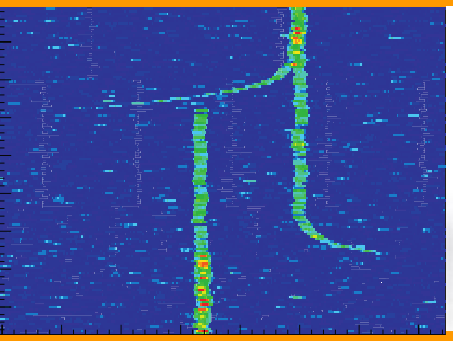
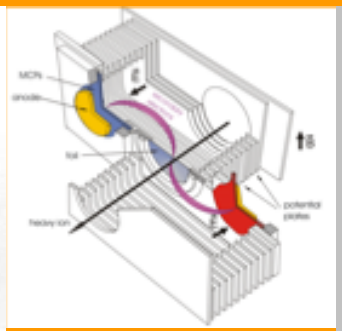
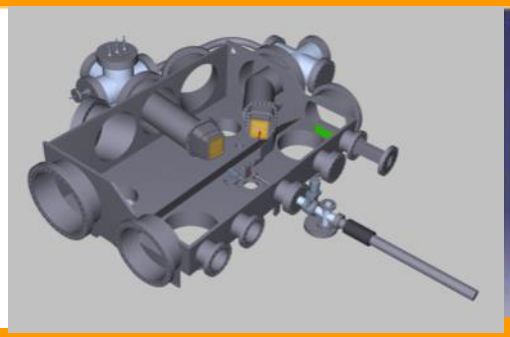


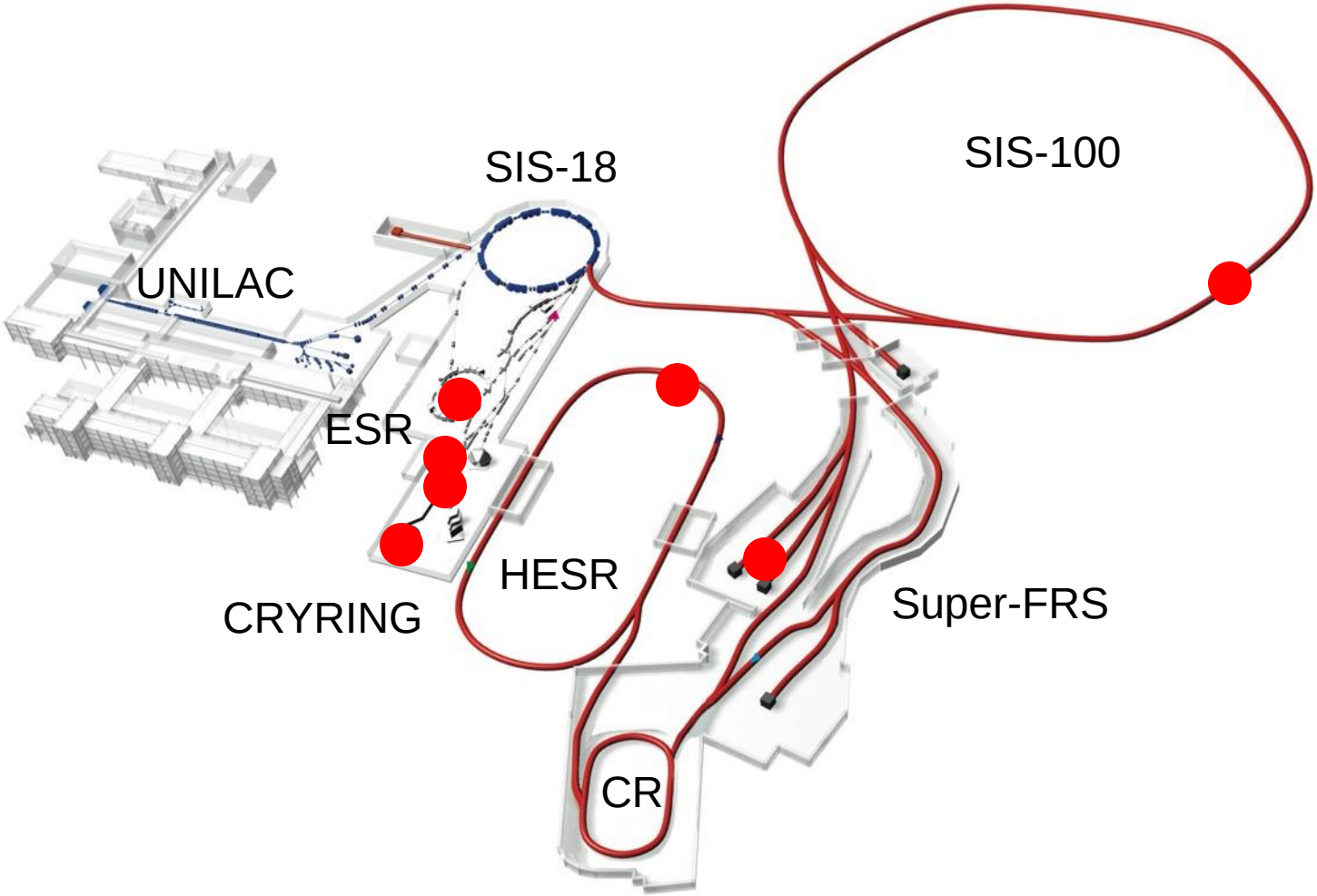




APPA SPARC:
The SPARC experimental program

Yuri A Litvinov
GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt

Journées FAIR-France
17-18 May 2017
Institut de Physique Nucléaire Orsay (IPNO), France

SPARC in FAIR MSV



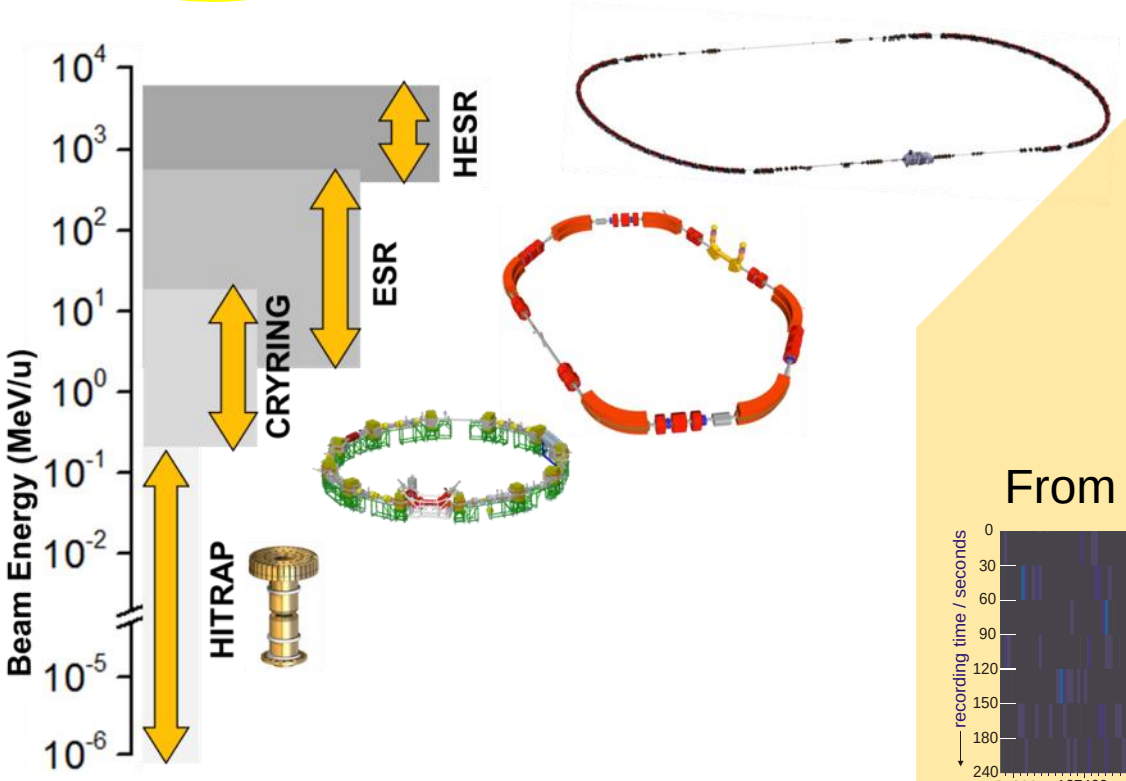
Ion Beam Facilities / Trapping & Storage

Worldwide Unique !

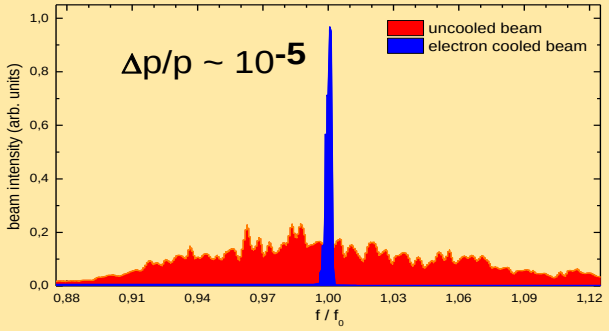
Stored and Cooled

Highly-Charged Ions (e.g. U^{92+}) and Exotic Nuclei

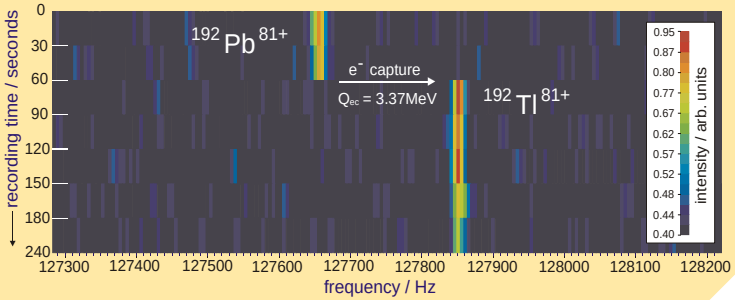
From Rest to Relativistic Energies (up to 4.9 GeV/u)



Cooling: The Key for Precision



From Single Ions to Highest Intensities



FAIR Green Paper

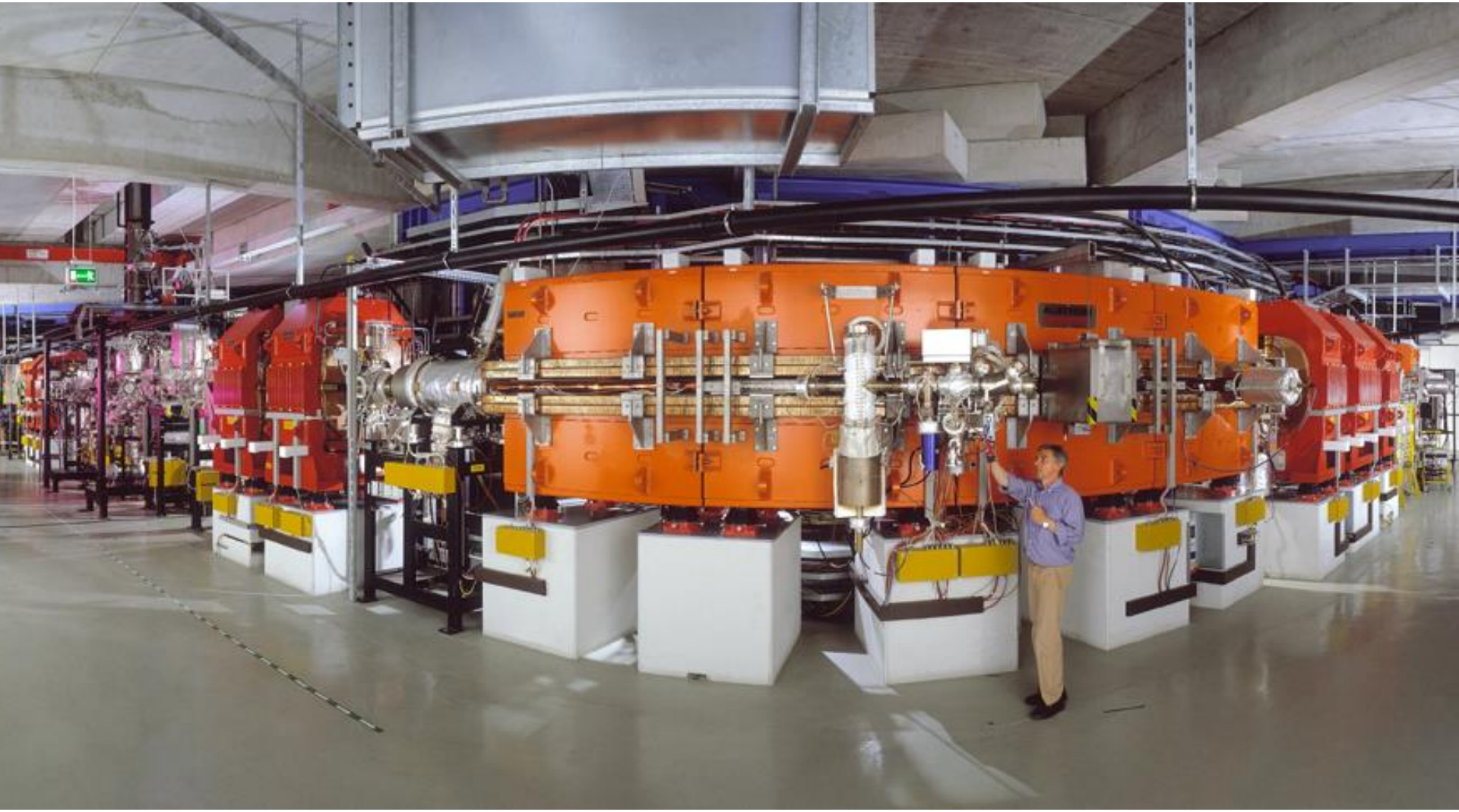
Beside the reaction microscope mentioned, novel instrumentations will be developed and used by the collaboration. These include micro-calorimeters and polarimeters for hard X-rays and spectrometers for electrons, positrons and ions. In addition, novel lasers and targets (gaseous, micro droplet, and superfluid targets) will be exploited. All these developments are also of particular relevance for future prospects of the SPARC physics programme which concentrates on storage rings and traps, and will become possible with Module 4. For the realization of this programme the ESR storage ring and the HITRAP facility need to be maintained in operation at GSI until they shall be surpassed by Module 4.

Green Paper

The Modularized Start Version

October 2009

Experimental Storage Ring ESR



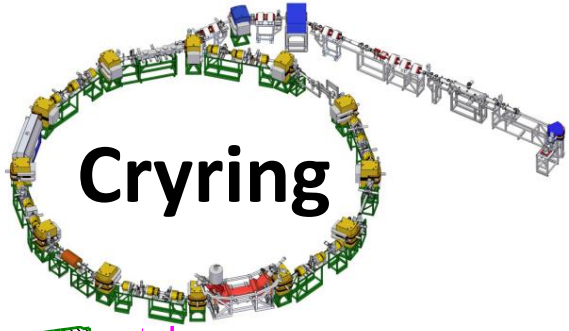
ESR: B. Franzke, NIM B 24/25 (1987) 18

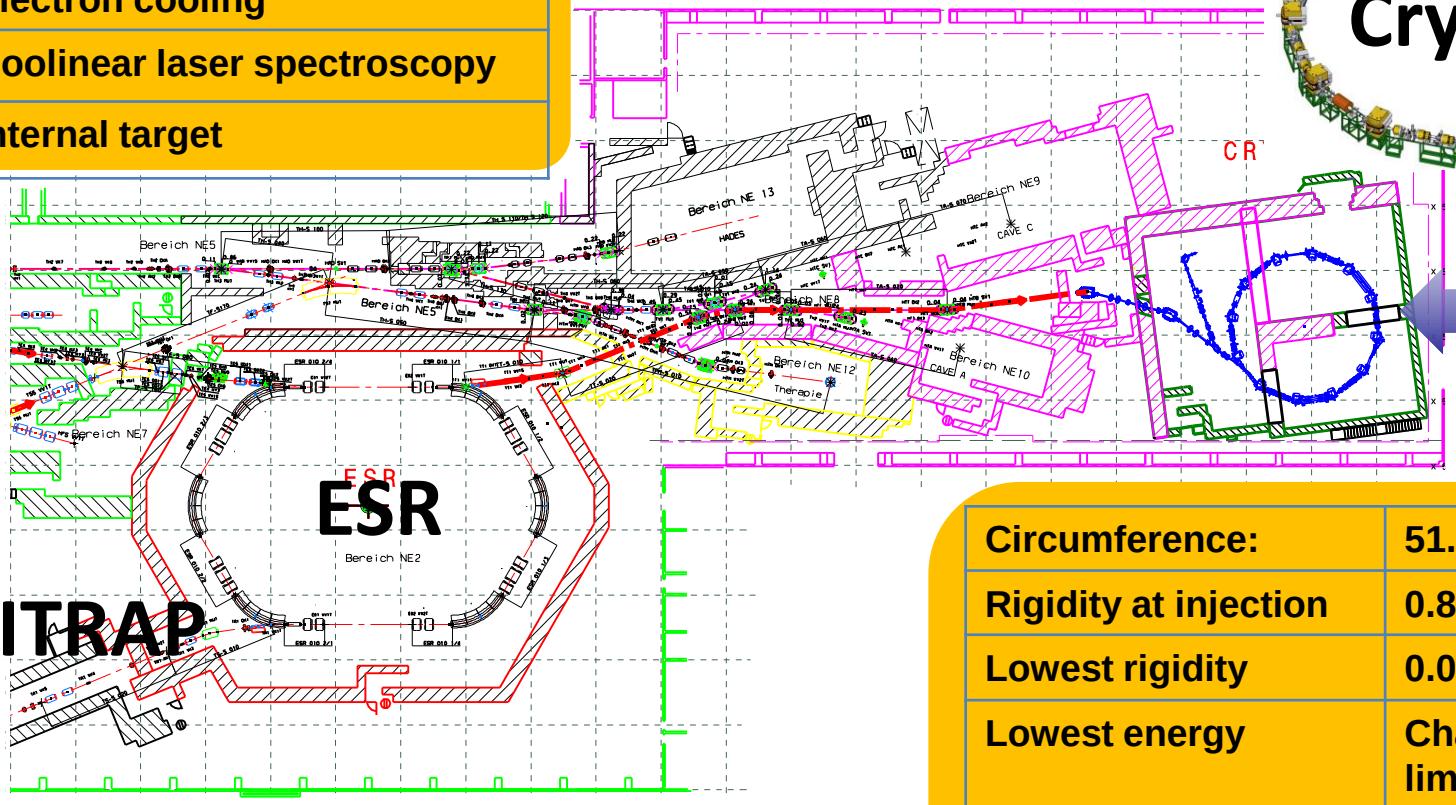
Stochastic cooling: F. Nolden et al., NIM B 532 (2004) 329
Electron cooling: M. Steck et al., NIM B 532 (2004) 357

CRYRING@ESR

Project coordination:
F. Herfurth & M. Lestinsky

- Electron cooling
- Coolinear laser spectroscopy
- Internal target





Circumference:	51.63 m
Rigidity at injection	0.88 Tm (1.44 Tm)
Lowest rigidity	0.054 Tm
Lowest energy	Charge exchange limited
Magnet ramping	7 T/s; 1 T/s
Vacuum system	10^{-11} -10^{-12} bar
Slow extraction	

Working group report: http://www.gsi.de/en/start/fair/fair_experimente_und_kollaborationen/sparc/news.htm

Eur. Phys. J. Special Topics **225**, 797–882 (2016)

DOI: 10.1140/epjst/e2016-02643-6

THE EUROPEAN PHYSICAL JOURNAL SPECIAL TOPICS

Review

CRYRING Physics Book

Physics book: CRYRING@ESR

M. Lestinsky[1], V. Andrianov[1,2,3], B. Aurand[1], V. Bagnoud[1], D. Ber
H. Beyer[1], S. Bishop[4], K. Blaum[5], A. Bleile[1,6], At. Borovik Jr.[7], F.
C.J. Bostock[8], C. Brandau[1,7], A. Bräuning-Demian[1], I. Bray[8], T. Da
B. Ebinger[7], A. Echler[1,6,3], P. Egelhof[1,6], A. Ehresmann[10], M. Engst
C. Enss[12], N. Ferreira[5], D. Fischer[5], A. Fleischmann[12], E. Förster[13]
S. Fritzsche[13,14], R. Geithner[13], S. Geyer[16], J. Glorius[16], K. Göbel[16],
J. Goullon[5], P. Grabitz[1,6], R. Grisenti[1], A. Gumberidze[1], S. Hagmann
A. Heinz[21], F. Herfurth[1], R. Heß[1], P.-M. Hillenbrand[1], R. Hubele[5], P.
A. Källberg[11], O. Kester[1,16], O. Kiselev[1], A. Knie[10], C. Kozhuharov[1],
S. Kraft-Bermuth[3], T. Kühl[22], G. Lane[17], Yu.A. Litvinov[1,5], D. Lie
X.W. Ma[18], R. Märtin[14], R. Moshammer[5], A. Müller[3], S. Namba[19], P
T. Nilsson[21], W. Nörtershäuser[22], G. Paulus[13,14], N. Petridis[1], M. R
R. Reifarth[1,16], P. Reiß[10], J. Rothhardt[14], R. Sanchez[1], M.S. Sanja
S. Schippers[7], H.T. Schmidt[11], D. Schneider[23], P. Scholz[3,7], R. Schuch[11],
M. Schulz[24,16], V. Shabaev[25], A. Simonsson[11], J. Sjöholm[11], Ö. Skeppstedt[11],
K. Sonnabend[1,16], U. Spillmann[1], K. Stiebing[16], M. Steck[1], T. Stöhlker[1,13,14],
A. Surzhykov[26], S. Torilov[25], E. Träbert[27], M. Trassinelli[28], S. Trotsenko[1,14],
X.L. Tu[1,18], I. Uschmann[13,14], P.M. Walker[29], G. Weber[1,14], D.F.A. Winters[1],
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N. Ferreira,[f] D. Fischer,[f] A. Fleischmann,[s] E. Förster,[i,j] S. Fritzsche,[1,c,q,r] R. Geithner,[i]
J. Goullon,[f] R. Grisenti,[1] A. Gumberidze,[b,c] S. Hagmann,[1] M. Heil,[1] A. Heinz,[e] R. Hubele,[f]
P. Indelicato,[t] A. Källberg,[n] C. Kozhuharov,[1] T. Kühl,[1] M. Lestinsky,[1] D. Liesen,[1]
Yu. A. Litvinov,[1,f] R. Märtin,[j] R. Moshammer,[f] A. Müller,[g] S. Namba,[3] P. Neumeyer,[b]
T. Nilsson,[e] G. Paulus,[i,j] R. Reifarth,[1,h] R. Reuschl,[b,c] S. Schippers,[g] H. Schmidt,[n] R. Schuch,[n]
M. Schulz,[p,h] V. Shabaev,[?] A. Simonsson,[n] J. Sjöholm,[n] Ö. Skeppstedt,[n] K. Sonnabend,[h]
U. Spillmann,[1] K. Stiebing,[h] Th. Stöhlker,[1,i,j] A. Surzhykov,[q] E. Träbert,[k] M. Trassinelli,[u]
S. Trotsenko,[j] I. Uschmann,[i,j] P. M. Walker,[l,m] G. Weber,[1,j] D. F. A. Winters,[1] P. J. Woods,[d]
H. Y. Zhao,[?] *et al.*

Presently:
63 Scientists from
24 Institutions in
10 Countries

CRYRING@ESR: Highly-Charged Ions at Low Energies

- **Spectroscopy for tests of QED**
  - High-precision x-ray spectroscopy
    - 1s-Lamb-Shift
    - Two-Electron-QED
  - Recoil ion momentum spectroscopy
    - Highly-excited stated
  - Laser spectroscopy
  - Recombination spectroscopy with high resolution
- **Atomic collisions**
  - Sub-femtosecond correlated dynamics
  - Unexplored regime: strong perturbation Q/v
- **Nuclear Physics at low-energies**
  - exotic nuclear decay modes
  - astrophysical reactions
  - Transfer reactions at Coulomb barrier

Features@Cryring

- Low-energy and electron cooled beams
- Electron cooling with adiabatic expansion
- High-luminosity for in-ring experiments
- Very fast deceleration 7 T/s
- Internal jet and electron target
- Slow extraction

Research with CRYRING@ESR Workshop

Research with CRYRING@ESR

24-25 April 2017
GSI Helmholtzzentrum für Schwerionenforschung
Europe/Berlin timezone

Overview

- Scientific Programme
- Timetable
- Contribution List
- Registration
  - Registration Form
- List of registrants
- Travel and accomodation

Support

t.litvinova@gsi.de

In the last few years, the CRYRING@ESR project has been a huge effort which is soon complete and is now gradually transiting into productive operation with commissioning presently ongoing. Soon, first scientific results will be produced at this new facility.

This wokshop shall celebrate the project status and preview the diversity of the future experimental programme by presentations and posters and guided tours around the new installation.

Starts Apr 24, 2017 13:00
Ends Apr 25, 2017 18:00
Europe/Berlin

GSI Helmholtzzentrum für Schwerionenforschung
Hörsaal KBW 1.017

Planckstraße 1
64291 Darmstadt
Germany

Dr. Herfurth, Frank
Dr. Lestinsky, Michael
Stöhlker, Thomas

SPARC@HESR Feasibility Study

FACILITY FOR ANTIPROTON AND ION RESEARCH

SPARC Experiments at the HESR:

A Feasibility Study

Thomas Stöhlker[1,2,3], Reinhold Schuch[4], Siegbert Hagmann[1,5], Yuri A. Litvinov[1,2]
for the SPARC Collaboration*←
Christina Dimopoulou[1], Alexei Dolinskii[1], & Markus Steck[1]

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[2] *Ruprecht-Karls-Universität Heidelberg, 69120 Heidelberg, Germany*
[3] *Helmholtz Institute Jena, 07743 Jena, Gemany*
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[5] *Goethe-Universität Frankfurt, 60438 Frankfurt, Germany*
*← *See Section 8*

UPDATED on January 26, 2012

Abstract

The physics program of the SPARC collaboration at FAIR focuses on the study of collision phenomena in strong and even extreme electromagnetic fields and on the fundamental interactions between electrons and heavy nuclei up to bare uranium. The current report documents the feasibility of the HESR storage ring operating with heavy-ion beams with particular emphasis given to the requirements of the experimental program of the SPARC collaboration.

FAIR

FAIR GmbH · Planckstr. 1 · D-64291 Darmstadt · Germany

Proposers of the
Feasibility Study for FAIR:
SPARC Experiments at the HESR
for APPA-SPARC

Facility for Antiproton and Ion Research in Europe GmbH

Planckstr. 1
D-64291 Darmstadt
Germany

Web: www.fair-center.eu

Prof. Dr. Günther Rosner
Research & Admin.
Managing Director
FAIR GmbH

Telephone: +49 6159 71-1678
Fax: +49 6159 71-3916

Email: guenther.rosner@fair-center.eu

10 April 2014

Dear colleagues,

Approval of Feasibility Study

We are happy to inform you that FAIR approves the Feasibility Study: *SPARC Experiments at the HESR* for APPA-SPARC, following the recommendation by the Expert Committee Experiments (ECE) on 10 April 2014. Please find attached comments by the ECE. We expect that you consider these seriously and take appropriate steps. In addition, please accept the offer of the expert panel and the ECE to continue working together to follow up the process.

Yours sincerely

Facility for Antiproton and Ion Research
in Europe GmbH

G. Rosner
Research & Admin.
Managing Director

FAIR GmbH

Managing Directors:
Professor Dr. Boris Y. Sharkov
Professor Dr. Günther Rosner

Registered office: Darmstadt
Amtsgericht Darmstadt HRB 89372

VAT No.: DE275595927

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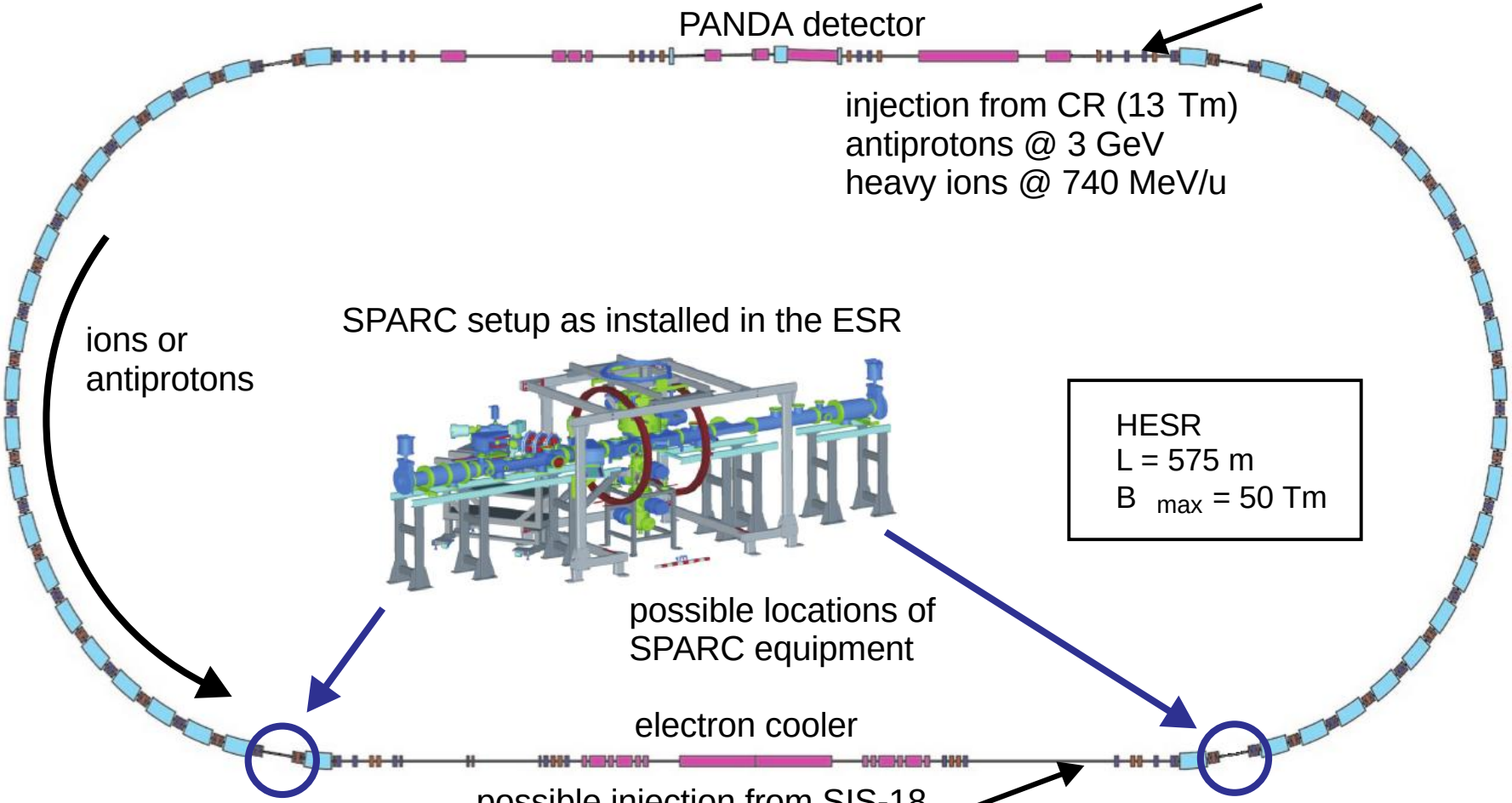
SPARC@HESR


PANDA detector
injection from CR (13 Tm)
antiprotons @ 3 GeV
heavy ions @ 740 MeV/u
ions or
antiprotons
SPARC setup as installed in the ESR
HESR
L = 575 m
B max = 50 Tm
possible locations of
SPARC equipment
electron cooler
possible injection from SIS-18
heavy ions @ 10-13 Tm

Precision Experiments at High Energies (HESR)

pair-production phenomena
- non-perturbative regime ($\alpha Z_1 \approx \alpha Z_2 \approx 1$)
- multiple pairs
- negative continuum dielectronic recombination

radiative processes
- recombination (polarization phenomena etc.)
- photon-photon angular correlation

target ionization
- correlated electron motion – ultrafast pulses
  extremely strong transient fields of relativistic ions

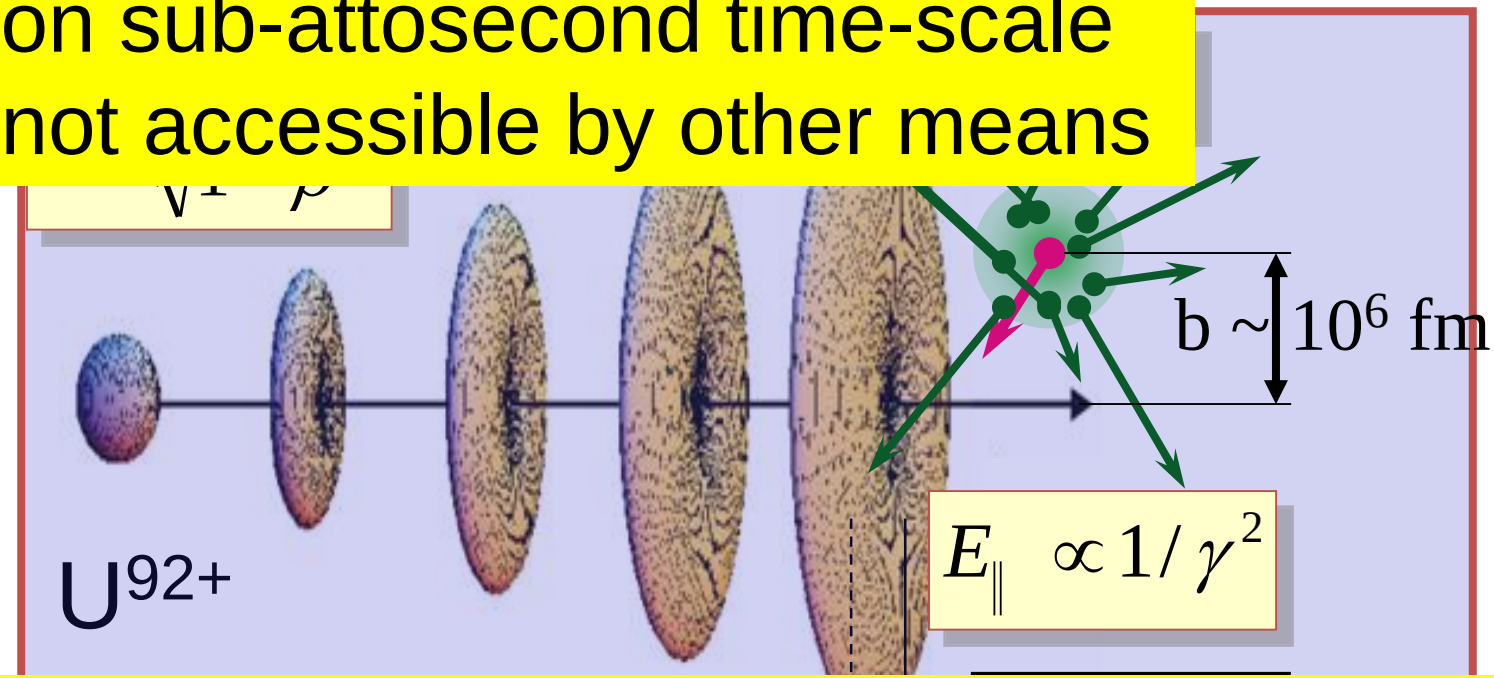
bound state QED and nuclear parameters
- laser excitation in Li-like ions ($\Delta n = 0$)

laser interaction at high γ
- test of special relativity
- laser cooling
- laser assisted pair creation

fundamental physics
- PNC effects in high-Z ions

Extreme Dynamic Fields

Explore correlated electron dynamics
- on sub-attosecond time-scale
- not accessible by other means



Relativistic quantum dynamics
- particle production
- non-perturbative regime
- coupling to the radiation field

SPARC Internal Target Station

Operation modes: supersonic cluster-jet; liquid droplet beam

FACILITY FOR ANTIPROTON AND ION RESEARCH

Technical Design Report for:
Internal Target@HESR

sparc

N. Petridis[1,2,3], A. Kalinin[1], and R. E. Grisenti[1,3]
for the SPARC Collaboration

[1] GSI Helmholtzzentrum für Schwerionenforschung, Planckstr. 1, 64291 Darmstadt, Germany
[2] Goethe-Universität Frankfurt/M, Max-von-Laue-Str. 1, 60438 Frankfurt/M, Germany
[3] Extreme Matter Institute EMMI, Planckstr. 1, 64291 Darmstadt,Germany

TDR Approved by ECE
10/04/2014

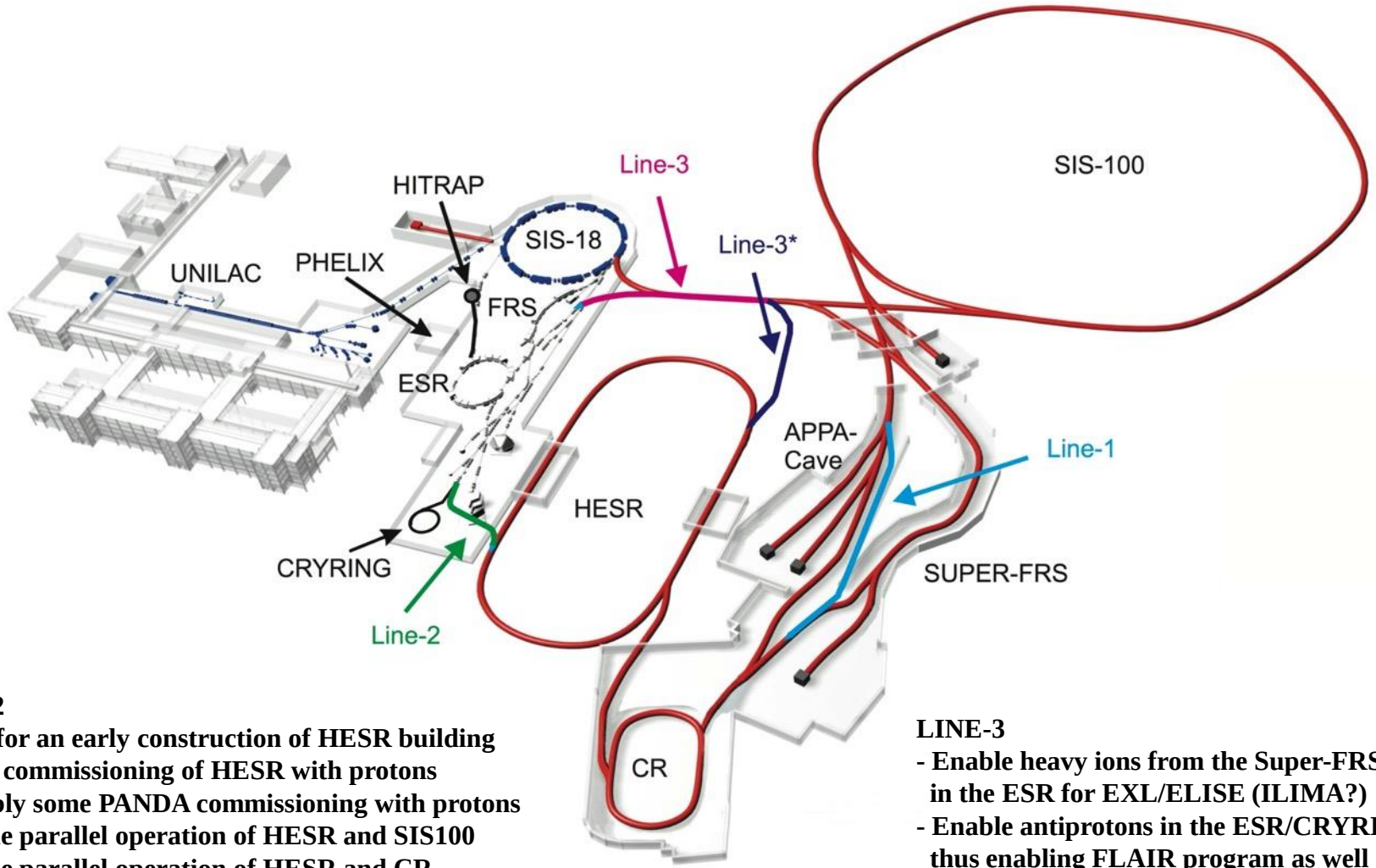
- Target area densities of the order of 10^{14} cm^2 (from hydrogen to xenon) can be expected.
- Will enable a small interaction length of about 1 mm.

Prototype target in operation at ESR

Target gas	Area density [cm^{-2}]	T_0 [K]
Helium	1×10^{13}	20
Hydrogen	3×10^{13}	40
Nitrogen	8×10^{12}	130
Argon	3.5×10^{12}	300
Krypton	1.5×10^{12}	300
Xenon	6×10^{12}	300

Synergies: SPARC prototype target enabled the first successful EXL experiment at ESR

Extensions of the MSV of FAIR



LINE-2
- **Push for an early construction of HESR building**
- **Early commissioning of HESR with protons**
- **Possibly some PANDA commissioning with protons**
- **Enable parallel operation of HESR and SIS100**
- **Enable parallel operation of HESR and CR**
- **Realization of SPARC program at the HESR**
- **Realization of a part of ILIMA with ESR-HESR**

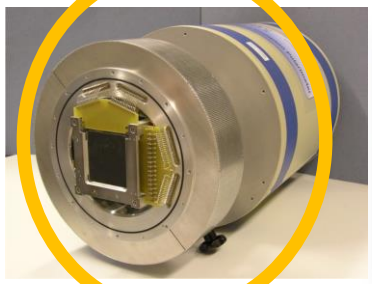
LINE-3
- **Enable heavy ions from the Super-FRS in the ESR for EXL/ELISE (ILIMA?)**
- **Enable antiprotons in the ESR/CRYRING, thus enabling FLAIR program as well as hadron physics with slow antiprotons**

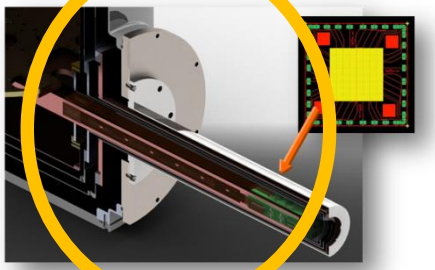
Sophisticated & Versatile Instrumentation

Observables: Photons, electrons, positrons, ion

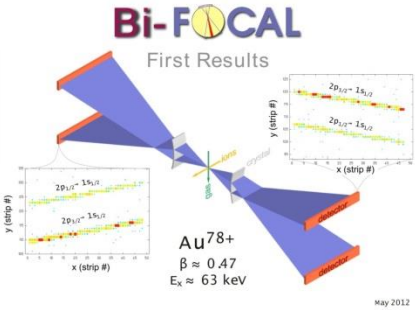
Equipment available/in preparation for HESR

Targets

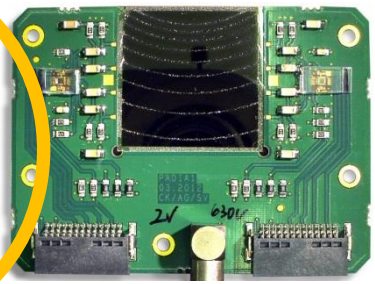




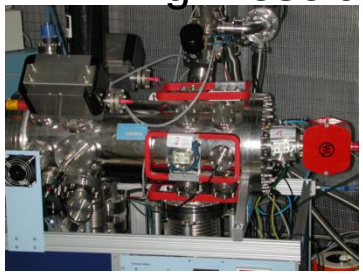
Position sensitive solid state detectors



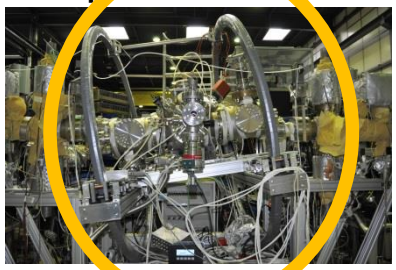
High resolution spectrometers



Particle detectors

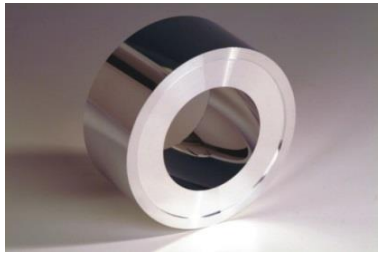


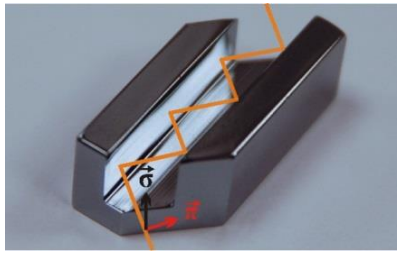
Particle spectrometers



Recoil Ion Spectr.

Traps





X-ray optics, channel cut crystalls

Laser systems