

Recent improvements in the BEAMnrc code

D. W. O. Rogers

Physics Dept, Carleton University

Iwan Kawrakow

B. R. B. Walters

Ionizing Radiation Standards

National Research Council

<http://www.physics.carleton.ca/~drogers>

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BEAMnrc

- a general purpose user-code for simulation of radiotherapy beams
 - built on EGSnrc
- freely available for non-commercial use
- lots of built in variance reduction to enhance efficiency, especially for accelerator photon beams

New statistical package

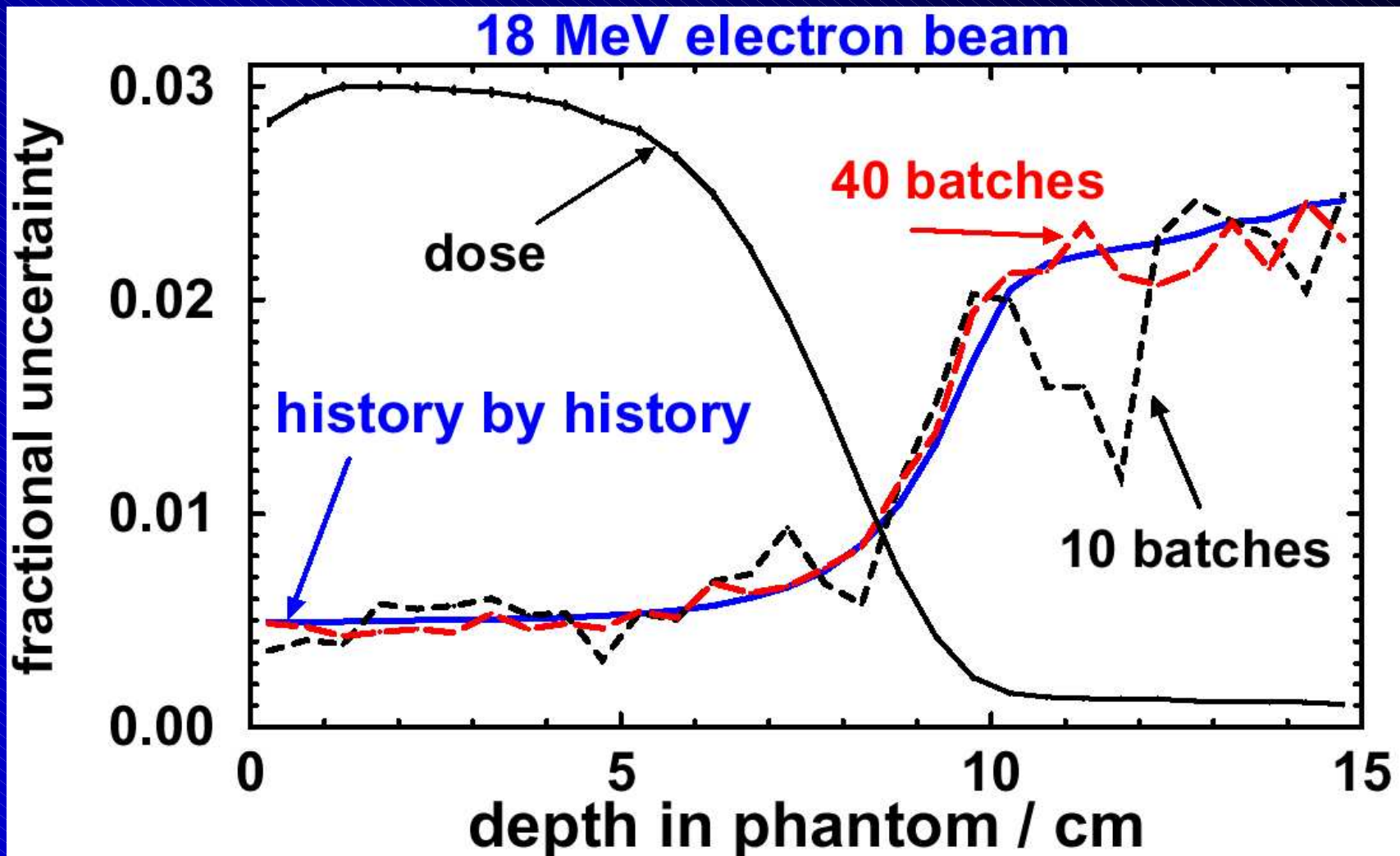
Batch method

- Break the cal'n into **N batches** and determine uncertainty by distribution of results for batches
- large uncertainty in the uncertainty

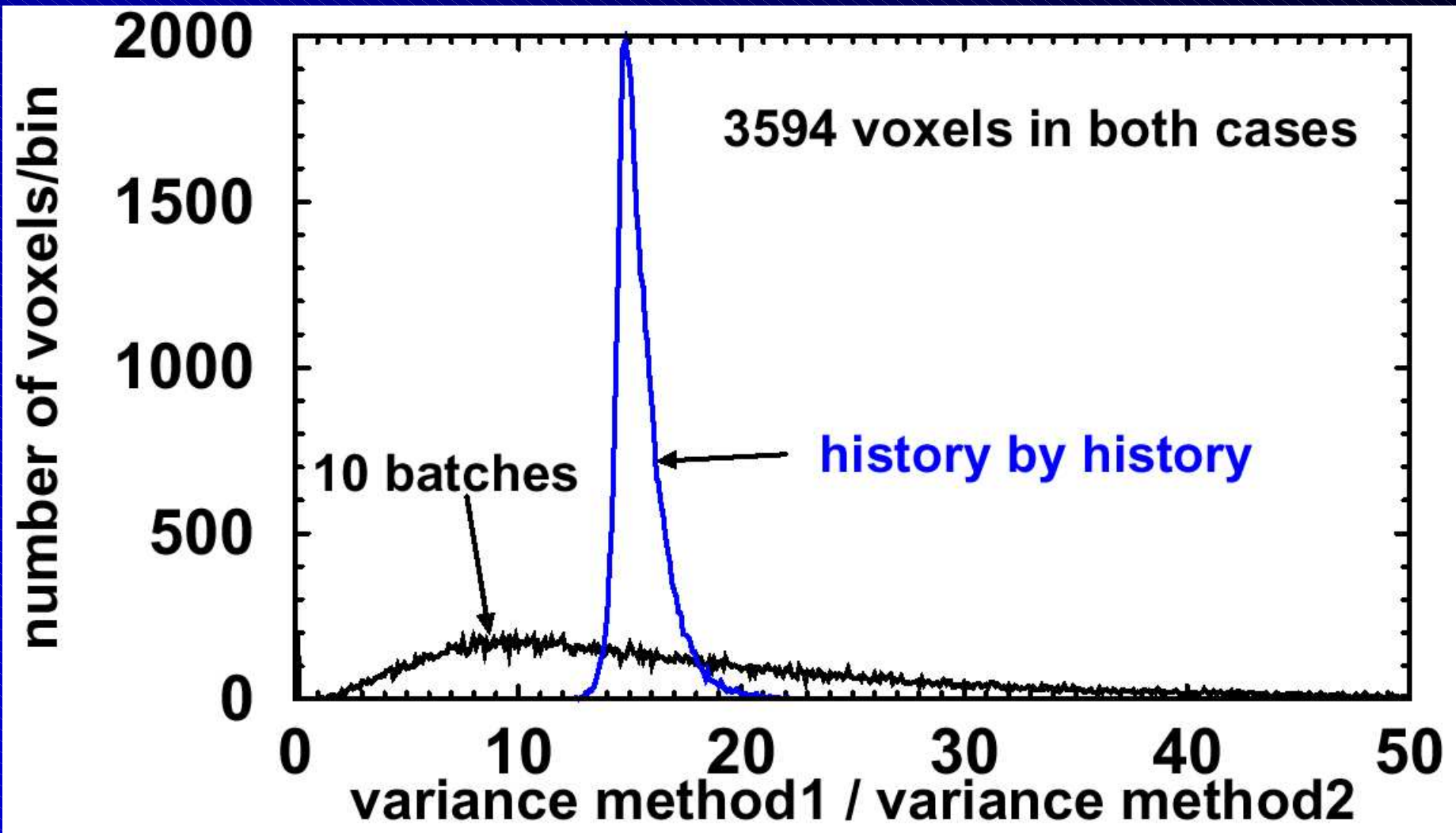
History by history method

- # batches = #histories
- much better estimate
- “trick” of Salvat allows for **efficient calculation**

History by history technique



Advantage of history by history



What is efficiency?

$$\epsilon = \frac{1}{\sigma^2 T}$$

T : computing time

σ^2 : variance on quantity of interest

- sum of uncertainty²

- **fluence** in 1x1cm² regions in beam

- **dose** on central axis or profile

Problems to overcome

-in photon accelerators, majority of time is spent **following electrons**

-most photons are absorbed in the **primary collimator**

Uniform Brem Splitting (UBS)

-when an electron undergoes a radiative event, create n_{split} photons with weight $1/n_{\text{split}}$

-overcomes most time being for electrons

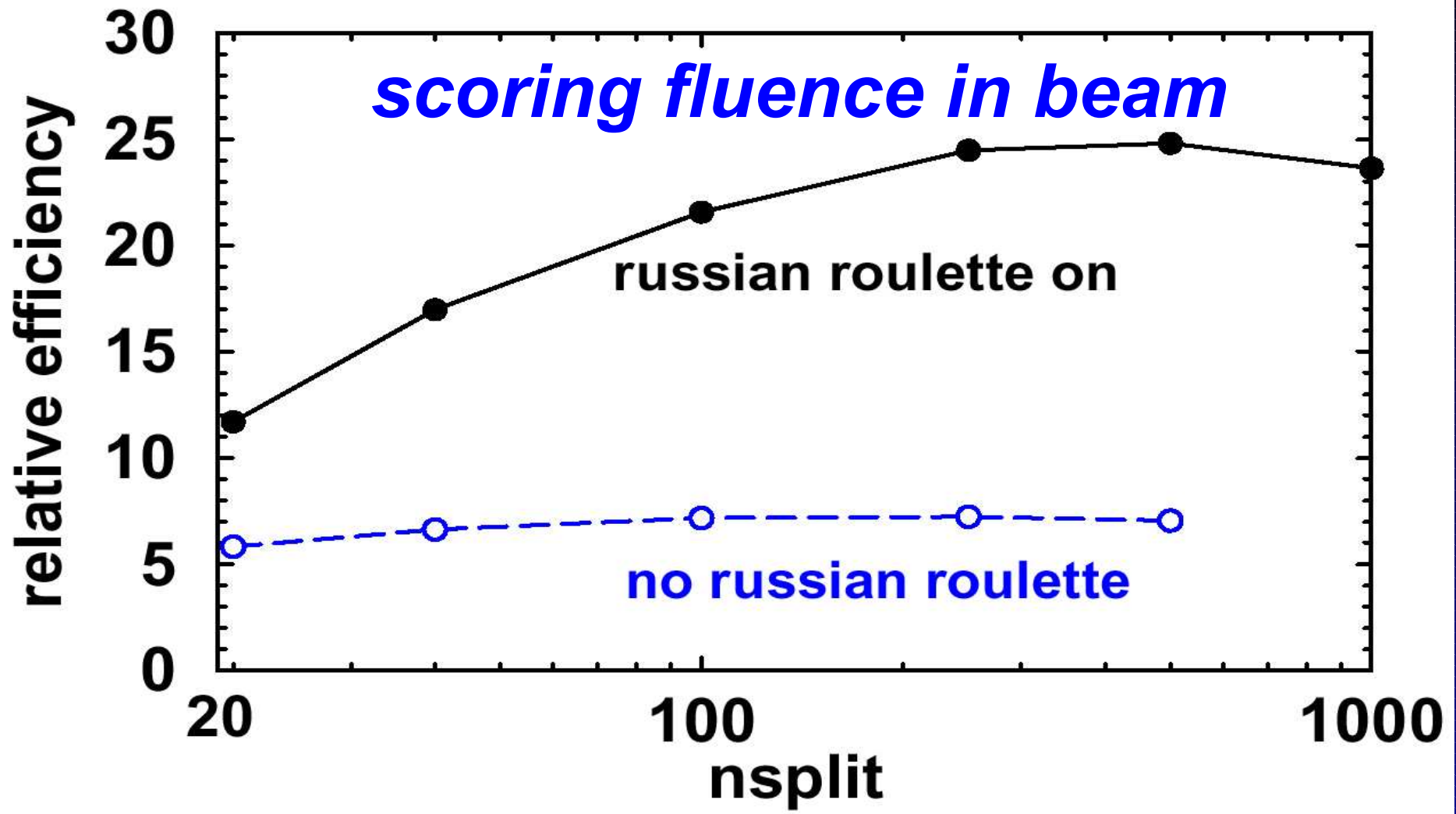
-particles have same weight

EGSnrc has an efficient algorithm

Russian Roulette

- Still creating a large number of **electrons** in collimators, jaws etc
- play **Russian Roulette** on **secondary electrons** (weight of e^- is 1)
 - split n_{split}** times in further radiative events
 - => **photons weight still $1/n_{split}$**
 - => not many electrons in **phase space**

Uniform Brem Splitting



Selective Brem Splitting (SBS)

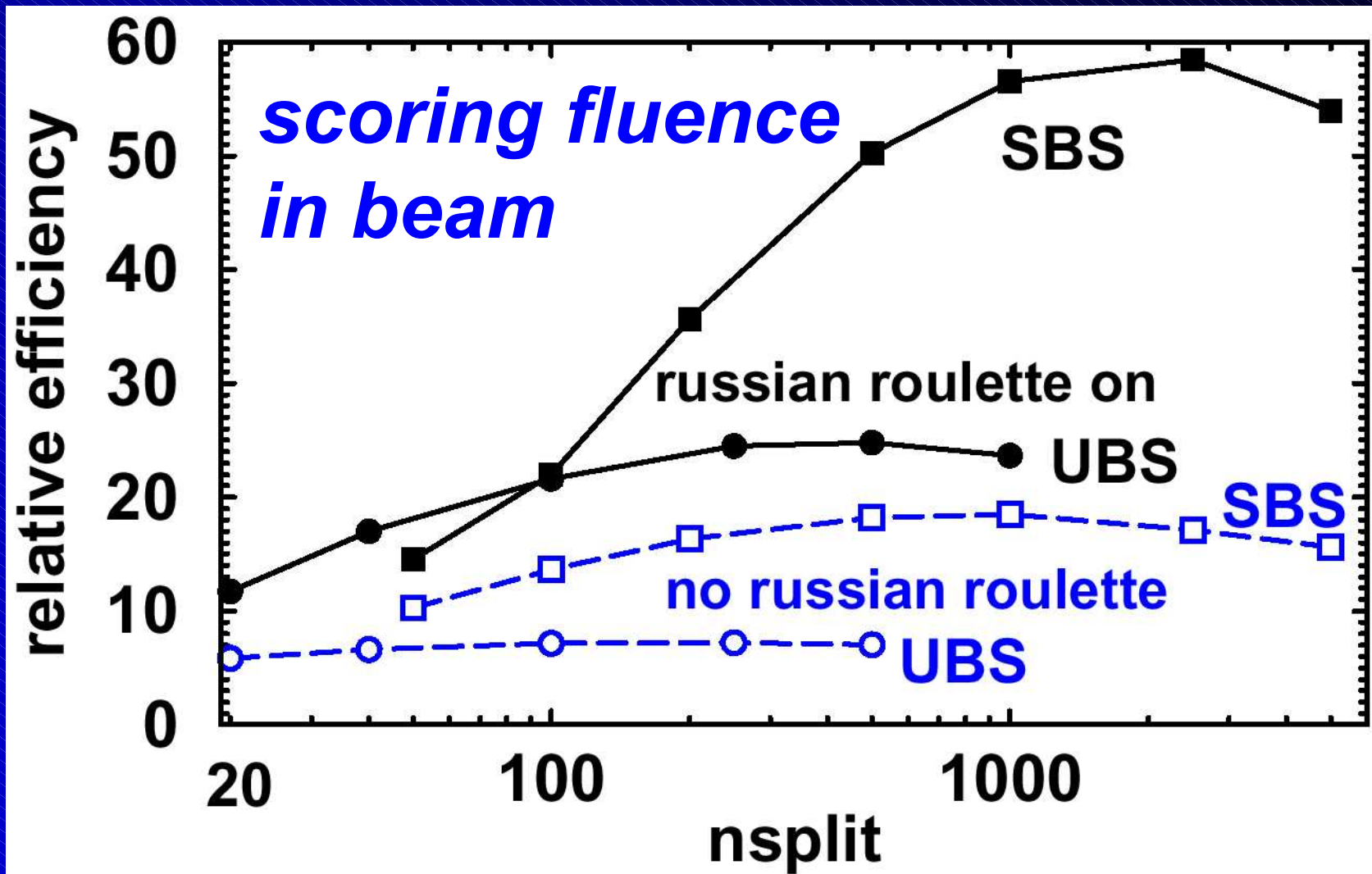
Daryoush Sheikh-Bagheri

-split photons more often **if likely to be in the beam** (calculated probability)

-`fat' photons a problem

=> **minimum split** about 10% of max

Selective Brem Splitting (SBS)



SBS problems

- large **variation in weights**
'fatter' photons still affect efficiency
- wasting lots of time on electrons which **cannot get to the phase-space file**
- with Russian roulette on, the **electron efficiency** is poor

Directional Brem Splitting (DBS)

-goal: **all particles** in field when reach phase space have **same weight**

Procedure

- i) brem from **all fat** electrons split **nsplit** times
- ii) if photon **aimed at field** of interest, **keep it**, otherwise Russian roulette it:
if it survives, weight is 1 (i.e. fat)
- iii) if using **only leading term** of Koch-Motz angular dist'n for brem: **do_smart_brems** and similar tricks for other interactions

DBS (cont)

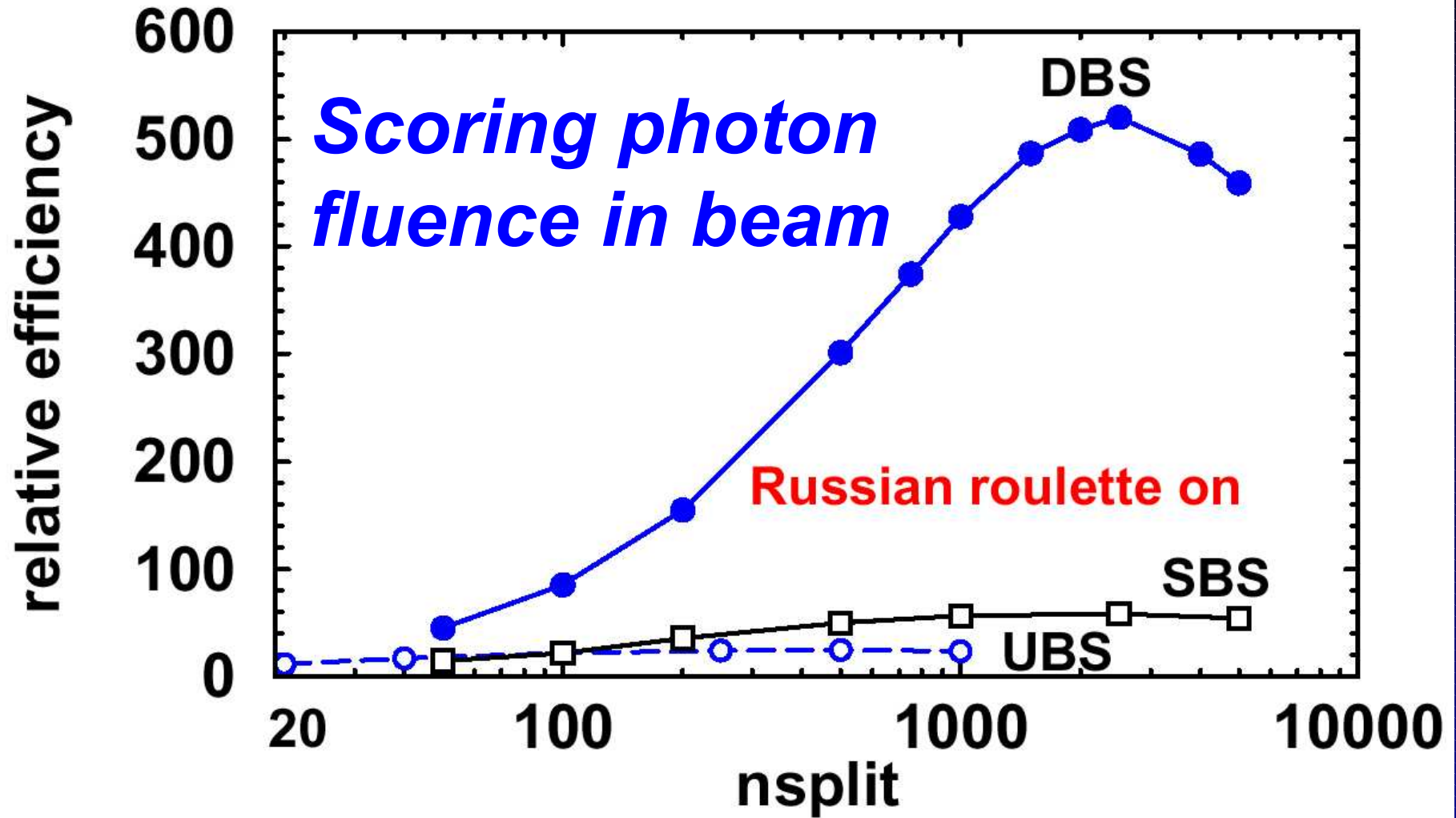
photons

- reaching field have weight $1/n_{split}$
- outside field are fat

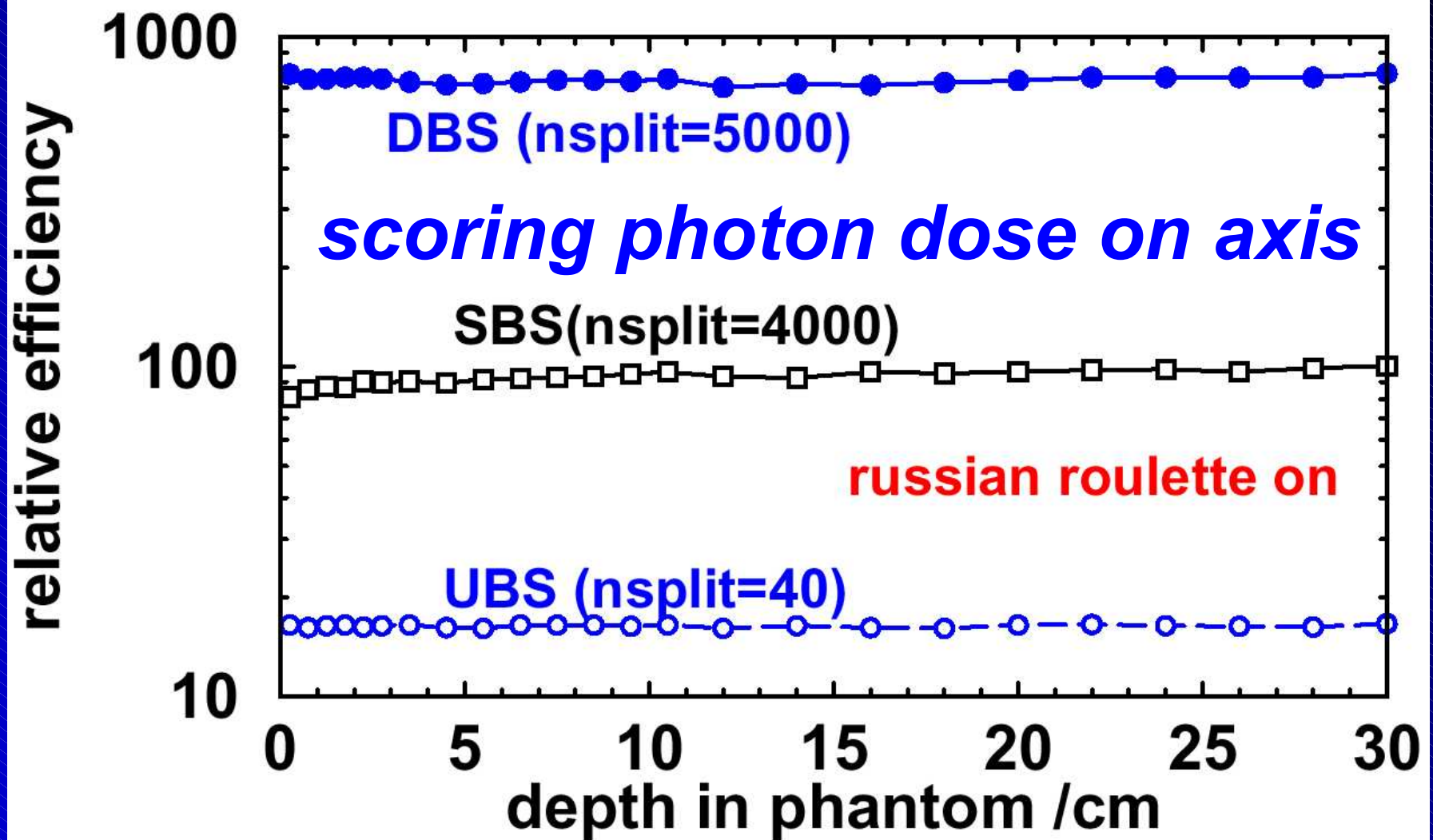
electrons in the field

- usually fat
- a few have weight $1/n_{split}$ from interactions in the air

Directional Brem Splitting



Directional Brem Splitting



Electron problem

-efficiency gain for electrons is only 2

Basis of the solution

-electrons are, almost entirely, from flattening filter and below

-major gains are from treatment of electrons in primary collimator

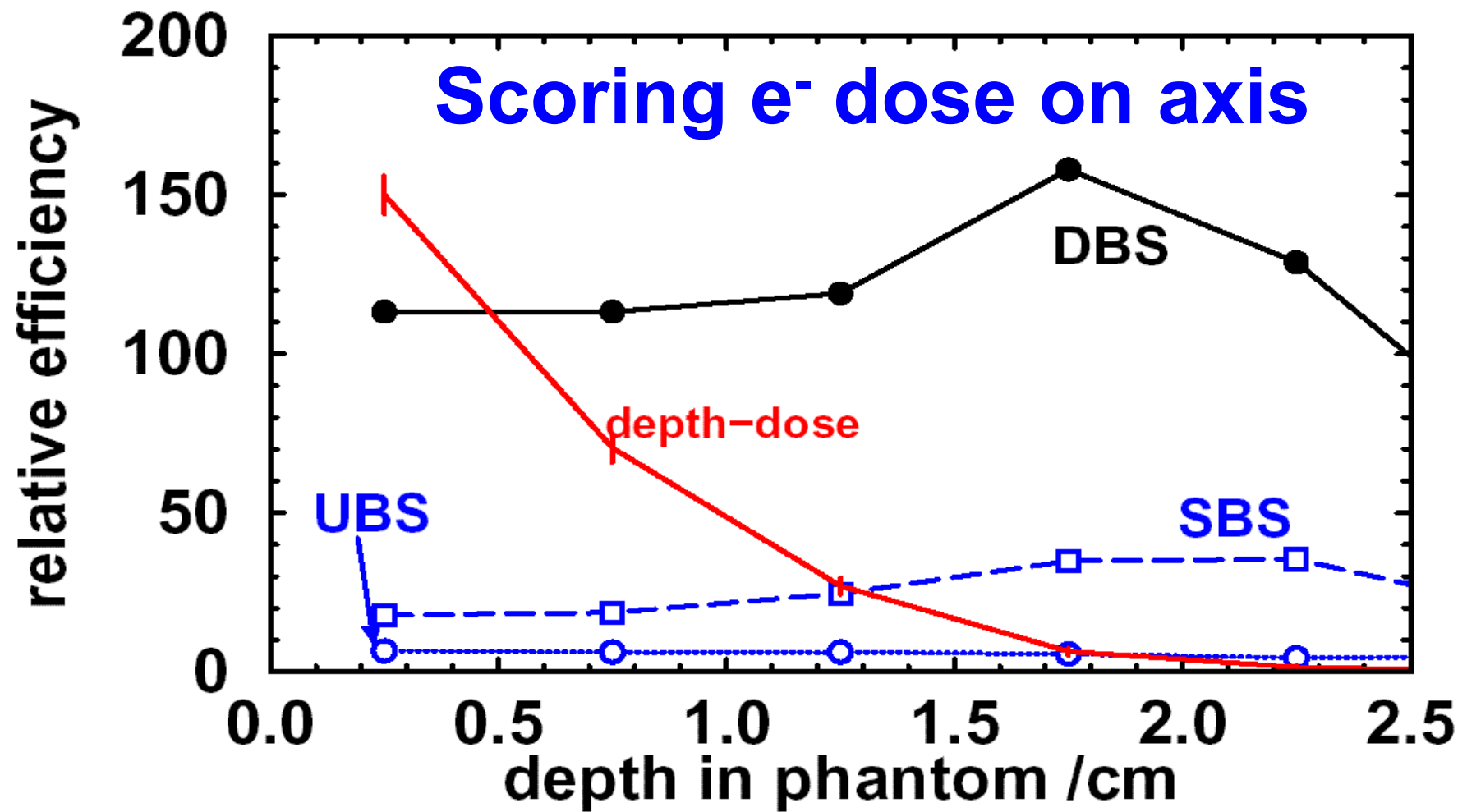
Electron solution

introduce 2 planes

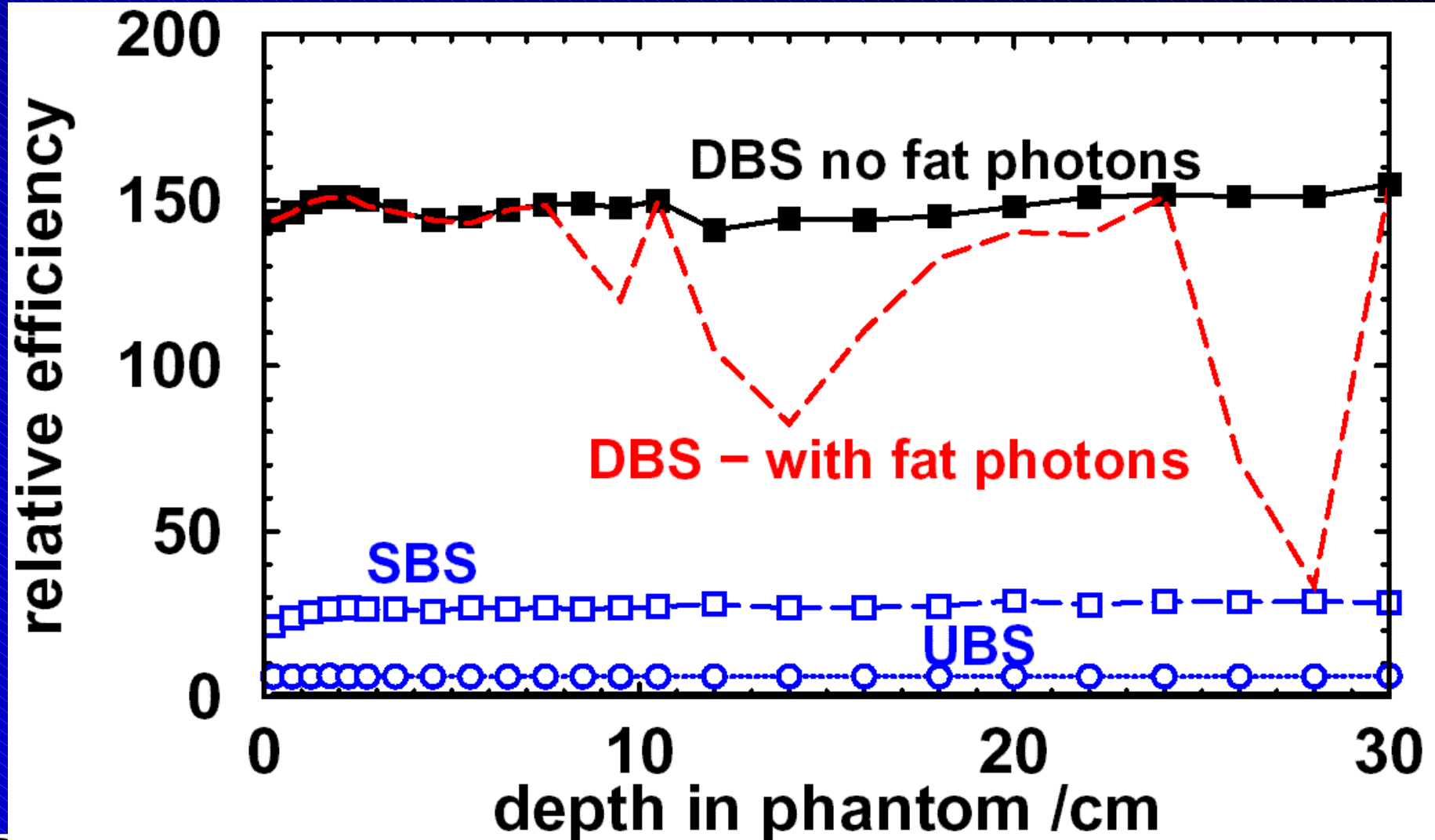
-**splitting plane**: split weight 1 charged particles **nsplit** times (may distribute symmetrically)

-**Russian roulette plane**: below this turn off **Russian roulette** and split all fat photon interactions **nsplit** times

Efficiency increase for e^-



Efficiency: total dose



Conclusions

DBS, directional brem splitting, improves BEAMnrc's efficiency by a factor of 800 (10 vs SBS) for photon beams (ignore small dose from photons outside field).

For total dose calculations the efficiency improves by factor of 150 (5 vs SBS)

SBS is optimized for greater nsplit than previously realized (5000)