High energy density plasma diagnostics at FAIR:
Novel laser based photon and particle sources

GSI, Darmstadt, Germany
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The excitation method of nuclei by femtosecond laser-plasma and the follow-up registration of nuclear transition emission

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Overview

1 Introduction

2 Goals and objectives

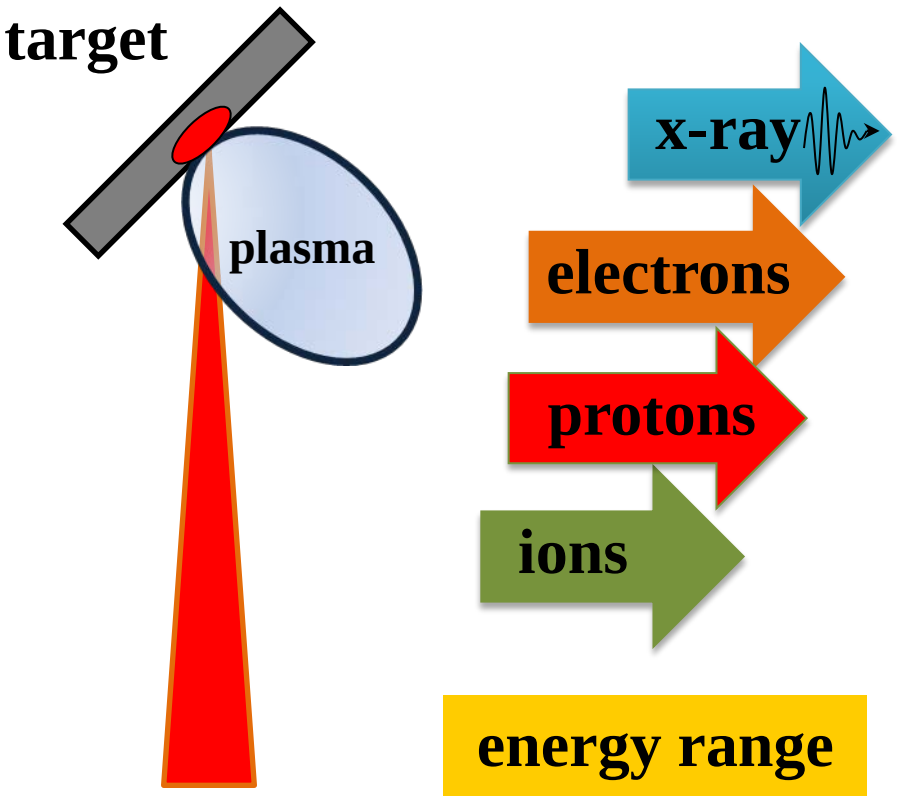
3 Experimental setup

4 Preliminary results

5 Conclusion

1 Introduction

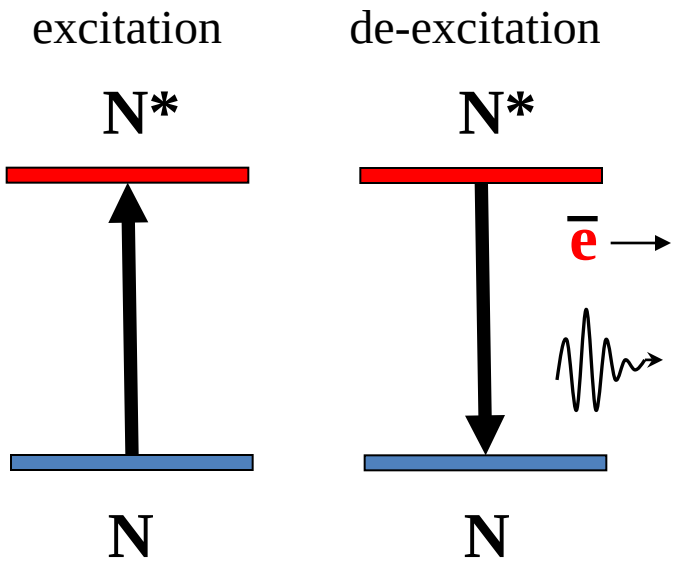
I ~ 10^{17} W/cm^2



femtosecond laser pulse

energy range 3 – 50 keV

The excitation of low-energy nuclear isomers



Excitation mechanisms
NEET, NEEC, inelastic electron scattering photoexcitation

De-excitation mechanisms
γ-ray, internally converted electrons

2 Goals and objectives

Goal:

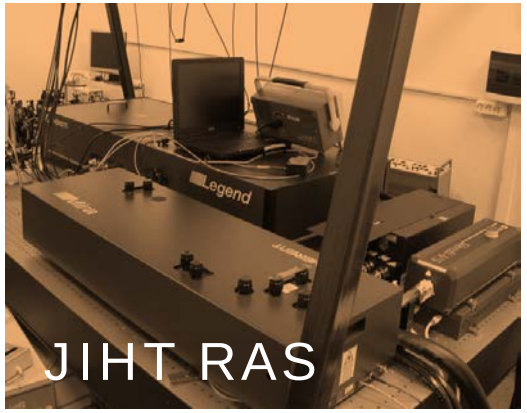
- The excitation of low-energy nuclear isomers by femtosecond laser-plasma and the subsequent registration of nuclear transition emission

Objectives:

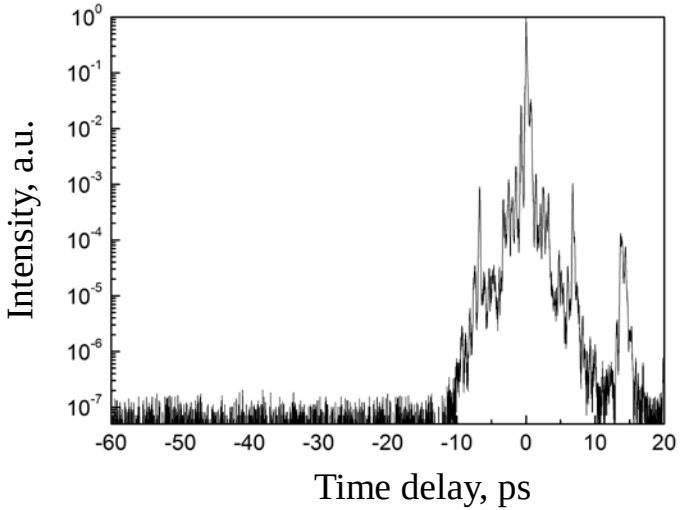
- Equipment check-out
  - Trouble-free operation of 1-kHz femtosecond laser system
  - Appropriate functioning of diverse set of diagnostics (for laser emission and laser-plasma source parameters)
- Required experimental conditions
  - to create a suitable plasma source of electrons and x-ray within the excitation energy range of considered atomic nucleus
  - to test the arrangement of two space-divided targets by using common iron (^{56}Fe) as the 2nd target

3 Experimental setup: Femtosecond Laser System

Sub-TW Ti:Sapphire 1-kHz femtosecond laser system



Temporal profile of laser pulse



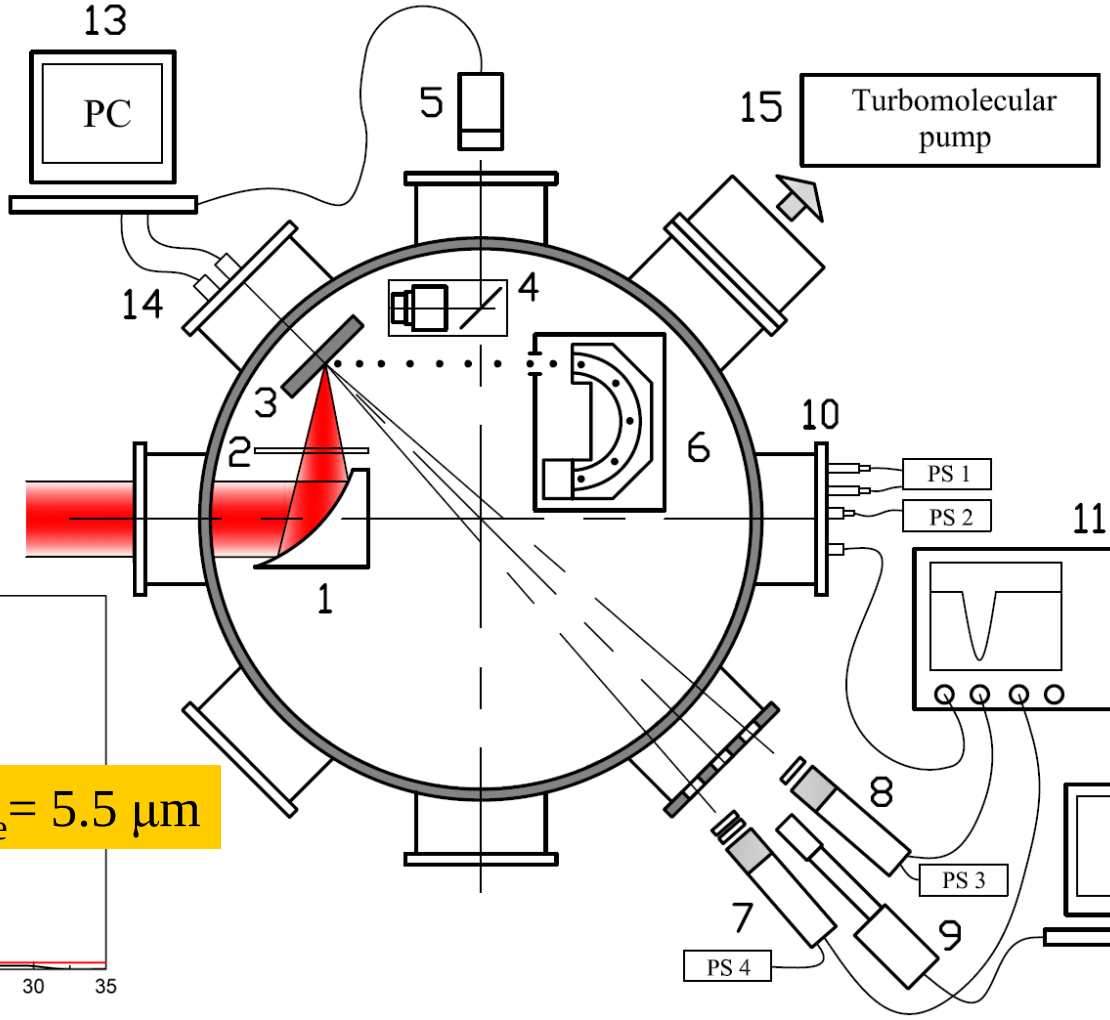
Beam quality:

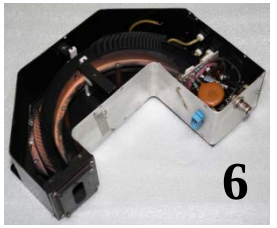
$M^2_x = 1.45$
$M^2_y = 1.22$

Output laser emission parameters:

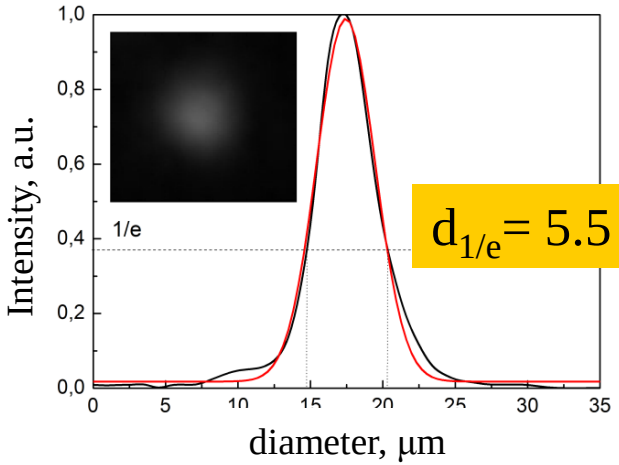
$\lambda = 800$ nm
$\tau = 40$ fs
$E = 1.5$ mJ

3 Experimental setup: laser-plasma source





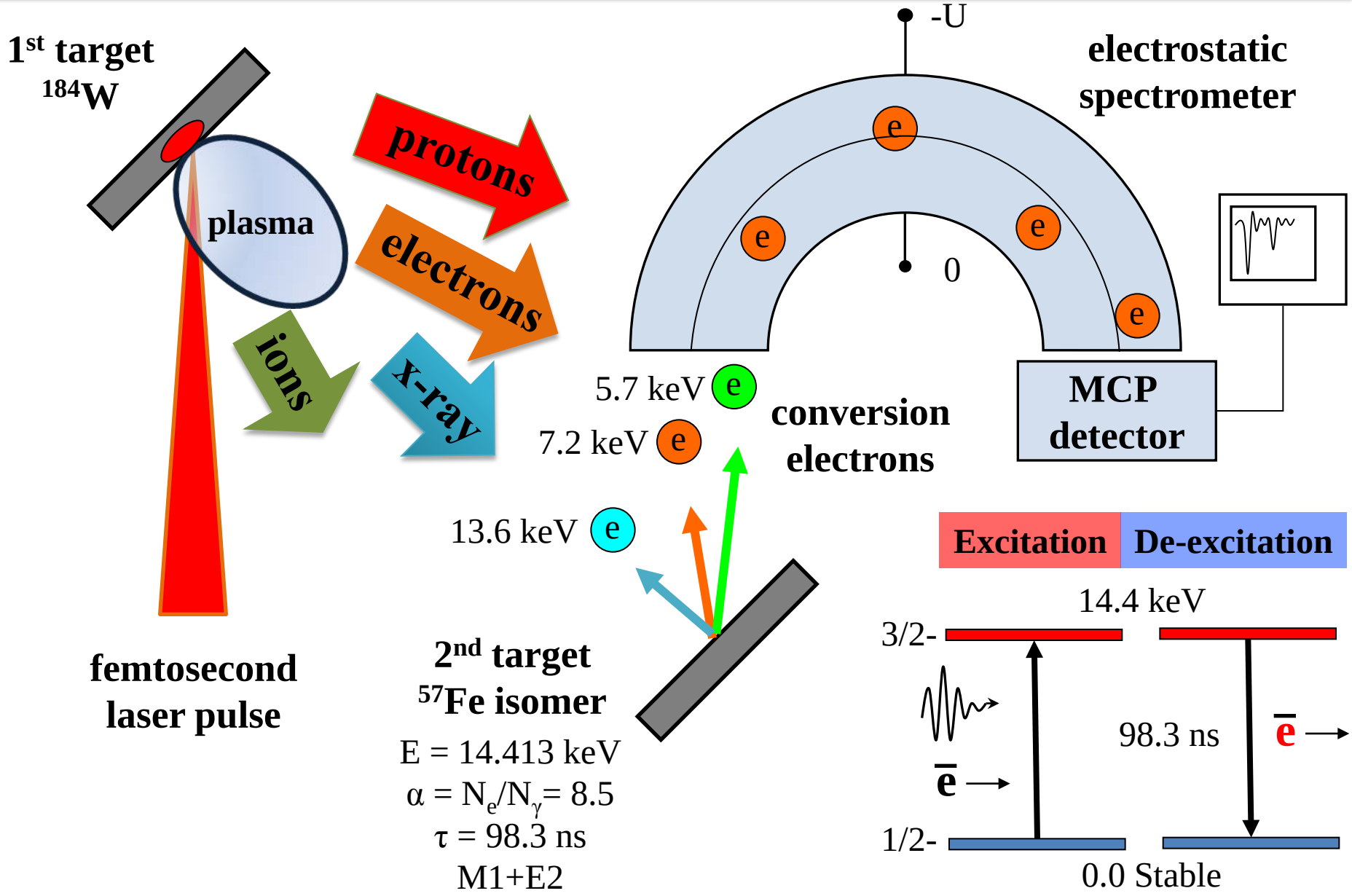
I ~ 10^{17} W/cm^2



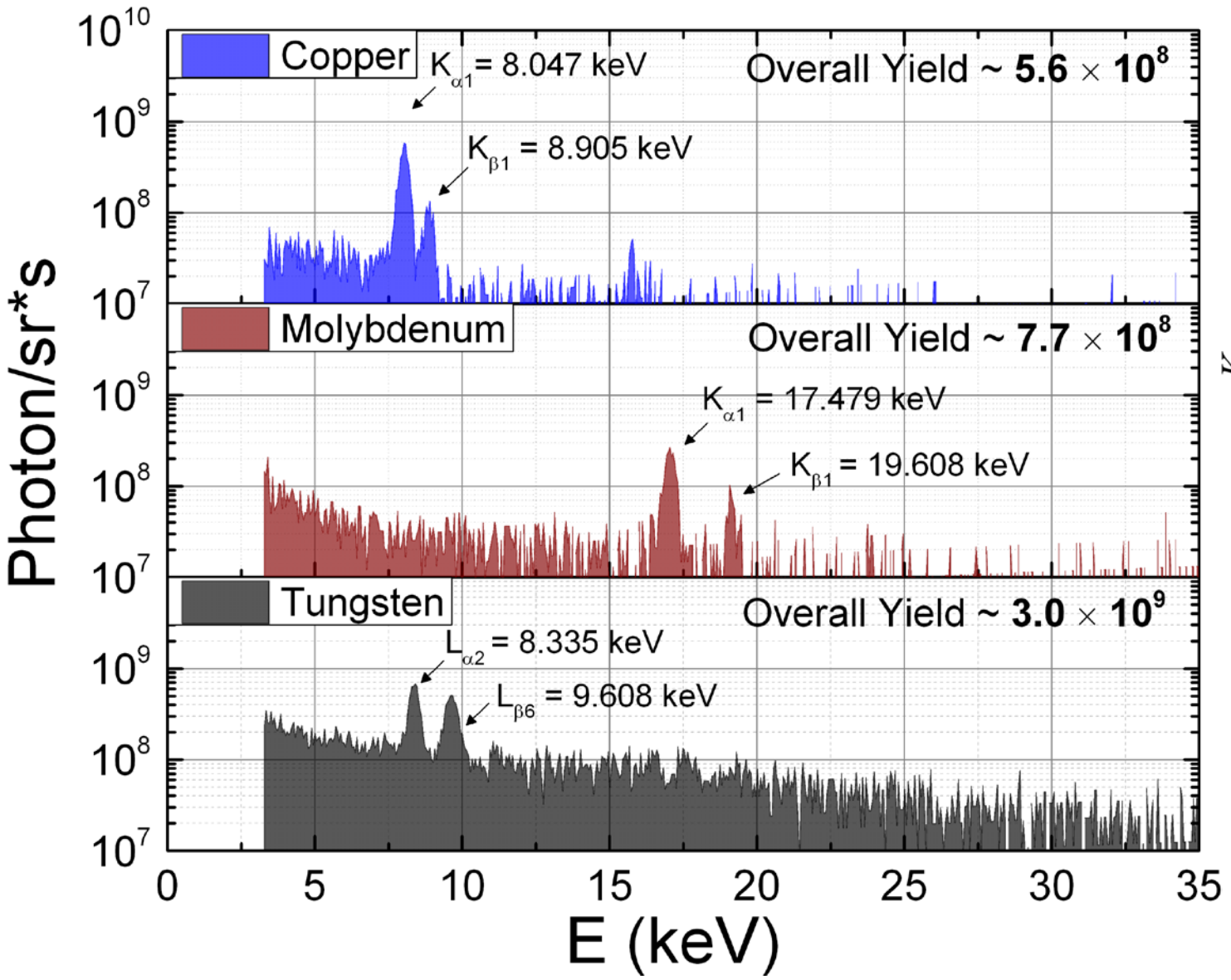
$d_{1/e}$= 5.5 μm

1 – off-axis parabolic mirror, 2 – rewind protective mylar film, 3 – target, 4 – objective, 5 – CCD-camera, 6 – electrostatic spectrometer, 7, 8 – PMT, 9 – x-ray spectrometer Amptek, 10 – flange for HV-connectors, 11 – oscilloscope, 12, 13 – PS, 14 – flange for motorized tables, 15 – oil-free turbomolecular pump

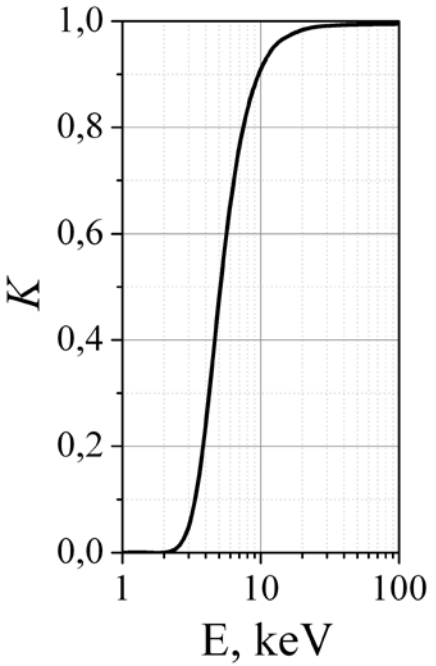
3 Experimental setup: nuclear isomer excitation



4 Preliminary results: x-ray spectra at 10^{17} W/cm^2



Transmission energy range 3.3 – 100 keV

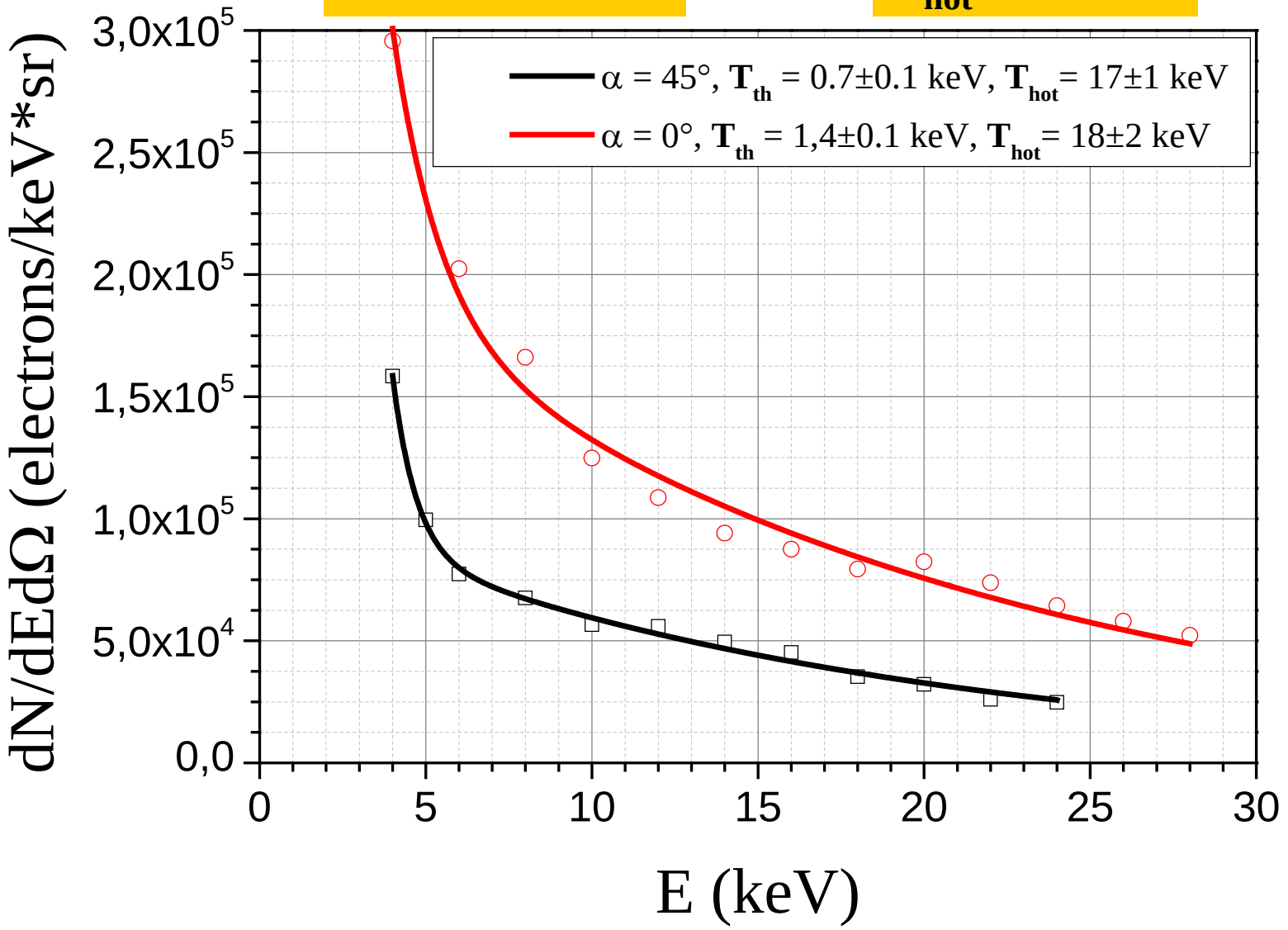


Target	Yield×10^9
Cu	**0.56**
Mo	**0.77**
W	**3.0**

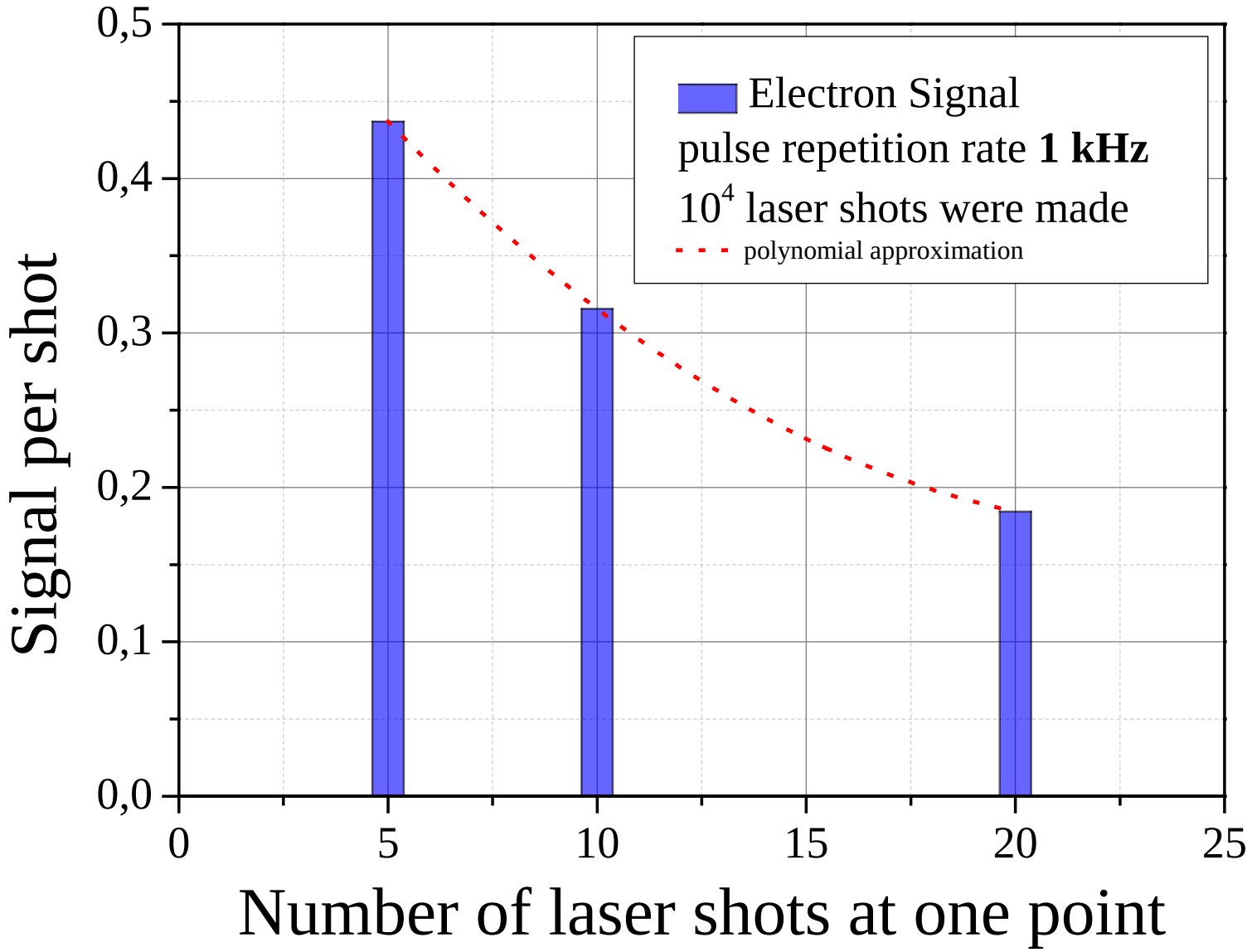
4 Preliminary results: plasma electron spectrum

$I \sim 10^{17}$ W/cm^2

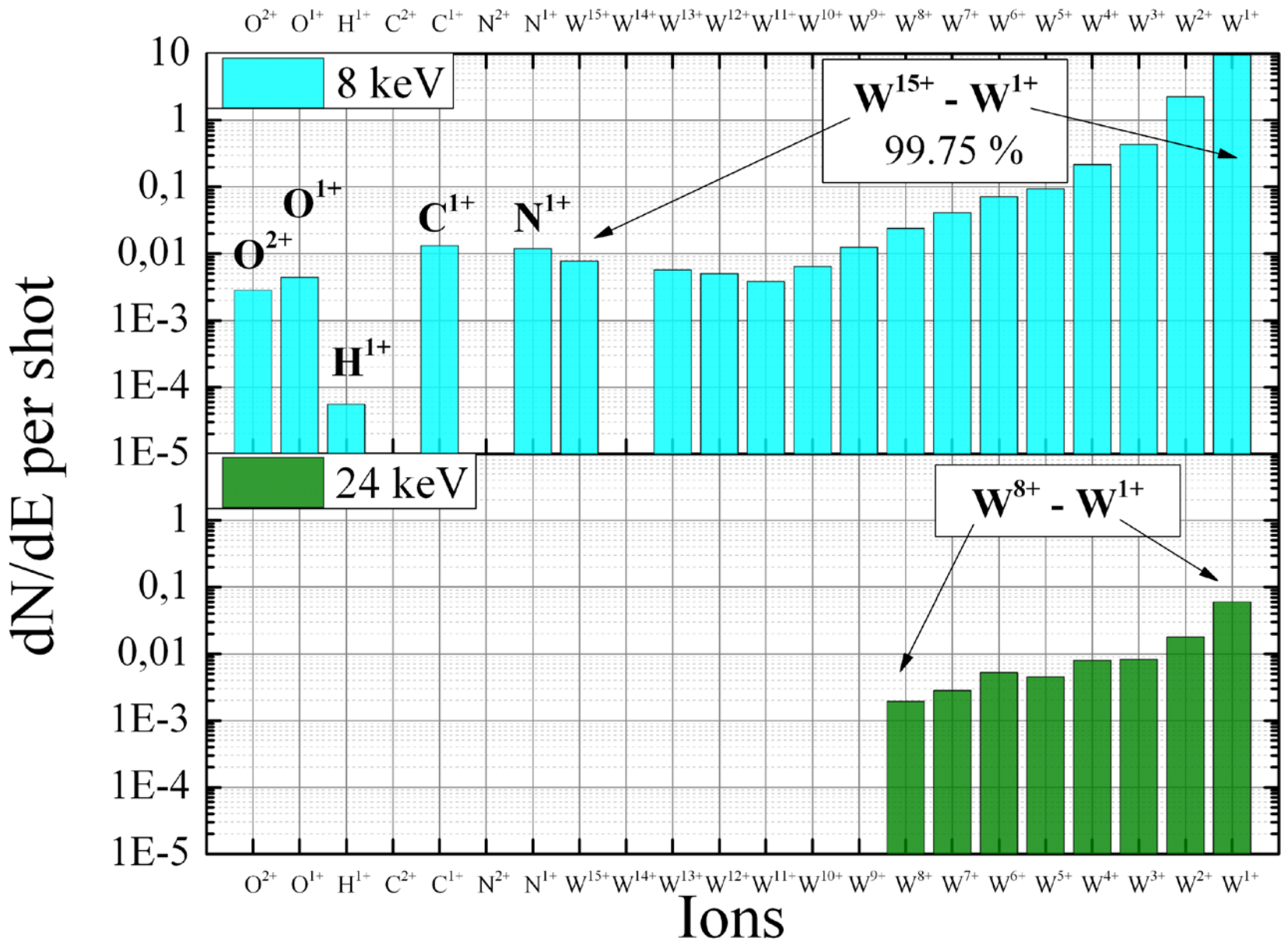
$T_{hot} \sim 17$ keV



4 Preliminary results: electron yield enhancement

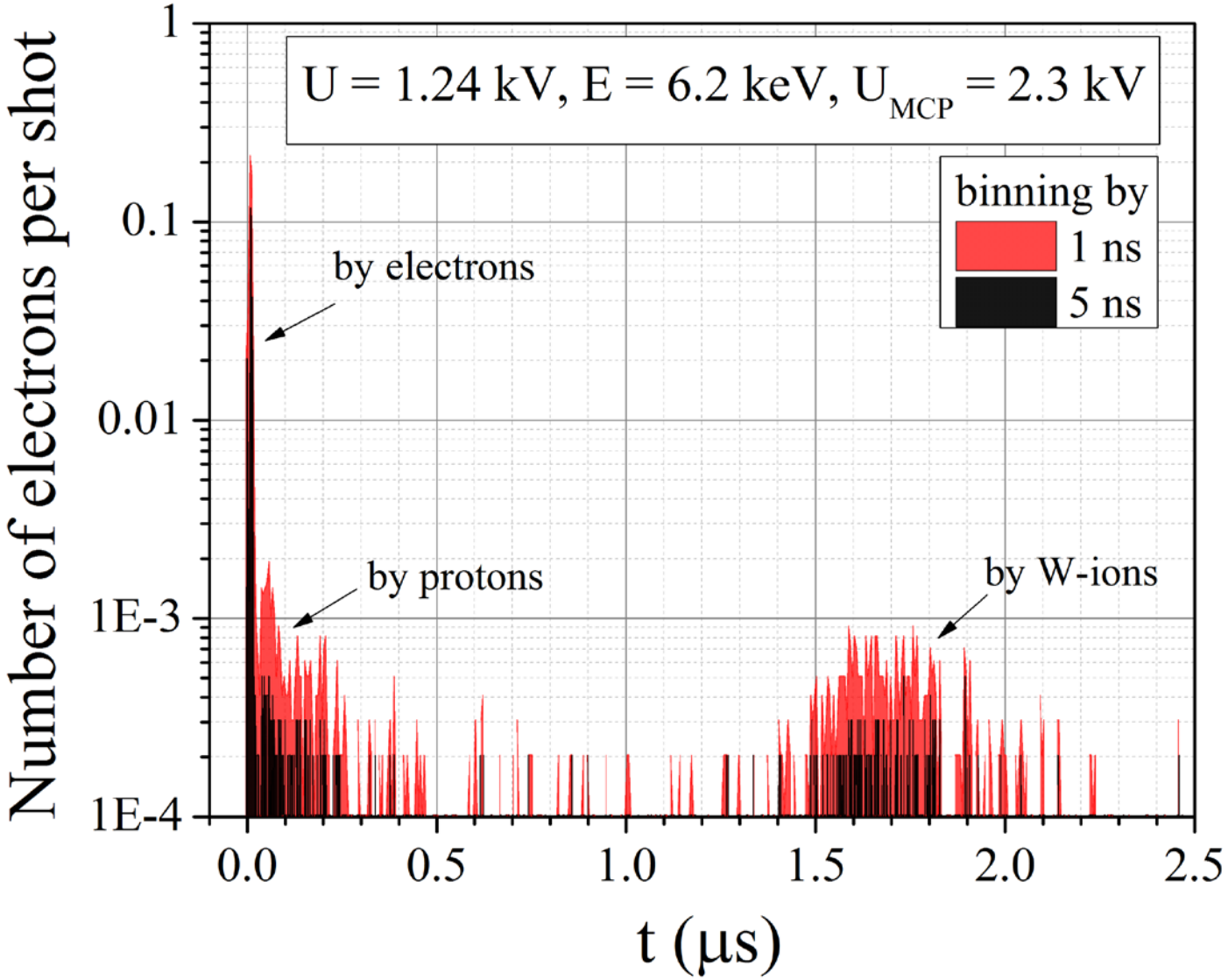


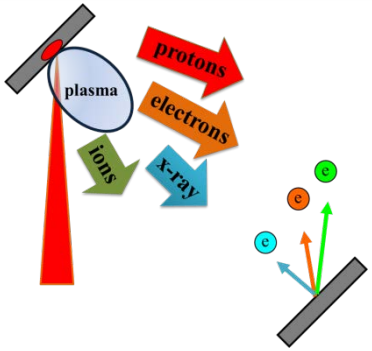
4 Preliminary results: ionic composition



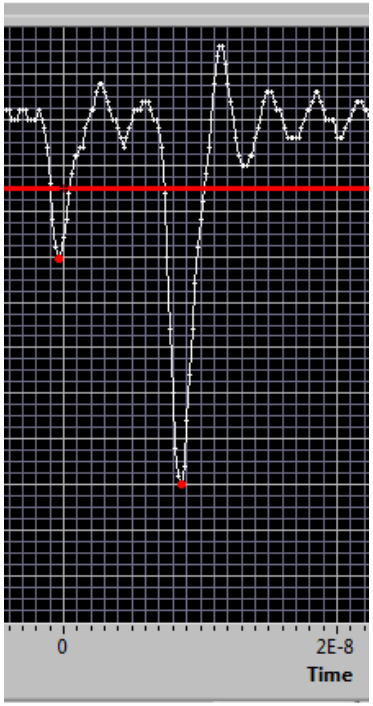
4 Preliminary results: “electron current”

The typical electron current (2.5 μs) from the 2nd target of ^{56}Fe

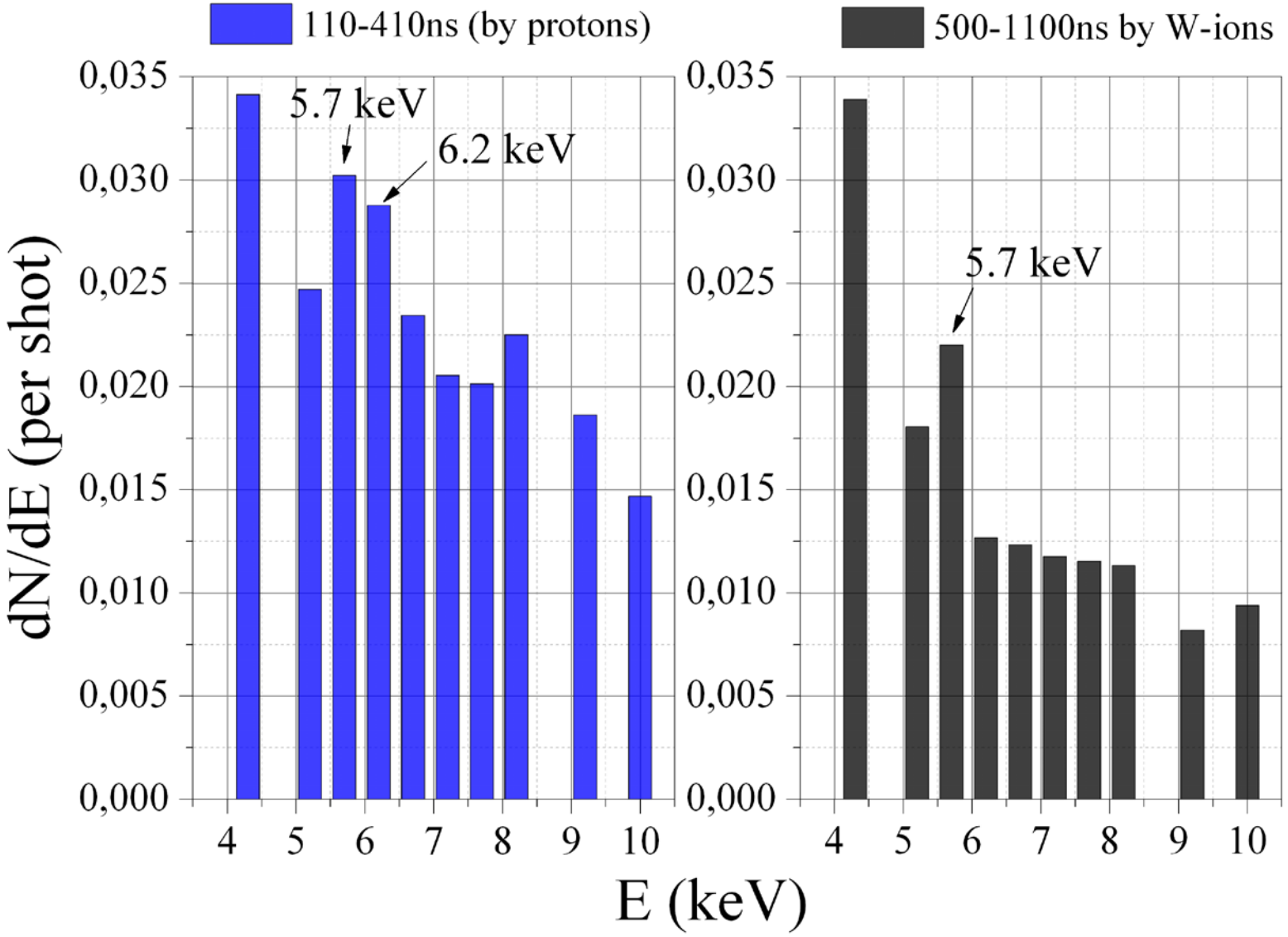




The example of oscillograph picture



4 Preliminary results: Auger lines for ^{56}Fe



5 Conclusion

We have

- provided a sustained performance of the 1-kHz femtosecond laser
- adjusted the proper diagnostics methods and devices
- measured all the necessary experimental parameters
- estimated the main characteristics of the laser-plasma source
- perfected the arrangement of two space-divided targets

We are on the way

- to analyze the obtained experimental in detail
- to understand what else can be done to improve the reliability and signal-to-noise ratio
- to excite nuclear isomers by femtosecond laser-plasma

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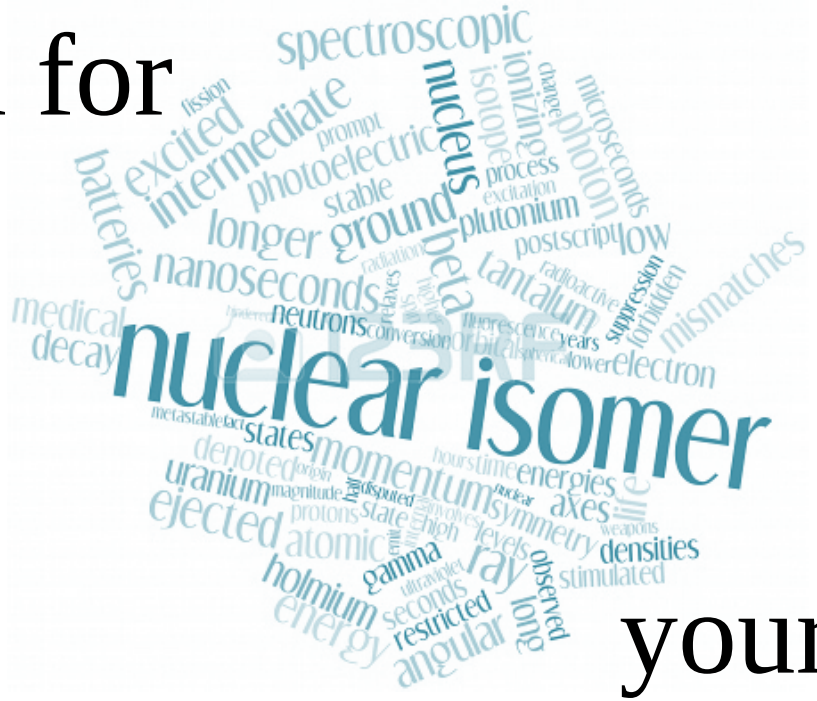
Thank you for



your attention.

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Savel'ev A.B., Shulyapov S.A.

GSI FAIR HELMHOLTZ ASSOCIATION Helmholtz Institute Jena JGU JOHANNES GUTENBERG UNIVERSITÄT MAINZ HELMHOLTZ ASSOCIATION GOETHE UNIVERSITÄT FRANKFURT AM MAIN EMMI