Compact Photon Source: Update

Carbon & LH Target Experiment, CPS Entrance Region with FLUKA

Parker Reid
Supervised by
Bogdan Wojtsekhowski

CPS Meeting March 27 2018

Jefferson Lab
Saint Mary's University Since 1802

Summary of Updates from last Meeting

1. Succeeded in FLUKA consistency check with carbon target, And RCS Study.

2. Added extra shielding in entrance region to ensure CPS benchmarks are met.

SAINT MARY'S UNIVERSITY SINCE 1802

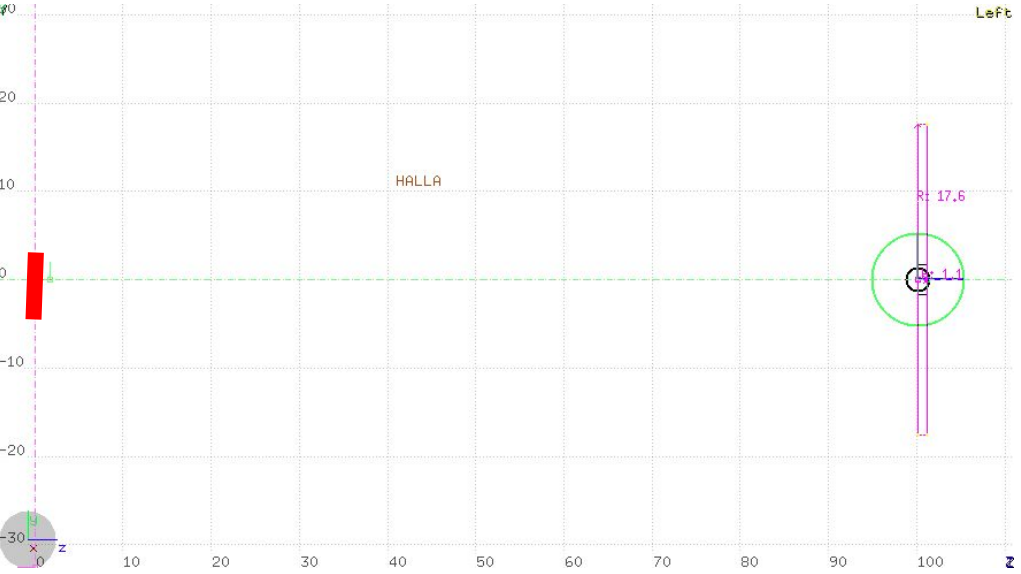
Carbon Electron Experiment (1/5)

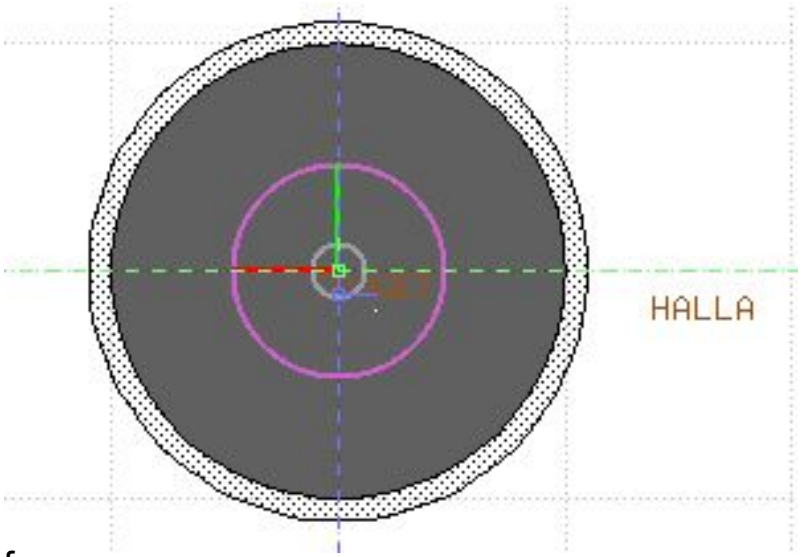
- Performing a consistency check with previously known data.
- Ensure FLUKA is working as intended
- Data obtained in 2001 with 1% carbon radiator at 11 GeV
- Replicated within FLUKA.
- Will look at Neutron, e-, and photon production

Carbon Electron Experiment (2/5)

P.Reid 03/27/18

11 Gev Electron beam incident on 0.1 cm carbon.



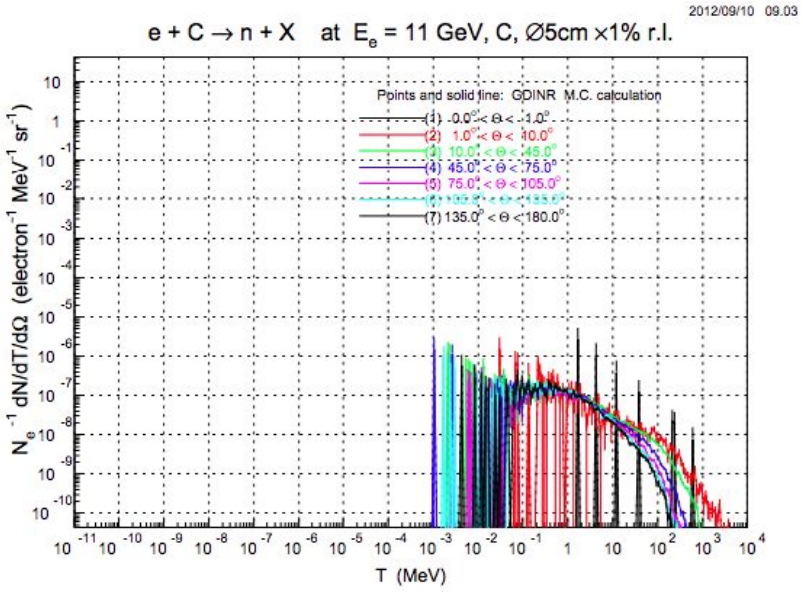


Pink outline is low angle detector, red is location of carbon target (cm)

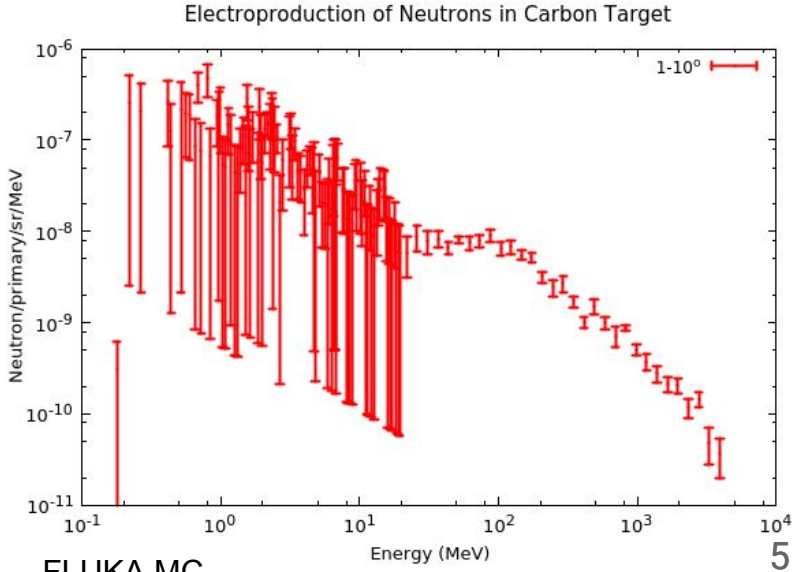
Carbon Electron Experiment (3/5) Neutron Production

P.Reid 03/27/18

	10 Mev	100 Mev	1000 Mev
P. Degtiarenko 2012(/electron/MeV/sr) (1-10°)	~$3*10^{-8}$	~$8*10^{-9}$	~$3*10^{-10}$
FLUKA (/electron/MeV/sr) (1-10°)	$2*10^{-8}\mp1*10^{-8}$	$6*10^{-9}\mp2*10^{-9}$	$3.8*10^{-10}\mp1*10^{-10}$



Degtiarenko, Pavel, 2012



FLUKA MC

Carbon Electron Experiment (4/5)
Electron Production

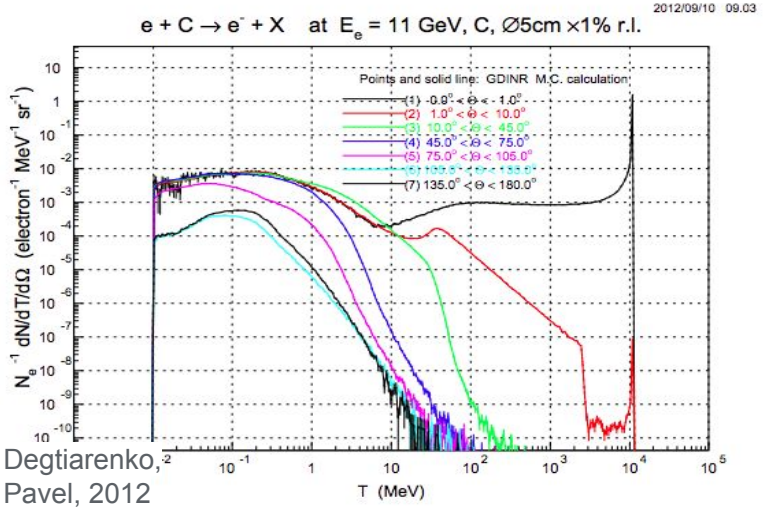
P.Reid 03/27/18

Electron Production Comparison ($< 1^o$).

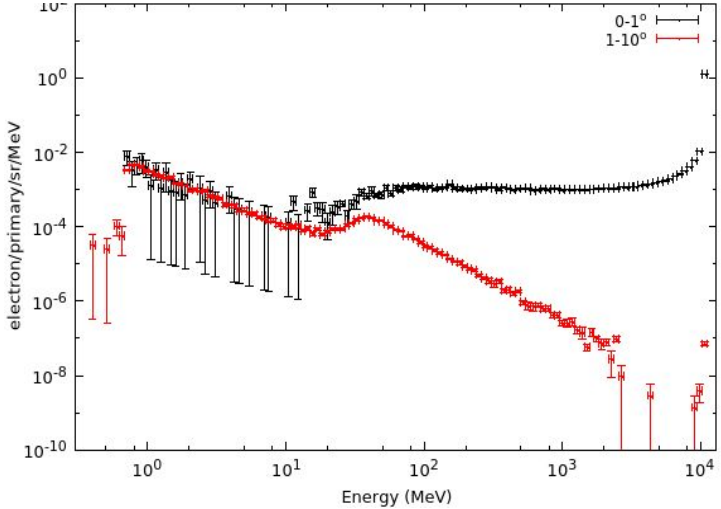
Energy	10 MeV ($< 1^o$)	100 MeV ($< 1^o$)	1000 MeV ($< 1^o$)
DINREG (/electron/MeV/sr)	$2 * 10^{-4}$	$9 * 10^{-4}$	$8 * 10^{-4}$
FLUKA (/electron/MeV/sr)	$2.0 * 10^{-4} \pm 1 * 10^{-4}$	$1.1 * 10^{-3} \pm 5 * 10^{-4}$	$1.0 * 10^{-3} \pm 1 * 10^{-4}$

Electron Production Comparison ($1 - 10^o$).

Energy	10 MeV ($1 - 10^o$)	100 MeV ($1 - 10^o$)	1000 MeV ($1 - 10^o$)
DINREG (/electron/MeV/sr)	$1 * 10^{-4}$	$3 * 10^{-5}$	$4 * 10^{-7}$
FLUKA (/electron/MeV/sr)	$1.1 * 10^{-4} \pm 1 * 10^{-5}$	$4.0 * 10^{-5} \pm 1 * 10^{-5}$	$3.5 * 10^{-7} \pm 1 * 10^{-7}$



Degtiarenko, Pavel, 2012



FLUKA MC

Carbon Electron Experiment (5/5)
Photon Production

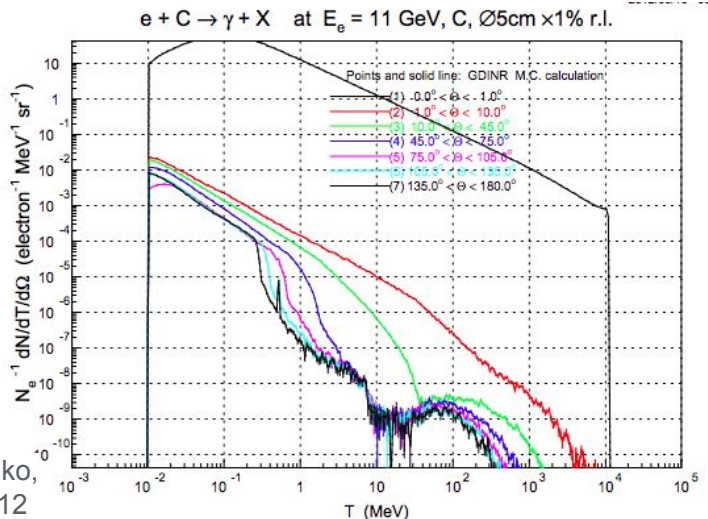
P.Reid 03/27/18

Photon Production Comparison ($< 1^o$).

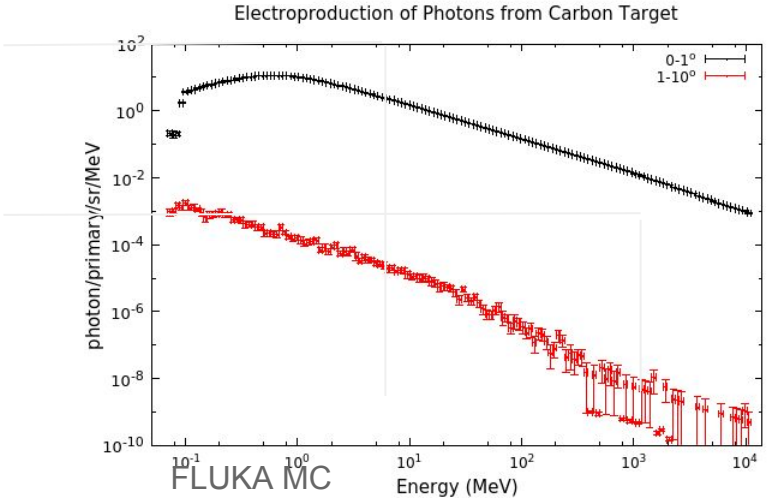
Energy	10 MeV $(1-10^o)$	100 MeV $(1-10^o)$	1000 MeV $(1-10^o)$
DINREG (/electron/MeV/sr)	1	0.1	0.01
FLUKA (/electron/MeV/sr)	1.4 ± 0.1	0.13 ± 0.01	$0.013 * 10^{-7} \pm 0.001$

Photon Production Comparison $(1-10^o)$.

Energy	10 MeV $(1-10^o)$	100 MeV $(1-10^o)$	1000 MeV $(1-10^o)$
DINREG(/electron/MeV/sr)	$1 * 10^{-5}$	$3 * 10^{-7}$	$6 * 10^{-9}$
FLUKA (/electron/MeV/sr)	$1.2 * 10^{-5} \pm 5 * 10^{-6}$	$3.6 * 10^{-7} \pm 1 * 10^{-7}$	$5.0 * 10^{-9} \pm 3 * 10^{-9}$



Degtiarenko, Pavel, 2012



FLUKA MC

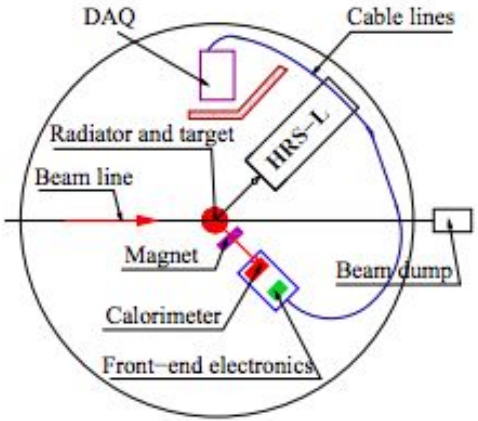
Real Compton Scattering

P.Reid 03/27/18

Study is a good benchmark for radiation levels

Electronics precision from 5% to only 10% by the end of RCS experiment lifetime.

A consistency check for radiation level analysis.



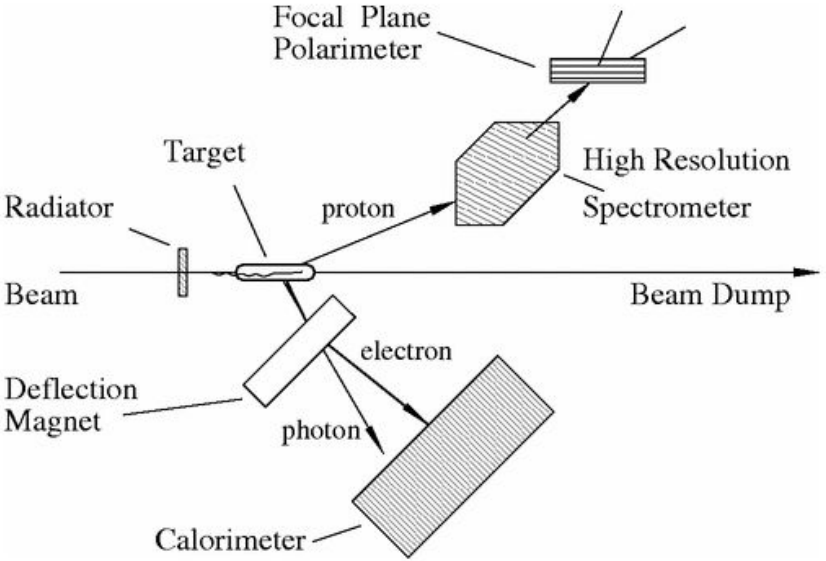
D. J. Hamilton, , A. Shahinyan , B. Wojtsekhowski , et al

Basic RCS Reproduction

15cm LH2 Target

6% copper radiator.

Previous simulation data obtained with energy 3.48 Gev



RCS Experimental Geometry. D. J. Hamilton et al. (Jefferson Lab Hall A Collaboration, 2005

RCS FLUKA

P.Reid 03/27/18

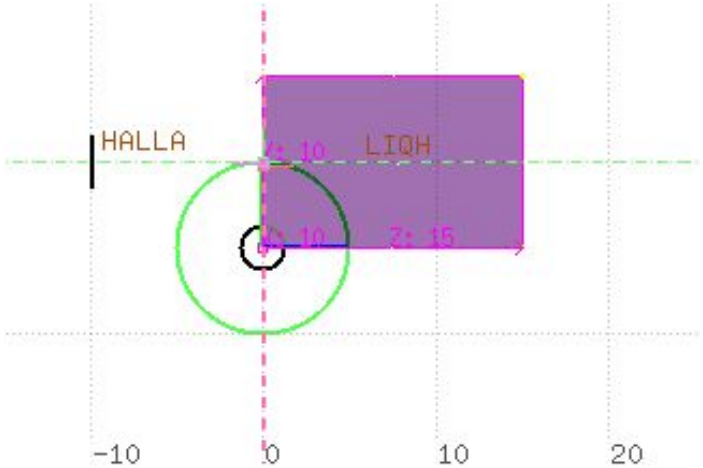
Simple Geometry, No beamline shielding

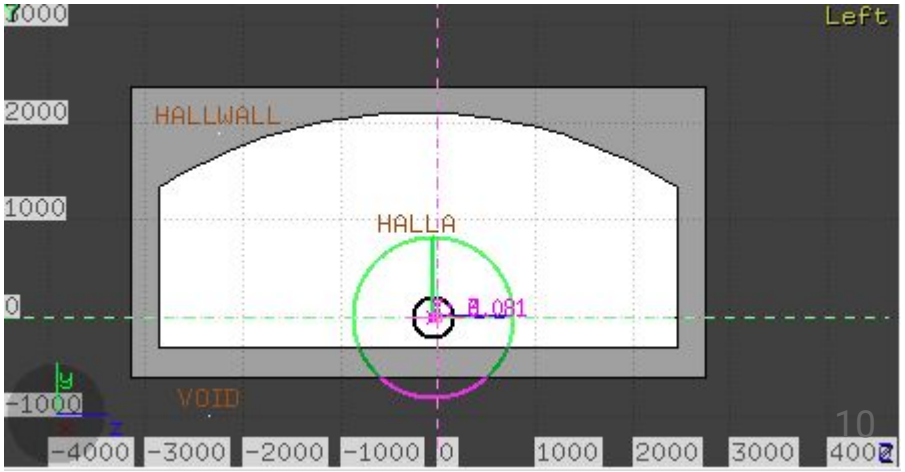
Placed near center of Hall A

Updated 40 cm radius “blackhole” beam dump

Hall filled with Air

All Lengths in cm



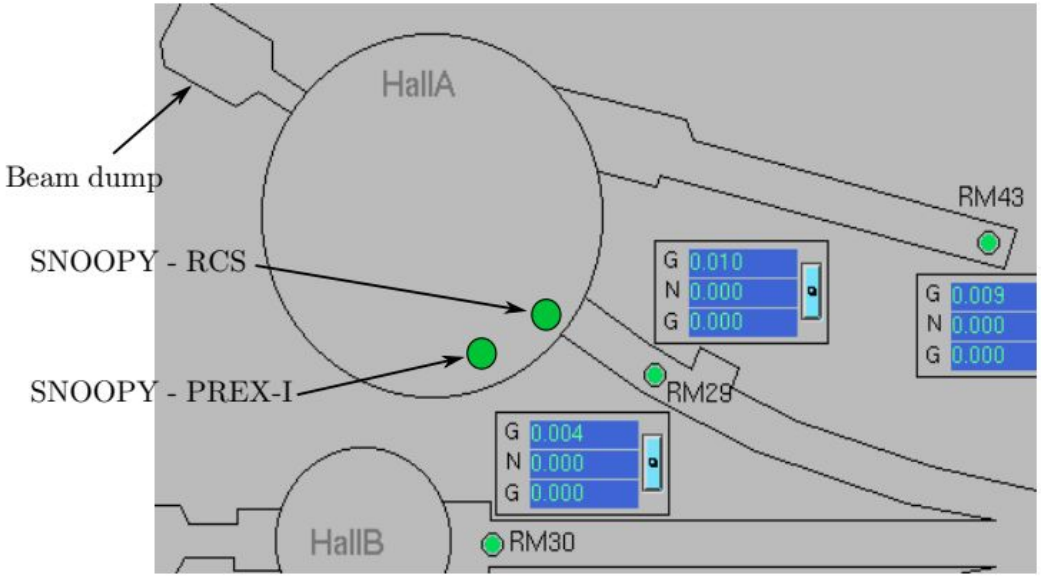


Radiation Comparison

RCS experiment has benefit of experimental, and simulated Data.

GEANT4 Model has scoring model 16m upstream from center of Hall

SNOOPY (Neutron dose detector) approximately same location



RCS Results, Comparison

P.Reid 03/27/18

1 Mev neutron-EQ comparison

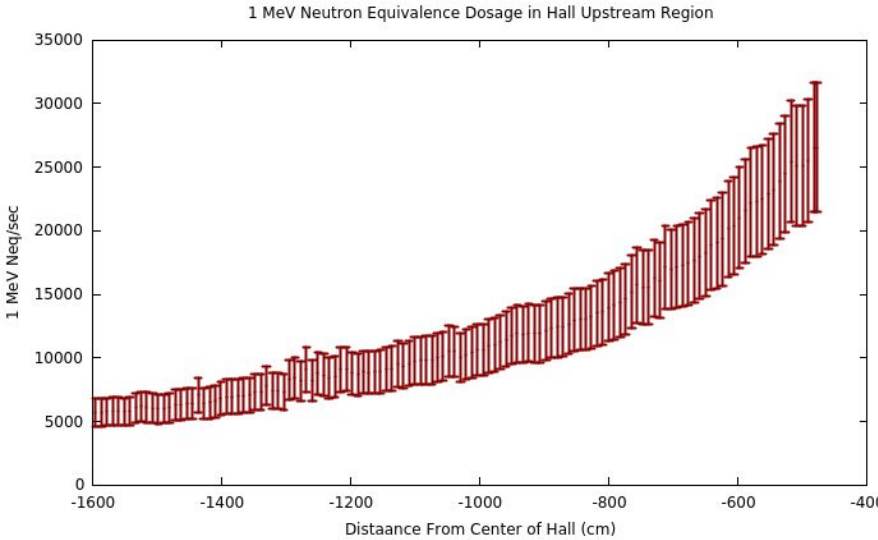
RCS GEANT simulation

Experiment	Days	Radiation type	1 MeV neutron equivalent fluence rate ($n_{eq}cm^{-2}s^{-1}$)	Total 1 MeV neutron fluence ($n_{eq}cm^{-2}$)
RCS, 3.481 GeV 40 μA	16 effective days	e^+/e^-	1.8E+03	2.5E+09
		neutrons	5.1E+03	7.0E+09

Combined 1 MeV Fluence rate

Neutron expectation ~5,100 neq/cm^2/sec

FLUKA calculated neutron dose at 16m
5,750 ∓ 700 neq/cm^2/sec

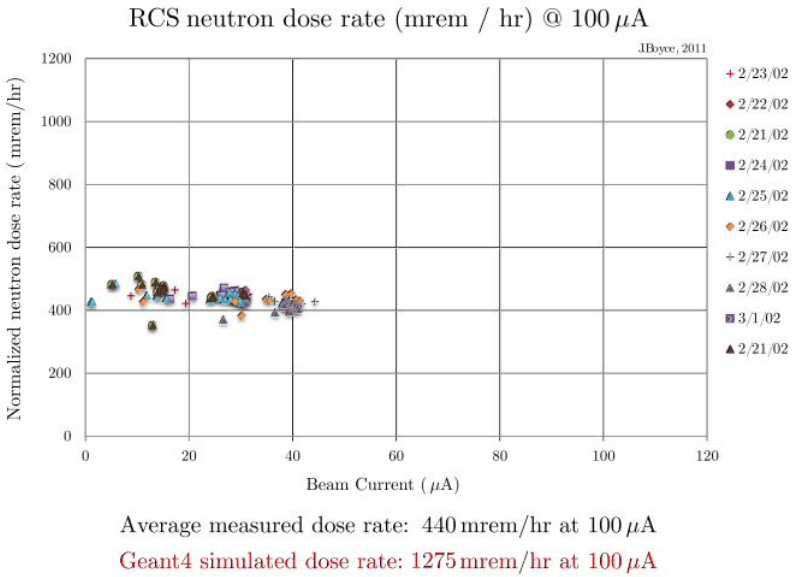


RCS Results, Comparison

P.Reid 03/13/18

Dose Rate mrem/hr

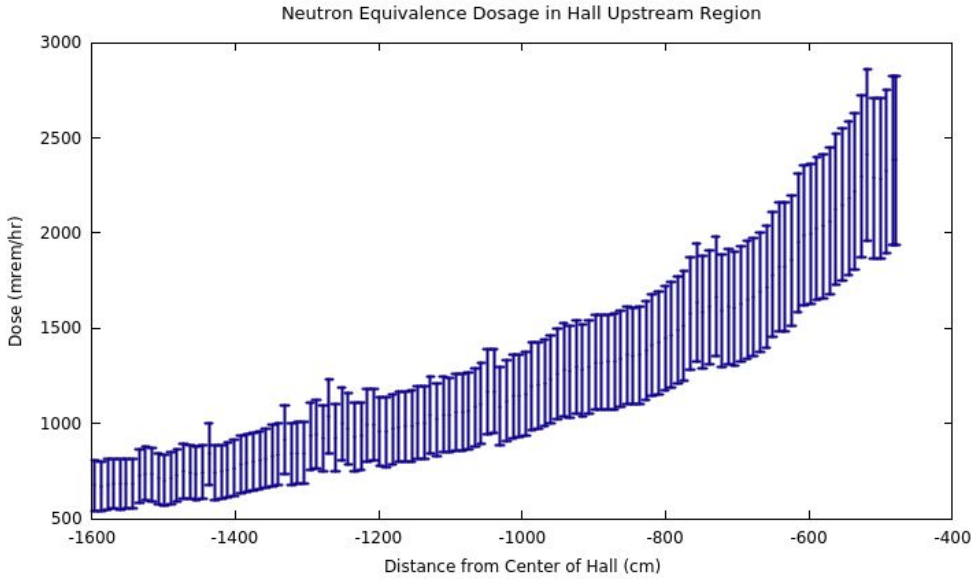
*note the 1275 was a GEANT4 calculation performed by K. Maduka in 2017



J. Boyce 2011

Expected: 440 mrem/hr @ 100 μA

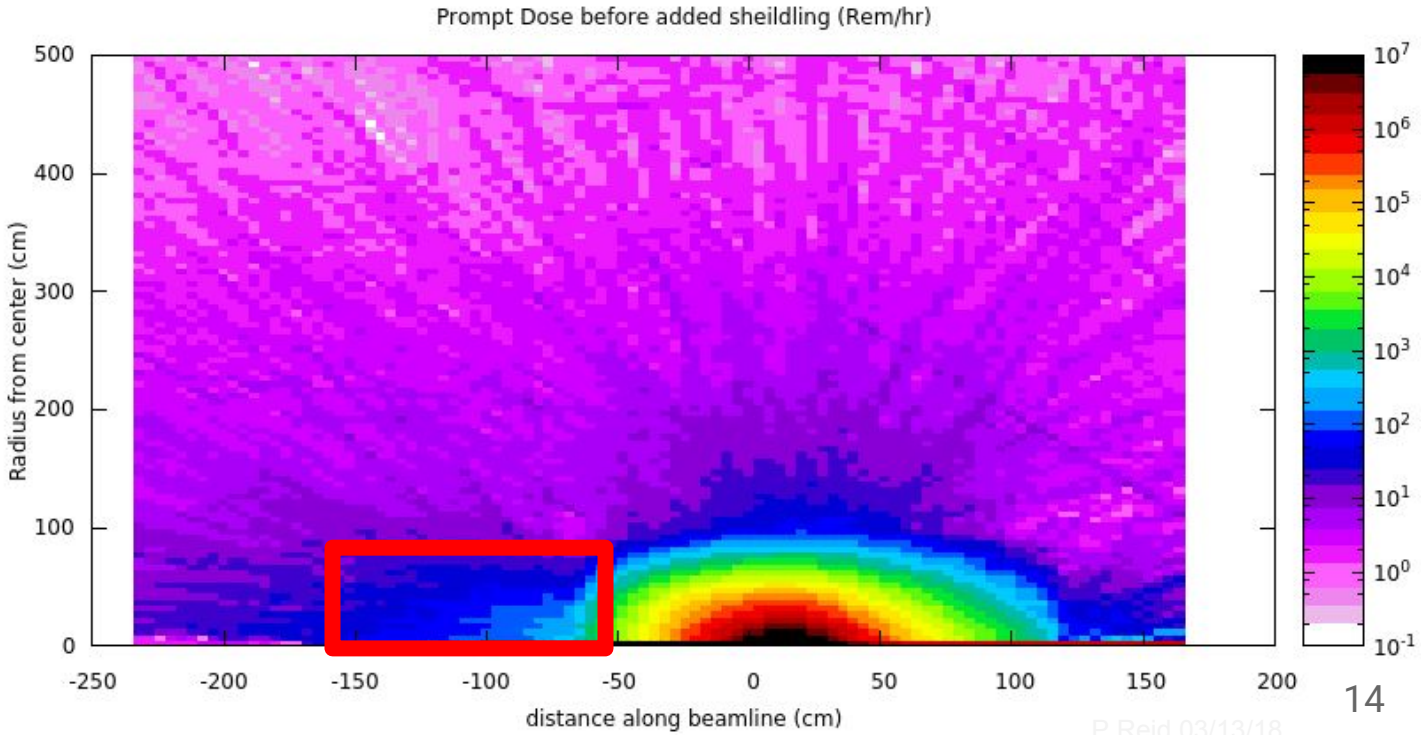
Calculated: 665 ∓ 140 mrem/hr @ 100 μA



CPS Entrance Region Study

Purpose:

Find sufficient shielding in Entrance region to stop this "spilling" of radiation.



Shielding in Backwards Region (1/2)

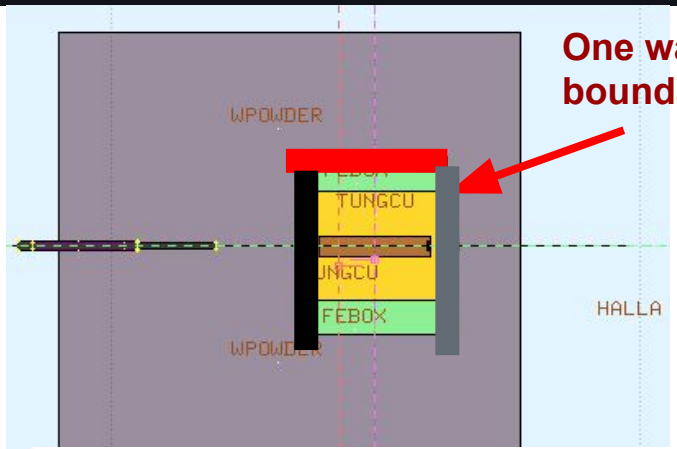
P.Reid 03/27/18

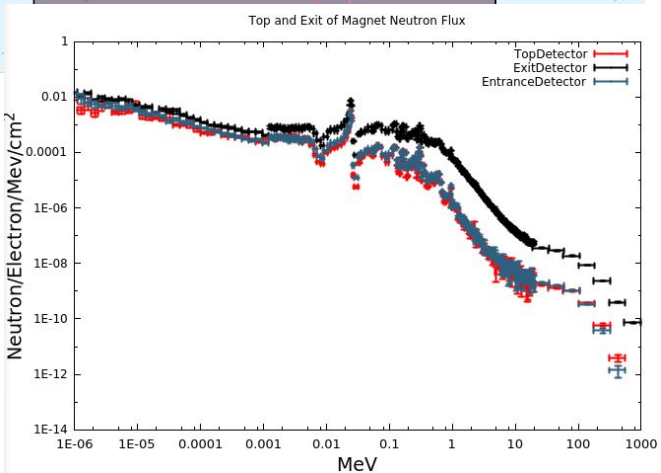
From February presentation some things to note:

WIthout any W shielding

- CPS Entrance and Top exhibit very similar neutron spectra shapes
- Neutron rate/MeV between top and entrance detectors within ~50%

No different materials should be required for Entrance shielding (assuming radiator contribution is small).





Shielding in Backwards Region (2/2)

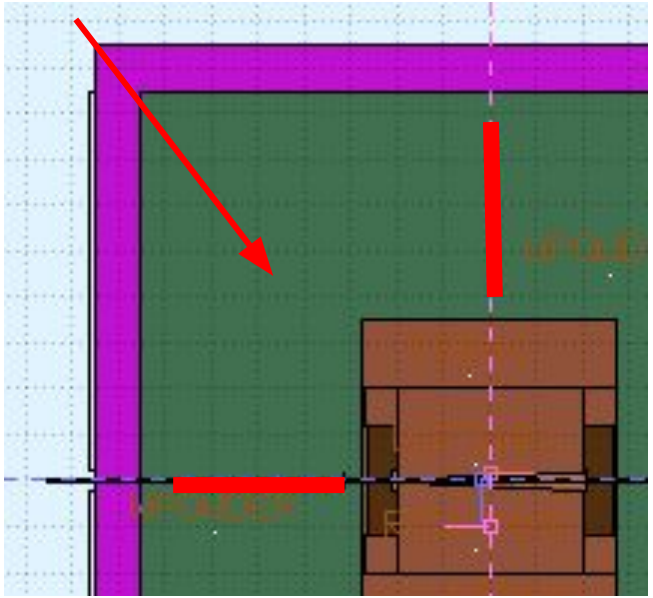
SAINT MARY'S UNIVERSITY SINCE 1802
P.Reid 03/27/18

Top of detector had ~50 cm of W powder shielding

Added 10cm of W shielding to entrance region, now ~50cm W of shielding

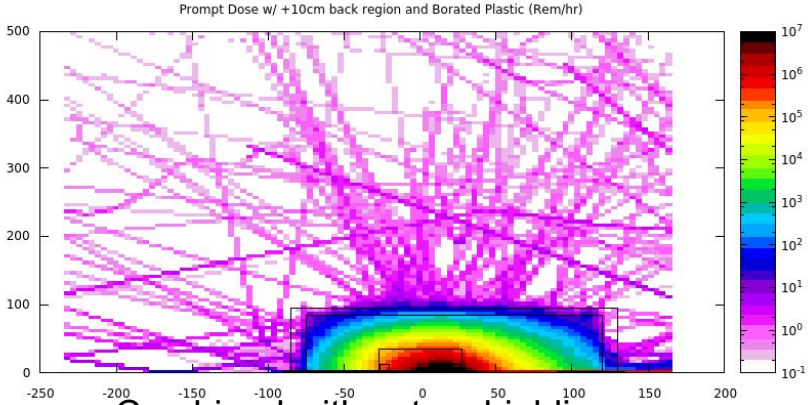
Added 10 cm of 5% (by mass) borated polyethylene to all boundaries of CPS (effective at removing thermal neutrons)

Both now ~50 cm

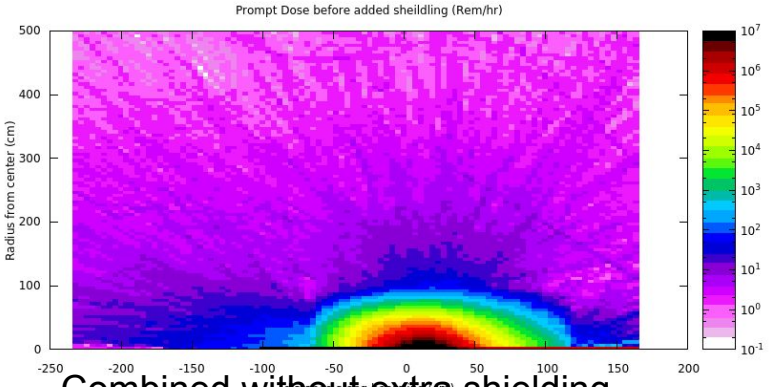


Prompt Dose results (1/2) All same Scale

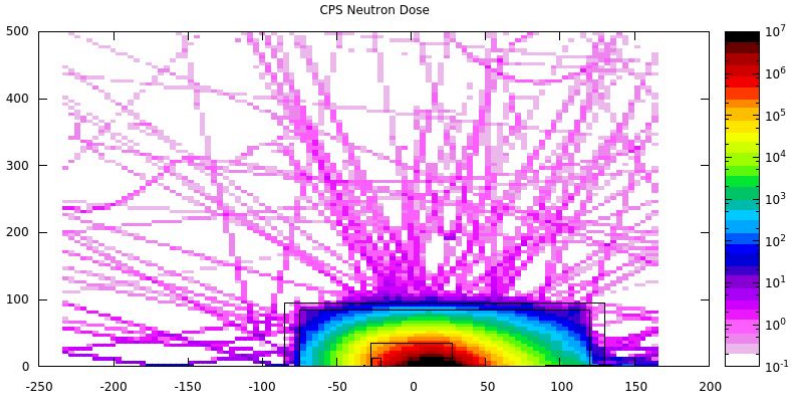
P.Reid 03/27/18



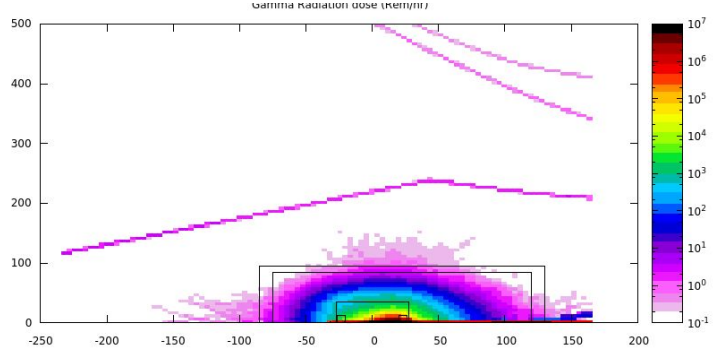
Combined with extra shielding



Combined without extra shielding



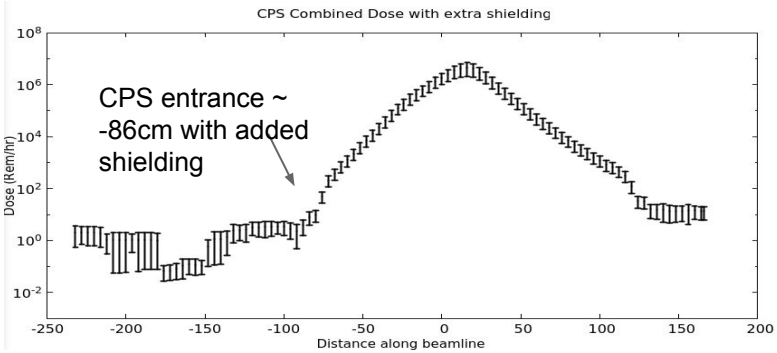
Neutron Contribution with extra shielding



Gamma Contribution with extra shielding

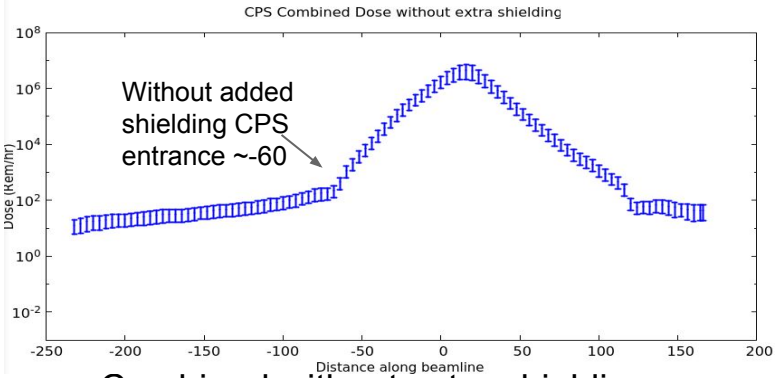
Prompt Dose results (2/2) All same Scale

P.Reid 03/27/18

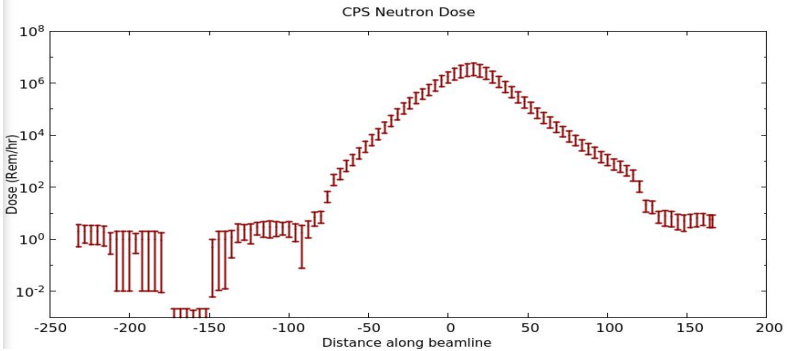


Combined with extra shielding

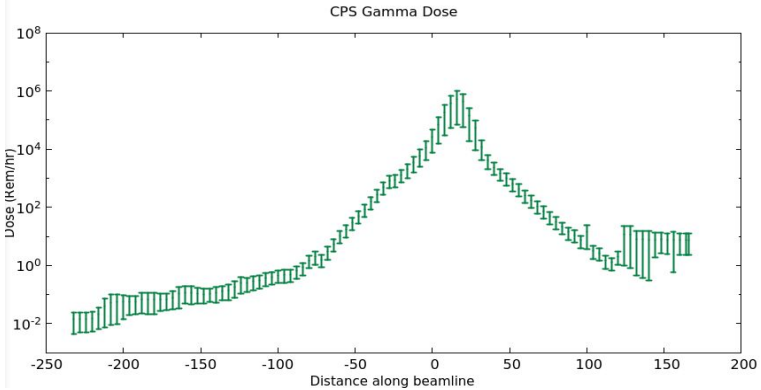
Projected from R=5cm->30 cm



Combined without extra shielding



Neutron Contribution with extra shielding



Gamma Contribution with extra shielding

1000 hour run @ 1 hour cooling

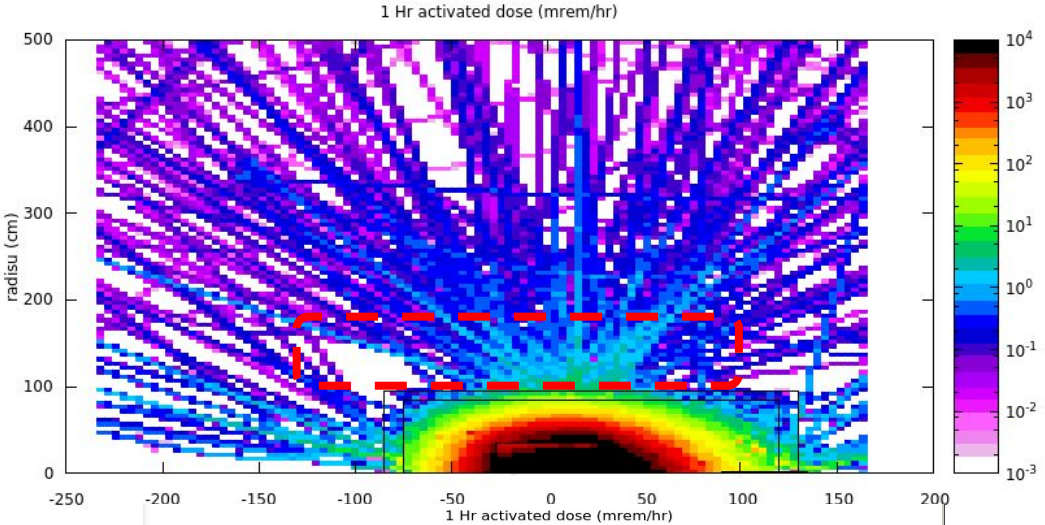
P.Reid 03/27/18

Benchmark: <few rem/hr after 1 hour cooling after 1000 hour run.
At 1 foot outside envelope (~30cm)

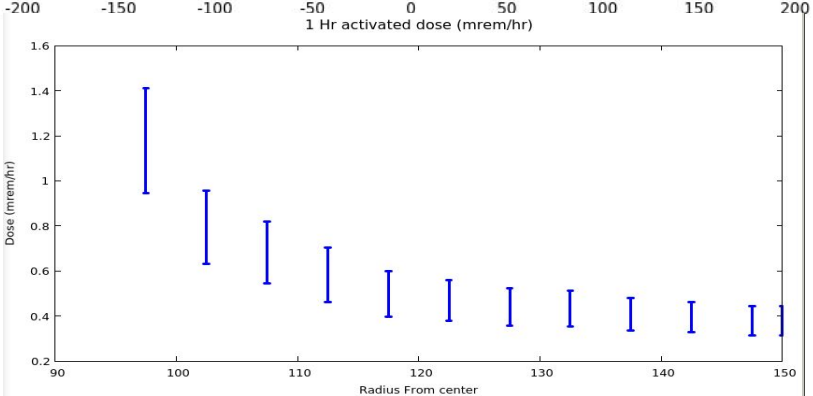
Working with low statistics, will average along cylindrical shell ~30cm away from CPS (in red outline)

~0.8 mrem/hr ∓ 50% at 30 cm from CPS

need more statistics



Dose as a function of Radius



Notes

Prompt dose around entrance on the order of rem/hr <1 m from the CPS (benchmark is order of rem/hr at 10 m)

Neutron Main Contributor to exit dosage.

Appears the "spilling" has been stopped with the extra 10cm + borated plastic.

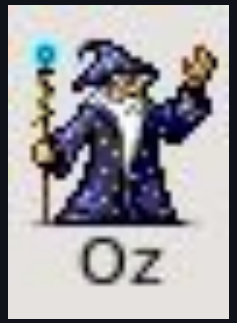
Need to run 10x more statistics to reduce uncertainties in entrance regions for both prompt and activated dosages (especially activated dose)

10 cm Addition to entrance W shielding is likely an effective addition to entrance radiation (barring more statistics)

Moving Forward....

1. Increase statistics
2. Calculate dosage in upstream region for other cooling times
3. Determine dosage at boundary (Benchmark <1μrem/hr)

Questions/Comments/Concerns?



As always, FLUKA insight is greatly appreciated!

Thank you