



Institutt for energiteknikk

Ease of use of radiation transport tools for dose rate calculations

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Introduction and Aims

- My aims today are:
 - Remind you about the significance of dose rate calculations.
 - Describe the differences in context between radiation transport simulation in nuclear physics and in dose rate calculations.
 - Show you how we can make our lives easier with more user-friendly software for predicting dose rates and get you to appreciate the importance of ease of use in nuclear codes.

Why calculate dose rates?

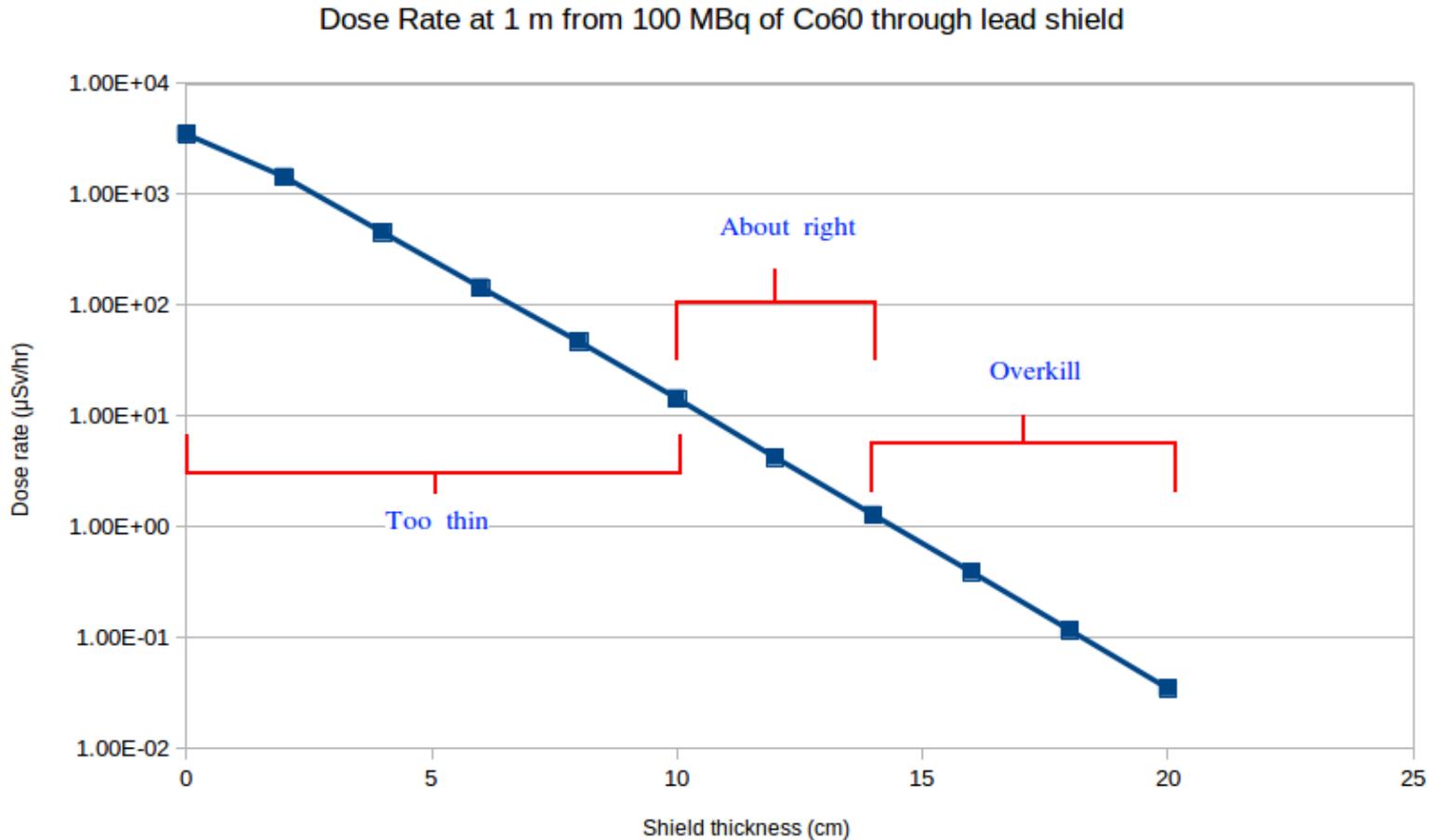
- Plan ahead and make sure doses to workers are ALARA (as low as reasonably achievable).



Image: Halden reactor, IFE

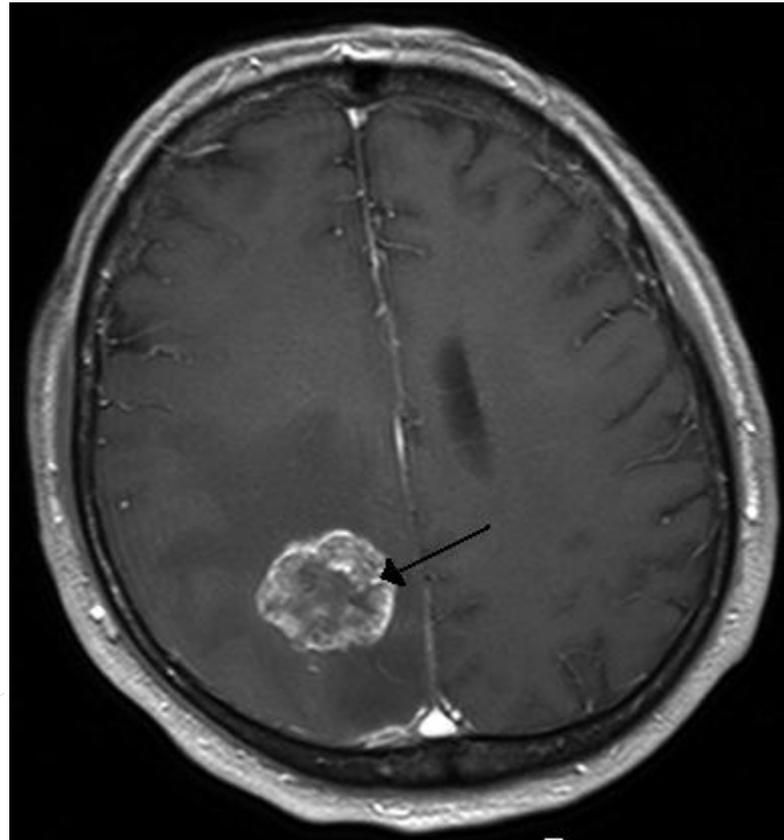
Why calculate dose rates?

- Optimise design of shielding.



Why calculate dose rates?

- Radiation therapy – deliver the correct dose to the right place (i.e. a tumor)



Radiation Transport Calculations in Nuclear Physics

- Radiation transport means modelling the way particles move through and interact with their environment

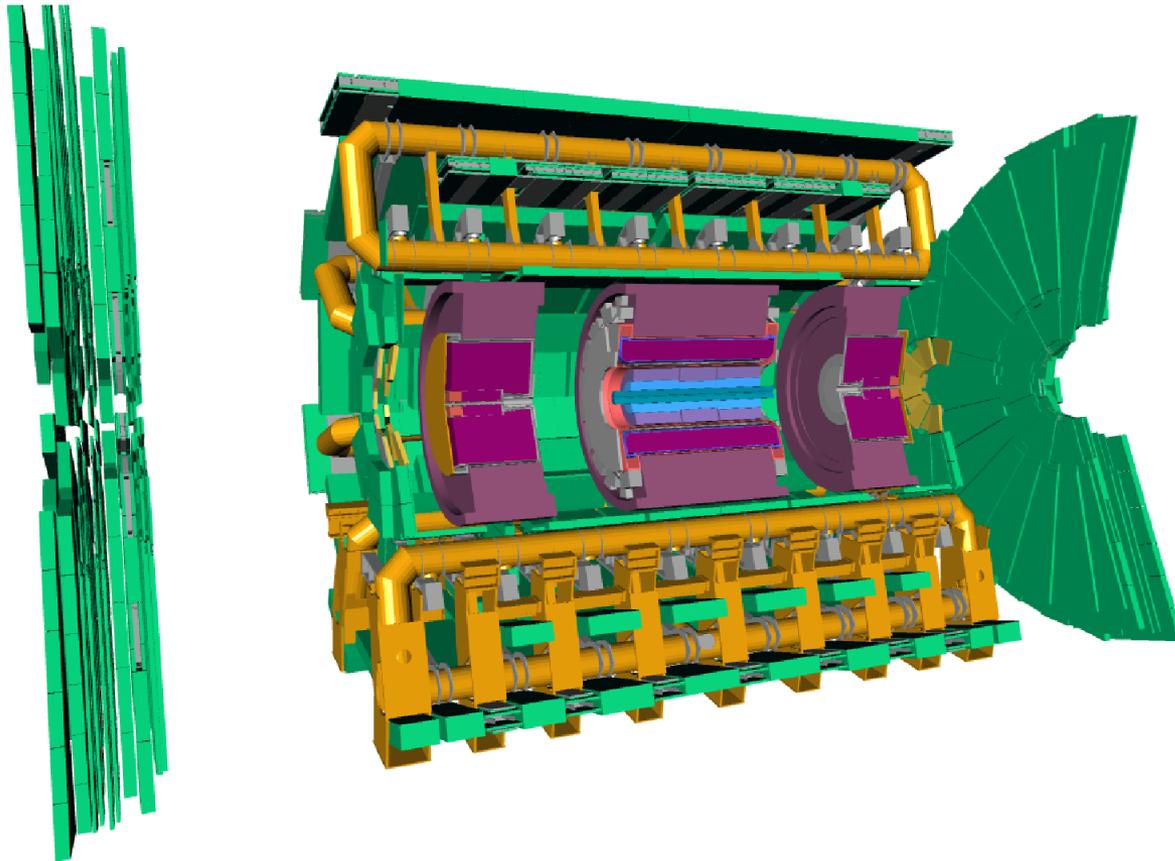


Image: ATLAS Experiment/CERN

Differing contexts – Nuclear Physics vs Dose Rate Assessment

- The context of radiation transport calculations – and therefore the priorities – are not the same in nuclear physics as opposed to dose rate assessments.

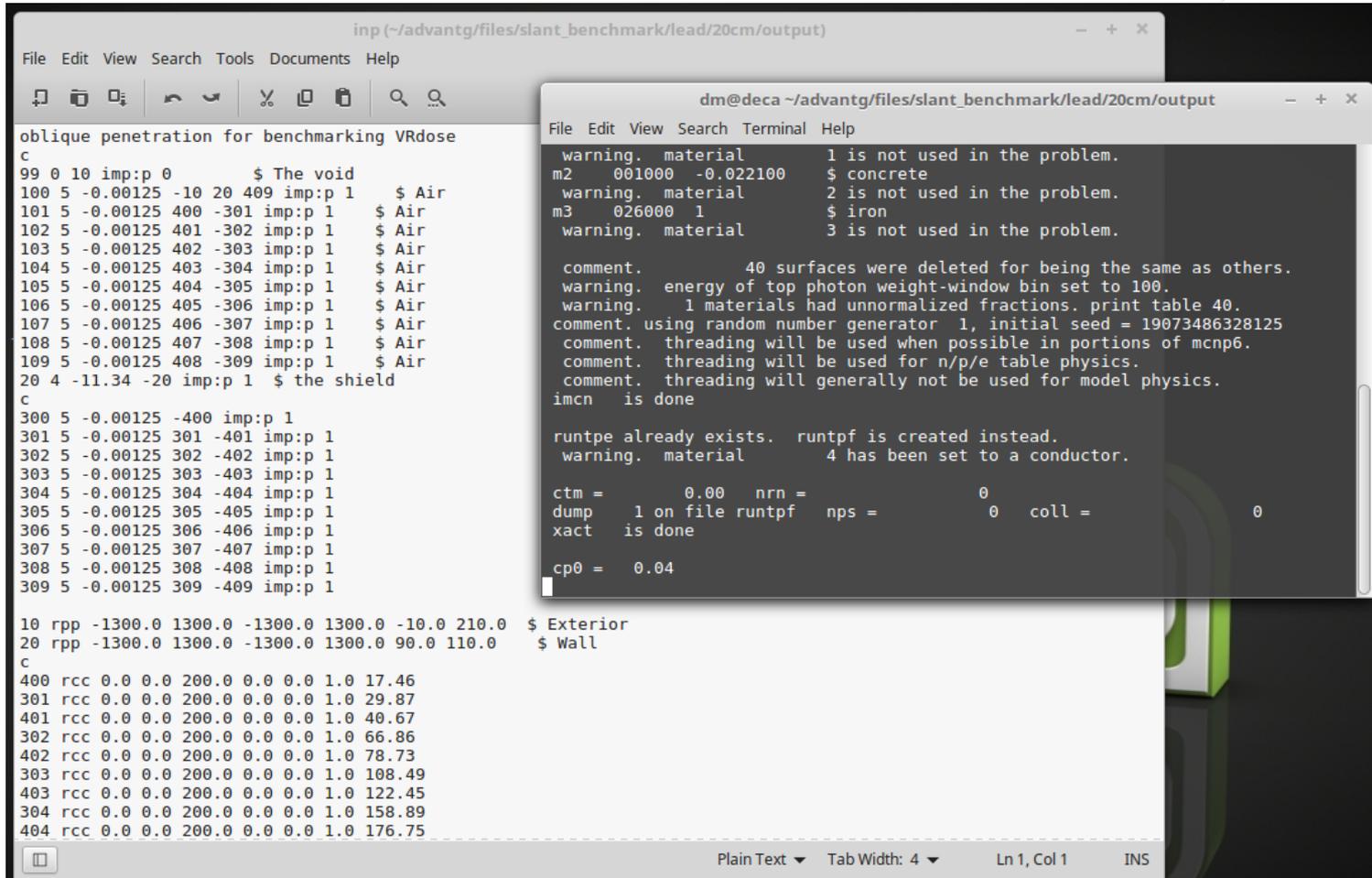
Nuclear Physics Research	Dose Rate Calculations
High accuracy	“Good enough” accuracy
Less time sensitive	Fast answers needed
Expert users	User expertise varies
Detailed models	Simplified models

Tools for radiation transport – Monte Carlo codes

- Uses random numbers to generate particles and move them through the user defined geometry.
- Count particles reaching your detector to calculate detector response, or dose rate, or reaction rate.
- Common codes: GEANT4, MCNP, etc...

Monte Carlo downsides...

- Tedious text input



The image shows two overlapping terminal windows. The background window is titled 'inp (~/advantg/files/slant_benchmark/lead/20cm/output)' and displays MCNP input text for a benchmark problem. The foreground window is titled 'dm@deca ~/advantg/files/slant_benchmark/lead/20cm/output' and displays the corresponding output text, including material definitions, surface definitions, and simulation parameters.

```
inp (~/advantg/files/slant_benchmark/lead/20cm/output)
File Edit View Search Tools Documents Help
oblique penetration for benchmarking VRdose
c
99 0 10 imp:p 0          $ The void
100 5 -0.00125 -10 20 409 imp:p 1  $ Air
101 5 -0.00125 400 -301 imp:p 1  $ Air
102 5 -0.00125 401 -302 imp:p 1  $ Air
103 5 -0.00125 402 -303 imp:p 1  $ Air
104 5 -0.00125 403 -304 imp:p 1  $ Air
105 5 -0.00125 404 -305 imp:p 1  $ Air
106 5 -0.00125 405 -306 imp:p 1  $ Air
107 5 -0.00125 406 -307 imp:p 1  $ Air
108 5 -0.00125 407 -308 imp:p 1  $ Air
109 5 -0.00125 408 -309 imp:p 1  $ Air
20 4 -11.34 -20 imp:p 1  $ the shield
c
300 5 -0.00125 -400 imp:p 1
301 5 -0.00125 301 -401 imp:p 1
302 5 -0.00125 302 -402 imp:p 1
303 5 -0.00125 303 -403 imp:p 1
304 5 -0.00125 304 -404 imp:p 1
305 5 -0.00125 305 -405 imp:p 1
306 5 -0.00125 306 -406 imp:p 1
307 5 -0.00125 307 -407 imp:p 1
308 5 -0.00125 308 -408 imp:p 1
309 5 -0.00125 309 -409 imp:p 1

10 rpp -1300.0 1300.0 -1300.0 1300.0 -10.0 210.0  $ Exterior
20 rpp -1300.0 1300.0 -1300.0 1300.0 90.0 110.0  $ Wall
c
400 rcc 0.0 0.0 200.0 0.0 0.0 1.0 17.46
401 rcc 0.0 0.0 200.0 0.0 0.0 1.0 29.87
402 rcc 0.0 0.0 200.0 0.0 0.0 1.0 40.67
403 rcc 0.0 0.0 200.0 0.0 0.0 1.0 66.86
404 rcc 0.0 0.0 200.0 0.0 0.0 1.0 78.73
405 rcc 0.0 0.0 200.0 0.0 0.0 1.0 108.49
406 rcc 0.0 0.0 200.0 0.0 0.0 1.0 122.45
407 rcc 0.0 0.0 200.0 0.0 0.0 1.0 158.89
408 rcc 0.0 0.0 200.0 0.0 0.0 1.0 176.75

dm@deca ~/advantg/files/slant_benchmark/lead/20cm/output
File Edit View Search Terminal Help
warning. material 1 is not used in the problem.
m2 001000 -0.022100 $ concrete
warning. material 2 is not used in the problem.
m3 026000 1 $ iron
warning. material 3 is not used in the problem.

comment. 40 surfaces were deleted for being the same as others.
warning. energy of top photon weight-window bin set to 100.
warning. 1 materials had unnormalized fractions. print table 40.
comment. using random number generator 1, initial seed = 19073486328125
comment. threading will be used when possible in portions of mcnp6.
comment. threading will be used for n/p/e table physics.
comment. threading will generally not be used for model physics.
imcn is done

runtpe already exists. runtpe is created instead.
warning. material 4 has been set to a conductor.

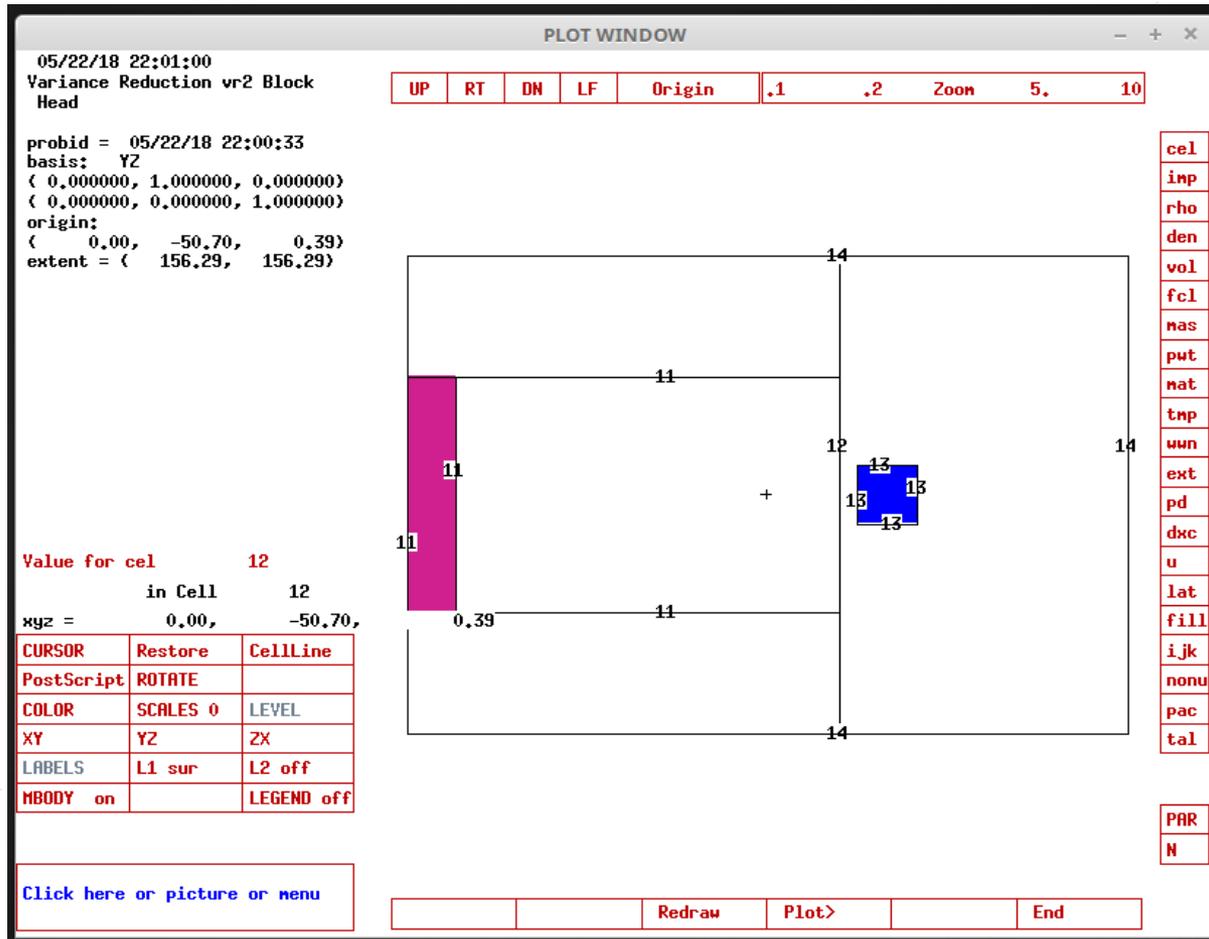
ctm = 0.00 nrn = 0
dump 1 on file runtpe nps = 0 coll = 0
xact is done

cp0 = 0.04

Plain Text Tab Width: 4 Ln 1, Col 1 INS
```

Monte Carlo downsides...

- Clunky visualisation



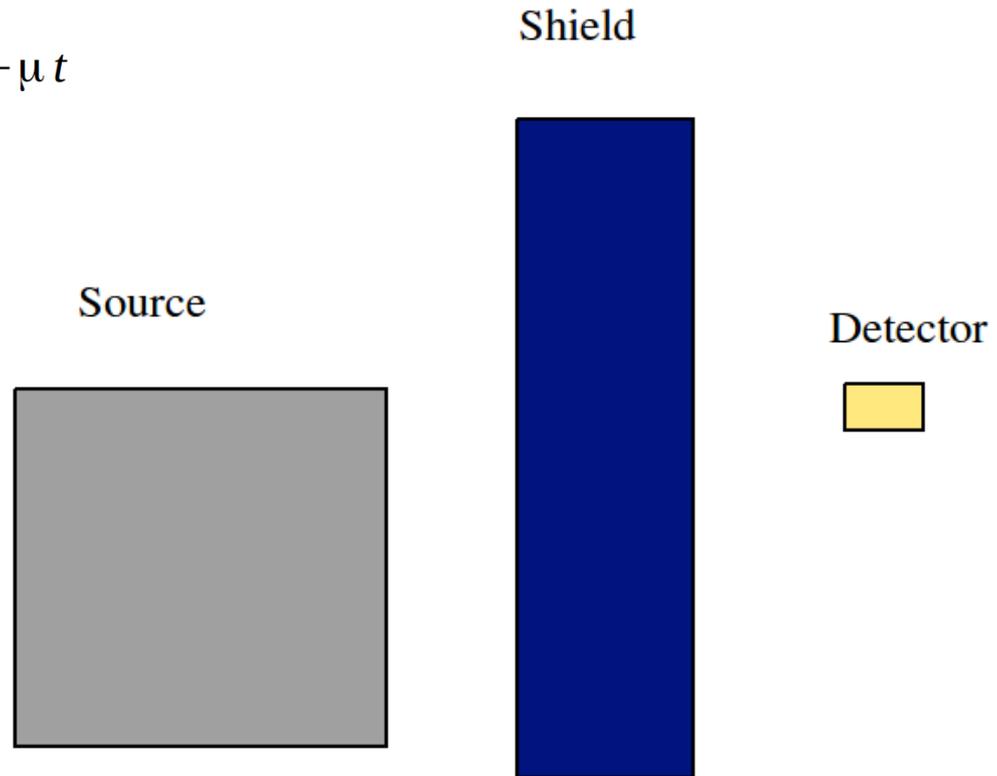
Monte Carlo downsides...

- Difficult to use and slow

So instead we can use... Point Kernel Method

- Discretise a large source and treat it as a collection of point sources.
- Compute the contribution from each point with the equation:

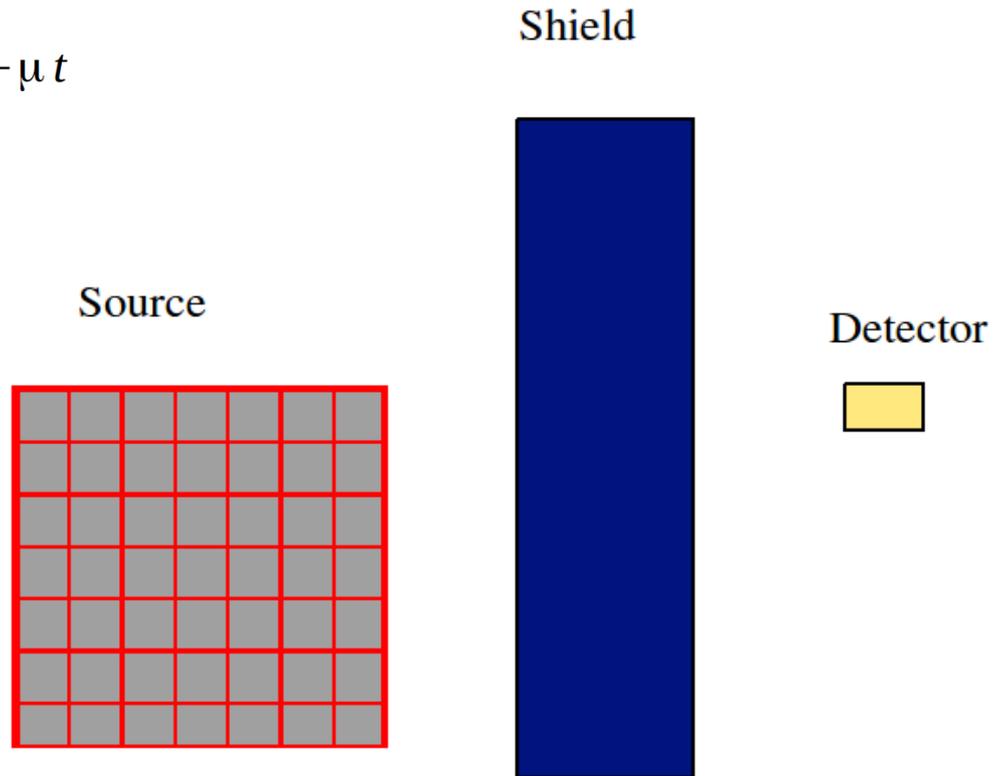
$$\phi = \frac{S}{4\pi r^2} \times B e^{-\mu t}$$



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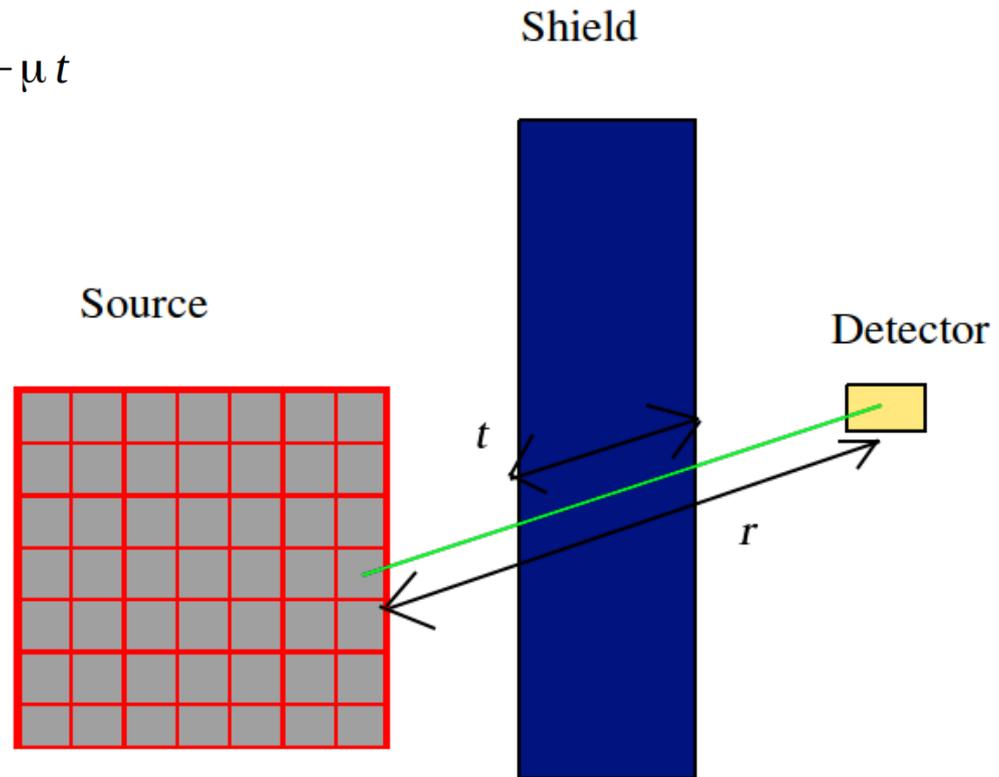
$$\phi = \frac{S}{4\pi r^2} \times B e^{-\mu t}$$



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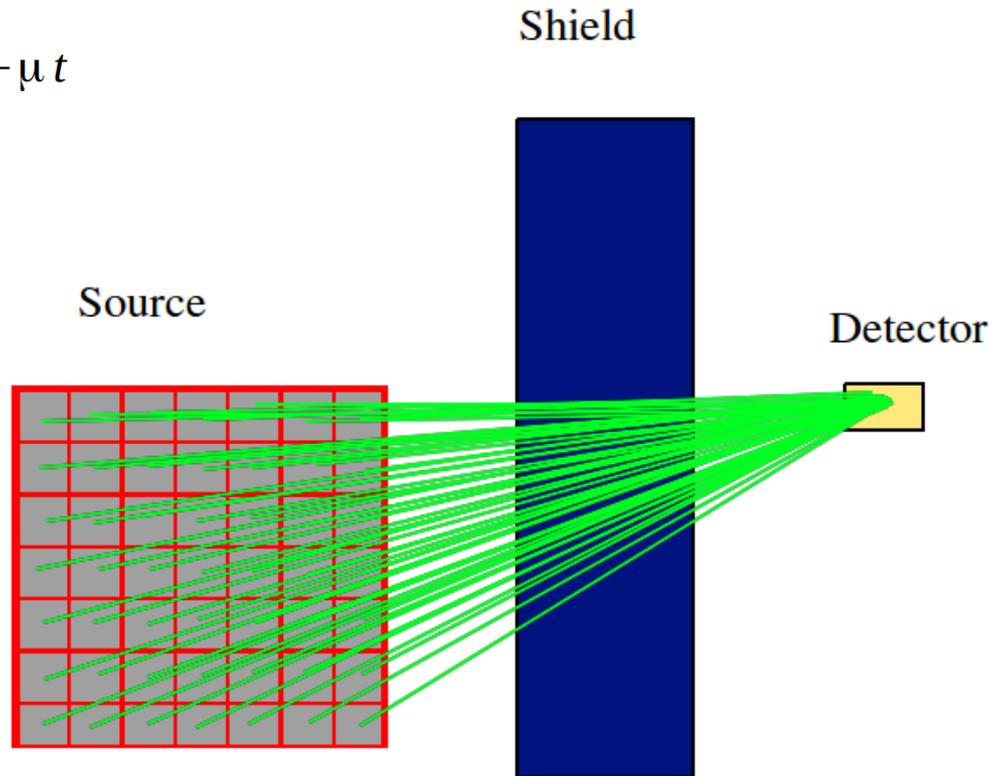
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So instead we can use... Point Kernel Method

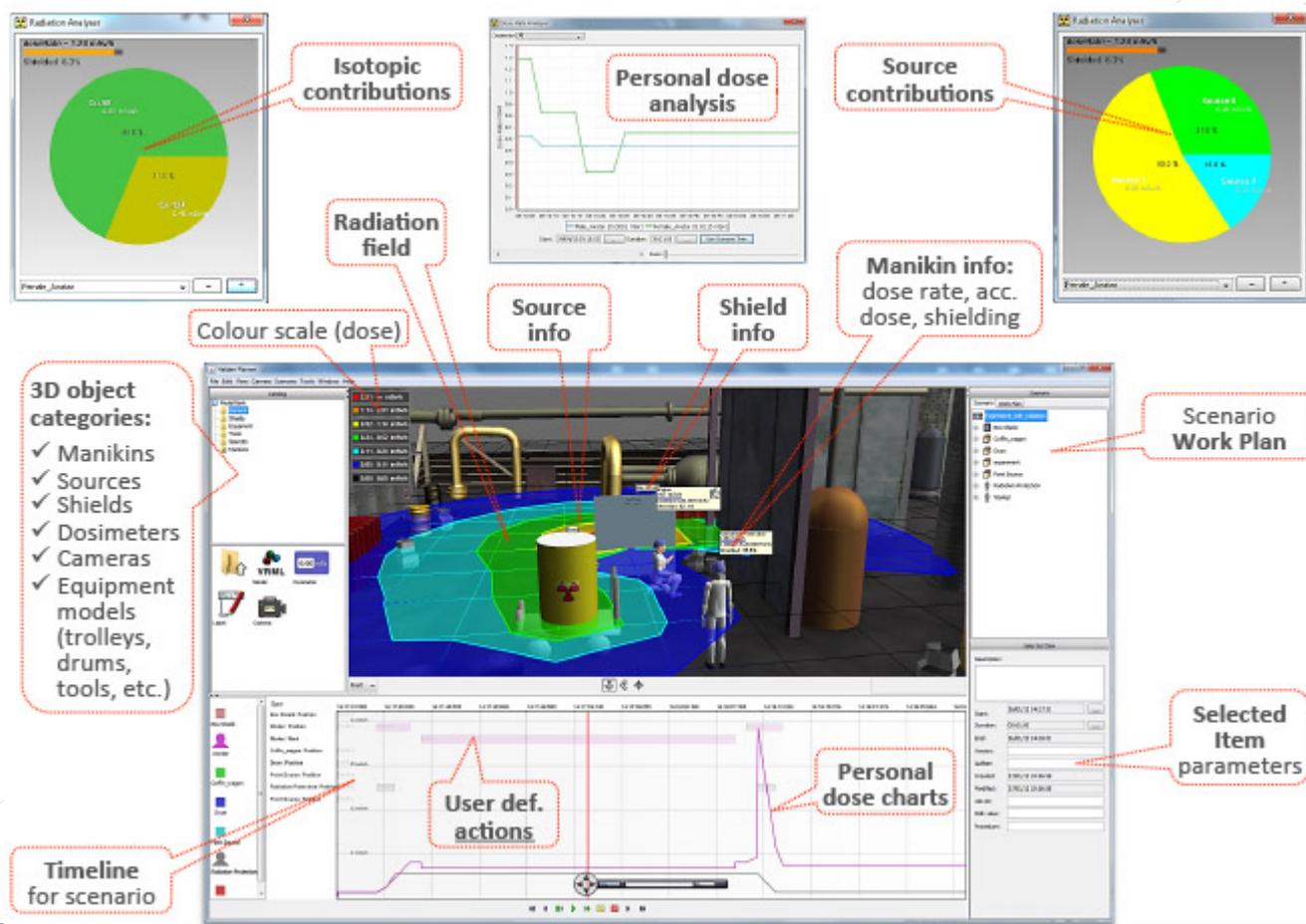
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VRdose – A point kernel code from IFE!

- Make things easy for dose assessors with modern GUI, visualisation, and instant results.



VRdose – A point kernel code from IFE

- VR = Virtual Reality. Workers can practise a task in VR and see how much dose they would receive.



VRdose demonstration

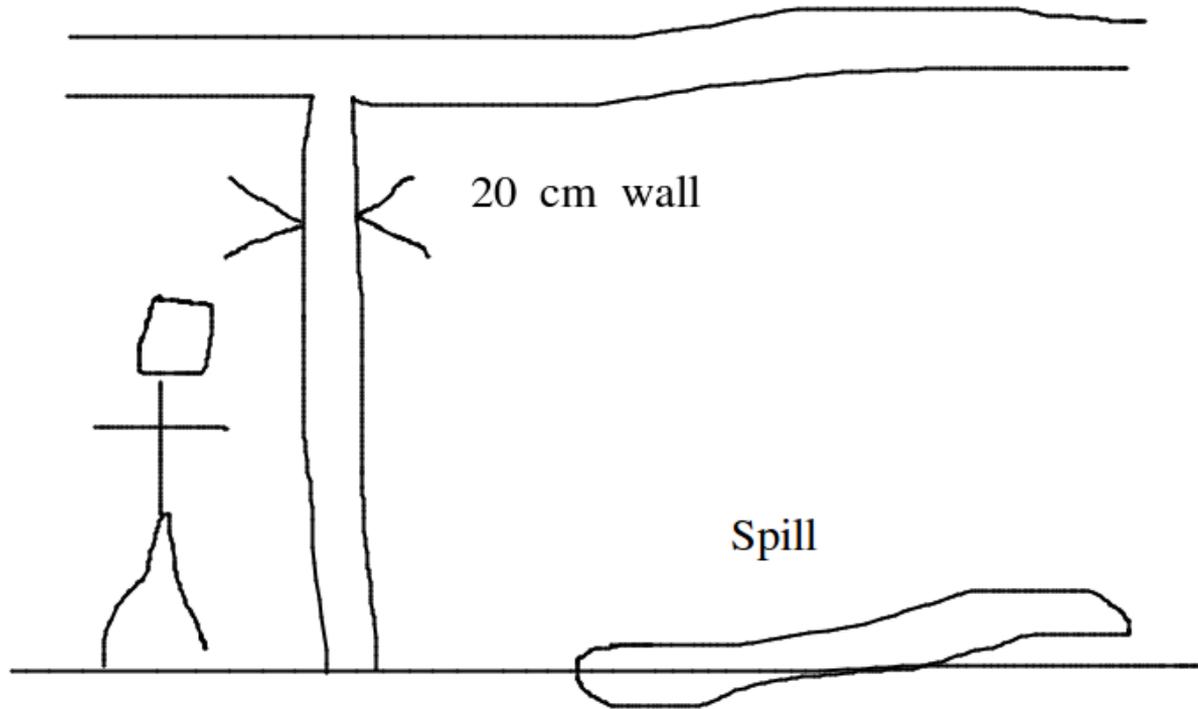
ring ring

Hello, is this the shielding assessment department? We have a problem – we were transporting a sample for analysis and we spilled about 2 litres of it on the floor. It contains about 5 GBq of ^{137}Cs per litre.

Access has been restricted and we are working on a cleanup strategy, but in the meantime there is a corridor adjacent to the room which operators use regularly to access their work area elsewhere in the facility. Is it safe for them to continue using the corridor?

I have emailed you a drawing of the situation.

VRdose demonstration



VRdose demonstration

Within a few minutes, we can reply...

I expect the maximum dose rate inside the corridor due to the spill to be around $14 \mu\text{Sv/hr}$.

I recommend entering the corridor to perform a detector survey - if an elevated dose rate is found directly opposite the location of the spill, then I suggest installing temporary maze shielding (or similar) equivalent to 1 cm of lead.

Also, in the room with the spill, the dose rate directly above it is likely to be around $400 \mu\text{Sv/hr}$ and around $100 \mu\text{Sv/hr}$ 2m away. What are the options for cleaning it? Let's cooperate on the cleaning strategy.

MCNP for comparison

```

x1spill.o (~)
File Edit View Search Tools Documents Help
26000.84p      442254  1.3932E-01  8.
tally         4      nps = 3174337
tally type 4   track length estimate of particle flux.
particle(s): photons
this tally is modified by dose function DE4 and DF4.

this tally is modified by cm, em or tm cards.

volumes
  cell:      30
           5.00000E+03

cell 30
energy
1.0000E+01  1.34346E+01  0.0199

-----
results of 10 statistical checks for the estimated answer
tfc bin  --mean--  -----relative error-----
behavior  behavior  value  decrease  decrease rate  va
desired  random  <0.10  yes      1/sqrt(nps)  <0
observed  random  0.02   yes      yes          0
passed?   yes     yes     yes      yes

this tally meets the statistical criteria used to form confidence
the results in other bins associated with this tally may not meet

----- estimated confidence intervals: -----

estimated asymmetric confidence interval(1,2,3 sigma): 1.3170E+01 to 1.3706E+01; 1.2902E+01 to 1.3974E+01; 1.2635E+01 to 1.4241E+01
estimated symmetric confidence interval(1,2,3 sigma): 1.3167E+01 to 1.3702E+01; 1.2899E+01 to 1.3970E+01; 1.2632E+01 to 1.4238E+01

Analysis of the results in the tally fluctuation chart bin (tfc) for tally         4 with nps = 3174337 print table 160
    
```

05/23/18 20:51:14
spill

probid = 05/23/18 20:50:43
basis: XY
(1.000000, 0.000000, 0.000000)
(0.000000, 1.000000, 0.000000)
origin:
(188.03, 207.17, 100.00)
extent = (312.58, 312.58)

Value for cel	40
in Cell	40
xyz =	188.03, 207.17,

CURSOR	Restore	CellLine
PostScript	ROTATE	
COLOR	SCALES 0	LEVEL
XY	YZ	ZX
LABELS	L1 sur	L2 off
MBODY	on	LEGEND off

[Click here or picture or menu](#)

PLOT WINDOW

UP	RT	DN	LF	Origin	.1	.2	Zoom	5.	10
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cel	inp	rho	den	vol	fcl	nas	put	nat	tnp	uun	ext	pd	dx	u	lat	fill	ijk	nonu	pac	tal	
PAR	N																				

Redraw	Plot>	End
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Conclusions

- My aims today were:
 - Remind you about the significance of dose rate calculations.
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 - Show you how we can make our lives easier with more user-friendly software for predicting dose rates and get you to appreciate the importance of ease of use in nuclear codes.

With thanks to...

- Istvan Szoke and Tom-Robert Bryntesen – VRdose development
- Bill Beere and Sunniva Siem – My PhD supervisors
- You – Remaining awake

Comments or questions?