Recycler BPM Dynamic Range Study

Look at these different beam conditions:

1. 2.5 MHz low end - 2E10 total in four gaussian bunches with 50nsec sigma
2. 2.5 MHz high end - 30E10 total in four gaussian bunches with 25nsec sigma
3. 7.5 MHz low end – 2.4E10 total in twelve gaussian bunches with 16nsec sigma
4. 7.5 MHz high end - 48E10 total in twelve gaussian bunches with 8nsec sigma
5. Unbunched beam low end – 20E10 in 111/53MHz (2094nsec) wide bunch with 30/53MHz (566nsec) edges
6. Unbunched beam high end – 400E10 in 104/53MHz (1962nsec) wide bunch with 18/53MHz (340nsec) edges
7. Unbunched beam way-low end – 20E10 in 468/53MHz (8830nsec) wide bunch with 30/53MHz (566nsec) edges
8. 53 MHz beam – 100E10 total in forty bunches with 2nsec sigma

Plot beam current as a check and plot voltage, due to "centered" proton beam, appearing at input of what I understand to be proposed preamp. I assume 136 pF electrode plus cable capacitance to ground, 0.01 microfarad blocking capacitor, followed by network to ground consisting of 150 ohm resistor in series with parallel combination of 647 ohm resistor and 47 pF capacitor, and finally high amplifier input impedance.

See plots that follow and find:

	Peak Beam Current
Case 1	6 mA
Case 2	190 mA
Case 3	8 mA
Case 4	310 mA
Case 5	16 mA
Case 6	325 mA
Case 7	3.7 mA
Case 8	800 mA

Beam current range (excluding 53 MHz) is then ~3.7 to 325 mA (range of 89).

	"Beam-on-Center" Preamp Input Voltage
Case 1	+12 / -7 mV
Case 2	+425 / -160 mV
Case 3	+20/ -8 mV
Case 4	+900 / -200 mV
Case 5	+14 / -14 mV
Case 6	+400 / -400 mV
Case 7	+3.3 / -3.3 mV
Case 8	+2500 / -200 mV

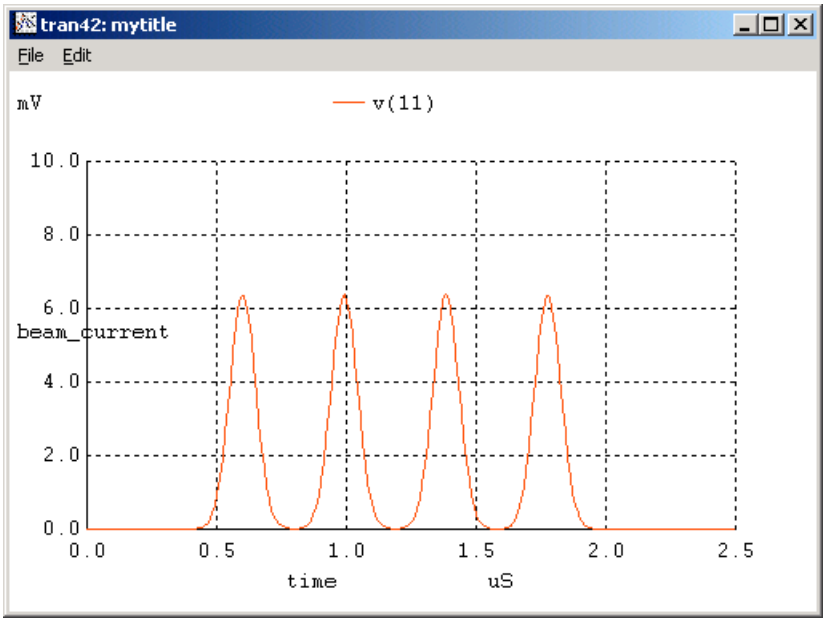
Range (excluding 53 MHz) is then ~6.6 to 1100 mV (range of 167) at preamp input for "centered" beam and up to twice that for "off-center" beam. 53 MHz peak is 2.5 volts.

Interpreting dynamic range in terms of bits.

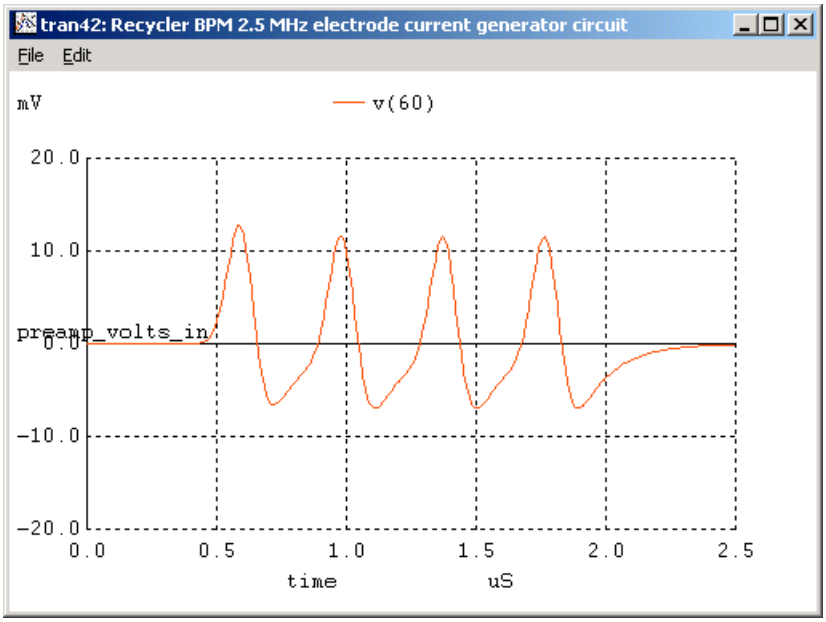
Want 0.4mm resolution on 100 mm aperture. Imagine signal on plate A varies from 0 for beam-far-left to 64 for beam-on-center to 127 for beam-far-right (this is like 7 bits). In this case each 0.8mm movement changes signal by one unit; claim 0.4mm resolution since B signal changes opposite direction from A signal. For a 14-bit digitizer, 7 bits (factor of 128) remain for common-mode signal range above the level that gives a signal of 64LSB for beam-on-center. [Beam on center takes 6 bits for resolution, beam at range takes another bit, and that leaves 7 bits common mode range.] (Note: if signal is uni-polar, you lose one bit since signals can occupy only half of the digitizer range for any one beam.)

Alternatively, assume 1.1Vpp 14-bit digitizer. LSB corresponds to 0.067mV. This gives 1/128 resolution for a beam-on-center plate signal of 4.3mV (64 times LSB) and permits a maximum plate signal of plus or minus 550mV. Considering the numbers in the preamp voltage table, this digitizer makes the Case 7 measurement with a factor of 1.53 to spare (compare 6.6mV p-p signal to the 4.3mV required) and falls a factor of 1.64 short (compare 900mV peak signal to 550mV peak max input) of making the Case 4 measurement. The overall range is short only by a factor of 1.07. Considering the numbers in the beam current table and scaling the gain (550/325=1.7mV/mA) to just make the Case 4 measurement, the 14-bit digitizer then makes the Case 7 measurement with a factor of 1.46 to spare (1.7 times 3.7 divided by 4.3).

Case 1:
2E10 total in four 2.5 MHz gaussian bunches with 50nsec sigma

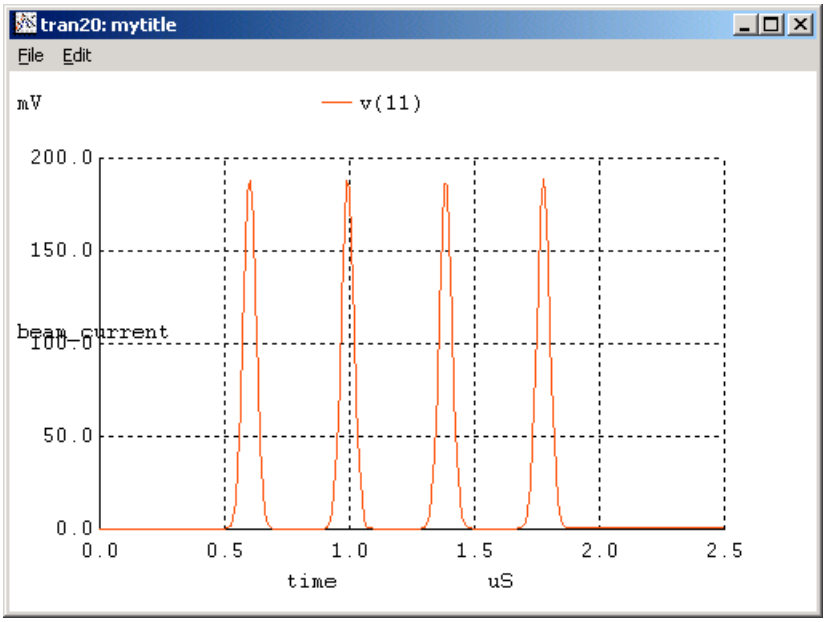


Beam Current (vertical scale is mA) with 2E10 and 50nsec sigma

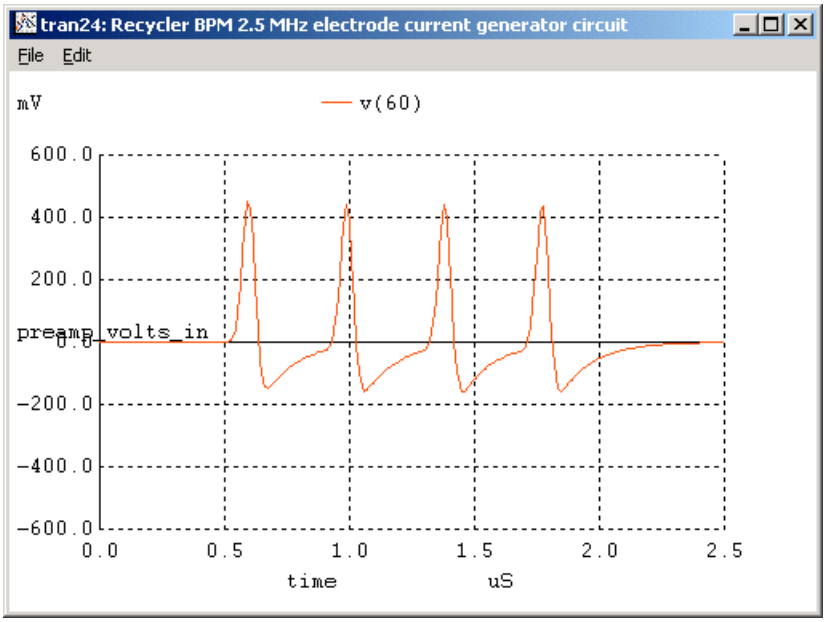


PreAmp Input Voltage (vertical scale is mV)
"Beam-on-Center" with 2E10 and 50nsec sigma

Case 2:
30E10 total in four 2.5 MHz gaussian bunches with 25nsec sigma

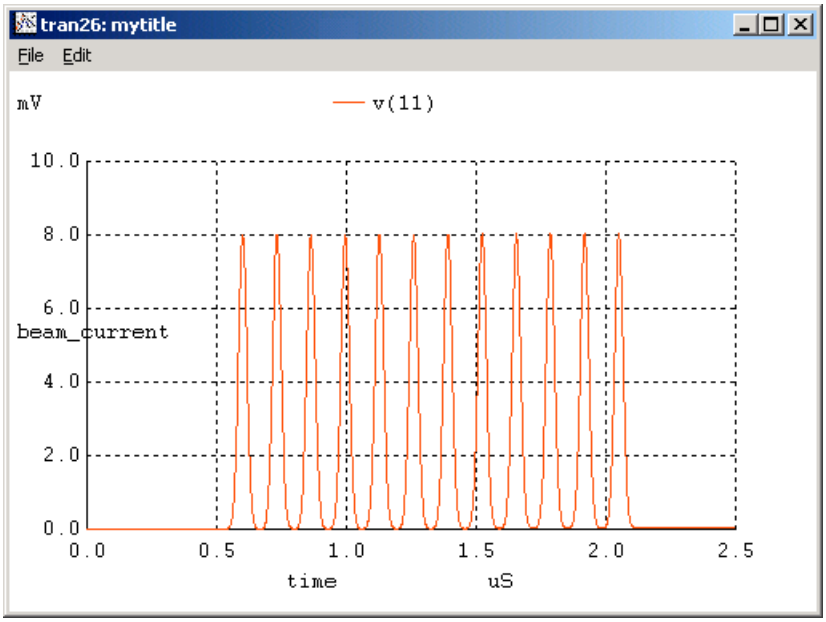


Beam Current (vertical scale is mA) with 30E10 and 25nsec sigma

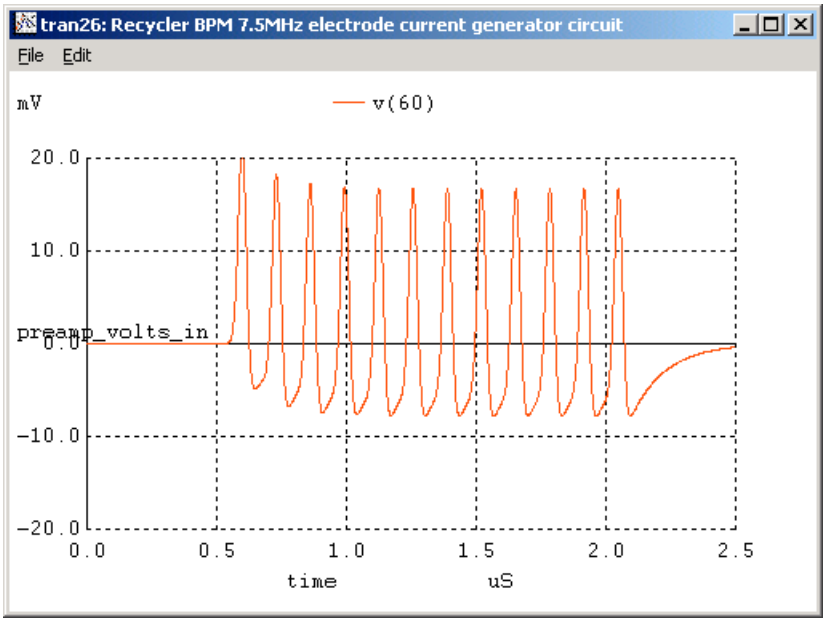


PreAmp Input Voltage (vertical scale is mV)
"Beam-on-Center" with 30E10 and 25nsec sigma

Case 3:
2.4E10 total in twelve 7.5 MHz gaussian bunches with 16nsec sigma

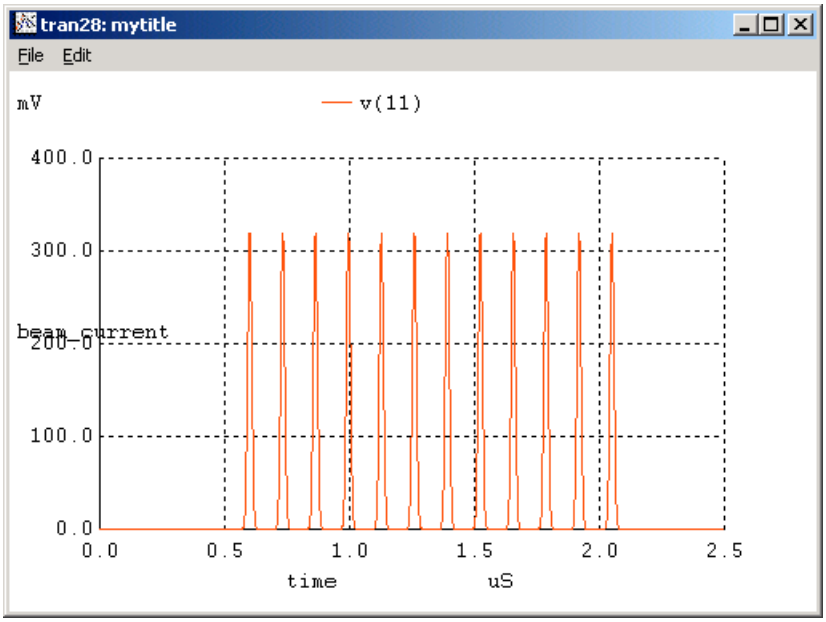


Beam Current (vertical scale is mA) with 2.4E10 and 16nsec sigma

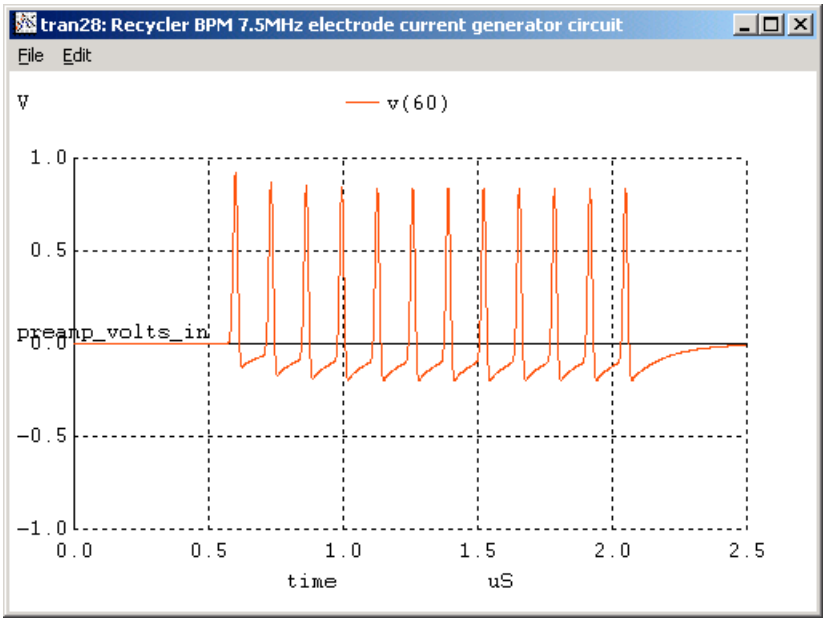


PreAmp Input Voltage (vertical scale is mV)
"Beam-on-Center" with 2.4E10 and 16nsec sigma

Case 4:
48E10 total in twelve 7.5 MHz gaussian bunches with 8nsec sigma

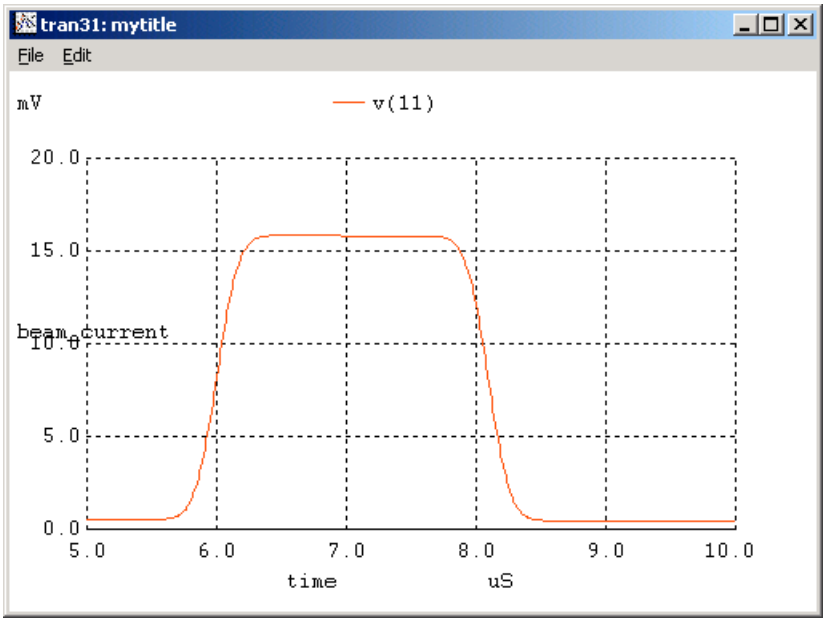


Beam Current (vertical scale is mA) with 48E10 and 8nsec sigma

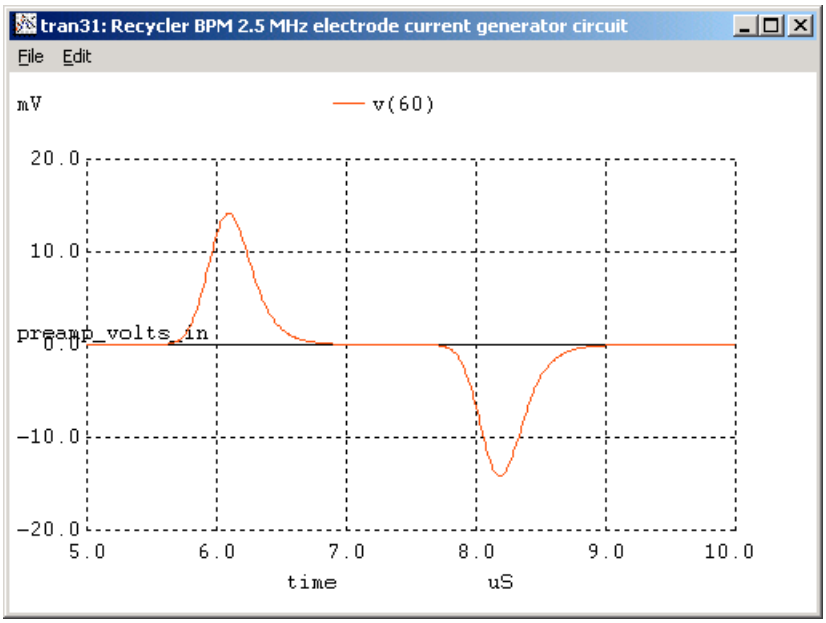


PreAmp Input Voltage (vertical scale is Volts)
"Beam-on-Center" with 48E10 and 8nsec sigma

Case 5:
20E10 in 111/53MHz (2094nsec) wide bunch with 30/53MHz (566nsec) edges

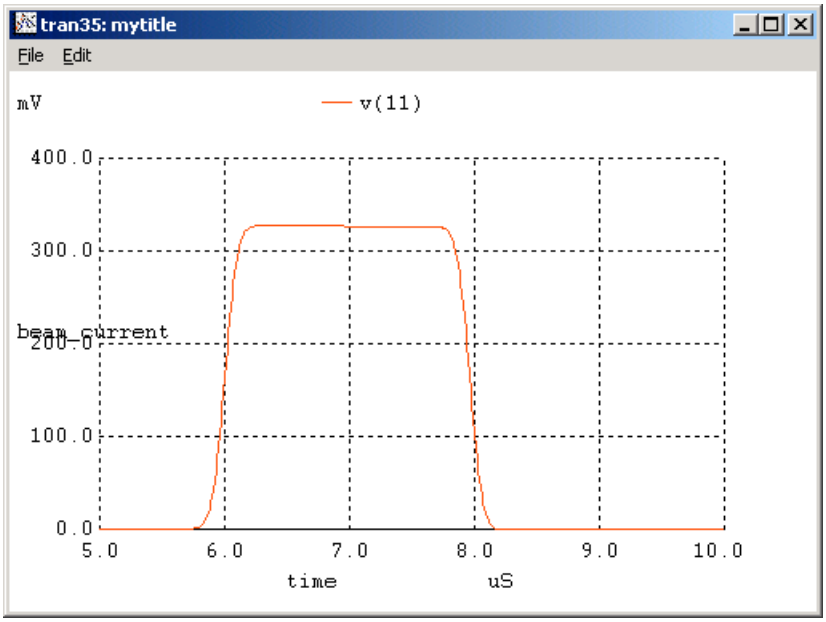


Beam Current (vertical scale is mA) with 20E10 in 2094nsec bunch with 566nsec edges

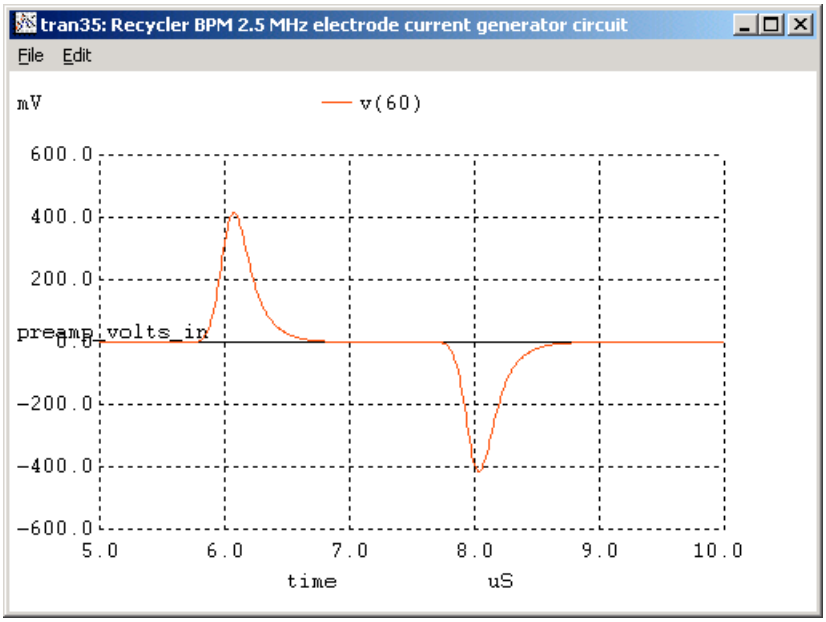


PreAmp Input Voltage (vertical scale is mV)
"Beam-on-Center" with 20E10 in 2094nsec bunch with 566nsec edges

Case 6:
400E10 in 104/53MHz (1962nsec) wide bunch with 18/53MHz (340nsec) edges

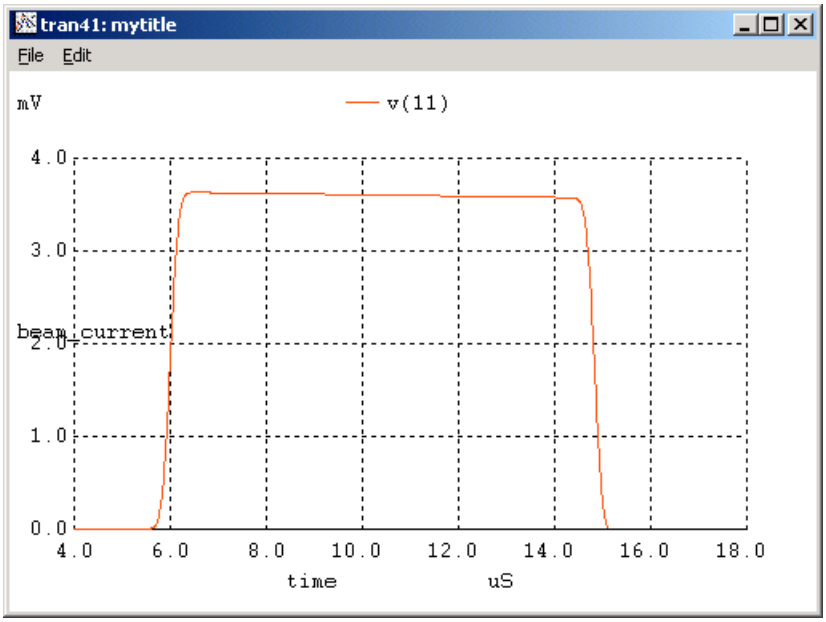


Beam Current (vertical scale is mA) with 400E10 in 1962nsec bunch with 340nsec edges

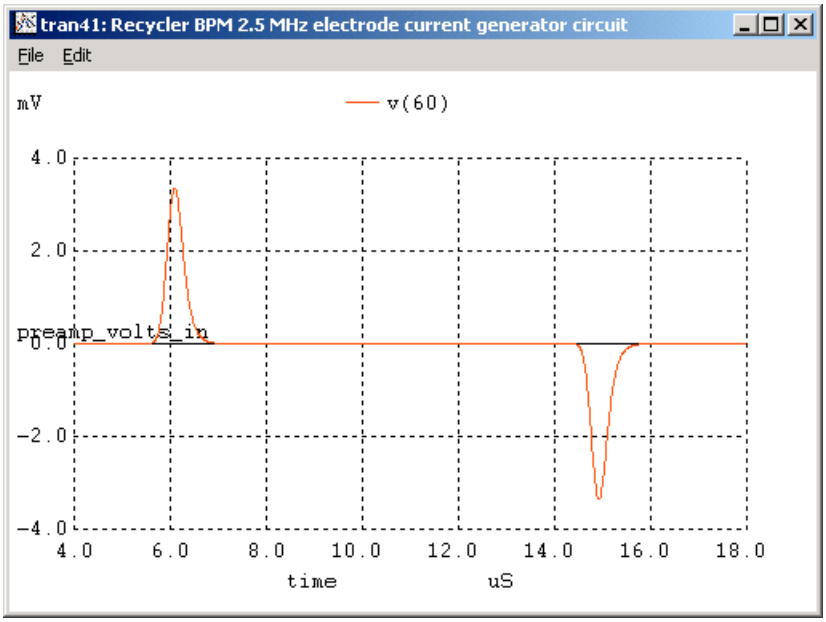


PreAmp Input Voltage (vertical scale is mV)
"Beam-on-Center" with 400E10 in 1962nsec bunch with 340nsec edges

Case 7:
20E10 in 468/53MHz (8830nsec) wide bunch with 30/53MHz (566nsec) edges



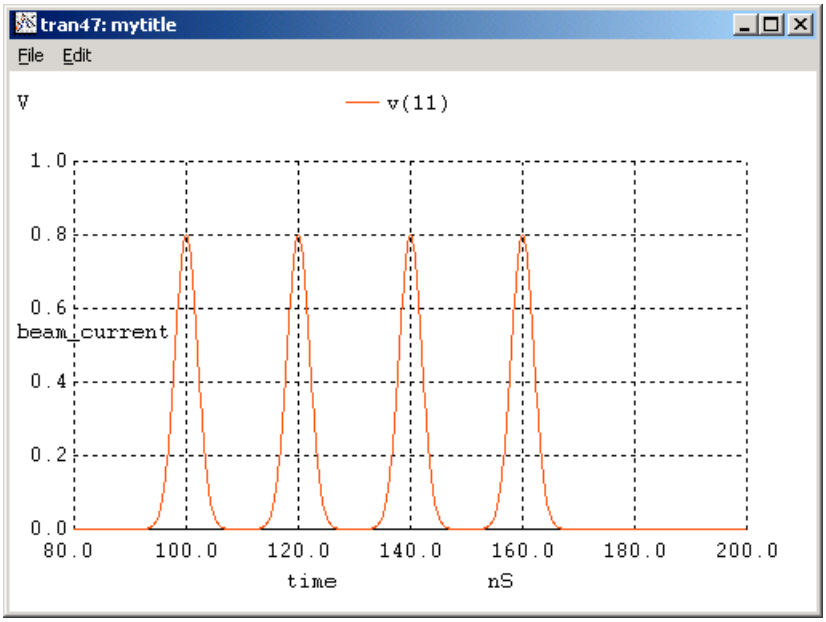
Beam Current (vertical scale is mA) with 20E10 in 8830nsec bunch with 566nsec edges



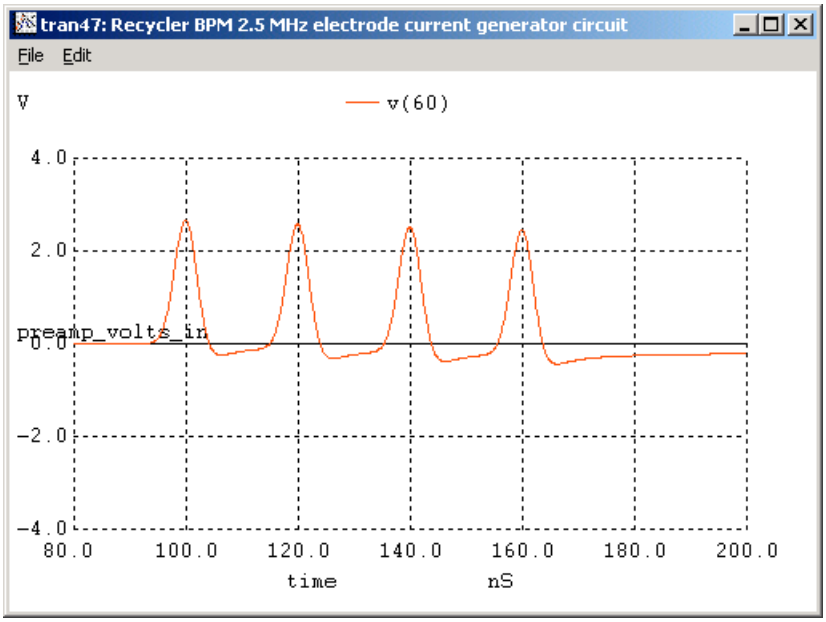
PreAmp Input Voltage (vertical scale is mV)
"Beam-on-Center" with 20E10 in 8830nsec bunch with 566nsec edges

Case 8:

100E10 total in forty 53 MHz gaussian bunches with 2nsec sigma (2.5E10/bunch)



Beam Current (vertical scale is Amperes) with 2.5E10/bunch in 53 MHz gaussian bunches with 2nsec sigma



PreAmp Input Voltage (vertical scale is Volts)
"Beam-on-Center" with 2.5E10/bunch in 53 MHz gaussian bunches with 2nsec sigma