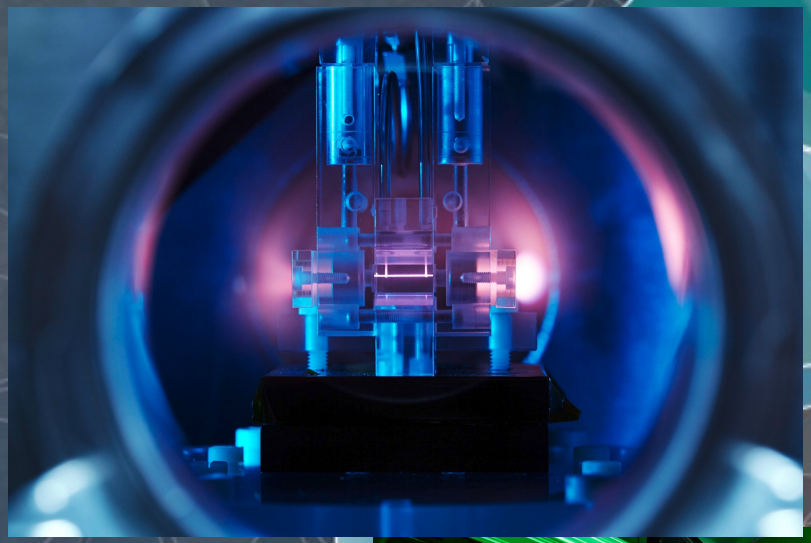
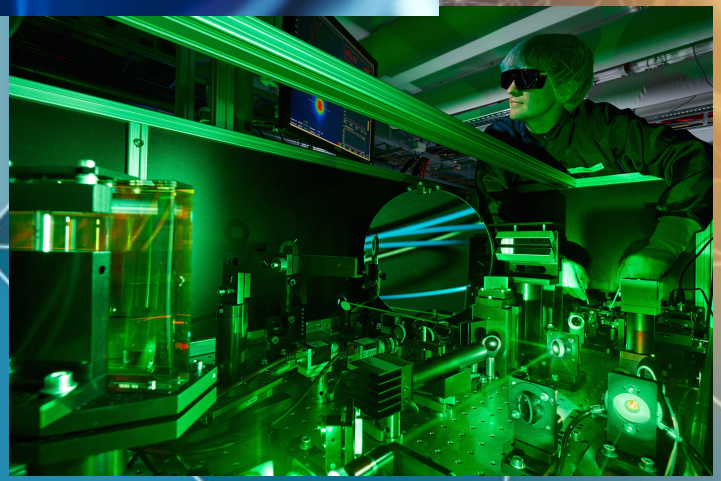
DESY ACTIVITIES ON PLASMA ACCELERATION



Ralph W. Aßmann

Leading Scientist DESY

HELMHOLTZ VI MEETING



Elba, 13.09.2015

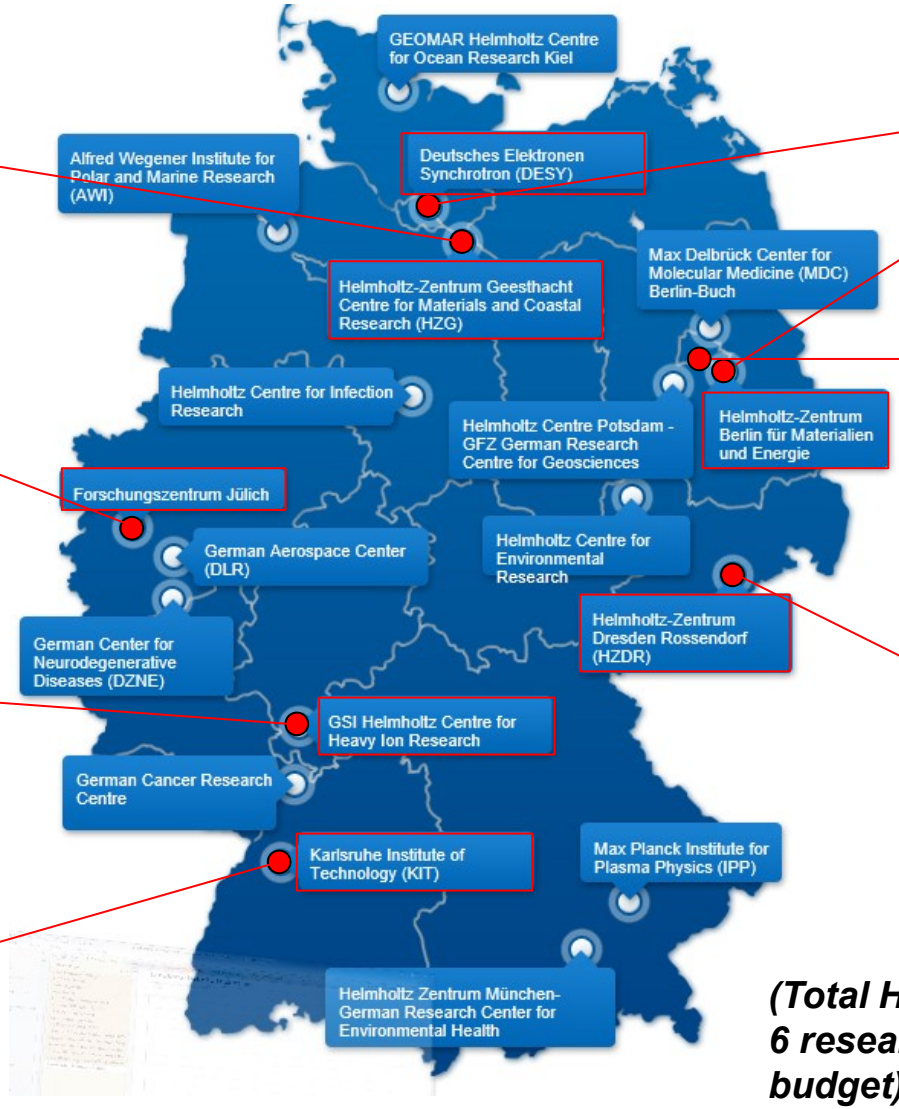
Accelerator Research and Development ARD A program by the Helmholtz association

European Network EuroNNAc for Novel Accelerators

EuCARD²

Research field Matter in the Helmholtz Association

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research



DESY

Hamburg and Zeuthen

HZB Helmholtz Zentrum Berlin

JÜLICH FORSCHUNGSZENTRUM

GSI

+ Helmholtz Institutes Jena and Mainz

HZDR

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

since 2011

KIT Karlsruher Institut für Technologie

(Total Helmholtz: 18 centers, 6 research fields, ~3B€ yearly budget)

DESY

HELMHOLTZ (Germany) – Research Field Matter

new programme structure as of 1.1.2015

Matter and the Universe

- Fundamental Particles and Forces
- Cosmic Matter in the Laboratory
- Matter and Radiation from the Universe

From Matter to Materials and Life

- In-House Research on the Structure, Dynamics and Function of Matter at Large Scale Faciltities
- Facility Topic: Research on Matter with Brilliant Light Sources
- Facility Topic: Neutrons for Research on Condensed Matter
- Facility Topic: Physics and Materials Science with Ion Beams
- Facility Topic: Research at Highest Electromagnetic Fields

Matter and Technologies

- Detector Technologies and Systems

Accelerator Research and Development ARD A program by the Helmholtz association

LK II
„performance category II“
= user operation of large scale facilities

HELMHOLTZ ARD *(coordinator: R. Brinkmann)*

Four Research Sub-Topics:

1. **SRF Science and Technology**
2. **Concepts & Technology for Hadron Acc.**
3. **ps-fs Electron and Photon Beams**
4. **Novel Acceleration Concepts**

Helmholtz ARD is:

6 Helmholtz centers

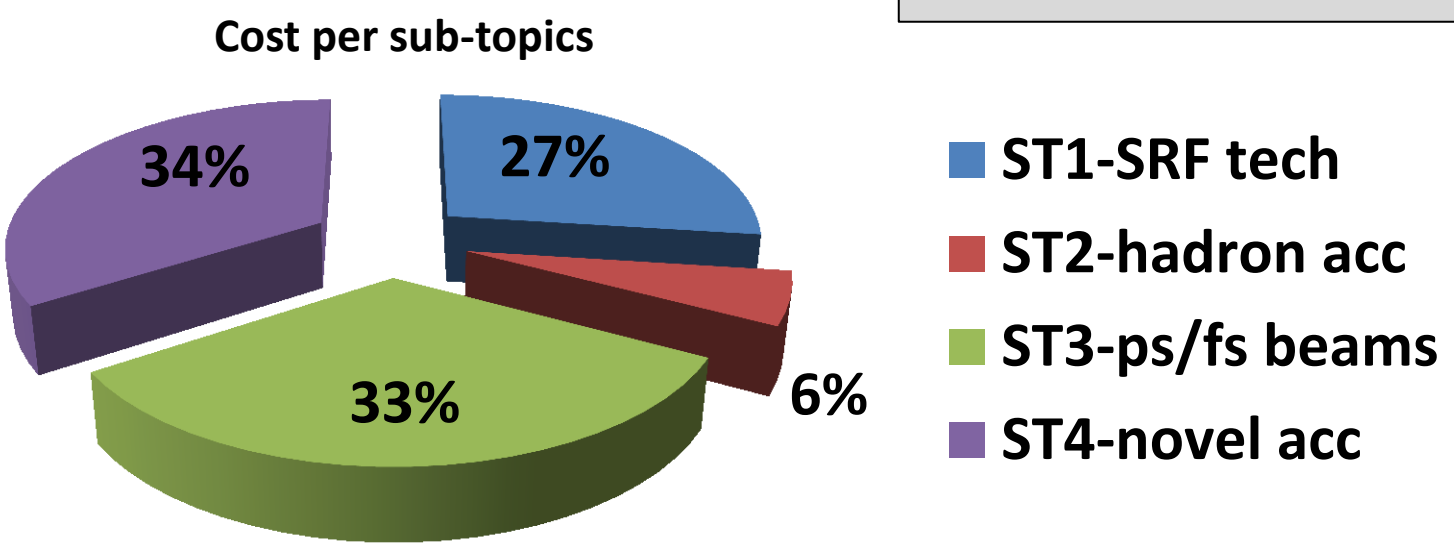
4 research themes (ST)

≈ 32 M€ / year (full cost)

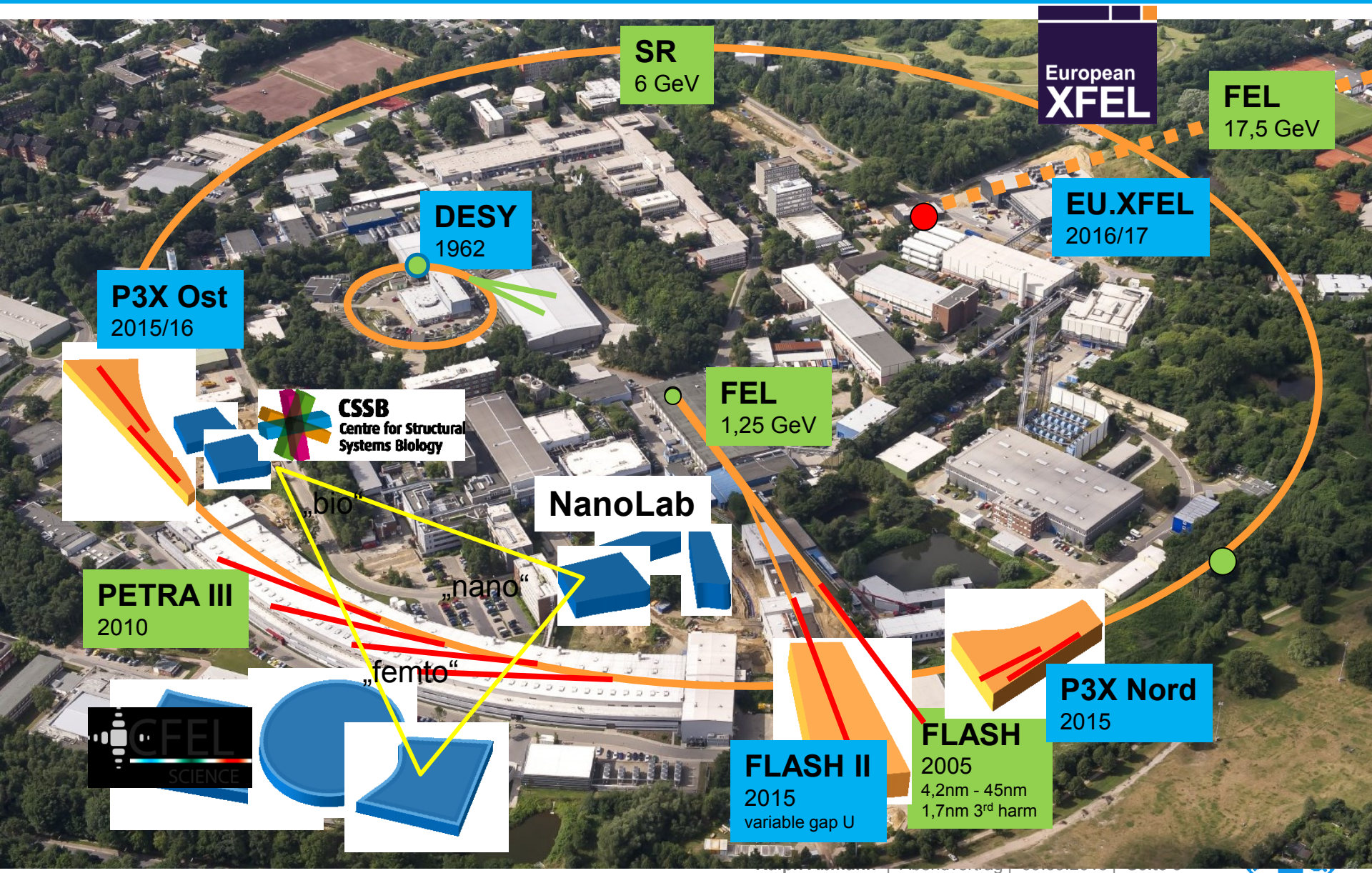
≈ 160 FTE / year

plus ≈ 6 M€ /year 3rd party

(universities + EU grants)



Mission: Developing the Future Accelerators for DESY.



SINBAD "Short Innovative Bunches & Accelerators at DESY"

Accelerator Research at DESY

FEL Seeding
(sFLASH, FLASH2 seeding, ongoing)

SINBAD (ultra-short bunches, LAOLA, proto-type table-top FEL, 2017+)

SC Processes
(large series production & testing of sc cavities and modules, AMTF, ongoing)

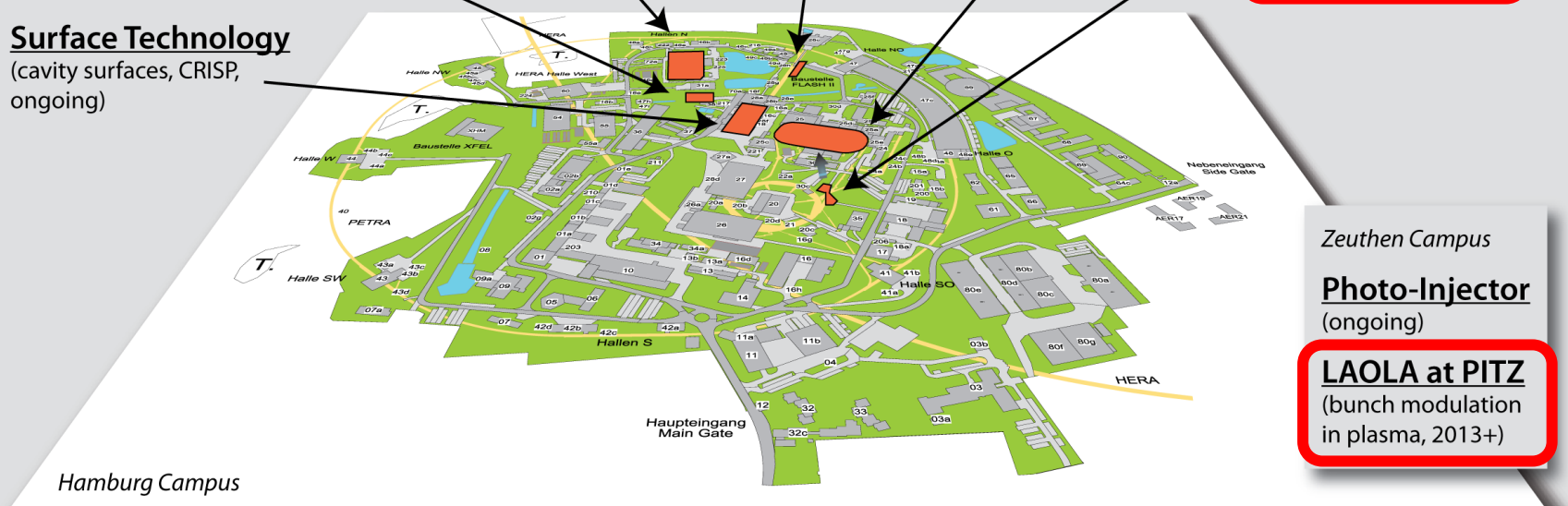
FLASHForward
(beam-driven plasma acceleration, 2016+)

AXSIS (atto-second bunches, ICS, 2014+)

SC Technology
(R&D on CW, cryo module test bench, ongoing)

LAOLA at REGAE
(laser-driven plasma acceleration, 2013-2016)

Surface Technology
(cavity surfaces, CRISP, ongoing)



Hamburg Campus

Zeuthen Campus

Photo-Injector
(ongoing)

LAOLA at PITZ
(bunch modulation in plasma, 2013+)

LAOLA Collaboration Hamburg

Laser: Ti:Sa 200 TW, 25 fs pulse length, 5 Hz repetition rate

- *Initially: Laser-driven wakefields in REGAE. LUX exp. towards FEL*
- *Later: Move to SINBAD facility.*

F. Grüner

A. Maier

Beams:

- **REGAE**: *5 MeV, fC, 7 fs bunch length, 50 Hz*

- **FLASH**: *1.25 GeV, 20 – 500 pC, 20 - 200 fs bunch length, 10 Hz.*
  Beam-driven plasma wakefields. Beam-driven plasma wakefields with shaped beams and innovative injection methods. Helmholtz VI with UK collaboration.

FLASHForward

J. Osterhoff

- **PITZ**: *25 MeV, 100 pC, 20 ps bunch length, 10 Hz.*
  Beam modulation experiment in a plasma cell, preparation to CERN experiment AWAKE

F. Stephan

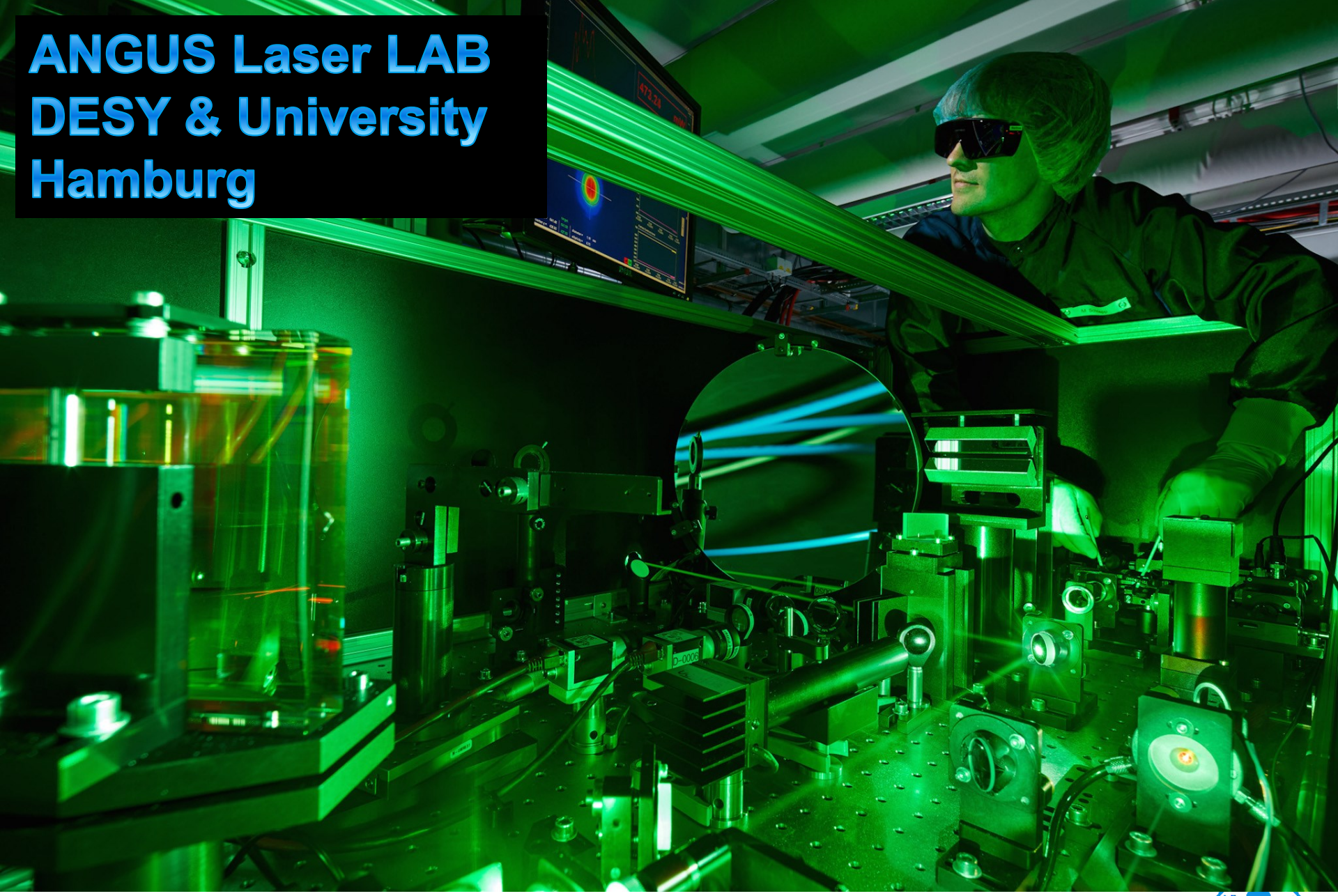
- **SINBAD**: dedicated R&D, multi purpose, *150 MeV, 0.01 – 3 pC, down to < 1 fs bunch length, pulse rate 10 – 1000 Hz*
  → **Home of AXSIS ERC Synergy Grant**
  → **Home of ATHENA$_e$**

U. Dorda

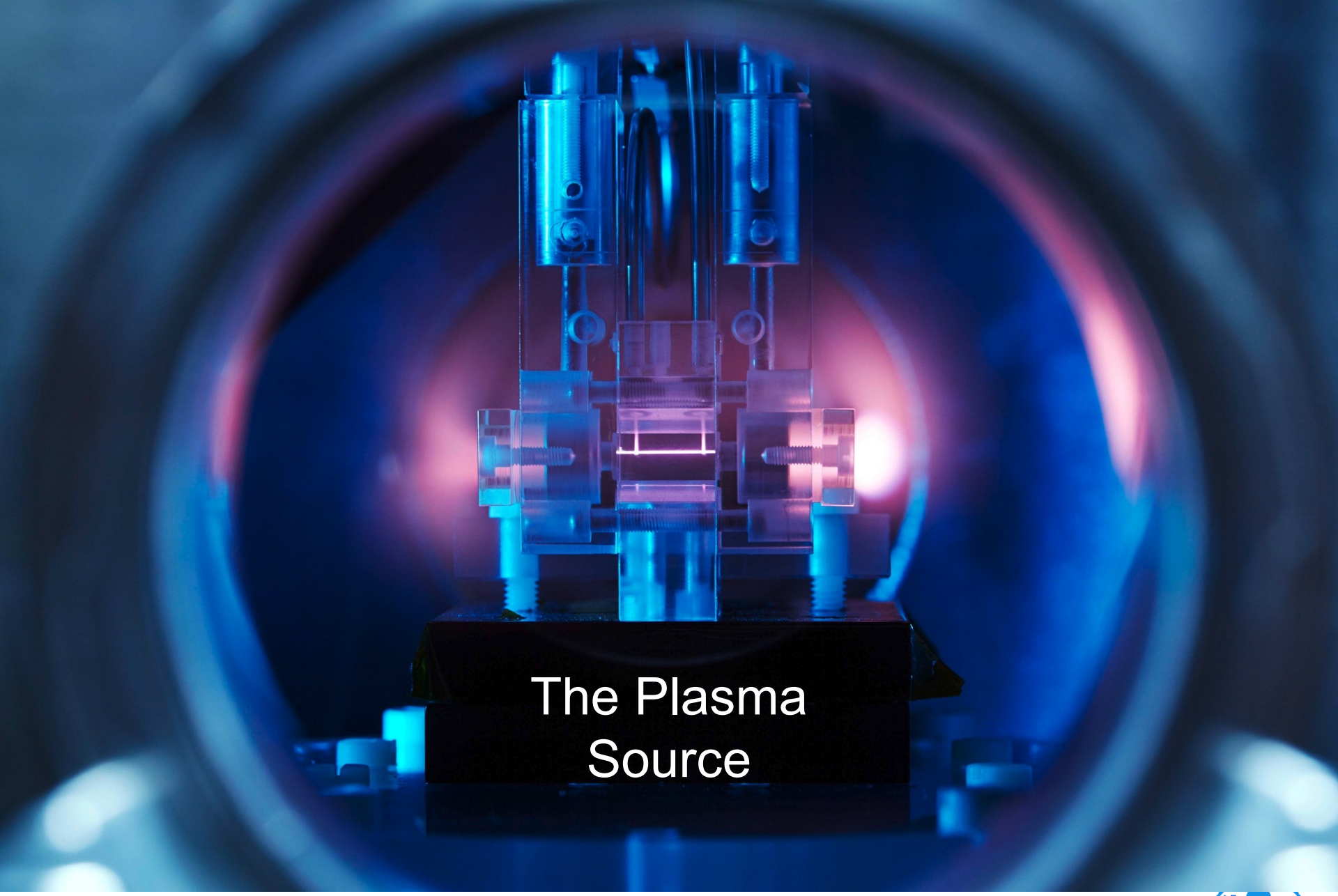
B. Marchetti

Similarly strong teams in other Helmholtz centers!

ANGUS Laser LAB DESY & University Hamburg

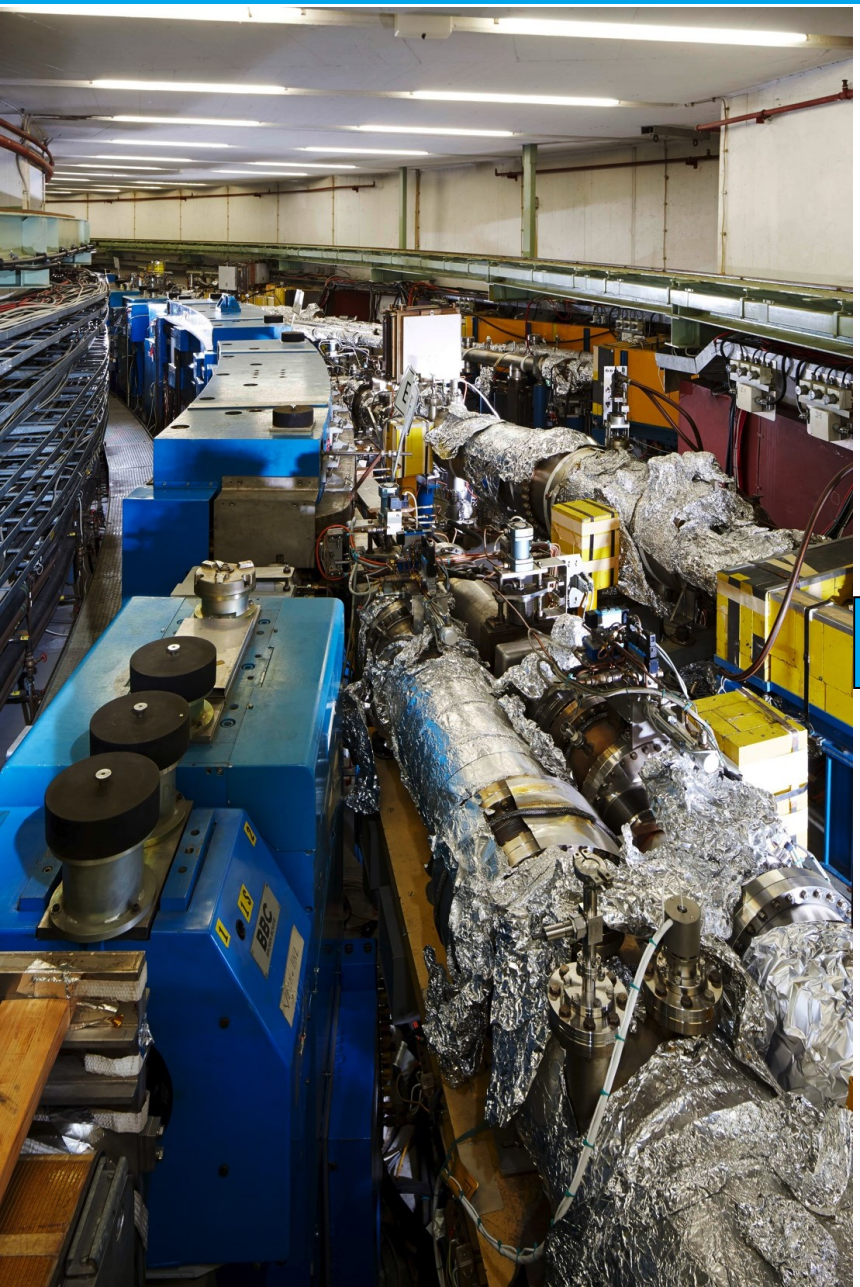


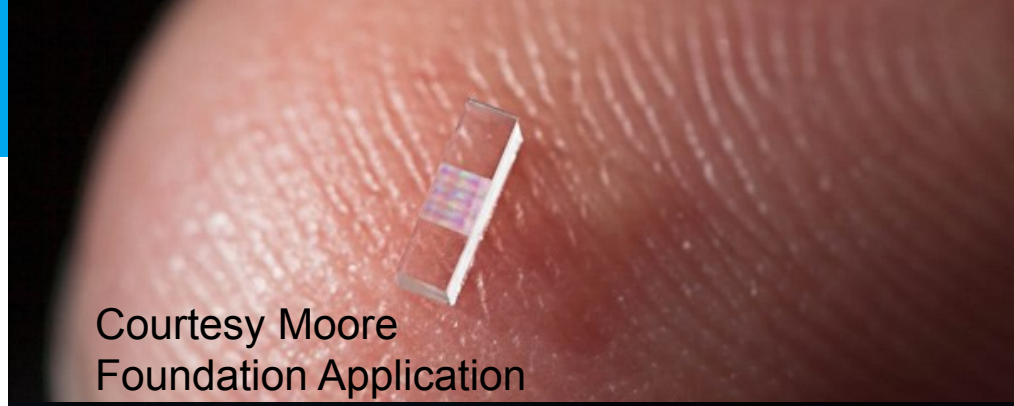
ANGUS Laser, DESY & Univerisity Hamburg



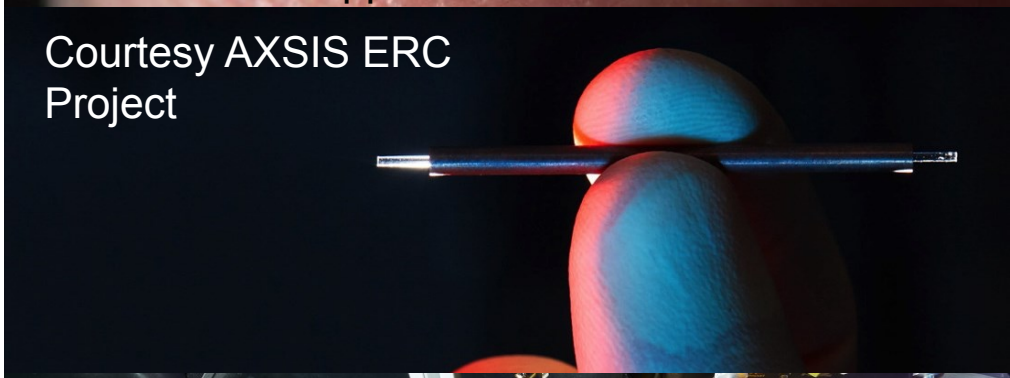
The Plasma Source

DORIS transforming to SINBAD...

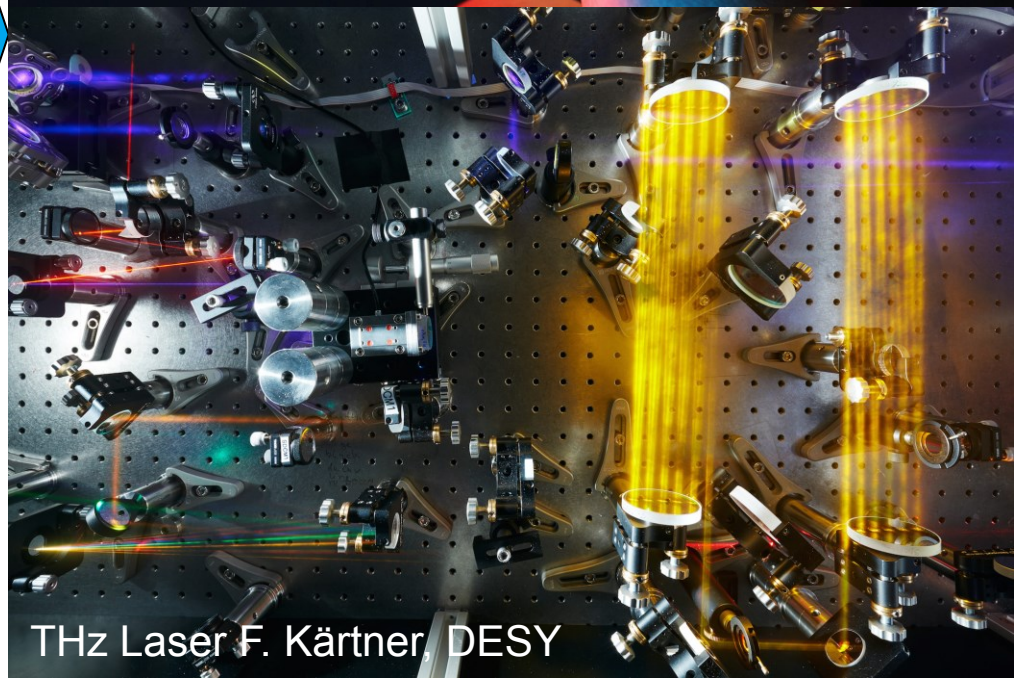




Courtesy Moore Foundation Application



Courtesy AXSIS ERC Project

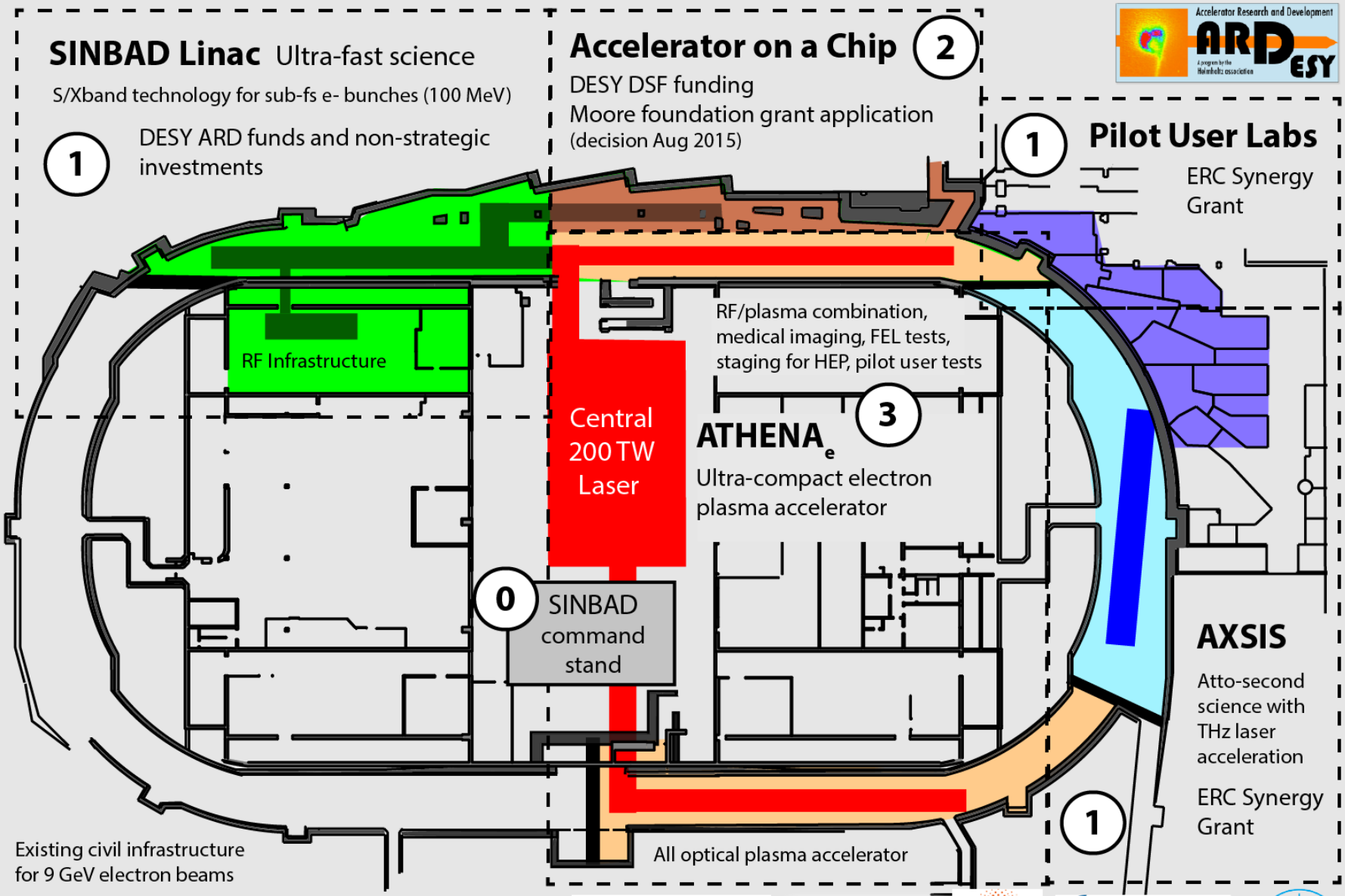


THz Laser F. Kärtner, DESY

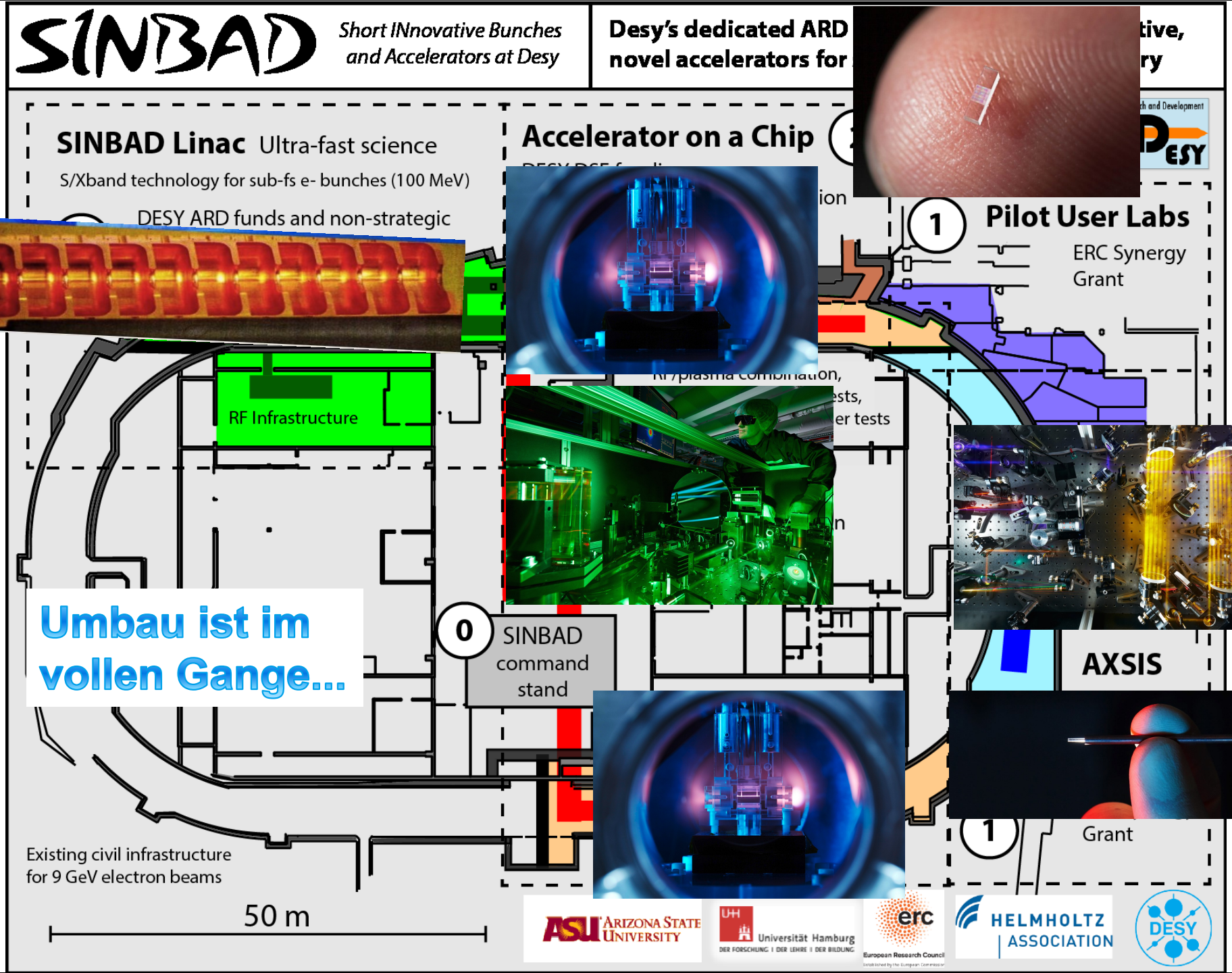
SINBAD

Short INnovative Bunches and Accelerators at Desy

Desy's dedicated ARD facility for R&D on innovative, novel accelerators for science, health and industry

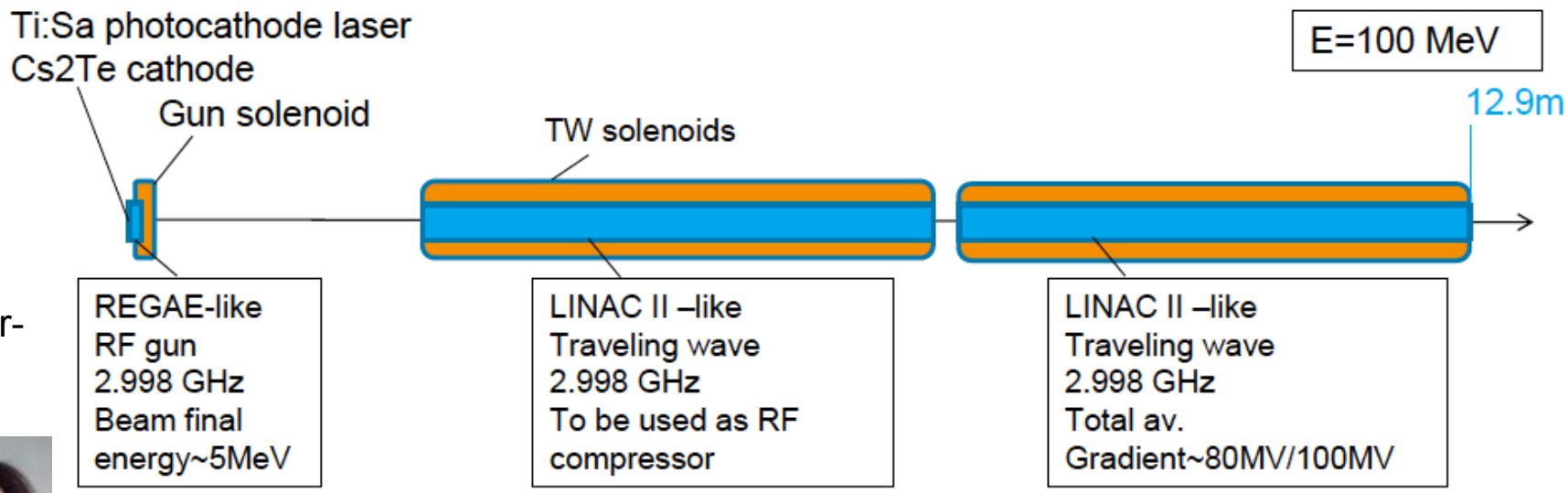


ASU Arizona State University · UH Universität Hamburg · erc European Research Council · HELMHOLTZ ASSOCIATION · DESY



Umbau ist im vollen Gange...

SINBAD Beam Infrastructure → SINBAD Linac Phase 1



PI:
B. Marchetti

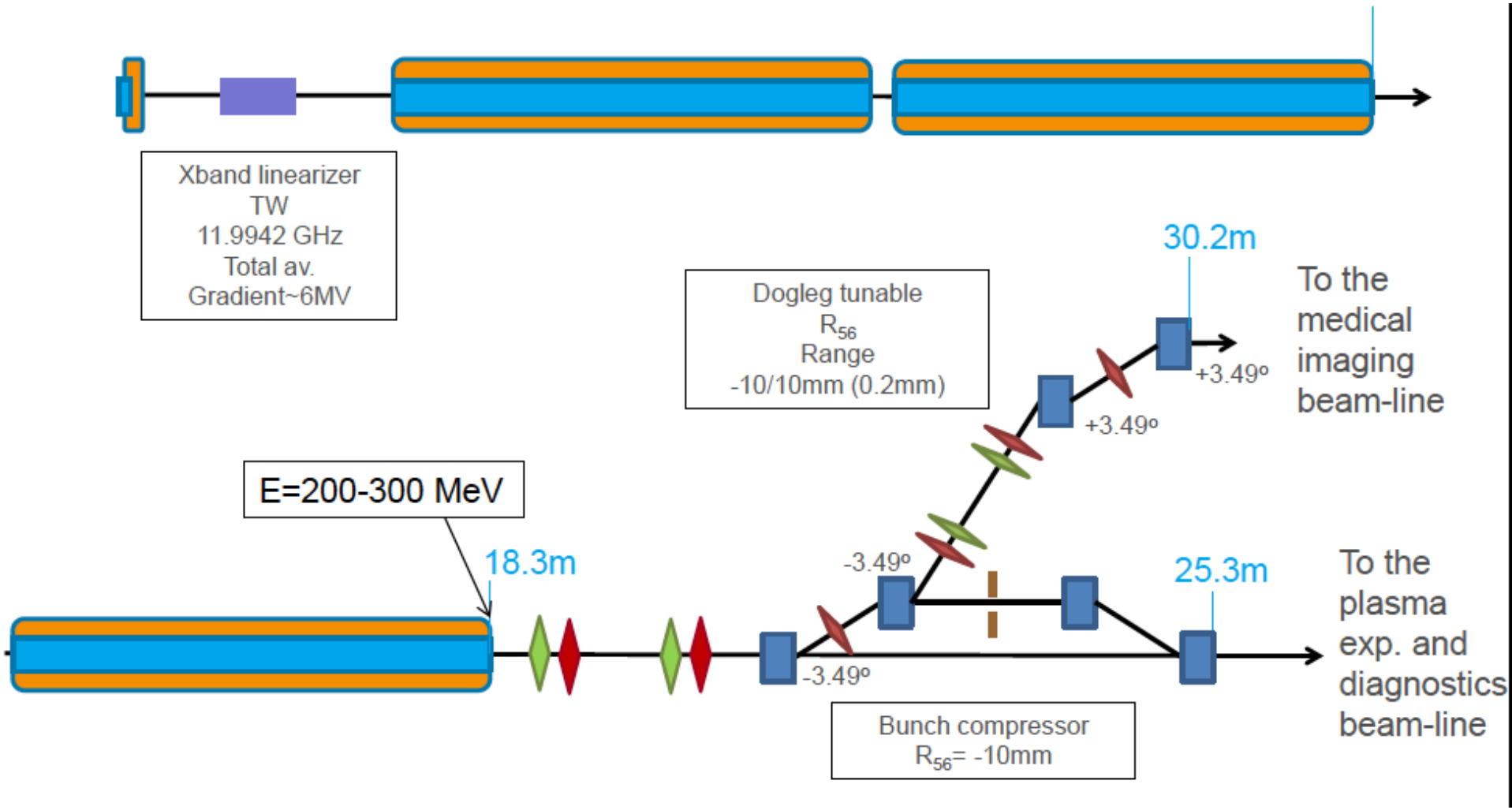
Q=0.5 pC, Ne=3.12*10^6

Beam at the exit of the linac for 3 different working points

$FWHM_z$ [fs]	Q % in 1 FWHM	E [MeV]	ΔE/E	$\sigma_{x,y}$ [mm]	$n\varepsilon_{x,y}$ [mm*mrad]	($\alpha_{x,y}$,$\beta_{x,y}$ [m])	(I_p local, I_p 1FWHM)[A]
2.1	50.6	110	0.1%	0.6	0.07	-71, 1284	150, 133
2.7	62.2	111	0.1%	0.15	0.05	0.9,79	150, 115
4	70	111	0.3%	0.009	0.05	0.03, 0.3	100, 87

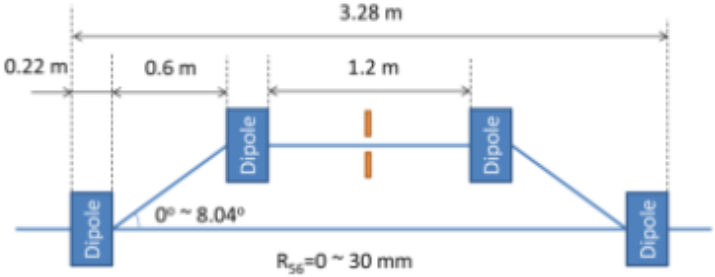
→ 2.1 – 4 fs

SINBAD Beam Infrastructure → SINBAD Linac Phase 2



Discussing collaboration with CLIC on X-band technology for linearizer and transverse deflecting structure

Bunch Compressor



→ 200 atto-s

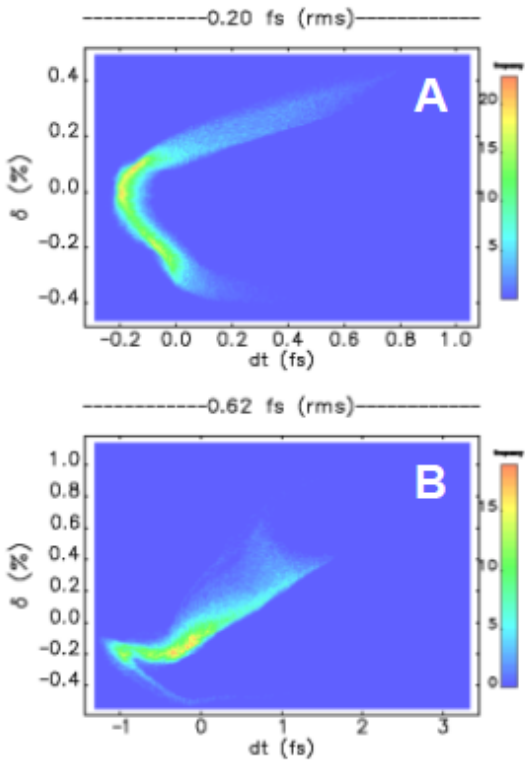
→ 620 atto-s

Working point A

Initial charge (pC)	10
Gun gradient (MV/m)	110.0
Gun phase (deg)	0.0
Laser pulse duration (ps)	3.0
TW1 gradient (MV/m)	23.9
TW1 phase (deg)	-59.2
TW1 gradient (MV/m)	23.9
TW1 phase (deg)	-59.2
R56 (mm)	10.0
Slit width (mm)	0.4
Final charge (pC)	0.38
ε_x (μm)	0.05
ε_y (μm)	0.05
Energy spread	0.0019
Current (A)	650

Working point B

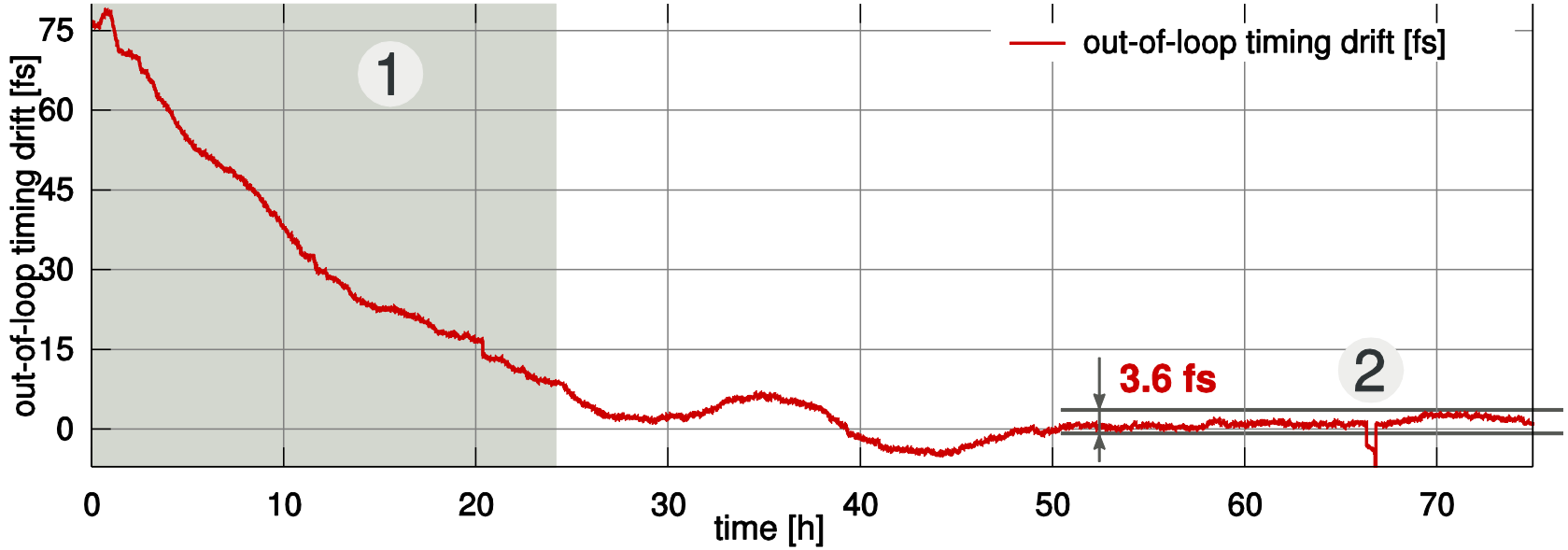
Initial charge (pC)	100
Gun gradient (MV/m)	110.0
Gun phase (deg)	0.0
Laser pulse duration (ps)	3.0
TW1 gradient (MV/m)	23.9
TW1 phase (deg)	-60.0
TW1 gradient (MV/m)	23.9
TW1 phase (deg)	-60.0
R56 (mm)	10.0
Slit width (mm)	0.4
Final charge (pC)	2.77
ε_x (μm)	0.24
ε_y (μm)	0.18
Energy spread	0.0022
Current (A)	1528



Study and simulations: J. Zhu

References:
P. Emma, Phys. Rev. Lett. 92, 074801(2004)
S. Di Mitri, PRSTAB 16, 042801 (2013)

Ultra-Precise Timing and Synchronization



Femtosecond Precision in Laser-to-RF Phase Detection

(from H. Schlarb, T. Lamb, E. Janas et al. Report on DESY Highlights 2013).

HELMHOLTZ (Germany) – Research Field Matter: new programme structure, starting 1.1.2015

Matter and the Universe

- Fundamental Particles and Forces
- Cosmic Matter in the Laboratory
- Matter and Radiation from the Universe

From Matter to Materials and Life

- In-House Research on the Structure, Dynamics and Function of Matter at Large Scale Faciltities
- Facility Topic: Research on Matter with Brilliant Light Sources
- Facility Topic: Neutrons for Research on Condensed Matter
- Facility Topic: Physics and Materials Science with Ion Beams
- Facility Topic: Research at Highest Electromagnetic Fields

Matter and Technologies

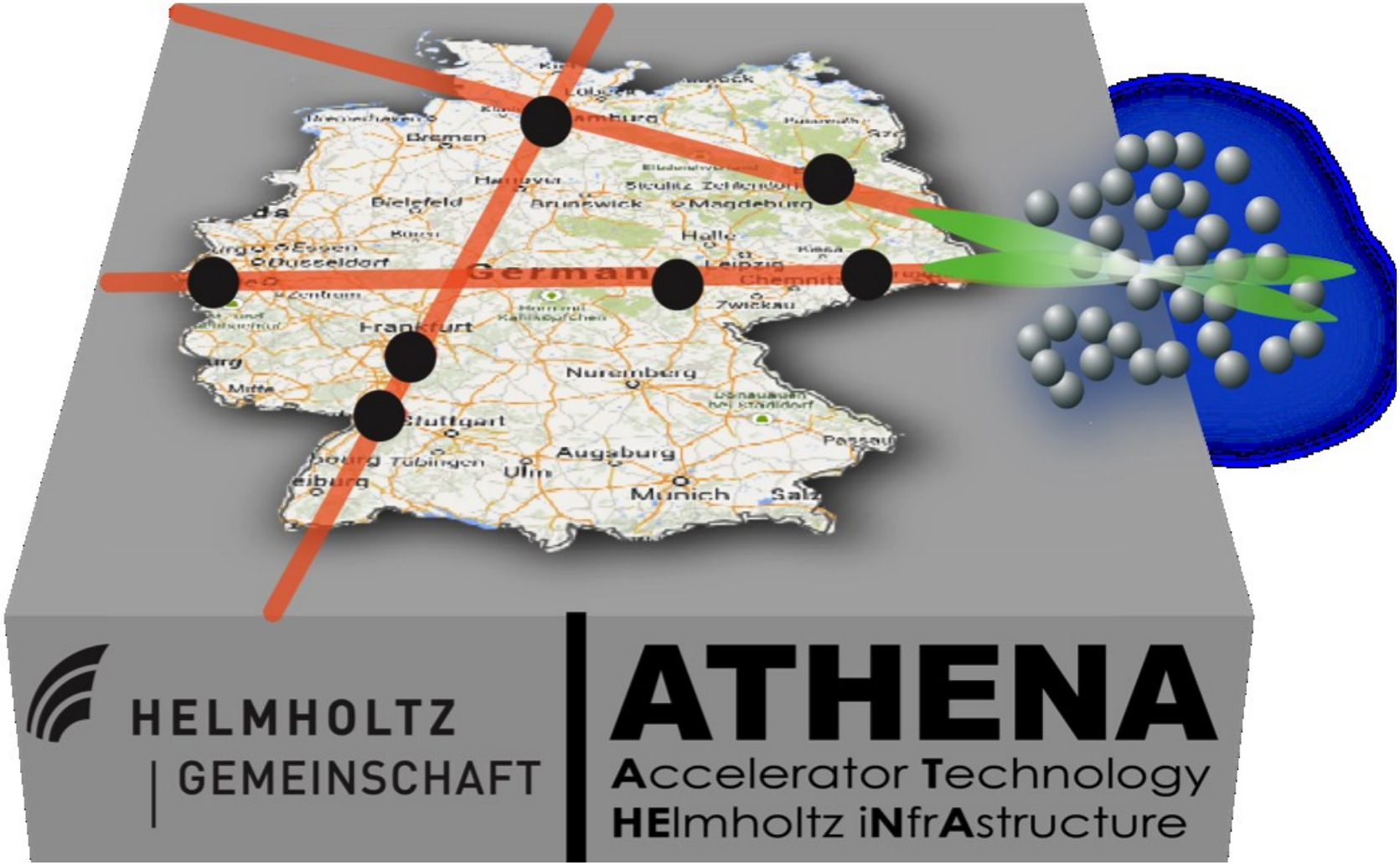
- Detector Technologies and Systems

ARD

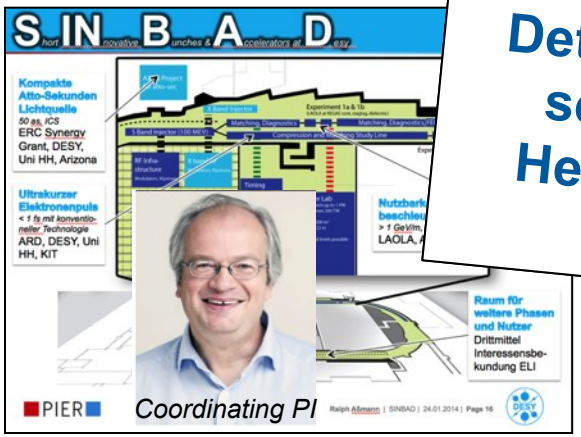
ATHENA =
Accelerator Technology
HElmholtz iNfrAstructure

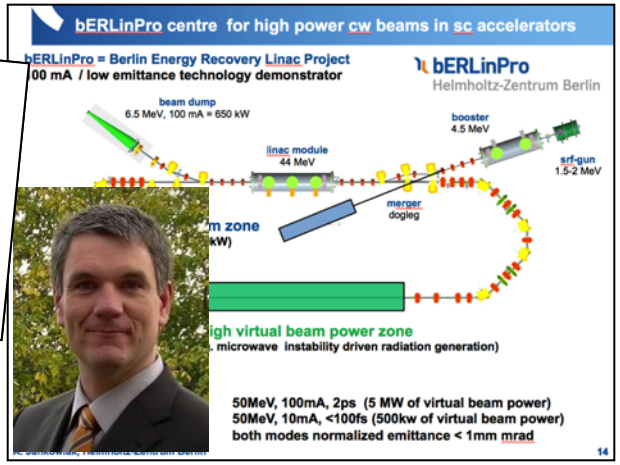
LK II
„performance category II“
= user operation of large scale facilities

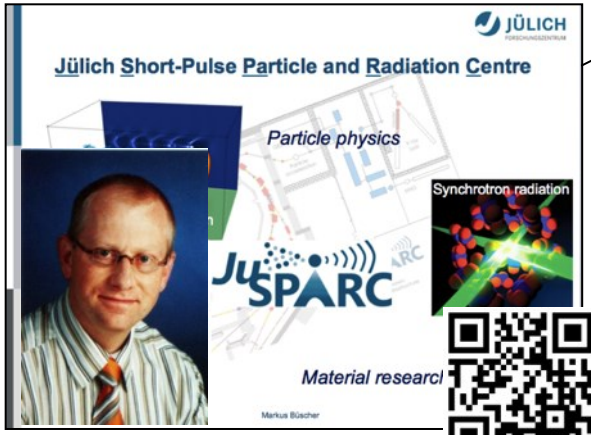
Plasma Accelerator Project in Helmholtz – Germany

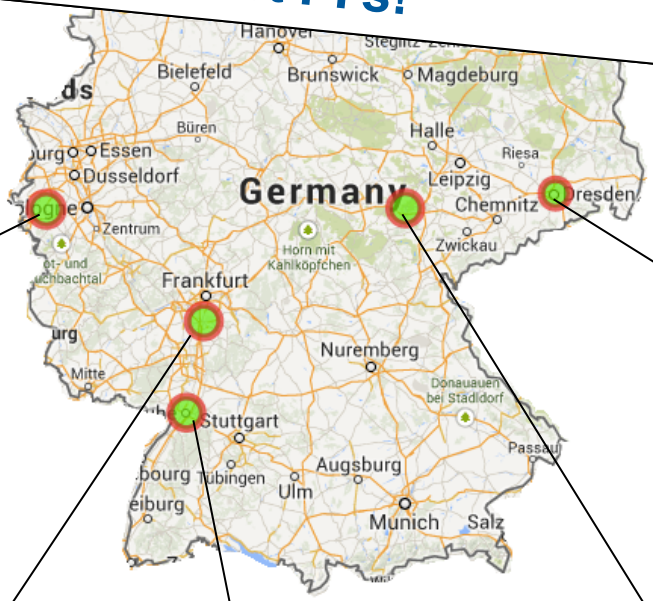


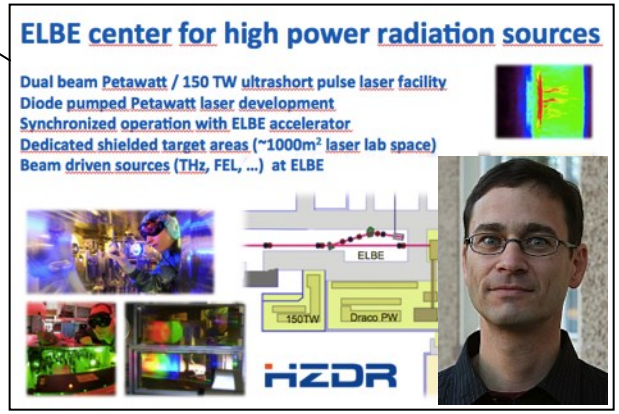
Details on included facilities see presentations on the Helmholtz ARD web site or contact PI's!

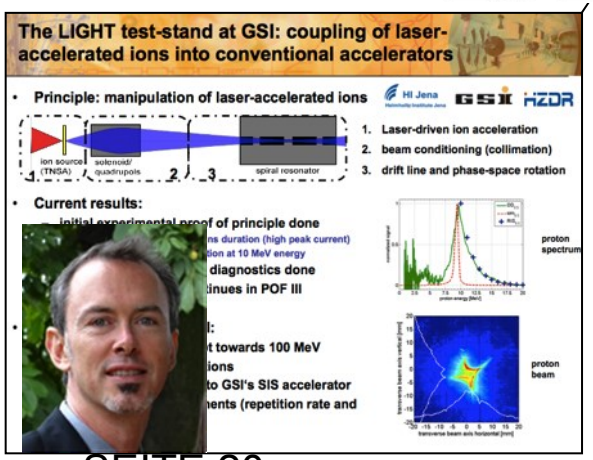


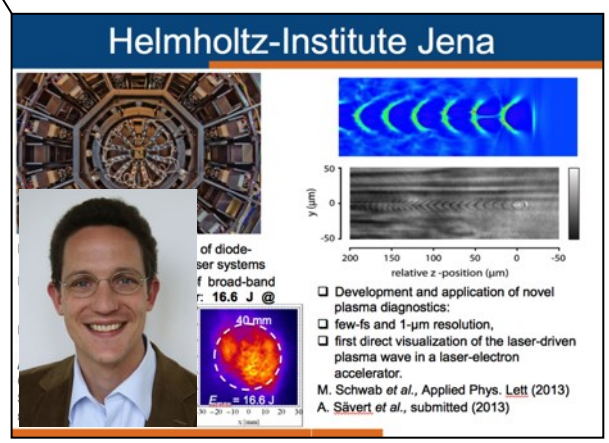


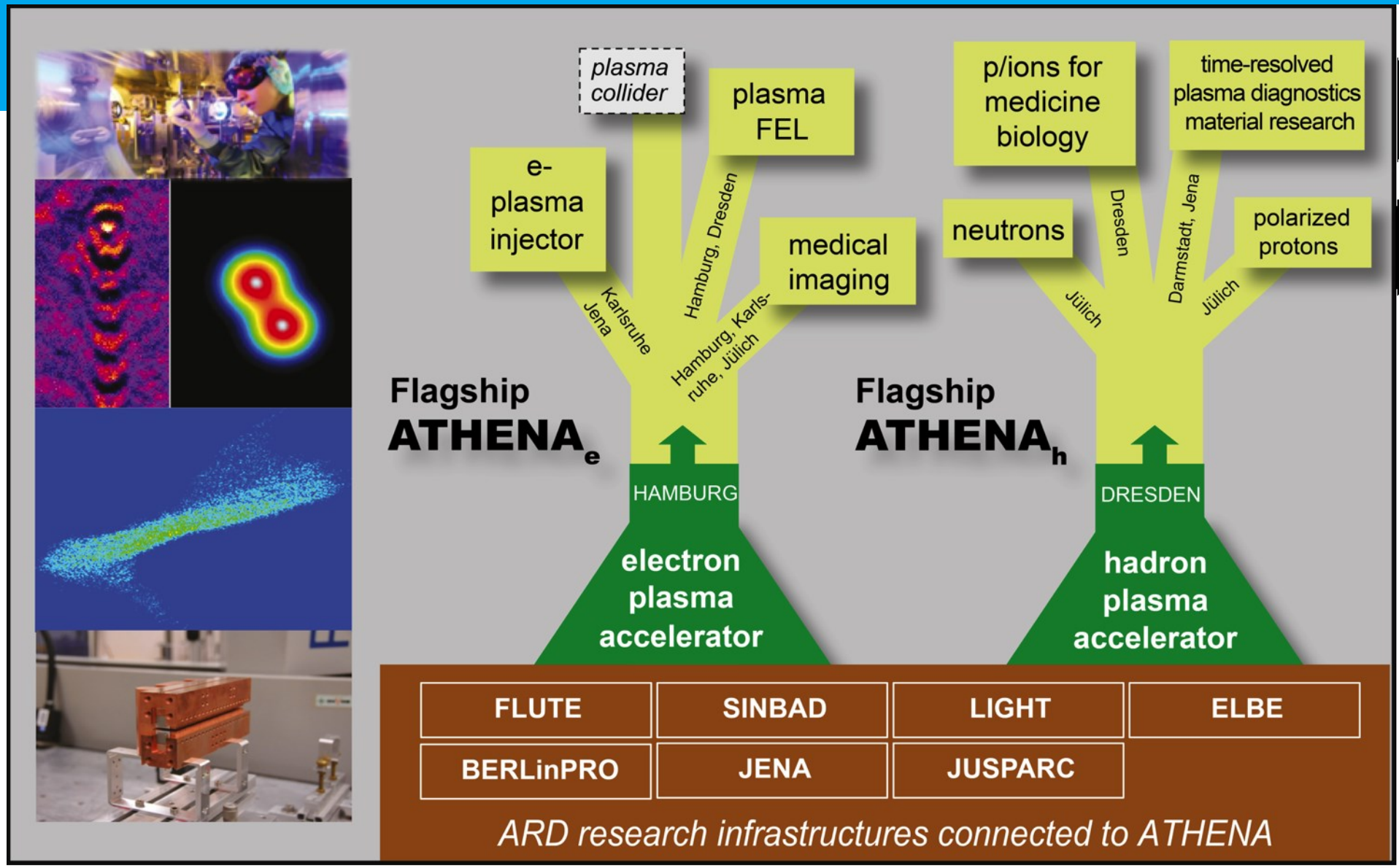










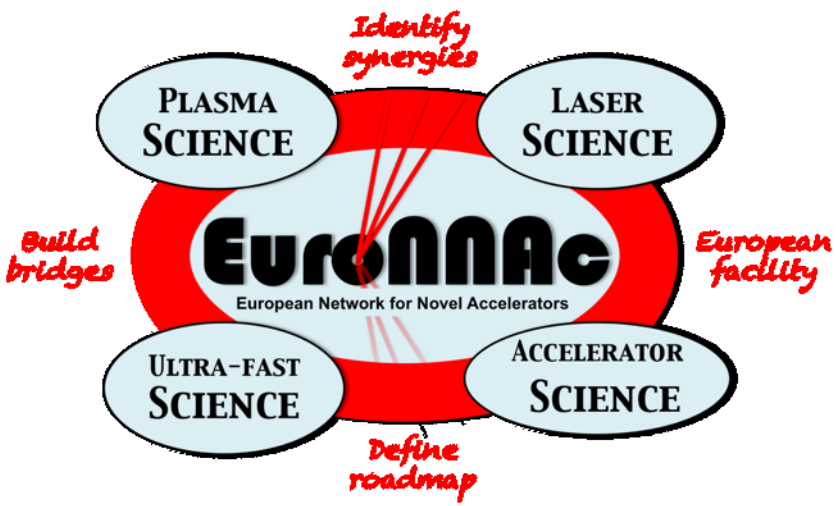


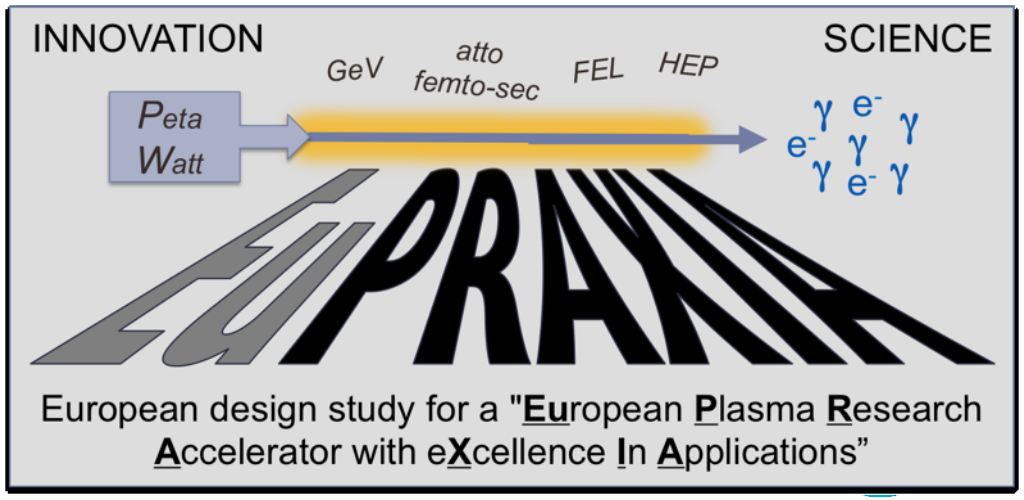
ATHENA: 2016 – 2021, proposal to be submitted, 6 centers + 1 institute + universities + international collaborators, using infrastructures together, 2 future technologies for the Helmholtz strategy, high relevance for applications in many centers.

Proposal for a H2020 Design Study "European Plasma Research Accelerator with eXcellence In Applications" (EuPRAXIA*)

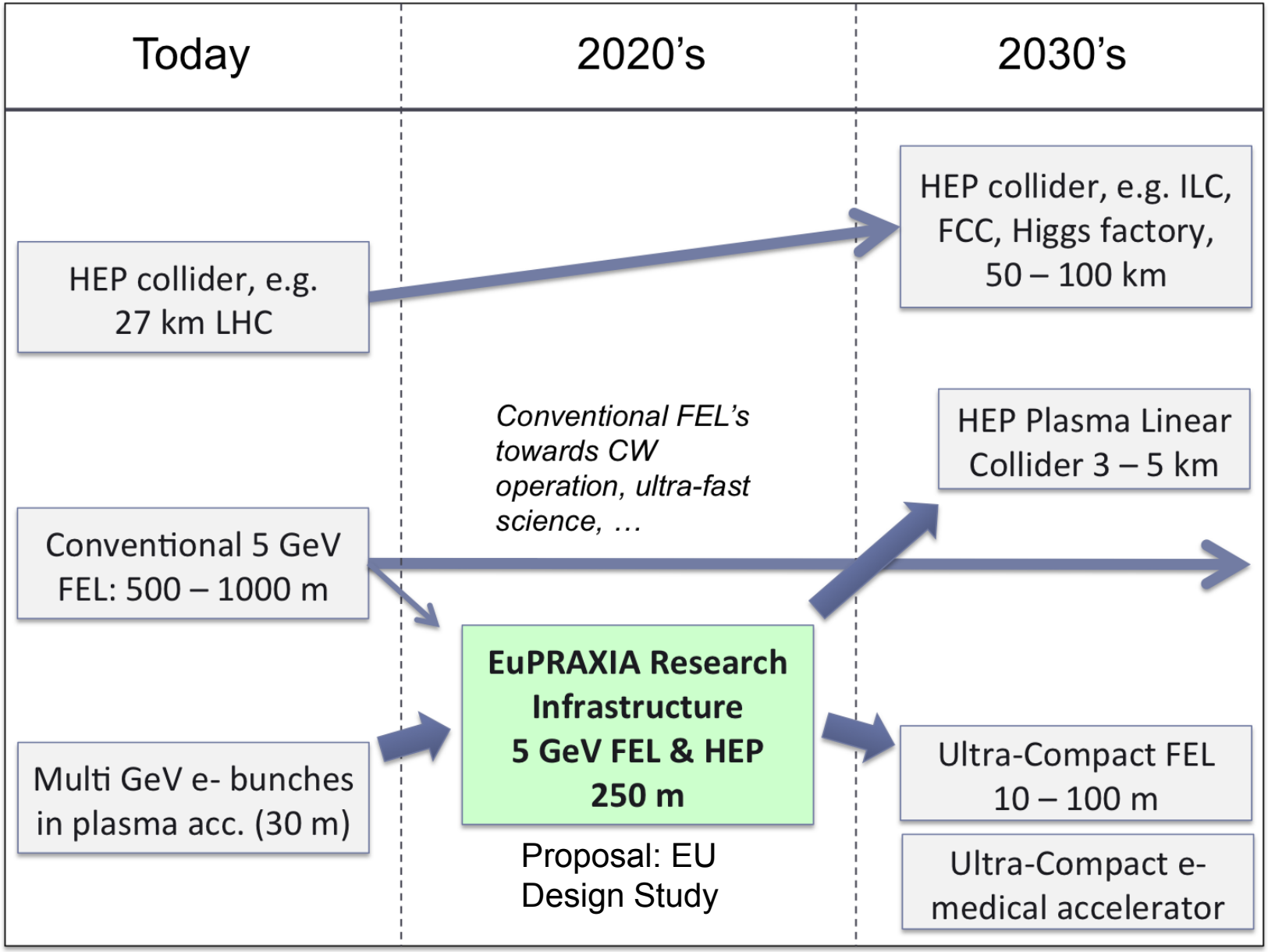
Collaborative Project

* In Greek mythology, Eupraxia was the personification of well-being. In medicine the term Eupraxia describes the normal ability to perform coordinated movements.





Strategy European Network Novel Accelerators



EuPRAXIA – Connected Labs and Institutes

List of participants:

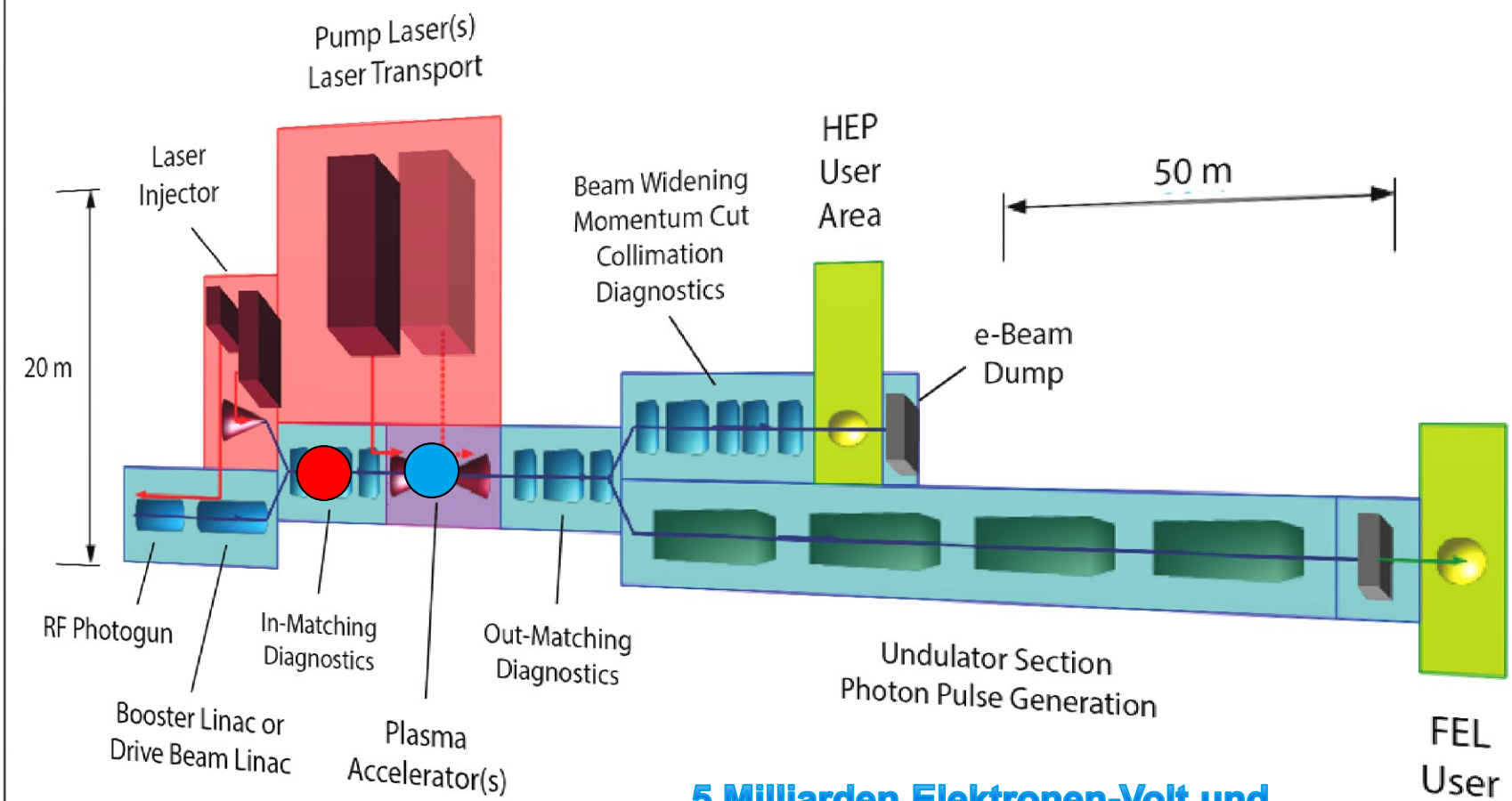
Participant no.	Participant organisation name	Short name	Country
1 (Coordinator)	Stiftung Deutsches Elektronen Synchrotron	DESY	Germany
2	Istituto Nazionale di Fisica Nucleare	INFN	Italy
3	Consiglio Nazionale delle Ricerche	CNR	Italy
4	Centre National de la Recherche Scientifique	CNRS	France
5	University 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 sostenible	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

EuPRAXIA



5 Milliarden Elektronen-Volt und zwei Nutzergebiete