The ICFA ANA ALEGRO initiative

ALEGRO

Advanced LinEar collider study GROup

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CERN

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Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

ICFA – ICFA-ANA

ICFA

SPONSORED BY THE PARTICLES AND FIELDS COMMISSION OF IUPAP

International Committee for Future Accelerators

ICFA, the International Committee for Future Accelerators, was created to facilitate international collaboration in the construction and use of accelerators for high energy physics. It was created in 1976 by the International Union of Pure and Applied Physics. Its purposes, as stated in 1985, are as follows:

- 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.

The Committee has 16 members, selected primarily from the regions most deeply involved in high-energy physics.

Panels

- 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)

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ICFA-ANA

International Committee for Future Accelerators

Panel on Advanced and Novel Accelerators

Mission:

To extend and support the international collaboration and communication in the field of new acceleration techniques.

- To promote and encourage international collaboration/workshop/school on advanced and novel accelerators.
- Especially emphasize on advanced compact accelerator and their application to not only high energy physics, particle physics, nuclear physics but also medical physics, nondestructive evaluation, security and so on, in order to maintain accelerator science and technology.

ANA Panel Members (2013-2016)

Name	Affiliation
Brigitte Cros (chair)	LPGP-CNRS- Univ Paris Sud, France
Bruce Carlsten (Contact USA)	Los Alamos National Laboratory, USA
Massimo Ferrario	INFN, Italy
Brian Foster	Univ. Hamburg & Univ. Oxford, DESY, Germany
Ryoichi Hajima	Japan Atomic Energy Agency, Japan
Dino Jaroszynski	Uni Strathclyde, UK
Patric Muggli (Contact Europe)	Max-Planck-Institut für Physik, Germany
Philippe Piot (Contact USA)	Northern Illinois Univ (USA), Fermi Nat Accel. Lab.
James Rosenweig	Univ California Los Angeles, USA
Carl Schroeder	Lawrence Berkeley National Laboratory, USA
Chuanxiang Tang (Contact Asia)	Tsinghua University, China
Mitsuru Uesaka	Univ. Tokyo, Japan
Mitsuhiro Yoshida	KEK, Japan

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

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ADVANCED & NOVEL ACCELERATORS (ANAs)

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"Advanced"

↕

"High-gradient"

↕

>1GeV/m (ICFA-ANA)

↕

Average gradient over m–scale

↕

GeV to TeV or beyond e^-/e^+

 *do not include laser vacuum/direct acceleration

ADVANCED & NOVEL ACCELERATORS (ANAs)

"Advanced"

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>1GeV/m (ICFA-ANA)

Average gradient over m–scale

GeV to TeV or beyond e^-/e^+

Novel materials with higher damage threshold:

- ✧Dielectrics (~GV/m)
- ✧Plasmas (10-100GV/m or ∞)

Novel drivers:

- ✧Laser pulse(s)*
- ✧Charged particle bunch(es)

*do not include laser vacuum/direct acceleration

ADVANCED & NOVEL ACCELERATORS (ANAs)

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Novel drivers:

- ✧Laser pulse(s)*
- ✧Charged particle bunch(es)

Medium / Driver	Dielectric	Plasma
Laser Pulse	Dielectric Laser Accelerator DLA	Laser Wakefield Accelerator LWFA
Particle Bunch	Structure Wakefield Accelerator SWFA	Plasma Wakefield Accelerator PWFA

*do not include laser vacuum/direct acceleration

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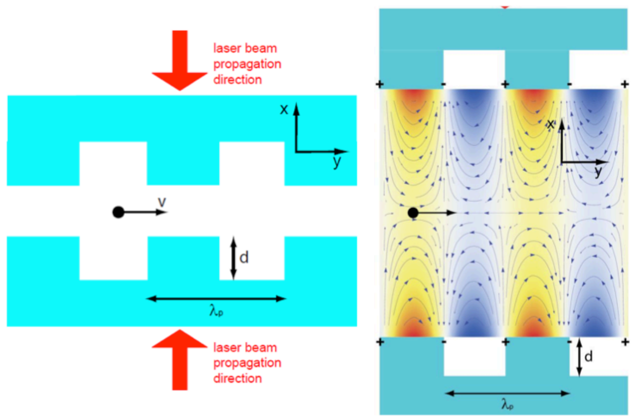
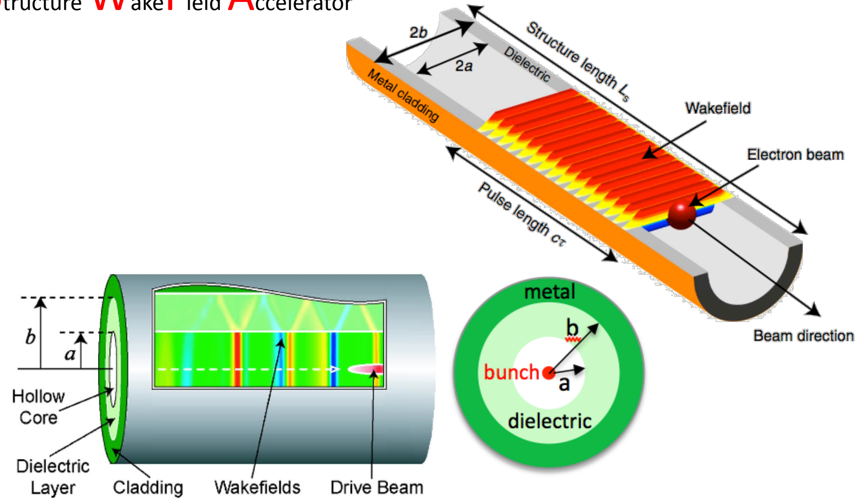
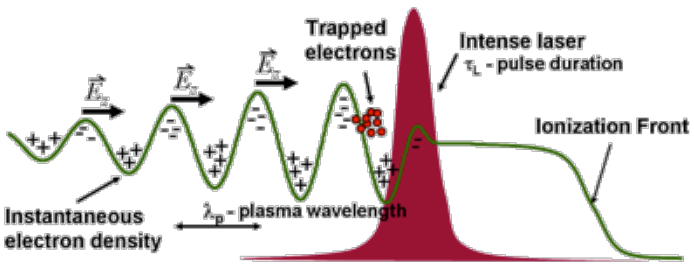
Dielectric Laser Accelerator

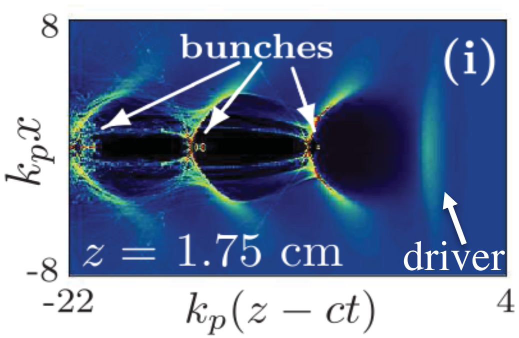


Structure WakeField Accelerator

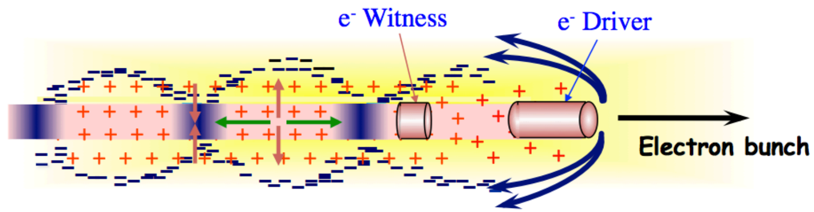


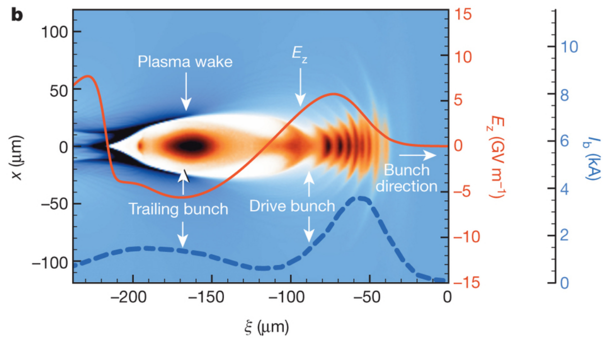
Laser WakeField Accelerator





Pasma WakeField Accelerator





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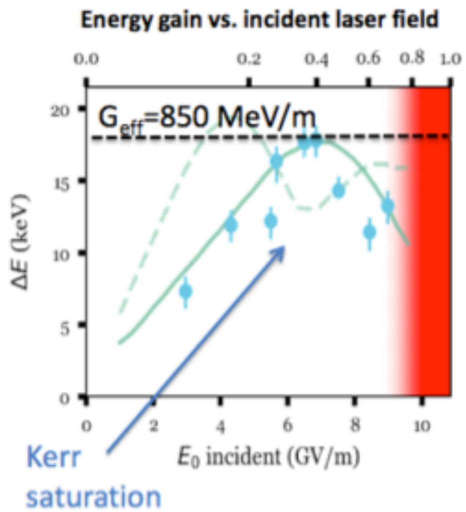
DEMONTRATiONS OF "ADVANCED"

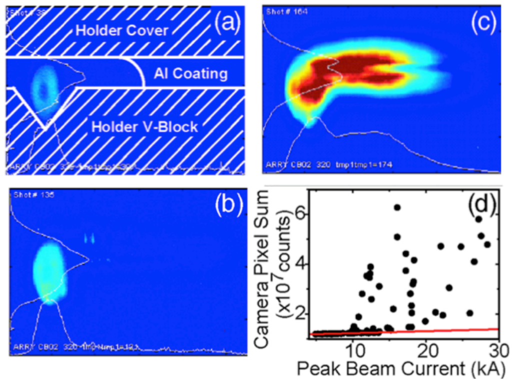
Max-Planck-Institut für Physik

Dielectric Laser Accelerator



Presented by D. Cesar (UCLA) @ EAAC 2017

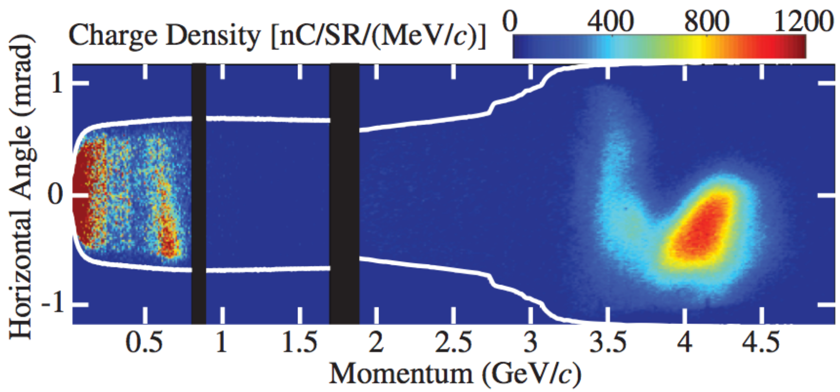
Structure WakeField Accelerator



- ✧ Breakdown field: 13.8±0:7GV/m
- ✧ Estimated max. decelerating field: 11GV/m
- ✧ Estimated max. accelerating field: 17GV/m

Thompson, PRL 100, 214801 (2008)

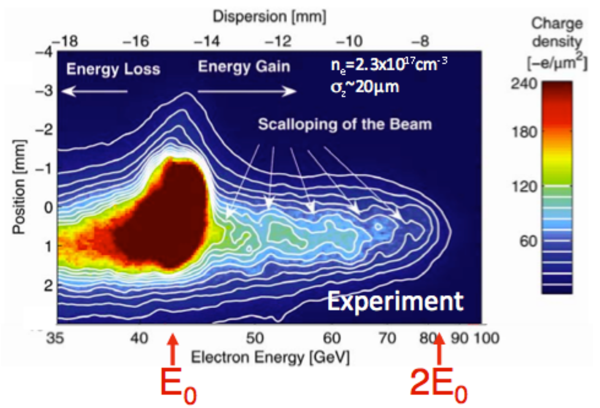
Laser WakeField Accelerator



- ✧ Peak energy gain 4.2GeV in 9cm (46GeV/m)
- ✧ Self-trapped plasma e⁻, 6pC (no injector needed)

Leemans, PRL 113, 245002 (2014)

Pasma WakeField Accelerator



42 => 84GeV in 85cm! 50GeV/m

Blumenfeld, Nature 445, 741 (2007)

✧ Many more key and interesting results

https://indico.cern.ch/event/667672/contributions/2730847/

DEMONTRATiONS OF "ADVANCED"

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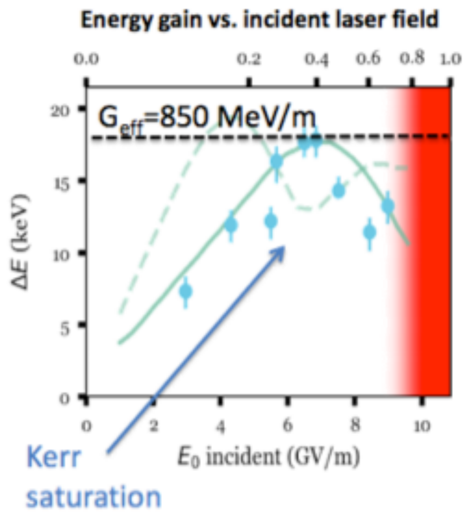
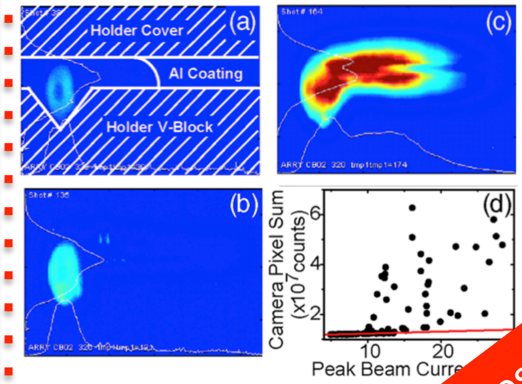
Dielectric Laser Accelerator



Presented by D. Cesar (UCLA) @ EAAC 2017

Structure WakeField Accelerator



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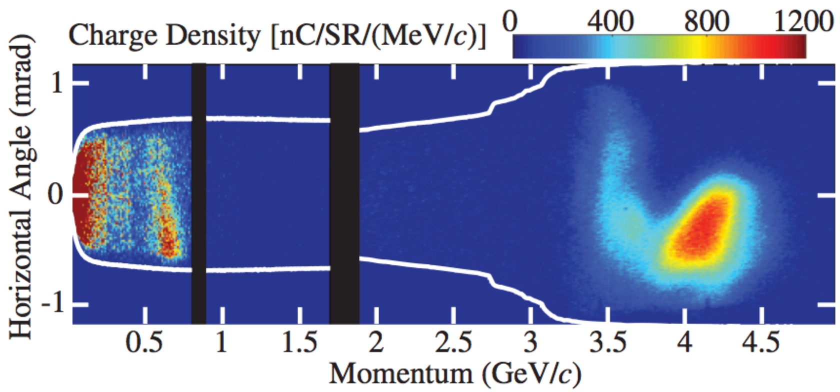
✧ Est...ted max. ...rating field: ...GV/m

Thompson, PRL 100, 2... (2008)

Missing proper drive/witness bunhes

Laser WakeField Accelerator



✧Peak energy gain 4.2GeV in 9cm (46GeV/m)

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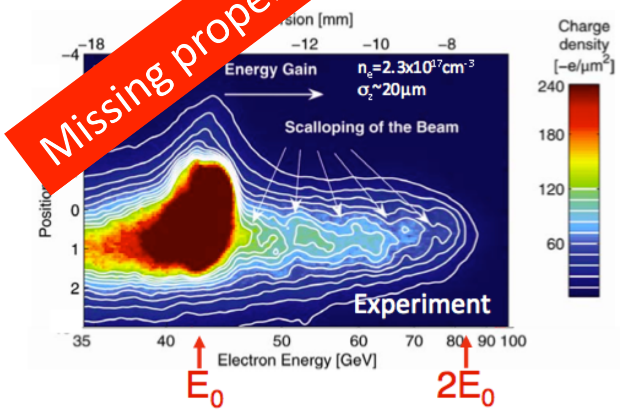
Leemans, PRL 113, 245002 (2014)

Pasma WakeField A...



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Blumenfeld, Nature 445, 741 (2007)

✧Many more key and interesting results

https://indico.cern.ch/event/667672/contributions/2730847/

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APPLiCATiONS OF ANAs

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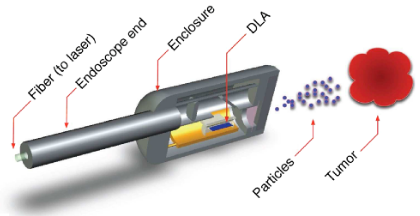
✧X-ray for radiography (advanced: phase contrast, etc.)
✧e^- for medical applications

✧Require low energy <GeV
✧Can operate at very large peak gradient, mm-cm accelerator
✧Efficiency not an issue
✧Luminosity “not an issue”
✧Special characteristics: ultra-short, synchronized (laser), pump probe, etc.
✧Biological advantage …
✧Unique applications, compact

<1GeV

GeV-TeV

Dielectric Laser Accelerator DLA	Laser Wakefield Accelerator LWFA
Structure Wakefield Accelerator SWFA	Plasma Wakefield Accelerator PWFA



England, Rev. Mod. Phys., 86, 1337, (2014)

✧Powerful radiation source, THz to γ-rays (x-ray FEL)
✧High-energy physics (HEP)
  ✧e^-/e^+ collider
  ✧e^-/p^+ collider
  ✧Energy upgrade for a conventional, future collider (ILC, CLIC)

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(Werner-Heisenberg-Institut)

APPLiCATiONS OF ANAs

"Small"

<1GeV

✧X-ray for radiography (advanced: phase contrast, etc.)
✧e^- for medical applications

✧Require low energy <GeV
✧Can operate at very large peak gradient, mm-cm accelerator
✧Efficiency not an issue
✧Luminosity "not an issue"
✧Special characteristics: ultra-short, synchronized (laser), pump probe, etc.
✧Biological advantage …
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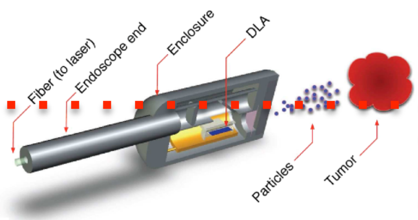

England, Rev. Mod. Phys., 86, 1337, (2014)

Dielectric Laser Accelerator DLA	Laser Wakefield Accelerator LWFA
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GeV-TeV

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  - ✧e^-/e^+ collider
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"Large"

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APPLiCATiONS OF ANAs TO HEP

✧ICFA-ANA subpanel:
- ✧Application to HEP does require World-wide cooperation
- ✧ANA community quite fragmented (by nature)
- ✧Urgent need for ANA community gathering
- ✧Urgent need to overlap with non-ANA accelerator community
- ✧Wealth of experience in non-ANA accelerator community
- ✧Need to think an ANA-collider (or Advanced Linear Collider) globally, from injector to IP

GeV-TeV

Dielectric Laser Accelerator DLA	Laser Wakefield Accelerator LWFA
Structure Wakefield Accelerator SWFA	Plasma Wakefield Accelerator PWFA

✧Powerful radiation source, THz to γ-rays (x-ray FEL)

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"Large"

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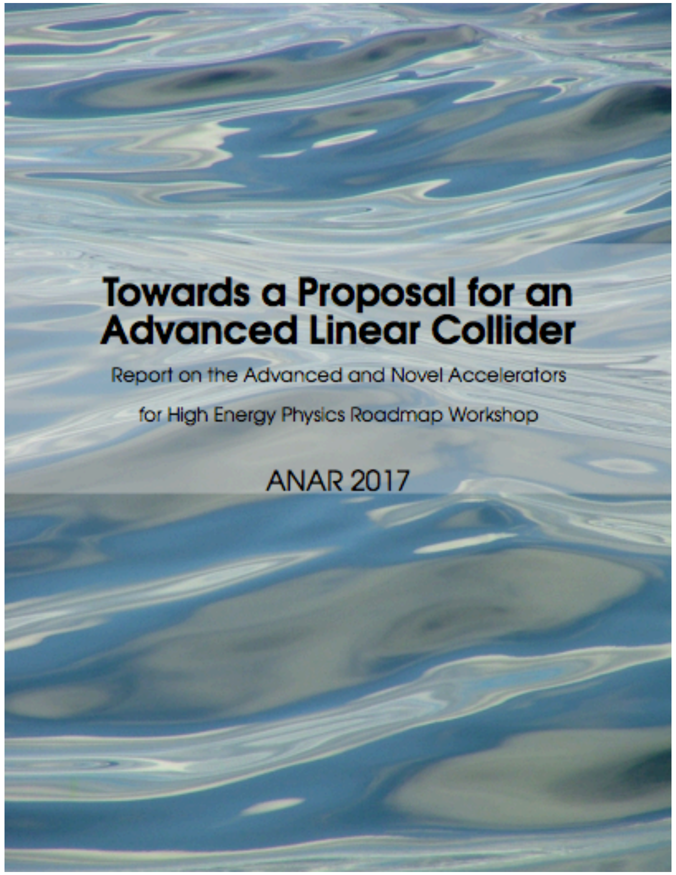
ANAR WORKSHOP 2017 (April)

Advanced and Novel Accelerators Roadmap workshop

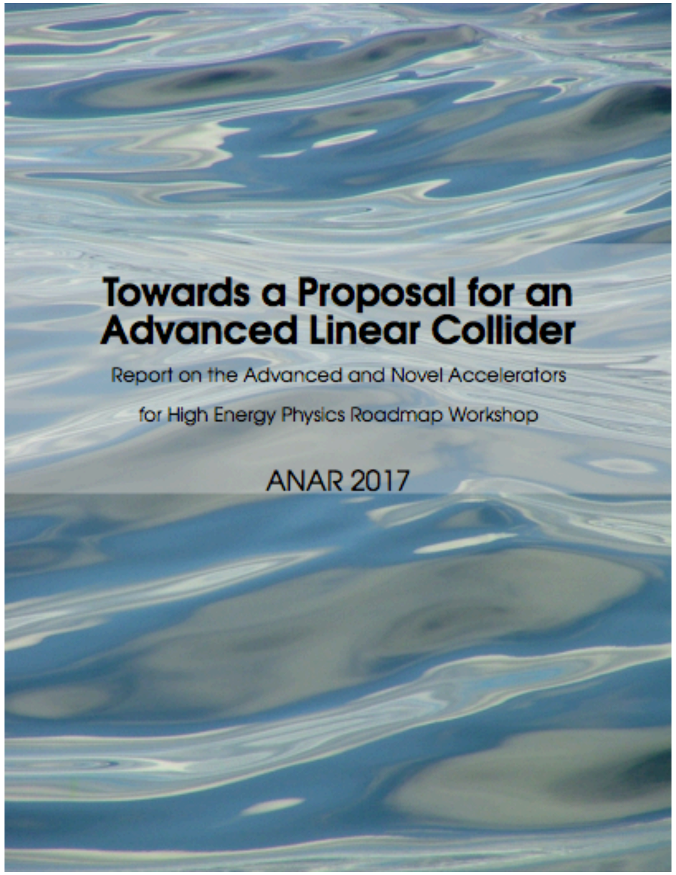
Contents



http://www.lpgp.u-psud.fr/icfaana/ANAR2017_report.pdf

ANAR Workshop 2017 (April)

Max-Planck-Institut für Physik (Werner-Heisenberg-Institut)



Advanced and Novel Accelerators Roadmap workshop

Contents

Science (sections 3–3.2.8)

Strategy (sections 4–4.3)

http://www.lpgp.u-psud.fr/icfaana/ANAR2017_report.pdf

ANAR WORKSHOP 2017 (April)

3 Main Challenges Towards an ALC

3.1 Challenges Related to Novel Accelerator Components

- 3.1.1 Injectors
- 3.1.2 Accelerating Structures
- 3.1.3 Diagnostics
- 3.1.4 Staging
- 3.1.5 Stability, Reproducibility, Reliability, Need for Dedicated Experiments

3.2 Challenges Related to Beam Dynamics at High Energy

- 3.2.1 Narrow Energy Spread
- 3.2.2 Efficiency and Beam Loading
- 3.2.3 Emittance Preservation
- 3.2.4 Scattering
- 3.2.5 Beam Break-up and Hosing Instabilities
- 3.2.6 Spin-Polarization Preservation
- 3.2.7 Ion Motion
- 3.2.8 Numerical Simulations

*Larger scale experiments

http://www.lpgp.u-psud.fr/icfaana/ANAR2017_report.pdf

EXiSTiNG "LOCAL" ROADMAPS

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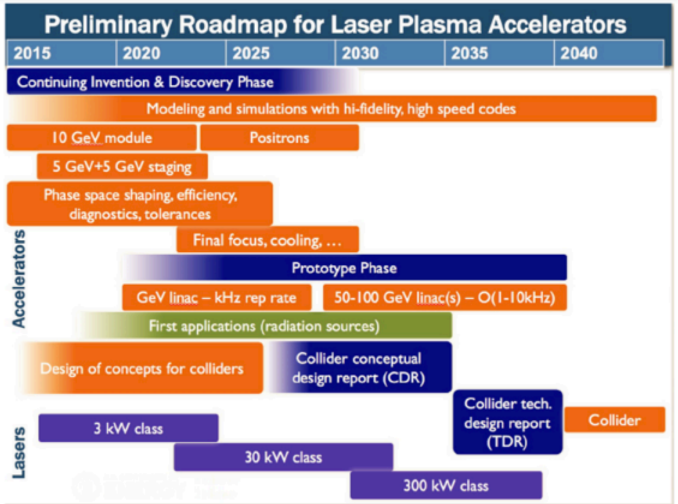

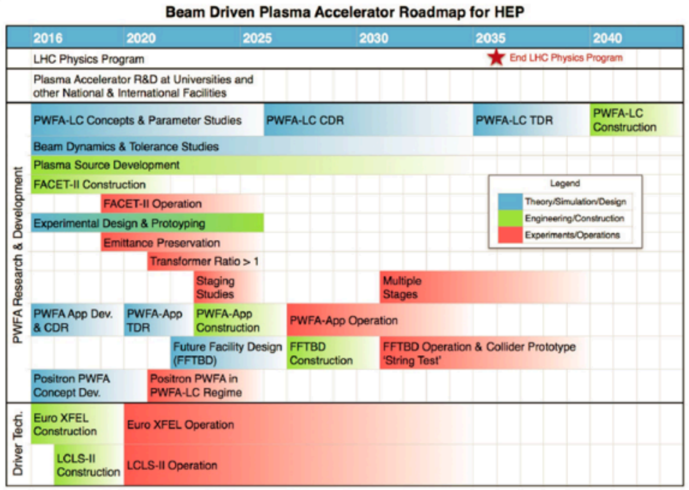

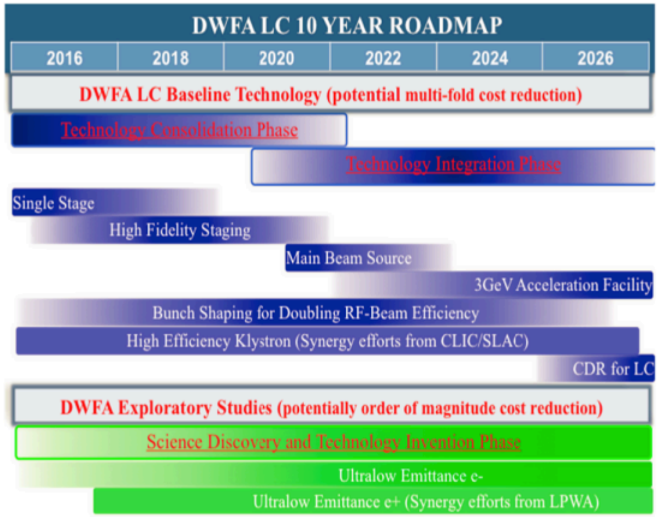

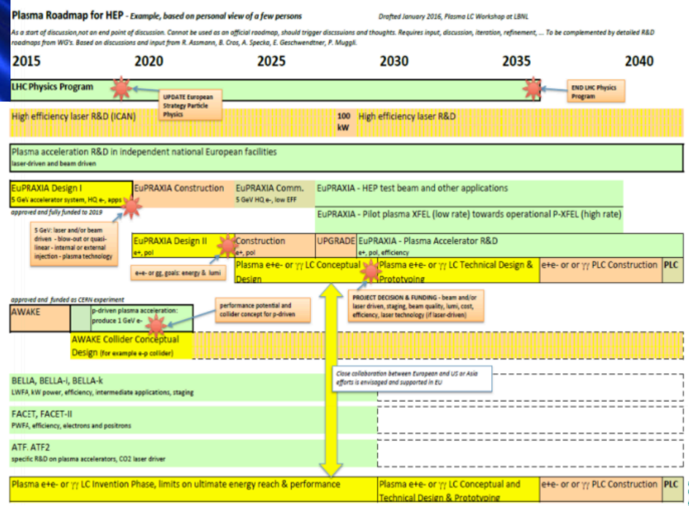

SWFA, LWFA, PWFA, x-ray FEL and e^-/e^+ collider

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

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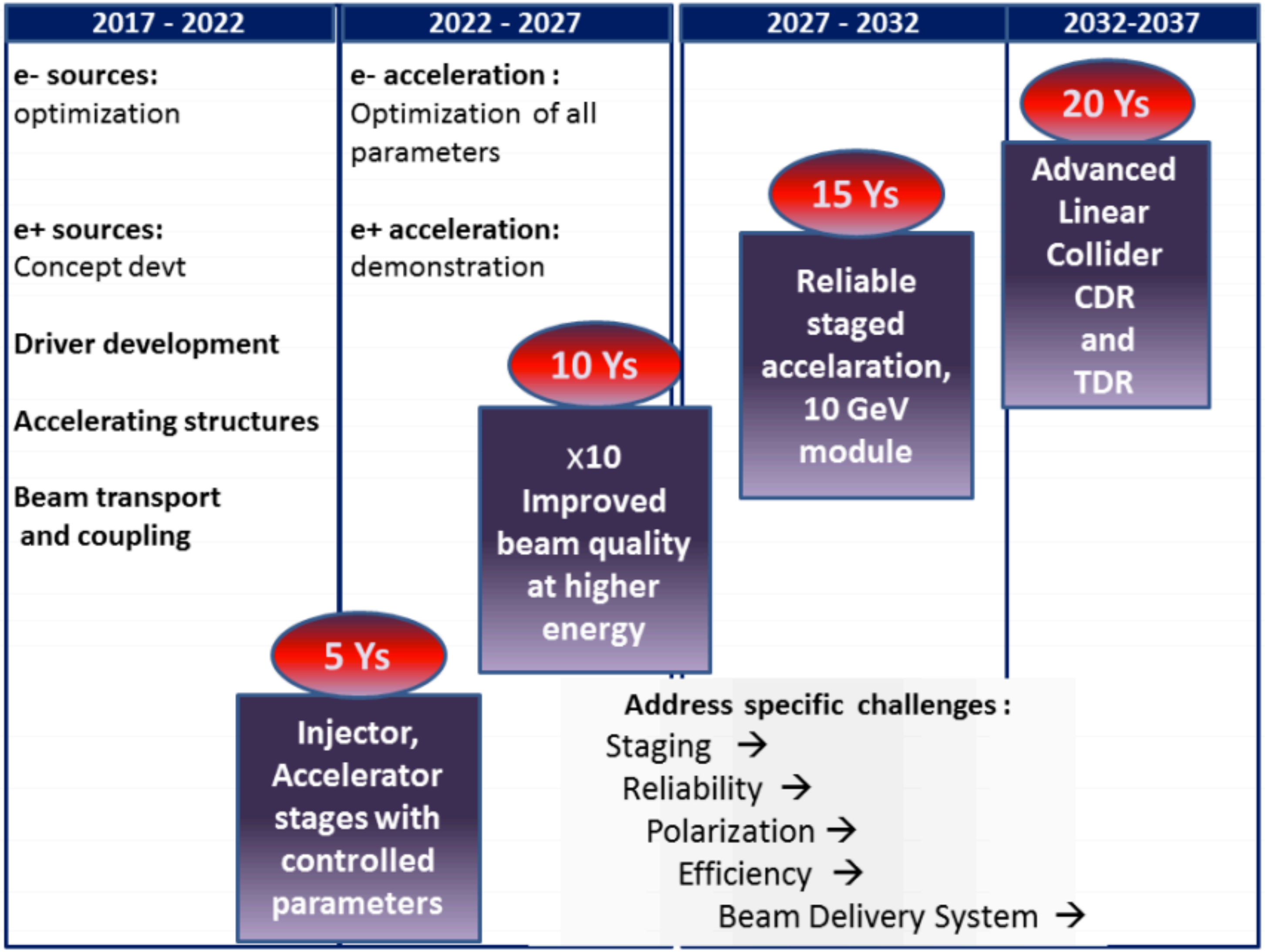
WORLDWIDE ROADMAP

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

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

ANAR SCiENTiFiC ROADMAP



✧Schedule driven by LHC physics/schedule and ILC/CLIC?

ANAR WORKSHOP OUTCOME

As an outcome of the workshop, it was decided to constitute a study group towards Advanced Linear Colliders, named ALEGRO for Advanced LinEar collider study GROup. ALEGRO's general charge will be to coordinate the preparation of a proposal for an advanced linear collider in the multi-TeV energy range.
The ALEGRO will consist of (30) scientists with expertise in advanced accelerators concepts or accelerator physics and technology, drawn from national institutions or universities in Europe, America and Asia.

The ALEGRO will organize a series of workshops on relevant topics where the scientific community should, in a first phase, discuss and iterate the roadmaps, discuss ways to tackle key challenges, and, over time, monitor the progress of the community as a whole on collider-oriented R&D.

The first objective of ALEGRO is to prepare and deliver by the end of 2018 a document detailing the roadmap and strategy of ANAs, with clear priorities, as input for the European Strategy Research Group (ESRG).
In order to prepare the document for the ESRG, three workshops are planned:
the first is scheduled during the EAAC 2017 where a WG on colliders is organized; a second at the beginning of 2018 hosted by the JAI, and a third jointly with the AAC2018.

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ANAR WORKSHOP OUTCOME

ALEGRO 2018

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Max-Planck-Institut für Physik

ALEGRO WORKSHOP (A. Seryi, P. Muggli)

ALEGRO 2018

Advanced LinEar collider study GROup Workshop 2018

26-29 March 2018, University of Oxford, JAI

https://indico.cern.ch/event/677640/

Four to eight WGs:

- Physics Case (PC); WG1 coordinators: M. Peskin (SLAC), Junping Tian (U. Tokyo), TBD ()
- Collider machine design/definitions (CMD) ; WG2 coordinators: D. Schulte (CERN), A. Seryi (JAI), Hitoshi Yamamoto (Tohoku Uni)
- Theory, Modelling, Simulations (TMS); WG3 coordinators: J.-L. Vay (LBNL), J. Vieira (IST)
- LWFA; WG4 coordinators: C. Schroeder (LBNL), S. Hooker (JAI/Oxford), B. Cros (CNRS/U. Paris Sud)
- PWFA; WG5 coordinators: J. Osterhoff (DESY), E. Gschwendter (CERN), P. Muggli (MPP)
- SWFA; WG6 coordinators: P. Piot (NIU), J. Power (ANL)
- DLA; WG7 coordinators: J. England (SLAC), B. Cowan (Tech-X)
- Joint sub-WG on positron acceleration (PAC); WG8 coordinators: S. Corde (LOA), S. Gessner (CERN)

✧Extended to reflect ANAs-based global and Worldwide collider design needs

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ALEGRO WORKSHOP CHARGE

ALEGRO 2018

Advanced LinEar collider study GROup Workshop 2018

26-29 March 2018, University of Oxford, JAI

https://indico.cern.ch/event/677640/

Charge to the working groups:

- Identify physics programme
- Identify scientific objectives and challenges of advanced accelerators
- Identify an Advanced Accelerator Project (medium/long term)
- Identify required high priority R&D, with possibly the construction of a test facility
- Identify partners and cost of R&D

- Detailed charge:
- Identify parameters/elements necessary for the scheme
- Determine to what extend they have been proved and demonstrated
- Evaluate likelihood and timescales for testing/proving solutions
- Identify key experiments to be performed
- Identify existing or new facilities to perform key experiments
- Identify realistic time scales
- Identify panorama, what is in the making?

ALEGRO WORKSHOP (A. Seryi, P. Muggli)

Advanced LinEar collider study GROup
Workshop 2018

26-29 March 2018, University of Oxford, JAI

https://indico.cern.ch/event/677640/

Open to community at large

Prepare document for ESRG (2018)

Mark the date in your calendar, <u>you</u> are invited!

http://www.physics.ox.ac.uk/confs/alegro2018/index.asp

ALEGRO CURRENT AGENDA

- ✧Working groups (WGs) and WG leaders work continuously towards input document for European Strategy Research Group (ESRG, 2018-20)
- ✧First draft will be started at the March 2018 ALEGRO workshop at JAI
- ✧Almost final version ready for the ALEGRO meeting at August 2018 Advanced Accelerators Concept workshop in Colorado, USA
- ✧Final version ready for Fall 2018
- ✧Provide a framework to amplify international coordination at the scientific level and to foster worldwide collaboration towards an ALC (ANA-based linear collider)
- ✧Broaden the community (ANA and non-ANA)
- ✧Identify topics requiring R&D, propose joint activities and work plans
- ✧Identify existing and needed facilities
- ✧... CDR for an ALC ~2035

SUMMARY

- ✧ICFA-ANA panel identified the need for Worldwide collaboration towards an Advanced Linear Collider
- ✧The ALEGRO group was formed as an outcome of the 2017 Advanced and Novel Accelerators Roadmap workshop
- ✧ALEGRO gathers the ANA community and includes the broader accelerator community
- ✧ALEGRO organizes workshops to summarize and gather the work of the working groups (WGs)
- ✧ALEGRO has eight WGs covering the global approach towards and ALC
- ✧WGs work continuously towards:
  - ✧an input document for European Strategy Research Group (ESRG, 2018-20)
  - ✧a CDR for an ANA –based ALC in ~2035
- ✧ALEGRO is an open group and welcome active contributions towards its stated goals

http://www.mpp.mpg.de/~muggli

muggli@mpp.mpg.de

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DiSCUSSiON TOPiC

Table 1: ALEGRO megatable – overall parameters of advanced acceleration collider concepts

Parameter	Concept 1	Concept 2	...	Concept N
Colliding species	e^+e^-	...	...	...
Upgrade or stand-alone	...	...	...	...
Final E CM, TeV	1.0	...	...	...
Luminosity, 10^{34}cm^{-2}s^{-1}	...	...	...	...
Effective L*, m	...	...	...	...
Detector forward exclusion angle, mrad	...	...	...	...
Total length, km	...	...	...	...
Length of beam delivery, km	...	...	...	...
Repetition rate, Hz	...	...	...	...
Total wall plug power, MW	...	...	...	...
Colliding beam power, MW	...	...	...	...
IP beam sizes, X/Y, nm	...	...	...	...
IP beam length, Z, mm	...	...	...	...
IP beam n-emittance, X/Y, nm	...	...	...	...
IP beam E-spread, %	...	...	...	...
Colliding bunch population, 10^{10}	...	...	...	...
Initial E of colliding bunches, GeV	...	...	...	...
Driver type	laser	e-bunch	p-bunch	...
Adv.acc. media	plasma	diel	...	...
Driver E/bunch, J	...	...	...	...
Adv.acc. transformer ratio	...	...	...	...
Length of single adv.acc stage, m	...	...	...	...
Number of adv.acc stages	...	...	...	...
Effective gradient of adv.acc media	...	...	...	...

- ✧MEGAtable proposed by A. Seryi
- ✧Similar tables:
  - ✧https://www.slac.stanford.edu/xorg/ilc-trc/ilc-trchome.html
  - ✧http://www.slac.stanford.edu/xorg/ilc-trc/2002/2002/report/PAPERS/TRC03C2.PDF

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https://www.slac.stanford.edu/xorg/ilc-trc/ilc-trchome.html

Click here to update your machine information for Table 1.1.	TESLA		SBLC		JLC (C)		JLC (X)	NLC	JLC/NLC**	VLEPP		CLIC**		
	TRC 12/95	Updated* 8/98	TRC 12/95	Updated* 10/96	TRC 12/95	Updated* 9/99	TRC 12/95	TRC 12/95	Updated* 12/98	TRC 12/95	Updated* 10/96	TRC 12/95	Updated* 9/99	
Initial energy (c.m.) (GeV)	500		500		500		500	500	500	500		500		Initial energy (c.m.) (GeV)
RF frequency of main linac (GHz)	1.3		3		5.7		11.4	11.4	11.4	14		30		RF frequency of main linac (GHz)
Nominal luminosity $(10^{33}\ cm^{-2}\ s^{-1})^{\dagger}$	2.6	16.2	2.2	3.16	7.3	5.02	5.1	5.3	5.1(4.2)	12.3	11.9	0.7-3.4	7.8	Nominal luminosity $(10^{33}\ cm^{-2}\ s^{-1})^{\dagger}$
Actual luminosity $(10^{33}\ cm^{-2}\ s^{-1})^{\dagger}$	6.1	30	3.75	5.3	6.1	7.18	5.2	7.1	6.54(5.45)	9.3	9.7	1.07-4.8	14.2	Actual luminosity $(10^{33}\ cm^{-2}\ s^{-1})^{\dagger}$
Linac repetition rate (Hz)	10	5	50		100		150	180	120(100)	300		2530-1210	200	Linac repetition rate (Hz)
No. of particles/bunch at IP (10^{10})	5.15	2	2.9	1.1	1	1.11	.63	.65	.95	20		.8	.4	No. of particles/bunch at IP (10^{10})
No. of bunches/pulse	800	2820	125	333	72		85	90	95	1		1-10	154	No. of bunches/pulse
Bunch separation (nsec)	1000	337	16	6	2.8		1.4		2.8	2.8	-	.67		Bunch separation (nsec)
Beam power/beam (MW)	16.5	11.3	7.26	7.25	2.9	3.07	3.2	4.2	4.5(3.7)	2.4		.8-3.9	4.9	Beam power/beam (MW)
Damping ring energy (GeV)	4	3.2	3.15		2	1.98	2	2	1.98	3		2.15	1.98	Damping ring energy (GeV)
Unloaded/loaded†† (MV/m)	25/25	21.7/21.7	21/17		40/32	44/34	73/58	50/37	72.3/55	100/91		80/78	172/150	Unloaded/loaded†† (MV/m)
Total two-linac length (km)	29	30	33	32	18.8	16	10.4	15.6	10.5	7		8.8	4.6	Total two-linac length (km)
Total beam delivery length (km)	3	2.5	3		3.6		3.6	4.4	NA	3		2.4	10 (3 TeV)	Total beam delivery length (km)
$\gamma\varepsilon_x / \gamma\varepsilon_y$ (m-rad × 10^{-6})	20/1	10/.03	10/.5	5/.25	3.3/.05		3.3/.05	5/.05	4.5/0.1	20/.08		3/.15	2/.02	$\gamma\varepsilon_x / \gamma\varepsilon_y$ (m-rad × 10^{-6})
β_x^* / β_y^* (mm)	25/2	15/.4	22/.8	11/.45	10/.1	15/.2	10/.1	10/.1	12/0.12	100/.1		10/.18	10/.15	β_x^* / β_y^* (mm)
σ_x^* / σ_y^* (nm) before pinch	1000/64	553/5	670/28	335/15.1	260/3	318/4.3	260/3.1	320/3.2	330/4.9	2000/4		247/7.4	202/2.5	σ_x^* / σ_y^* (nm) before pinch
σ_z^* (μm)	1000	400	500	300	120	200	90	100	120	750		200	30	σ_z^* (μm)
Crossing Angle at IP (mrad)	0	0	3	6	6	8	6.1	20	20(6)	6		1	10	Crossing Angle at IP (mrad)
Disruptions D_x / D_y	.56/8.7	.3/33	.36/8.5	.32/7.1	.2/18	.25/17.9	.096/8.3	.07/7.3	0.12/7.9	.4/215		.29/9.8	.03/2.7	Disruptions D_x / D_y
H_D	2.3	1.8	1.8	1.68	1.4	1.7	1.4	1.34	1.36	2	0.82	1.42	1.81	H_D
Upsilon sub-zero	.02	.02	.037		.14	.21	.12	.089	.11	.059		.07	.289	Upsilon sub-zero
Upsilon effective	.03	.03	.042		.144		.12	.09	.11	.074		.075	.291	Upsilon effective
δ_B (%)	3.3	2.8	3.2	2.8	6.5	4.1	3.5	2.4	3.7	13.3	10.0	3.6	4.4	δ_B (%)
n_γ (no. of γ's per e)	2.7	2.0	1.9	1.4	1.5	1.5	.94	.8	1.1	5	4.7	1.35	.7	n_γ (no. of γ's per e)
N_{pairs} (p_T^{min} = 20 MeV / c, Θ_{min} = 0.15)	19	31	8.8	7.1	10.3	20.1	2.9	2	9.8	1700	1219	3	4.4	N_{pairs} (p_T^{min} = 20 MeV / c, Θ_{min} = 0.15)
$N_{hadrons}$ / crossing	.17	.13	.1	.04	.23	.13	.05	.03	.07	45.9	11	.05	.05	$N_{hadrons}$ / crossing
$N_{jets} \times 10^{-2}$ (p_T^{min} = 3.2 GeV / c)	.16	.3	.14	.1	.66	.37	.14	.08	.2	56.4	28	.10	.24	$N_{jets} \times 10^{-2}$ (p_T^{min} = 3.2 GeV / c)

E. Adli et al., arXiv:1308.1145

Table 1: Main parameters at various beam collision energies

E at IP, CM	GeV	250	500	1000	3000	6000	10000
N, experimental bunch		1.0E+10	1E+10	1.0E+10	1.0E+10	1.0E+10	1.0E+10
Main beam bunches / train		1	1	1	1	1	1
Main beam bunch spacing,	nsec	3.33E+04	5.00E+04	6.67E+04	1.00E+05	1.43E+05	2.00E+05
Repetition rate,	Hz	30000	20000	15000	10000	7000	5000
n exp.bunch/sec,	Hz	30000	20000	15000	10000	7000	5000
Avg current in exp beam	uA	48.06	32.04	24.03	16.02	11.21	8.01
peak current in exp beam	A	4.81E-05	3.20E-05	2.40E-05	1.60E-05	1.12E-05	8.01E-06
Power in exp. beam	W	6.0E+06	8.0E+06	1.2E+07	2.4E+07	3.4E+07	4.0E+07
Effective accelerating gradient	MV/m	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Overall length of each linac	m	125	250	500	1500	3000	5000
BDS (both sides)	km	2.00	2.50	3.50	5.00	6.50	8.00
Overall facility length	km	2.25	3.00	4.50	8.00	12.50	18.00
IP Parameters							
Exp. bunch gamepsX,	m	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05
Exp. bunch gamepsY,	m	3.50E-08	3.50E-08	3.50E-08	3.50E-08	3.50E-08	3.50E-08
beta-x,	m	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02
beta-y,	m	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
sigx,	m	6.71E-07	4.74E-07	3.35E-07	1.94E-07	1.37E-07	1.06E-07
sigy,	m	3.78E-09	2.67E-09	1.89E-09	1.09E-09	7.72E-10	5.98E-10
sigz,	m	2.00E-05	2.00E-05	2.00E-05	2.00E-05	2.00E-05	2.00E-05
Y		8.44E-02	2.39E-01	6.75E-01	3.51E+00	9.93E+00	2.14E+01
Dx		1.03E-02	1.03E-02	1.03E-02	1.03E-02	1.03E-02	1.03E-02
Dy		1.83E+00	1.83E+00	1.83E+00	1.83E+00	1.83E+00	1.83E+00
Uave		0.17	0.48	1.35	7.00	19.79	42.59
delta_B	%	2.75	6.66	12.76	23.10	27.67	29.88
P_Beamstrahlung [W]	W	1.7E+05	5.3E+05	1.5E+06	5.6E+06	9.3E+06	1.2E+07
ngamma		0.57	0.73	0.88	1.05	1.11	1.14
Hdx		1.00	1.00	1.00	1.00	1.00	1.00
Hdy		4.62	4.62	4.62	4.62	4.62	4.62
Hd		1.7	1.7	1.7	1.7	1.7	1.7
Geometric Lum (cm-2 s-1)		9.41E+33	1.25E+34	1.88E+34	3.76E+34	5.27E+34	6.27E+34
Total Luminosity (cm-2 s-1)		**1.57E+34**	**2.09E+34**	**3.14E+34**	**6.27E+34**	**8.78E+34**	**1.05E+35**
Integrated Lum. (fb-1 per 1E7s)		**157**	**209**	**314**	**627**	**878**	**1045**
Lum1%		**9.41E+33**	**1.15E+34**	**1.57E+34**	**2.51E+34**	**3.07E+34**	**3.14E+34**

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A. Seryi et al, SLAC-PUB-13766, Proceedings of PAC09, Vancouver, BC, Canada

Main beam: bunch population, bunches per train, rate	1×10^{10}, 125, 100 Hz
Total power of two main beams	20 MW
Drive beam: energy, peak current and active pulse length	25 GeV, 2.3 A, 10 μs
Average power of the drive beam	58 MW
Plasma density, accelerating gradient and plasma cell length	1×10^{17} cm^{-3}, 25 GV/m, 1 m
Power transfer efficiency drive beam=>plasma =>main beam	35%
Efficiency: Wall plug=>RF=>drive beam	50% × 90% = 45%
Overall efficiency and wall plug power for acceleration	15.7%, 127 MW
Site power estimate (with 40MW for other subsystems)	170 MW
Main beam emittances, x, y	2, 0.05 mm-mrad
Main beam sizes at Interaction Point, x, y, z	0.14, 0.0032, 10 μm
Luminosity	3.5×10^{34} cm^{-2}s^{-1}
Luminosity in 1% of energy	1.3×10^{34} cm^{-2}s^{-1}

Table 1: Key parameters of the conceptual multi-stage PWFA-based Linear Collider.

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