Approaches to High Intensities for FAIR

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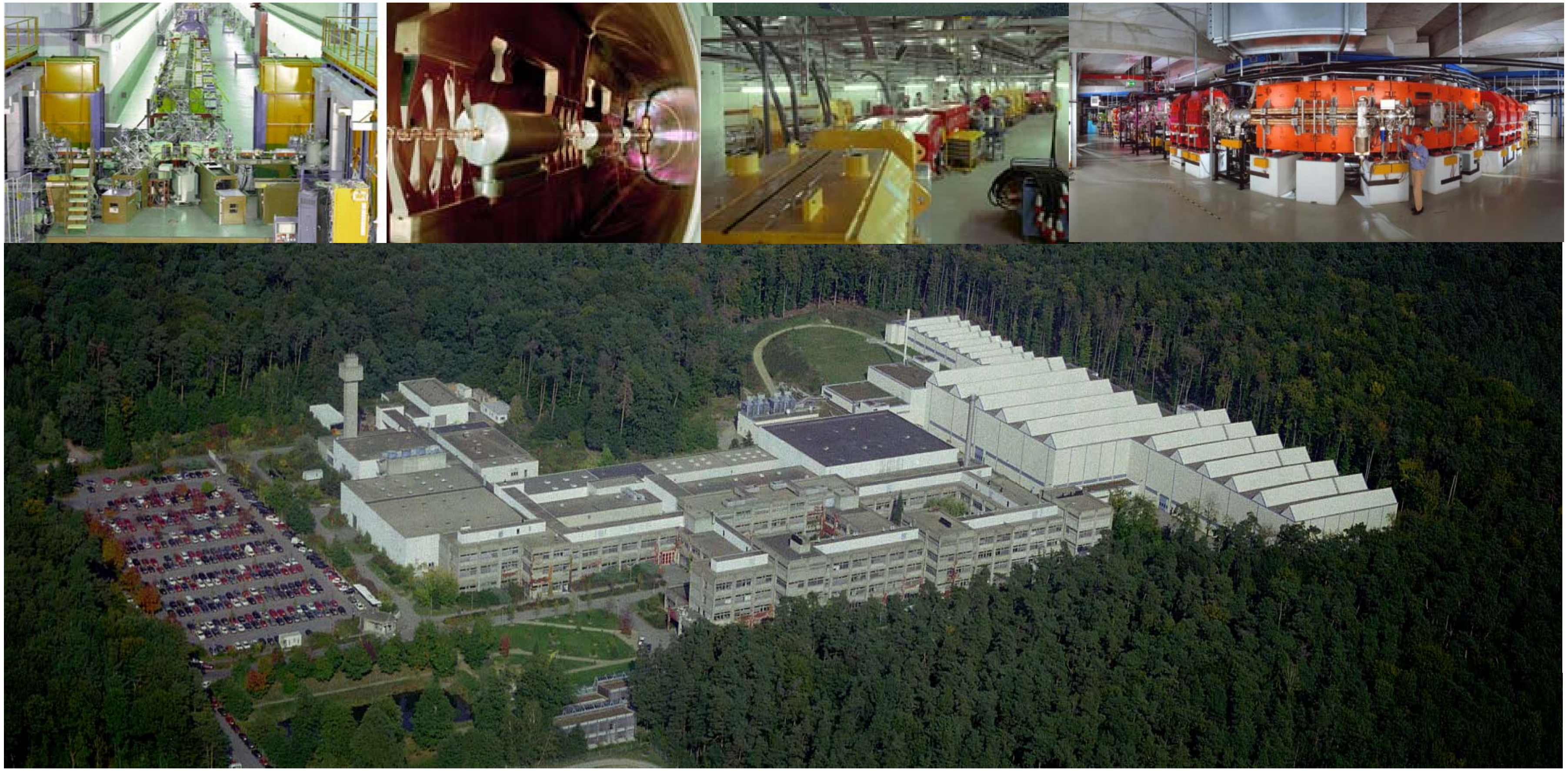
on behalf of the GSI and FAIR project teams

GSI, Darmstadt

EPAC

February 26, 2006

GSI

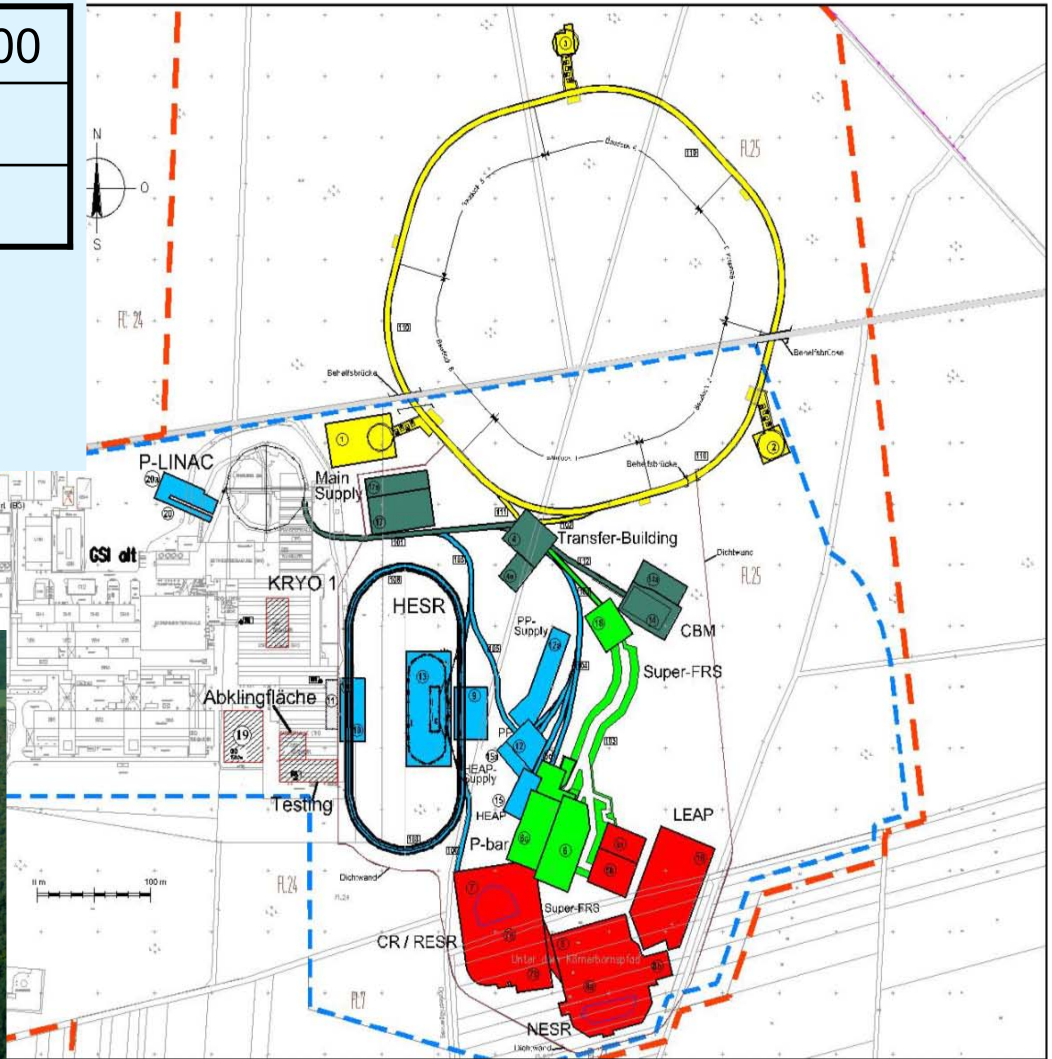


FAIR Accelerator Facility

Primary Beam Intensity	x 100-1000
Secondary Beam Intensity	x 10 000
Heavy Ion Beam Energy	x 30

- New: Cooled pbar Beams (15 GeV)
- Intense Cooled Radioactive Beams
- Parallel Operation

Poster: D. Krämer
(FAIR division leader)



Primary Beams: Two Stage Synchrotron

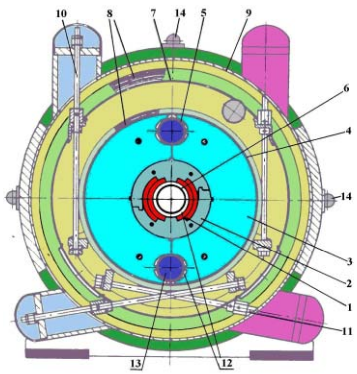
- **1. High Intensity- and Compressor Stage**

SIS100 with fast-ramped superconducting magnets and a strong bunch compression system.

$B\rho$= 100 Tm - B_{max} = 2 T - dB/dt = 4 T/s

Intermediate charge state ions e.g. U^{28+}-ions up to 2715 MeV/u
Protons up to 30 GeV

- **2. High Energy- and Stretcher Stage**

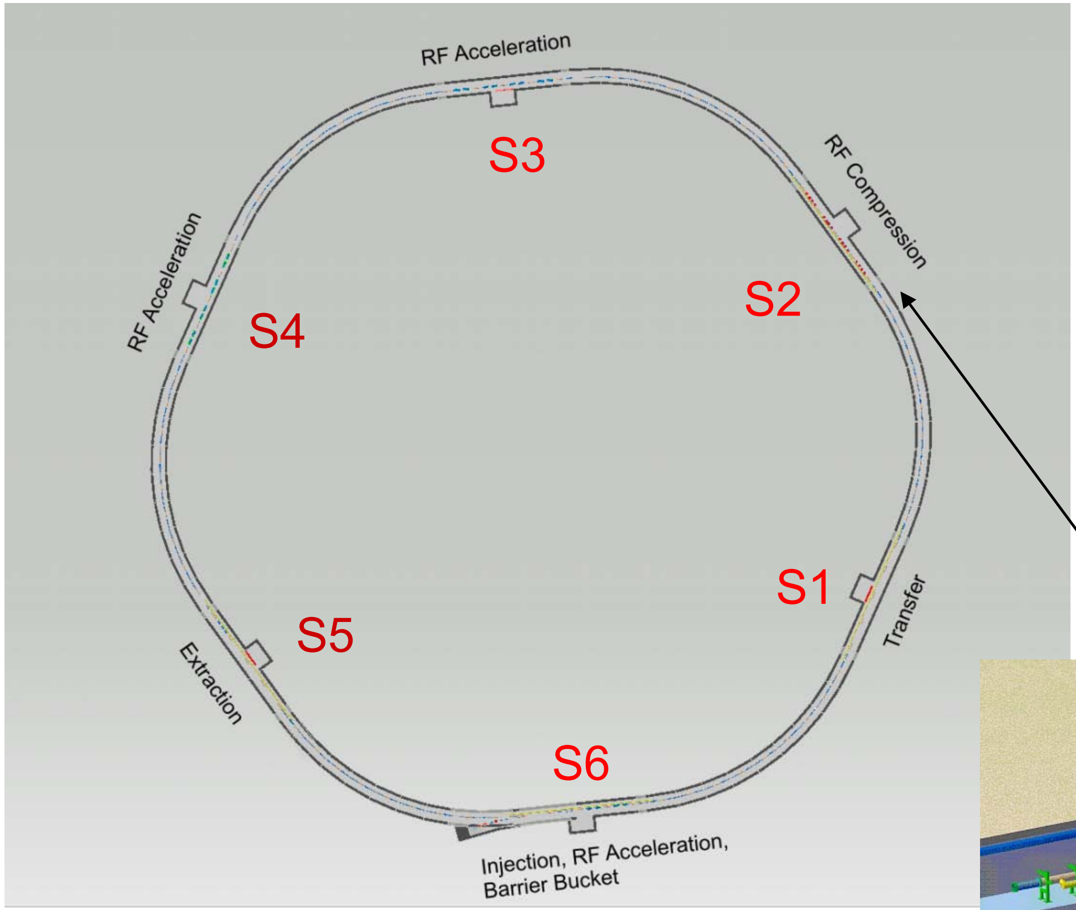


SIS300 with superconducting high-field magnets and stretcher function.

$B\rho$= 300 Tm - B_{max} = 6 T - dB/dt = 1 T/s (short straight dipoles)
or B_{max} = 4.5 T - dB/dt = 1 T/s (long bent dipole)

Highly charges ions e.g. U^{92+}-ions up to 34 GeV/u
Intermediate charge state ions U^{28+}- ions at 1.5 to 2.7 GeV/u with 100% duty cycle

Talk Beam Stability and Impedances:
O. Boine-Frankenheim



S1: Transfer to SIS300

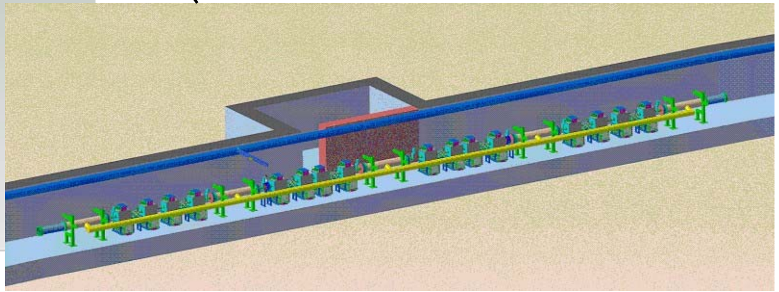
S2: Rf Compression (MA loaded)

S3: Rf Acceleration (Ferrite loaded)

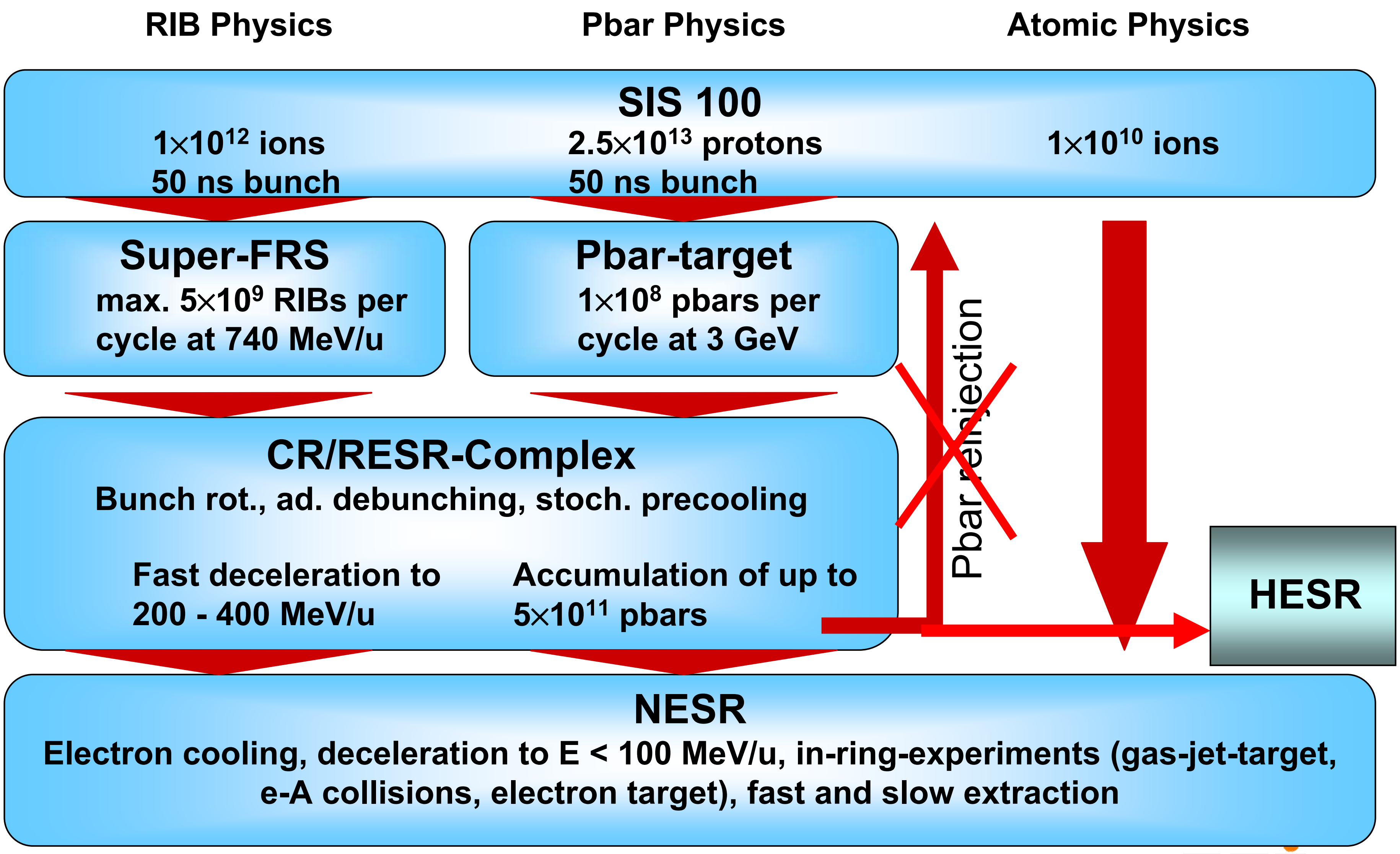
S4: Rf Acceleration (Ferrite loaded)

S5: Extraction Systems (slow and fast)

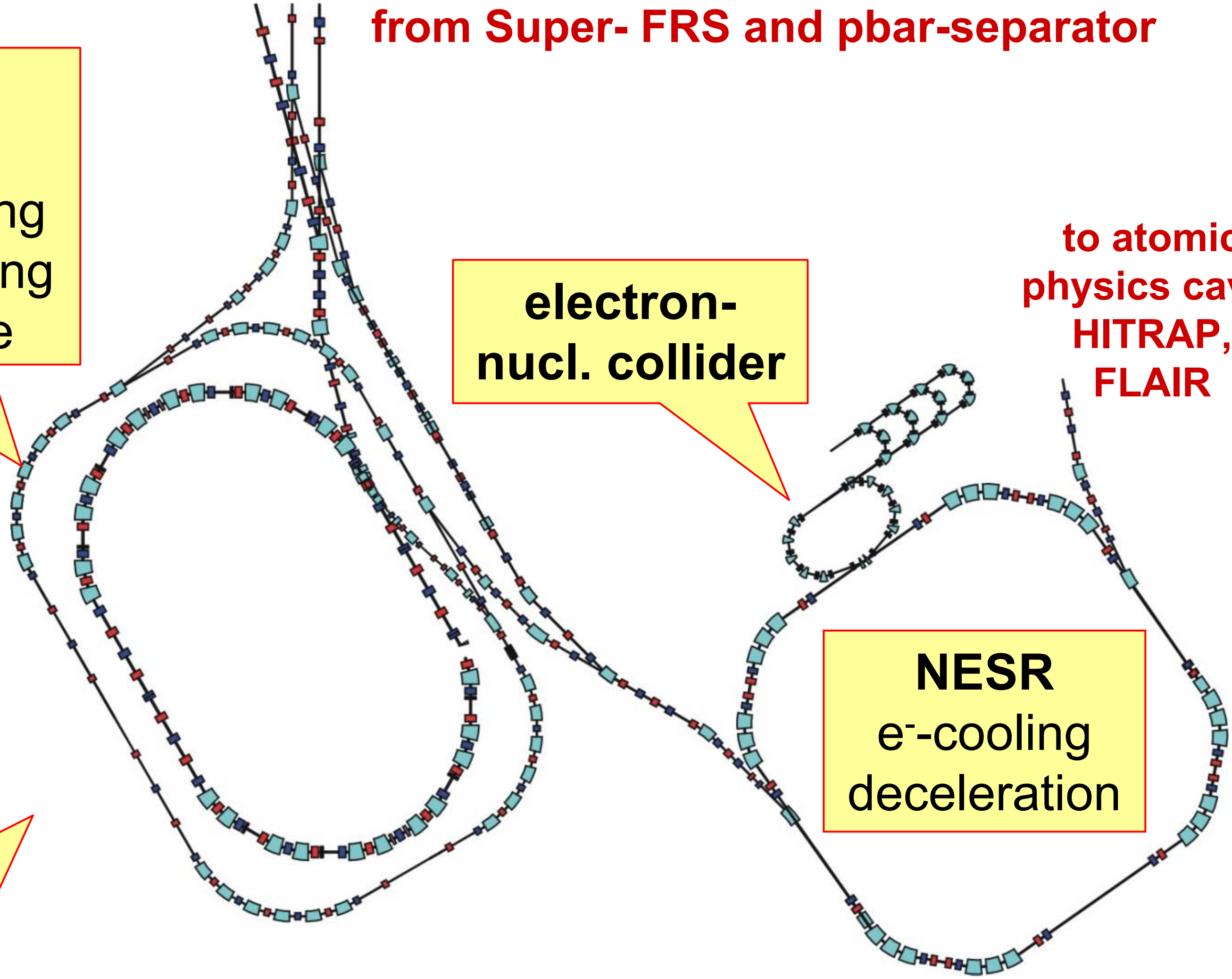
S6: Injection System plus RF Acceleration and Barrier Bucket



Secondary Beams and Storage Rings



Secondary Beams Storage Ring Complex



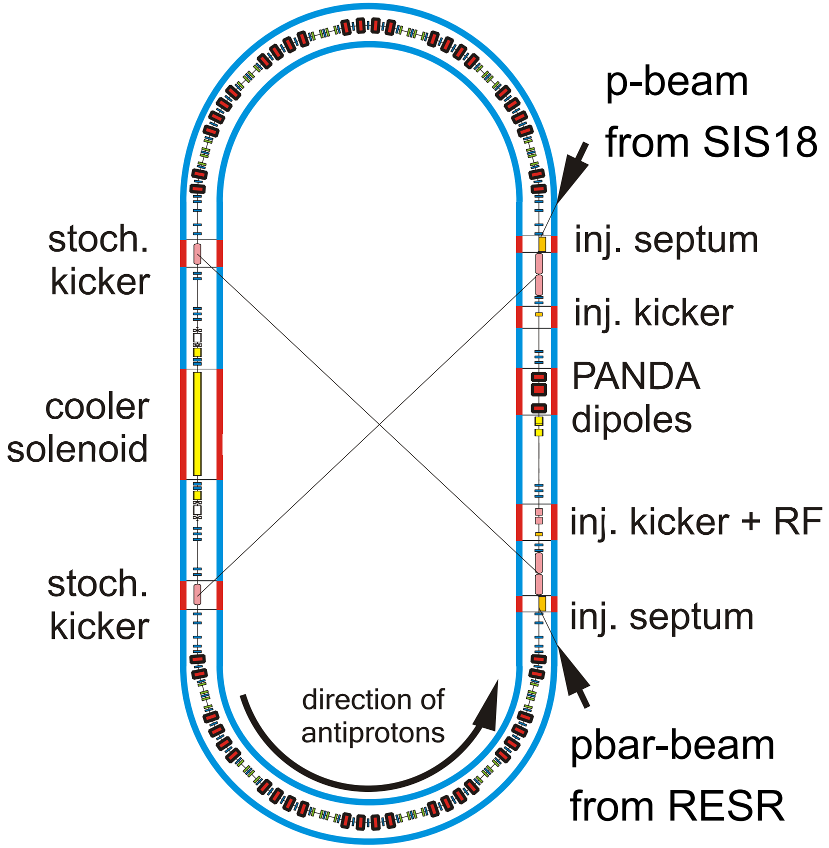
Collector Ring
bunch rotation
adiabatic debunching
fast stochastic cooling
isochronous mode

electron-nucl. collider

NESR
e^--cooling
deceleration

RESR
pbar accumulation
fast RIB/pbar
deceleration

Secondary Beams: High Energy Storage Ring



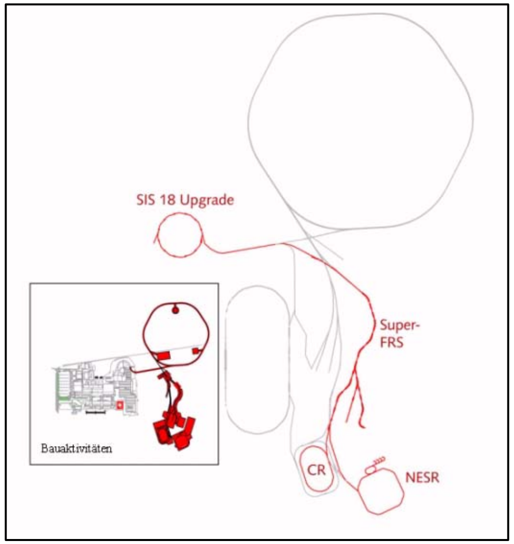
Circumference	574 m
Max. Rigidty	50 Tm
Bmax	4 T
High resolution (HR) mode: N=10^{10} particles	E < 8 GeV $2 \cdot 10^{31}$ $cm^{-2}sec^{-1}$ dp/p =10^{-5} Magnetized electron cooling
High luminosity (HL) mode: N <10^{11} particles	1.5 < E < 15 GeV $2 \cdot 10^{32}$ $cm^{-2}sec^{-1}$ dp/p= 10^{-4} Stochastic cooling (long. + transv.)
Pellets	H_2, 20 000/s

HESR consortium: FZ Jülich, TSL, GSI

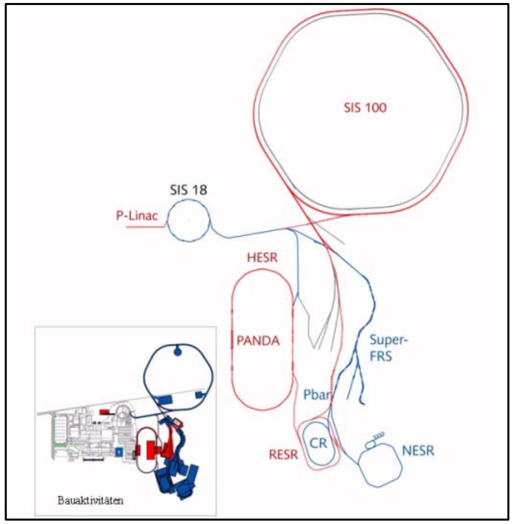
INTAS study group on beam cooling equilibrium

FAIR Project (staged planning)

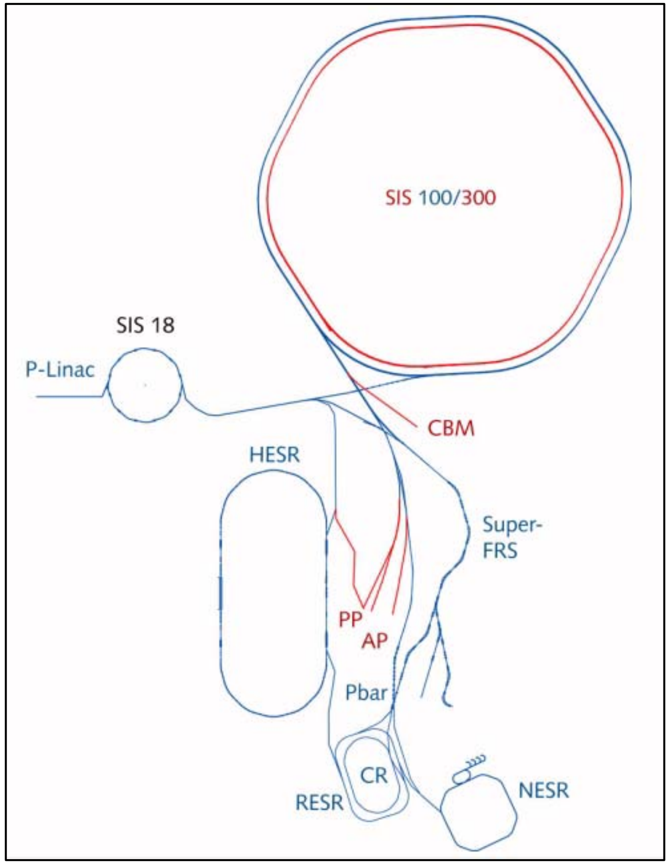
Stage 1



Stage 2



Stage 3

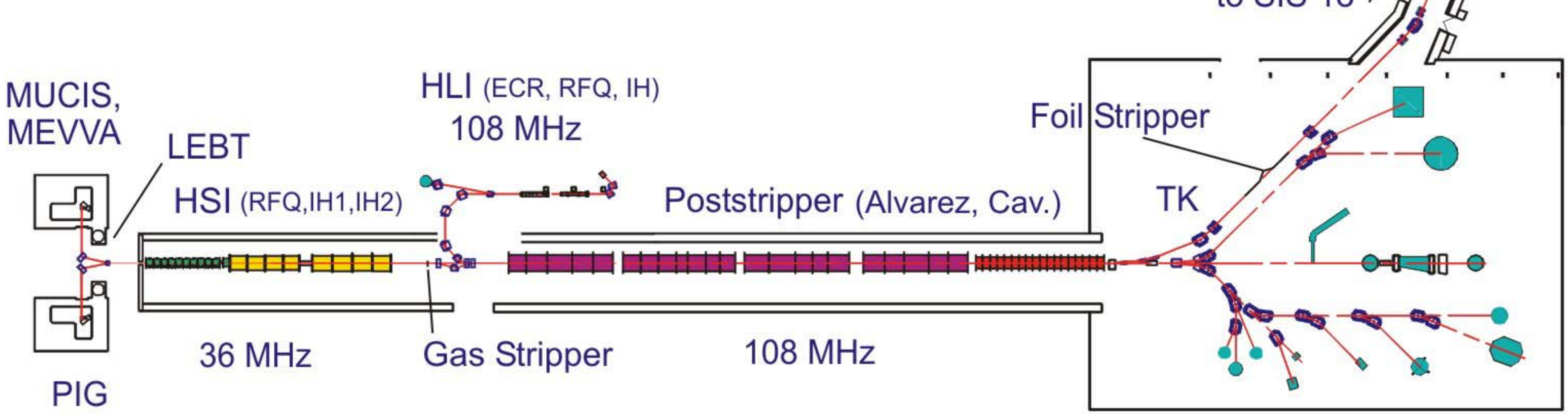


SIS18 - Requirements for FAIR

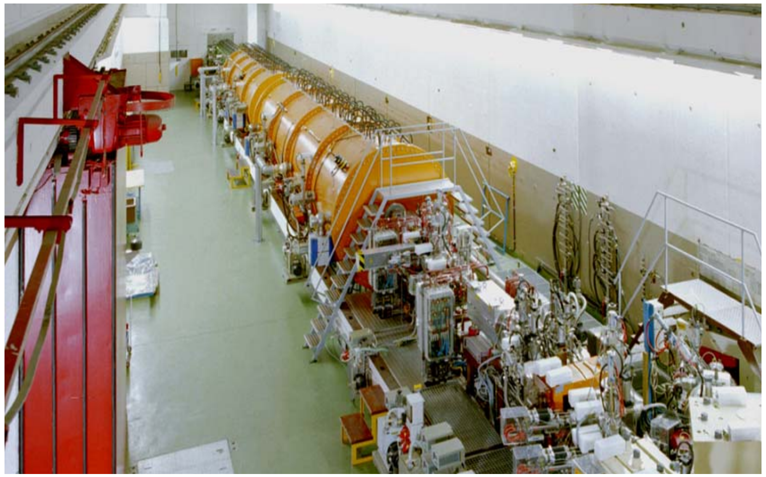
Fair Stage	Today	0 (Existing Facility after upgrade)	1 (Existing Facilty supplies Super FRS, CR, NESR)	2,3 (SIS100 Booster)
Reference Ion	U^{73+}	U^{73+}	U^{73+}	U^{28+} (p)
Maximum Energy	1 GeV/u	1 GeV/u	1 GeV/u	0.2 GeV/u
Maximum Intensity	$3x10^{9}$	$2x10^{10}$	$2x10^{10}$	$2x10^{11}$
Repetition Rate	0.3 Hz	1 Hz	1 Hz	2.7 – 4 Hz
Approx. Year		2008/2009	2011/2012	2012/2013

UNIversal Linear ACcelerator

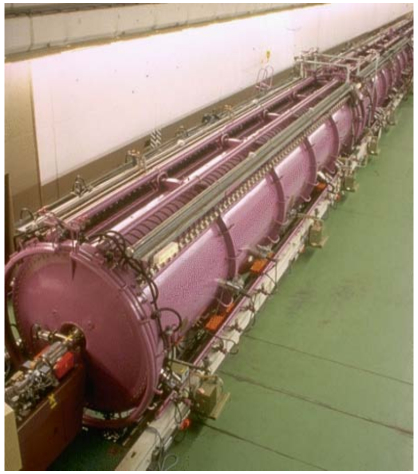
Machine coordination: W. Barth, L. Dahl



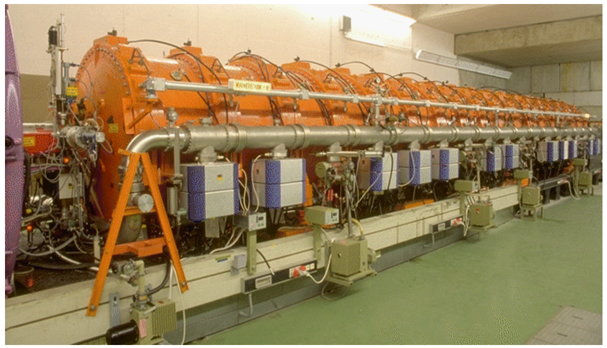
High Current Injector HSI



ALVAREZ

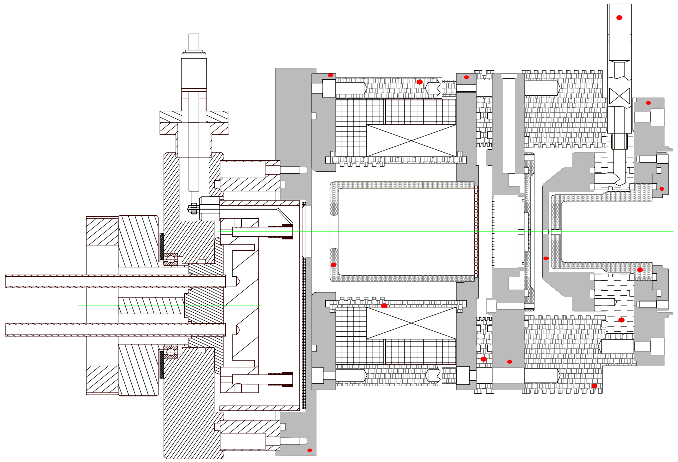


Single Gap Resonators



MEVVA and VARIS Ion Sources

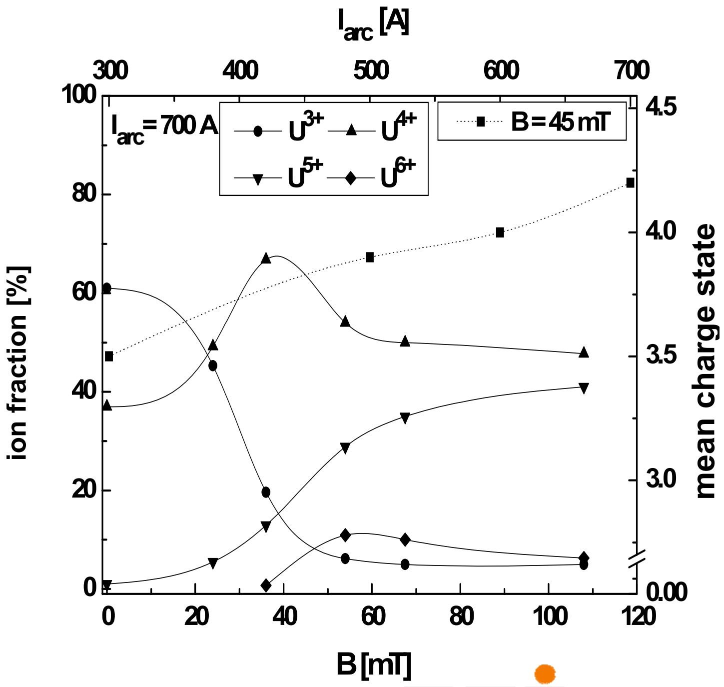
MEVVA
metal vapor vacuum arc



VARIS
vacuum arc ion source

Machine coordination:
P. Spaedtke, R. Hollinger

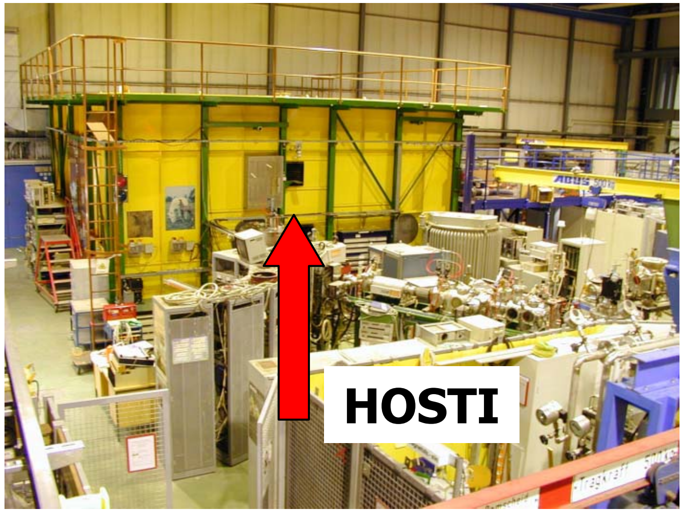
Optimization of plasma parameters and geometry

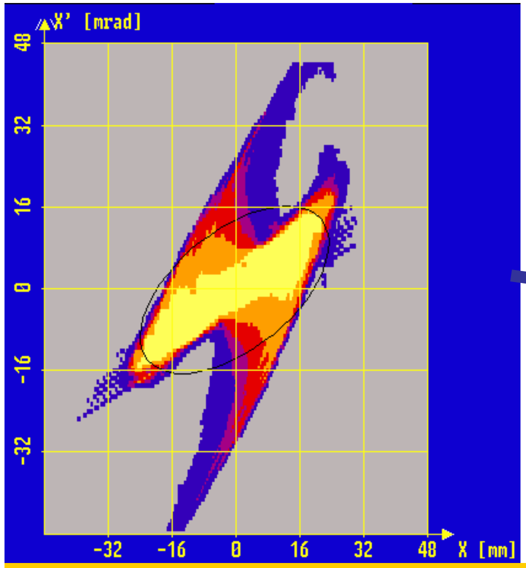


22 emA (67%) U^{4+} were reached during test runs at HSI-RFQ input

High Current Test Injector HOSTI

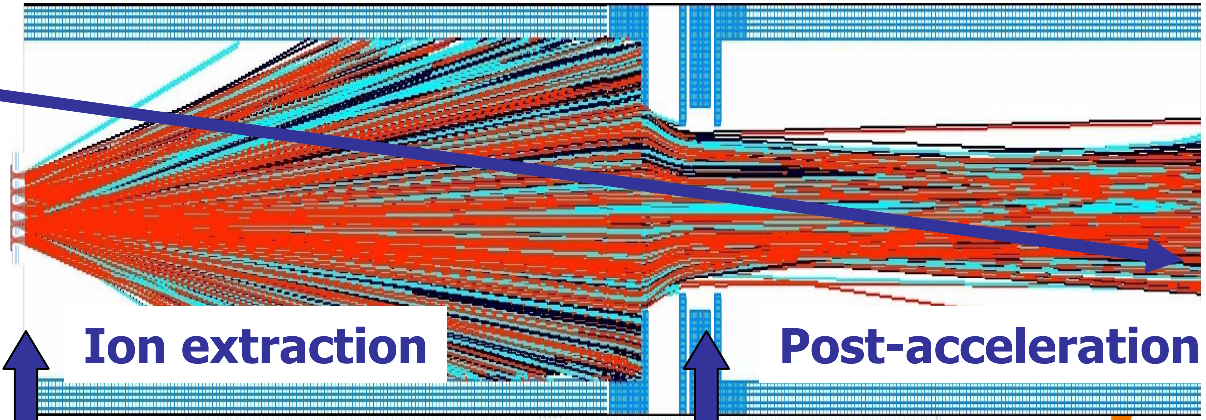
- Assembly of a High Current Test Injector for the exploration of the matching of maximum ion currents to the post- acceleration gap.
- Optimizing the post acceleration gap and LEBT system concerning beam quality (Brillance).
- Minimization of transmission losses.



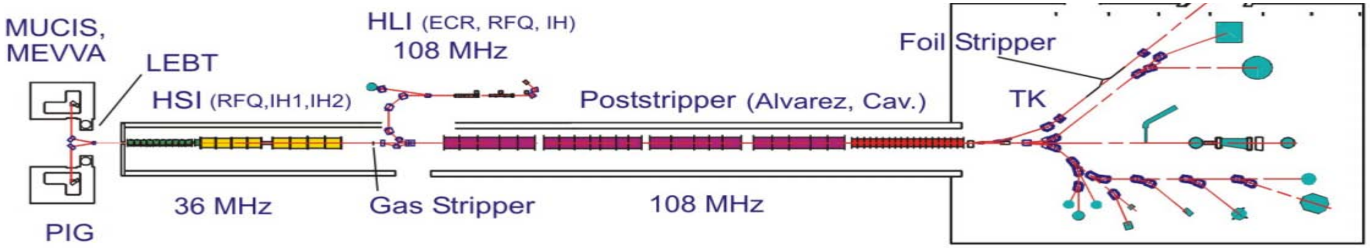


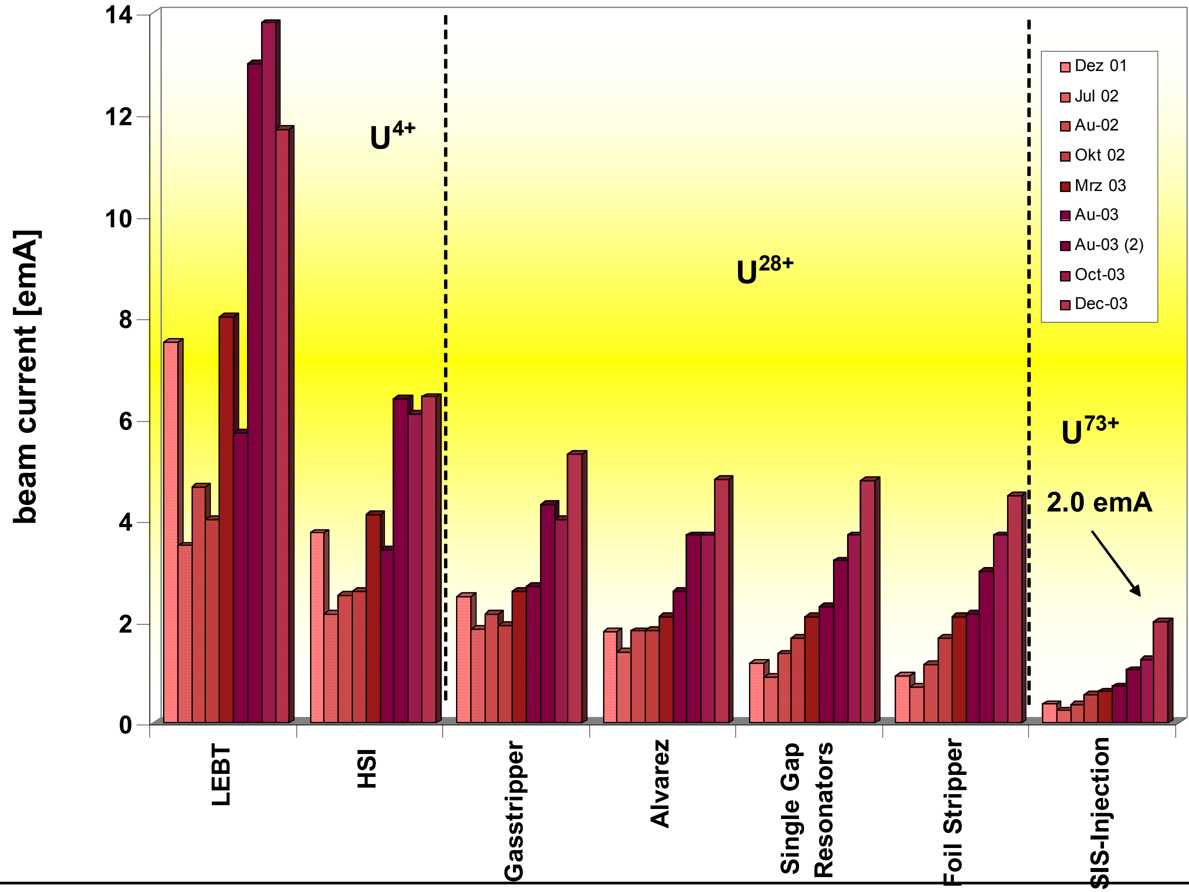
Emittance at 2.2 keV/u

From 94 emA U^{4+} only 37 emA are accelerated to 2.2keV/u
Only 17 emA arrive at RFQ entrance : Losses > 80 %

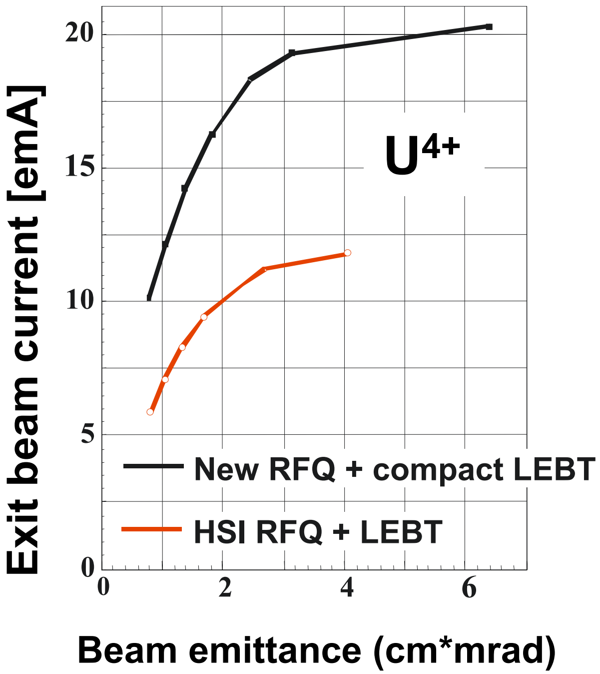


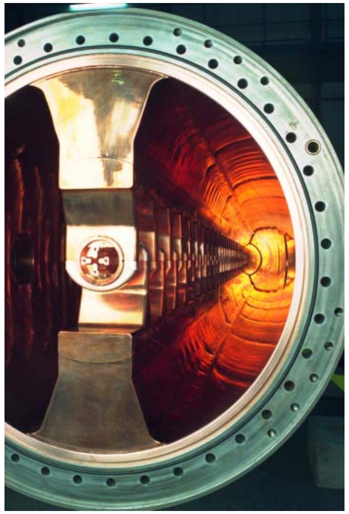
Status – Uranium Beams



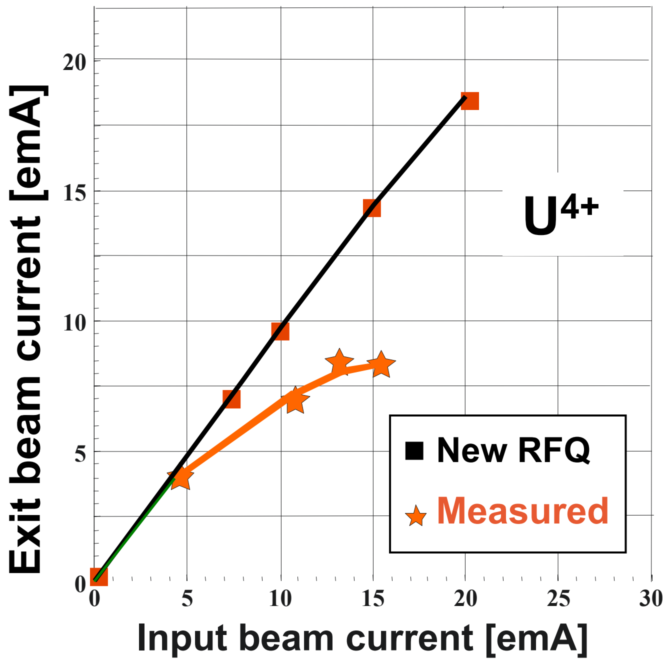


New Front-end System for U^{4+}





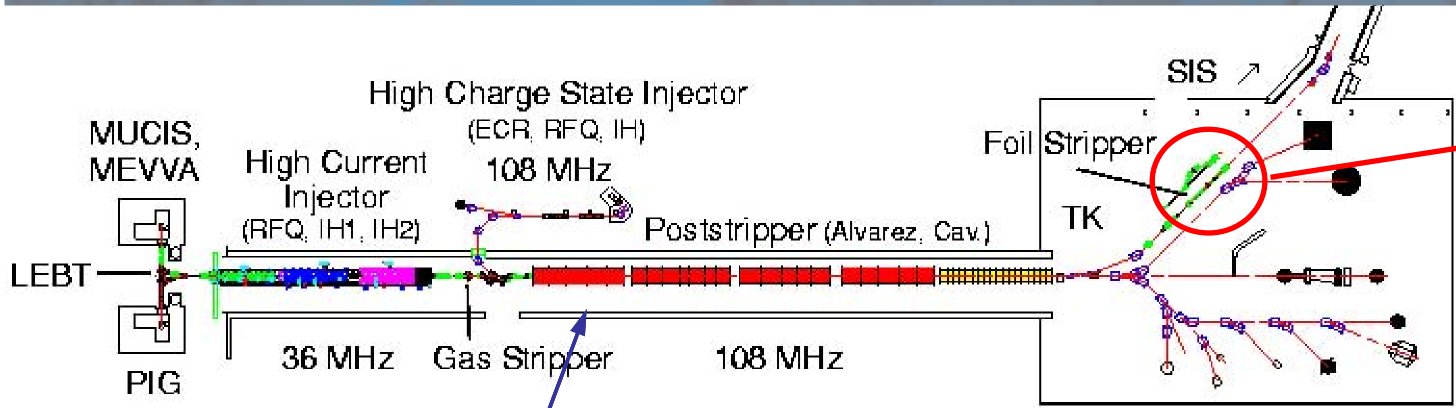
RFQ intensity gain factor: 1.8



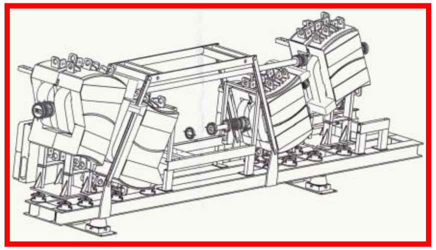
RFQ-Upgrade: Exchange of RFQ-rods, modified IRM,

> longer and larger acceptance

Conservation of Emittance for SIS-Injection

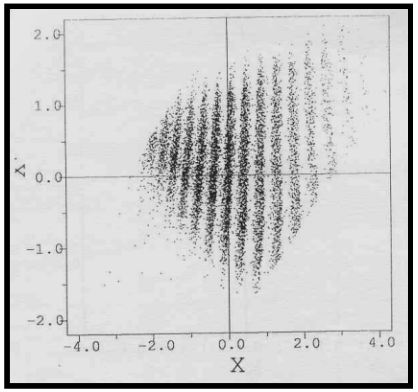


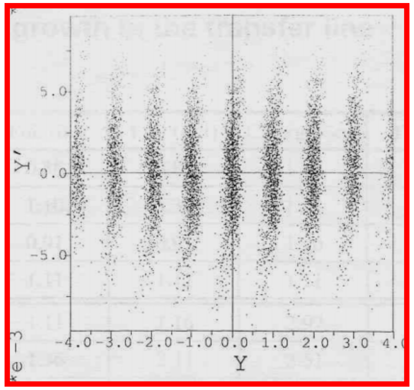
TK charge state separator

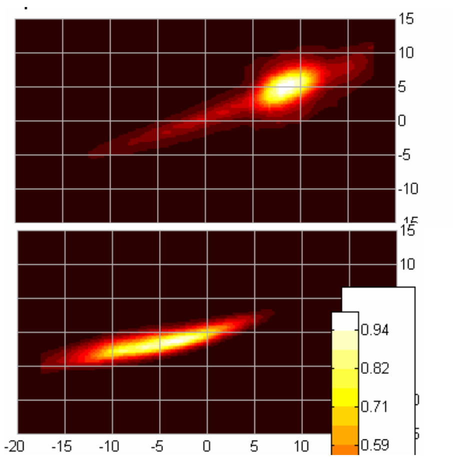


New power supplies → higher focusing strength (phase advance) in Alvarez-Quadrupoles

Beam line separation







$\Delta\Phi_o$ = 39°

$\Delta\Phi_o$ = 51°

- Improvement of beam brilliance: 40-50 %
- Charge state separation at high intensities
- Lower transmission losses in TK and the SIS

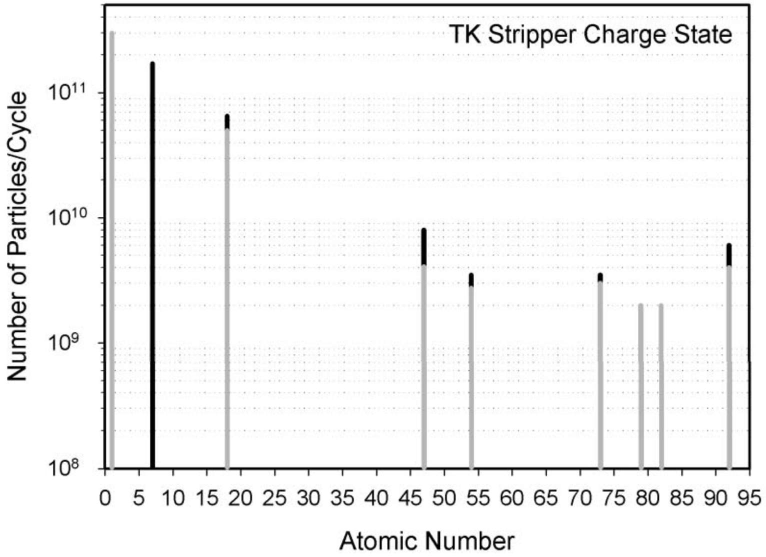
Improvement of beam brilliance: 30 %

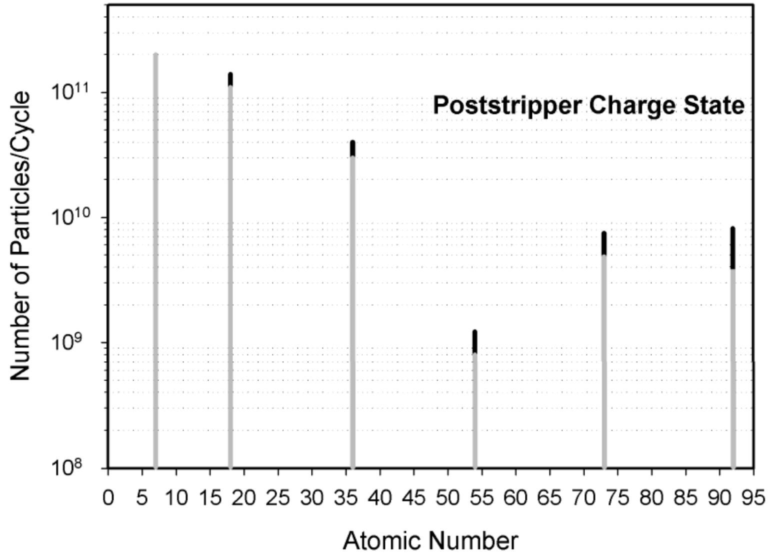
UNILAC Upgrade (2005-2009)

- High Current Test Bench for Ion Development (Post acceleration)
- Dedicated U^{4+}-High Current-Frontend (Compact LEBT + RFQ upgrade)
- Further investigation of the high current matching to Alvarez-DTL
- Increased zero current phase advance in the Alvarez-DTL
- High current beam diagnostics along whole UNILAC
- Compact charge separator for the separation of U^{73+} under sc-conditions

SIS18 - Intensity Status and Requirements

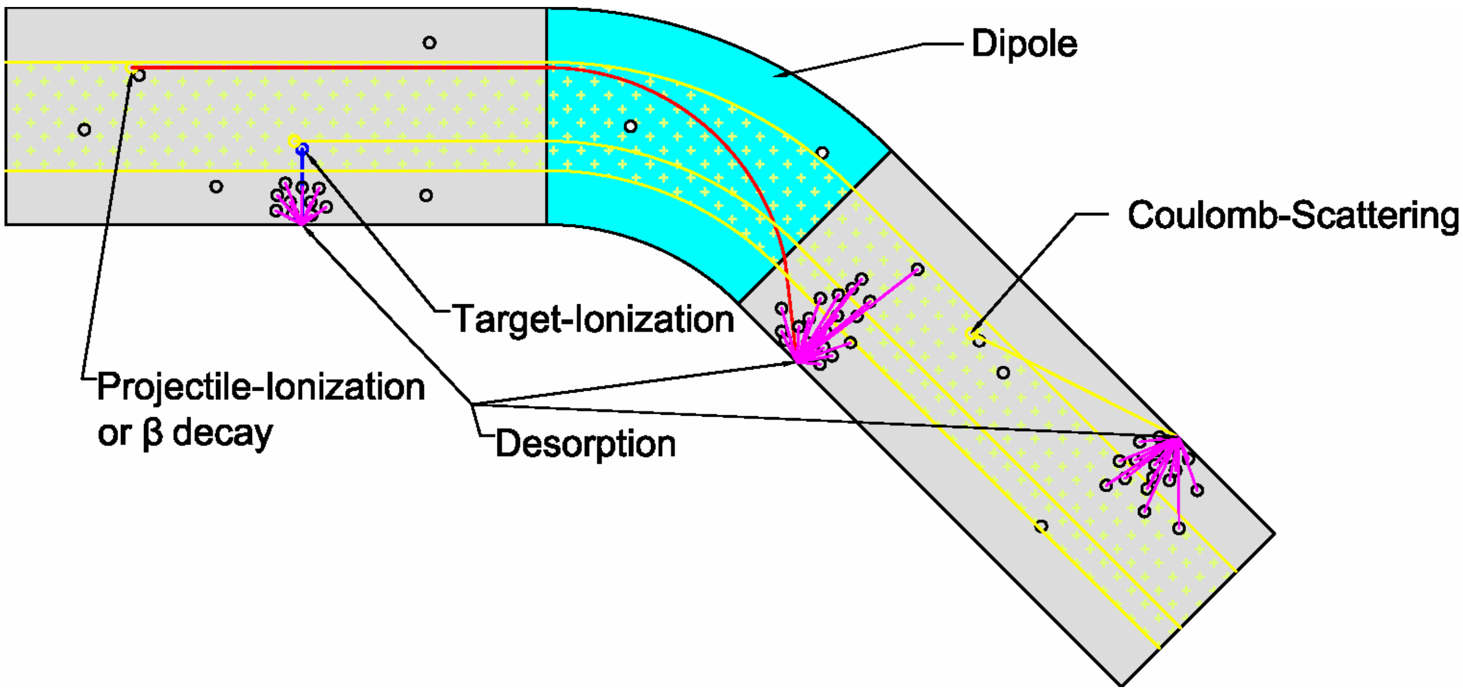
- **Space charge limit for light ions almost achived**
- **Low-charge state heavy ion operation characterized by major ionization loss**





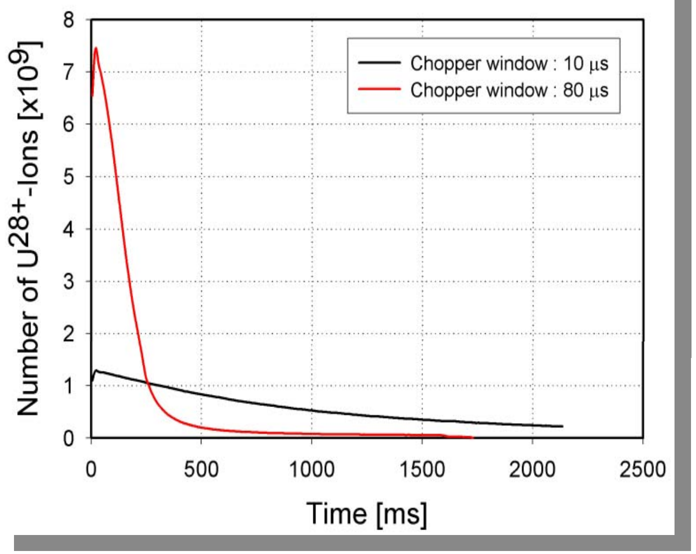
	U^{73+} operation - Stage 1	U^{28+} -operation - Booster Mode
UNILAC Status	**2 mA**	**3 mA**
UNILAC FAIR	**5 mA**	**15 mA (1.5 MW)**
SIS18 Status	**4×10^{9}**	**3×10^{9}**
SIS18 FAIR	**2×10^{10}**	**2.7×10^{11}**

Beam Loss by Charge Change $U^{28+} \rightarrow U^{29+}$

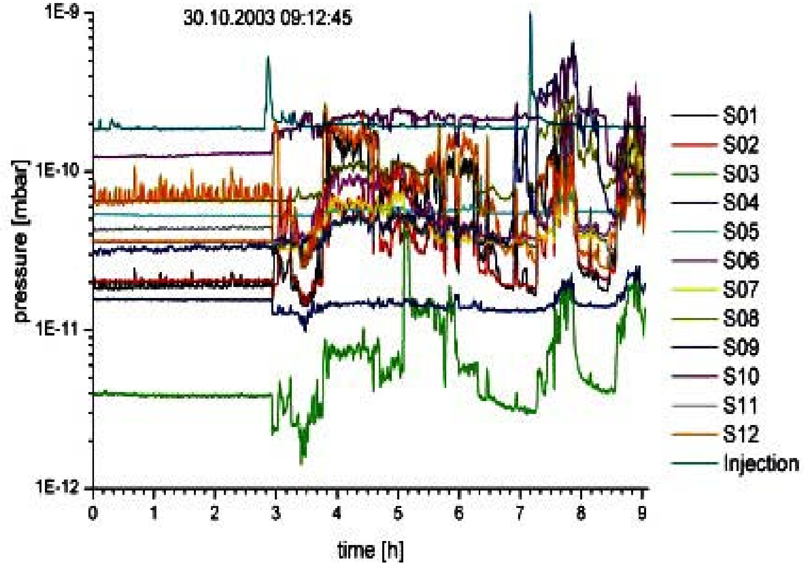


Beam Loss and Dynamic Vacuum

Beam Loss



Dynamic Pressure



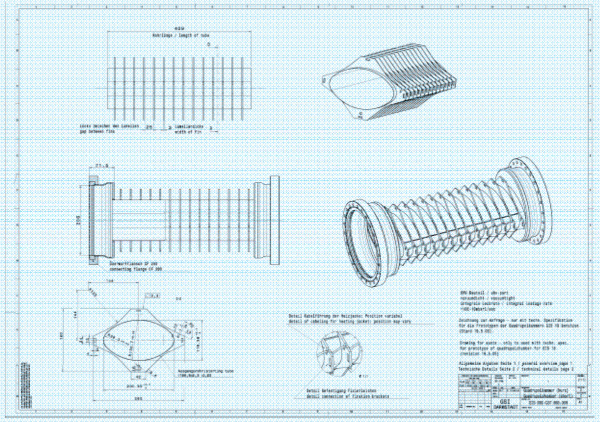
- Beam loss induced desorption degenerates the residual gas pressure and composition
- Degenerated residual gas pressure reduces the beam life time

> Instable during high intensity operation, heavy ion operation

UHV system upgrade

- Generation of extremly low static pressures of $p_0 < 5x10^{-12}$ mbar and increased average pumping speed by up to a factor of 100
- Stabilization of dynamic pressure to $p(t)_{max} < 10^{-9}$ mbar
- Removement of contamination with heavy residual gas components

- **Replacement of all dipole- and quadrupole chambers by new, NEG coated chambers**
- **Improved bake-out system for operation up to 300K**

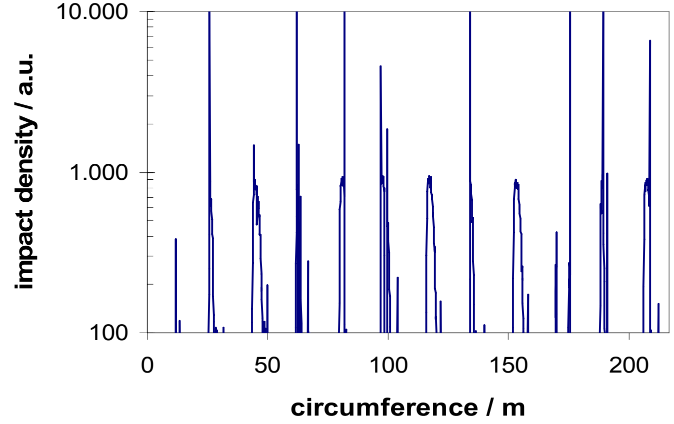


Poster: TUPCH174

Scraper System

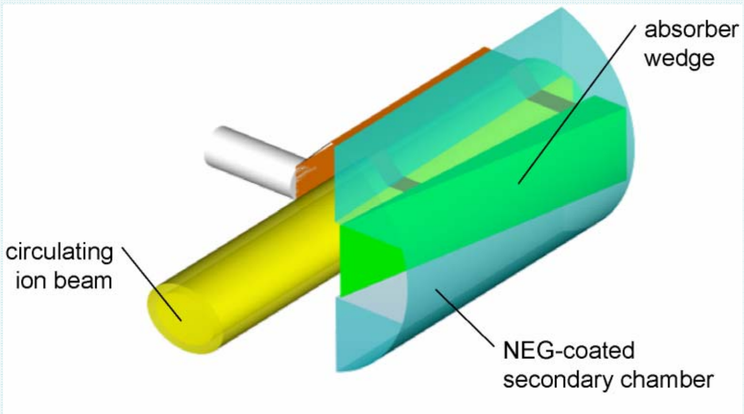
Goals:

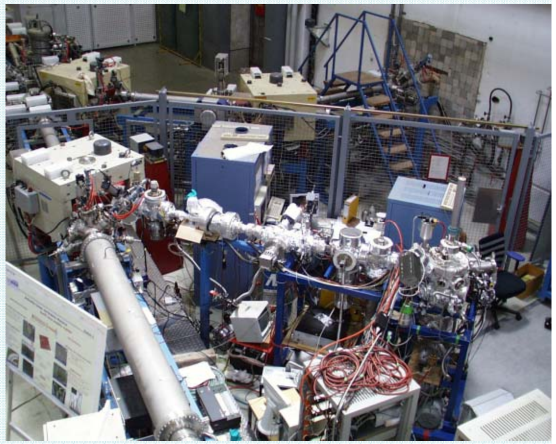
- Minimization of desorption gas production
- Capture and removal of desorbed gas
- Stabilization of the dynamic pressure



Loss Distribution

Poster: TUPCH173

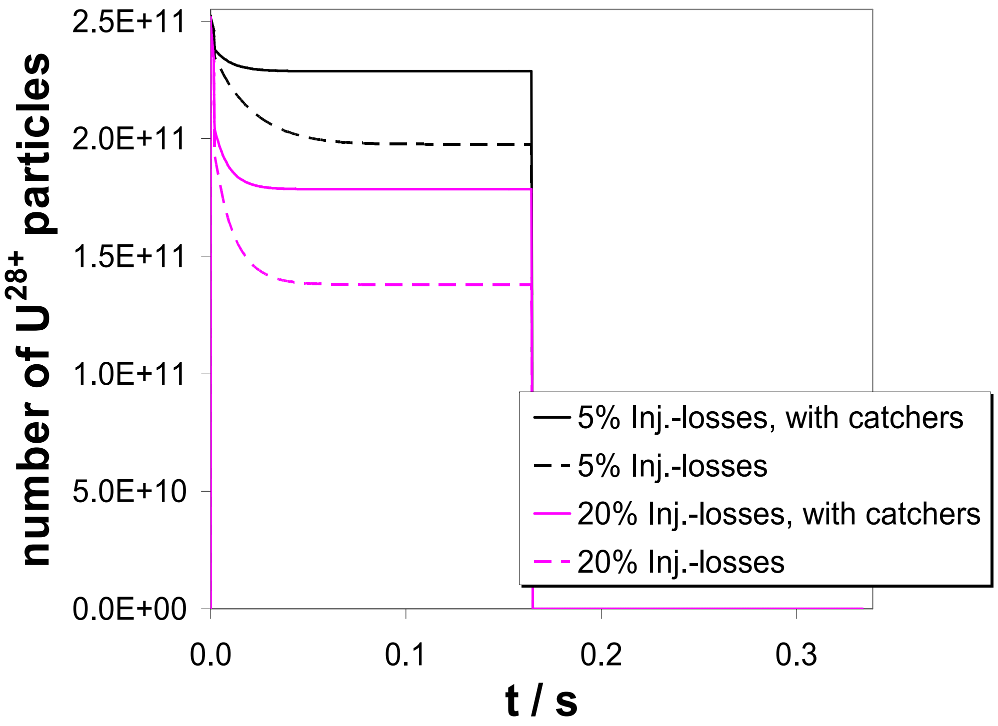




Insertion **Wedge Geometrie** **Low Desorption Material**

Low charge state, U^{28+} operation

Final U^{28+}-operation



Simulation with STRAHLSIM

Only the combination of the following measures leads to the desired results:

1. New NEG coated chambers
2. Catcher system for ionized beam ions in combination with low desorbtion yield materials
3. Fast ramping - short cycle time
4. Minimization of systematic beam losses

Poster: MOPCH078

Power Grid Connection

- The construction and set-up of the new 110 kV connection is finished !

- The new planned operation mode of SIS18 with 10 T/s up to 18 Tm (instead of 12 Tm) has even higher pulse power requirements which must be evaluated.

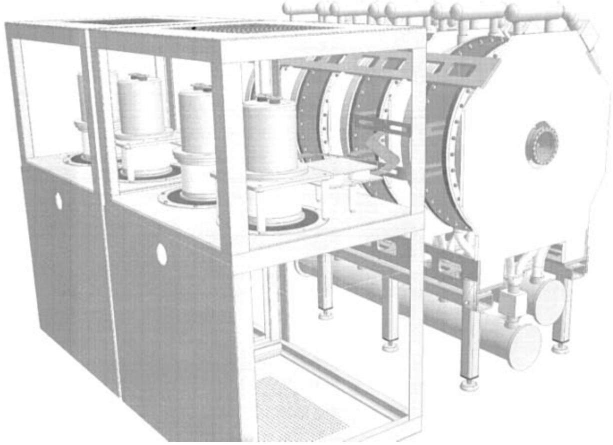
Power measurements in the power grid and near large power plants where conducted succesfully and promising.

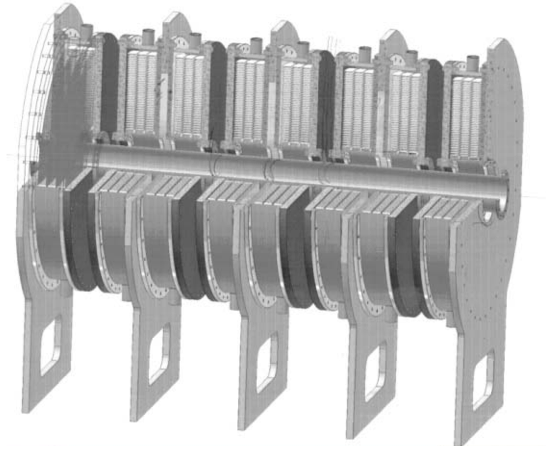
	Peak Power	Field Rate
SIS18	+ 42 MW	10 T/s
SIS100	± 30 MW	4 T/s
SIS300	± 30 MW	1 T/s

High average intensity means fast ramping and short cycle times and high pulse power

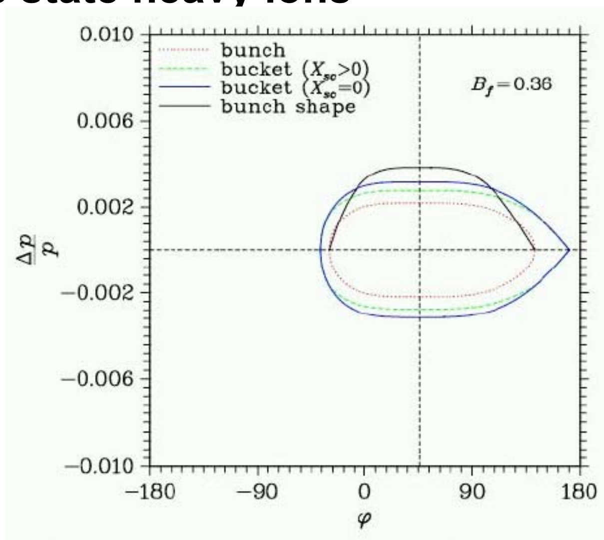
New Acceleration Cavity

Two or three Gap MA (Finemet) Cavity (1.5 MW)





- **Sufficient Rf voltage for fast ramping with low charge state heavy ions**
  U^{73+} acceleration with 4 T/s ($2x10^{10}$ ions)
  U^{28+} acceleration with 10 T/s ($2.7x10^{11}$ ions)
- **Sufficient bucket area for low loss acceleration**
- **Flat bunch profile (larger Bf) for less inc. tune shift**
  Two harmonic acceleration
  h=4 (existing cavity) and h=2 (new Kavität)
- **Compatibility with SIS100 Rf cycle**

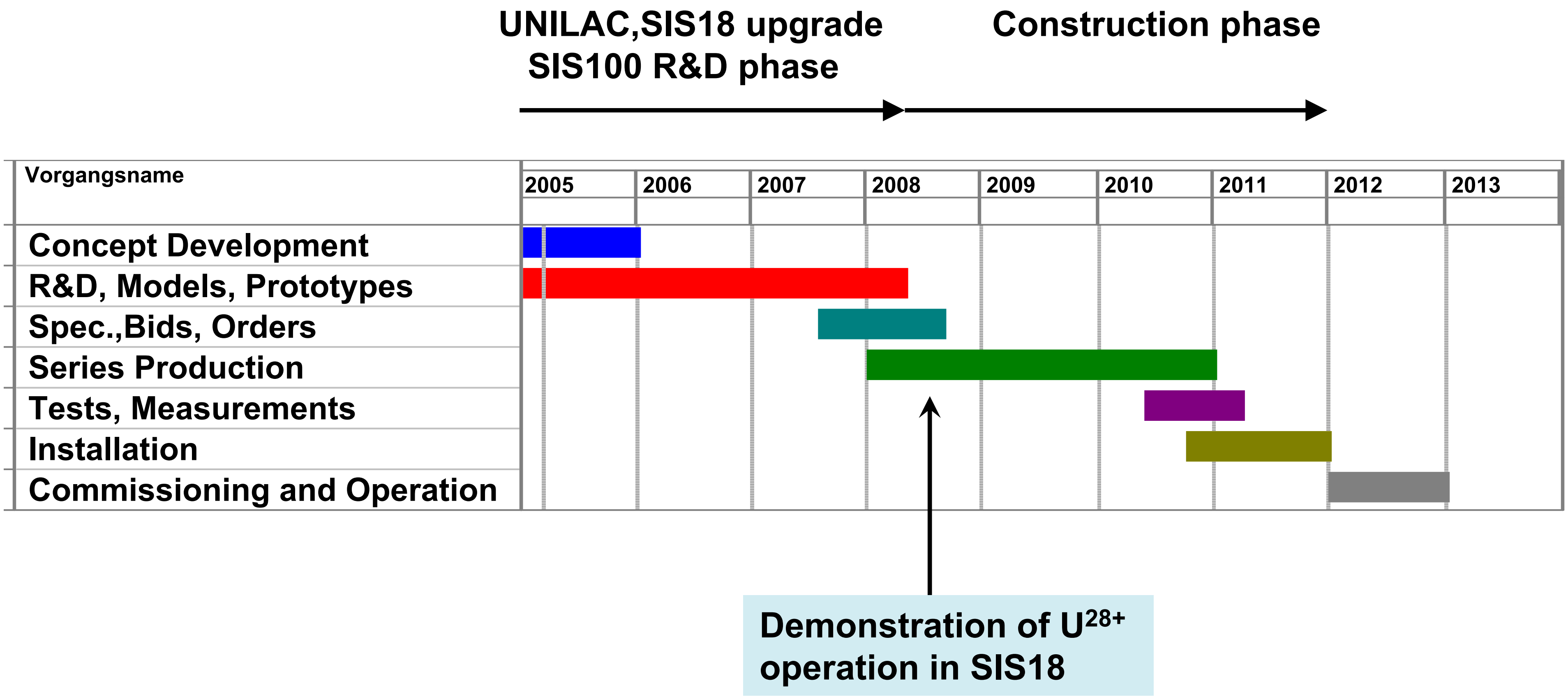


SIS18 upgrade program

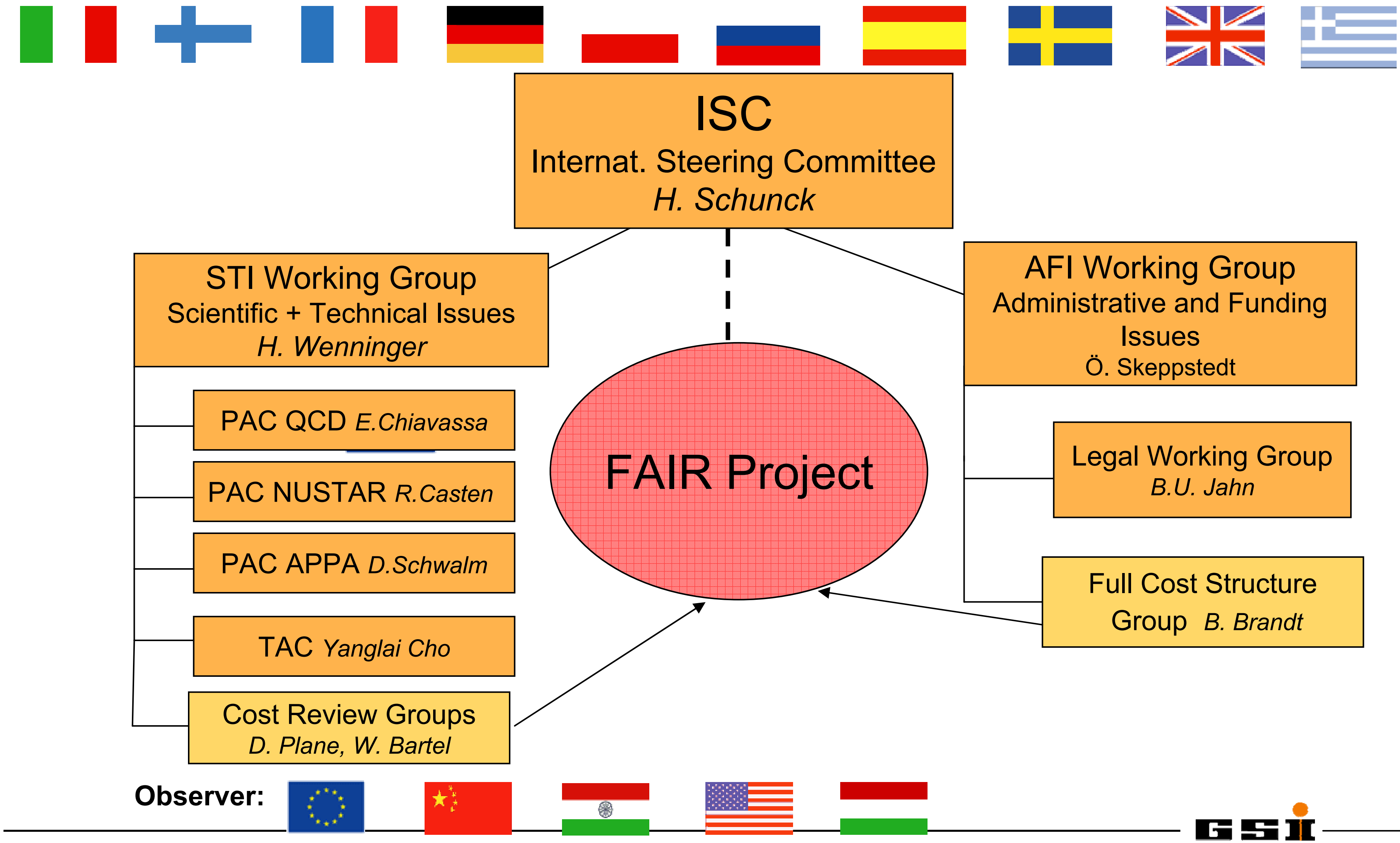
Supported by EU Construction contract:

- Task 1: RF System
  New h=2 acceleration cavity and bunch compresion system for FAIR stage 0, 1
  (2009)
- Task 2: UHV System
  New, NEG coated dipol- and quadrupole chambers
  (2006/2008)
- Task 3: Insertions
  Set-up of a „desorption“ collimation system
  (2007/2008)
- Task 4: Injection / Extraction Systems
  New injection septum, HV power supply and large acceptance extraction channel
  (2007)
- Task 5: Beam Diagnostics Systems
  Fast residual gas profile monitor and high current transformer
  (2007)
- Task 6: Injector
  Set-up of a TK charge separator
  (2007)

SIS100 Project Overview



FAIR (Organisational Structure)



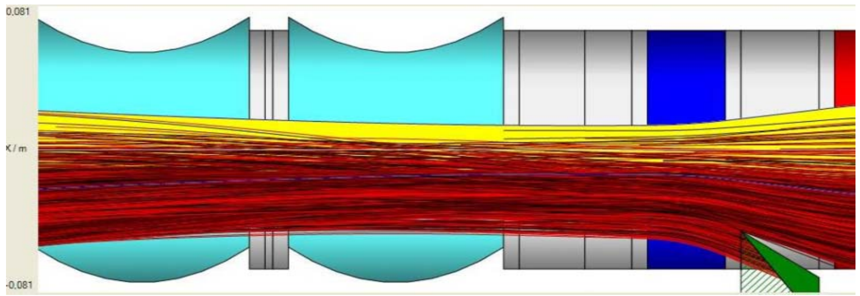
FAIR Baseline Technical Report 2006

submitted to ISC on March 23^{d}, 2006

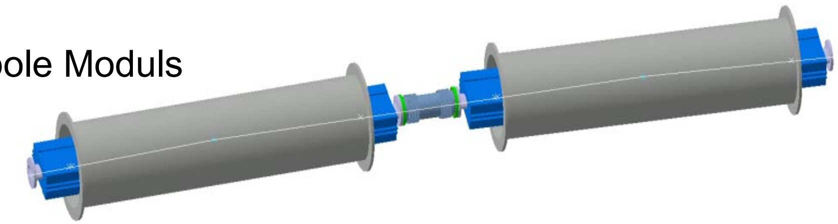
6 Volumes with more ca. 3400 pages and more than 2500 authors

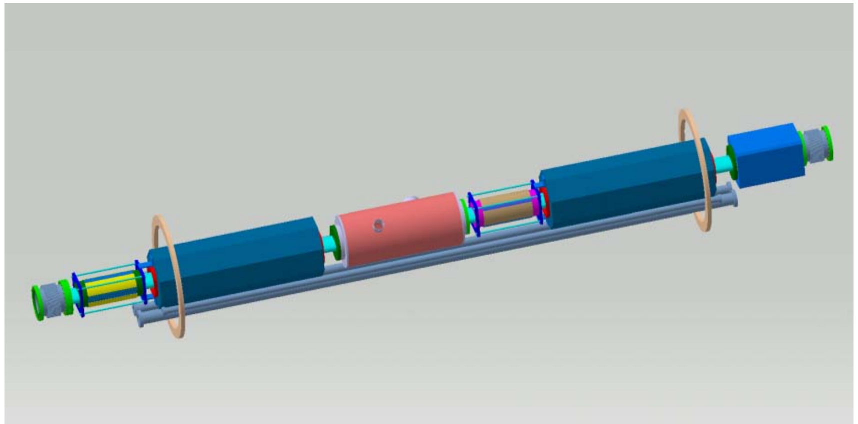
plus Cost Book

SIS100 Layout of Lattice Cell



Dipole Moduls





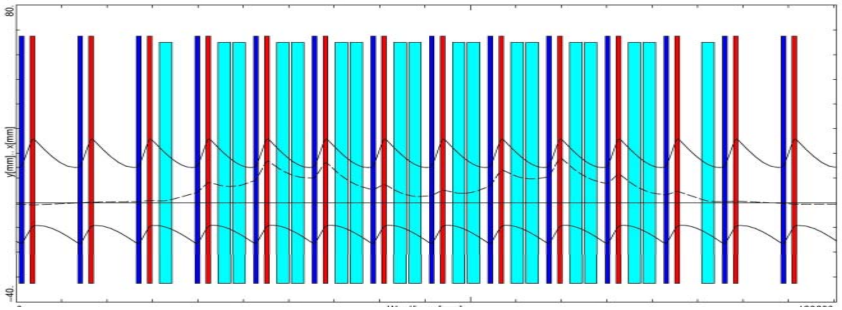
Quadrupol unit of the arcs includes sextupole, BPM and collimator

- The lattice has been optimized for low charge state, heavy ion operation.
- Each lattice cell is a charge separator

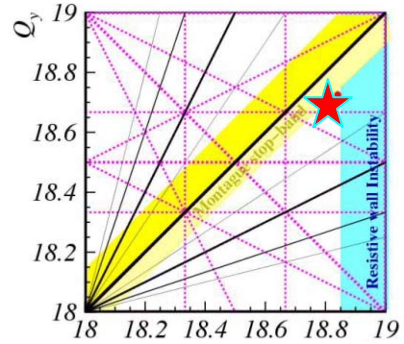
Poster: MOPCH079

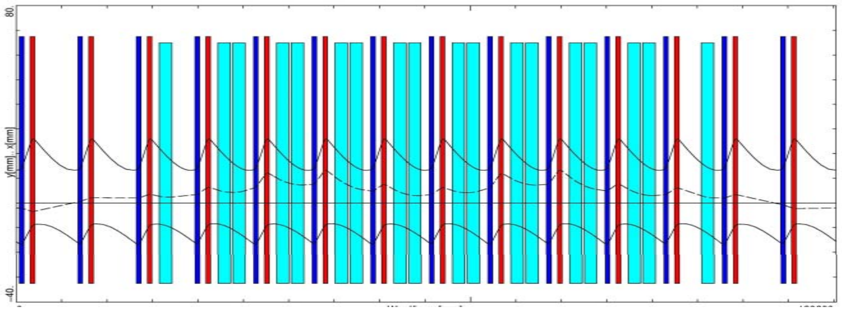
- Maximum beam acceptance („small“ aperture magnets for fast ramping)
- Dispersion free straight sections (no transverse-longitudinal coupling in rf systems)
- Low dispersion in the arcs (momentum spread during compression) D_x= 2.5m
- Six superperiods (space for large tune spread and long storage time)

Operation Modes – Working Point

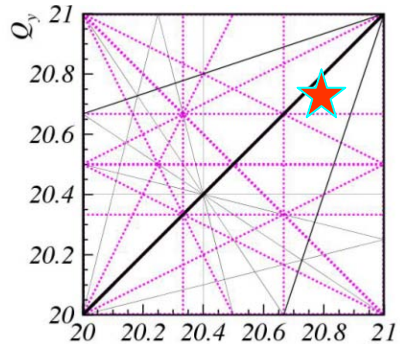


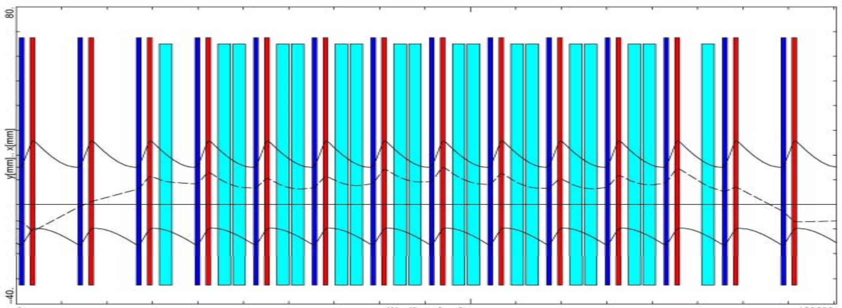
Standard for compression, fast extraction and shift of transition energy – dispersion free, reduced collimation



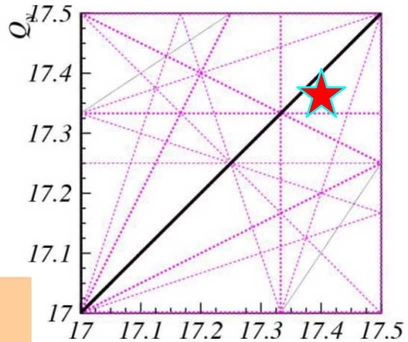


Optional for compression, fast extraction and shift of transition energy – almost dispersion free, good collimation





Standard for slow extraction



Poster: G. Franchetti