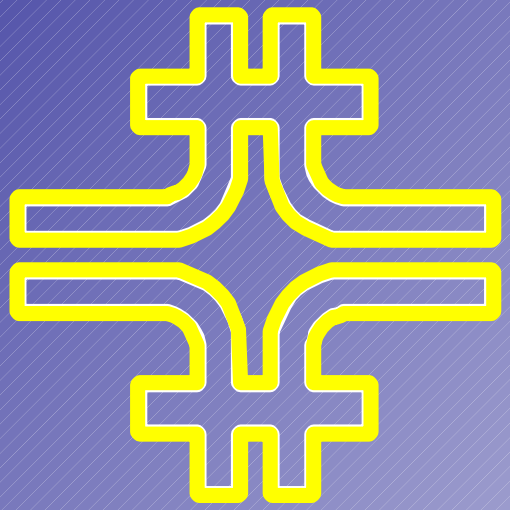
Debuncher ring RF cavities control.



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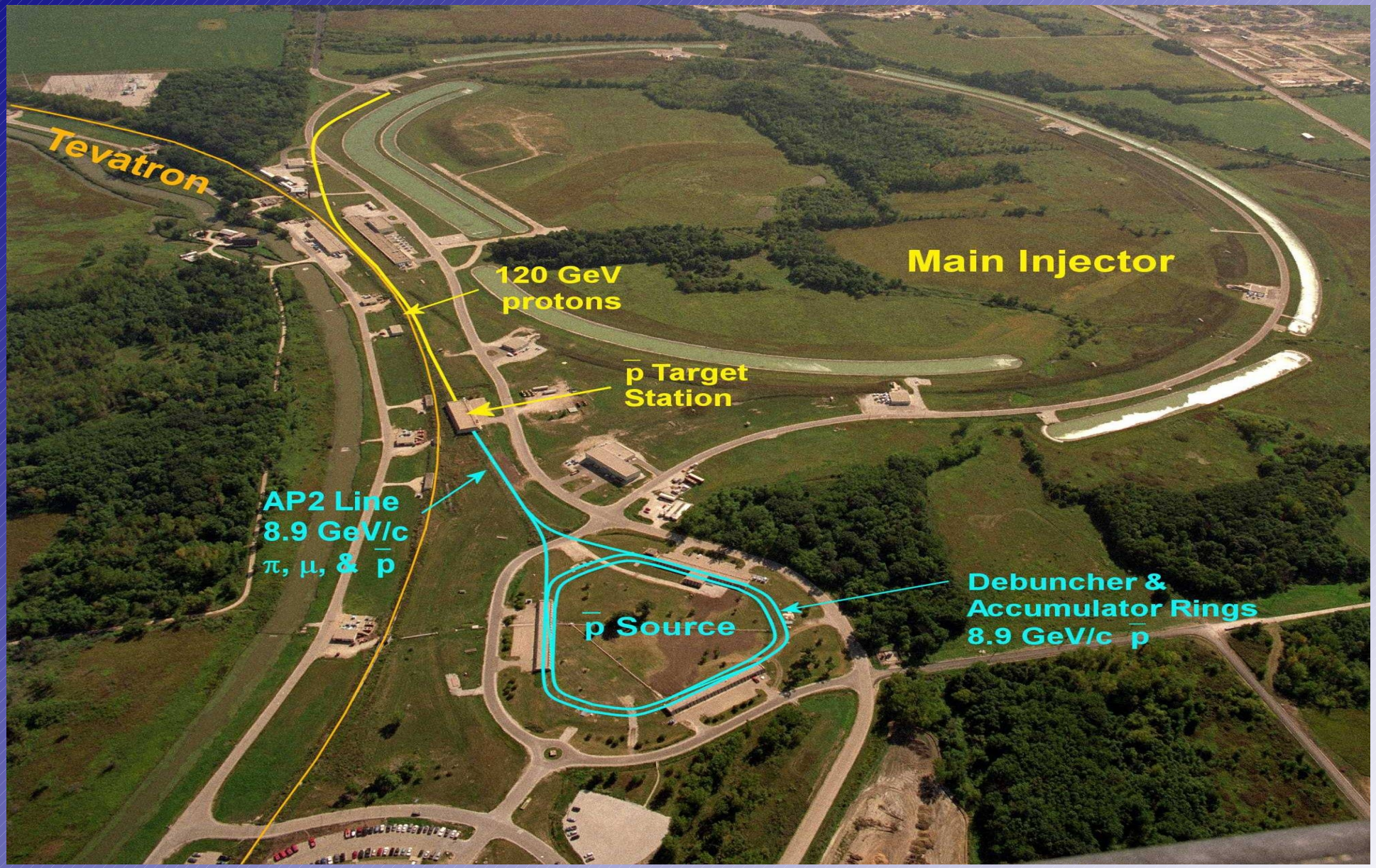
Fermilab 2006

Abstract.

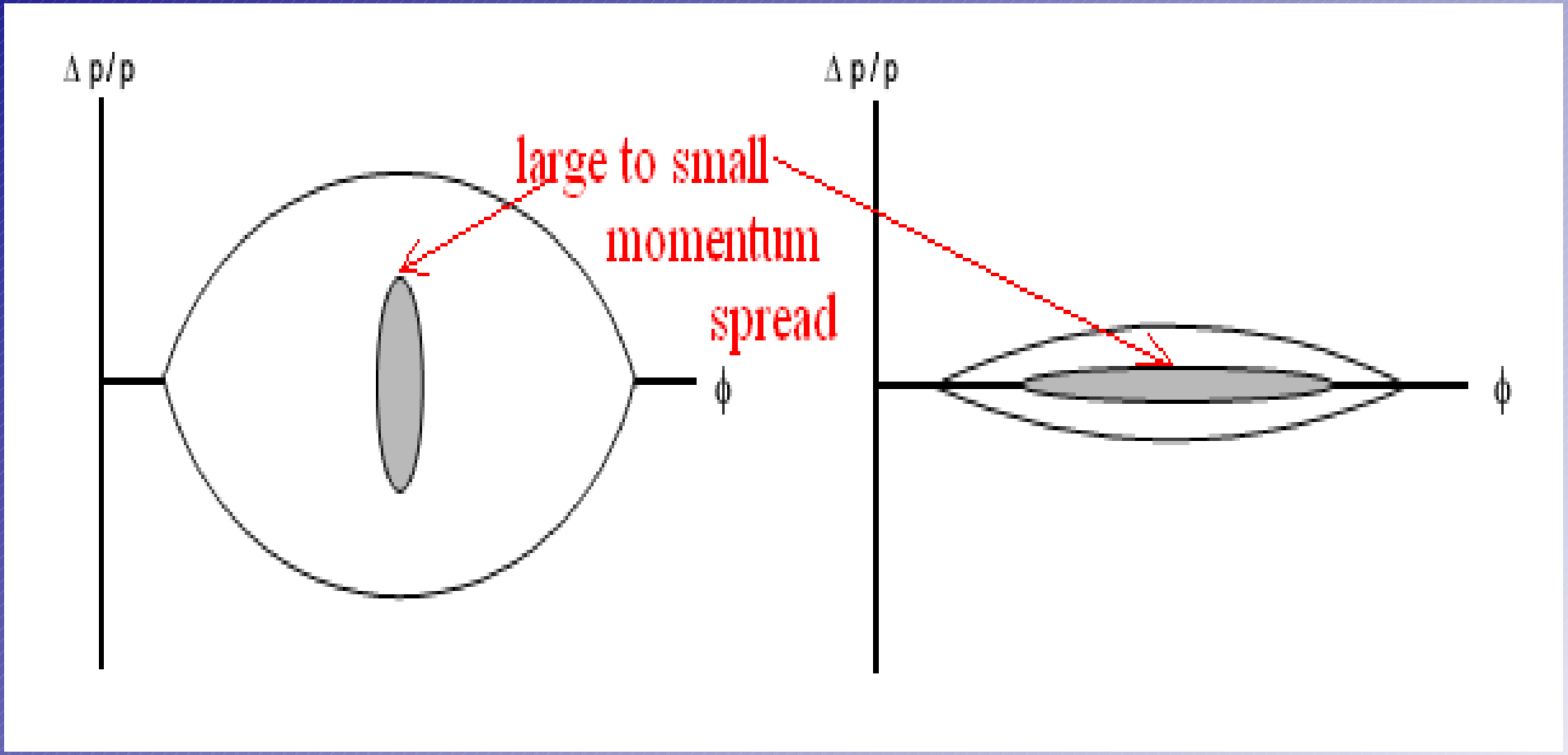
Manipulations with the beam using RF cavities: bunching the beam and unbunching the beam.

Development of application to generate curves for RF cavities, calculate RF buckets and adiabaticity during the manipulations.

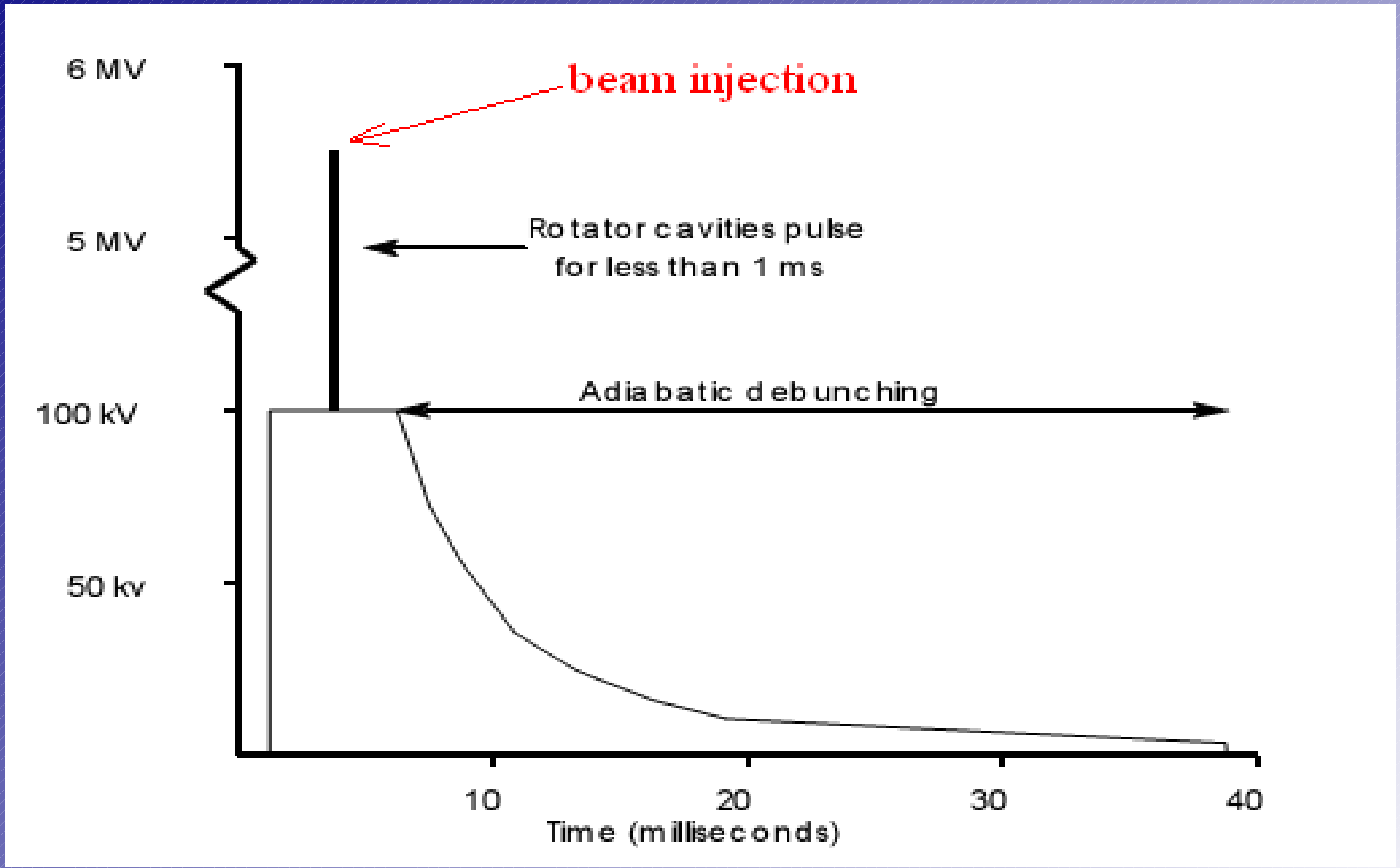
Introduction.



Initial phase space area of the beam in debuncher and it's changing.



DRF-1 cavity voltage during debunching.



Theory.

Hamiltonian of longitudinal motion:

$$H(\delta E, \phi) = \frac{1}{2}\cdot\Lambda\left(\frac{\delta E}{\omega_{rf}}\right)^2 - \frac{e\cdot V}{2\cdot\pi\cdot h}\cdot\left[\cos(\phi) - \cos(\phi_0) + (\phi - \phi_0)\cdot\sin(\phi_0)\right]$$

where $$\Lambda = \frac{(\omega_{rf})^2\,\eta}{(\beta_0)^2\,E_0}$$

Equations of the motion.

$$\frac{d}{dt}\phi = \frac{(\omega_{rf})^2\,\eta}{(\beta_0)^2\,E_0}\left(\frac{\delta E}{\omega_{rf}}\right)$$

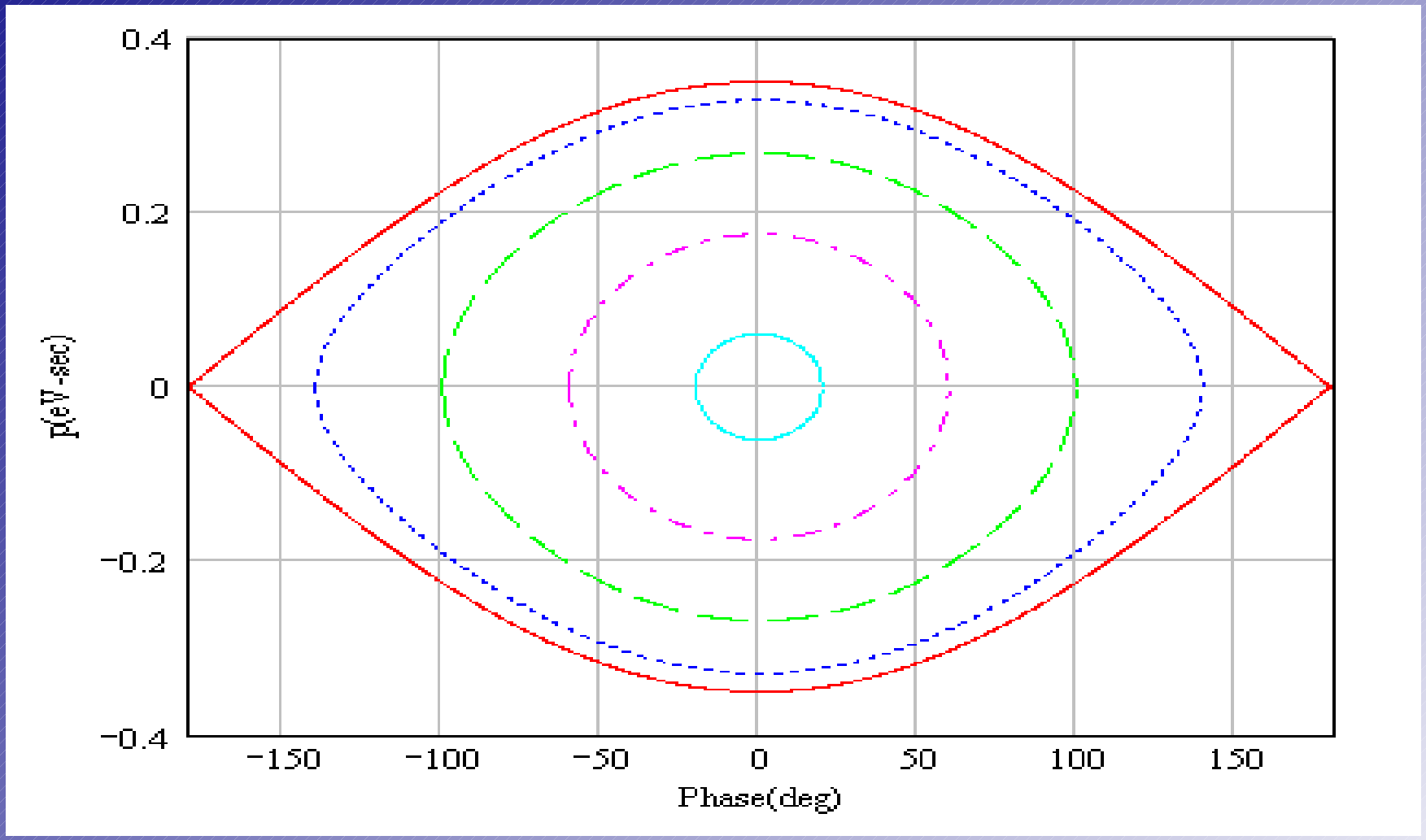
$$\frac{d}{dt}\left(\frac{\delta E}{\omega_{rf}}\right) = \frac{e\cdot V}{2\cdot\pi\cdot h}\cdot\left(\sin(\phi) - \sin(\phi_0)\right)$$

DRF-1 and beam parameters.

Frequency	ω_{rf}	53,1 MHz
Harmonics number	h	90
Peak voltage of "rotators"		5,5 MV
of "adiabatic" cavities	V	100 kV
Energy	E_0	8 GeV
Beta	β_0	0,992
Slip factor	η_0	-0,006

Phase space trajectories.

$$W(\phi, \phi_m) = \pm \sqrt{\frac{e \cdot V}{\pi \cdot h \cdot \Lambda} \cdot (\cos(\phi) - \cos(\phi_m))}$$



Separatrix and the bucket area calculation.

$$Ws(\phi) = \pm W_m \cdot \sqrt{1 + \cos(\phi)} = \pm \sqrt{2}\, W_m \cos\left(\frac{\phi}{2}\right), \text{where}$$

$$W_m = \sqrt{\frac{eV}{\pi\, h \cdot \Lambda}}$$

Stationary bucket area.

$$B_0 = \sqrt{2}\, W_m\, 4 \int_0^{\pi} \cos\left(\frac{\phi}{2}\right) d\phi = 8\sqrt{2}\, W_m = \frac{16 \cdot \beta_0}{\omega_{rf}} \sqrt{\frac{eVE_0}{2\pi\, h\eta}}$$

Synchrotron frequency

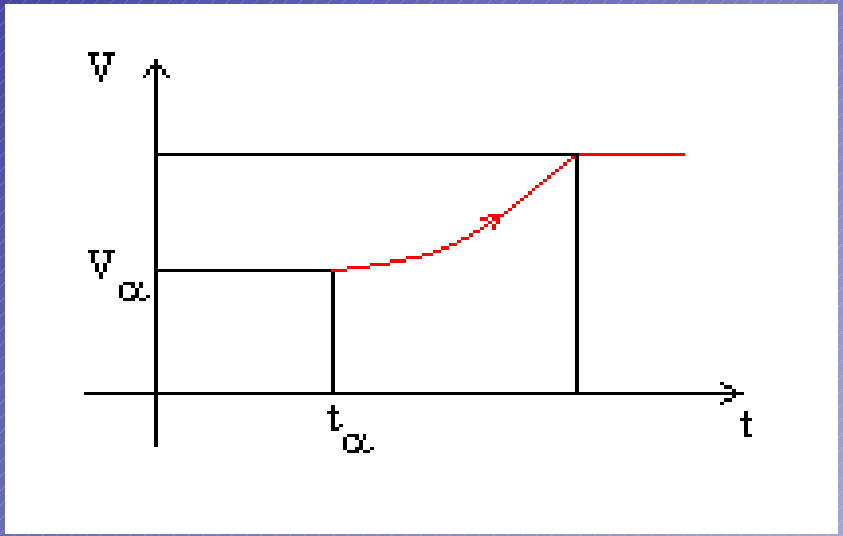
$$T_s = \int \frac{1}{\Lambda\, W(\phi)}\, d\phi = \frac{4}{\Lambda} \cdot \int_0^{\phi m} \frac{1}{W(\phi)}\, d\phi \qquad \omega_s = \frac{\omega_{rf}}{\beta_0} \sqrt{\frac{\eta\, eV}{2\pi\, hE_0}}$$

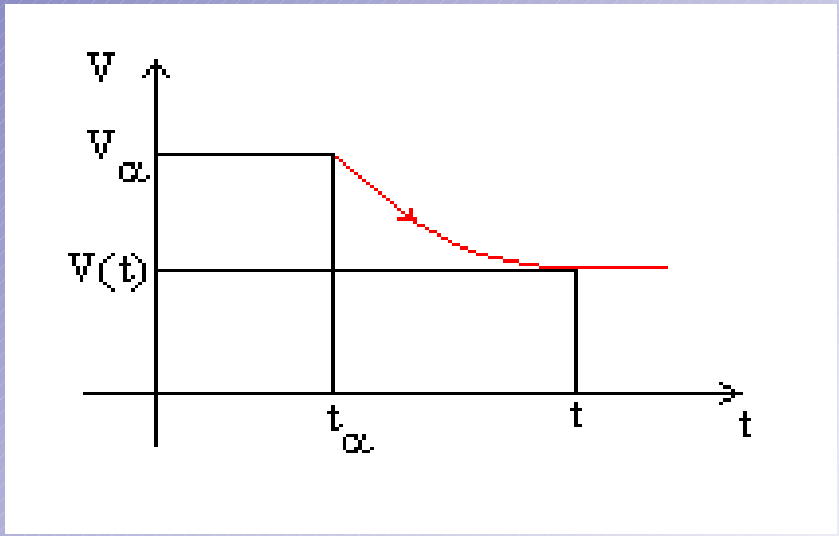
Adiabaticity.

$$\varepsilon = \frac{d\omega_s}{\omega_s}\,\frac{1}{dt\cdot\omega_s} \qquad \varepsilon = \frac{1}{(\omega_s)^2}\left(\frac{\partial}{\partial V}\omega_s\right)\cdot\left|\frac{d}{dt}V\right| = \frac{1}{(\omega_s)^2}\left(\frac{1}{2}\,\frac{\omega_s}{V}\right)\cdot\left|\frac{d}{dt}V\right|$$

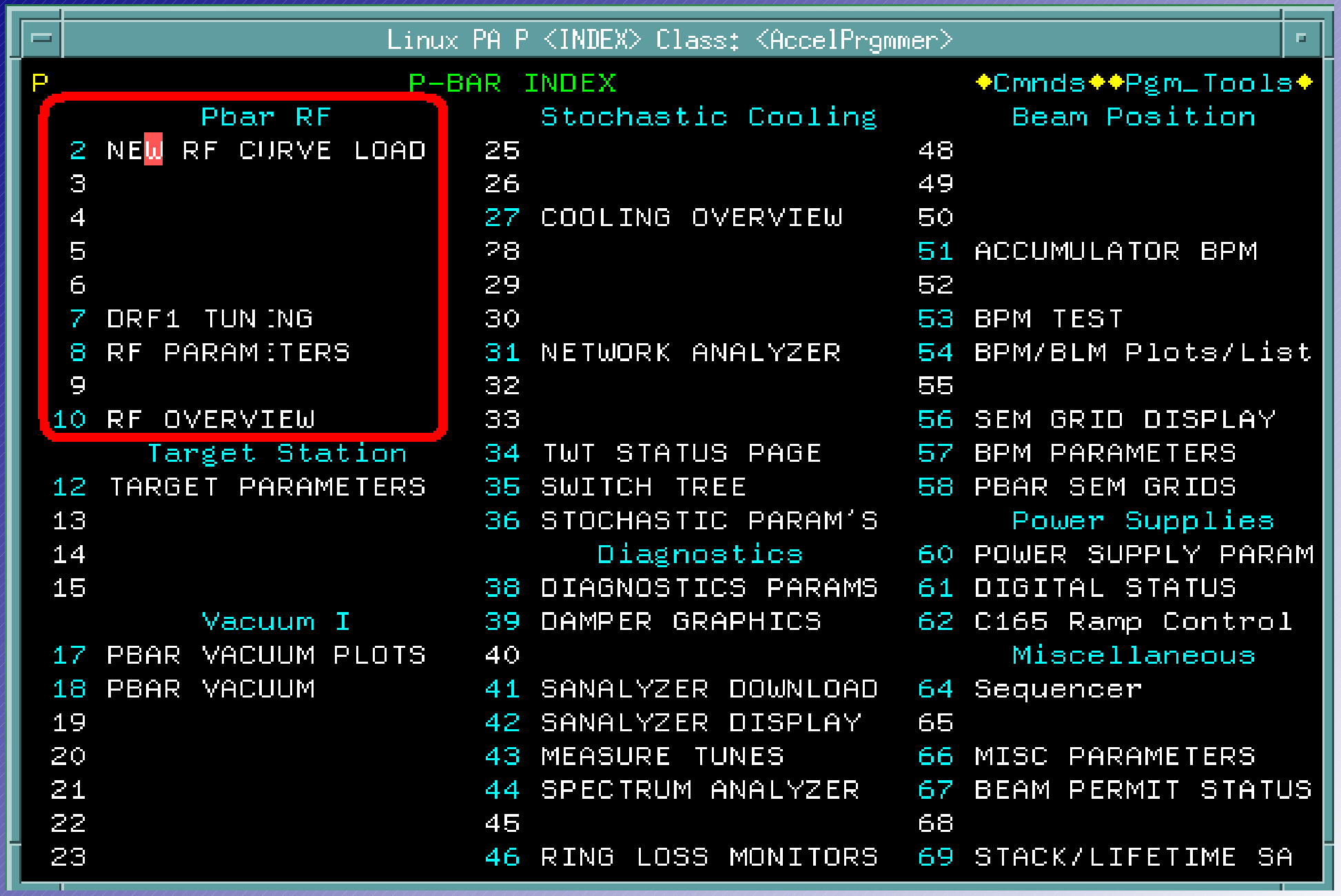
Bunching/debunching voltage ramps.

$$V(t) = \frac{V_\alpha}{\left[1 - \omega_s\cdot(V_\alpha)\cdot\varepsilon\cdot(t - t_\alpha)\right]^2} \qquad V(t) = \frac{V_\alpha}{\left[1 + \omega_s\cdot(V_\alpha)\cdot\varepsilon\cdot(t - t_\alpha)\right]^2}$$

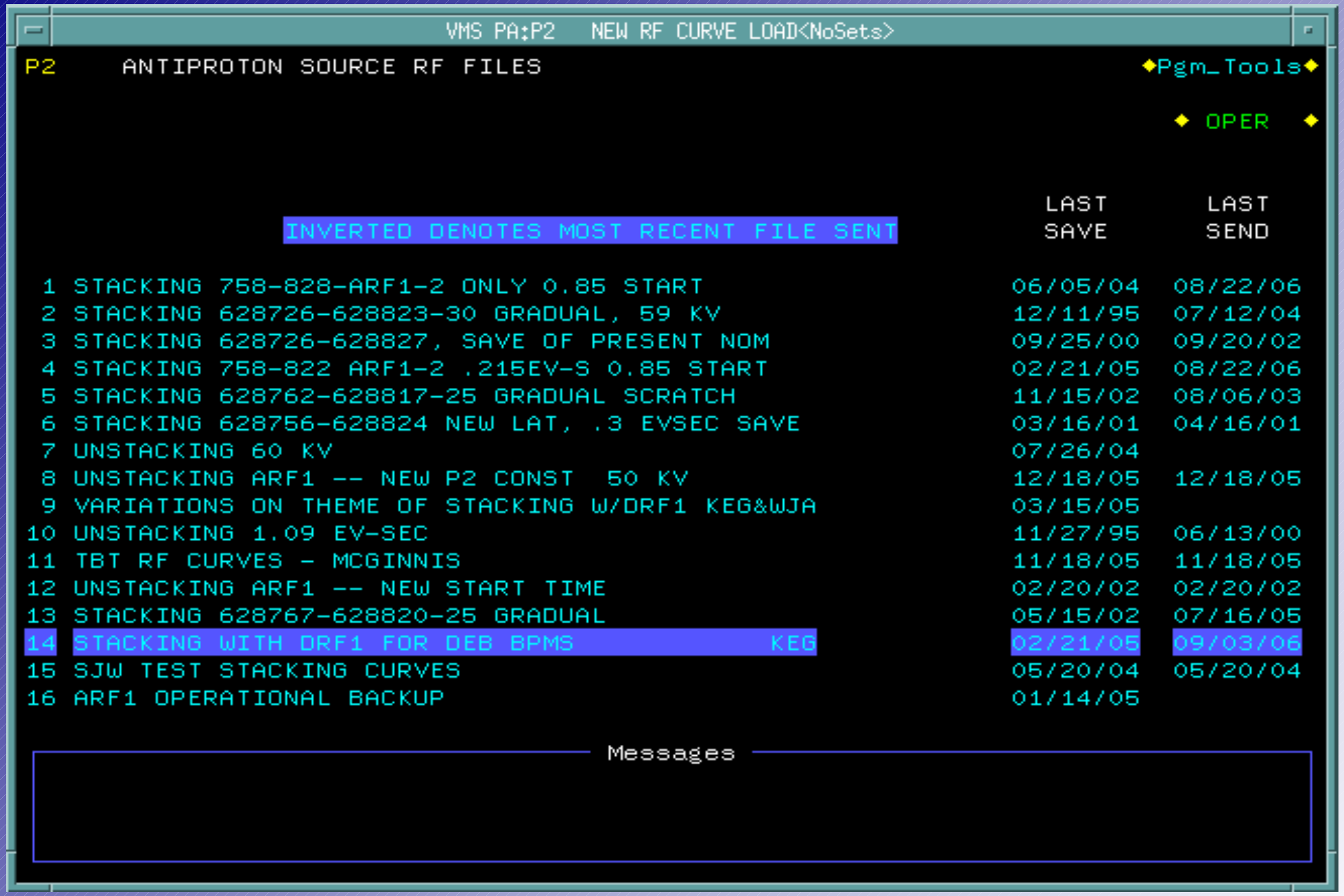




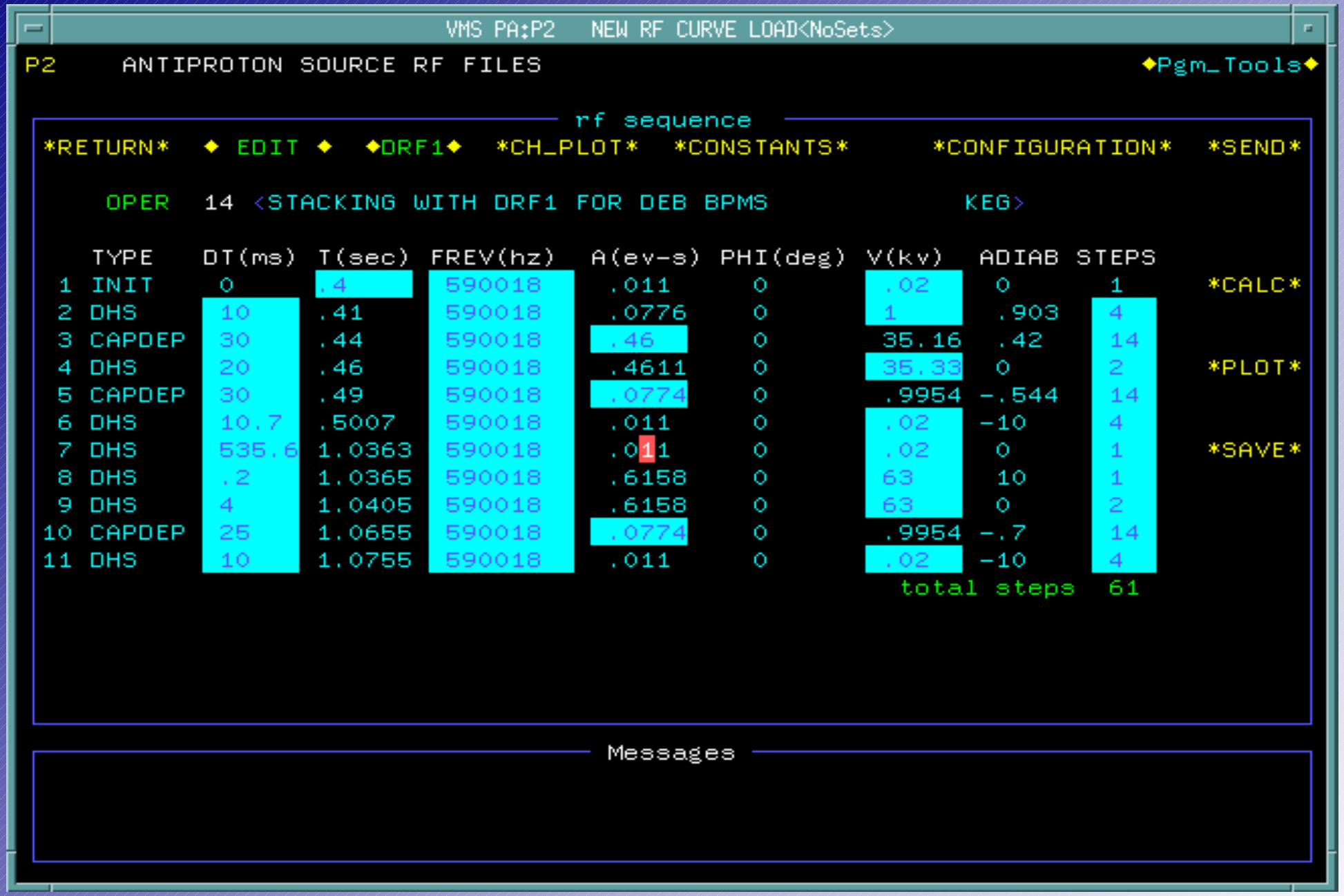
Control application.



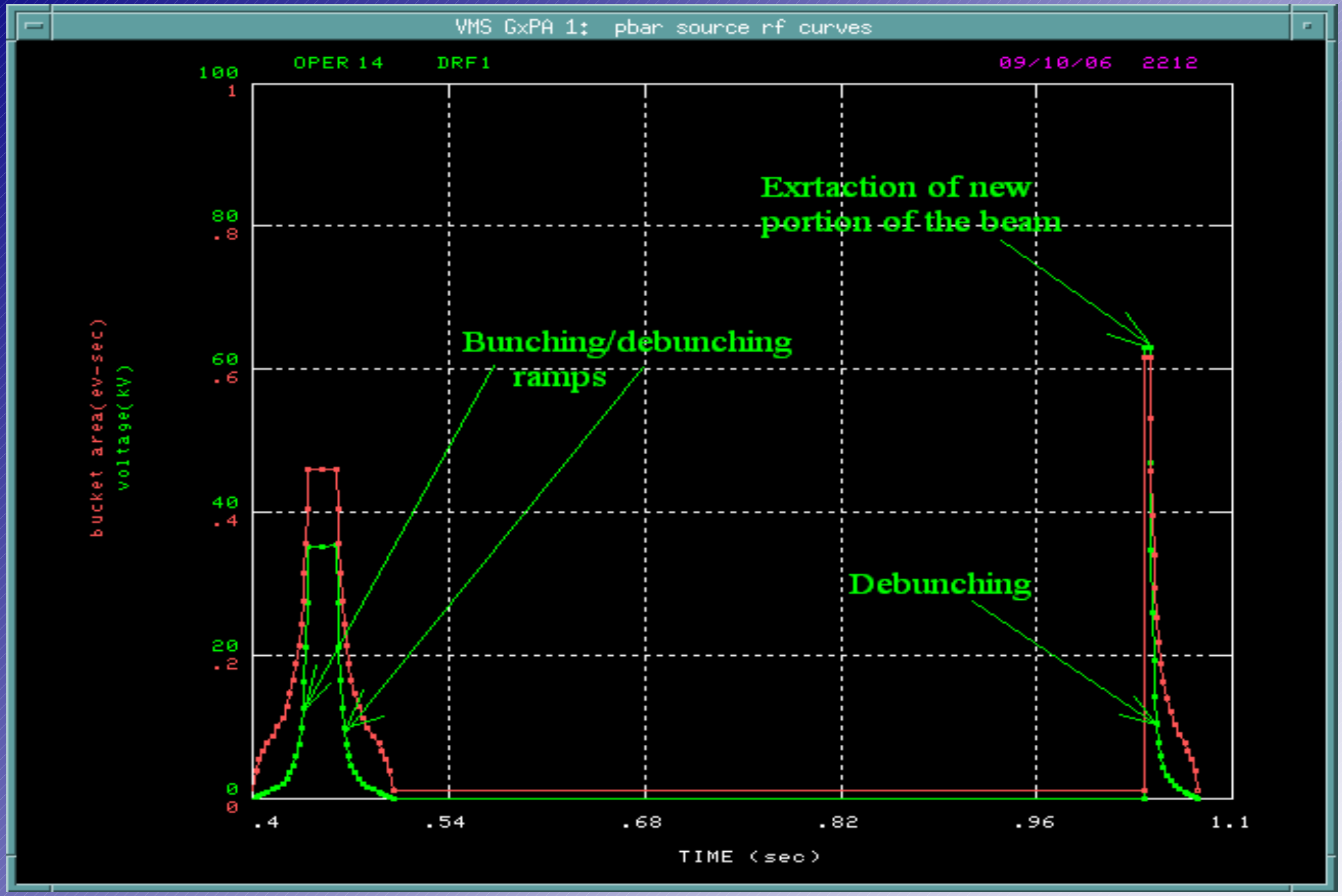
P2 program. New RF curve load.



Stacking with DRF-1 for debuncher BPMs.



Voltage and bucket area plot.



Requirements to the new P2 program.

1. Perform the same tasks as old P2 program for DRF-1
2. Work under Linux
3. Appropriate and clear interface
4. Properly work with hardware

Results.

1. the theory of the RF manipulation were studied, all necessary formulas had been derived
2. the program was developed which can calculate the voltage ramps and all other things for bunching and debunching process
3. Steel a lot of need to be done

Thank You!