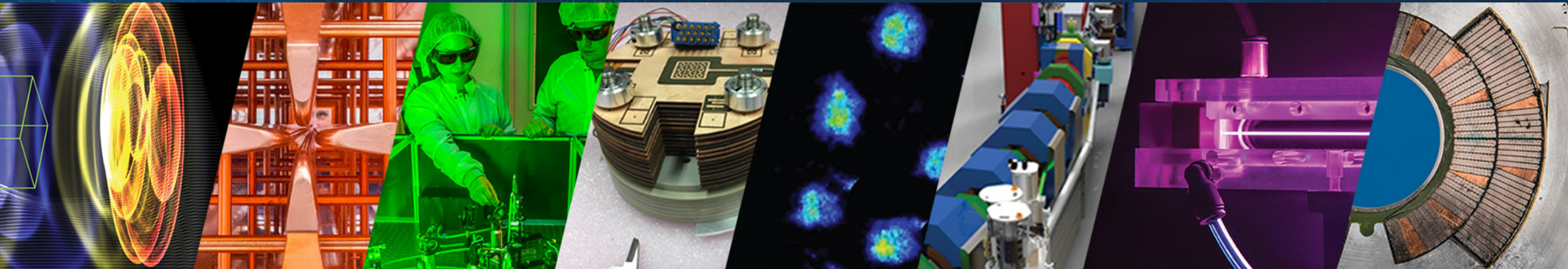


Simon van der Meer Early Career Award in Novel Accelerators

Alex Picksley

Accelerator Technology & Applied Physics Division



7th European Advanced Accelerator Conference – Elba, Italy

September 23rd 2025



ACCELERATOR TECHNOLOGY &
APPLIED PHYSICS DIVISION



U.S. DEPARTMENT OF
ENERGY

Office of
Science

A huge thank you to

- Simon Hooker for the nomination
- Jens Osterhoff, Tony Gonsalves, Karl Krushelnick for reference letters
- Edda Gschwendtner, Ralph Assman, Massimo Ferrario and the prize selection committee for trusting me with this award
- Everyone that made this conference so wonderful

- The previous winners:

SIMON VAN DER MEER EARLY CAREER AWARD IN NOVEL ACCELERATORS WAVE OF FAME



2019: Spencer Gessner
For his leading contributions to the AWAKE experiment as the Run Coordinator and for driving the overall physics programme. He is also a world-leading expert on accelerating positrons in plasma wakefields.

2021 (2022): Carl Lindström
For his numerous outstanding experimental and theoretical contributions to the field of beam-driven plasma accelerator, including the demonstration of beam-quality preservation and efficient acceleration, study of advanced beam transport concepts and the invention of self-stabilizing multi-stage acceleration.

2023 Marlene Turner
For her pioneering work on proton driven wakefield beam self modulation and acceleration of electrons, stability of laser driven wakefield acceleration and concepts for future collider.

Simon van der Meer

- A European accelerator physicist, born November 1925 in the Hague, Netherlands
- Joined CERN in 1956 after studying Engineering in TU Delft, Netherlands
- Developed the magnetic horn a widely used tool in neutrino physics even today
- Invented stochastic cooling — enabling accumulation of intense beams of antiprotons
- Shared Nobel Prize in Physics in 1984 with Carlo Rubbia - *“for their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction”*
- Described by many as a modest man



Simon van der Meer – An early adopter of plasma based concepts !

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

SVDM/afm

CERN/PS/85-65 (AA)
CLIC Note No. 3

IMPROVING THE POWER EFFICIENCY
OF THE
PLASMA WAKEFIELD ACCELERATOR

S. van der Meer

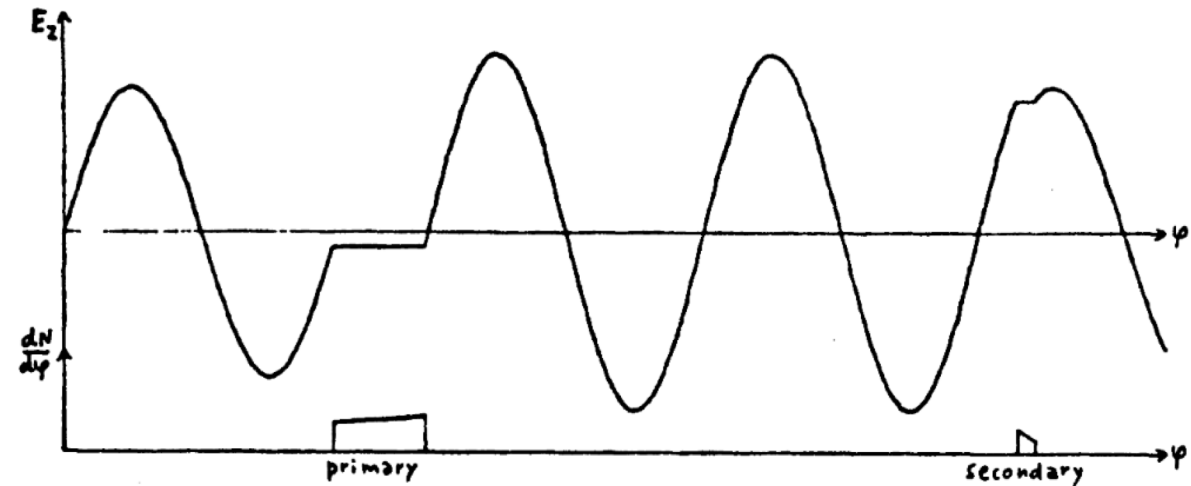


Fig. 3 - Continuous operation. Intervals between primary and secondary bunches may be changed by multiples of 2π .



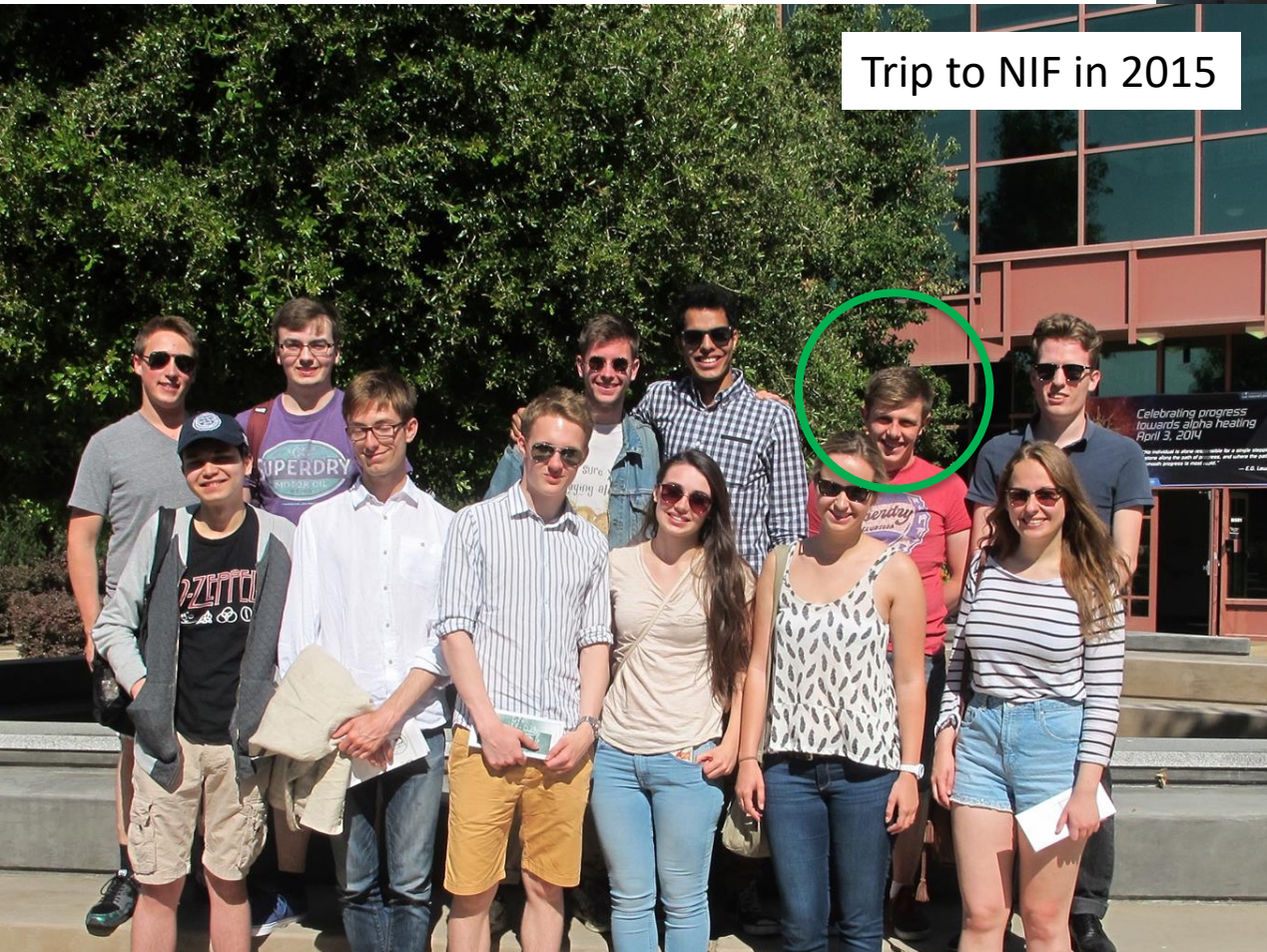
Plasma Channels for 10-GeV-class Laser Plasma Accelerators

Looking for a way to combine a newfound interest in high energy physics

Trip to LHCb at CERN in 2014



Trip to NIF in 2015



... and high power laser-plasma experiments

Oxford LPAG group over the years...

2018



2019

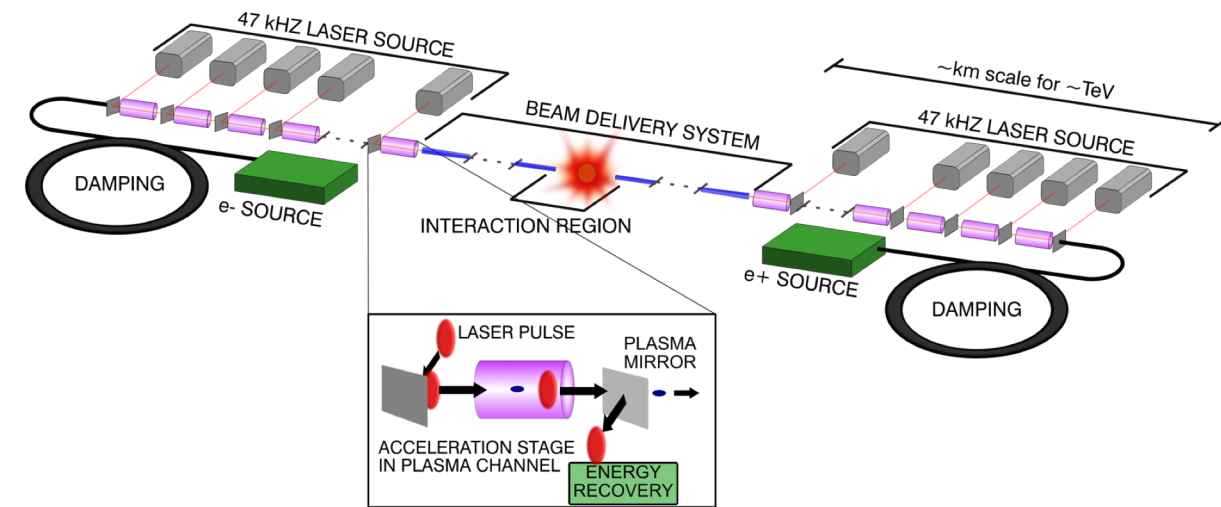


2020



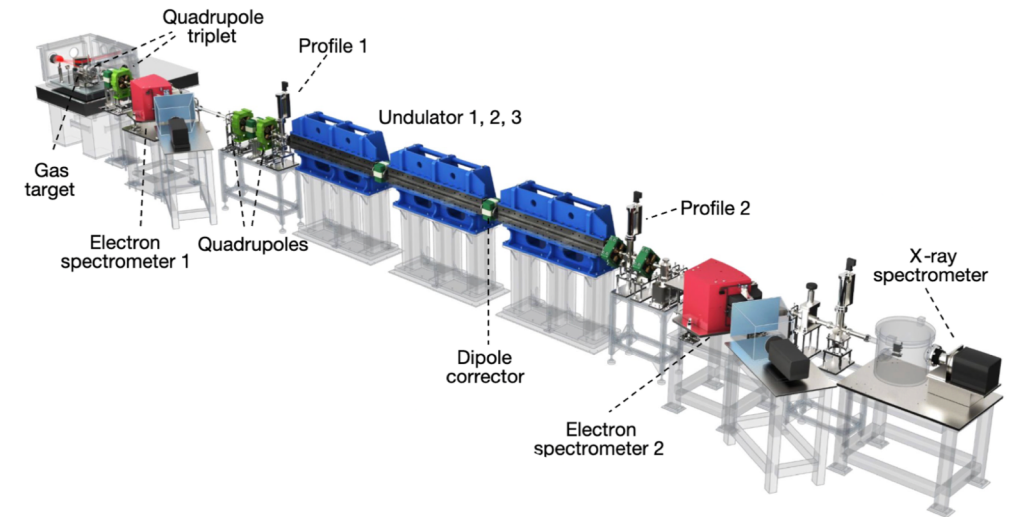
Demanding challenges on technology for applications of laser-plasma accelerators

Compact linear colliders



C. Schroeder, et al., *J. Instrum.* 18, T06001 (2023)
C. B. Schroeder et. al. *PRSTAB* 13, 101301 (2010)
W. Leemans, and E. Esarey. *Physics today* 62.3 (2009)

Compact X-FELs



Wang, W, et al. *Nature* 595.7868 (2021)
Barber, S. K., et al. *Physical Review Letters* 135.5 (2025)
M. Labat et al., *Nat. Photonics* 17, 150 (2023).
R. Pompili et al., *Nature (London)* 605, 659 (2022)

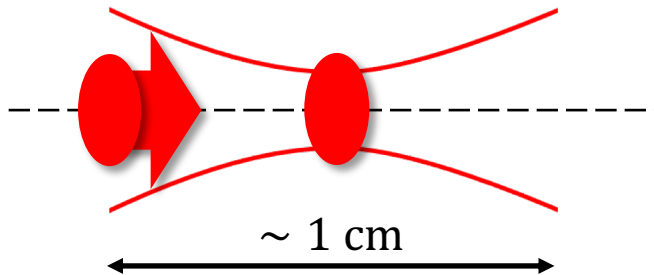
One of the main challenges is diffraction mitigation

Scaling laws

$$\text{Energy gain} \propto \frac{1}{n_e}$$

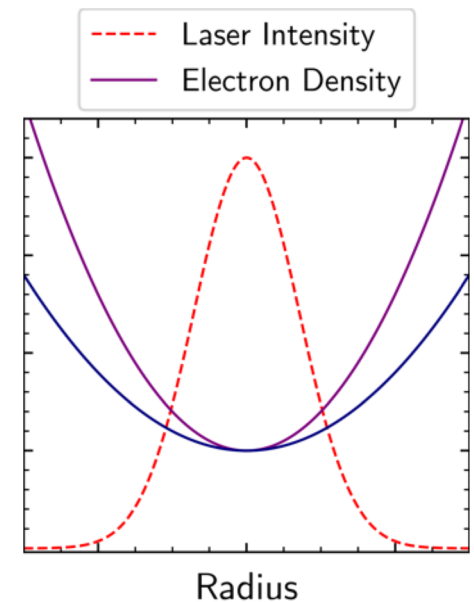
$$\text{Accelerator length} \propto \frac{1}{n_e^{3/2}}$$

Vacuum diffraction over Rayleigh length



- Scaling laws for LPAs indicate that 10-GeV-class stages
 - Several centimeters long
 - Density $n_{e0} \sim 10^{17} \text{ cm}^{-3}$
- Guiding either:
 - Self-focusing through relativistic and ponderomotive effects
 - Preformed plasma waveguide

Plasma Channel



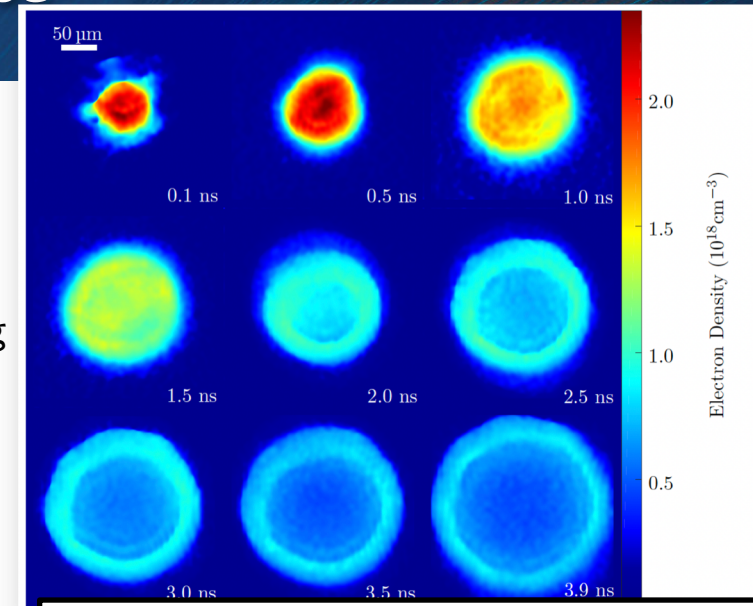
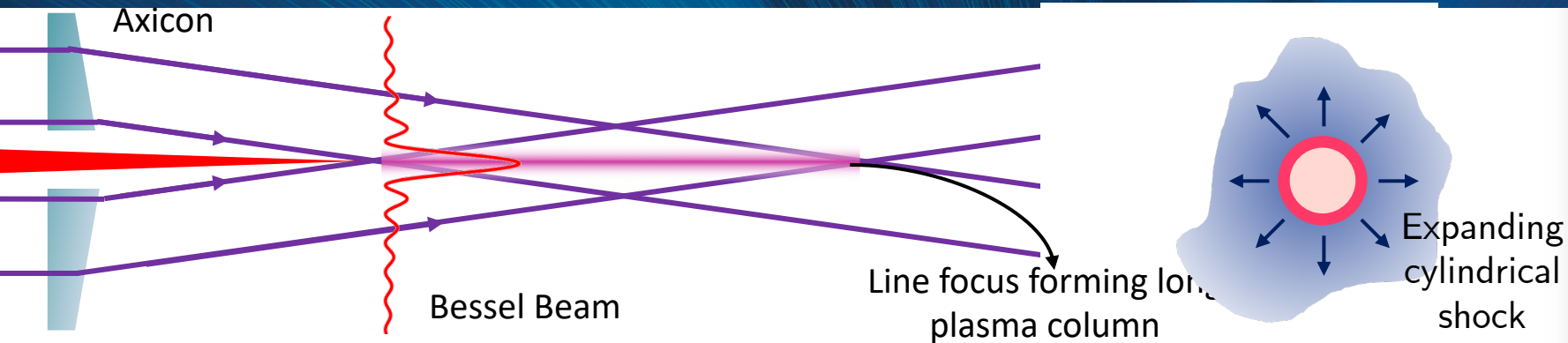
BELLA 10 GeV Stage

$$L_{\text{acc}} \sim 40 - 60 \text{ cm}$$
$$n_e(0) \sim 1 - 2 \times 10^{17} \text{ cm}^{-3}$$

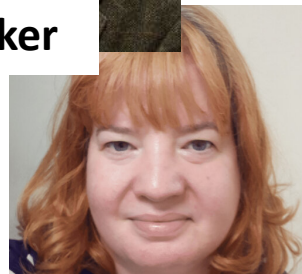
EuPRAXIA 5 GeV Stage

$$L_{\text{acc}} \sim 10 \text{ cm}$$
$$n_e(0) \sim 2 \times 10^{17} \text{ cm}^{-3}$$

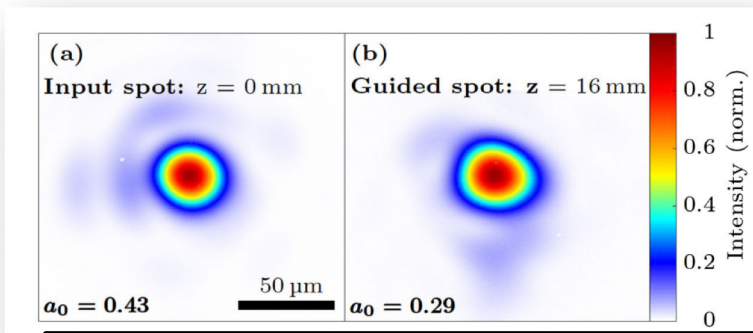
HOFI Plasma Channels offered promise



Proposed low-density channels:
Shalloo, R. J., et al., (2018), *PRE*, 97(5)



George Hine
Howard Milchberg
A. von Boetticher
Chris Thornton
Roman Walczak



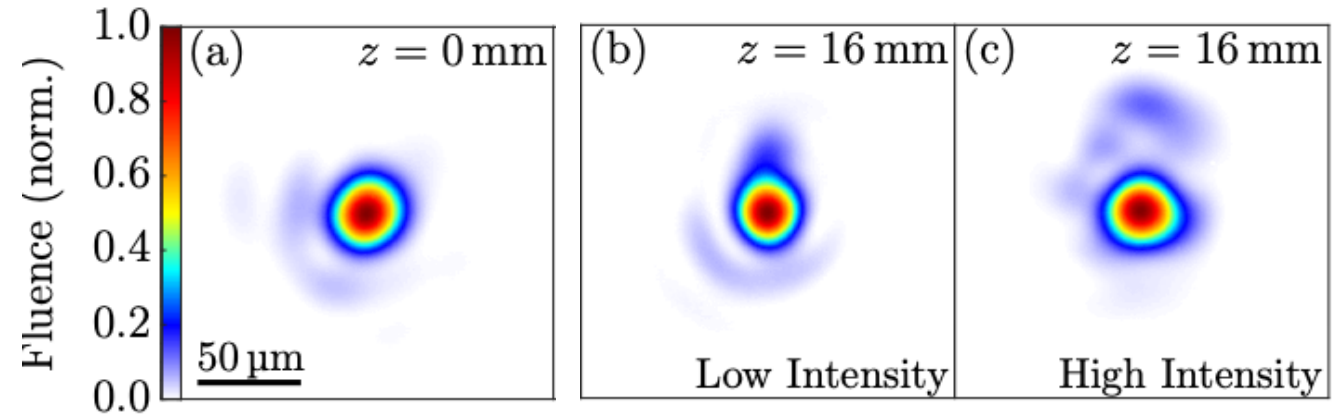
High-power guiding in low-density channels
Shalloo, R. J., et al. (2019), *PRAB*, 22(4)

Hydro plasma channels at $n_0 > 1 \times 10^{18}\text{ cm}^{-3}$
Durfee & Milchberg., *PRL*, 71(15) (1993).
Volfbeyn, P., et al. *PoP* 6.5 (1999).

Low density Plasma Channels
Hooker, S. M. *AAC Workshop* (2016)
Shalloo, R. J., et al., (2018), *PRE*, 97(5)

Next challenge – extending the length

- Noticed that increasing the intensity of the guided mode increased the relative transmission
- Found it to be linked to ionization of the neutral collar surrounding the channel



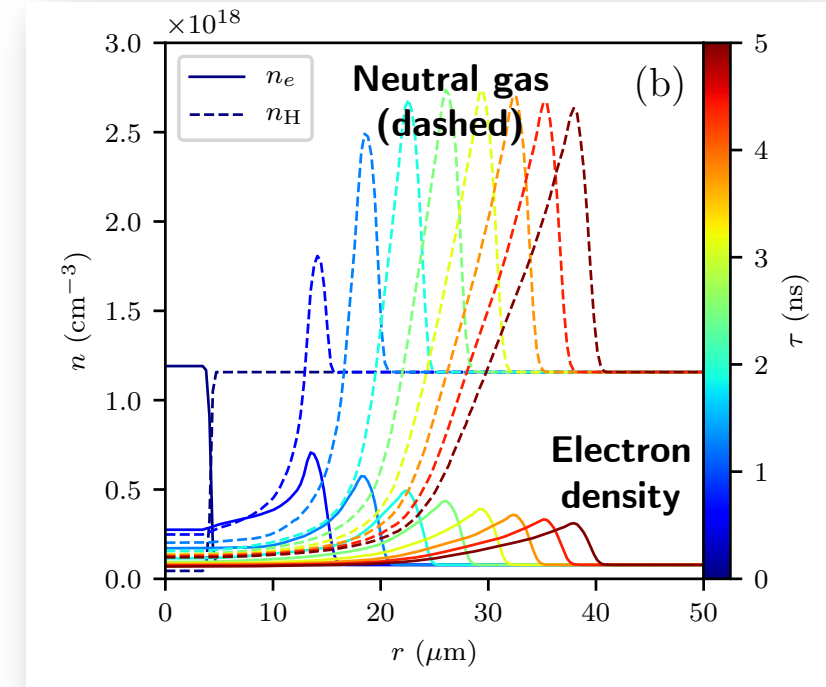
Rob Shalloo



Aaron Alejo



Simon
Hooker



Overcome leakage by ionizing neutrals:
Morozov, A et al. (2018). *PoP*, 25(5)
Shalloo, R. J. *Thesis* 2018

Miao, B. et al. (2020) *PRL*
Picksley, A., et al. (2020). *PRE*, 102(5)
Feder, L., et al. (2020). *PRR*, 2(4)
Picksley, A. *Thesis* 2021

Lockdown over - Back to RAL in 2021 – Oxford campaign on Astra-Gemini TA3 Laser



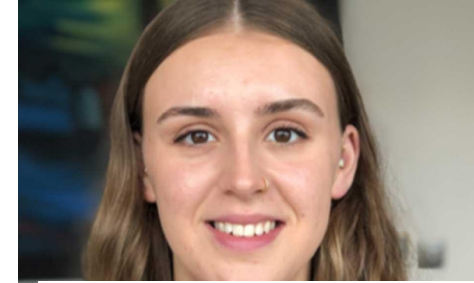
**Simon
Hooker**



Aimee Ross



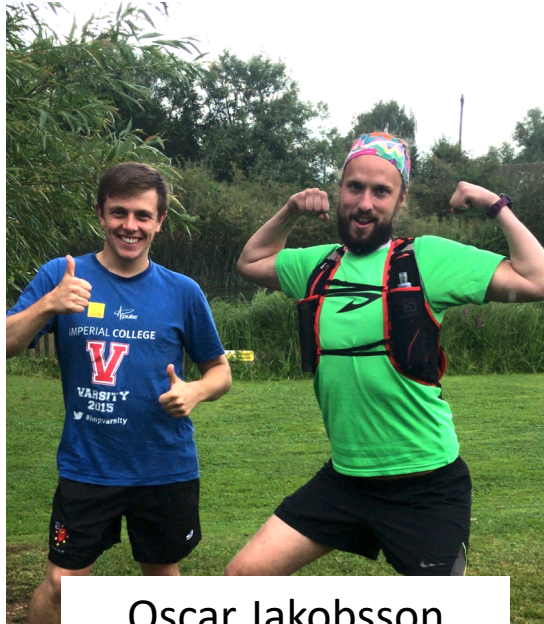
James Chappell



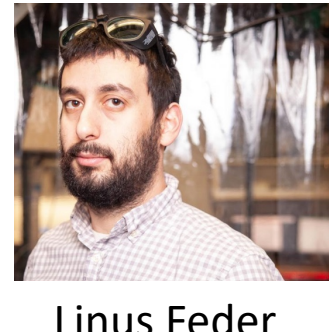
Emily Archer



Roman Walczak



Oscar Jakobsson

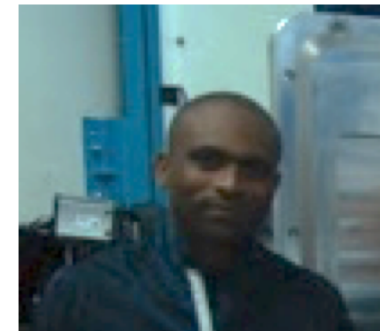


Linus Feder



James Cowley

**Wei-Ting Wang
David Emerson
Xiojun Gu**



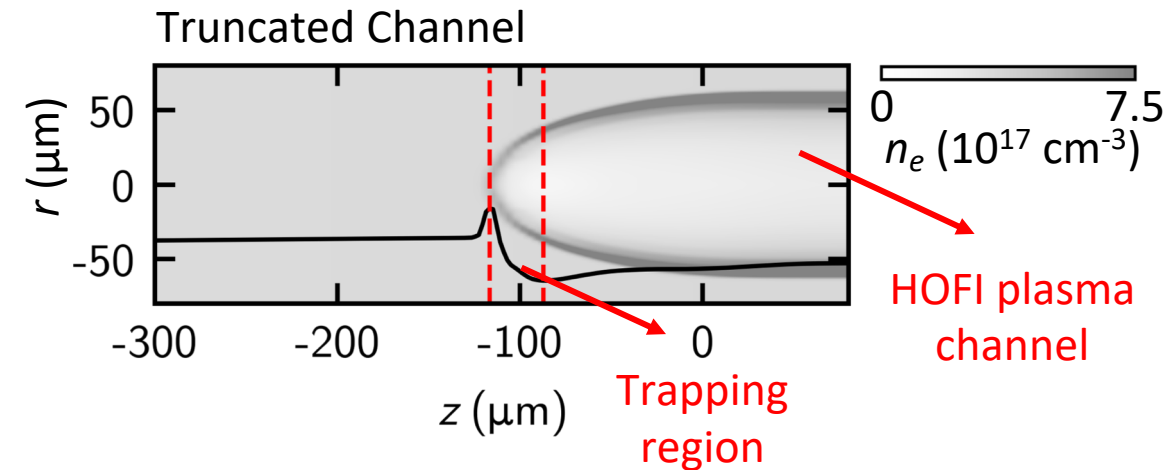
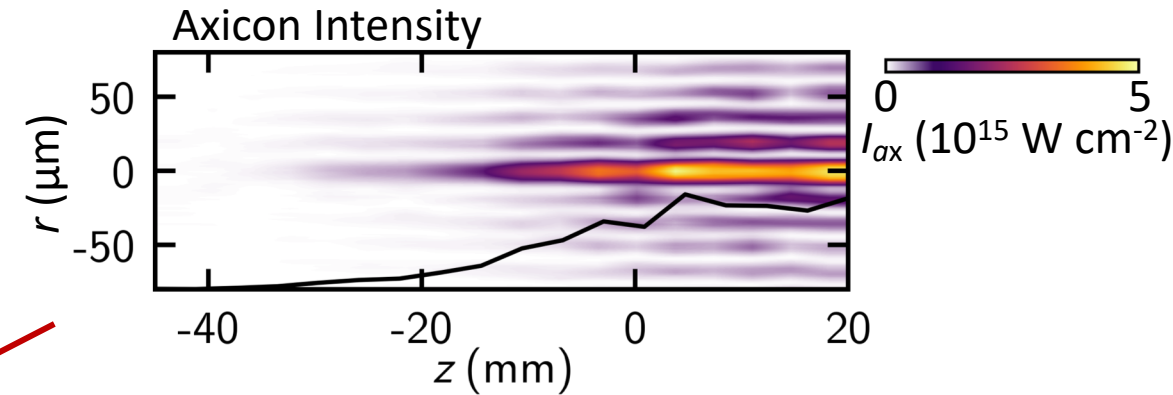
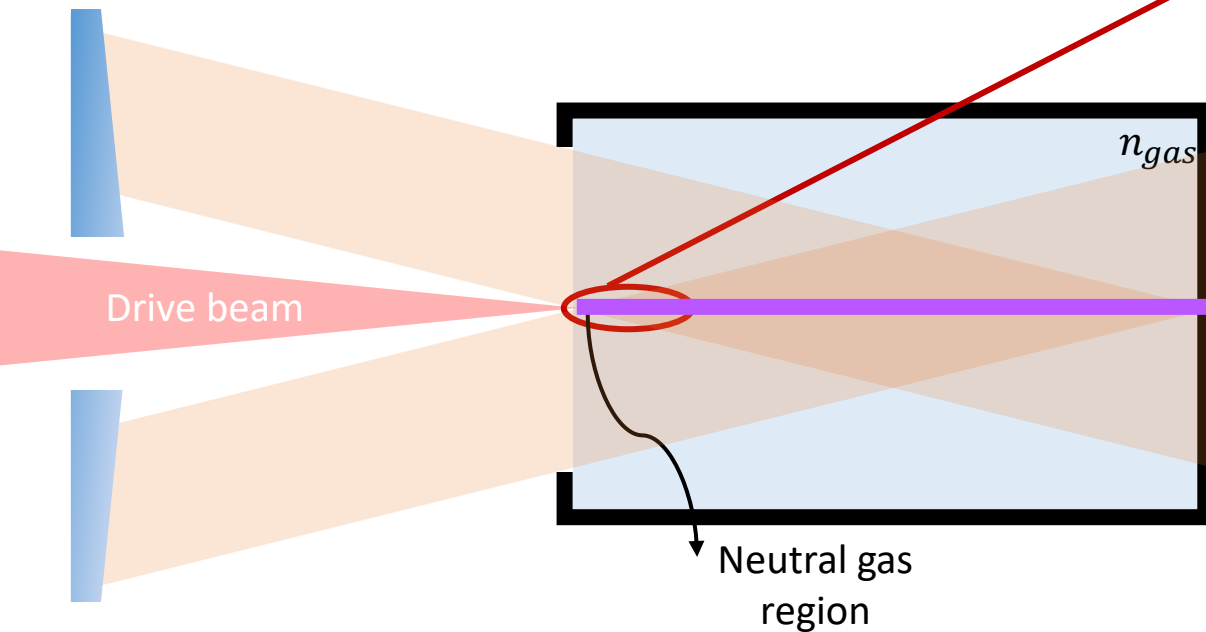
Nicolas Bourgeois

**Rajeev Pattathil
Dan Symes
Steve Hawkes**

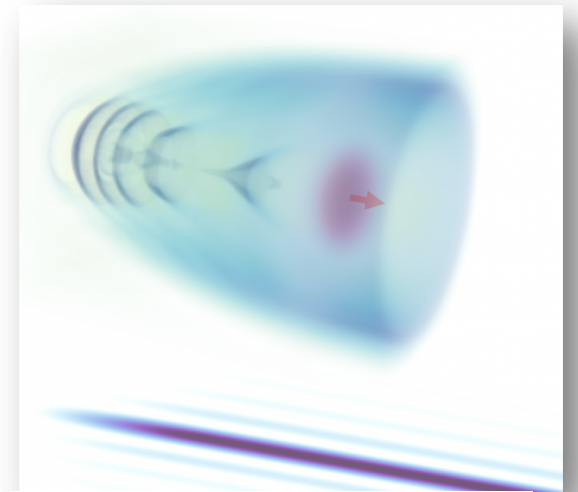
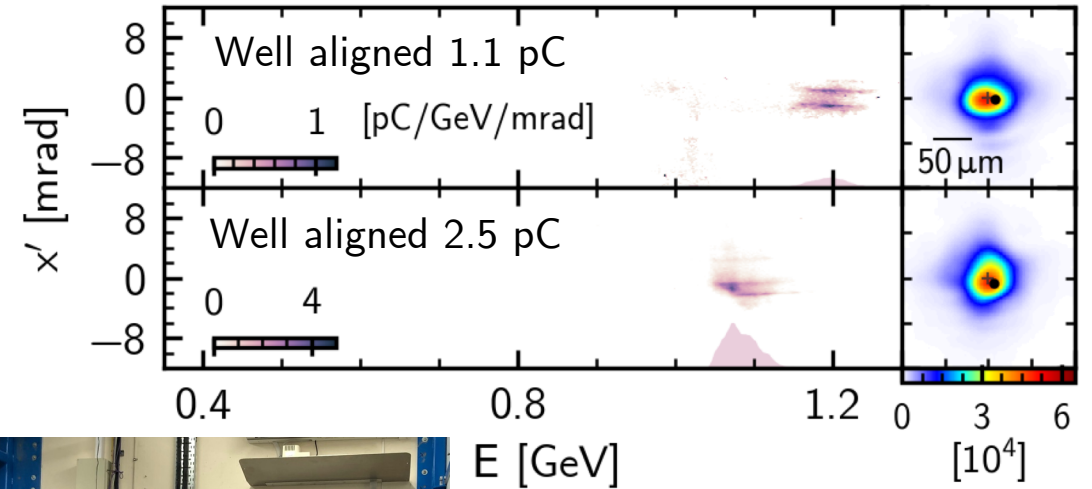
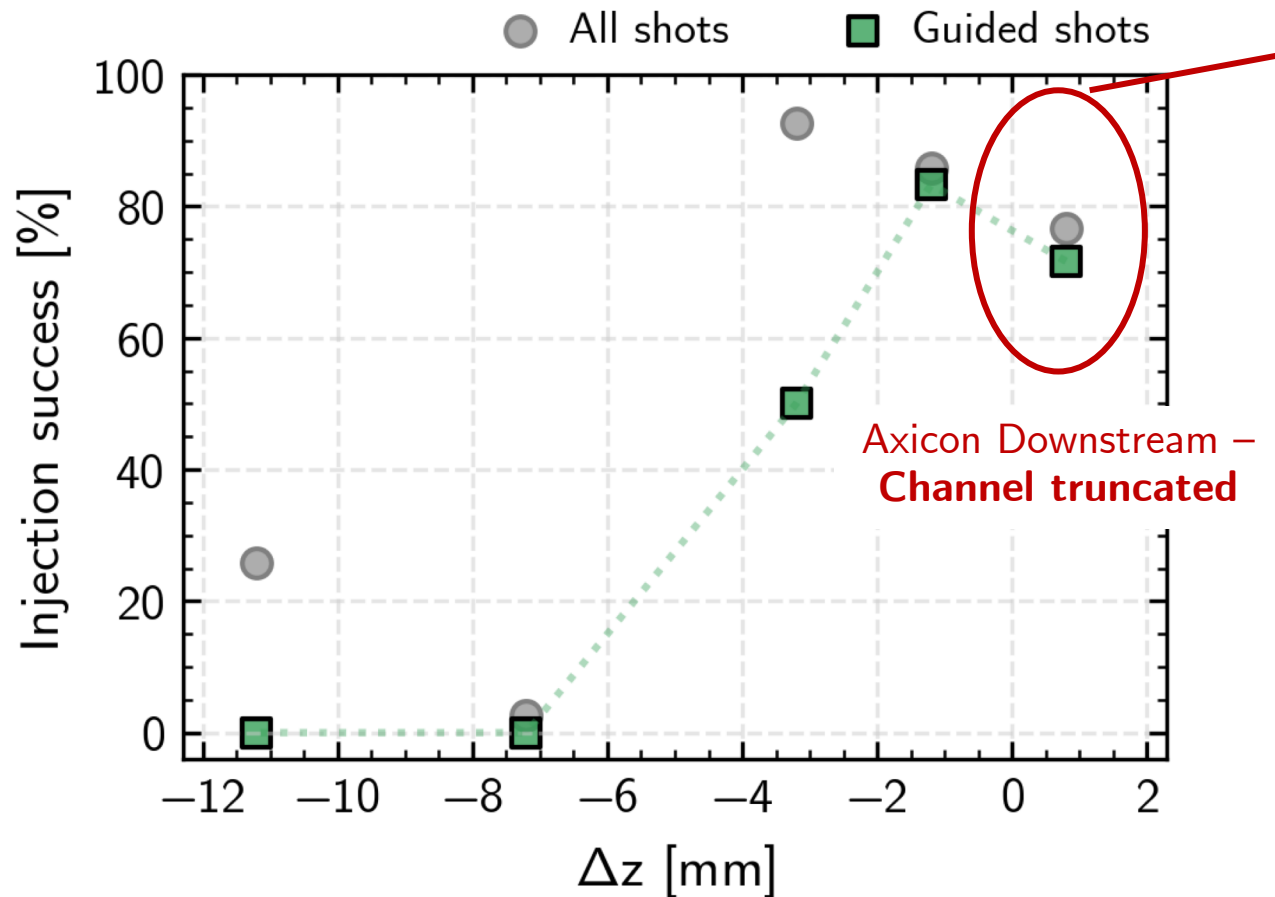


What else can we do with optically formed plasma channels?

- **Sculpting** (truncation) of the plasma channel by delaying the start of the axicon focus promotes injection
- Leave short zone of neutral gas between cell entrance and start of channel
- Naturally forms a **density down-ramp**



2021 - Localized injection demonstrated !

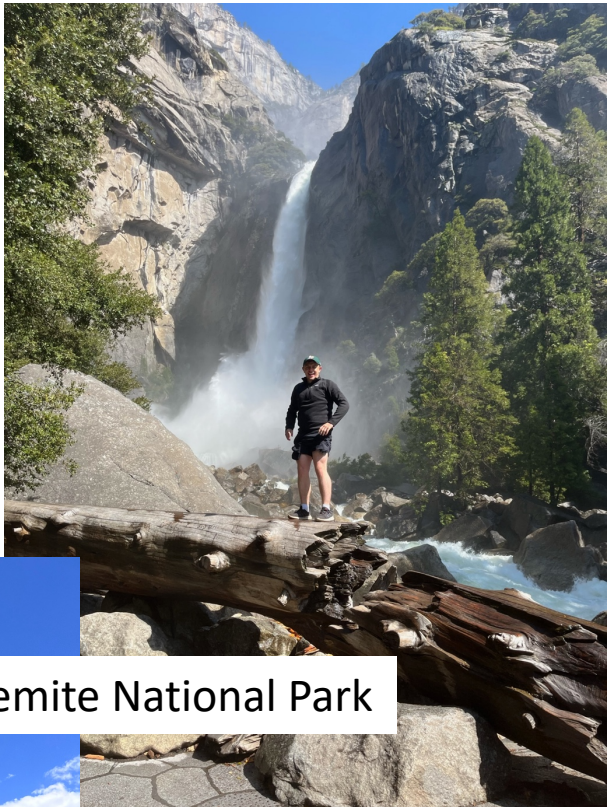


Picture credit Dr. James Chappell



HOFI Plasma Channels at ***BELLA***

November 2021 – First day at Berkeley Lab (One day after the localized injection result!)



Yosemite National Park



San Francisco



BELLA Center 2025



Fantastic Team of Scientists, Engineers, Support Staff

Mechanical / Electrical



Zachary
Eisentraut

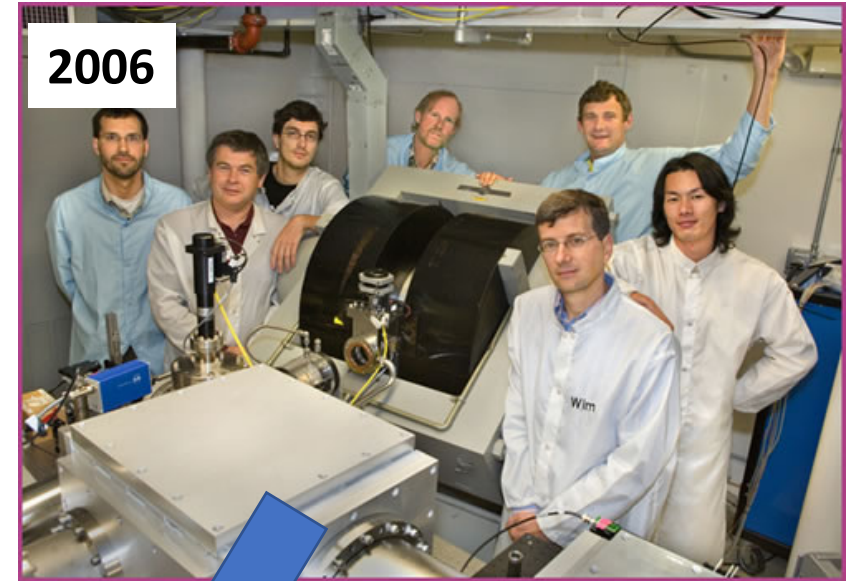


Mark
Kirkpatrick



Federico
Mazzini

Derrick McGrew
Thorsten Stezelberger
Nathan Ybarrolaza
Paul Centeno



2006

Scientific



Mackinley
Kath



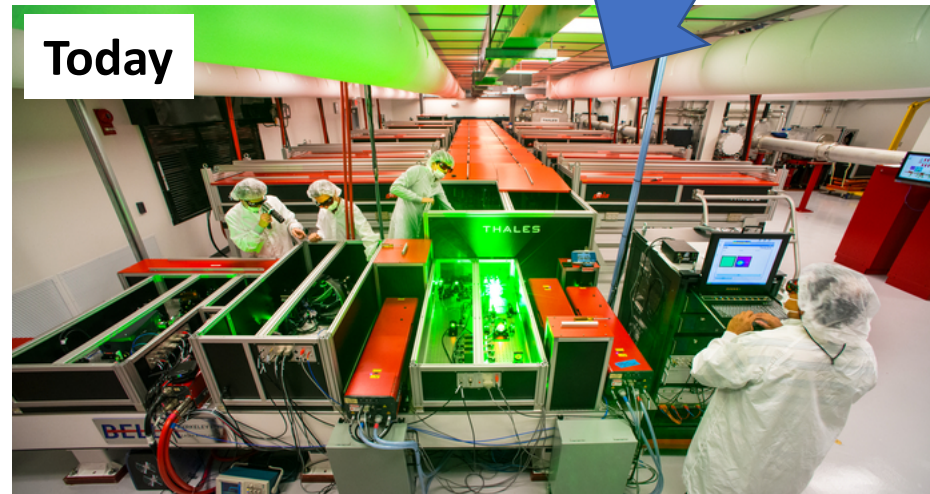
Teo Maldonado



Chetany Jain

Arturo Magana

Joe Riley

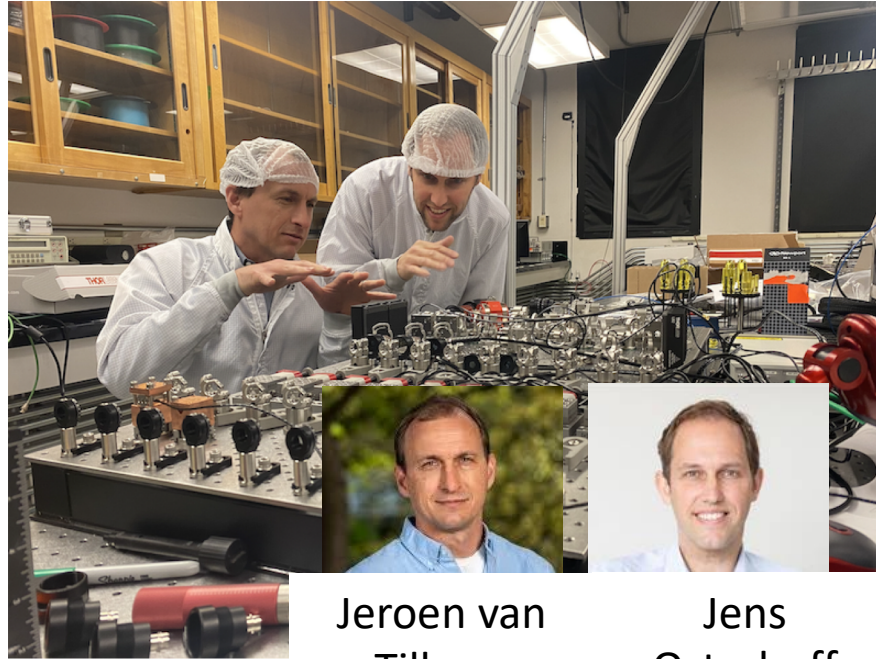


Today

ATAP and BELLA Leadership



**Tony
Gonsalves**



**Jeroen van
Tilborg**

**Jens
Osterhoff**



**Cameron
Geddes**



Jean Luc Vay



Asmita Patel



**Kei
Nakamura**



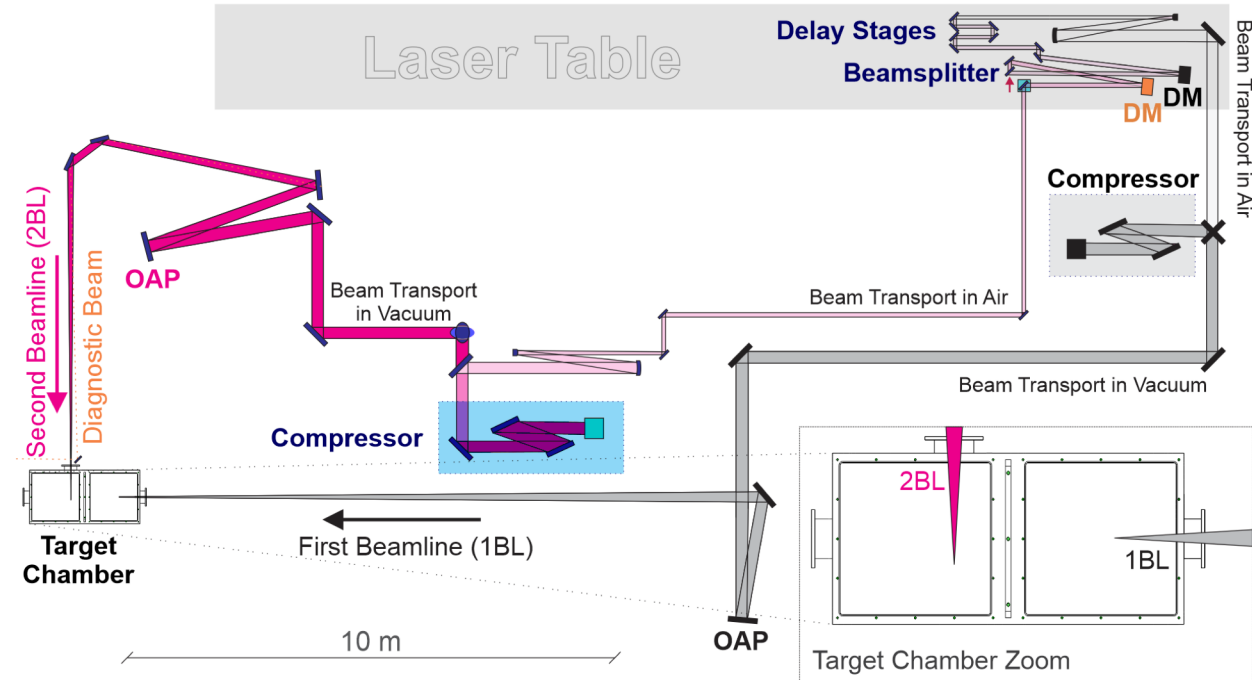
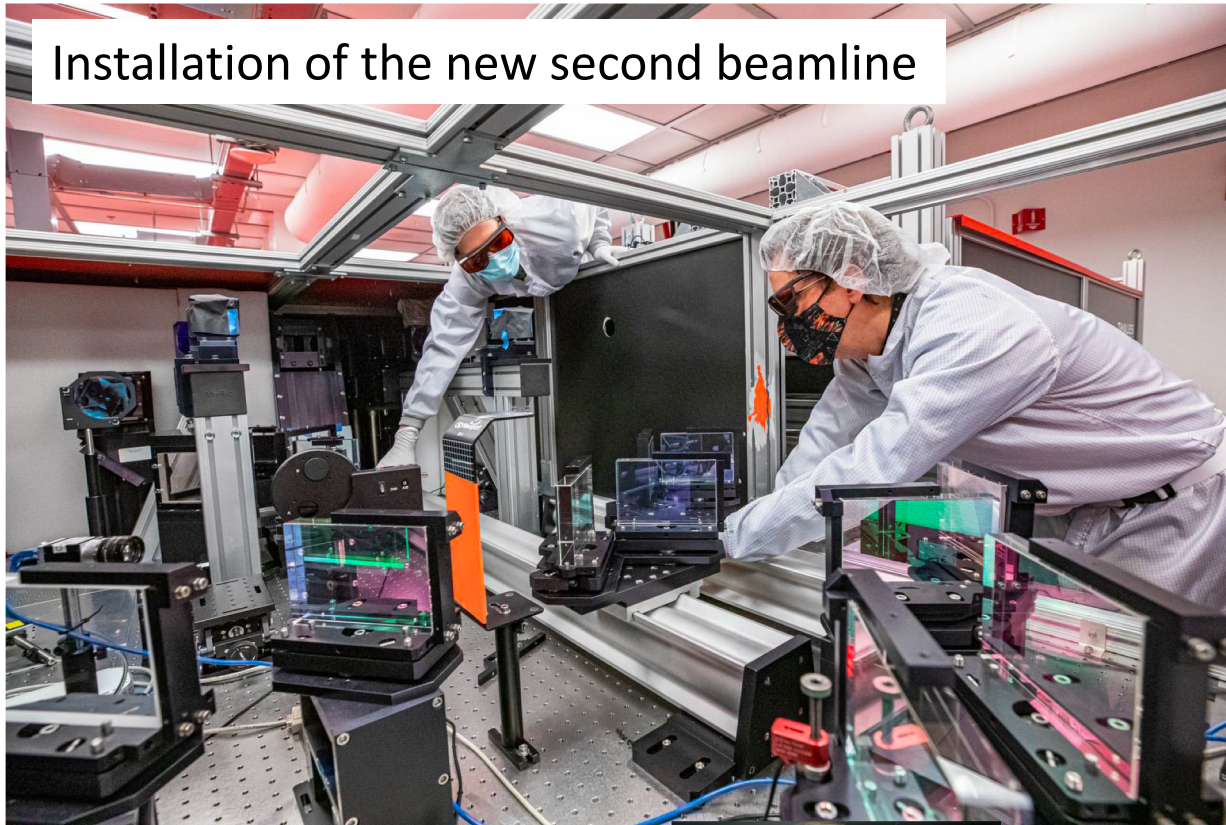
**Carl
Schroeder**



Eric Esarey

First things first...Installing the second beamline (2021)

Installation of the new second beamline



Tony
Gonsalves



Kei
Nakamura



Lotti Obst-
Huebl

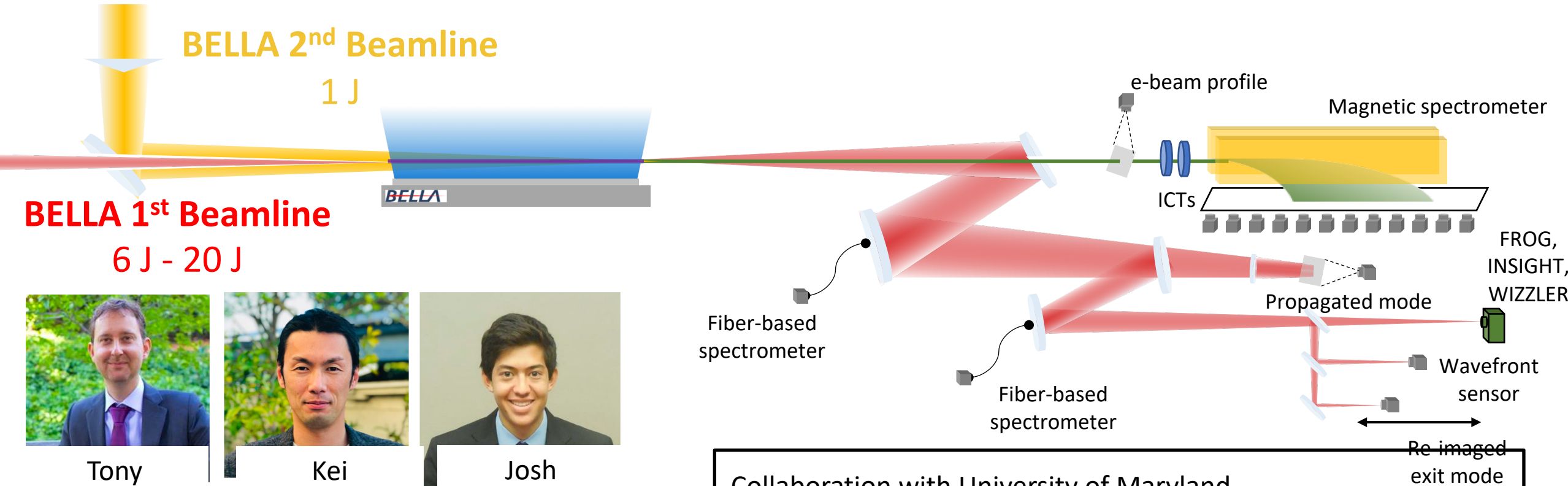


Josh
Stackhouse



Marlene
Turner

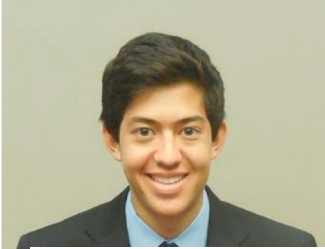
HOFI Plasma Channels on BELLA ??



Tony
Gonsalves



Kei
Nakamura



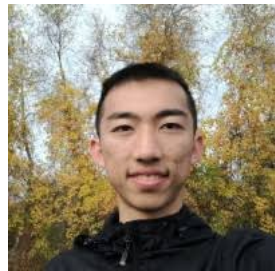
Josh
Stackhouse



Carlo Benedetti

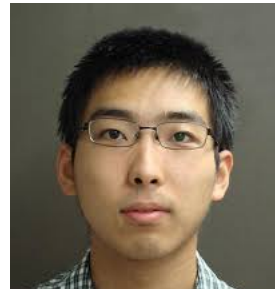


Hai-En Tsai



Raymond Li

Collaboration with University of Maryland



Bo Miao



Jaron Shrock

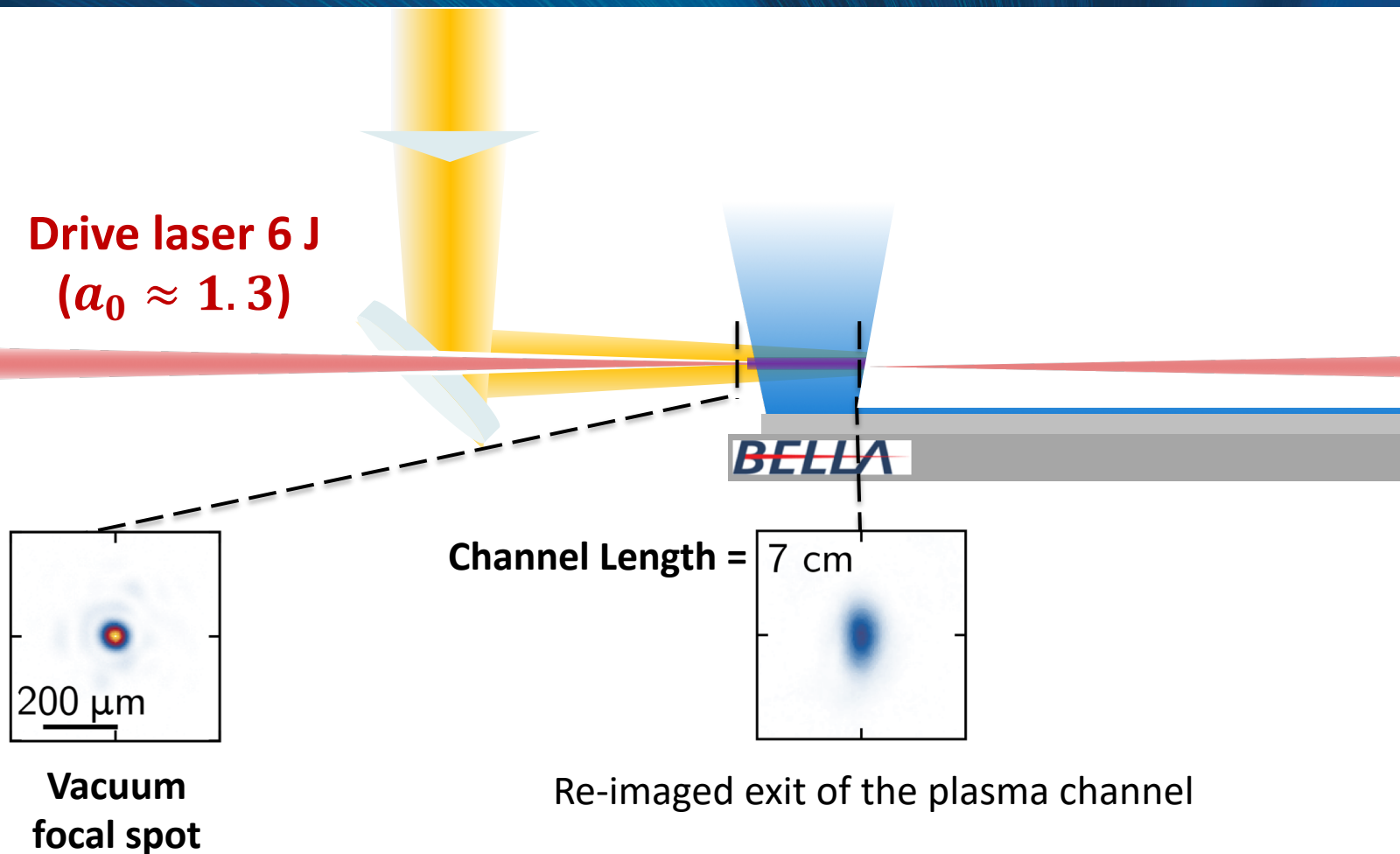


Ela
Rockafellow

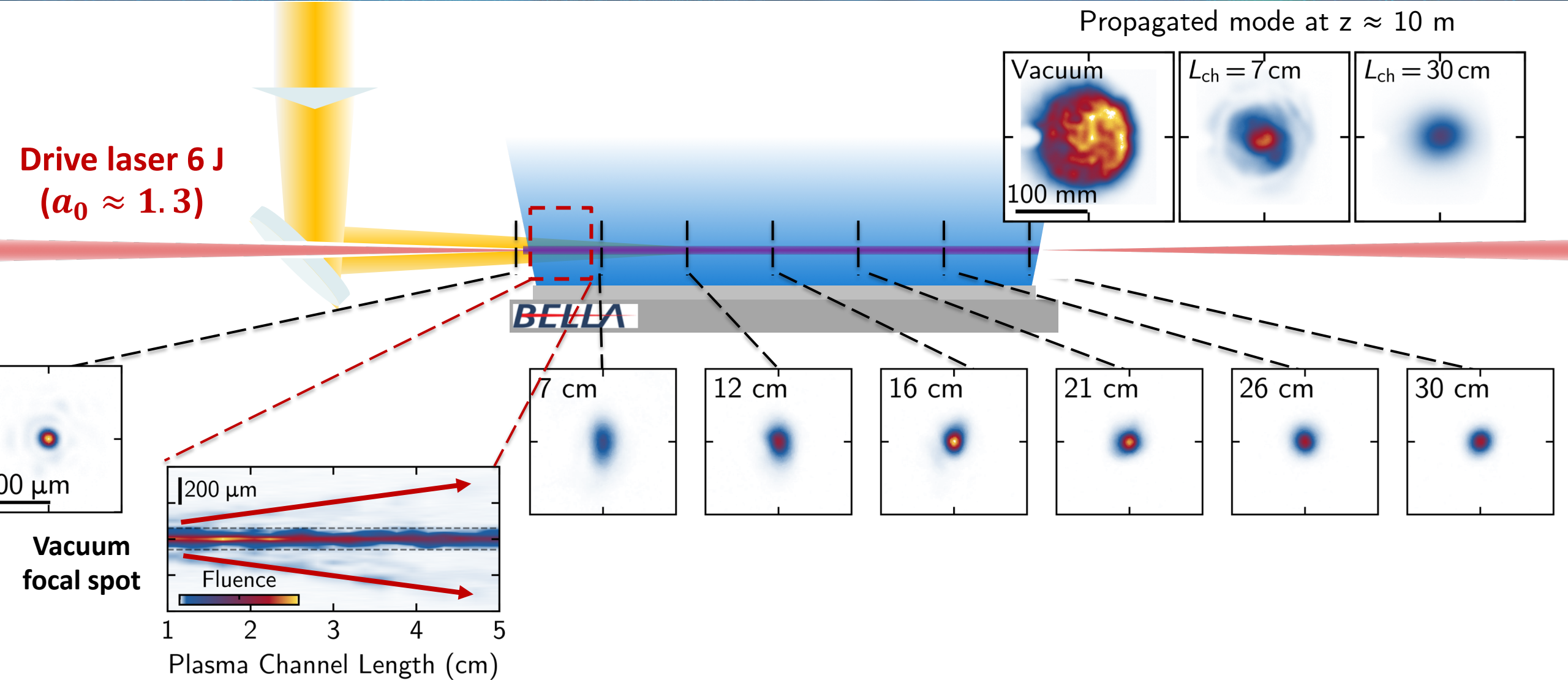


Howard
Milchberg

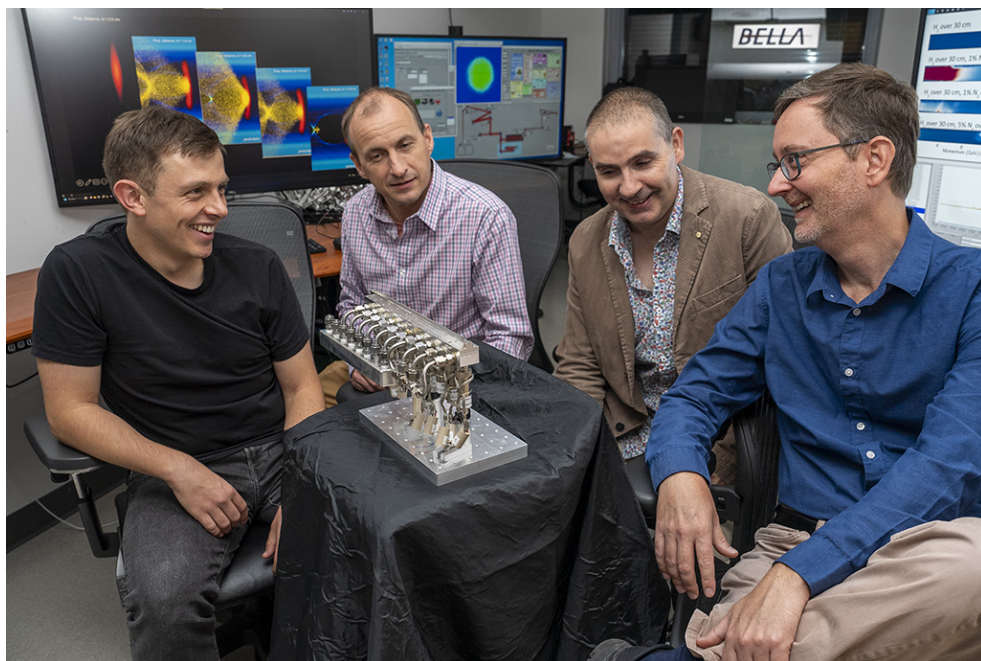
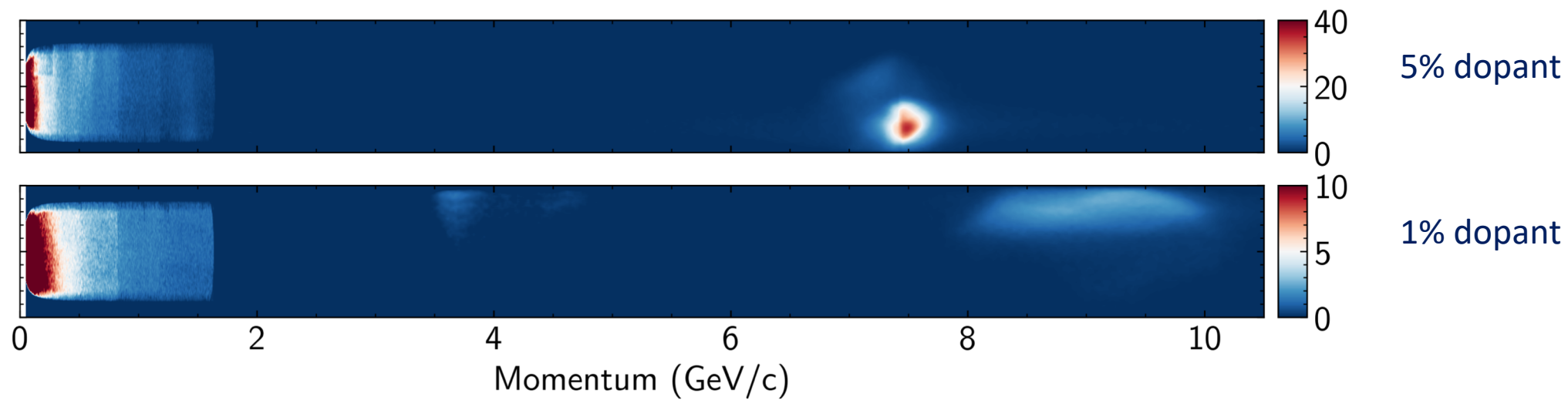
2023 - High quality guiding !



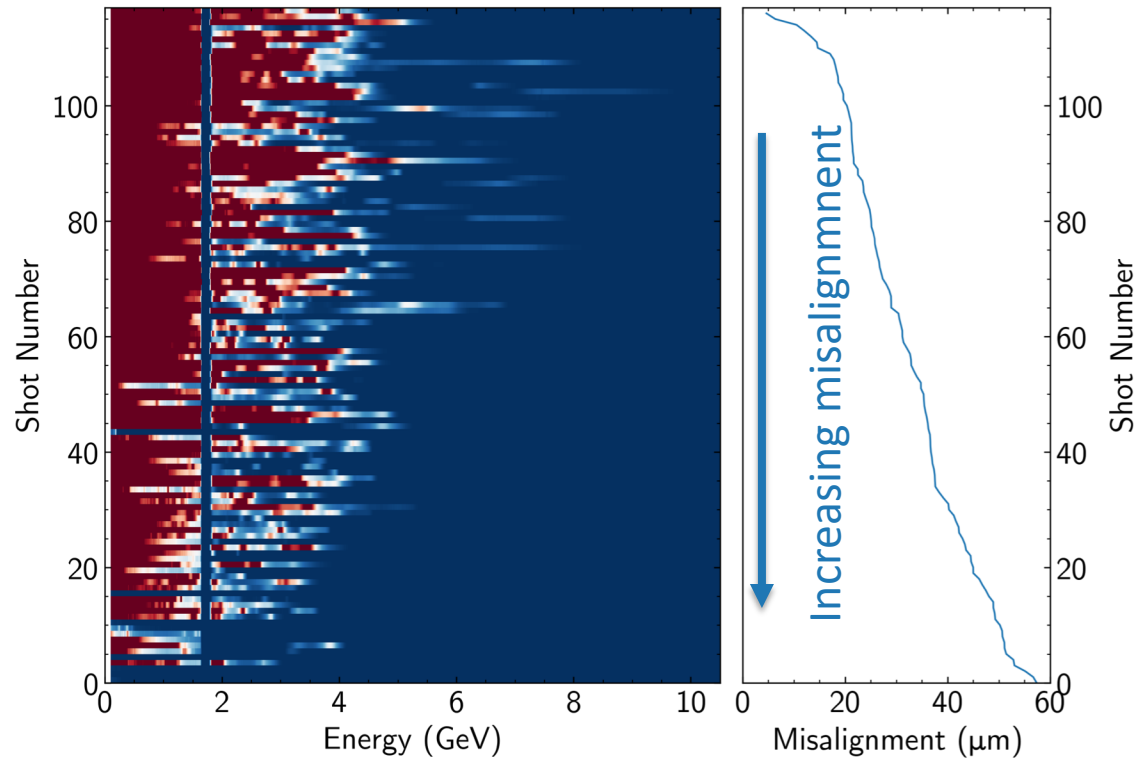
Matched guiding ?



High quality beams generated! Jan 2024

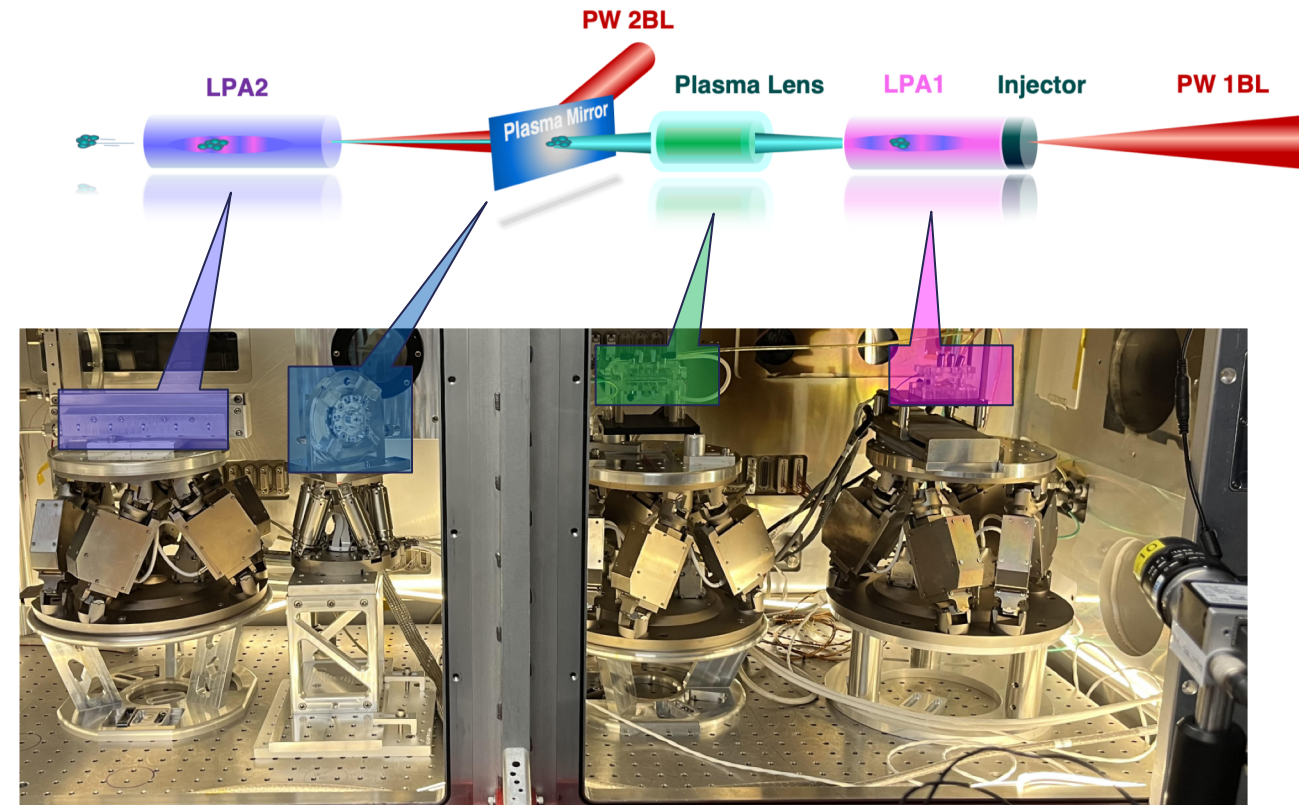


What's next ?



- Electron beam energy directly correlates with pointing offset at the channel entrance !
- Even more reason for stable, high-repetition rate lasers !

- Staged acceleration to reach the highest energies



Accelerator Physics is Team Science

- Oxfor LPAG Group



- BELLA Center



Accelerator Physics is Team Science – with wonderful supervision

- Simon Hooker and Roman Walczak



- Tony Gonsalves



And a fantastic community! – Thank You!

2025 – EAAC Football match



2025 – EAAC Social Dinner



2019 – My first EAAC

