Clinical Radiotherapy on the Grid

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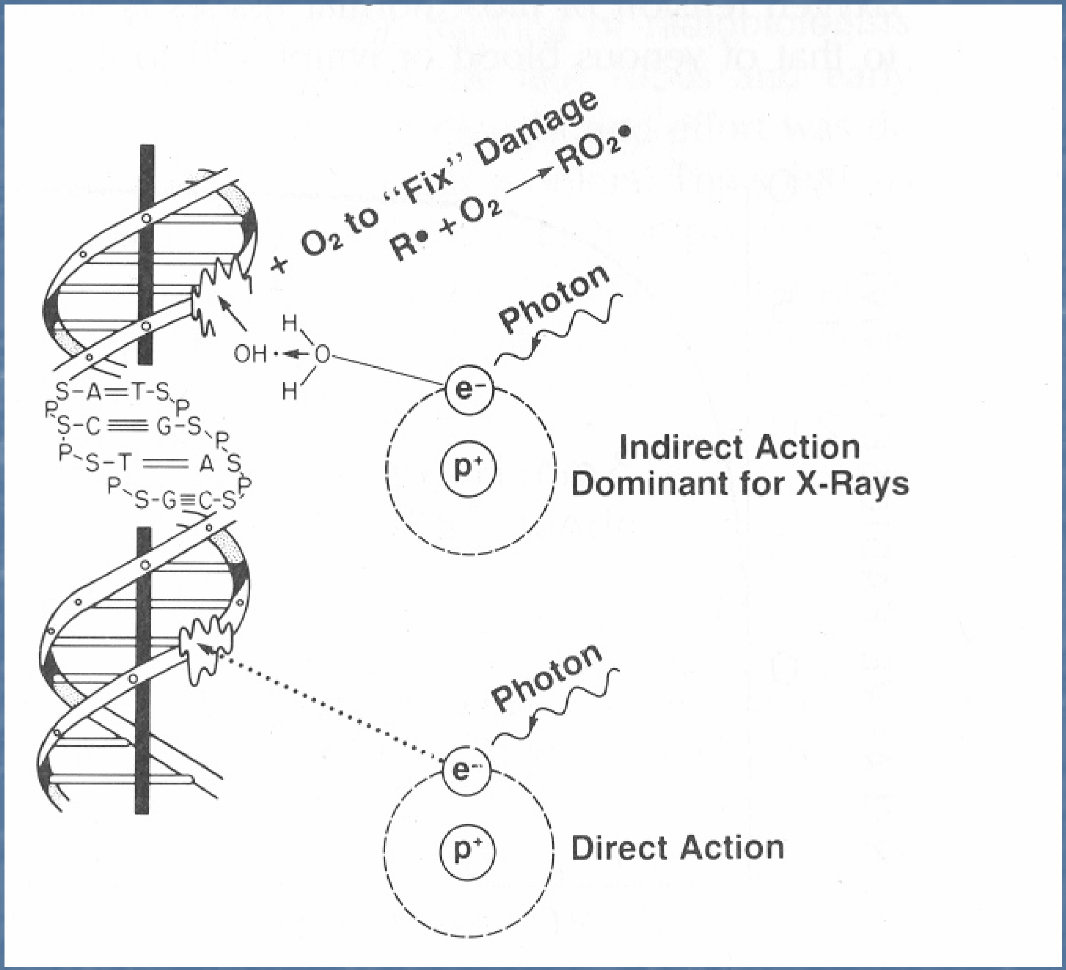
Background

- Radiotherapy is....

the treatment of malignant tumours using high energy ionising radiation with the intention of permanent cure or the relief of suffering.

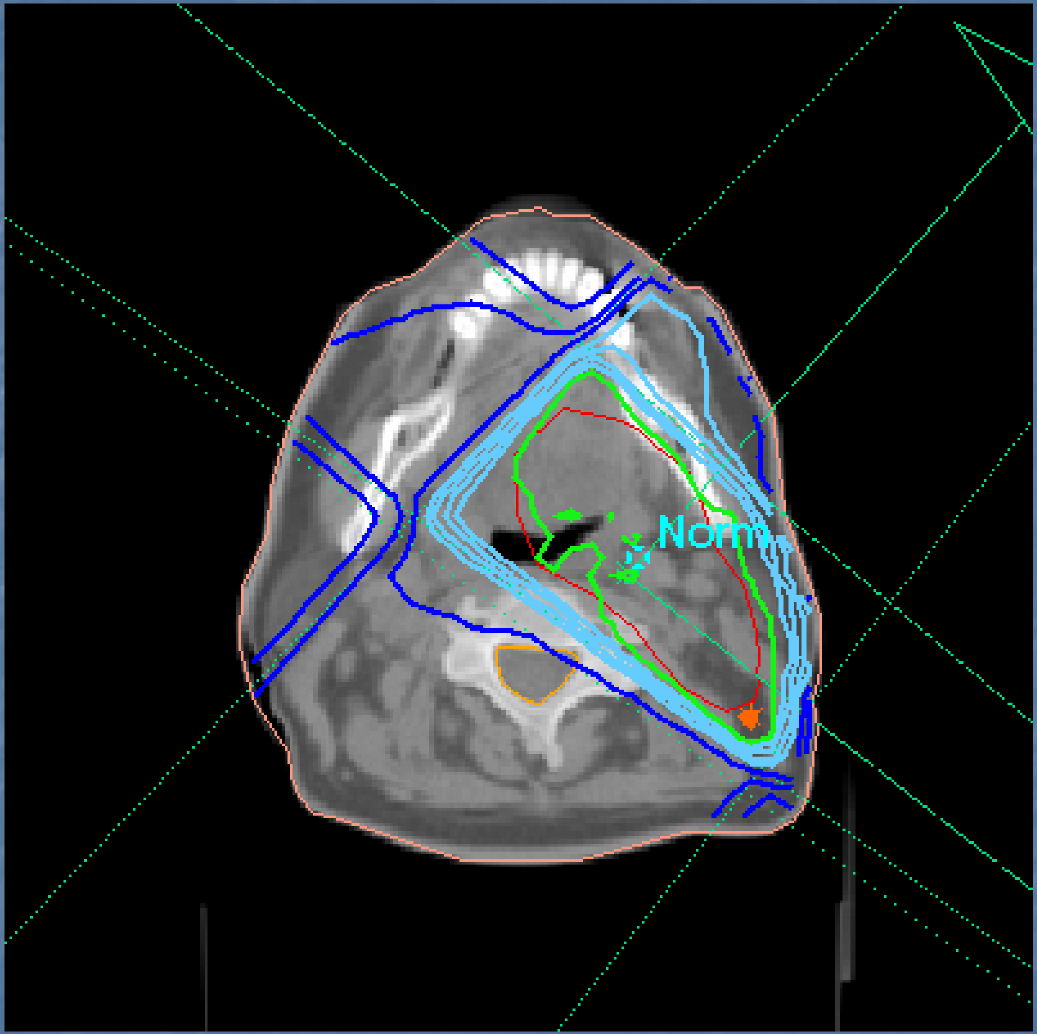
Effective mechanism is damage of cellular DNA



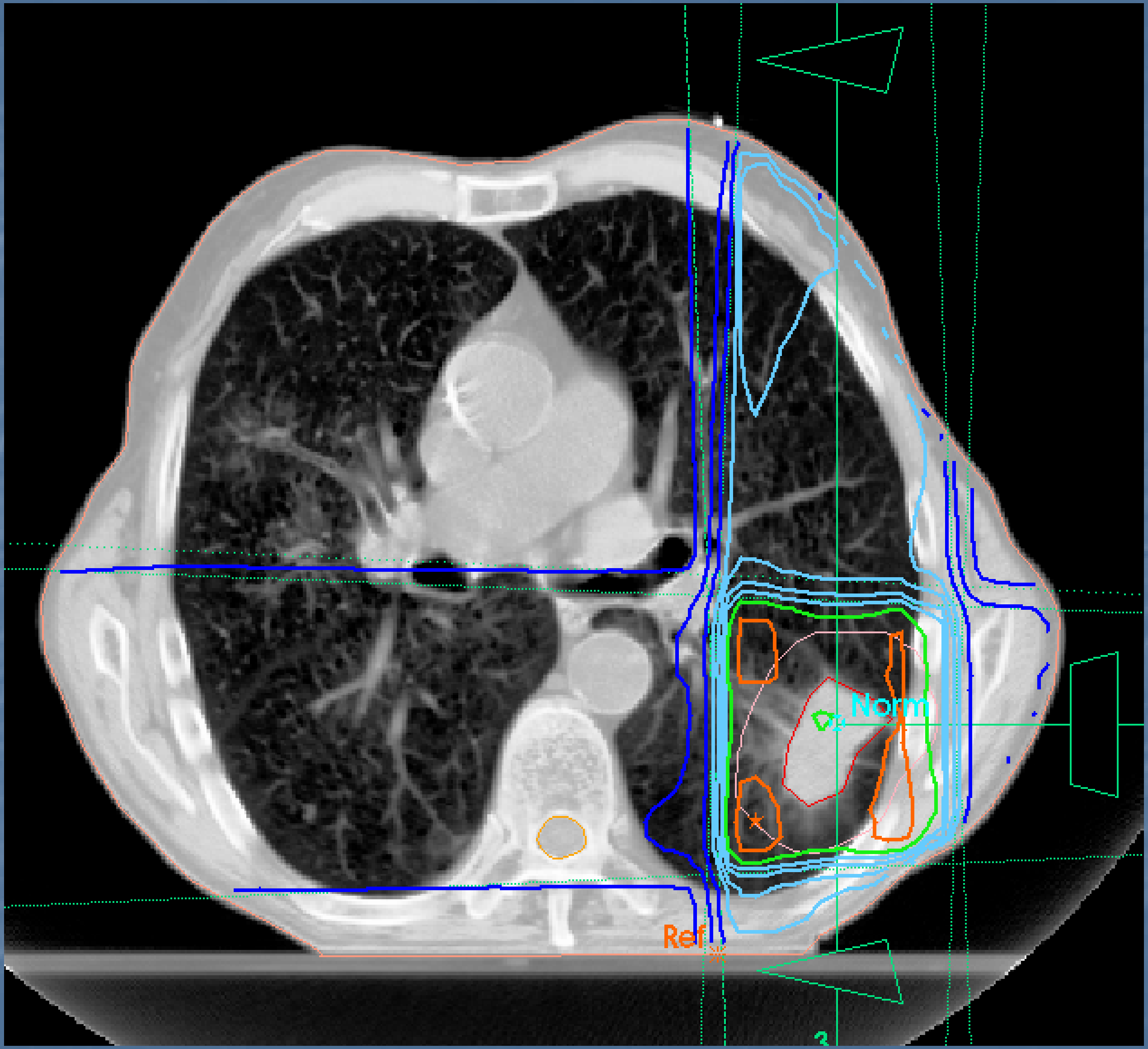
+ O2 to "Fix" Damage
R• + O2 → RO2•
OH•
H
O
H
S-A=T-S
P
S-C≡G-S
P
P-S-T=A S
P
P-S-G≡C-S
P
Photon
e⁻
p⁺
Indirect Action
Dominant for X-Rays
Photon
e⁻
p⁺
Direct Action

CT Based Planning

CT Based Planning 2



Lung - Pencil Beam



105
100
95
90
80
70
50
30
10

Need for Accuracy ?

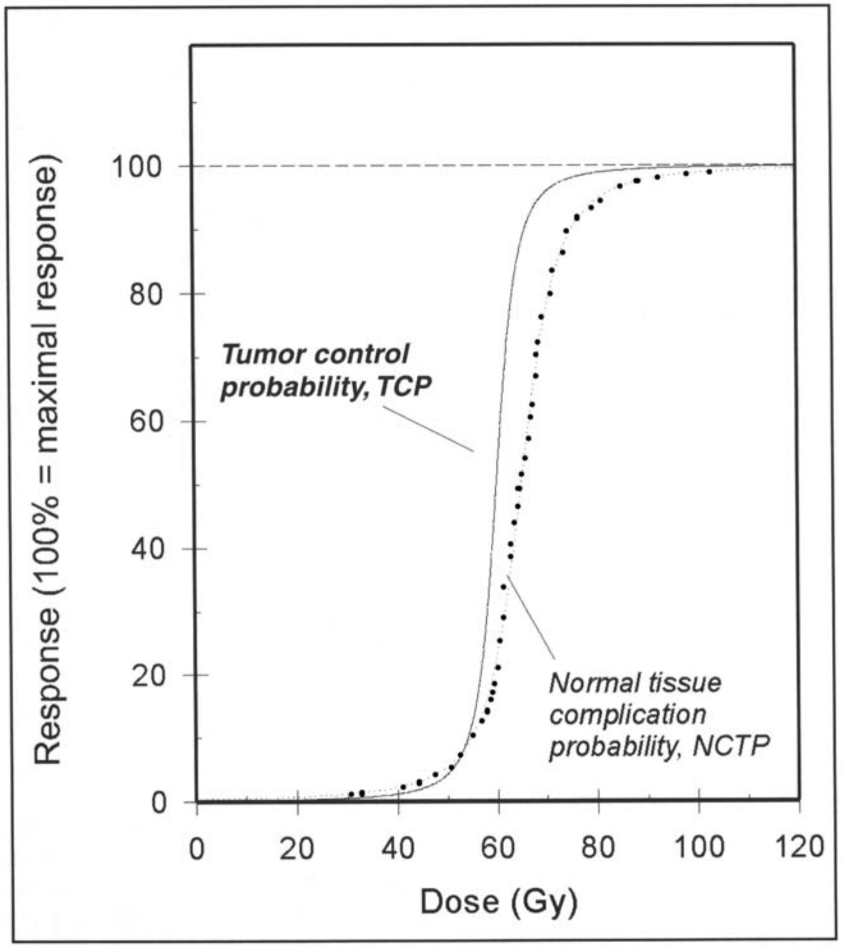
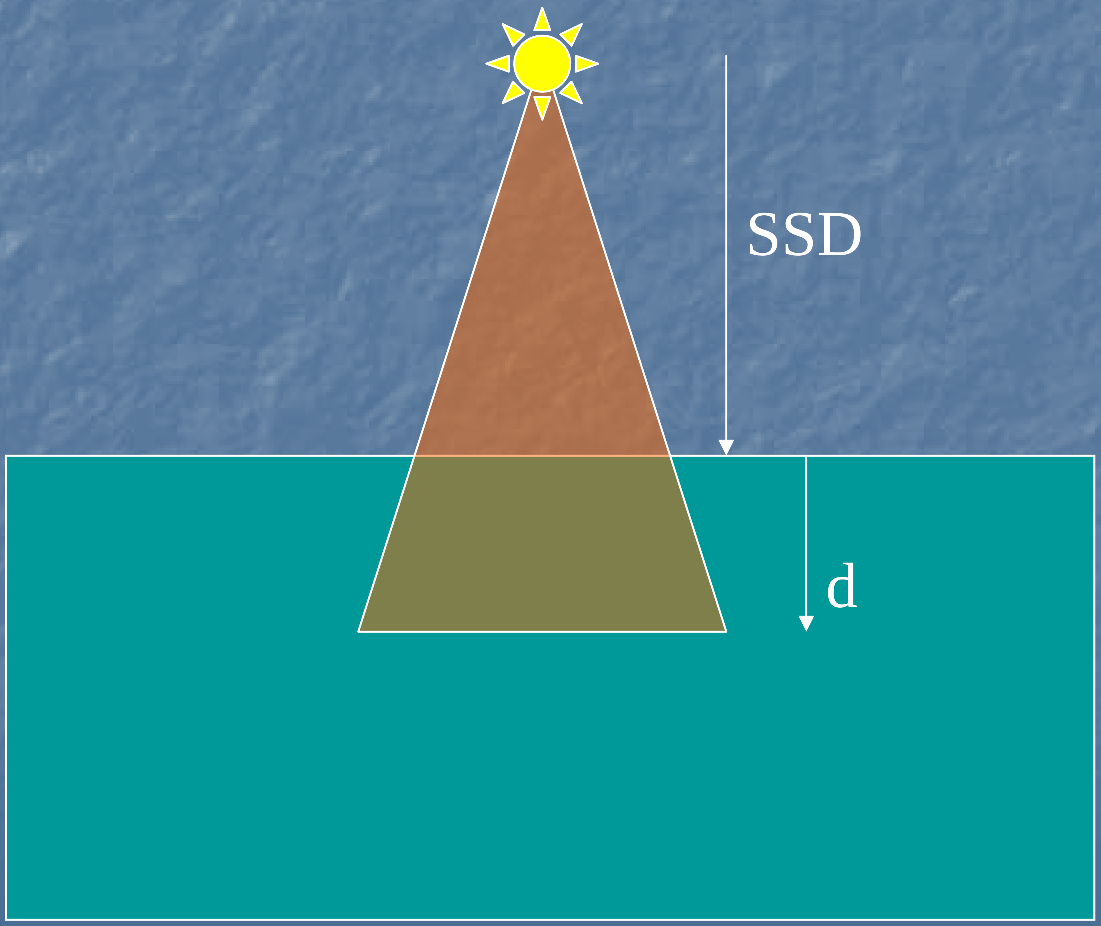


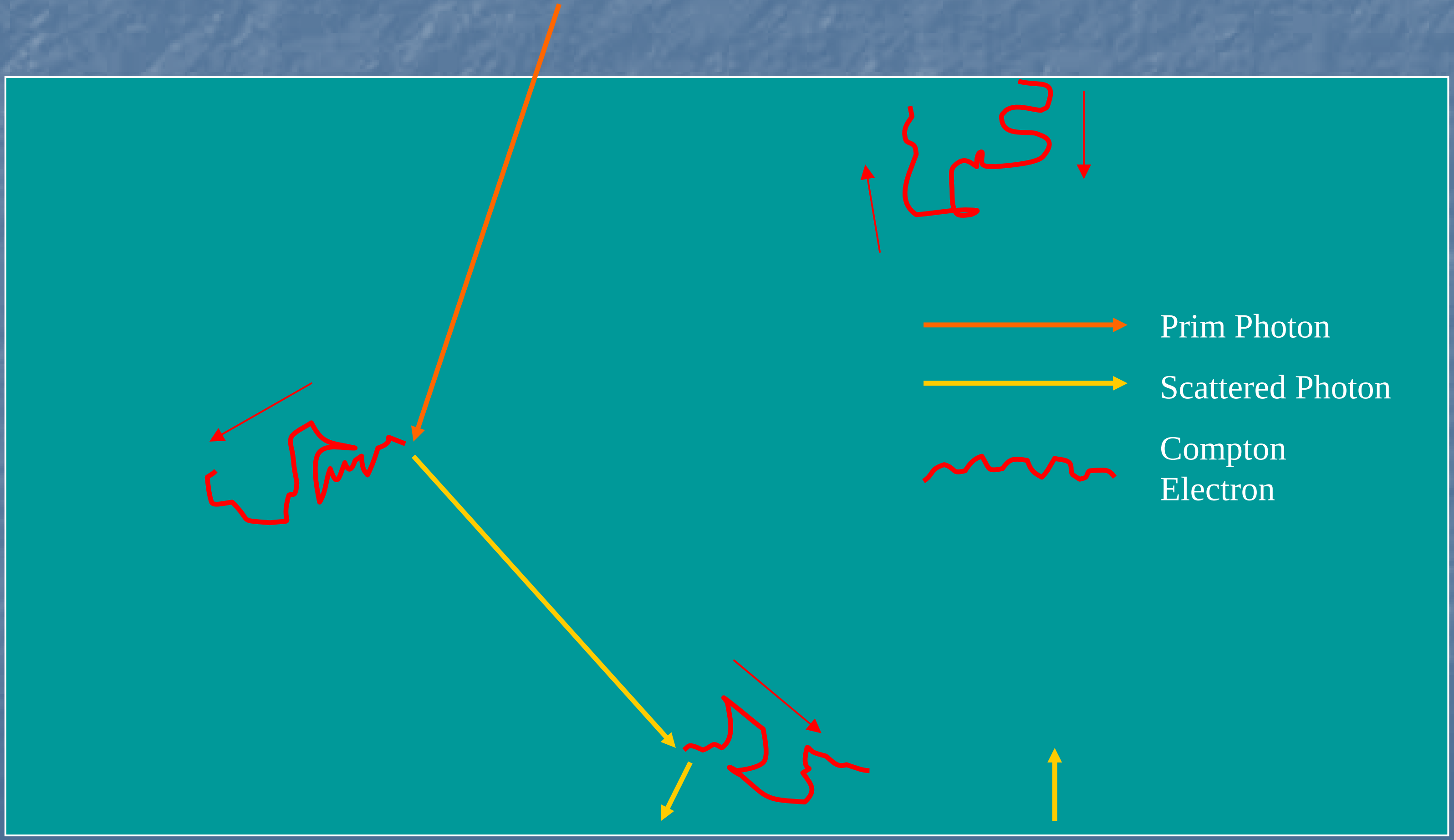
Figure 3.2: Dose-response curves for tumor and normal tissues assuming a standard fractionation schedule (2 Gy fractions daily).

Steep dose response curves indicate that radiotherapy has to be delivered with a high degree of accuracy. However we cannot measure radiation doses directly in the patient.

Basic Concepts -1



Basic Concepts - 2

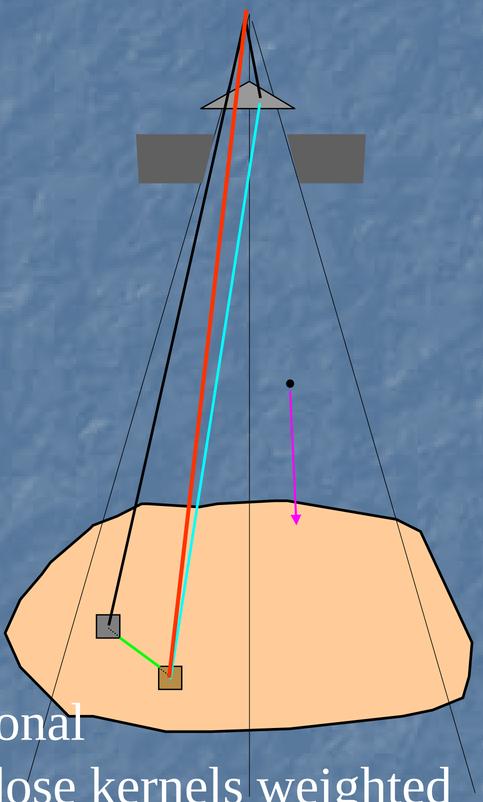


Dose Modelling

- It is possible to characterise radiation beams in test objects.
- Dose distributions within patients are calculated using various algorithms and data measured in test objects.
- Good agreement in regions with uniform density and routine field shapes.
- Agreement is poor in interface regions and when using unusual fields.

Dose engine

The dose calculation engine gives the absolute dose per unit direct energy fluence at the isocenter



$$d(\mathbf{r}) = \frac{D(\mathbf{r})}{\Psi_0}$$

The dose is calculated as a sum of several components

$$d = d_{prim} + d_{scat} + d_{headscat} + d_{e-contam}$$

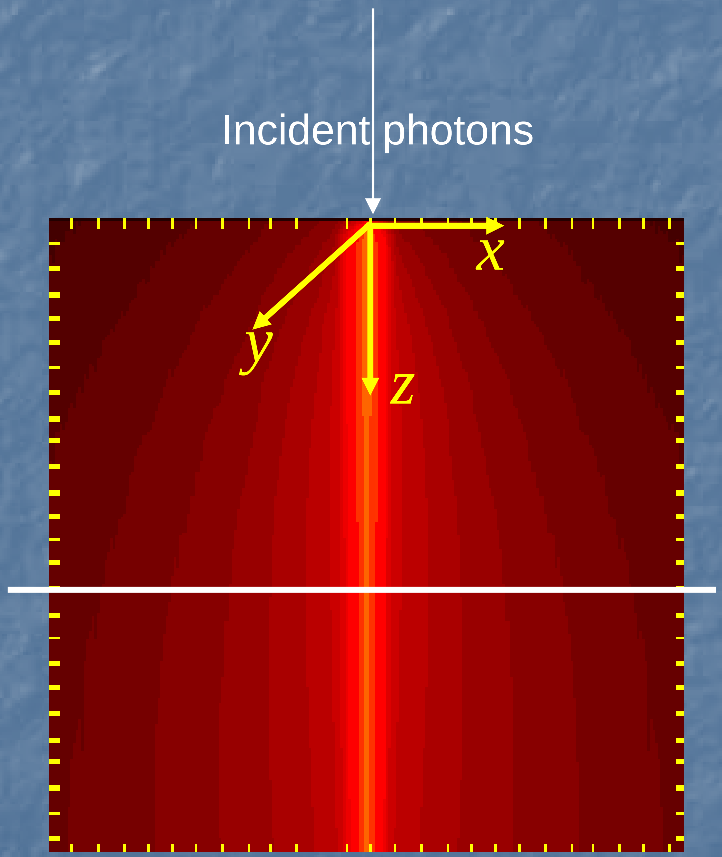
Each component is the result of a two-dimensional integration, over the beam aperture, of pencil dose kernels weighted with their energy fluence.

$$d_{\dots} = d_{\dots}(x,y,z) = \frac{1}{\Psi_0} \iint_{\text{Beam opening}} \Psi(x',y') \cdot \frac{p}{\rho}(x-x', y-y', z) \cdot \mathrm{d}x' \, \mathrm{d}y'$$

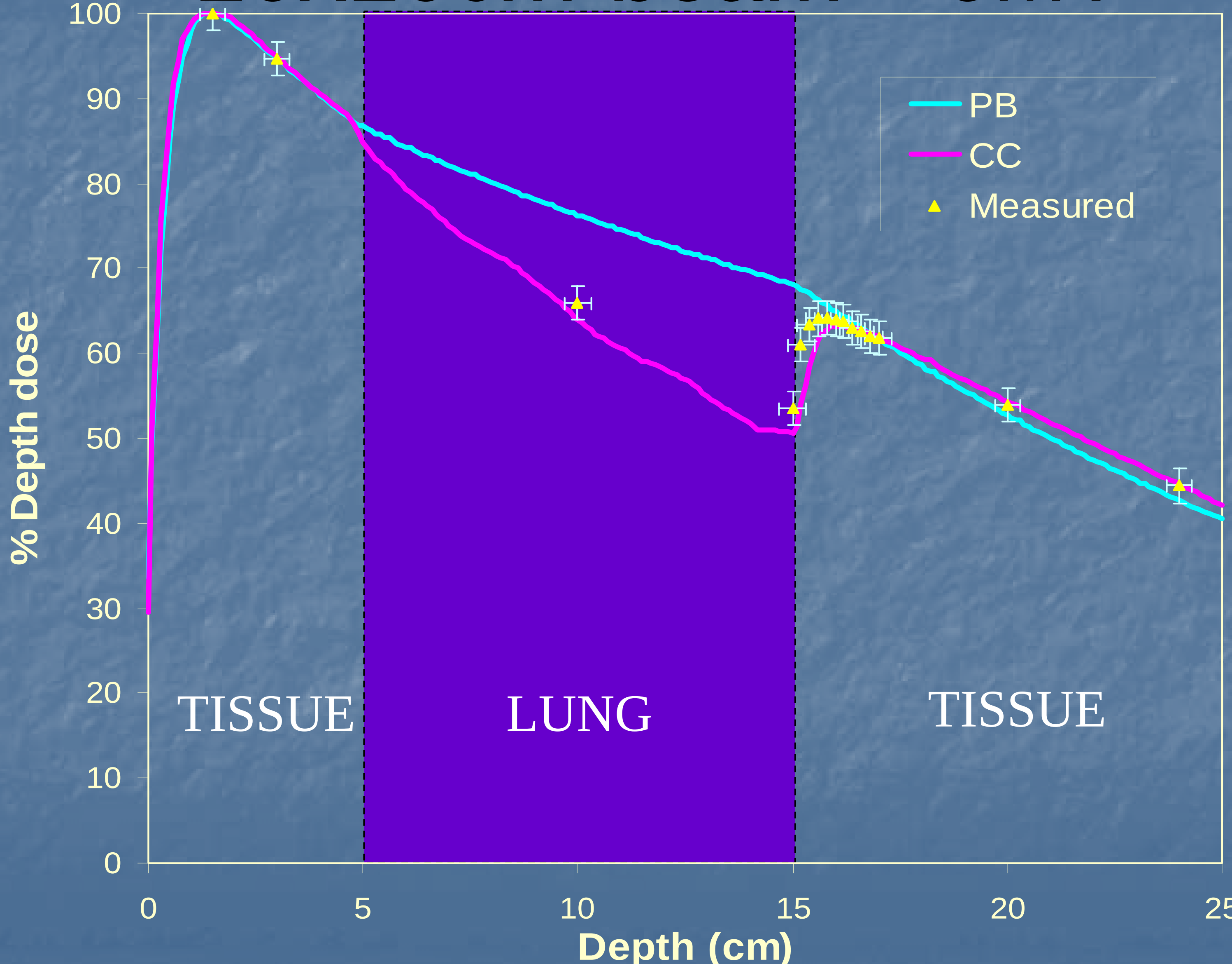
Pencil kernels I

• Describes dose distribution in a water phantom per energy entering in a thin beam through the surface.

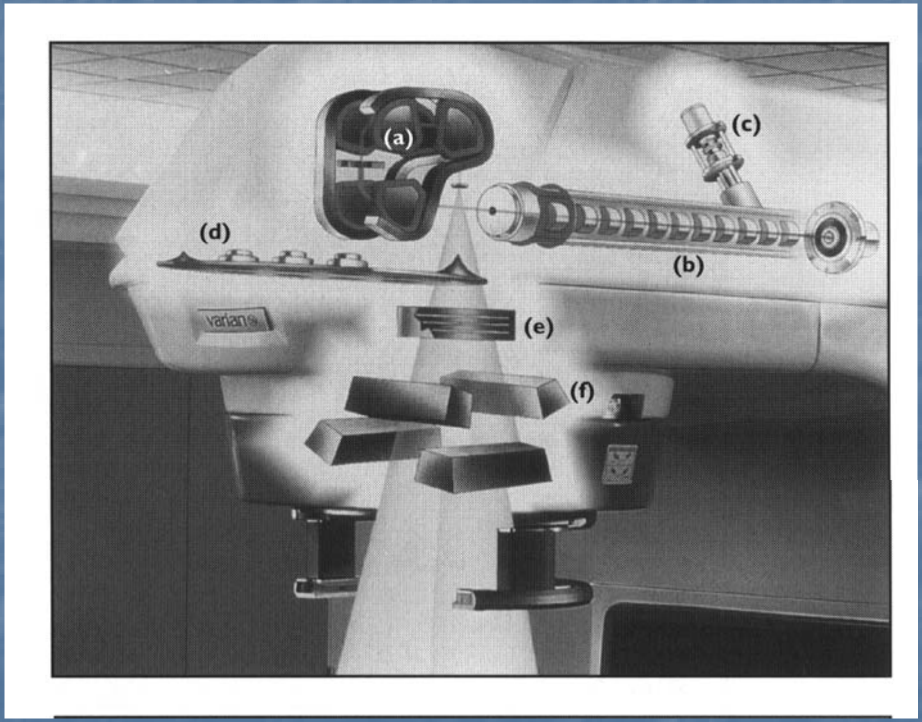
• Sampled on planes perpendicular to the beam axis.

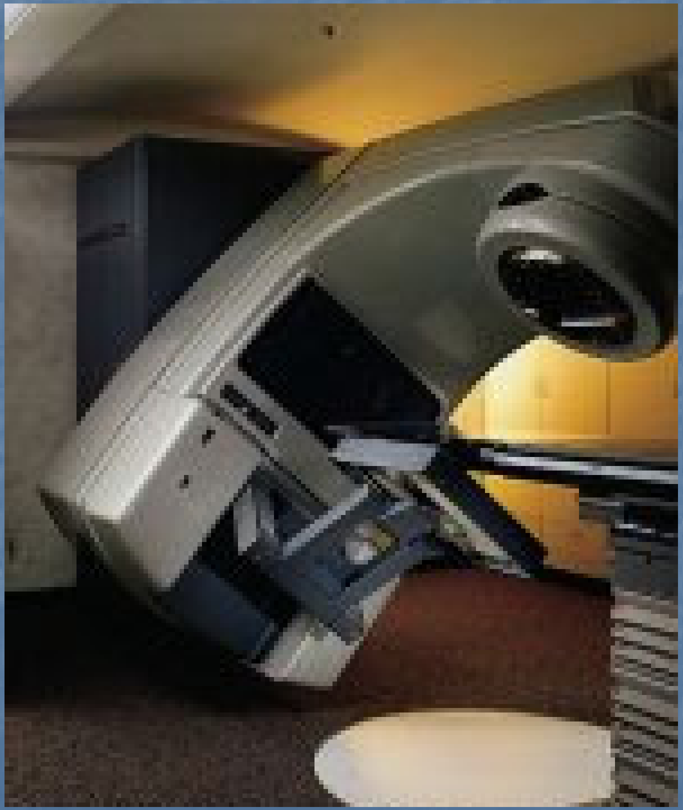


Lung slab phantom results 10x10cm beam - 6MV



The Problem





Simulation

- Most accurate method of calculating dose distributions is Monte Carlo simulation.
- Electron histories are tracked though photon generation and the scattering and absorption of radiation through to the patient.
- Each radiotherapy fraction involves about 100 trillion ‘histories’.
- Accurate simulation requires 200 million histories.

Solutions

- Large computational overhead
- Usual Hospital solution is a cluster of pc's.
- Appeals to a physicist but is delivers poor economy.
- External HPC facilities offered by the Grid supply a much better solution.

Monte Carlo Code

- Simulations run on freely available codes, BEAMnrcMP and EGSnrc obtained from NRC Canada

- Since 2004, BEAM will run on Windows, Linux and most flavours of Unix

- BEAM software installed directly onto NGS head node (~150 MB of disk space)

- Without use of grid, a typical simulation will take ~30 hours on a single PC (2.8 GHz Athlon, 1 GB RAM).

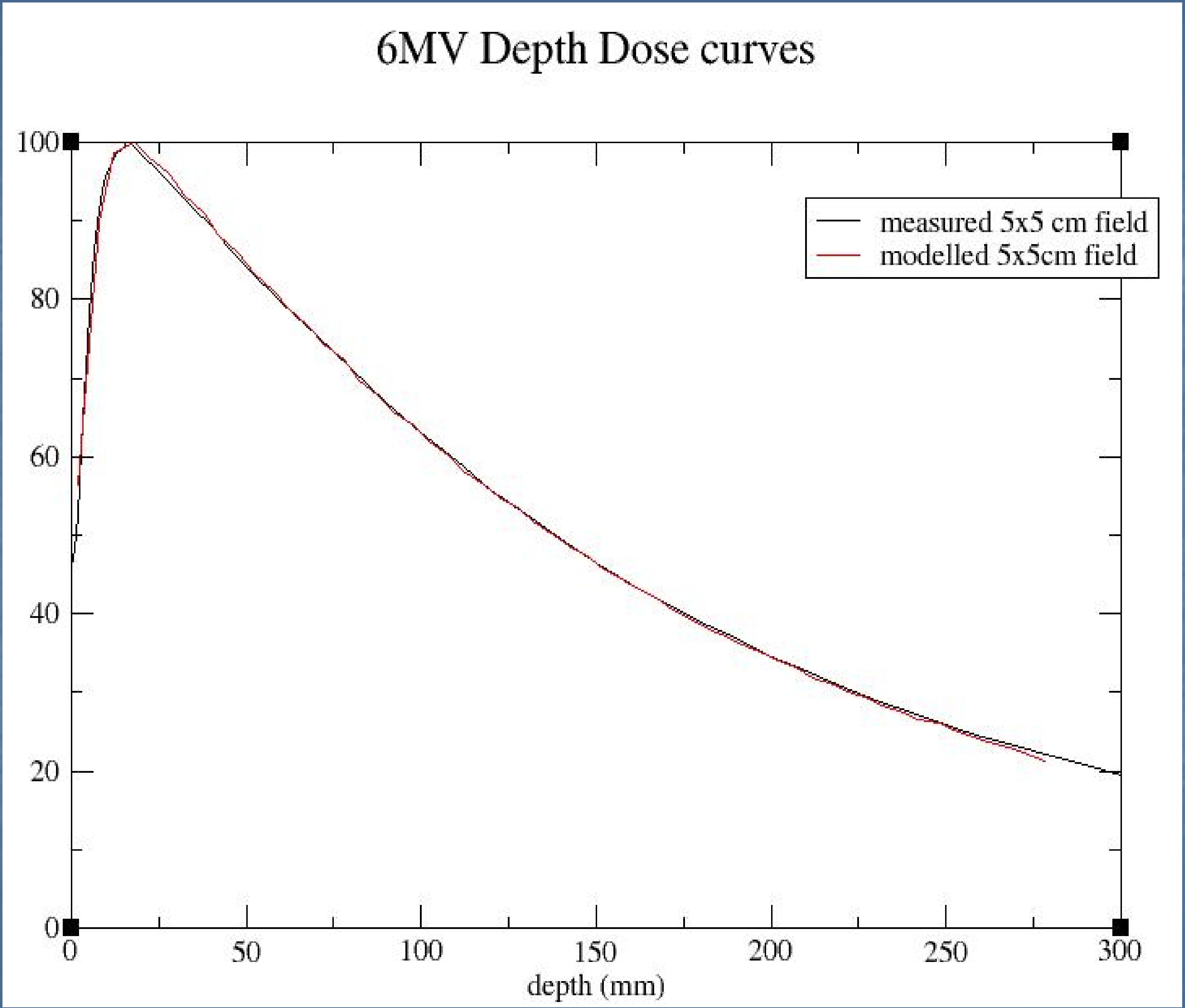
Monte Carlo over the NGS

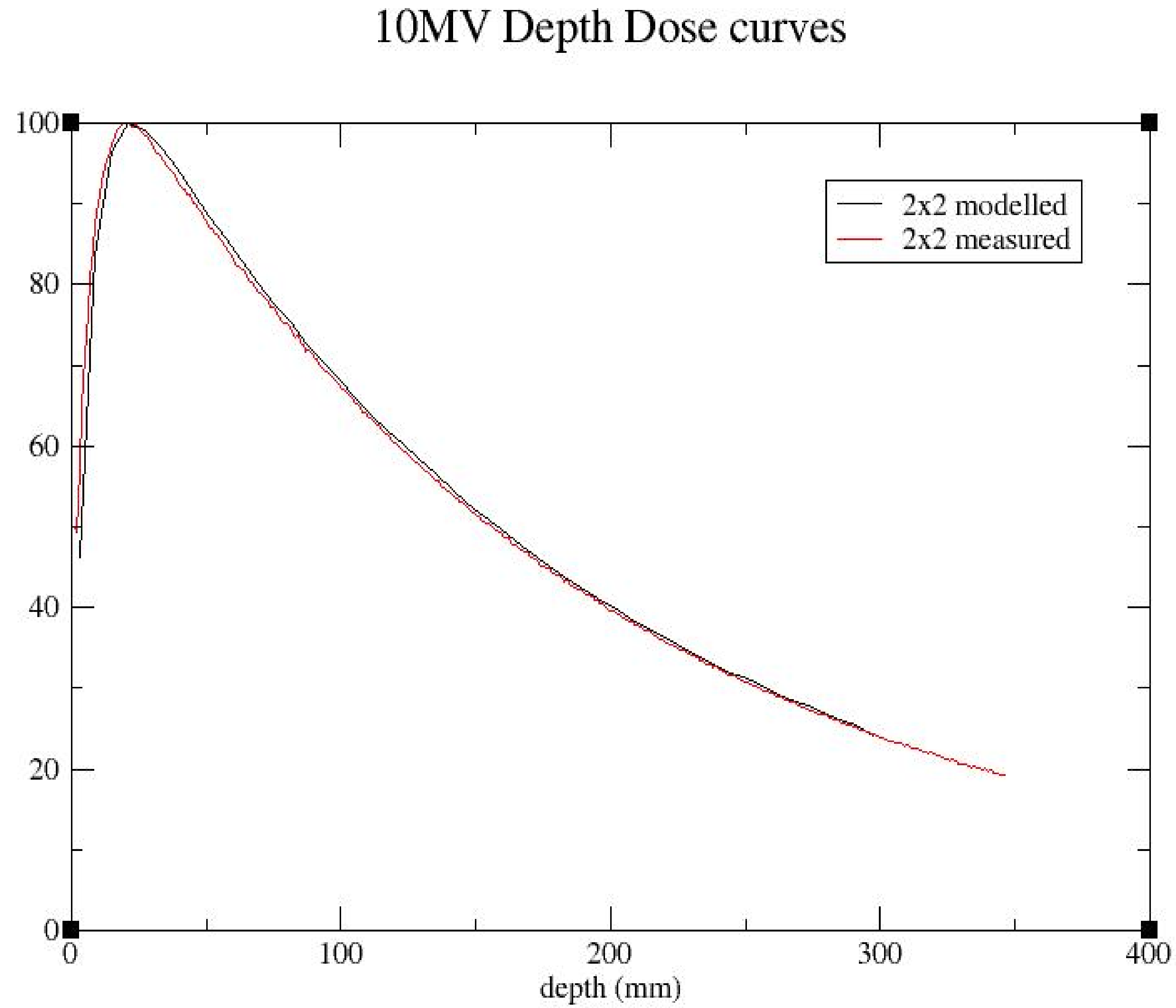
- Access to NGS head nodes, primarily Leeds, via GLOBUS toolkit (gsissh and gsiscp) from a Linux shell

- Job submission via standard PBS, 8 processors available to us

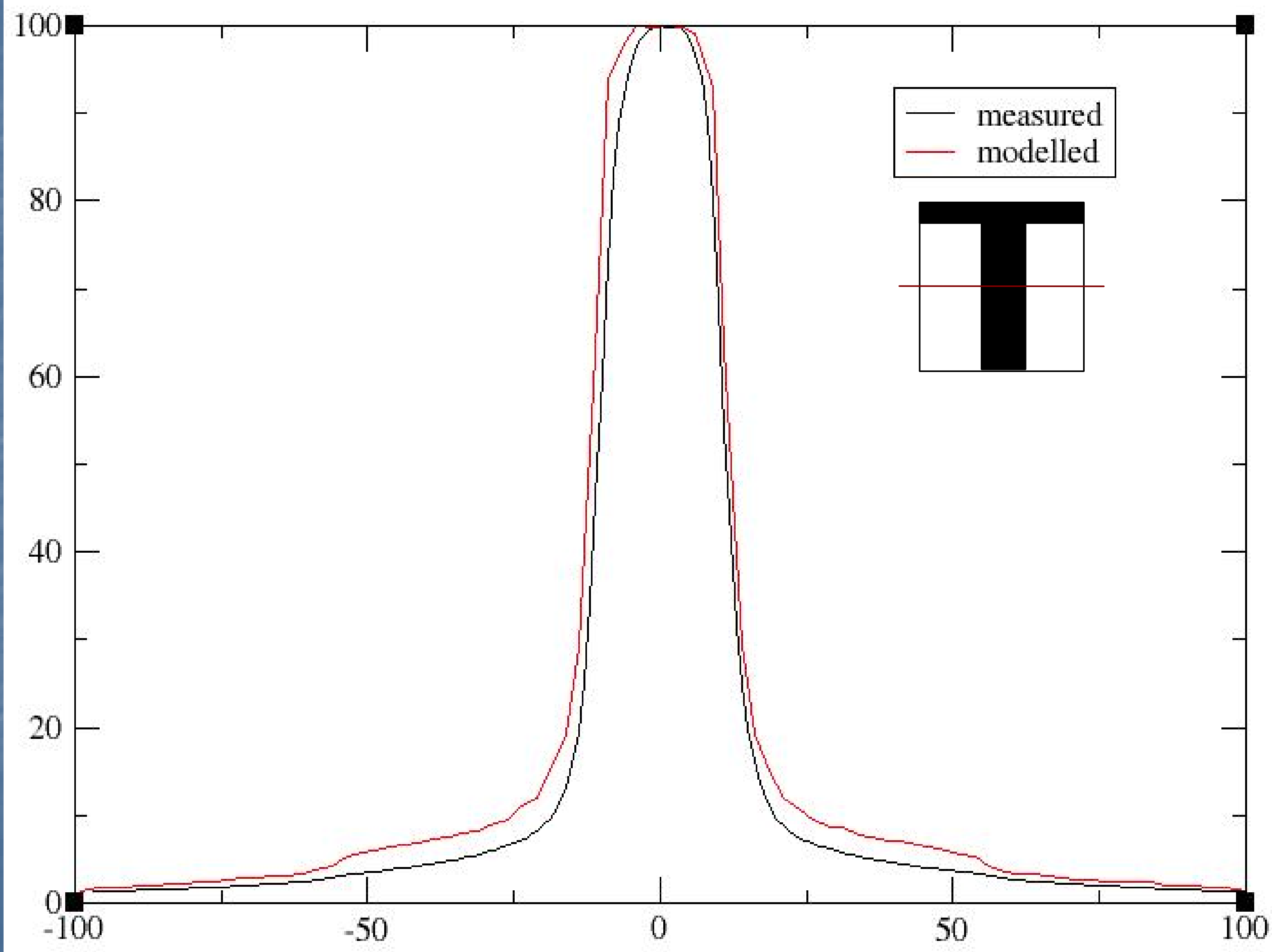
- Monte Carlo often referred to as *embarassingly parallel*! In other words, using *n* processors will decrease runtime by a factor of *n*

- Intermediate output from the code includes large *phase space files* (up to 2GB) so access to large amounts of disk space also very useful


6MV Depth Dose curves
measured 5x5 cm field
modelled 5x5cm field
100
80
60
40
20
0
0
50
100
150
200
250
300
depth (mm)


10MV Depth Dose curves
2x2 modelled
2x2 measured
100
80
60
40
20
0
0
100
200
300
400
depth (mm)

6MV Profiles in T-shaped field



“We’ll be back.......(hopefully)”

Thank you for your attention !!

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