First Electron Beams from KALDERA

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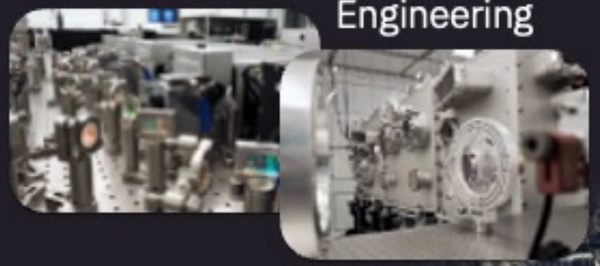
DESY. Plasma Acceleration and Laser Group
High Average Power LPA

mpl.desy.de

Video: DESY, scicomlab, S. Jalas / M. Kirchen
kaldera.desy.de

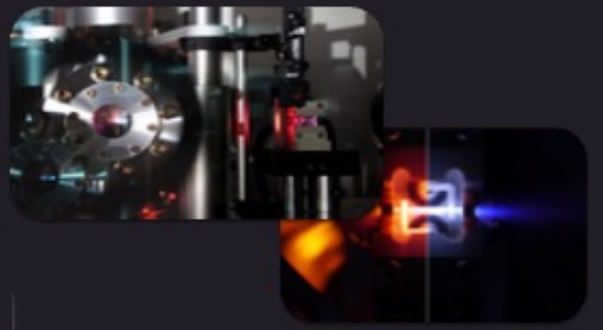
Plasma accelerator research at DESY

Our portfolio



Scientific
Engineering

Theory &
Simulations



Laser-Plasma Accelerator
Applications

LUX Laser-Plasma
Accelerator

KALDERA
High Average Power
Laser-Plasma Acceleration

FLASHForward
Beam-Driven Plasma Acceleration

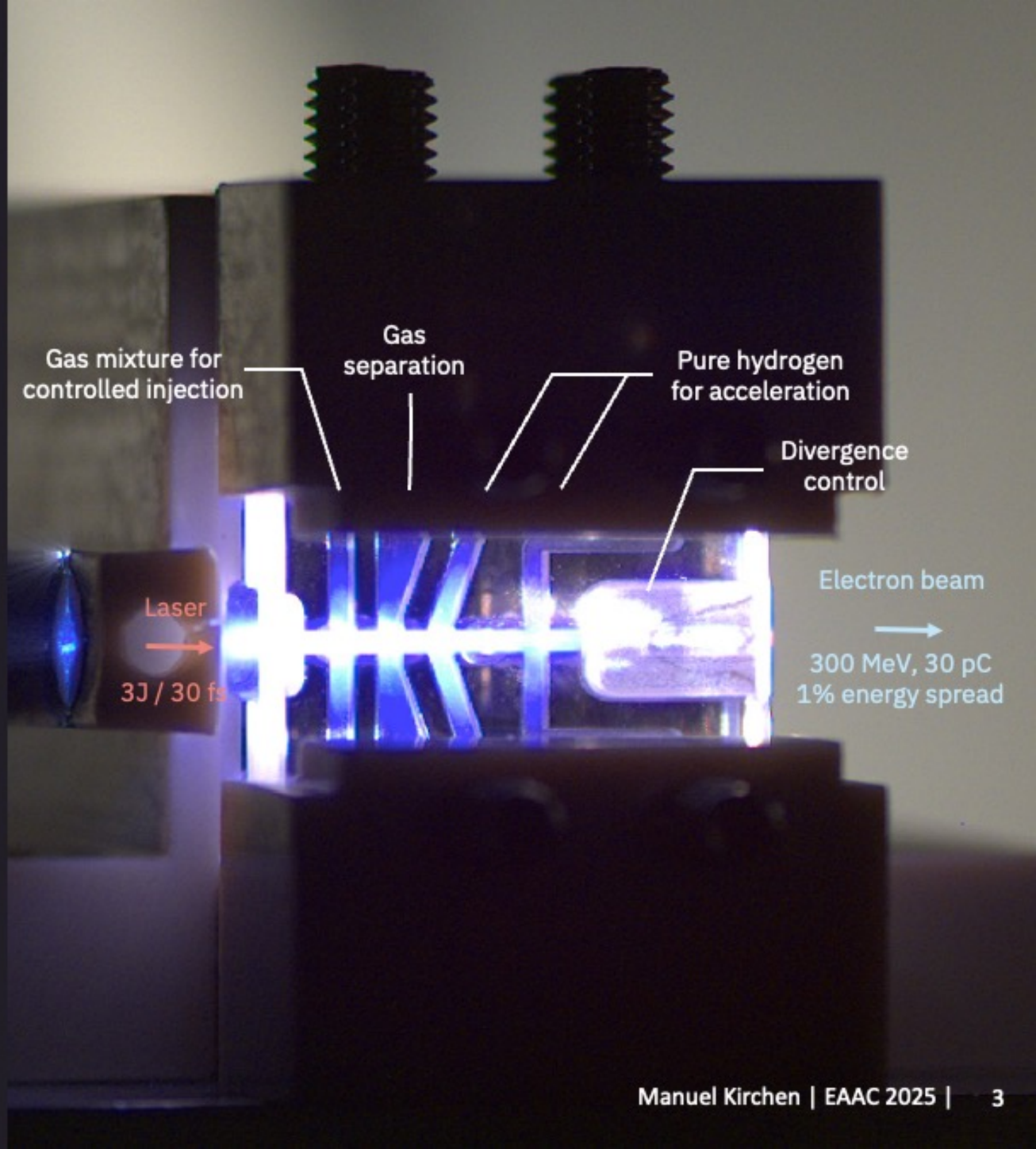
High quality beams

Localized ionization injection

Developed concept over many years at LUX

Stable plasma conditions & long-term durability

Sub-% energy spreads under ideal conditions



A.R. Maier et al. PRX 10, 031039 (2020)

M. Kirchen et al. PRL 126, 174801 (2021)

S. Jalas et al. PRL 126, 170801 (2021)

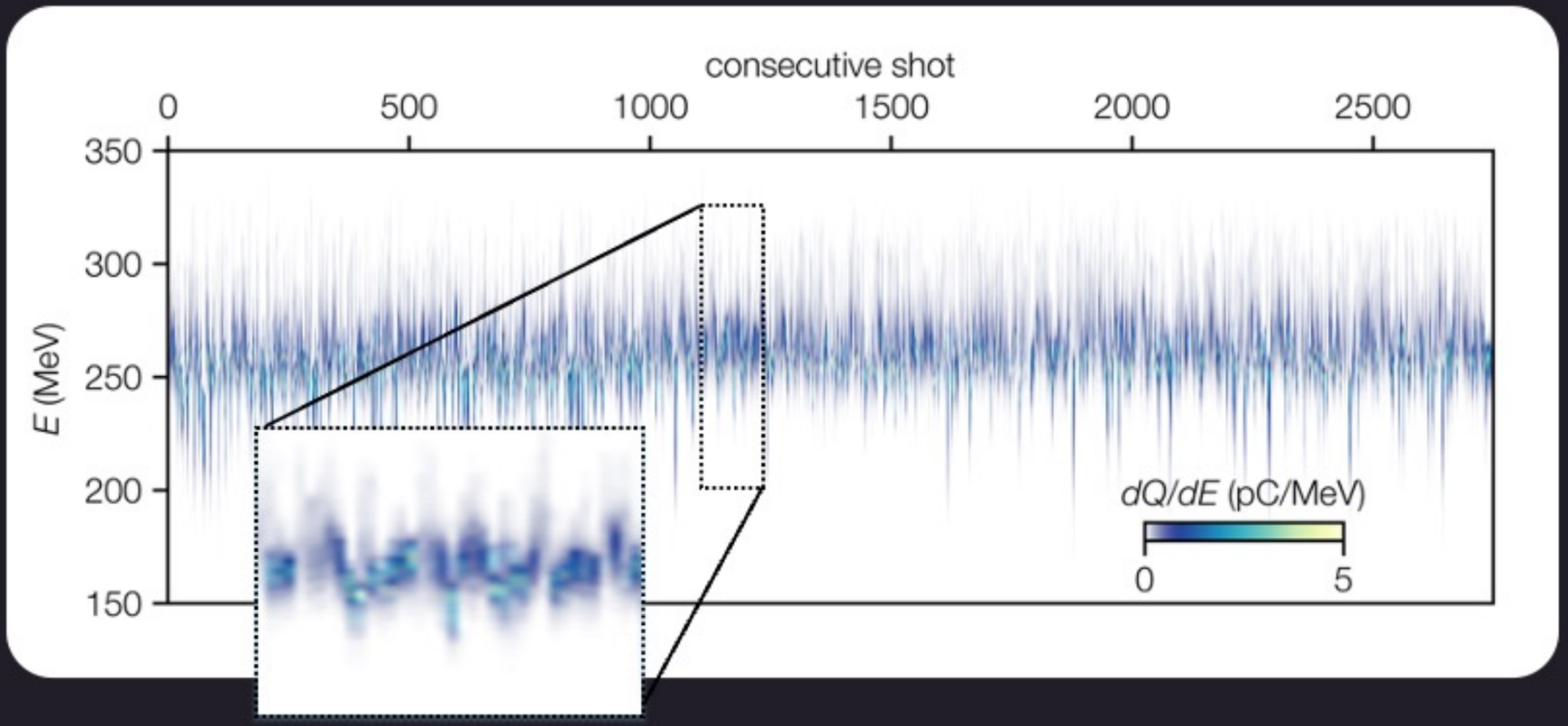
S. Jalas et al. PRAB 26, 071302 (2023)

P. Winkler et al. Nature (2025)

Chasing quality on shaky ground

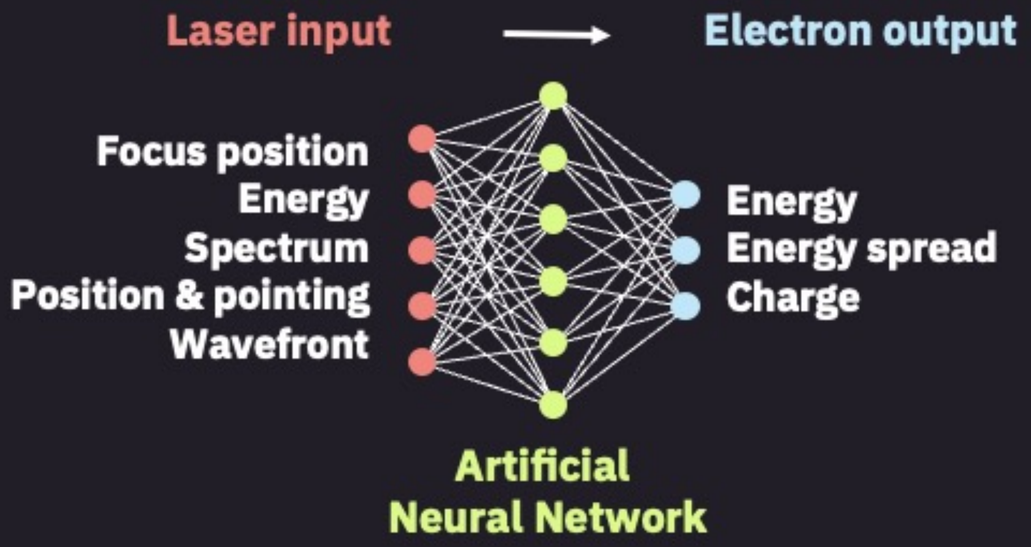
Percent-level jitter prevents further beam quality improvements

1 Hz data from LUX

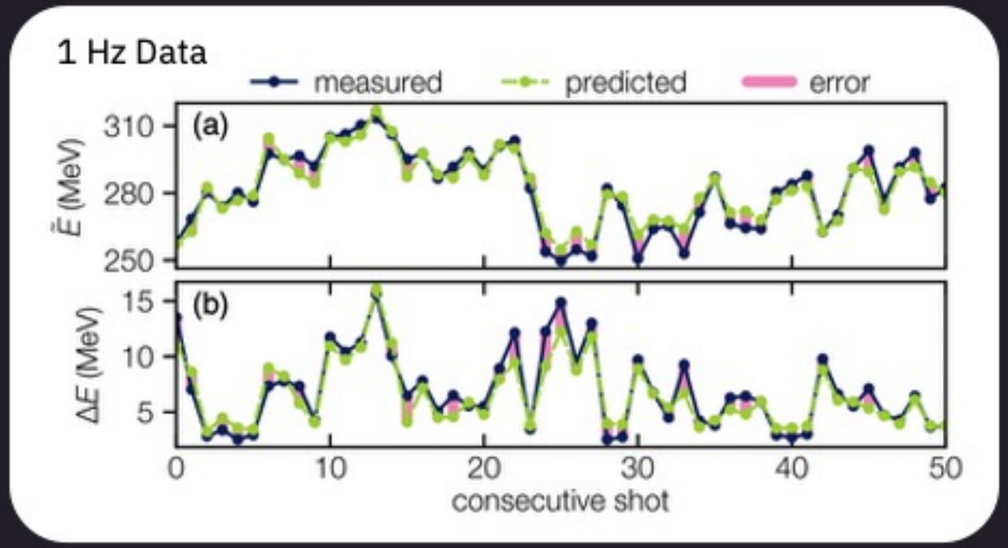


Decoding sources of jitter

The case for active stabilization at higher repetition rates



M. Kirchen et al. PRL 126, 174801 (2021)



LPA stability is determined by comparably slow laser fluctuations

Active stabilization at higher repetition rates?

KALDERA

High repetition rate LPA

Initiated by
Wim Leemans

Drive laser

Scale Ti:Sa technology to kW level
100 TW at up to 1 kHz
Demonstrate active feedback for high stability

Andreas Maier
Plenary on Monday

Guido Palmer
Laser Development

Lutz Winkelmann
Scientific Engineering

T. Hülsenbusch

Towards stable beams

Roadmap for High Average Power LPA development at DESY

Andreas Maier

Rob Shalloo
High Energy LPA

High average power
LPA operation

MAGMA LPA

Active feedback
Sub-% energy stability

KALDERA Phase 1
0.5 J @ 100 Hz

HOFI @
MAGMA

BEETLE

Trumpf laser + MPC
0.2 J @ 5 kHz

Demonstration
of kHz operation

Future LPA

KALDERA Phase 2
3 J @ 100 Hz

Sub-%
energy spread

Future
KALDERA

Guido Palmer
Laser Development

Lutz Winkelmann
Scientific Engineering

Towards stable beams

Roadmap for High Average Power LPA development at DESY

Andreas Maier

A. Puchert
Laser Pulse Tailoring for HOFI Waveguides
Talk on Wednesday

Rob Shalloo
High Energy LPA

High average power
LPA operation

Active feedback
Sub-% energy stability

HOFI @
MAGMA

Demonstration
of kHz operation

Sub-%
energy spread

MAGMA LPA

KALDERA Phase 1
0.5 J @ 100 Hz

BEETLE

Future LPA

Future
KALDERA

T. Eichner
LPA using a post-compressed Yb laser
Talk on Tuesday

Guido Palmer
Laser Development

Lutz Winkelmann
Scientific Engineering

MAGMA

Compact platform for high average power LPA

100 Hz electron acceleration driven by KALDERA

100 MeV, 20 pC @ 500 mJ

Active stabilization and fast feedback control

Demonstrate sub-% energy stability

Vacuum System

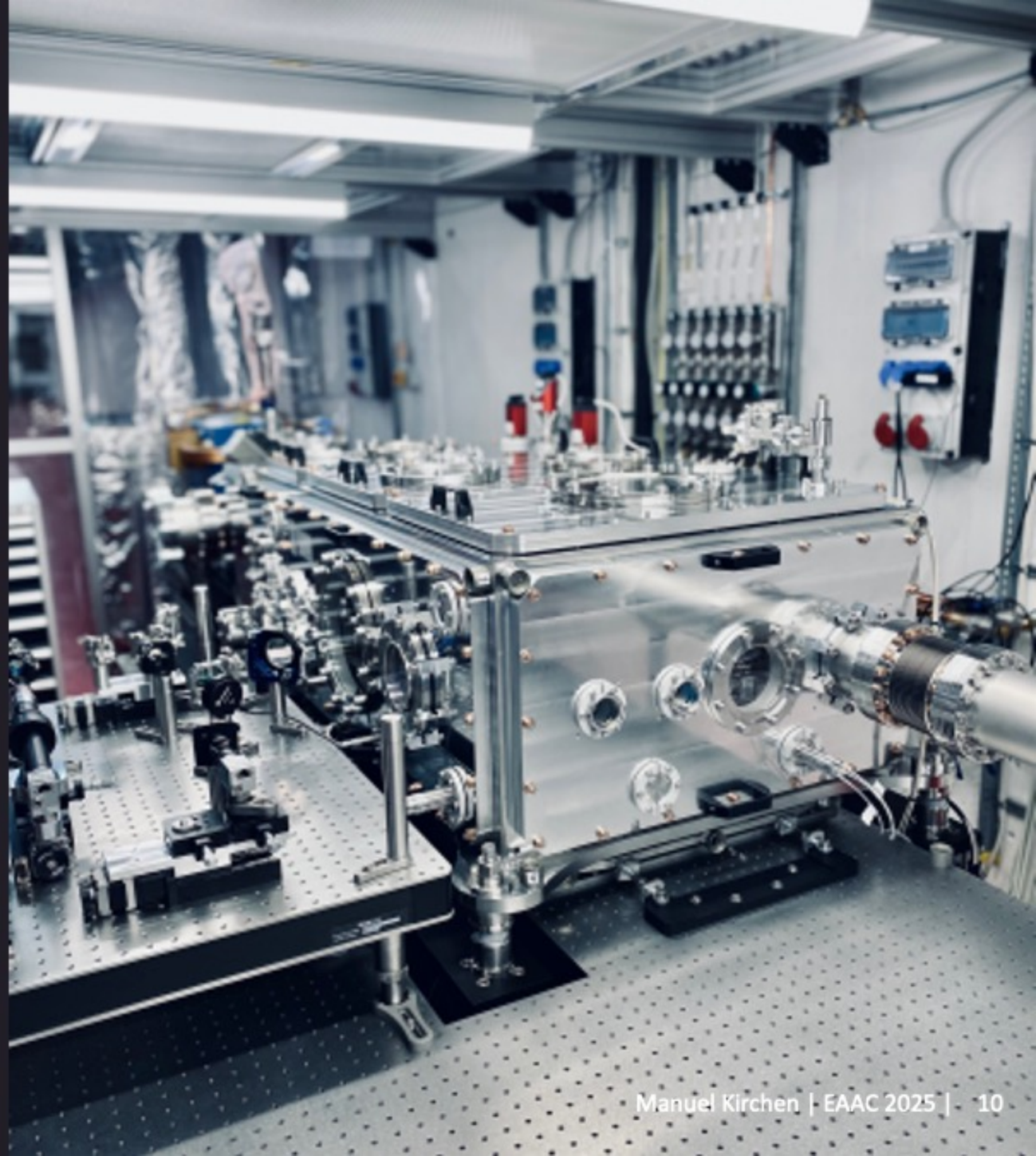
Designed for high rep rate operation

Decoupled optical setup

Differential pumping enables 1 l/min H_2 flow

UHV standards to prevent optics degradation

Cooled laser beam dumps in vacuum



Laser diagnostics

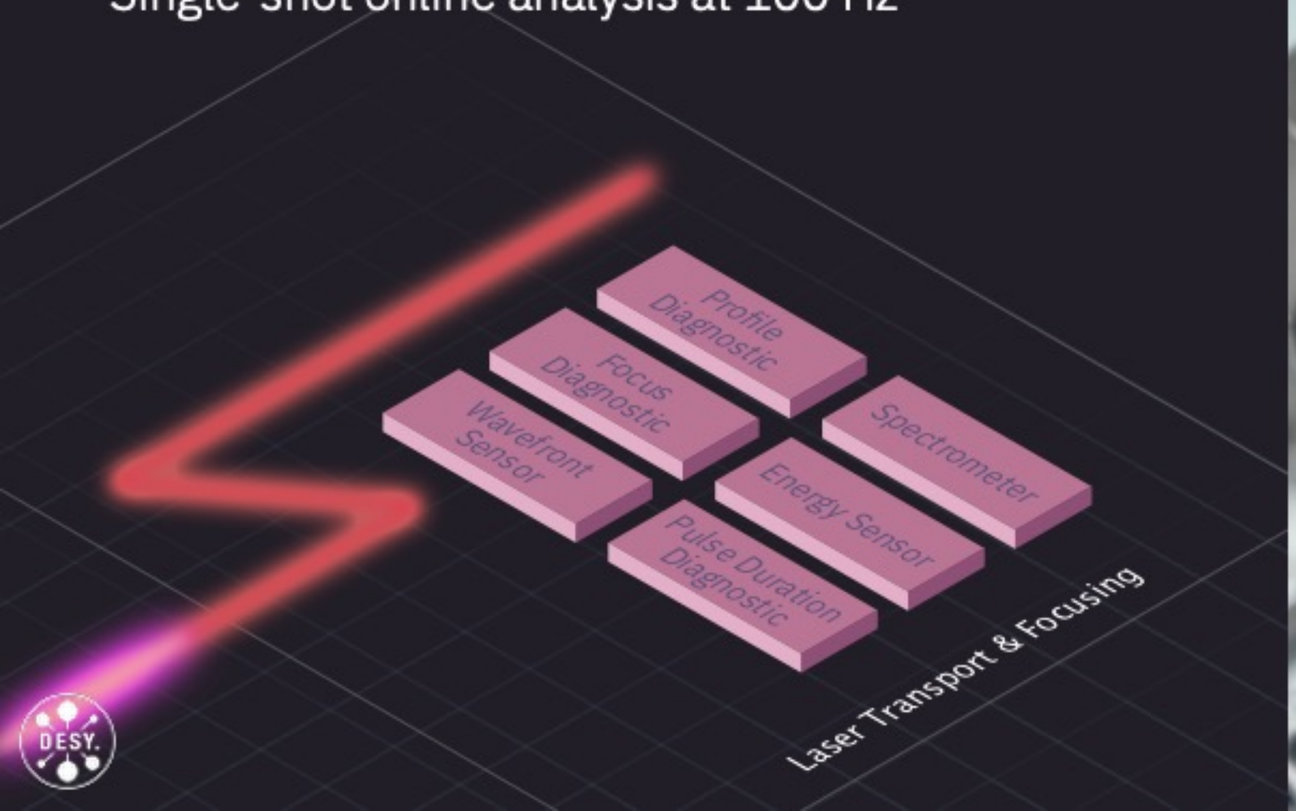
Single shot online characterization

Accurate sampling of high power pulses

Full characterization of each individual pulse

Profile, Wavefront, Energy, Spectrum, Duration

Single-shot online analysis at 100 Hz



Plasma source

High quality beams

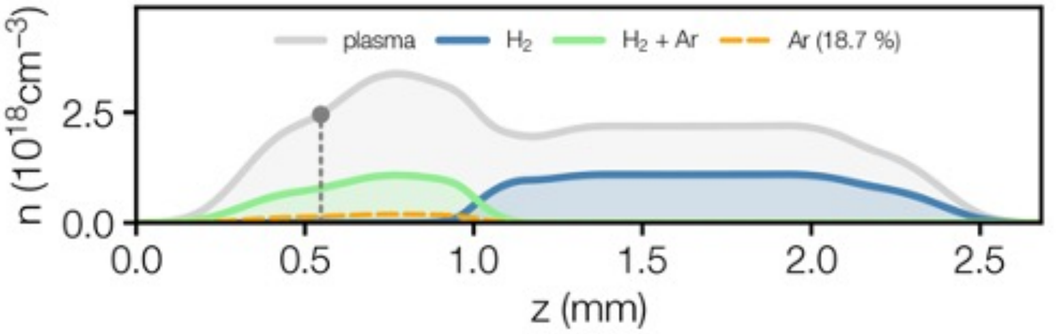
Downramp-assisted localized ionization injection

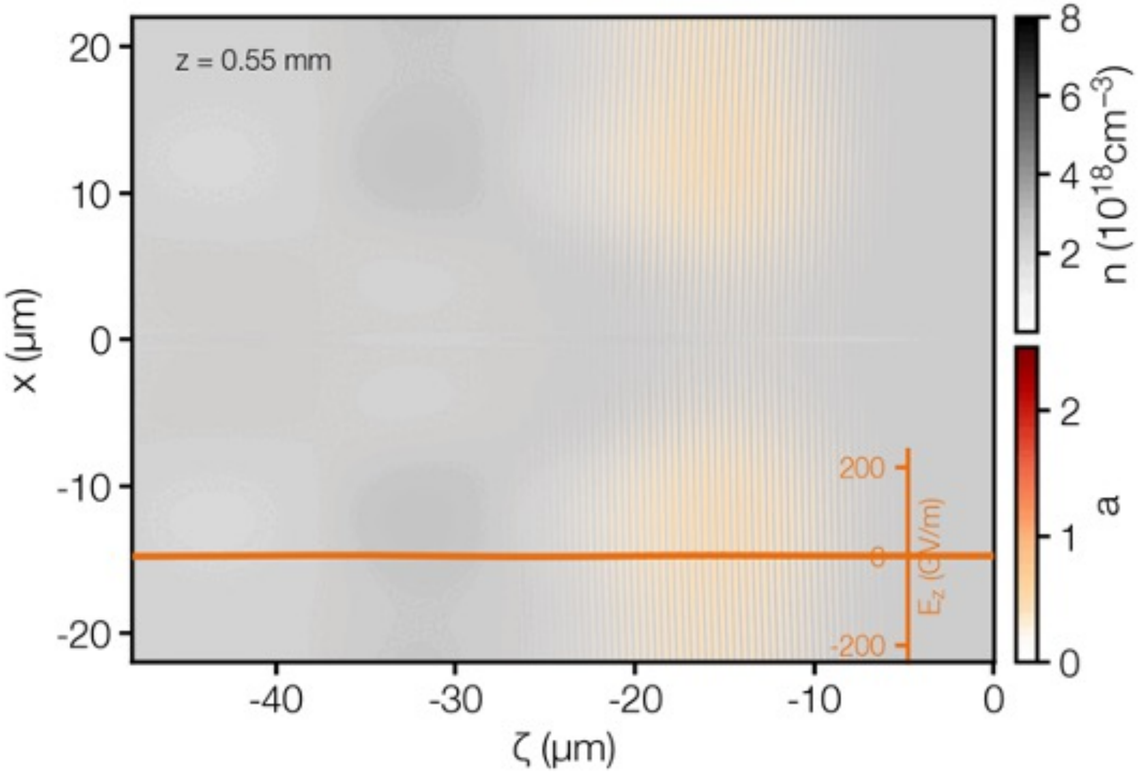
Robust & tunable

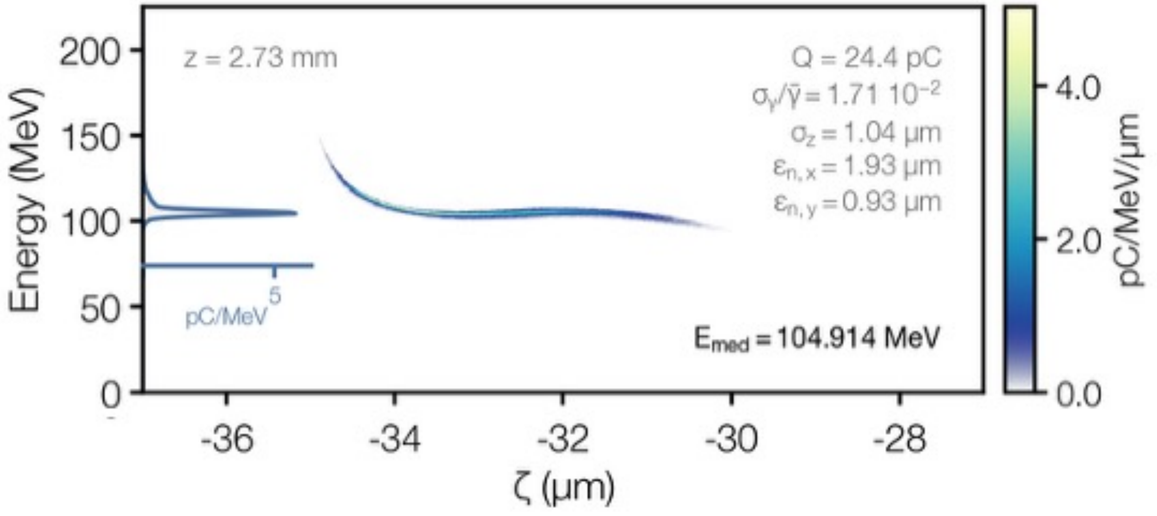
100 – 150 MeV, 10 – 40 pC

Few % energy spreads

Simulations by A. Martinez de la Ossa







Plasma source

Electron generation at 100 Hz

Continuous flow & multi-gas species

50 W of laser focused into sub-mm scale channel

Material selection & degradation management

Active cooling

Electron transport & diagnostics

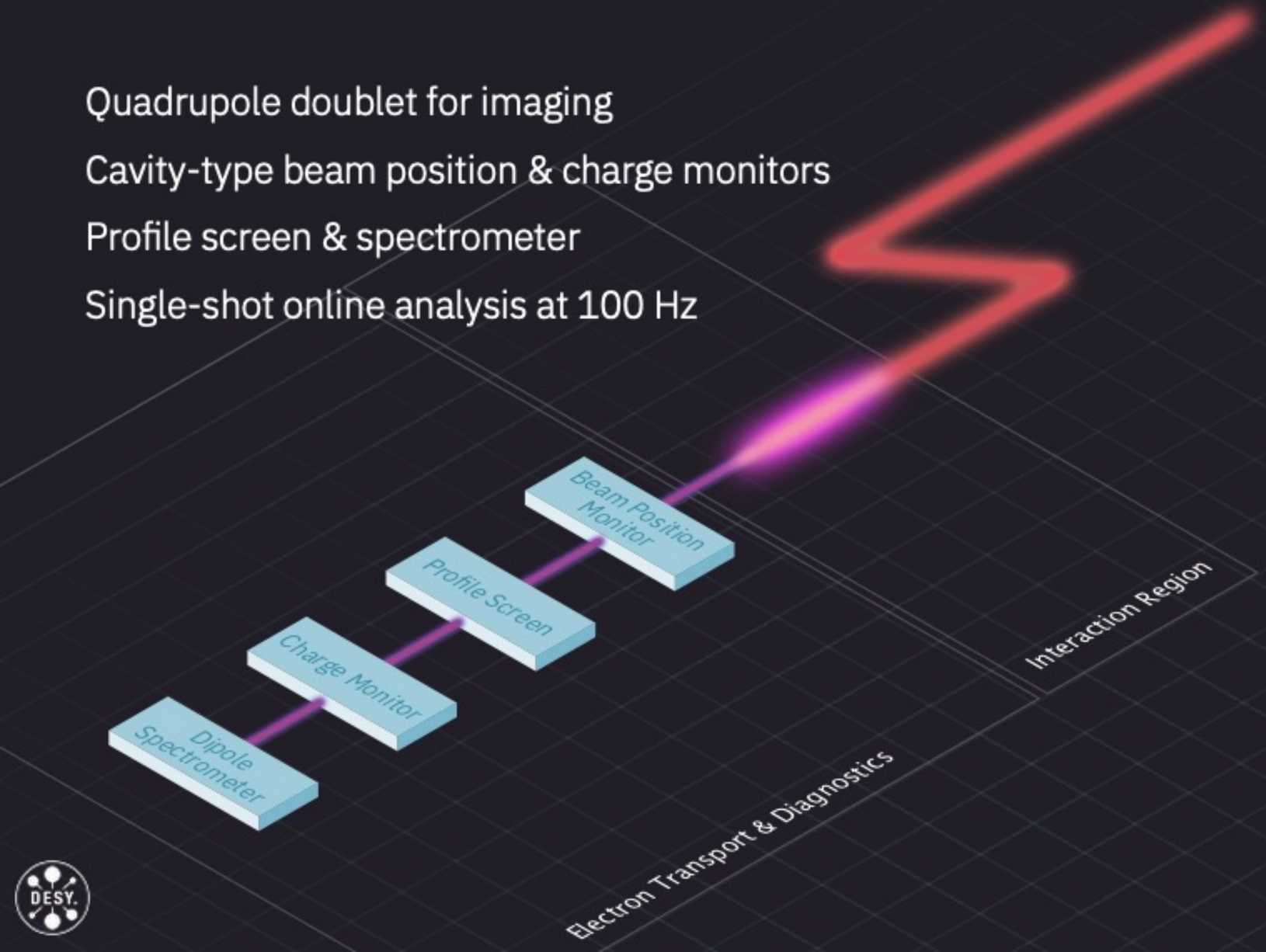
Compact beam line

Quadrupole doublet for imaging

Cavity-type beam position & charge monitors

Profile screen & spectrometer

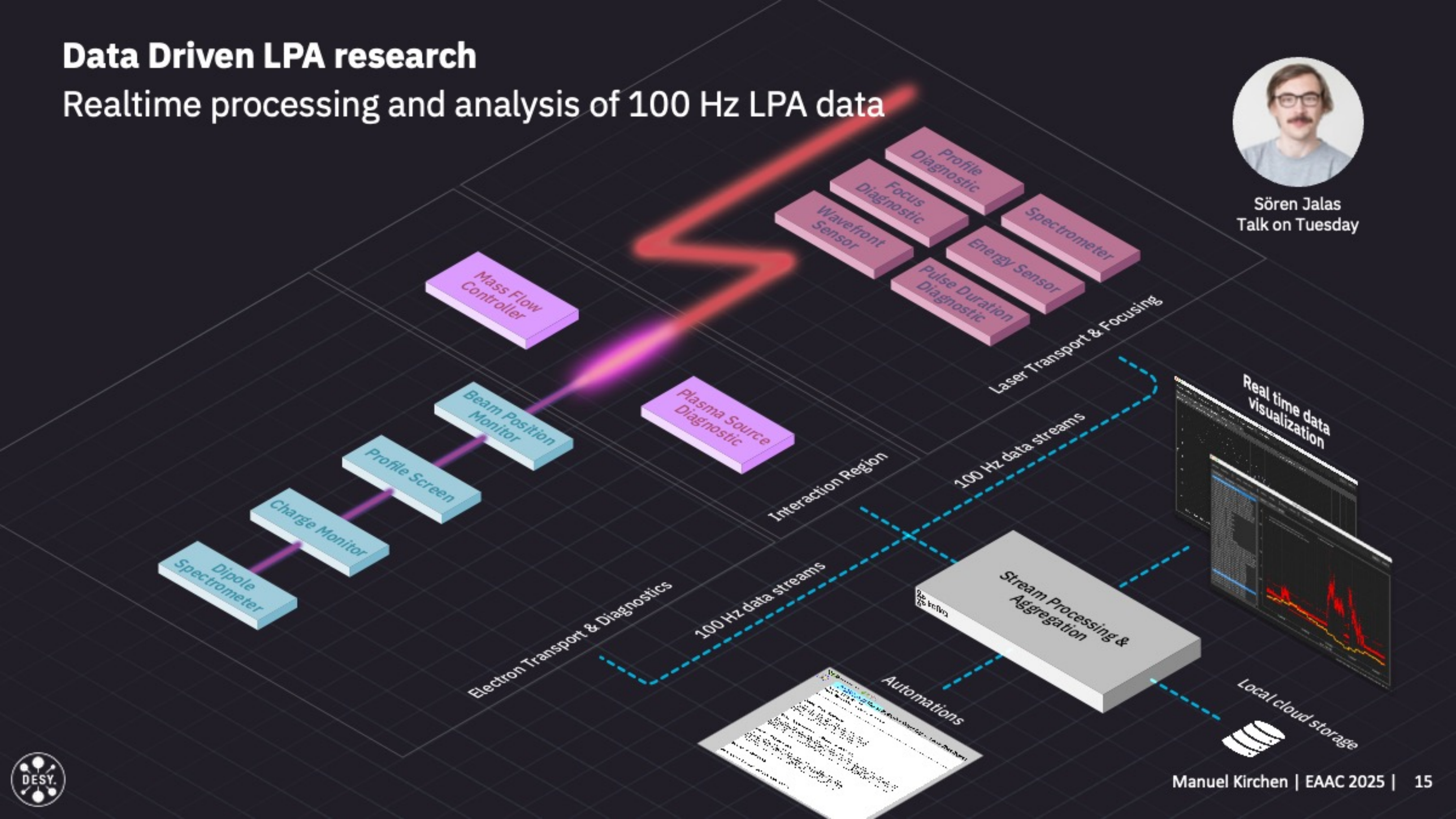
Single-shot online analysis at 100 Hz



Data Driven LPA research

Realtime processing and analysis of 100 Hz LPA data

Sören Jalas
Talk on Tuesday



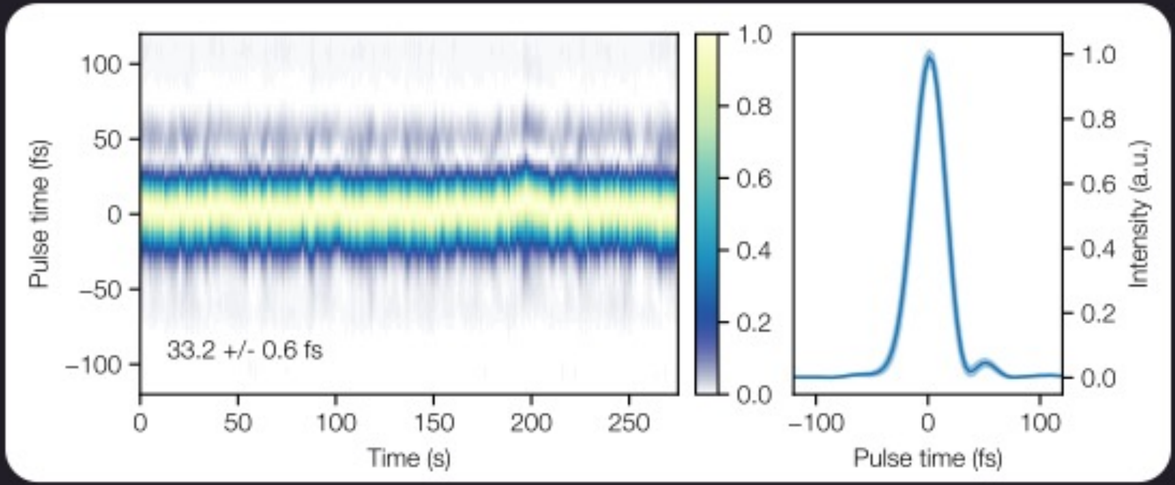
KALDERA Performance

Pulse compressor operation

Compressed to < 32 fs with < 2% stability

Continuous high power operation demonstrated

No heating or beam quality degradation observed



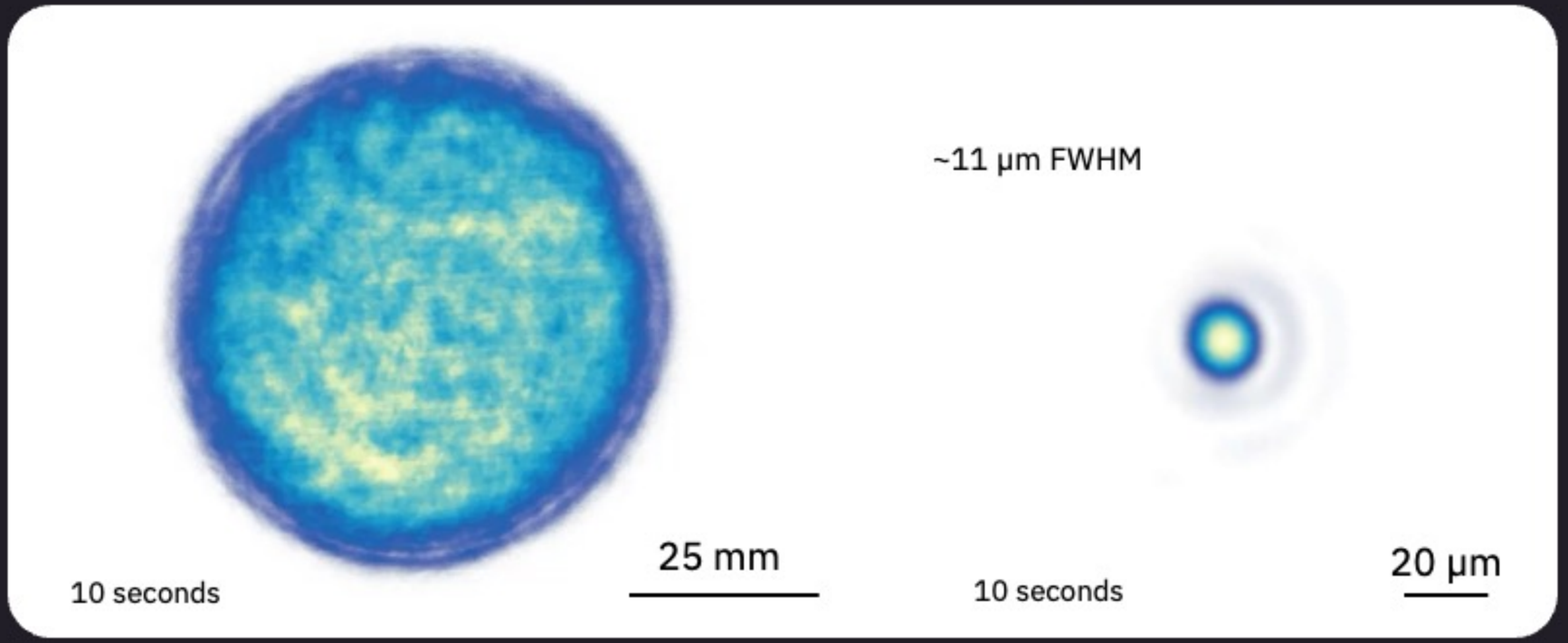
C. Werle

KALDERA Performance

Spatial beam quality & stability

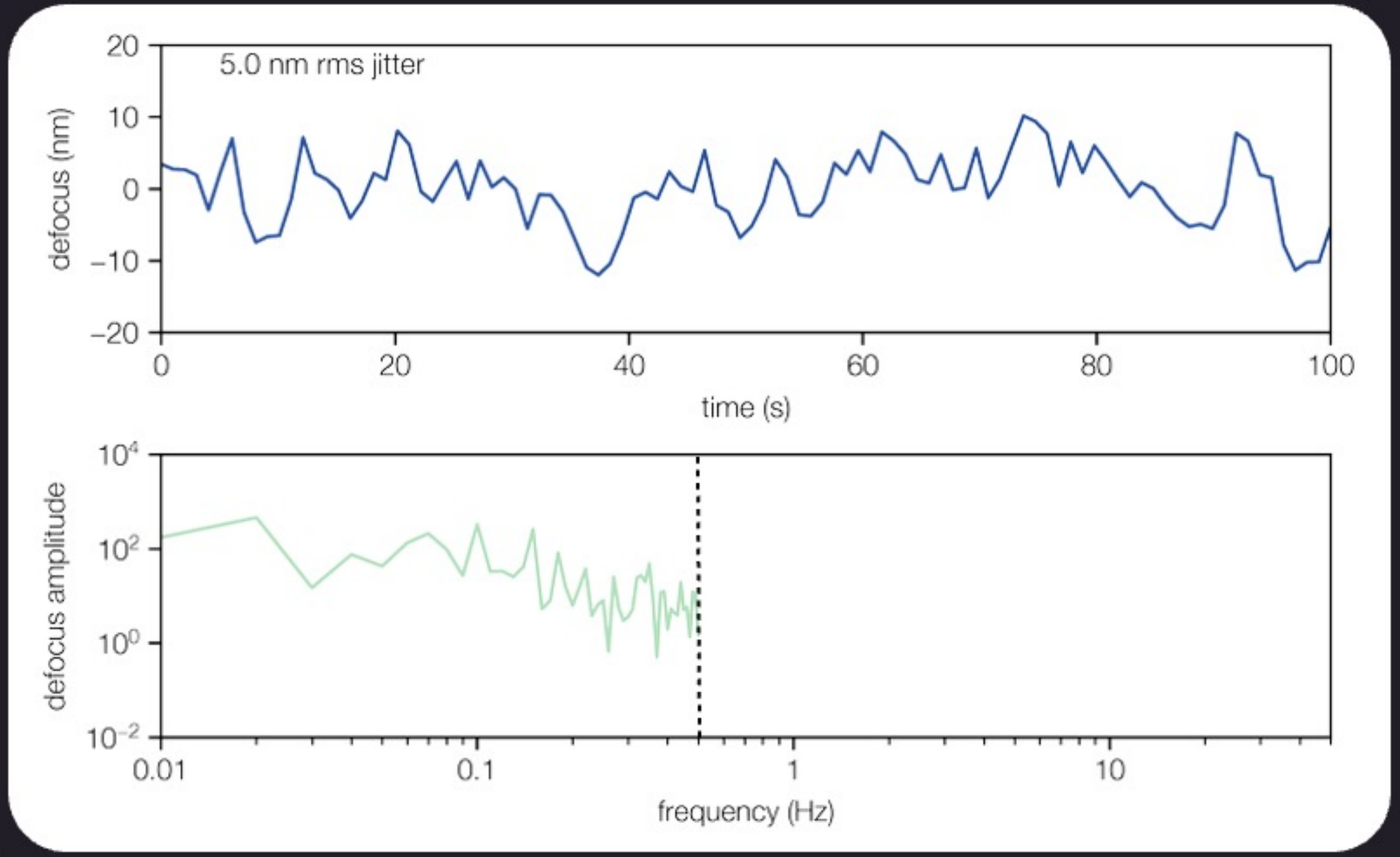
Beam profile at interaction point

Focal spot on target



KALDERA Performance

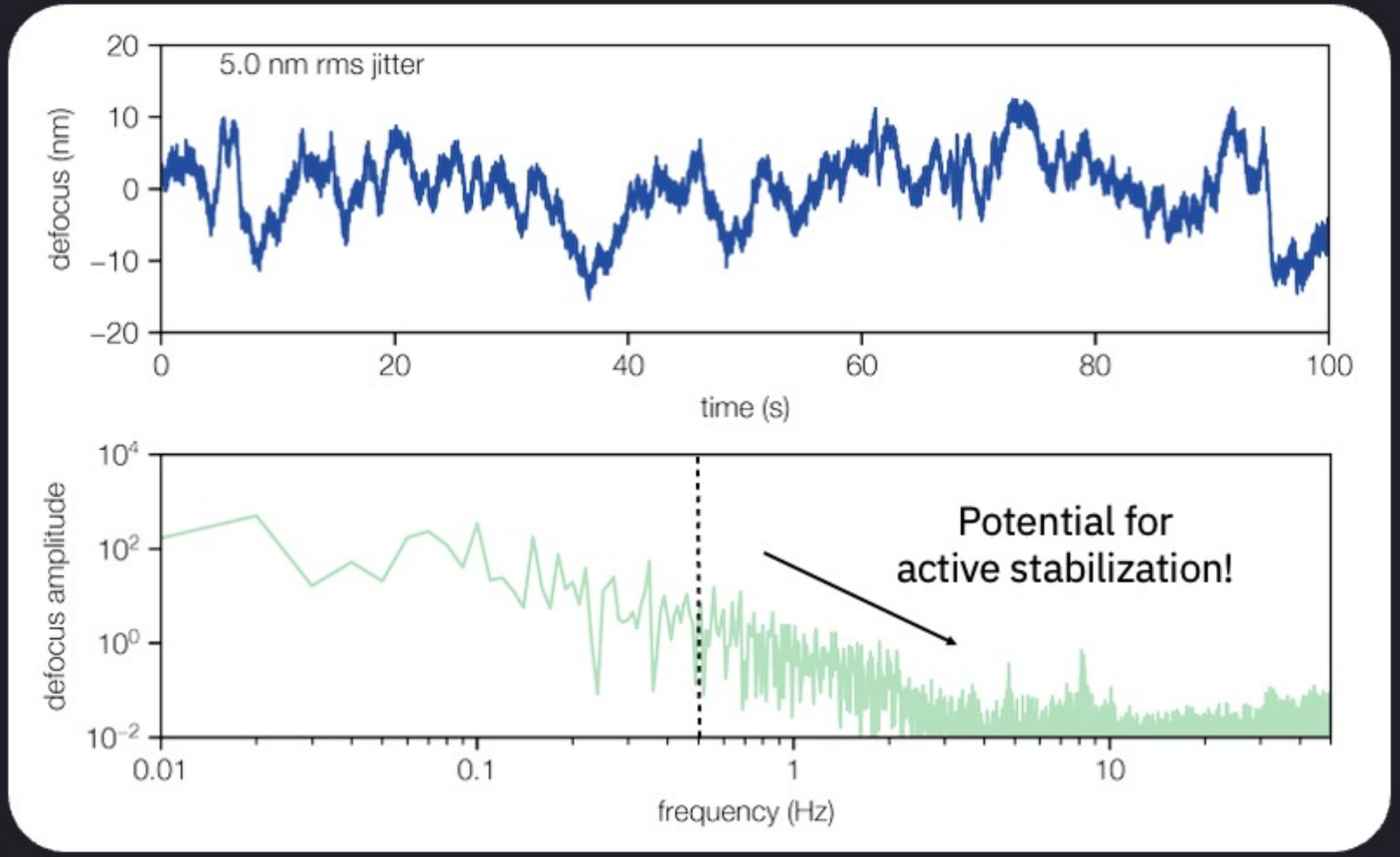
Wavefront stability & jitter bandwidth



1 Hz data

KALDERA Performance

Wavefront stability & jitter bandwidth



100 Hz data

100 Hz electron acceleration

Commissioning & Operation

First Electron beams Early 2025

Reliable beam generation at 100 Hz

~0.3 W electron beam power reached

System optimization ongoing

Beam Time Summary

Beam Start	Beam End	Total Duration
11:33	19:16	7 h 42 min

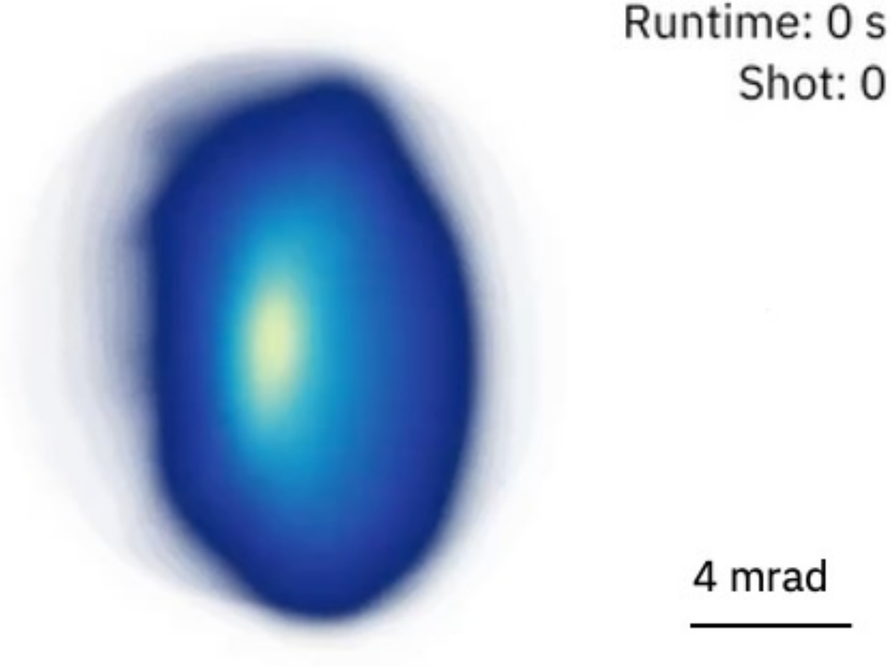
Beam Parameters (Laser > 200 mJ)

Integrated Charge	Average Charge / Pulse	Average Beam Energy
18421 nC	10.66 pC	0–150 MeV

Laser Parameters

Total high power shots	Max. energy	Mean energy
1726640	404 mJ	351 mJ

Unfocused beams with ~20 pC on profile screen

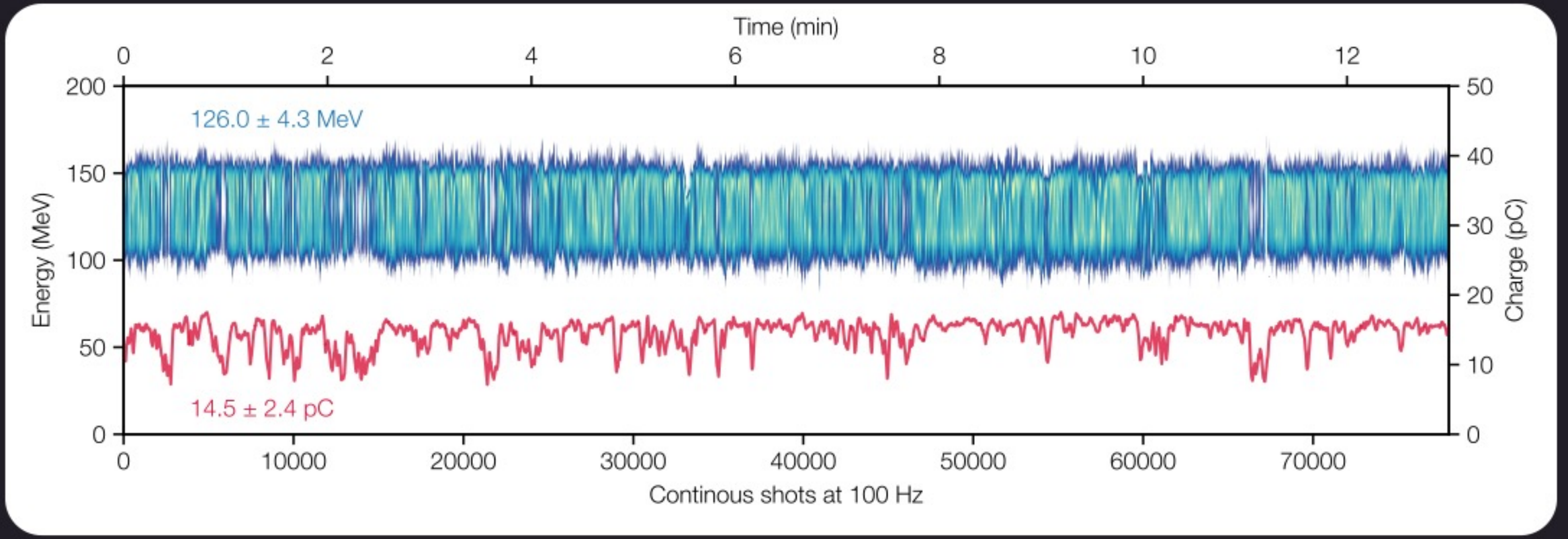


0.8 / 1.9 mrad pointing jitter

2.3 / 3.5 mrad divergence

100 Hz electron acceleration

Unprecedented amount of data



Time to record 100,000 shots

LUX (1 Hz): 24 hours

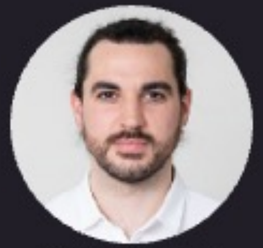
MAGMA (100 Hz): 16 minutes

DESY Plasma Acceleration and Laser Group

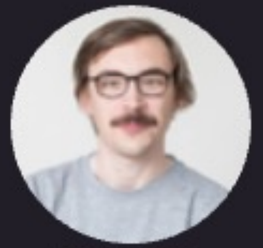
Andreas Maier
Group Leader

Wim Leemans
Division Director

High Average Power LPA team



Manuel Kirchen



Sören Jalas

Philipp Messner

Lars Hübner

Tatiana Nechaeva

Lisa Thrun

Luisa Niggemeier

Jeremy Hörning

Milo Gerhard

Thanks for your attention!