PHELIX and Nuc. Phys. In HEDP

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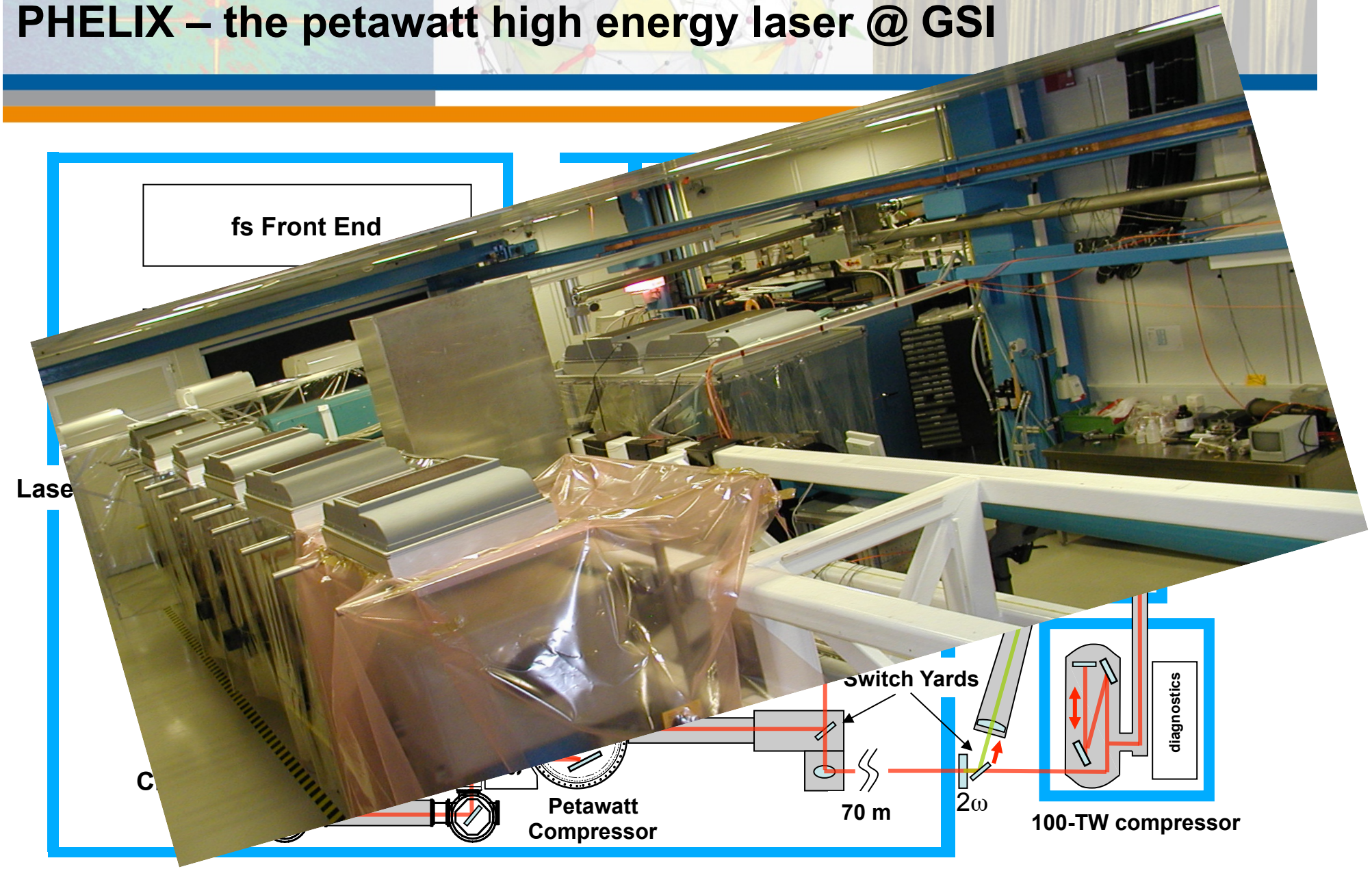
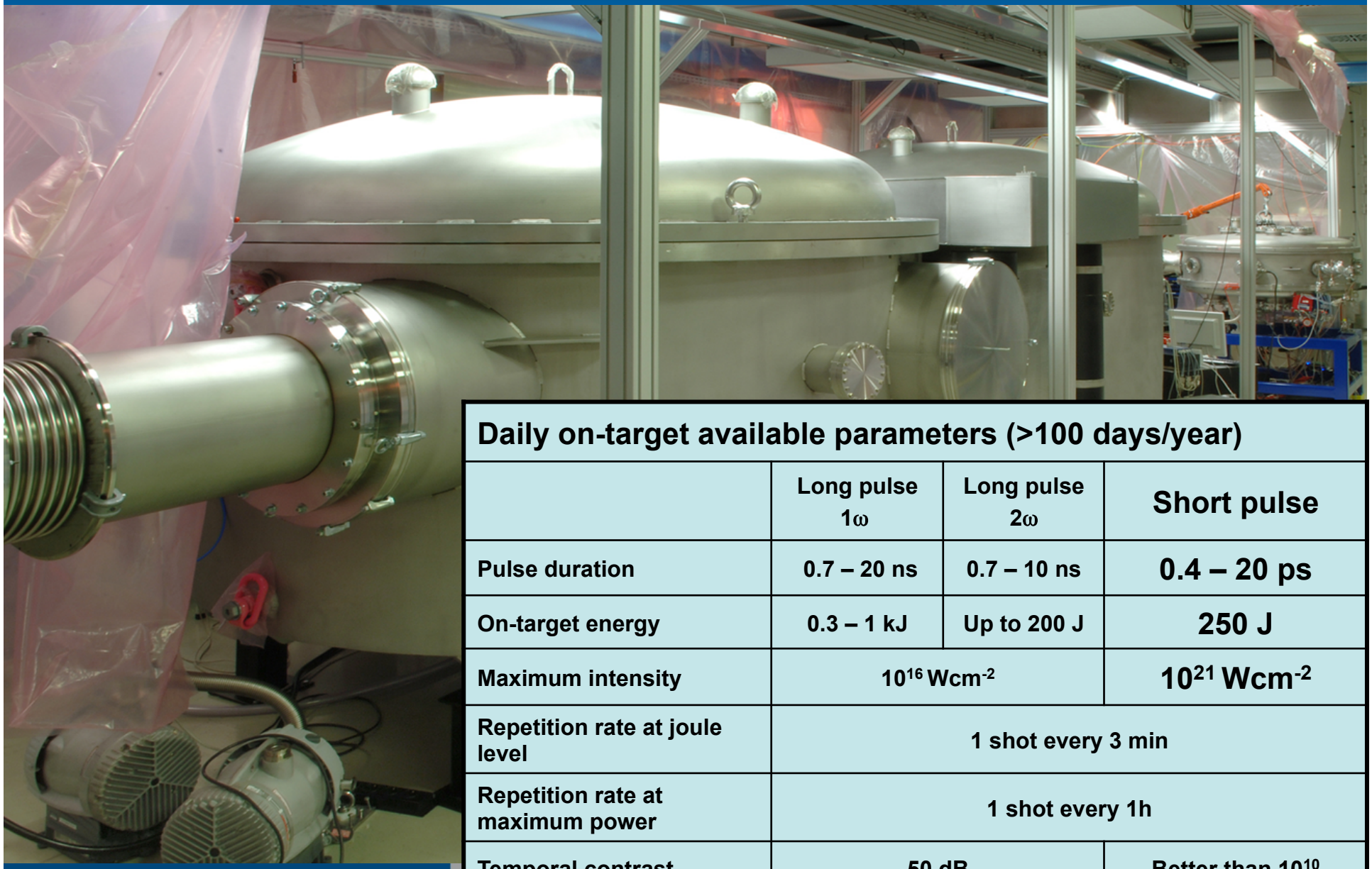
PHELIX and GSI are the ideal place for many nuclear physics experiments with HEPW lasers

- PHELIX is a world-class user facility offering worldwide unique laser-ion experiment capabilities
- GSI has the expertise to prepare the next generation of laser at FAIR
- Current nuclear physics experiments include
  - NEET experiment (PI: F. Hannachi, CENBG, France)
  - Nuclear activation from laser accelerated particles (LIGHT project, PI M. Roth, TU-Darmstadt)
- Future experiments at FAIR could include
  - Research on laser-assisted nuclear waste transmutation
  - Neutron sources

PHELIX – the petawatt high energy laser @ GSI

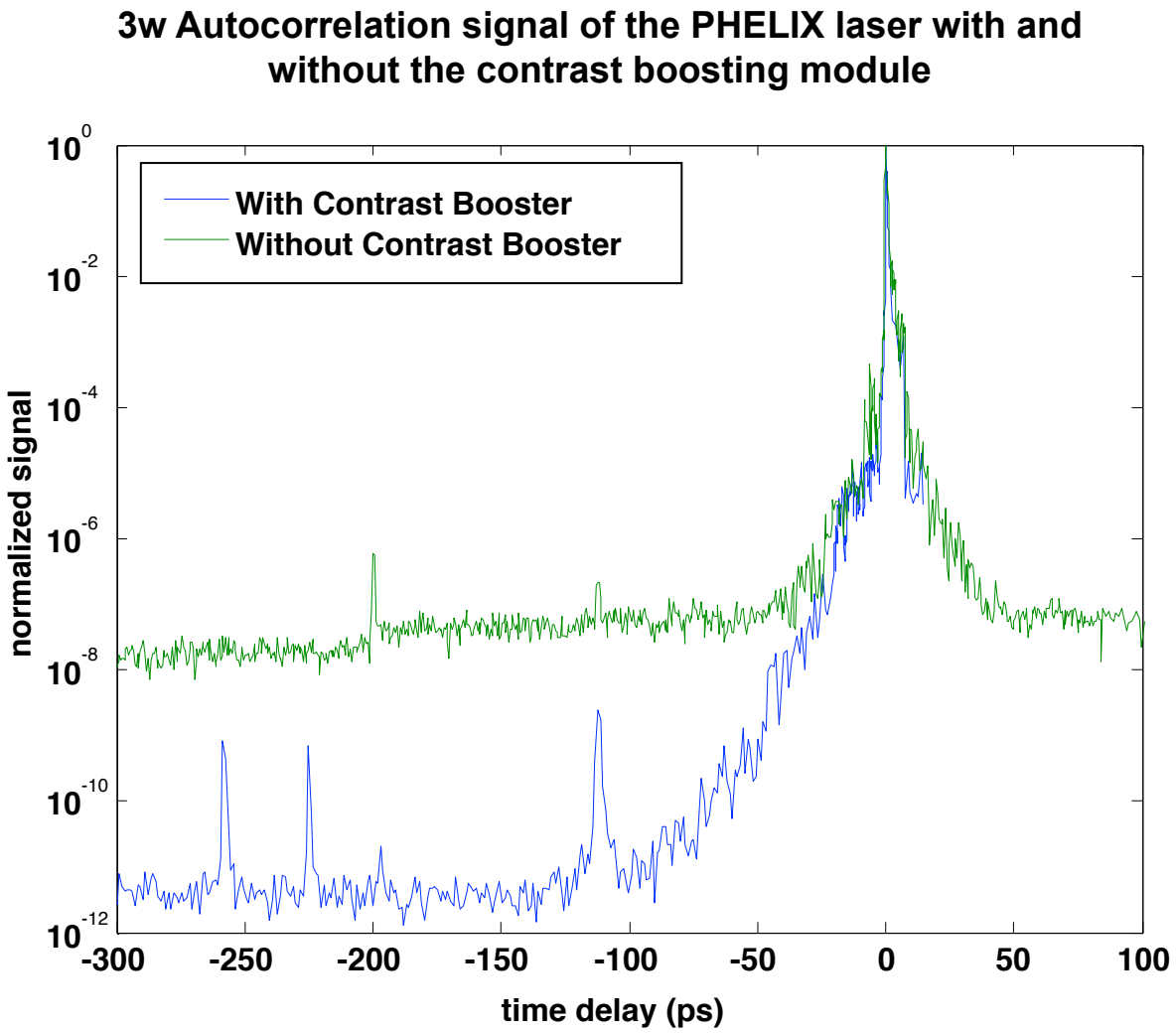


PHELIX is a reliable machine available to the user community

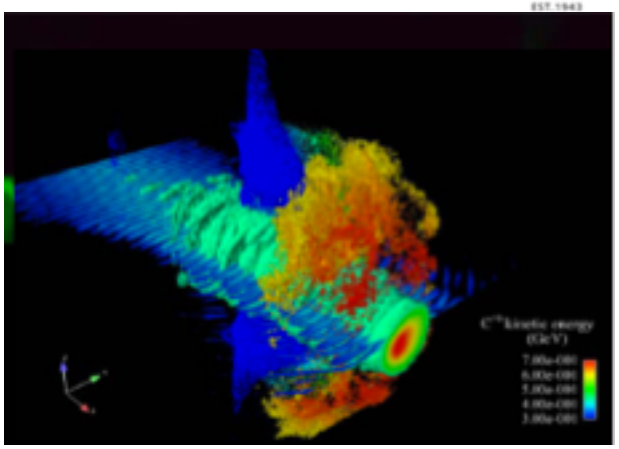


Daily on-target available parameters (>100 days/year)			
	Long pulse 1ω	Long pulse 2ω	Short pulse
Pulse duration	0.7 – 20 ns	0.7 – 10 ns	0.4 – 20 ps
On-target energy	0.3 – 1 kJ	Up to 200 J	250 J
Maximum intensity	10^{16} Wcm^{-2}		10^{21} Wcm^{-2}
Repetition rate at joule level	1 shot every 3 min		
Repetition rate at maximum power	1 shot every 1h		
Temporal contrast	50 dB		Better than 10^{10}

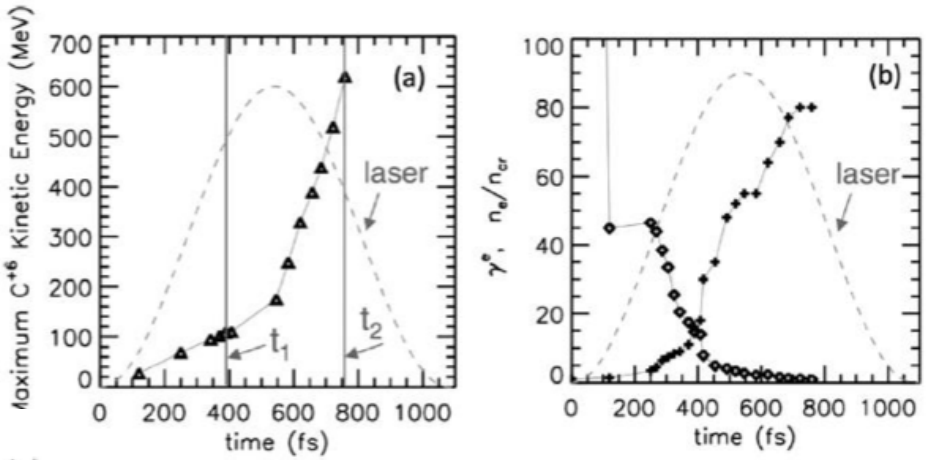
A recent upgrade of PHELIX to high-contrast improves the experimental capabilities

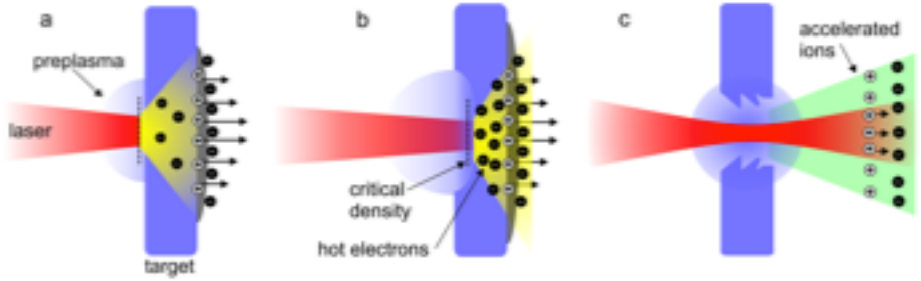


High temporal contrast pulses are a pre-requisite for studying new laser-assisted particle acceleration processes



2D-VPIC: 58nm DLC target & Trident laser with 5x10^{20}W/cm^2





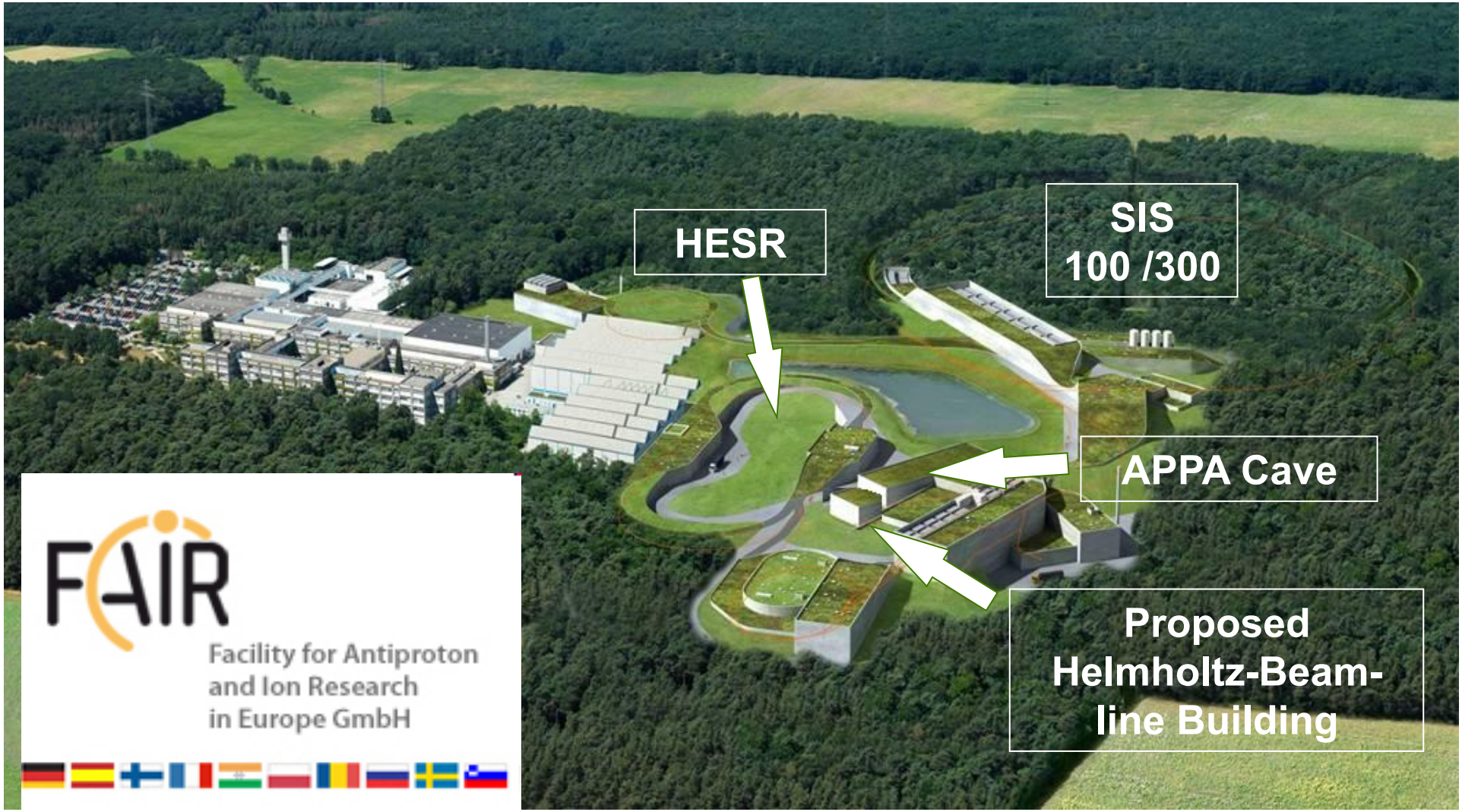
a) Target Normal Sheath Acceleration (TNSA) phase
b) Intermediate phase
c) Laser Breakout Afterburner (BOA) phase

Maximum proton energy (MeV)								
Thickness (μm)	0.2	0.3	0.4	0.6	0.8	1.0	1.5	2.5
H2			145			205	230	190
SiO2 + H2	130		190	225	250	220	180	
CH2	70	80	90					

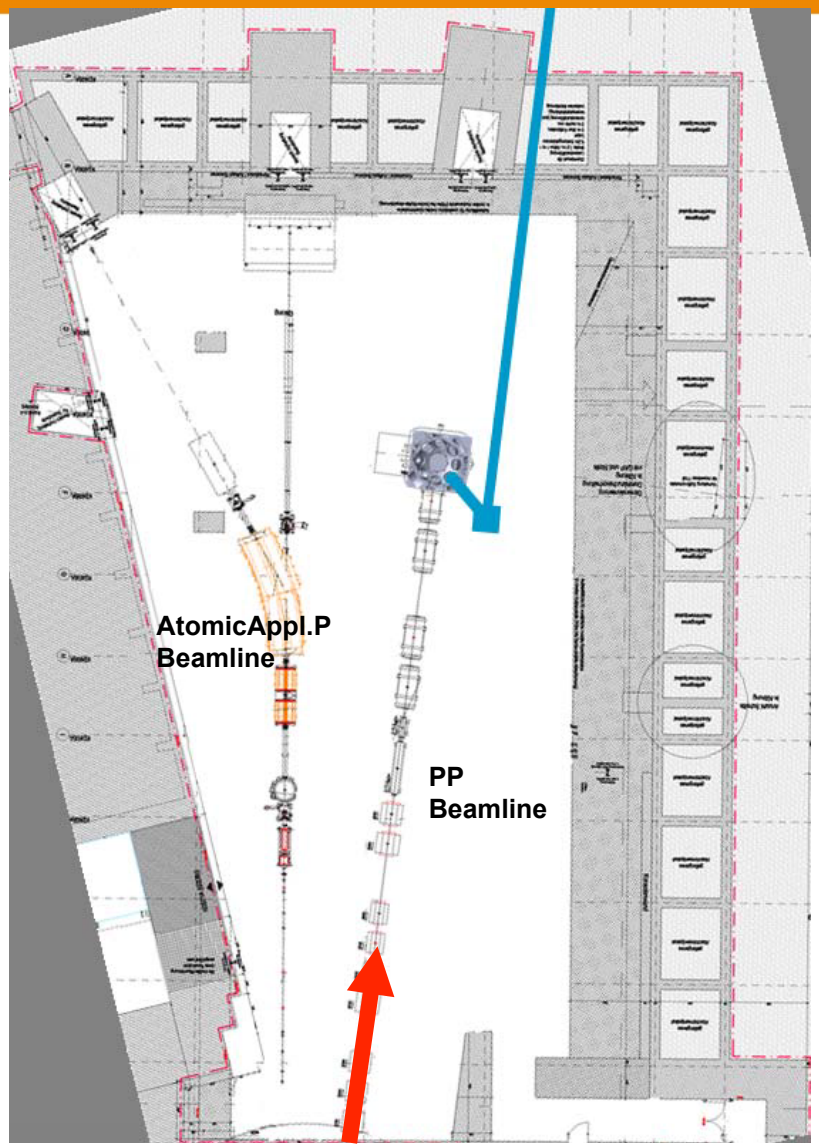
VPIC: 100nm CH2 target & Trident laser with 2x10^{20}W/cm^2

Max. energy	proton	carbon
Ideal laser	132 MeV	450 MeV
Real laser	121 MeV	447 MeV

FAIR – A key laboratory for HEDP and ultra-high field physics !

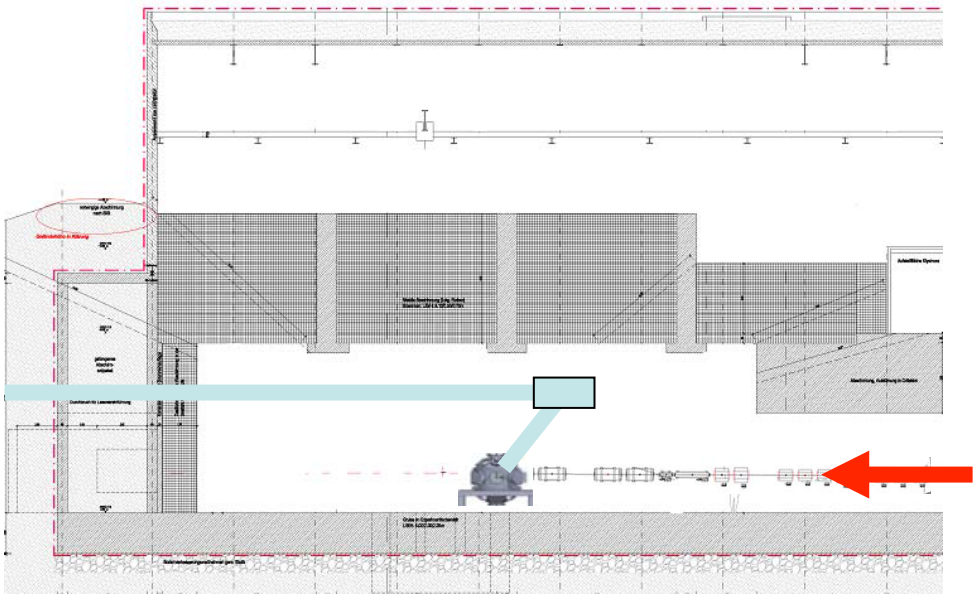


APPA Building at FAIR



Area: 860 m²

Sufficient radiation shielding:
- 4 m concrete + soil around
- 6.5 m concrete ceiling

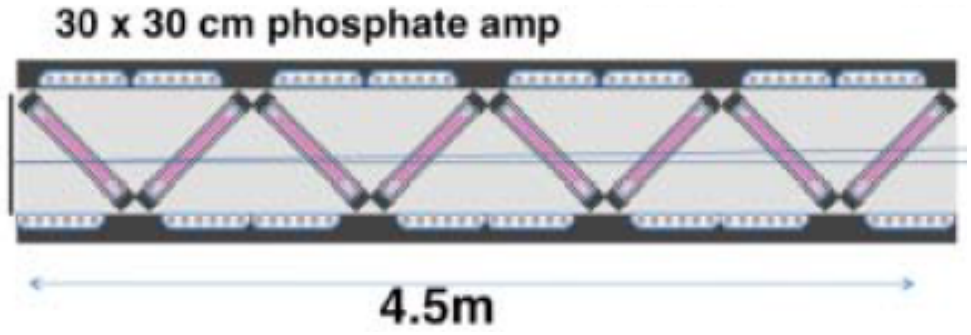


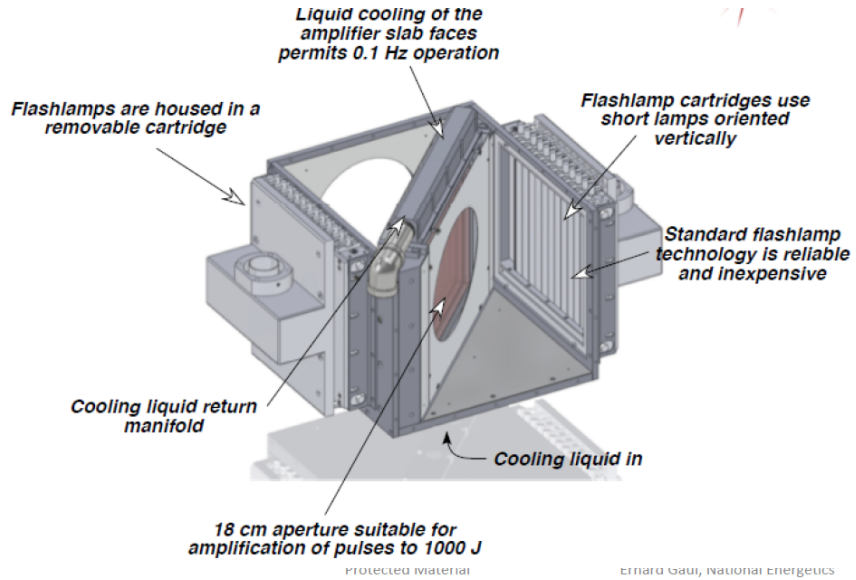
There is a growing community supporting a laser @ FAIR

- 120 participants from Europe (mainly), north America and Asia
- High intensity, high-energy lasers in the context of FAIR

Joined IZEST- Helmholtz Beamline meeting

PHELIX could develop to a compact 1/10s kJ laser



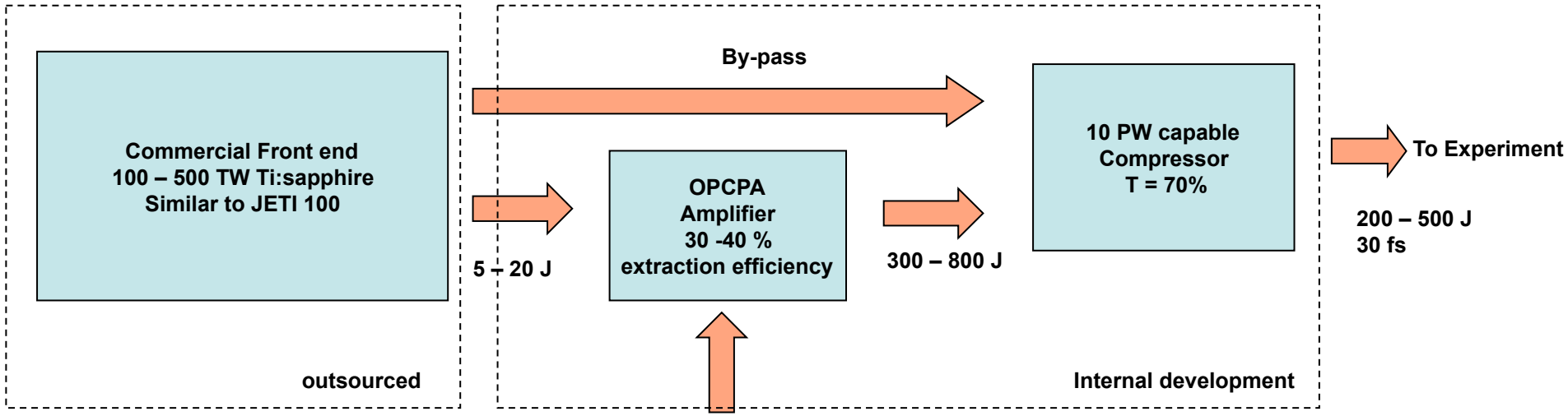


Specifically designed main amplifier section could be more compact than present PHELIX technology

Even more compact cooled 18 cm aperture amplifier (~1 kJ possible energy) has been demonstrated at 1/10 shot rate

(National Energetics, Texas)

A kJ laser is the ideal pump for a 10 PW short pulse laser

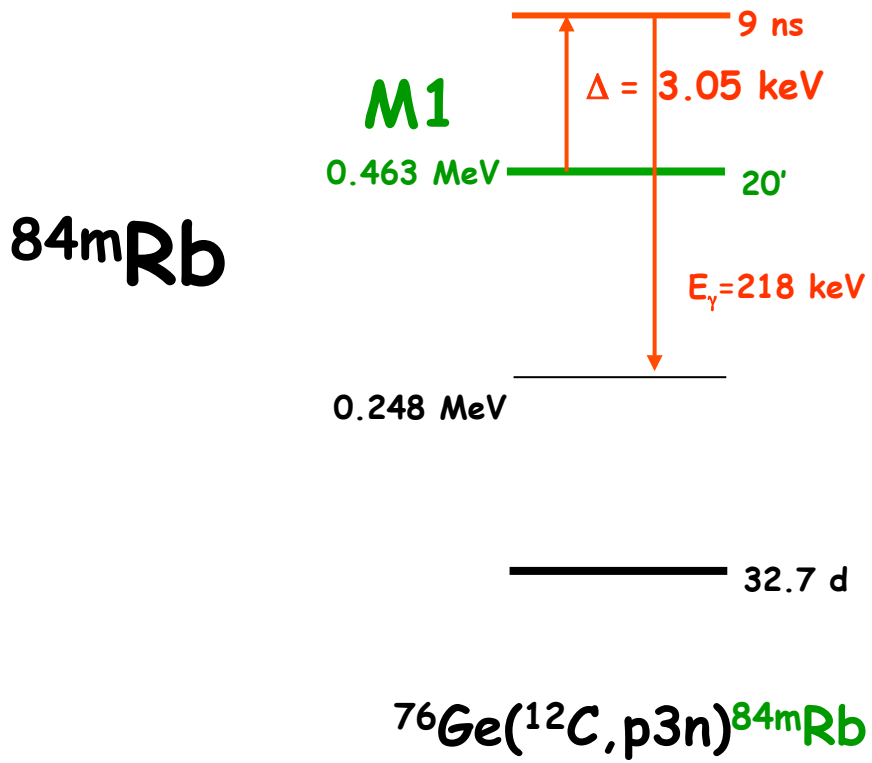


- 100 TW front end (also stand alone) for experiments up to 10^{19} W/cm^2
  - Ti:sapphire @ 900 nm, 1-10 Hz
  - 10 PW compatible compressor
- 10 PW OPCPA stage
  - Setup using PHELIX-like ns pump laser

Current Nuclear Physics Experiments with PHELIX

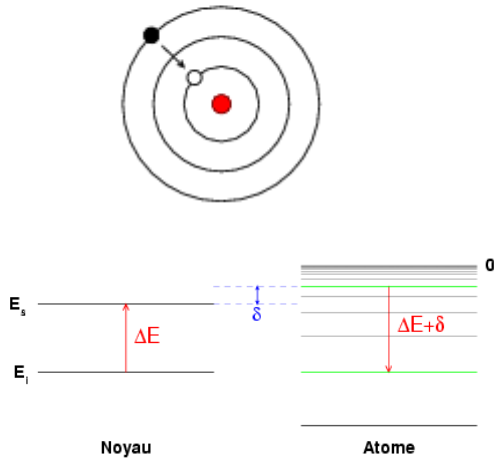
Nuc. Excitation via Electron Transition (NEET) with PHELIX and UNILAC

- **NEET is relevant to understand nuclear excitations processes in a photon bath (JINA lectures on Nuc. Astrophysics)**
- **NEET is an indirect nuclear excitation process**



$^{76}Ge(^{12}C,p3n)^{84m}Rb$

« Indirect » processes
- interaction with atomic electrons
- Resonant processes possible only for very special “electronic configurations”

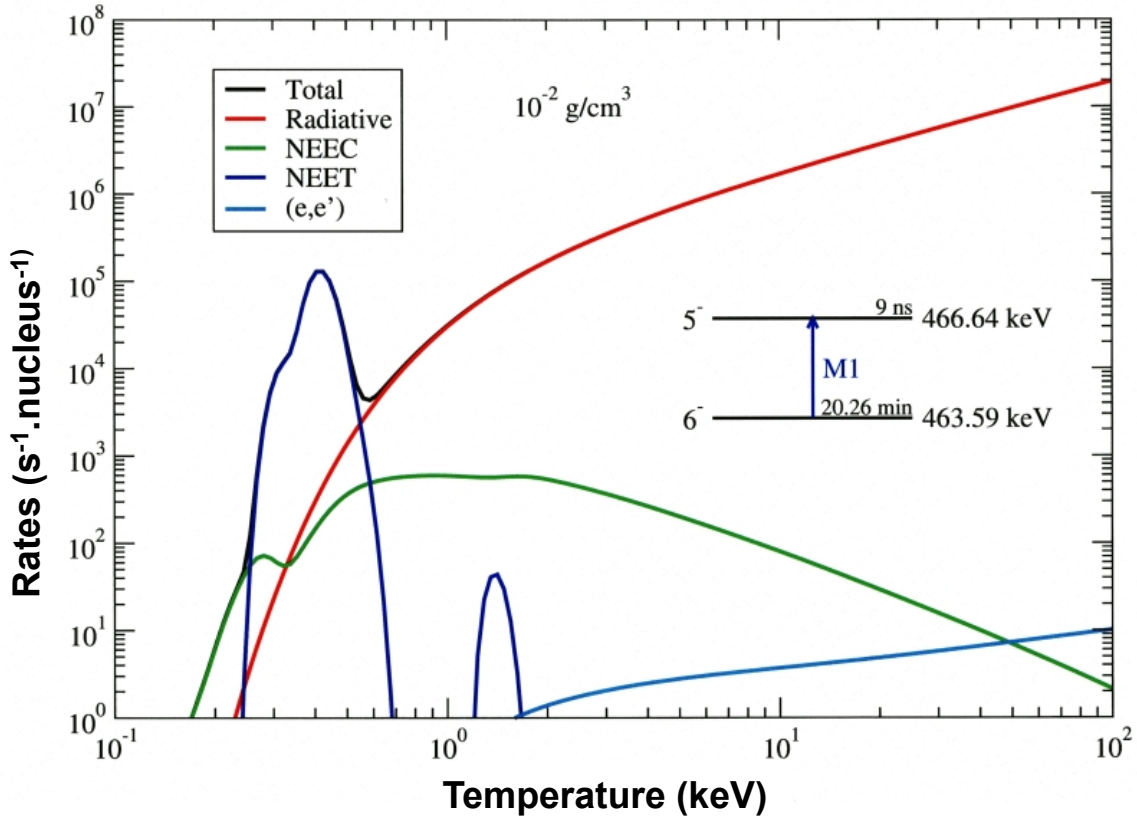


Proposed by M.Morita (1973)

Observed: ^{197}Au, ^{189}Os synchrotron

Excitation of the 84mRb isomeric state in a plasma: predictions by G. Gosselin, P. Morel and V. Meot

Excitation rates as function of plasma temperature



NEET is the dominant excitation process for plasma temperature of 300 – 400 eV (Average charge state of 32)

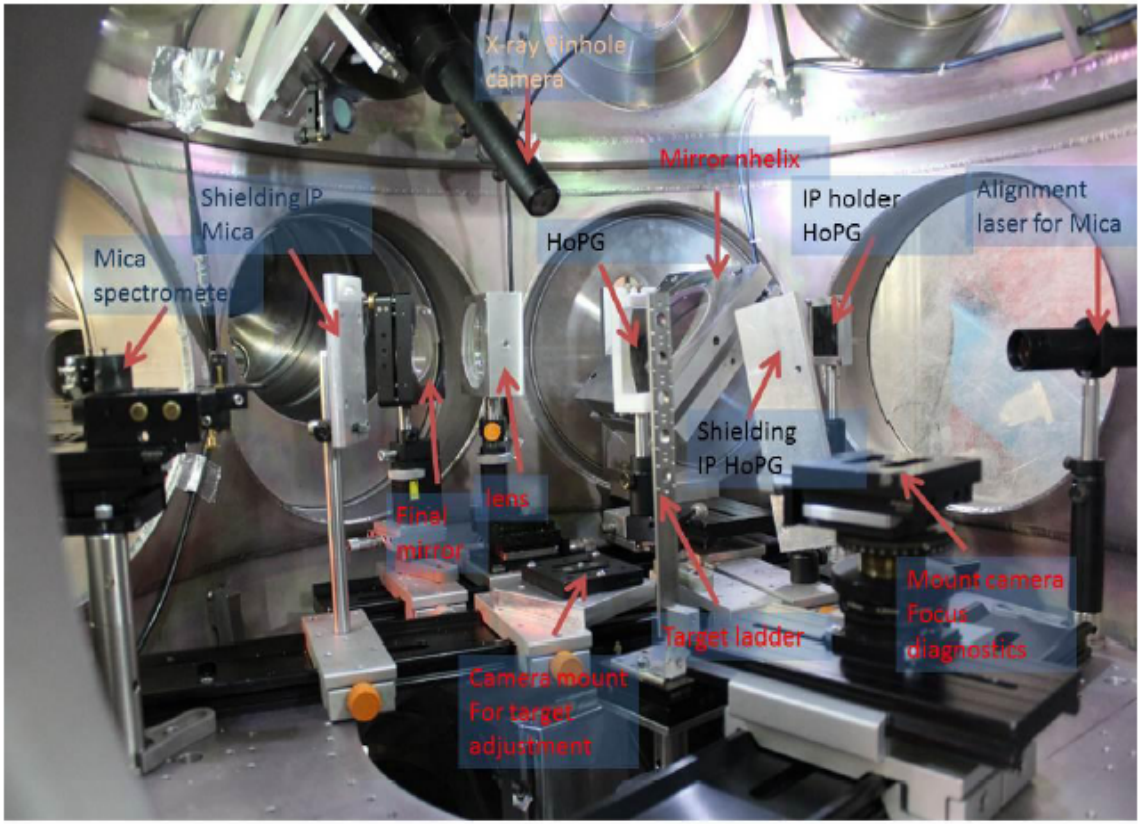
Photoexcitation is dominant for higher temperature

(e,e') weak!

Nanosecond plasma are far from equilibrium – non LTE calculation are necessary

Preparatory experiments at GSI and in Orsay

- The GSI experiment has goals:
  - Record atomic spectra the signature of ioniza levels 30+ to 34+ in Rb
  - Make sure Germanium detectors are not affec EMP and there is a no background

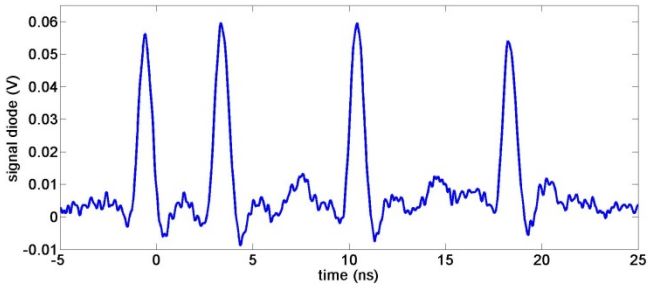


- Simulation for Germani being made by An. Tau (until Nov. 2012)

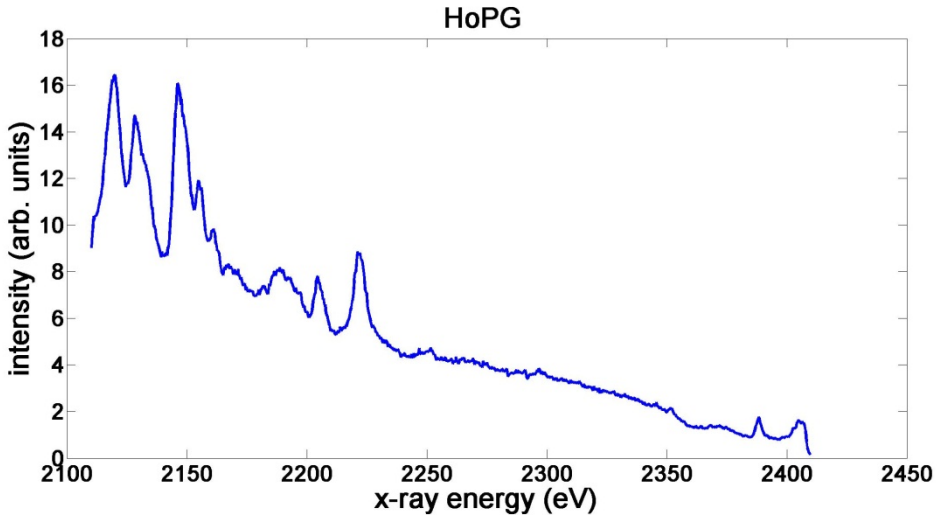
- The exact nuclear level 463,59 (9) and 466,64 (16) keV, must be known with an accuracy of a few eV. These levels are being measured this month at the Alto facility in Orsay.

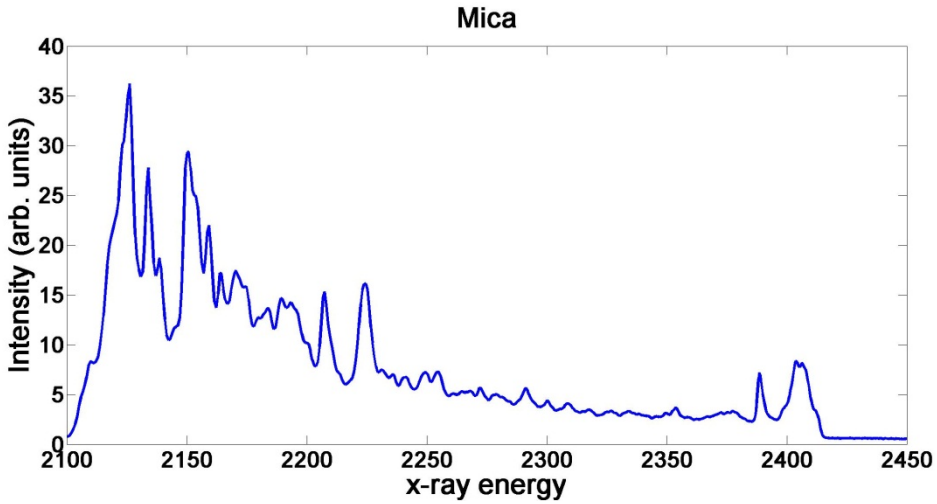
Preliminary results and next steps

- During the campaign different laser intensities and pulse shapes have been tested (up to 450 J at 2ω)

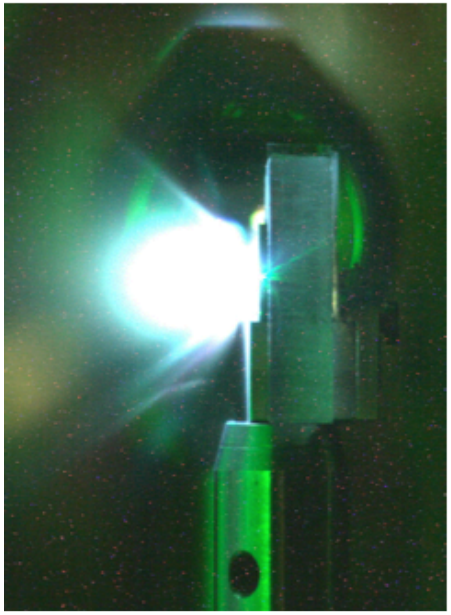


- Multiple spectrometer configurations have been used to record different energy ranges
- The detailed spectra are consistent and currently under analysis

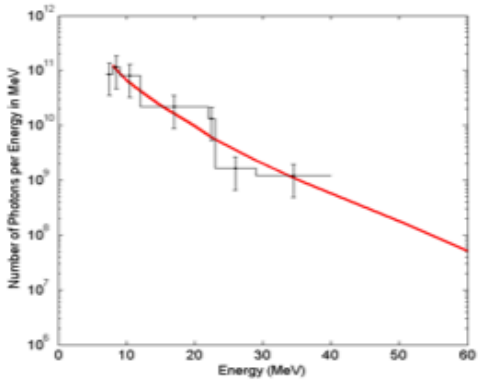


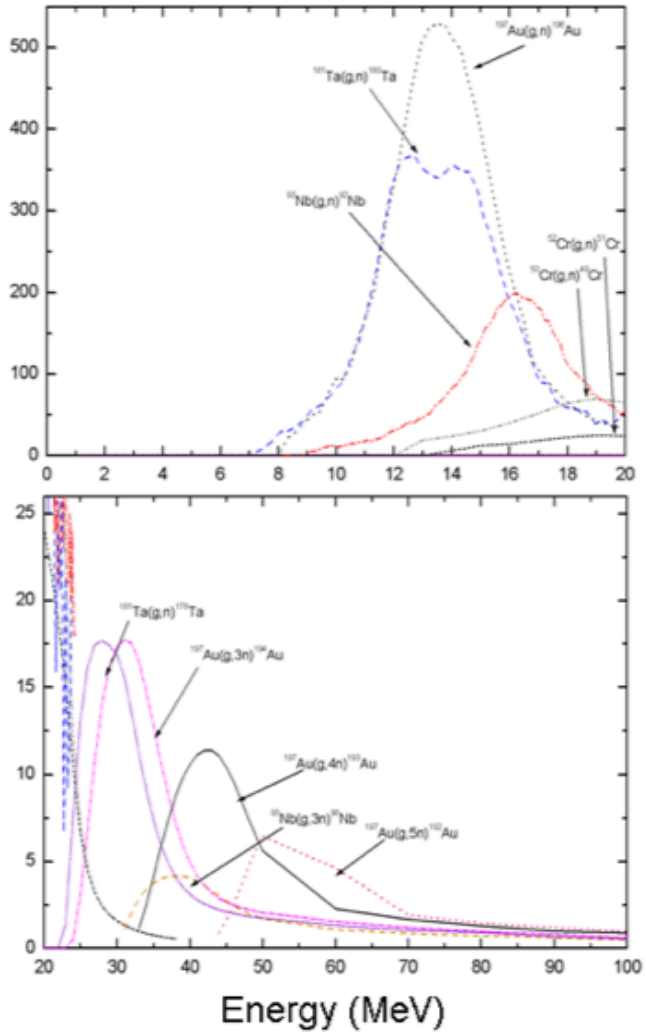


Nuclear activation with Laser-accelerated particles



- **Compound target as a pseudo alloy:**
  composition of several stable elements with different photon-neutron disintegration thresholds
- **Large energy range accessible:**
  - **7 - 20 MeV via (γ,n)-reaction**
  - **7 - 50 MeV via (γ,xn)-reaction**
- **All components close to laser-plasma interaction zone**
- **High mass density (13 g/cm^3)**
- **Suitable half-lives for all isotopes**





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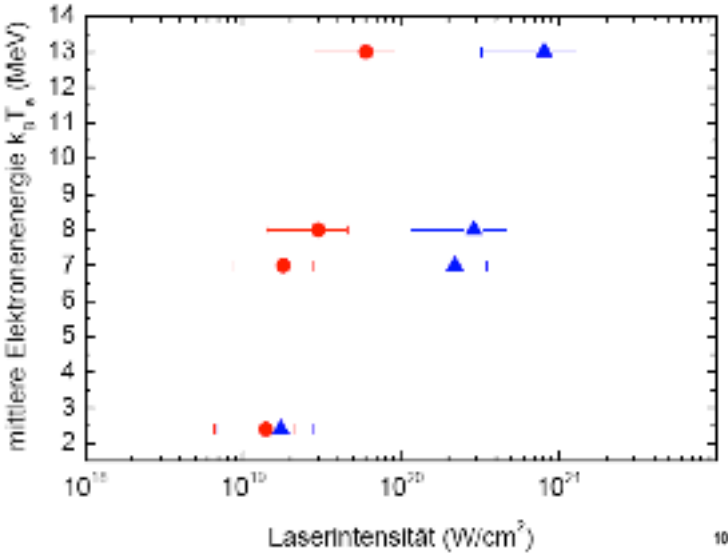

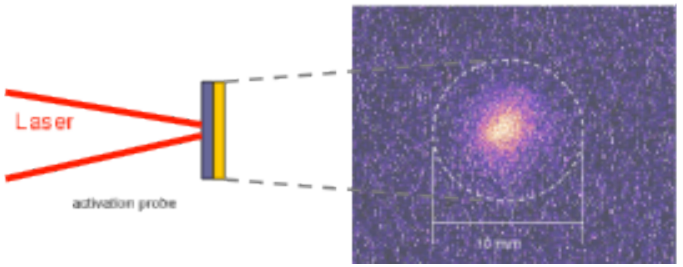

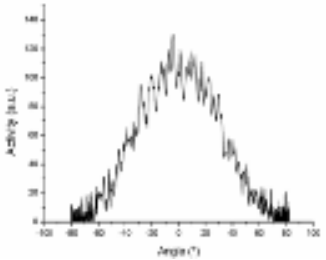

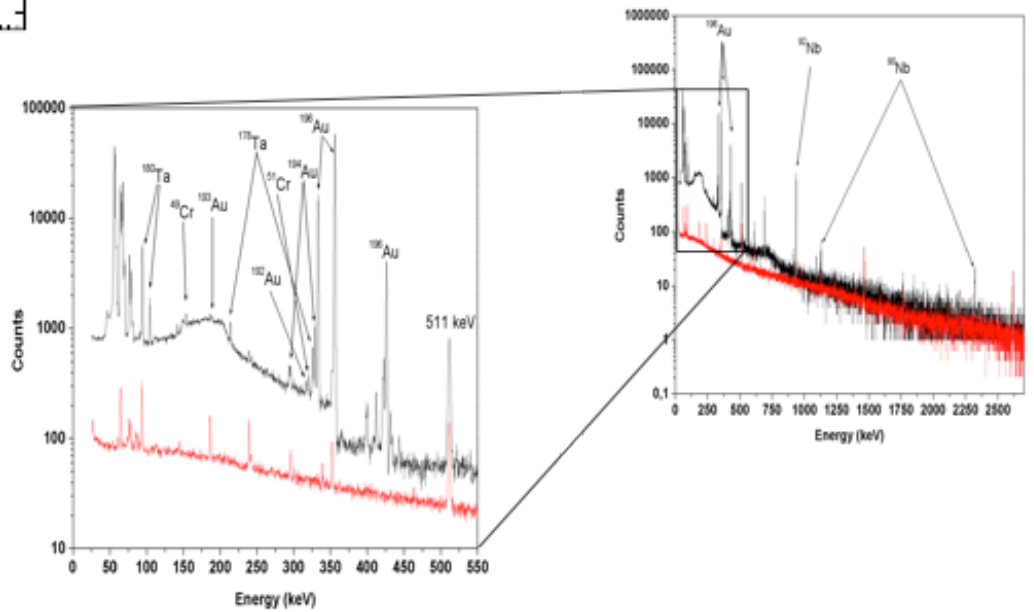

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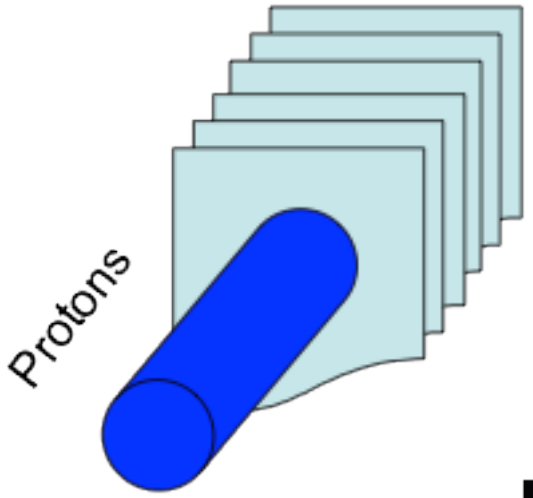
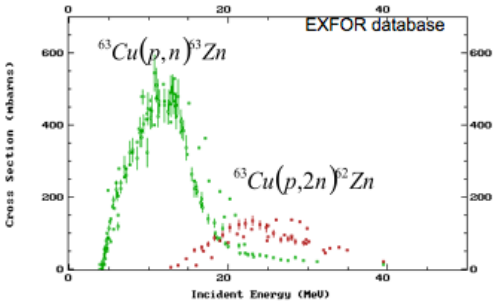
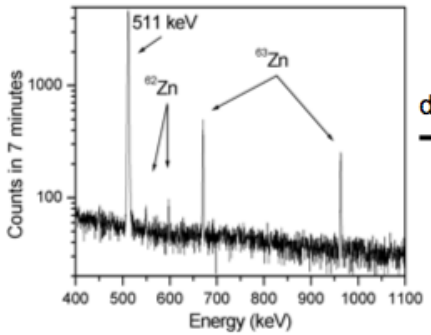
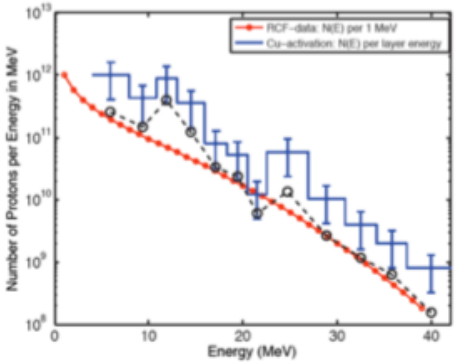






deconvolution



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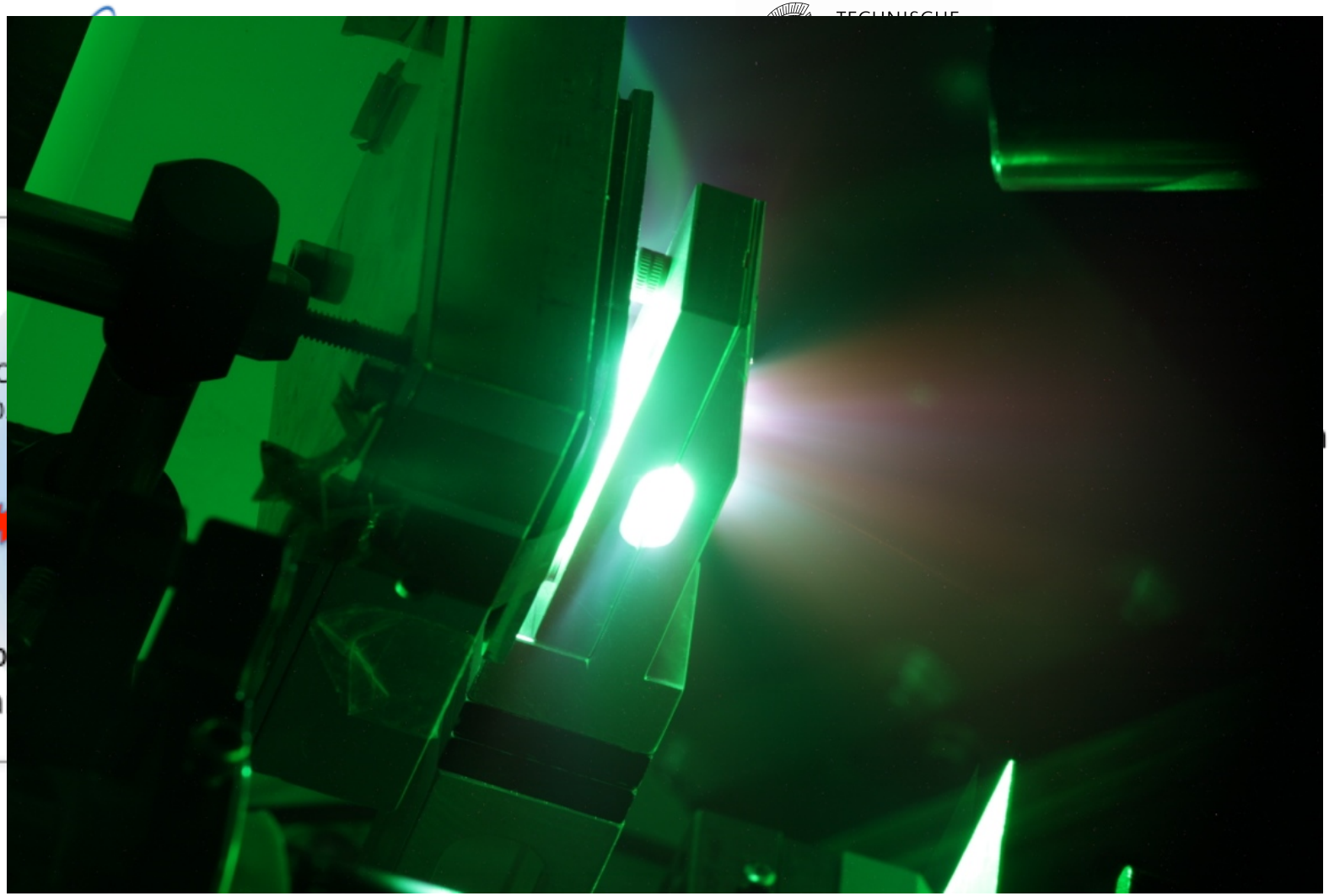
NAIS: Nuclear Activation Imaging Spectroscopy

Nuclear physics with lasers at FAIR

Neutron sources



Laser-assisted nuclear waste treatment research

- **ICAN (EU Program FP7) aims at developing high-peak-power high-average-power light sources**
  - **10 J, short pulse (10^{20} W/cm^2 intensity)**
  - **10 kHz repetition rate (based on coherent coupling of fibers)**
  - **20-50% wall plug efficiency**

- **GSI via Helmholtz institute Jena works in close collaboration with world-leading fiber-laser research groups**
  - **Coherent combination of several fibers (~10) is being demonstrated at the HI-Jena**

- **While ICAN targets electron acceleration around 10 GeV, the laser source can be applied to the direct transmutation of nuclear waste. This could be studied at FAIR where all kind of isotopes will be available.**