

CPS Radiation Simulation Update

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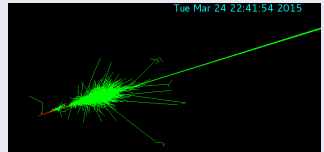
**CPS Collaboration Meeting,
JLab, Newport News, Va**

February 3, 2020

Introduction

Time permitting, I shall talk about...

- CPS needs/wants
- CPS simulation tools
- Latest* simulation results
- Outlook



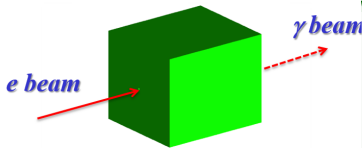
Disclaimer

- Many people contributed (directly or indirectly) to this talk (collab. from CUA, Glasgow, GWU, St. Mary's, UVa, JMU, JLab). Thanks!
- This is just GN's \$0.02 worth...
- Therefore, all **inaccuracies, miss-statements, controversial, or just plain wrong statements** are mine alone!





Compact Photon Source Concept



CPS Wants:

- “Designer reactions” → **high intensity**,
- ..**pure** beams (esp. for pol. tgt.)
- **small** transverse size (and footprint!).
- **unaltered** γ beam: m/E angular size
- capability of operating for **~ 1 kh**

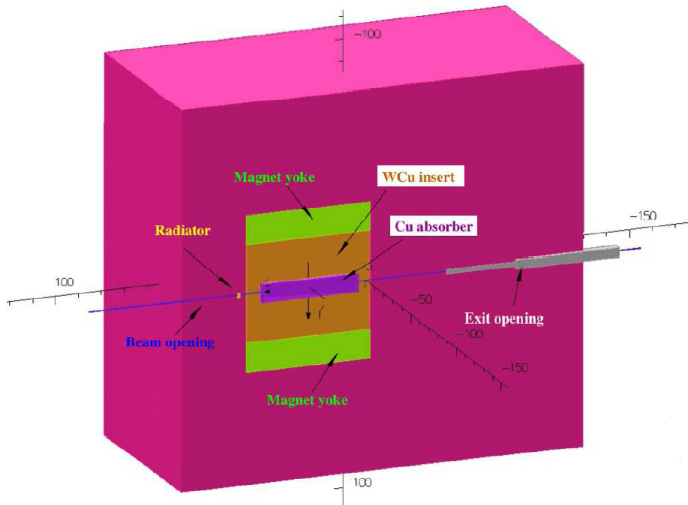
CPS Needs to:

- be **possible** (to build)
- safely **dispose** of residual e beam
- contain radiation (ALARA)
- mitigate **heat** and **co\$**t

To do these one needs to...

- Assess the **dimension** of the problem(s) through simulation:
- radiation, heat, activation
- dims., materials, infrastructure...

Compact Photon Source 2.0



credit: B.W.

CPS software tools



To answer these (and other) Questions...

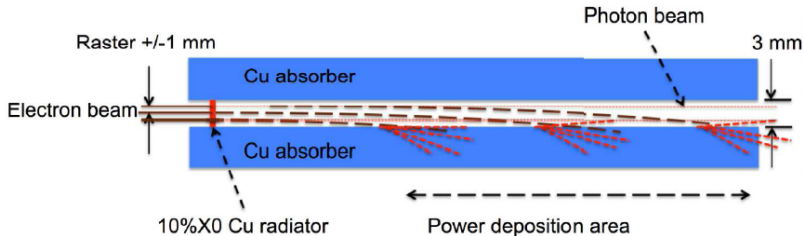
- How big will the magnet be? How will the γ beam look like?
- Will the central piece melt? How hot will it get?
- Is the shielding adequate? How about activation?
- How heavy, co\$tlly will this thing be? Can we optimize this?
- Is fabricating such device possible?

we use the development tools:

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

CPS Central piece

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



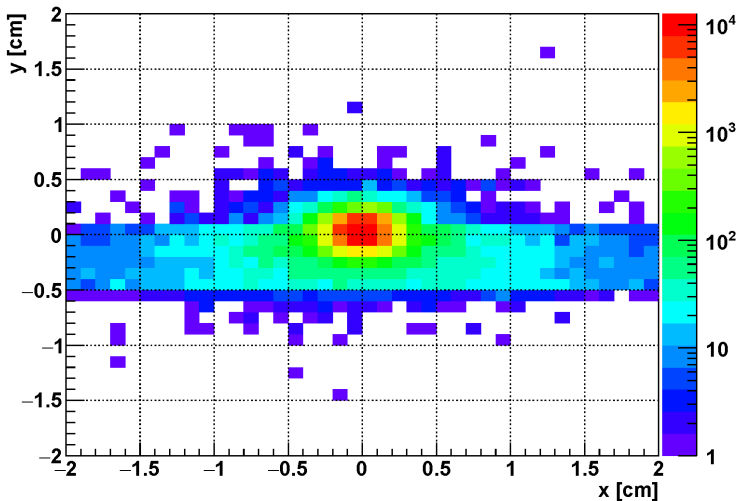
credit: B.W.

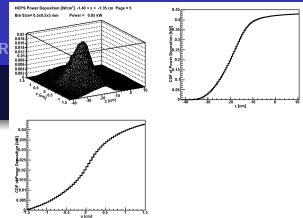
For the current design...

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

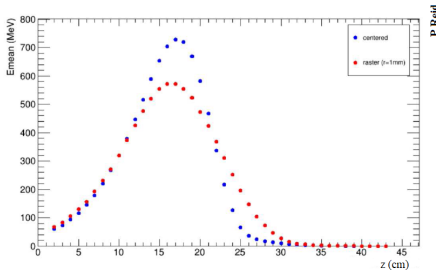
Beam Profile

Photon Energy Density [MeV/cm²/electron] @3m





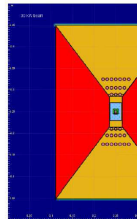
Central Piece Power Dissipation



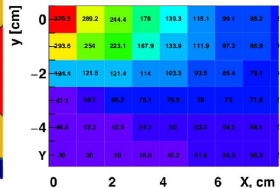
CP Power Dissipation

- 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!



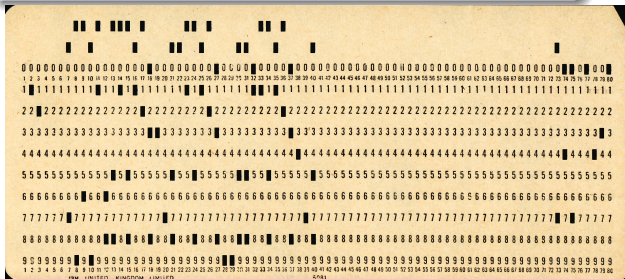
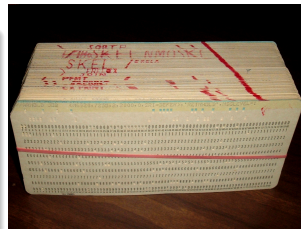
The Cu core, beam of 30 kW,
at maximum power density location



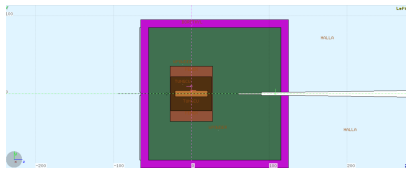
GN's CPS workshop...

Current Simulation work focuses on:

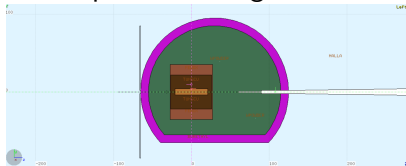
- Optimizing CPS shielding (ACARP)
- CPS/LPT interaction
- neutron (esp. low energy!) flux
- code modularity & portability



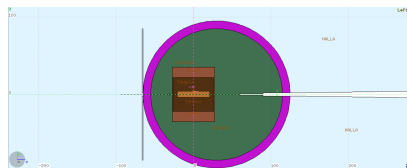
CPS Shielding Configurations:



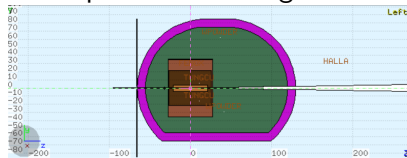
01 - Square shielding. Offset.



03 - Cut Spherical shielding.



02 - Spherical shielding.



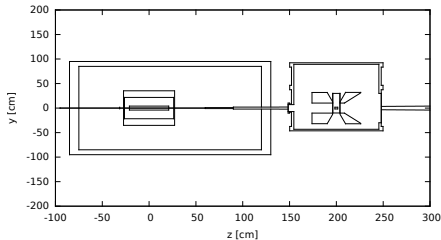
04 - Cut "egg-shape".

As suggested by RE, BW, PR. GN Fluka implementation.

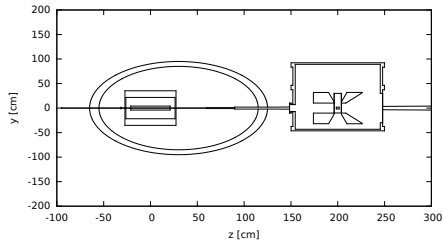
NOTE: Figures not to scale! Powder W volume is reduced:
 4.8 m^3 , 2.2 m^3 , ... 1.8 m^3 . Weight and \$\$ scale accordingly!

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

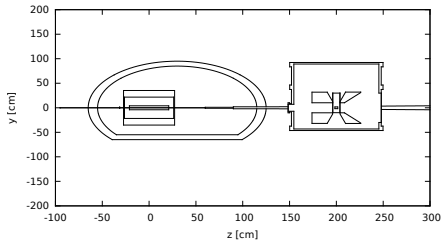
CPS2_1 a: Geometry



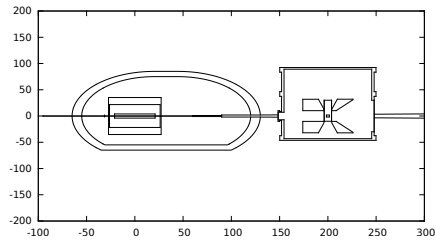
CPS2_1 002: Geometry



CPS2_1 003: Geometry



CPS2_1 004: Geometry



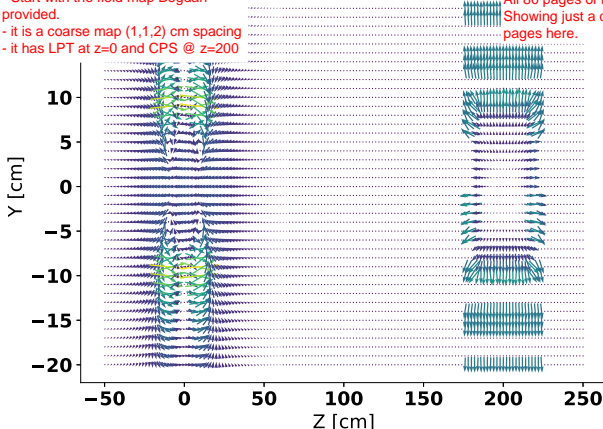
Pretend that the spheres are spheres and that the first model is a cube...



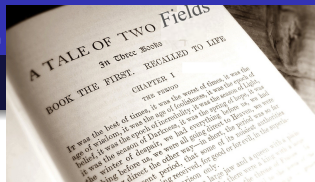
“...He was turned to steel In the great magnetic field...”

CPS+LPT field. $x = -20$ cm

- 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 @ $z=200$



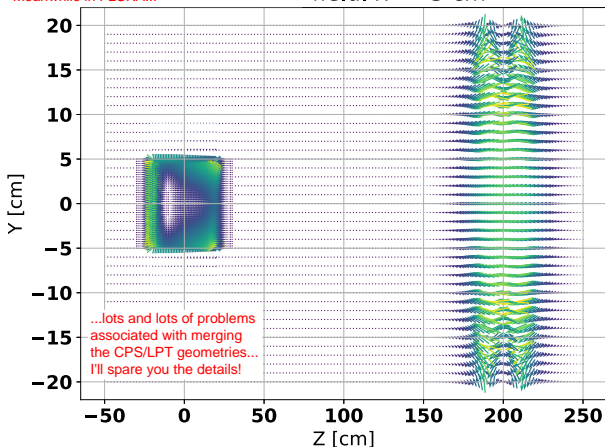
I have all of this mapped out for steps in x and y .
All 80 pages of it.
Showing just a couple of pages here.



A tale of two fields...

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

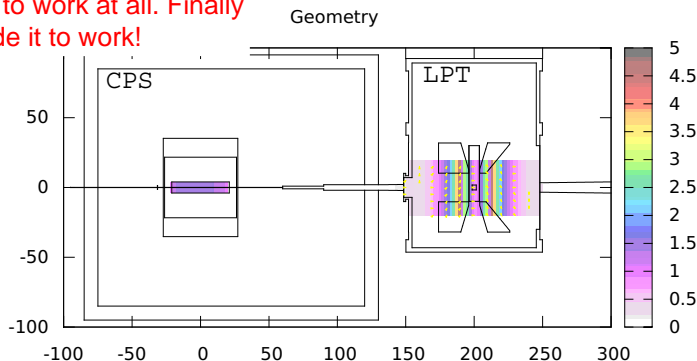
field. $x = -3$ cm



Habemus campus magneticus



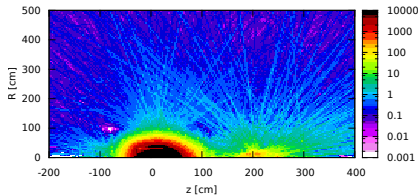
for awhile I could not get
this to work at all. Finally
made it to work!



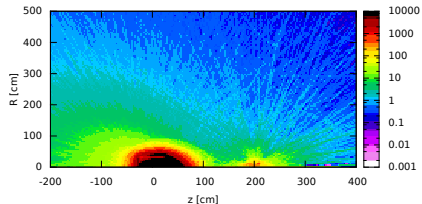


Residual Dose. 1h Cooling [mrem/h].

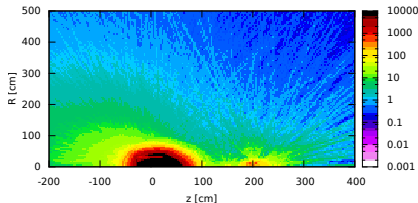
CPS2_1 a: Activation, 1 h cooldown



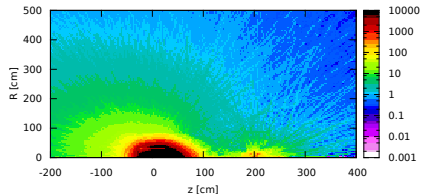
CPS2_1 002: Activation, 1 h cooldown [mrem/h]



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



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

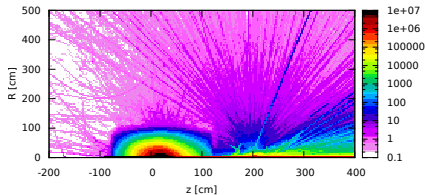


First “splotch” is the CPS, second one the LPT.

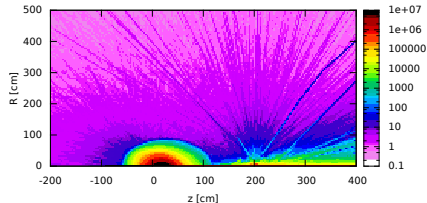


Prompt Dose. n and γ combined [rem/h].

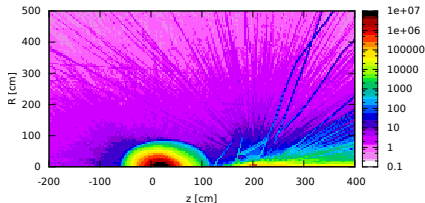
CPS2_1 a: Prompt Dose (Combined)



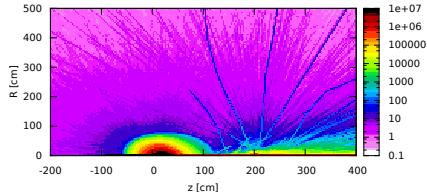
CPS2_1 002: Prompt Dose (combined) [rem/h]



CPS2_1 003: Prompt Dose (Combined) [rem/h]

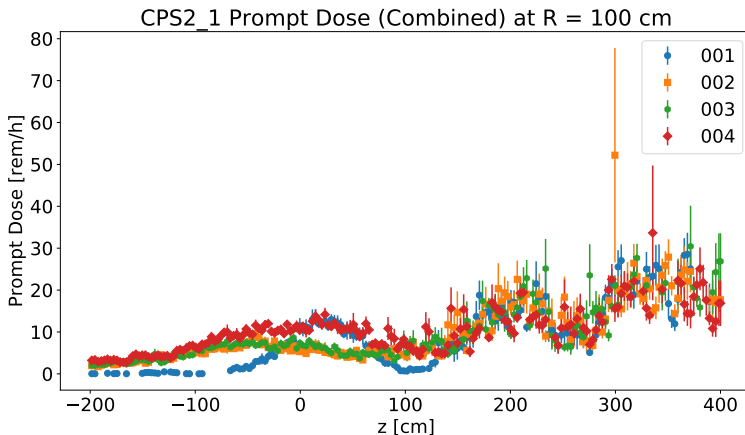


CPS2_1 004: Prompt Dose (Combined) [rem/h]

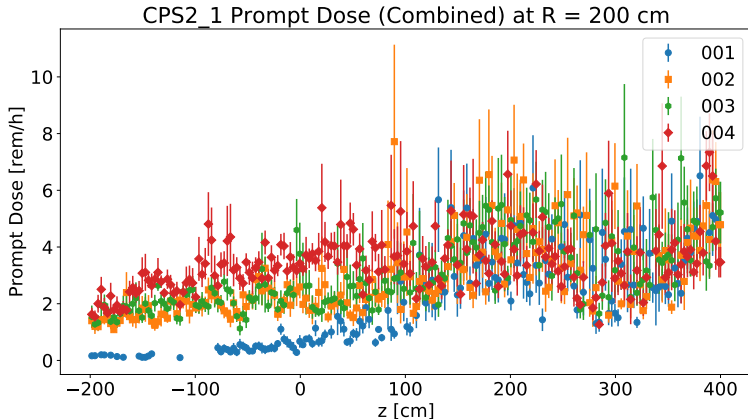


Available in γ a/o n -only versions too!

Prompt combined Dose at 1 m from the beamline.



Prompt combined Dose at 2.0 m from the beamline.

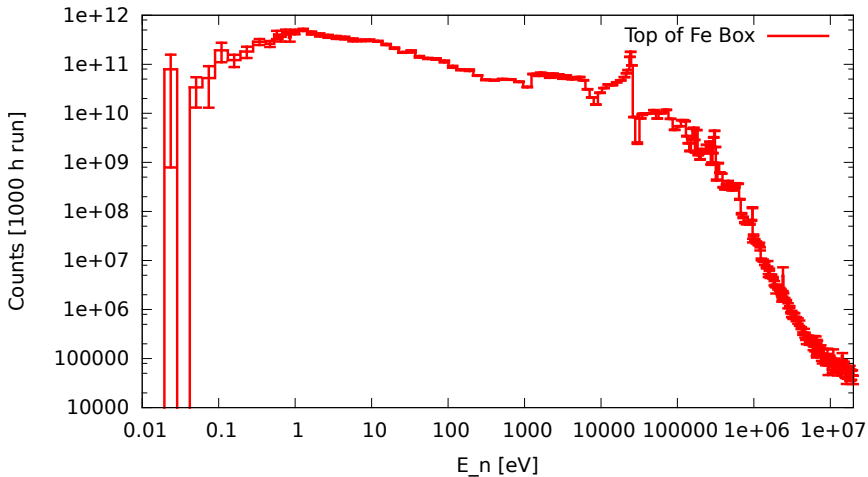


$20/4 = 5$. ALARA seems to work!



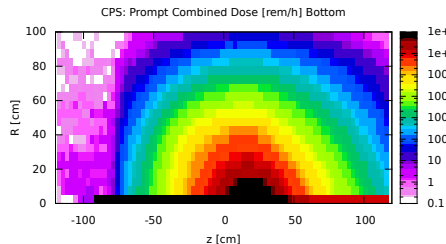
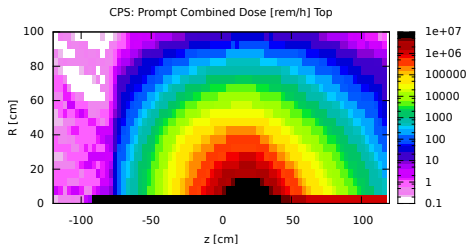
Neutron Spectrum... (special request of...

Neutron Energy Spectrum. Top of Fe box.





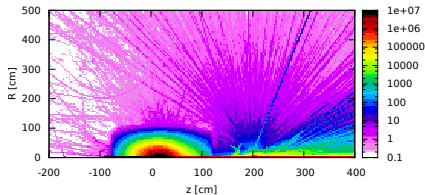
Top/bottom asymmetry (special request of...



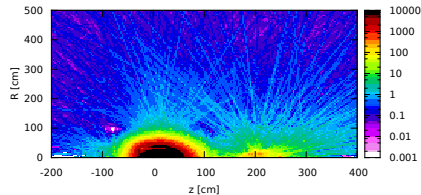
Very subtle differences. Check out the top of each picture, maybe.

CPS+LPT @2.7 μA vs LPT @ 100 nA (e-only)

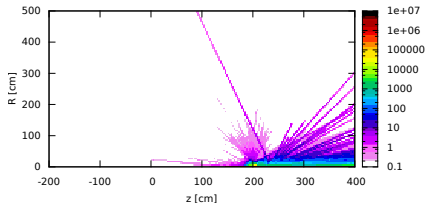
CPS2_1 a: Prompt Dose (Combined)



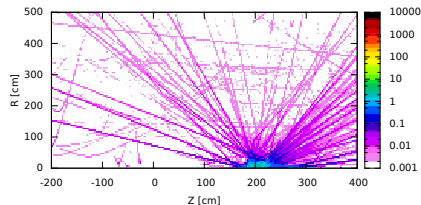
CPS2_1 a: Activation, 1 h cooldown



LPT: Prompt Combined Dose [rem/h]



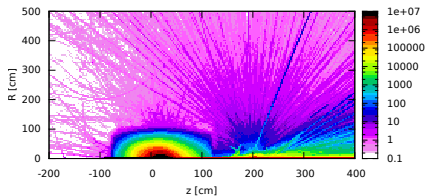
LPT: Activation, 1h cooldown [mrem/h]



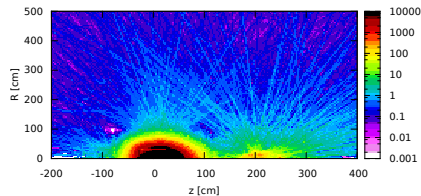
Prompt dose comparable, activation not so much.

CPS+LPT @2.7 μA vs LPT @ 100 nA (mixed beam)

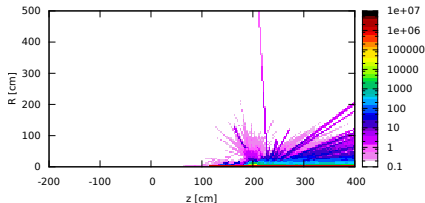
CPS2_1 a: Prompt Dose (Combined)



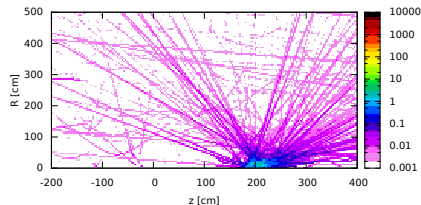
CPS2_1 a: Activation, 1 h cooldown



LPT: mixed beam @ 100 nA. Prompt Combined Dose [rem/h]



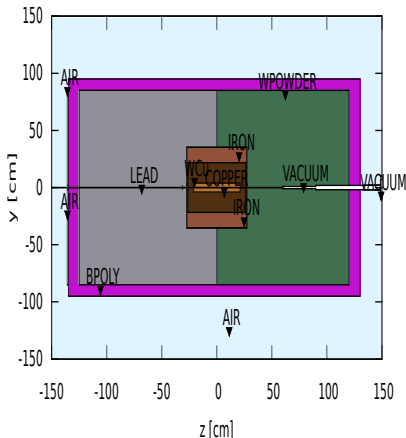
LPT: mixed beam @ 100 nA. Activation, 1h cooldown [mrem/h]





Can we “kick it up another notch?”

CPS chimera02: Geometry & Materials



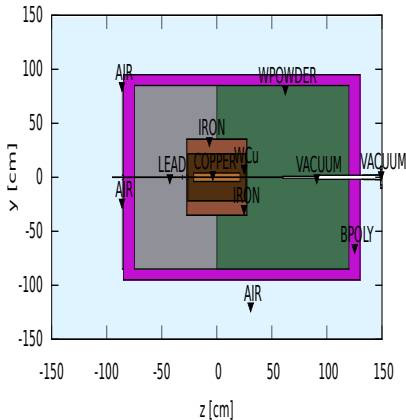
Yes we can!

- As suggested by Bogdan; check out this beauty!
- Back half of shielding is Pb
- Front is still W-powder



...

CPS chimera01: Geometry & Materials

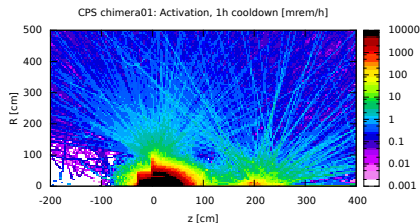
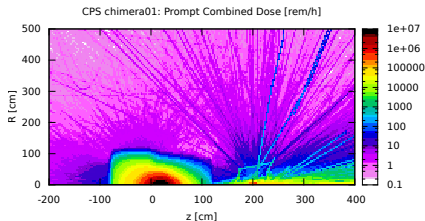
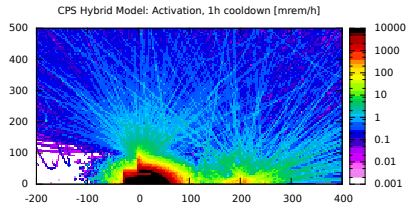
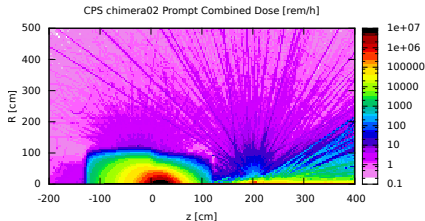


Ditto.

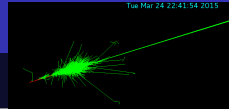
- In case we cannot afford the space in the bwd direction
- Back half of shielding is Pb
- Front is still W-powder



And the results do not look too bad!



This looks promiss\$sing!



Summary & Outlook

GN's to do list ...in no particular order

and excluding teaching, other Hall duties, life, etc.

- More “hybrid” configurations...
- n spectrum @ several locations (where it actually it might matter!)
- Documentation. Streamlining/easing learning curve ... Fluka update

Hopefully I convinced you that using Fluka ...

- is absolutely essential for designing/optimizing CPS in terms of:
 - prompt and delayed radiation levels (**safety**)
 - informing engineering decisions (materials, interference)
 - cost-cutting/savings to the taxpayer and the government
- much was learned; much is yet to be uncovered.
- **FUN!** so join me, won't you?

Thank you!