Studies of the effect of 2nd harmonic on the e-p instability and RF control of instabilities

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SNS Ring parameters

Ring parameters:

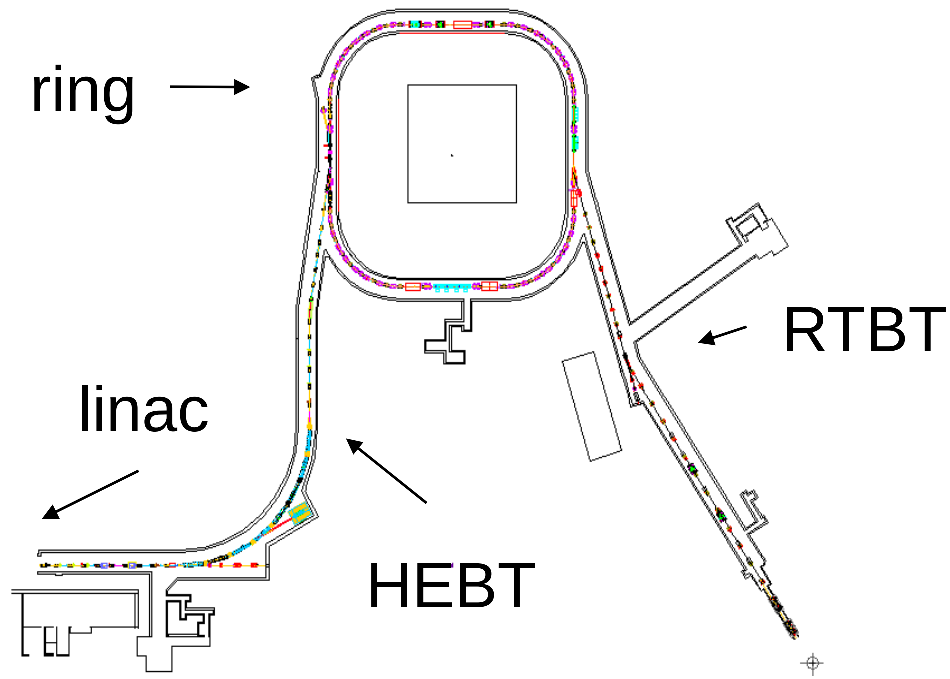
∀ ~ 1GeV (860-931 MeV in our studies)

- 248 m perimeter

∀ ~10 cm VC radius

- Working point (6.23,6.21)

  (5.795,5.81) – optional
- Design intensity – 1.4×10^{14} protons
- Power on target – 1.4 MW at first stage
- The ring design was low-loss high intensity oriented



Instability-related Features of Ring Design

Common high intensity design features:

high energy spread design and broadband

feedback provision +

For E-p instability mitigation:

a) Electron collection near stripper foil;

b) Experiments of 1999 showed significant reduction of electrons in a coated spool piece of PSR vacuum chamber. This led to a decision to coat all pieces of VC with TiN;

c) Solenoids near the regions with high loss;

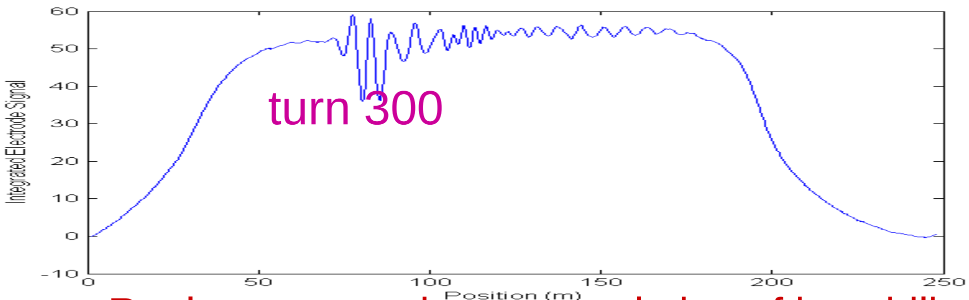
d) clearing electrode near the stripper foil;

e) Electron detectors for electron accumulation study.

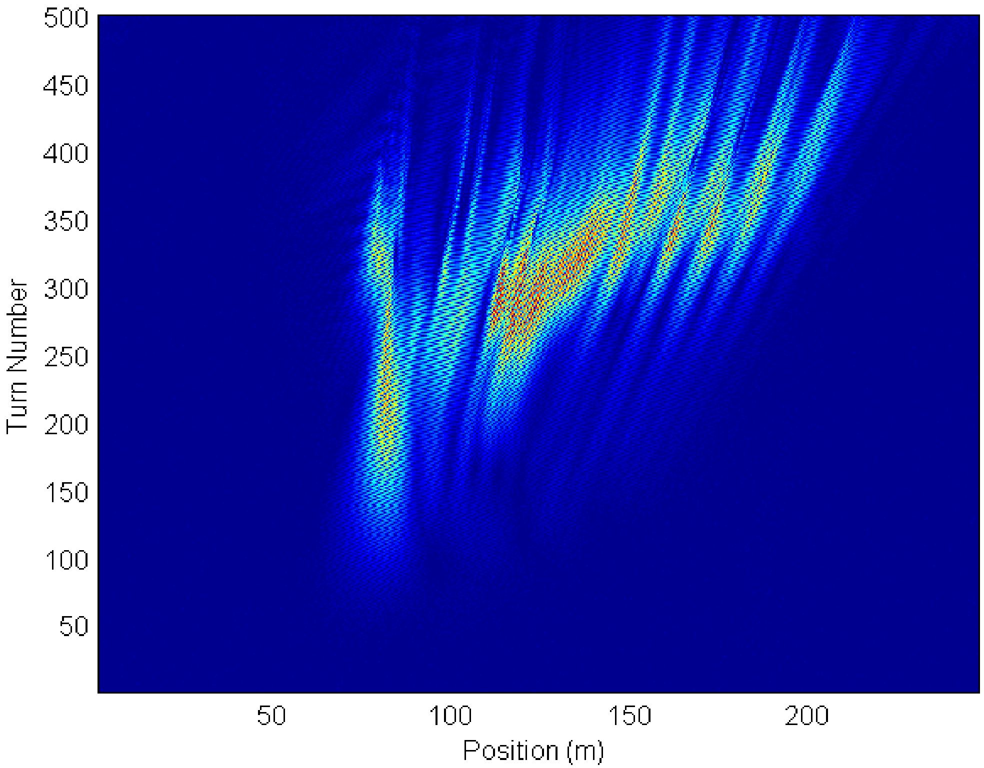
Also we have minimization of other impedances. We see extraction kicker and resistive wall instability, but they are much weaker than e-p instability

Some of the first observations of e-p instability

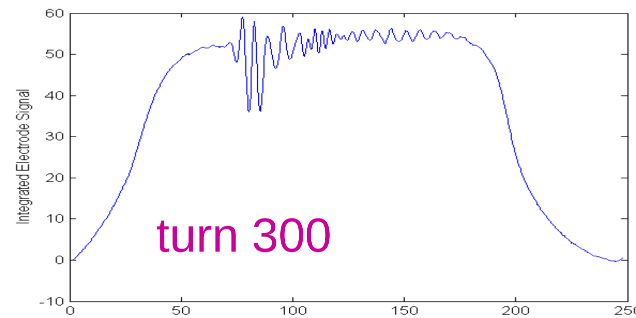
Instability occurs near flat top, closer to front of the beam, and moves backwards.

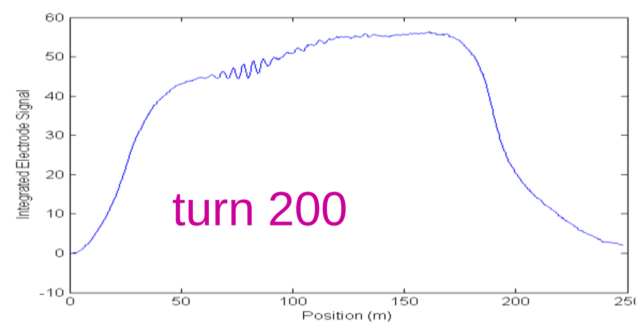


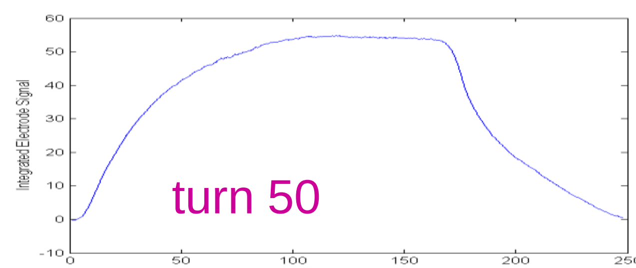
Real space turn-by-turn evolution of instability



Integrated signal for one electrode







Improvement of the threshold (2006-2010)

- 2006 – 10^14 protons per pulse with instability
- 2007- 1.1* 10^14 protons per pulse with instability
- 2008- 1.3* 10^14 protons per pulse with instability
- 2009 – now – 1.1*10^14 without instability and around 1.4*10^14 with small instability

We attribute the improvements to low loss more “clean” beam in the ring

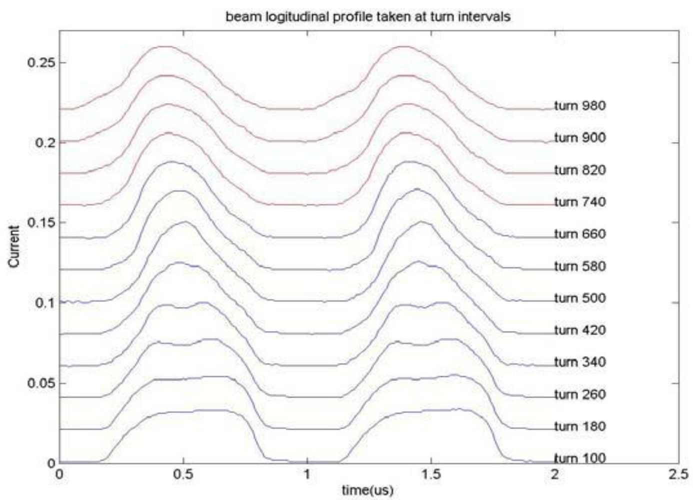
We noticed that manipulations with RF helped to eliminate instability

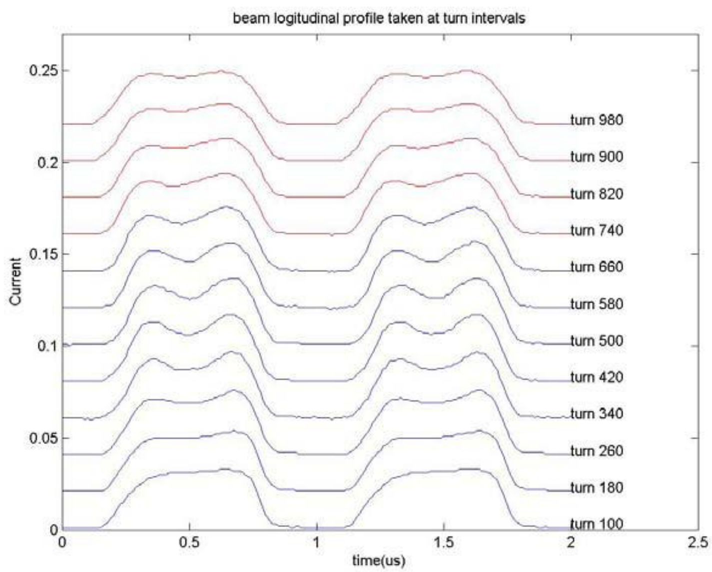
SNS RF has 3 1st harmonic cavities (around1 MHz, 20 kV each)

and 1 2nd harmonic cavity (2 MHz around 20 kV voltage)

In our experiments we had 1 1st harmonic station off.

2009 experiments with RF manipulations



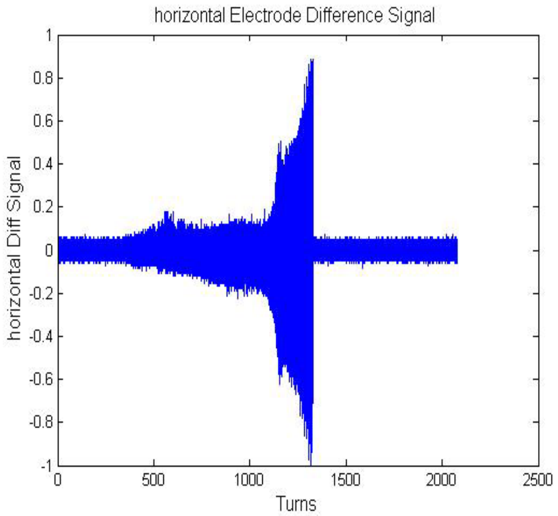


Intensity – 1.1*10^14 ppp
980 turns of accumulation

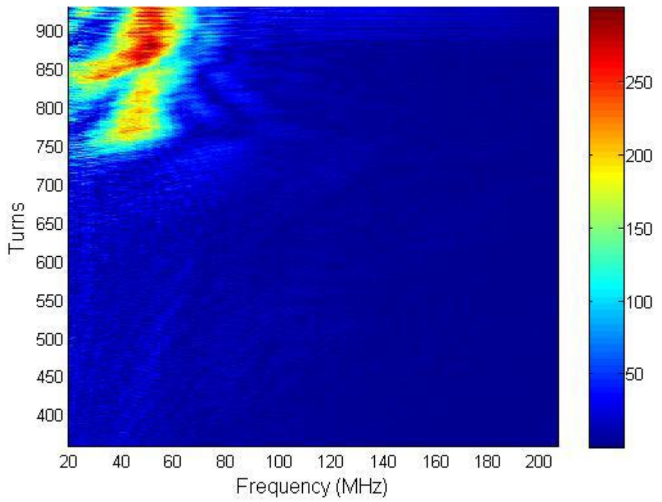
Upper plot – 1st harmonic RF voltage 10 kV, 2nd V=15 kV
2nd harmonic phase = -5 deg

Lower plot - 1st harmonic RF Voltage 5.5 kV, 2nd V=15 kV
2nd harmonic phase = -15 deg

E-p instability signatures for these cases



1st



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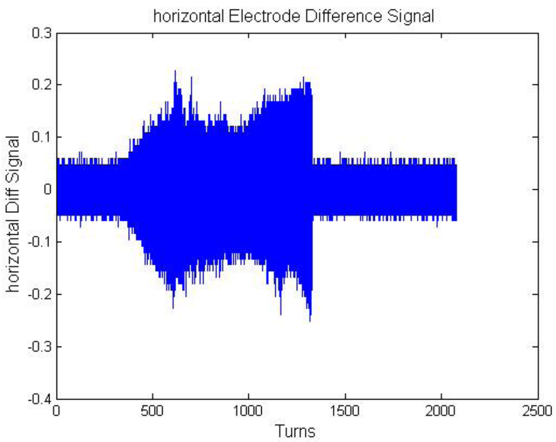
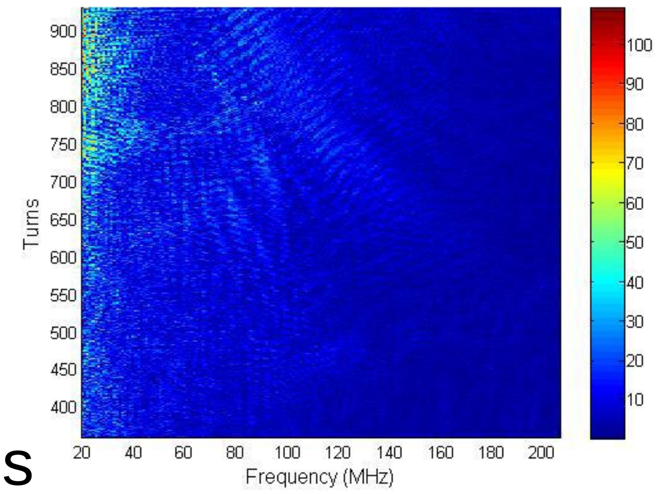
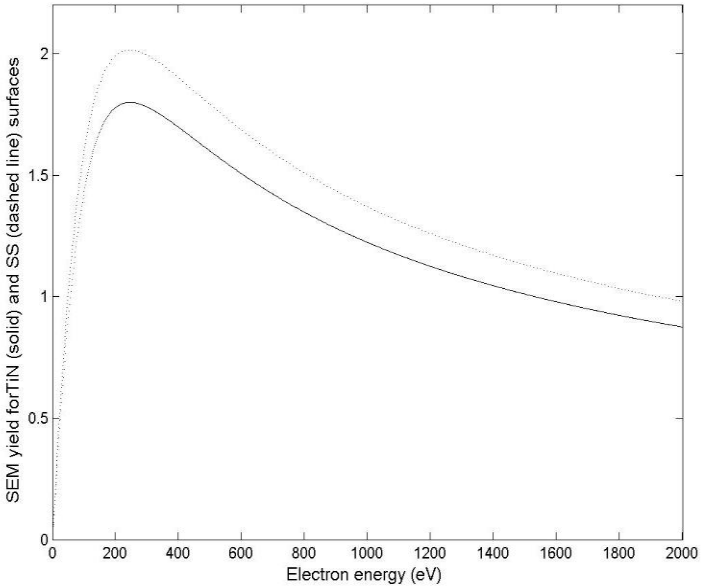
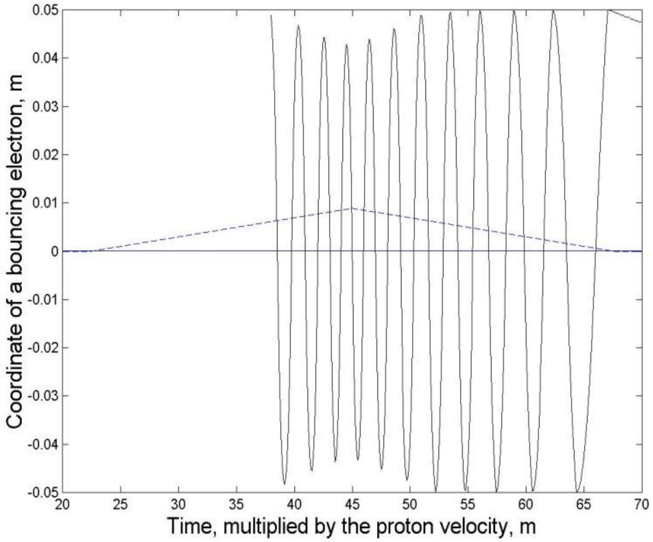


2nd cases



Possible explanations of the phenomenon



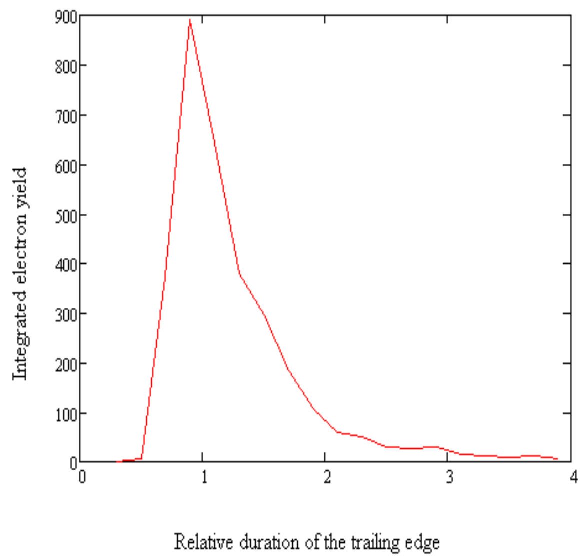


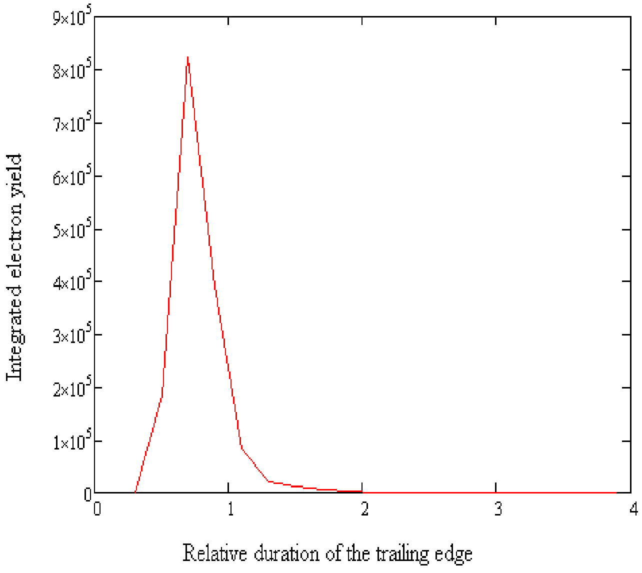
Pivi-Furman model for SEM yield : SS and TiN surfaces

Electron motion in a proton bunch field

SNS case – electrons have energy from 50 to 300 eV when striking the vacuum chamber at the trailing edge

Possible explanations (cont.)

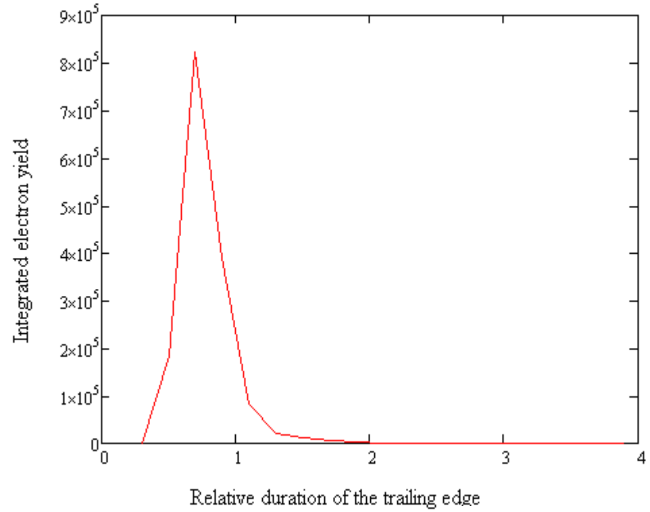




Integrated yield as a function of trailing edge steepness s=200ns/(trailing edge duration)
Left – SS chamber
Right- aluminum chamber

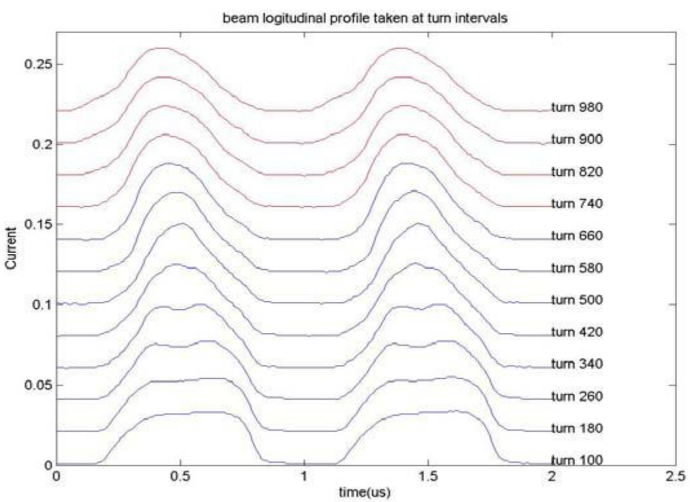
Possible explanations (cont.)

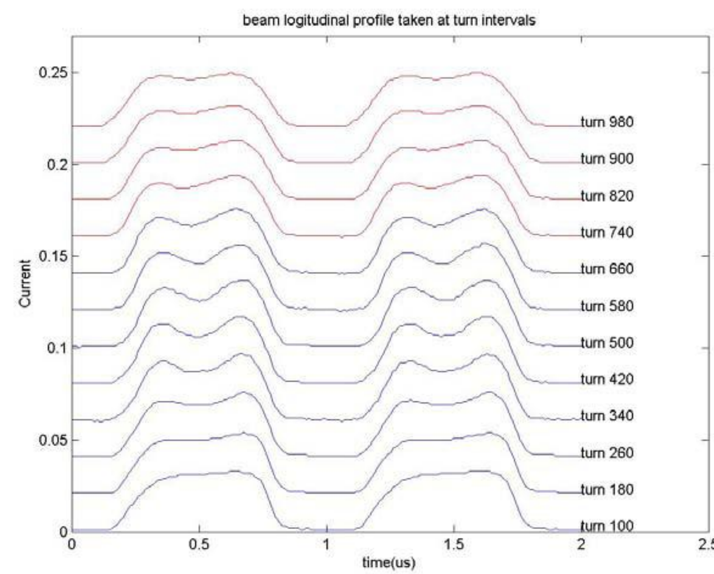
Integrated yield for aluminum



s=0.7

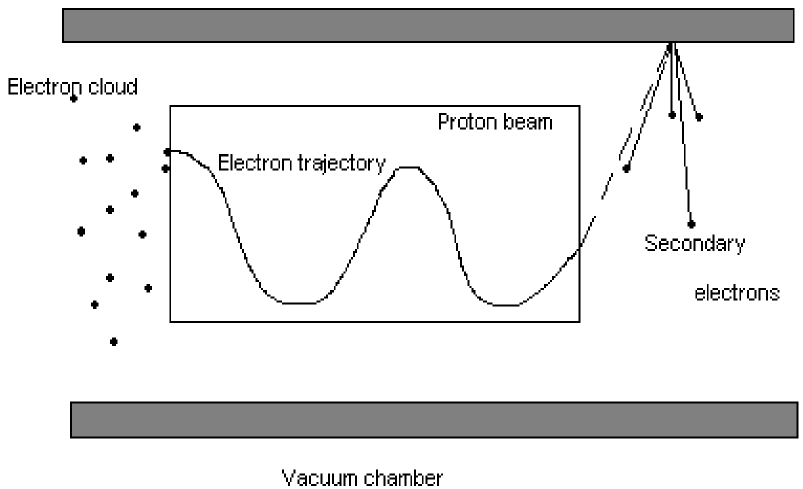
s=1.4





Optimal longitudinal distributions

1) Long trailing edge. Its drawback – the minimal parameter *s* can be around 0.5 only (sharp leading edge and the whole bunch is just trailing edge);
2) Short trailing edge. Parameter s can be in principle very high (high voltage barrier cavity) –it kills both trailing edge and in-gap electrons.



Conclusion

- SNS e-p instability experiments showed strong dependence of instability signals on RF configuration;
- Possible explanation – electron accumulation dependence on longitudinal distribution of the proton bunch;
- Two opposite cases (with long and short trailing edges) are identified to be the best for mitigating e-p instability
- The most promising case seems to be longitudinal distribution, created by high-voltage barrier cavity (this case is also very good for minimizing space charge effects, and even creating self-consistent space-charge distributions (SNS presentation in Tsukuba HB2006)