Long-term Accelerator R&D as an Independent Research Field

Reinhard Brinkmann, DESY

Spokesperson for the ARD program topic in the Helmholtz Association

Introduction

- Accelerator R&D has since a long time often been driven by Particle Physics – and will continue to do so ***(F. Gianotti, FRYCA01)***
- Accelerators as enabling technology for a very broad spectrum of sciences and applications require a balanced approach to acc. R&D

- **Facility/project-specific**
- **Direct, short-term applicable**
- **“guaranteed” success**

↔

- **Generic, versatile**
- **Visionary, long-term**
- **High-risk/high potential**

ARD in Helmholtz Association

- Implementation of acc. R&D as **an own research topic** started in 2011 – fully integrated in Helmholtz structure for next funding period 2015-19
  - Generate improvements and novel concepts for existing facilities and new projects (e.g. ANKA, BESSY-II, ELBE, FLASH, FAIR, EU-XFEL)
  - Link to other research fields like Health and to technology transfer and industrial applications
  - Foster generic future oriented research including high-risk/high-impact activities with ambitious goals
- Strengthen networking and cooperation
  - Joint projects between Helmholtz centers, transfer of knowledge and technologies, joint usage of infrastructure
  - Collaboration with universities – improve visibility of our field, attract young talents
  - Basis for large and growing number of international cooperations

Research field *Matter* in Helmholtz

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

JÜLICH
FORSCHUNGSZENTRUM

GSI

+ Helmholtz Institutes
Jena and Mainz

KIT
Karlsruher Institut für Technologie

DESY

Hamburg and Zeuthen

HZB Helmholtz Zentrum Berlin

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

since 2011

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

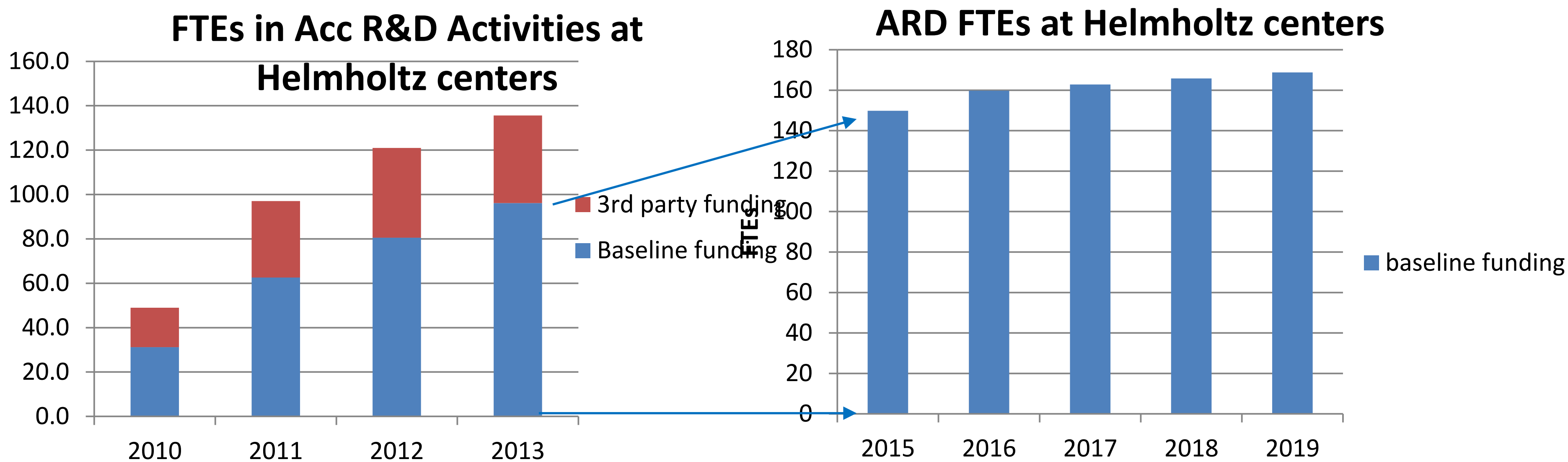
New programme structure in *Matter*

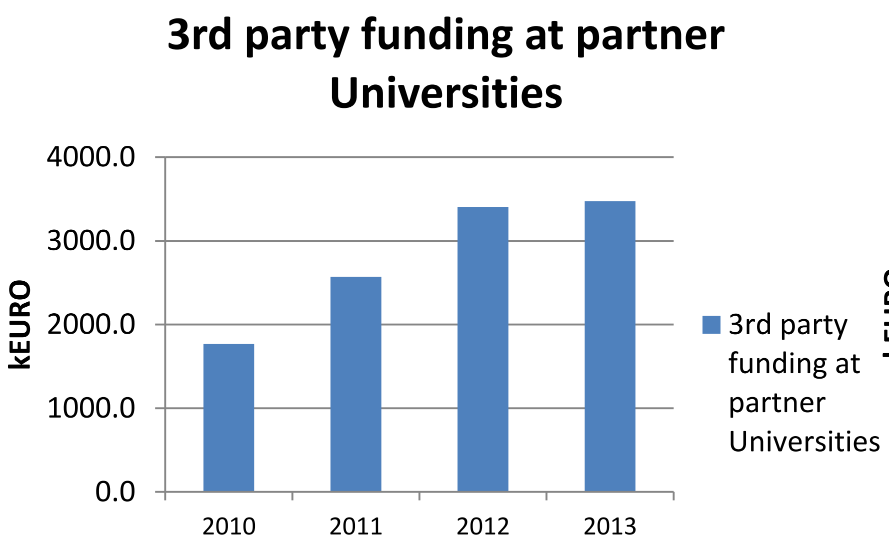
Matter and the Universe	From Matter to Materials and Life	Matter and Technologies
Fundamental Particles and Forces	In-House Research on the Structure, Dynamics and Function of Matter at Large Scale Faciltities	Accelerator Research and Development
Cosmic Matter in the Laboratory	Facility Topic: Research on Matter with Brilliant Light Sources	Detector Technologies and Systems
Matter and Radiation from the Universe	Facility Topic: Neutrons for Research on Condensed Matter	
	Facility Topic: Physics and Materials Science with Ion Beams	
	Facility Topic: Research at Highest Electromagnetic Fields	

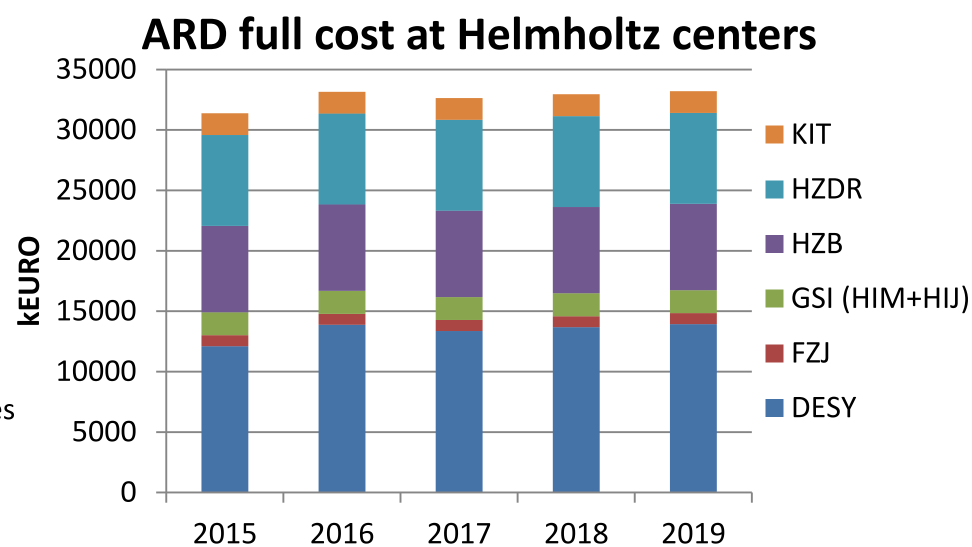
LK II
„performance category II“
= user operation of large scale facilities

Evaluation for the programme oriented funding 2015 – 19 in the research field* Matter *was recently completed

Past and future resources in accelerator R&D



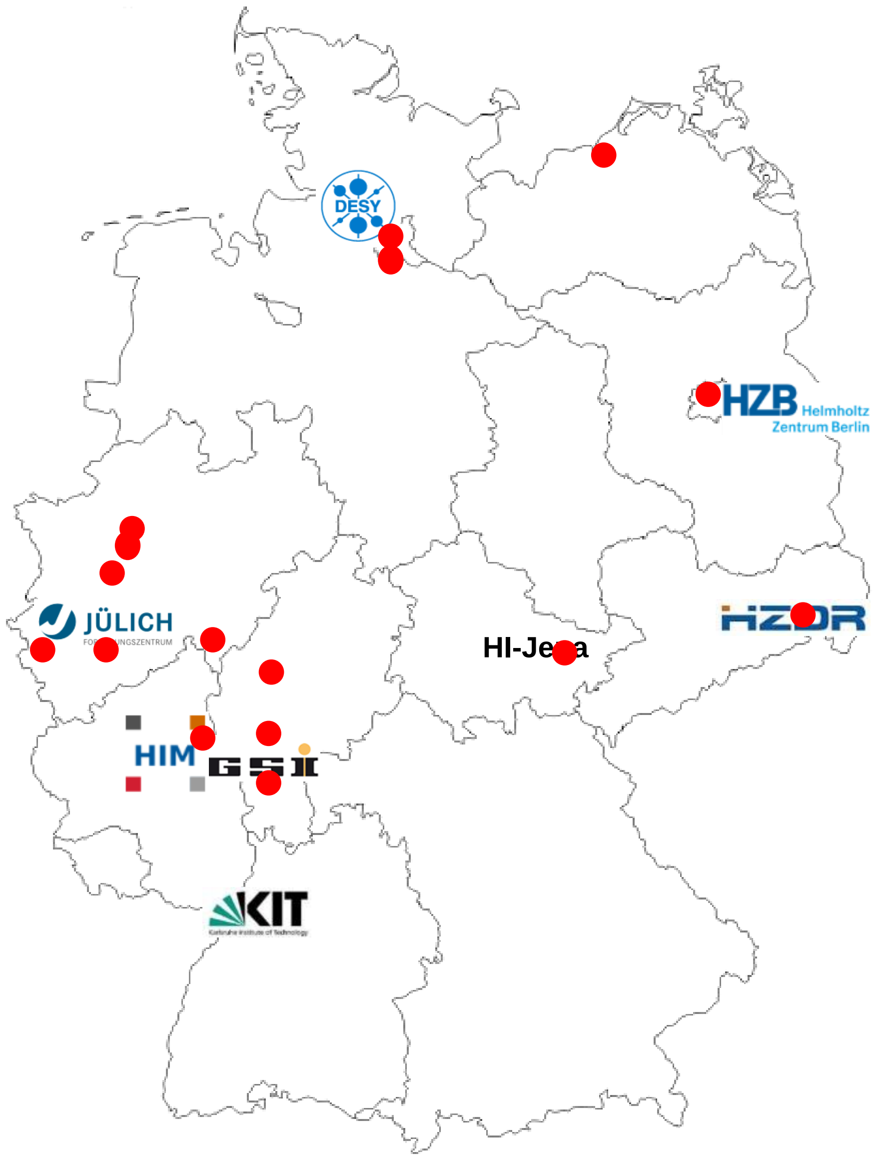




ARD and German Universities

● **Partner universities**

TU-Dortmund
U-Bochum
U-Wuppertal
RWTH Aachen
U-Bonn
U-Siegen
U-Giessen
U-Mainz
U-Frankfurt
TU-Darmstadt



U-Rostock
U-Hamburg
TU-Harburg
HU-Berlin
TU-Dresden
U-Jena

KfB Komitee für Beschleunigerphysik ***committee for accelerator physics***
1st meeting 17 Jan 2011

… + >30 further cooperation partners

MPP-Munich
MBI
PTB
U-hospital Dresden

TRIUMF

IMP-CAS

ASG S.p.A.
INFN

KEK
RIKEN

IBS-RISP

KVI

NCBJ
TU-Lodz
TU-Warsaw

BINP
INR
Moscow State U.
St. Petersb. State U.

PSI

STFC-Daresbury Lab
J. Adams Inst.
U-Strathclyde

BNL
Cornell U.
FNAL
JLAB
LBNL
MI State U.
MIT
SLAC
UCLA

CERN

Integration in EU programs and responsibilities for coordination, e.g.

EuroNNAc

EuCARD^2

TIARA

Structure and coordination of ARD programme

Topic 1: Accelerator Research and Development ARD

Speaker: R. Brinkmann/DESY, co-speaker: A. Jankowiak/HZB

ST1: SRF science and technology	ST2: concepts & techn. for hadron acc.	ST3: ps – fs electron and photon beams	ST4: Novel acceleration concepts
Coordination: J. Knobloch/HZB, P. Michel/HZDR	Coordination: A. Lehrach/FZJ, P. Spiller/GSI	Coordination: H. Schlarb/DESY, A.-S. Müller/KIT	Coordination: U. Schramm/HZDR, F. Grüner/U-Hamburg

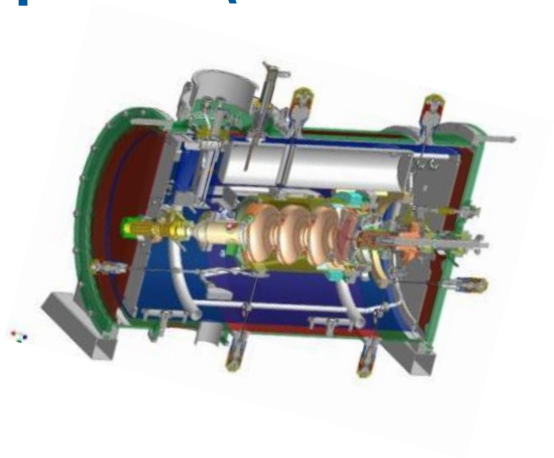
Networking, workshops, joint projects and usage of infrastructure, transfer of new technologies between centers

Cooperation with German universities, international partners and industry

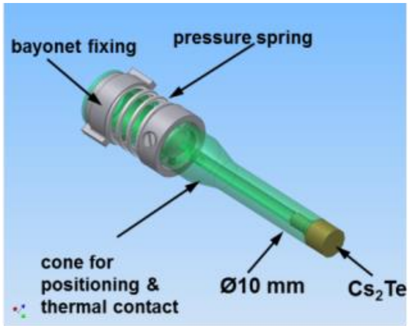
ST1: SRF science and technology

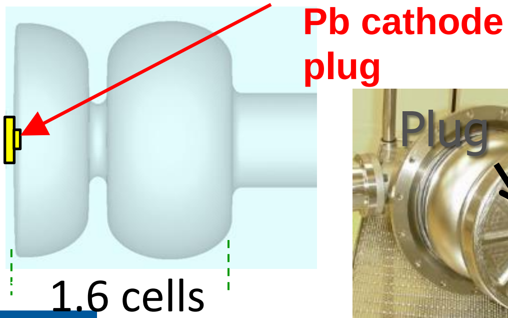
- Focus on development of high duty cycle/CW superconducting accelerators for electron and hadron beams
  - Pushing the limit *(Q_b, I_b, emittance, …)* of beam sources/injectors
  - Pushing the limit *(E_{acc}, Q_0, I_b/HOM-damping, …)* of CW acceleration
- Towards highly efficient generation of high quality beams for a broad range of applications
  - High intensity proton/ion beams
  - CW FEL
  - ERLs for light sources, nucl./particle physics and industry
  - Storage rings

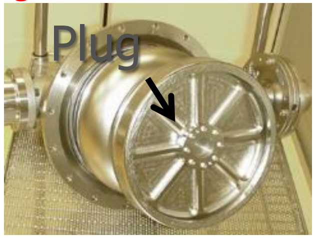
ST1 SRF gun development *(→ J. Teichert MOZB01)*



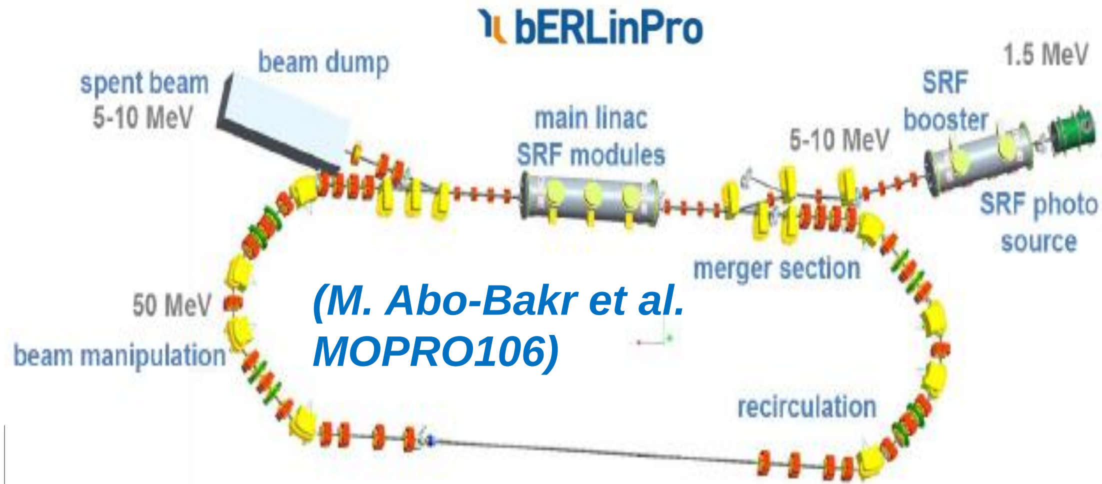
- Operation experience at ELBE facility – new gun under test ***(A. Arnold, MOPRI022)***
- Explore different photocathode materials ***(L. Cultrera MOZB02)***
  - "classical" Cs_2Te
  - Multi-alkali ***(M. Schmeisser et al. MOPRI019, T. Rao et al. MOPRI059)***
  - GaAs ***(R. Xiang et al. MOPRI024)***
  - s.c. Pb ***(J. Smedley et al. IPAC2011-THPC109)***
- GunLab for future developments ***(J. Voelker et al. MOPRI020)***





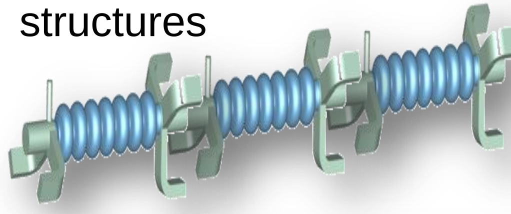


ST1 High beam intensity/ERL *(→ C. Mayes FRXBB01)*

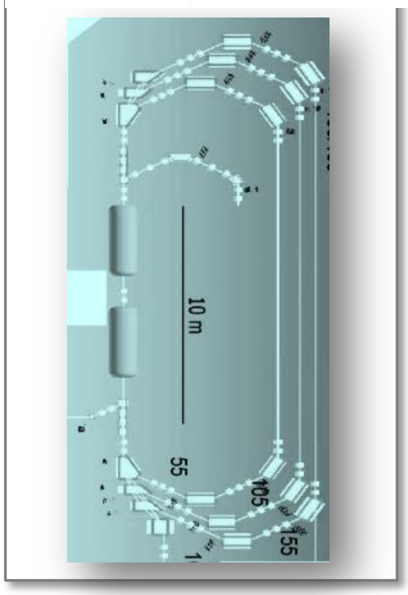


(M. Abo-Bakr et al. MOPRO106)

HOM damped structures



Acc module design
Industrialization



Nucl. Phys.
MESA

ST3

Light sources
XFELO
Storage rings

Bunched-beam
electron cooling
MEIC/JLAB *(Y. Zhang et al, MOPRO009)*

LHeC

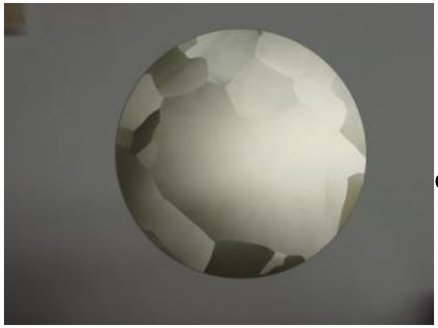
Industrial
application
(lithography)

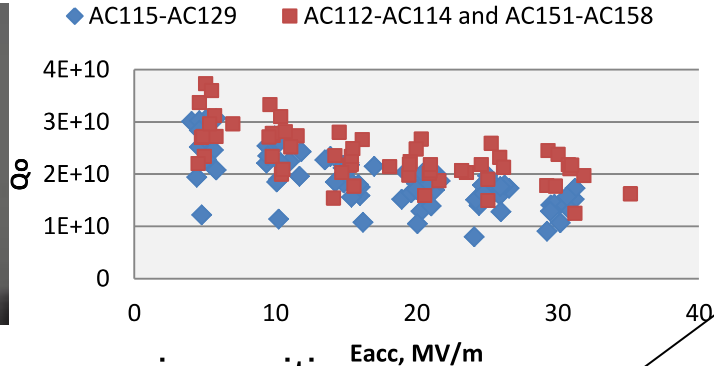

Concept study on an accelerator based source for 6.x nm lithography

HZB ZEISS

Atoosa Meseck, Johannes Bahrdt , Andreas Jankowiak, Jens Knobloch — Helmholtz-Zentrum Berlin
Diana Türke, Udo Dinger, Michael Patra, Erik Sohmen — Carl Zeiss SMT
We would like to acknowledge fruitful discussion with E. A. Schneidmiller, M. V. Yurkov, E. Saldin, H. Weise, et al. in earlier stages. — DESY Hamburg

ST1 Minimize cryo losses





Higher Q_0 with large-grain cavities

(W. Singer et al., PRST-AB 2013)

Test with 8-cav acc module

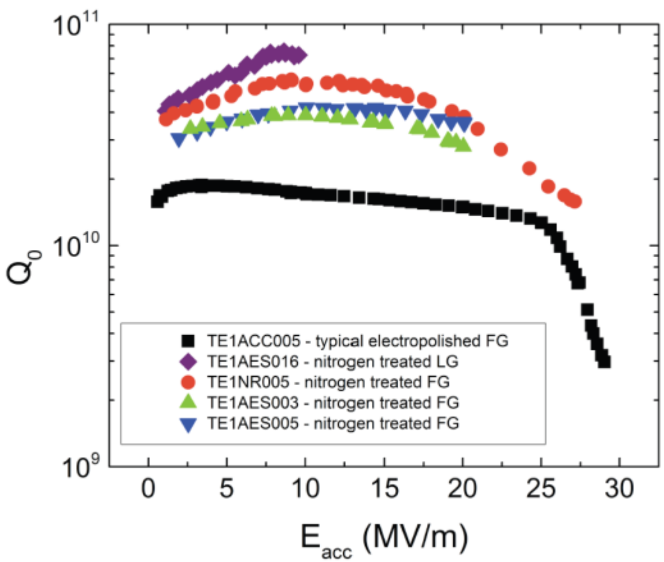
Cooling procedure	Q_0 at 1.8K
Standard "DESY"	4.7×10^{10}
"HZB" + slow transition	3.3×10^{10}

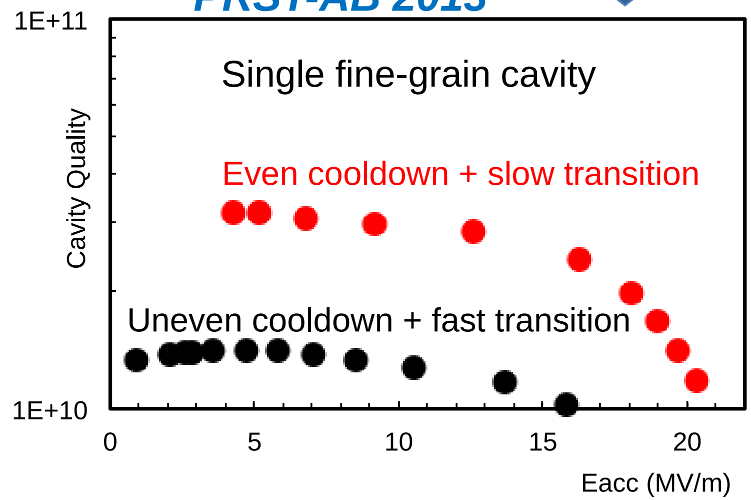
?

J. Vogt et al., PRST-AB 2013

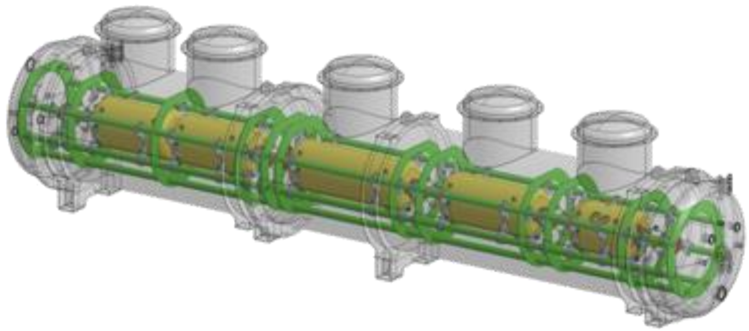
Higher Q_0 with N_2 baking + few µm chemistry

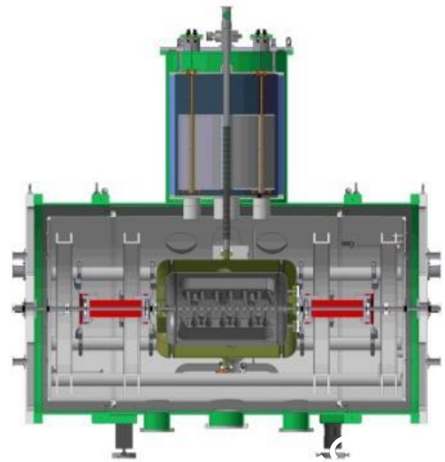
(A. Grasselino et al., 2013)





ST1 SRF for proton/ion acceleration



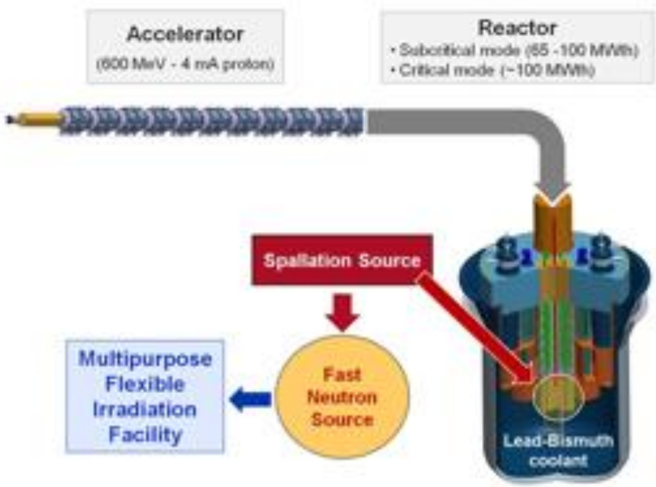


s.c. heavy ion linac development GSI/FAIR ***(W. Barth et al. THPME004)***

CH Structures

F. Dziuba et al., PRST-AB 2010

MYRRHA (Radioactive waste transmutation, energy production)



ST 2: Concepts & technologies for hadron accelerators

- R&D towards accelerators for ultimate heavy ion intensities
  - Crucial for future development of FAIR ***(P. Spiller WEOBA01)***
  - Generic for other applications and projects

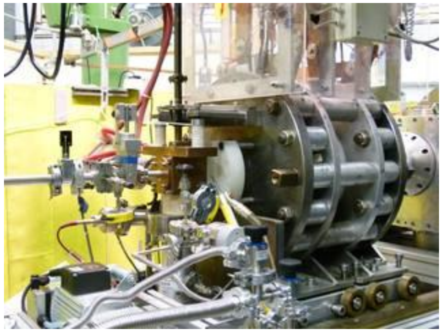
Fast ramping magnets

Electron/stochastic beam cooling

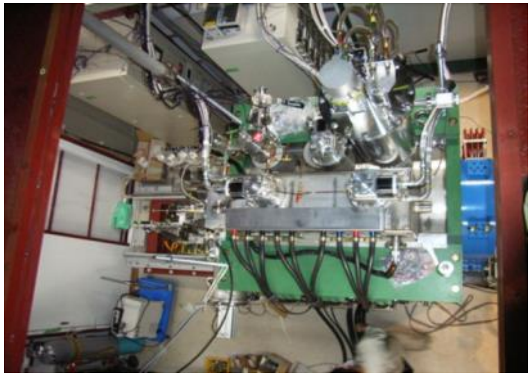
(V Kamerdzhiev et al. MOPRI070, H. Stockhorst et al. MOPRI071)

Laser cooling: ***M-H. Bussmann et al MOPRI068***

Ion sources



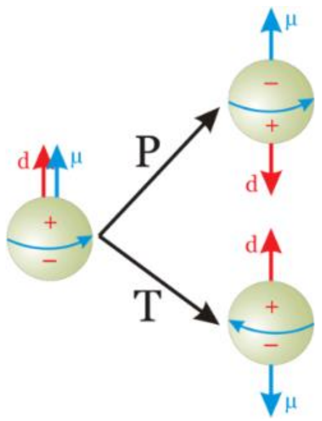
Dynamic vacuum



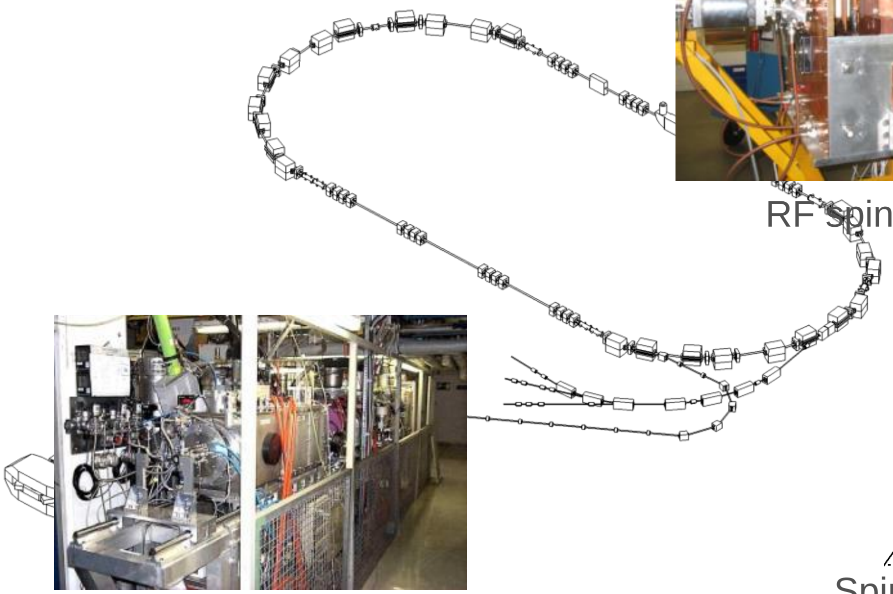
(T. Nakagawa ECRIS2010)

MA cavity

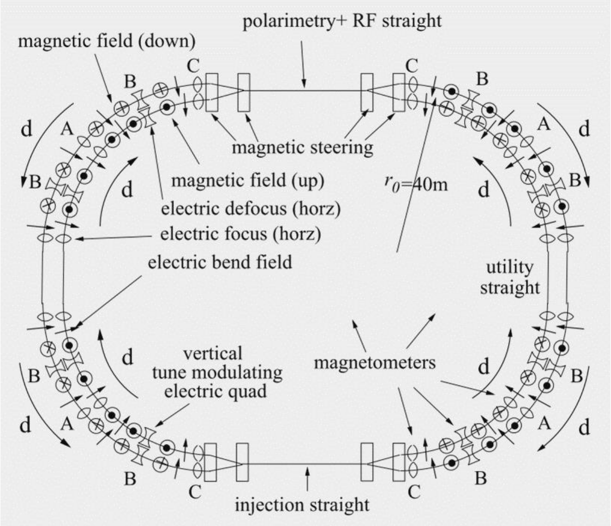
ST2: Concepts & technologies for hadron accelerators



- Search for electric dipole moment
  - R&D and precursor exp. at COSY ***(A. Lehrach et al. 2012)***
  - Development for dedicated storage ring (→ 2019+)

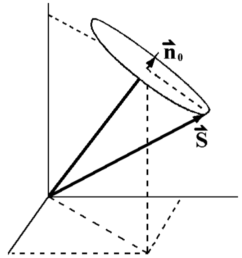


RF spin flipper



JEDI collaboration

Polarized source



Spin dynamics

(S. Chekmeniev THPRO056)

ST3: ps and fs electron and photon beams

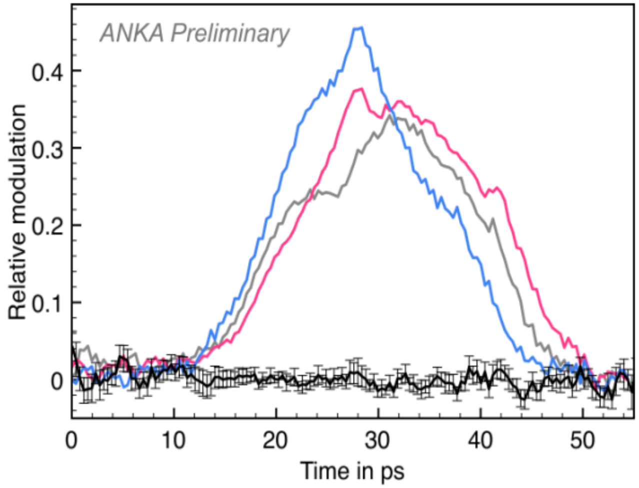
- Beam dynamics & photon sources
  - Short bunches in storage rings and linacs
  - Coherent radiation, bunch shaping/seeding
  - Magnetic & Compton radiators
- ps-fs beam diagnostics
  - THz spectrometry
  - Femtosecond resolution timing & profile
- Stability, controls and synchronization
  - Femtosecond optical & rf synchronization
  - Precision LLRF control & stabilization
  - High-performance electronics

ST1 **SRF**

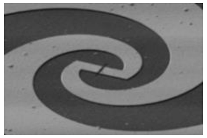
ST4 **Plasma acc.**

ST1 **SRF**

ST3 Storage rings



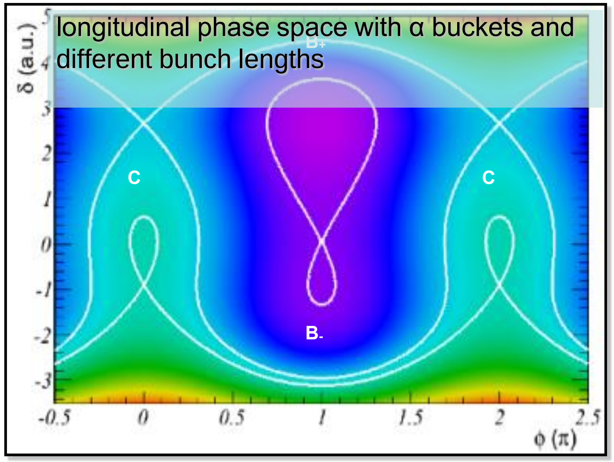
El.-optical single-shot bunch profile

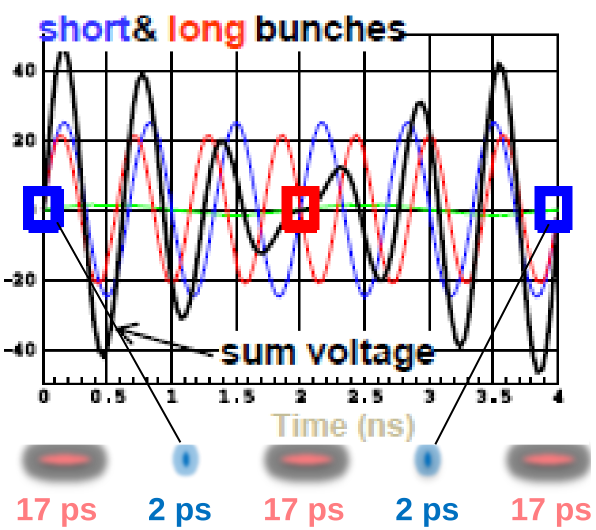


CSR/THz radiation

(A.-S. Müller et al. MOPRO063)

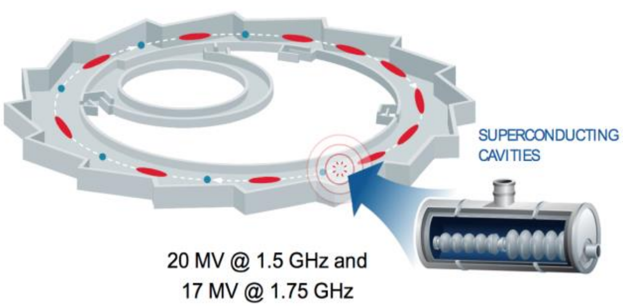
Low → zero α_c long. dynamics



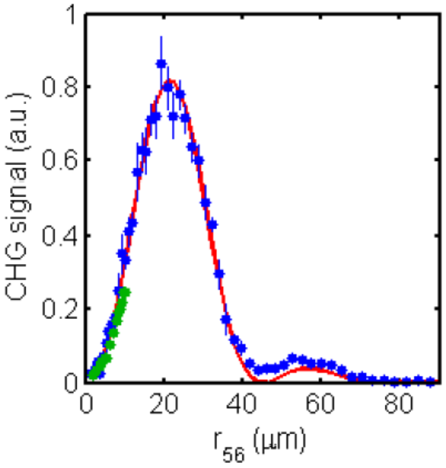


(G. Wüstefeld et al. IPAC2011)

BESSY VSR (HZB)

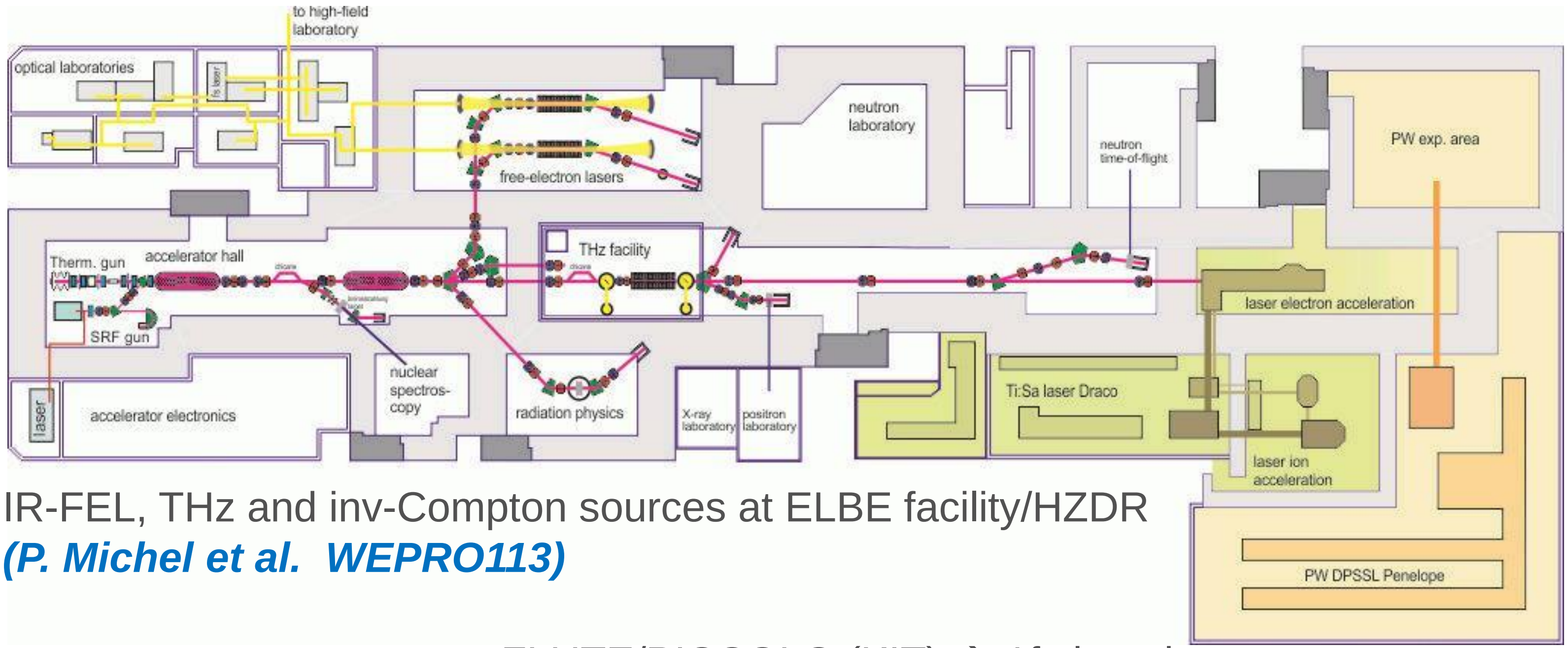


Seeding/CHG at DELTA/TU-Dortmund



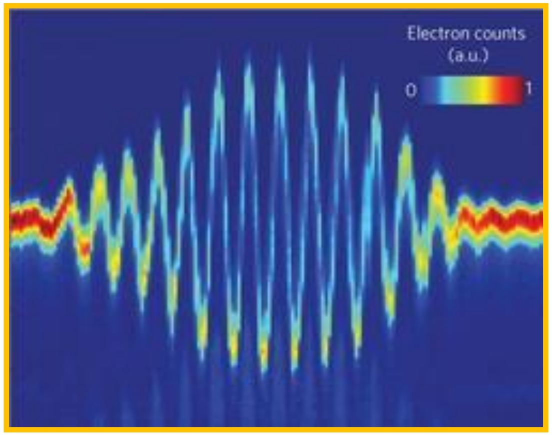
(M. Huck et al. WEOAA03)

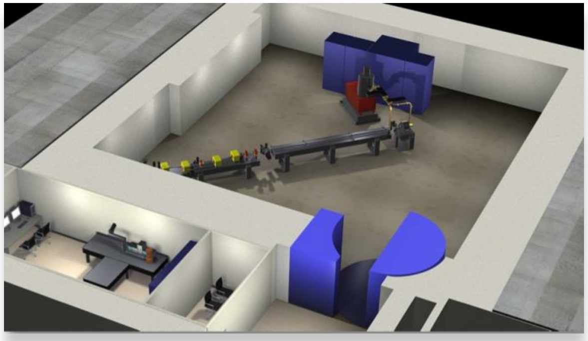
ST3 Linac-driven sources

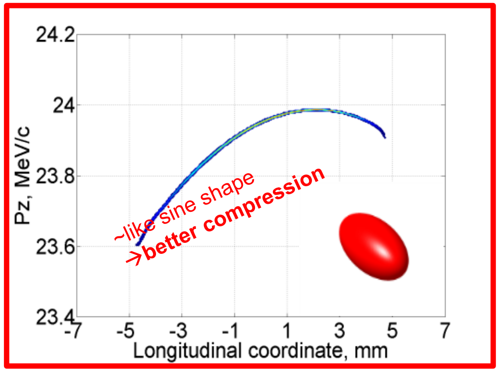


IR-FEL, THz and inv-Compton sources at ELBE facility/HZDR
(P. Michel et al. WEPRO113)

FLUTE/PICCOLO (KIT) → 1fs bunches
(M. Schwarz et al. MOPRO066)





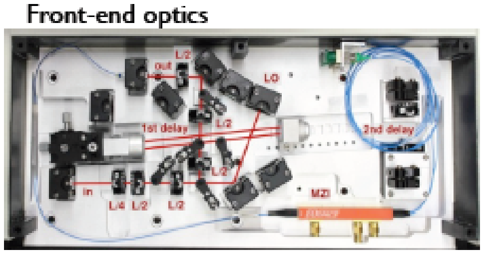


1st synchronized THZ-pump/X-ray probe at FLASH/DESY *(Nat. Phot. 2009, 2011)*

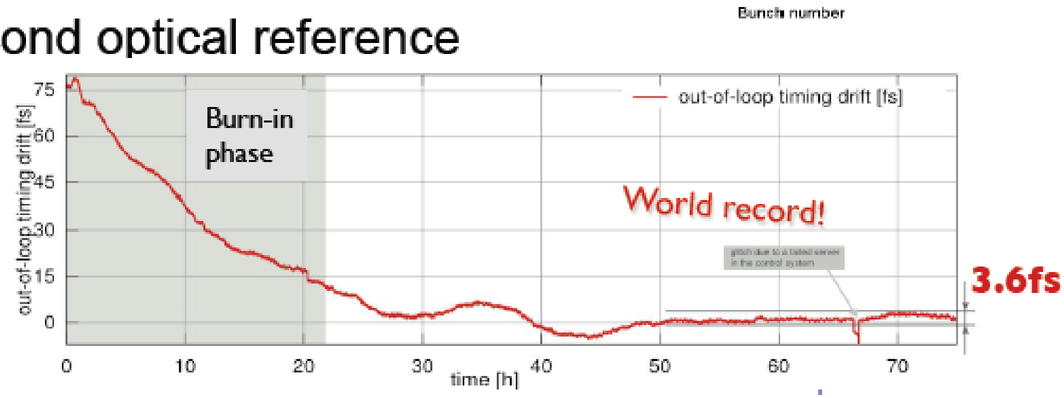
Optimized bunch shaping at RF gun (PITZ/DESY) *(M. Kojoyan, this conf. THPRO043)*

ST3 Femtosecond technologies

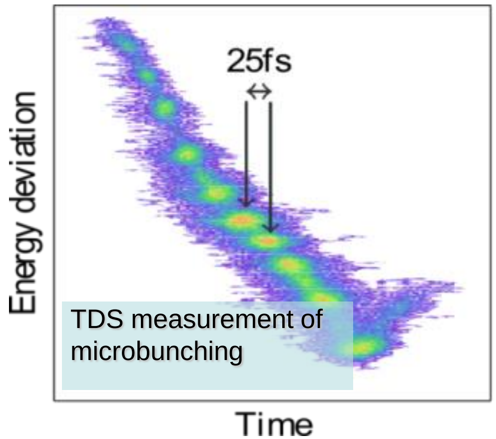
- RF stabilization to femtosecond optical reference



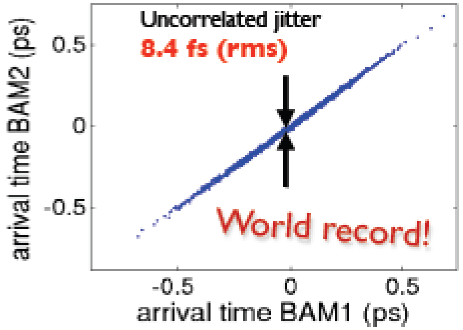
(T. Lamb, IBIC2013)



fs resolution bunch profile (pioneered at SLAC)

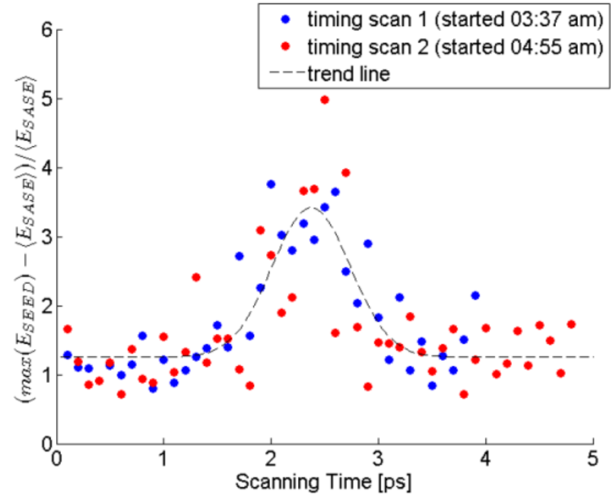


new beam arrival monitor (coop. TU-Darmstadt)



(F. Löhl et al., PRL 104, 2010)

HHG seeding at 38nm (DESY, U-Hamburg ***Phys Rev Lett 111, 2013***)

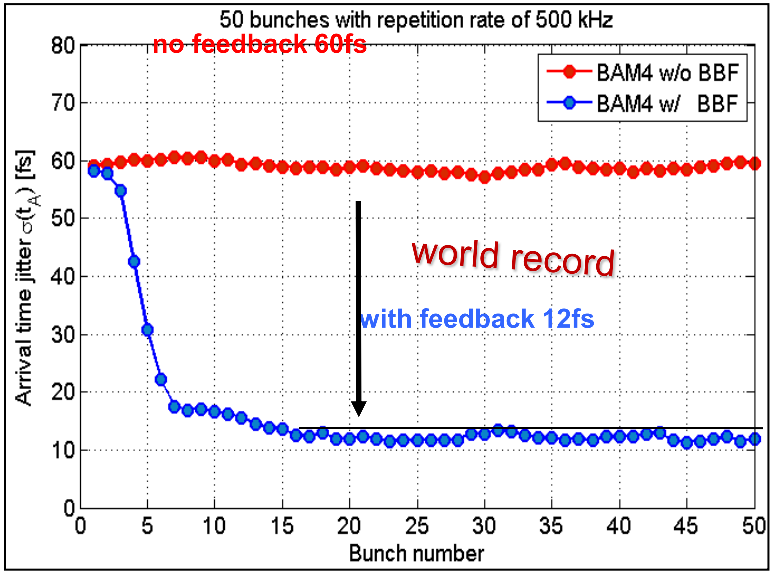


ST3 Beam stabilization

- Intra bunch train feedback in s.c. FLASH linac using B.A.M. → **12fs rms**

- High precision LLRF control with new mTCA electronics standard

(M. Hoffmann et al. WEPME067)



- mTCA becomes widely used at different laboratories and projects (ESS, ITER, SLAC, HEP experiments,…)

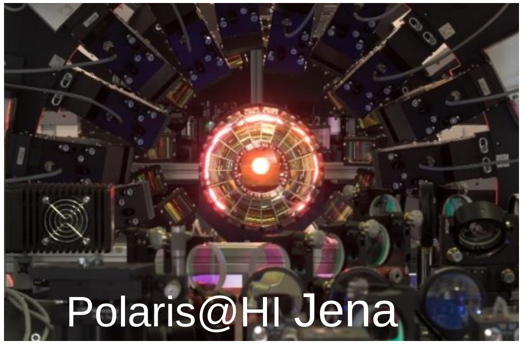
- Successful technology transfer project supported by Helmholtz

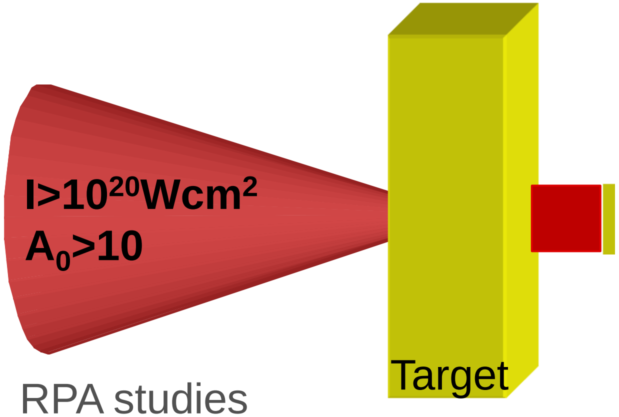
(T. Walter et al. WEPME081)

ST4: Novel acceleration concepts

- Focus on usable electron and ion beams from beam- and laser-driven plasma-wakefields - **“From acceleration to accelerators”** *(R. Assmann TUOBB01)*

Laser-PWA of ions





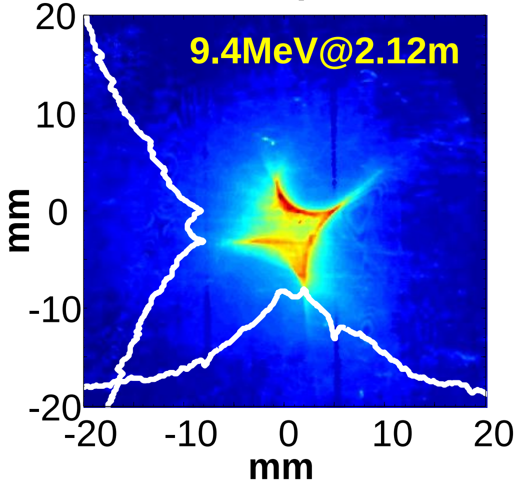
RPA studies *(P. Schmidt et al. TUPME031)*

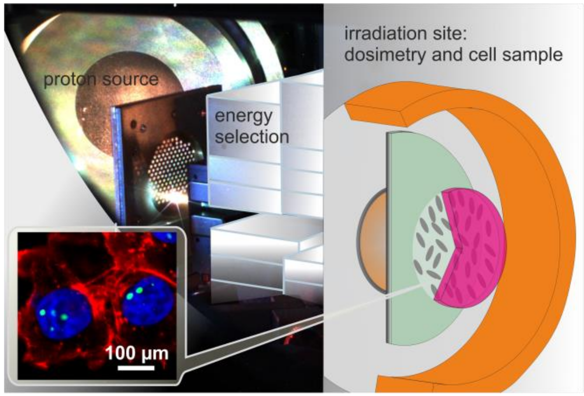
LIGHT – Laser Ion Generation, Handling and Transport

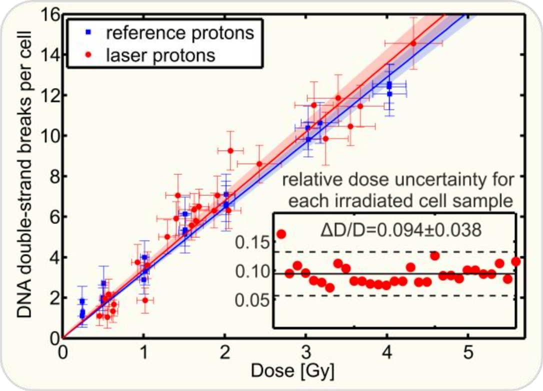
Generation & transport of ion beam from LPWA

(M. Roth et al. WEXB01)

ion beam profile



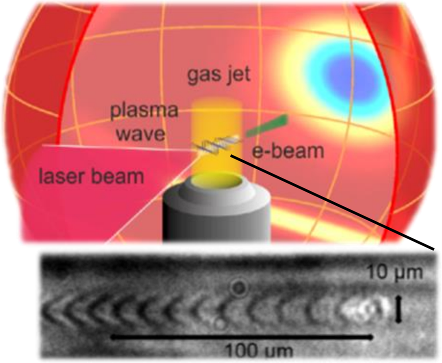


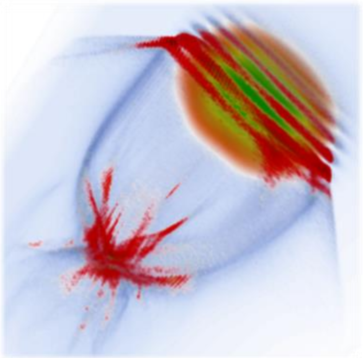


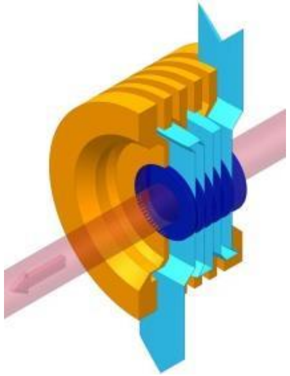
towards medical applications (*L. Obst et al. TUPME033)*

ST 4 Laser-driven PWA of electrons

- Plasma cell technology
- Advanced simulation capability
- Next generation laser development
- Beam extraction from plasma & transport without spoiling emittance
- **→ towards demonstration of usable, compact x-ray sources**





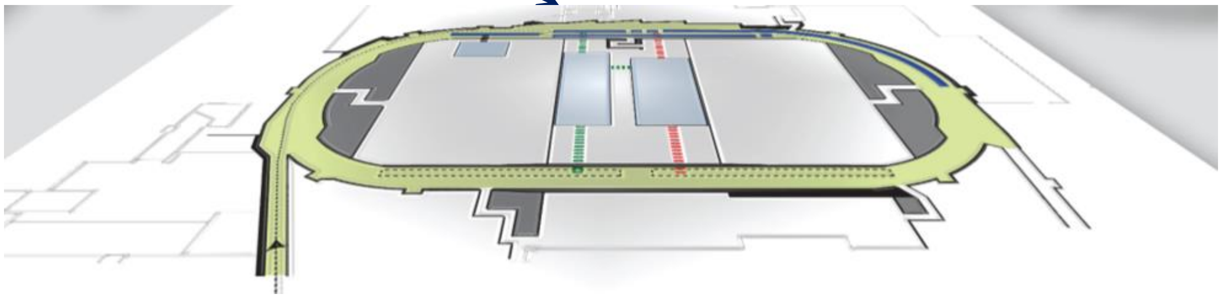


***(T. Seggebrock et al., PRST-AB 16, 2013
M. Bussmann et al., WEPRO053,
V. Afonso Rodriguez et al. WEPRO036)***

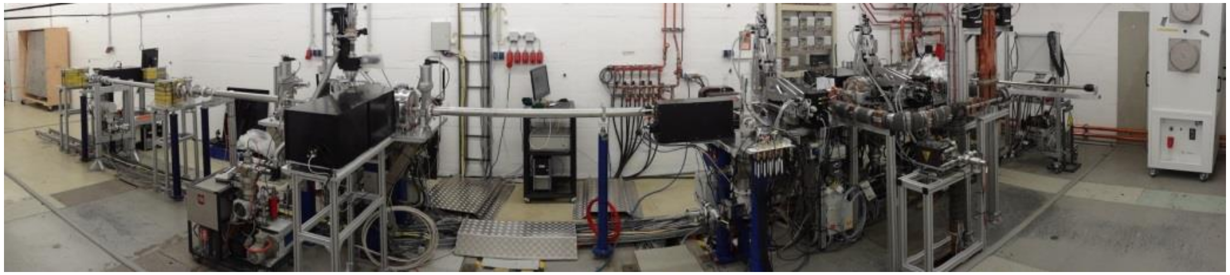
ST 4 Laser-driven PWA of electrons

- Merging of PWA expertise with conventional high-level capabilities, technology & infrastructure
  - Femtosecond technologies ← ST3
  - External injection of fs-bunches into plasma wakefield from e-beam source (REGAE, ELBE, FLASH, *SINBAD*)

(R. Assmann et al TUPME047)



(J. Grebenyuk et al., AAC Austin 2012)



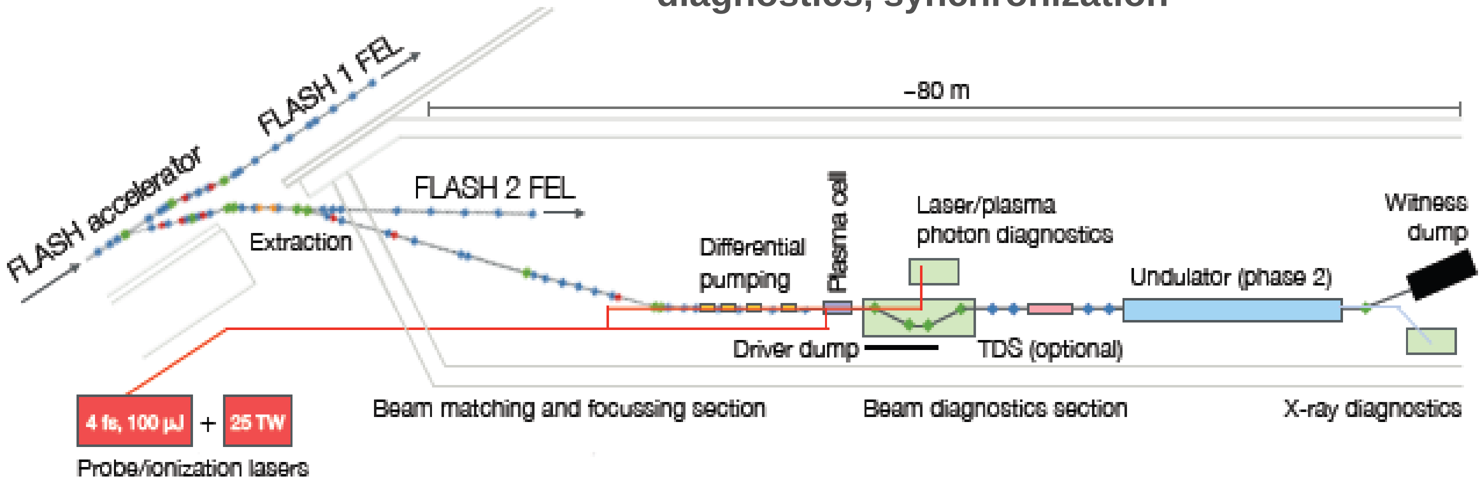
ST 4 Beam-driven PWA of electrons

- Pioneered at SLAC (I. Blumenfeld et al. Nature 544, 2007)
- Experiments at FACET with new concepts (2nd gas with higher ionization level) for controlled internal probe-bunch injection (Trojan horse laser pulse ***G. Wittig et al. TUPME072***, field-induced ***A. Martinez de la Ossa et al. Phys. Rev. Lett. 111, 2013***)
- Beam driven plasma acceleration in FLASH (FLASH*forward* experiment)

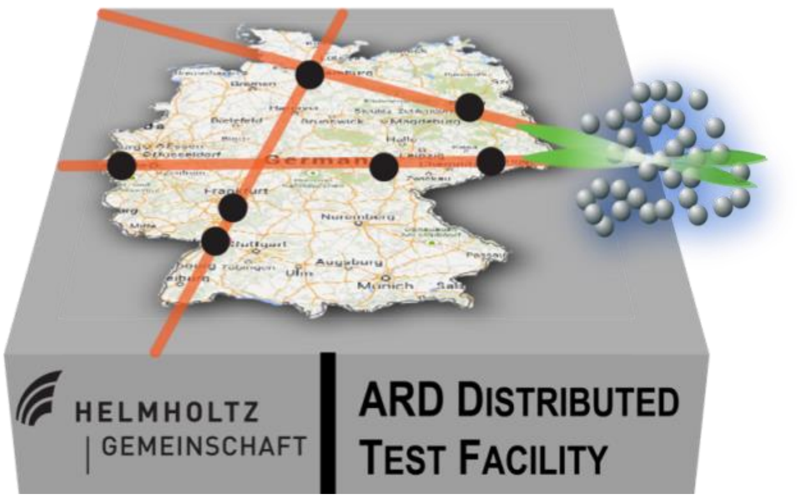
(V. Libov et al TUPME066)

fs timing stability with sc linac, beam diagnostics, synchronization

Helmholtz Virtual Institute with SLAC, LBNL, JAI, U-Hamburg, MPP-Munich



Upgrade of research infrastructure: Distributed ARD test facility ST1 - ST3 - ST4



Proposal for strategic investment funds will be submitted in 2015

Preparation team:

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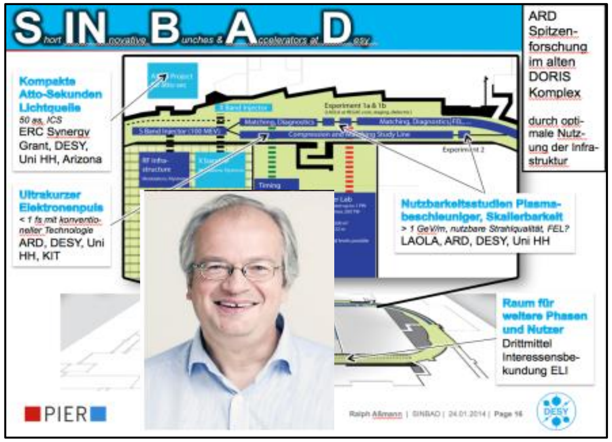
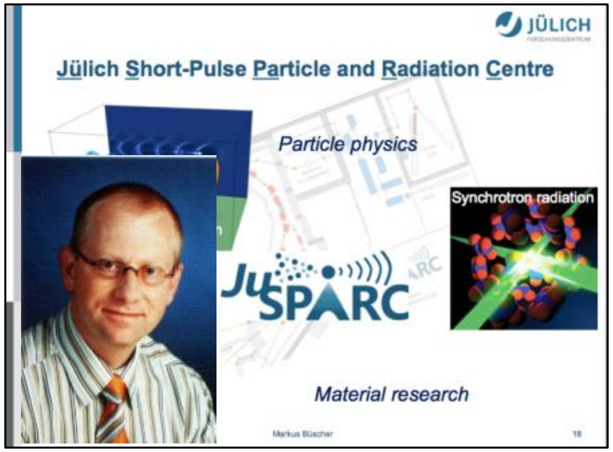
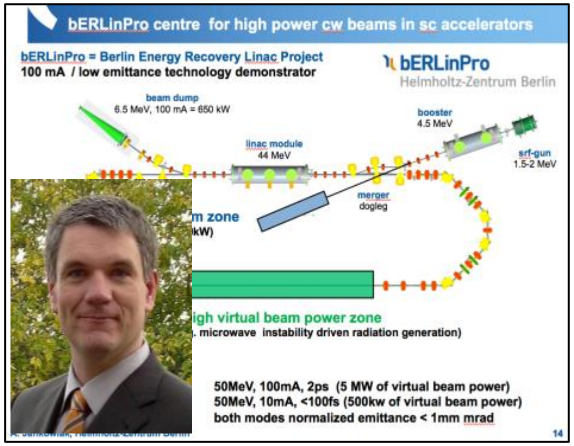
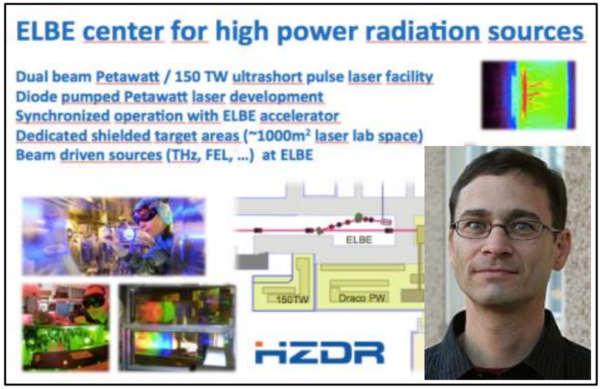
- Collaboration
  - Networking of research infrastructures and platform for national and international cooperation
- Synergy
  - Extension of facilities for joint usage by participating centers
- Leadership
  - International leading flagship projects towards ultra-compact accelerators and radiation sources

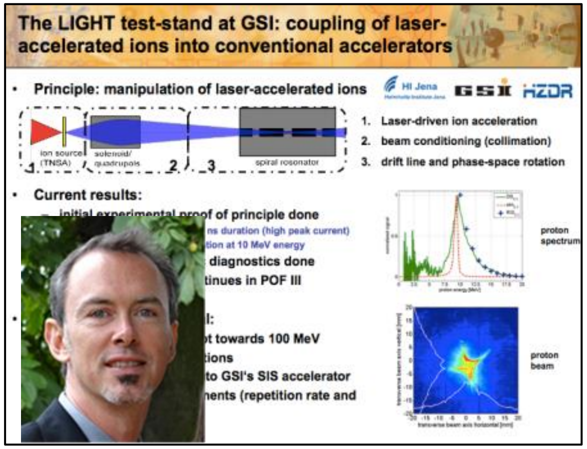
Teaming up for the DTF proposal

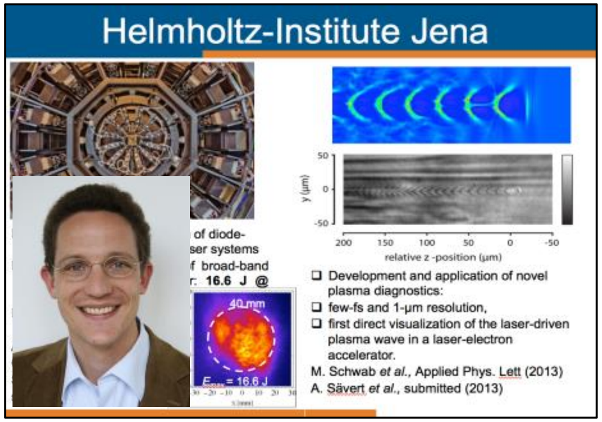












Conclusion

- The implementation phase of ARD as an own research topic in the Helmholtz portfolio since 2011 has already proven extremely valuable and a healthy development for our field

  - Realization of synergies and new joint activities
  - Attracting students and young scientists to our field
  - Strengthening and launching new international co-operations

- We are looking forward to a rich and exciting accelerator research programme for the next five years and beyond

Acknowledgment

Many thanks to the team members in the Helmholtz ARD initiative!

ARD team at the rehearsal for the Helmholtz programme evaluation, HZDR Feb. 2014

Thank you very much for your attention!