IX Международный семинар по проблемам ускорителей заряженных частиц памяти В.П.Саранцева

EXPERIMENTAL STUDIES OF SECONDARY ELECTRON-ELECTRON EMISSION BY VACUUM CHAMBER SURFACE

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JINR DNLP

Dubna 2011

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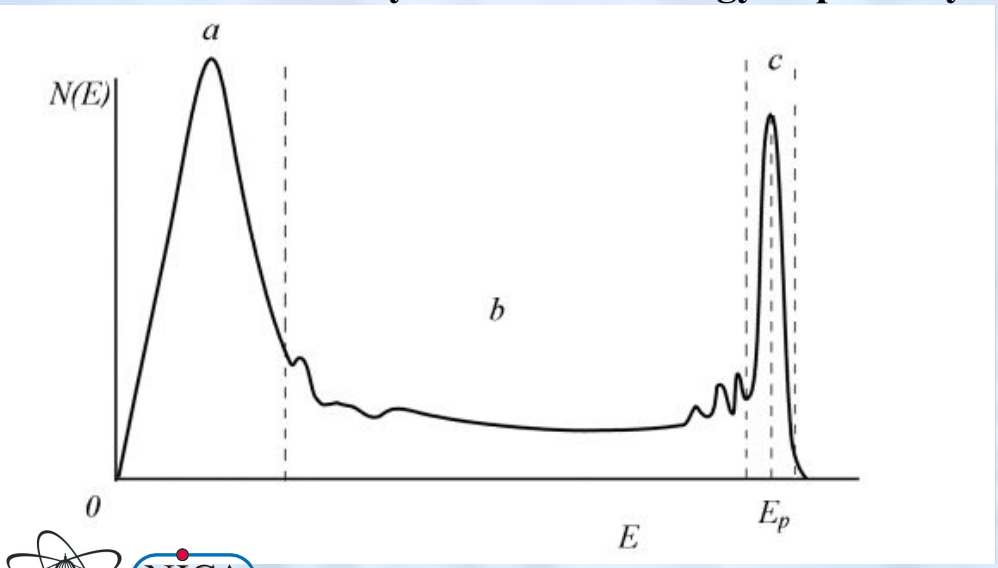
Secondary emission

Secondary Electron Emission is the emission of electrons by the surface of a solid object when it is bombarded by electrons. It was discovered in 1902 by the German physicists L. Austin and H. Starke. The electrons bombarding the object are called ***primary***, and the emitted electrons are called ***secondary***. Some of the primary electrons are reflected without energy loss (***elastically reflected primaries***), and the remaining electrons are reflected with a loss of energy; the energy is mainly consumed in exciting the electrons of the solid object to higher energy levels. If the electrons' energy and momentum prove to be sufficiently great to surmount the potential barrier on the surface of the object, they leave the surface (***truly secondary***).

Number of secondary electron vs Energy of primary electron



Typical SEE spectrum

Energy groups:

a) - truly secondary e-

b) - inelastic e-

c) - elastic e-

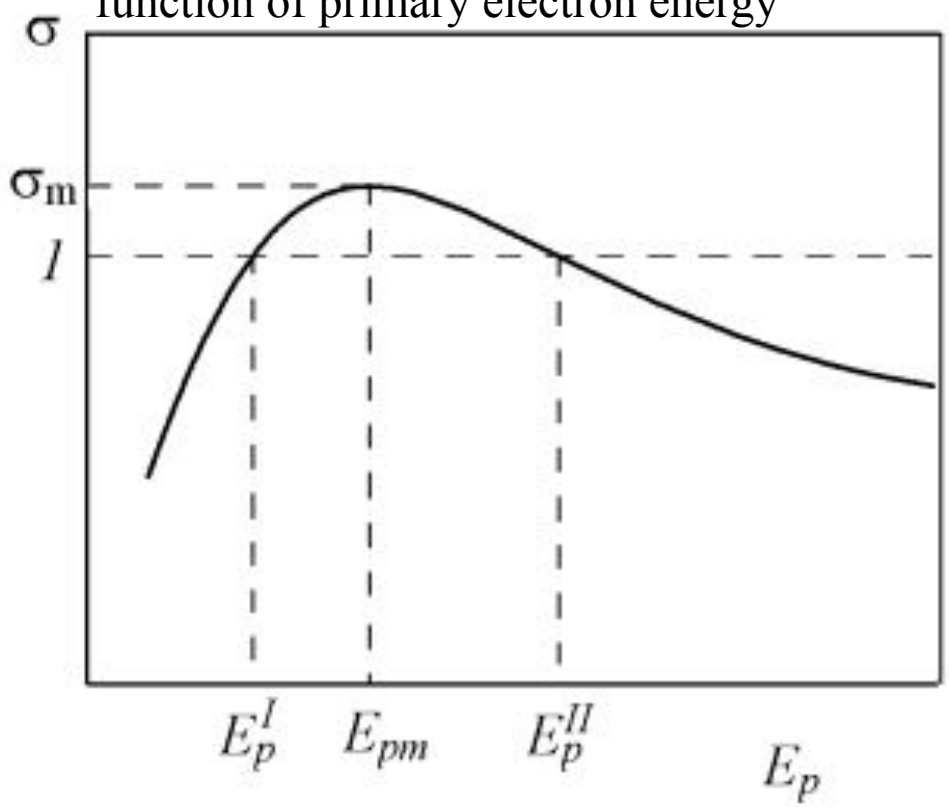
Secondary Electron Yield (SEY)

$$\sigma = \frac{N_2}{N_1} = \frac{I_2}{I_1}$$

N_1, I_1 – primary electrons (*incident electrons*)

N_2, I_2 – secondary electrons (*leaving the surface*)

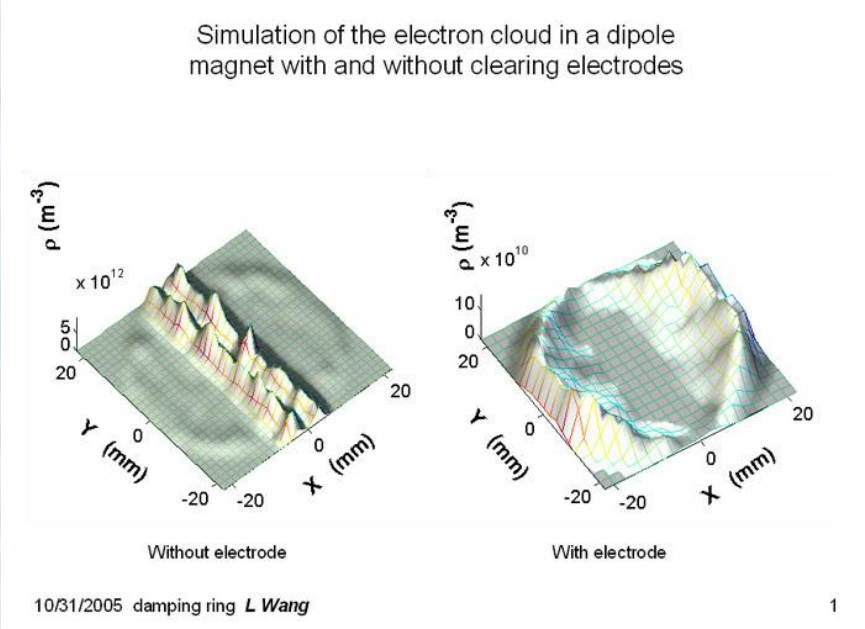
Secondary electron yield as a function of primary electron energy



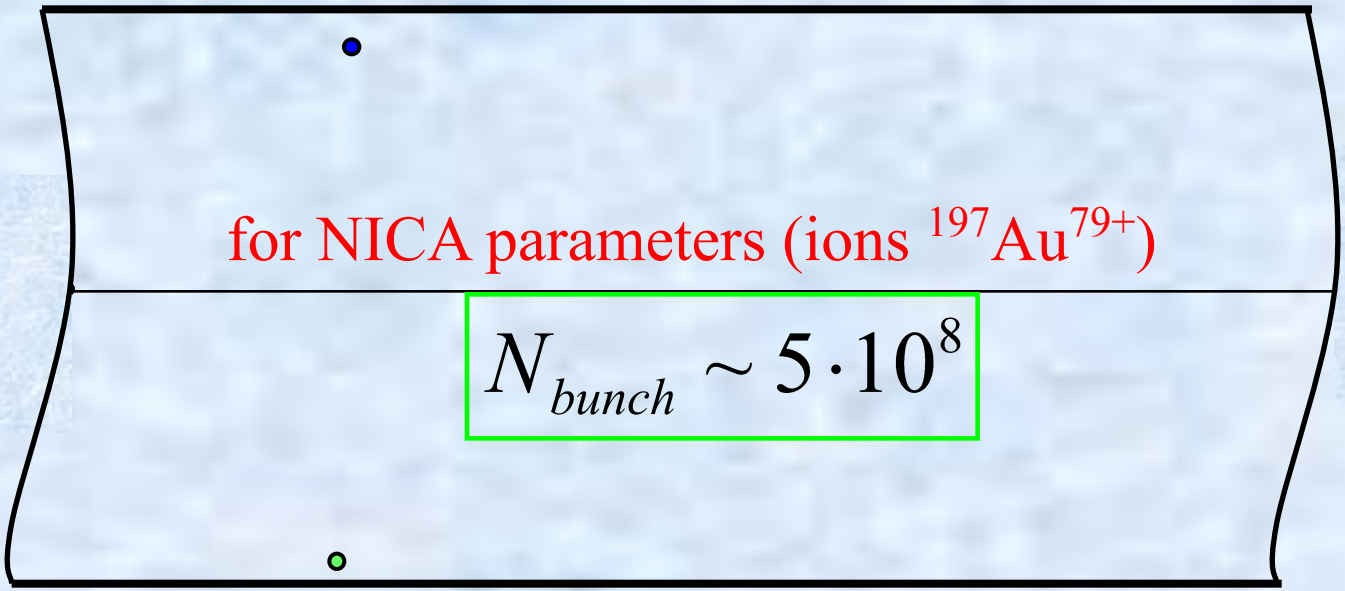
Electron-cloud effect

Electron cloud effects are expected to be enhanced and play a central role in limiting the performance of the collider at the NICA complex. Electron cloud phenomena in beam pipes are based on electron multiplication and can be sufficiently suppressed if the Secondary Electron Yield (SEY) of the surface of the beam pipes is lower than unity. The goal of this work is to find and study a thin film coating with reliably low initial SEY, which does not require bake-out or conditioning in situ with photons, is robust against air exposure and can easily be applied in the beam pipes of accelerators.

Electron cloud density depends on effective secondary electron yield of material of coating vacuum chamber. The formation of electron clouds can be simulated by specialized software (eg ***ECLOUD***)



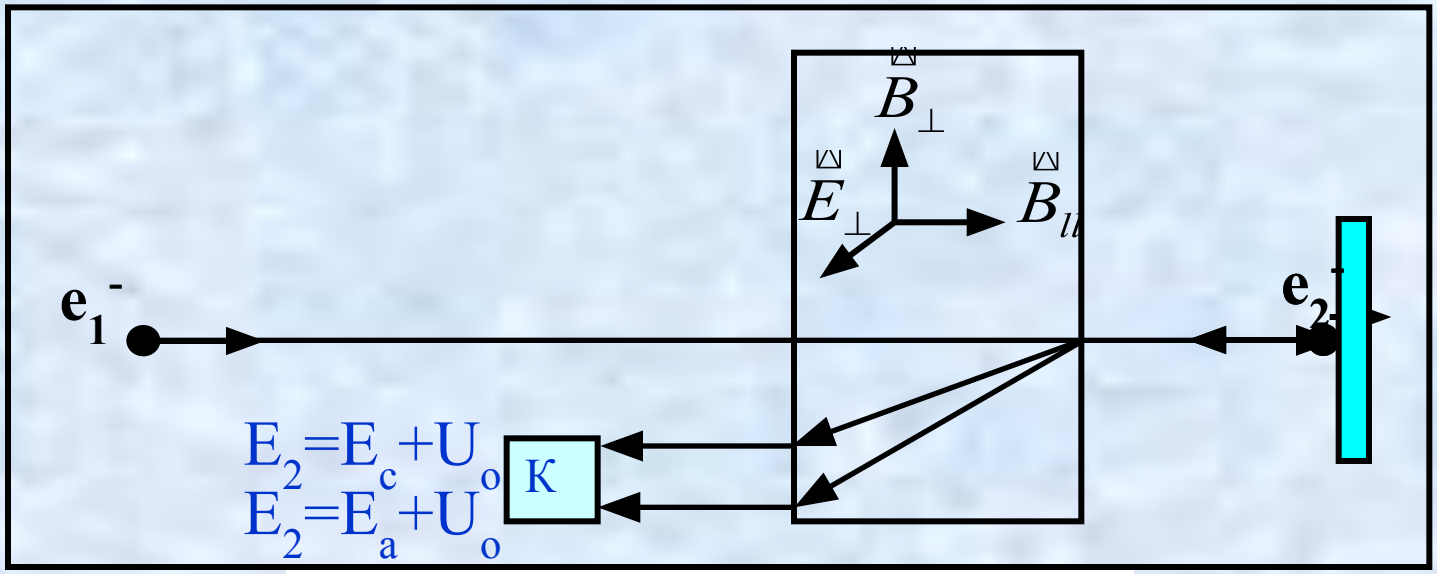
Electron clouds accumulation

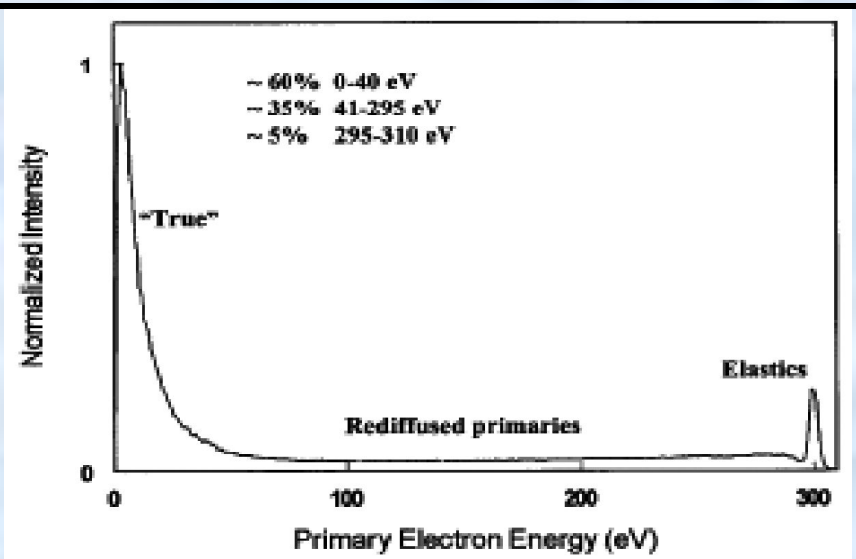


$$N_{bunch} \geq \beta^2 \cdot \frac{b^2}{Z\, r_e\, l_{space}}$$

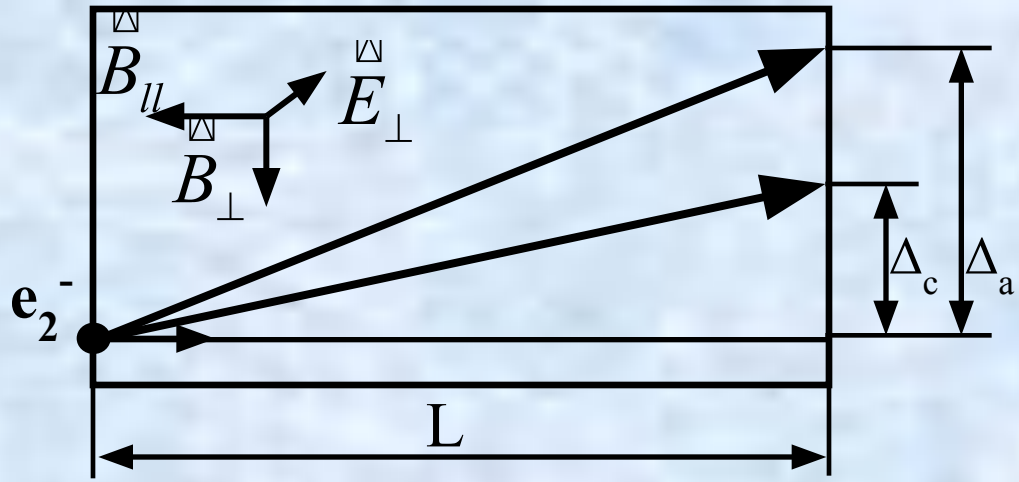
β – bunch velocity
b – radius of the vacuum chamber
Z – ion charge
r_e – electron classic radius
l_{space} – space between bunches in the circulating ion beam

Scheme of the experiment on SEY measurement





Calculation of displacement of the secondary electron



$$E_{\perp} = \frac{-U_{up} + U_{down}}{2 \cdot h_{plate}}$$

$$E_e(E_O, y_e) = E_O + E_{\perp} \cdot (h_{plate} - y_e)$$

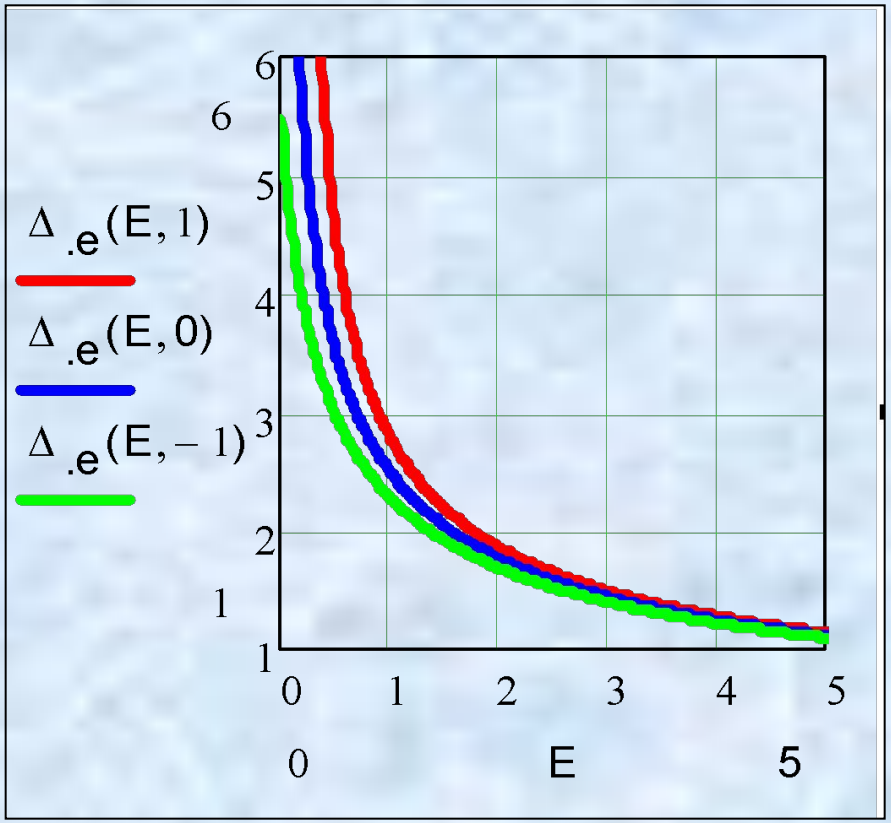
$$\beta_e(E_O, y_e) = \sqrt{2 \cdot \frac{E_e(E_O, y_e)}{511}}$$

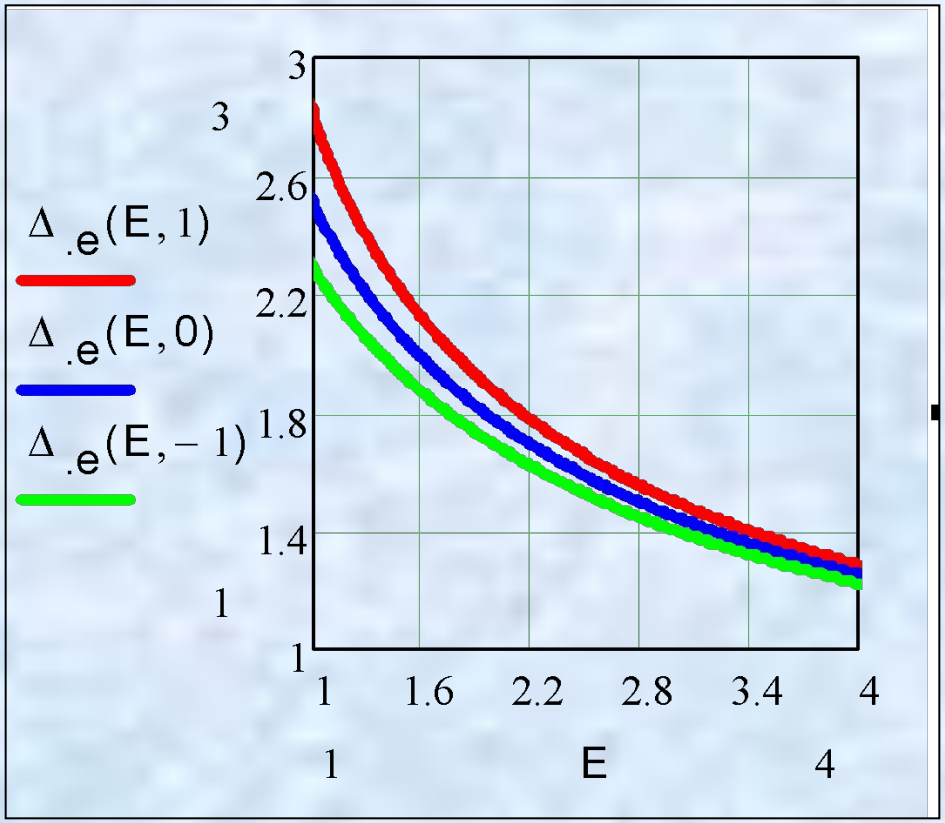
$$\Delta_e(E_O, y_e) = \frac{E_{\perp}}{0.3 \cdot B_{ll}} \cdot \frac{L_{plate}}{\beta_e(E_O, y_e)}$$

$$E_O \in [U_O, E_{e_cath}] \qquad \Delta_a - \Delta_c < d_{coll}(4см)$$

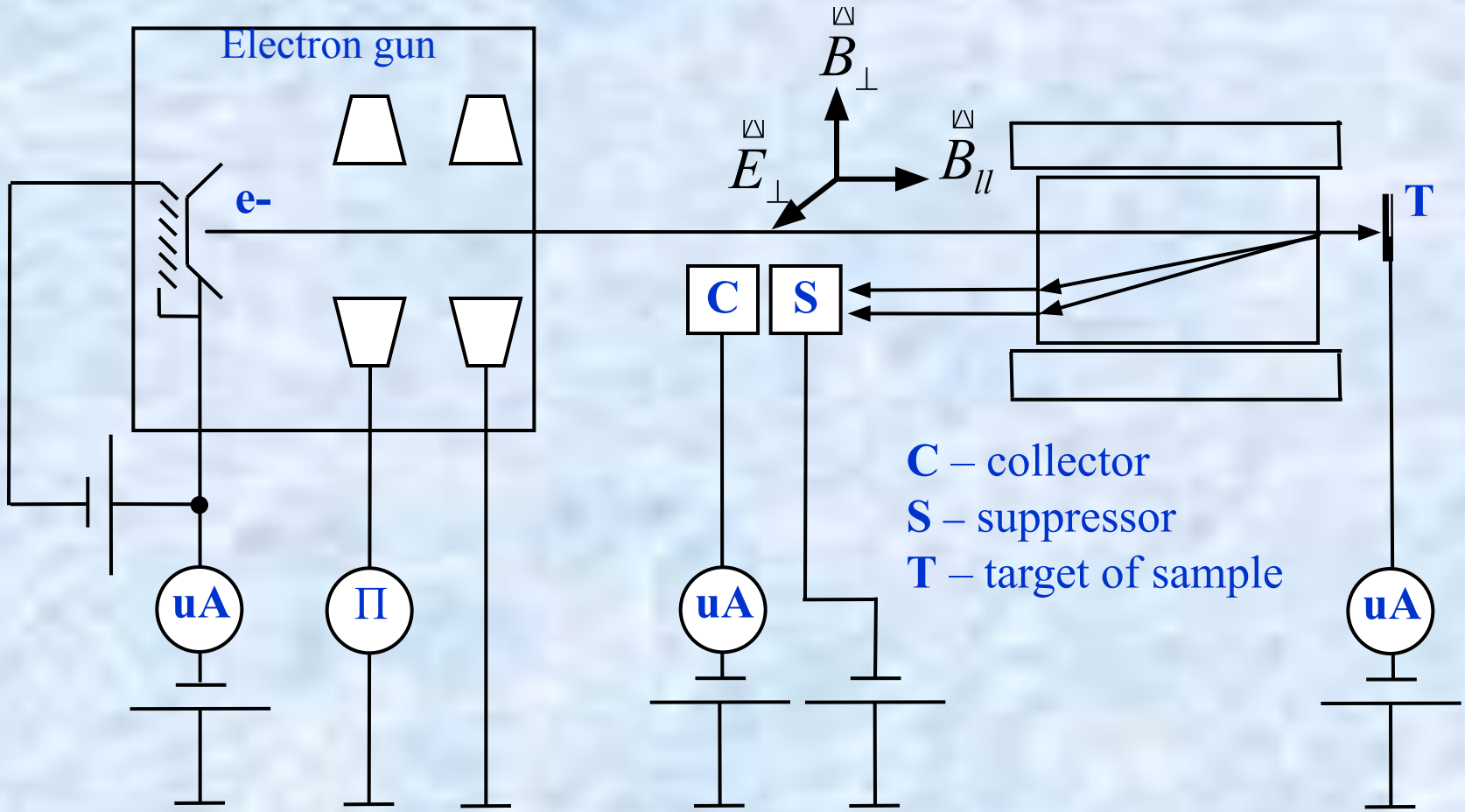
E_O – начальная энергия вторичных e^-	B_{ll} – продольное магнитное поле
E_e – энергия вторичных e^- пришедших в коллектор	$E_{\perp}$ – электрическое поле отклоняющих пластин
Δ_e – смещение вторичных e^- прошедших пластины	h_{plate} – расстояние от средней плоскости до пластины
Δ_a – смещение истинно вторичных e^-	y_e – расстояние от средней плоскости до e^-
Δ_c – смещение упруго отражённых вторичных e^-	L_{plate} – длина пластины
β_e – скорость вторичных e^-	

The displacement of the secondary electrons

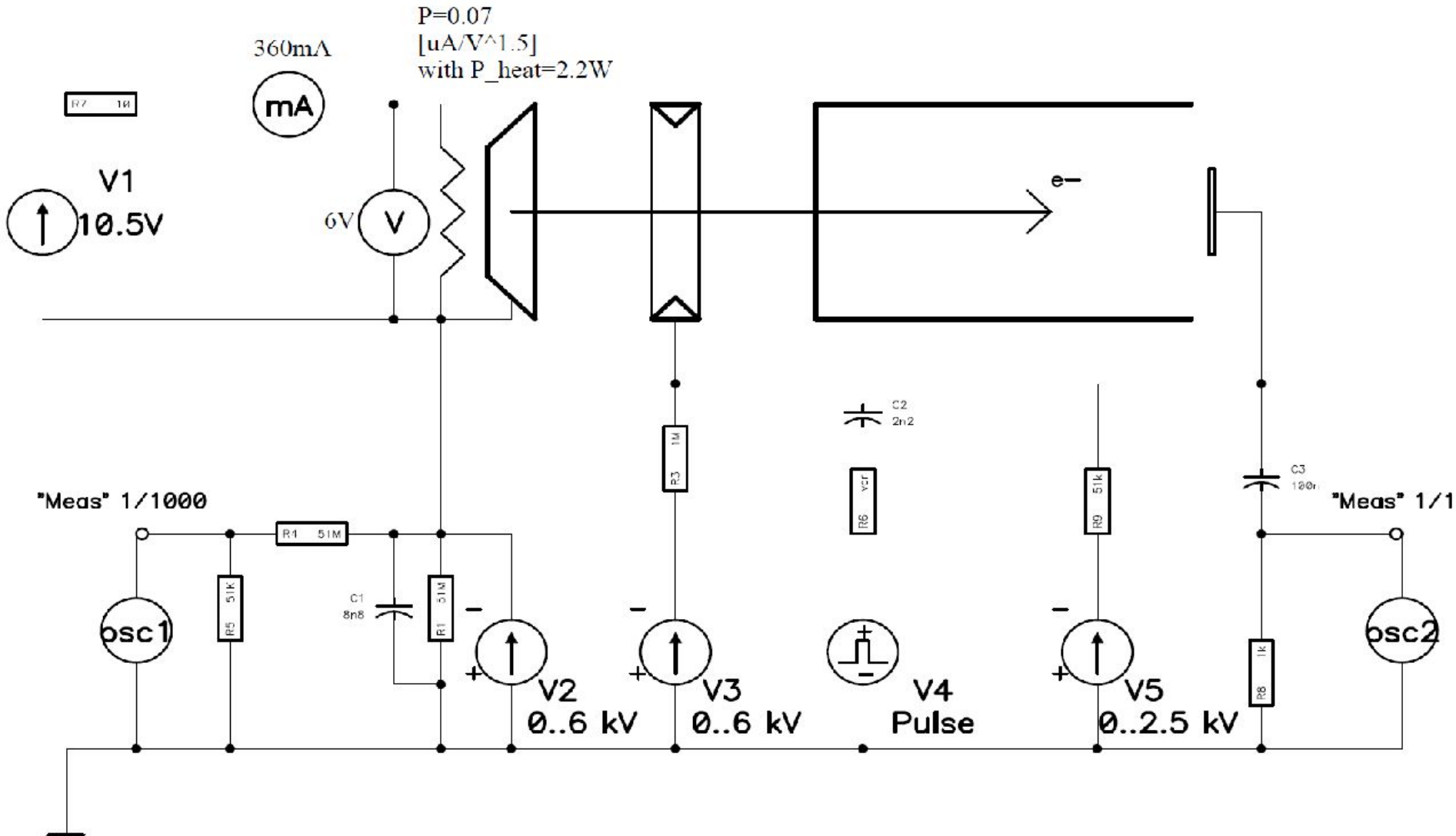




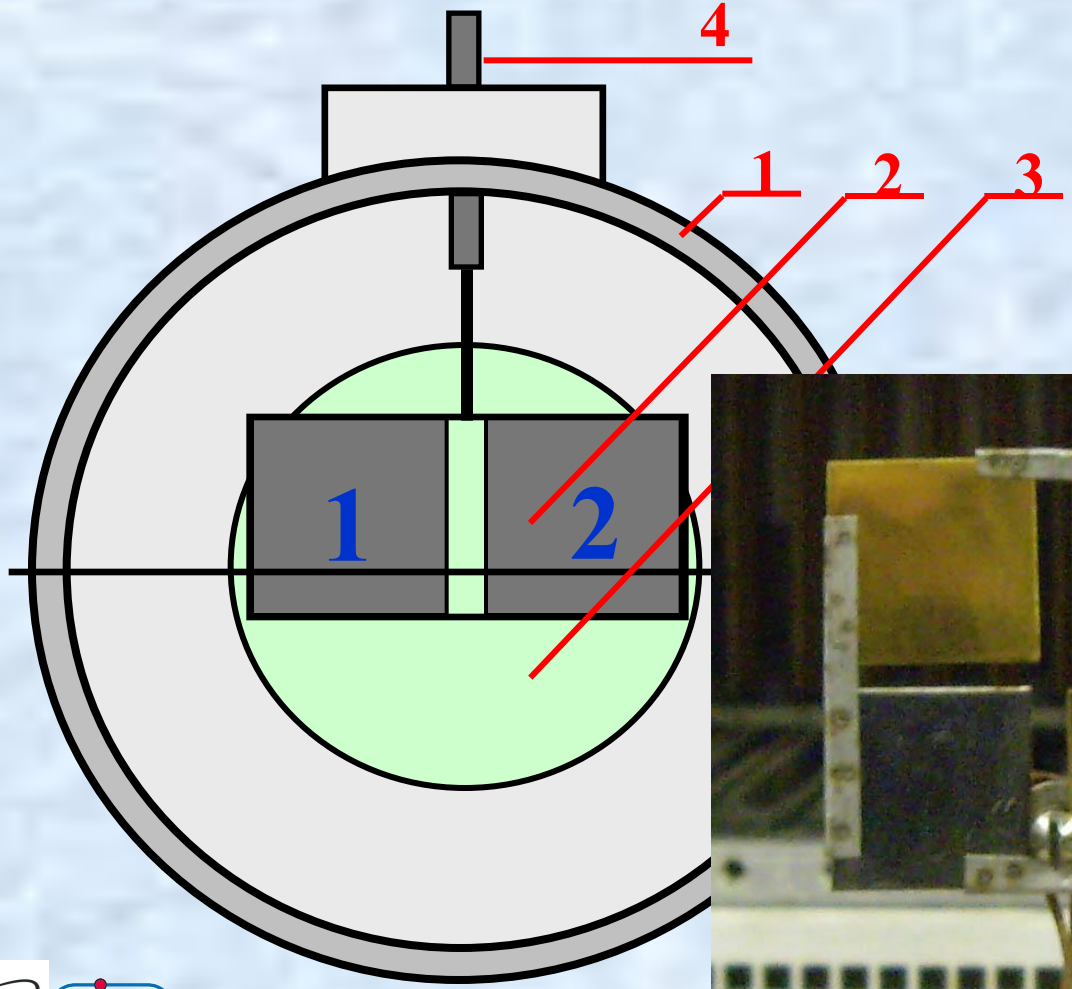
Scheme of the set up for SEY measurement



Scheme of the set up for SEY measurement (cont.)



Samples mounting

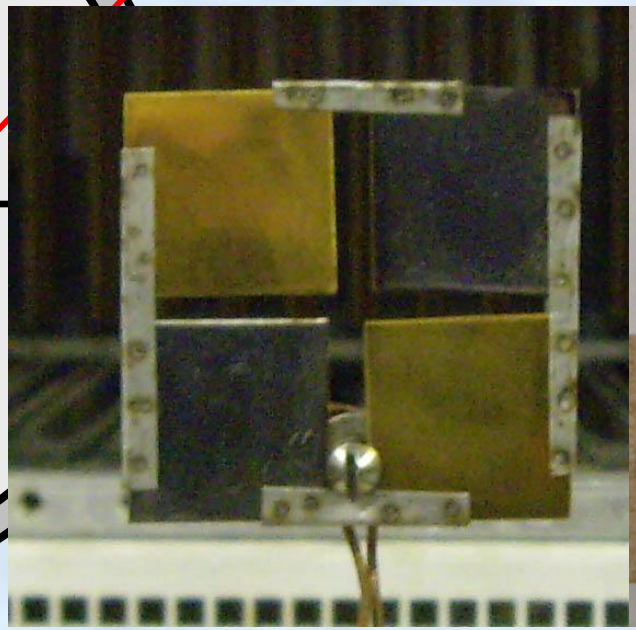


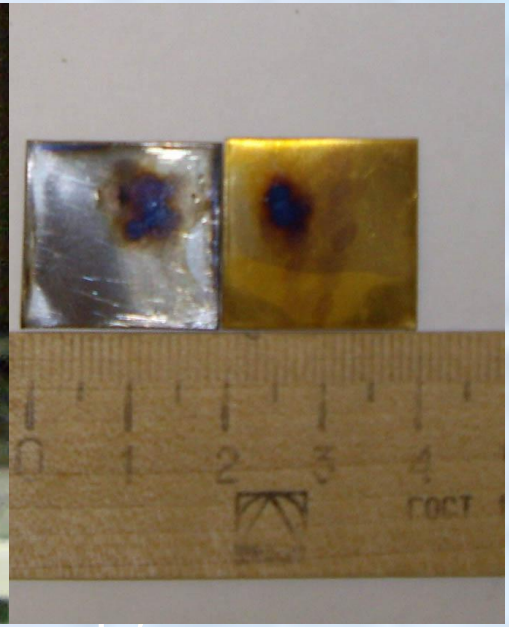
1 – Vacuum chamber

2 – Samples

3 – Luminescent screen

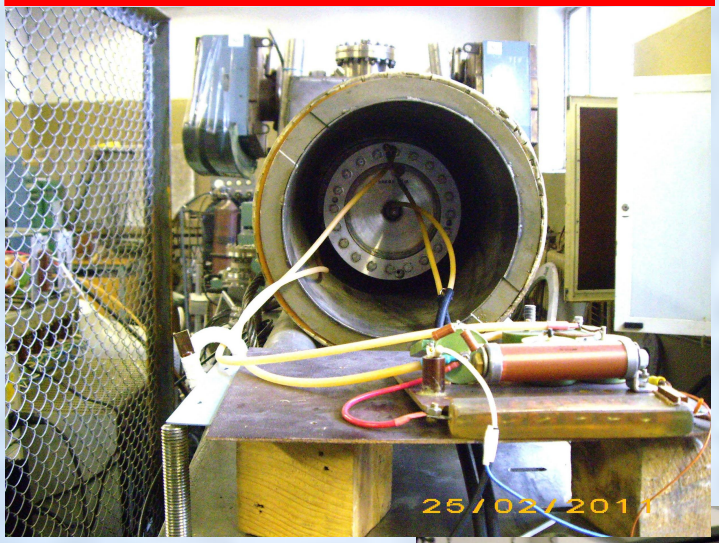
4 – Vacuum feed through



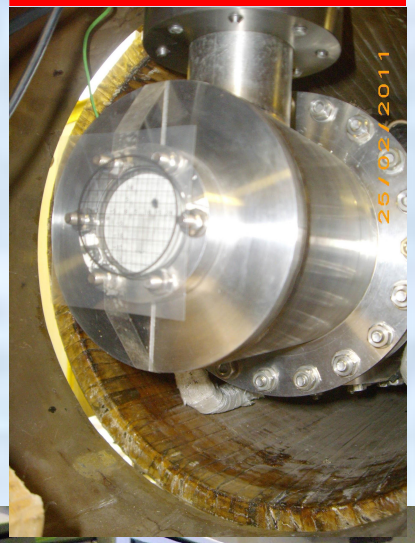


Test Bench «Recuperator»

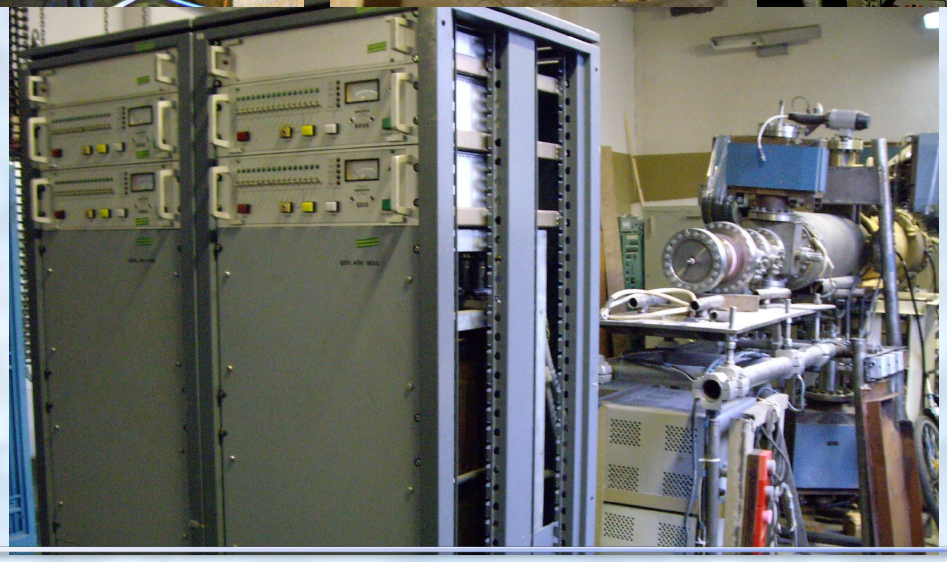
electron gun



target



HV power supply of TB



Experiment description

SEY from the surfaces of the samples was measured under the following conditions:

1. Образцы «подвешивались» под отрицательный потенциал. При этом потенциал катода и образца изменялись так, что сохранялась величина энергии электронов, падающих на пластину-образец.

2. Очистка пластин-образцов производилась электронным пучком

а) на измеряемой энергии

б) по всему диапазону энергии от 50 эВ до потенциала катода с шагом 50эВ

3. Ток электронного пучка:

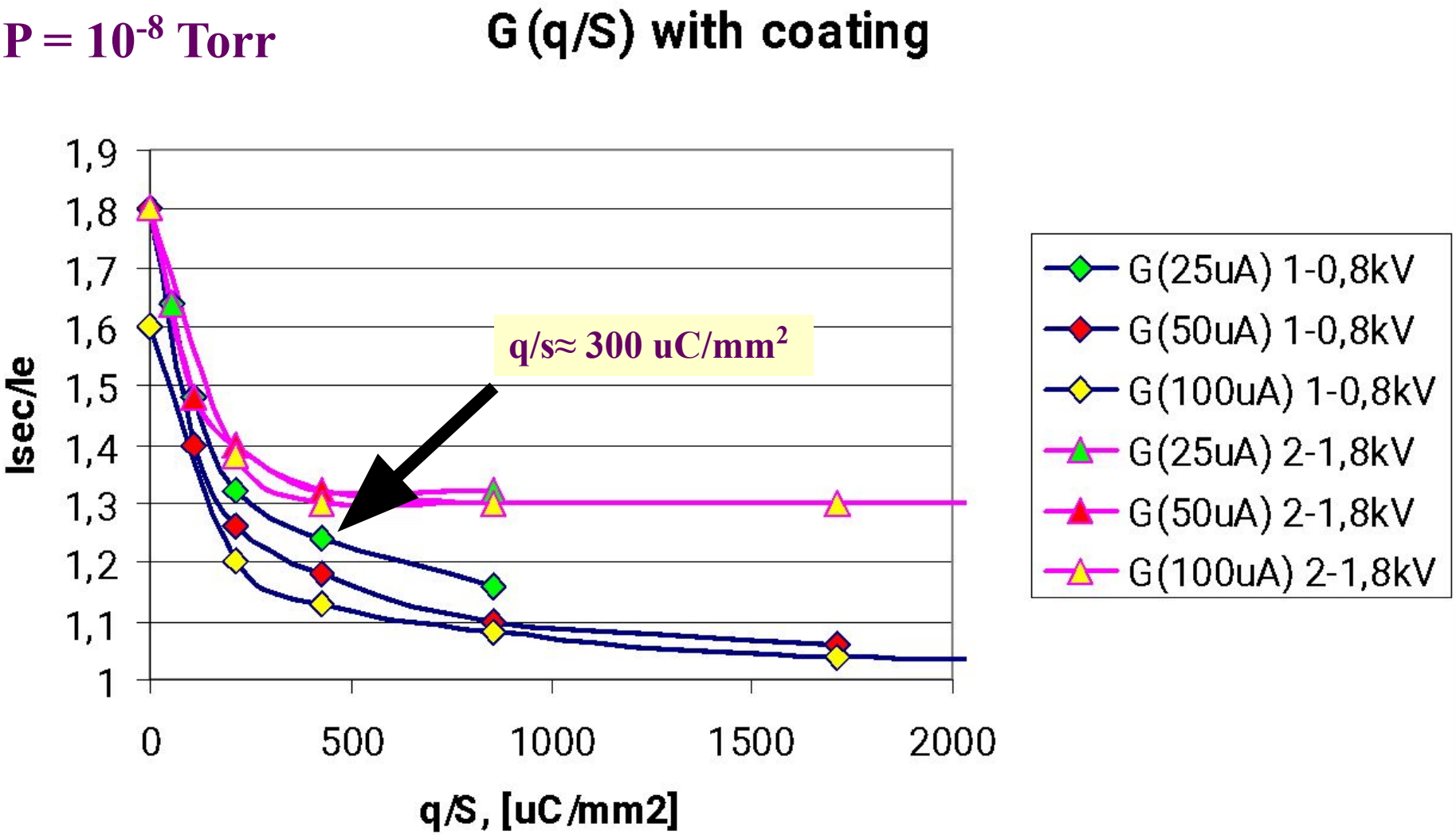
а) Постоянный – при очистке пластин-образцов и измерении КВЭЭ

б) Импульсный – при измерении тока вторичных электронов без очистки образца. В данном режиме ток первичных электронов не измерялся

SEY

Electron Stimulated Desorption (ESD): The Surface Cleaning

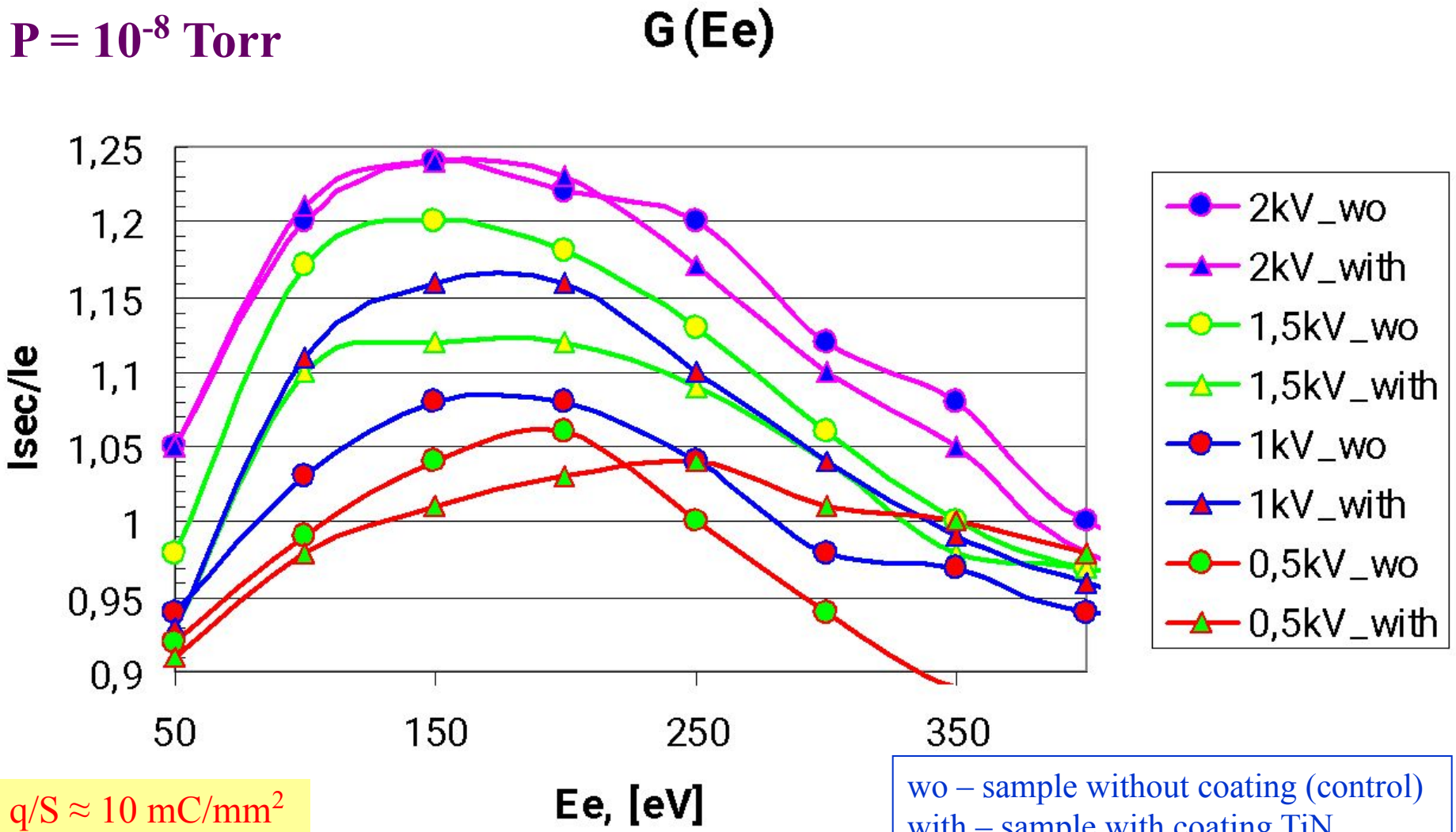
P = 10^{-8} Torr



SEY

Cleaning the sample was carried out only at the measurement energy

P = 10^{-8} Torr



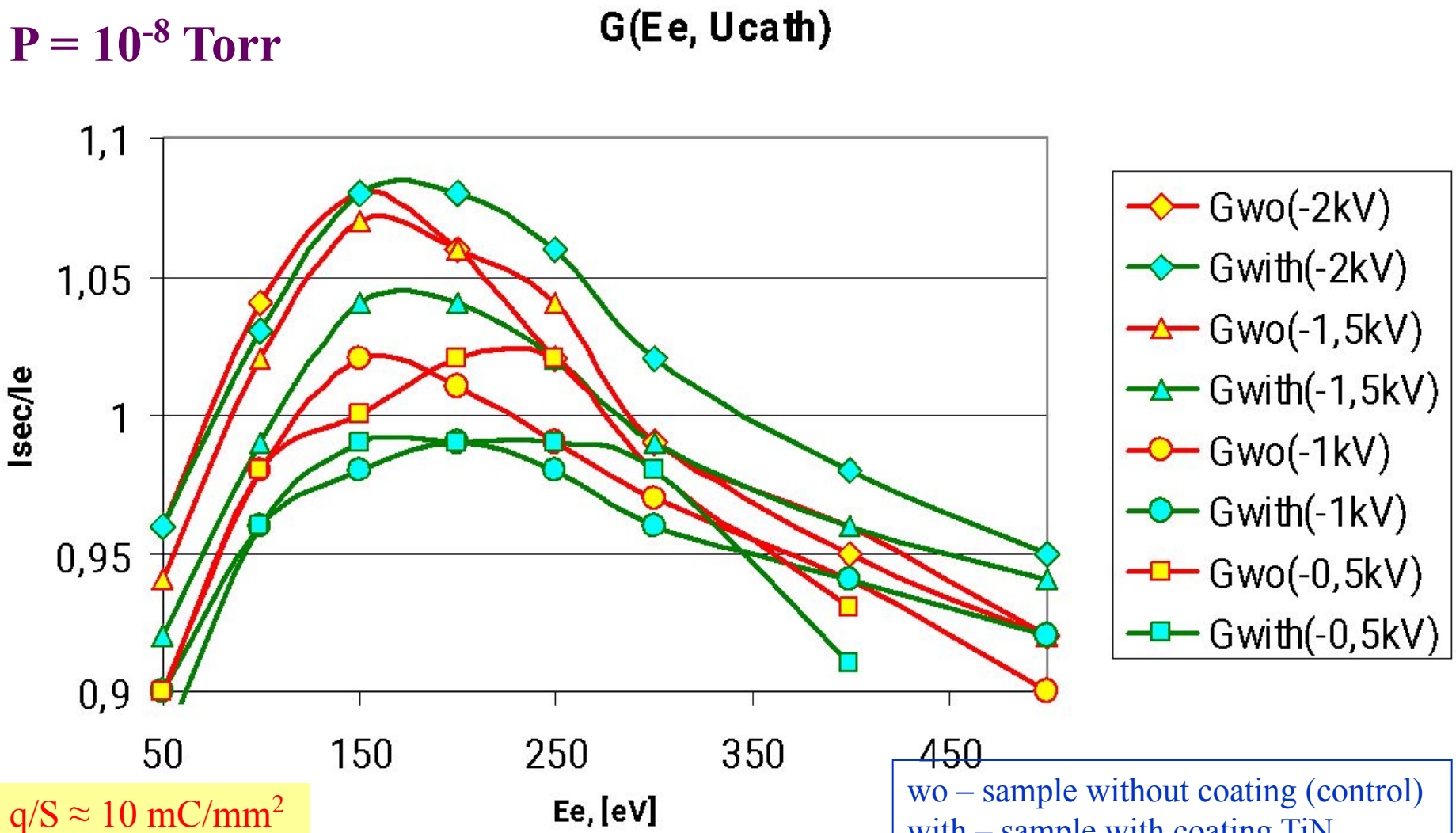
q/S ≈ 10 mC/mm^2

wo – sample without coating (control)
with – sample with coating TiN

SEY

Cleaning the sample was carried out with the measurement of energy spectrum

P = 10^{-8} Torr



q/S ≈ 10 mC/mm^2

wo – sample without coating (control)
with – sample with coating TiN

Work done

Стенд «Рекуператор» введён в эксплуатацию в начале 2011.
Отработана методика измерения тока вторичных электронов

Основные параметры сэо стенда «Рекуператор».	
Энергия электронов, кэВ	0.5…20
Ток электронного пучка, А	0…1.0
Микропервеанс электронной пушки: Катод 10 мм, ток накала 3.8 А, мка/В$^{(1.5)}$	0.18
Диаметр катода электронной пушки, мм	**10** (3)
Максимальное продольное магнитное поле, Гс	500
Длина вакуумной камеры в продольном магнитном поле, м	4
Вакуум в районе катода, Тор	10^{-8}

Next time…

Ближайшие планы:

1. Измерения КВЭЭ с пластин при активации образцов омическим нагревом.

Изменение КВЭЭ от времени нахождения в вакууме после активации.

Измерения провести при достигнутом вакууме:

$$10^{-7} \div 10^{-9}\ \text{Тор}$$

Экстраполировать полученные результаты на вакуум 10^{-10} Тор

2. Измерения при вакууме 10^{-10} Тор и лучше с использованием криогенного насоса.

3. Отработка методик очистки поверхностей электронным пучком.

4. Работа с покрытиями другого состава: TiZrV, TiCN, TiZr

(сотрудничество с Госкорпорацией «Порошковая металлургия», г.Минск)

Thank you for attention