# HCPS Report
## (aka "Homework #1")

*Gabriel Niculescu (JMU)*

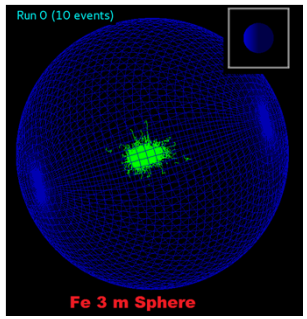
**Outline:**

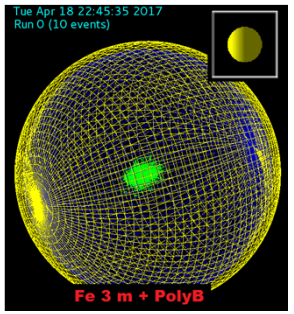
- **Charge**
- **Pavel's, Igor's results**
- **JMU setup. Results. Lessons learned.**
- **Quo Vadis? (aka GN's $0.02)**

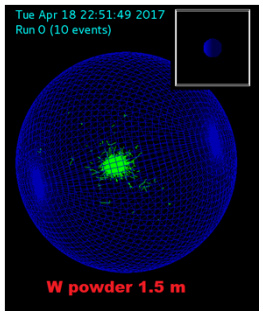
# Charge

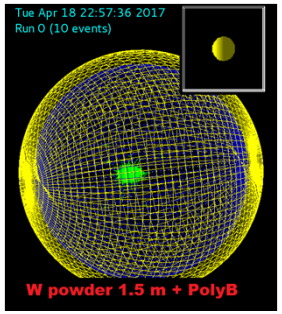
- Define simple geometry to simulate the transport of radiation through it. … and activation due to said radiation.
- Ensure consistency between different groups' approaches.

- **Beam:** E = 11.5 GeV electrons, I = 2.6 uA, (30kW)
- **Setup #1:** $\phi$ = 3m Fe sphere, e @ z = - 30 cm
- **Setup #2:** $\phi$ = 1.5 m W powder ($\rho$=15.6 g/cm$^3$), e @ z = -15 cm
- **Setups #3-4:** same as above + 10 cm borated (5%) polyethylene.



# Pavel and Igor results

- To date* Pavel and Igor generously provided results of their DINREG/G3 and, respectively, MCNP6 simulations.
  - Summary table in a few slides!

Dear All,

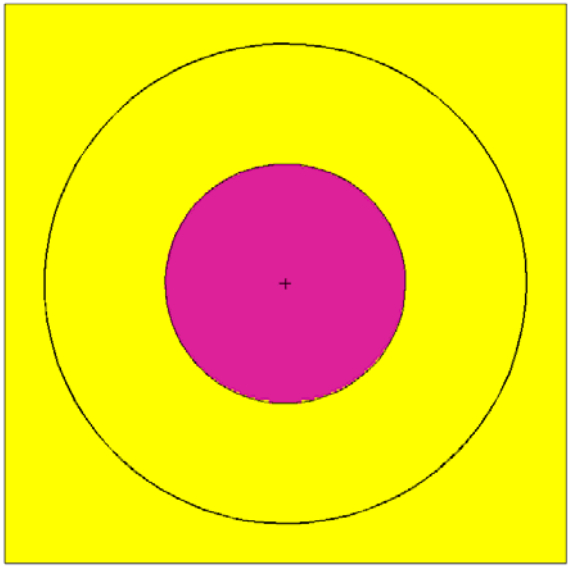
I've got the first estimates of [illegible]
spheres, and also a couple numbers for the
from the toy runs in Hall C.
I did run the simulations using my old DINREG/GEANT3 package.

The runs evaluating the source terms were set in vacuum, using the 300
cm dia. Fe and 150 cm dia. W spheres, irradiated by 11.5 GeV electron
beam from inside as specified, and scoring the matrix of the dose rates
and spectral responses around them, function of energy and polar angle.
In addition I also ran the same setups but with the spheres surrounded
by the 10 cm layer of standard Borated Polyethylene (5% Boron by
weight), to help thermalize and absorb the low energy neutrons exiting
the heavy metal spheres. This would be important for the dose rates
around the CPS, especially in the case of iron shielding, as the iron
layers do not stop low energy neutrons effectively enough.

The integrated numbers are given for the points at 90 degrees around the
spheres, at 3 m radial distance from the beam line. Other angles and
also energy spectra are available for further discussion if needed.

Setup / Score
Only the metal sphere shielding
Dose rates in rem/h
at 90 degrees 3 m from the beam
Including 10 cm outer Borated Poly layer
Dose rates in rem/h
at 90 degrees 3 m from the beam
Dose rate estimate
in microrem/h
RBM-3 Boundary position
Iron 7.8 g/cm^3, 300 cm dia sphere
11.5 GeV, 30 kW beam starting inside,
30 cm upstream from the center
neutrons: 146.0
gamma: 0.44
total: 146.4
neutrons: 0.8
gamma: 2.8
total: 3.6
neutrons: 0.19
gamma: 0.05
total: 0.24
Tungsten 15.6 g/cm^3, 150 cm dia sphere
11.5 GeV, 30 kW beam starting inside,
15 cm upstream from the center
neutrons: 13.0
gamma: 0.06
total: 13.1
neutrons: 2.7
gamma: 0.003
total: 2.7
neutrons: 1.9
gamma 0.5
[illegible] 2.4

**Pavel's**



**Igor's**

# JMU simulation setup

- GN's JMU setup:
  - **Geant4:** version 10.1.0
    - G4NDL4.5 (low en. neutron Xsect), GDML, etc.
    - Running on CentOS 6.6 and 7.3 machines
    - "QGSP_BERT_HP", "shielding" – physics lists, no cuts*
    - ROOT output
    - n flux to Dose Rate conversion as per FLNPSV (G. Stapleton NCOEF.INP table) x-checked vs this paper →

*Journal of the Korean Nuclear Society*
*Volume, 12, Number3, September, 1980*

《Original》

**Calculation of Neutron and Gamma-Ray Flux-to-Dose-Rate Conversion Factors**

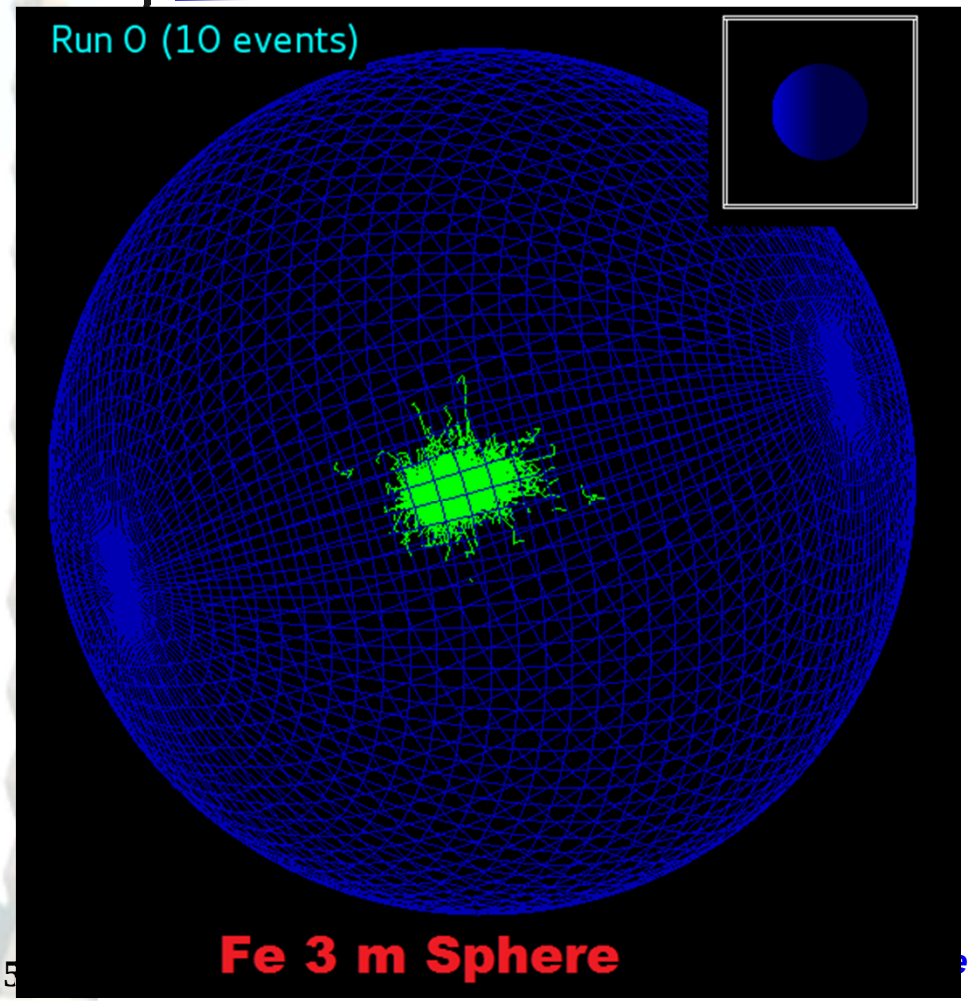
Seog-Guen Kwon, Kyung-Eung Kim*, Chung-Woo Ha,
Philip S.Moon and Chong-Chul Yook*.

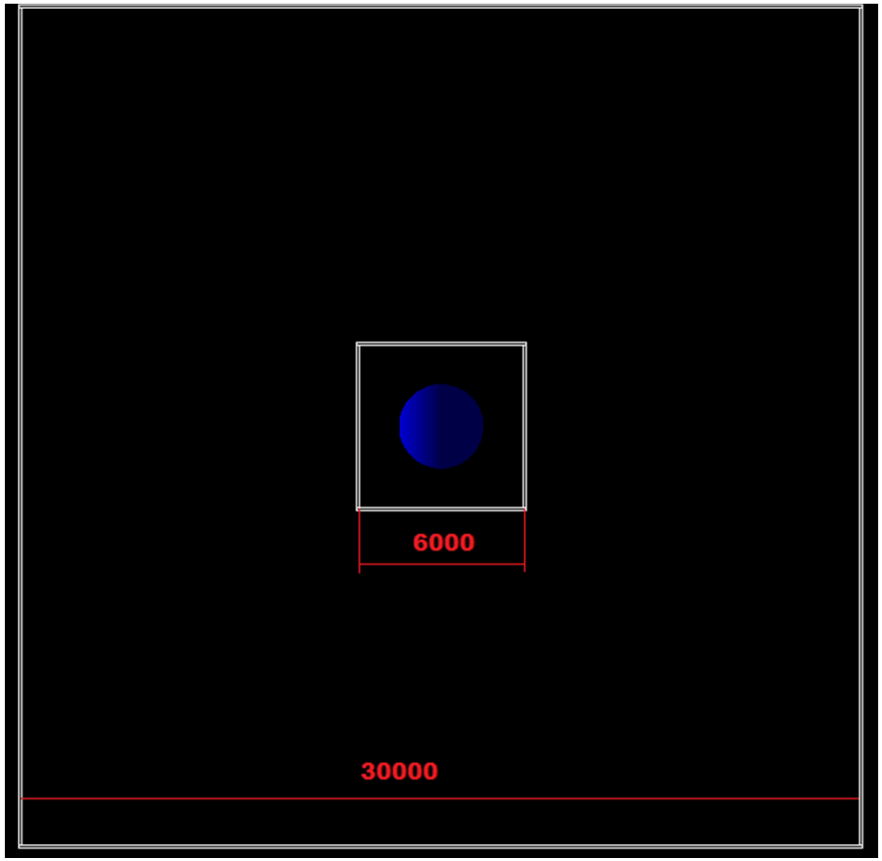
Korea Atomic Energy Research Institute

  - **Fluka:**
    - fluka-2011.2c-5, 64 bit
    - flair 2.2-5 (fluka GUI/plotting)
    - Running on the same machines as above + in Window$/flupix (VirtualBox – slowish)

# JMU simulation setup

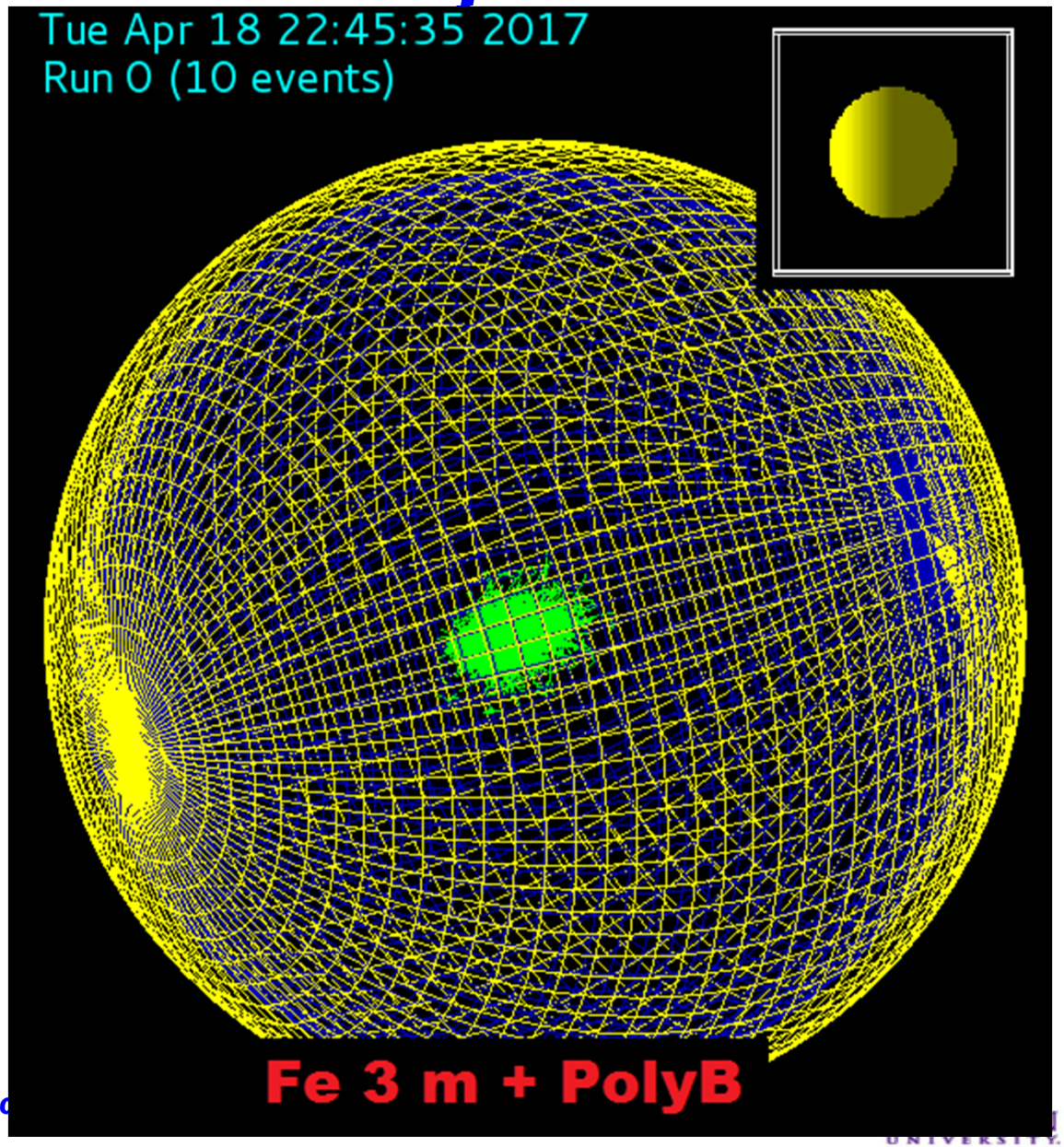
- **G4 Setup for the 3 m Fe Sphere.**



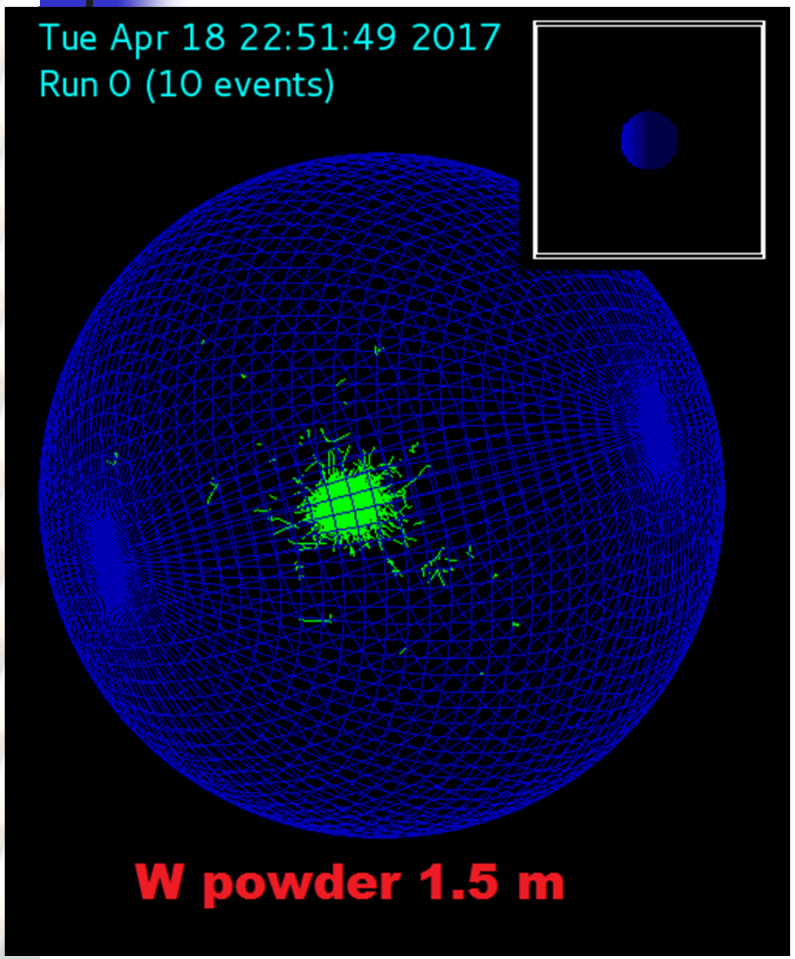
# JMU simulation setup

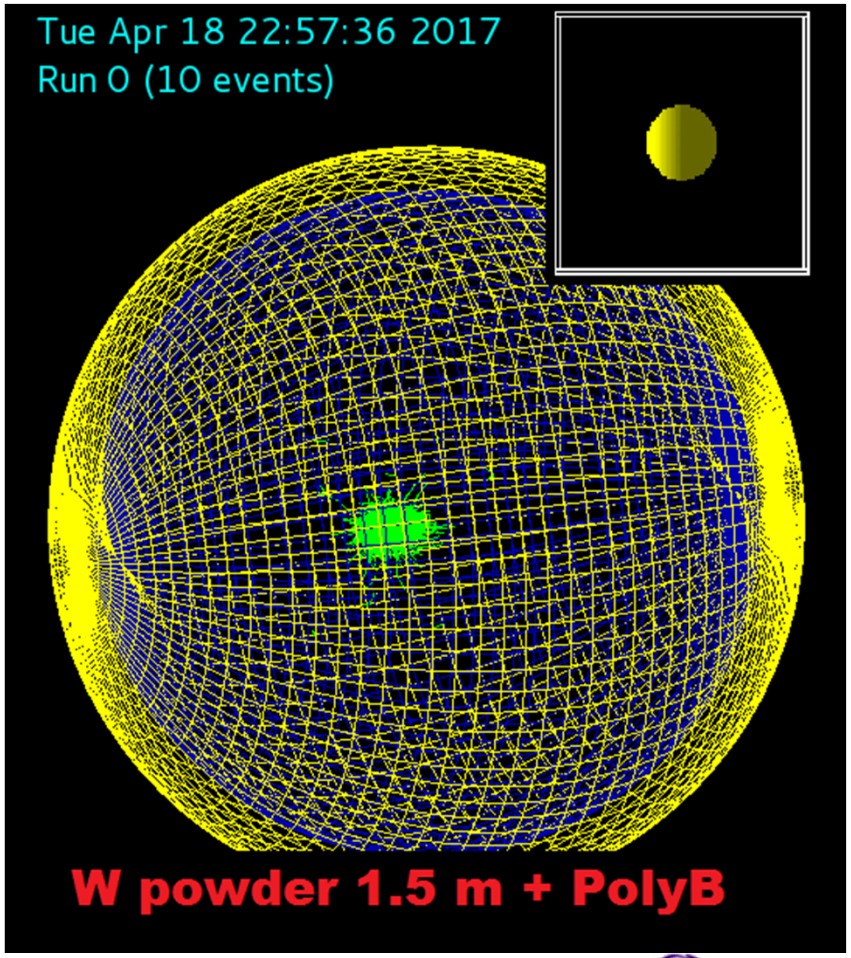
- **G4 Setup for the 3 m Fe + 10 cm borated poly layer**



# JMU simulation setup

- **Tungsten sphere setups**



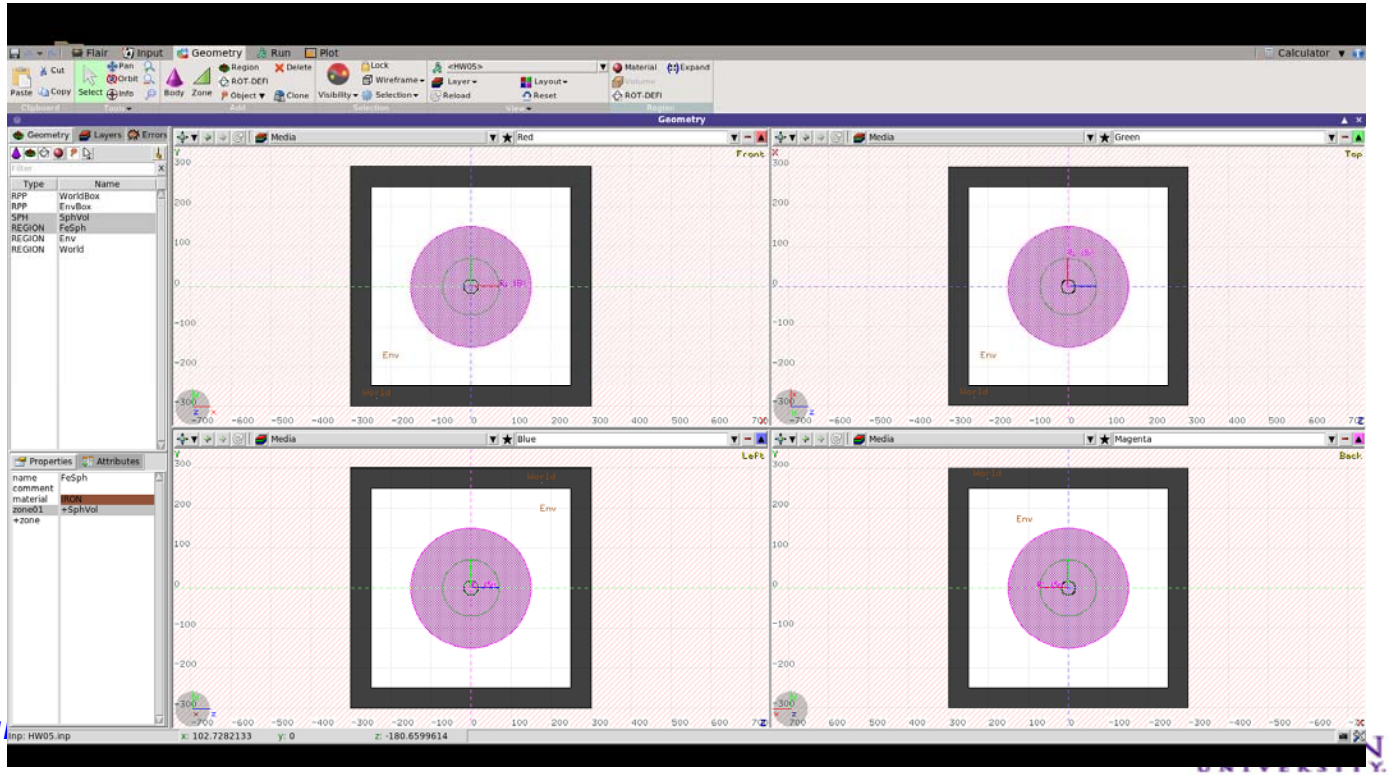
# Prompt Radiation Results

- Apologies if I misunderstood Pavel's a/o Igor's #s!

| | at 3 m from center | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pavel | | | Igor | | | Gabriel | | |
| | DINREG/GEANT3 | | | MCNP6 | | | GEANT4 | | |
| Dose Rates [rem/h] | n | g | total | n | g | total | n | g | total |
| 3m Fe | 146 | 0.44 | 146.4 | 12.5 | 0.13 | 12.63 | 123.2 | 0.56 | 123.8 |
| 3m Fe+PolyB | 0.8 | 2.8 | 3.6 | | | | 0.284 | 0.56 | 0.844 |
| 1.5m W | 13 | 0.06 | 13.1 | 4.5 | 0.03 | 4.53 | 6.34 | 0.33 | 6.67 |
| 1.5m W+PolyB | 2.7 | 0.003 | 2.7 | | | | 1.76 | 1.28 | 3.04 |

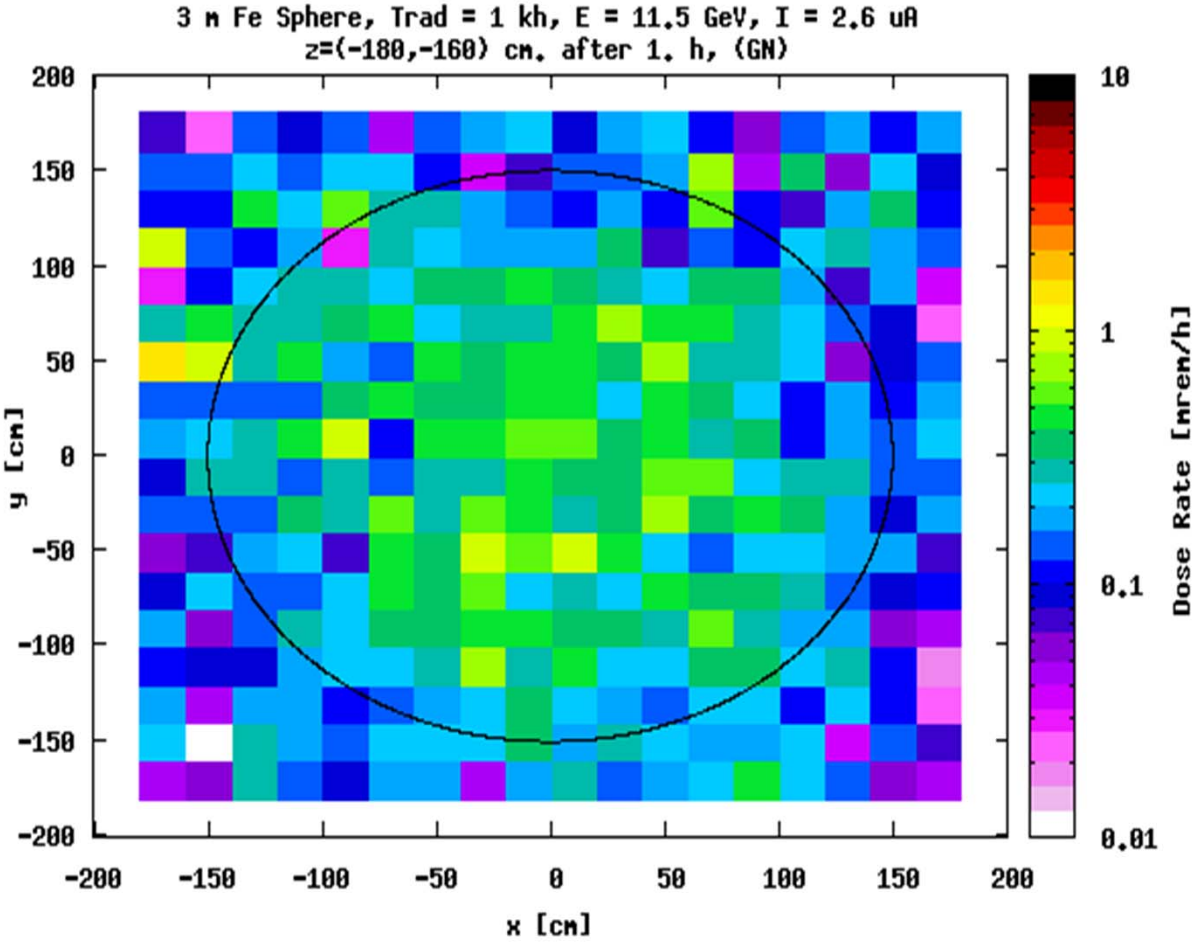
# Activation Results (Fluka)

- PRECISIOn, 11.5 GeV e, 2.6 uA, 1 kh radiation
- EVAPORATion, COALESCE, GEOBEGIN
- USRBIN 3D scoring grid, 20 cm boxes
- Dose rate after 1h, 24h, 7d, 30d
- For all 4 setups*



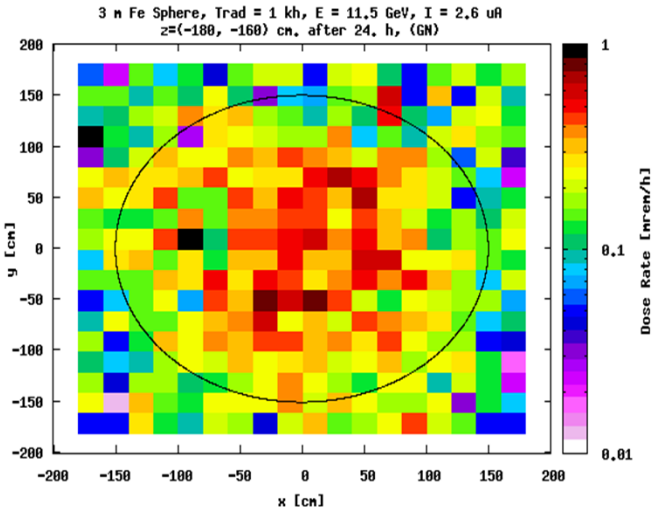
# Activation Results (Fluka)

- 3 m Fe Sphere
- z slices
- after 1 h

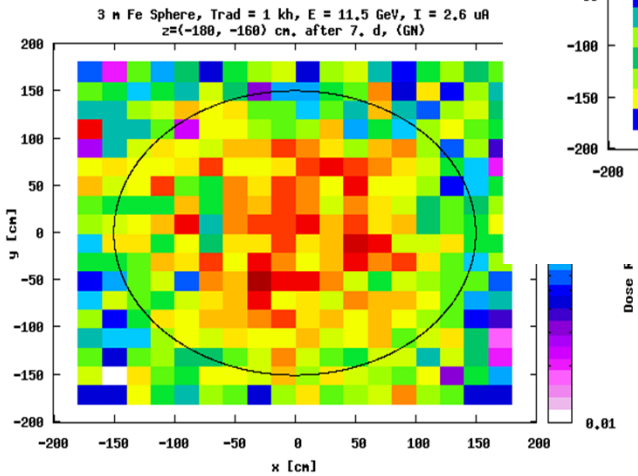


# Activation Results (Fluka)

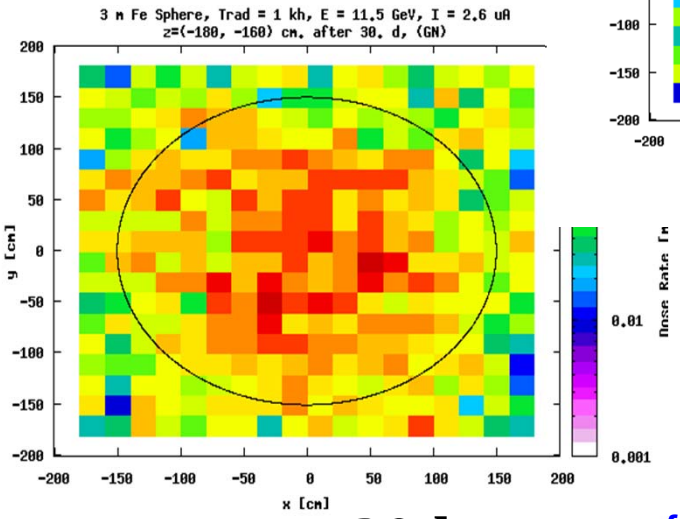
- 3 m Fe Sphere
- z slices
- after …




24 h




7d

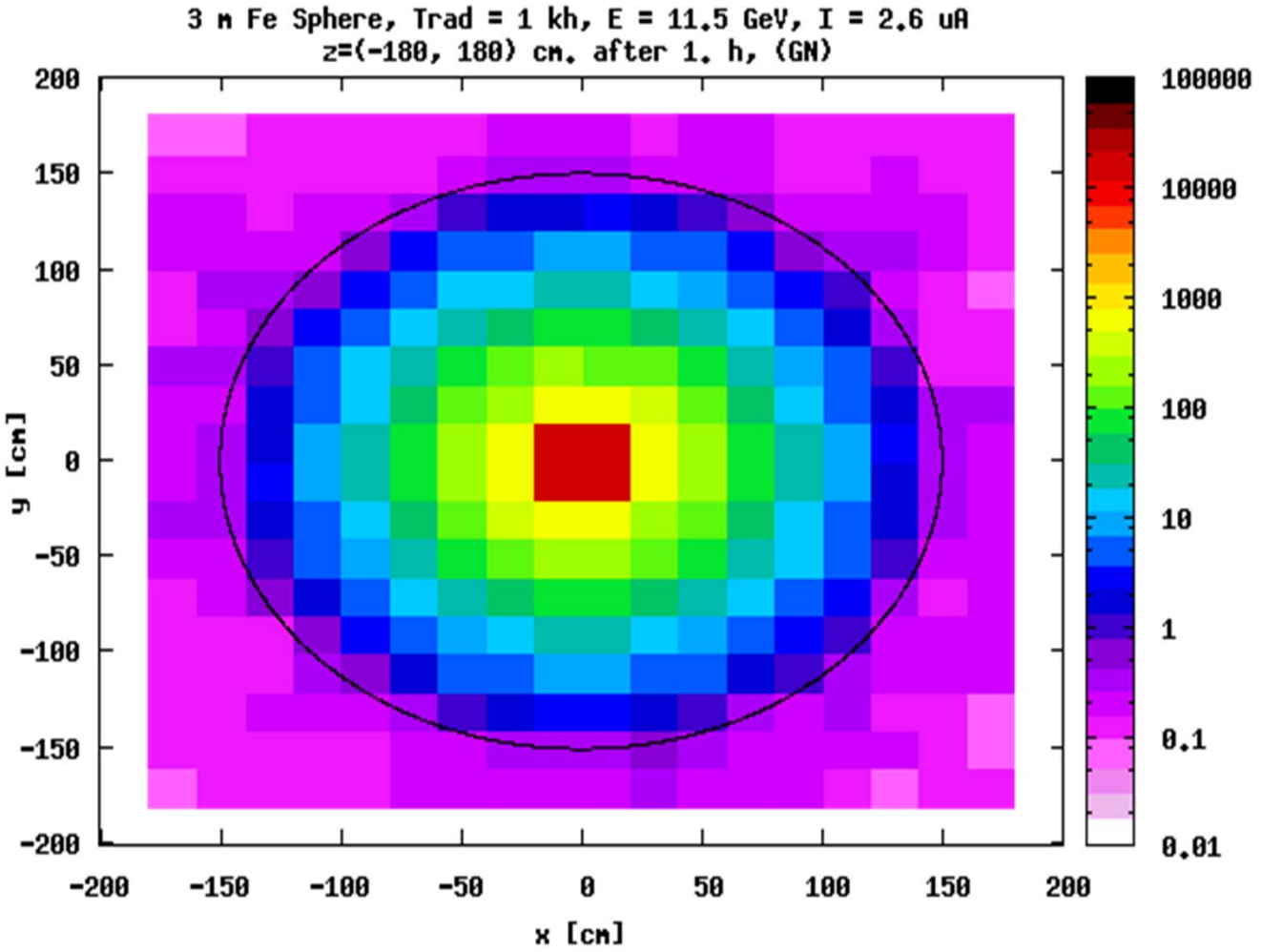



30d

- Last slide with animation!

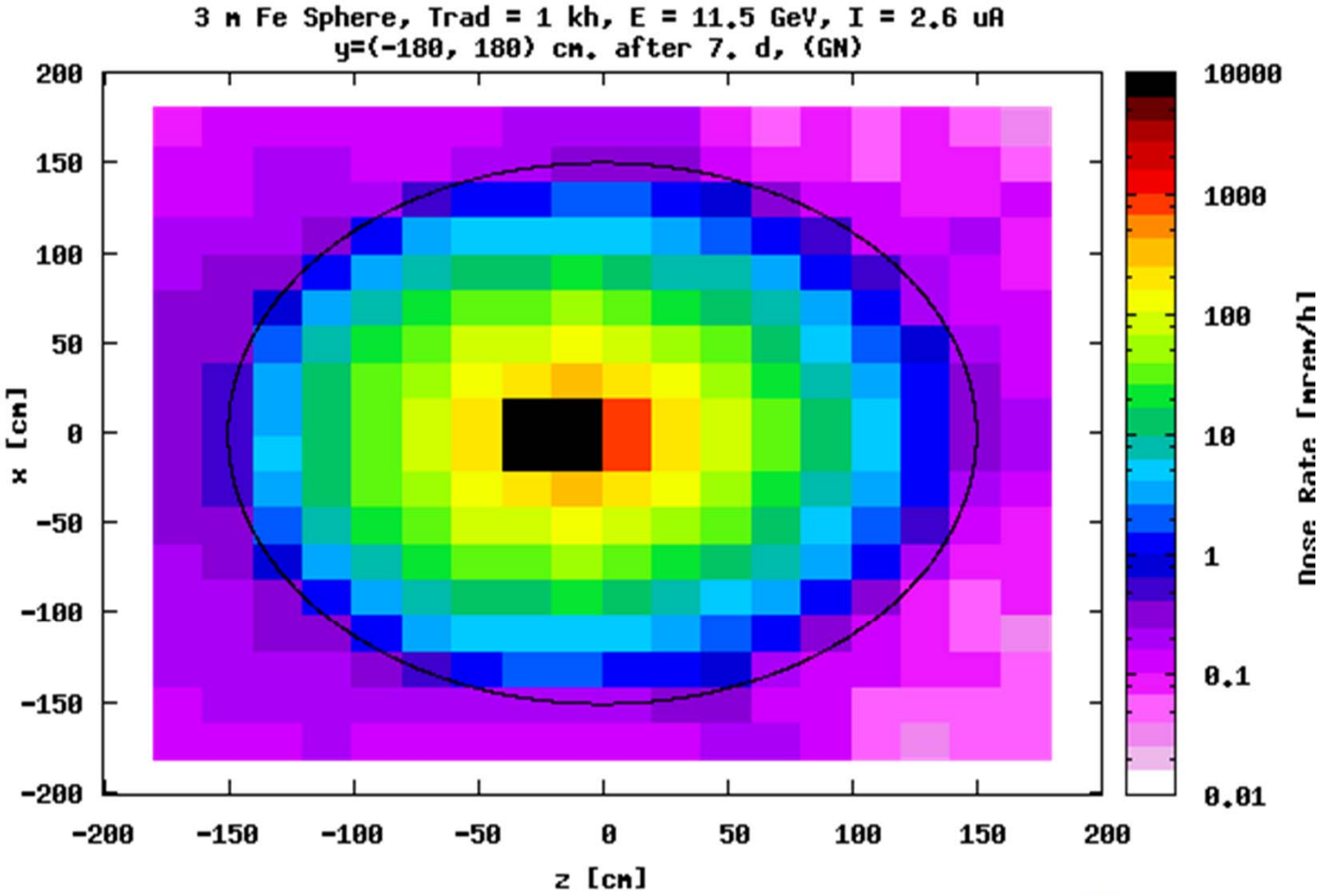
# Activation Results (Fluka)

## 3 m Fe



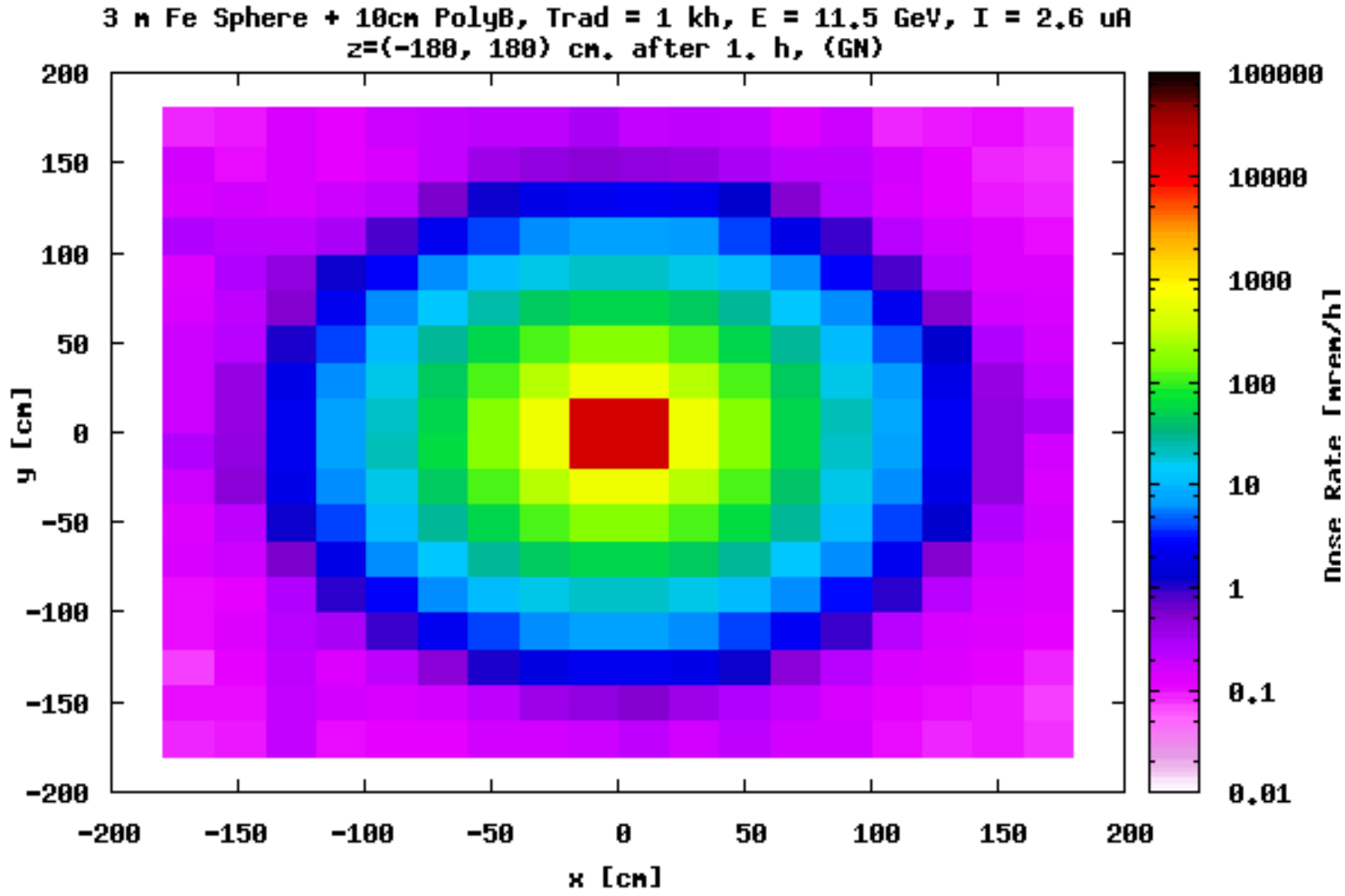
# Activation Results (Fluka)

## 3 m Fe, z-x view (7d)



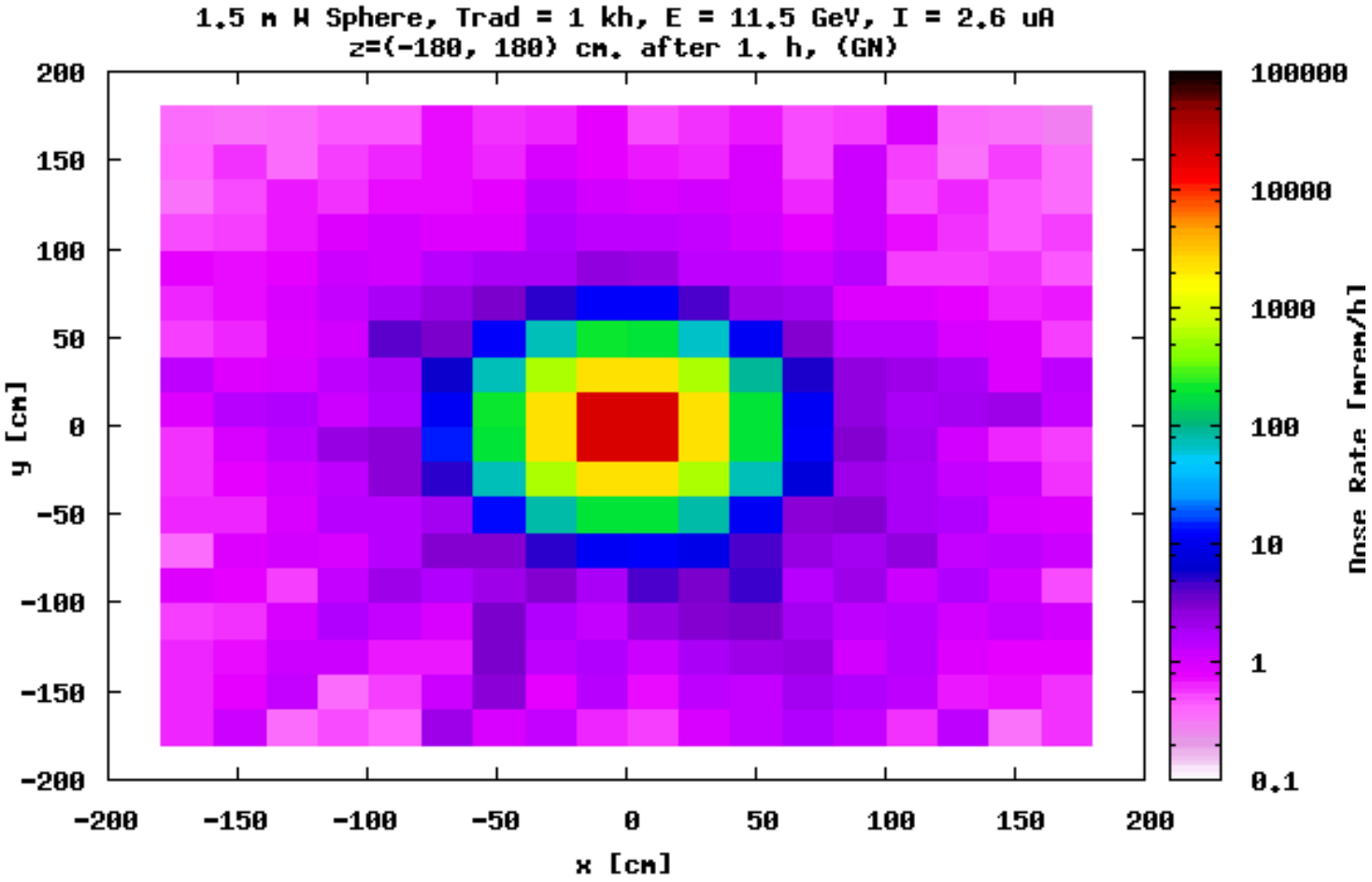
# Activation Results (Fluka)

## 3 m Fe + PolyB



# Activation Results (Fluka)

## 1.5 m W, lower statistics ☹



# Quo Vadis?

- MC sims for 3 m Fe and 1.5 W powder sph. (w w/o PolyB layer)
- … in both Geant 4 and Fluka
- Compared G4 w/ G3 and MCNP6 (ver?) results
- Fluka results: no significant activation after 1 kh radiation.

- GN's $0.02:
  - Spheres like the ones studied do contain* 30 kW of 11.5 GeV beam!
  - G4/G3 results consistent; factors of 1-2 not excluded (G3 ~y2k, cuts, etc.)
  - PolyB outer layer: A MUST!
  - W is expensive!! 3 m Fe ~ 110 tons. 1.5 m W ~ 27.5 tons


- *THANK YOU!*