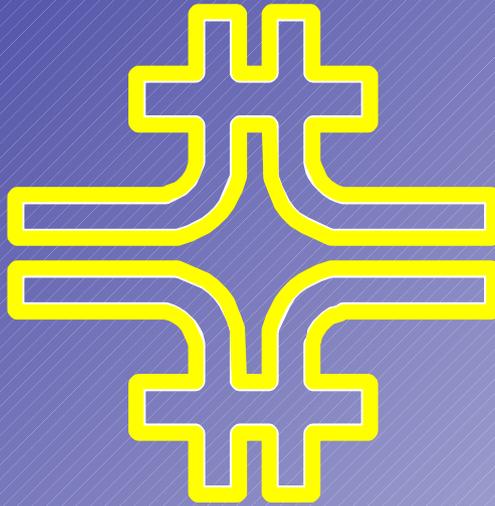


Debuncher ring RF cavities control.



Summer student: A.Netepenko, NSU.
Supervisor: Keith Gollwitzer.

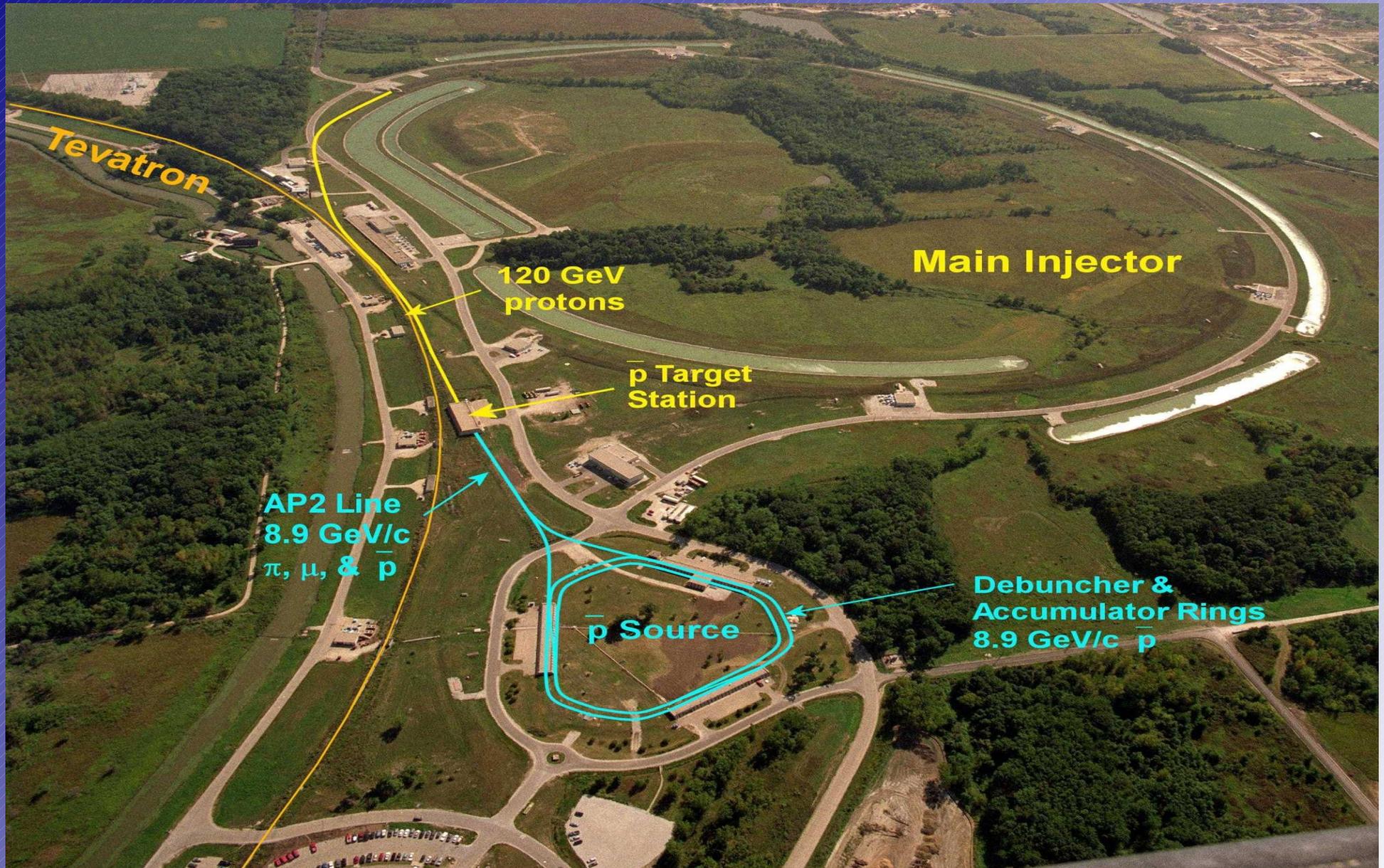
Fermilab 2006

Abstract.

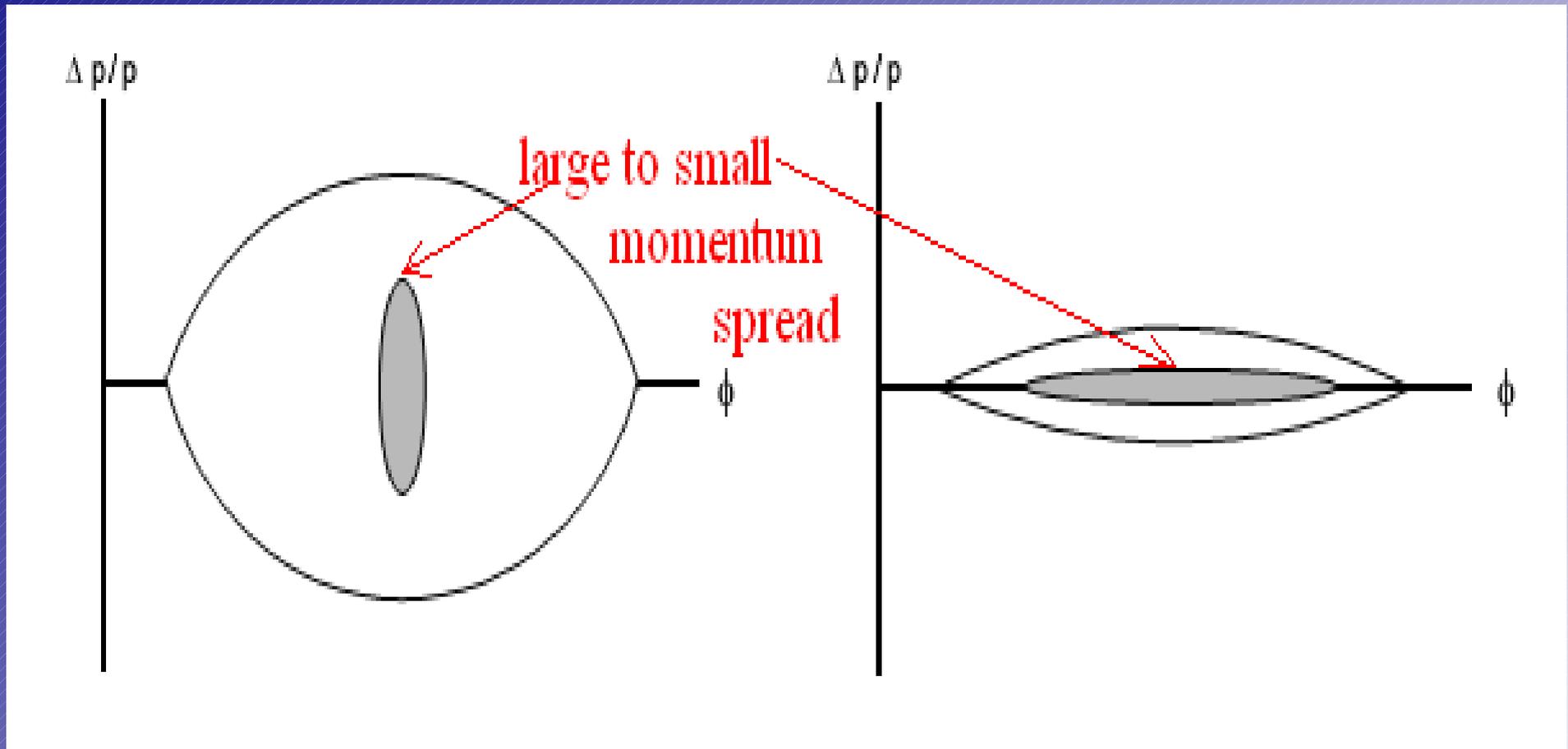
Manipulations with the beam using RF cavities: bunching the beam and unbunching the beam.

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

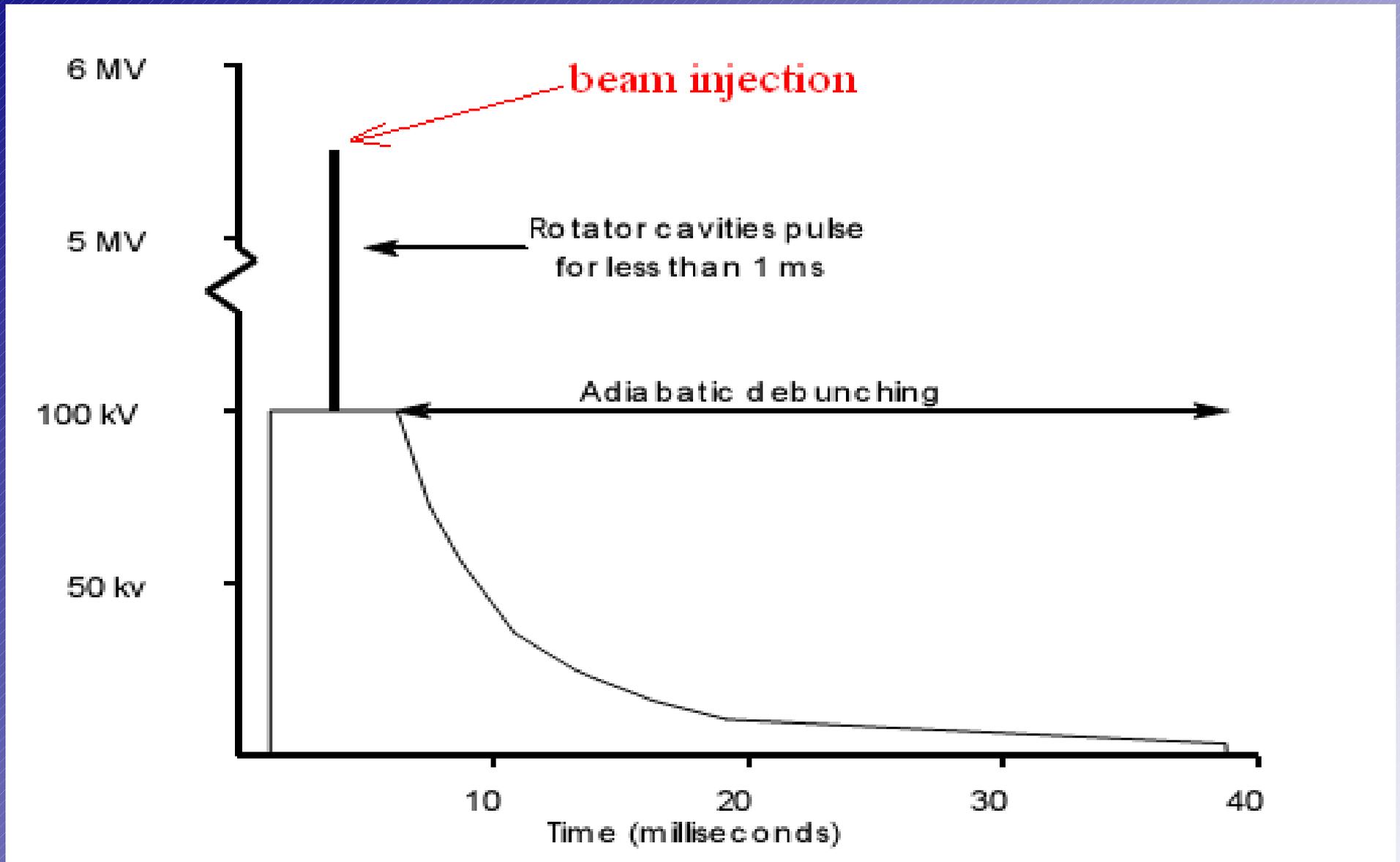
Introduction.



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



DRF-1 cavity voltage during debunching.



Theory.

Hamiltonian of longitudinal motion:

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

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

Equations of the motion.

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

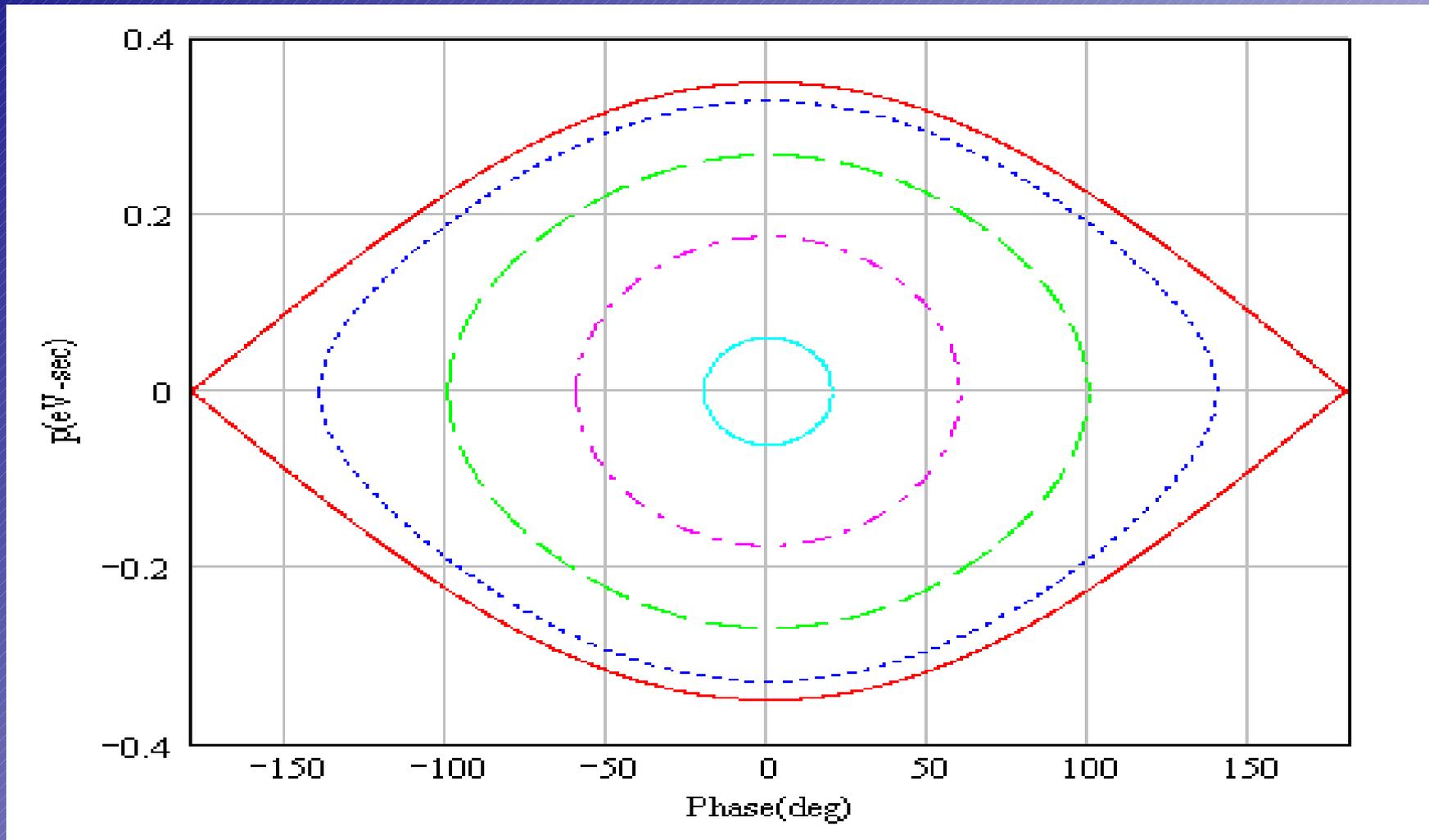
$$\frac{d}{dt} \left(\frac{\delta E}{\omega_{\text{rf}}} \right) = \frac{e \cdot V}{2 \cdot \pi \cdot h} \cdot (\sin(\phi) - \sin(\phi_0))$$

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.

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

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

Stationary bucket area.

$$B_0 = \sqrt{2} W_m 4 \int_0^{\pi} \cos\left(\frac{\phi}{2}\right) d\phi = 8 \sqrt{2} W_m = \frac{16 \cdot \beta_0}{\omega_{rf}} \sqrt{\frac{eV E_0}{2 \pi h \eta}}$$

Synchrotron frequency

$$T_s = \int \frac{1}{\Lambda W(\phi)} d\phi = \frac{4}{\Lambda} \int_0^{\phi_m} \frac{1}{W(\phi)} d\phi \quad \omega_s = \frac{\omega_{rf}}{\beta_0} \sqrt{\frac{\eta eV}{2 \pi h E_0}}$$

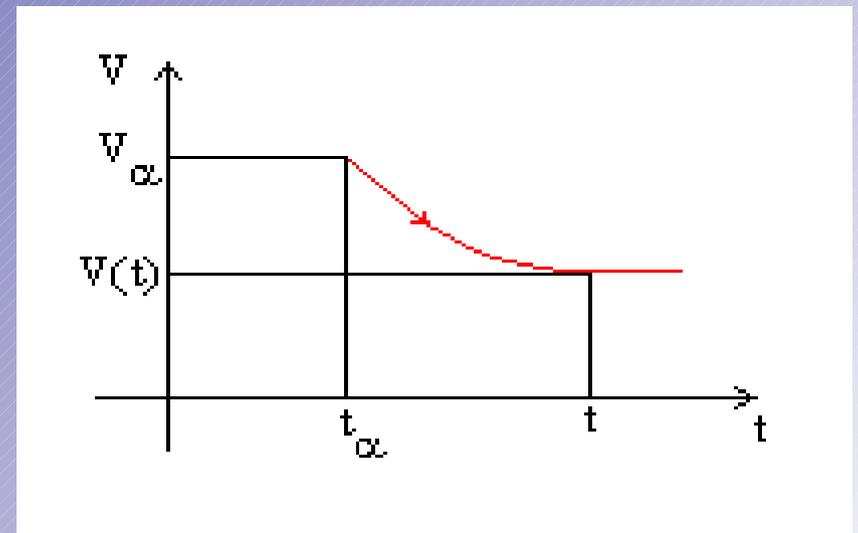
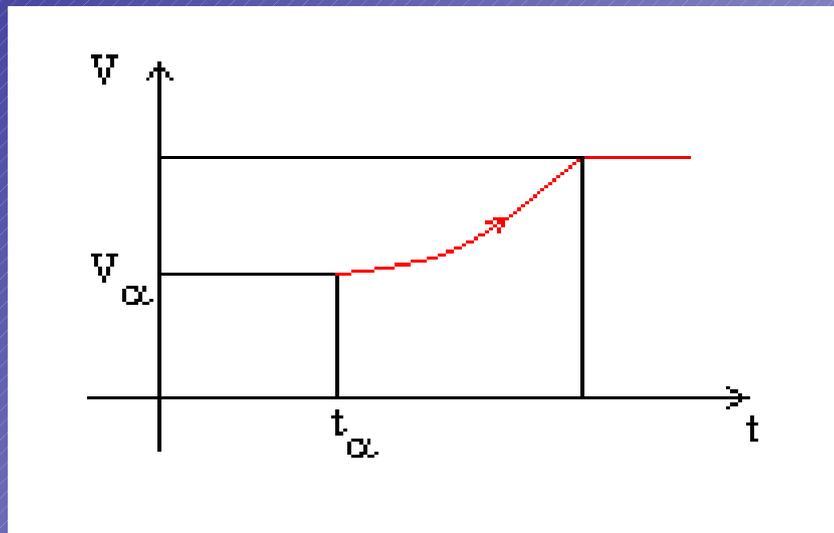
Adiabaticity.

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

Bunching/debunching voltage ramps.

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

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



Control application.

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Linux PA P <INDEX> Class: <AccelPrgrmer>
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P	P-BAR INDEX		◆Cmnds◆◆Pgm_Tools◆
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P2 program. New RF curve load.

VMS PA:P2 NEW RF CURVE LOAD<NoSets>		
P2 ANTIPROTON SOURCE RF FILES		
◆Pgm_Tools◆		
◆ OPER ◆		
	LAST SAVE	LAST SEND
INVERTED DENOTES MOST RECENT FILE SENT		
1	STACKING 758-828-ARF1-2 ONLY 0.85 START	06/05/04 08/22/06
2	STACKING 628726-628823-30 GRADUAL, 59 KV	12/11/95 07/12/04
3	STACKING 628726-628827, SAVE OF PRESENT NOM	09/25/00 09/20/02
4	STACKING 758-822 ARF1-2 .215EV-S 0.85 START	02/21/05 08/22/06
5	STACKING 628762-628817-25 GRADUAL SCRATCH	11/15/02 08/06/03
6	STACKING 628756-628824 NEW LAT, .3 EVSEC SAVE	03/16/01 04/16/01
7	UNSTACKING 60 KV	07/26/04
8	UNSTACKING ARF1 -- NEW P2 CONST 50 KV	12/18/05 12/18/05
9	VARIATIONS ON THEME OF STACKING W/DRF1 KEG&WJA	03/15/05
10	UNSTACKING 1.09 EV-SEC	11/27/95 06/13/00
11	TBT RF CURVES - MCGINNIS	11/18/05 11/18/05
12	UNSTACKING ARF1 -- NEW START TIME	02/20/02 02/20/02
13	STACKING 628767-628820-25 GRADUAL	05/15/02 07/16/05
14	STACKING WITH DRF1 FOR DEB BPMS KEG	02/21/05 09/03/06
15	SJW TEST STACKING CURVES	05/20/04 05/20/04
16	ARF1 OPERATIONAL BACKUP	01/14/05

Messages

Stacking with DRF-1 for debuncher BPMs.

VMS PA:P2 NEW RF CURVE LOAD<NoSets>

P2 ANTIPROTON SOURCE RF FILES ◆Pgm_Tools◆

rf sequence

RETURN ◆ EDIT ◆ ◆DRF1◆ *CH_PLOT* *CONSTANTS* *CONFIGURATION* *SEND*

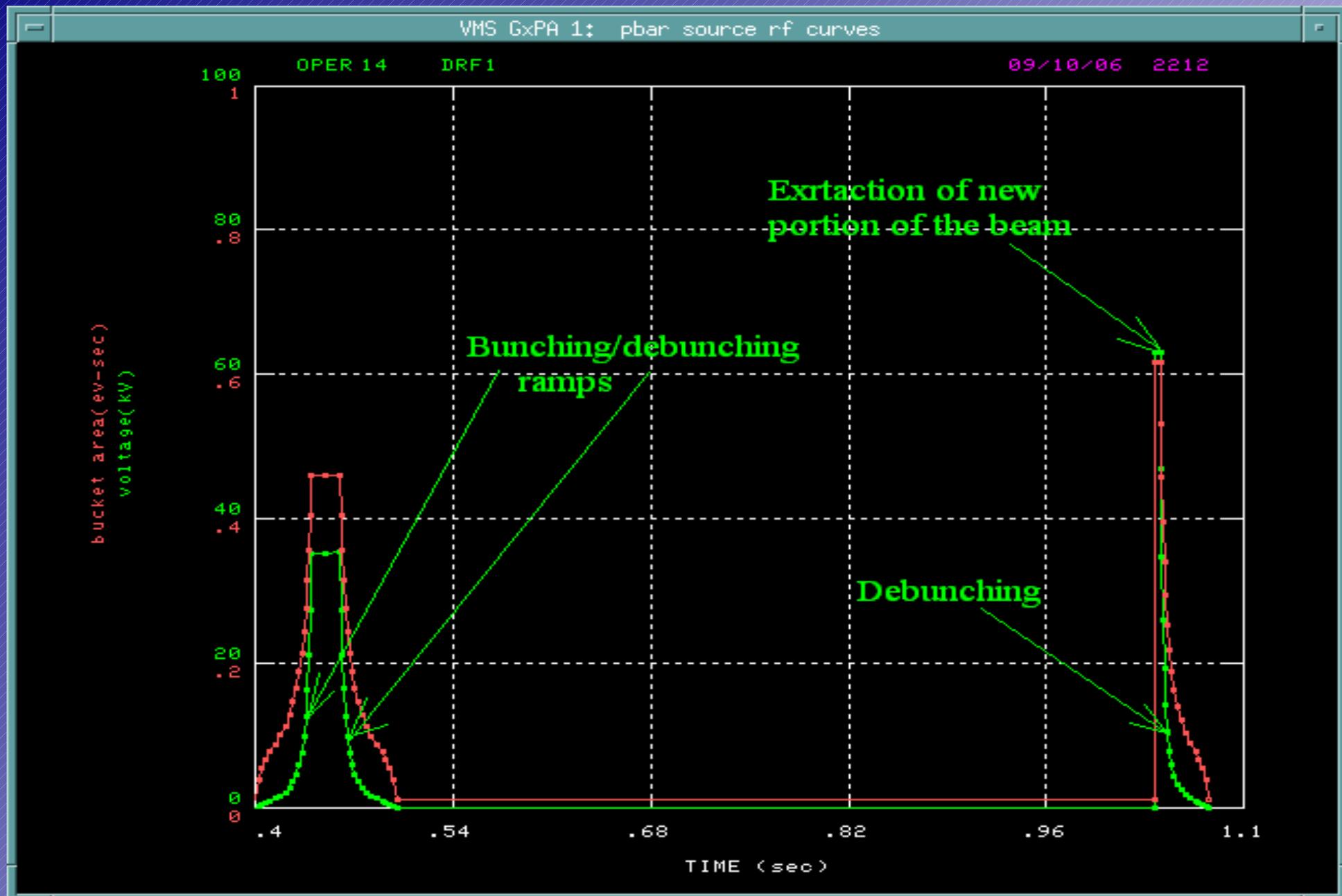
OPER 14 <STACKING WITH DRF1 FOR DEB BPMS KEG>

	TYPE	DT(ms)	T(sec)	FREV(hz)	A(ev-s)	PHI(deg)	V(kv)	ADIAB	STEPS	
1	INIT	0	.4	590018	.011	0	.02	0	1	*CALC*
2	DHS	10	.41	590018	.0776	0	1	.903	4	
3	CAPDEP	30	.44	590018	.46	0	35.16	.42	14	
4	DHS	20	.46	590018	.4611	0	35.33	0	2	*PLOT*
5	CAPDEP	30	.49	590018	.0774	0	.9954	-.544	14	
6	DHS	10.7	.5007	590018	.011	0	.02	-10	4	
7	DHS	535.6	1.0363	590018	.011	0	.02	0	1	*SAVE*
8	DHS	.2	1.0365	590018	.6158	0	63	10	1	
9	DHS	4	1.0405	590018	.6158	0	63	0	2	
10	CAPDEP	25	1.0655	590018	.0774	0	.9954	-.7	14	
11	DHS	10	1.0755	590018	.011	0	.02	-10	4	

total steps 61

Messages

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!