A Compact Photon Source

Sergey Abrahamyan (YerPhI)
Gabriel Niculescu (JMU)
Bogdan Wojtsekhowski (JLab)

A Compact Photon Source

It is a part of the PR12-15-003

Polarization Observables in
Wide-Angle Compton Scattering
at Photon Energies up to 8 GeV

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A Compact Photon Source

Motivation

Key parameters

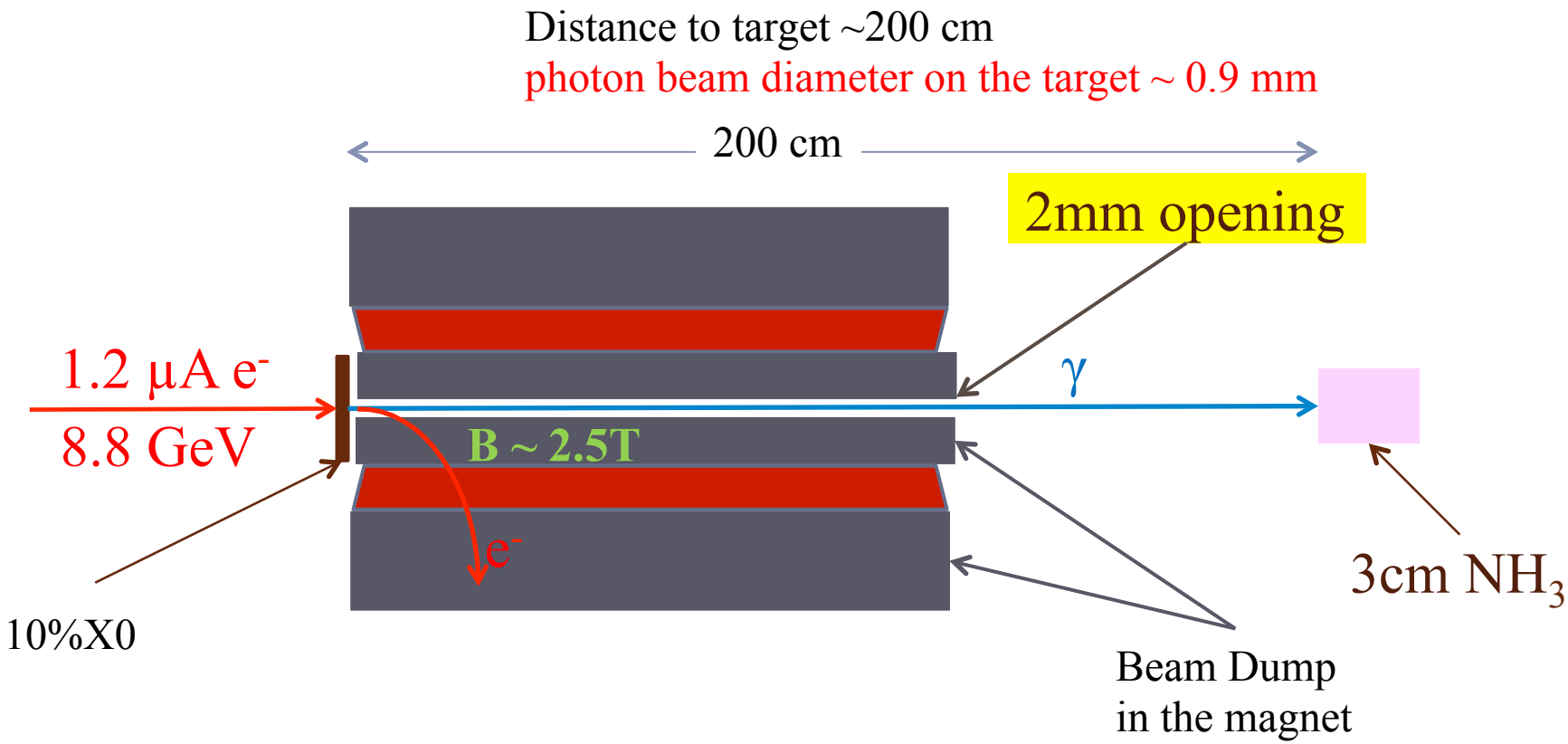
Concept and analysis

A Compact Photon Source

The key parts of our approach are:

1) A dump is at the same time a sweep magnet.
2) A small opening just for the photons which provides collimation of the radiation background (γ/n).
3) A moving hole provides the best match of #1, #2 and the desirable size of the beam spot at the target.
4) Confining radiation (outside $(1\text{mrad})^2$ solid angle) using a full length from the radiator to the target can.

Compact Photon Source



A Compact Photon Source

The advantages for the experiment are:

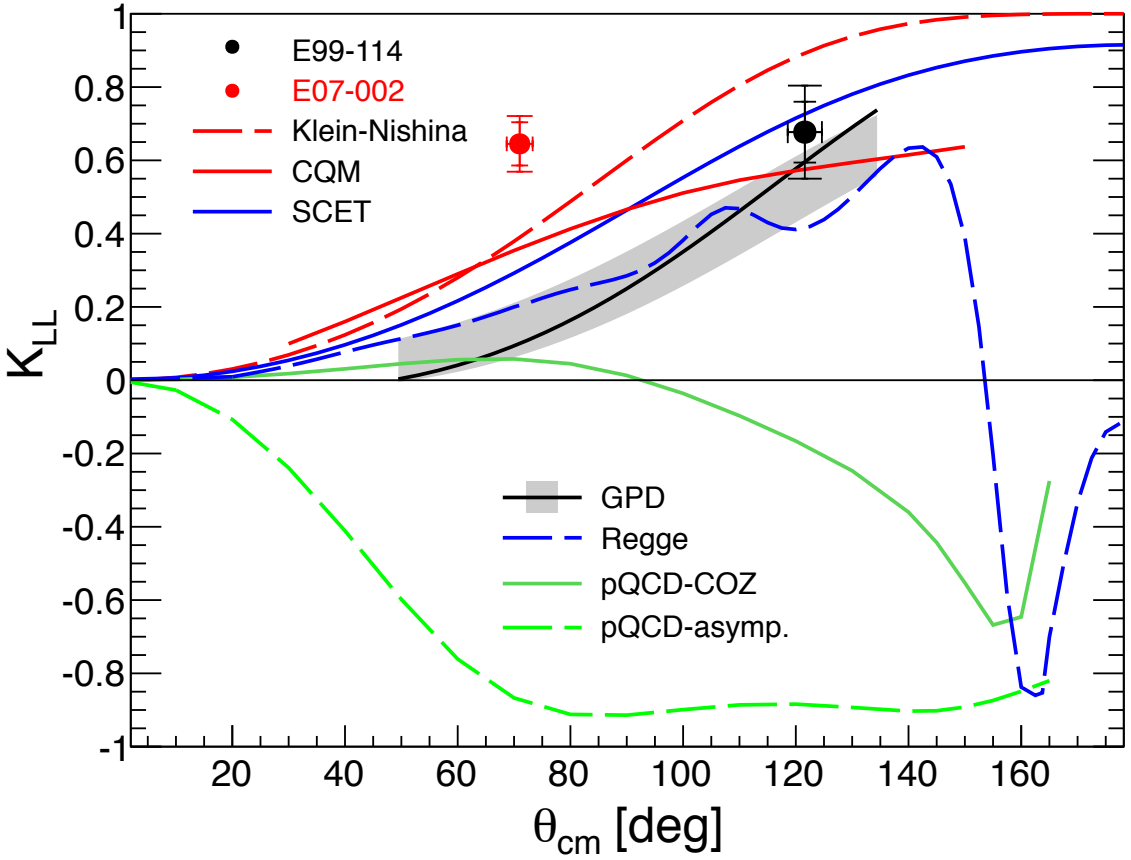
1) A 10 times higher beam intensity (vs. a mixed e/γ beam) with acceptable radiation level in the hall, target, detector.

2) A 0.9 mm beam diameter on the target.

3) The source is good for the par. and perp. pol. target.

4) A simple beam line without a chicane (needed in the case of a mixed e/γ for a transversely polarized NH3 target).

Physics Motivation and a surprise



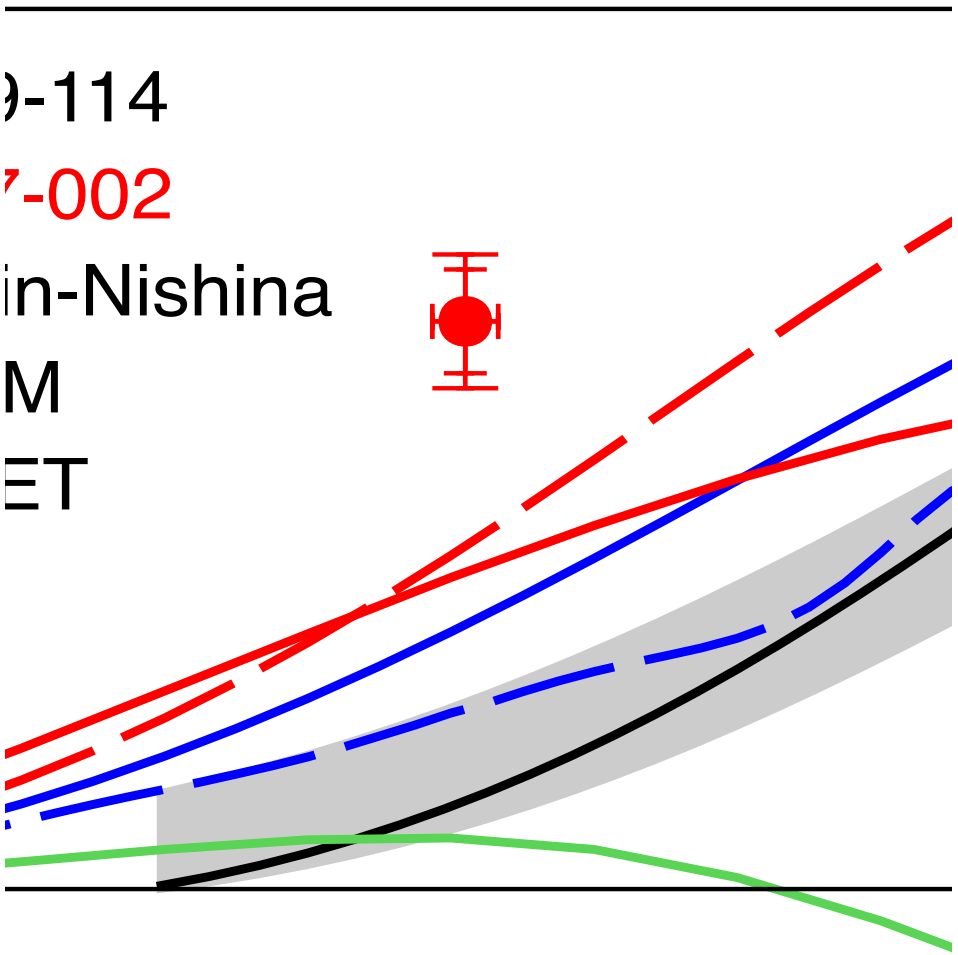
E99-114
s=6.9, t=-4.0, u= -1.1 GeV^2

E07-002
s=7.8, t=-2.1, u= -4.0 GeV^2

PRL 115, 152001 (2015)

New measurement at large (doubled) s, t, u values is necessary to clarify the mechanism of WACS.

Physics Motivation and a big surprise



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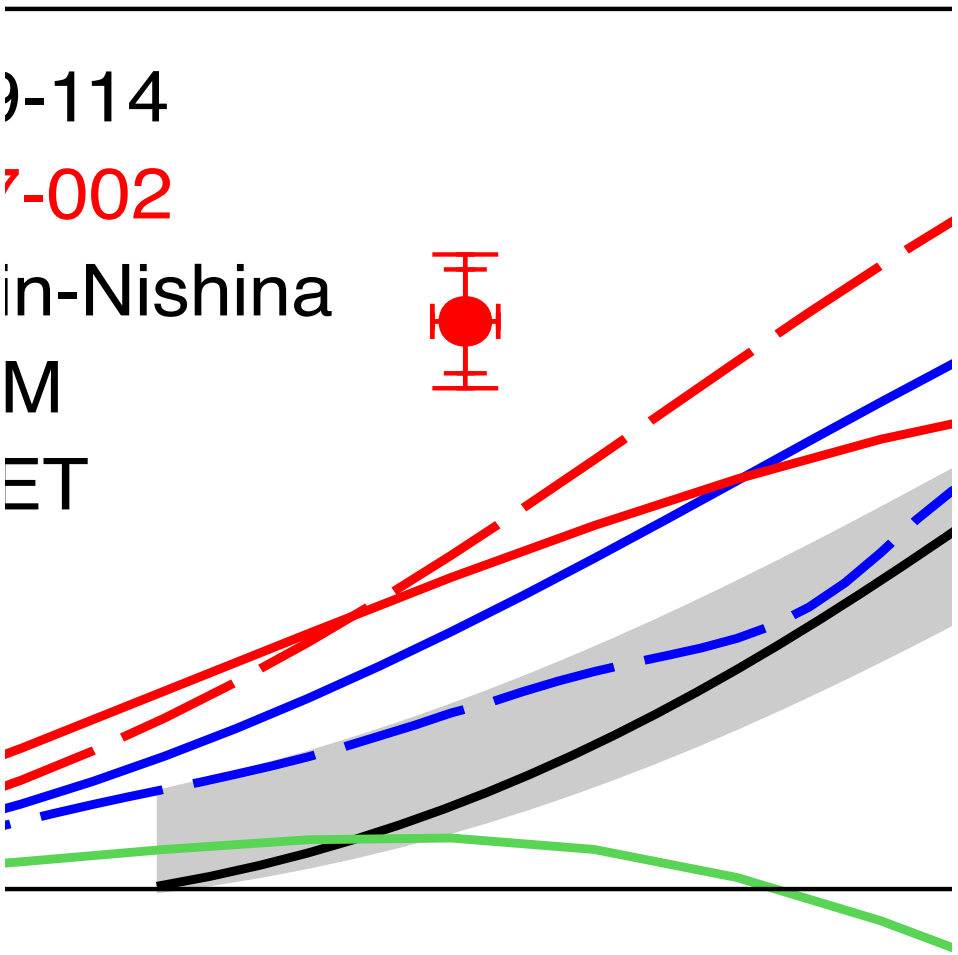
PRL 115, 152001 (2015)

3.4 σ from the CQM
5.5 σ from the GPD band

Physics Motivation and a big surprise



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What is the origin of large K_{LL}?

Quark OAM?

Diquark u-d correlations?

Most likely there is a resonance!

WACS experimental challenges

$$rate \propto 1/s^{7.5}$$

s=8 -> s =16: ~ 1/180

- Photon beam intensity:
- Polarimeter figure-of-merit (A_Y~1/p) or polarized target power limit (< 90 nA electrons)
- Solid angle of apparatus: HRS/HMS ~ 6-7 msr
- Neutral pion background (dilution): 4+ (for 1 mm beam spot)

WACS experimental challenges

- Photon beam intensity: An easy way (mixed e-γ beam) has limited intensity due to the polarized target cooling rate.
A clean photon beam typically leads to a large photon spot size (or low intensity due to collimation) – a loss of tight p-γ angular correlation (e.g. a Cornell experiment of 1977).

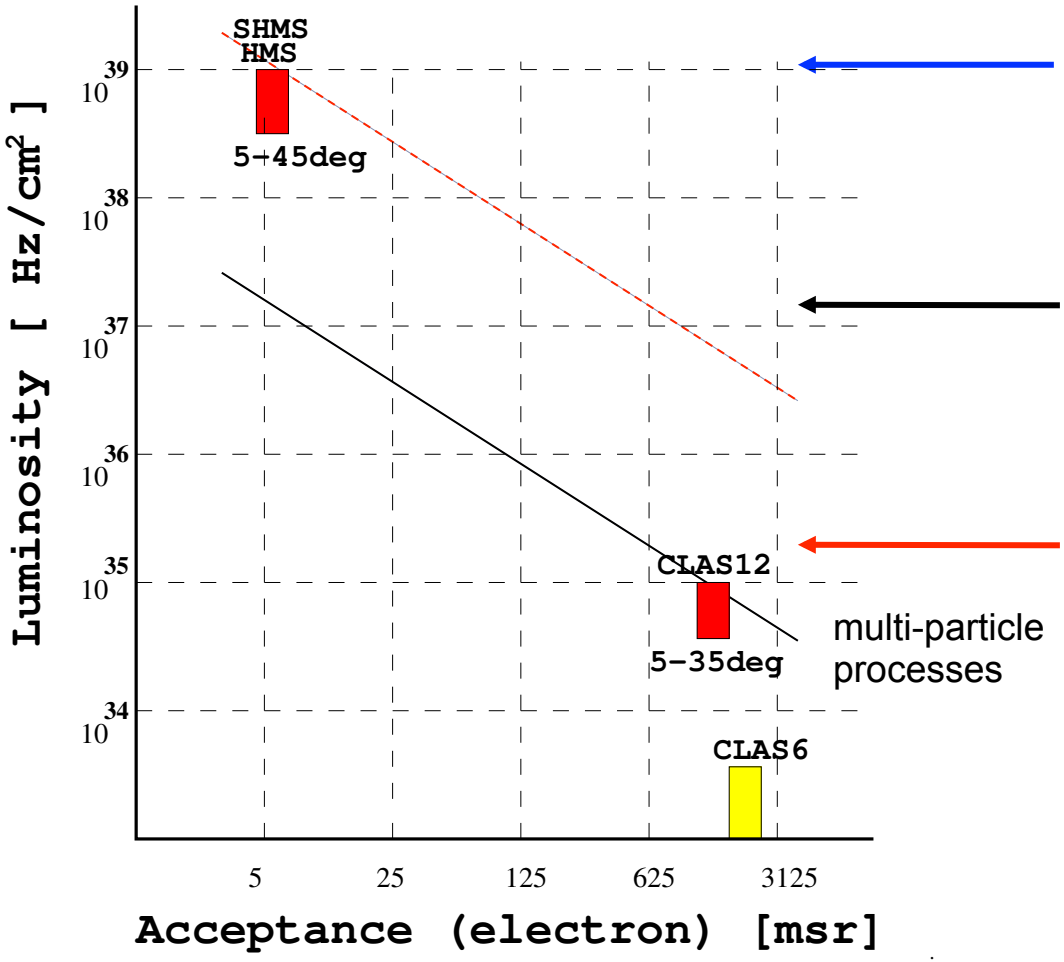
- Neutral pion background (dilution): It could be reduced ONLY by means of a cut in a p-γ angular correlation.

WACS experimental challenges

- Photon beam intensity: An easy way (mixed e-γ beam) has limited intensity due to the polarized target cooling rate. It was used in JLab WACS experiments, 2005 approved proposal.
A clean high intensity compact photon beam was developed in the 2015 ALL proposal.
- Neutral pion background (dilution): It could be reduced ONLY by means of a cut in a p-γ angular correlation. The claim of "code training" and suppression of the pion background by a factor of 100 could not be correct (obviously that particle kinematics defines the angular distributions).

Proton spectrometer

A range of 10^4 in luminosity.



The LH_2 target can be used up to L ~ 10^{39}

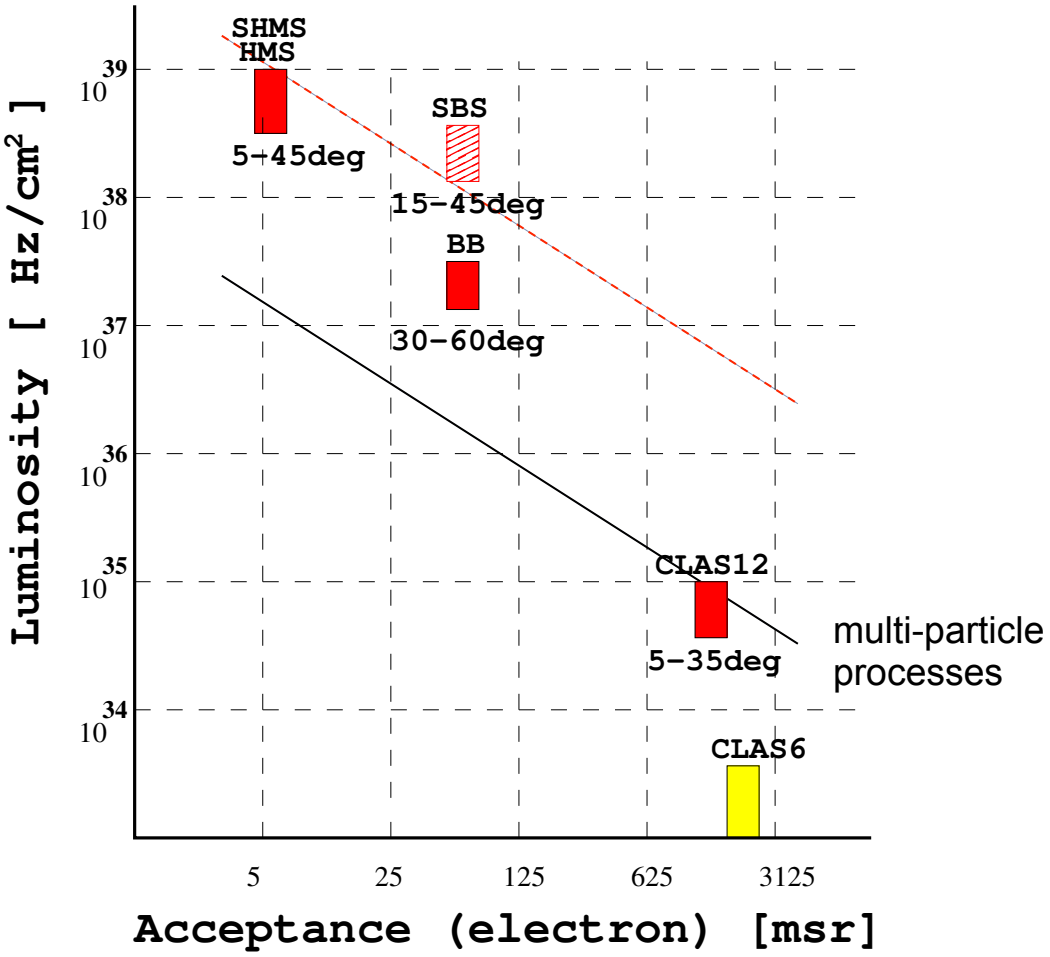
Unpolarized WACS has such L

The polarized ^{3}He at L ~ 10^{37}

The polarized NH_3 at L ~ 10^{35}

Why didn't CLAS6 study WACS? Most likely the main problem is a large pion dilution due to a lower angular resolution.

Proton spectrometer



A range of 10^4 in luminosity.

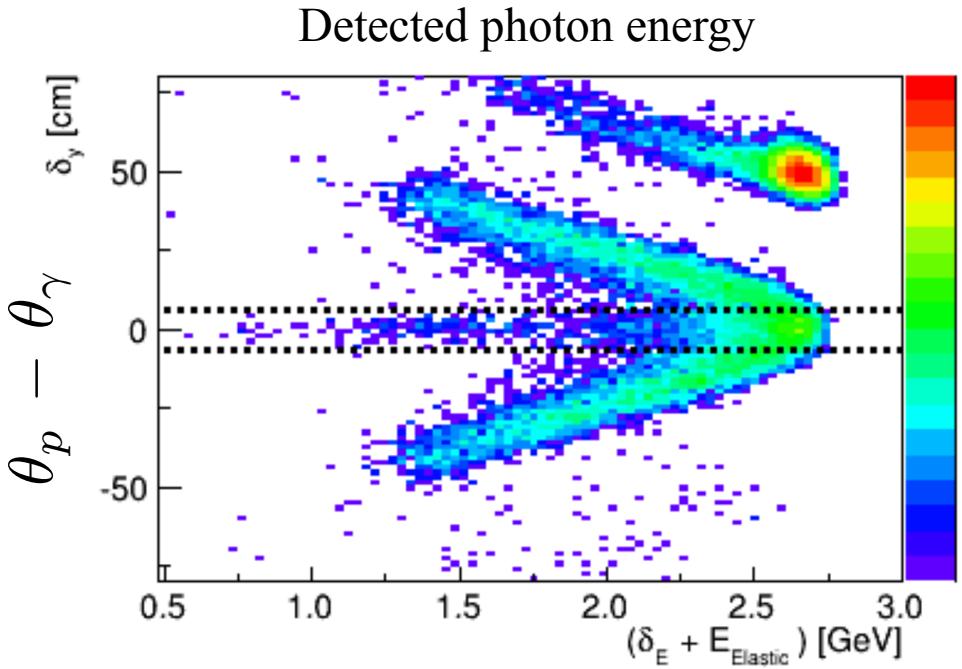
A big range in solid angle:
from 5 msr (SHMS)
to about 1000 msr (CLAS12).

==========

The SBS is in the middle:
for solid angle (up to 70 msr)
and high luminosity capability.

Small photon spot is very important

- It defines the width of the out-of-plane photon–proton angular correlation
- It contributes to the proton momentum resolution



$$H(\gamma, p\gamma)X$$

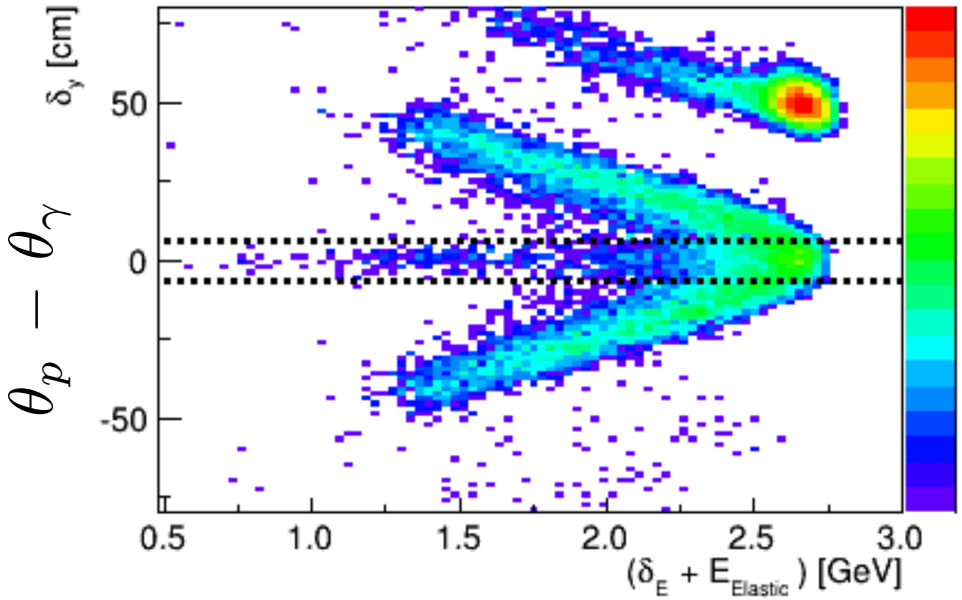
Small photon spot is very important

$$H(\gamma, p\gamma)X$$

Observed parameters are the proton momentum, angles, vertex and the photon energy and coordinates at calorimeter.

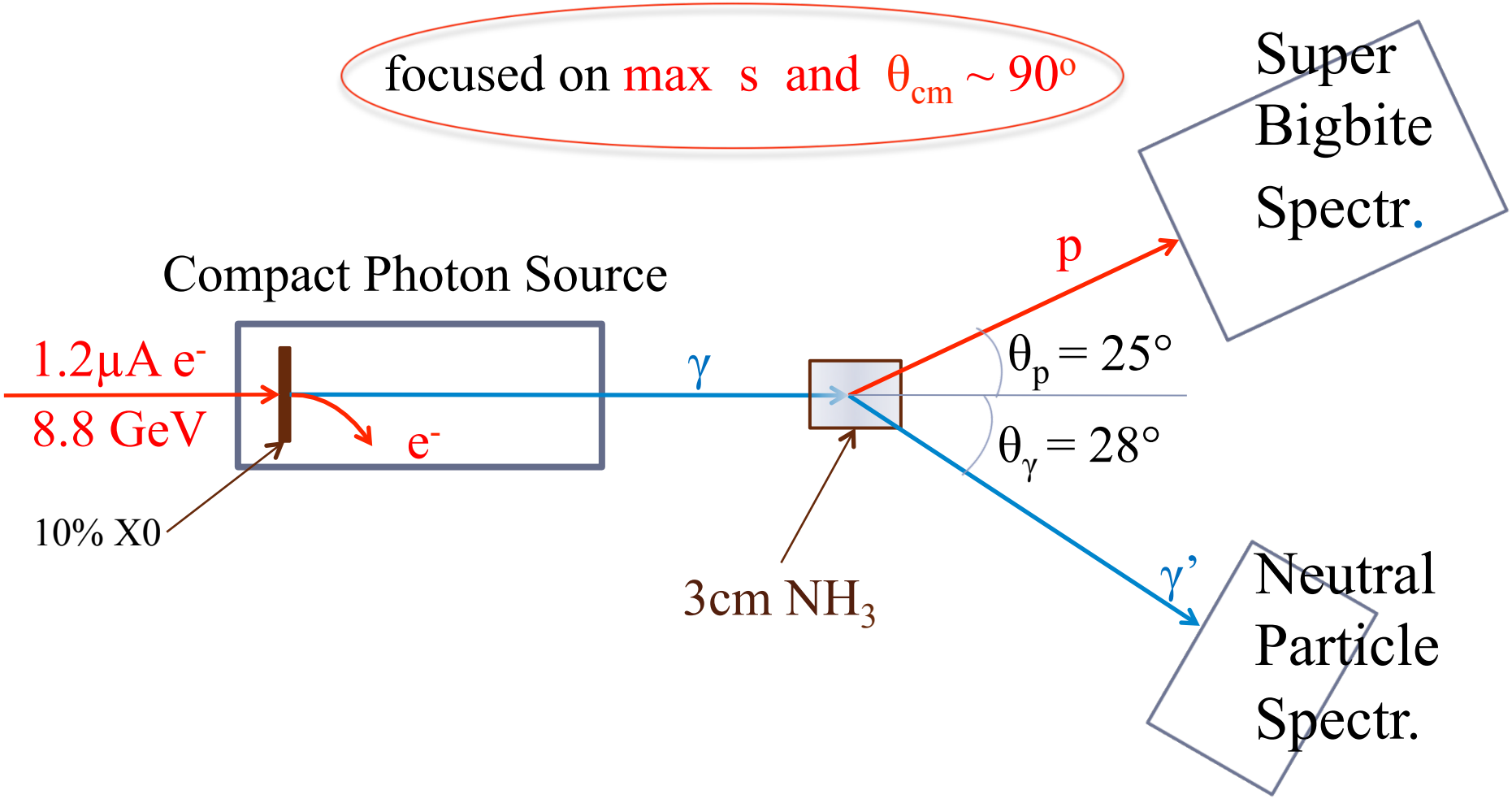
After reconstruction of the incident photon energy and scattered angles one parameter could be used to check exclusivity: an out-of-plane angle correlation.

Detected photon energy



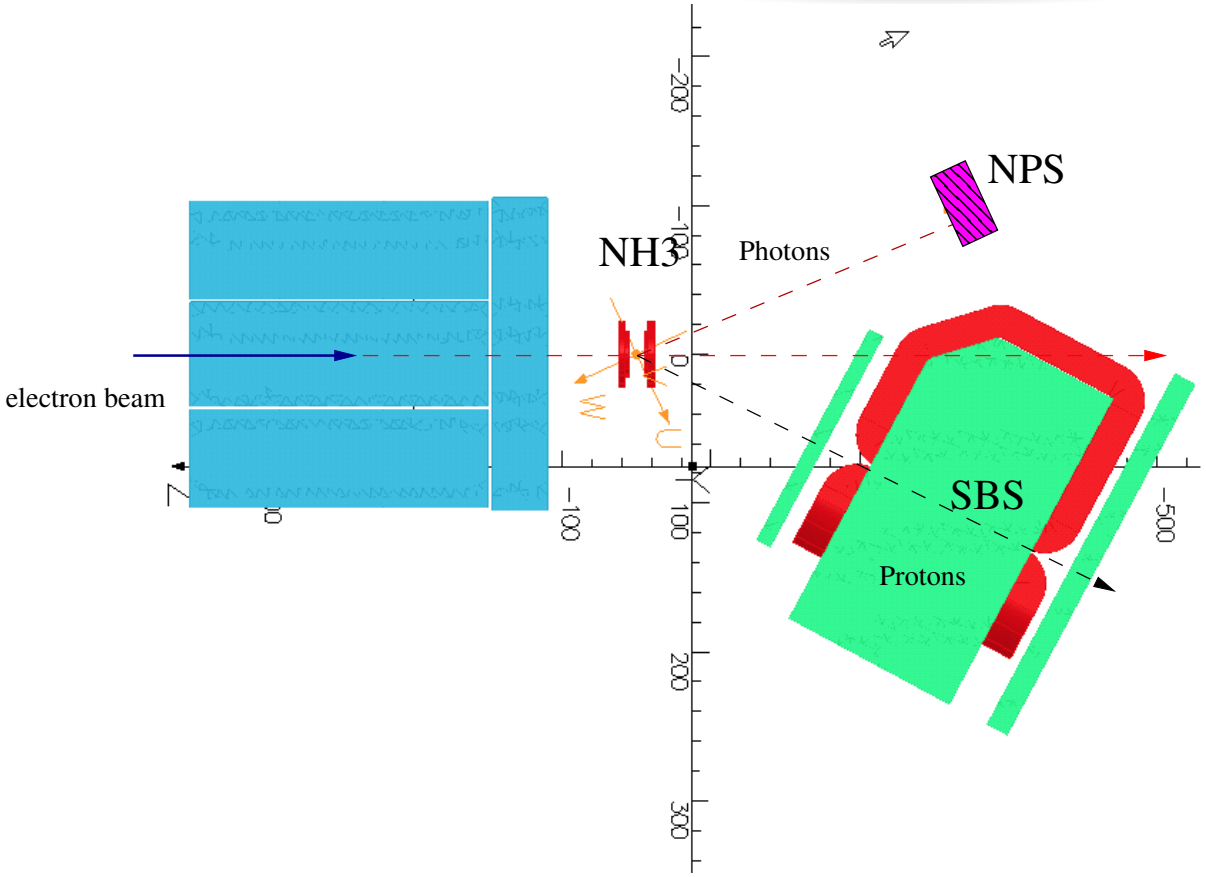
At the δy ~ 0 point where WACS events are located, the photon energy - angle correlation is "zero" and there are only angular correlations, which allows us to differentiate the Compton from π^0 events.

Proposed Experimental Setup



Proposed Experimental Setup (WACS)

focused on max s and $\theta_{cm} \sim 90^o$



A floor plan:

the 3D model used in GEANT simulation of physics, radiation and magnetic field calculations

Neutral Particle Spectrometer

Key parameters:

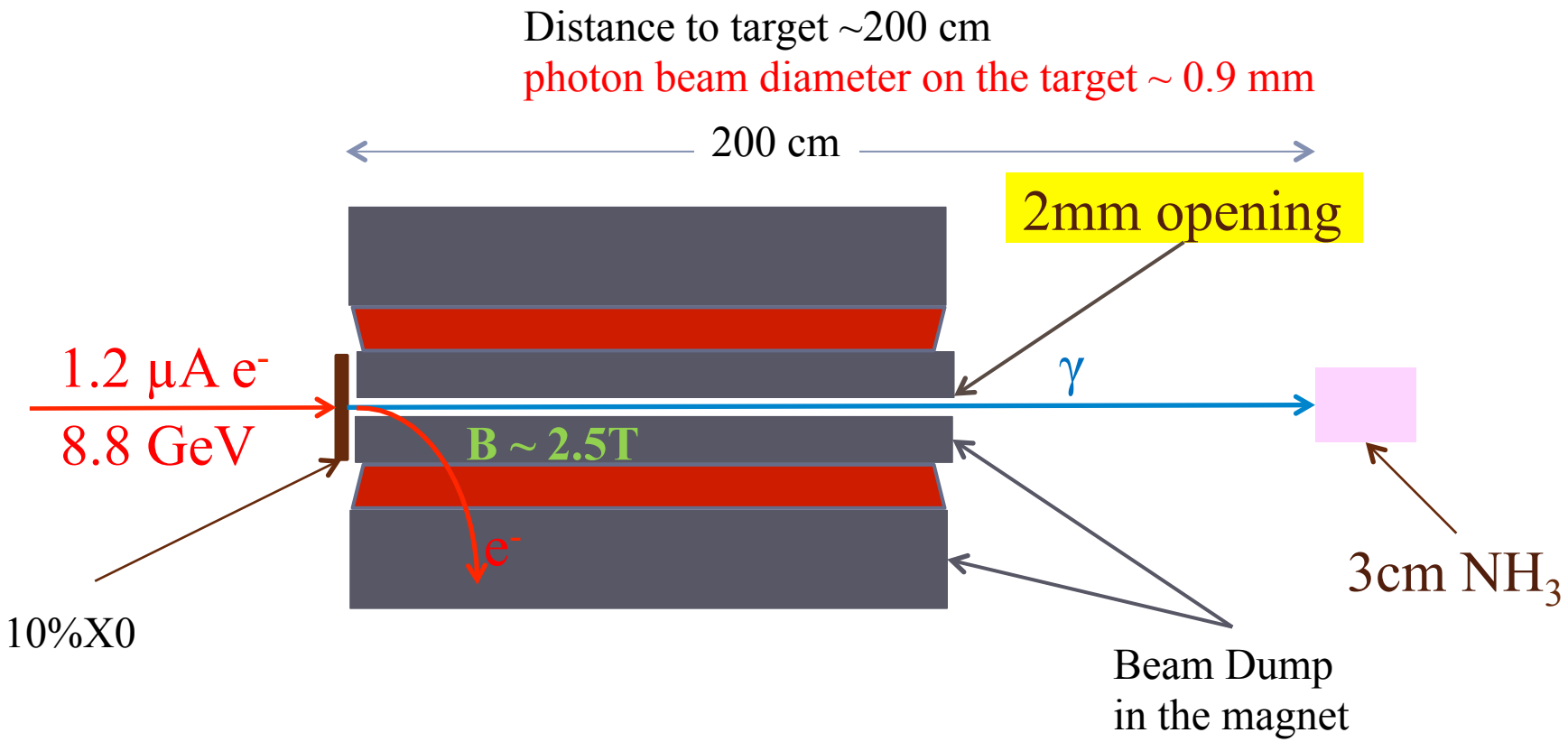
- Energy resolution ~$2\%/\sqrt{E}$
- Radiation hardness PbWO4
- Area/segmentation: 72 cm x 60 cm /1100 crystals
- Coordinate resolution: 2-3 mm

Super Bigbite Spectrometer

Key parameters:

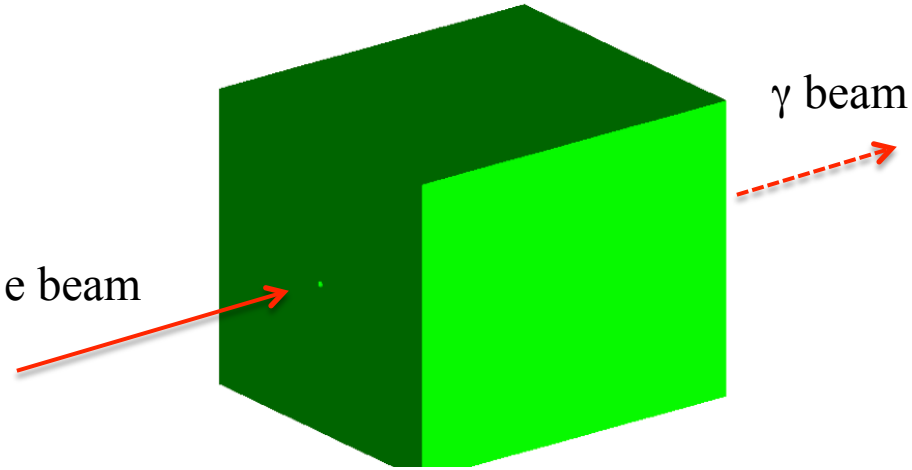
- Solid angle: 70 msr for angle above 15^o
- Momentum acceptance: 2-10, GeV/c
- Angular range: from 5^o (12 msr) to 45^o
- Momentum resolution: 0.29 + 0.03xP, [%]
- Angular resolution: 0.14 + 1.3/P, [mrad]

Compact Photon Source

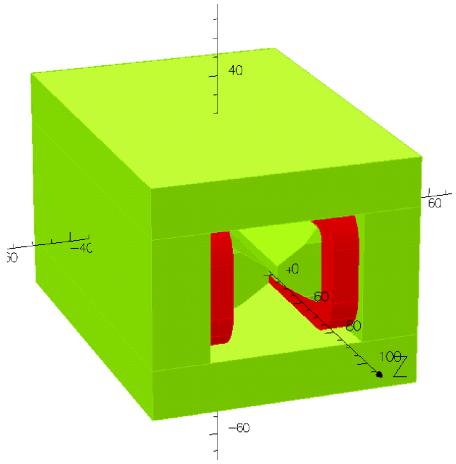


MC simulation and direct calculations show acceptable background rates on SBS and NPS.

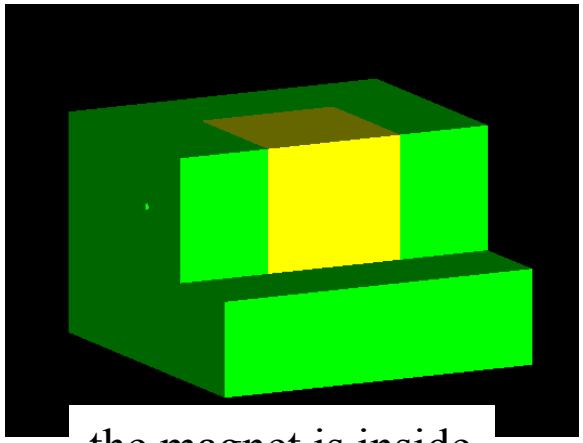
Compact Photon Source – structure



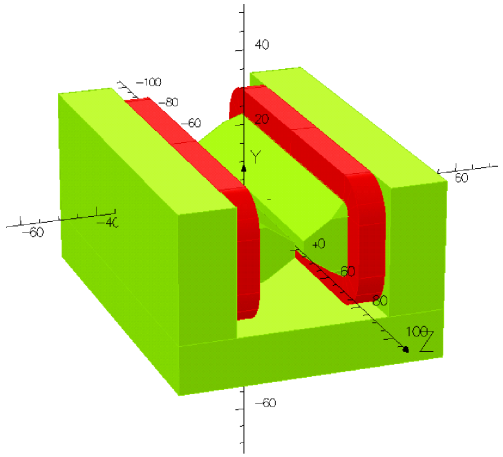
2.6 m x 2.5 m x 2.5 m structure



1 m x 0.6 m x 0.5 m magnet



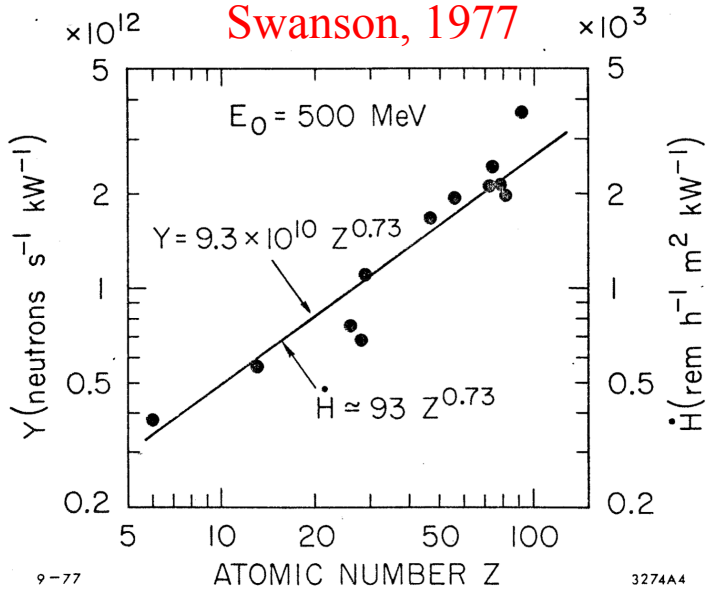
the magnet is inside



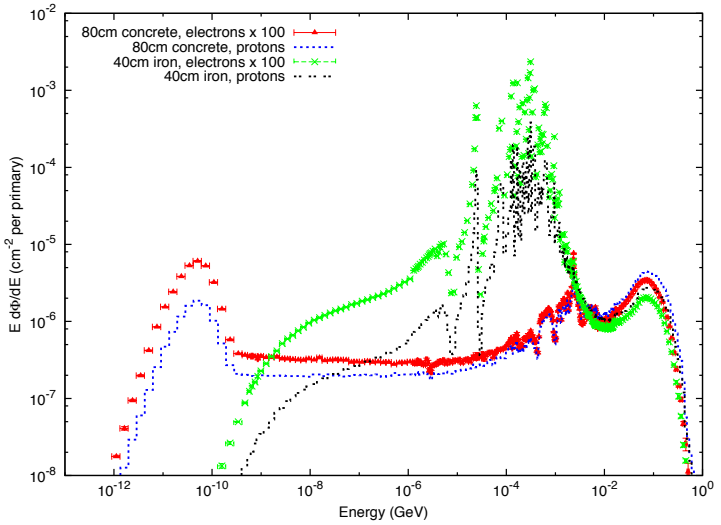
the magnet top plate is removed

Compact Photon Source: radiation

Swanson, 1977



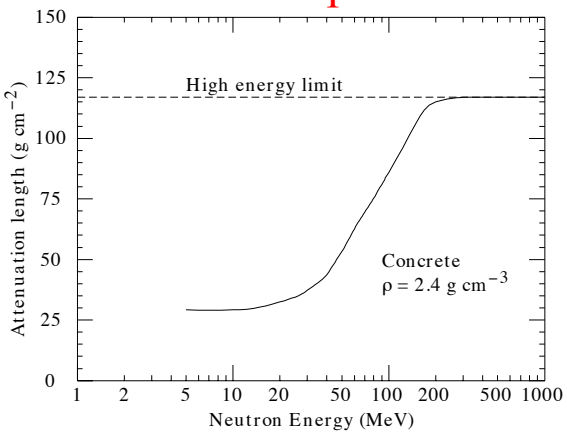
PDG report



1.2 μA x 8.8 GeV => 10kW

10 kW => 20 kRad/hour
at 1 m without a shield

PDG report

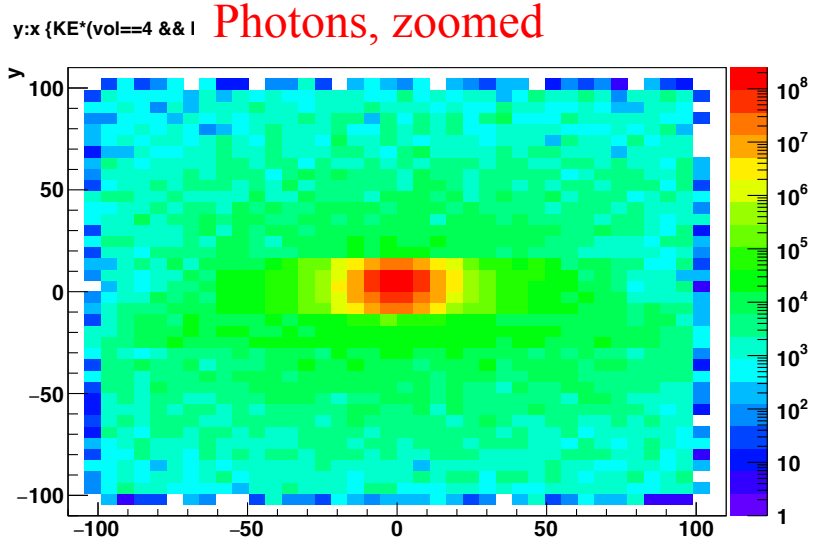


10 kW => 0.1 Rad/hour
at 15 m with a 1 m shield

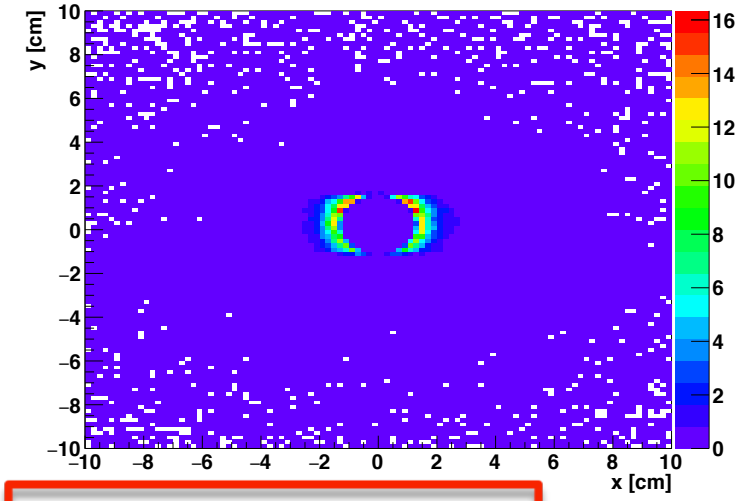
GEANT4-based analysis of the radiation level has been performed.

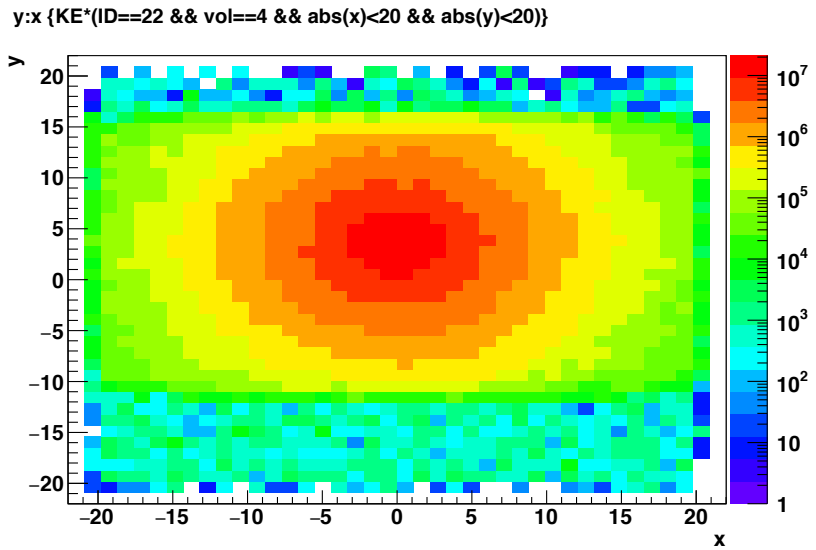
Compact Photon Source: GEANT4 results

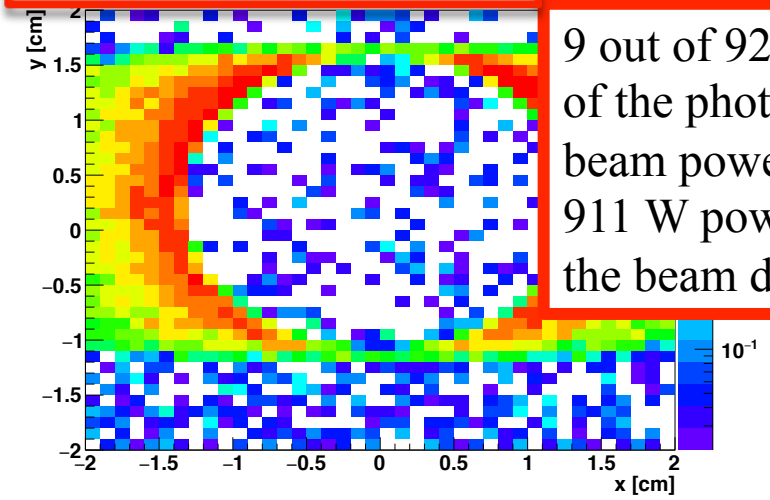
Photons, zoomed



Photons, zoomed. exclude 0.05 deg.

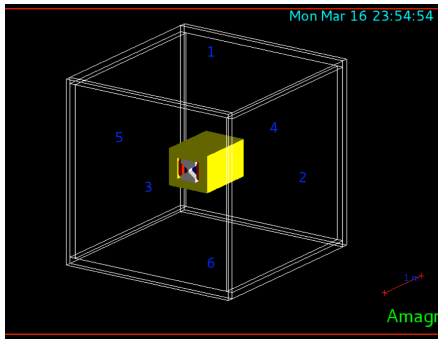


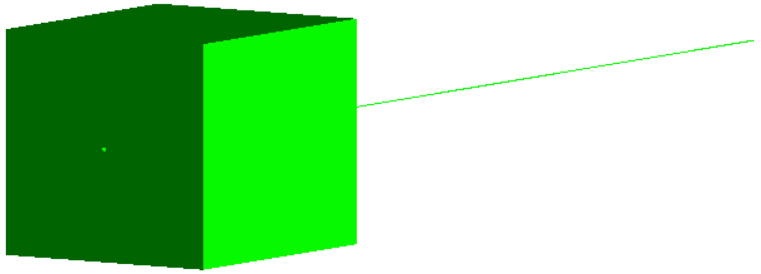




9 out of 920 W of the photon beam power.
911 W power is in the beam dump.

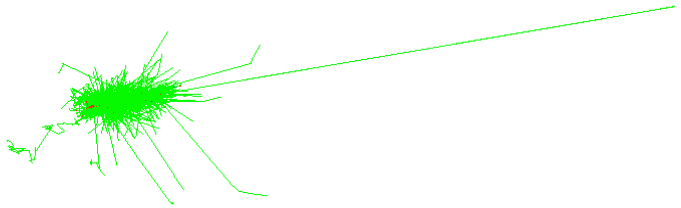
Compact Photon Source: GEANT4 results





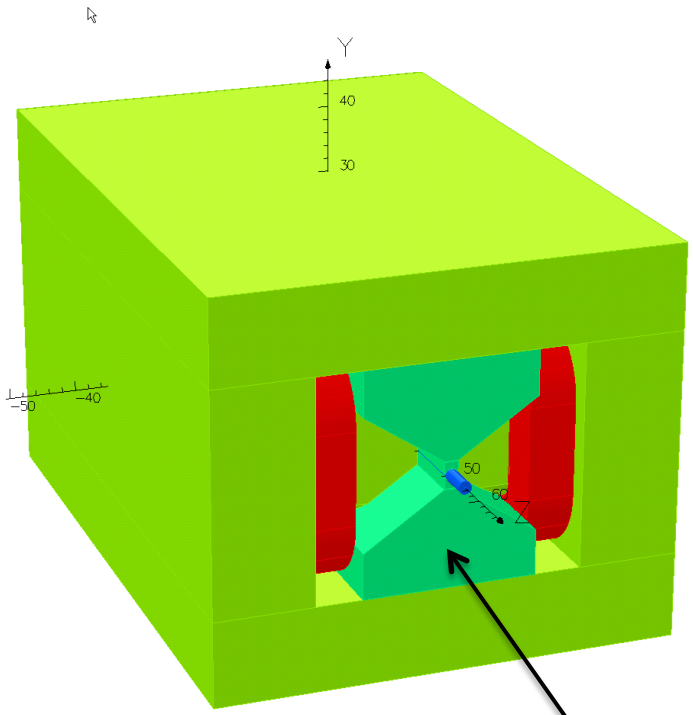
For the beam of 1.2 μA x 8.8 GeV
Radiation dose rates summary

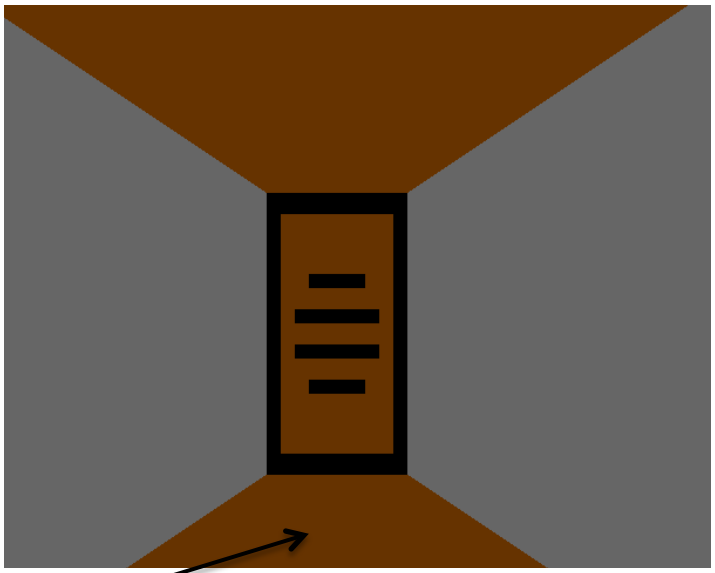
15-20 mrem/hour at 90-degree direction (15 m)
9 mrem/hour in the backward direction (15 m)
3.9 Rad/hour on the target solenoid (1.8 m)
2-3 Rad/hour on the SBS/NPS (~ 4-5 m)
80 kRad/hour on dipole coils (~0.5 m)
27 mrem/hour outside 0.5 degree cone (15 m)



Sample of tracks in the GEANT4

Compact Photon Source: magnet views





magnet with the Copper inserts

front view with the slots
in the diffuser-absorber

Beam parameters

Compact Photon Source	
Photon flux	6 x 10^{11} eq. γ/s
Beam spot size	0.9 mm diam.
Slow beam spot	2 cm diameter

Key features of the proposed CPS

- Photon flux, local Beam Dump: 6 x10^{11} eq. γ/s - 10x of mixed e/γ
- Compact photon spot: 0.9 mm by means of the magnet-dump configuration (key importance for "background" reduction).
- Applicability for the transversely polarized NH3 target.

Plan of the CPS development

(assuming approval of the proposal by PAC)

1. Low intensity test of the shielding concept and the detector counting rates using a narrow tilted channel in a CuW80 bar located inside a pile of "green" blocks.

2. Design and testing of an oscillating CuW80 bar with a set of four narrow channels for the photon beam.

3. Development of monitoring of the force on the target solenoid.

4. Design of a slow raster with fast current control.

5. Search for funding and collaborations.

High-tech aspects of CPS development

1. Radiation-hard coils for the dipole: A proven technology has been identified. Now the project is ready for design of the prototype.

2. The CuW80 bar with a set of four narrow channels: The conceptual design of the motion mechanism for the bar and construction method of the channels and cooling have been found.

3. Development of a force monitoring sensor for the target solenoid.

4. Design of a slow raster with fast current control: The existing raster needs a synchronization controlled by the bar motion sensor.

Use of the Compact Photon Source

A 10x gain in the pol. γ intensity with a small photon spot at the target should benefit a number of other experiments:

- time-like DVCS from the pol. proton (LOI12-15-007)
- pion photo-production A_{LL}, $A_{LS'}$ and A_U
- φ-meson from the polarized target
- A_{LS} in WACS at large θ_{cm}

In each of these experiments a small beam size will help to do event selection. Another application of the CPS magnet-dump concept is in a K_L beam proposal in Hall D.