View on future accelerators/concepts (>2050)

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F3IA Workshop
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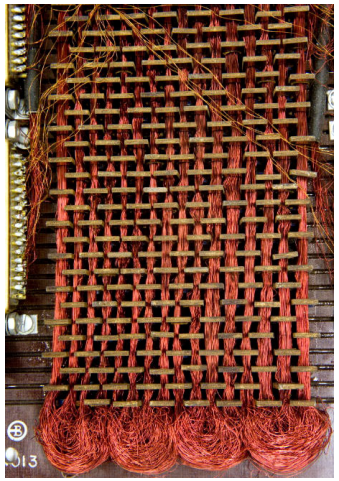
HELMHOLTZ ASSOCIATION

DESY

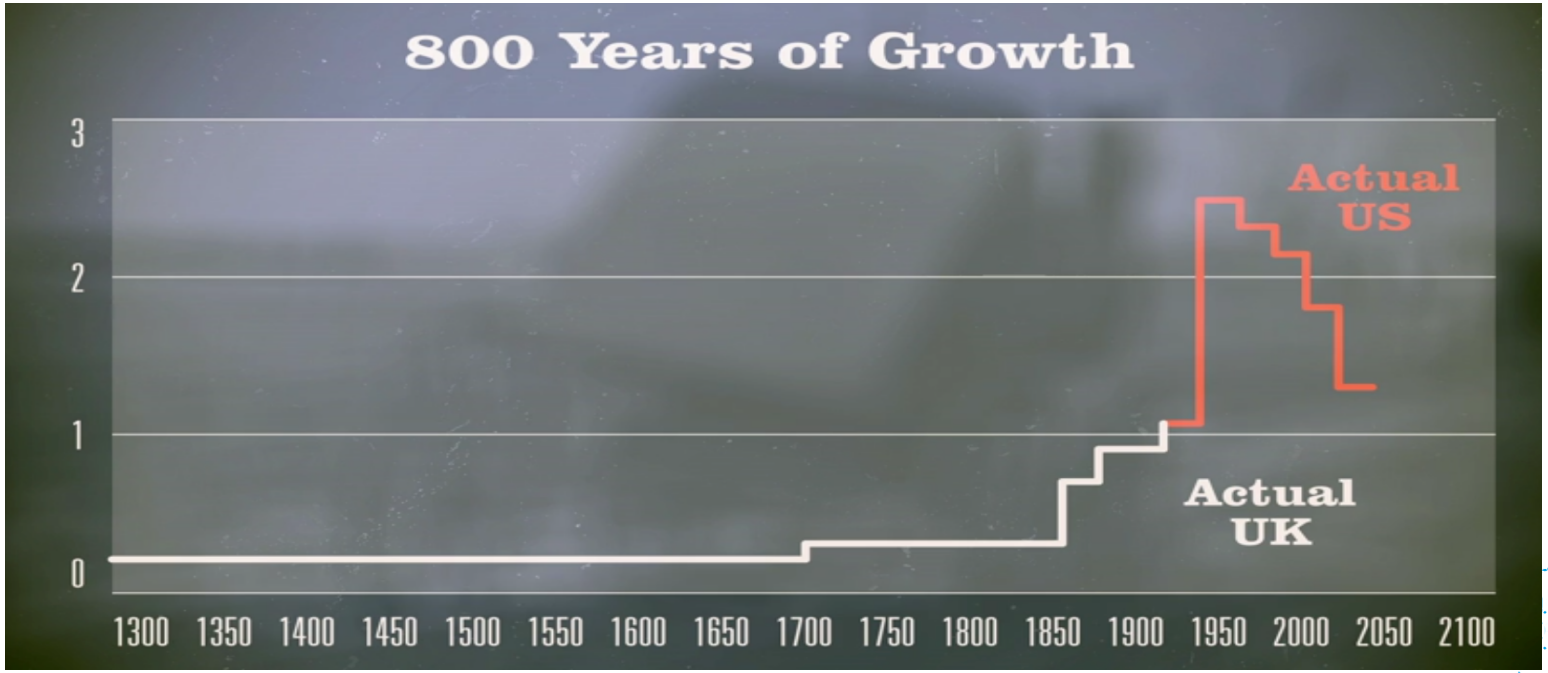
The world outside accelerators

http://www.computerhistory.org

- 1969: Apollo guidance read only rope memory
- 1970: IBM: first full-semiconductor computer



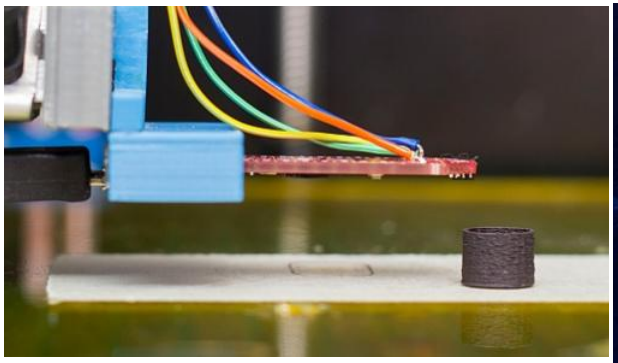
Economic growth over the last 800 years… The invention of the computer did not really help … yet



Robert Gordon, 2013

No matter which type of accelerator we will build, I think the way we build/operate it, will change drastically

- 3D printing
  - E.g. Vacuum tanks, diagnostics
  - Free-shaped magnets
  - Girder & support



TU Vienna

http://www.airbusgroup.com

- Robotics
  - Complete installation incl. technical infrastructure
  - Remote maintenance
  - Building/Tunnel cost significantly reduced
- Electronics & machine learning
  - Faster & more reliable: Increase beam power with reduced safety margins
    - Including reduced shielding
  - Machine operation completely automatized
    - Beam commissioning/turn around times reduced to minimum
- Other simpler steps like sandwich construction

→ Does this allow to make big machines affordable?
→ Does this allow to build more small accelerators?

Towards higher frequencies → Lasers!

High Gradients (1-100 GV/m) → High Frequencies (> 100 GHz) → Small Dimensions (< 1 mm)

- No klystrons for high frequencies! → Use particle bunches or laser pulses as drivers.
- Material limitations → dielectric materials, plasma cavities, …

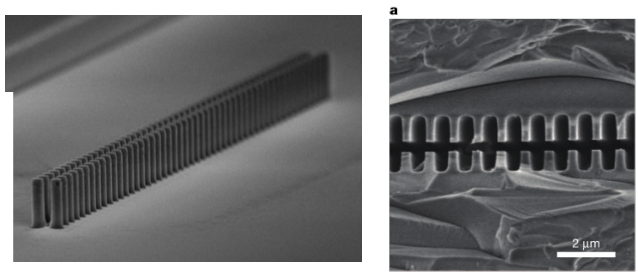
Two main directions:

1 **Microstructure Accelerator**
Laser- or beam driven
Vacuum accelerators
'Conventional' field design

2 **Plasma Accelerator**
Laser- or beam driven
Dynamic Plasma Structure
Plasma field calculations

Acceleration of Relativistic Electrons in Microstructured Dielectrics → *ACHIP collaboration*

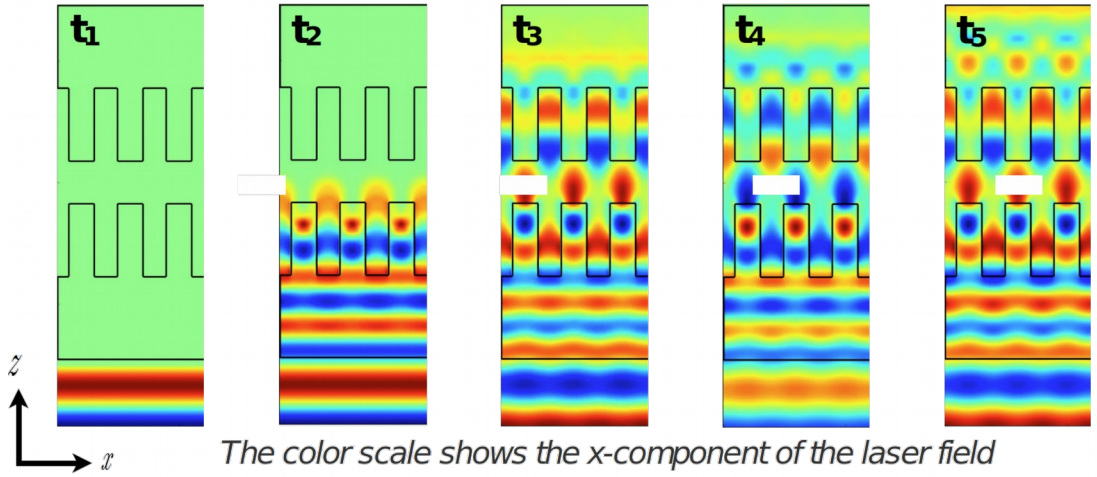
- **General Idea**: Irradiation of a dielectric structure with laser light with the goal to excite electromagnetic fields inside the structure, which are *usable for particle acceleration.*
  - The dielectric needs to be microstructured according to the laser wavelength.



Structure images by Peralta, E. A. et al. *Demonstration of electron acceleration in a laser-driven dielectric microstructure*. Nature 503, 91–94 (2013) and the ACHIP Collaboration

- **How it works**
  - Lin. polarized (along channel) laser field perp. to channel, electrons travel along channel
  - Dielectric structure acts as a phase reset mask
  - Resulting field pattern allows for net acceleration in the near-field
  - If the grating period is matched to the laser wavelength, relativistic electrons are phase-sync
  - Very high damage threshold allows for accelerating gradients of **100's of MV/m**

- **Status: very initial stage..**
  - keV energy gain of single electrons demonstrated.



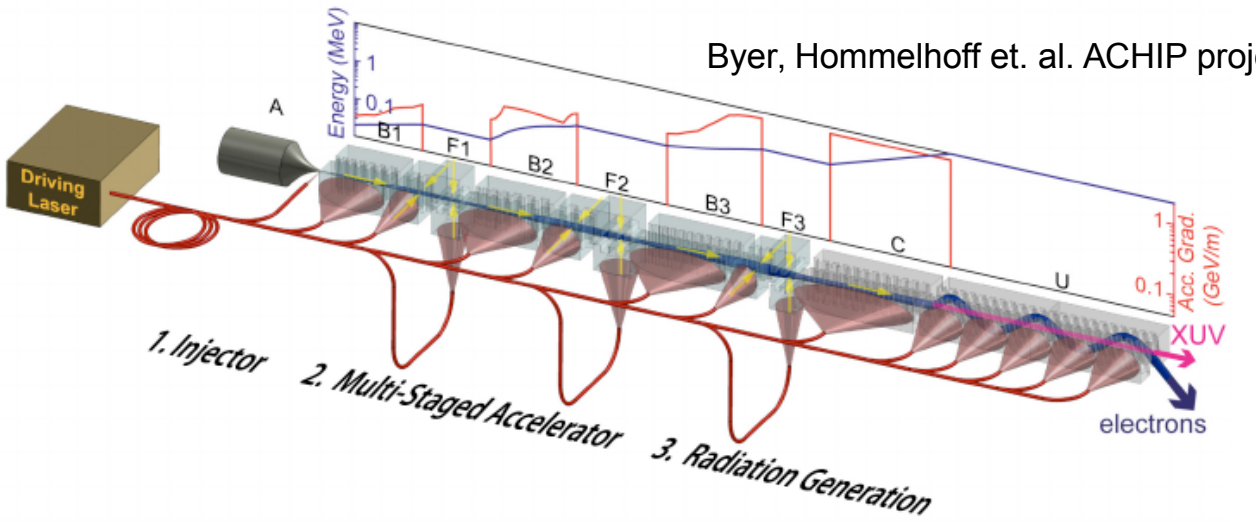
The color scale shows the x-component of the laser field

- **Typical Structure Parameters**
  - Material: **Fused Silica, Silicon**
  - Grating/pillar period **um range** (laser wavelength)
  - Channel width of **400-800nm**
  - Structure length: **500um**

PS: Some collaborators try to use machine learning to optimize the structure shapes

Dielectrics ultimate goal

- Technology in the best case complimentary to big machines
  - But possibly opening new applications
- Current main challenges: Gun & focusing
  - some basic diagnostics available)
- Structures (will have to) evolve towards photonic crystals
- Community quite small, so give us time...



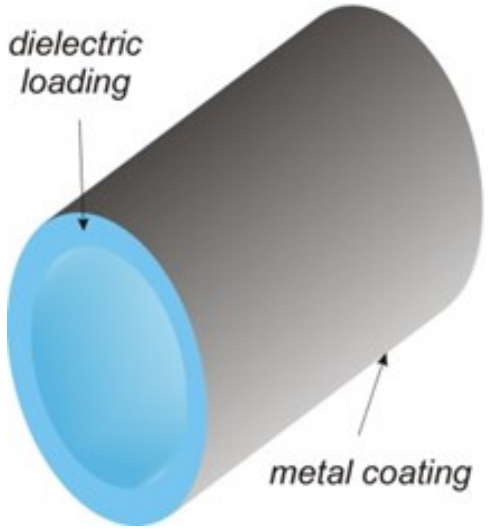
Byer, Hommelhoff et. al. ACHIP project proposal

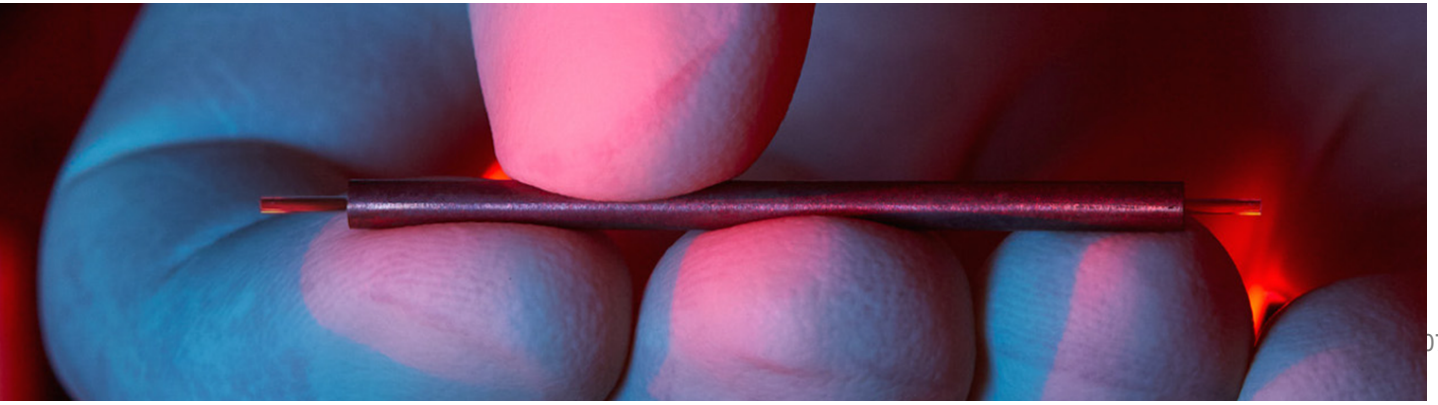
Add decelleration stage!

I want this in my mobile phone...

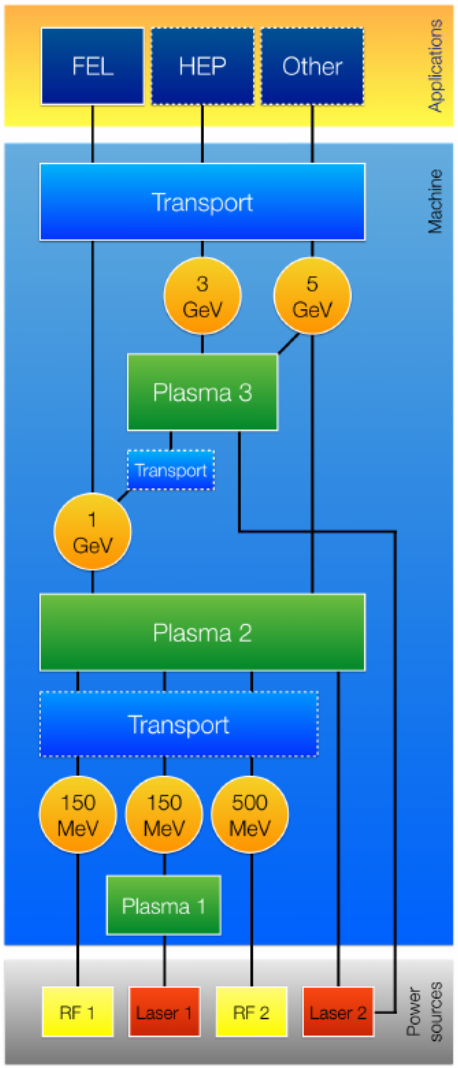
Dielectric loaded waveguides – THz laser acceleration

- TM01 mode in waveguide
- Difference: Slow down phase-velocity by loading it with dielectric material
- ≈ 200MeV/m, f = 300GHz
- Status: very initial stage, keV gain shown
- Matching gun design very hard
    - High frequency of linac demands very short bunches
- Combined with ICS?





Some thoughts on laser acceleration



P.A. Walker et. al. EuPRAXIA study basline parameters

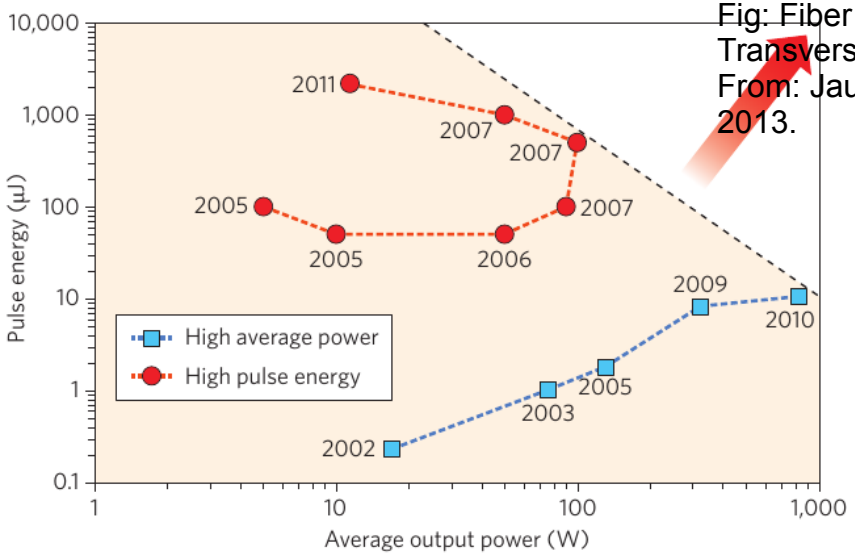


Fig: Fiber laser power evolution → Transverse mode instability
From: Jauregui et. al. Nature photonics 2013.

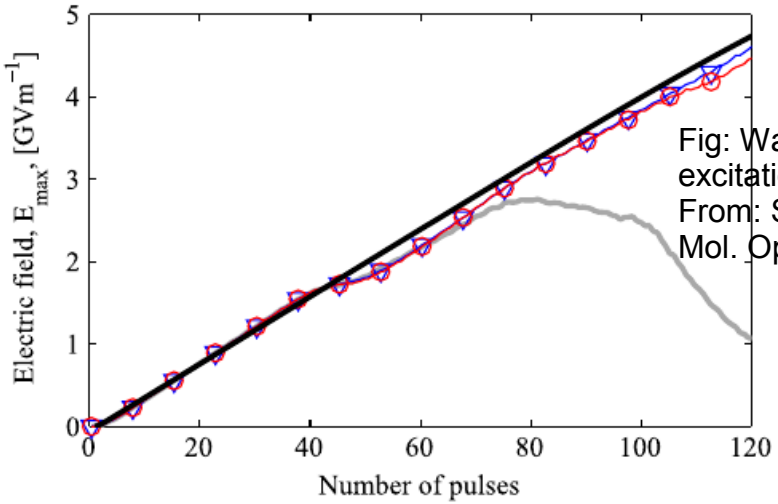
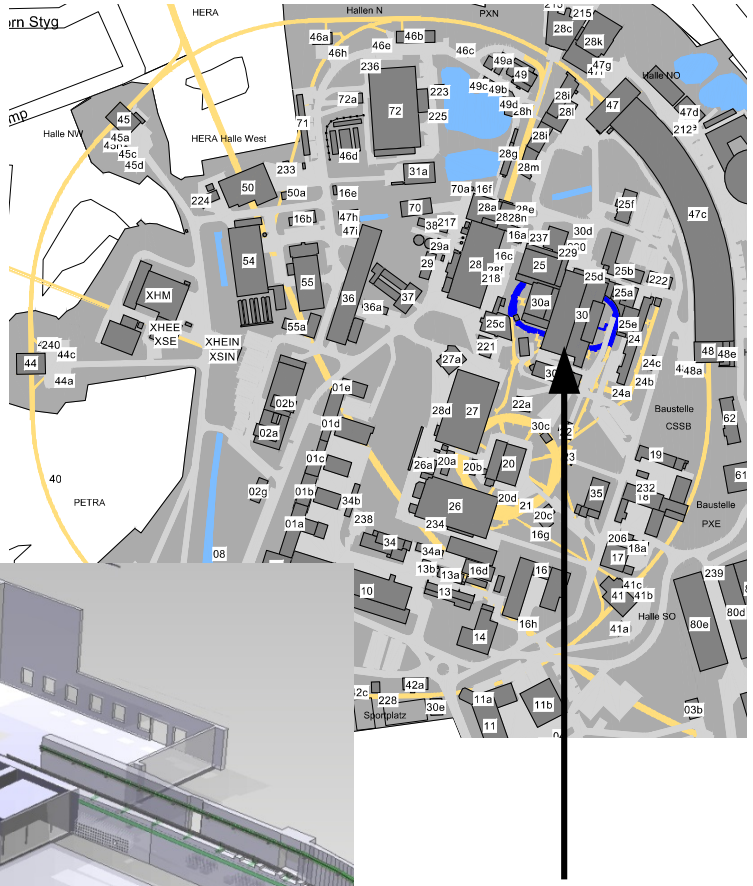


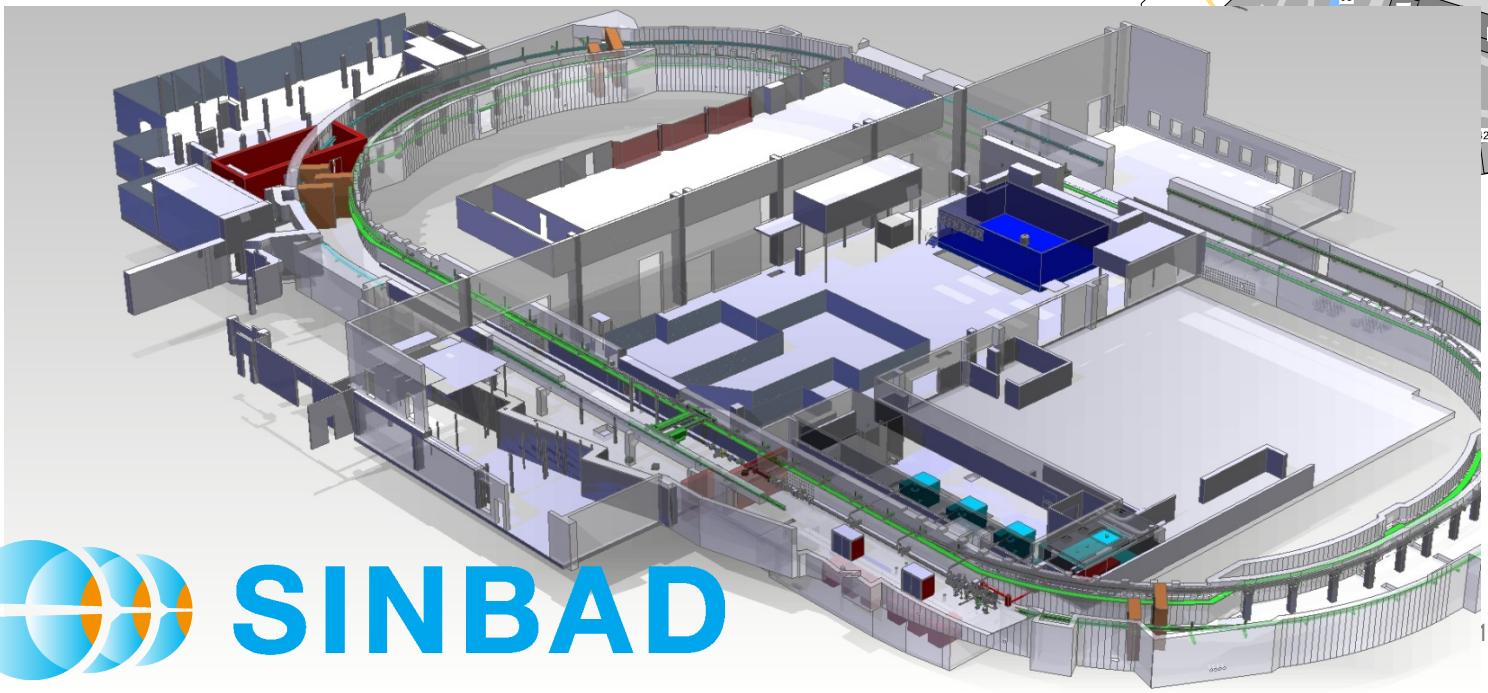
Fig: Wakefield amplitude for multipulse excitation
From: S. Hooker et. al. J. Phys. B: At. Mol. Opt. Phys. 47 (2014)

Other initial uses e.g. decellerator…?

SINBAD - a dedicated ARD facility for DESY

- In the old DORIS facilities
- Next to the central DESY control room
- Beam line to DESY II synchrotron (currently deactivated, but still installed)
- 290 m long, 5-9 m wide RP-shielded tunnel in racetrack shape
- 2 long straight sections of >70m length
- Central hall (650m2) + additional side rooms & cellar
- Multiple laser labs directly adjacent





SINBAD

2 INITIAL EXPERIMENTS

SINBAD will initially host 2 experiments:

ARES

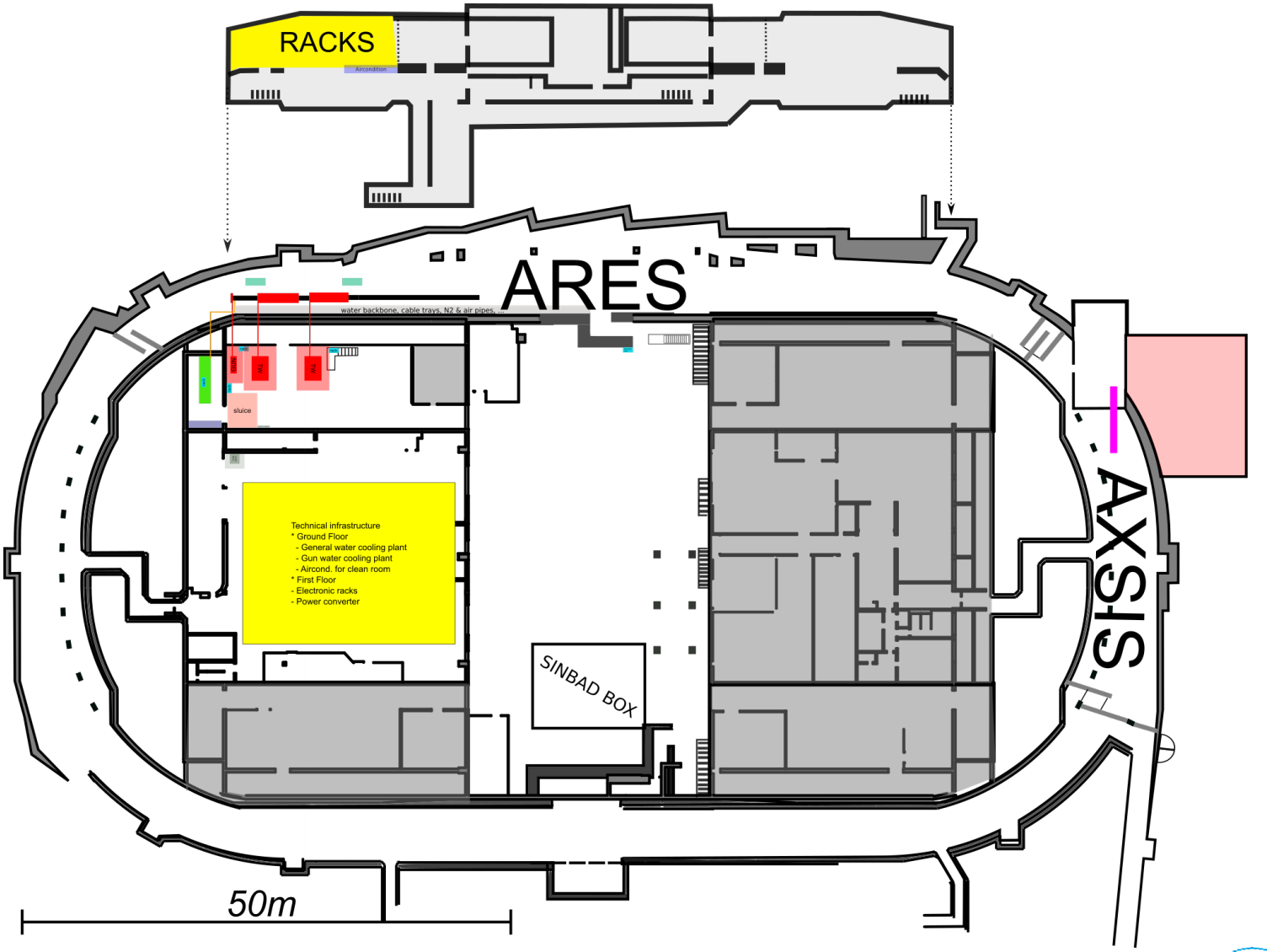
- "**A**ccelerator **R**eseach **E**xperiment at **S**inbad"
- 1st step: Build A 100MeV electron linac for ultra-short bunches
  - Target: operational 2019 → **ARIES TNA access!**
- 2nd step: Optimize performance and compare various compression techniques
- 3rd step: Use beam to inject into advanced acceleration concepts
  - DLA → ACHIP
  - THz driven dielectric loaded waveguides
  - ATHENAe: External injection into plasma

AXSIS

- "**A**ttosecond **X**-ray **S**cience: **I**maging and **S**pectroscopy"
- THz acceleration in dielectric loaded waveguides
- ICS for X-ray generation

SINBAD layout is chosen to allow future upgrades (e.g. ATHENAe) and has significant free space left in the tunnel!

Stage 0


RACKS
ARES
water backbone, cable trays, N2 & air pipes, ...
sluice
Technical infrastructure
* Ground Floor
- General water cooling plant
- Gun water cooling plant
- Aircond. for clean room
* First Floor
- Electronic racks
- Power converter
SINBAD BOX
AXSIS
50m

What are current test-facilities lacking/helping/limitations ? How will future facilities differ?, other,,,

- Diagnostics, especially TDS
  - X-band → THz-TDS, plasma TDS
  - I want it “like a BPM” (many affordable along the machine)
- Most money & time is required on technical issues
- High gradient focusing structures
- Interdisciplinary becoming even more important
- How far will we be able to go before we hit the “surrounding” fundamental limitations e.g. regulation speed by cable lengths?

Accelerators have already been to space...

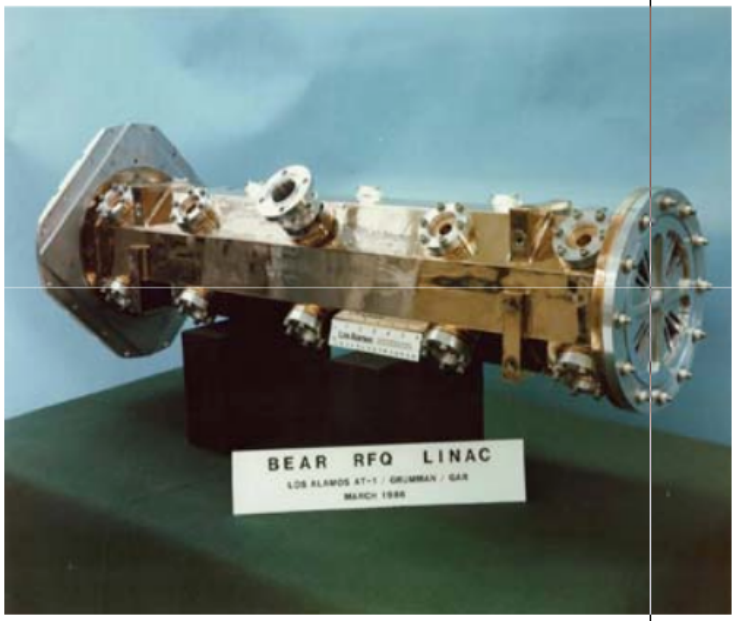
- M. Vretenar. CAS Bilbao. 2011

CAS

Examples of RFQs - 2

CERN

"BEAR" RFQ (beam experiment aboard a rocket)(partly classified) 1989
30 KeV – 1 MeV, 20 mA, <1% duty H-minus
425 MHz, solid-state RF system
Cu plated Al quadrants, joined by electroforming, 55 kg
Operated in sub-orbital flight with a "neutral" beam, LANL



Summary

- “Advance of technology is overestimated on the short run, but underestimated on the long term.“ - Roy Amara
- Ceterum censeo ADSR esse constructam