COOL’15, Sept.28- Oct.3 Jlab Newport News

Formation of bunched electron beam at the electron cooler of CSRm

Xiaodong Yang
IMP, CAS

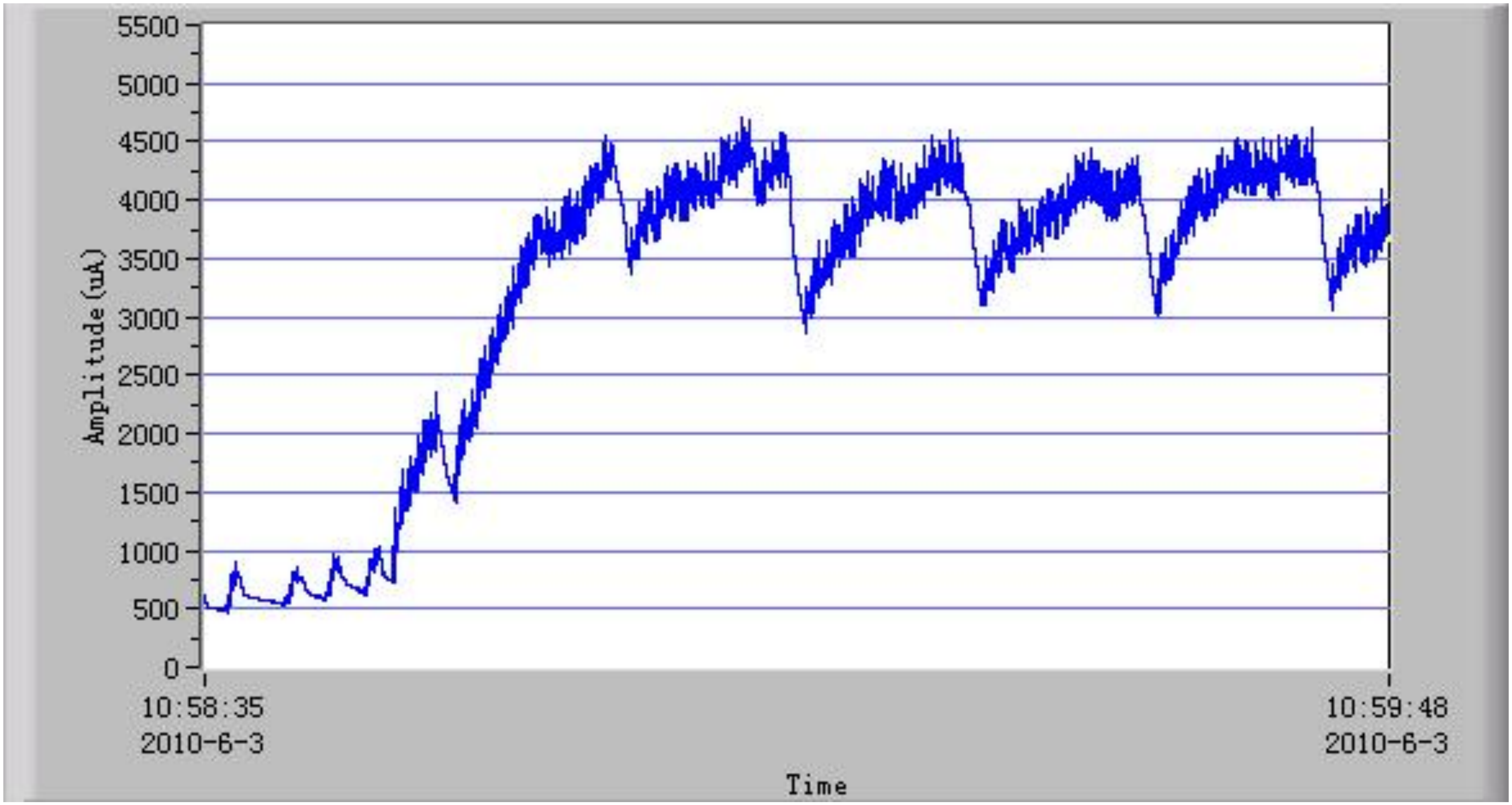
contents

- Introduction
- Some considerations
- Limitation
- Plan and procedure
- Toroid
- Offline test
- Conculsion

Motivation

- Suppression of instability developed in the high intensity ion beam after accumulation
- The electron beam was required to turn on and off in the different period of the atomic physics experiments
- Demonstration of electron cooling by the bunched electron beam

Instability after accumulation



CELSIUS 2000

4. Modulation of electron beam energy to improve stability of electron-cooled ion beams

Although the CELSIUS accelerating cavity is equipped with a relay and shorted as soon as the RF voltage is set to zero, electron cooled beams of more than a few mA tend to become longitudinally unstable (self-bunching). Although the presence of internal targets have a stabilising effect, such instabilities can create beam loss and are a disturbance to experiments, and have forced experimenters to limit the stored beam intensity to lower values, than would otherwise be possible.

The situation can be improved by artificially increasing the electron beam energy spread. This is done at CELSIUS by connecting the electrically insulated inner structure in the drift tube to a hi-fi amplifier, and modulating the voltage on this structure.

Square-wave modulation has turned out to be the most effective. Fig. 3 show the effect on the Schottky noise spectrum of modulating the electron beam in this way with 0, 30 V, and 50 V p–p on a 220 MeV deuteron beam, and Fig. 4 shows the effect on the lifetime of a 250 MeV/u $^{14}N^{7+}$ beam. An internal cluster-jet target of about 10^{13} atoms/cm^2 of xenon was present during the measurement of both curves in Fig. 4. The combination of the modulation of the electron energy and the presence of the internal target was necessary to remove the sudden beam losses, which are visible in the figure.

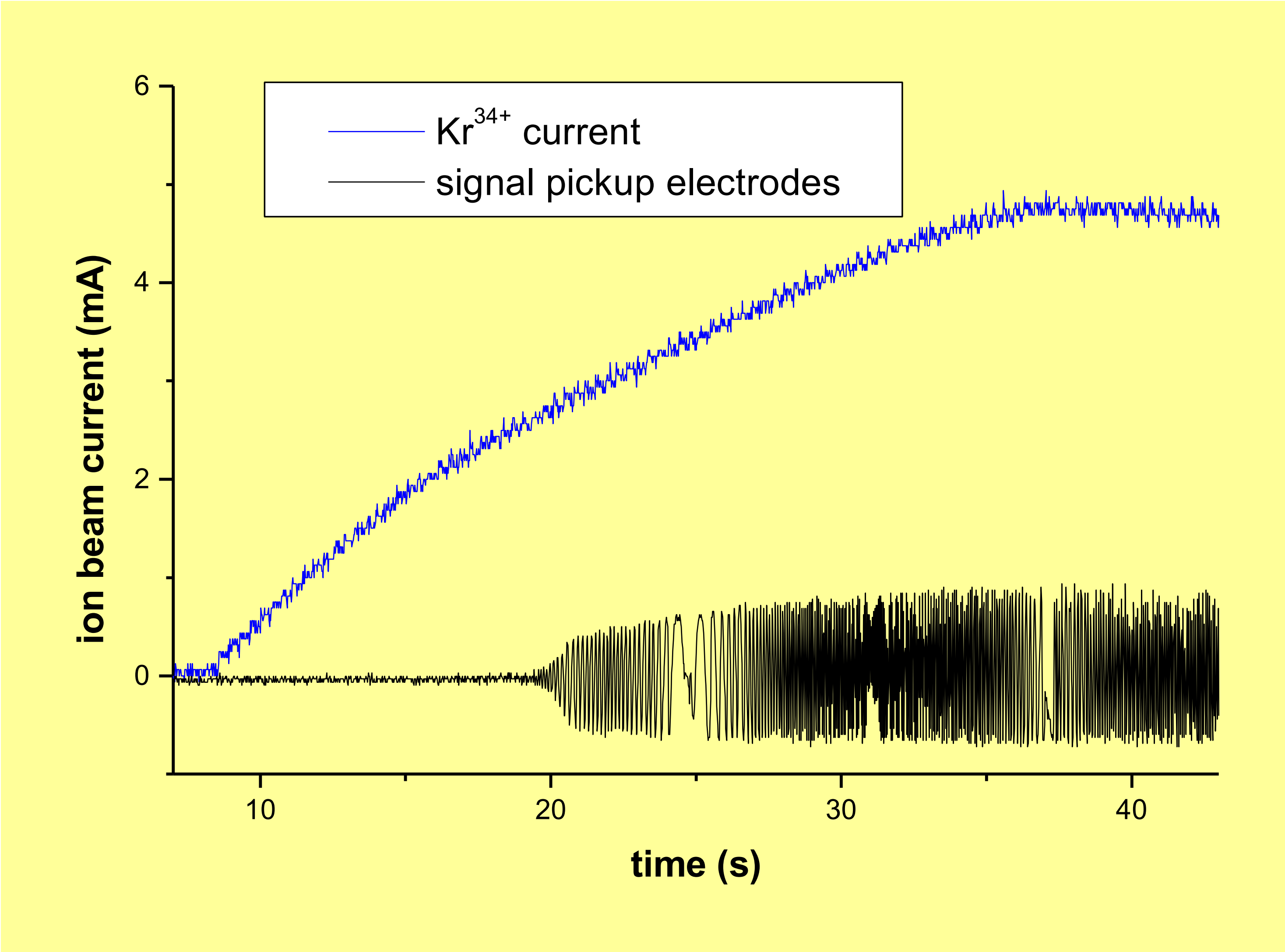
Nuclear Instruments and Methods
in Physics Research A 441 (2000) 140–144

Electron cooling at CELSIUS

L. Hermansson, D. Reistad*

The Svedberg Laboratory, Box 533, S-751 21 Uppsala, Sweden

COOL 2001



Kr^{34+} current
signal pickup electrodes
ion beam current (mA)
time (s)
6
4
2
0
10
20
30
40

COSY

- Feedback system

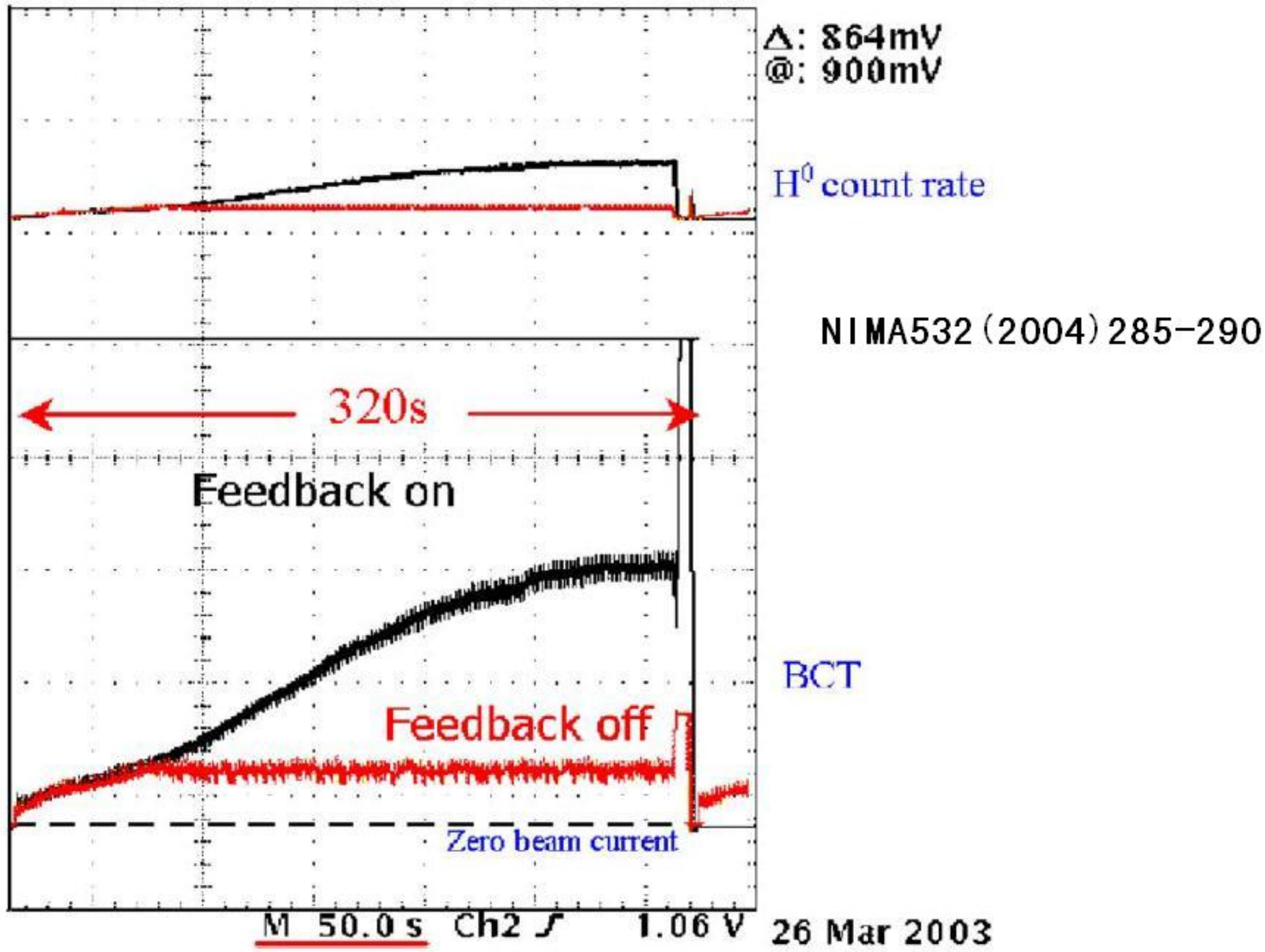


Fig. 6. Stacking process over 320 s with feedback on and off. Here the single injection intensities were reduced to 0.4 mA to simulate the lower current from the polarized source (vertical axis BCT 200 mV/div, horizontal 50 s/div) [3].

ESR

EPAC1988-WEPO5A.PDF The electron beam could be switched off by a fast high voltage switch acting on the anode voltage. This was used to stop the electron beam after accumulation just before the adiabatic increase of the rf amplitude and the ramping of the frequency in order to avoid interferences between cooling and rf system. But also with permanent electron beam no adverse effects on the acceleration process were observed.

CESIUS 2004

The experience of the CELSIUS cooling system operation demonstrated that more effective way to suppress the stored beam instability is artificial increase of the electron beam energy spread. This was done by connecting the electrically insulated inner structure in the drift tube to a hi-fi amplifier, and modulating the voltage at this structure. For instance, at 115 keV electron energy at CELSIUS it was demonstrated that most effective is square-wave modulation at amplitude of 50 V [5].

Formation in the electron gun the hollow electron beam is another and, as one can expect, more effective way to avoid overcooling the ion beam core and related instabilities. The results of experimental investigations of the electron beam profile in such a gun were presented in [6].

RuPAC 2006

INSTABILITY SUPPRESSION

The "standard" method of coherent instability suppression is an application of feed back system (FBS). At COSY the vertical FBS made it possible to stabilize the cooled proton beam at a level of 2×10^{10} particles (1.8 mA) after a single injection. With the stacking technique a maximum of 1.2×10^{11} cooled protons (9.2 mA) at injection energy were stored without instability.

Applying additionally the horizontal FBS did not bring any essential effect. Application of FBS at S-LSR showed its very high sensitivity to proper choice of time delay between PU and kicker [5].

Another way to suppress instability is based on idea to avoid of "overcooling" of the beam core. At CELSIUS and later at COSY an additional external heating of the beam in longitudinal and transverse degrees of freedom and/or misalignment of the electron beam were tested for instability suppression. However, both of these methods stabilize the stored beam but do not give a substantial increase of its intensity. As it was demonstrated at CELSIUS, more effective way is an artificial increase of the electron beam energy spread by its modulation. Another method developed recently [6] and tested preliminary at LEIR is formation in the electron gun the hollow electron beam.

New solution

Proceedings of COOL 2007, Bad Kreuznach, Germany

ELECTRON BEAMS AS STOCHASTIC 3D KICKERS

V.V. Parkhomchuk, V.B. Reva, A.V. Ivanov
BINP, Novosibirsk, Russia

Abstract

This article describes an idea combining electron and stochastic cooling in one device. The amplified signal of displacements of the ion from the pick-up electrode is applied to the control electrode of an electron gun. Thus, a wave of space charge in the electron beam is induced. This wave propagates with the electron beam to the cooling section. The space charge of the electron beam acts on the ion beam producing a kick. The effectiveness of the amplification can be improved with using a structure similar to a traveling-wave tube.

Scheme of electron beam as kick COOL 2007

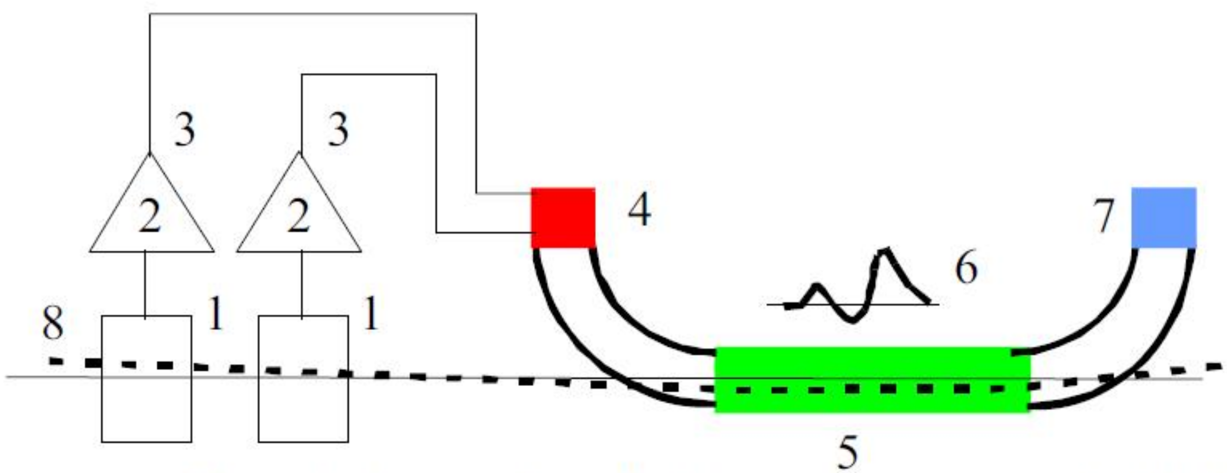


Figure 1: Scheme of stochastic cooling with electron cooler as 3D kicker. 1 – pick-up system, 2 – hybrid and amplifier, 3 – cable system, 4 – electron gun with the current modulation, 5 – cooling section, 6 – modulation of the space-charge density in the cooling section, 7 – collector of the electron beam, 8 – ion trajectory.

Sketch of the electron gun

Control electrode

cathode

anode

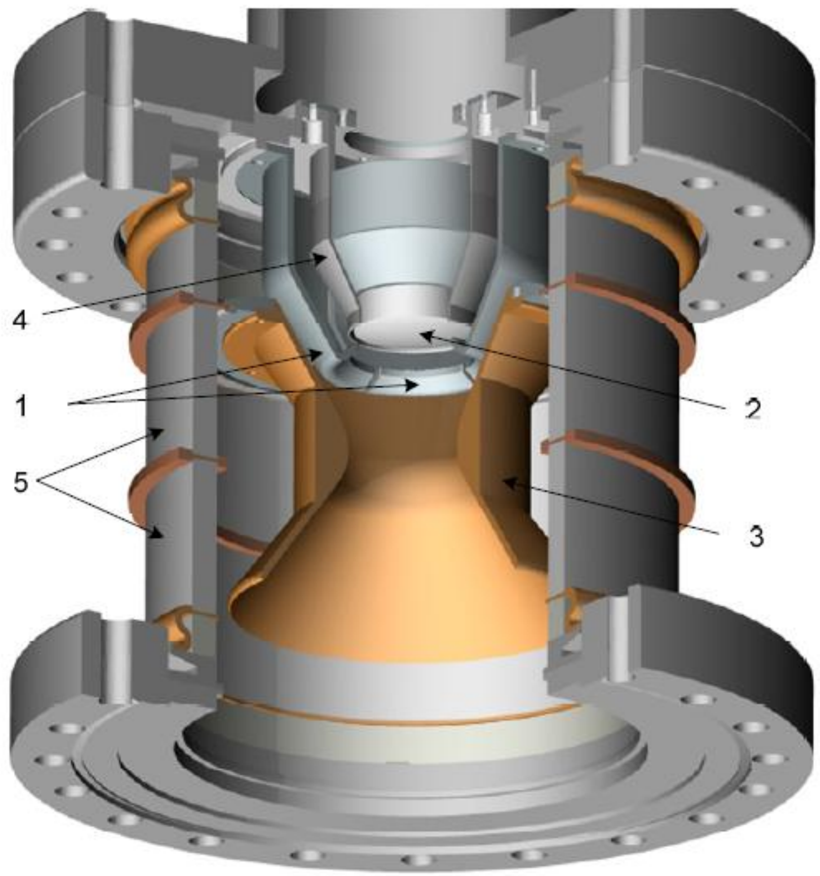
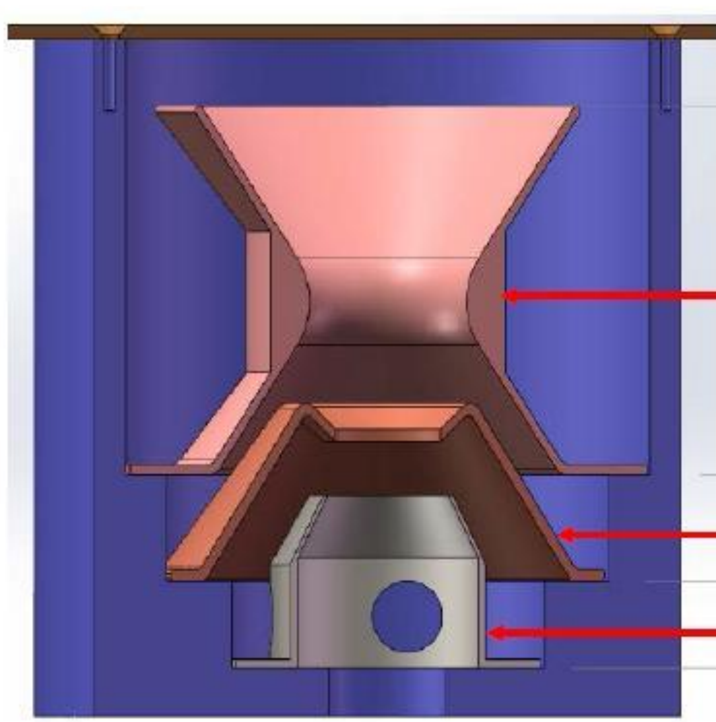


Fig.1 The sketch of the electron gun

1 – four-sector control electrode, 2 – oxide cathode,
3 – anode, 4 – cathode housing, 5 – ceramics.

Capacity of the gun



$C_{cathode-control}$ =20pF

$C_{control-anode}$ =24pF

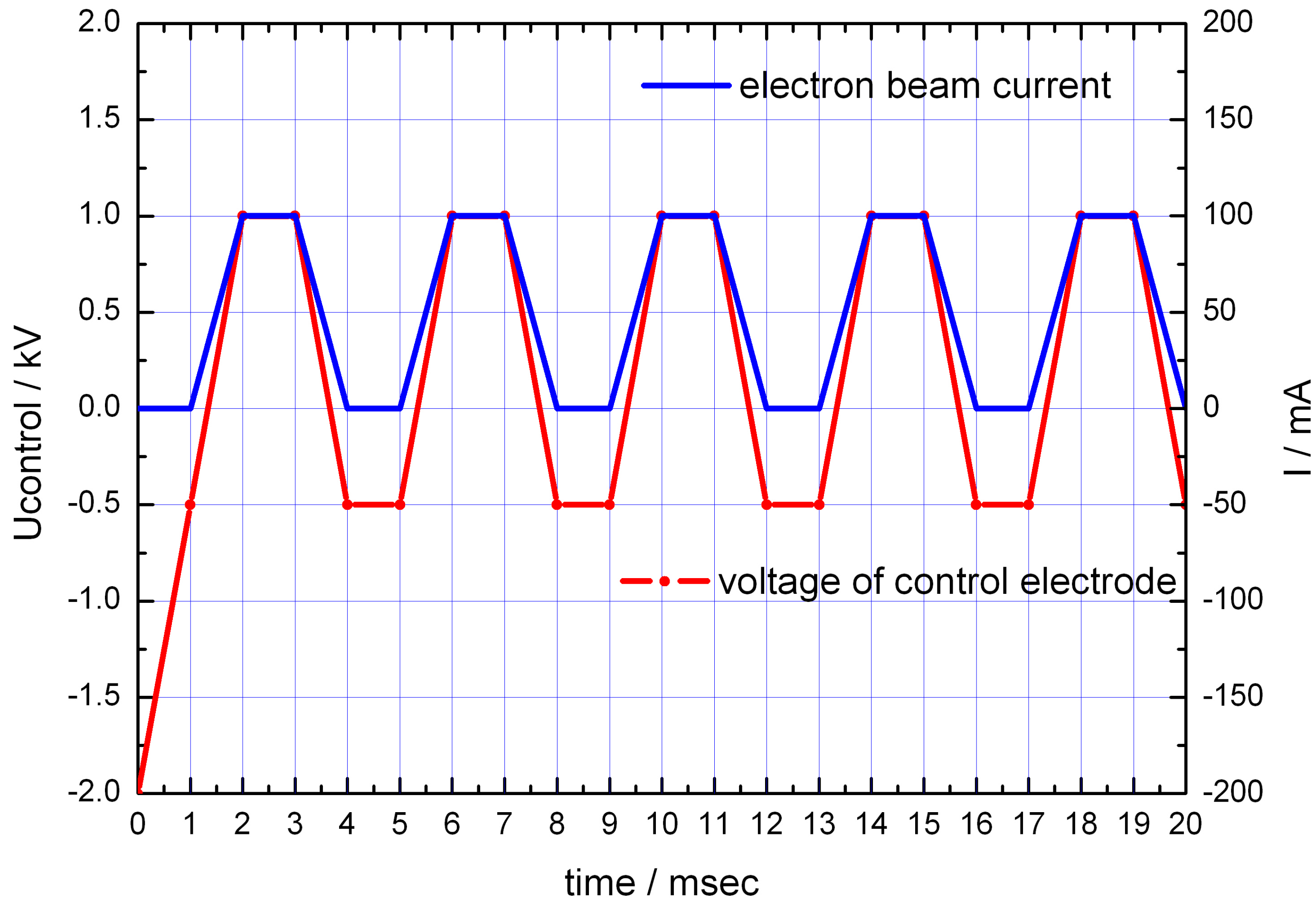
$C_{cathode-anode}$ =13pF

$C_{control-shell}$ =4.5pF

Limitation

- Thermal dispenser cathode
- Capacitive character of gun
- Heavy load of beamtime

Waveform of voltage on the control electrode and the electron beam



Some consideration

- Charge of the gun(turn on electron beam)
- Discharge of the gun(turn off electron beam)
- Charge rate
- Discharge rate

Diagram of the test bench

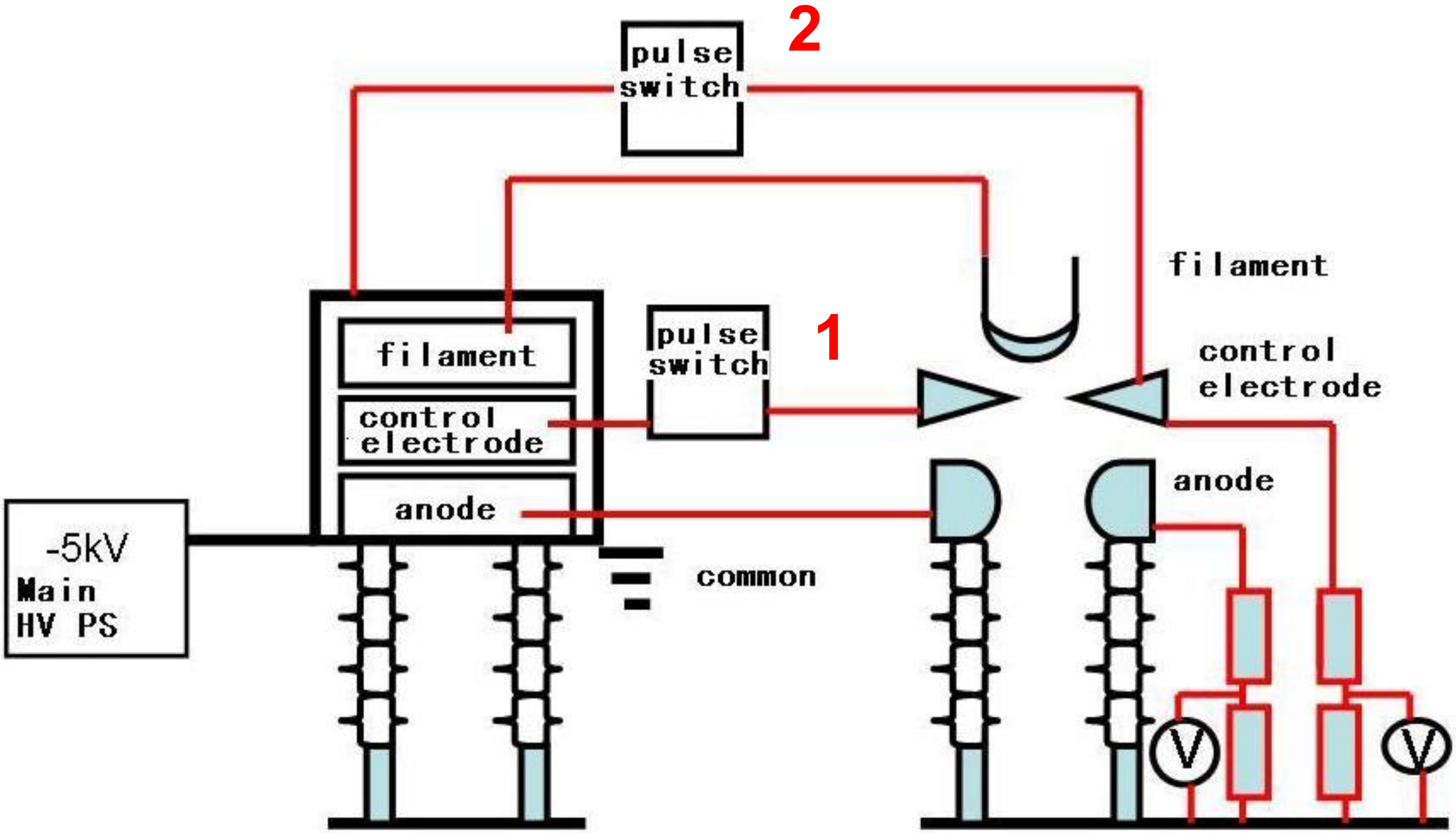
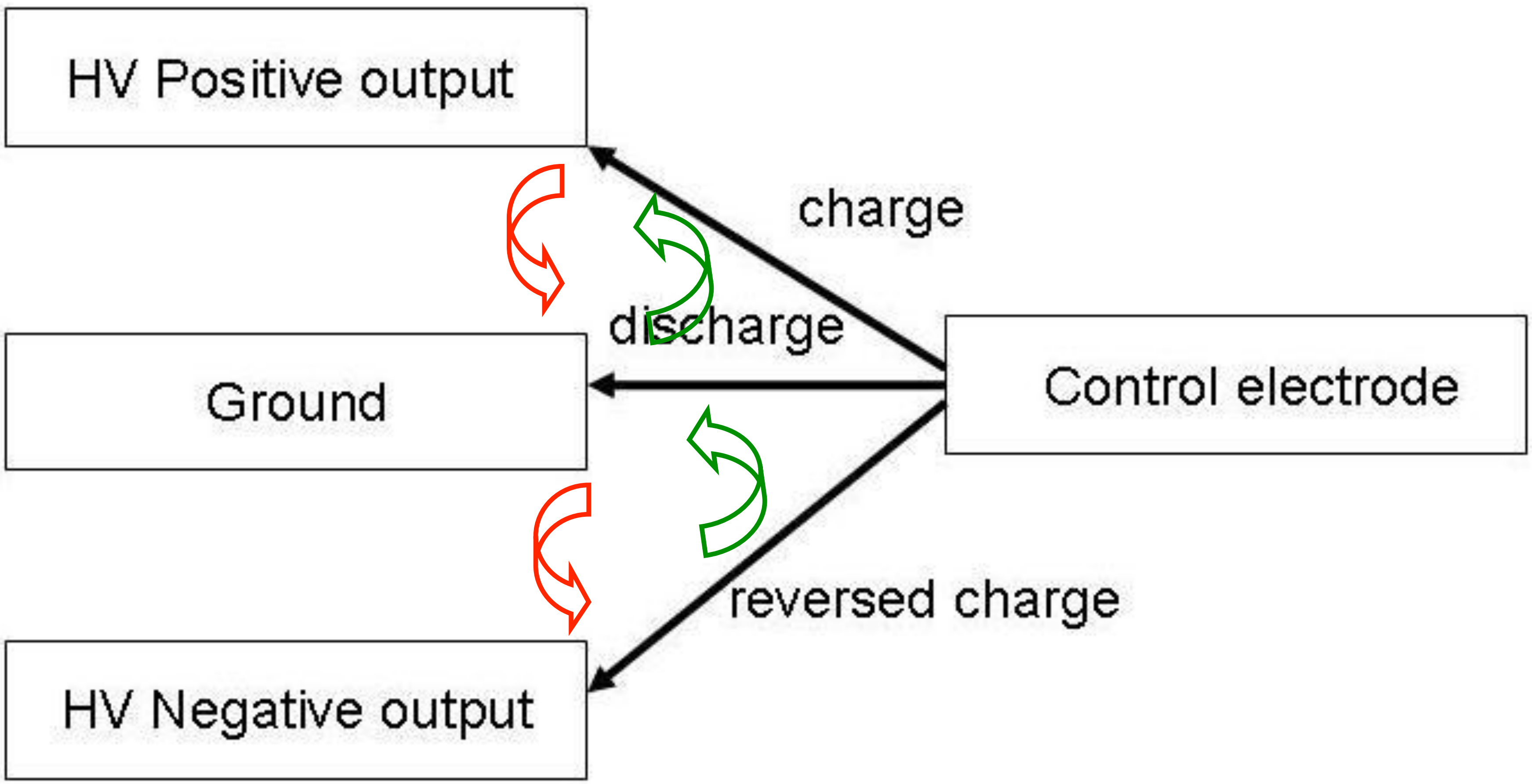
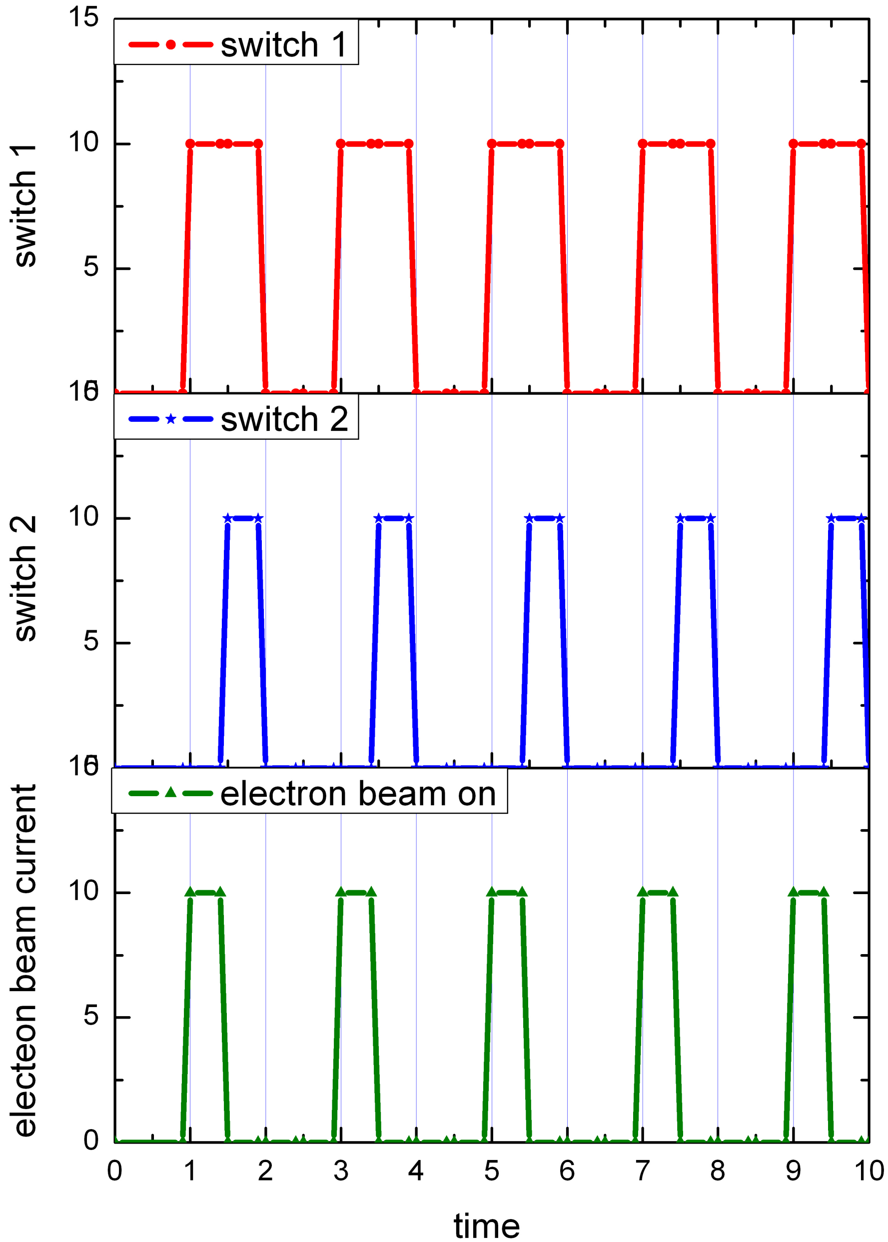


Diagram of testbench

Charge and discharge



Chopper



Switch 1

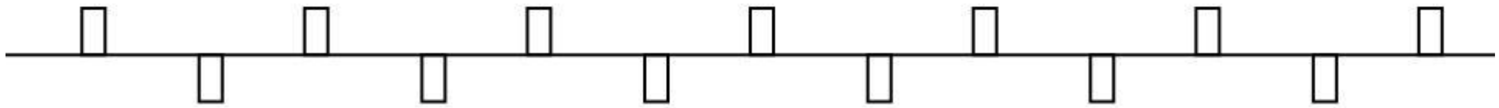
charge

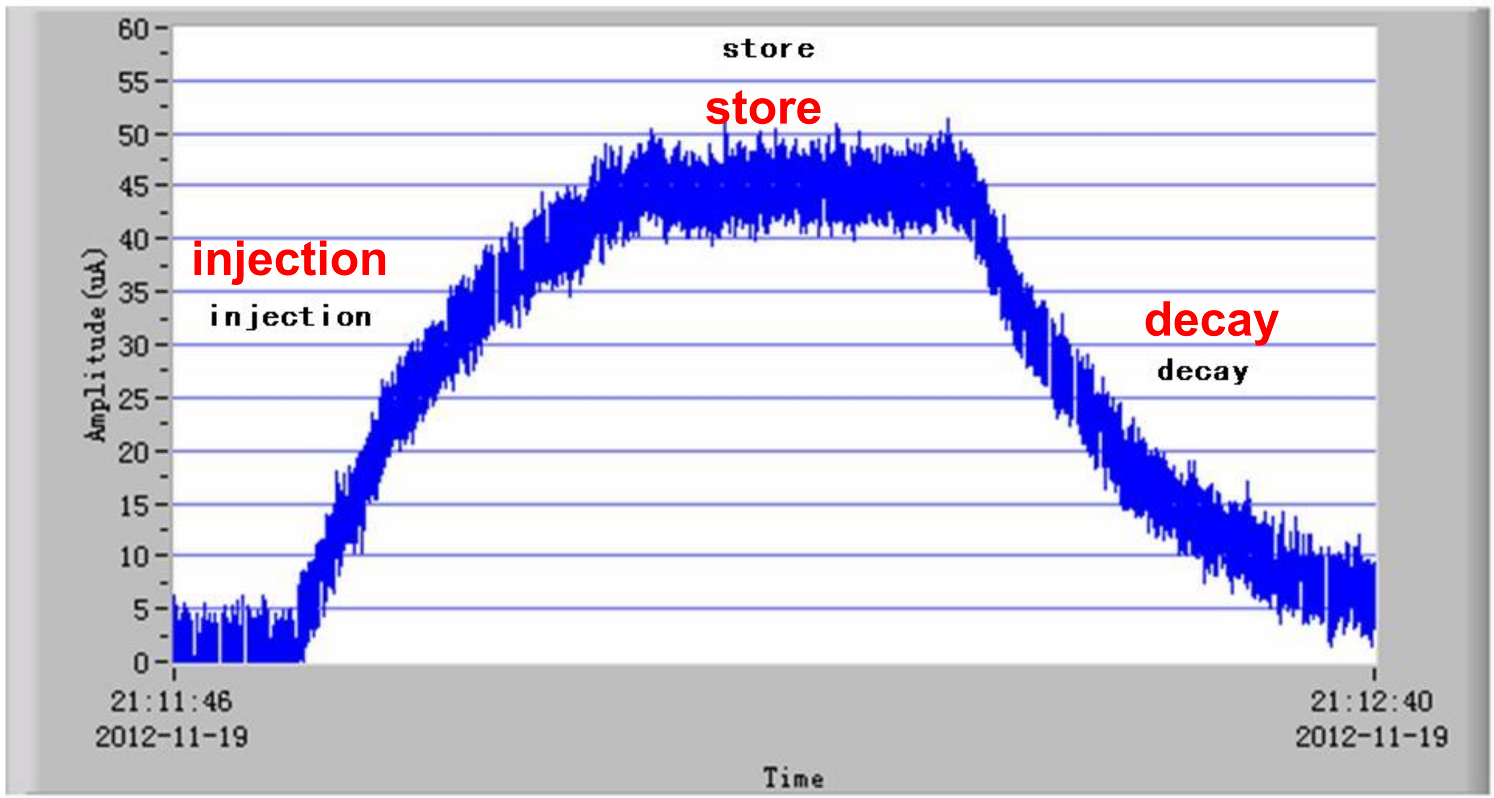
Switch 2

discharge

Electron pulse

Atomic physics experiment





DCCT signal

Offline test

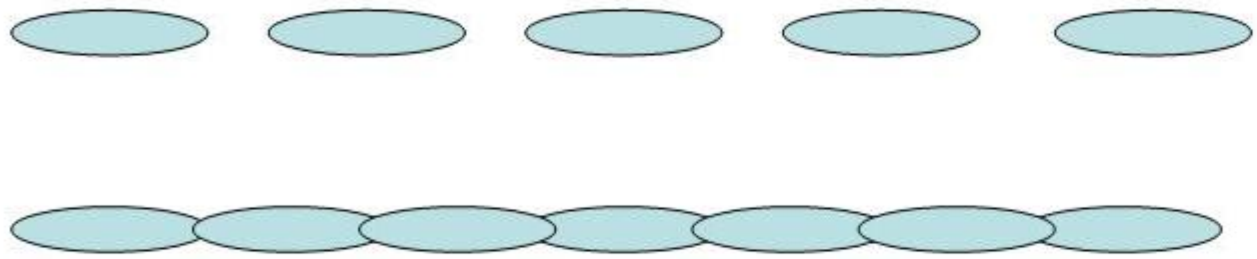
- pulse width,
- interval of pulses,
- longitudinal distribution of pulse
- Transverse distribution of pulse

Bunch length and interval

- Injection interval
- Revolution period
- Expected cooling time

Bunch Diagnostics

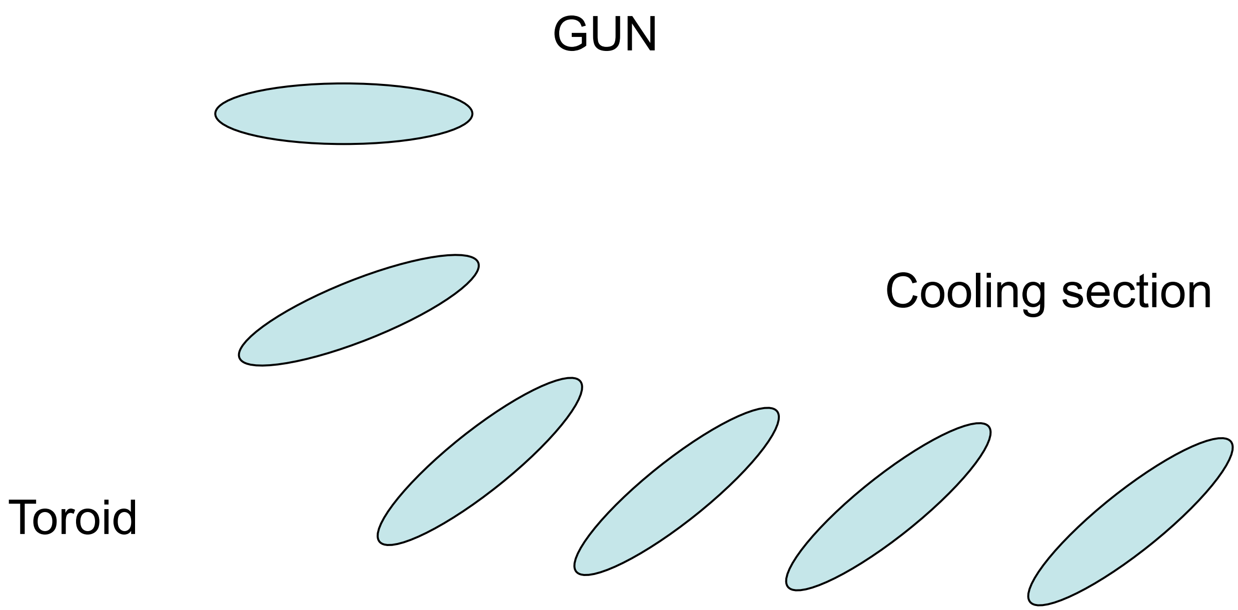
Seperated bunch



fluctuation

Toroid

- Bunch incline
- Procession motion



Plan and procedure

- Design
- Offline test on the testbench
- Offline test with electron beam in the cooler
- Online test with ion beam in the storage ring

- Accumulation
- Instability
- Cooling force and time
- Atomic physics experiments

Conclusion

- suppress the instability of ion beam,
- increase the maximum accumulated ion beam intensity,
- improve the beam stability after accumulation,
- decrease the cooling time,
- verify the results of bunched electron beam cooling ability in the lower energy range.

Thanks for your attention!