Fixed Frequency Phase Rotator for the Neutrino Factory (GEANT4 Simulation)

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Abstract:

The phase rotation schemes for the neutrino factory studied so far involve the development of new technology with its associated high cost: low frequency r.f. systems or induction linacs.

In this note, we study a realistic GEANT4 simulation of the alternative design proposed by D. Neuffer & A. Van Ginneken (MuCool Notes # 181, 210, 220) consisting of a high frequency buncher and then a phase rotator, using established high frequency r.f. systems. We concentrate on the phase rotation section.

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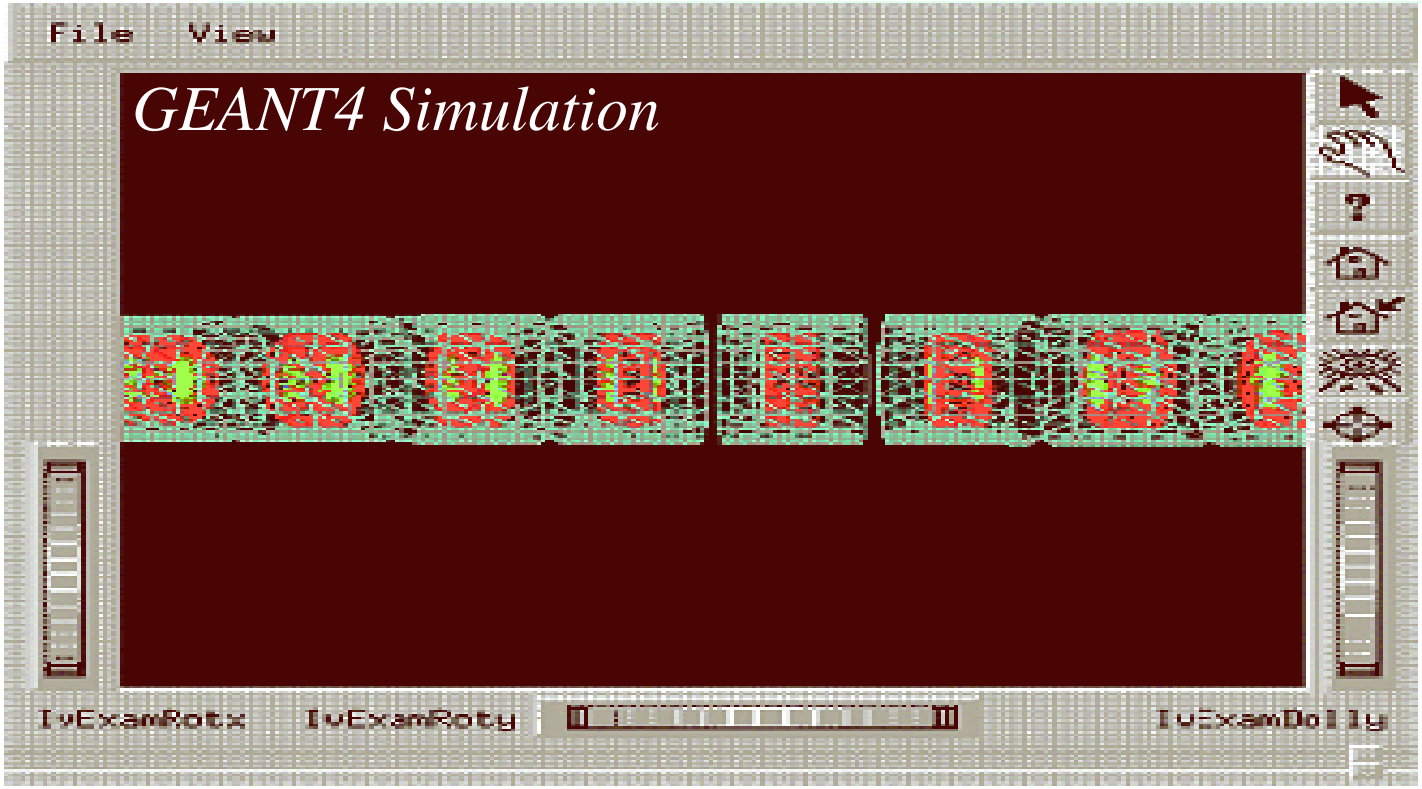
60-frequency Buncher, Design

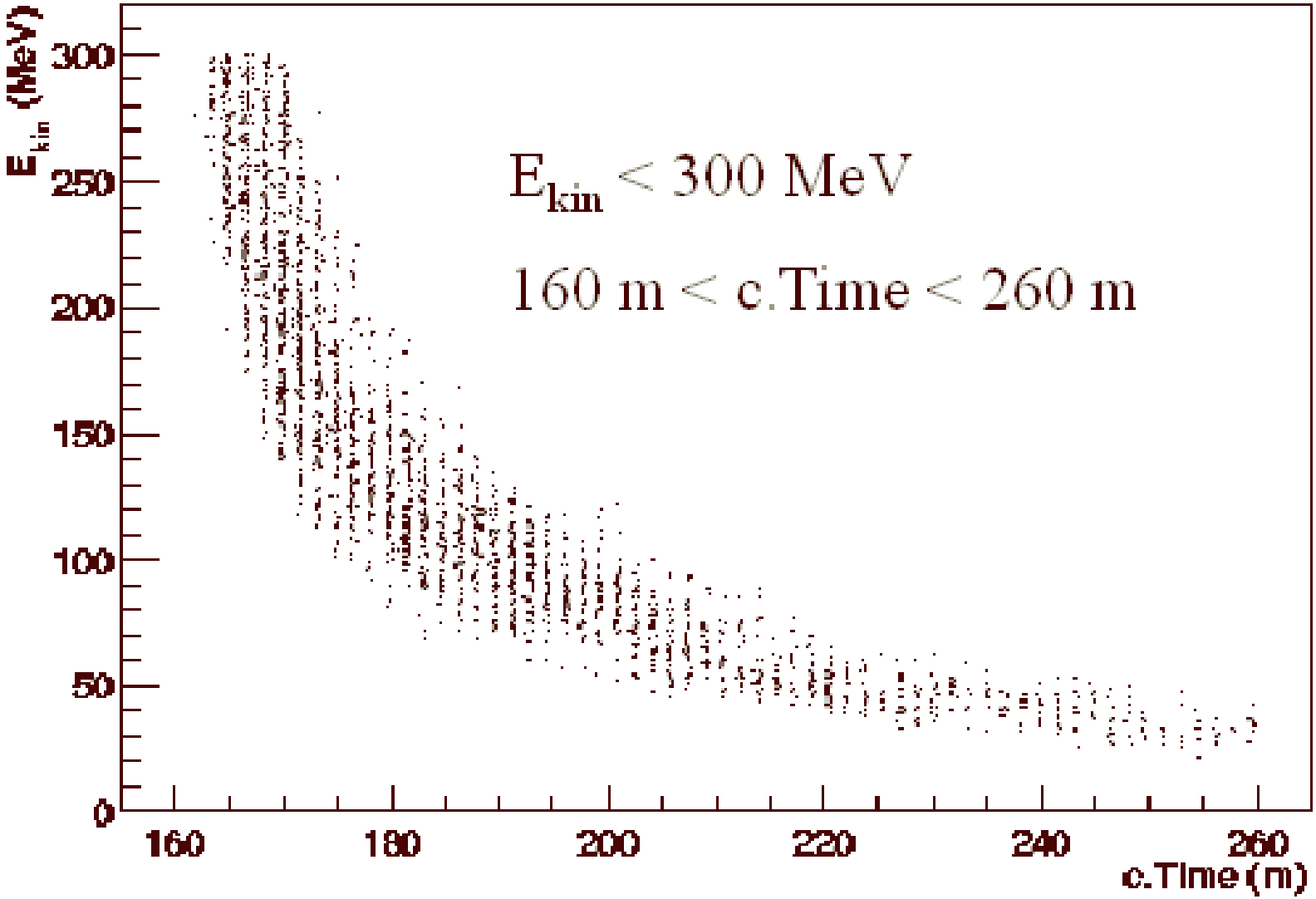


$$\nu_{r.f.} = 15 \frac{c}{d\left(\frac{1}{\beta_{75}} - \frac{1}{\beta_{175}}\right)}$$

Solenoid, 70 cm in radius, 2 cm thick, 85 cm long with 15 cm gaps, B_z=1.25 T on axis

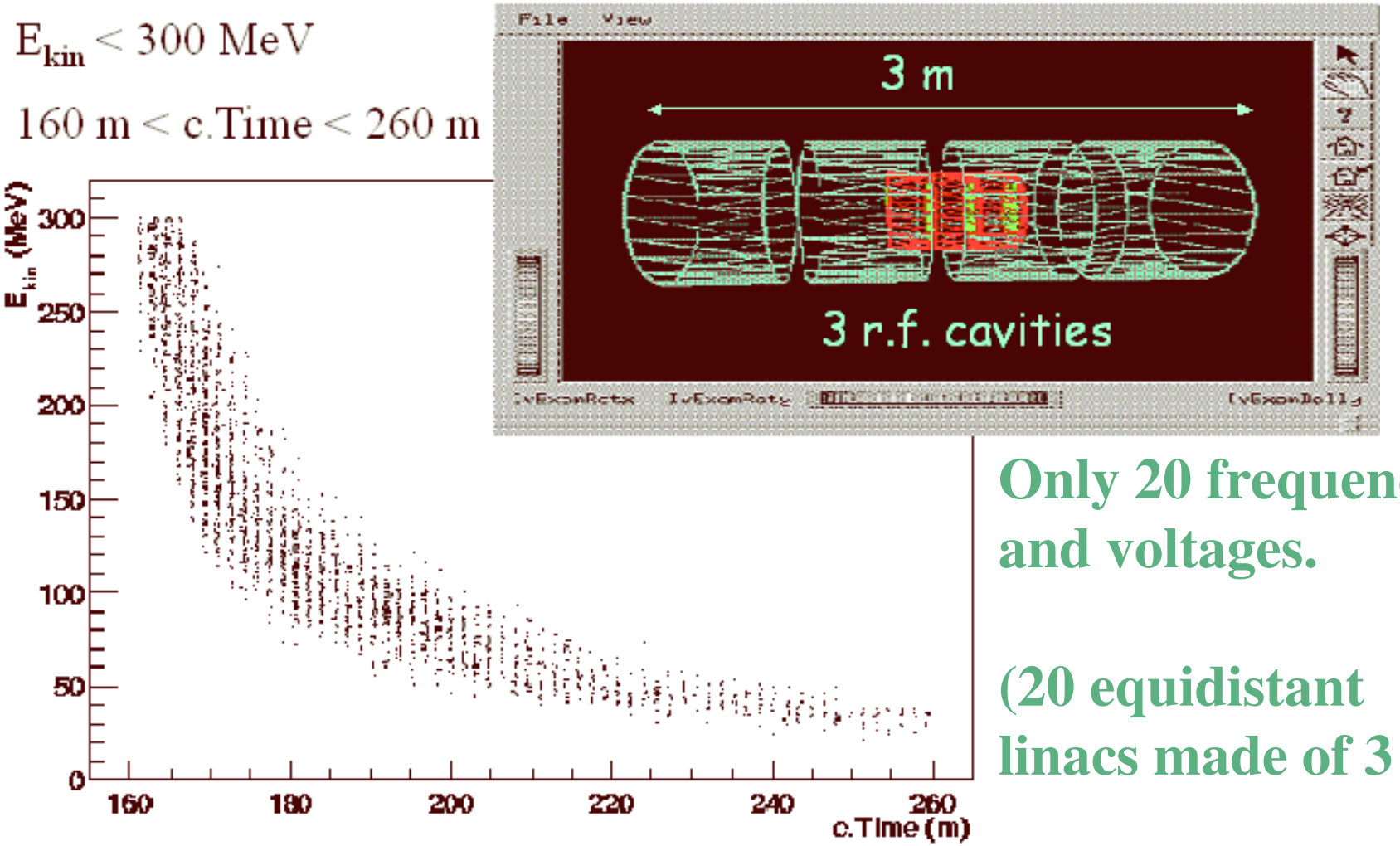
Pill Box cavities, 290-180 MHz r.f. system

Beam After *60-frequency* Buncher



64.6% of the particles survive at the end of the buncher within the E-kinetic, c.Time interval.

20-frequency Buncher



Only 20 frequencies and voltages.

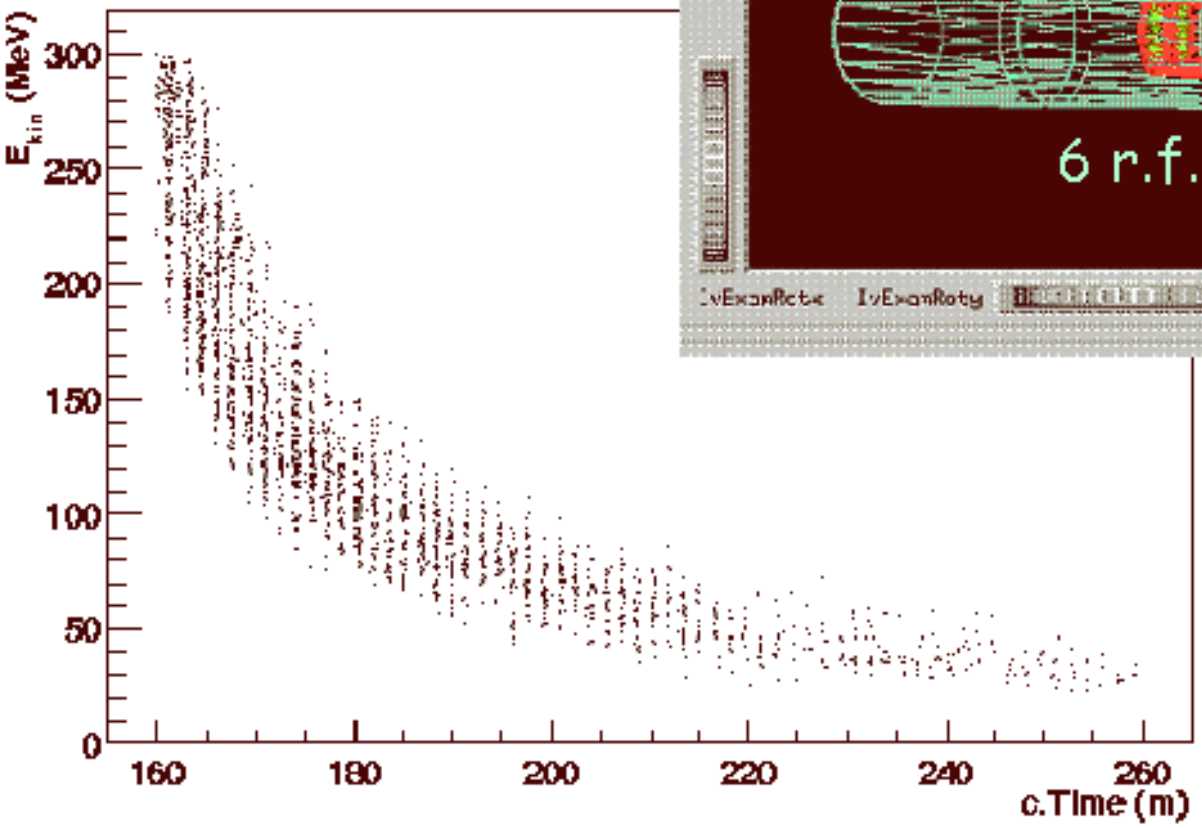
(20 equidistant linacs made of 3 cells)

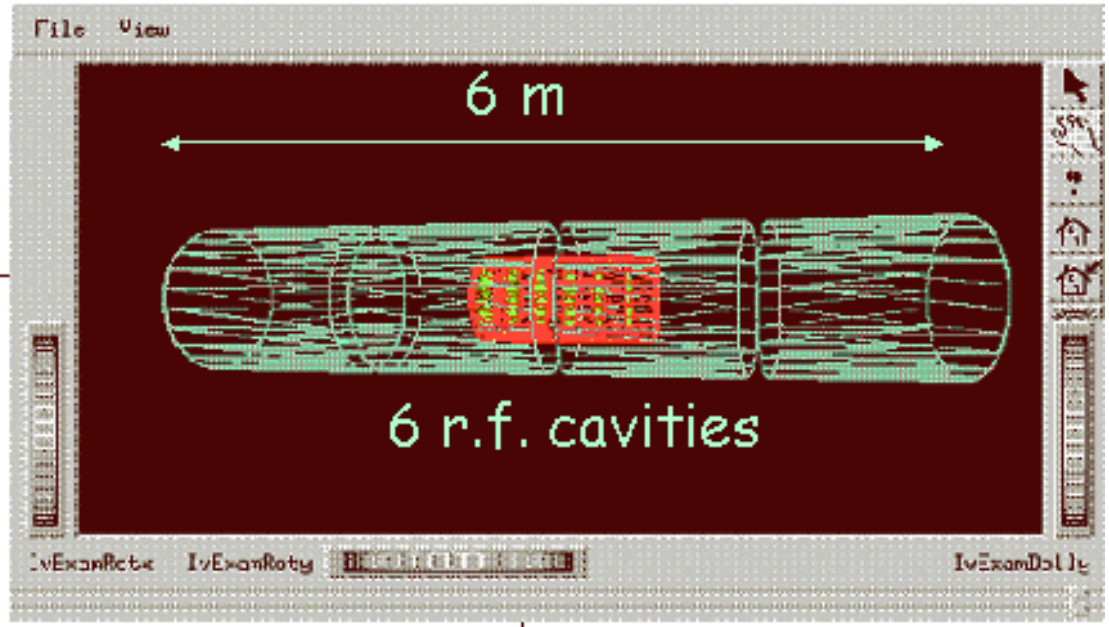
64.9% of the particles survive at the end of the buncher.

10-frequency Buncher

$E_{kin} < 300$ MeV

160 m < c.Time < 260 m





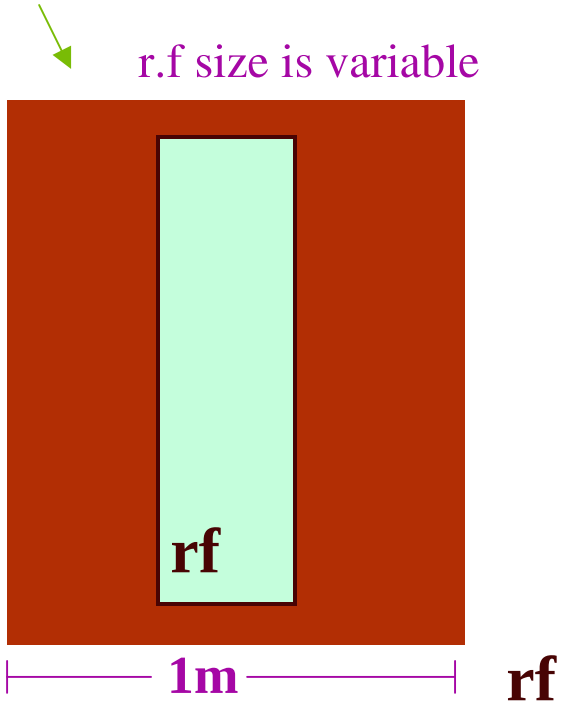
Only 10 frequencies and voltages.

(10 equidistant linacs made of 6 cells)

62.2% of the particles survive at the end of the buncher.

Phase Rotator, Same Lattice Structure

Unit Cell, Buncher

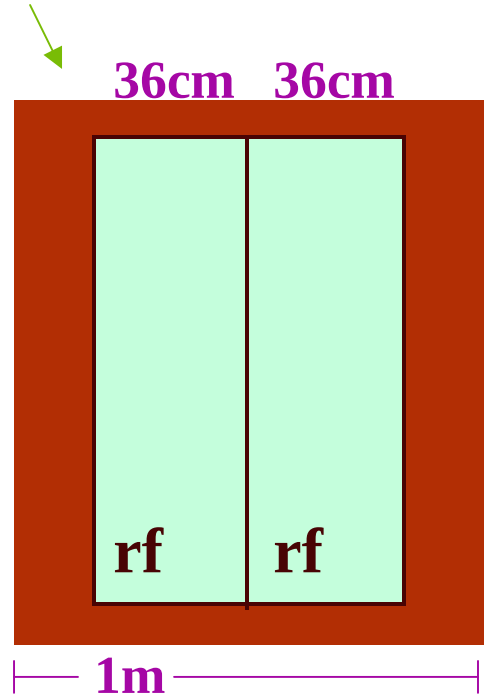


Variable Frequency: 290-180 MHz

$$\nu_{r.f.} = 15 \frac{c}{d\left(\frac{1}{\beta_{75}} - \frac{1}{\beta_{175}}\right)}$$

Gradient of electrostatic potential = 4.8 MV/m

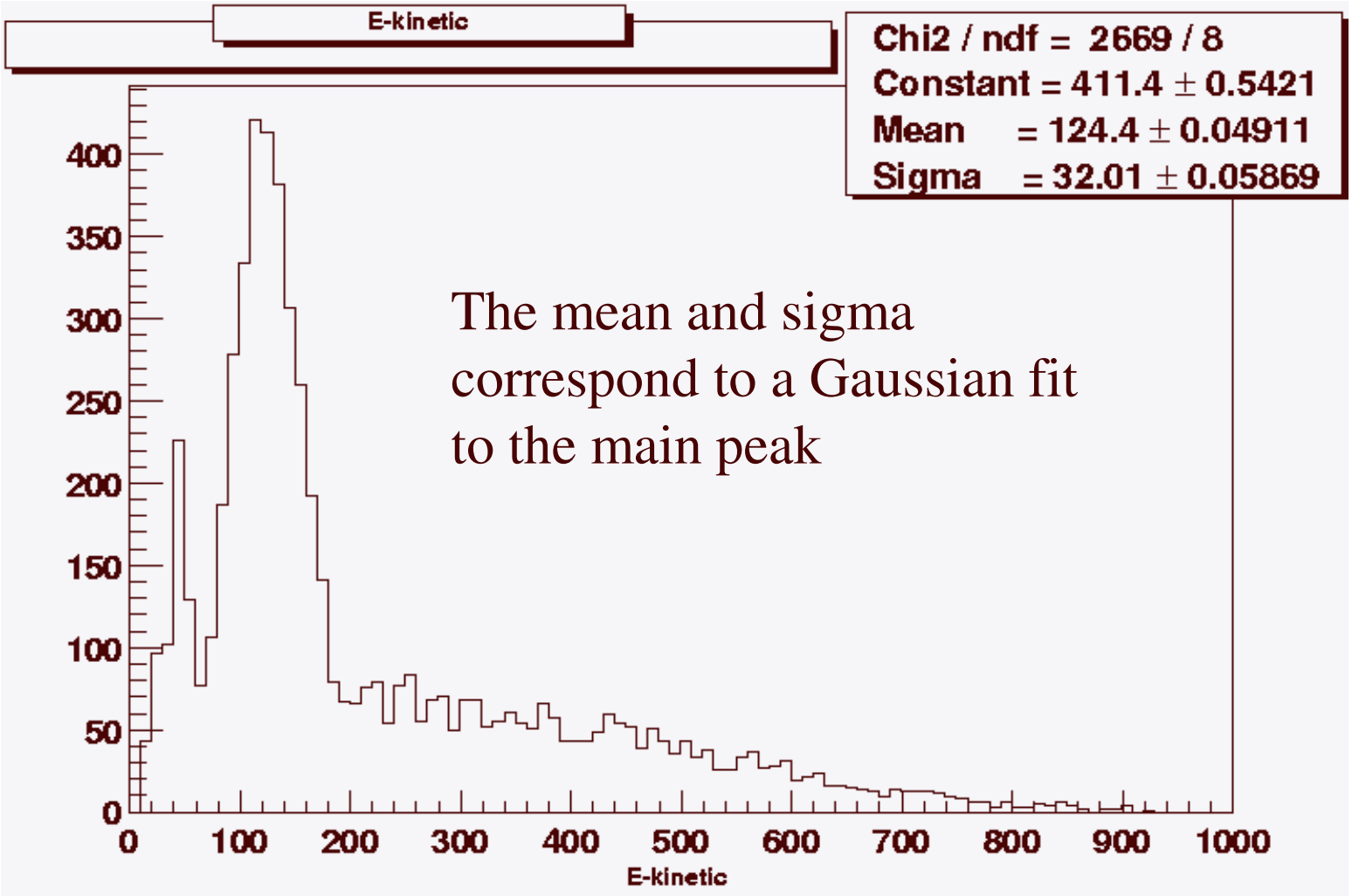
Unit Cell, Phase Rotator



Fixed Frequency: 183 MHz

Gradient of electrostatic potential = 10 MV/m

60-frequency Buncher Beam After Phase Rotation

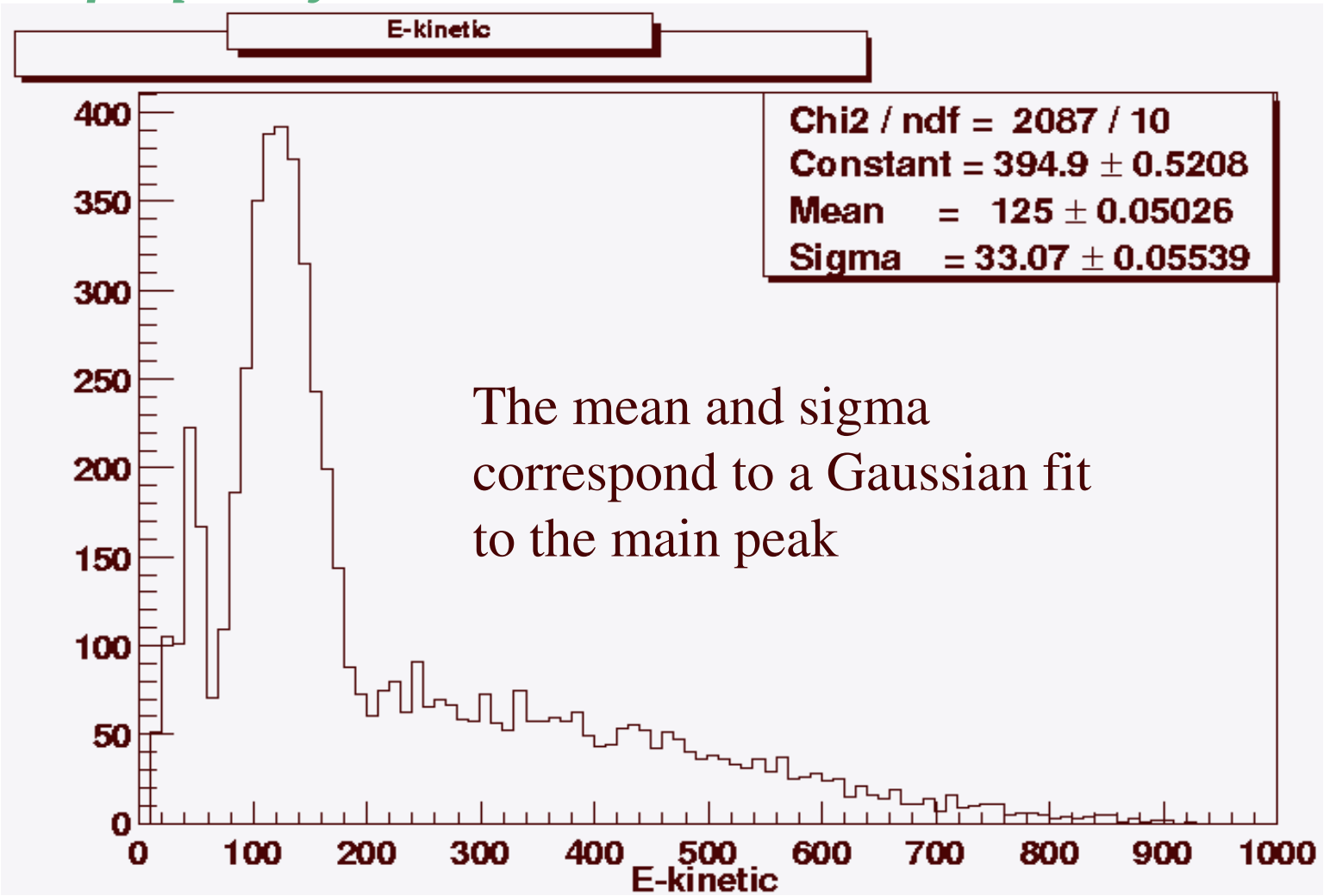


The mean and sigma correspond to a Gaussian fit to the main peak

Transmission ratios:

Total = 0.817 muons/proton
Within 40 MeV of mean = 0.341 muons/proton
Within 50 MeV of mean = 0.383 muons/proton

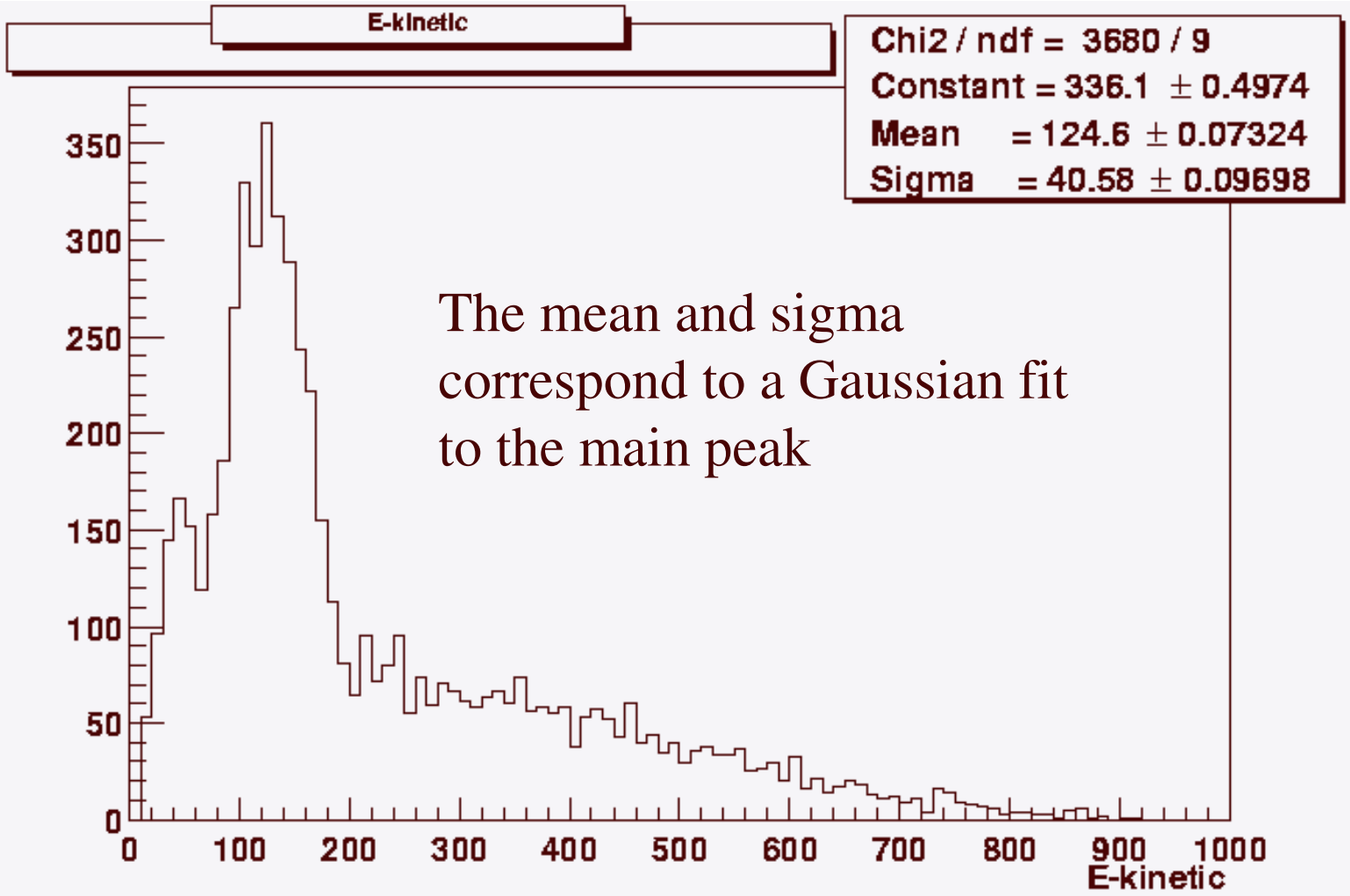
20-frequency Buncher Beam After Phase Rotation



Transmission ratios:

Total = 0.822 muons/proton
Within 40 MeV of mean = 0.336 muons/proton
Within 50 MeV of mean = 0.379 muons/proton

10-frequency Buncher Beam After Phase Rotation



The mean and sigma correspond to a Gaussian fit to the main peak

Transmission ratios:

Total = 0.811 muons/proton
Within 40 MeV of mean = 0.307 muons/proton
Within 50 MeV of mean = 0.353 muons/proton

Conclusions

At the end of the phase rotator, we see:

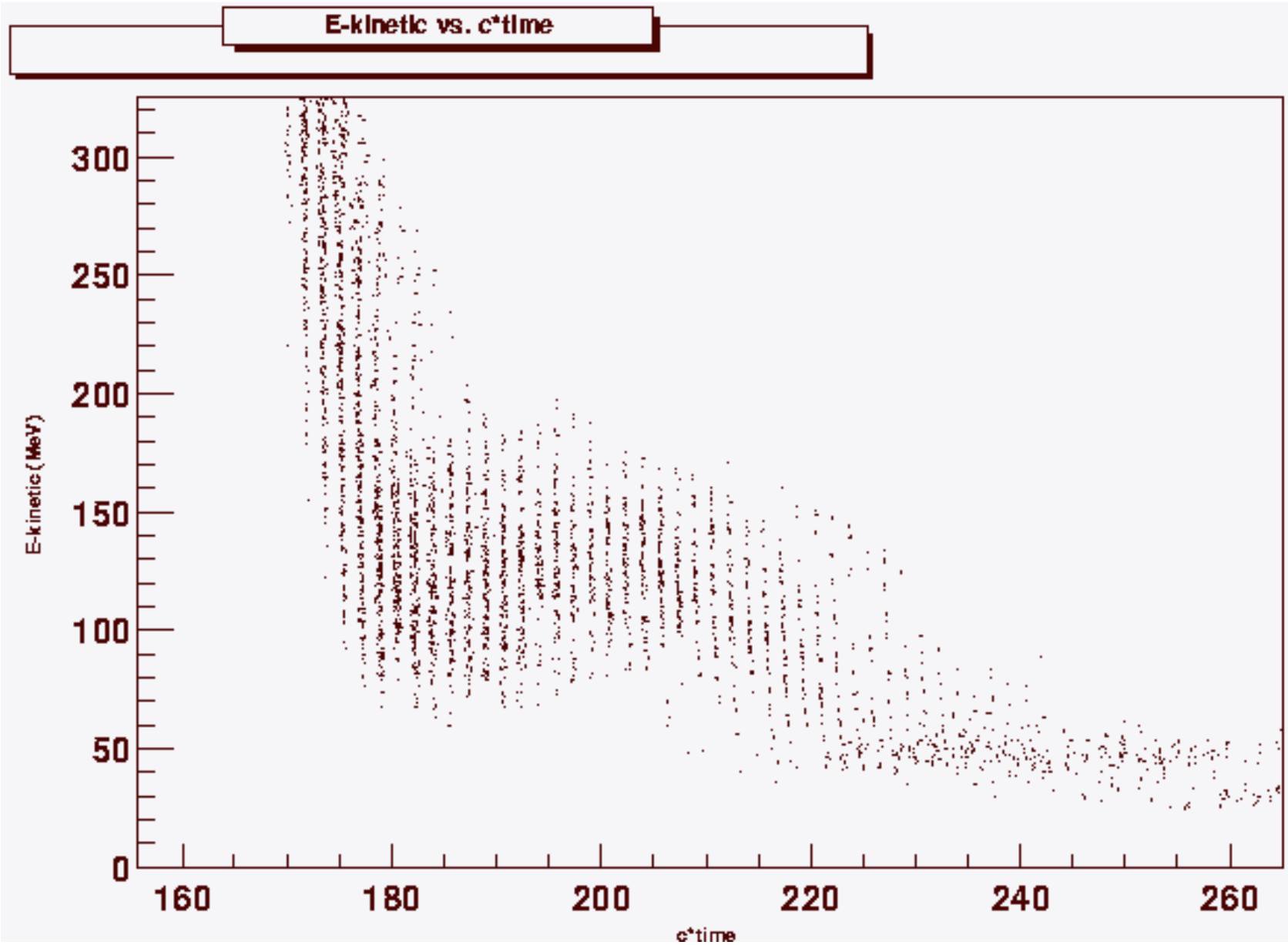
- **Good quantitative agreement between GEANT4 realistic simulation and ideal 60 frequencies result from D.Neuffer & A. Van Ginneken.**

- **The simpler 20 and 10 frequencies bunchers show good performance as well.**

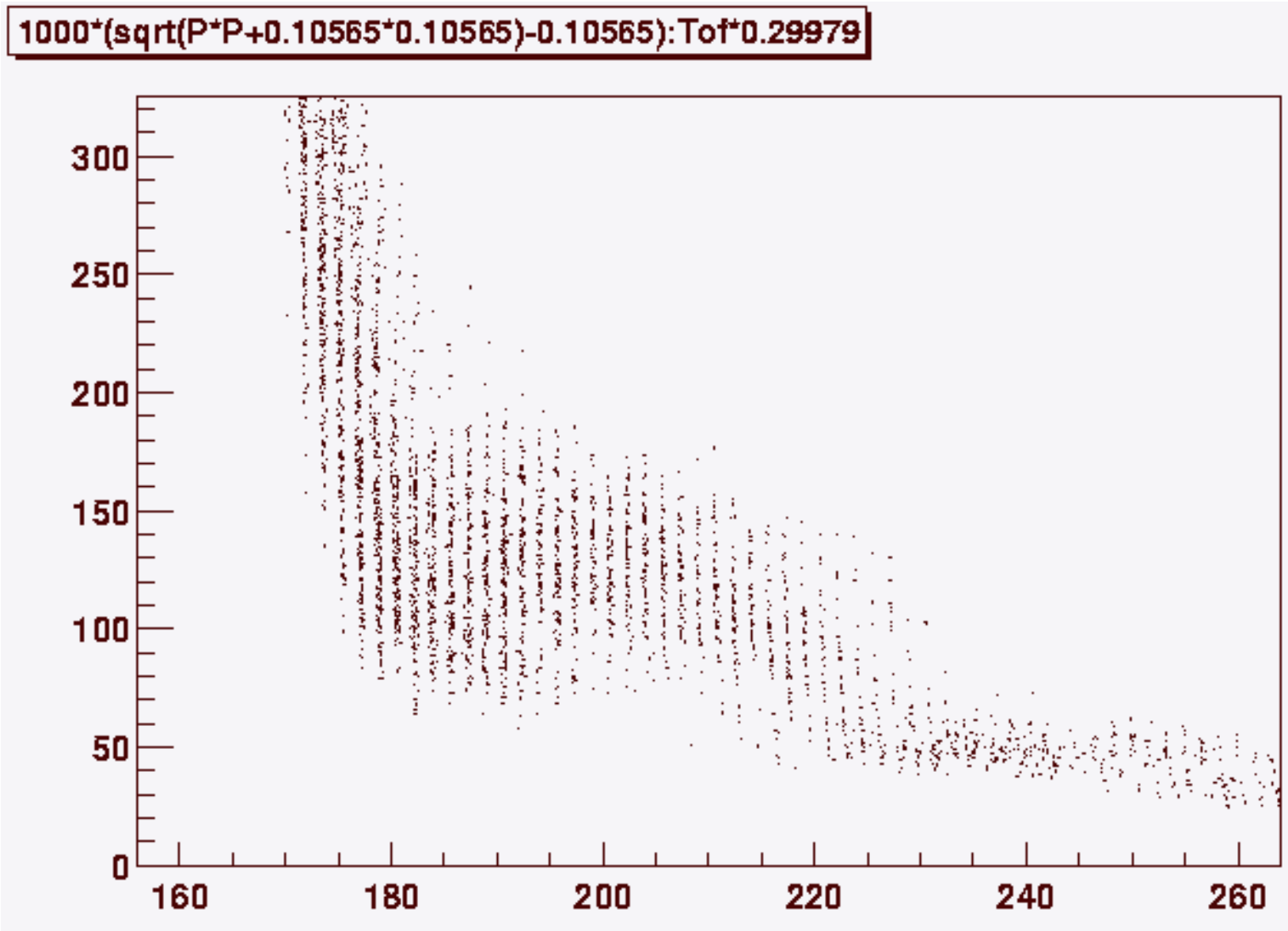
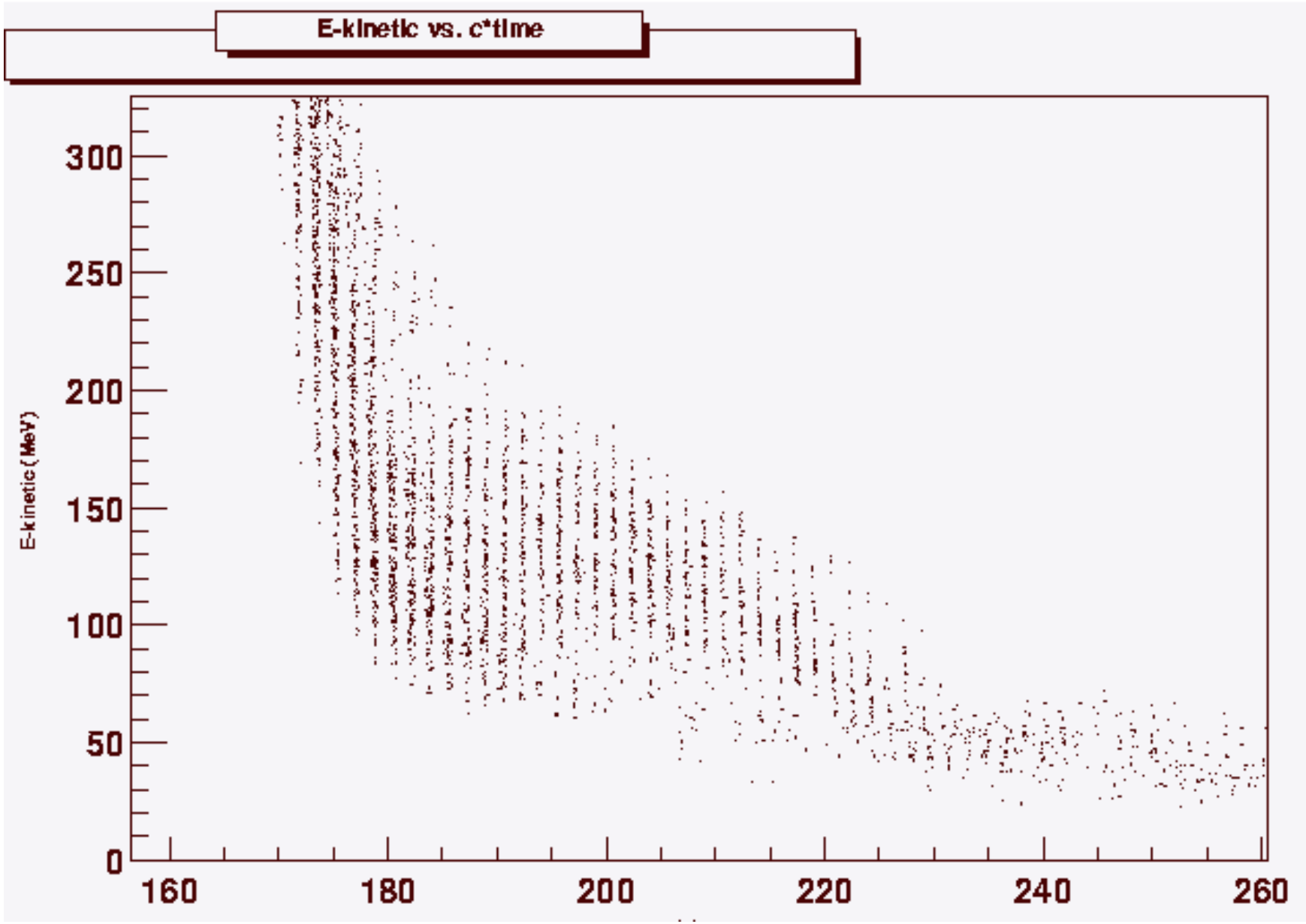
Future:

The buncher and phase rotator parameters should be optimized for whatever cooling channel follows them. A matching section should handle the transition, to achieve maximum acceptance of the beam by the cooling channel. The whole system should be re-optimized for maximum transmission and cooling.

60 Frequency, E-kinetic vs. c*time



20-frequency, E-kinetic vs. c*time



10-frequency, E-kinetic vs. c*time