The Collector Ring

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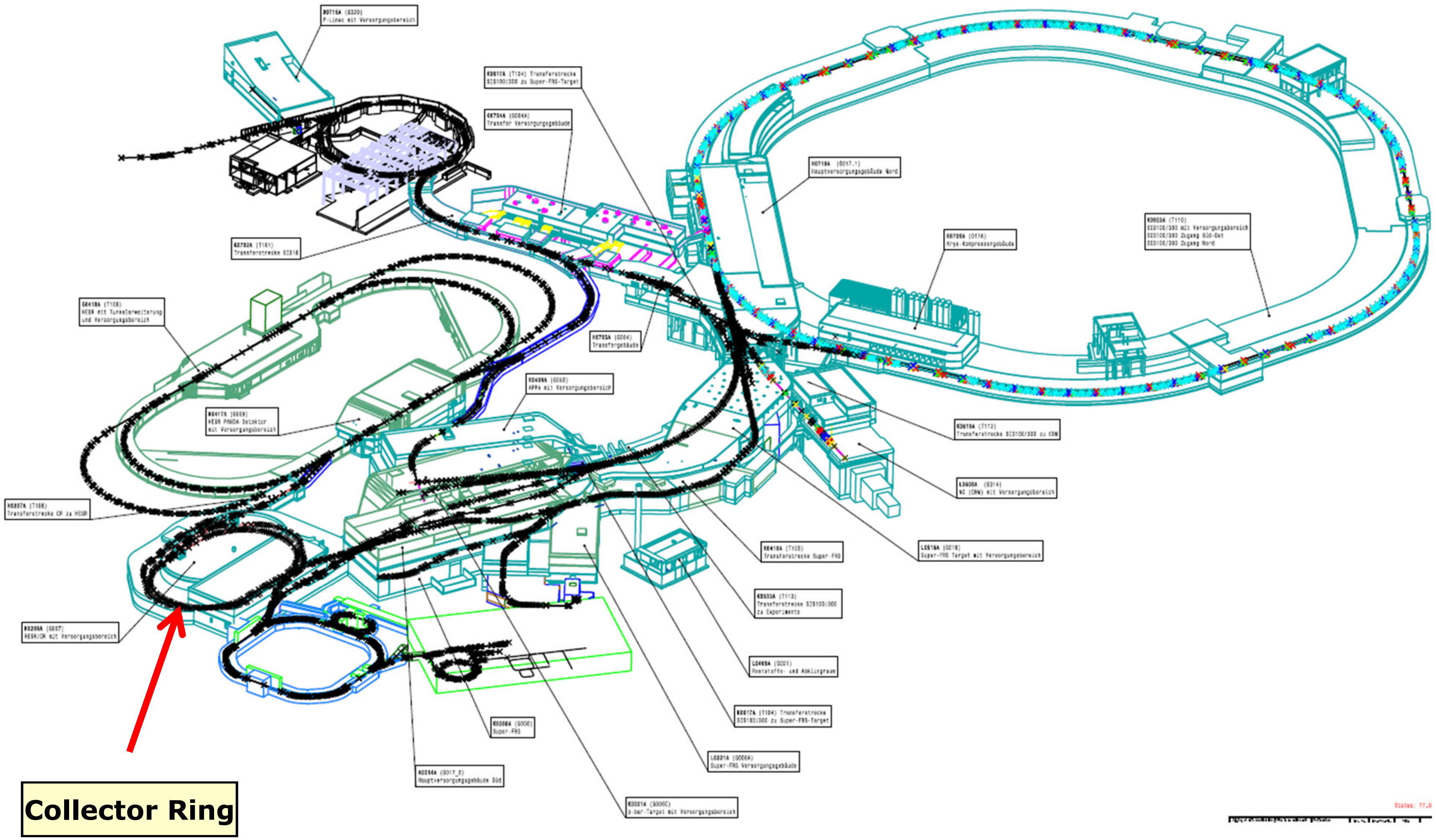
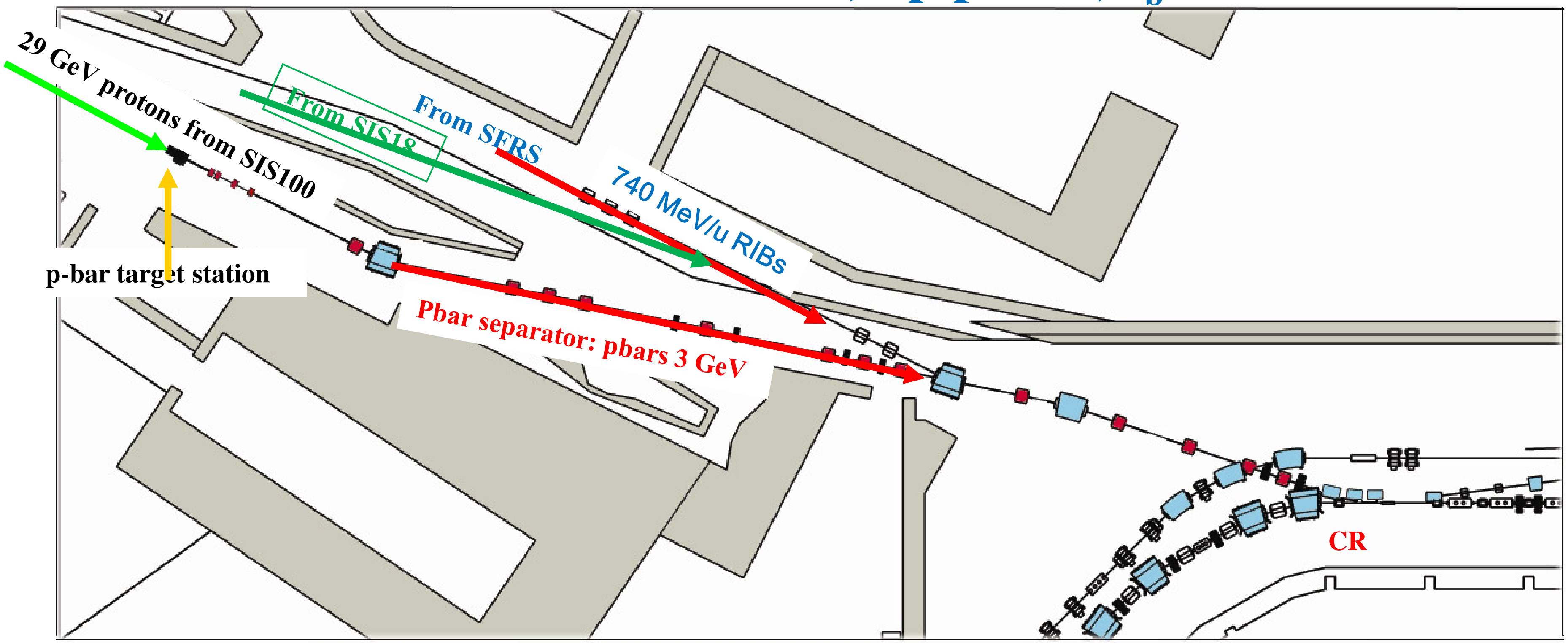
FAIR layout of accelerators



Collector Ring

Beams for CR

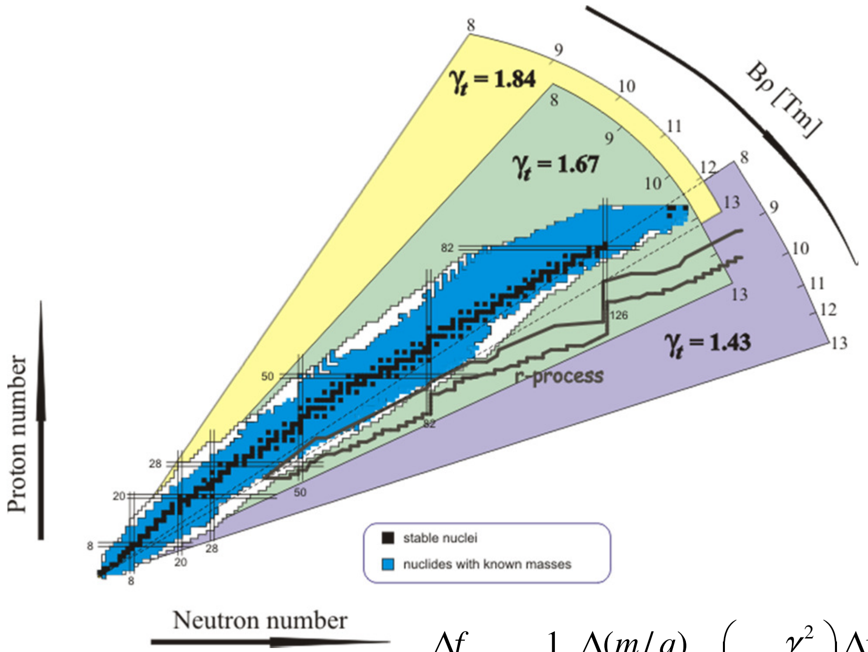
RIBs from SFRS: 200 mm mrad; Δp/p=3%; t_b=50 ns



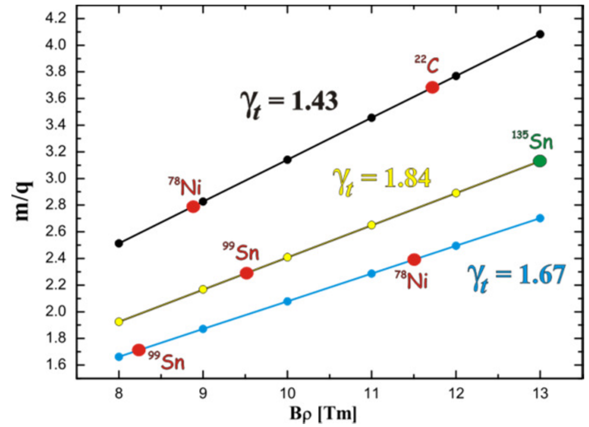
Antiprotons from pbar-sep.: 240 mm*mrad; Δp/p=6%; t_b=50 ns

Ions from SIS18: 50 mm mrad, Δp/p=10^{-3}; t_b=300 ns (??)

Mass measurements in CR



1. $\gamma_t = \gamma = 1.84$ (E = 782.5 MeV/u)
2. $\gamma_t = \gamma = 1.67$ (E = 624.1 MeV/u)
3. $\gamma_t = \gamma = 1.43$ (E = 400.5 MeV/u)



$$\frac{\Delta f}{f} = -\frac{1}{\gamma_{tr}^2}\frac{\Delta(m/q)}{m/q} + \left(1 - \frac{\gamma^2}{\gamma_{tr}^2}\right)\frac{\Delta v}{v} + \left(\frac{\delta f}{f}\right)_{error}$$

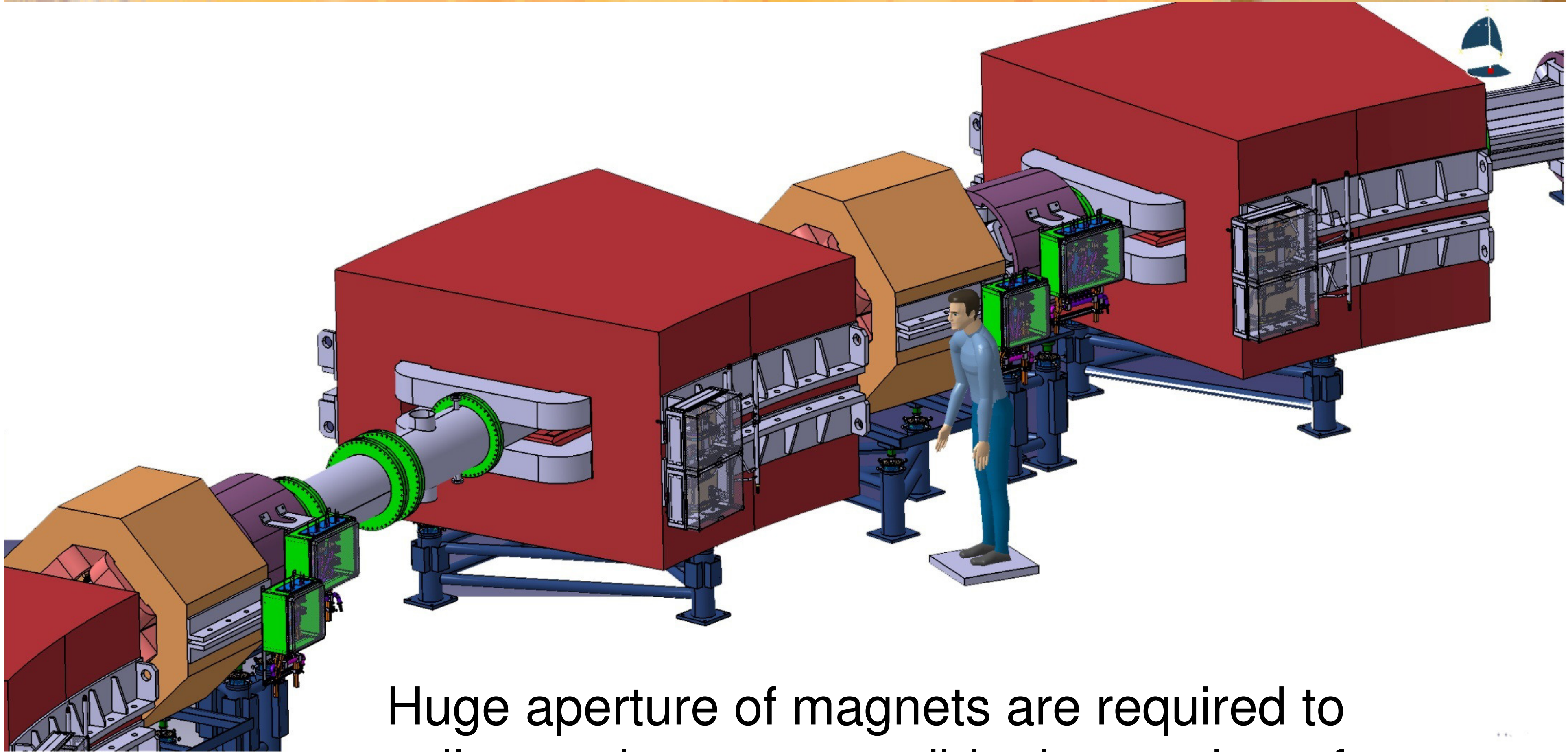
Isochronous mode ($\gamma_{tr} = \gamma$) is required for fast mass measurements.
Methods: TOF, Schottky spectroscopy

RIBs from SFRS: 100 mm*mrad; $\Delta p/p=1\%$; t_b=50 ns

Produced beams on the targets have the large momentum spread and transverse emittances.

The CR needs large aperture magnet to collect the maximum possible beam intensity.

Layout of the CR



Huge aperture of magnets are required to collect as large as possible the number of antiprotons and RIBs.

The main tasks of the CR

Fast pre-cooling of the hot ion beams coming from separators at the maximum magnetic rigidity of BR=13 Tm.

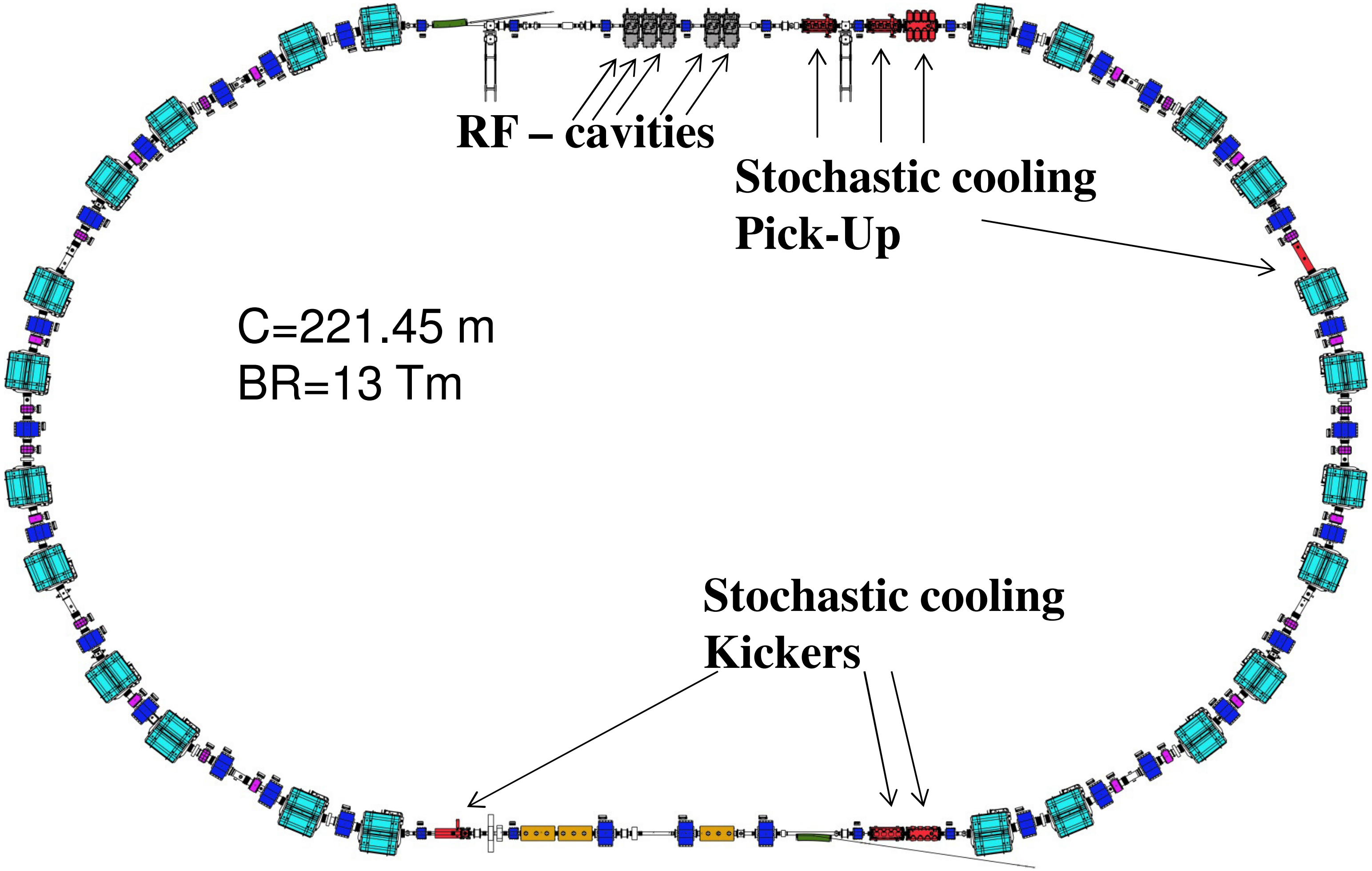
Mass measurement at energies 400 - 790 MeV/u

Layout of the CR

The CR layout is optimized to have optimal Stochastic Cooling (SC) system for both antiproton and rare isotope beams.

The specific ring parameters have been adjusted specially for SC system.
(gamma-tr, phase advances, beta-functions, dispersion, place in ring).

Layout of the CR

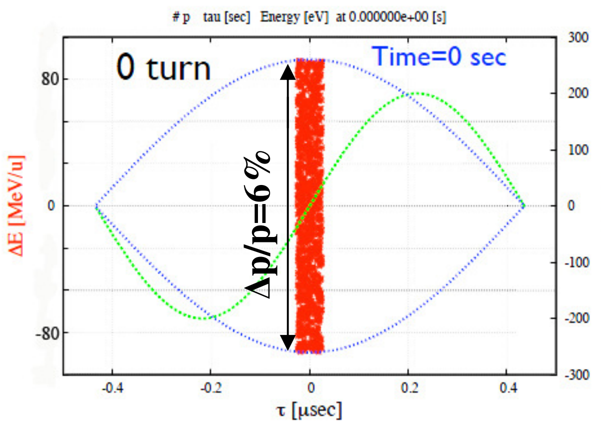


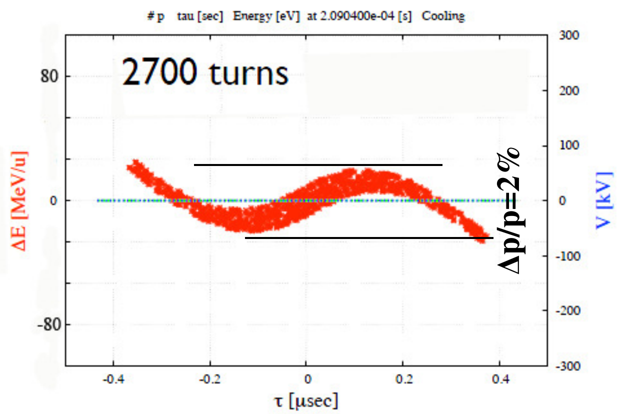
The CR operation cycle

- **Injection using full aperture kicker magnets**
- **RF bunch rotation**
- **Stochastic cooling**
- **RF re-bunching**
- **Extraction to the HESR**

RF bunch rotation

After RF bunch rotation the momentum spread is reduced to:
P-bars : 2%
RIBs : 1 %





Stochastic cooling

After bunch rotation Stochastic cooling is applied to reduce both the beam emittance and momentum spread

Pbar	:	Momentum spread:	0.1%
	:	Emittance :	5 mm*mrad
	:	Cooling time:	10 s
RIBs	:	momentum spread:	0.05 %
	:	Emittance:	0.5 mm*mrad
	:	Cooling time :	1.5 s

To extract beam the re-bunching process must be done.
The momentum spread is increased at least by a factor of 2.

Basic beam parameters

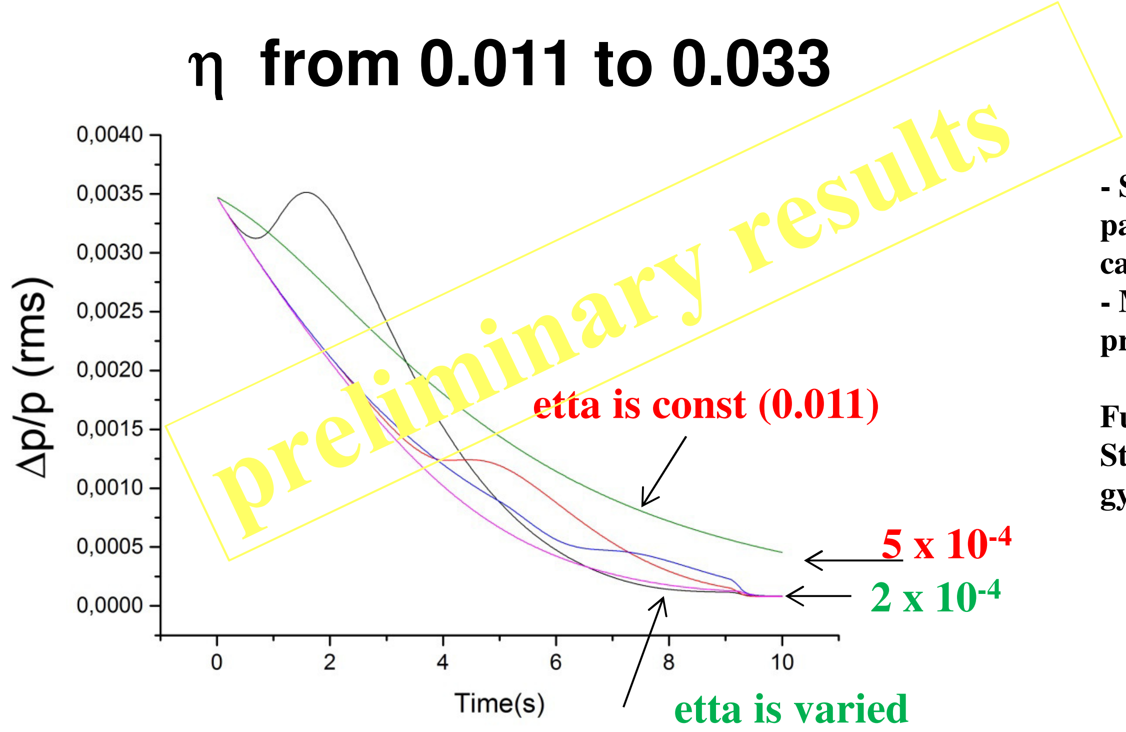
		Antiprotons SIS100 – pSep - CR –HESR		RIBs SIS100 – SFRS – CR - HESR		Mass measurements SIS100-SFRS-CR
		Injection into CR	Extraction to HESR	Injection into CR	Extraction to HESR	Injection into CR
Kinetic energy	MeV/u	3000	3000	740	740	400 - 790
Δp/p	%	6	0.2 ?	3	0.1	1
Emittance	mm*mrad	240	5	200	0.5	100
Bunch length	ns	50	400	50	500	50
Number of particles		2 x 10^8	10^8	10^8	10^8	1 - 10^8
Cooling time	s	10		1.5		-
Cycle time	s	10		1.5 - 5		1.5
Beam loss	%	30	20 ?	10	1	0

beam cooling with variable eta - parameter

Preliminary simulations show that the eta increasing by a factor of 3 during cooling brings to the momentum reduction by a factor of 2 after 10 s .

The required quadrupole ramp dB/dt = 0.25 T/s

η from 0.011 to 0.033



- Stochastic Cooling with variable parameters (eta, plunging) must be calculated.
- Momentum spread under re-bunching process must be calculated.

Further simulations are required. Stochastic cooling in combination with RF gymnastics).

Basic beam parameters

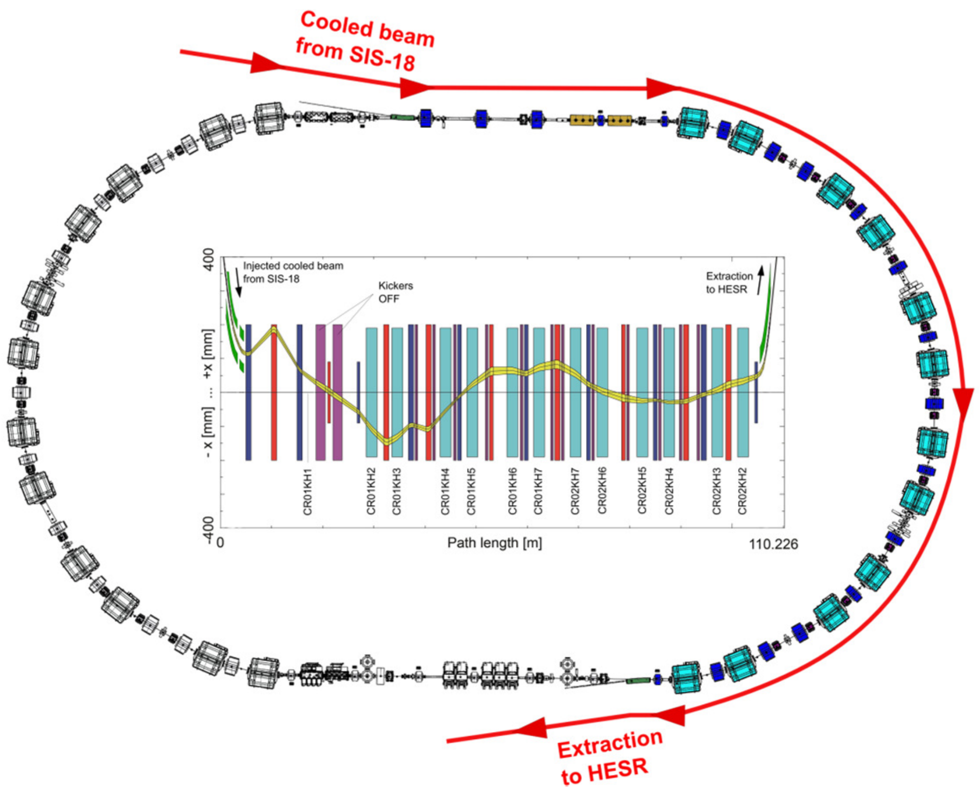
		RIBs SIS18 – SFRS – CR - HESR		Primary ions SIS18 – CR - HESR		Mass measurements SIS18 – SFRS –CR
		Injection	Extraction	Injection	Extraction	Injection
Kinetic energy	MeV/u	740	740	400 – 790	400 – 790	400 - 790
Δp/p	%	3	0.1	0.1	0.1	1
Emittance	mm*mrad	200	0.5	50	0.5	100
Bunch length	ns	100 ?	500	100 - 300	500	100 – 300
Number of particles		10^8	10^8	10^{10} ?	10^{10} ?	1 - 10^8
Cooling time	s	1.5 - 5		1.5 – 5		-
Cycle time	s	1.5 – 5		1.5 – 5		0.27
Beam loss	%	10	1	3	1	0

CR as a transfer line to the HESR

half of the ring magnets can be switched off to save operation cost (by 2 MW)

It depends on the beam parameters from SIS18.

Is cooling needed for beam coming from SIS18 ?



The extraction system of CR is limited by a max. emittance of 20 mm*mrad and momentum spread 0.5 %.

Beam Intensity and Beam Loss in CR

Fragment Beams in CR for Reaction Experiments in HESR

Ion species	^{132}Sn	
Number of ions	5 x 10^7 /cycle	based on 5 x 10^{11} U/cycle primary
Energy	740 MeV/u	
Cycle time	5 s	Given by duty cycle in HESR
Beam loss in the CR	10^7 /s	90 % loss of contamination
Beam loss in the HESR	10^6 /s	10 %

Primary Uranium Beams for APPA in HESR

Ion species	Uranium	
Number of ions	10^8 /cycle	
Energy	740 MeV/u	
Cycle time	10 s	Given by APPA experiments in HESR
Beam loss	10^6 /s	10 % loss in CR per cycle

TOF mass measurements in CR, Schottky mass measurements of RIBs in CR

Ion species	Uranium	
Number of ions	1E3 /cycle	
Energy	400-790 MeV/u	
Cycle time	0.37 s	Given by SIS18
Beam loss	$2.7x10^3$ /s	