# An Improved Model for Photoemission of Space Charge Dominated Picosecond Electron Bunches: Theory and Experiment.

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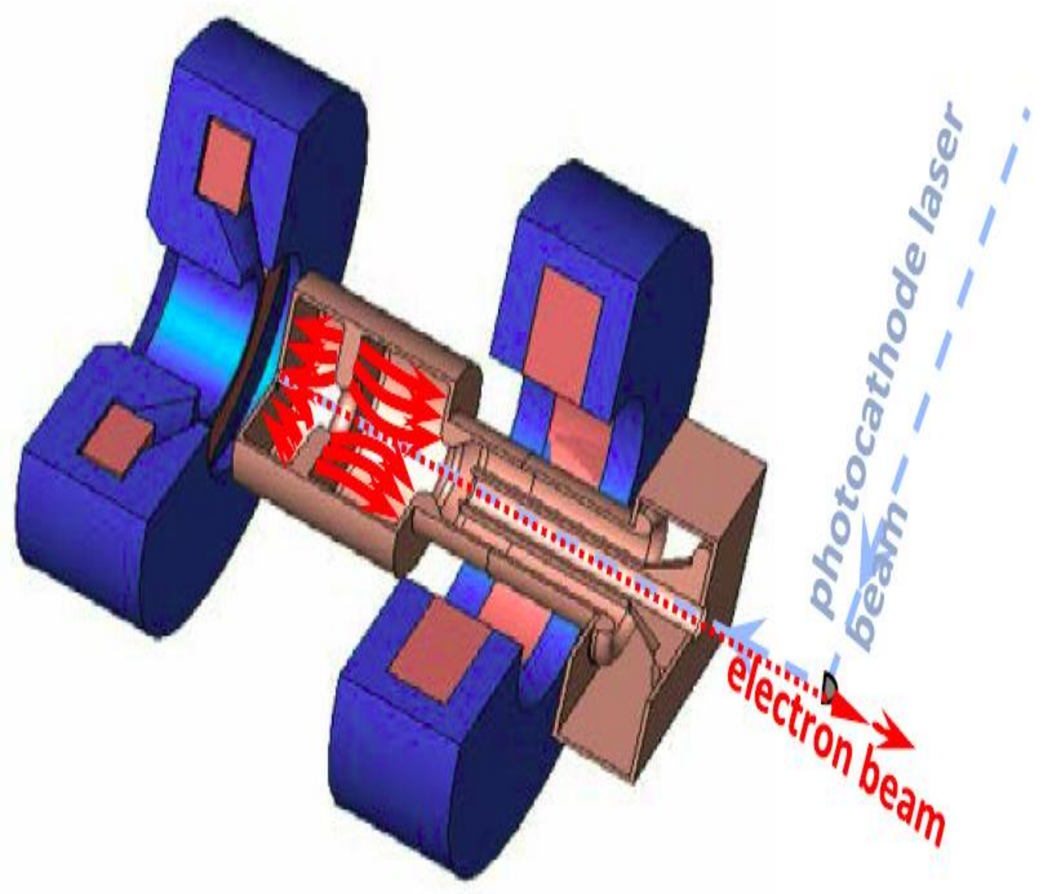
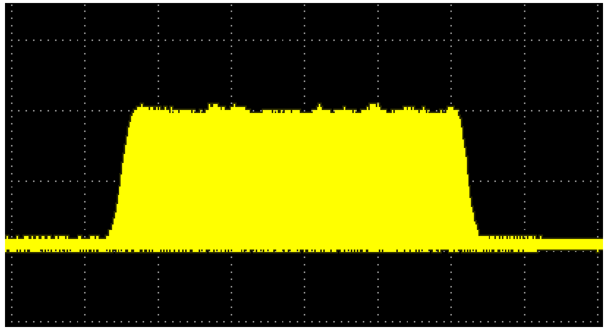
# PITZ RF gun and photo cathode laser



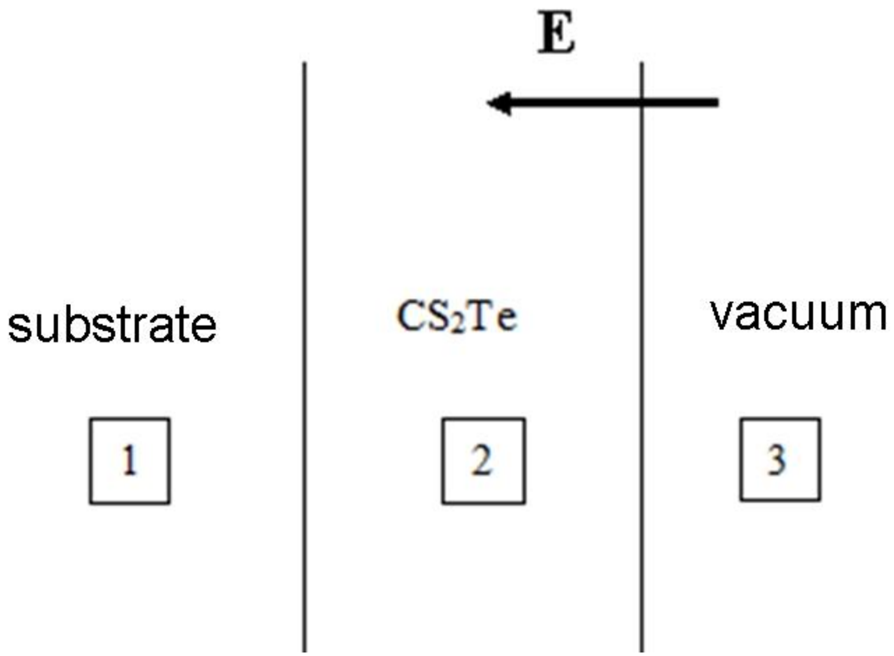

**RFgun:** L-band (1.3 GHz) nc (copper)
**standing wave** 1½-cell cavity
Peak rf power: up to 7MW
Ez@cathode: > 60MV/m

**Photo cathode** ($Cs_2Te$) QE~0.5-5%

**Cathode laser** 257nm ~20ps (FWHM )



# Photocathodes inside the high gradient RF gun




Field penetration depth

$$E = \frac{\sigma}{2\varepsilon\varepsilon_0} = \frac{qN}{2\varepsilon\varepsilon_0}$$

To compensate $E \sim 10^7 V/m$

$$\varepsilon \approx 10; N = 10^{11} cm^{-2}; \rho = 10^{15} cm^{-3}$$

$$d = N/\rho = 1\,\mu m$$

The field penetrates the entire depth of the semiconductor film <0.1μm

# Charge balance in a semiconductor film

The electron exit rate is determined by the magnitude of the electric field

$$v_- = \frac{eEt}{\varepsilon\gamma m} \approx 10^6 m / \mathrm{s}$$

The rate of positive charge inflow is determined by the difference in carrier concentrations (Fick law)

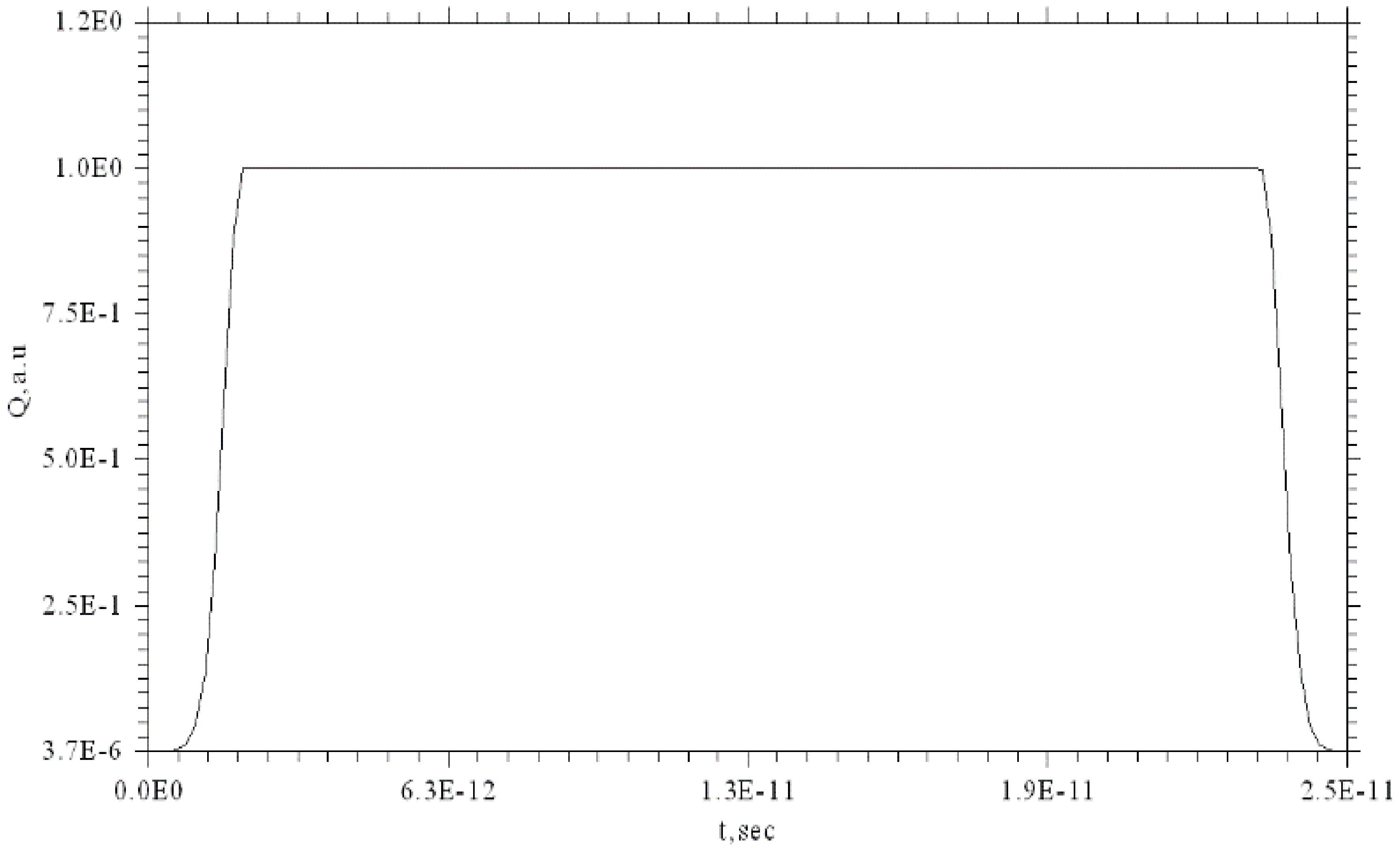
$$\vec{j} = \rho\vec{v}_+ = -eD\,\mathrm{grad}\,n$$

The diffusion coefficient D is related to the mobility of charge carriers $\mu$ by the Einstein relation

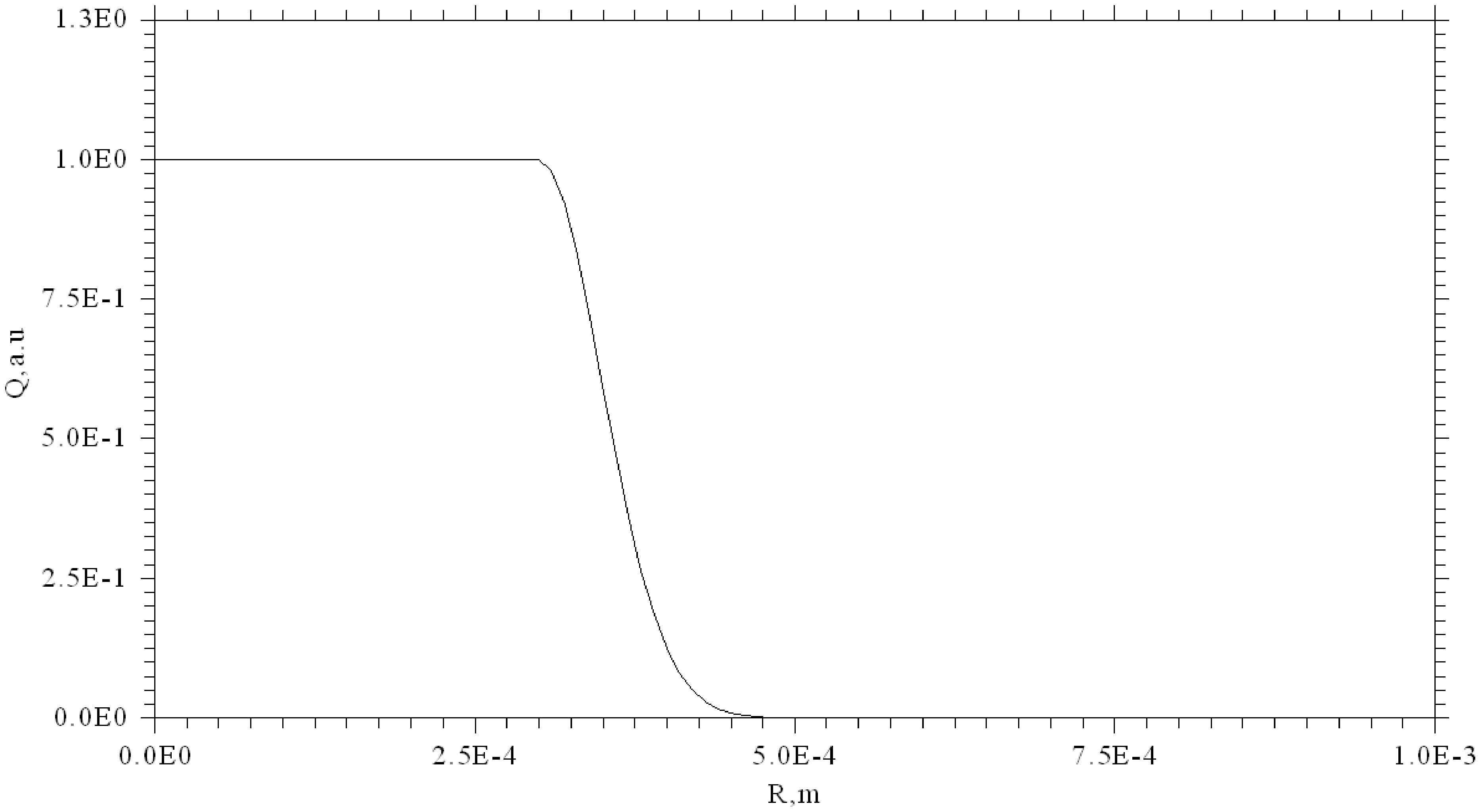
$$D = \frac{kT}{e}\mu$$

In the picosecond time range $v_- > v_+$

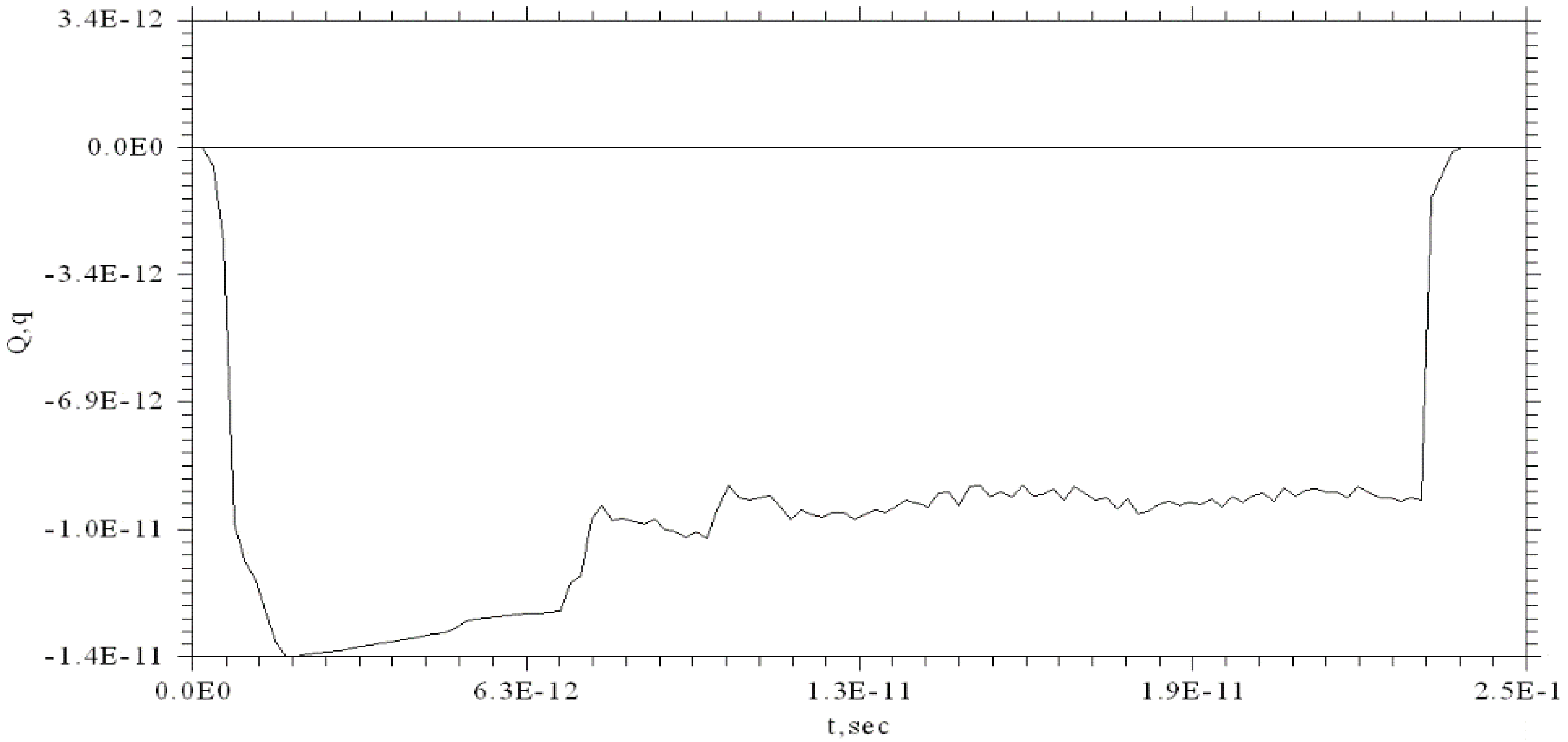
# Laser pulse shape



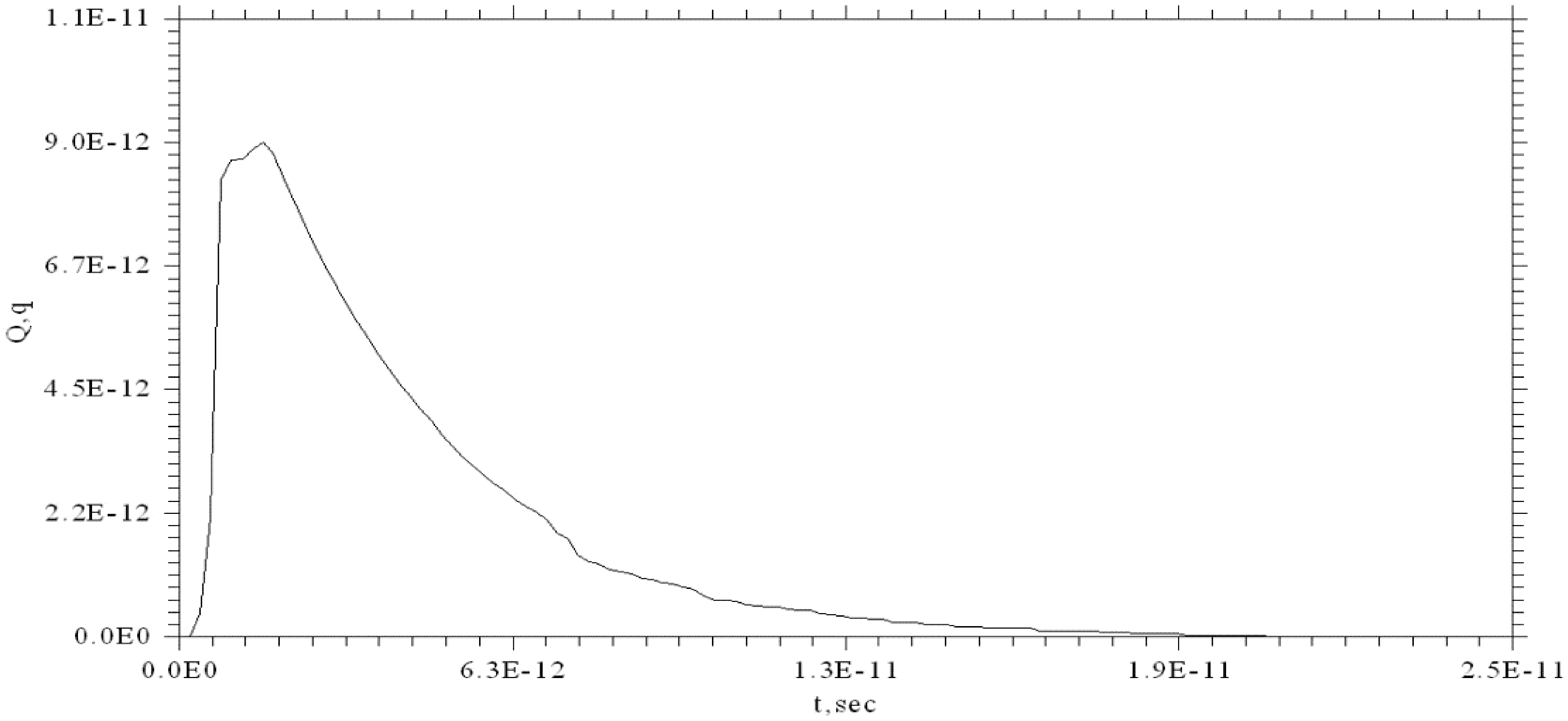
# Radial charge density distribution in the bunch



# Emitted charge time profile

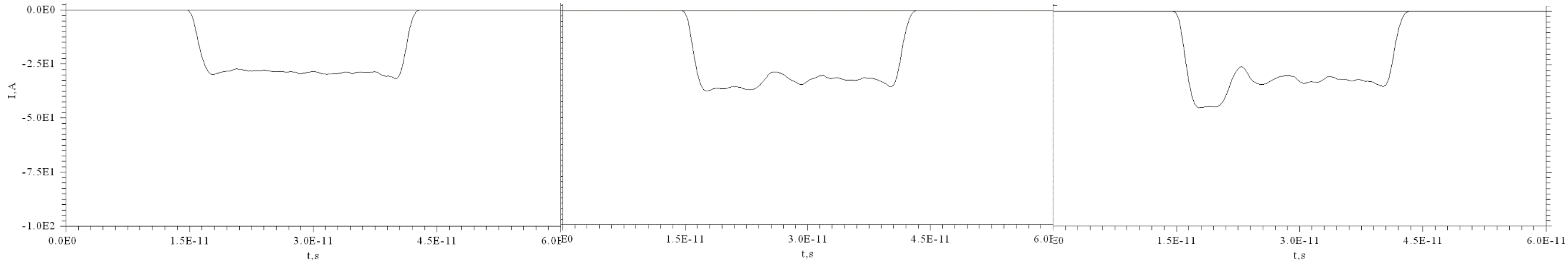


# Positive charge time profile  on a semiconductor film

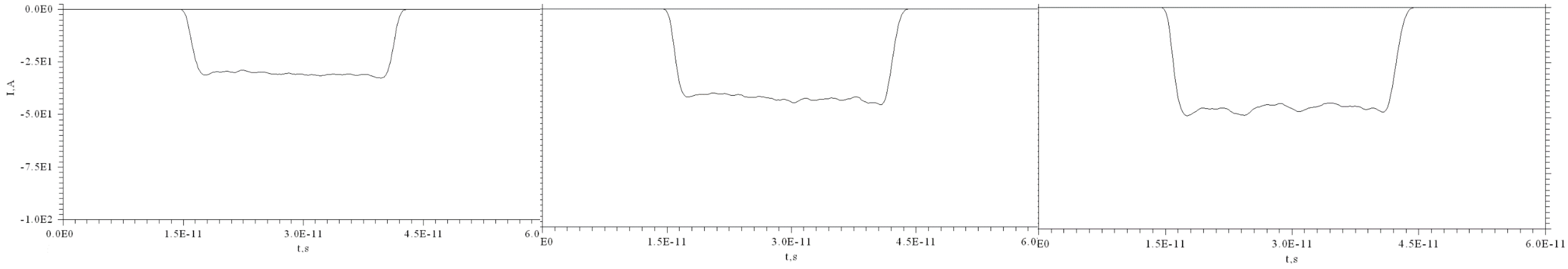


# Gun current( $Q_{inp}$: 0.4nC, 0.7nC, 1.0nC)

Old model



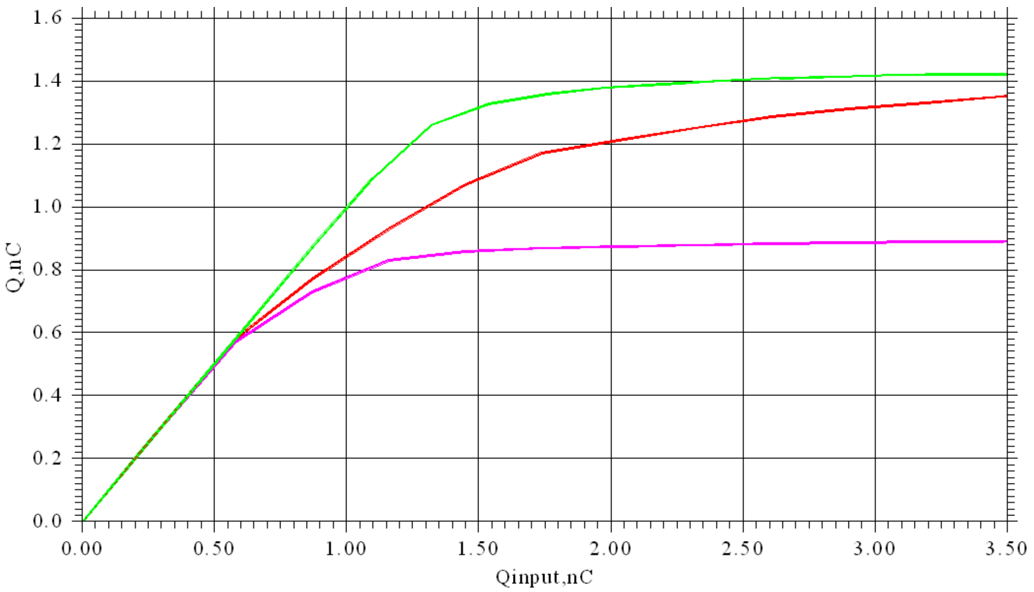

New model

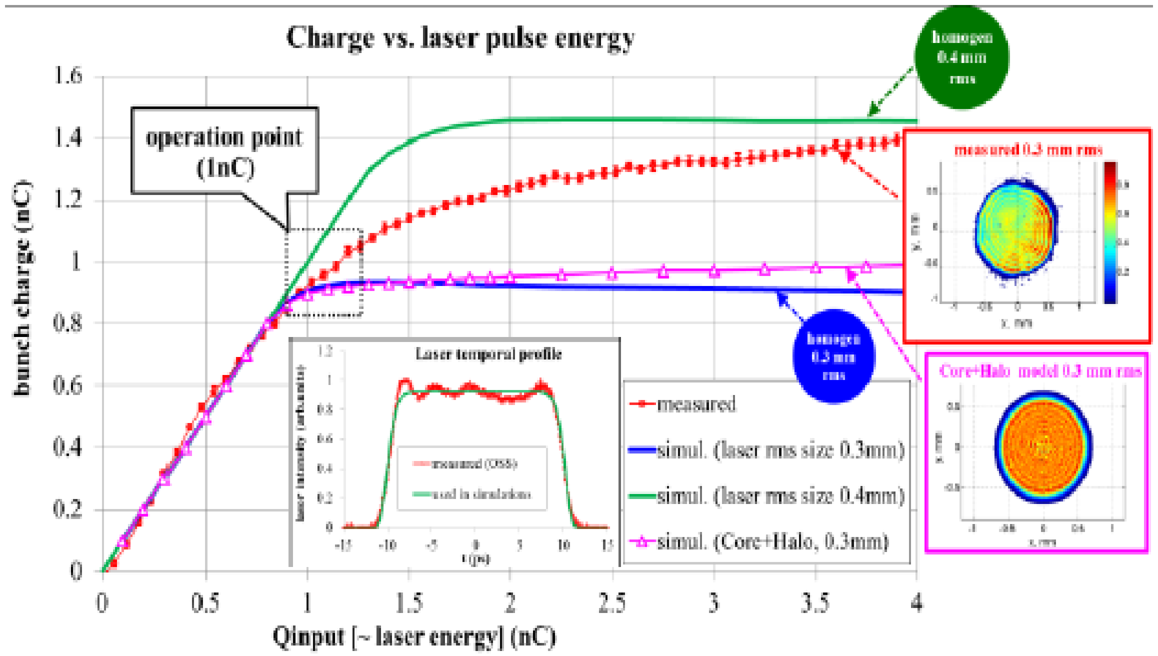


# Emission curves

SUMA

PITZ

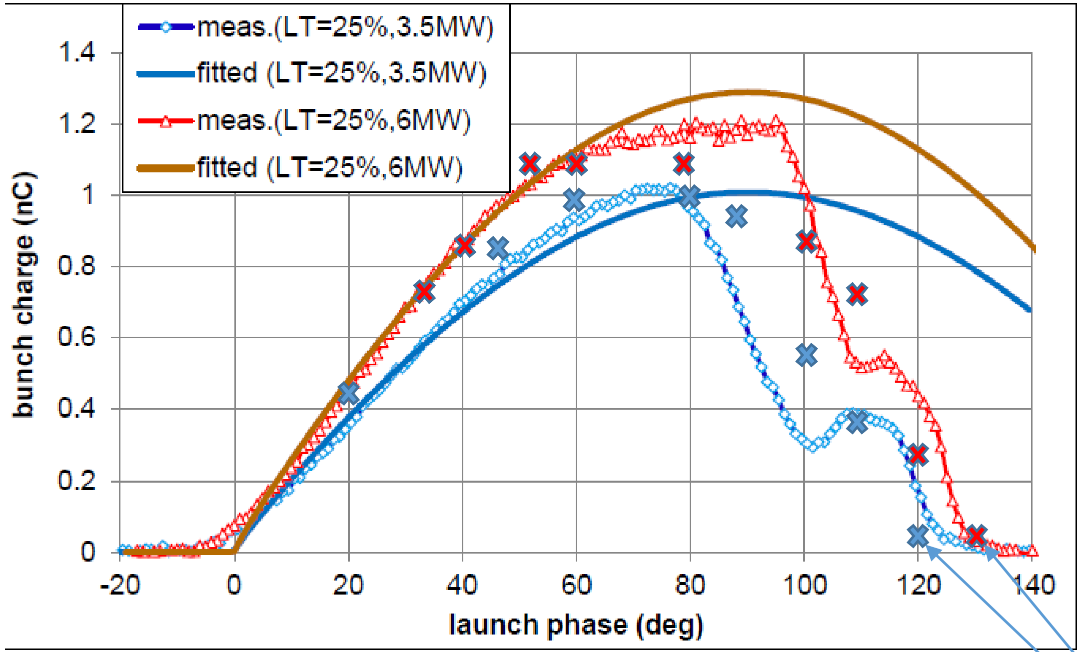


# Emission studies: modeling → RF field influence (LT=25%)

$$Q \propto \eta \cdot LT \cdot \left(1 + b\sqrt{E}\right)^m$$

$LT$ = laser transmission (%)
$E$ – field at the cathode (MV/m)
$\eta, b, m$ – fitting parameters




$LT = LT0$ = 25% (1nC at MMMG phase for 6MW)

| RF power (MW) | Ecath (MV/m) | max <Pz> (MeV/c) |
|---|---|---|
| 6.02 | 62.0 | 6.83 |
| 3.54 | 47.6 | 5.43 |

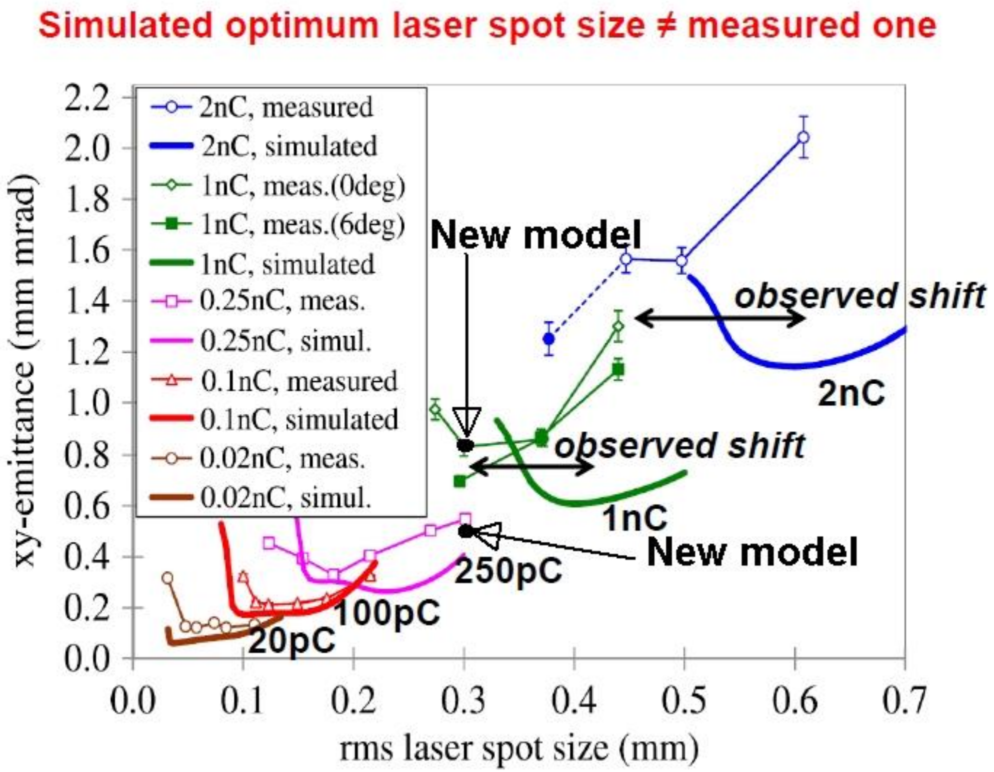
Fitting:
Phase range: 10→70deg
$E = E_{cath} \cdot sin\varphi_0$
$\eta$=1.2148E-5
$b$=10.9222
$m$=1.8705 (1.8977-2.1081)→2
+convolution with laser temporal profile

**Measurements:**
Laser:
- *Temporal → flattop 2/20\2ps*
- *Transverse → 0.3 mm rms*

Main solenoid: 400A
Charge measured by LOW.ICT1 → z=0.9m

SUMA simulation

# Emittance experimental curves and SUMA simulation




M. Krasilnikov, et al., Phys. Rev. ST Accel. Beams 15, 100701 (2012)

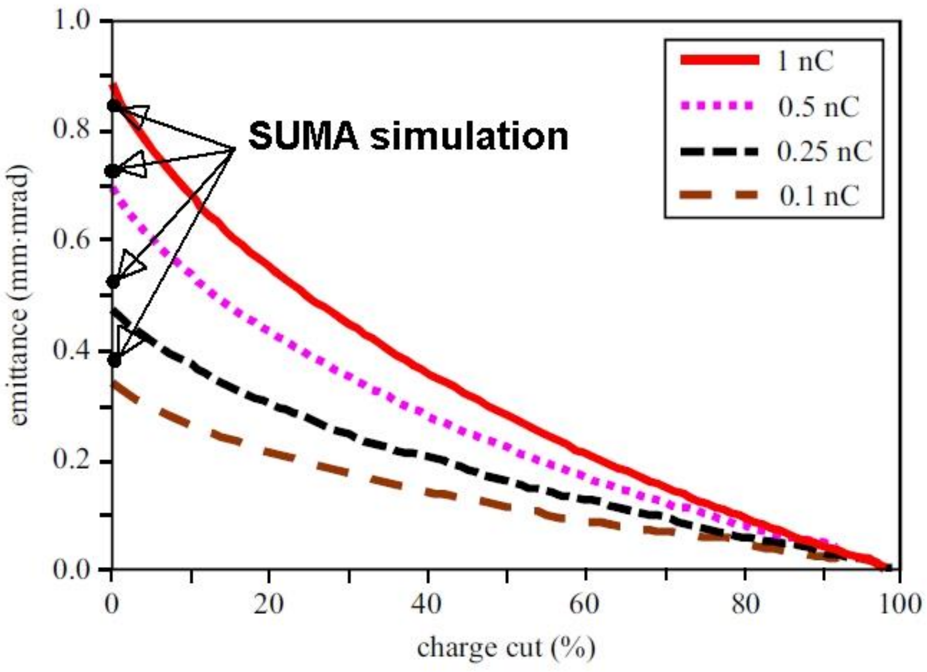



**Fig. 13.** Minimum geometric mean emittance ($\varepsilon_{xy}$) as a function of a charge cut starting from the lowest density tails in the phase-space distribution for a bunch charge of 1, 0.5, 0.25 and 0.1 nC. The 100% emittance values reported here are for a charge cut 0% (no charge cut).

S. Rimjaem, F.Stephan, M.Krasilnikov et al. Nuclear Instruments and Methods in Physics Research A 671 (2012) 62–75

Thanks for attention