Compact Photon Source

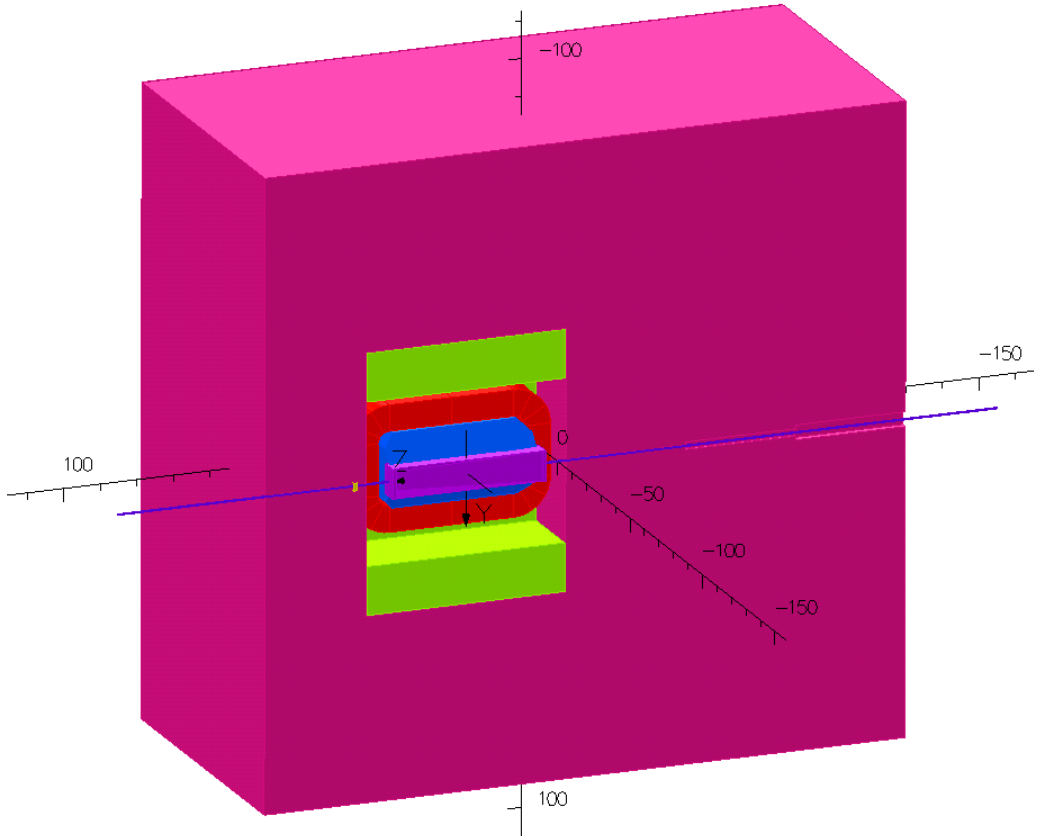
Bogdan Wojtsekhowski

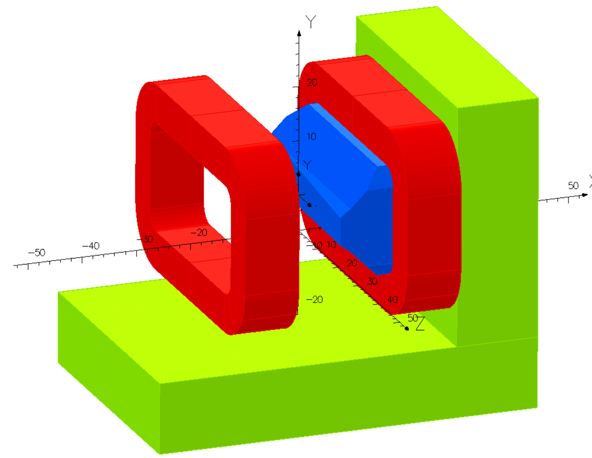
"A conceptual design study of a Compact Photon Source (CPS) for Jefferson Lab"

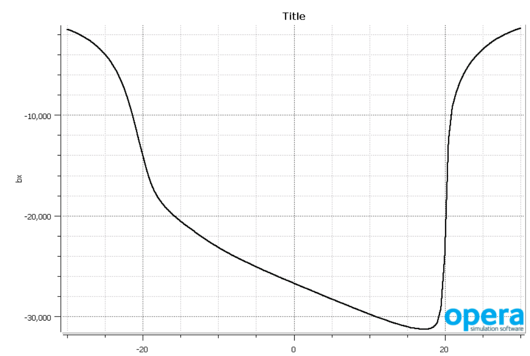
The paper is published in NIM A 957 (2020) 163429.
The project has significant momentum and collaboration!

Thank you for this opportunity which may advance photon physics

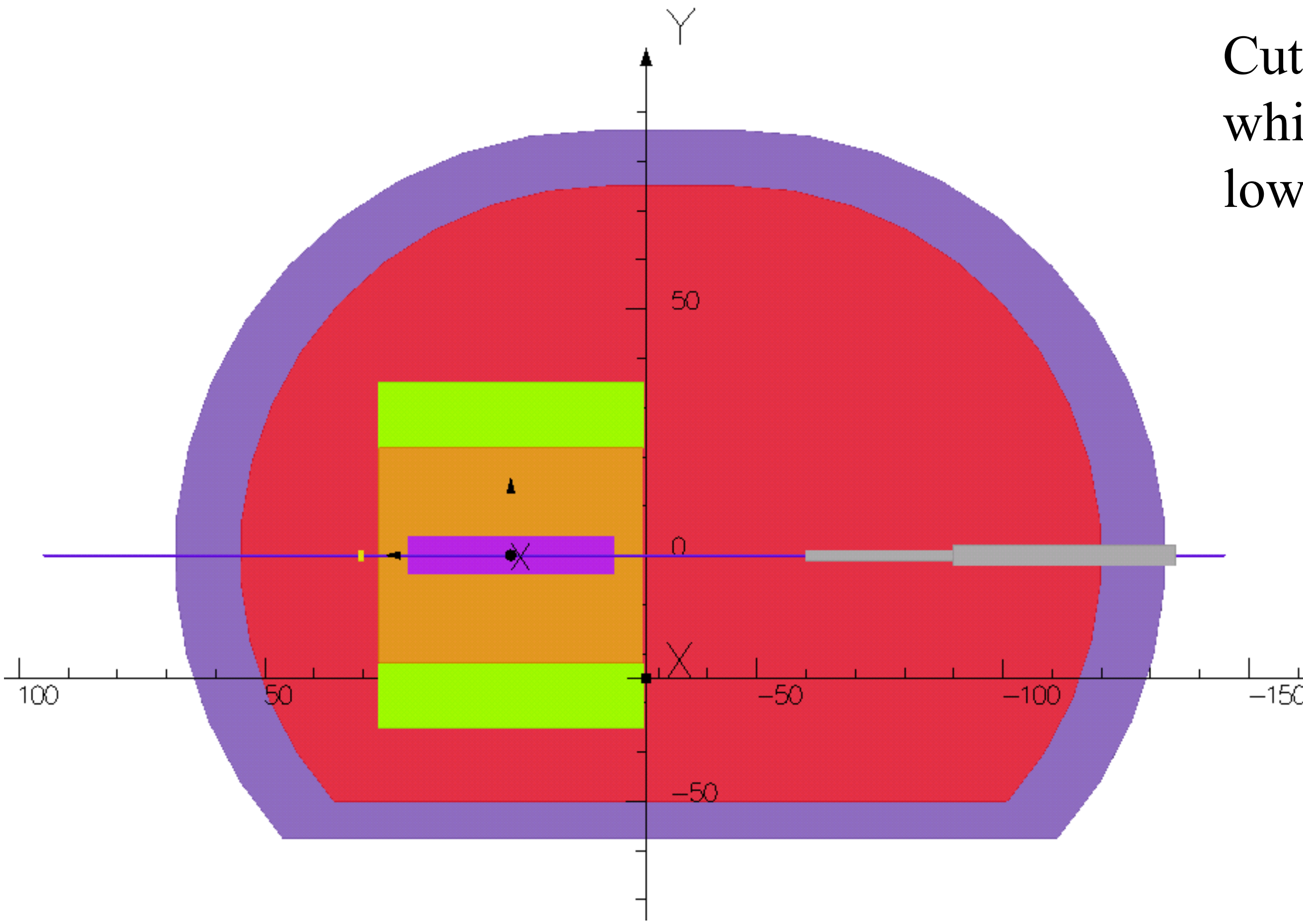
CPS as in 2017





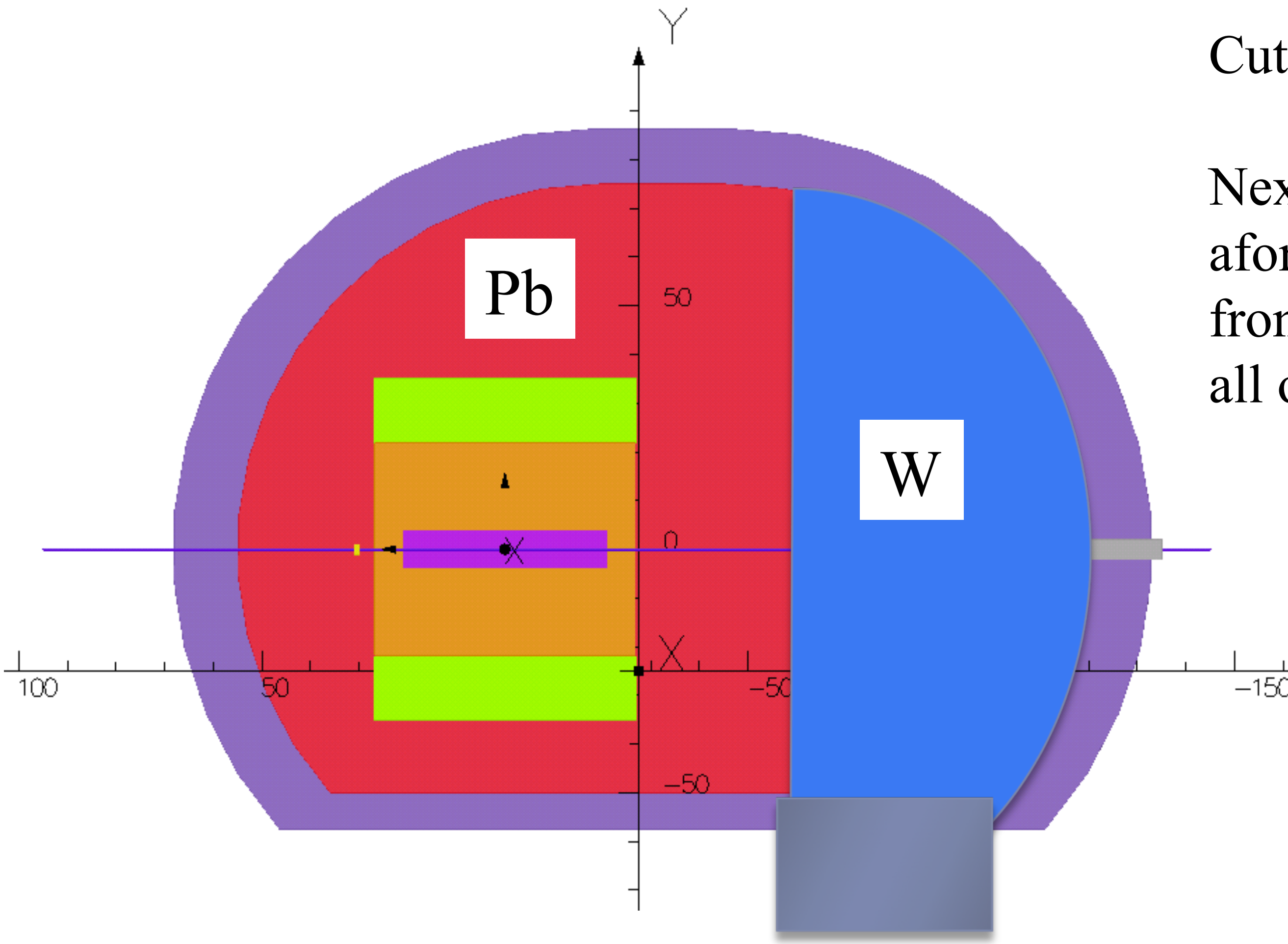


CPS optimization



Cutting the “fat” corners while keeping sufficiently low radiation level

CPS optimization



Cutting the “fat” corners.

Next step is to concentrate afordable W powder in the front section and use Pb in all other parts of the shield.

$\rho_{Pb} = 11.3$

$\rho_{Wp} = 16$

Design concept status: List

1. Beam line: BPMs, raster, radiation monitors, 10% radiator

2. Magnet:
   a) yoke, $95k quotation from NZ
   b) rad hard coils, FLUKA analysis, $65k quotation
3. Absorber: Cu insert, water cooling, 30 kW closed loop chiller
4. WCu shielding insert

5. Support of the 2.5 ton magnet with alignment
6. Segmented radiation shield:
   a) front section - W-powder, cost
   b) other sections – Lead, cost
7. Post CPS beam monitor(s)
8. Support structure for the 150 ton device

9. Installation features and post experiment storage

Physics of the photon source

1. Photon beam intensity should be as high as the NH3 can take ~ 1.6 x 10^{12} γ/s

2. Photon beam needs to be narrow, diam. 2 mm, to allow for an accurate reconstruction of the photon angle for an exclusive process. For a 4 GeV beam energy the distance less than 4 m is a must. Use a short distance from a radiator to the target or consider a big loss in the collimator. So, we need a photon source with a local beam dump!

How to make a compact beam dump?

a) How large is the beam dump shielding? Answer is 20 Λ_{nucl} for the "in-hall" dump. 20 x100 g/cm^2 => 2 meters could be sufficient. Opening for the photons is 1/γ => small leak of radiation; Abrahamyan made first Geant simulation in a few weeks in 2014.

b) How to absorb beam power? Answer is raster the beam with initial momentum near and parallel to the absorber in the magnetic field. Confirmed by Sergey's and Gabriel's MC.

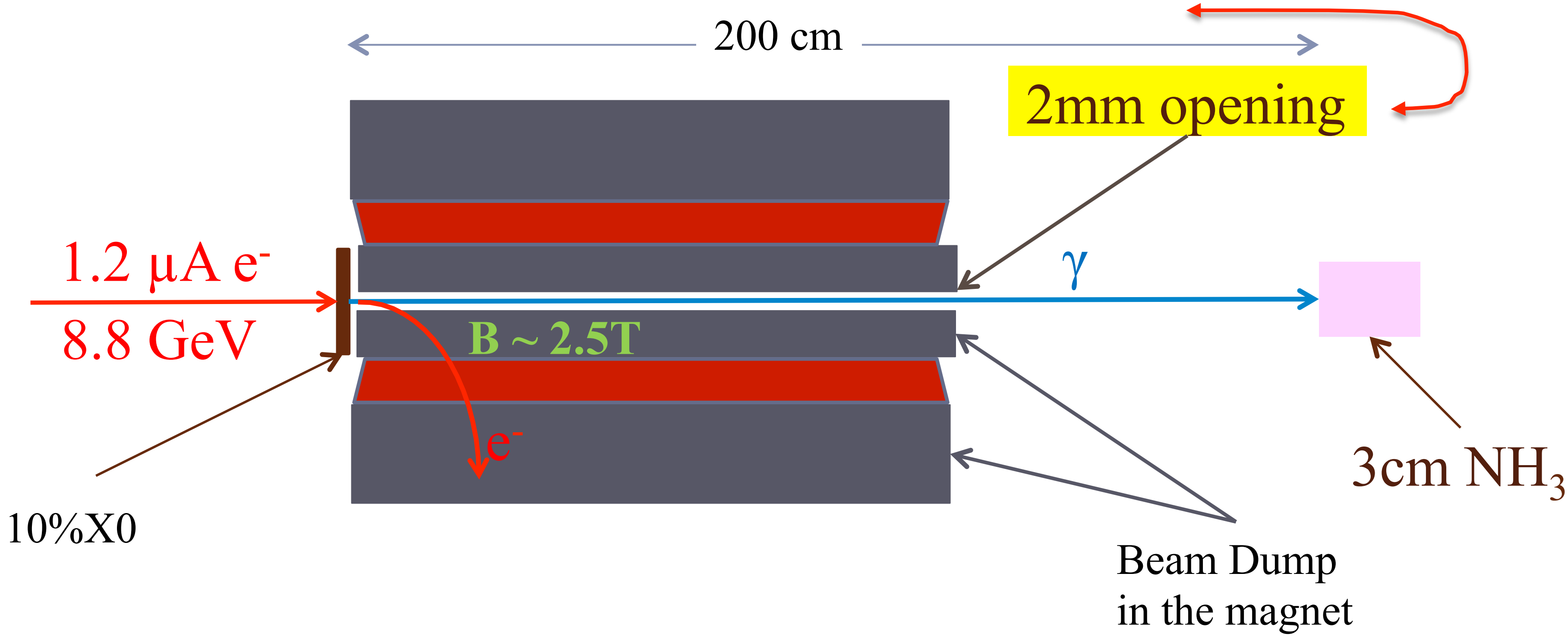
How to distribute the photon load over the target area?

a) Rotation of the target is a nice solution – Dustin's concept.
b) Vertical angle oscillation of the magnet (5 mr) is a backup.

Physics of the photon source

S. Abrahamyan and BW

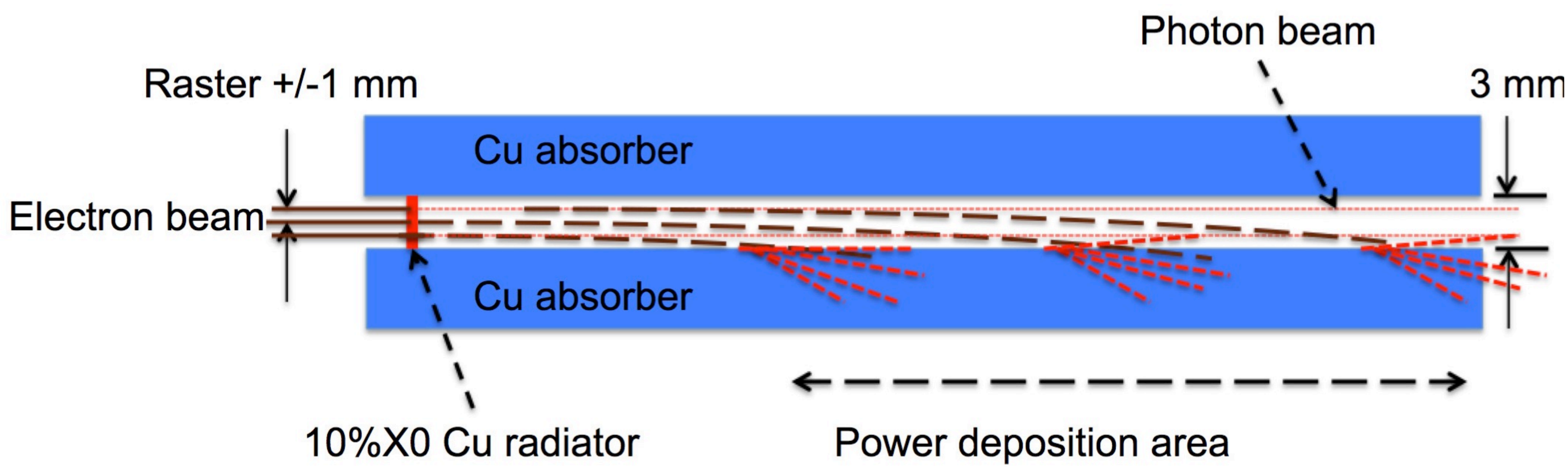
Distance to target ~200 cm
photon beam diameter on the target ~ 0.9 mm



Physics of the photon source

S. Abrahamyan and BW

Longitudinal distribution of the beam power
is a key item of the CPS design



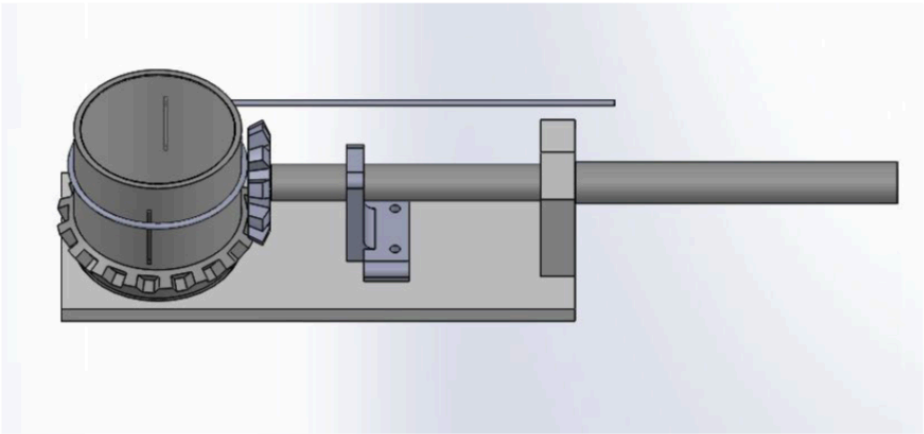
$$L = \sqrt{R^2 - (R-y)^2} \approx \sqrt{2 \cdot R \cdot y}$$

$$\delta L = \sqrt{2 \cdot R \cdot y} \times \frac{\delta y}{2y}$$

Power distribution

D. Keller & C. Keith

Rotation of the target is a solution for rastering
(in combination with vertical movement of the ladder)



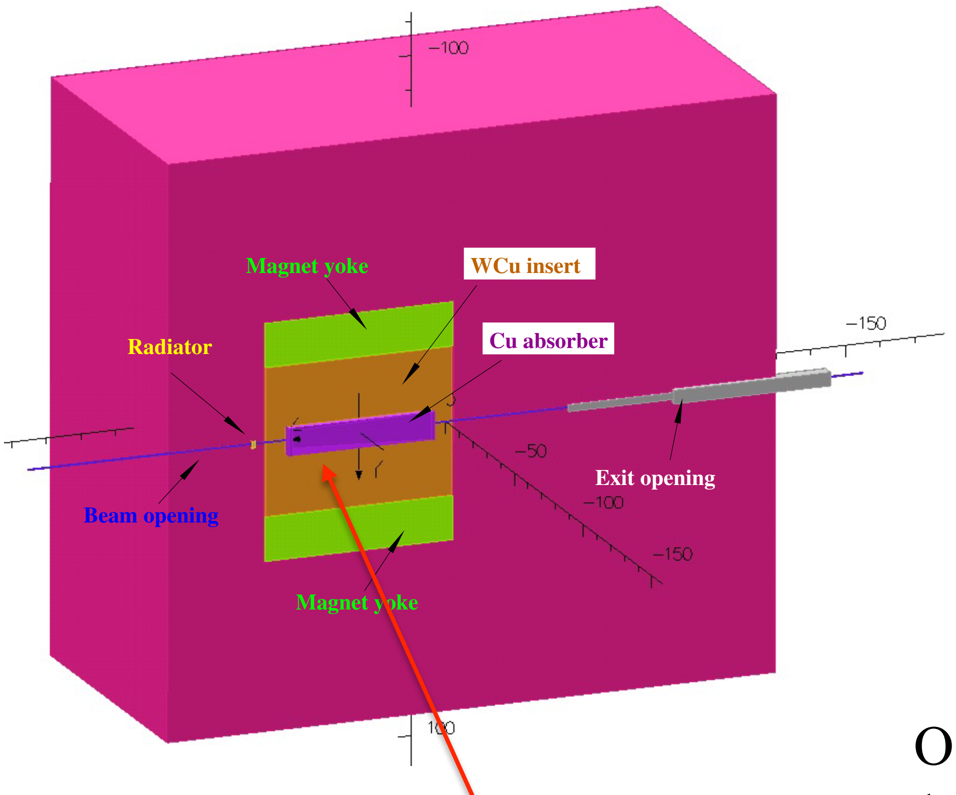
The rotating target cup driven by a gear and shaft with the NMR loop

The rate of rastering is an important parameter:
Recent studies show that 1 Hz is sufficient!

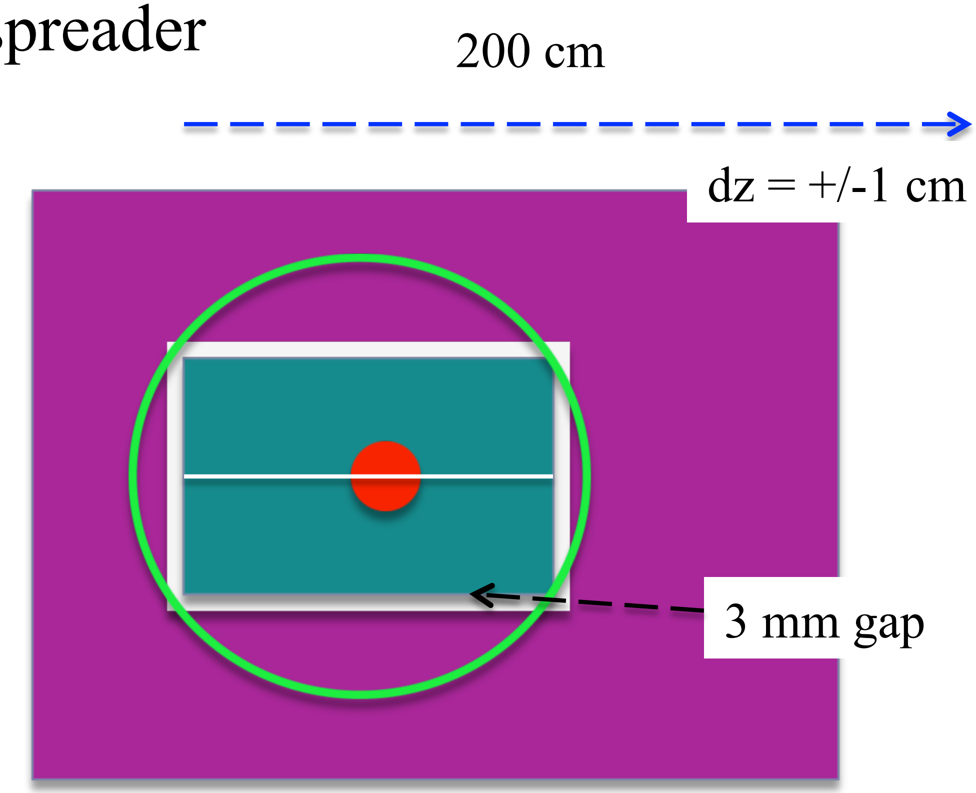
However, 10^5 vertical cycles per day needs also
some type rotation mechanism

Movement of the photon beam

A possible option for the vertical spreader



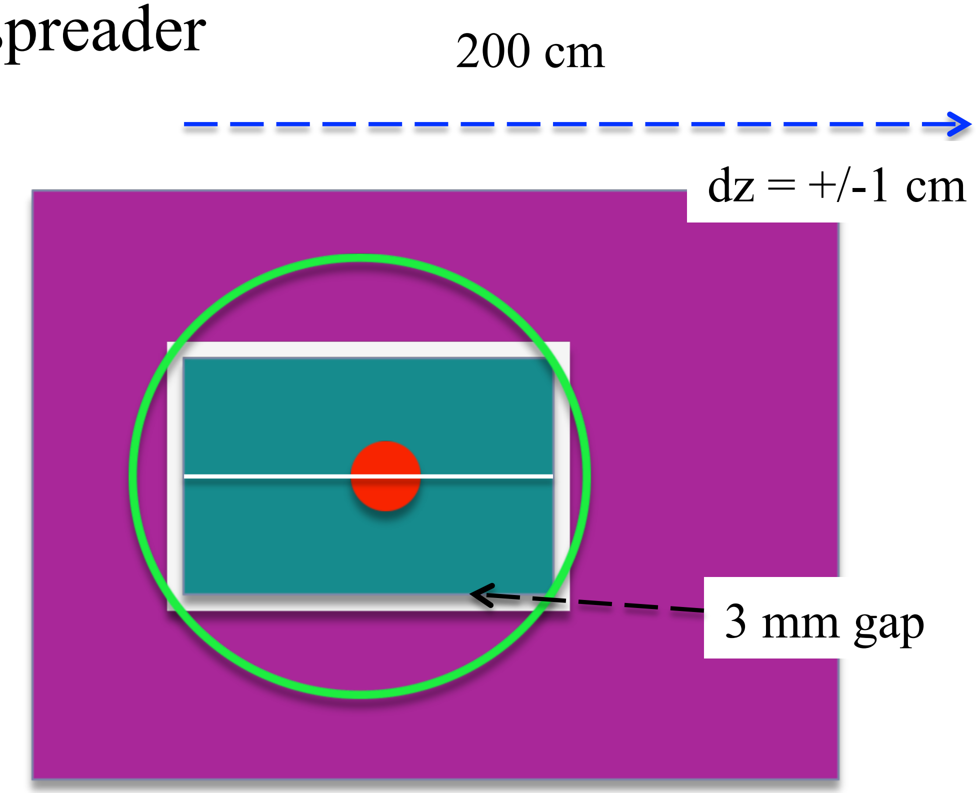
Magnet mass is 2.5 ton
(including the inserts)



Oscillation of the magnet by +/-5 mrad at 1 Hz rate requires a 100 Watt motor

Movement of the photon beam

A possible option for the vertical spreader



It takes a very little energy
to move the seesaw at 1 Hz.

Oscillation of the magnet by +/-5 mrad at 1 Hz rate requires a 100 Watt motor

Application to Hall D (KL source)

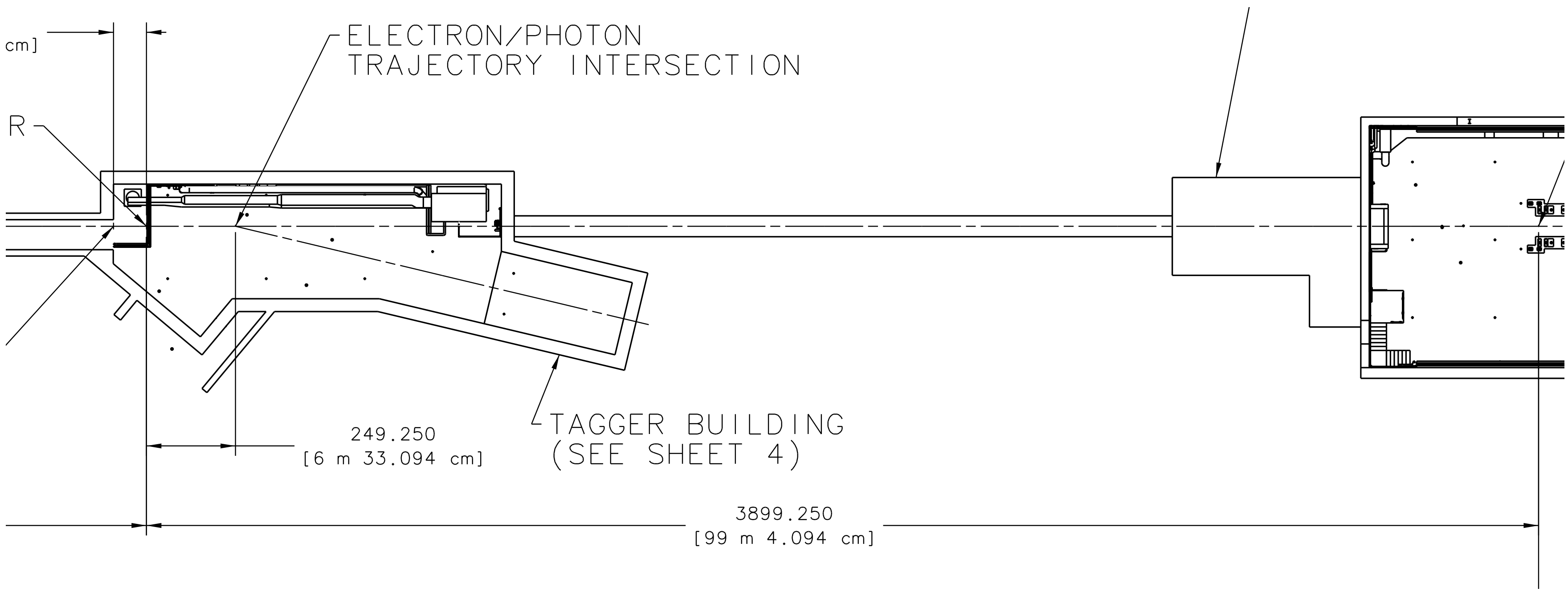
Pavel started with CPS and developed a KL beam line for 2015 workshop

Optimization to high power – weaker and longer magnet

Additional changes – larger vertical and horizontal rasters

Correlated position/angle raster allows us to “focus” photons on Be target

Application to Hall D (KL source)



5μA with thin 10% radiator: 60 kW beam power for $3 \times 10^{12}\, \gamma/\mathrm{s}$
Beam spot size on Be at 75 m is $7500 \times 14/12000 \times \sqrt{0.1} = 2.8$ cm

Need to add the beam spot size at the radiator (+/- 1 cm) and an m/E factor

A horizontal raster size ~ +/- 1 cm would allow us to distribute beam power and add a little to beam size if proper beam angle is applied to focus on Be

Application to the Hall D (KL source)

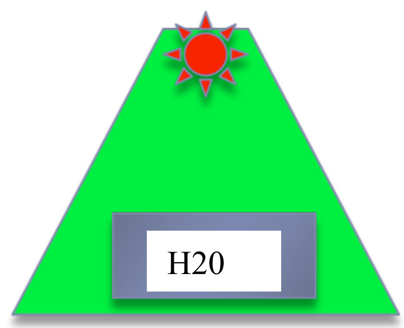
Vertical raster of +/- 2.5 mm; central beam at 5 mm from the Cu absorber

Magnetic field of 5 kG => R = 12GeV/300/5000 = 80 m =>

L_z = \sqrt (8000**2 – (8000-0.5)**2) ~ (\sqrt (2*8000*0.5) = 90 cm

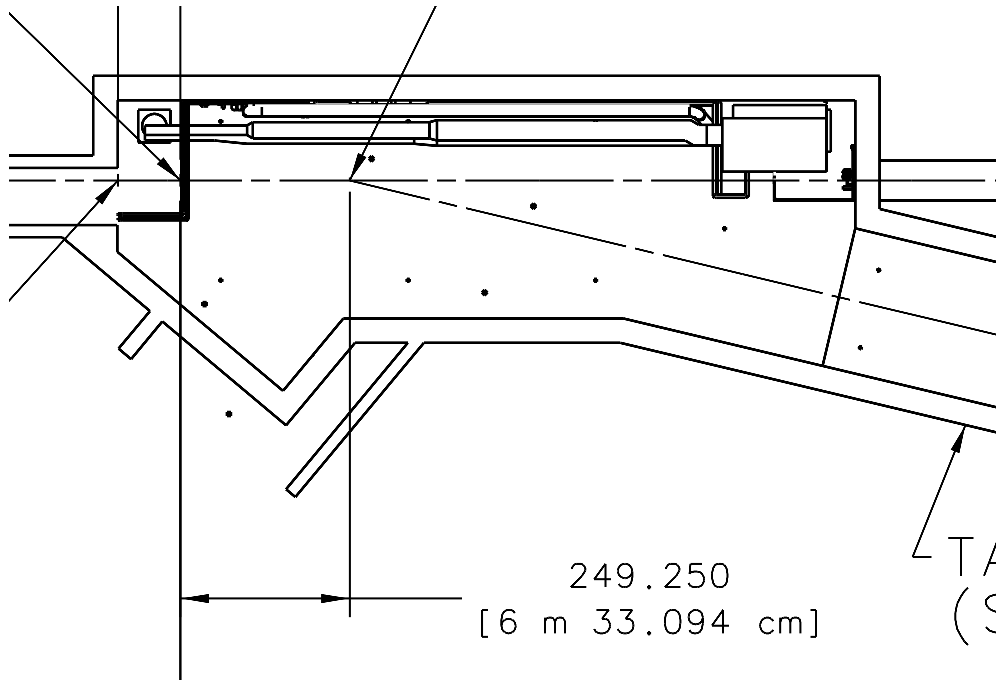
$dL_z/L_z = ½ (dy/y) = ¼$!

The power deposition area is 45 cm long x 2 cm wide => 660 W/cm^2



Cu absorber for heat transport => the temperature gradient ~ 150 C/cm

Application to the Hall D (KL source)



The power deposition area is 45 cm long x 2 cm wide => 660 W/cm^2

Cost of the shielding is up due to the magnet length, lead should be OK

Wider raster should allow a shorter magnet – close to one in Hall C design

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