CW 100 mA Electron RF Gun for Novosibirsk ERL FEL

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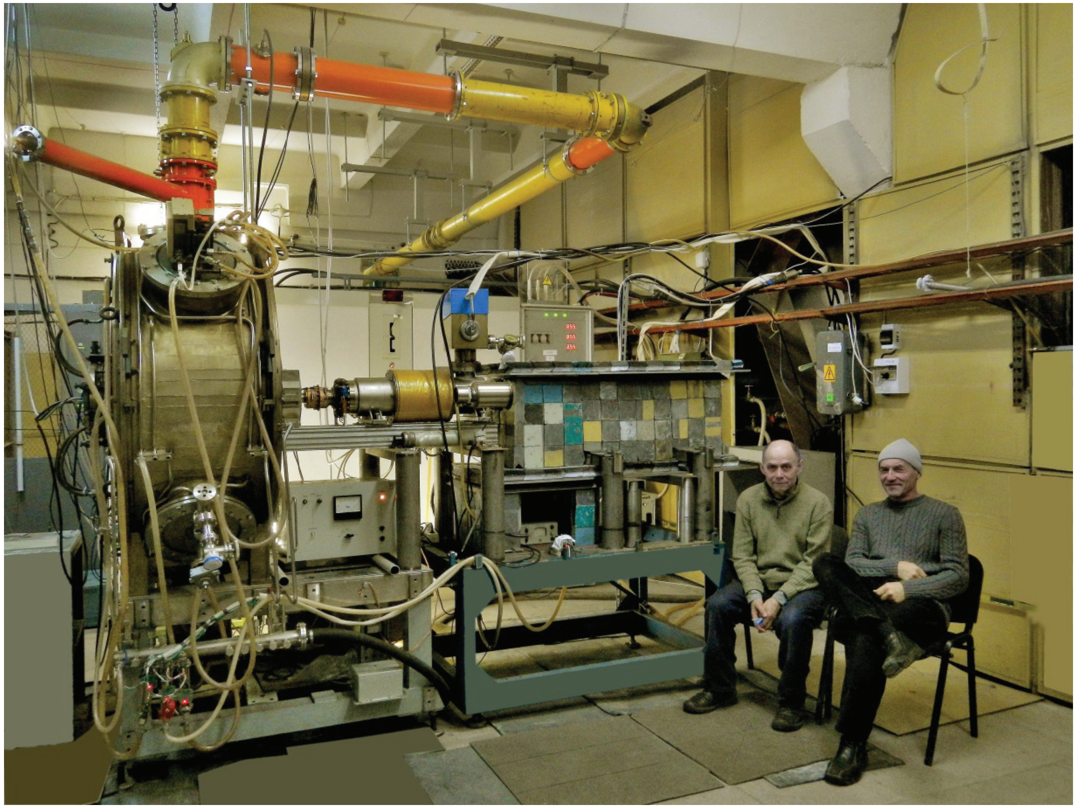
RF Gun Stand

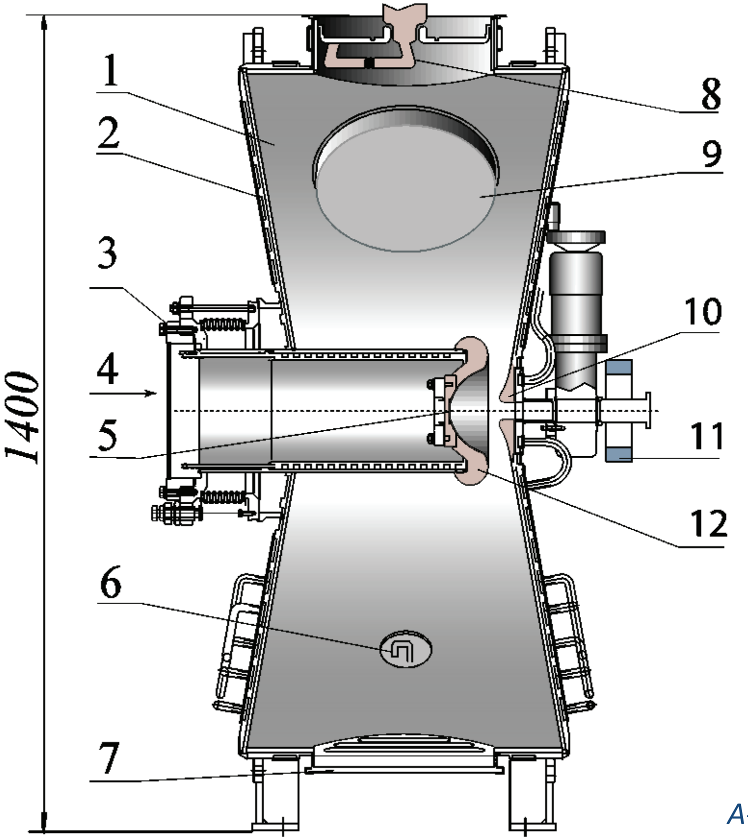


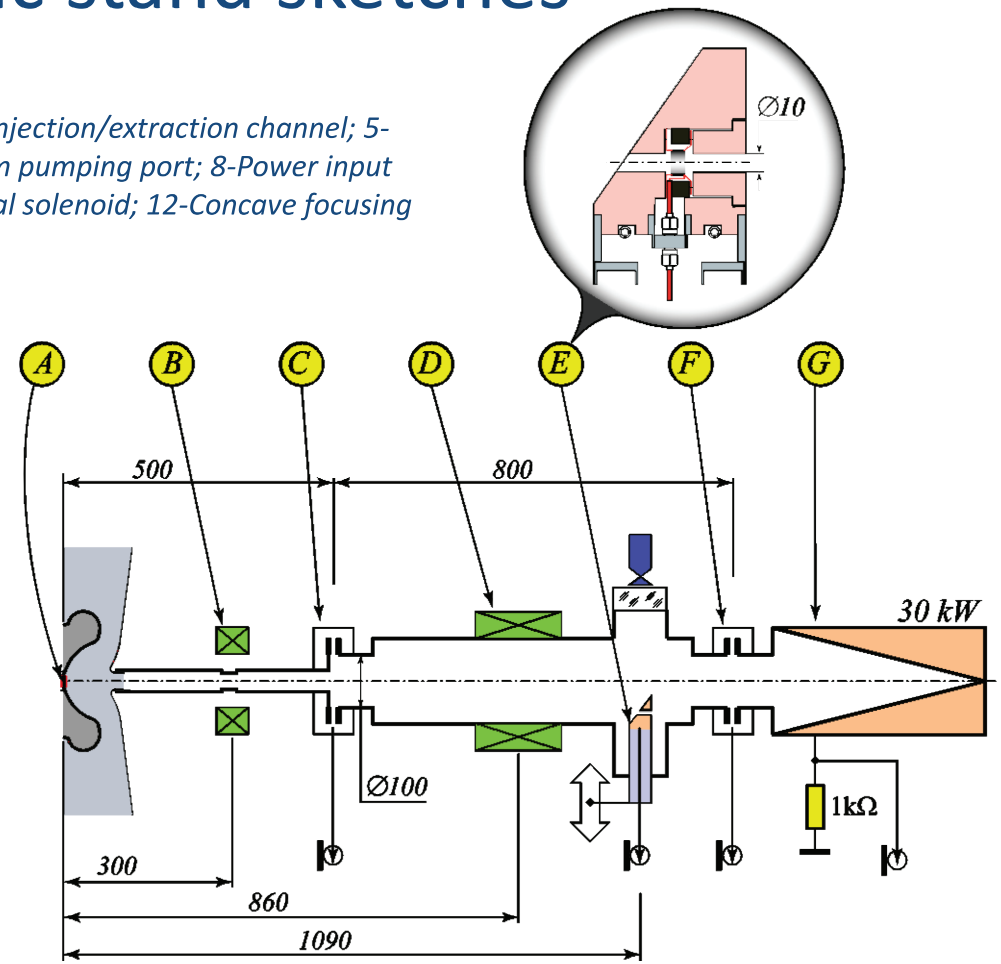
Measured rf gun characteristics	
Average beam current, mA	0.003 ÷ 100
Bunch energy, keV	100 ÷ 400
Bunch duration (FWHM), ns	0.2 ÷ 2.0
Bunch emittance, mm mrad	10
Bunch charge, nC	0.3 ÷ 3.8
Repetition frequency, MHz	0.01 ÷ 90

Perfections: 30 kW water cooled beam dump, 5 cm lead radiation shield, wideband Wall Current Monitor (WCM), New scheme of cathode-grid modulator with GaN rf transistor, Transition radiation sensor, and pair of standard WCM

RF Gun and Diagnostic stand sketches

1- Cavity shell; 2-Cavity back wall; 3-Insert; 4-Cathode injection/extraction channel; 5-Thermionic cathode-grid unit; 6-Loop coupler; 7-Vacuum pumping port; 8-Power input coupler; 9-Sliding tuner; 10-Cone like nose; 11-Peripheral solenoid; 12-Concave focusing electrode

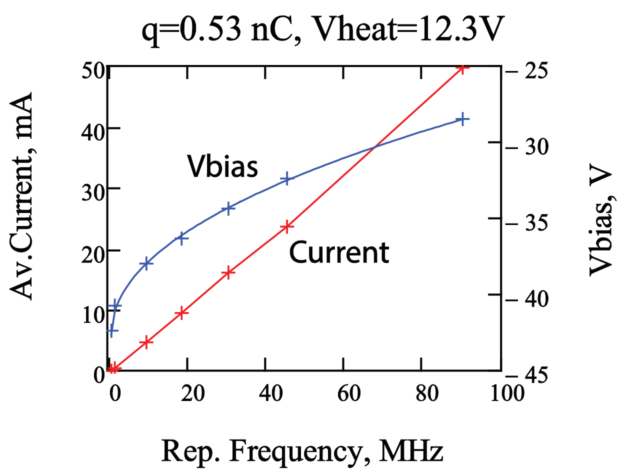




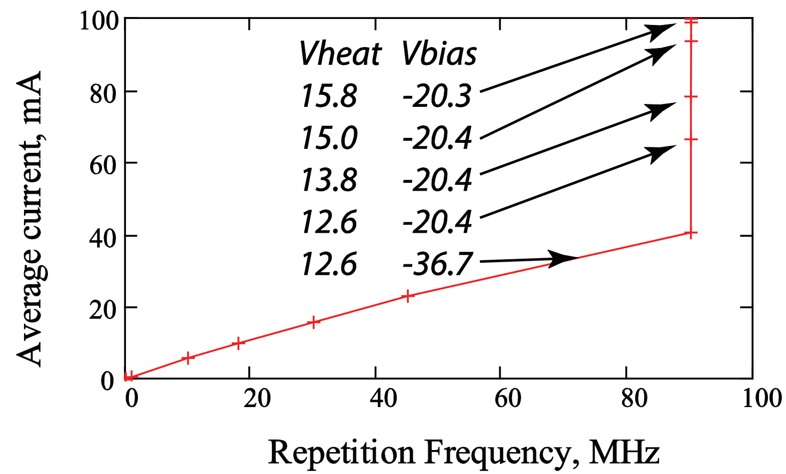
A-Thermionic cathode-grid unit; B-Emittance compensation solenoid; C-First Wall Current Monitor (WCM); D-Solenoid ; E-Wideband WCM and transition radiation sensor; F-third WCM; G-Faraday cup and Water-cooled beam dump

Beam current vs Repetition frequency *(F)*

Vpulse=100 V



Vpulse=120 V



Typical mode of load rise

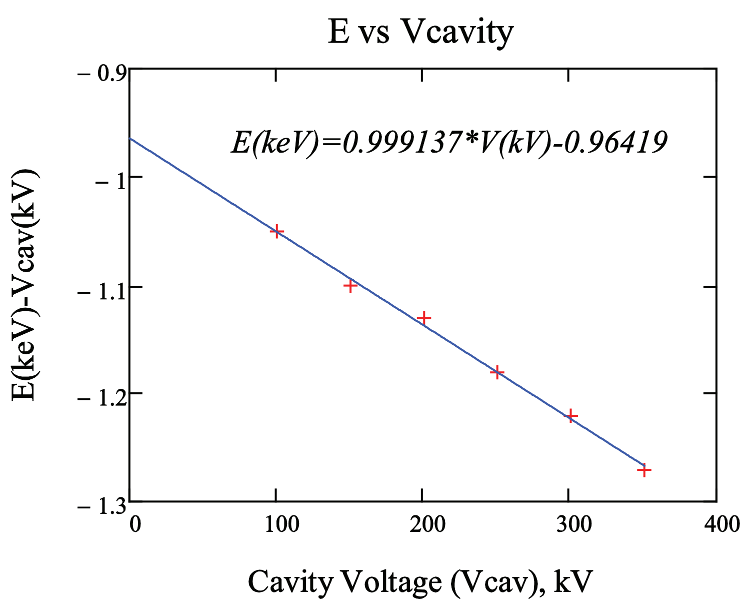
The current depends on the heating voltage (Vheat) because the cathode-grid distance is changed inversely of heating power due to thermal elongation. *Optimal heating voltage for maximal cathode life time is 14 ÷ 15 V instead of 12.6 V established for rf tubes due to the presence of reflecting anode surface*.

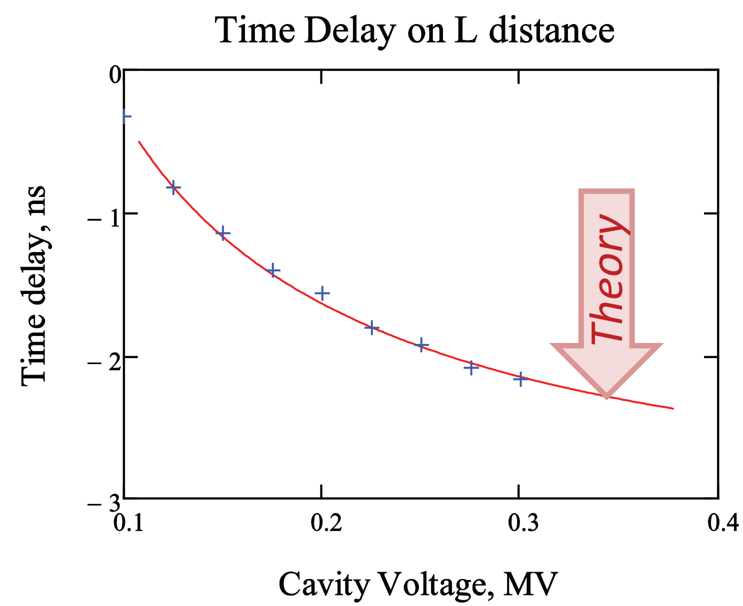
Also it depends on bias voltage (Vbias), and Modulator pulse voltage (Vpulse)

Calibration of Cavity Voltage meter

with using of two wall current monitors

by time delay measuring between them





Calibtated L=0.96078 m

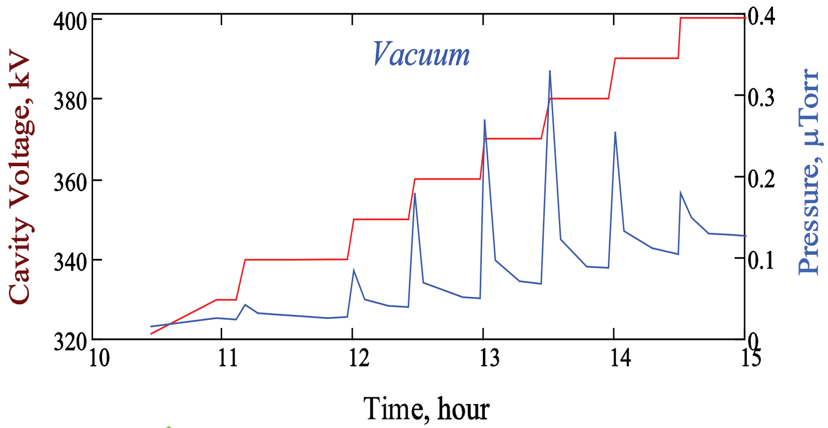
Bunch velocity (β) vs bunch energy (E)

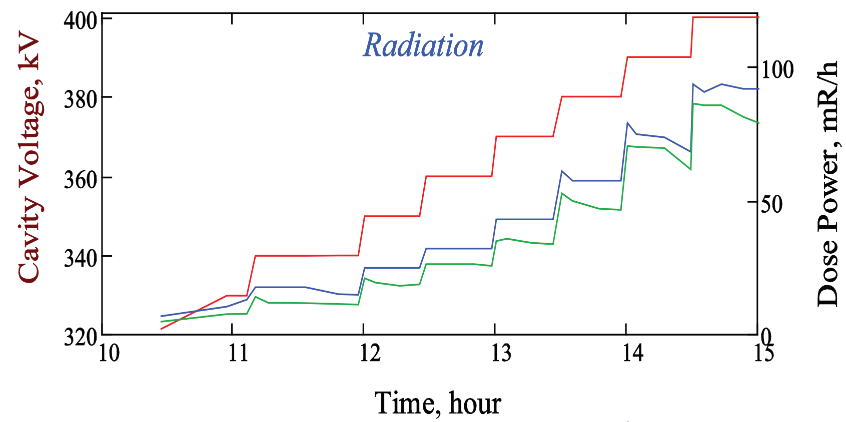
$$\beta(E) := \sqrt{1 - \frac{1}{\left(1 + \frac{E}{mc2}\right)^2}}$$

Time delay (T) vs Energy

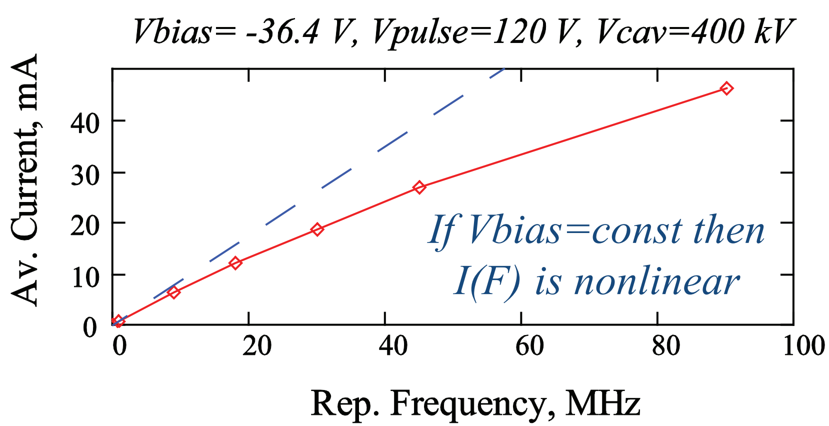
$$T(E) := \frac{L \cdot 10^9}{299792458 \cdot \beta(E)}$$

Cavity testing up to 400 kV





½ hour operation time needs to normalize pressure level



Two radiation sensors, one at the distance of 1.5 along axis, second 2 m aside

Maximal Beam Dump power (30 kW) limits the current

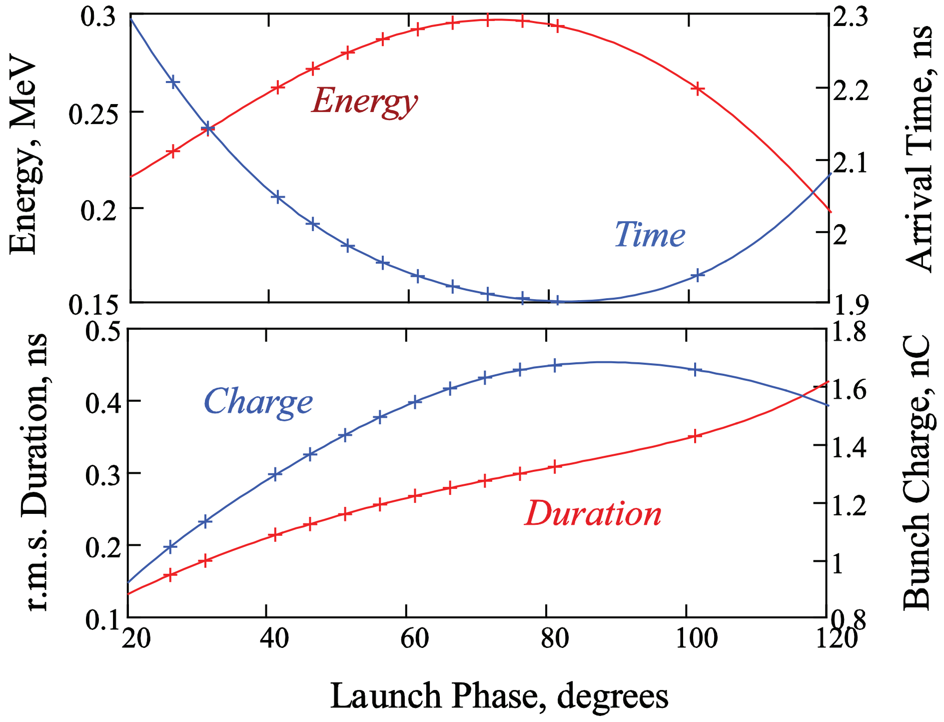
Launch Phase functions

determines bunching and jitter compensation effects.

Numerical calculation results

Vcav=300 kV

Launch Pulse duration is 1 ns FWHM



Launch Phase must be <120 degrees, otherwise there appeared back bombardment electrons with maximal power of 300 W at the cathode.

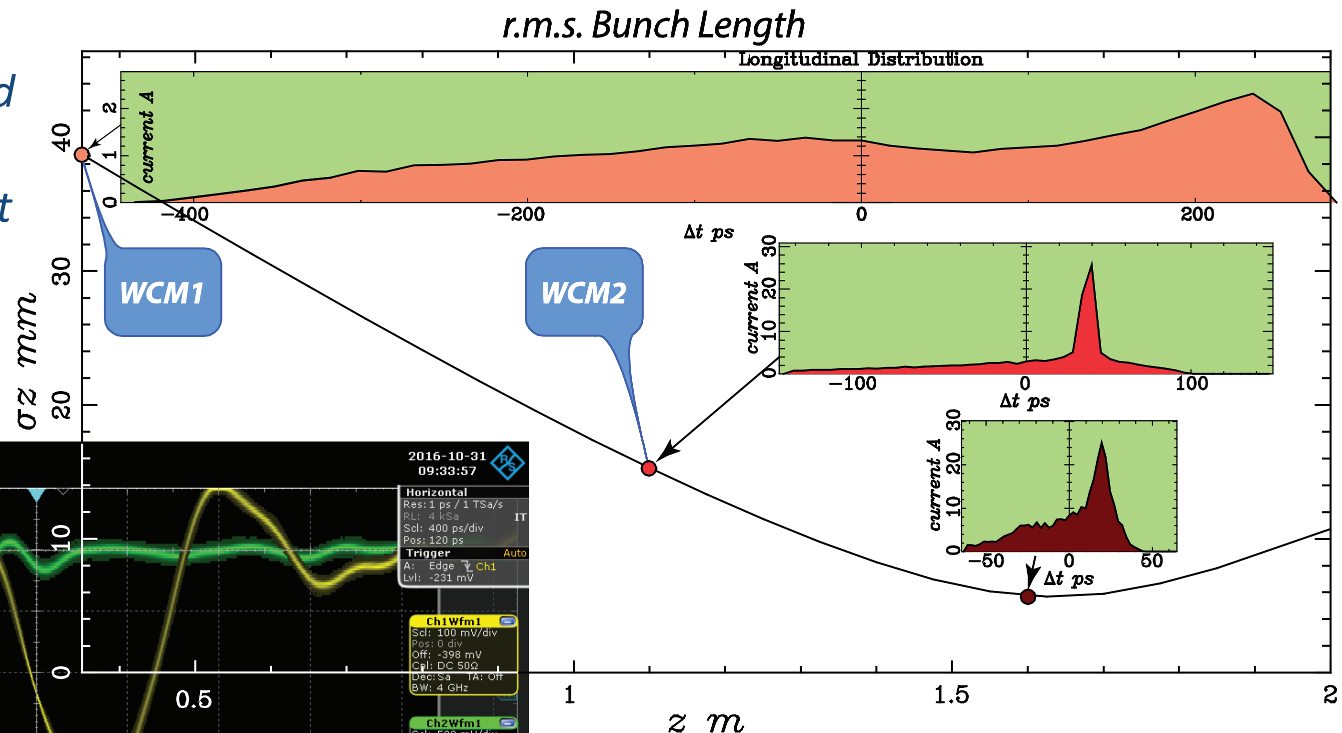
Launch Pulse duration determines minimal Launch Phase >20 degrees

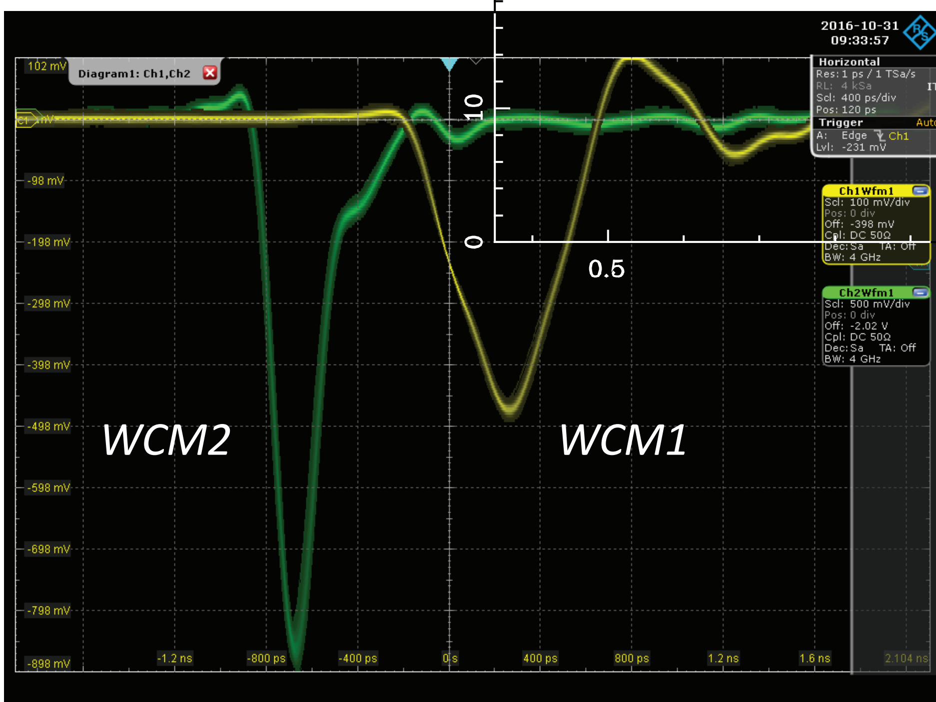
Velocity Modulation Bunching

measured with wideband WCM2 and 4 GHz oscilloscope

Wall Current Monitor (WCM)

Frontal spike is formed into cathode-grid gap due to bunching effect there.





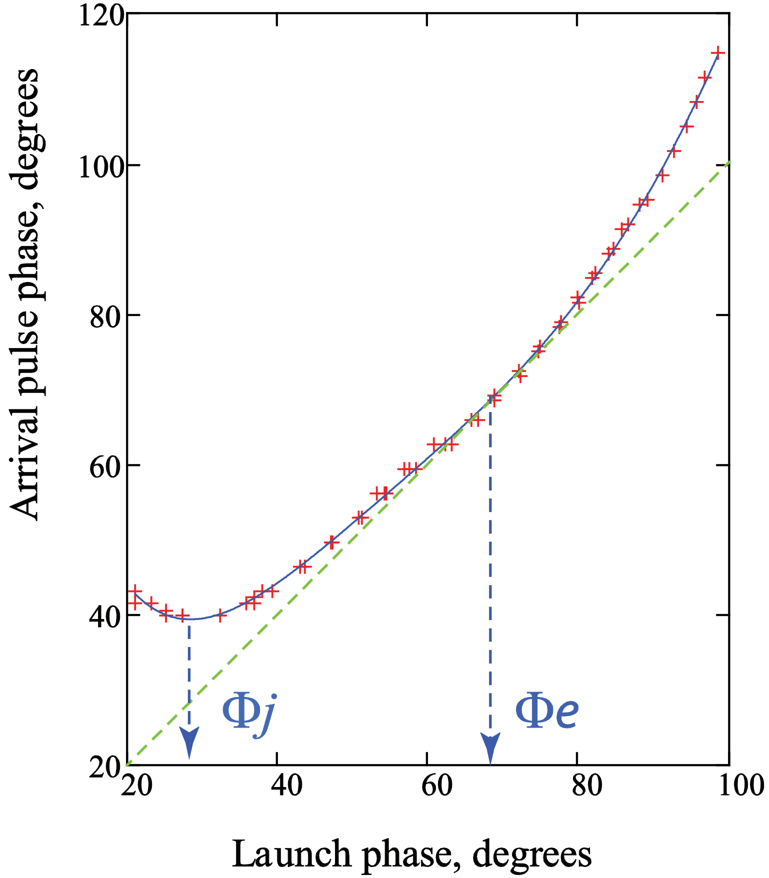
r.m.s. and FWHM be differ a lot

Numerical calculations predict FWHM τ_{FWHM}=20 ps, unfortunately the 4 GHz oscilloscope cannot show pulses τ<200 ps, it all viewed as τ=200 ps

Modulator Jitter Compensation

measured with Wall Current Monitor 3 (L=1.2 m)

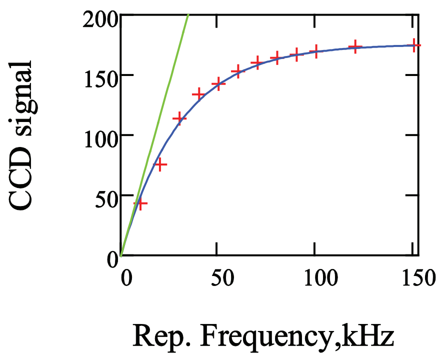
Arrival pulse phase is independent on Launch phase at Φj=27 degrees, i.e. the jitter is compensated there

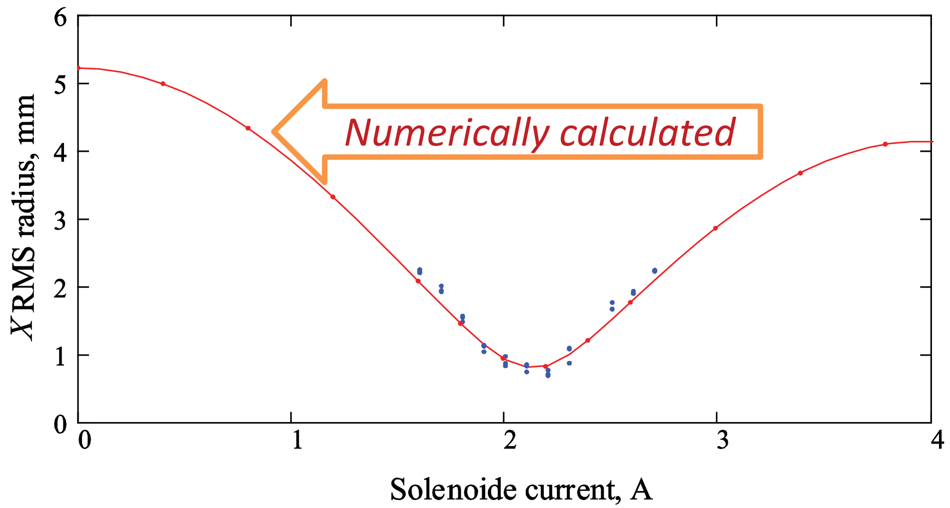


Maximal bunch energy is at Φe=68 degrees where it coincides with arrival one by accurate within some constant

Emittance Measurements

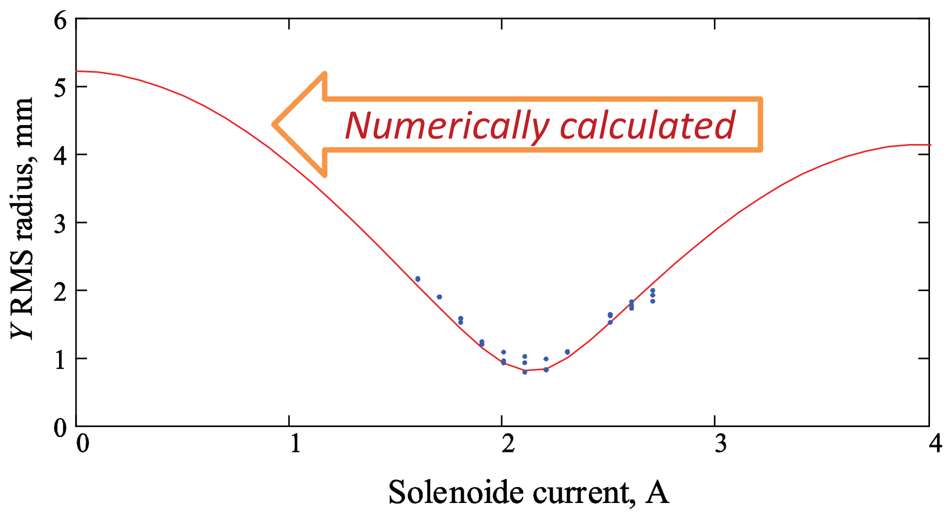
by solenoid focusing method with using transition radiation sensor





Measured normalized emittance ε=15.5 mm mrad can be compensated by solenoid focusing to ε=10 mm mrad.

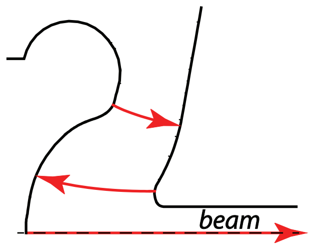
Numerical data processing of CCD camera image and distortion compensated optics were used.



Deviation of measured radius from calculated one is 9% so we can trust to our numerical calculations.

Dark and Leakage Currents

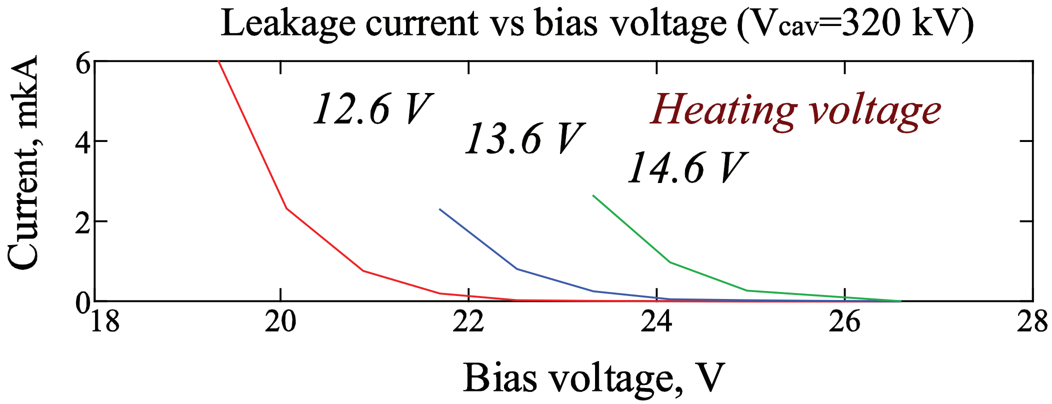
Two places with peak surface field of 10-14 MV/m are the sources of field emitted dark currents



Accelerating gap geometry
Dark current trajectories

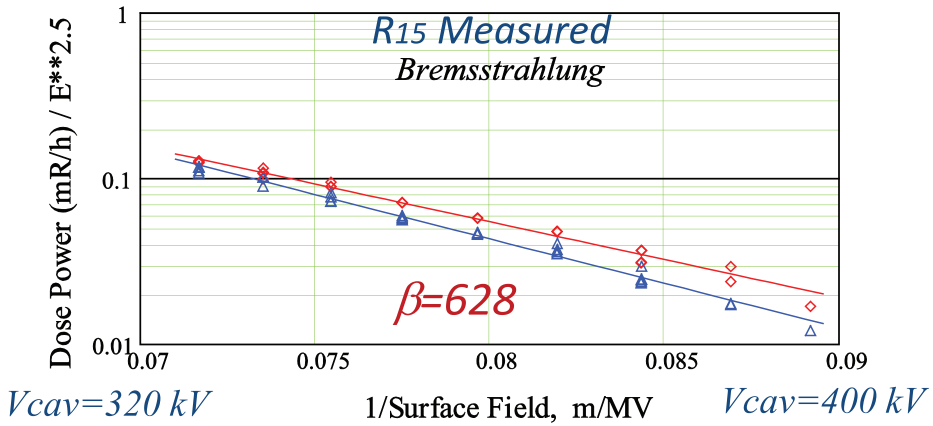
There are no dark currents in the beam absolutely

Leakage current depends on heating voltage because cathode-grid gap changed.
To exclude leakage current from the beam we must chose proper bias voltage.



Radiation Background

measured with radiation sensor at 1.5 m along axis and 2 m aside one



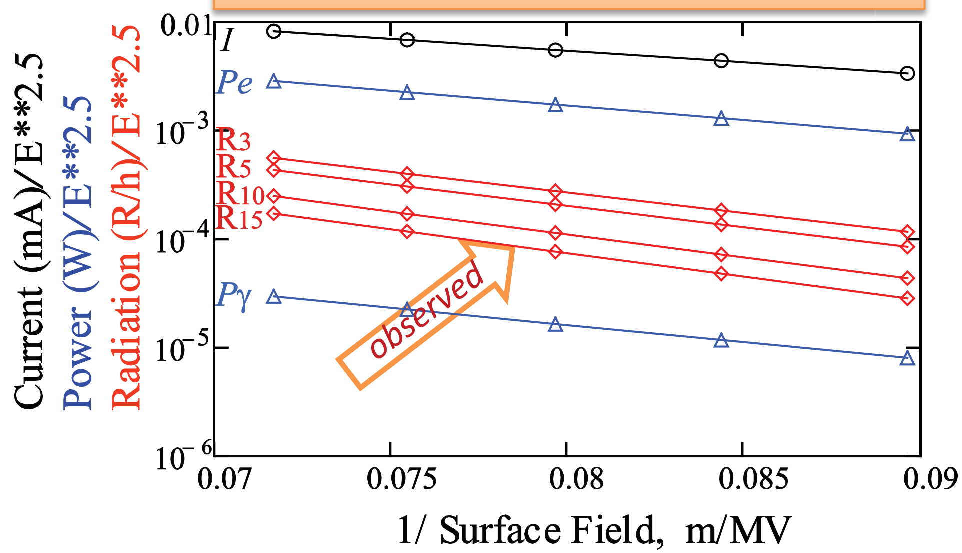
Fowler-Nordheim equation
ϕ=4.5 eV, B=6830, E (MV/m)

$$I \approx (\beta E)^{2.5} exp\left(-\frac{B\varphi^{1.5}}{\beta E}\right)$$

Enhancement factor (β) variance

Name		label	β
Dark Current of Field Emission		I	1264
Dark Current Power		Pe	1003
Bremsstrahlung Power		$P\gamma$	865
Cu Shielded Dose Power	d=3 mm	R3	721
	d=5 mm	R5	695
	d=10mm	R10	649
	d=15mm	R15	628

All Calculated have F-N nature!



Thank you for your attention!