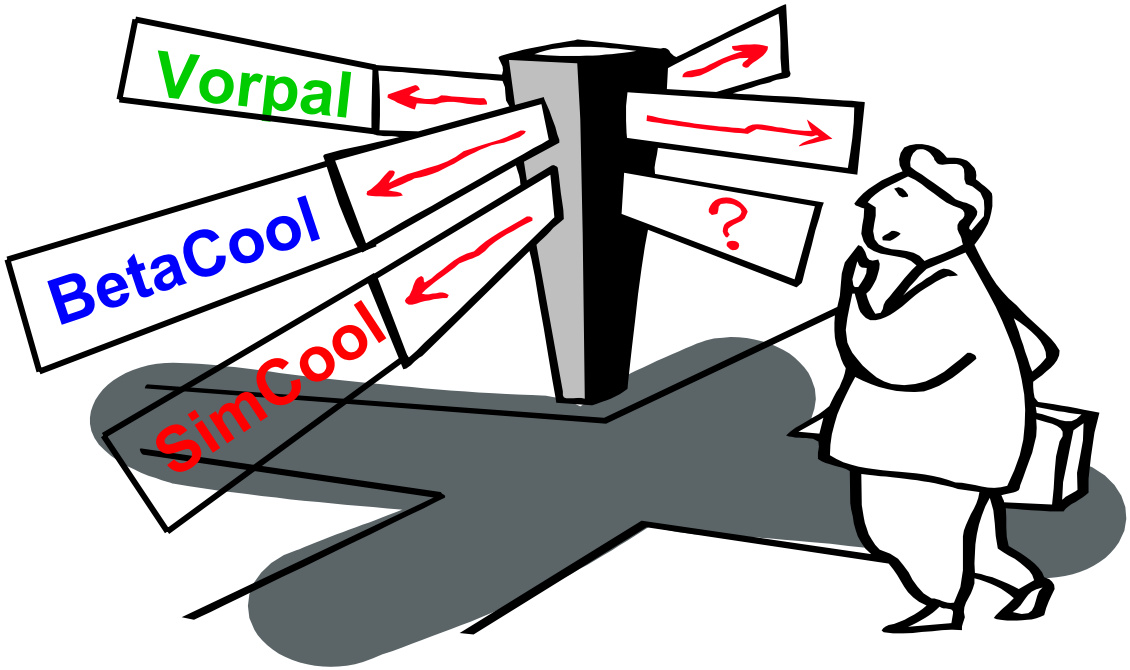
SimCool: recent developments



Code "SimCool" – first version (1)

First original version (V. Parchomchuk):

- The following values for each "time slices" are calculated:
  - Five individual coordinates for each of the "probe" particles
  - Two transversal emittances (*x* and *z*)
  - Radial distributions of the ion beam density
- Calculations take into account the following effects:
  - Space charge influence on the motion of the electrons
  - Cooling
  - Intra beam scattering (IBS)
  - Diffusion
  - Recombination

Code "SimCool" – first version (2)

The following approaches to calculate the velocity kicks are used (moving frame and "Parchomcuk" units):

- **Cooling:**

$$\frac{\Delta V_{i\_rel}}{V_{i\_rel}} = \exp\left[-\frac{4 r_e r_i c \Lambda n_e(r_\perp) \beta_{cool}^3 \Delta t}{(\beta\gamma V_{i\_rel})^3 L_{cool}/L_{ring}} \right]$$

- **IBS:**

$$\Delta V_i = \sqrt{"12\ ". \frac{2 r_i^2 c \Lambda l_i \beta_{cool}^3 \Delta t}{(\beta\gamma a_{ib})^3}}$$

- **Diffusion:**

$$\Delta V_i = \sqrt{"12 \cdot \log 100". \frac{2(r_i/Z)^2 c \Lambda n_e(r_\perp) \beta_{cool}^3 \Delta t}{(\beta\gamma)^3 V_{i\_rel}}}$$

Important: All kicks are the same for all three components of the velocity !

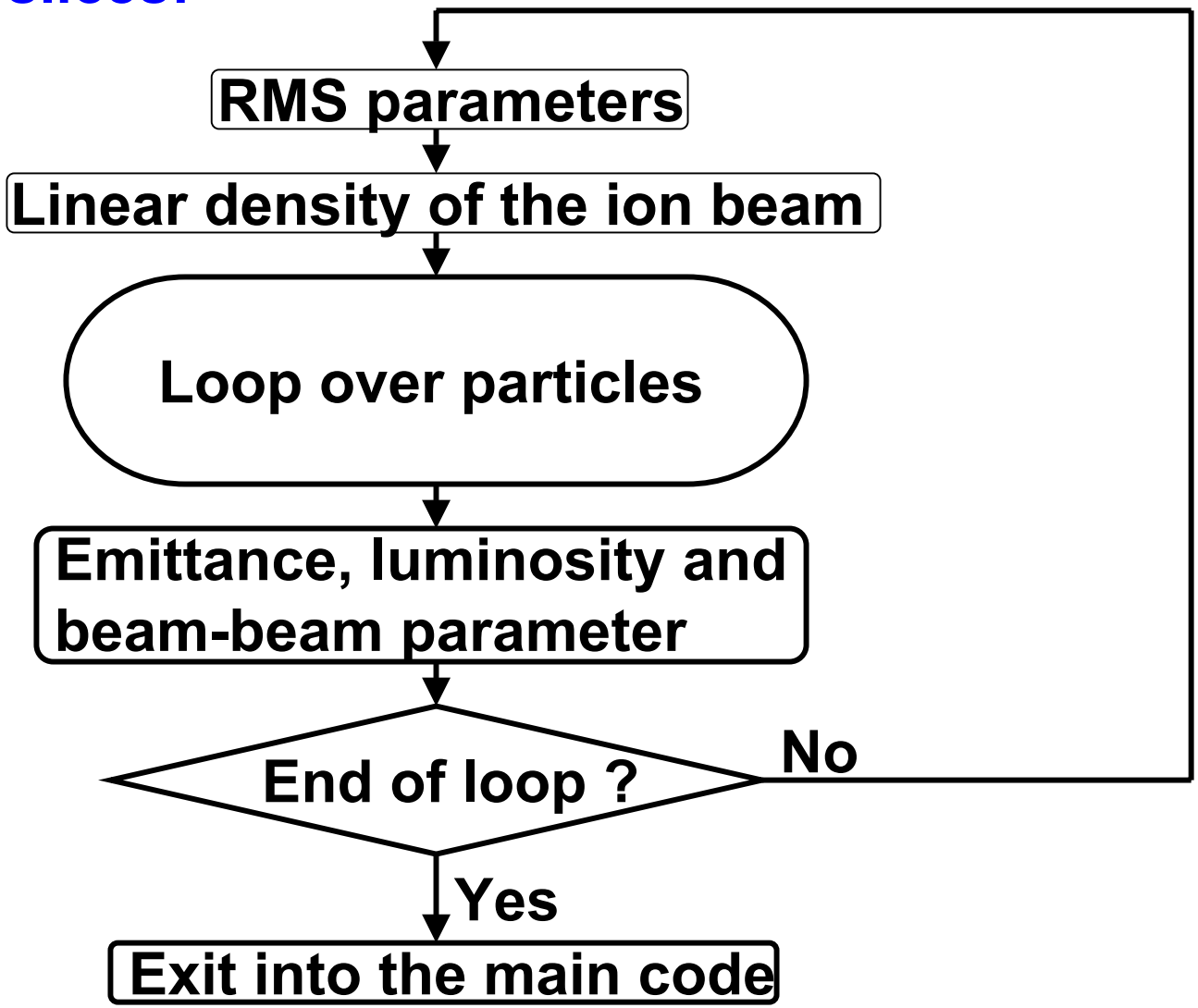
Code "SimCool" – second version

Second generation (I. Ben-Zvi; It is my own understanding of the code changes):

- **The following features were added:**
  - **Calculation of the widths of the beam density distributions (FWHM and for 95% of the beam)**
  - **Luminosity calculation**
  - **Beam-beam parameter calculation**
  - **Possibility to take into account the number of bunches**
  - **Possibility kept constant luminosity by adjusting electron current (Flag "Gain" and factor "tiecor")**
- **The first comments in the code were included**

Flow-chart (2)

Loop over time slices:



Code "SimCool" – third version (1)

Current version (Yu. Eidelman)

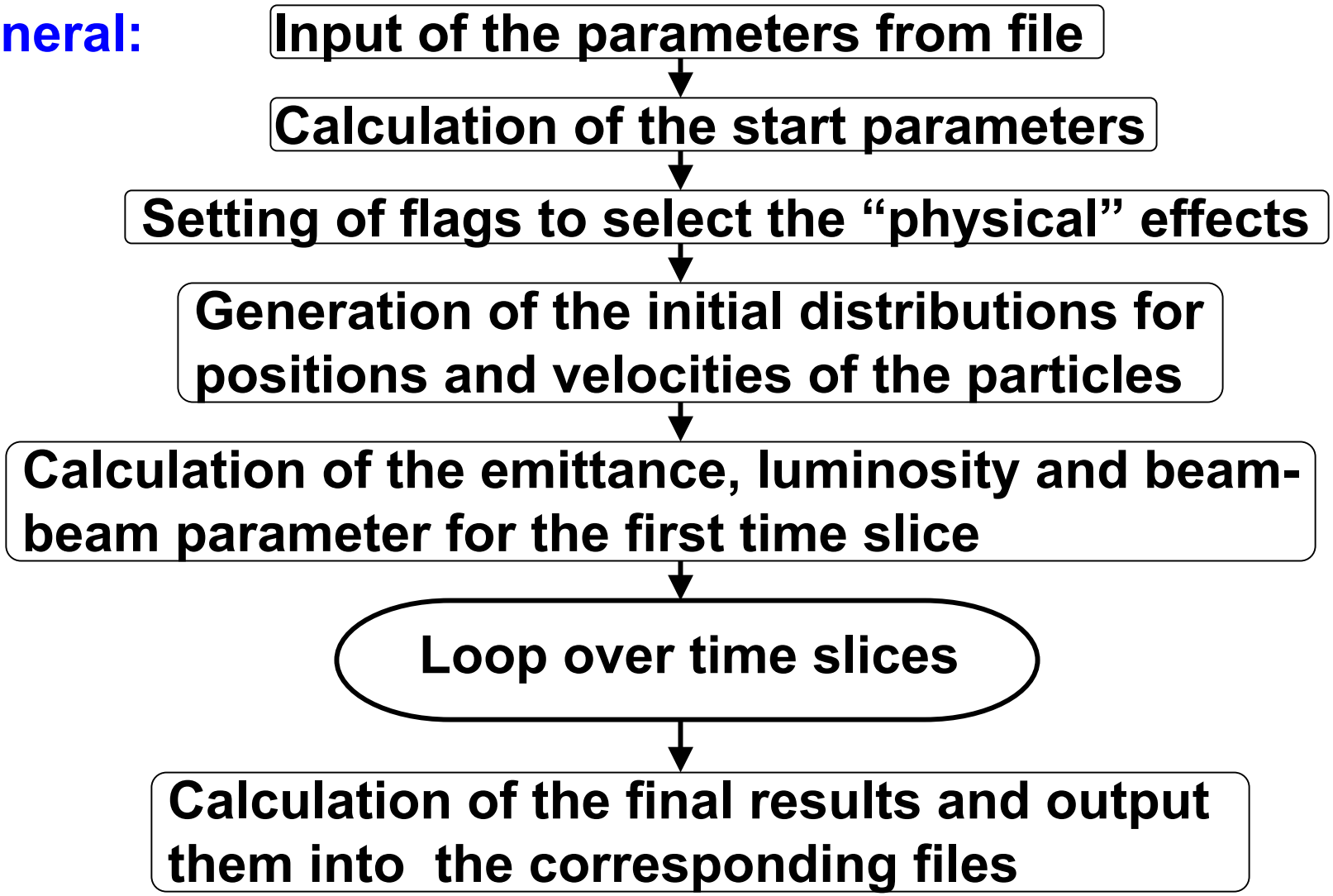
- **Calculations development:**
  - Initial distributions for positions and velocities of the "probe" particles can be generated as homogeneous or Gaussian
  - Cooling, IBS, and diffusion can be included into calculation in any combination
  - Synchrotron motion of the particles is included
  - Energy spread and longitudinal beam size are recalculated for each time slice
  - RMS parameters of the beam are calculated
  - Possibility to decrease a time step if the kick due to cooling is larger then predefined value (for example, 5%)

Code "SimCool" – third version (2)

- **Calculation development (cont'd):**
  - Ion linear density (for IBS effect) is recalculated taking into account the longitudinal beam size
- **Programming:**
  - Subroutines and functions are created to improve the program structure
  - Some misprints were fixed
  - Additional output for "physical" testing is included
  - Gistogramming of the distributions for "physical" testing is added
  - Very detail comments were written

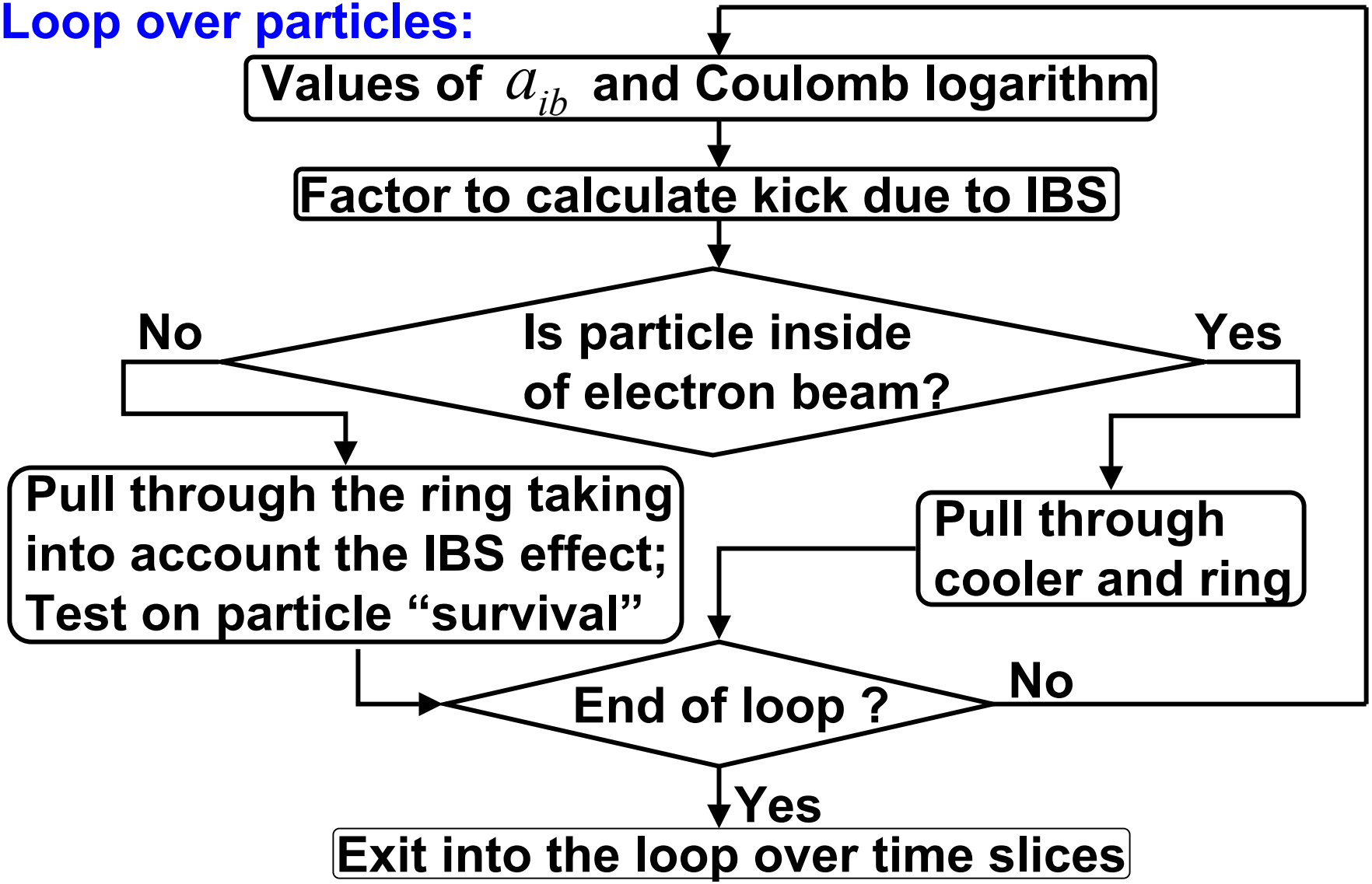
Flow-chart (1)

General:



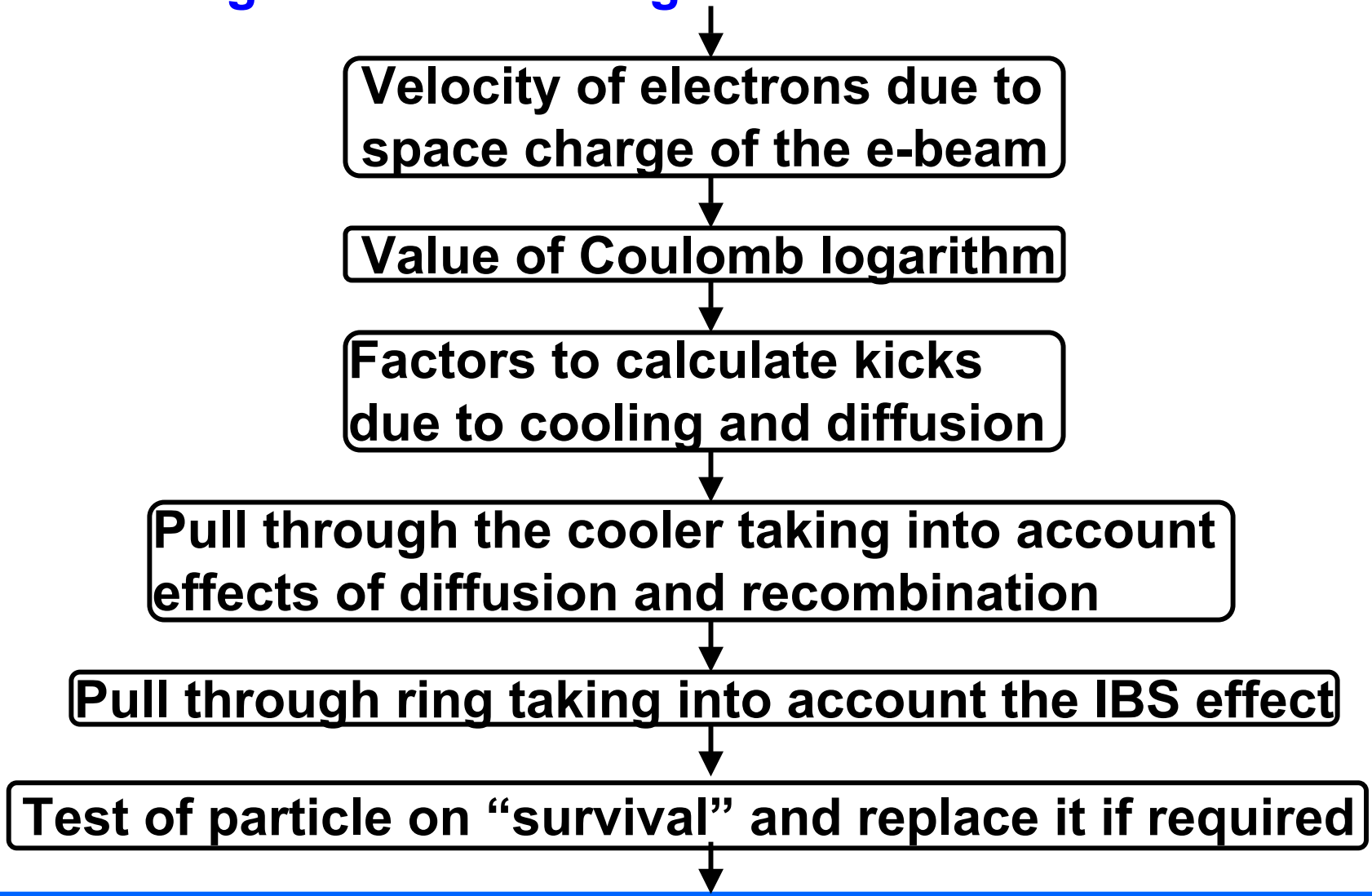
Flow-chart (3)

Loop over particles:



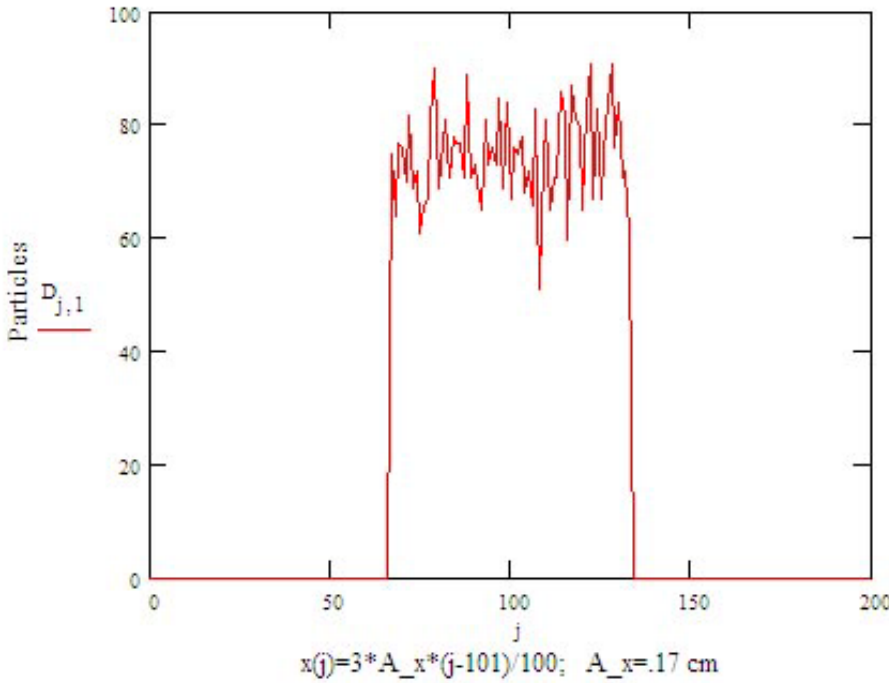
Flow-chart (4)

Pull through cooler and ring:



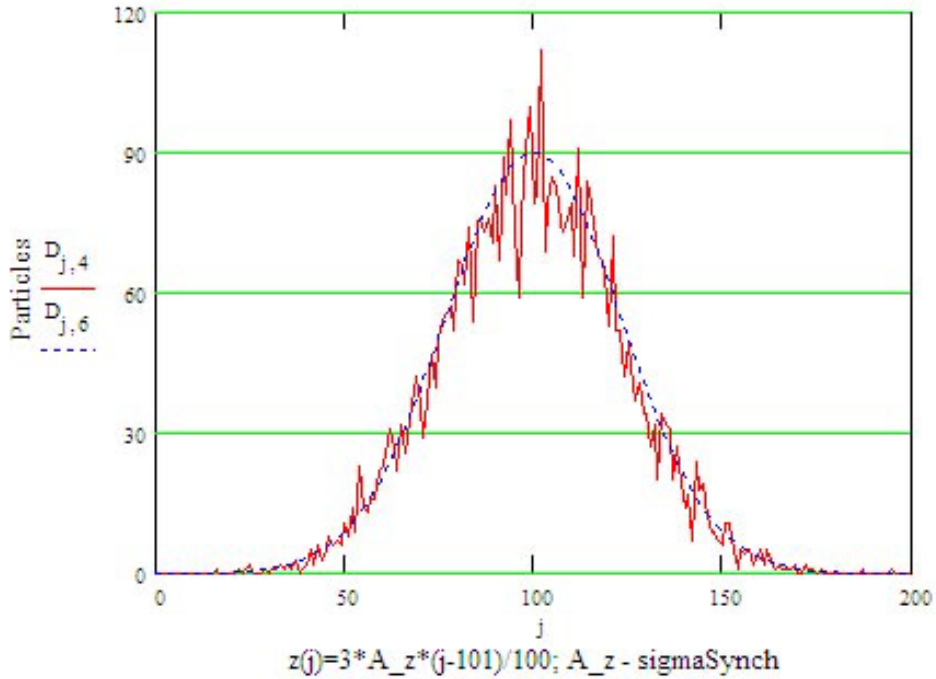
Distributions

Homogeneous



Gaussian

$A\_z := 23.33 \qquad D_{j,6} := 90 \cdot \exp\left[\frac{-\left\langle D_{j,0} - 101\right\rangle^2}{2 \cdot A\_z^2}\right]$



Energy spread ("Origin")

e-Cooling

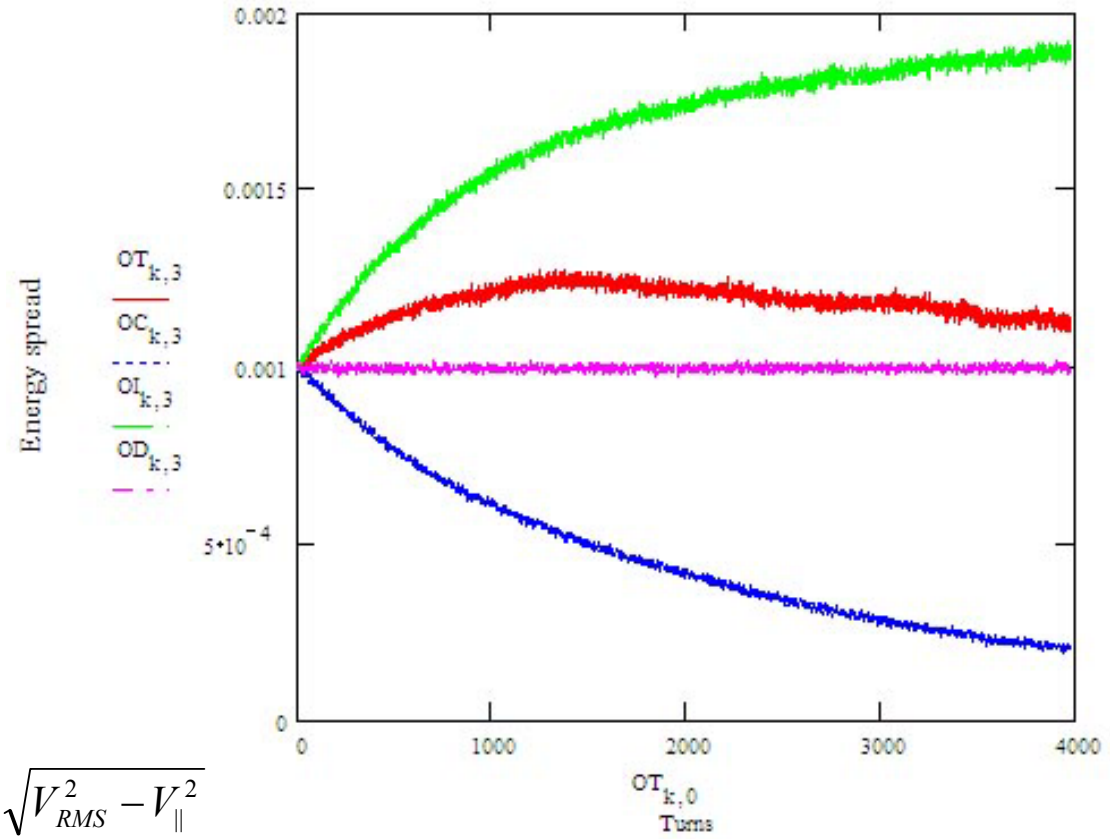
Main formulas:

$$V_{RMS} \equiv V_{\|}^{RMS} = \sqrt{\frac{\sum_{particles} V_z^2}{N_{particles}}}$$

$$\overline{V_{\|}} = \sqrt{\frac{\sum_{particles} V_z}{N_{particles}}}$$

$$\overline{\Delta V_{\|}} = \sqrt{\frac{\sum_{particles} \left(V_z - \overline{V_{\|}}\right)^2}{N_{particles}}} = \sqrt{\frac{\sum_{particles} V_z^2}{N_{particles}} - V_{\|}^2} = \sqrt{V_{RMS}^2 - V_{\|}^2}$$

$$\left(\frac{\Delta p}{p}\right)_{\|} = \sqrt{2}\,\frac{\beta}{c}\,\overline{\Delta V_{\|}}$$



Legend: Total Cooling IBS Diffusion

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Longitudinal beam size ("Origin")

e-Cooling

Synchrotron size:

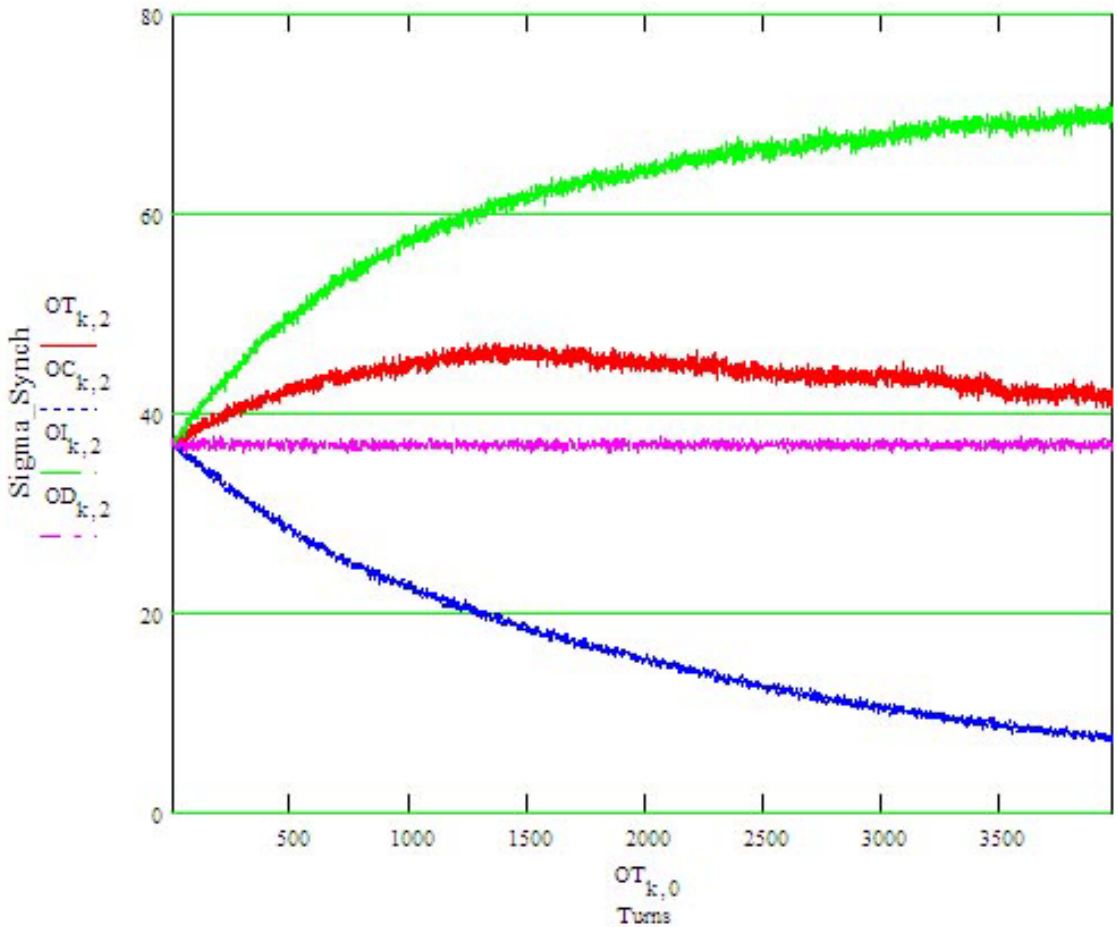
$$\sigma_s = \frac{L_{ring}\eta}{\Omega_s}$$

Phase-slip factor:

$$\eta = \frac{1}{\gamma_{tr}^2} - \frac{1}{\gamma^2}$$

Synchrotron frequency:

$$\Omega_s = \sqrt{\frac{2\pi h \eta Ze V_{RF}}{E_o}}$$



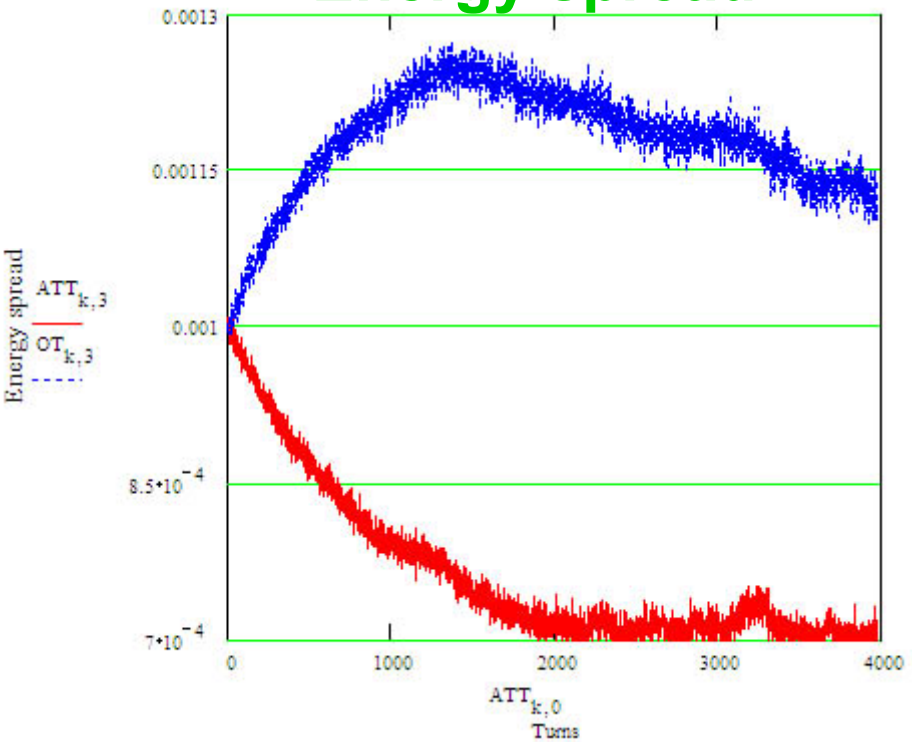
Legend: Total Cooling IBS Diffusion

Some preliminary results (1)

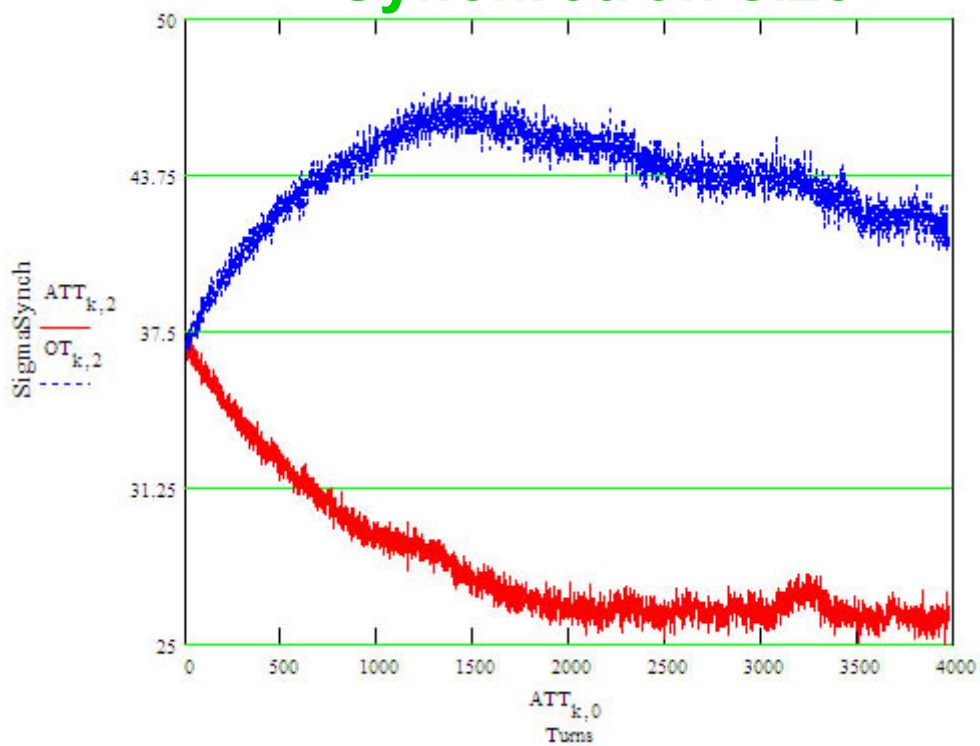
e-Cooling

Contribution of the recalculation of the linear ion density (all effects are included)

Energy spread



Synchrotron size



Legend: "Developed code (recalculation is included)"
"Origin code (recalculation is excluded)"

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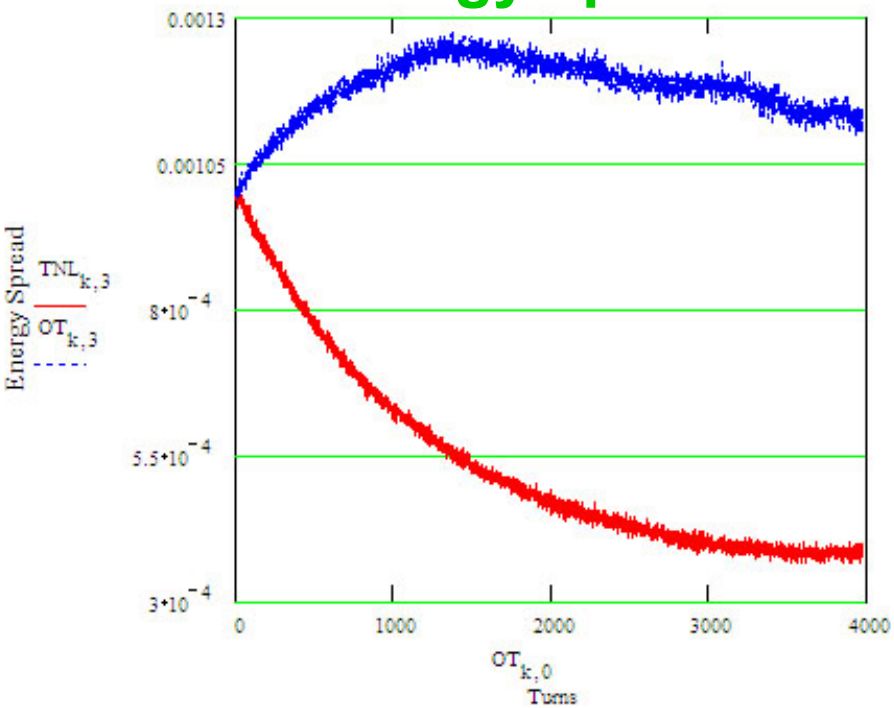
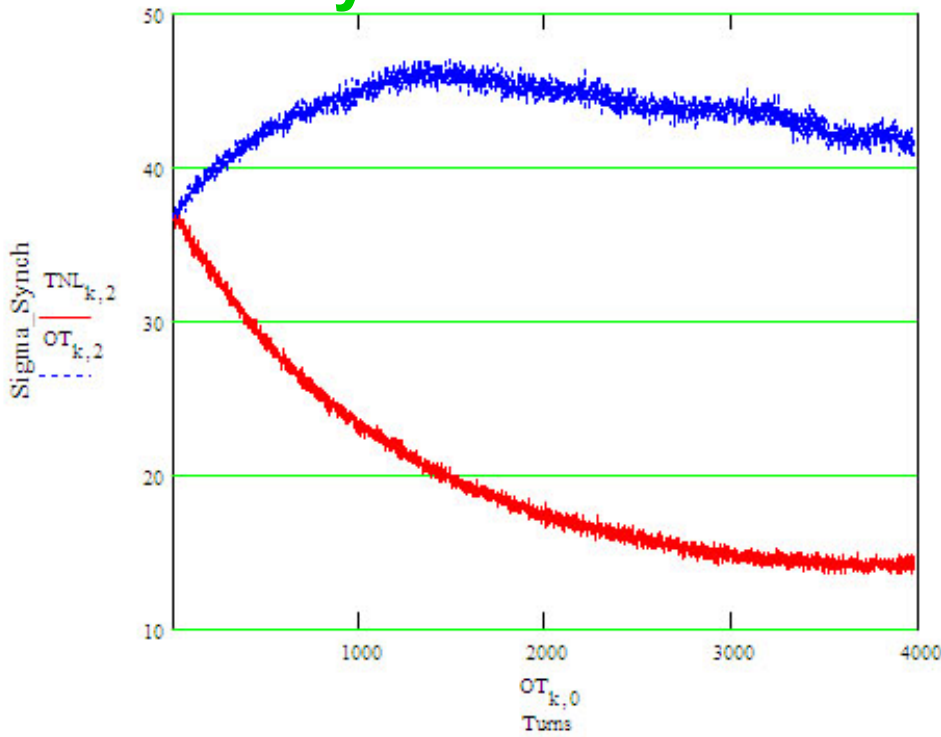
Some preliminary results (2)

Contribution of the factor "sqrt(12)" for the kick due to IBS (all effects are included)

Energy spread



Synchrotron size



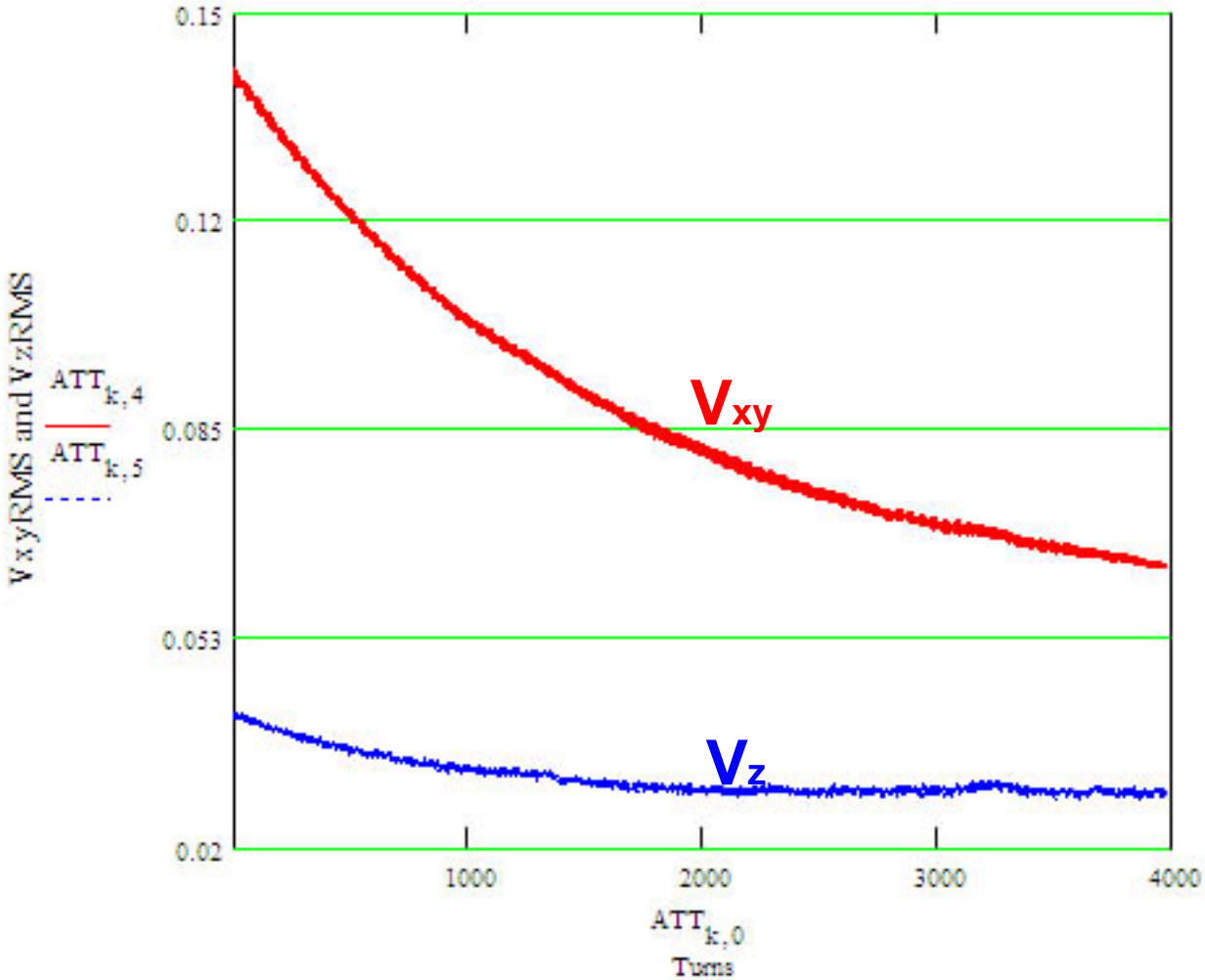
Legend: "Developed code" (factor is excluded)
"Origin code" (factor is included)

Some preliminary results (3)

Transversal and longitudinal RMS Velocities

$$V_{xy}^{RMS} = \sqrt{\frac{\sum_{particles}\left(V_x^2 + V_y^2\right)}{N_{particles}}}$$

$$V_z^{RMS} = \sqrt{\frac{\sum_{particles} V_z^2}{N_{particles}}}$$



Future plans

Will be corrected during this meeting

RHIC luminosity due to our combined efforts