HIRFL-CSR

Construction and Commissioning

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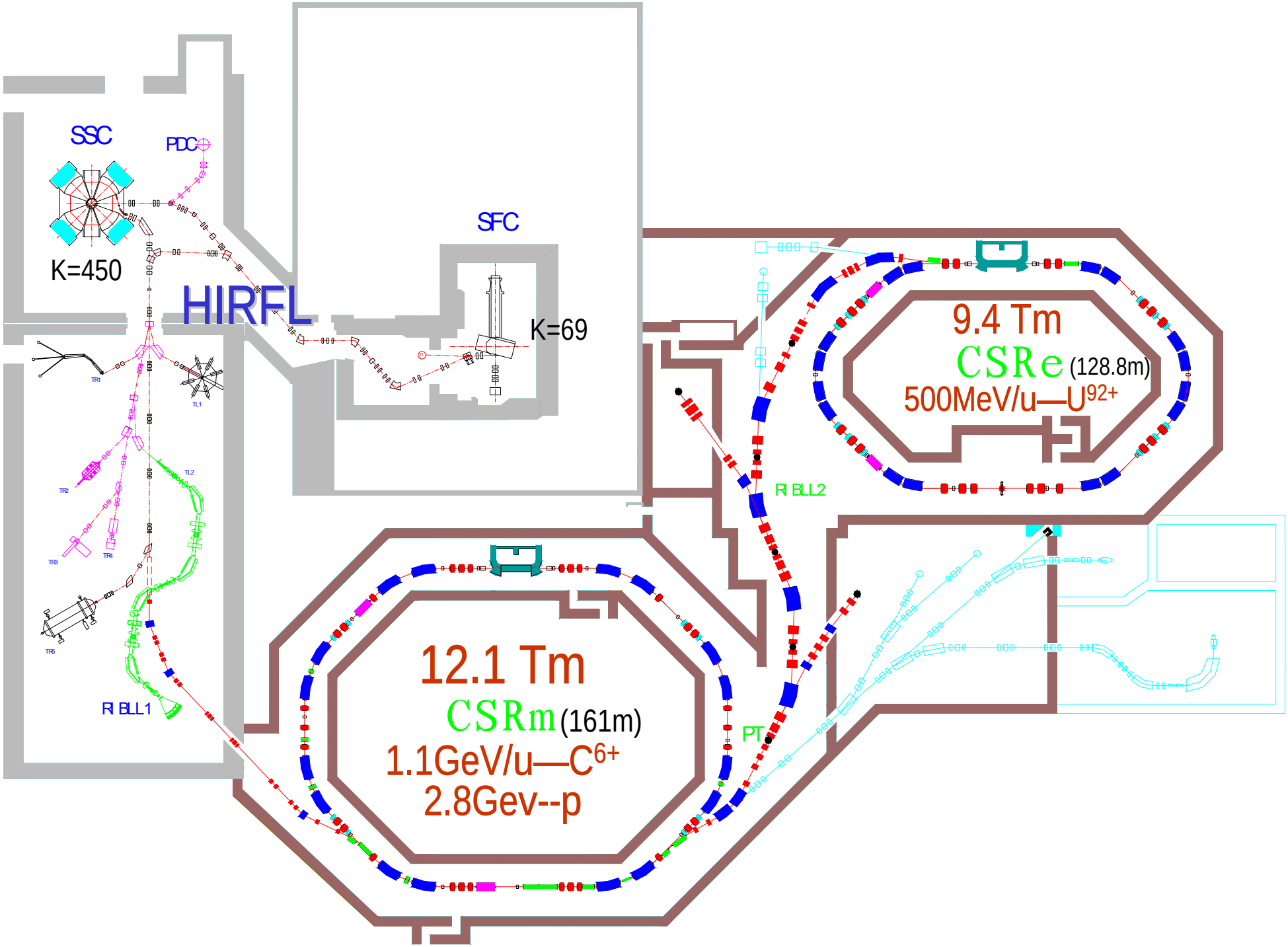
Major accelerator projects in China

HIRFL-CSR Layout



- Project construction start: 1999
- Total cost: ~US$30M
  - Including two cooler-synchrotrons, transport lines, experiments, civil engineering (new buildings)

Physics Program of CSR

RIB physics
(With Radioactive Ion Beams)

Researches of hot nuclei
(With high-energy beams)

Atomic physics
(With highly charged heavy ions)

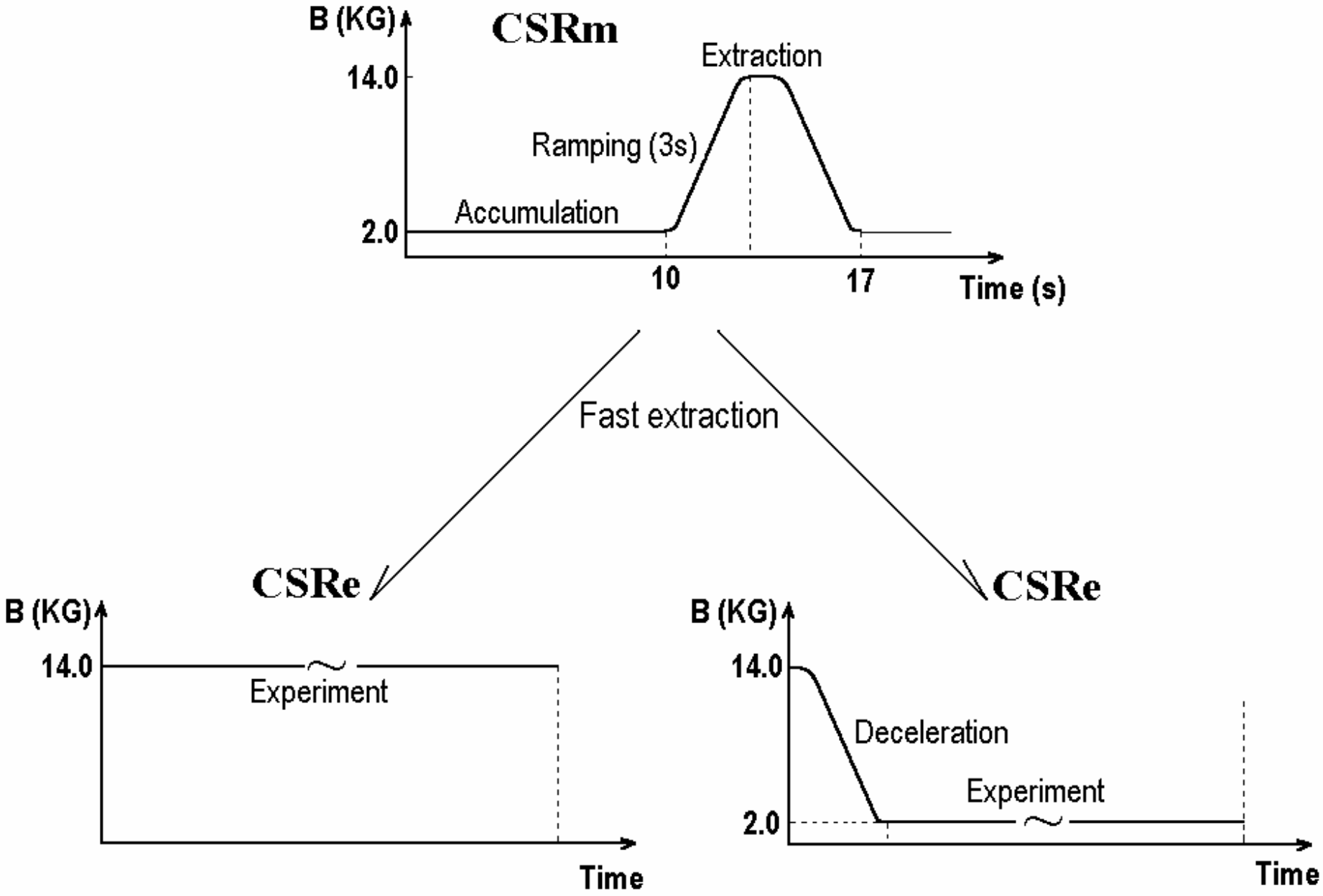
Related applications

CSR major parameters

	CSRm	CSRe
rcumference (m)	161.0014	128.8011
verage radius (m)	$8R_{SSC}=34R_{SFC}=25.62416$	$4/5R_{CSRm}=20.499328$
eometry	Race-track	Race-track
ax. energy (MeV/u)	2800 (p) 1100 (C^{6+}) 500 (U^{72+})	2000 (p) 750 (C^{6+}) 500 (U^{92+})
ρ (Tm)	0.81/12.05	0.50/9.40
(T)	0.10/1.60	0.08/1.60
amping rate (T/s)	0.05 ~ 0.4	-0.1 ~ -0.2
epeating circle (s)	~17 (~10s for Accumulation)	
cceptance	Fast-extraction mode	Normal mode
A_h (π mm-mrad)	200 ($\Delta p/p = \pm 0.3$ %)	**150** ($\Delta p/p = \pm 0.5$%)
A_v (π mm-mrad)	40	**75**
Δp/p (%)	1.4 (ε_h= 50 π mm-mrad)	**2.6** (ε_h= 10 π mm-mrad)

	CSRm		CSRe
E-cooler			
Electron energy (KeV)	35		300
Eff. cooling length (m)	3.4		3.4
RF system	Accel.	Accum.	Decelerati
Harmonic number	1	16, 32,64	1
f_{min}/f_{max} (MHz)	0.24/1.81	6.0 / 14.0	0.4 / 2.0
Voltages (n × kV)	1 × 7.0	1 × 20.0	2 × 10.0
Vacuum (mbar)	(3.0×10^{-11})		

CSR Operation Scheme



CSRm injection scheme

C, N, O, F, Ne, Ar, Ca, A≤40, E = 7---10 MeV/u

SFC + CSRm

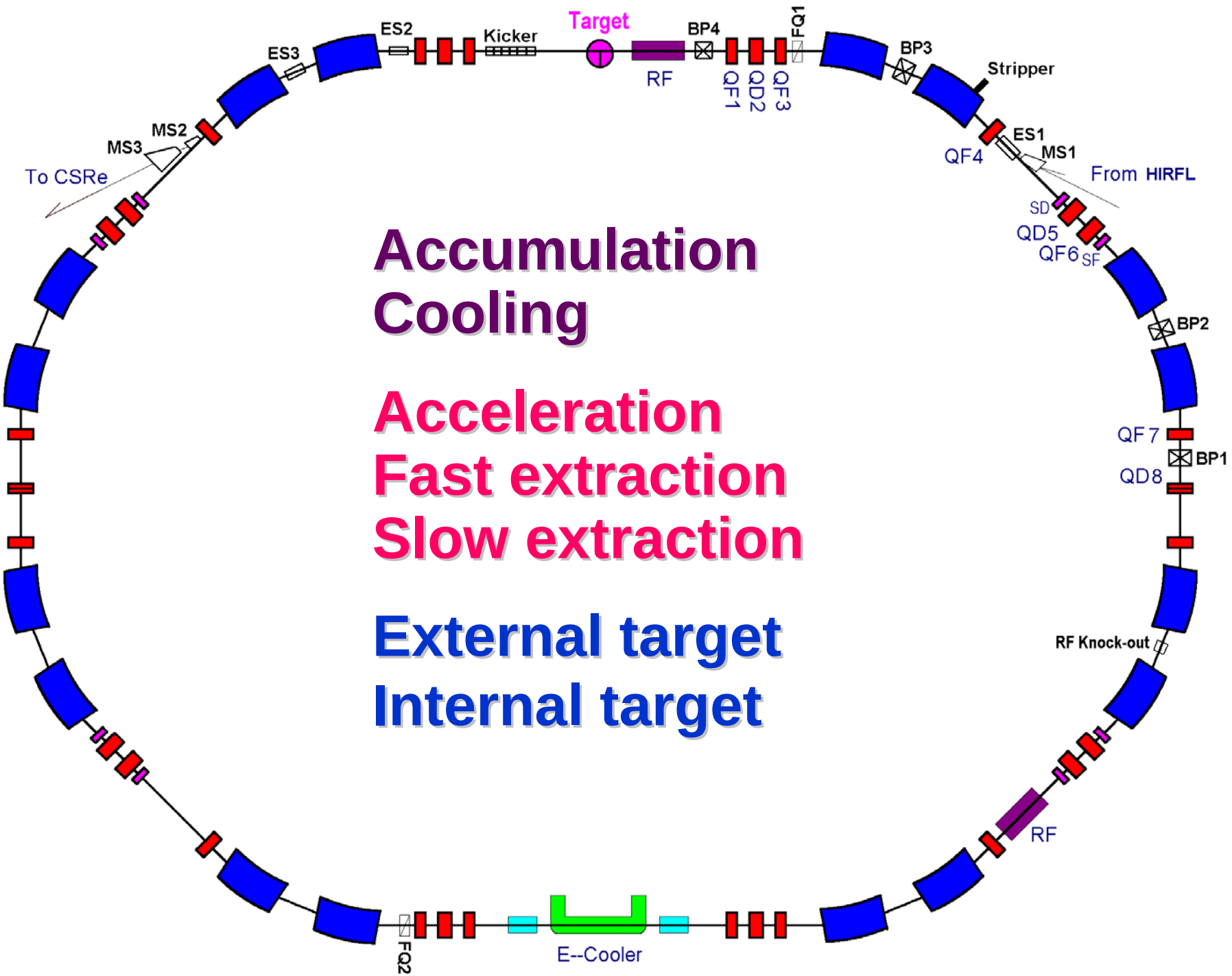
Stripping injection (A≤20) + e-cooling →→ I=10^9

MMI + RF stacking (20≤A<40) + e-cooling →→ I=10^9

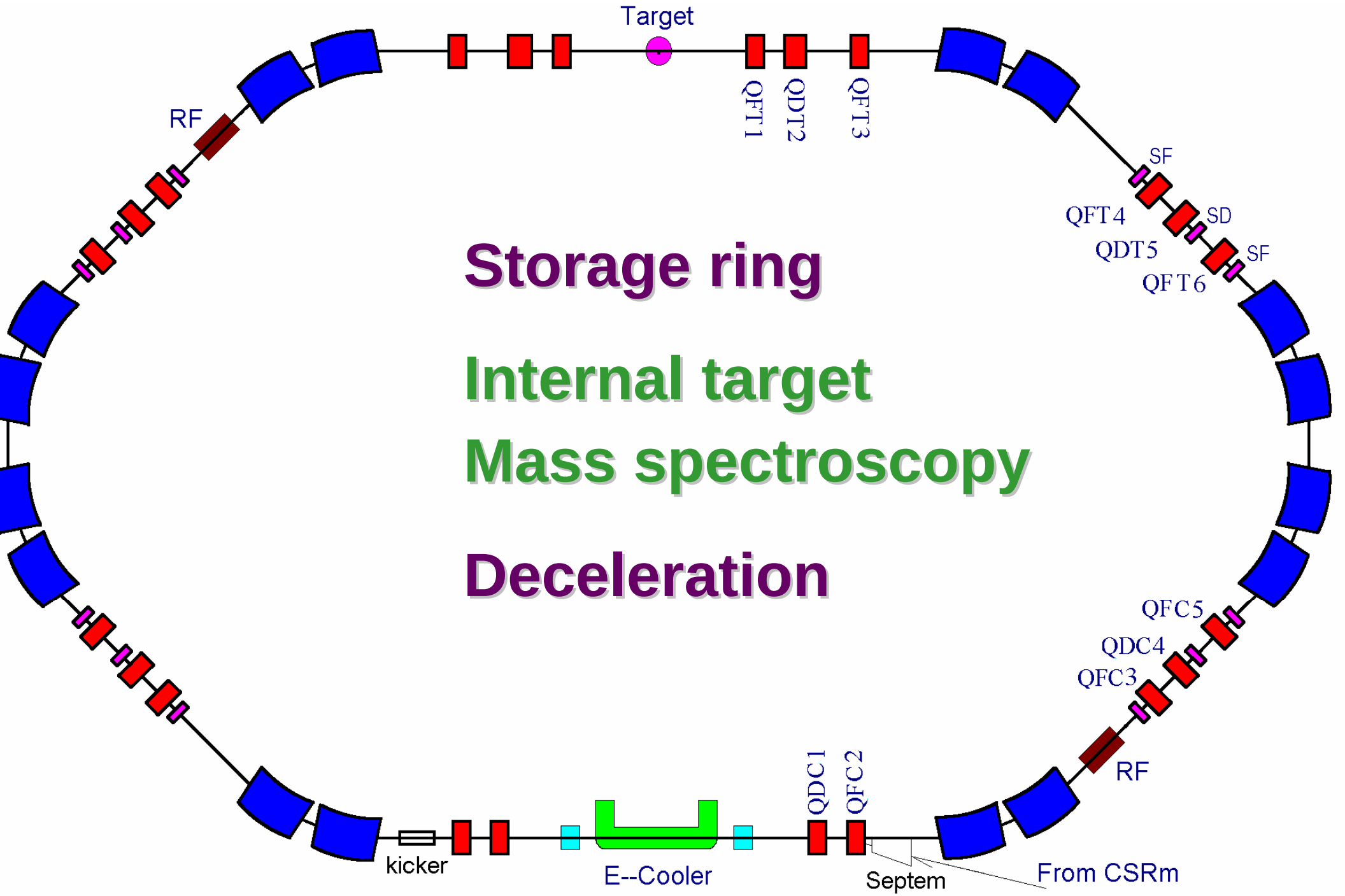
Kr, Xe, Ta, Au, Pu, U, A ≥ 40, E = 10---25 MeV/u

SFC + SSC + CSRm

MMI + e-cooling (A≥40) →→ I=10^7



CSRm Lattice Layout



Storage ring

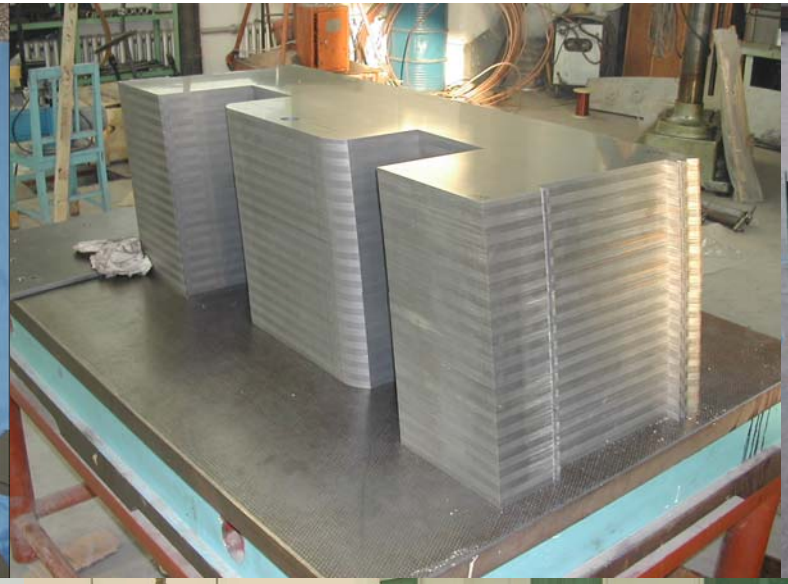
Internal target

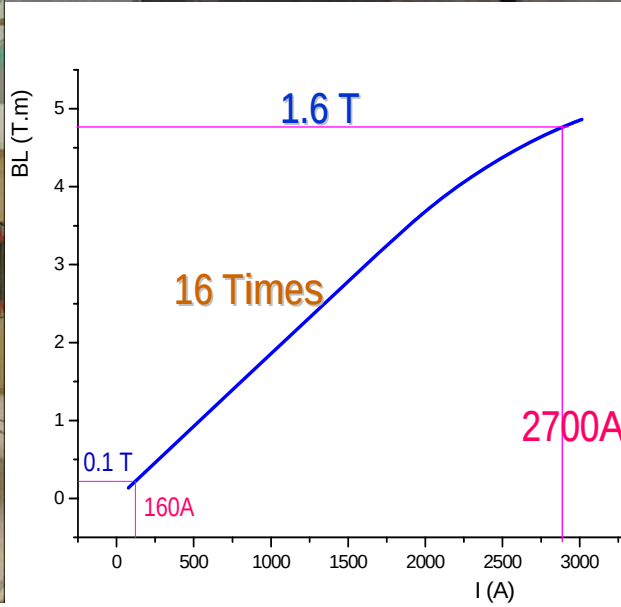
Mass spectroscopy

Deceleration

CSRe lattice layout

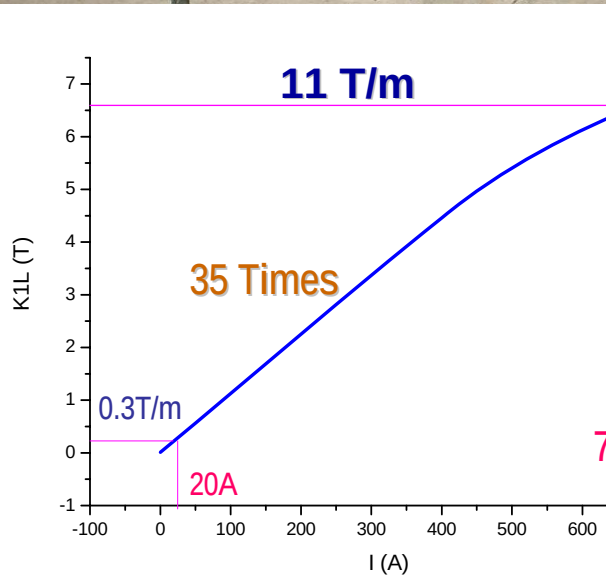
CSRm-dipole Fabrication





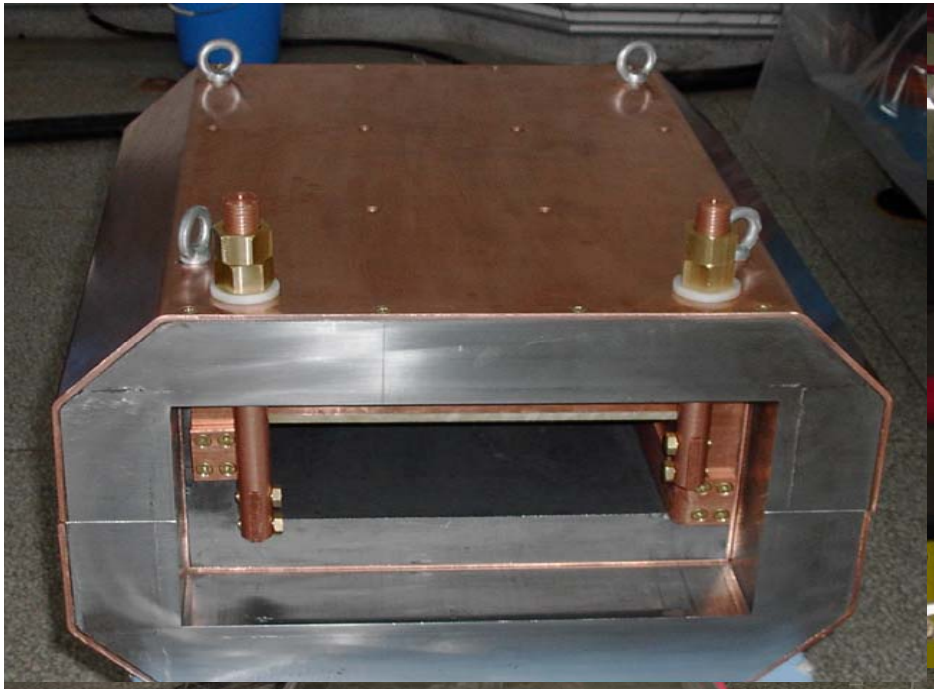
-Type, Angle=22.5^0, Rbend, Radius=7.6m, Air Gap=80mm, Useful aperture= **$140\times60mm^2$**, Precision= **3×10^{-4}**

CSRm-Quadruple Fabrication

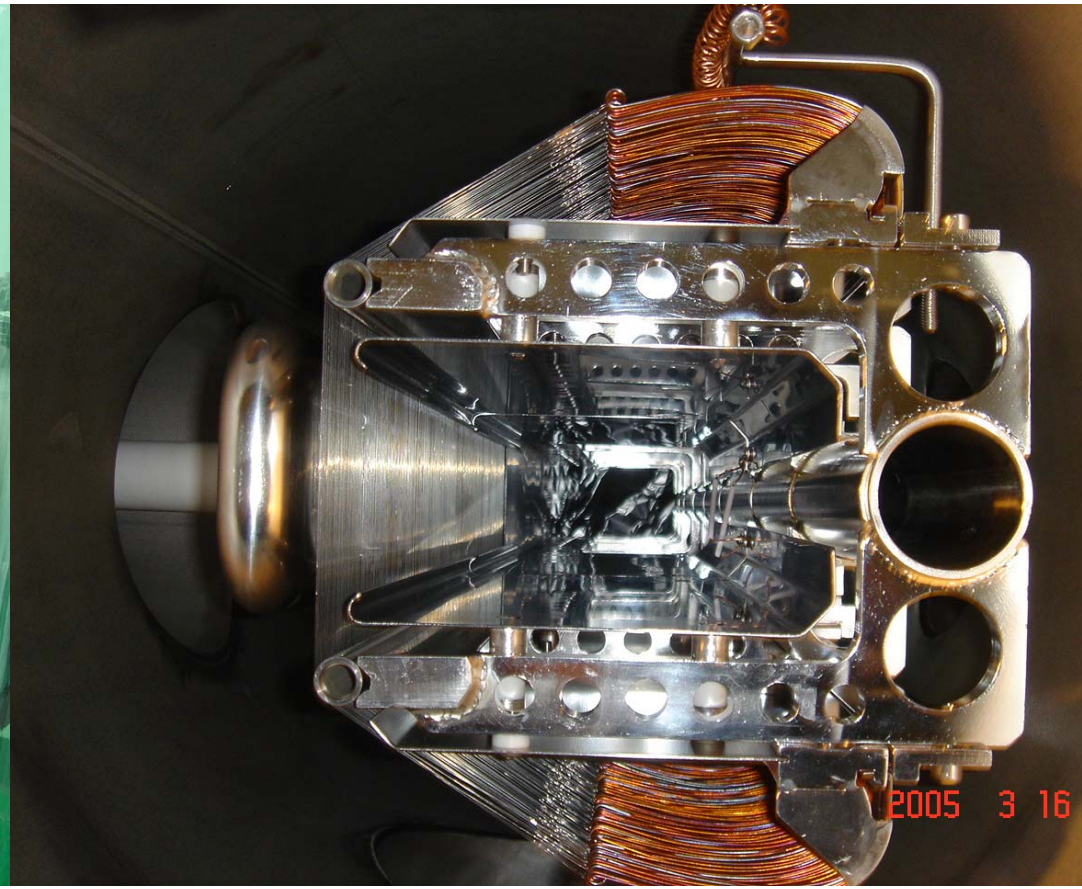


L=0.5m, 0.65m, Φ=170mm, Useful aperture= **160x100mm^2**, Precision= **1.5×10^{-3}**

Special magnets of CSRm



Static-electric septum (for multi-turn injection)



L = 2 m, $V_{max.}$ = 160 kV, Septum = **0.1mm**

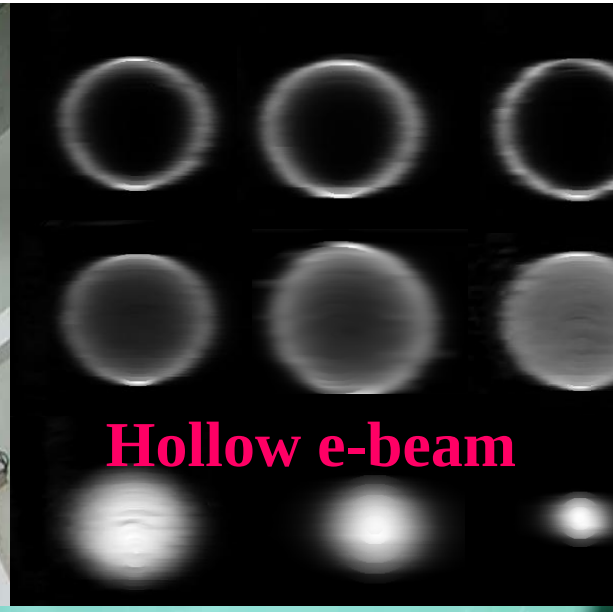
Kicker for fast extraction

$I_{max.}$ = 2700A

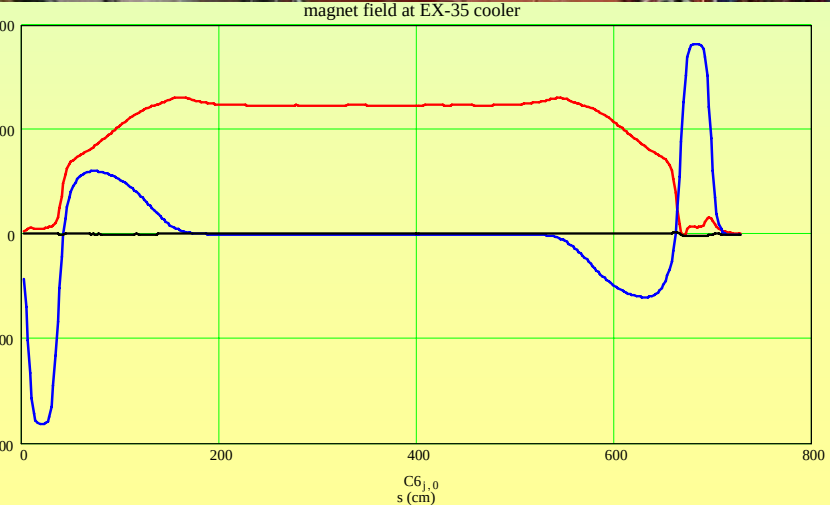
$V_{max.}$ = 60 kV

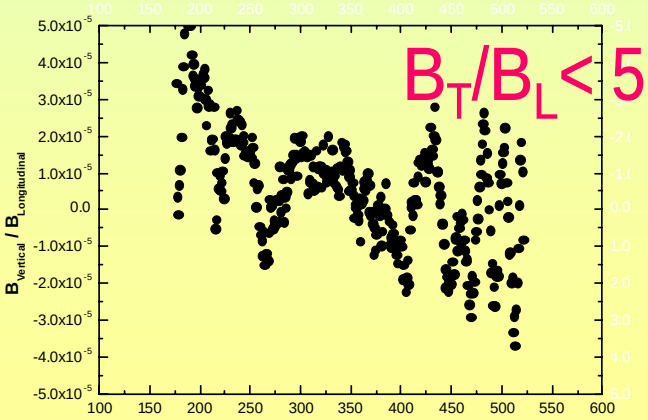
Rising time: 150ns

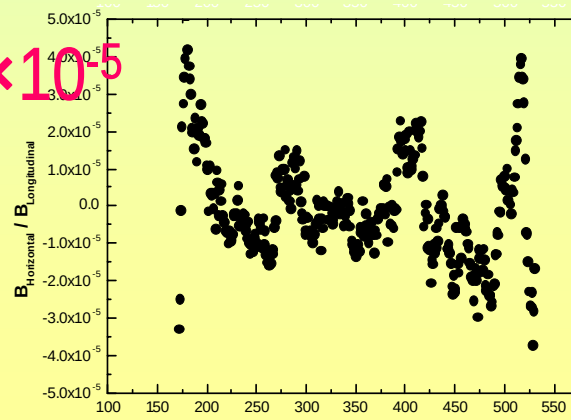
e-cooler
for ion cooling



magnet field at EX-35 cooler







CSRm RF System

RF-station for acceleration

f = 0.24 ~ 1.81 MHz, V_m= 7 kV

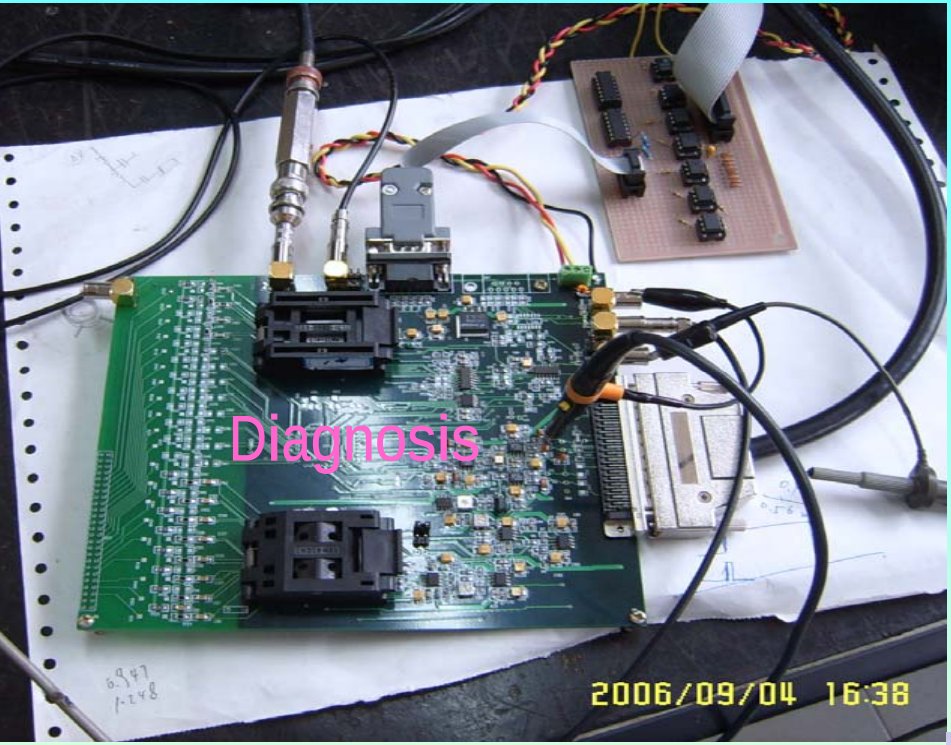
RF for beam accumulation

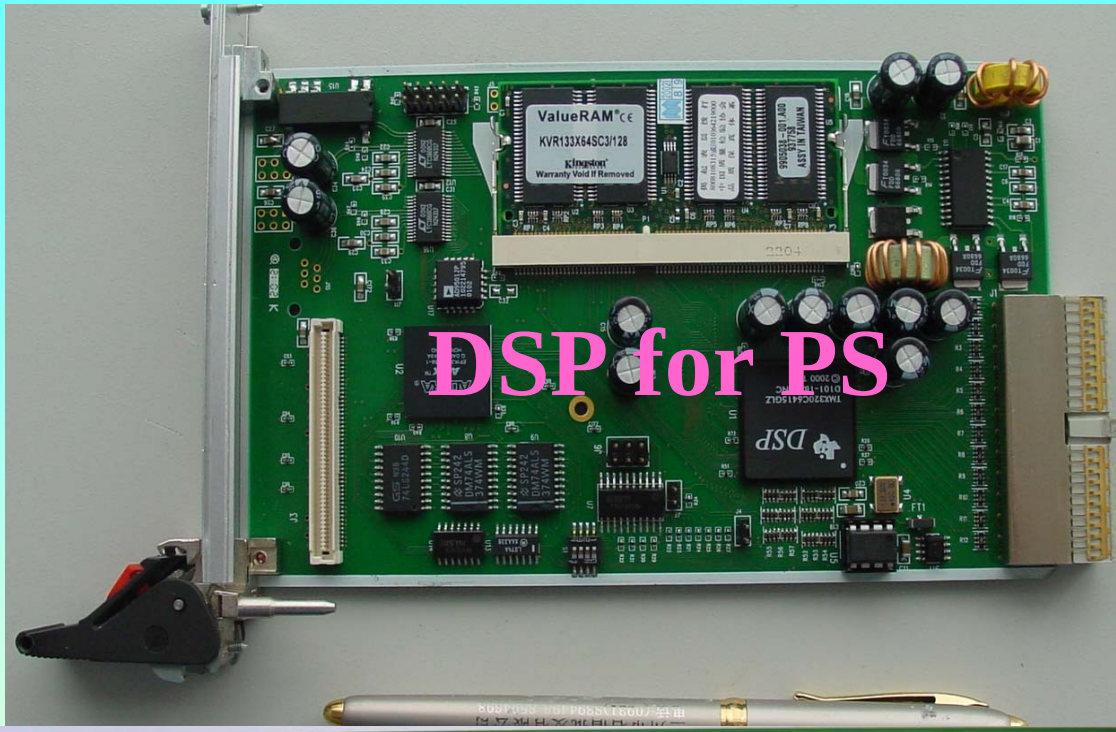
f = 6 ~ 14 MHz, V_m= 20 kV

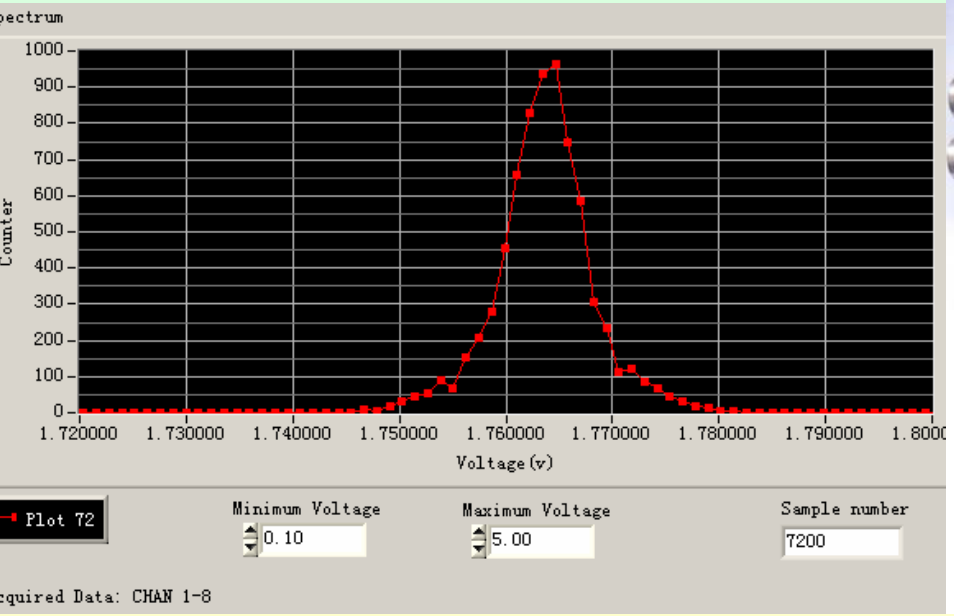
UHV System of CSR

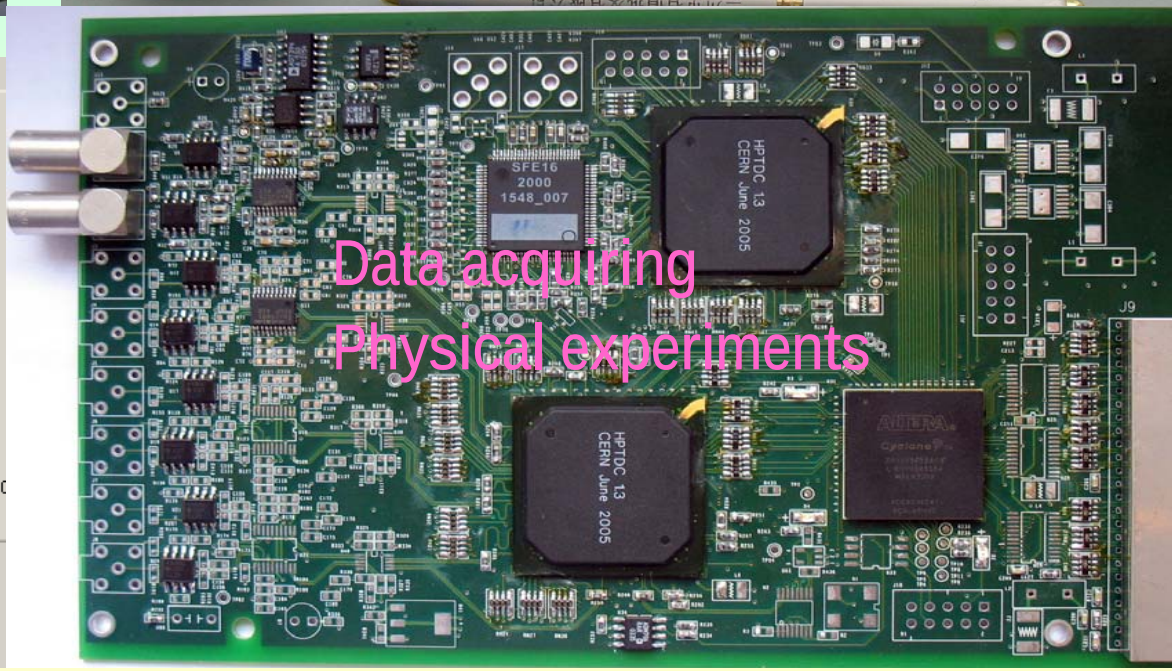
Bake-out temperature: 250°C, Pressure: 5×10^{-12} mbar

Electronics Development









SRm hall

SRe hall


SRm Injection Beam line
2004 3 2


Line between CSRm & CSR


Power supply system
2005 4 5


Ring hall
2005 4 8

CSRm 1st-Commissioning in 2006

Scheme

Ion: C^{6+}

Stripping injection

Electron-cooling

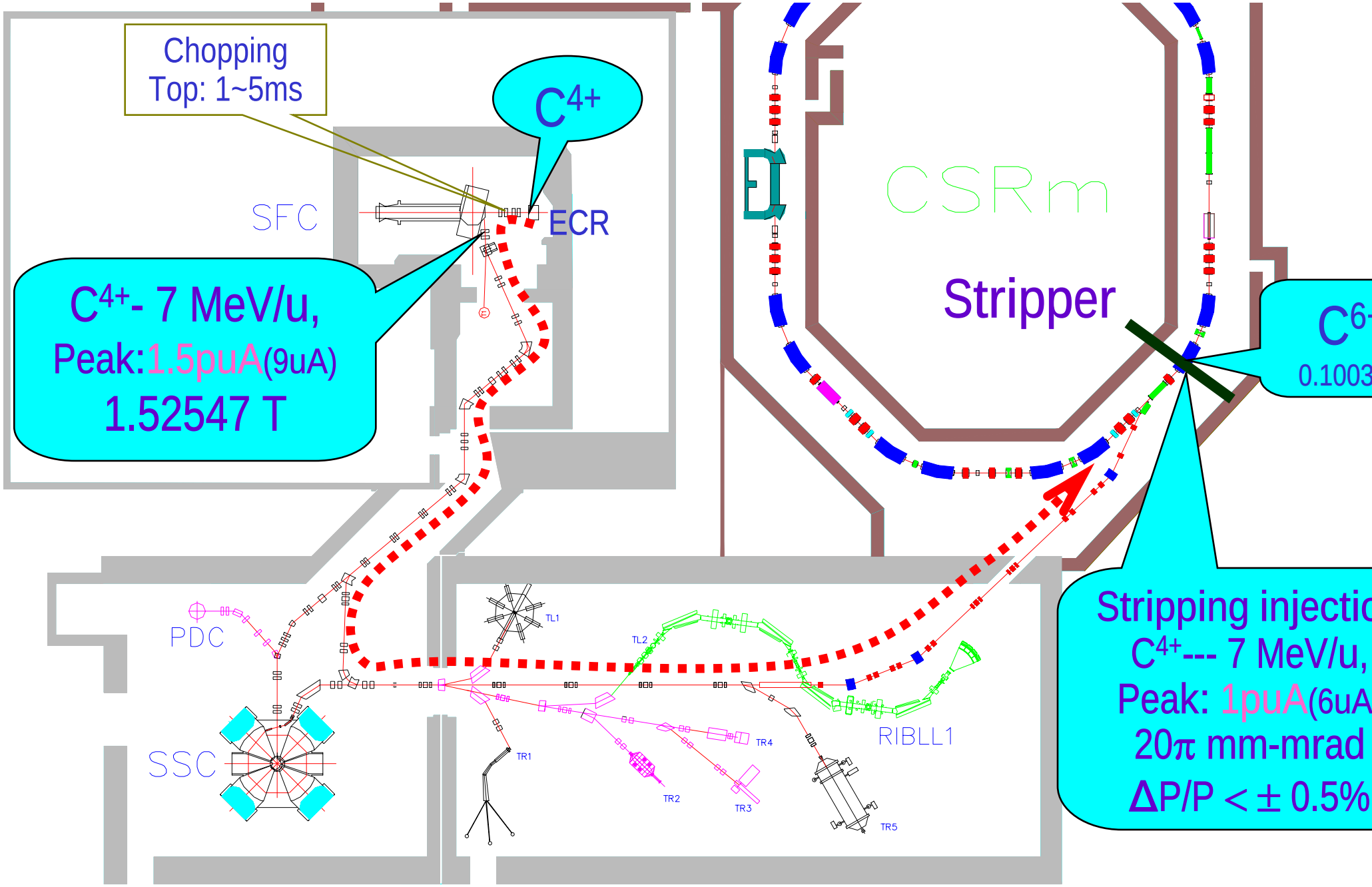
Cooling-Accumulation + Acceleration

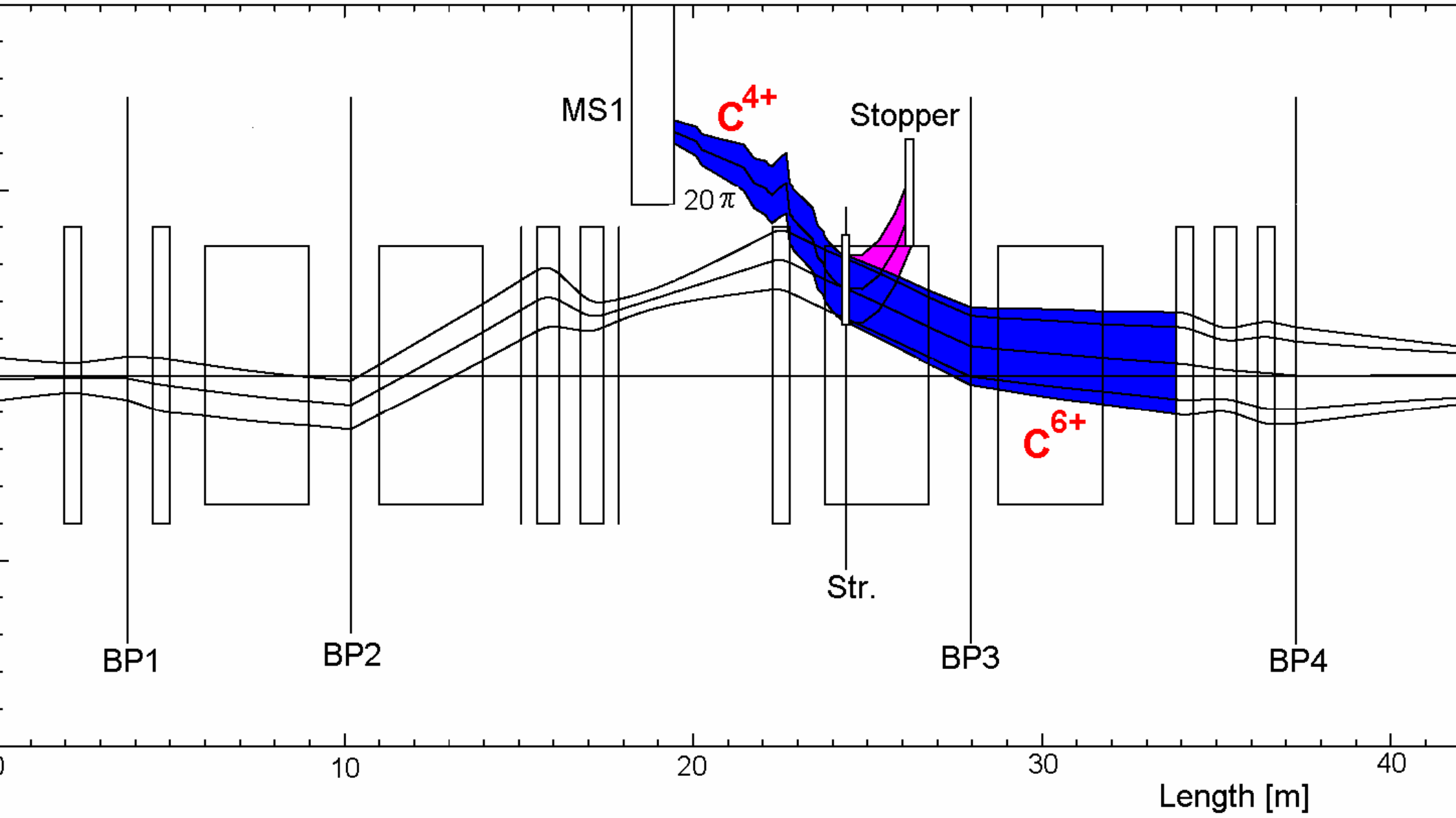
Particles: 10^8

Energy: 1 GeV/u

Scheme of the stripping injection in CSRm

05/4/2

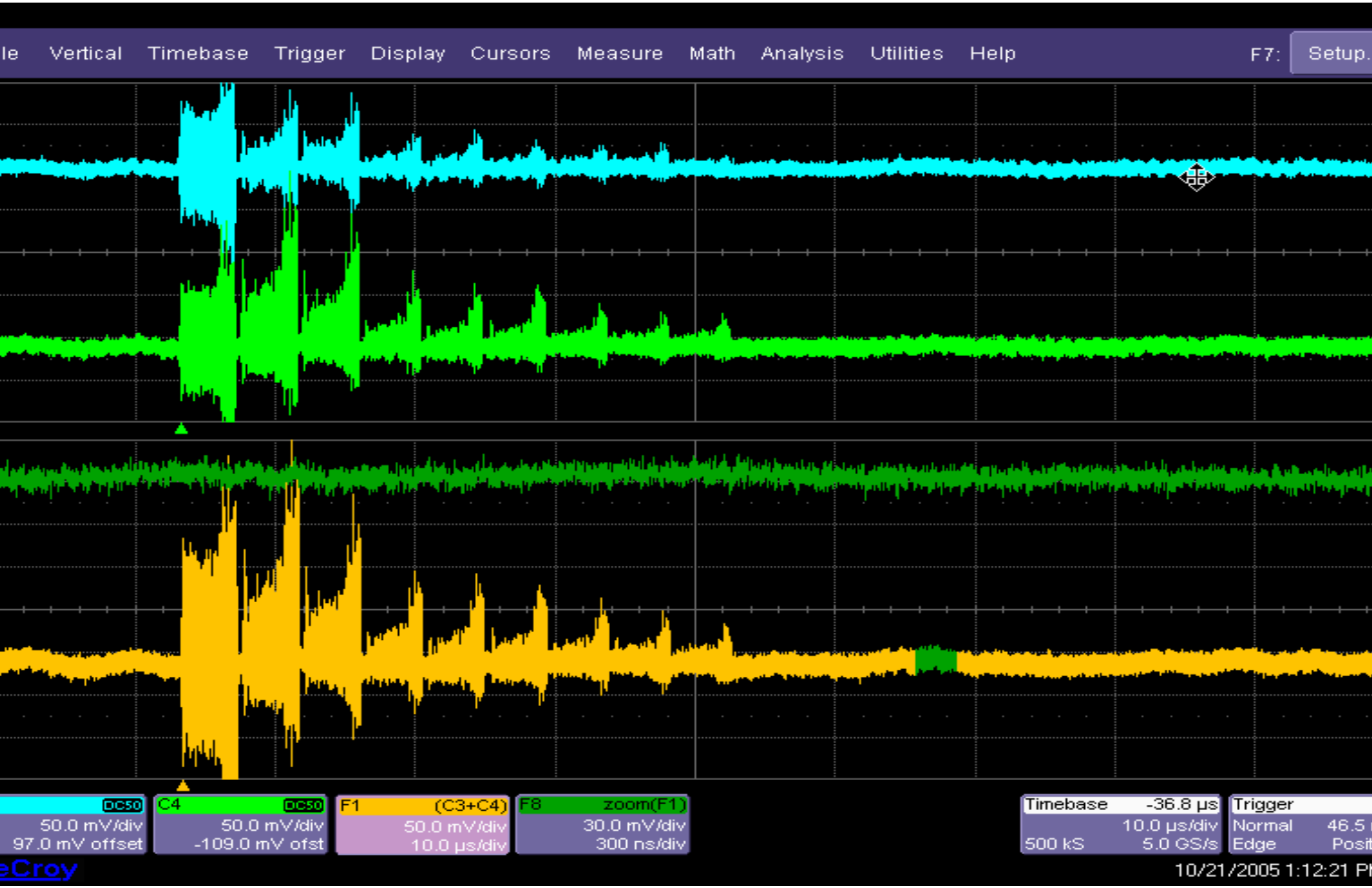




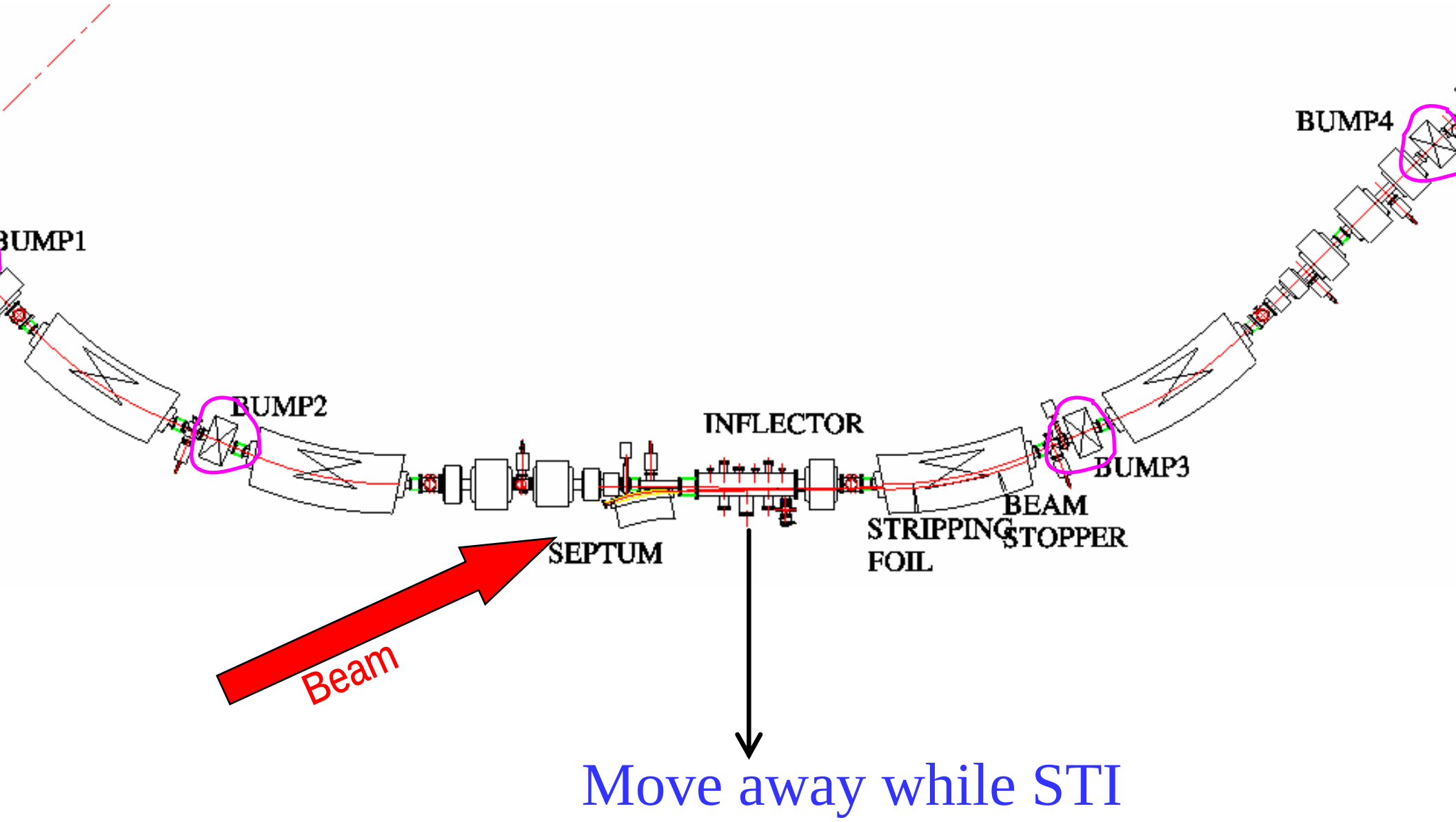
Orbits of the stripping injection in CSRm

9 turns beam signal from BPM with zero-bumping

Single-turn injection. All PS were controlled by hand 05/10/22 01:0



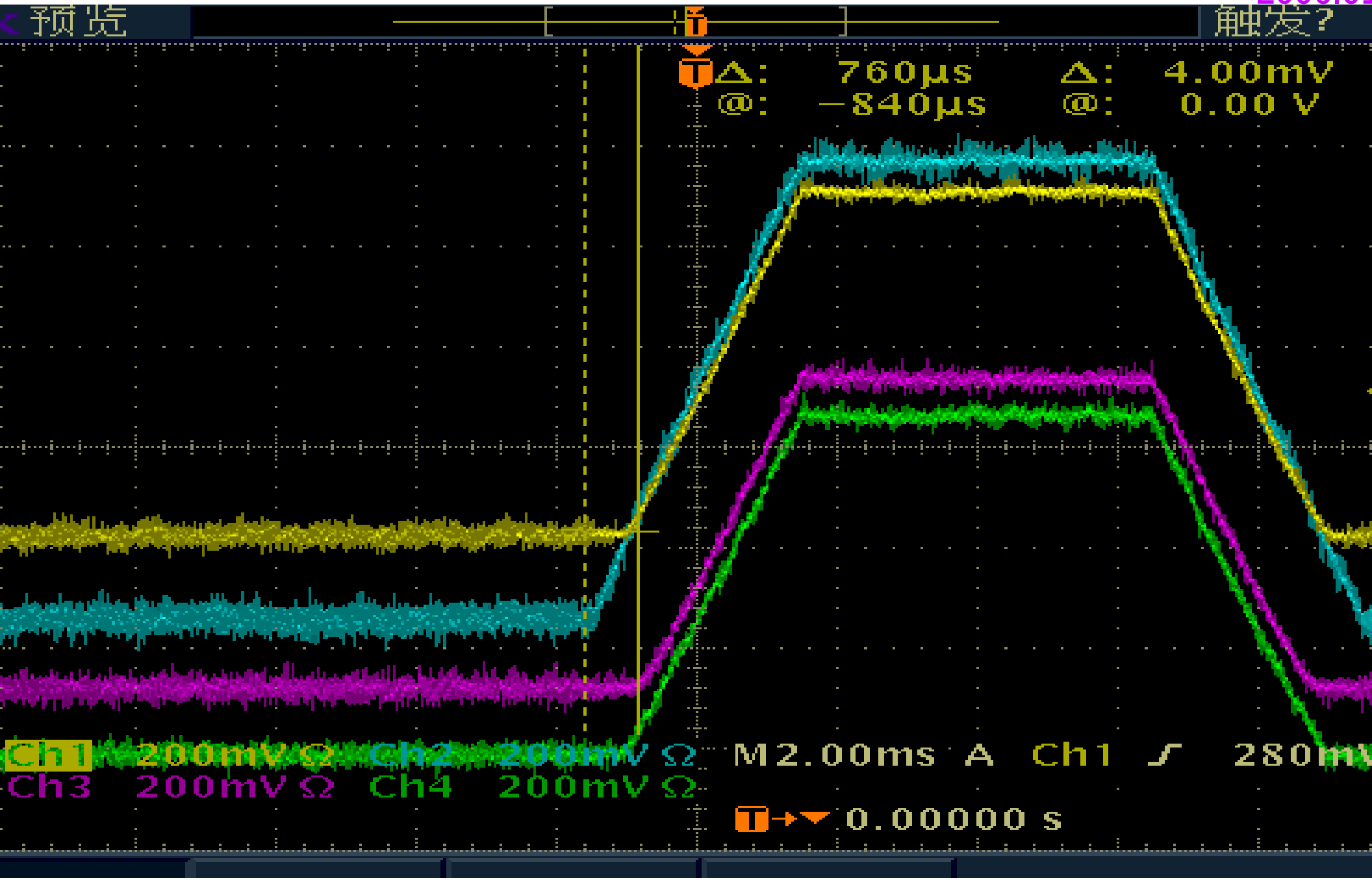
4 Bumps layout for the CSRm Injection



Current signals of 4 bump-PS for dynamic bumping orbit

Bump-PS controlled by the new DSP

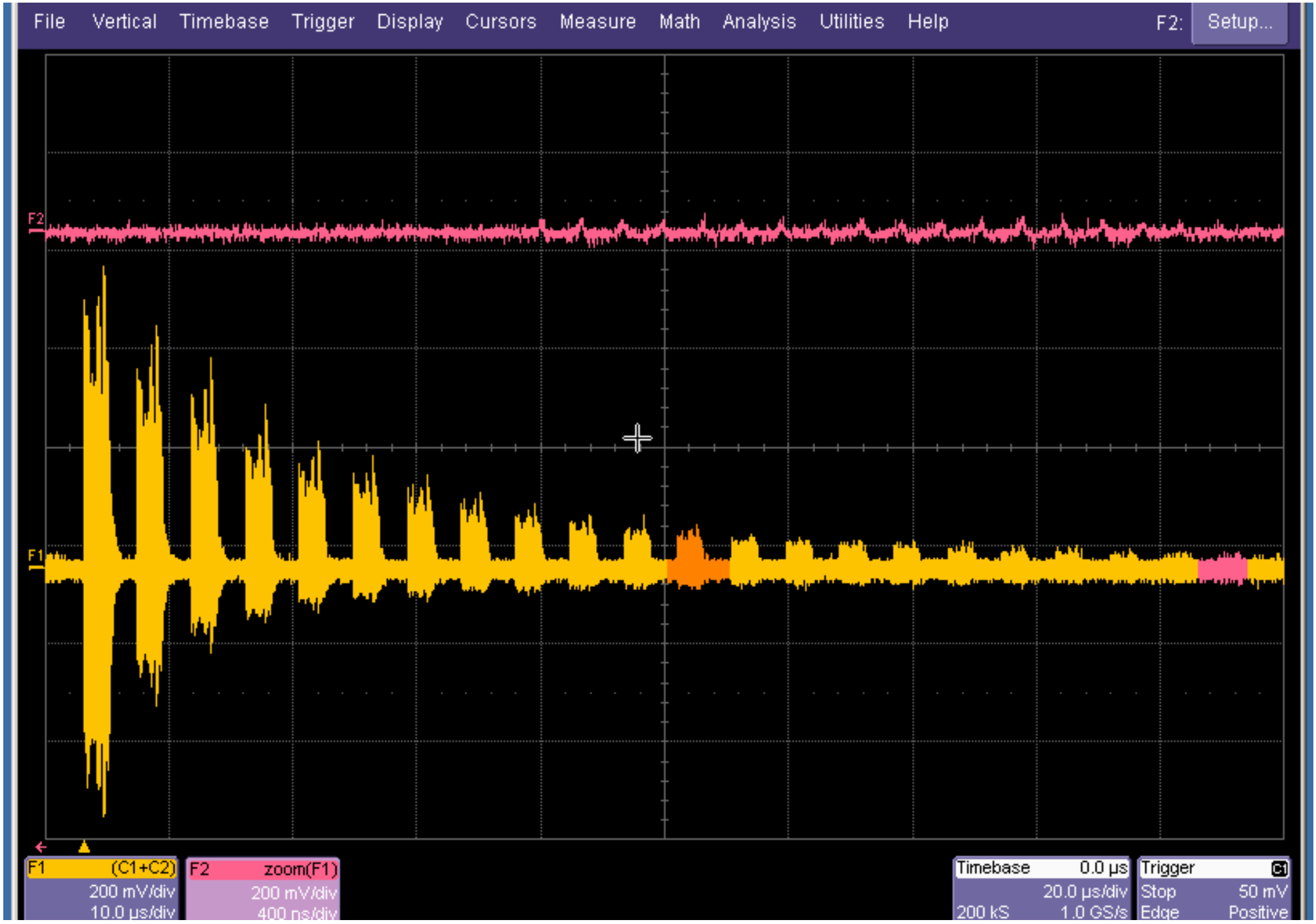
2006.01



22 turns beam signal from BPM with dynamic bumping orbit

Single-turn injection

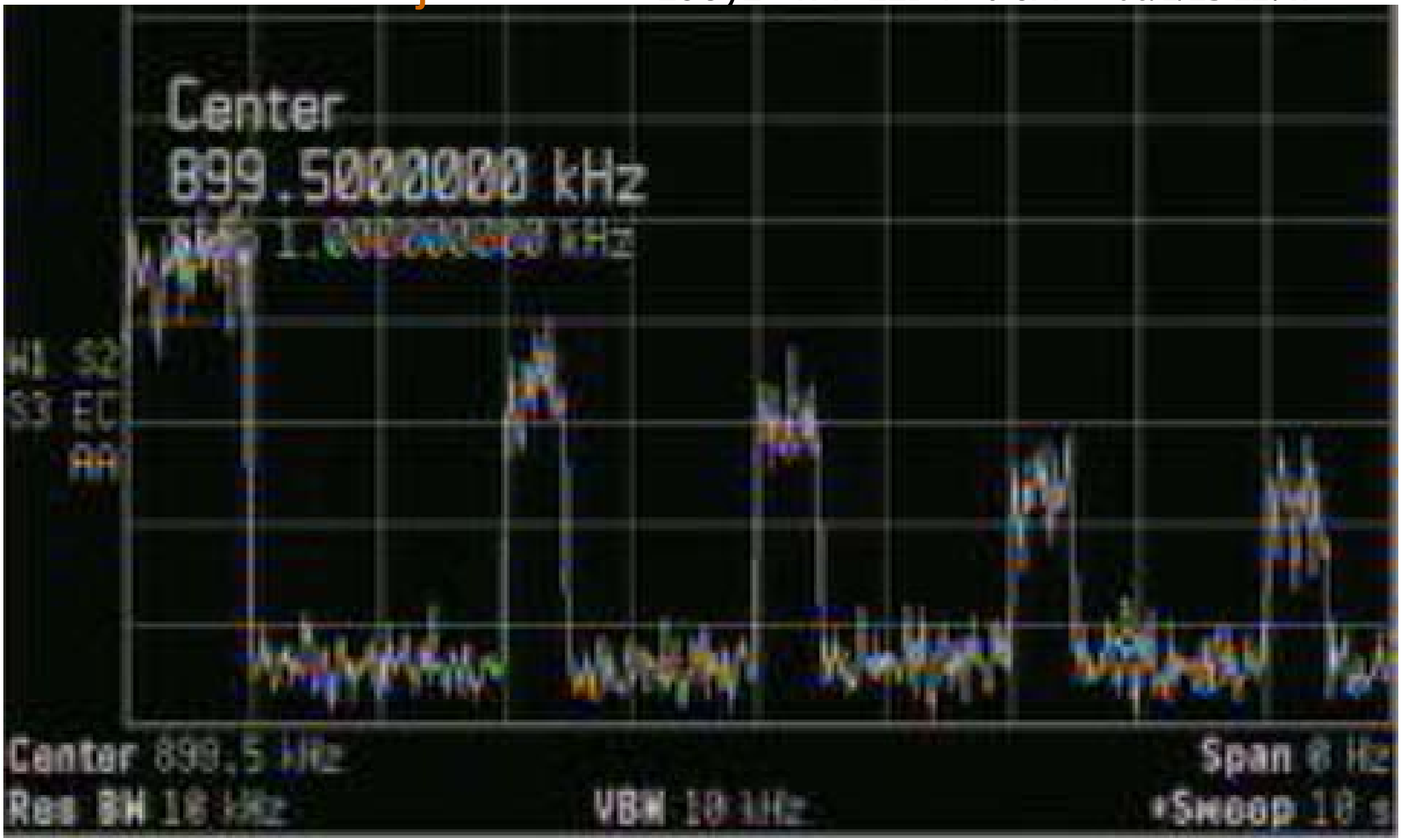
2006.01



First stored beam signal from spectrum analyzer

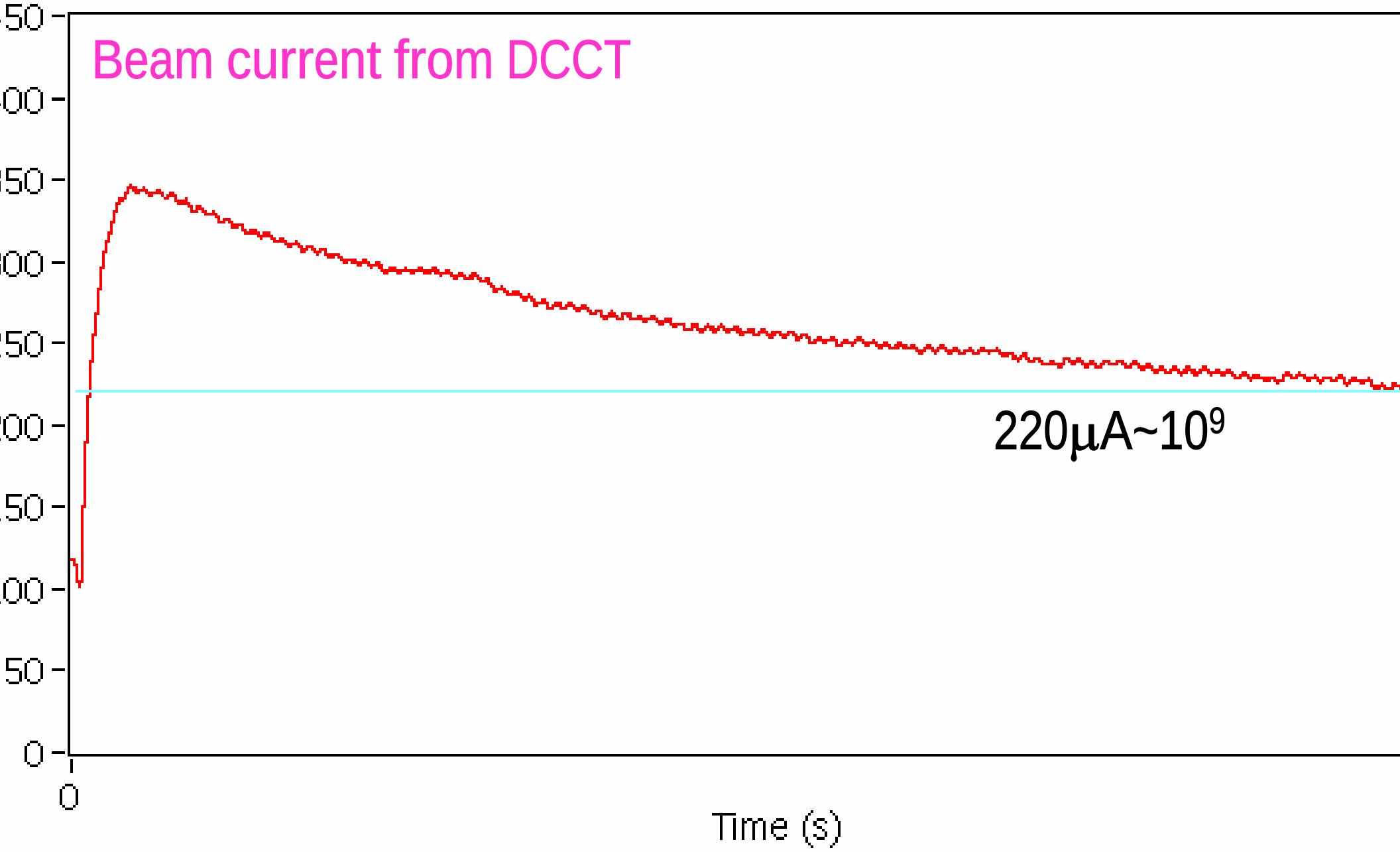
Bumping orbit , RF modulation (1.3Kv), Spe. Ana. in zero-span mode

Multi-turn injection 23Cy2 =7A 21D4 =0.5A 06/1/23 22:47



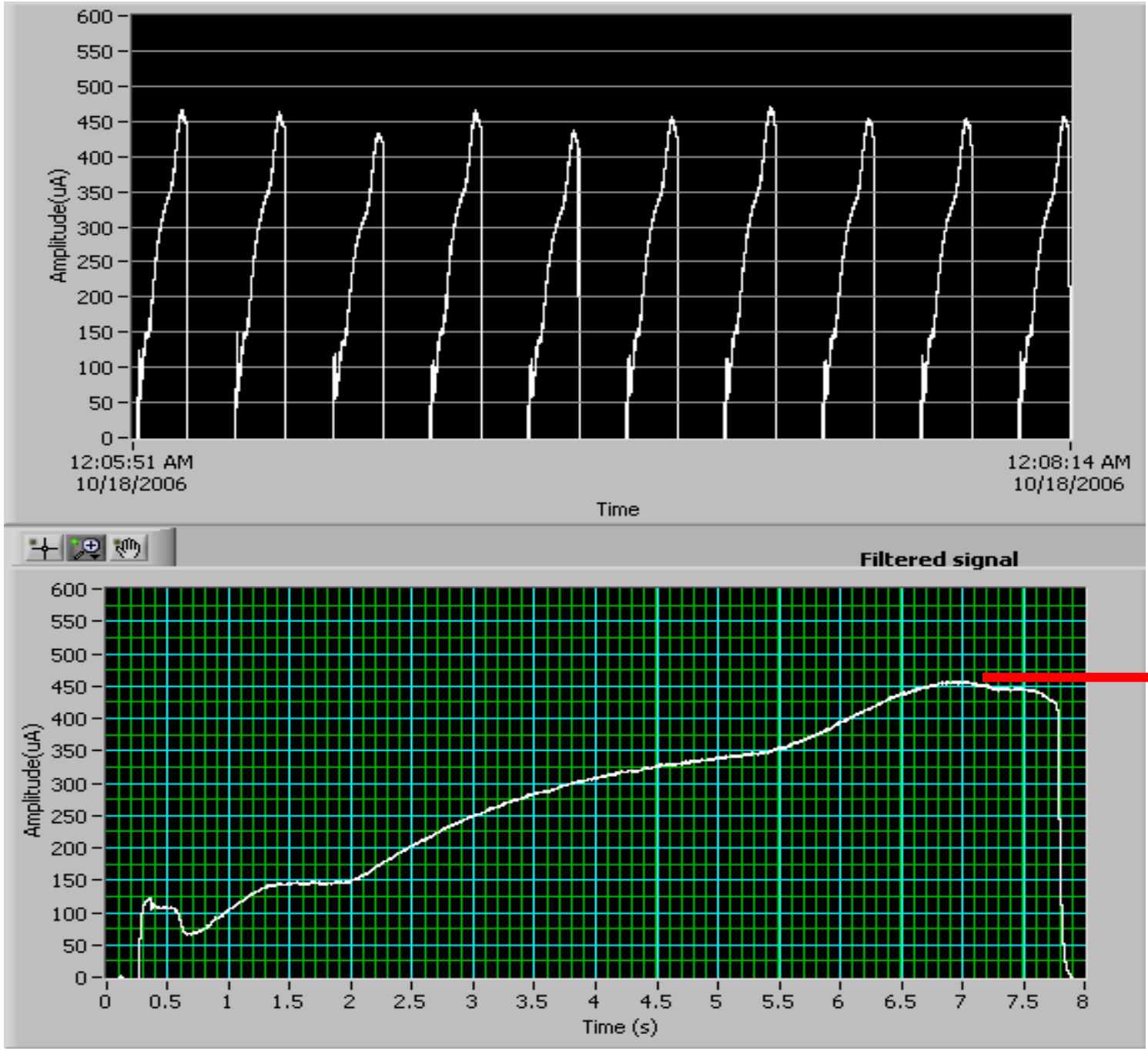
5 times of RF in 10s 1/e life-time ≈ 10s

C^{6+}-beam accumulation test in CSRm



7→1000MeV/u (C^{6+}) Ramping Test

Move back the tune before 50MeV/u

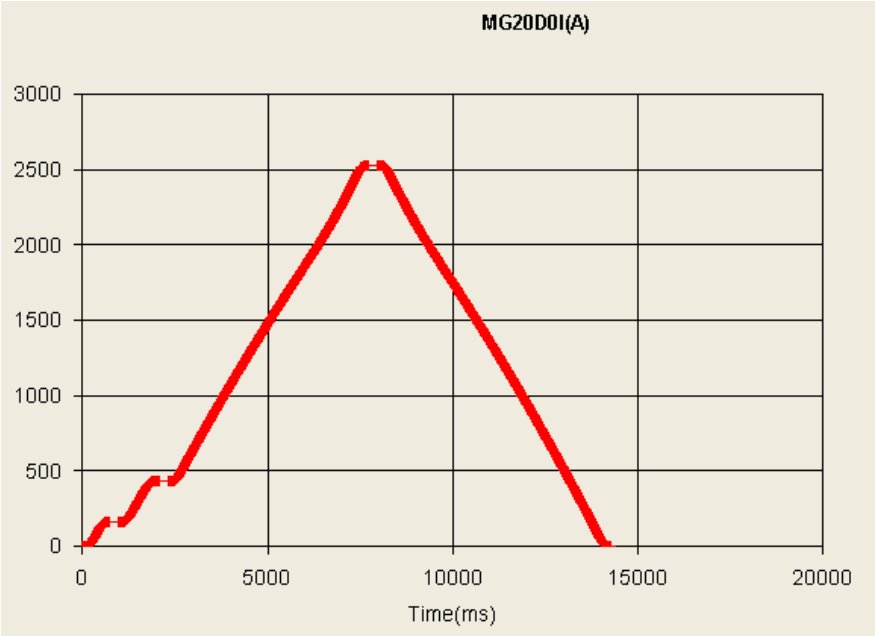


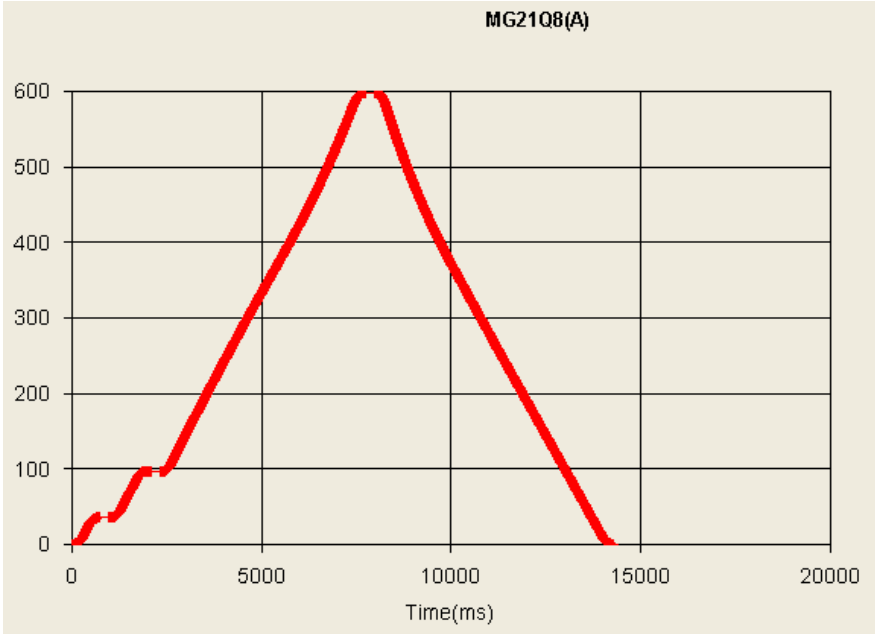
Particles: 2x

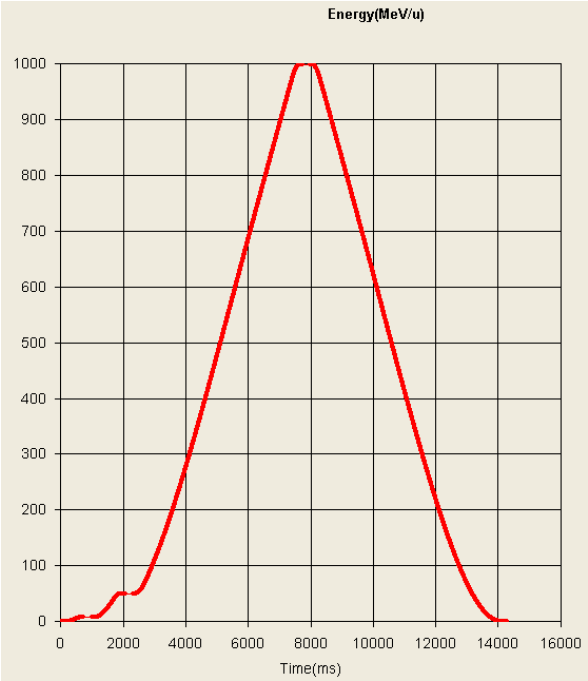
$\eta_{ramping}$ 90%

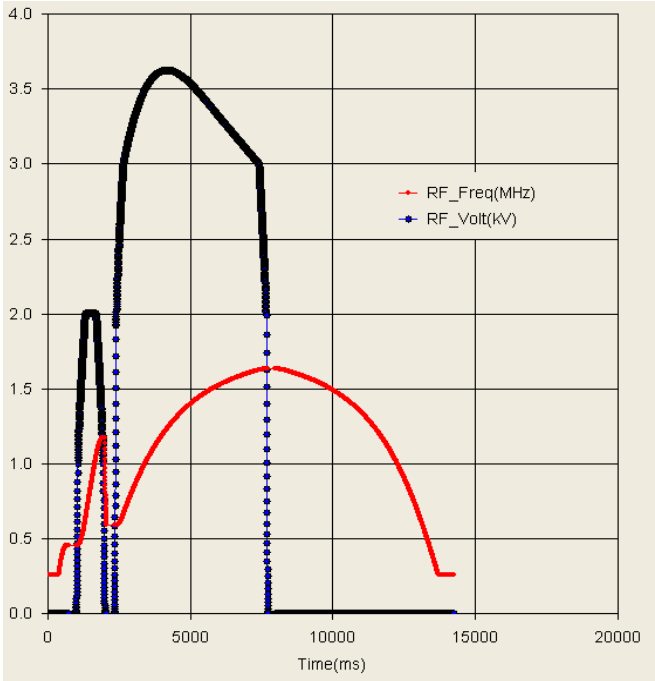
PS & RF Setting

7→1000MeV/u Ramping









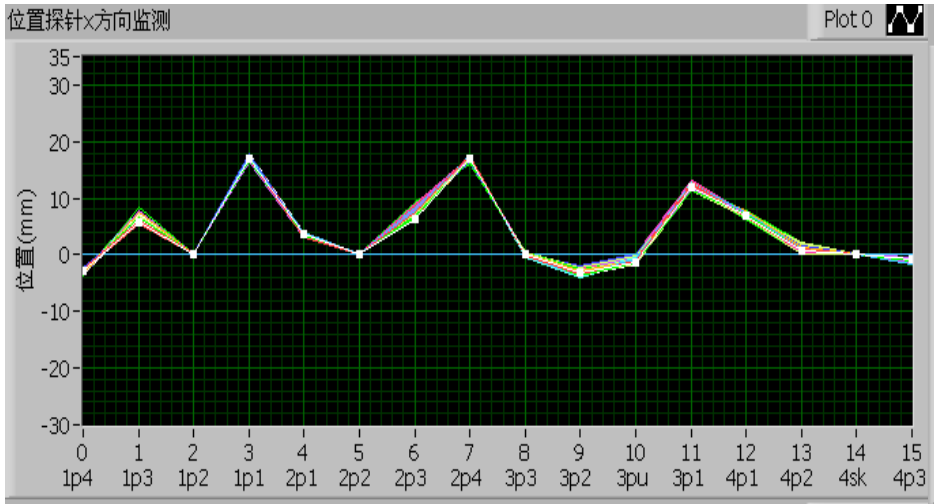
Major Parameters of 1GeV/u Acceleration

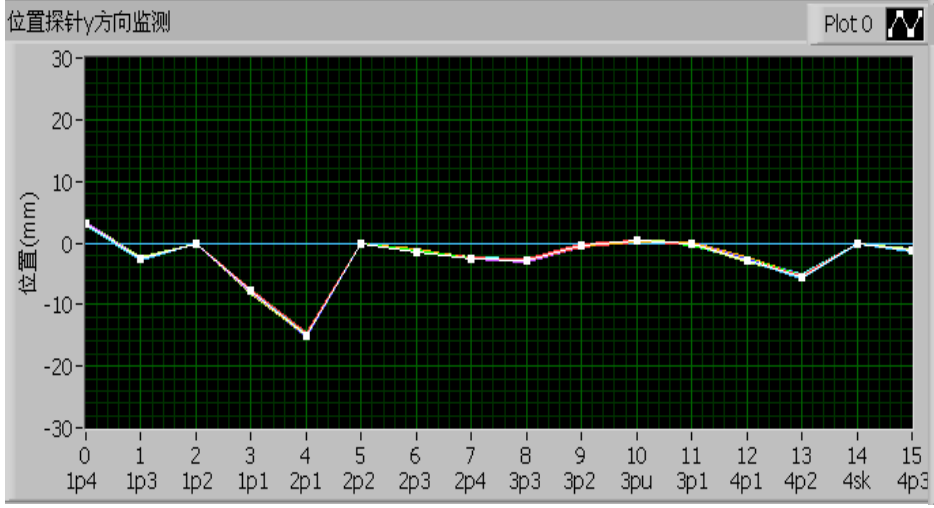
C^{6+}-Beam	7→1000MeV/u	0.76Tm→11.3Tm	I_{top}=1mA
Dipole	140x60 mm^2 0.1→1.5T	160A→2500A	450A/s
Quadruple	160x110 mm^2 0.6T/m → 9T/m	20A →600A	100A/s
RF	f = 0.45→1.63MHz	H = 2→1	$V_{max.}$= 3.5KV
Machine	$T_{ramping}$= 7s	Top Power 3MW	Vacuum $5x10^{-12}$ mbar

First COC for CSRm

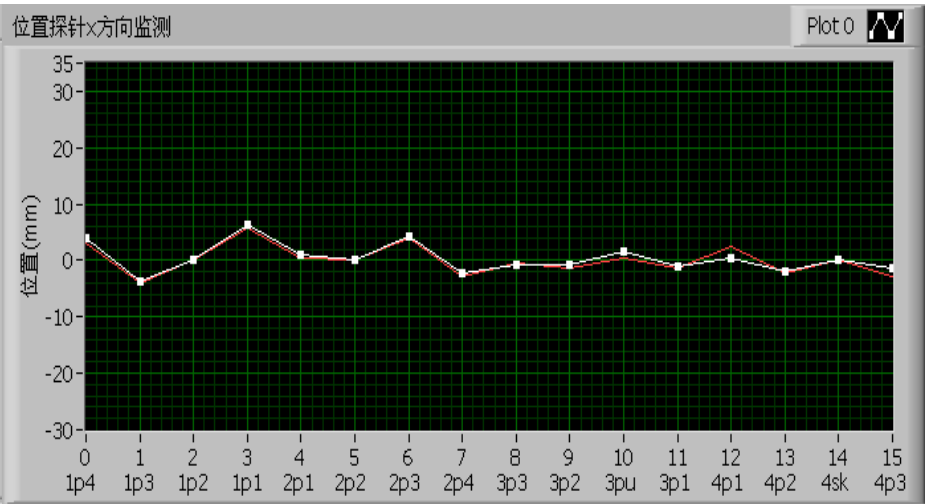
06/12/27 21:00

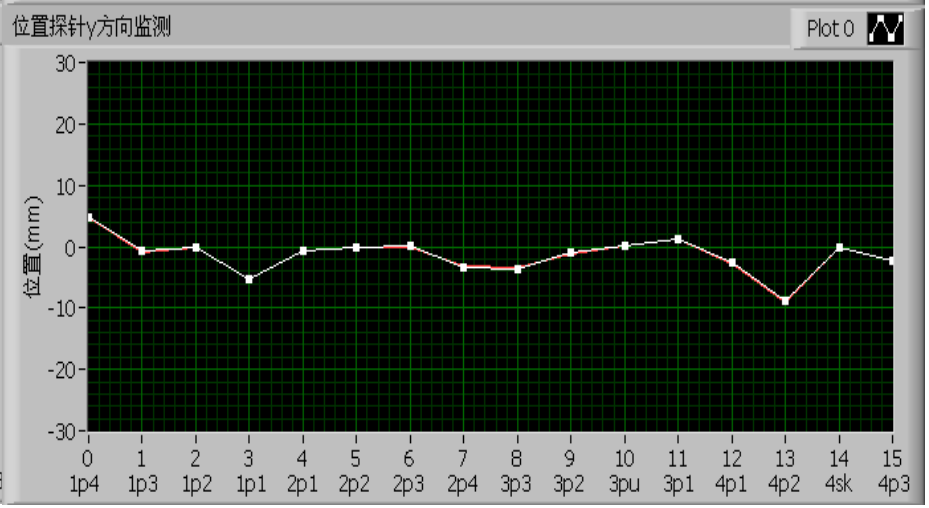
Before correction



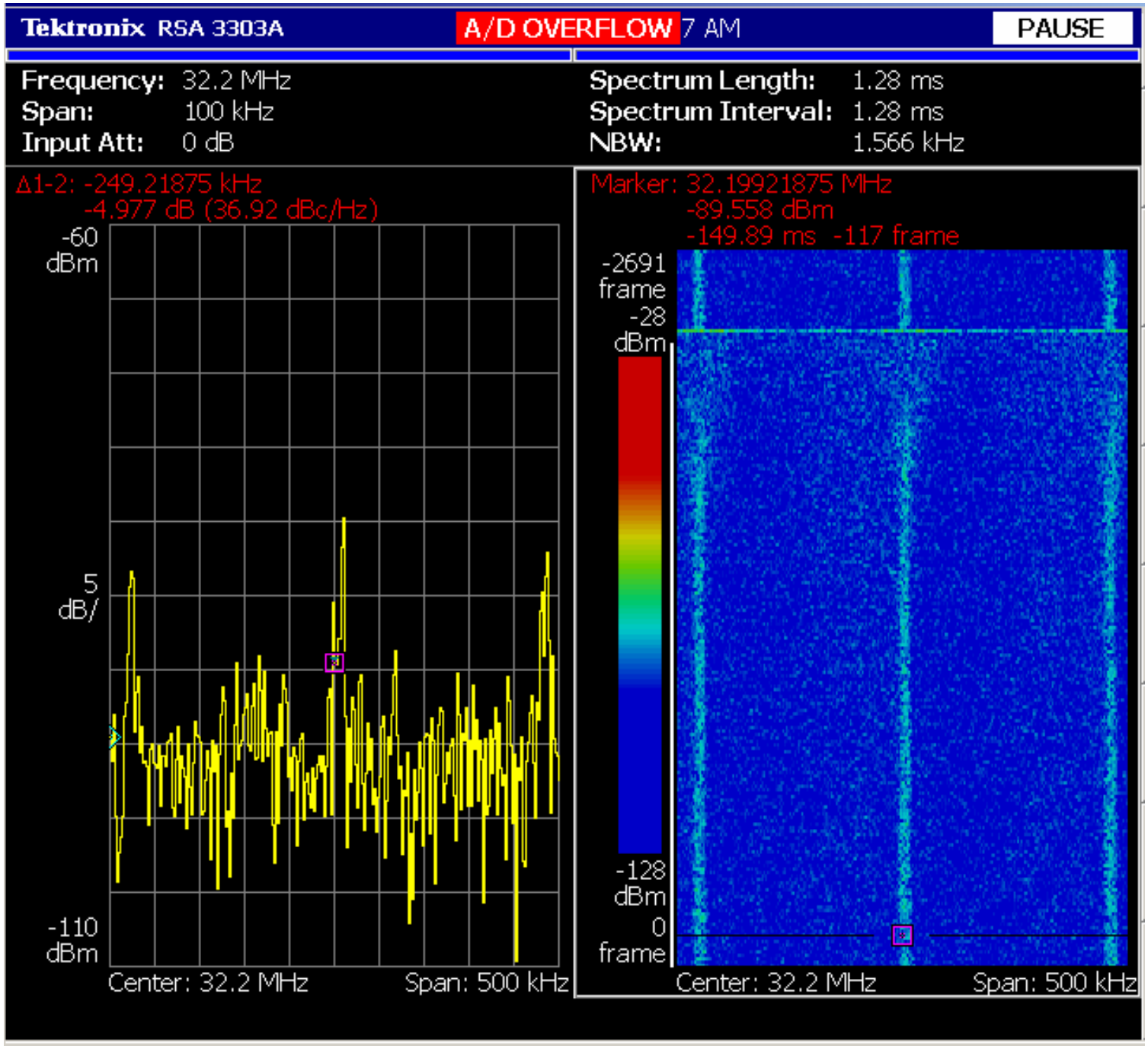


After correction





e-cooing for C^{6+}-beam at 7MeV/u



ΔP/P

4×10^{-3}

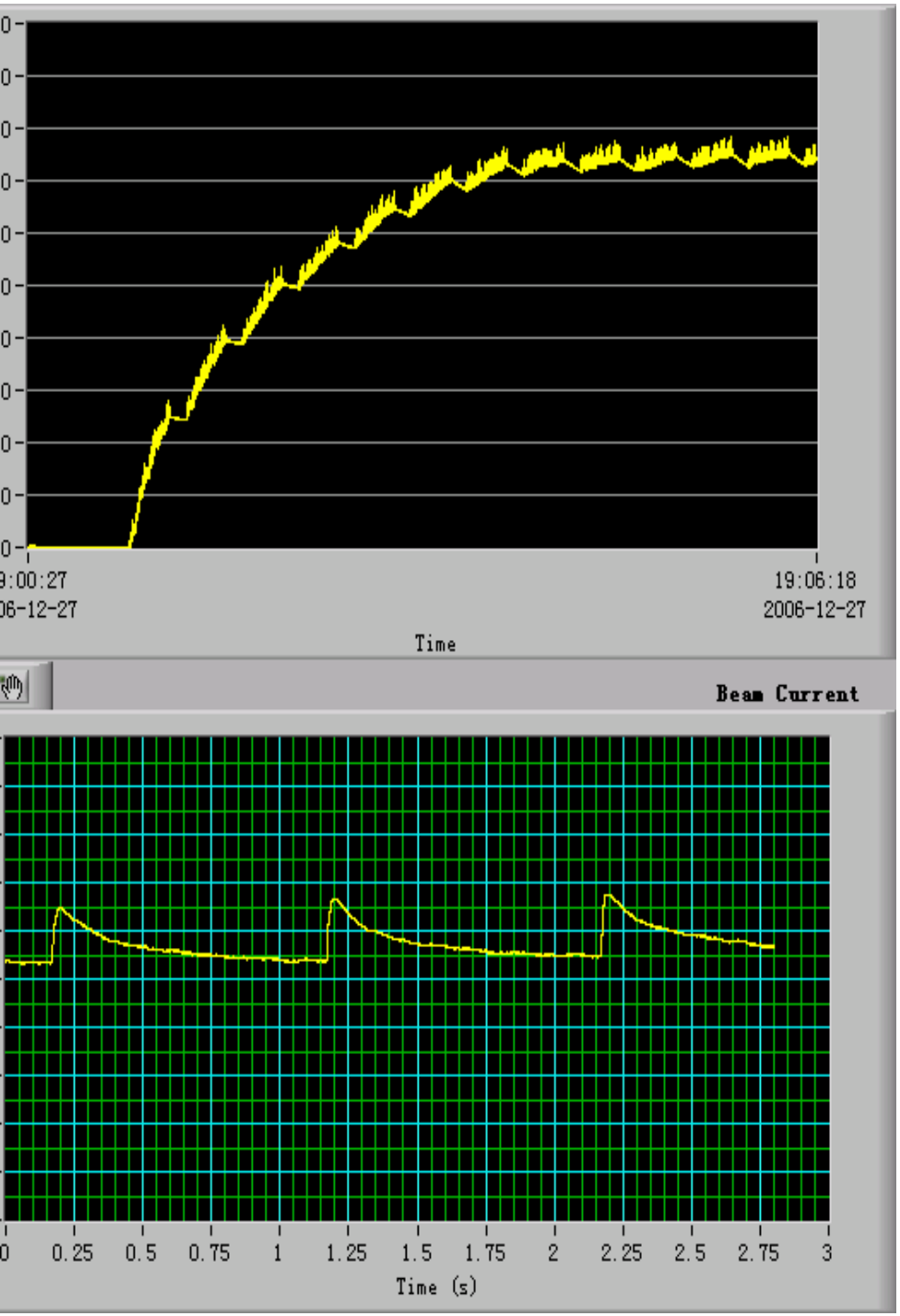
↓

↓

↓

2×10^{-4}

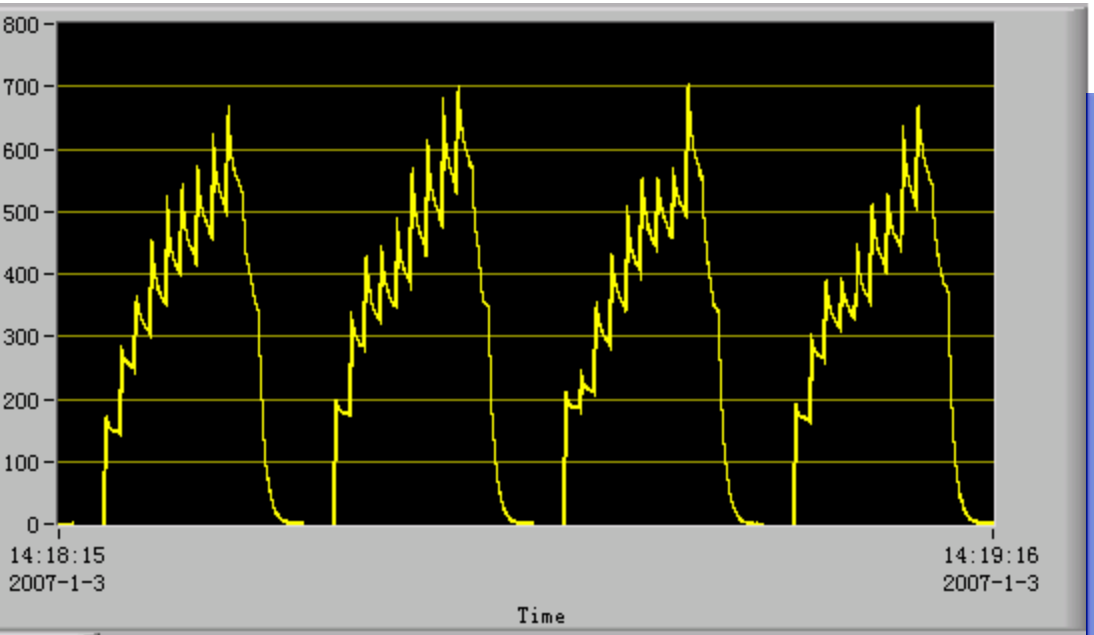
Beam Accumulation with e-cooing in CSRm

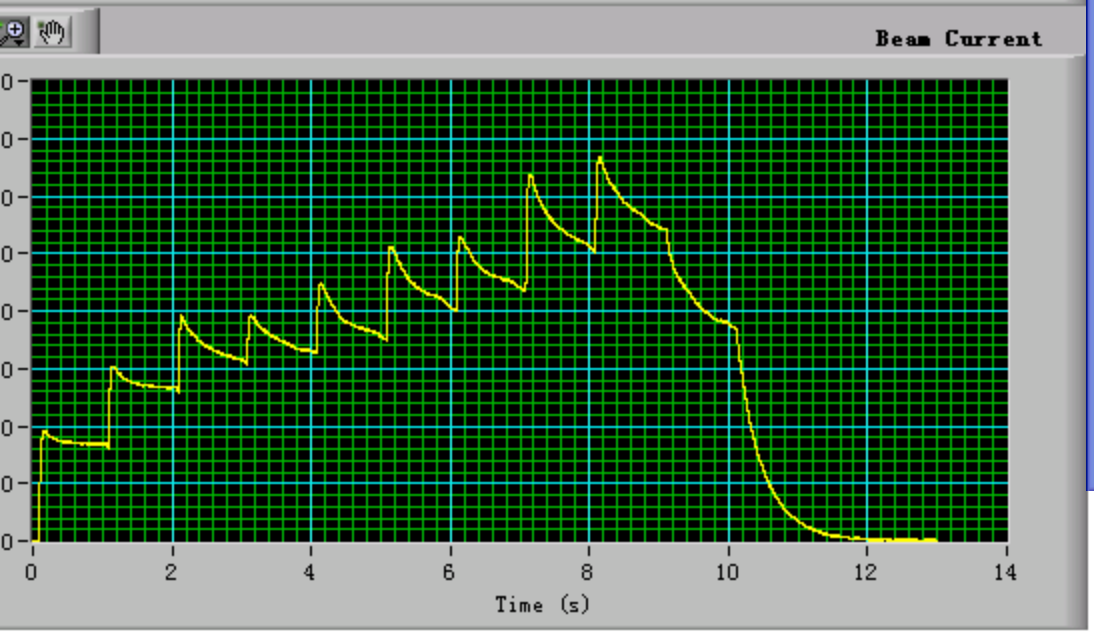


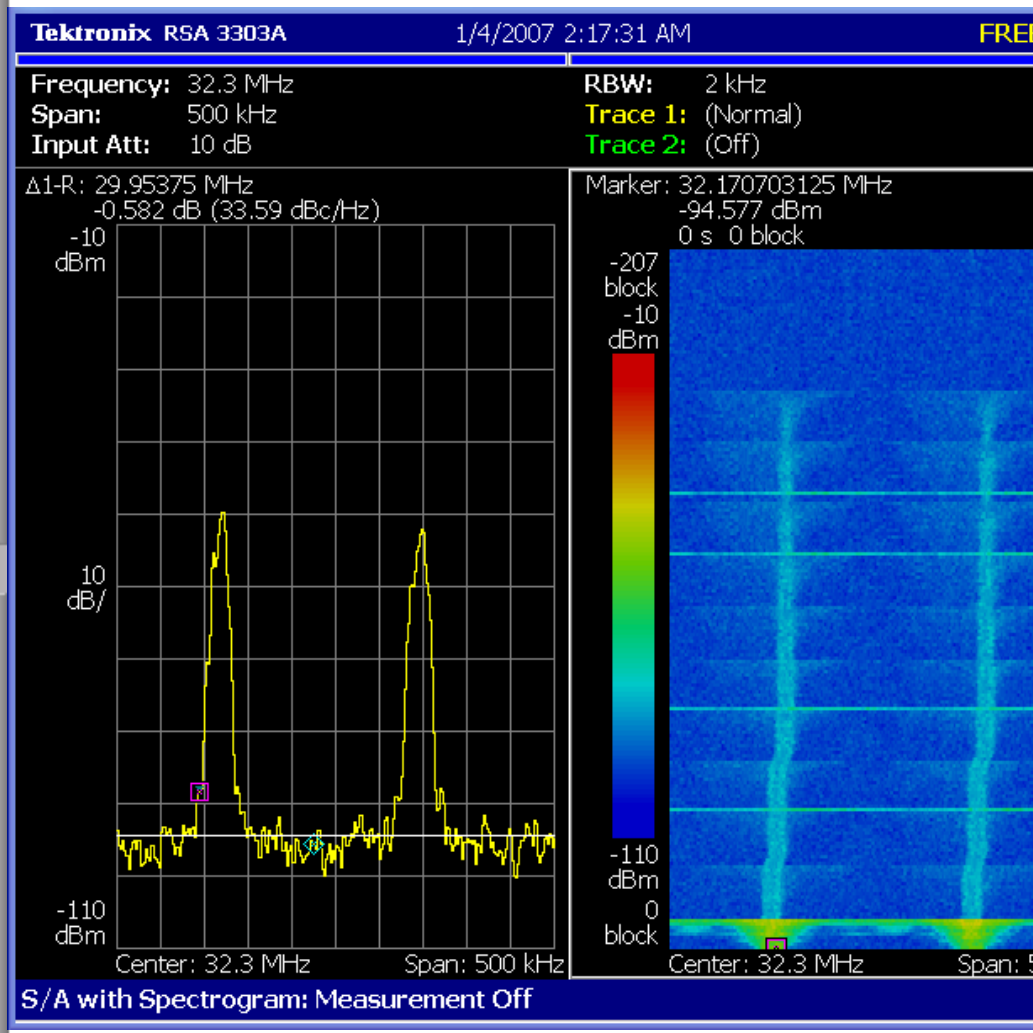
Beam current: 1.5mA

Cooing-accumulation in CSRm

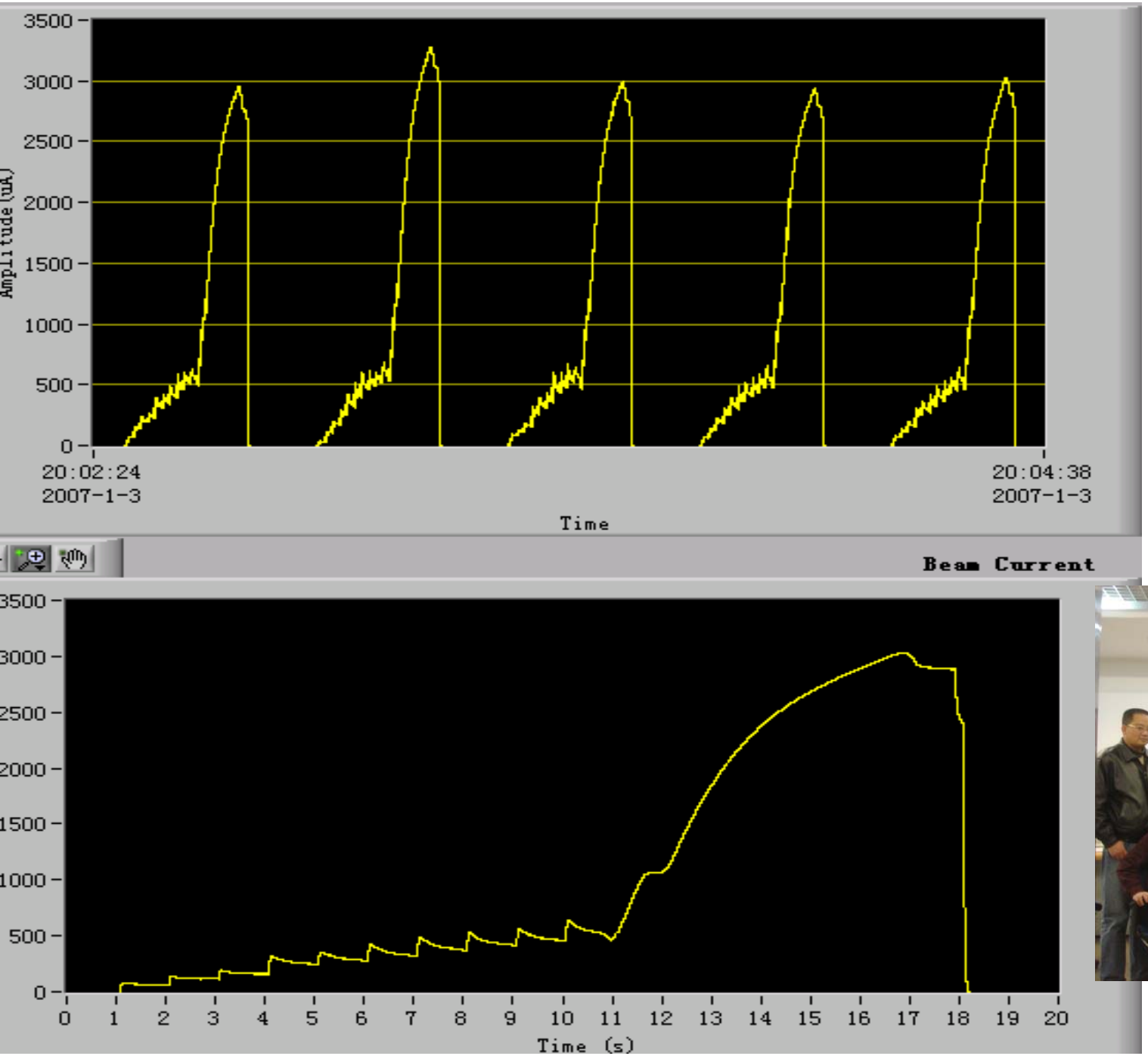
With 9 times of beam injection







Cooing-Accumulation and Acceleration in CSRm



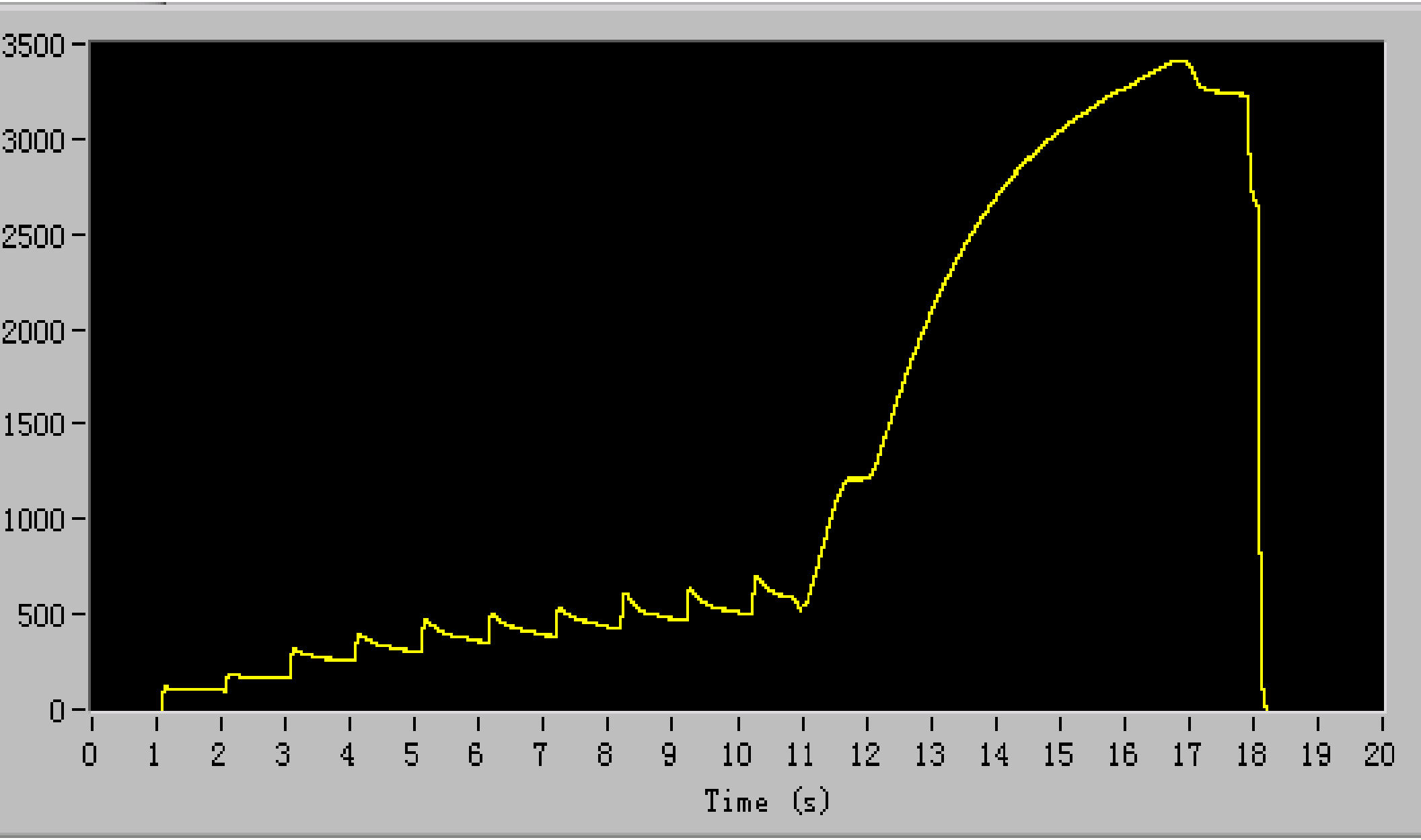
7→→1000 MeV/u

Top current: 3 mA

~ 2×10^9

Cooing-Accumulation and Acceleration in CSRm

7→1000 MeV/u, Top current (final record) : 3.4 mA, 2.1×10^{9} 07/01/03 20:3



Schedule of CSR 1st-Commissioning

2006.01	Get the CO beam
2006.03-04	Accumulation: 10^8 Particles (C^{6+})
2006.05-10	1GeV/u-Accelerating
2006.11-12	COC, e-cooling
2007.02-04	SSC+CSRm---MMI (Ar^{18+}), Fast extraction
2007.05-08	Stored beam in CSRe, Experiments

Thank You!