WACS experiment with NPS and SBS

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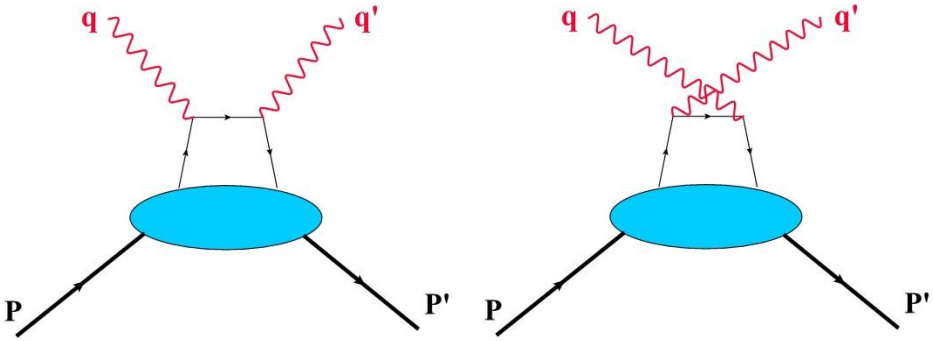
NPS collaboration

Overview

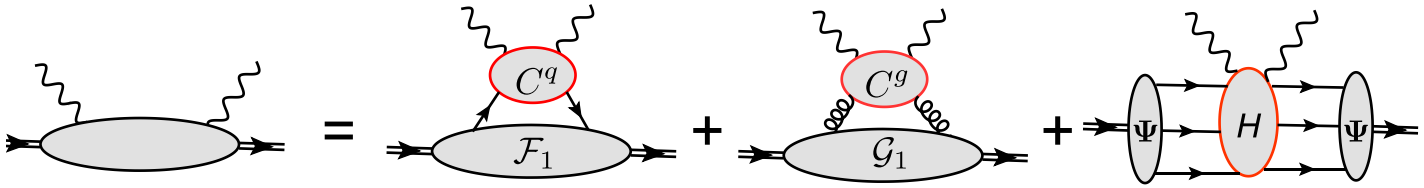
- Physics motivation
- Key components of the experiment
- Kinematics and statistics
- Projected accuracy

Compton scattering



In GPD approach interaction goes with single-quark and the "handbag" diagram dominates.

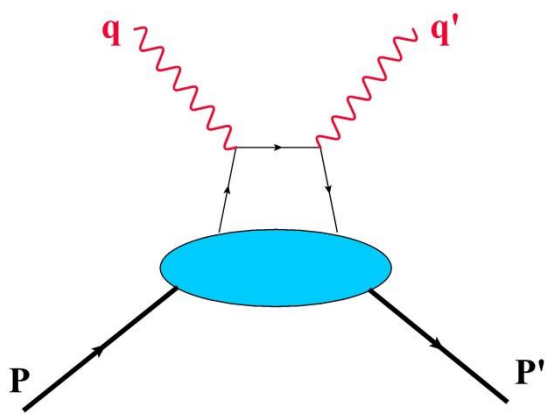
$$\frac{d\sigma}{dt} = \frac{d\sigma}{dt}_{KN}\left(\frac{1}{2}\left[R_V^2 + \frac{-t}{4m^2}R_T^2 + R_A^2\right] - \frac{us}{s^2+u^2}\left[R_V^2 + \frac{-t}{4m^2}R_T^2 - R_A^2\right]\right)$$



Kivel and Vanderhaeghen (QCD Factorization Approach)

$$\frac{d\sigma}{dt} = \frac{\pi\alpha^2}{s^2}\left|R(\mathrm{s},\mathrm{t})\right|^2(-\mathrm{su})\left(\frac{1}{2}\left|C_2(\mathrm{s},\mathrm{t})\right|^2 + \frac{1}{2}\left|C_4(\mathrm{s},\mathrm{t})\right|^2 + \left|C_6(\mathrm{s},\mathrm{t})\right|^2\right)$$

FF-s, GPD-s and Polarization Observables



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

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

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

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

Kivel and Vanderhaeghen, NLO calculations

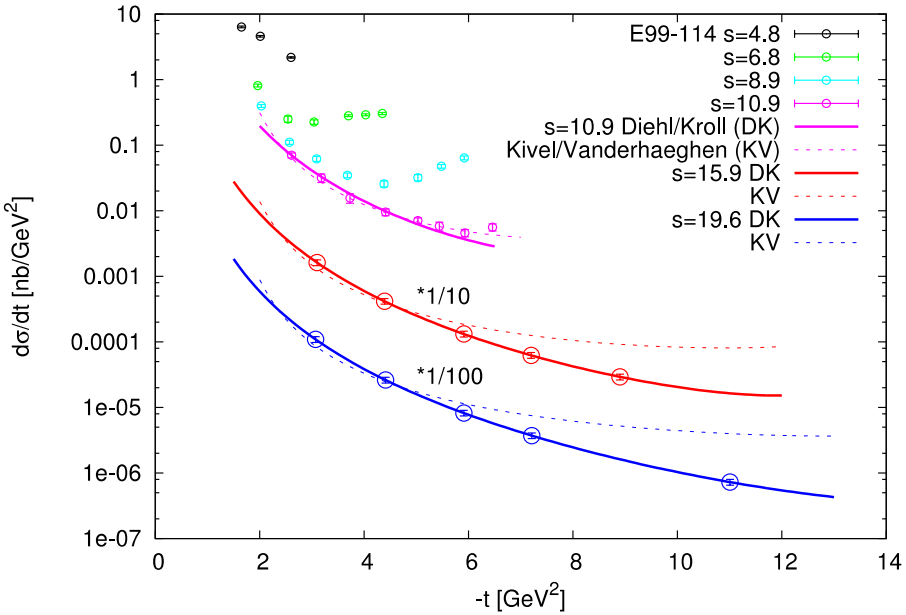
$$K_{LL}^{KN} = \frac{s^2 - u^2}{s^2 + u^2}$$

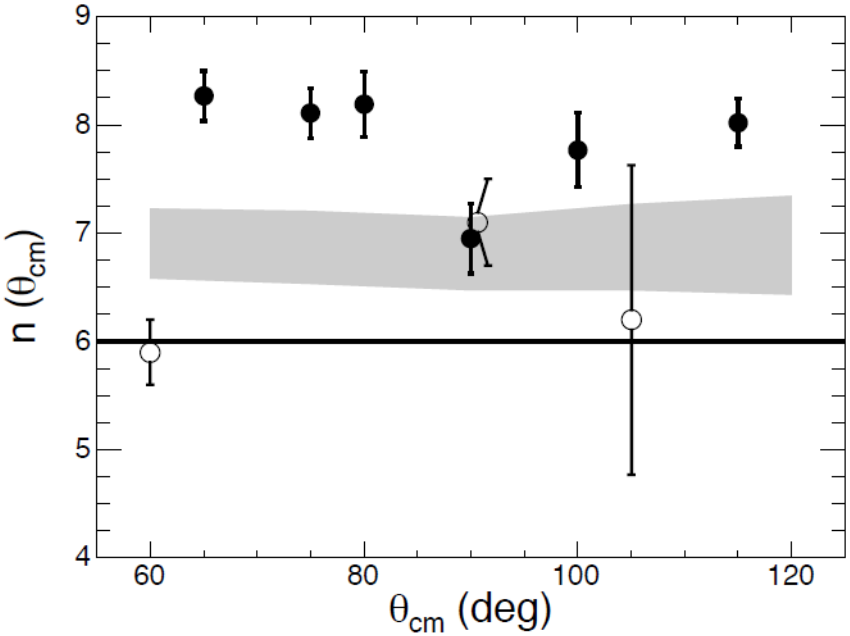
$$K_{LL} = \frac{\sigma_{\parallel}^R - \sigma_{\parallel}^L}{\sigma_{\parallel}^R + \sigma_{\parallel}^L} = K_{LL}^{KN} + \frac{\alpha_s}{\pi} C_F K_{LL}^{NLO}$$

Cross-section and scaling

Diehl/Kroll and Kivel/Vanderhaeghen predictions of cross-section t-dependance for different s values.

Cross-section results from PRL-98 152001 (2007) show that n = 7.0 – 8.0, while pQCD predicts n = 6.

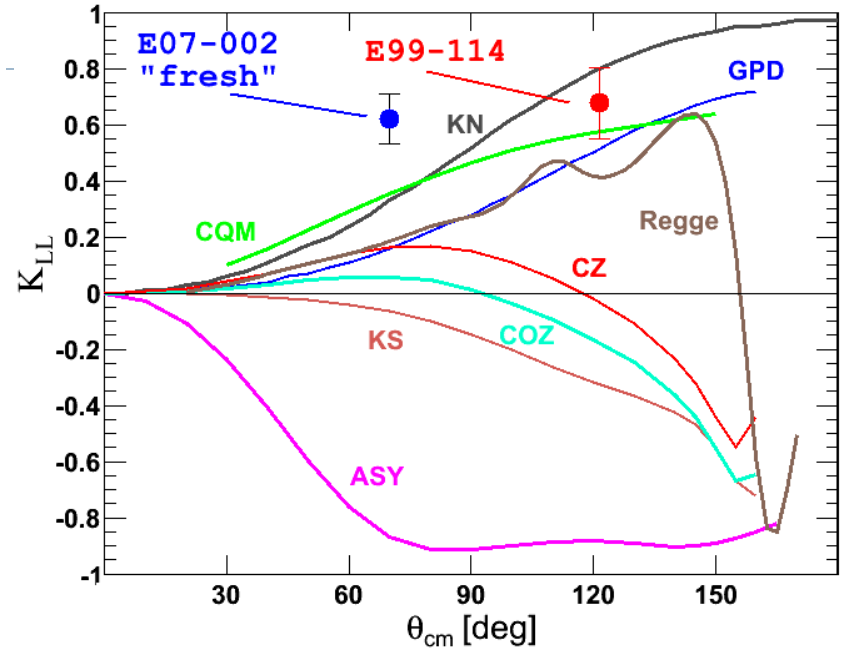


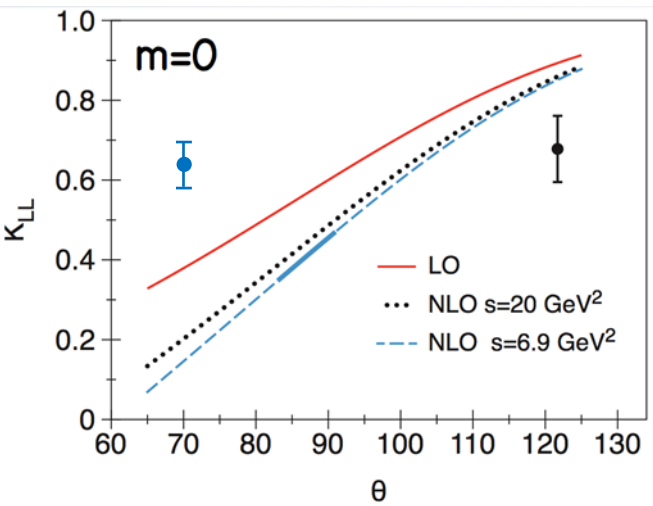


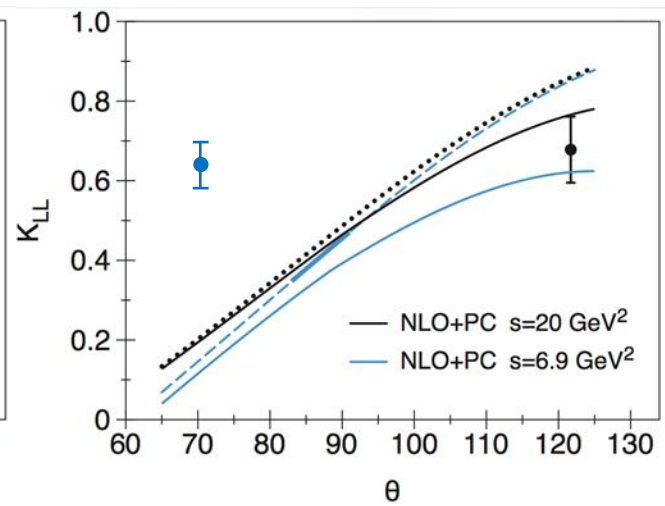
Physics Motivation

- Test of the handbag predictions to the <10% level is an important task
- The K_{LL}/A_{LL} asymmetry is an observable of choice
- NLO corrections are suppose to vary as 1/s (Kivel and Vanderhaeghen)

E99-114: $s = 6.9,\ t = -4.0,\ u = -1.1$
E07-002: $s = 7.8,\ t = -2.0,\ u = -4.0$



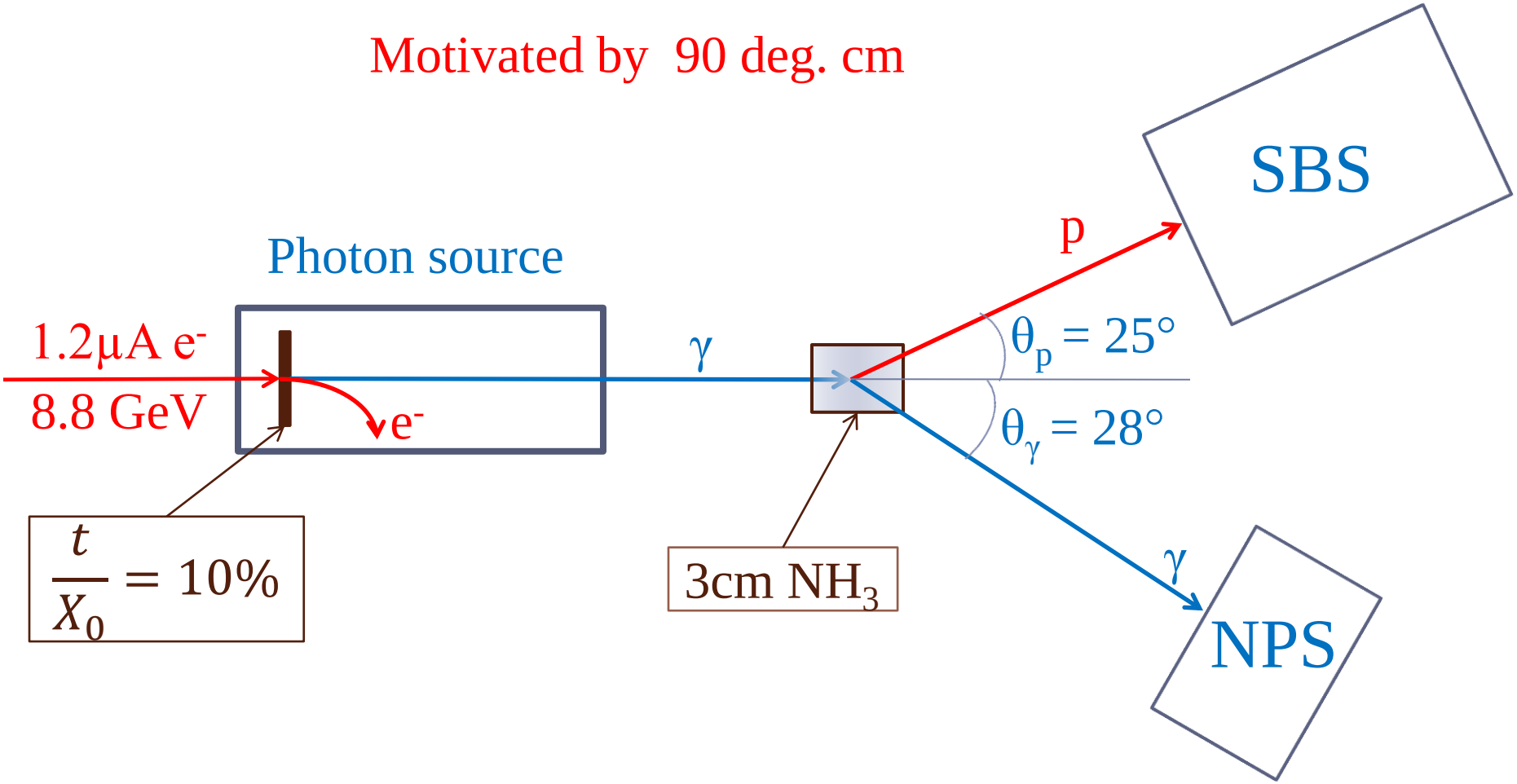




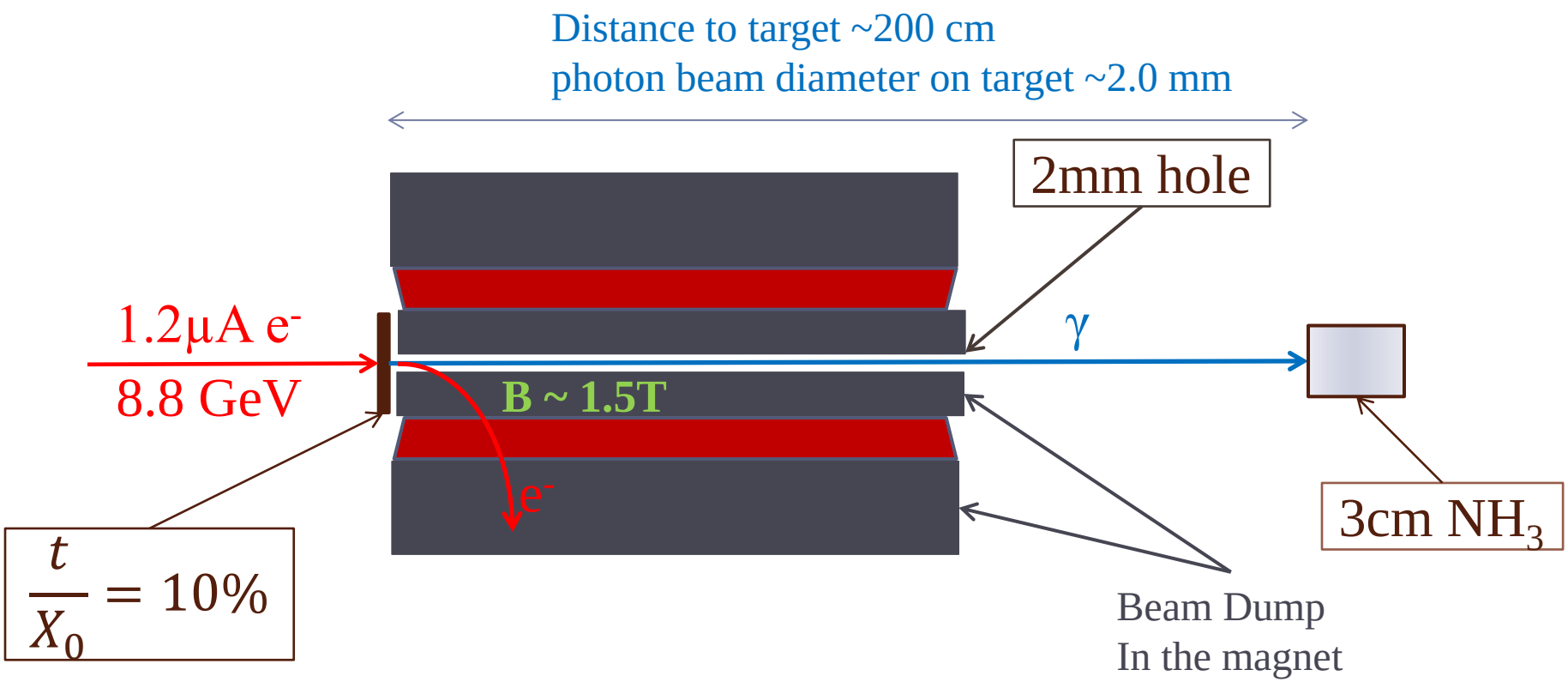
New measurements at double s, t, u and wide θ_{CM} range are necessary to understand the mechanism of WACS.

Experimental Setup

Motivated by 90 deg. cm



γ-Source



Initial MC simulation shows acceptable background rate on SBS and NPS
Detailed analysis of radiation level is in progress

Main Experimental Parameters

SBS	
Angle	25°
Distance [cm]	371 (to detector) 160 (to magnet)
ΔΩ [msr]	70
δp [%]	$0.29 + 0.03 \cdot p[GeV]$
δθ [mrad]	$0.14 + 1.34/p[GeV]$
δϕ [mrad]	$0.09 + 0.59/p[GeV]$

NPS [60cm x 70cm]	
Angle	28°
Distance [cm]	200
ΔΩ [msr]	105
δp [%]	$3/\sqrt{E[GeV]}$
δX [mm]	3
δY [mm]	3

Beam	
I [μA]	1.2
E_e[GeV]	8.8
E_γ[GeV]	4 – 8
P_γ	0.45 – 0.78

NH_3 target	
ρ [g/cm^3]	0.87
L [cm]	3.0
$f_{packing}$	0.6
P_p	0.75

Key Features

- Photon detector, NPS: E, x and y high resolution; 100 msr
- Proton detector, SBS: 70 msr solid angle (10x of universal spectrometer)
- Photon flux, local beam-dump: 10x of mixed beam
- Compact photon spot: ~2.0 mm by means of magnet-dump configuration.

Kinematic range

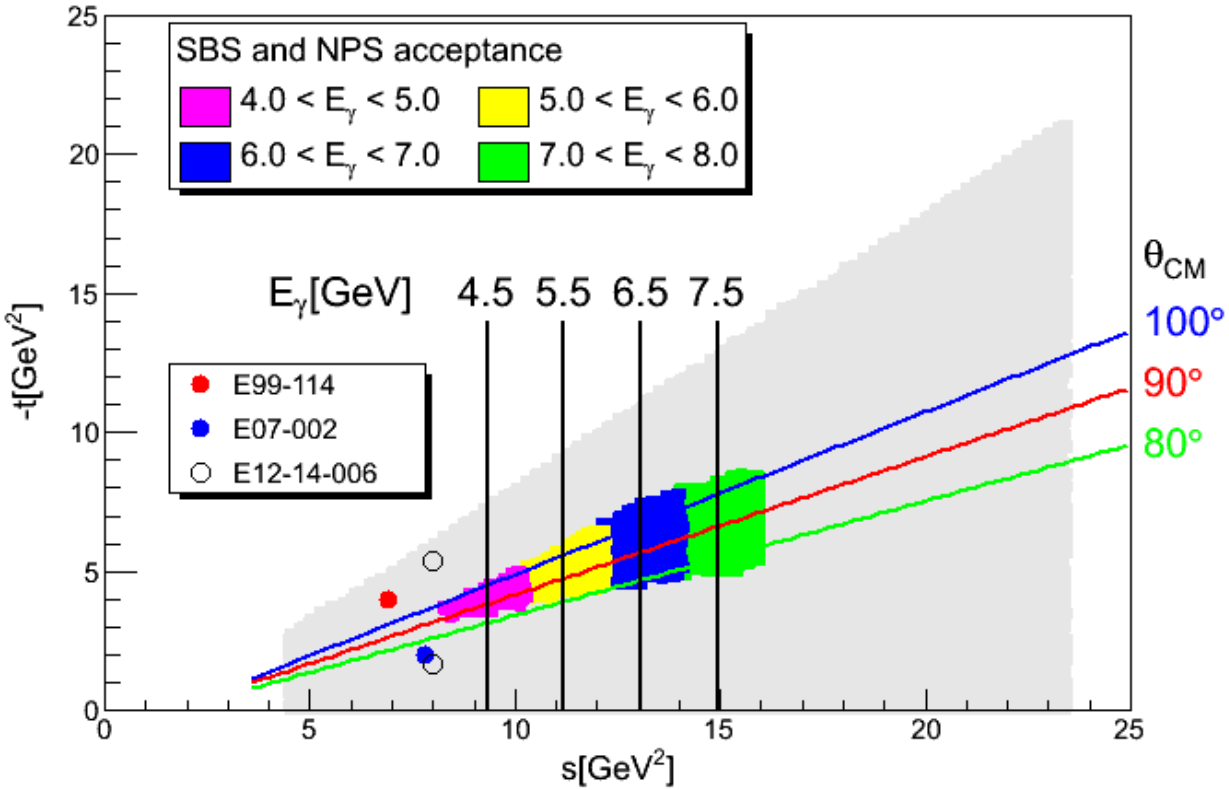
Detectors acceptance covers wide kinematic range in one setting.

s: 8.0 – 16.0 GeV^2

-t: 3.0 – 7.0 GeV^2

-u: 3.0 – 7.0 GeV^2

θ_{CM}: 80° – 100°



Statistics and estimated uncertainty

Scattered photon energy

Cross-Section

Number of protons

$$N_{RCS} = \frac{d\sigma}{dt} \cdot \frac{\left(E'_{\gamma}\right)^2}{\pi} \cdot \Delta\Omega_{\gamma} f_{\gamma p} \cdot N_p \cdot N_{\gamma}$$

Detectors acceptance

Number of photons

$$\Delta A_{LL} = \frac{1}{\sqrt{\frac{N_{RCS}}{D} P_p P_{\gamma}}}$$

Photon polarization

Dilution due to pion background

Proton polarization

Cross-Section

$$N_{RCS} = \frac{d\sigma}{dt}\frac{\left(E_\gamma^{'}\right)^2}{\pi}\cdot\Delta\Omega_\gamma f_{\gamma p}\cdot N_p\cdot N_\gamma$$

E99-114 Results

$$\left.\frac{d\sigma}{dt}\right|_{s,t} = \left.\frac{d\sigma}{dt}\right|_{s_0,t_0}\cdot\left(\frac{s}{s_0}\right)^{3.5}\cdot\left(\frac{t}{t_0}\right)^{4.0}$$

$$\left.\frac{d\sigma}{dt}\right|_{\substack{s_0=8.0\\ t_0=3.6}} = 35\cdot 10^{-36}\ \mathrm{cm}^{-2}\mathrm{GeV}^{-2}$$

Kin	1	2	3	4
s (GeV^2)	9.4	11.0	13.0	15.0
-t (GeV^2)	4.0	4.9	5.8	6.5
$E_\gamma^{'}$ (GeV)	2.4	2.7	3.3	4.0
$\frac{d\sigma}{dt}$ ($GeV^{-2}cm^{-2}$)	$21\cdot 10^{-36}$	$5.3\cdot 10^{-36}$	$1.5\cdot 10^{-36}$	$0.6\cdot 10^{-36}$

Photon flux and number of protons

$$N_{RCS} = \frac{d\sigma}{dt}\frac{\left(E_\gamma^{'}\right)^2}{\pi}\cdot\Delta\Omega_\gamma f_{\gamma p}\cdot N_p\cdot N_\gamma$$

$$N_p = \frac{Z}{A}\cdot t\cdot f_{pack}\cdot N_A$$

NH_3 target	
t [g/cm^2]	1.57

$$N_p = 1.65\cdot 10^{23}$$

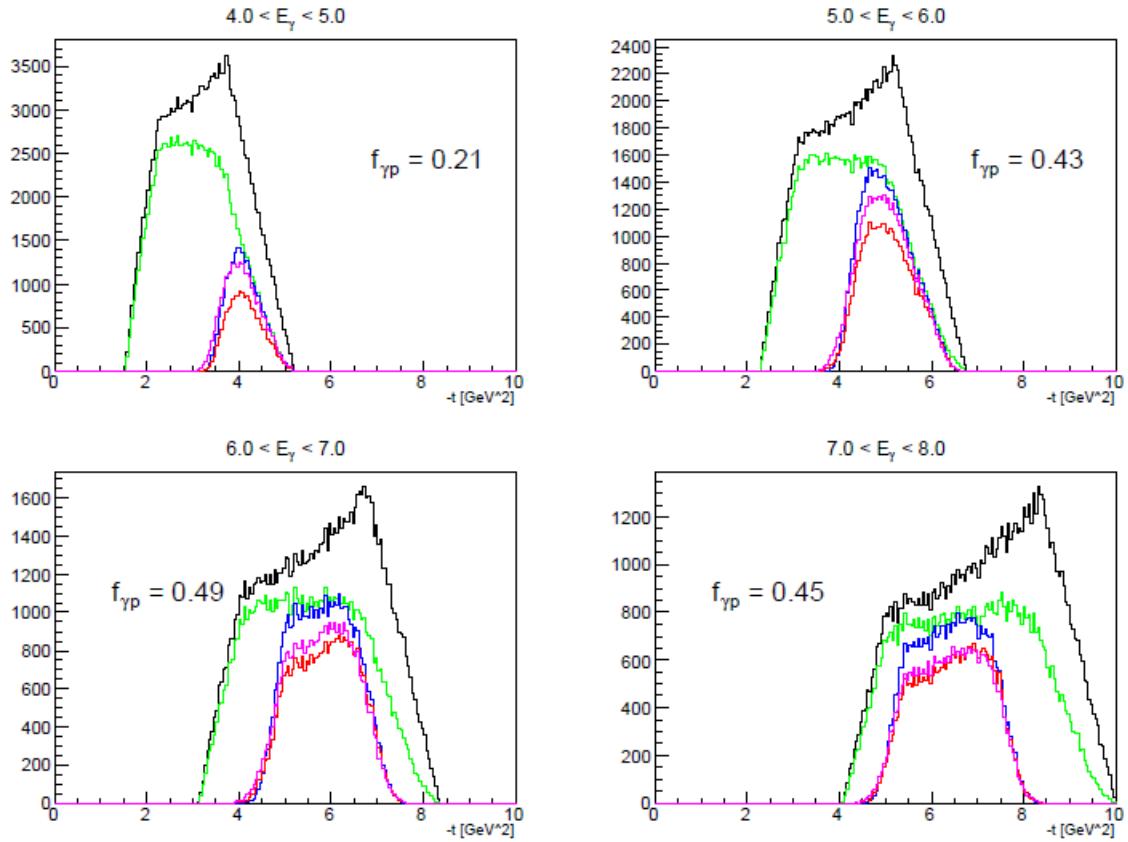
For 1.2 μA beam and 10% radiator

Kin	1	2	3	4
E_γ [GeV]	4 – 5	5 – 6	6 – 7	7 – 8
N_γ (per sec)	$1.5\cdot 10^{11}$	$1.2\cdot 10^{11}$	$1.1\cdot 10^{11}$	$0.9\cdot 10^{11}$

Solid angle

$$N_{RCS} = \frac{d\sigma}{dt}\frac{\left(E_\gamma^{'}\right)^2}{\pi} \cdot \Delta\Omega_\gamma f_{\gamma p} \cdot N_p \cdot N_\gamma$$

- NPS acceptance
- SBS acceptance (no field)
- SBS acceptance (with SBS and target fields)
- SBS acceptance (with SBS and target fields, NPS shifted to match)



$$\Delta\Omega_\gamma = 100 \text{ msr}$$

Kin	1	2	3	4
$f_{\gamma p}$	0.21	0.43	0.49	0.45

Statistics

$$N_{RCS} = \frac{d\sigma}{dt}\frac{\left(E'_\gamma\right)^2}{\pi}\cdot\Delta\Omega_\gamma f_{\gamma p}\cdot N_p\cdot N_\gamma$$

$$\Delta\Omega_\gamma = 100\ \text{msr}$$

$$N_p = 1.65\cdot 10^{23}$$

$$\Delta A_{LL} = \frac{1}{\sqrt{\frac{N_{RCS}}{D}P_p P_\gamma}}$$

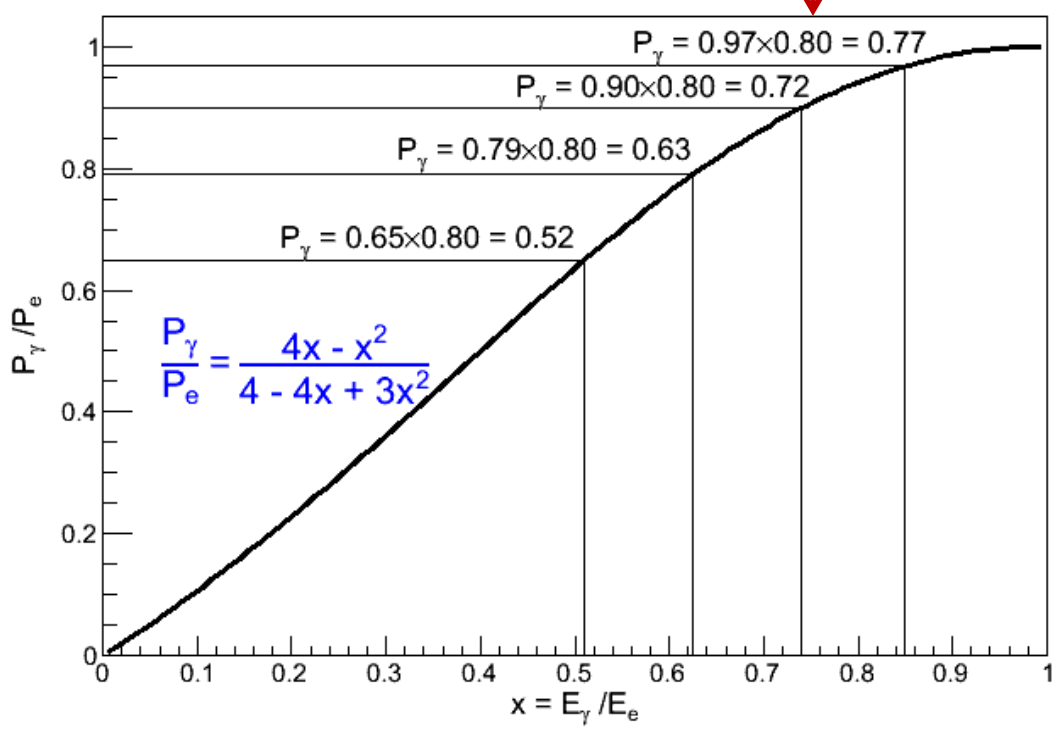
Kinematic	1	2	3	4
s (GeV^2)	9.4	11.0	13.0	15.0
-t (GeV^2)	4.0	4.9	5.8	6.5
E'_γ (GeV)	2.4	2.7	3.3	4.0
$\frac{d\sigma}{dt}$ ($GeV^{-2}cm^{-2}$)	$21\cdot 10^{-36}$	$5.3\cdot 10^{-36}$	$1.5\cdot 10^{-36}$	$0.6\cdot 10^{-36}$
$f_{\gamma p}$	0.21	0.43	0.49	0.45
N_γ (per sec)	$1.5\cdot 10^{11}$	$1.2\cdot 10^{11}$	$1.1\cdot 10^{11}$	$0.9\cdot 10^{11}$
N_{RCS} (per hour)	72	36	18	7.2
N_{RCS} (250 hours)	18000	9000	4500	1800

Proton and photon polarization

$$\Delta A_{LL} = \frac{1}{\sqrt{\frac{N_{RCS}}{D} P_p P_\gamma}}$$

$$P_p = 0.75$$

$$P_e = 0.8$$

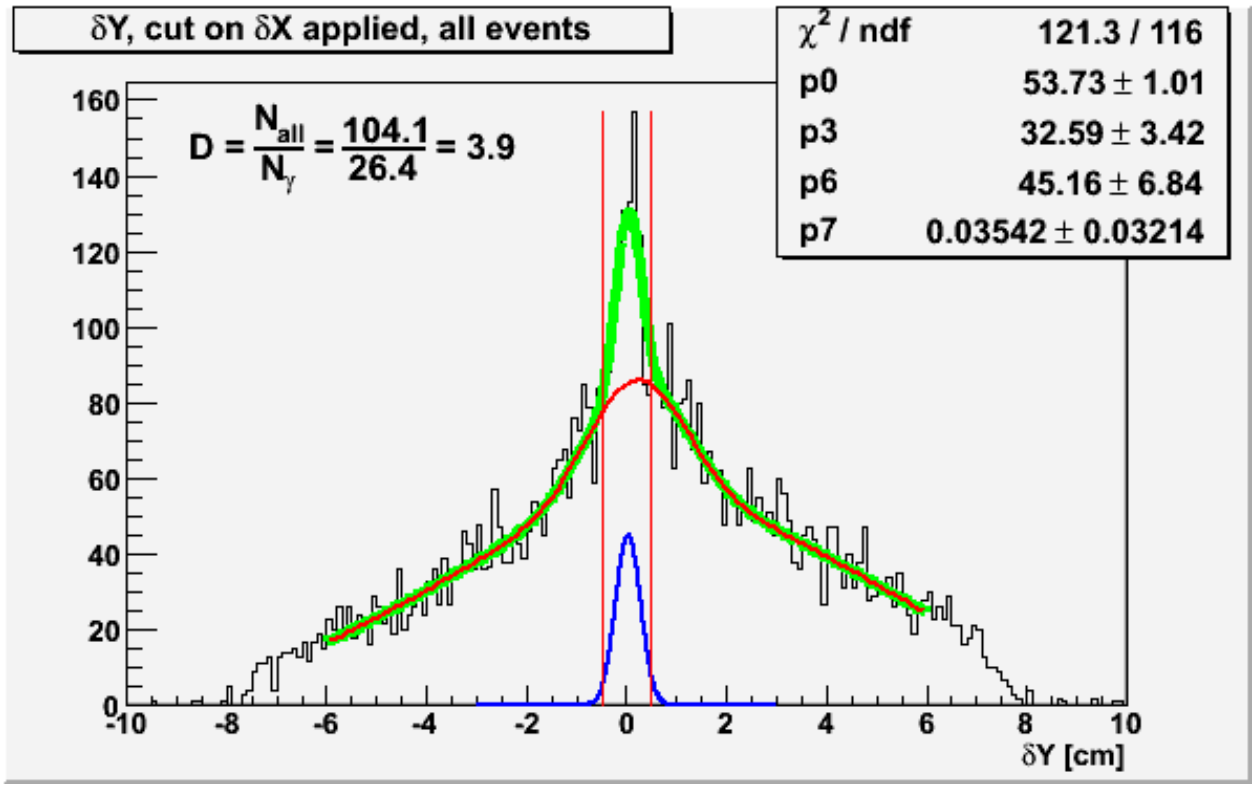


	Kin 1	Kin 2	Kin 3	Kin 4
P_γ	0.52	0.63	0.72	0.77

Dilution due to pion background

	Kin 1	Kin 2	Kin 3	Kin 4
D	3.1	3.8	4.0	3.9

$$\Delta A_{LL} = \frac{1}{\sqrt{\frac{N_{RCS}}{D} P_p P_\gamma}}$$



Estimated statistics and A_{LL} uncertainties

$$\Delta A_{LL} = \frac{1}{\sqrt{\frac{N_{RCS}}{D}} P_p P_\gamma}$$

$$P_p = 0.75$$

Kinematic	1	2	3	4
s (GeV^2)	9.4	11.0	13.0	15.0
-t (GeV^2)	4.0	4.9	5.8	6.5
P_γ	0.52	0.63	0.72	0.77
D	3.1	3.8	4.0	3.9
N_{RCS} (250 hours)	18000	9000	4500	1800
ΔA_{LL}	0.034	0.043	0.055	0.081

Projected impact of the results