Laser-Plasma Acceleration in Hamburg

IPAC 2015

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LAOLA. is a collaboration of

Outline

1. *LAOLA - Strategy in Hamburg*
2. *ANGUS Laser and LUX Beamline*
3. *Summary*

Why another laser-plasma lab?

Calvin&Hobbes: (c) B. Watterson

electron energy & charge ≠ quality

quality ≠ stability

stability ≠ availability

Why another laser-plasma lab?

„From acceleration to accelerators…"

Combine university research with accelerator facility resources and expertise.

LAOLA Collaboration in Hamburg

Reinhard Brinkmann	Andreas Maier
Klaus Flöttmann	Florian Grüner
Ralph Aßmann	...
Holger Schlarb	
Bernhard Schmidt	
Brian Foster	
Eckhard Elsen	
Jens Osterhoff	
...	

LAOLA Collaboration in Hamburg

LAOLA.

	Reinhard Brinkmann	**Andreas Maier**	group of ~10 people
	Klaus Flöttmann	**Florian Grüner**	group of ~10 people
group of ~10 people	**Ralph Aßmann**	...	
	Holger Schlarb		
	Bernhard Schmidt		
	Brian Foster		
	Eckhard Elsen		
group of ~10 people	**Jens Osterhoff**		
	...		

LAOLA can contribute significant manpower and resources to its plasma-related activities.

Joint LAOLA Strategy

laser-driven

A. R. Maier: ANGUS laser & LUX beamline

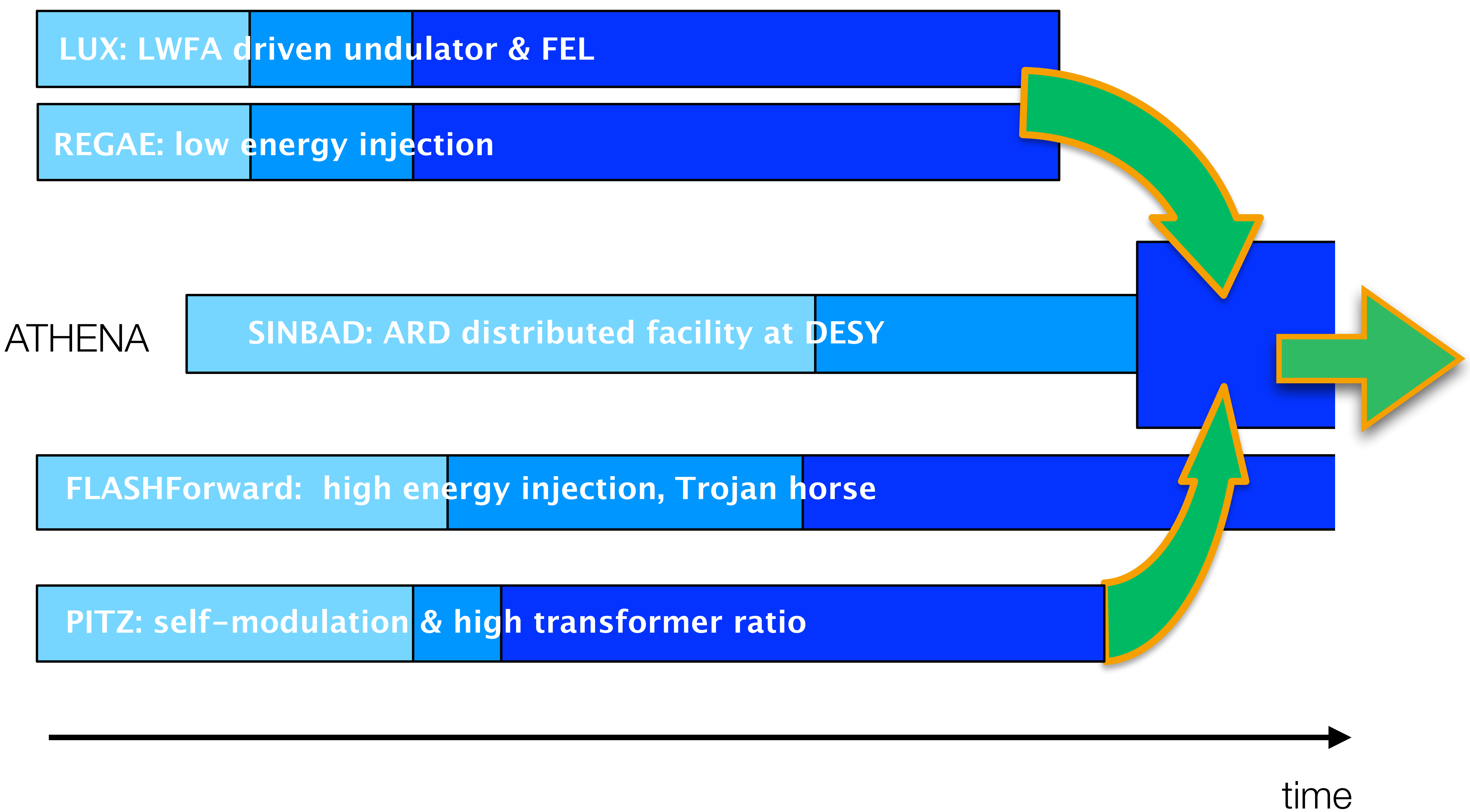
K. Flöttmann: REGAE beamline

Ralph Aßmann: SINBAD facility & ATHENA

beam-driven

J. Osterhoff: FLASHForward

F. Stephan: PITZ



Joint LAOLA Strategy

R. Aßmann: SINBAD facility & ATHENA

@ IPAC15 see Barbara's and Ulrich's work:
TUPWA028, TUPWA029, TUPWA030,
WEPMA031, MOPWA042

laser-driven

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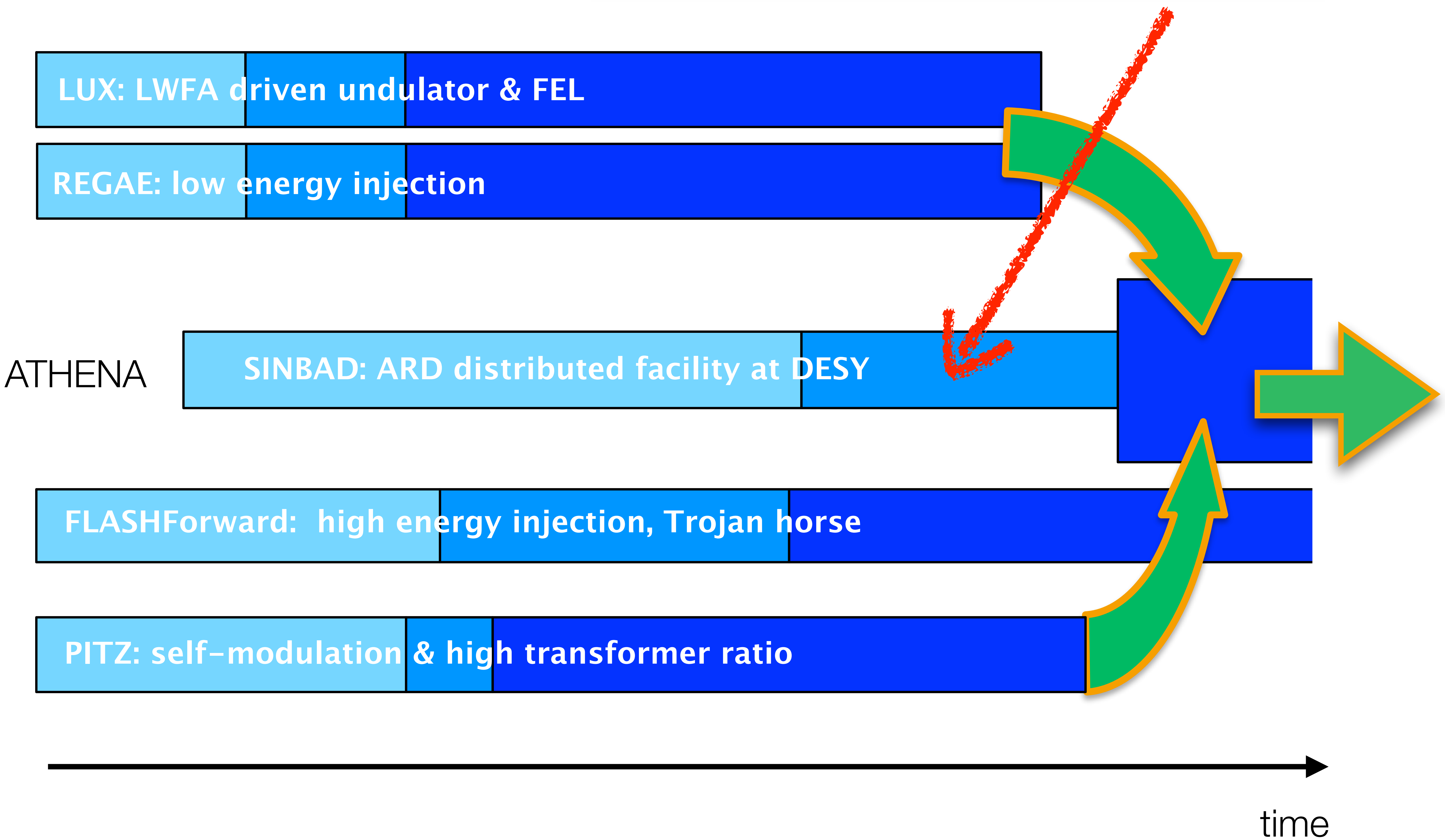

Joint LAOLA Strategy

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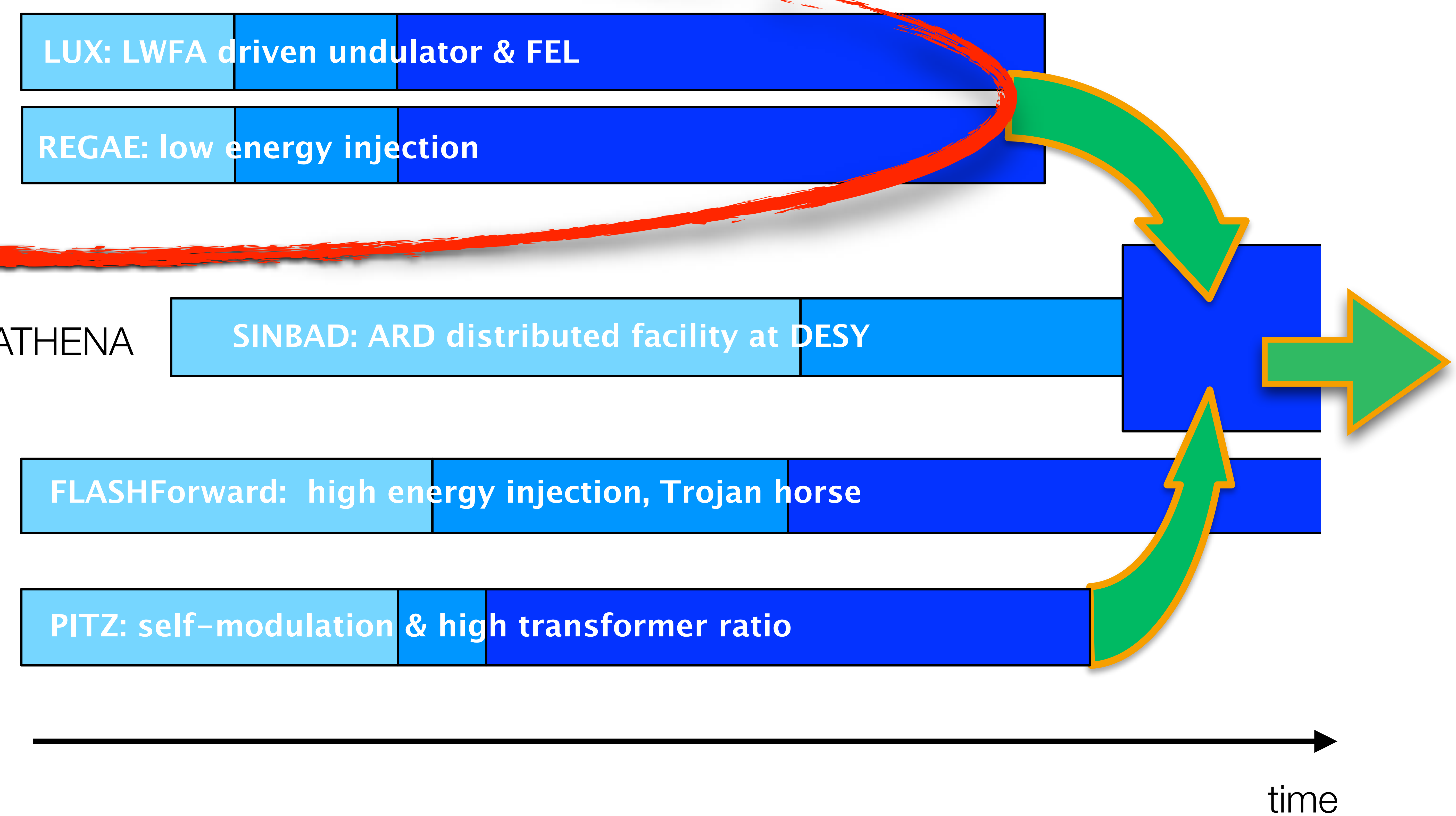


ANGUS Laser & LUX Beamline

LUX Junior Research group

Junior Research group at CFEL and Hamburg University

commission & operate 200 TW ANGUS laser system

build and operate the LUX beamline for laser-plasma driven undulator radiation

lux.cfel.de


Andi Maier

Andi Walker



Matthias (Prof. Grüner group, UHH)


Chris

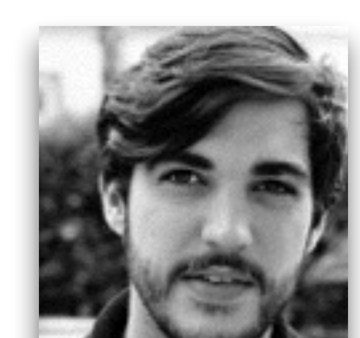

Niels


Vincent *


Spencer *


Max


Paul


Manuel

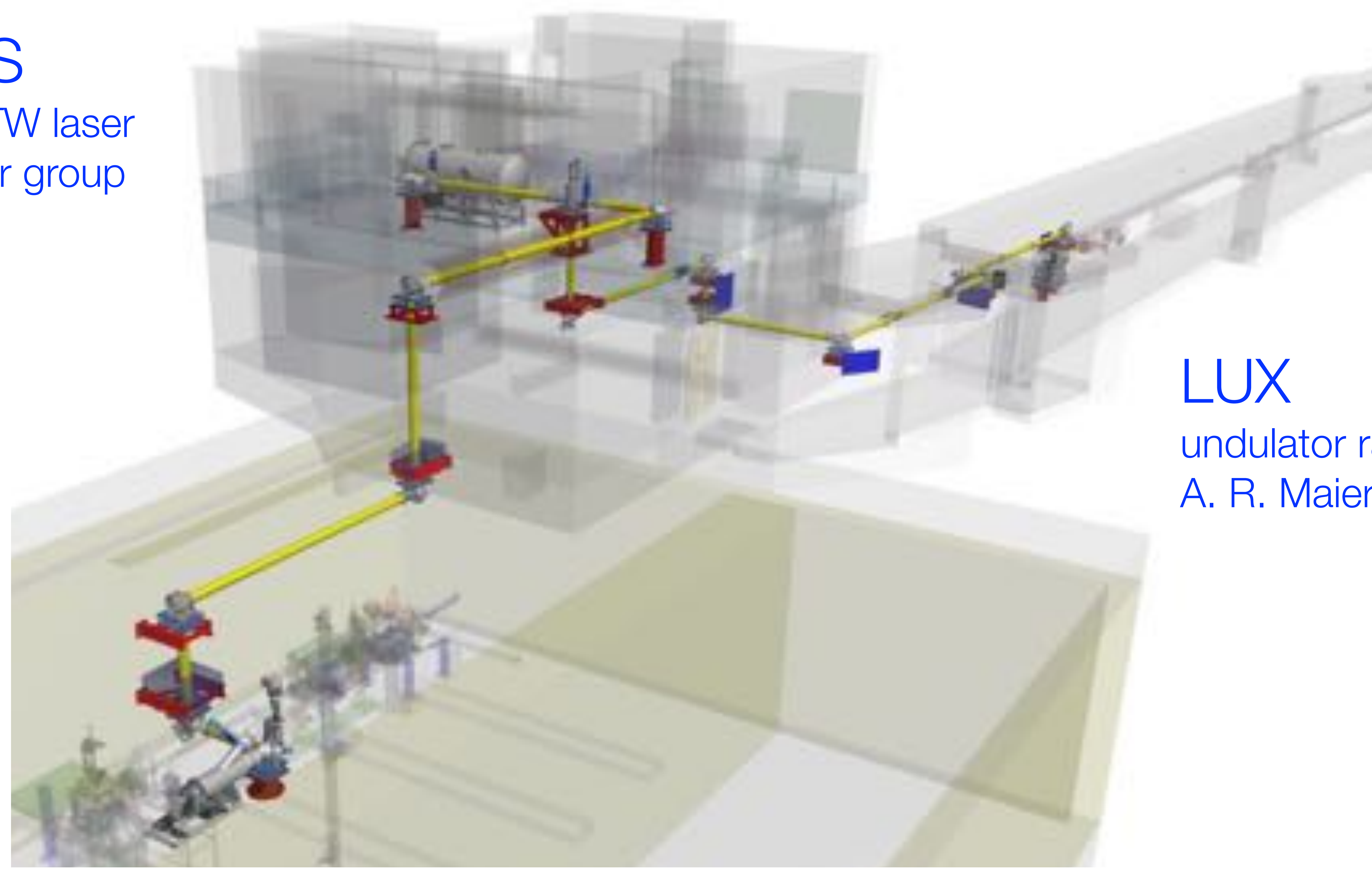

Dominik


Sören

* eli beamlines
also group Georg Korn

UHH CFEL SCIENCE

Laser-Driven Plasma Acceleration



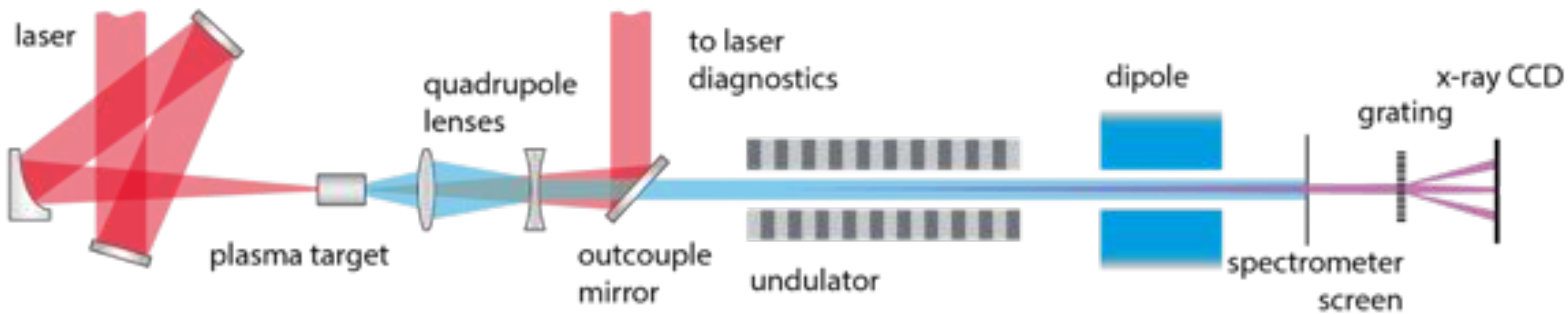
ANGUS
new 200 TW laser
A. R. Maier group

LUX
undulator radiation
A. R. Maier group

REGAE
external injection
K. Flöttmann, B. Zeitler

see M. Hachmann & F. Mayet
WEPMA030
MOPHA027

ANGUS Laser & LUX Beamline



dedicated beamline for undulator radiation

re-built 4-nm experiment, with accelerator standards in mind… (and all the nice toys you get at an accelerator lab…)

Design Aspects & Commissioning

1. *ANGUS Laser*
2. *Vacuum*
3. *Target*

ANGUS Laser Lab

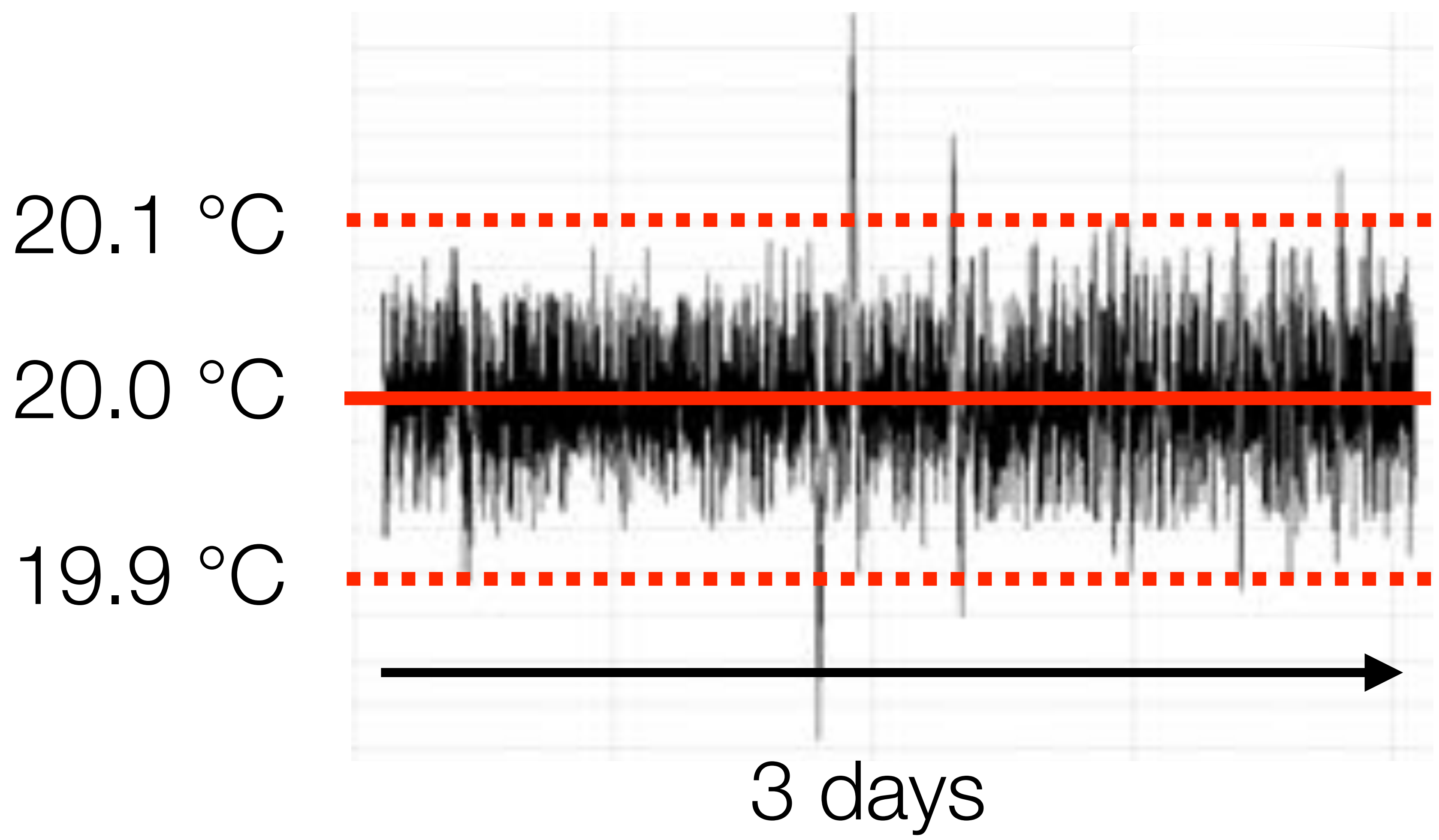
- early decisions:
    - laser is just a tool („just a klystron“)
    - we want to adopt concepts from the accelerator community
    - no laser development except for diagnostics

- TW-class lasers have a pretty bad reputation
    - (poor quality)
    - poor stability
    - poor availability

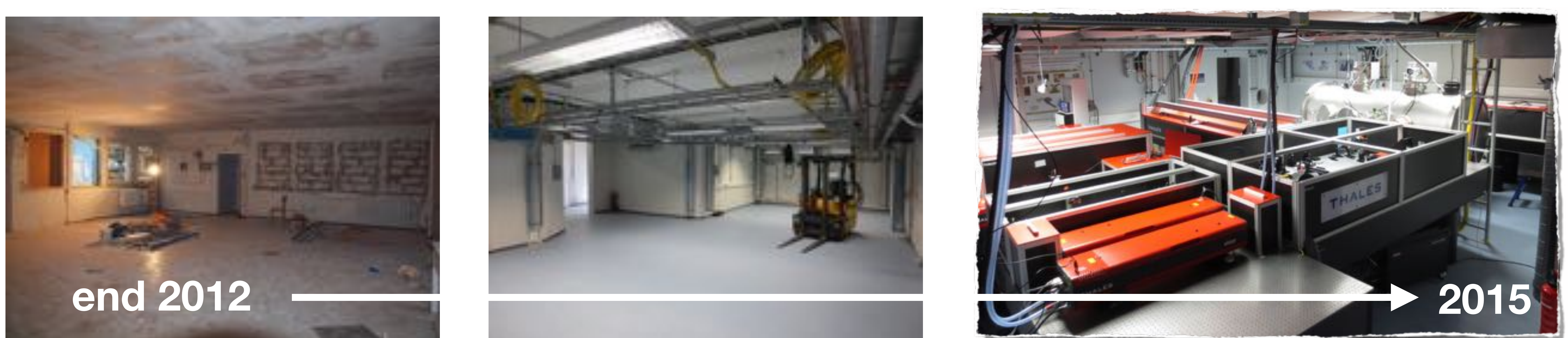
depends on laser design; 5 Hz, 25 fs, 5 J, <1% energy stability, strehl better 0.9

depends on **how** you operate the laser and the lab; here we can adopt concepts from the accelerator community

ANGUS Laser Lab



lab conditions
- better 0.1°C rms temperature stability
- stable by few % relative humidity
- consequently remove all heat sources
- get everything in water-cooled racks
- challenge is to keep the standards up high in day-to-day operation



Control System

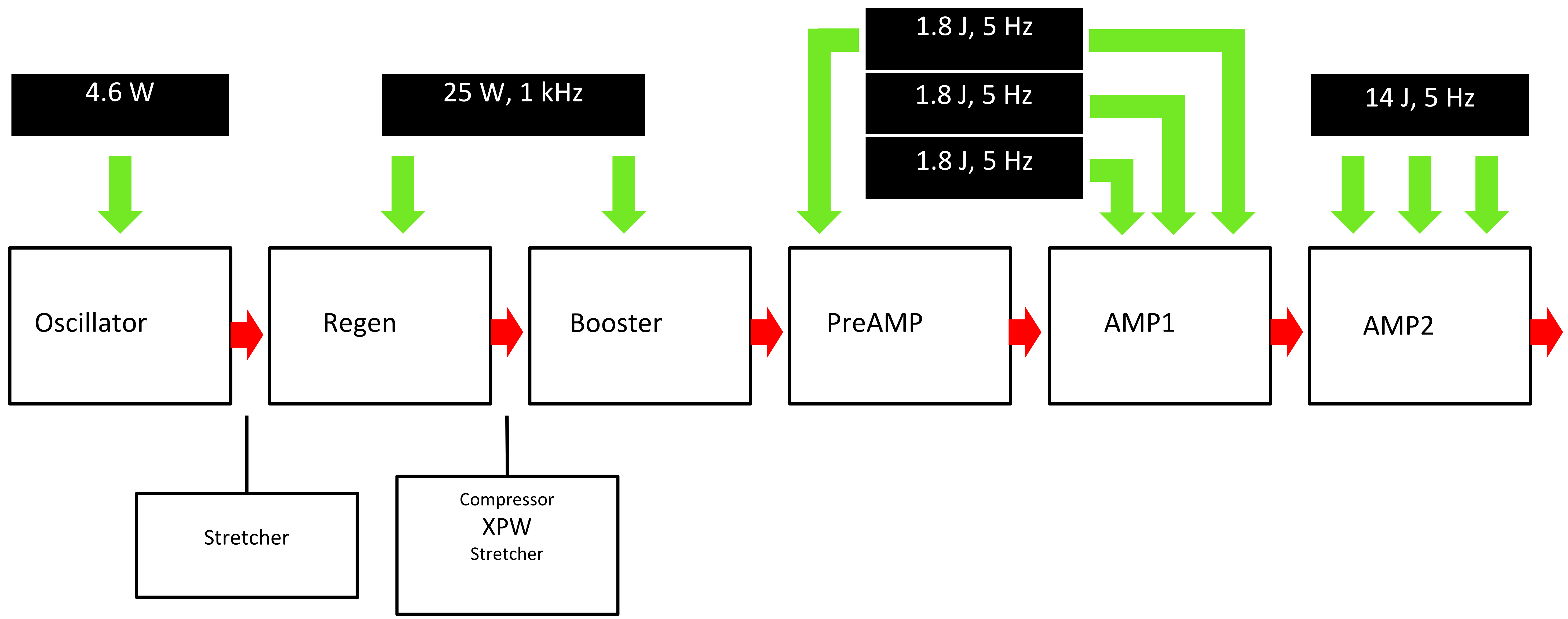
get laser into the accelerator controls system

typically the lasers are
- stand-alone systems
- w/ minimum online diagnostics
- trends / correlation charts are not (easily) generated
- difficult to monitor machine status

- and have no machine protection system

→ get in more diagnostics and integrate it in accelerator control system

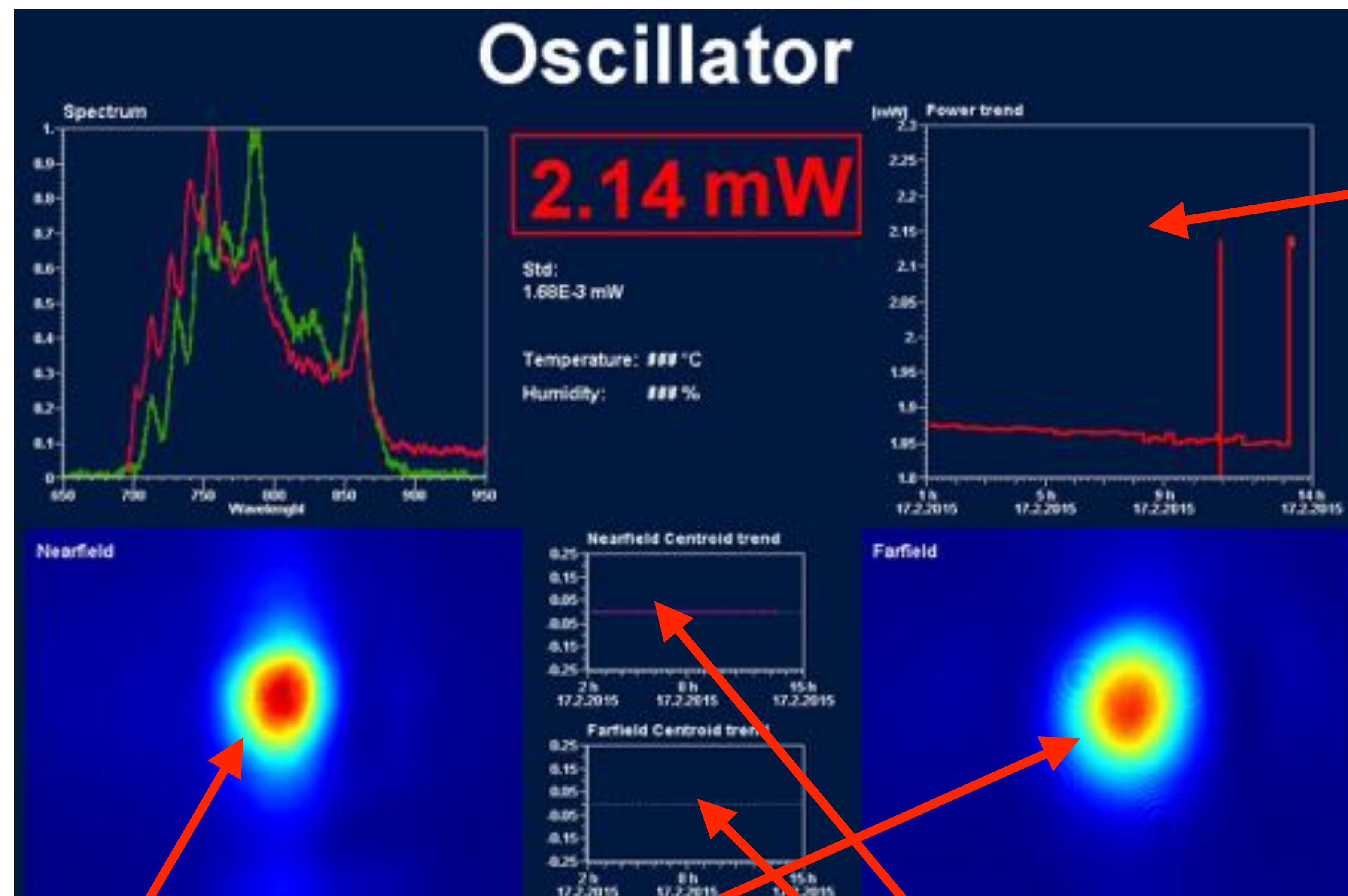
Control System



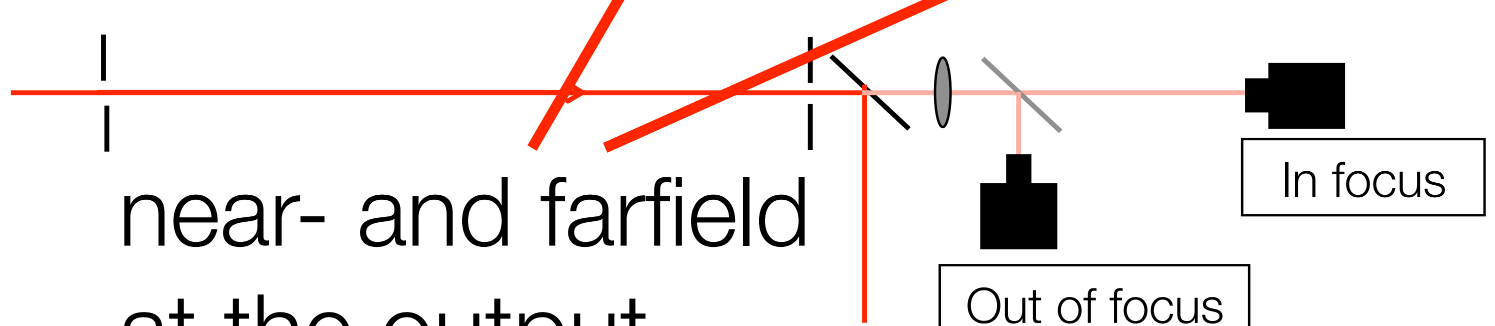
ANGUS - 200 TW Laser System

spectrum w/
reference

built with TINE/DOOCS/jddd



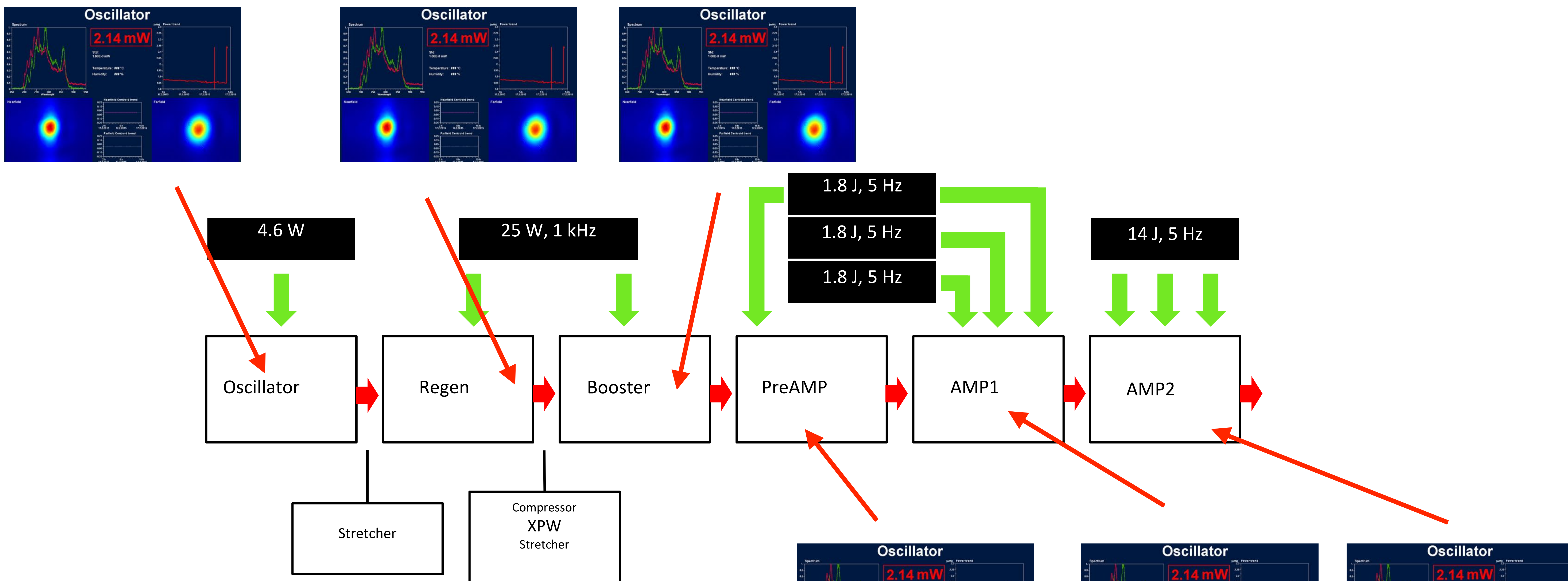
online energy / power
w/ trend chart

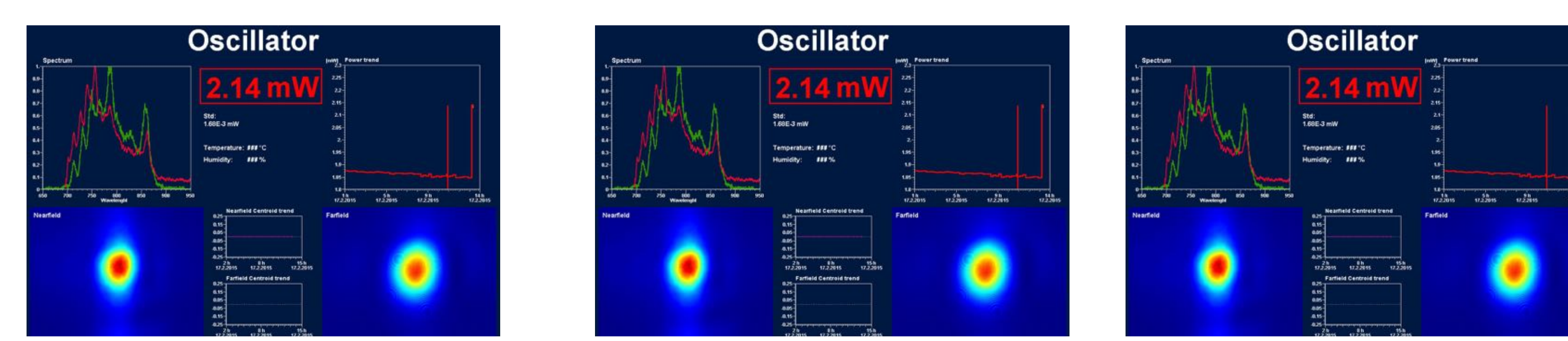


near- and farfield
at the output

get centroids of NF/FF and
display trend chart on laser
position and direction

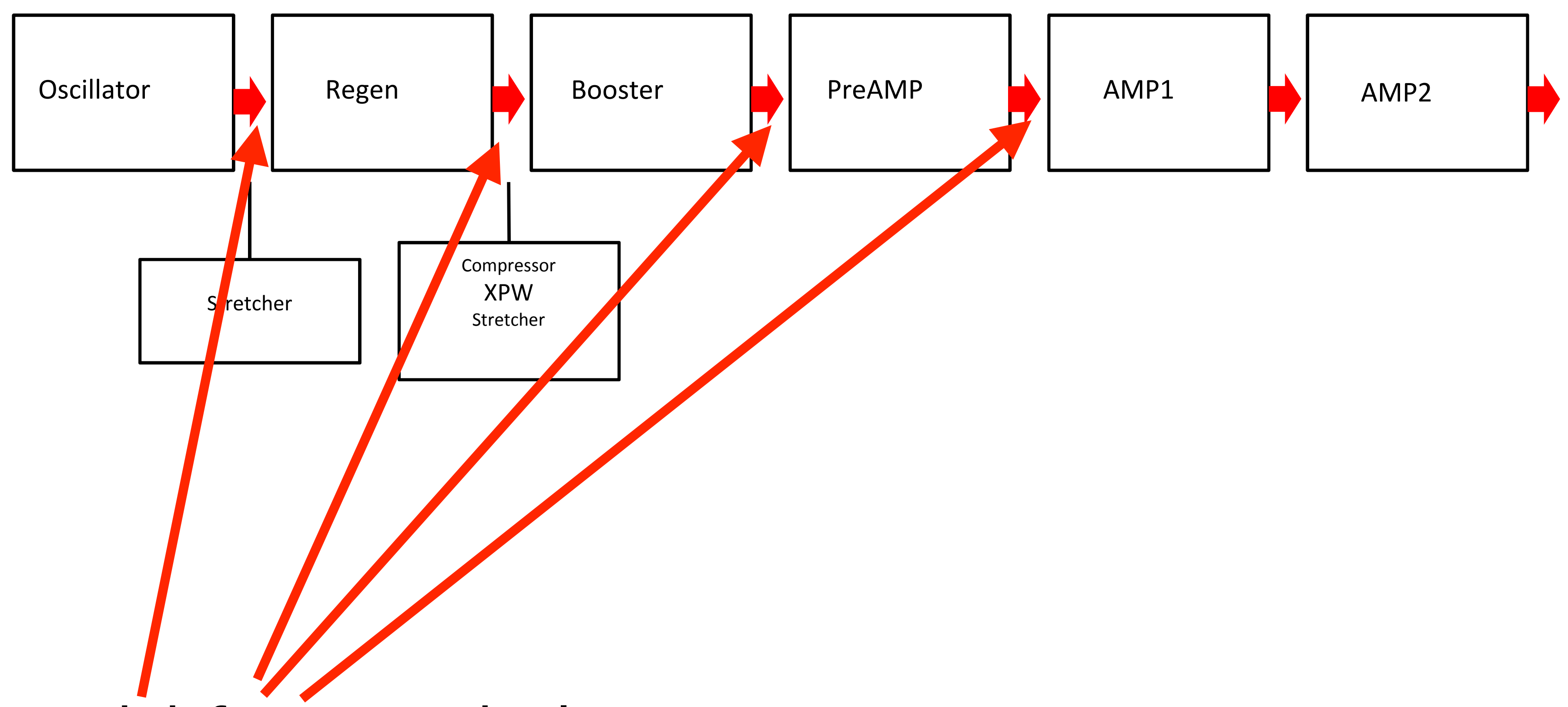
ANGUS - 200 TW Laser System





isolate errors in the system

ANGUS - Auto-Alignment



add fast and slow auto-alignment between stages

- is a safety requirement (!)
- better day-to-day reproducibility
- faster start-up
- compensate drifts

Is it worth it?

- a lot of investment into a something that you wont get the Nobel Prize for…
- not there yet…
- you get a quantified measure of the performance, not just „good“ or „bad“
- we learn a lot about the system
- and have days where we turn it on in less than 1 hour…

26.02.2015 11:09 Spencer, Timo **Laser Chain Alignment**

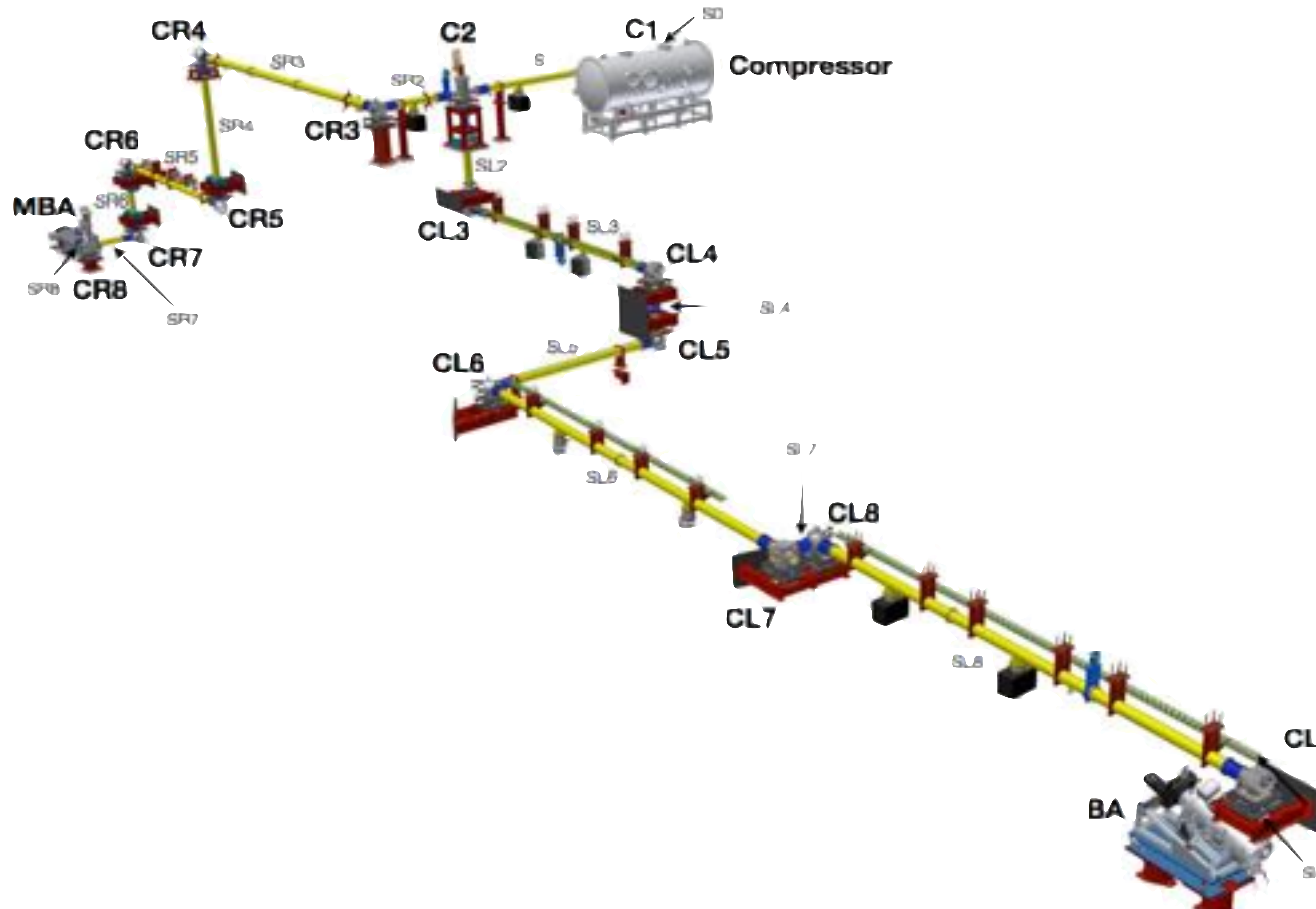
Alignment is maintained from yesterday and the beam is on the T-table

Design Aspects & Commissioning

1. *ANGUS Laser*
2. *Vacuum*
3. *Target*

Vacuum Conditions

- vacuum conditions determine long-term laser performance
- dirt deposited on mirrors, changes beamprofile and deteriorates laser quality



Vacuum Conditions

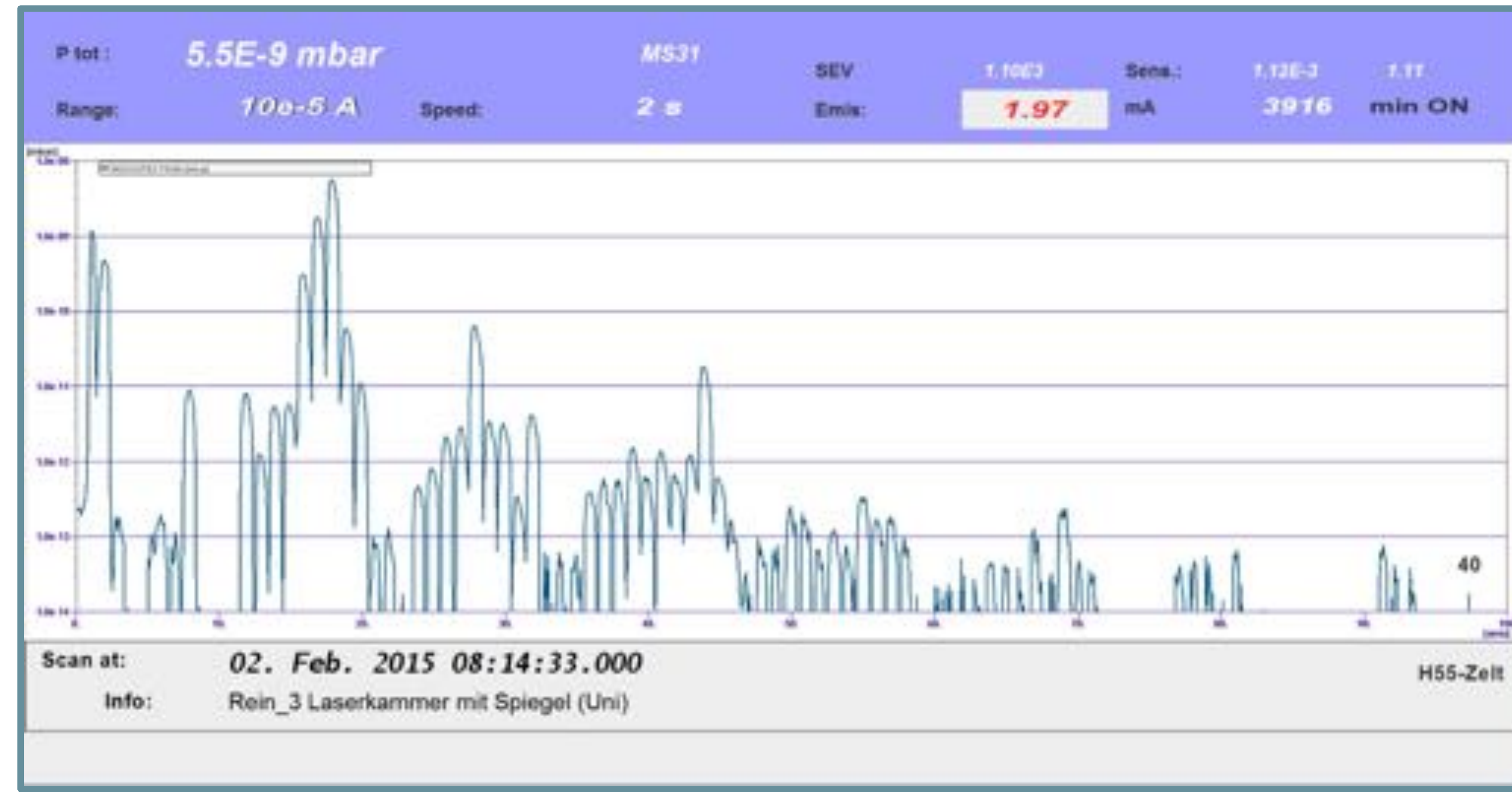
early decision: we adopt DESY machine vacuum standards

- no hydrocarbons
- no particles
- take RG-spectra of EVERY item

far reaching consequences:

- have to built mirror/mounts, transport beamline, … in house
- lot of standard laser community solutions do not work anymore

… and hope that in the end it will pay off



a „clean" (per DESY definition) residual gas spectrum

Design Aspects & Commissioning

1. *ANGUS Laser*
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High Rep-Rate Plasma Target

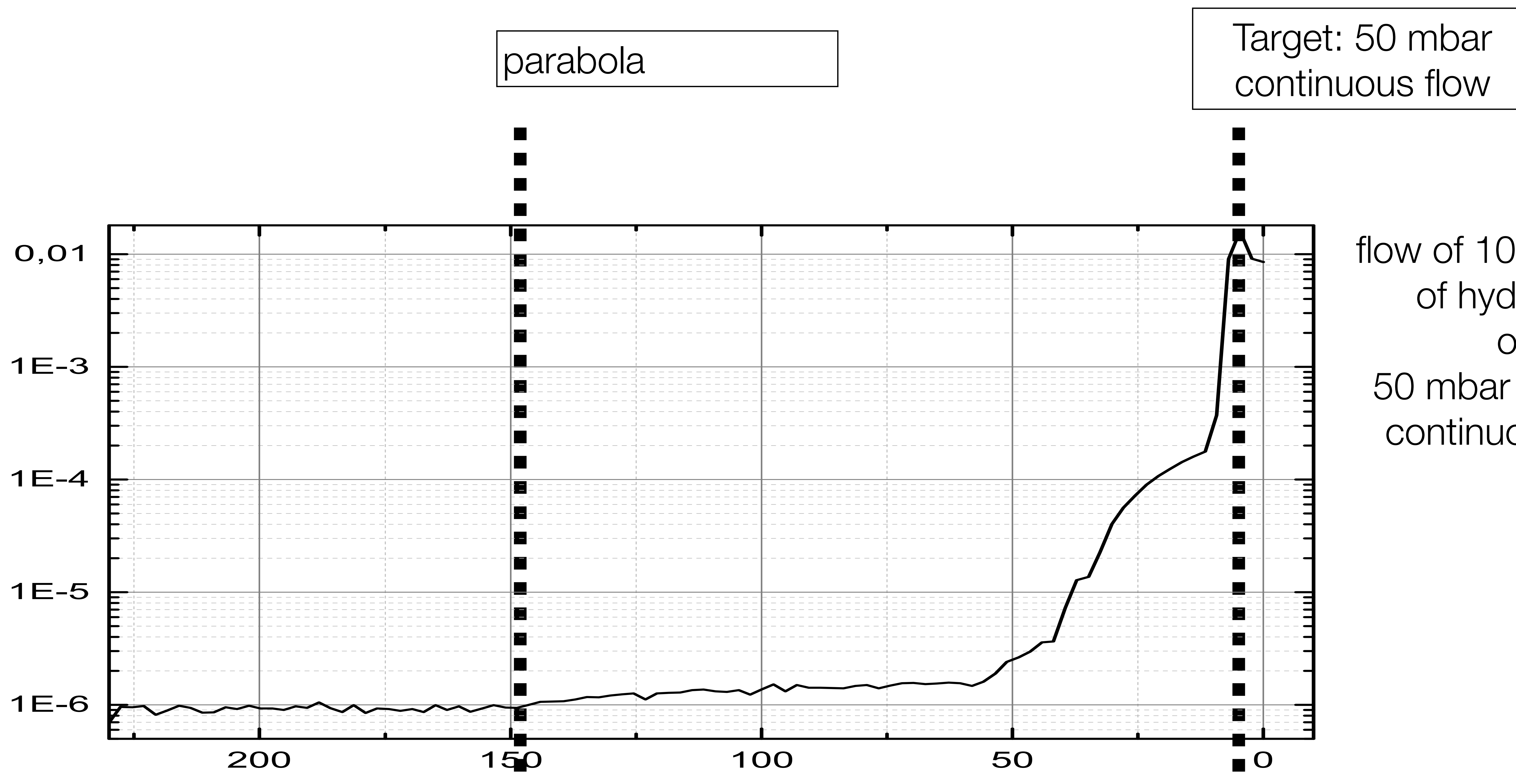
We still need to learn a lot about plasma acceleration. And therefore need statistics, scans, error bars …

- Rep-rate is determined by gas load in the target chamber.
- Typical experiments so far have one shot every few seconds.

Building a beamline from scratch we can design it for max. rep-rate…

… which is full 5 Hz

High Rep-Rate Plasma Target

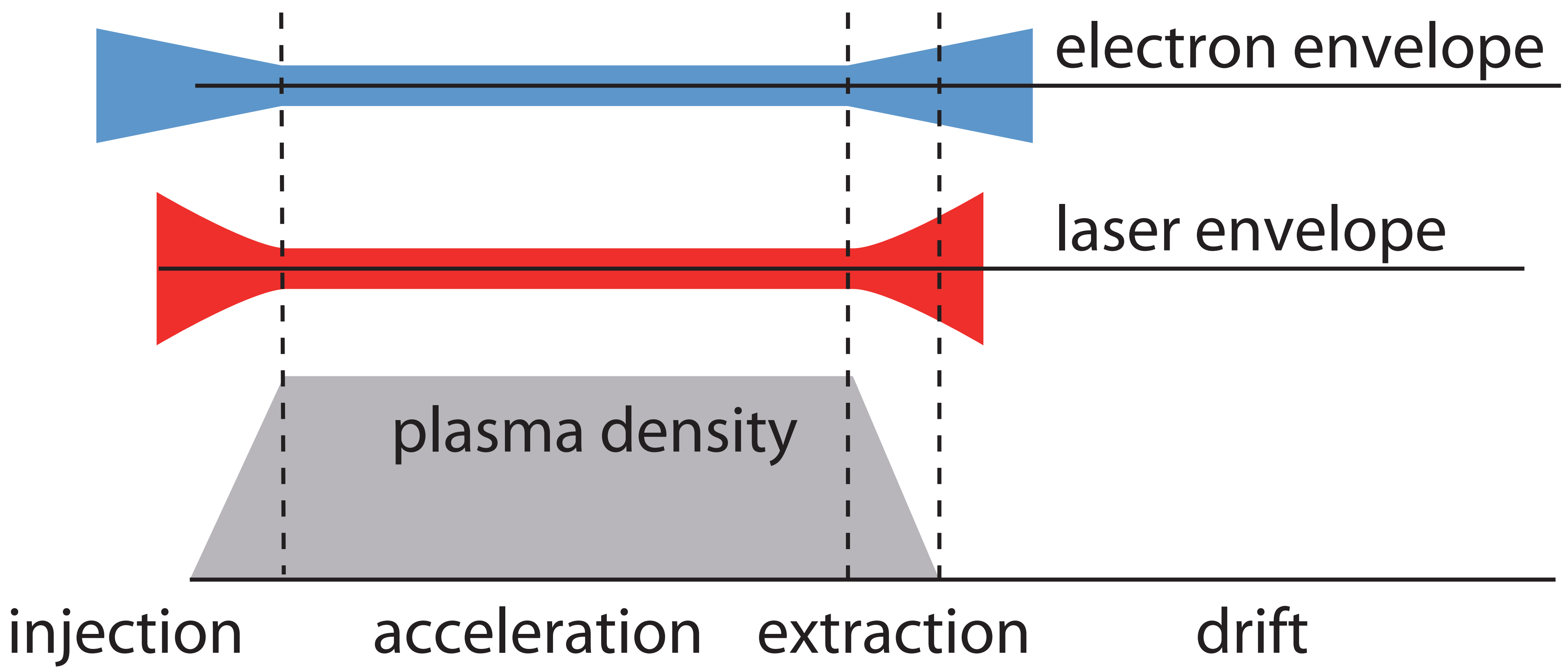


flow of 10 mbar l /s
of hydrogen
or
50 mbar in target
continuous flow

more examples…

adiabatic matching

Adiabatic Matching



- its very difficult to externally inject into a plasma, due to large focussing forces
- chromatic emittance growth due to large divergence after the plasma

- use adiabatic matching via density downramp at the plasma exit

- just published
  I. Dornmair, K. Flöttmann, A. R. Maier
  Phys. Rev. ST-AB 18, 041302 (2015)

nice collaboration between plasma groups and accelerator physicists

discussion on emittance growth

- T. Mehrling et al., PRST-AB 15, 111303 (2012)
- R. Assmann et al., NIM A 410, 544 (1998)
- P. Antici et al., J. Appl. Phys. 112, 044902 (2012)
- M. Migliorati et al., PRST-AB 16, 011302 (2013)

Summary

- LAOLA combines university groups with large research facilities and a joint strategy
- LUX junior research group for plasma-driven light sources
- We operate the ANGUS laser and LUX beamline
- „clash of cultures“ :-) between laser physicists, plasma acceleration and acclerator physicicsts can be very beneficial

Acknowledgement

funding

project HHH20

partners

DESY - M

group Florian Grüner

DESY FS-LA

LBNL
J.-L. Vay
WARP code

group Brian McNeil

group Georg Korn

group Johannes Bahrdt

group Jens Osterhoff