WORLD-WIDE REVIEW OF FORESEEN R&D AND TESTS PROGRAMS

Ralph W. Aßmann *(DESY)*

Coordinator European Network for Novel Accelerators

FACET-II

Science Opportunities Workshops

Plasma Acceleration Based Linear Colliders

12-16 October, 2015

SLAC, Menlo Park, CA

EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453

Disclaimer

- I cannot and **will not present a world-wide review in a 20 minutes** presentation.
  - We can do this another time...
  - In 20 minutes and during a remote talk there would be great risk of omission and trouble caused by such an attempt.
- Instead: I focus on the **strategy that many of us adopt at present as the fastest route to success and to a plasma linear collider**.
- I will mention some of the new non-US projects that at the moment are emerging
- You know all about the pioneering US projects...

Recent Overview: EAAC2015 and AAC 2014

EAAC2015:

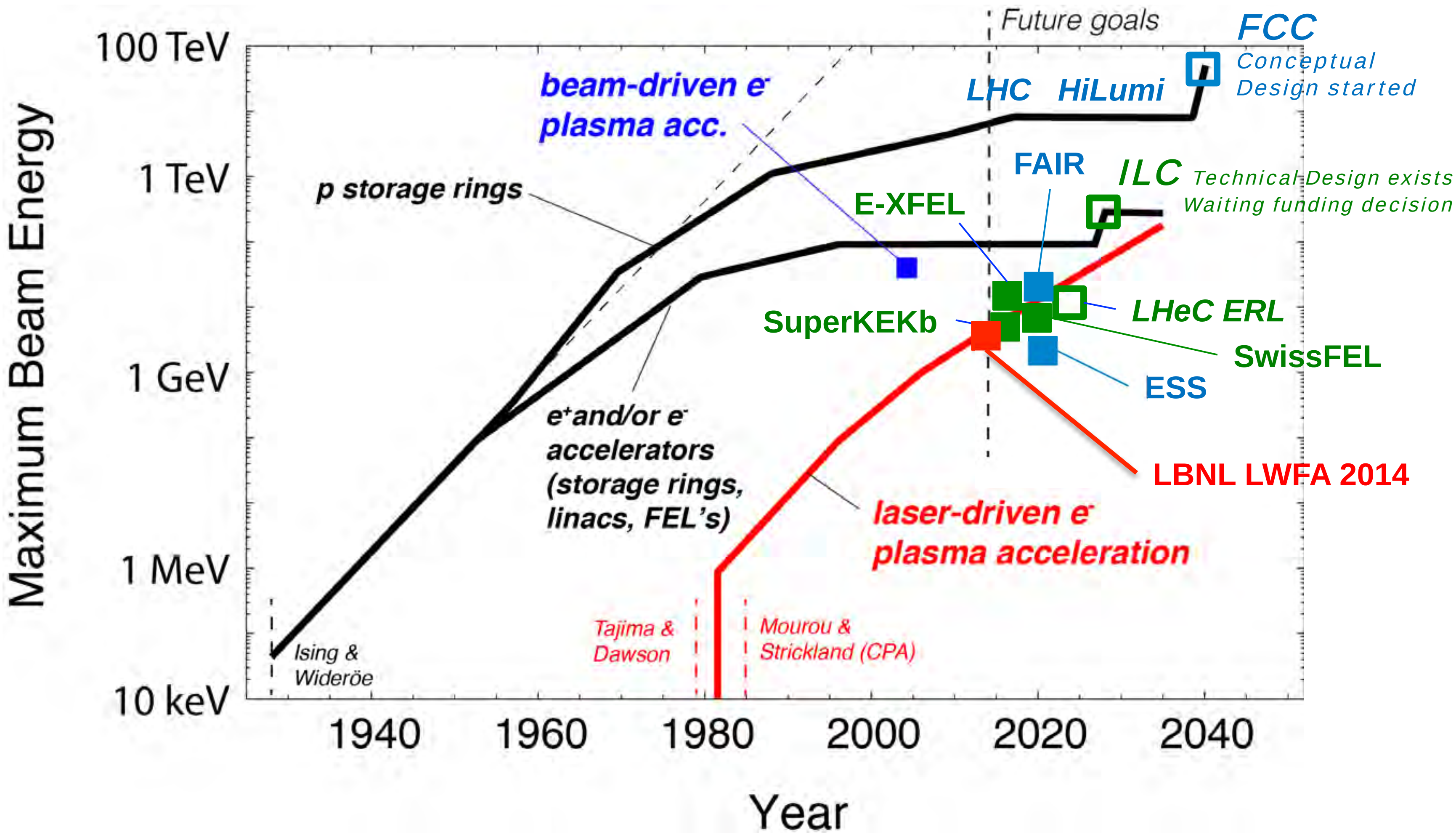
- WG's + Summaries: 7
- Invited Talks: 30
- Special Science Talk: 1
- WG Talks: 138
- Posters: 76

258 registered participants. 45 sponsored students. Participants from 23 countries in 4 continents (incl. 11 EU member states)

To come:
Proceedings
Special Volume NIM
Lead editor: Ulrich Dorda

History and Outlook Particle Accelerators

European Network EuroNNAc for Novel Accelerators

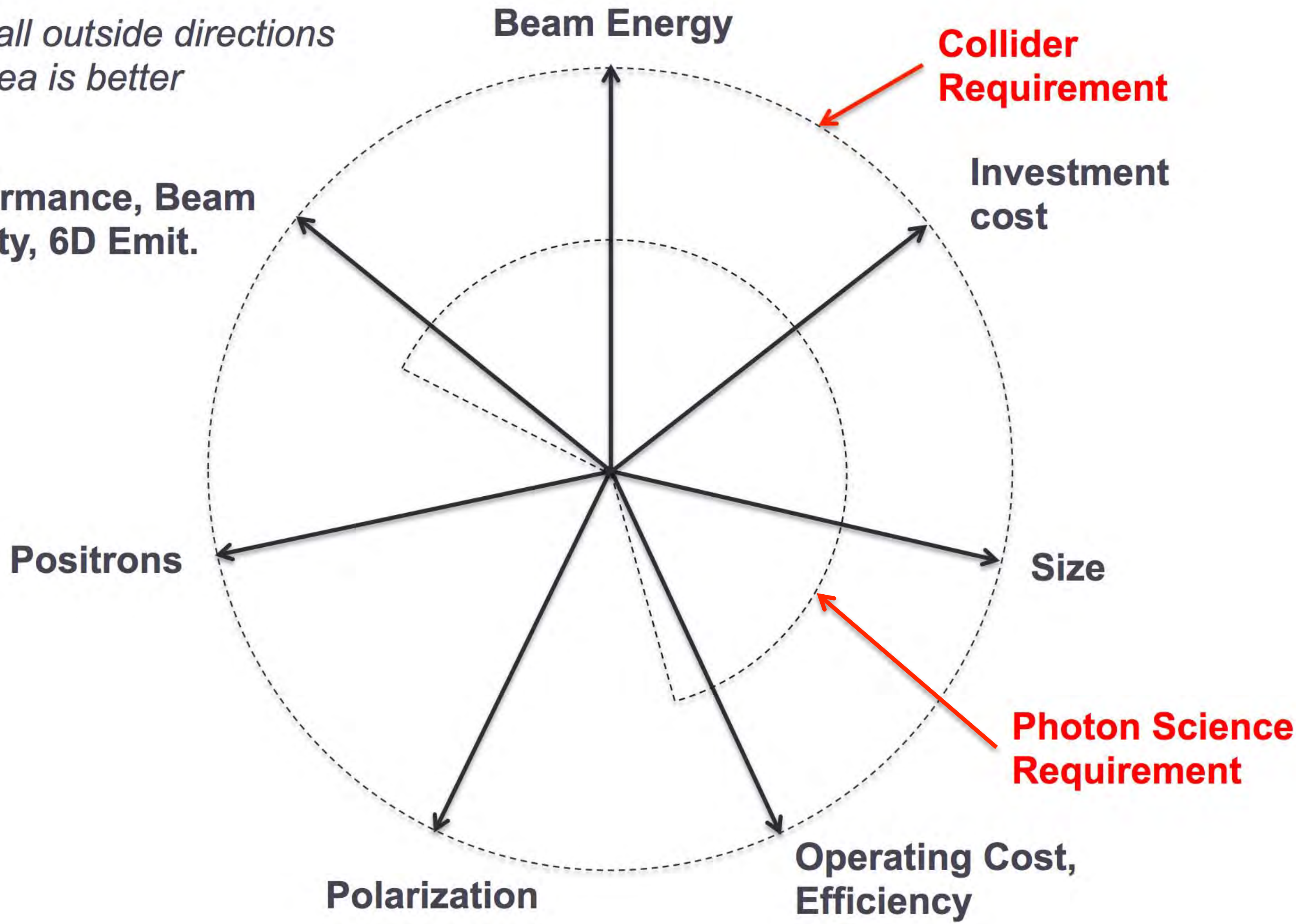


■ Hadron acc. project ■ Lepton acc. project

□ Hadron acc. proposal □ Lepton acc. proposal

Accelerator Radar Chart

Better in all outside directions
Larger area is better



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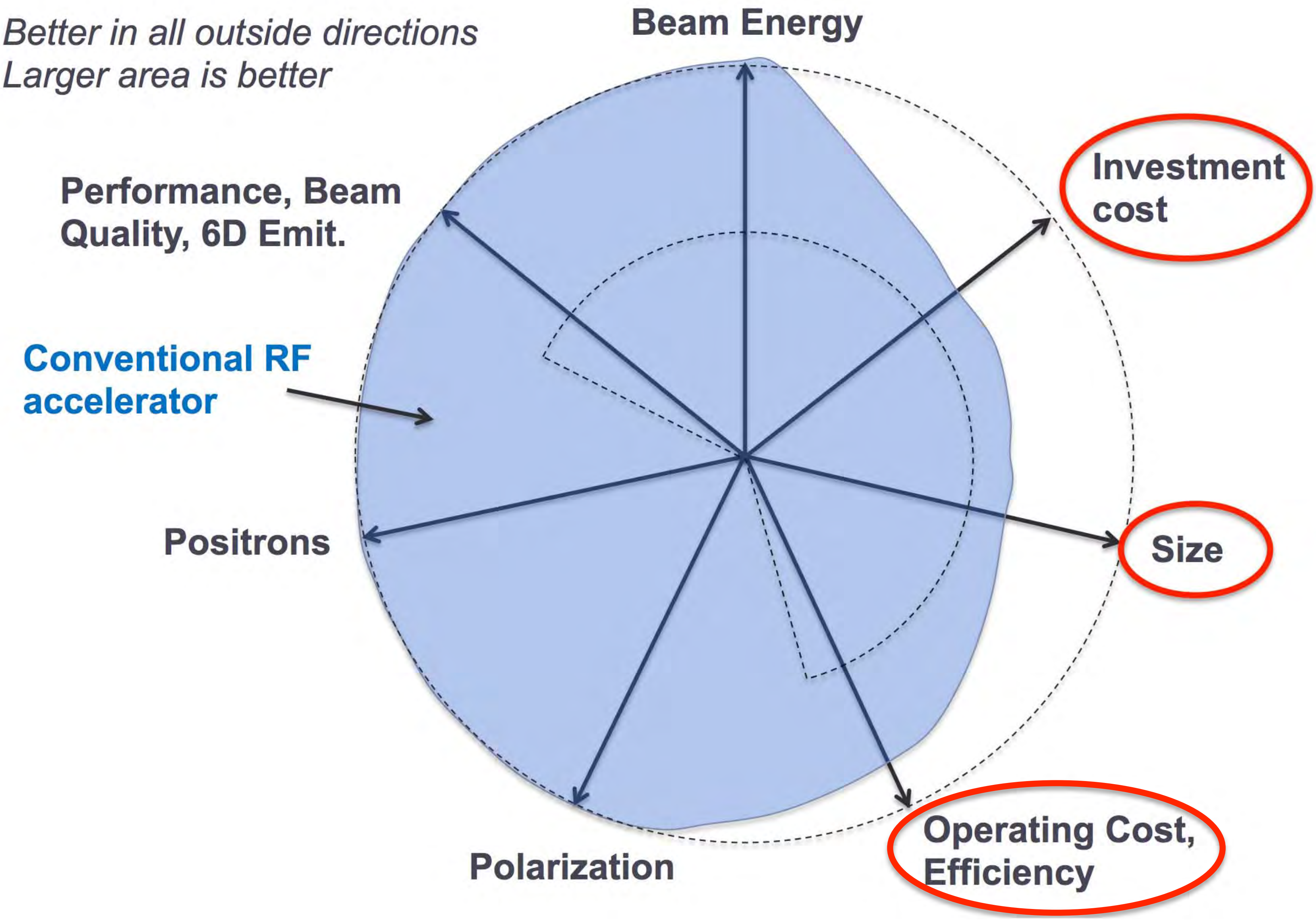

Comments on Conventional RF Accelerator

- **Great success story of our field**.
- **Success raises the bar higher and higher** → difficulties:
  - (1) investment cost (can we get the budget?)
  - (2) operating cost (can we get the budget?)
  - (3) size (does it fit the lab or local region?)
- The **limits encountered presently can change**:
  - (1) new physics convinces science policy
  - (2) new clever designs and projects raise the interest
  - (3) change in political priorities
- Colleagues perform **excellent work on all fronts** but we must take into account practical limits in our means...

Plasma Accelerators

New kid on the block with quite a different footprint and level of maturity.

Very rapidly growing!

Accelerator Radar Chart

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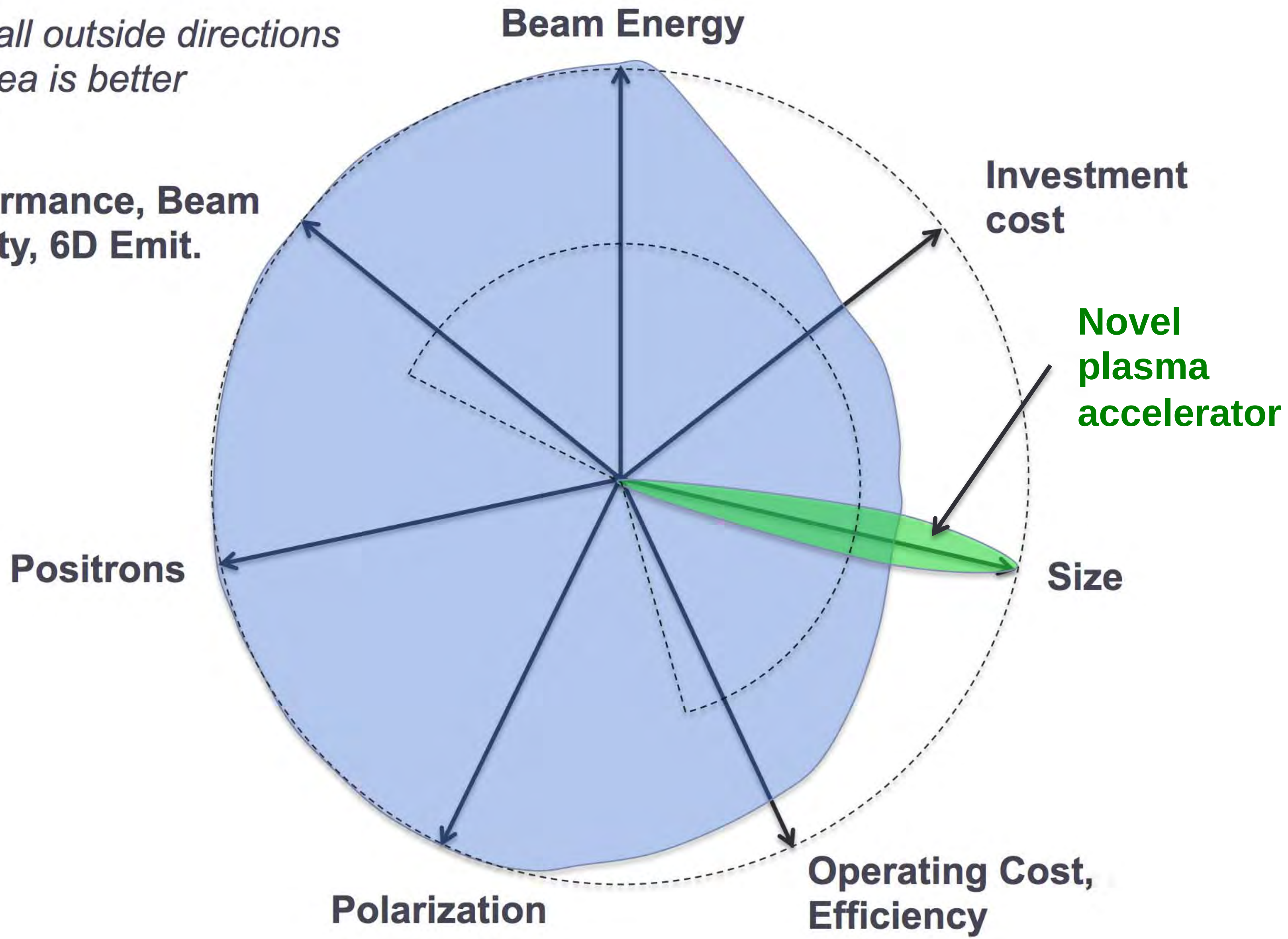
Larger area is better



Accelerator Radar Chart

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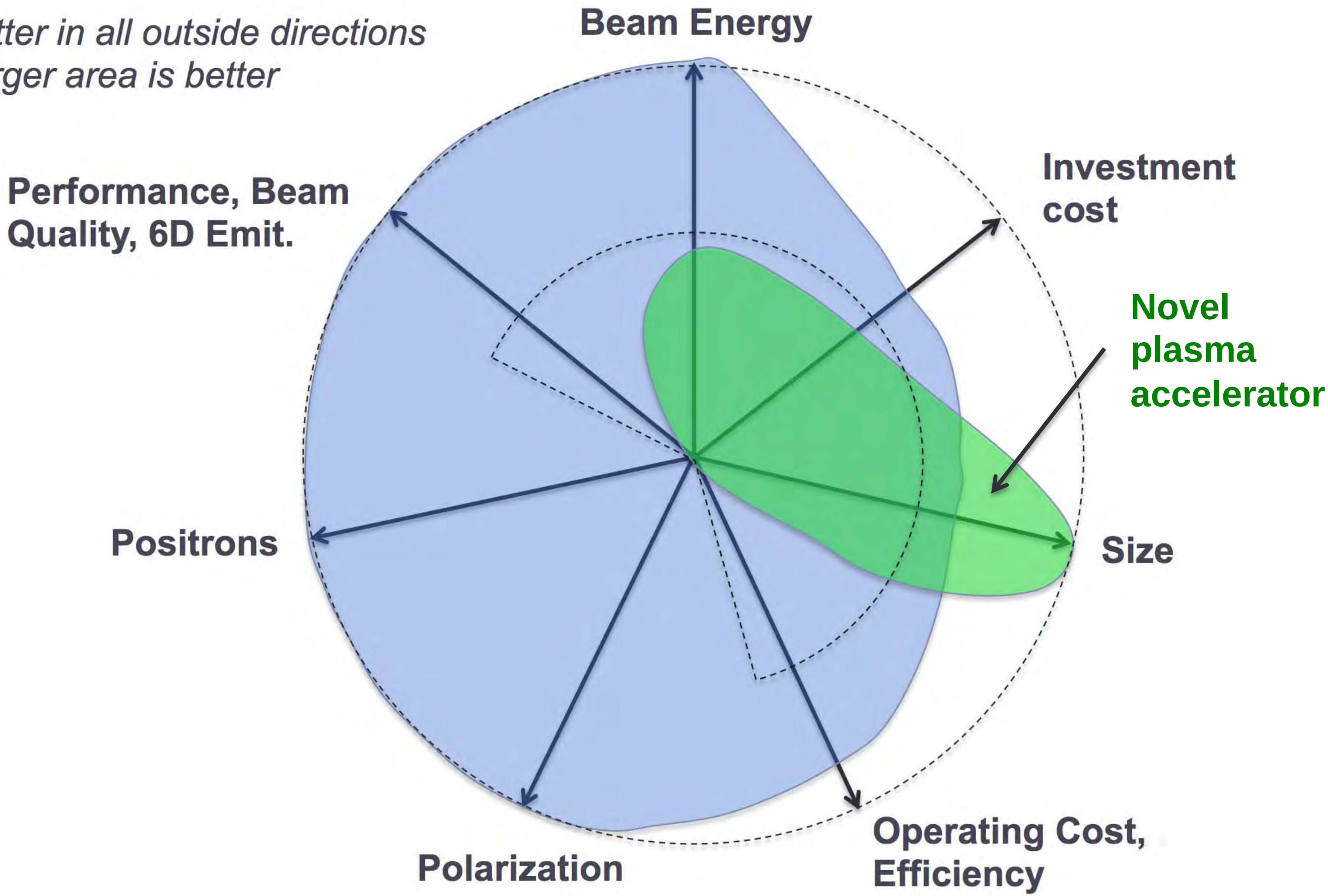
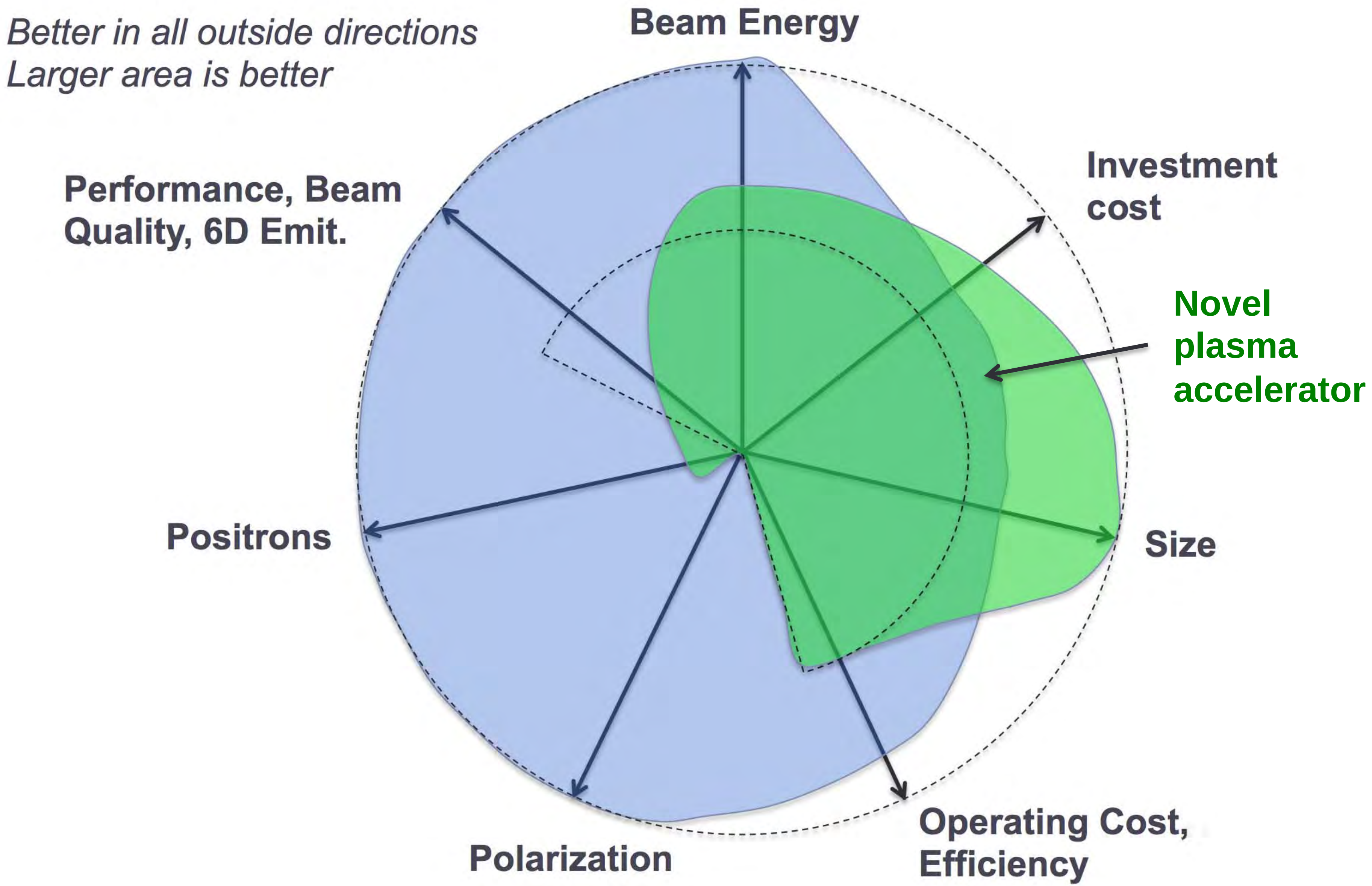


Accelerator Radar Chart



Comments on Plasma Accelerator I

- Excellent progress achieved → **exponential progress in several areas**.
- Not competitive with conventional RF accelerators yet, but getting closer.
- Many **projects (10 M€ - 50 M€) around the world are pushing forward**...
- Next **step beyond this (150-200 M€)** is expensive and probably should be done in a multi-national collaboration.

Accelerator Radar Chart

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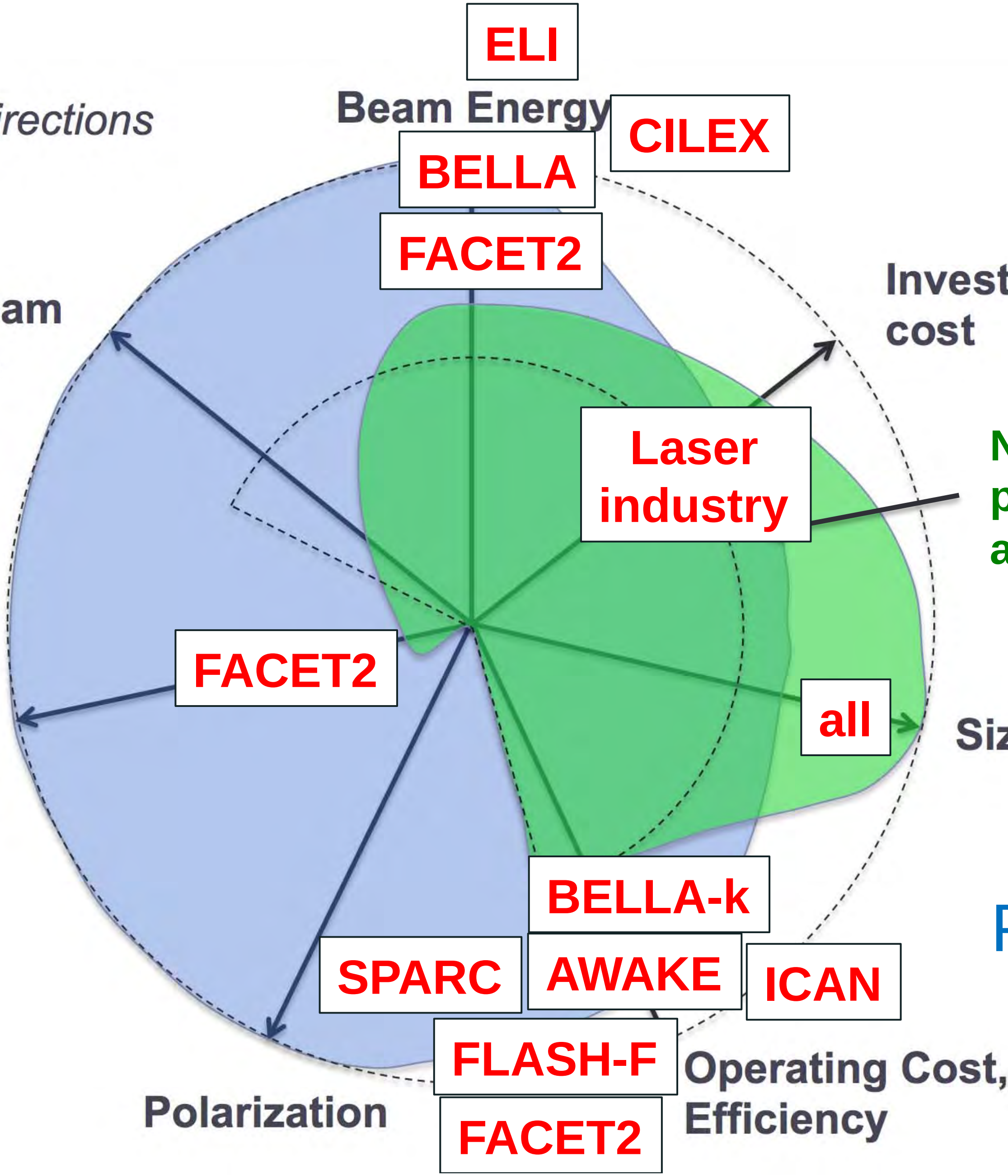
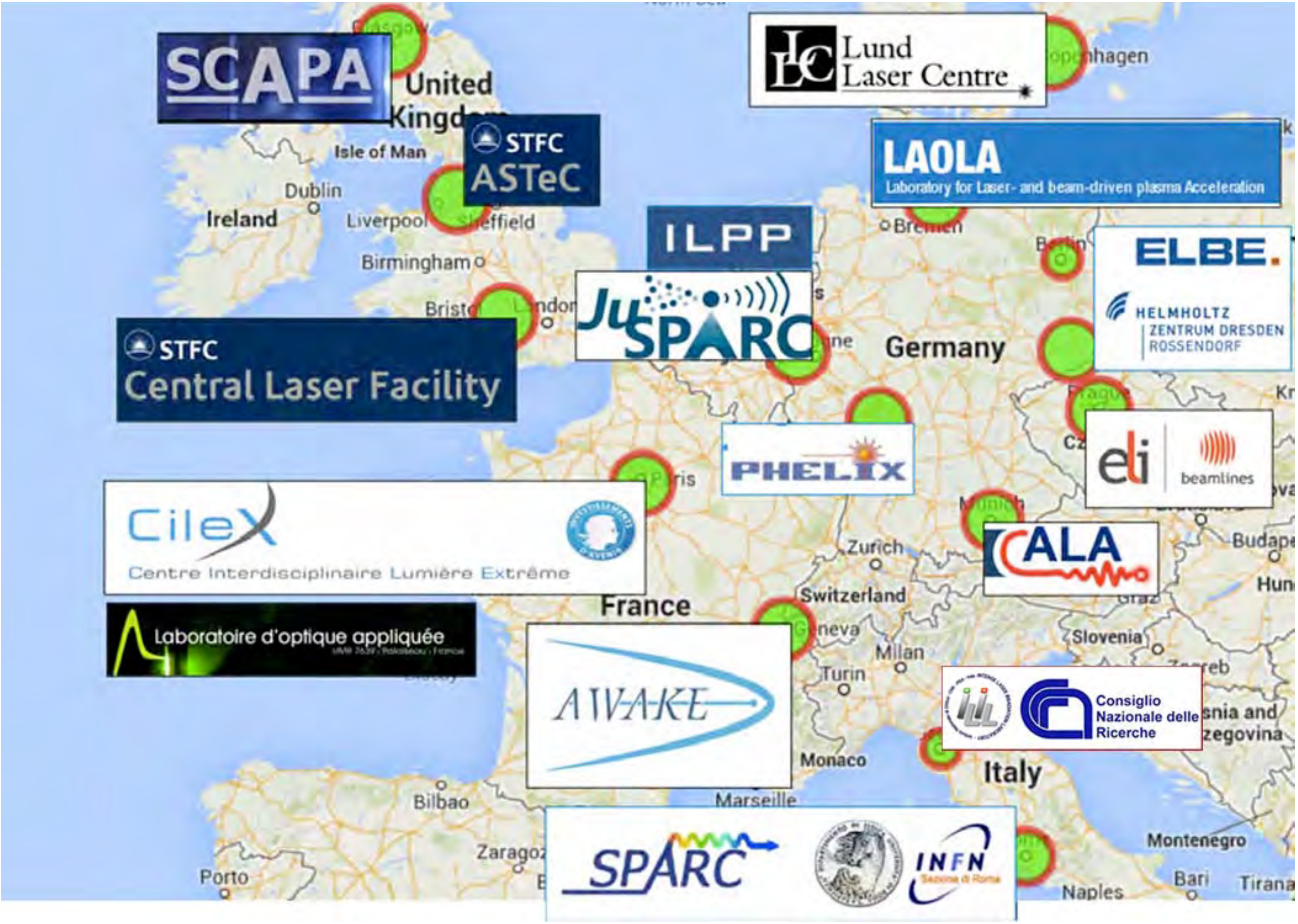
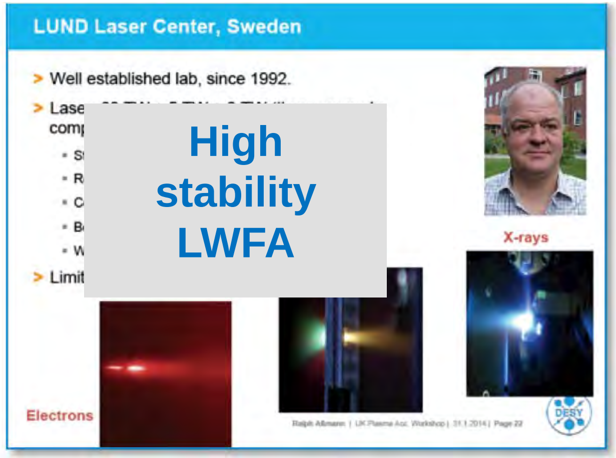
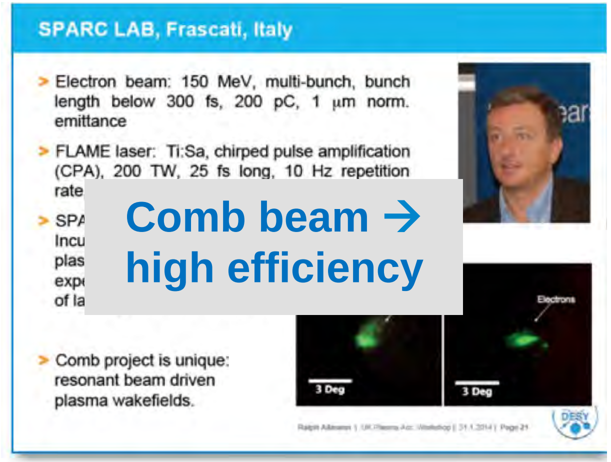


PLUS...

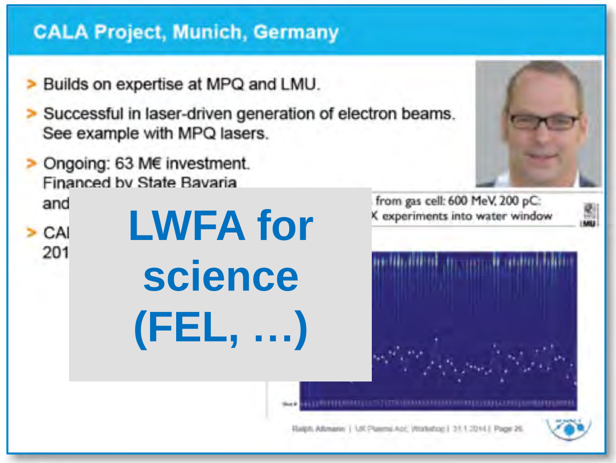

SCAPA
STFC ASTeC
STFC Central Laser Facility
Lund Laser Centre
LAOLA
Laboratory for Laser- and beam-driven plasma Acceleration
ILPP
JuSPARC
ELBE.
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF
PHELIX
eli beamlines
CALA
CileX
Centre Interdisciplinaire Lumière Extrême
Laboratoire d'optique appliquée
AWAKE
Consiglio Nazionale delle Ricerche
SPARC
INFN
United Kingdom
Isle of Man
Dublin
Ireland
Liverpool
Birmingham
Germany
France
Switzerland
Zurich
Milan
Turin
Monaco
Marseille
Italy
Slovenia
Bilbao
Porto
Montenegro
Bari
Naples

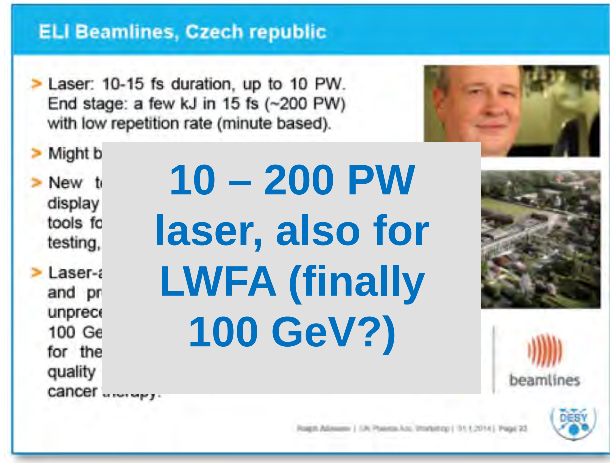

CILEX Project, Plateau de Saclay, France
The big French project.
5 PW laser and LWFA area
Ralph Aßmann | UK Plasma Acc. Workshop | 31.1.2014 | Page 17

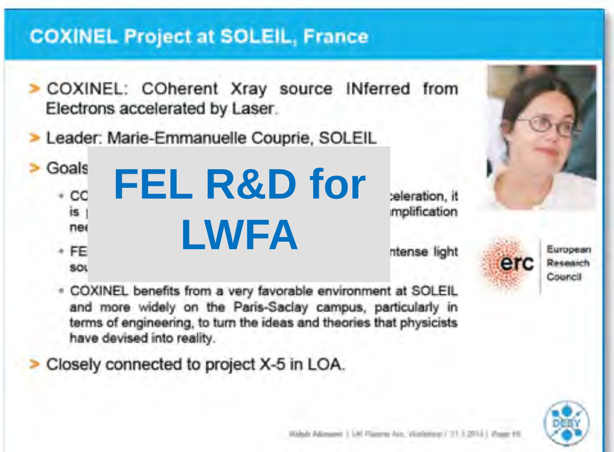

LUND Laser Center, Sweden
Well established lab, since 1992.
High stability LWFA
X-rays
Electrons
Ralph Aßmann | UK Plasma Acc. Workshop | 31.1.2014 | Page 22


SPARC LAB, Frascati, Italy
Electron beam: 150 MeV, multi-bunch, bunch length below 300 fs, 200 pC, 1 μm norm. emittance
FLAME laser: Ti:Sa, chirped pulse amplification (CPA), 200 TW, 25 fs long, 10 Hz repetition rate
Comb beam → high efficiency
Comb project is unique: resonant beam driven plasma wakefields.
Electrons
3 Deg
3 Deg

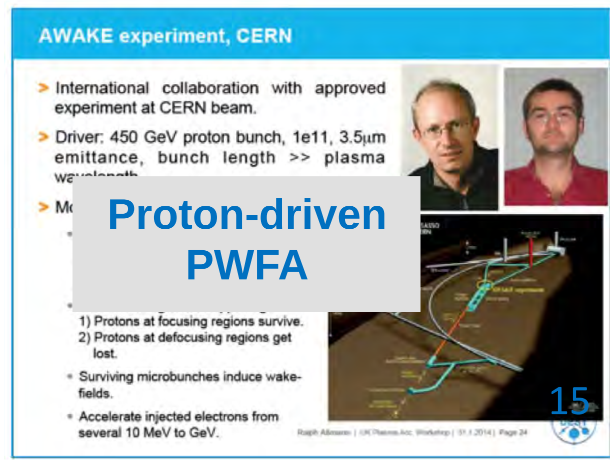

X-5 Project at LOA, France
Salle Jaune Laser: 70 TW, repetition rate 10 Hz, pulse duration of 30 fs
Goals:
Exploration of new laser plasma accelerator
Laboratoire d'optique appliquée
Victor Malka
Researcher at CNRS and Lecturer
An excellence grant for LOA.
LWFA for FEL
European Research Council

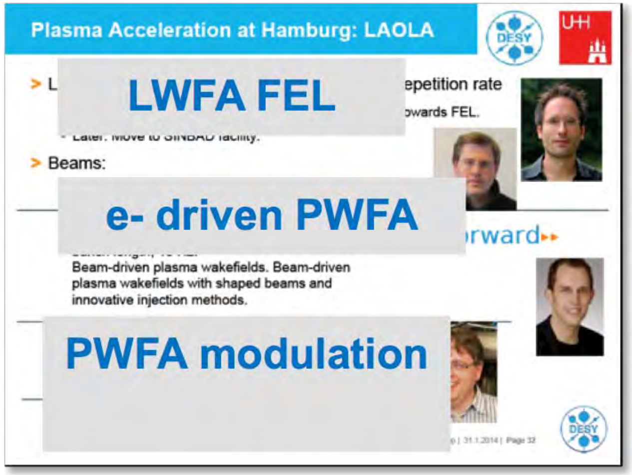

CALA Project, Munich, Germany
Builds on expertise at MPQ and LMU.
Successful in laser-driven generation of electron beams. See example with MPQ lasers.
Ongoing: 63 M€ investment.
Financed by State Bavaria
LWFA for science (FEL, …)
from gas cell: 600 MeV, 200 pC:
X experiments into water window
Ralph Aßmann | UK Plasma Acc. Workshop | 31.1.2014 | Page 26

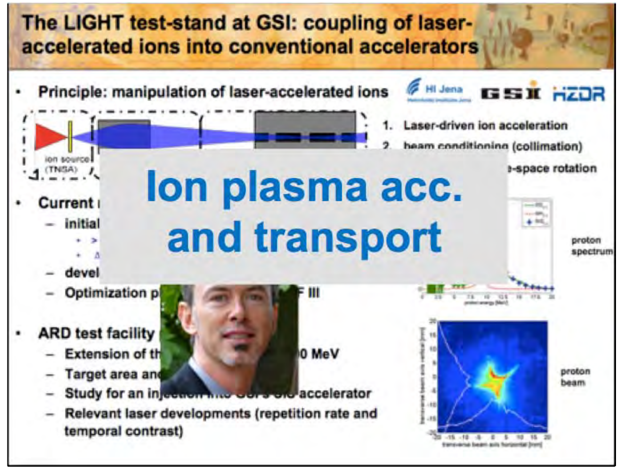

ELI Beamlines, Czech republic
Laser: 10-15 fs duration, up to 10 PW. End stage: a few kJ in 15 fs (~200 PW) with low repetition rate (minute based).
10 – 200 PW laser, also for LWFA (finally 100 GeV?)
beamlines


COXINEL Project at SOLEIL, France
COXINEL: COherent Xray source INferred from Electrons accelerated by Laser.
Leader: Marie-Emmanuelle Couprie, SOLEIL
Goals
FEL R&D for LWFA
COXINEL benefits from a very favorable environment at SOLEIL and more widely on the Paris-Saclay campus, particularly in terms of engineering, to turn the ideas and theories that physicists have devised into reality.
Closely connected to project X-5 in LOA.
European Research Council

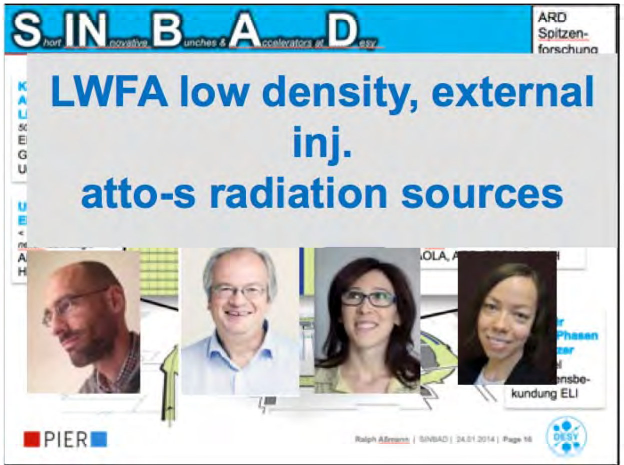

ICAN Project
ICAN for high efficiency
Coherent Amplification Network
The future is fibre accelerators

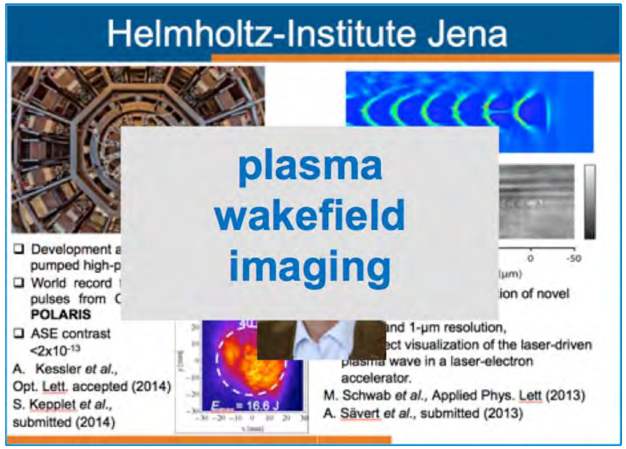

AWAKE experiment, CERN
International collaboration with approved experiment at CERN beam.
Driver: 450 GeV proton bunch, 1e11, 3.5μm emittance, bunch length >> plasma
Proton-driven PWFA
1) Protons at focusing regions survive.
2) Protons at defocusing regions get lost.
Surviving microbunches induce wake-fields.
Accelerate injected electrons from several 10 MeV to GeV.


Plasma Acceleration at Hamburg: LAOLA
LWFA FEL
e- driven PWFA
PWFA modulation
Beams:
Beam-driven plasma wakefields. Beam-driven plasma wakefields with shaped beams and innovative injection methods.

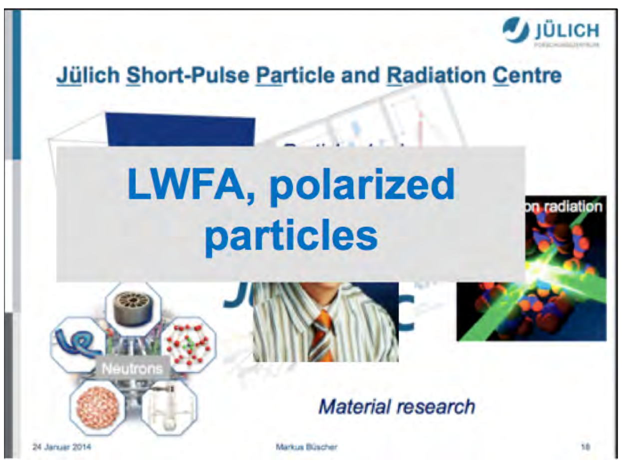

The LIGHT test-stand at GSI: coupling of laser-accelerated ions into conventional accelerators
Principle: manipulation of laser-accelerated ions
Ion plasma acc. and transport
1. Laser-driven ion acceleration
ARD test facility
Relevant laser developments (repetition rate and temporal contrast)


Cockcroft Institute and CLARA Project
Cockcroft Institute: Universities of Lancaster, Liverpool and Manchester,
FEL, industrial applications, PWFA
Ultra-short
Training.
J. Clarke
C. Welsch
S. Smith

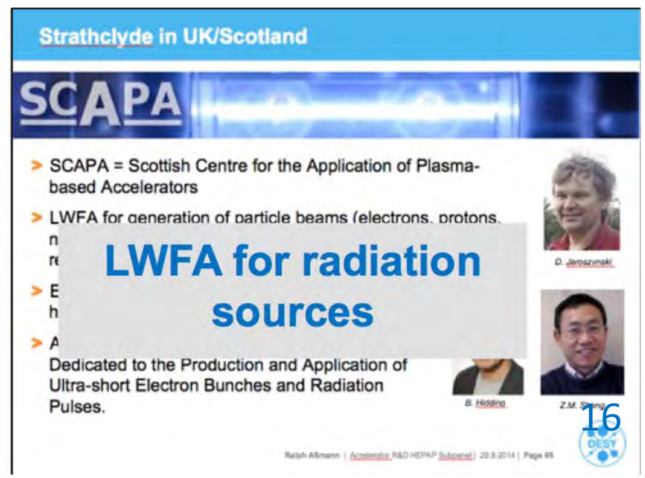

S hort IN novative B unches & A ccelerators at D esy
ARD Spitzen-forschung
LWFA low density, external inj. atto-s radiation sources
PIER


Helmholtz-Institute Jena
plasma wakefield imaging
Development a pumped high-p
World record pulses from POLARIS
ASE contrast <2x10-13
A. Kessler et al., Opt. Lett. accepted (2014)
S. Keppler et al., submitted (2014)
M. Schwab et al., Applied Phys. Lett (2013)
A. Sävert et al., submitted (2013)

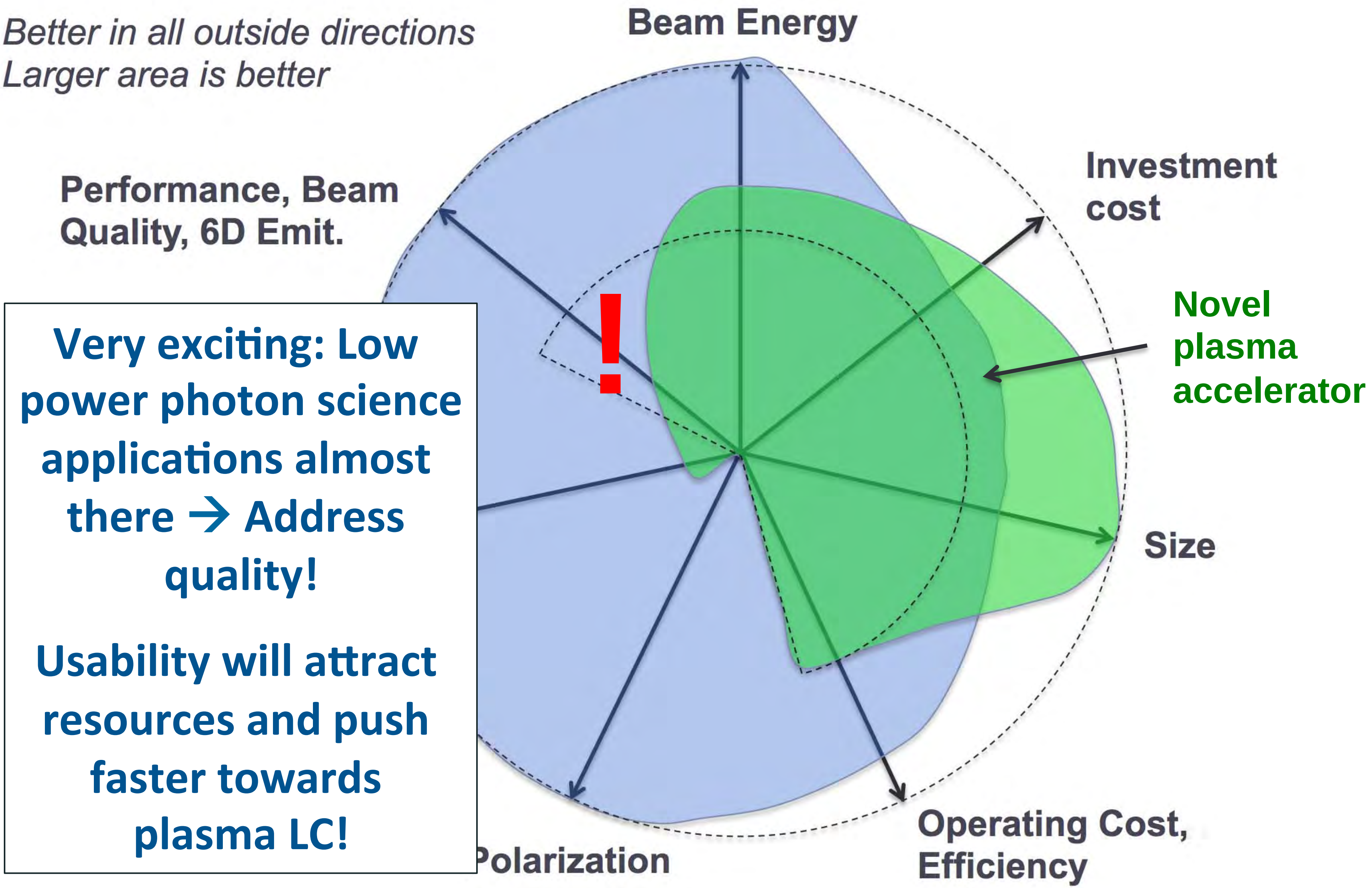

ELBE center for high power radiation sources
Two 1 PW laser, ion/ p plasma acc., radiation therapy R&D
HZDR
Penelope diode pumped PW


JÜLICH
Jülich Short-Pulse Particle and Radiation Centre
LWFA, polarized particles
Neutrons
Material research


STFC – CLF and John Adams Institute in UK
STFC Central Laser Facility used also for LWFA.
LWFA, medical imaging, training
Training of accelerator specialists, also in advanced methods.
S. Hooker
Z. Najmudin
A. Seryi
R. Walczak


Strathclyde in UK/Scotland
SCAPA
SCAPA = Scottish Centre for the Application of Plasma-based Accelerators
LWFA for generation of particle beams (electrons, protons,
LWFA for radiation sources
Dedicated to the Production and Application of Ultra-short Electron Bunches and Radiation Pulses.
D. Jaroszynski
B. Hidding

Accelerator Radar Chart



Very exciting: Low power photon science applications almost there → Address quality!

Usability will attract resources and push faster towards plasma LC!

Accelerator Radar Chart

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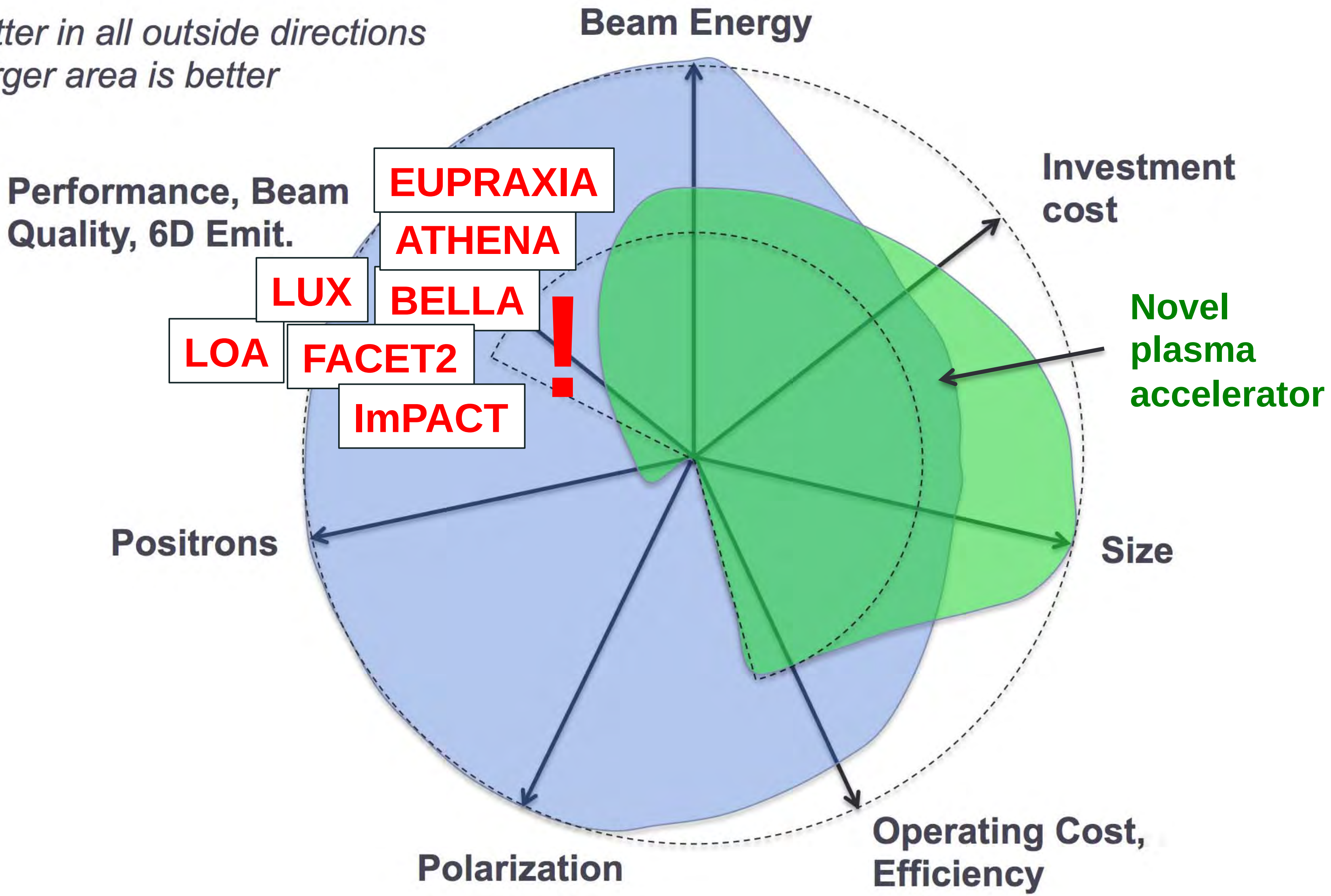


The Most Serious Challenge: Quality

- Issues: **Beam quality, 6D emittance, shot-to-shot stability, tolerances**
- Many projects gear up to attack this by various means:
  - **Low plasma density → relaxed tolerances**
  - **Improved lasers, stabilized optical paths, ...**
  - **Cutting-edge timing technology**
  - **Working points optimized for quality instead of max. energy**
- If quality improved, then potential for photon science user application as **first usage at “lower” energy**
  - **Draws in additional resources and interest**
  - **Will accelerate progress, also towards plasma LC**

... Quality costs a lot of money and manpower ...

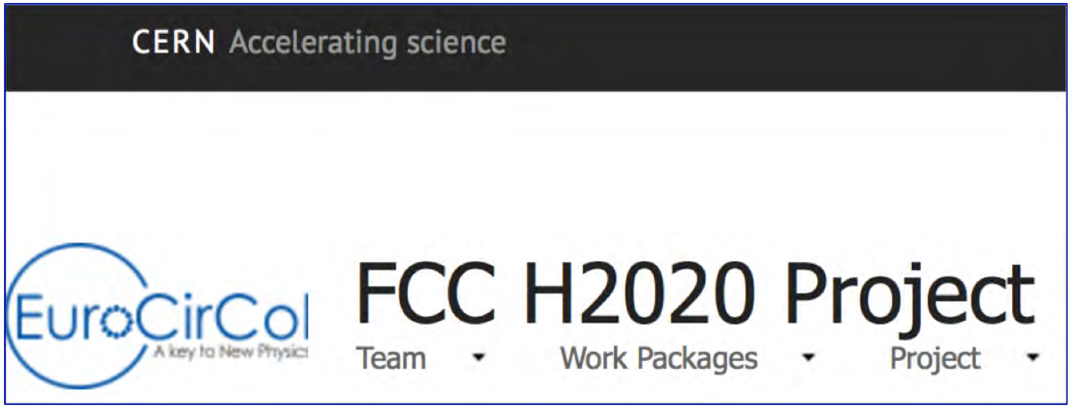
See experience with conventional accelerators!

Moving towards a European Plasma Acc. in the 2020's

Approved with full funding → Excellent signal from European Commission – Research and Innovation

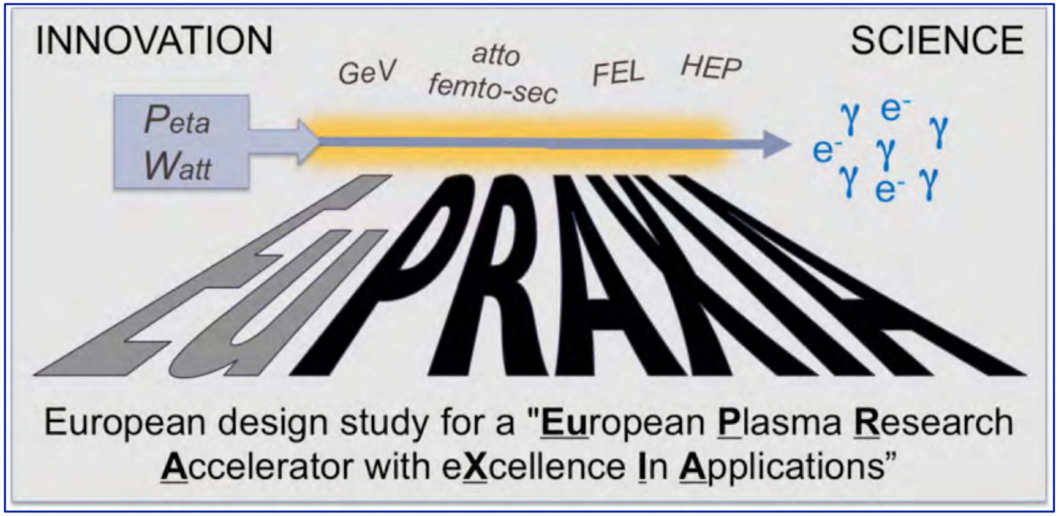
Horizon 2020: First Decisions on EU Design Studies in 2015

- **Two design studies approved in the accelerator area.**

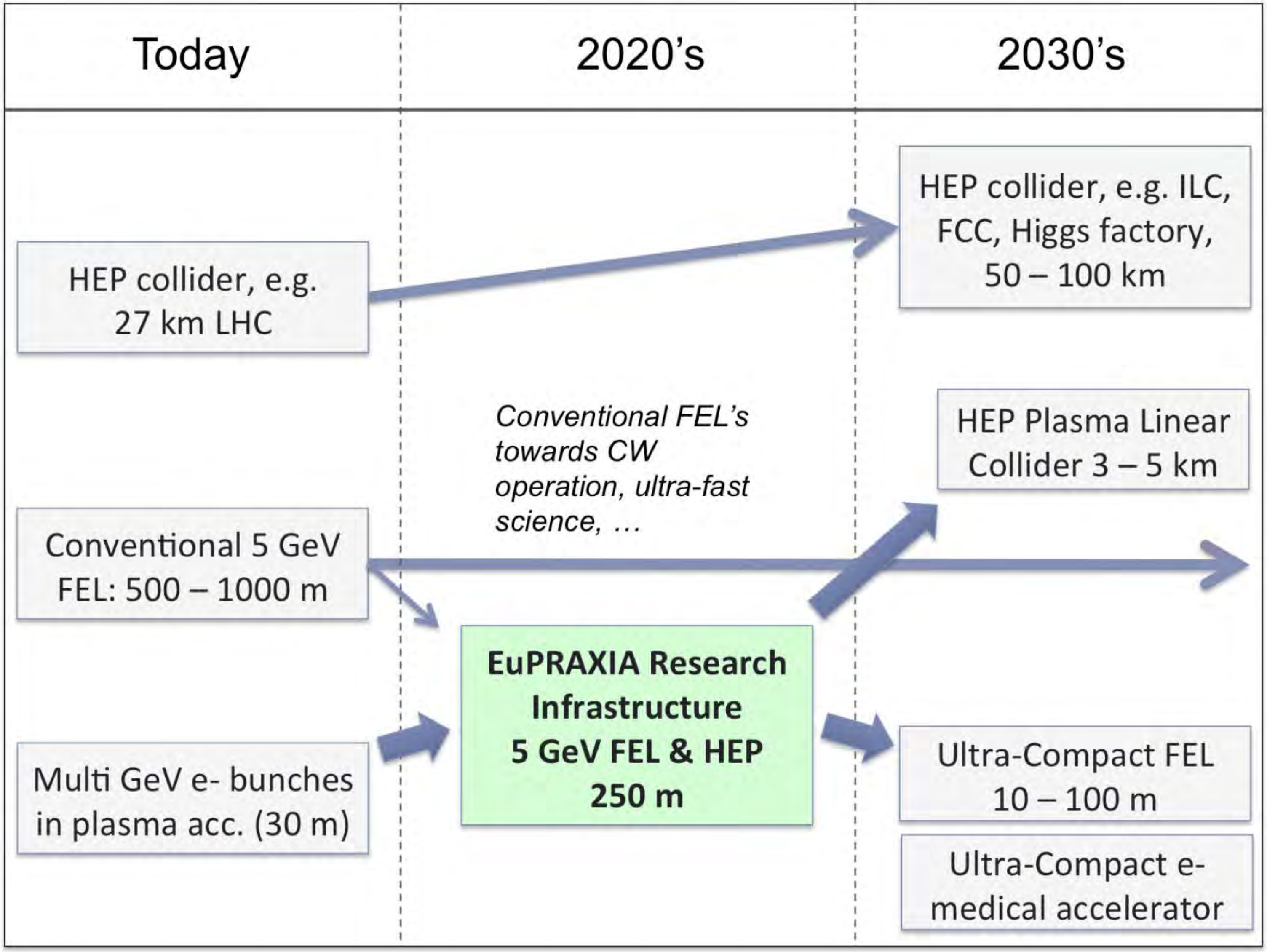


Big success for accelerator field!

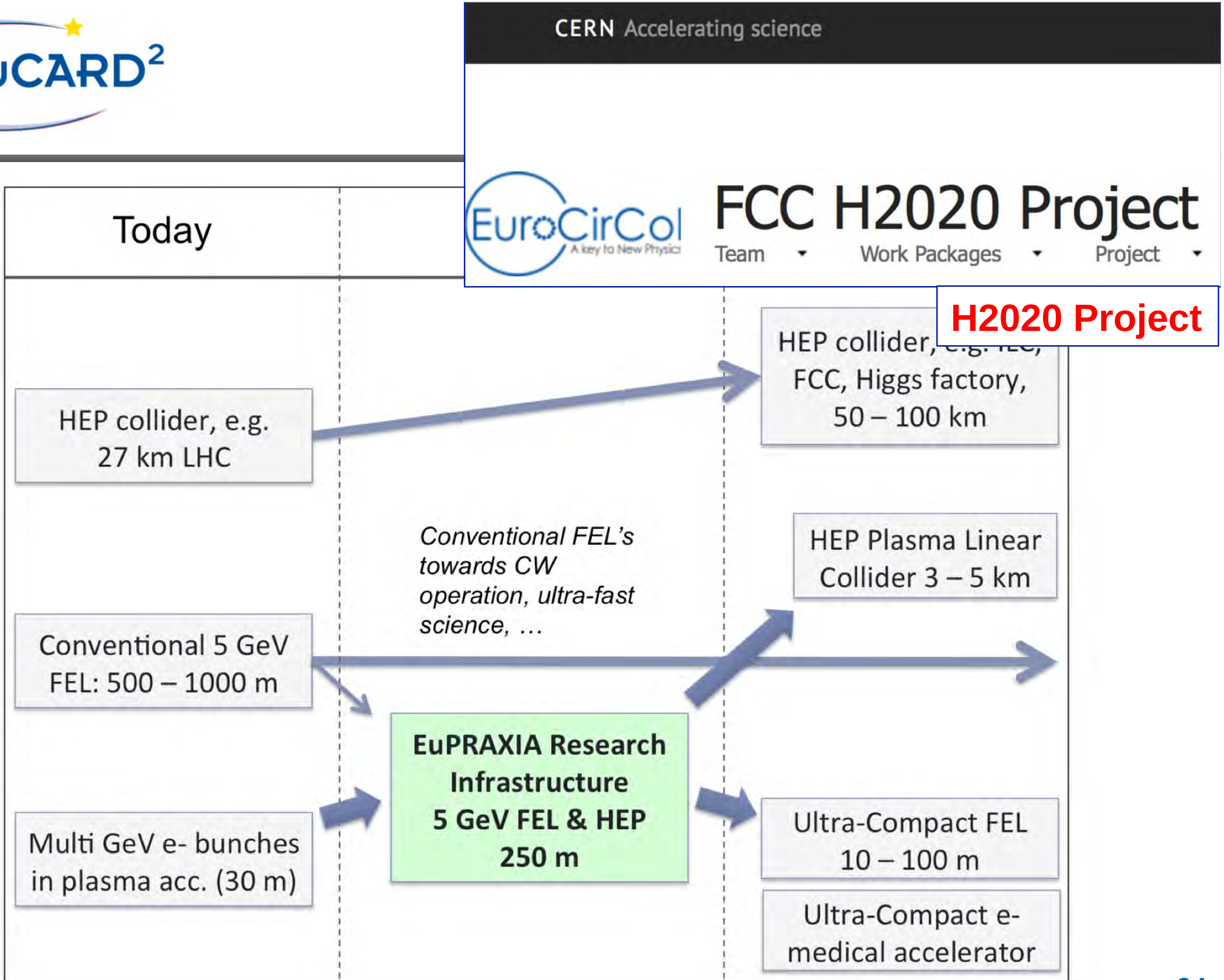
Amazing success for novel accelerators!



EuPRAXIA Strategy

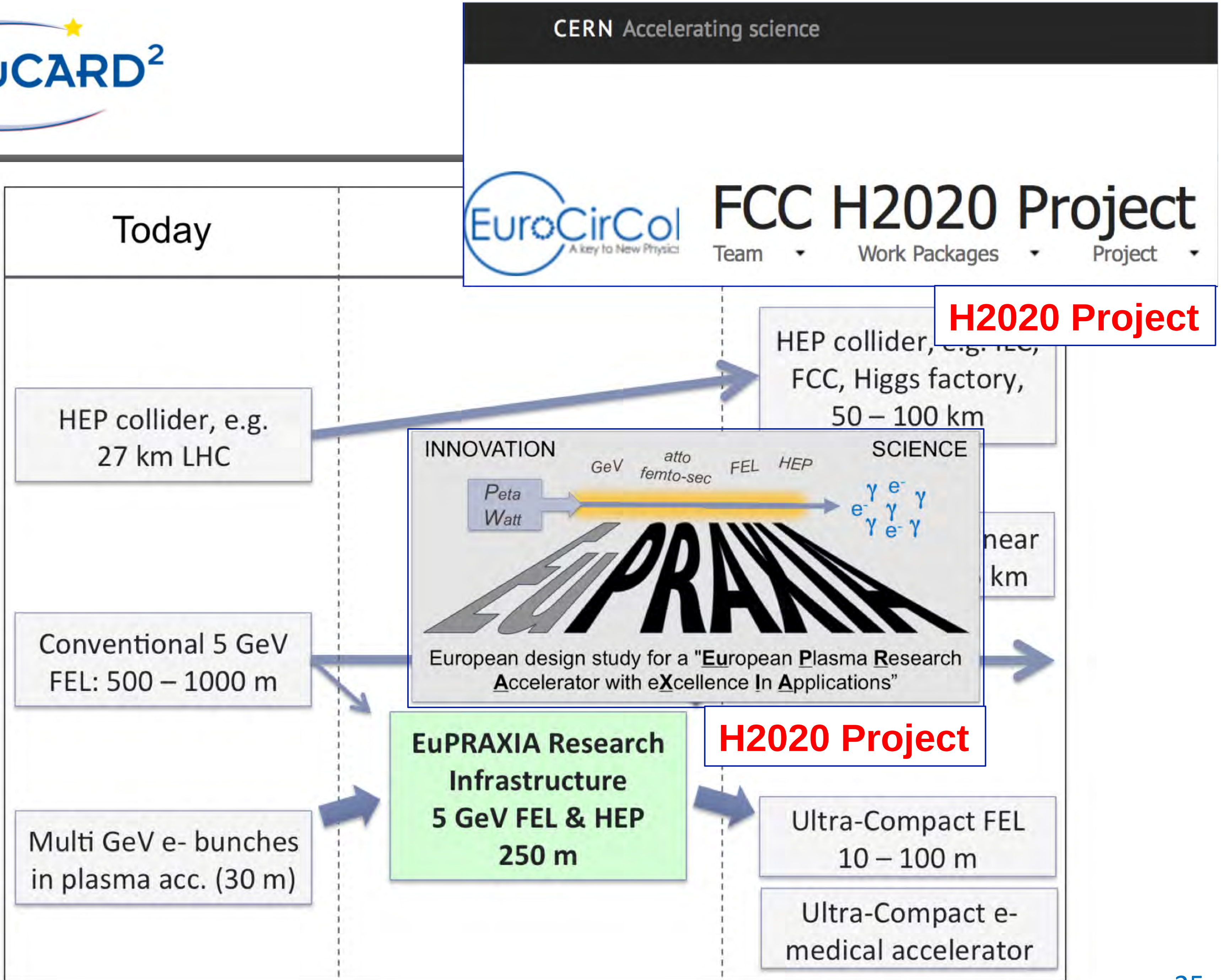


EuCARD²



CERN Accelerating science
EuroCirCol
A key to New Physics
FCC H2020 Project
Team
Work Packages
Project
H2020 Project
Today
HEP collider, e.g.
27 km LHC
HEP collider,
FCC, Higgs factory,
50 – 100 km
Conventional FEL's towards CW operation, ultra-fast science, …
HEP Plasma Linear
Collider 3 – 5 km
Conventional 5 GeV
FEL: 500 – 1000 m
EuPRAXIA Research
Infrastructure
5 GeV FEL & HEP
250 m
Multi GeV e- bunches
in plasma acc. (30 m)
Ultra-Compact FEL
10 – 100 m
Ultra-Compact e-
medical accelerator

EuCARD²


CERN Accelerating science
EuroCirCol
A key to New Physics
FCC H2020 Project
Team
Work Packages
Project
H2020 Project
Today
HEP collider, e.g.
27 km LHC
HEP collider,
FCC, Higgs factory,
50 – 100 km
INNOVATION
SCIENCE
GeV
atto
femto-sec
FEL
HEP
Peta Watt
EuPRAXIA
European design study for a "European Plasma Research Accelerator with eXcellence In Applications"
near
km
Conventional 5 GeV
FEL: 500 – 1000 m
EuPRAXIA Research Infrastructure
5 GeV FEL & HEP
250 m
H2020 Project
Multi GeV e- bunches
in plasma acc. (30 m)
Ultra-Compact FEL
10 – 100 m
Ultra-Compact e-
medical accelerator

EuPRAXIA – Connected Labs and Institutes

European Network EuroNNAc for Novel Accelerators

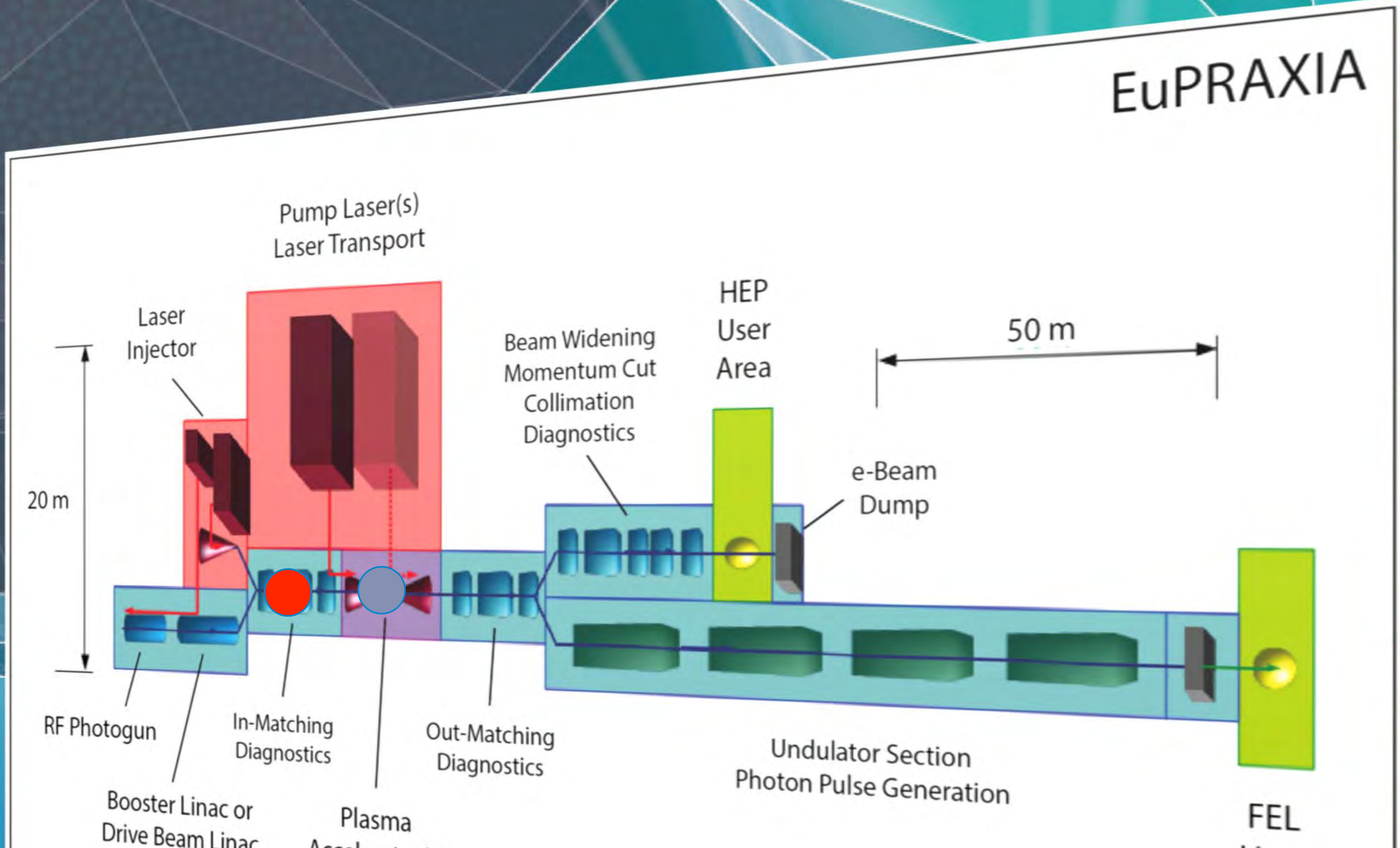
List of participants:

Participant no.	Participant organisation name	Short name	Country
1 (Coordinator)	Stiftung Deutsches Elektronen Synchrotron	DESY	Germany
2	Istituto Nazionale di Fisica Nucleare	INFN	Italy
3	Consiglio Nazionale delle Ricerche	CNR	Italy
4	Centre National de la Recherche Scientifique	CNRS	France
5	University of Strathclyde	USTRAH	UK
6	Instituto Superior Técnico	IST	Portugal
7	Science & Technology Facilities Council	STFC	UK
8	Synchrotron SOLEIL – French National Synchrotron	SOLEIL	France
9	University of Manchester	UMAN	UK
10	University of Liverpool	ULIV	UK
11	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile	ENEA	Italy
12	Commissariat à l'Énergie Atomique et aux énergies alternatives	CEA	France
13	Sapienza Universita di Roma	UROM	Italy
14	Universität Hansestadt Hamburg	UHH	Germany
15	University of Oxford	UOXF	UK
16	Imperial College London	ICL	UK

16 beneficiaries from 5 EU member states

plus 18 associated partners

Associated partner organisation name	Short name	Country
Jiaotong-Universität Shanghai	JUS	China
Tsingua University Beijing	TUB	China
Extreme Light Infrastructures - Beams	ELI-B	Czech Repu
Lille University	PHLAM	France
Helmholtz Institute Jena	HIJ	Germany
Helmholtz-Zentrum Dresden-Rossendorf	HZDR	Germany
Ludwig-Maximillians-Universität München	LMU	Germany
Wigner Research Center of the Hungarian Academy of Science	WIGNER	Hungary
European Organization for Nuclear Research	CERN	IEIO[1]
High Energy Accelerator Research Organization	KEK	Japan
Kansai Photon Science Institute, Japan Atomic Energy Agency	KPSI-JAEA	Japan
Osaka University	OU	Japan
RIKEN SPring-8 Center	RSC	Japan
Lund University	LU	Sweden
Center for Accelerator Science and Education at Stony Brook U & BNL	CASE	USA
Lawrence Berkeley National Laboratory	LBNL	USA
SLAC National Accelerator Laboratory	SLAC	USA
University of California, Los Angeles	UCLA	USA



5 GeV and two user areas for pilot users

EuPRAXIA Research Infrastructure Goal Parameters

Beam Parameter	Unit	Value
Particle type	-	Electrons
Energy	GeV	1 – 5
Charge per bunch	pC	1 – 50
Repetition rate	Hz	10
Bunch duration	fs	0.01 - 10
Peak current	kA	1 – 100
Energy spread	%	0.1 – 5
Norm. emittance	mm	0.01 – 1

Concept EuPRAXIA

- Goal is to **design one operational facility at one location.**
- **Resources will be distributed** to all partners:
  - **Model of big particle physics detector: Many institutes team up to build one detector at one place, each contributing a part.**
- **Site study** with the goal to propose the best site:
  - **Existing infrastructure, host lab support, scientific user community, support from funding agency, …**
- Facility will be **devoted to provide for pilot users:**
  - **Ultra-compact X-ray FEL**
  - **Ultra-compact GeV electron source for HEP detector development**
- **EuPRAXIA must prove the potential of plasma accelerators.**
- Needed step before building a linear collider or operational plasma FEL.

ImPACT project (FY2014-2018)

ImPACT=Impulsing Paradigm Change through disruptive Technologies Program

"Ubiquitous Power Laser for Achieving a Safe, Secure and Longevity Society" (PM: Dr. Sano)

■ Overview

Ubiquitous quantum beam technologies and devices will be developed through power laser ultra-miniaturization and integration with plasma and accelerator technologies, which will have applications in equipment diagnosis, security, advanced medicine and other fields, and will help to achieve a safe, secure and longevity society.

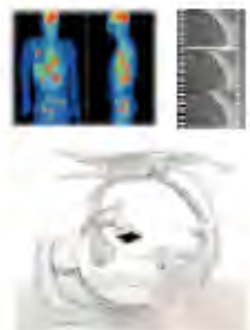
■ Impact on Industry and Society in the Event of Achievement

- ✓ Enabling the use of XFEL* (a National Critical Technology), which currently exists in only two locations in the world, at each institution.
- ✓ Industrial innovation through analysis on the atomic level, ubiquitous equipment diagnosis and repair, biological imaging, quantum beam radiotherapy and so on, anytime, anywhere

XFEL (SACLA)

Conception of tabletop XFEL

Diagnosis and life-extension of structures



Advanced medical solutions

Japan

SLIDE
M. Kando

Disruptive technology=laser acceleration!, Hi-risk, Hi-return

Conclusion

- Novel accelerators should give us **more science for the money (cost and size) or open new parameters.** Price to pay: **Technical complexity and difficulty.**

- **FACET-2, ATF2 and BELLA/iBELLA/BELLA-k** keep pushing the technology in the US. Excellent for the community and science.

- **New big projects** outside US, trying to establish intermediate steps with users before we can attack a plasma LC for HEP:
  - **EuPRAXIA for plasma acceleration of electrons for photon science and HEP has been fully funded.**
  - **ImPACT project in Japan** for a plasma FEL with significant funds!
  - **ATHENA project in Germany** for user-readiness of electron and hadron beams from plasma accelerators.


EAAC2015
Towards useable, novel accelerators with reduced size, better cost efficiency, excellent science and multiple applications for HEP, photon science, medicine and others...

Thank you for your attention