Workshop on Computational Medical Physics (Nara, September. 2, 2012)

Current status of EGS5

- Comparison with experiment on e- backscattering -

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History of EGS System

Period	Program	Language	Authors
1963～1965	SHOWER1	Fortran	Nagel
1966	SHOWER2	Fortran	Nicoli
1967～1972	SHOWER3/PREPRO	Fortran	Ryder, Talwar, Nelson
1970～1972	SHOWER4/SHINP	Fortran	Ford
1974	EGS1/PEGS1	Fortran	Ford, Nelson
1975	EGS2/PEGS2	Mortran 2	Ford, Nelson
1976～1977	EGS3/PEGS3(SLAC-210)	Mortran 2	Ford, Nelson
1982～1985	EGS4/PEGS4(SLAC-265)	Mortran 3	Nelson, Hirayama, Rogers
2005	EGS5(SLAC-R-730 and KEK Report 2005-8)	Fortran	Hirayama, Namito, Bielajew, Wilderman and Nelson

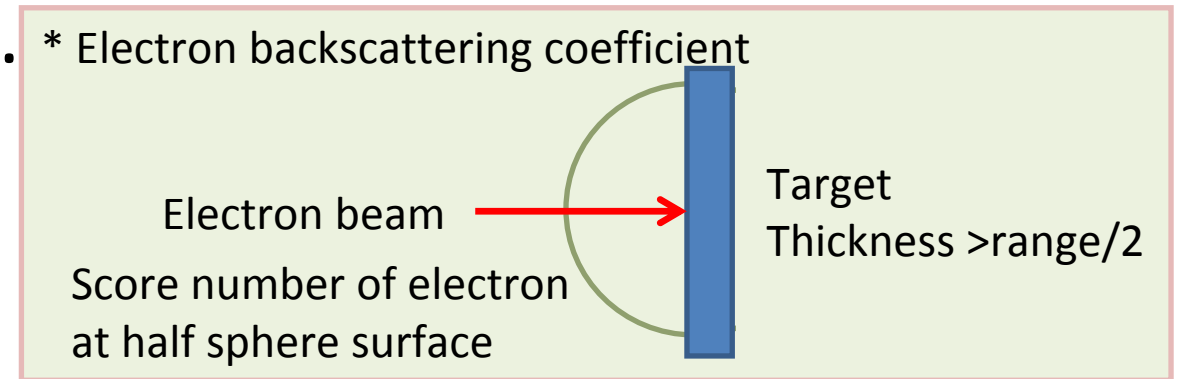
- Comparison with experiment on
e- backscattering –
as the benchmark of electron transprt

Benchmark of electron/photon transport calculation code

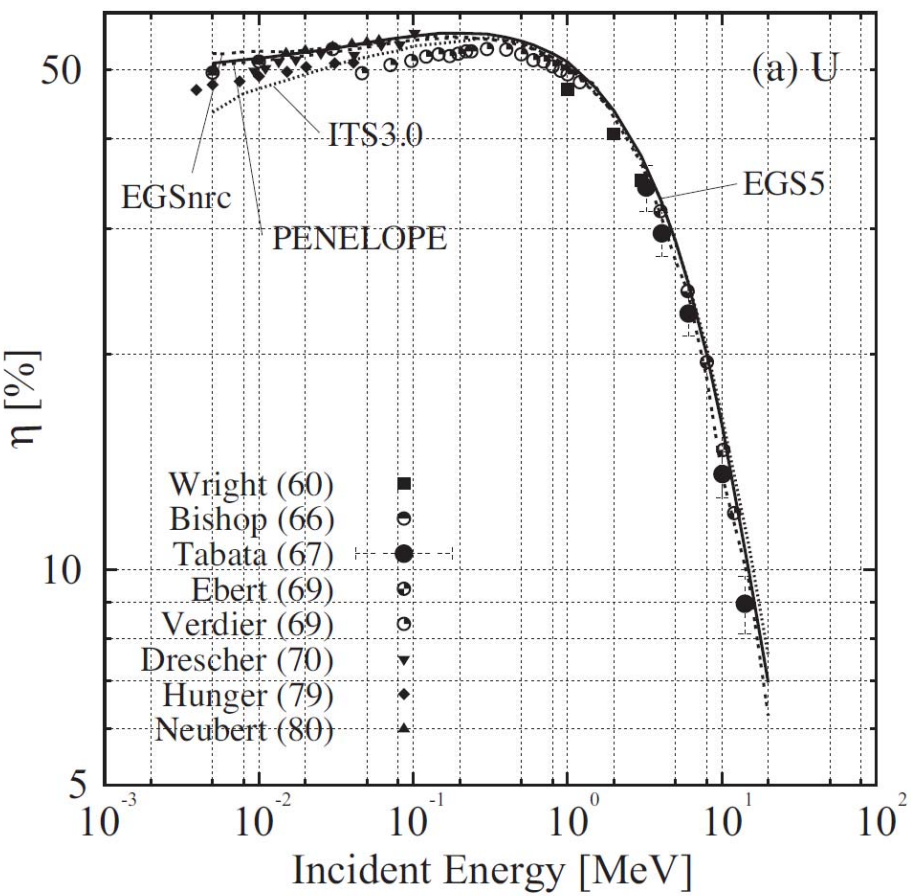
Incident particle	Transport process	Estimated value
(E) Electron, Positron	(i) Backscattering	(a) Coefficient
(P) Photon		(b) Energy spectrum
		(c) Angular distribution
	(ii) Transparent	(a) Coefficient
		(b) Energy spectrum
		(c) Angular distribution
		(d) Dose
	(iii) Deep penetration	(a) Energy deposition
		(b) Charge deposition
		(c) Dose
		(d) Detector response

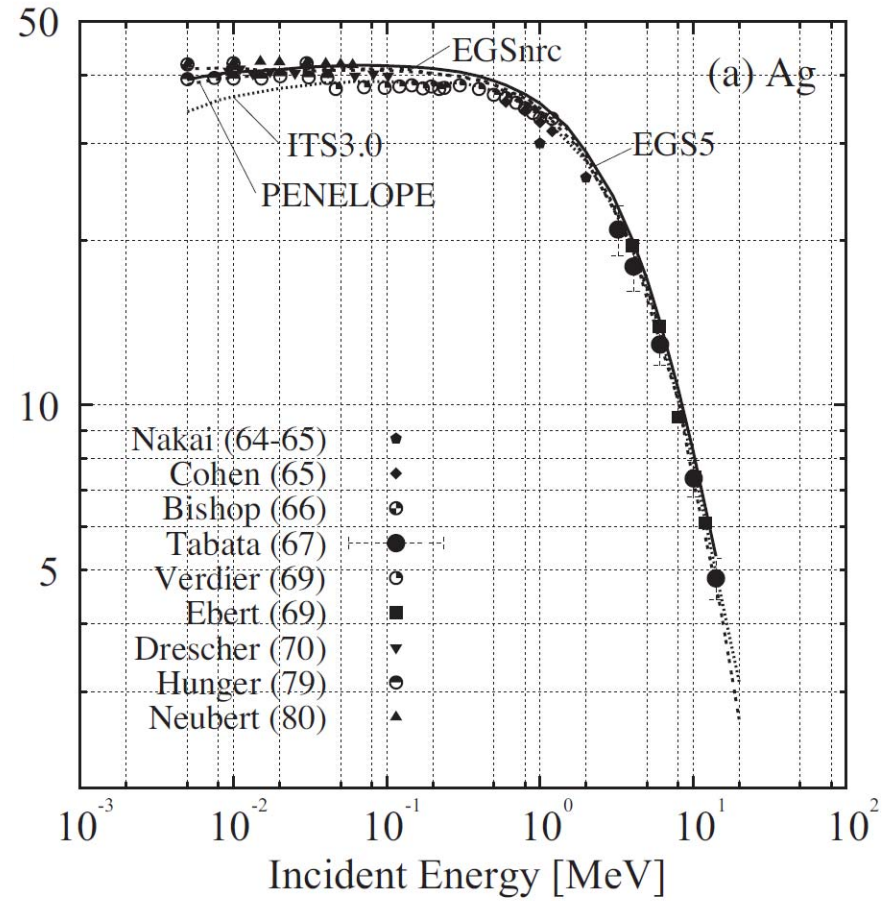
Benchmark calculation of general purpose electron/photon transport code

- Until now, general purpose electron/photon transport code (EGS, ETRAN, ITS, Penelope, MCNP, Fluka, Geant etc) has been benchmarked for many experiment.
- Among them, electron backscattering* is one of the most severe test, because electron multiple scattering calculation tends to fail for backscattering.



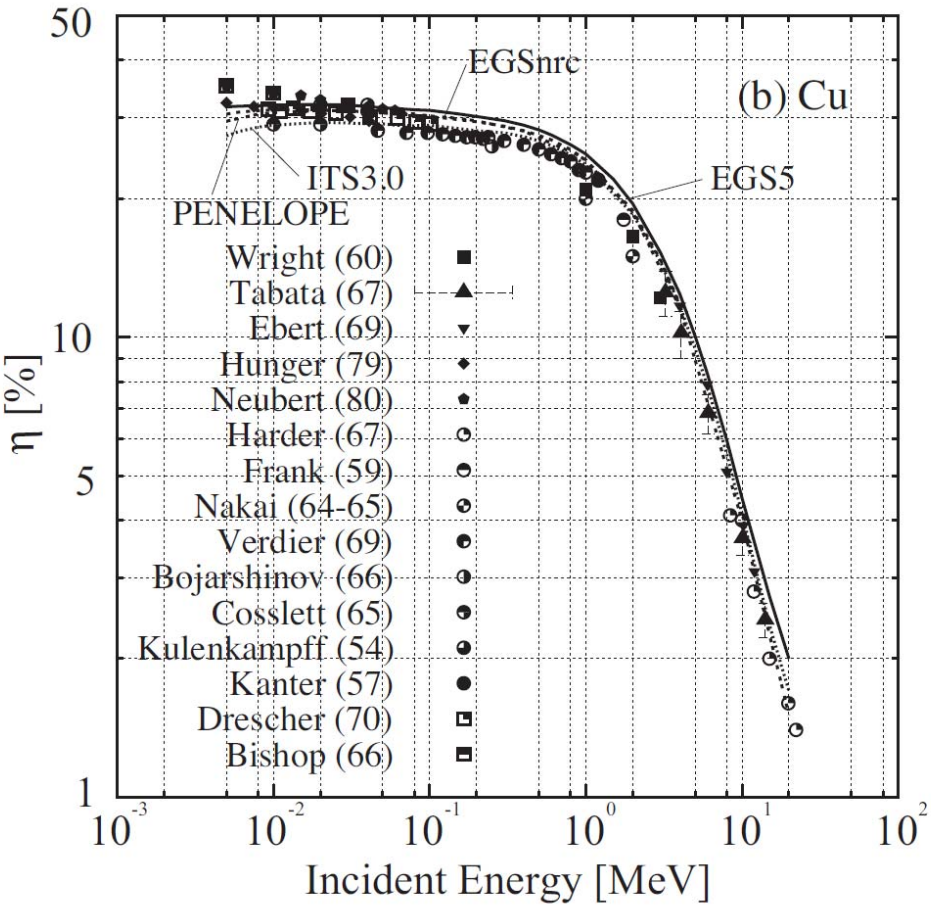
BS coefficient from U, Ag target

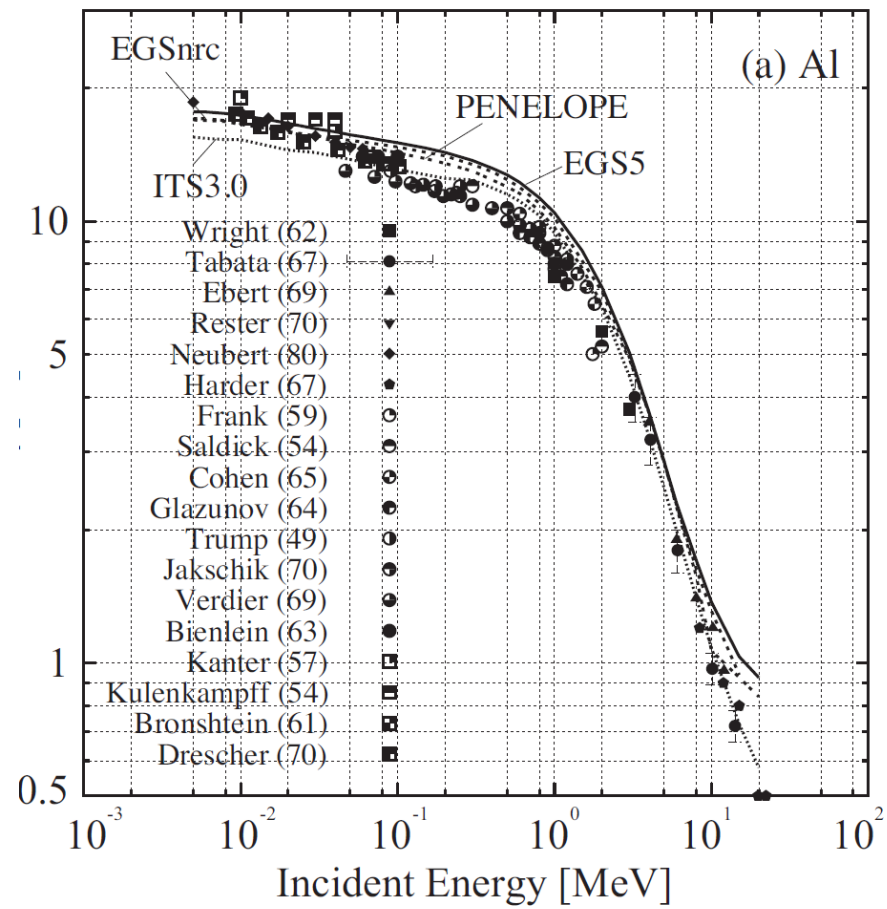




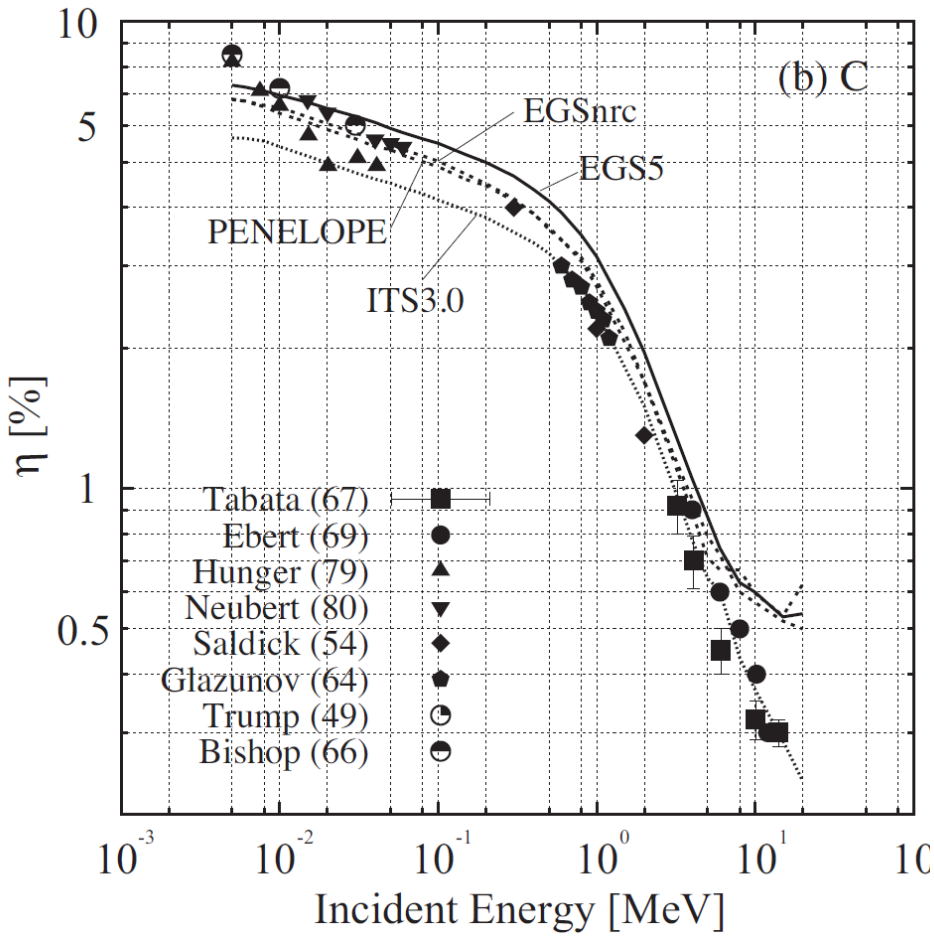
Calculation condition:
Multiple Scattering angle: Goudsmit-Sauderson theory
Spin relativistic effect is considered.

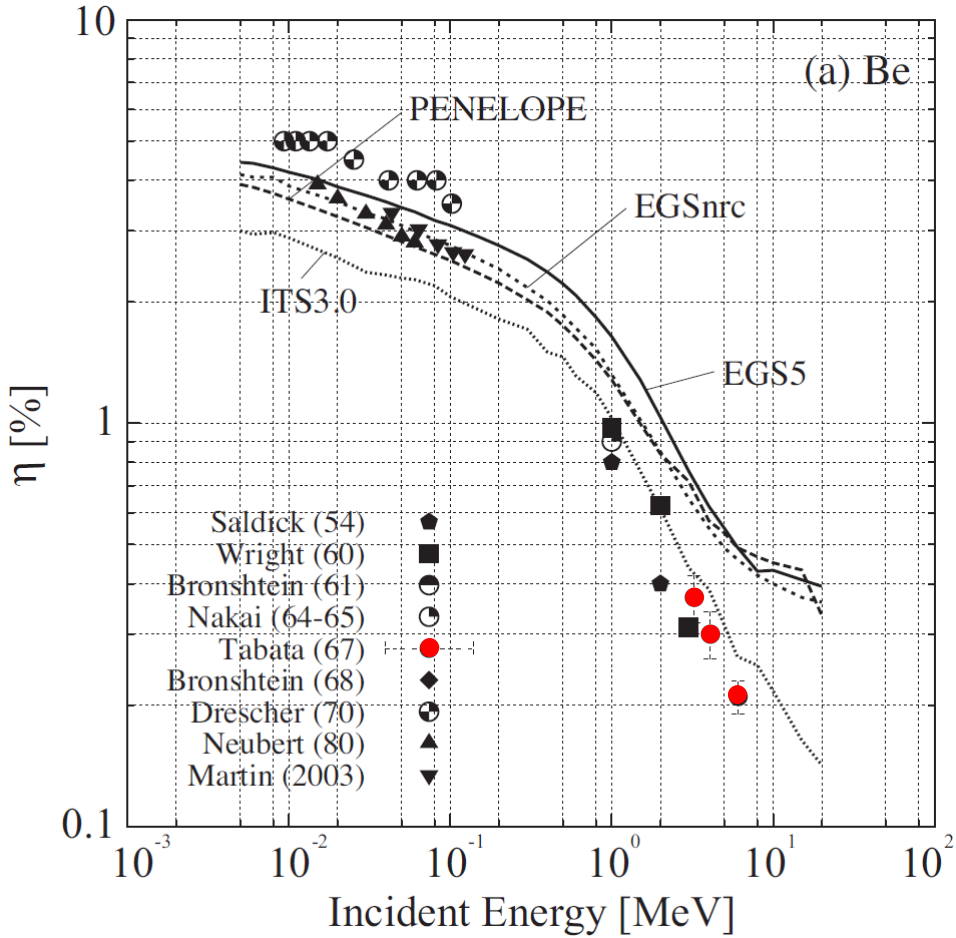
BS coefficient from Cu, Al target





BS coefficient from C, Be target





Tendency of BS coefficient η

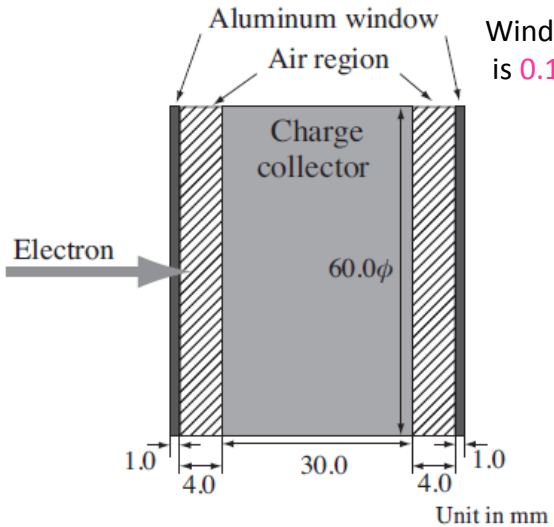
- Calc. and Exp. values agrees well for U-Al.
- Calc. and Exp. values differ for C and Be.
  - Among calc., ITS is close with exp. at MeV region. why?
- EGS5, EGSnrc and Penelope agreed with 20% for all target/energy.

⇓

- We study and re-evaluate Tabata's exp.
  - Covers wide Z range in MeV region.
  - Experimental condition and analytical method are expressed in detail.

Outline of Tabata's exp

Tabata used ionization chamber to detect backscattered electron.



Window thickness is 0.1mm not 1mm

Structure of Tabata's Ion chamber

$$I = \int_{E_{\mathrm{cut}}}^{E_0} \frac{d\eta(E)}{dE} R(E) dE$$

- η : Number of back scattered electron
- R(E): Response function of ion chamber
- E_{cut} : Electron cut-off energy
- I : Output of ion chamber

Question : How do we get η from *I* ?

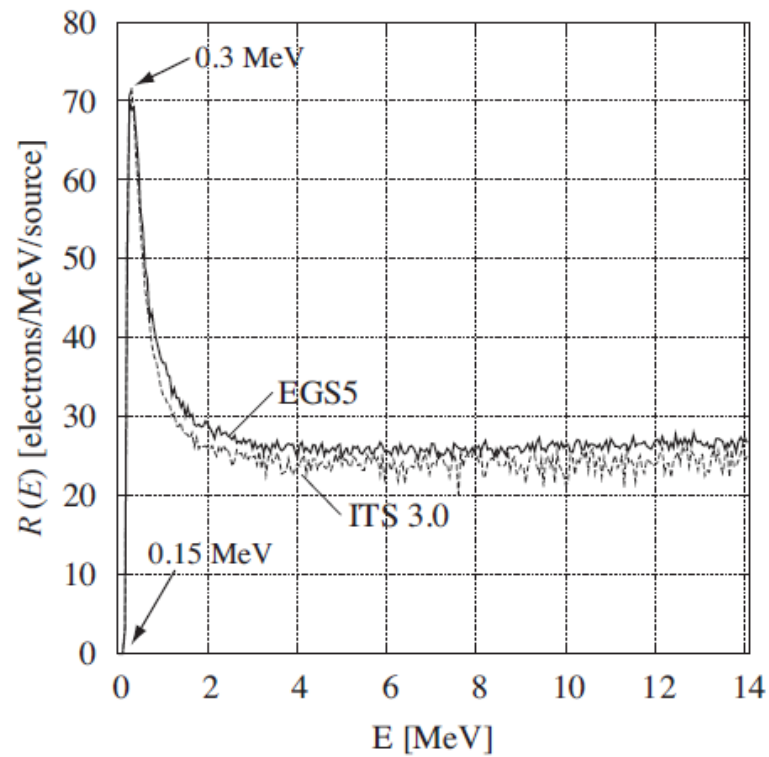
Tabata's solution: $\eta = I/f(E_{av})$

- *f* is a multiplication factor of ion chamber which depends on E_{av}.
- E_{av} is average energy of back scattered electron. He assumed that E_{av} is a function of the source electron energy and atomic number of the target.
  E_{av} for Al, Cu, Pb and 1,2,3 MeV is obtained from other experiment.
  E_{av} for various *Z* and *E* is obtained by interpolation and extrapolation.
- $f(E_{av})$ for the Au target was estimated by η obtained from the Faraday cup.

EGS5 approach 1

- Follow Tabata's method
  - Calculate response function of Tabata's IC, R(E)
    - E_{cut} is set to 1keV
  - Calculate backscattered electron spectrum, $\eta(E)$, and calculate η and E_{av}
  - Calculate *I* by using $\eta(E)$ and R(E)
  - Then, calculate *f*

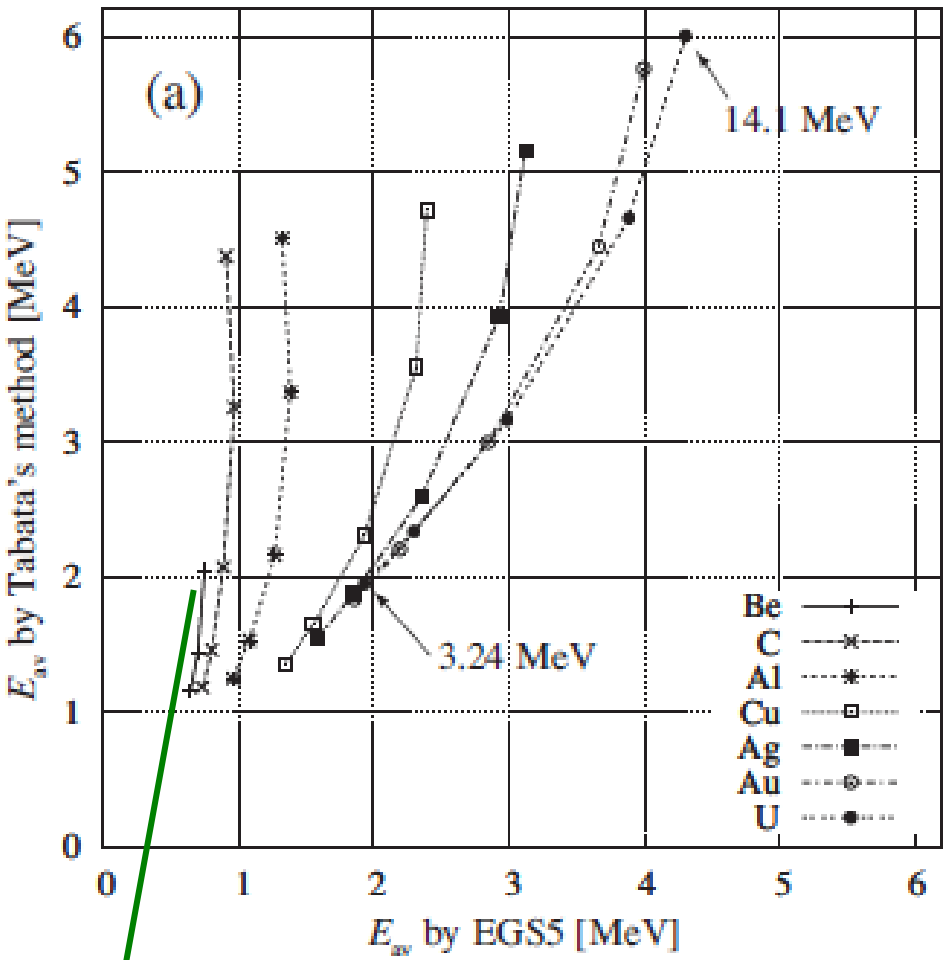
$$f = I/\eta$$



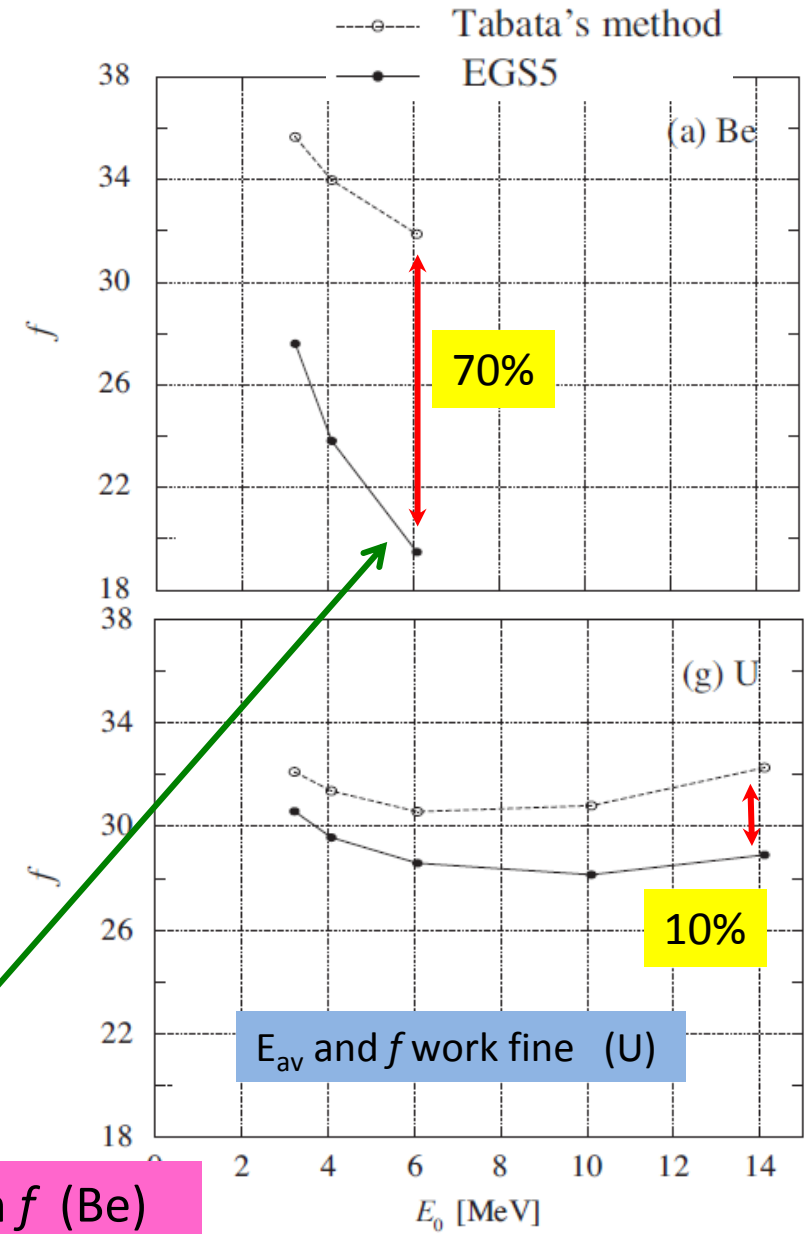
Response function of Tabata's IC by EGS5 & ITS 3.0

The value of R(E) below 0.15 MeV is zero due to Al window.

Error of E_{av} and multiplication factor f



Comparison of E_{av}

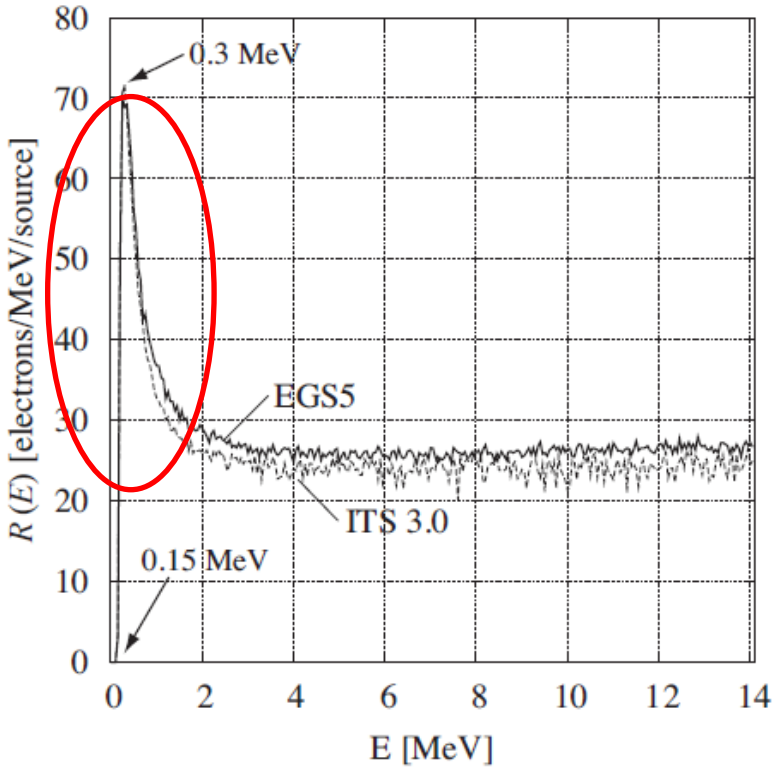


E_{av} and f work fine (U)

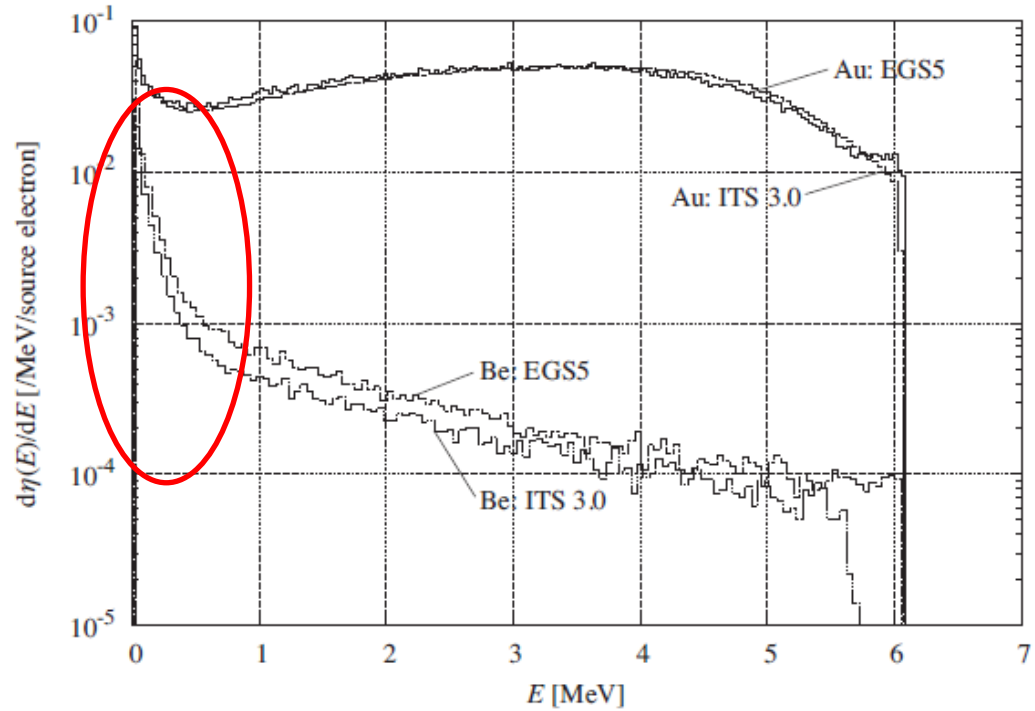
Error of E_{av} results in an error of factor 1.7 in f (Be)

Reason of large error for Be target

Resonant enhancement of detector response & electron spectrum



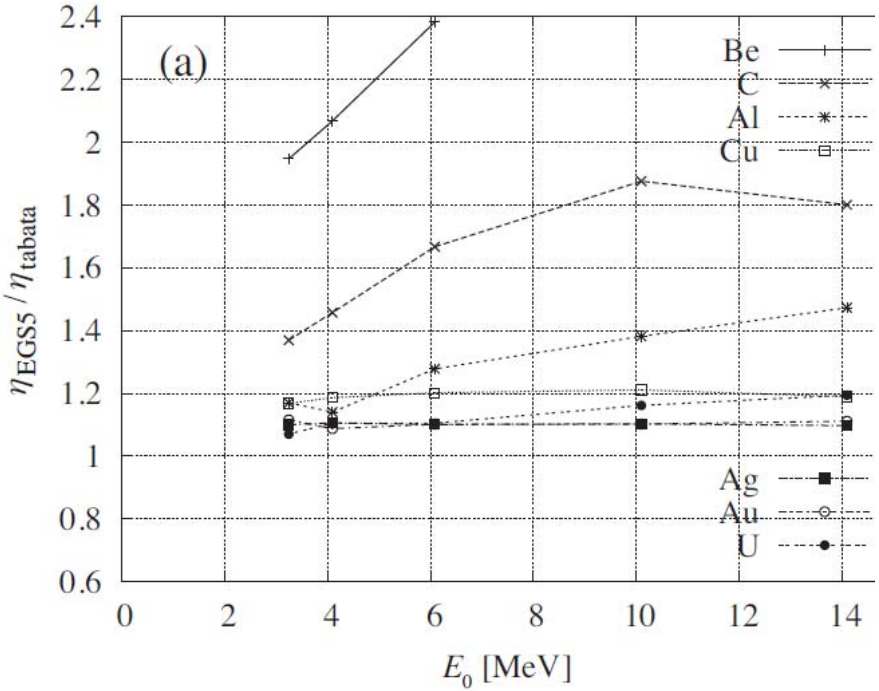
Response function of Tabata's IC

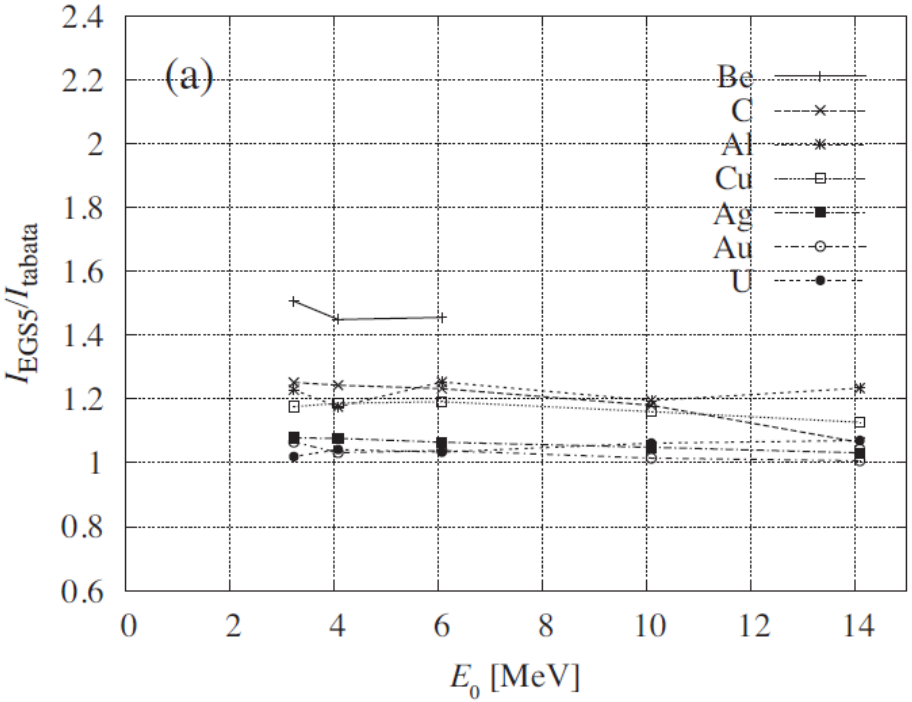


Energy spectrum of backscattered electron

-> Instead of $f(E_{ab})$, $R(E)$ should be employed ! Or, I should be compared!

EGS5 approach 2: Instead of η, Compare *I*





Comparison in η:
Original condition

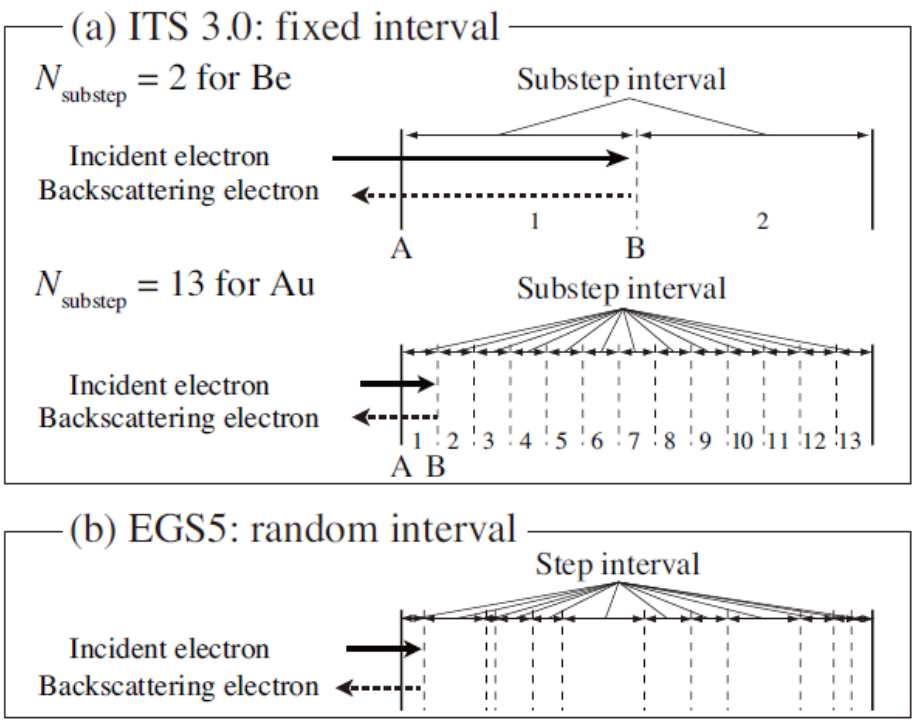
Comparison in *I* :
(Treated *R*(E))

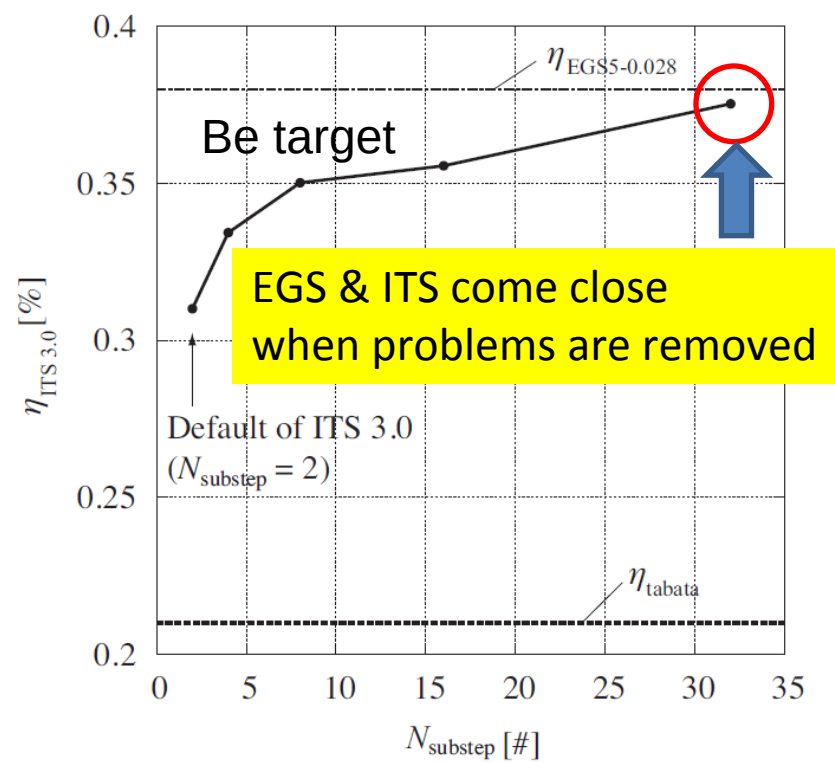
1<C/E<1.2 for C,Al,Cu,Ag,Au,U
C/E=1.5 for Be

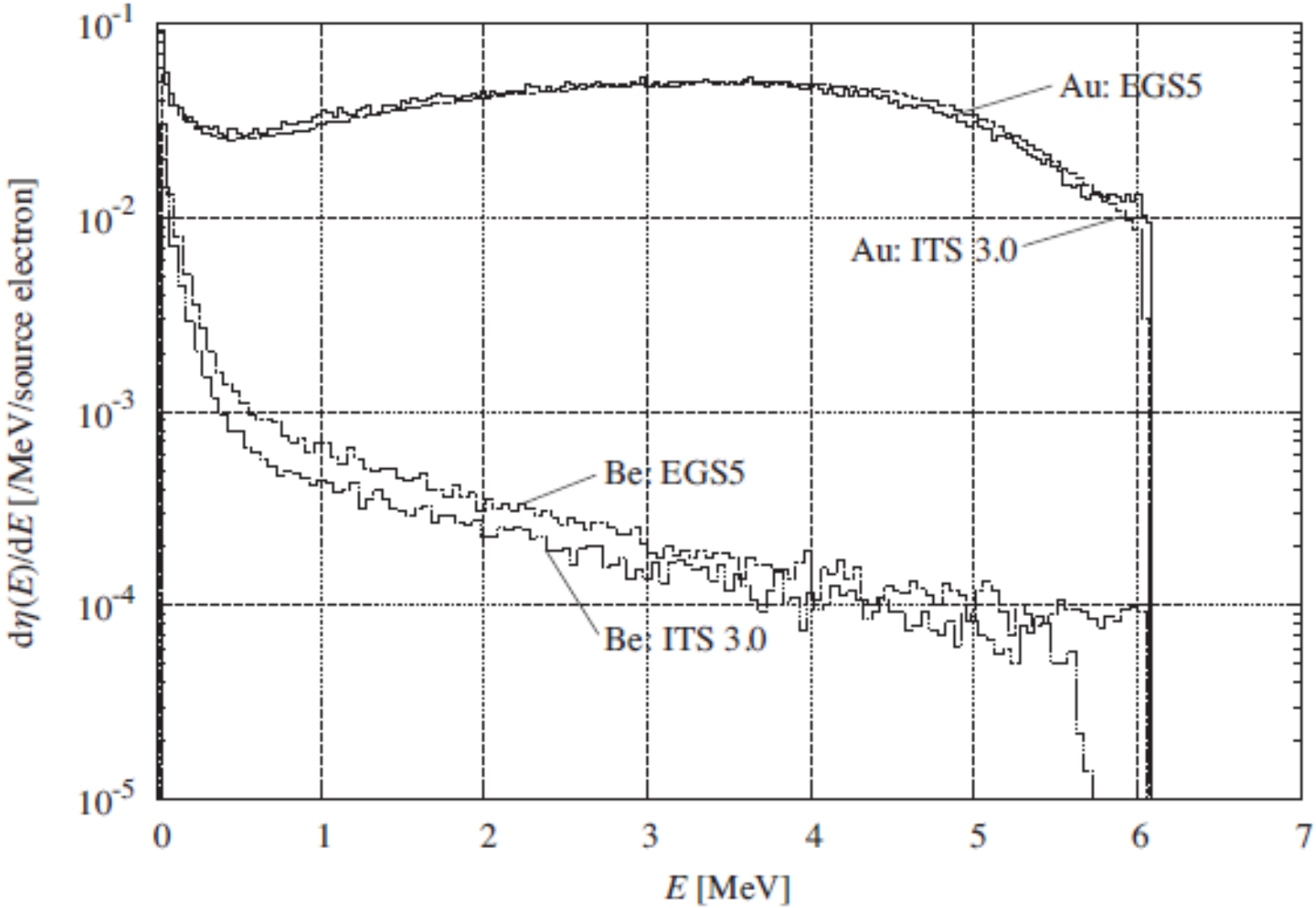
Remaining question 1: Why C and E differs? Error in calculation?
… New experiment is waited.

Remaining question 2

- Why was ITS closer to exp?
  - Investigate transport mechanism of ITS.
    - Number of substep = 2 for Be. This causes too long path length for electron and too small η.(Problem A)
    - Number of step = 64. This introduces effective cutoff energy (0.028MeV for 6.08MeV electron) which affects η largely for Be. (Problem B)

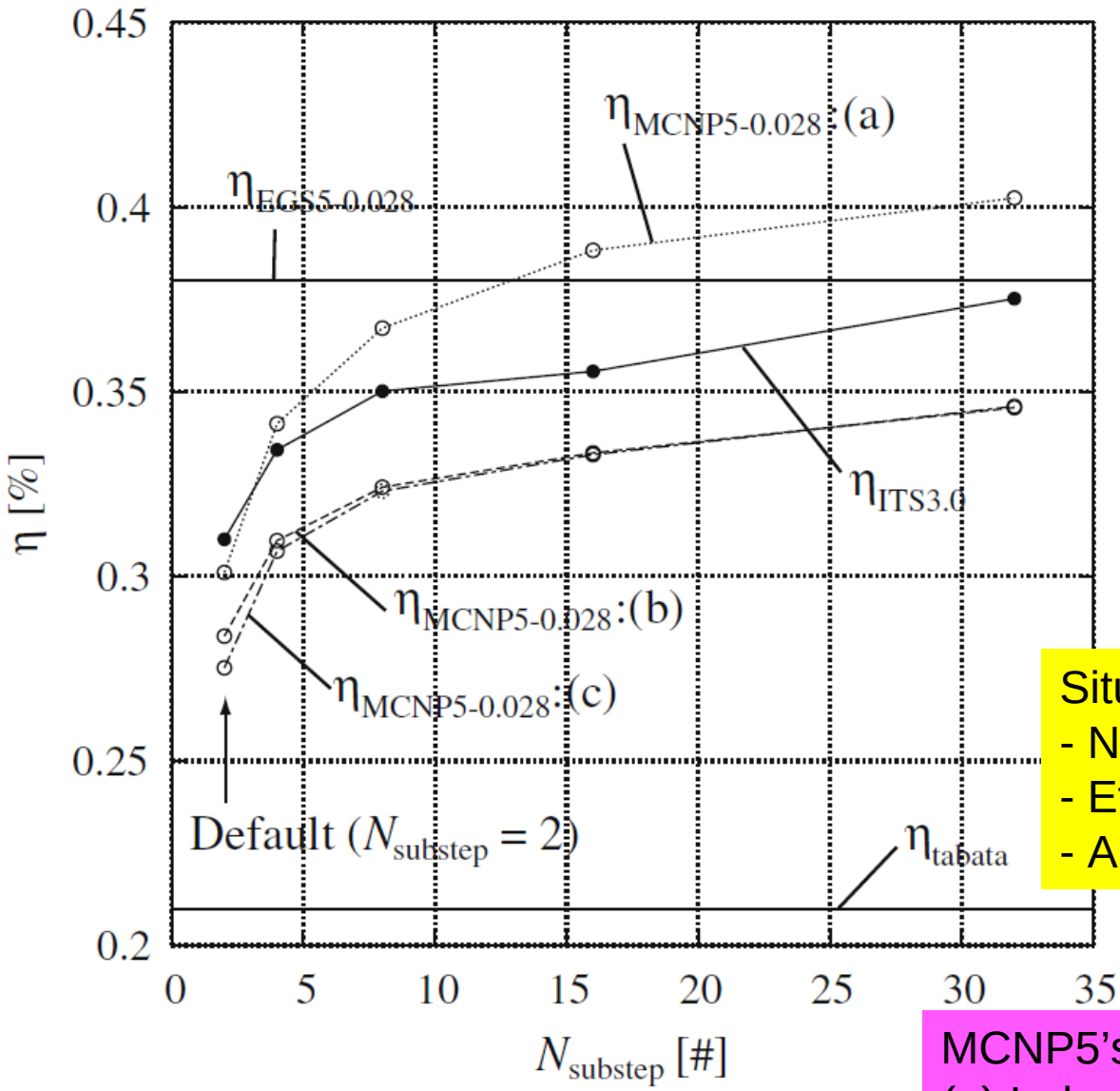






Energy spectrum of backscattered electron by 6.08 MeV electron

MCNP5-ITS3.0-EGS5 comparison



Situation in MCNP5
- $N_{substep}$ dependence is seen.
- Effective cutoff problem removed.
- Algorithm dependence is seen.

6.08 MeV electron backscattering from Be target

MCNP5's electron transport algorithm
(a) Indexing algorithm (default)
(b) ITS indexing algorithm
(c) New energy and step-specific method

Summary

- During benchmark activity of egs5 code, we re-evaluated Tabata's electron backscattering experiment.
- We find BS coefficient η was distorted for factor 1.7 by using multiplication factor $f(E_{av})$.
  - We obtained better agreement between egs5 and experiment by comparing ion chamber output.
- We also find incorrect η calculated by ITS.
  - This and Tabata's experiment formed "a good agreement (by chance)", which has been believed as truth for more than 20y.
- Better experiment data is still needed to verify electron and photon transport calculation code.
- We appreciate Prof. Tabata's help to understand the exp.

Part of this talk is already published as Kirihara's PhD thesis at Sokendai and NIMB 268(2010) 2384.

Backup slide for Q and A