

# HadronTherapy simulations with **GEANT4** at NPL

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GEANT4 Workshop

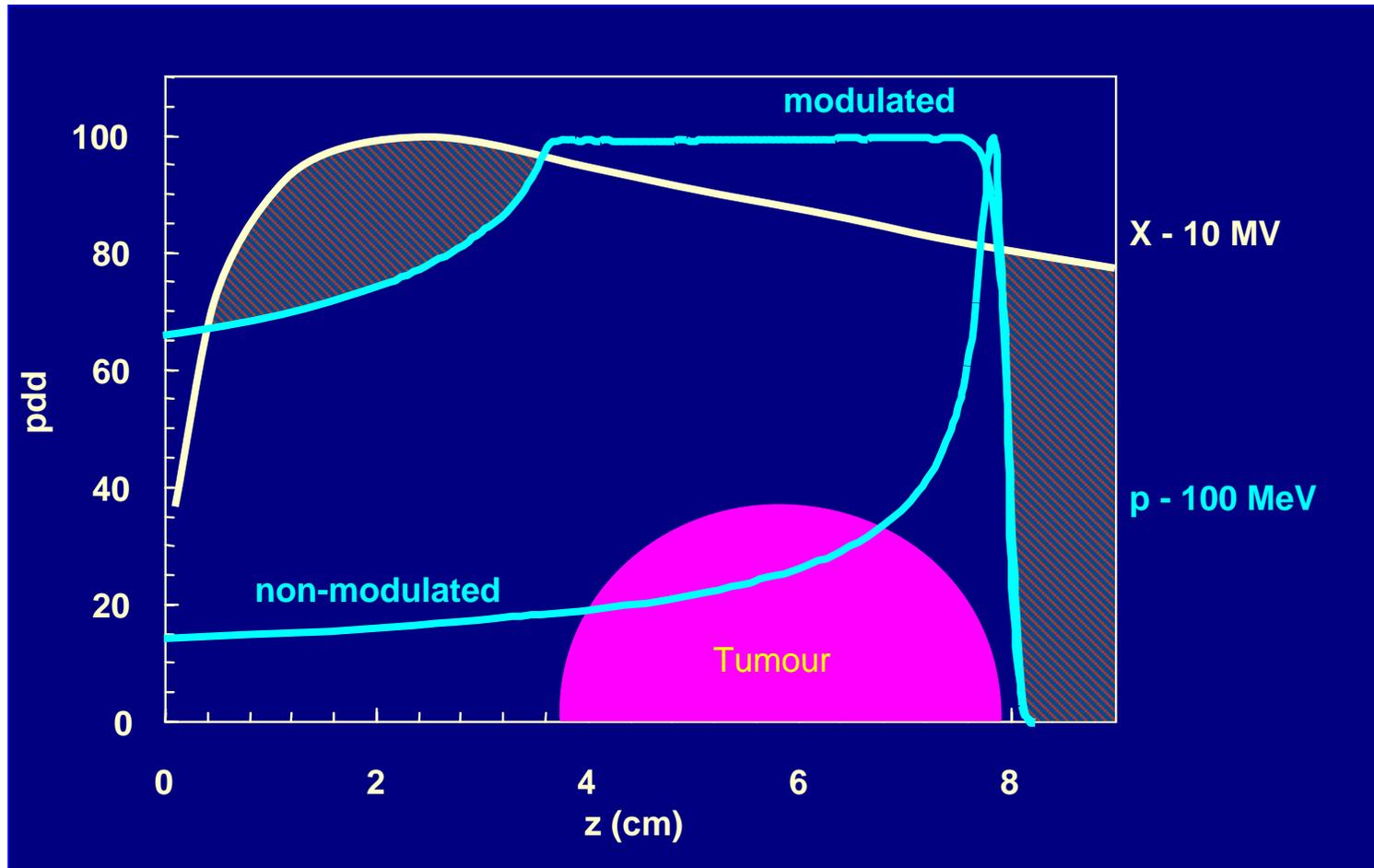
Genoa, Italy

13 - 20 July 2005

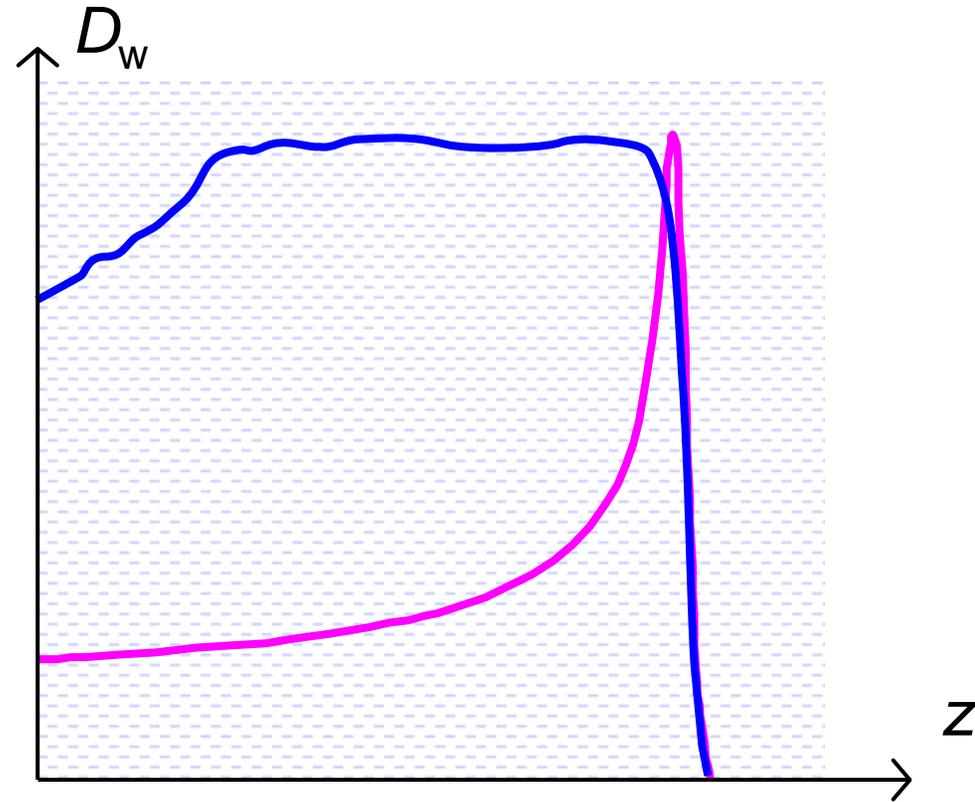
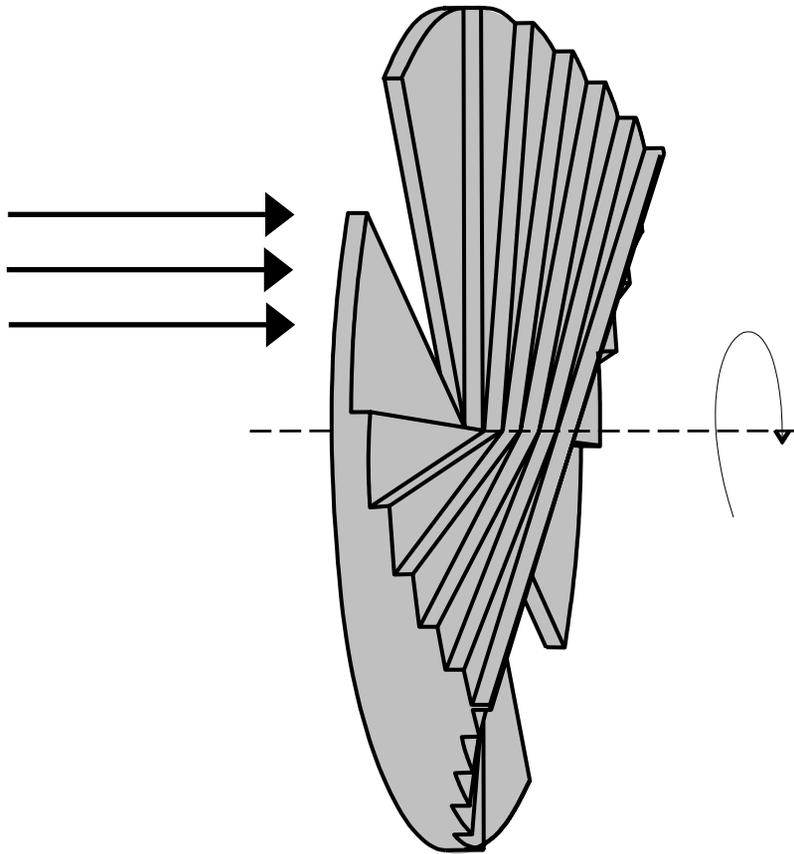
- Brief introduction and advantages of proton therapy
- GEANT4 simulation of a typical low-energy clinical proton therapy facility:
  - 62 MeV ocular proton beam at the Clatterbridge Centre for Oncology (CCO), UK
  - presented at Monte Carlo 2005, Chattanooga, Tennessee, April 2005
  - co-authors: H. Palmans, C. Baker, A. Kacperek
- Compare calculated dose distributions for full-energy and modulated CCO beam line with measurement
- [Key physical processes and dose distributions for 50, 150, 250 MeV monoenergetic beams]
- Conclusions and future work

- Proton therapy is on the increase due to commercial availability of turnkey facilities and reduced cost
- Main treatment site is eye (melanoma) but more and more deep seated tumours
- Dosimetry is not as well established as for x-ray therapy; NPL has research projects for improved proton dosimetry
- Monte Carlo is essential for studying dosimetry, detector perturbation factors, stopping powers, etc.

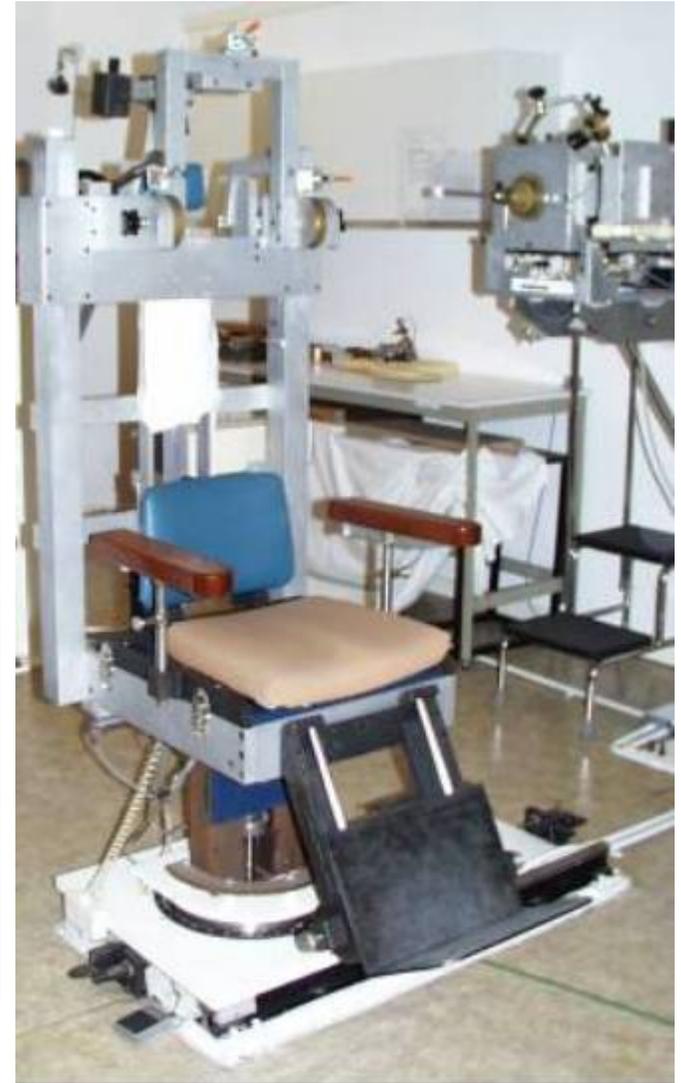
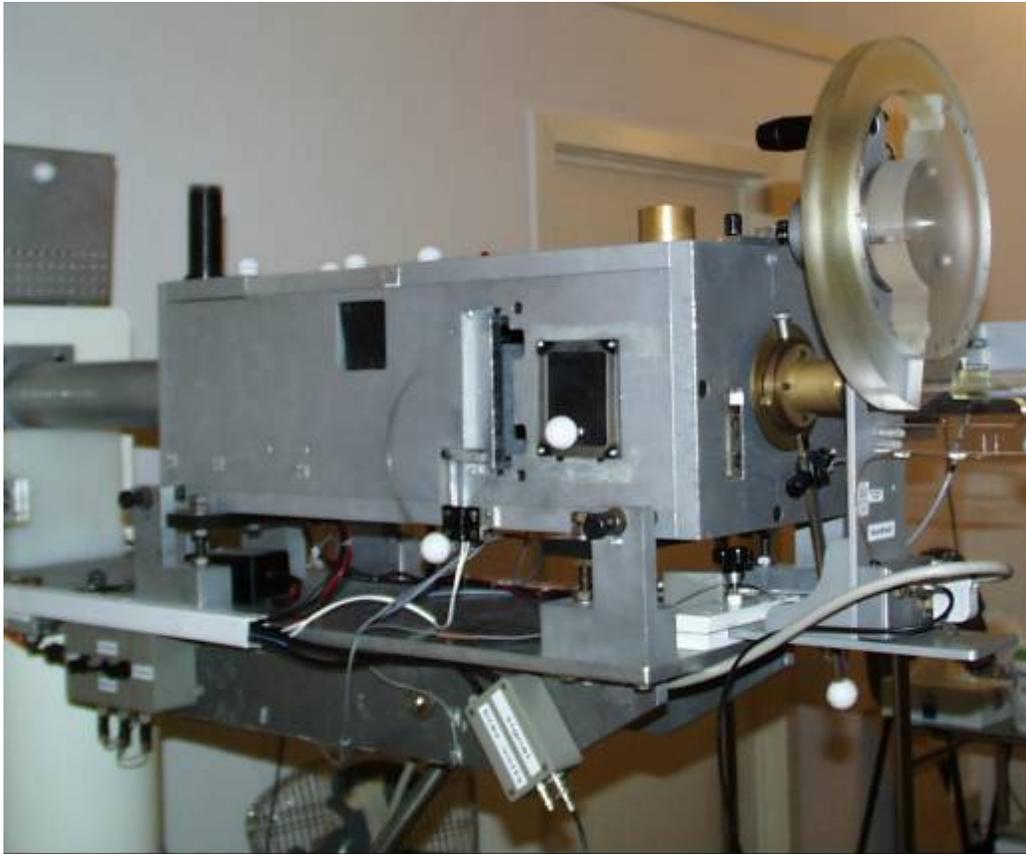
# Background: Improved therapy using protons versus x-rays



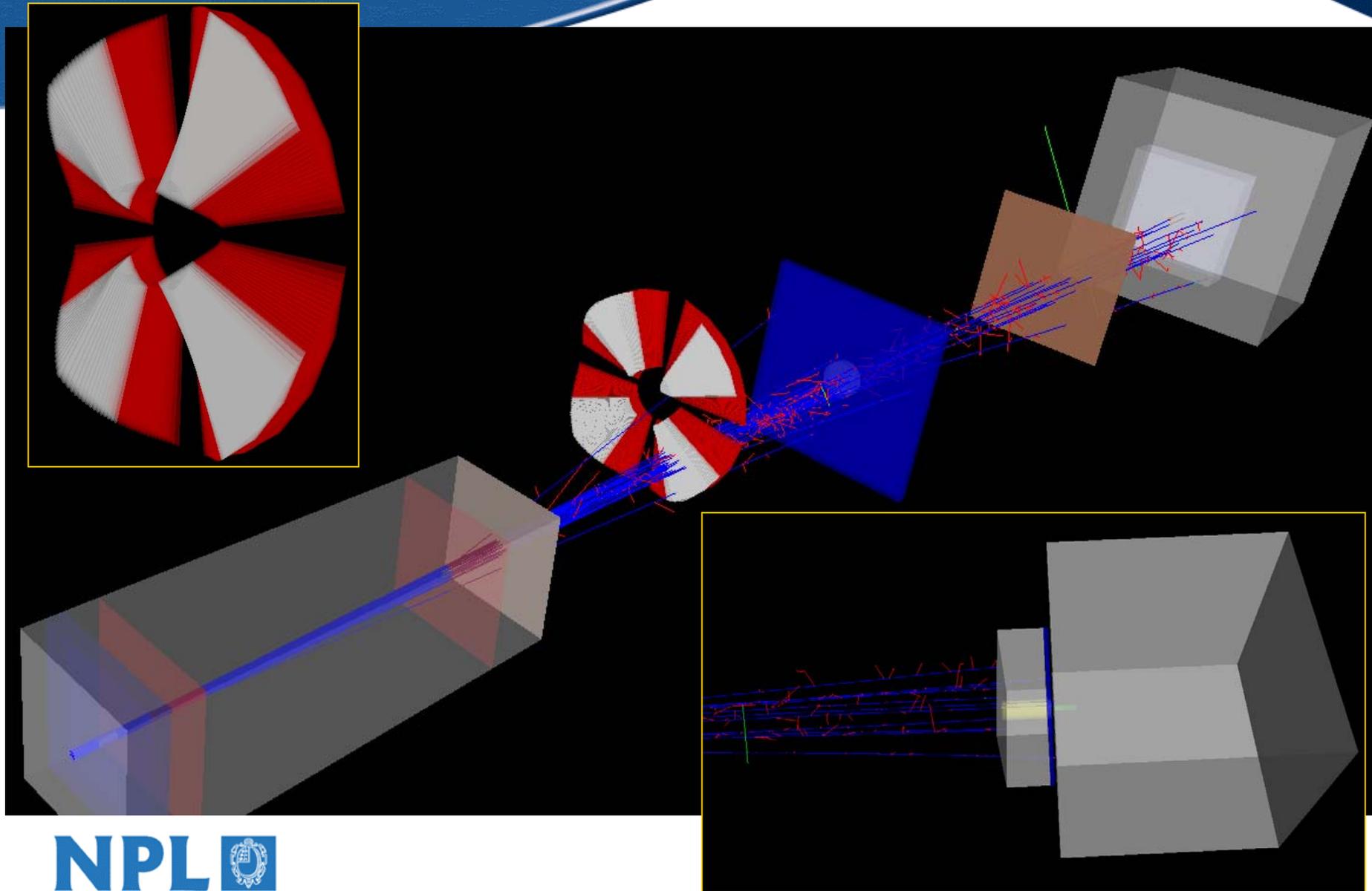
# Principle of range modulation



# CCO proton beam line – treatment room



# CCO proton beam line – VRML



## **GEANT4 with Low Energy EM Physics package (G4EMLOW 2.3).**

- a *toolkit* for the Monte Carlo simulation of the passage of particles through matter.

## **Physics processes (first iteration)**

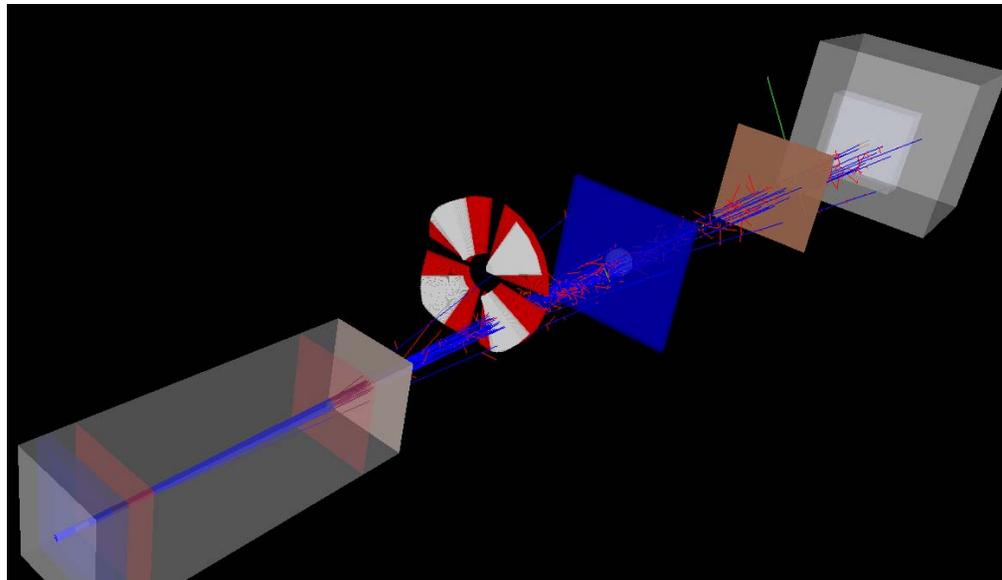
- ICRU 49 parameterisation: proton energy loss (EM interactions)
- LHEP and HEP models: hadronic processes (inelastic nuclear interactions)
- recommended for use in medical applications (?)

## **Cuts**

- 0.02 mm in phantom ( $\ll$  dose scoring region), 10 mm elsewhere
- minimize any dependencies of particle transport on geometry

- **HadronTherapy (GEANT4):**

- derived from the advanced example distributed with GEANT4
- calculates depth dose and lateral dose distributions in a PMMA phantom for the CCO beam line
- modulated and full-energy (no modulator wheel) beams



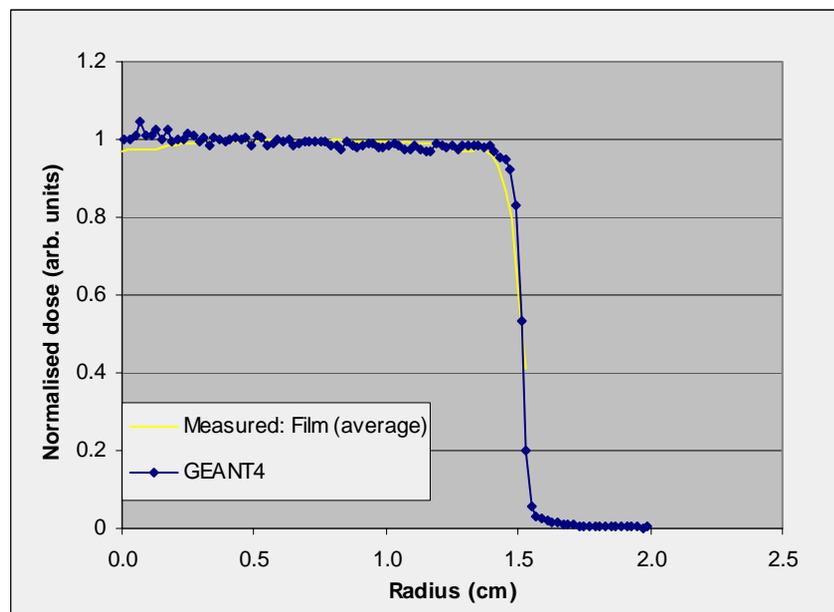
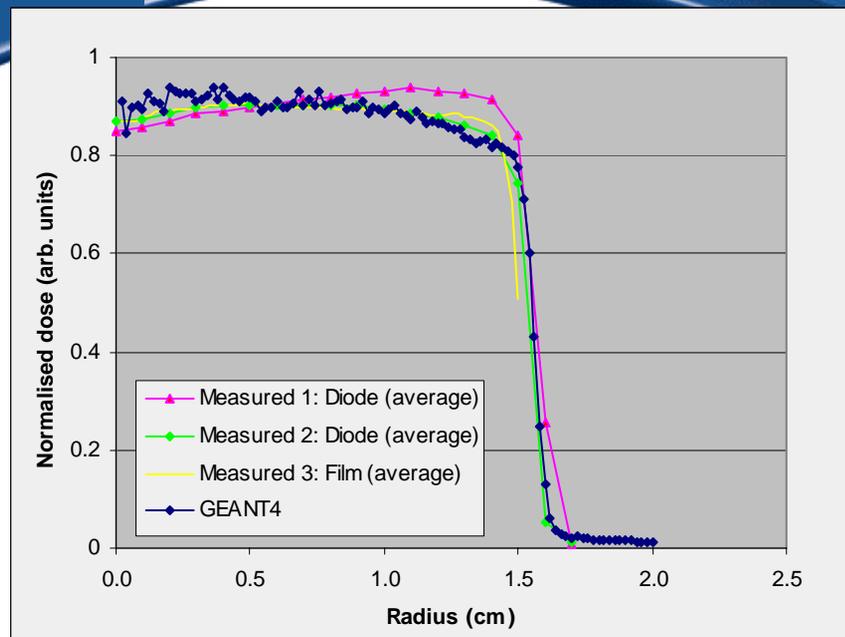
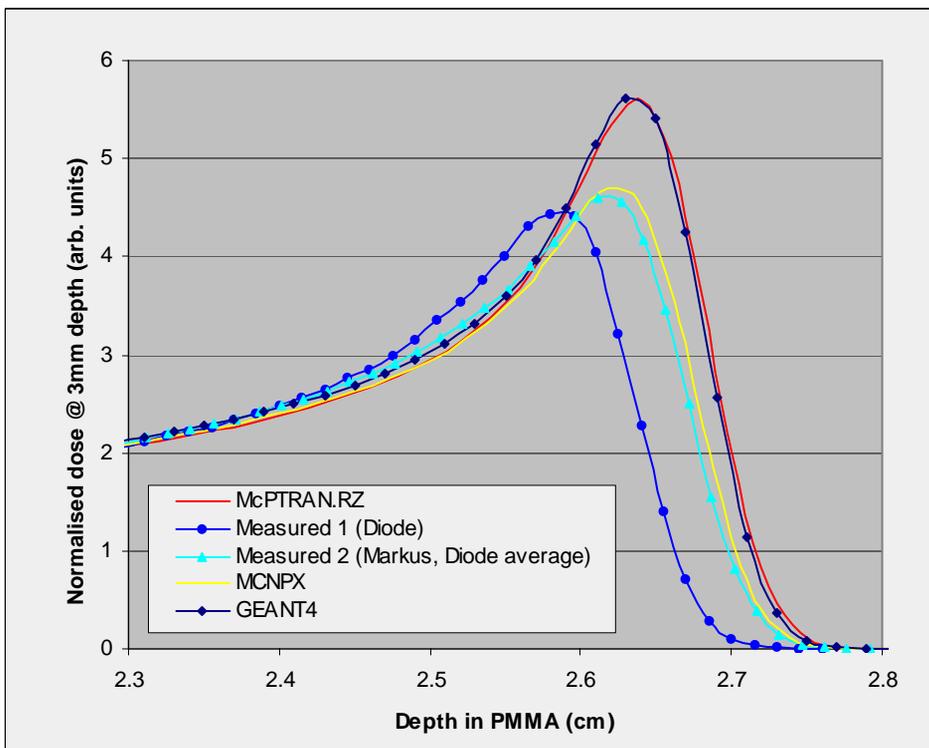
## Compare with:

- McPTRAN.RZ: Palmans, NPL (2005)
- MCNPX
- Film and diode measurements

# Depth & lateral dose distributions in PMMA: CCO full-energy beam

Lateral dose:  
front face

Depth dose

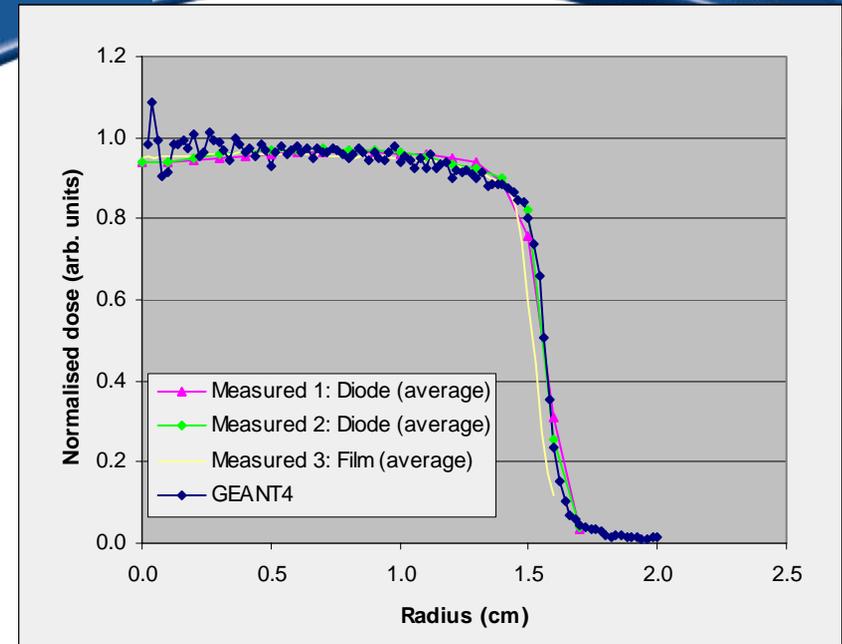
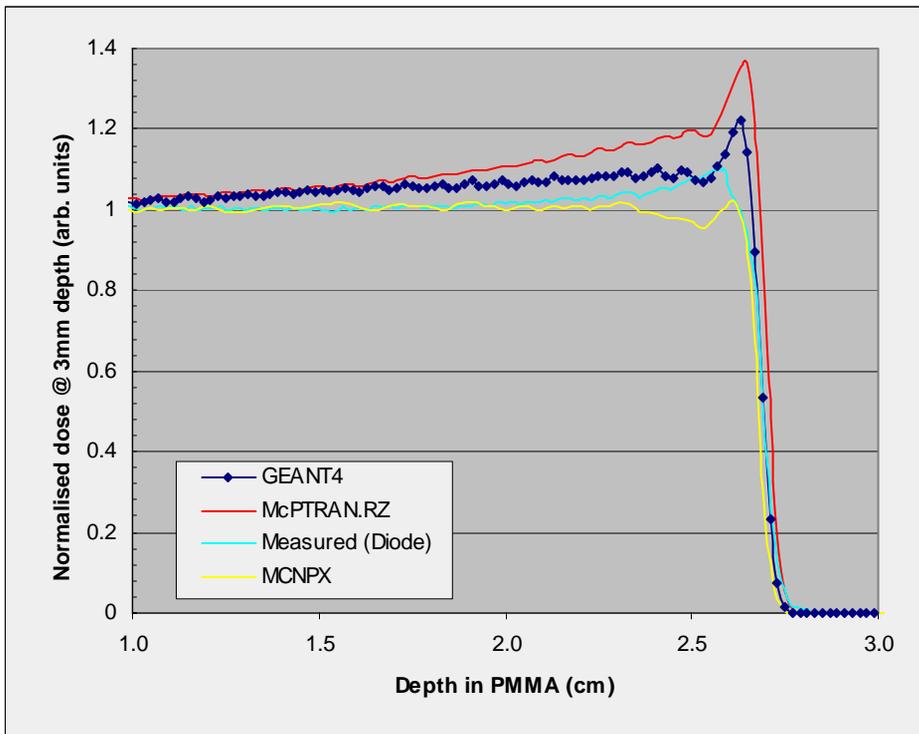


Lateral dose:  
 $0.5 \times r_0$

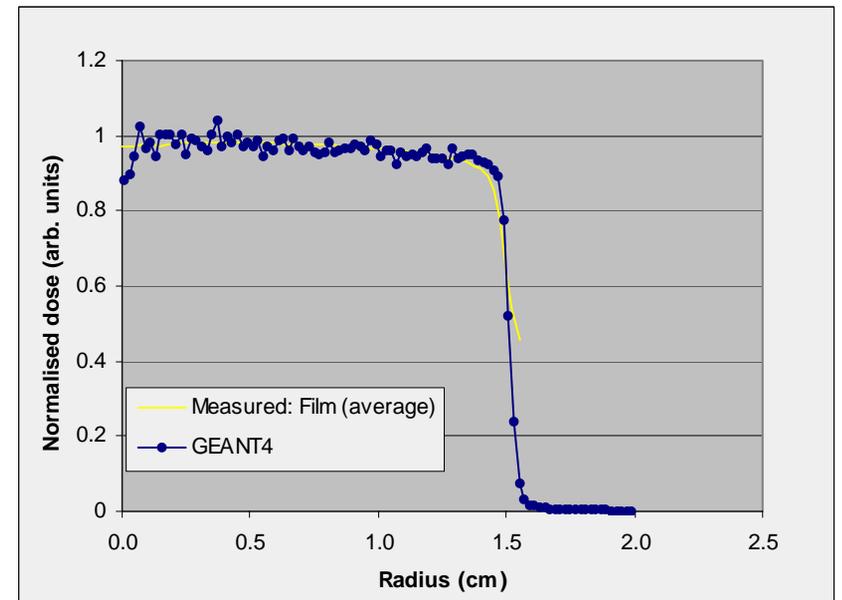
# Depth & lateral dose distributions in PMMA: CCO full modulation

Lateral dose:  
front face

Depth dose

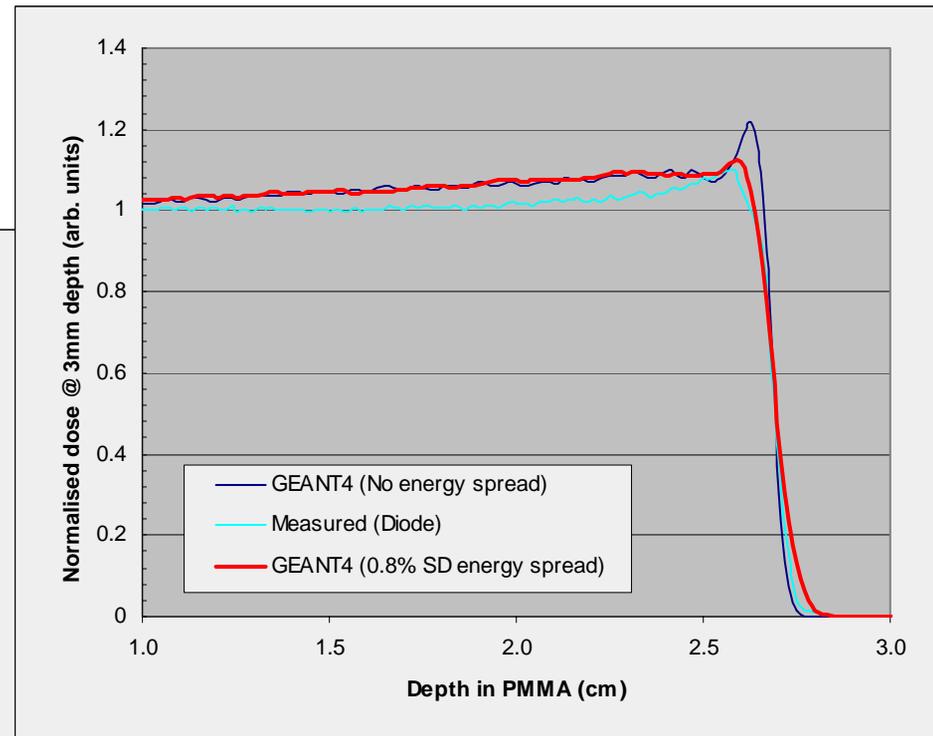
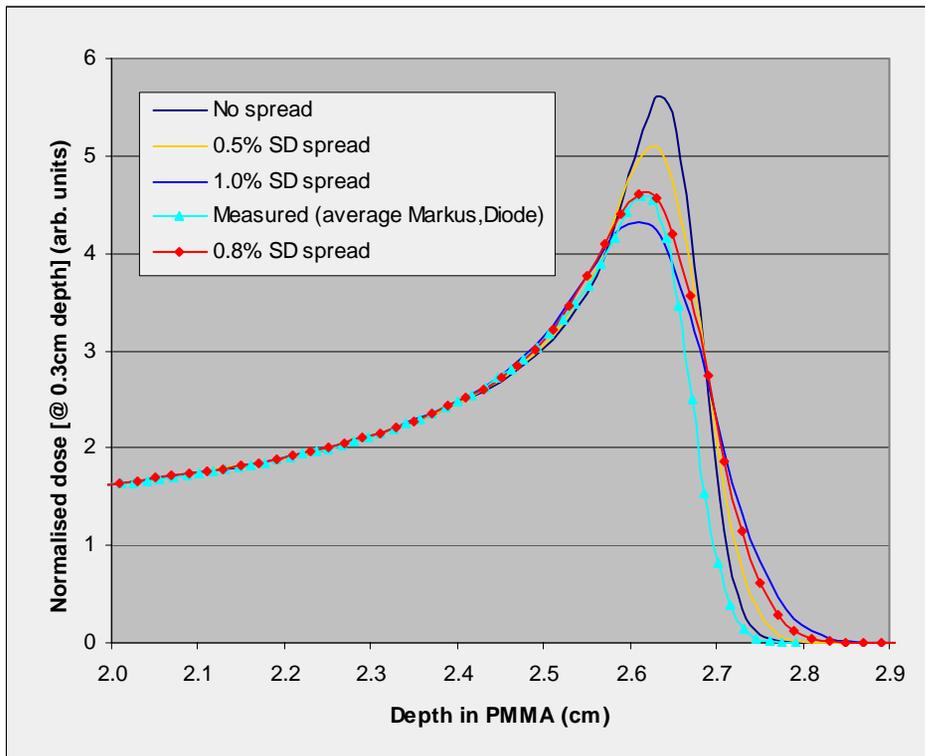


Lateral dose:  
 $0.5 \times r_0$



# Depth dose distributions in PMMA: Gaussian energy spread

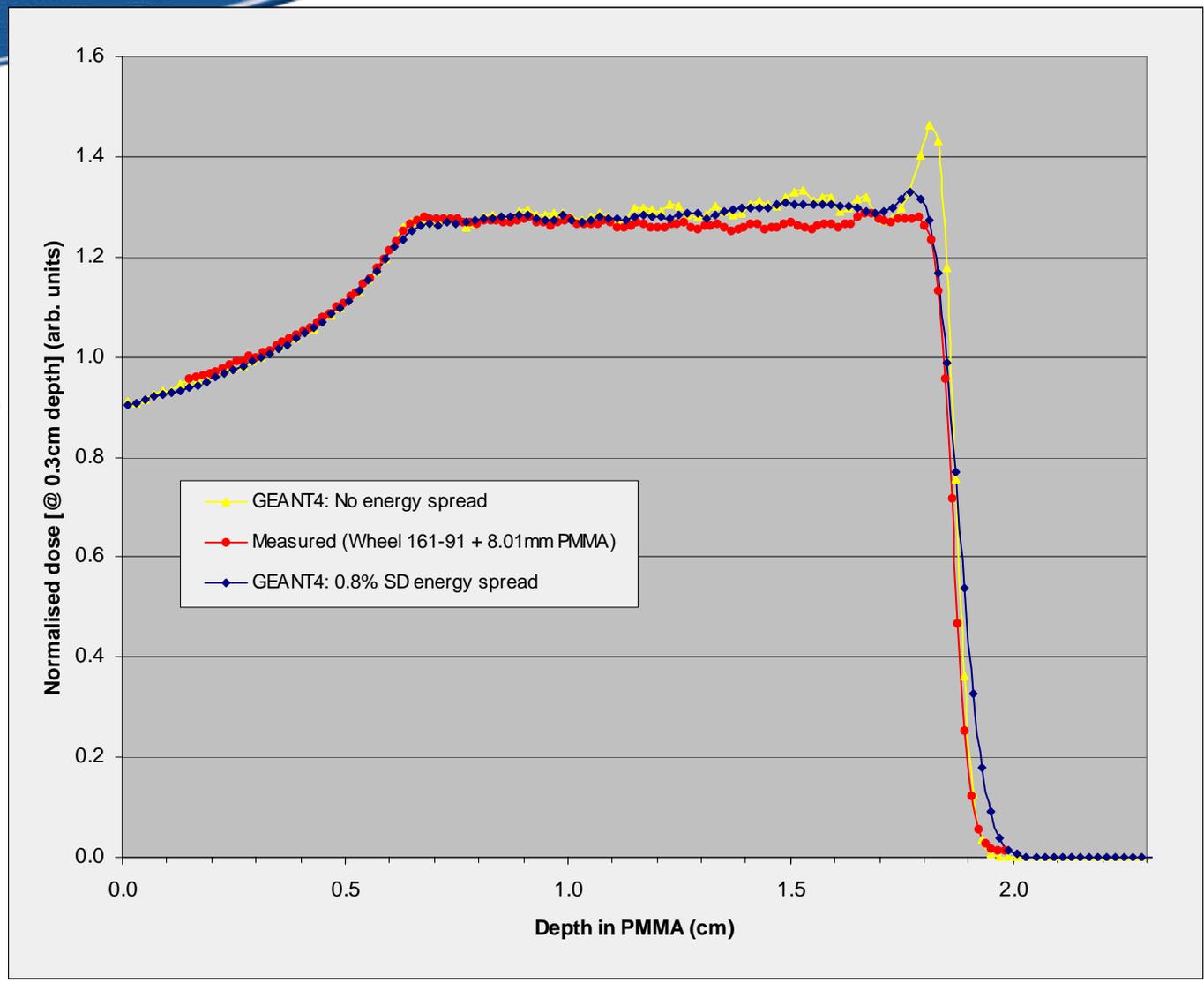
## Depth dose: full energy



## Depth dose: full modulation

# Depth dose distributions in PMMA: typical clinical conditions

Mod wheel: **161-91**  
with range shifter:  
**9mm Eye Tissue Eq.**  
(8.01 mm PMMA)



- **GEANT4: low-energy clinical proton beam (CCO)**
  - depth dose profiles:
    - overestimates Bragg peak by ~20%
    - large energy spread improves agreement at end of range & gives good agreement for a typical clinical condition
  - lateral dose profiles:
    - good agreement with measurement (both at FF and depth)
    - penumbra accurately reproduced
  - some dependence on GEANT4 models, daily beam variations and type of detector
- **GEANT4: compared with other codes (clinical energies)**
  - different physical models (or their implementation) in the MC codes give distinct differences in dose distributions at these energies
  - improvements in GEANT4 model used is still needed (or a better physical model chosen)

- Proton stopping powers for clinical beams:
  - directly using Monte Carlo
  - from fluence spectra at depth
- Perturbation factors for detectors
- Graphite-to-water conversion factors
  - proton calorimetry (NPL)