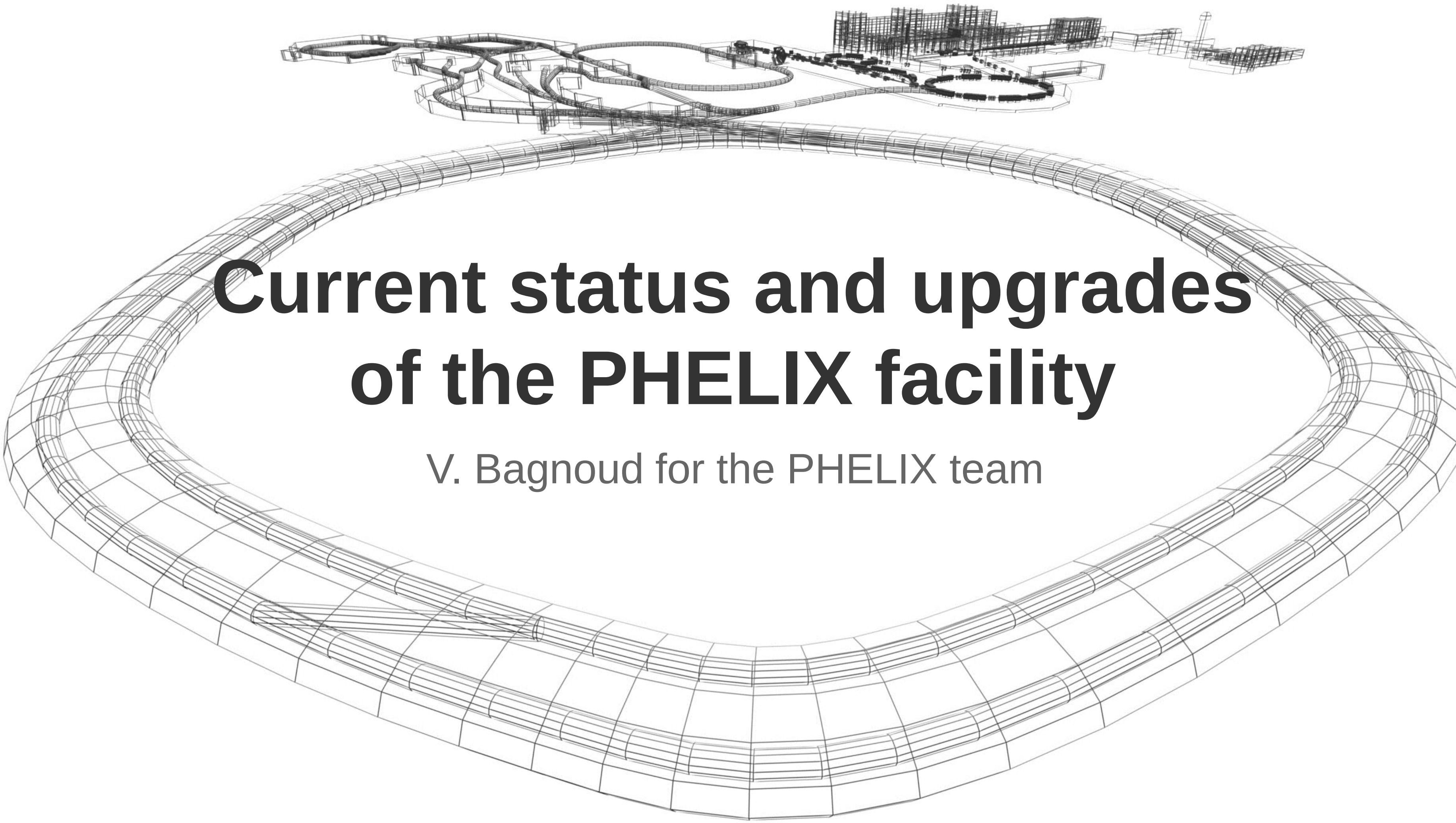
GSI Helmholtzzentrum für Schwerionenforschung GmbH



Current status and upgrades of the PHELIX facility

V. Bagnoud for the PHELIX team

NEILS Workshop
GSI Darmstadt, 9th – 11th May 2016

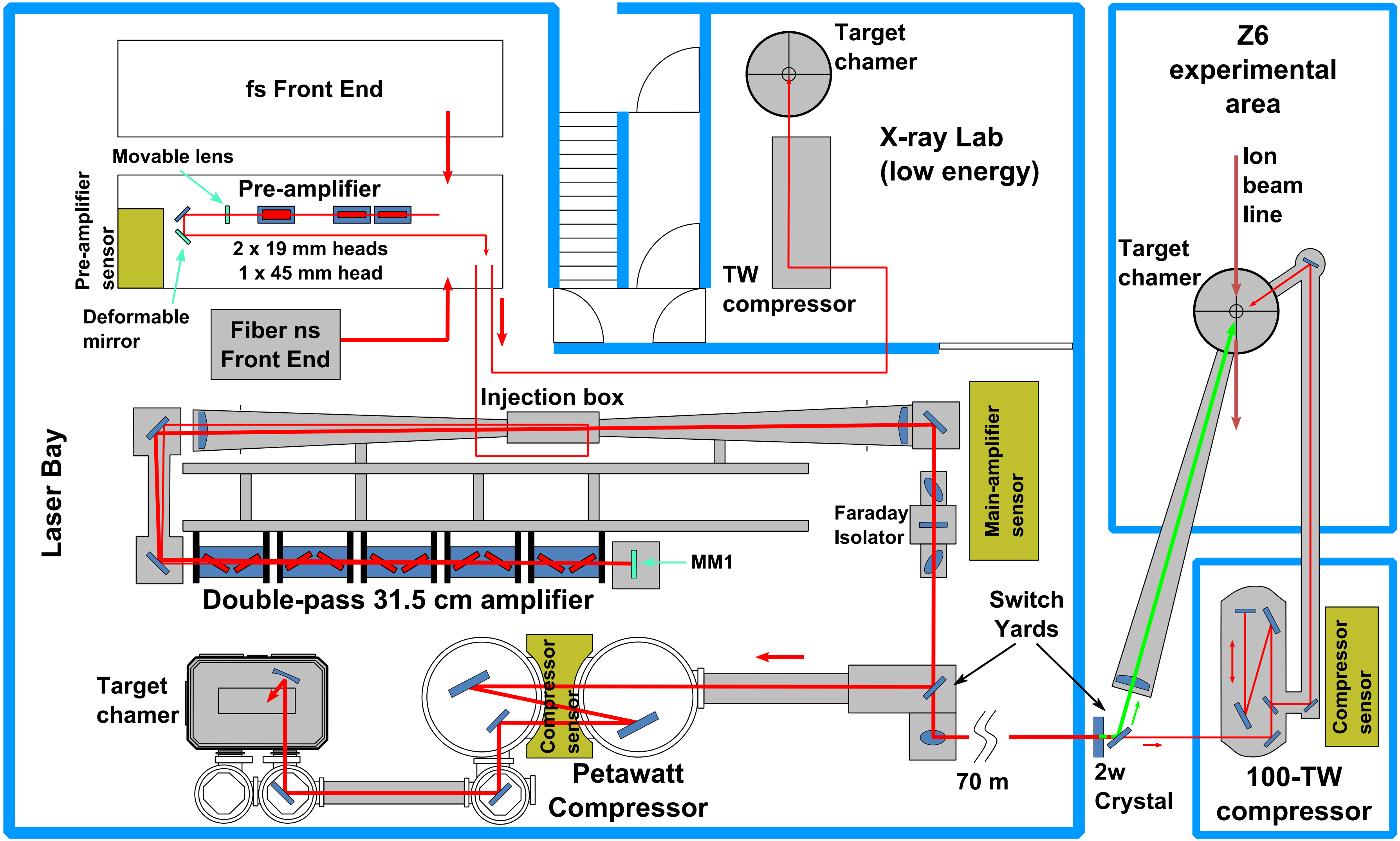
summary

PHELIX: a user-oriented facility

- PHELIX operates as a user-oriented facility during the construction of FAIR
  - 8 months of operation/year
  - Active control on the beam intensity ensures beam intensities above 10^{20} W/cm^2 in routine operation
  - dual science and program-driven (FAIR & Helmholtz) studies

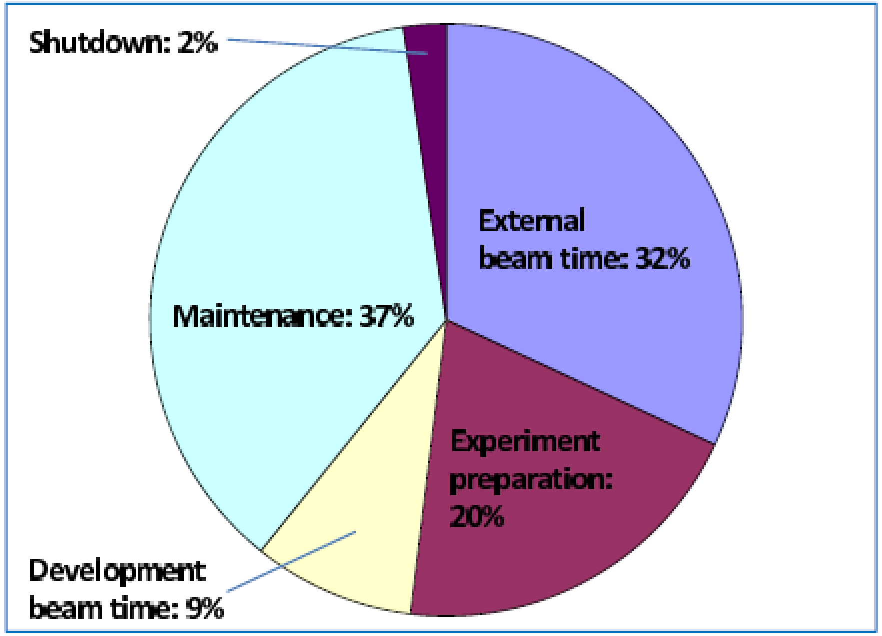
- Towards FAIR
  - The LIGHT beamline and the Athena project should ensure a visible mid-term research program
  - Laser activities for the plasma physics cave: 100 J laser for FAIR
  - PHELIX pre-amplifier upgrade as a testbed for high repetition rate glass amplifiers

PHELIX – An Overview



PHELIX: a user-oriented facility

- Operation since 2008
- 60% beam time in 4 week cycles
  - 1 week preparation
  - 2 weeks experiments
  - 1 week maintenance/reconfiguration
- 700 – 1000 target shots per year
  - 3 % failed shots (2015)



operation statistics 2015

Beam aberration control at PHELIX

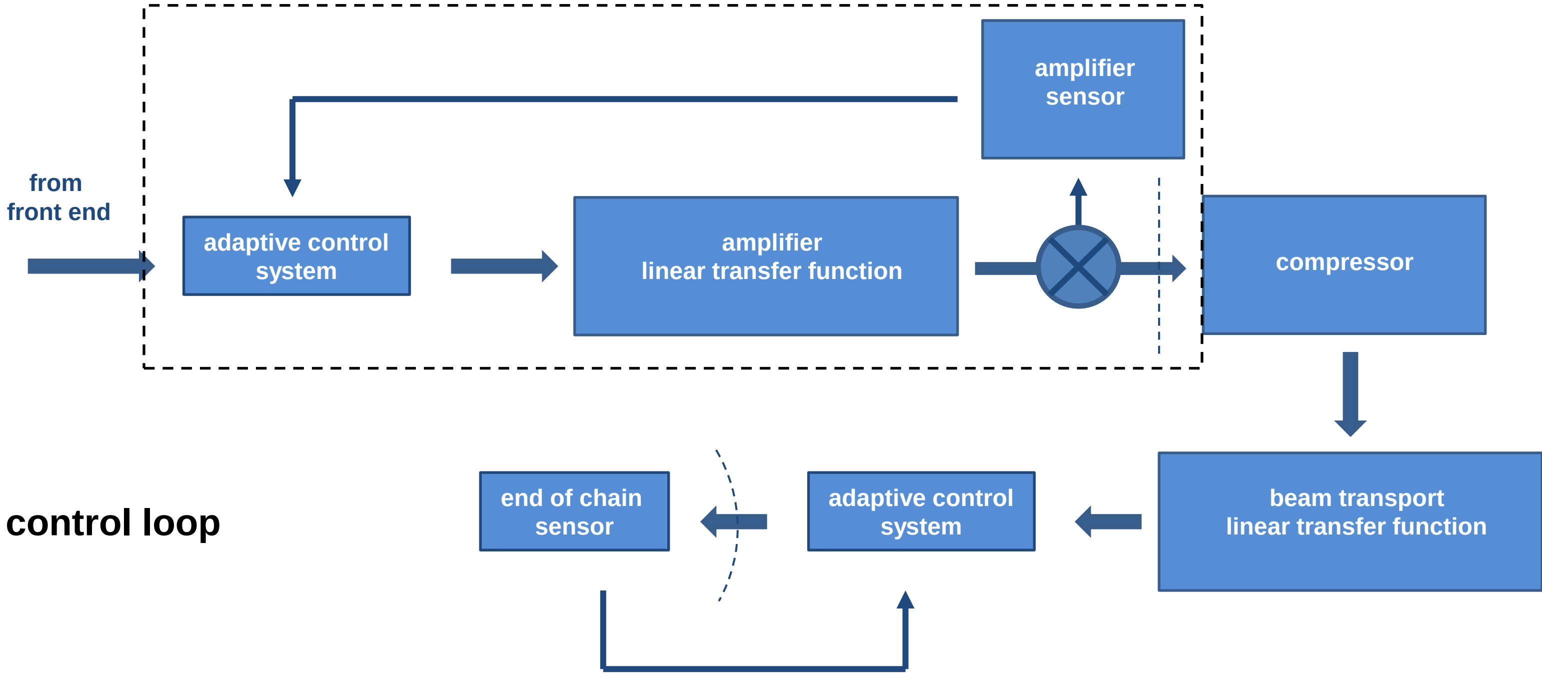
- principle estimates of the a_0 parameters for PHELIX give values of >100

$$a_0 = \frac{1}{F\#}\sqrt{\frac{P(W)}{0.8 \times 10^{10}}}$$

- Experimentally intensities at 10^{19} W/cm^2 (a_0 ~ 3 - 7) have been observed when no active beam control is applied and intensities in the mid 10^{20} W/cm^2 (a_0 = 15 – 20) when active correction is applied.
- The reason for that is: large-aperture system suffer from many types of beam aberration
  - static aberration (components, alignment)
  - on-shot aberration
  - thermal aberration
- Expectations of users - > no aberration or as little as possible
  - minimizing static and thermal aberration
  - WYSIWYG (minimizing on-shot aberration), good characterization

Beam aberration control at PHELIX

- The principle of beam wavefront correction is simple but it has some pre-requisite
  - an excellent understanding of the system is necessary
  - enough dynamic range of the active device
    - -> outsource simple beam distortions (defocus, pointing, astigmatism)
  - A correction at the compressor input is mandatory to avoid spatio-temporal coupling

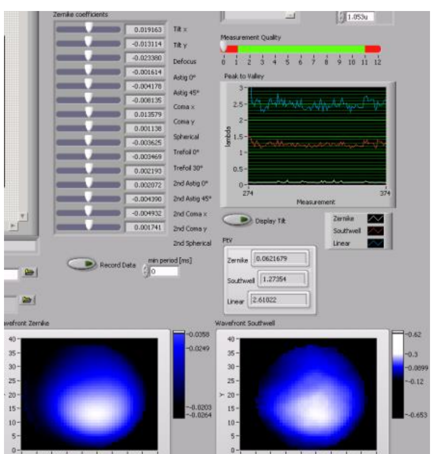


typical beam control loop

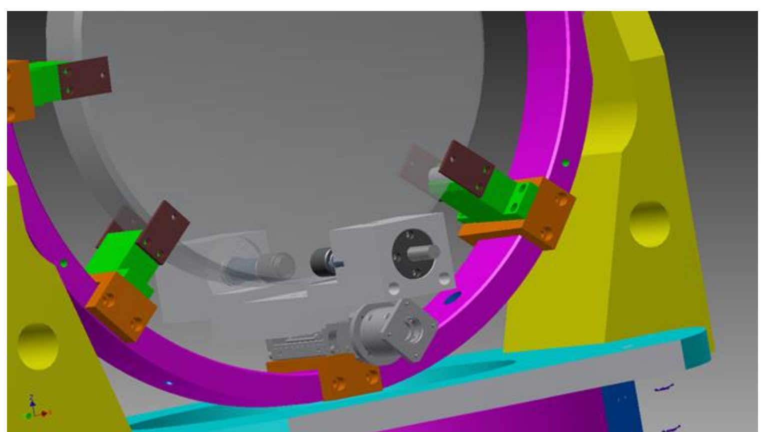
Beam quality control and management

knobs	Aberration		
	static	on-shot	thermal
specification	x		
Adaptive optics (DM)	x	x	x
Defocus (lens)		x	x (in the future)
Astigmatic mirror		x	
High-perf diagnostics	x	x	x

control system



astigmatic mirror

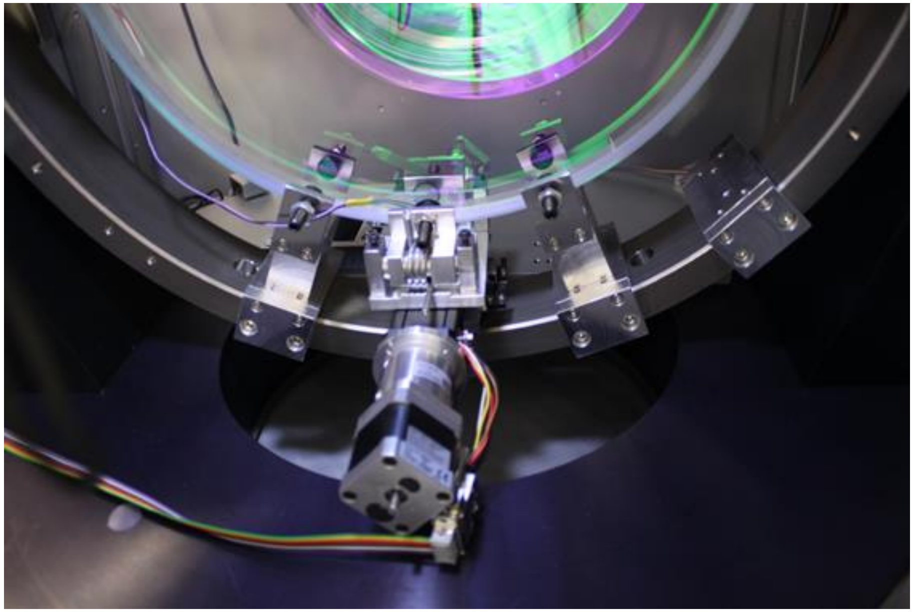


deformable mirror

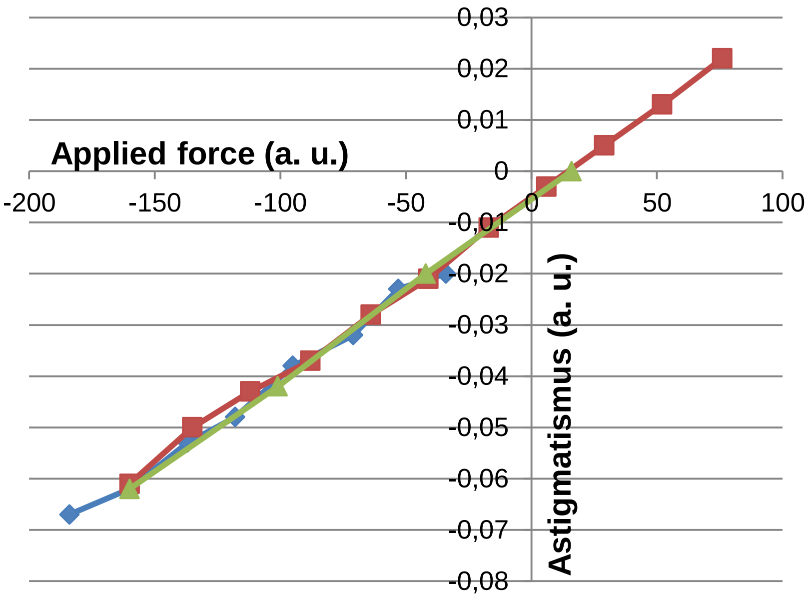
Functional requirements for on-shot aberration

- On-shot aberration must be
  - pre-compensated just before the shot (max 1 min) – D.M., lens, Astig. Mirror.
  - blind (without retro-action, optimization)

MM1 mirror with astigmatism compensation



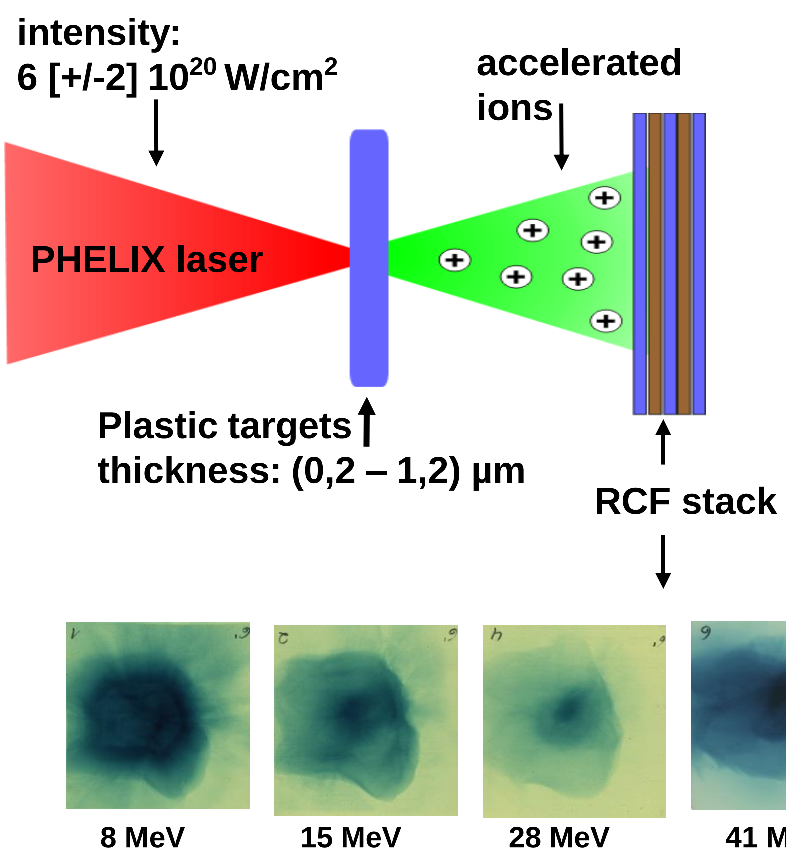
test of linearity

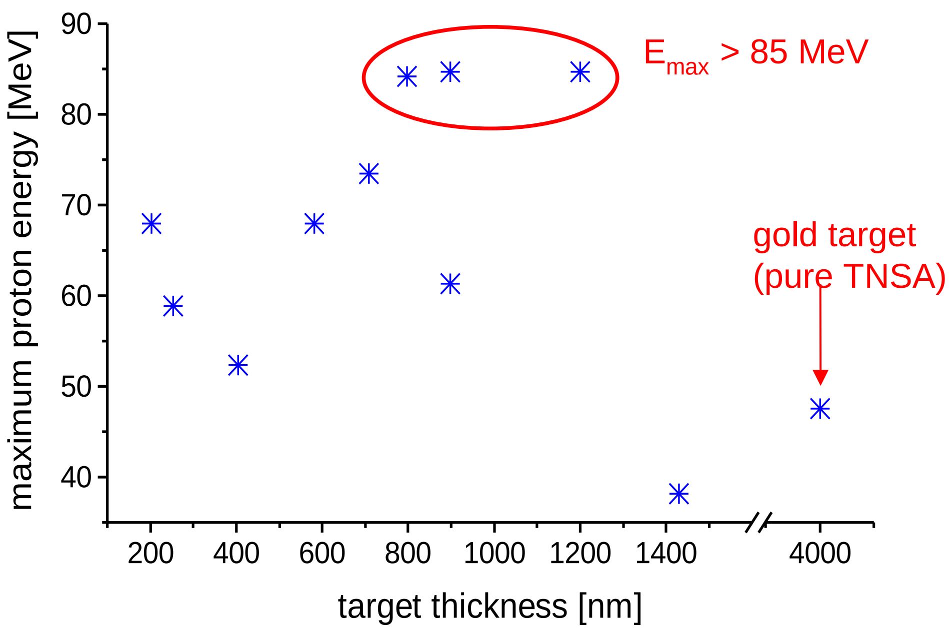


in standard operation Feb. 2016

Some recent results owing to the better focus

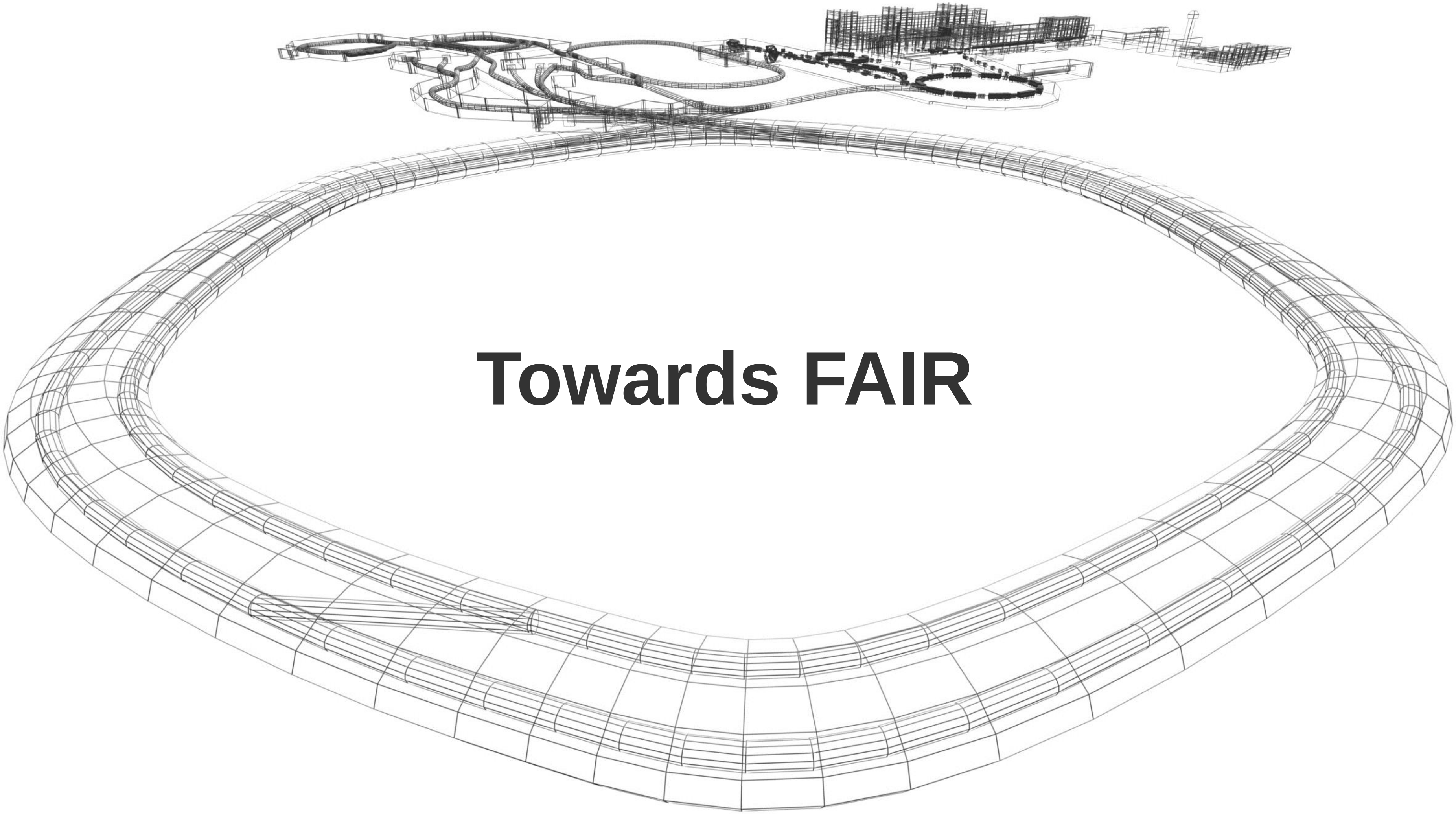
- in a recent experiment, 85 MeV protons were observed using PHELIX and sub-micrometer foils





F. Wagner et al. accepted for PRL

GSI Helmholtzzentrum für Schwerionenforschung GmbH

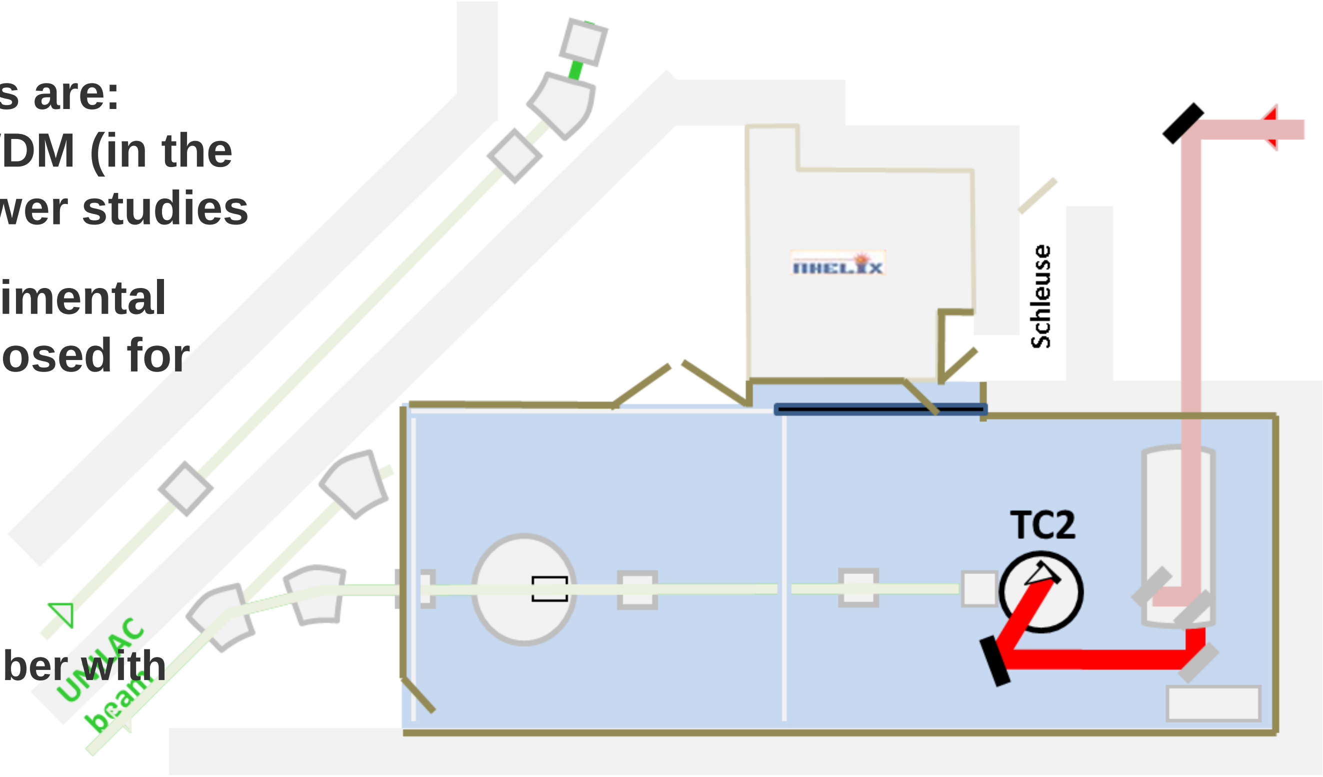


Towards FAIR

NEILS Workshop
GSI Darmstadt, 9th – 11th May 2016

Upgrade of LIGHT & ATHENA

- **The LIGHT beamline at GSI shows promising results: sub nanosecond, > 10^9 particles pulses**
- **possible applications are: material research, WDM (in the future), stopping power studies**
- **A pump-probe experimental setup has been proposed for LIGHT**
  - **100 m^2 CR**
  - **dedicated TC**
  - **experimental chamber with nhelix**



Status of the early laser diagnostic at FAIR

☑ Requirements have been settled

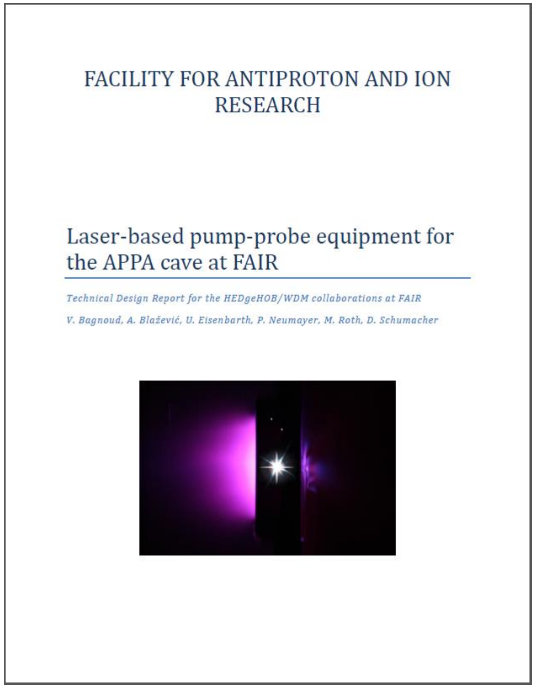
Energy	Repetition rate	Pulse duration	Pulse shaping	frequency
100 J	1 shot per min	0.1 – 20 ns	yes	2ω

☑ Concept for the laser architecture proposed

– procurement of test sample for critical components started (glass rods)

☑ Concept for the implementation in the building done

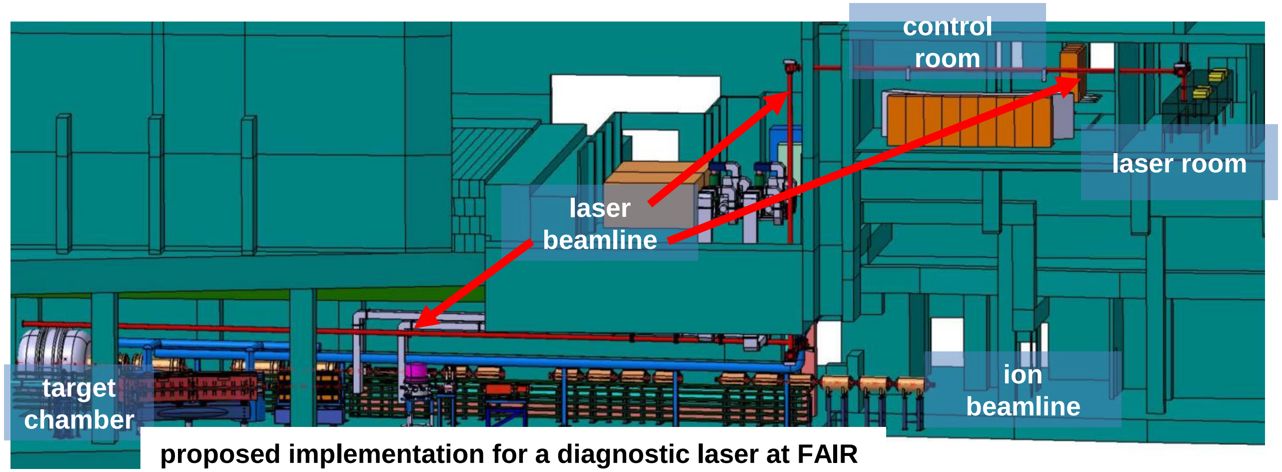
☑ TDR has been approved, R&D partially funded by BMBF


FACILITY FOR ANTIPROTON AND ION RESEARCH

Laser-based pump-probe equipment for the APPA cave at FAIR

Technical Design Report for the HEDgeHOB/WDM collaborations at FAIR

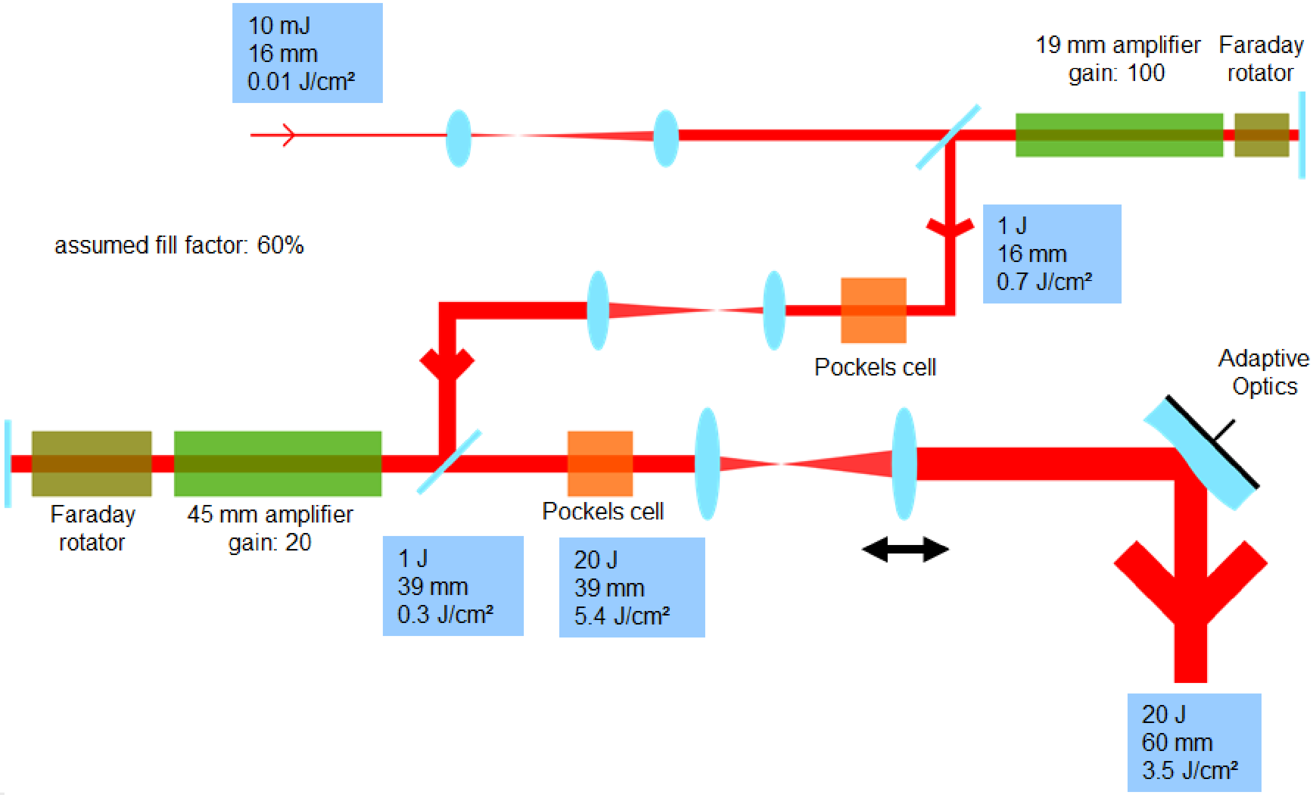
V. Bagnoud, A. Blažević, U. Eisenbarth, P. Neumayer, M. Roth, D. Schumacher



proposed implementation for a diagnostic laser at FAIR

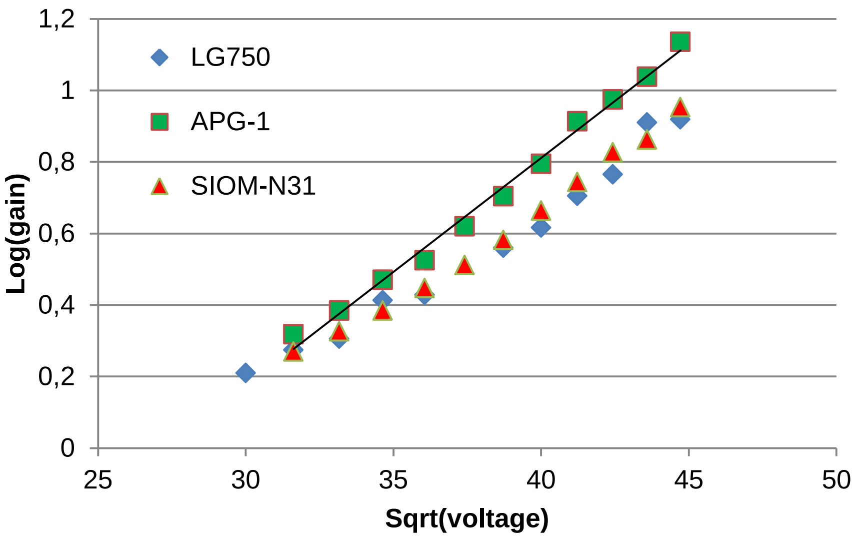
PHELIX Pre-amplifier Upgrade (2016)

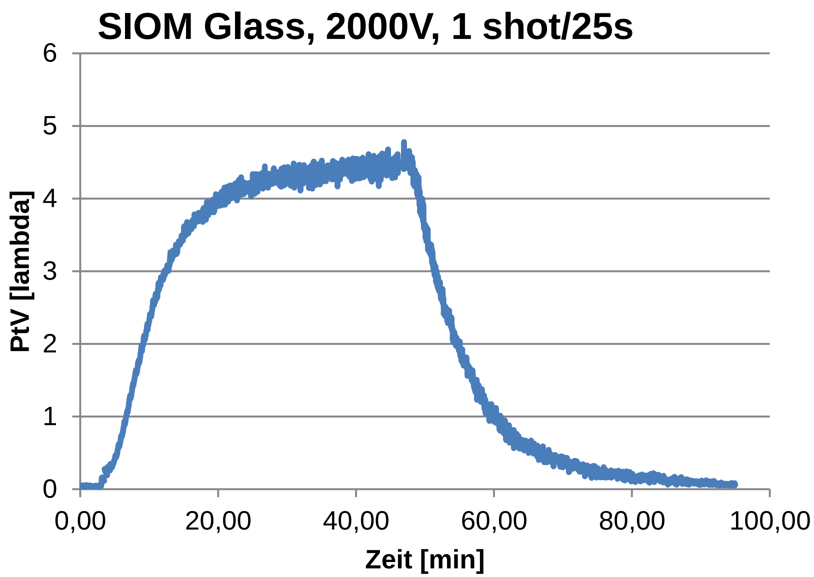
- **Motivation: gain some experience with thermally loaded amplifiers**
  - **thermal effect compensation**
  - **operation in with repetition rate**
  - **prototype for the 100 J laser for FAIR**
- **Goals: 20 J, 3 shots/min (0.05 Hz)**



Validation of the 45-mm glass-rod head

- Power supply from commercial provider (Continuum, 2kV max)
- GSI head design
  - test of glass from SIOM (N31) and Schott (APG-1)





implementation in June –July 2016 (6 weeks shut down)

PHELIX shows steady improvements while serving the community

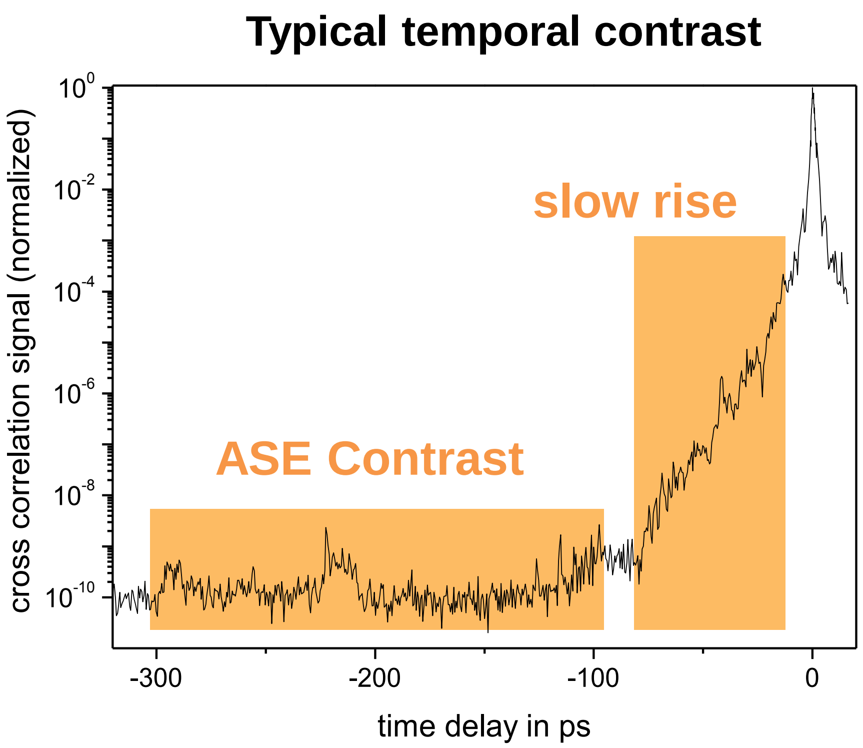
- **PHELIX operates as a user-oriented facility during the construction of FAIR**
  - **8 months of operation/year**
  - **Active control on the beam intensity ensures beam intensities above 10^{20} W/cm^2 in routine operation**
  - **dual science and program-driven (FAIR & Helmholtz) studies**

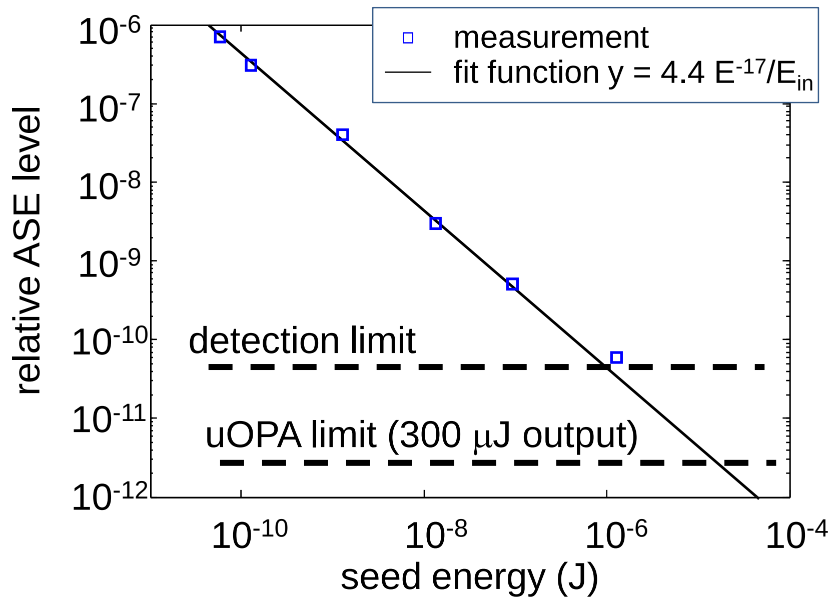
- **Towards FAIR**
  - **The LIGHT beamline and the Athena project should ensure a visible mid-term research program**
  - **Laser activities for the plasma physics cave: 100 J laser for FAIR**
  - **PHELIX pre-amplifier upgrade as a testbed for high repetition rate glass amplifiers**

THANK YOU!

Temporal contrast - Status

- ultimate contrast around 10^{-12} (non directly measurable)
- A tunable contrast between 10^{-6} and 10^{-10} (measurable)
  - pre-amplification with an uOPA* for improved signal-to-noise ratio





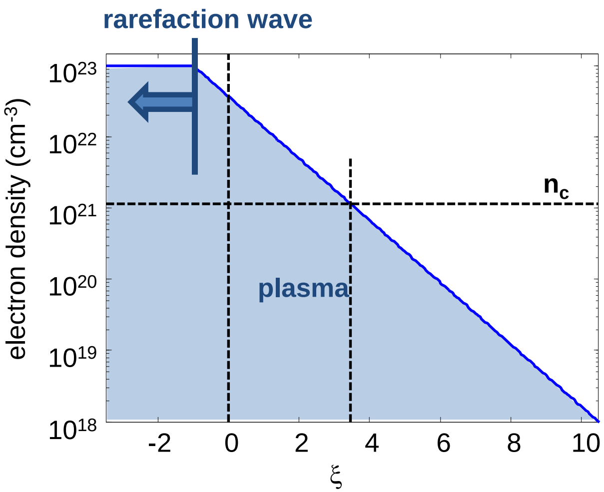
Poster from V. Schanz, Wednesday

*Wagner, F., et al *Applied Physics B* **116**.2 (2014): 429-435.

Temporal contrast - Influence of the slow rise

- an instantaneous onset of the laser light is not the most ideal case
  - reduced absorption/coupling efficiency to a few % for solid targets
    - plasma mirror effect
    - verified in PIC codes

- **but, pre-ionization leads to pre-plasma expansion**



$$\xi = \frac{S_0 x}{t}, \qquad S_0 = \sqrt{\frac{Z_i k_B T_e}{m_i}},$$