The KEK-All Ion Accelerator (KEK-AIA)

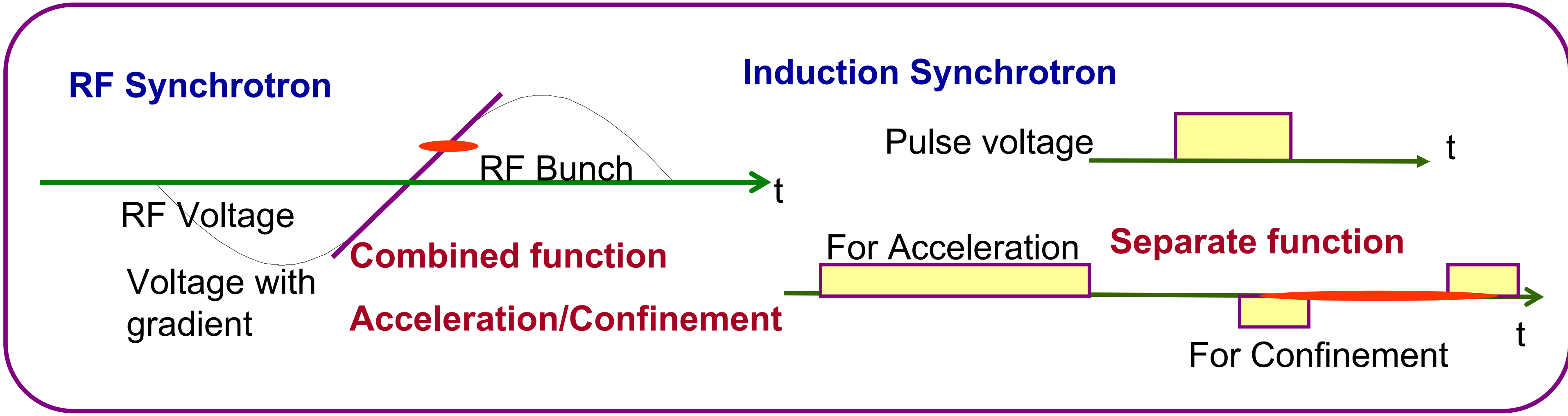
Tanuja Dixit

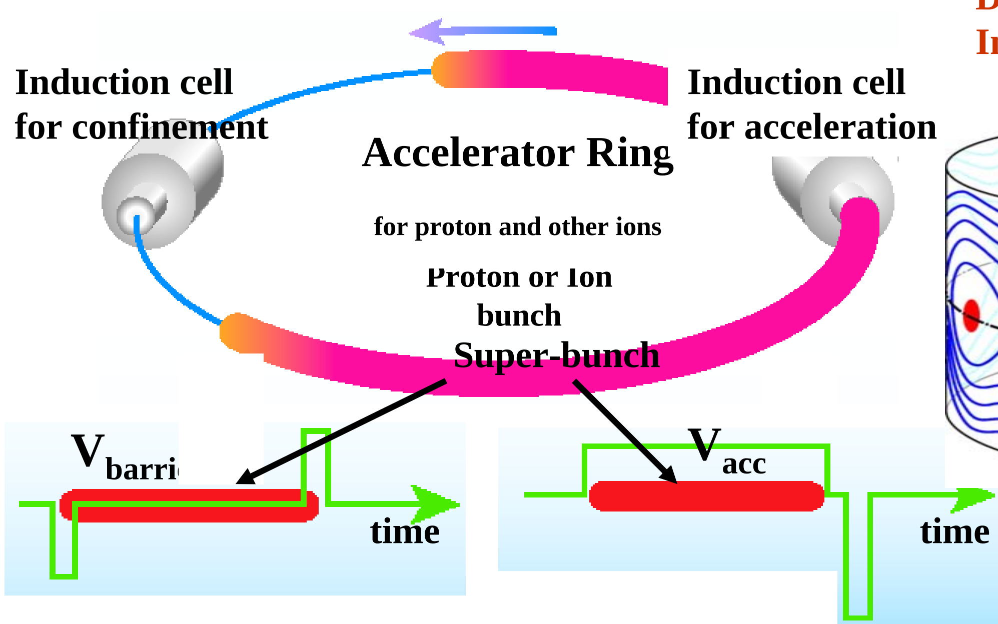
The Graduate University for Advanced Studies, SOKENDAI
High Energy Accelerator Research Organization, KEK, JAPAN

Contents

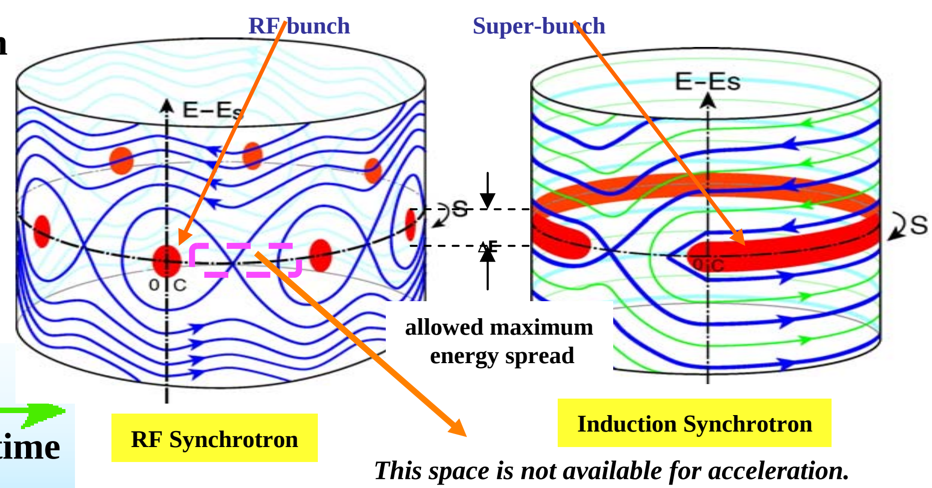
- Introduction of Induction synchrotron concept and its POP experiment
- Motivation for AIA
- KEK-PS Booster modification for AIA
- Acceleration scenario in the AIA
- New cell – 2 μsec long pulse cell
- Gate control system
- Summary

Induction Synchrotron Concept

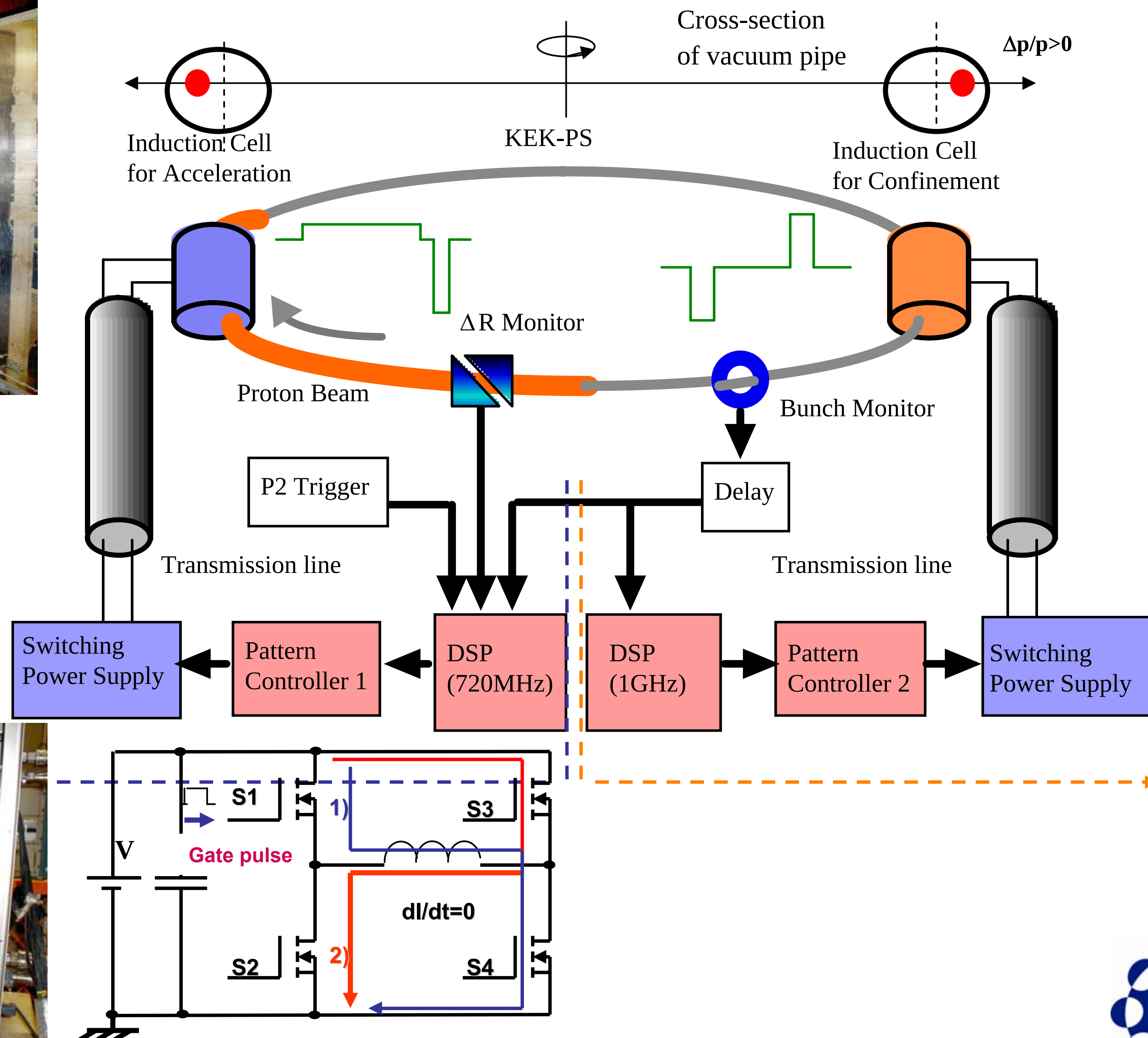




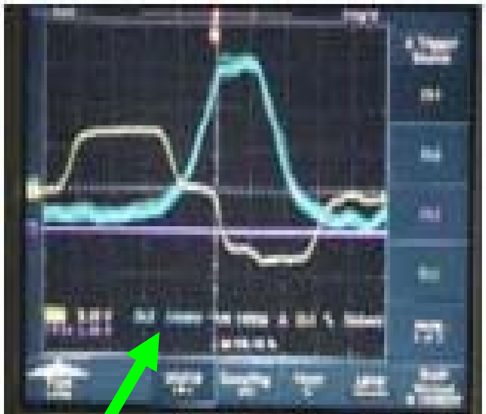
Difference between RF Synchrotron and Induction Synchrotron seen in Phase-space



Induction acceleration system and controls for POP

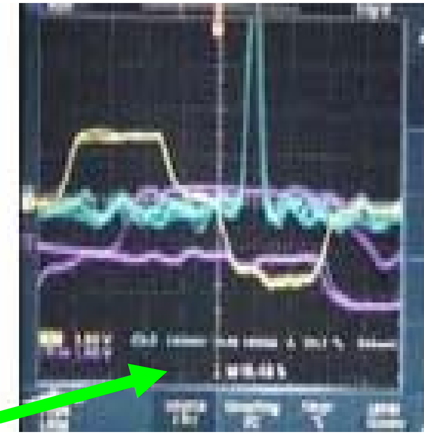


P2 (just start of accel.)



P2+400 msec

near end of accel. (6GeV)



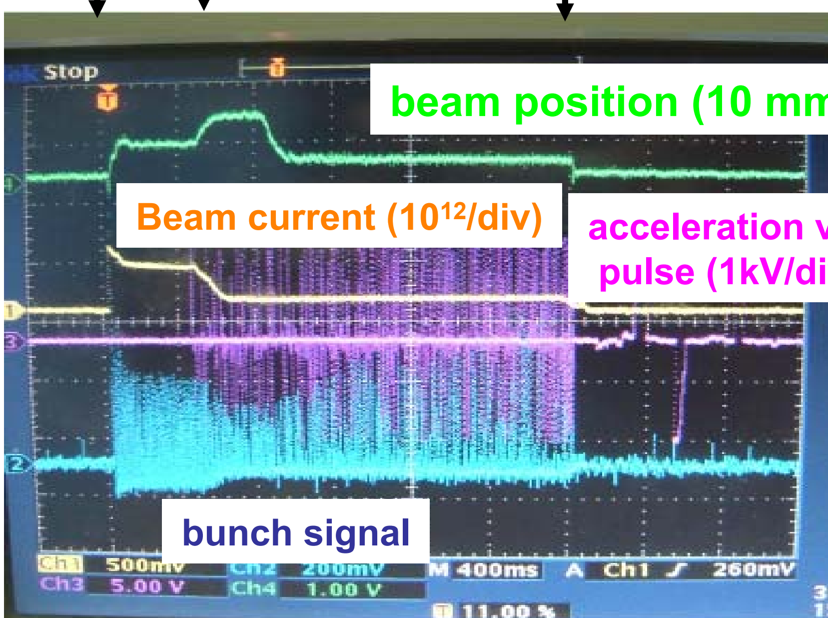
T.Dixit et.al. " Adiabatic damping of bunch length in Induction Synchrotron" NIM-A 582 (2007)

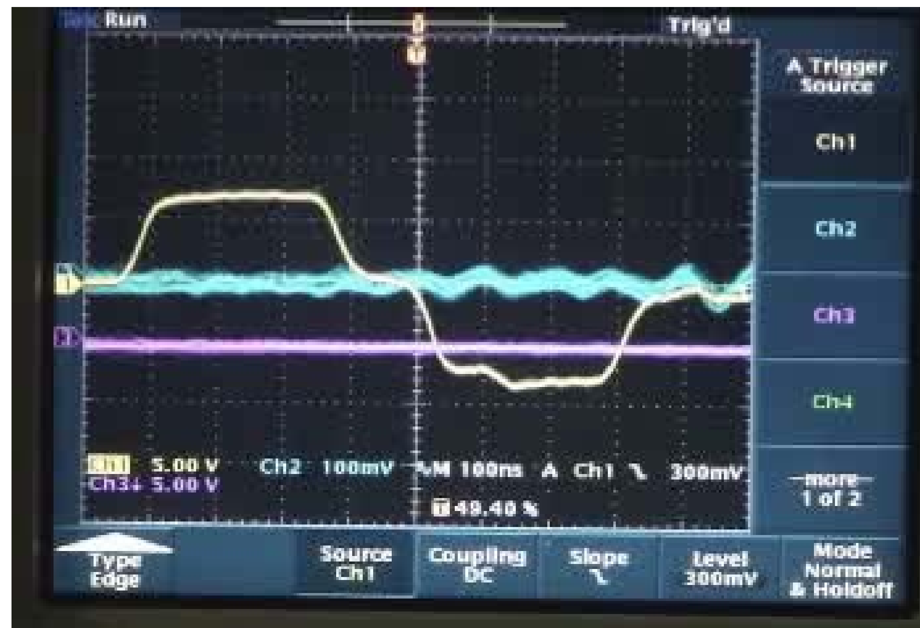
Movie of the POP experiment

Injection (500MeV)

Start of acceleration

End of acceleration (6GeV)





K.Takayama et al., "Experimental Demonstration of the *Induction Synchrotron*", *Phys. Rev. Lett.* 98, 054801 (2007)

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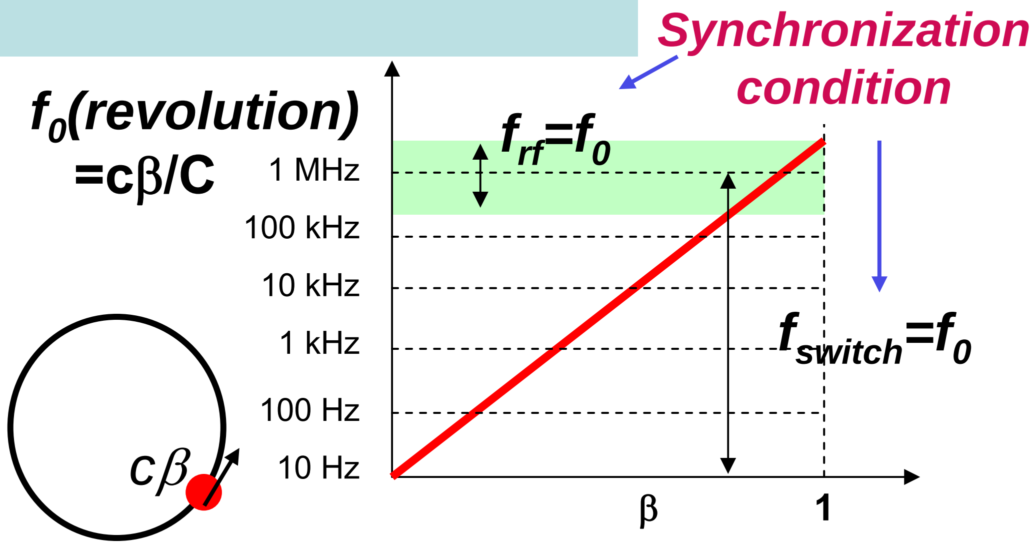
- Gate control system
- Goal and time table

from the Induction Synchrotron to All-ion Accelerators

from the experimental demonstration of induction acceleration in the KEK-PS

- Stable performance of the switching power supply from ~0Hz to 1MHz
- Master trigger signal for the switching P.S. can be generated from a circulating beam signal

Allow to accelerate even quite slow particles



A single circular strong-focusing machine can accelerate from proton to uranium, maybe including **cluster ions**.

All-ion accelerators

almost <u>injector-free</u> for a low intensity beam

K.Takayama, K.Torikai, Y.Shimosaki, and Y.Arakida, "All Ion Accelerators", (Patent 3896420, PCT/JP2006/308502), and *J. of Appl. Phys.* 101, 063304 (2007)

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AIA Working Groups

Main Magnet/Orbit

Low field operation
COD correction

Source/ Injection group
ECR ion source
200 keV beam line
Electrostatic kicker
Extraction kicker

AIA

Monitor system

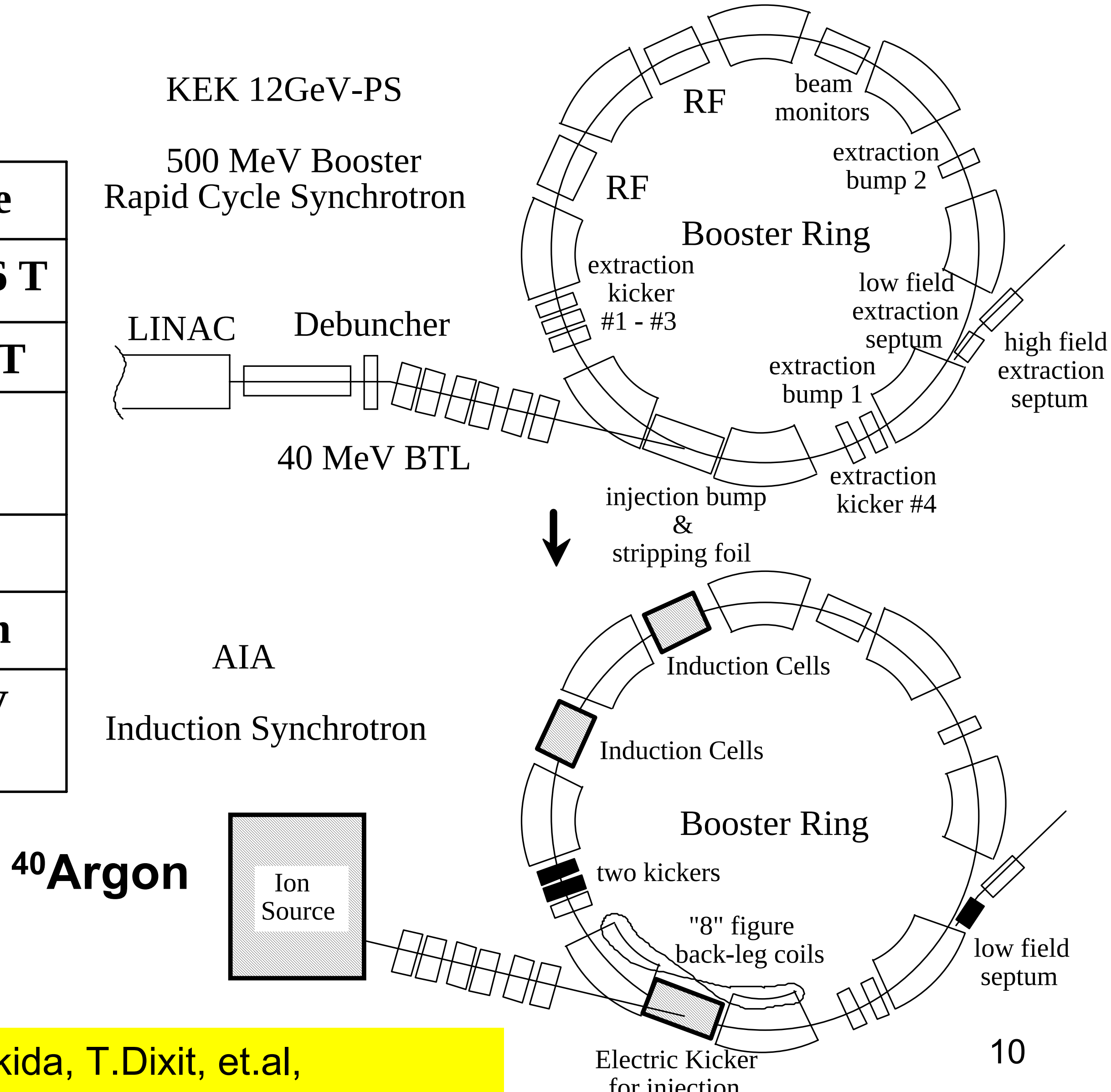
Low current bunch monitor
Low current ΔR monitor

Acceleration system

Acceleration scenario
New cell
Gate control system

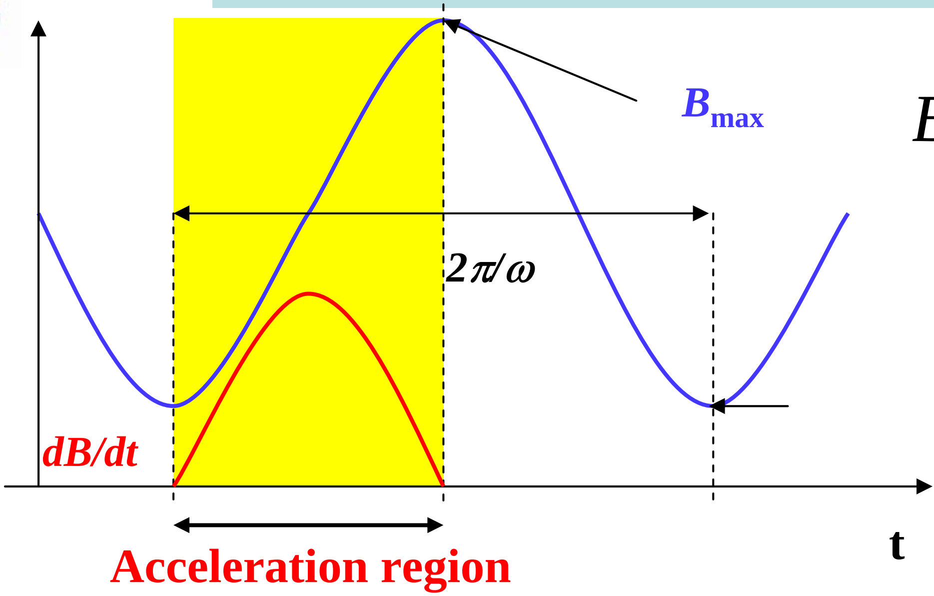
AIA using KEK PS-Booster

Parameters	Value
Magnetic flux, B_{min}	0.02916 T
Magnetic flux, B_{max}	0.8583 T
Frequency of magnet ramping	10 Hz
Bending radius, ρ	3.3 m
Circumference, C_0	37.71 m
Maximum acceleration voltage	3.24 kV



E. Nakamura, Y.Arakida, T.Dixit, et.al, Proceedings of PAC07, Albuquerque, NM USA

Booster Synchrotron –A Rapid cycle synchrotron



$$B(t) = B_{dc} - B_{ac} \cos \omega_{B_{ac}} t$$

$$V_{ac} = \rho C_0 \frac{dB(t)}{dt}$$

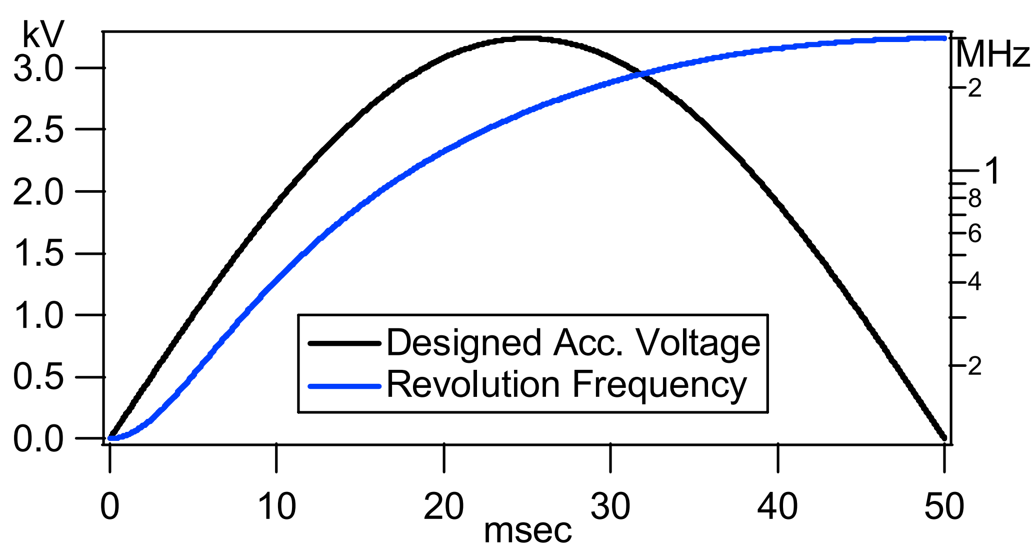
V_{ac}=3.24 kV (peak)

for 10 Hz operation

Acceleration voltage requirement always transient from 0 V to peak to 0 V

Solution - Pulse density control

Near injection, revolution time is large therefore longer flat acceleration voltage pulse is required

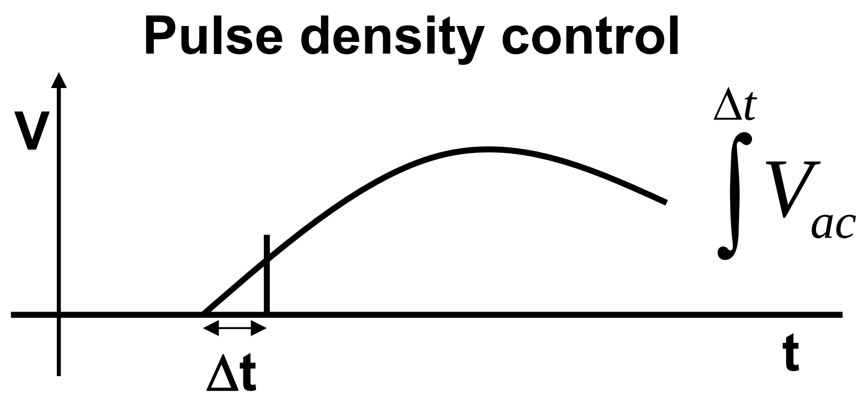


Pulse density control

- Trigger based system – acceleration voltage pulses can be controlled using trigger

Acceleration voltage requirement is dynamic ∝ dB/dt ⟷ **Induction acceleration cells output is fixed**

↓



$$\int^{\Delta t} V_{ac}\,dt = V_{cell}$$

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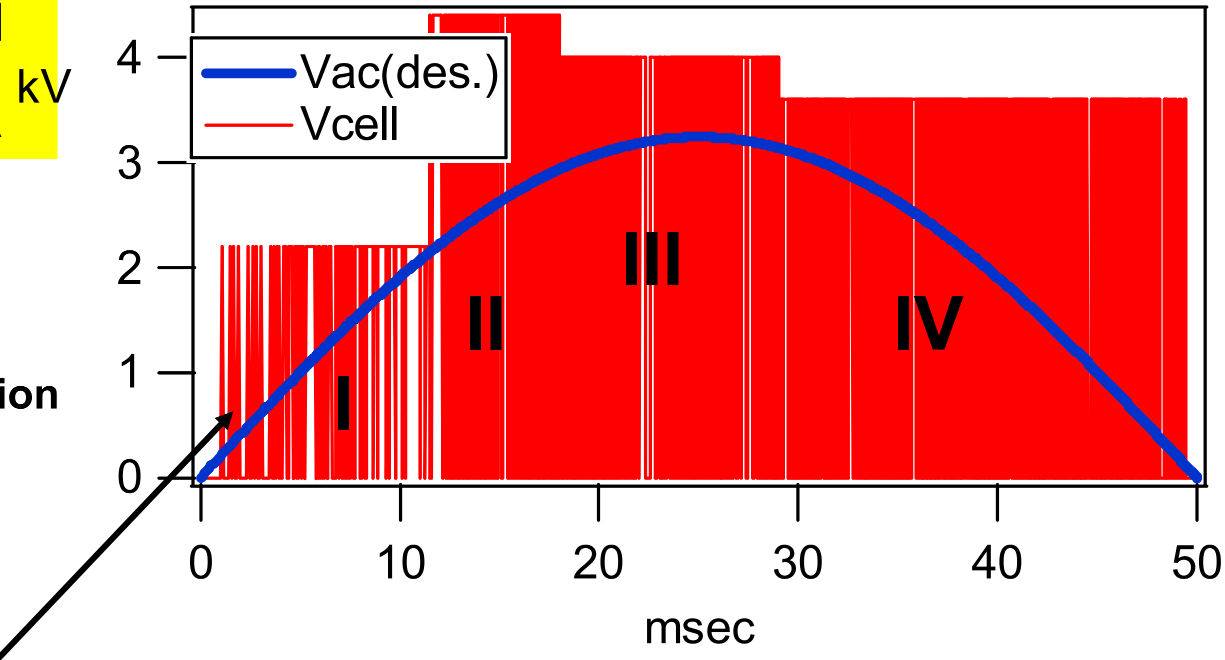
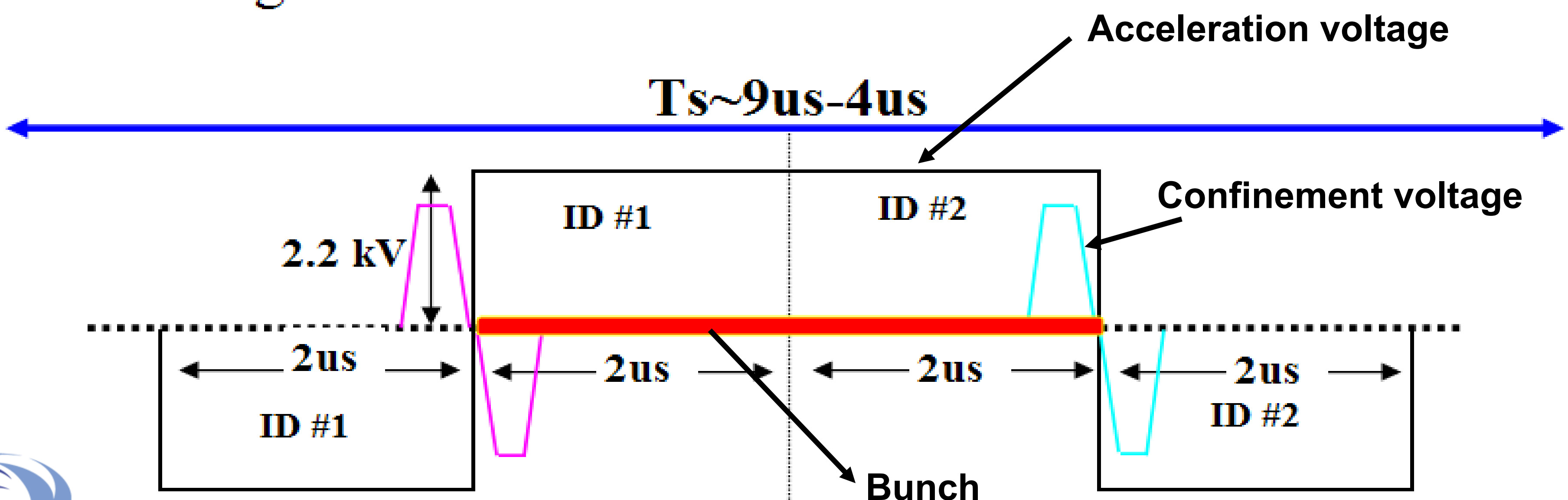
ACCELERATION SCHEME for AIA



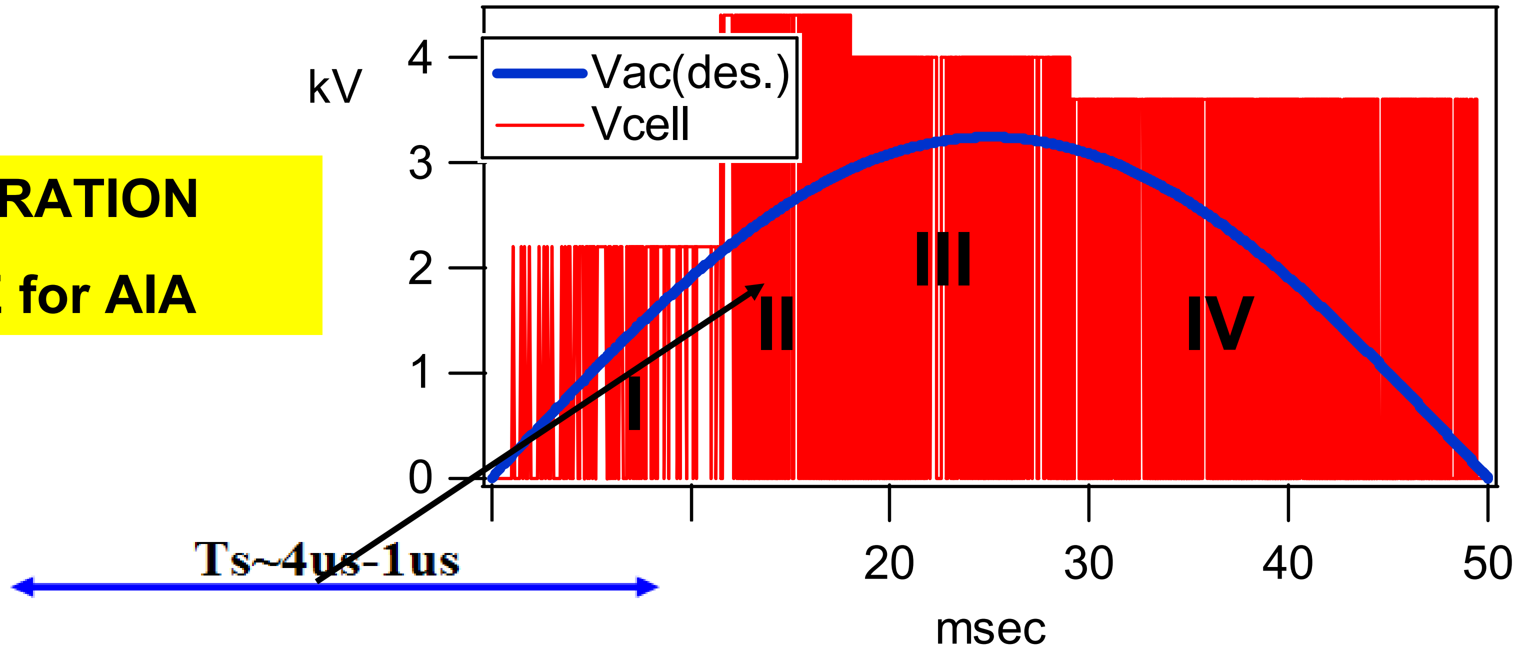
Prerequisites

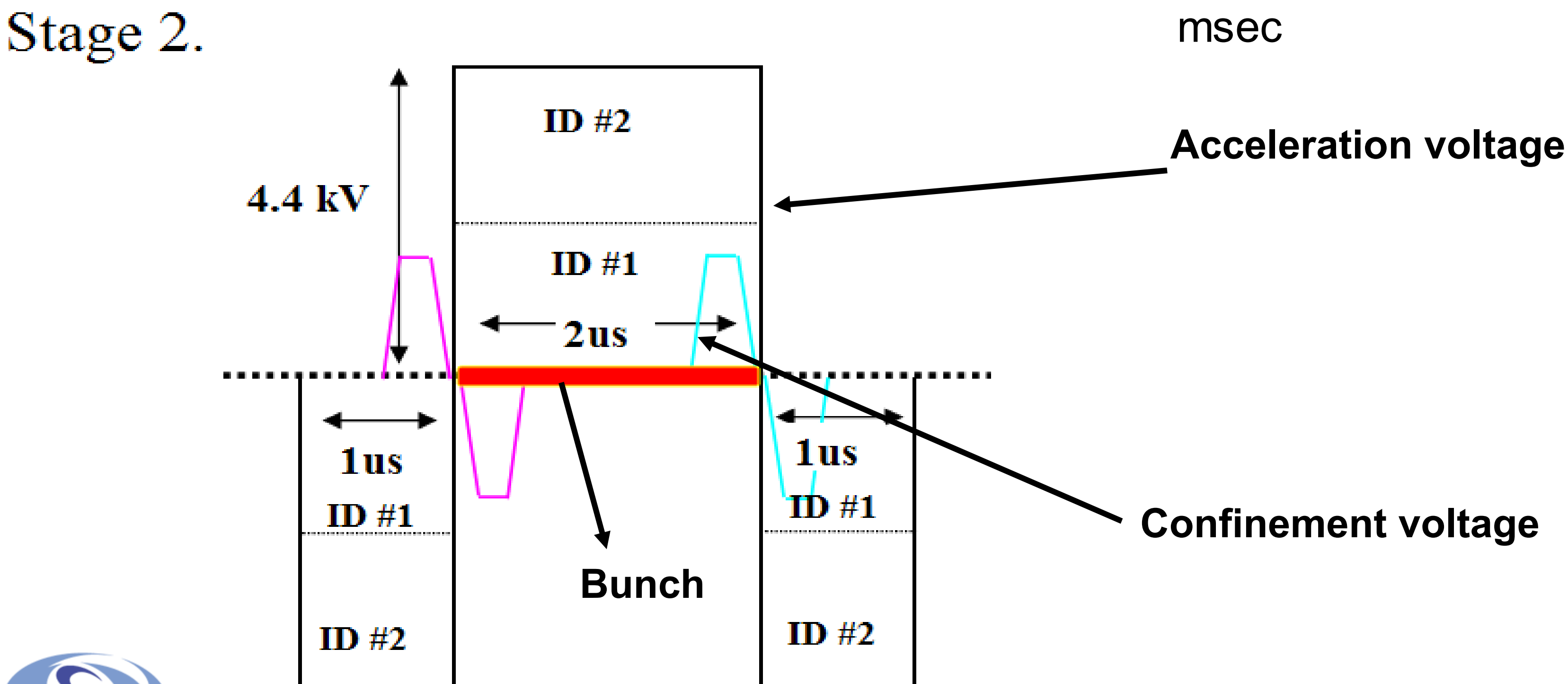
- •4 usec injected bunch
- •2.2 kV and 2 usec Acceleration voltage pulse
- •1.8 kV and 250nsec confinement voltage pulse

Stage 1.

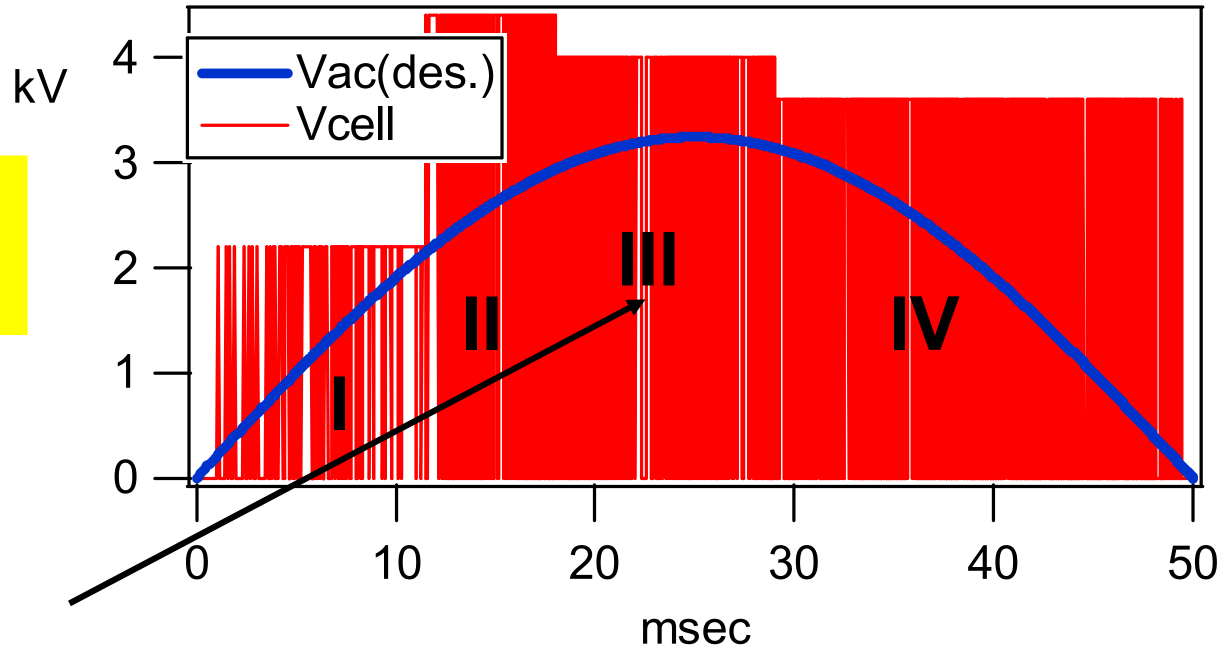


ACCELERATION SCHEME for AIA

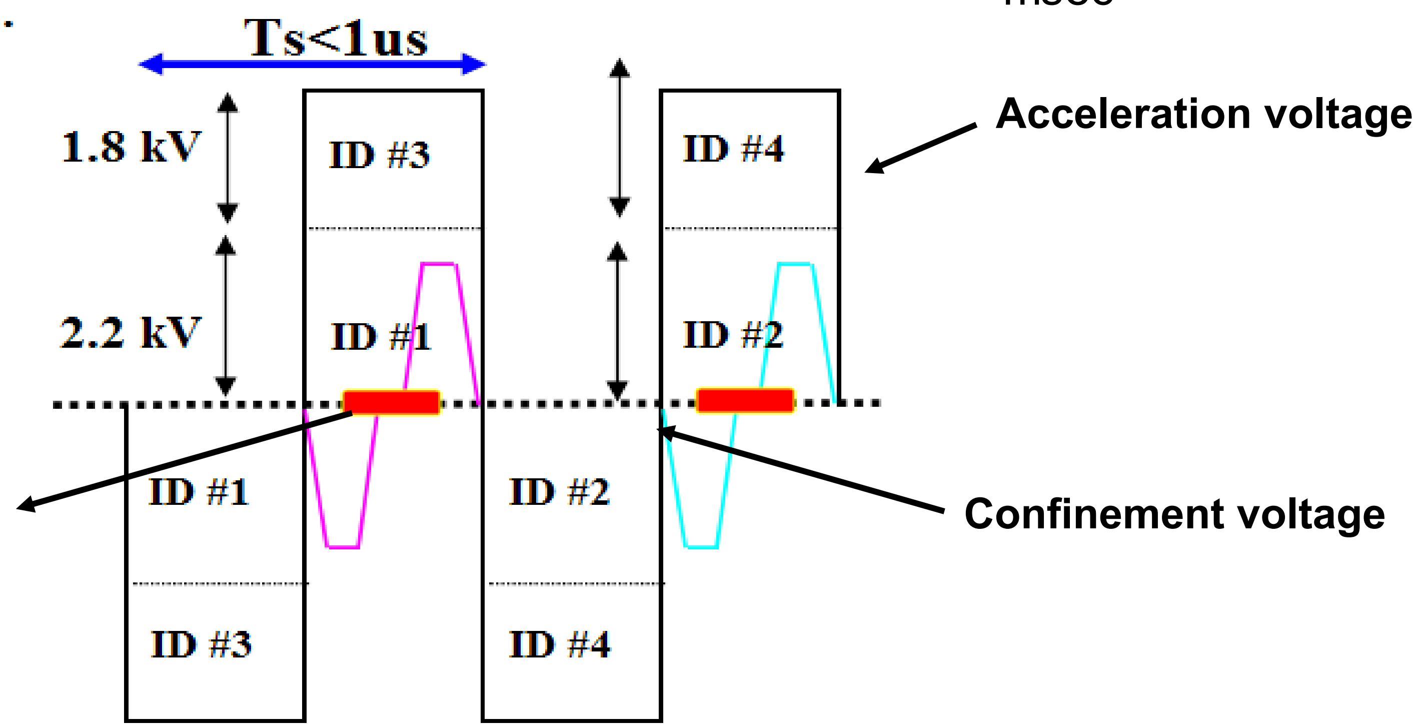




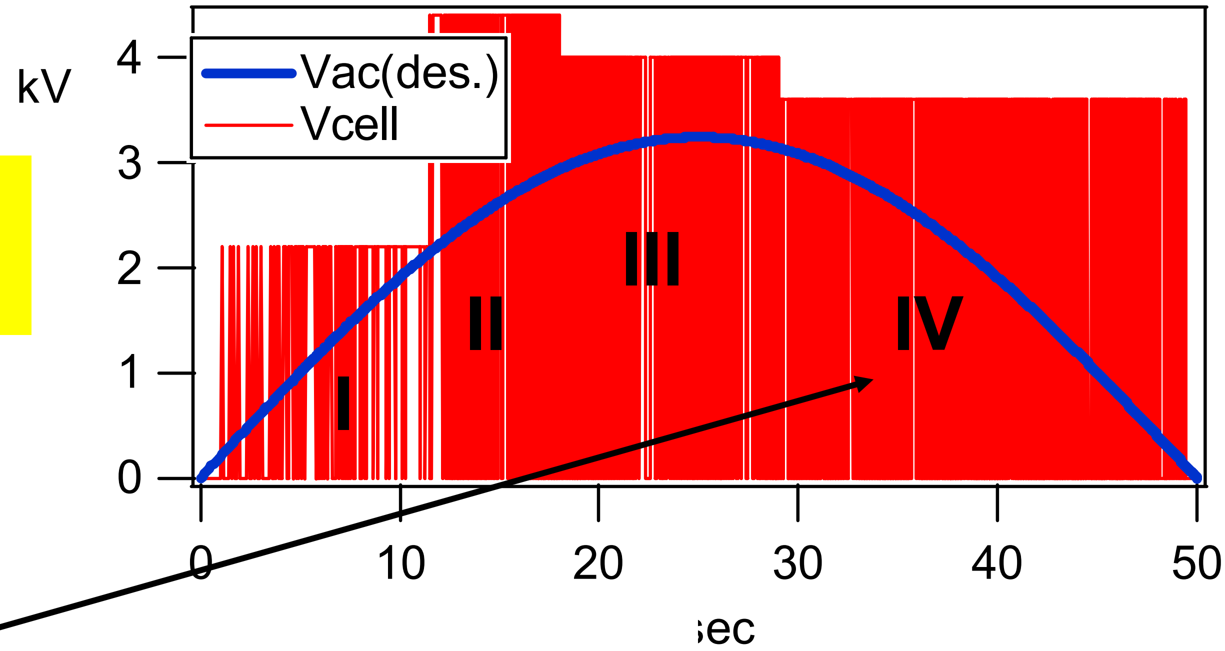
ACCELERATION SCHEME for AIA



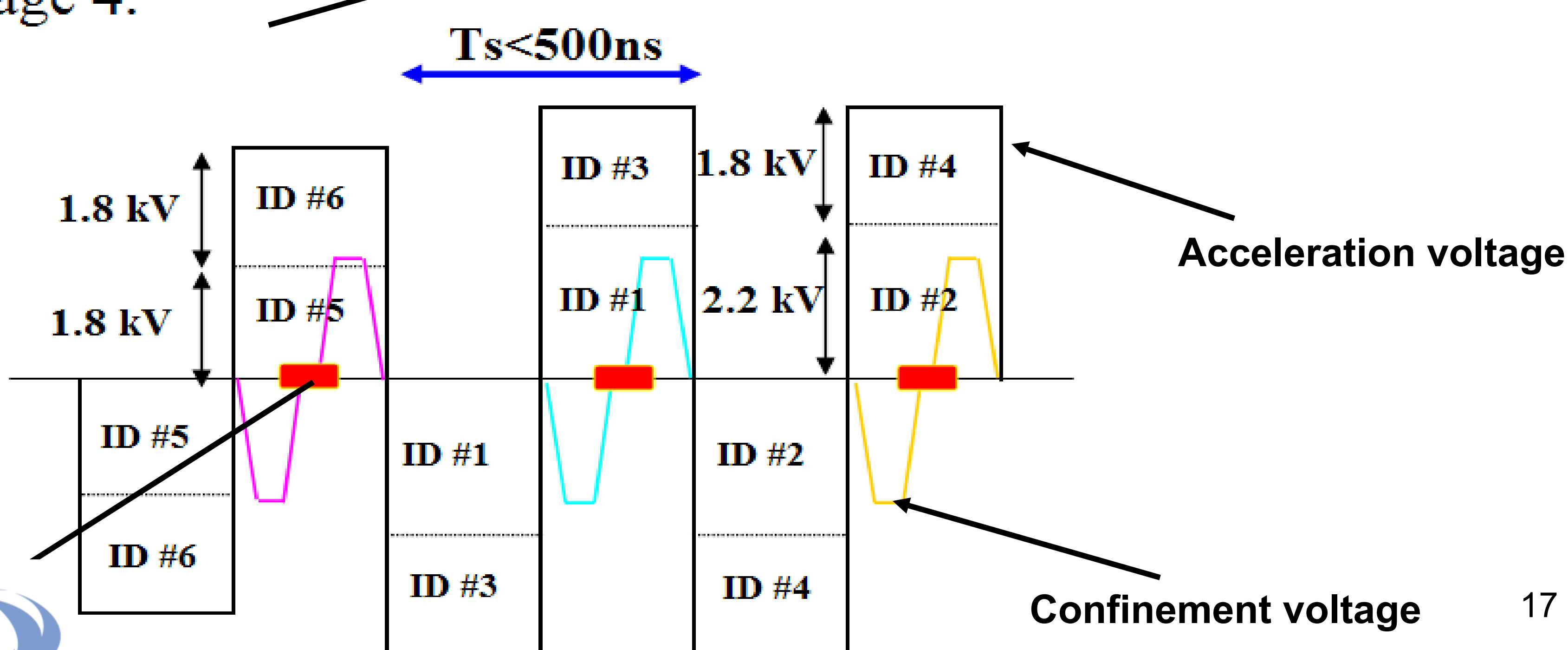
Stage 3.



ACCELERATION SCHEME for AIA



Stage 4.



Simulation results

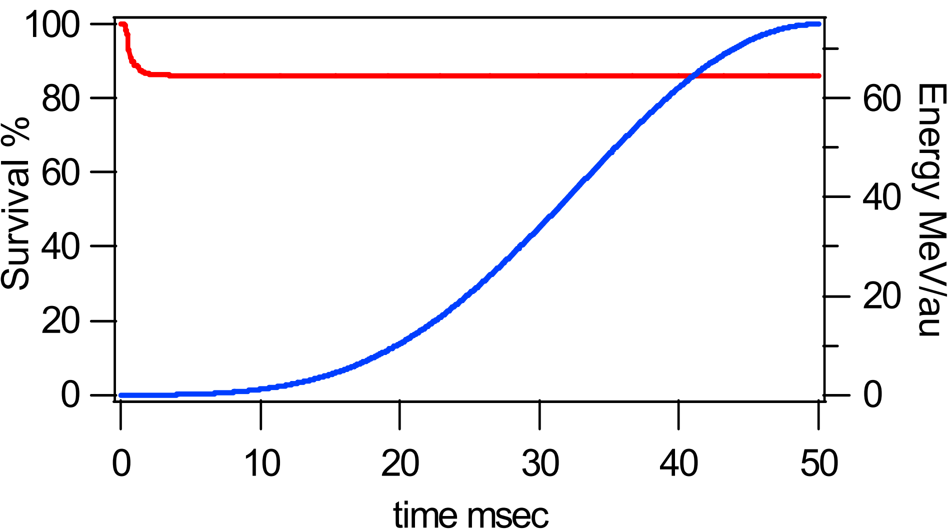
No. of particles – 10000

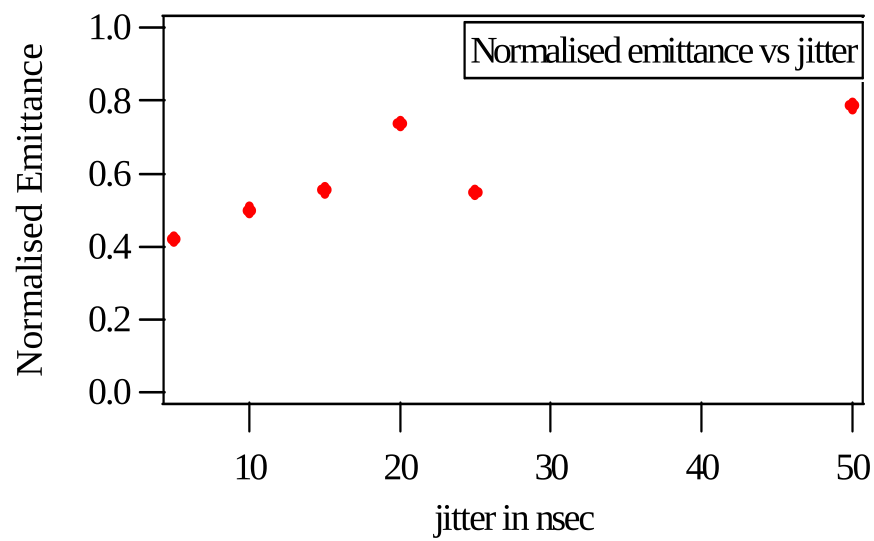
Initial beam Δp/p - ± 0.4% (assumption)

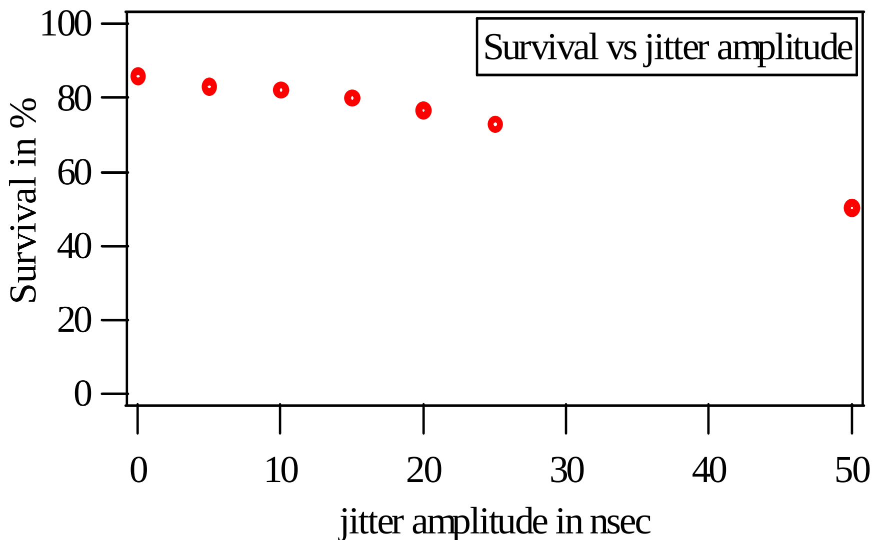
Momentum aperture - ± 1%

Barrier voltage - 1.8 kV

Beam survival & Energy gain Vs Time

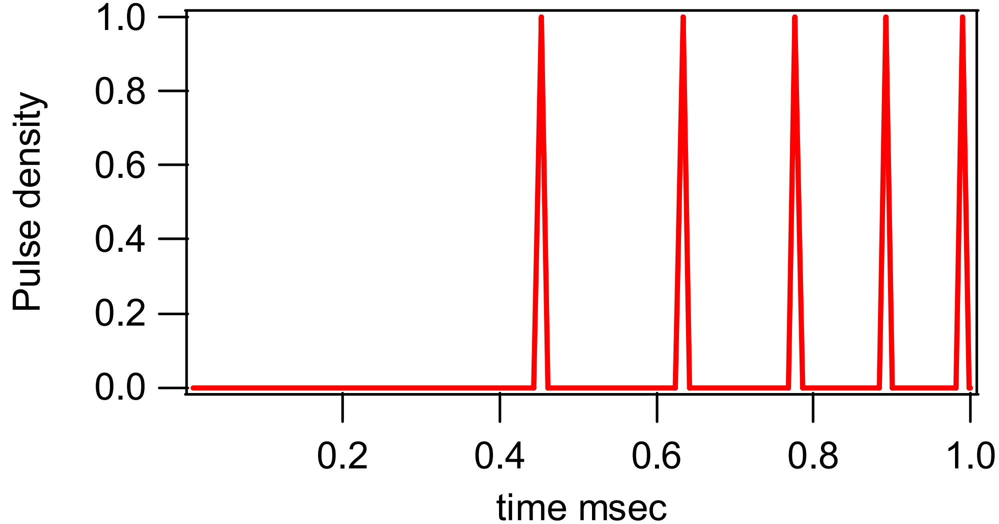


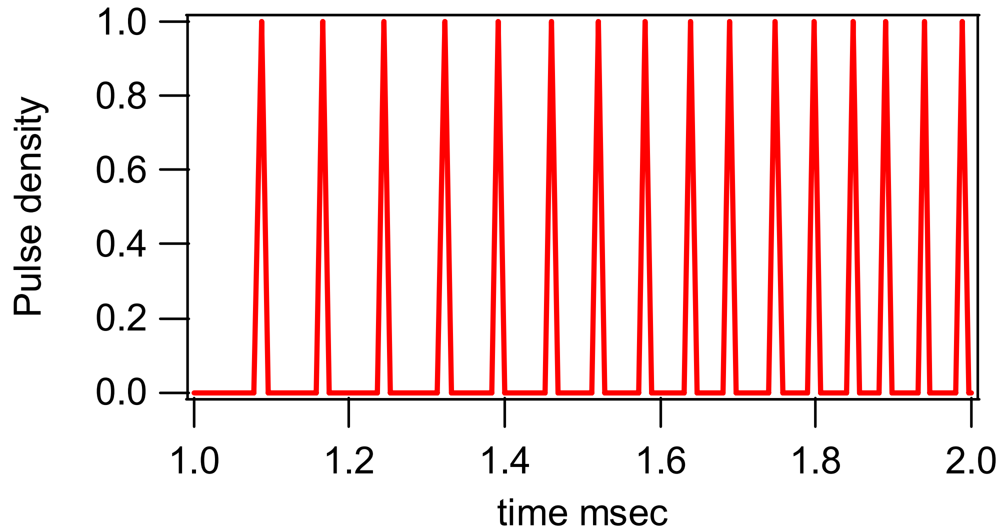




Simulation results

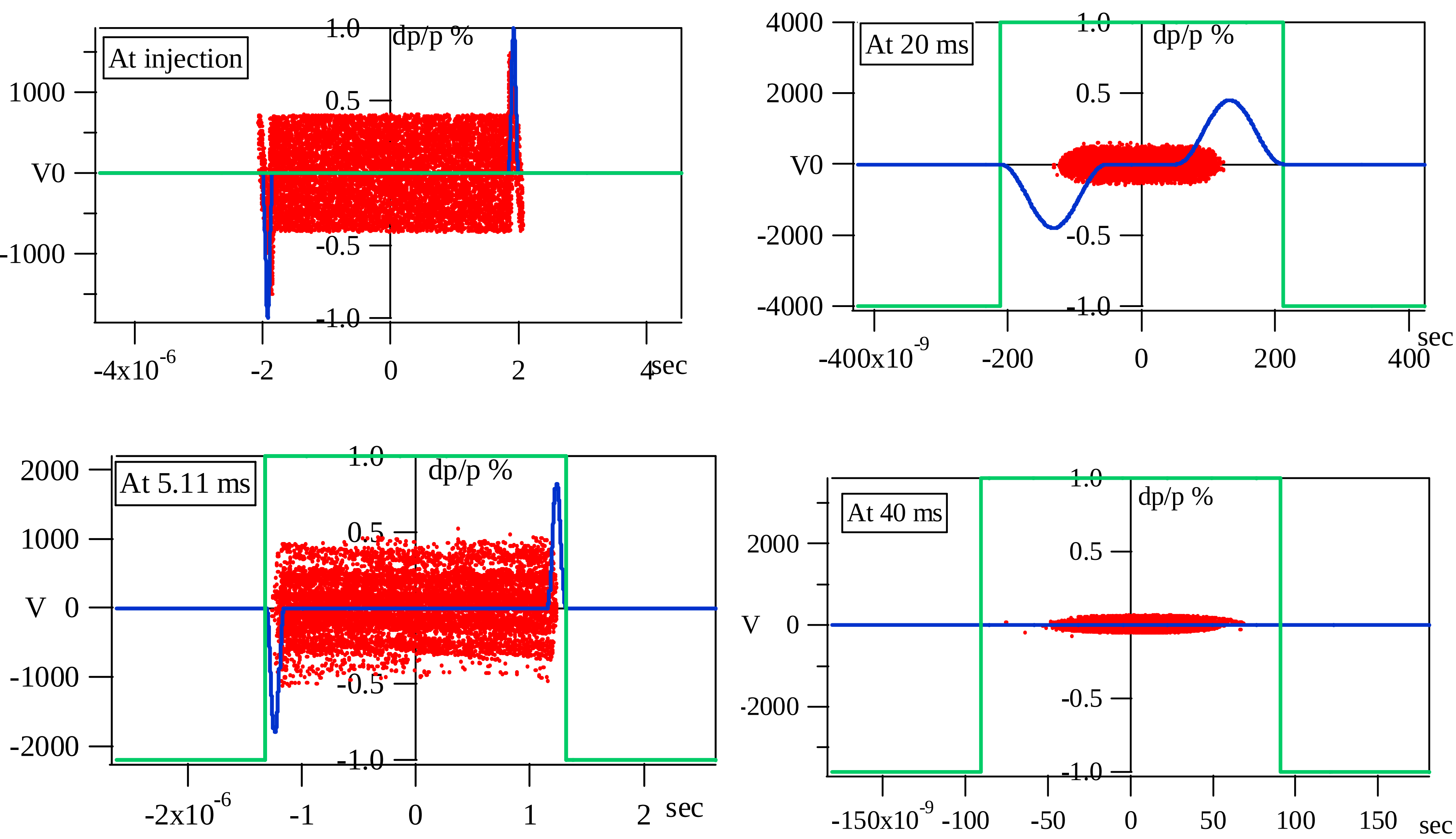
Pulse density Vs Time



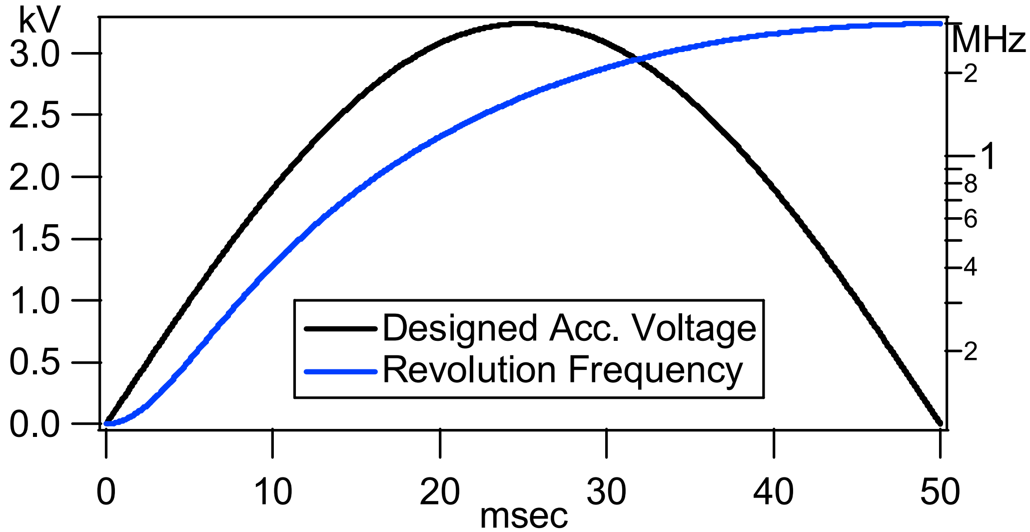


Argon Ion Longitudinal phase space plots

Blue- Barrier voltage pulse   Green-Acceleration voltage pulse   Red- Particles



New requirement-



Designed Acceleration voltage , Revolution Frequency Vs Time

- **Long acceleration voltage pulse**
- **Dynamic allocation of induction acceleration cells using DSP's**

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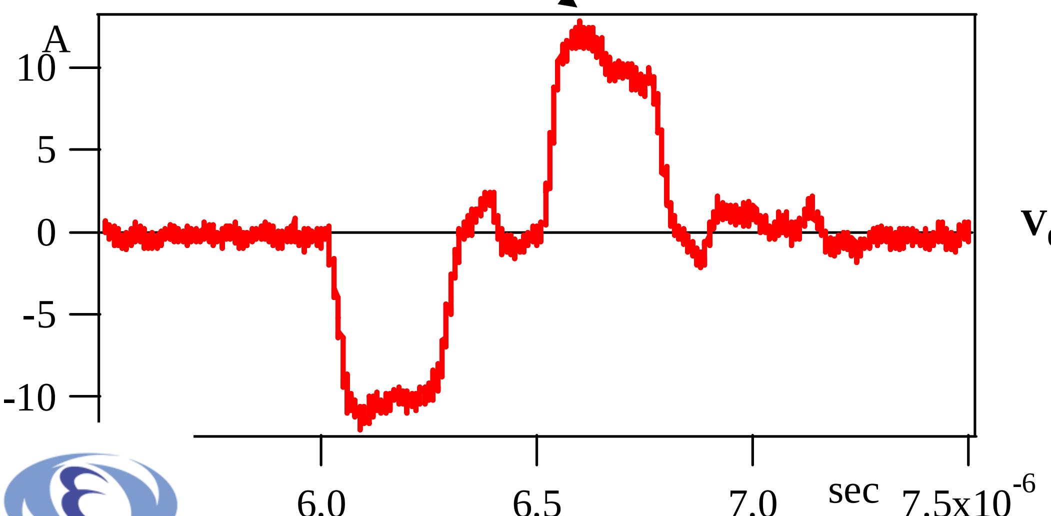
Existing Induction acceleration cell

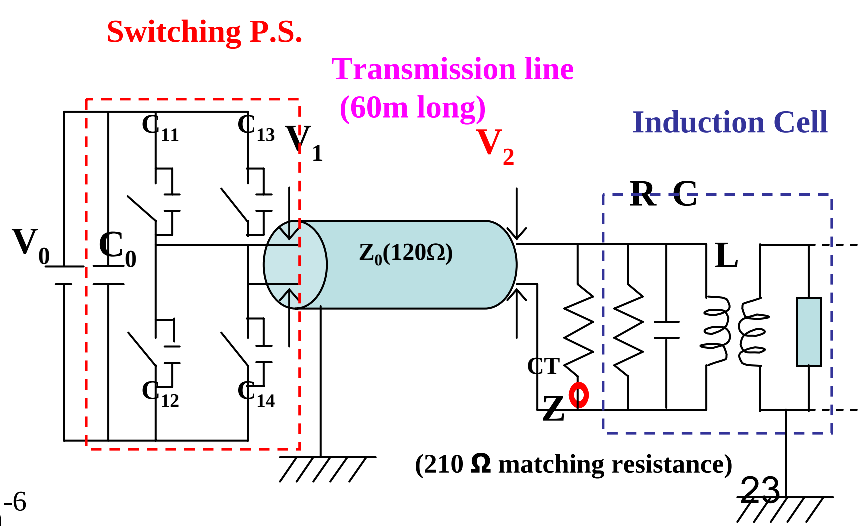
- Maximum rep-rate of 1 MHz
- Maximum output voltage of 2 kV with a droop of 15% in 250 ns

$$droop \propto \exp(-Zt/L)$$

where Z is total impedance (Cell + Matching resistance)

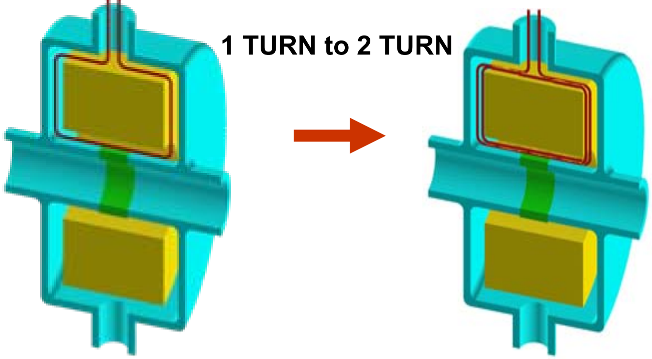
L is Inductance of Cell

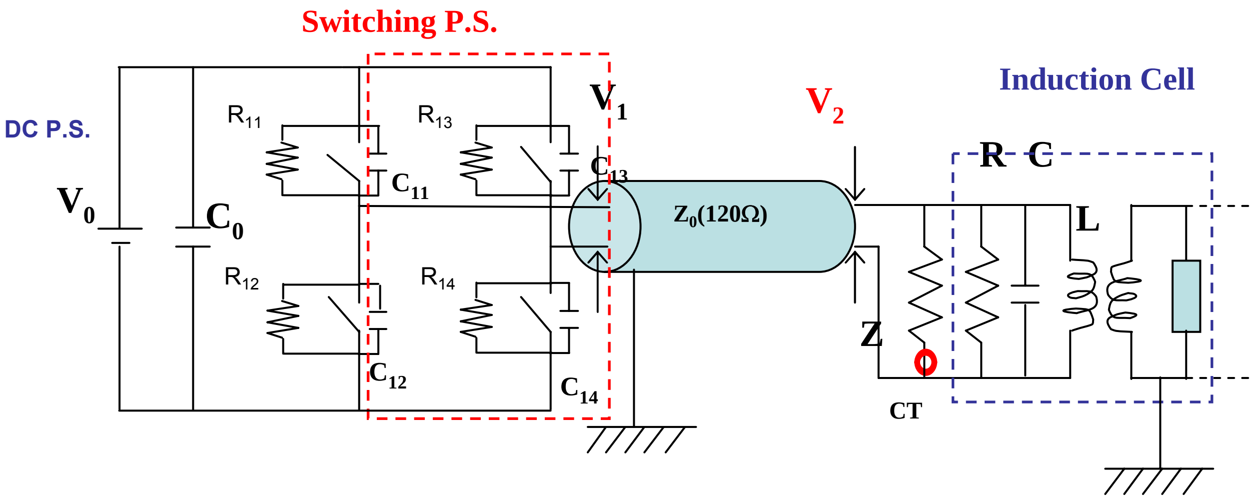


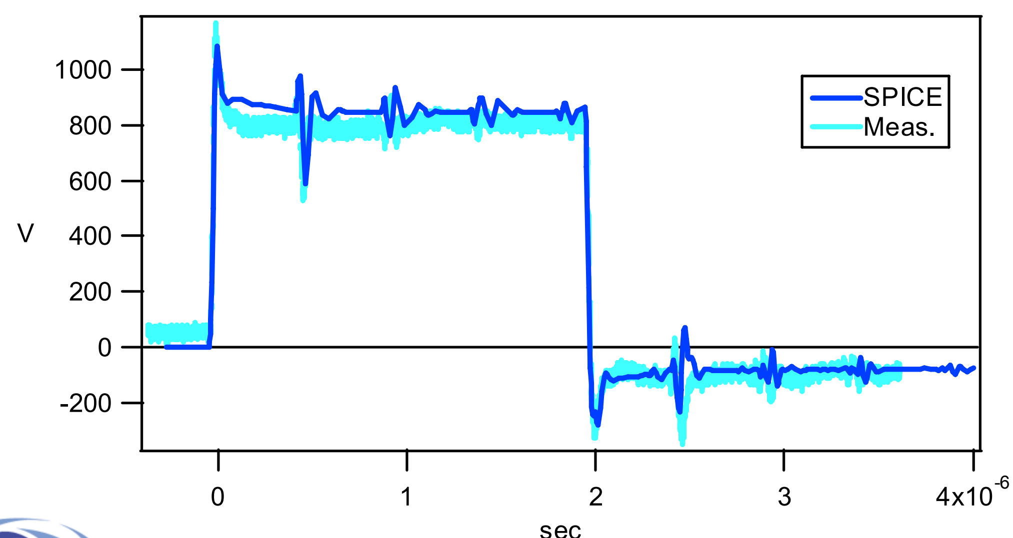


SPICE SIMULATION

Equivalent circuit







Demerit -

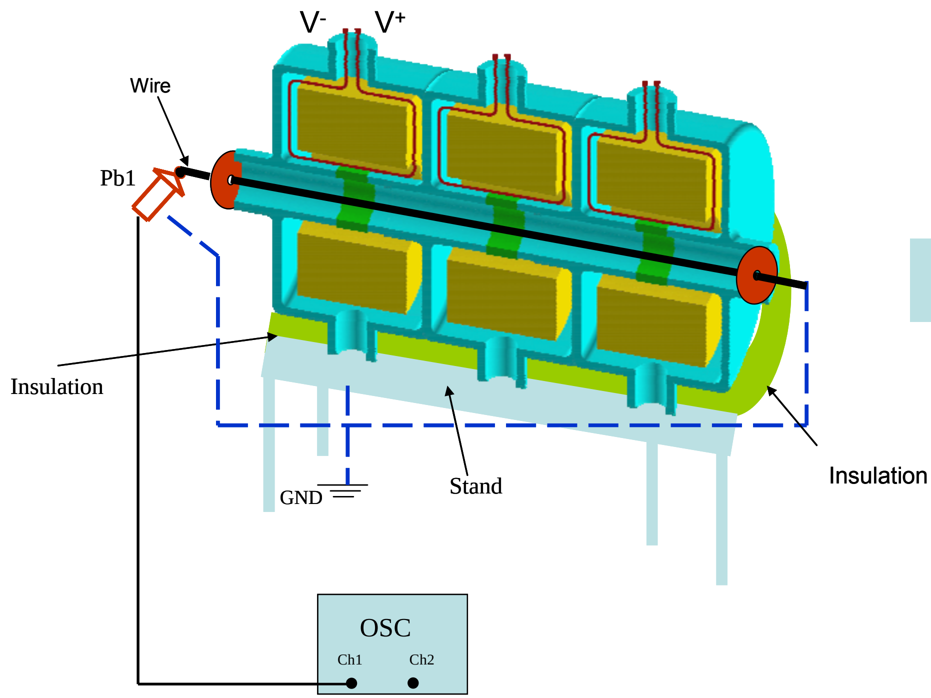
Secondary voltage becomes HALF

$V_s=V_p/2$

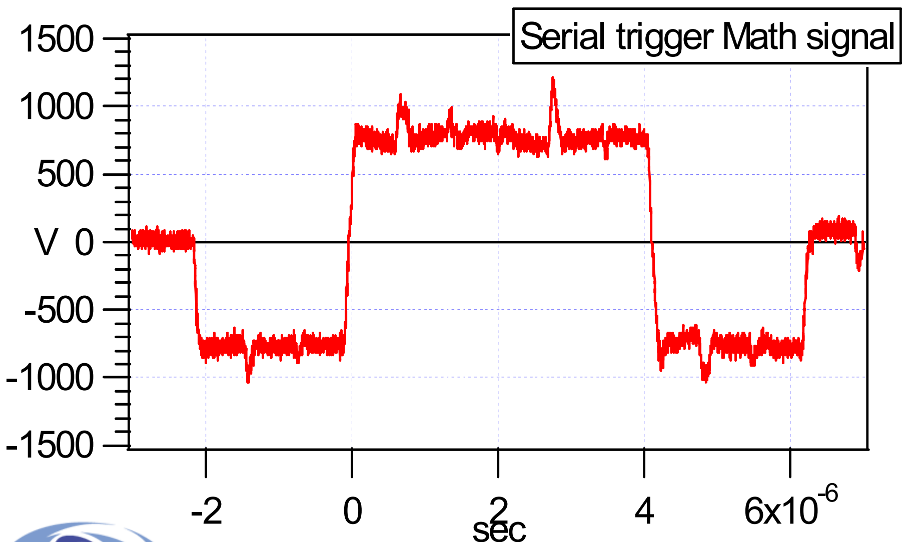
1 turn cell	2 turn cell
L=110 μH	L=440 μH
C=260 pF	C=180 pF
R=330 Ω	R=1280 Ω
R_m=220 Ω	R_m=134 Ω

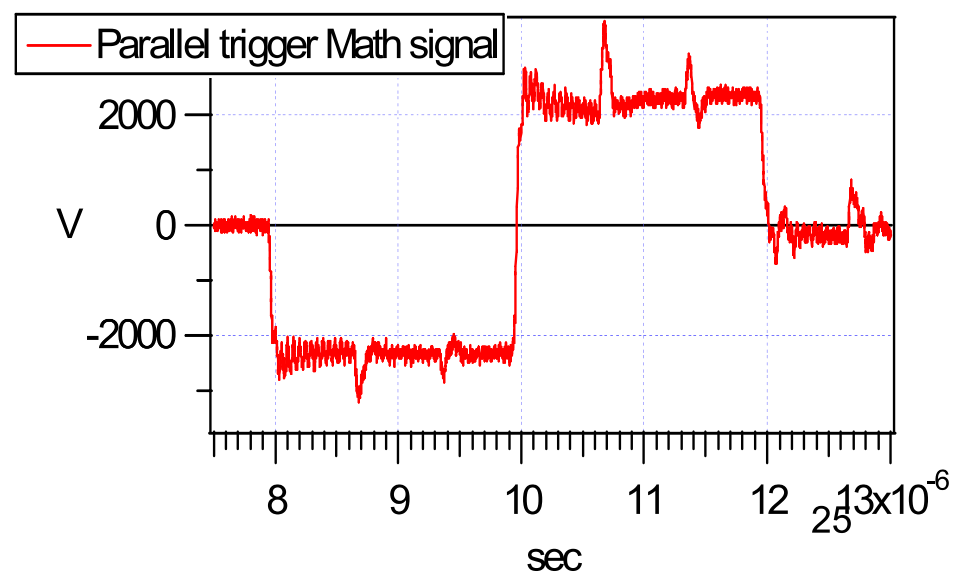
- **Flatness due to multiple reflections**
- **Undershoot because of downstream circuit conditions**

Wire experiment setup for 3 cells (2 turn)



Wire Measurement





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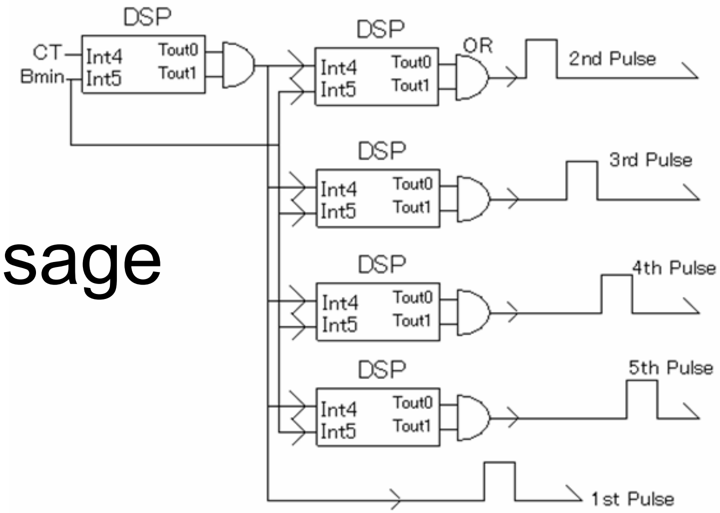
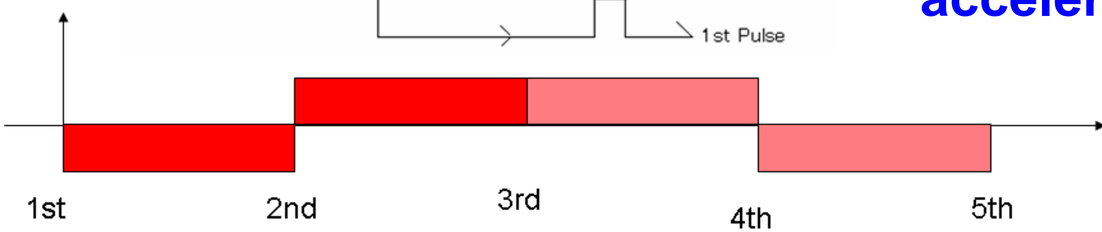
DSP usage



5 DSP's needs to be synchronized for start and stop of generation of SET/RESET pulse of acceleration



beam simulator

DSP

Gate control

Optical trigger unit

Switching Power Supply

Power line

DC power supply

Acceleration cell

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Year	2007	08	09
Accelerator			
ECR ion source	→	→	
cluster ion source	→	→	→
modification works			
•beam line	→	→	
•replacement of RF by IAS		beam commission →	→