Stochastic Cooling for FAIR

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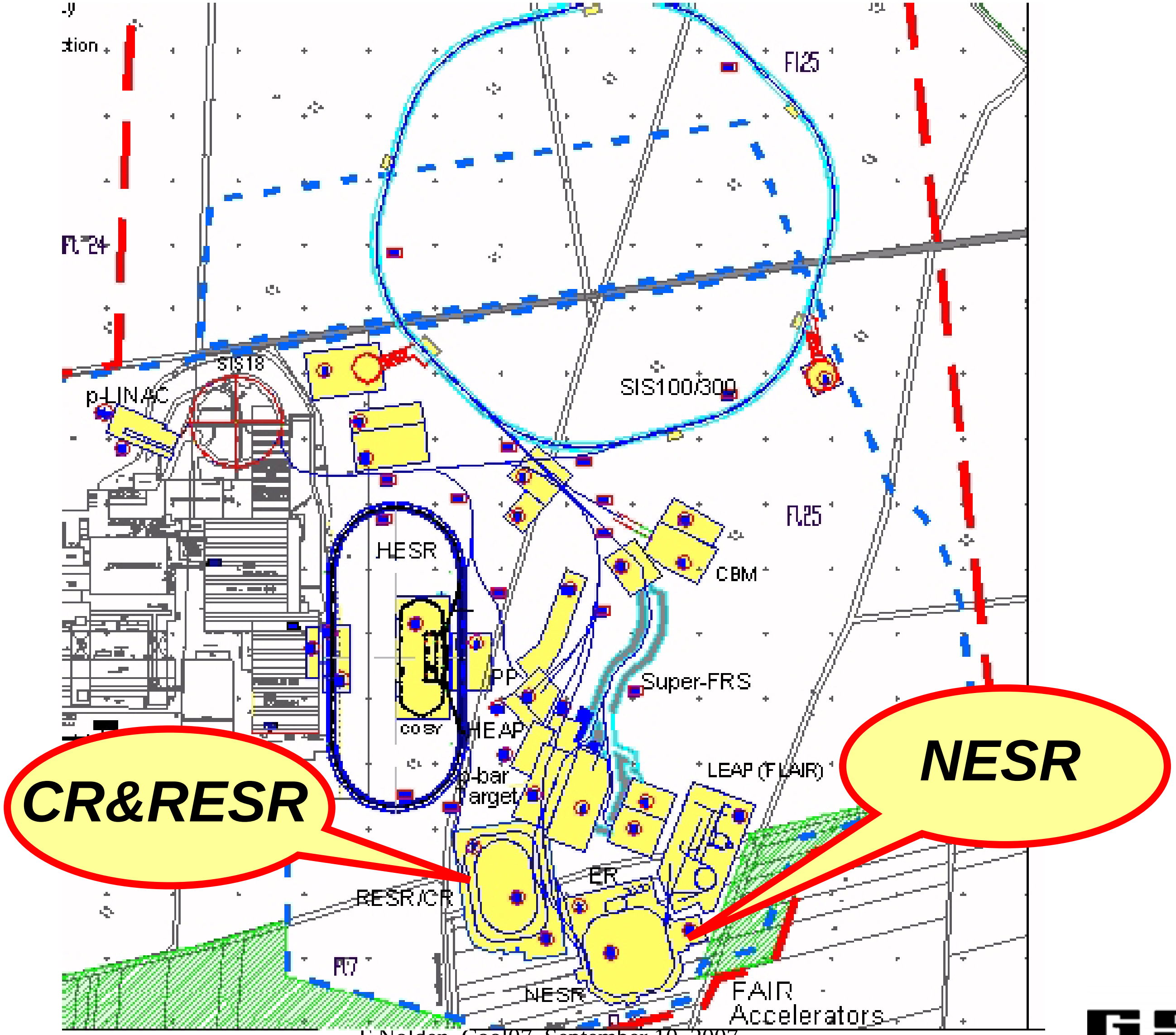
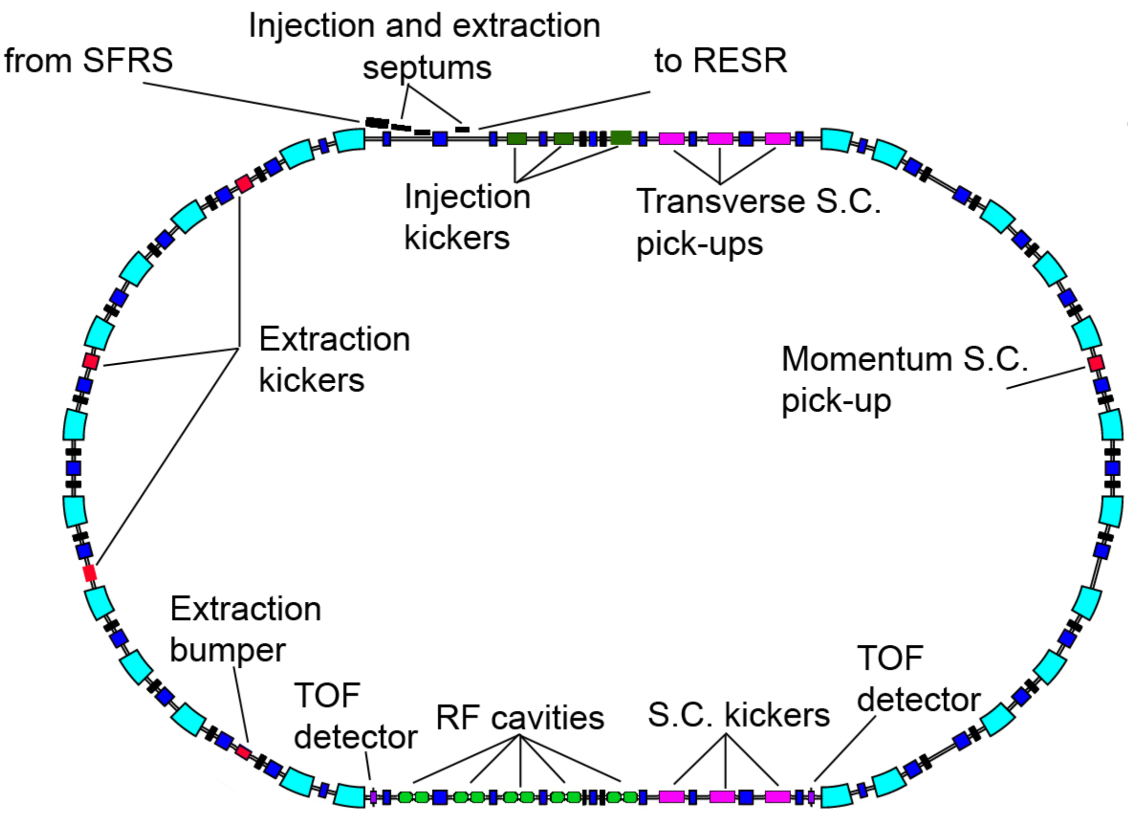
Location in Fair Layout



CR Collector Ring



Purpose:
Stochastic Cooling of fresh secondary beams

Circumference	214	m
Max. bending power	13	Tm
Number of dipoles	24	
Number of quadrupoles	44	
Number of sextupoles	24	

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Power amplifier

- 1-2 GHz power amplifier prototype ordered
- Power 2 times 100 W
- First on-site tests performed
- Delivery due this month

Purpose of RESR

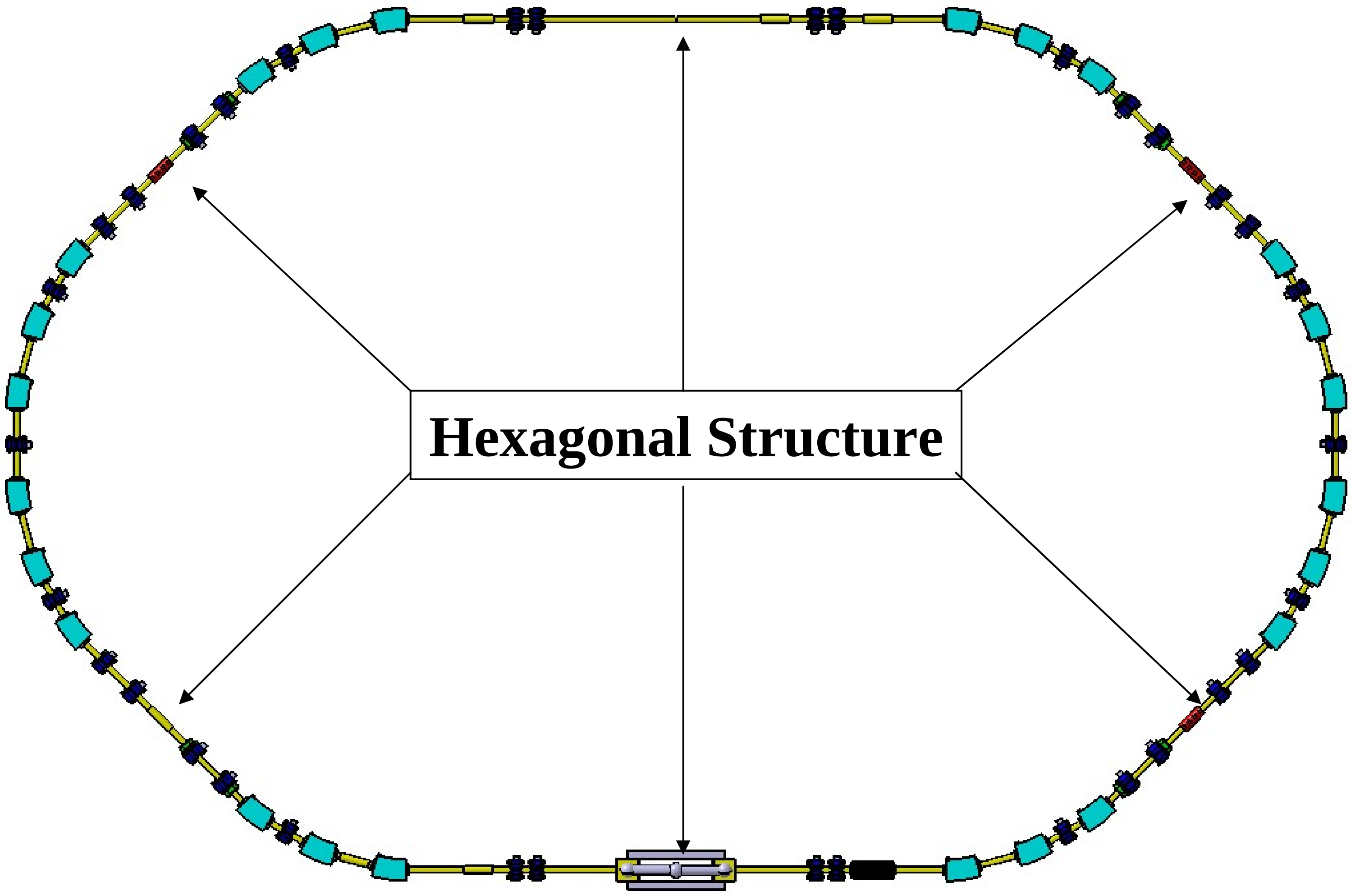
- Accumulation of antiprotons
  - for HESR (PANDA)
  - and low energy antiproton experiments (FLAIR)
- Deceleration of RIBs (NESR internal experiments)
- Deceleration of antiprotons towards ER (only for AIC)
- Electron cooling of antiprotons (only for AIC)

AIC: antiproton-ion collider

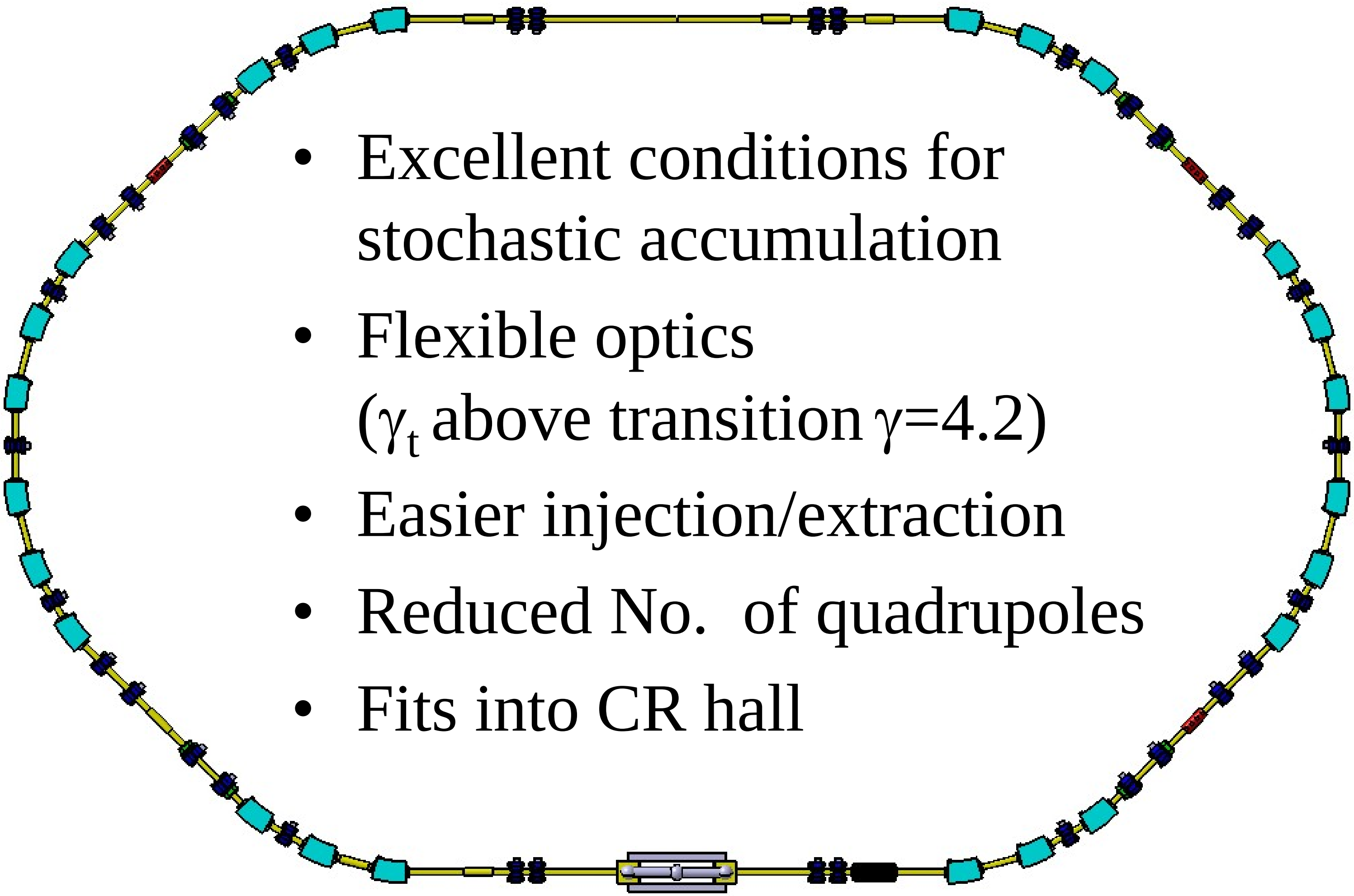
RESR Parameters for Antiprotons

Kinetic energy [MeV/u]	**3000**
Ring circumference [m]	**239.91**
Transition gamma	**5.331**
Revolution frequency [MHz]	**1.21**
Number of injected ions from CR	**$1 * 10^{8}$ Kinetic energy**
Number of accumulated ions	**$< 2 * 10^{11}$**
Injection cycle time [s]	**10**

New RESR Lattice



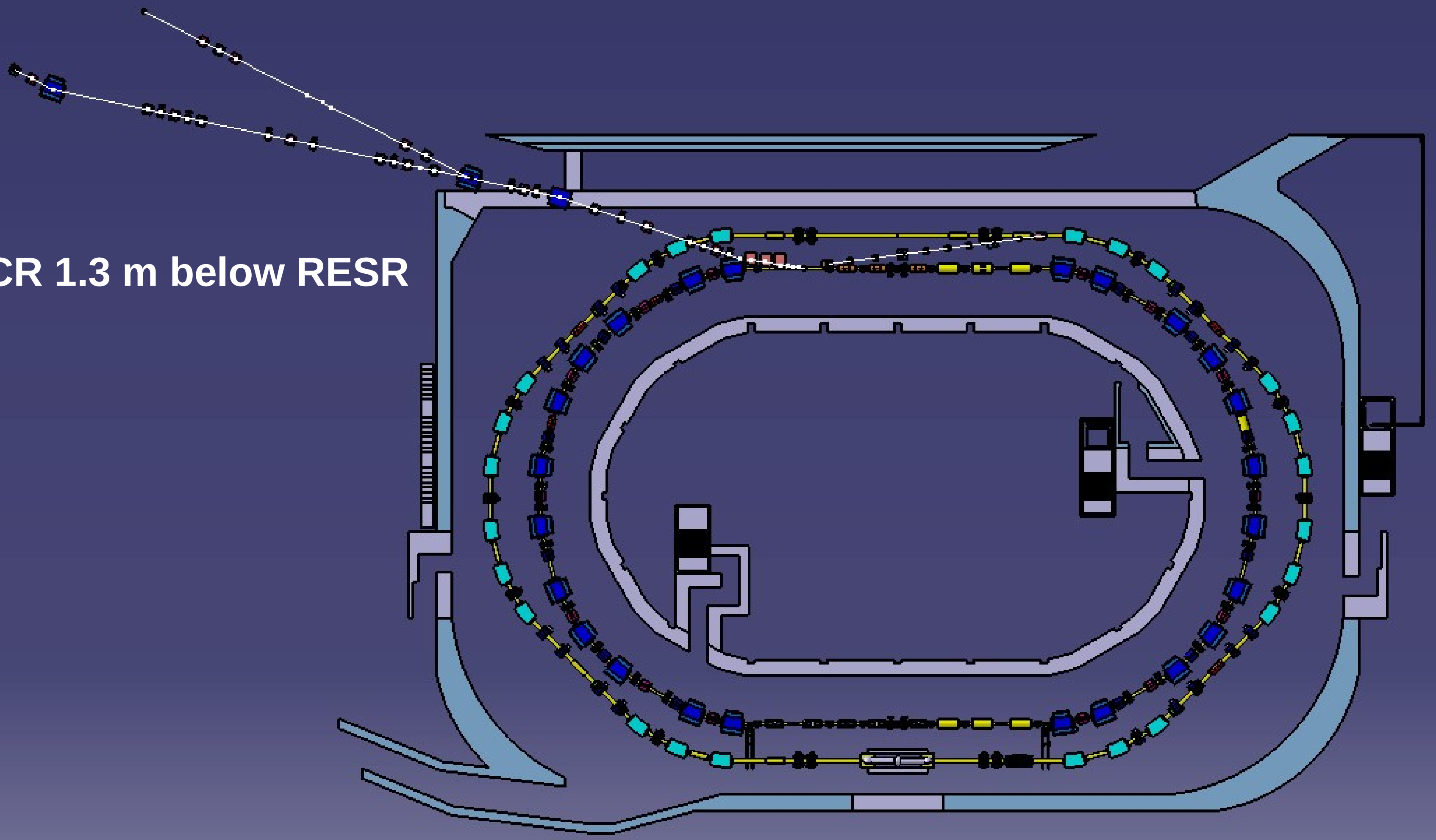
New RESR Lattice



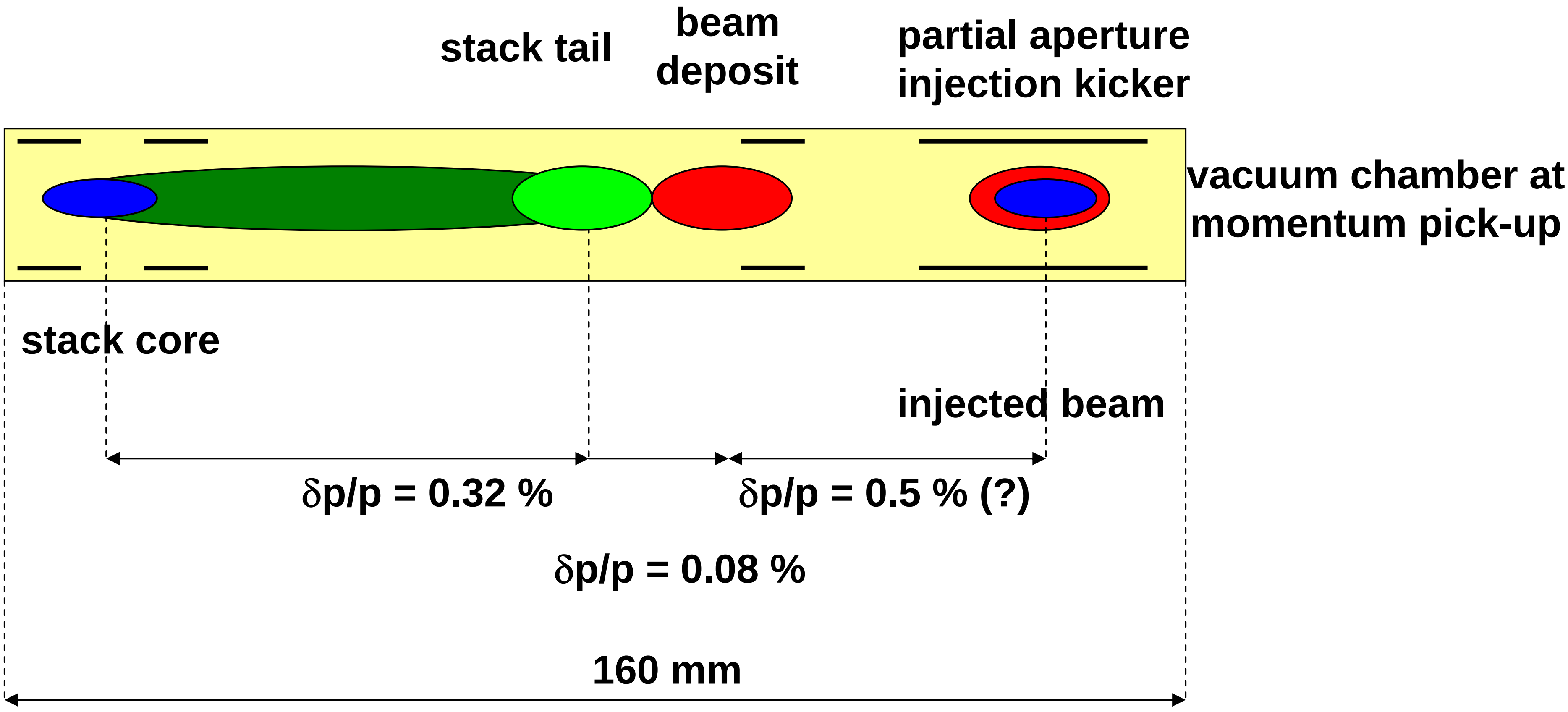
- Excellent conditions for stochastic accumulation
- Flexible optics
  (γ_t above transition γ=4.2)
- Easier injection/extraction
- Reduced No. of quadrupoles
- Fits into CR hall

RESR and CR Rings

CR 1.3 m below RESR



Antiproton Accumulation (1)



Antiproton Accumulation (2)

(after D. McGinnis, FNAL)

≈55 dB
Fermilab (2000) :
Intensity ratio $3*10^5$

FAIR:
Intensity ratio only $2*10^3$

Core-Tail Geometry

- Exponential gain profile stack tail to stack core
- Exponential decrement given by intensity ratio
- Can be realized by suitable pick-up
- Yields distance tail-core

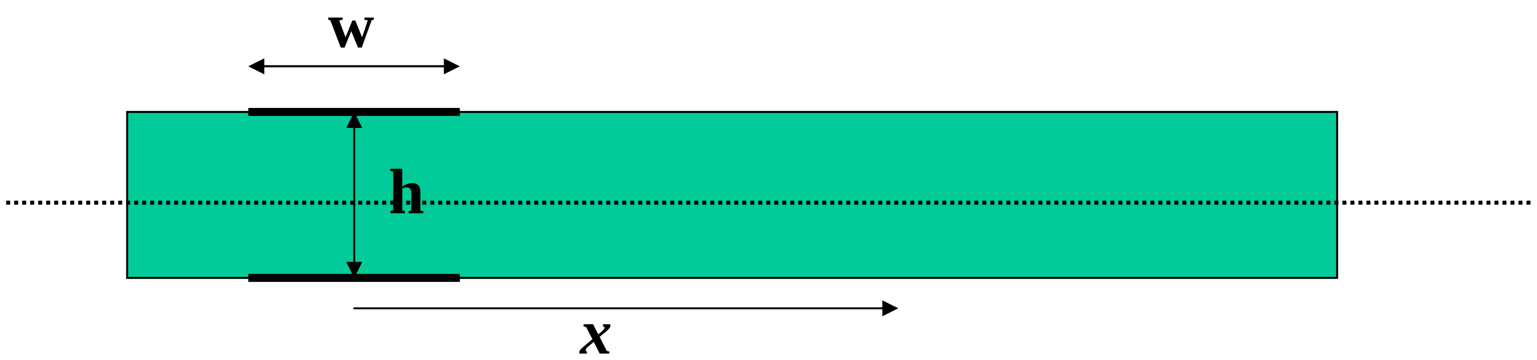
$$g = g_t \exp\left(-\frac{x - x_t}{\delta x}\right)$$

$$\frac{\Psi_c}{\Psi_t} = \frac{g_t}{g_c}$$

$$S(x) \propto \exp\left(-\frac{\pi (x - x_t)}{h}\right)$$

$$\frac{x_c - x_t}{h} = \frac{\ln(2000)}{\pi} \approx 2.42$$

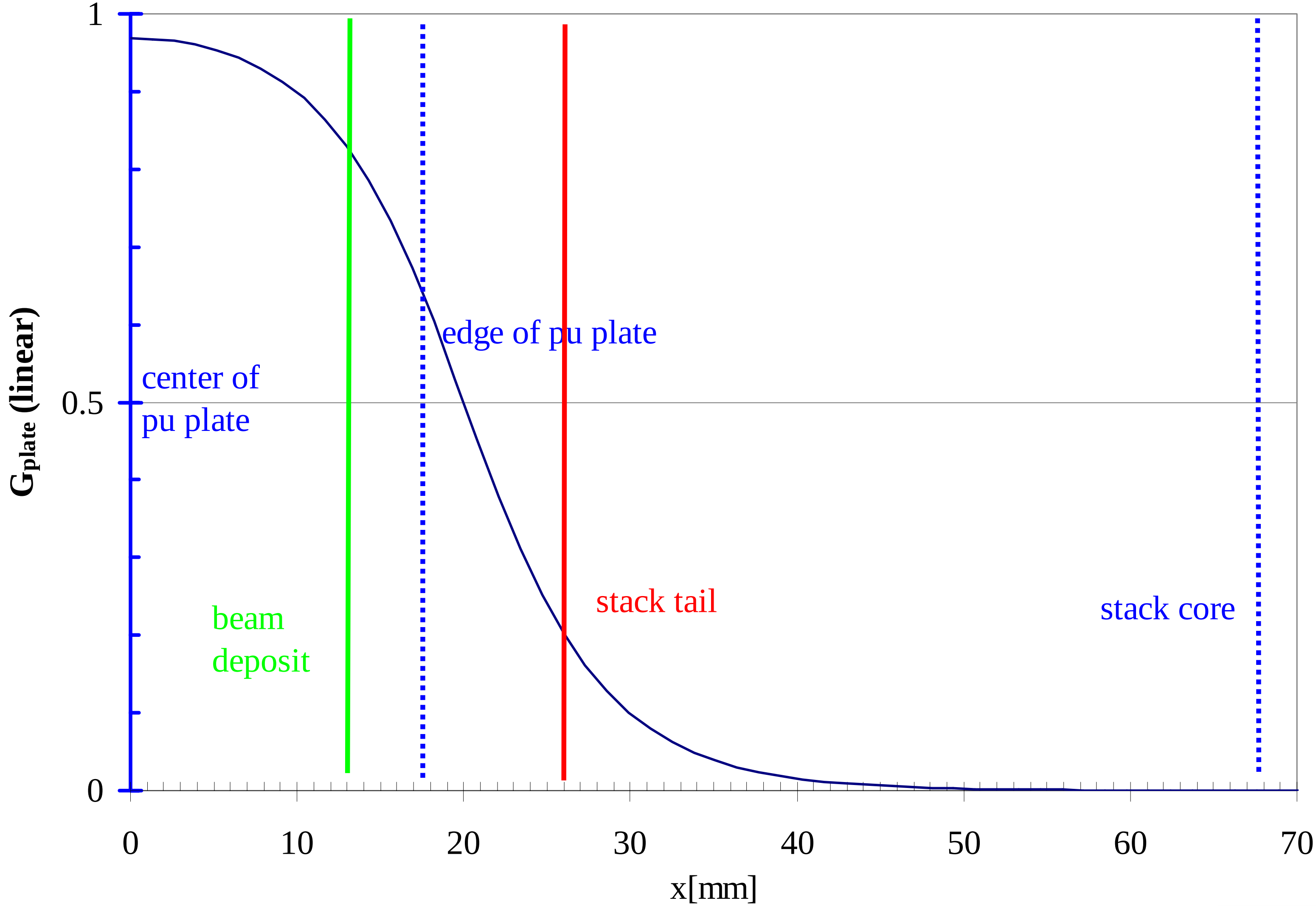
Simple Electrode Model(1)



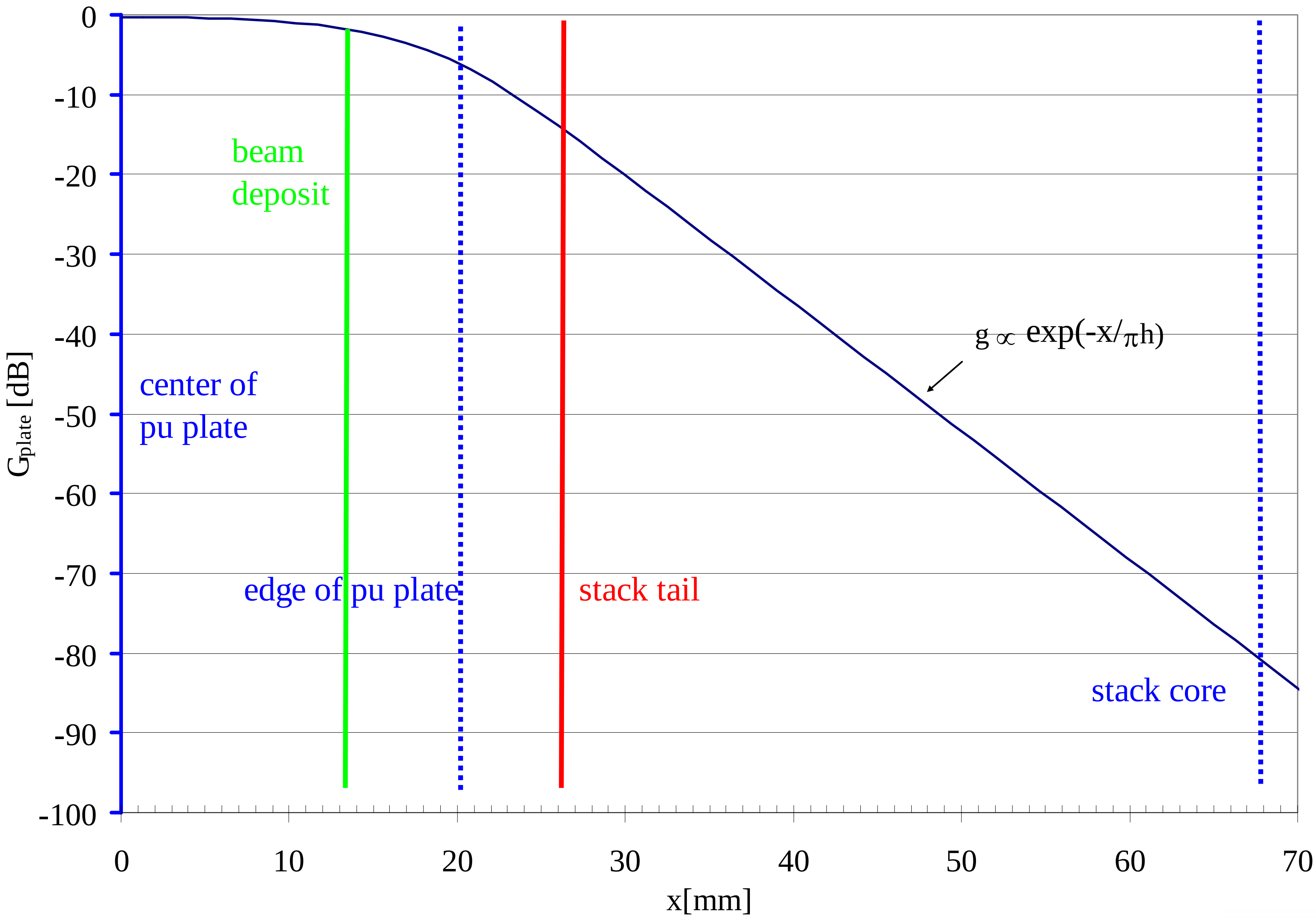
$$S(x) = \frac{2}{\pi}\arctan\left[\frac{\sinh\left(\pi w/2h\right)}{\cosh\left(\pi x/h\right)}\right] \propto \exp\left(-\frac{\pi|x|}{h}\right) \quad \text{for } |x| >> h$$

(valid on the central line if $v \approx c$)

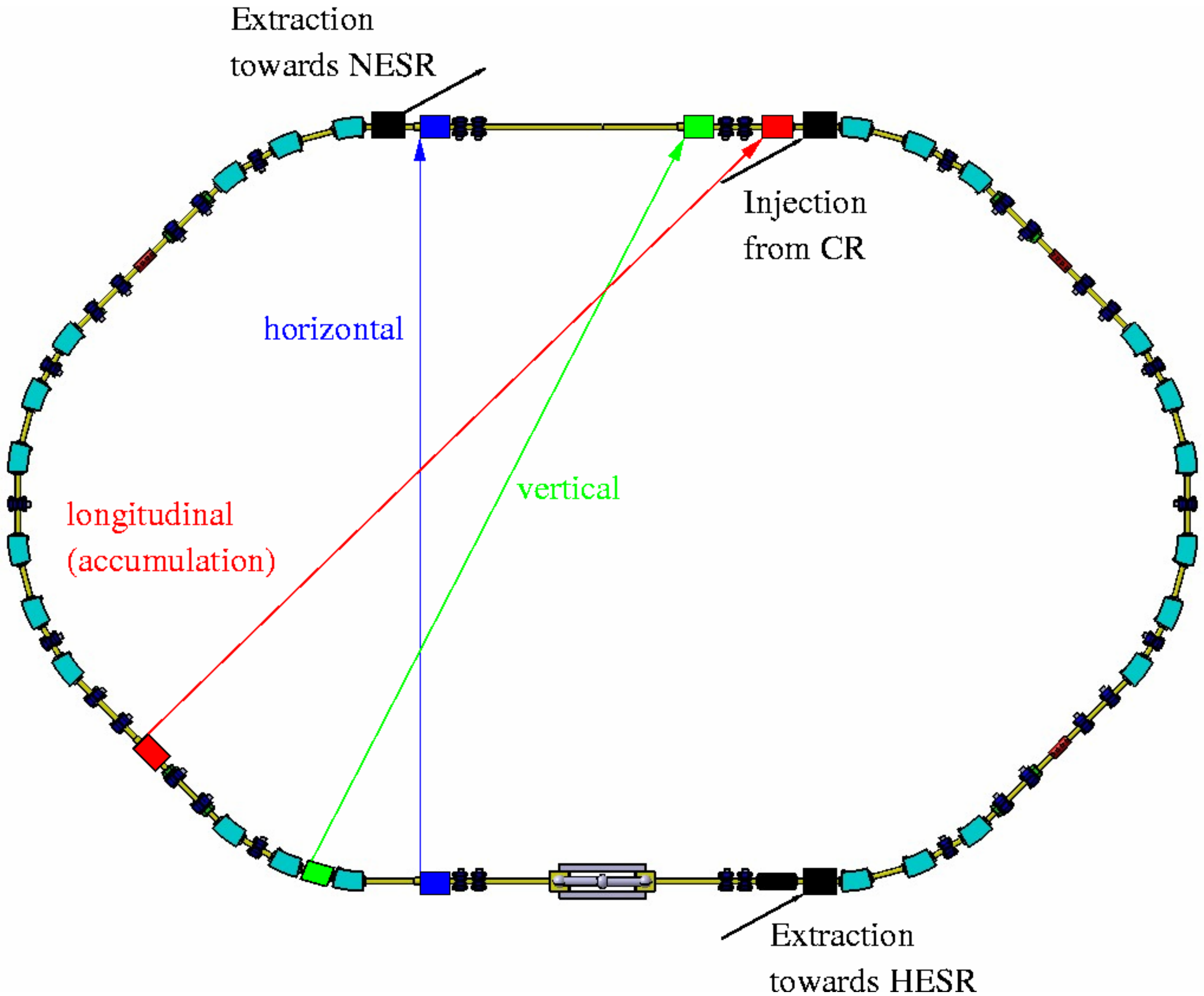
Simple Electrode Model: Linear Scale



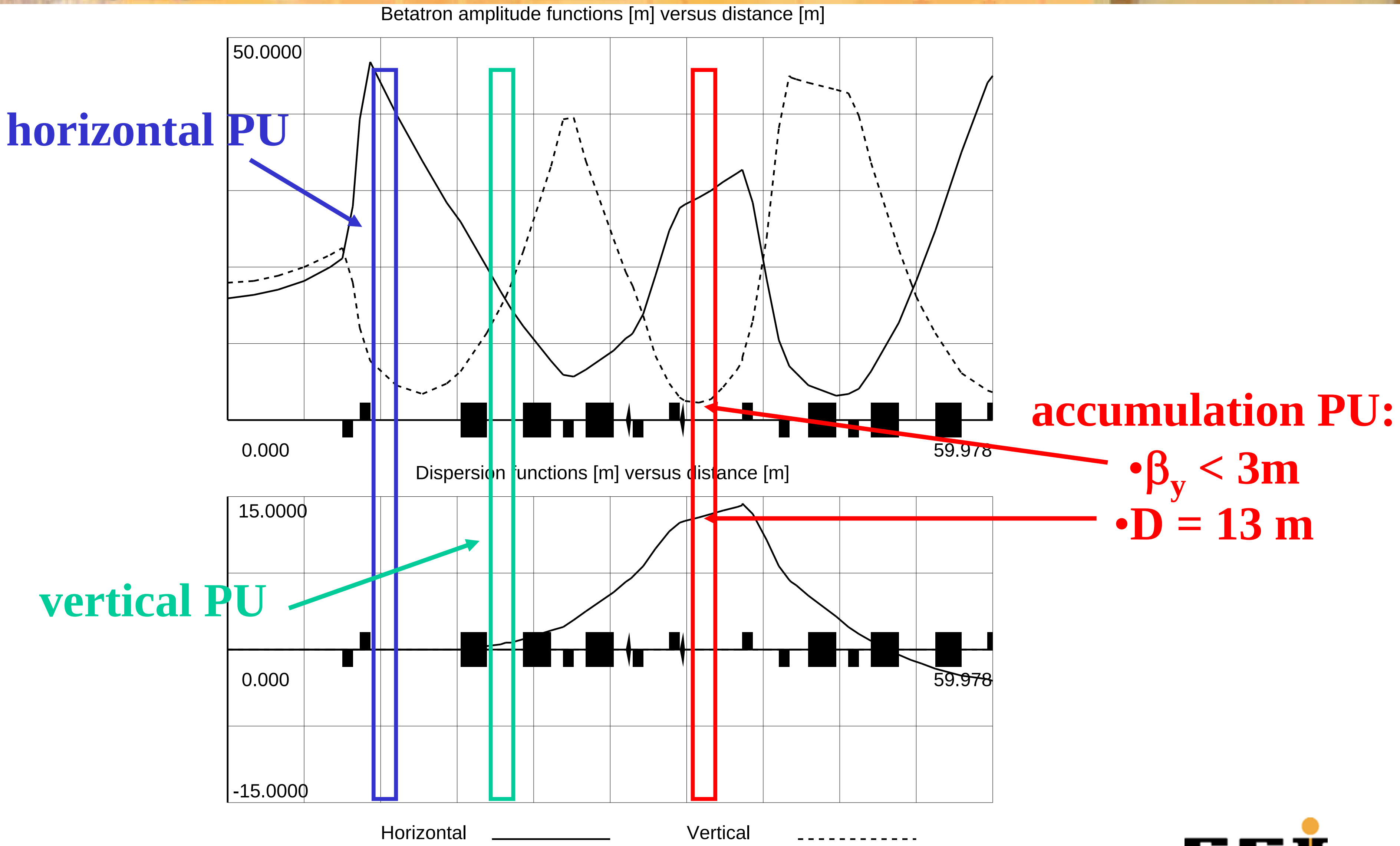
Simple Electrode Model: Log Scale



RESR Stochastic Cooling



RESR Twiss Functions



Analytic Approximation: Optimum Frequency Slip for Stochastic Cooling (1)

Cooling Rate:

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

Optimum Gain:

$$g_{opt} = \frac{B}{M+U}$$

Optimum Rate:

$$\frac{1}{\tau_{opt}} = \frac{2W}{N}\frac{B^2}{M+U}$$

Undesired mixing:

$$B = \cos\left(\pi\, x\, m_c\, \eta_{pk}\left(\frac{\delta p}{p}\right)_{tot}\right)$$

Desired mixing:

$$M = \left[m_c\, \eta\, \frac{\delta p}{p}\right]^{-1}$$

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Analytic Approximation: Optimum Frequency Slip for Stochastic Cooling (2)

Assumptions:

- Schottky signal dominates electronic noise
- η_{pk}/η remains constant if γ_t is varied

$$\left(\frac{1}{\tau}\right)_{opt} \propto \eta \cos^2(b\eta), \quad b = \pi x m_c \left(\frac{\delta p}{p}\right)_{tot}$$

$$(\eta)_{opt} = \left(\frac{0.208}{\pi x m_c \dfrac{\delta p}{p}}\right)$$

Tends to zero if U gets much larger than M

Gets larger in the process of cooling

Gets very small for large bandwidth

Thank you