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Beam Cooling at HESR in the FAIR Project

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HESR Consortium

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Instrumentation Technologies

Outline

- Design requirements for the HESR
- Requirements for Cooling
- p-bar injection and accumulation
- Summary

Modes of Operation with PANDA

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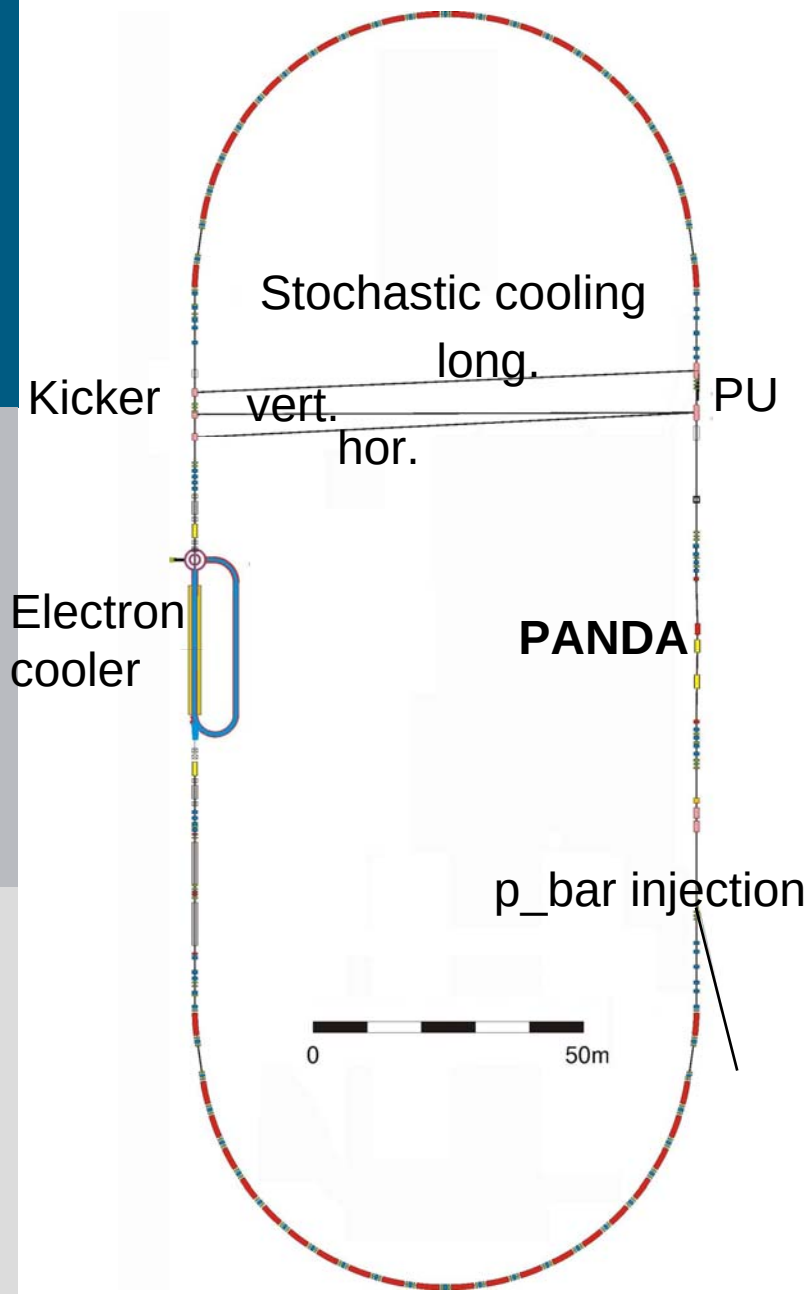
Experiment Mode	High Resolution Mode	High Luminosity Mode
Target	Hydrogen Pellet target with $4*10^{15}$ cm^{-2}	
rms-emittance	1 mm mrad	
Momentum range	1.5 – 8.9 GeV/c	1.5 – 15.0 GeV/c
Intensity	$1*10^{10}$	$1*10^{11}$
Luminosity	$2*10^{31}$ cm^{-2} s^{-1}	$2*10^{32}$ cm^{-2} s^{-1}
rms-momentum resolution	$5*10^{-5}$	$1*10^{-4}$

Basic Data of HESR

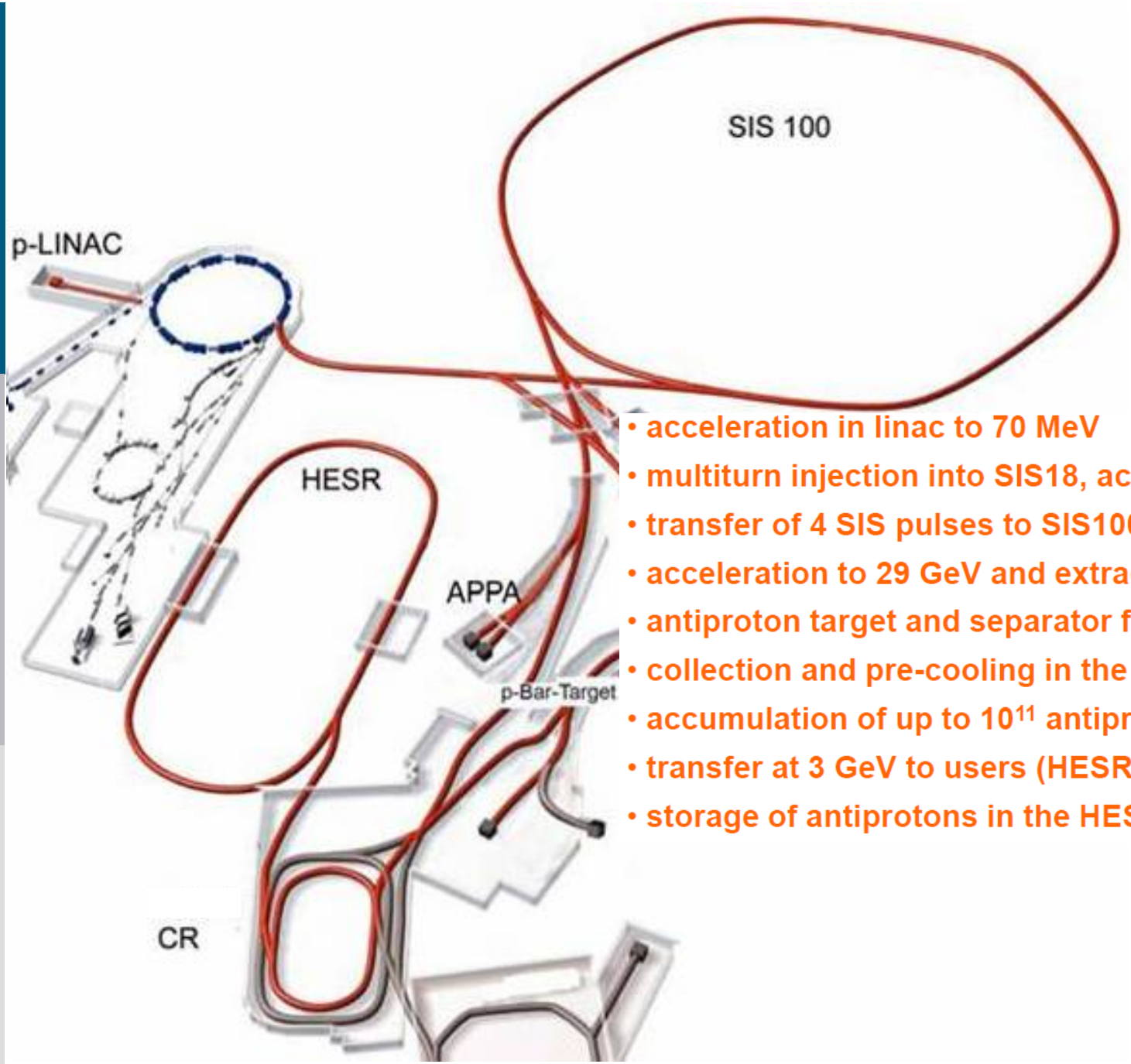


- Circumference 574 m
- Momentum (energy) range
  1.5 to 15 GeV/c (0.8-14.1 GeV)
- Injection of (anti-)protons from CR / RESR at 3.8 GeV/c
- Maximum dipole field: 1.7 T
- Dipole field at injection: 0.4 T
- Dipole field ramp: 0.025 T/s
- Acceleration rate 0.2 (GeV/c)/s

Cooling requirements for HESR

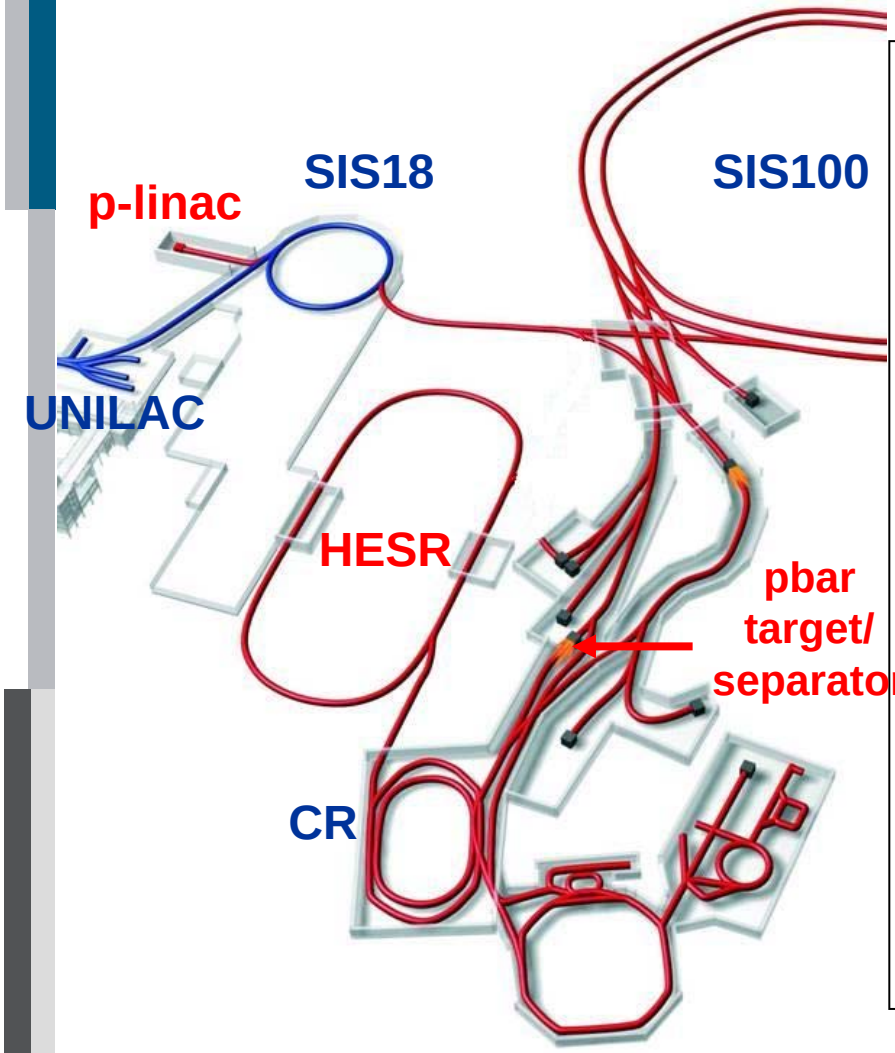
- Internal target (d=$4*10^{15}$ cm^{-2}):
  - *Emittance growth*
  - *Mean energy loss*
  - *Small momentum spread (10^{-5})*

- Accumulation of p-bars in the HESR



- acceleration in linac to 70 MeV
- multiturn injection into SIS18, acceleration to 4 GeV
- transfer of 4 SIS pulses to SIS100
- acceleration to 29 GeV and extraction of single bunch
- antiproton target and separator for 3 GeV antiprotons
- collection and pre-cooling in the Collector Ring CR
- accumulation of up to 10^{11} antiprotons in RESR
- transfer at 3 GeV to users (HESR and NESR)
- storage of antiprotons in the HESR (0,8 - 14 GeV)

Antiproton Chain (Modularised Start Version)



- acceleration in p-linac to 70 MeV
- multiturn injection into SIS18, acceleration to 4 GeV
- transfer of 4 SIS pulses to SIS100
- acceleration to 29 GeV and extraction of single bunch
- antiproton target and separator for 3 GeV antiprotons
- collection and pre-cooling of 10^8 p-bars in the Collector Ring CR

- transfer of 10^8 p-bars at 3 GeV to HESR
- accumulation and storage of antiprotons in the HESR

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p-bar injection and accumulation in the HESR

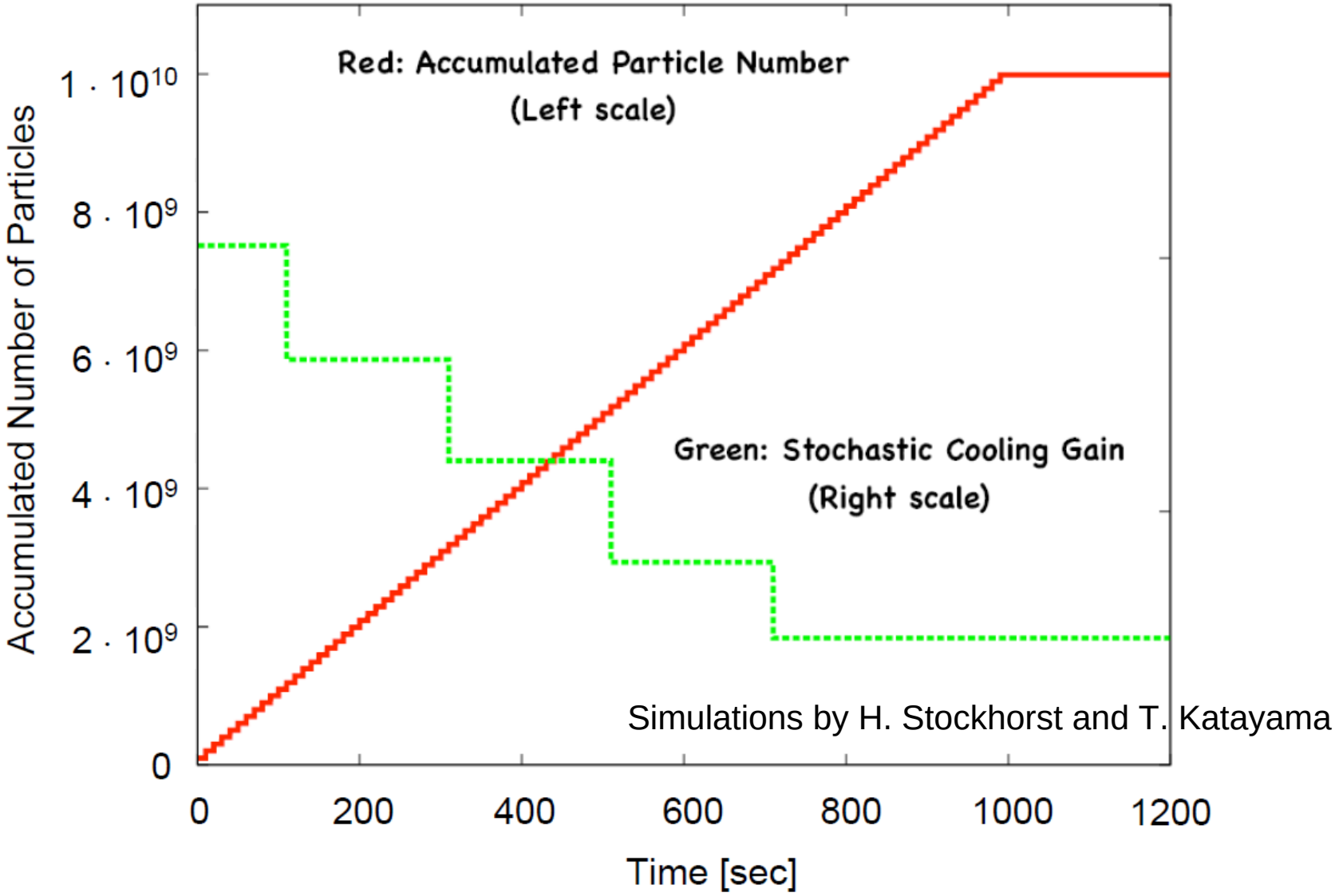
The p-bar accumulation without RESR

- 10^8 p-bars collected in the CR
- 10 s cooling time in CR
- Transfer of 10^8 p-bars to HESR
- In parallel:
  - Cooling of 10^8 p-bars in CR
  - Cooling of 10^8 p-bars in HESR
- Transfer of 2nd CR-stack into HESR
- 100 times repetition of that procedure

$\Rightarrow$ Accumulation of 10^{10} p-bars in HESR in 1000 s

- Acceleration, cooling, experiment

The accumulation process in HESR



Simulations by H. Stockhorst and T. Katayama

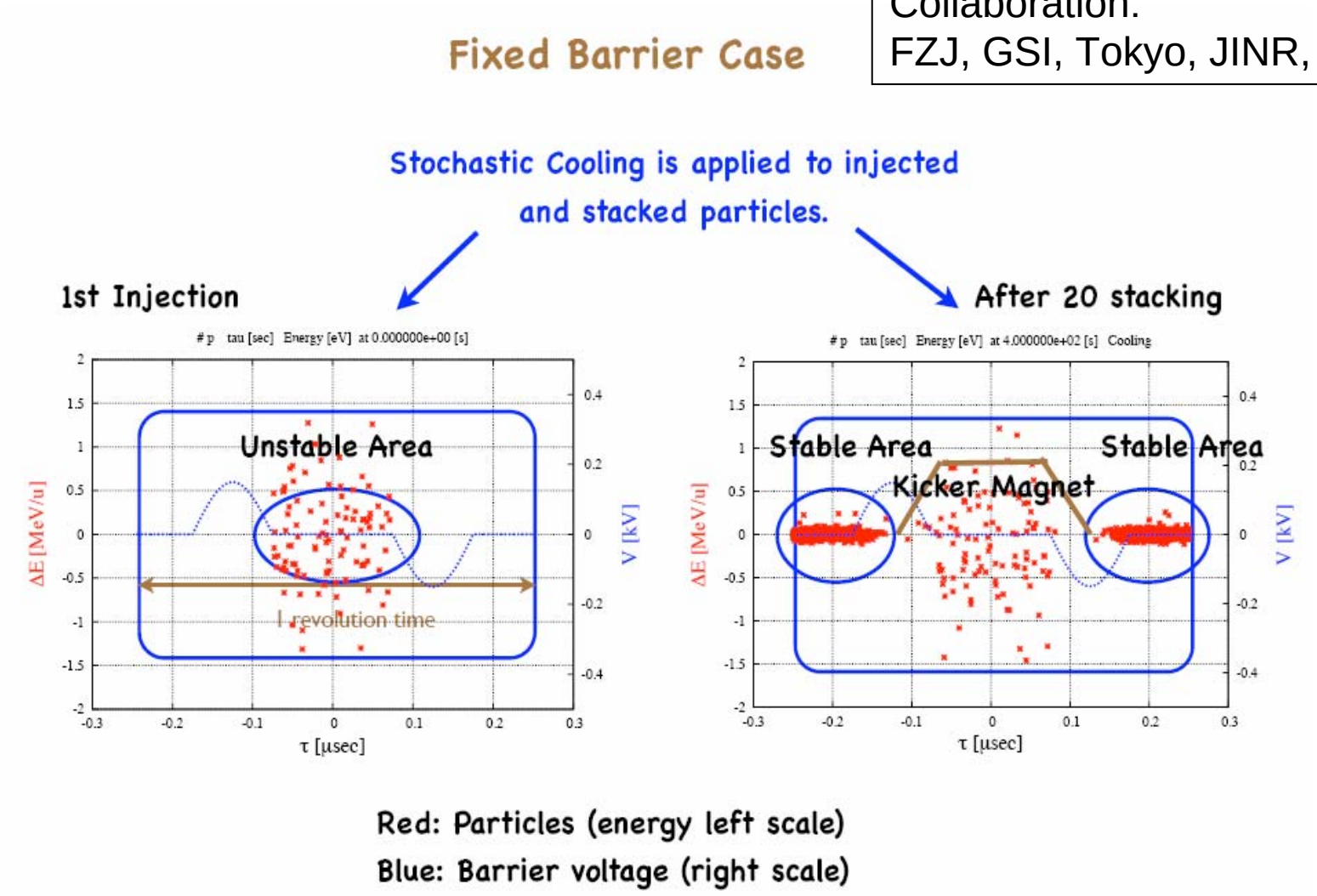
Proof of principle experiment in the ESR

Properties of the ESR

circumference	108	m
$\gamma_{transition}$	2.37	
beam	ARGON	
mass number	40	
charge state	18	
kinetic energy	400	MeV/u
β	0.71	
γ	1.43	
revolution period	507	ns
$\Delta p/p$ injected	$1.5*10^{-3}$	
emittances hor./vert.	1	mm mrad

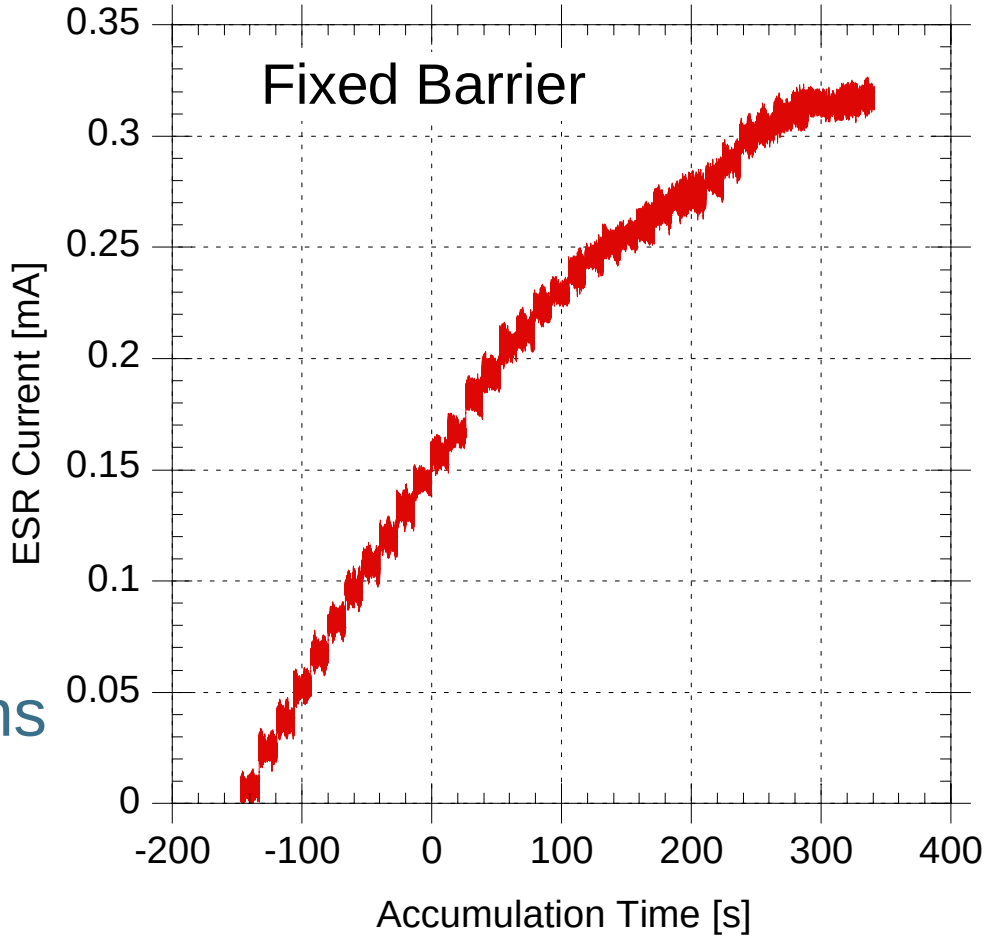
Experimental study of accumulation in ESR with barrier bucket and stoch. cooling

Collaboration:
FZJ, GSI, Tokyo, JINR, CERN



Measured intensity increase by accumulation in the ESR

- Injection every 13 s
- Accumulation over 500 s
- Saturation with $6*10^7$ Ar ions



Results

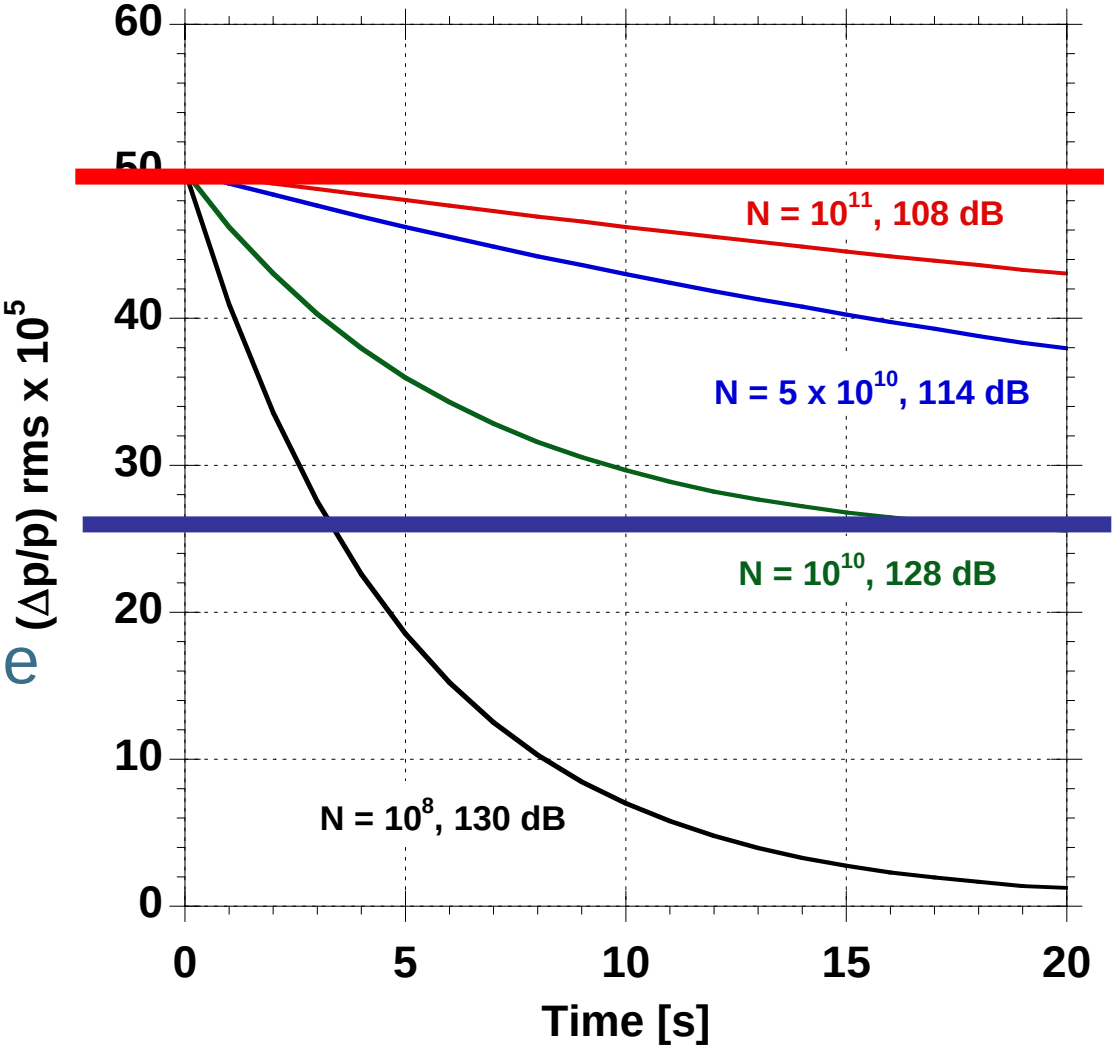
- The idea of injection into the barrier bucket works
- Stochastic cooling is necessary to cool injected ions into the stable area
- Electron supports the efficiency by cooling oscillations by kicker ringing
- Simulation results agree with the experimental data

Question of the experimentalists:

Accumulation in HESR to more than 10^{10} p_bars ?

Cooling time for different intensities

- The beam from CR with $\Delta p/p = 5*10^{-4}$ has to be cooled to $2.5*10^{-4}$
- Due to longer cooling times than 10 s the efficiency decreases
- $5*10^{10}$ p_bars seem to be possible within 5000 s accumulation time



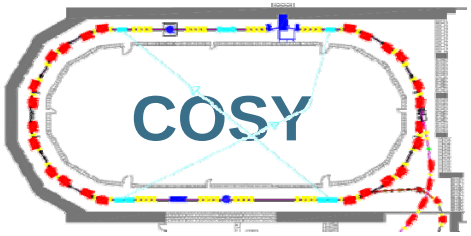
Study of internal Target effects

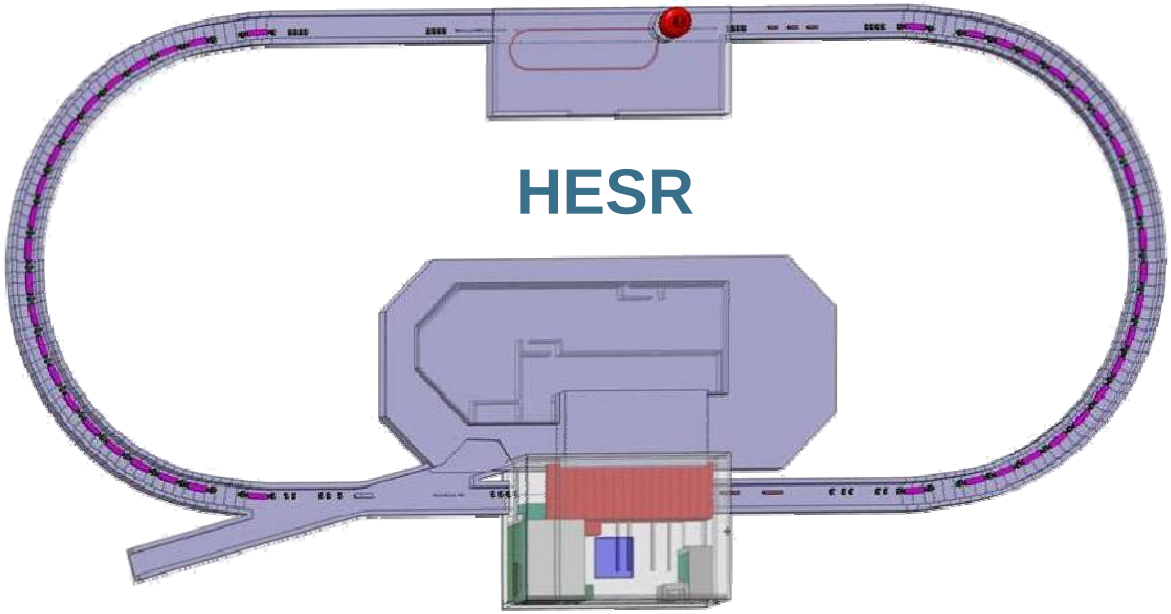
Operation of COSY

- Circumference: 184 m
- Maximum momentum: 3.7 GeV/c (Bρ=12 Tm)
- (un-)pol. Protons and Deuterons
- Electron and stochastic cooling

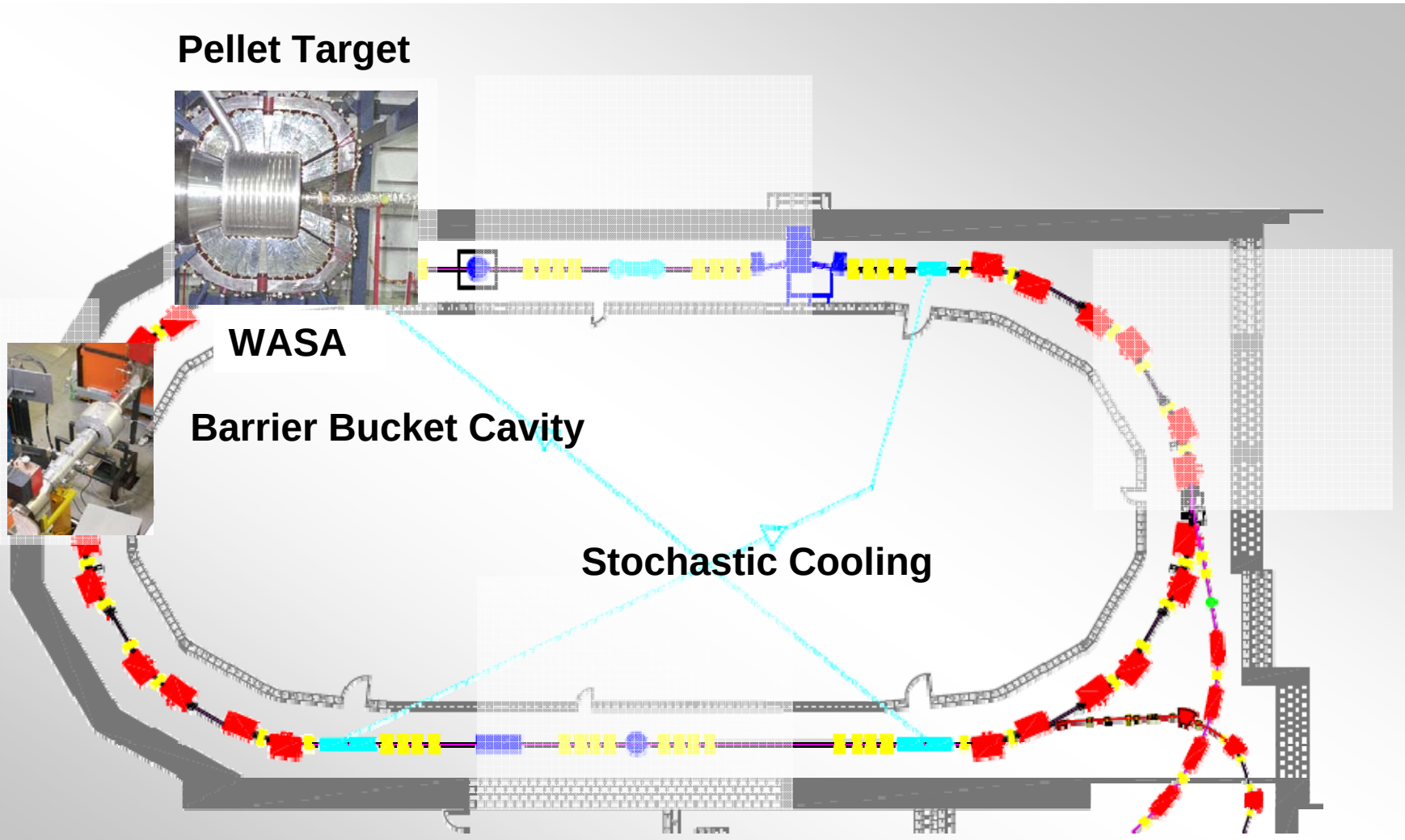
Design and Construction of HESR

- Circumference: 574 m
- Maximum momentum: 15 GeV/c (Bρ=50 Tm)
- (un-)pol. Anti-protons
- stochastic (and electron) cooling

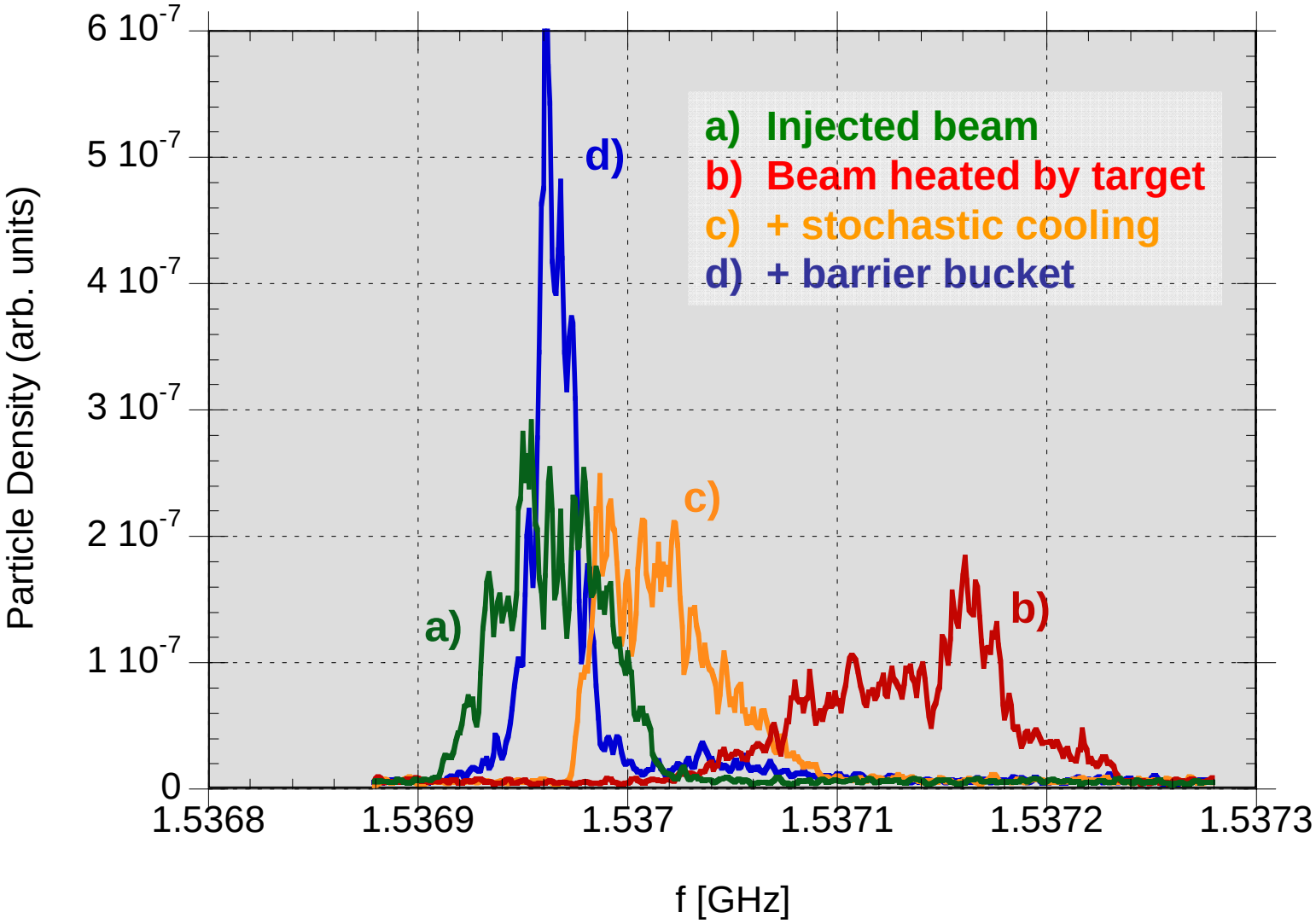




HESR Prototyping and Tests with COSY



Example: Beam Cooling with WASA Pellet Target



Parameters for the HESR stochastic cooler:

Momentum range (antiprotons): 1.5 - 15 GeV/c

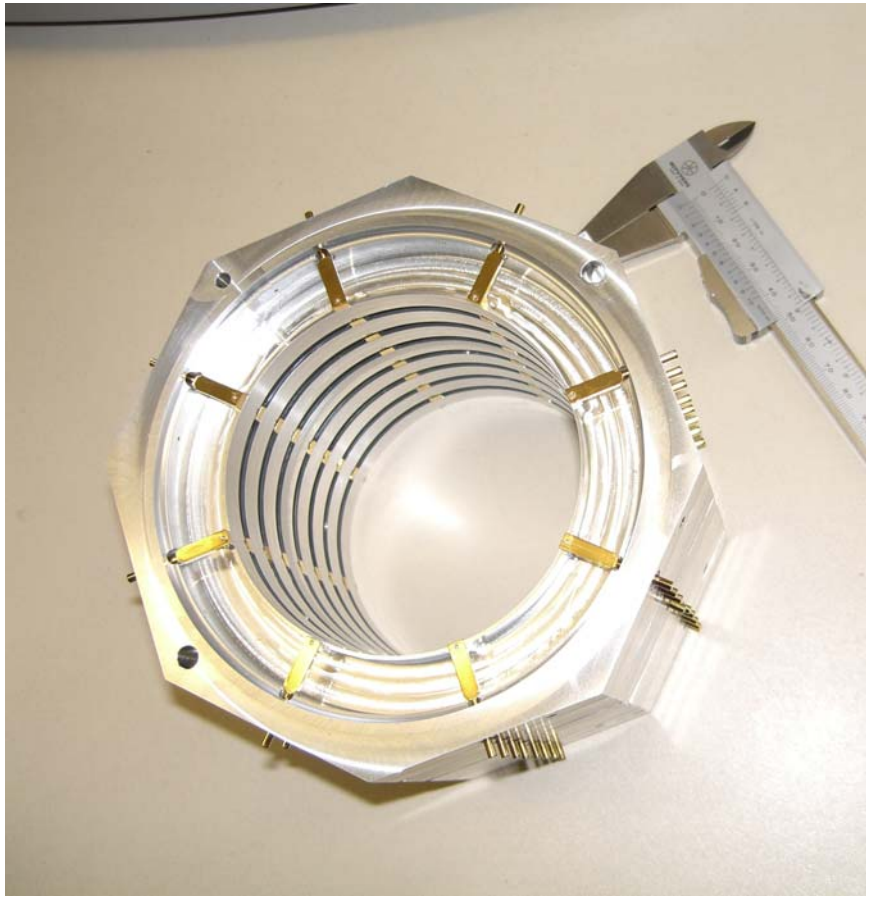
Band width: 2 - 4 GHz, high sensitivity

Longitudinal cooling: Notch-Filter, ToF

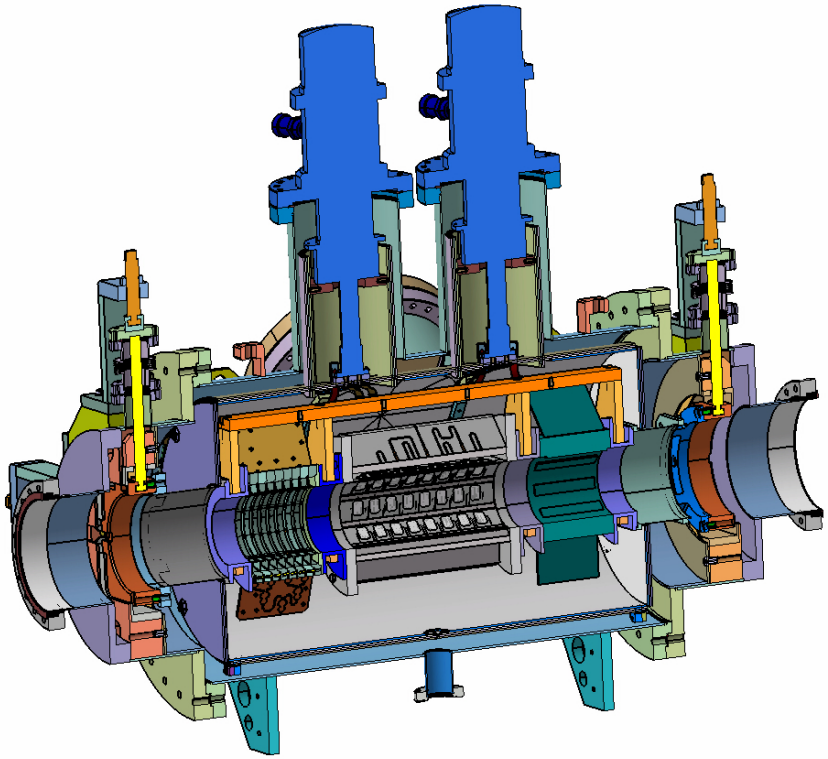
Aperture of couplers: 89 mm

Octagonal Printed-Loop Coupler

Octagonal Slot-Coupler

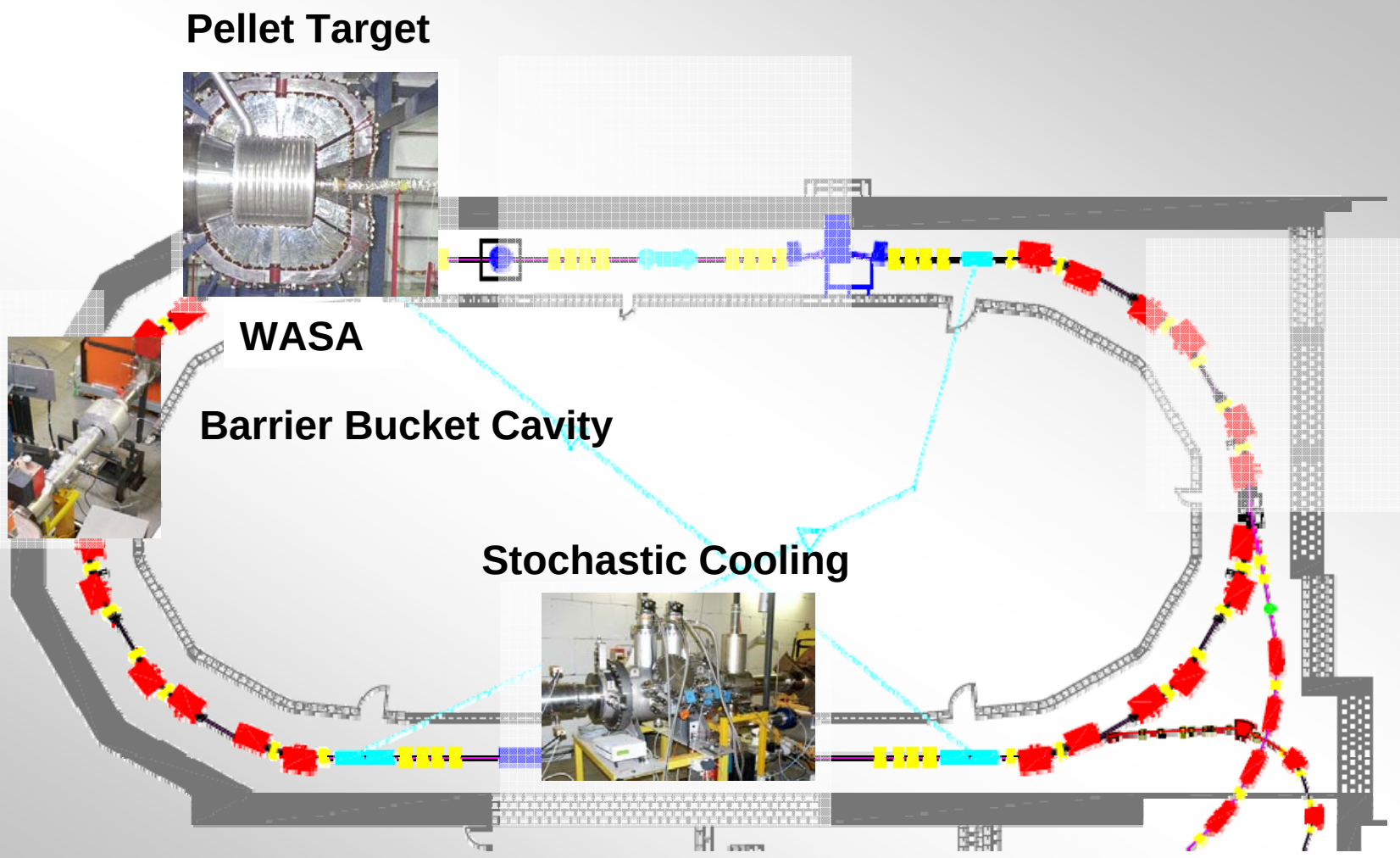


Stochastic cooling pickup (prototype) installed in COSY



Same sensitivity as movable $\lambda/4$ structures

HESR Prototyping and Tests with COSY



Poster by Rolf Stassen

Next step in COSY: Electron cooling up to maximum momentum

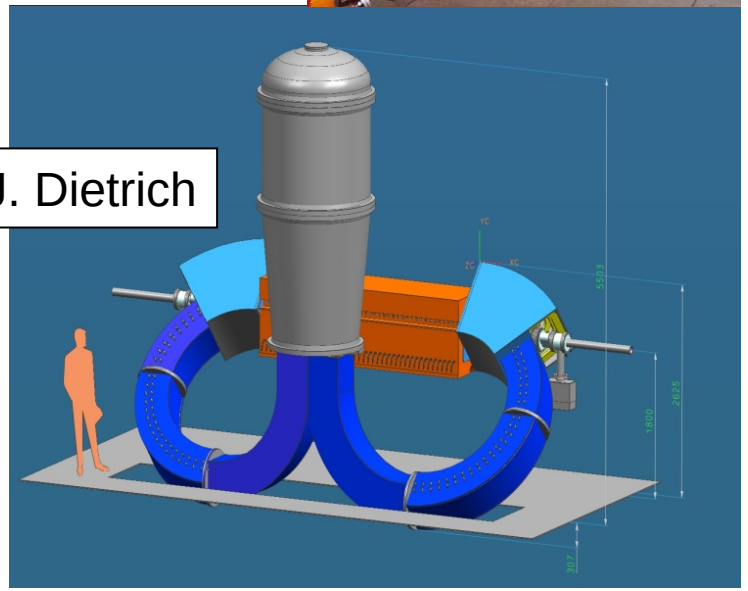
Electron Cooling: Development Steps

HESR: 4.5 MeV

Upgradeable
to 8 MeV

COSY:
from 0.1 MeV
to 2 MeV

Talk by J. Dietrich



Technological challenge

Summary

- Strong cooling is essential for HESR
- Stochastic cooling is designed, prototype structures for 2-4 GHz tested
- Electron cooling in HESR will improve the experimental conditions and the accumulation efficiency

- Tests will be performed at COSY with simultaneous electron and stochastic cooling in interaction with a thick internal target

Thank you for your attention