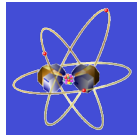


PAC09, Vancouver, Canada, May 4-9, 2009

HIRFL-CSR Facility

Jiawen Xia

xiajw@impcas.ac.cn



Institute of Modern Physics (IMP), Chinese Academy of Science (CAS)



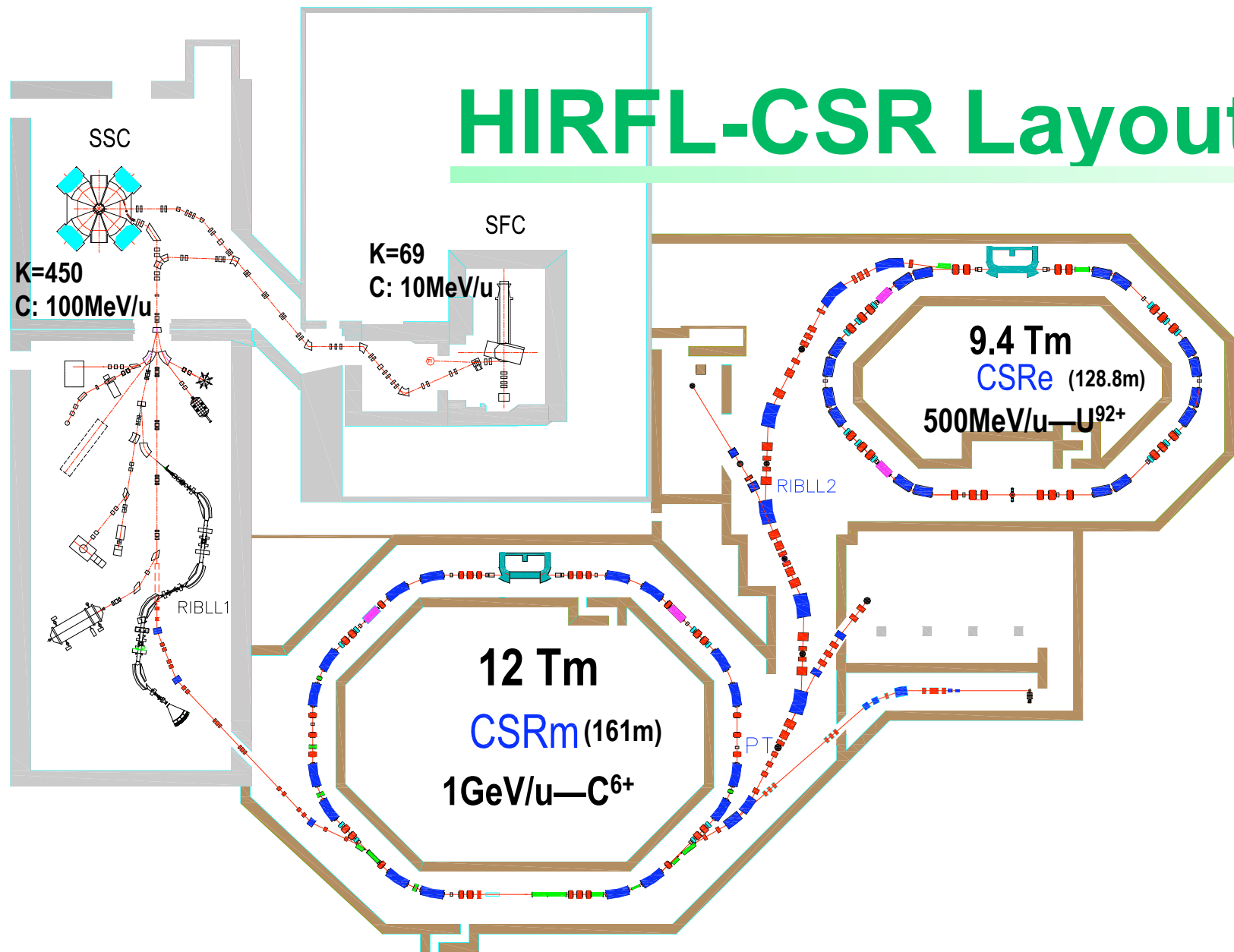
Lanzhou, China

History of CSR

Heavy-ion **C**ooler **S**torage **R**ing & Synchrotron in Lanzhou

1993	Original idea
1996	Proposal
1998	Approved
2000-2005	Construction
2006-2007	<i>Commissioning</i>
2008-2009	Operating & Experiments

HIRFL-CSR Layout



Pre-accelerator system of CSR



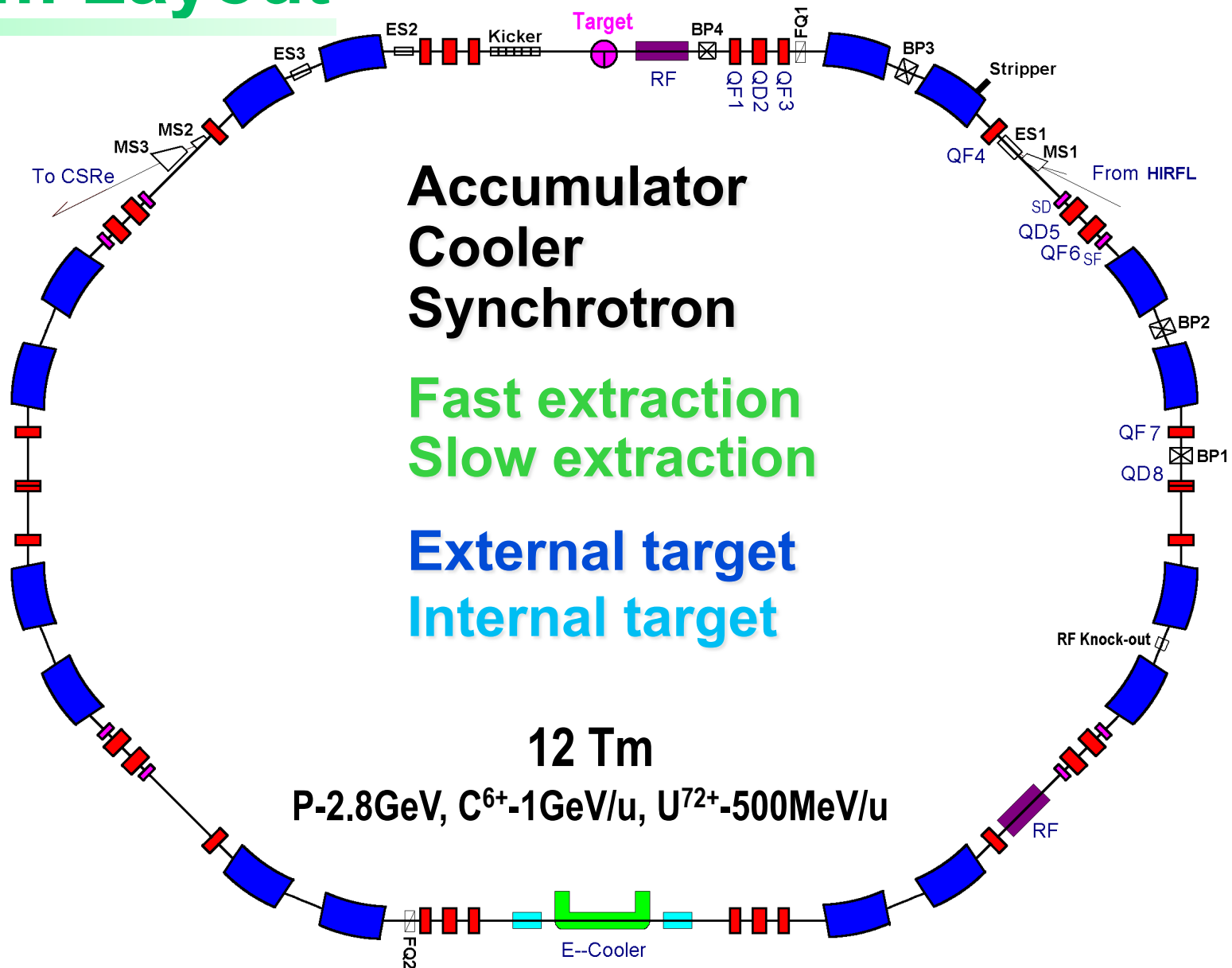
$A \geq 40$

CSRm

$A < 40$



CSRm Layout

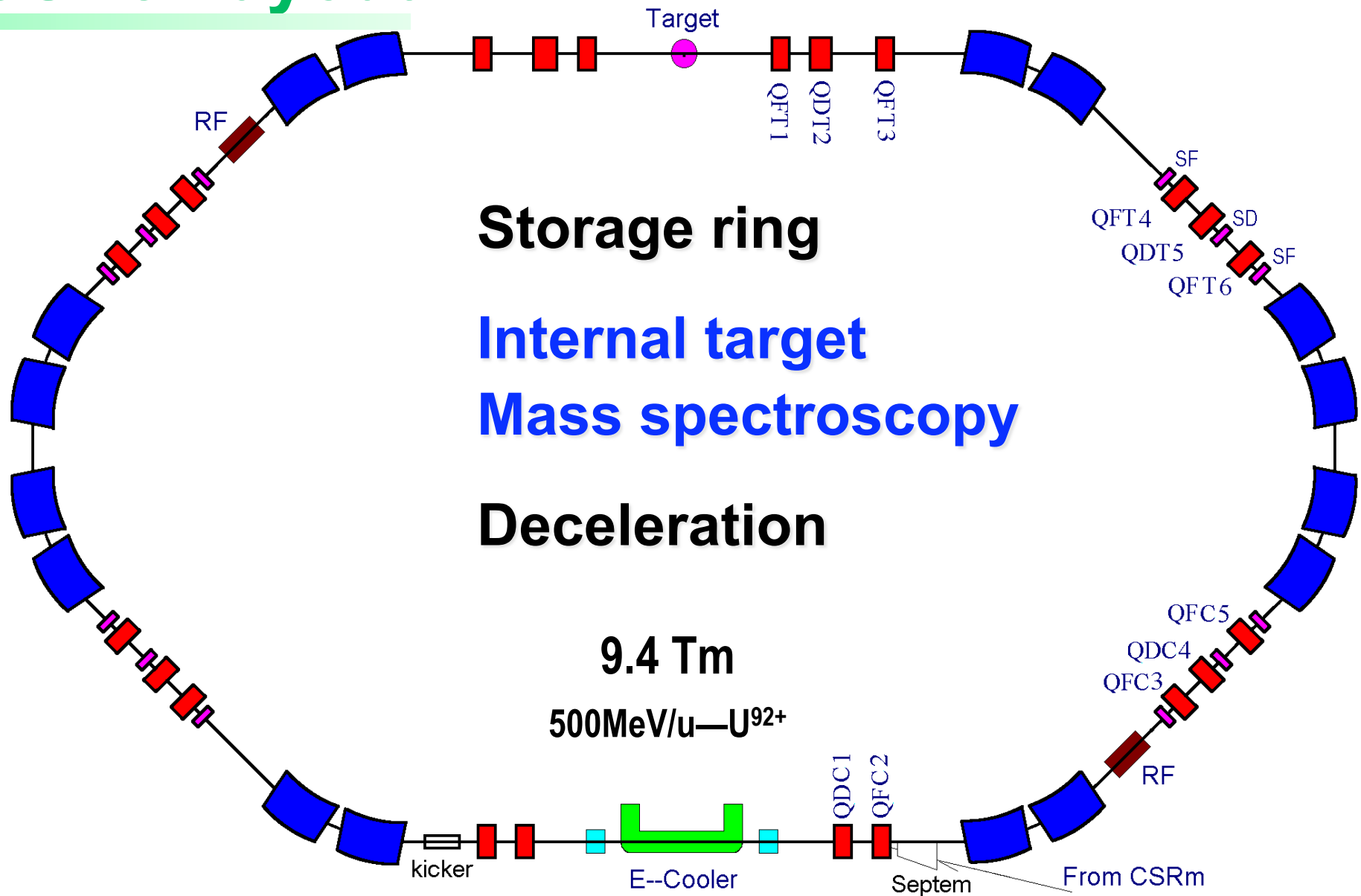


CSRm Tunnel



2004.6

CSRe Layout





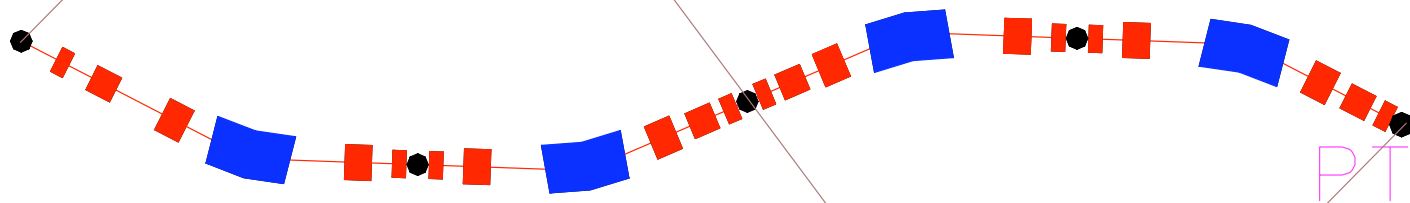
2005.10



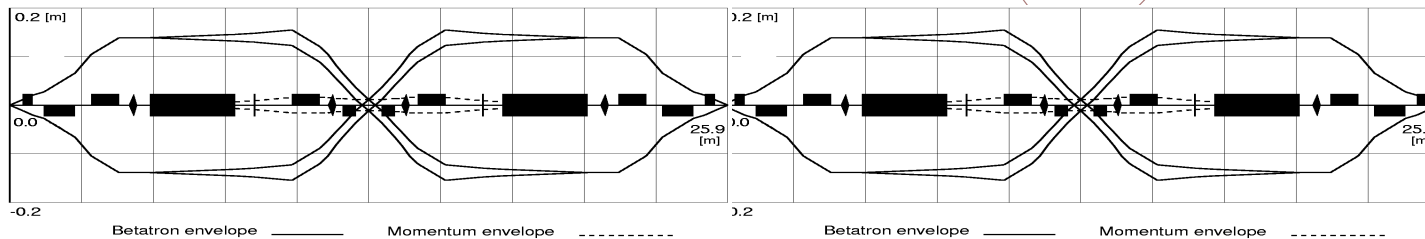
Radioactive Ion Beam Line **RIBLL2** between CSRm and CSRe

Double Separator

RIBLL2



$\Delta P/P = \pm 1\%$, Emittance = 25π mm-mrad



RIBLL2

Tunnel

B:40T

2005.3

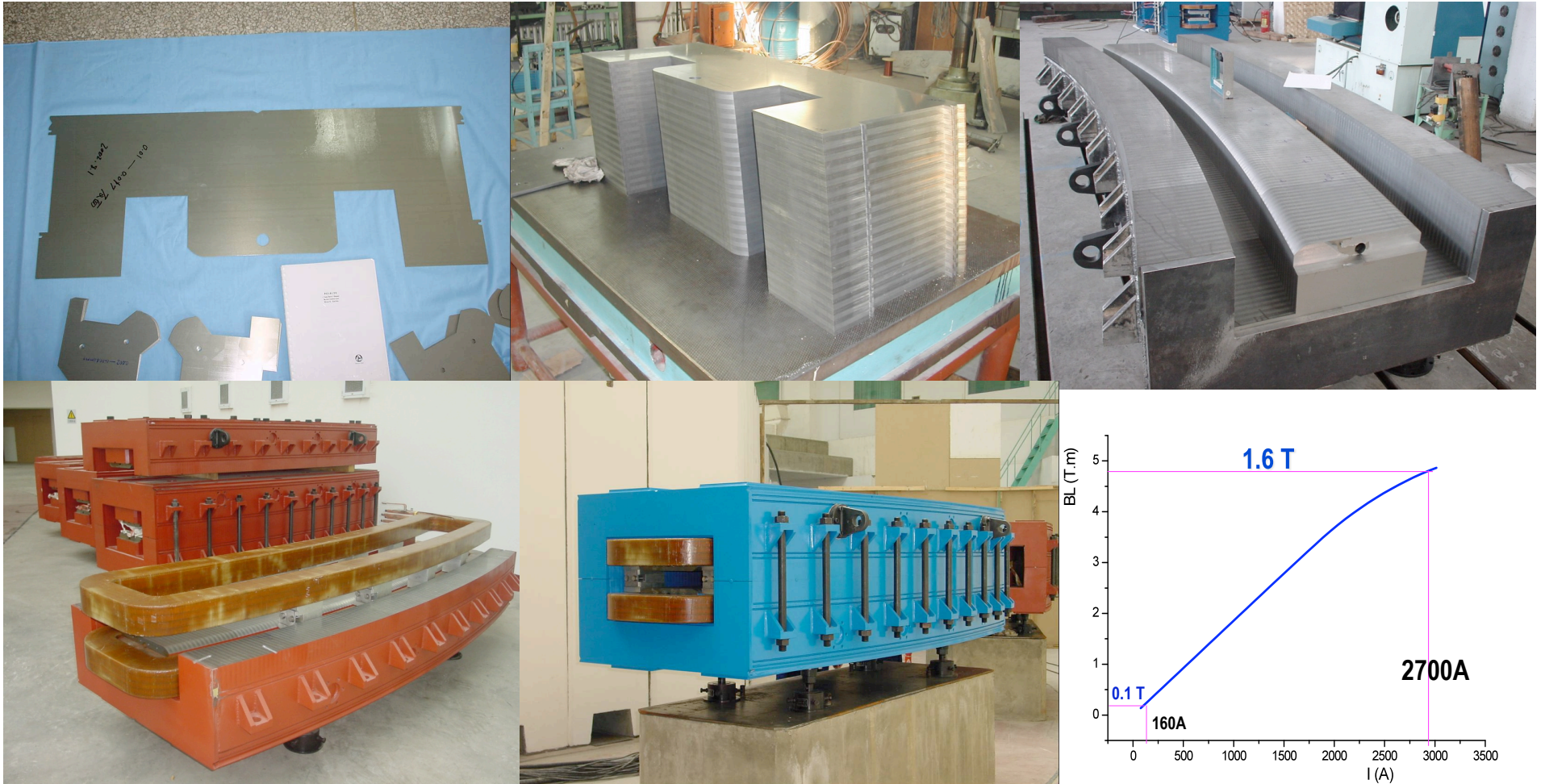


HIRFL-CSR

Major subsystems

Construction: 2000--2005

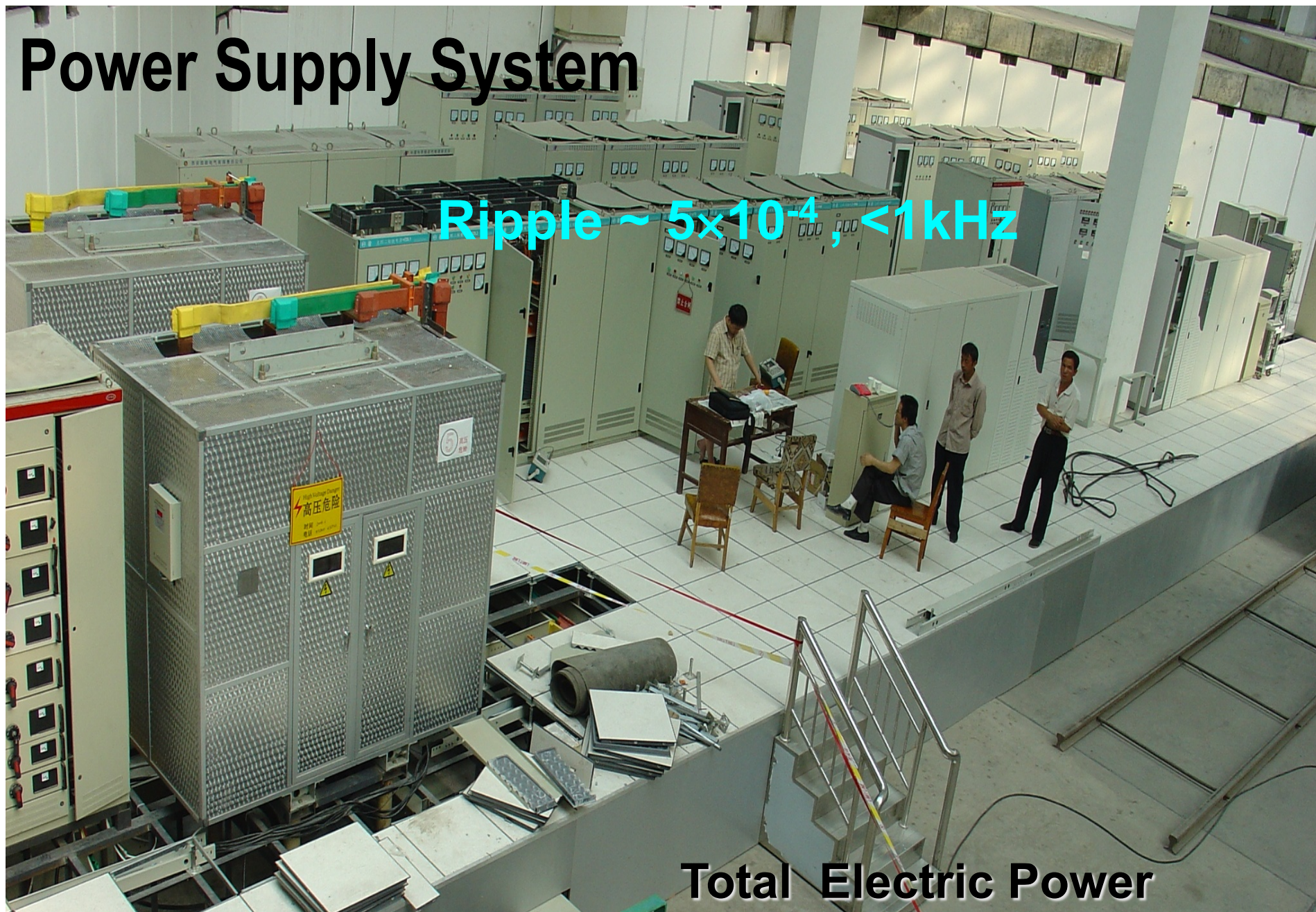
CSRm-dipole Fabrication



H-Type, Angle=22.5°, Rbend, Radius=7.6m, Air Gap=80mm, Useful aperture=**140×60mm²**, Precision= **3×10⁻⁴**

Power Supply System

Ripple $\sim 5 \times 10^{-4}$, $< 1\text{kHz}$



Total Electric Power
 $\sim 20\text{MW}$

CSRm RF System



RF-station for acceleration

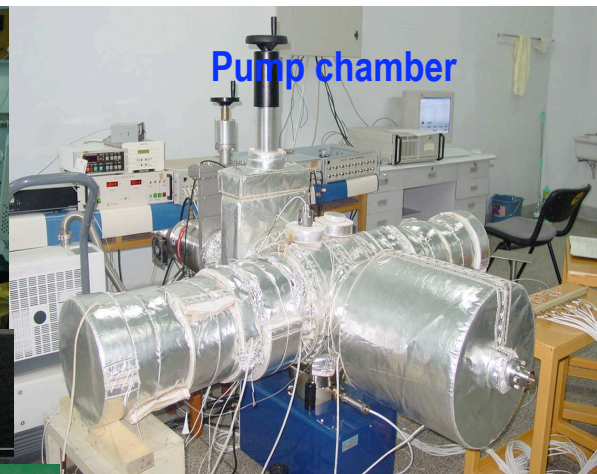
$f = 0.24 \sim 1.81 \text{ MHz}$, $V_m = 7 \text{ kV}$

RF for beam accumulation

$f = 6 \sim 14 \text{ MHz}$, $V_m = 20 \text{ kV}$

UHV System of CSR

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

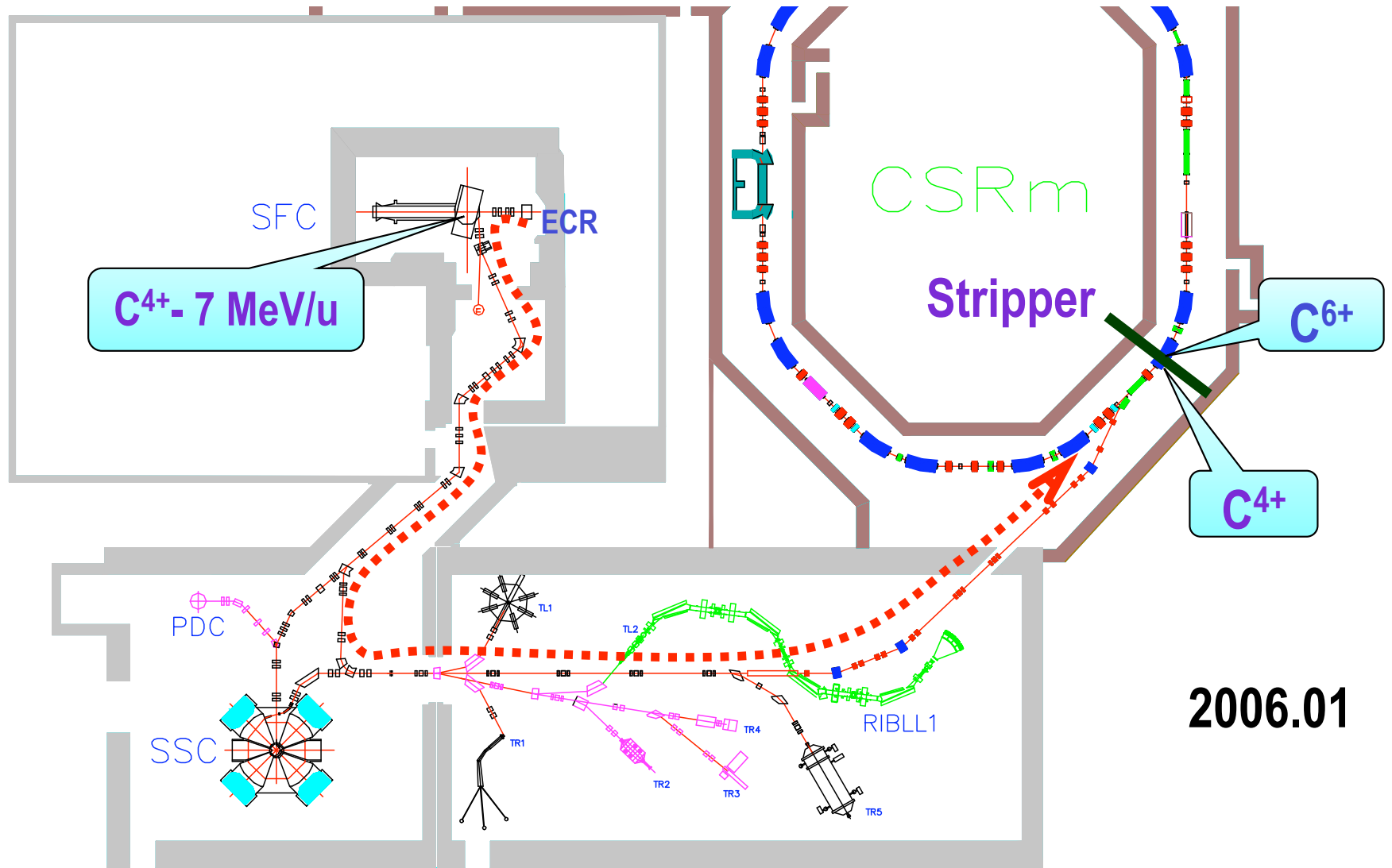


HIRFL-CSR

Commissioning

2006---2007

Stripping Injection Scheme

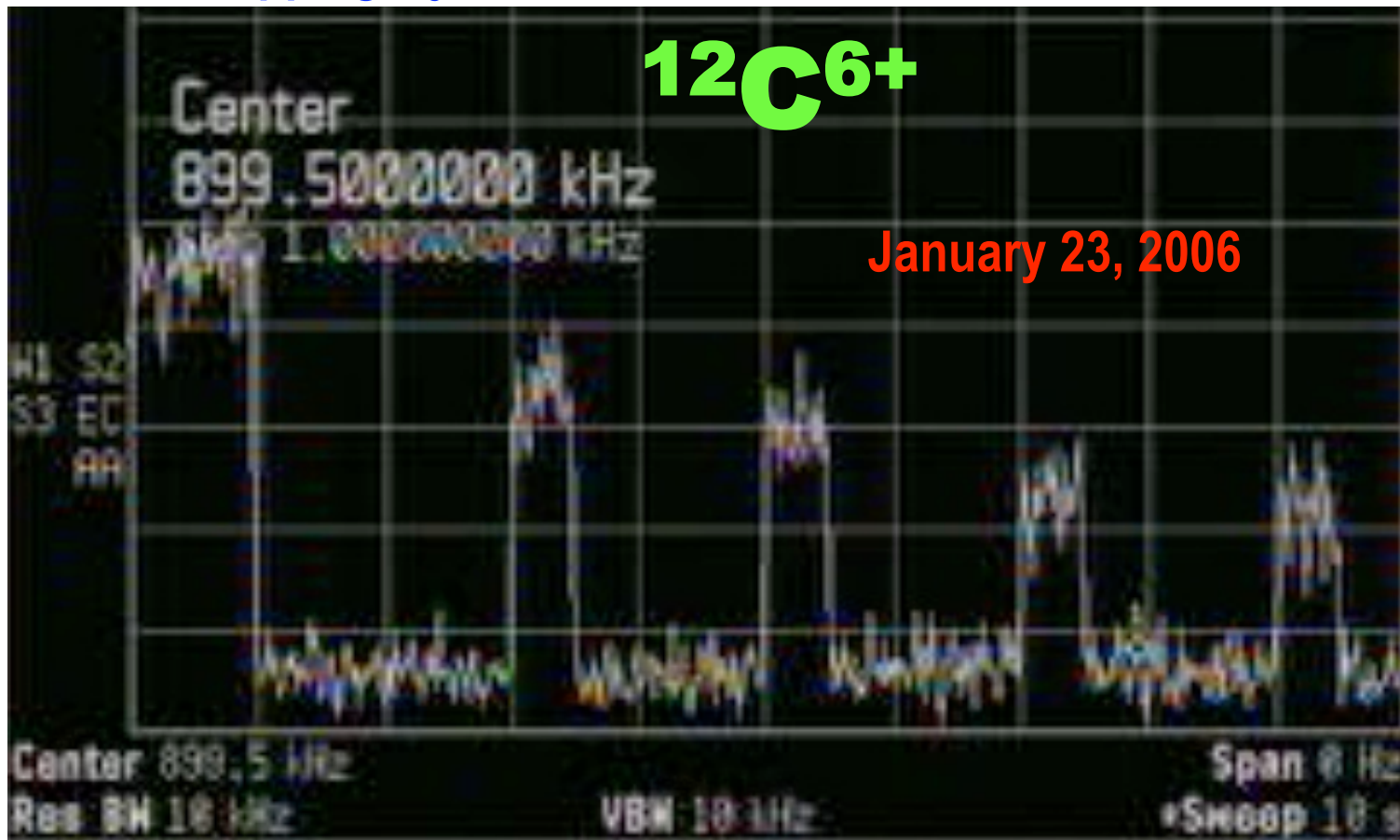


First stored beam signal from spectrum analyzer in CSRm

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

Stripping injection

23Cy2 =7A 21D4 =0.5A

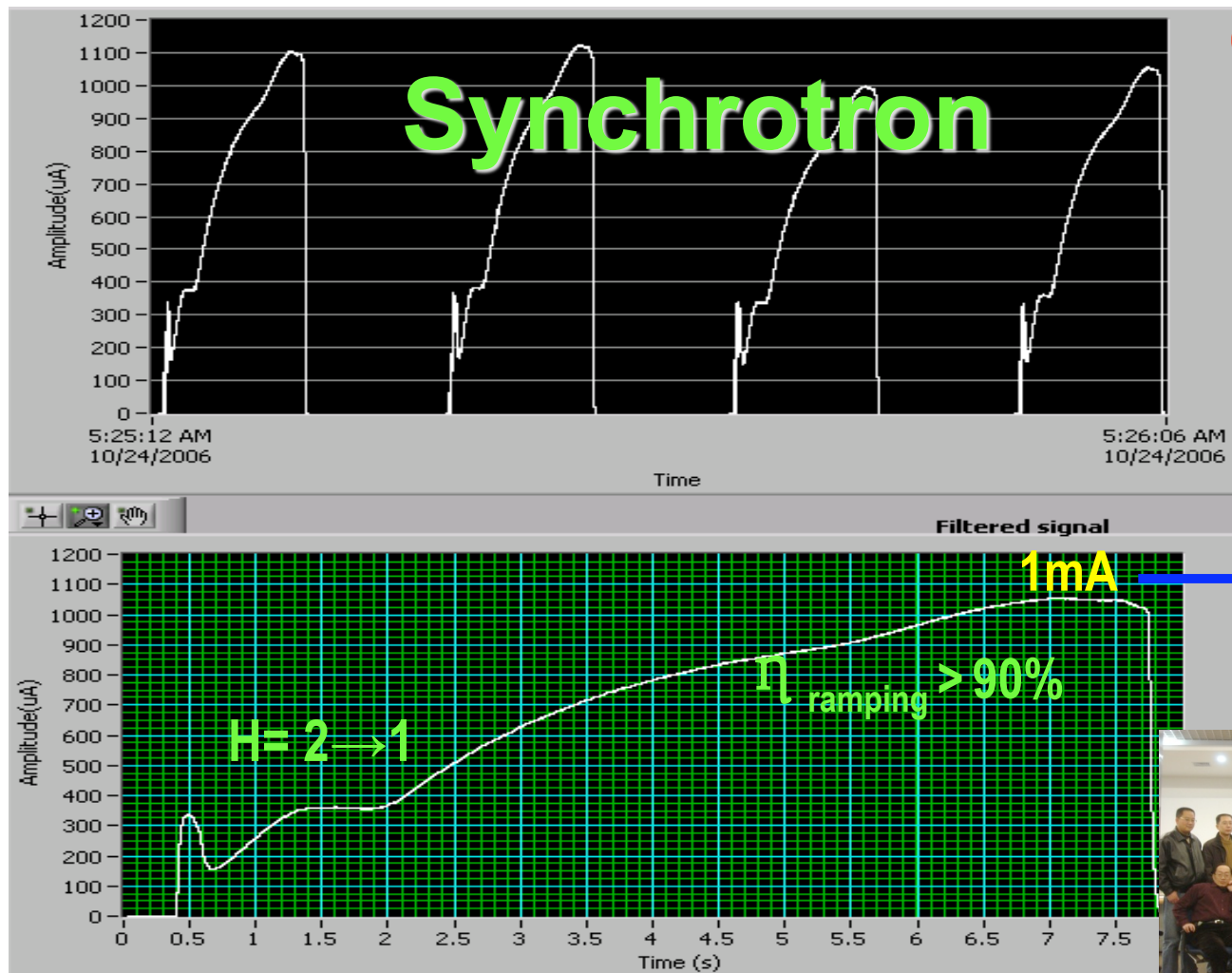


5 times of RF in 10s

7MeV/u $\rightarrow$ 1GeV/u (C^{6+}) Ramping

$H = 2 \rightarrow 1$, $f_{rf} = 0.45 \rightarrow 1.63$ MHz, $G = 11.3$ Tm

Oct. 24, 2006

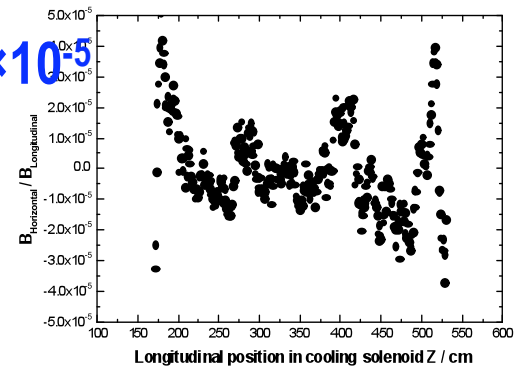
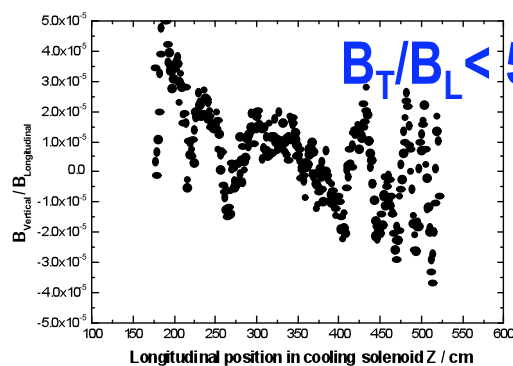
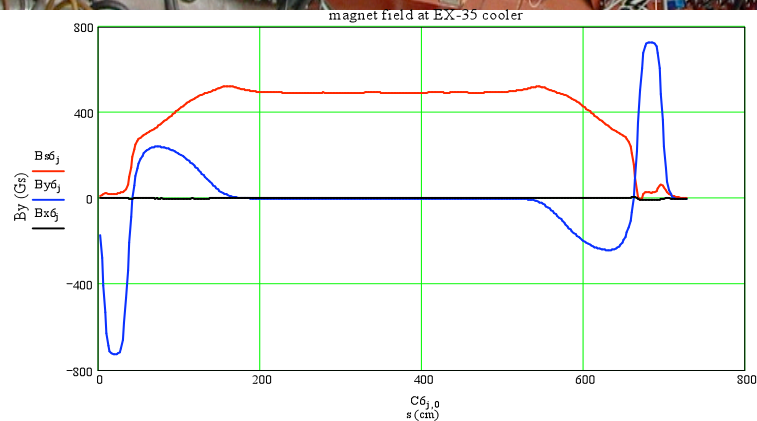
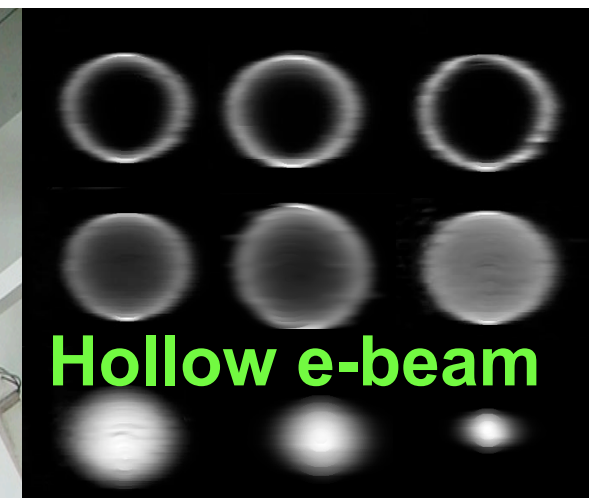


2006.12

e-cooler

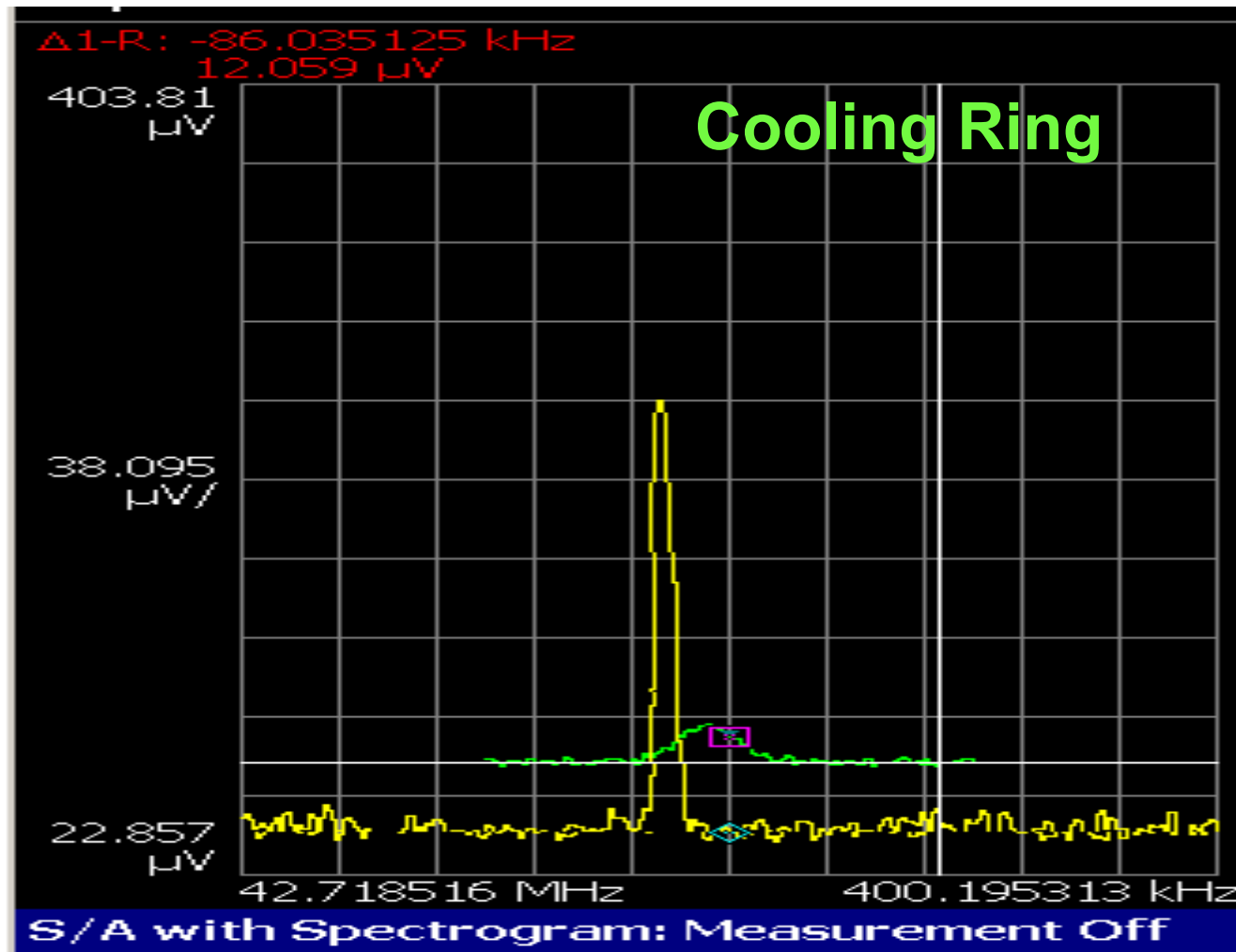
cooling for beam stacking

Hollow e-beam



First e-cooling effect in CSRm

C⁶⁺-7MeV/u , observed the longitudinal schottky signal from spectrum analyzer



Dec. 27, 2006

$\Delta P/P$

4×10^{-3}

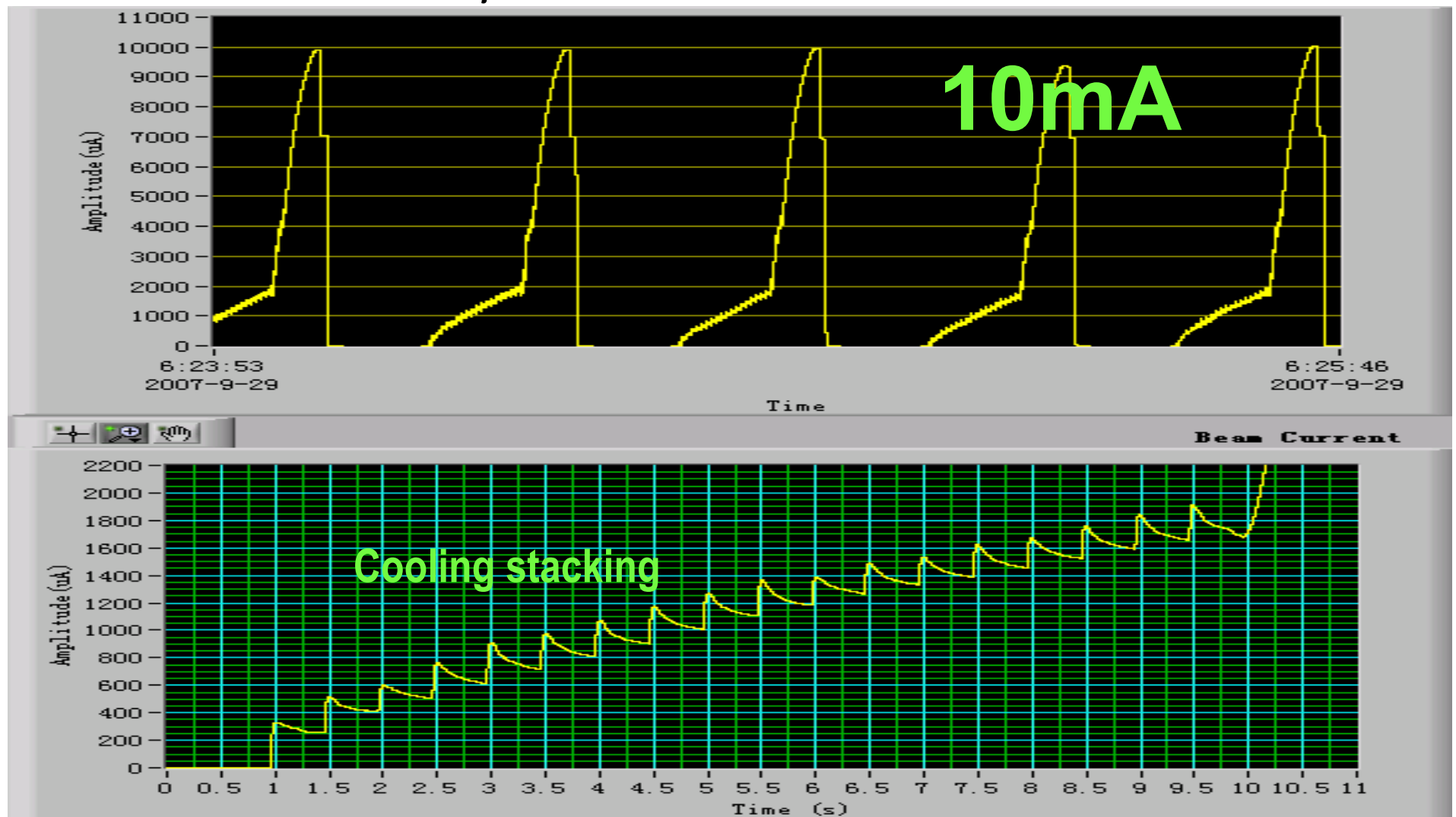


2×10^{-4}

C^{6+} -600MeV/u Ramping in CSRm

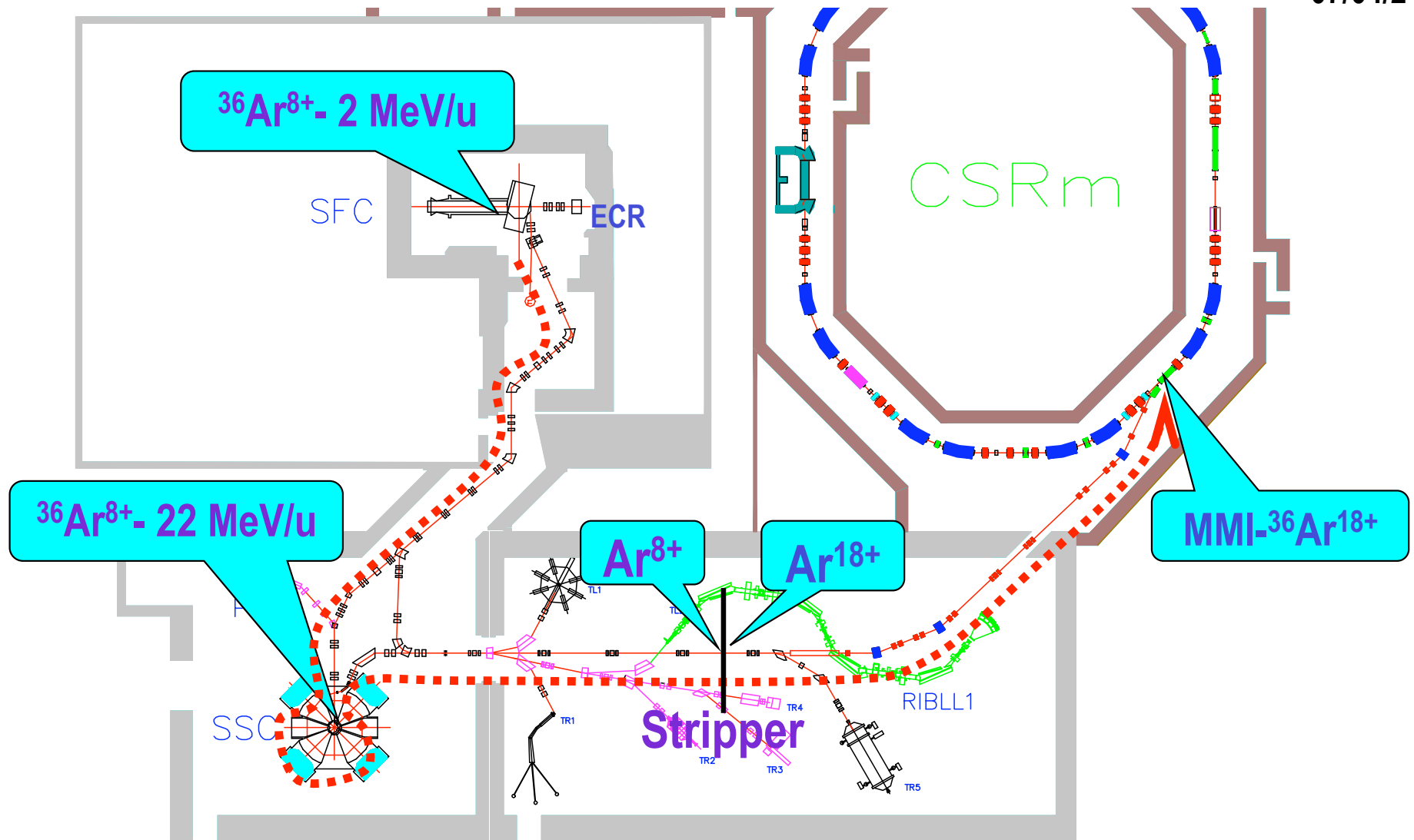
07/09/29 06:25

SFC- $^{12}C^{4+}$ -7MeV/u, $I_{inj.} = 11\mu A$, STI, 1800 μA in 10s, 10000 μA on top, 7×10^9



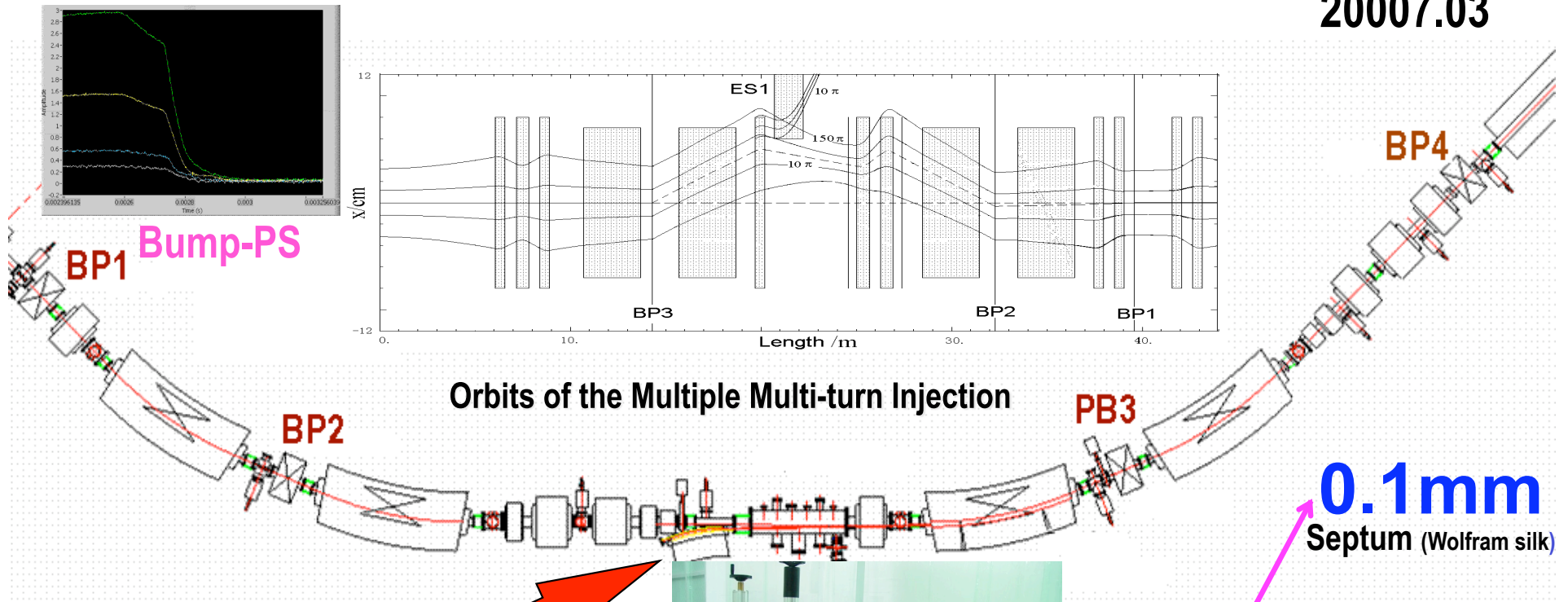
Scheme of the **MMI** for Ar-beam in CSRm

07/04/24



Bump section for CSRm Multi-turn injection

20007.03

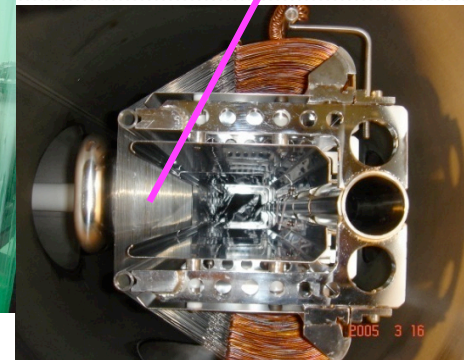


Beam

$L = 2 \text{ m}$
 $V_{\text{max.}} = 160 \text{ kV}$
 $\text{Gap} = 23 \text{ mm}$



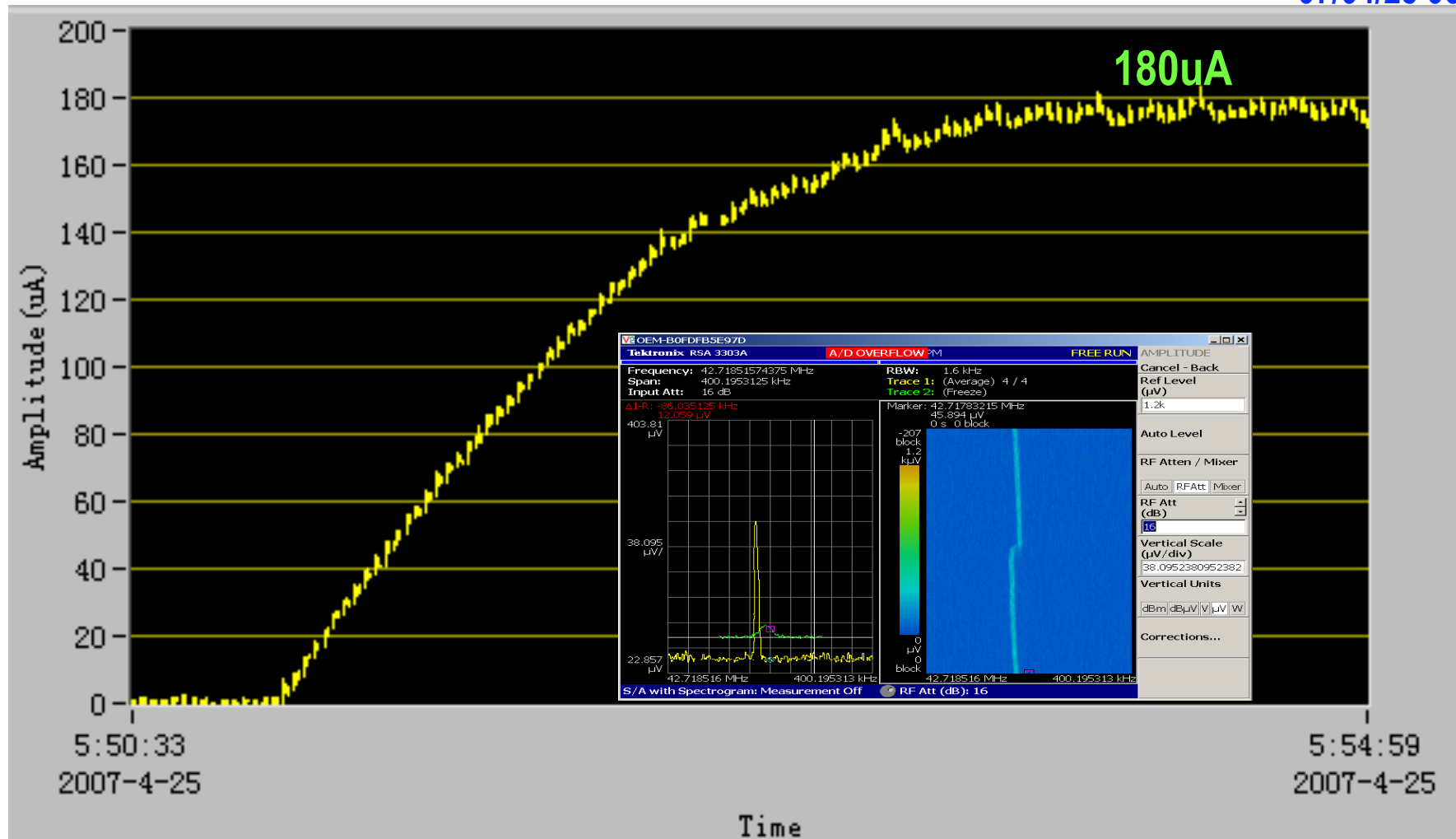
Static-electric septum



MMI for Ar-beam in CSRm with e-cooling

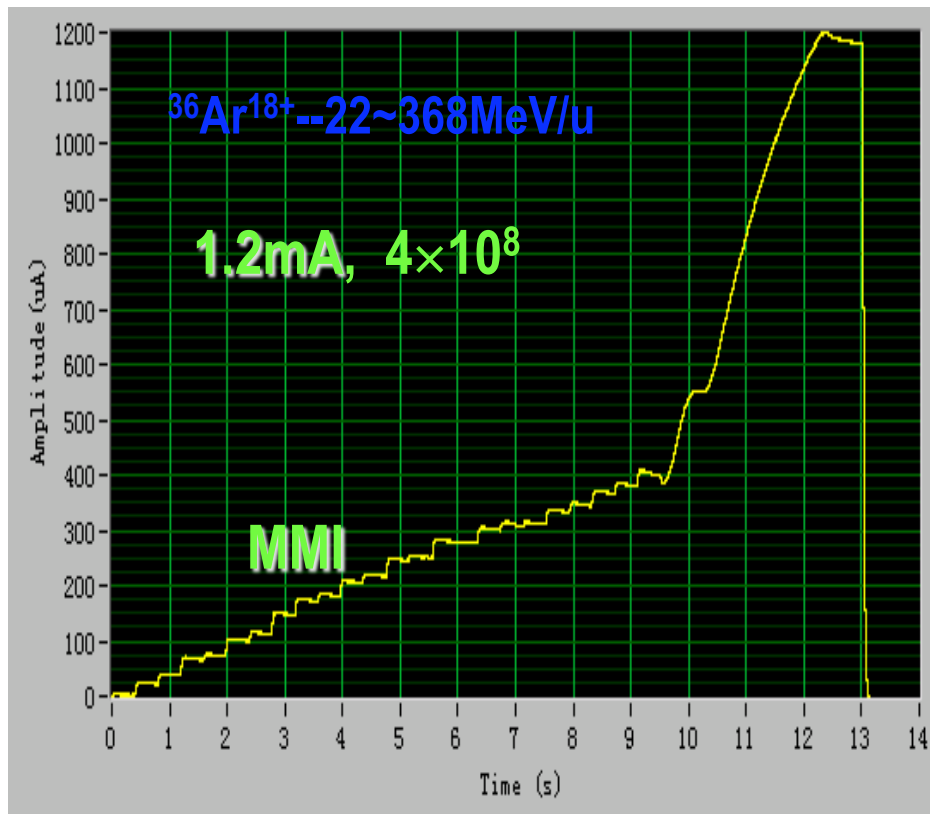
SSC-Ar-22MeV/u, $I_{inj.} \sim 2\mu\text{A}$, DCCT $\sim 180\mu\text{A}$, Period=2min., Gain ~ 90

07/04/25 06:00

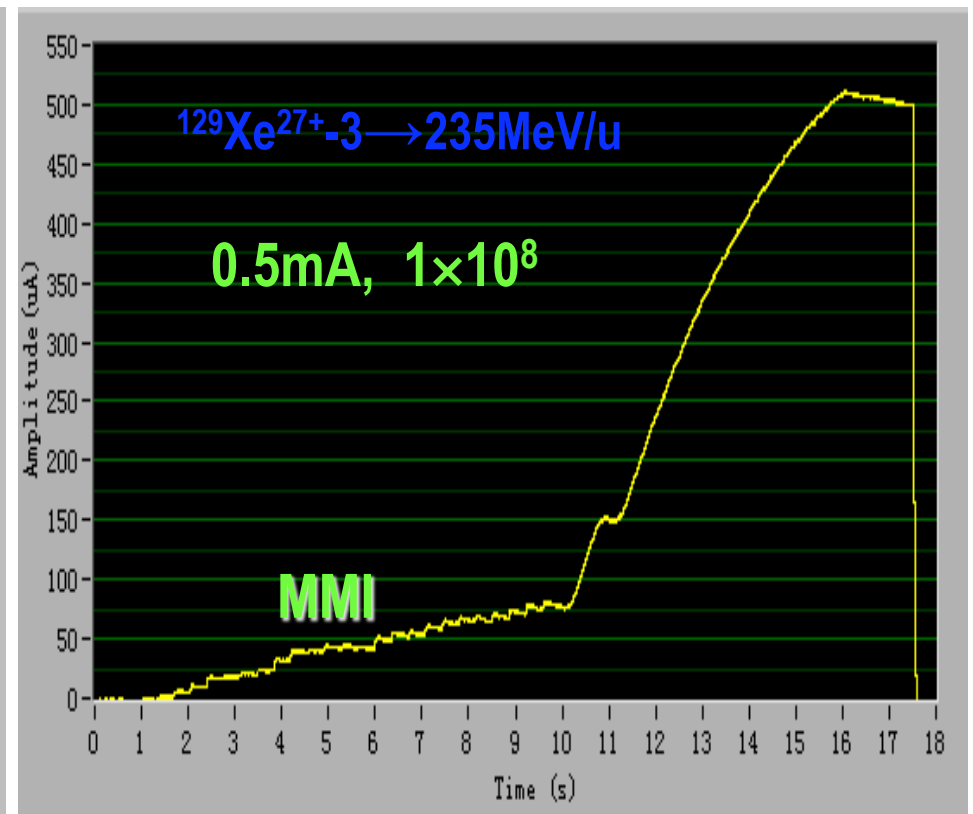


MMI + Ramping in CSRm

07/12/10 00:08

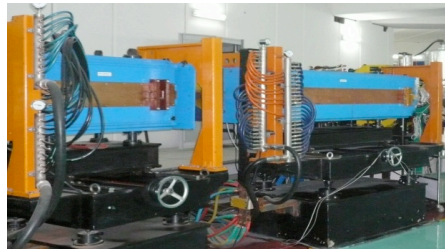


07/06/25 07:20

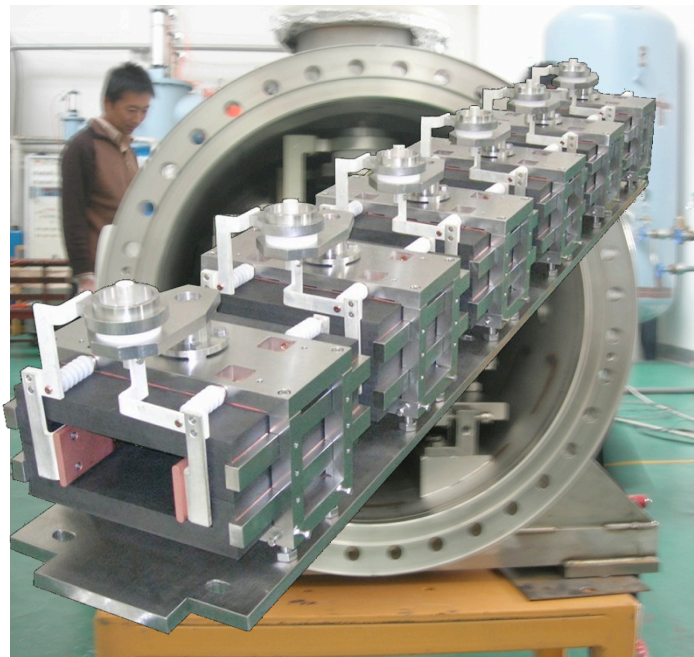
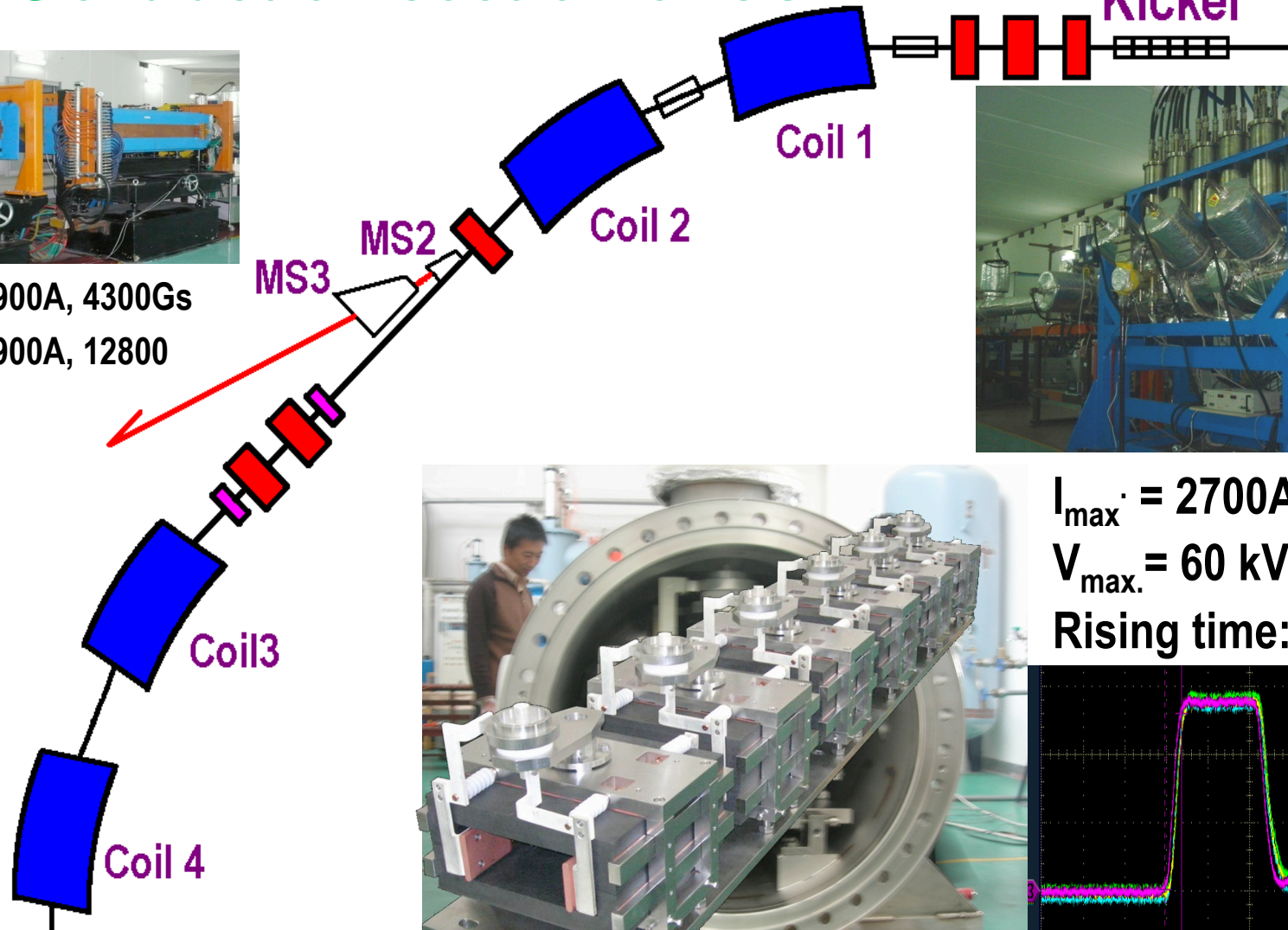


Fast extraction section of CSRm

07/08



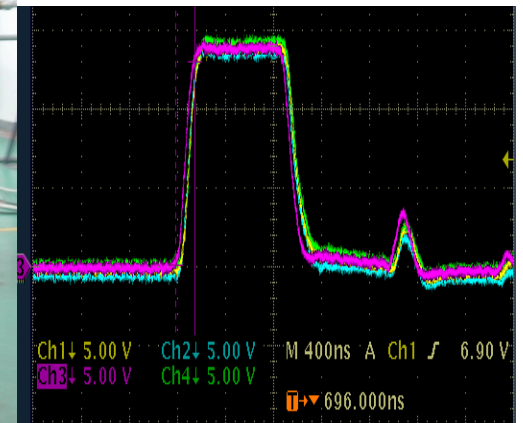
MS2: 2900A, 4300Gs
MS2: 2900A, 12800



$I_{\max} = 2700\text{A}$

$V_{\max} = 60\text{ kV}$

Rising time: **150ns**

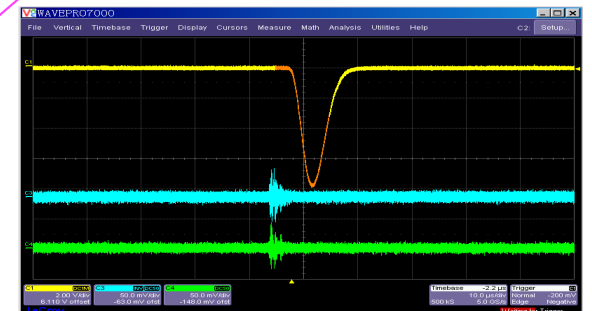


Fast-extraction from CSRm Success

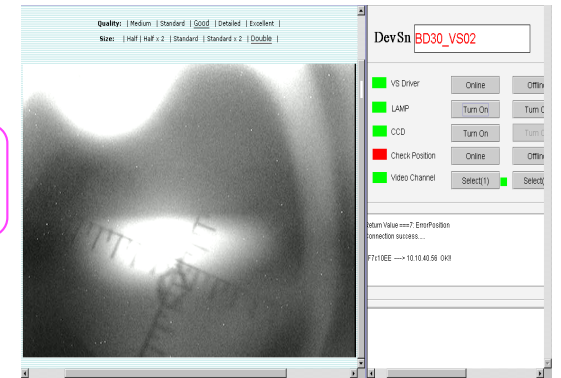
07.8.4

PT

30FC1



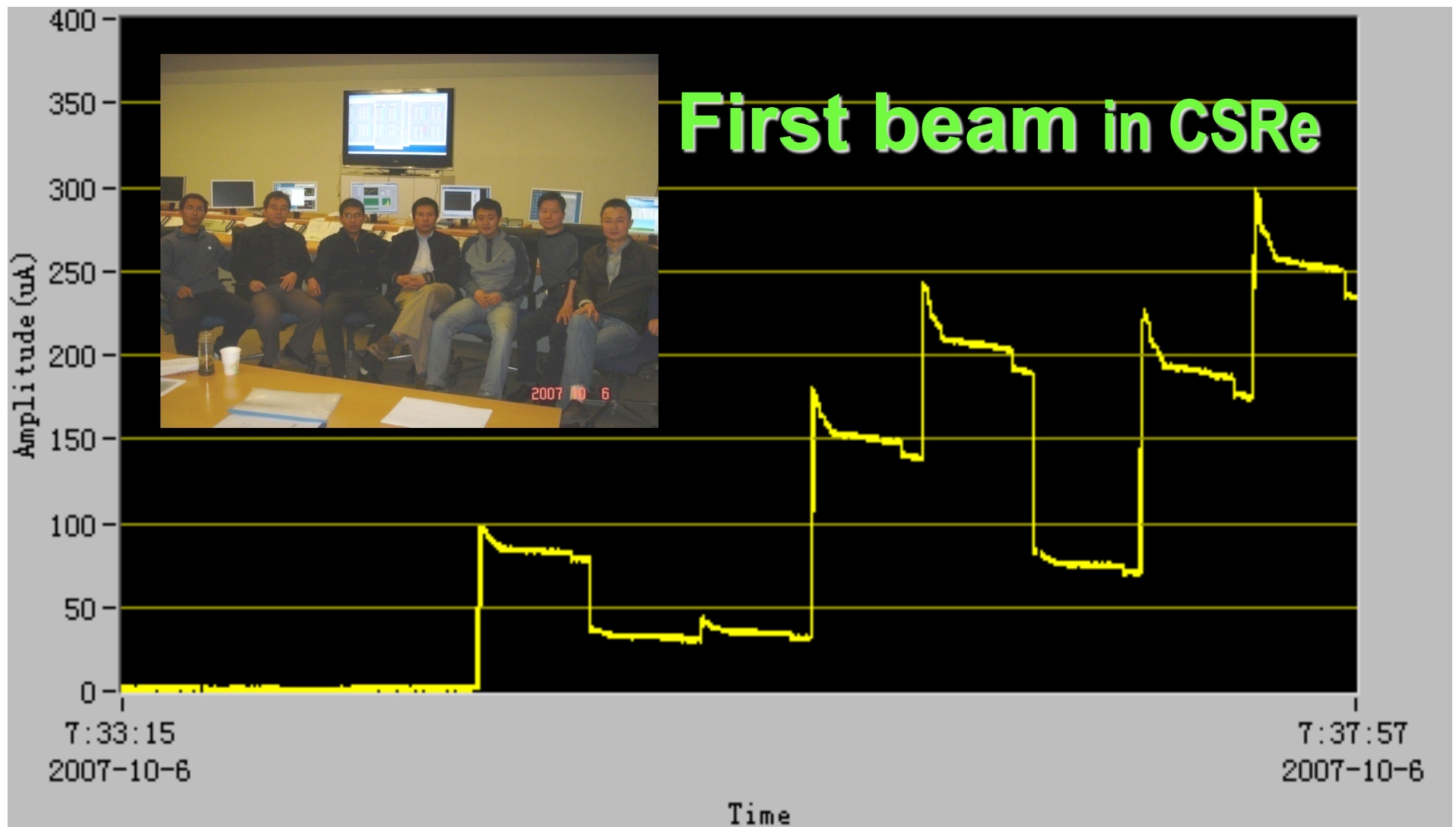
30VS2



Storage-beam for CSRe 1st Commissioning

$^{12}\text{C}^{6+}$ -600MeV/u

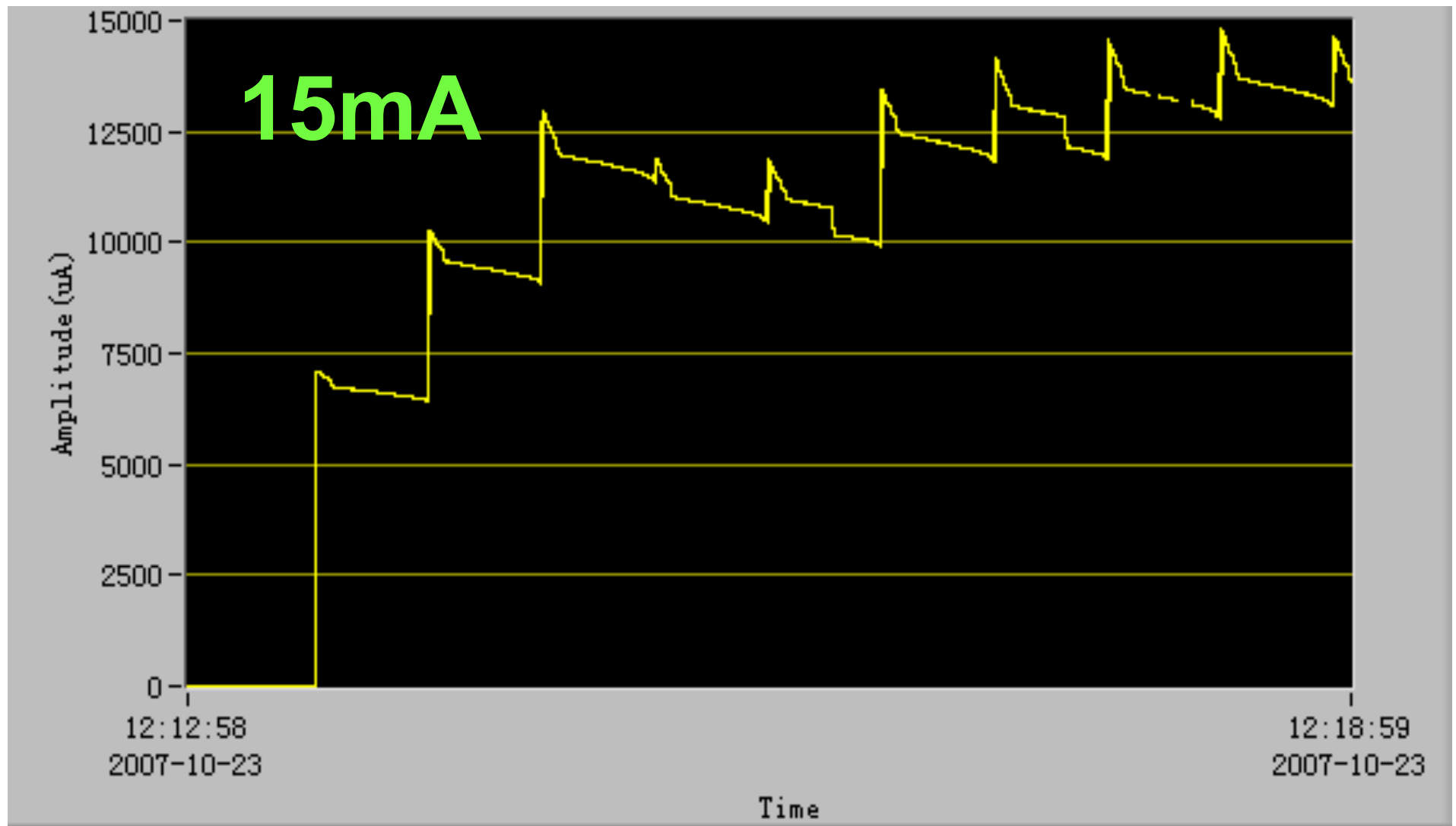
07/10/06 07:40



Multi-time Injection for CSRe 1st Commissioning

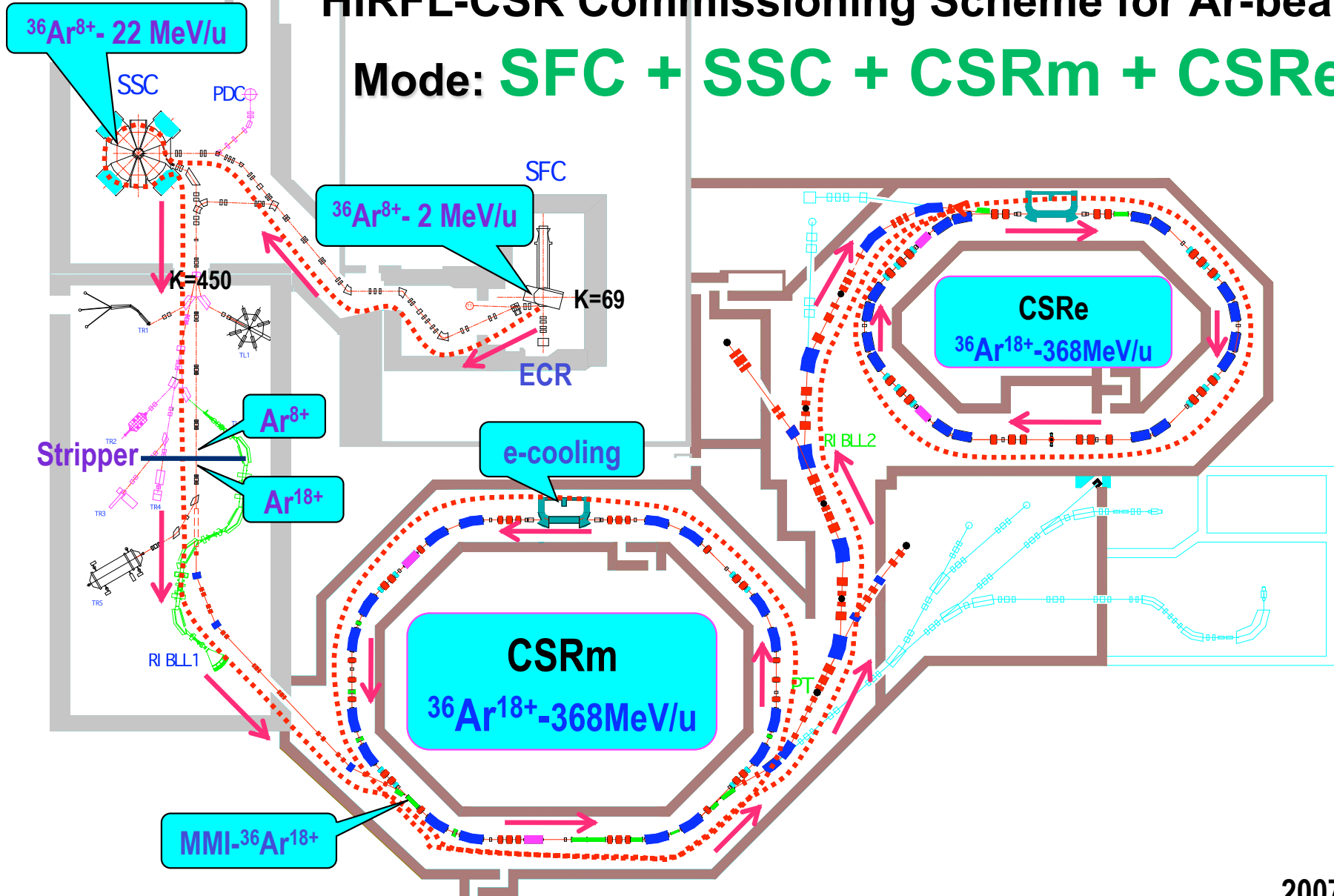
$^{12}\text{C}^{6+}$ -660MeV/u

07/10/23 12:18



HIRFL-CSR Commissioning Scheme for Ar-beam

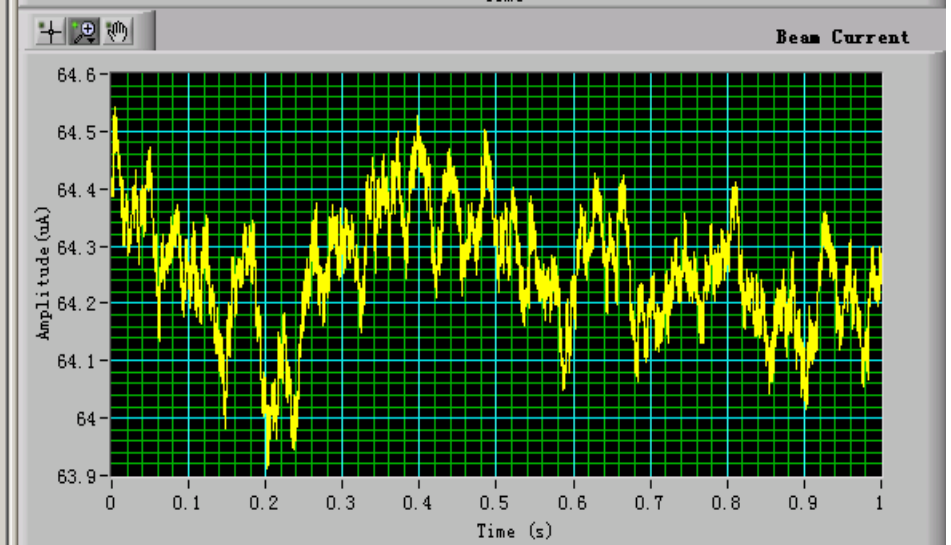
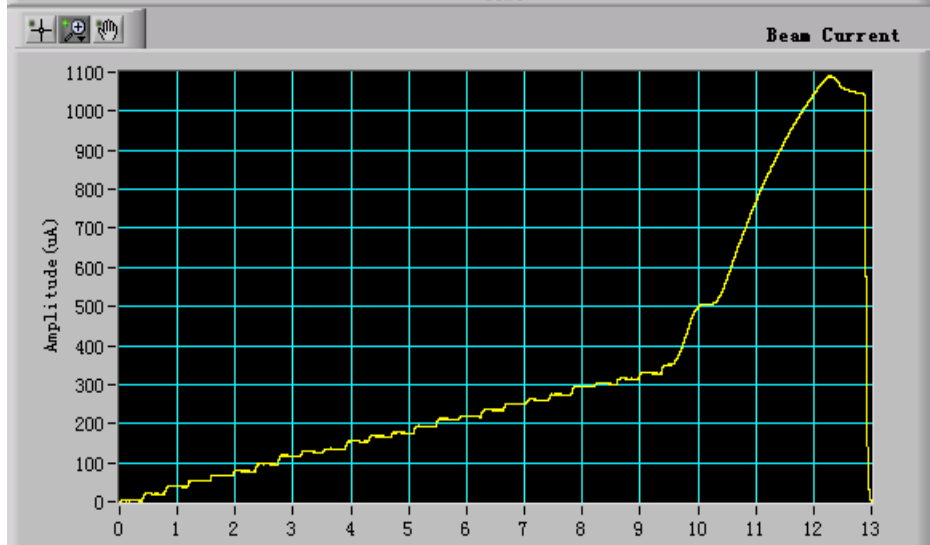
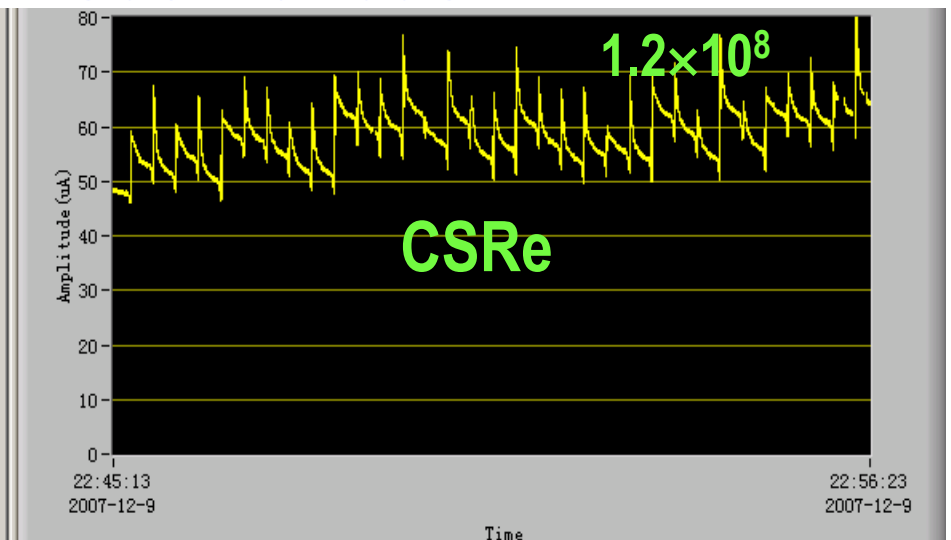
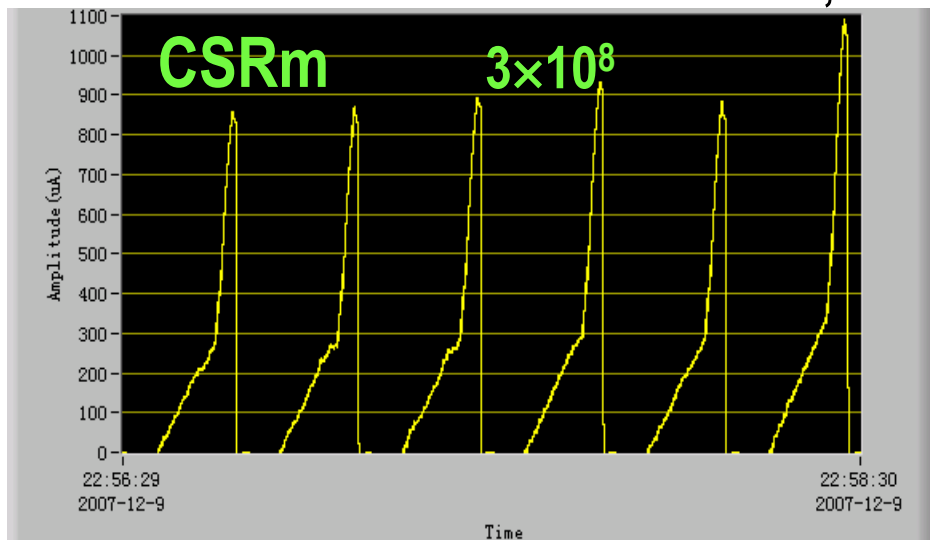
Mode: **SFC + SSC + CSRm + CSRe**



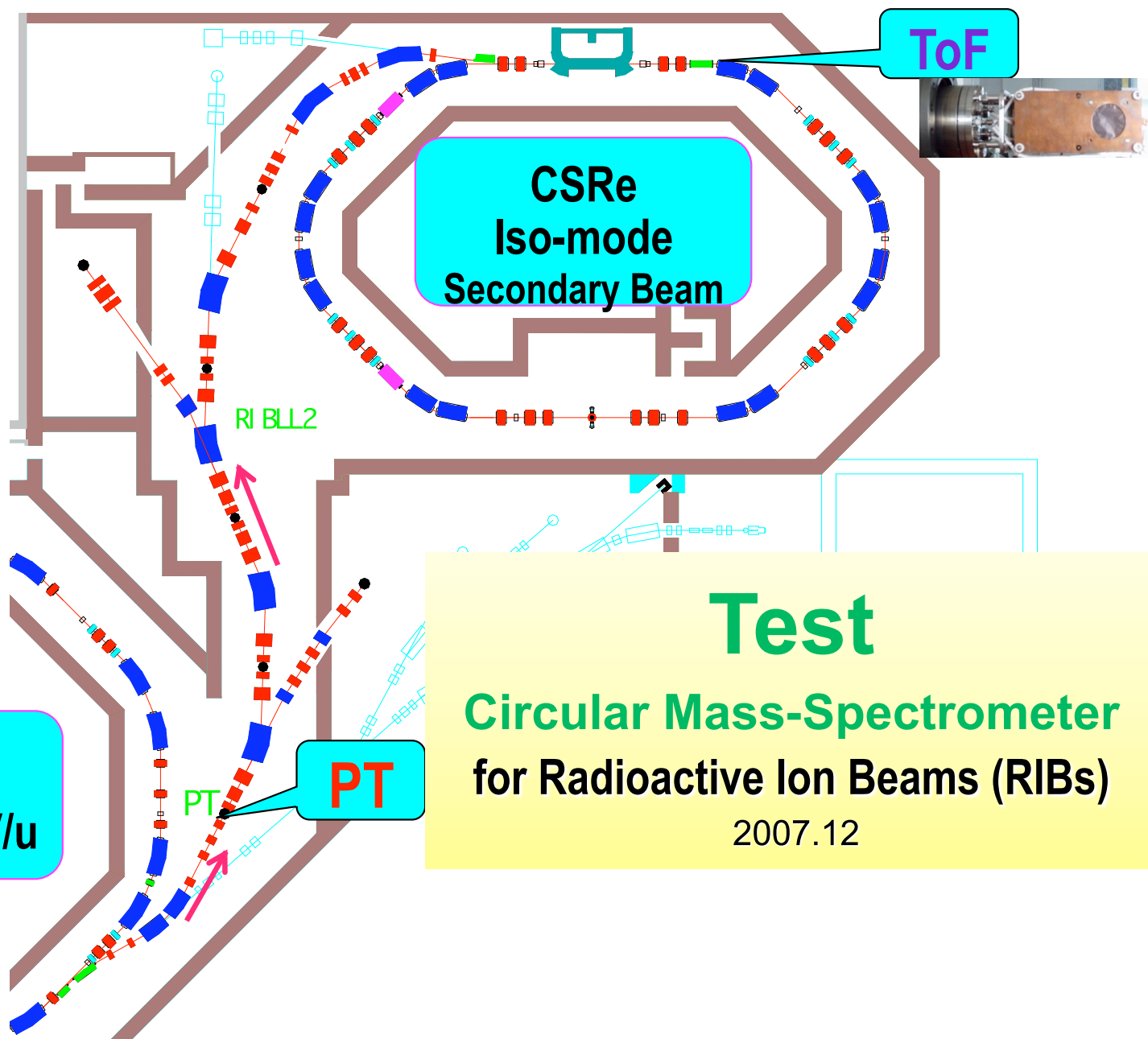
Ar-beam in CSRm and CSRe

$^{36}\text{Ar}^{18+}$ -368MeV/u, Mode = Isochronous

07/12/09 22:56



CSRm
 $^{36}\text{Ar}^{18+}$ -368MeV/u



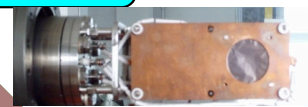
CSRe
Iso-mode
Secondary Beam

RI BLL2

PT

PT

ToF



Test

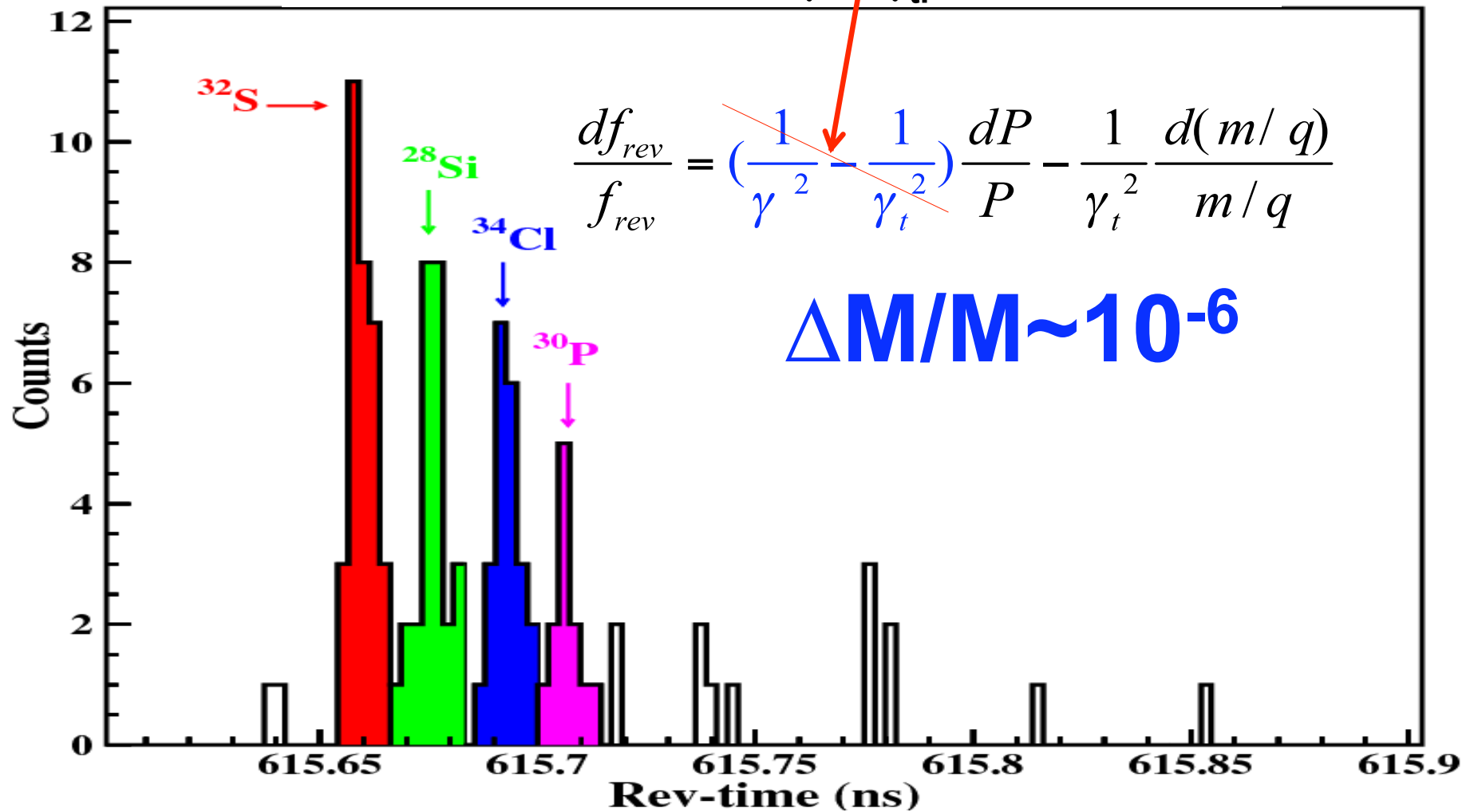
Circular Mass-Spectrometer
for Radioactive Ion Beams (RIBs)

2007.12

2007.12.07

Mass Measurement of RIBs in CSRe

Isochronous Mode: $\gamma = \gamma_{tr} = 1.395$, ToF

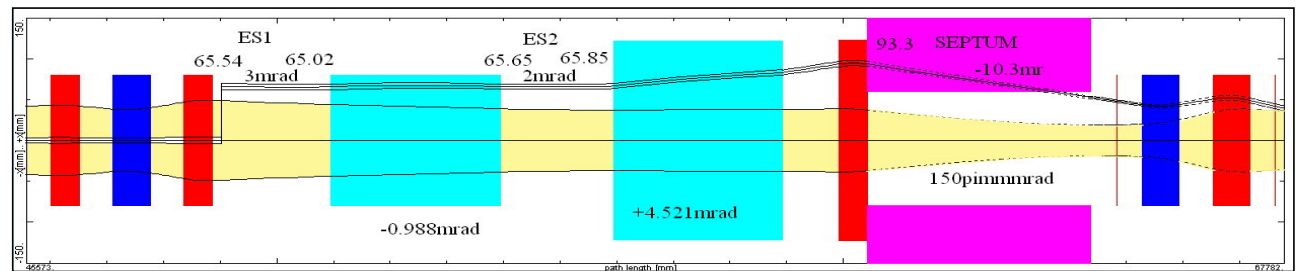
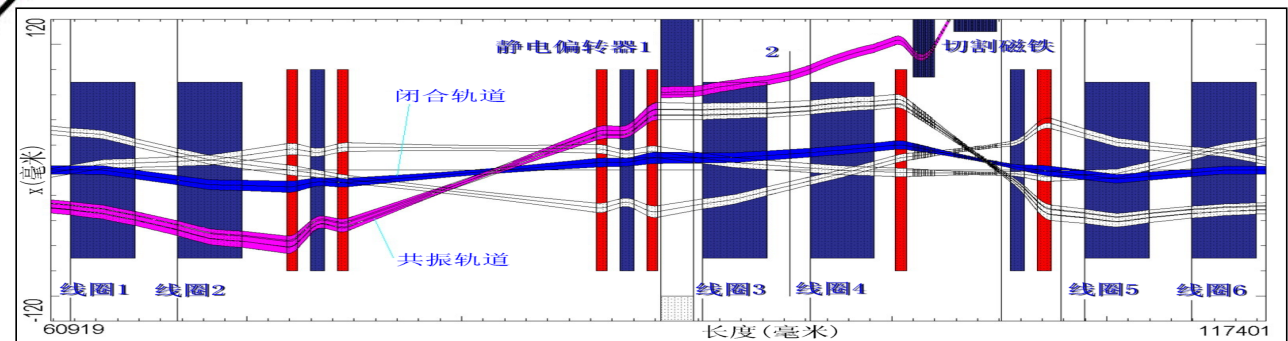
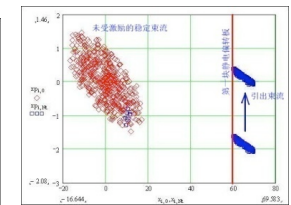
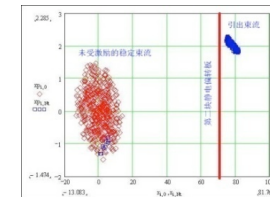
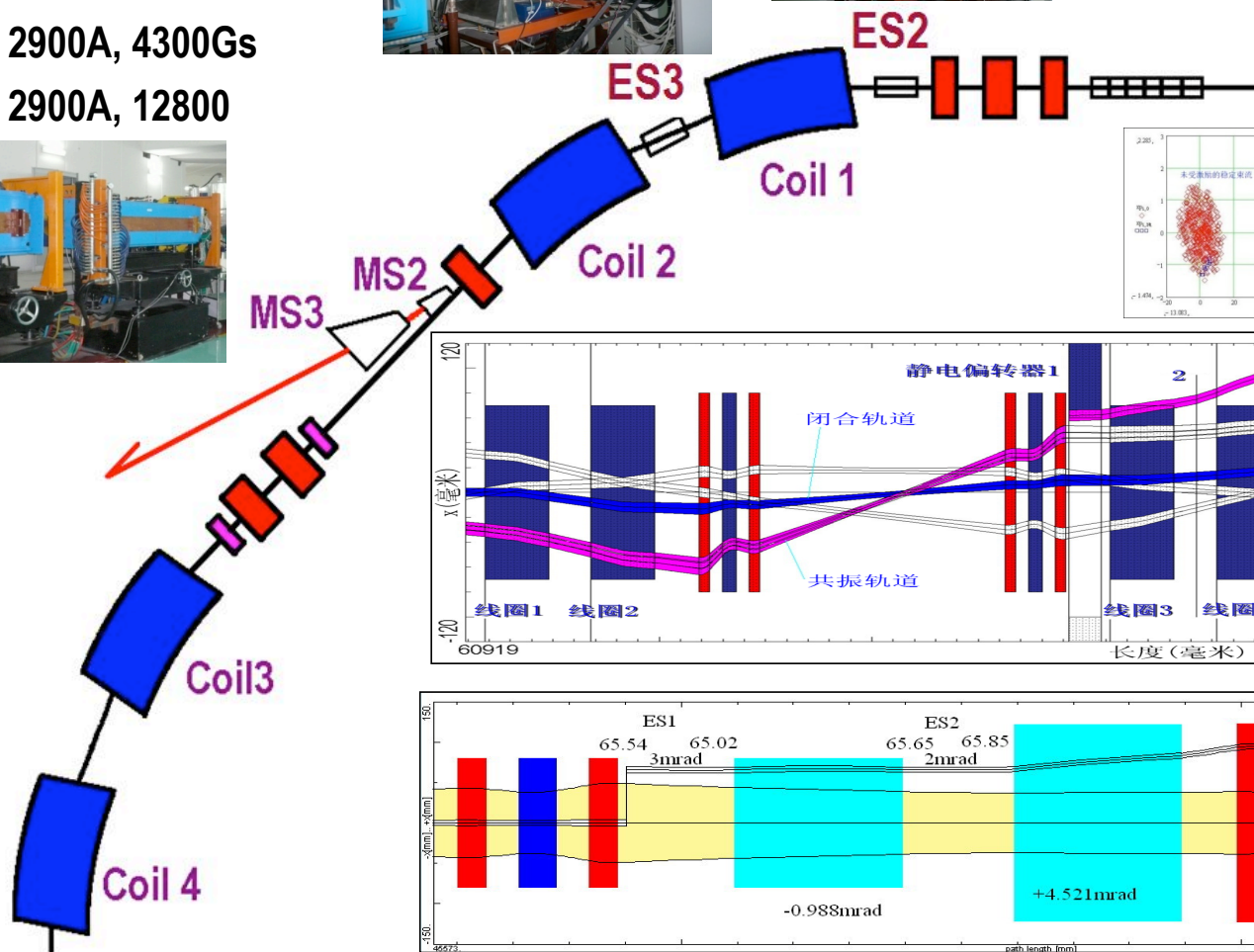


Slow extraction of 1/3 Resonance in CSRm

2008.01.10

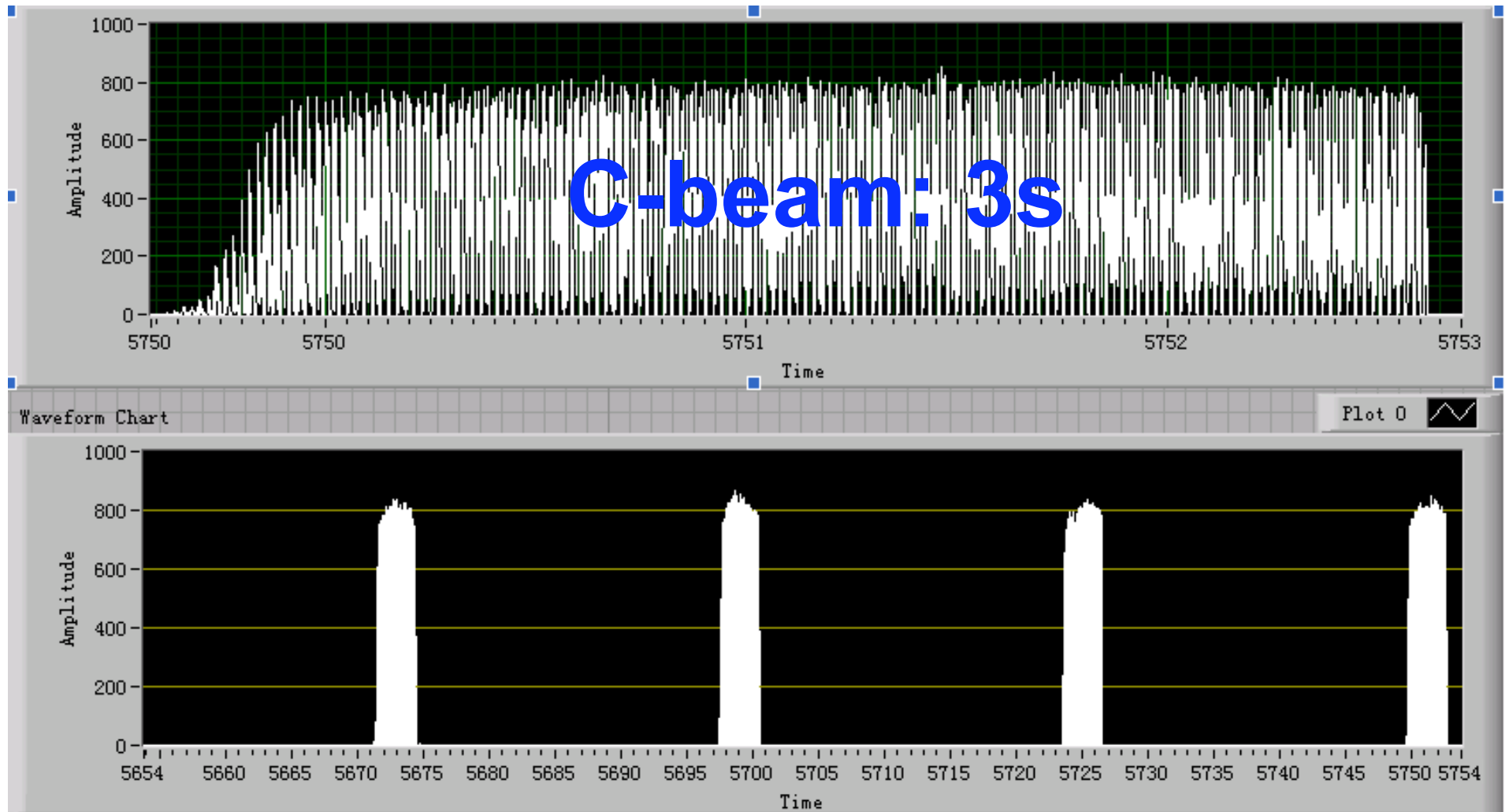
MS2: 2900A, 4300Gs

MS2: 2900A, 12800



Slow extraction for $^{12}\text{C}^{4+}$ -300MeV/u in CSRm

From Scintillation Crystal Monitor



HIRFL-CSR

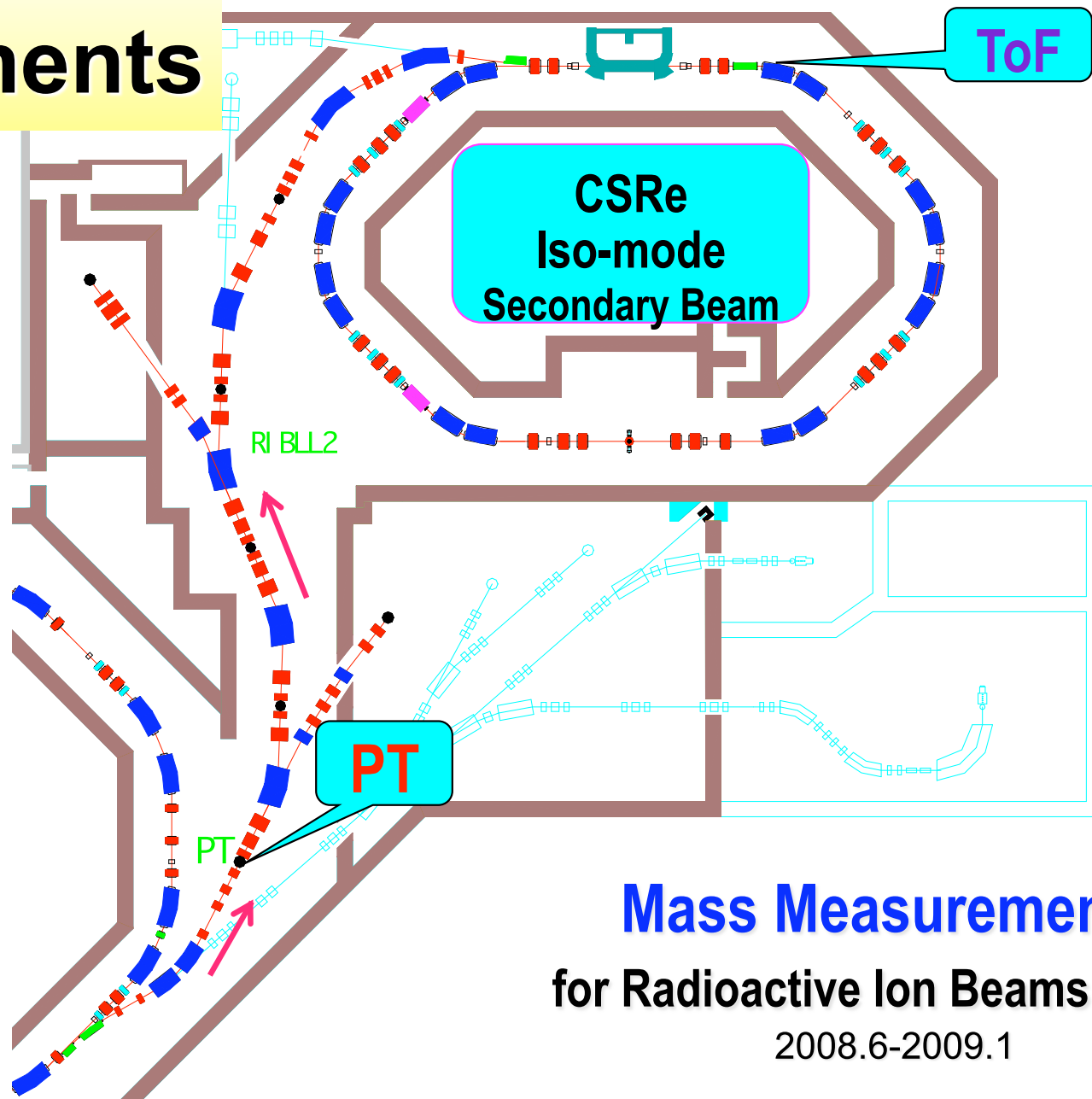
Operation & Experiments

2008---2009

HIRFL-CSR Control Room



Experiments



CSRm

$^{78}\text{Kr}^{28+}$

447.8 MeV/u

451.1 MeV/u

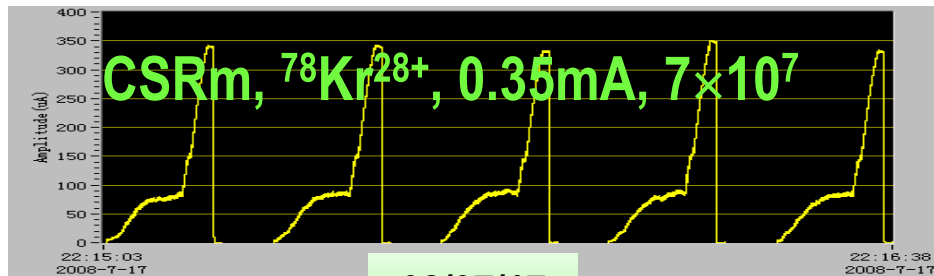
458.4 MeV/u

481.9 MeV/u

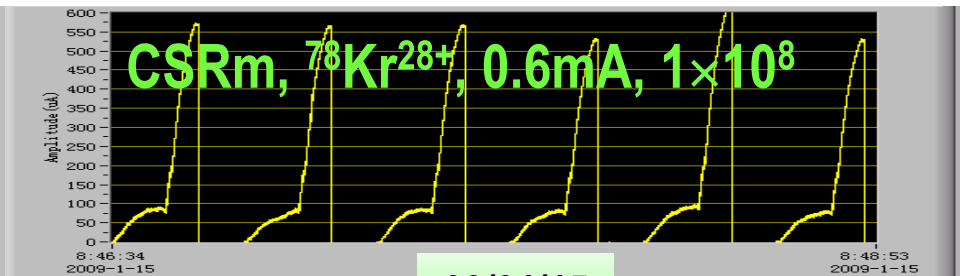
**Mass Measurements
for Radioactive Ion Beams (RIBs)**

2008.6-2009.1

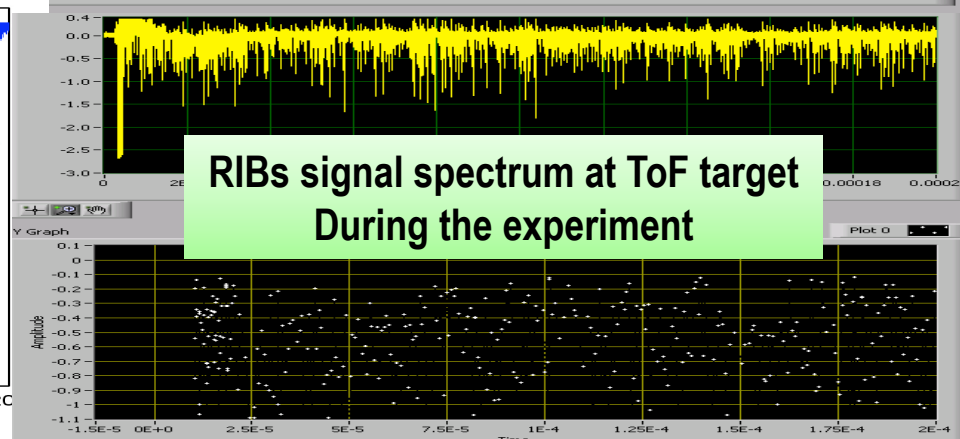
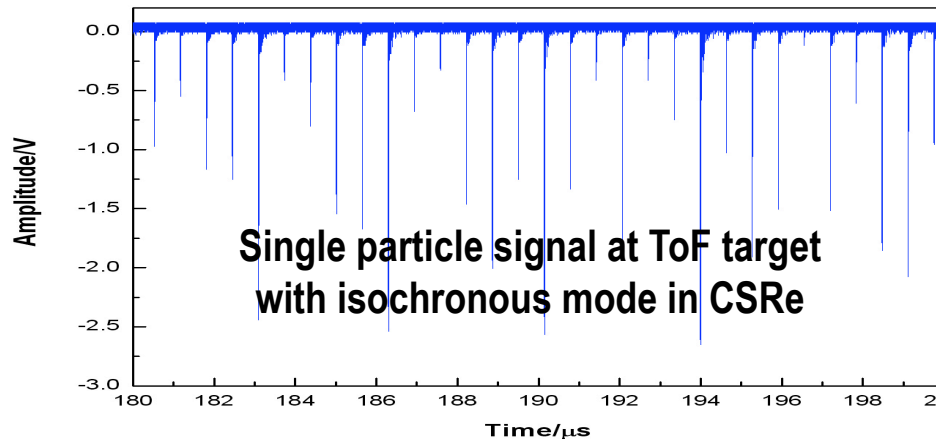
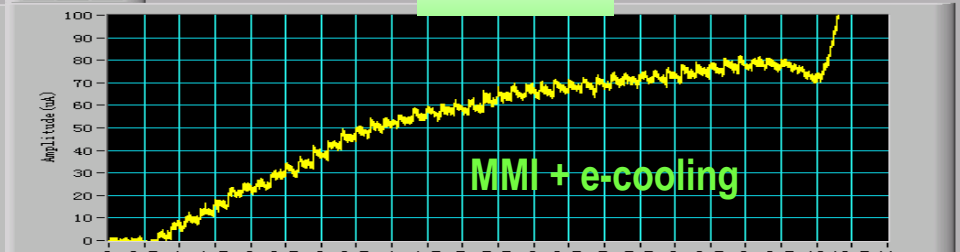
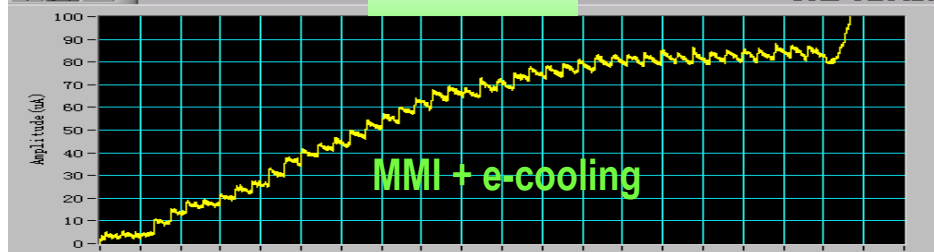
Experiments for RIBs spectroscopy



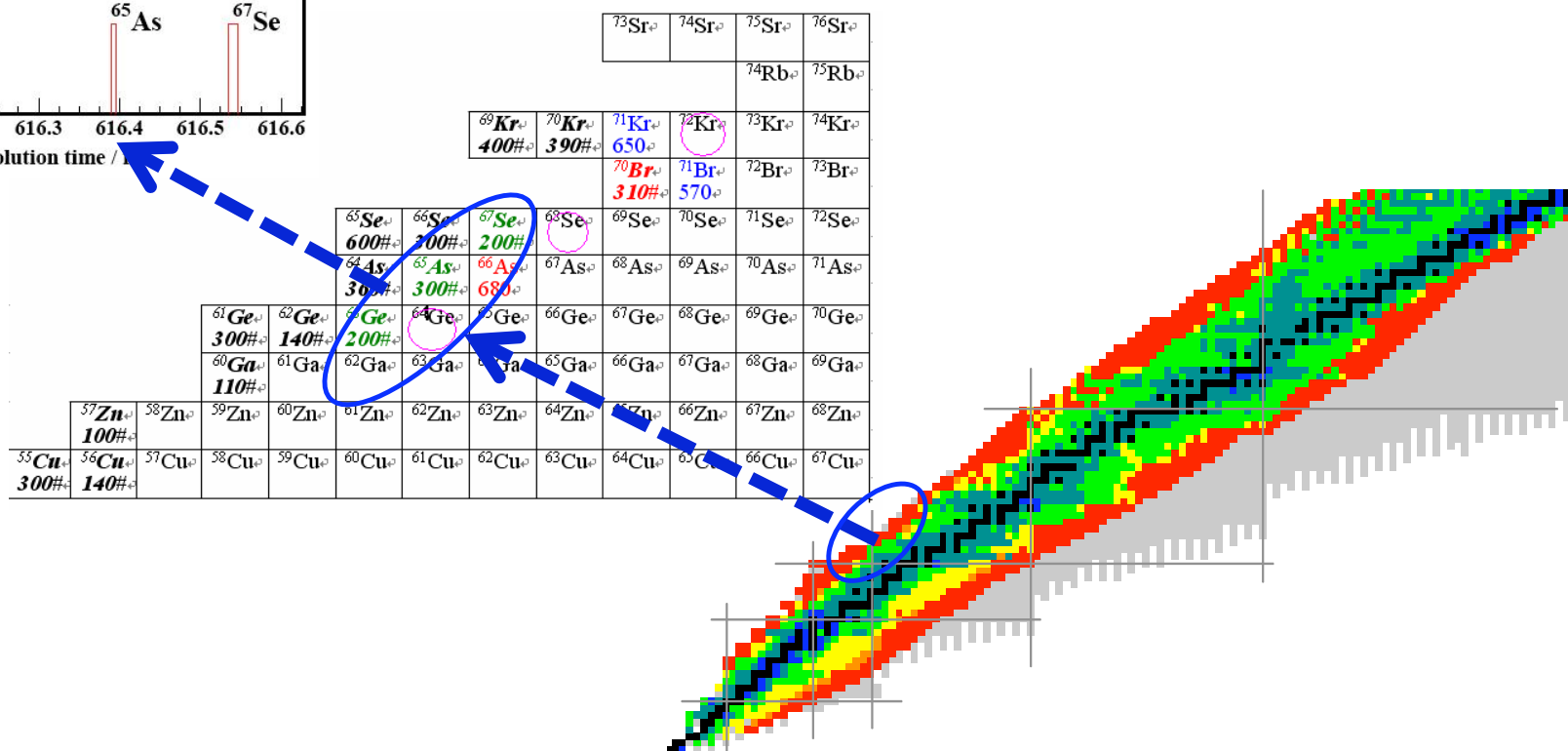
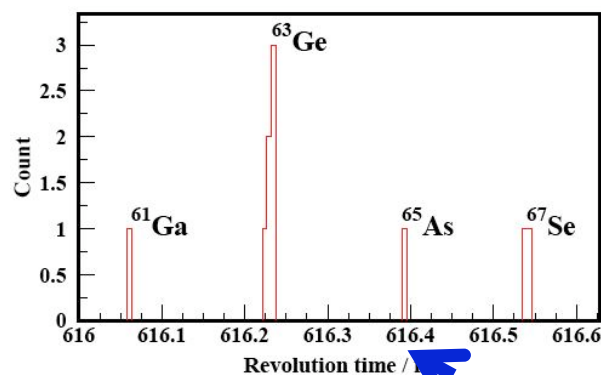
08/07/17



09/01/15

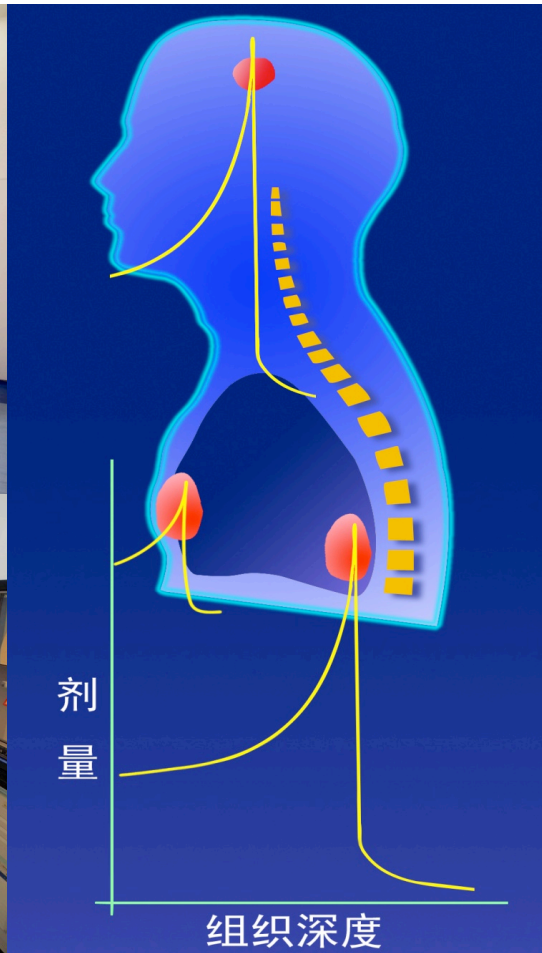


For the 3 drop-line nuclei ^{63}Ge , ^{65}As , ^{67}Se with the life-time of 100ms

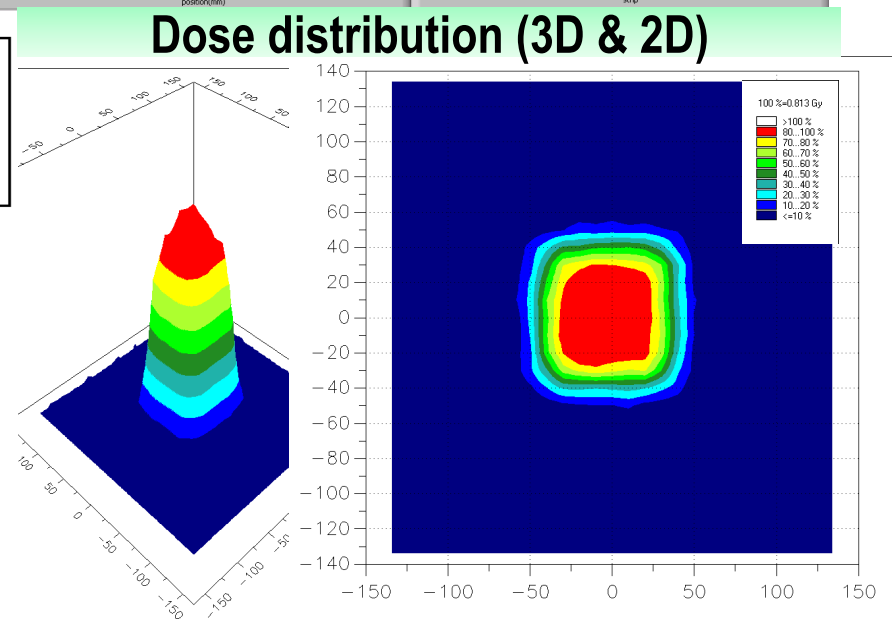
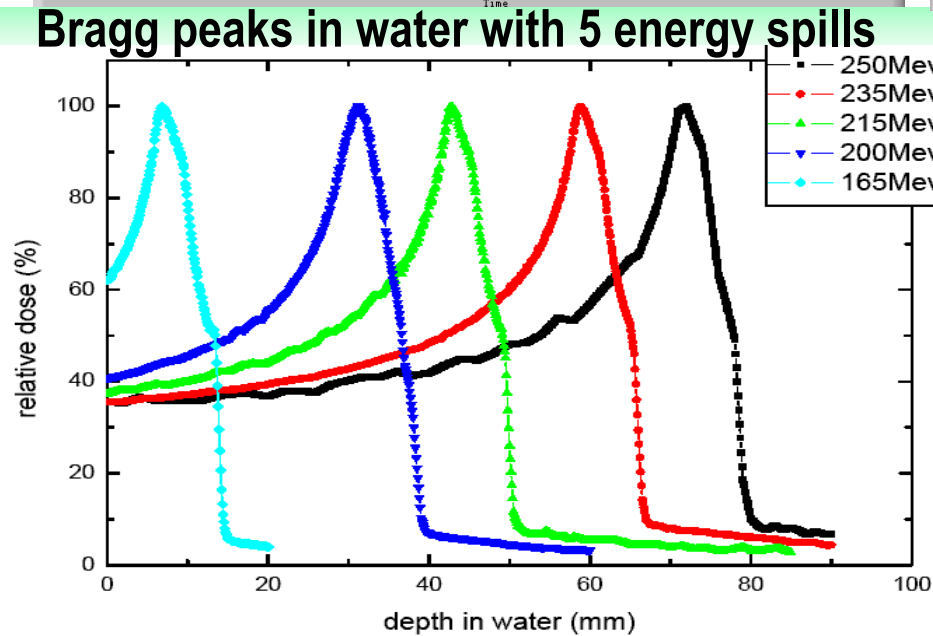
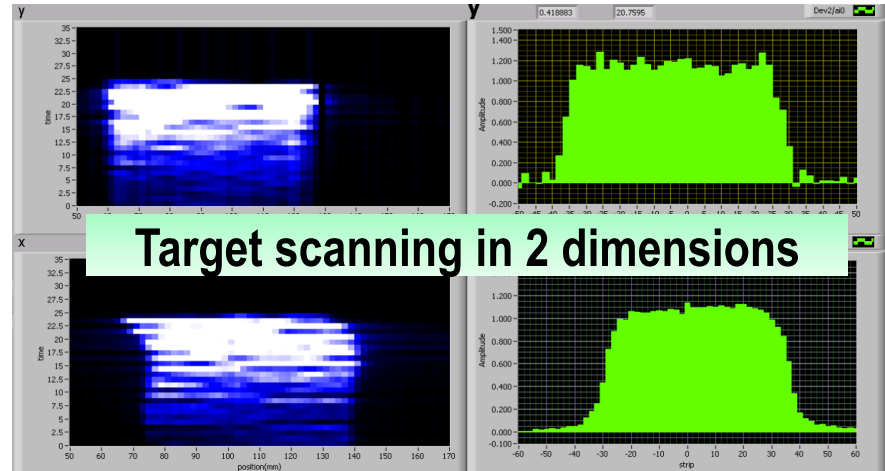
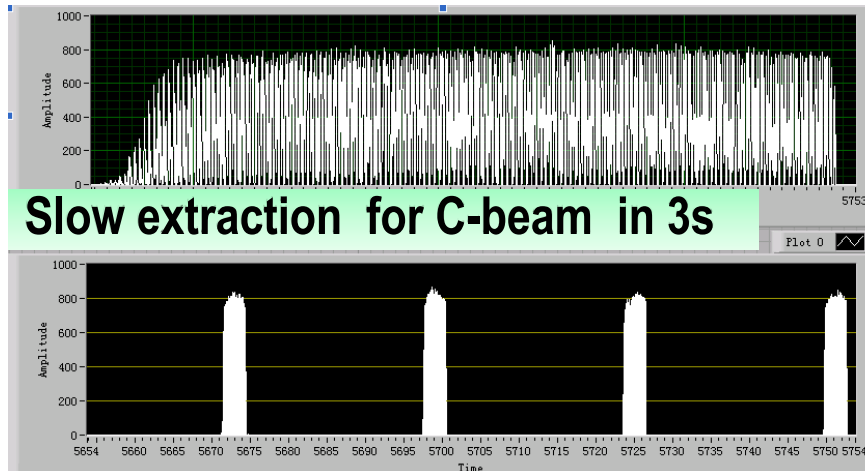


Cancer Therapy with CSRm (2009.03-04)

First batch: 6 patients

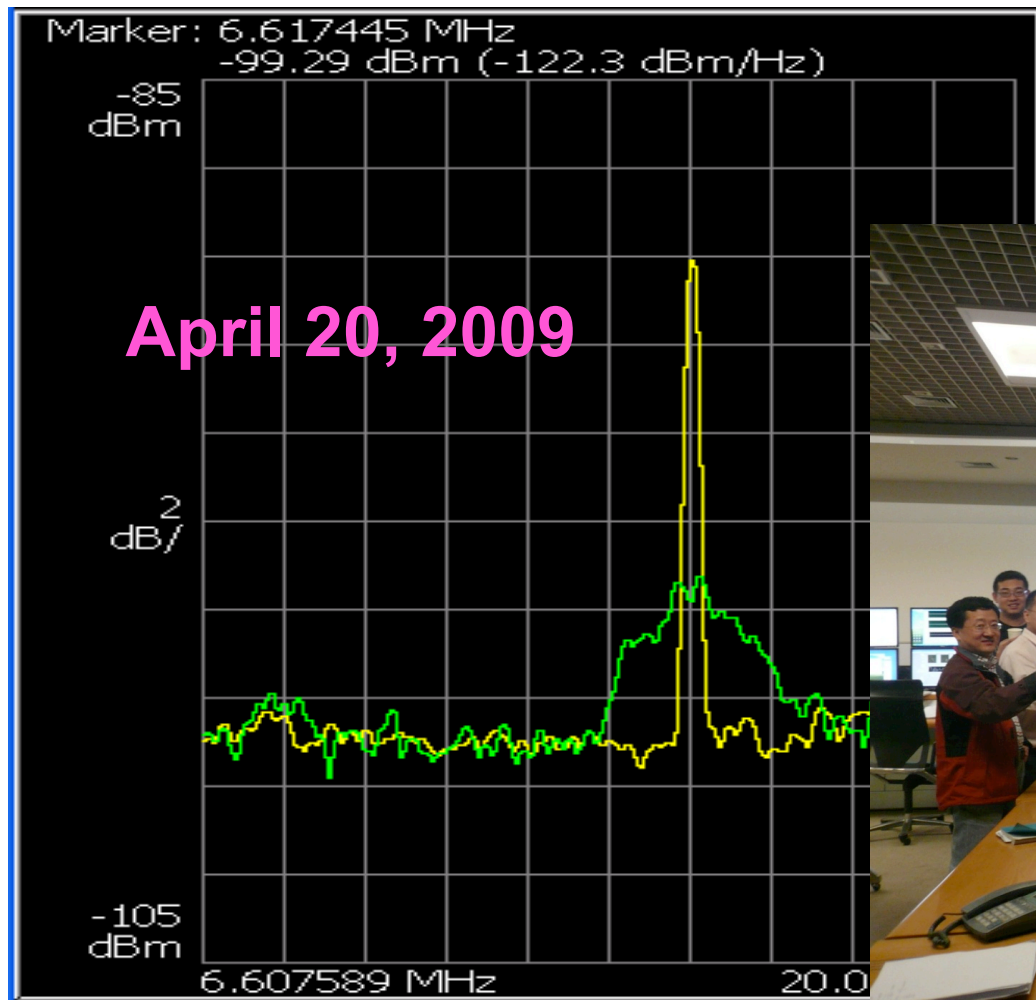


Cancer Therapy with CSRm (2009.03-04)



First e-cooling effect in CSRe

C⁶⁺-200MeV/u , 100uA, longitudinal schottky signal from spectrum analyzer



$$\Delta P/P: 9 \times 10^{-4} \rightarrow 7.5 \times 10^{-5}$$



Summarize for CSR Beam Status

Ion : $^{12}\text{C}^{6+}$, $^{36}\text{Ar}^{18+}$, $^{78}\text{Kr}^{28+}$, $^{129}\text{Xe}^{27+}$

Energy: 1GeV/u for C & Ar in CSRm

Intensity: 10mA (7×10^9) for C-600MeV/u in CSRm
1.2mA (4×10^8) for Ar-368MeV/u in CSRm
0.6mA (1×10^8) for Kr-480MeV/u in CSRm
0.5mA (1×10^8) for Xe-235MeV/u in CSRm
15mA (8×10^9) for C-660MeV/u in CSRe

Experiment: RIBs mass-measurement, isochronous mode of CSRe , $\Delta M/M \sim 10^{-6}$

Slow-extraction: For external-target experiments and cancer therapy

Thanks

