Compact Photon Source, An Update

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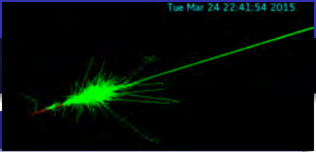
James Madison University

SBS Monday Meeting, JLab

December 5, 2022

Introduction



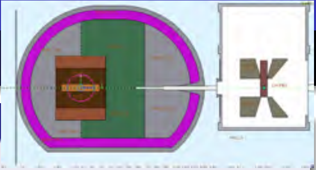
Time permitting, I shall talk about...

- CPS: what? why? how? (intro/refresher/memento)
- CPS: Ongoing work (design, optimization, prototyping...)
- CPS: Sample applications.
- Summary & Outlook ("Are we there yet?")

Disclaimer . . . as usual:

- Lots of ppl contributed to this talk.
- ...and they've done their level best! (and are credited here 🤞)
- Any mistakes/misrepresentations/mis–anything are purely mine!
- This is also on (very) short notice so I apologize for any mistakes, omissions and the like.

Enter CPS



what ...is CPS?

- ...as proposed in 2014 (BW)...
- CPS: **C**ompact **P**hoton **S**ource; novel untagged $\vec{\gamma}$ source design.

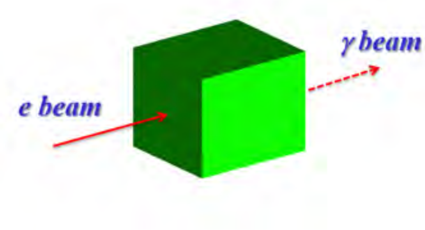
what ...might it be used for?

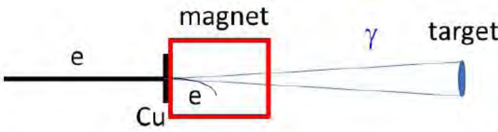
- low cross–section γ–nucleon interactions (such as high s, t WACS)
- narrow photon beam (good 4 identifying exclusive reactions)
- optimized for work w/ polarized NH3–type targets
- high intensity* ($\sim$ 30$\times$ better than alternatives)

Specs?

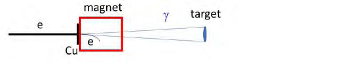
Power:	30 kW	Radiator:	10% rl
Beam size (@ 2 m):	$\sim$1 mm	Lifetime (est.):	1000+ h

How? CPS Concept



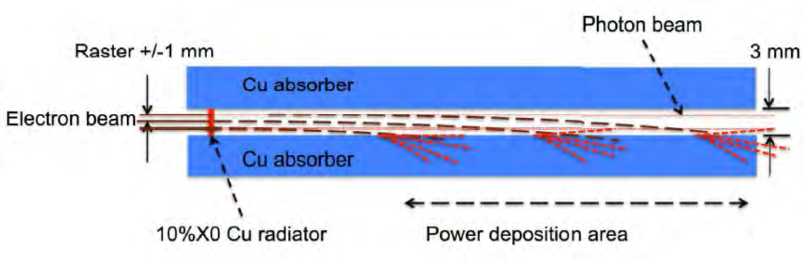


- Traditional γ beam approaches?
  no hermeticity. large. $$$. ("Thank you, next")
- Idea: Use the magnet* both as a beam–shaping and beam–dump device, *ergo*, problem is solved! **How?**



How? (II) CPS Central piece (Power Absorber)

2014 Concept (BW): sliding power absorption...



Back of the envelope calc.

- Radius R for 11 GeV e^- $\sim$10 m
- For 0.3 cm channel power deposition area 17 ± 12 cm
- Total field integral: $\sim$1000 kG-cm, iron dominated magnet.

mini–Summary

Based on what you've seen thus far... CPS...

- high intensity, untagged, polarized photon source
- narrow beam, compact (in x-y-z space). good for pol. target work.
- suitable for low cross–section γ–nucleon (exclusive) reactions

To actually hope to build it... Design & Optimization

- radiation & heat mitigation.
- compactness (in $$$ space). weight too!
- advertise it! (more physics, followers, likes, and (hopefully) funding!)

Next (drumroll for engineers!) we...

- tidy up design.
- coil design & fabrication. *ditto* for center piece, inner section, support.
- shielding procurement & stacking. (all these already **in progress**!)

CPS knowledge dissemination

tell the world...

- CPS concept, design, and simulation results, expected performance, usage, lifetime ... published in NIM, 2020
- also workshops, conference & other professional meeting presentations.

Nucl.Instrum.Meth.A 957 (2020) 163429

A Conceptual Design Study of a Compact Photon Source (CPS) for Jefferson Lab

D. Day,[1] P. Degtiarenko,[2] S. Dobbs,[3] R. Ent,[2] D.J. Hamilton,[4] T. Horn,[5,2,*] D. Keller,[1] C. Keppel,[2] G. Niculescu,[6] P. Reid,[7] I. Strakovsky,[8] B. Wojtsekhowski,[2] and J. Zhang[1]

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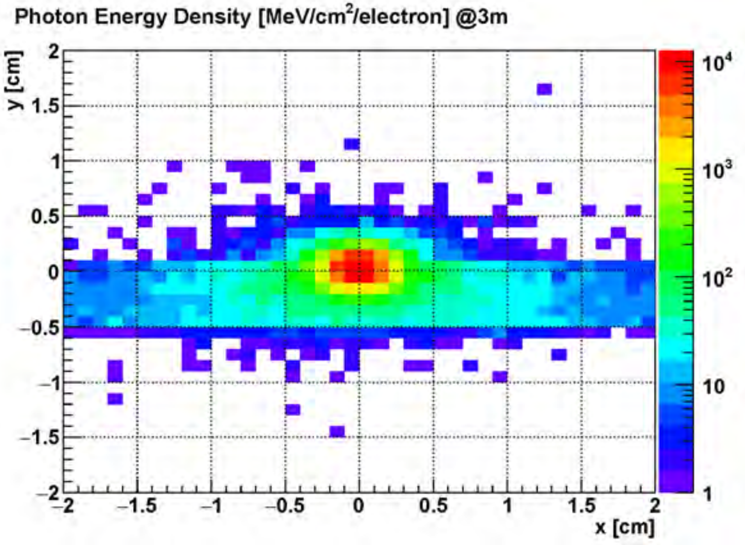
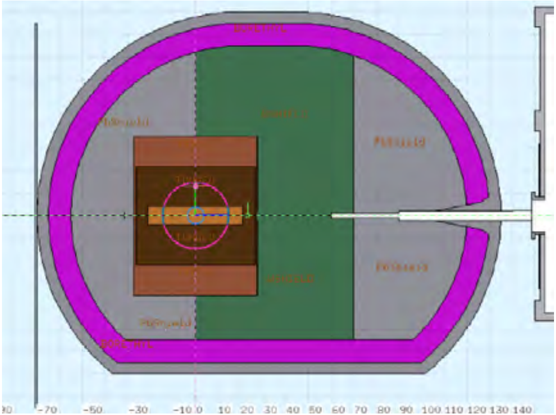
[8]*George Washington University, Washington, D.C. 20052, USA*

(Dated: December 17, 2019)

Will it work? (Beam Profile, Intensity...)



Is it safe to use? How about cost & weight?

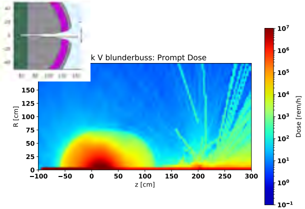


Simulation

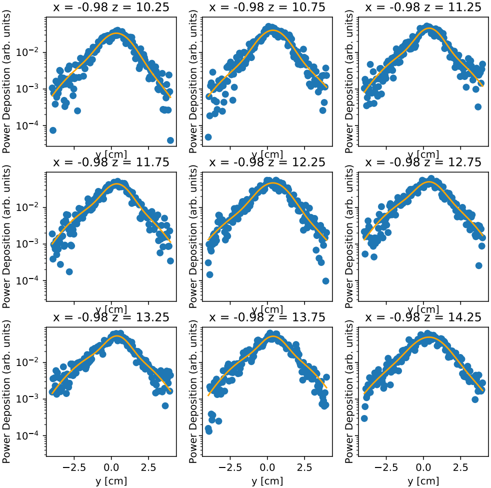
- ...fields, shielding mats.
- prompt/activation dose
- power deposition

...

- substantial savings in weight and $$$
- ... safe to operate.



Power deposition in the Central Piece

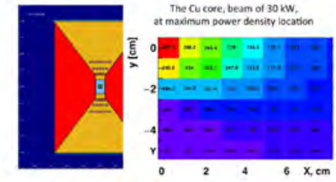


Simulation details...

- 0.5x0.5x5 mm grid
- available as df or param.

Heat Dissipation

- Bogdan: analytic calc.
- GN: 2D simulation
- Amy, Steve: 3D (ongoing)



(Possible) CPS Experiments

Experiments that use CPS

- WACS (E12-17-008), A-, 45 days.
- TCS (C12-18-005), "it's a C2, still work to do!"
- CPS as a e+/e- source!
- Hall-D K0L facility

Left purposefully empty to allow your imagination to wonder...

WACS (I)

WACS $\vec{\gamma} + \vec{p} \rightarrow \gamma + p$

David Hamilton (Glasgow), Gabriel Niculescu (JMU), Bogdan Wojtsekhowski (Jlab)

from a 2016 SBS presentation (GN)

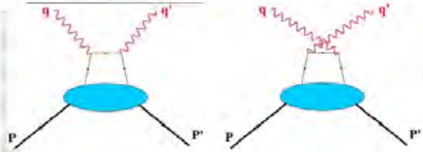
- *Mechanism of the reaction is a key question*
- *If we can measure the process: What do we learn?*
- *What do we learn from polarization observables?*

- *JLab 6-GeV era WACS experiments (2002, 2008)*
- *Experimental results for polarization K_{LL}* $\vec{\gamma} + p \rightarrow \gamma + \vec{p}$
- *Motivation for further measurements*

- *An approach for the most productive A_{LL} experiment*
- *... and the avenues it might open.*

WACS (II)

Compton scattering & GPDs



In the GPD approach, interaction goes with a single quark, and the handbag diagram dominates.

M.Diehl & P.Kroll

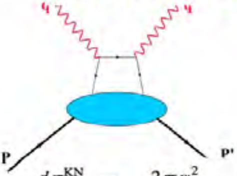
$$\frac{d\sigma}{dt} = \frac{d\sigma}{dt}_{KN}\left(\frac{1}{2}\left[R_V^2 + \frac{-t}{4m^2}R_T^2 + R_A^2\right] - \frac{us}{s^2+u^2}\left[R_V^2 + \frac{-t}{4m^2}R_T^2 - R_A^2\right]\right)$$

$$K_{LL} = A_{LL} \qquad K_{LL}\frac{d\sigma}{dt} \equiv \frac{1}{2}\left[\frac{d\sigma(+,\uparrow)}{dt} - \frac{d\sigma(-,\uparrow)}{dt}\right]$$

- *Test of the handbag predictions to the <10% level is an important task.*
- *The K_{LL} (A_{LL}) asymmetry: observable of choice to test reaction mechanism.*
- *NLO corrections are supposed to vary as 1/s (N.Kivel & M.Vanderhaeghen).*

WACS (III)

FFs, GPDs and Polarization Observables



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

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

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

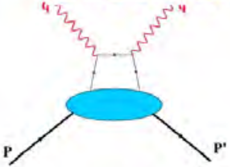
M.Diehl & P.Kroll

$$\frac{d\sigma^{KN}}{dt} A_{LL}^{KN} = \frac{2\pi\alpha_{em}^2}{(s-m^2)^2} \times \left[-\frac{s-m^2}{u-m^2} + \frac{u-m^2}{s-m^2} - \frac{2m^2t^2(s-u)}{(s-m^2)^2(u-m^2)^2} \right], \quad (9)$$

$$\frac{d\sigma^{KN}}{dt} K_{LL}^{KN} = \frac{2\pi\alpha_{em}^2}{(s-m^2)^2} \times \left[-\frac{s-m^2}{u-m^2} + \frac{u-m^2}{s-m^2} - \frac{4m^2t^2(m^4-su)}{(s-m^2)^3(u-m^2)^2} \right],$$

WACS (IV)

FFs, GPDs and Polarization Observables



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

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

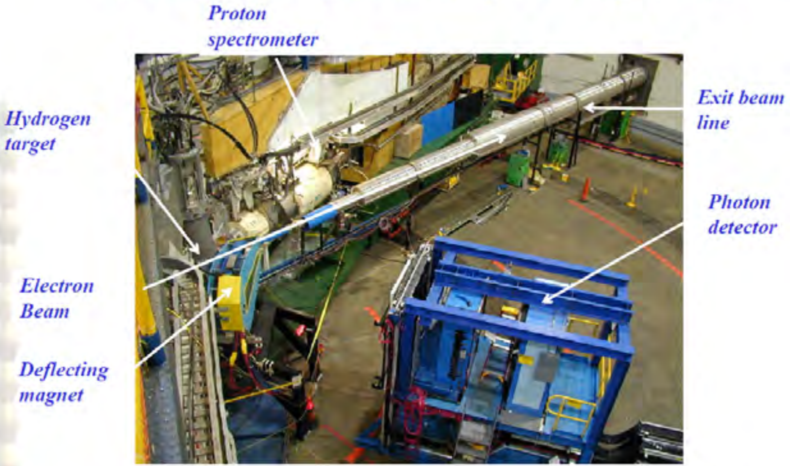
$$R_T(t) = \sum_a e_a^2 \int_{-1}^{1} \frac{dx}{x} E^a(x,0,t)$$

for m=0 $K_{LL}^{KN} = \frac{s^2 - u^2}{s^2 + u^2}$

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

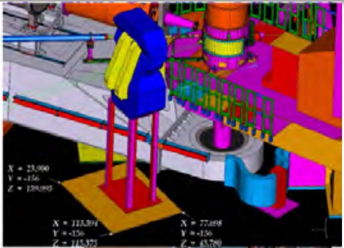
WACS (V)

E99-114 experiment, Hall A, 2002



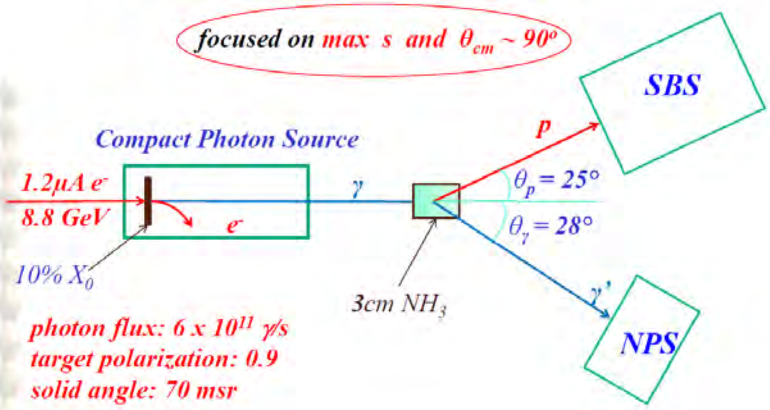
WACS (VI)

E07-002 experiment, Hall C, 2008



WACS (VII)

Plan to measure A_{LL}



TCS (I)

Timelike Compton Scattering off transversely polarized proton

C12-18-005

PAC 48, August 13th, 2020

Marie Boër (VT), Dustin Keller (UVa), Vardan Tadevosyan (ANSL), et al.

Proposal for Hall C, with NPS and CPS collaborations

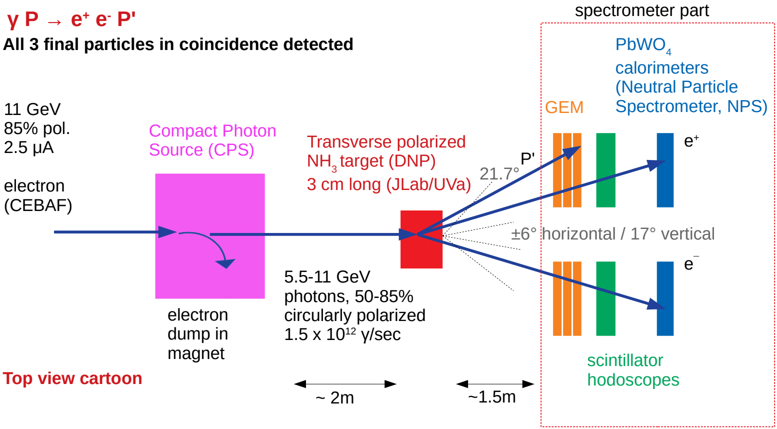
(credit: M. Boer[1] *et al*)

TCS (II)

Experimental setup

$\gamma P \rightarrow e^+ e^- P'$

All 3 final particles in coincidence detected



Trigger: GEMs, hodoscopes, calorimeters (all 3 particles)

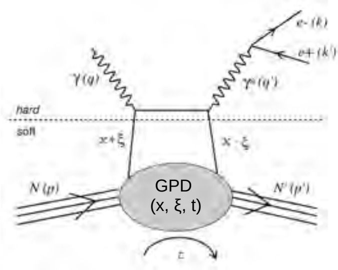
(credit: M. Boer *et al*)

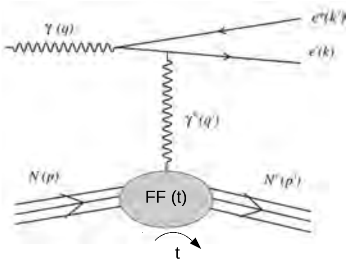
Integrated luminosity: 5.85×10^5 pb^{-1} for 30 PAC days of "physics"

TCS (III)

Timelike Compton Scattering

$\gamma P \rightarrow e^+e^- P'$ = TCS + Bethe-Heitler





Why measuring TCS off a transversely polarized proton?

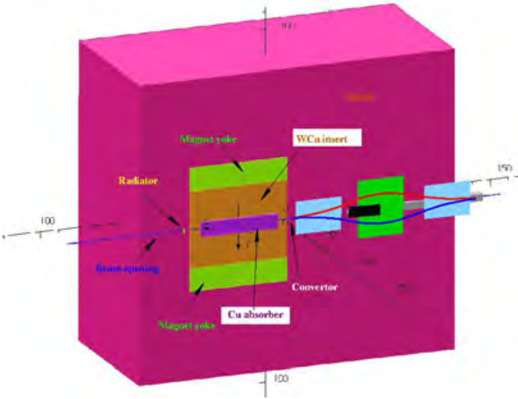
- **Unique access to GPD E of the proton**
- **GPD universality studies (TCS vs DVCS)**
- **Independent observables for GPD data sets and global fits in valence region**
- **Most knowledge on GPDs from DVCS: complex conjugate, TCS access same information**

(credit: M. Boer *et al*)

CPS in EIC era

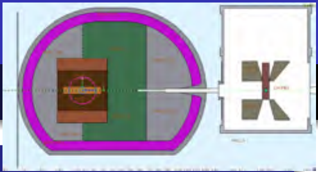
CPS as a e^+e^- source

- Shed light (!) on the TPE size
- 15x more productive than similar Hall B effort ($2 \times 10^{10}\ e^+/s$)
- Reduced systematics: non–magnetic calorimetry
- Rates @$Q^2 = 3GeV^2$: 0.5/2.5 Hz (∼500 h)
- BSM studies possible (dark photons, etc.)



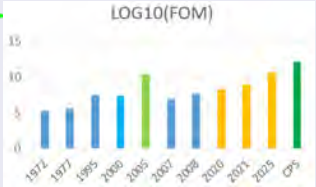
(credit: DM *et al*, Hall C Future Whitepaper...)

Quo Vadis? (Outlook)



I hope I convinced that...

- CPS: novel, efficient tool for (exclusive) photon–nucleon studies.
- Two approved* leading exp., exciting future physics prospects.
- Project at the prototyping, procurement, construction stage.
- I'm likely out of time but if you do have projects/ideas/possible experiments that could use CPS please **JOIN IN!**.



THANK YOU!