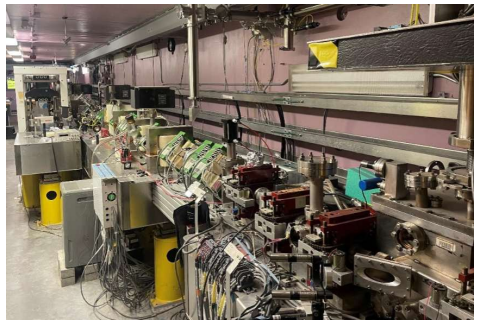



Accelerator R&D Opportunities:

in the US, at U.Hawai'i

Vladimir SHILTSEV (NIU)

US-Japan Beam Monitor Workshop, February 19, 2025

University of Hawai'i at Mānoa, February 19, 2025

Content:

e+e- Frontier: Super-KEK-B *et al*

Next: Higgs Factories

e-Beam R&D at Universities (UHM…)

e+e- Colliders: Forefront of Beam Physics (1964-now) – *Great Machines of the Past*

- **CESR (1979-2008): 6+6 GeV, Luminpsity=1.3e33**
  - Pretzel-separation, SC RF, β*=1.8cm, Mobius ring ξ=0.09
- **LEP (1989-2000): 104+104 GeV, L=1e32**
  - dE/E=0.001% calibration, total SR loss 3% (3.5GV RF), blackbody radiation losses, TMCI feedback, ξ=0.089/IP
- **KEK-B and PEP-II (1999-2100): 3.5+8 GeV, L=2.1e34**
  - Asymmetric collisions, top-up injection, transv. and long. FB systems, crab cavities, 3.2 A of e+ (!), record luminosities

e+e- Colliders: Forefront of Beam Physics (1964-now) – *Present Day Factories*

- **DAFNE (1997 - now): 0.51+0.51 GeV, L=4.5e32**
  - Crab-waist scheme with large Piwinski angle
- **VEPP-2000 (2010 - now): 1+1 GeV, L=4e31**
  - Round beams optics, record ξ=0.33(?)
- **Super KEK-B (2018 - now): 7+4 GeV, L=5.1e34**
  - Nanobeams collision scheme, β*=1mm →0.3mm, world record luminosity, numerous challenges towards 40(80?)e34 – beam-beam, SBLs, nonlinear collimation, etc

Future Circular e+e- Colliders

- Energy of interest – at least Higgs proc
- High luminosity *O*(1e34-1e35)…(10^4-1(
- High beam energy 120 GeV → huge S

$$U_0[\mathrm{keV}] = 88.46 \frac{E[\mathrm{Ge}}{\rho[\mathrm{n}}$$

- High luminosity needs high current → h
- As the result – large rings, ~100MW po

$$\mathcal{L} = \frac{3}{16\pi r_0^2 (m_e c^2)} \frac{P_{\mathrm{SR}} \xi_y \rho}{\beta_y^* \gamma^3}$$

PHYSICS TODAY

Japan accelerator pursues nanobeams to boost luminosity FREE

11 February 2025

Squeezing beams of electrons and positrons for the Belle II experiment at the SuperKEKB facility proceeds with halting progress.

Toni Feder

DOI: https://doi.org/10.1063/pt.imsn.ildq

The Belle II experiment gets a makeover before its 2024 run. (Photo from the KEK/Belle II collaboration.)

US-FCC Collaboration

- Theory, detectors, accelerators; annual *Workshops*'23(BNL),'24(MIT) ,'25 (04/15-17, FNAL/ANL)
- *Snowmass'21* proposal to *P5* (accel.):

RF Systems:

1) 800 MHz SRF for Booster and Collider (28 → 244 CMs)
2) 800 MHz RF power sources (klystrons >80% eff.)
3) RF for 6-20 GeV e+/e- injector linac (C3 tech.)

Magnets Systems:

1) IR magnets and cryostats (for 4 IRs)
2) Collider ring and Booster ring magnets (low field)
3) FCC-hh collider ring magnets (14-20 T)

Optics/Design/Instrumentation:

1) Beam physics (beam-beam, instabilities, optics/DA, …)
2) Interaction region design, MDI, integrated machine design
3) Polarization (simul., wigglers, etc), collimation
4) Beam Instrumentation (BPMs, feedback, etc)

* possible University contributions

Part III:

Accelerator R&D Opportunities at Universities and e-beam Facilities

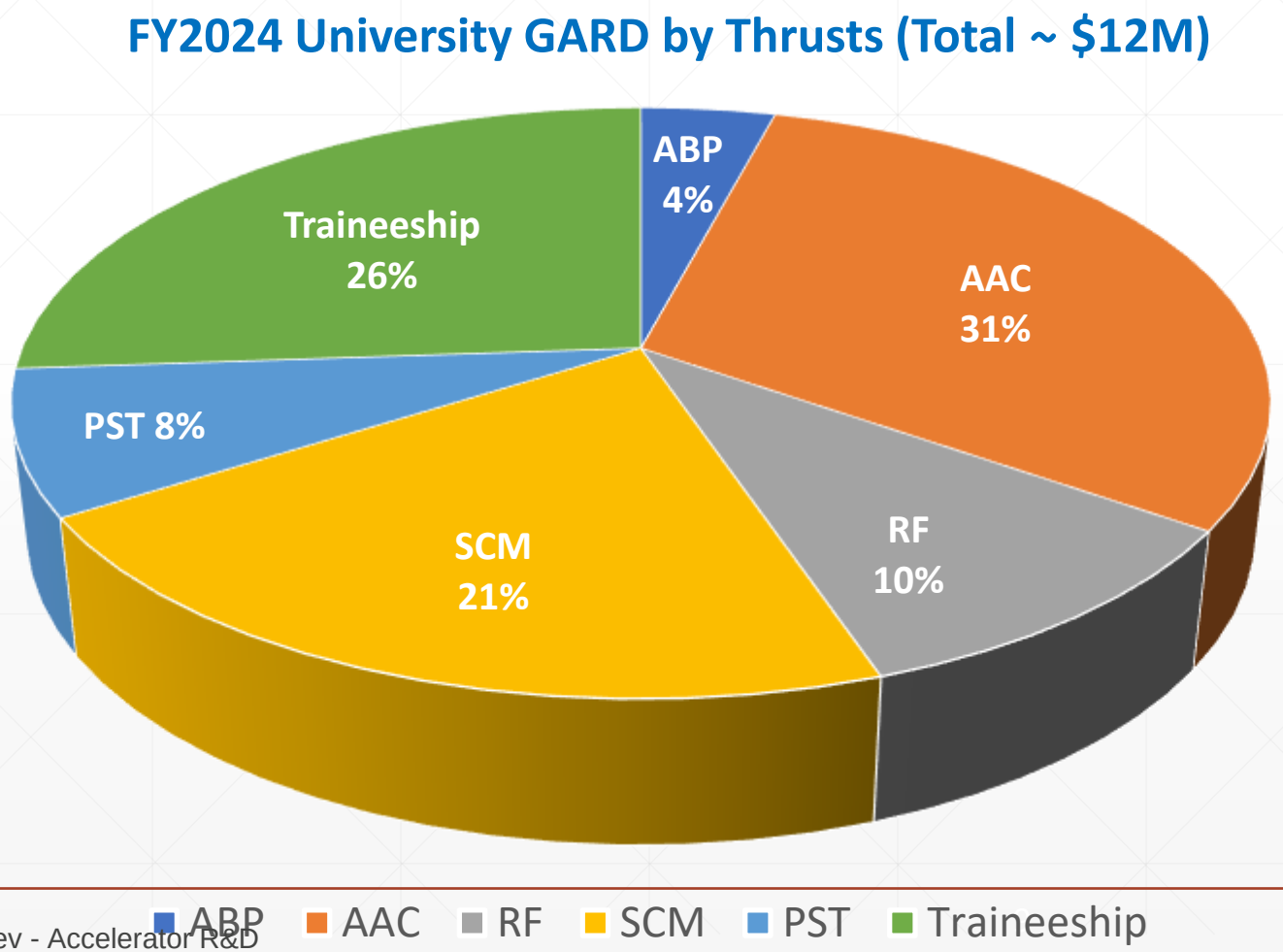
- Fundamental beam physics
- Involvement in future colliders R&D
- FELs (“Trillion transistors on a chip”)
-FLASH-RT

Opportunities at UHM

- Establish a *Traineeship in Accelerator Science & Engineering*
- Join/Collaborate/Lead the *US Center of Accelerator Physics* (*US CAP* – GARD ABP)
- Join US Future Collider Programs (EIC, FCCee, Muon Collider) – R&D topics:
  - Beam modeling and simulations (beam-beam, space-charge, collimation/MDI, etc)
  - Collaborative tests at other facilities
  - Design and prototyping (halo monitoring, collimation systems, magnets, RF, beam diagnostics, etc)
- Develop a program of research at the UHN 40 MeV linac facility
  - Many possible topics (FELs, RF, diagnostics, irradiation, AAC…)
  - AI/ML-based accelerator optimization, nonlinear optics, and halo control
- Applications for chip-making industry, medicine (FLASH-RT), and environment

FY 2024 GARD University by Thrusts ($12.14M)

GARD = General Accelerator R&D Program in the US DOE Office of High Energy Physics (total ~85 M$/yr now)



- ABP includes Beam Instrumentation and Controls
- RF Technology includes SRF and NC High gradient RF and RF sources.
- Accelerator Traineeship supports four areas (5 active awards now):
  1. Physics of large accelerators and systems engineering.
  2. Superconducting radiofrequency accelerator physics and engineering.
  3. Radiofrequency power system engineering.
  4. Cryogenic systems engineering (especially liquid helium systems).

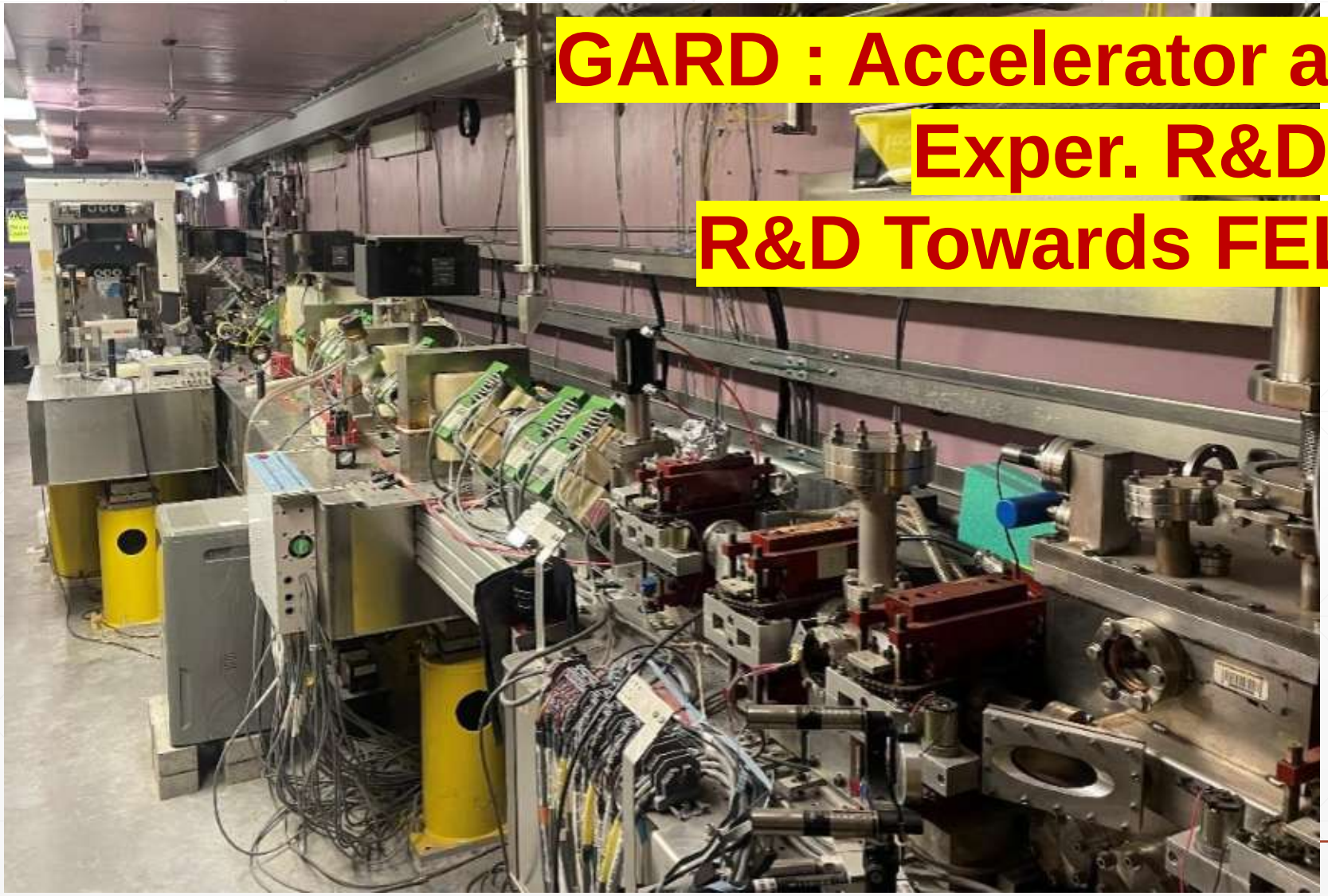
P5 Area Recommendations for DOE OHEP

	Now (FY24 $)	P5 Recomm.
*General Accelerator R&D **	~55M$/yr	+10 M$/yr
Targeted Collider R&D	0 M$/yr	+35 M$/yr
FNAL Accel.Complex Plan	0 M$/yr	+10 M$/yr

~1 B$ combined over the next decade

* Note: in addition, GARD Facility Ops are supported at ~30M$/yr – these are of great relevance for R&D and projects (eg tests and pre-project R&D)

UHM 40+ MeV Electron Linac



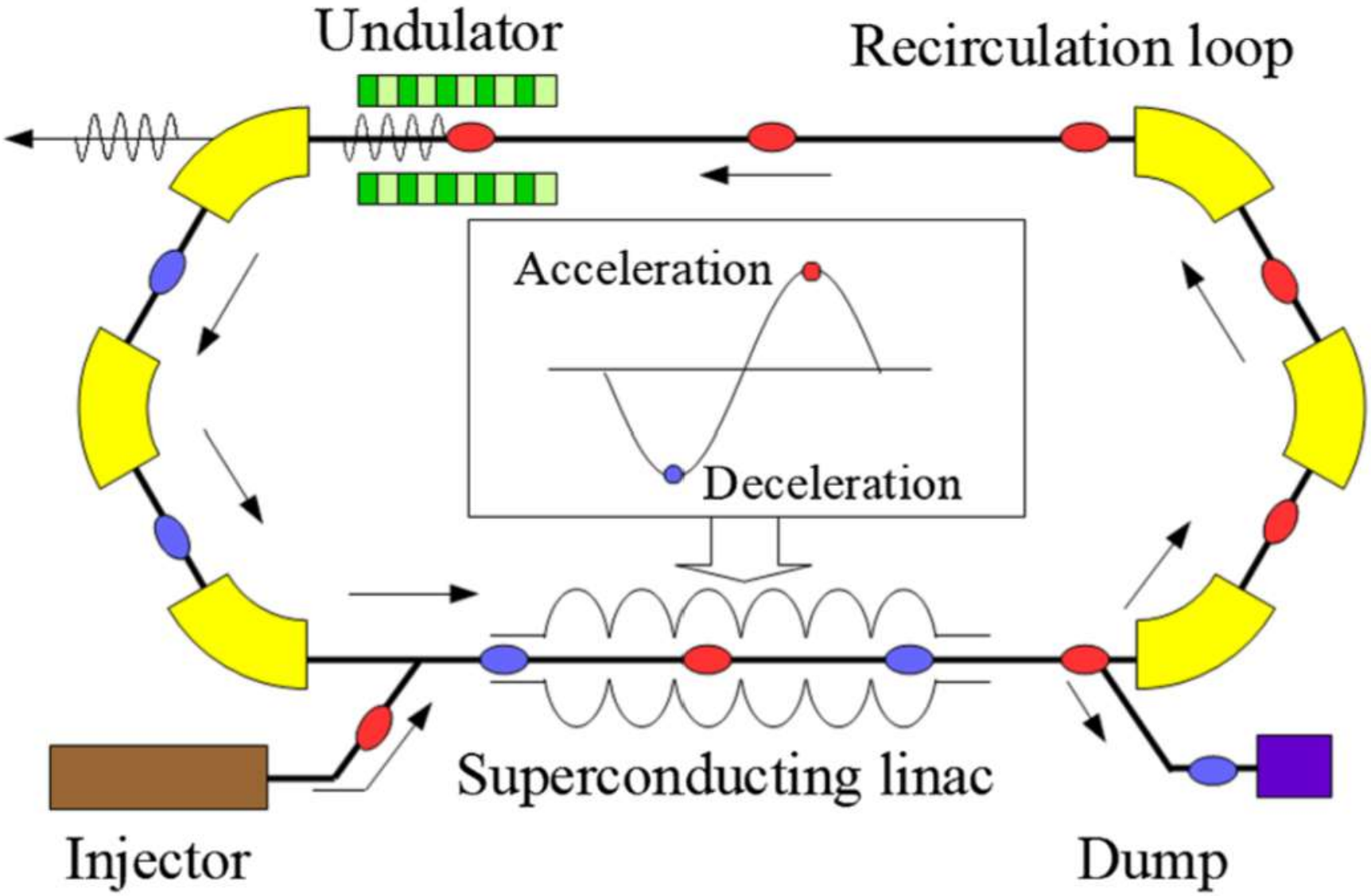
GARD : Accelerator and Beam Physics

Exper. R&D Toward Colliders

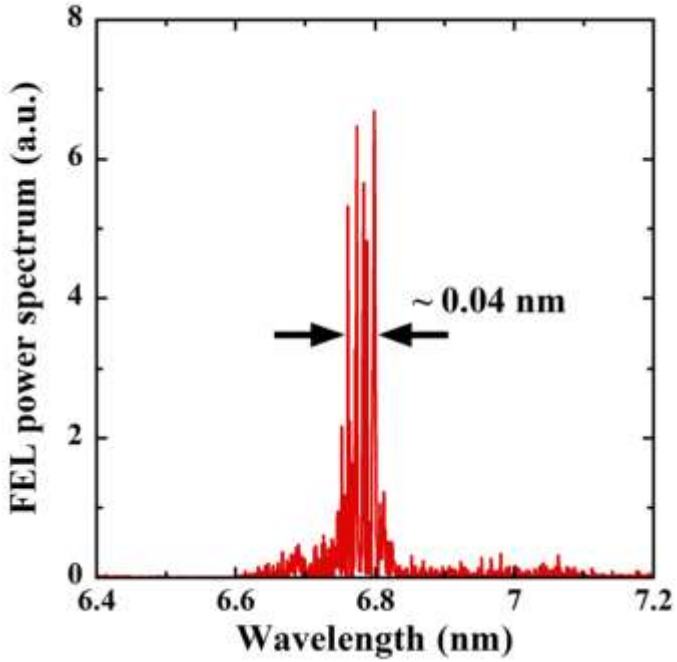
R&D Towards FEL for Chip-making

FLASH-RT R&D

Efficiency Boost: Energy Recovery



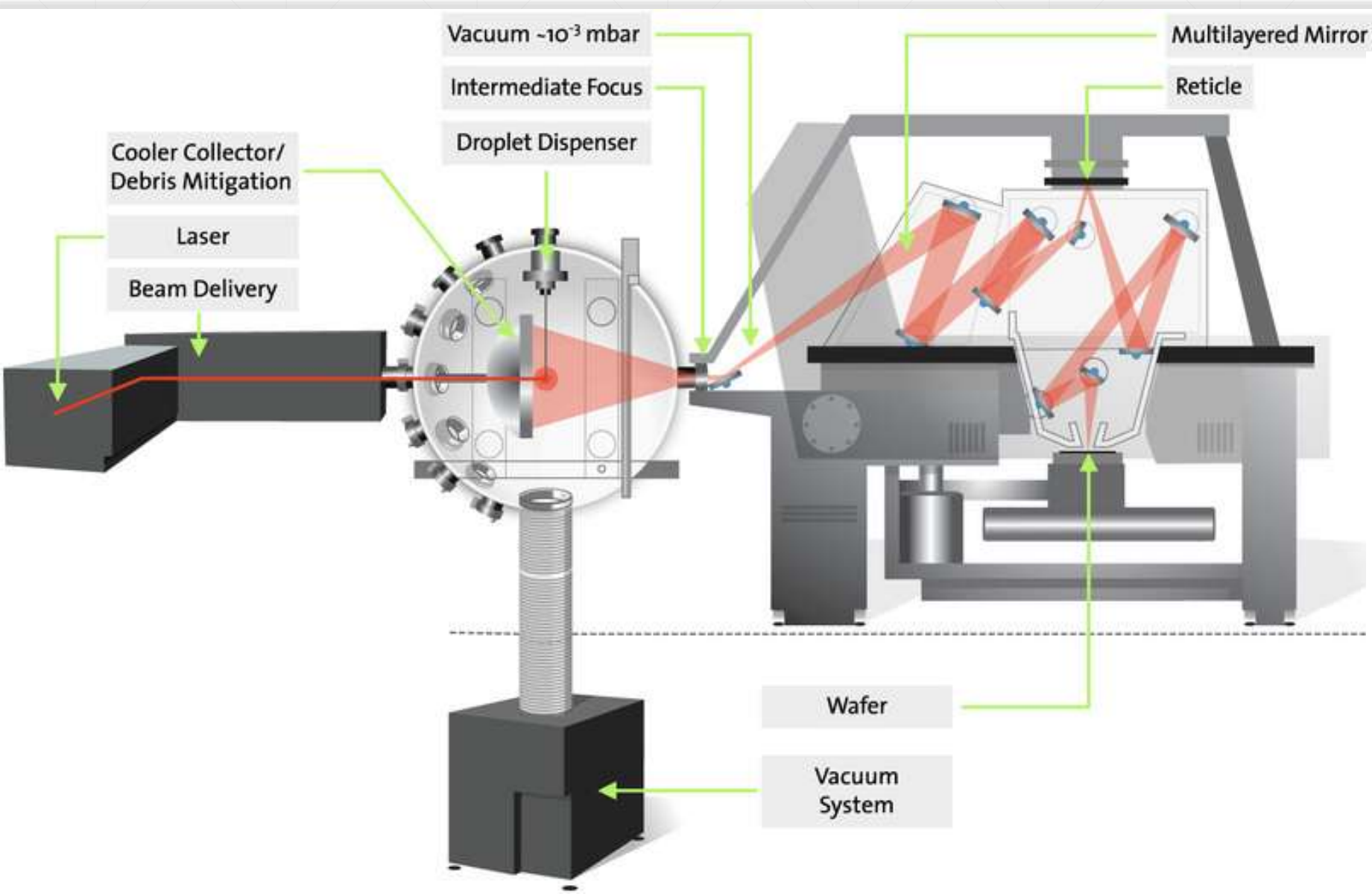
Other benefits:
spectral density



Wavelength spread of the FEL spectrum at 6.75-nm wavelength. The FWHM is ~0.04 nm, which is narrow enough to match the acceptance of the multilayer mirror.

H.Kawata, et al, J. Micro/Nanopattern. Mater. Metrol. 021210, 2022 • Vol. 21(2)

Current State-of-the-Art: 14nm → 7 nm…



ASML

EUV-LPP
CO2 laser on tin droplets
1000/sec

Issues:

Broad spectrum of EUV
Stability of tin source
It's lifetime (clean x4/yr)
500W source → few Watts
on the wafer (~10 mirrors)

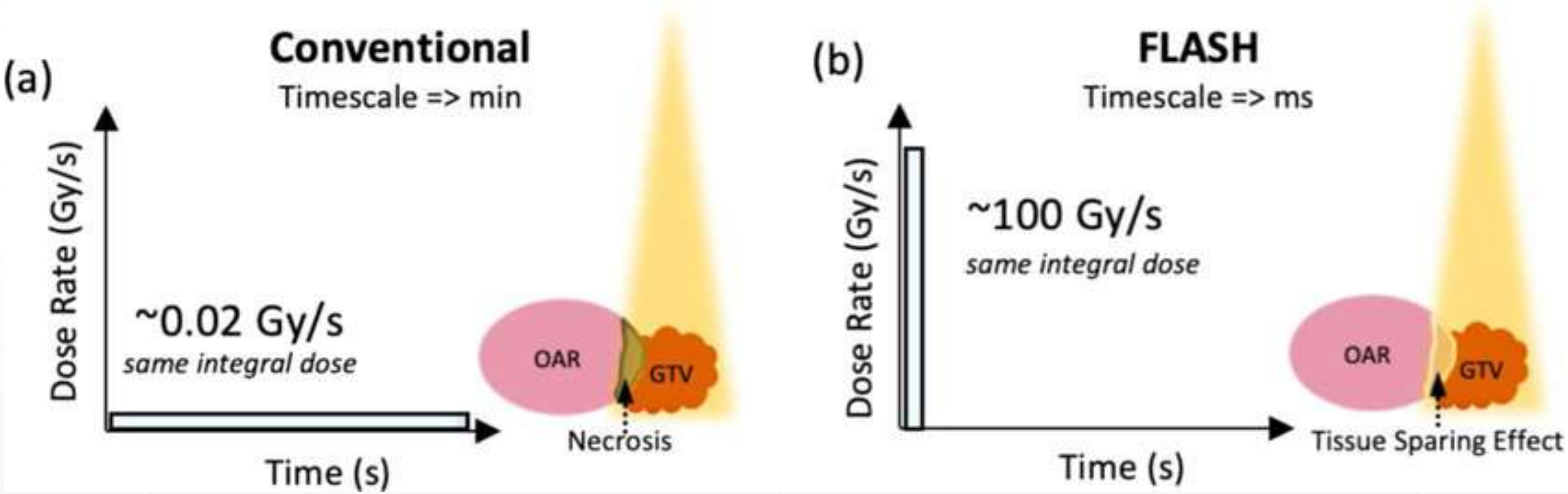
Overall wall-plug efficiency

~0.1% (!)

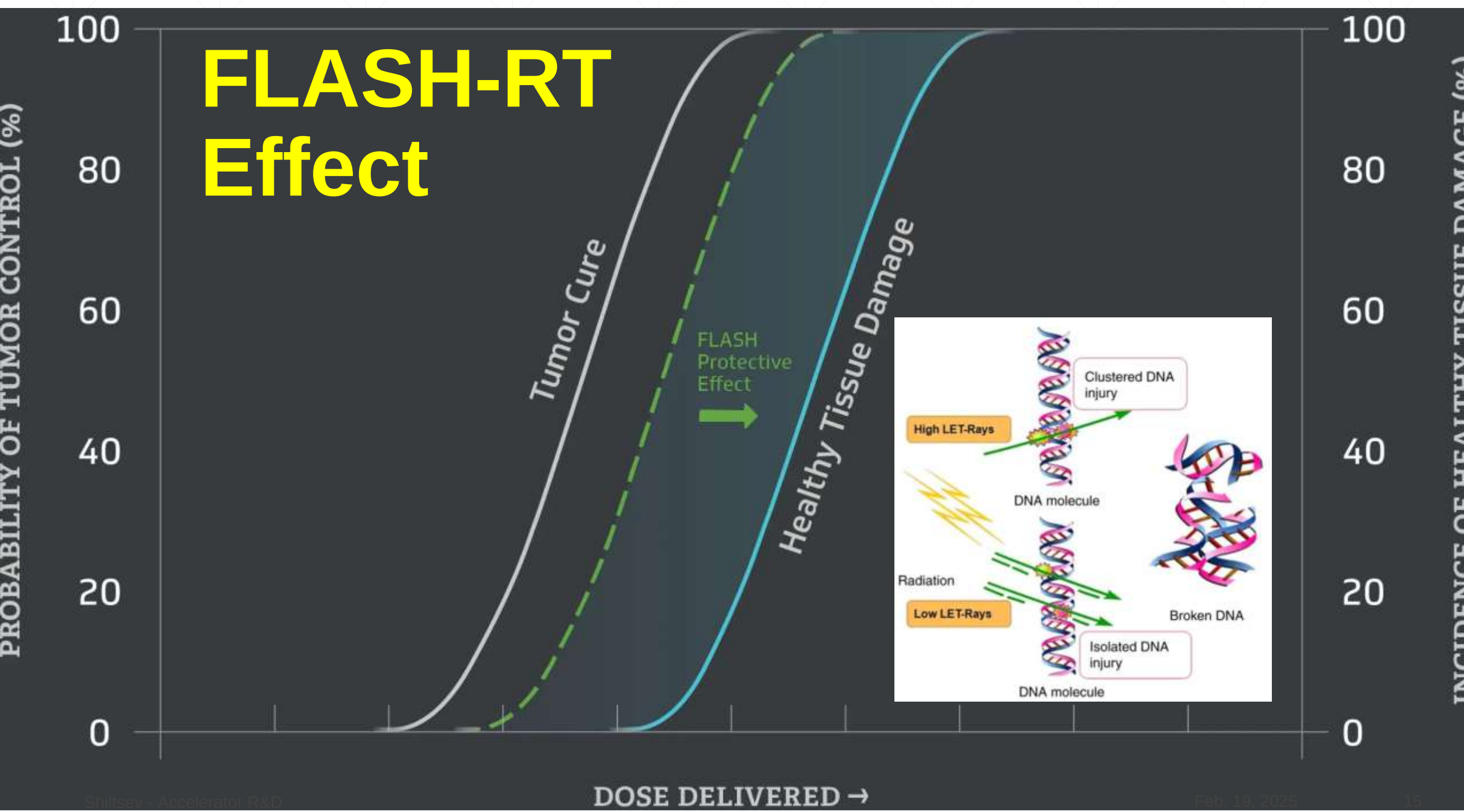
Accelerators can do

1-10%

FLASH - Radiation Therapy

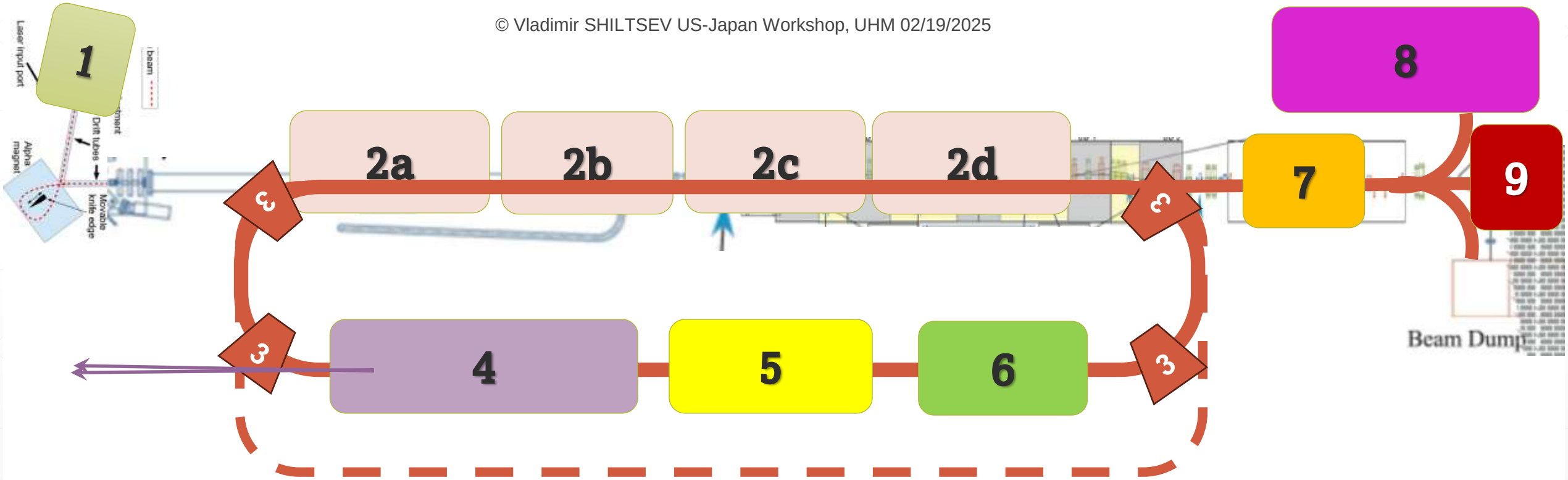


FLASH-RT Effect



PASTUH: Program in Accelerator Science and Technology @ Univ. Hawaii

"Now" = therm. RF gun + S-band linac + chicane and FEL + 42 MeV beamdump



1 – Cold Copper RF photoinjector

2 – Additional S-band RF sections

3 – ERL return loop/storage ring

4 – Chicane & EUV FEL

5 – Collimator & diagn. test

6 – Beam optics/phys.test

7 – Nanostructure Wake

8 – FLASH-RT area

9 – Irradiation area

PASTUH: Program in Accelerator Science and Technology @ Univ. Hawaii

The program will support unique studies in several fields:

- HEP and NP colliders (elements #1, 5, 6, 7)
- Light sources/FELs (elements #1, 3, 4, 6)
- Instrumentation and technology development (elements #1, 6, 8, 9)
- Medical and electronics applications (elements #3, 8, 9)
- Training students, physics, AI/ML (elements #1, 2, 3, 4, 5, 6, 7, 8, 9)

1 – Cold Copper RF photoinjector
2 – Additional S-band RF sections
3 – ERL return loop/storage ring
4 – Chicane & EUV FEL
5 – Collimator & diagn. test
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Thanks for your attention!