Compact Photon Source

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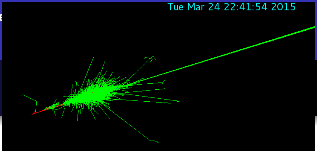
James Madison University

2021 Hall C Users Meeting, 01/28-29/2021 JLab (virtual)

January 29, 2021



Introduction

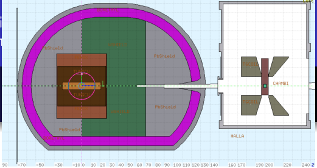
Time permitting, I shall talk about...

- What is CPS? (Definition)
- What can it be used for? (Justification)
- How does it work? (Key concepts & features)
- Current development status.

- Summary & Outlook

Jefferson Lab

Enter CPS



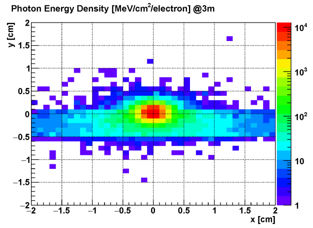
What is CPS?

- stands for **C**ompact **P**hoton **S**ource
- novel arrangement of untagged photon source

What is it for?

- high s, t photon–nucleon interactions such as WACS
- narrow photon beam - 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

Potential Clients?

- polarized photon–induced reactions using NH3–type targets
- ...emphasizing low cross–section, exclusive reactions
- any other experiment that might use CPS as their "primary" beam

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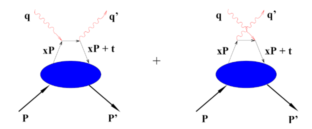
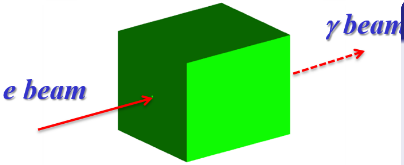


Figure 1: The handbag diagram for WACS.

Experiments using CPS

- E12-17-008 "Polarization Observables in Wide-Angle Compton Scattering at large s, t and u", D. Hamilton *et al.*, A^{-}, 46 days.
- C12-18-005, "Timelike Compton Scattering off a transversely polarized proton", M. Boer, D. Keller, V. Tadevosyan, 49.5 days.
- Two–photon exchange study using CPS - (LOI in preparation).

Compact Photon Source Concept

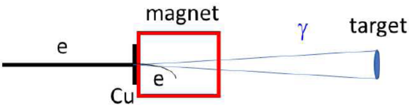


ideas and facts. (why?)

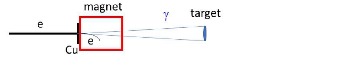
- ...as proposed in 2014 (BW)
- **Outgoing γ beam:** $\vartheta \sim m/E$ **angular size**
- **Source could be hermetic!!!**

what & how?

- What to do w/ the electron beam?
- How about: traditional approaches? **NO!** No hermeticity; large, $$$.
- Idea: Use the magnet as a dump, *ergo*, problem is solved! **How?**

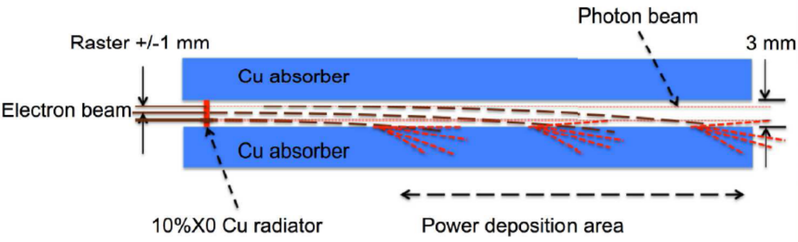


CPS Central piece (CP)



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

Deflect, degrade, (begin to) dispose of residual e^- beam



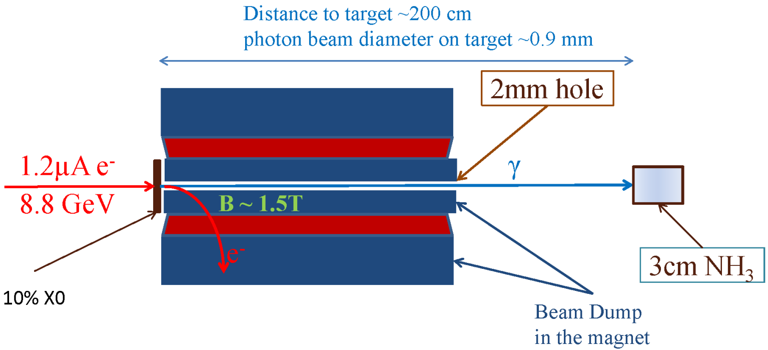
For the current design...

- 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.

Compact Photon Source Development (I)

from the November 2014 talk at the NPS meeting

γ-Source



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

B. Wojtsekhowski

Compact Photon Source Development (II)

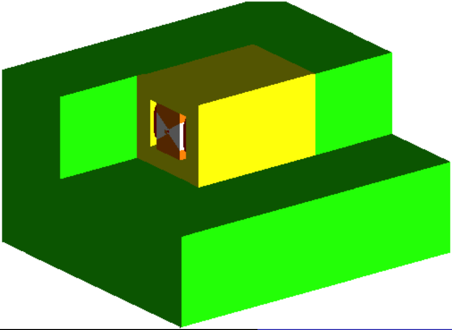
from the tech note for the 2015 WACS proposal

Conceptual Design Report
A Compact Photon Source

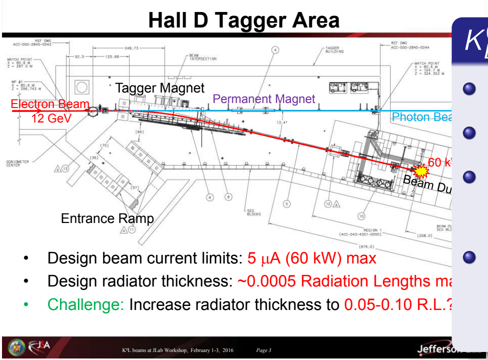
B. Wojtsekhowski
Thomas Jefferson National Accelerator Facility, Newport News, VA 23606

G. Niculescu
James Madison University, Harrisonburg, VA 22807

June 22, 2015



CPS knowledge dissemination (I)



K_L^0 facility:

- CPS-like source in Hall D.
- sliding power dep...
- see proceedings of KL2016 workshop
- Hall C CPS model made available to the Hall D team currently pursuing this project

CPS Development Group

...

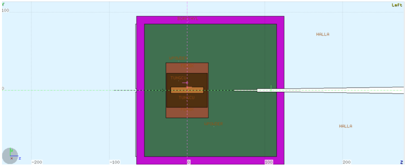
- ...
- **2017:** Breakthrough (TH): CPS development group organized by CUA after workshop in Feb. 2017

page | discussion | view source | history

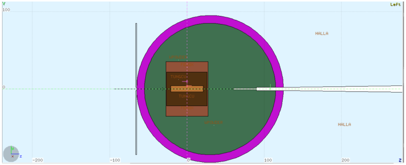
CPS Collaboration

1. Arshak Asaturyan (AANL, YerPhI)
2. Moskov Amaryan (ODU)
3. Vladimir Berdnikov (CUA)
4. William J. Briscoe (GWU)
5. Marie Boer (Temple U.)
6. Josh Crafts (CUA)
7. Eugene Chudakov (JLab)
8. Pavel Degtiarenko (JLab)
9. Donal Day (UVa)
10. Sean Dobbs (FSU)
11. Hovanes Egian (JLab)
12. Rolf Ent (JLab)
13. Cristiano Fanelli (MIT)
14. David J. Hamilton (U Glasgow)

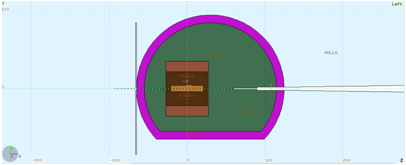
Compact Photon Source Development (III)



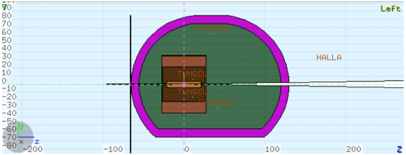
01 - Square shielding. Offset.



02 - Spherical shielding.



03 - Cut Spherical shielding.

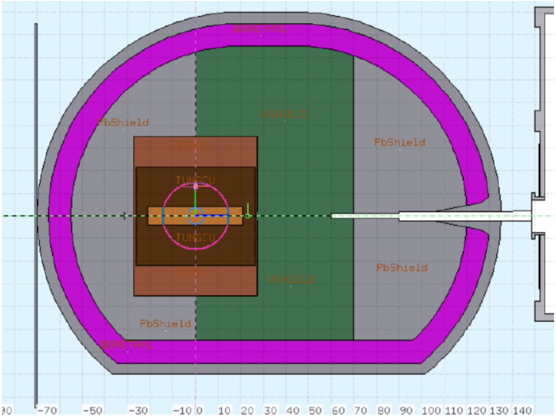


04 - Cut "egg-shape".

NOTE1: Figures not to scale! Powder *W* volume is reduced: 4.8 m^3, 2.2 m^3, ... 1.8 m^3.

NOTE2: Prompt and activation results for all these (and more!).

“Final” CPS version (FLUKA)



Simulation

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

...

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

CPS knowledge dissemination (II)

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]

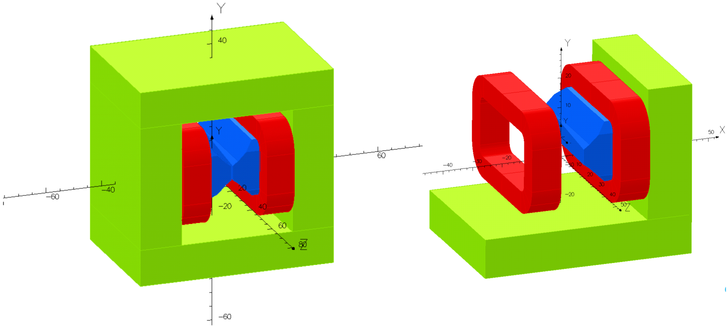
[1]*University of Virginia, Charlottesville, Virginia 22904, USA*
[2]*Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23606, USA*
[3]*Florida State University, Tallahassee, Florida 32306, USA*
[4]*University of Glasgow, Glasgow G12 8QQ, Scotland, United Kingdom*
[5]*Catholic University of America, Washington, D.C. 20064, USA*
[6]*James Madison University, Harrisonburg, Virginia 22807, USA*
[7]*Saint Marys University, Halifax, Nova Scotia, Canada*
[8]*George Washington University, Washington, D.C. 20052, USA*
(Dated: December 17, 2019)

NIM Paper

- CPS concept, design, and simulation results
- expected performance, usage, lifetime
- ... published in NIM, 2020

Can we build it?

View of the magnet

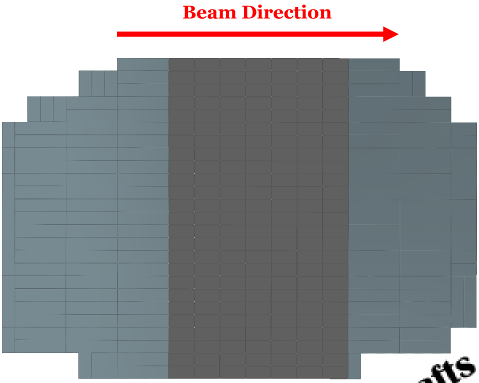


CPS Magnet Evolution B. Wojtsekhowski 8

Stacking of *Pb* and *W* blocks...

CPS Shielding Stack Profile Update

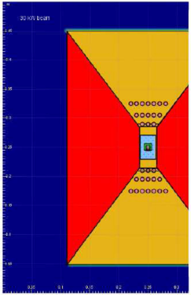
- The CPS shield interior now contains a total of 1508 lead bricks. Note: This does not include the exterior skin.
- The number of Tungsten Bricks is now 2109.

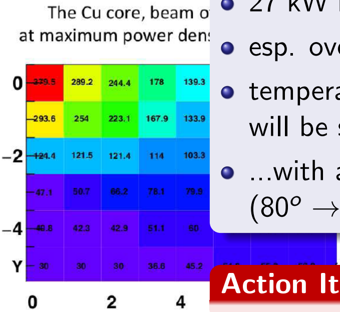


Lead Bricks
Tungsten Blocks

Josh Crafts

How About?...





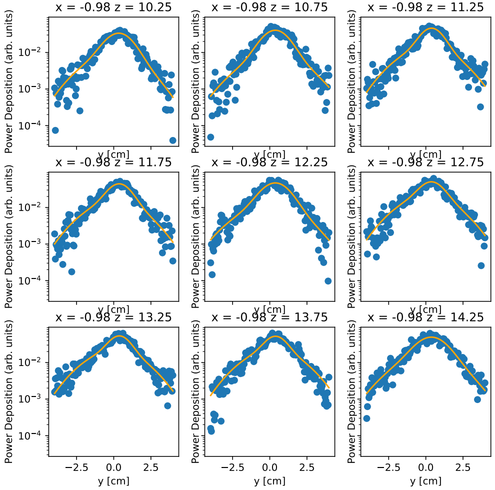
Heat dissipation...

- 27 kW is a lot of heat to get rid of
- esp. over a relatively small space
- temperature of the center piece will be substantial
- ...with a large temp gradient ($80^o \rightarrow\sim 500^o$ or so)

Action Items:

- heat dissipation/cooling
- temp-induced stress

Power deposition in the Central Piece



Simulation details...

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

Heat Dissipation

- Water @110 psi
- Bogdan: analytic calc.
- GN: 2D simulation
- Amy, Steve: 3D (in progress)

Simple analytic calculation

Thermal elongation and related stress

Copper thermal expansion, $\alpha = 17 \cdot 10^{-6}$ per deg. K

Copper Young module, $E = 1.2 \cdot 10^{6}$ kg/cm^2

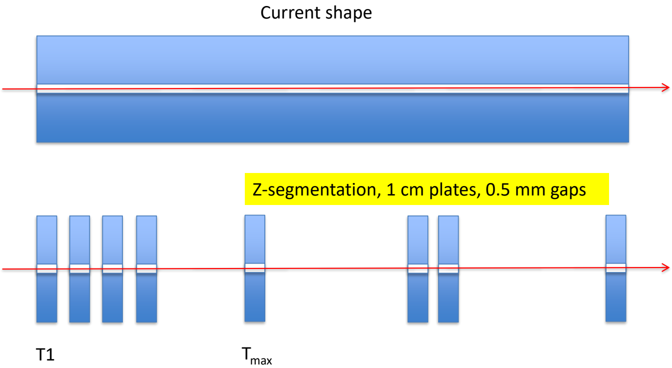
$$\delta l = \alpha \cdot \Delta T \cdot l \sim 17 \cdot 10^{-6} \times 400 \times 200 = 1.4 \text{ mm}$$

$$\sigma = E \cdot \frac{\delta l}{l} = \alpha \cdot \Delta T \cdot E =$$

$$17 \cdot 10^{-6} \times 400 \times 10^{6} \text{ atm} = 7200 \sim 10 \times \sigma_Y$$

Mitigation...

Reduction of the deformation risk
by a few design changes



$$\delta y \sim \alpha \cdot T_{max} \cdot \Delta y / 2 = 0.1 \text{ mm}$$

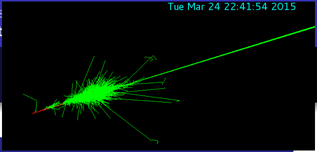
...and there is a plan to prototype/test this approach.

Projected Timeline

Anticipated Project Progression:

- ⇒ **radiation analysis:** completed; **design of shielding:** advanced; *Pb* from SLAC is moving
- ⇒ **power deposition:** completed
- ⇒ **stress analysis:** in progress. Goal is to complete it by 03/01/2021.
- ⇒ **production drawings** for the central part for internal review - by 07/01/2021
- ⇒ **order** the magnet+inserts ∼08/15/2021

Quo Vadis?



I hope I convinced that...

- CPS a very helpful tool for probing (exclusive) photon–nucleon interactions.
- Project not only “feasible” but mature enough to seriously plan (detailed) prototyping and construction.
- ... ERR underway
- I'm likely out of time but if you do have projects/ideas/possible experiments that could use CPS please **JOIN IN!**.

THANK YOU!