ELECTRON CLOUDS IN THE NICA: NEW RESULTS

A.V. Philippov for NICA team
Veksler and Baldin Laboratory of High Energy Physics
Joint Institute for Nuclear Research, Dubna, Russia

NICA Machine Advisory Committee
meeting at Joint Institute for Nuclear Research, Dubna, Russia
June, 7-8, 2018

ABSTRACT

The new calculation results of electron-cloud (e-cloud) build-up in NICA is given. The results has been performed with PyECLOUD simulation code (CERN). The influence of e-cloud density on the coherent tune shift frequency at various bare gold nuclei beam intensities, their energies, and the secondary emission coefficient from the surface of the vacuum chamber is investigated. The influence of e-cloud build-up to the NICA vacuum conditions is also given.

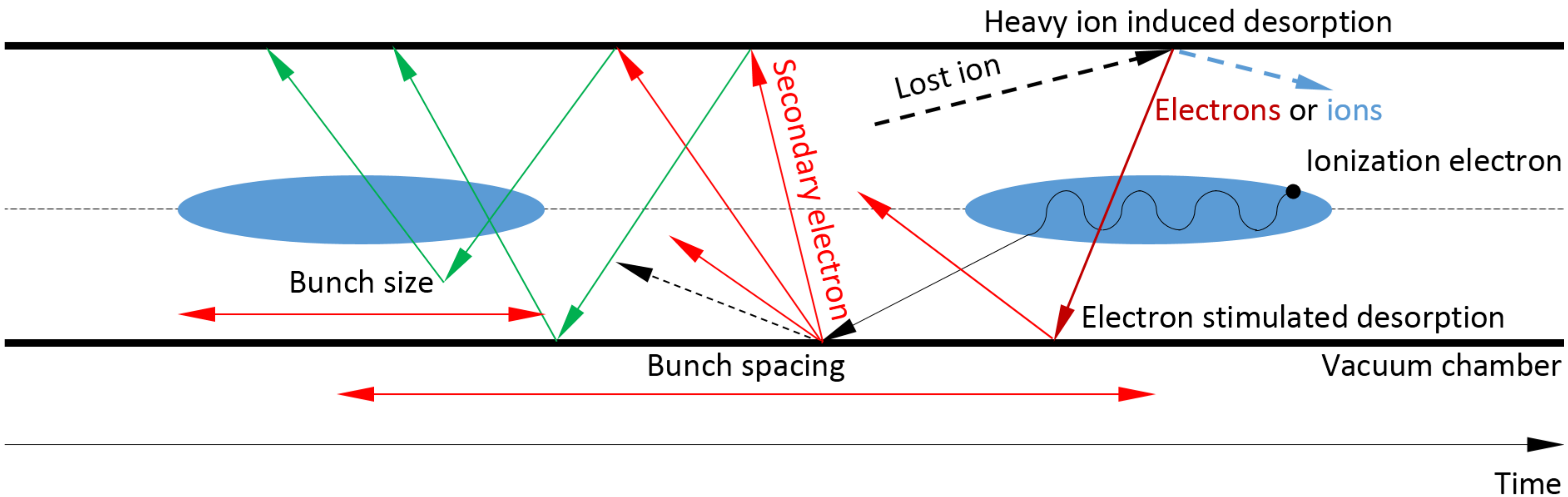
OUTLINE

1 A BRIEF REVIEW OF E-CLOUD BUILD-UP

The circulating beam particles can produce electrons due to different mechanisms, e.g. residual gas ionization in the vacuum chamber. This “primary” electrons are attracted by the passing particle bunch and can be accelerated to energies up to several hundreds of eV (for NICA this value 450 eV).

When an electron with this energy impacts the wall, “secondary electrons” are likely to be emitted. The secondaries have energies up to few tens of eV and, if they impact the wall with these energies, they are either absorbed or elastically reflected but cannot produce any secondary. On the other hand, if they survive until the passage of the following bunch they can in turn be accelerated, projected onto the wall and produce secondaries. This can trigger an avalanche multiplication effect which builds up the e-cloud during the passage of an entire bunch train.

1 A BRIEF REVIEW OF E-CLOUD BUILD-UP (Cont.)



Scheme of the e-clouds build-up in a circular accelerator

1.1 CONDITIONS OF E-CLOUD BUILD-UP

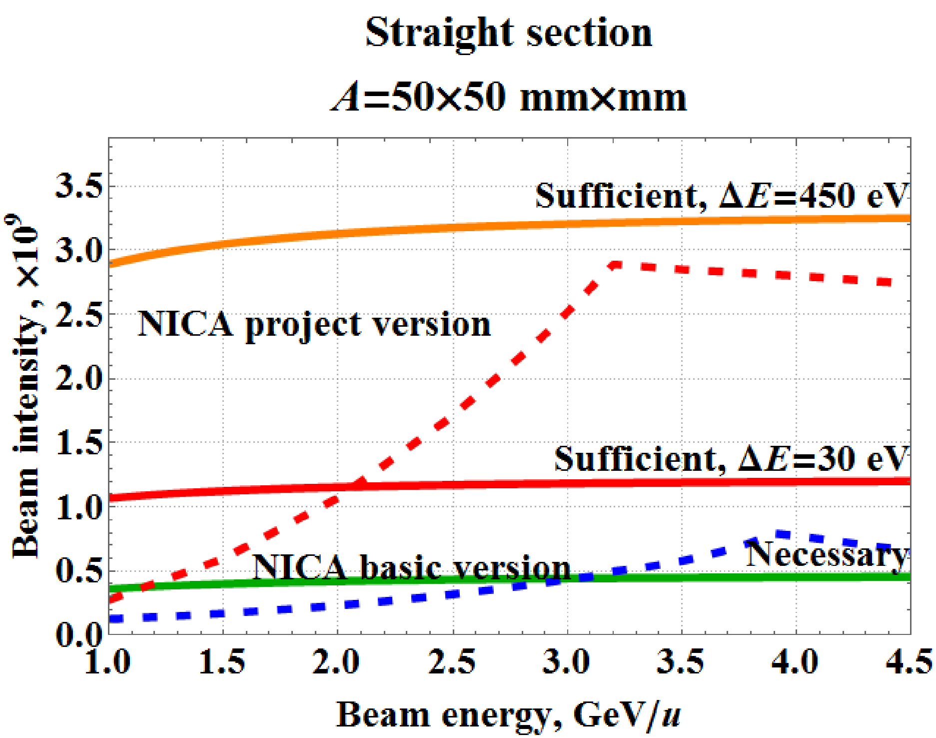
Criteria for electron cloud build-up can be formulated in the following way.
The **necessary condition** (the transit time of electrons from wall to wall must be equal to or less than the time between the passage of successive bunches) for e-cloud build-up is:

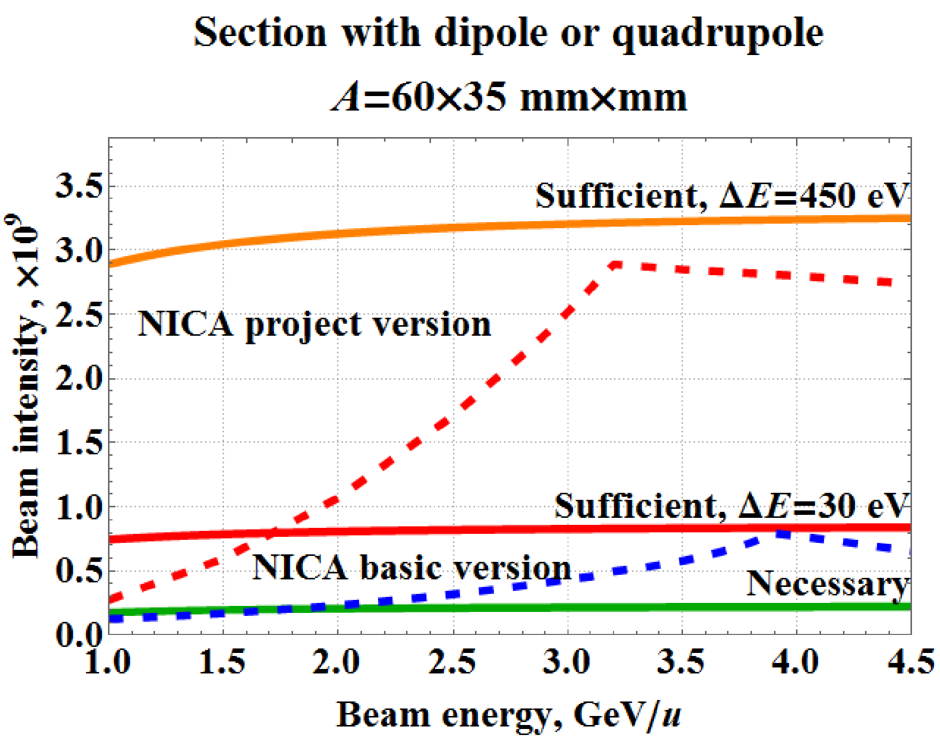
$$N_b > \frac{\beta^2 R^2}{Z r_e S_b}, S_b = \frac{C}{n_b}.$$

Here N_b is the number of ions per bunch; βc is the ion velocity; R is the vacuum chamber radius; Z is the ion charge; r_e is the classic electron radius; S_b is the interbunch distance; C is the circumference, and n_b is the number of bunches.
The **sufficient condition** (acceleration of secondary electrons in the bunch electric field up to energy ΔE sufficient for kicking out of the chamber wall more than one electron) is the following:

$$N_b > \frac{\beta R}{Z r_e} \sqrt{\frac{\Delta E}{2 m_e c^2}}.$$

1.1 CONDITIONS OF E-CLOUD BUILD-UP (Cont.)





The combination of the necessary and sufficient conditions for two energy values $\Delta E = 30,\ 450$ eV sufficient for kicking out of the chamber wall more than one electron is shown

1.2 INPUT PARAMETERS FOR PyECLOUD CODE SIMULATIONS

List of the NICA parameters

Ion type	$^{197}Au^{79+}$
Number of bunches	22
Ring circumference, m	503.04
Bunch spacing, m	22.87
RMS beam emittance *x*/*y*, π mm·mrad	**1.1/1 ÷ 0.7 varied with energy**
RMS bunch length, m	0.6
Bending magnet field/quadrupole gradient, T/T/m	1.8/23.1
Length of dipole/quadrupole/straight section, m	1.94/0.47/15
Aperture dipole/quadrupole/straight section, m×m	0.06×0.035/0.05×0.05
Total residual gas ionization cross-section, Mb	**1276 ÷ 1186 varied with energy**
Total gas pressure, nTorr	0.01

List of the varied parameters

Energy, GeV/*u*	**1 ÷ 4.5, variation step 0.5**
Number of particles per bunch	**$5\cdot10^8 \div 5\cdot10^9$, variation step $5\cdot10^8$**
Secondary emission yield	**1.1 ÷ 1.9, variation step 0.1**

1.3 TUNE SHIFT RELATED E-CLOUD EFFECT

A bunch passing each turn through a static e-cloud with uniform spatial density ρ_e, experiences a coherent tune shift $\Delta Q_{x/y}^{\mathrm{EC}}$ (**see *Blaskiewicz M. and Iriso U.* // BNL Report. (2006) C-A/AP/260**):

$$\Delta Q_{\mathrm{EC}}^{x/y} = \rho_e \frac{r_p Z}{\gamma A} \frac{\overline{\beta_{x/y}} h_{x/y} L}{h_x + h_y}.$$

Here r_p is the classical proton radius; Z is the nuclear number, A is the atomic number; $\overline{\beta_{x/y}}$ is the average beta functions; $h_{x/y}$ are the vacuum chamber semi-axes; L is the sections length with e-cloud, and γ is the Lorentz factor.

The tune shift limit for NICA $\Delta Q \leq 0.05$ in all energy range.

1.4 VACUUM CONDITIONS RELATED E-CLOUD EFFECT

In the equilibrium state one can expected the additional pressure rise caused by e-clouds derived as

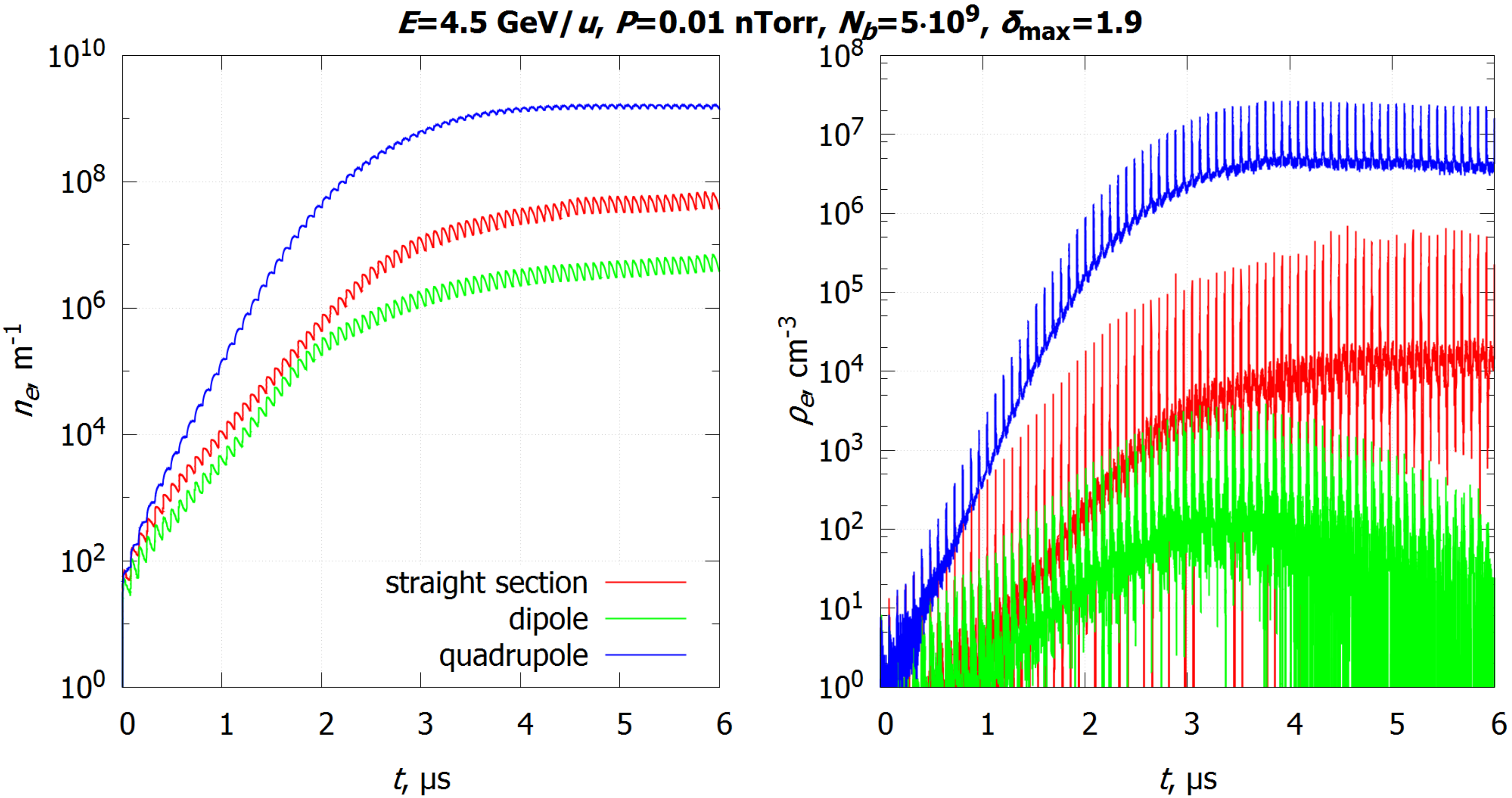
$$\Delta P = \frac{\Delta q_{EC}}{S} A, \Delta q_{EC} = \frac{k_B T}{\Pi} \frac{d\Phi_{EC}}{dl} \eta_{EC}.$$

The outgassing from cloud electrons hitting the walls Δq_{EC} can be related with the additional heat load to the vacuum system ΔP_{EC} as

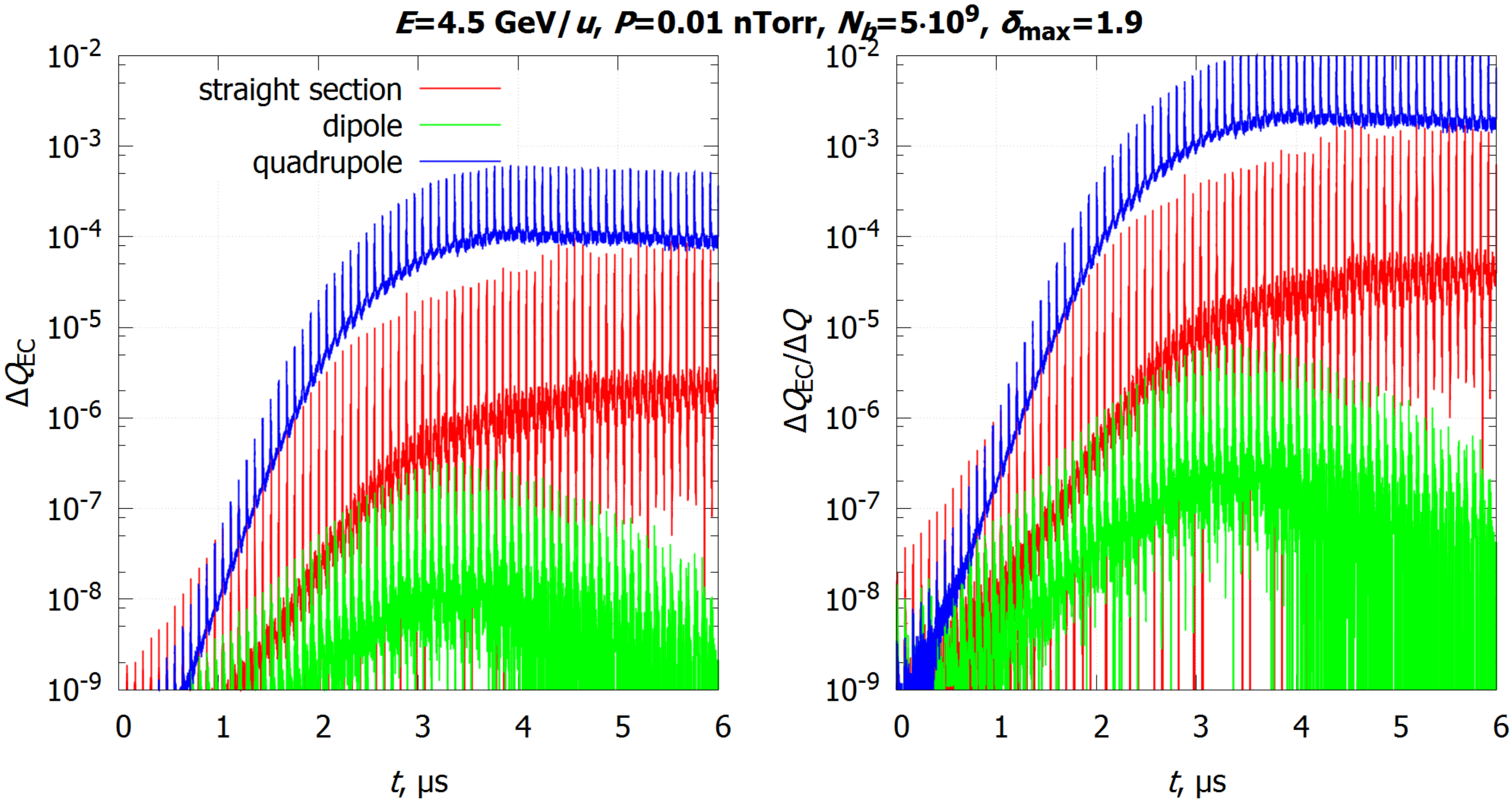
$$\Delta P_{EC} = \frac{k_B \overline{E_{EC}}}{A_\perp} \Delta q_{EC}.$$

Here S is the pumping speed; k_B is the Boltzmann constant; T the absolute temperature; A, Π and $A_\perp$ the vacuum chamber net wall area, net wall area per unit length and transverse cross-section correspondingly; $d\Phi_{EC}/dl$ the flux of cloud electrons into the vacuum chamber wall per unit length; η_{EC} is the desorption coefficient (**$\boldsymbol{\eta_{EC} = 0.01 \div 0.001}$ see *Gröbner O.* // Vacuum. 60 (2001). 25-34**) for the cloud electrons and $\overline{E_{EC}}$ the average energy of electrons striking the vacuum chamber wall.

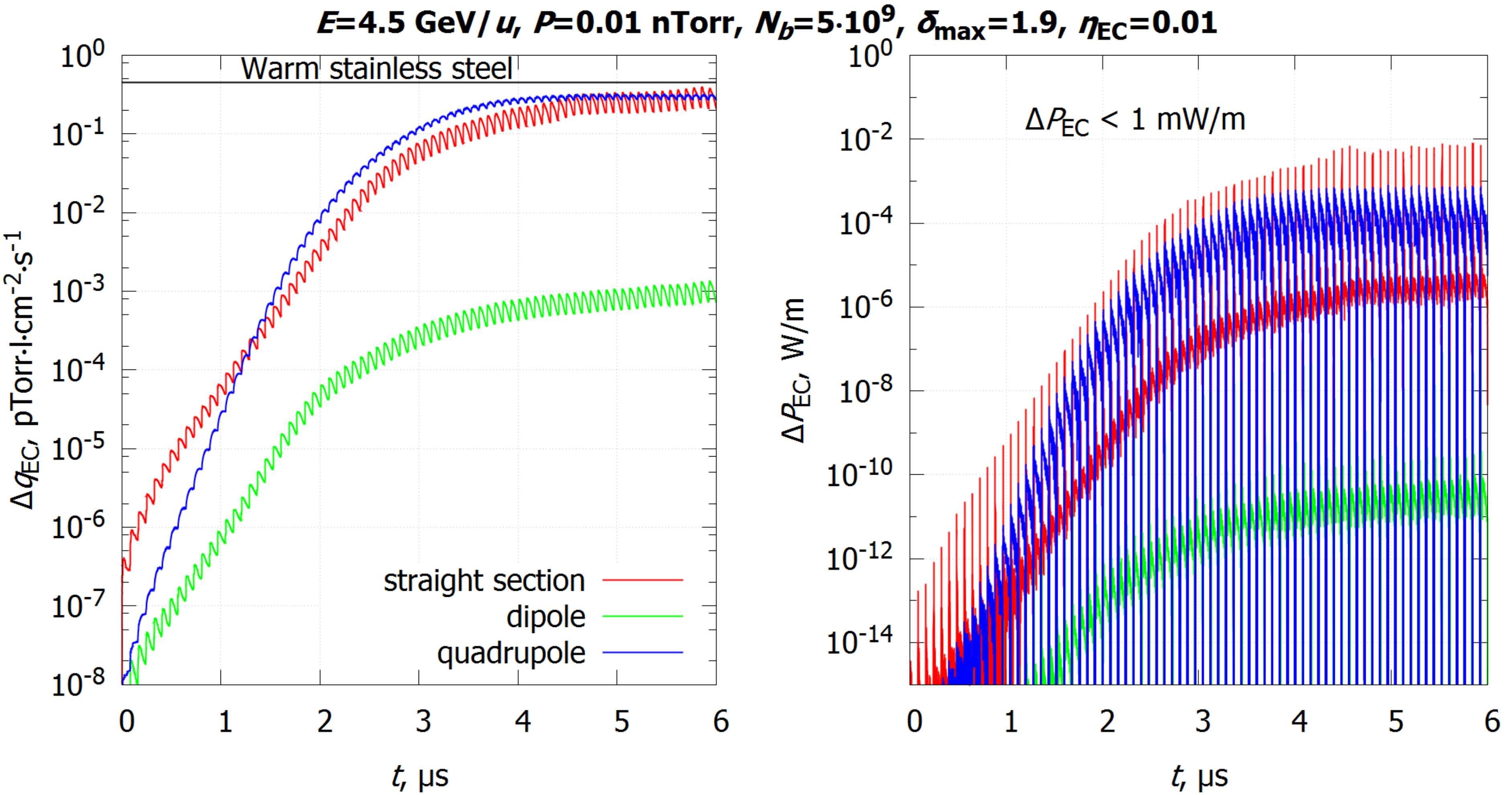
2 CALCULATION RESULTS



2 CALCULATION RESULTS (Cont.)



2 CALCULATION RESULTS (Cont.)

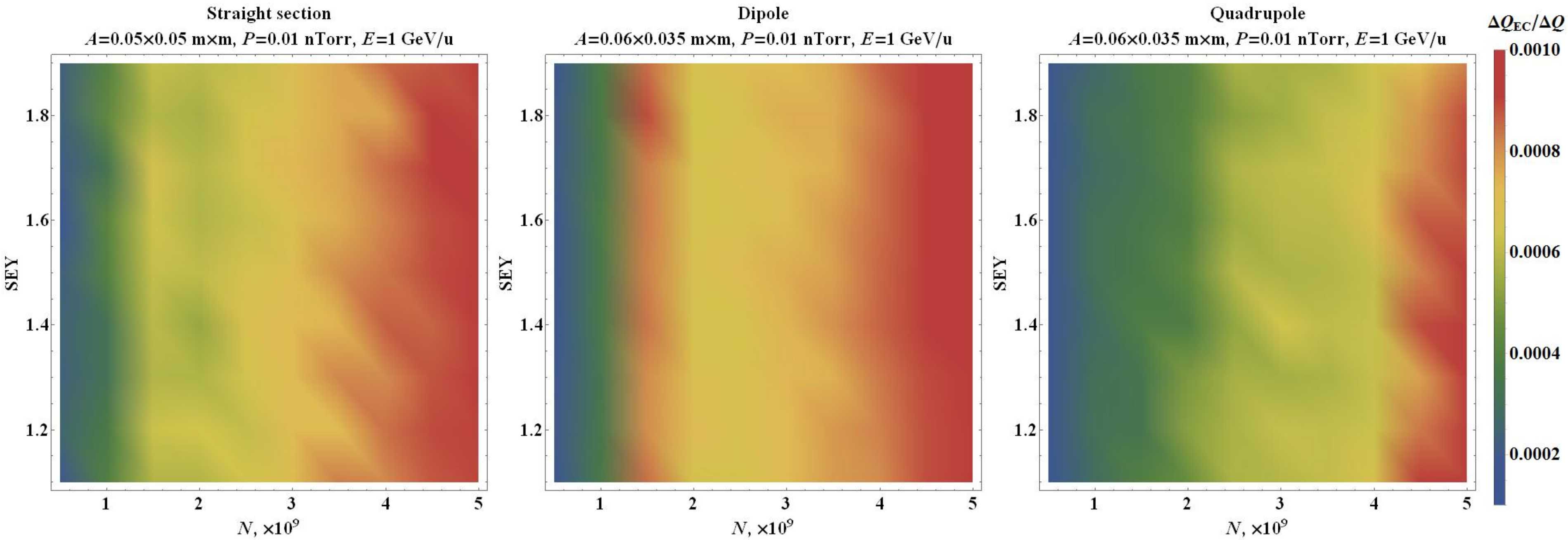


3 CONCLUSION

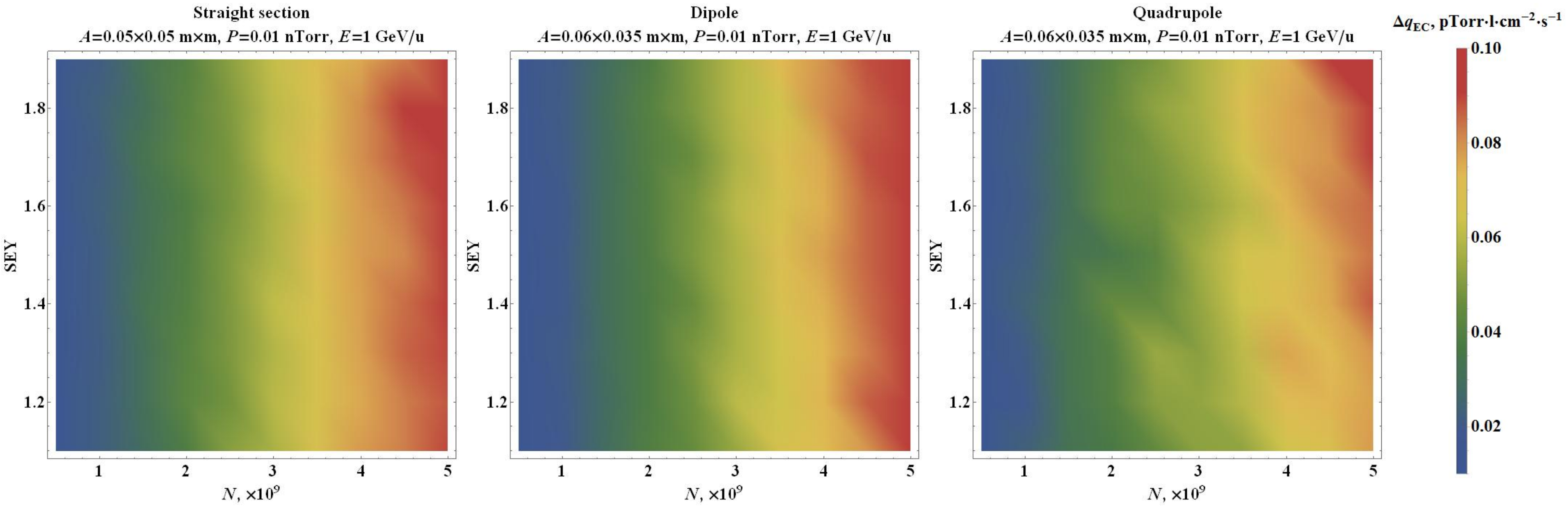
- The analysis of the results shows that the tune shift caused by e-cloud build-up is negligible (slide 11).
- The cloud electrons bombarding the vacuum chamber wall caused additional gas loading of $10^{-2} \div 10^{-1}$ pTorr·l·cm^{-2}·s^{-1} at desorption coefficient of cloud electrons $\eta_{EC} = 0.01$ (slide 12 left).
- The additional heat load provoked by cloud electrons less 1 mW/m (slide 12 right).

Thank you for attention and welcome your questions

EXTRA SLIDES: CALCULATION RESULTS



EXTRA SLIDES: CALCULATION RESULTS (Cont.)



EXTRA SLIDES: CALCULATION RESULTS (Cont.)