

Compact Photon Source (CPS) update

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James Madison University

Introduction

Time permitting, I shall talk about...

- need for & (very) brief history of photon sources
- CPS: concept, design, engineering
- Outlook



Jefferson Lab



Disclaimer:

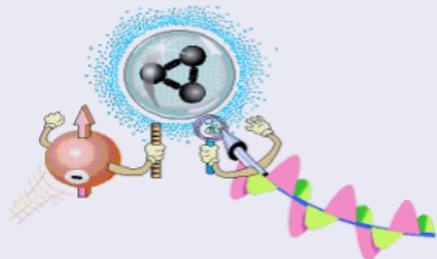
This is just GN's \$0.02 worth...

- Many people (BW, PD, CL, DH, apologies if I did not mention **you** here!) contributed (directly or indirectly) to this talk.
Collaborators 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, polarization
- “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 the problem or at least it presents a diff. perspective!)

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.

photon source options

- ~ few MeV - radioactive isotopes. > few TeV – cosmic rays.
- In-between (~GeV-ish range) - need to build our own.
- Several ideas, with their own plus-es and minus-es (see next page)

GeV-scale Photon Beams... (II)

photon beam preparation solutions:

- **bremsstrahlung:** potentially high intensity (up to 10^{14} equiv. γ/s)
 - **untagged:** high intensity
 - **tagged:** good energy resolution ($\sim 10^{-3}$), low intensity ($< 10^8 \gamma/s$)
 - **end-point-method:** limited $\frac{dE}{E}$. need (almost) exclusive final state...
- **positron annihilation:** almost monochromatic near E_{max} . need e^+ !
- **laser backscattering:** wide range of possible polarizations (E_γ vs ϑ_γ)
- **quasi real:** intense beam, compact size
- if **polarization** is important (it is, most of the time!):
 - circularly polarized e^- beam
 - crystal radiator
 - laser backscattering
 - small angle e^- tagging

A few photon beam examples (III) (credit: B. Wojtsekhowski)

Cornell, 1975

Energy 2-6 GeV

Photon flux

1.2×10^{10} eq. ph/s

The experiment was performed at the Wilson 12-GeV Electron Synchrotron at Cornell University. The incident photons were generated by an extracted electron beam focused to a spot approximately 3 mm in diameter on a 0.10-radiation-length aluminum target. The electrons in the resulting beam were magnetically diverted into a water-cooled dump. The bremsstrahlung photon beam passed through a collimator, sweeping magnet, scraper, and another sweeping magnet before entering the hydrogen target which was 11.5 m downstream of the radiator. At this point the beam was about 1.3 cm in diameter at the lowest energy. The hydrogen target cup was a cylinder

A few photon beam examples (IV) (credit: B. Wojtsekhowski)

ELSA, 1991
Tagged beam

Energy 3 GeV

Photon flux
 1×10^7 eq. ph/s

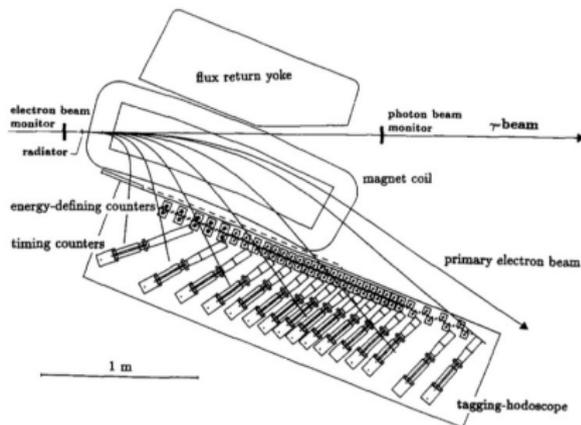
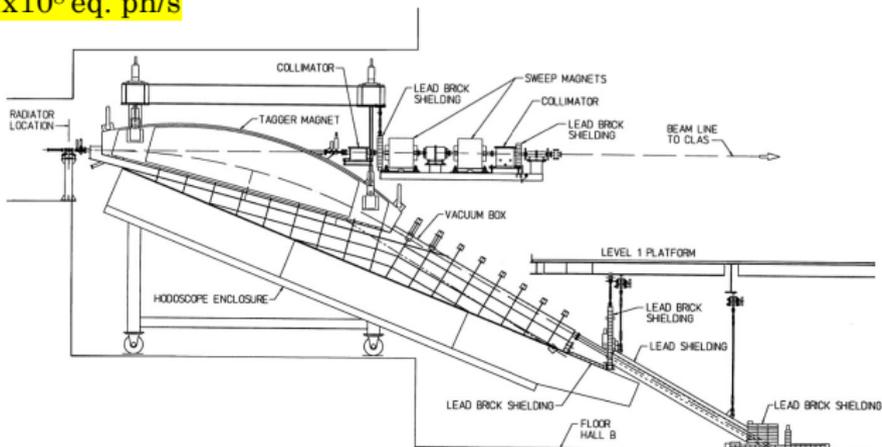


Fig. 1. Schematic view of the PHOENIX tagging system.

A few photon beam examples (V) (credit: B. Wojtsekhowski)

JLab, Hall B,
Tagged beam
 1×10^8 eq. ph/s

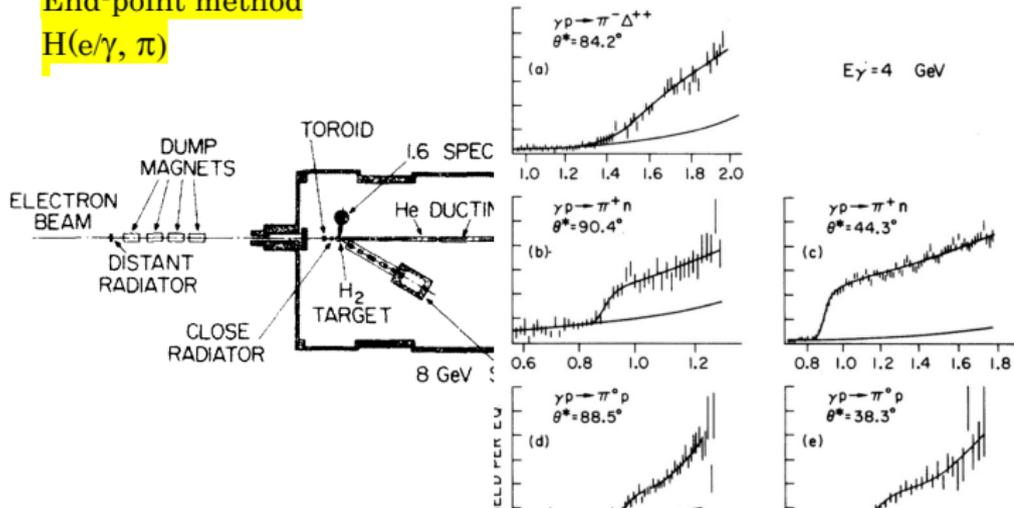


A few photon beam examples (VI) (credit: B. Wojtsekhowski)

SLAC,

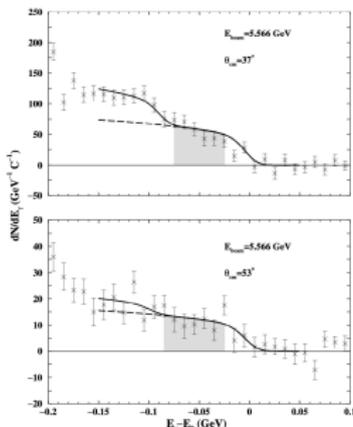
End-point method

$H(e/\gamma, \pi)$



A few photon beam examples (VII) (credit: B. Wojtsekhowski)

JLab, Hall A/C,
End-point method
 1×10^{11} photons/s



PHYSICAL REVIEW C, VOLUME 60, 052201

Coherent π^0 photoproduction on the deuteron up to 4 GeV

D. G. Meekins,^{1,2} D. J. Abbott,² A. Ahmidouch,³ C. S. Armstrong,¹ J. Arrington,⁴ K. A. Assamagan,⁵ O. K. Baker,^{2,5} S. P. Barrow,⁶ D. P. Beatty,⁶ D. H. Beck,⁷ S. Y. Beedoe,⁸ E. J. Beise,⁹ J. E. Belz,¹⁰ C. Bochna,⁷ P. E. Bosted,¹¹

VOLUME 67, NUMBER 10

PHYSICAL REVIEW LETTERS

3 SEPTEMBER 2001

Measurement of the High Energy Two-Body Deuteron Photodisintegration Differential Cross Section

E. C. Schulte,¹ A. Ahmidouch,² C. S. Armstrong,³ J. Arrington,⁴ R. Asaturyan,⁵ S. Avery,⁶ O. K. Baker,^{1,6} D. H. Beck,¹ H. P. Blok,⁷ C. W. Bochna,¹ W. Boeglin,⁸ P. Y. Bosted,⁹ M. Bouwhuis,¹ H. Breuer,¹⁰ D. S. Brown,¹⁰

VOLUME 86, NUMBER 14

PHYSICAL REVIEW LETTERS

2 APRIL 2001

Polarization Measurements in High-Energy Deuteron Photodisintegration

K. Wijesooriya,^{10,*} A. Afanasev,^{20,26} M. Amarian,¹¹ K. Aniol,³ S. Becher,⁹ K. Benslama,²³ L. Bimbot,²² P. Bosted,¹⁶

PHYSICAL REVIEW C 66, 034614 (2002)

Polarization measurements in neutral pion photoproduction

K. Wijesooriya,^{1,*} A. Afanasev,^{21,27} M. Amarian,¹² K. Aniol,⁴ S. Becher,¹⁰ K. Benslama,²⁴ L. Bimbot,²³ P. Bosted,¹⁷ E. J. Brash,²⁴ J. Calarco,¹⁹ Z. Chai,¹⁸ C. C. Chang,¹⁶ T. Chang,¹¹ J. P. Chen,²⁷ S. Choi,²⁶ E. Chudakov,²⁷ S. Churchwell,¹⁷

PHYSICAL REVIEW C 71, 044603 (2005)

A few photon beam examples (VIII) (credit: B. Wojtsekhowski)

JLab, Hall A/C,
Mixed e/γ beam
Exclusive process

$$H(e/\gamma, \gamma + p)$$

Energy 2-6 GeV

Photon flux
 2×10^{13} eq. ph/s

1×10^{12} photons/s

JLab, Hall A, Wide Angle Compton Scattering

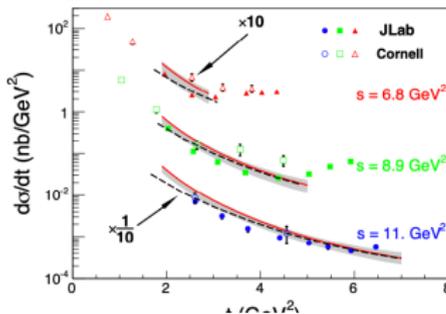
PRL 94, 242001 (2005)

PHYSICAL REVIEW LETTERS

week ending
24 JUNE 2005

Polarization Transfer in Proton Compton Scattering at High Momentum Transfer

D. J. Hamilton,¹ V. H. Mamyan,^{2,3} K. A. Aniol,⁴ J. R. M. Annand,¹ P. Y. Bertin,⁵ L. Bimbot,⁶ P. Bosted,⁷ J. R. Calarco,⁸
A. Camsosne,⁹ G. C. Chang,⁹ T.-H. Chang,¹⁰ J.-P. Chen,³ Seonho Choi,¹¹ E. Chudakov,³ A. Danagoulian,¹⁰ ...



If WACS on polarized target is (one of) the goal(s)...

Might want to pay attention to:

- **beam size:** small. helps separate Compton scattering from (the much larger!) π^0 production
- **radiator–target distance:** short
- **beam intensity:** high. essential if one wants to reach s, t, u in the $\sim GeV^2$ range!
- γ s on NH_3 **target:** 10–30x higher than a 100 nA quasi–real beam!
- **setup & tear–down t :** reasonable (< 3 months?)
- **\$\$:** minimize. this is always on the menu!

Polarized WACS Exp. Approved (46 PAC days)!

D. Day, D. Hamilton, D. Keller, GN,
B. Wojtsekhowski, J. Zhang: **E12-17-008**

(but I want to highlight the source that will make it possible)

Cornell, 1978

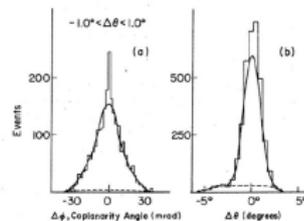


FIG. 3. Angular-difference distribution at 6 GeV and $t = -2.45 GeV^2$. (a) Coplanarity-angle distribution. The solid line is a fit assuming neutral-pion photoproduction, the dashed line is the estimated background from other processes, and the peak at $\Delta\phi = 0$ is due to proton-Compton scattering. (b) Angular-difference distribution in the reaction plane. The curves have the same interpretation as in (a). The excess at $\Delta\theta = 0^\circ$ is due to Compton scattering.

1.3 cm beam diameter
clean photon beam

JLab, 2002

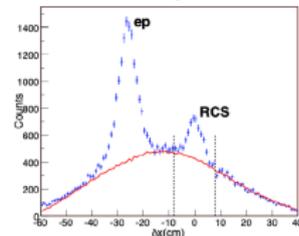


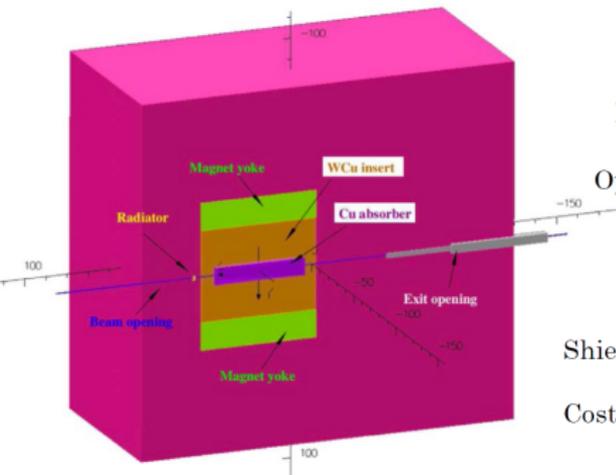
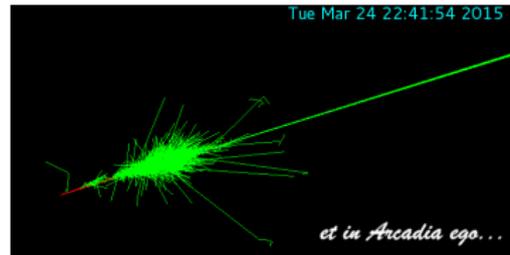
FIG. 3: The $5x$ -distribution for a coplanarity cut $|\delta\phi| < 15$ cm, with the RCS and ep peaks indicated. The curve is a distribution of the continuum e^+e^- events. The vertical dashed lines show the cuts used to calculate the number of RCS events.

0.2 cm beam diameter
mixed e/γ beam

Compact Photon Source (CPS) (credit: B. Wojtsekhowski)

A conceptual design study of a Compact Photon Source (CPS) for Jefferson Lab [NIM-A 957 \(2020\) 163429](#)

D. Day^a, P. Degtiarenko^b, S. Dobbs^c, R. Ent^b, D.J. Hamilton^d, T. Horn^{e,b,*}, D. Keller^a, C. Keppel^b, G. Niculescu^f, P. Reid^g, I. Strakovsky^b, B. Wojtsekhowski^b, J. Zhang^a



Concept of shielding:

Radiation is wide, angle ~ 1

Open angle of γ is $\sim m_e/E_e \ll 1$,
so the leak is suppressed

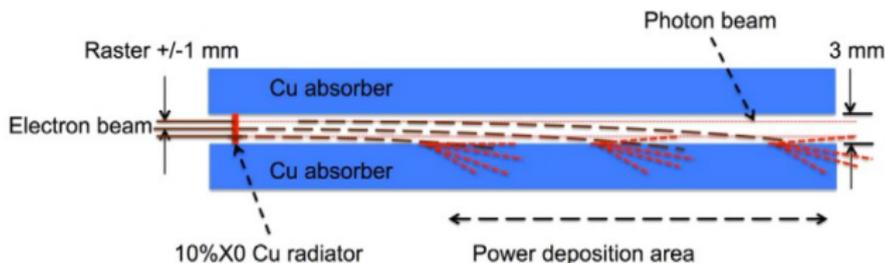
Compact device cost:

Shield thickness $R = C \times \ln(P_i/P_o)$

Cost is proportional to $(LxR^2 + R^3)$

CPS central piece (credit: B. Wojtsekhowski)

Concept of beam power distribution

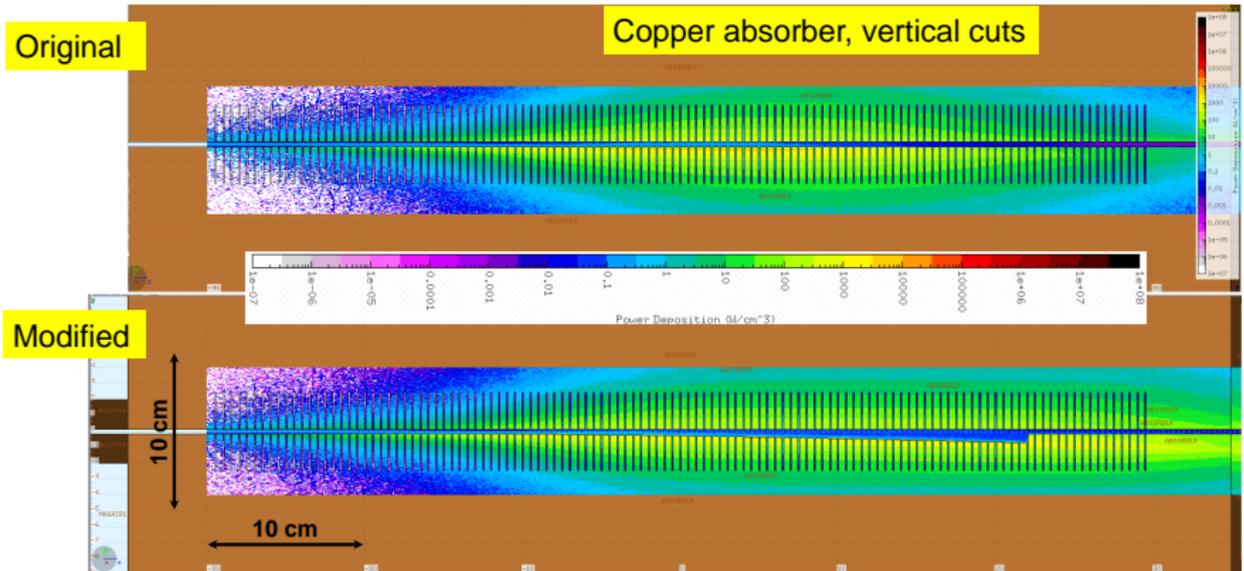


Main concepts/ideas:

- **need** to dissipate a lot of power ... over a relatively small distance
- raster the beam. use high melting point materials. cooling.
- pay attention to heat transport and heat-related phenomena
- shape of the channel matters!
- **NOTE:** this is NOT a collimator!

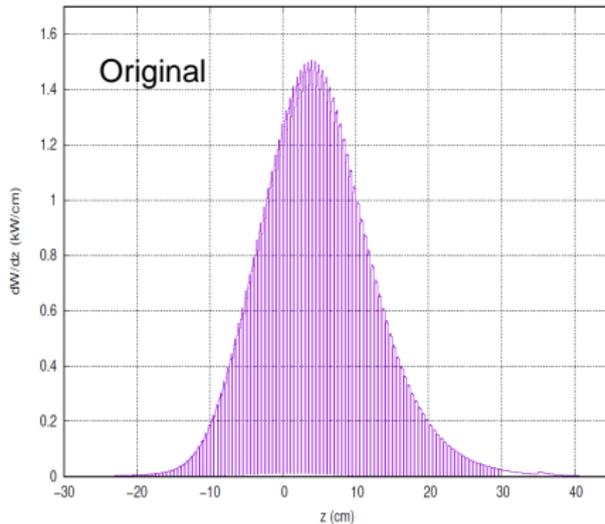
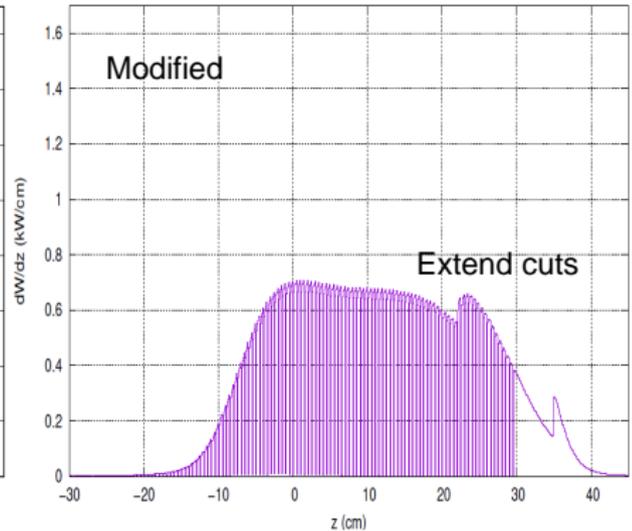
CPS & target simulation (FLUKA model and slides: P. Degtiarenko)

Power dissipation (I) (credit: P. Degtiarenko)



Note the subtle but important change in the **shape** of the channel.

Power dissipation (II) (credit: P. Degtiarenko)

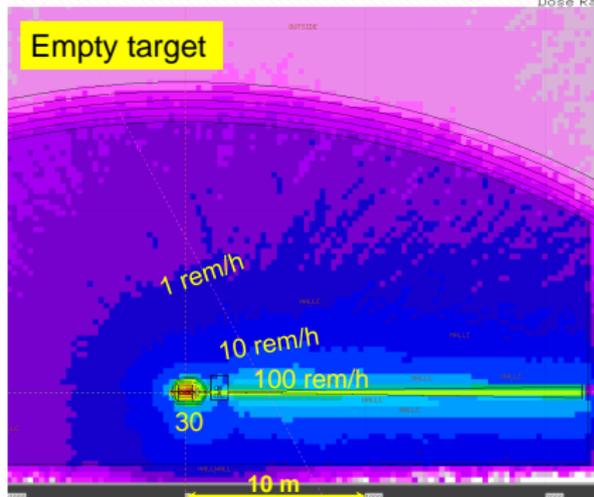
Linear power density dW/dz , along the absorber, within 2 cm radiusLinear power density dW/dz , along the whole absorber, within 2 cm radius

...a factor of ~ 2 reduction in the power deposition spike!

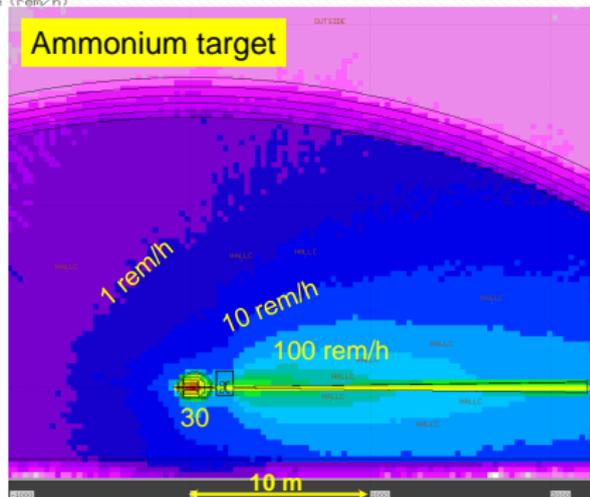
Radiation levels in the Hall... (credit: P. Degtiarenko)



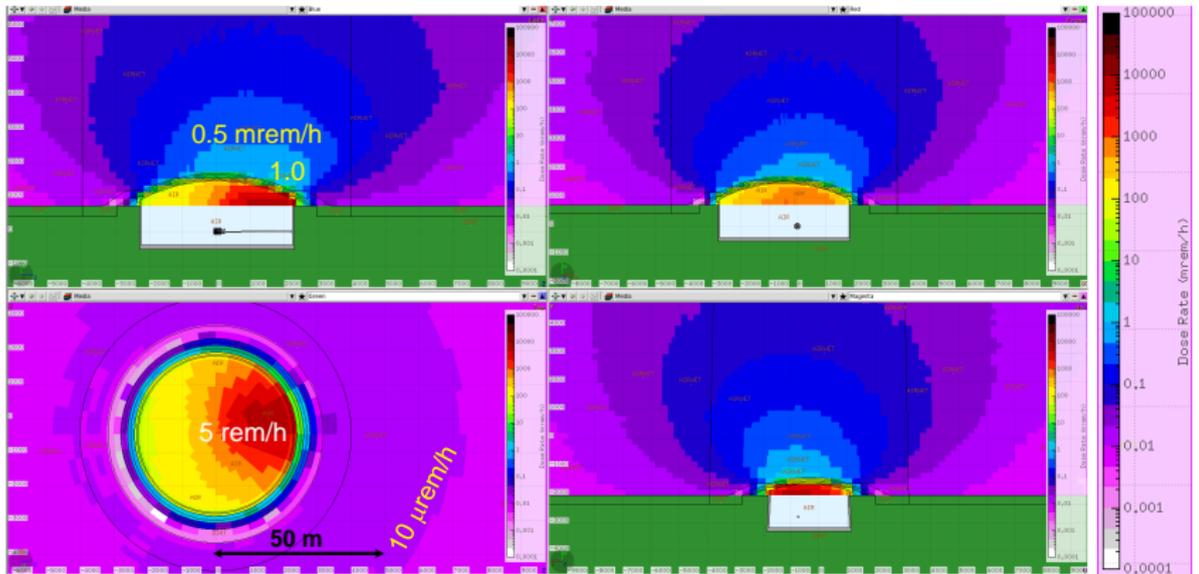
Empty target



Ammonium target

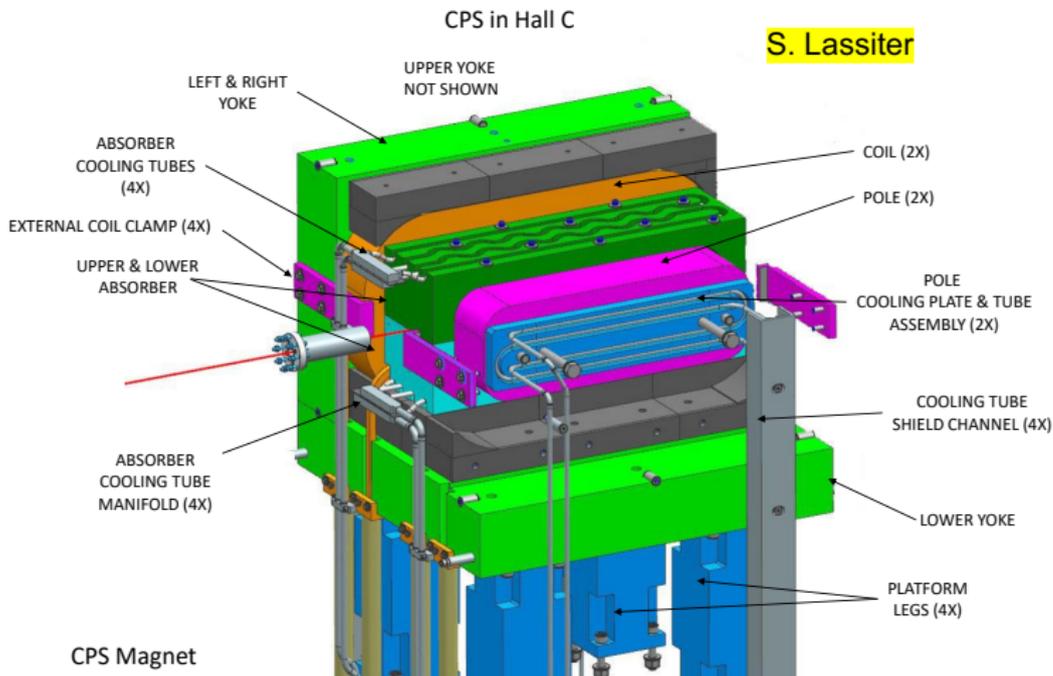


...and in outside (credit: P. Degtiarenko)



- FLUKA also gives (not shown here) activation levels (which are OK!)
- It looks like we might be able to build & operate this!

Central piece (credit: S. Lassiter, Hall C engineering)



CPS Project Status

Thus far

- extensive FLUKA–based **simulation**:
 - radiation levels: acceptable
 - inform & guide design (central piece segmenting, cooling, block stacking)
- Layout of **mechanical** components (essentially done)
- **Magnet**: procured (yoke, poles, rad. hard coils)
- **W blocks**: procured, received
- **Pb bricks**: 28 tons, received
- **power absorber (aka central piece)**: designed, prototype test setup ready

CPS & polarized solid target experiments

Increasing list of topics:

- WACS, E12-17-008
- Pion photoproduction from neutron. A_{LL} vs K_{LL}
- Proton polarization in $d(\gamma, pn)$ @ higher photon energy
- Pion photoproduction from proton - GPDs

$$D(\vec{e}, \vec{p})n$$

Figure-of-Merit is $P_e^2 \times \Omega_p \times \epsilon A_{pol}^2 \times \frac{\Delta E_\gamma}{E_\gamma} \times Flux_\gamma$

FOM gain is $10/1 \times 0.5^2 / (0.115 \times 0.27^2) \times 0.1/0.02 \times 1/20 = 75$

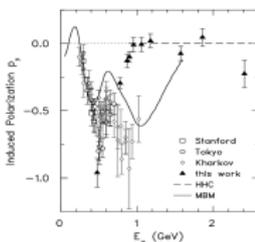


FIG. 1. Induced polarization p_e in deuteron photodisintegration at $\theta_{cm} = 90^\circ$. Only statistical uncertainties are shown. The curves are described in the text.

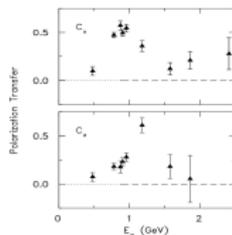


FIG. 2. Polarization transfers C_1 and C_2 in deuteron photodisintegration at $\theta_{cm} = 90^\circ$. Only statistical uncertainties are shown.

credit: B. Wojtsekhowski



Quo Vadis?

I showed & hope I convinced you that:

- Compact Photon Source providing 1 kW of 11 GeV photon beam will soon be ready for an experiment (NPS RG3)
- CPS has a large (& growing, several important proposals under development) experimental program.
- Suggestions, help, leading some of the effort are welcome!
- **THANK YOU!**

