The GSI Accelerator Project, Plan and R&D Activities

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GSI Future Project

An International Accelerator Facility for Beams of Ions and Antiprotons

GSI Accelerator Facility

Ion sources

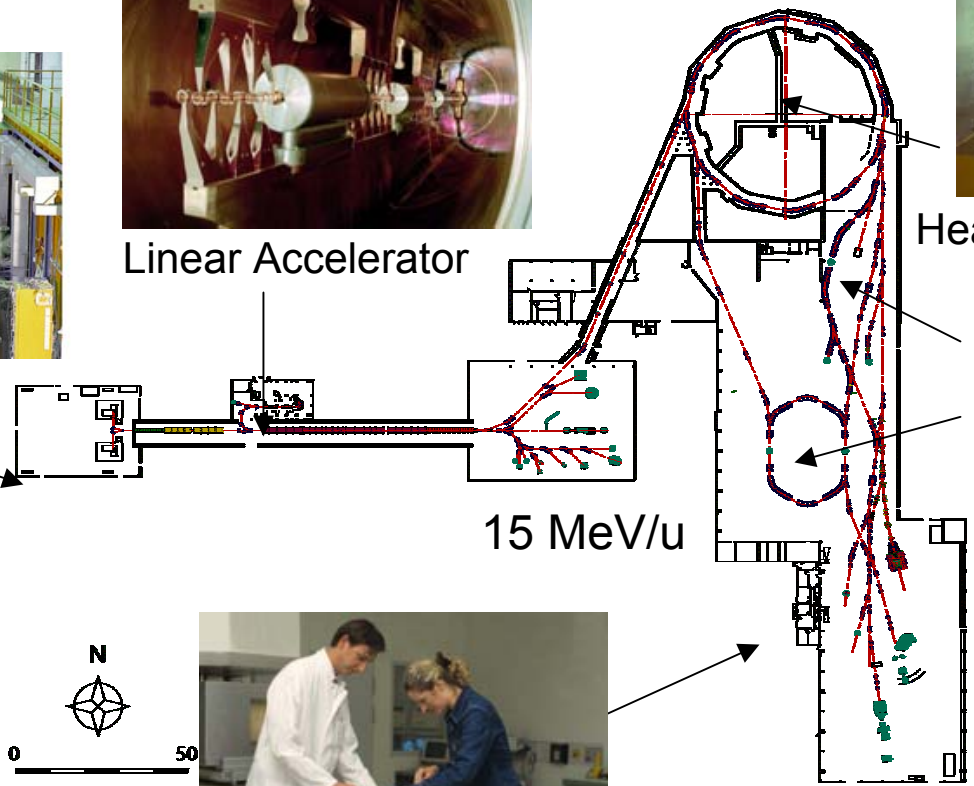
Linear Accelerator

Heavy Ion Synchrotron

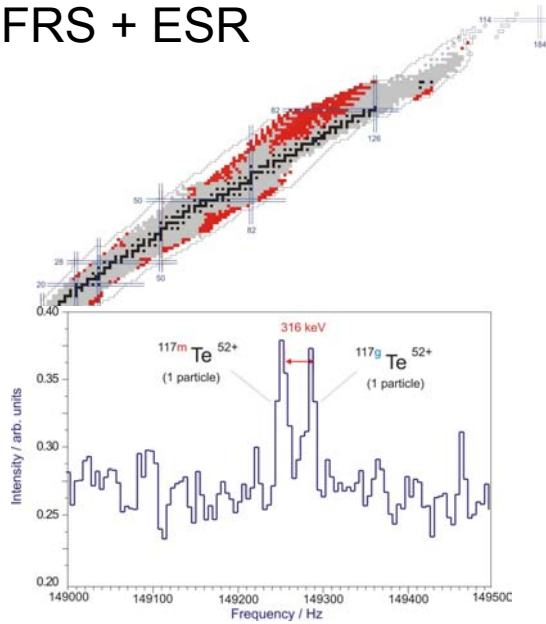
1 -2 GeV/u

FRS + ESR

15 MeV/u



Therapy



The Research Programs and their Requirements on the Proposed New GSI Accelerator Facility

✓Nuclear Structure and Astrophysics

Primary beam: 1.5 GeV/u 10^{12}/s Uranium ions
Pulse structure on the target: 50 ns single pulse (1 Hz) or 'dc'
Secondary beams: Exotic nuclei 0-900 MeV/u

✓Research with Antiprotons

Primary beam: 30 GeV $2x10^{13}$/pp Protons
Pulse structure on target: 50 ns single pulse (0.2 Hz)
Secondary beams: Stored antiprotons 1-15 GeV

✓Nucleus-Nucleus Collisions at High Energy

Primary beam: 20-30 GeV/u 10^{9}/s Uranium ions
Pulse structure on the target: 'dc'

✓Dense Plasma Physics

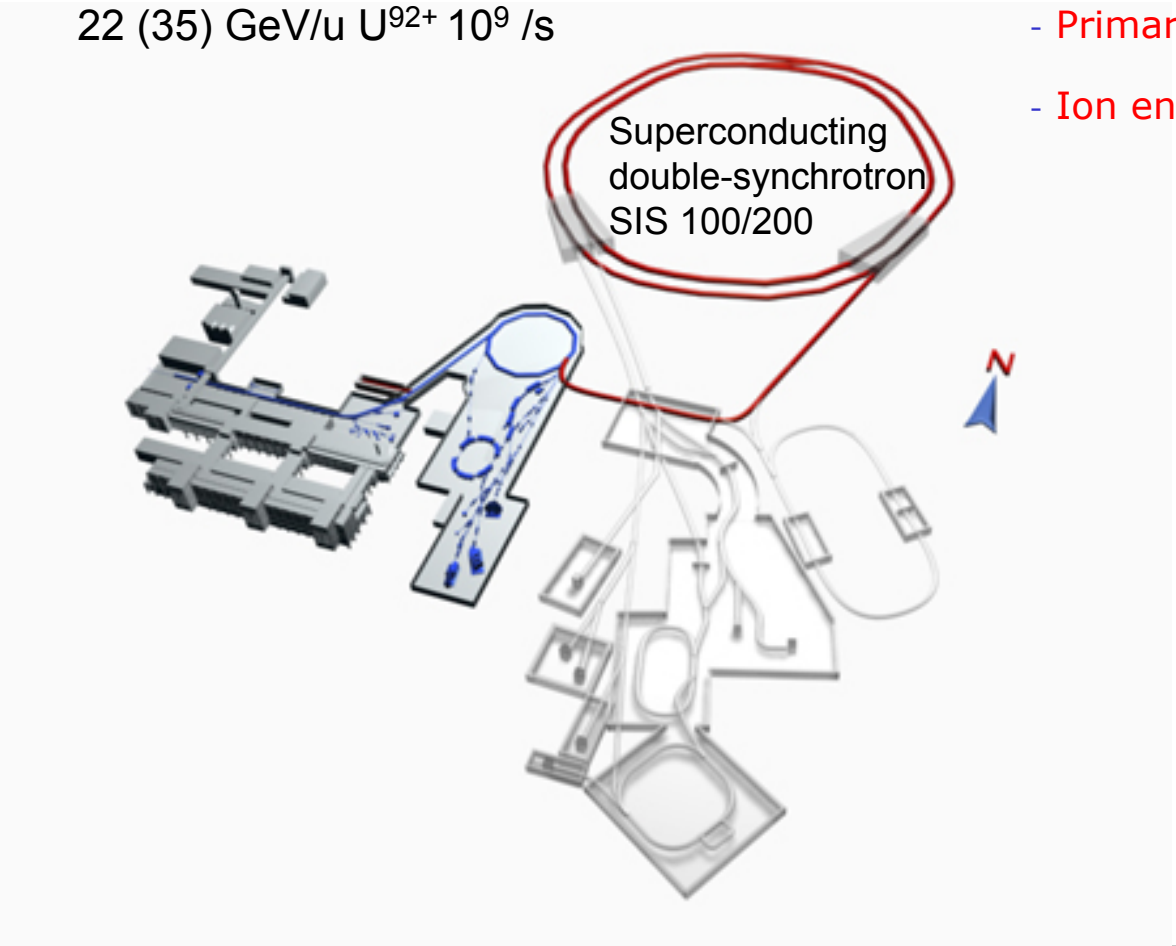
Primary beam: 0.4-1 GeV/u $>10^{12}$/pp Uranium ions
Pulse structure on the target: 50 ns single pulse

Scheme of the New Accelerator Facility

1.5 GeV/u U^{28+} 10^{12} /s

29 GeV p 10^{13} /s

22 (35) GeV/u U^{92+} 10^{9} /s



- Gain compared to the existing facility / new and special beam propoerties:
  - Primary beam intensities: Factor 100 – 1000
  - Ion energy: Factor 15 (25)

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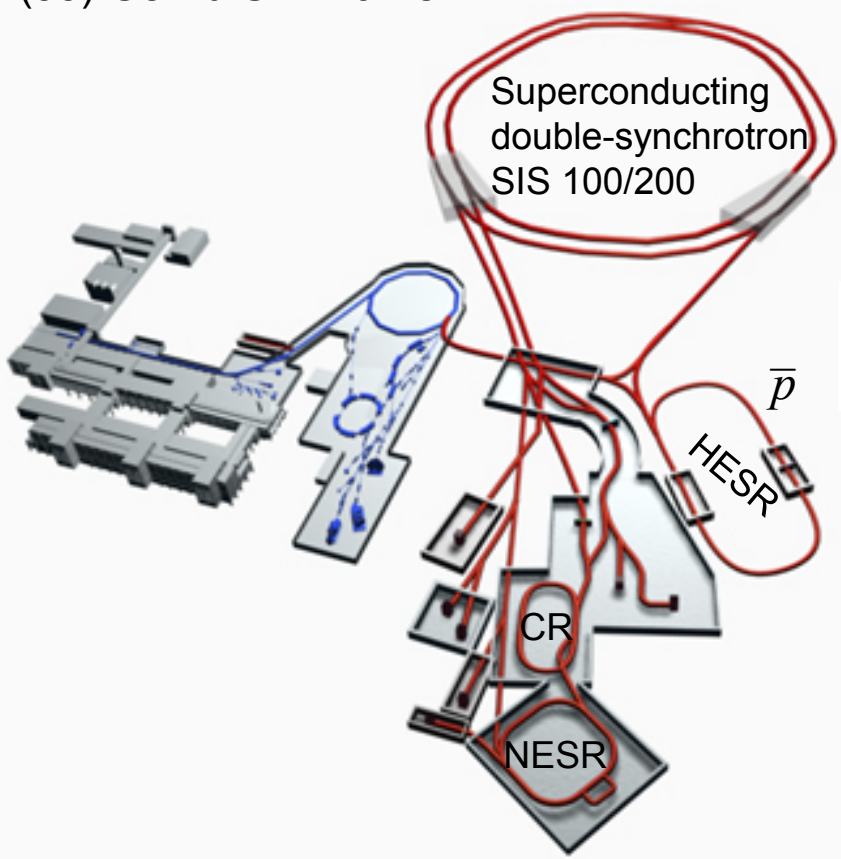
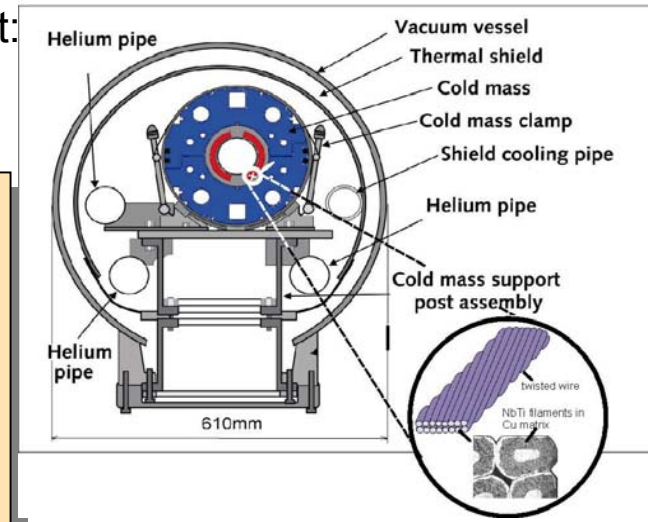
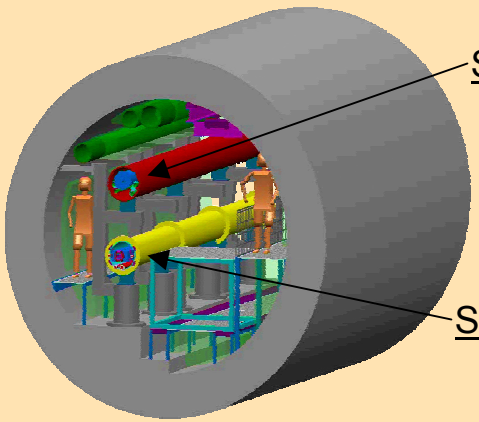


- Gain compared to the existing facility / new and special beam properties:
  - Primary beam intensities: Factor 100 – 1000
  - Ion energy: Factor 15
  - Secondary beam intensities for radioactive ions: up to a factor 10000
  - New: cooled antiproton beams up to 15 GeV
  - Special: intense cooled radioactive ion beams
  - efficient parallel operation of several experiments

The SIS 100/200 Double-Synchrotron

RHIC-type dipole magnet:
B=4T (6T), dB/dt=1T/s



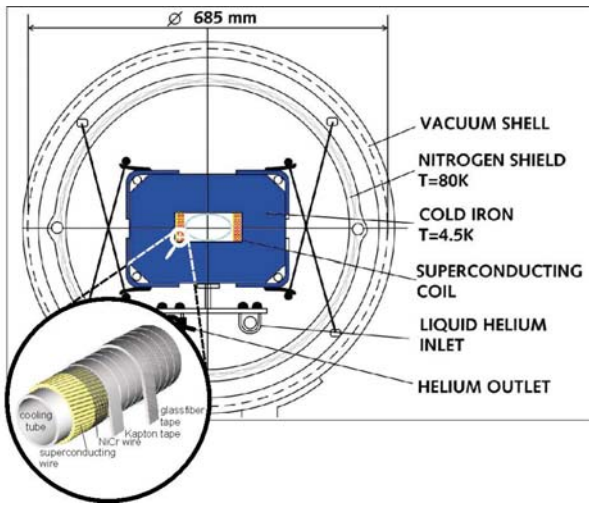


SIS 200: ‚Stretcher' and high energy ring

Two synchrotrons in one tunnel
(Circumference: 5xSIS=1080 m)

SIS 100: Booster and compressor ring

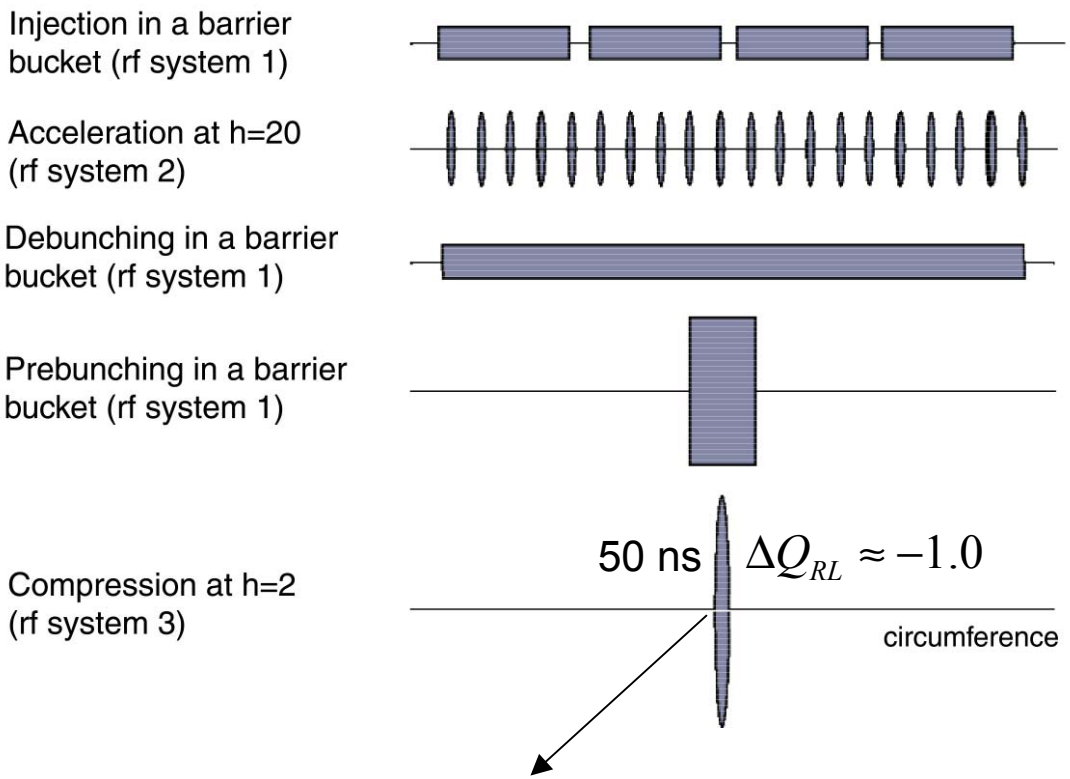
Nuclotron dipole magnet:
B=2T, dB/dt=4T/s



2x120 superconducting (SC) dipole magnets
132+162 SC quadrupole magnets

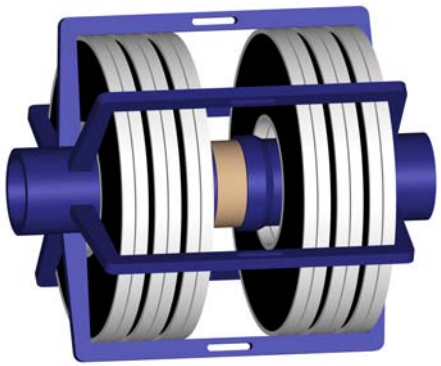
U^{28+} Bunch Compression in SIS 100

RF-Manipulations and Bunch Structure in the SIS100



10^{12} U^{28+} 1 GeV/u 50 ns ⇨ $P_{max} \approx$ 1 TW ⇨

26 compressor cavities (20 m) filled with high-μ cores:



50 kV/m
500 kHz

+ about 20 'normal' acceleration cavities

Beam loss budget:
- Projectile range in steel ≈1 cm

Control of Intense Beams in SIS 100/200

Quenching of SC magnets (SIS 200):

tolerable beam loss in the SC coils: 1‰ !

Structure activation (SIS 100/200):

Hands-on maintenance requires losses < 1 %

SIS 18 (2003/2004) average power:

10^{10}/s 1.0 GeV/u U^{73+}: 0.4 kW

SIS 100/200 average (peak) power:

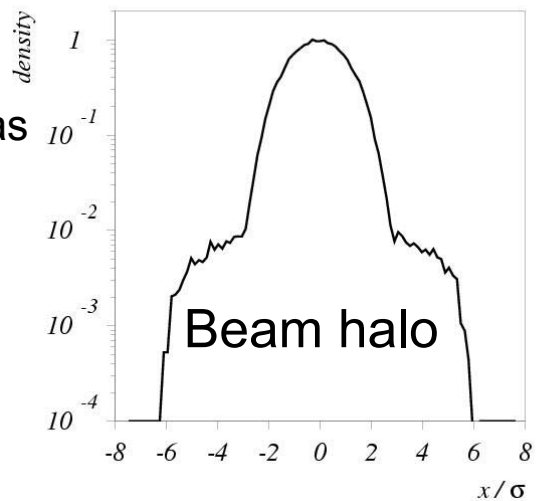
10^{12}/s 2.5 GeV/u U^{28+}: 100 kW (1 TW)

Beam loss due to:

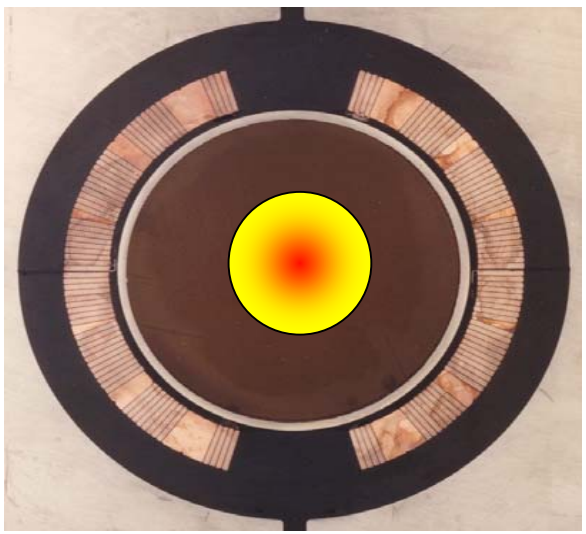
- Resonance crossing
- Dynamic aperture
- U^{28+} stripping in the restgas
- Collective instabilities

Measures:

- Low loss design
- Novel collimators
- X-UHV (10^{-12} mbar)
- Broadband feedback

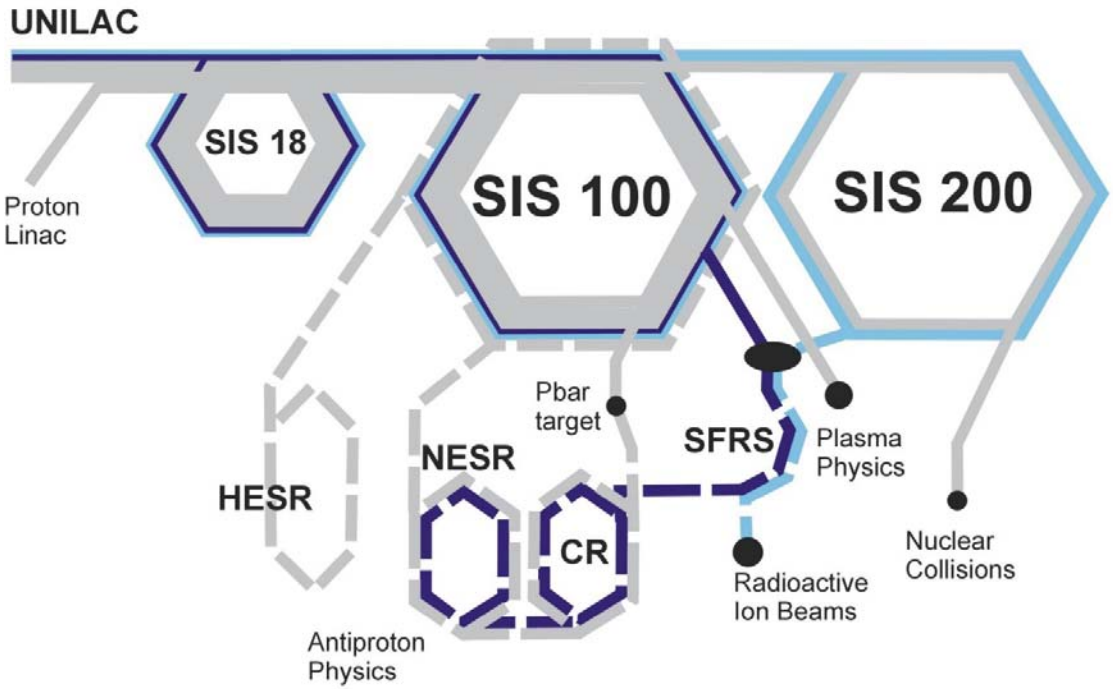


Sketch of beam profile in SIS 200 dipole:



Long-time simulation (10000 turns) on parallel computers !

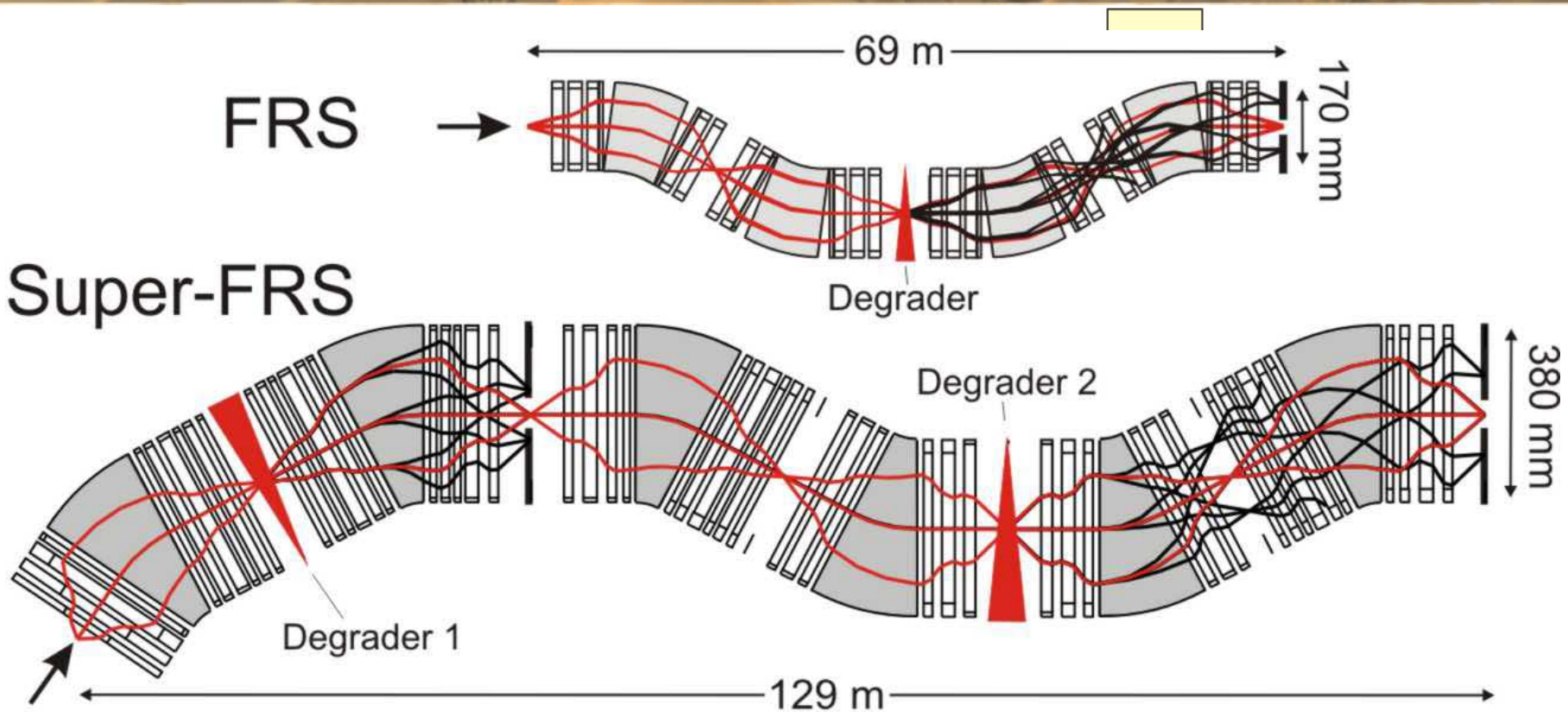
Rare Isotope Beams



For storage ring experiments
10^{12} ions, 50 ns pulse/s

For fixed target experiments
10^{12} ions/s
Duty factor near 100%

Super-FRS a Large-Acceptance High-Resolution Spectrometer for Exotic Nuclei

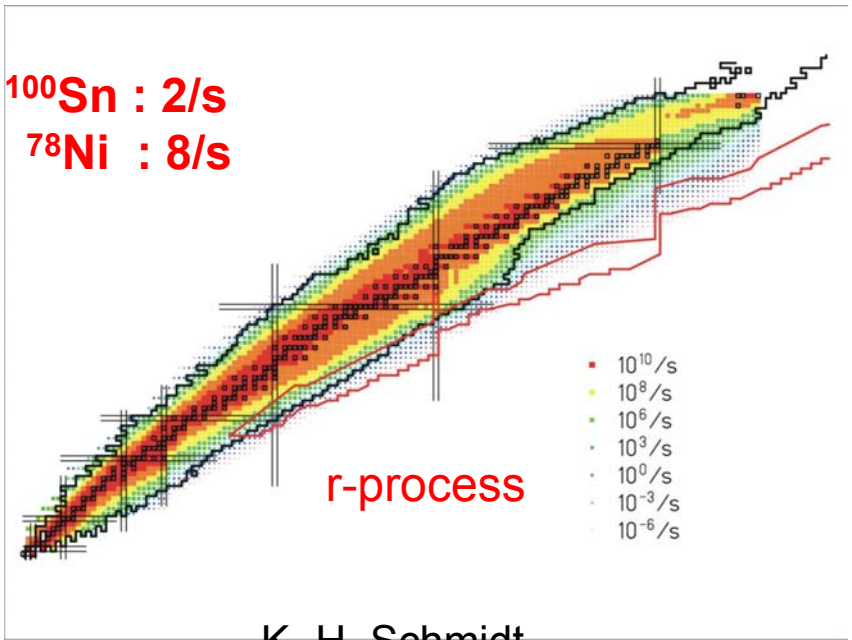


- The gain factor for projectile fission fragments is more than 10.
- The two-stage degrader separation provides pure isotopic beams.
- Overall gain up to 10000.

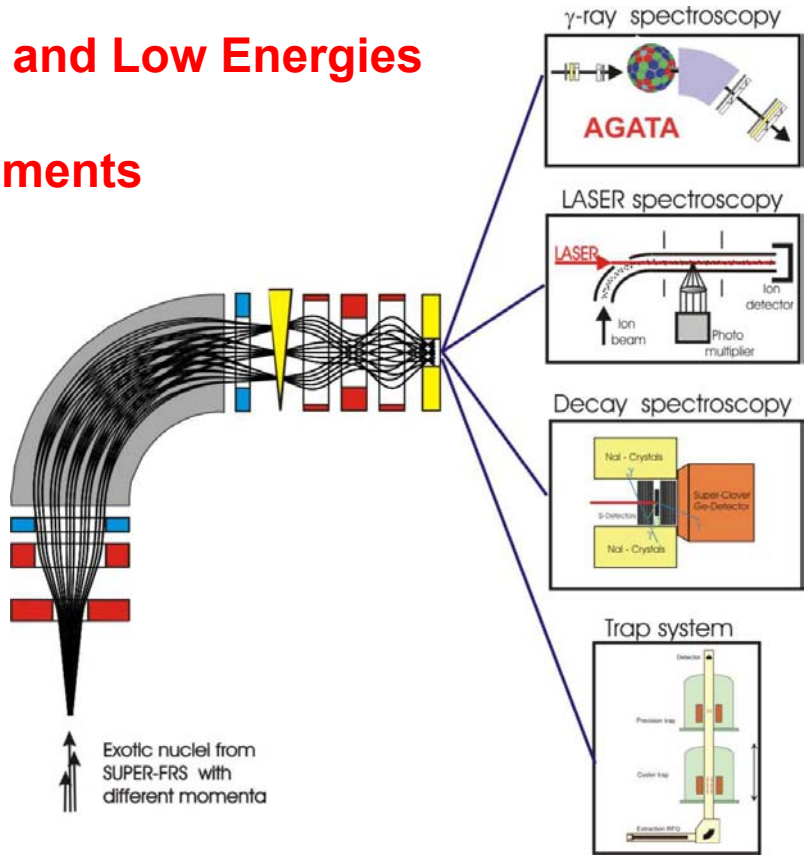
H. Geissel et al. NIM B 204 (2003) 71

Super-FRS a Tool for Studies in Nuclear Structure and Astrophysics

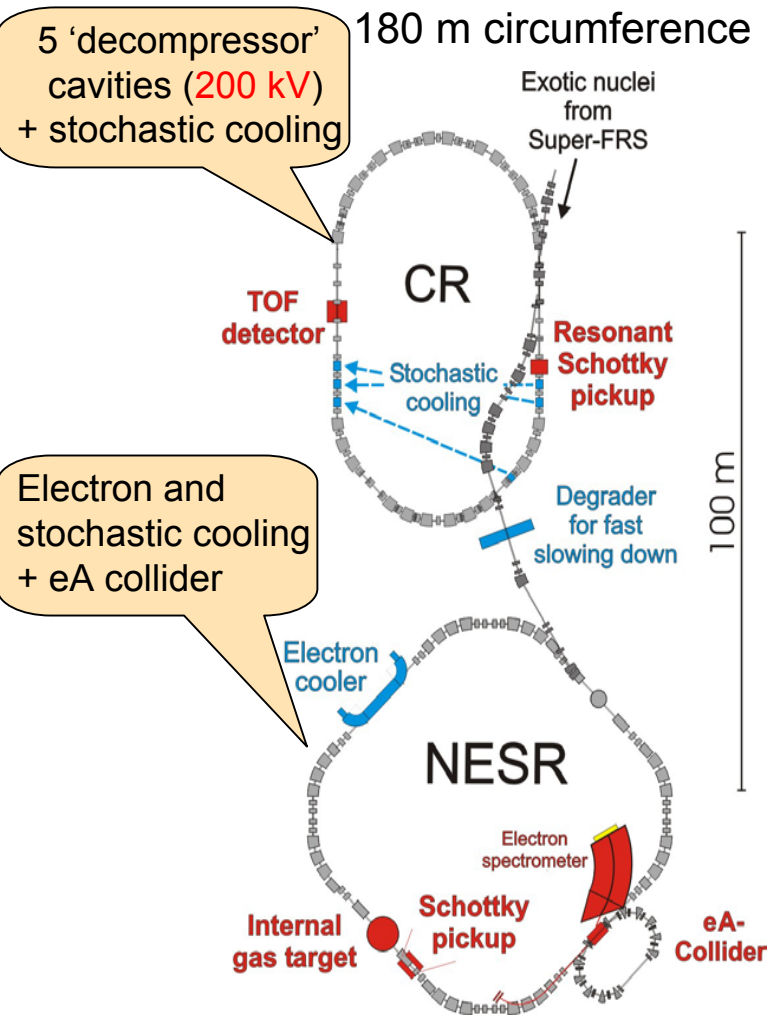
- Access to Exotic Nuclei at the Paths of the Nuceosynthesis in Stars
- New Spectroscopy Experiments at High and Low Energies
- Precision Experiments with Stored Fragments



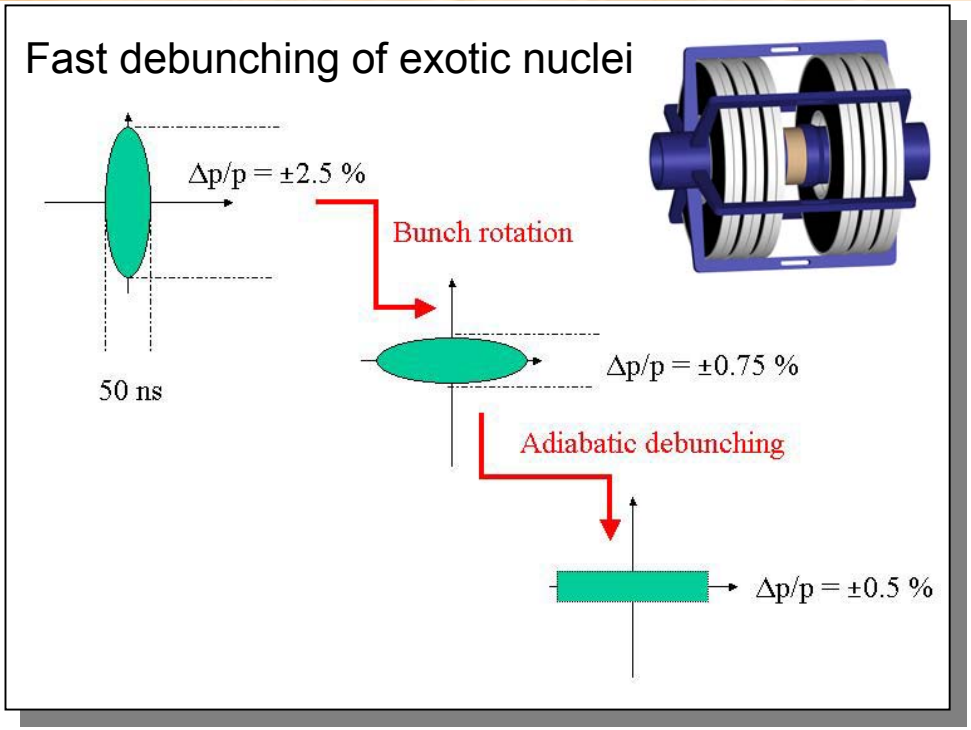
K.-H. Schmidt



Collector and Accumulator Rings for Exotic Ions

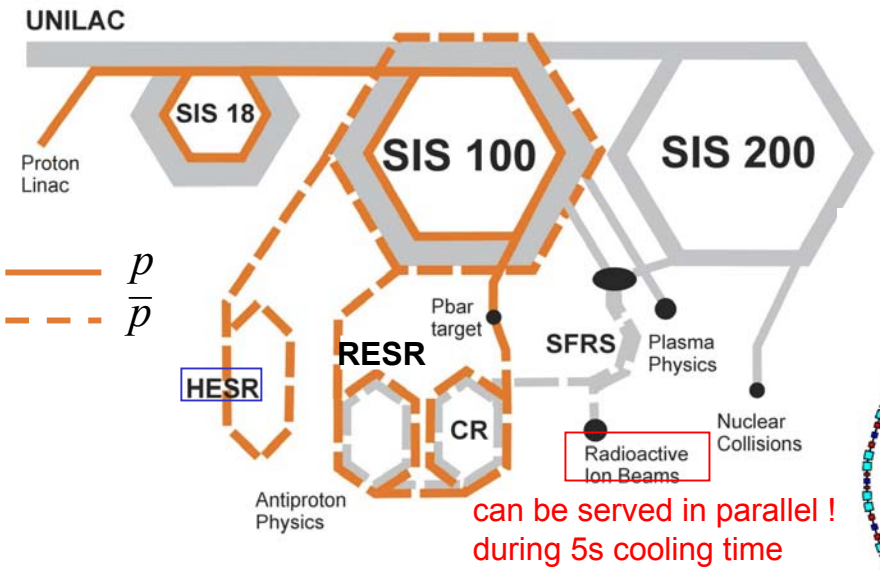


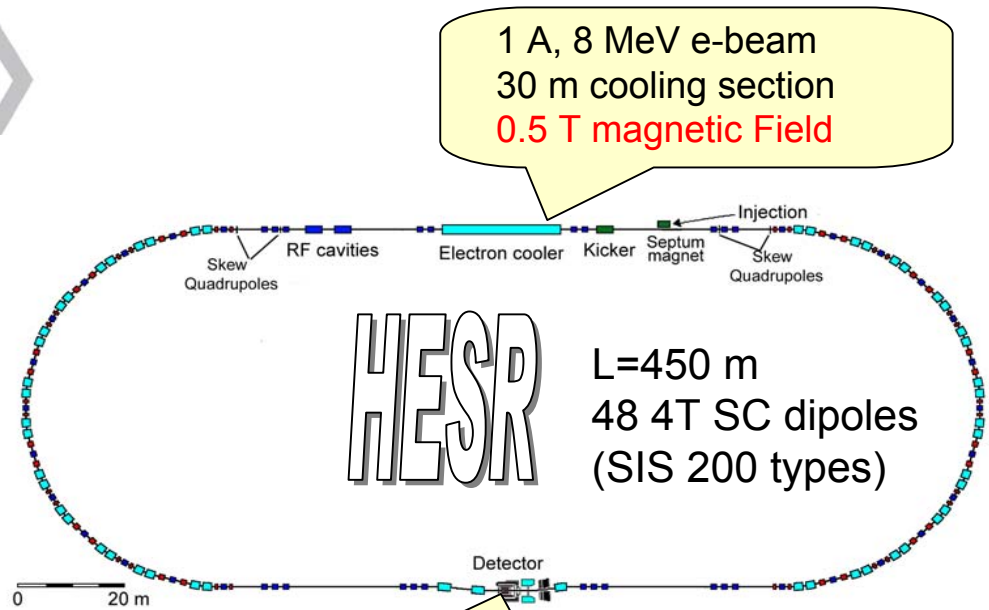
210 m circumference (approx. 2xESR)



CR+NESR: 2x24 large aperture (±180 mm) superferric (1.6 T) dipole magnets

Antiproton Generation, Accumulation and Storage



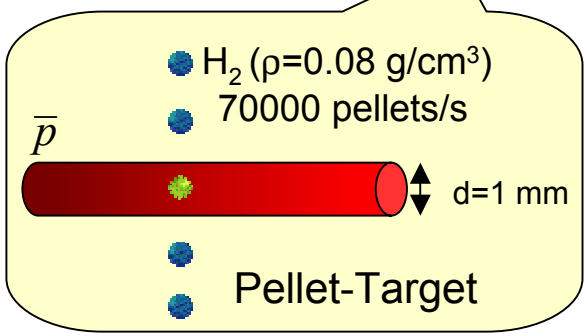


1-15 GeV $\bar{p}$

$N_{max}=10^{11}$

$L=2\times10^{32}\ cm^{-2}s^{-1}$

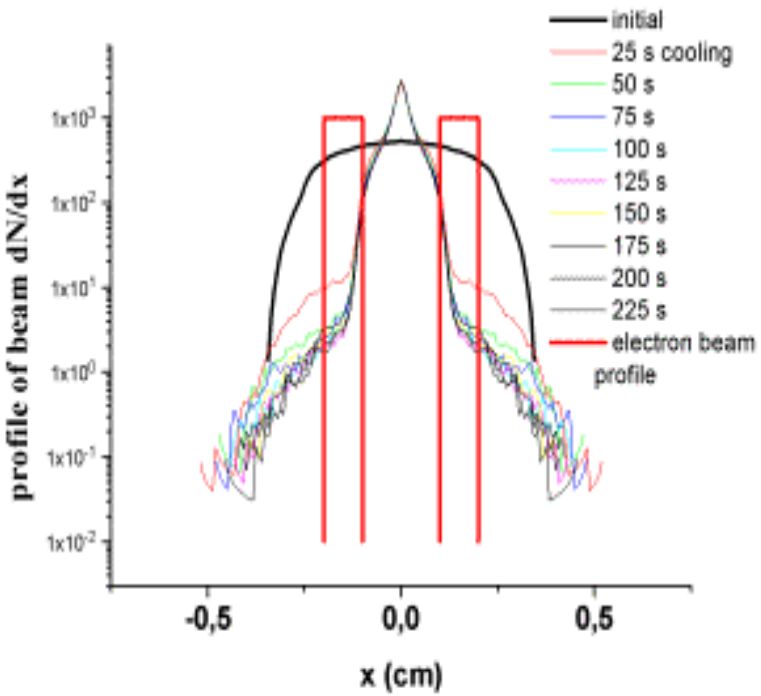
$\Delta E=100$ keV ($\Delta p/p=10^{-5}$)

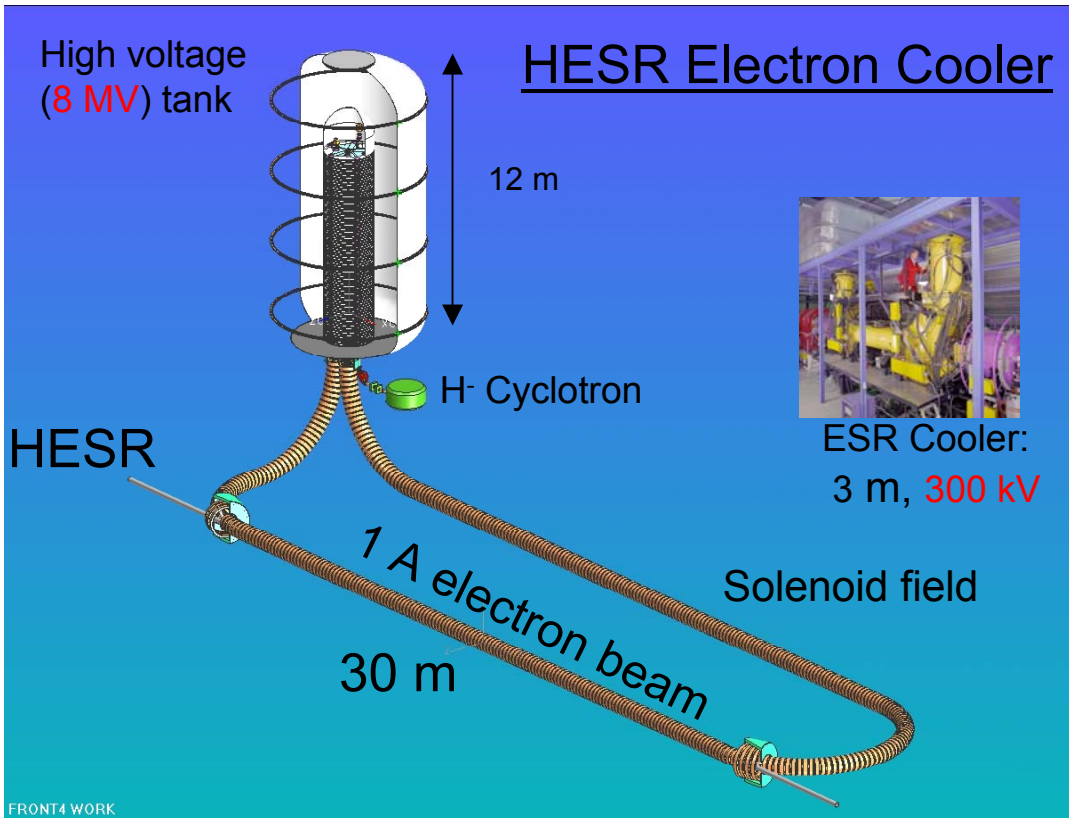


Control of Antiproton Beam Quality at High Energies

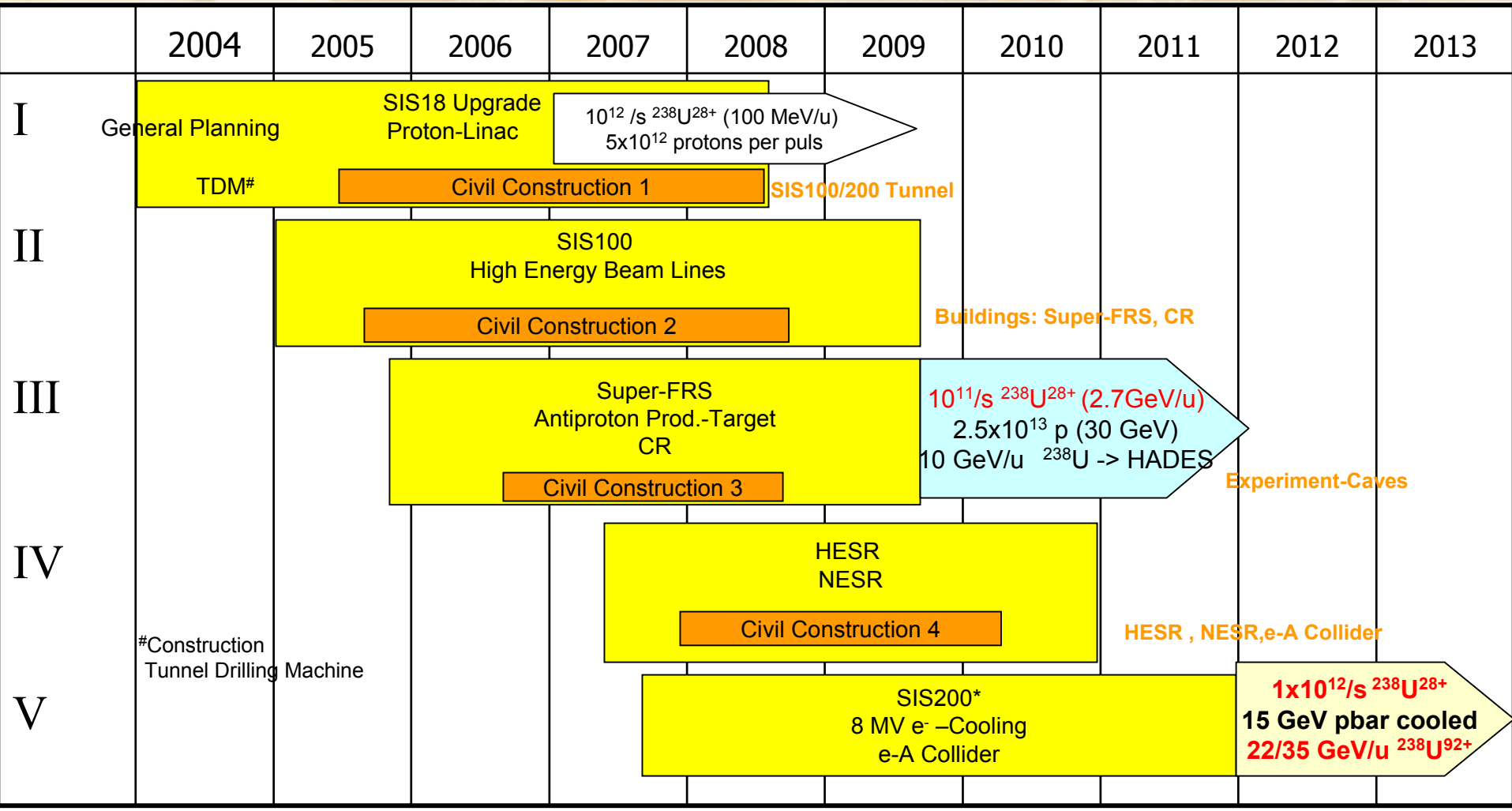
Feasibility study of fast electron cooling for the HESR, Budker Institute, Novosibirsk, RUS

Monte-Carlo-Simulation of pbar cooling:



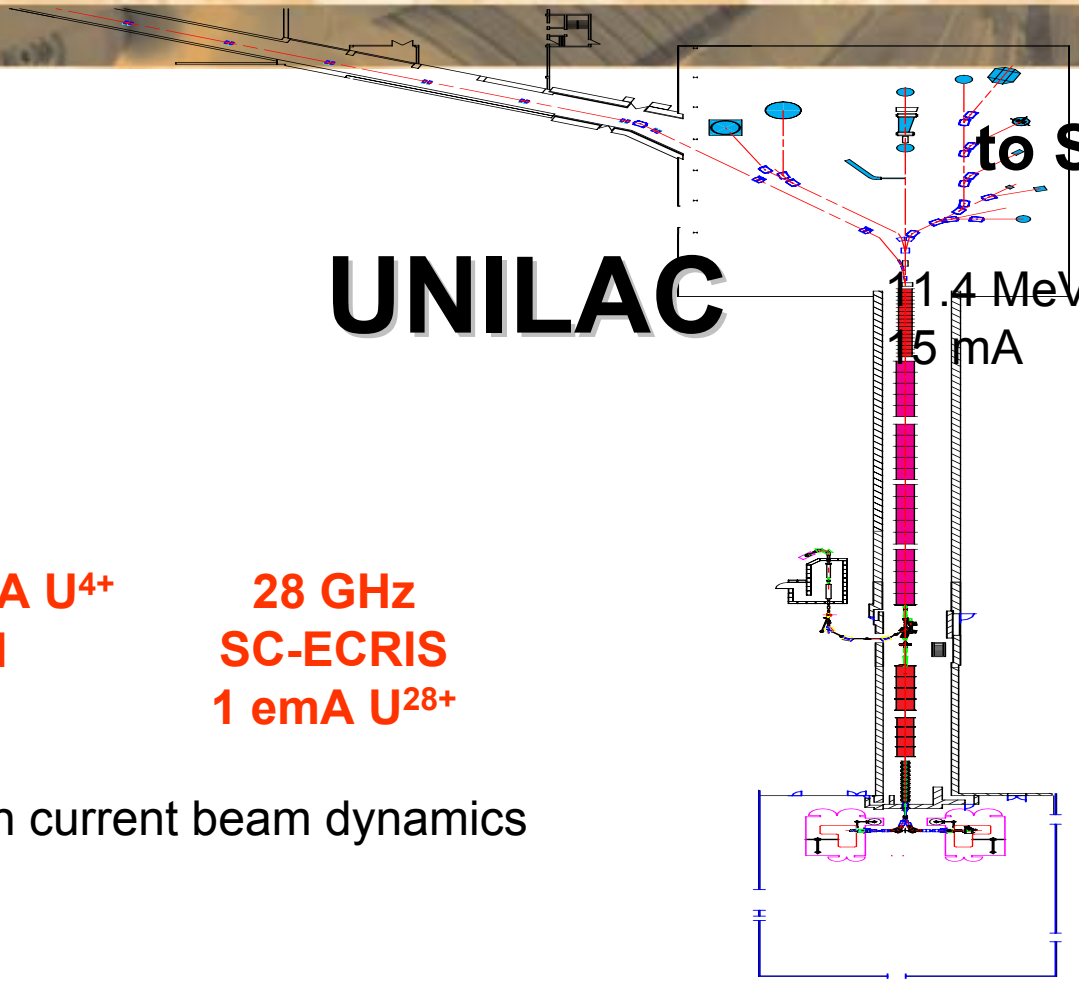


Project plan



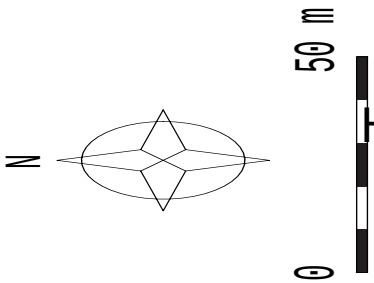
*SIS200 installation during SIS100 shut down

Linac R&D



MEVVA: 30 emA U^{4+}
0.3 π mm mrad

28 GHz
SC-ECRIS
1 emA U^{28+}



High current beam dynamics

2.2 keV/u

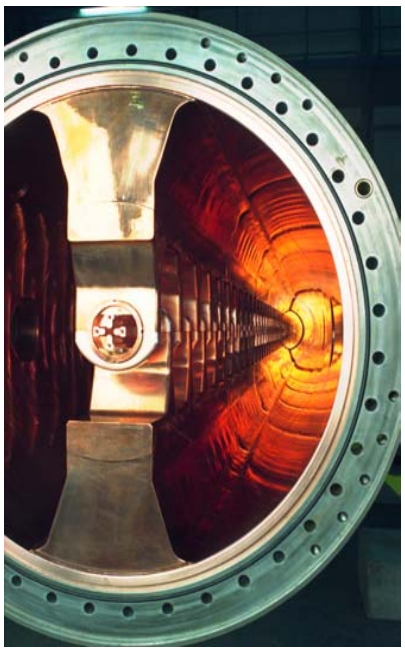
1.4 MeV/u

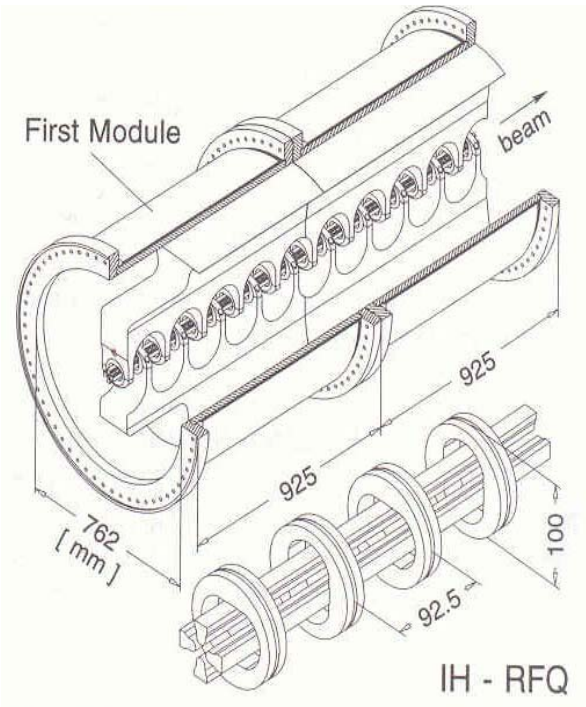
13 MeV/u

Linac R&D

Radio Frequency Quadrupole (RFQ), 36 MHz

2.2 keV/u – 130 keV/u , A/q = 65





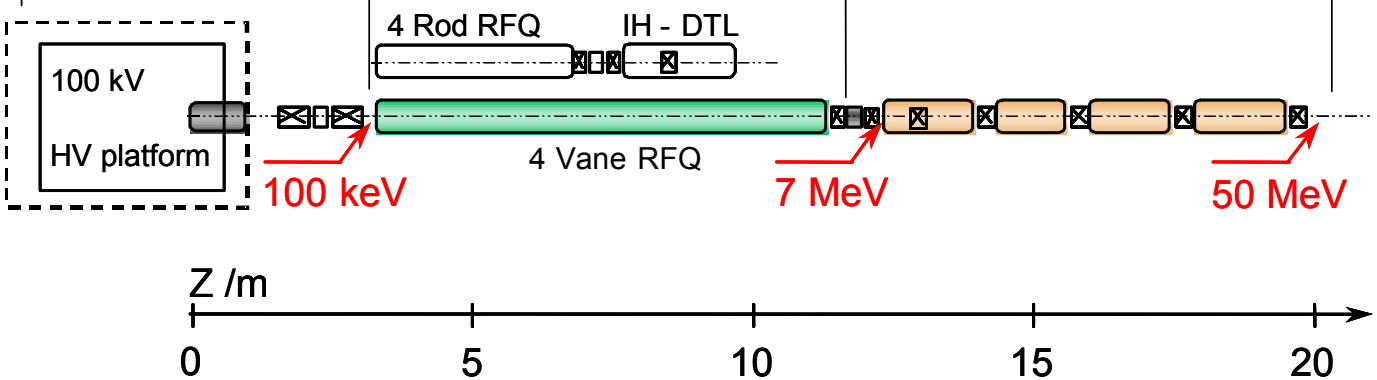
electrode voltage / kV at A/q = 65	137
min. aperture diameter / mm	7.6
min. van-vane distance / mm	4.9
ρ/R_0	0.85
needed duty factors:	
for beams with A/q ≤ 65	1 %, 10 Hz
for beams with A/q ≤ 24	30 %, 50 Hz
distribution of heat losses / %:	
mini-vanes	4
stems with carrier rings	24
ridges	24
tank wall	48

50 MeV, 50 mA Proton Linac,Univ.Frankfurt

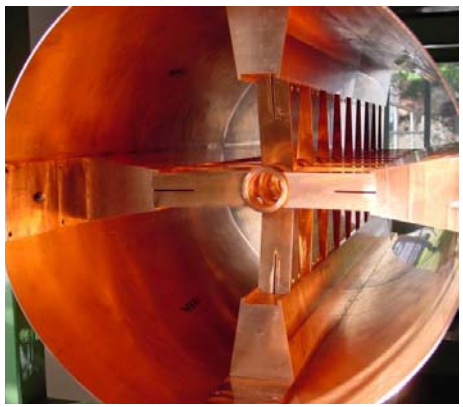
Ion source
(Arc Discharge Volume Source or ECR ; H^+ or H^-)
and **LEBT**

RFQ
433 MHz, 4 Vane
(216.5 MHz, 4 Rod & 216.5 MHz IH-DTL)

DTL
433 MHz, CH



Beam energy	
Injection to RFQ	100 keV
At linac exit	50 MeV
Rf acceleration	
Accelerating structure	RFQ and DTL (H210 mode)
Operating frequency	433 MHz
Rf-pulse length	1 ms
Rf-pulse frequency	5 Hz
Accelerator length	20 m
Beam parameters	
Max. pulse current	50 mA
Useful pulse length	0.1 ms
Transverse beam Emittances	≤5 π mm mrad (50 MeV)
Beam momentum spread	$\leq 1\times10^{-3}$ (50 MeV)



CH-structure

Collaboration Network for Superconducting Magnets

Collaboration Network

SIS 200: cosθ magnet

BNL (US) 1/2001
Twente University (NL)
Jena University (D)
IHEP (RU) 6/2002

SIS 100: window-frame magnet

JINR (RU) 2/2000
LBNL (US)
Bochvar Institute (RU)
BINP (RU) 6/2002

Large Aperture Magnets (Storage Rings, SFRS, R3B)

NSCL/MSU (US) 1/2002
CEA (F)

Scientific Coordination
Magnet and Cryogenic Design
Magnet Test Facility
GSI

Magnet Design Software

CERN (CH)
TU Darmstadt (D)

Consulting

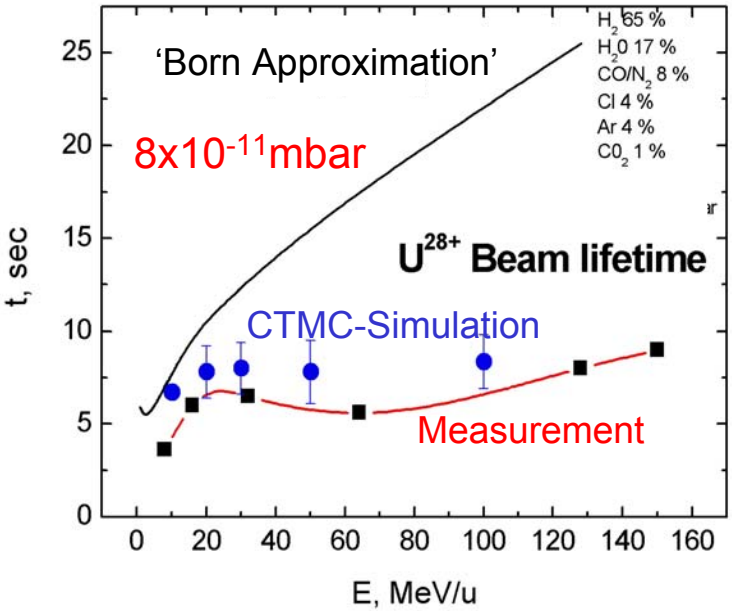
CERN (CH) 8/2002
FZ Karlsruhe (D)
DESY (D)
M.N. Wilson (GB)
B. Hassenzahl (US)

Cryogenics

TU Dresden (D)
ACT Inc. (US)

Control of Extreme-UHV in SIS 100/200
Ion Induced Gas Desorption

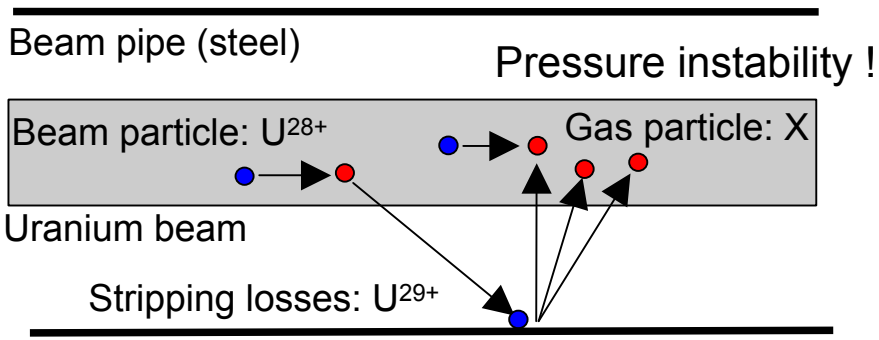
U^{28+} Beam lifetime measurements in SIS:



U^{28+} operation with 1 % stripping loss means:

10 s lifetime in SIS (4 Hz)
or $P=5\times10^{-11}$ mbar

100 s lifetime in SIS 100/200 (T= 1 s)
or $P=5\times10^{-12}$ mbar



Desorption coefficient: $\eta \approx 10^4$!!!

Control of dynamic Vacuum !

Desorption Measurement: warm & cold surfaces

Summary R&D I

- High current beam formation
- Superconducting 28 GHz ECR
- RFQ (high current) A/q = 65
- Heavy ion induced desorption
- Collimation concepts
- Fast ramped superconducting magnets

Summary R&D II

- Superconducting magnets in high radiation areas
- RF-systems for acceleration and beam manipulation
- Targets for high intensity beams
- Fast stochastic cooling for ions and antiprotons
- Medium energy electron cooling for 15 GeV antiprotons
- Large scale beam dynamics simulations
  (high current/density, long storage time)