Stochastic Cooling Developments at GSI

F. Nolden

Cool05

Galena, IL

September 20, 2005

Authors

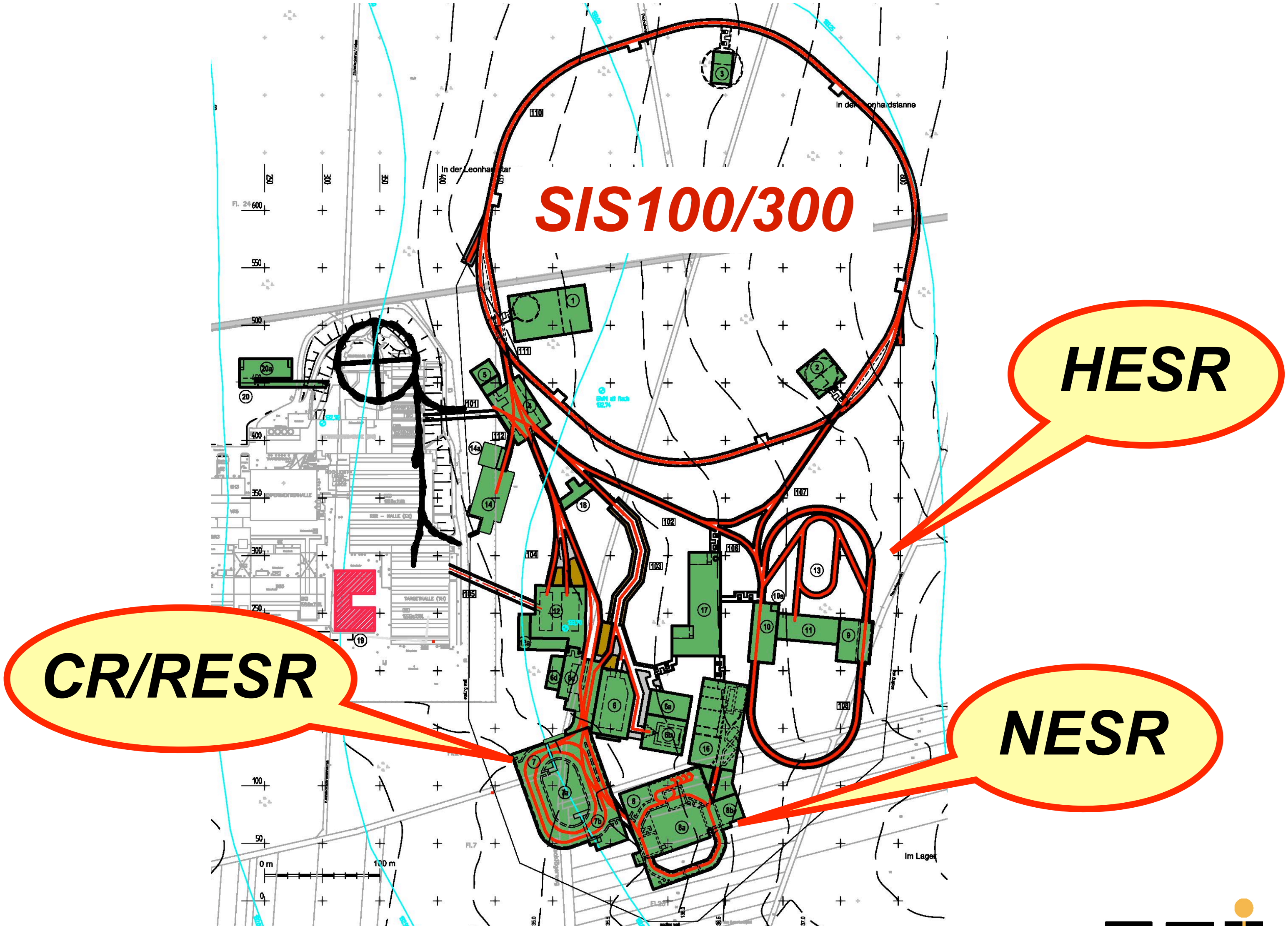
GSI

- K.Beckert
- P.Beller
- A.Dolinskii
- B.Franzke
- U. Jandewerth
- I.Nesmiyan
- F. Nolden
- C.Peschke
- P. Petri
- M. Steck

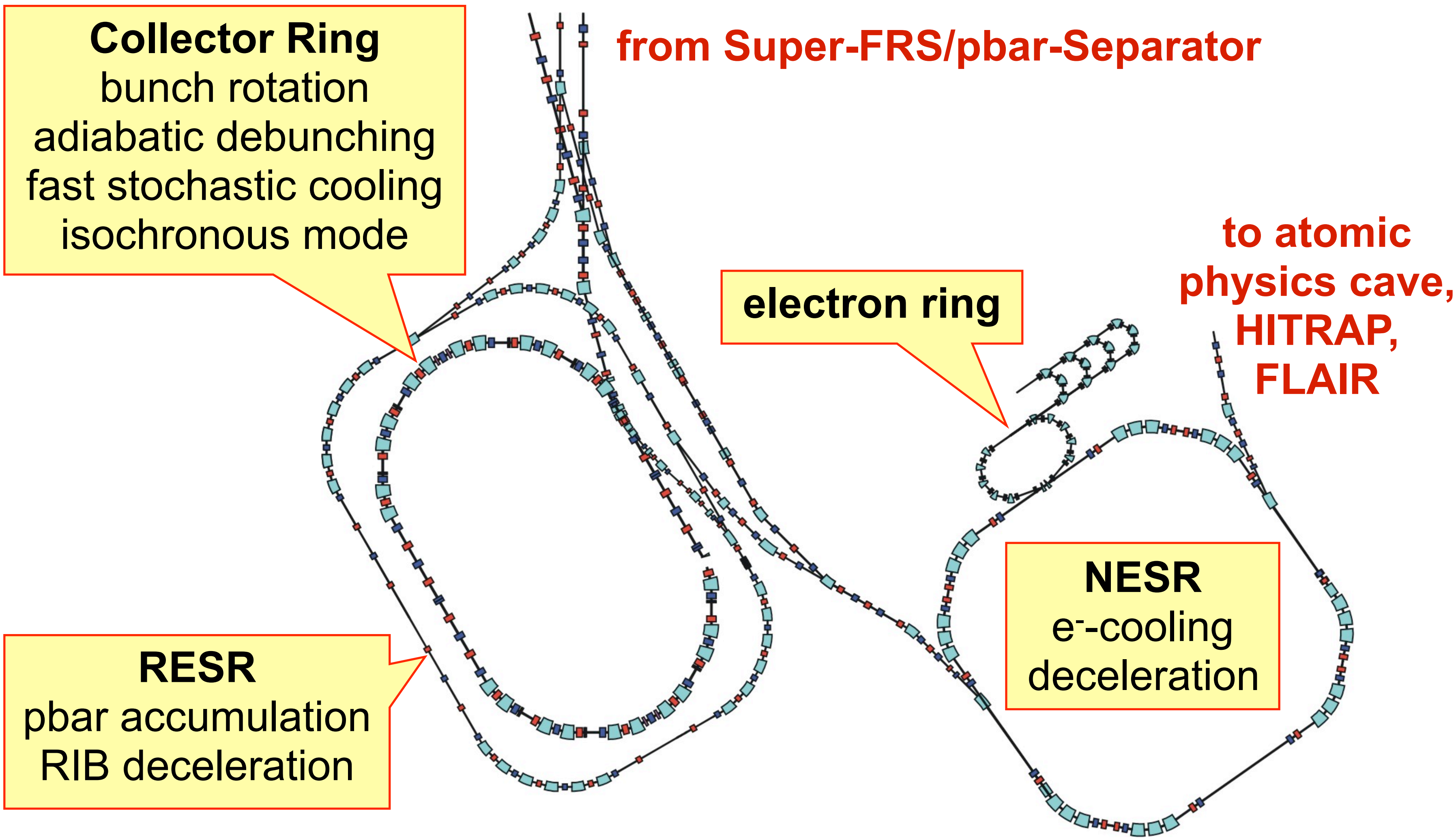
CERN

F. Caspers
D. Möhl
L. Thorndahl

Overview of the FAIR Complex



The Small Storage Rings



CR Beam Parameters

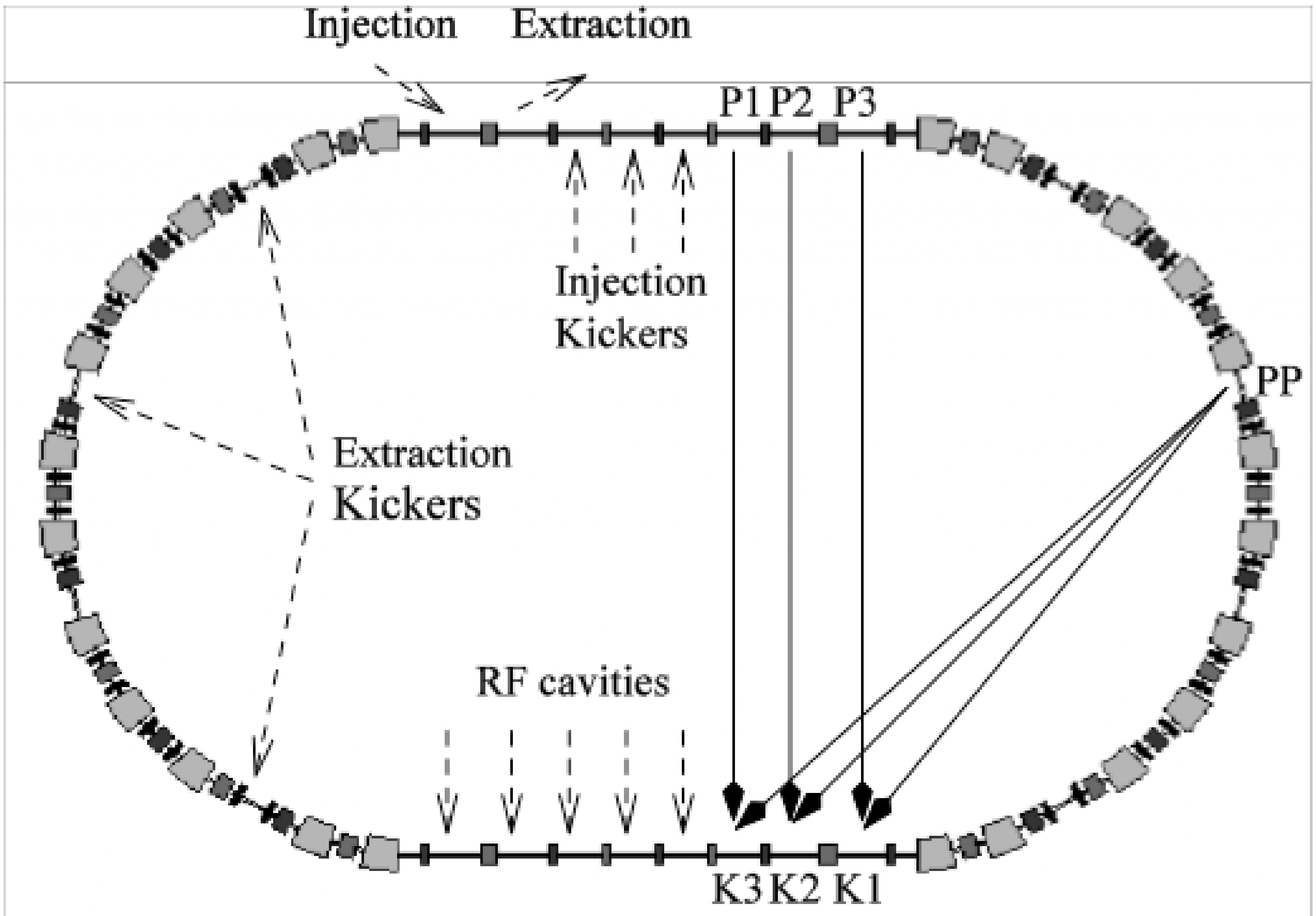
RI Beam Parameters

Injection energy [MeV/u]	740
Transverse emittance at injection/extraction [mm mrad]	200/0.5
Momentum spread at injection/extraction	$\pm 1.5\times 10^{-2}/\pm 5\times 10^{-4}$
Cooling time constant [s]	0.2
Number of antiprotons	$<1\times 10^{9}$

pbar Beam Parameters

Injection energy [GeV]	3
Transverse emittance at injection/extraction [mm mrad]	240/5
Momentum spread at injection/extraction	$\pm 3\times 10^{-2}$ / $\pm 1\times 10^{-3}$
Cooling time constant [s]	1
Number of antiprotons	1×10^{8}

CR: Collector Ring Stochastic Cooling



Basic Cooling Equation

$$\frac{1}{\tau} = \frac{2W}{N}\left(2Bg - g^2\left[M + U\right]\right)$$

Undesired mixing

$$B = \cos m_c \phi_u$$

$$\phi_u = \omega T_{p \rightarrow k} \eta_{p \rightarrow k} \frac{\delta p}{p}$$

Ratio of path p→k to circumference

Local frequency slip

Desired mixing

$$M = \left(m_c \eta \frac{\delta p}{p} \right)^{-1}$$

Noise to Signal

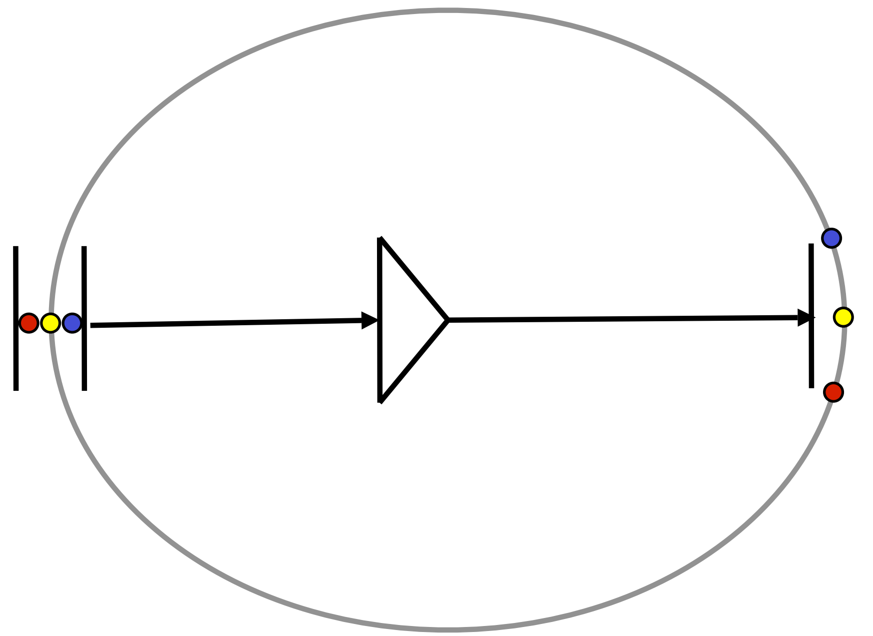
$$U = \frac{\text{Noise Power Density}}{\text{Schottky Power Density}}$$

Stochastic Cooling Slip Factor

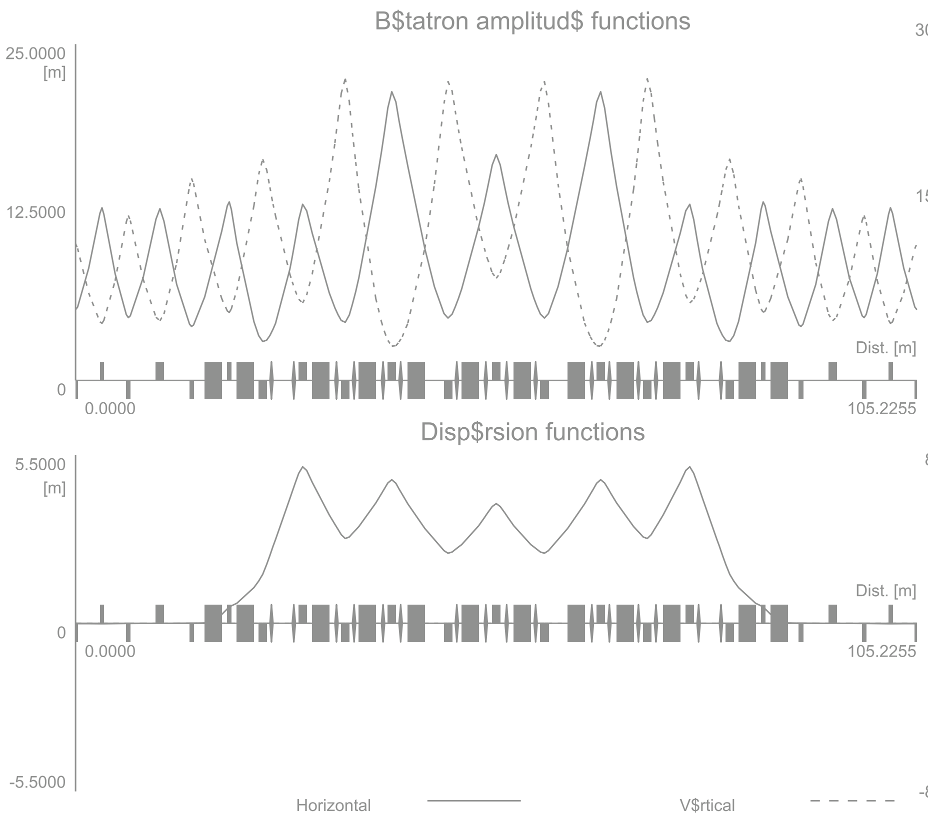
$$\eta_{pk} = \frac{1}{\gamma^2} - \alpha_p = \frac{1}{\gamma^2} - \frac{1}{\gamma_{tr}^2}$$

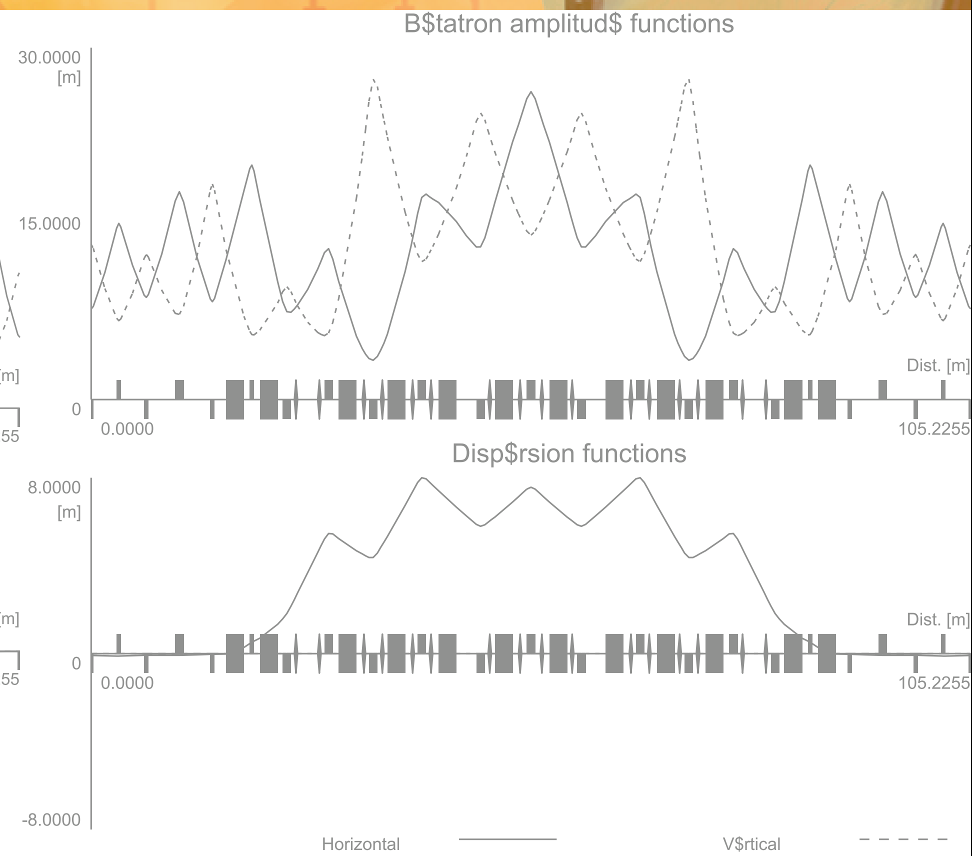
$$\updownarrow$$

$$\alpha_p = \frac{1}{s_k - s_p} \int_{s_p}^{s_k} \frac{D(s)}{\rho(s)} ds$$



CR pbar and RI Optics





Moderate dispersion for pbars

γ_T=3.67

Large dispersion for RI's

γ_T=2.80

Rare Isotope Beam Stochastic Cooling

Cooling Rate is limited due to:

2. Undesired Mixing:
   - The various η's cannot be decreased further.
   - That would increase *D(s)* in the dipoles too much,
   - making the magnets unaffordable.
3. Less than optimum beam parameters at Palmer pu
   - $\sqrt{\beta_x} E_x$ is comparable to $D\, \delta p/p$ (mutual diffusive heating)
   - $\sqrt{\beta_y} E_y$ is equally large (low signal, but high charge state)
   - Less than optimum situation, make the best of it, use all three

Rare Isotope Cooling

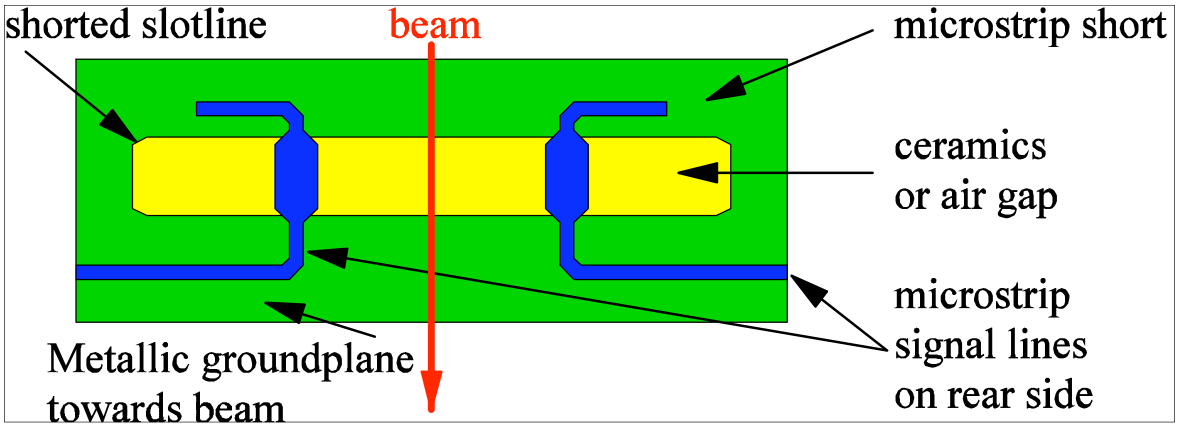
Parameters for 740 MeV/u ($\gamma = 1.79$) at $\delta p/p = 0.4$ %

	total	P3-K1	PP-K1 (hor.)	PP-K3 (vert.)
α_p	0.1318	0.181	0.193	0.164
γ_t	2.754	2.352	2.279	2.471
η	0.1787	0.130	0.118	0.147
$T_{p\text{-}k}$ [ns]	845	308	180	212
Freqency limit [GHz]		1.56	2.94	2.01

Antiproton Stochastic Cooling

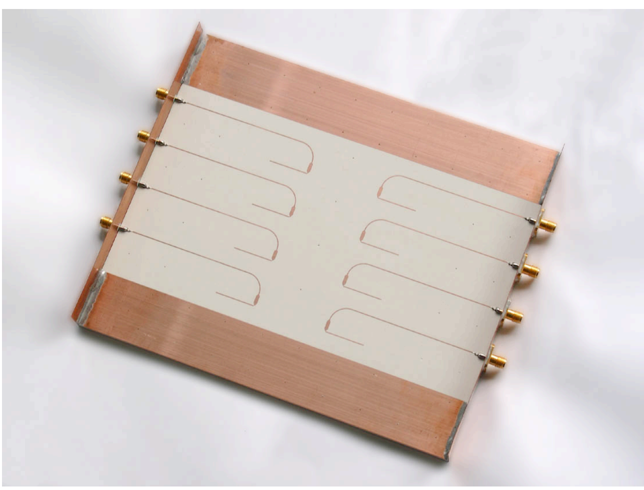
- Cooling rate is less than optimum due to limited signal to noise
- Ring is operated at η = *-0.017*, close to optimum

Stochastic Cooling Electrode Development



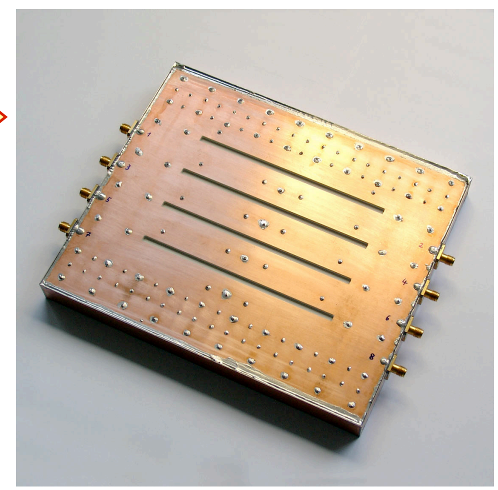
3D field calculations:
L. Thorndahl (CERN)

Prototype design:
C. Peschke (GSI)
See his poster on Wednesday!

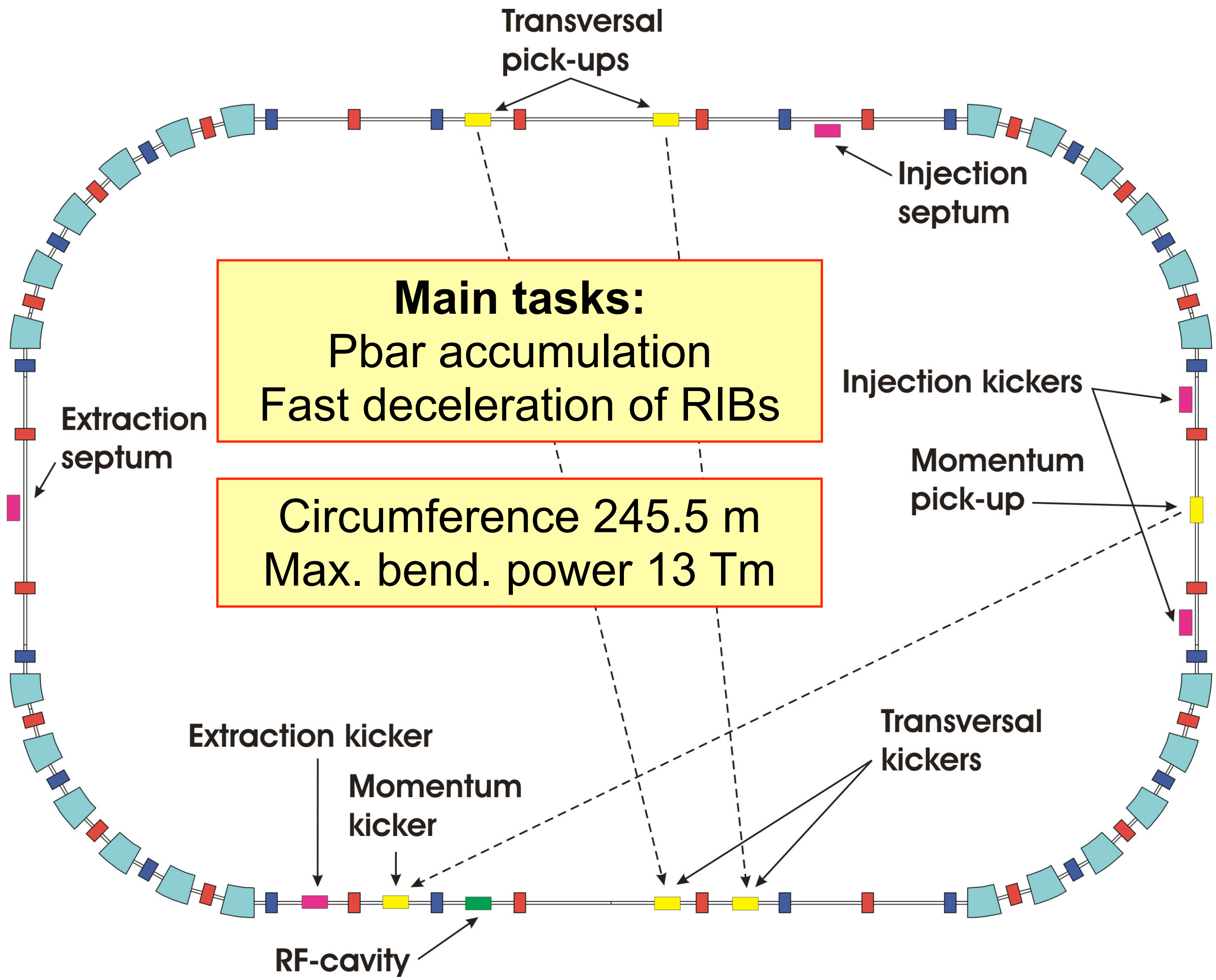


Front side (towards beam)

Rear side



Layout of the RESR Lattice

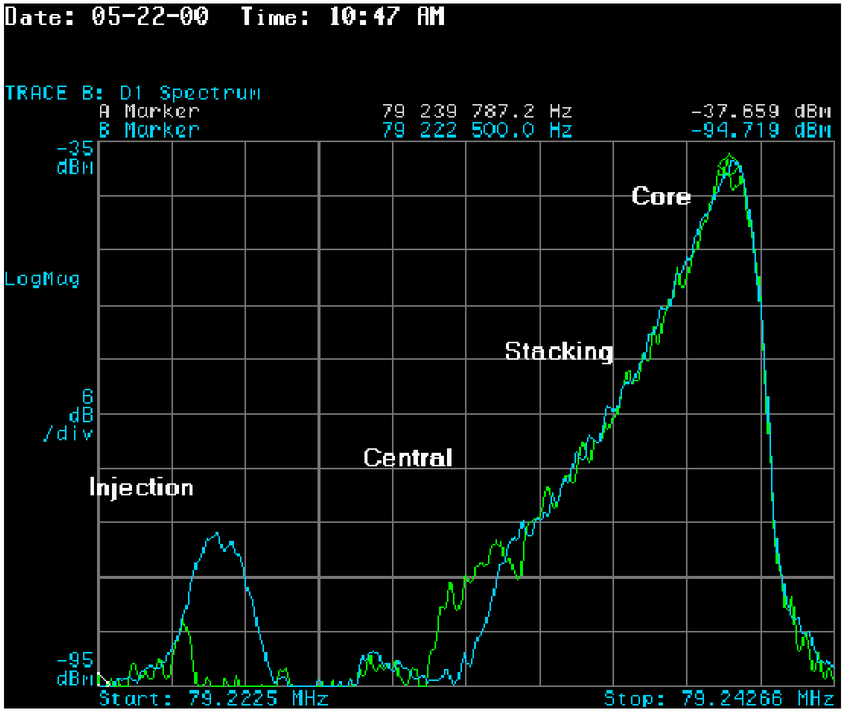


Main tasks:
Pbar accumulation
Fast deceleration of RIBs

Circumference 245.5 m
Max. bend. power 13 Tm

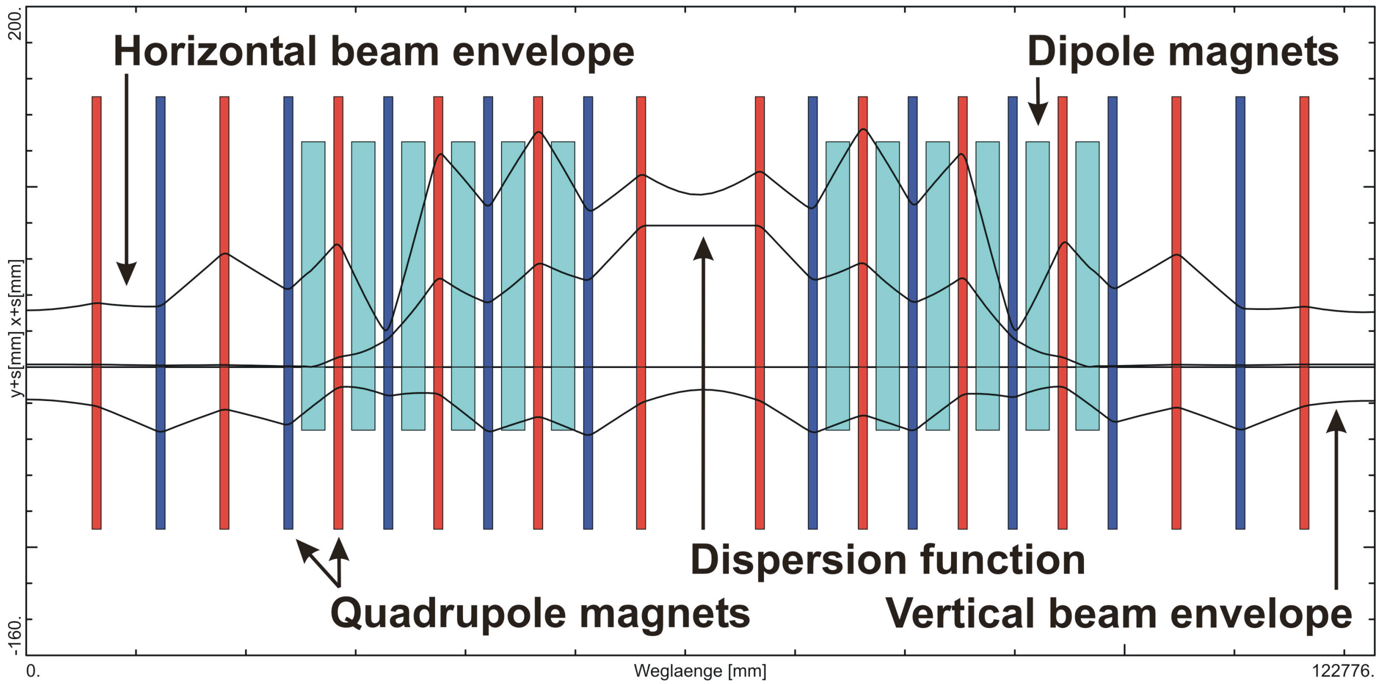
Classical Stochastic Cooling Accumulator Scheme

- Exponentially rising particle density from tail to core
- Exponentially falling gain profile from tail to core
- Constant particle flux everywhere



(adapted from D. McGinnis)

RESR Beam Envelopes and Dispersion Function



Transverse acceptance [mm mrad]	80/35
Momentum acceptance [%]	±1
Horizontal/vertical tune	3.8/3.3
Transition energy	3.62
Maximum dispersion [m]	8

RESR Antiproton Beam Parameters

Energy [GeV]	3
Accumulation rate [pbar/h]	7×10^{-10}
Accumulation time [h]	0.5 - 2
Transverse emittance after deceleration [mm mrad]	5 – 13
Momentum spread after deceleration	$\pm1 - 2.6\times10^{-3}$

Outlook

CR
- Lattice and ion optics close to settled
- Stochastic cooling scheme is defined
- Tank design is worked on, electrode type is decided
- Superferric magnet design is most probable

RESR
- Different accumulation schemes are worked on
- Stochastic cooling electrode design has started