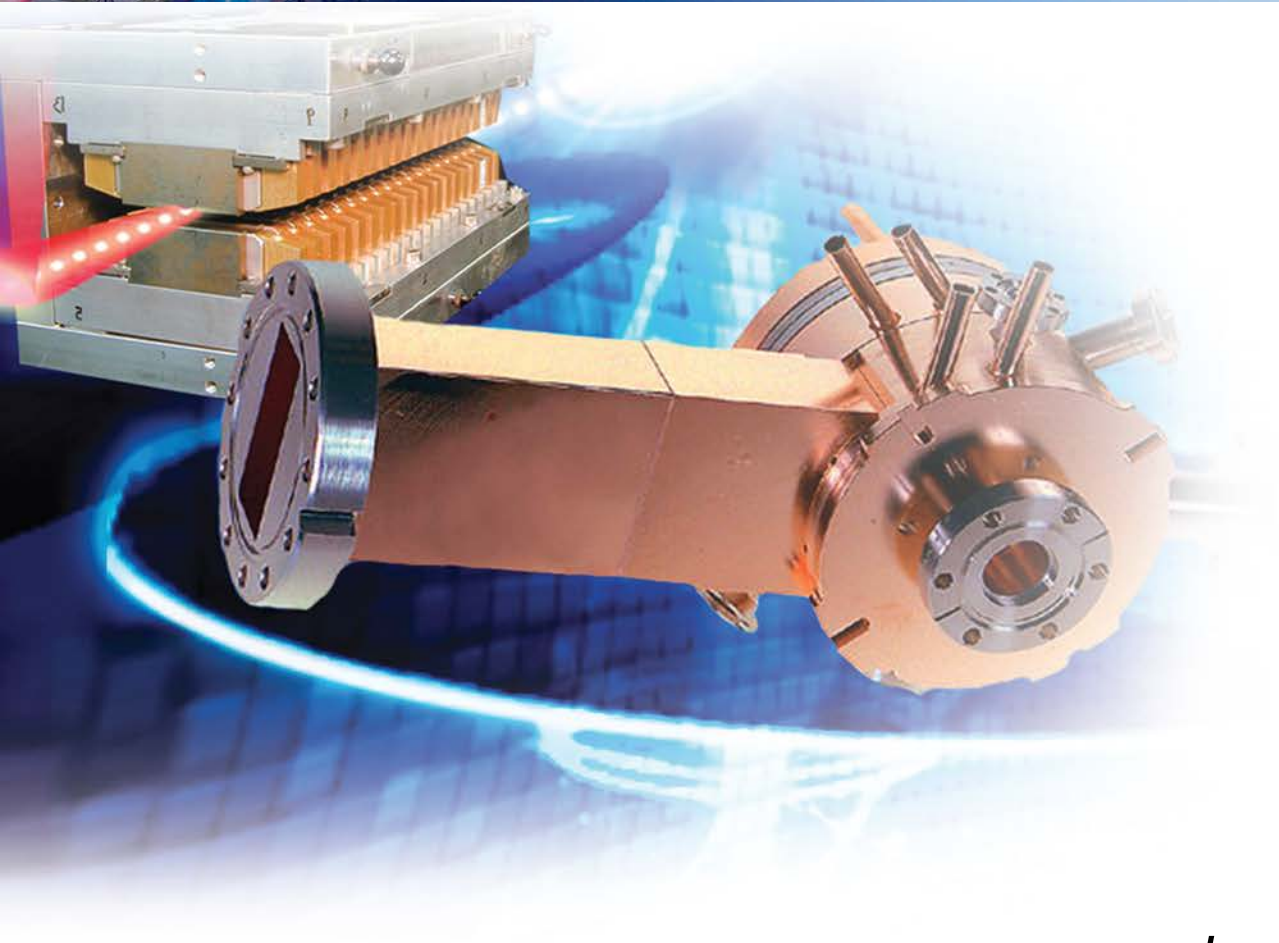


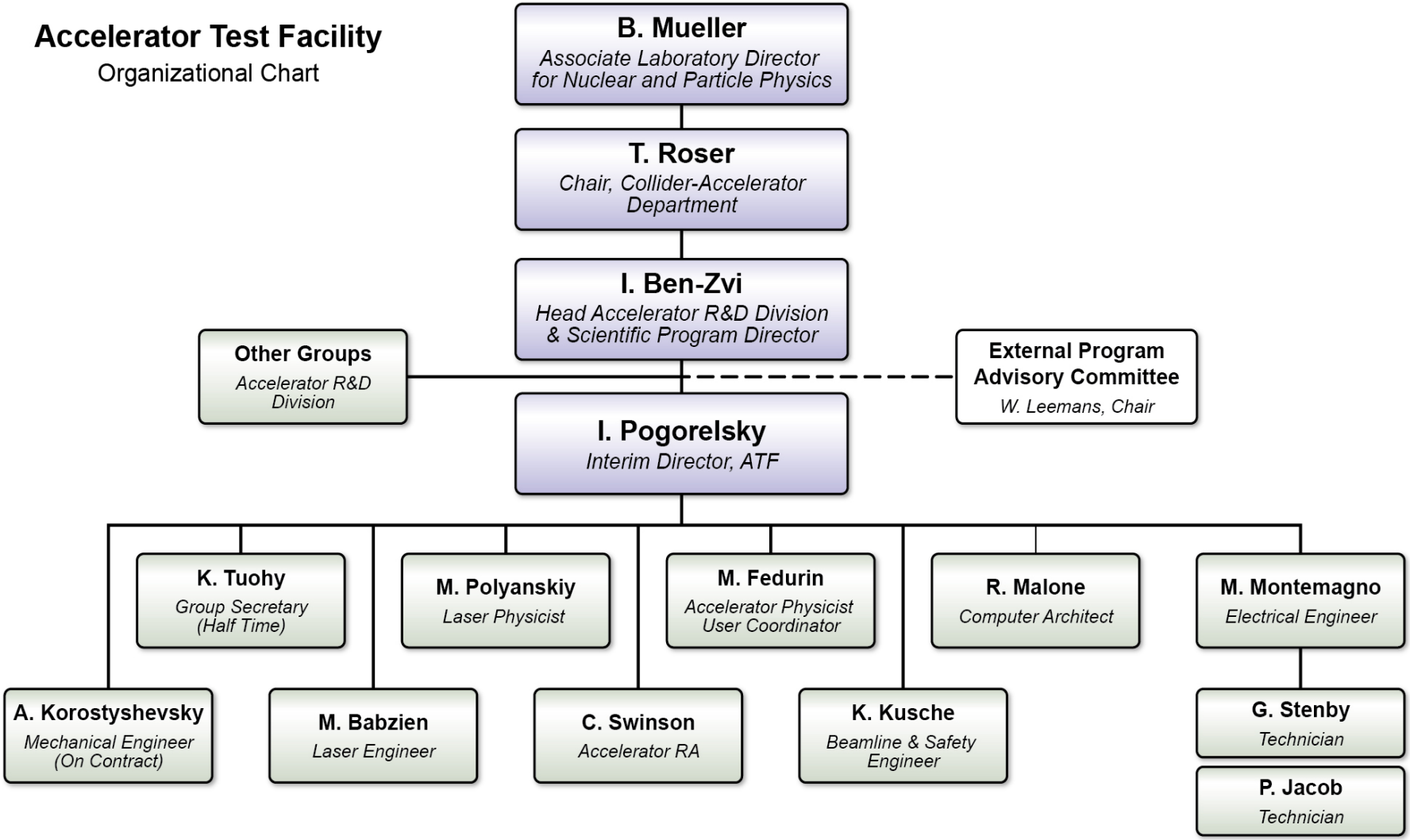
Igor Pogorelsky

ATF status and vision

BROOKHAVEN NATIONAL LABORATORY
a passion for discovery
U.S. DEPARTMENT OF ENERGY | Office of Science

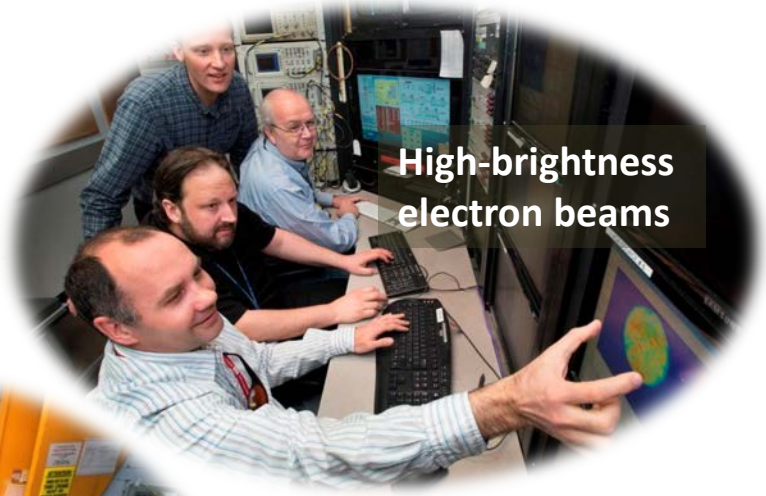
Accelerator Test Facility

Organizational Chart

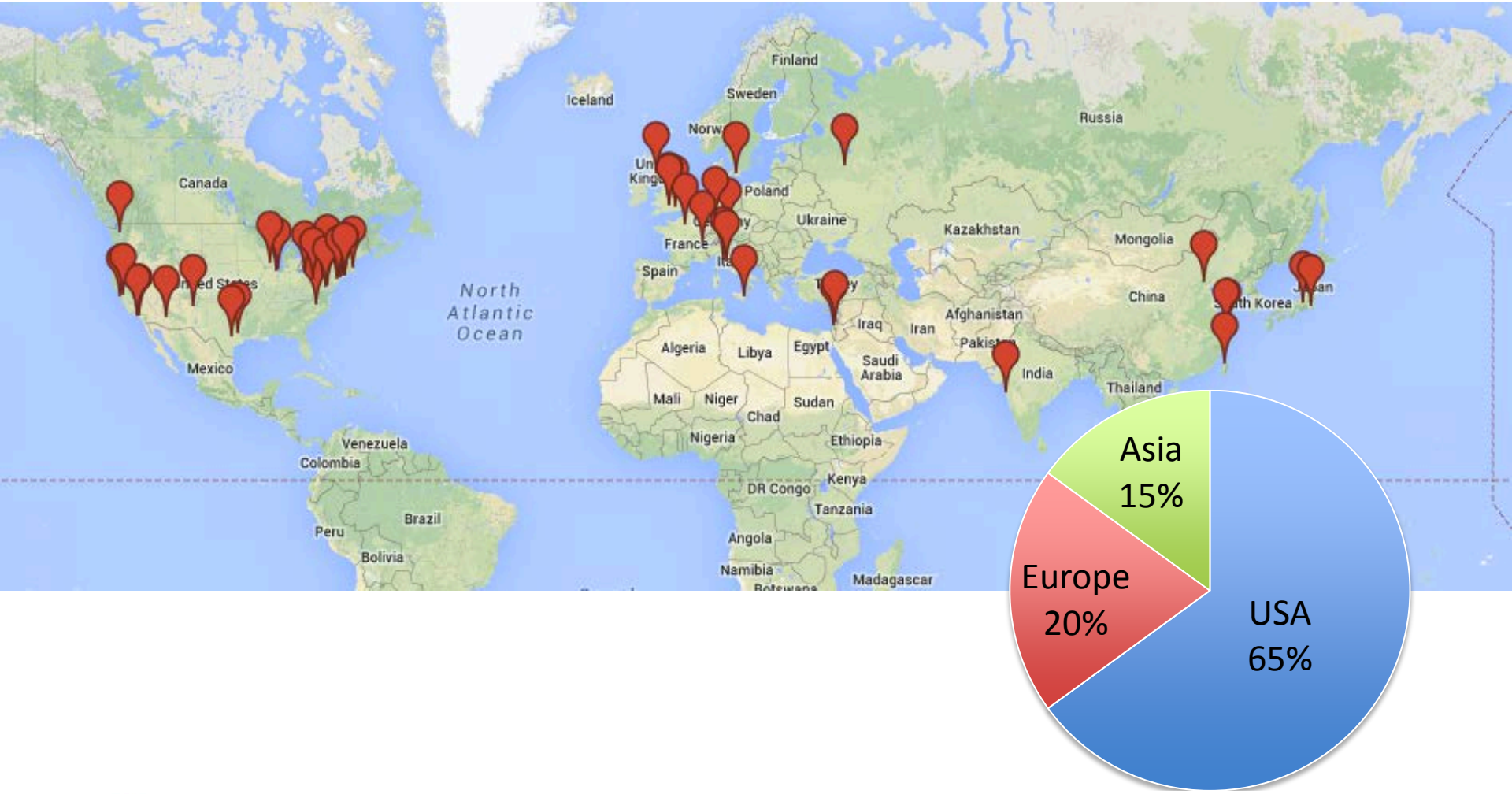


The BNL Accelerator Test Facility

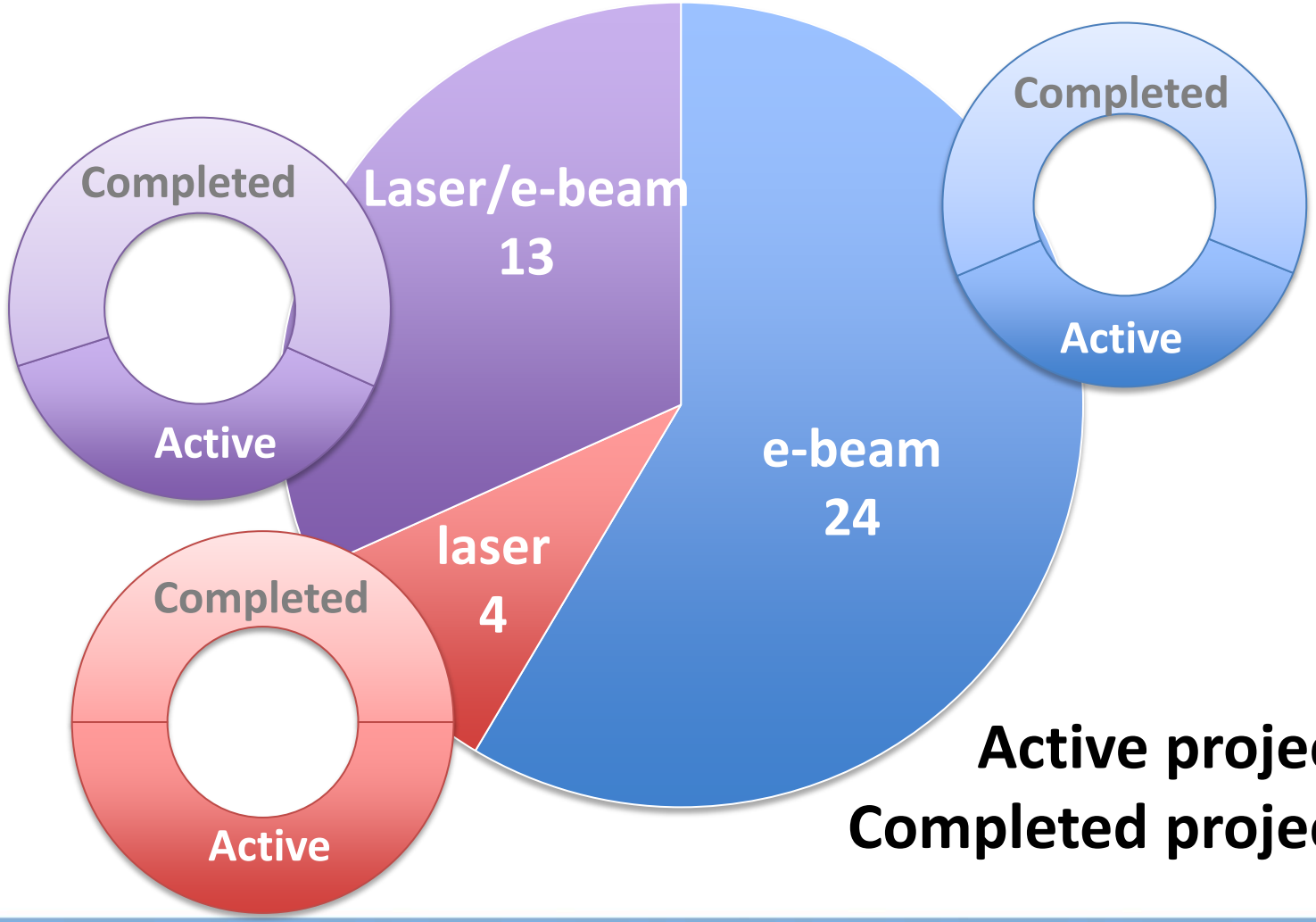
- *well established,* serves accelerator community successfully for over 20 years
- *unique flexibility,* scope of research diversified
  → stewardship, high-energy physics, photon science
- one-of-a-kind combination of lasers, high-brightness e^--beams, diagnostics



Geography of User Institutions



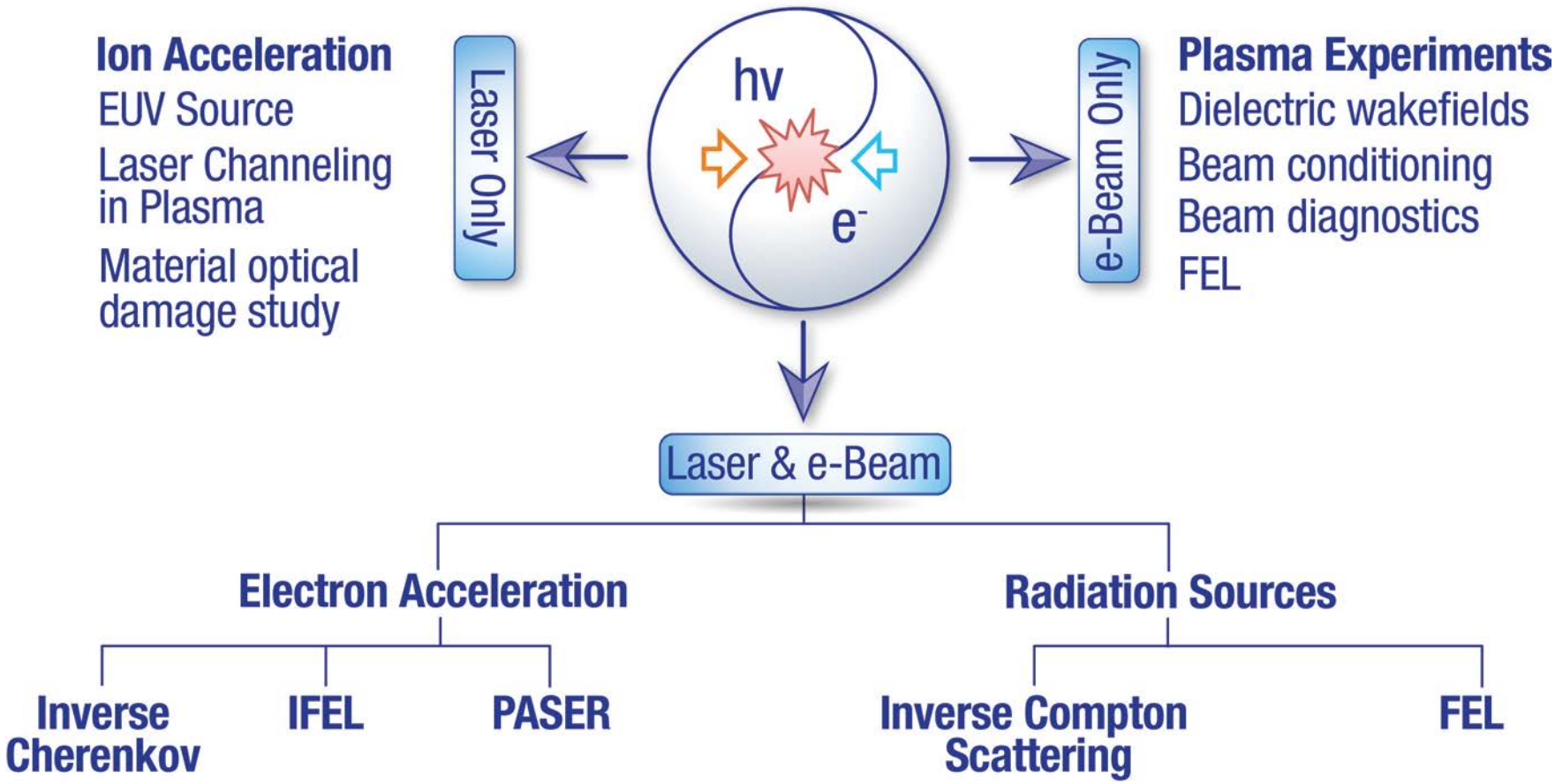
Experimental Program



Active projects: 16

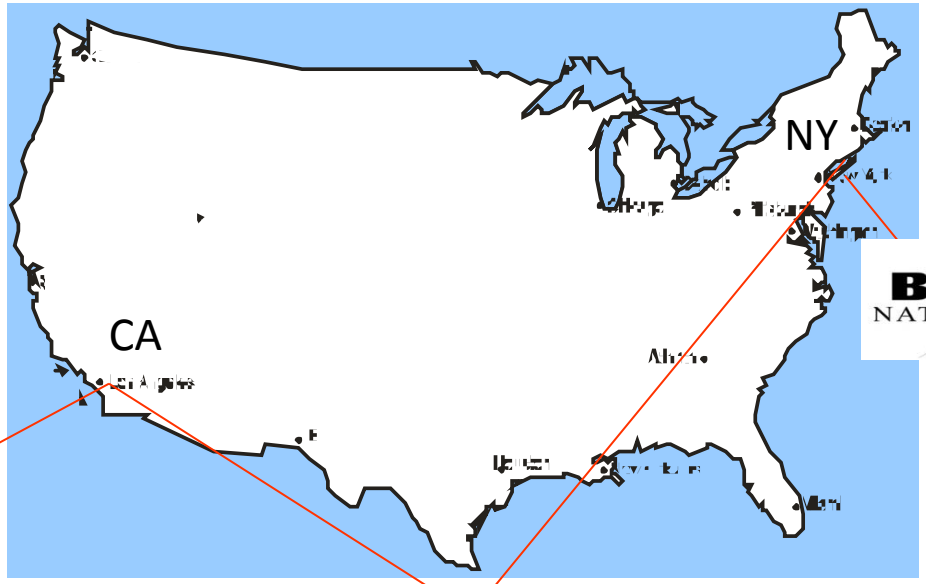
Completed projects: 25

ATF diversity in addressing needs of the accelerator community

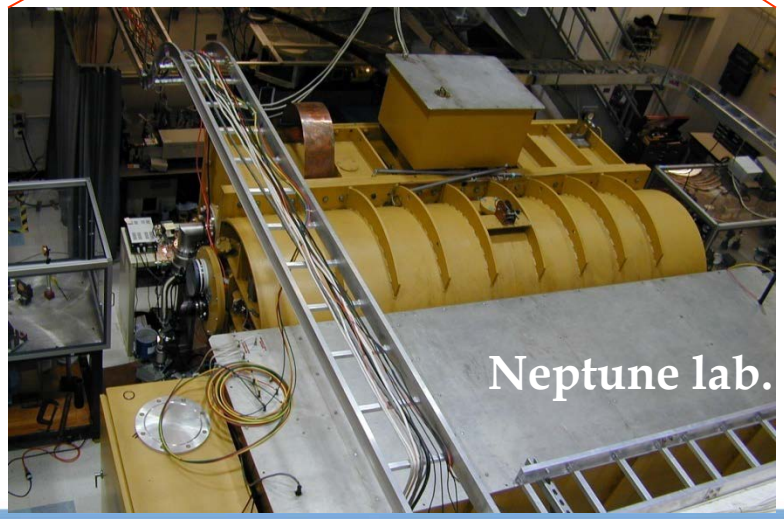


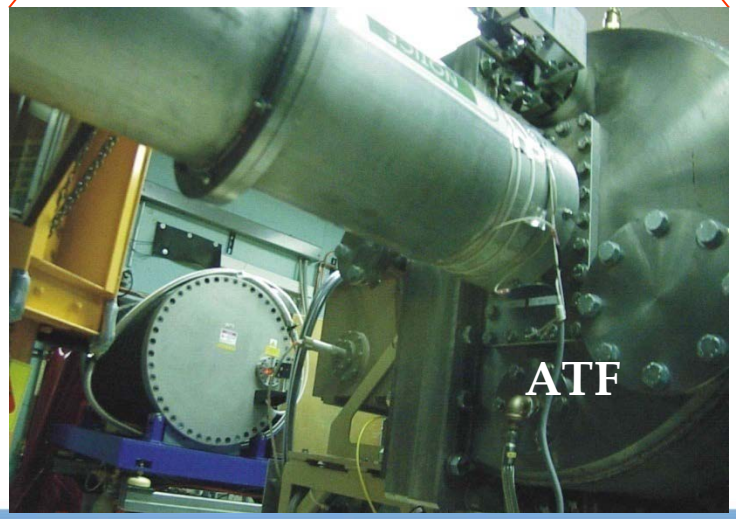
CO_2 Laser Facilities for Strong-Field Physics

UCLA



BROOKHAVEN NATIONAL LABORATORY





Picosecond CO_2 gas laser

a tool for exploring
novel methods of particle acceleration
and radiation sources.

CO_2 (λ=10 μm) advantages
as compared to solid-state ($\lambda \approx 1$ μm) lasers:

#1 favorable scaling of accelerating structures, better electron phasing into the field (staged IFEL accelerator)

#2 100 times stronger ponderomotive effects at the same laser intensity (ion acceleration from foil)

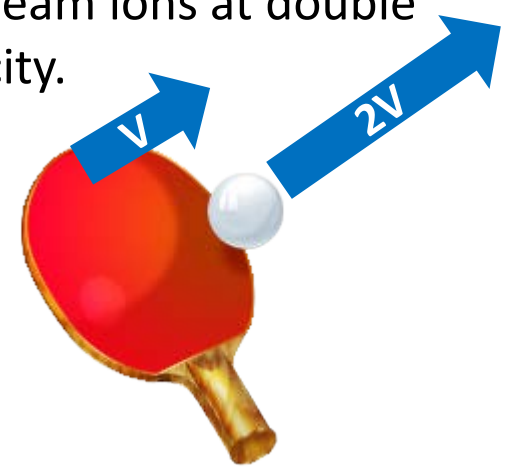
#3 10 times more photons per Joule (Compton scattering)

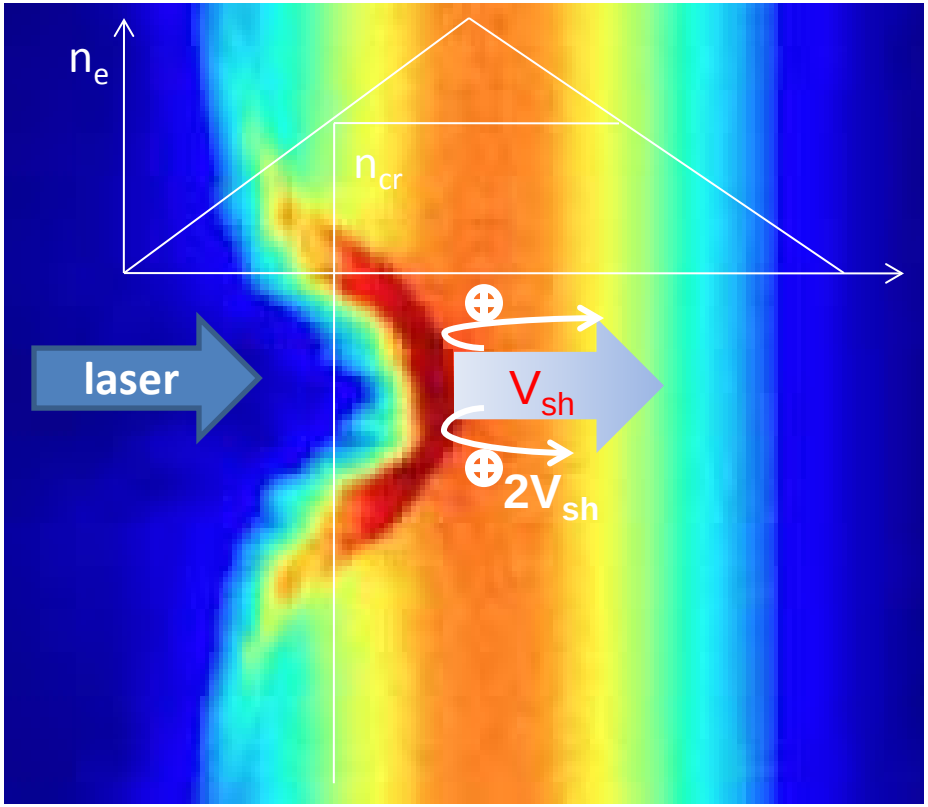
#4 100 times lower critical plasma density (Shock Wave acc.)

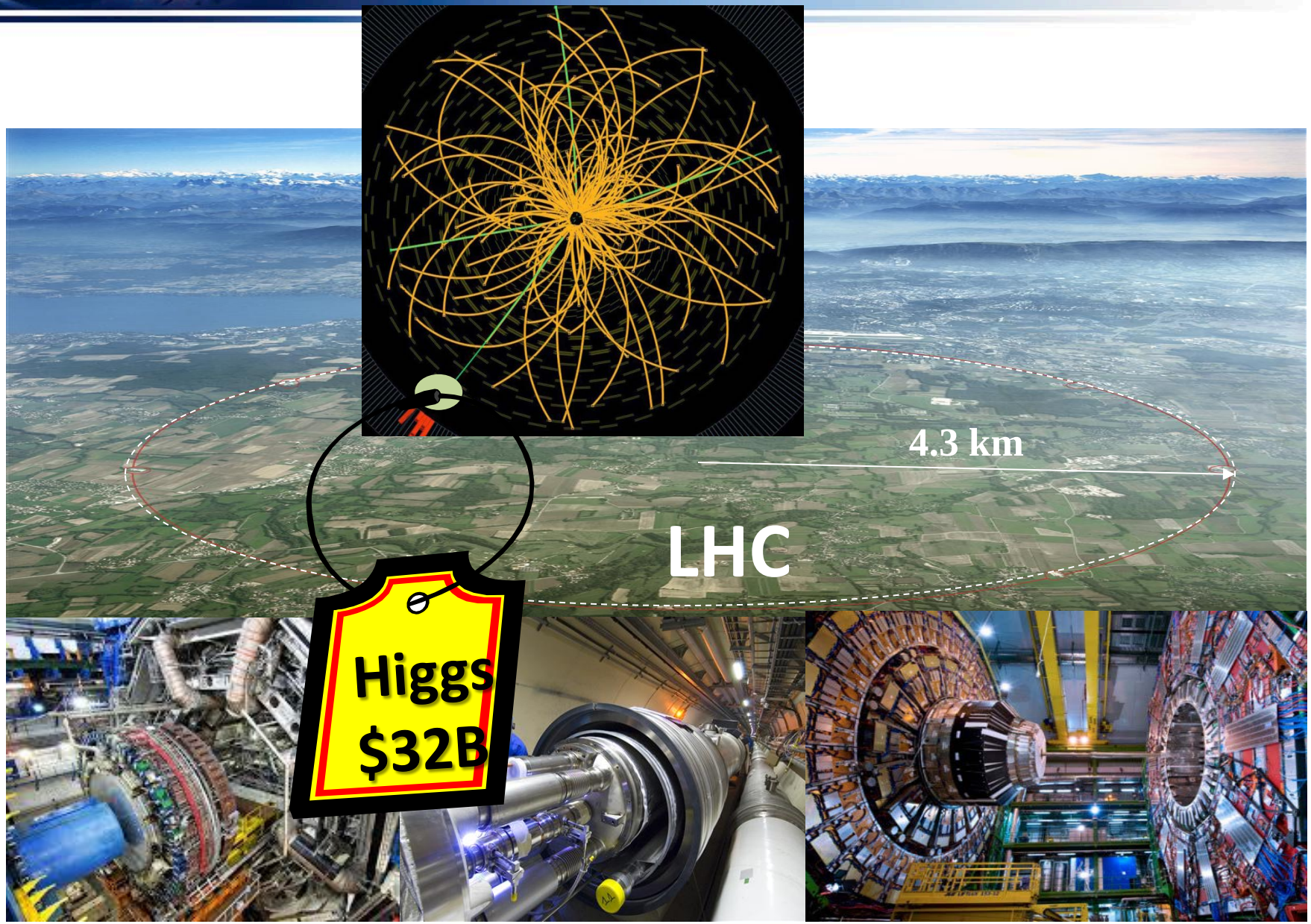
Shock Wave Ion Acceleration

- Laser energy absorbed within critical plasma layer creates electrostatic shock wave at velocity $v_{sh} = \sqrt{I/n_{cr}}$

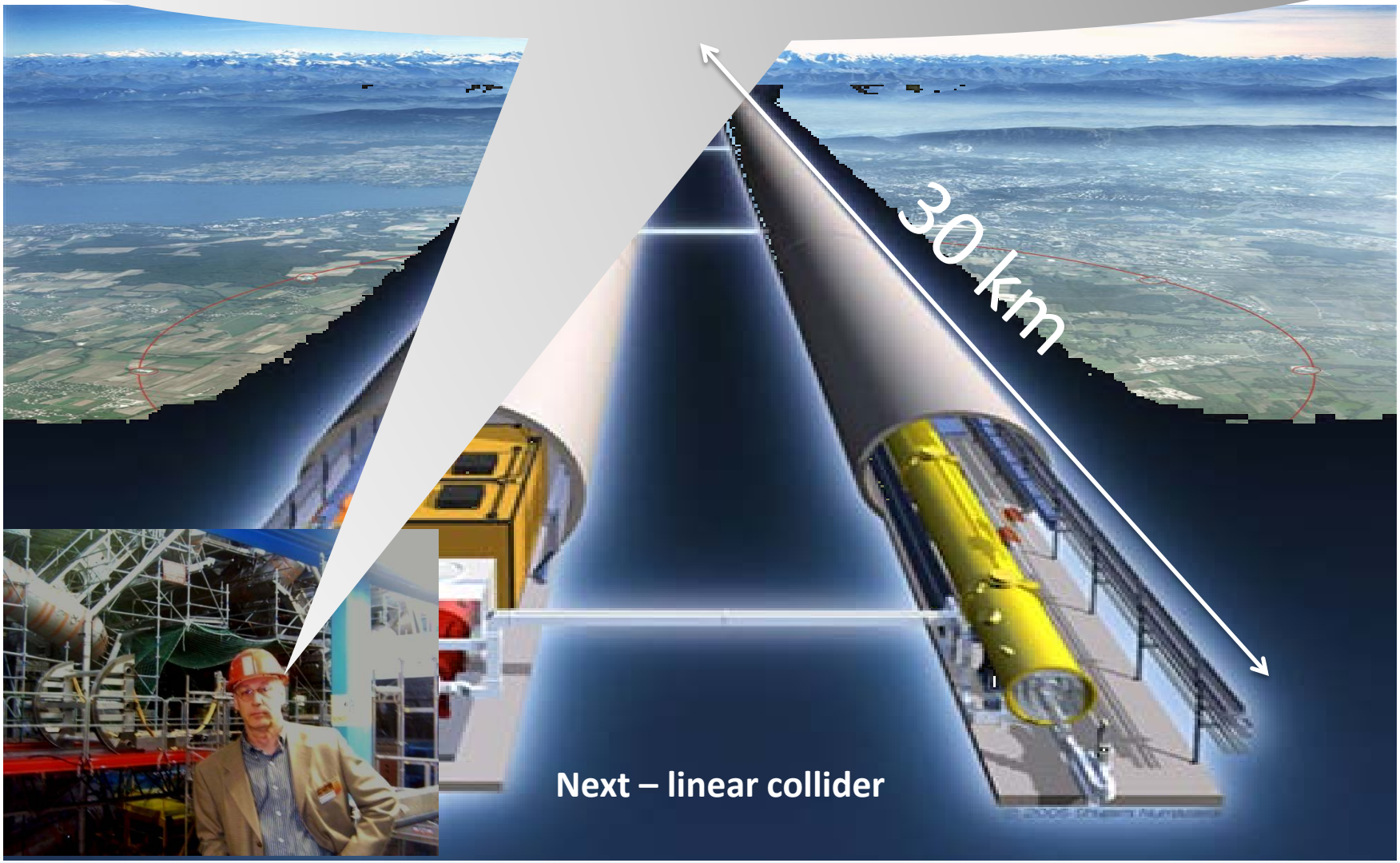
- The shock field reflects upstream ions at double velocity.



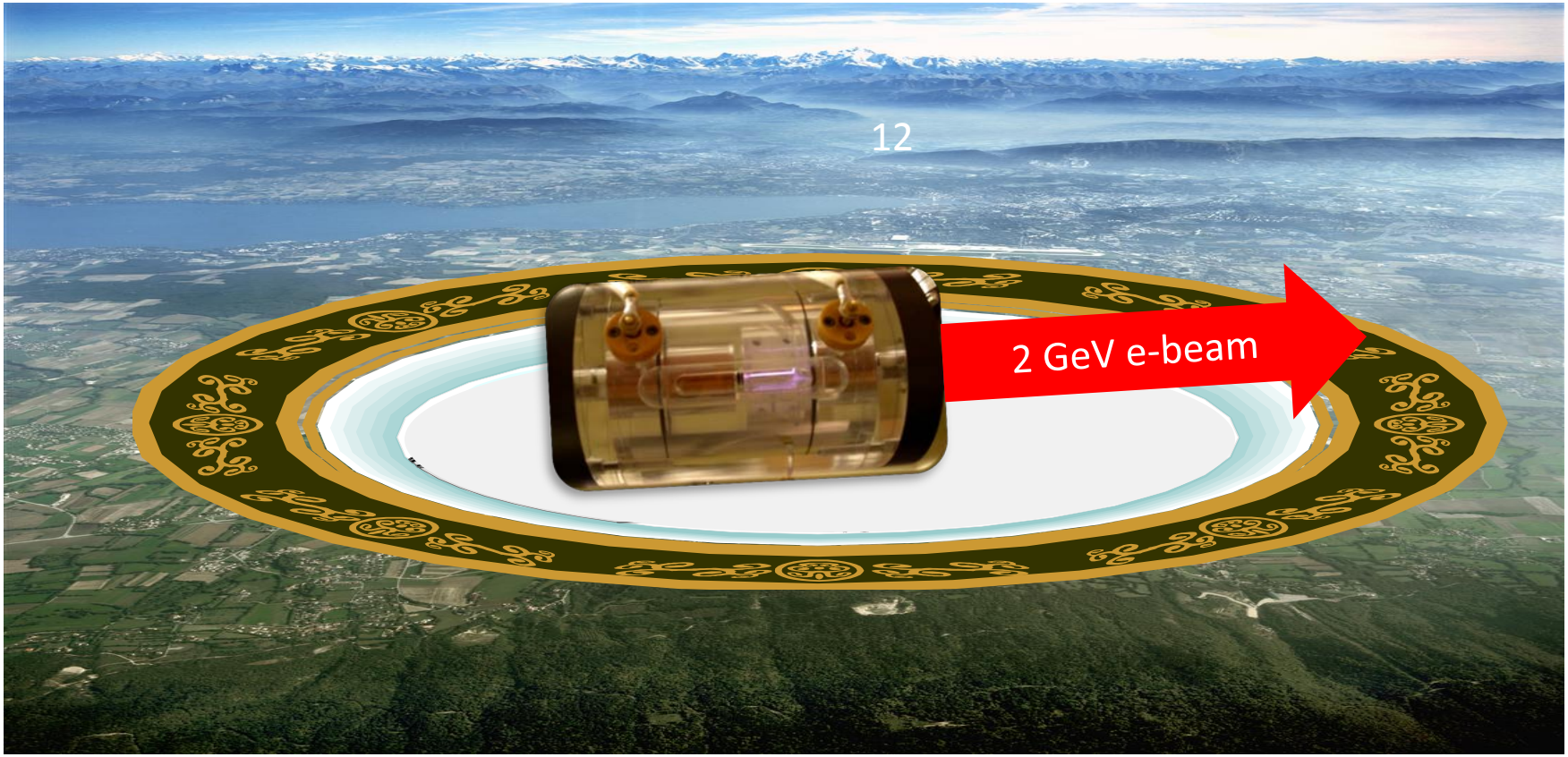



4.3 km
LHC
Higgs
$32B

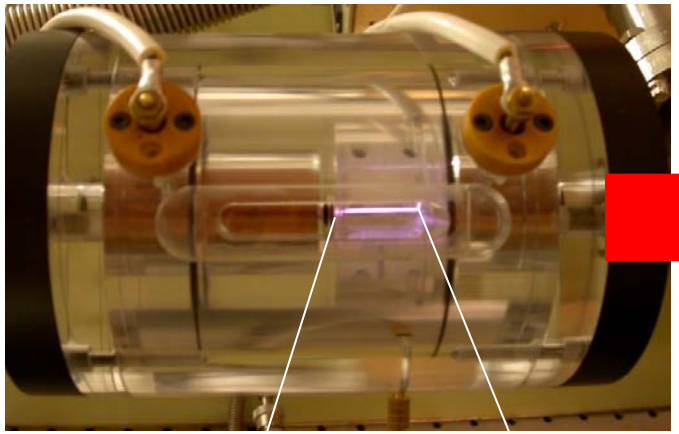
need ideas for compact and affordable accelerators



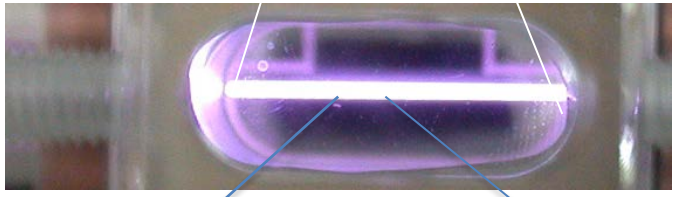
100 m linac on a palm of your hand

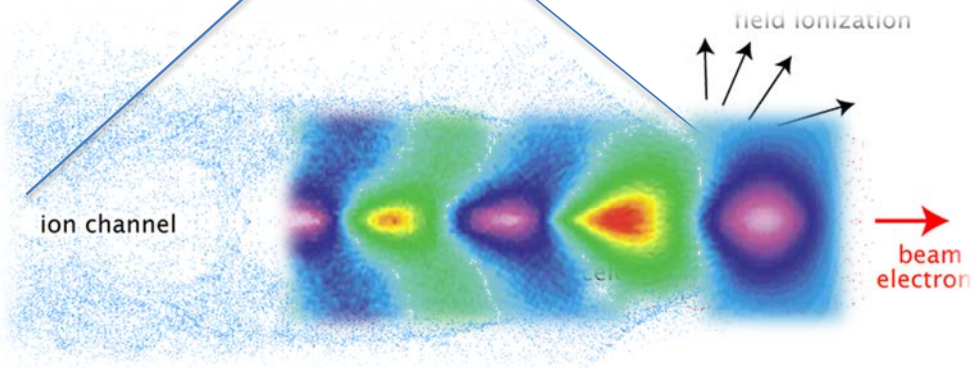


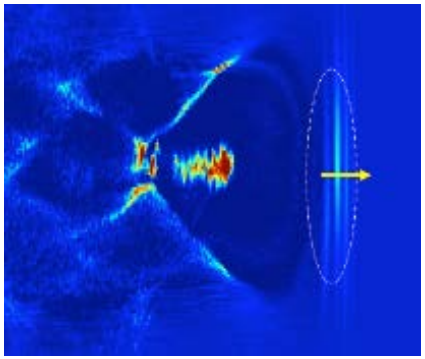
100 m linac on a palm of your hand



2 GeV





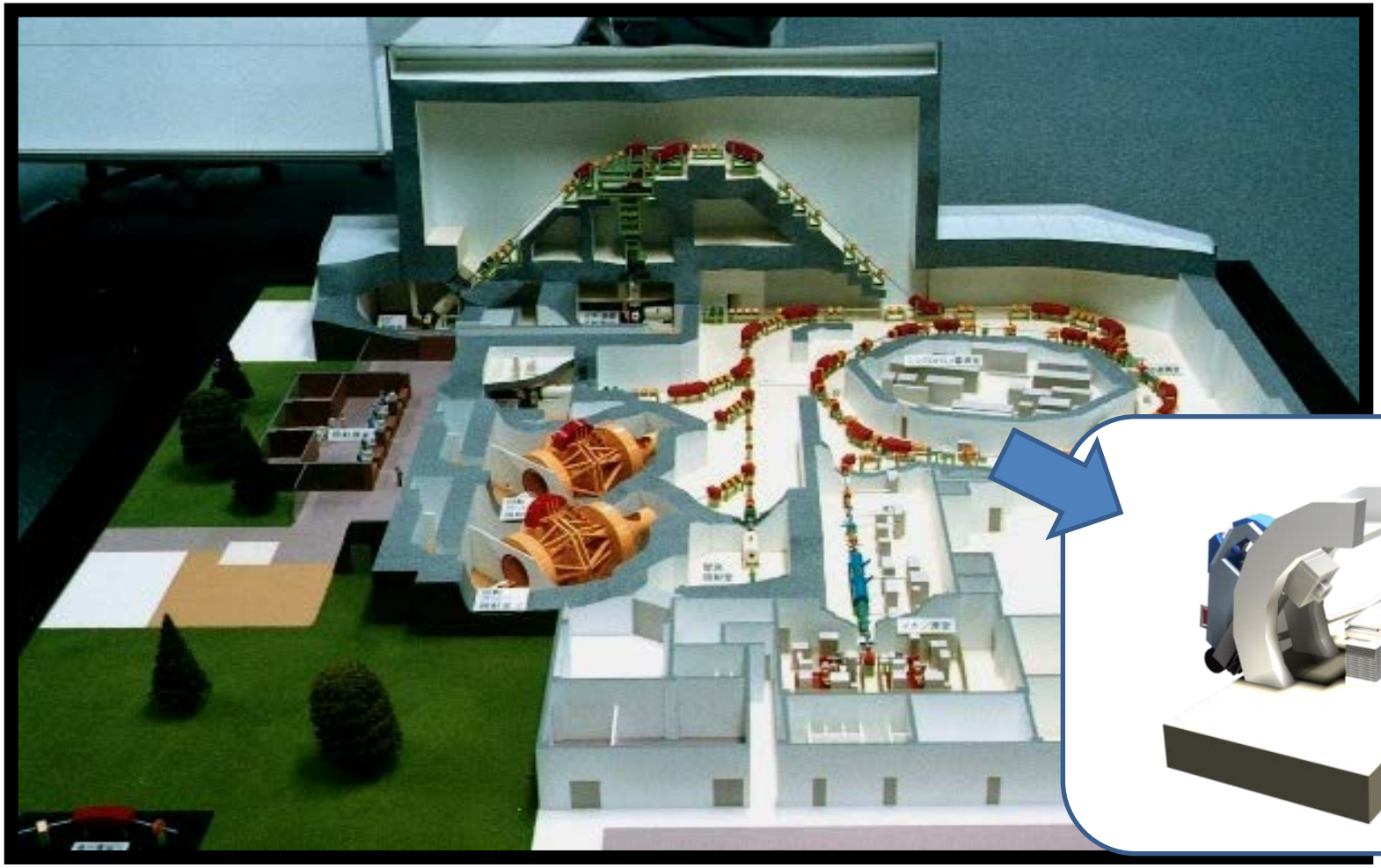


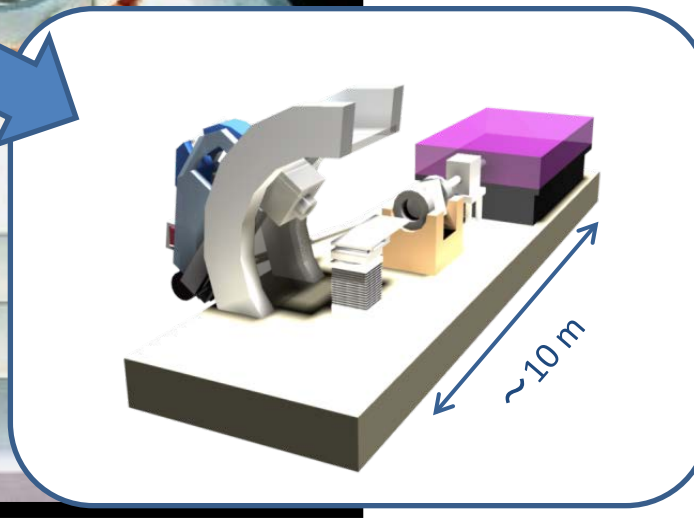
$\Delta E \sim 5\%$

$\varepsilon_n \sim 20\ \mu rad$

Proton beams for cancer treatment

100m



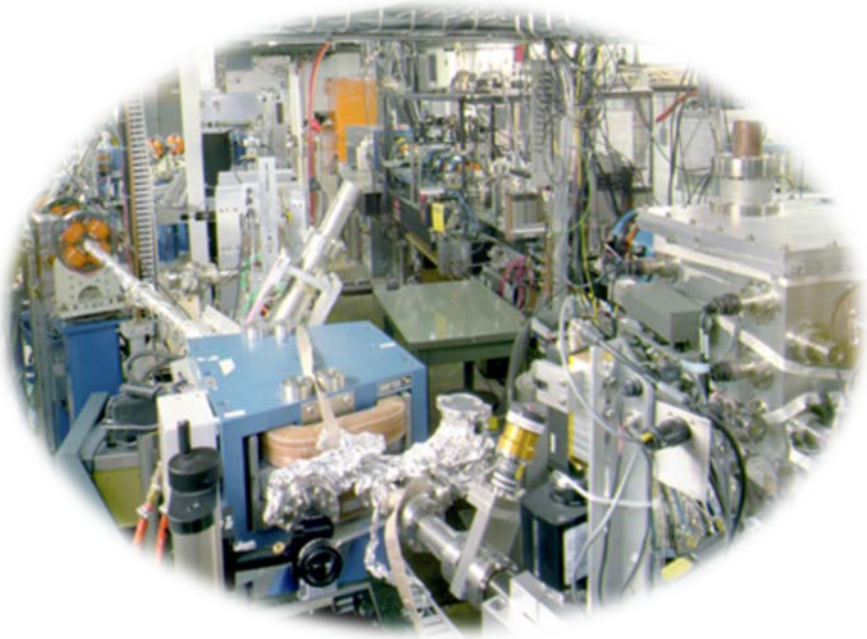


Over 100 M US$ for construction

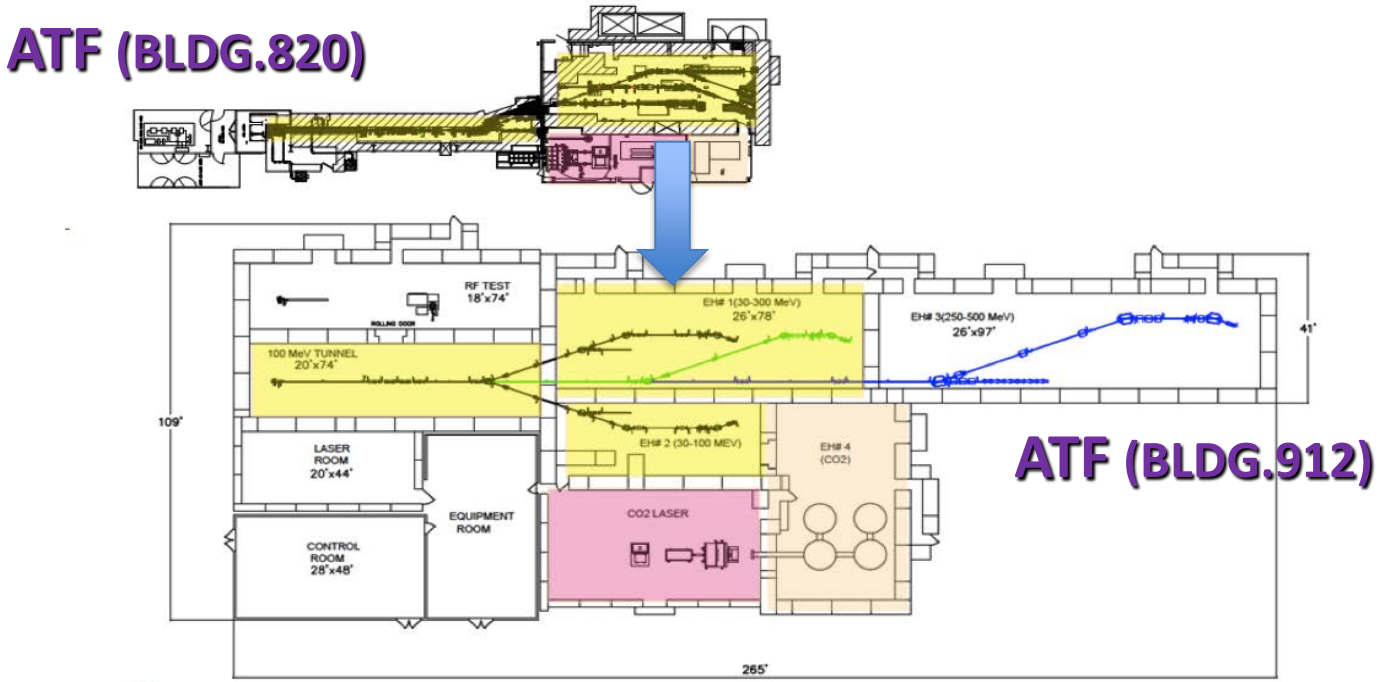
~10 M US$

Vision for the ATF

- *retain* its uniqueness and diverse program and *build* upon it
- *strengthen* the ATF in the innovative field of wakefield-based accelerator research and its applications
- *expand* its user base and *increase* its scientific impact

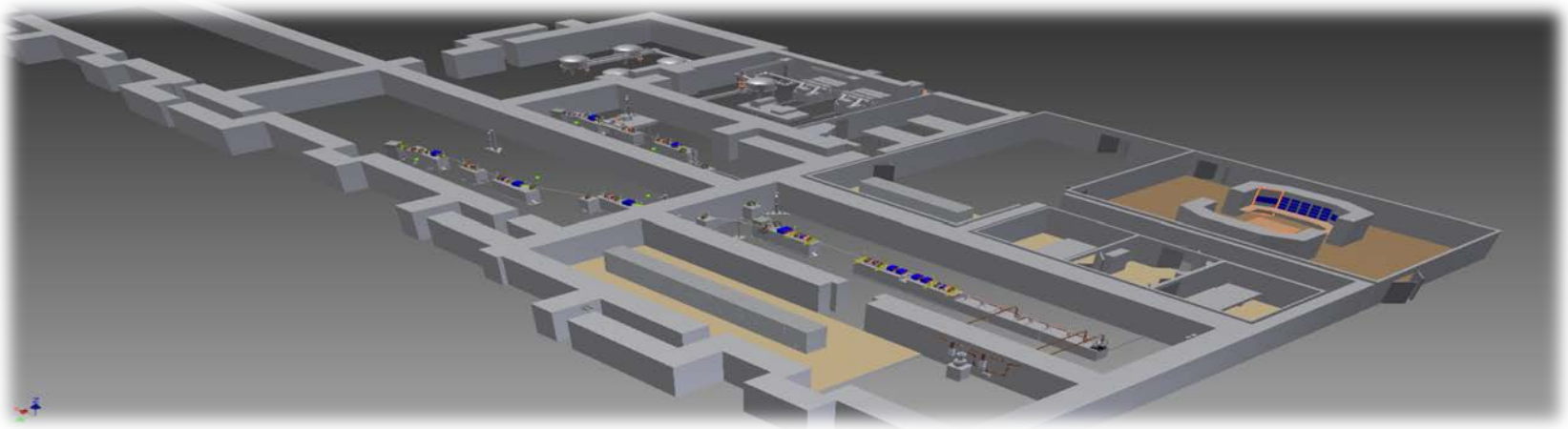


ATF will be upgraded to address these challenges


ATF (BLDG.820)
RF TEST
18'x74'
ROLLING DOOR
100 MeV TUNNEL
20'x74'
EH# 1(30-300 MeV)
26'x78'
EH# 3(250-500 MeV)
26'x97'
41'
109'
LASER
ROOM
20'x44'
EH# 2 (30-100 MEV)
EH# 4
(CO2)
ATF (BLDG.912)
EQUIPMENT
ROOM
CO2 LASER
CONTROL
ROOM
28'x48'
265'

ATF upgrade plan

E-beam energy	80 MeV	→	500 MeV
Laser peak power	1 TW	→	100 TW
Experimental halls	1	→	5
Shielded area		7×	
Total floor		3×	



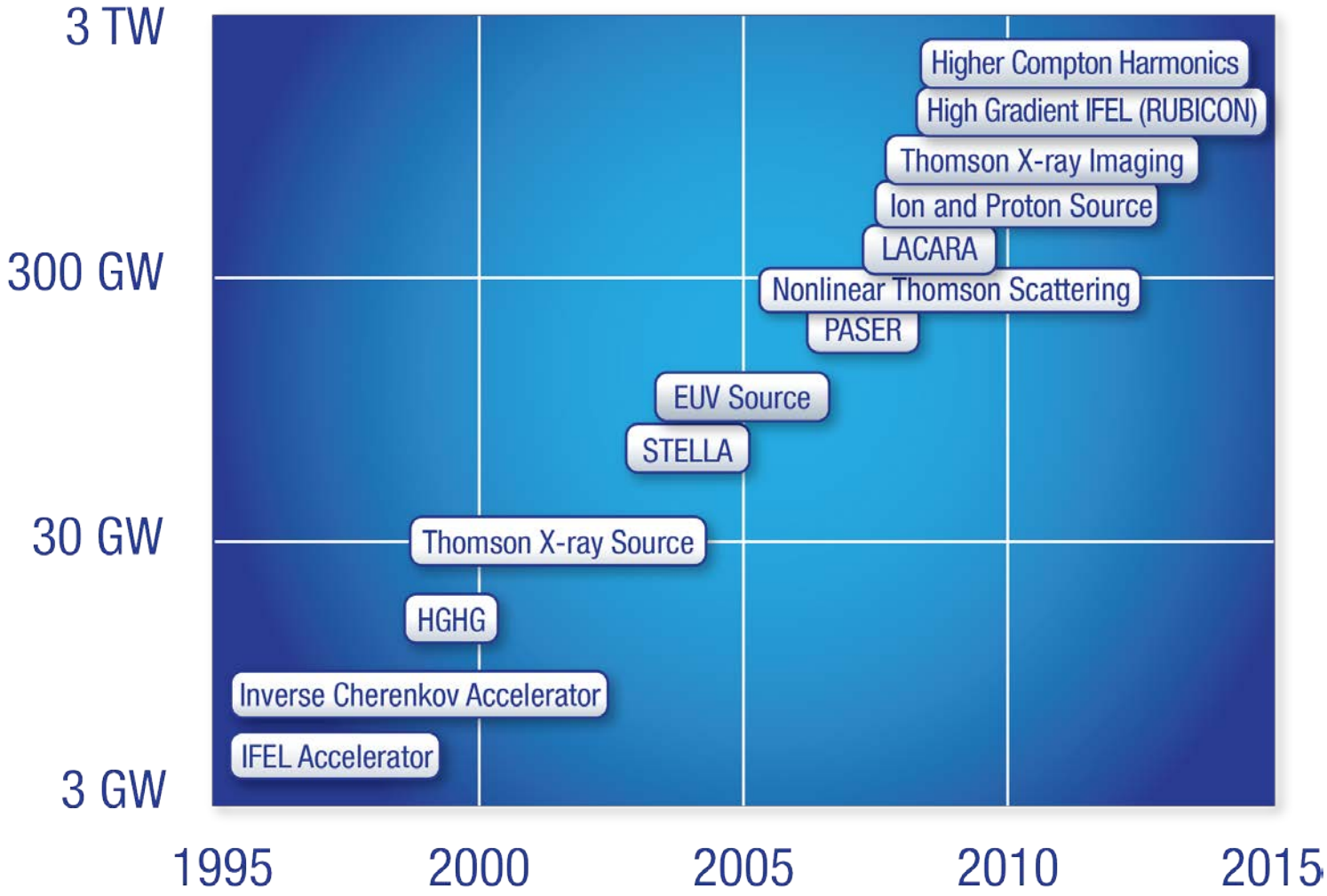
Upgrading the ATF for plasma wakefield studies

- exciting strong plasma wakefields requires
  - *short driver bunch* lengths < plasma wavelength
  - *high currents* to excite nonlinear plasma wakes
  - *low emittance* for focusability
- space charge forces and coherent synchrotron radiation to cause transverse emittance growth, limit beam compression $F_{sc} \propto \frac{1}{\gamma^2}$
- 80 MeV ATF has demonstrated peak currents of 1.5 kA at ~100 fs bunch duration, on the verge to drive nonlinear wakefields
- beams may be further compressed while preserving quality at higher energies
- propose energy upgrade to 500 MeV and additional bunch compressor for beams with durations ≪ 100 fs and increased current > 1.5 kA

  → *allows for driving strong plasma wakes into the non-linear regime with beams accelerated to ~1 GeV at $n_e = 10^{17}$ cm^{-3} plasma density*

- quality of accelerated beams strongly linked to control over initial population of wake-phase space at injection
- in-plasma injection at ~10 GV/m field strength may be explored at ATF

History of ATF user experiments enabled by continuing CO_2 laser power upgrade



CO_2 laser upgrade Path

Peak power improvement up to 100×

100 TW
10 J, 100 fs

25 TW
50 J, 2 ps

5 TW
10 J, 2 ps

2.5 TW
5 J, 2 ps

1 TW
5 J, 5 ps

2017

Nonlinear compression

2nd power amplifier

Large-aperture regenerative amplifier

Chirped-pulse amplification

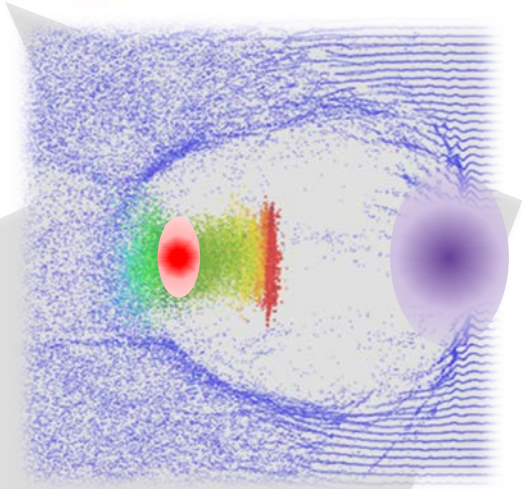
Solid-state, μJ seed

2013

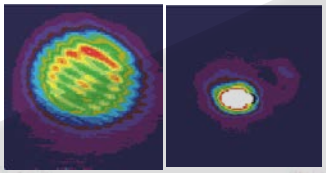
...through series of upgrades

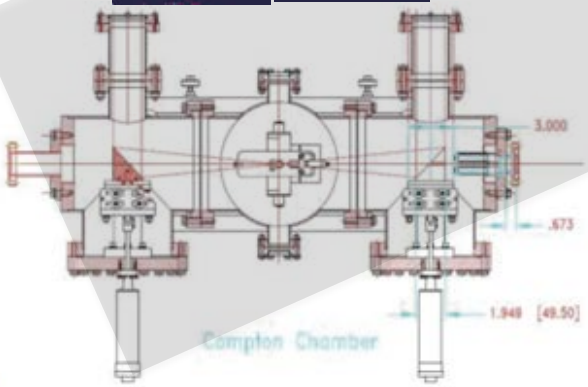
LWFA research

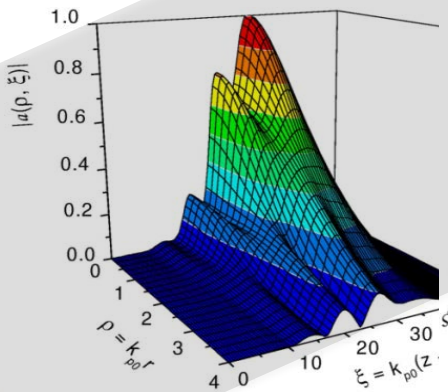
Future 100 TW –
Bubble LWFA
20 GeV/m
16 nC



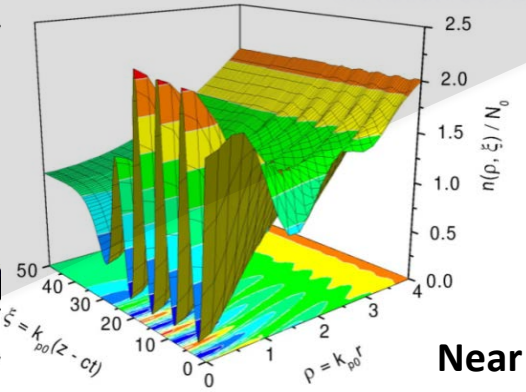
Past –
Plasma source,
CO_2 laser channeling







Laser pulse



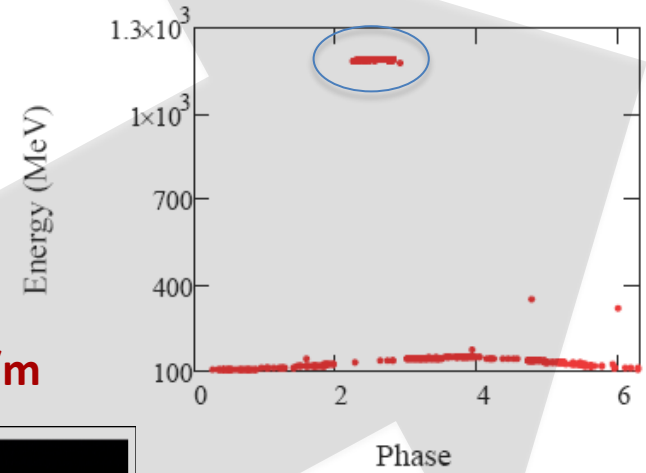
Wake field

Near future –
Self-modulated LWFA
with external injection,
> 1 GeV/m
@ 2.5 TW, 2 ps

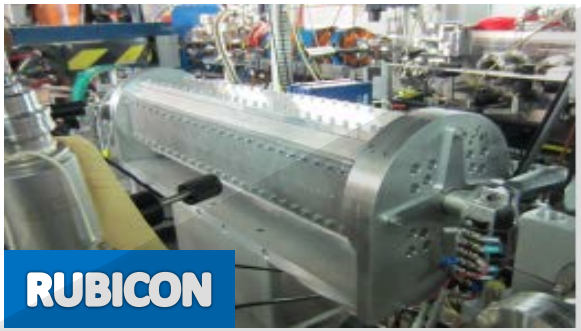
IFEL research

Future –
Record-high gradient for vacuum accelerators

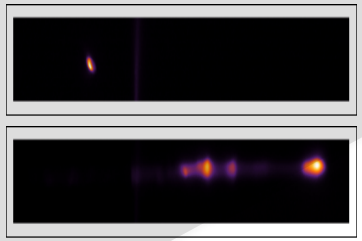
1 GeV/m @ 100 TW



Present –
record for IFELs energy gain and acceleration gradient

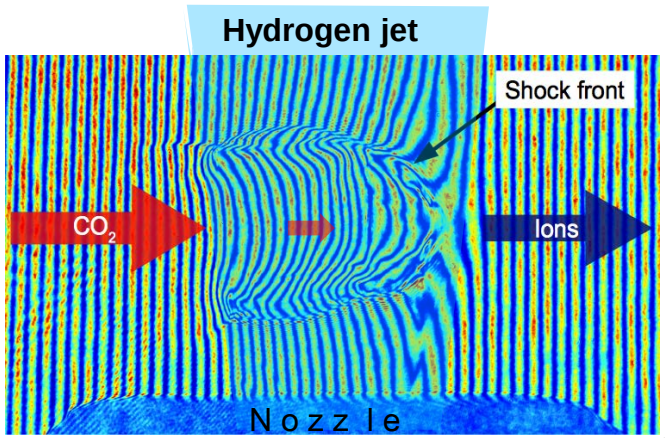


100 MeV/m

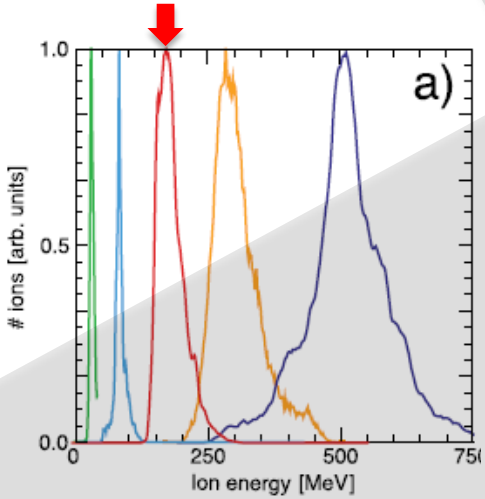


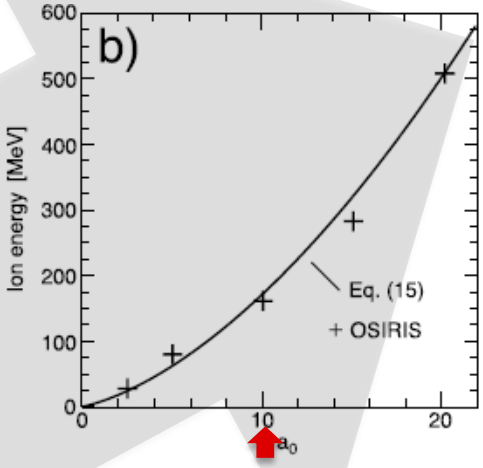
Past –
first staged monoenergetic laser accelerator

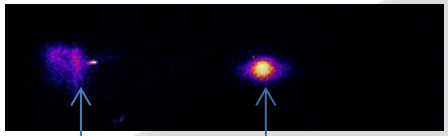
Shock Wave Proton Acceleration



Laser-induced electrostatic shock reflects protons upon its propagation through the ionized H_2 jet.



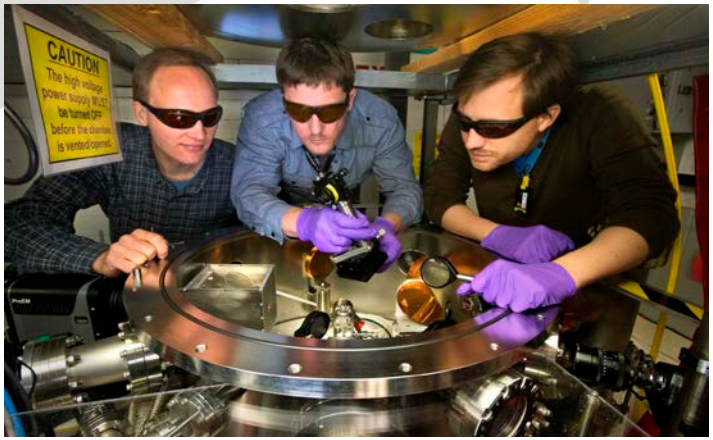




(light or neutrals)

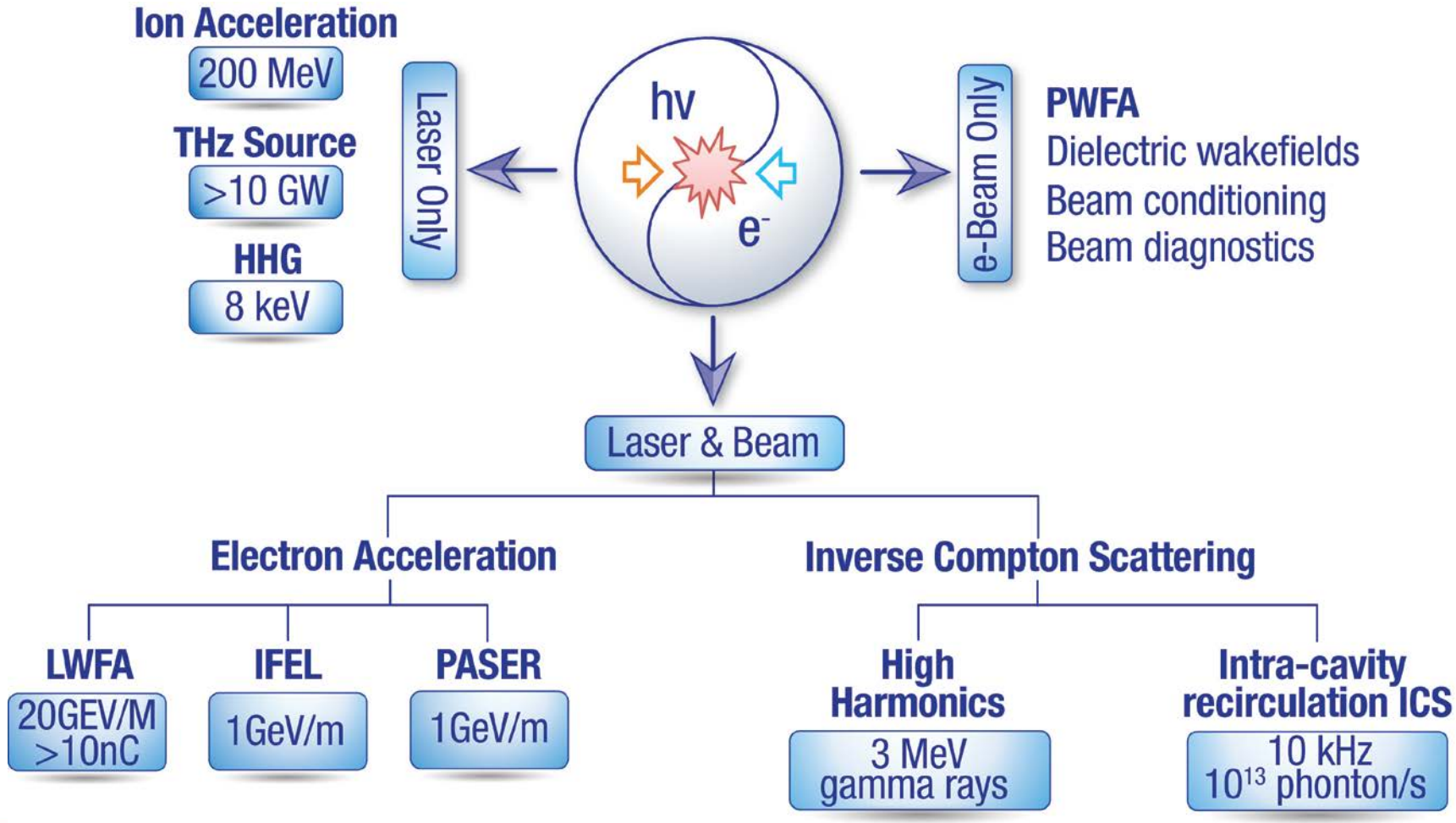
1.7 MeV protons

$$E_p \propto I/n_{cr}$$



- Energy spread 10%
- Spectral brightness 10^{12} proton/MeV/str
- Proton energy up to 3.2 MeV

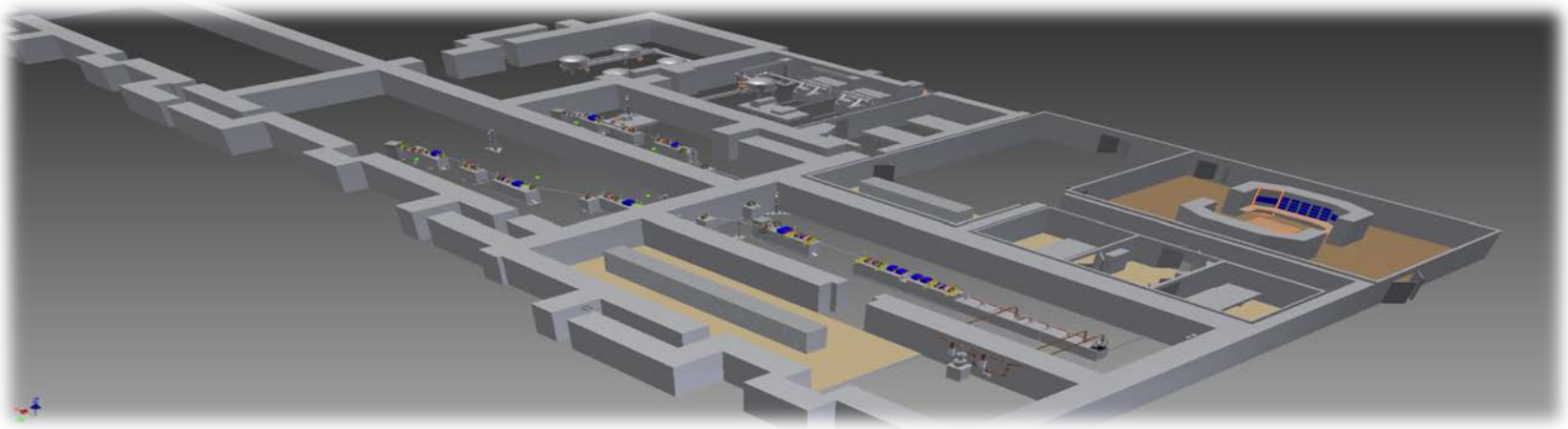
ATF upgrade opens up many new science opportunities



ATF vision

Providing users with research opportunities :

- not available elsewhere,
- at the cutting edge of strong-field physics and advanced accelerator science,
- with diverse coverage of multiple DOE missions in accelerator R&D and stewardship.



Accelerator Test Facility

BROOKHAVEN NATIONAL LABORATORY *Accelerator Test Facility* U.S. DEPARTMENT OF ENERGY

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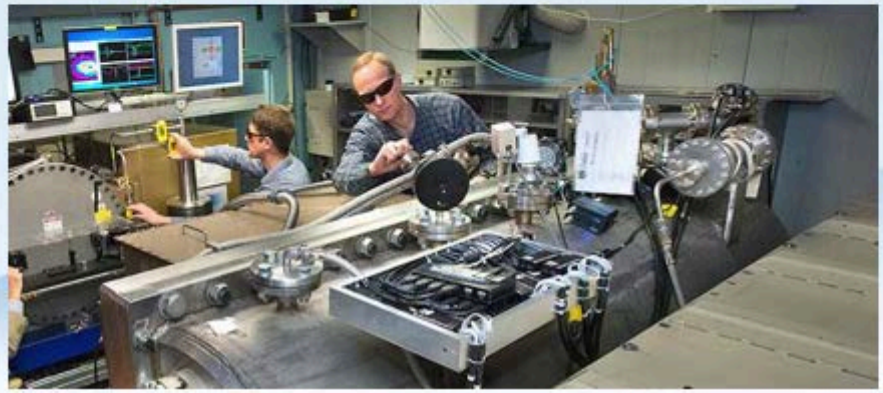

A user facility for the advancement of laser and accelerator physics

The Accelerator Test Facility provides experimenters with the equipment necessary for the advancement of accelerator technologies, with a view to develop smaller machines and more cost-effective methods of particle acceleration.

> Contact Us

Electron/Laser Facility

The ATF provides a very high brightness electron beam to four beam lines, synchronized with high-power lasers. The electrons are produced by a photoinjector, whose photocathode is illuminated by a frequency quadrupled solid-state laser. Two S-band linear accelerator sections accelerate the electrons. The beam can be manipulated in the transport line to deliver it to one of several targets in the experimental hall. There are more than 40 quadrupoles along four transport lines to tailor the beam to particular experiments. More than 50 high-resolution profile monitors measure the beam's particle distribution.

CO_2 Laser

ATF's carbon dioxide laser is the only tera-watt

Experimental Work

Plasma Wakefield Acceleration is a method for accelerating particle beams over much shorter distances than traditional accelerators. An electron bunch travelling through a plasma creates wakefields through which subsequent electron bunches may be accelerated at a high gradient. This technique produces more compact, more energy-efficient high-energy particle beams.

Medical Imaging. Interaction of the ATF electron beam with the CO_2 laser is a viable source of fast x-rays with wavelengths on the scale of pico- or femtoseconds. These x-rays have uses in ultrafast imaging, positron production, and many other applications.

Ion Generation. MeV proton beams generated by

ATF Newsletter (PDF), Fall 2013

ATF Experiments

Active | Completed / Terminated

Updates from ATF

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Newsletter sneak peek: Experimental demonstration of a tunable de-chirper.
Expand

ATF @ATFatBNL 24 Sep

Thank you
for your attention