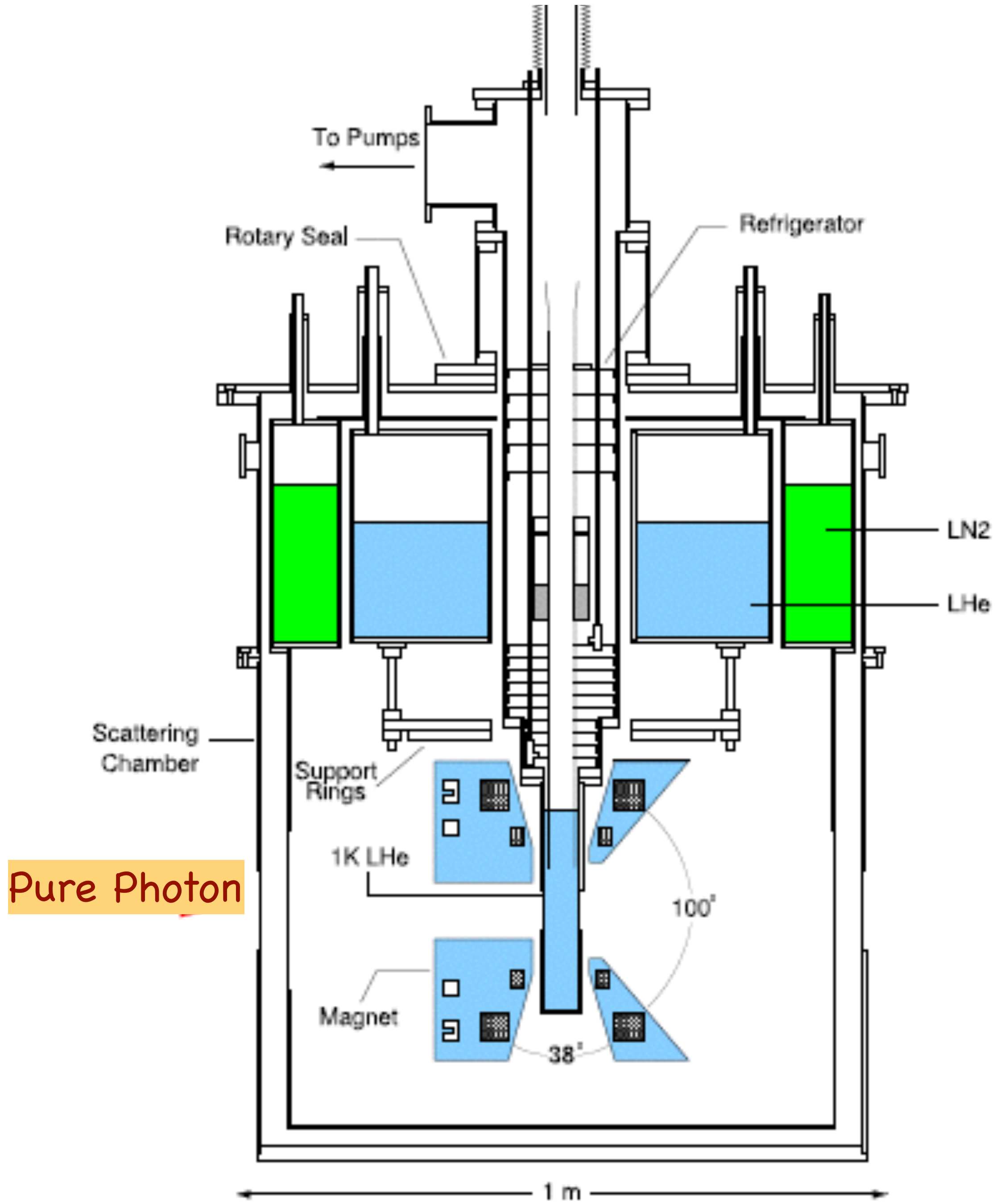


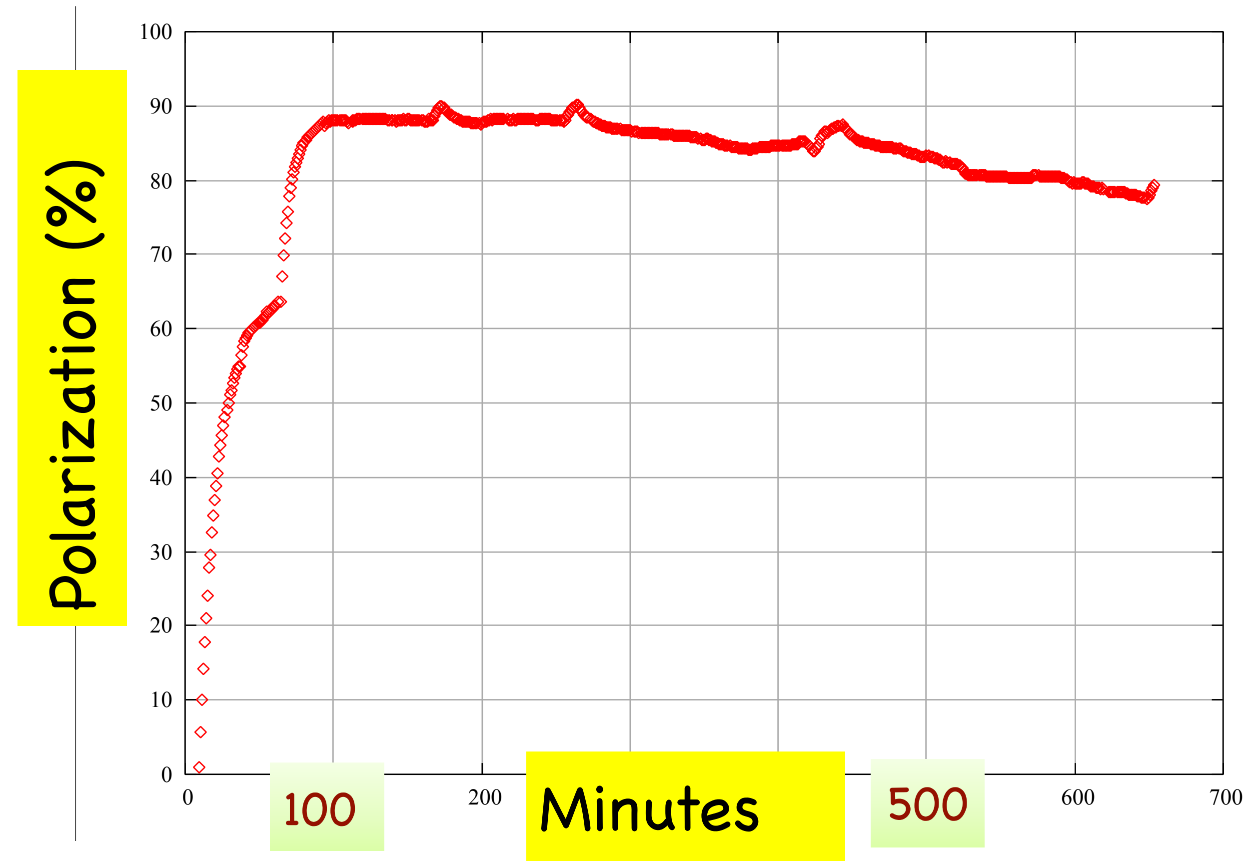
Flux from 6% smaller than 10% by 20%

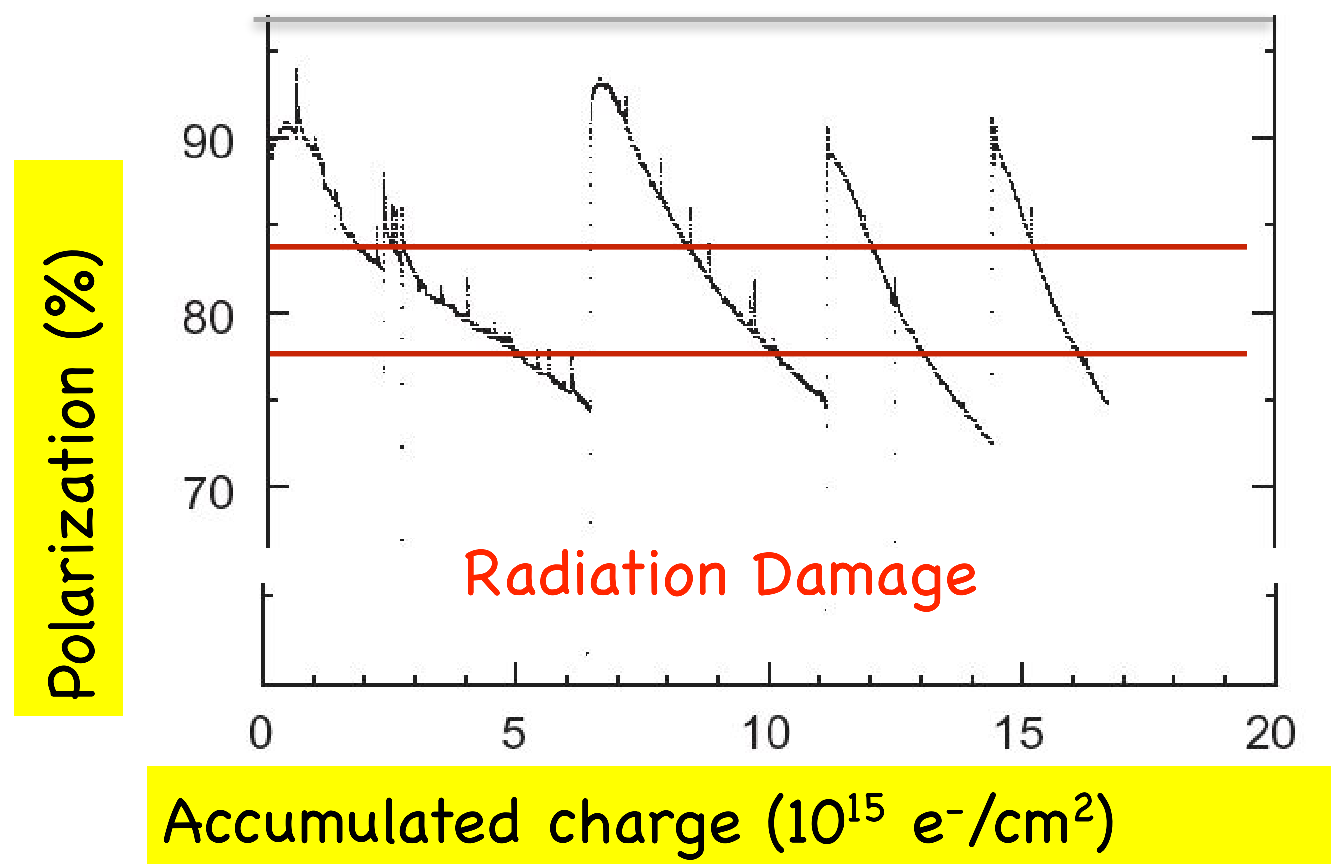
Polarized Target

Solid polarized proton target, NH_3

- ^4He evaporation refrigerator
- 5 T polarizing field
- Dynamic Nuclear Polarization

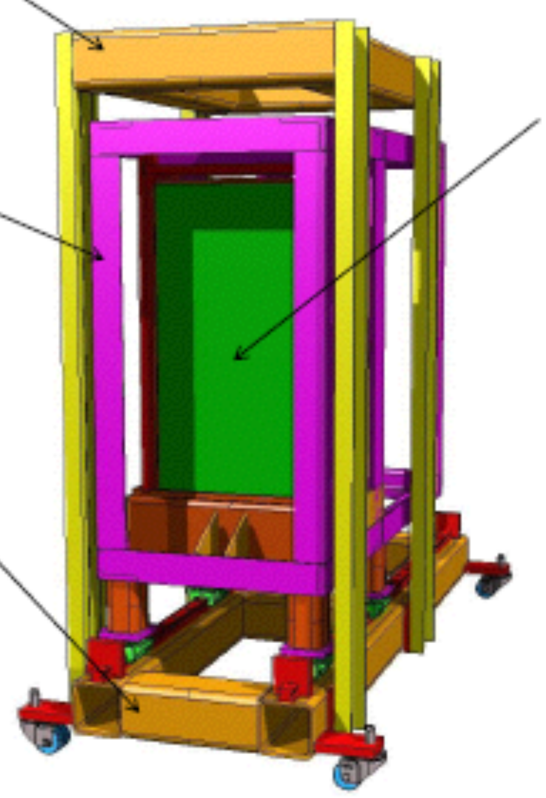






We expect that at 3 μA, rate of decline reduced by factor of ~3

Neutral Particle Spectrometer



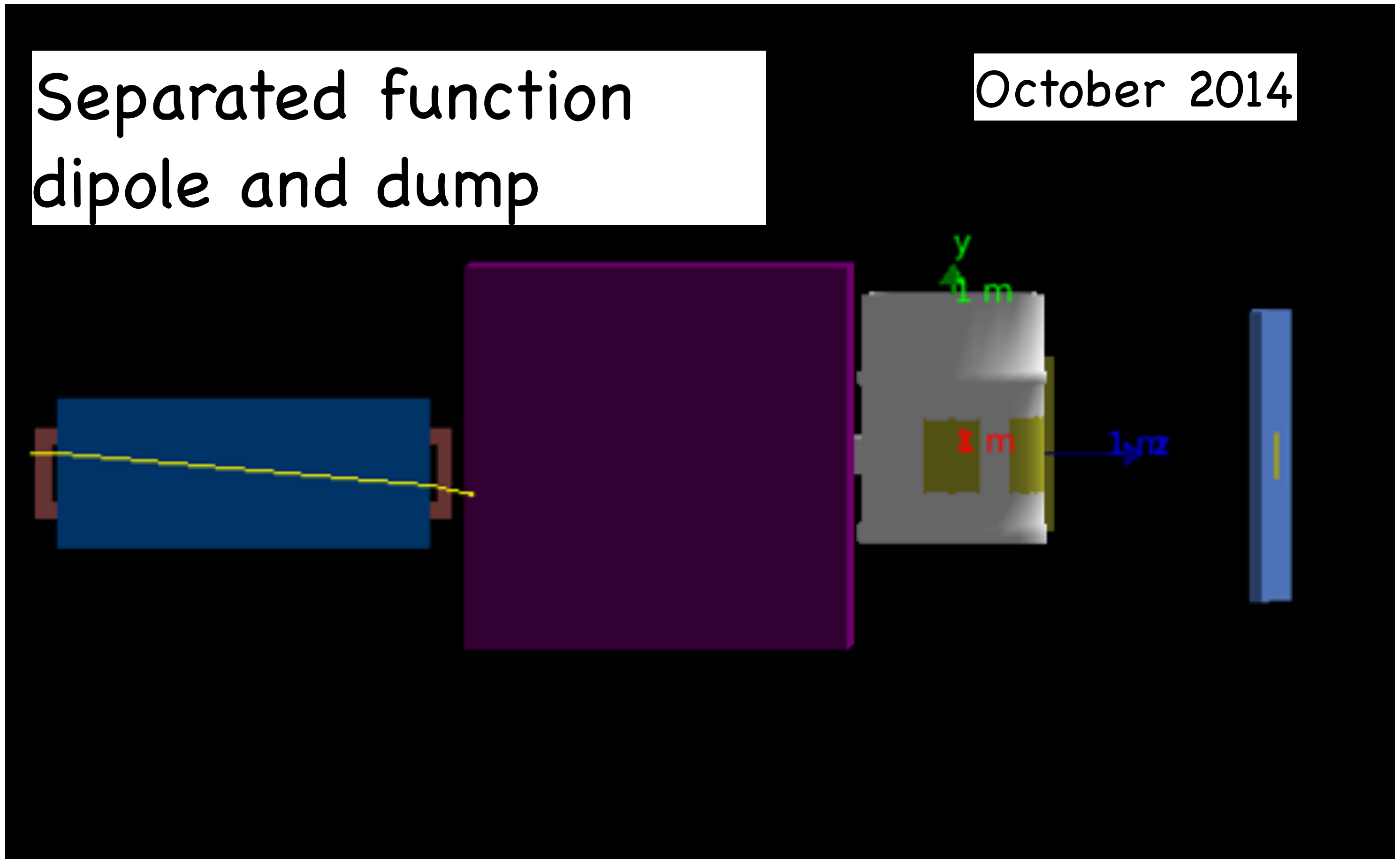
- Energy Resolution: high light yield, best available crystals
- Coordinate resolution: find granularity. small Moller radius, best 2 x 2 cm^2 or 3 x 3 cm^2
- Angular resolution: combine fine granularity with distance from target

NPS will enveloped by an iron box to suppress fringe magnetic degradation of PMT performance

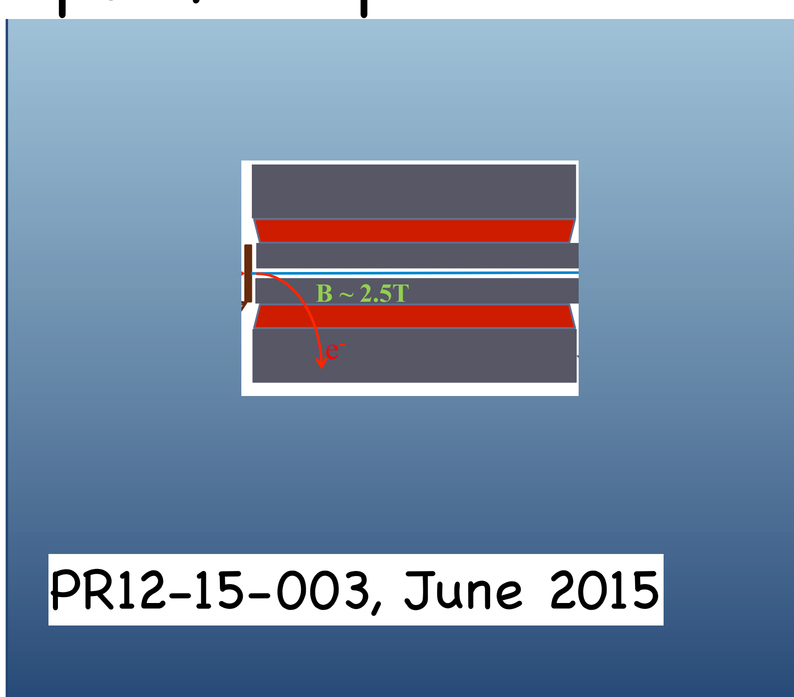
We assume 3mm position and 3% energy resolution; to fully exploit position resolution spot on target needs to be known with +/- 2mm

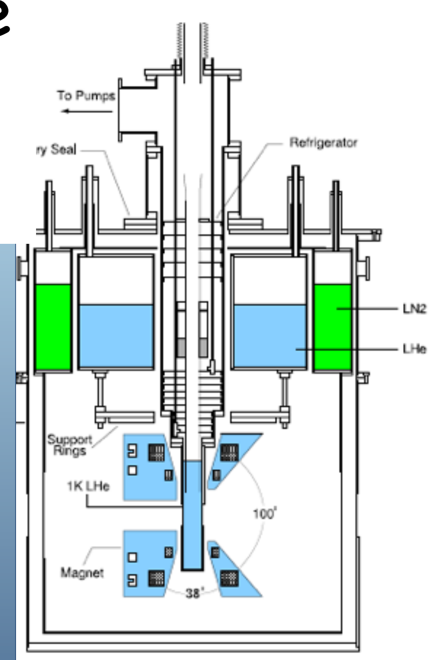
Parameters	Distance (m)	Position Res.(mm)	Angular Res.(mrad)	Energy Res. (% /√E)
E12-13-010(DVCS)	3-6	3-4	1-2	5-6
Pol.3He-DVCS	3-4	3-4	1-2	6
E12-12-009(WACS)	3-5	3-4	1-2	5
E12-13-010(DES π^o)	4	2-3	0.5-0.75	2-3
E12-13-007(SIDIS π^o)	4	2-3	0.5-0.75	2-3
E12-14-006(Pol.WACS)	1-5	2-3	2-3	2-3
PR12-16-009(Tran. WACS)	2-3	2-3	1-1.5	2-3

Pure Photon Source



Compact Photon Source
Combined Function
dipole/dump

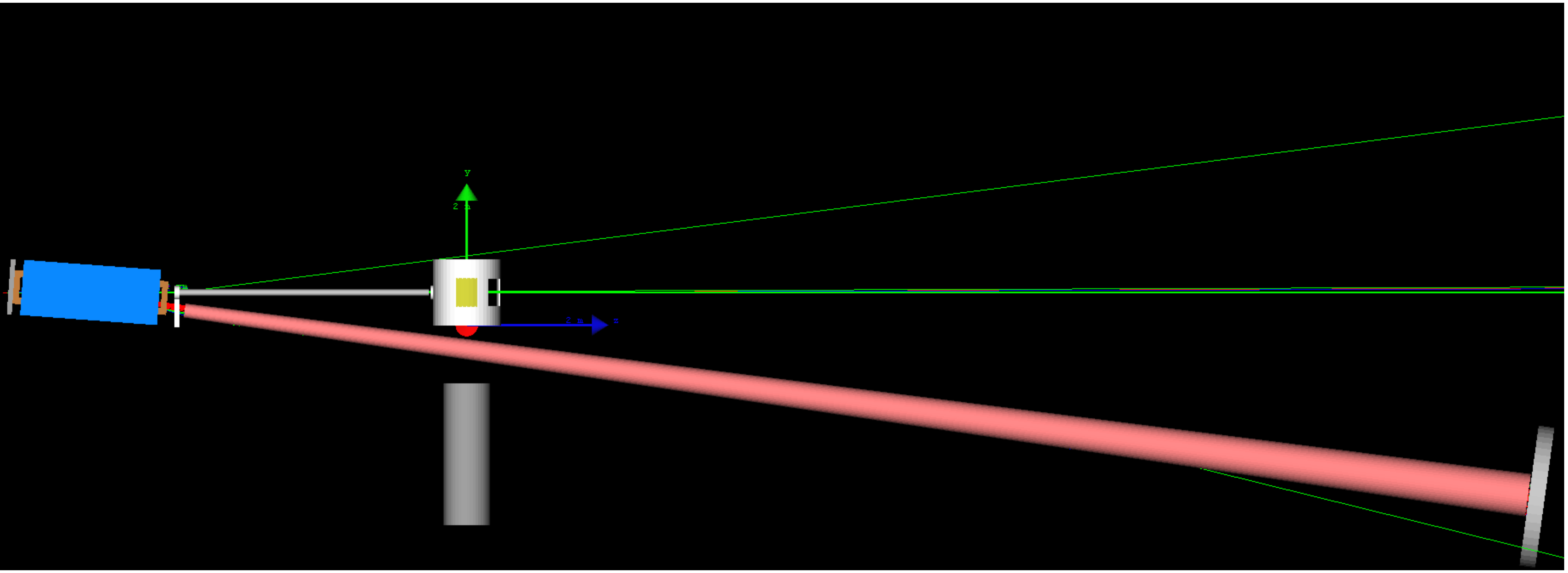




A beam dump at the target only if there are absolutely no other possible choices!

Target hangs on a platform above the pivot post

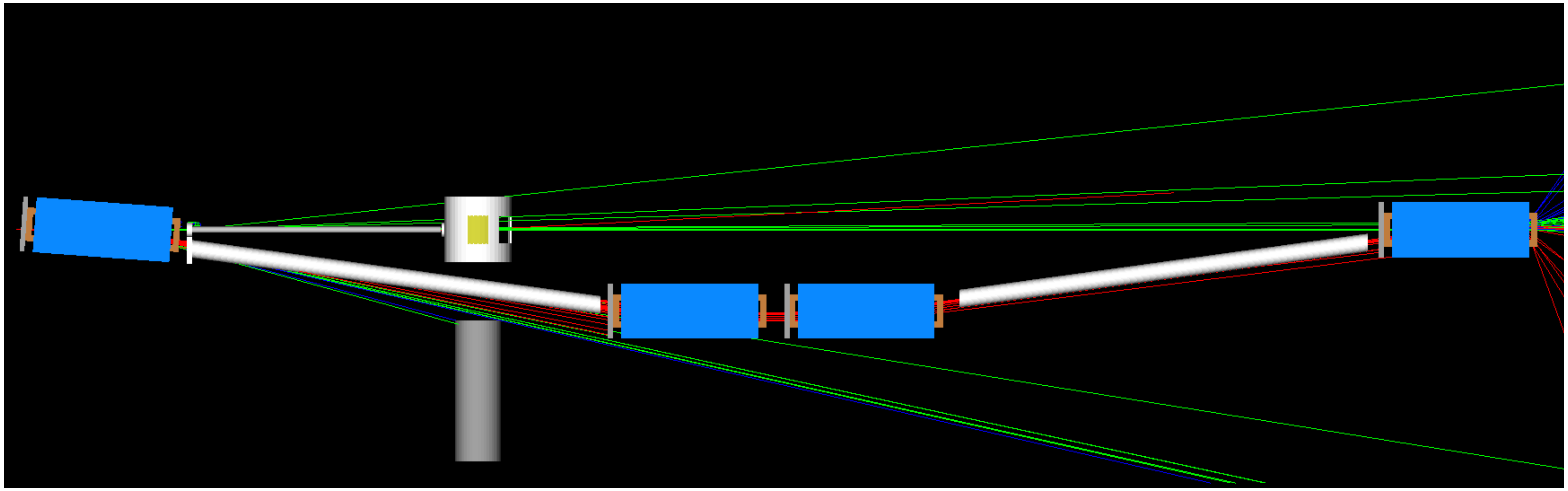
Move the dump 20 meters downstream



- Dipole ends 4.3m upstream of target.
- Large space available to shield radiator, collimator, beam pipe - no possibility of charged particles to be transported by HMS
- No disruptive magnetic forces on target.
- Opportunity for radiation exposure minimized.
- Distance and shielding minimizes singles background in NPS.
- Hermetic local dump can be made with as many meters of material as necessary - the 'green blocks' - the space exists.

10% (19%) of beam power lost in radiator/dipole/collimator/beam pipe
90% (81%) of beam power in local dump and Hall C dump NS 7%

Transport beam to Hall C dump



- Dipole ends 4.3m upstream of target.
- Large space available to shield radiator, collimator, beam pipe - no possibility of charge particles to be transported by HMS
- No disruptive forces on target.
- Opportunity for radiation exposure minimized
- Distance and shielding minimizes singles background in NPS.
- Ample space to shield beam line - primarily the absorbers at each dipole

4.5% (9%) of beam power is deposited in radiator/first dipole/collimator
75% (60)% of beam power in Hall C dump (last dipole, 11 and 17%)

NS 7%

Pure Photon Source Performance

Photon Flux

Spot size +/- 2mm
$0.5E_e / < E_\gamma < 0.9E_e$

E	I	RL	D	Lost	γ/s
4.4	3.0 uA	10%	633cm	71.6%	3.0E11
8.8	3.0 uA	10%	633cm	40.6%	6.6E11

Power Deposition

Ebeam (MeV)	Radiator length(%)	Power deposit 1uA beam (Watts)
4400	6	0.009
4400	10	0.015
8800	6	0.024
8800	10	0.035

Past use pf PT: electrons @ 100nA, 0.36 W are deposited in target: 10 times more than from the photon flux generated by 1 μA on a 10% radiator!

If cooling power was only issue we could put 8-10 μA on radiator to illuminate the PT: target would operate "normally".

The RCS Event Rate

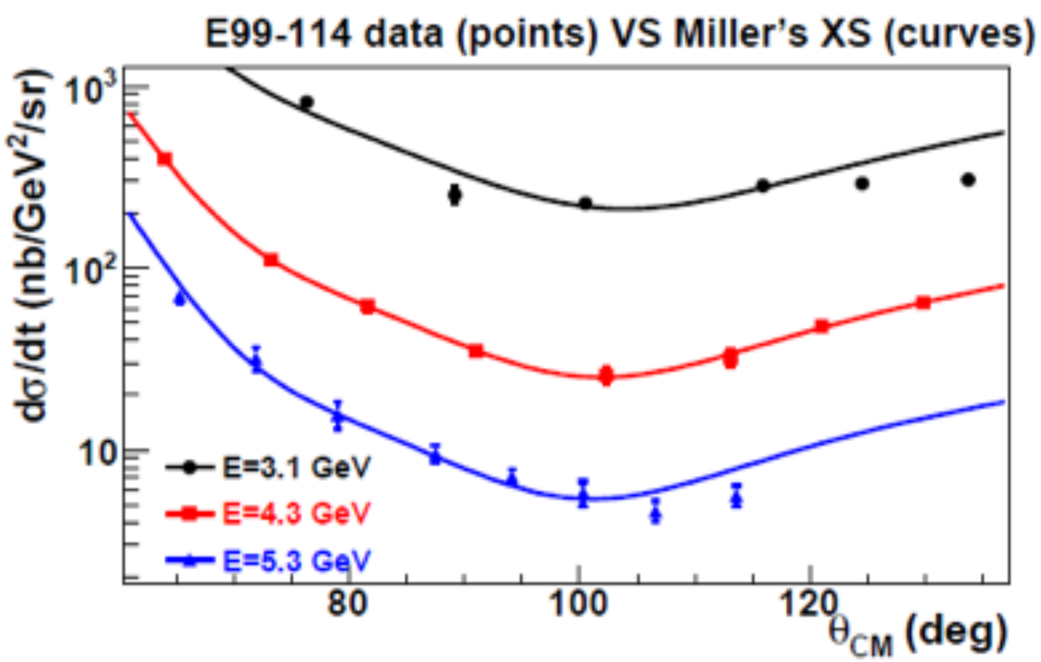
$$N_{RCS} = \frac{d\sigma_{RCS}}{dt} \frac{(E_\gamma^f)^2}{\pi} Q_{\gamma p}^{lab} F_\gamma L_{ep}$$

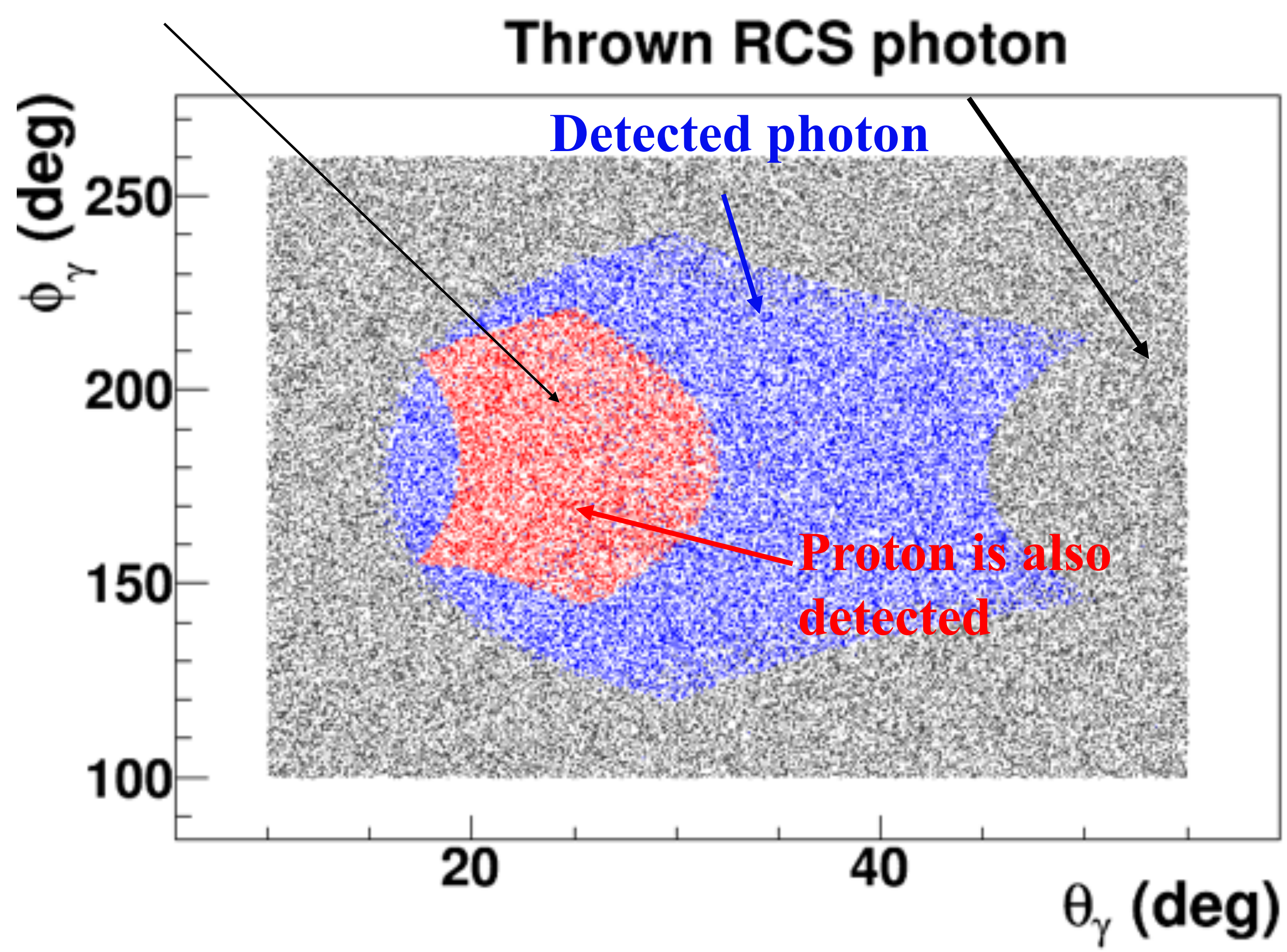
photon# per electron

L_{ep}= electron-target luminosity

From Modified Miller's Model

Red region is the solid angle of the photon detector where the corresponding recoil proton are also detected by the proton arm



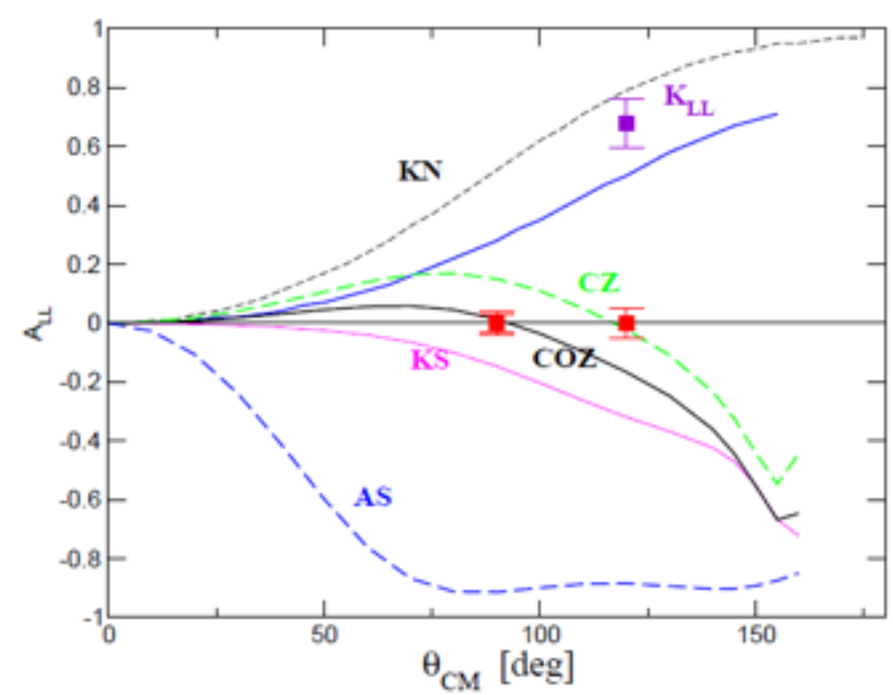


Proposed Kinematics: E12-16-009

kin. P#	Beam GeV	θ_γ^{cm} deg	θ_{field} deg	θ_γ^{lab} deg	θ_p^{lab} deg	$< E_\gamma^{lab} >$ GeV	P_p GeV/c	L cm	H cm	threshold GeV
P4	4.4	90	0	39	31	3.49	2.40	300	15.9	1.5
P5	8.8	90	0	29	26	6.83	4.00	300	7.2	2.5
P6	8.8	120	-5	47	15.5	6.78	5.80	200	6.8	1.5
P7	8.8	120	275	47	15.5	6.90	5.80	200	17.8	1.5

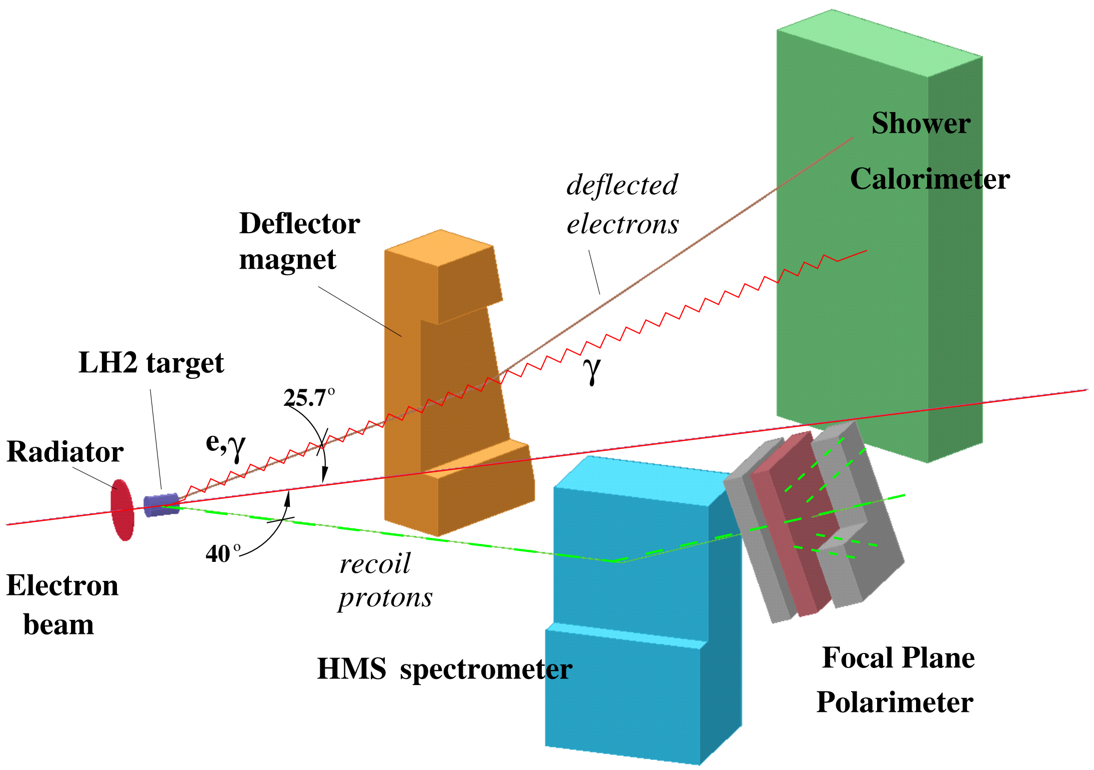
kin. P#	Beam GeV	θ_γ^{cm} deg	θ_{field} deg	time hour	D	stat.	δA_{LL}	s (GeV/c)^2	$-t$ (GeV/c)^2	$-u$ (GeV/c)^2
P4	4.4	90	0	58	3.4	13172	3.0%	7.6	3.0	2.8
P5	8.8	90	0	292	4.5	9814	4.0%	13.6	5.9	6.0
P6	8.8	120	-5	106	4.0	5596	5.0%	13.6	9.0	3.0
P7	8.8	120	275	158	4.1	5724	5.0%	13.6	9.0	3.0

We propose to measure A_{LL} at θ_{CM}=90° for s=7.6 and s= 13.6 GeV^2, and A_{LL} and A_{LS} at θ_{CM}=120° for s=13.6 GeV^2.

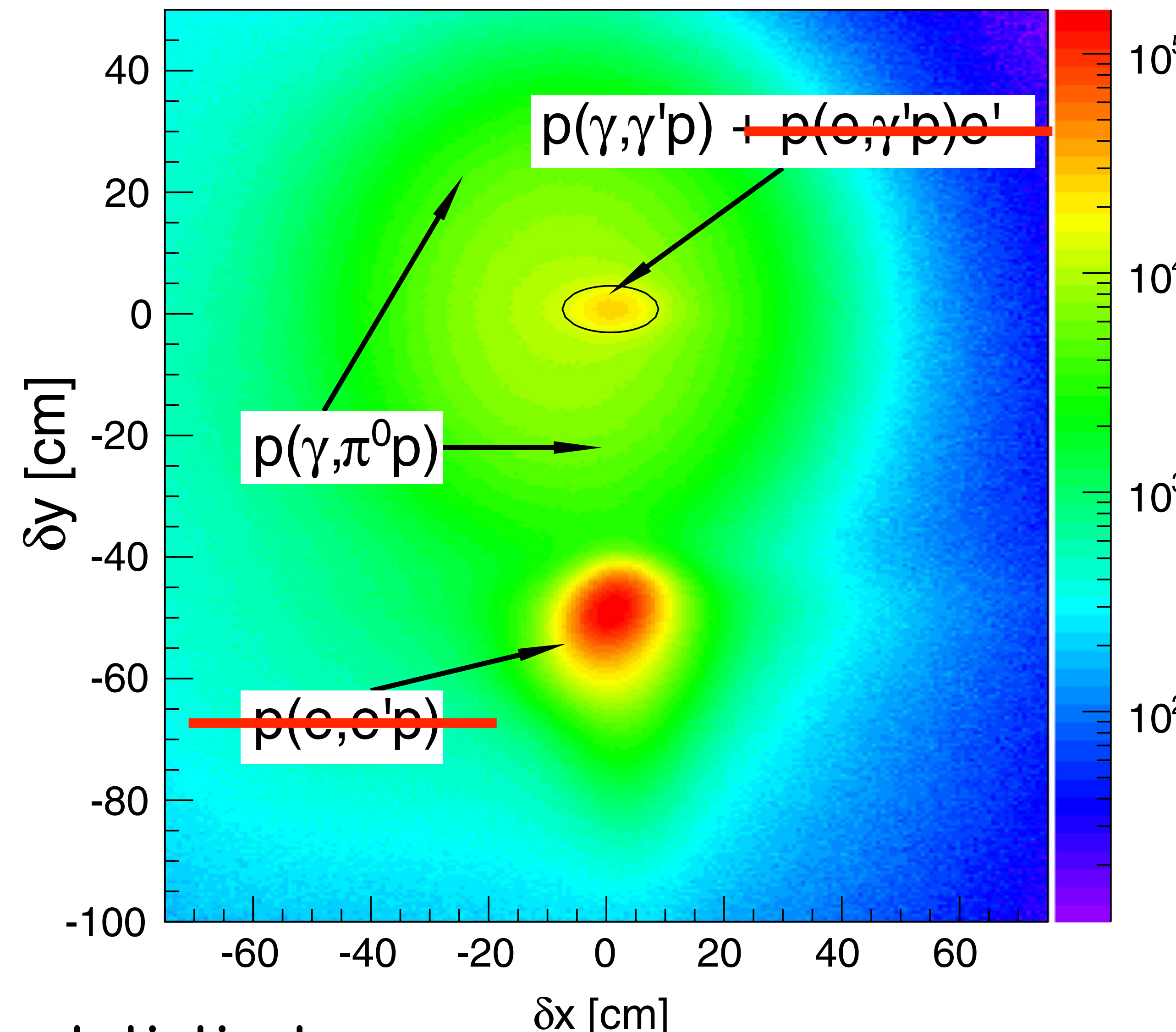


Data Analysis

Approach well established by E99-114 and E07-002

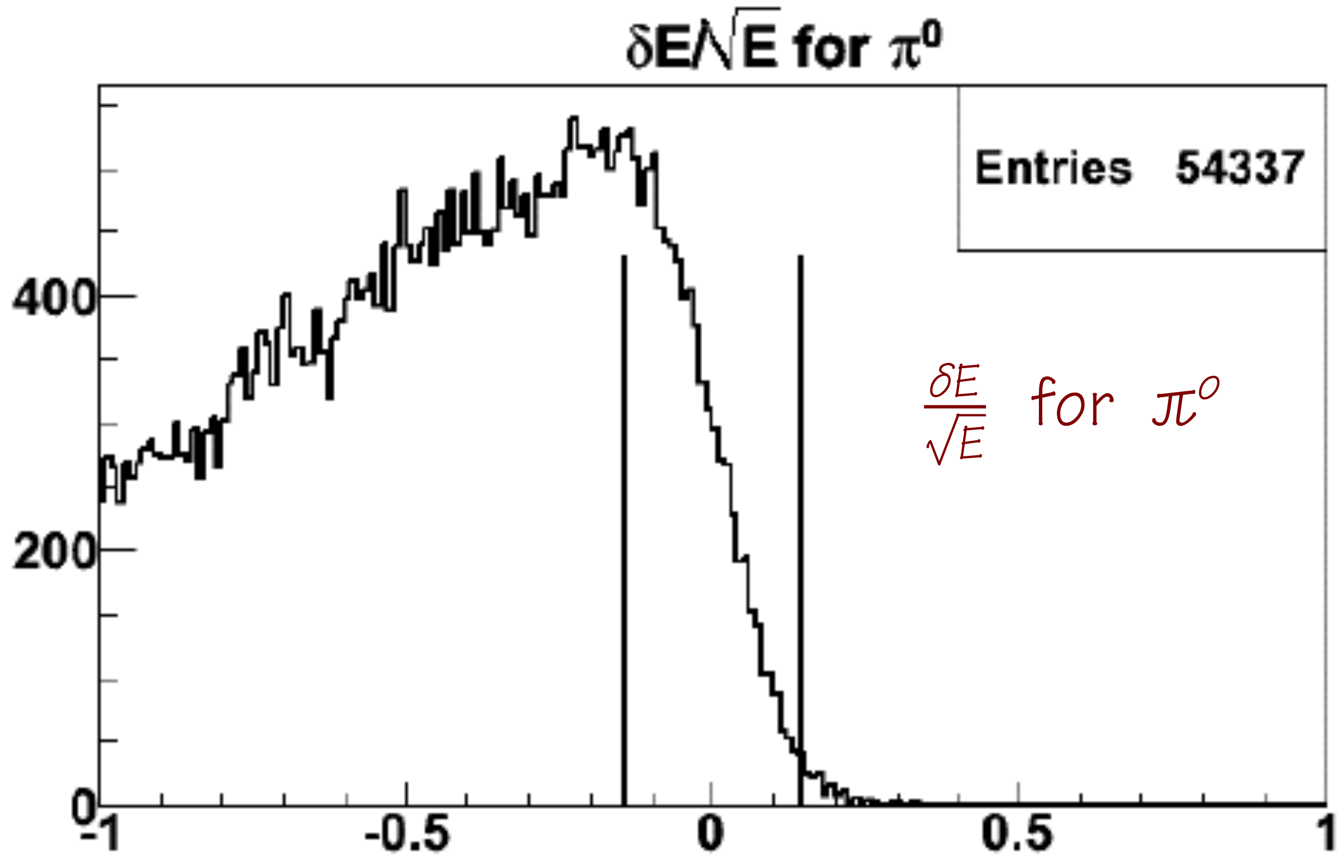


Fanelli et al., PRL 115, 152001 (2015)

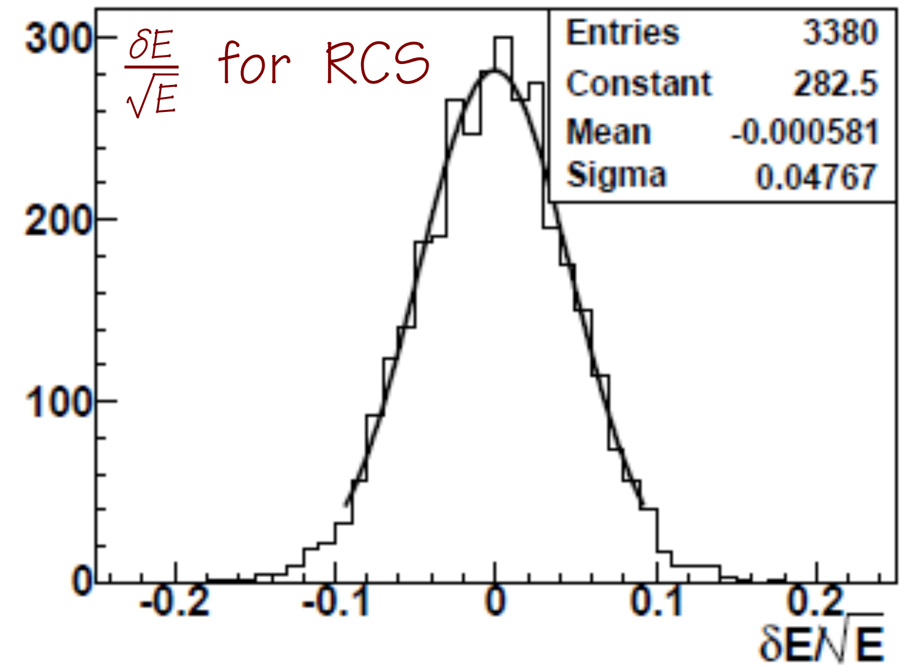


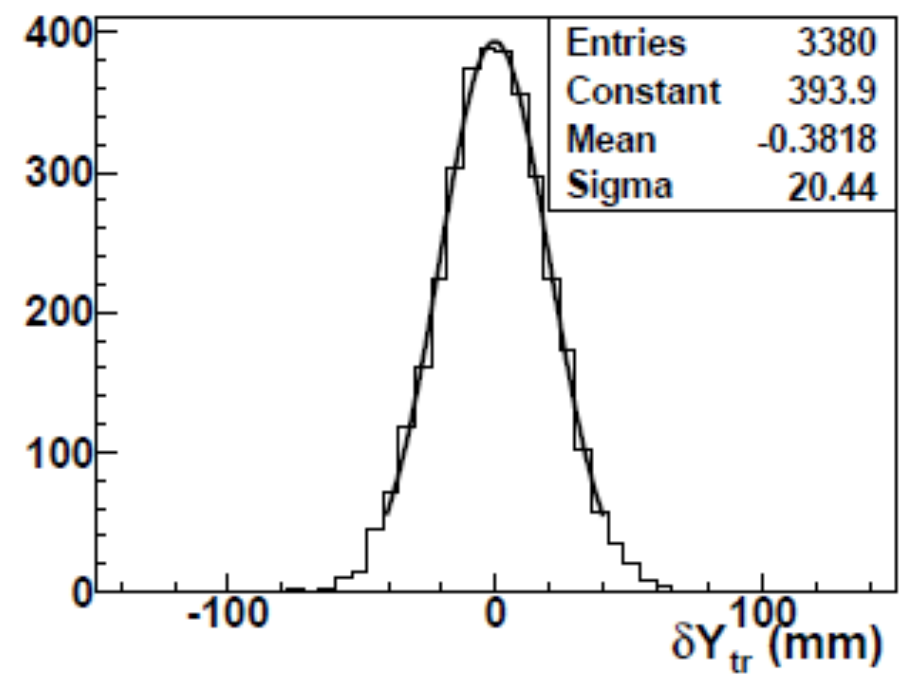
The π⁰s can not be separated except by statistical methods: they dilute the signal. We have addition dilution: Nitrogen in NH_3, helium in target. Fermi motion broadens these. We have long history accounting for dilution at SLAC (3x) and JLAB (5x).

Data Analysis



RCS events for P4





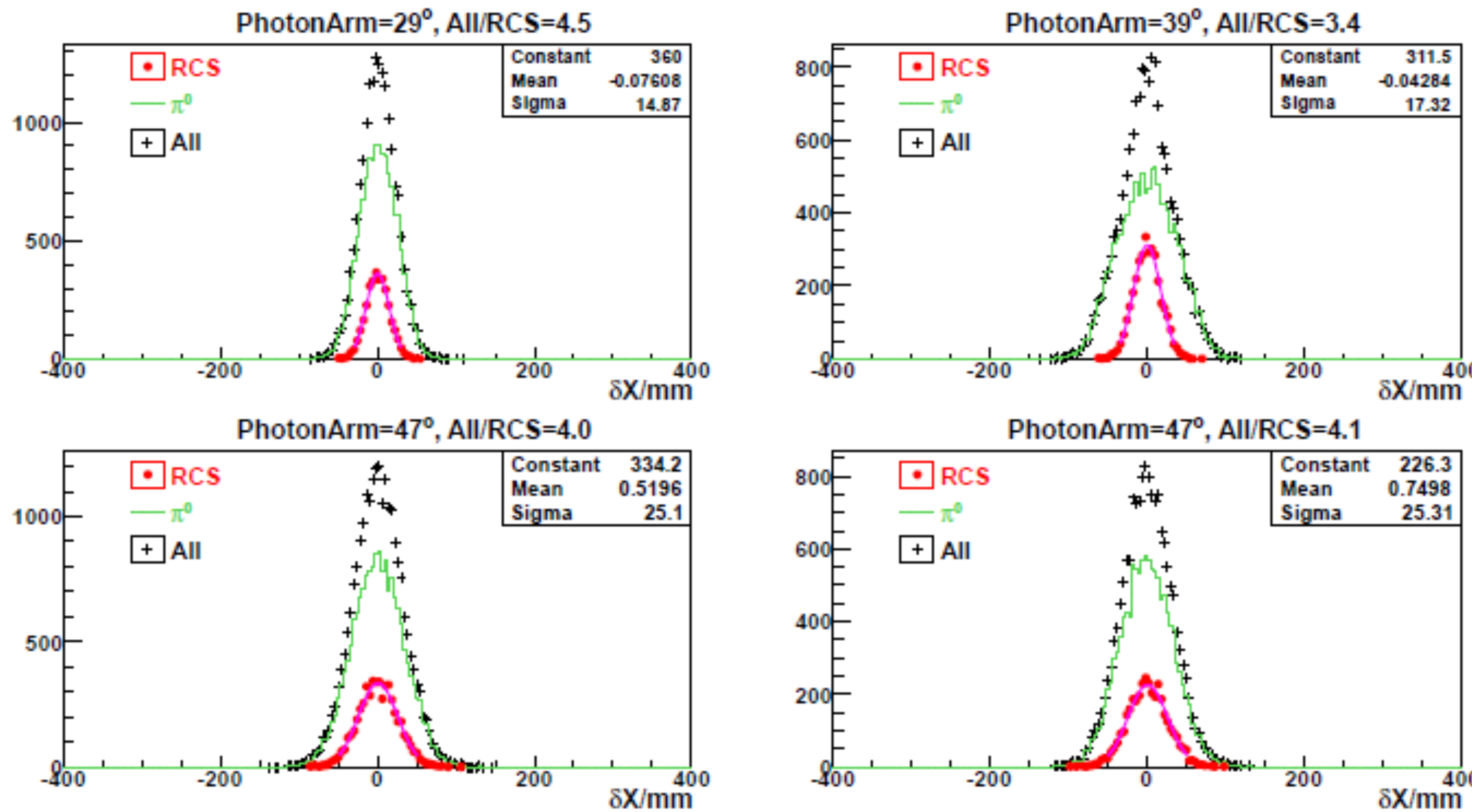
δY

Procedure:

1) Determine Proton initial momentum and vertex using HMS, then infer scattered photon's momentum
2) Using reconstructed vertex and inferred scattered photon momentum, predict the hit location in the NPS
3) Check NPS cluster, require both the deposited energy and hit location matched within 2-sigma.
4)π background can not be separated. Use statistical methods

dY: the difference between the measured RCS photon horiz. position and the inferred horiz. position.

Data Analysis: dX Distribution



dX: the difference between the measured RCS photon vertical position and the inferred vertical position.

After both dY and dE cuts; Fit Background and signal to set the dX resolution; determine dilution (D) of RCS events.

$$N_{RCS,required} = D/(P_e P_p f_{e\gamma} \Delta A_{LL})^2$$

To reduce uncertainty in the extracted real Compton events it is possible to use a boosted decision tree with multiple discriminating variables. A decision tree is a binary tree structure classifier which organizes the data into regions analyzing event by event.

Kinematics

	kin. P#	Beam GeV	θ_γ^{cm} deg	θ_{field} deg	time hour	D	stat.	δA_{LL}	s $(GeV/c)^2$	$-t$ $(GeV/c)^2$	$-u$ $(GeV/c)^2$
A_{LL}	P4	4.4	90	0	58	3.4	13172	3.0%	7.6	3.0	2.8
A_{LL}	P5	8.8	90	0	292	4.5	9814	4.0%	13.6	5.9	6.0
A_{LL}	P6	8.8	120	-5	106	4.0	5596	5.0%	13.6	9.0	3.0
A_{LS}	P7	8.8	120	275	158	4.1	5724	5.0%	13.6	9.0	3.0

Beam Request

Kin. P#	Procedure	beam, uA	time hours
P4	production	3	58
P5	production	3	292
P6	production	3	106
P7	production	3	158
	Packing Fraction	3	33
	Moller Measurements	1	42
	Data Beam Time		689
	Target Anneals		54
	Stick Changes		24
	Target commissioning		24
	Kinematics change		12
	BCM,BPM calibration		24
	HMS Optics		8
	Beamline commissioning		24
	Total Requested Time		835

Systematics

Source	Systematic
Target Polarimetry	3.0%
Beam Polarimetry	1%
Packing fraction	3%
Trigger/Tracking efficiency	1.0%
Background subtraction	3.0%
Total	$\sim 5\%$

Summary: Existing, Approved and this Proposal

Exp.#	$\theta_{CM}(^o)$	s(GeV^2)	-t(GeV^2)	-u(GeV^2)	Observables	
E99-114	120	6.9	4.0	1.1	K_{LL}, K_{LS}	
E07-002	70	8.0	2.1	4.1	K_{LL}, K_{LS}	
E12-14-006	60	8.0	1.7	4.5	A_{LL}	P1
E12-14-006	136	8.0	5.4	0.8	A_{LL}	P3
PR12-16-009	90	7.6	3.0	2.8	A_{LL}	P4
PR12-16-009	90	13.6	5.9	6.0	A_{LL}	P5
PR12-16-009	120	13.6	9.0	3.0	A_{LL}	P6
PR12-16-009	120	13.6	9.0	3.0	A_{LS}	P7

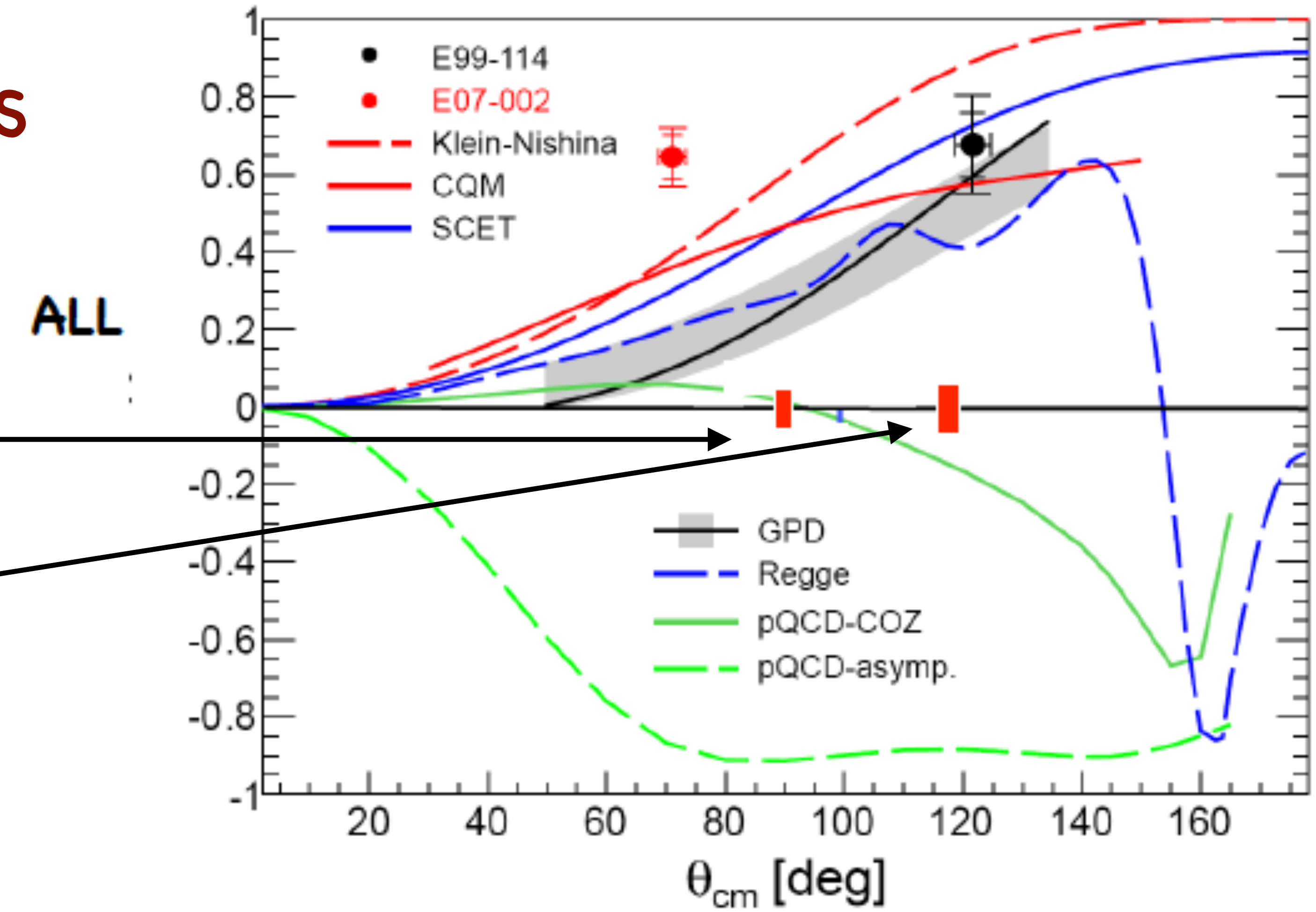
P3: Test Miller's model difference between A_{LL} and K_{LL} is large. Miller's CQM $E_\gamma < 6$ GeV

P4, P5: All same angle, different s. If $K_{LL} = A_{LL}$ gives strict test of s-dependence. If not then we must make as many measurements as possible

P6: Overlap with existing K_{LL} at same angle (120) with but better kinematic reach

P7: A_{LS}: same s,t, u, θ_{CM} as P6; compare to K_{LS} (at 120). K_{LS} is at different s but most models show little s-dependence for transverse case

Expected Results



A_{LL} @ 7.6 and 13.6

A_{LL} and A_{LS} @ 13.6

P3: (E12-14-006) Test Miller's model difference between A_{LL} and K_{LL} is >>. Miller CQM E_γ < 6 GeV

P4, P5: A_{LL} same angle, different s. If $K_{LL} = A_{LL}$ gives strict test of s-dependence. If not then we must make as many measurements as possible

P6: Overlap with existing K_{LL} at same angle (120) with but better kinematic reach

P7: A_{LS}: same s,t, u, θ_{CM} as P6; compare to K_{LS} (at 120). K_{LS} is at different s but most models show little s-dependence for transverse case

Summary

- Polarization observables can provide particularly sensitive tests of the reaction mechanism of RCS.
- E12-16-004 was approved by PAC42 for 15 days of beam time. It would be the first ever measurement of A_{LL}, the initial state correlation asymmetry.
- The measurement of A_{LL} would not only extend the pioneering measurement of K_{LL} , but also shed light on the nature of quark helicity−flip processes.
- A pure photon source is possible and increase the F.O.M by a factor of 30. It allows us to propose new WACS experiment with new kinematics (higher t, higher s) and measuring A_{LS}. It also opens the door for new experiments, for example TCS.

Collaboration

Longitudinal and Transverse Target Correlation Asymmetries in Wide Angle Compton Scattering

A Proposal to Jefferson Lab PAC 44

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The Neutral Particle Spectrometer collaboration
`https://wiki.jlab.org/cuawiki/index.php/Collaboration`

We welcome the principals of PR12-15-003 join us in leadership roles.

Collaboration

Longitudinal and Transverse Target Correlation Asymmetries in Wide Angle Compton Scattering

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We welcome the principals of PR12-15-003 join us in leadership roles.

Backup

Photon Flux

E	I	RL	D	Lost	γ/s
8.8	3.0 uA	10%	633cm	40.6%	6.6E11

Power Deposition

Ebeam (MeV)	Radiator length(%)	Power deposit 1uA beam (Watts)
4400	6	0.009
4400	10	0.015
6600	6	0.017
6600	10	0.022
8800	6	0.024
8800	10	0.035

Electron experiments use 100nA and 0.36 W are deposited in target: an order of magnitude more than from the photon flux generated by 1 μA on a 10% radiator.

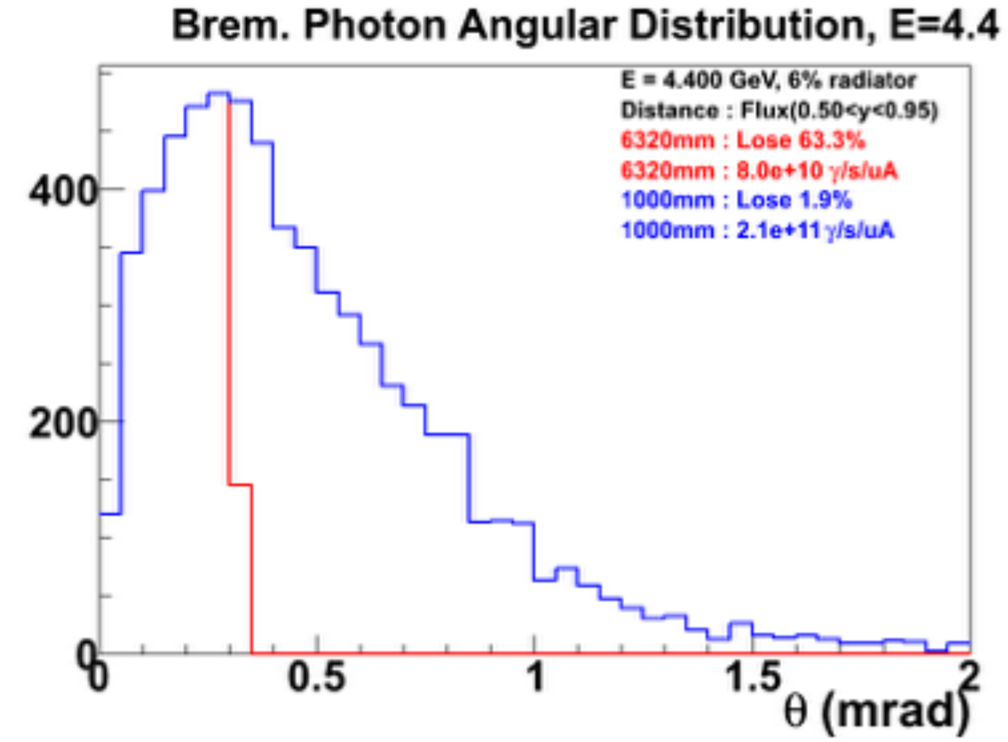
If cooling power was only issue we could put 8-10 μA on radiator to illuminate the PT: target would operate "normally".

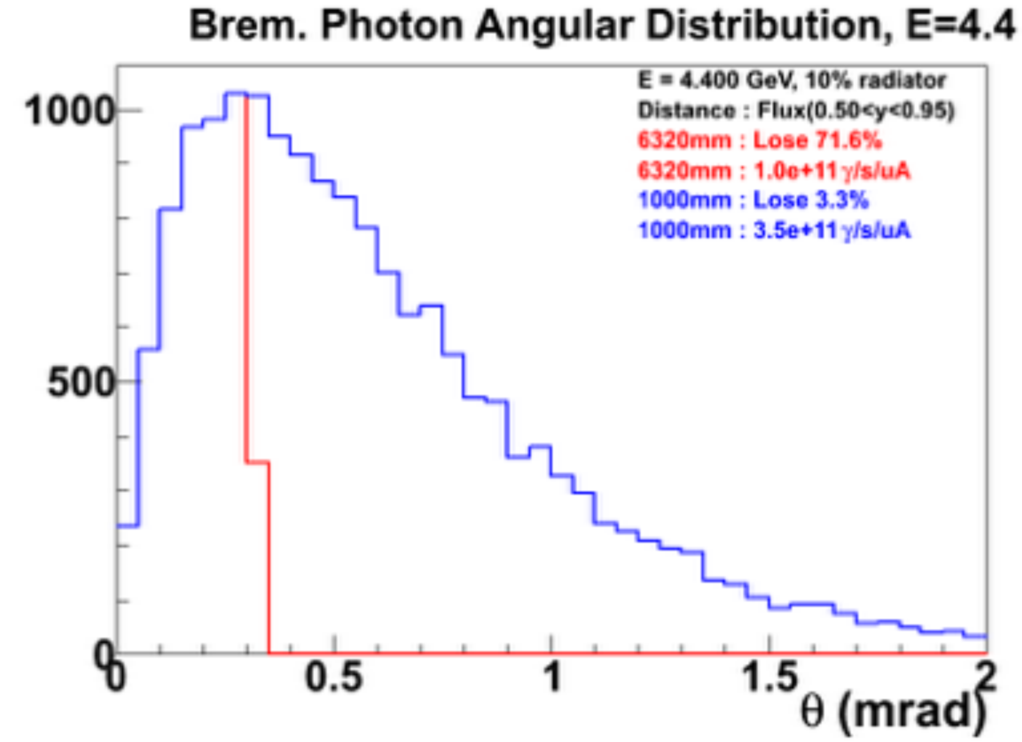
Pure Photon Source Performance

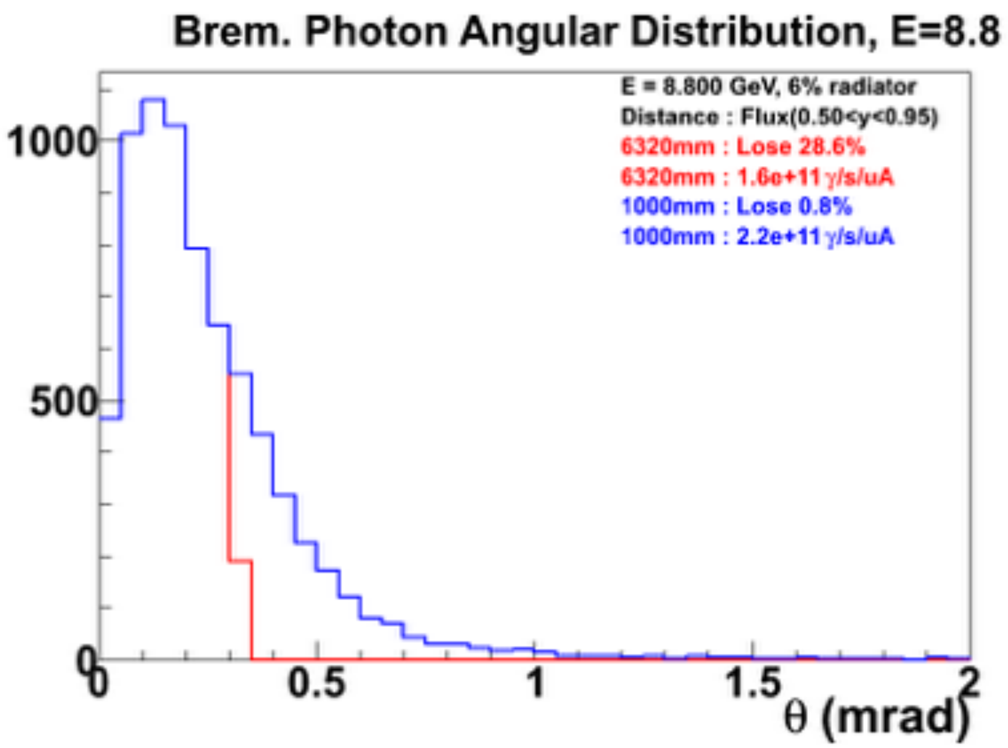
0.5<E_gamma/Beam<0.95, requiring the spot size on target within a 2mm radius circle.

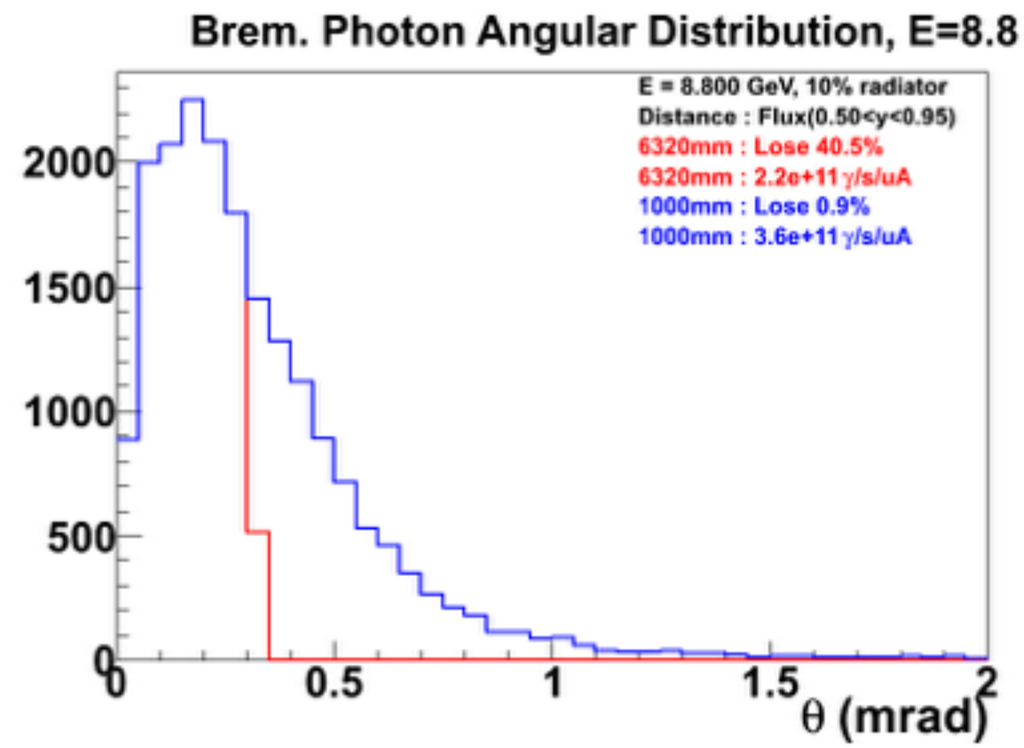
beam	beam_current	radiator	distance	flux_lost	#gamma/s
4.4	0.1 uA	6%	100cm	1.9%	2.1E10
4.4	3.0 uA	6%	633cm	63.4%	2.4E11
4.4	0.1 uA	10%	100cm	3.3%	3.5E10
4.4	3.0 uA	10%	633cm	71.6%	3.0E11
8.8	0.1 uA	6%	100cm	0.8%	2.2E10
8.8	3.0 uA	6%	633cm	28.7%	4.8E11
8.8	0.1 uA	10%	100cm	0.9%	3.6E10
8.8	3.0 uA	10%	633cm	40.6%	6.6E11

Photon Flux/μA



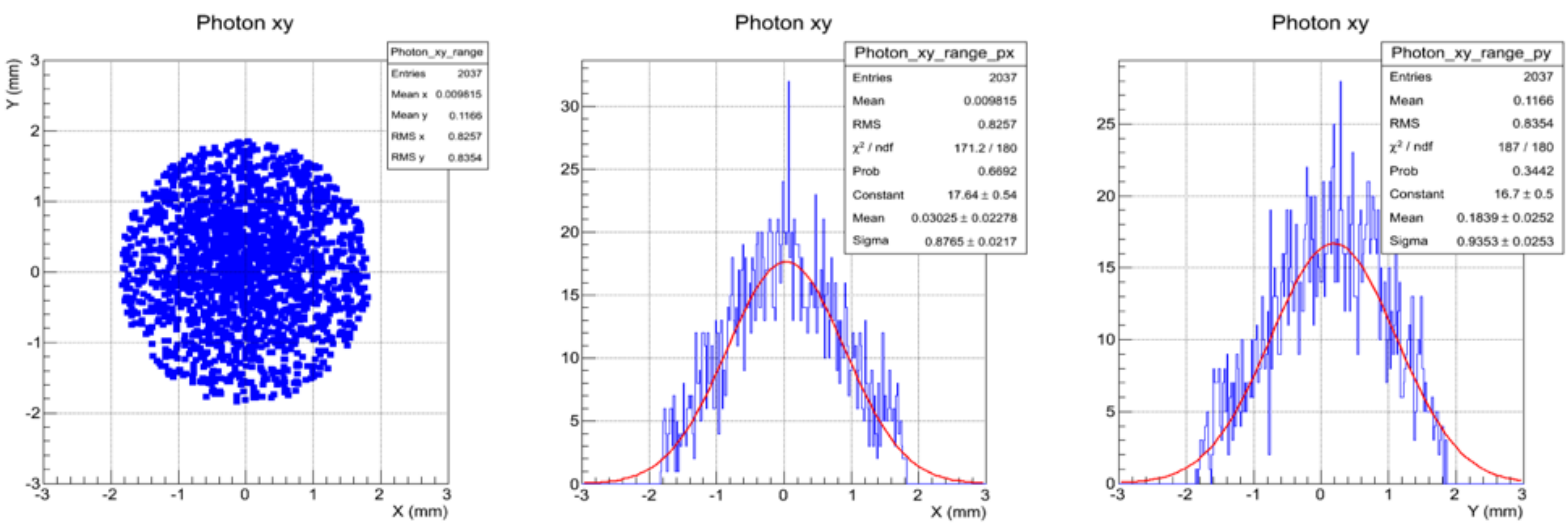






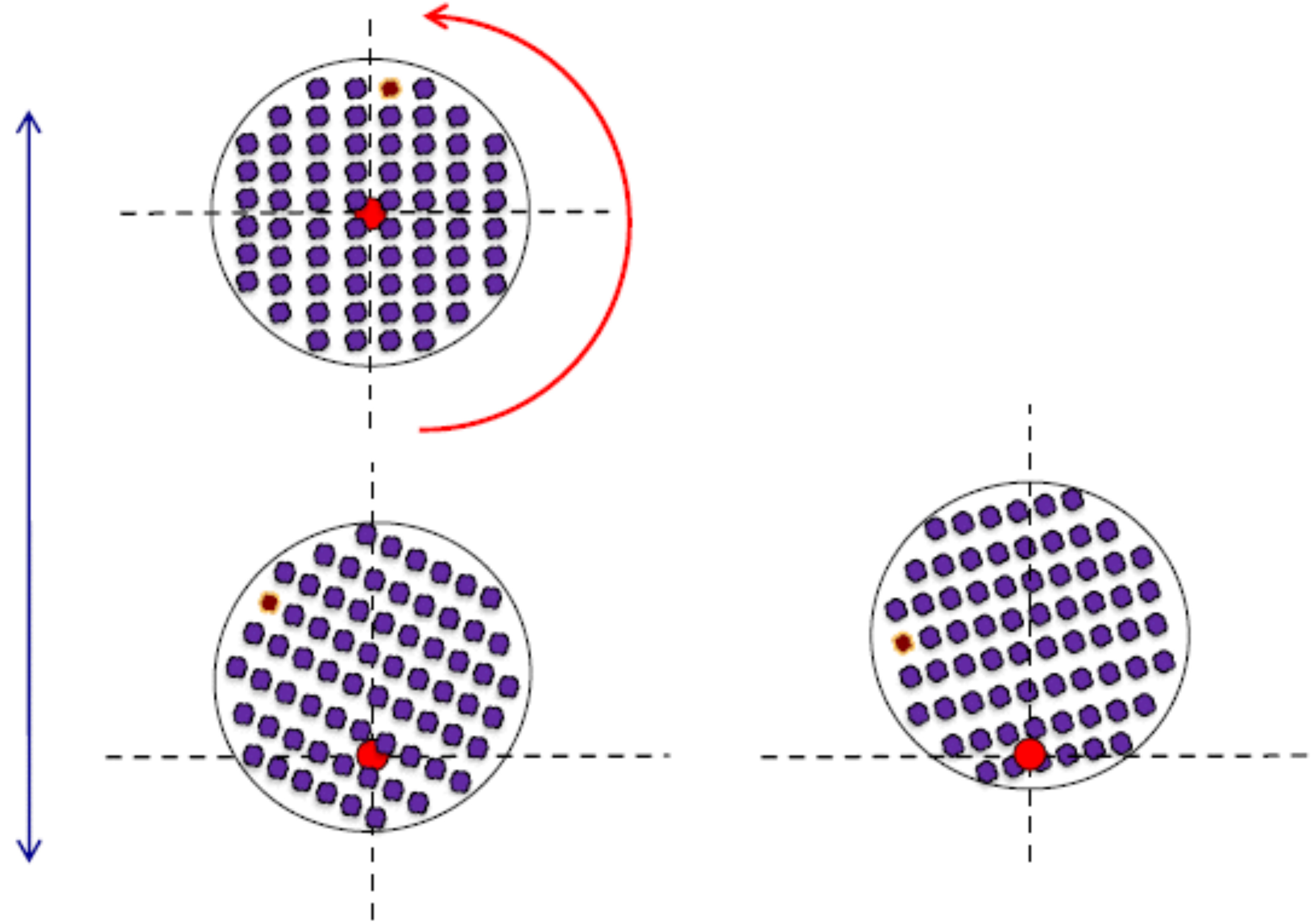
Spot size on target: +/- 2 mm to insure NPS resolution is fully exploited.

Configuration	Beam(GeV)	Current(μA)	Distance(cm)	Photon/s
PR12-16-009	8.8	3.0	632	6.6E+11



Raster Over Face of Target

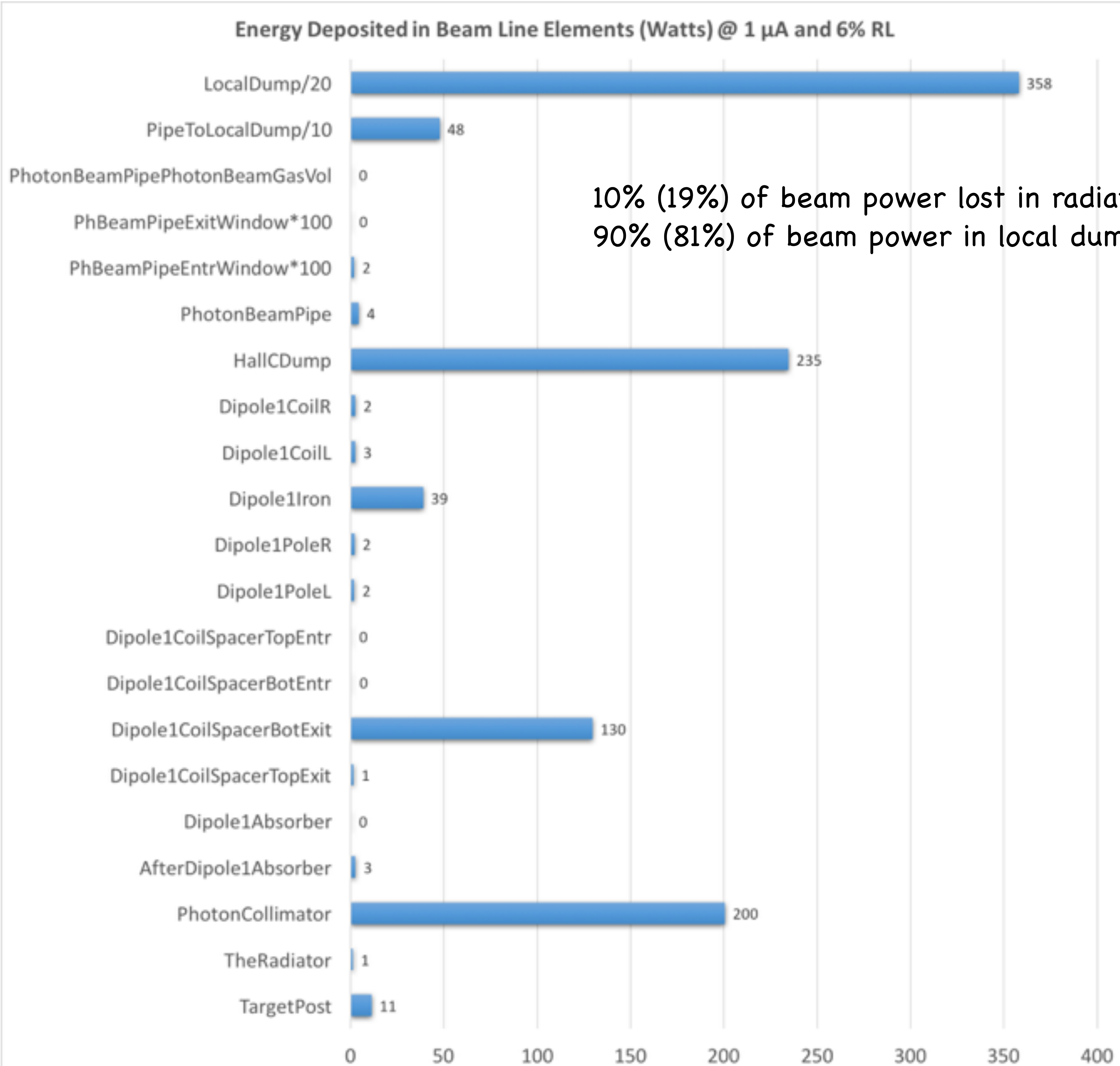
Incident electron not subject to large scale raster
Full and uniform irradiation of target still needed



Rotation already implemented at UVa though for different reasons.

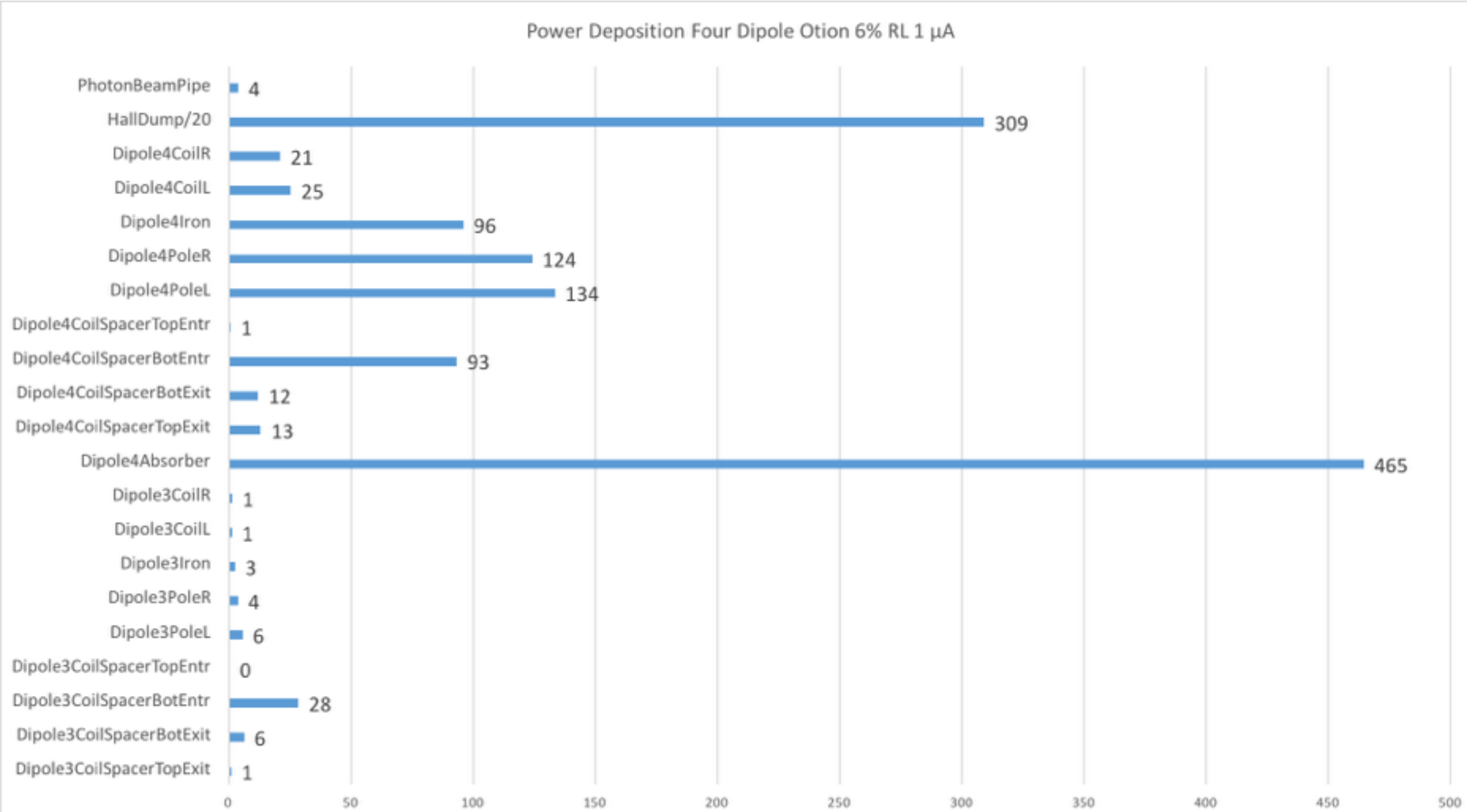
Photon spot fixed in space, target cell moves up and down with rotation

Single Dipole, Local Dump Option



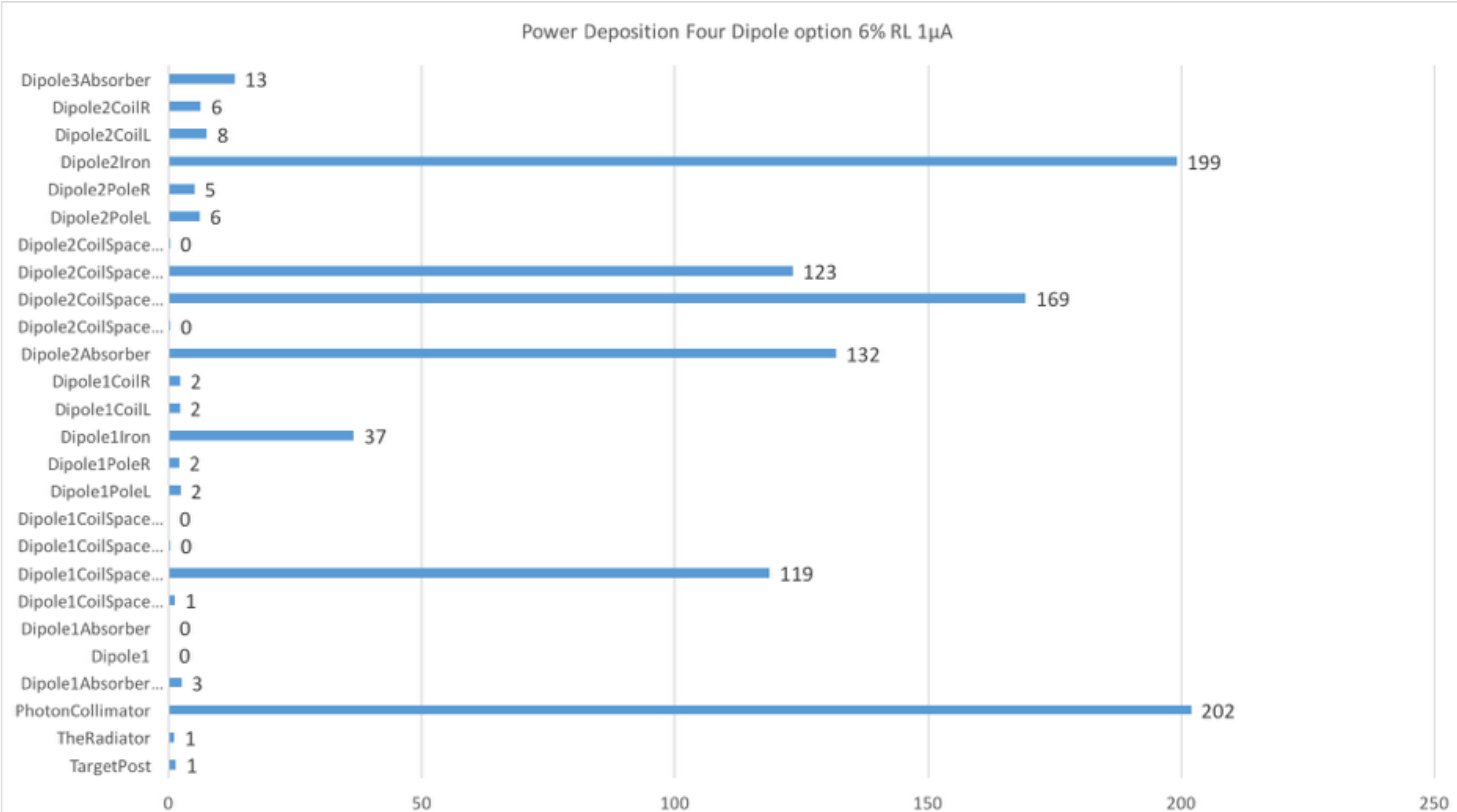
10% (19%) of beam power lost in radiator/dipole/ collimator/beam pipe
90% (81%) of beam power in local dump and Hall C dump

Four Dipoles Hall C Dump Option Page 1



4.5% (9%) of beam power is deposited in radiator/first dipole/collimator
75% (60)% of beam power in Hall C dump (last dipole, 11 and 17%)

Four Dipoles Hall C Dump Option Page 2



4.5% (9%) of beam power is deposited in radiator/first dipole/collimator
75% (60)% of beam power in Hall C dump (last dipole, 11 and 17%)

Field at NPS PMTs

Sheet1

Detector	PMT angle degrees	Field-NPS angle degrees	Field-beam angle degrees	z_NPS cm	R_NPS cm	Z field cm	R field cm	BZ T	BR T	B|| PMT G	B_|_ PMT G
WACS P4	0	39	180	318	0	247	-200	0.0007	0.0012	12.8	5.1
WACS P5	0	29	180	318	0	278	-154	0.0011	0.0011	14.5	4.0
WACS P6	0	47	-5	218	0	149	-159	0.0010	0.0039	34.8	19.0
WACS P7	0	47	275	218	0	149	-159	0.0010	0.0039	34.8	19.0

Photon Power Deposition

Ebeam (MeV)	Radiator length(%)	Power deposit 1uA beam (Watts)
4400	6	0.009
4400	10	0.015
6600	6	0.017
6600	10	0.022
8800	6	0.024
8800	10	0.035

0.1 μA electron beam deposits 0.36 W, factor of 10 more

If cooling power was only issue we could put 10 μA on radiator to illuminate the PT

Pure Photon Source
Cost? $250k - $1M

JLAB
MRI
DOE
other..

….could result in as much as **$100 million invested annually in initiatives** with the highest promise to significantly improve the University and enhance quality and access for students.

….Proposals for grants from the fund will be solicited from across the University community, with emphasis on ideas with the potential to transform a critical area of knowledge or function and to enhance the academic, **research** or clinical standing of the University in a significant way.

https://news.virginia.edu/content/fund-propel-strategic-investments-academic-research-and-health-care-excellence