DVCS using a positron beam in Hall C

Proposal to PAC48
based on
LoI to PAC46

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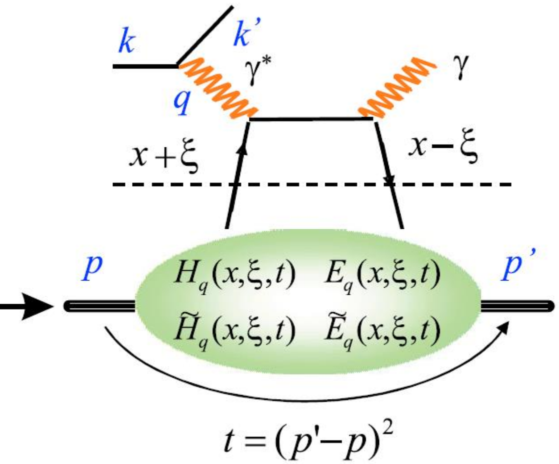
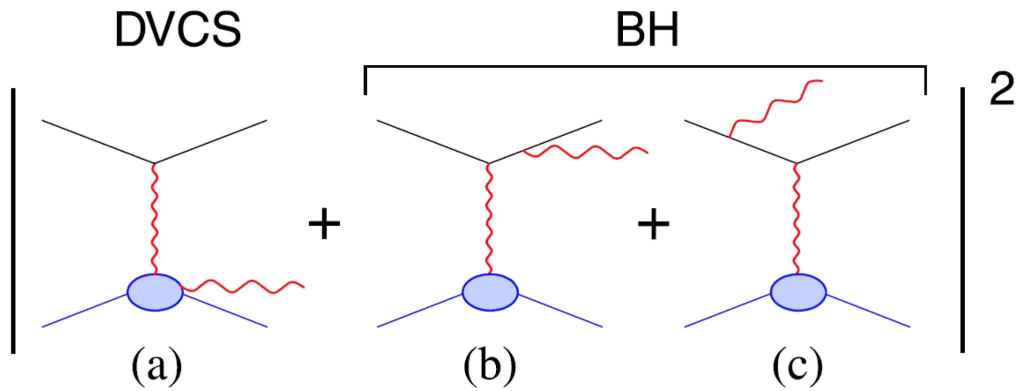
NPS Collaboration proposal

Motivation



ep ⟶ epγ =



$$|\mathcal{T}(\pm ep \to \pm ep\gamma)|^2 = |\mathcal{T}^{BH}|^2 + |\mathcal{T}^{DVCS}|^2 \mp \mathcal{I}$$

Opposite sign for e- & e+

At leading twist:

$$d^5\overrightarrow{\sigma} - d^5\overleftarrow{\sigma} = \Im m\,(T^{BH}\cdot T^{DVCS})$$
$$d^5\overrightarrow{\sigma} + d^5\overleftarrow{\sigma} = |BH|^2 + \Re e\,(T^{BH}\cdot T^{DVCS}) + |DVCS|^2$$

$$\mathcal{T}^{DVCS} = \int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi+i\epsilon} + \cdots =$$

$$\underbrace{\mathcal{P}\int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi}} \quad - \quad \underbrace{i\pi\, H(x=\xi,\xi,t)} \quad + \ldots$$

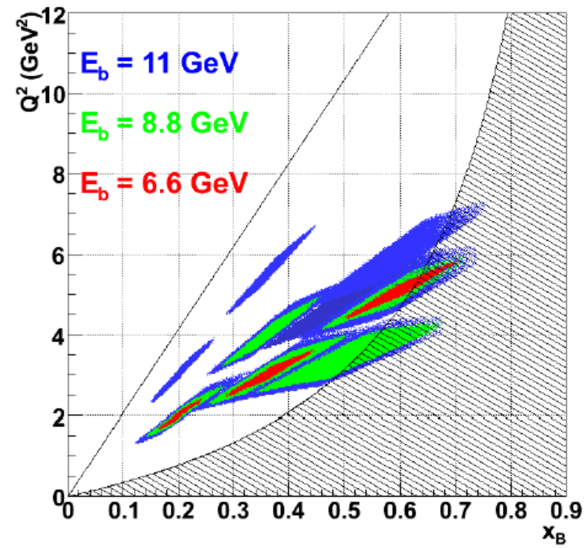
Access in helicity-independent cross section — Access in helicity-dependent cross-section

DVCS with positrons and NPS (proposal to PAC48)

Physics goals and motivation:

- ✓ Precise determination of the absolute photon electro-production cross section
- ✓ Clean separation of DVCS^2 and DVCS-BH interference
- ✓ More stringer constraints on CFFs by combining e^- & e^+ data

Same kinematics settings as approved E12—13-010 with electrons



- ➢ Same experimental configuration as approved experiment E12-13-010 (exactly)
- ➢ Expected positron beam momentum spread comparable with current electron beam
- ➢ Positron beam emittance about a factor of 2 larger than current electron beam
- ➢ No additional systematic uncertainties expected due to the use of positrons

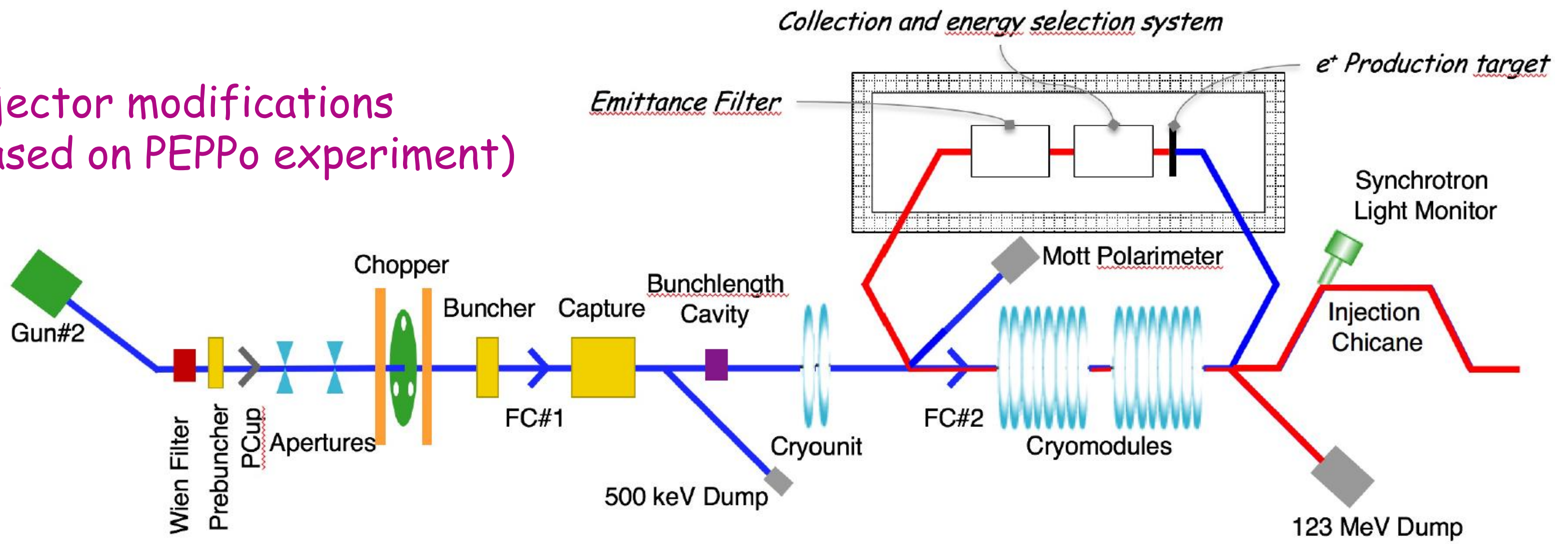
x_{Bj}	0.2				0.36						0.5			0.6			
Q^2 (GeV)^2	2.0			3.0	3.0			4.0		5.5	3.4		4.8	5.1			6.0
k (GeV)	6.6	8.8	11		6.6	8.8	11	8.8	11		8.8	11		6.6	8.8	11	
k' (GeV)	1.3	3.5	5.7	3.0	2.2	4.4	6.6	2.9	5.1	2.9	5.2	7.4	5.9	2.1	4.3	6.5	5.7
θ_{Calo} (deg)	6.3	9.2	10.6	6.3	11.7	14.7	16.2	10.3	12.4	7.9	20.2	21.7	16.6	13.8	17.8	19.8	17.2
D_{Calo} (m)	6	4		6	3			4	3	4	3						
$\sigma_{M_X^2}$ (GeV^2)	0.17			0.22	0.13		0.12	0.15		0.19	0.09		0.11	0.09			
I_{beam} (μA)	5																
Days	1	1	3	1	2	3	2	3	4	13	4	3	7	7	2	7	14

77 days, >5 μA of positrons (unpolarized)

Positron data: 25% of statistics of electron data

Positron production and transport

Injector modifications
(based on PEPPo experiment)



Dominated by damping in the LINACS

Dominated by synchrotron rad. in Arcs

Electrons

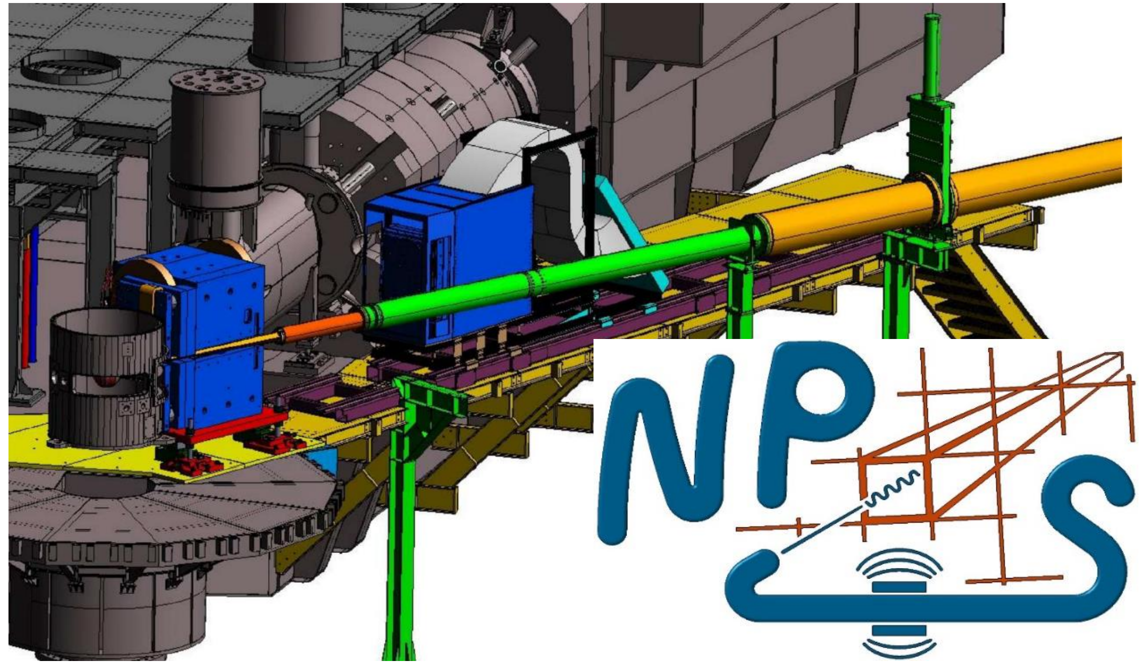
Area	δp/p [x10-3]	ε_x [nm]	ε_y [nm]
Chicane	0.5	4.00	4.00
Arc 1	0.05	0.41	0.41
Arc 2	0.03	0.26	0.23
Arc 3	0.035	0.22	0.21
Arc 4	0.044	0.21	0.24
Arc 5	0.060	0.33	0.25
Arc 6	0.090	0.58	0.31
Arc 7	0.104	0.79	0.44
Arc 8	0.133	1.21	0.57
Arc 9	0.167	2.09	0.64
Arc 10	0.194	2.97	0.95
Hall D	0.18	2.70	1.03

Positrons

Area	δp/p [x10-3]	ε_x [nm]	ε_y [nm]
Chicane	10	500	500
Arc 1	1	50	50
Arc 2	0.53	26.8	26.6
Arc 3	0.36	19	18.6
Arc 4	0.27	14.5	13.8
Arc 5	0.22	12	11.2
Arc 6	0.19	10	9.5
Arc 7	0.17	8.9	8.35
Arc 8	0.16	8.36	7.38
Arc 9	0.16	8.4	6.8
MYAAT01	0.18	9.13	6.19

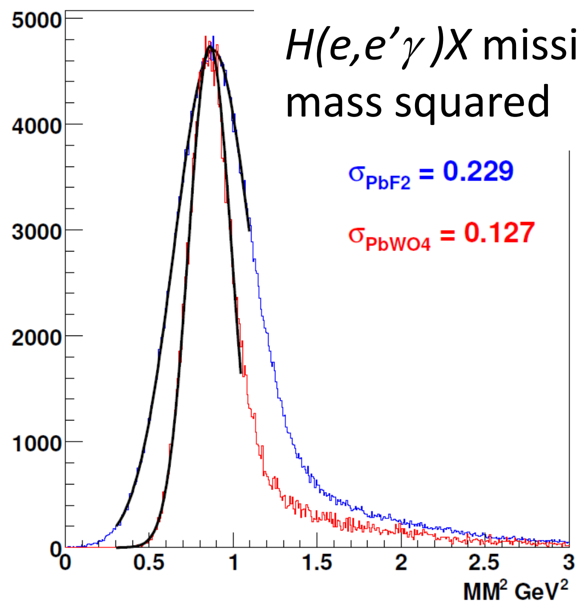
Neutral Particle Spectrometer (NPS)

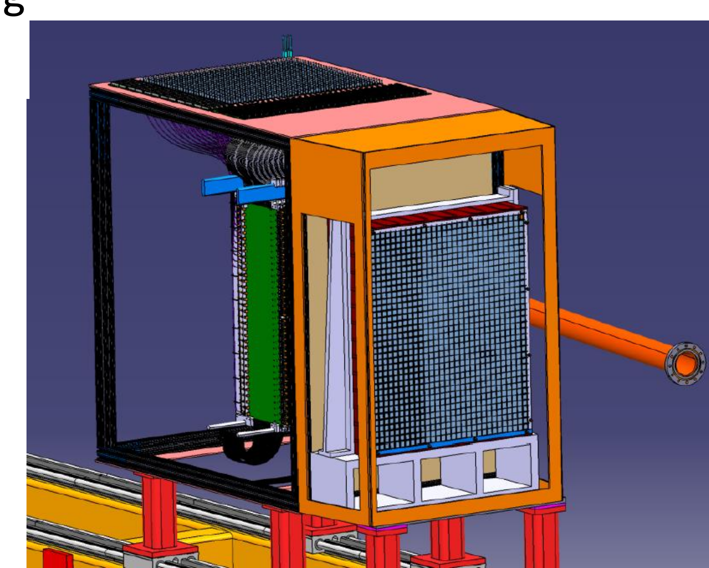
- 1080 $PbWO_4$ crystals
- 0.6 Tm sweeping magnet
- F250ADC sampling electronics
- Large opening angle beam pipe
- SHMS as carriage for rotation



Calorimeter frame being assembled

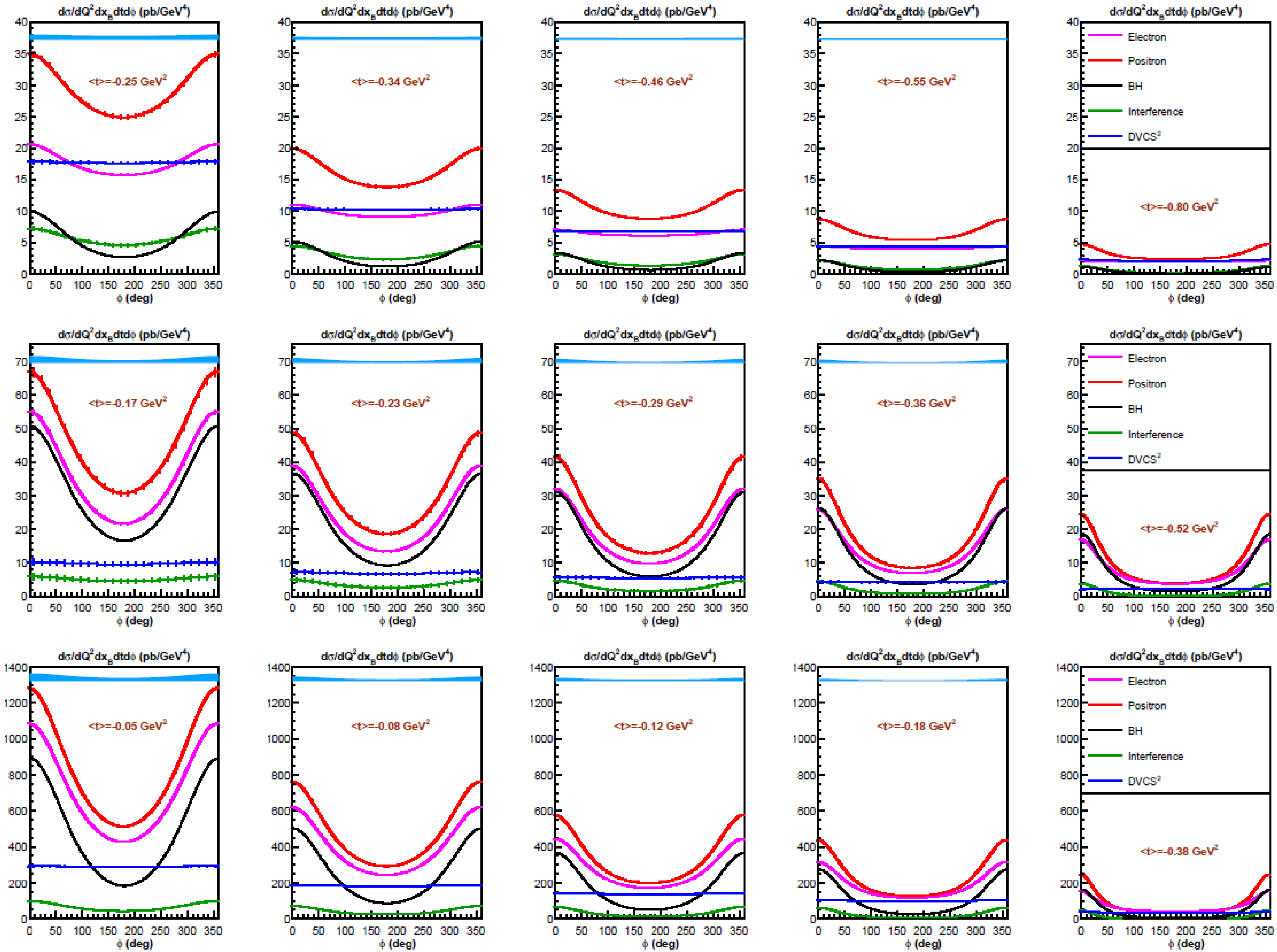
H(e,e'γ)X missing mass squared





Separation of DVCS^2 and BH-DVCS interference

Projections based on the KM15 model (Kumericki and Mueller, 2015)



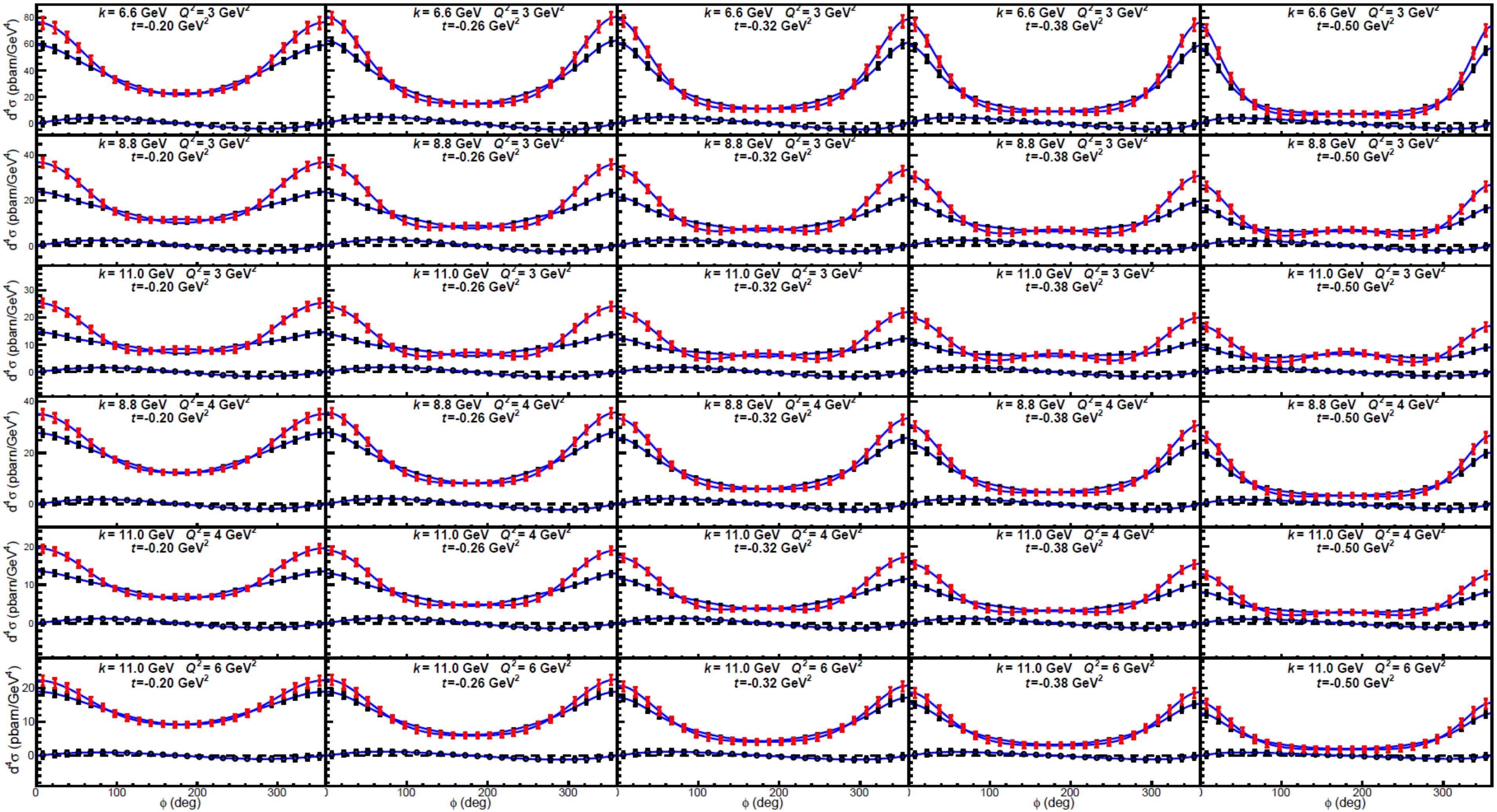
x_B=0.2, Q^2=2.0 GeV^2

x_B=0.3, Q^2=4.0 GeV^2

x_B=0.5, Q^2=3.4 GeV^2

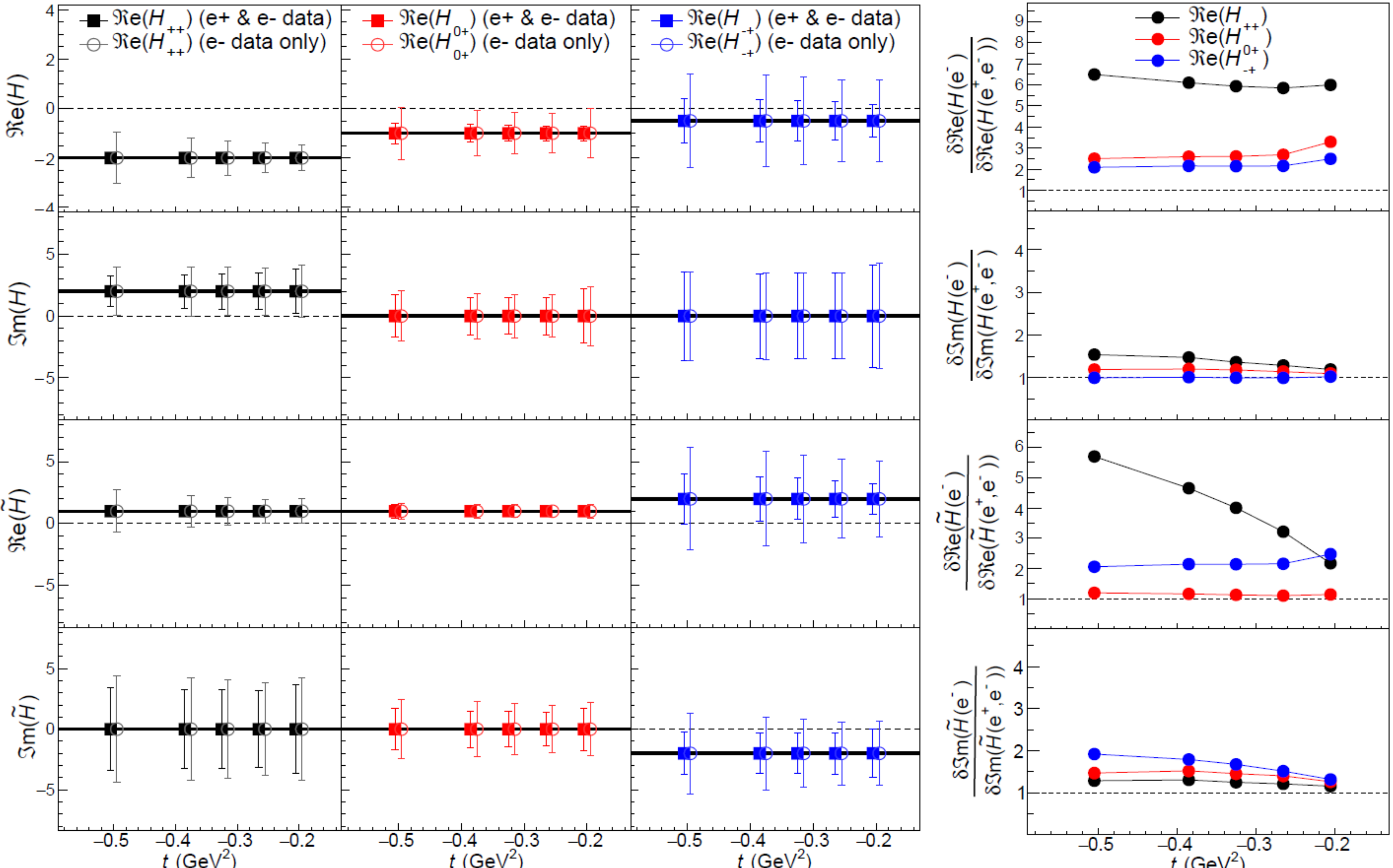
Impact on Compton Form Factors (CFFs) extraction

- ✓ Combined fit of all electron data from approved experiment E12-13-010
  (helicity-dependent AND helicity-independent cross sections)
- ✓ Fits include LO & LT CFFs, but also +1 helicity-flip CFFs ("HT") and +2 helicity-flip CFFs ("NLO")
- ✓ Cross sections generated with CFFs values fitted to 6 GeV data



Fits and analysis by M. Mazouz (U. of Monastir)

Impact on Compton Form Factors (CFFs) extraction



A factor or 4-6 improvement in the extraction of LO/LT CFFs Re(H) and Re($\tilde{H}$)

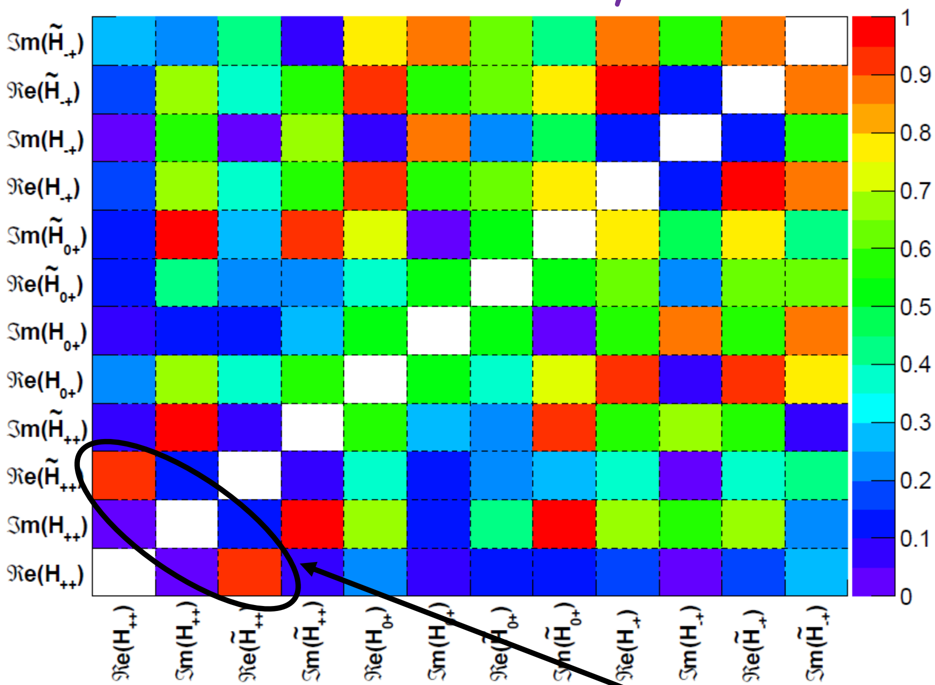
(factor of ~2 for HT and NLO)

Correlation coefficients (t=-0.26 GeV^2)

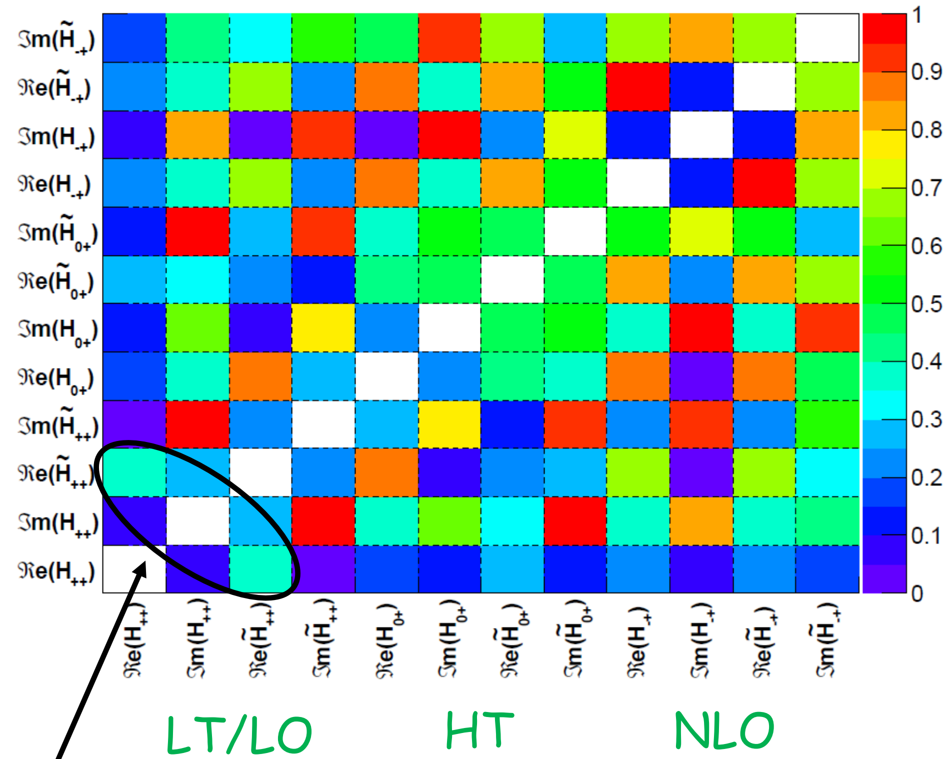
Correlations between different CFFs are significantly improved by a combined fit with positrons

$$|\rho_{i,j}| = \left|\mathrm{cov}[\mathbb{F}_i, \mathbb{F}_j]/(\sigma_i\sigma_j)\right|$$

Electrons only



Electrons & Positrons



Much better separation of
H & Ht CFFs at LT/LO

(from -94% without positrons to -39% when electron and positrons are combined, in this *t*-bin)

Summary and conclusion

- Positrons will help to cleanly separate $DVCS^2$ and BH-DVCS interference

- Strong impact on GPD CFFs fits and extraction

- We request **77 PAC days** of (unpolarized) positrons at $I \geq 5\ \mu A$

- Same setup (HMS+NPS) and kinematics of approved experiment E12-13-010