The Prospectives of SPARC in the FAIR **Modularized Start Version**

Stored Particle Atomic Research Collaboration

284 participants, 26 countries, 83 institutes

sparc
Stored Particles Atomic Physics Research Collaboration

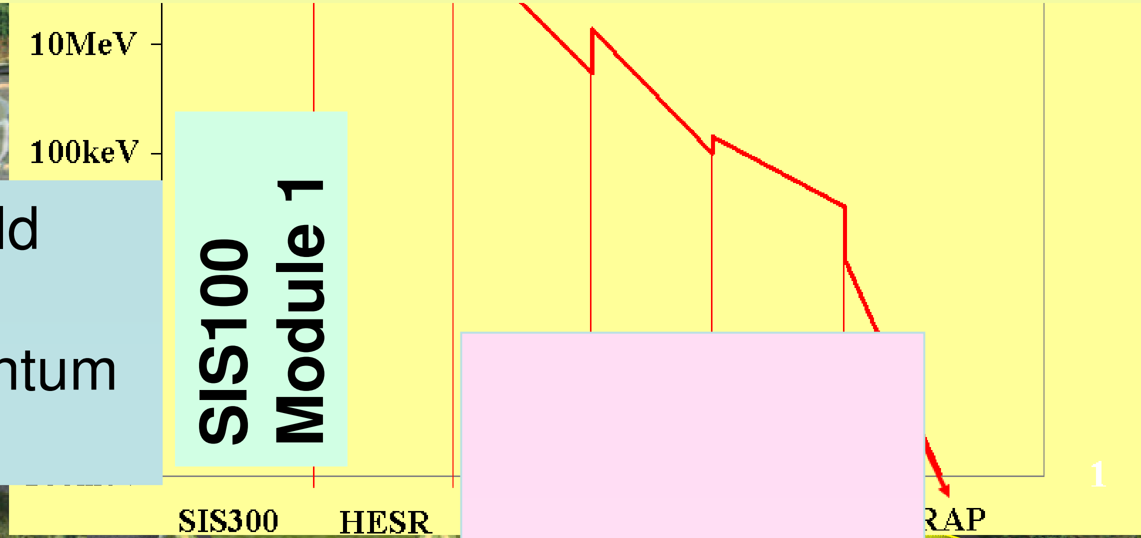
Atomic Physics with HCI

Reinhold Schuch
Stockholm University, Sweden

Observers

CN DE ES FI FR GB GR IN IT PL RO RU SE

The Program of the SPARC -Collaboration: Quantum Dynamics in Extrem Fields by Precision Studies of Atomic Systems binding Electrons in Critical and Super-Critical Fields



- New concepts of Strong Field QED
- Correlated Many-Body Quantum Dynamics

SIS100
Module 1

- Precision Determination of Fundamental Constants
- New Decay of Highly Ionized Atomic Nuclei
- Tests of Fundamental Symmetries
- Fundamental Nuclear Properties from Atomic Data

ESR , HITRAP NESR ↓ modules 4/ 5

<u>Observables in high-resolution:</u> x-rays, electrons, positrons, projectiles, and recoil-ions

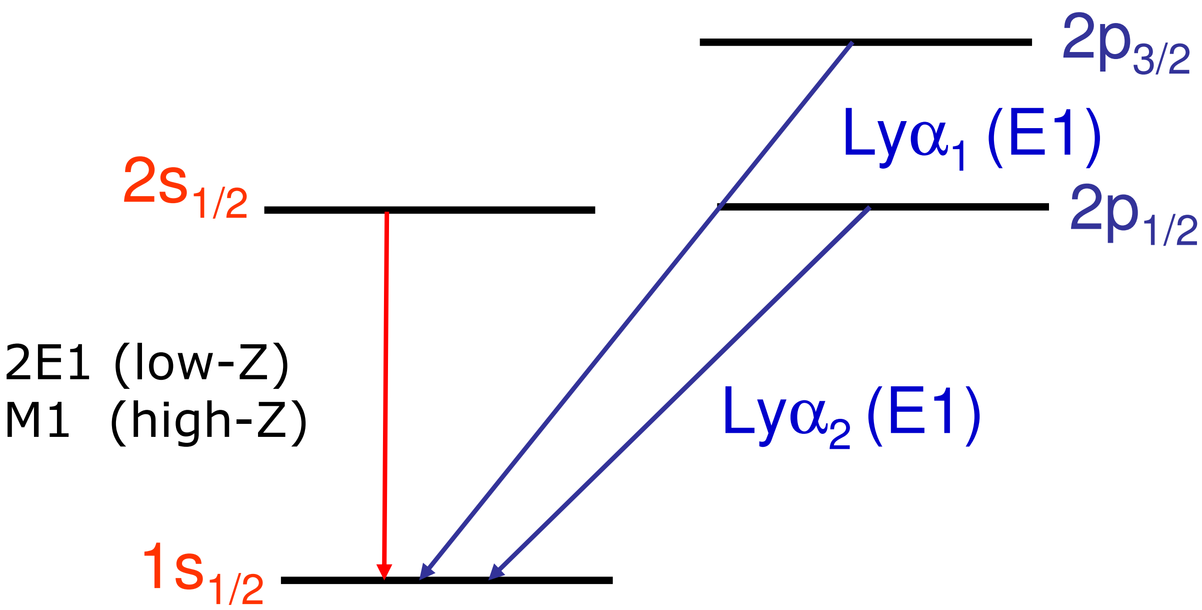
First excited states of H-like ions

$$E_{1s} = mc^2\sqrt{1-(Z\alpha)^2}$$ (total energy)

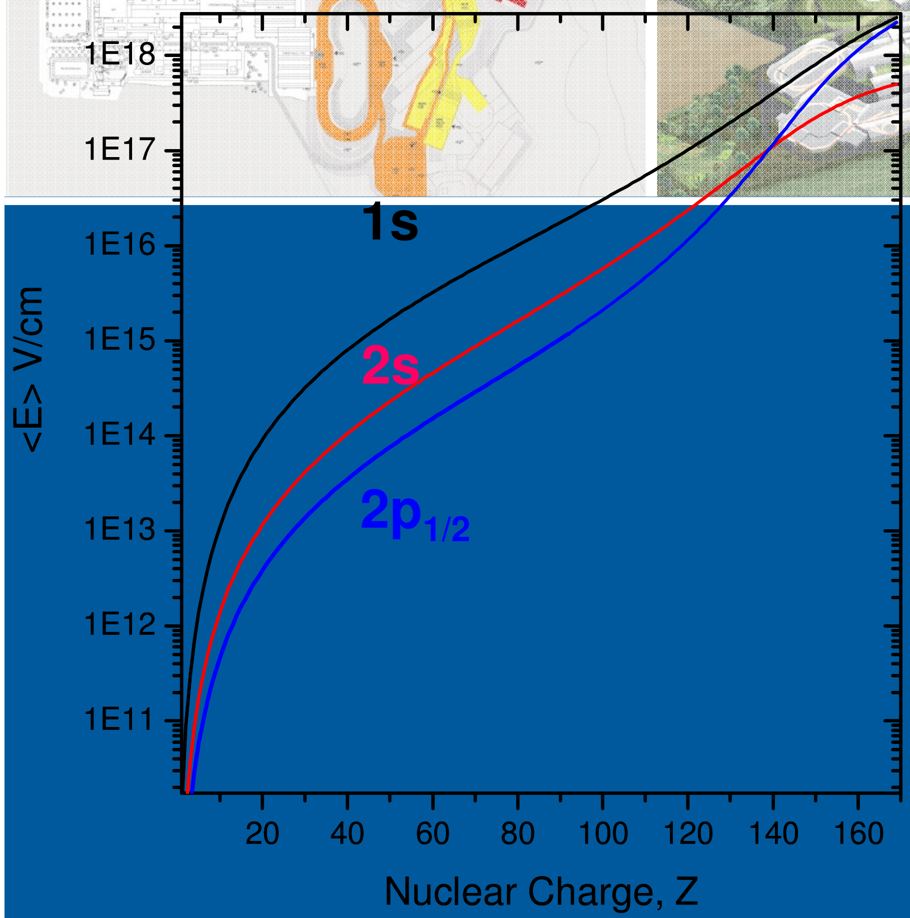
$$E_{1s}^B = mc^2(\sqrt{1-(Z\alpha)^2}-1)$$ (binding energy)

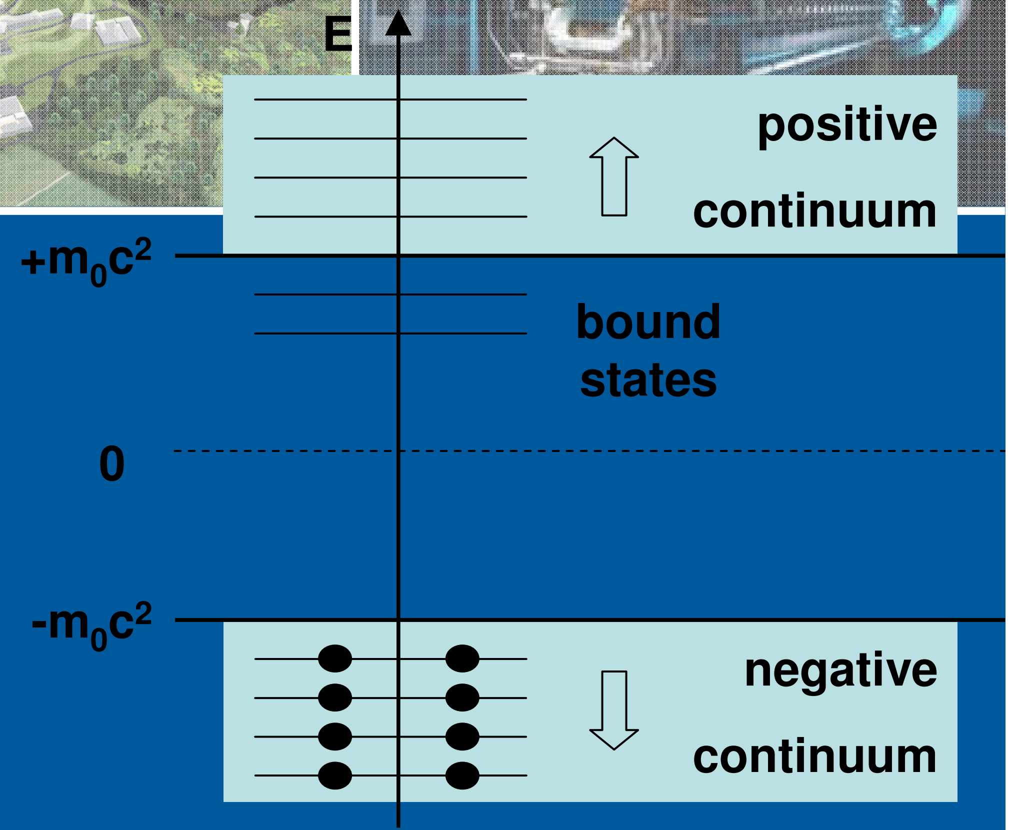
α = 1/137

Z>137 ?



Critical- and Supercritical Fields





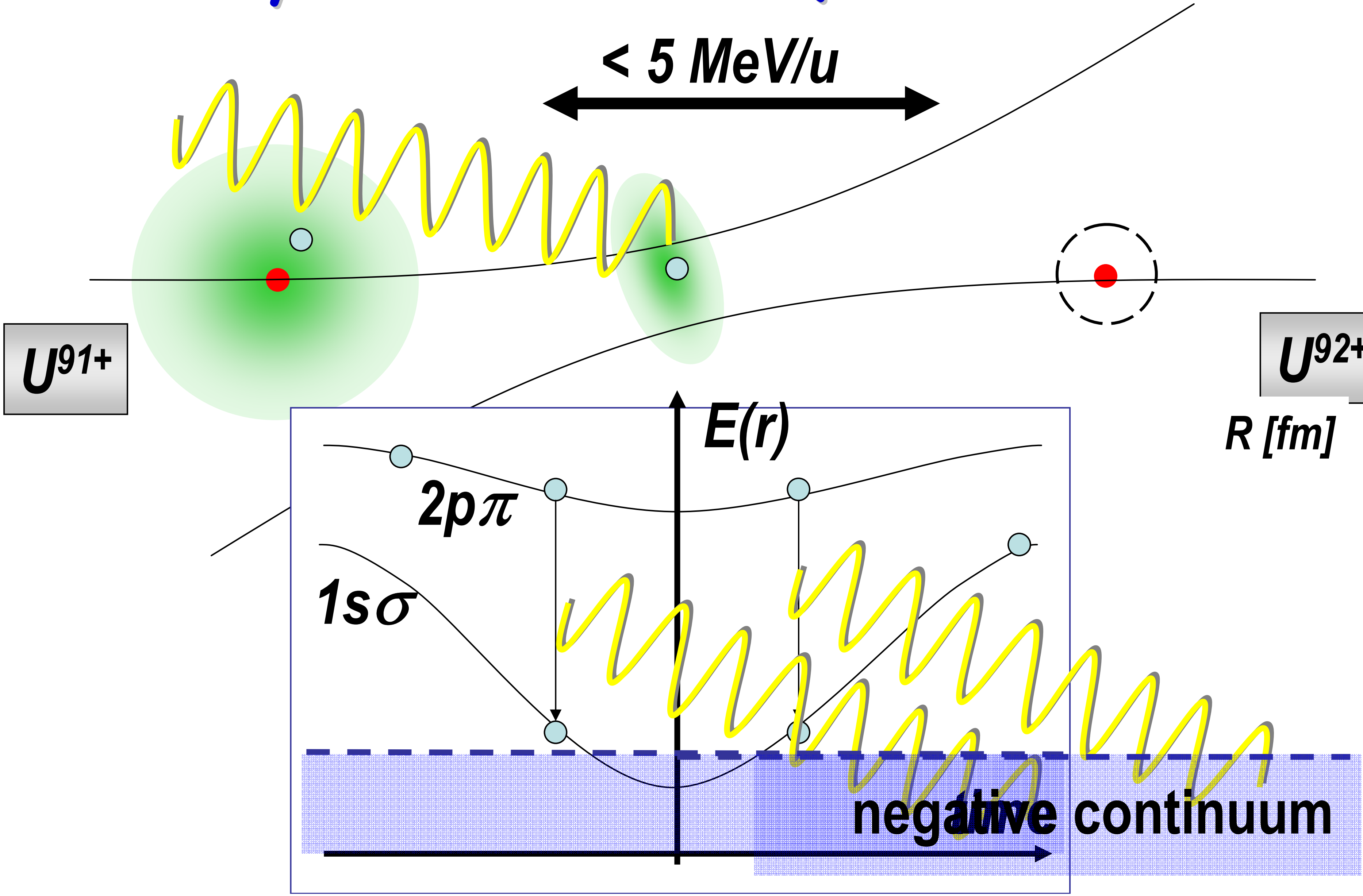
$U^{92+} \rightarrow U$ =>

U^{91+} + MO-X-Ray, positrons..

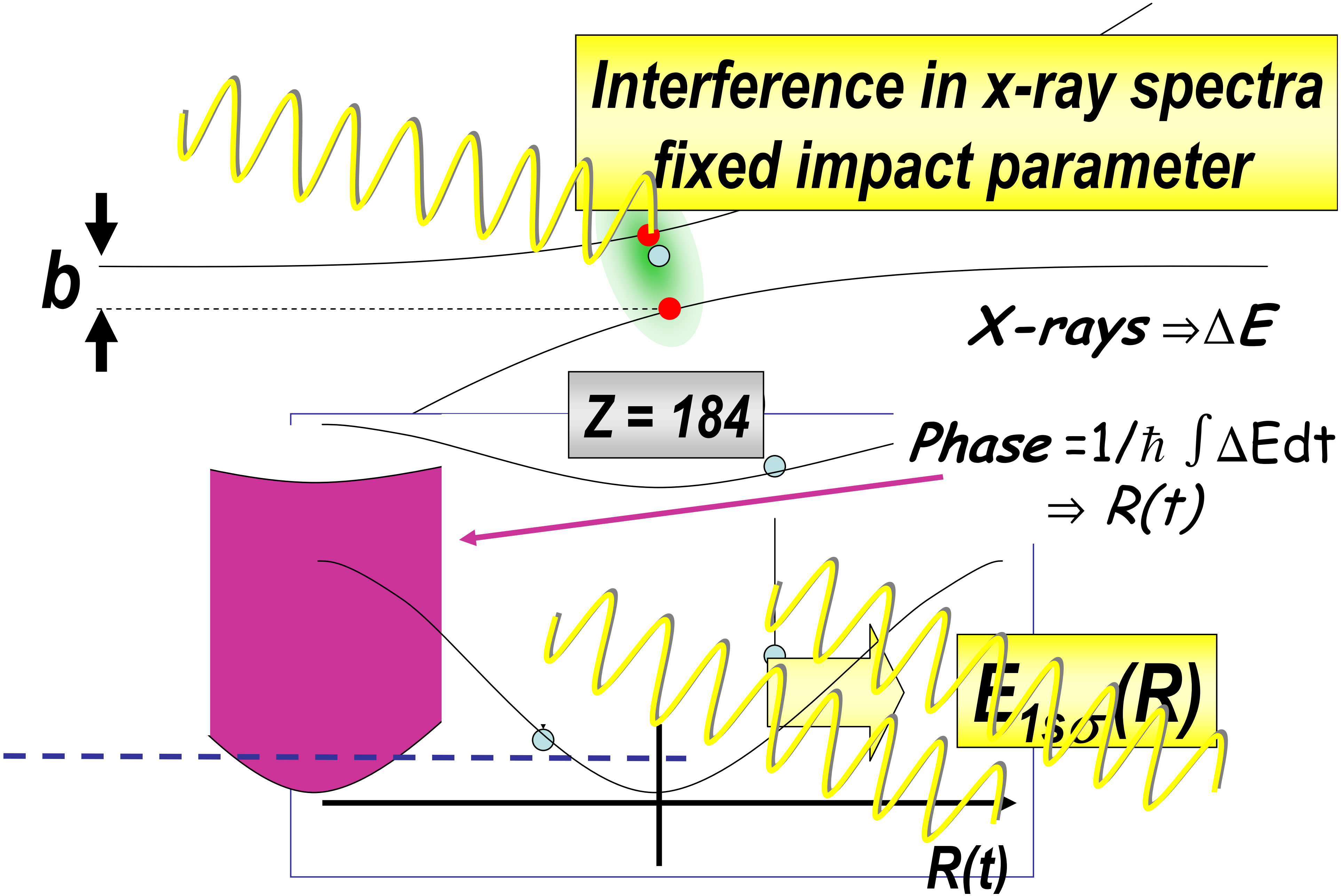
as function of
impact parameter

FAIR

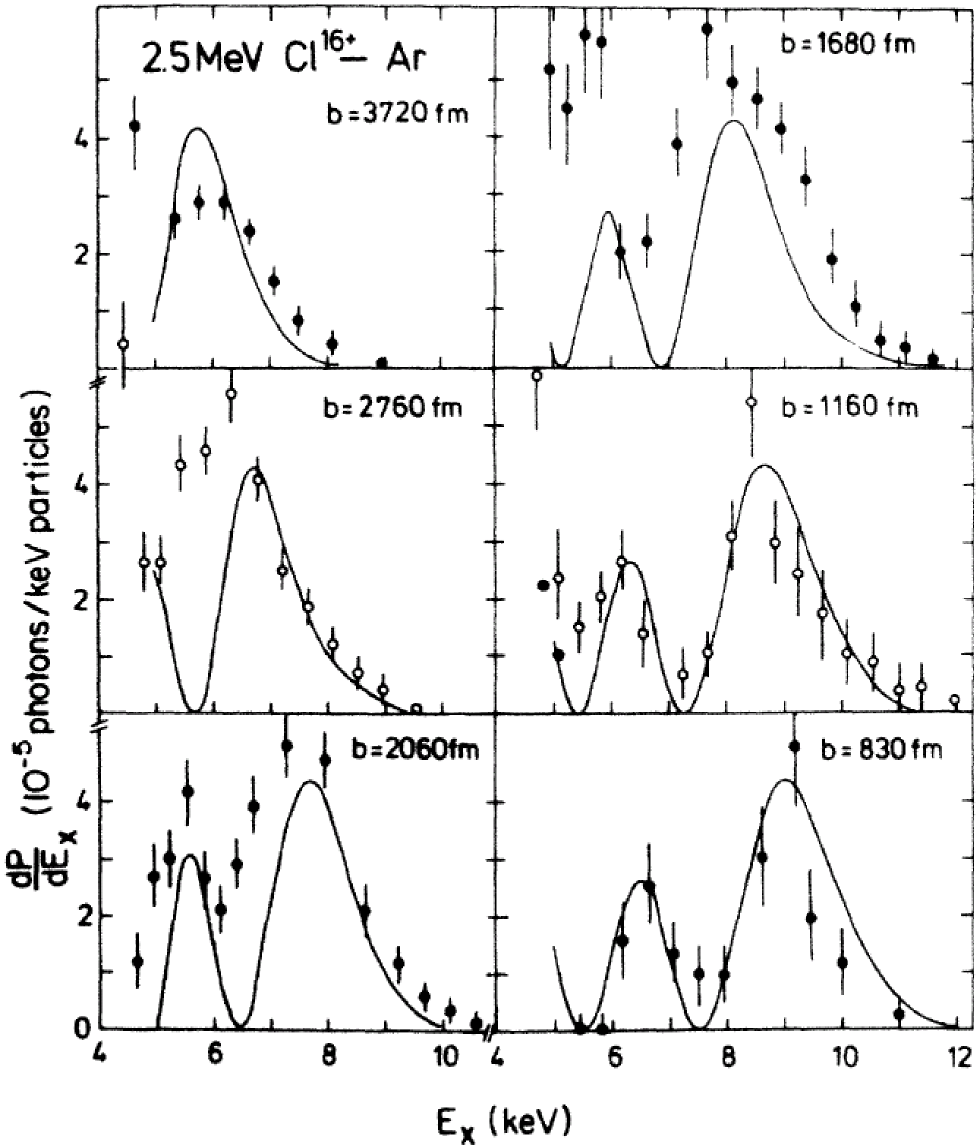
Spectroscopy of Super-heavy Atoms by X-ray Emission from Quasimolecule

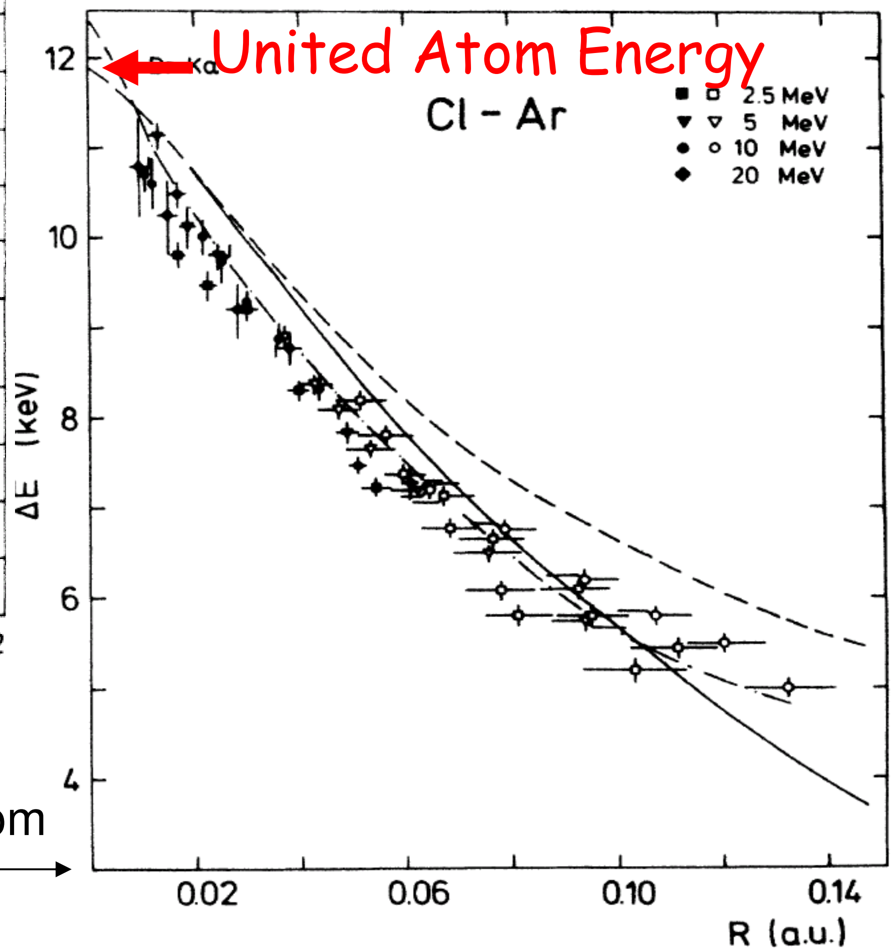


X-ray Emission from Quasimolecule



Test Case Cl^{16+} - Ar (Z_{ua} =35) goal U^{91+} - U (United atom Z=184) for Super Critical Fields,



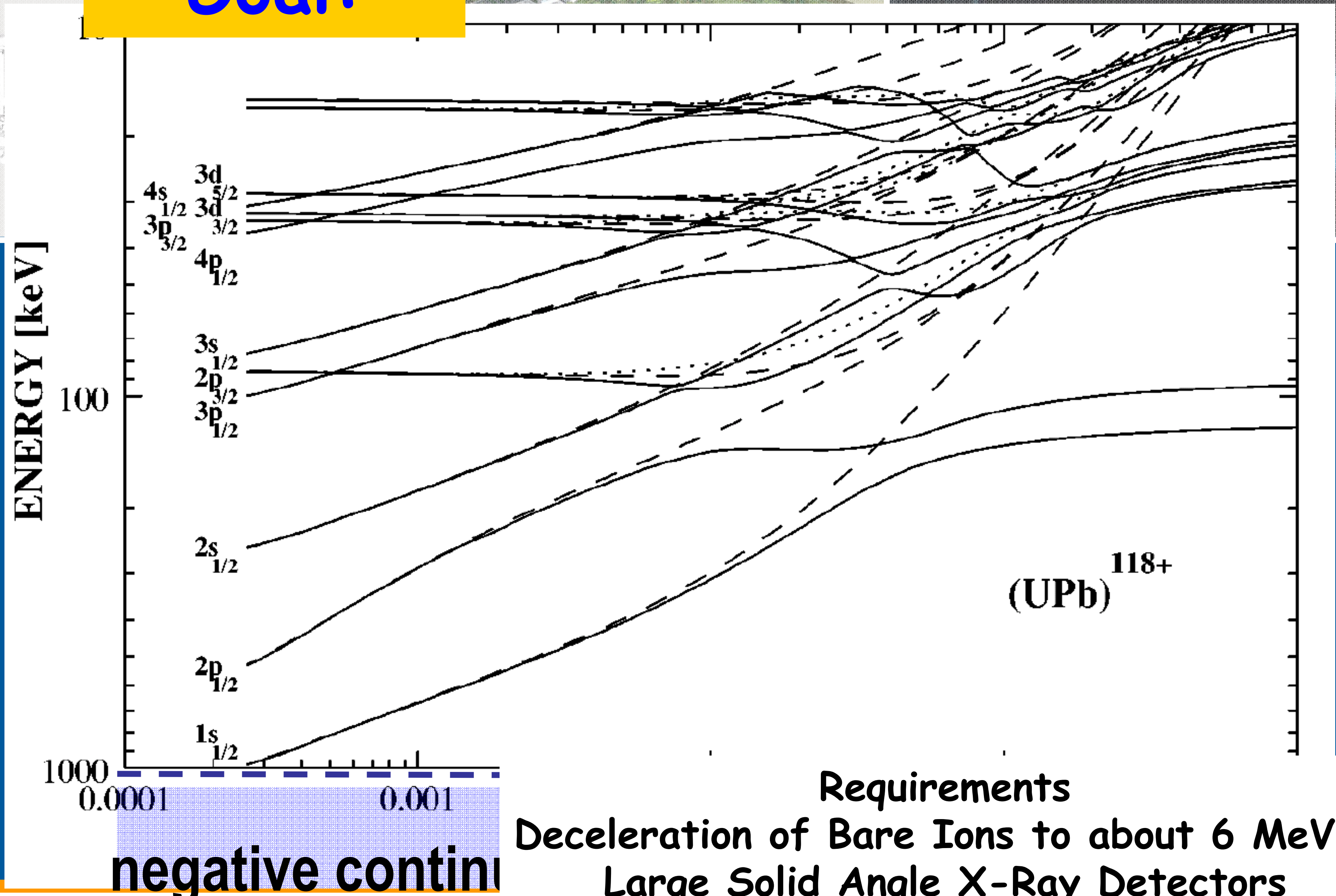


separated atom energies →

R. S. et al., PRA**37**, 3313, '88

FIG. 9. Transition energies between $1s\sigma$ and $2p\pi$ MO states

Goal:



Requirements

Deceleration of Bare Ions to about 6 MeV/u

Large Solid Angle X-Ray Detectors

Monolayer Target (Uranium)

Position Sensitve Particle Detectors

B. Fricke et al. P.Rev.A59,1578('98)

Challenges & Opportunities - SIS100

Extreme Dynamic Fields

"Heisenbergs dream"
shot out the nucleus,
let electrons explode

$$\gamma = \frac{1}{\sqrt{1-\beta^2}}$$

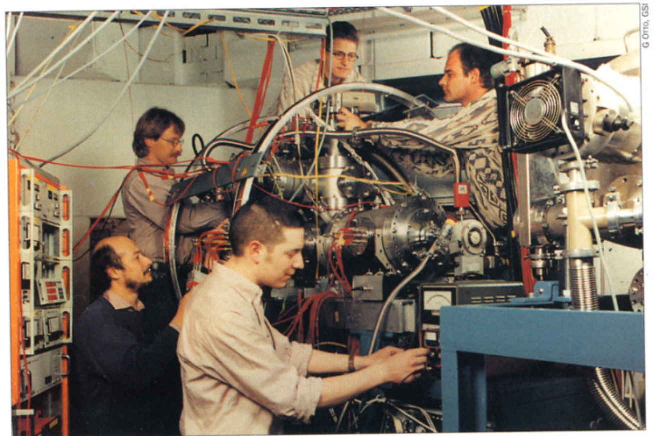
PH … ION

Ten thous … ster than a laser, an … rong

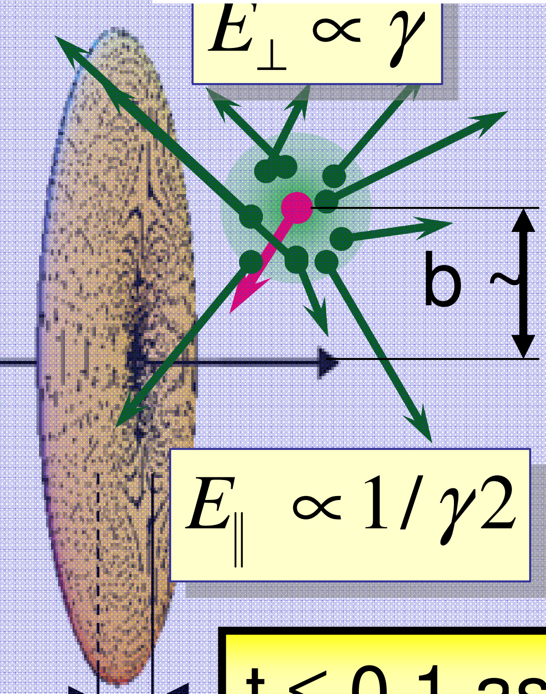
From **Jim McGuire** in the Department of Physics, Tulane University, New Orleans, US, and **Bruce W Shore** in the Fachbereich Physik, Universität Kaiserslautern, Germany

The kinetic energy of a fully stripped uranium ion accelerated to 1 GeV per nucleon is about 10^{10} times greater than the binding energy of the electrons in a helium atom. It is no surprise, then, that such an ion can cause a helium atom to explode. What is surprising, however, is that such a collision can be described as "gentle" because the ion, which is travelling at close to the speed of light, transfers essentially no momentum to the atom. Such collisions therefore allow the dynamics of electronic transitions in helium atoms – in particular the dynamics of the correlations between the electrons – to be probed in great detail (R Moshammer *et al.* 1997 *Phys. Rev. Lett.* **79** 3621). How can this happen?

The first important point is that the particles do not collide head on – rather the



The GSI reaction microscope used to study collisions between fully stripped uranium ions and helium atoms. The ions generate electromagnetic pulses much shorter than those available with radiation sources.



$E_\perp \propto \gamma$

b ~ 10^6 fm

$E_\| \propto 1/\gamma 2$

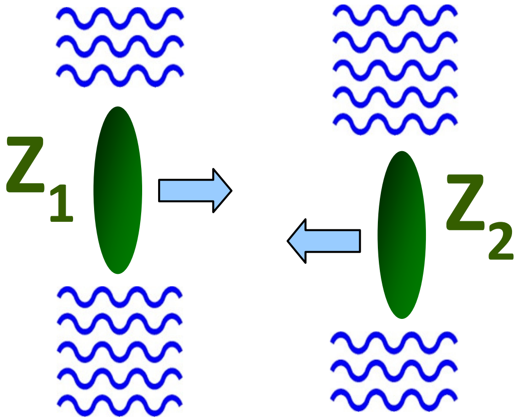
t ≤ 0.1 as

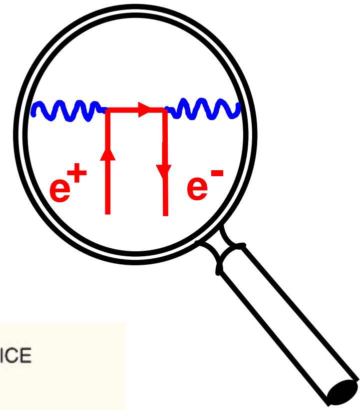
W/cm²

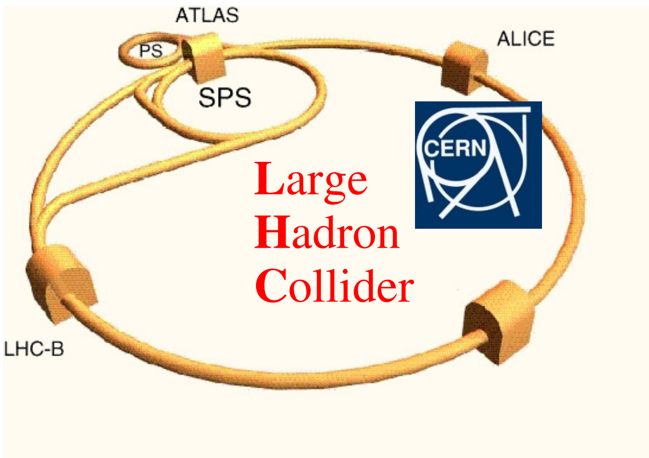
Explore correlated electron dynamics
- on sub-attosecond time-scale
- not accessible by other means

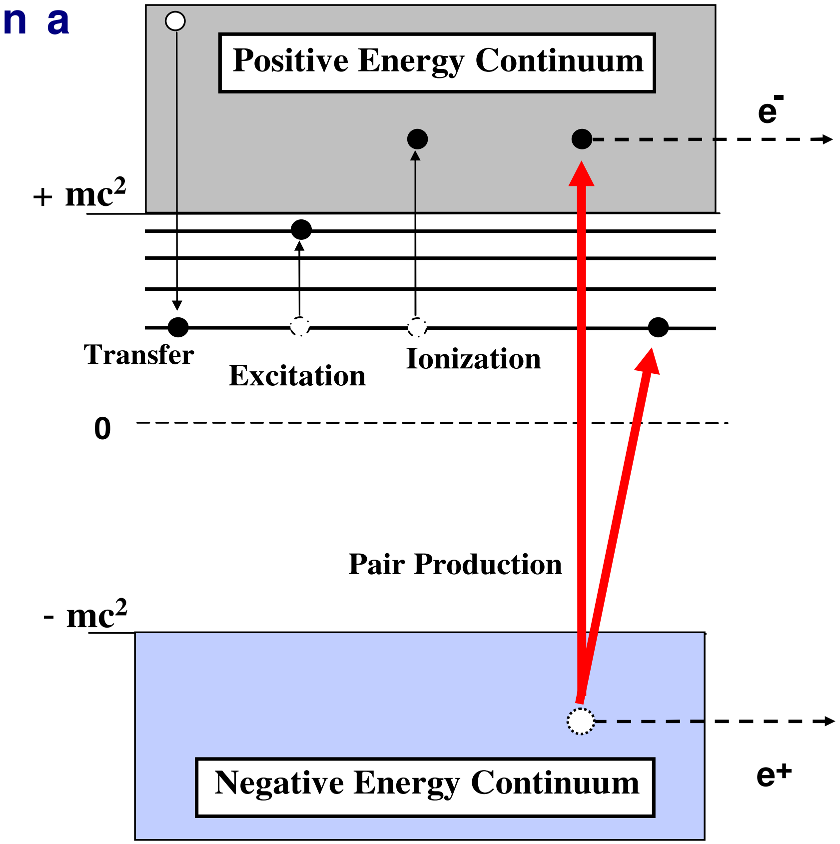
Relativistic Ion-Atom Collisions

- **Dynamically induced strong fields result in a large number of atomic processes**









- Bound-free pair production limits the heavy ion performance of the LHC at CERN!

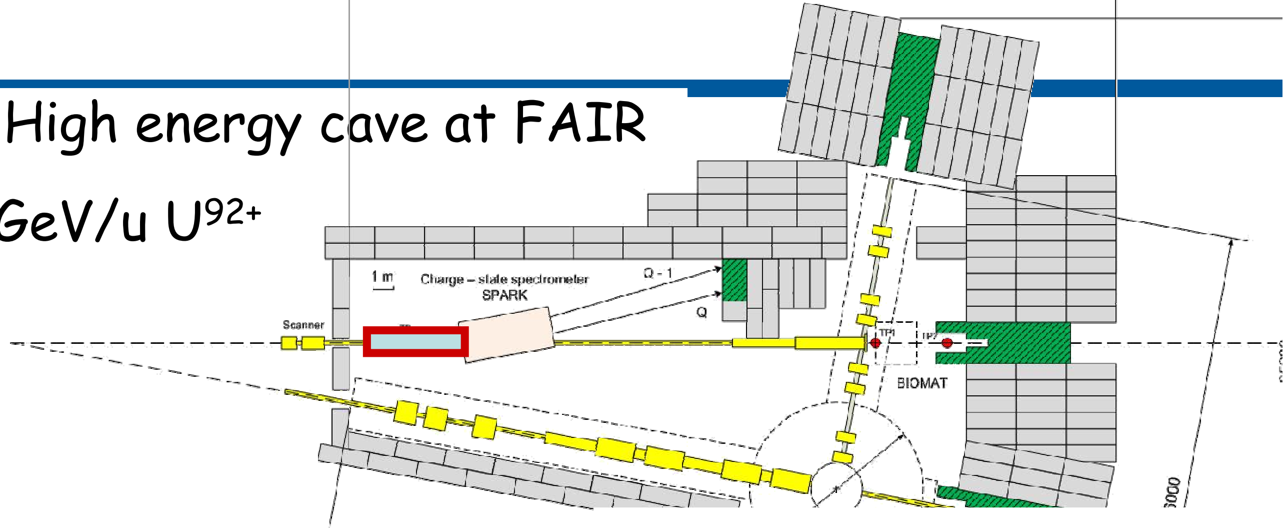
*CERN Courier **47** (2007) 7*

SPARC Collaboration

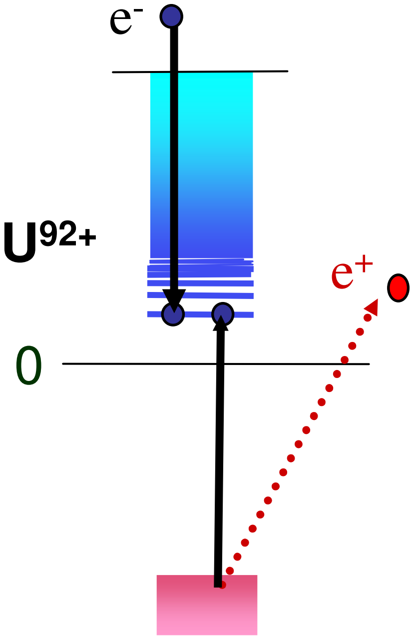
Near Relativistic Collisions

High energy cave at FAIR

SIS100 → 10GeV/u U^{92+}



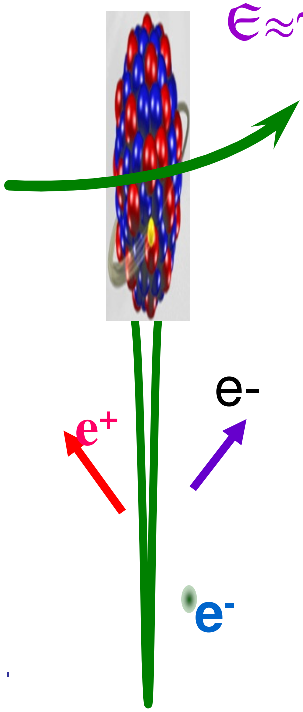
Di-Electronic Capture by Pair Production

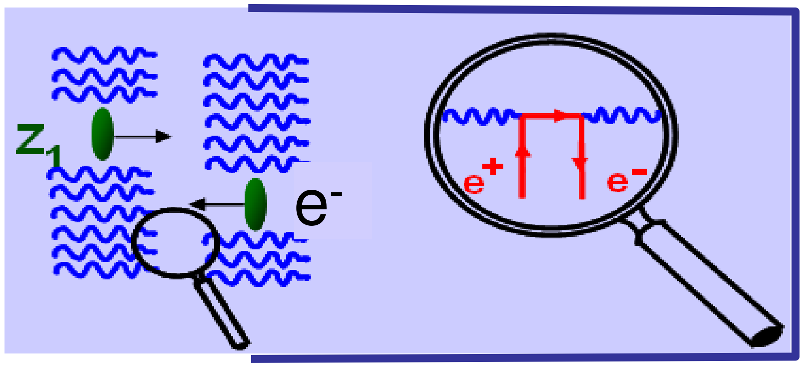


$U^{92+} + Z_T \rightarrow U^{90+} + e^+$

Artemev, C. Kozoharov et al.

$\epsilon \approx \gamma Ze/b^2$





e^+ - e^- pairs
in e- field

SPARC Collaboration

Near Relativistic Collisions

High energy cave at FAIR

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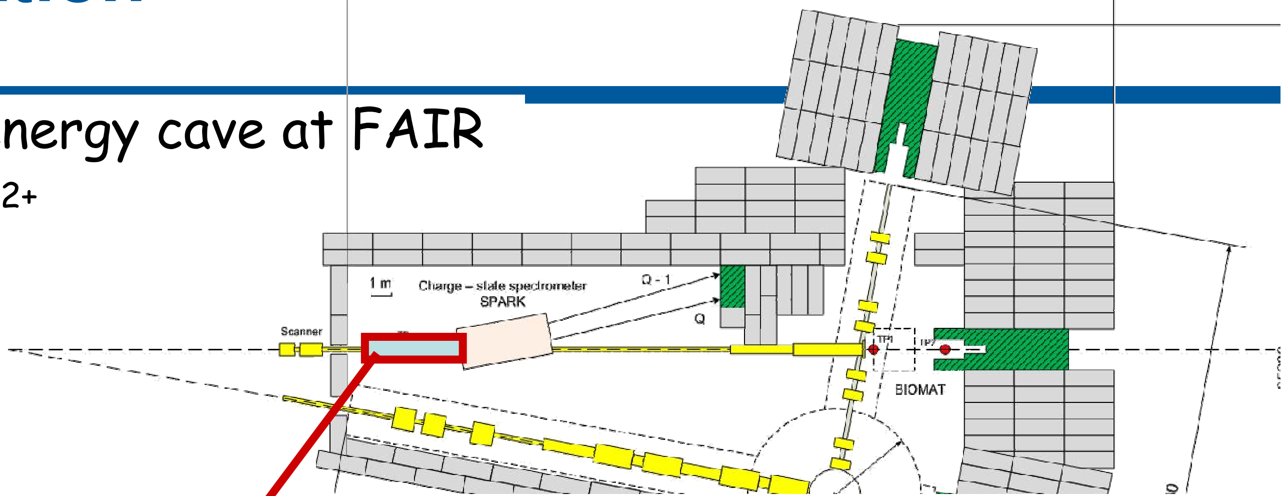
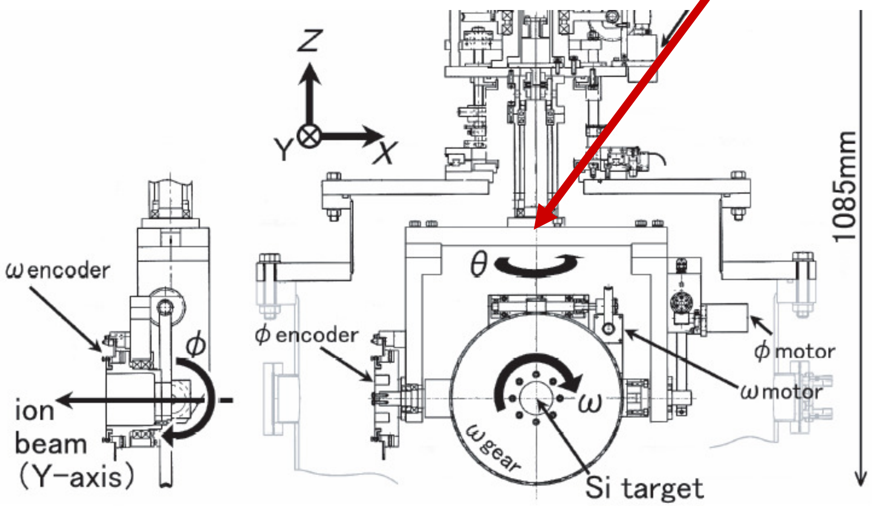
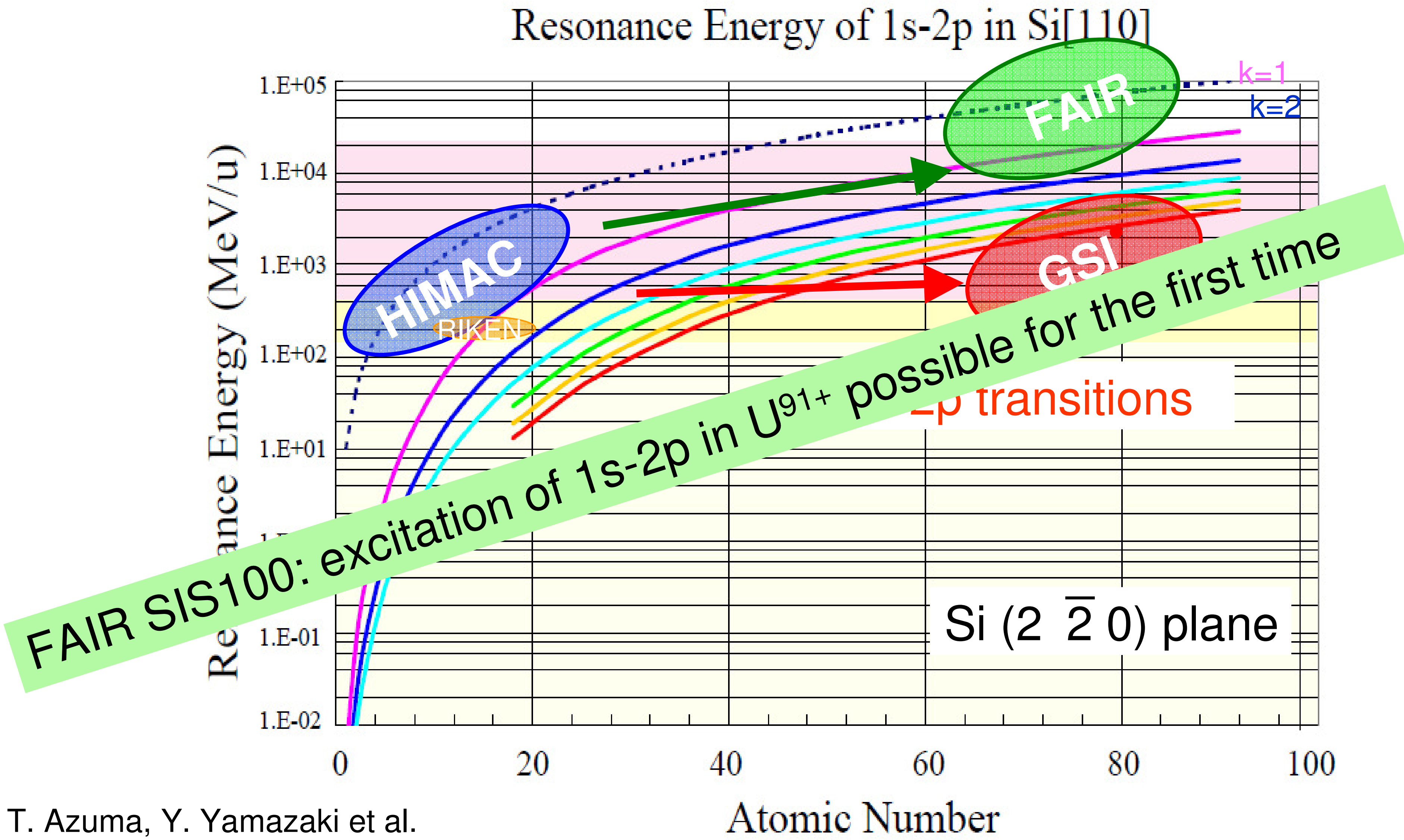




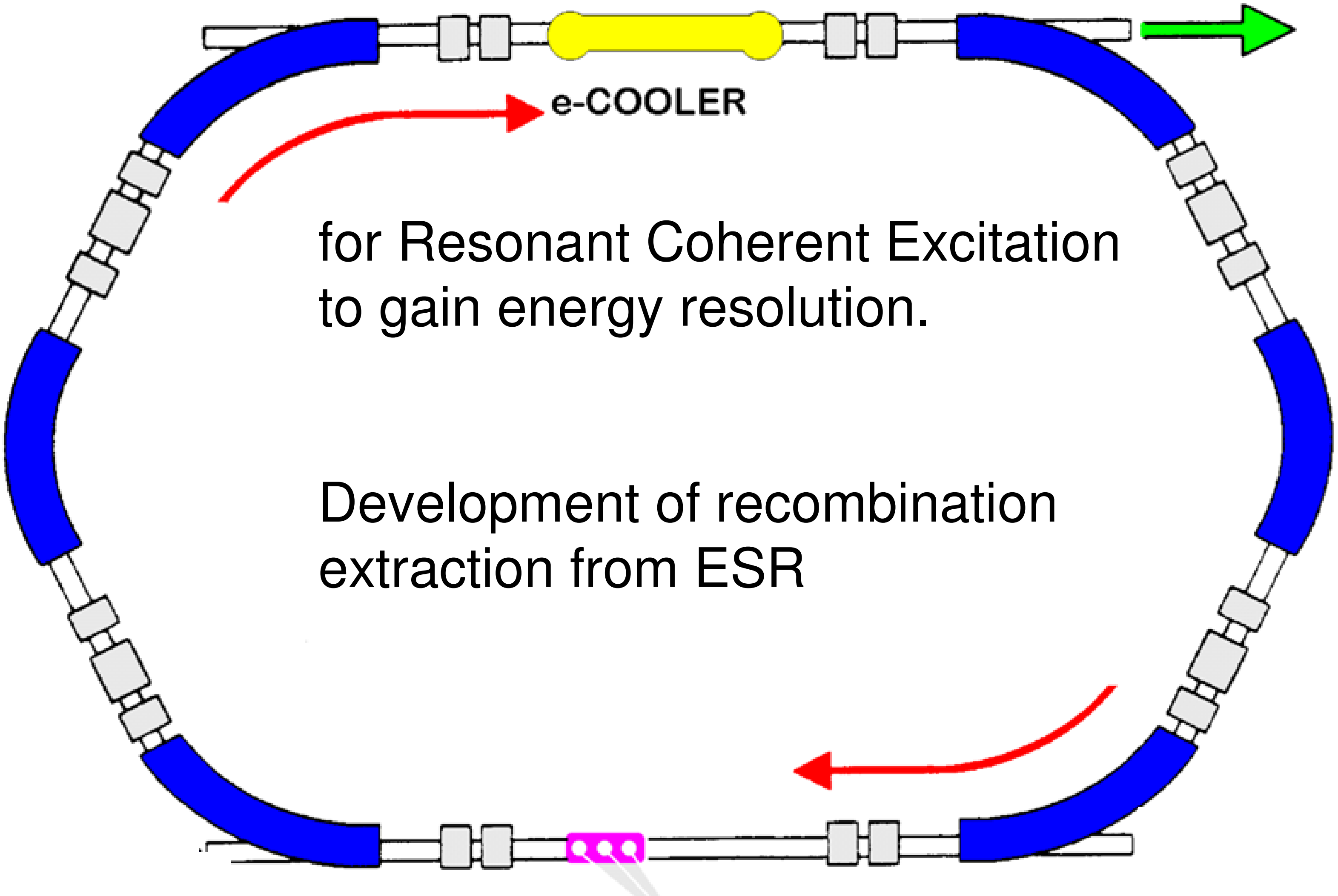
goniometer with single crystall for channeling of relativistic heavy ions

Virtual Photon Spectroscopy by Relativistic Channeling of Heavy Ions



T. Azuma, Y. Yamazaki et al.

Using cooled beams from the ESR and later NESR for low emittance and high momentum definition



for Resonant Coherent Excitation to gain energy resolution.

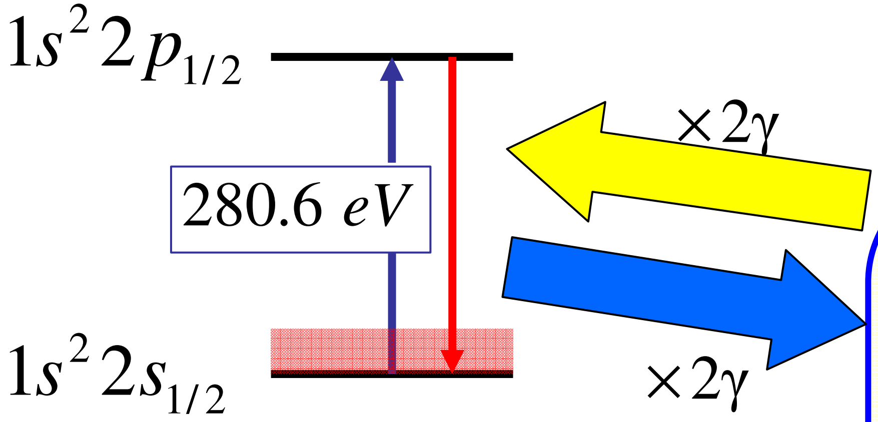
Development of recombination extraction from ESR

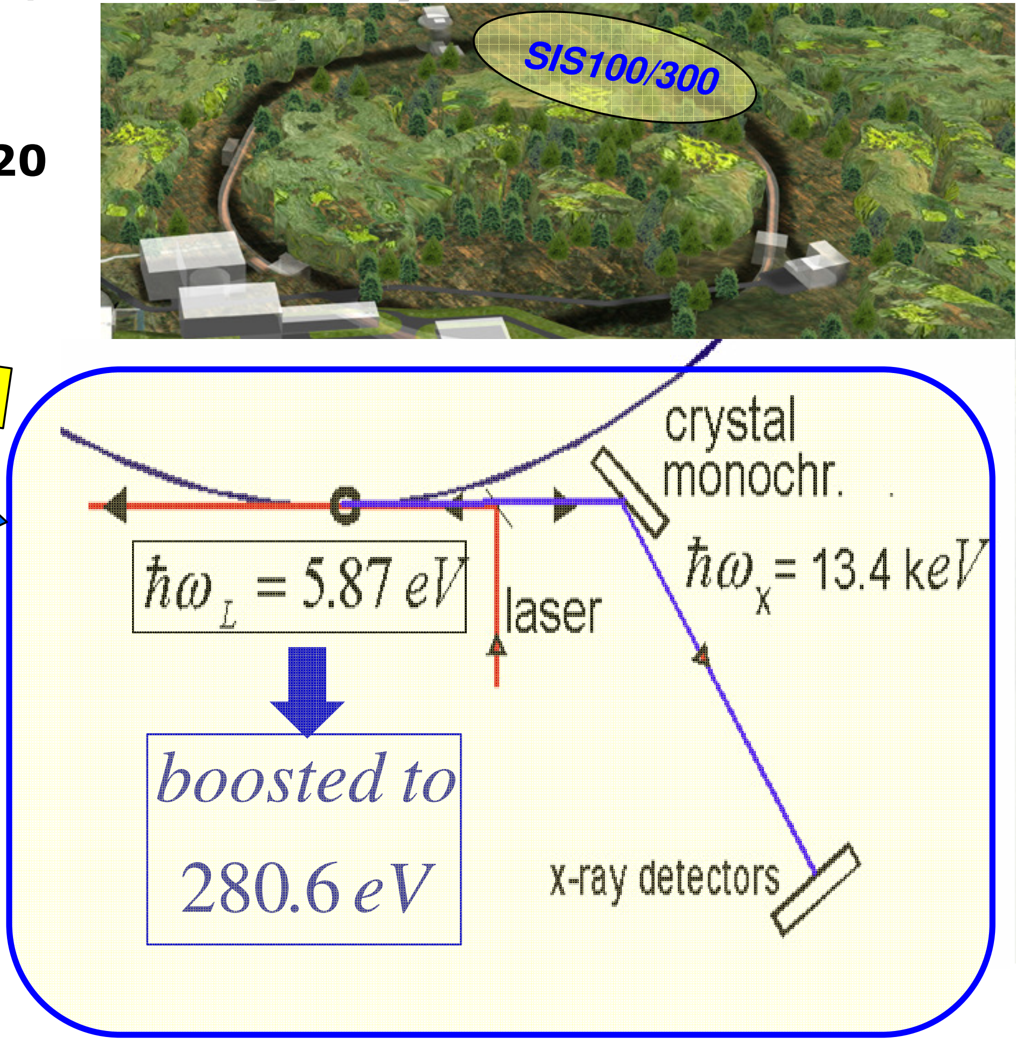
@ Relativistic Energies SIS100

Quantum Electrodynamics, Cooling, Crystalline Beams

QED in Li-like systems

improved resolution factor of 10 to 20

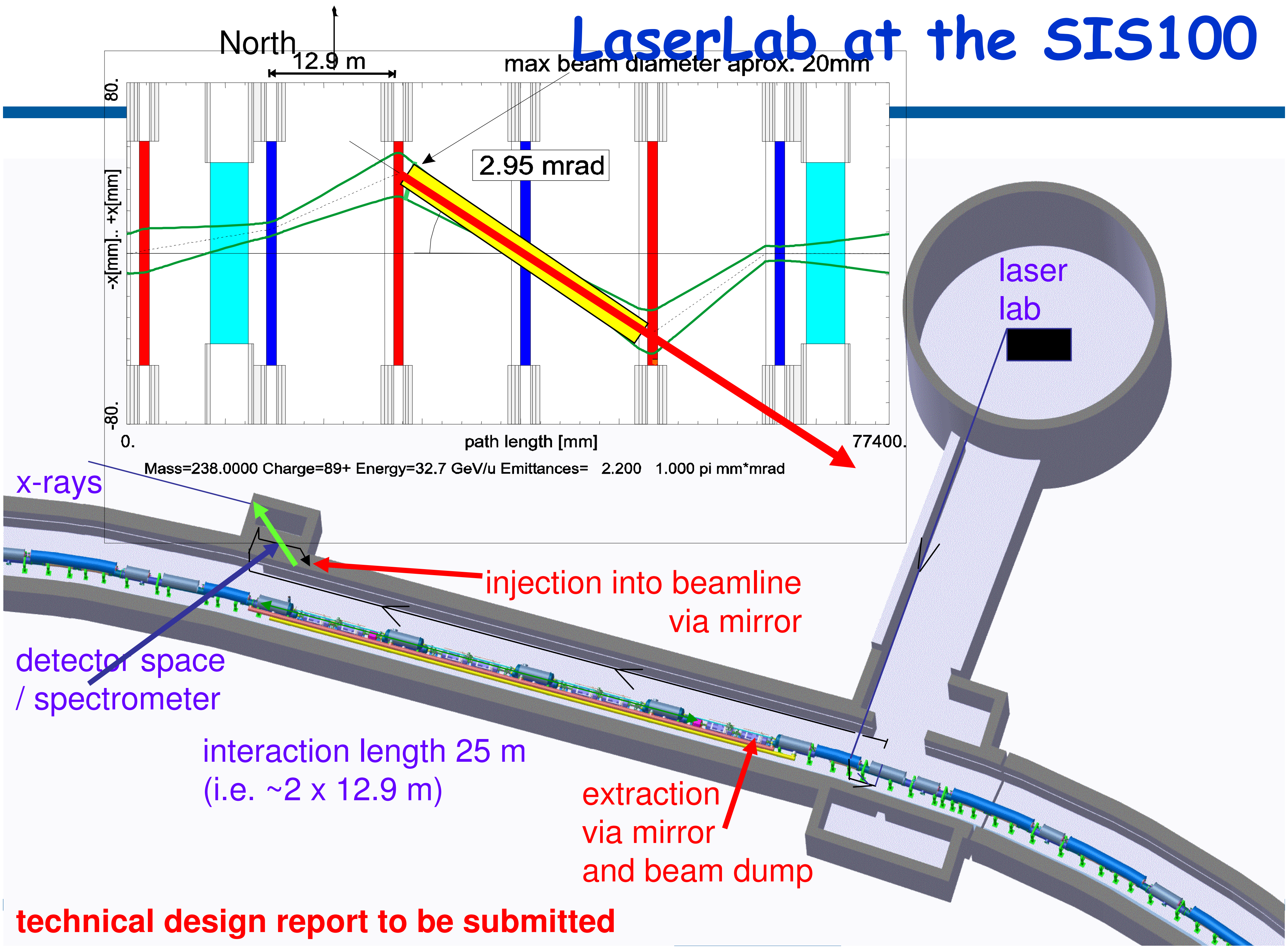




$\Delta E = \sqrt{\hbar\omega_x \hbar\omega_L}$

H. Backe, arXiv:physics/0701056 (2007)

LaserLab at the SIS100



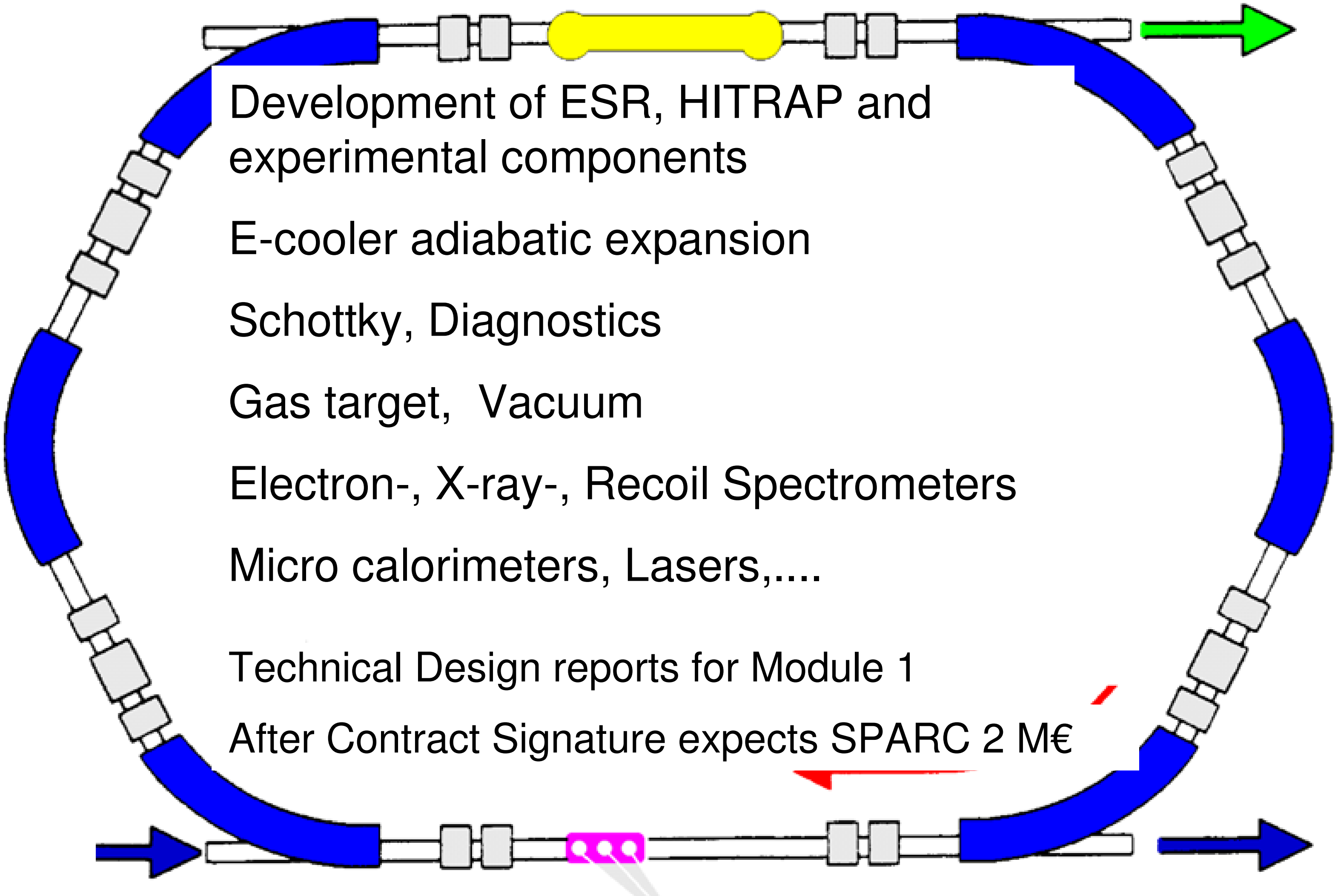
technical design report to be submitted

SPARC is Organized within 13 Working Groups

Responsible Working Groups	Working Packages (WP)
High Energetic Ion-Atom Collisions	(WP 2.1) Cave for High-Energy (< 10 GeV/u) Atomic Physics (WP 2.2) Resonant Coherent Excitation (WP 2.3) Pair Production
Reaction Microscope	(WP 3.9) Large Solid Angle Spectrometer for Recoil Ions and Electrons (WP 3.10) Imaging Fast Forward Electron Spectrometer (WP 4.3) Reaction Microscope for Slow-HCI
Electron and Electr	
Photon and X-ray S	
Photon Detector Development	(WP 3.5) Calorimeter (WP 3.6) 2D Detector Systems/Polarimeter for Hard X-rays (WP 4.5) X-ray Studies
Target Developments (in ring)*	(WP 3.2) Dense H_2/He Internal Jet Target (WP 3.12) Infrastructure NESR
Electron Cooler/Target	(WP 3.1) Electron Target (WP 3.12) Infrastructure NESR
Low Energy Setups	(WP 4.1) Low-Energy Cave (WP 4.4) Ion-Surface Interaction Experiments
Traps/HITRAP	(WP 4.2) HITRAP Facility (WP 4.6) g-Factor Measurements (WP 4.7) Mass Measurements (WP4.8) Laser Experiments
Ion Sources	(WP 4.1) Low-Energy Cave (WP 4.2) HITRAP
Laser Spectroscopy/Laser Cooling	(WP 1.1) Laser Cooling (WP 3.11) Implementation of a Laser Setup (WP 4.8) Laser Experiments
Laser/Ion Interaction (Intense Laser)	(WP 1.2) High Intensity Laser (WP 3.11) Implementation of a Laser Setup

Technical Design Reports need to be prepared

SPARC enters FAIR with the ESR and HITRAP works for module1=SIS 100 + high energy cave



Development of ESR, HITRAP and experimental components

E-cooler adiabatic expansion

Schottky, Diagnostics

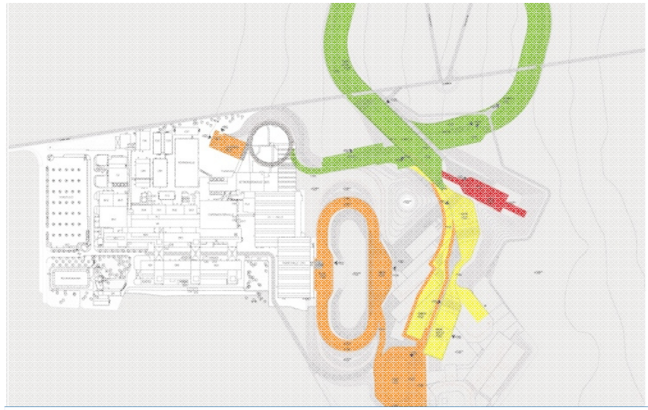
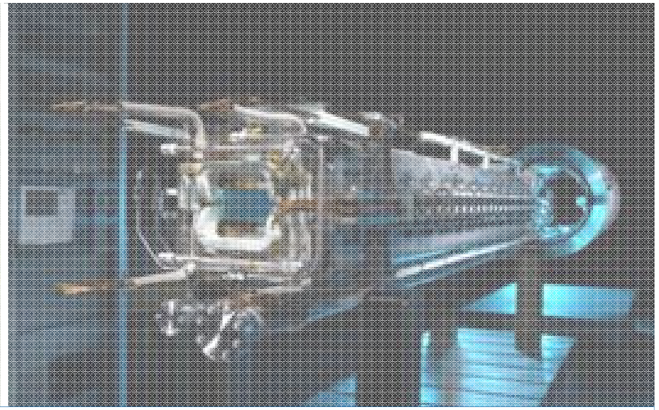
Gas target, Vacuum

Electron-, X-ray-, Recoil Spectrometers

Micro calorimeters, Lasers,....

Technical Design reports for Module 1

After Contract Signature expects SPARC 2 M€

THANK YOU!