Update on CPS

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**Hall C Collaboration Meeting,
JLab, Newport News, Va**

January 28, 2020

Introduction

Time permitting, I shall talk about...

- electromagnetic probes in nuclear/particle physics
- Brief history of photon sources

- CPS concept.
- CPS design & simulations.

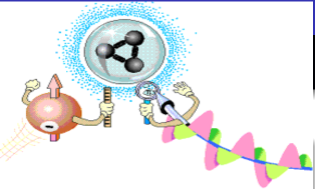
- Outlook

Disclaimer:

This is just GN's $0.02 worth...

- Many people contributed (directly or indirectly) to this talk (collab. from CUA, Glasgow, GWU, St. Mary's, UVa, JMU, JLab).
- ...and they all have done their level best! Thanks!
- Therefore, all **inaccuracies, miss-statements, controversial, or just plain wrong statements** are mine alone!
- That said, onward to the:
Why should one want/need photon beams? question...

Electromagnetic probes...



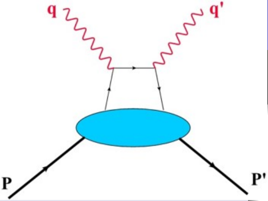
excellent for probing nuclear substructure:

- High energy, intensity, "clean"
- QED is well understood

However...

- target is not static!
- probe affects the dynamics (recoil, pair prod., relativistic eff.)
- e^- **beam**: low cross–section, radiative corrections, ...
- **photon beam**: possible alternative/complementary to e^- beams. (Avoids some problems or at least it presents a diff. perspective!)

GPD formalism holds to promise of...



"nuclear femtography":

- 3D picture of the nucleon substructure.
- use **exclusive** reactions at high mom. transfer $-t$, high s too.
- e^- and γ can/should be used over a wide range of s and $-t$ to disentangle H, $\tilde{H}$, E, $\tilde{E}$ (Compton FFs?).
- simultaneous access to all of these functions requires target polarization (ideally both long. and trans. pol. targets!)
- for the particular case of RCS: $\vec{\gamma} + \vec{p} \to \gamma + p$

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

...

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

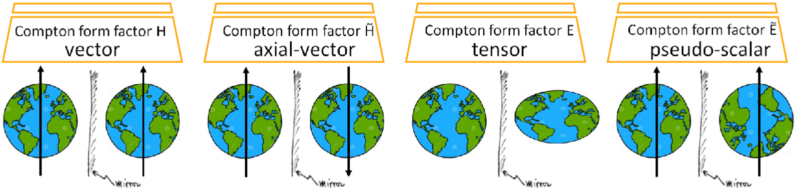
$$R_A(t) = \sum_a e_a^2 \int_{-1}^{1} \frac{dx}{x} sign(x) \hat{H}^a(x,0,t)$$

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

M.Diehl & P.Kroll

Looking at polarization obs.

one gets access to ratios of *Rs* and thus to (integrals of) GPDs.



Photon Sources: a lightning–quick history (I)

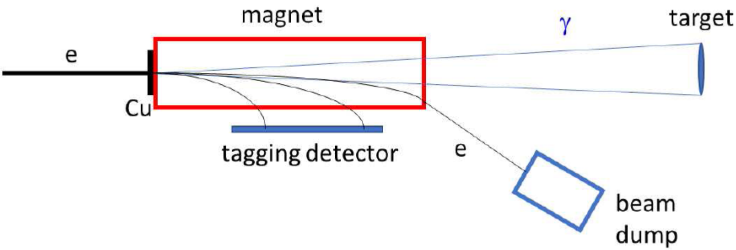
alas...

- “designer” exclusive reactions come at a price:
- competing processes/backgrounds, (very)low cross–sections.
- thus the need of developing high energy, high intensity photon beams.
- brief review of possible options follows...

photon source options

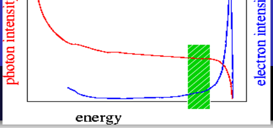
- $\sim$ few MeV - radioactive isotopes
- $>$ few TeV – cosmic rays
- In-between – use bremsstrahlung radiation to “build” your own.
- For RCS work: high s and $-t$, so $\sim$10 GeV (or more) would be ideal.

Photon sources (II)

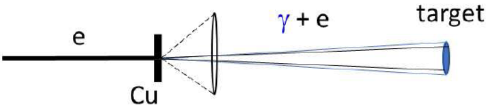


Radiator, Sweeper, (Tagger), Dump.

- early examples: DESY (1971), SLAC (1971), CEA (‘72-’73)
- $s > 2GeV^2$, low t. Flux $\sim 2 \times 10^8 \gamma/s$
- Cornell (1975), flux $\sim 1.5 \times 10^{10} \gamma/s$.
- Bauer-Spital-Yennie review, RMP 50 (1978)
- If tagging, usable flux much lower ($\sim 10^{7-8} \gamma/s$). See CLAS6.



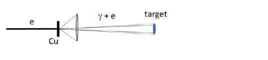
Photon sources (III)

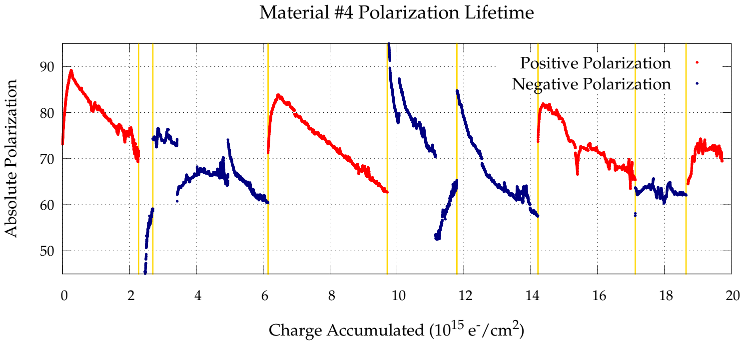


Mixed e^-/γ beams.

- JLab (2002, 2008). Flux $\sim 2 \times 10^{13} \gamma/s$!
- competing reactions: π^0 photoproduction, $e - p$ elastic.
- difficult analysis (low cross-section, solid angle).
- low efficiency & analyzing power of the proton polarimetry
- if polarized target - luminosity much lower.

Photon sources (IV)

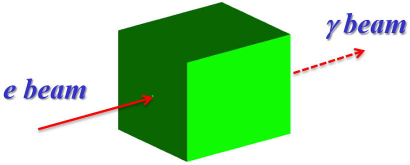




from SANE exp. (J. Maxwell Ph.D. Thesis)

- mixed e/γ beam + pol. target = lots of problems
- frequent annealing needed. change of material as well.
- ...and for awhile this was the "state-of-the-art" in the field!

Compact Photon Source Concept

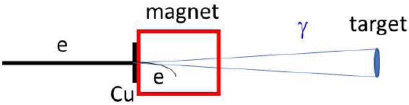


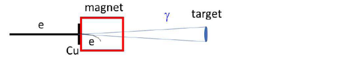
CPS.

- Incident beam: small trans. size
- Outgoing γ beam: m/E angular size
- Source could be hermetic!!!

...

- What to do w/ the electron beam?
- Traditional approaches - **NO!**
- no hermeticity, large, $$$.
- Idea: Use the magnet as a dump, *ergo*, problem is solved!
- Can this be done?

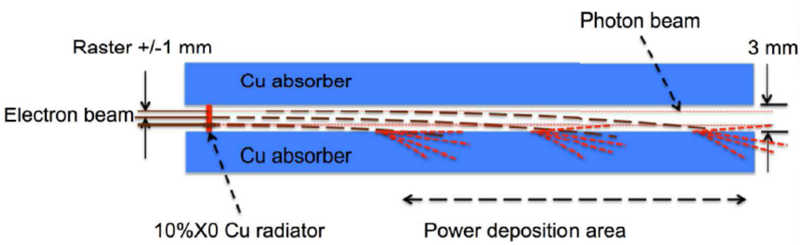




CPS Central piece

...

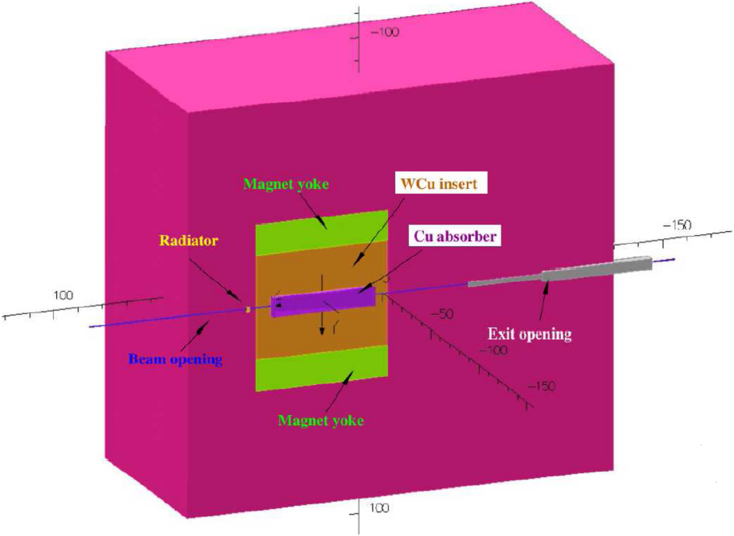
Deflect, degrade, (begin to) dispose of residual e^- beam



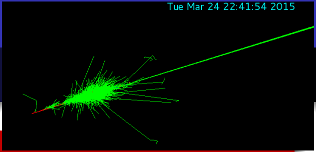
For the current design...

- Radius R for 11 GeV e^- $\sim$10 m
- For 0.3 cm channel power deposition area 17 $\pm$ 12 cm
- Total field integral: $\sim$1000 kG-cm. 50 cm iron dominated magnet.

Compact Photon Source 2.0



CPS Q&A:



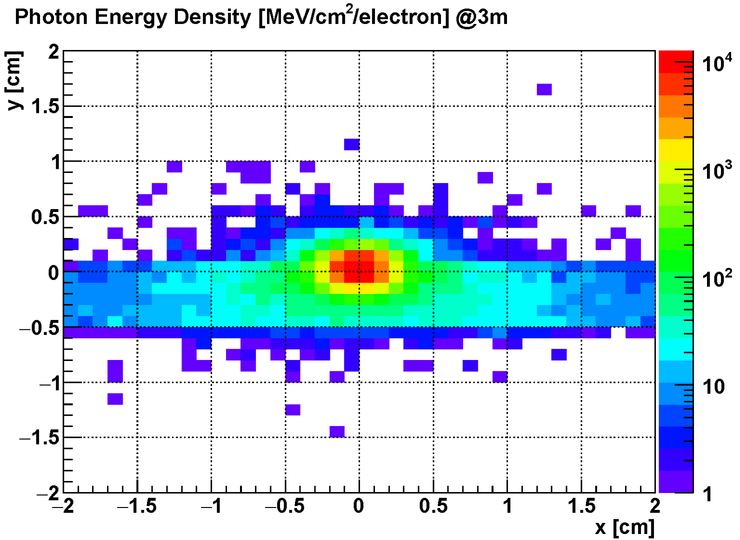
CPS Questions

- How will the γ beam look like?
- Will the central piece melt? How hot will it get?
- Is the shielding adequate? How about activation?
- How heavy, co$tly will this thing be?
- Is fabricating such device possible?

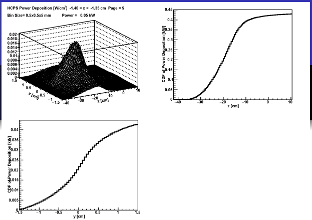
CPS development tools

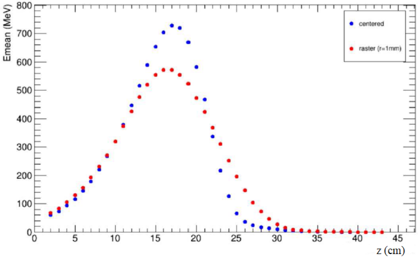
- OPERA (magnet)
- Geant 4 (γ beam profile, prompt radiation, power deposition)
- Fluka (prompt and activation calculations)
- ROOT/C++, Python.

Beam Profile



Central Piece Power Dissipation



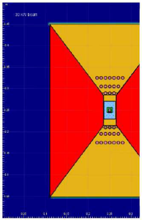


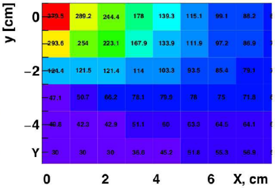
CP Power Dissipation

- Study CP power deposition.
- Position, extent, amount.

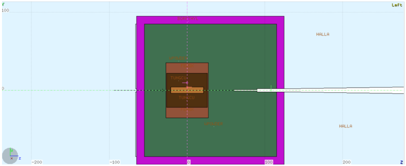
...

- Focus on the z region w/ the most energy deposited.
- Heat transport simulation.
- ... w/ various cooling options.
- **Hot but VERY FAR from melting!**

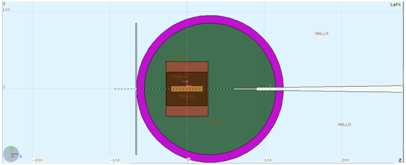




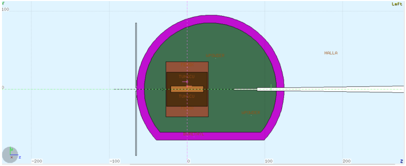
CPS Shielding Configurations (P.R.:



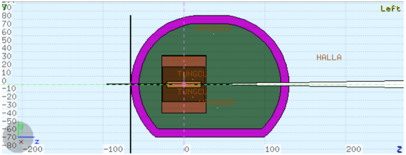
01 - Square shielding. Offset.



02 - Spherical shielding.



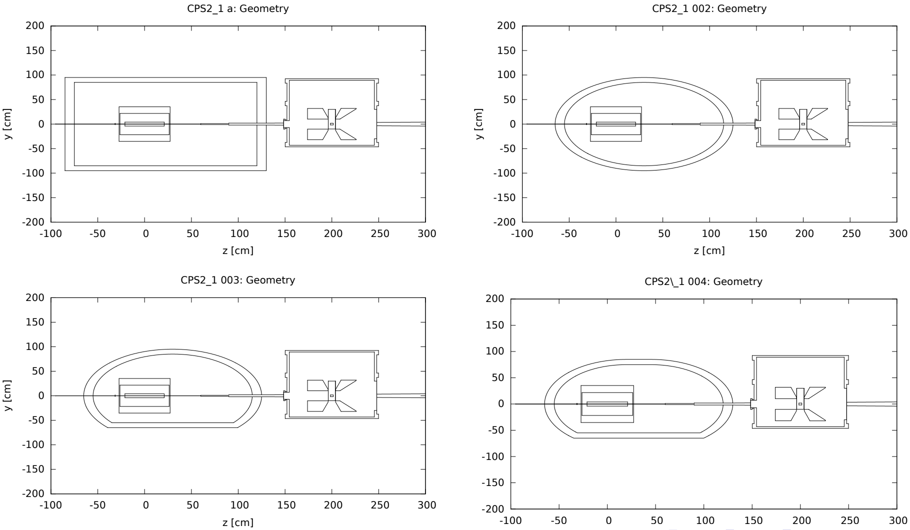
03 - Cut Spherical shielding.



04 - Cut "egg-shape".

NOTE: Figures not to scale! Powder W volume is reduced: $4.8\ m^3$, $2.2\ m^3$, ... $1.8\ m^3$. Weight and $$ scale accordingly!

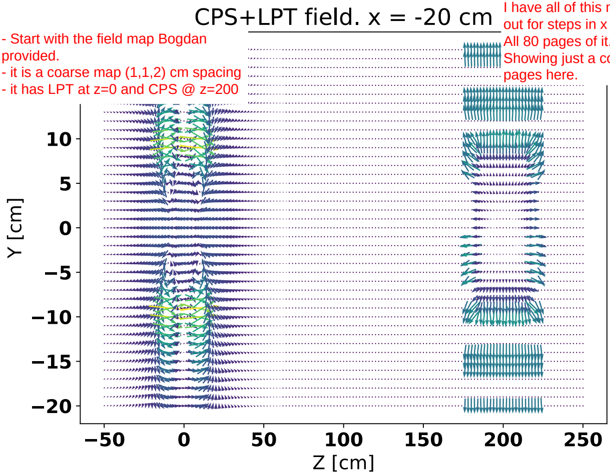
Just the geometry. Add LPT (J.Z.)



Pretend that the spheres are spheres and that the first model is a cube...

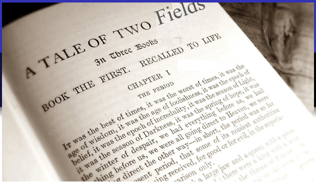
"...He was turned to steel In the great magnetic field..."

- Start with the field map Bogdan provided.
- it is a coarse map (1,1,2) cm spacing
- it has LPT at z=0 and CPS @ z=200

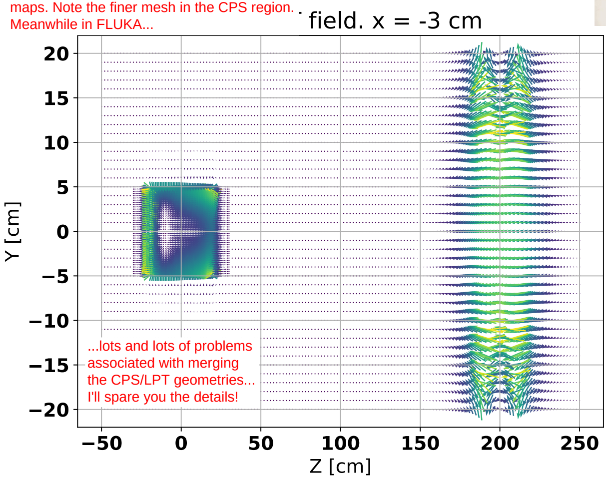


I have all of this mapped out for steps in x and y. All 80 pages of it. Showing just a couple of pages here.

A tale of two fields...



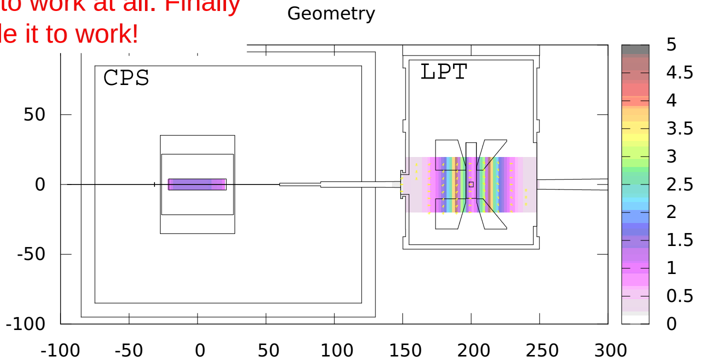
Merged field map. Actually two superimposed maps. Note the finer mesh in the CPS region. Meanwhile in FLUKA...



...lots and lots of problems associated with merging the CPS/LPT geometries... I'll spare you the details!

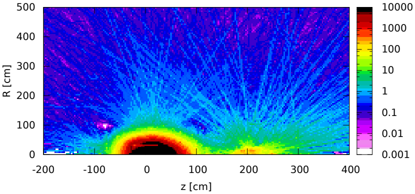
Habemus campus magneticus

for awhile I could not get this to work at all. Finally made it to work!

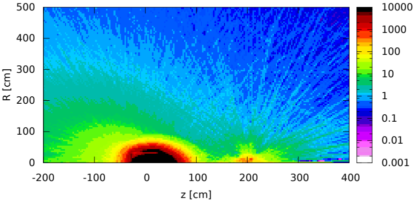


Residual Dose. 1h Cooling [mrem/h].

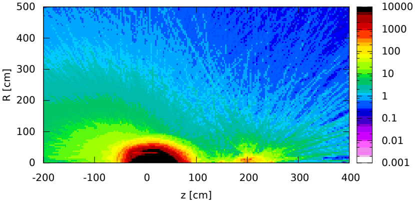
CPS2_1 a: Activation, 1 h cooldown



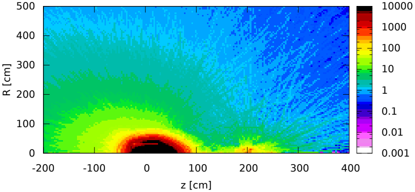
CPS2_1 002: Activation, 1 h cooldown [mrem/h]



CPS2_1 003: Activation, 1h cooldown [mrem/h]

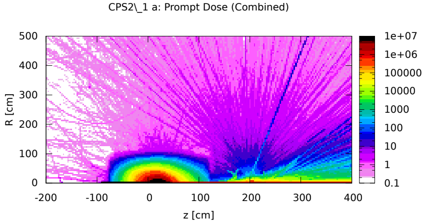


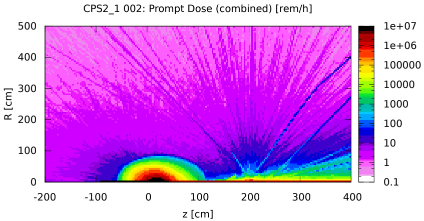
CPS2_1 004: Activation, 1 h cooldown [mrem/h]

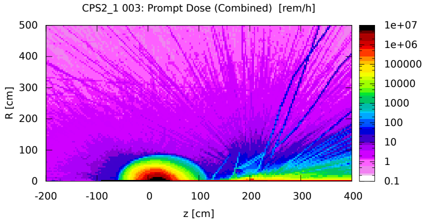


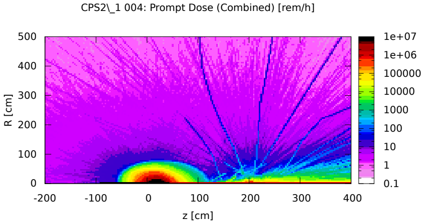
First “splotch” is the CPS, second one the LPT.

Prompt Dose. n and γ combined [rem/h].

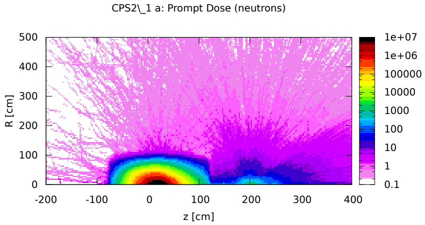


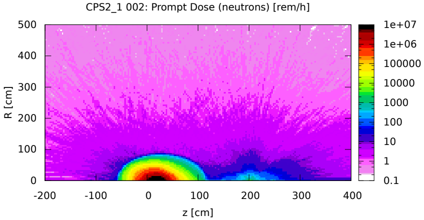


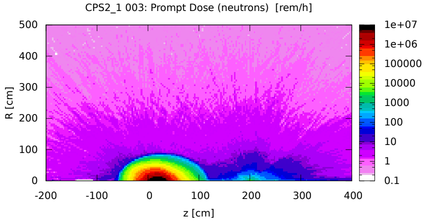


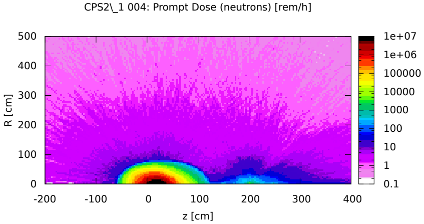


Prompt Dose. Just neutrons[rem/h].

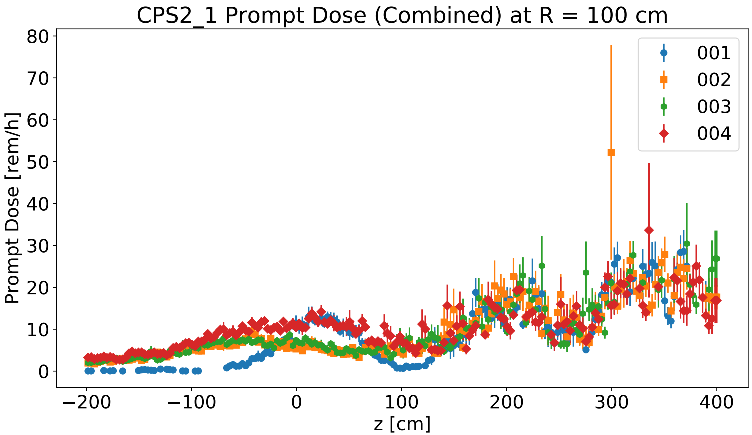




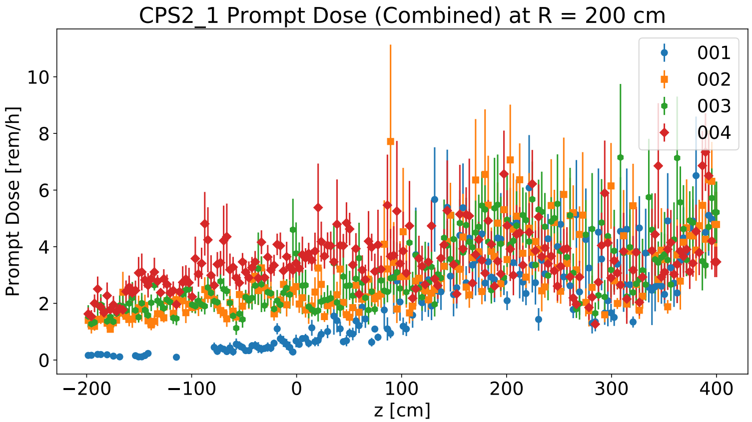




Prompt combined Dose at 1 m from the beamline.

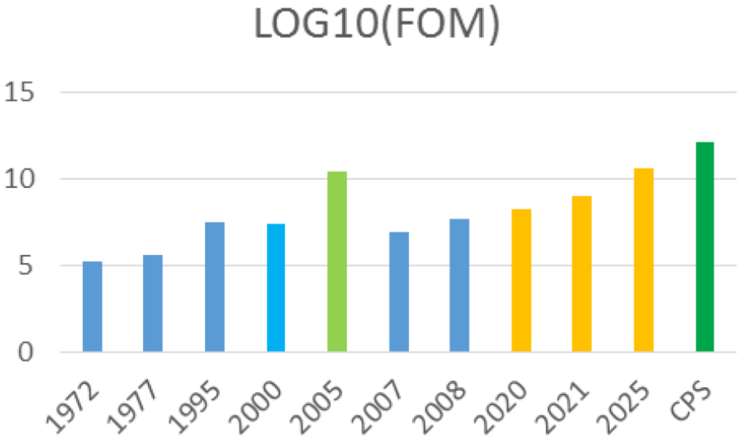


Prompt combined Dose at 2.0 m from the beamline.



$20/4 = 5$. ALARA seems to work!

High energy photon sources, past/present/future



Fresh off the press!

Nuclear Inst. and Methods in Physics Research, A 957 (2020) 163429

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FRESH OFF THE PRESS

A conceptual design study of a Compact Photon Source (CPS) for Jefferson Lab

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ARTICLE INFO

Keywords:
Photon source
Hadronic physics
Radiation dose
Tungsten powder shield

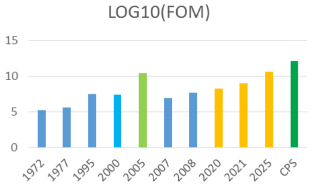
ABSTRACT

This document describes the technical design concept of a compact high intensity, multi-GeV photon source. Capable of producing 10^{12} equivalent photons per second this novel device will provide unprecedented access to physics processes with very small scattering probabilities such as hard exclusive reactions on the nucleon. When combined with dynamic nuclear polarized targets, its deployment will result in a large gain in polarized experiment figure-of-merit compared to all previous measurements. Compared to a traditional bremsstrahlung photon source the proposed concept presents several advantages, most significantly in providing a full intensity in a small spot at the target and in taking advantage of the narrow angular spread associated with high energy bremsstrahlung compared to the wide angular distribution of the secondary radiation to minimize the operational prompt and activation radiation dose rates.

The very latest...

Funding proposal submitted to a (hopefully friendly) funding agency by: CUA, UVA, JMU.

Outlook



Hopefully I convinced you that CPS is...

- a novel technique for producing untagged γ beams (JLab).
- well matched w/ the UVa polarized target & Hall C/A setups.
- $\times$ **30 FOM** improvement over current and projected setups!
- relatively low cost; concept adaptable to other areas.
- cost–cutting design and funding opportunities are aggressively pursued.

Thank you!