Commissioning and Early Experiments at the PHELIX Facility

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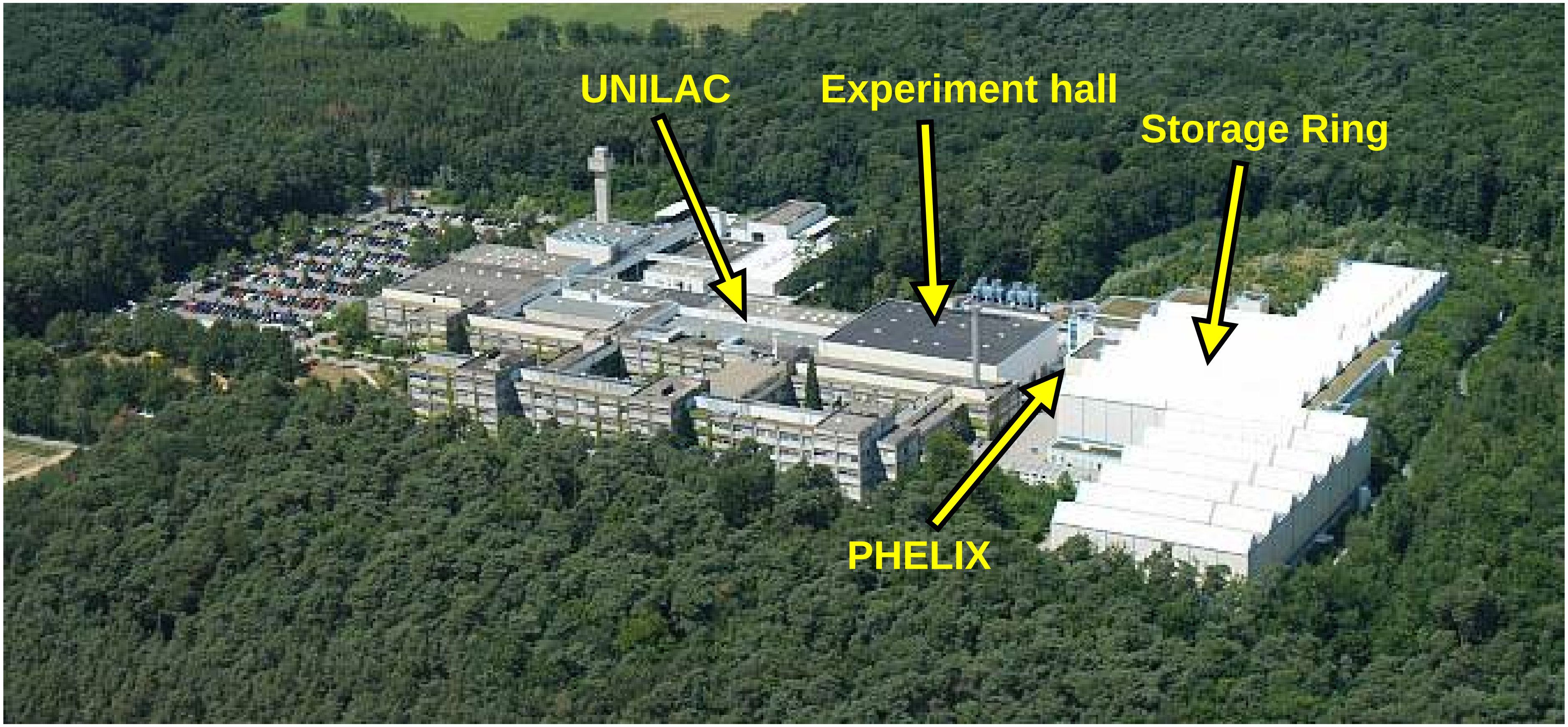
PHELIX

summary

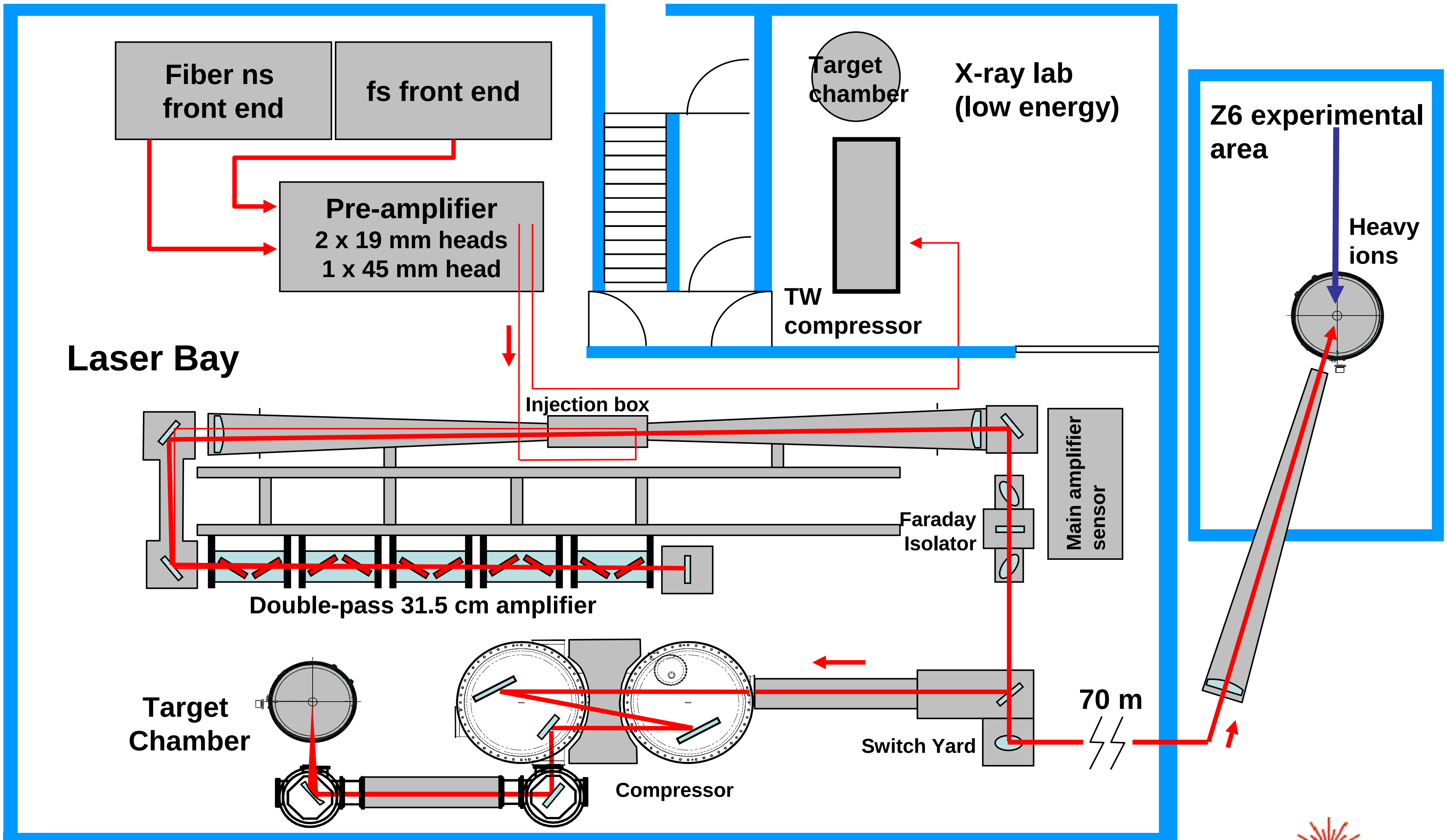
PHELIX is in operation since May 2008.

- PHELIX has been commissioned for use with short pulses (120 J, 700 fs) and nanosecond pulses (300 J - 1kJ)
- The short-pulse beamline uses a 90-degree off-axis parabolic mirror to achieve high on-target intensity, confirmed by the energy spectrum of accelerated protons
- The nanosecond beamline has been used to support the GSI plasma physics program with first encouraging results on ion stopping in laser generated plasma
- A call for proposal for experiments in 2009 is running until 3-11-2008, please see me for details

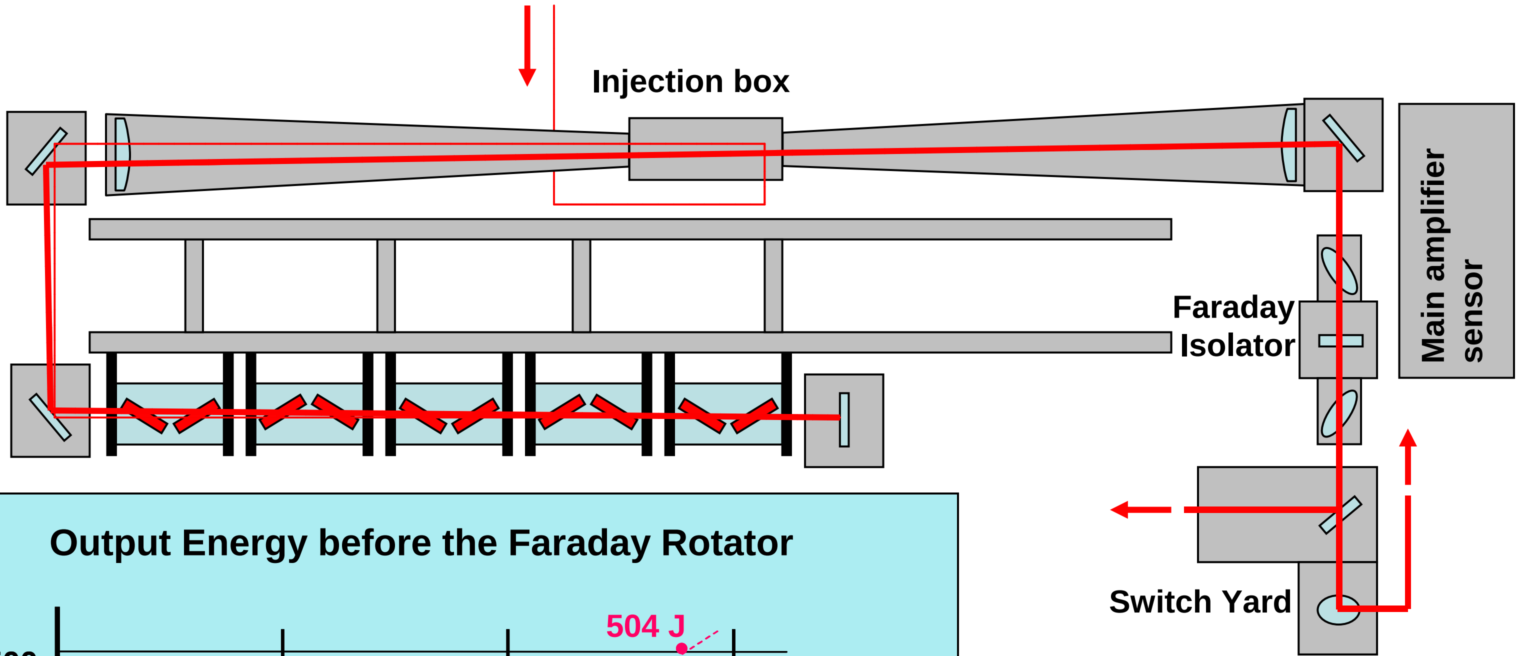
PHELIX is commissioned and part of the GSI-infrastructure.

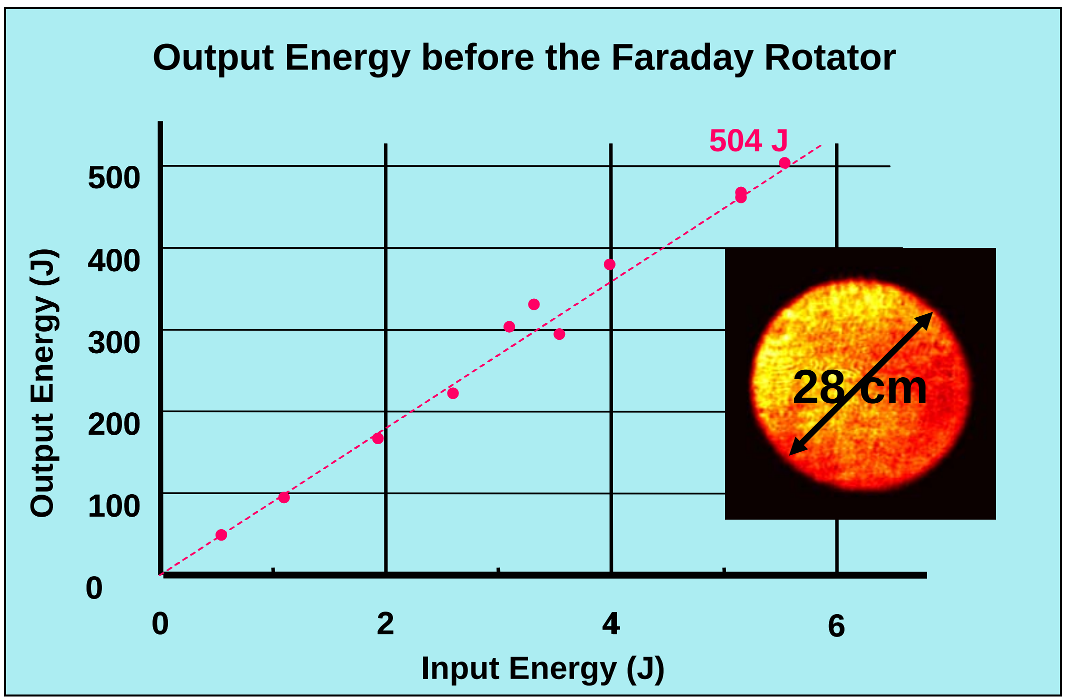


The PHELIX laser serves three experimental areas.



The main amplifier delivers the targeted gain of 100 for 17 kV.





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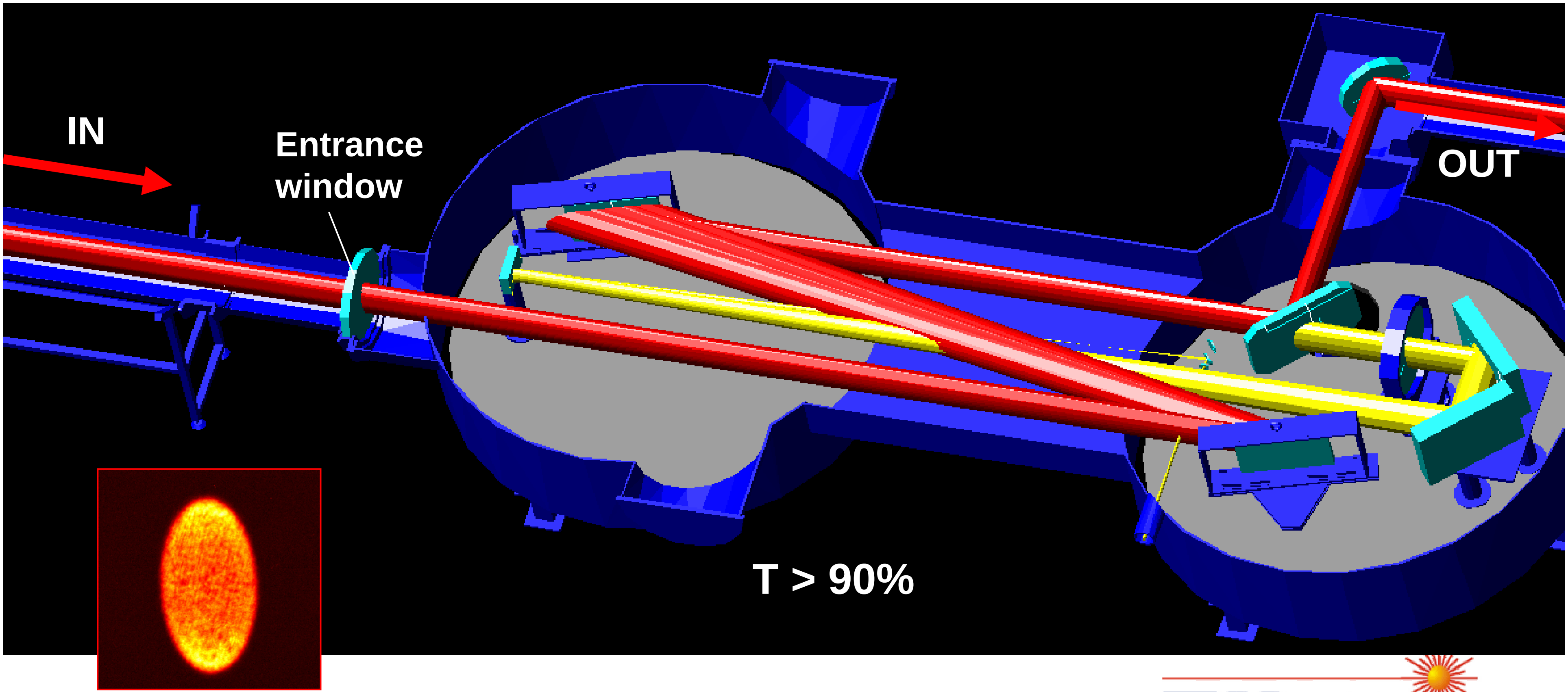
We use a single-pass two-grating compressor.

- The advantage is high throughput but at the expense of pulse lengthening
- An elliptical beam is used to better fill the MLD gratings: Horiba-Jobin-Ivon gratings 47 x 35 cm^2 at 72° incidence require an 12 x 23 cm^2 elliptical beam

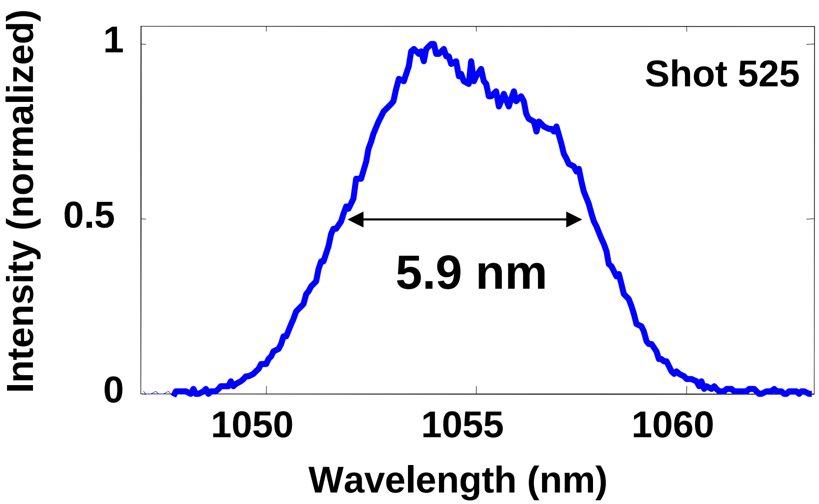


elliptical beam

The pulse compressor has been successfully commissioned.

We use a birefringent filter* in the front-end to pre-compensate gain narrowing.

- **The PHELIX two-regenerative-amplifier front-end is particularly suited to the method,**
- **Without loss in output energy, a birefringent plate and a polarizer are introduced between the amplifiers to spectrally shape the spectrum and create a hole at the gain peak of the glass amplifier,**
- **Spectra > 5 nm wide are routinely obtained at the end of the main amplifier, capable of supporting < 350 fs (Fourier transform limited) pulses.**

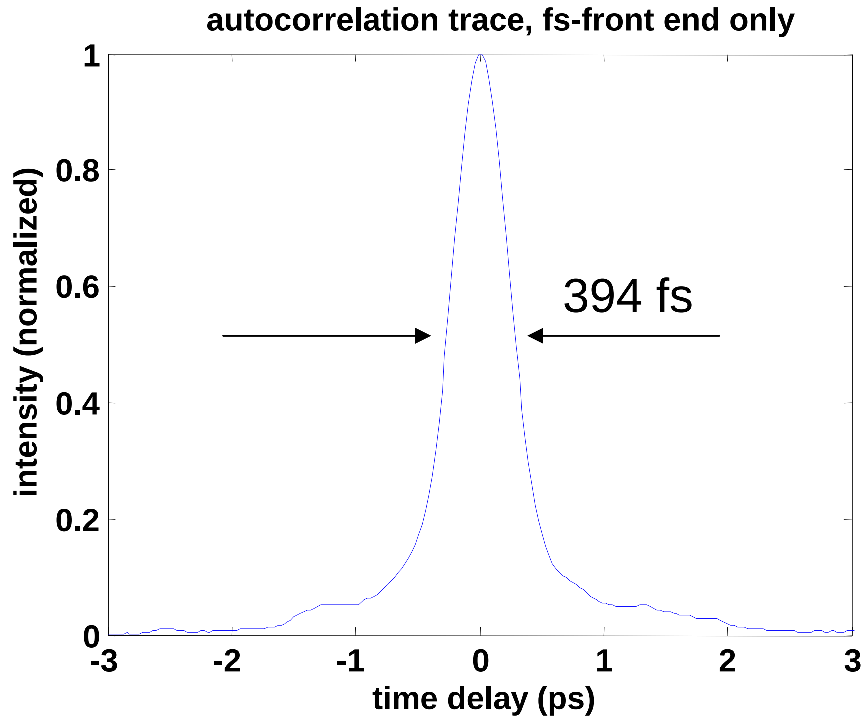


*** Barty et al.: Optics Letters, Vol. 21 Issue 3, pp.219-221 (1996)**

PHELIX

Characterization of the compressed short pulse is under way.

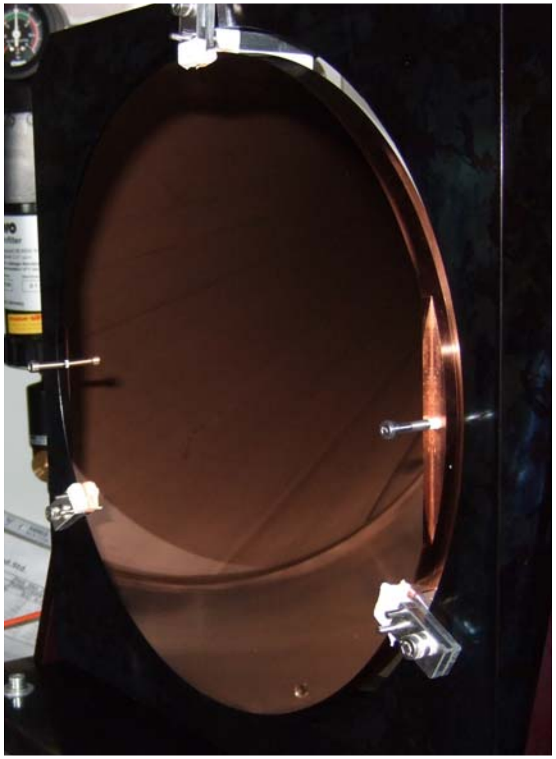
- On a sub-aperture, the short pulse compresses well (see below)
- Over the full aperture, an increase to 700 fs is visible
  - This is a strong effect due to the geometry (single pass) and the ratio between beam size and wavelength spread.
- The data needs to be confirmed at full power



A 90-degree low-cost off-axis metallic parabola achieves good focusing capability.

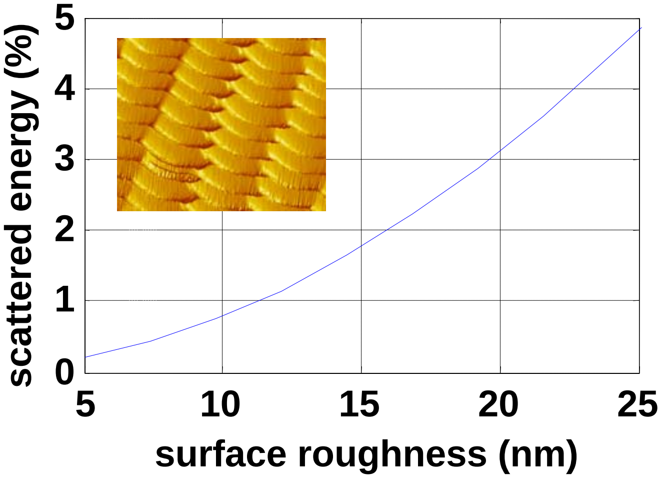
- The 90-degree massive metallic mirror is machined to ~1 micron accuracy (PV),
- The surface roughness and machining precision have to the balanced to get the best trade-off between scattering losses and wavefront error.

Mirror in its Holder



Back View

Estimation of scattered energy based on simulated surface roughness



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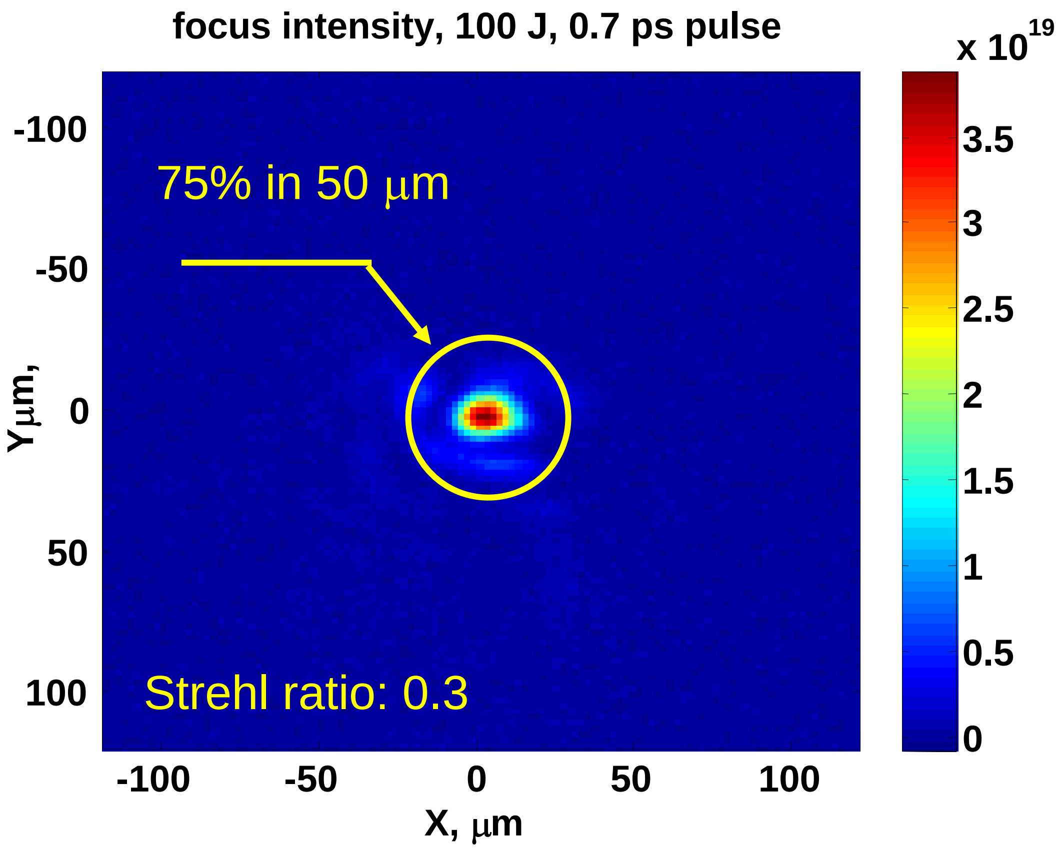
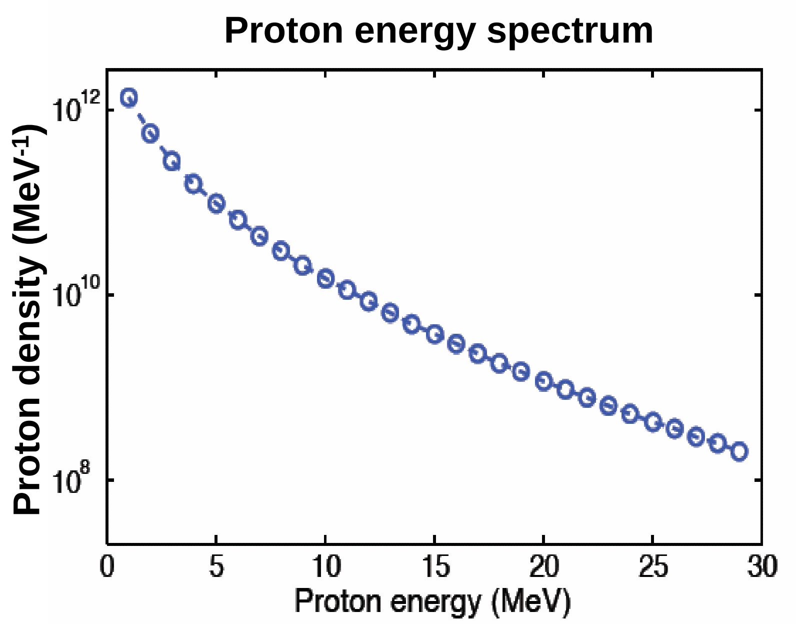
Experimental evidence indicates an on-target intensity > 10^{19} W.cm^{-2}

- **A calculation based on the far-field intensity distribution yields 3.5 10^{19} W.cm^2**

- **According the accelerated proton spectra obtained by the Technical University Darmstadt (TUD), the intensity is rather ~10^{20} W.cm^2**





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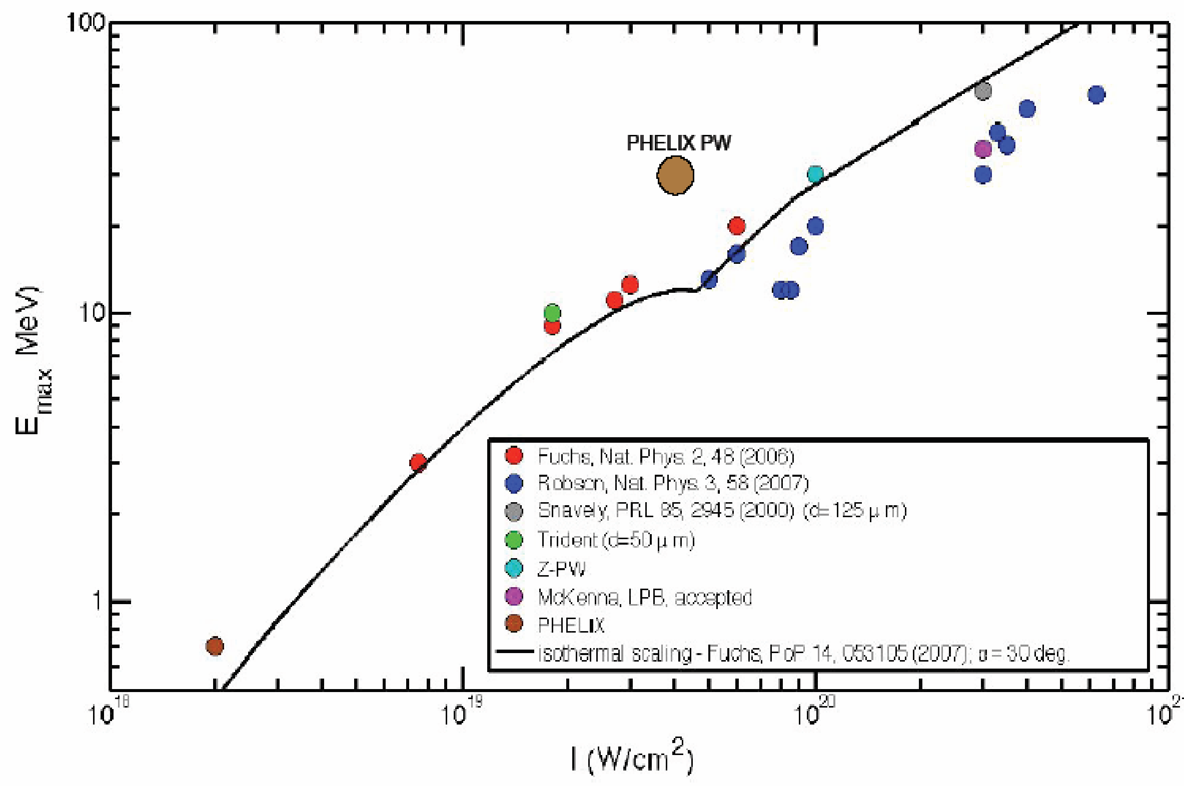
Currently proton acceleration is being evaluated

- **Laser accelerated ions are of interest to GSI as a complementary tool to the existing accelerator**
- **First experiments are aimed at helping with the commissioning of the system**
- **So far > 30 MeV protons have been accelerated with PHELIX, indicating that high intensity conditions (~ 10^{20} W.cm2) are obtained at the focus**



More on-target intensity estimates are planned in the near term

TECHNISCHE UNIVERSITÄT DARMSTADT

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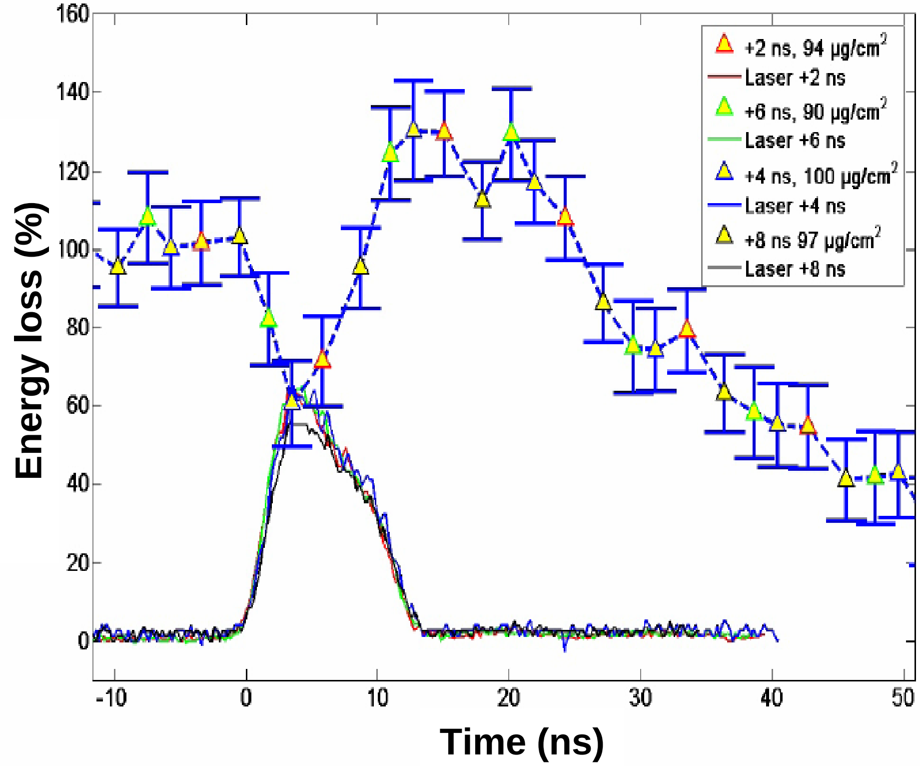
Combined ion-laser experiments were conducted twice this year to study the stopping power of plasmas.

- In the context of inertial fusion with heavy ions, we study the energy loss of ions in laser-generated plasma,
- We used PHELIX pulses with 7-15 ns and 50 - 315 J, to compare to measurements done at lower energy using nhelix
  - 1-mm focal spot achieved with 4-m lens + phase mask and,
  - UNILAC S 15+ and Ar 16+; 0.3 mm diameter
- We measure the ion-energy loss via time-of-flight measurements
- In a plasma, the theory predicts that ion-energy loss is dominated by free electrons but our experiments do not only illustrate this.

Time evolution of the ion-energy loss
100 corresponds to the cold target



Our program requires PHELIX for improving the experimental data

- **A higher energy allows for a full ionization of thicker foils with higher Z to improve the measurement accuracy**
  - **We have experiment plan to extend the on-target deposited energy to 500J- 1 kJ**

- **A major limitation to our setup is the non-uniformity of the plasma:**
  - **In the best case, the plasma is one dimensional,**
  - **This is further reduced by the on-target beam non-uniformities**

- **We are currently looking into two solutions to this problem**
  - **Indirect heating using 2ω light creates uniform conditions**
  - **Under critical foams have shown good smoothing capabilities and volume absorption to create uniform conditions**

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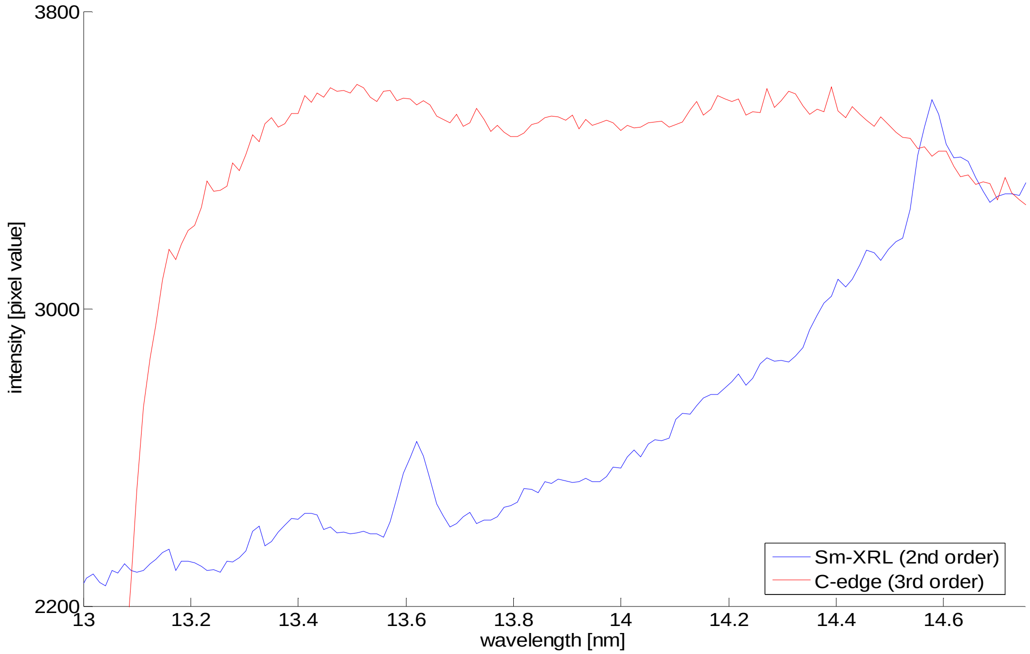
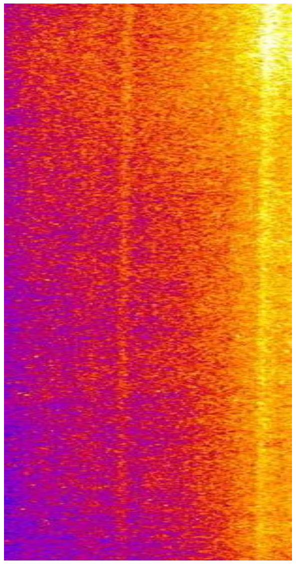
We applied PHELIX to the investigation of X-ray laser in the sub-10 nm regime.

- We are using PHELIX to pump X-ray laser with Ni-like Samarium (6.8 nm)
  - We have developed an innovative two pulse scheme* to create transient collisionaly excited (TCE) plasma X-ray laser





Laserlab Europe

* Zimmer et al.: Optics Express, 16, pp.10398-10404 (2008)

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