View on future accelerators/concepts

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DESY

F3iA

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HELMHOLTZ | ASSOCIATION

European Network EuroNNAc for Novel Accelerators

EuCARD²

DESY

Remarks

The Crystal Ball workshop...

Can we predict the future?

Almost everything was already said... Just my view on top!

The situation 1893 in New York

Photo IV.4. Horse manure piled up on a New York City Street, 1893. Source: George E. Waring, Jr., *Street-Cleaning and the Disposal of a City's Wastes* (New York, 1898).

1898 – Call for an International Conference

"In 1898, delegates from across the globe gathered in New York City for **the world's first international urban planning conference**.

One topic dominated the discussion.

It was not housing, land use, economic development, or infrastructure.

The delegates were driven to desperation by horse manure."

Eric Morris, in the Spring 2007 edition of Access, the official magazine of the University of California Transportation Center.

The outlook in 1898

“The **situation seemed dire**.

In 1894, the Times of London estimated that by 1950 every street in the city would be buried nine feet deep in horse manure.

One New York prognosticator of the 1890s concluded that by 1930 the horse droppings would rise to Manhattan’s third-story windows.

A **public health and sanitation crisis of almost unimaginable dimensions loomed**.”

Eric Morris, in the Spring 2007 edition of Access, the official magazine of the University of California Transportation Center.

The solution in 1898

"All **efforts to mitigate the problem were proving woefully inadequate**.

Stumped by the crisis, the urban planning **conference declared its work fruitless and broke up in three days instead of the scheduled ten**."

Eric Morris, in the Spring 2007 edition of Access, the official magazine of the University of California Transportation Center.

The situation 2016 in New York

The situation 2016 in New York

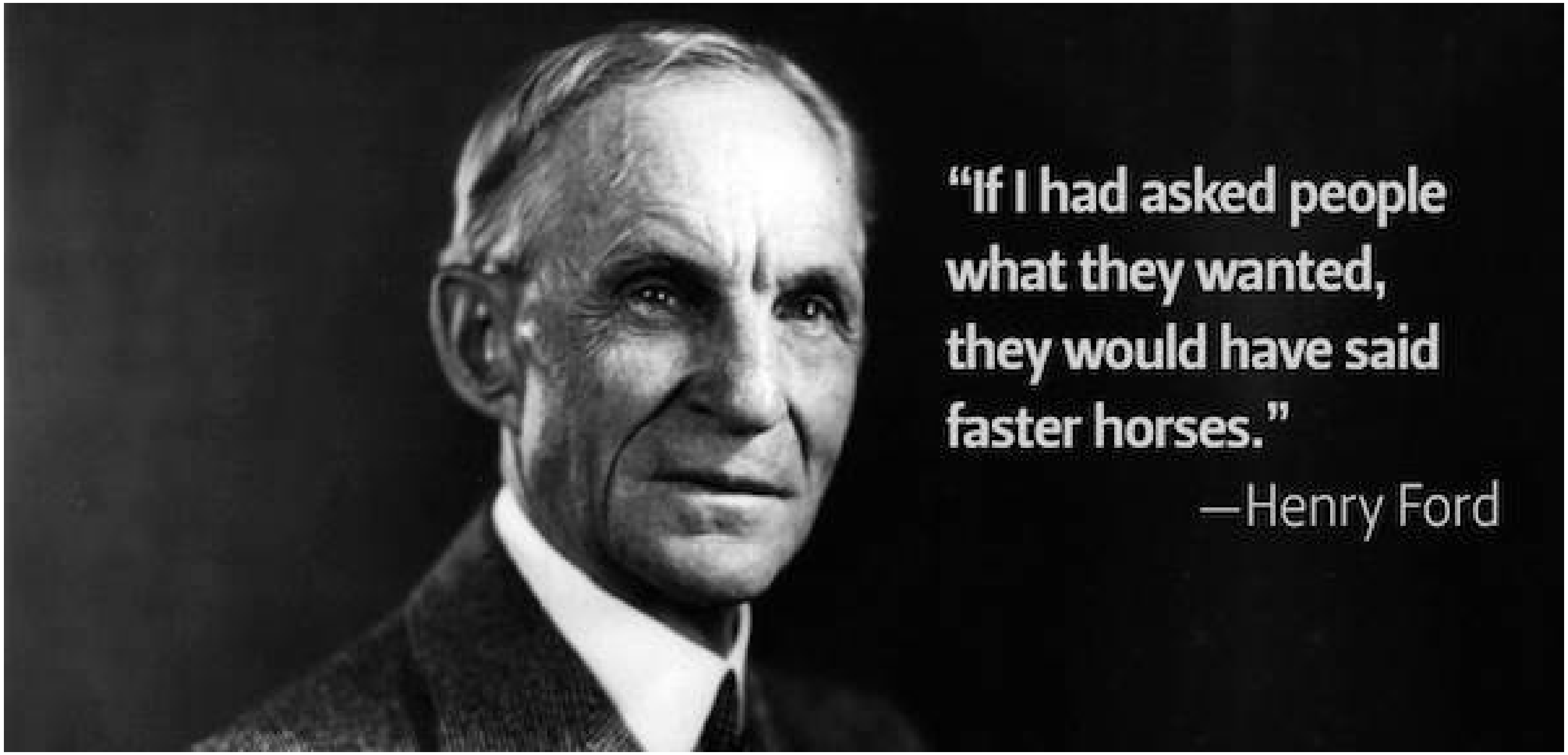
No horse manure !?

What has happened ?

The situation in 2016

The situation in 2016

Developing New Technologies



This is the F3iA Workshop: Knowing our customers we look at possible future directions for our field.

(but at the moment we do ask our customers what they want)

Our customers in 21st century: my impressions I

> **Physical Research:**

- Higher beam energy and higher luminosity.
- Biggest machines that mankind built: masterpieces of science.

Physics case?
Where is new physics?
Risk of great desert up to Planck scale?

> **Structural biology, chemistry, ...:**

- Understanding detailed functioning of nature: photo-synthesis, viruses, bacteria, resistance, ...
- Biological engineering
- Engineering of chemical processes

Societal impact.
Centuries of work...

> **Materials:**

- Understanding materials.
- Designing new materials (will change our world)...
- Testing new materials.
- Energy storage options.

Energy application seems is (also) in here

Our customers in 21st century: my impressions II

> **Health:**

- Medical imaging in real time and high resolution, e.g. tracking moving organs during remote operations...
- Radiation therapy.
- Production of isotopes.

Needs of ageing societies.
Developing and emerging nations.

> **Inspection (industrial devices):**

- Non-destructive Infrastructure testing
- X ray of containers

Needs in industrial nations with ageing infrastructure

> **Fusion driver, ADS, ...:**

- Lot's of well-established competition of small devices
- Carbon-based fuels still in strong supply
- Advent of renewable energies

Not progressing very fast
Trend to small distributed devices

New Technologies → New Possibilities I

> **Digital feedbacks:**

Storage rings and colliders can operate in a regime where beams were unstable before

> **Production tolerances:**

Can build new devices that were formerly impossible. E.g. X band TDS with variable polarization → 3D tomography of FEL bunches, measurement as bunches, ...

Computer design of custom devices, 3D printing → new life for accelerators with new (decaying) particle beams (Muons)

> **Ultra-fast electronics:**

Femto-second timing and synchronization → ultra-fast science but also injection into small buckets of novel accelerators

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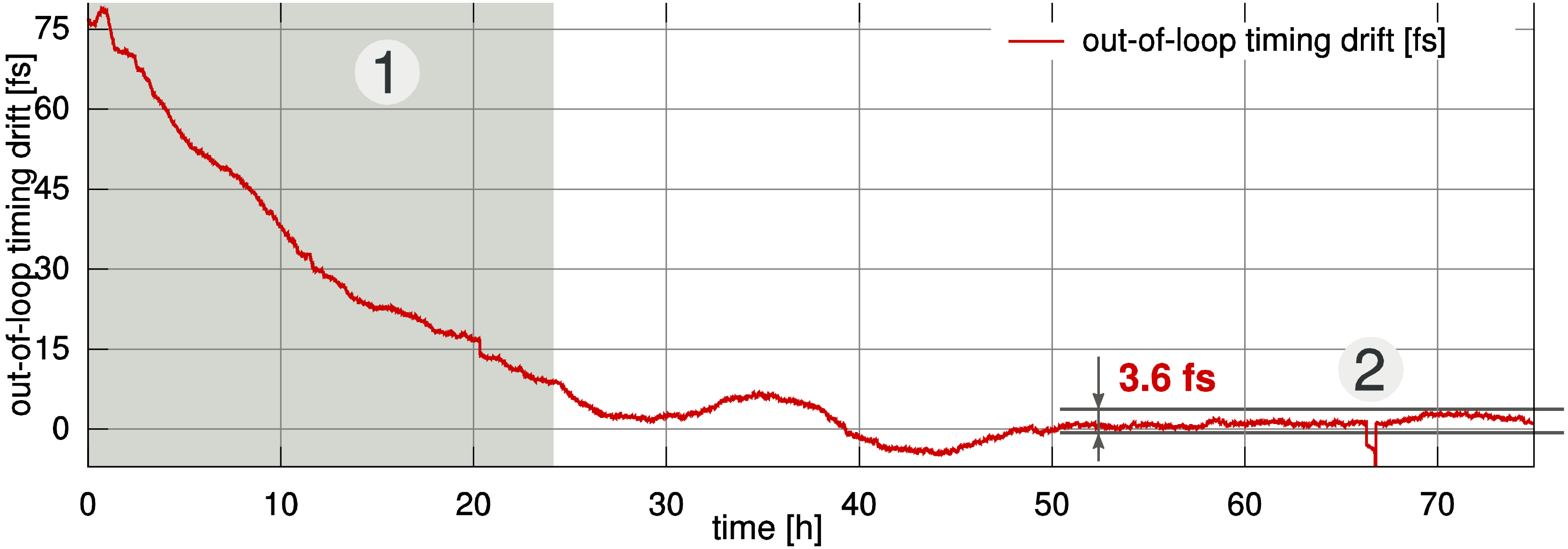
Accelerator Builder's Challenge – Feasible?

> Difficult but we believe solutions can be found. Will not come for free…



Femtosecond Precision in Laser-to-RF Phase Detection

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

> Again: **No fundamental limit here, but strong technical challenges!**

New Technologies → New Possibilities II

> **Maintenance-free "sealed" accelerators with high availability:**

Opens new possibilities for industrial applications: lithography, ADS, ...

Allows going to accelerators without human access

Use in space, constrained tunnels, hospitals, ...

> **Distributed infrastructure:**

Avoid long cables (WiFi), many service stations, ...

> **Tunnel boring:**

Small diameter tunnels with low cost per meter

Repair by robotic devices, remotely operated

> **High power lasers, plasma accelerators, accelerators on a chip, ...:**

Wide spread use. New 3 dimensional concepts → 3D matrix

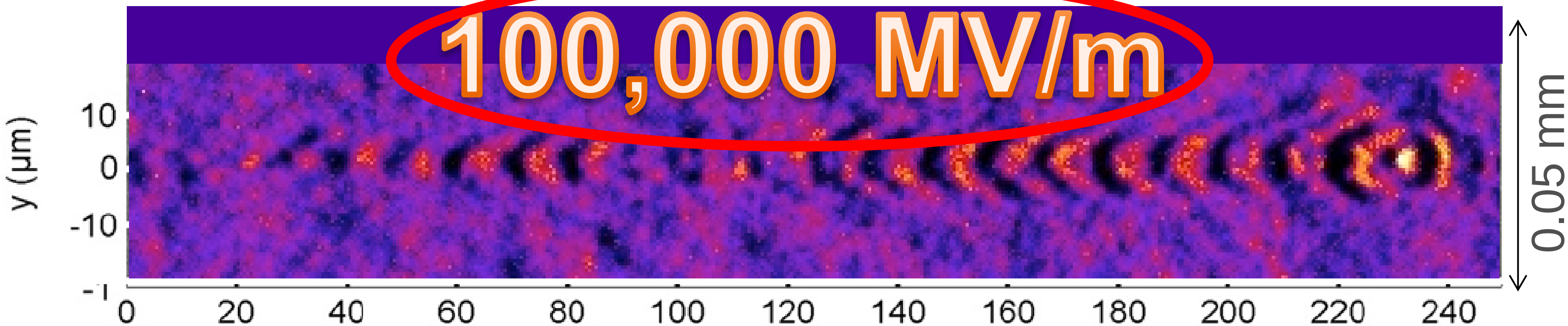
Photo Laser-Plasma Accelerator

APPLIED PHYSICS LETTERS 103, 191118 (2013)

Few-cycle optical probe-pulse for investigation of relativistic laser-plasma interactions

M. B. Schwab,[1,a)] A. Sävert,[1] O. Jäckel,[1,2] J. Polz,[1] M. Schnell,[1] T. Rinck,[1] L. Veisz,[3] M. Möller,[1] P. Hansinger,[1] G. G. Paulus,[1,2] and M. C. Kaluza[1,2]
[1]Institut für Optik und Quantenelektronik, Max-Wien-Platz 1, 07743 Jena, Germany
[2]Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena, Germany
[3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

2013



0.25 mm

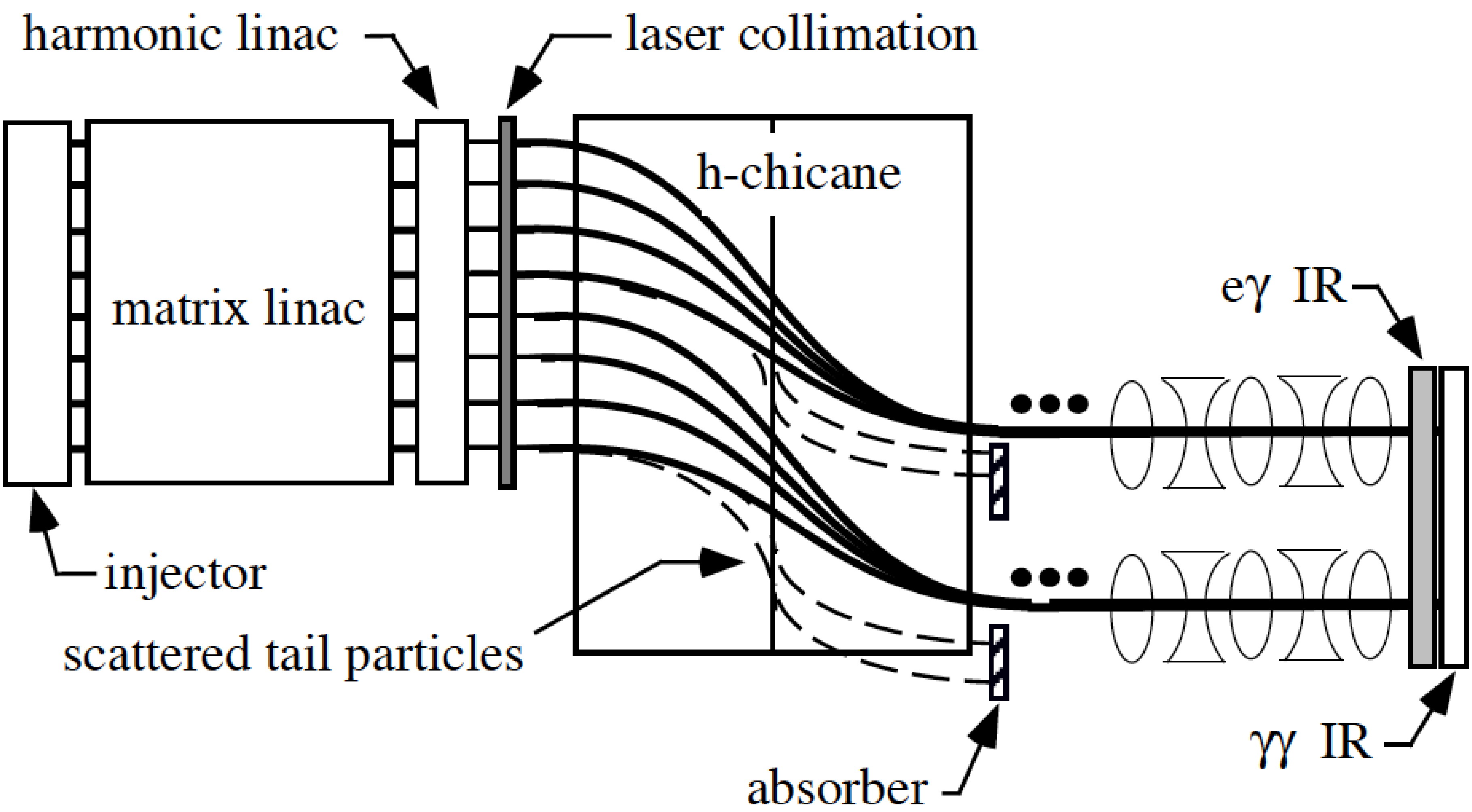
Metall (Kupfer) S band Linac Struktur

Mikro-Wellen zur Wellener-zeugung

100 mm

500 mm

Matrix Accelerators



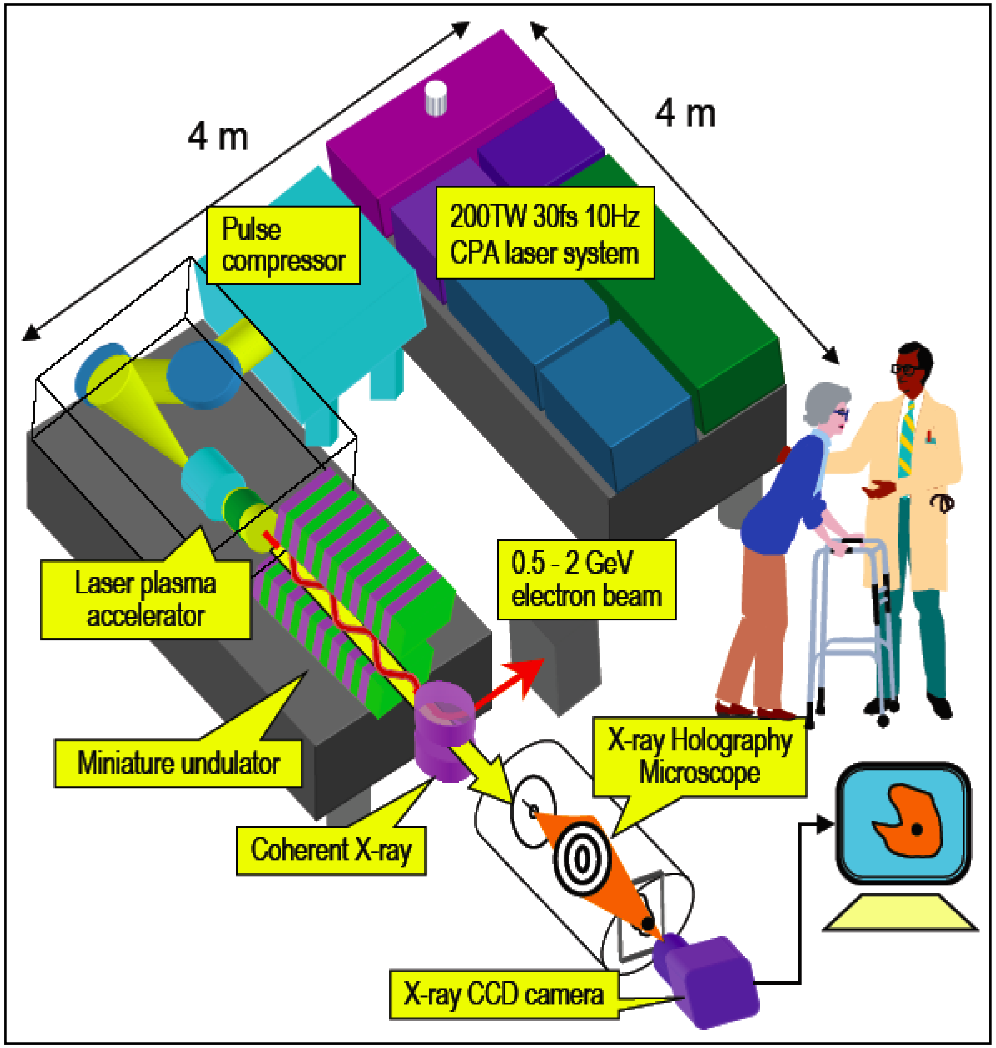
ADVANCED CONCEPTS FOR HIGH-GRADIENT ACCELERATION*

D. H. Whittum
SLAC, Stanford University, Stanford, California 94309 USA

Health Applications with Compact Accelerators

Will it really be laser-driven?

Excellent concepts also from “conventional” technology.



Visualization by T. Tajima, 2010

Beam Dynamics → New Possibilities III

> **Beams at ultimate beam density, limited by physics laws:**

Focus on beam shaping (precise beam loading)

Focus on time structure (micro-bunching)

Can we reach crystalline beams?

Opening the atto-second frontier with beams → damage free obs.

Nano-Beams
Atto-Beams

> **Spin polarization:**

Control spin of particles. Use for new precisions tests for particle physics.

> **Radiation generation:**

Control detailed generation of photons (γ → e- → γ)

Handling spectral density, coherence, flux, ... in unprecedented detail

Achieved Beam Sizes with New Optics Scheme in ATF2

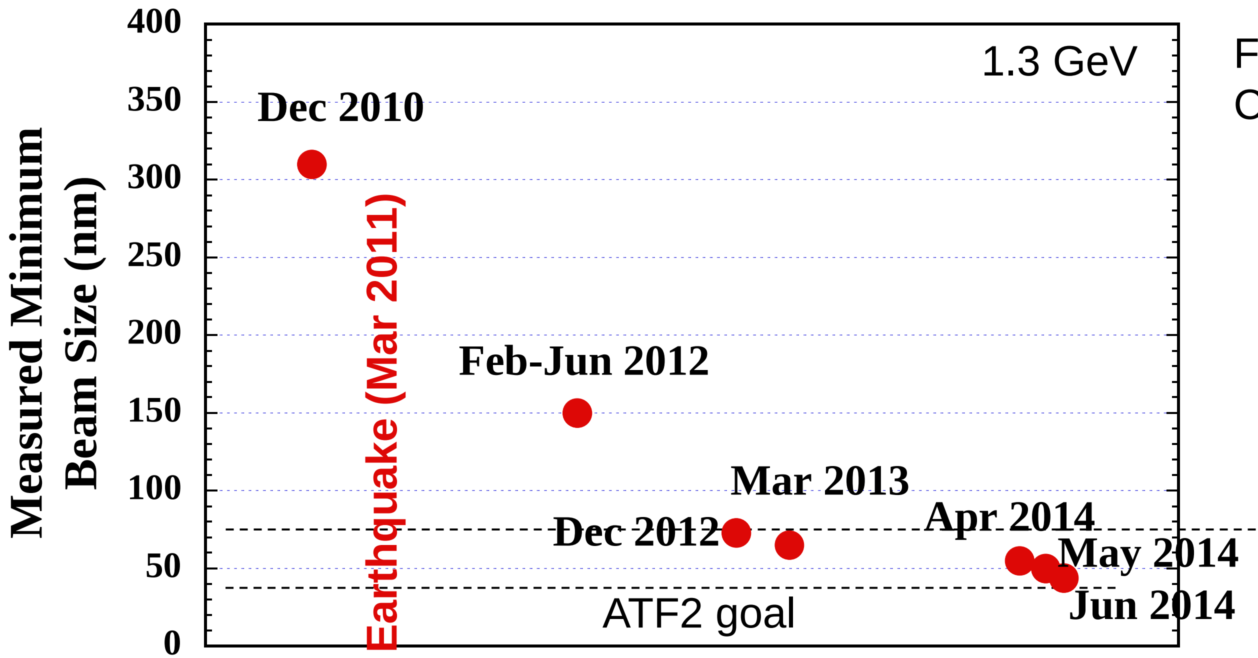


Figure by ATF2 coll.
Courtesy N. Walker

Previous HEP accelerator **world record** from 1994 with 46.6 GeV at SLAC

Note: Scanning Transmission Electron Micro-scopes achieve sub-nm spot size!

Note:

Adiabatic emittance damping → means that physical emittance shrinks with 1/Energy → Beam size shrinks with 1/SQRT(Energy) → 37 nm corresponds to 2.7 nm at 250 GeV.

Higher energy means less sensitivity to perturbations like wakefields with higher currents!

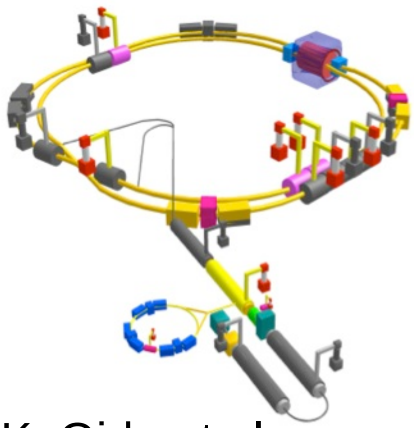
New record 40 nm beam size at ATF2 → towards ILC

SuperKEKB (in construction for beam commissioning in 2016)

Table 1: Main Machine Parameters of SuperKEKB.

	LER(e^+)	HER(e^-)	units
Beam energy	4	7.007	GeV
Circumference	3016.315		m
Crossing angle: full	83		mrad
Horizontal emittance	3.2	4.6	nm
Vertical emittance	8.64	11.5	pm
Coupling	0.27	0.28	%
β^*_x / β^*_y	32 / 0.27	25 / 0.30	mm
Vert. beam size at IP	48	62	nm
Energy spread	8.10	6.37	10^{-4}
Beam current	3.60	2.60	A
Number of bunches	2500		
Energy loss/turn	1.86	2.43	MeV
RF frequency	508.9		MHz
RF voltage	9.4	15.0	MV
Bunch length	6.0	5.0	mm
Vert. b-b param.	0.088	0.081	
Luminosity	8×10^{35}		$cm^{-2}s^{-1}$

Sub mm beta* in SuperKEKb upgrade



K. Oide et al

Will break into new territory for e+e- colliders!

nano-beam scheme

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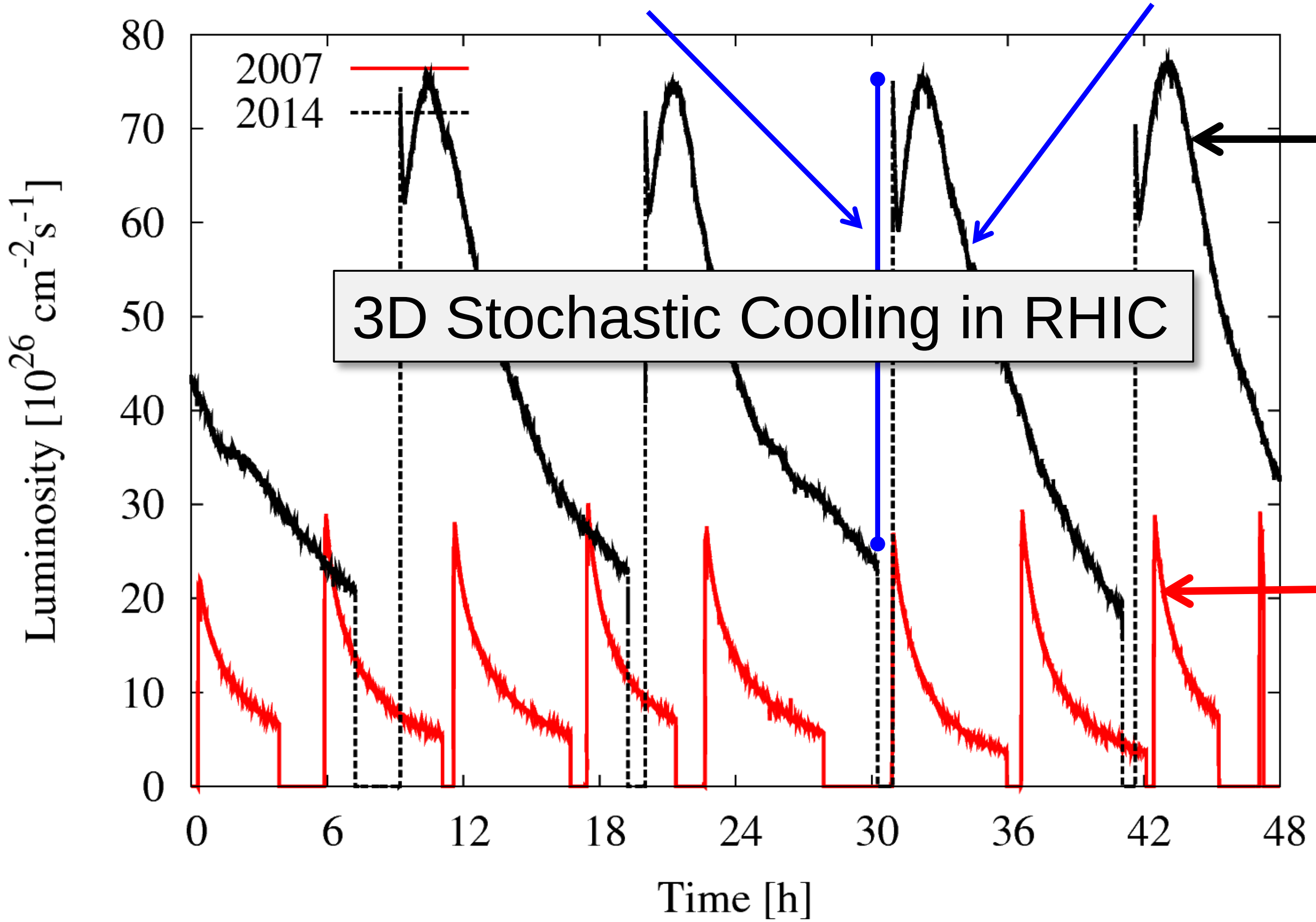
Delivering RHIC-II luminosity

Increase in initial luminosity result of larger bunch intensity

Increase in luminosity lifetime result of **3D stochastic cooling**, >90% burn-off



2014, End of RHIC-II upgrade 25x design luminosit

2007, Beginning of RHIC-II upgrade 6x design luminosity

Stochastic cooling: M. Blaskiewicz, J. M. Brennan, and K. Mernick, PRL 105, 094801 (20

Today: 30,000 acc. → In 2100: 300,000 acc. !?

> Most particle accelerators will be small, cost-effective, easy to use

> Accelerators will be **used in areas which are today void of science and undersupported for health**: e.g. some parts of Europe/Asia/South America, almost all Africa, ...

> There will be about 10-20 facilities at > 1 billion € investment level, concentrated in developed nations.

> There will be **globalization also in accelerators**:

- International standards will need to established.
- Big facilities as part of an international e-Infrastructure.
- International decision process for coordinated investments.

Site Choice for the Big Projects

- **Globalization for accelerators will impact site choice** for the very big projects beyond FCC.
- Search for **best site on the planet** versus particular lab interests.
- Criteria
  - Energy supply
  - Environmental impact
  - Availability of space
  - Cost for construction and operation
- Clustering of big infrastructure
  - Grouping accelerator infrastructure only virtually or also in real space?
  - Combining various specialties (collider, photon science, spallation source, ...) at one location?
- Access: Via modern IT tools, world-wide possible.

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- Crit…
  - …
  - r…
  - A…
  - C…

I might be overly optimistic here. Progress in science and technology might be faster than in human collaboration across nations!

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