Recent improvements in the BEAMnrc code

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NRC-CNRC

BEAMnrc

- a general purpose user-code for simulation of radiotherapy beams

- built on EGSnrc

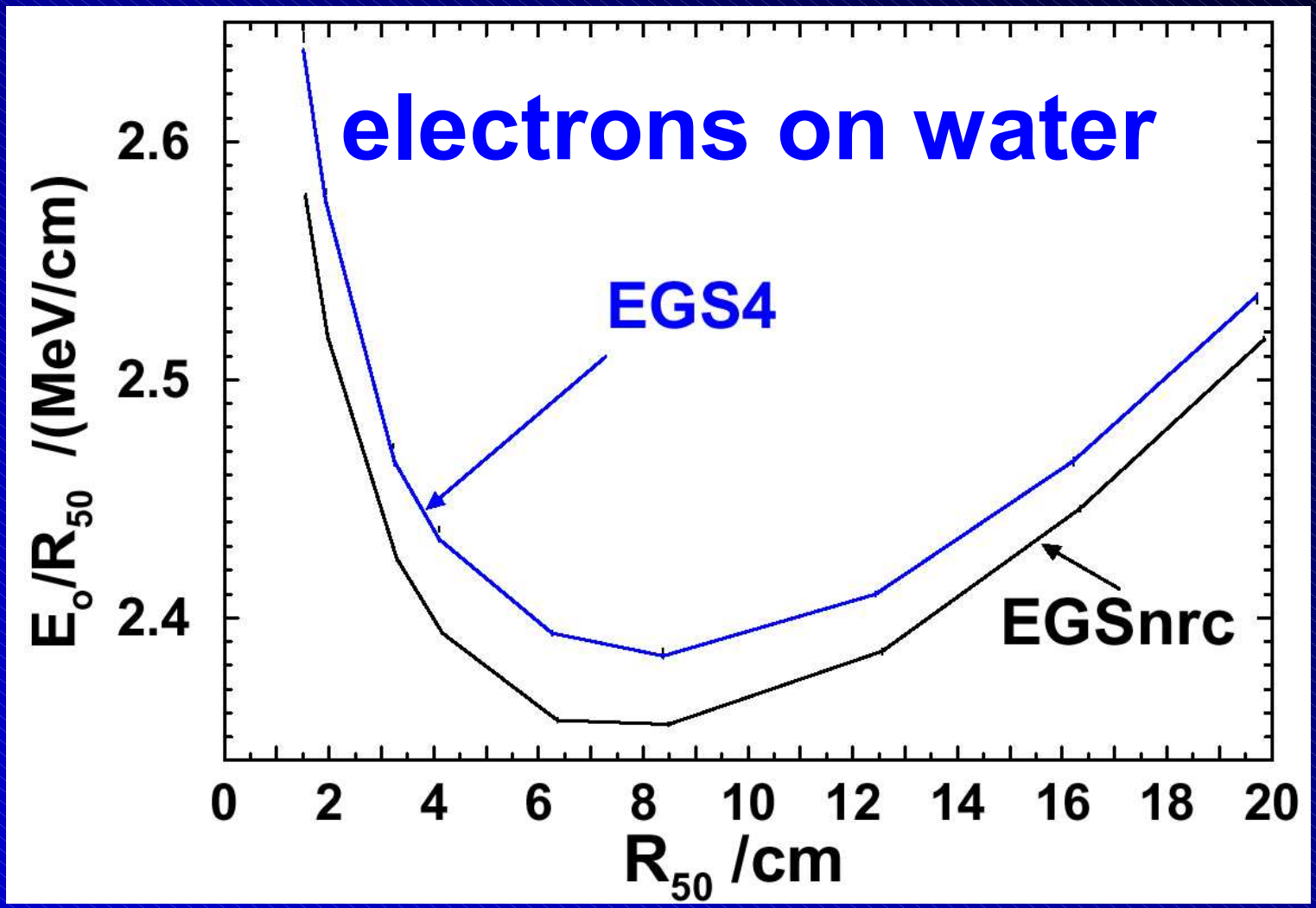
- freely available for non-commercial use

- lots of built in variance reduction to enhance efficiency, especially for accelerator photon beams

BEAMnrc built on EGSnrc

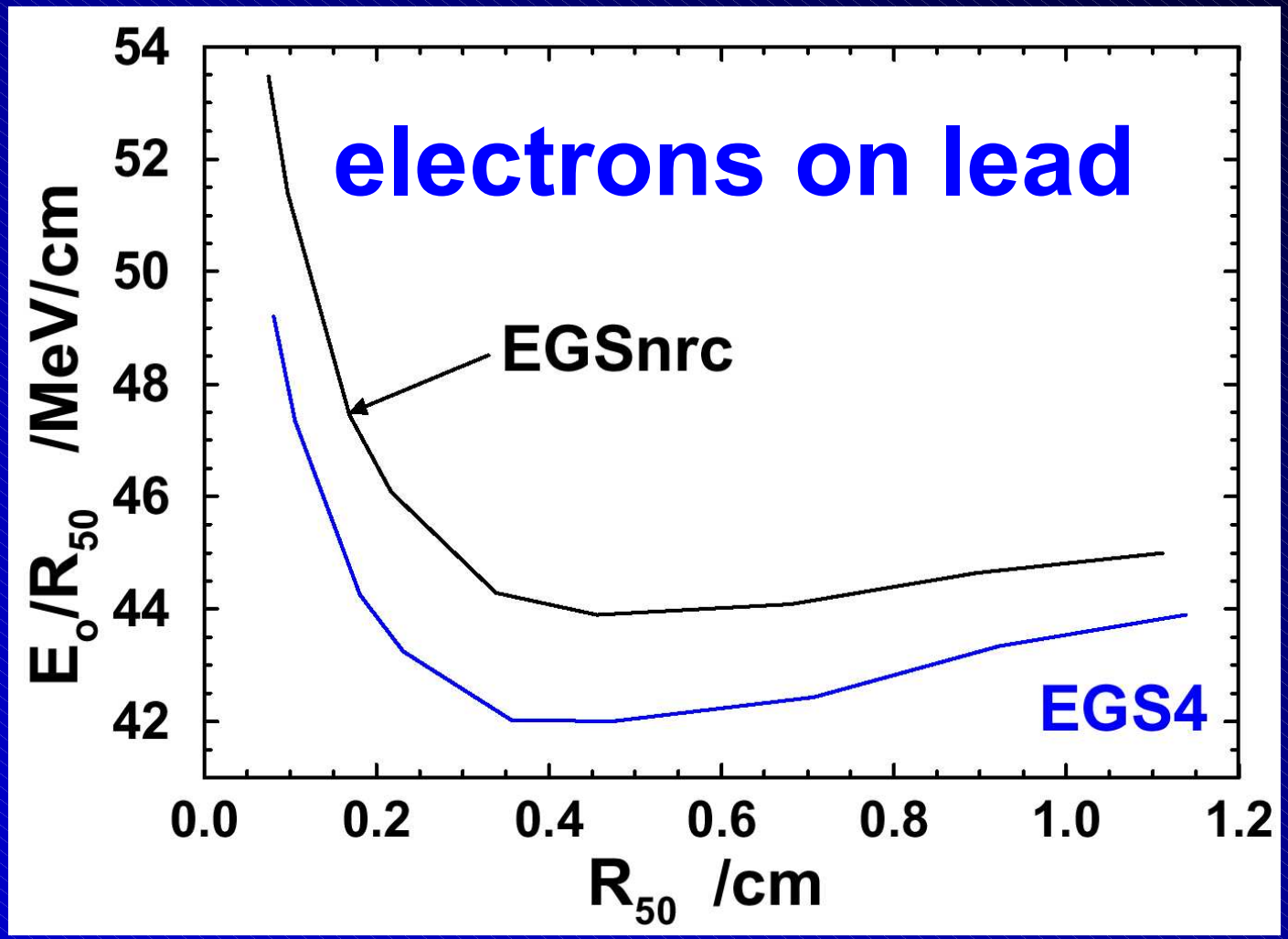
- with default EGSnrc transport parameters
  - a factor 2 or 3 slower
  - most parameters have no effect
- thus BEAMnrc defaults are like EGS4/PRESTA
  - in particular PRESTA-I boundary crossing
  - Klein Nishina compton
  - no relaxation
- BEAMnrc uses relativistic spin effects for scattering since this changes things
- uses EGSnrc transport away from boundaries

EGSnrc: spin effects



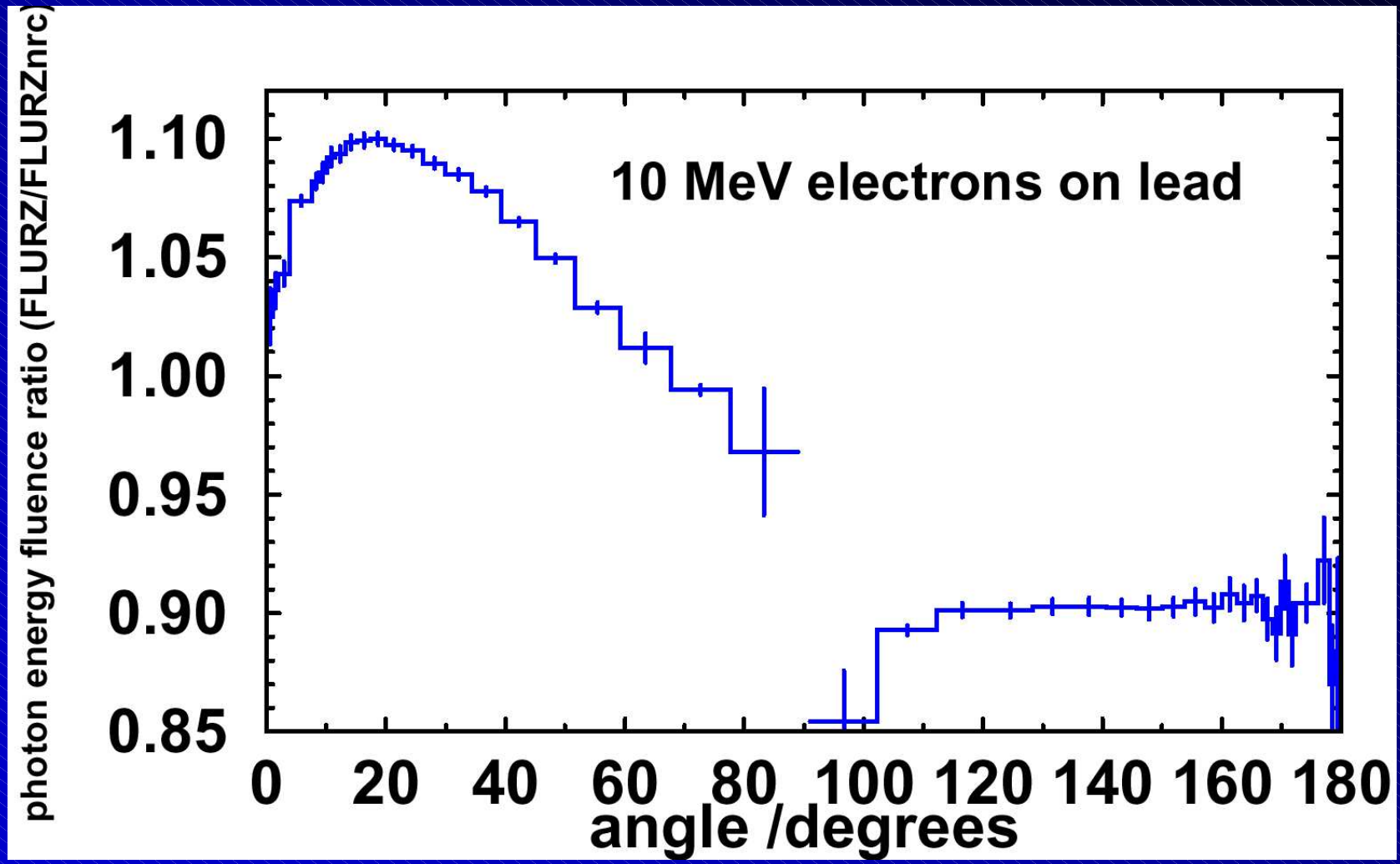
e^- go 1-2.4% deeper for a given energy

EGSnrc: spin effects

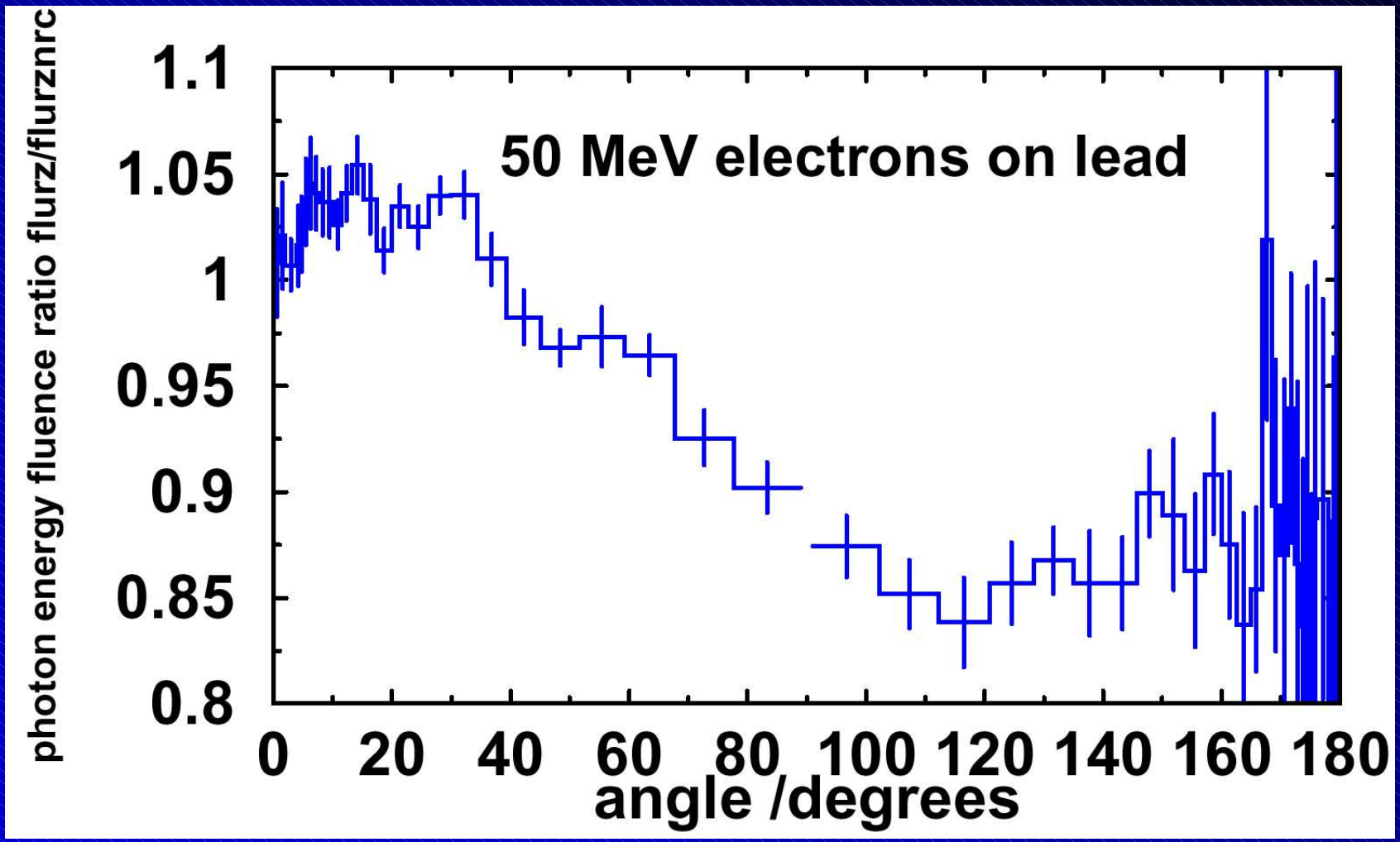


e^- go 3-8% less for a given energy

EGSnrc: spin effects



EGSnrc: spin effects



PIRS-703

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

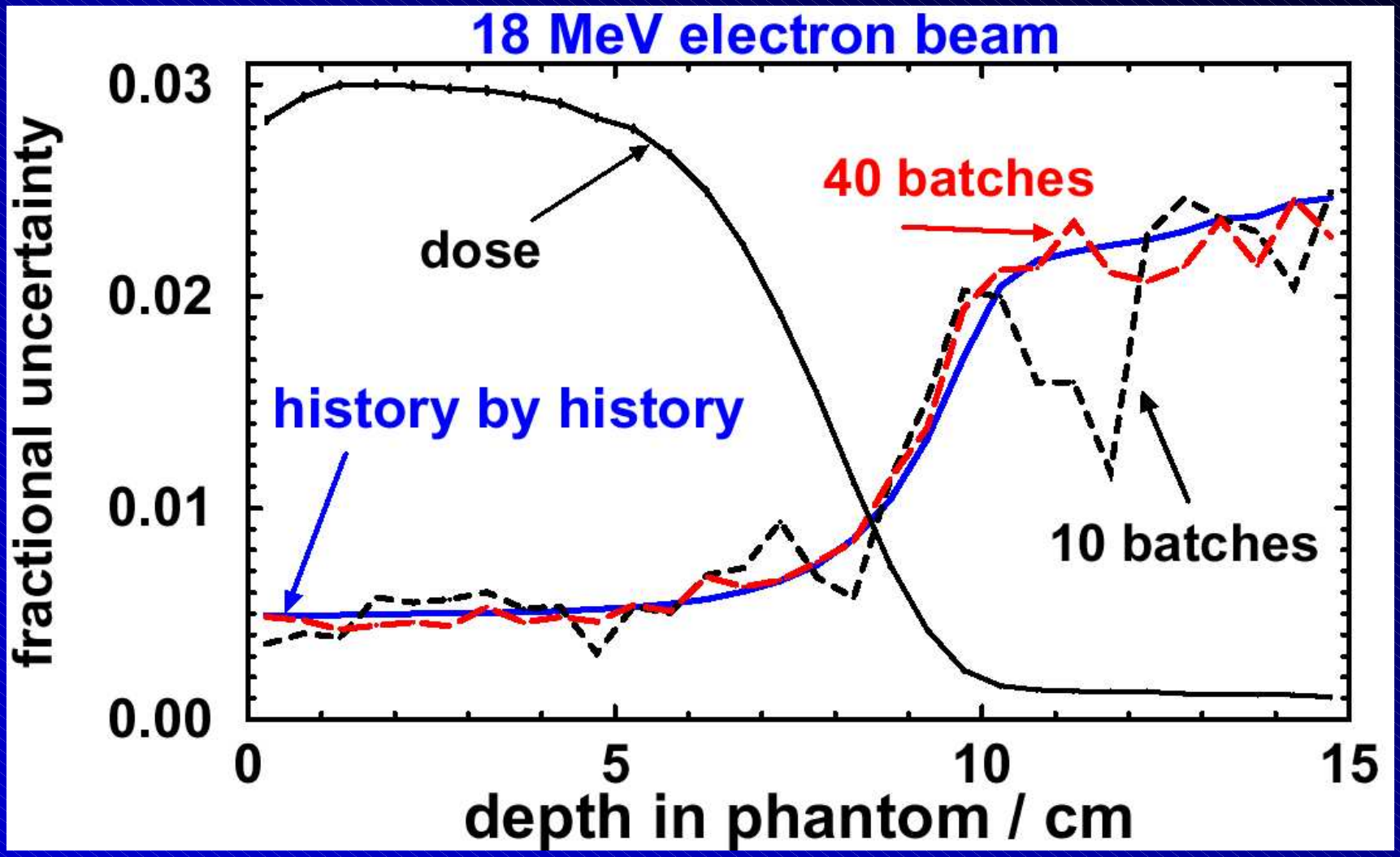
History by history method

batches = #histories

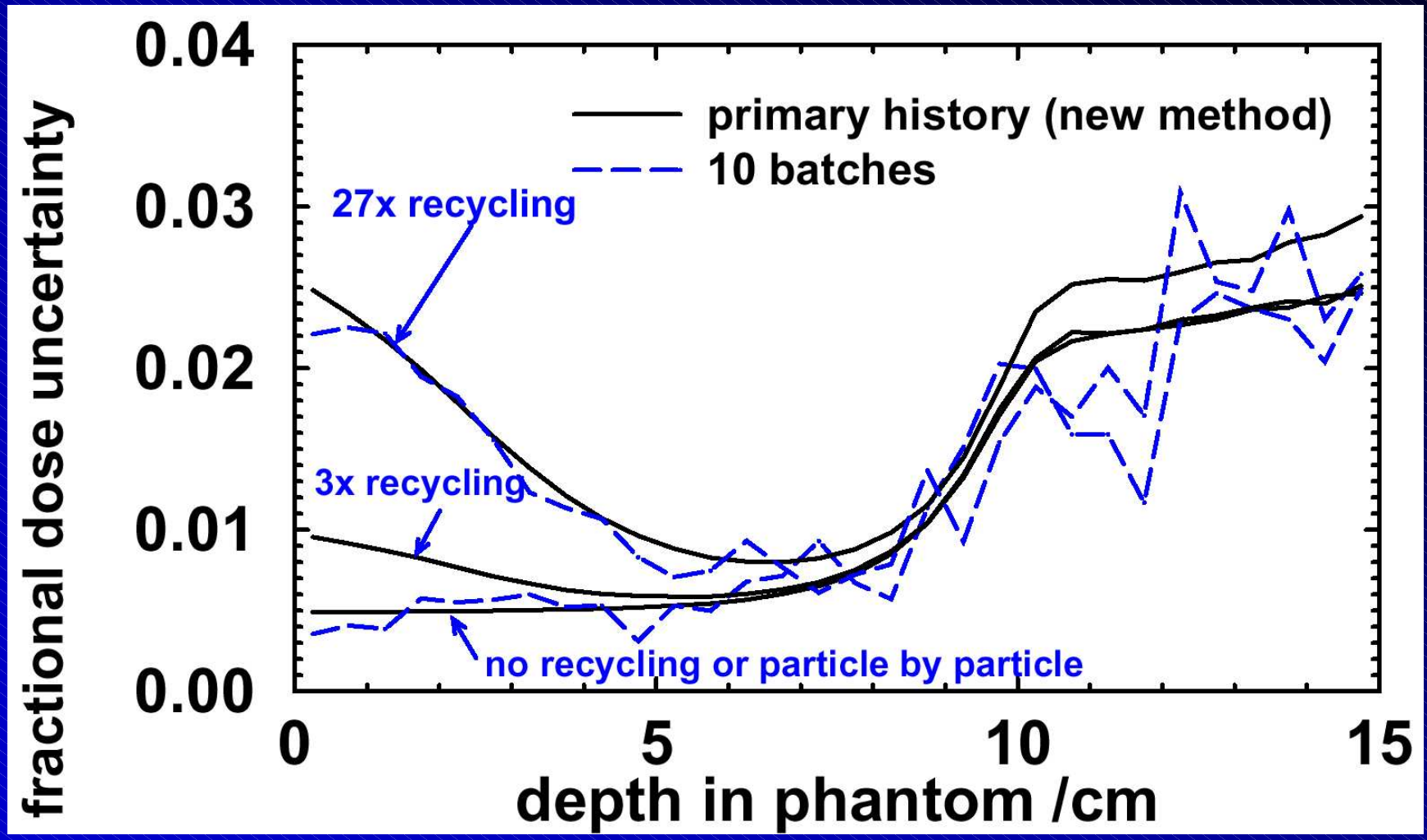
-much better estimate

-``trick" of Salvat allows for efficient calculation

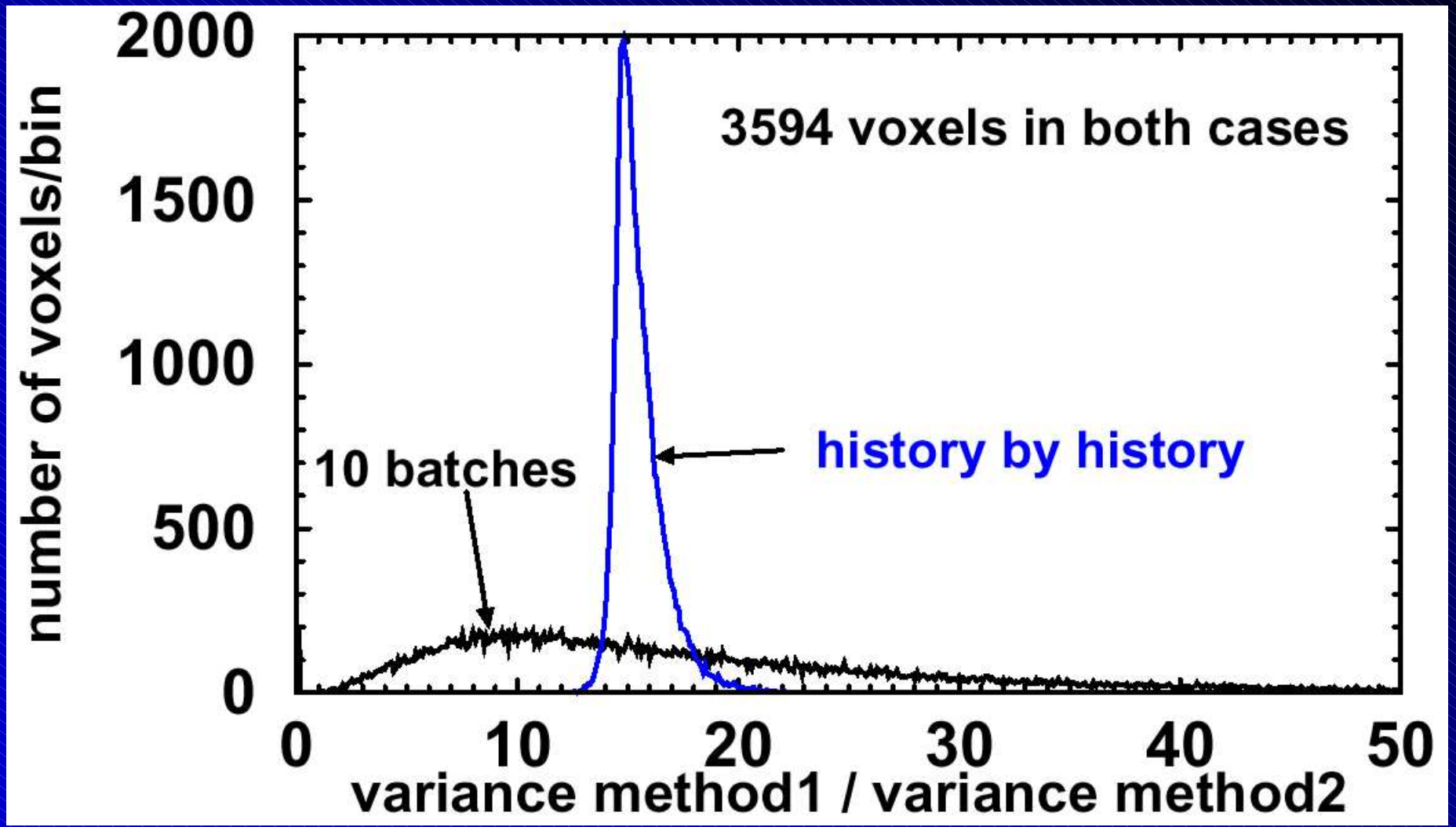
History by history technique



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

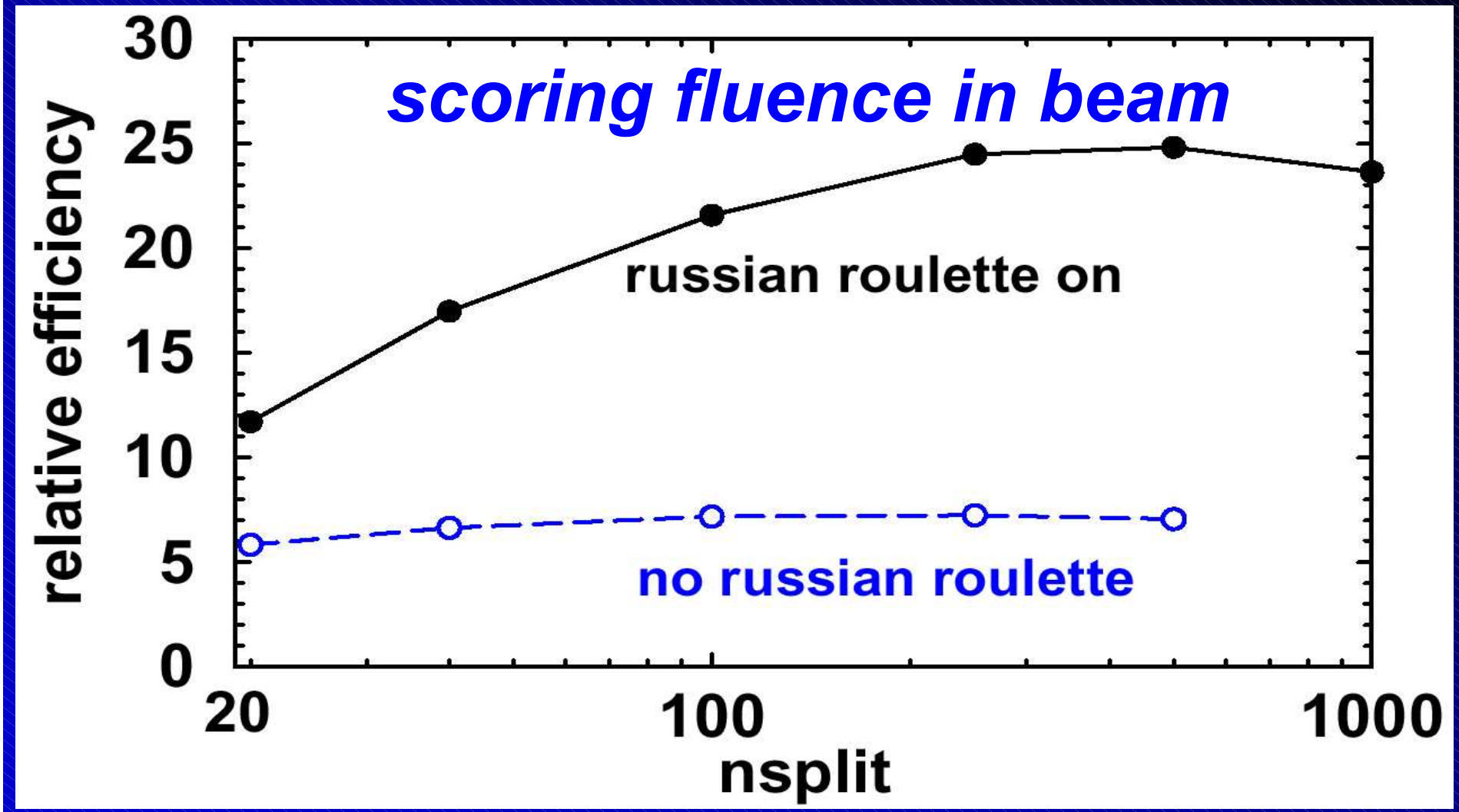
- sum of uncertainty^2
  - -fluence in 1x1cm^2 regions in beam
  - -dose on central axis or profile

Problems to overcome

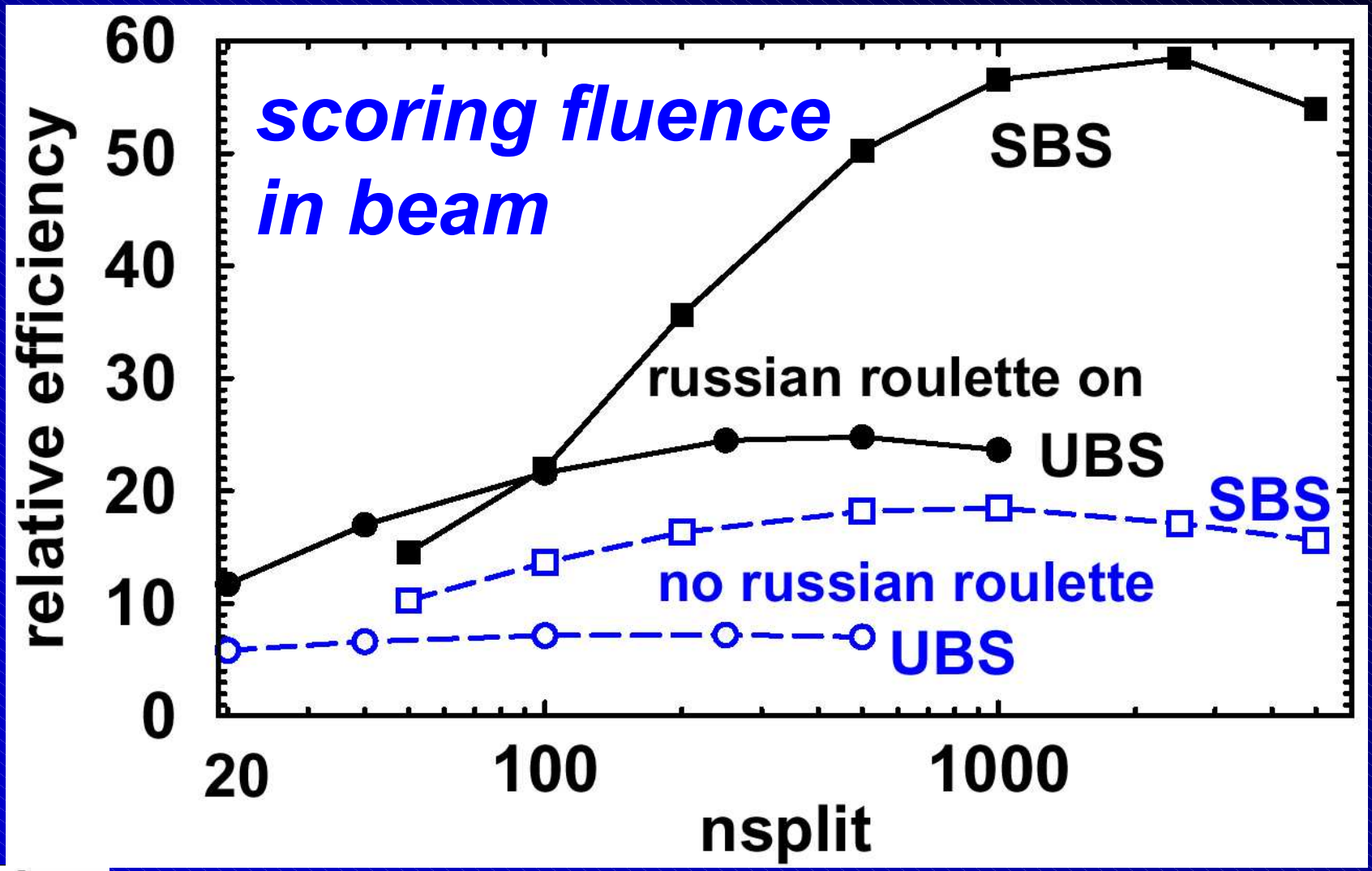
-in photon accelerators, majority of time is spent following electrons

-most photons are absorbed in the primary collimator

Uniform Brem Splitting



Selective Brem Splitting (SBS)



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

do_smart_brems

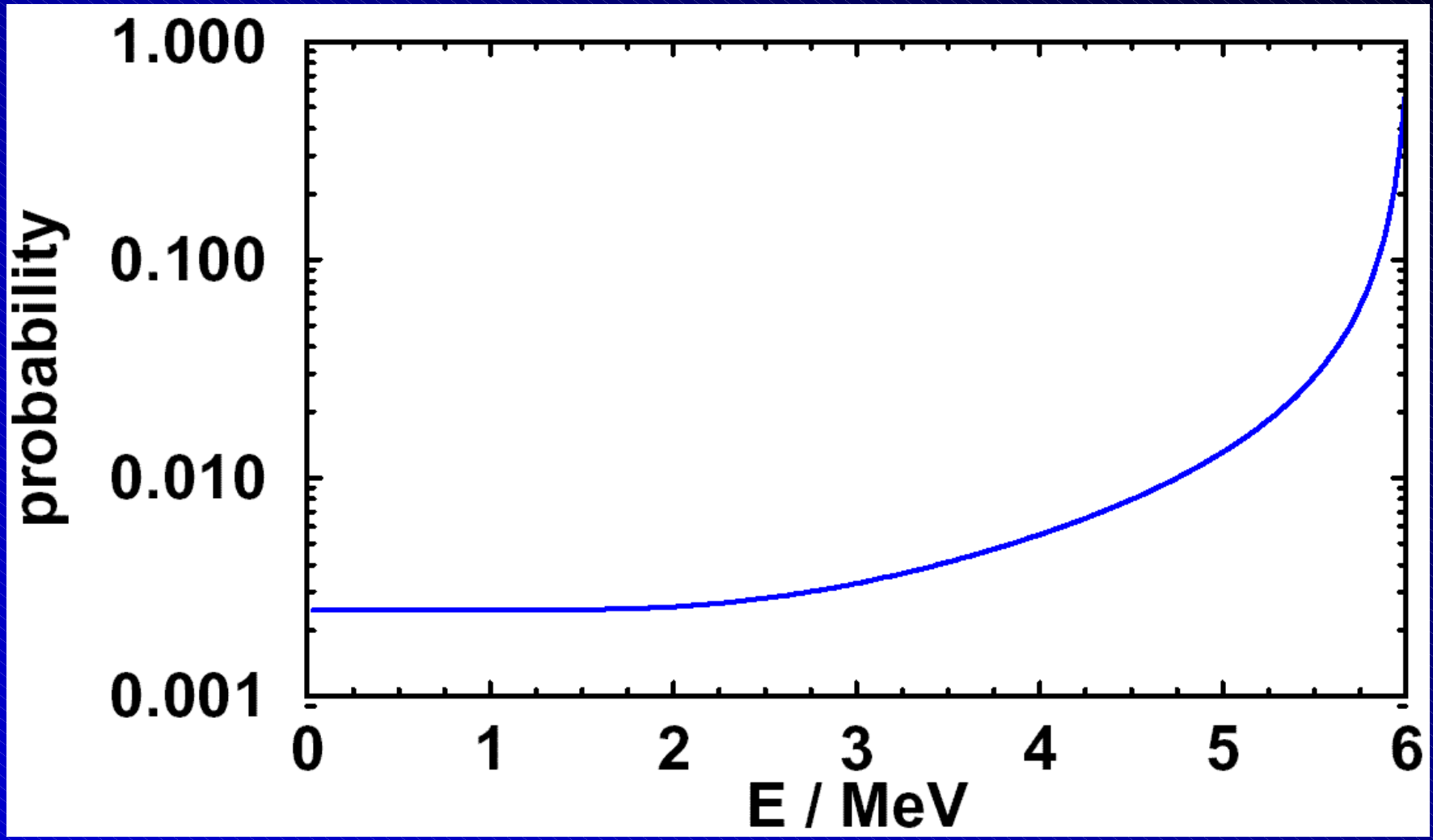
-if EGSnrc is using the leading term of the Koch-Motz distribution, then:

do_smart_brems calculates how many of the nsplit brem photons will head to the field and only generates those photons;

+

samples 1 photon from the entire dist'n -if not heading into the field, kept with weight 1.

Probability photon heading at field



DBS continued

play similar tricks for other quantities

-e+ annihilation: (`uniform_photons`)

-Compton scattering:
(`do_smart_compton` if Klein Nishina)

-pair production/photo-effect: (Russian roulette **before** sampling)

-fluorescence: (`uniform_photons`)

DBS (cont)

photons

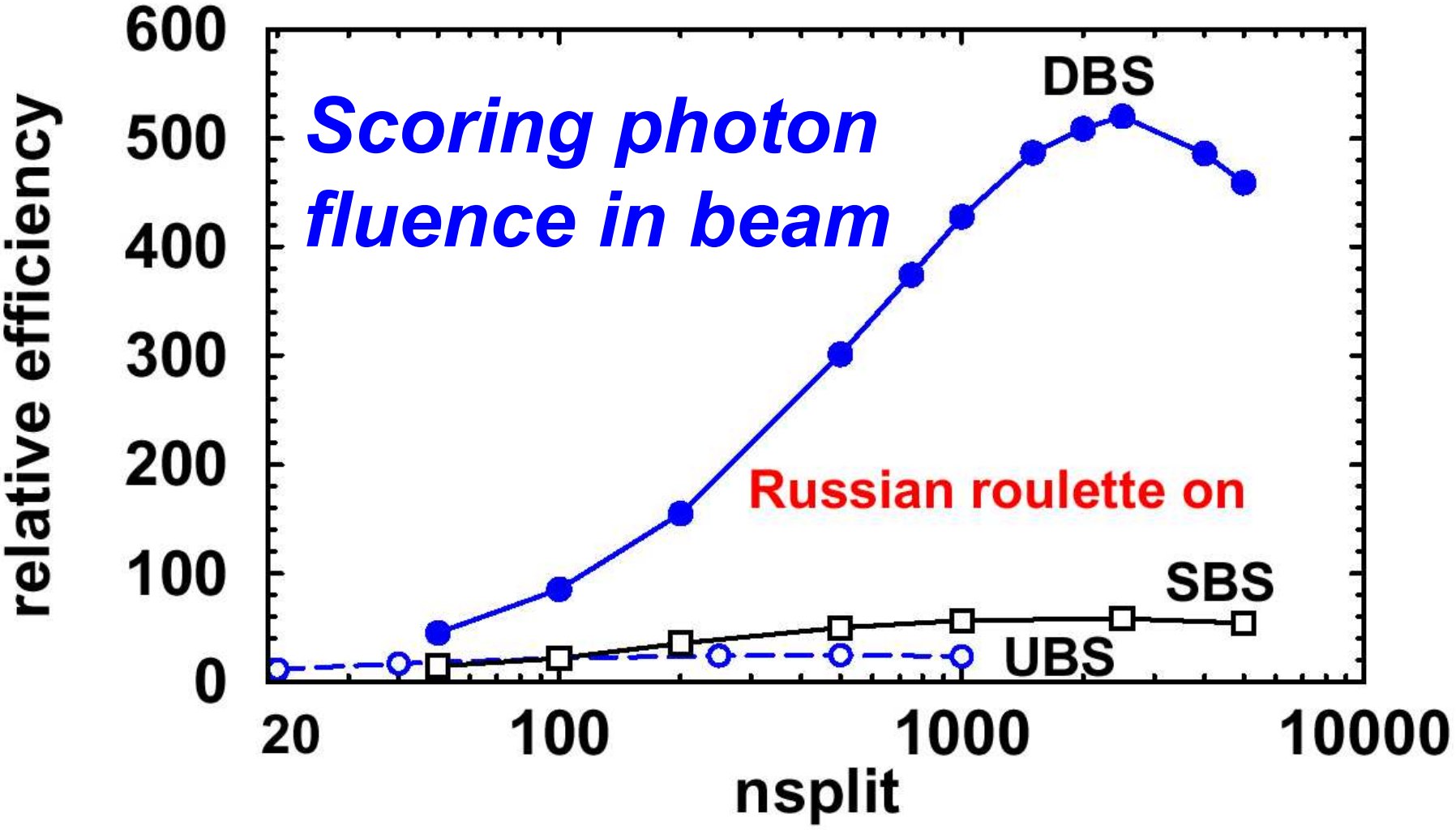
- reaching field have weight 1/nsplit
- outside field are fat

electrons in the field

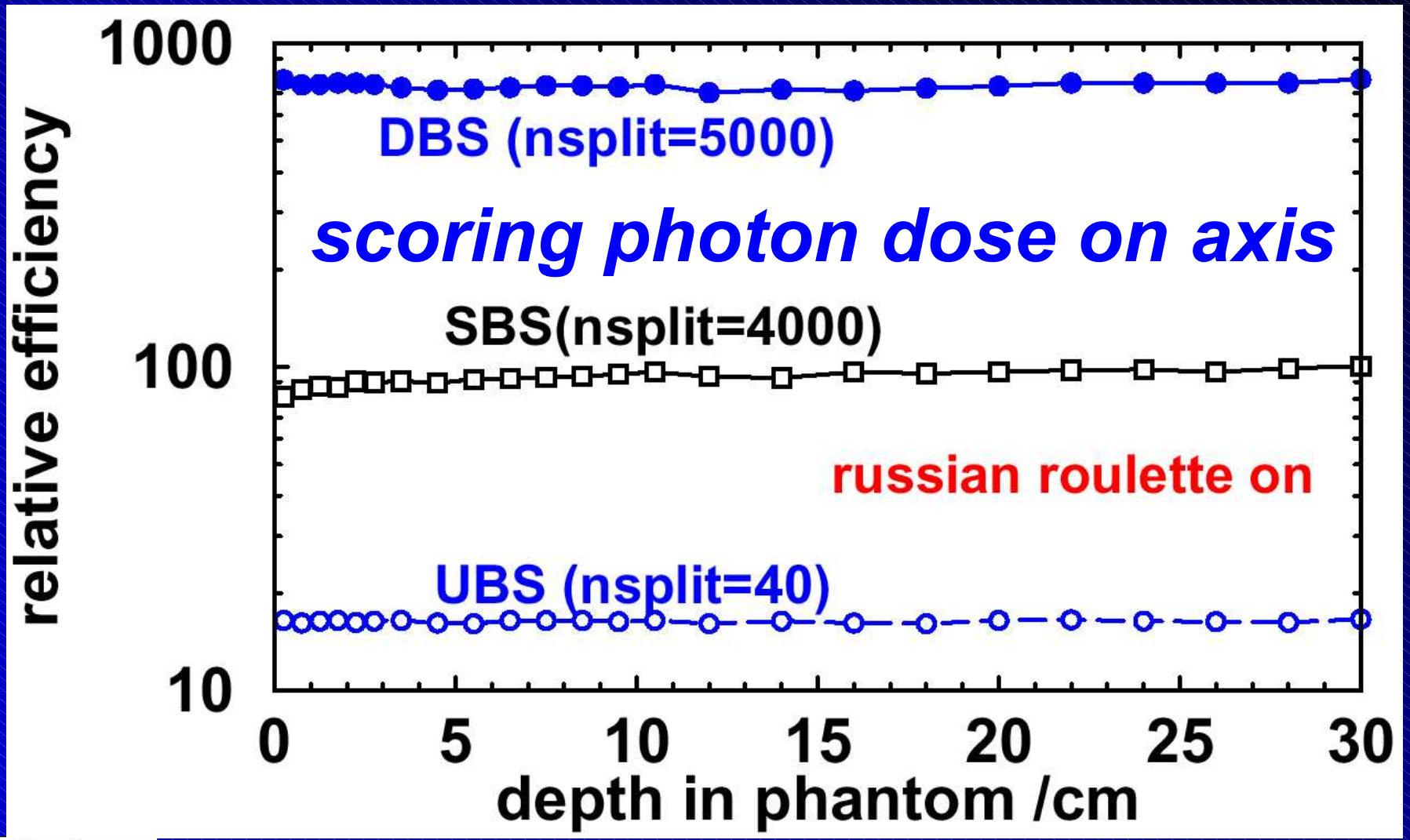
-usually fat

-a few have weight 1/nsplit from interactions in the air

Directional Brem Splitting



Directional Brem Splitting



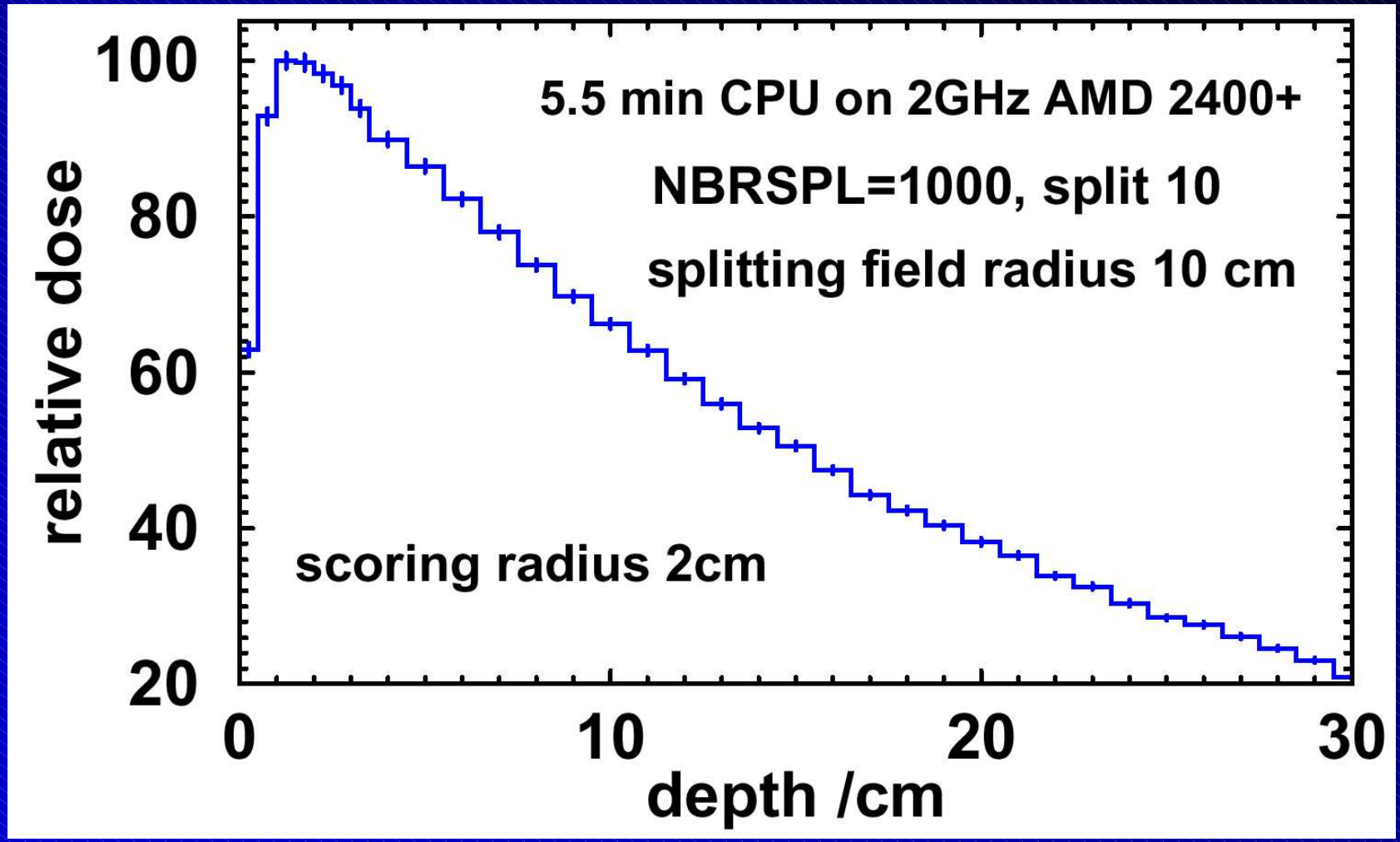
Kawrakow's `tricks'

		do_smart_brems	
		ON	OFF
do_smart_compton	ON	1.0	5.3
	OFF	3.3	7.6

No electron splitting.

		do_smart_brems	
		ON	OFF
do_smart_compton	ON	1.0	2.43
	OFF	1.77	3.2

6 MV Varian: 10x10 cm² CAX



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

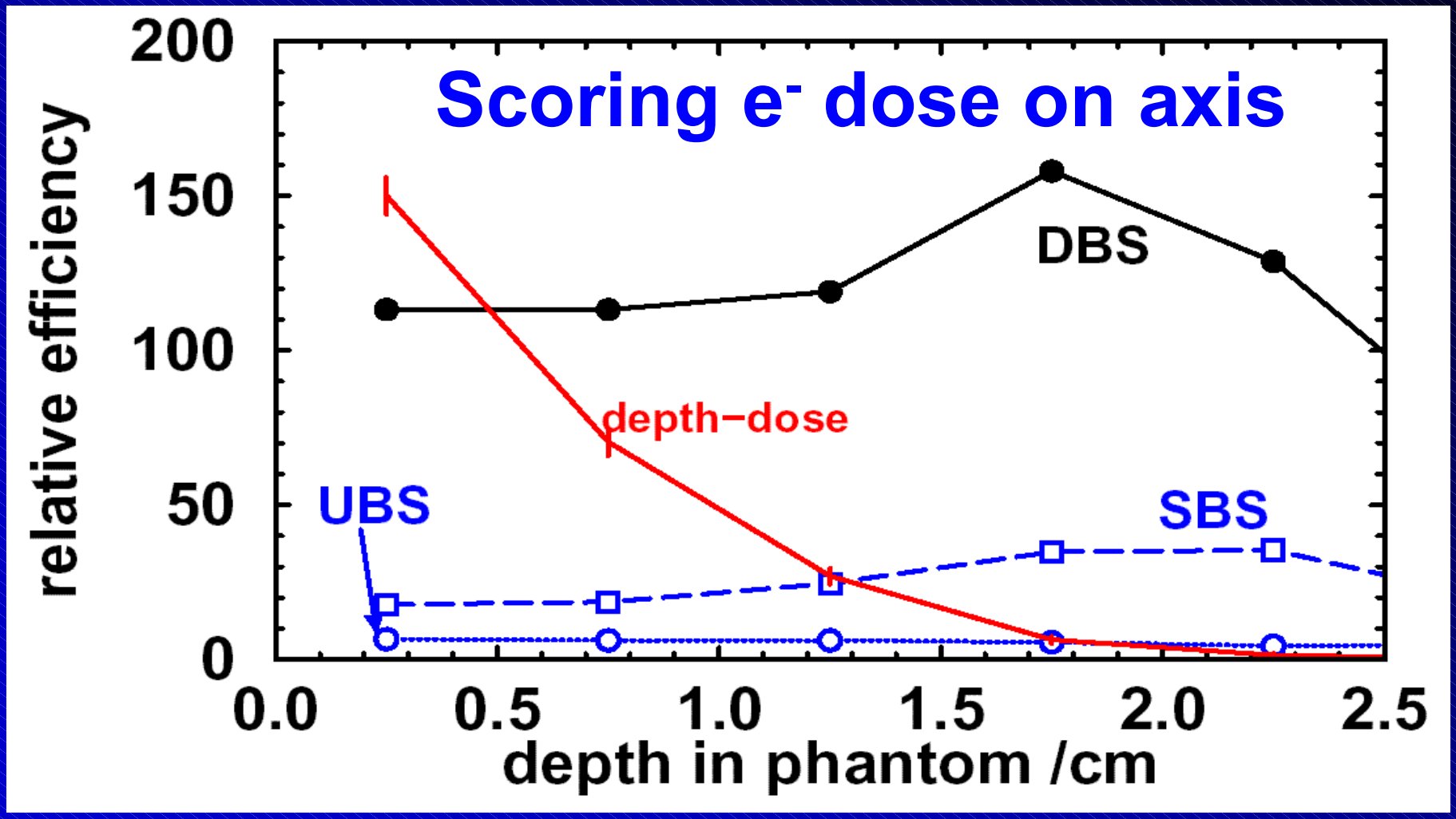
Electron solution

introduce 2 planes

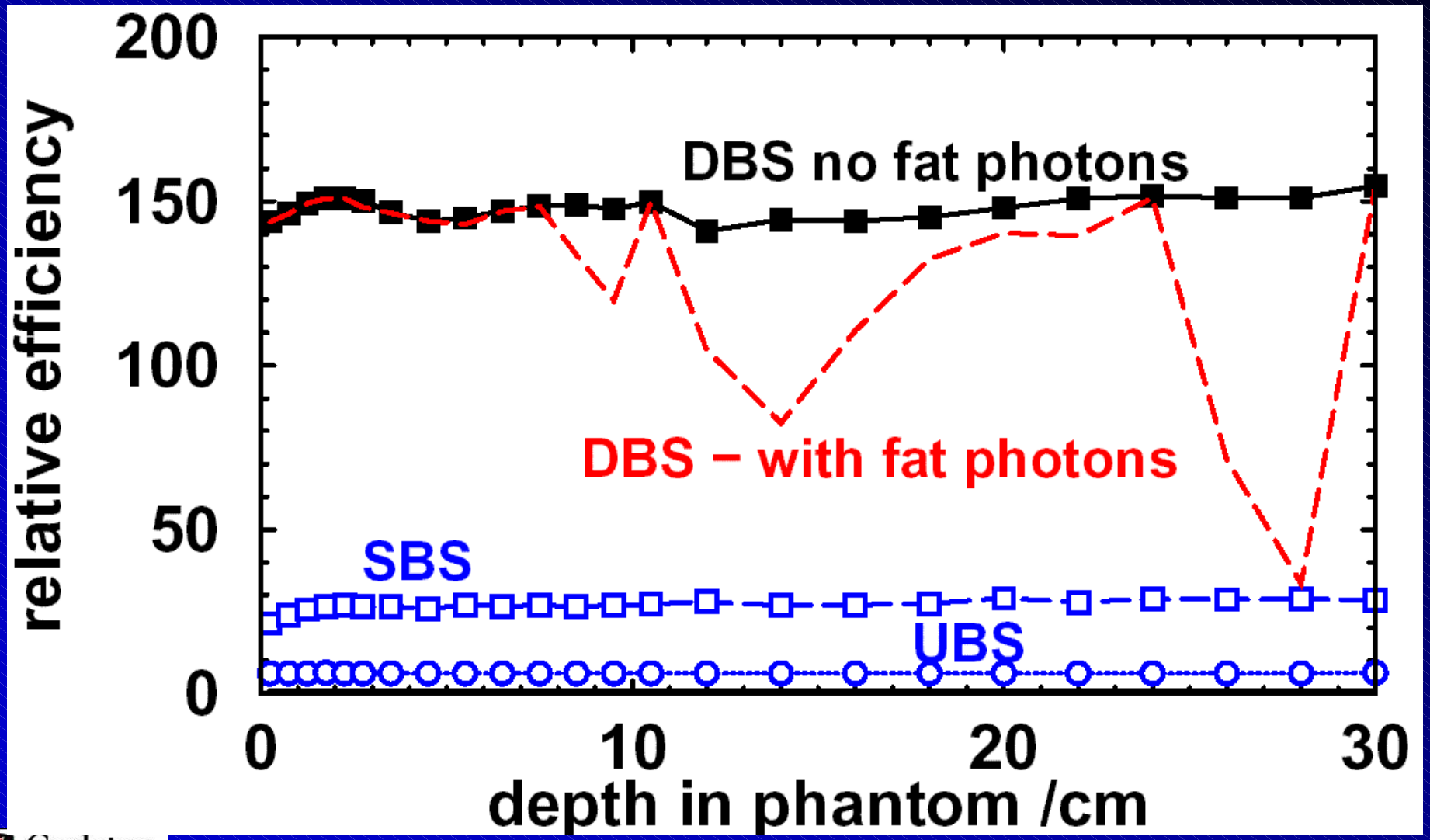
-splitting plane: split weight 1 charged particles nsplit times (may distribute symmetrically)

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

Efficiency increase for e⁻



Efficiency: total dose



DBS summary

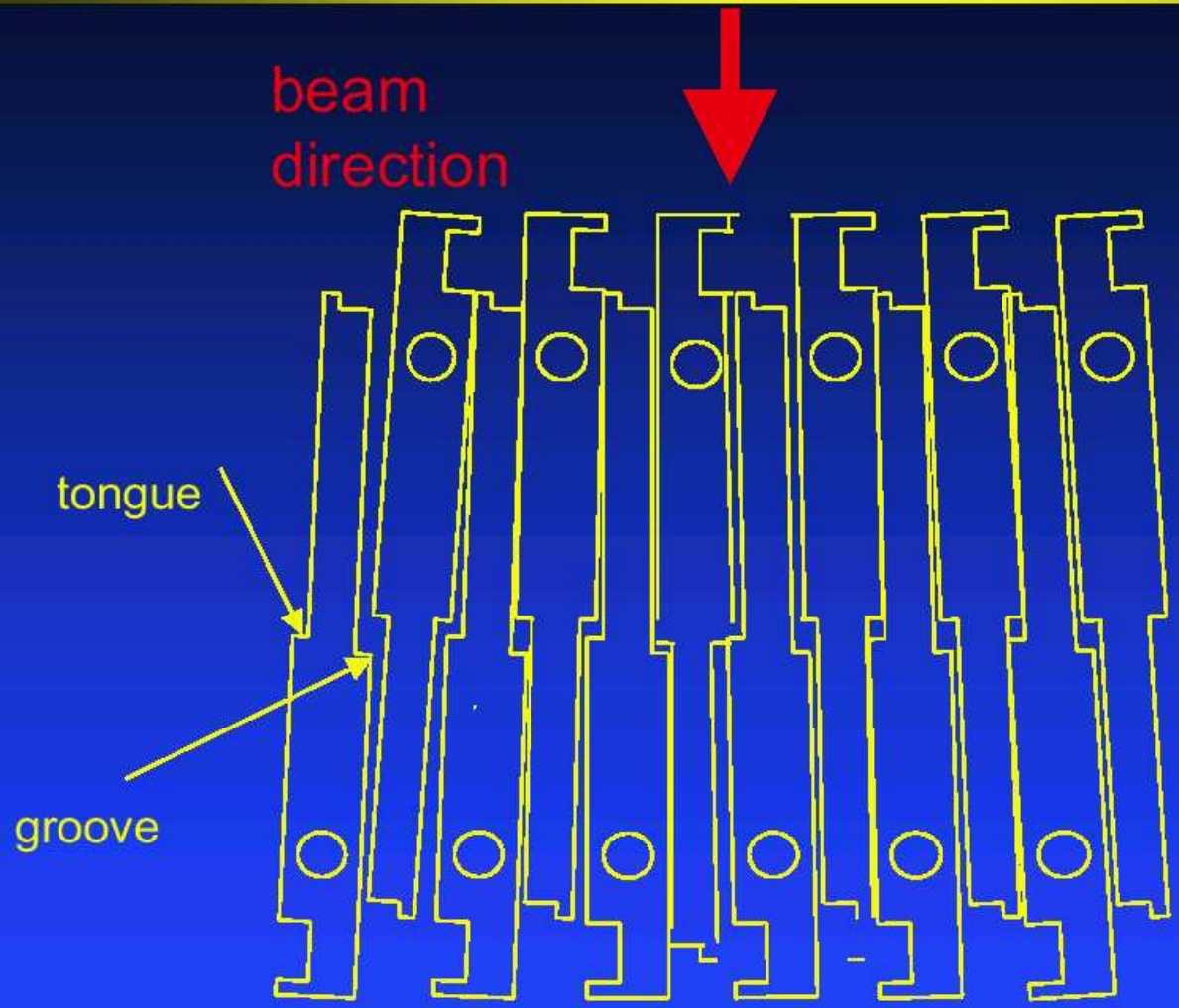
DBS, directional brem splitting, improves BEAMnrc's efficiency by a factor of 800 (10 vs SBS) for photon beams (ignore small dose from photons outside field).

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

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

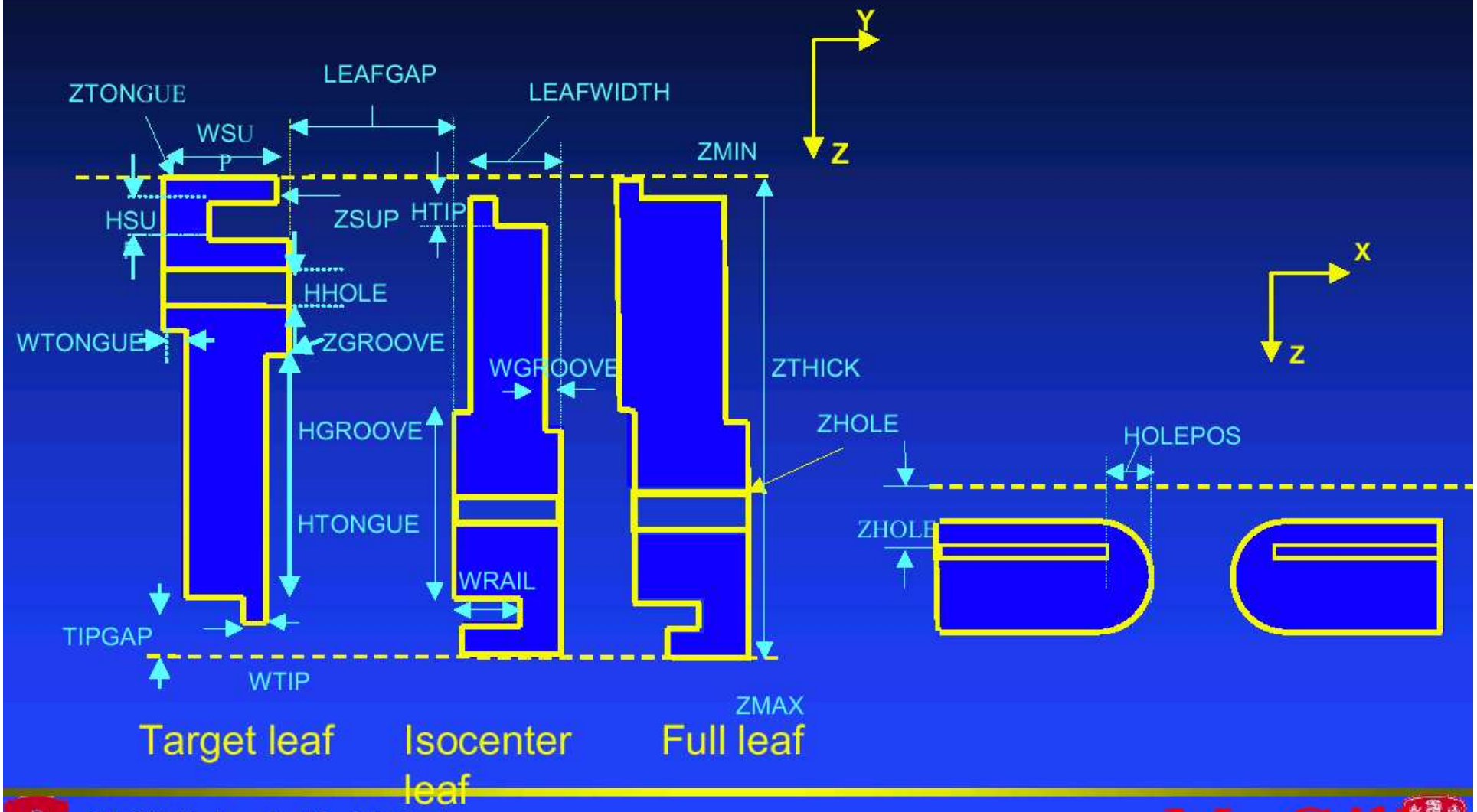
Varian Millennium 120 leaf MLC

Millennium MLC - Inner Leaves

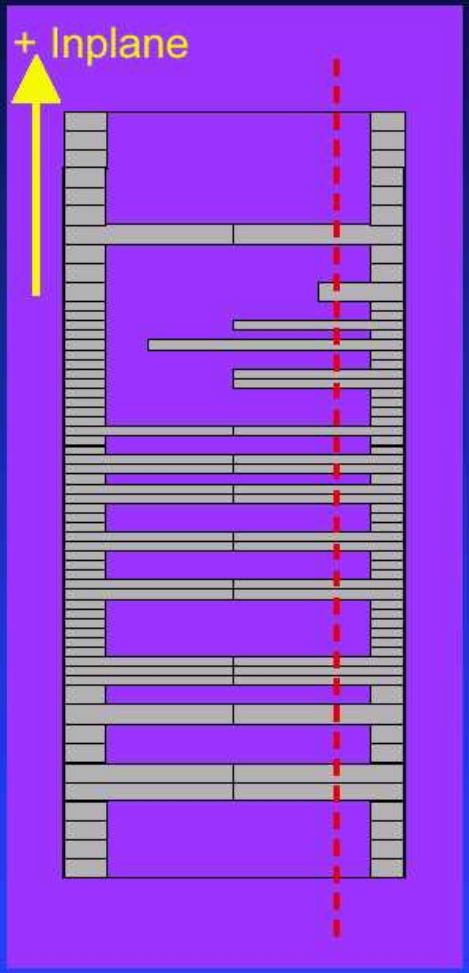


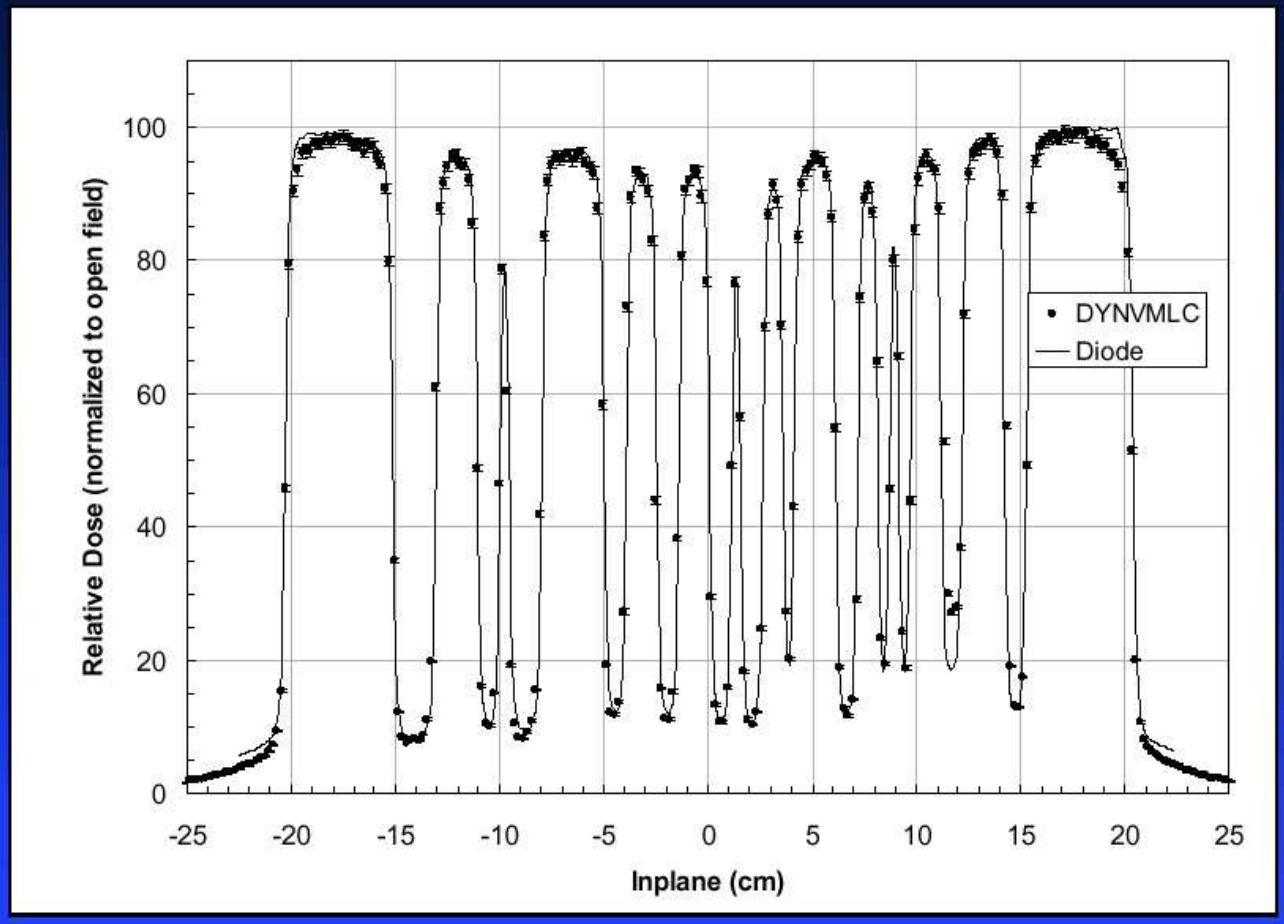
- leaf sides diverge with focus at 0 cm
- adjacent leaves are offset vertically
- leaf width = 0.23 cm

DYNVMLC Component Module



MLC bar pattern





Summary

- BEAMnrc continues to be developed
  - EGSnrc port -statistics upgrade -DBS
  - port to EGSnrcMP environment is underway
- wide users base has contributed a great deal to the system
- Thanks to the many contributors over the years
  - most recently, Emily Heath and Jan Seuntjens of McGill and literally dozens of others
  - Ernesto Mainegra-Hing and Michel Proulx of NRC