Towards a Proposal for an Advanced Linear Collider

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

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On behalf of ICFA ANA Panel

http://www.lpgp.u-psud.fr/icfaana/ana-publications-2017

3rd EAAC workshop, 25th September 2017, Isola d’Elba, Italy
Advanced and Novel Accelerators for High Energy Physics Roadmap Workshop 2017

Was held at CERN 25-28 April 2017

~80 participants, 4 Working Groups

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

Sponsored by
Organised at the initiative of the ICFA panel for Advanced and Novel Accelerators (ANA)

Organizing Committee (OC)

ICFA ANA Panel members
• Brigitte Cros (chair), CNRS- U PSud, France
• Patric Muggli, MPP, Germany
• Bruce Carlsten, LANL, USA
• Massimo Ferrario, INFN, Italy
• Brian Foster, U Hamburg, Oxford, DESY, Germany
• Ryoichi Hajima, NQIRST, Japan
• Dino Jaroszynski, U Strathclyde, UK
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• James Rosenweig, UCLA, USA
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• Mitsuru Uesaka, U Tokyo, Japan
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Other members
• Ralph Assmann, DESY, Germany
• Edda Gschwendtner, CERN, Switzerland
• Bernhard Holzer, CERN, Switzerland

http://www.lpgp.u-psud.fr/icfaana/front-page
Goal of the workshop

- To define an international roadmap towards colliders based on advanced accelerator concepts, including intermediate milestones, and to discuss the needs for international coordination.
- Slides available at
- https://indico.cern.ch/event/569406/overview
Outline

- Scientific frame
- Challenges and global roadmap items
- Review of strategy worldwide
- Next steps toward a collider roadmap
Challenging question for the community of ANA

Can we envisage the delivery of an Advanced Linear Collider design at >1TeV (10 TeV) in 2035?

- Electron- positron Collider at the energy frontier
- Parameters defined for/by HEP (Luminosity)

Four different concepts of Advanced Accelerators were discussed

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Advanced Accelerator concepts discussed in 4 WGs

- 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
Status of ANAs

- Acceleration of electrons: strong peak gradient
- LWFA also for electron sources, short kA bunches

<table>
<thead>
<tr>
<th>ANA</th>
<th>Energy</th>
<th>Gain</th>
<th>ΔE/E %</th>
<th>Charge (pC)</th>
<th>Peak Gradient GeV/m</th>
<th>Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWFA</td>
<td>4.2 GeV</td>
<td>3</td>
<td>6</td>
<td></td>
<td>47</td>
<td>-</td>
</tr>
<tr>
<td>PWFA</td>
<td>42 GeV</td>
<td>100</td>
<td>-</td>
<td></td>
<td>53</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1.6 GeV</td>
<td>0.7</td>
<td>74</td>
<td></td>
<td>4.4</td>
<td>30</td>
</tr>
<tr>
<td>SWFA</td>
<td>30 MeV</td>
<td>0.7</td>
<td>944</td>
<td></td>
<td>0.32</td>
<td>80</td>
</tr>
<tr>
<td>DLA</td>
<td>24 keV</td>
<td>100</td>
<td>-</td>
<td></td>
<td>0.69</td>
<td>-</td>
</tr>
</tbody>
</table>

- Positron acceleration demonstrated by PWFA
- Response of dielectric structures (SWFA, DLA) symmetric to the charge of drive and witness bunches
Main challenges towards an ALC

- $e^- \leftrightarrow e^+$
- Injector + accel modules

- 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
# 4ANAs scientific roadmap up to design report delivery

<table>
<thead>
<tr>
<th>2017 - 2022</th>
<th>2022 - 2027</th>
<th>2027 - 2032</th>
<th>2032-2037</th>
</tr>
</thead>
<tbody>
<tr>
<td>e- sources: optimization</td>
<td>e- acceleration: Optimization of all parameters</td>
<td>Reliable staged acceleration, 10 GeV module</td>
<td>Advanced Linear Collider CDR and TDR</td>
</tr>
<tr>
<td>e+ sources: Concept devt</td>
<td>e+ acceleration: demonstration</td>
<td>[15 Ys]</td>
<td></td>
</tr>
<tr>
<td>Driver development</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accelerating structures</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Beam transport and coupling</td>
<td></td>
<td></td>
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<tr>
<td><strong>5 Ys</strong></td>
<td>x10 Improved beam quality at higher energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>10 Ys</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>20 Ys</strong></td>
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</tbody>
</table>

- Injector, Accelerator stages with controlled parameters
- Address specific challenges:
  - Staging
  - Reliability
  - Polarization
  - Efficiency
  - Beam Delivery System
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
Connection with existing roadmaps in the US and Europe?

Preliminary Roadmap for Laser Plasma Accelerators

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
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<tbody>
<tr>
<td>Lasers</td>
<td>3 kW class</td>
<td>30 kW class</td>
<td>300 kW class</td>
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<tr>
<td>Accelerators</td>
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<tr>
<td>GeV linac - kHz rep rate</td>
<td>50-100 GeV linac(s) - Q&lt;1-10kHz</td>
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<tr>
<td>First applications (radiation sources)</td>
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<tr>
<td>Design of concepts for colliders</td>
<td>Collider conceptual design report (CDR)</td>
<td></td>
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<tr>
<td>Prototype Phase</td>
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<tr>
<td>GeV linac - iTx rate</td>
<td></td>
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<tr>
<td>5 GeV+ GeV staging</td>
<td></td>
<td></td>
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<tr>
<td>Phase space shaping, efficiency, diagnostics, tolerances</td>
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<tr>
<td>Final focus, cooling, ...</td>
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<tr>
<td>Colliders tech. design report (TD3)</td>
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<tr>
<td>Colliders</td>
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</tbody>
</table>

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All roadmaps point to an ALC design by 2035

- Very important challenges remain, but no show stopper
- Proposed time frame achievable only with
  - Intensive and coordinated international R&D
  - Sufficient funding for ANA technology with HEP application
- Common dedicated funding should support common roadmaps
- Coordination necessary to define common R&D objectives and propose future facilities
Summary and Next steps

- Advanced concepts offer promising options for colliders
- Key scientific milestones were identified
- Detailed program and resources need to be identified

Advanced LinEar collider study GROup (ALEGRO) being created to foster and trigger ALC 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 is being planned (WG8 EAAC this week, 26-29 March 2018 Oxford, AAC 2018)

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WG8 program this week
SALA ELENA (SE) meeting room

❖ Two sessions on Tuesday afternoon 16:00 to 19:30
  ❖ Several topics addressed: BDS, energy spread, plasma lens, multistage, energy scaling in DLA, collider modelling tools
  ❖ Discussion of collider detailed roadmap, organisation of ALEGRO

❖ Joint session WG1-WG8, Wednesday 18:00-19:45
  ❖ Facilities for collider relevant R&D
  ❖ Talks on some facilities
  ❖ Discussion about existing/needed facilities following our survey
Thank you to all ANAR 2017 workshop participants and to CERN and EuCARD$^2$ for support.