Status of the FAIR Project

Markus Steck

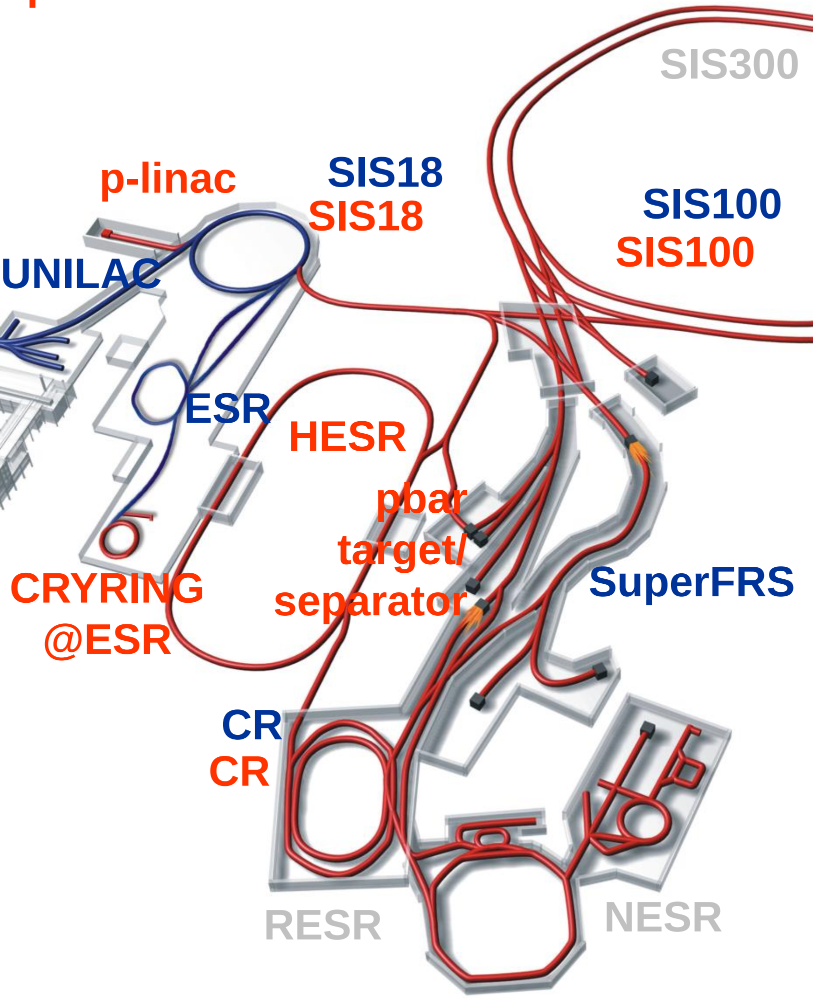
Stored Beams in FAIR@GSI

GSI Helmholtzzentrum Darmstadt

COOL 13, Mürren, Switzerland

FAIR - Modularized Start Version (MSV)

Modularized Start Version (MSV)
pbar and RIBs



not included in MSV:

(can be added later depending on funding)

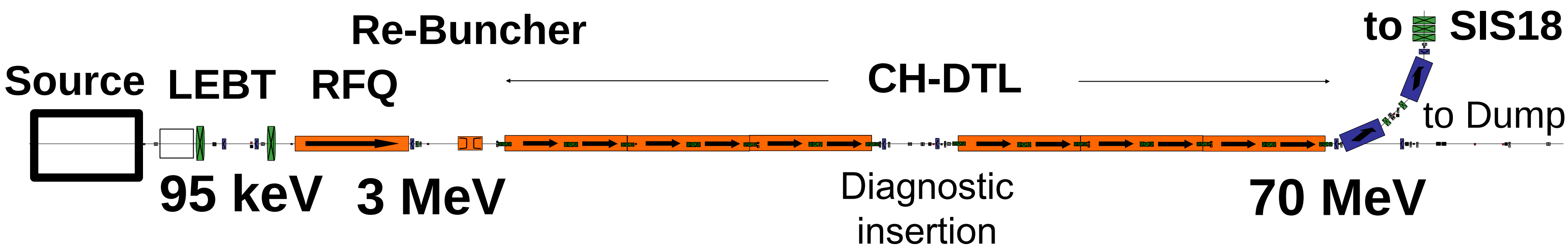
SIS300 high energy 300 Tm synchrotron
RESR accumulator ring for antiprotons
NESR storage ring for experiments and deceleration of ions an pbars
FLAIR low energy antiprotons

part of MSV:

SIS100 heavy ion and proton synchrotron
SuperFRS and pbar target
CR pre-cooling of pbars (RIBs)
isochronous mass measurements of RIBs
HESR accumulation of pbars and ions
experiments with stored pbars and ions
ESR operation will be continued
CRYRING@ESR installation after the ESR

Proton Linac

The proton linac is designed to fill SIS18 with protons up to the space charge limit
main goal: production of antiprotons

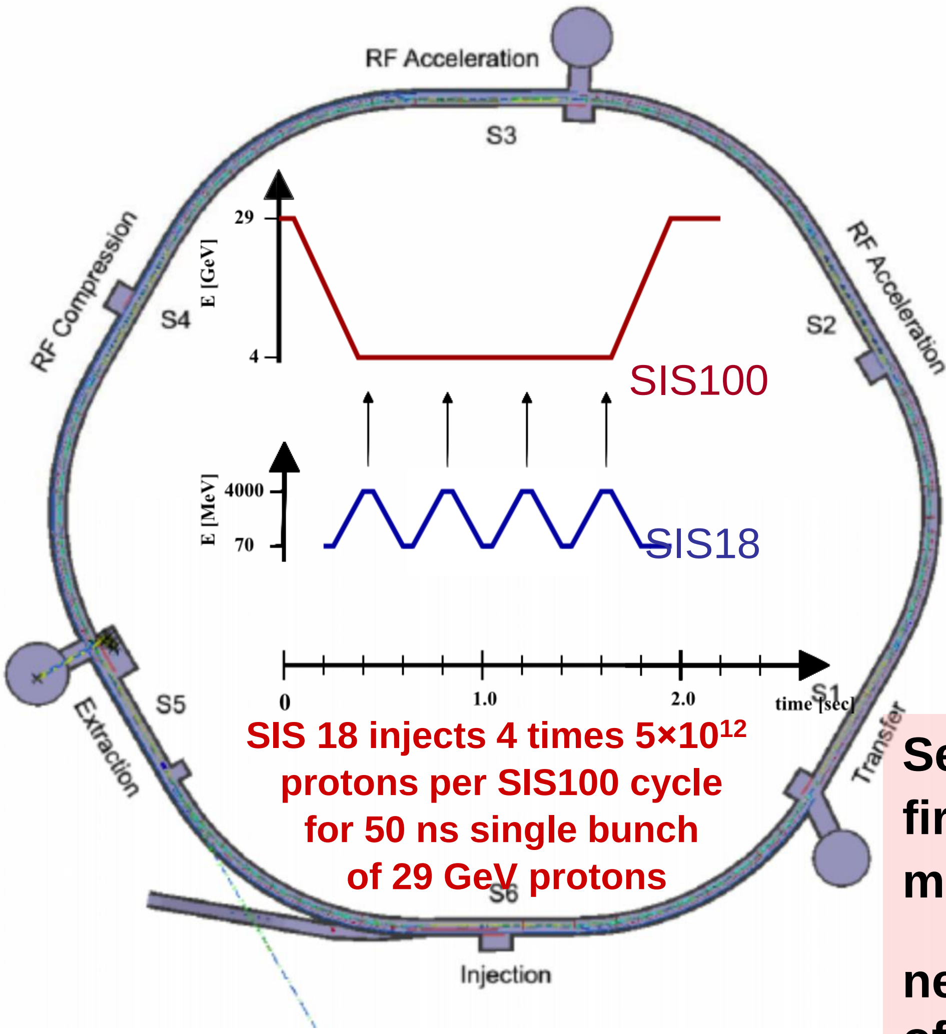


collaboration with: University of Frankfurt
CEA/Saclay, IN2P3, GANIL

- **ECR proton source & LEBT**
- **RFQ**
- **2 re-bunchers**
- **2 * 6 accelerating cavities**
- **5 MW of beam loading (peak), 720 W (ave.)**
- **11 MW of total rf-power (peak), 5 kW (ave.)**
- **2 dipoles, 46 quadrupoles, 7 steerers**

Energy	70 MeV
Current (oper.)	35 mA
Design current	*70 mA*
Beam pulse length	36 µs
Repetition rate	4 Hz
Rf-frequency	325.224 MHz
Norm. horiz. emit.	2.1 / *4.2* µm
Tot. mom. spread	≤ ± 10^{-3}
Linac length	≈ 35 m

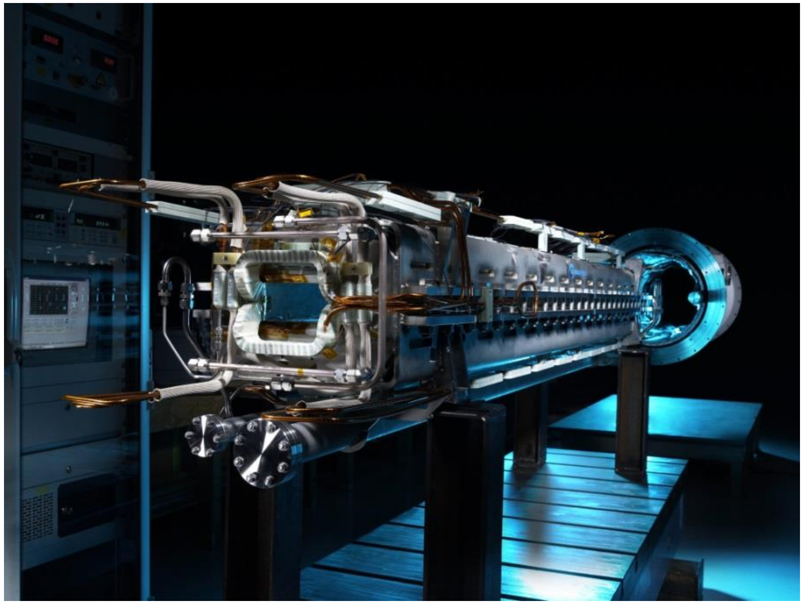
SIS 100



SIS 18 injects 4 times 5×10[12] protons per SIS100 cycle for 50 ns single bunch of 29 GeV protons

circumference 1080 m

fast ramping super-ferric dipole (4 T/s)



Series production of dipole magnets started
first magnet expected soon
magnet testing facility in preparation

negotiations about production and testing of super-ferric quadrupoles

The RIB Separator SuperFRS

Design Parameters

$$\varepsilon_x = \varepsilon_y = 40\,\pi\,\text{mm mrad}$$

$$\varphi_x = \pm 40\ \text{mrad},$$

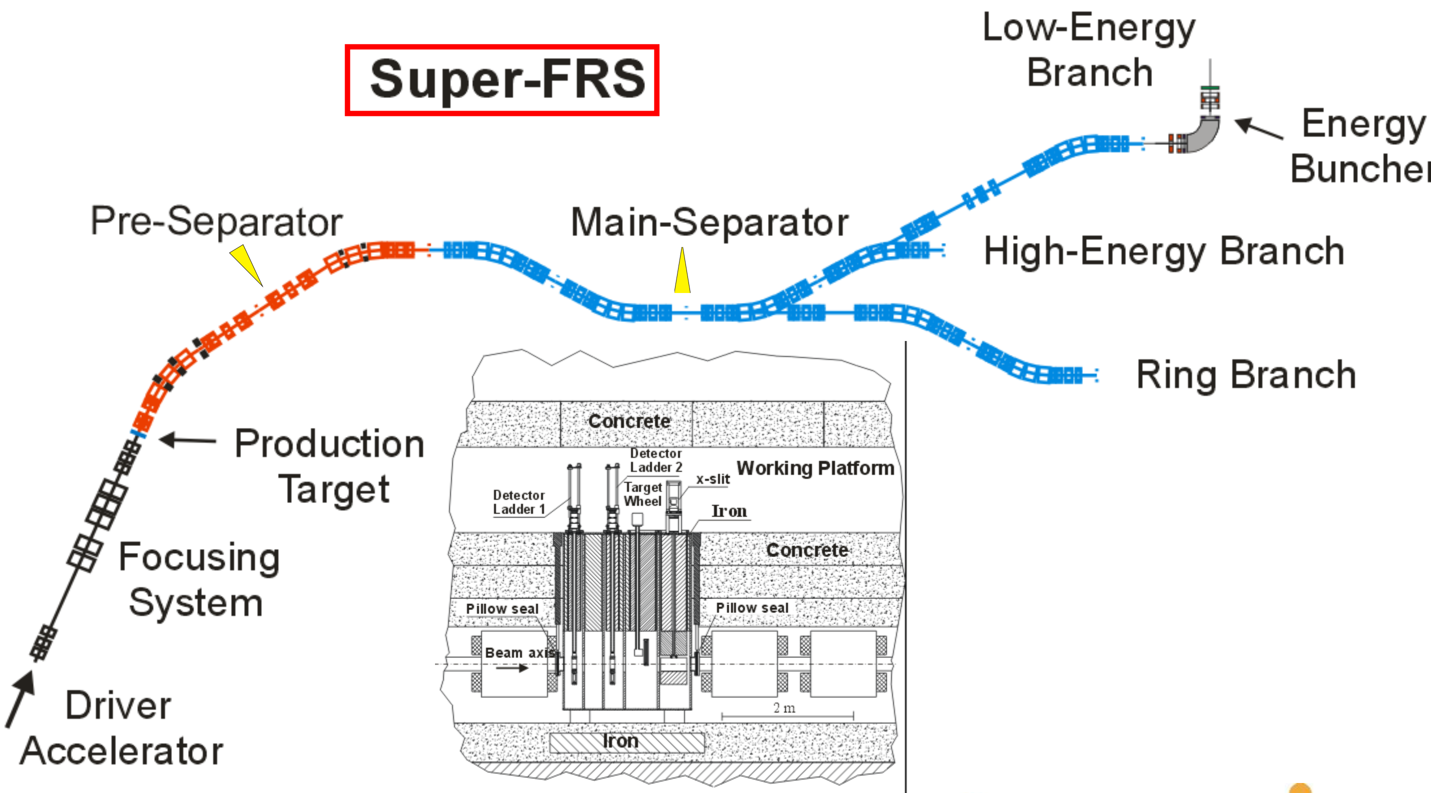
$$\varphi_y = \pm 20\ \text{mrad}$$

$$\frac{\Delta p}{p} = \pm 2.5\ \%$$

$$B\rho_{max} = 20\ \text{Tm}$$

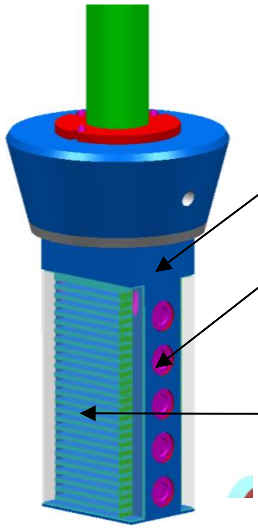
$$R_{ion} = 1500$$

- Multi-Stage
- Multi-Branch
- Superconducting
- Large Acceptance



Antiproton Target and Separator

Target

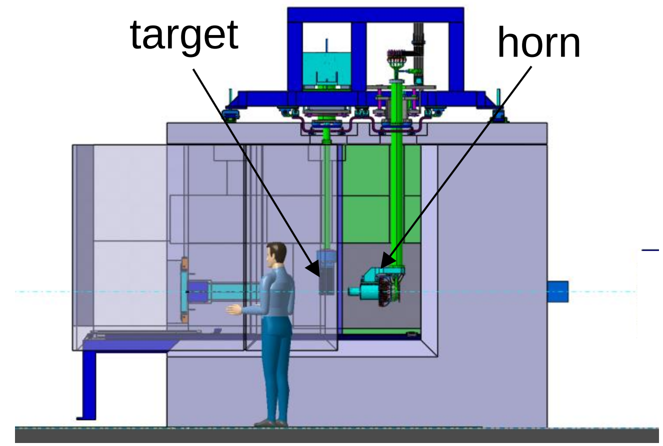


Al block

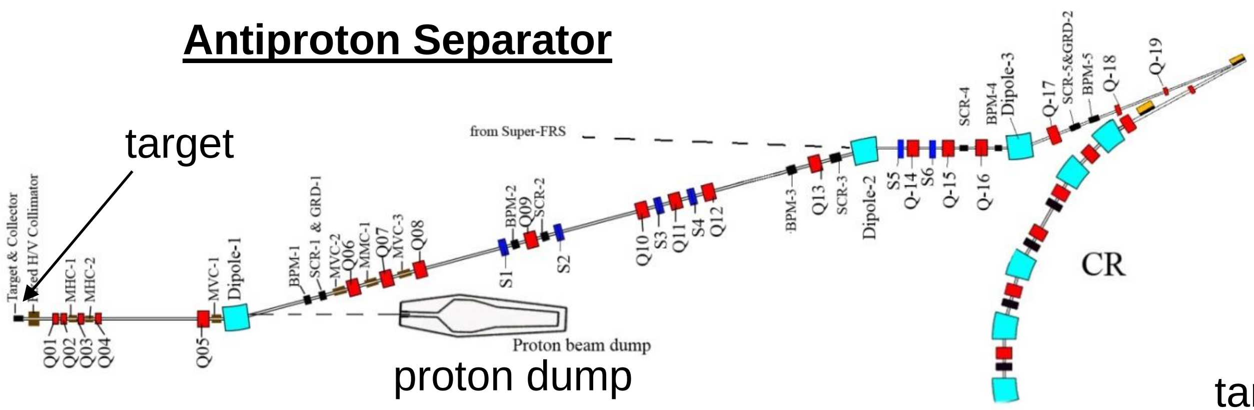
Ti window, inside:
Ni rod (r = 0.15 cm, l = 10 cm)
in graphite cylinder (r = 1 cm)

air cooling

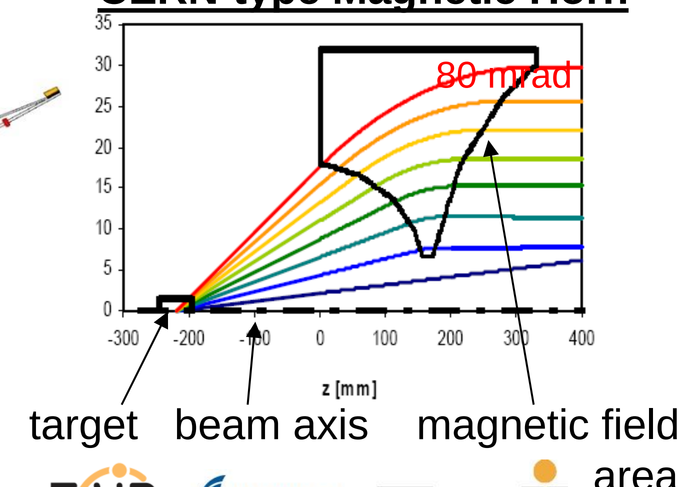
Target Station



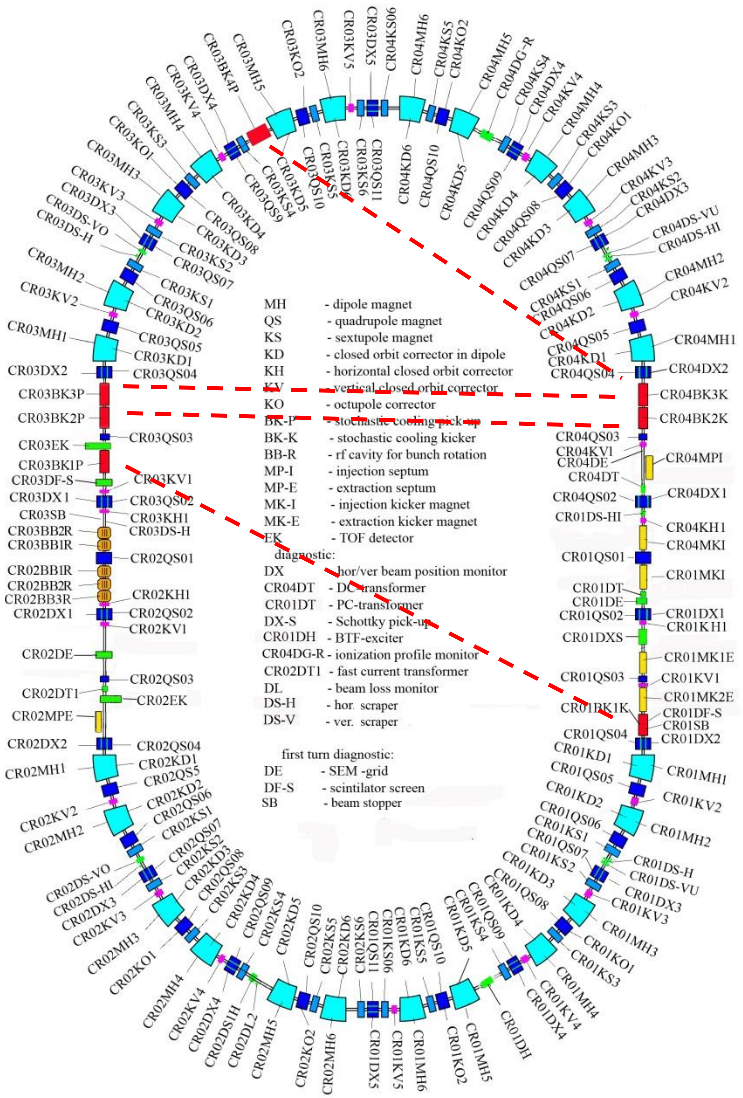
Antiproton Separator



CERN-type Magnetic Horn



The Collector Ring CR



circumference 221.5 m
magnetic bending power 13 Tm
large acceptance $\varepsilon_{x,y}$ = 240 (200) mm mrad
$\Delta p/p = \pm$ 3.0 (1.5) %

fast stochastic cooling (1-2 GHz) of antiprotons (10 s) and rare isotope beams (1.5 s)

- *fast bunch rotation at h=1 (U_{rf} =200 kV)*
- *adiabatic debunching*
- *optimized ring lattice (slip factor) for proper mixing*
- *large acceptance magnet system*

additional feature:
isochronous mass measurements of rare isotope beams

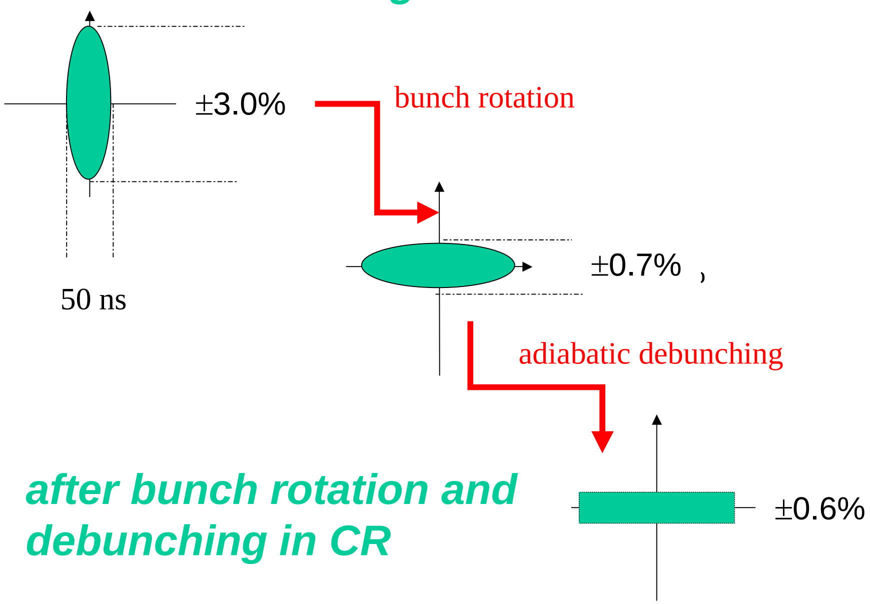
option: upgrade of rf system to 400 kV and stochastic cooling to 1 - 4 GHz

Fast Bunch Rotation in CR

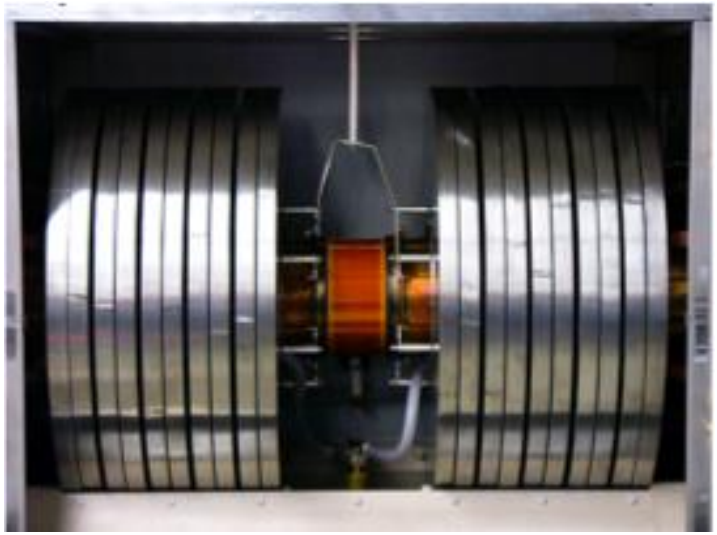
Fast bunch rotation of SIS100 bunch to provide optimum initial parameters for stochastic cooling

total rf voltage 200 kV at h=1 reduces the momentum spread (± 3.0 → ± 0.7 %) after passage of production target

SIS100 bunch after target



after bunch rotation and debunching in CR



SIS18 bunch compressor cavity

CR bunch rotation cavity filled with magnetic alloy

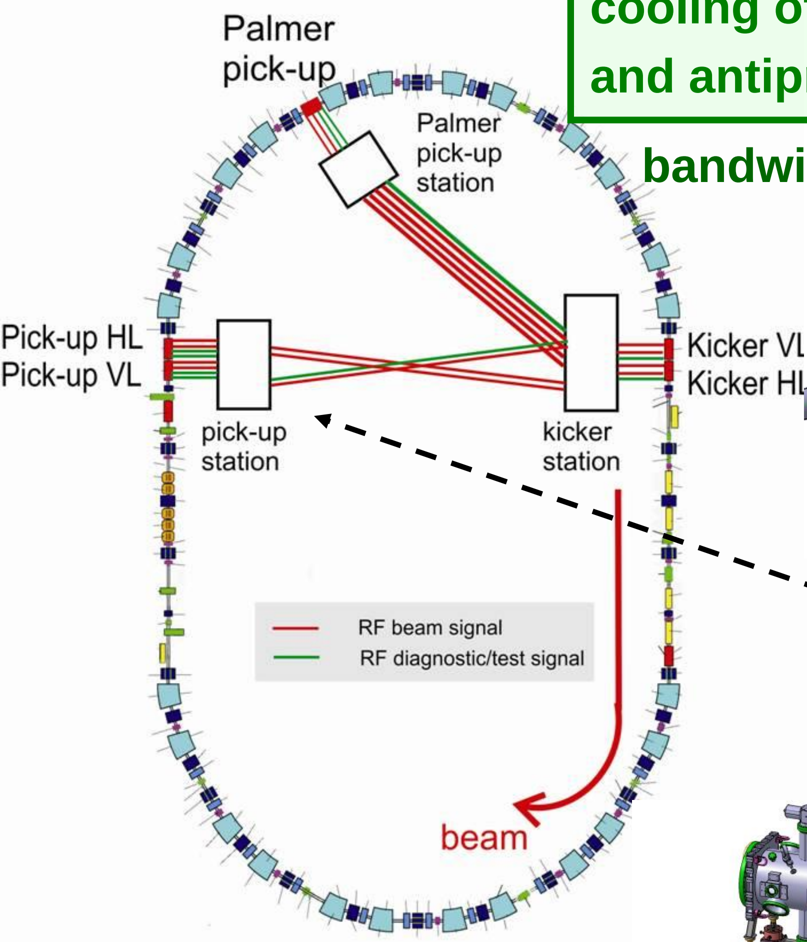
voltage 40 kV
length 1 m
frequency range 1.13 – 1.32 MHz
rotation time 1000 μs (pbars)
600 μs (RIBs)

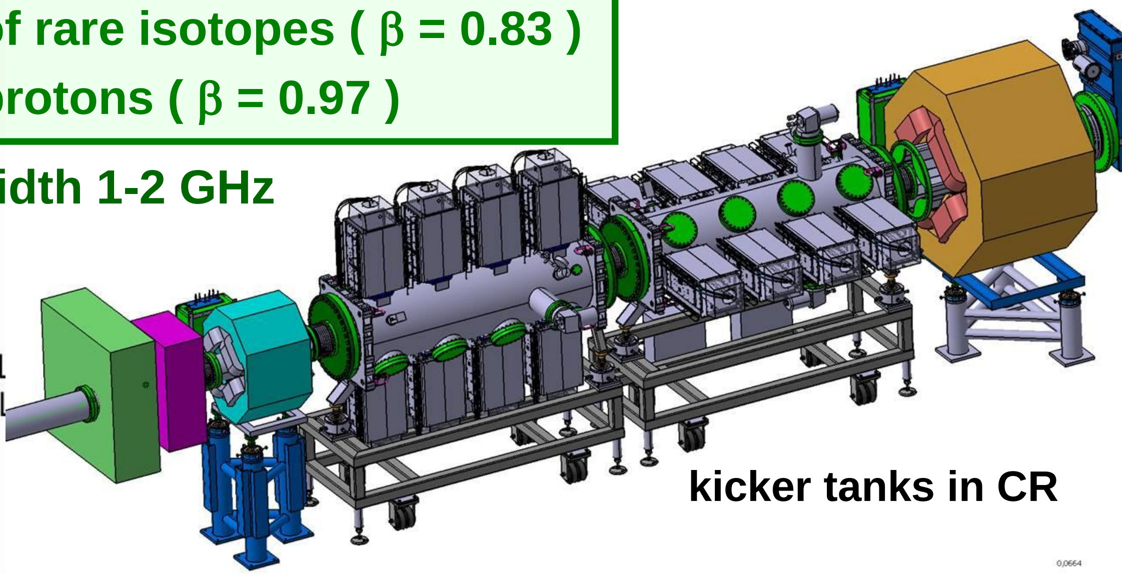
Debuncher rf system ordered as German In-kind

CR Stochastic Cooling

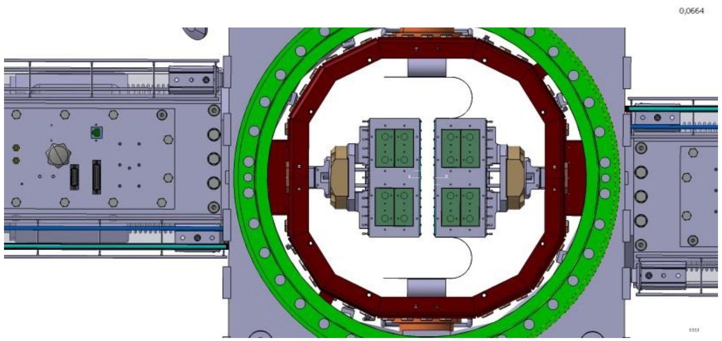
cooling of rare isotopes ($\beta = 0.83$)
and antiprotons ($\beta = 0.97$)

bandwidth 1-2 GHz

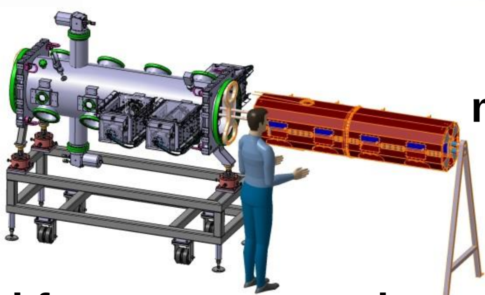




kicker tanks in CR



movable electrodes in pick-up tank
electrodes can be cooled



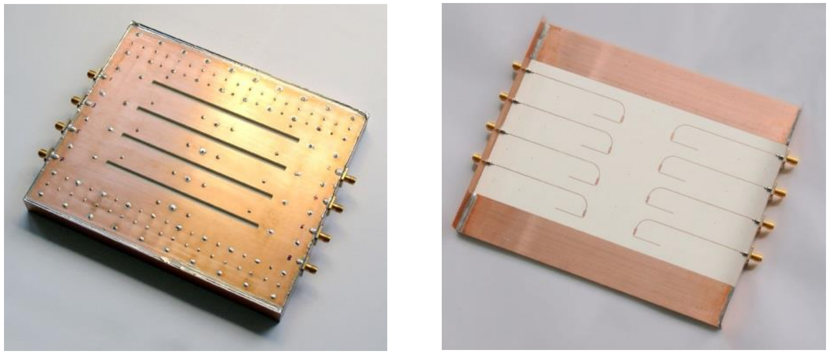
heat-shield for prototype tank

presentation by C. Dimopoulou

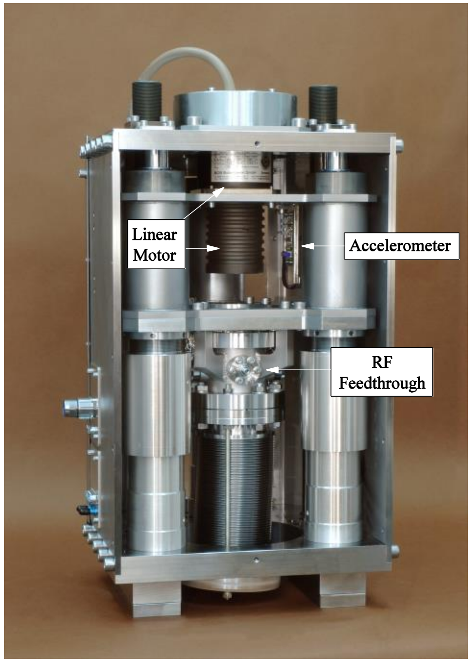
CR Stochastic Cooling Prototypes

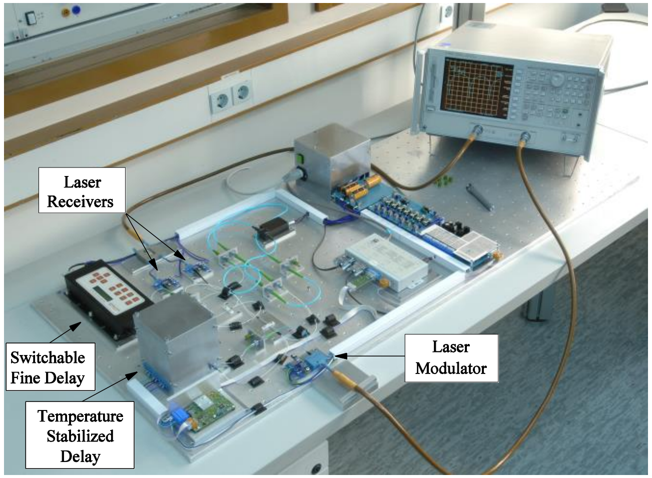
vacuum tank for moving electrodes

Electrode prototype (slot line type)



programmable linear actuator



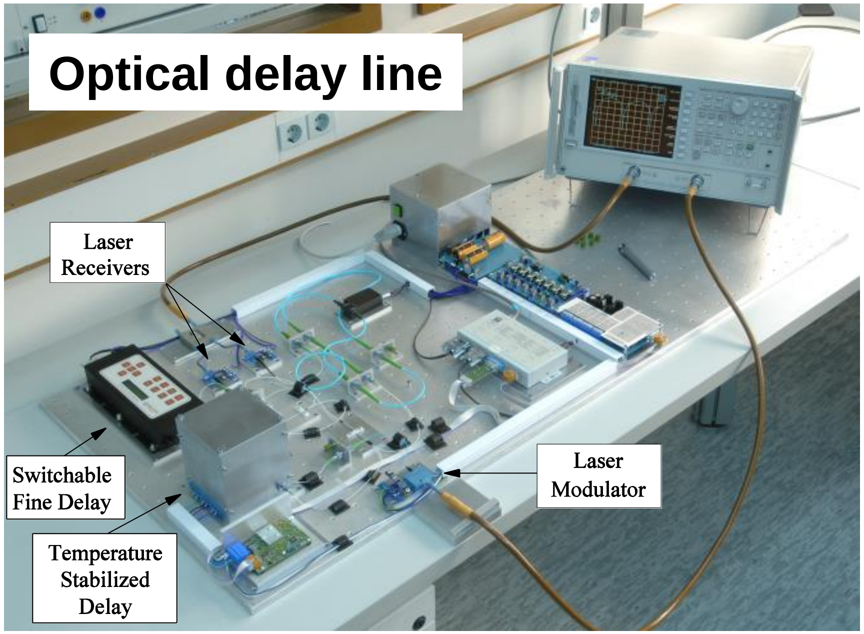


optical delay line

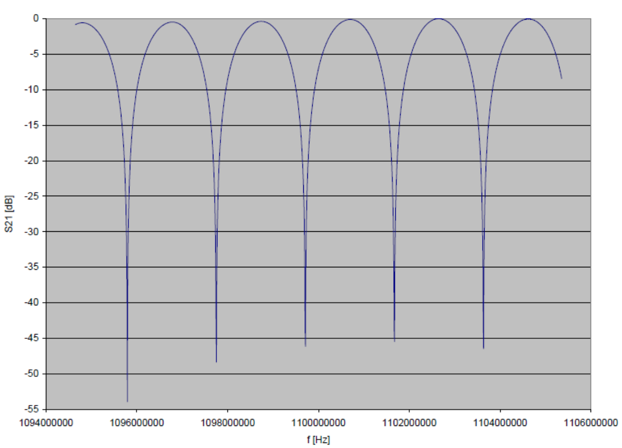
milled module body with combiner board

poster by C. Peschke

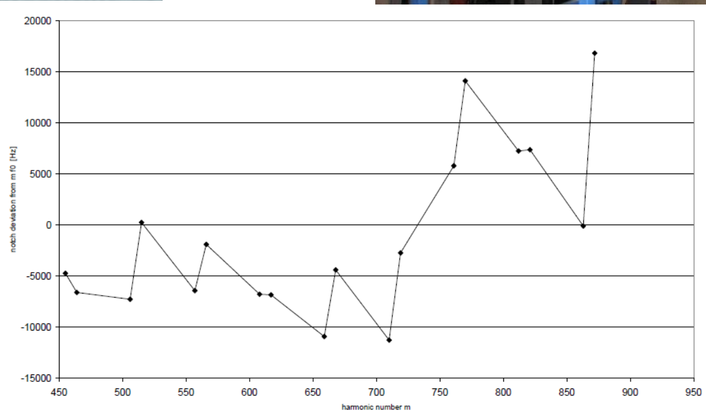
Notch Filter Development



Test set-up of notch filter at ESR



notch depth better than 45 dB



frequency deviation $\leq 5 \times 10^{-5}$

poster by W. Maier

Palmer Cooling for RIBs

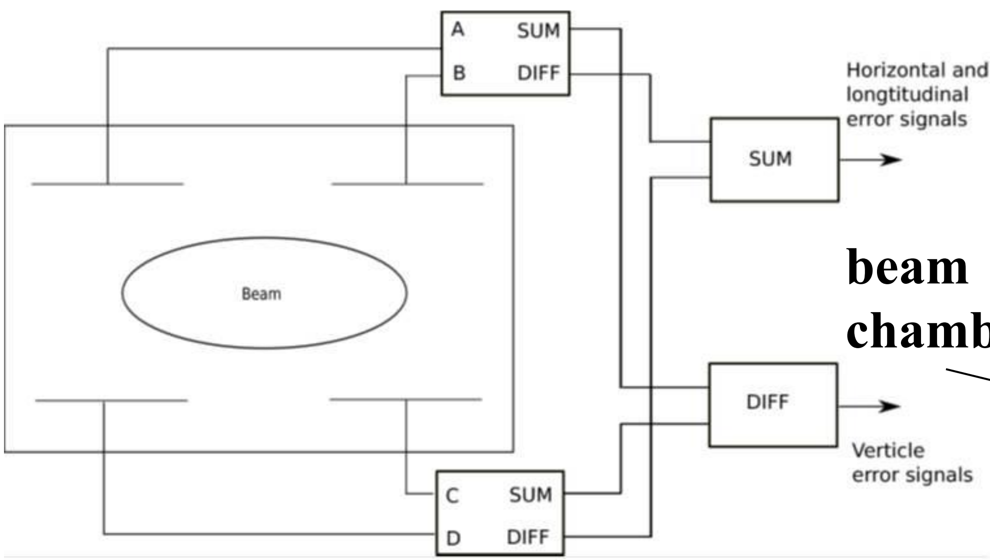
Design of the Palmer pick-up for pre-cooling of RIBs

Rare isotopes have high charge, hence offer strong signal.

Faltin electrodes have flat frequency response but are large and insensitive.

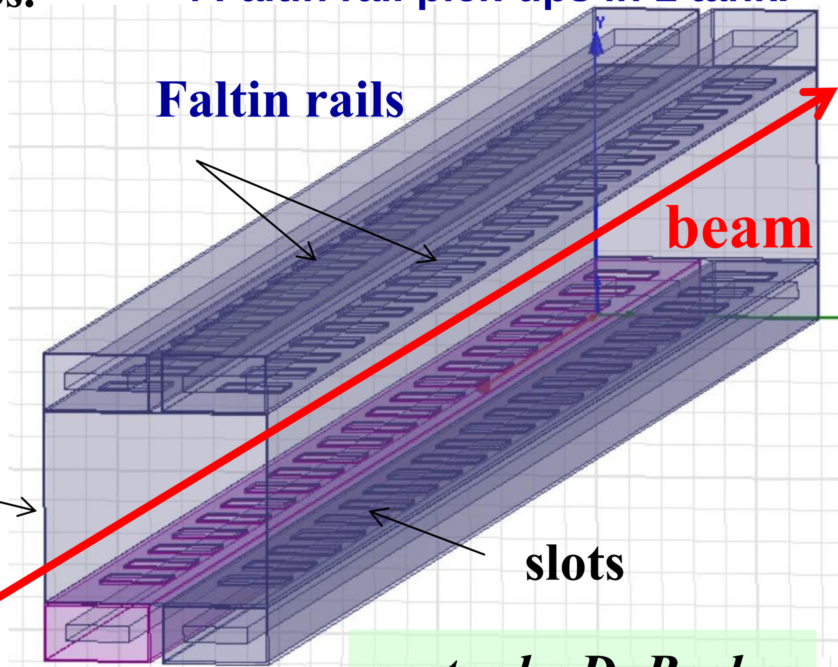
Faltin pick-ups are suitable for pre-cooling of RIBs.

Plunging is not necessary.



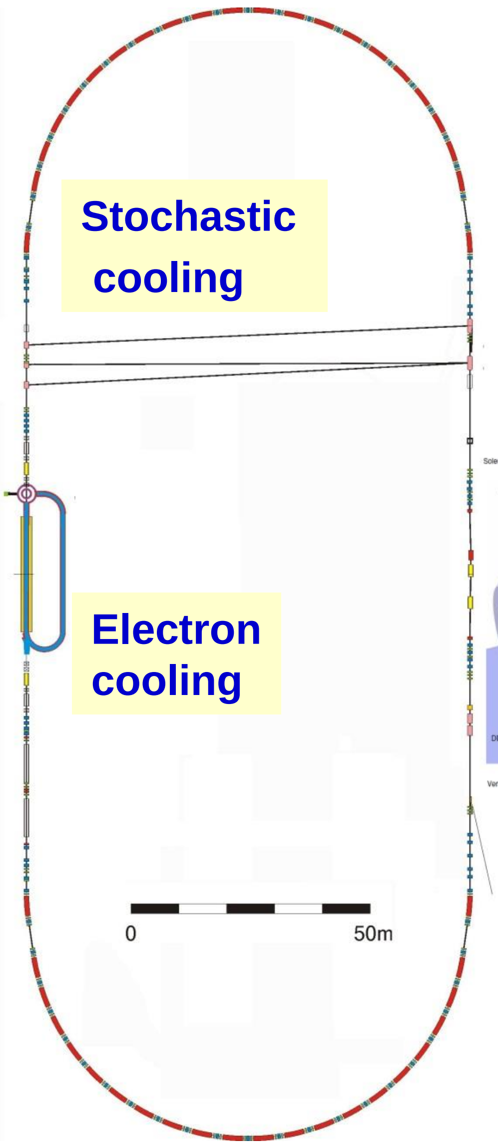
Palmer cooling signal combination for vertical and simultaneous horizontal and longitudinal cooling.

4 Faltin rail pick-ups in 1 tank.



poster by D. Barker and L. Thorndahl

The High Energy Storage Ring HESR

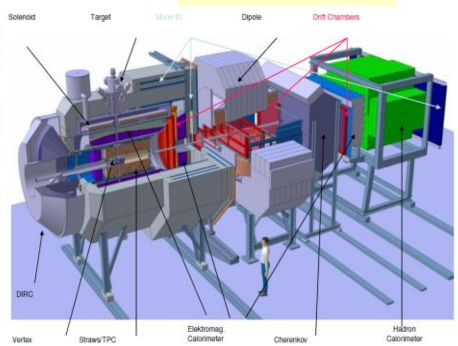


Stochastic cooling

Electron cooling

responsibility of FZ Jülich (German in-kind contribution)

PANDA experiment



presentation by D. Prasuhn

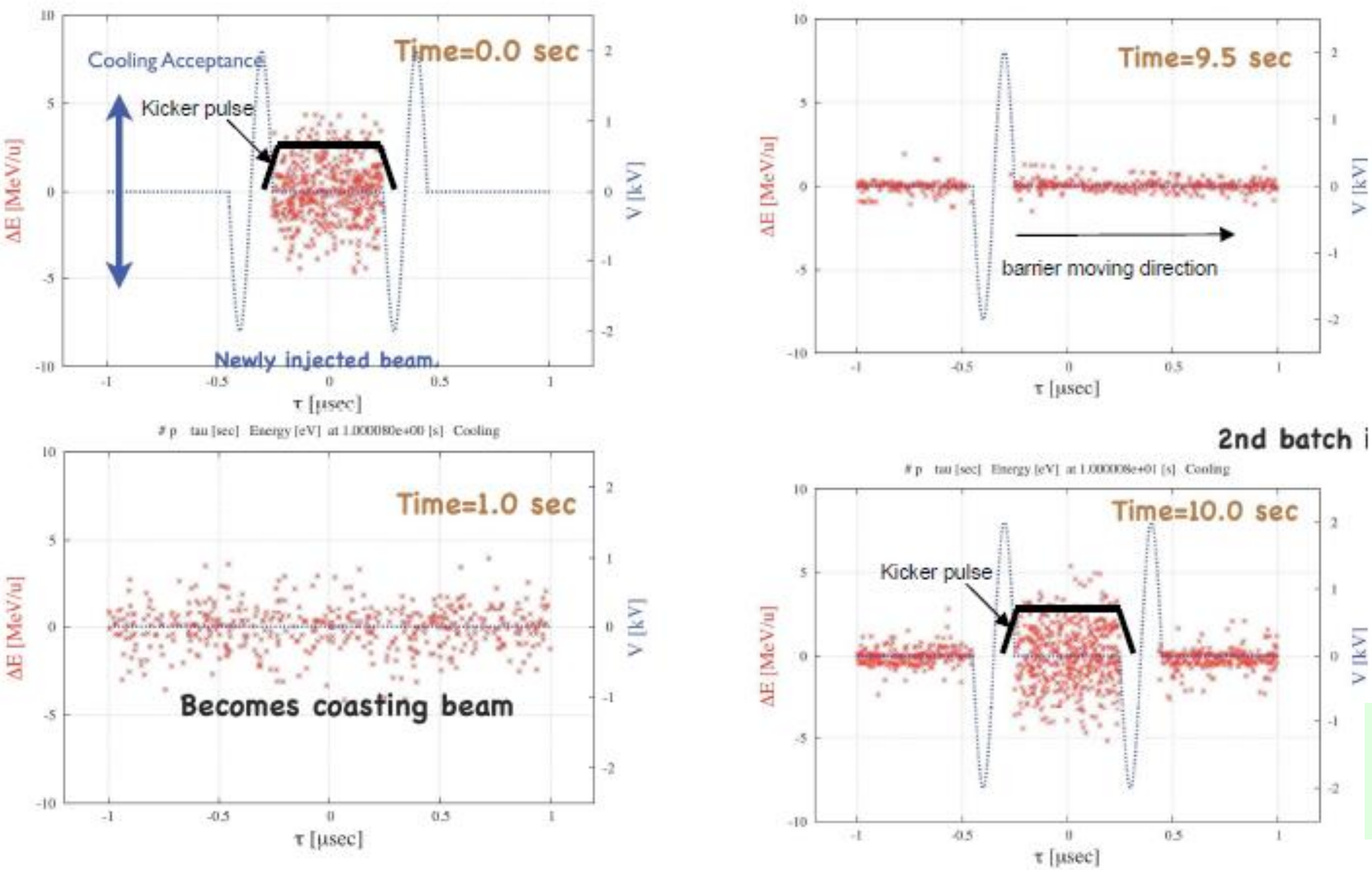
Storage of antiprotons

HESR Parameters

- circumference 574 m
- momentum (energy) range 1.5 to 15 GeV/c (0.8-14.1 GeV)
- injection of antiprotons from CR accumulation with barrier bucket and stochastic cooling (later accumulation in RESR)
- 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
- internal experiment PANDA: dipole field ramp: 0.015 T/s internal hydrogen target
- option: high energy electron cooling

Accumulation in the HESR

idea: accumulate pre-cooled antiprotons from CR
by combination of barrier buckets and stochastic cooling



presentation
by T. Katayama

Electron Cooling in the HESR

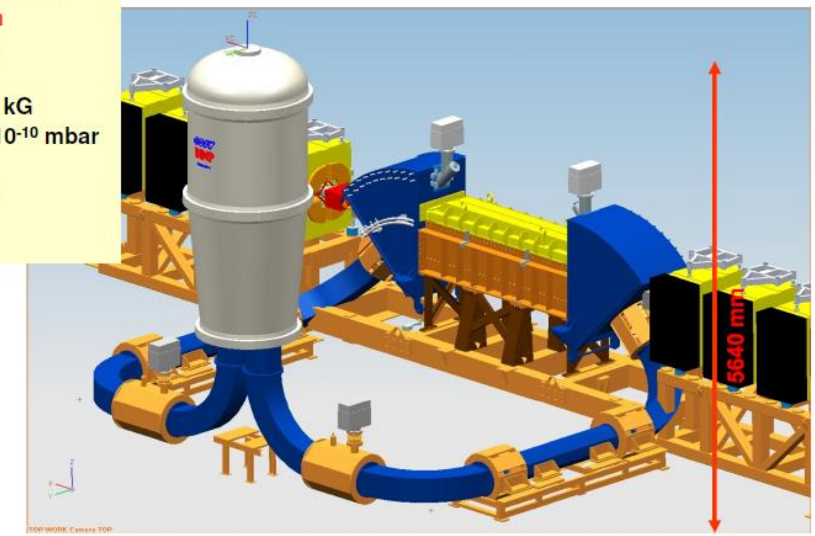
The COSY (HESR) 2 MeV Electron Cooler

Technical Design – Layout BINP

Basic Parameters and Requirements

JÜLICH FORSCHUNGSZENTRUM

Energy Range:	0.025 ... 2 MeV
High Voltage Stability	< 10^{-4}
Electron Current	0.1 ... 3 A
Electron Beam Diameter	10 ... 30 mm
Cooling section length	2.694 m
Toroid Radius	1.00 m
Variable magnetic field	
(cooling section solenoid)	0.5 ... 2 kG
Vacuum at Cooler	10^{-9} ... 10^{-10} mbar
Available Overall Length	6.390 m
Maximum Height	5.7 m
COSY beam Axis above Ground	1.8 m



Final Version from January 2010

presentation
by V. Kamerdzhiev

Antiproton Cooling:
at injection energy and below: 0.8 – 3 GeV

Ion and RIB Cooling:
In the energy range 0.2 – 3.5 GeV/u
injection at 0.74 GeV/u

applications:
- compensation of target heating and intrabeam scattering
- accumulation of ions

presently assembled for commissioning at COSY

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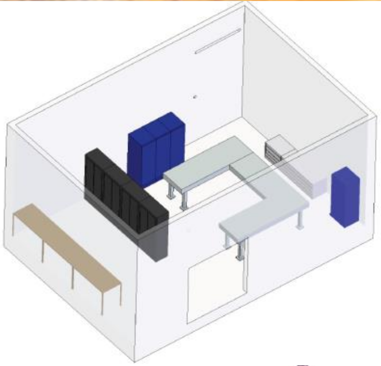
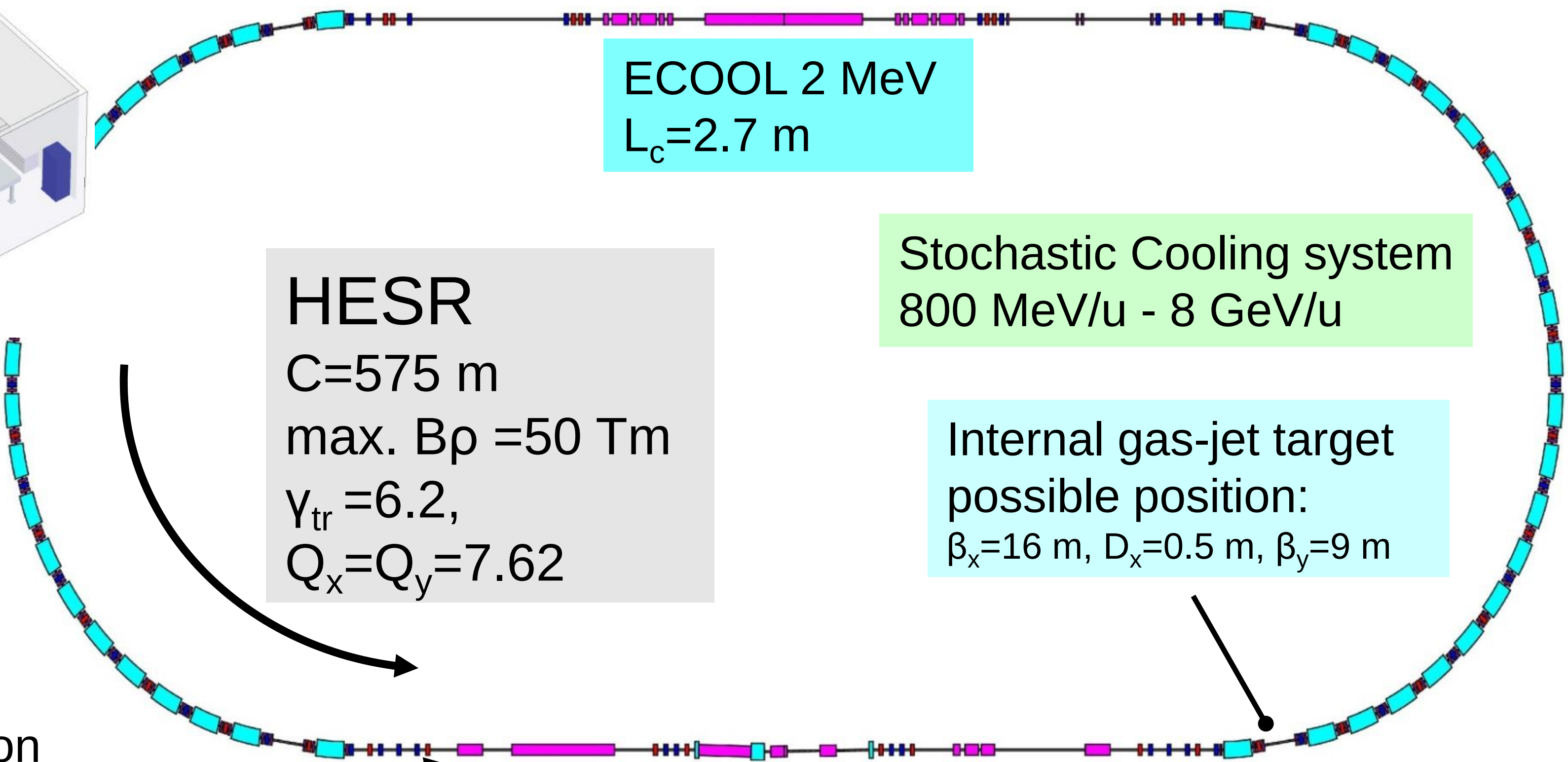
Operation of the HESR with Ions



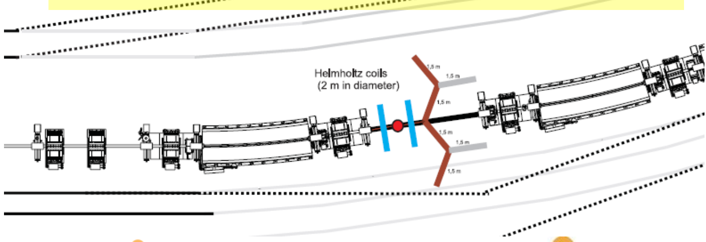
SPARC laser lab



3 GeV antiprotons
740 MeV/u ions

SPARC experiments with stored and e-cooled ion beams
Energy range: 200 MeV/u – 3 GeV/u
Reference ions: $^{238}U^{92+}$ and $^{132}Sn^{50+}$

SPARC Experimental Set-up



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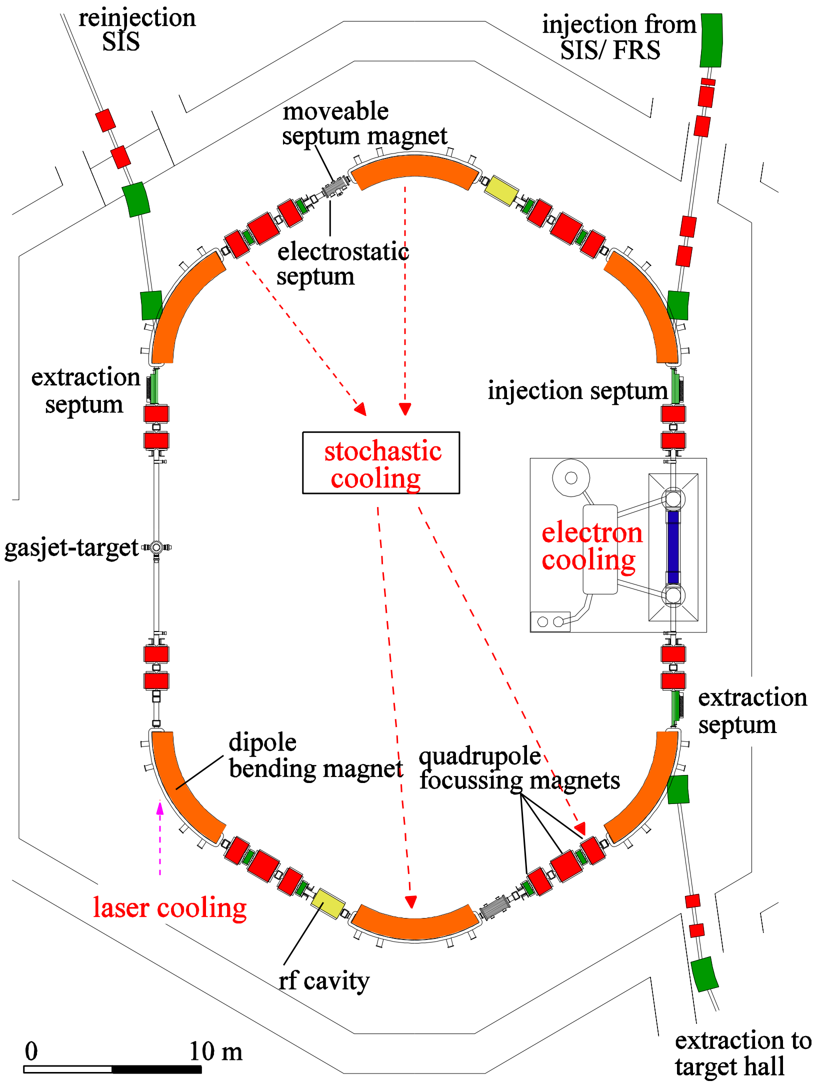
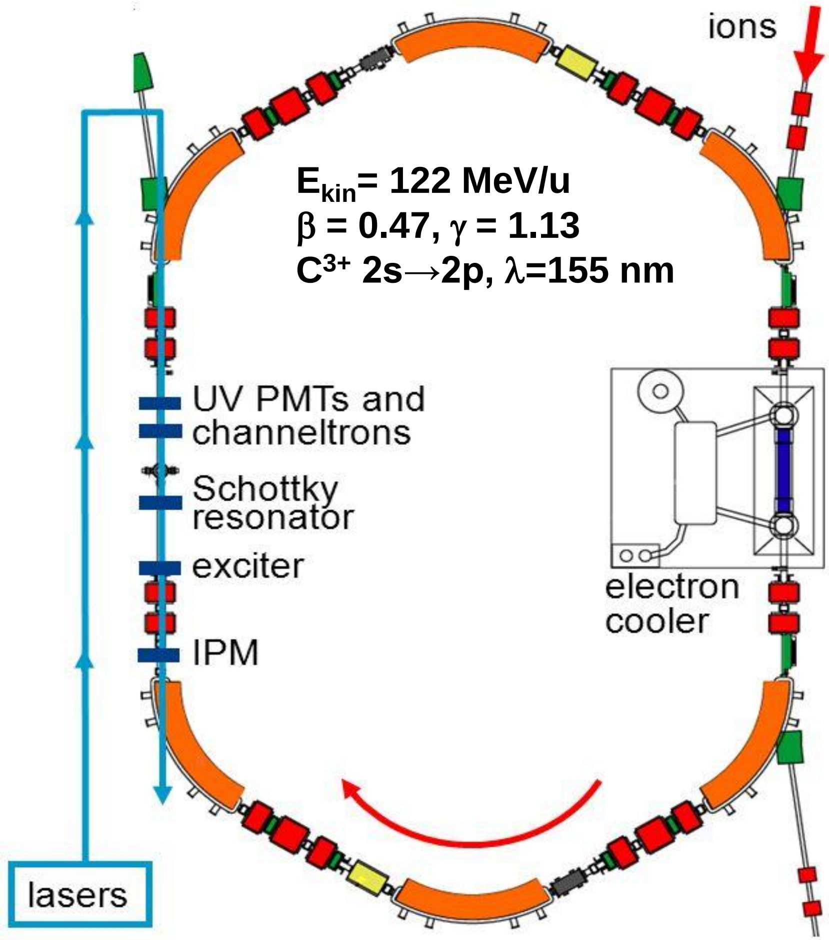
The Existing ESR

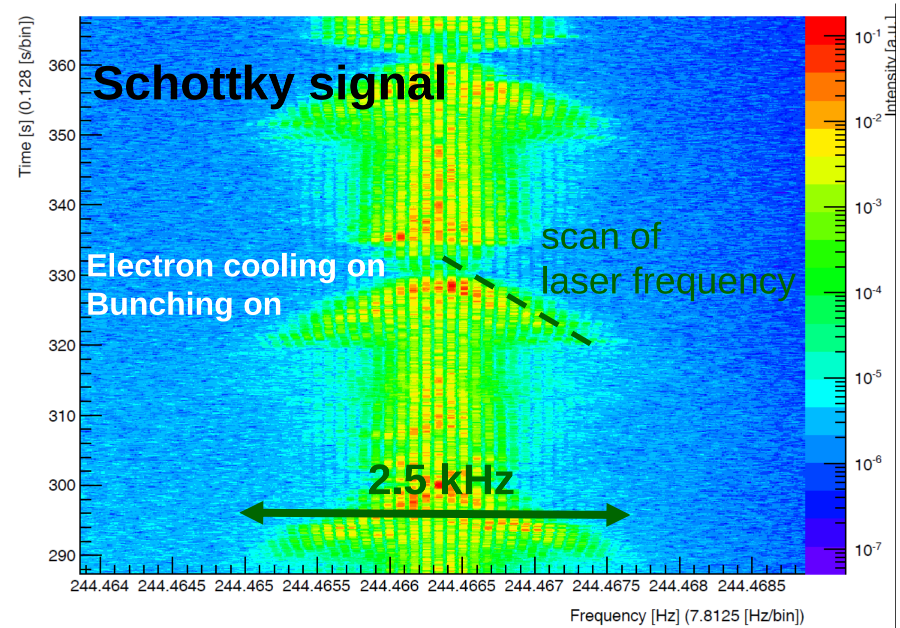


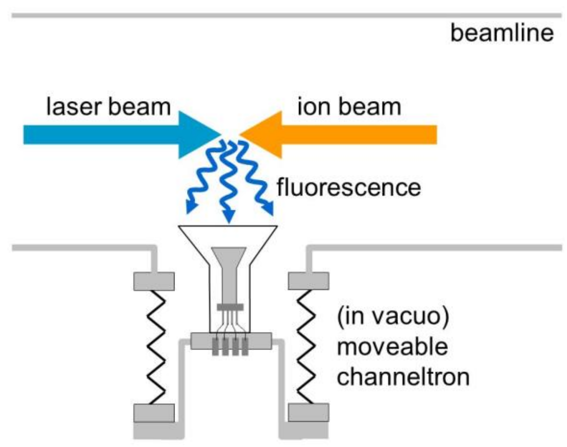
Fast injection (stable ions / RIBs)
Stochastic cooling (≥ 400 MeV/u)
Electron cooling (3 - 430 MeV/u)
Laser cooling (C^{3+} 120 MeV/u)
Internal gas jet target
Acceleration/deceleration (down to 3 MeV/u)
Fast extraction (reinjection to SIS / HITRAP)
Slow (resonant) extraction
Ultraslow extraction (charge change)
Beam accumulation
Multi charge state operation
Schottky mass spectrometry
Isochronous mode (TOF detector)

The ESR will be a valuable test bed to develop techniques for FAIR

Laser Cooling of C^{3+} at the ESR



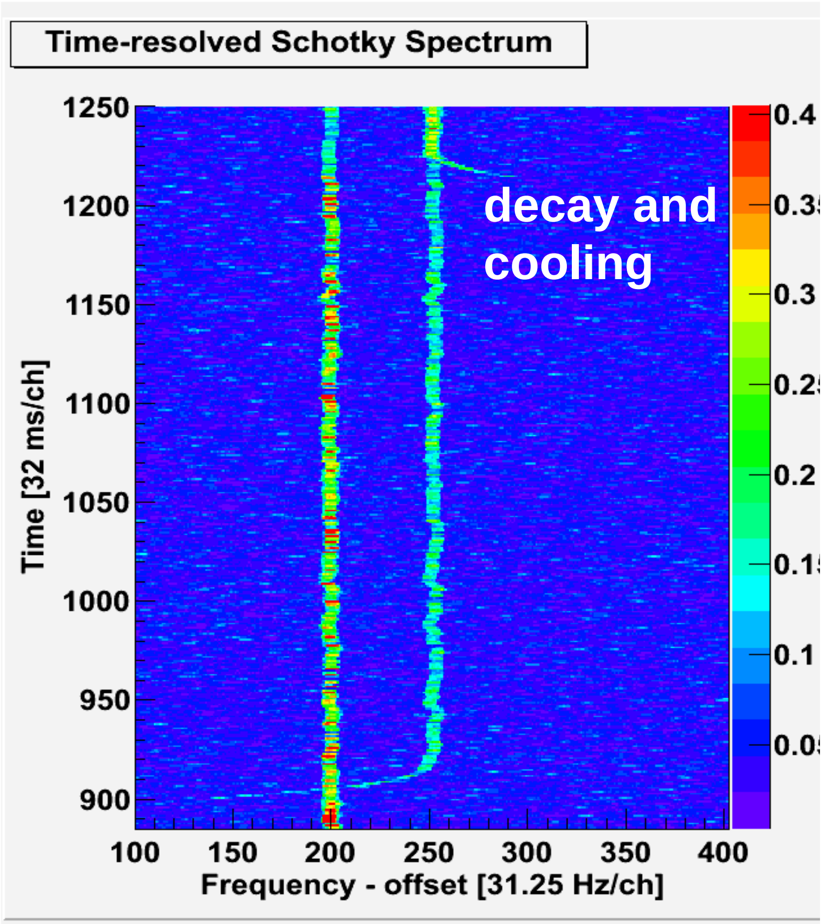




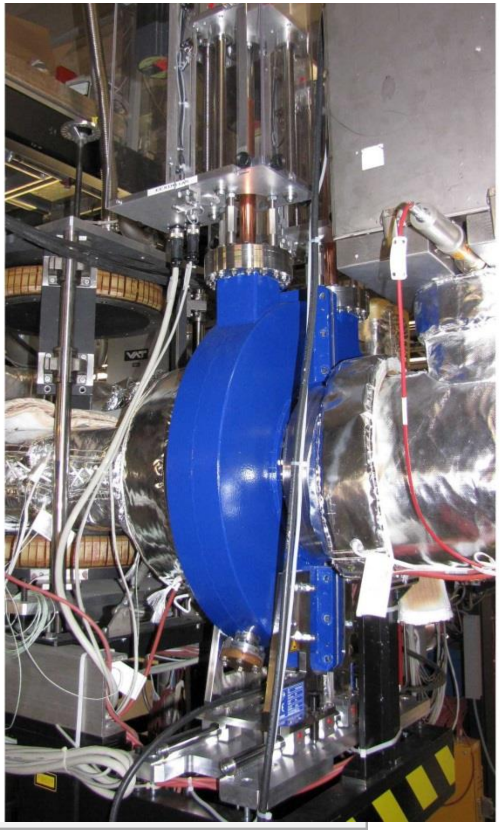
presentation by D. Winters

optical diagnostics

Single Ion Detection at the ESR



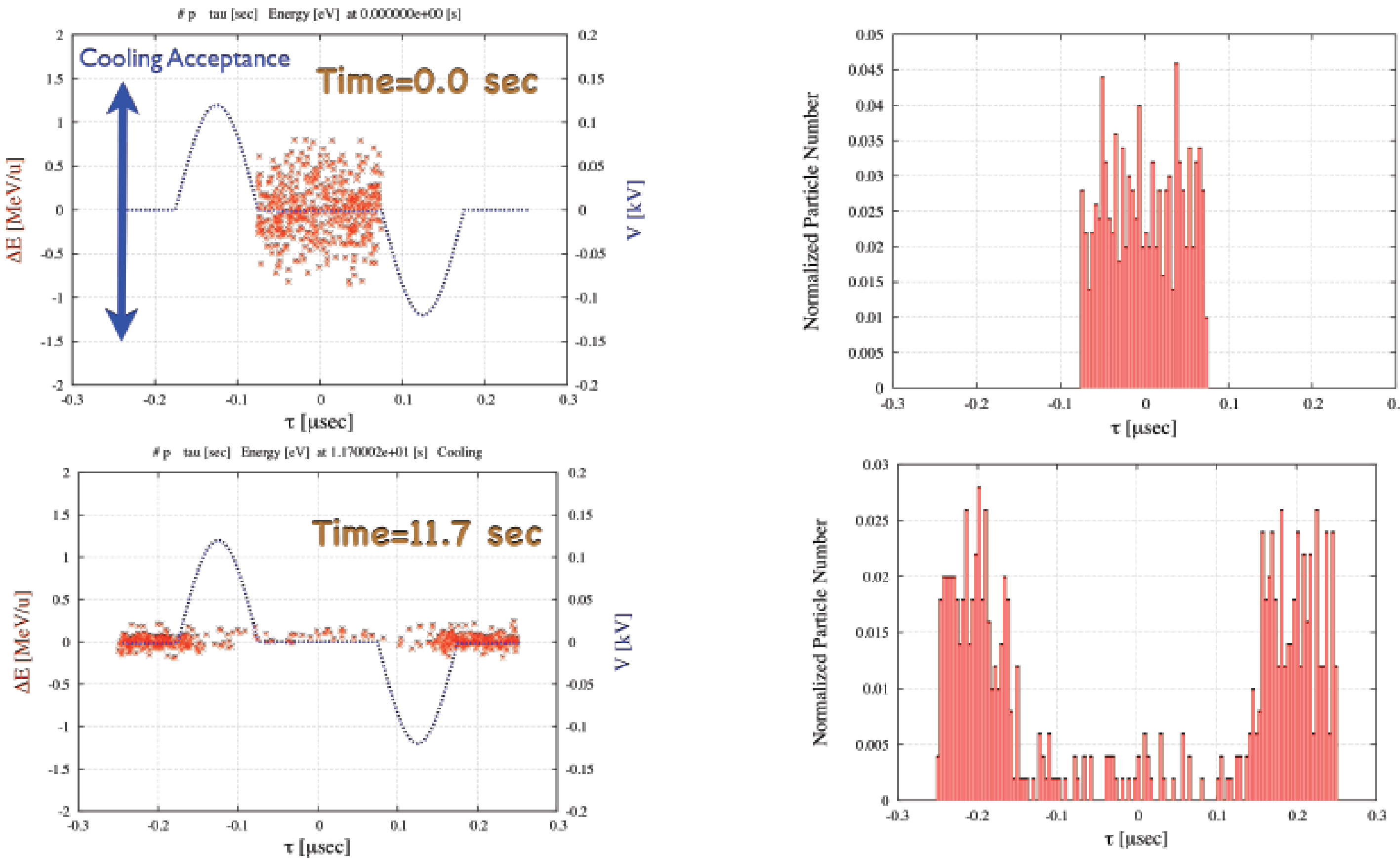
resonant cavity for Schottky noise detection



allows analysis of cooling dynamics for single ions

Proof-of-Principle Experiment in the ESR

using a single bunch of Ar^{18+} at 400 MeV/u from SIS



presentation by T. Katayama

mainly to demonstrate the method and benchmark codes,

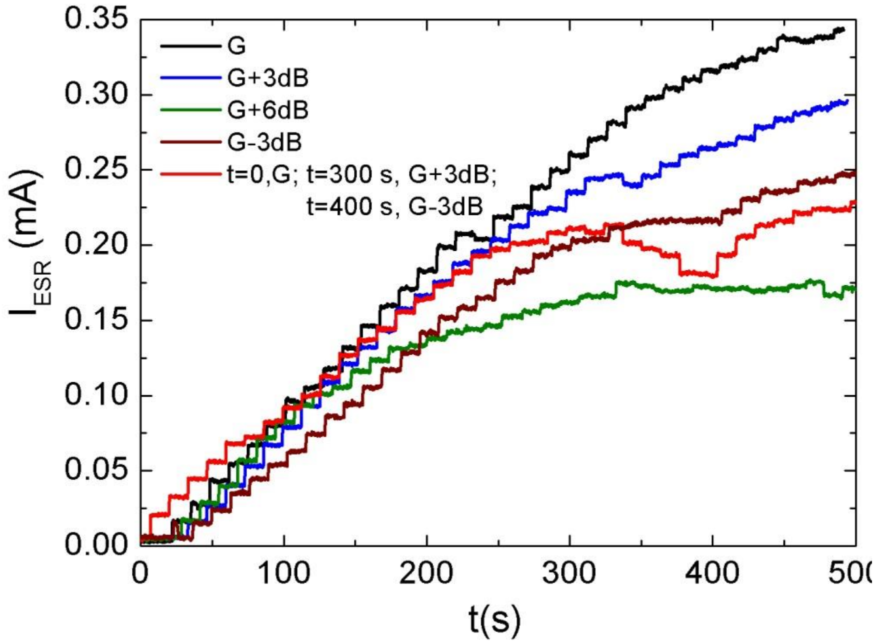
limited by ESR hardware (no dedicated barrier bucket rf system)

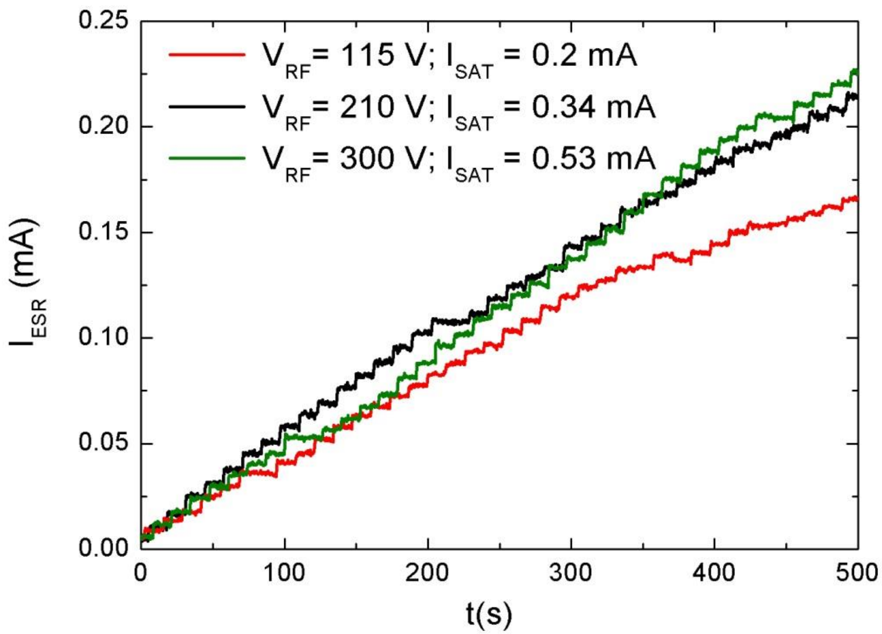
PoP-Experiment ESR

Stacking by combination of rf and stochastic cooling

with good efficiency and reliability

Ar^{18+} 400 MeV/u





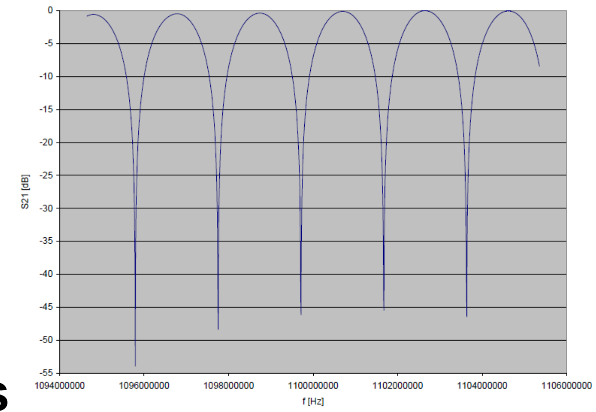
rf h=1 stacking on unstable fixed point | **stacking with fixed barriers**

stacking with moving barriers unsuccessful due to limited rf amplitude

Test of Notch Filter Cooling at the ESR

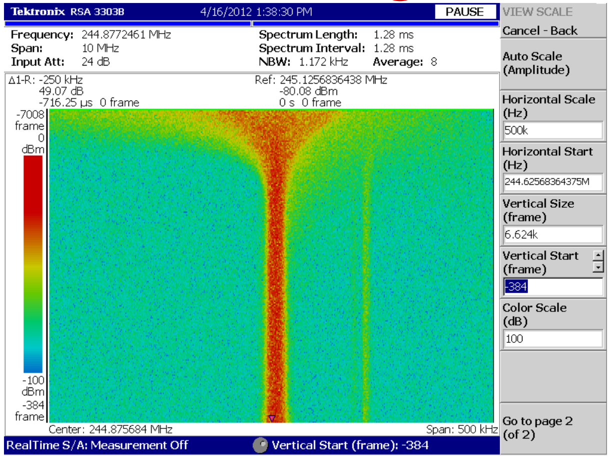
Optical delay line installed in the ESR for tests of TOF and notch filter cooling

using existing electrodes designed for Palmer cooling

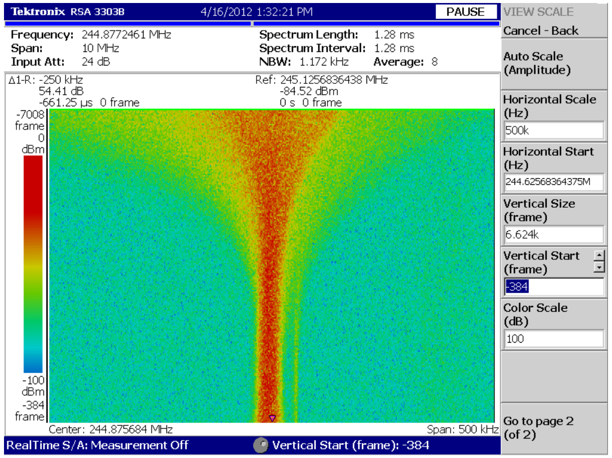


poster by W. Maier

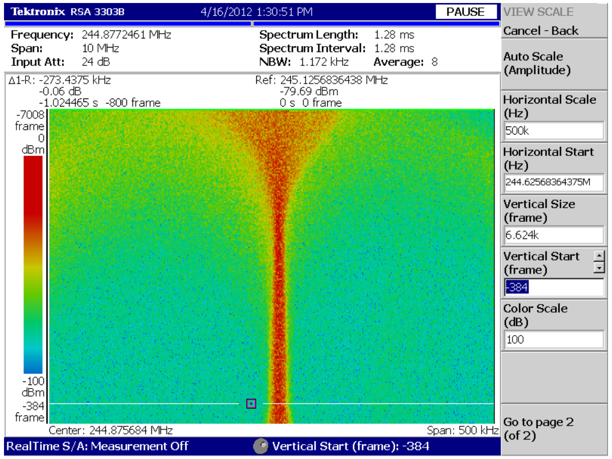
Palmer cooling



Time-of-Flight cooling

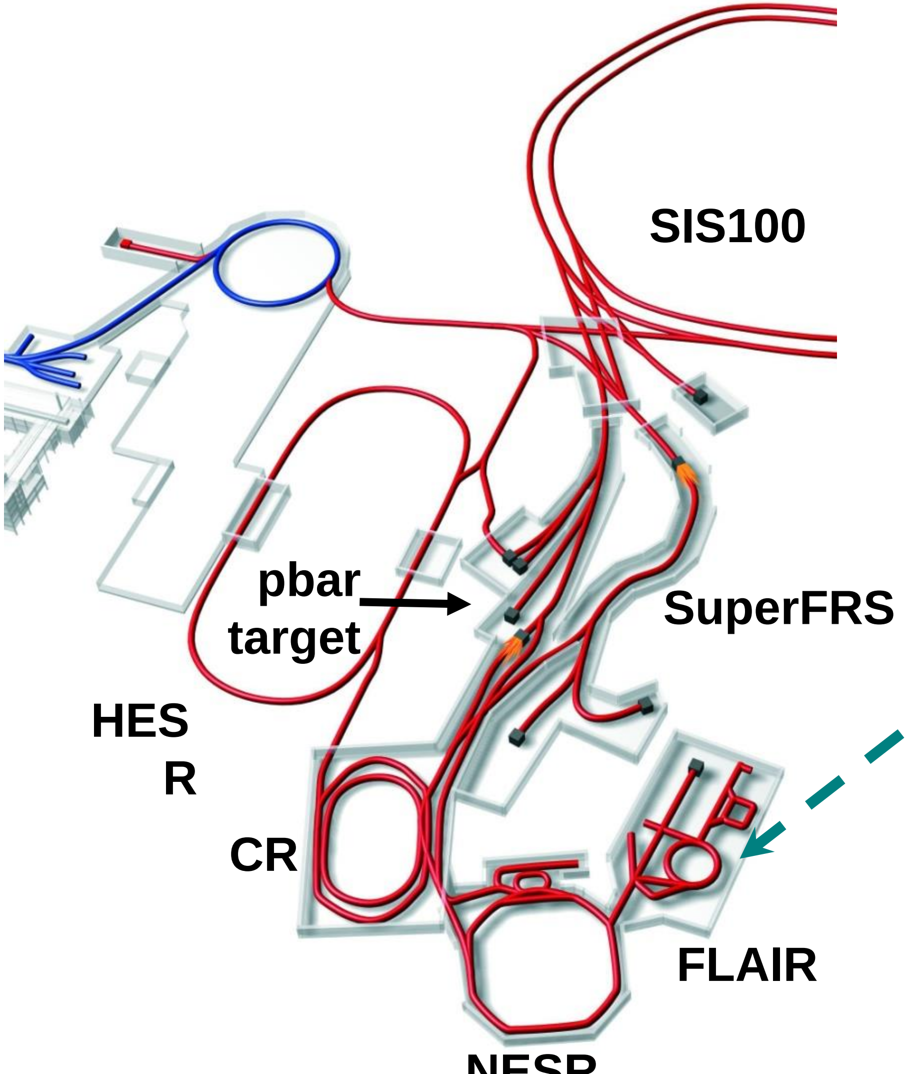


Notch filter cooling



Ar^{18+} 400 MeV/u

CRYRING as Low Energy Storage Ring



Stockholm University

FLAIR

offered as a Swedish in-kind contribution to FAIR of value 2 M€

C = 51.6 m

$B\rho_{max}$ = 1.44 Tm

dB_{dip}/dt = 7 T/s

goal:

provide decelerated (secondary) beams

1) antiprotons of 300 keV – 30 MeV

2) highly charged ions and RIBS energies 40 keV/u – 4 MeV/u

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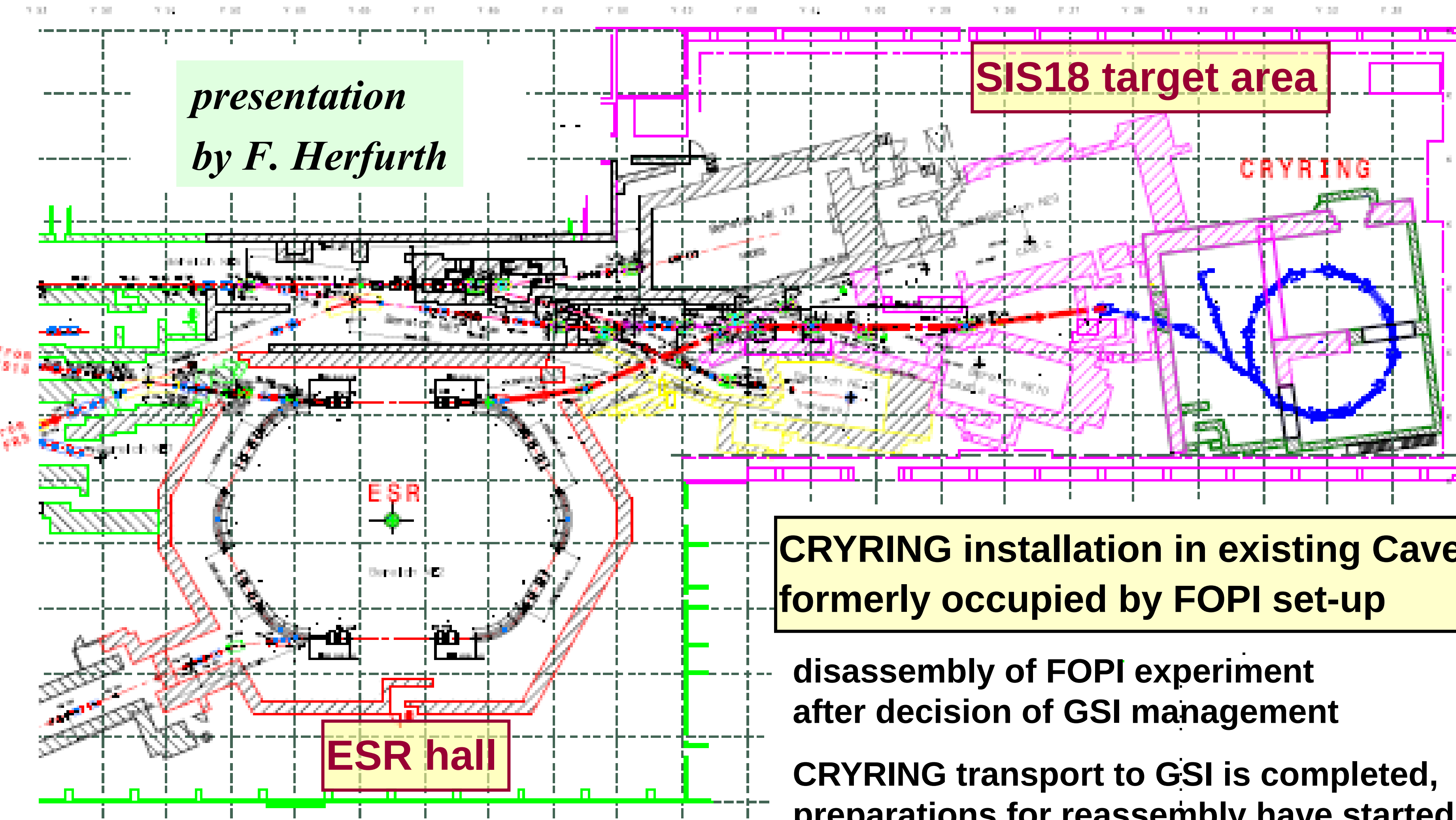
CRYRING@ESR



CRYRING installation in existing Cave B formerly occupied by FOPI set-up

disassembly of FOPI experiment after decision of GSI management

CRYRING transport to GSI is completed, preparations for reassembly have started

CRYRING Moving to GSI

departing from Stockholm

arriving at GSI

disassembly of FOPI detector

magnet straight section at GSI

CRYRING dipoles at GSI

plan: reconstruction of cave in 3rd quarter

start of CRYRING reassembly still in 2013

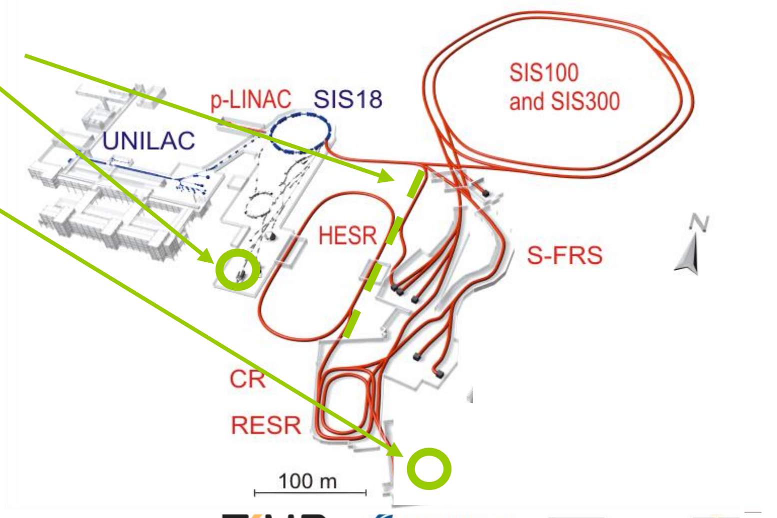
Future Use of CRYRING@ESR

Stand alone operation with beam injected from ion source + RFQ
test bed for accelerator developments for FAIR
e.g. diagnostics, new control system, training of operators

Experiments with decelerated ions and RIBS from the ESR
in-ring experiments
slow (fixed target) and fast extraction (traps)

options in future:

- **transfer secondary beams (antiprotons, RIBs from SuperFRS) from CR/RESR to ESR and CRYRING**
- **move CRYRING behind RESR sharing antiprotons with HESR**



Start of FAIR GmbH

Signing of the Convention by 9 countries in Castle Biebrich, Wiesbaden

4 October 2010

FAIR GmbH Shareholders

Germany (October 2010)
GSI Helmholzzentrum für Schwerionforschung GmbH, Darmstadt

Russia (October 2010)
State Atomic Energy Corporation ROSATOM, Moscow (17,4%)

India (October 2010)
Bose Institute, Kolkata (3,5%)

Sweden and **Finland** (October 2010)
Swedish Research Council, Stockholm (1,5%)

Romania (October 2010)
Romanian National Authority for Scientific research, Bucarest (1,2%)

Slovenia (October 2012)
Ministry of Education, Science, Culture and Sport, Ljubljana

Poland (March 2013)
Jagiellonian University, Krakow (2.33 %)

– Ratification process in **France** continued after election of new parliament

Associate Partner UK (May 2013)
Science and Technologies Facilities Council, London

FAIR after 2020

Preparation of Building Site

handing of building permit by city council

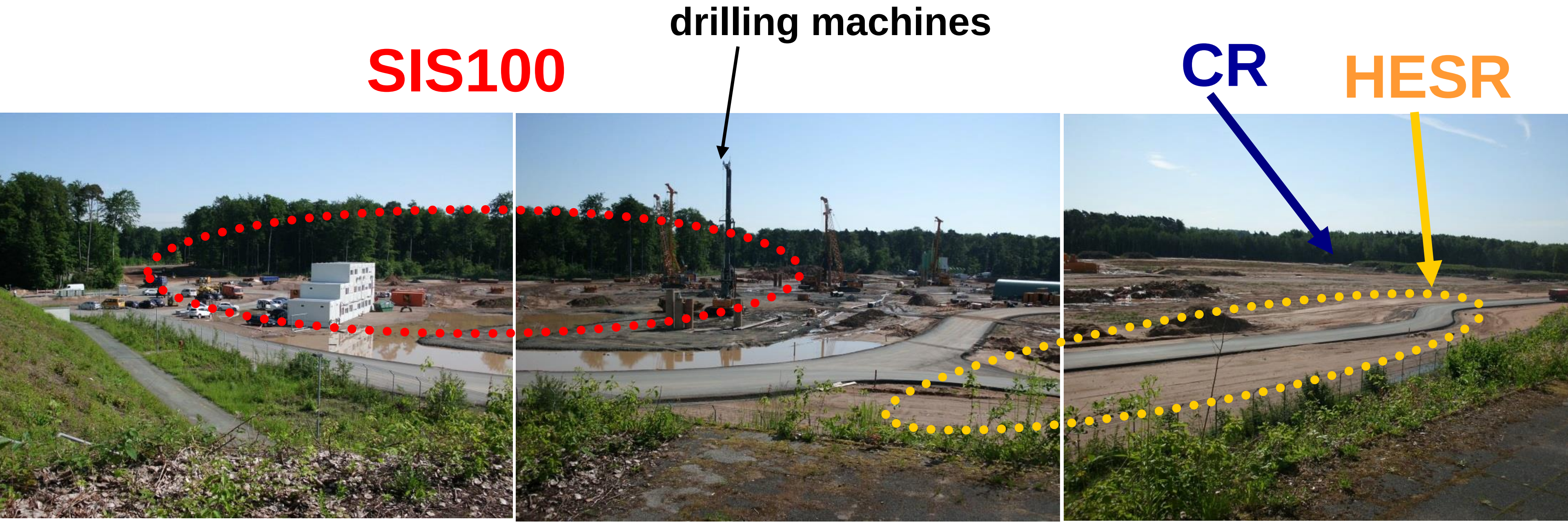
B. Sharkov, H. Stöcker
(FAIR) (GSI)
preparing the ground

new construction road

drilling of holes for pillars

Building Site May 29, 2013

buildings and civil construction are responsibility of the FAIR GmbH



so far no update of the schedule for construction of buildings

original plan to finish buildings in 2017 is compromised

most of 2013 will be needed to complete detailed planning

Procurement of Accelerator Components

contracts so far:

SIS100 dipole modules (BNG, Germany)

HESR dipoles and quadrupoles (SigmaPhi, France)

Beam line magnets and vacuum chambers (Russian consortium)

CR debuncher cavities (RI, Germany)

in preparation:

SIS100 rf systems

SIS100 quadrupole modules (JINR Dubna, Russia)

CR dipole and sextupole magnets incl. vacuum chambers (BINP, Russia)

CR stochastic cooling power amplifiers

SuperFRS dipole magnets

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