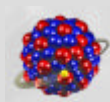




on the New International  
Accelerator Facility  
at Darmstadt,  
Warsaw, November 24, 2003



# Atomic Physics

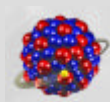
## Atomic Physics at the New International Accelerator Facility at GSI in Darmstadt



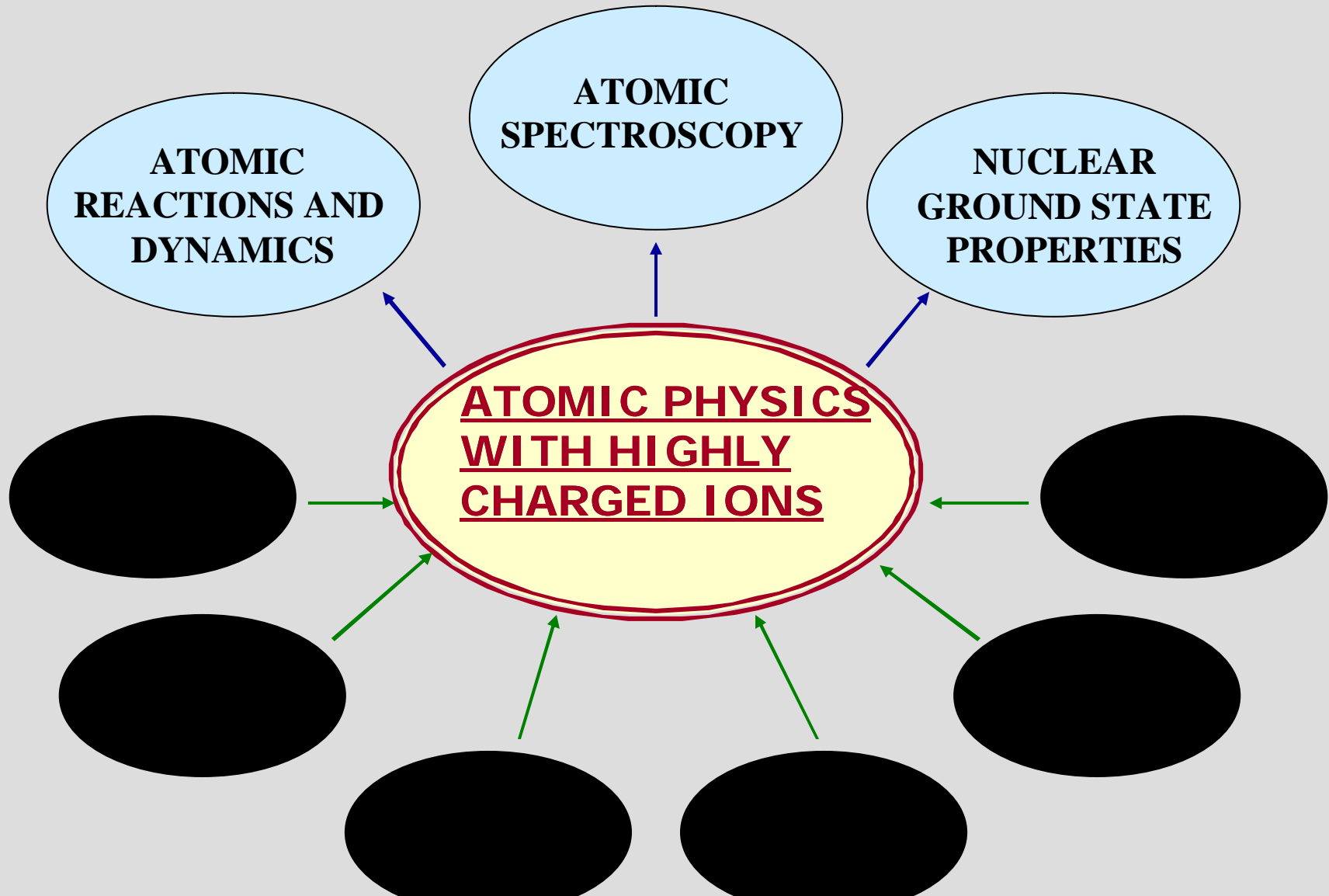
## Atomic Physics under Extreme Conditions

**Andrzej Warczak**

**Jagiellonian University, Institute of Physics, Kraków, Poland**

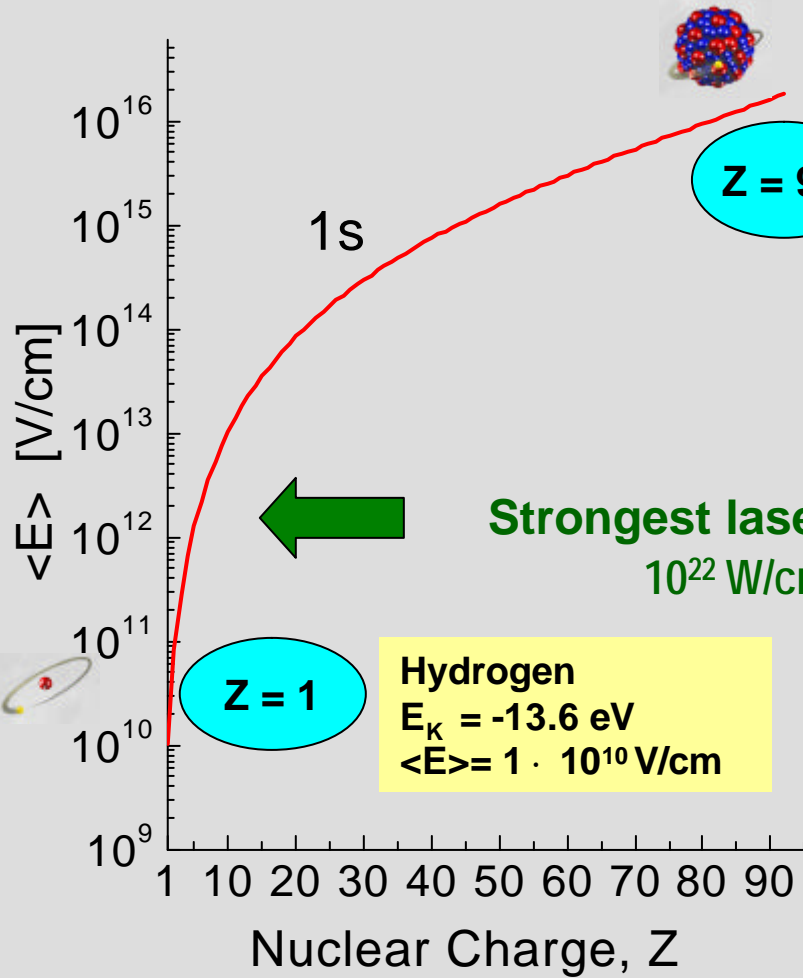


# Atomic Physics





# Extreme Static Fields

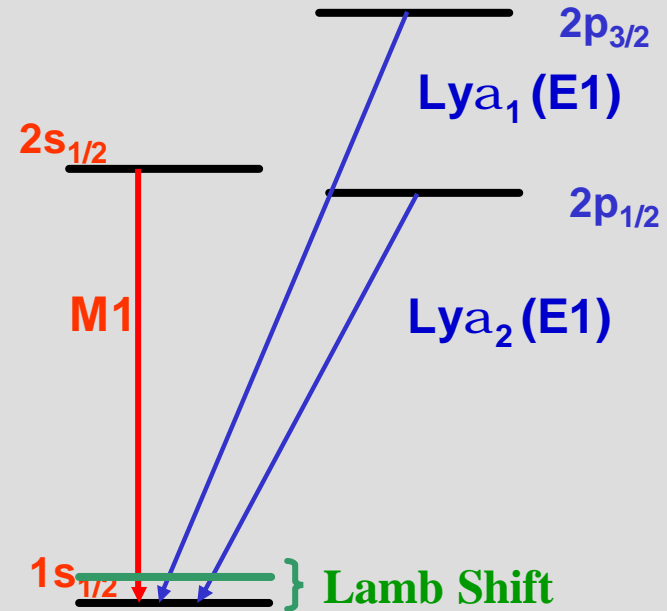


Strongest laser fields :  
 $10^{22}$  W/cm<sup>2</sup>

H-like Uranium  
 $E_K = -132 \cdot 10^3$  eV  
 $\langle E \rangle = 1.8 \cdot 10^{16}$  V/cm

Hydrogen  
 $E_K = -13.6$  eV  
 $\langle E \rangle = 1 \cdot 10^{10}$  V/cm

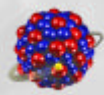
## Quantum Electro-Dynamics



*1s-ground state: increase of the electric field strength by six orders of magnitude*



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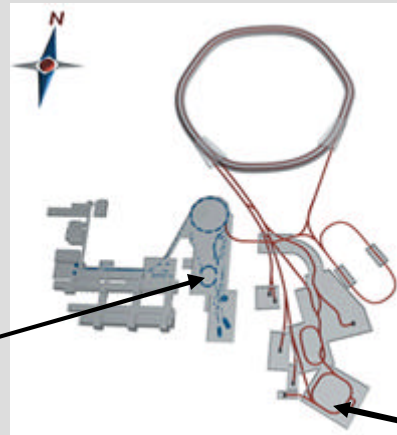
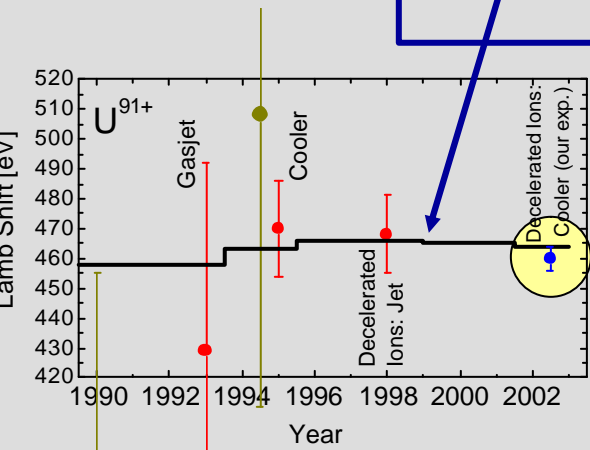


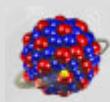
The ground state Lamb shift  
of  $^{91}\text{U}^{31+}$  like uranium

About 20 Joint Papers

**Theory:  $463,95 \pm 1 \text{ eV}$**   
V. A. Yerokhin and V. M. Shabayev(2001)

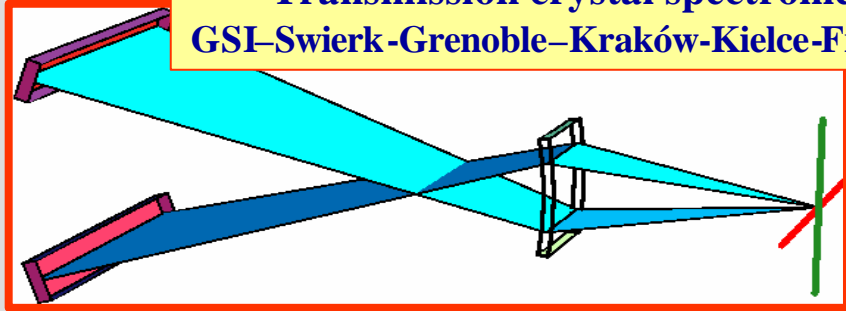
**Experiment:  $459.8 \pm 4.8 \text{ eV}$**   
The recently achieved accuracy of 4.8 eV is a considerable improvement by a factor of 3 compared to the most precise value up to now.



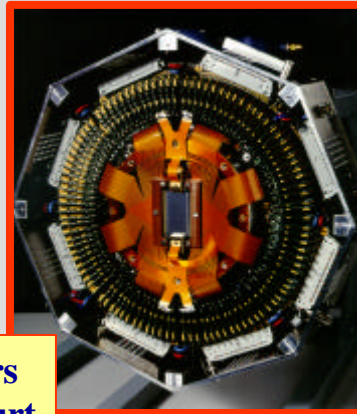
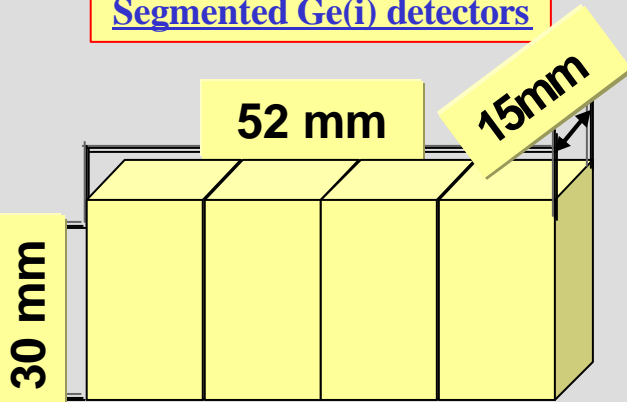


## Development of x-ray detection techniques

**Transmission crystal spectrometer**  
GSI-Swierk-Grenoble-Kraków-Kielce-Frankfurt



Segmented Ge(i) detectors

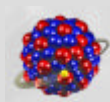


Calorimeters

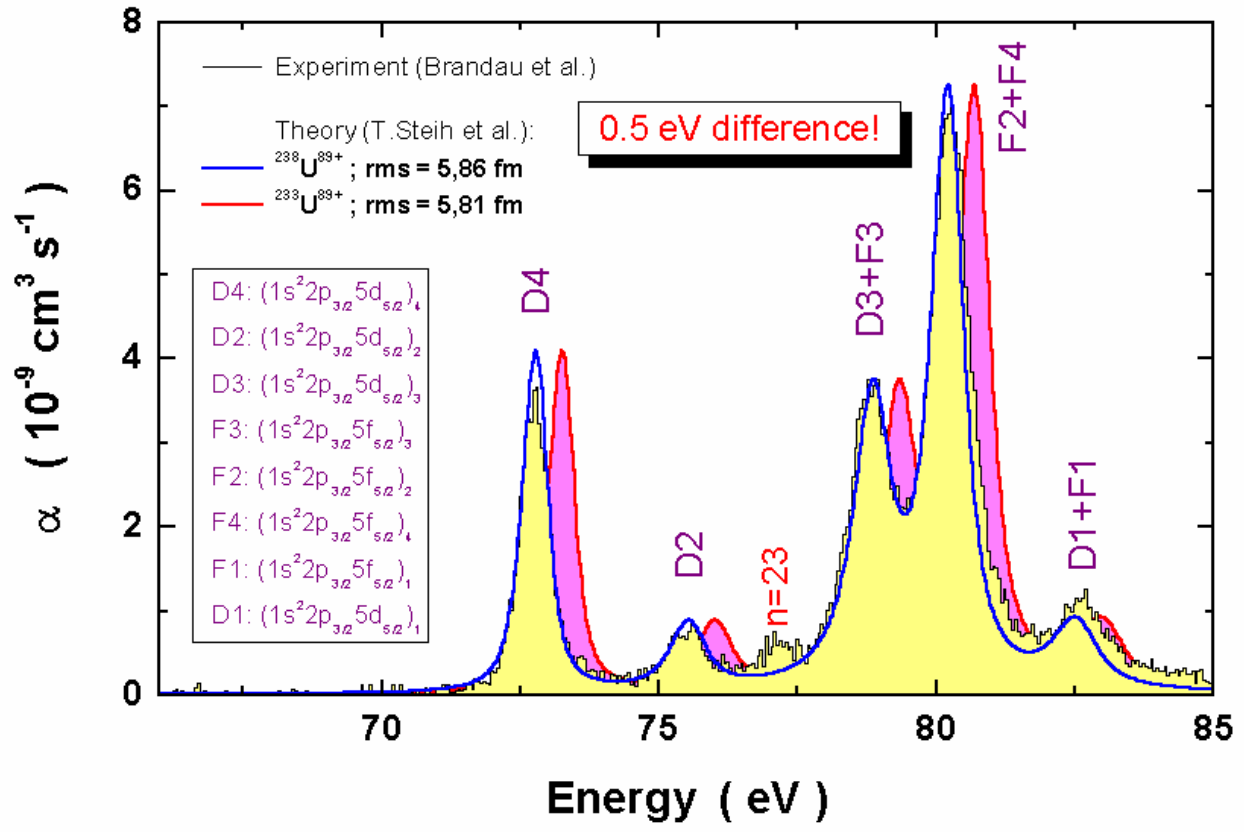
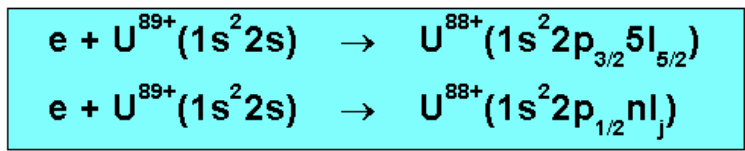
Mainz-GSI

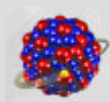


**Micro-strip Ge(i) detectors and polarimeters**  
Juelich-GSI-Swierk-Kraków-Kielce-Frankfurt

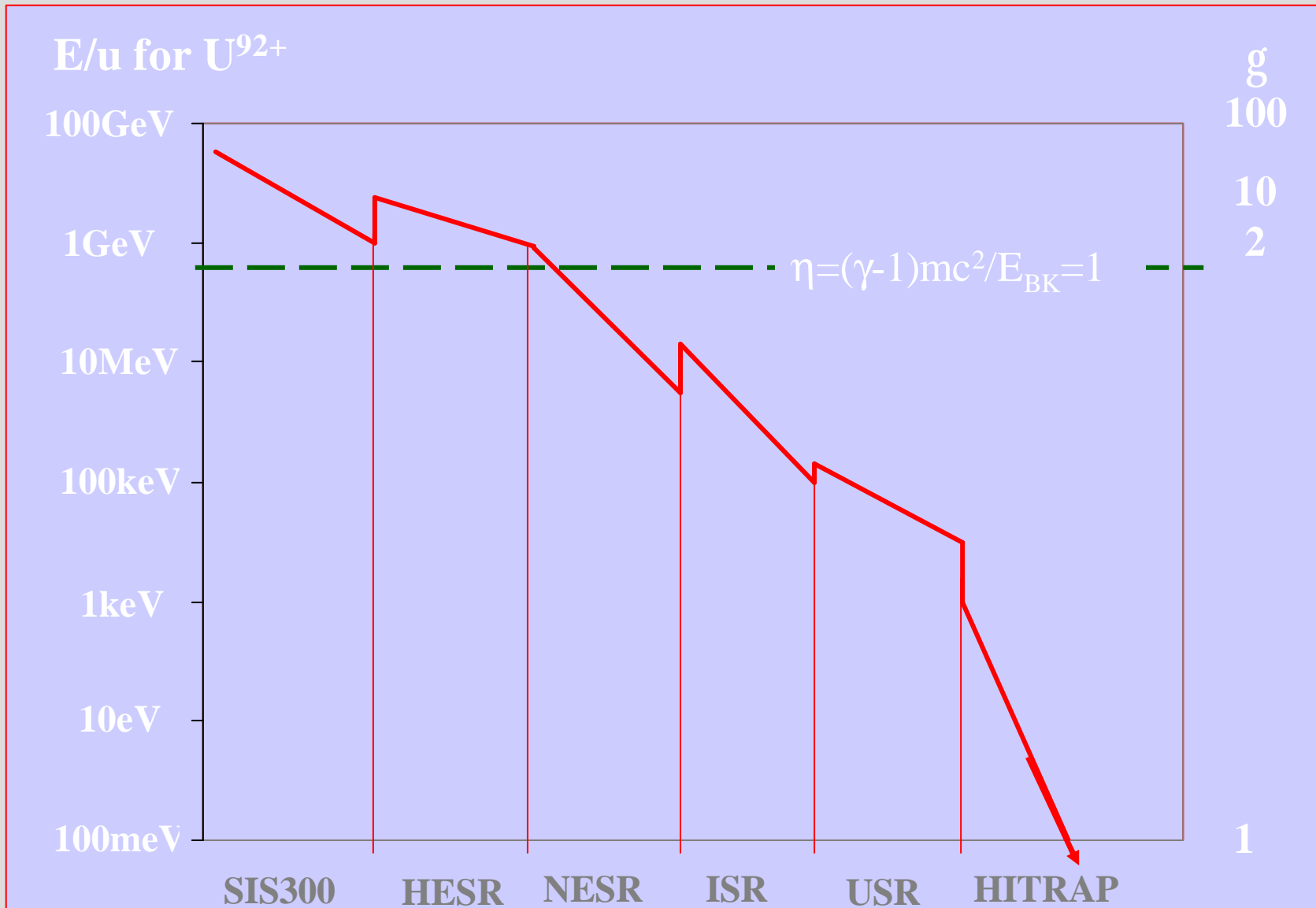


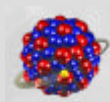
## Sensitivity of DR Experiments on Nuclear Effects



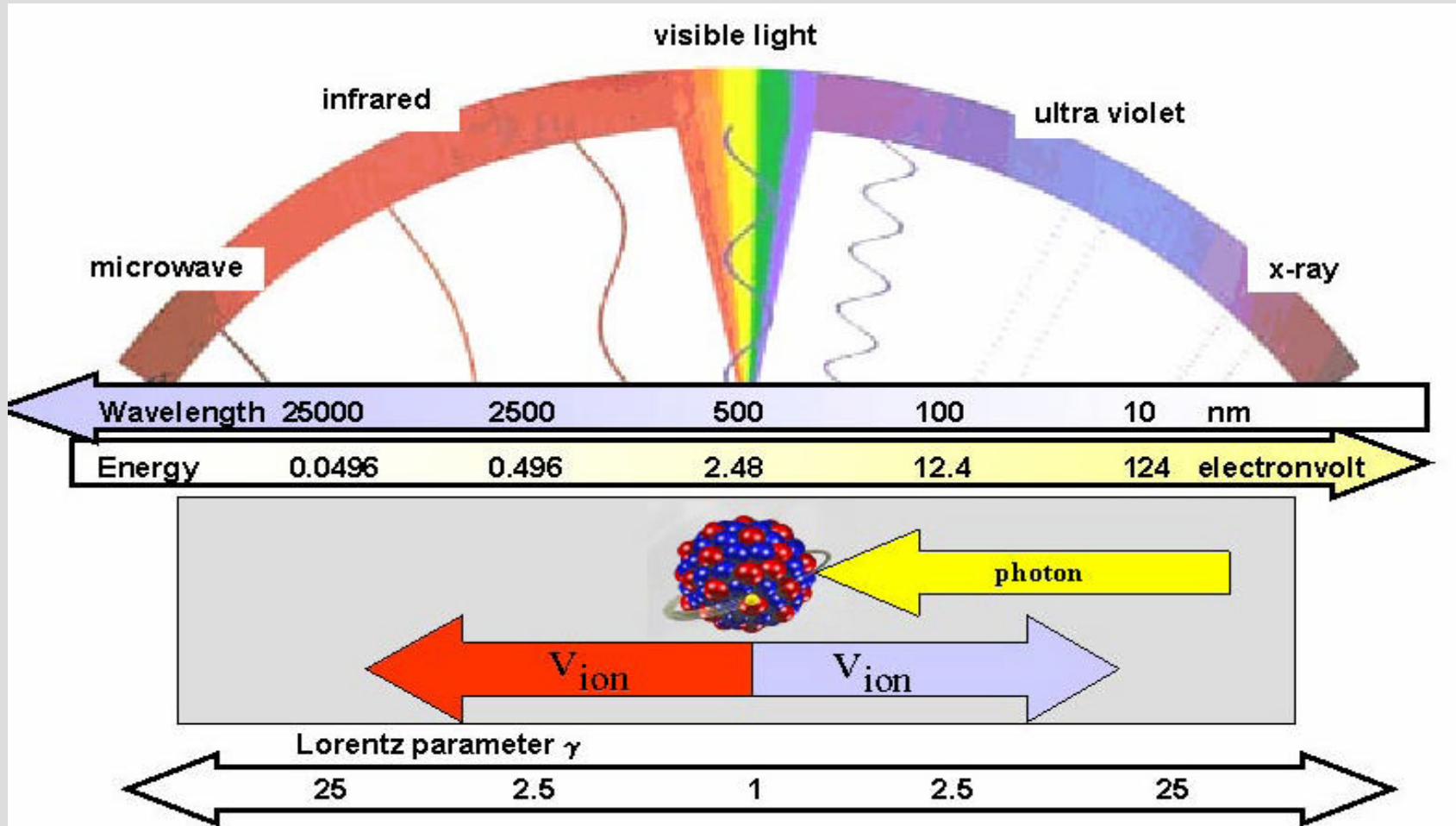


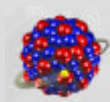
# Extreme Velocities Extreme Dynamic Fields





## Lorentz Shifted (g-boosted) Laser Cooling/ Spectroscopy





## Precision Measurements of 2s Lamb Shift in Strong Fields of High-Z Li-like Ions

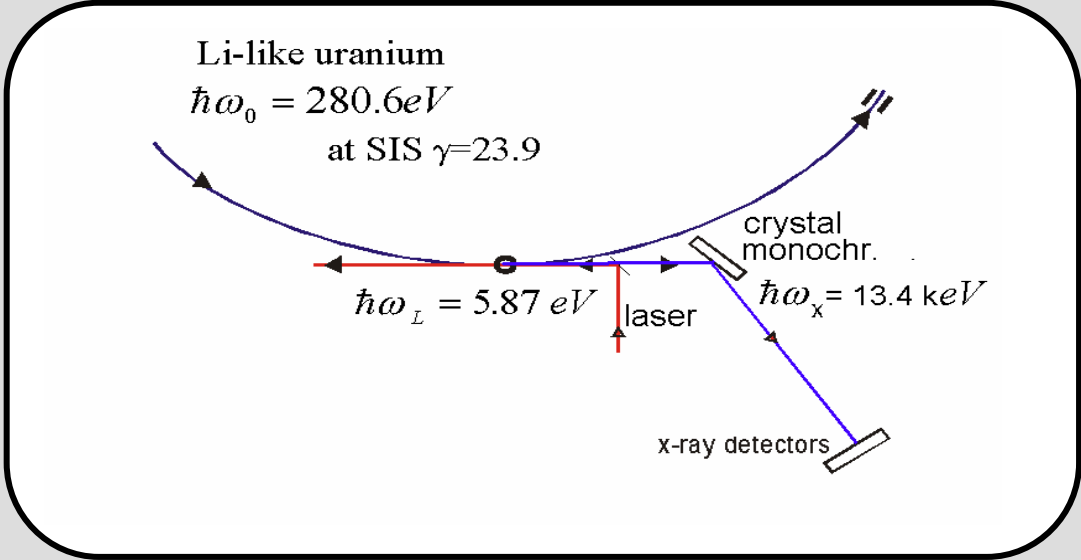
Lab.System (laser)  
 $\hbar\omega_L = 5.87 eV$

$\gamma=23.9$  ↓

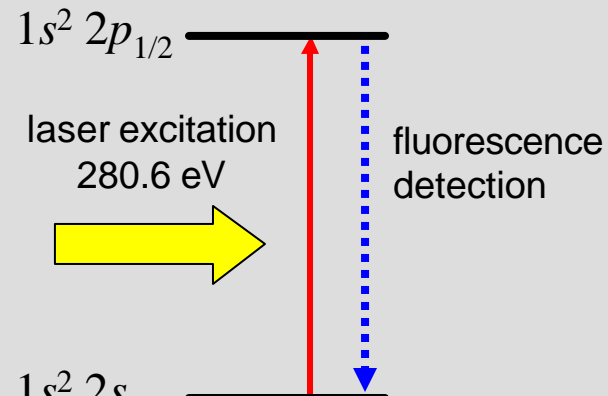
Projectile frame  
excitation  
 $\hbar\omega_0 = 280.6 eV$   
fluorescence

$\gamma=23.9$  ↓

Lab. System  
fluorescence  
 $\hbar\omega_X = 13384 eV$



The **large Doppler shift** allows us to use **visible laser** sources to excite transitions in the energy range up to **280 eV**, e.g. 2s-2p transitions in lithium-like heavy ions

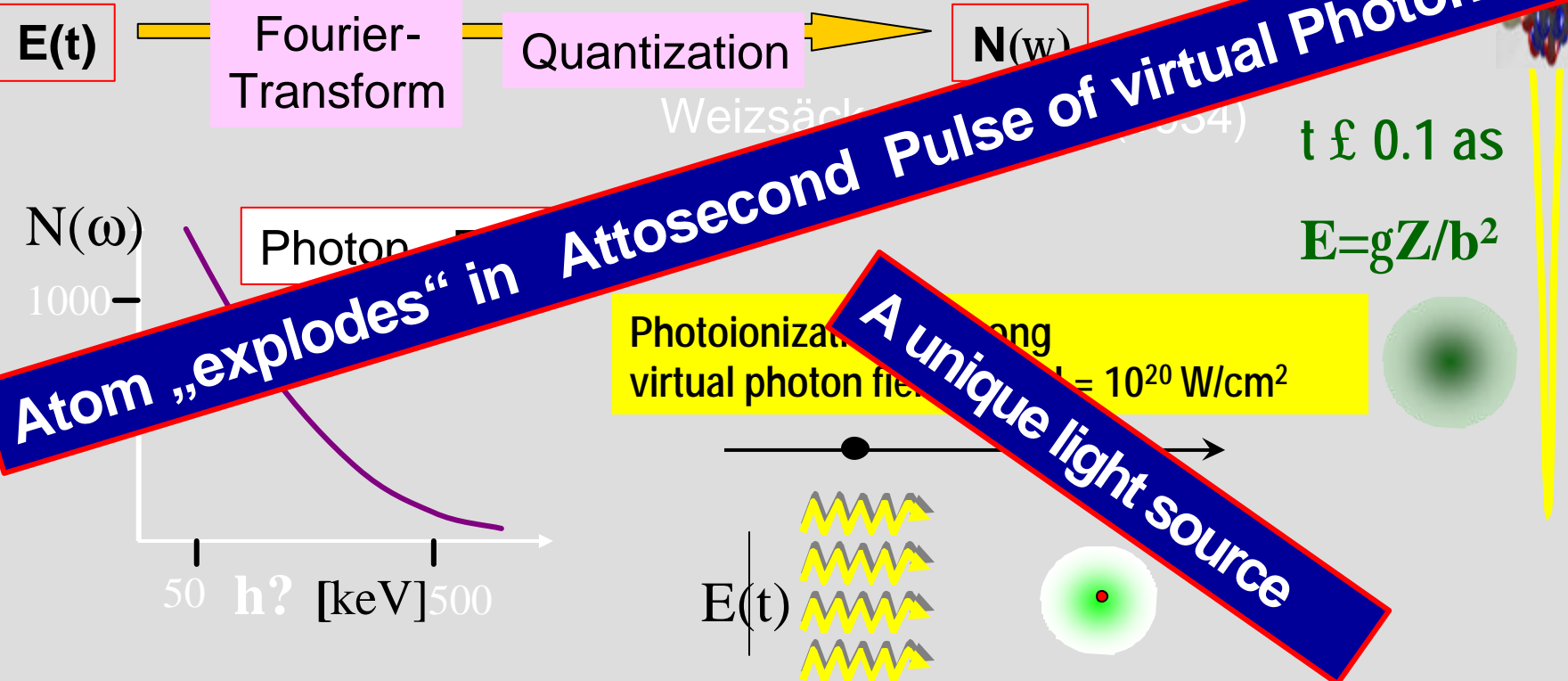
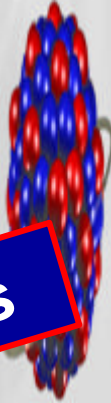
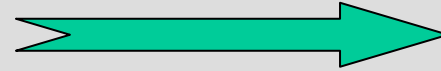
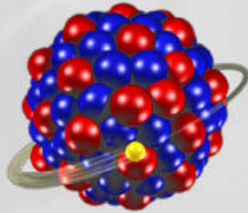


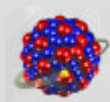


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Accelerator Facility  
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Warsaw, November 24, 2003



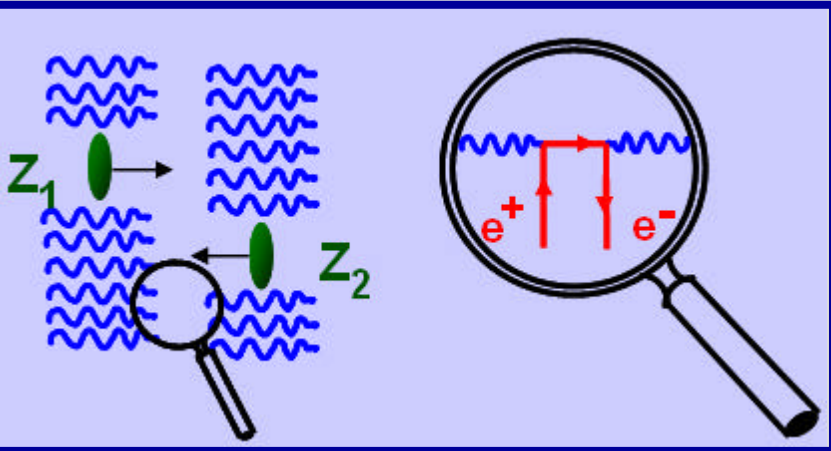
# Extreme Dynamic Fields





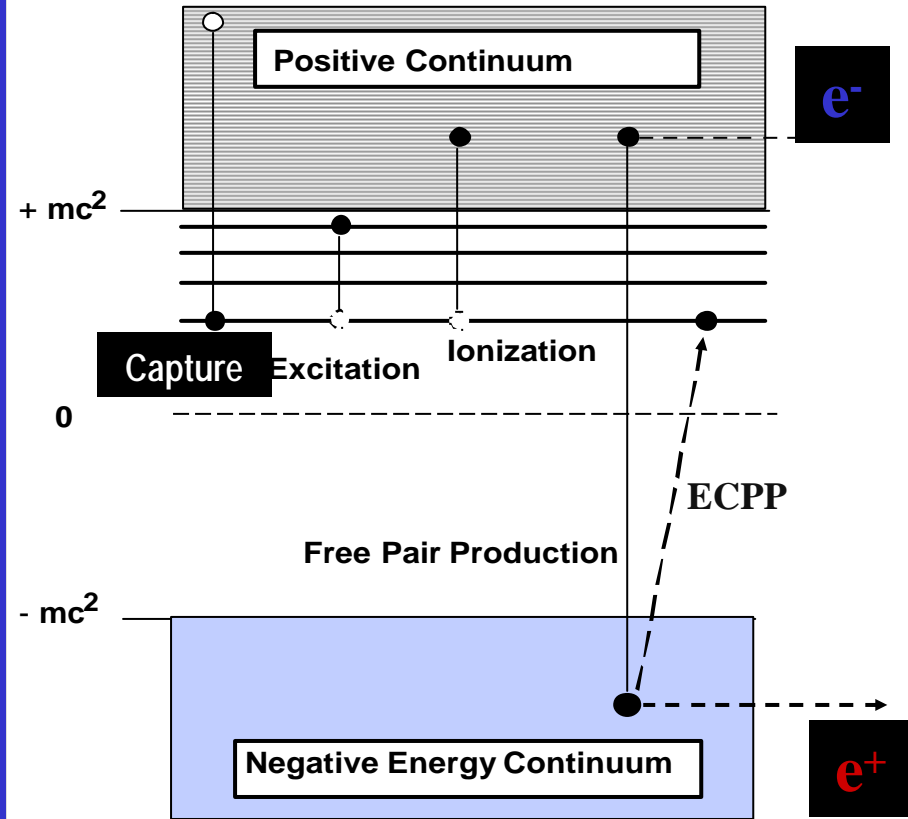
# Extreme Dynamic Fields

High-  $g$



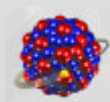
$$E \gg \frac{gZ}{b^2}$$

Collision times in the sub-attosecond regime  
( $10^{-22} \text{ s} < t < 10^{-18} \text{ s}$ )

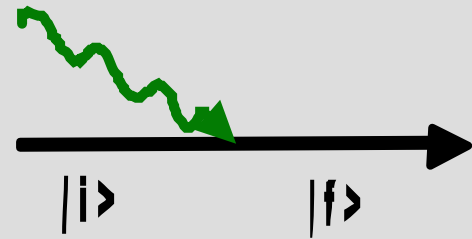




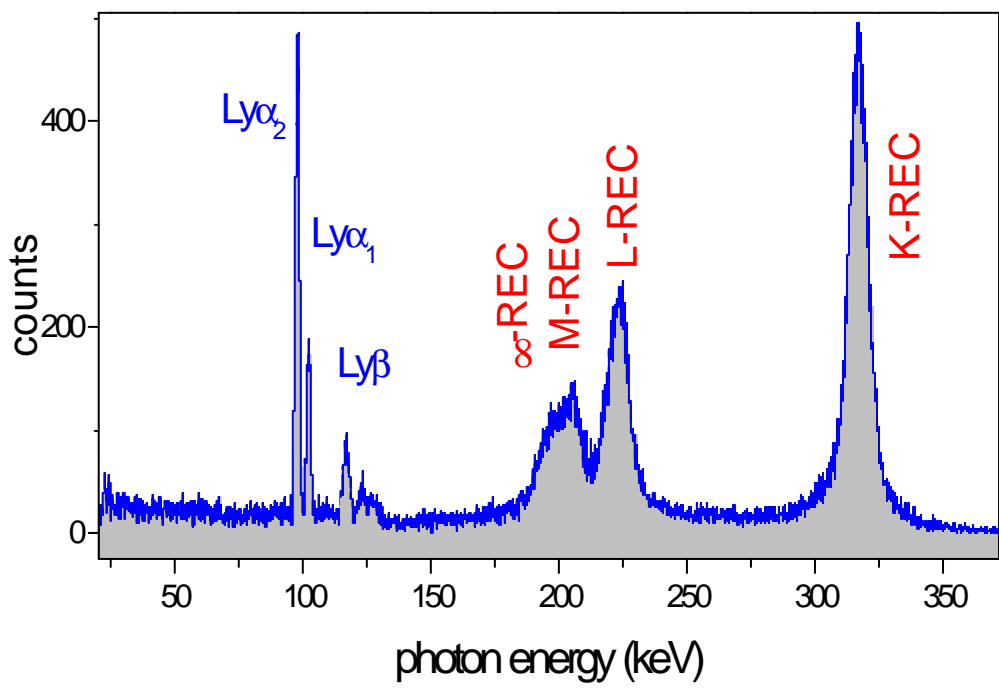
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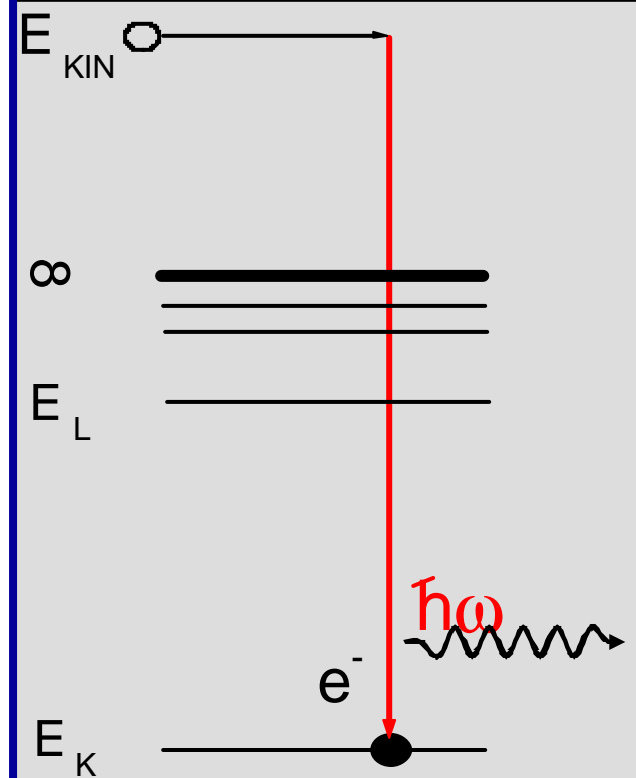
# Photon-Matter Interaction in the Relativistic Regime



$U^{92+} \Rightarrow N_2, 358 \text{ MeV/u}$

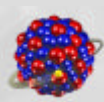


## Radiative Electron Capture



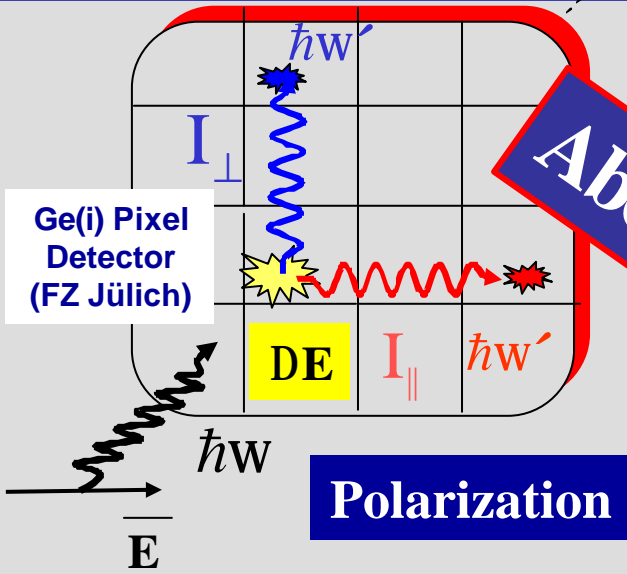
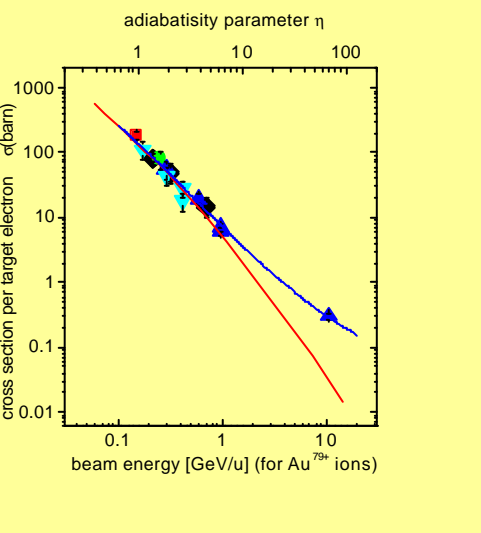


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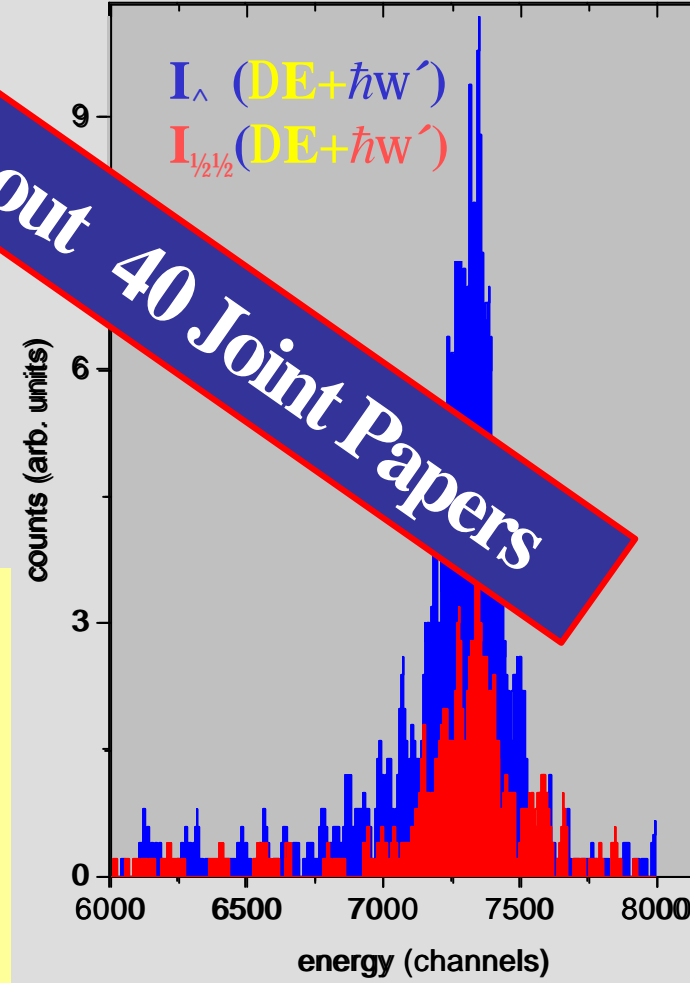


# Photon-Matter Interaction in the Relativistic Regime

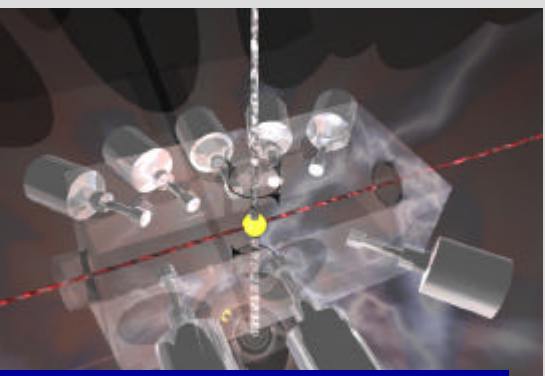
## Total cross sections



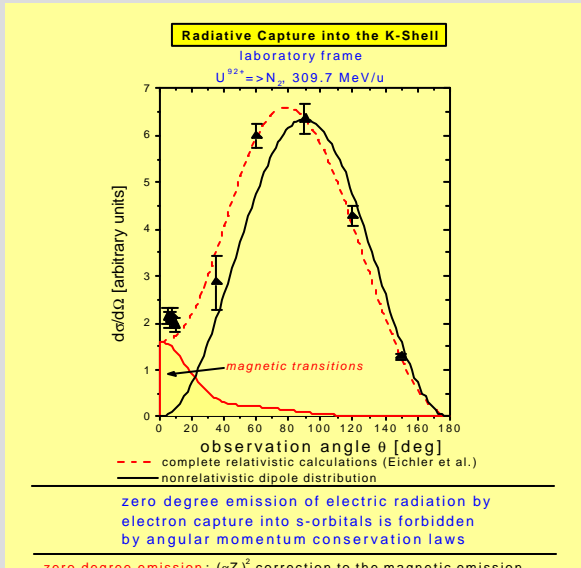
About 40 Joint Papers



## Gas Jet target



## Angular distribution



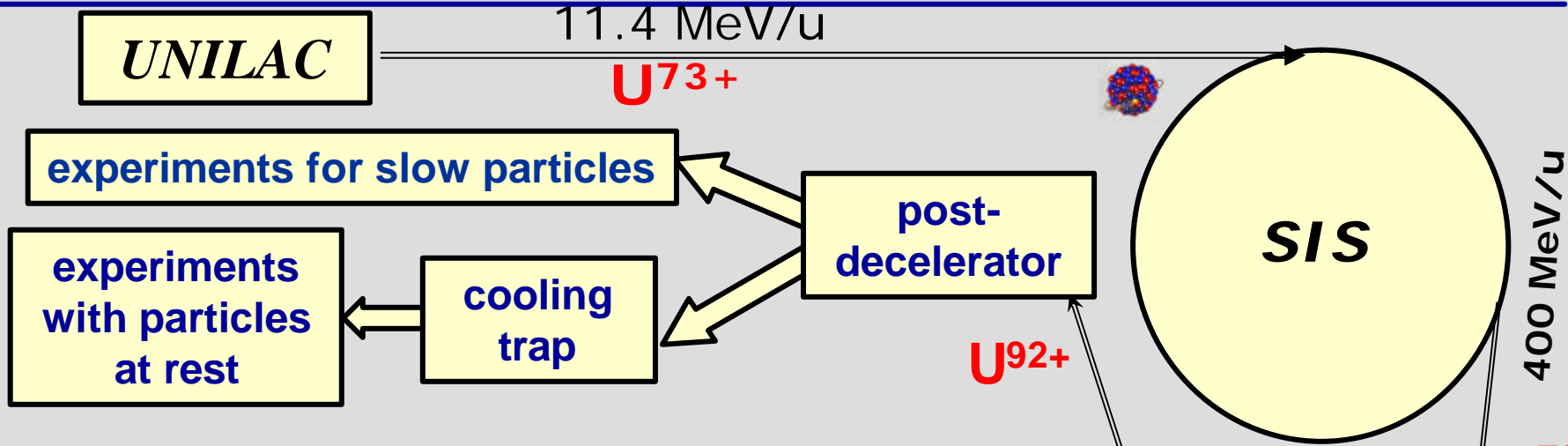
Frankfurt-GSI-Krakow-Kielce-Swierk  
Lanzhou-Argonne-Kassel-Berlin



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Warsaw, November 24, 2003



# The HITRAP Project at GSI



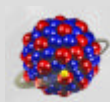
The HITRAP project will be a part of FLAIR

## **FACILITY FOR LOW-ENERGY ANTI-PROTONS and IONS RESEARCH**

electron cooling and deceleration



on the New International  
Accelerator Facility  
at Darmstadt,  
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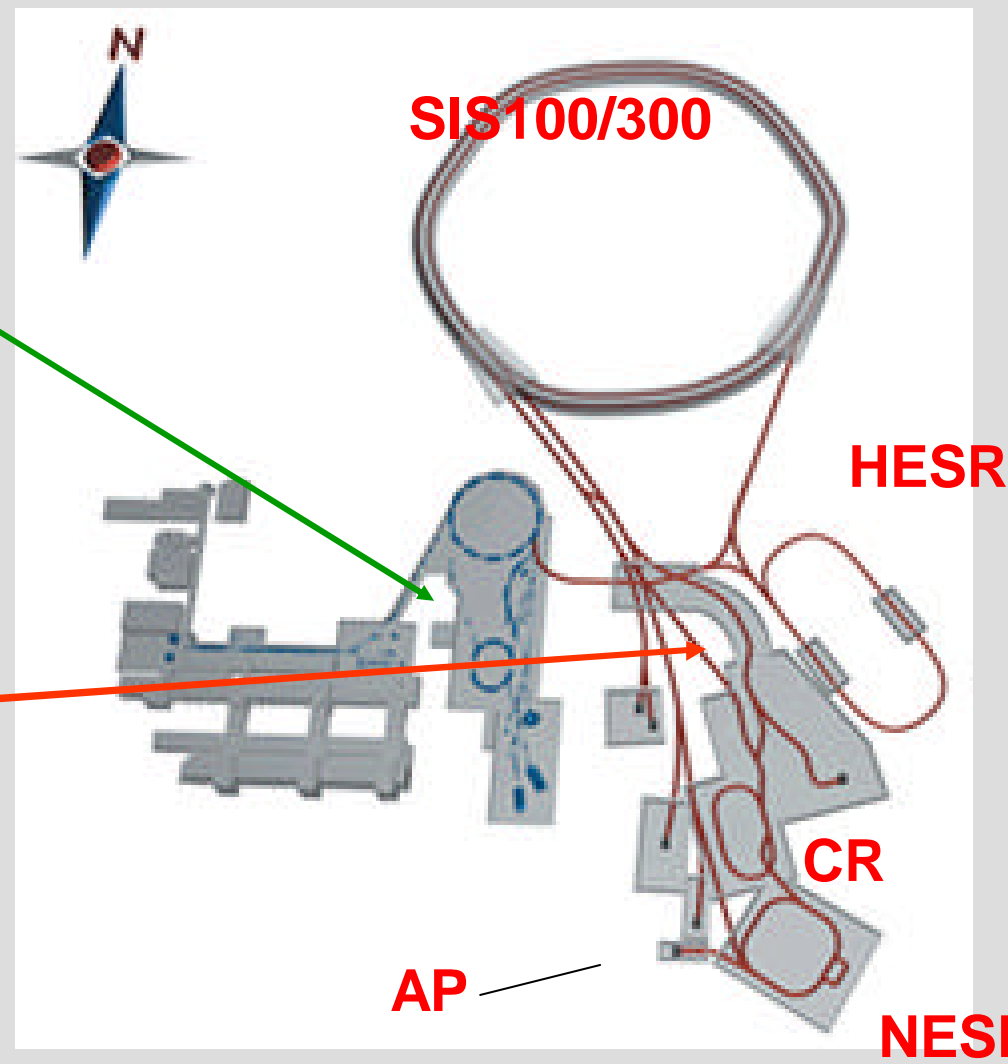
# Antiproton Factory

**Z – range**  
**1 => 92**

*New accelerator facility*

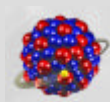
**Z – range**  
**-1 => 92**

**Parameters:**  
antiprotons  
up to 30 GeV,  
stored and cooled



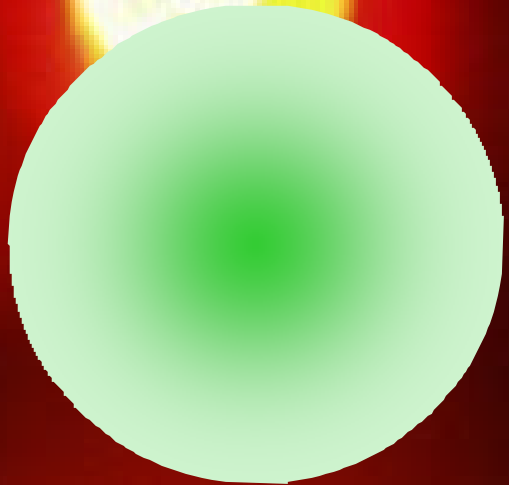


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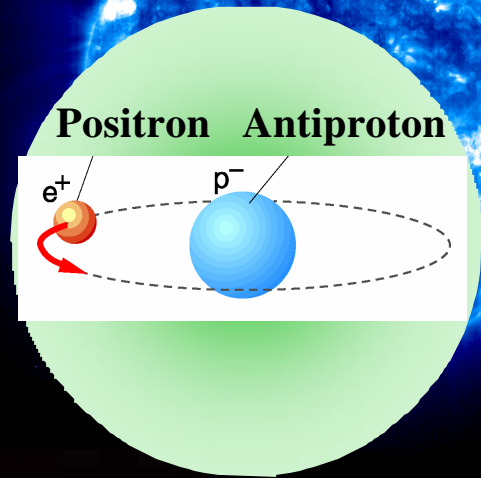


# Ultra-Slow and Trapped Antiprotons

Hydrogen



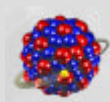
Antihydrogen



**Why is there no Antimatter**  
GSI will provide the Most Intense  
**in the Universe?**  
Source of Antiprotons



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Accelerator Facility  
at Darmstadt,  
Warsaw, November 24, 2003



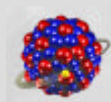
# Ultra-Slow and Trapped Antiprotons

## *What to Do with FLAIR*

- Test of fundamental symmetries: CPT
- Exotic systems: "Atomcules"
- Interaction of matter with antimatter



on the New International  
Accelerator Facility  
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Warsaw, November 24, 2003



# Atomic Physics

## Stored Particles Atomic Research Collaboration

*Atomic Physics Group, GSI, Darmstadt, Germany*  
*University of Frankfurt, Germany*  
*Jagiellonian University, Kraków, Poland*

*Institute of Nuclear Physics, PAN, Kraków, Poland*  
*Kansas State University, Kansas, USA*

*Institute of Nuclear Studies, Swierk, Poland*  
*Institute of Modern Physics, Lanzhou, China*

*Tbilisi State University, Tbilisi, Georgia*  
*Swietokrzyska Academy, Kielce, Poland*

*Fudan University, Shanghai, China,*  
*University of Giessen, Germany*  
*University of Tokyo, Japan*  
*LBNL, Berkeley, USA*  
*LLNL, Livermore, USA*

*Lebedev Institute, Moscow, Russia*  
*University of Dresden, Germany*  
*MPI Heidelberg, Germany*  
*University of Heidelberg, Germany*  
*University of Mainz, Germany*  
*University of Stockholm, Sweden*  
*Warsaw University, Warsaw, Poland*  
*ANL, Argonne, USA*  
*HMI, Berlin, Germany*  
*University of St. Petersburg, Russia*  
*University of Kassel, Germany*