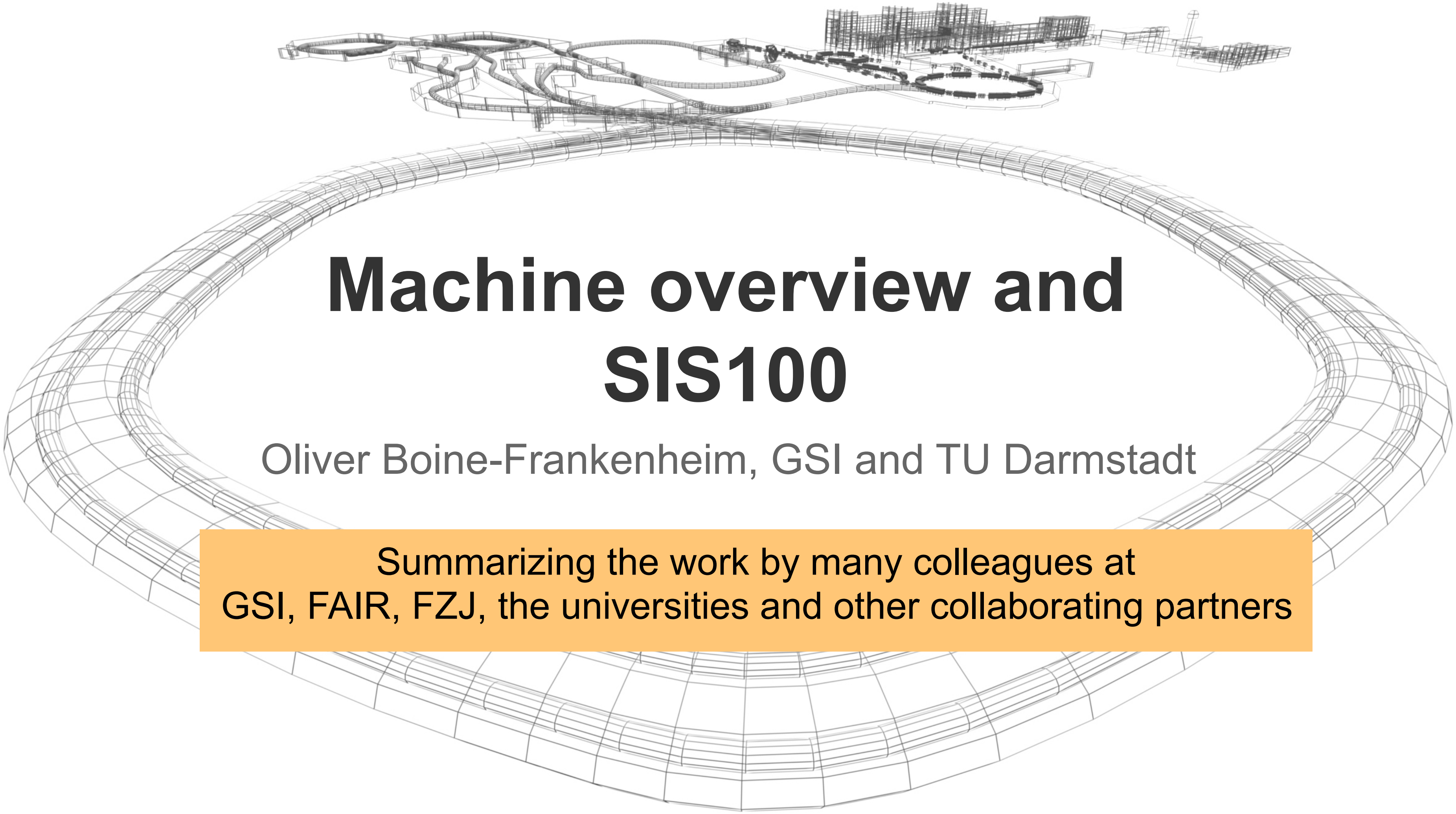
GSI Helmholtzzentrum für Schwerionenforschung GmbH

Machine overview and SIS100

Oliver Boine-Frankenheim, GSI and TU Darmstadt



Summarizing the work by many colleagues at
GSI, FAIR, FZJ, the universities and other collaborating partners

Contents

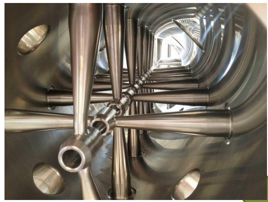
- **The injectors:** UNILAC, p-linac and SIS18
- **The FAIR workhorse:** SIS100
- **Secondary beams:** CR and HESR
- Beam intensity goals and present status
- Technical status (examples)

(Only the FAIR **modularized start version** will be covered)

Other FAIR accelerator presentations during the conference:
H. Simon (today) -> Secondary beams
R. Hollinger (Wednesday) -> Ion sources
W. Barth (Wednesday) -> UNILAC and p-Linac
S. Yaramyshev (Wednesday) -> RFQs
D. Winters (Wednesday) -> SIS100 laser cooling
P. Schnizer (Friday) -> superconducting magnets
K. Knie (Friday) -> production targets

FAIR injectors: UNILAC, p-Linac and SIS18

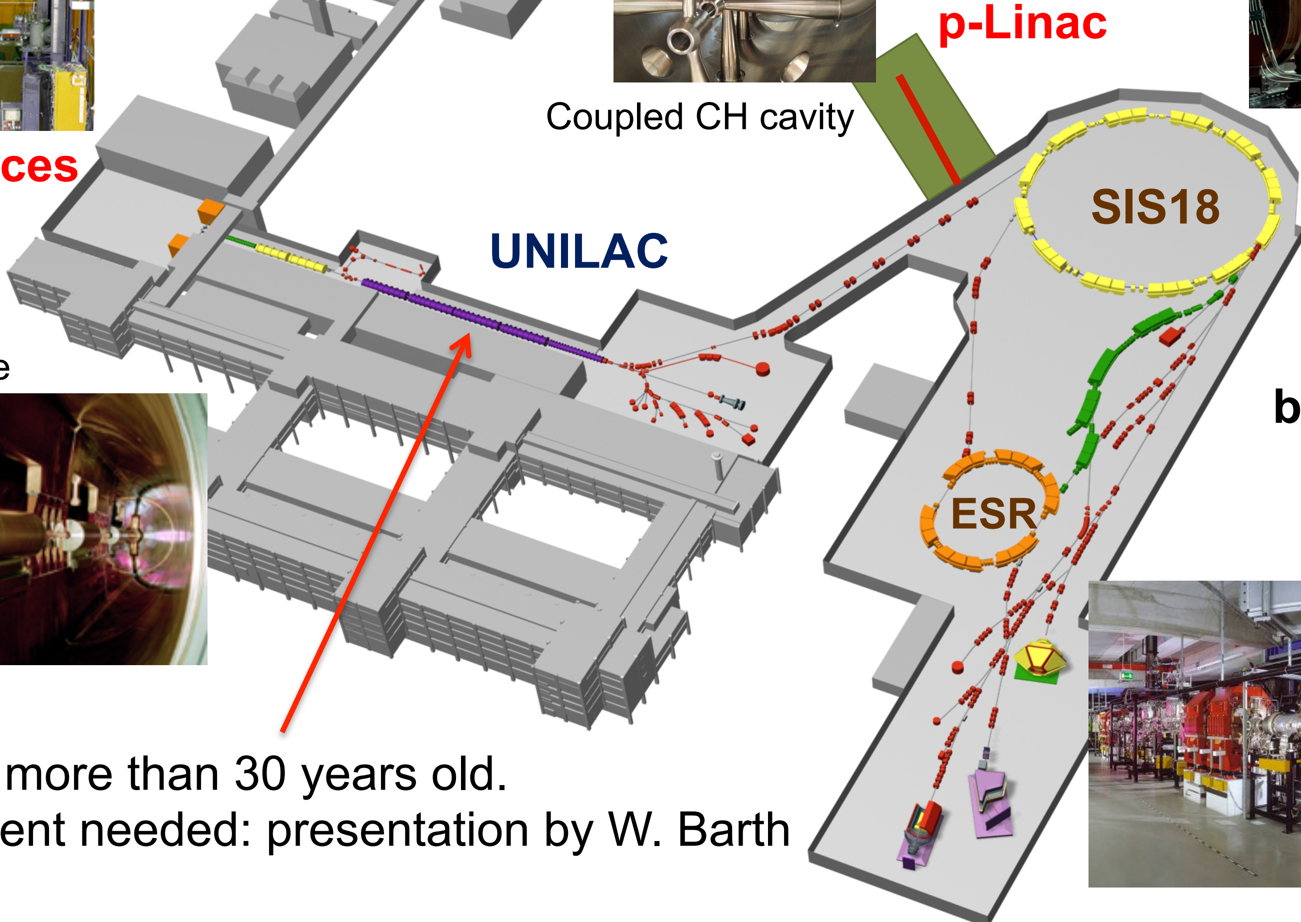
Ion sources



Coupled CH cavity

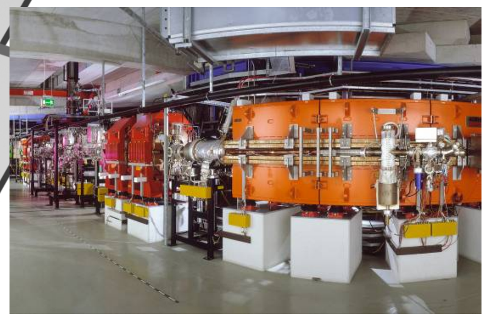
p-Linac

SIS-18 upgrade for FAIR



beams to SIS100

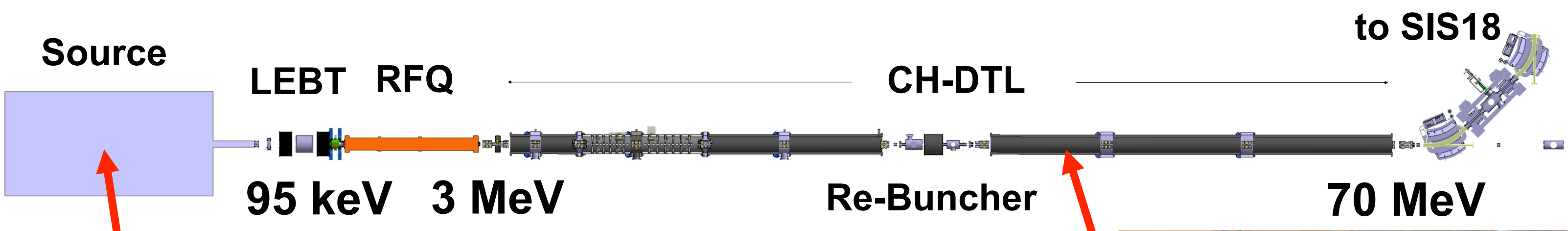
IH structure

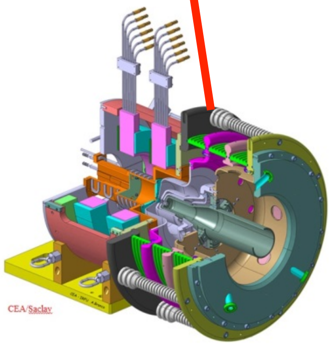


Alvarez is more than 30 years old.
Replacement needed: presentation by W. Barth

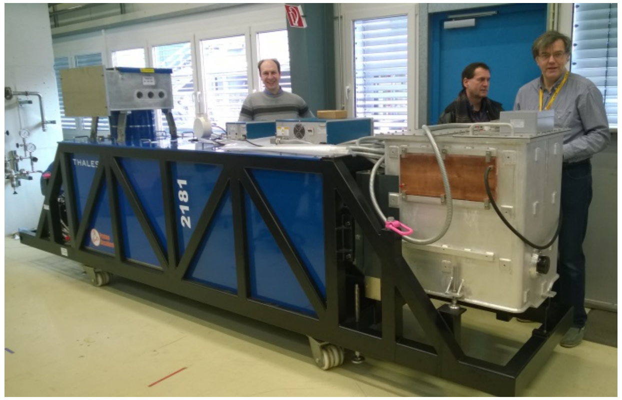
UNILAC: world's highest beam power (MW) machine for heavy-ions !
SIS18: world's highest number of heavy-ions per cycle (> 10^{10}) !

p-Linac overview



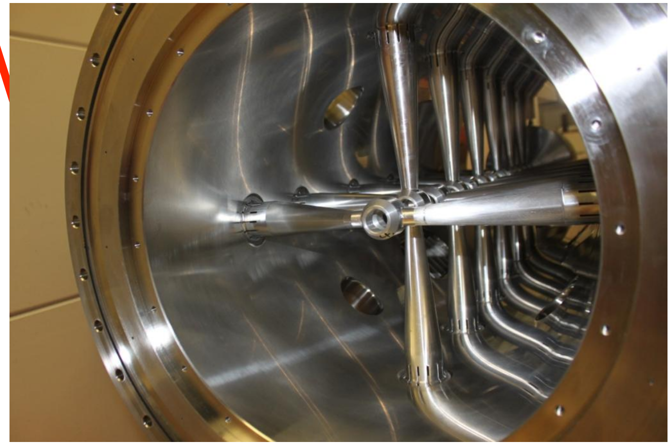


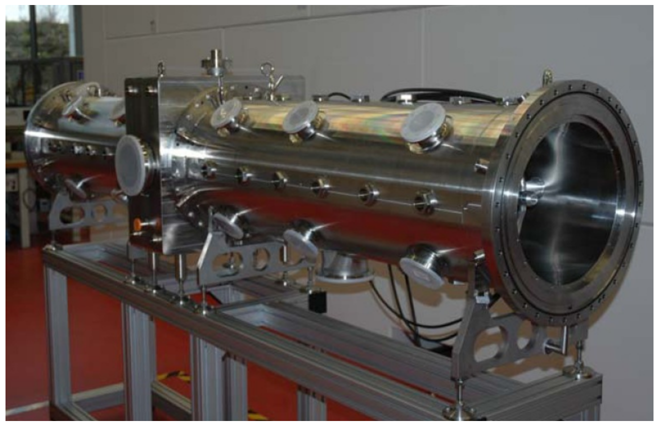
ECR Source
by CEA France
100 mA



THALES Klystron
by IN2P3/CNRS France
2.8 MW per pulse

CCH cavity
by IAP Frankfurt
JWG University

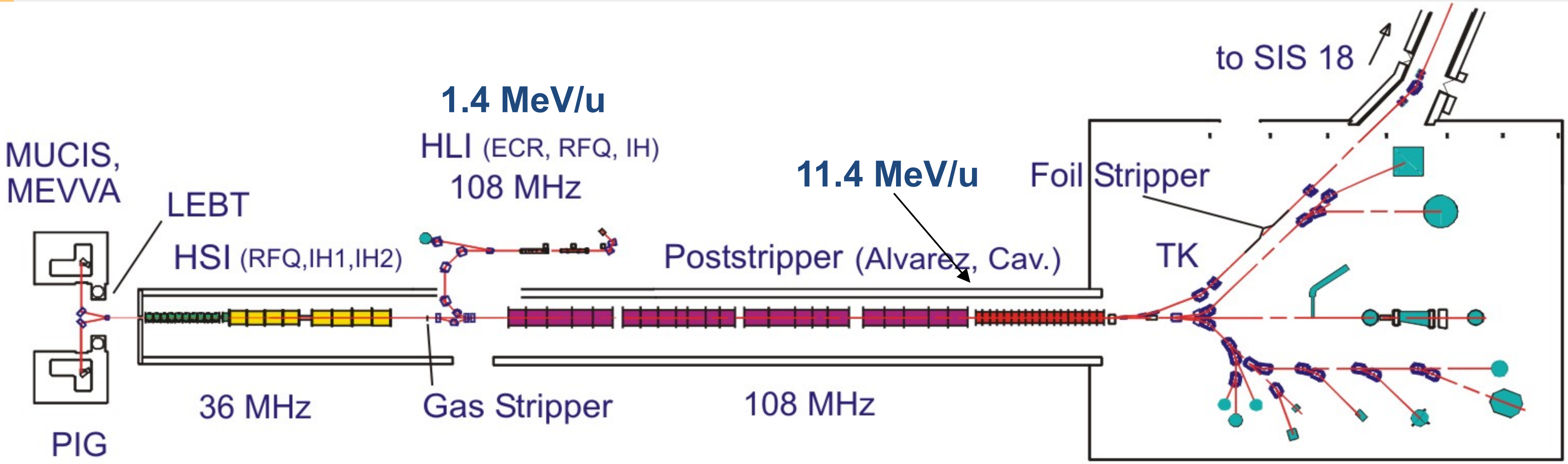




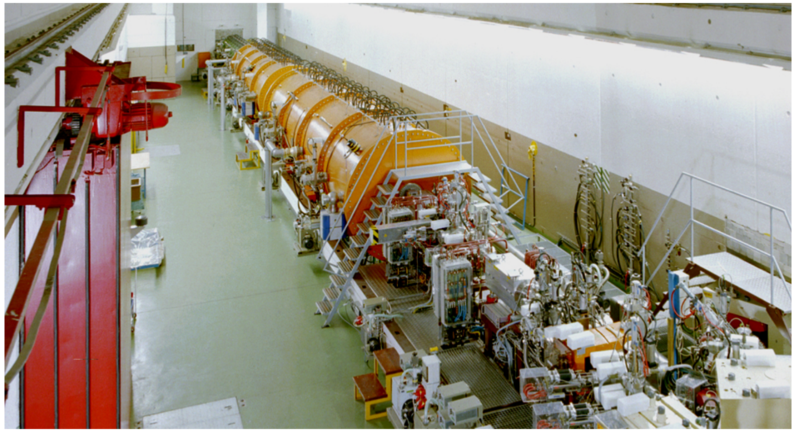
70 mA proton beam current (35 mA)
for multi-turn injection into SIS18

See presentation by W. Barth (Wednesday)

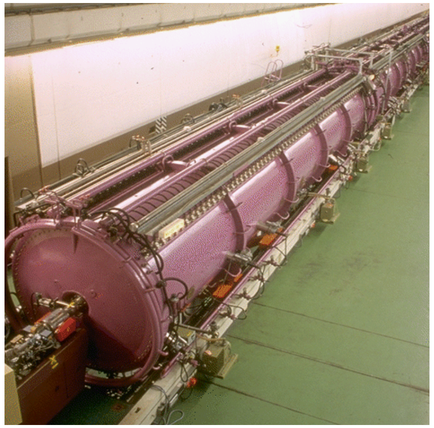
The UNILAC



High-current injector

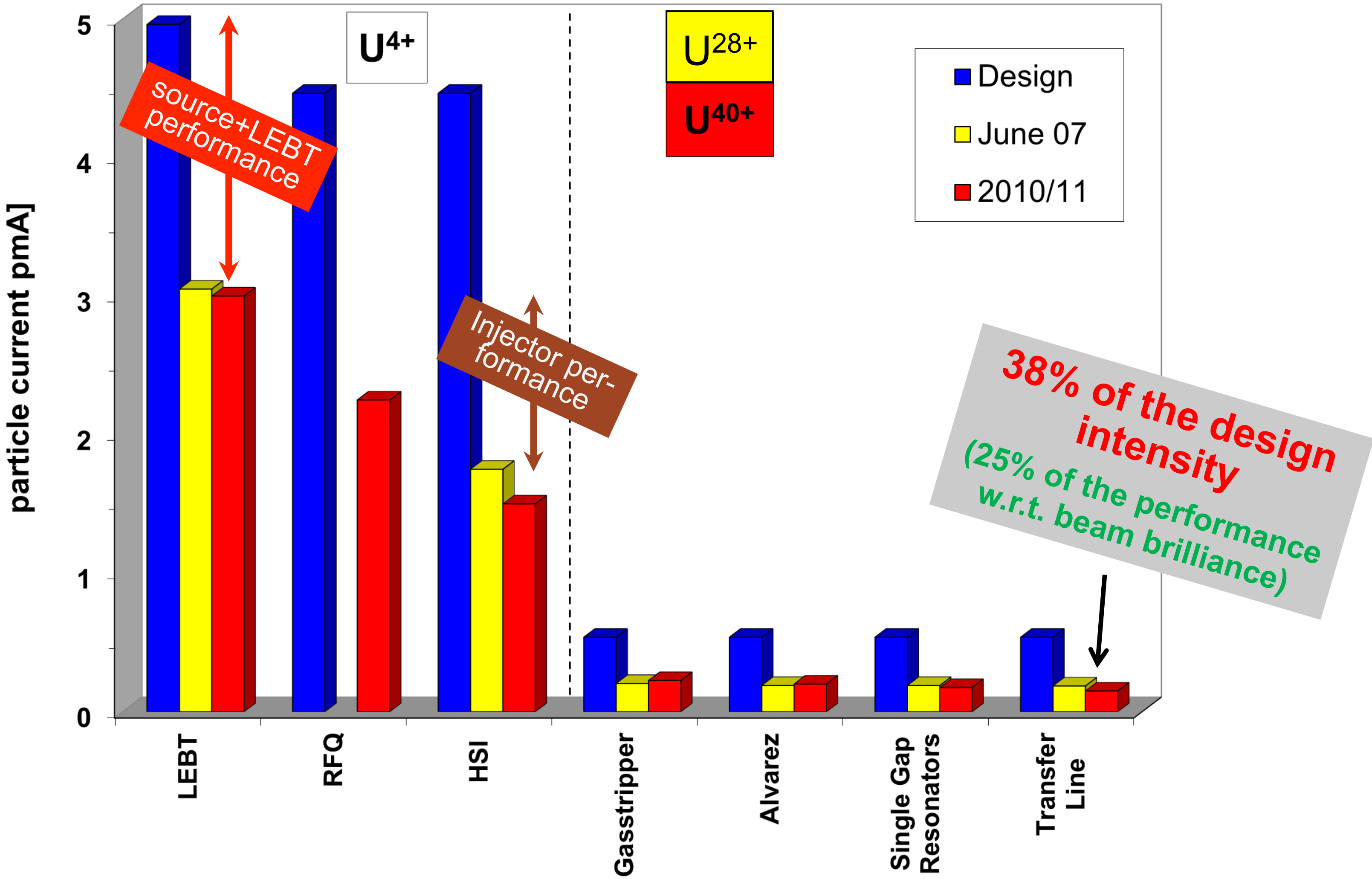


Alvarez Tanks



Individual resonators

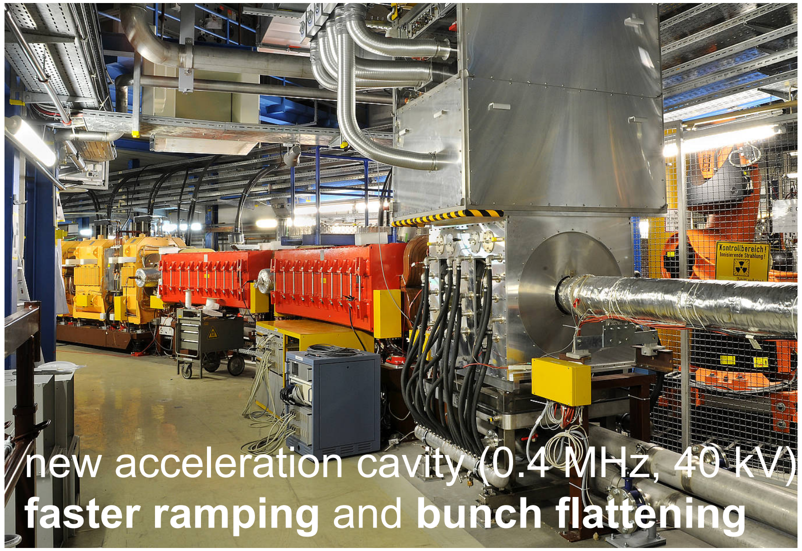
UNILAC performance



See presentation by W. Barth (Wednesday)

SIS18 heavy ion (and proton) intensities
upgrade program

The SIS-18 upgrade program: Booster operation with intermediate charge state heavy ions



	SIS-18 today	FAIR design
Reference primary ion	U^{28+}	U^{28+}
Reference energy	200 MeV/u	200 MeV/u
Ions per cycle	**4E10 (-> record)**	**1.5E11**
cycle rate (Hz)	1 Hz	2.7 Hz

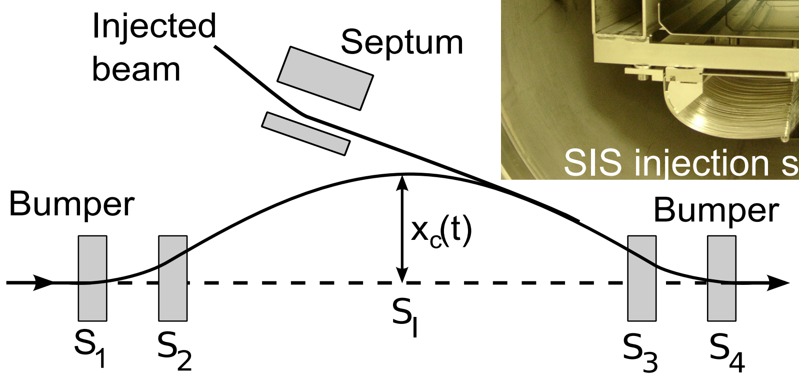
≈ 25% of design intensities (for uranium)

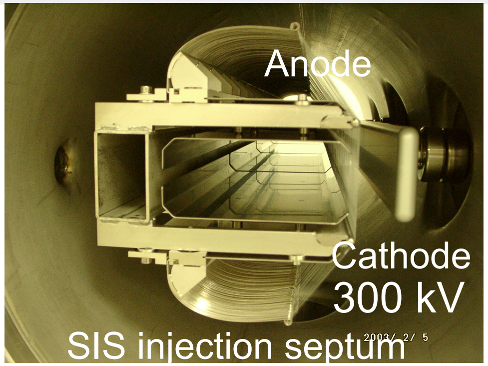
SIS-18 upgrade for the FAIR booster operation:

- New injection system (completed)
- **NEG coating of the vacuum pipe (completed)**
- Reduction of multi-turn injection loss (ongoing)
- Fast ramping with 10 T/s (ongoing)
- **Dual (h=2/4) rf system (partly completed): one of the three modules installed and tested**

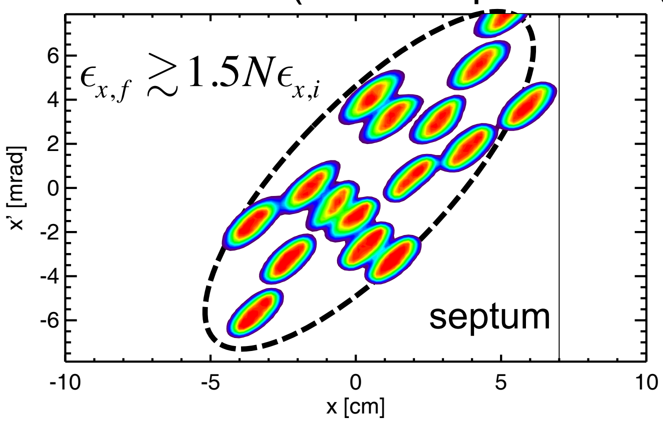
Example: SIS18 multi-turn injection (MTI)

From UNILAC/p-linac



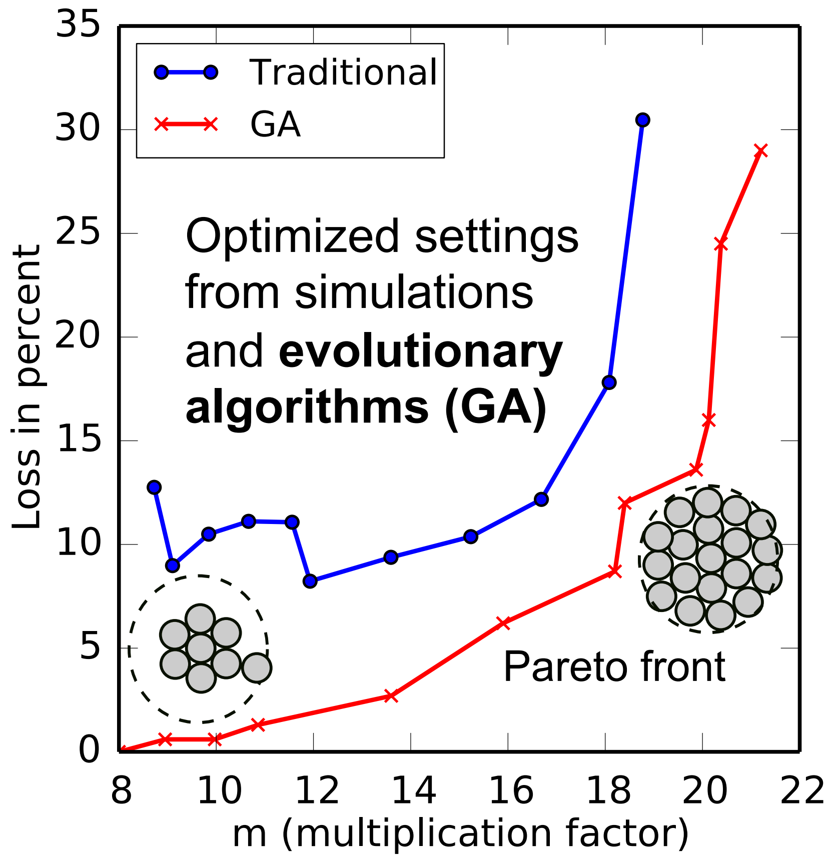


MTI Simulation (without space charge)



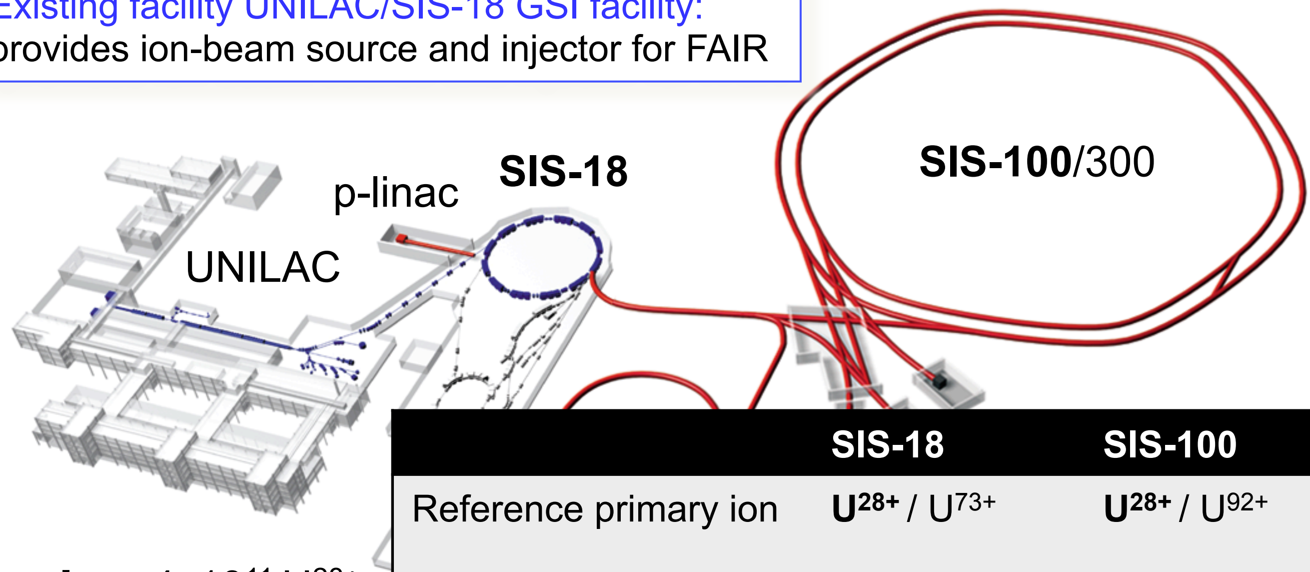
Goal: Inject 10-20 turns with minimum loss.
Injected intensity and emittance is important !

-> EMittance Transfer EXperiment (EMTEX)

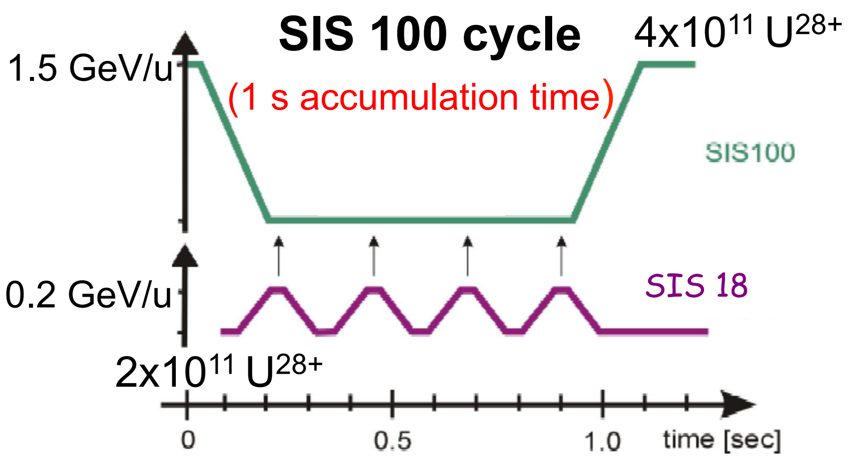


FAIR primary beam chain

Existing facility UNILAC/SIS-18 GSI facility:
provides ion-beam source and injector for FAIR



SIS-100 extraction:
- short (60 ns) bunch
- slow extraction

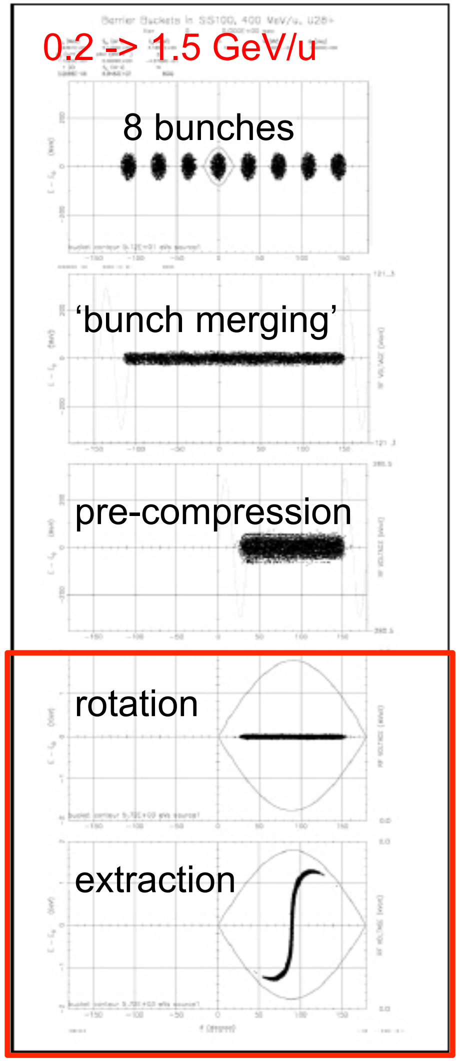


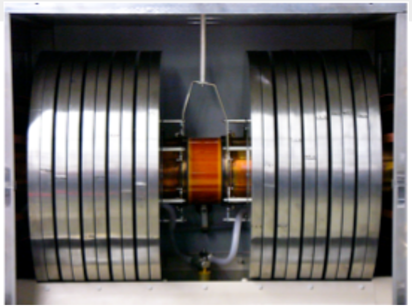
	SIS-18	SIS-100
Reference primary ion	**U^{28+}** / U^{73+}	**U^{28+}** / U^{92+}
Reference energy	**0.2** / 1 GeV/u	**1.5** / 10 GeV/u
Ions per cycle	**1.2E11** / 2E10	**4E11** / 1E10
cycle rate (Hz)	2.7	**0.5** / 0.1
FAIR parameter booklet, **April 2007**, (Ed.) O. Boine-F., P. Spiller, M. Steck + corrections for MSV -> update under way		

Protons from SIS-100: 29 GeV, $4x10^{13}$, 1 bunch, 0.2 Hz

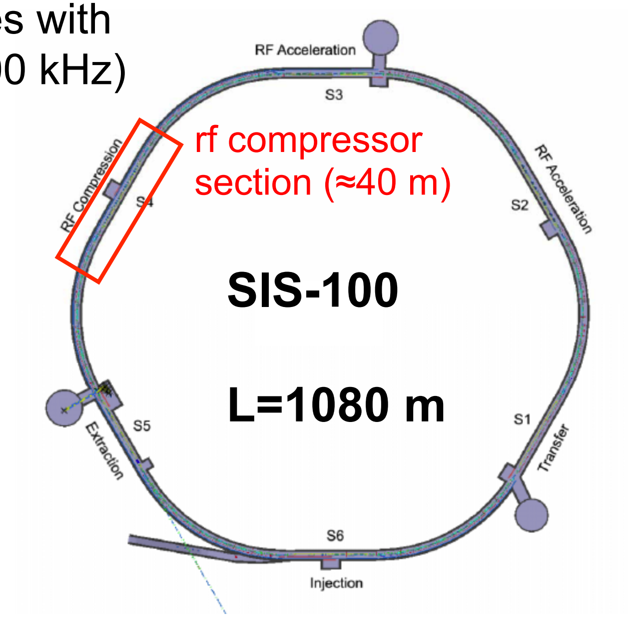
Final bunch compression in SIS100

Single bunch formation

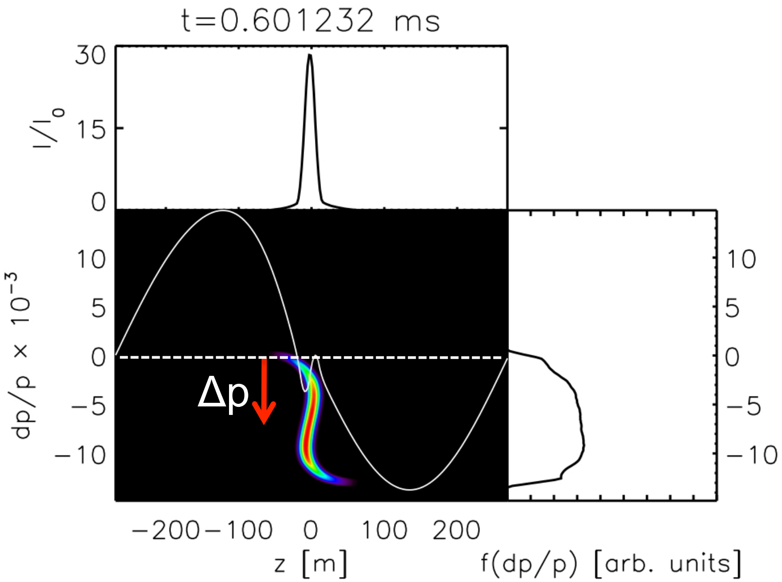




16 magnetic alloy (MA) loaded rf cavities with total: 600 kV (400 kHz)



Effect of beam loading on the bunch rotation:



Challenge:

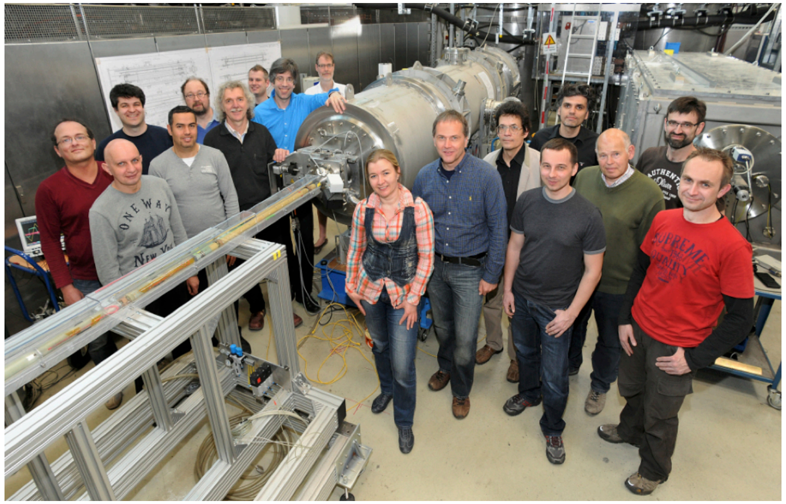
Extreme transverse space charge

$$\Delta Q_y^{sc} \approx -0.8$$

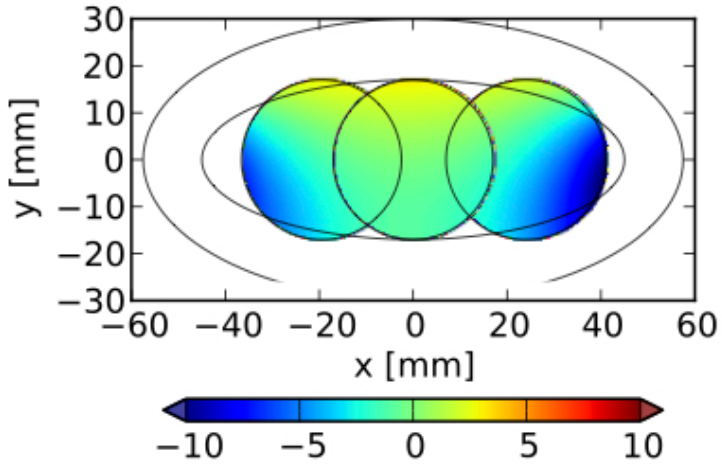
(during the last turns)

SIS100 dipole modules: First of series magnet

Delivered to GSI: June 3rd 2013



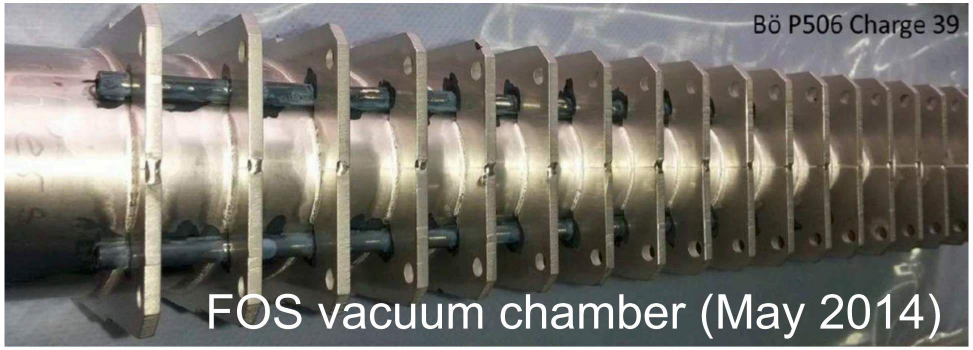
Measured B_y field at 1.9 T

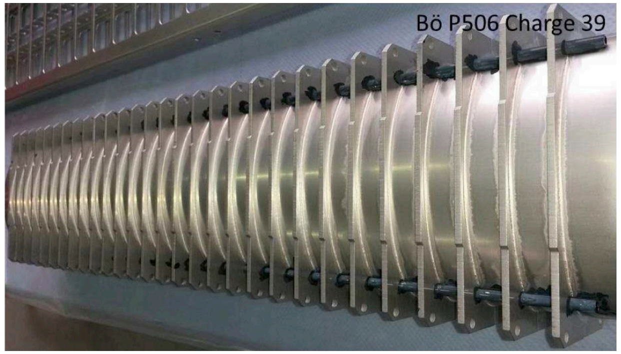


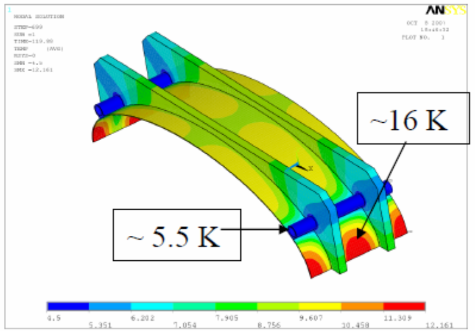
Sophisticated high accuracy field measurements
Indicated geometry errors outside specification.

See presentation by P. Schnizer (Friday)

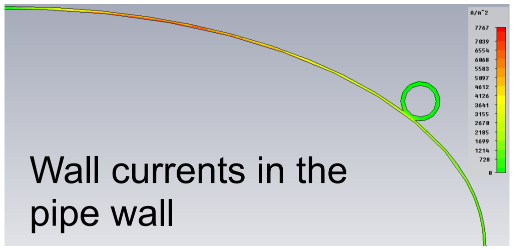
SIS100 beam pipe







Temperature distribution with attached cooling tube



Wall currents in the pipe wall

Special stainless steel (Böhler P506) for all dipole and quadrupole magnet chambers.

SIS100 beam pipe: thin (0.3 mm) stainless steel pipe with attached cooling pipes

- still mechanically robust (with supporting rips) for 10^{-12} mbar
- tolerable eddy current heating (< 10 W/m) and field distortion
- sufficient shielding of beam induced EM fields above 50 kHz
- active pumping (< 20 K wall temperature)

One of the most critical components in SIS100 !

Short remark: protons vs. heavy ions

UNILAC, SIS18/100:
Operation with intermediate charge state ions to reduce space charge effects
+ light ions + protons

Lifetime of intermediate charge state heavy-ions in rings
- Large cross sections for electron stripping/capture
- (stable) residual gas pressure of the order of 10^{-12} mbar required for sufficient lifetime
- Beam loss causes dynamic pressure instabilities.

-> at present heavy-ion intensities are limited not limited by space charge !

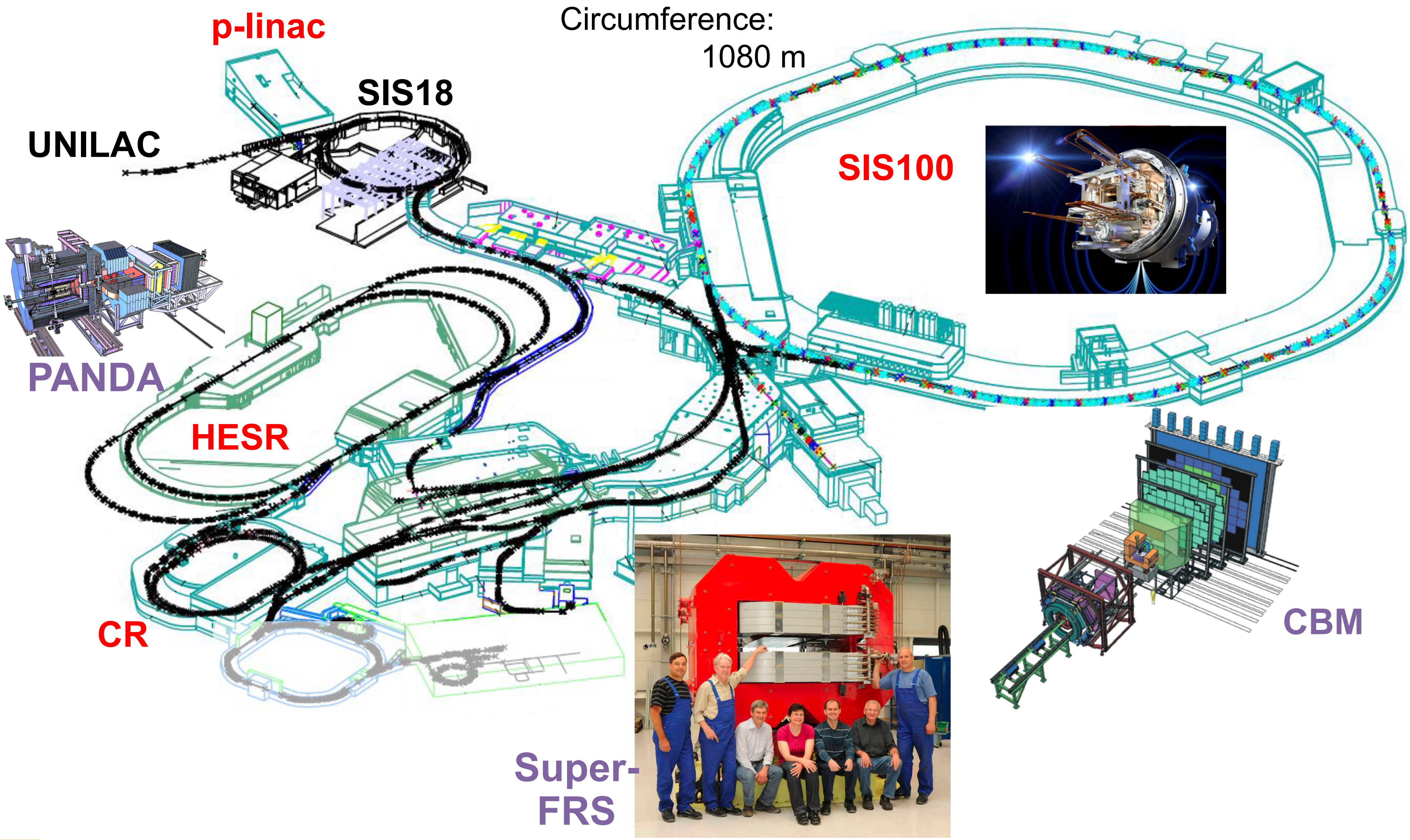
Production of intermediate charge state ions
- Performance of ion sources compared to proton sources.
- Stripping efficiency of heavy-ions at low energies.
- Conventionally 'Liouvillian' multi-turn injection into rings.

-> 'space charge limited' intensities in more difficult to reach for heavy-ions.

Protons and light ions: Operation close or above transition energy in SIS100

-> possible additional beam loss for protons

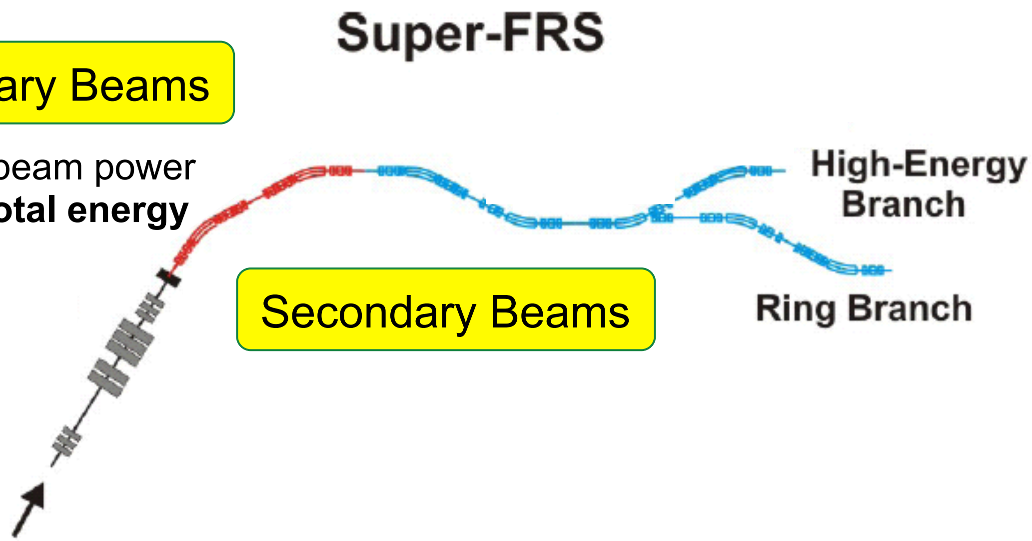
The FAIR facility: technical design



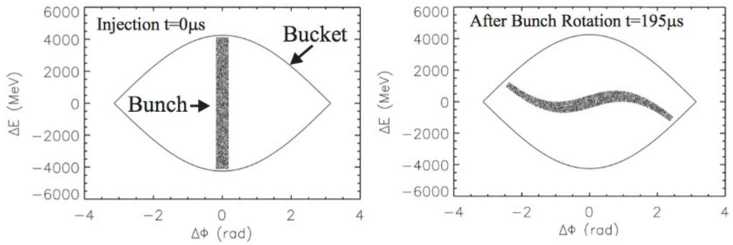
End of the primary beam uranium chain: Bunch compression and production target

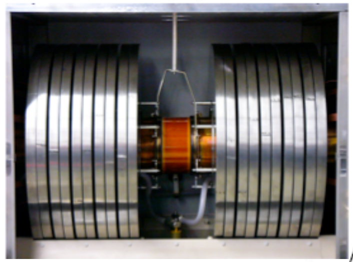
Primary Beams

15 kW beam power
30 kJ total energy



Bunch rotation in the CR





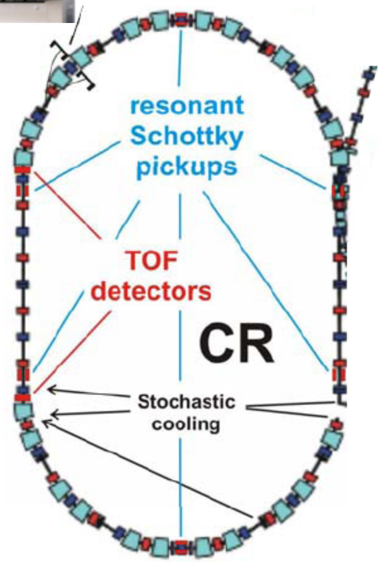
CR debuncher cavity

	SIS-100
Reference primary ion	U^{28+}
Reference energy	1.5 GeV/u
Ions per cycle	4E11
Bunch length	60 ns
Momentum spread	± 1 %
cycle rate (Hz)	0.5

NuSTAR: Primary heavy-ion beam intensity from SIS100 is essential !

-> 2E11/s (short bunch)
-> 1E11/s (slow extraction)

Remark: CDR/2001 -> 1E12/s
(NuPECC/2000 recommendation)



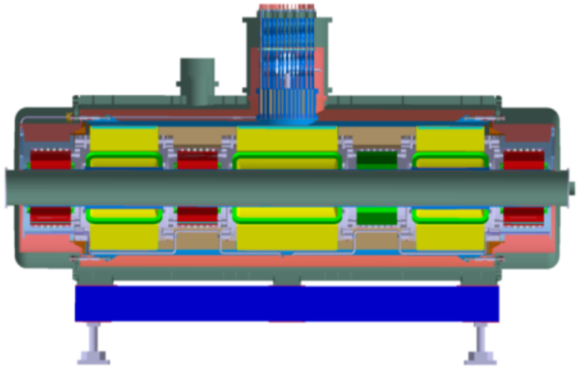
Presentation by H. Simon (today)

Super-FRS: technical status

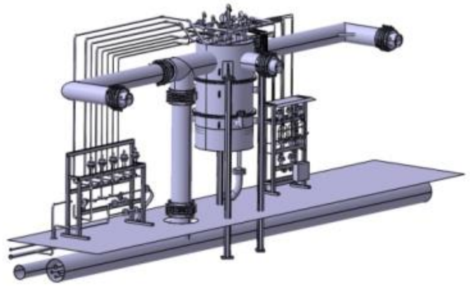
Remote Handling

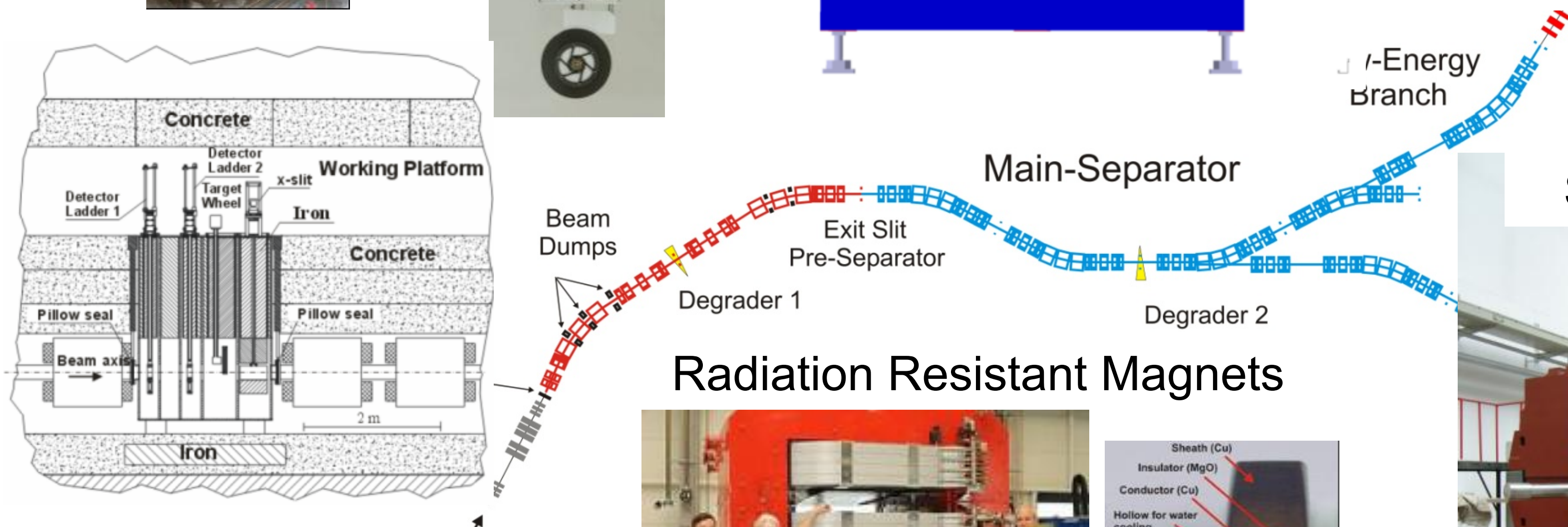
Target

SC Multiplets



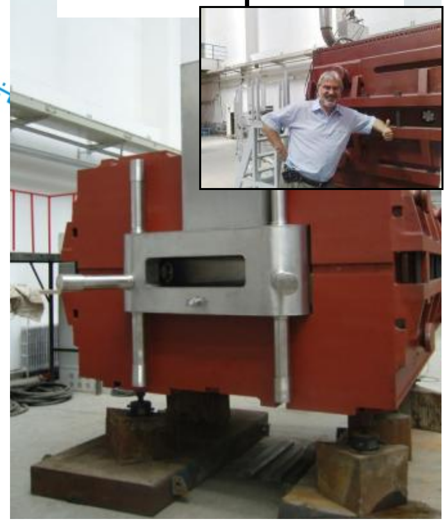
Local Cryogenics



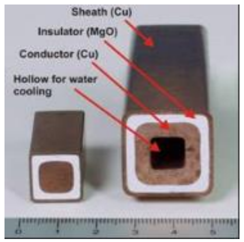


Driver Accelerator

SC Dipoles

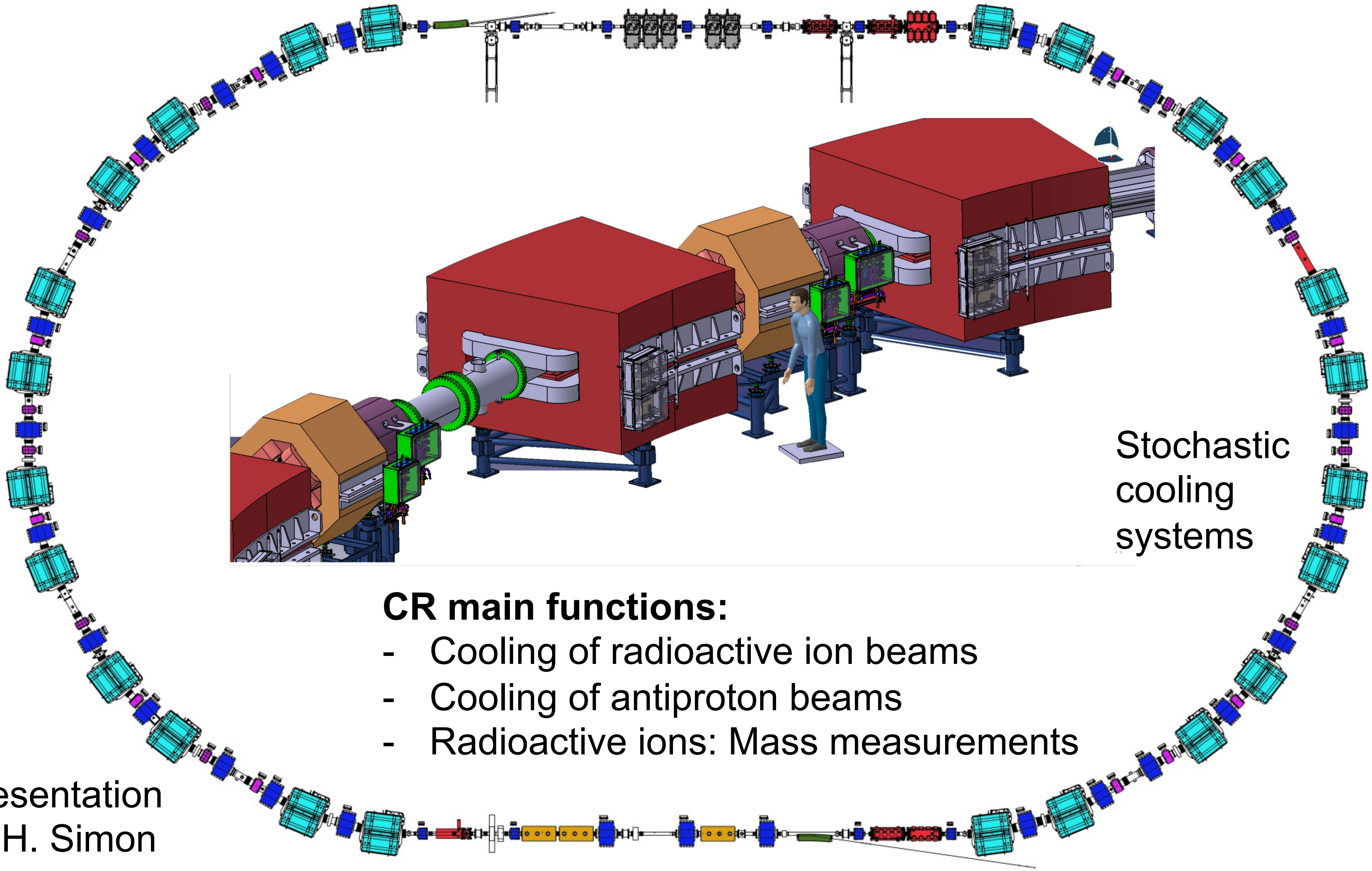


Radiation Resistant Magnets



Presentation by H. Simon

The CR: Large aperture collector ring



Stochastic cooling systems

CR main functions:

- Cooling of radioactive ion beams
- Cooling of antiproton beams
- Radioactive ions: Mass measurements

Presentation by H. Simon

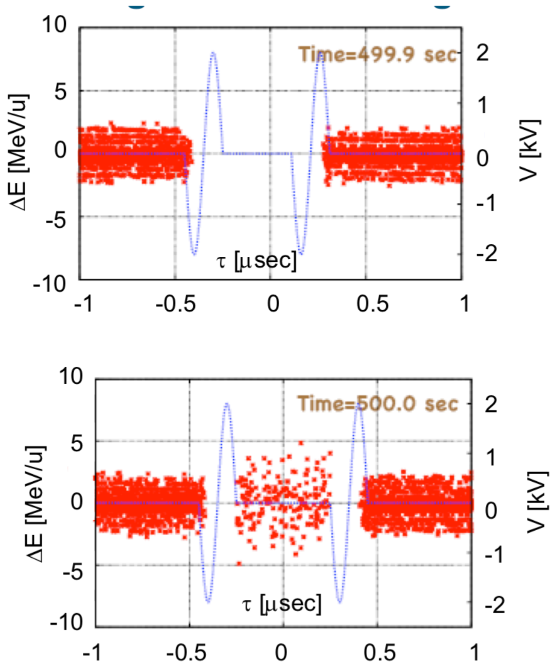
HESR operation in the start version

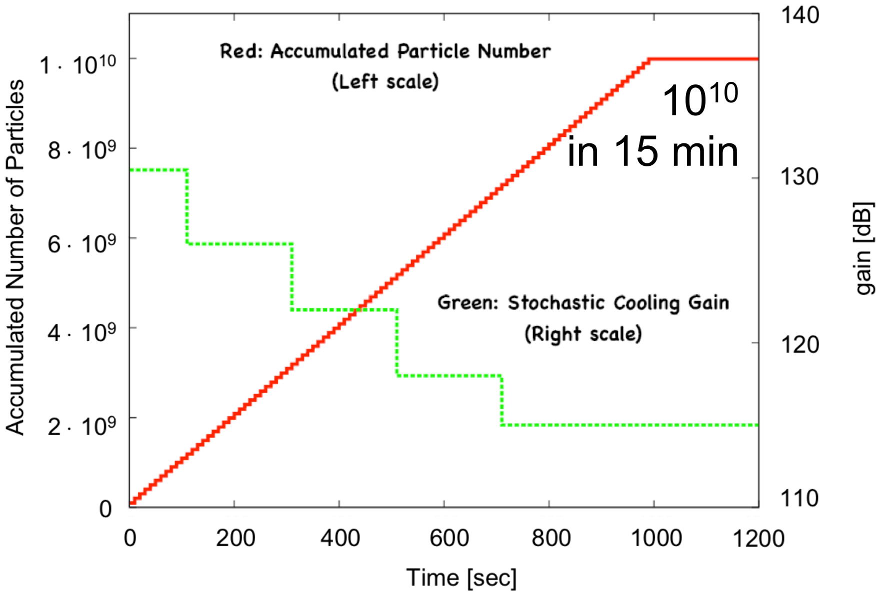
Effective target thickness (pellets): $4 \cdot 10^{15}$ cm^{-2}		
	High Resolution Mode	**High Luminosity Mode**
Energy range	**0.8 - 8 GeV**	**3 – 14.5 GeV**
Number of antiprotons	10^{10}	10^{11}
Peak luminosity	$2 \cdot 10^{31}$ cm^{-2}s^{-1}	$2 \cdot 10^{32}$ cm^{-2}s^{-1}
Momentum spread	$5 \cdot 10^{-5}$	$1 \cdot 10^{-4}$

Start version:
only High Resolution mode possible.

+ heavy ion mode !

Antiproton production:
K. Knie (Friday)

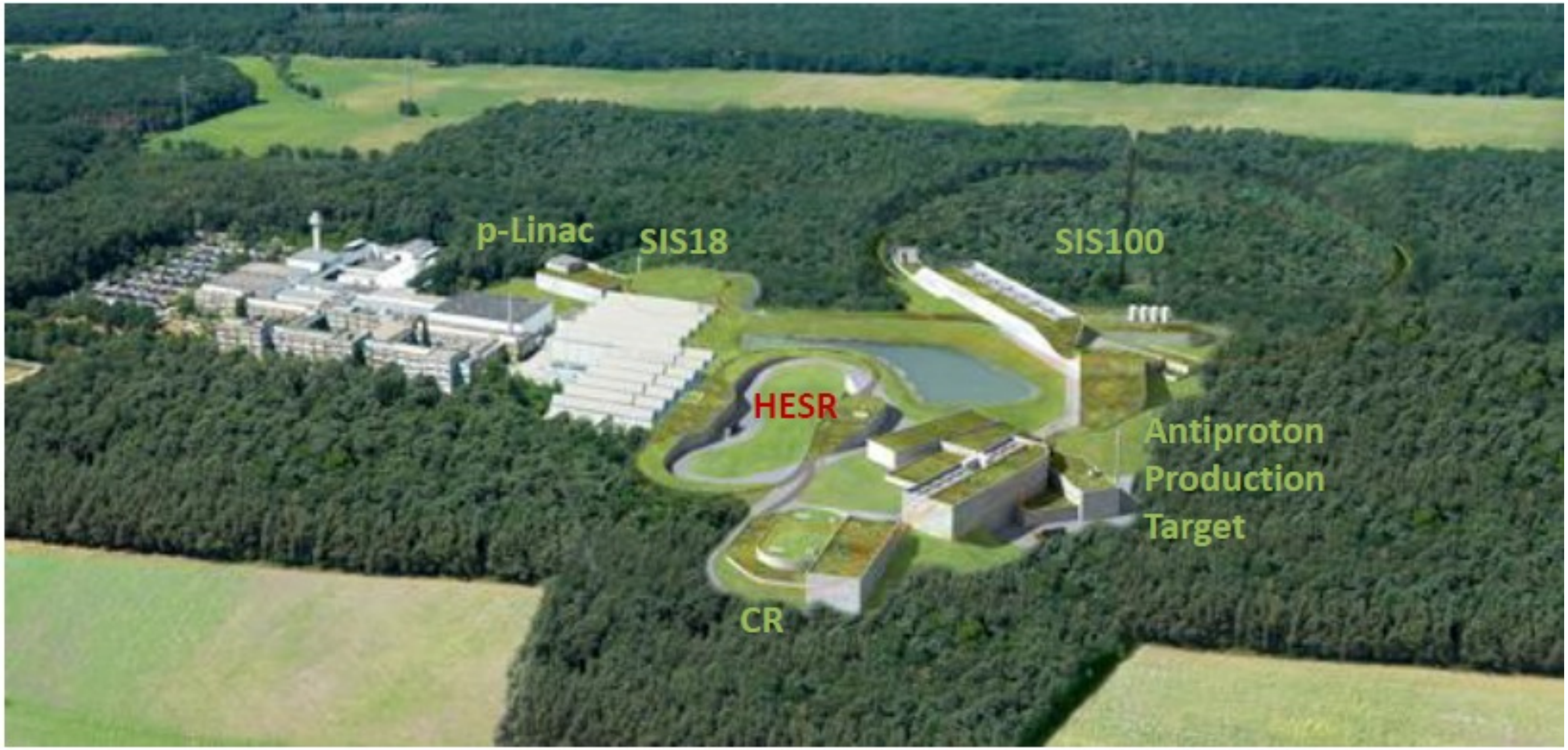




Barrier bucket stacking with stochastic momentum cooling.
(Stockhorst et al.)

-> Sucessfull demonstration in the GSI ESR.

The FAIR accelerators



Thank you for your attention !