

SUMMARY OF ALEGRO 2024



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With:
Brigitte Cros, U. Paris Sud
Jorge Vieira, IST Lisbon

WARNING



- ✧ Most illustrations “borrowed” from slides presented at the workshop ...
(Thank you for not pressing charges against me ...)
- ✧ All credit goes to the authors ...
- ✧ All mistakes/misrepresentations are mine ...
- ✧ I apologize for not choosing YOUR favorite ...



International Committee For Future Accelerators (ICFA)

Panels:

ILC International Development Team (Chair – Tatsuya Nakada, EPFL, Lausanne)

ICFA Instrumentation Innovation and Development Panel (Chair – Ian Shipsey, Oxford)

ICFA Beam Dynamics Panel (Chair – Yuan He, IMPCAS)

ICFA Panel on Advanced and Novel Accelerators (Chair – Patric Muggli, MPP)

ICFA Panel on Sustainable Accelerators and Colliders (Chair – Thomas Roser, BNL)

ICFA Panel on the Data Lifecycle (Chair – Kati Lassila-Perini / Helsinki Institute of Physics)

ANA ⇔ >1GeV/m

ICFA-ANA PANEL MEMBERS



- ✧ Bruce Carlsten, Los Alamos National Laboratory (LANL), USA
- ✧ Brigitte Cros, Centre National de la Recherche Scientifique (CNRS), Université Paris Sud, France
- ✧ Massimo Ferrario, Istituto Nazionale di Fisica Nucleare (INFN), Italy
- ✧ Simon Hooker, University of Oxford, UK
- ✧ Tomonao Hosokai, Univ. Osaka, Japan
- ✧ Masaki Masaki Kando, National Institutes for Quantum and Radiological Science and Technology, Japan
- ✧ **Patric Muggli, Max Planck Institute for Physics (MPP), Germany, (chair, May 1, 2024)**
- ✧ Jens Osterhoff, Lawrence Berkeley National Laboratory (LBNL), USA
- ✧ Philippe Piot, Northern Illinois University (NIU), Fermi National Accelerator Laboratory, (FNAL), USA
- ✧ James Rosenzweig, University of California, Los Angeles (UCLA), USA
- ✧ Carl Schroeder, Lawrence Berkeley National Laboratory (LBNL), USA
- ✧ Chuanxiang Tang (previous chair), Tsinghua University, China



HOW DID WE GET HERE?

<https://indico.cern.ch/event/569406/>



ANAR2017: Advanced and Novel Accelerators
for High Energy Physics Roadmap Workshop
2017



Chair:
Brigitte Cros (2013-18)

Endorsed by



HOW DID WE GET HERE?

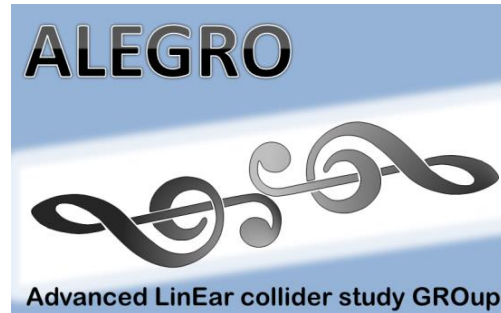
<https://indico.cern.ch/event/569406/>



ANAR2017: Advanced and Novel Accelerators
for High Energy Physics Roadmap Workshop
2017



Chair:
Brigitte Cros (2013-18)



Endorsed by


... is one of the major outcome of the ANAR 2017 workshop!

(Advanced LinEar collider study GROup) is a study group towards Advanced Linear Colliders.
ALEGRO's general charge is to coordinate the preparation of a proposal for an advanced linear collider in the multi-TeV energy range.

HOW DID WE GET HERE?

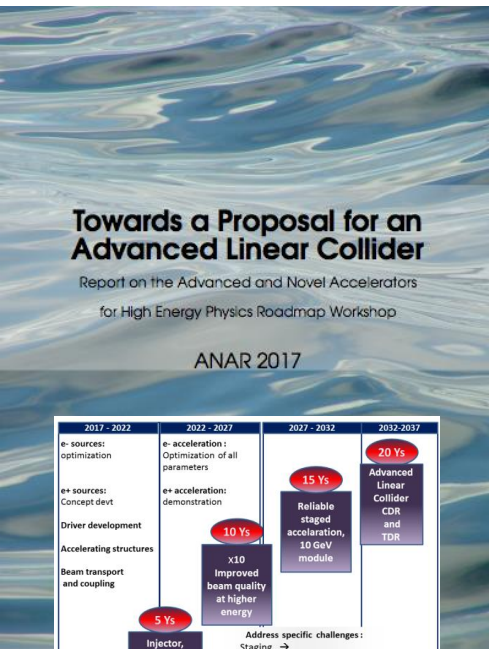
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ANAR2017: Advanced and Novel Accelerators for High Energy Physics Roadmap Workshop 2017

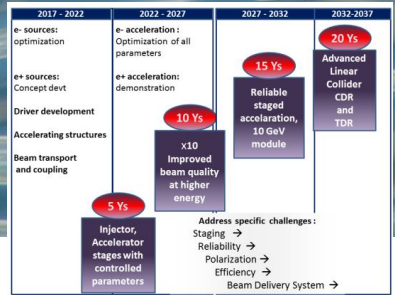


Contents



Document broadly distributed to laboratories management and funding or deciding agencies...
to demonstrate the existence of a community and of a plan for ANA* applications to high-energy physics

... is another major outcome of the ANAR 2017 workshop!



*Advanced and Novel Accelerators

WHAT IS ALEGRO?

ALEGRO



Advanced LinEar collider study GROUp

is the Advanced LinEar collider study GROUp

is driven by the ICFA-ANA panel

workshops endorsed by ICFA

is inclusive

structures, plasma, particle beams, laser pulses, ...

worldwide


has no source of funding (so far)

did, and will continue to promote ANAs for applications to particle physics and high-energy physics

Founded in 2016 by B. Cros, P. Muggli and the ICFA-ANA panel



SERIES OF WORKSHOPS



ANAR2017: Advanced and Novel Accelerators for High Energy Physics Roadmap Workshop 2017

2017



ALEGRO 2024

ALEGRO Workshop 2024, Lisbon, 19-22 March

2024



Somerville College

ALEGRO 2018 workshop at Oxford

26 March - 29 March 2018, Oxford, UK



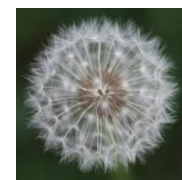
2018



ALEGRO WORKSHOP 2019

ALEGRO WORKSHOP 2019 CERN
26-29 March

2019



2023



ALEGRO 2023
22-24 MARCH


ALEGRO 2023

Location: DESY Hamburg, Germany
Organisation: Brigitte Cros, Richard D'Arcy, Patric Muggli, Jens Osterhoff
Administration: Daniela Koch

ALEGRO2023 Workshop



SERIES OF WORKSHOPS



ANAR2017: Advanced and Novel Accelerators for High Energy Physics Roadmap Workshop 2017

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ALEGRO 2024

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UNIVERSITY OF OXFORD
JAI
Somerville College

ALEGRO 2018 workshop at Oxford

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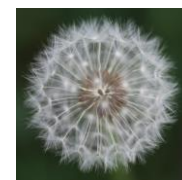
2018



ALEGRO WORKSHOP 2019

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ALEGRO2023 Workshop

Next: USA 2025?
Driven by US ANA panel members?



ALEGRO INPUT FOR ESPP (2019)

Towards an Advanced Linear International Collider

ALEGRO collaboration

Abstract

This document provides additional information to support the ALEGRO proposal for R&D relevant to an Advanced Linear International Collider, ALIC, based on high gradient acceleration concepts.

Keywords

Advanced and Novel Accelerators, multi-TeV electron-positron linear collider

Editing Board

Brigitte Cros, Patric Muggli, Carl Schroeder, Simon Hooker, Philippe Piot, Joel England, Spencer Gessner, Jorge Vieira, Edda Gschwendtner, Jean-Luc Vay, Michael Peskin

ALEGRO collaboration members as of September 2018 : Erik Adli¹, Weiming An², Nikolay Andreev³, Ozgur Apsimon⁴, Ralph Assmann⁵, Jean-luc Babigean⁶, Robert Bingham⁷, Tom Blackburn⁸, Christopher Brady⁹, Michael Bussmann¹⁰, Bruce Carlsten¹¹, James Chappetti¹², Jian Bin Ben Chen¹³, Sebastien Corde¹⁴, Laura Corner¹⁵, Benjamin Cowan¹⁶, Brigitte Cros¹⁷, Joel England¹⁸, Eric Esarey¹⁹, Ricardo Fonseca²⁰, Brian Foster²¹, Spencer Gessner¹³, Leonida A Gizzi²², Daniel Gordon²³, Edda Gschwendtner¹³, Anthony Hartin⁵, Bernhard Hidding²⁴, Mark Hogan¹⁸, Simon Hooker²¹, T. Hughes²⁵, Alexei Kanareykin²⁶, Stefan Karsch²⁷, Valentin Khoze²⁸, Pawan Kumar²⁹, Wim Leemans¹⁹, Francois Lemery⁵, Ang Li³⁰, R. Li¹⁸, Vladyslav Libov⁷, Emily Sistrunk Link³¹, Michael Litos³², Gregor Loisch⁵, Nelson Lopes^{20,33}, Olle Lundh³⁴, Alexey Lyapun³⁵, Edu Mann¹³, Mattias Marklund⁸, Timon Mehrling¹⁹, Patric Muggli^{13,27}, Pietro Musumeci², Zulikar Najmudin³³, Uwe Niedermayer³⁶, Jens Osterhoff⁵, Marc Palmer¹⁴, Rajeev Pattathil⁷, Michael Peskin¹⁵, Philippe Piot³⁸, John Power³⁹, Alexander Pukhov⁴⁰, Heather Ratcliffe⁴¹, Marc Rieblum⁴², Veronica Sanz⁴³, Gianluca Sarni⁴⁴, Yuri Saveliev⁷, Levi Schachter⁴⁵, Lucas Schaper⁵, Norbert Schoenenberger³⁰, Carl Schroeder¹⁹, Sarah Schroeder⁵, Daniel Schulte¹³, Andrei Seryi⁴⁶, Sergey Shchelkunov³⁰, Craig Siders³¹, Evgenya Simakov¹¹, Christophe Simon-Boisson⁴⁷, Michael Spannowsky²⁸, Christina Swinson³⁷, Andrzej Szczepkowicz⁴⁸, Roxana Tarkeshian⁵, Johannes Thomas⁴⁹, Jumpang Tian⁴⁹, J.V. Tilborg¹⁹, Paolo Tomassini²², Vasili Tsakanov⁵⁰, Jean-Luc Vay¹⁹, Jorge Vieira²⁰, Henri Vincenti²¹, Roman Waczkak²¹, Dan Wang⁵², Stephen Webb⁵³, Glen White¹⁸, Guoxing Xia⁴, Hitoshi Yamamoto⁵⁴, Tevong You⁵⁵, Igor Zagorodnov⁵

International
ANA
Community

arXiv:1901.10370v2 [physics.acc-ph] 30 Jan 2019

arXiv.1901.10370

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⁶ LAL, Orsay, France

⁷ STFC, UK

⁸ Chalmers, Sweden

⁹ Warwick, UK

¹⁰ HZDR, Germany

¹¹ LANL, Los Alamos, New Mexico, USA

¹² University College London, UK

ALEGRO 2024 PROGRAM

Tue 19/03 Wed 20/03 Thu 21/03 Fri 22/03 All days

Print PDF Full screen Detailed view Filter

Season legend

EU and US Roadmaps Welcome Session and Introduction

14:00	Registration
15:00	Opening Words
15:00 - 15:30	ROAD Roadmap of the European Particle Physics Strategy
15:30 - 16:00	US perspective on plasma based accelerators and future colliders
16:00 - 16:30	Discussion on Organisation / Funding
16:30 - 17:00	Coffee Break
17:00 - 17:30	Physics considerations for laser-plasma linear colliders: achievements and perspectives
17:30 - 18:00	Advances in Structure Wakefield Accelerator R&D for integration in a Linear Collider
18:00 - 18:30	

Tue 19/03 Wed 20/03 Thu 21/03 Fri 22/03 All days

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Season legend

Advanced collider concepts Staging Staging and scalability Sustainability

10:00	Sustainability
10:30 - 10:50	Sustainability at CERN: strategy for future machines
10:50 - 11:00	Discussion on sustainability/efficiency budget prospects for LWFs, PMWAs
11:00 - 12:00	Coffee Break
12:00 - 12:30	Prospects and challenges for high-repetition-rate plasma sources for future colliders
12:30 - 13:00	General staging issues
13:00 - 13:30	Lunch Break
13:30 - 14:30	Plasma mirrors for coupling stages
14:30 - 15:00	Multilayer LWFA based on curved plasma channels
15:00 - 15:30	Hybrid LWF A-driven PMWAs as a test platform for staged plasma acceleration
15:30 - 16:00	Simulations of Next-Generation Colliders
16:00 - 16:30	Coffee Break
16:30 - 17:00	HALIF
17:00 - 17:30	Towards a Higgs Factory based on Proton Driven Plasma Wakefield Acceleration
17:30 - 18:00	Discussion
18:00 - 18:30	

Tue 19/03 Wed 20/03 Thu 21/03 Fri 22/03 All days

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Season legend

Applications of advanced accelerators Deam Delivery System and positron acceleration Poster Session Structured Wakefield Accelerators

10:00	Existence mixing of flat beams in plasma accelerators
10:30 - 10:50	Challenges for flat focusing
10:50 - 11:00	Laser driven production of ultra short high quality positron beams
11:00 - 11:30	Coffee Break
11:30 - 12:00	Experiences with Wakefield Acceleration at SASEdSL
12:00 - 12:30	Beam quality preservation using multi staged dielectric based rectangular waveguides
12:30 - 13:00	Lunch Break
13:00 - 14:30	AWAKE a plasma wakefield accelerator for particle physics
14:30 - 15:00	The EuPRAXIA project: a plasma-based accelerator user facility for the next decade
15:00 - 15:30	Injector for PLSTIA IV
15:30 - 16:00	Injector for a circular electron positron collider
16:00 - 16:30	Coffee Break
16:30 - 17:00	Poster Session
17:00 - 18:00	

Tue 19/03 Wed 20/03 Thu 21/03 Fri 22/03 All days

Print PDF Full screen Detailed view Filter

Season legend

Open Discussion and Conclusion Posters and divergence physics

10:00	SFQED - Disruption Interplay in Lepton Beam Interaction for Future Colliders
10:30 - 10:50	Positron acceleration in plasma wakefields for linear colliders: a review of progress and challenges
10:50 - 11:00	SLAC FACET II Positron Source
11:00 - 11:30	Generation and acceleration of polarized electron bunches in plasma accelerators
11:30 - 12:00	Coffee Break
12:00 - 12:30	Discussion on Simulations
12:30 - 13:00	Conclusions
13:00 - 13:30	

❖ Monitor progress

❖ Understand the landscape (science, collaborations)

❖ ESPP, Snowmass, P5

❖ Sustainability: feature advantages, sustainability:

❖ ANA collider: 2x shorter, 2x less concrete, less SF₆, γ(>4)x more sustainable!



Wim Leemans, Europe

- ✧ ESPP supports investigation of potential of LWFA/PWFA for PP and HEP
- ✧ Pre-CDR 2026
 - ✧ based on HALHF, asymmetric (conventional $31e^+$ GeV, PWFA $500e^-$ GeV) Higgs factory
 - ✧ many possible upgrades presented
 - ✧ higher CM energies, multiple IPs and detectors, $\gamma\gamma$ collider
- ✧ Roadmap includes:
 - ✧ AWAKE, EuPRAXIA, HALHF
 - ✧ all R&D for PP or HEP applications: staging, high rep-rate drivers, etc.



Cameron Geddes, USA

- ✧ Snowmass, P5
 - ✧ 10TeV lepton collider, i.e., e^-e^+ for advanced concepts
 - ✧ existing effort, LBNL, SLAC, Argonne



- ✧ Complement existing coordination programs/collaborations/projects (next slide)
- ✧ Coordination of Europe/USA/Asia R&D towards pre-CDR for 10TeV collider: e^-e^+ , e^-e^- , $\gamma\gamma$
 - ✧ obtain funding (no funding, no progress) in Europe and EU/USA
 - ✧ consider all advanced concepts options
 - ✧ feature advantages, sustainability:
 - ✧ high gradient, shorter machine, less land and concrete
 - ✧ short bunches, higher luminosity per beam power
 - ✧ more exciting for young scientists (who will build and operate it ...)
- ✧ Short time scale (2026), cost of experimental programs, need dedicated facility(ies)
 - ✧ mainly focus on a numerical simulation effort

CONTRIBUTIONS TO PP AND HEP

✧ HALHF, Higgs factory (Richard d'Arcy)

- ✧ best of e^- in plasma and e^+ in RF structures
- ✧ many upgrade possibilities
 - ✧ higher energies, multiple interaction point, $\gamma\gamma$ collider, etc.

✧ p^+ -driven Higgs factory (Alexander Pukhov)

- ✧ no staging, p^+ bunch with large energy, GeV, kJoules
- ✧ emerging rapid-cycling magnets for synchrotron rep.-rate and luminosity

✧ AWAKE (Marlene Turner)

- ✧ no staging, p^+ bunch with large energy, eV, Joules
- ✧ existing program/collaboration with clear plan
- ✧ fixed target experiments, dark photons

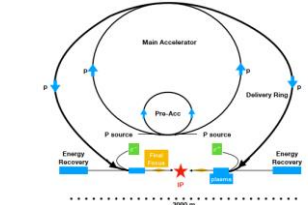
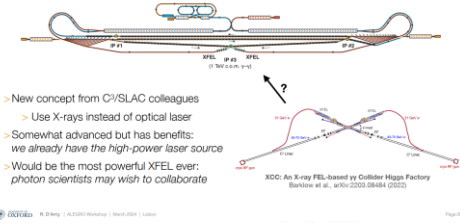
✧ EuPRAXIA (Massimo Ferrario)

- ✧ quality e^- beams, FELs and HEP
- ✧ existing and growing collaboration

✧ Injector for DESY PETRA IV, CePC

✧ 10TeV lepton collider

Upgrade: TeV $\gamma\gamma$ collider (XFEL version)



<https://arxiv.org/abs/2401.14765>

Run 2d: demonstration of scalability
 Use scalable plasma source technology for acceleration



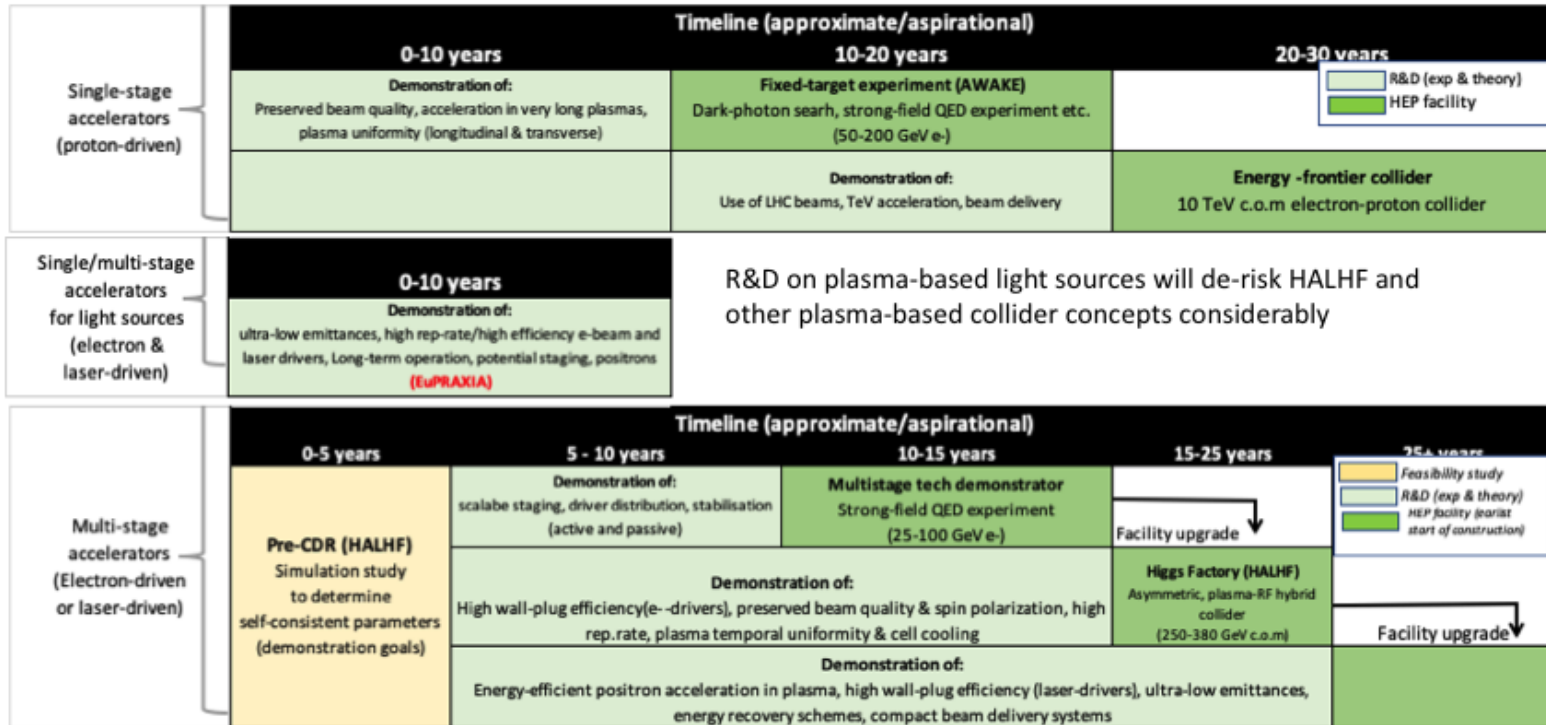

EUROPEAN PLASMA RESEARCH ACCELERATOR WITH EXCELLENCE IN APPLICATIONS

The EuPRAXIA project
 a plasma-based accelerator user facility for the next decade

M. Ferrario (INFN-LNF)
 On behalf of the EuPRAXIA Collaboration



Timelines for R&D on plasma-based colliders



ESPP clearly mentions need for R&D of ANAs

Update of the ESPP roadmap

Driven by the laboratory directors group (LDG), Wim, Rajeev

Emphasis on “other than TeV collider” contributions!

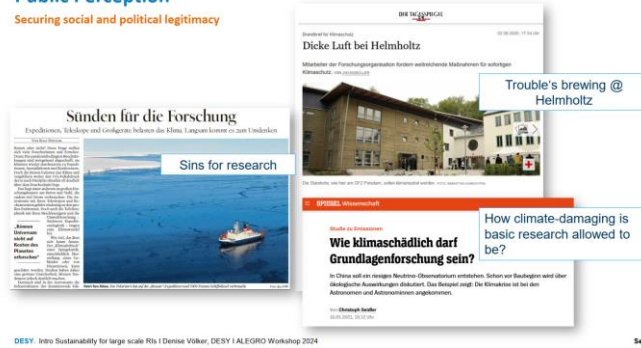
SUSTAINABILITY

What is being looked at?

Not only Greenhouse Gases



Public Perception Securing social and political legitimacy



Sünden für die Forschung
Expeditionen, Mikroskope und Collider: helfen die Klima. Langen können es zum Umdenken

Dicke Luft bei Helmholtz
Mitarbeiter der Forschungszentren suchen anerkennende Maßnahmen für weiteren Klimaschutz im Wissenschaftsbereich

Trouble's brewing @ Helmholtz

Wie klimaschädlich darf Grundlagenforschung sein?
In China soll ein einziges Neutronen-Observatorium entstehen. Schon vor Baubeginn wird über ökologische Auswirkungen diskutiert. Das Beispiel zeigt: Die Klimakrise ist bei den Akteuren und Akteuerinnen angekommen.

How climate-damaging is basic research allowed to be?

DESY | Intro Sustainability for large scale RIs | Denise Voelker, DESY | ALEGRO Workshop 2024

Seite 5



- Denise Voelker, Roberto Losito
- ❖ (Wasting is never acceptable!)
- ❖ Planet boundaries
- ❖ Public perception
- ❖ Sustainable research centers
- ❖ Impact degree
- ❖ Life cycle
- ❖ (More effective, efficient = cheaper)
- ❖ Examples:
 - ❖ DESY, CERN
- ❖ Sustainability MUST BE PART of any design
- ❖ Must include “sustainability” chapter in (thoughts and) documents
- ❖ We must learn ...
- ❖ ICFA Panel on Sustainable Accelerators and Colliders

❖ The next collider will be sustainable or won't be

LWFA "TYPICAL" PARAMETERS (SiMS)

Carlo Benedetti

✦ High peak gradient

✦ High average gradient, plasma mirrors

✦ Staging

✦ 100's of stages energy gain 10-20GeV?

✦ Laser:

✦ wavelength TBD pulse energy 10's J repetition rate 10's kHz

✦ Plasma

✦ $n_e = 10^{17} \text{ cm}^{-3}$ $L_p = 10$'s cm

✦ Witness bunch:

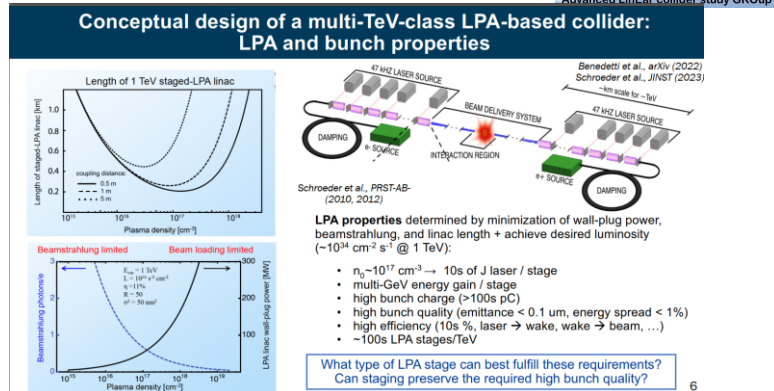
✦ $Q = 100$'s pC $\Delta E/E < 1\%$ normalized emittance < 100 nm-mrad

✦ Efficiency:

✦ laser to plasma: 10's of % plasma to witness: 10's of %

✦ Need global, general parameters to start ...

✦ Need end-to-end, self-consistent design concept, NUMERICAL SIMULATIONS



Simon Hooker

Options

✧ gas jets

✧ discharges

✧ HOFI, CHOFI channels

✧ alkaline vapor

✧ Single event challenges

✧ Repetition rate challenges

✧ energy/heat deposited, cooling

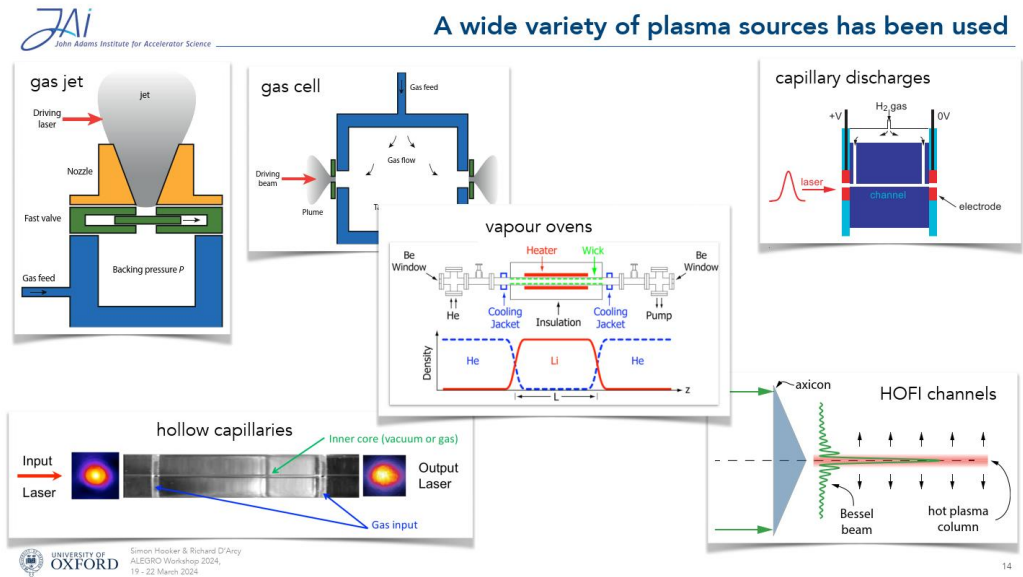
✧ maximum rate

✧ material (if any) damage

✧ optics (if any)

✧ Extraction of wakefields energy with “extractor” pulse

✧ Need engineering, funding, global project ...



✧ Major component of a LWFA and PWFA!

Philippe Piot

✧ TBA (CLIC-like)

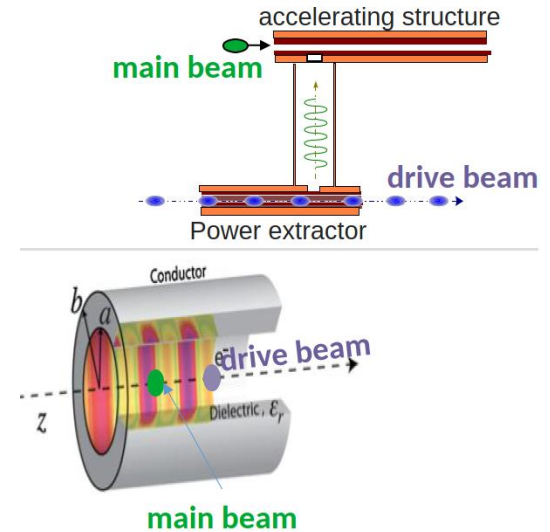
- ✧ decouple D-W beams
- ✧ not interstage (larger average gradient)
- ✧ X-band (e.g., 26GHz)
- ✧ 1GW/DB extracted power
- ✧ <10ns pulse length => lower break-down rate

✧ CWA (PWFA-like)

- ✧ design for an FEL facility
- ✧ transverse stability challenge
- ✧ large transformer ratio: 5?

✧ Need for numerical tools, SIMULATIONS

✧ Dielectric structures to control bunch parameters, FEL (Evan Ericson, Ozgur Apsimon)



What is the positron problem today?

Unloaded plasma wakefield suitable for e⁺ acceleration (accelerating&focusing)?

NO

Loaded plasma wakefield with efficiency, beam quality, and ultimately competitive luminosity-per-power for e⁺ arm?

YES

With loading comes plasma electron motion, basically ion motion with a much smaller mass

7

❖ Challenge to reach collider bunch parameters in plasma

❖ Structures offer a symmetric alternative, 'a la HALHF'

❖ compatibility of parameters?

❖ Need a facility to test concepts (Sebastien Corde)

❖ Demo with test positrons from LWFA (Gianluca Sari)

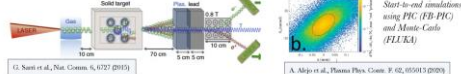
❖ FACET II only possibility for (PWFA) collider studies (Mark Hogan)

❖ Bunches with "collider" parameters

❖ Drive electron bunch available

QUEEN'S UNIVERSITY BELFAST Numerical modelling EPSRC

The simplest option to generate short positron beams (~fs) is to propagate a laser-wakefield electron beam through a high-converter target.



Start-to-end simulations using PIC (FD-PIC) and Monte Carlo (FLUKA).

For example, if one considers a PW-scale laser (5 GeV electron beam with nC-scale charge)

For a 100 μm converter

Parameter	2	1
E (GeV)	2	1
ΔE/E (%)	5	5
Q (pC)	1	2
ε (nm)	5	20
ℓ (μm)	18	30
τ (fs)	-20	-20

Gianluca Sari

FACET-II Layout and Beams
A plan is being developed to restore positron capability

FACET-II Technical Design Report SLAC-R-1072



- Simultaneous delivery of up to 1nC e⁺ & 2nC e⁻ to S20 IP region
- Expected performance modeled with particle tracking, including dynamic errors
- More details in TDR Ch. 8

Positron Beam Parameter	Baseline Design	Operation at 15.5 GeV
Final Energy [GeV]	10	4.9-15.5
Charge per pulse [nC]	1	0.2-2
Repetition Rate [Hz]	5	1-5
Norm. Emittance $\epsilon_{x,y}$ at S19 [μm]	10, 10	0-20
Spot Size at IP $\sigma_{x,y}$ [μm]	16, 16	5-20
Min. Bunch Length σ_z [μm]	18	8
Max. Peak current I_{pk} [kA]	6	12

SLAC

17

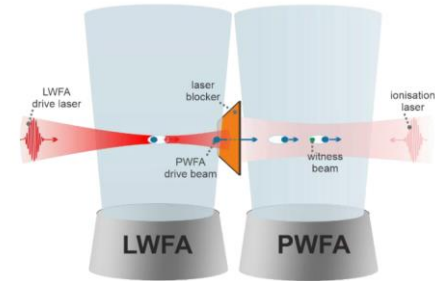
SOURCE OF e^-

❖ Plasma-based? (Susanna Schoebel)

❖ many injection mechanisms, geometries

❖ Polarized e^- from polarized plasma? (Kristjan Poder)

❖ Preservation of polarization of narrow beams in PWFA/LWFA possible (Vieira et al.)

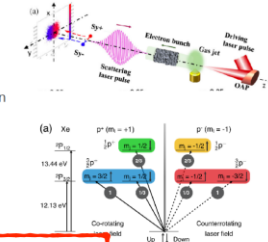


Susanne Schoebel s.schoebel@hzdr.de ALEGRO Workshop 2024

Alternative sources of spin polarised electron beams

Many novel ideas developed over the last years

- > Spin-filter ⁽¹⁾
- > "Stern-Gerlach" beam splitter ⁽²⁾
- > Intense lasers interactions
 - > Spin-dependent radiation reaction of relativistic electron beams ⁽³⁾
 - > Sokolov-Ternov in colliding laser fields ⁽⁴⁾
- > Plasma-based methods
 - > Selective multi-photon ionisation ⁽⁵⁾
 - > Pre-polarised plasma sources ⁽⁶⁻¹¹⁾



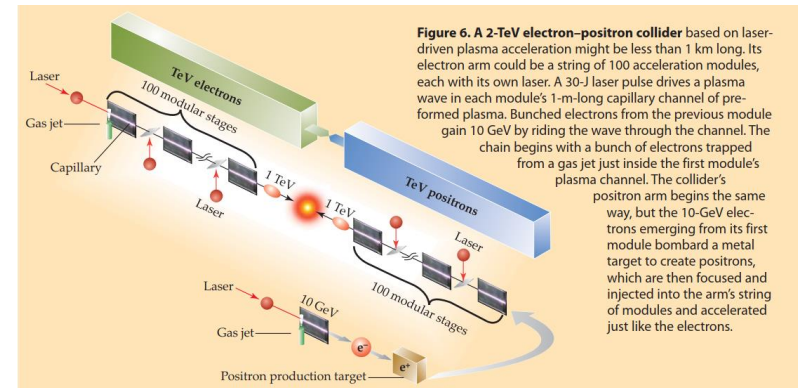
No experimental demonstrations yet!

(1) DeYoung & Mills, PRL **118** 073603 (2017)
 (2) Batschelet et al. PRL **82** 042116 (1999)
 (3) Li et al. PRL **122** 134801 (2019)
 (4) Sokolov-Ternov et al. PRL **66** 053407 (2017)
 (5) Nie et al. PRL **126** 054801 (2021)
 (6) Palacios et al. Science **300** 1906 (2003)
 (7) Wien et al. PRL **122** 214801 (2019)
 (8) Wu et al. PRL **109** 043002 (2012)
 (9) Wu et al. New J. Phys. **21** 073032 (2019)
 (10) Fan et al. New J. Phys. **22** 083047 (2020)
 (11) Sun et al. PRL **132** 045001 (2024)
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❖ Parameters of a collider bunch?

M. Backhouse

- ✧ Allow for short focusing (90° turn on a dime), low contribution to gradient dilution
- ✧ Small position variations for small timing and energy variations over 100's of stages
- ✧ Need two mirrors per stage? in/out coupling, N or 2N
- ✧ Thin, close to W-beam waist: scattering, emittance growth?
- ✧ Large surface B-fields => focusing, CFI, ...
- ✧ Inverse Compton scattering (out)
- ✧ Destructive event
 - ✧ tape with fast motion (m/s)
 - ✧ debris
 - ✧ fluid layer (liquid crystal)
 - ✧ fluid ...
- ✧ Alternative
 - ✧ bent plasma channels for laser and particle beam? (Boyuan Li)
 - ✧ accelerated bunch never leaves the plasma



Leemans, Phys. Today 62(3), 44 (2009)

NUMERICAL SIMULATIONS

❖ Numerical simulations are key ... to ALEGRO's plans ...

❖ ... mostly based on numerical simulations (ready, affordable)

❖ Many suites of codes (Alex Huebl): **LASY, I'll have a BLAST if you PICMI up and don't WARP me**

❖ EM-ES, full-reduced, 2D-3D, etc.-etc.

❖ need to be compatible, benchmarked, ...

❖ need to describe reality (Kristjan Poder)

❖ e.g., real laser pulse (LASY)

❖ ALEGRO approach

❖ first (when appropriate) demonstrate collider parameters with simplest set up

❖ cylindrical geometry, fixed ions, reduced models, etc

❖ second include more reality

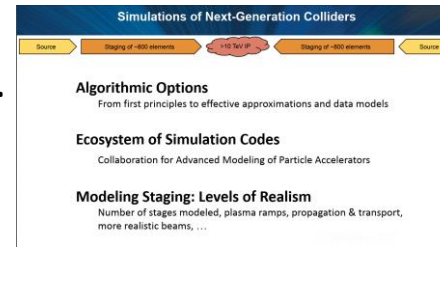
❖ higher order effects, 3D, full PIC, ion motion, etc.

❖ tolerance studies

❖ numerical simulations to address fundamental problems

❖ e.g., matched W-bunch size smaller than average distance between plasma ions

(Jorge Vieira)



Simulations of Next-Generation Colliders

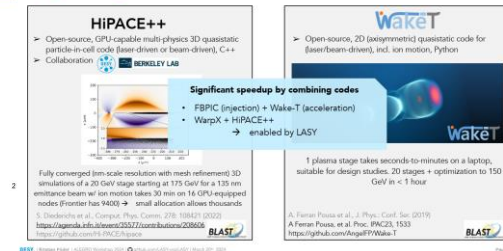
Source → Staging of ~100 elements → 100 GeV @ → Staging of ~100 elements → Source

Algorithmic Options
From first principles to effective approximations and data models

Ecosystem of Simulation Codes
Collaboration for Advanced Modeling of Particle Accelerators

Modeling Staging: Levels of Realism
Number of stages modeled, plasma ramps, propagation & transport, more realistic beams, ...

Fully converged simulations with reduced models at modest cost



HIPACE++

- Open-source, GPU-capable multi-physics 3D quasistatic particle-in-cell code (beam-driven or beam-driven), C++
- Collaboration: KEK, SLAC, DESY, LBNL

WakeT

- Open-source, 2D (axisymmetric) quasistatic code for (beam-beam-driven), incl. ion motion, Python

Significant speedup by combining codes

- FBPIC (injection) + Wake-T (acceleration)
- WarpX + HIPACE++
- enabled by LASY

Fully converged (1m-scale resolution with mesh refinement) 3D simulations of a 20 GeV stage starting at 175 GeV for a 135 nm emittance beam w/ ion motion takes 30 min on 16 GPU-equipped nodes (Brentner has 9400) → small allocation allows thousands

1 plasma stage takes seconds-to-minutes on a laptop, suitable for design studies. 20 stages + optimization to 150 GeV in < 1 hour

References:
1. Dielerich et al., Comput. Phys. Comm., 279: 108421 (2022) <https://agenda.infn.it/event/20277/contributions/208668>
2. A. Ferrari-Pozza et al., Phys. Conf. Ser. (2019)
A. Ferrari-Pozza et al., Proc. PAC23, 1533 <https://physics.com/Ampere/WakeT>

BLAST

❖ Beam delivery system (BDS)

❖ start from ILC-CLIC designs (**Vera Cilento**)

❖ Flat/round beams?

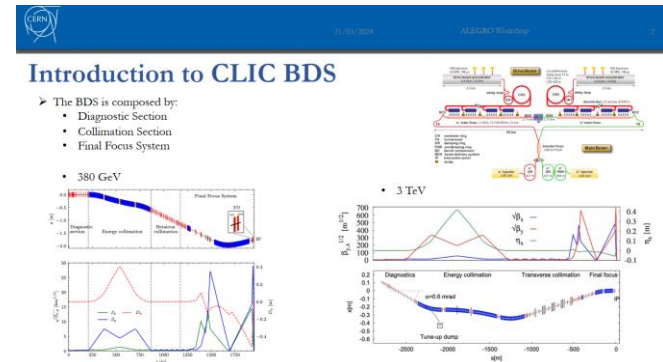
❖ flat bunches with collider parameters suffer from coupled emittance (**Severin Diedrich**)

❖ must include IP 'plasma physics' or 'plasma physics at the IP' in numerical simulations (**Thomas Grismayer**)

❖ naturally-short bunches may lead to more luminosity, higher luminosity per beam power

❖ less beamstrahlung

❖ smaller disruption parameter



Report on the Advanced Linear Collider Study Group (ALEGRO) Workshop 2024

ALEGRO 2024



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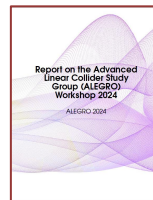
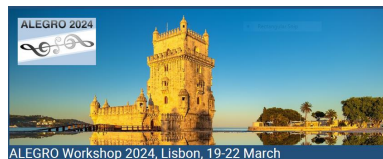
- Summary of the workshop
- “One-pager” from each presenter
- International, ANA community
- To be distributed: arxiv, ICFA panel, etc.

ROLE OF ALEGRO



- ✧ Complement existing effort through coordination and quest for funding
- ✧ Contribute to 10TeV CM collider pre-CDR, already on-going in the US
- ✧ Determine through general studies and numerical simulations parameters of key elements:
 - ✧ interstage concepts, scaling of interstage; plasma mirrors; witness bunch parameters; plasma-based injector; IP physics; beam delivery system; plasma sources; accelerator module, two plasmas and inter-stage, 100GeV(?) modules; drivers; sustainability
- ✧ Gather a group of 'enthusiasts' to:
 - ✧ determine state-of-the art
 - ✧ prepare a funding request:
 - ✧ US DoE ongoing effort
 - ✧ EU funding
 - ✧ joint US-EU finding (NSF?)

SUMMARY



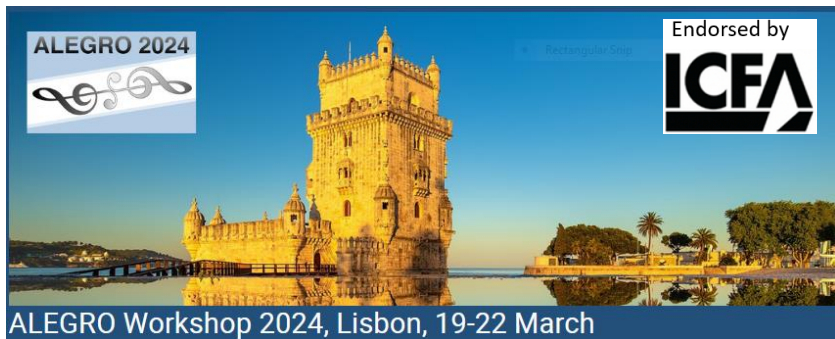
- ✧ ALEGRO has been active since 2016, five workshops
- ✧ ALEGRO 24 was quite interesting and successful
 - ✧ ALEGRO 2024 summary document
- ✧ ANAs can contribute to PP and HEP
 - ✧ Elements of a “conventional” machine
 - ✧ ANA-based collider?
 - ✧ HALHF
 - ✧ TeV linear collider?
- ✧ Progress requires funding, but not only ...
- ✧ ALEGRO initiative to apply for funding for studying a 10TeV lepton collider
- ✧ ALEGRO needs YOUR participation..



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Thank you: Brigitte and Jorge
Thank you to all ALEGRO 2024 participants

Thank you!

 See you at ALEGRO 25 

ROLE OF ALEGRO

High-energy particle physics is the largest supporter of wakefield R&D in the US (DoE-HEP)



P5:

Highlights the importance of accelerators and the need for R&D to meet the needs of the future of the field

Supports a offshore Higgs factory this decade based on ready to build technology: either ILC or FCCee
Other Higgs factory options may be evaluated by the next P5 if neither goes forward

Supports R&D toward a cost-effective 10 TeV pCM collider based on proton muon or possible wakefield technologies including an evaluation of options for US siting of such a machine with a goal of being ready to build major test facilities and demonstrator facilities within the next 10 years
10 TeV is the motivating target, and staging steps at lower energies should support this goal

Emphasis on targeted collider R&D investments for developing comprehensive designs with cost models guiding technology advancements and collider pathways establishing advanced performance benchmarks for detectors and accelerators and training the next generation of experts. Including accelerator and detector.

A key next step for the wakefield community is delivery of an end-to-end design concept for 10 TeV including cost scales with self-consistent parameters throughout

ROLE OF ALEGRO?

- Gather the community to discuss progress and plans towards ...
- Structure the community around the development of a linear collider
- Monitor progress in, and determine the state-of-the-art of the ANA field
- Understand the landscape ...
- Inform ICFA about activities about worldwide ANA activities (ICFA panel!!!)



Coordinate US/Europe/Asia efforts

Possibilities to obtain funding:

Identify best tools among existing collaborative programs funded by EU (e.g. , doctoral network, ERC synergy,...) to fund a simulation design study towards a pre-CDR for a TeV collider

Other options to be identified (US, ...)

Requires strong community involvement!

Expected outcome of this workshop!

THANK YOU!!!



HUGE **thank you** to Jorge and all the LOC!

Enjoy the workshop!

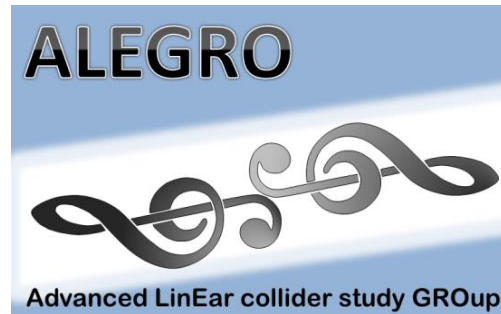
Thank you for participating!

HOW DID WE GET HERE?

<https://indico.cern.ch/event/569406/>



ANAR2017: Advanced and Novel Accelerators
for High Energy Physics Roadmap Workshop
2017



... is one of the major outcome of the ANAR 2017 workshop!

Advanced and Novel Accelerator (ANA) \Leftrightarrow $>1\text{GeV/m}$