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Simplified ILC Target Hall Activation Study

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UChicago Argonne LLC

A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

- Goal: gain qualitative understanding of the ILC target hall radiation level after a year's operation.
- Tools: The application is developed based on Geant4 toolkit.
- current studies:
  - highly simplified geometry system, model verifications.
- to be completed

  – realistic geometry simulation and charged particle tracking in EM field
- Challenges:

  1) activation covers many physics reactions. Need accurate and complete list of all physics processes.

  2) statistic fluctuation due to sampling and, particularly for long half life radionuclide decay

Simplified Target Model

- Assume all the secondary beam (e+ and e-) from the target traveling in Z-direction (50 MeV average) are lost into a Cu cube
- The target is a 10*10*10 [cm] cube, all decay particles through an observing sphere are registered.

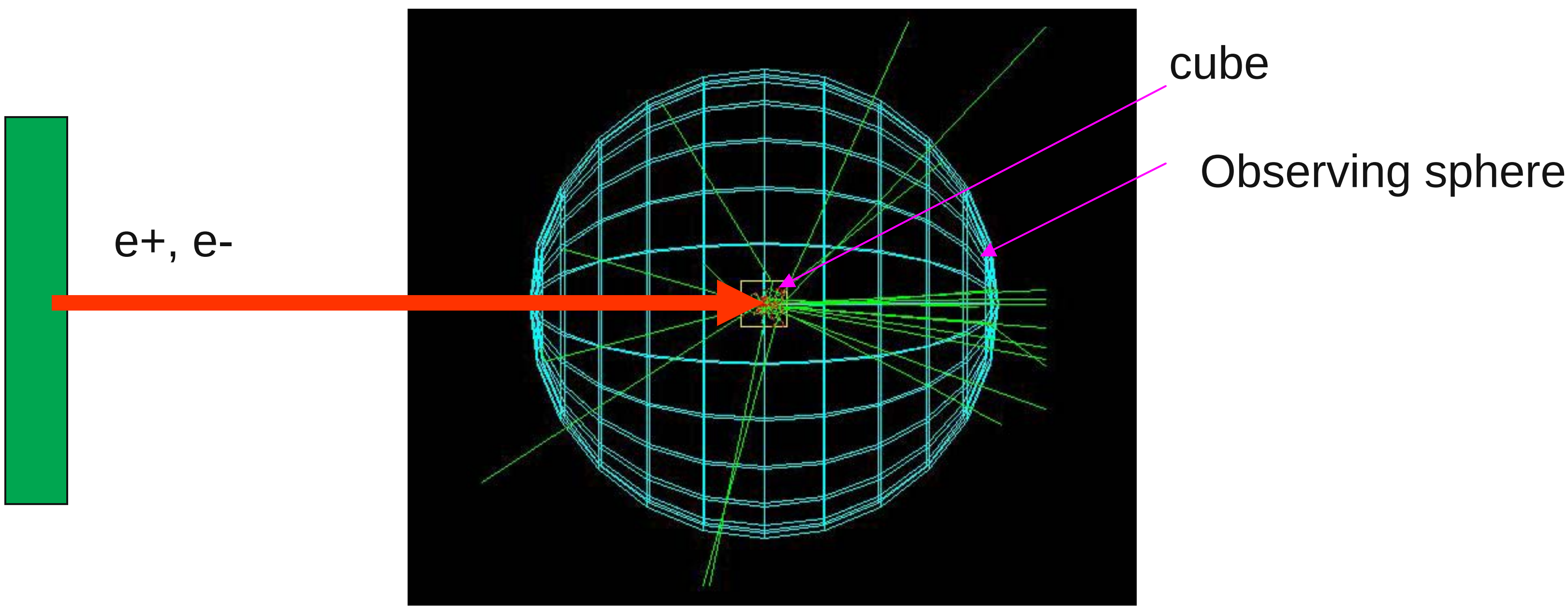

Fig.1 the layout of the simulation

Four cases have been done

1) e+, Cu cube case

2) e+, Fe cube case

3) e-, Cu cube case

4) e-, Fe cube case

The final results are scaled according to ILC accelerator parameters, assume:

pulse repetition 5Hz;

2820 bunches per pulse;

2e10 electron per bunch;

7.5 e+ per e-, 70% e+ will loss in the cube

Case 1, e+ & Cu cube, number & species of radio-nuclei produced.

Isotopes' name	Half life	Source type	energy	Yield ×1e15/ day
Cu62	9.74 m	Beta+	1.28MeV	396.2
Cu64	12.7 h	Beta+& Auger e-	112keV	207.9
Cu61	3.333 h	Beta+	310keV	38.5
Ni63 ,	**100.1 a**	**Beta+ &gamma**	**17keV/(Bq.s) 17.4keV**	**22.0**
Co61	1.65 h	Beta+	310 keV	6.06
Ni59	**7.6 y**	**Auger e-**	**4.2 keV /(Bq.S)**	**0.72**
Co60	**5.27 y**	**Gamma**	**1.17MeV**	**0.703**
Cu66	5.12m	e-	1.06MeV	0.243
Cu60	23.7 m	Beta+	0.9MeV	0.217
Ni65	2.5h	e-	0.628MeV	0.205
Co63	27.4 s	e-	1.53MeV	0.038

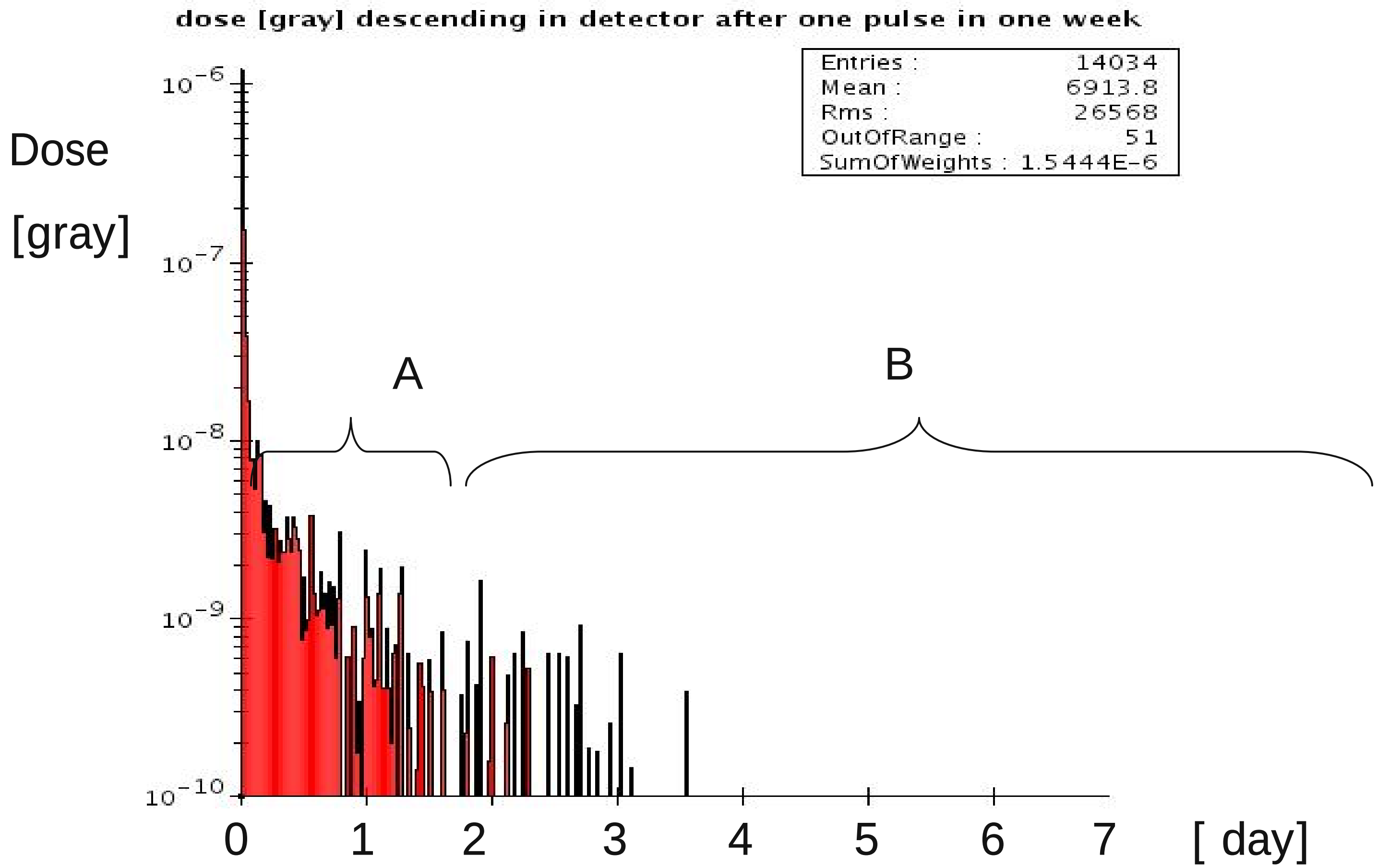

Fig.2 dose descending trend in one day after one electron pulse, bin width [30min]

Region A: dose mainly dominated by short half life isotopes, such as Cu62, Cu64,Cu61

Region B: dose mainly dominated by long half life isotopes, such as Co60 Ni63,Ni59, Dose time dependence

A : Short life isotopes

Short time (days) , statistical Fluctuation Acceptable, function value is accurate, can be done with a single run

Time Convolution

Dose level short time after accelerator stop running

B: long life isotopes

long time (years), low events/per unit time But the total number of the isotope is high,

Use analytical decay equation

Dose level after long time from the isotopes

Short half life isotopes

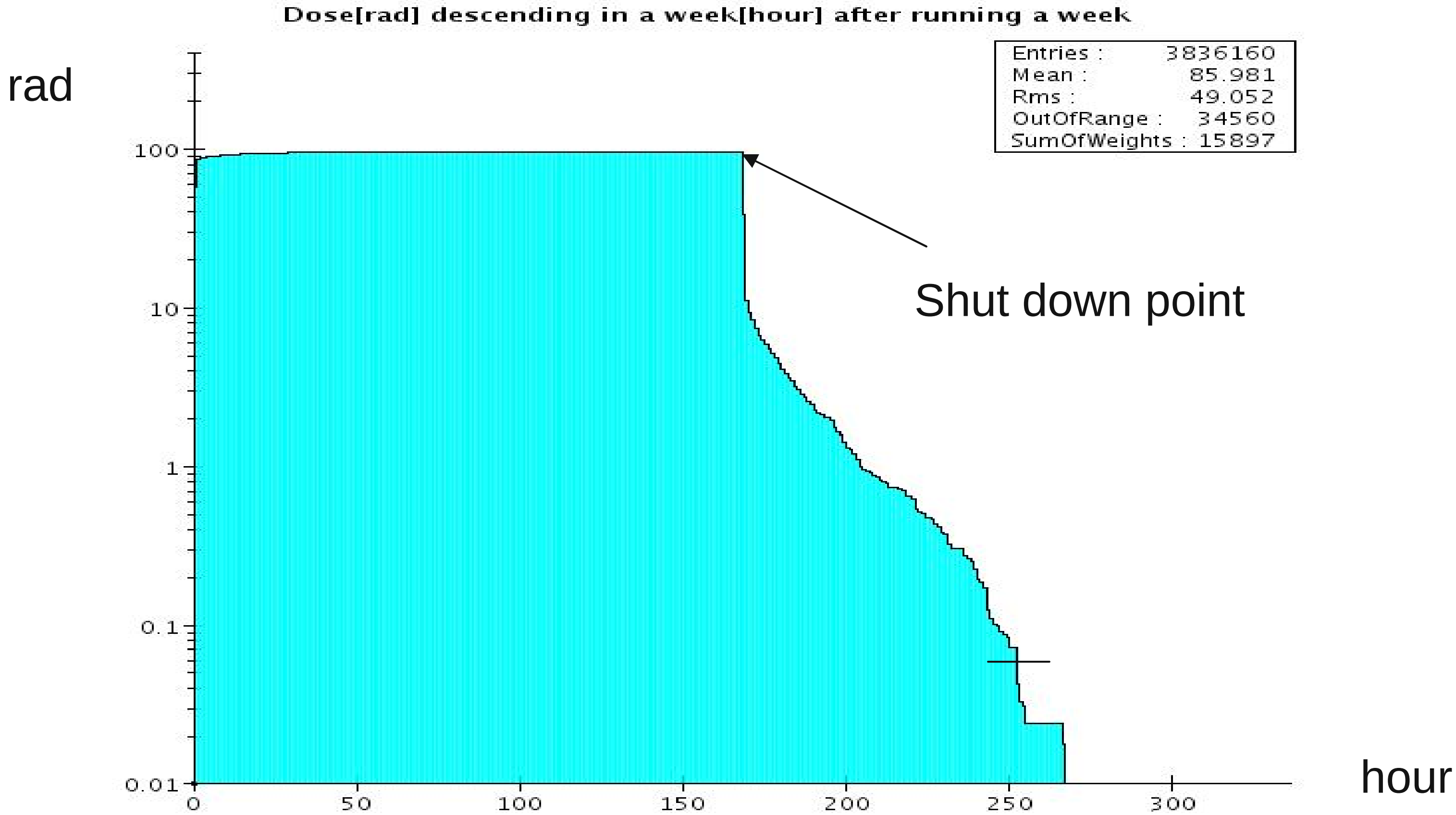

Fig.3 dose descending trend in a week after the accelerator running for a week, bin width [1 hour]

Methodology for long-life radionuclide

Decay equation

$$N = N_0 \cdot e^{-\frac{t}{\tau}} \quad (1)$$

Differential equation for time dependent isotope's number:

$$dN = \eta \cdot dt - N \cdot \frac{dt}{\tau} \quad (2)$$

N : present number of Co60, η : yield rate of isotope, for Co60 $2.06 \times 10^6 / day$ from G4, τ : average life of isotope, $\tau = \frac{T_{1/2}}{\ln 2}$, $T_{1/2}$: half life of isotope, dt : time differential quantity

Some important *analytic deduction*

- Number of isotope

$$N(t) = \eta\tau\left(1 - e^{-\frac{t}{\tau}}\right) \qquad (3)$$

- Equilibrium level:

$$N = \eta \cdot \tau \qquad (4)$$

- decay trend (after shutdown t0):

$$activity = \left|N'\right| = N(t_0)e^{-\frac{(t-t_0)\ln 2}{T_{1/2}}}\frac{\ln 2}{T_{1/2}} \qquad (5)$$

After the accelerator running for a year

The Co60 number could reach: **7.06e15**;

Corresponding Co60 source intensity : **0.027Ci.**

By rule of thumb equation [1]

$$\dot{H}(rem/h) = 0.5C \cdot E \cdot d^{-2} \qquad (6)$$

Here, C represents activity in Ci, E is energy released in gamma [MeV], d is distance in metres, In our case,

$$C = 0.027, E = 1.17MeV, d = 0.5m$$

$$\dot{H} = 0.054(rem/h) = 1.302rem/day$$

[1] Radiological safety aspects of the operation of electron linear accelerator, IAEA, technical reports series, No.188

Compared with Cu, the radioactive products of Fe have more long half life species

name	Half life	Source type	energy	Yield ×1e15/ day
Fe55	2.737 y	Beta	3.12keV	725.1
Mn53	3.7e6 y	Beta	3keV	64.9
Fe53	8.51 m	Beta+	1.1MeV	37.1
Mn54	**312.12 d**	**Gamma**	**0.834MeV**	**18.1**
Mn56	2.5789 h	Beta-&gamma	0.831MeV&0.837MeV	3.76
Mn52	5.591 d	Gamma	1.43MeV	2.97
Cr50	1.3e18 y	---	---	2.53
Fe52	8.275 h	Gamma	1.74MeV	0.87
Cr51	27.7 d	Gamma	30keV	0.41
Mn57	85.4s	Beta-	1.08MeV	0.13
Co57	271.74 d	Gamma	104keV	0.11

Short half life isotopes

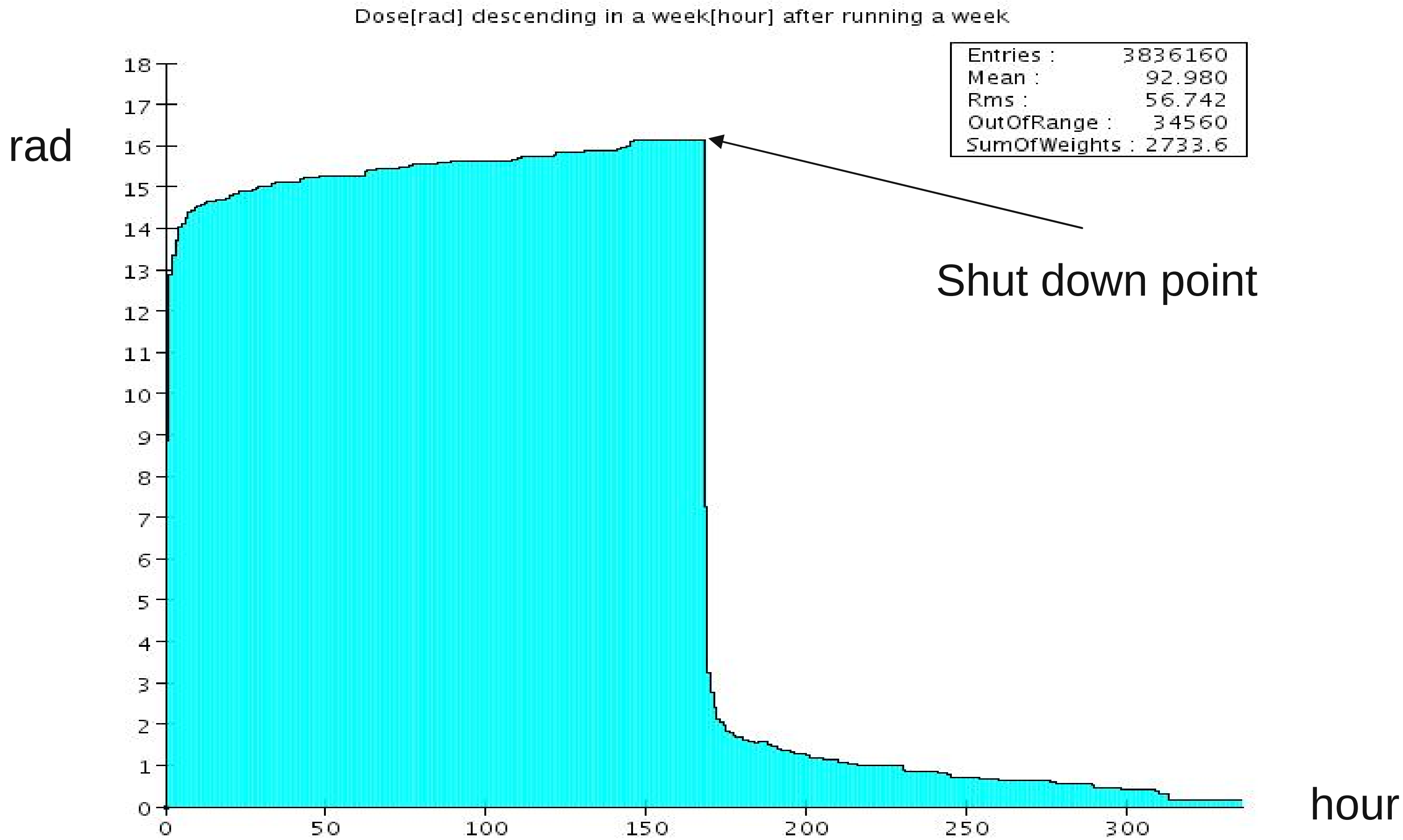

Fig.4 Dose trend in a week after the accelerator running for a week, bin width is an hour.

For long life isotopes,
After the accelerator running for a year

- Mn54-activity : **0.7 Ci**
- Mn54-Dose rate : **33.6 rem/day**

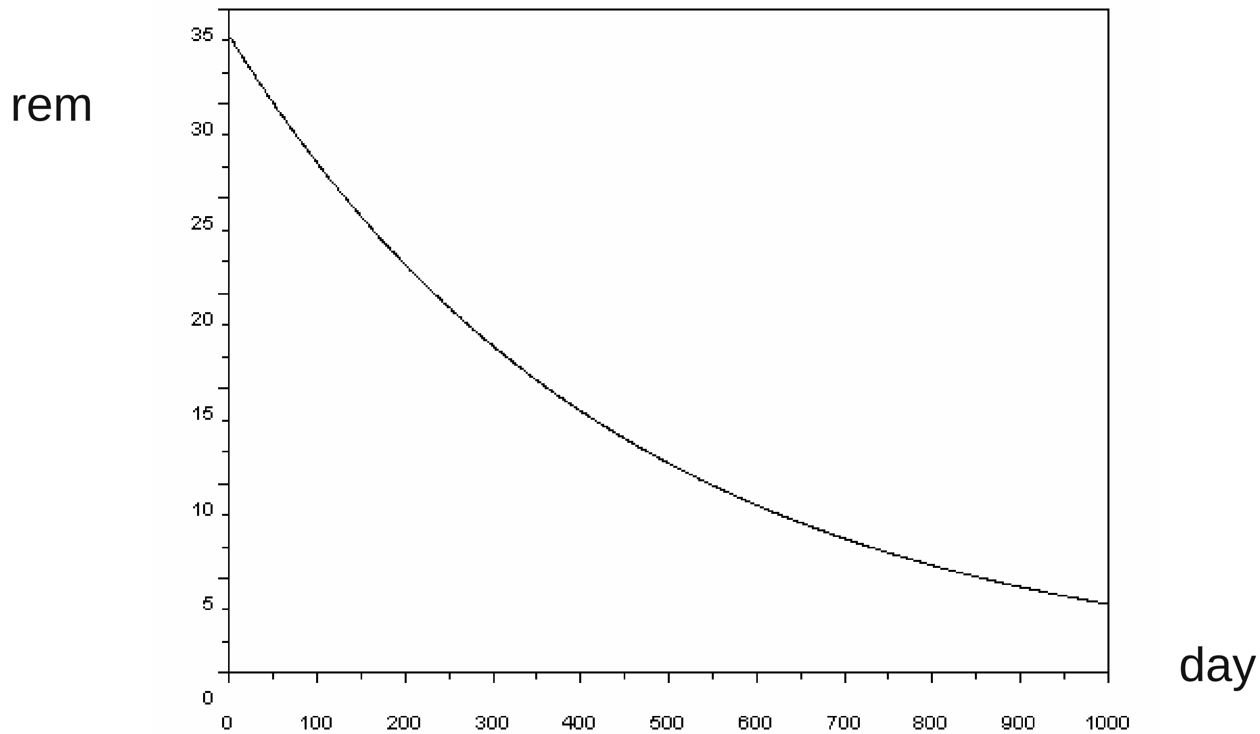

Fig.5 dose decline trend,produced by Mn54

Comparison Copper and Iron

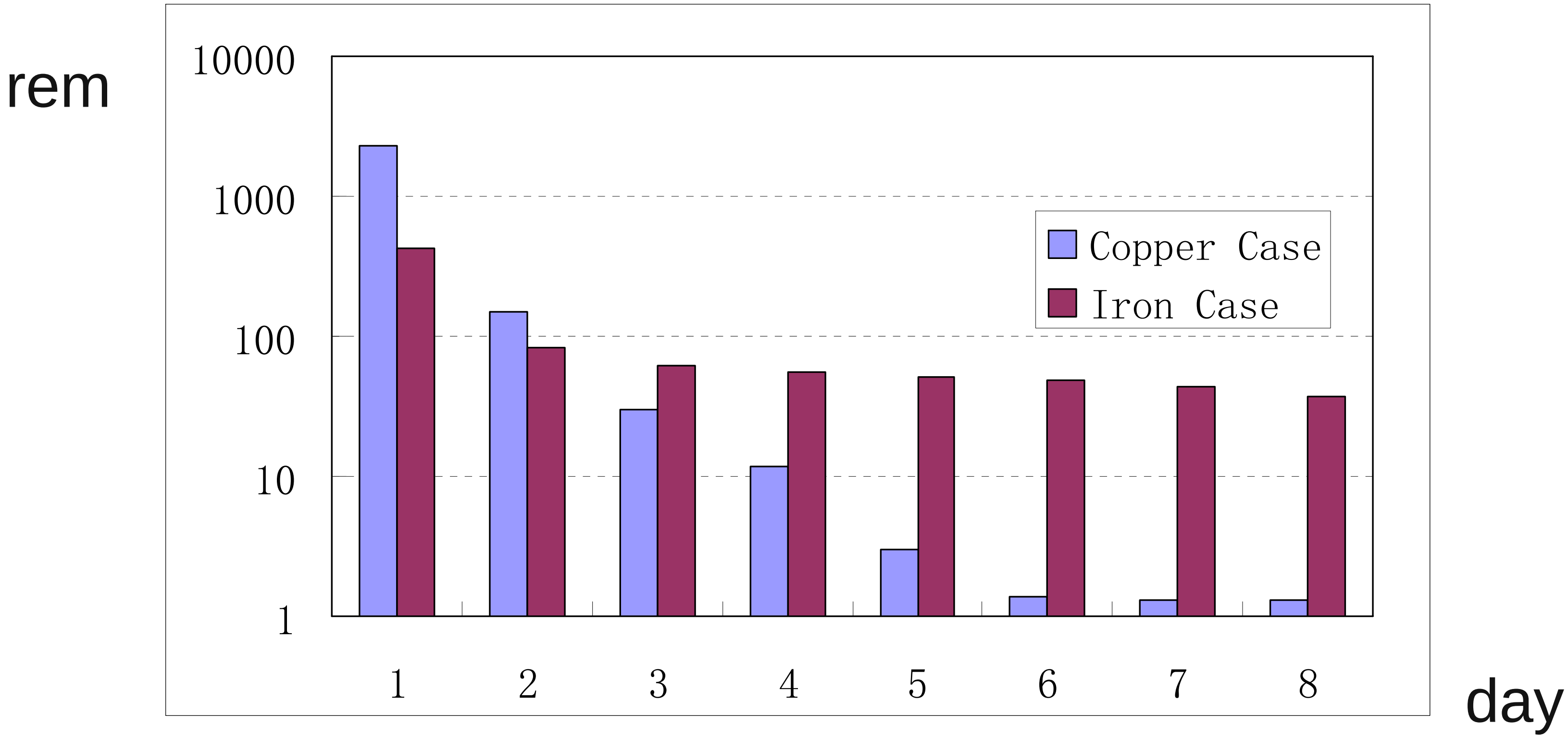

Fig.6 total dose (short life+ long life) drop trend in a week

Long term plan

Need Some New Work

- Real Geometry Input
- Real Particle Distribution Input
- Real Charged Particle Tracking in Fields

Challenges

- Real Computing Time

Thanks very much!