Space charge simulation update (5)

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Contents

- Multiple scattering in charge exchange foil
    - Elastic scattering to see transverse emittance increase
- Simulation with both space charge and multiple scattering

Basic of elastic scattering

- Total elastic scattering cross section is

$$\sigma_T = 4\pi r_e^2 (\frac{Z_1 Z_2^{2/3}}{\alpha\beta})^2$$

J.D.Jackson or
R. Fernow, "Intro to experimental particle phys."

r_e = classical electron radius (2.8E-13 cm)
Z_1 and Z_2 = atomic charge of the incident and the bound particle (1 and 6)
\alpha = 1/137
\beta = v/c (0.152)

- Average number of single scattering event.

$$m = Nt\sigma_T$$

$$N = N_A \rho / A$$

N = the number of atom per unit volume, t = thickness of foil (1E-5 cm)
N_A = Avogadro constant (6E23)
\rho = density of matter (2 g/cm^3 for carbon)
A = atom mass number (12)

Several models for "multiple" scattering

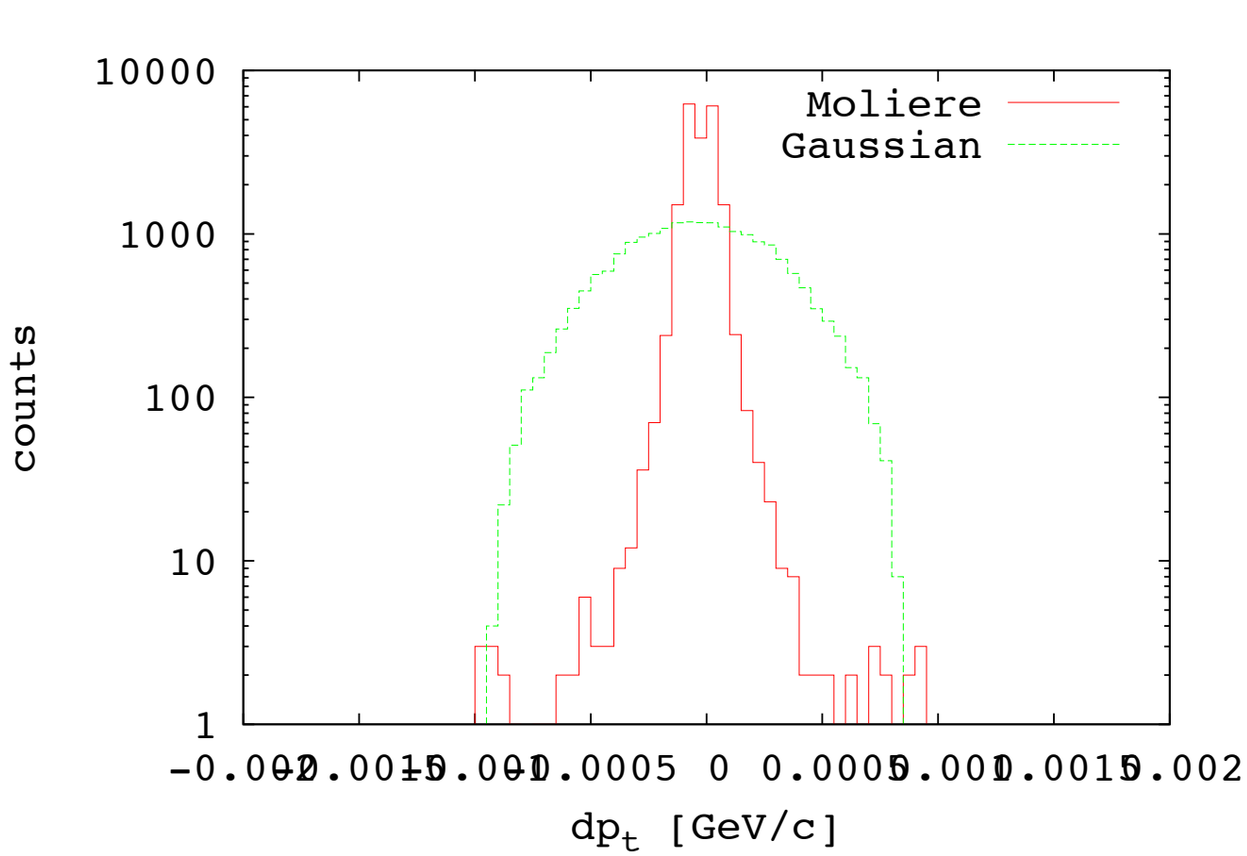
- Depending of average number of events
  - m > 20: multiple scattering
    - Moliere (Z. Naturforsch, 3A (1948) 78.)
    - Lewis (Phys. Rev. 78 (1950) 526.) c.f. Geant4
- m < 20: plural scattering
    - Keil, Zeitler and Zinn (Z. Naturforsh, 15A (1960) 1031.)

Model of foil in ERIT

- 20 micro g/cm^2 carbon foil with 11 MeV proton gives
    - m = 9
    - plural scattering region
- However, I use Moliere model because a look-up table (old CERN library: MLRL) was available
    - With a single scaling parameter to match the emittance growth by Mori&Okabe calculation.
    - Keep the distribution and do scaling of ampl.

Angular distribution

- Moliere model has extended tail
  - Comparison with a beam with Gaussian distribution.



- Assume emittance growth is mainly determined by the small angle scattering.
- Large angle contributes to the loss.

Adjust a single scaling parameter

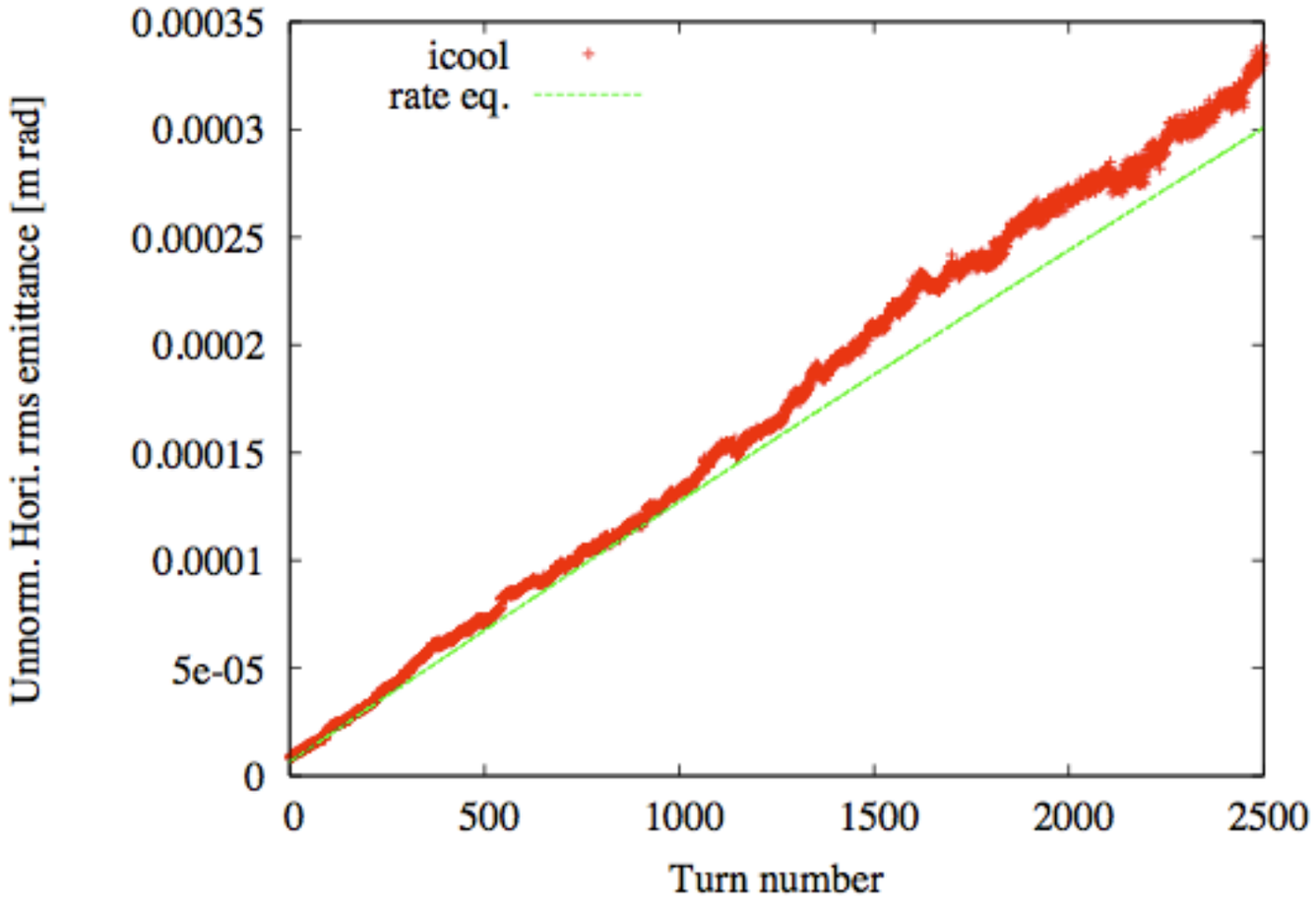
- Mori&Okabe calculation in 2011

3E-4 m rad/2500 turns (dE_s)
= 1.2E-7 m rad/turn

Initial emittance (Ei)
= 8E-6 m rad

E = d(yp) d(y)

Therefore, d(yp)_s/d(yp)_i
= Sqrt[1.2E-7/8E-6]
= 0.122

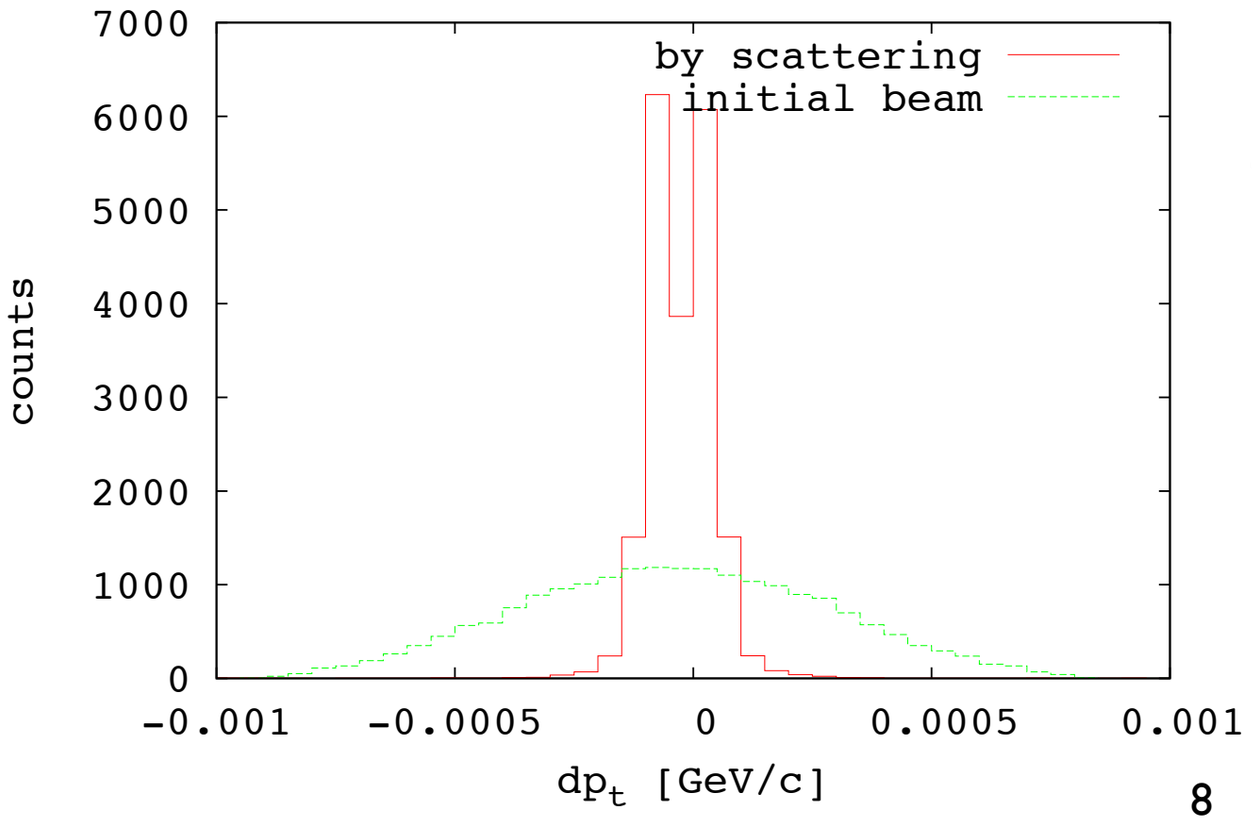


Horizontal emittance

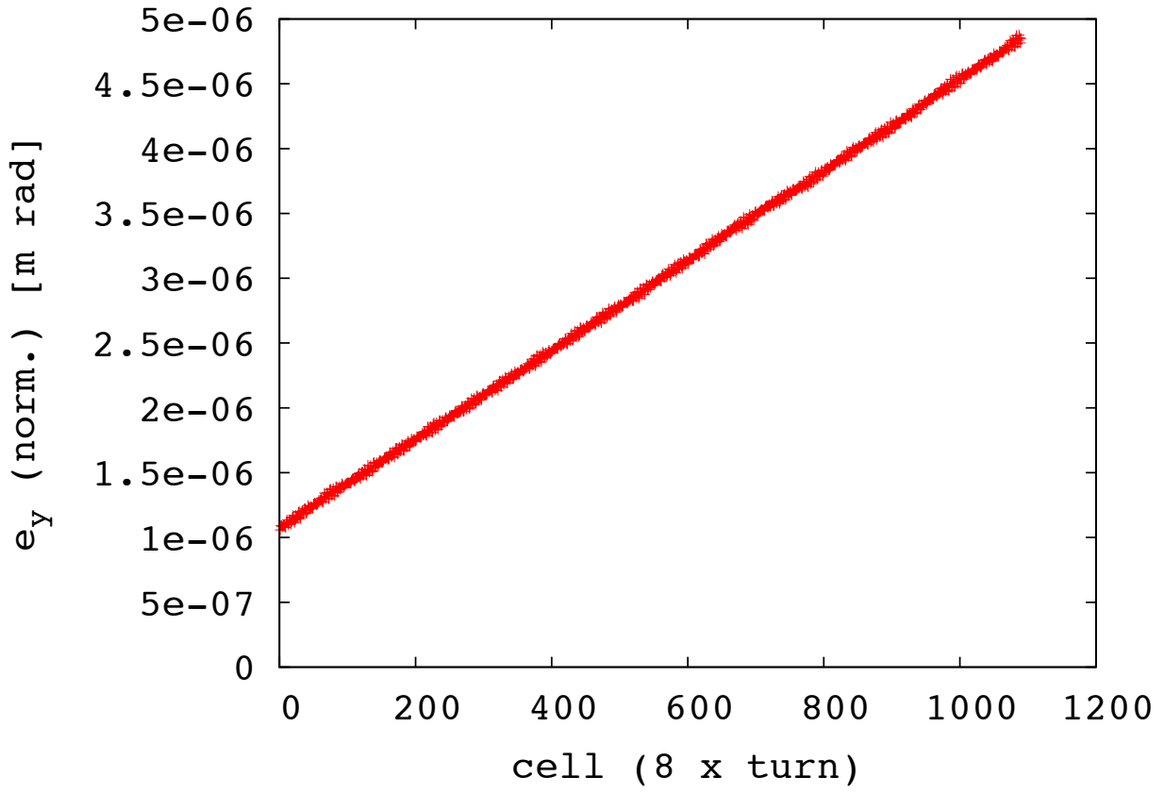
Emittance growth by foil scattering

- Scale the scattering angle.

d(yp)_s/d(yp)_i ~ 0.1



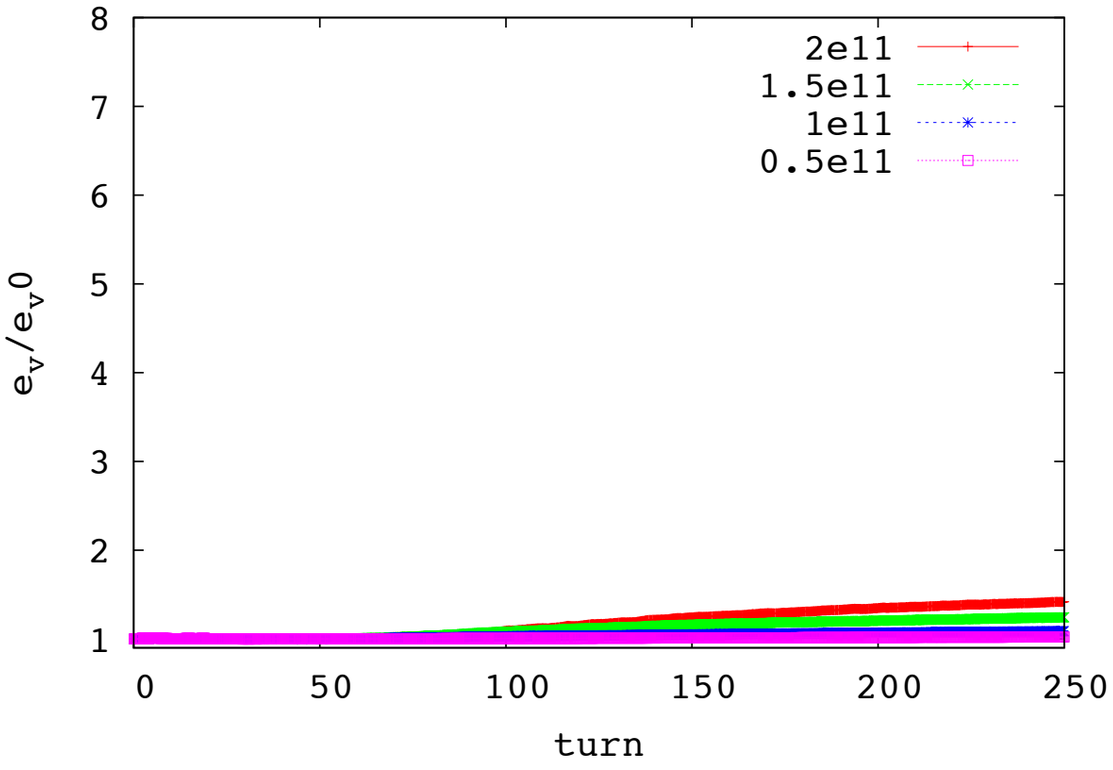
- As a result, it gives the similar growth rate as Mori&Okabe.



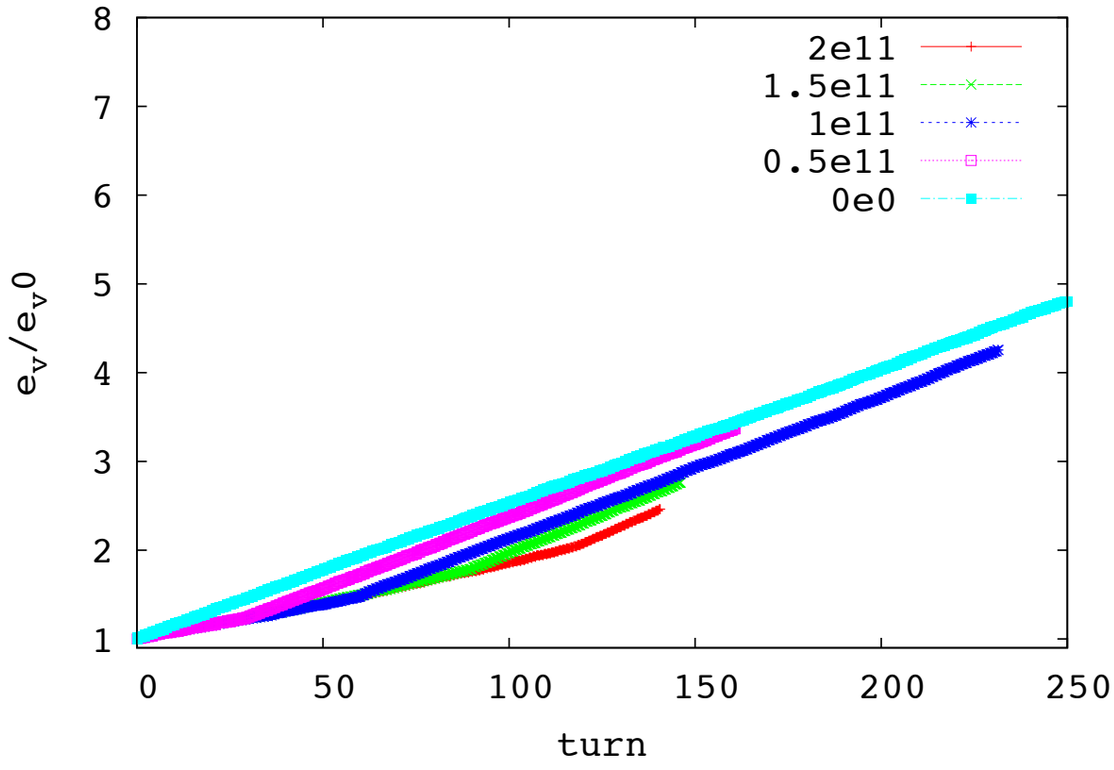
Preliminary tracking results with foil scattering and space charge

Intensity dependence without alignment error

- without foil scattering

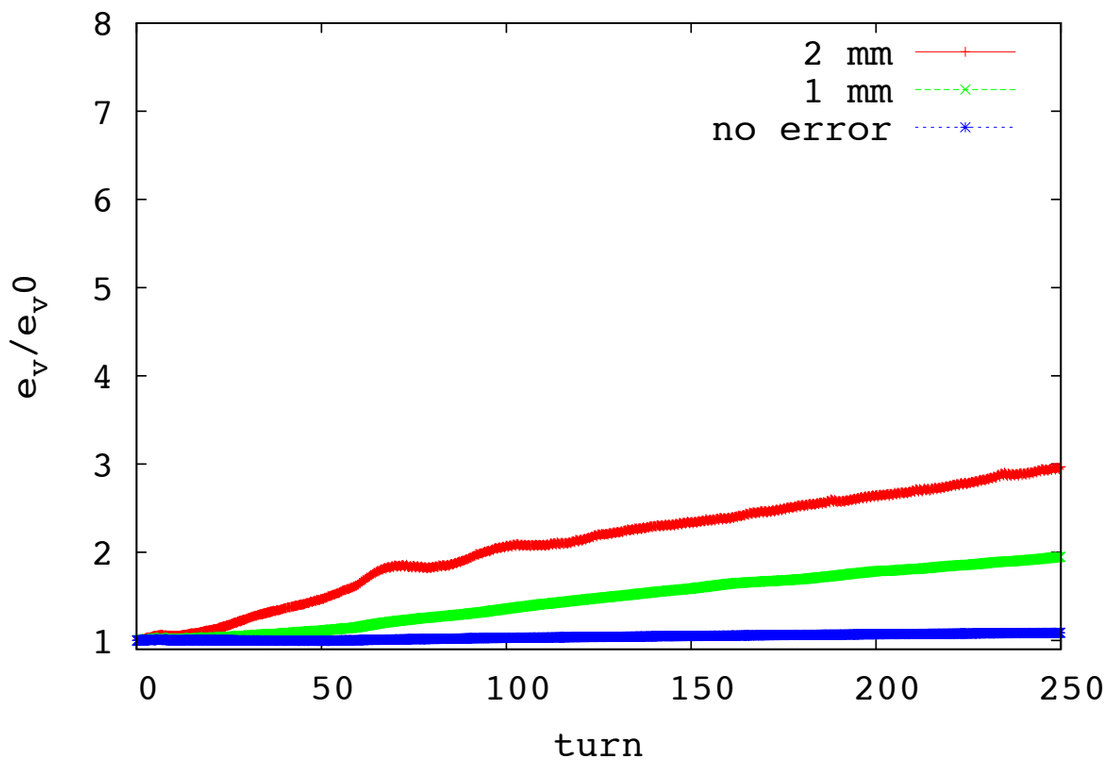


- with foil scattering

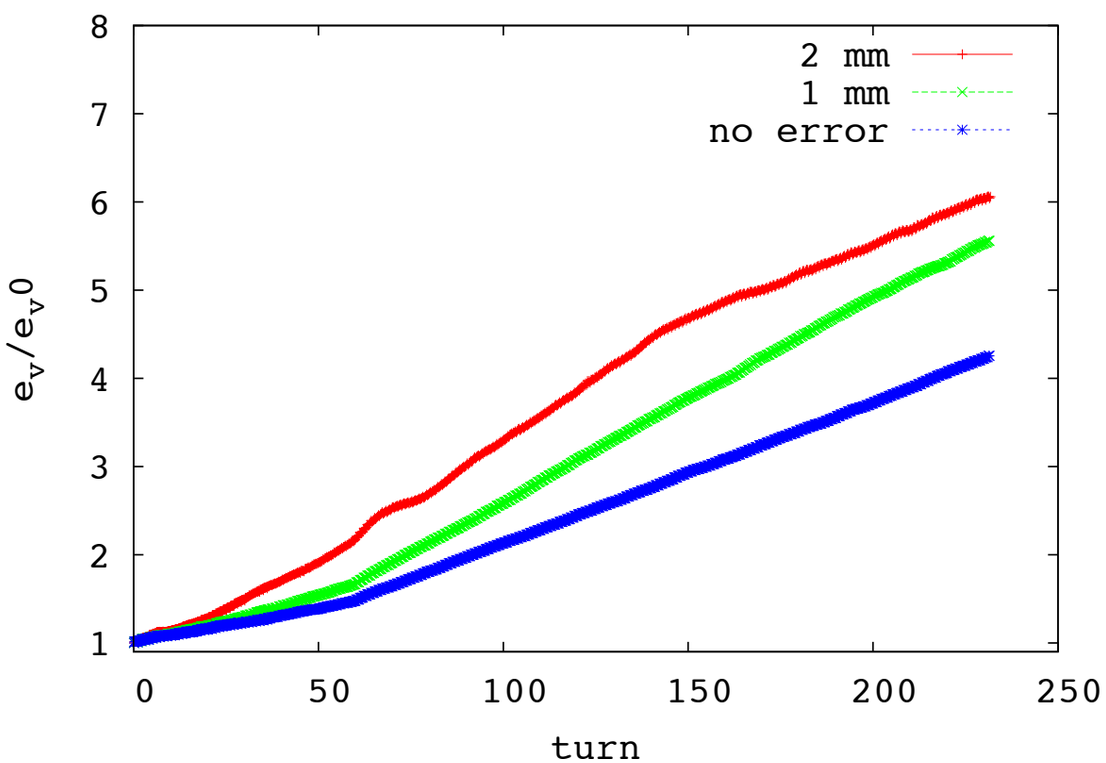


With alignment error intensity is fixed at 1E11 ppb

- without foil scattering



- with foil scattering



Summary

- During multi-turn injection, emittance growth rate is about a half because hitting probability is N_inj/2.
- Emittance seems to be dominated by foil scattering with the present parameters.

Next step

- More accurate scattering model: one in Geant4, OPAL, etc.
- Does the measurement of charge distribution identify the source of emittance growth?
- RMS emittance growth by foil scattering may be overestimated by tail particles.