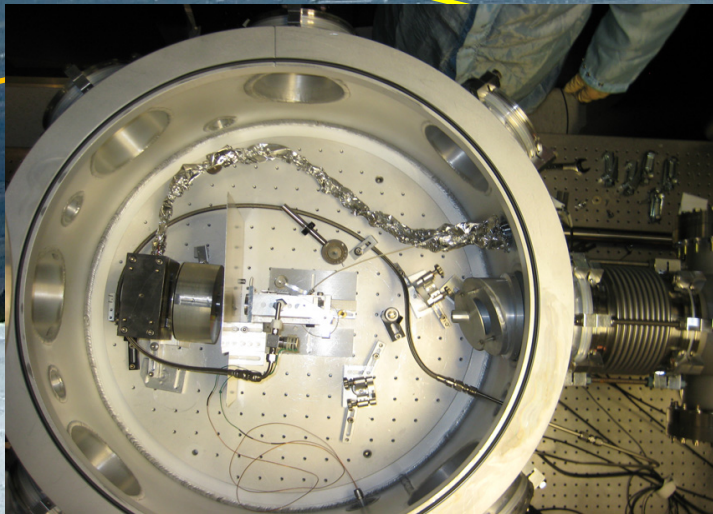


“Road Maps in Europe”

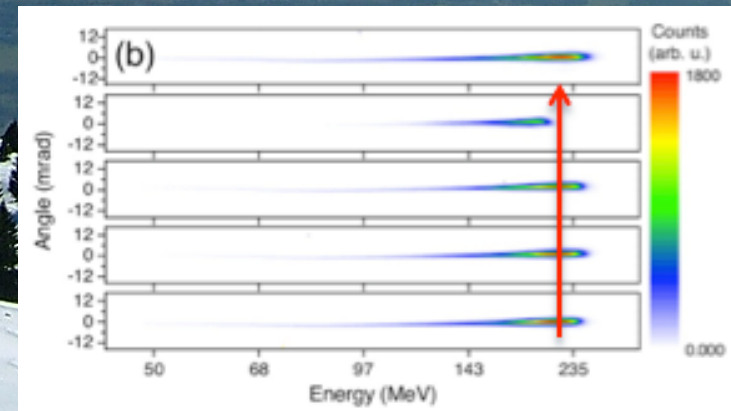
Bernhard Holzer,
CERN

Towards future Acceleration Concepts



Plasma cell Univ. Texas, Austin

$E_e = 2 \text{ GeV}$



“The European Landscape”

... to get an overview about the situation in different European Countries,

and discuss issues like:

*- is there in the countries **some coordination or roadmap** on advanced accelerator techniques*

*-**how is the field of new acc. techniques connected** with the conventional accelerator community*

*-are there **facilities where experiment/simulations are done** towards new acc. techniques*

*-are these institutes and colleagues **collaborating with other national/international groups?***

*- which **institutes play a major role** in the field*

“The European Landscape”

UK

Oxford
Strathclyde
Manchester
Lancaster
Liverpool
Astec
Cockcroft
STFC
JAI
Uni Coll. London
Imperial Coll London
Queens Uni Belfast
RAL

Port

Lisboa

F

Luli
Soleil
LPGP
LOA
CEA Lydil
Lab lePrince Ringuet
LAL
Ecole Poly

*Andrei Seryi, Simon Hooker
S. Cipiccia, D. Jaroszynski, R. Bingham
Andy Wolski
G. Burt, Alec Thomas
C. Welsch*

*G. Burt
Susie Sheehy
Andrei Seryi, Laura Corner, P. Burrows
P. Sherwood
Z. Najmudin, S. Mangles
Gianluca Sarri
R. Trines*

Luis Silva, R. Fonseca, J. Vieira

*P Audebert, JR Marquès
ME Couprie
B Cros
Victor Malka, J. Faure
P. Martin, S Dobosz,
A Specka
N Delerue
Gerard Mourou*

It

INFN (Sparc)
Pisa Uni
Consiglio Naz. Delle Rech. INO
La Sapienza

Czech / Romania / Hungary

ELI
Wigner Inst.

S

Lund

D

Uni Duesseldorf
LMU Muenchen
DESY
Darmstadt
Juelich
MPI Quant Optik
MPI Phys.
MPI Plasma Phys, Greifswald
Erlangen

CH

CERN, AWAKE
Plasma Center Lausanne

N

Oslo

*Massimo Ferrario
A. Giulietti
L. Gizzi*

*Gerad Mourou, Kazuo Tanaka
Daniel Barna*

C. Wahlstroem, O Lundh

*A. Pukhov
T. Tajima, Karsch
Brinkmann, Assmann, Gruener, Osterhoff
M. Roth, M. Schollmeier
Paul Gibbon
S. Karsch
Alan Caldwell, P. Muggli
Buttenschoen
Peter Hommelhoff*

*Edda, Freddy, Eckardt
Plyushchev*

Erik Adli

“The European Landscape”



Local activities

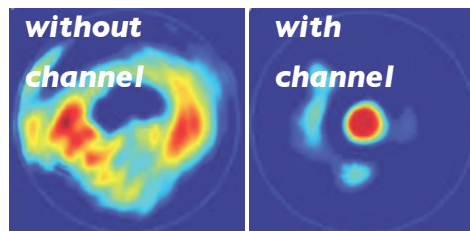
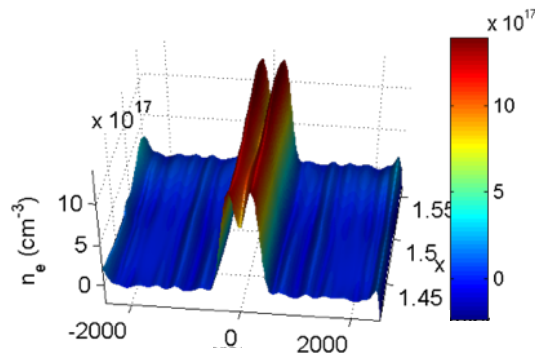
IST coordinates the plasma based accelerator efforts in Portugal.

National activities currently involve IST and ISCTE Lisbon University Institute.

Mission of the Associated Laboratory in which activity is included explicitly mentions Plasma Accelerators: two research faculty positions and technical staff, involved in several international efforts

Laboratory for Intense Lasers L²I

Key activities focus development of plasma channels for guiding



N. Lopes et al. and J. M. Dias et al.

Theory and simulations

With UCLA, IST develops OSIRIS and is a founder of the OSIRIS consortium



osiris framework

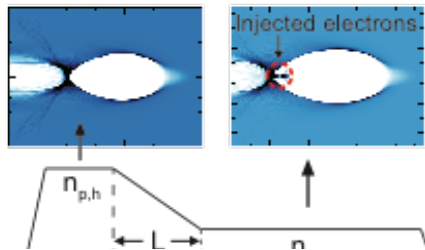
- **Massively Parallel, Fully Relativistic Particle-in-Cell (PIC) Code**
- **Visualization and Data analysis infrastructure**
- **Scalability to 1.6 M cores**
- **Advanced physics modules for efficient LWFA simulations**

Consulting activities for providing design reports for ELI-beamlines ELI-ALPS

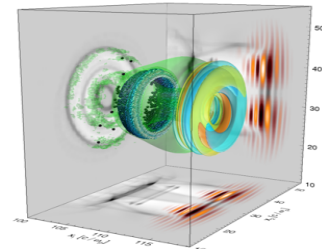
Scientific activities



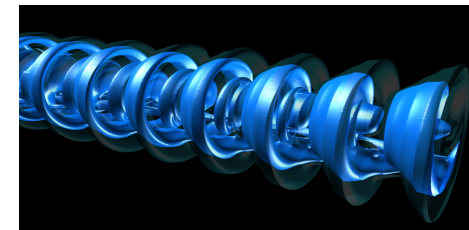
**Theory and simulations
work package co-leaders**



**Theory and simulations
work package co-leaders**



Task coordinators: plasma accelerators driven by exotic lasers



Collaboration with other national/ international groups

AWAKE experiment at CERN: Theory and simulation support, Novel techniques for plasma sources

LWFA experiments: Imperial College, Strathclyde, Laboratoire d'Optique Appliquée, CEA, Max Planck Institute for Quantum Optics

Accelerator laboratories: DESY, John Adams Institute

*Major activities are concentrated at Wigner RCP,
focus on these two subjects:*

Studies for Laser or plasma driven acceleration:

associated member of AWAKE

development and application of real-time diagnostics of rubidium plasma (experiment and theory), and for the numerical simulation of nonlinear propagation of strong ionizing pulses

A national roadmap is under construction; in the meantime it's Wigner's programme.

Wigner RCP has laser labs where experiments/simulations are done for plasma acceleration.

Working towards a construction / test lab together with our industrial partners.

ELI: Extreme Light Infrastructure court. Kazuo Tanaka

Czech Republic, Romania, Hungary



ELI: Research Infrastructure (RI), part of the European **ESFRI Roadmap**.

Aims to host the most intense beamline system world-wide, develop new interdisciplinary research opportunities with light from these lasers **and secondary radiation derived from them**, and make them available to an international scientific user community.

ELI is three (4) sites:

Prague, Czech Republic: **ELI Beam Lines**, Laser based plasma driven electron/ion acceleration

Bucharest, Romania: **ELI Nuclear Physics**, will focus on laser-based nuclear physics

Szeged, Hungary: **Electron dynamics in atoms, molecules, plasmas and solid states**

xxx

Highest Intensity Laser Pulse:

10 PW with 200J at 25 fsec pulse width $\rightarrow 10^{22}$ - 10^{23} W/cm².

Goal: Particle acceleration up to some 10 GeV for electrons.

Plan to do these highest energy demonstration experiments for **electron and ion at the beginning including LWFA scheme.**

Collaborations:

Max Born Institute (Germany), LLNL (USA), RAL (UK), France, Japan, Romania.

Norway:

court. Erik Adli



Are there facilities where experiment / simulations are done towards new acc. techniques ?

We have no dedicated NAT facilities in Norway.

No specific NAT laser or beam infrastructure.

PIC simulations (Osiris and QuickPIC) on Norwegian HPC-clusters.

Is there in your country some coordination or roadmap on advanced accelerator techniques

No, not needed I think with the current level of activity.

How is the field of new acc. techniques connected with the conventional accelerator community?

*We have done some paper studies on **how staging of plasma cells could be done** for collider applications.*

Are these institutes and colleagues collaborating with other national/international groups ?

*Yes, we **collaborate with CERN and SLAC**, and lately also **with DESY and Oxford** for plasma lens experiments*

Sweden:

court. Olle Lundh, Claes-Goeran Wahlstroem



Are there facilities where experiment / simulations are done towards new acc. techniques ?

*Atomic Physics division of **Lund University** in Sweden,
30 TW Ti:sapphire laser (30 fs, 1 J)
serves two experimental stations, located in separate rooms
and **dedicated to laser-based acceleration of ions and electrons** respectively.*

***New group**, lead by Laszlo Veisz, which is about to start experimental activities at **Umeå University**.*

Research is experimental, but we also perform simulations using the Particle-in-Cell code CALDER-CIRC.

How is the field of new acc. techniques connected with the conventional accelerator community?

*We **collaborate and coordinate our activities with two theory groups at Chalmers in Gothenburg**, lead by Tünde Fülöp and Matthias Marklund respectively.*

*We also coordinate and collaborate with the **accelerator machine group at the MAX IV Lab**.*

Sweden:

court. Olle Lundh, Claes-Goeran Wahlstroem



*Is there in your country some coordination or roadmap on advanced accelerator techniques
Laser activities in Lund are coordinated through the **Lund Laser Centre (LLC)***

Collaborations with other national/international groups ?

*Olle Lundh is representing Lund University in **EuCARD-2 and ARIES**,
and we are associated members in **EuPRAXIA**. Through **ARIES**,
which starts in May this year, we will provide trans-national access
for users to electron and x-ray beams produced by LPA.*

Germany: *court. Florian Gruener, Jens Osterhoff, Ralph Assmann, Peter Hommelhoff*
Duesseldorf, Muenchen, DESY, Uni-Hamburg, Darmstadt, Juelich, Greifswald, Erlangen, ...

Erlangen:

Dielectric Laser Acceleration: ACHIP collaboration “Accelerator on a Chip”



Are there facilities where experiment / simulations are done towards new acc. techniques ?

Experiments at the Swiss FEL, PSI

Theory partners at TU-Darmstadt (Boine-Frankenheim)

How is the field of new acc. techniques connected with the conventional accelerator community?

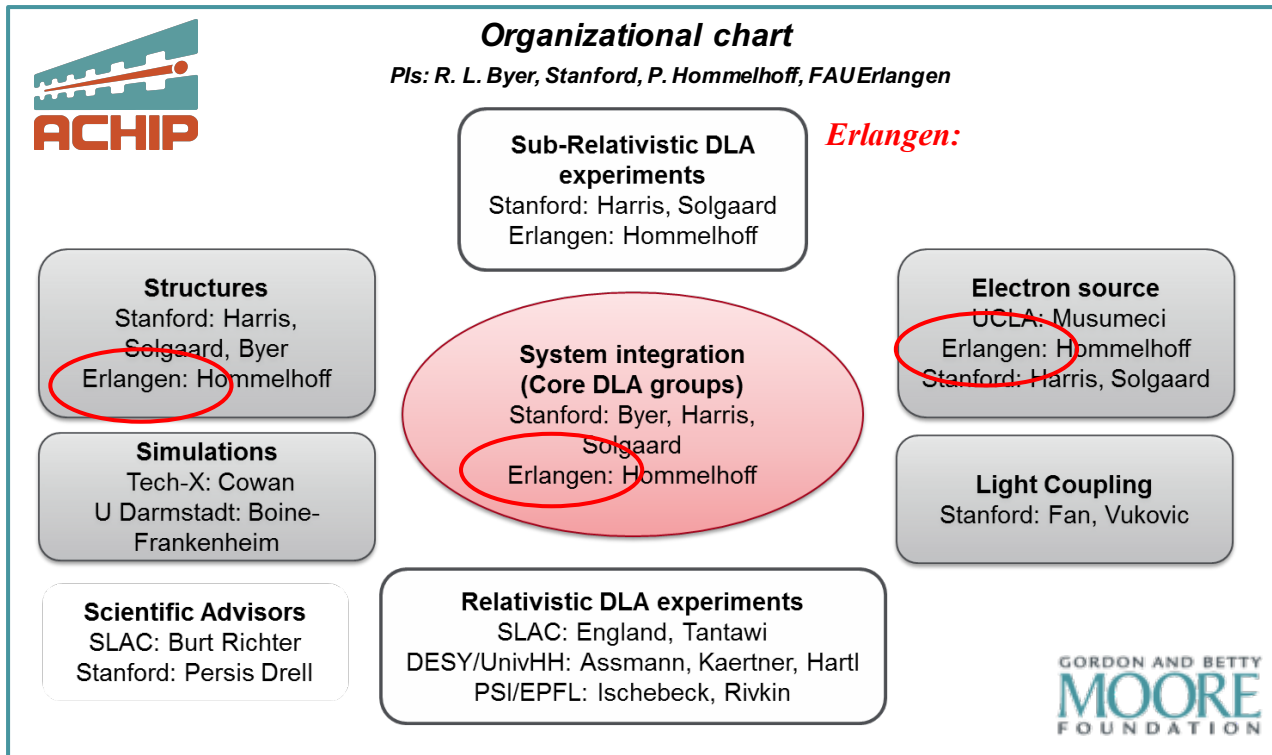
Collaborations with DESY, SLAC und PSI

Is there in your country some coordination or roadmap on advanced accelerator techniques

Goal 1: Demonstrate acceleration with an integrated multi-stage DLA with GV/m peak gradients and energy gain ≥ 1 MeV for sub-relativistic and relativistic electrons.

Goal 2: Exploration of capabilities enabled by the transverse fields in DLA structures, including X-Ray and EUV production, focusing, and sub-fs-level diagnostics. ... by 2020!

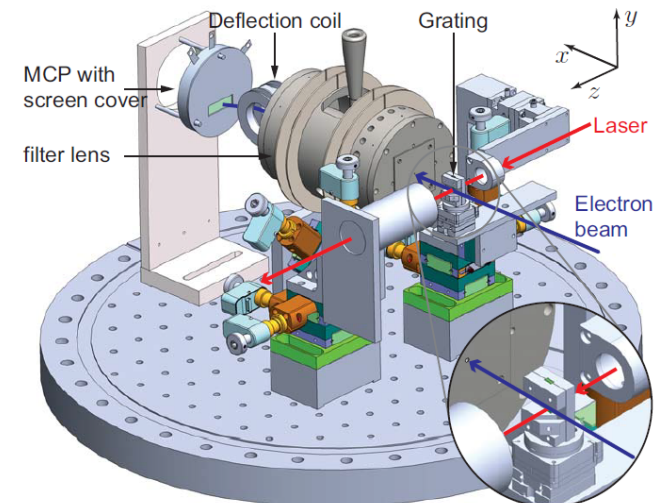
ACHIP: Accelerator on a Chip International Program



ACHIP Scientific Advisory Board: Chan Joshi, UCLA, Lia Merminga, SLAC, Reinhard Brinkmann, DESY

Program start: Dec. 2015

2013: Proof-of-concept experiments at FAU Erlangen J. Breuer, P. Hommelhoff with a 30 keV beam, Phys. Rev. Lett. and SLAC



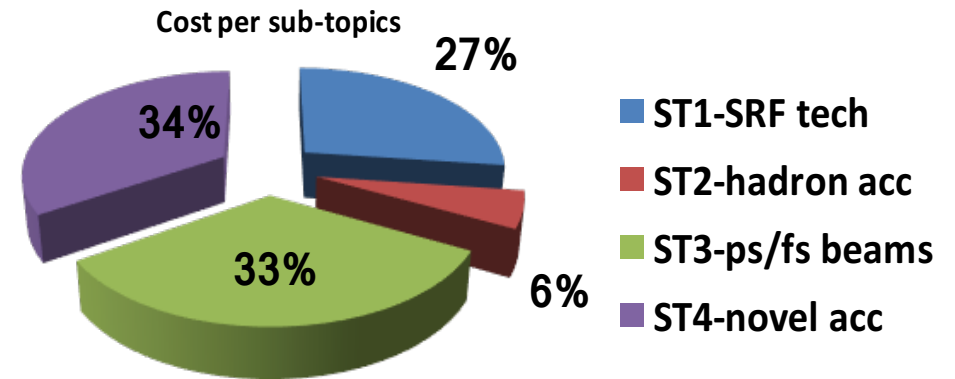
Germany:

Ralph Assmann, Ulrich Dorda, Florian Gruener, Jens Osterhoff et al



Helmholtz Association

= “the large national research centers”



Plasma acceleration: *LAOLA Collaboration* collaboration between University Hamburg, DESY plus a few Helmholtz centres

LAOLA Collaboration Hamburg



F. Grüner



A. Maier

Laser: Ti:Sa 200 TW, 25 fs pulse length, 5 Hz repetition rate

- *Initially: Laser-driven wakefields in REGAE. LUX exp. towards FEL*
- *Later: Move to SINBAD facility.*

Beams:

– **REGAE:** 5 MeV, fC, 7 fs bunch length, 50 Hz

– **FLASH:** 1.25 GeV, 20 – 500 pC, 20 - 200 fs bunch length, 10 Hz.

Beam-driven plasma wakefields. Beam-driven plasma wakefields with shaped beams and innovative injection methods. Helmholtz VI with UK collaboration.

FLASHForward ▶



J. Osterhoff

– **PITZ:** 25 MeV, 100 pC, 20 ps bunch length, 10 Hz.
Beam modulation experiment in a plasma cell, preparation to CERN experiment AWAKE



F. Stephan

– **SINBAD:** dedicated R&D, multi purpose, 150 MeV, 0.01 – 3 pC, down to < 1 fs bunch length, pulse rate 10 – 1000 Hz



U. Dorda



B. Marchetti



Similarly strong teams in other Helmholtz centers!

France: *court. Brigitte Cros, Nicolas Delerue et al*



Are there facilities where experiment / simulations are done towards new acc. techniques ?

Main laser facilities for LWFA : at LOA Salle Jaune laser, LIDYL UHI100 facility and LULI Apollon facility

A consortium of 12 labs is building the APOLLON CILEX facility with one target area dedicated to LWFA in gas targets with multi-PW beams

Photo-injector development at LAL (PHIL)

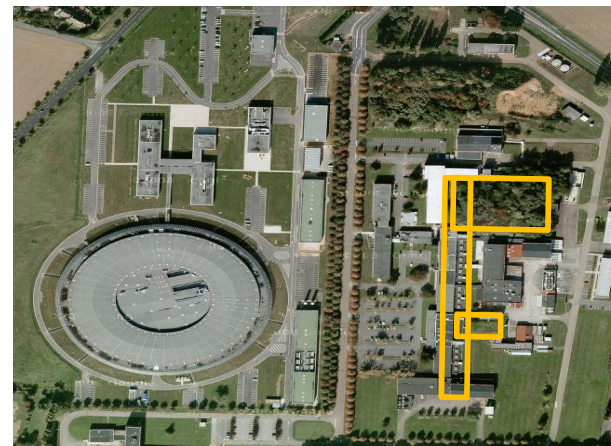
Simulations codes : CALDER: LOA, SMILEI: LULI, LLR, WARP, WAKE: LPGP, CEA irfu

Is there in your country some coordination or roadmap on advanced accelerator techniques

Short term coordination developed around the APOLLON CILEX facility

Long term roadmap not defined, under discussion at CNRS and CEA

Footprint of the APOLLON CILEX facility, located at l'Ormes de Merisiers, close to SOLEIL



France:

How is the field of new acc. techniques connected with the conventional accelerator community?

APOLLON CILEX brings together laser labs, plasma physics labs and conventional accelerator labs;

Existing active collaboration around preparatory experiments at UHI100 facility on the optical injector development and beam transport

*Common **multi-stage laser plasma experiment planned** at APOLLON CILEX*

Are these institutes and colleagues collaborating with other national/international groups ?

Most of the activity in this field is in Paris area (Université Paris Saclay)

Involvement in European projects , collaboration through JRAs (LASERLAB, EUCARD, ARIES), EUPRAXIA

Major contributions of the French teams to EUPRAXIA, leading 5 WP of the EUPRAXIA design study

LOA, UHI100, LULI are user facilities opened to international community, collaboration through access

Collaboration on theory/development of codes (ex. SMILEI, WARP)

France:



Mid- / long term plan / possible collaborations towards a future particle accelerator

APOLLON-CILEX is a major project

Strong involvement in Eupraxia DS,

France is a possible site for Eupraxia project (awaiting decision)

*Laser plasma acceleration is among the priorities of CEA IRFU and CNRS In2p3,
But a global roadmap has not been established*

Institutes that play the major role in the field

LOA: Pioneer group which contributed to the dream beam papers 10 years ago.

LPGP: Brigitte Cros has also a long tradition of working in that field.

LLR: Arnd Specka is deputy spokesman of Eupraxia.

CEA/LYDIL: High power lasers used for plasma acceleration.

CEA/IRFU: strong involvement in Eupraxia

LAL: ESCULAP project together with the LASERIX laser

Italy: *court. Massimo Ferrario et al*



Are there facilities where experiment / simulations are done towards new acc. techniques ?

SPARC_LAB (INFN Frascati), and CNR-INO Pisa

Is there in your country some coordination or roadmap on advanced accelerator techniques

*Coordinated under the umbrella of EuPRAXIA and in particular in the framework of the proposal for the Italian site named **EuPRAXIA@SPARC_LAB**.*

*All the **major Italian research institutes (INFN, ENEA, CNR, Universities of Roma and Milano)** are contributing to the Design Study and to the experimental activities under way in Frascati (LWFA and PWFA) and Pisa (LWFA).*

How is the field of new acc. techniques connected with the conventional accelerator community?

Major connection in Frascati (long tradition in conventional accelerators design, construction operation diagnostics etc ...)

We are investigating both the laser driven and beam driven plasma options.

In particular for the beam driven option we are designing a 1 GeV X-band linac in strong collaboration with the Frascati RF group in order to produce the required electron beam driver.

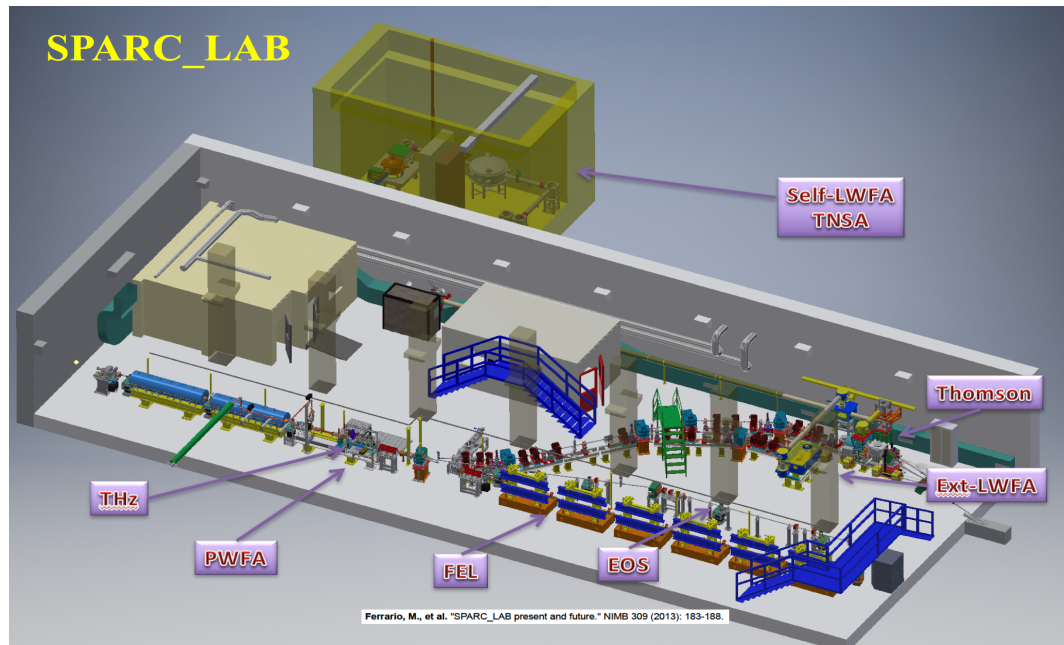
Italy: *court. Massimo Ferrario et al*



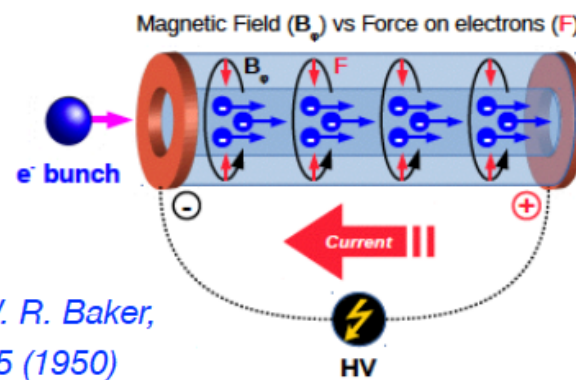
Are these institutes and colleagues collaborating with other national/international groups ?

*In addition to the Italian network (INFN, ENEA, CNR, Universities of Roma and Milano) we have a strong **collaboration with UCLA** (Prof. J.B. Rosenzweig) **and the Hebrew university of Jerusalem** (Prof A. Zigler) concerning the beam driven acceleration techniques, TNSA proton acceleration, simulations and capillary discharge design.*

***Collaboration with CERN** is growing around the X-band RF technology. **Collaborating with the EuPRAXIA** team.*



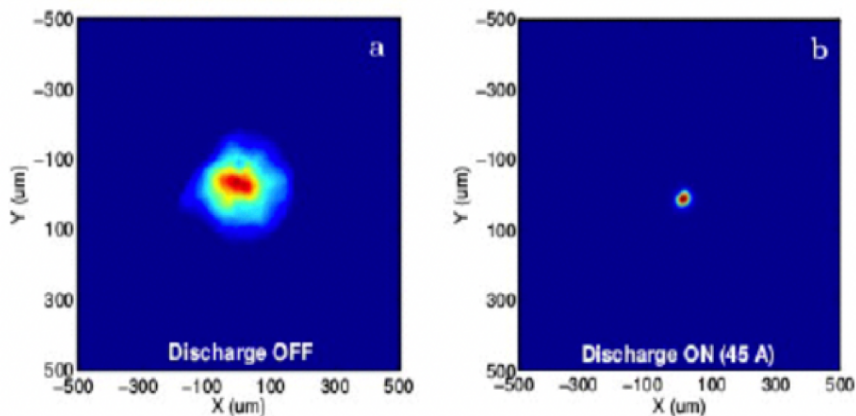
- ❖ Matching is critical for preserving beam quality, both when the bunch enters the plasma and when it leaves the interaction area
- ❖ Discharge current in a gas-filled capillary



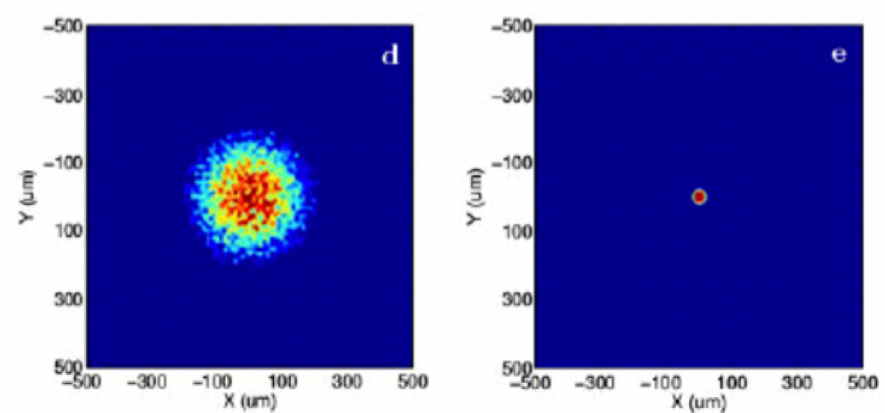
- Radial focusing

*W. K. H. Panofsky and W. R. Baker,
Rev. Sci. Instrum. 21, 445 (1950)*

Measurement



Simulation



UK: *court. Simon Hooker et al*



Plasma Wakefield Accelerator Steering Committee: *representing UCL, STFC, Imperial, York, Cockcroft, JAI, Oxford, QUB, Strathclyde, and Manchester*

- ▶ Formed in response to UK community meeting in February 2016
- ▶ Terms of reference (partial list)
 - **Develop a coherent strategy and roadmap** for the development and application of plasma acceleration in the UK
 - **Initiate joint activities** supporting UK roadmap and growth of the field in the UK
 - **Inform and support Research Councils** in the development of targeted funding calls
- ▶ Committee comprises representatives of:
 - UK universities
 - Central Laser Facility (RAL)
 - Accelerator Science and Technology Centre (ASTeC)
 - STFC Accelerator Strategy Board



UK: *court. Simon Hooker et al*
Plasma Wakefield Accelerator Steering Committee



Collaborations towards a future particle accelerator

AWAKE

CI/Lancaster providing the linac booster
CI/Liv and CI/Man providing diagnostics
CI/Man providing beamline design for future PP expts with AWAKE-like beams
University College London providing the electron spectrometer

CERN

AWAKE, CLEAR

Many US universities and facilities, e.g.

SLAC FACET (E203, E206, E210)

Brookhaven National Laboratory, University of Michigan, University of Maryland

EuPRAXIA

Provide 6 of 16 participants, Contributors to many WPs

ELI

Contributors to TDRs & commissioning experiments on ELI-NP, ELI-beamlines, ELI-Hungary

Helmholtz VI on Plasma wakefield acceleration

John Adams Institute, Strathclyde

UK: *court. Simon Hooker et al*
Plasma Wakefield Accelerator Steering Committee

Facilities:

Central Laser Facility

Astra-Gemini laser, Vulcan and Vulcan PW

ASTEC:

CLARA: PWFA, hybrid LWFA & PWFAs

University-based facilities

*SCAPA (Scottish Centre for the Application of Plasma-based Acc.)
Imperial, Oxford ...*

Accelerator institutes

Cockcroft Institute (CI), John Adams Institute (JAI)

Computing facilities

Hartree Centre: centre for HPC, data analytics, machine learning...

DiRAC: Distributed HPC; 5 installations; 27 universities

ARCHER: UK National Supercomputing Service;

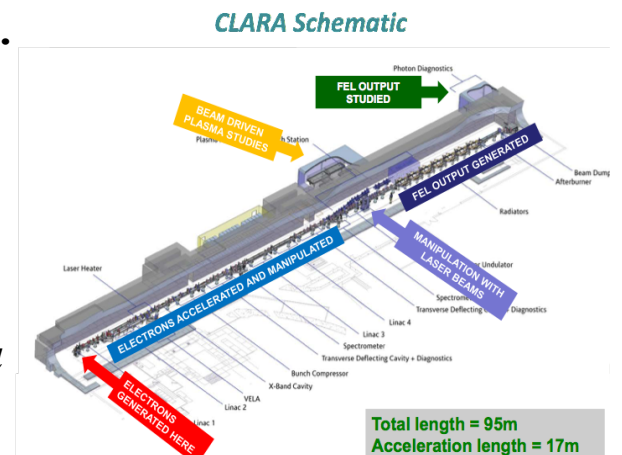
N8HPC: partnership of 8 universities

SCARF: HPC cluster at RAL for CLF users and collaborators

Many university-scale clusters

Collaborative Computation Project (CCP) on Computational Plasma Physics (Coordinated by Tony Arber, University of Warwick)

Coordinates code development (e.g. EPOCH)



“The European Landscape”

