SUMMARY OF ALEGRO 2024

Patric Muggli, for ALEGRO
Max Planck Institute for Physics
Munich
muggli@mpp.mpg.de
https://www.mpp.mpg.de/~muggli

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 …

How Did We Get Here?

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)

ALEGRO
Advanced LinEar collider study GROup

Endorsed by ICFA

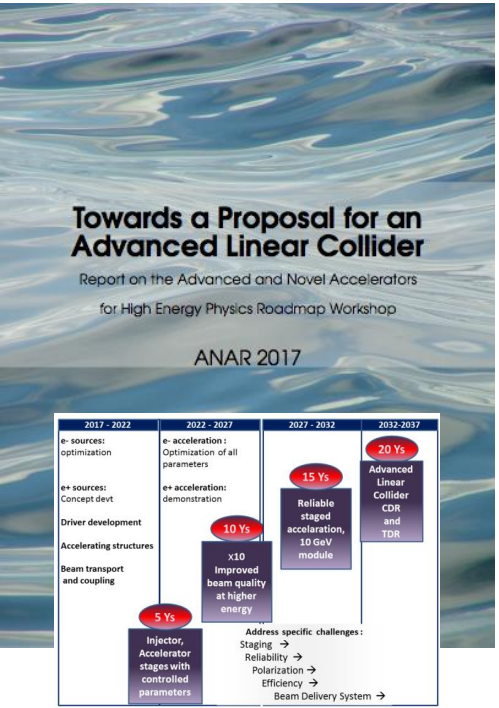
… is one of the major outcome of the ANAR 2017 workshop!

(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?

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

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



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

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WHAT IS ALEGRO?

ALEGRO
Advanced LinEar collider study GROup

ICFA

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

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SERIES OF WORKSHOPS

ALEGRO

ICFA ANA

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

2017

2024

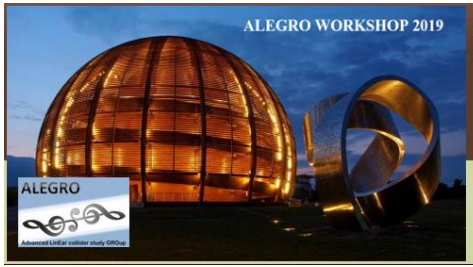
UNIVERSITY OF OXFORD

Somerville College

ALEGRO 2018 workshop at Oxford

26 March - 29 March 2018, Oxford, UK

2018



ALEGRO WORKSHOP 2019 CERN
26-29 March

2019

2023

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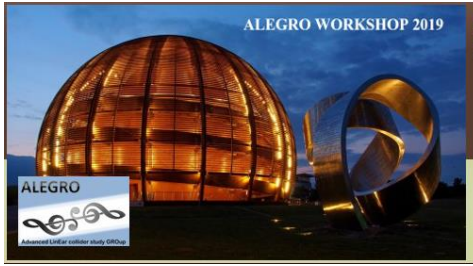

ALEGRO WORKSHOP 2019 CERN
26-29 March

2019

2023

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

ALEGRO collaboration members as of September 2018 : Erik Adli[1], Weiming An[2], Nikolay Andreev[3], Oznur Apsimon[4], Ralph Assmann[5], Jean-luc Babigeon[6], Robert Bingham[7], Tom Blackburn[8], Christopher Brady[9], Michael Bussmann[10], Bruce Carlsten[11], James Chappell[12], Jian Bin Ben Chen[13], Sebastien Corde[14], Laura Corner[15], Benjamin Cowan[16], Brigitte Cros[17], Joel England[18], Eric Esarey[19], Ricardo Fonseca[20] , Brian Foster[5,21], Spencer Gessner[13], Leonida A Gizzi[22], Daniel Gordon[23] , Edda Gschwendtner[13], Anthony Hartin[5], Bernhard Hidding[24], Mark Hogan[18], Simon Hooker[21], T. Hughes[25], Alexei Kanareykin[26], Stefan Karsch[27], Valentin Khoze[28], Pawan Kumar[29], Wim Leemans[19], Francois Lemery[5], Ang Li[30], R. Li[18], Vladyslav Libov[5], Emily Sistrunk Link[31], Michael Litos[32], Gregor Loisch[5], Nelson Lopes[20,33], Olle Lundh[34], Alexey Lyapin[35], Edu Marin[13], Mattias Marklund[8], Timon Mehrling[19], Patric Muggli[13,27], Pietro Musumeci[2], Zulfikar Najmudin[33], Uwe Niedermayer[36], Jens Osterhoff[5], Marc Palmer[41], Rajeev Pattathil[7], Michael Peskin[18], Philippe Piot[38], John Power[39], Alexander Pukhov[40], Heather Ratcliffe[41], Marc Riembau[42], Veronica Sanz[43], Gianluca Sarri[44], Yuri Saveliev[7], Levi Schachter[45], Lucas Schaper[5], Norbert Schoenenberger[30] , Carl Schroeder[19], Sarah Schroeder[5], Daniel Schulte[13], Andrei Seryi[46], Sergey Shchelkunov[50], Craig Siders[32], Evgenya Simakov[11], Christophe Simon-Boisson[47], Michael Spannowsky[28], Christina Swinson[37], Andrzej Szczepkowicz[48], Roxana Tarkeshian[5], Johannes Thomas[40], Junping Tian[49], J.V. Tilborg[19], Paolo Tomassini[22], Vasili Tsakanov[50], Jean-Luc Vay[19], Jorge Vieira[20], Henri Vincenti[51], Roman Walczak[21], Dan Wang[52], Stephen Webb[53], Glen White[18] Guoxing Xia[4], Hitoshi Yamamoto[54], Tevong You[55], Igor Zagorodnov[5]

[1] Univ Norway, Oslo, Norway
[2] UCLA, Los Angeles, California, USA
[3] IHED, Moscow, Russia
[4] Univ. Manchester, UK
[5] DESY, Hamburg, Germany
[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

International ANA Community

arXiv.1901.10370

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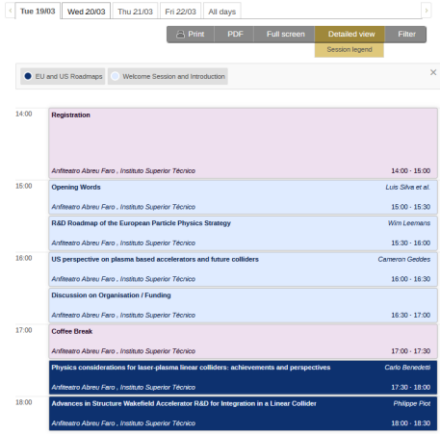
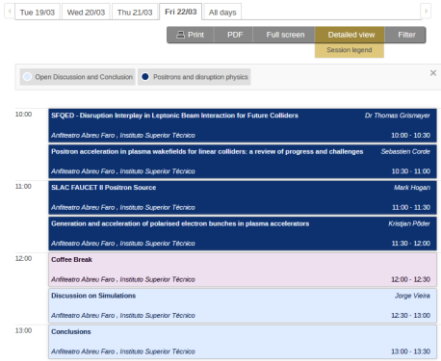
ALEGRO 2024 PROGRAM

ALEGRO





- ✧Monitor progress
- ✧Understand the landscape (science, collaborations)
  - ✧ESPP, Snowmass, P5
- ✧Sustainability: feature advantages, sustainability:
  - ✧ANA collider: 2x shorter, 2x less concrete, less SF_6, y(>4)x more sustainable!

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STRATEGIES

ALEGRO

der study GROup

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

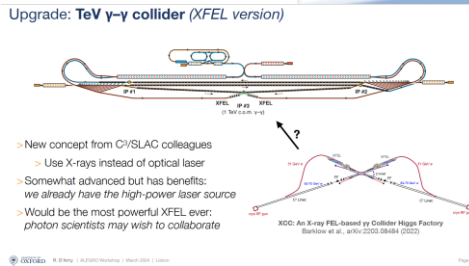
ALEGRO Discussions - Outcome

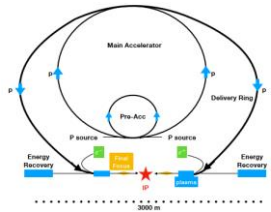
- Complement existing coordination programs/collaborations/projects (next slide)

- 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

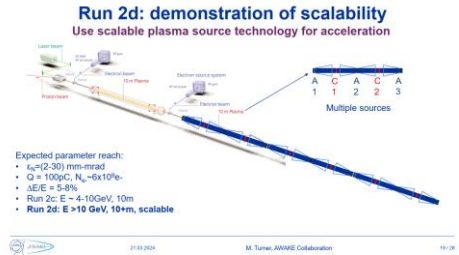
CONTRIBUTIONS TO PP AND HEP

- 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



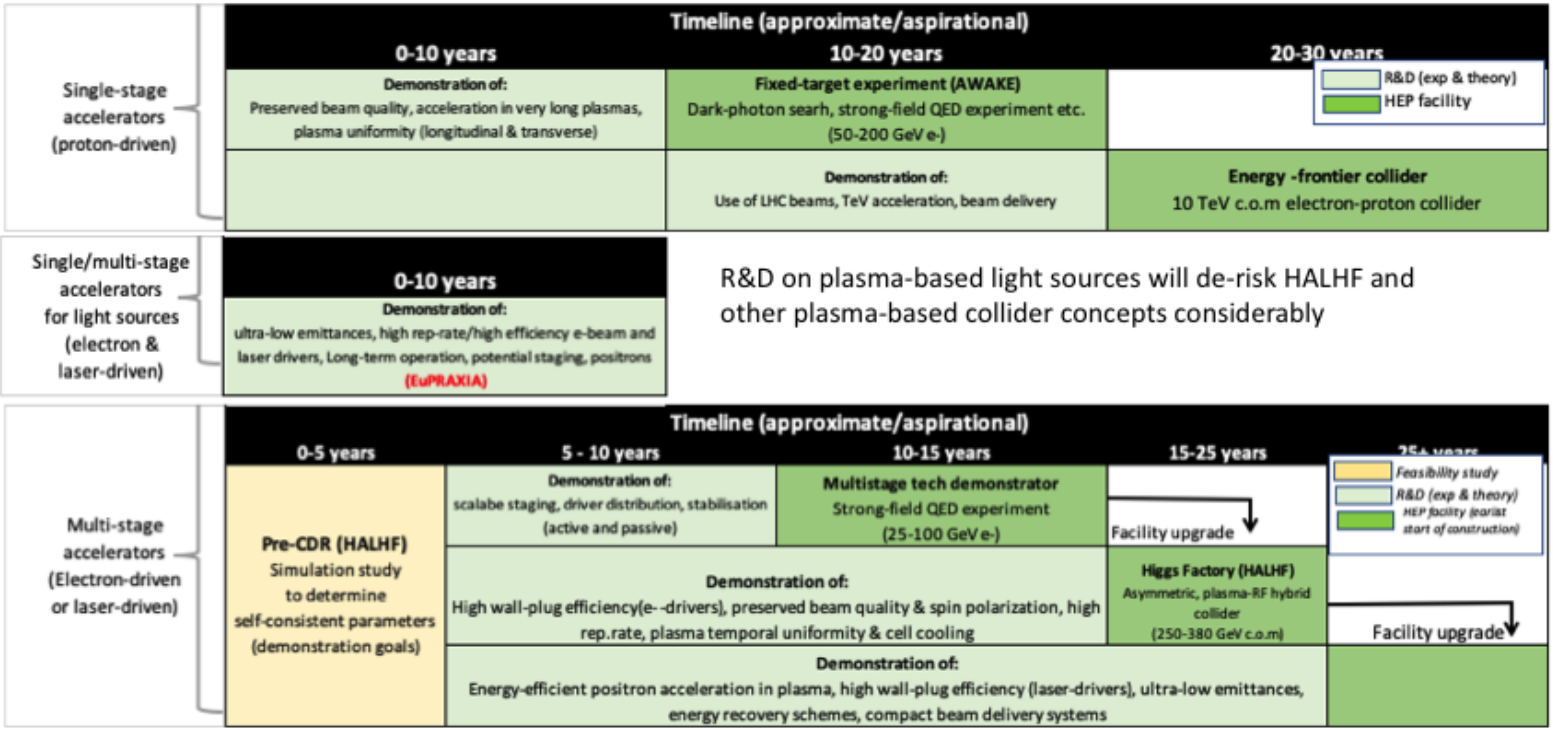


https://arxiv.org/abs/2401.14765



EU STRATEGY

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!

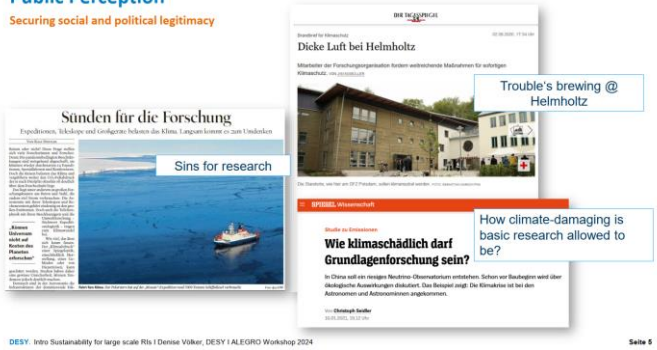
SUSTAINABILITY

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

Public Perception

Securing social and political legitimacy



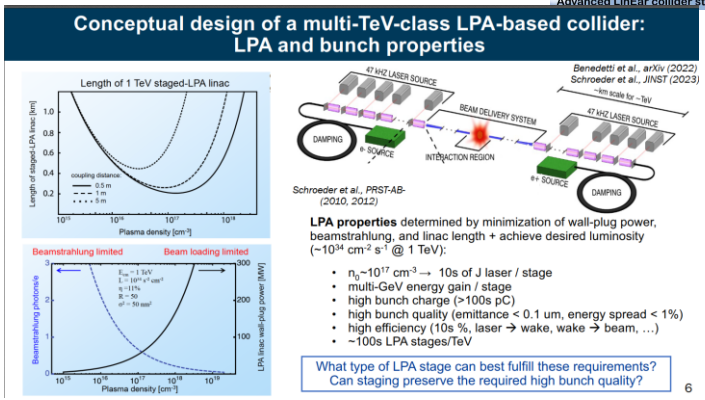
What is being looked at?

Not only Greenhouse Gases

- The next collider with be sustainable or won’t be

LWFA "TYPICAL" PARAMETERS (SIMS)

Carlo Benedetti



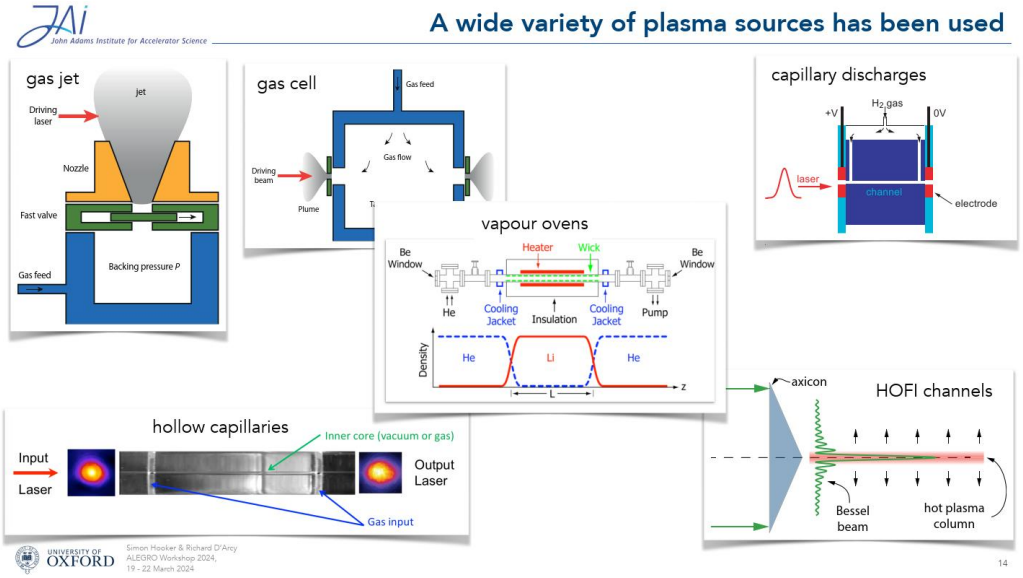
- High peak gradient
- High average gradient, plasma mirrors
- Staging
  - 100's of stages energy gain 10-20GeV?
- Laser:
  - wavelength TBD pulse energy 10's J repetition rate 10's kHz
- Plasma
  - $n_e=10^{17}cm^{-3}$ L_p=10's cm
- Witness bunch:
  - Q=100's pC ΔE/E<1% normalized emittance <100nm-mrad
- 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

PLASMA SOURCE

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 …

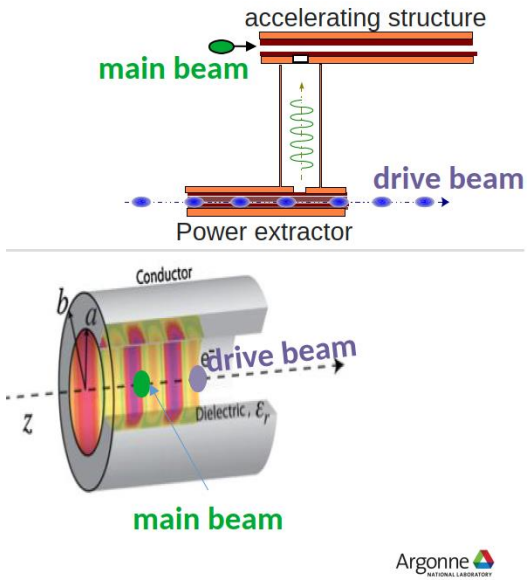


- Major component of a LWFA and PWFA!

SWFA

Philippe Piot

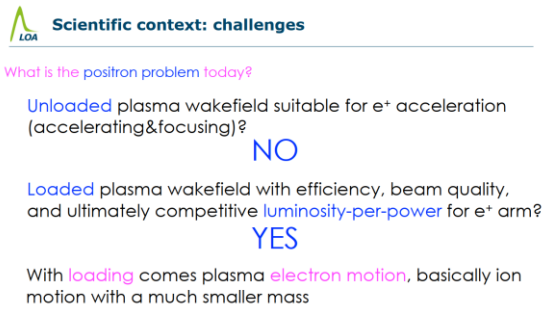
- TBA (CLIC-like)
  - decouple D-W beams
  - not interstage (larger average gradient)
  - X-band (e.g., 26GHz)
  - 1GW/DB extracted power
  - <10ns pulse length => lower break-down rate
- CWA (PWFA-like)
  - design for an FEL facility
  - transverse stability challenge
  - large transformer ratio: 5?
- Need for numerical tools, SIMULATIONS

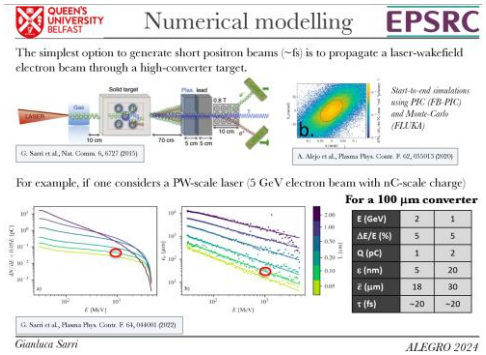


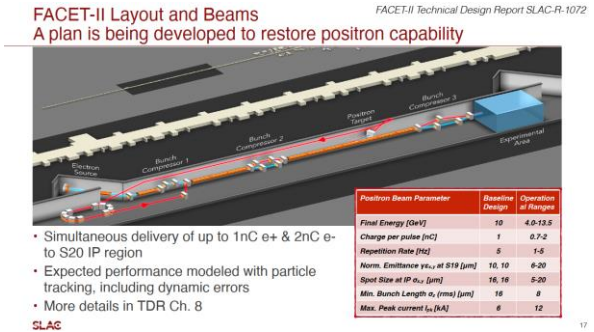
- Dielectric structures to control bunch parameters, FEL (Evan Ericson, Oznur Apsimon)

THE e+ CASE

- 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 form LWFA (Gianluca Sari)
- FACET II only possibility for (PWFA) collider studies (Mark Hogan)
  - Bunches with "collider" parameters
  - Drive electron bunch available







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SOURCE OF e^-

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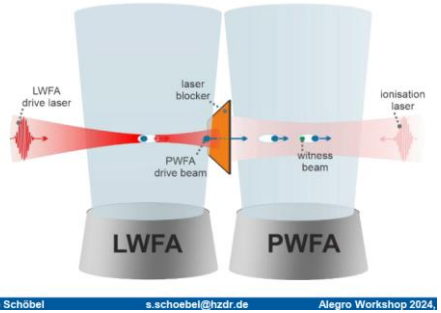
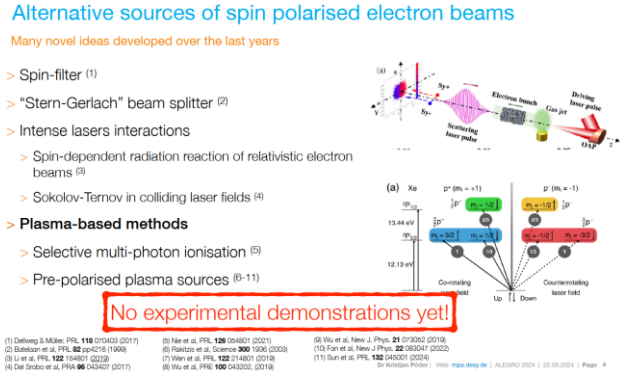
- Plasma-based? (Susanna Schoebel)
  - many injection mechanisms, geometries



- Polarized e^- from polarized plasma? (Kristjan Poder)
  - Preservation of polarization of narrow beams in PWFA/LWFA possible (Vieira et al.)



- Parameters of a collider bunch?

PLASMA MIRRORS

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

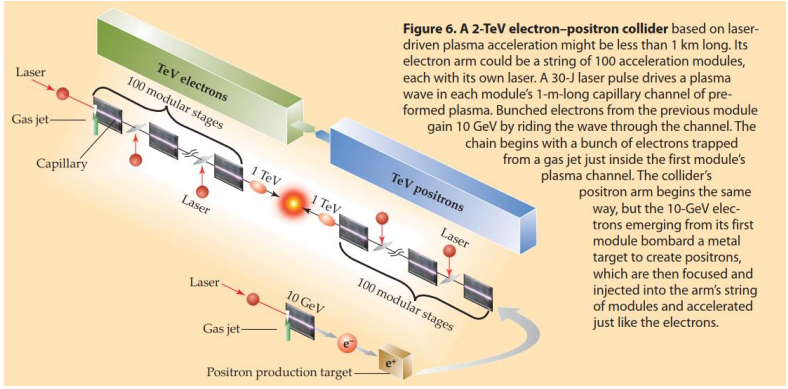


Figure 6. A 2-TeV electron–positron collider based on laser-driven plasma acceleration might be less than 1 km long. Its electron arm could be a string of 100 acceleration modules, each with its own laser. A 30-J laser pulse drives a plasma wave in each module's 1-m-long capillary channel of pre-formed plasma. Bunched electrons from the previous module gain 10 GeV by riding the wave through the channel. The chain begins with a bunch of electrons trapped from a gas jet just inside the first module's plasma channel. The collider's positron arm begins the same way, but the 10-GeV electrons emerging from its first module bombard a metal target to create positrons, which are then focused and injected into the arm's string of modules and accelerated just like the electrons.

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

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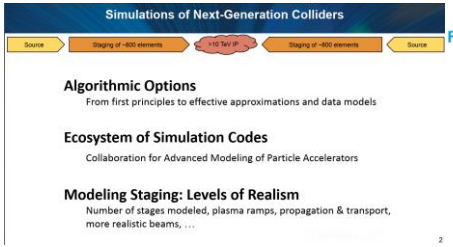
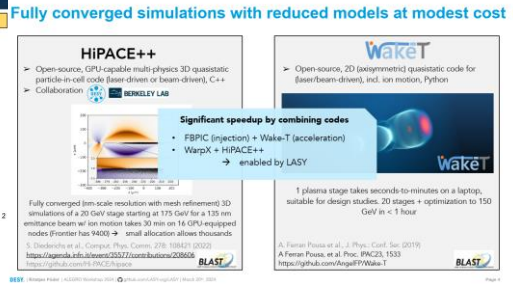
NUMERICAL SIMULATIONS

ALEGRO
Advanced LinEar collider study GROup

- 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)



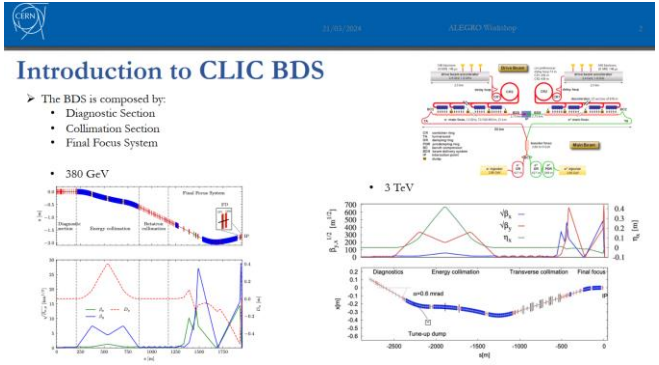


- ALEGRO approach
  - first (when appropriate) demonstrate collider parameters with simplest set up
    - cylindrical geometry, fixed ions, reduced models, etc
  - second include more reality
    - higher order effects, 3D, full PIC, ion motion, etc.
    - tolerance studies
  - numerical simulations to address fundamental problems
    - e.g., matched W-bunch size smaller than average distance between plasma ions (Jorge Vieira)

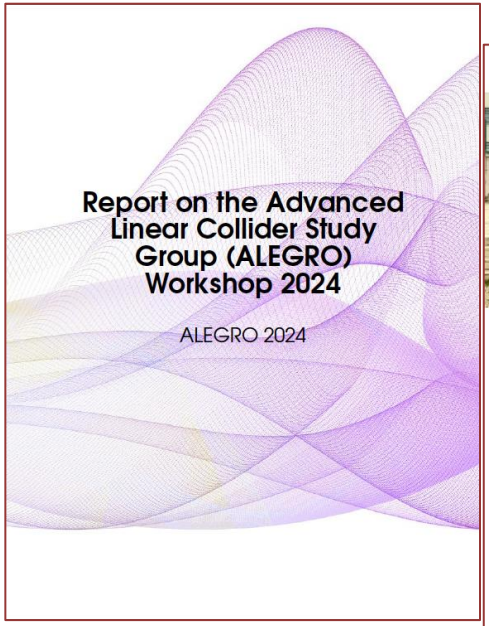
INTERACTION POINT

- Beam delivery system (BDS)
  - start form 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



ALEGRO 2024 DOCUMENT



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

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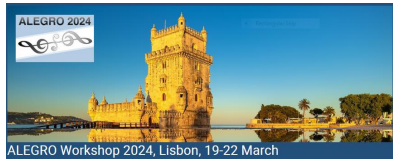
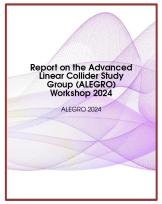
ROLE OF ALEGRO

- 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..

muggli@mpp.mpg.de
+41 75 411 4823

brigitte.cros@universite-paris-saclay.fr

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 sitting 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

<u>Possibilities to obtain funding:</u>

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

ALEGRO
Advanced LinEar collider study GROup

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

Advanced and Novel Accelerator (ANA) ⇔ >1GeV/m