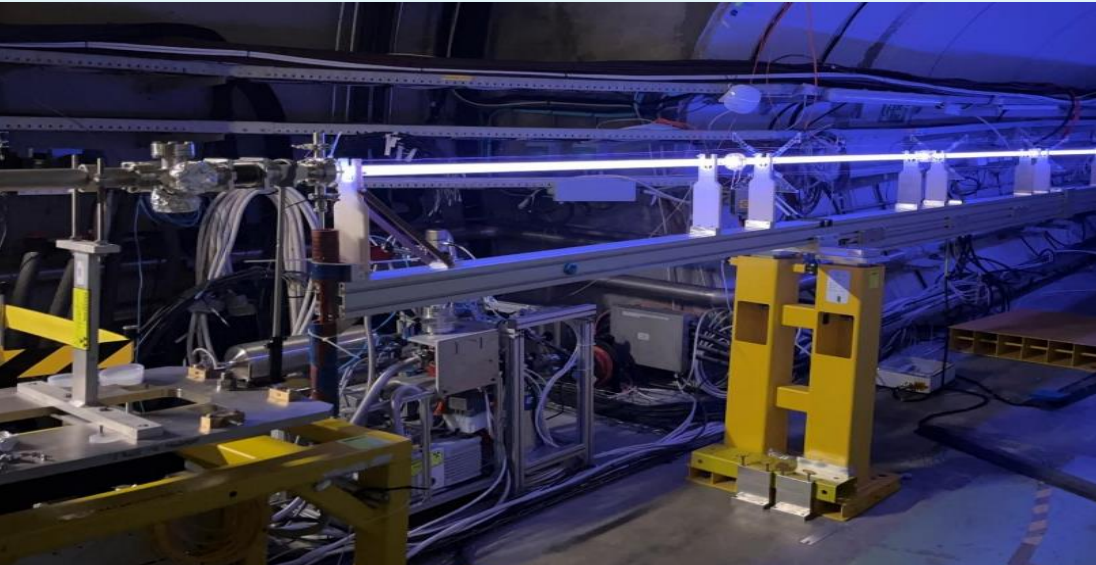


Proton driven wakefield beam self-modulation and acceleration of electrons, stability of laser driven wakefield acceleration and concepts for future colliders



2023 SvdM Award Talk
for Novel Accelerators
Marlene Turner

Thank you for Trusting me with the Simon van der Meer Early Career Award in Novel Accelerators

Thank you to our community.

A big thank you to:

- Cameron Geddes for the nomination
- Patric Muggli, Andrei Seryi, Cameron Geddes and Frank Zimmermann for writing reference letters
- The prize selection committee (Ulrich Schramm, Edda Gschwendtner, Stefan Karsch, Rajeev Pattathil, Alessandro Cianchi, Bernhard Holzer and Roman Walczak) for trusting me with this award
- The European Network for Novel Accelerators (EuroNNAc) under the umbrella of the EU project I.FAST for enabling this award and for supporting early-career scientists

2019: Spencer Gessner



2021 (2022): Carl Lindstrøm



Simon van der Meer



Photo from the Nobel Foundation archive.

- Accelerator Physicist, invented the technique of stochastic cooling of particle beams → to accumulate intense beams of antiprotons
- 1984 Nobel Prize ‘for decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction’
- Simon Van der Meer and Ernest Lawrence are the only two accelerator physicists who have won the Nobel prize.

Quotes:

My interest in matters more directly concerned with the handling of particles was growing, in the meantime, **stimulated by many contacts with people understanding accelerators.**

My father was a schoolteacher and my mother came from a teacher's family. Under these conditions it is not astonishing that **learning was highly prized**; in fact, my parents made sacrifices to be able to give their children a good **education.**

Early Teachers and Mentors

A big thank you to my High School Teachers and mentors for:

- 1) Their enthusiasm and willingness to teach
- 2) Motivating by example and being passionate
- 3) Believing in my abilities and support

Their hard work and their example during my teenager years made me believe that physics is also the right career for me.
They all went the extra mile.

**Math /
Physics**



MMag. Robert
Schantl

Math



Mag. Peter
Kaltenboeck

Physics



Mag.
Peter Rabl

My fascination with particle accelerators started when our high school physics teacher organized a trip to DESY during our final year....

→ First exposure with the field that stuck...

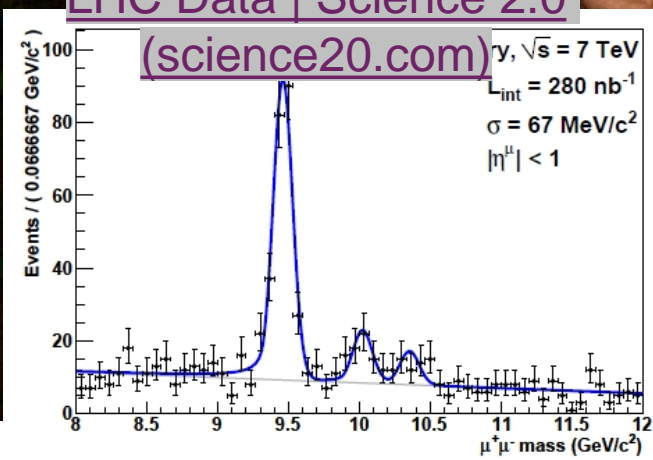
→ Many, many opportunities that followed



CMS cavern with solenoid on



Upsilon Mesons Popping Up In LHC Data | Science 2.0



2011 CERN Summer student
2012 CERN Technical Student
2014-2017 CERN Doctoral Student



Cloud chamber workshop

AWAKE: Proton Driven Plasma Wakefield Acceleration Experiment

Motivation: use the very energetic proton bunches (kJ-MJ) available at CERN to accelerate electrons to very high energies in a single plasma stage.

Published: 12 April 2009

Proton-driven plasma-wakefield acceleration

Allen Caldwell , Konstantin Lotov, Alexander Pukhov & Frank Simon

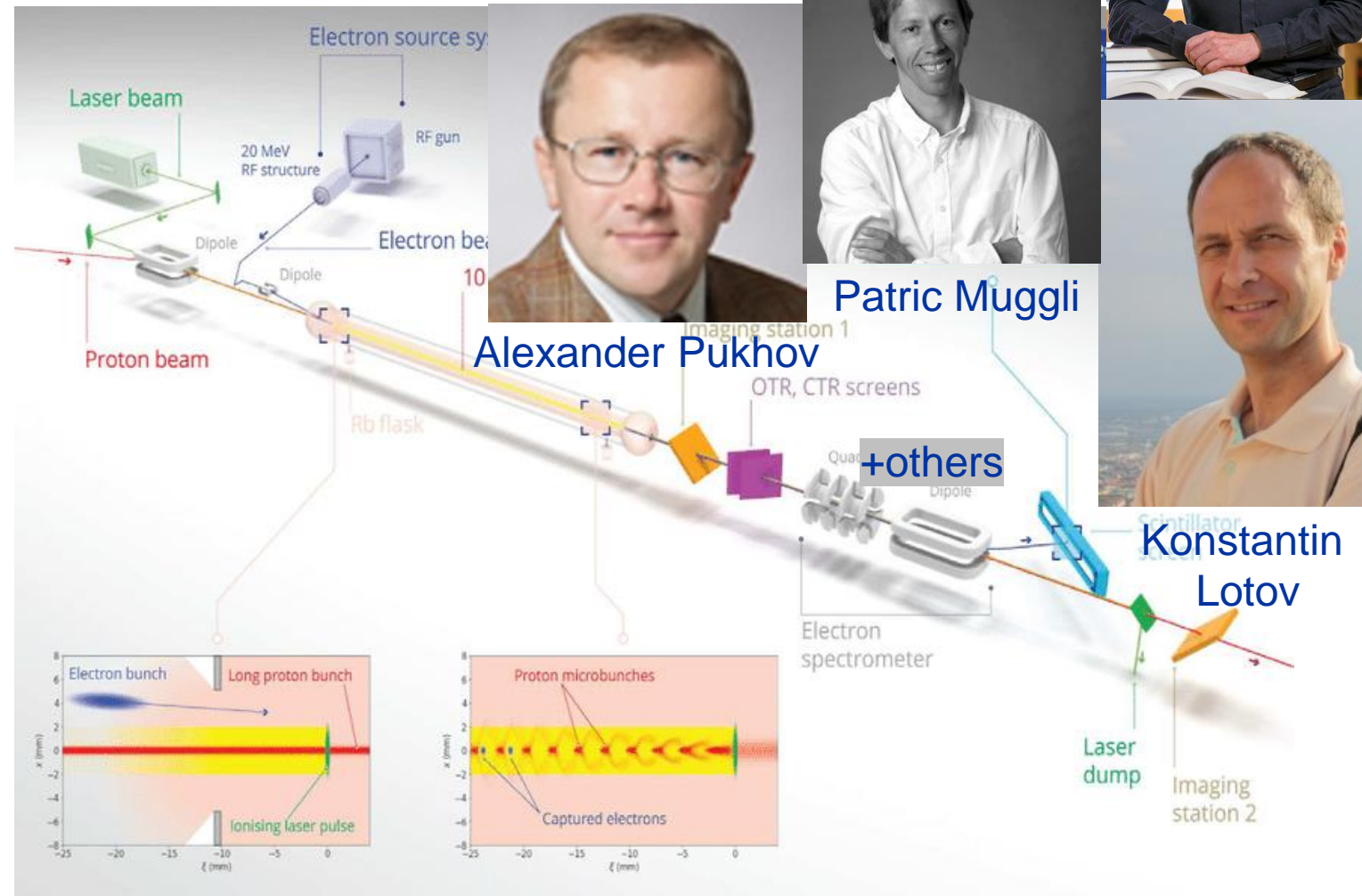
Nature Physics 5, 363–367 (2009) | [Cite this article](#)

Challenge:

Available bunches are long compared to the plasma wavelength.

Idea:

Use self-modulation instability to form a bunch train \rightarrow resonantly excite high amplitude wakefields.



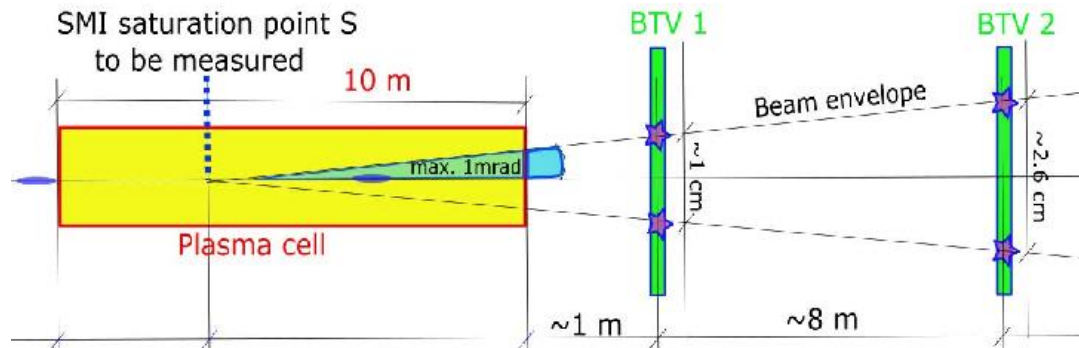
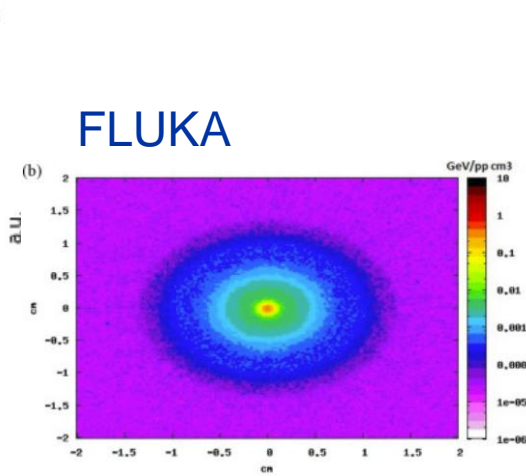
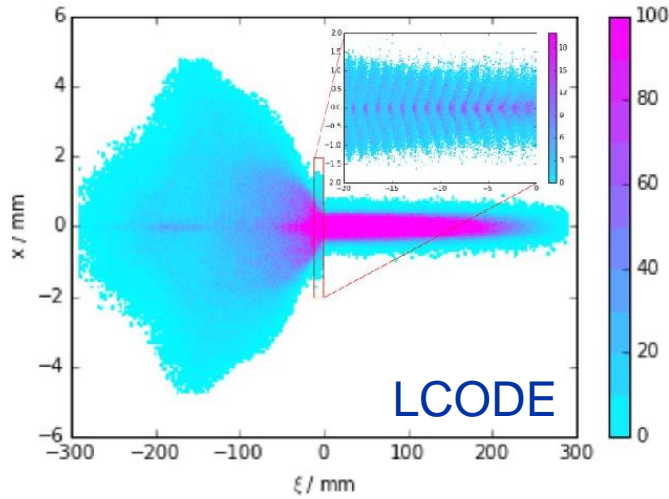
The AWAKE Experiment @ CERN

2014 - 2017: Proton Bunch Self-Modulation Design Phase

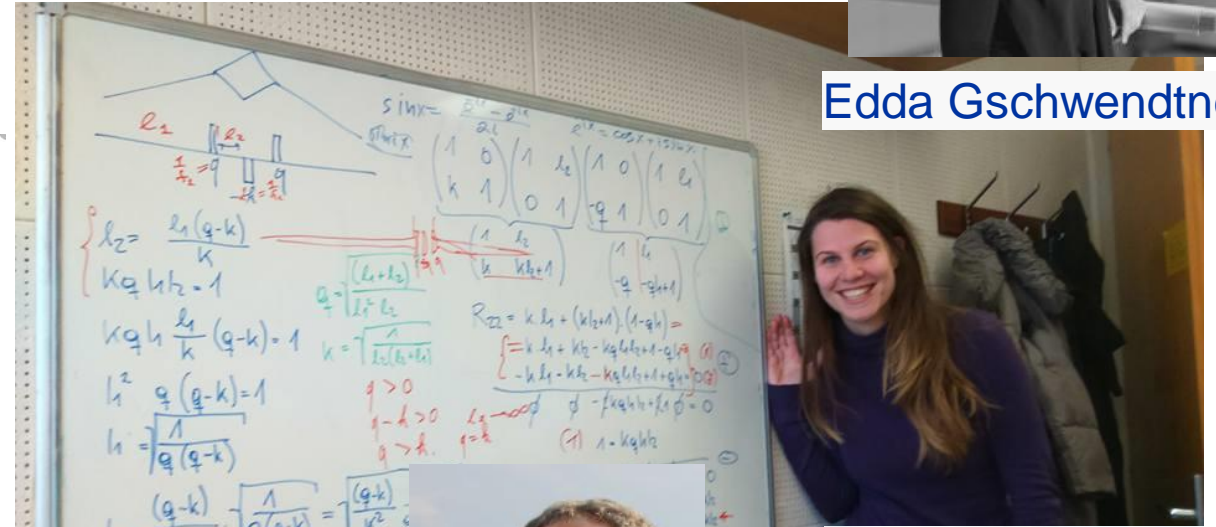


Edda Gschwendtner

- M. Turner, et al., NIM A Vol. 829 (2016)
- M. Turner, et al., NIM A Vol. 854, (2017)
- M. Turner, et al., J. Phys.: Conf. Ser. 874 012031 (2017)
- M. Turner, et al., NIM A, Vol. 909, (2018)



→ Design a system and understand the challenges of the measurements.



Helmut Vincke



Konstantin Lotov



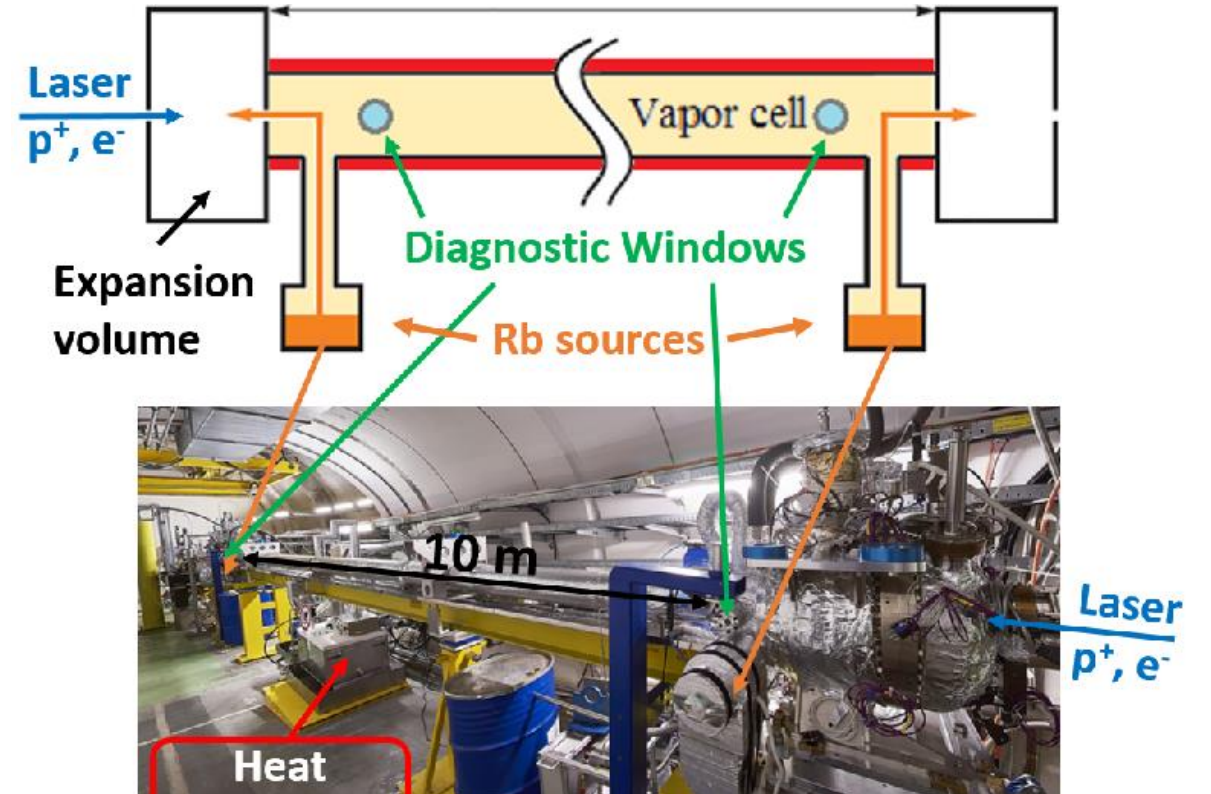
Alexey Petrenko

Preparation, Commissioning,...

Commissioning



From Power Point to Real Life

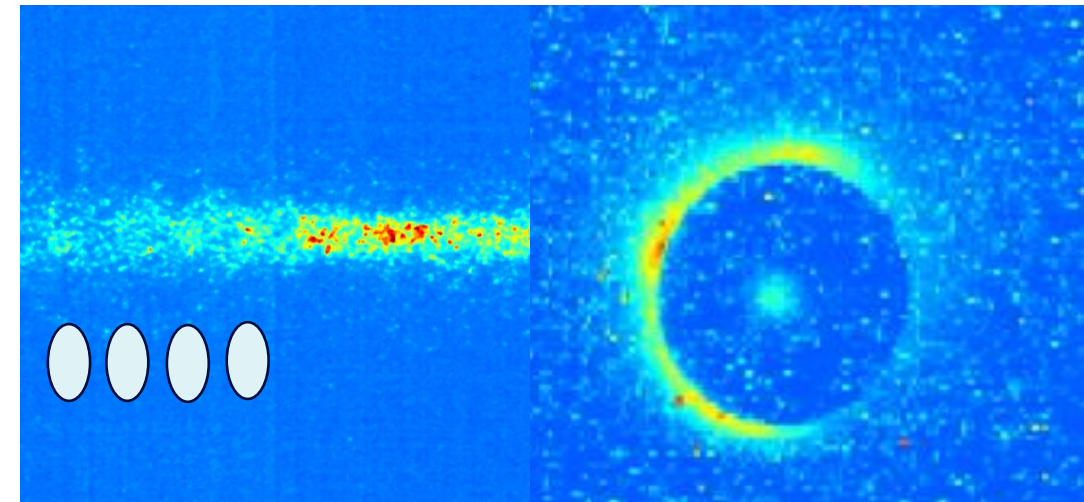


The First Experiment, Self-Modulation in AWAKE...

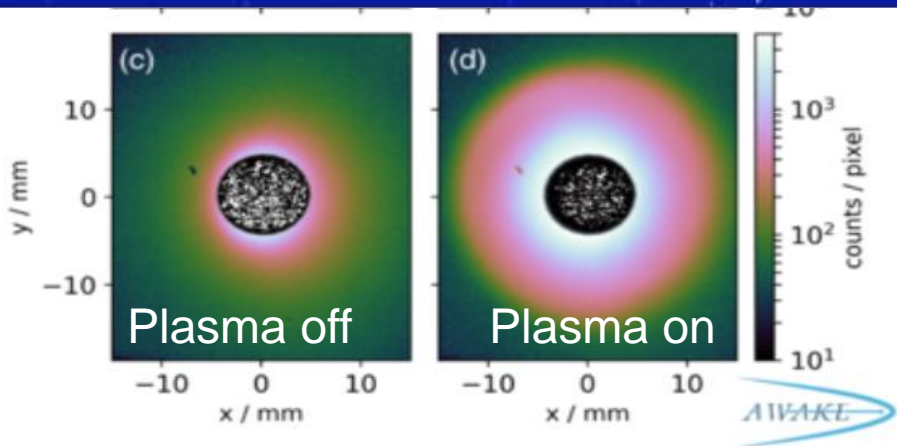
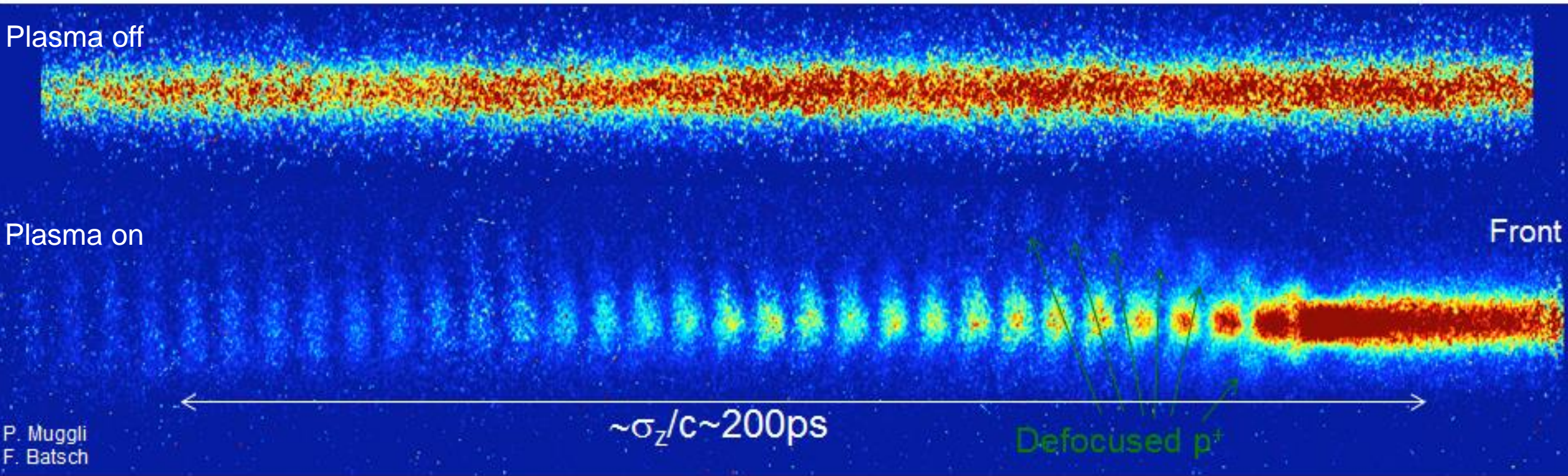


Dec 12, 2016

Streak camera image Transverse diagnostics



Many Ideas, Measurements, Improvements...



- Frequency measurement, PRL. 122, 054802 (2019)
- Wakefield Growth, PRL 122, 054801 (2019)
- Phase reproducibility, PRL 126, 164802 (2021)
- Density gradient, PRL 125, 264801 (2020)



2018 PhD Defense



Patric Muggli



Helmut Vincke



Arnd Specka



Dipl. Ing. Marlene Turner

**First Observation of the Seeded Proton Bunch
Self-Modulation in Plasma**

DOCTORAL THESIS

to achieve the university degree of
Doktorin der technischen Wissenschaften
submitted to

Graz University of Technology

Supervisor

Priv.-Doz. Dipl.-Ing. Dr.techn. Helmut Vincke

Institute of Theoretical and Computational Physics

in cooperation with CERN

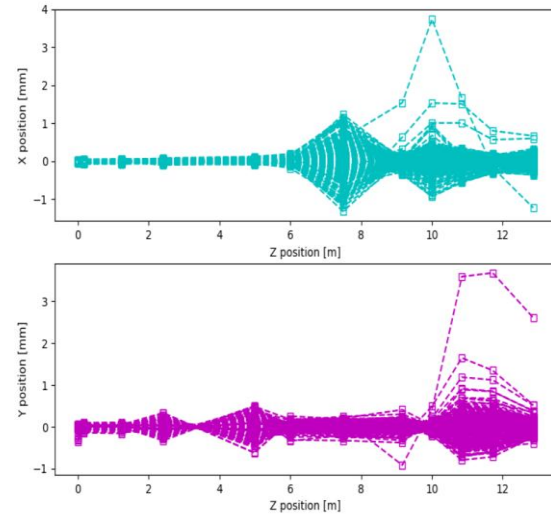
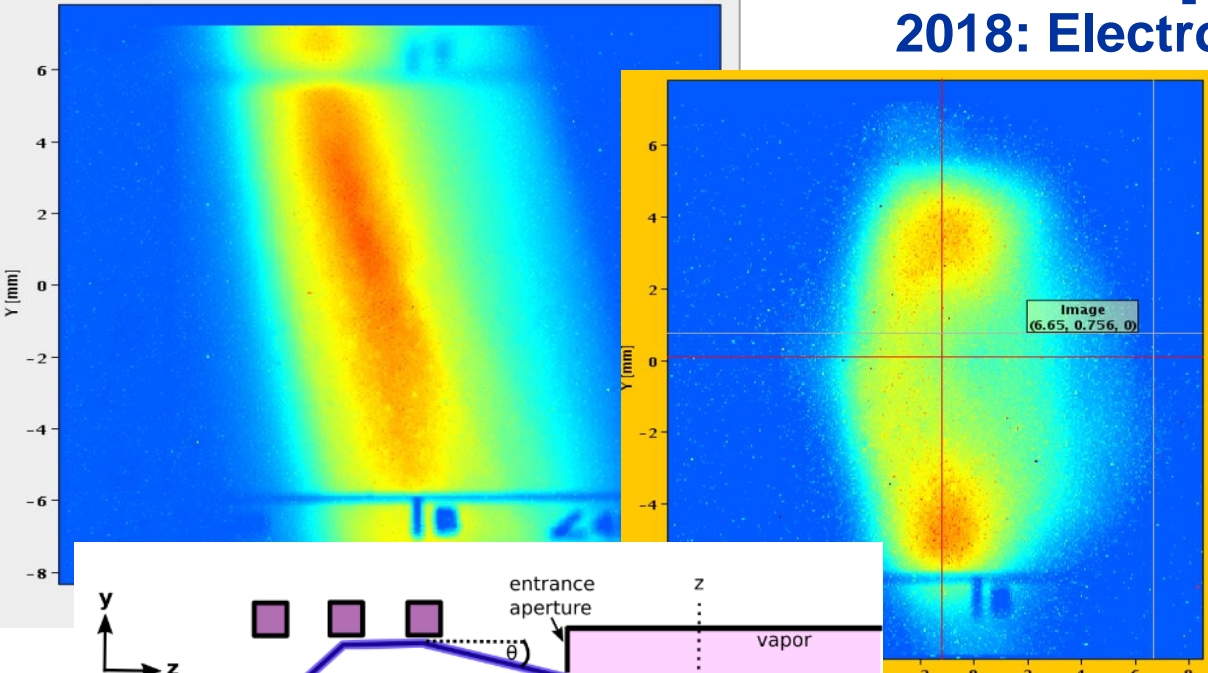
Graz, December 2017

Edda
Gschwendtner



The AWAKE Experiment @ CERN

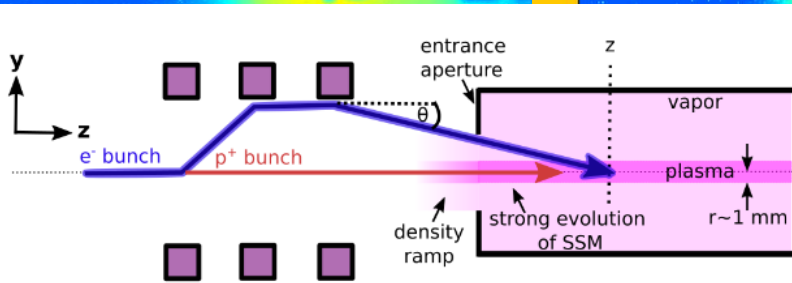
2018: Electron Acceleration



Biggest challenge:

- Controlling the electron beam
- Beamline debugging
- Jitter
- Earth Magnetic Field
- Steering while proton extraction

+ many others



Electron beam characterization with beam loss monitors in AWAKE
L. Verra, M. Turner, S. Gessner, E. Gschwendtner, F. Velotti, P. Muggli,
Phys.Rev.Accel.Beams 23, 032803 2020.

Status and prospects for the AWAKE experiment
M. Turner for the AWAKE Collaboration, J. Phys.: Conf. Ser. 1067
042007 (2018)

External electron injection for the AWAKE experiment
M. Turner, et al., Proceedings of AAC 2018.



Chiara Bracco



Steffen Doebert



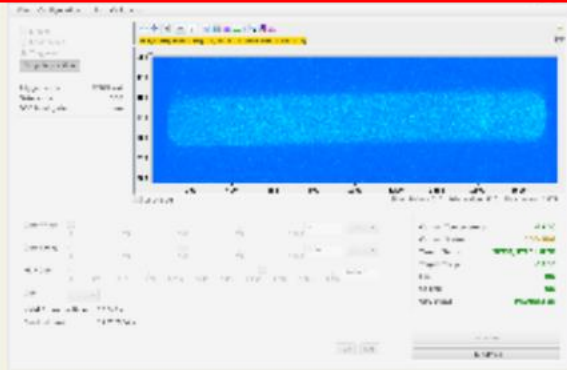
Spencer Gessner



Livio Verra

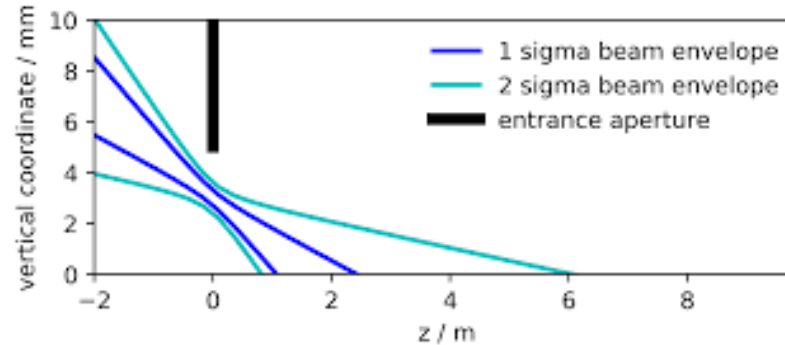
A First Hint....?

Do you see something in this image? Unbiased opinions welcome



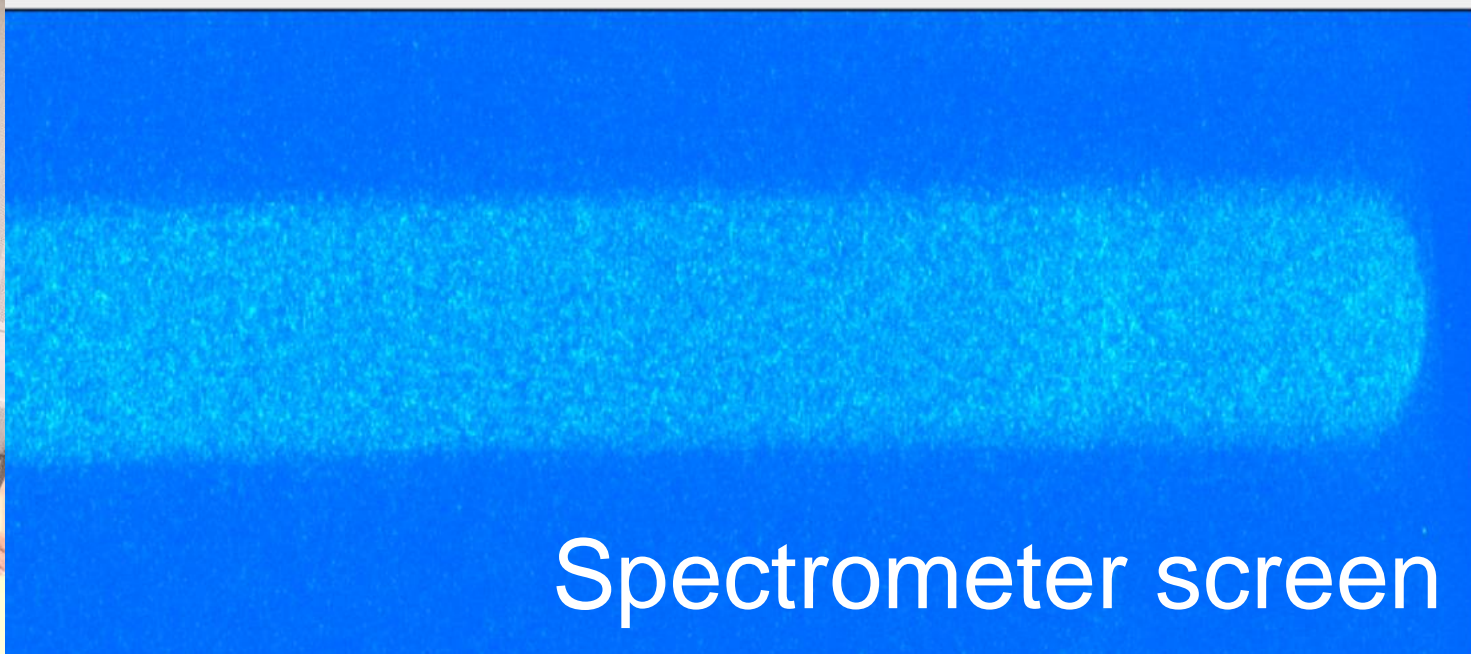
name: 2018052601

desc:



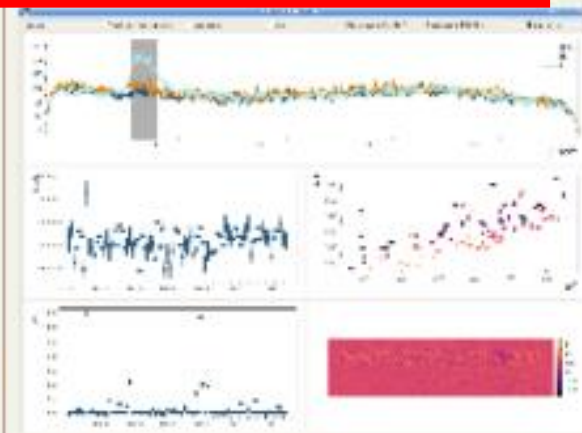
Felipe
Pena

00:59

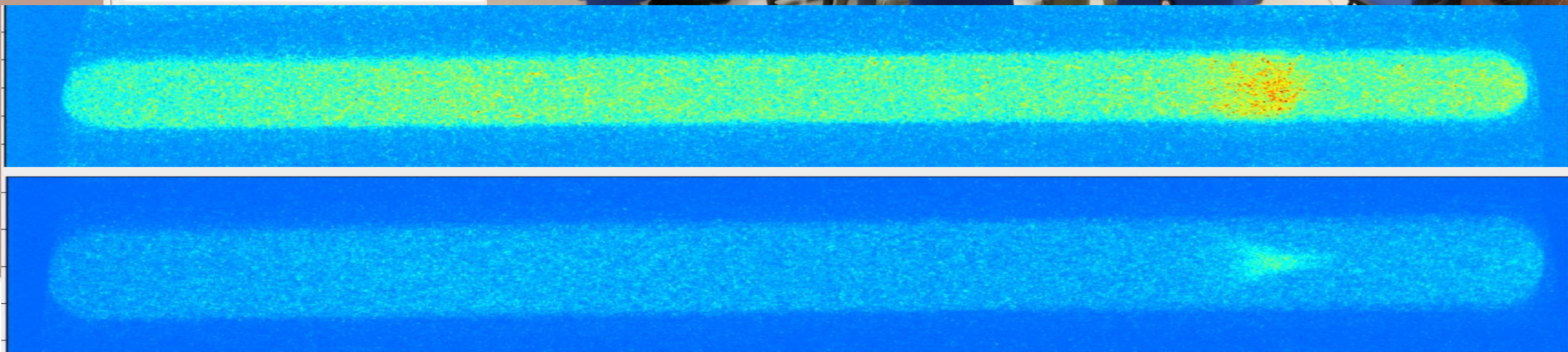


A Bit Later...

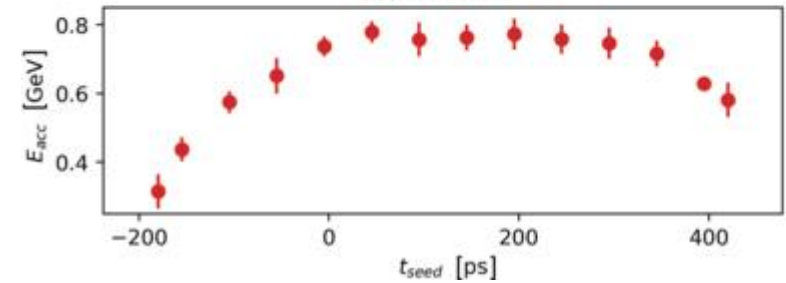
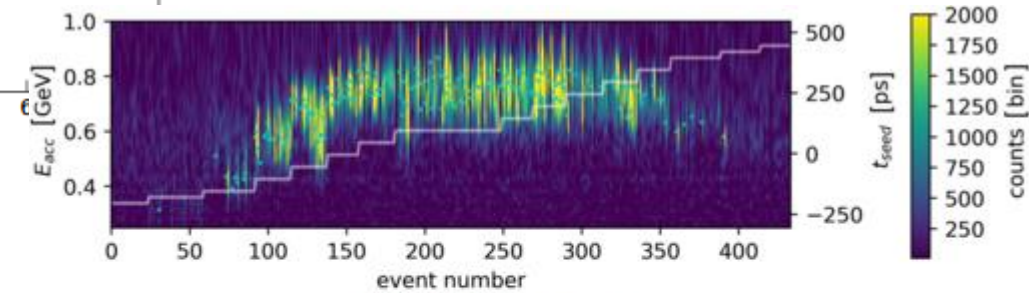
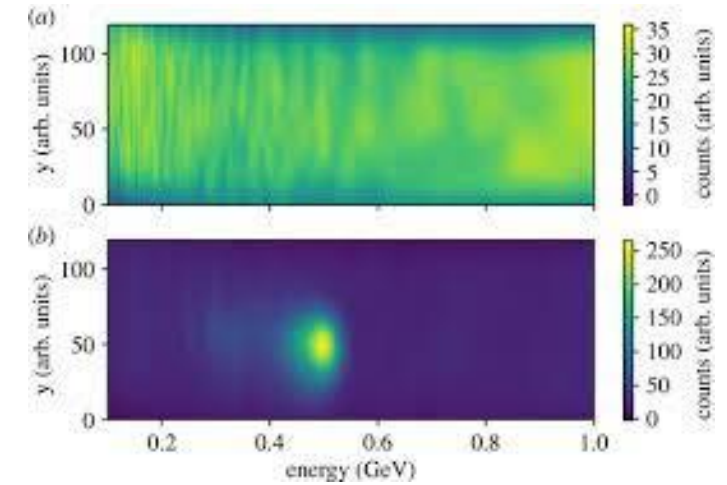
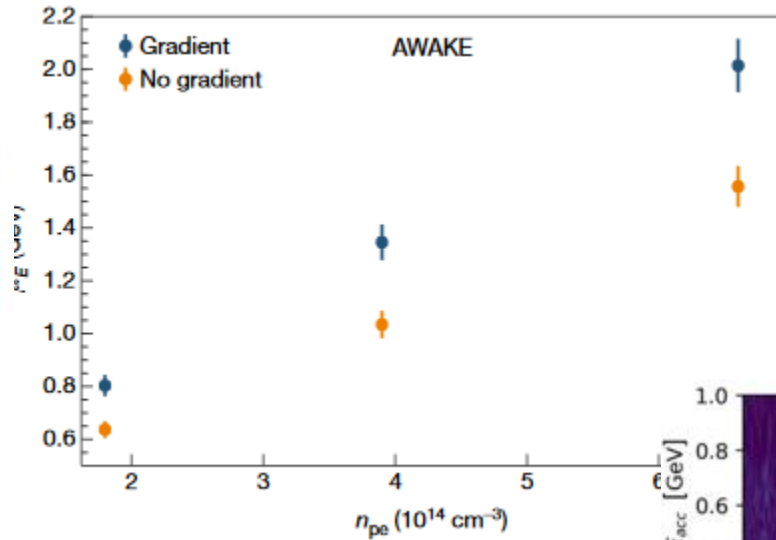
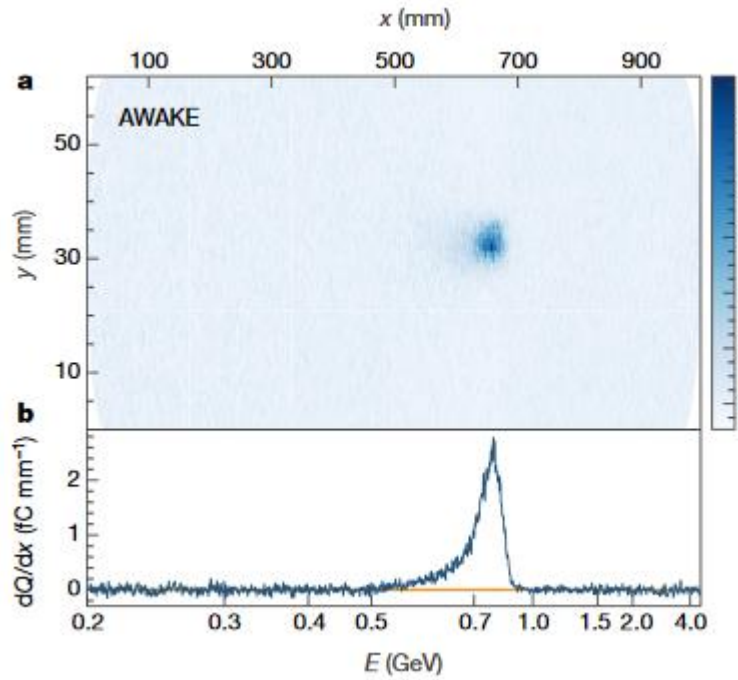
DING DING DING



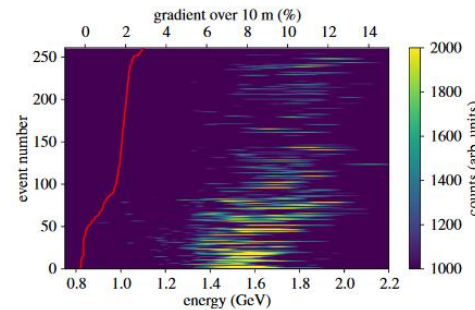
01:08



Electrons Accelerated!



AWAKE Collaboration, *Nature* volume 561, pages 363–367 (2018)



M. Turner and the AWAKE Collaboration, *Phys. Rev. Accel. Beams* 23, 081302 (2020)

AWAKE Run 1 Team @ CERN



Livio Verra



Karl Rieger



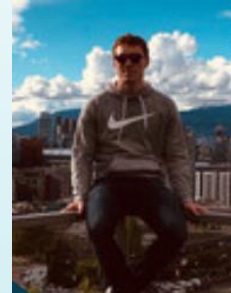
Joshua
Moody



Fabian
Batsch



Anna-Maria
Bachmann



Fearghus
Keeble



Felipe
Pena



Patric Muggli



Edda
Gschwentner



Mathias
Huether



James
Chappel



Falk
Braunmueller



Spencer
Gessner



Alexey
Petrenko



Pablo
Guzman



Ans
Pardons

Veronica Olsen

Tatiana Nechaeva

Mikhail Martyanov

+ many, many more



Allen Caldwell

A Big Thank You to Everyone Who Enabled the Success of AWAKE Run 1!



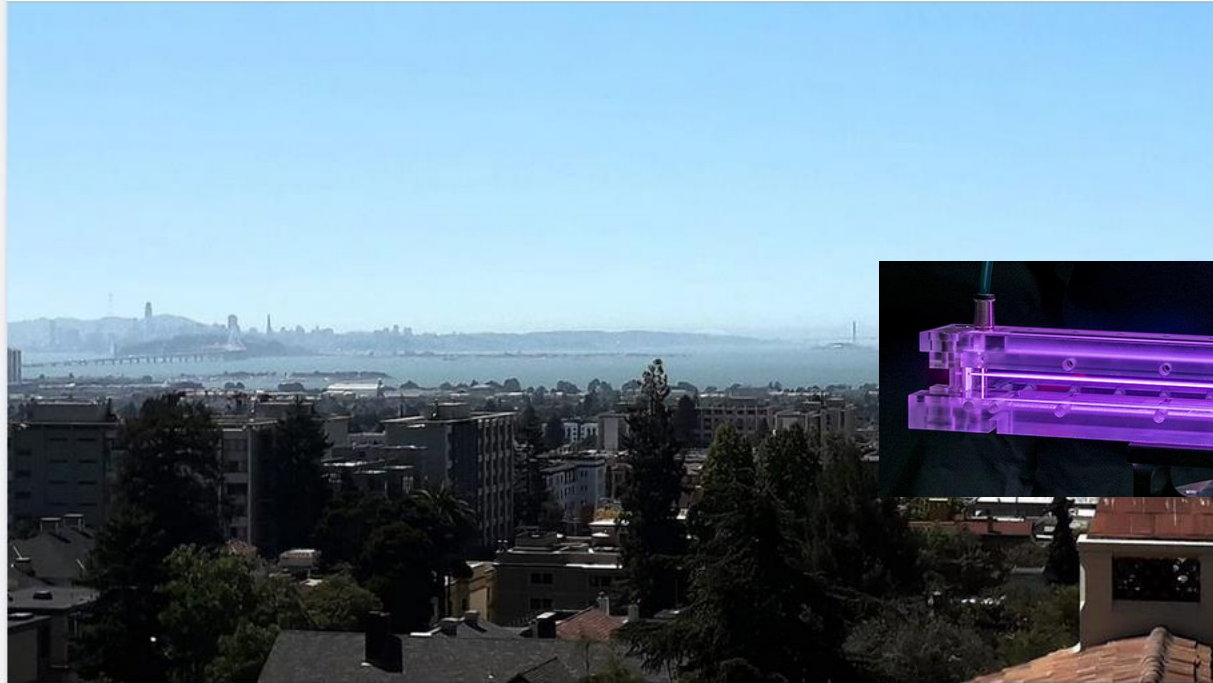


Marlene Cooper ist in Berkeley, Vereinigte Staaten.

31. August 2019 · 👥



Getting used to my new, sunny 🌞 life...



70

16

REVIEWS OF MODERN PHYSICS, VOLUME 81, JULY-SEPTEMBER 2009

Physics of laser-driven plasma-based electron accelerators

E. Esarey, C. B. Schroeder, and W. P. Leemans

Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

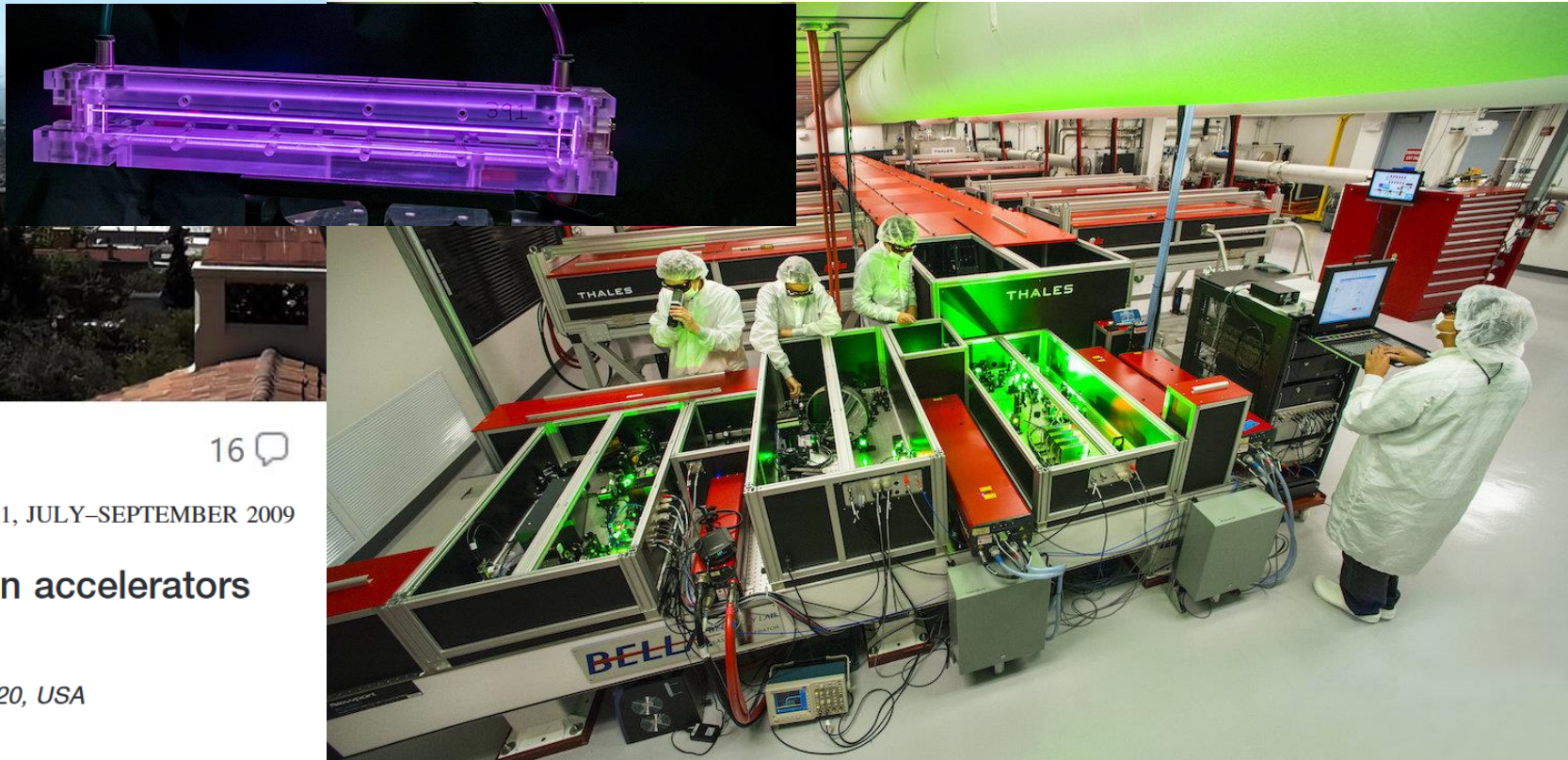
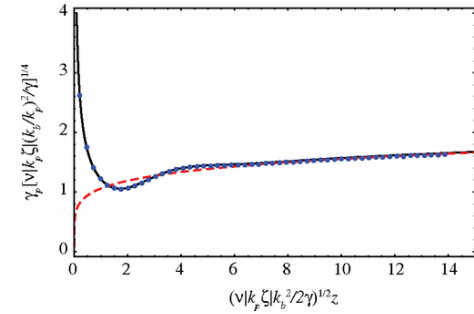
(Published 27 August 2009)

Growth and Phase Velocity of Self-Modulated Beam-Driven Plasma Waves

C. B. Schroeder, C. Benedetti, E. Esarey, F. J. Grüner, and W. P. Leemans
Phys. Rev. Lett. **107**, 145002 – Published 28 September 2011

$$\gamma_p [v |k_p \zeta| (k_b/k_p)^2 / \gamma]^{1/4}$$

$$(v |k_p \zeta| k_b^2 / 2\gamma)^{1/2} z$$



The BELLA PW Laser System

The BELLA Laser is a Ti:Sapphire CPA laser providing laser pulses at petawatt-level peak power with a repetition rate of 1 Hz.

The primary activities are focused on the research and development of **multi-GeV LPAs**. This includes controlled production, detailed characterization, and applications of the electron beams.



And Then... COVID

Thales Team @ LBNL, 2BL compressor installation



BELLA M/L Tech and Admin Staff

- Hard working
- Dedicated, passionate
- Positive
- Careful and accurate

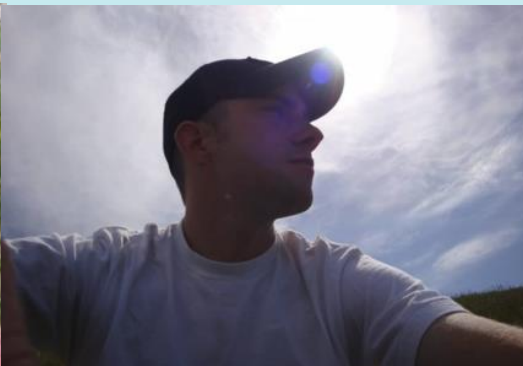


Joe Riley

Arturo Mangana



Zachary Eisentraut



Mark Kirkpatrick



Tyler Sipla



Felecia Harris

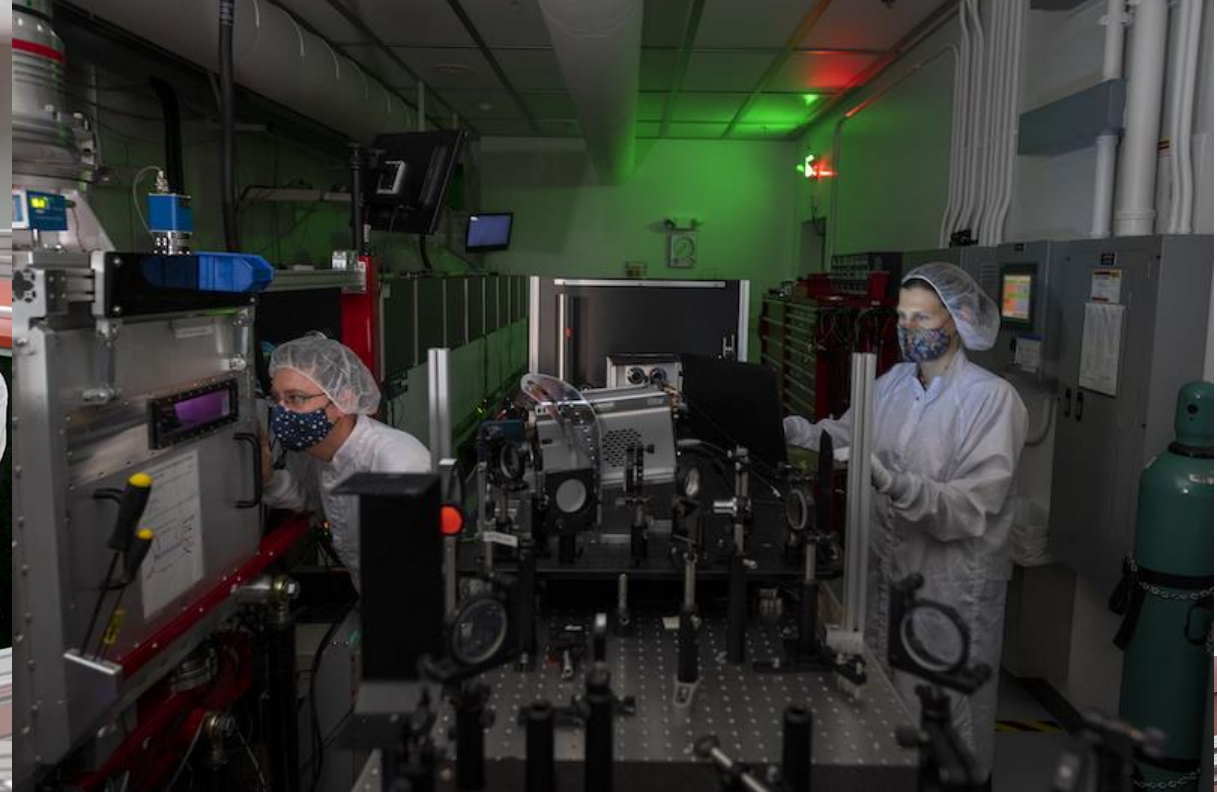


Asmita Patel

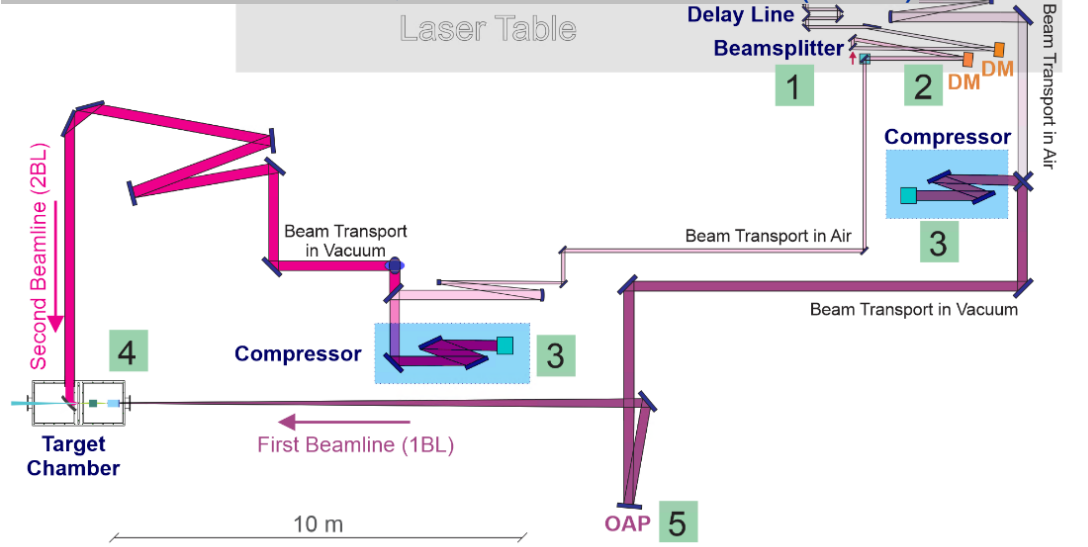


Wes Tabler

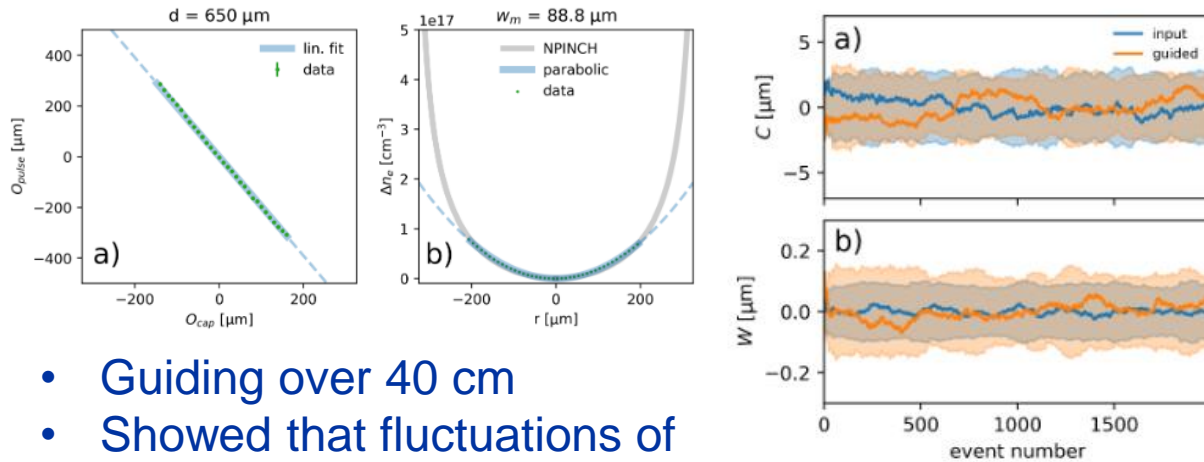
Stephanie Chan,
Sunny



Strong-Field QED Experiments using the BELLA PWLaser Dual Beamlines, M. Turner, et al., The European Physical Journal D volume 76, Article number: 205 (2022)



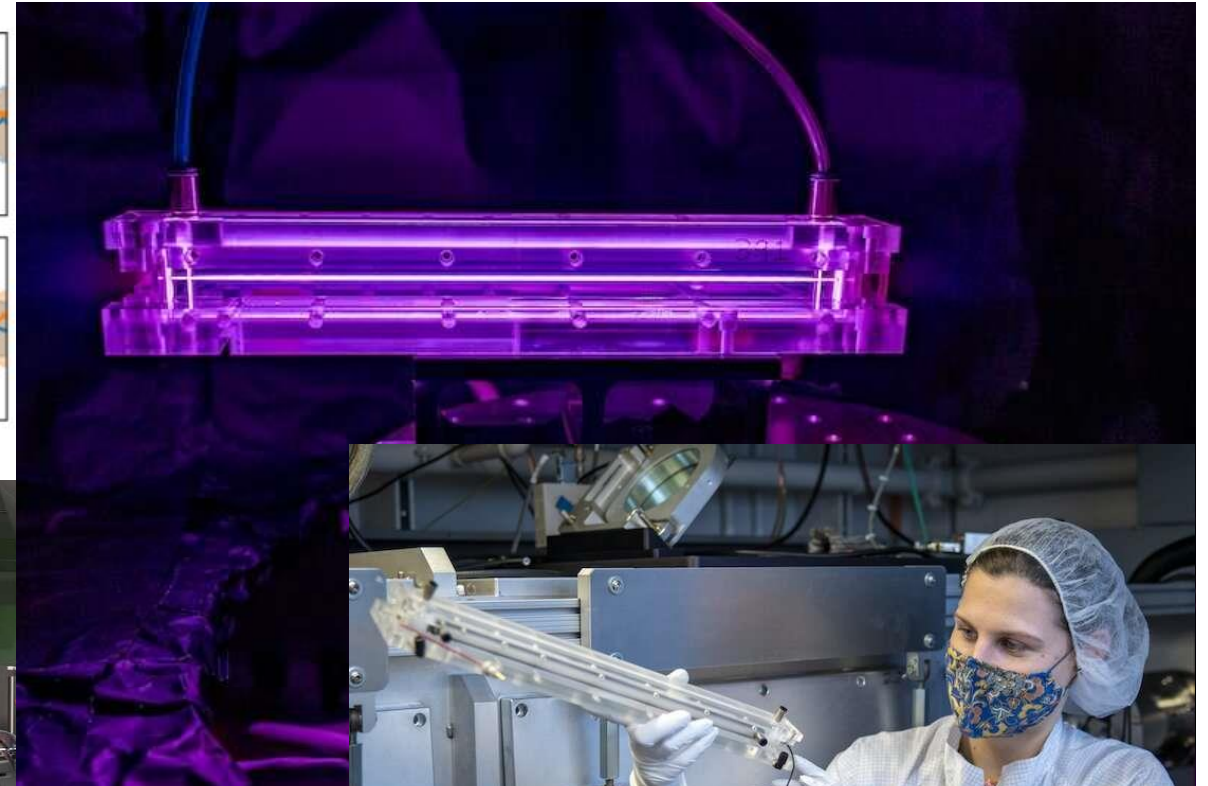
Stability of Capillary Discharge Plasma Waveguides



- Guiding over 40 cm
- Showed that fluctuations of plasma are negligible compared to laser fluctuations



Anthony Gonsalves



Radial density profile and stability of capillary discharge plasma waveguides of lengths up to 40 centimetres
M. Turner et al., High Power Laser Science and Engineering, 9, E17.



Anthony Gonsalves



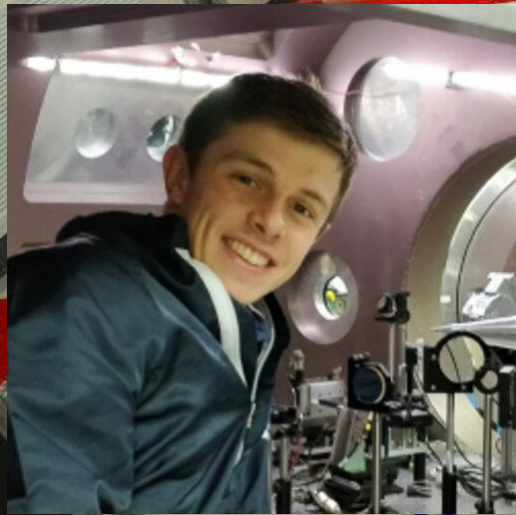
Kei Nakamura



Carlo Benedetti



Stepan Bulanov



Alexander Picksley



Lieselotte Obst-Huebl



Joshua Stackhouse



Davide Terzani

Snowmass 2021

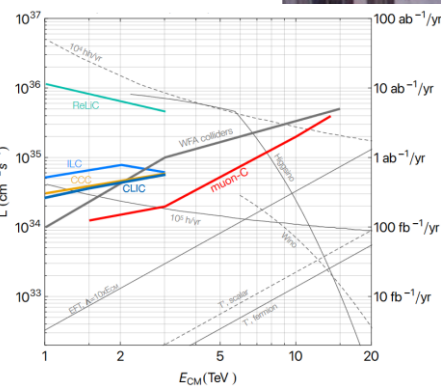
On the feasibility of future colliders: report of the Snowmass'21 Implementation Task Force Thomas Roser, Reinhard Brinkmann, Sarah Cousineau, Dmitri Denisov, Spencer Gessner, Steve Gourlay, Philippe Lebrun, Meenakshi Narain, Katsunobu Oide, Tor Raubenheimer, John Seeman, Vladimir Shiltsev, Jim Strait, Marlene Turner and Lian-Tao Wang, JINST 18 P05018 (2023)

Snowmass Community Planning Exercise: identify and document a scientific vision for the future of particle physics in the U.S. and its international partners. Snowmass will define the most important questions for the field of particle physics and identify promising opportunities to address them.



OVERVIEW OF THE EXECUTIVE SUMMARY

| | WFA | MuC | SppC | FCC-hh |
|--------------------|--|---|--|----------------|
| Collider Concepts | Collider-in-Sea MuIC | ReLIC (≤3 TeV) Multi-TeV ILC CCC (TeV) | FCC-eh | FCC-hh CLIC |
| Technical Maturity | <ul style="list-style-type: none"> Low maturity conceptual development. Proof-of-principle R&D required. Concepts not ready for facility consideration. | <ul style="list-style-type: none"> Emerging accelerator concepts requiring significant basic R&D and design effort to bring to maturity. | <ul style="list-style-type: none"> Designs have achieved a level of maturity to have reliable performance evaluations based on prior R&D and design efforts. Critical project risks have been identified and sub-system focused R&D is underway where necessary. | |
| Funding Approach | <ul style="list-style-type: none"> Funding for basic R&D required. Availability of "generic" accelerator test facility access often necessary. | <ul style="list-style-type: none"> Efforts would benefit from directed R&D funding to mature collider concepts. Availability of test facilities to demonstrate a broad range of technology concepts required. Some large-ticket demonstrators are generally necessary before a detailed "reference" design can be completed. | <ul style="list-style-type: none"> Funding approach typically transitions to "project-style" efforts with significant dedicated investment required. | |



MARK PALMER



NADIA PASTRONE



JINGYU TANG



MARLENE TURNER



ALEXANDER VALISHEV



Reinhard Brinkmann (DESY)



Sarah Cousineau (ORNL)



Dmitri Denisov (BNL)



Spencer Gessner (SLAC)



Steve Gourlay (LBNL)



Philippe Lebrun (CERN)



Meenakshi Narain (Brown U., deceased)



Katsunobu Oide (KEK)



Tor Raubenheimer (SLAC)



Thomas Roser (BNL, Chair)



John Seeman (SLAC)



Vladimir Shiltsev (FNAL)



Jim Strait (FNAL)



Marlene Turner (LBNL)



LianTao Wang (U. Chicago)

Snowmass 2021

Snowmass Community Planning Exercise: identify and document a scientific vision for the future of particle physics and its international partnerships. This exercise will define the most important scientific goals for the field of particle physics and the most promising opportunities to achieve them.

OVERVIEW OF THE EXECUTIVE SUMMARY

| ILC | WFA | MuC | SppC | FCC-hh |
|--|-----|-----|--|--------------|
| ReLIC (≤3 TeV) | | | FCC-eh | CLIC |
| CCC (TeV) | | | | TeV ILC (Nb) |
| <p>accelerator concepts requiring basic R&D and design effort to bring to maturity.</p> <ul style="list-style-type: none"> • Designs have achieved a level of maturity to have reliable performance evaluations based on prior R&D and design efforts. • Critical project risks have been identified and sub-system focused R&D is underway where necessary. | | | <p>• Funding approach typically transitions to "project-style" efforts with significant dedicated investment required.</p> | |

AF6 Conveners



Cameron Geddes



Mark Hogan



Pietro Musumeci



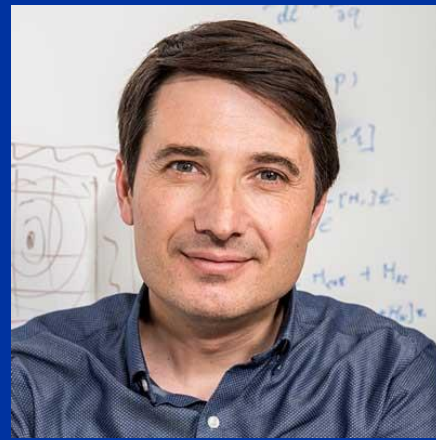
Ralph Assmann



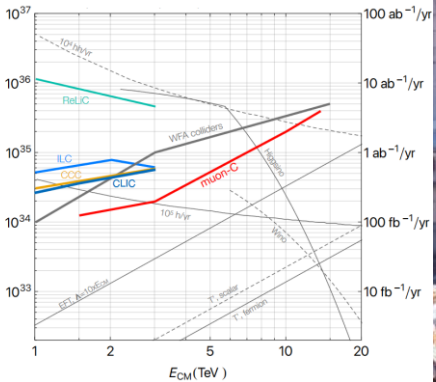
Spencer Gessner



Axel Huebl



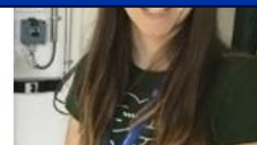
Jean-Luc Vay



MARK PALMER



NADIA PASCA



Tor Raubenheimer (SLAC)



Thomas Roser (BNL, Chair)



John Seeman (SLAC)



Vladimir Shiltsev (FNAL)



Jim Strait (FNAL)



Marlene Turner (LBNL)



LianTao Wang (U. Chicago)



Reinhard Brinkmann (DESY)



Sarah Cousineau (ORNL)



Dmitri Denisov (BNL)



Spencer Gessner (SLAC)



Steve Gourlay (LBNL)



Philippe Lebrun (CERN)



Meenakshi Narain (Brown U., deceased)



Katsunobu Oide (KEK)

Quite a Few 'Lessons Learned'

- Messaging is important

Really, really bad example !

The big + of our community:

- Young, dynamic, engaged
- A lot of progress
- Interesting scientific work

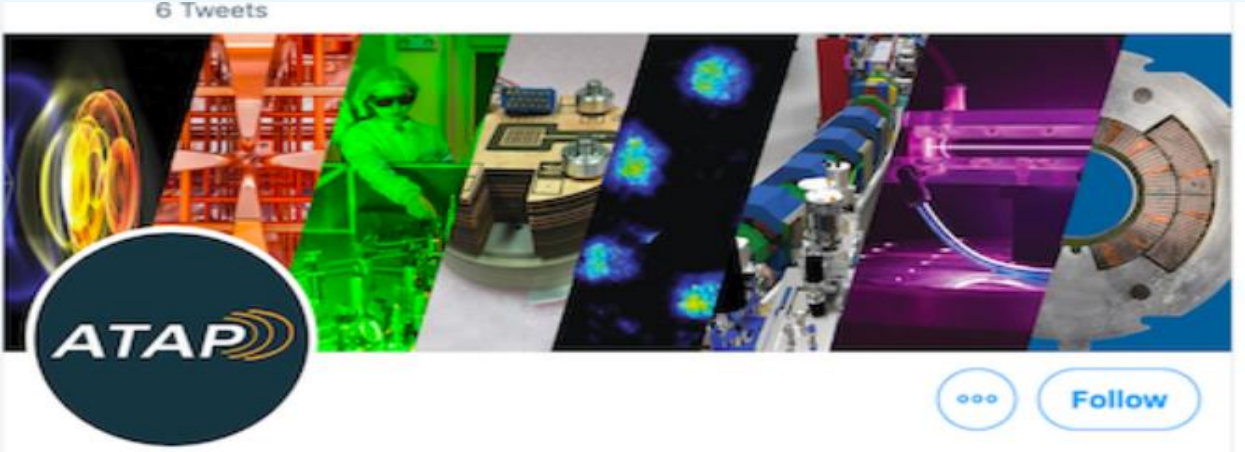
Moving forward- lets keep our enthusiasm while:

- Doing good science,
- Working together and supporting each other
- Being optimistic, yet reasonable
- Keep a good connection with the conventional accelerator community

Particles Prefer Plasma



BELLA / ATAP Leadership



Cameron Geddes



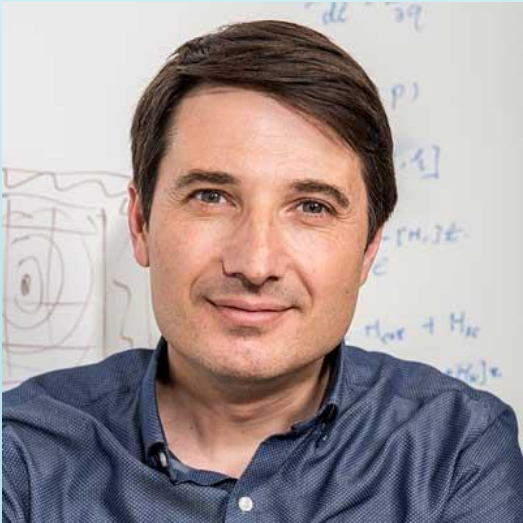
Jeroen van Tilborg



Carl Schroeder



Eric Esarey



Jean-Luc Vay



The Art of Management

Quote
(Anonymous):
Physics is the
easy part 😊

Management can be considered both an art and a science:

- Science because it has universally accepted principles and cause-and-effect relationships
- Art because it requires personal skills, creativity, and practical knowledge.



Cameron Geddes



Edda Gschwendtner

Teaching and Community Work

PHYSICAL REVIEW ACCELERATORS AND BEAMS

Highlights Recent Accepted Special Editions Authors Referees Sponsors Search Press About Editorial Team

Going beyond will require community investment and working together, skilled and experienced people to take over.

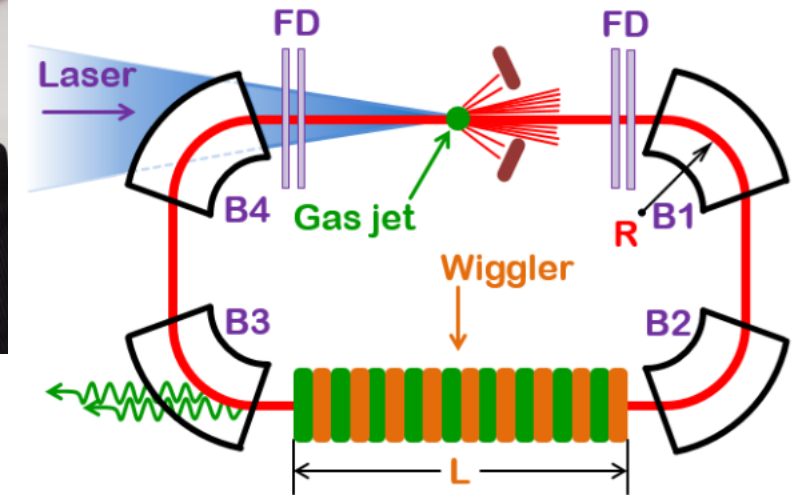


Frank Zimmermann



Andrei Seryi

M, Turner et al., Proceedings of NAPAC2016, Chicago, IL, USA



And now, back at CERN...
with AWAKE Run 2



Nelson Lopes



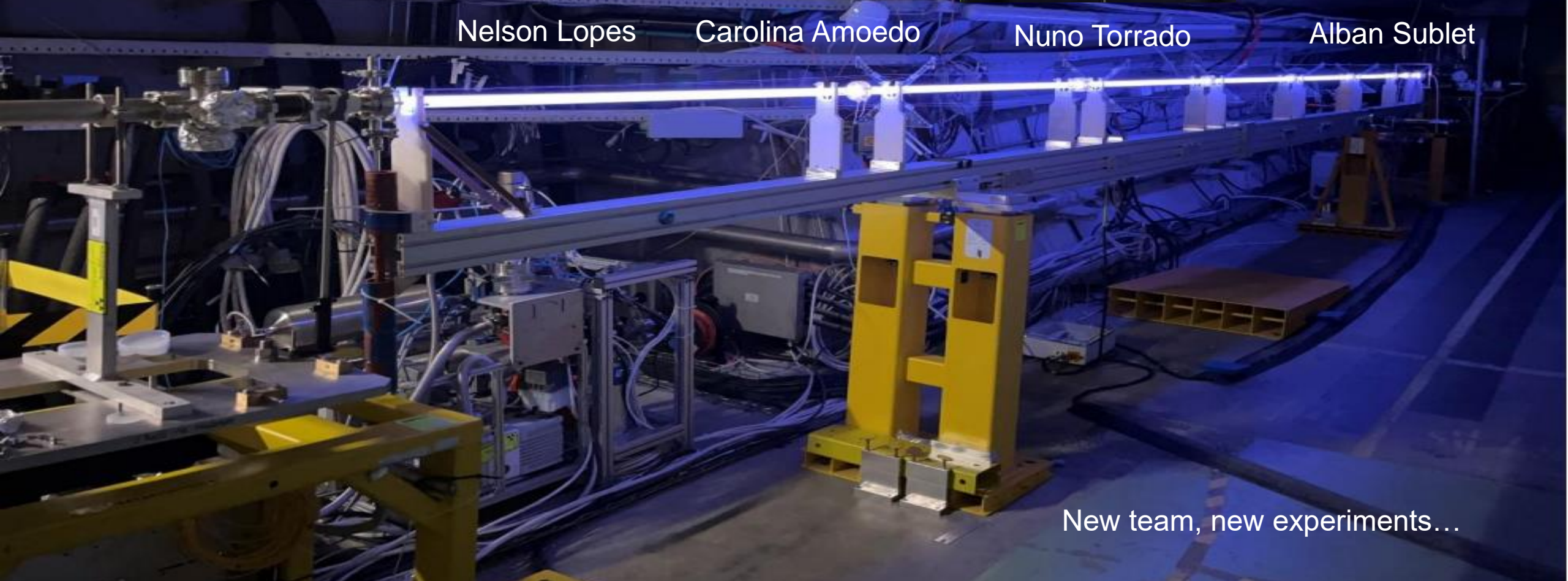
Carolina Amoedo



Nuno Torrado



Alban Sublet



New team, new experiments...

AWAKE@CERN now...



Luca Ranc



Eloise Guran



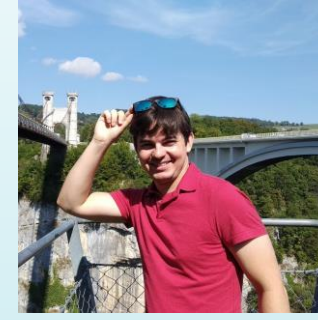
Giovanni
Zevi Della Porta



John Farmer



Michele
Bergamanschi



Jan Pucek

Arthur
Clairembeau

Erwin Walter



Fern Pannell



Nikita Zena van Gils



Jan Mezger

Nuno Torrado

Alban Sublet

Nelson Lopes



Patric Muggli



Edda Gschwendtner

Carolina Amoedo

Thank You to my Family for Enabling it All...



Mechanical Skills



Understanding Electronics



→ Education and high quality work was their highest priority...



EAAC 2015



Motivation

Feedback

Sharing

Teaching

Opportunities



EAAC 2015



Thank you!



This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.