ORANGE for dose calculations

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Outline

- Introduction: why ORANGE?
- ORANGE features
- Applications
  - γ, e^- dose
  - (high energy) neutron dose
  - proton dose
- Timing
- Conclusions

Why ORANGE?

- Increasing demand for Monte Carlo dose (distribution) analyses
- Increased need for additional features in Monte Carlo dose analyses (*e.g.* charged particles transport)
- Increased demand for *fast* Monte Carlo dose analyses

ORANGE features

- Based on MCNP-4C3 and on MCNPX-2.5e
- Faster, dedicated algorithms geared toward dose distribution calculations
- Identical tracking to MCNP(X)
- Retains all functionality of MCNP(X)
- $\longrightarrow$ faster *general purpose* Monte Carlo

Algorithms in ORANGE

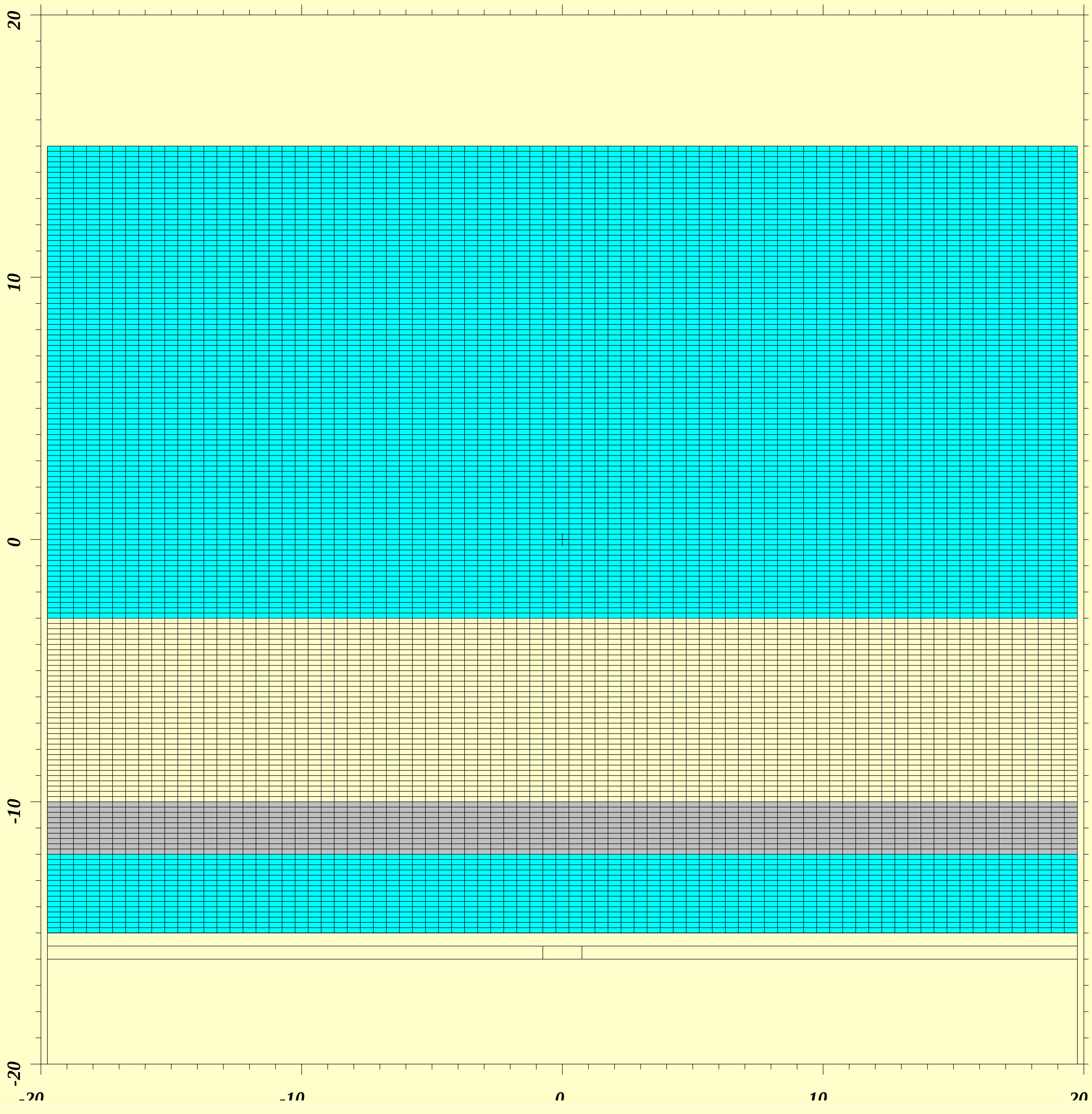
- Flexible algorithm to define dose grid (irregular grid possible)
- Highly efficient scoring algorithm:
  - ORANGE calculates dose contribution per *interaction*
  - MCNP tally F8 is per *cell* (*i.e.* slow!)
  - MCNPX mesh Tally 3 is based on *energy loss along particle track*
- The resulting dose tally is faster ...
- ... *and* more accurate

Application of ORANGE: γ, e^- dose

- ORANGE validated against
  - EGS-NRC code
  - experimental data
- Benchmark: ICCR-XIII benchmark
- Details: see

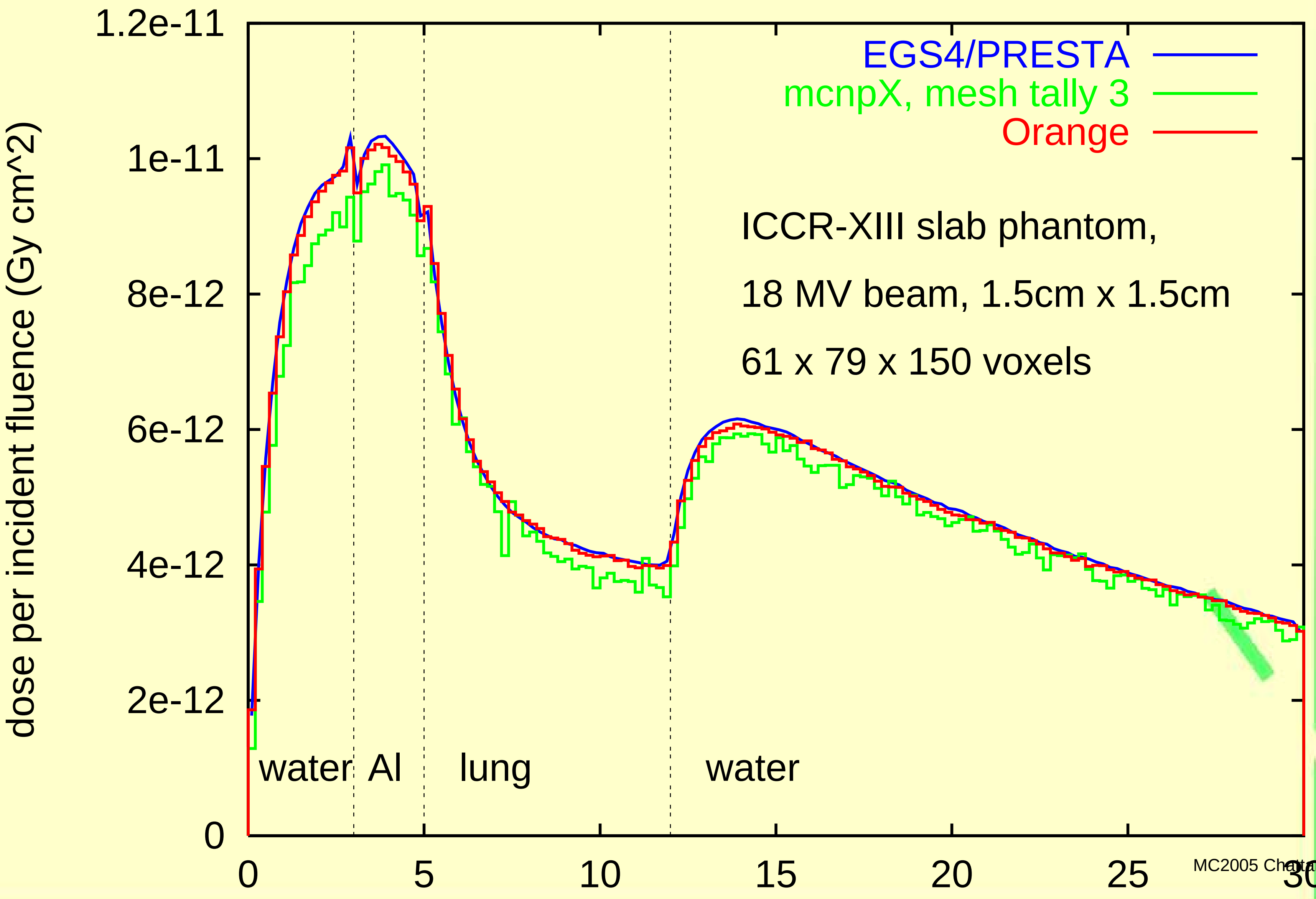
  W. van der Zee, A. Hogenbirk, and S.C. van der Marck, ORANGE, a Monte Carlo dose engine for radiotherapy, Phys. Med. Biol. **50** *(2005) 625 – 641*

ICCR-XIII geometry



Results: γ, e^- dose

ORANGE *vs* MCNPX, EGS4



Neutron dose

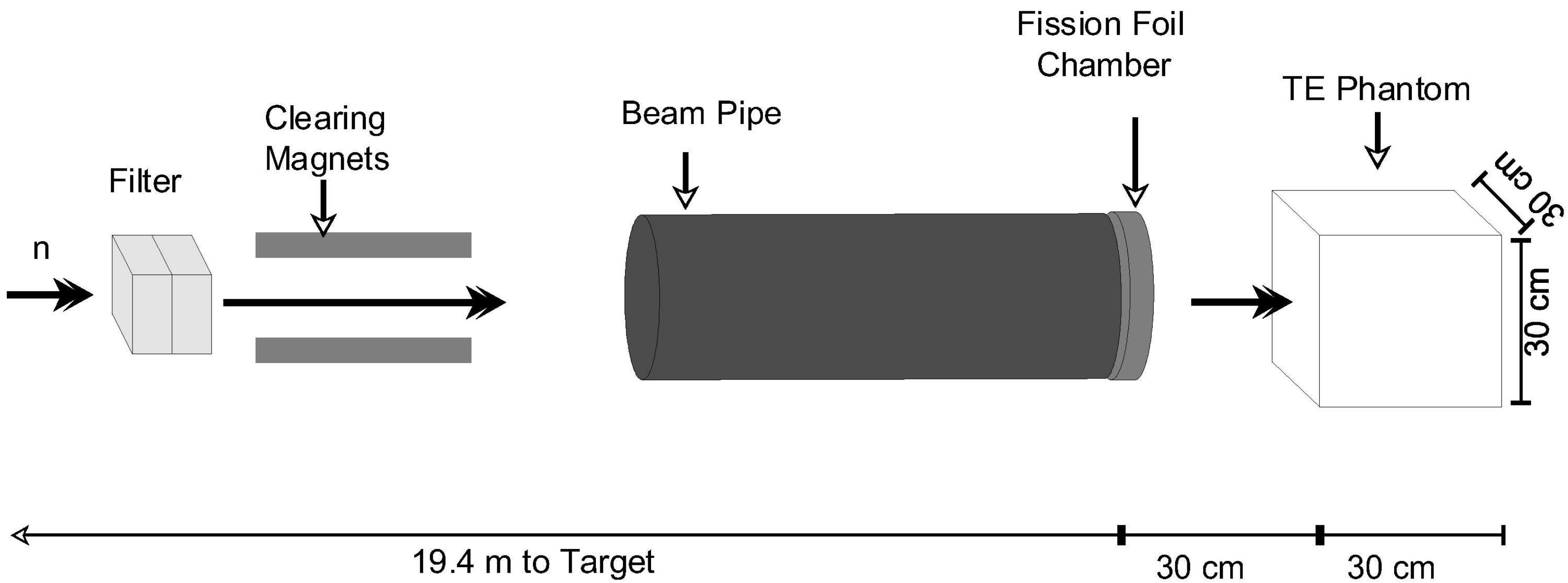
Sutton experiment (LANL):

M.R. Sutton, "High energy neutron dosimetry",

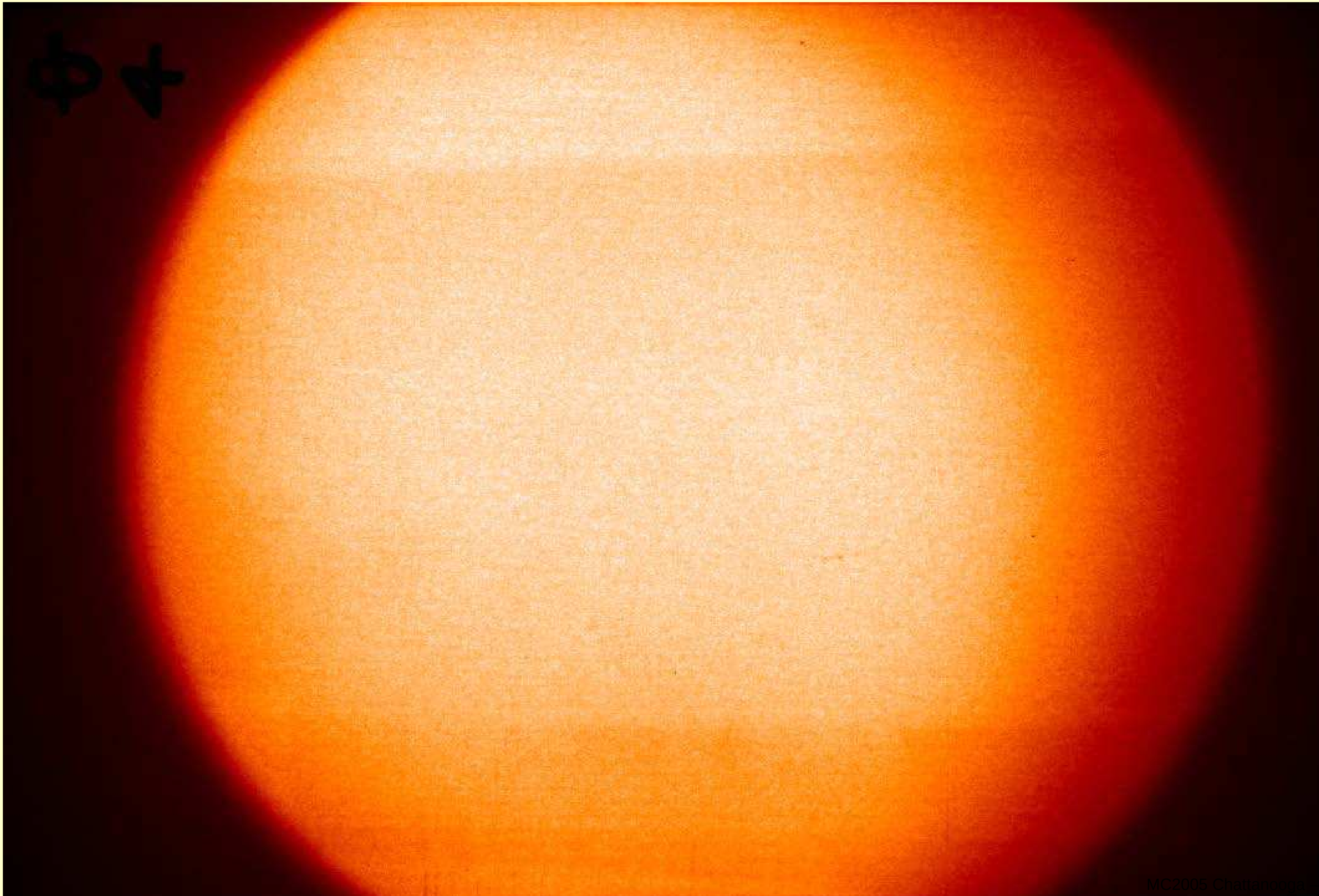
PhD Thesis, Georgia Inst. Techn. (2001)

- Neutron beam; E < 800 MeV
- Circular beam shape; radius 7.8 cm
- $30 \times 30 \times 30$ cm^3 phantom; Goodman liquid 1.07 g/cc
- 5 beams: unfiltered,
  lead (5cm, 10cm),
  CH_2 (40cm, 60cm)
- Dose measured along central axis and profiles at several depths

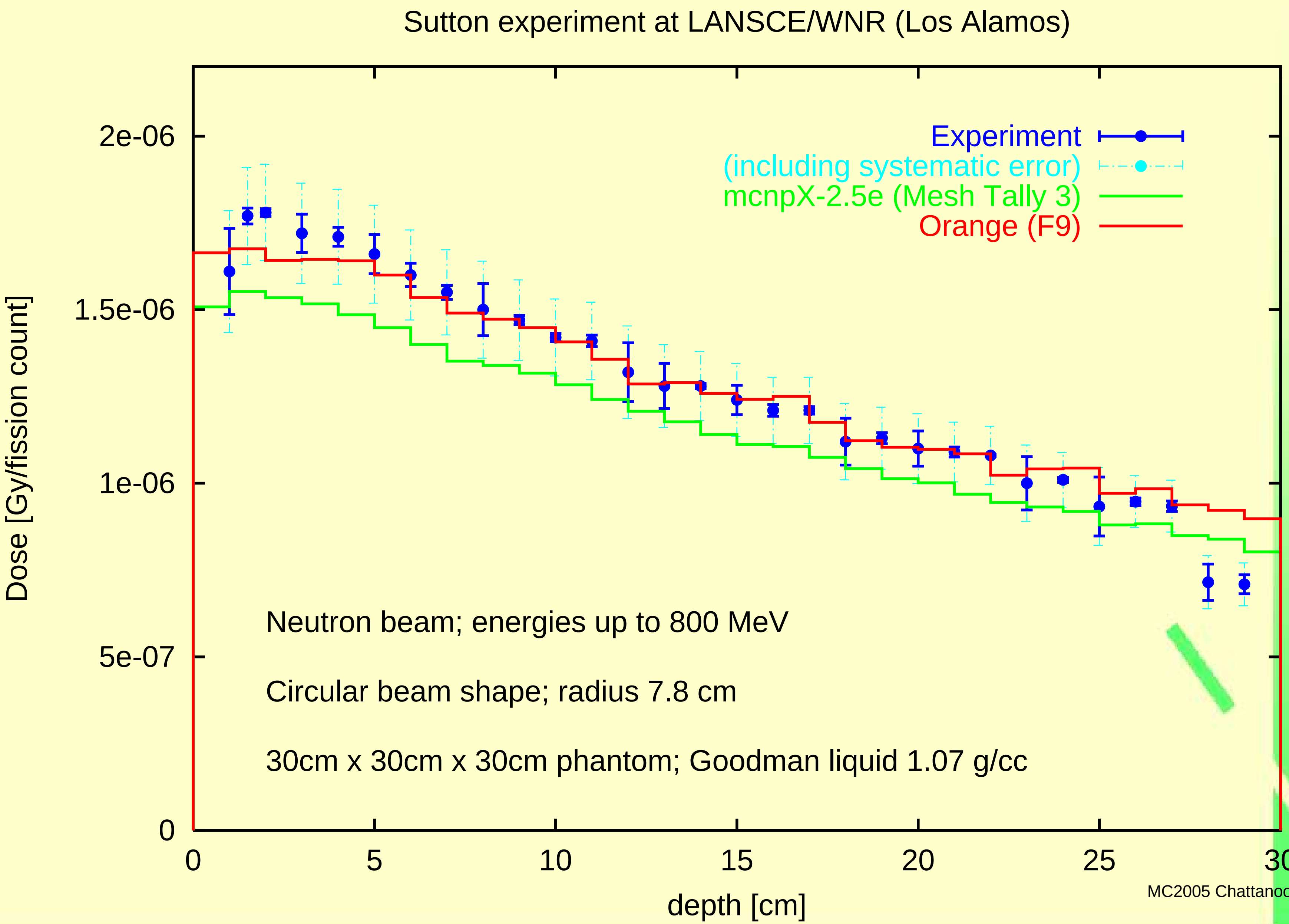
Experimental configuration



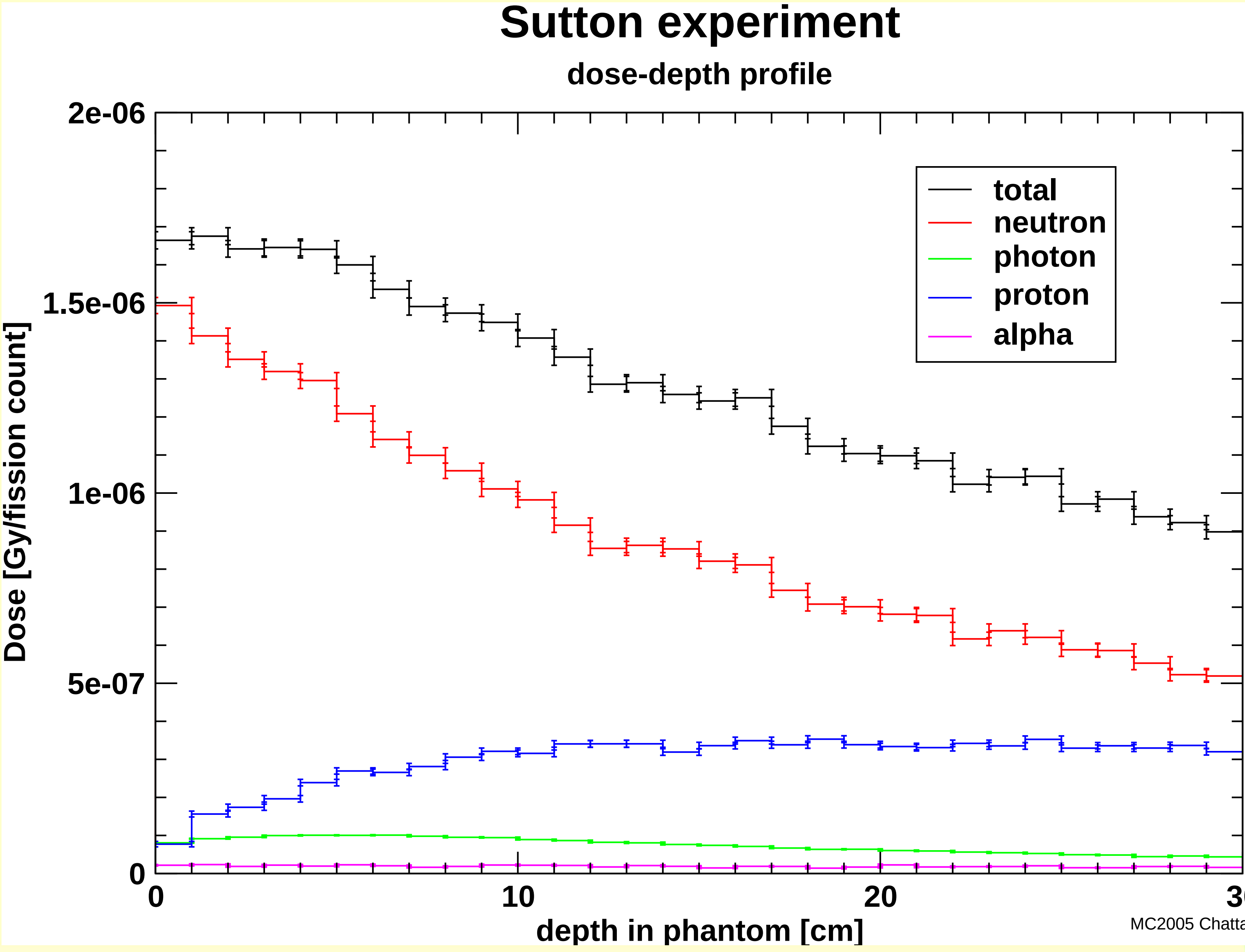
Neutron beam profile



Results: unfiltered beam



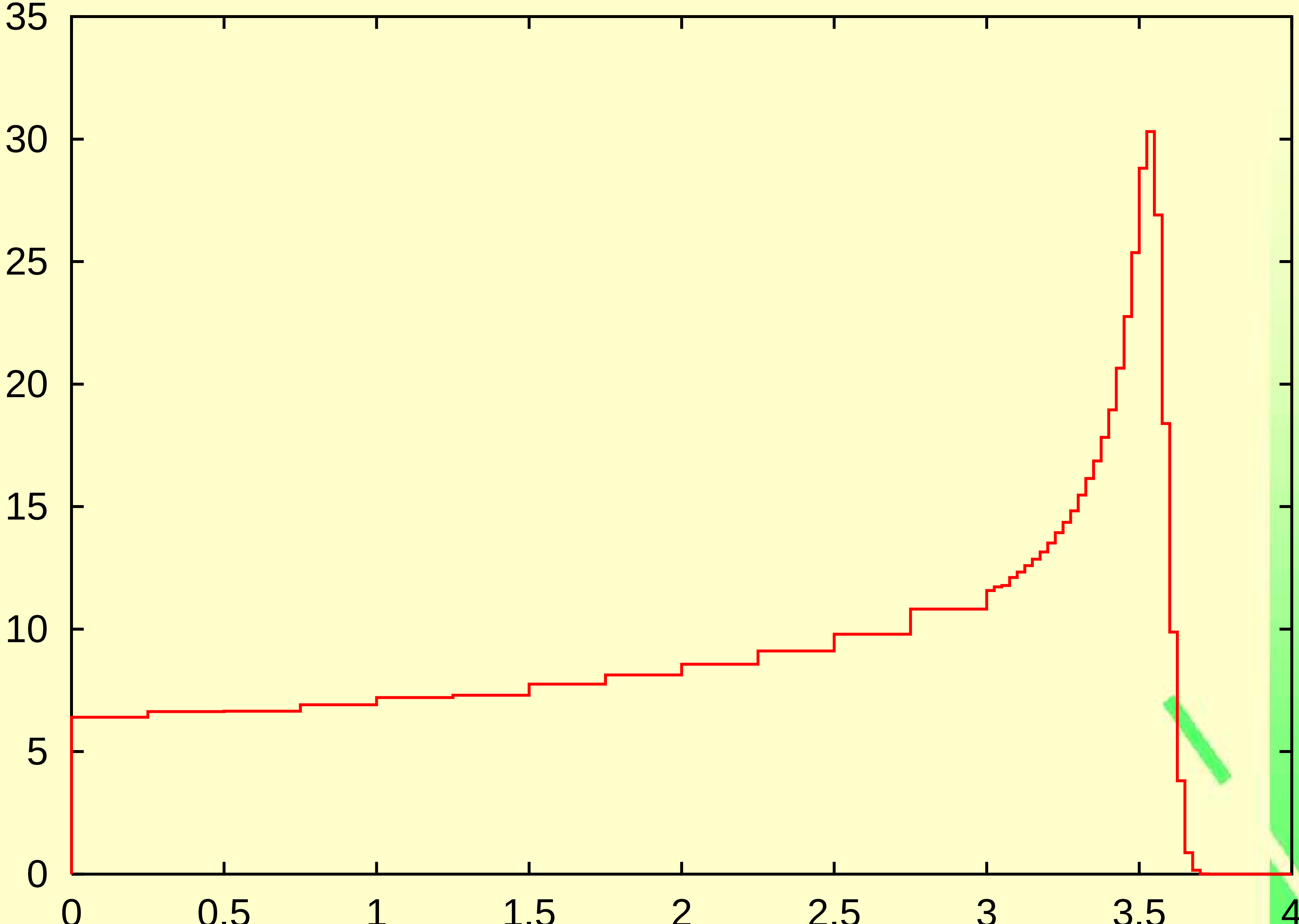
Results: dose decomposition



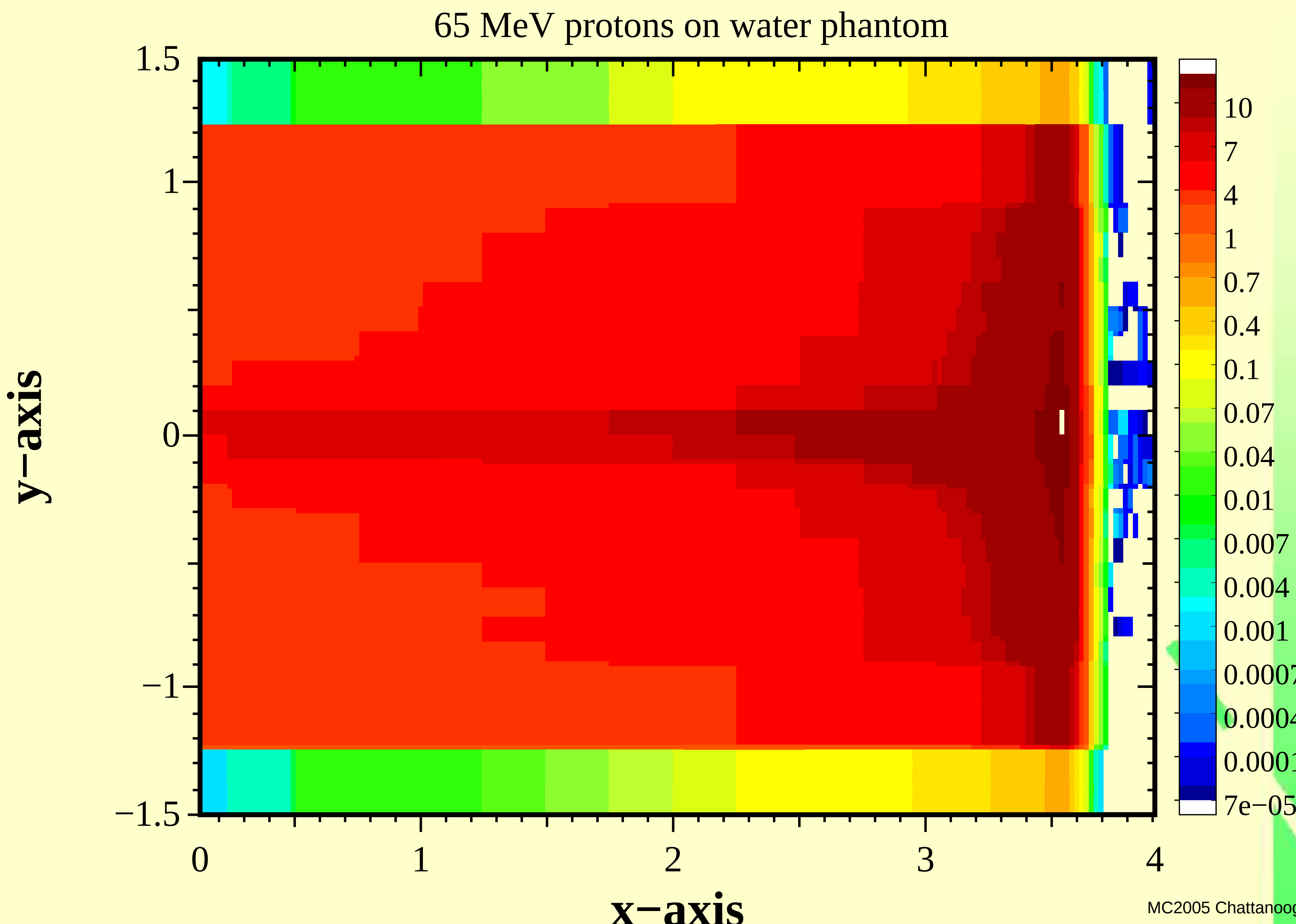
Proton dose

- Sample calculation using water phantom
- Calculation of dose deposition for 65 MeV proton beam
- Comparison with MCNPX mesh tally 3

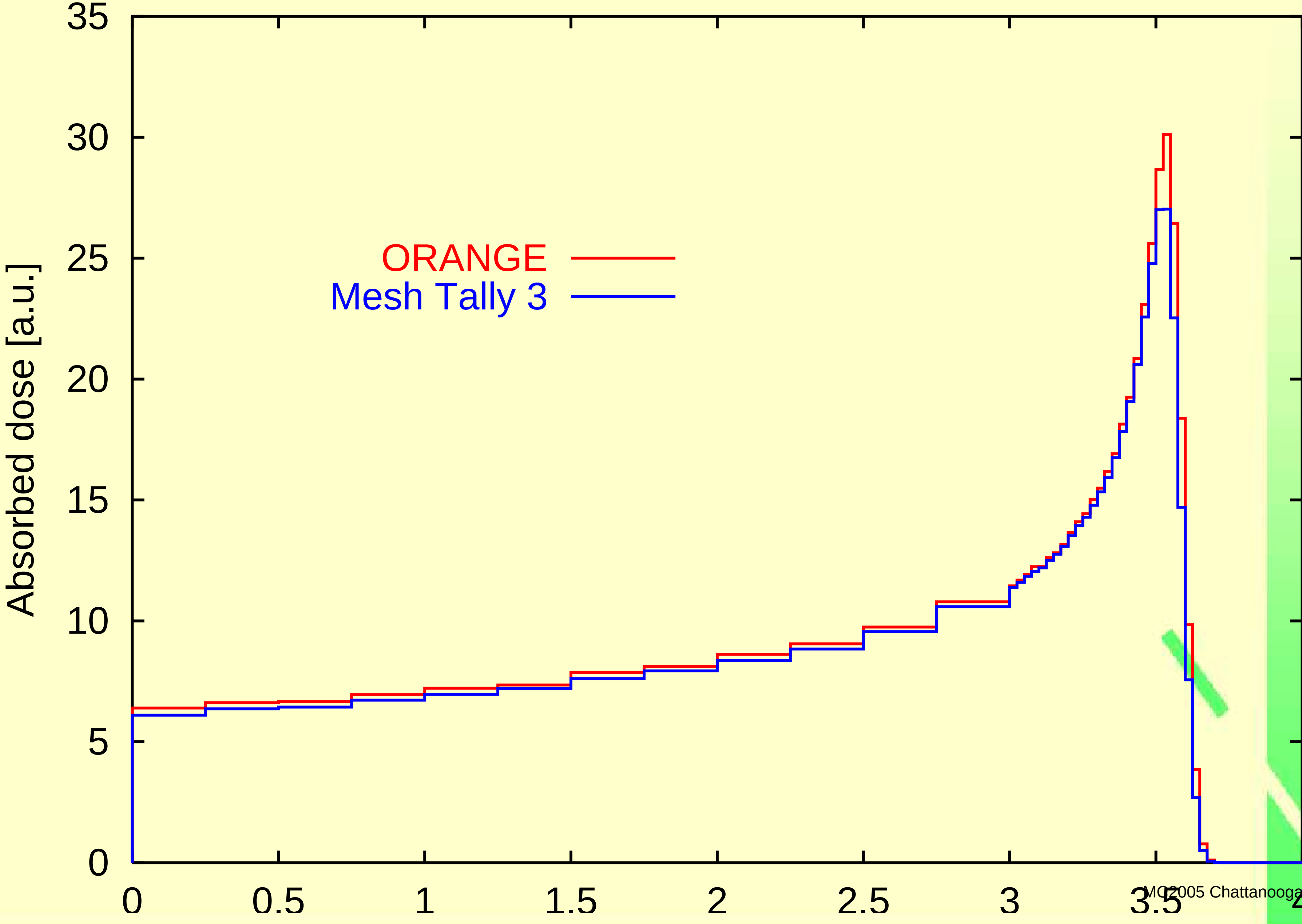
Proton pdd (65 MeV)



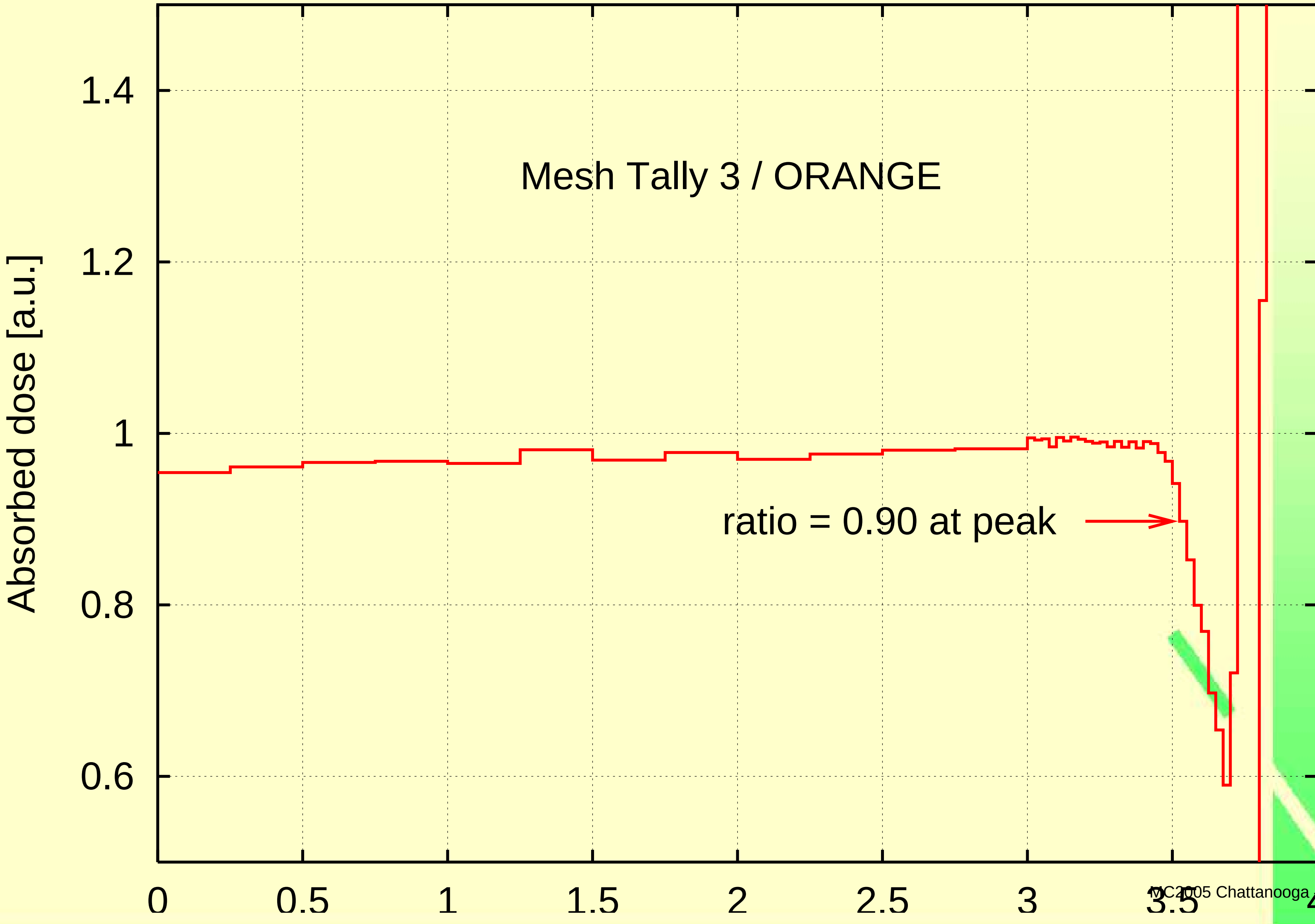
Proton dose distribution (65 MeV)



ORANGE/MCNPX comparison (I)



ORANGE/MCNPX comparison (II)



Timing

The speed increase of ORANGE *vs.* MCNP(X) depends on

- Particle type
  - neutrons, γ's: large increase in speed
  - charged particles: less pronounced increase in speed
- Number of voxels (more voxels $\rightarrow$ larger increase)

Examples are:

- ICCR-XIII: Orange $1000\times$ faster ($150 \times 79 \times 61$ voxels)
- Sutton expt: Orange $2\times$ faster ($30 \times 30 \times 30$ voxels)
  $8\times$ faster ($60 \times 60 \times 60$ voxels)
- Protons 65MeV: Orange $2\times$ faster ($76 \times 28 \times 28$ voxels)

Conclusions

- ORANGE has been developed, based on MCNP(X)
- All physics in MCNP(X) preserved
- Applicable for $\gamma, e^-, n, p, \alpha, \ldots$
- Dose results are good (within 2%)
- Tremendous speed-up w.r.t. MCNP(X)
- ORANGE excellent candidate for dose engine in (charged particle) RTP packages
- ORANGE now based on MCNPX-2.5e, soon on MCNPX-2.5f

Timing: ORANGE vs. MCNPX tally 3

- $30 \times 30 \times 30$ cm^3 water phantom
- 6MV photon beam
- In CPU minutes on a 2.4 GHZ Pentium PC:

N_V	N_p	MCNPX-2.5e	ORANGE
3^3	10^5	0.28	0.24
	10^6	2.71	2.30
10^3	10^5	0.42	0.33
	10^6	4.18	3.23
30^3	10^5	3.47	0.59
	10^6	34.27	5.74
60^3	10^5	22.69	1.04
	10^6	226.18	9.54

Timing: ORANGE vs. MCNP

- $30 \times 30 \times 30$ cm^3 water phantom
- 6MV photon beam
- In CPU minutes on 500 MHz Pentium-III:

N_V	N_p	per voxel		per collision
		MCNP	ORANGE	ORANGE
3^3	10^5	1.10	0.63	0.60
	10^6	7.99	6.06	5.91
10^3	10^5	60.67	1.10	0.68
	10^6	606.22	10.97	9.01
30^3	10^5	5487.00	6.37	1.71
	10^6	–	62.59	16.29
60^3	10^5	86731.11	48.85	3.02
	10^6	–	485.96	28.14