FOCUSED ENERGY

Pioneering Laser Fusion Energy

Prof. Dr. Markus Roth, Chief Science Officer

Berlin
June, 2023

Focused Energy is the leading laser fusion company on both sides of the atlantic

A US-German Deep-Tec Startup assembling the best scientists of both sides of the Atlantic

- Strongly supported by the US and EU IFE community
- Peer reviewed scheme accepted and based on >20 years of experiments and theory
- Best science team of all IFE startups
- Award winning: 2 INFUSE proposals
- Chosen by the DOE Public Private Partership Program (PPP) of the Biden Administration
- Chosen as partner of two OFES IFE centers of excellence (IFE hub) in the US

A trans-atlantic bridge to hire the best people on both sides

- Founded in July 2021
- Offices in Austin, Texas and Darmstadt, Hessen.
- Unique laser-fusion approach, extending the breakthrough results to IFE using the **direct-drive proton-fast-ignition** scheme

Compared to other IFE Startups

FOCUSED ENERGY

Focused Energy (direct-drive proton fast ignition):

- ✓ Science directly supported by NIF result (same fuel, same burn propagation)
- ✓ >24 years of int. research on PFI
- ✓ Laser technology demonstrated
- ✓ Clear path to target technology
- ✓ Power plant conceptual design study

Xcimer Fusion (KrF, indirect drive hot spot ignition):

- ✓ Science directly supported by NIF result (same fuel, same burn propagation)
- ✓ >40 years of int. research in ICF
- – Laser technology unproven, high risk
- – No clear path to high-gain targets / proliferation
- ✓ Power plant conceptual design study with large targets

Longview Fusion (indirect drive hot spot ignition):

- ✓ Science directly supported by NIF result (same fuel, same mechnaism, same burn propagation)
- ✓ >40 years of int. research in ICF
- ✓ Laser technology demonstrated
- – No clear path to high-gain targets / proliferation
- ✓ Power plant conceptual design study

Marvel Fusion (non-thermal ignition of pB11):

- – Science different from NIF result (different fuel, different mechanism)
- – No peer reviewed documents on mechanism
- – Laser technology unproven, high risk
- – Exawatt laser absorber targets
- – Power plant parameters extreme (DDFIW 2023)

We assembled the most renowned IFE Team in private Industry

FOCUSED ENERGY

>1850 peer reviewed publications on the concept

BOARD

Chief Executive Officer
Thomas Forner
- 20+ years experience as CEO/CFO
- Expert in developing and leading of international High-Tec companies

Chief Science Officer
Prof. Dr. Markus Roth
- Professor TU Darmstadt, GER
- APS – Fellow, Rosen Award
- Founder of the IC for Nuclear Photonics
- 25+ years in fusion research
- Invented the Proton Fast Ignition Concept

Dr. William Goldstein
- Lawrence Livermore National Laboratory
- Director Emertius

Dakin Sloss
- Prime Movers Lab Partner
- Deep-Tec Lead Investor

STAC

Prof. Riccardo Betti
- University of Rochester
- Leading expert for direct-drive fusion

Dr. Juan Carlos Fernandez
- Los Alamos National Laboratory
- >20 years of leading plasma and fusion as group leader at LANL
- Expert in Fast Ignition and ion acceleration

Dr. Kurt Schoenberg
- Los Alamos Neutron Science Center
- Director Emertius
- >35 years of experience leading large science infrastructures

Prof. Vladimir Tikhonchuk
- University of Bordeaux, France and ELI Beamlines, Czech Republic
- Expert for theory in laser- and plasma physics

IFE EXPERTS

Leading IFE experts have quit their positions in National Laboratories and Universities to join FE

Dr. Pravesh Patel
- NIF ICF Program Element Lead
- Lead of the LLNL Fast Ignition Program

Dr. Debbie Callahan
- 35 years at LLNL
  Group leader Target design
- Co-leader of ignition campaign
- 2012 Dawson Price

Dr. Wolfgang Theobald
- Leading expert on direct drive experiments at LLE / OMEGA laser
- Expert in Fast Ignition experiments

Prof. Dr. Stefano Atzeni
- Professor at the LaSapienza University, Rome, Italy
- The theory expert in IFE

Prof. Dr. Paul Gibbon
- Professor and Director theory at Forschungszentrum Jülich
- Expert in laser-plasma Interaction

Prof. Dr. Javier Honrubia
- Professor at Politechnica Madrid Spain
- Leading expert in fast ignition simulations

Dr. Charlie Jarrott
- Simulation and Modeling expert at LLNL
- Expert in integrated experiment simulations

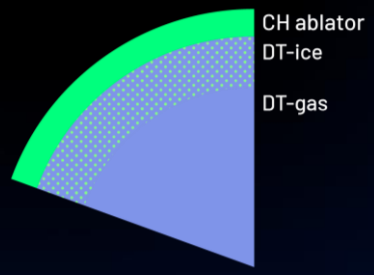
Dr. Cris W. Barnes
- Lead of the LANL-physics programs
- Expert in nuclear and plasma physics

(9/23)

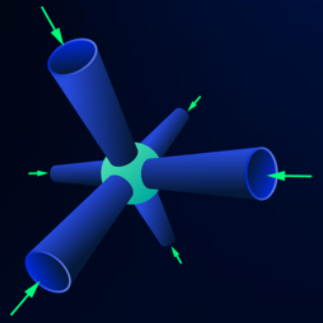
Prof. Dr. Jose Manuel Perlado
- Professor and Director Insituto Fusion Nucleaire at Politechnica Madrid, Spain
- Expert in reactor structural materials and activation

Inertial Fusion is a pulsed, high-density path to Fusion Energy

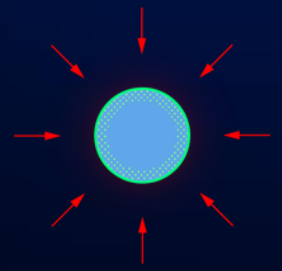
Fusion is when light nuclei are merged into heavier nuclei which results in **large releases of energy**.



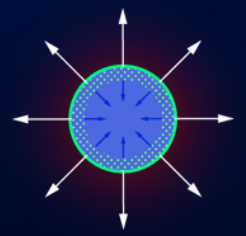
Fuel cell



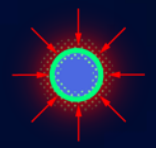
Direct Drive Lasers



1 Absorption and heat transport



2 Acceleration and rocket effect



3 Deceleration and compression

4 Ignition and fusion burn

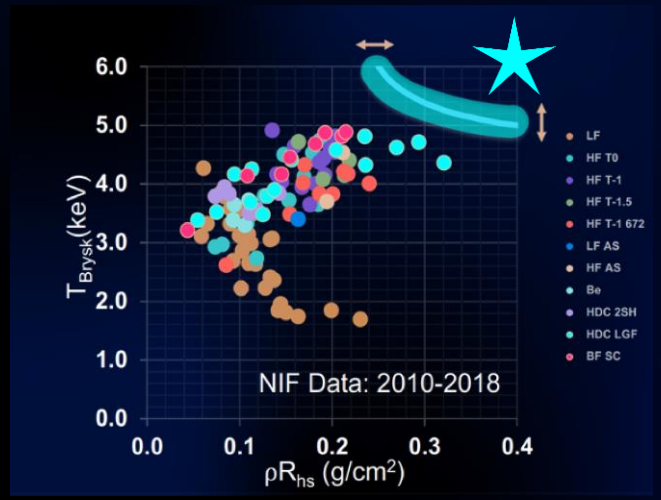
Compression

December 6th, 2022

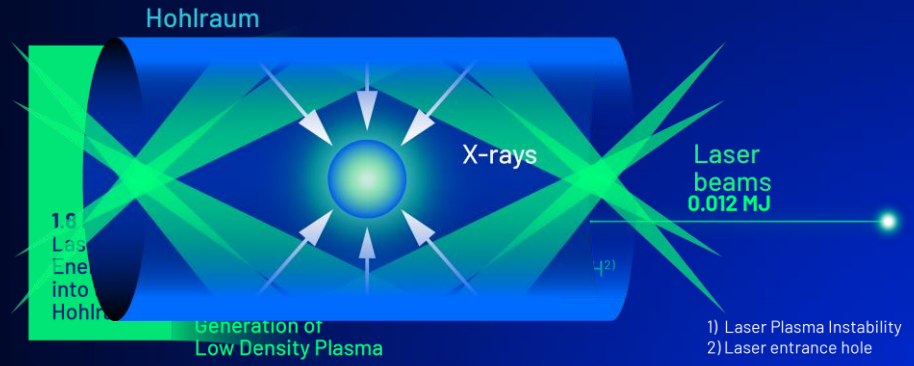
Singular scientific event that changed commercial viability of IFE

> 3 MJ of fusion yield was produced

150% Scientific target gain

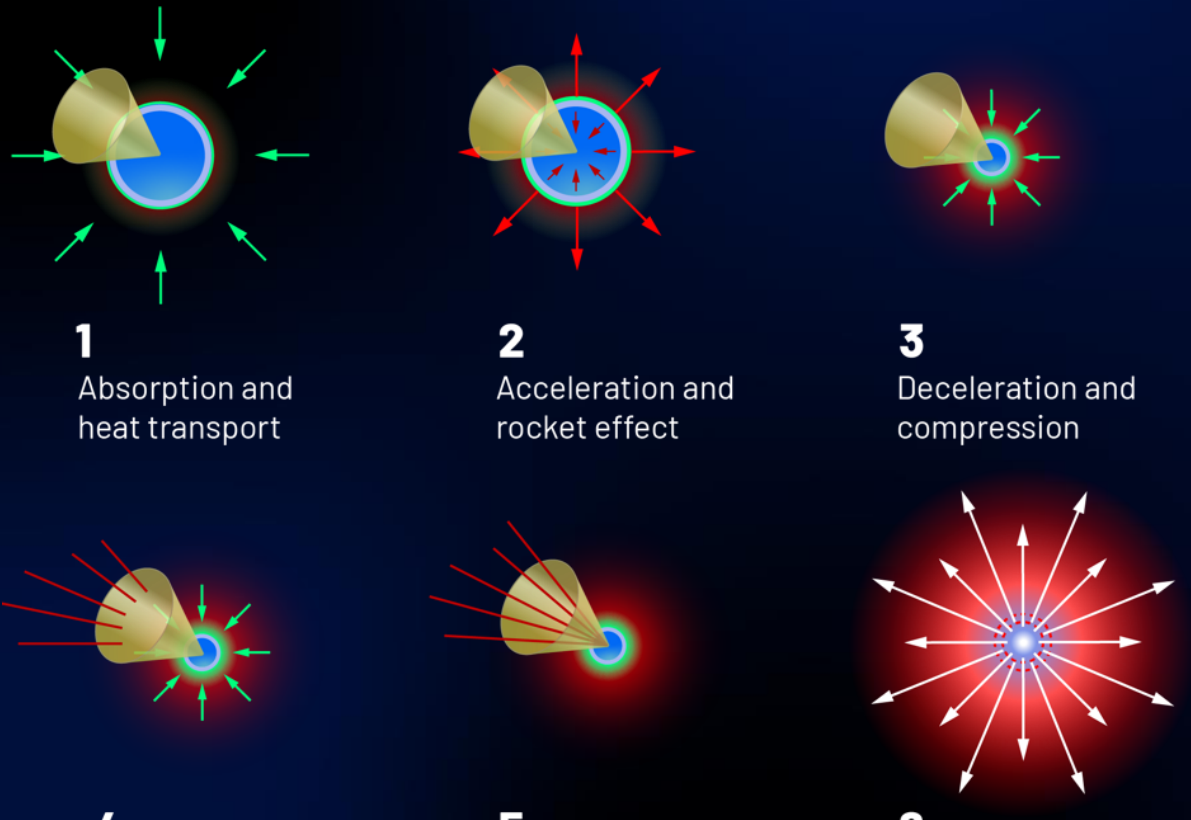


Losses due to Indirect drive



We took IFE to a new level

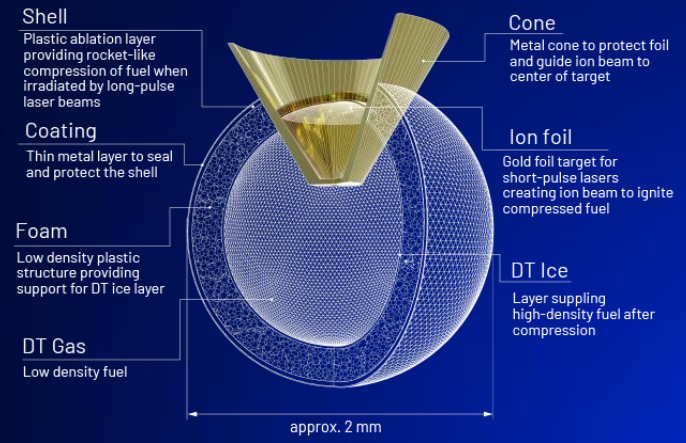
... by combining direct-drive laser fuel compression with **proton fast ignition**



WHAT DOES THIS MEAN?

A commercially viable path to harvest energy

- Better energy coupling
- Applicable to fusion energy
- Uses higher efficiency green light
- Less sensitive to instabilities
- Higher fusion gain
- Capsule protection in a power plant



Direct-drive**, Proton Fast Ignition** using a cone-guided capsule

Comparison NIF <> Focused Energy

We are aiming at a laser energy output of 0.9 MJ for QUASAR, our FOAK Fusion power plant.

Modern lasers are at least 10% efficient. Therefore, we just need 9 MJ of laser energy input.

NATIONAL IGNITION FACILITY → QUASAR

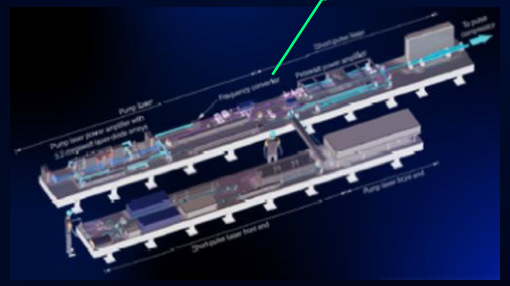
COMPANY	NATIONAL IGNITION FACILITY	INCREASE OF EFFICIENCY	QUASAR
Laser Electrical Energy Input	400 MJ	20x: Laser Efficiency >10%	9 MJ (due to diode pumped lasers efficiency)
Laser Energy Output	2 MJ	150 KJ Ignition Laser 750 kJ compression laser	0.9 MJ
Conversion X-Rays	0.2 MJ		
Burn Fraction of DT Fuel	2%	10x: better burn of fuel due to better assembly and fast ignition	20%
Energy Output	3.1 MJ G=1.5 (Laser gain) G=0.008 (Electrical to Fusion)		165 MJ G=180 (laser gain) G= 20 (Electrical to Fusion)

Right time for laser fusion

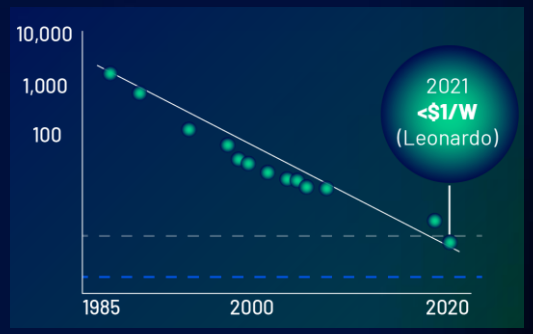
Breakthrough in laser technology

Laser with 10 Hz repetition rate, high energy and wall-plug efficiency have been developed in recent years

100 J pulsed laser with 10 Hz
HAPL, DIPOLE, Mercury



Multi-PW lasers have now been built and can be commercially obtained

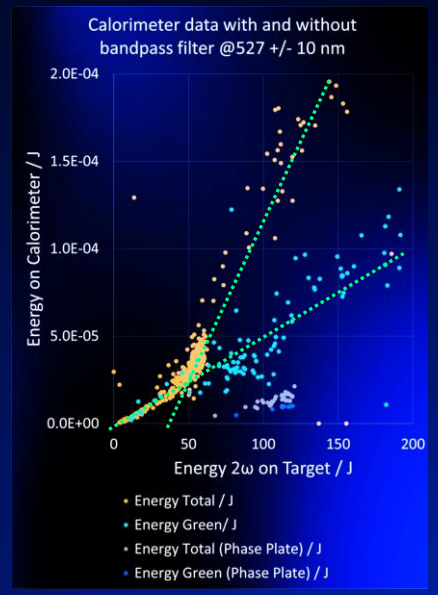


Cost for laser diodes dropped to $0.4/W
< $0.05/W is expected

New target technology production methods will lead to mass fabrication
Cost will come down significantly

Test facilities will lead to >100 experiments a day

Rapid progress due to machine learning based on real physics data

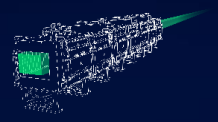


New test facilities could be operational by 2026 (T-STAR)

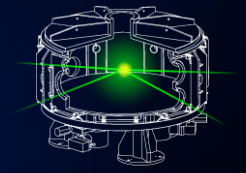
Focused Energy builds upon apon a scaled approach to Fusion Energy

We are targeting a LCOE < 40 $/MWh due to lower CAPEX and operating cost

Existing Infrastructure → Physics De-risk → Ignition Optimization → FOAK Power plant → FPP Roll-Out

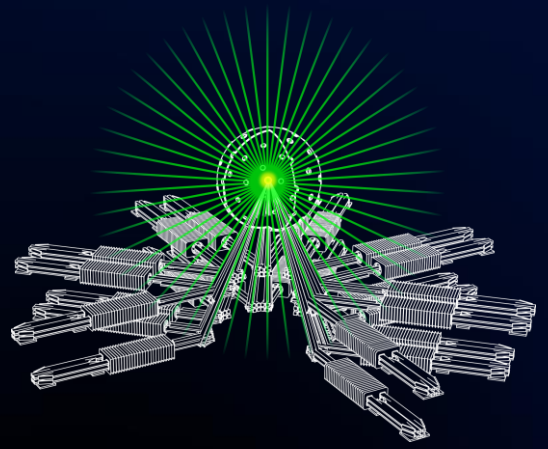


L4-LASER



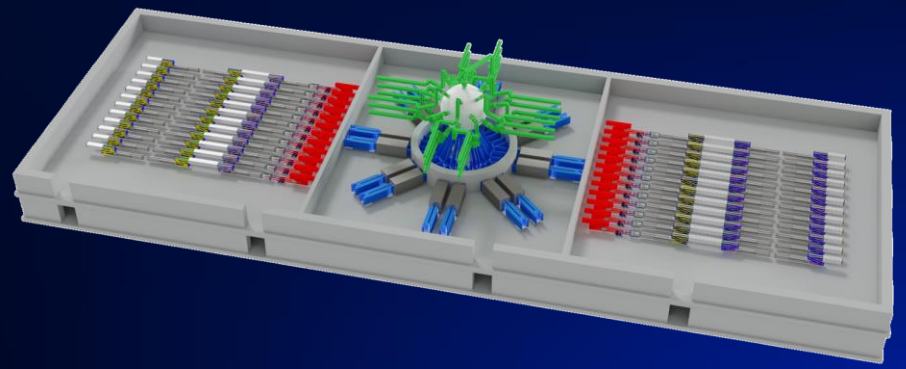
T-STAR

8 laser lines



SUPER-NOVA

200 laser lines



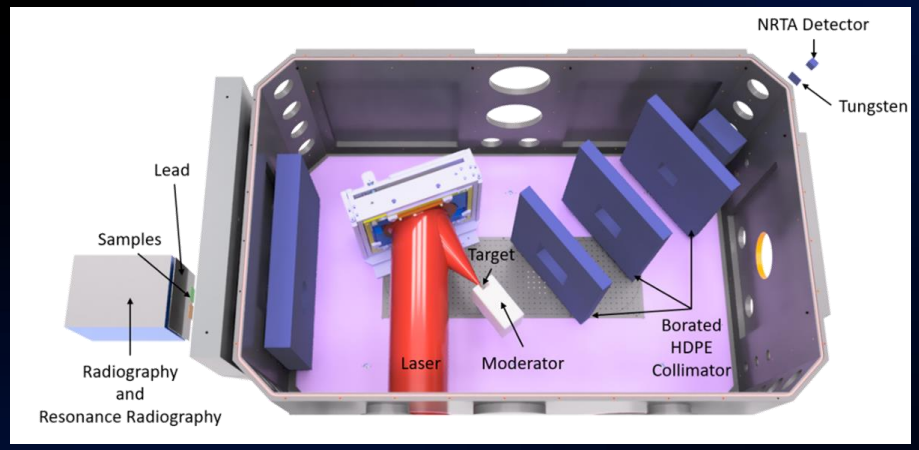
QUASAR

600 laser lines

Spin-off technologies will address societal needs and generate revenue

FOCUSED ENERGY

High-power lasers and specialized targets will
Result in utlra-bright radiation sources

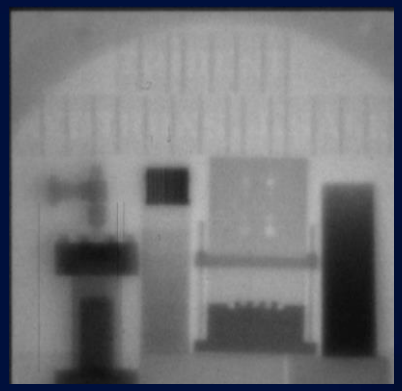


Experiments at the PHELIX laser (GSI- Darmstadt)

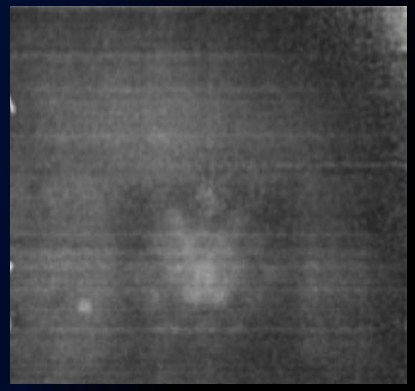
Hard X-ray
radiography

Laser-driven image: through 3cm of aluminum, <1ns exposure

Neutron radiography (TRIDENT laser LANL)



LDRS (< 1ns)



Plasma tube (> 15min)

Interest from potential customers:

Fraunhofer LBF

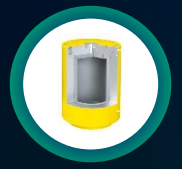
Test Hydrogen embrittlement and fuel cells

GNS HLNUG

Characterizing nuclear waste

AIRBUS

CFK testing
H-storage and
leakage

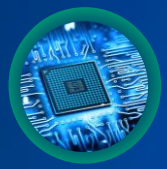


RWE

Zertifizierung von befüllten Nuklearcontainern

thyssenkrupp

Certify welds in ships and submarines



intel

Radiation hardening of electronic components

Focused Energy
INDUSTRY EcoSystem

INDUSTRY PARTNER

LEONARDO
TRUMPF
Plymouth Grating LABORATORY
ZEISS
Heraeus
SCHOTT

EU RESEARCH LABS

eli
GSI
TECHNISCHE UNIVERSITÄT DARMSTADT
UNIVERSIDAD POLITÉCNICA MADRID

INTL RESEARCH LABS

Lawrence Livermore National Laboratory
Los Alamos NATIONAL LABORATORY
SRNL SAVANNAH RIVER NATIONAL LABORATORY
OAK RIDGE National Laboratory

Thank you

Markus Roth
Chief Science Officer
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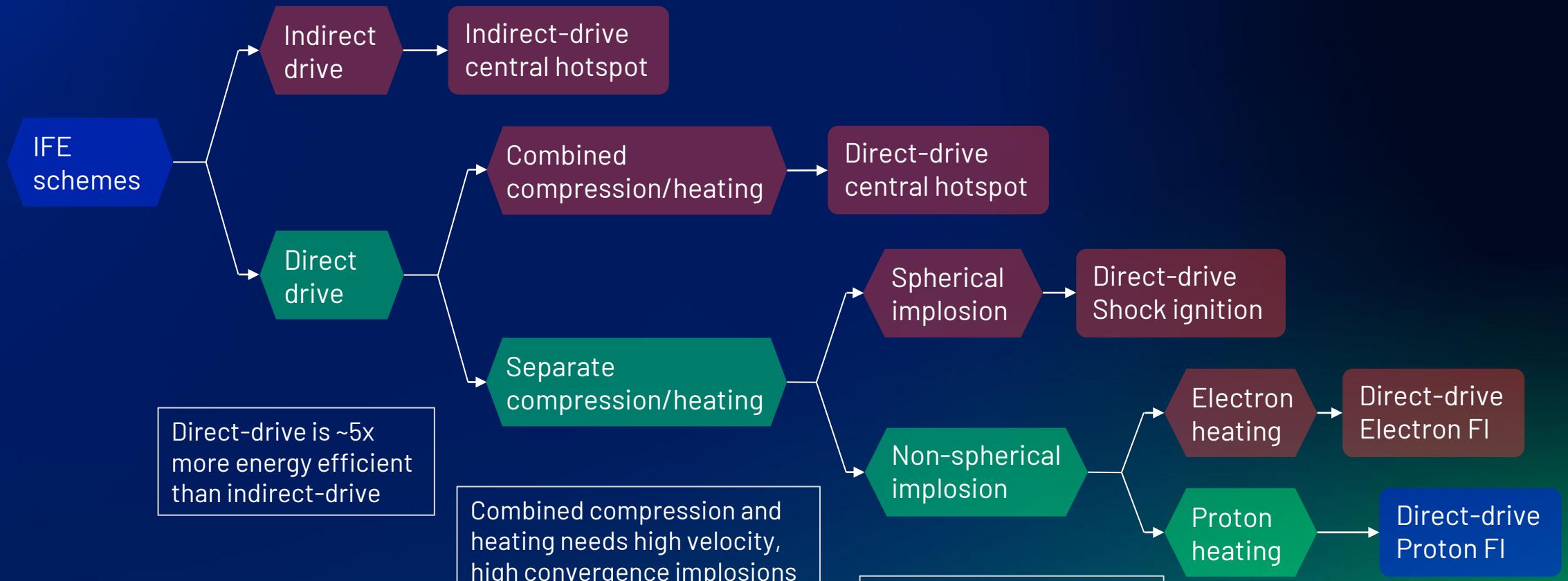
FE has taken a thorough down-select on the fusion scheme



Direct-drive is ~5x more energy efficient than indirect-drive

Combined compression and heating needs high velocity, high convergence implosions

Separate phases allows for lower implosion velocity and thus higher mass and yield

Spherical implosions demand very high symmetry requirements on laser and target – hard to make *robust*

Proton acceleration is robust, well understood physics, protons can be focused to small volume