

# The advanced and novel accelerator roadmap in Europe

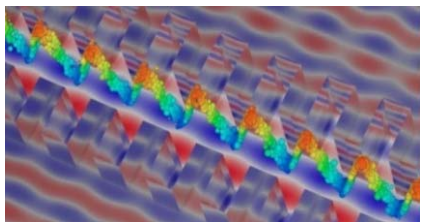
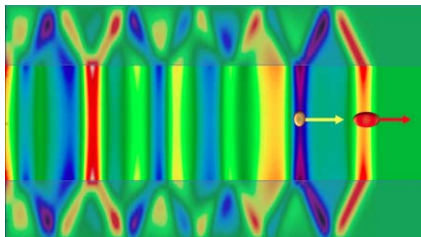
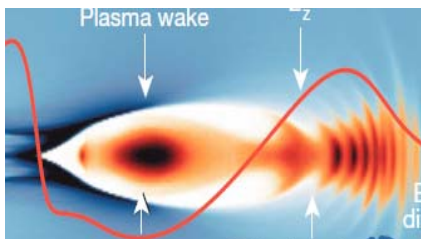
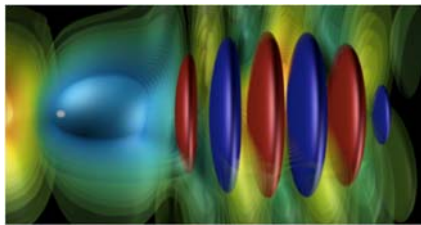
**Brigitte CROS**

CNRS- Laboratoire de Physique des Gaz et des Plasmas- France



# Advanced and Novel Accelerator concepts (ANAs): definition

Acceleration gradients larger than 1GV/m



- ❖ Wakefields driven in **plasma** by **intense** laser beams : **LWFA**
- ❖ Wakefields driven in **plasma** by **particle** beams: **PWFA**
- ❖ Wakefields driven in **structures** (e.g.dielectric tubes) by **particle** beams: **SWFA**
- ❖ Wakefields driven in **dielectric structures** by **short-pulse** lasers: **DLA**

# Outline

- ❖ Organization of the field
  - ❖ European Commission programs
  - ❖ ICFA and ANA panel
    - ❖ ALEGRO for HEP long term programs
- ❖ Roadmap and challenges for ANAs
  - ❖ Scientific road map
  - ❖ European Strategy Update, World wide impact
  - ❖ Next priorities

# Organization of accelerator research in Europe



- ❖ National funding and initiatives
- ❖ Cooperation fostered by European funding
  - ❖ Bottom-up initiatives
  - ❖ Call for proposals from the European commission
  - ❖ Involvement of non European countries in the projects
- ❖ Efforts coordinated by CERN for HEP applications



# 16 national projects in Europe for ANA R&D



# Example of EU funded project

## EuPRAXIA Horizon2020 Design Study

European Plasma Accelerator Infrastructure with Pilot Users, site-independent (now mid-term)

- Collaboration of **40 institutes**
  - **16 EU laboratories** are beneficiaries
  - **24 associated partners** from EU, Europe, Asia and US contribute in-kind, 4 joined after 1<sup>st</sup> year:  
KIT (Germany), FZJ (Germany),  
University Jerusalem (Israel), IAP (Russia)
  - 2 additional associate partners just joined: University Belfast, Ferdinand-Braun-Institute, Leibniz Association, Berlin
- Collaboration brings together:
  - Big science labs: photon science, particle physics
  - Laser laboratories: high power lasers
  - International laboratories: CERN, ELI (associated)
  - Universities: accelerator research, plasma, laser
- Organized in **8 EU-funded work packages** and **6 in-kind work packages**
- **125 scientists** in our work list



It is a relatively small infrastructure so several bids for hosting it are being prepared in Italy, Germany, ...

# European Accelerator R&D steered by Esgard/TIARA

- ❖ 15 AR&D INFRA projects funded by EC between 2003 and 2017 (30% = 93Meuros from EC)
- ❖ Current projects with ANA contribution : Eupraxia, ARIES



Funded by EU  
Horizon2020 as EU  
Design Study



NETWORK, ACCESS, JRA



<https://aries.web.cern.ch/>

## Objectives of coordination in ARIES (WP)

- Reflect on most effective way to ensure sustainable collaborative effort for AS&T in Europe
- Propose appropriate mechanism, including funding scheme
- Propose new and ambitious EC instruments

# Synergy with industry through European projects

## ❖ Industrial participation(ex Eupraxia)

**Industry:** involved through workshops and Scientific Advisory Board



Contacts still evolving, several cooperations under discussion



## ❖ New tools and strategies to enhance industry academia cooperation in the particle accelerator community in preparation

<https://indico.cern.ch/event/682411/overview>

**ACCELERATOR-INDUSTRY CO-INNOVATION WORKSHOP**  
*Tools and strategies to enhance industry-academia cooperation in the particle accelerator community*

**Organisers:**  
The TIARA Consortium of European Research Institutions, the ARIES Integrating Activity for particle accelerators, RMC, the AMCC Coordination and Support Action for accelerator and magnet technological infrastructure.

**6-7th February 2018  
Crown Plaza Brussels  
Le Palace  
Brussels, Belgium**

**The Workshop may be of interest to:**

- Executives from European industry, including SMEs engaged in particle accelerator technologies, interested in learning about present funding schemes and in contributing to the definition of future schemes.
- Researchers and directors of research in European universities and laboratories engaged in R&D on particle accelerators willing to contribute to the definition of common industry-academia projects.

**Organising & Programme Committee:**  
Roy Atkinson (CEA)  
Valérie Brunner (CERN)  
Jean-Luc Lencoste (SDMAPH)  
Sylvie Leyry (CEA)  
Marcello Lottano (CERN)  
Mauro Morandini (INFN)  
Mark Peicko (COSYLAB)  
Toni Sorres (IFU)  
Maurizio Vignerani (CERN)

The Workshop is open to all, but attendance is limited. Advance registration is required.

Programme & registration:  
<https://indico.cern.ch/event/682411>





# EU contributes to the growth of ANA community

- ❖ Field is getting mature (18th AAC workshop),



The banner for the 2016 AAC workshop features a Ferris wheel icon at the top center, with the dates "July 31 - August 5" and the title "ADVANCED ACCELERATOR CONCEPTS" to its right. Below this, the year "2016" is prominently displayed. The main banner area includes the "AAC" logo, a silhouette of a deer, and the text "Breckenridge COLORADO AUG 12-17, 2018 BEAVER RUN RESORT AND CONFERENCE CENTER". A navigation bar at the bottom lists: Home, Important Dates, Committees, Accommodations, Program, Working Groups, Sponsors & Supporters, Proceedings, and Contact Us. The background of the banner depicts a mountain landscape with trees and birds.

About 300 participants per year at AAC or EAAC workshops



# ANAs have the potential for a wide range of applications

✧ X-ray for radiography (advanced: phase contrast, etc.)

✧ e<sup>-</sup> for medical applications

“SMALL” ✧ Require low energy <GeV

✧ Can operate at very large peak gradient, mm-cm accelerator

✧ Special characteristics: **ultra-short**, synchronized beams

✧ **Unique applications, compact**

<1GeV

Dielectric Laser Accelerator DLA

Laser Wakefield Accelerator  
LWFA

Structure Wakefield Accelerator  
SWFA

Plasma Wakefield Accelerator  
PWFA

GeV-TeV

✧ Powerful radiation source, THz to  $\gamma$ -rays (x-ray FEL)

✧ High-energy physics (HEP)

✧ e<sup>-</sup>/e<sup>+</sup> collider

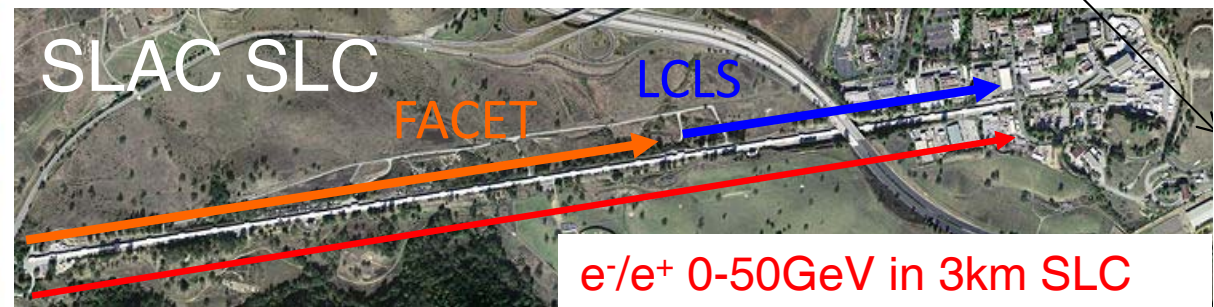
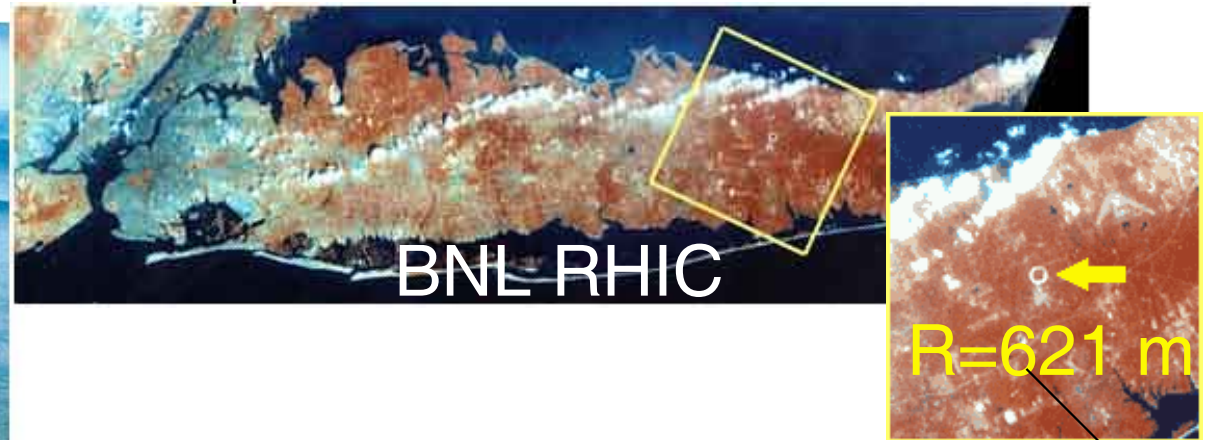
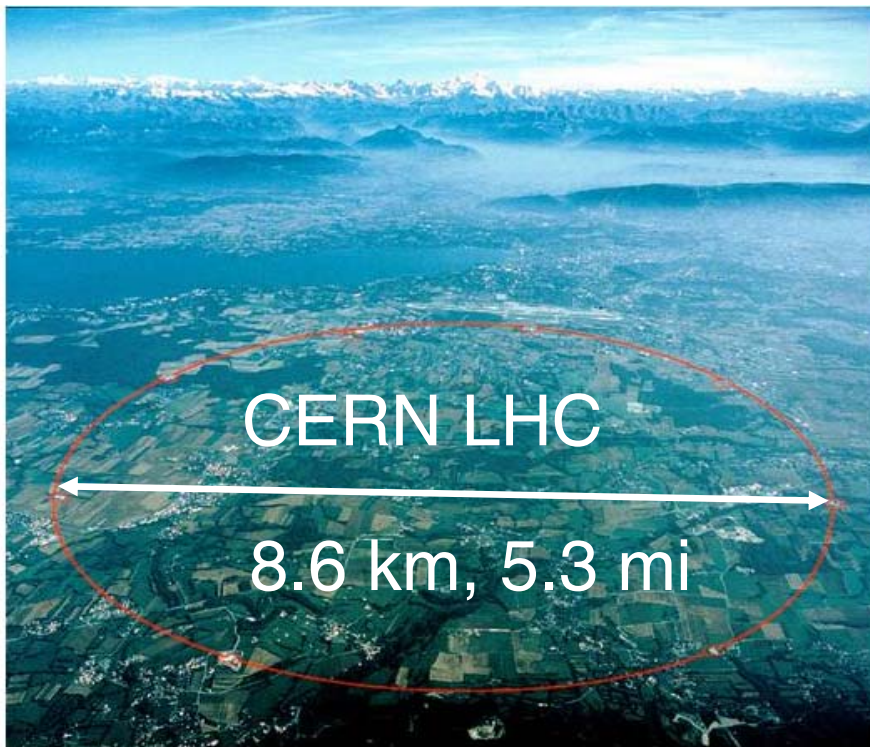
✧ e<sup>-</sup>/p<sup>+</sup> collider

“LARGE”

✧ Energy upgrade for conventional, future collider (ILC, CLIC)

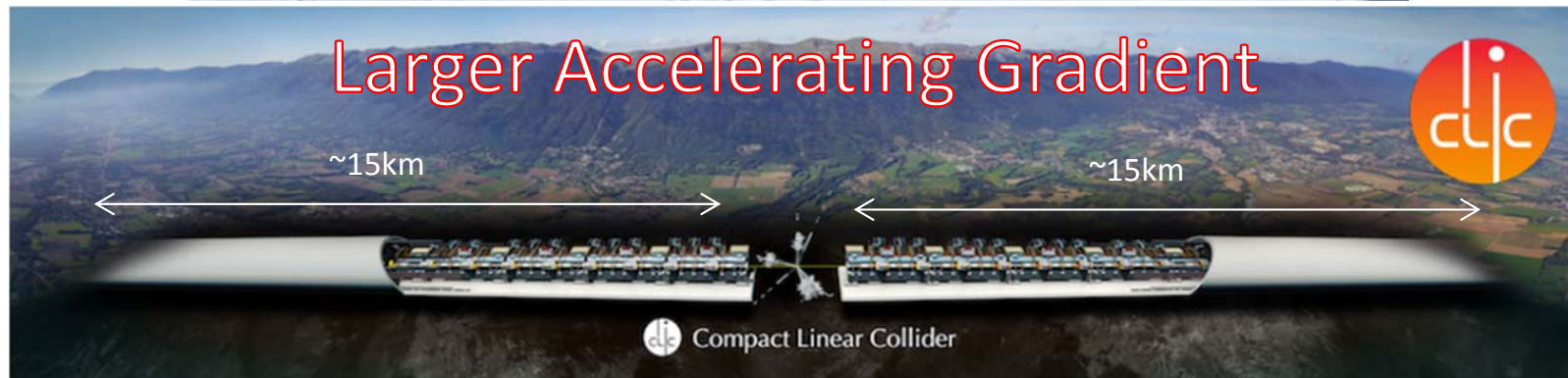
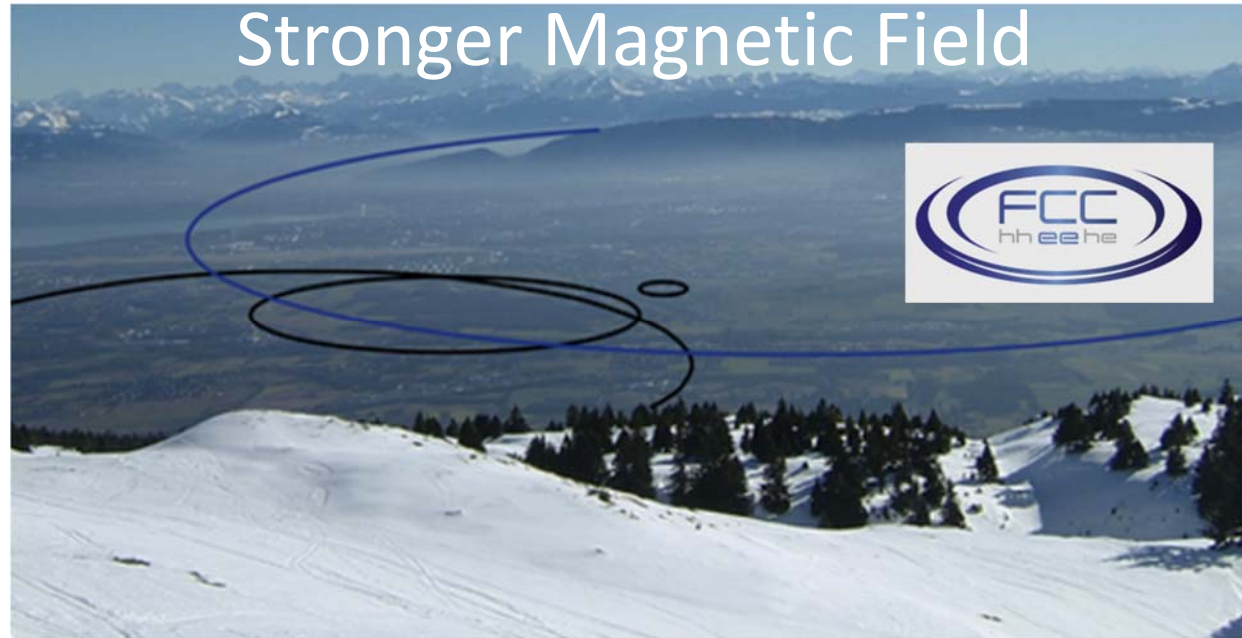
# Particle accelerators can be very large structures

“The 2.4-mile circumference RHIC ring is large enough to be seen from space”



$e^-/e^+$  0-50GeV in 3km SLC  
 $e^-/e^+$  0-20GeV in 2km FACET  
 $e^-$  0-14GeV in 1km LCLS

# Future colliders at higher energy need to control size and cost increase

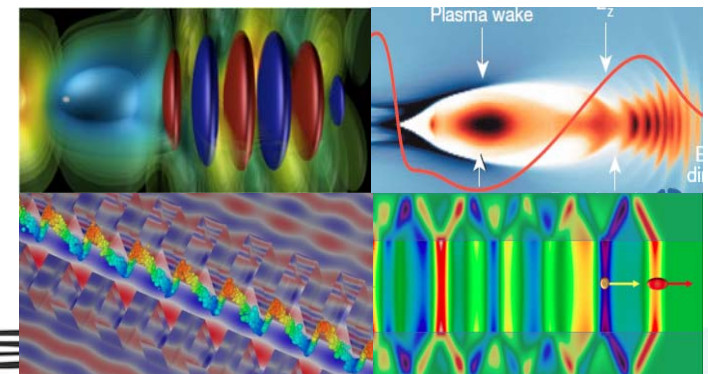


Can ANAs help to make colliders smaller ?

# Challenging question for the community of ANAs

- ❖ Can we envisage the delivery of an **Advanced Linear Collider design** at  $>1\text{TeV}$  (30 TeV) in 2035?
- ❖ Electron- positron Collider at the energy frontier
- ❖ Parameters defined for/by HEP (Luminosity)

Subject addressed in the frame of ICFA



# Mission of ICFA and ICFA panels



SPONSORED BY THE PARTICLES AND FIELDS COMMISSION OF IUPAP

## International Committee for Future Accelerators

- To promote international collaboration in all phases of the construction and exploitation of very high energy accelerators.
- To organize regularly world-inclusive meetings for the exchange of information on future plans for regional facilities and for the formulation of advice on joint studies and uses.
- To organize workshops for the study of problems related to super high-energy accelerator complexes and their international exploitation and to foster research and development of necessary technology.

- [ICFA Instrumentation Innovation and Development Panel](#) (Chair — Ariella Cattai, CERN)
- [ICFA Beam Dynamics Panel](#) (Chair — Yong Ho Chin, KEK)
- [ICFA Panel on Advanced and Novel Accelerators](#) (Chair — Brigitte Cros, Paris)
- [ICFA Standing Committee on Interregional Connectivity](#) (Chair — Harvey Newman, Caltech)
- [ICFA Study Group on Data Preservation in High Energy Physics](#) (Chair – Cristinel Diaconu, CPPM, Marseille)
- [Linear Collider Board](#) (Chair – Tatsuya Nakada, EPFL, Lausanne)
- [ICFA Neutrino Panel](#) (Chair — Kenneth Long, Imperial College London)
- [ICFA Panel on Sustainable Accelerators and Colliders](#) (Chair — Mike Seidel, PSI)



# Advanced and Novel Accelerators

## >> ANA panel members in 2018



To promote and encourage international collaboration/workshop/school on advanced and novel accelerators

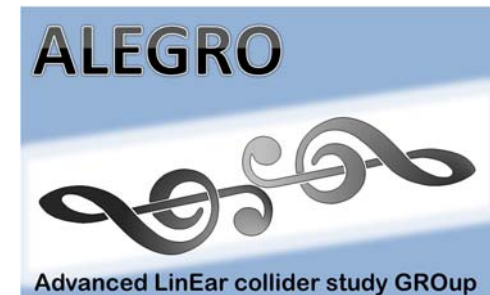
- **Brigitte Cros (chair)**, CNRS- Univ Paris Sud, France
- Bruce Carlsten, Los Alamos National Laboratory, USA
- **Massimo Ferrario**, INFN, Italy
- **Brian Foster**, Univ. Hamburg, Oxford, DESY, Germany
- **Simon Hooker**, Univ Oxford, UK
- **Masaki kando**, Nat Inst. Quantum & Radiological Science & Tech , Japan
- Patric Muggli, Max-Planck-Institut für Physik, Germany
- Philippe Piot, Northern Illinois Univ , Fermi Nat Accel. Lab., USA
- **James Rosenweig**, Univ California Los Angeles, USA
- **Carl Schroeder**, Lawrence Berkeley National Laboratory, USA
- Chuanxiang Tang, Tsinghua University, China
- **Mitsuru Uesaka**, Univ. Tokyo, Japan
- **Tomonao Hosokai**, Univ. Osaka, japan

# ICFA ANA panel initiative based on several observations



- ✧ Application to HEP does require world-wide cooperation
- ✧ ANA community quite fragmented (by nature)
- ✧ Urgent need for ANA community to get together
- ✧ Urgent need to overlap with non-ANA accelerator community
- ✧ Wealth of experience in non-ANA accelerator community
- ✧ Need to approach ANA-collider (or Advanced Linear International Collider) globally, from physics case to IP

❖ **Led to the organisation of ALEGRO**





# Advanced LinEar collider study GROup: missions



- ❖ To foster and trigger Advanced Linear Collider related activities
- ❖ Provide a framework to amplify international coordination, broaden the community, involving accelerator labs/institutes
- ❖ Identify topics requiring intensive R&D and facilities needed
- 1st action : **Report** on ANA priorities as **input for the European Research Strategy Group for HEP: due end of 2018**
- A series of **workshops** to discuss and finalize the roadmap and priorities has started (WG8 EAAC sep 2017, 26-29 March 2018 Oxford, AAC 2018, **CERN April 2019**)

# Advanced LinEar collider study GROup: organisation



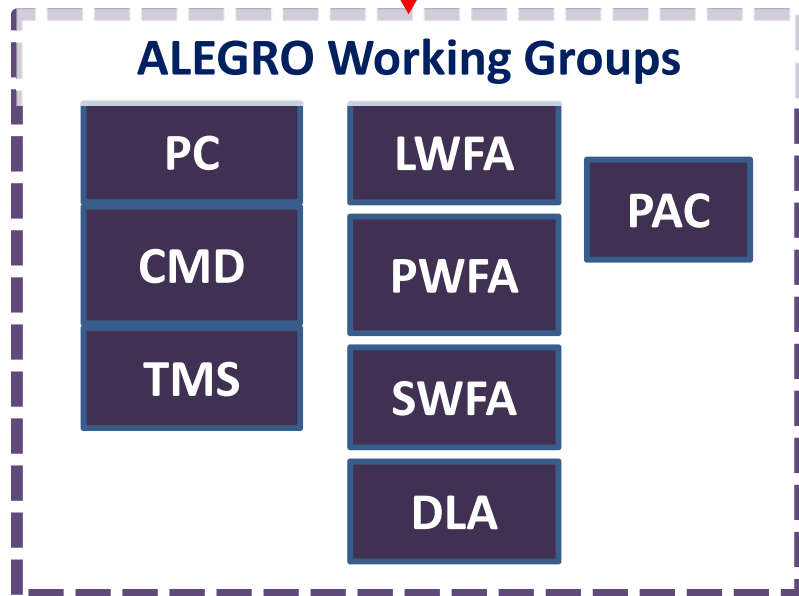
ICFA  
ICFA ANA

Opened to contributions from  
interested scientists worldwide

B Cros  
C Schroeder  
P Muggli

ALEGRO  
Steering Group

**Euronnac**



**ALEGRO WG titles and leaders:**

**PC: Physics Case** (M Peskin, J Tian)

**CMD: Collider Machine Design** (A Seryi, D Schulte, H Yamamoto)

**TMS: Theory, Modelling, Simulations** (JL Vay, J. Vieira)

**LWFA: Laser wakefield Accelerators** (C. Schroeder, S. Hooker, B. Cros)

**PWFA: Plasma wakefield Accelerators** (J Osterhoff, E Gschwendter, P Muggli )

**PAC: Positron acceleration** (S. Gessner, S. Corde)

**SWFA: Structure wakefield accelerator** (P Piot, J Power)

**DLA: Dielectric laser accelerator** (J England, B Cowan)



# Outline

- ❖ Organization of the field
  - ❖ Motivation
  - ❖ ICFA and ANA panel
  - ❖ ALEGRO for HEP long term programs
- ❖ Roadmap and challenges for ANAs
  - ❖ Scientific road map
  - ❖ European Strategy Update, World wide impact
  - ❖ Next priorities



UNIVERSITY OF  
OXFORD



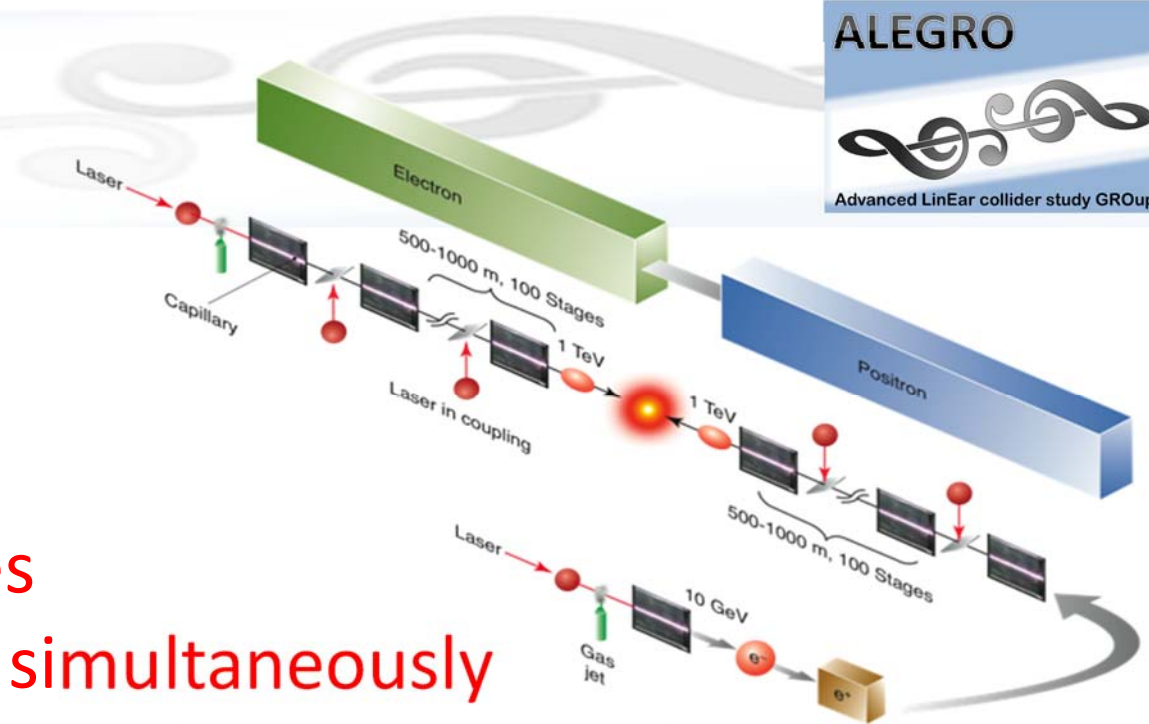
Somerville  
College

**ALEGRO 2018 workshop at  
Oxford**

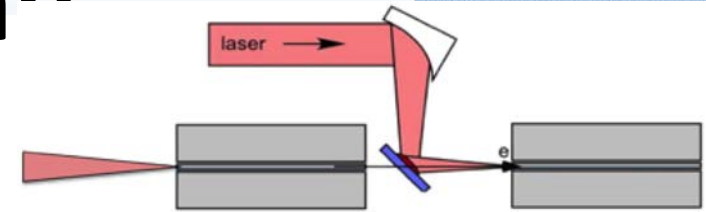


# Main challenges towards an ALIC

- ❖  $e^- \rightarrow e^+$
- ❖ injector + accel modules
- ❖ Address all parameters simultaneously
- ❖ Beam acceleration with small **energy spread**
- ❖ Preservation of small e-beam **emittance**
- ❖ Concepts for **positron acceleration** with high brightness
- ❖ **High efficiency** of acceleration for  $e^-$  and  $e^+$
- ❖ **Staging** required to reach very high energies
- ❖ **Repetition rates** averaging 10s of kHz
- ❖ Beam **stability and reproducibility**



# Challenges related to novel accelerator components

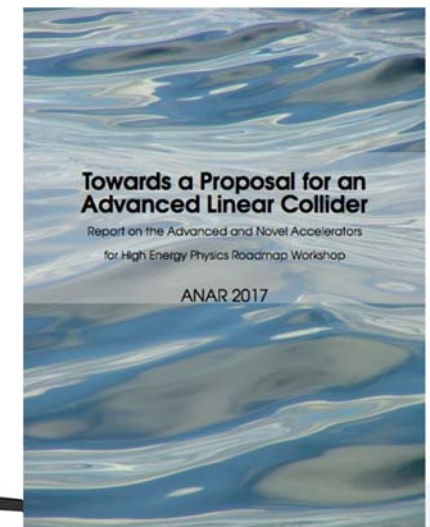


- ❖ **Injectors:** e-/e+ high 6D brightness (RF PI, Plasma bubble, nanotips)
- ❖ Accelerating **structures:** dielectrics or plasma, sustaining high rep rate, stable m-long media
- ❖ **Diagnostics:** for micron x fs resolution
- ❖ **Staging:** in- out-coupling, drive-witness beams management, alignment, imaging, compact transport
- ❖ **Stability, reproducibility, reliability:** feedback and control system, dedicated facilities

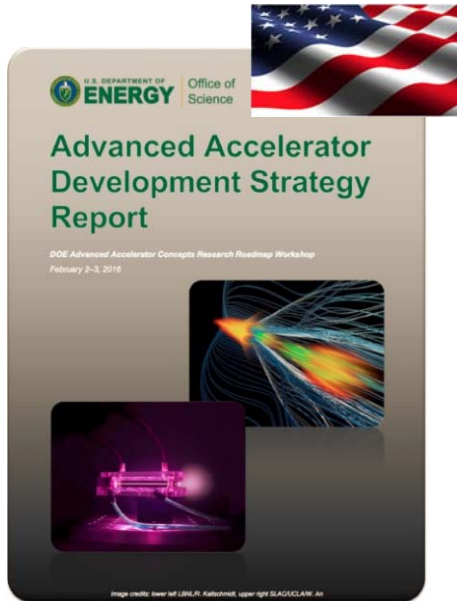
# Challenges related to beam dynamics at high energy

- ❖ Narrow **energy spread**
- ❖ **Efficiency** and beam loading
- ❖ **Emittance** preservation
- ❖ Scattering (plasma)
- ❖ Beam break-up and hosing instabilities
- ❖ Spin polarization preservation
- ❖ Ion motion (plasma)
- ❖ Structure charging and radiation damage
- ❖ **Numerical simulation**

<http://www.lpgp.u-psud.fr/icfaana/>



# Roadmaps to address these topics developed in the USA and in Europe



SWFA, LWFA, PWFA, x-ray FEL and  $e^-/e^+$  collider



LWFA, PWFA, x-ray FEL and  $e^-/e^+$  and  $e^-/p^+$  collider

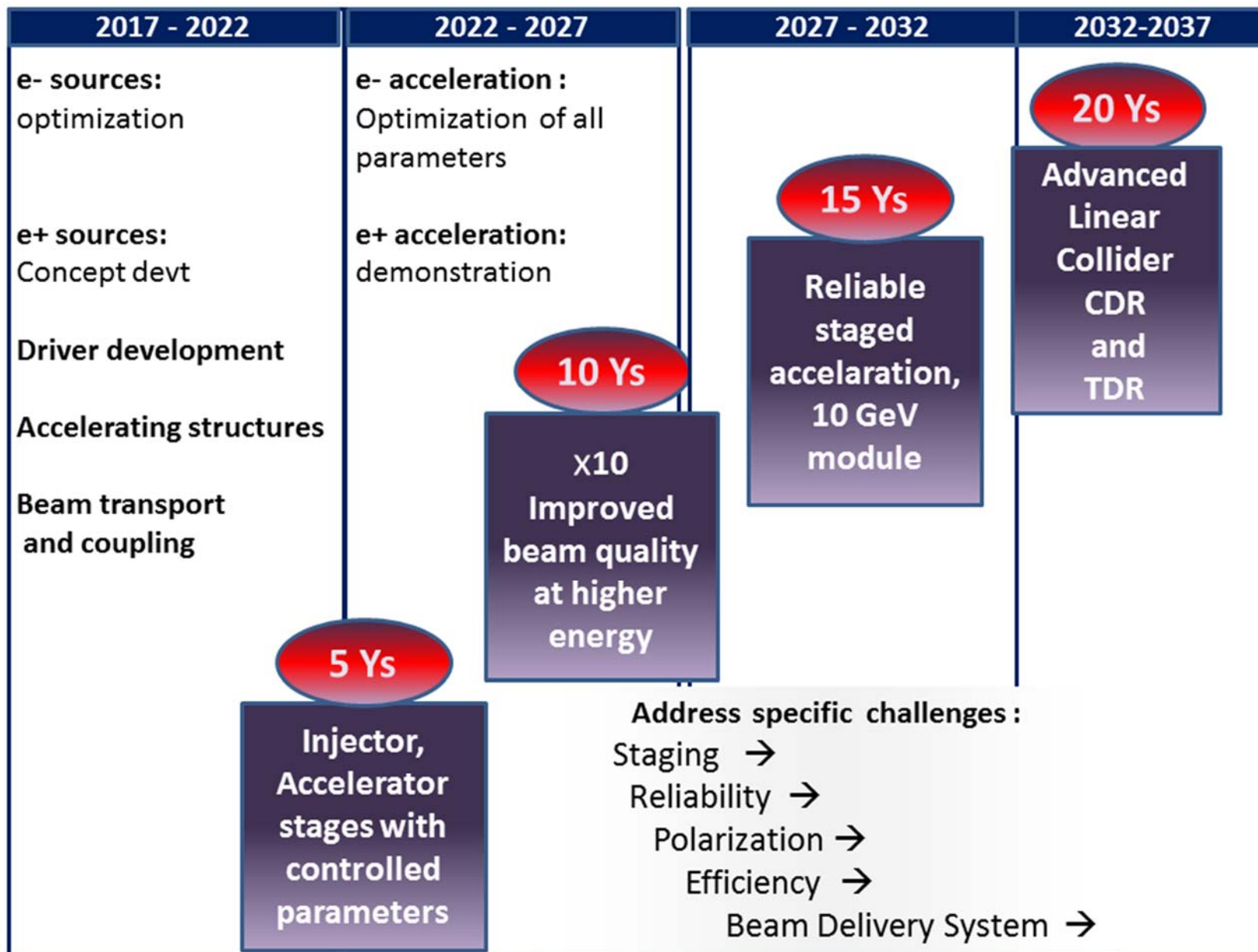
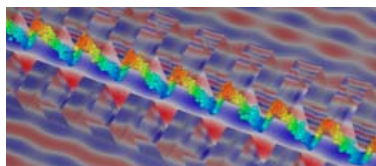
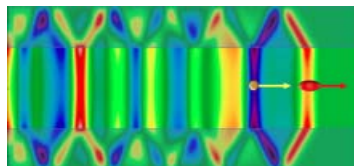
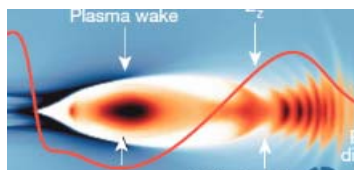
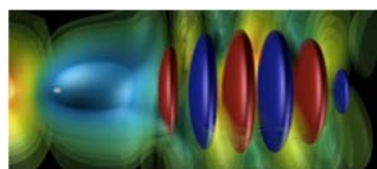


Report

# Scientific roadmap for a collider up to design report delivery

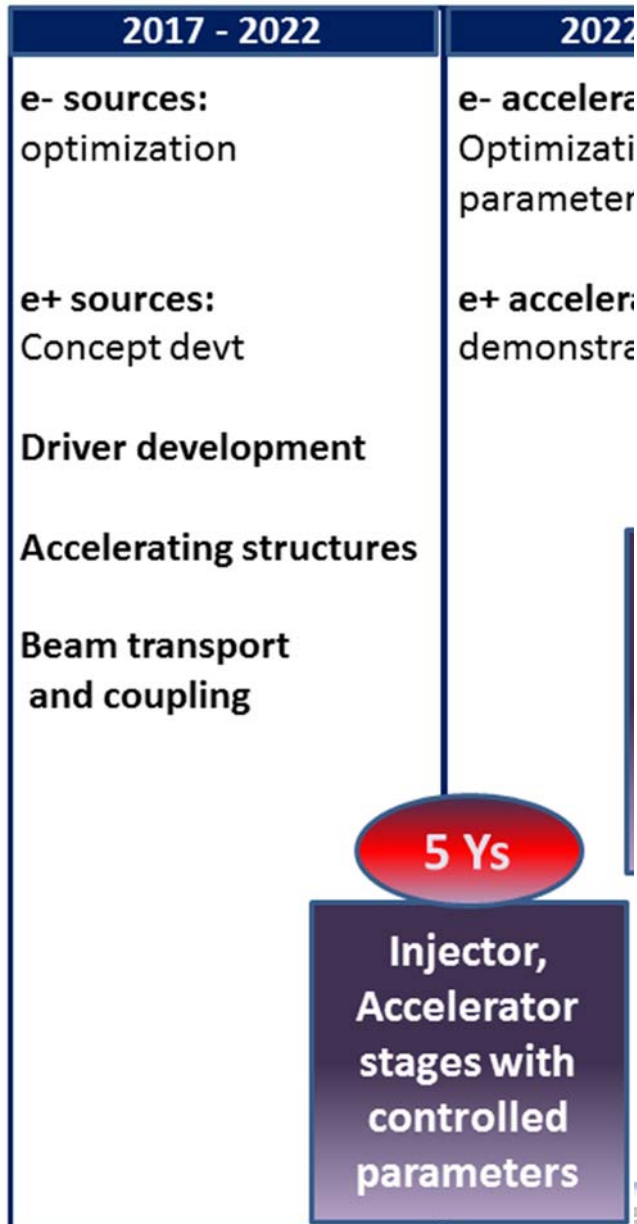
ANAR2017 workshop and report

<http://www.lpgp.u-psud.fr/icfaana/>



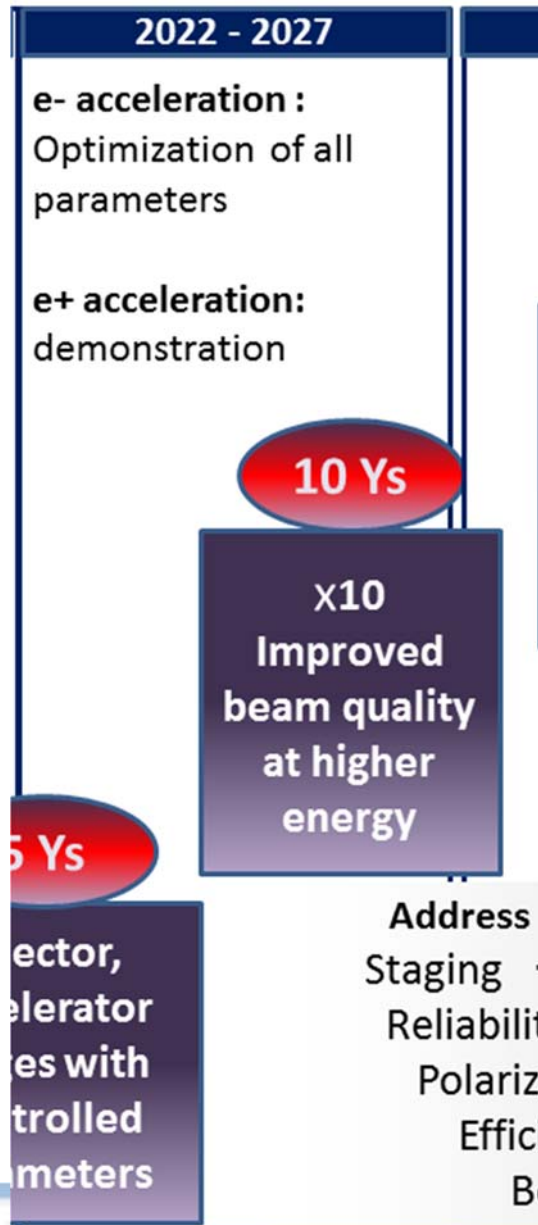


# 5-year milestone



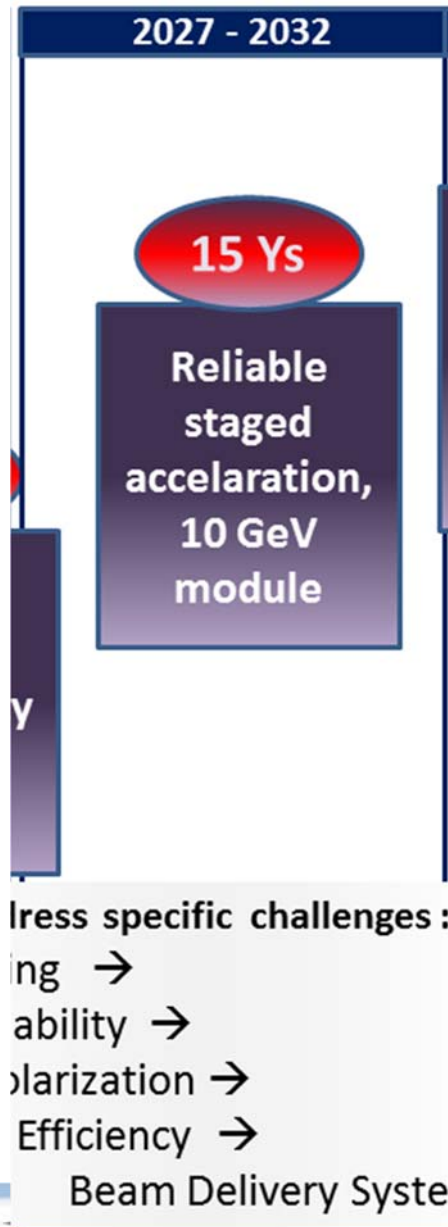
- ❖ **5-10 GeV ANA stage producing stable, good quality e- beam**
- ❖ **Sustained efforts on all accelerator components needed**
- ❖ **Increase of drivers stability and efficiency should be addressed**

# 10-year milestone



- ❖ **Improved bunch quality at high energy and staging of two structures**
- ❖ **Optimize all beam parameters  $e^-$ , test  $e^+$**
- ❖ **Start addressing in detail specific collider challenges : reliability, compact staging, polarization, efficiency, BDS**

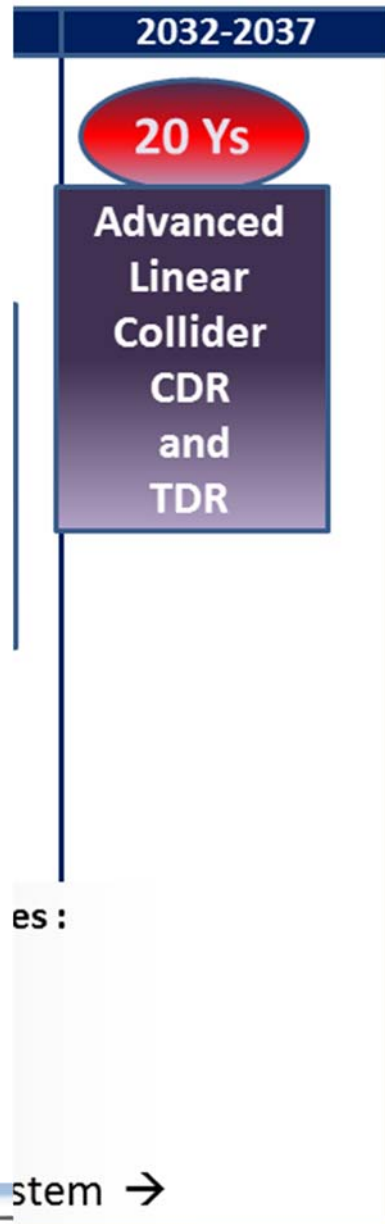
# 15-year milestone



- ❖ e- beam with reliable parameters, collider quality level in a staged process multi-GeV range
- ❖ Large scale facilities needed to demonstrate staging and efficiency
- ❖ Multi-stage prototypes
- ❖ Strawman design of multi-TeV machines for 4 ANA concepts



# 20-year milestone



- ❖ **Delivery of conceptual and technical reports**
- ❖ Following continuous development of collider concepts
- ❖ **Performance** of each ANA assessed from **simulations and prototyping experiments**
- ❖ Proposed designs could be based on multiple ANA schemes

# Moving further with 1st ALEGRO workshop, March 2018



GLOBAL design: Physics case, injector, accelerator, BDS, detector

GLOBAL approach: Asia, Europe, USA, ...

# First ALEGRO Goal

- ❖ Input for the 2020 European Particle Physics Strategy Update



- ❖ 2018: Input from the physics community - collaborations, projects, national institutes, individuals, etc.

- ❖ 2019: discussion by the Physics Preparation Group

- ❖ 2020: EPPSU proposal to and approval by the CERN Council

<http://vms.fnal.gov/asset/detail?recid=1952953>

# ALEGRO workshop highlights

- ✧ **Long term and ambitious goals** for HEP to give a new impulse to ANA development: need coordinated efforts to be undertaken for faster progress and increased funding
- ✧ ANAs are still partly in the exploratory/discovery phase
- ✧ **Mid term milestones identified** associated to the construction of specific facilities (e.g. EuPRAXIA, kBella, FACET II, ...)
  - ✧ to validate the **reliability** of ANAs
  - ✧ to demonstrate their capability to achieve **higher average power**
  - ✧ to develop compact **positron sources**

# ALEGRO workshop output

- ✧ Ambitious long term goals (0.5 to 30TeV)
- ✧ Advanced Linear Collider (ALIC), 30 TeV CM collision energy, luminosity in the  $10^{36} \text{ cm}^{-2}\text{s}^{-1}$  for studying Higgs coupling to the top quark, Higgs self-coupling and for precision measurements
- ✧ ALEGRO will submit (dec 2018) a document for the European Particle Physics Strategy Update



# ALEGRO community should grow and meet regularly



- ✧ Next ALEGRO workshop at CERN, **March 26-29, 2019**
- ✧ WGs organized according to colliders systems:
  - ✧ physics case
  - ✧ acceleration (plasma, dielectrics)
  - ✧ power sources (drive beam, laser, etc)
  - ✧ luminosity delivery (beam sources, beam cooling, tolerances, stabilization, focusing)
  - ✧ detector (machine detector interface)

✧ Other workshops will follow ..



# Summary

- ❖ Europe is getting organized supported by EC funding
- ❖ Close collaboration with industry in progress
- ❖ Projects are opened to the participation of world wide collaborators
- ❖ Ambitious projects for HEP machines are under study: creation of ALEGRO, ICFA initiative, worldwide support
- ❖ Next workshop at CERN  
March 26-29, 2019

<http://www.lpgp.u-psud.fr/icfaana/>

## ALEGRO input for the 2020 update of the European Strategy for Particle Physics: comprehensive overview

Contacts: B. Coust, P. Maggi<sup>2</sup>  
ALEGRO collaboration: list of names  
LIR of Institutes  
<sup>1</sup>LPGP, CNRS, Université Paris Sud, Orsay France,  
<sup>2</sup>Max Planck Institute for Physics, Munich, Germany

### Abstract

Following the achievement of outstanding progress of Advanced and Novel Accelerators (ANAs) over the last ten years, the Advanced Linear collider study GROUP, ALEGRO, was formed at the initiative of the ICFA ANA panel to foster studies on accelerators based on advanced accelerator concepts for applications to high energy physics. The mission of ALEGRO is to propose a machine that would allow reaching parameters meeting the requirements needed by particle physics. This document summarizes the current view of the international community on this topic, and proposes a list of priorities towards which the community would like to invest efforts over the next five to ten years.

Although ALIC, the Advanced Linear International Linear Collider, is an e+e- multi-TeV collider objective on the horizon of 2035, several stepping stones have to be established along the way, leading to spin-offs at lower energy for societal applications and contributing to the advancement of knowledge. The delivery by ANA of high quality, multi-TeV, stable electron beams, suitable for injection into a successive stage is a major goal for the community over the next 5 to 10 years.

Machine facilities dedicated to address key issues related to what is foreseen as the first stages of ALIC, producing beams in the 5-25 GeV range, are essential tools that should become available to the ALEGRO community. Joint efforts are also necessary to develop ultra-fast beam instrumentation and the simulation tools needed for the design of an advanced multi-TeV collider.

### Keywords

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

### Editing Board

Beatrice Coust, Patrizia Maggi, Carl Schroeder, Philippe Piot, Joel England, Spencer Geiser, Jorge Vieira, Eda Gschwendner

## Towards a Proposal for an Advanced Linear Collider

Report on the Advanced and Novel Accelerators  
for High Energy Physics Roadmap Workshop

ANAR 2017



# Acknowledgement

- ❖ ICFA ANA members
- ❖ ALEGRO members: 140 contributors Today

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