Focus: High Power/Intensity
View on future accelerators/concepts

G. Franchetti, GSI

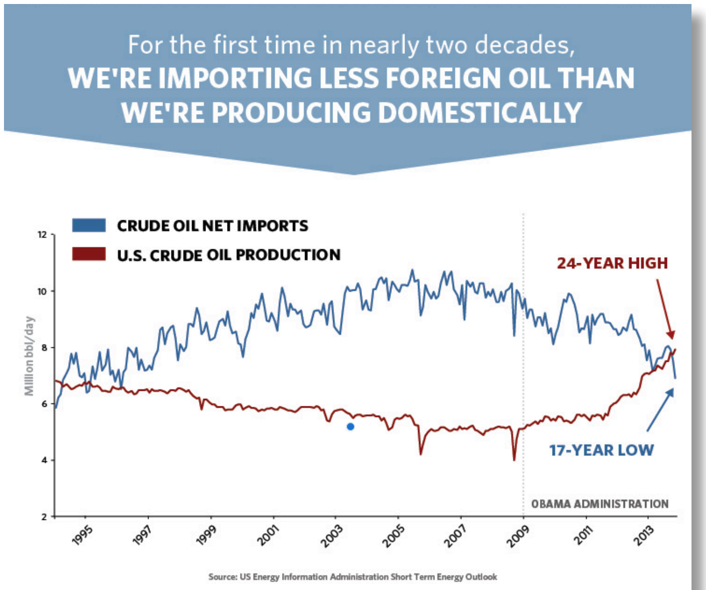
F3iA 2016, 5-9 December 2016

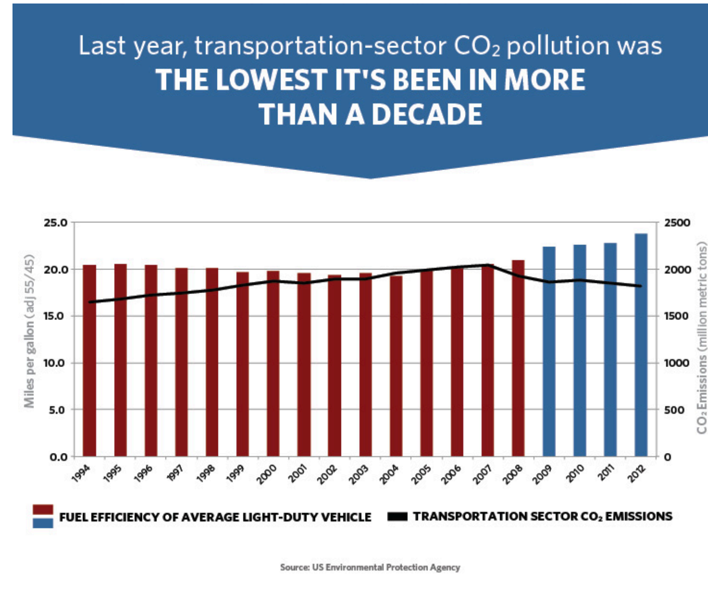
Views

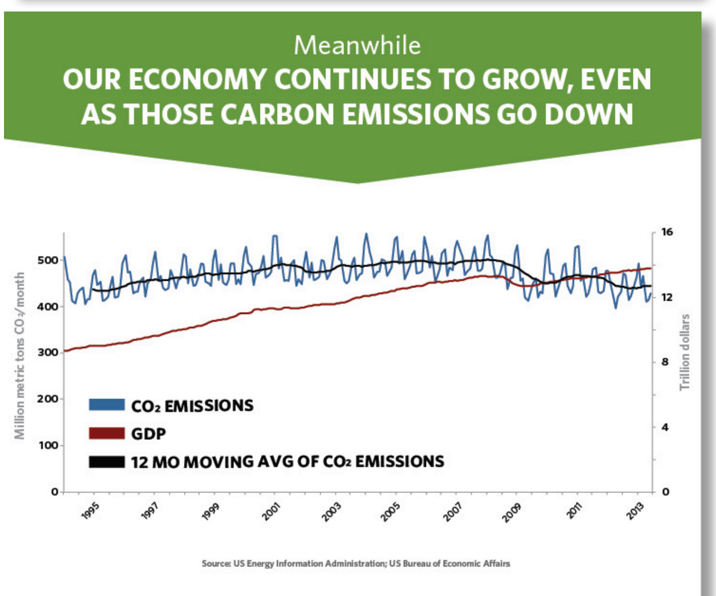
- Need for high intensity in the future: a global view, the energy issue

- Present Trends for the future

News from USA





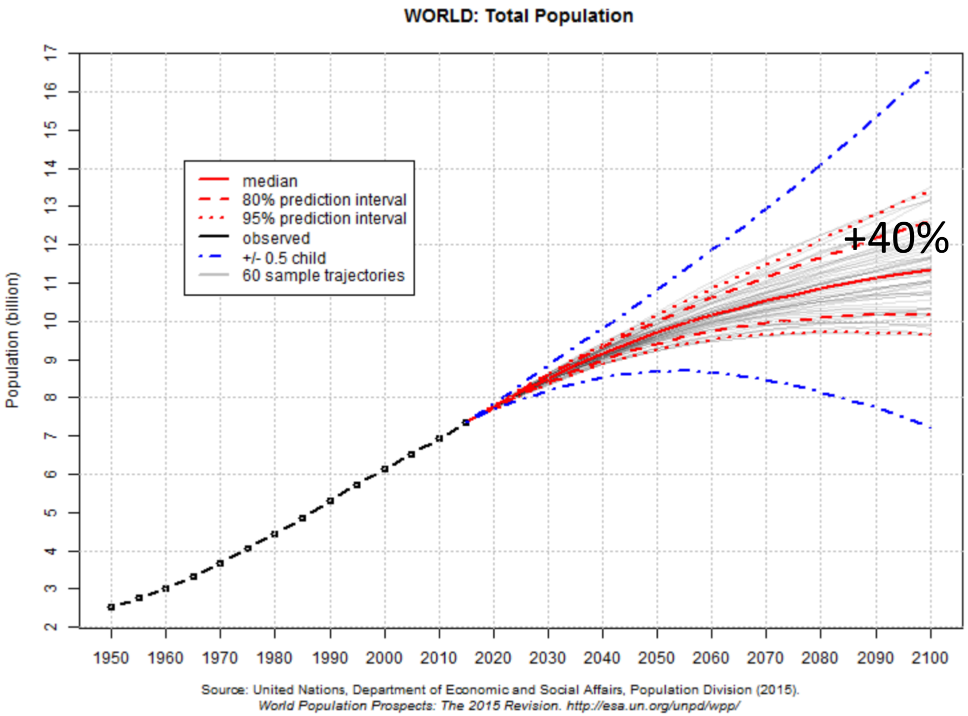


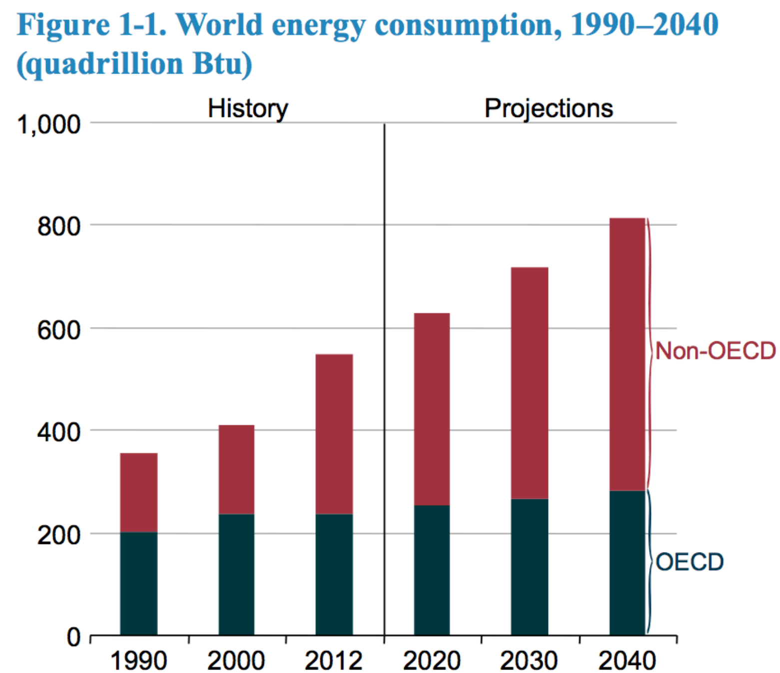
Source "The White House"

US seems to keep oil consumption constant, but GPD continue to grow.

→ Oil consumption will eventually grow and CO2 emission

Trends & Needs





DOE/EIA-0484(2016)

U.S. Information Administration (EIA)

OECD includes all members of the organization as of January 1, 2016, throughout all the time series included in this report. OECD member countries as of January 1, 2016, were Austria, Australia, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

Energy use: projections

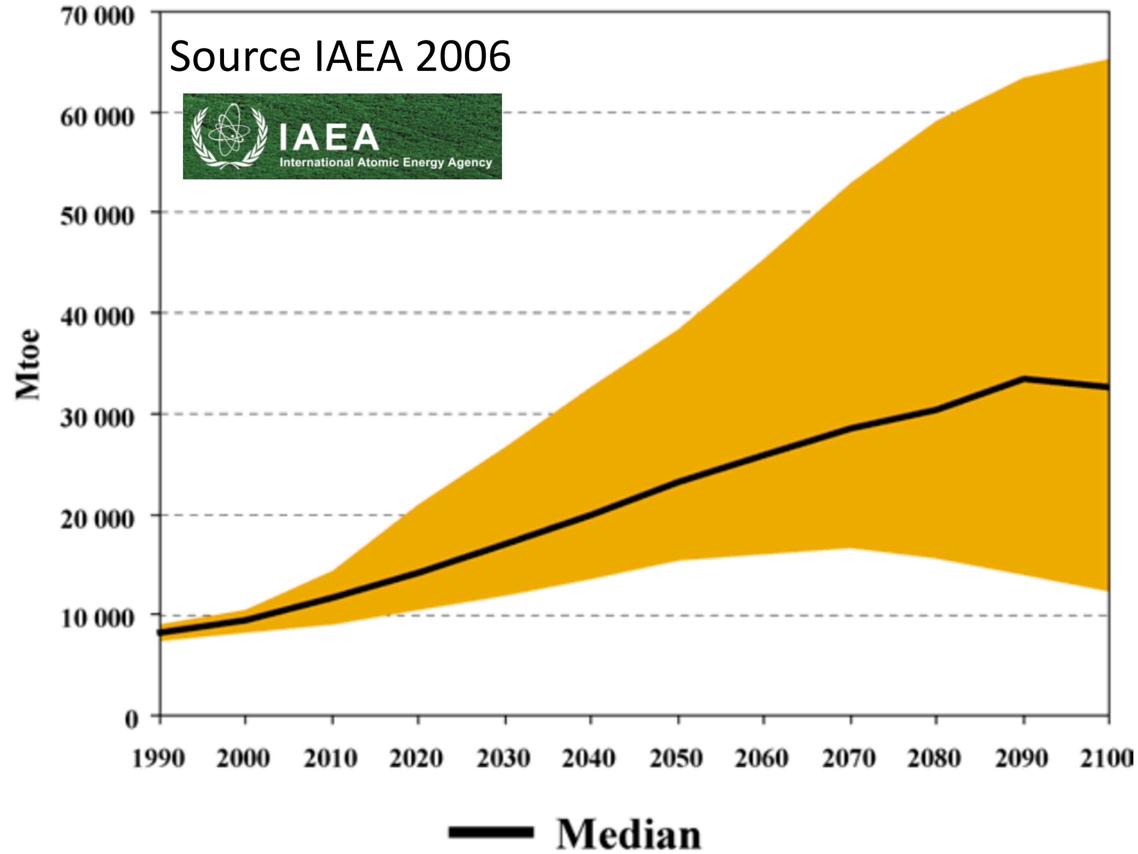
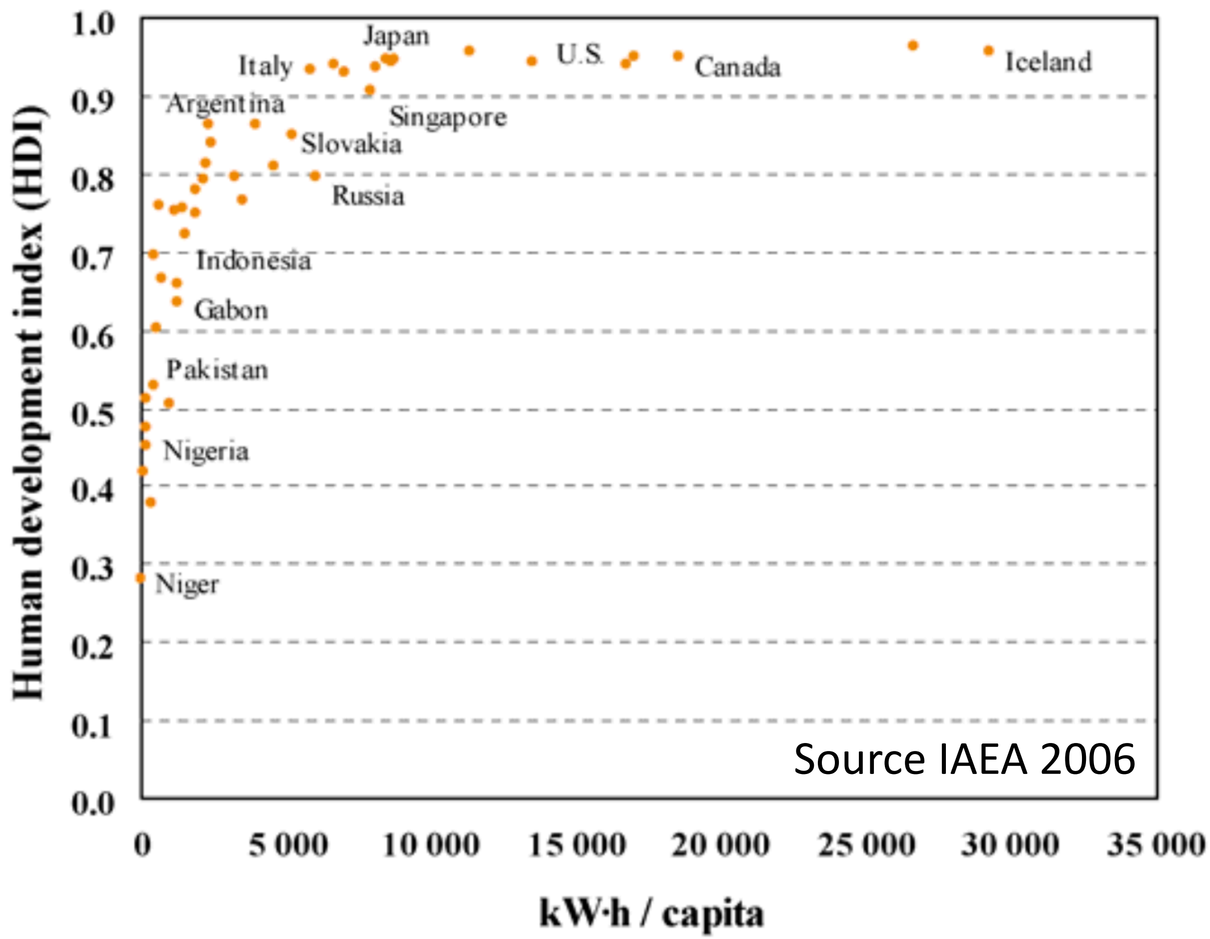


FIG. 6. Projected global primary energy use through 2100 in 40 IPCC SRES scenarios (adapted from IPCC (2000)).

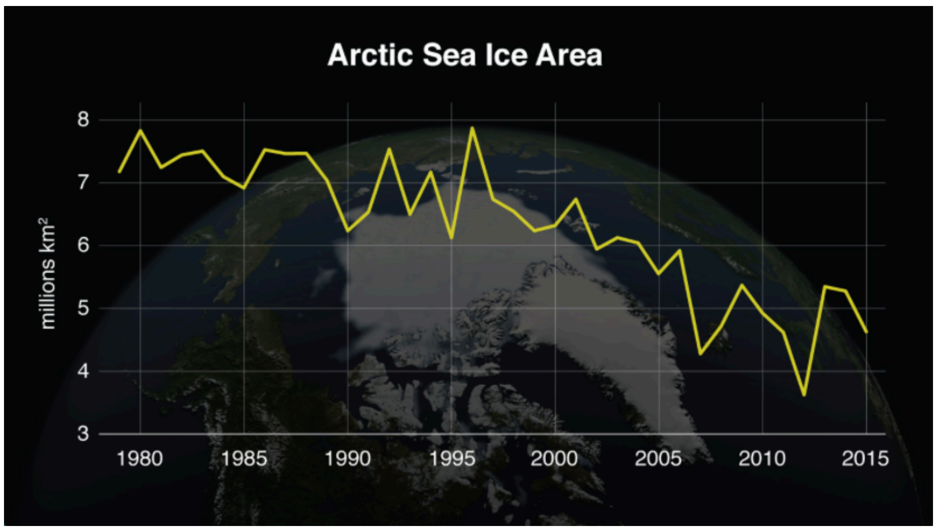
Development = Energy Availability



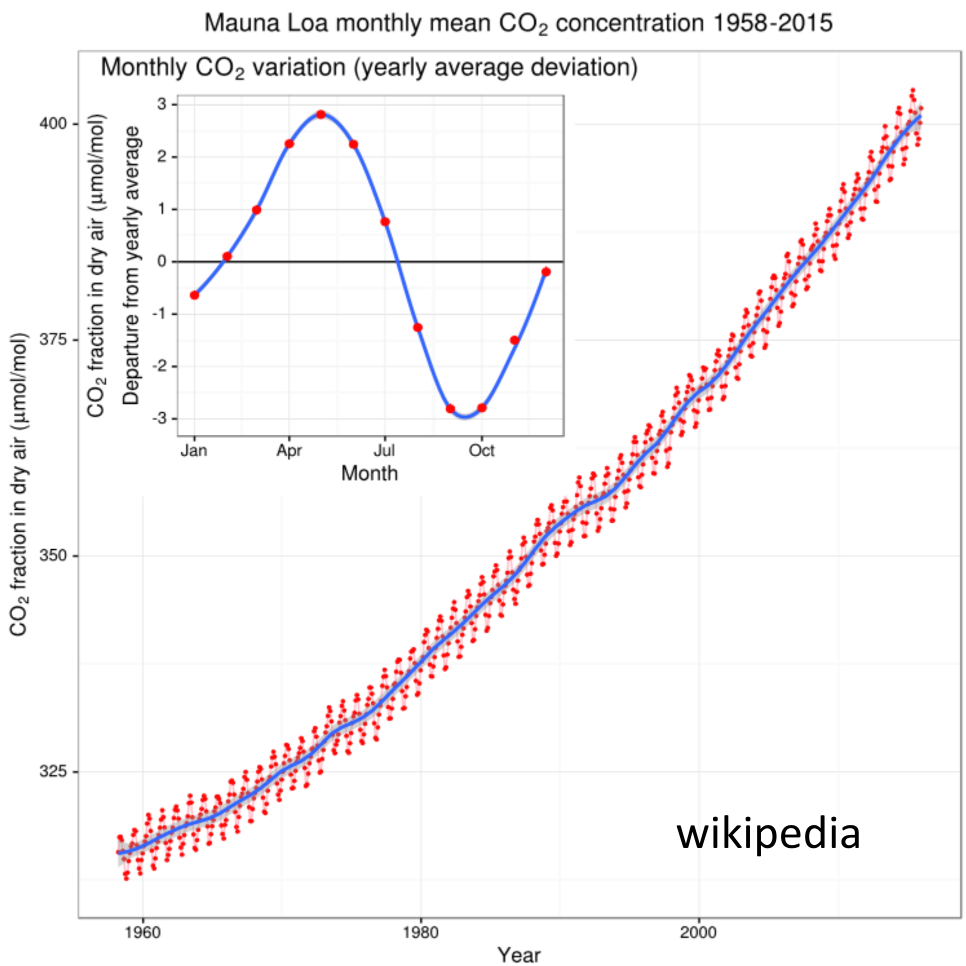
Climate change

WCRP
World Climate Research Programme

Source NASA

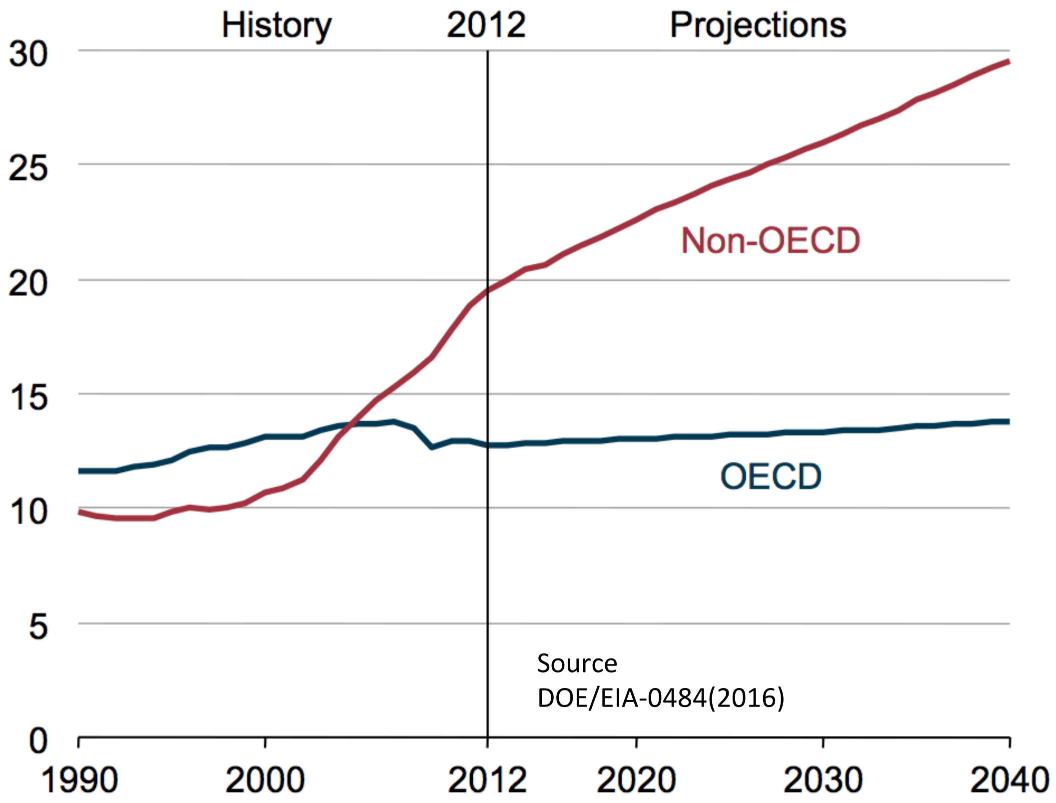


CO_2 increases



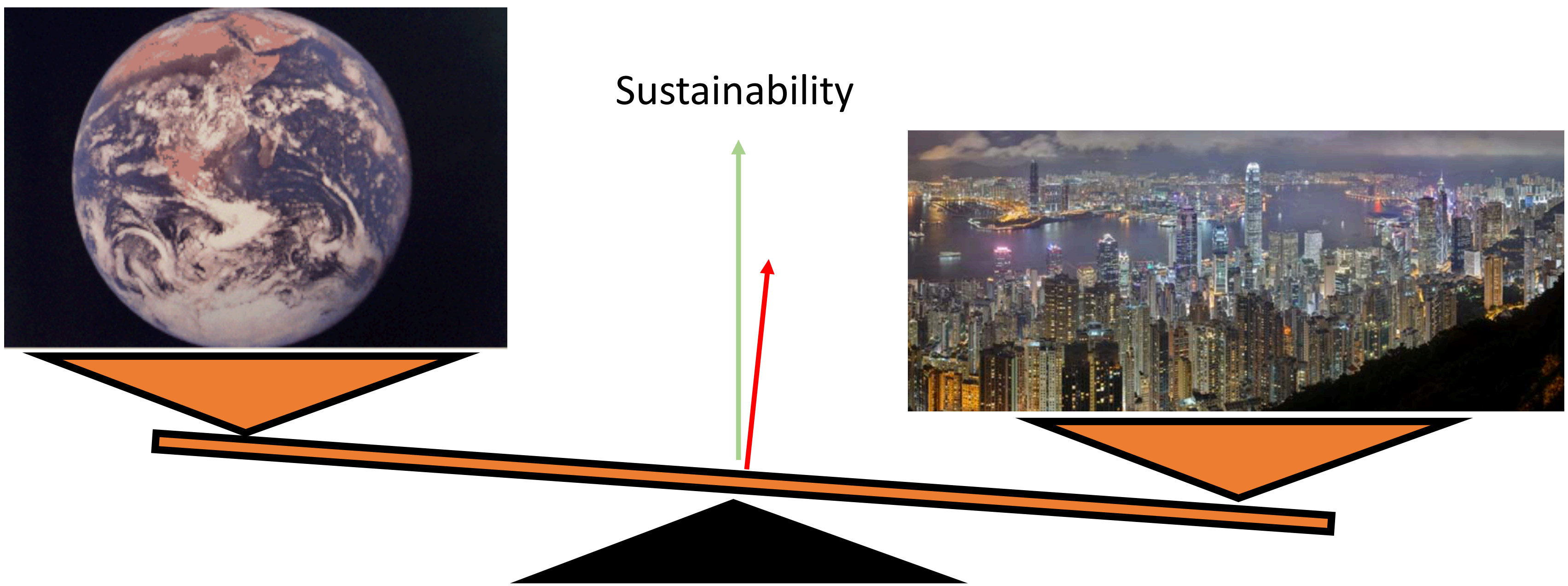
Trends & Needs

Figure 9-1. OECD and non-OECD energy-related carbon dioxide emissions, 1990–2040 (billion metric tons)

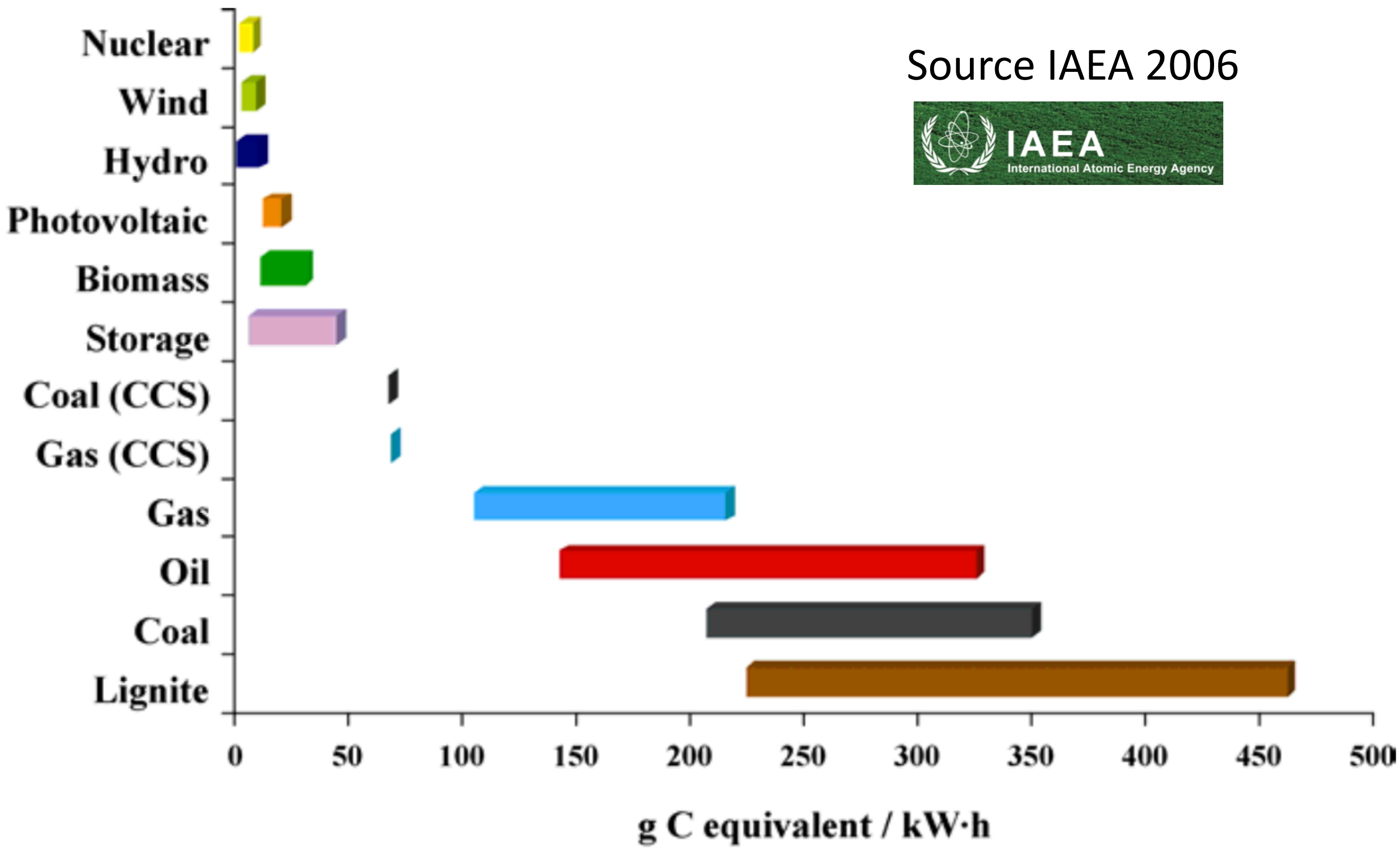


The Energy Sustainability Dilemma

"A sustainable energy future is not out of reach but will be hugely challenging – the U.S. and Canada have no real energy strategy – this must be a high priority for the future. "

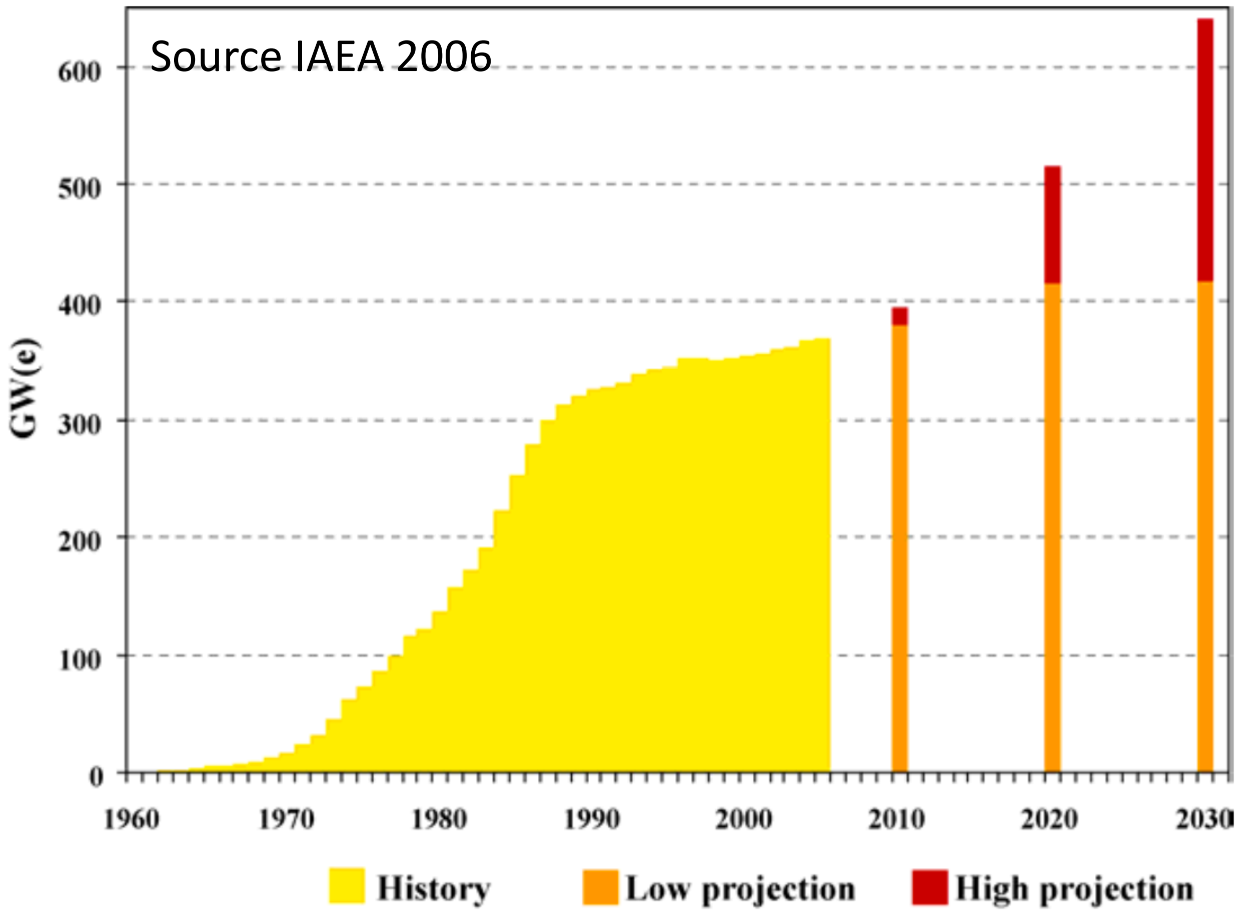


CO2 emission



Source IAEA 2006

Nuclear plants



Industry moves independently

Volkswagen CEO Matthias Mueller (R) and chairman of the Board of Management of the Volkswagen car brand Herbert Diess (L) pose in front of the I.D. electric car concept at the Paris motor Show (Photo credit ERIC PIERMONT/AFP/Getty Images)

OCT 13, 2016 Forbes Magazine

No global energy strategy

Science should explore options for solutions to the energy sustainability dilemma

Beyond governments policies

For advancement of society

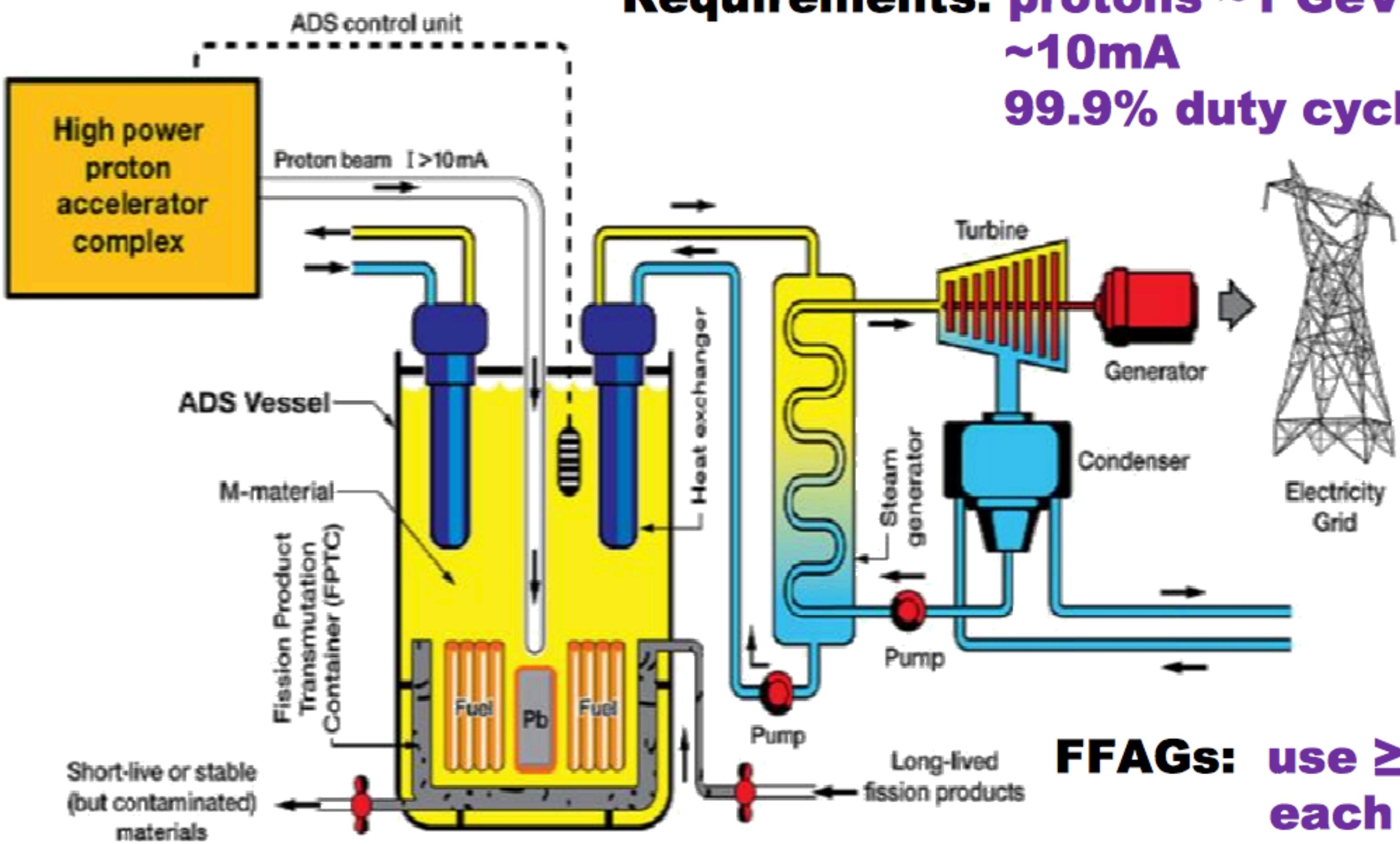
For science advance

The difficulties of too long term plans:
do not get political impact in the present

Accelerators for future

ADSR

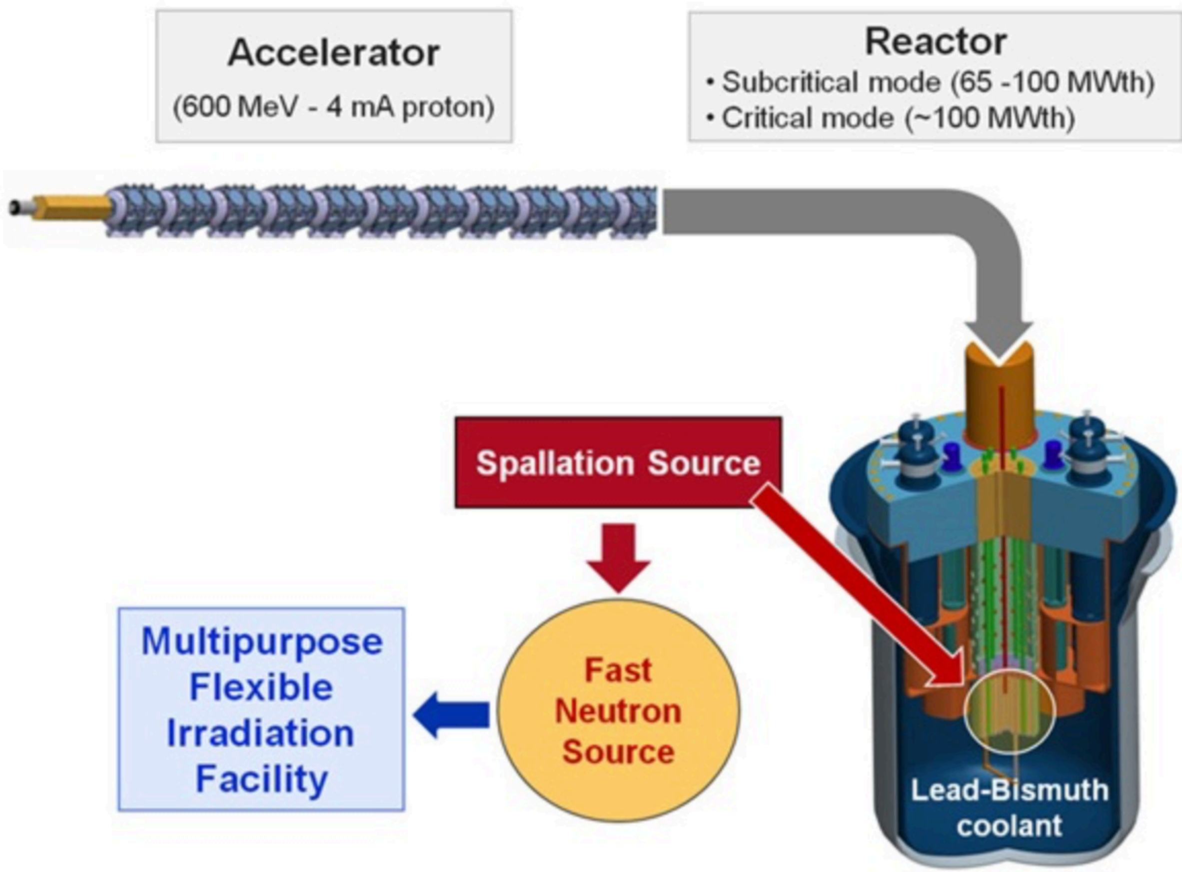
Requirements: protons ~1 GeV
~10mA
99.9% duty cycle



FFAGs: use ≥3
each ~carbon
except mAs!!
Work in early stages

R. Edgecock

MYRRHA



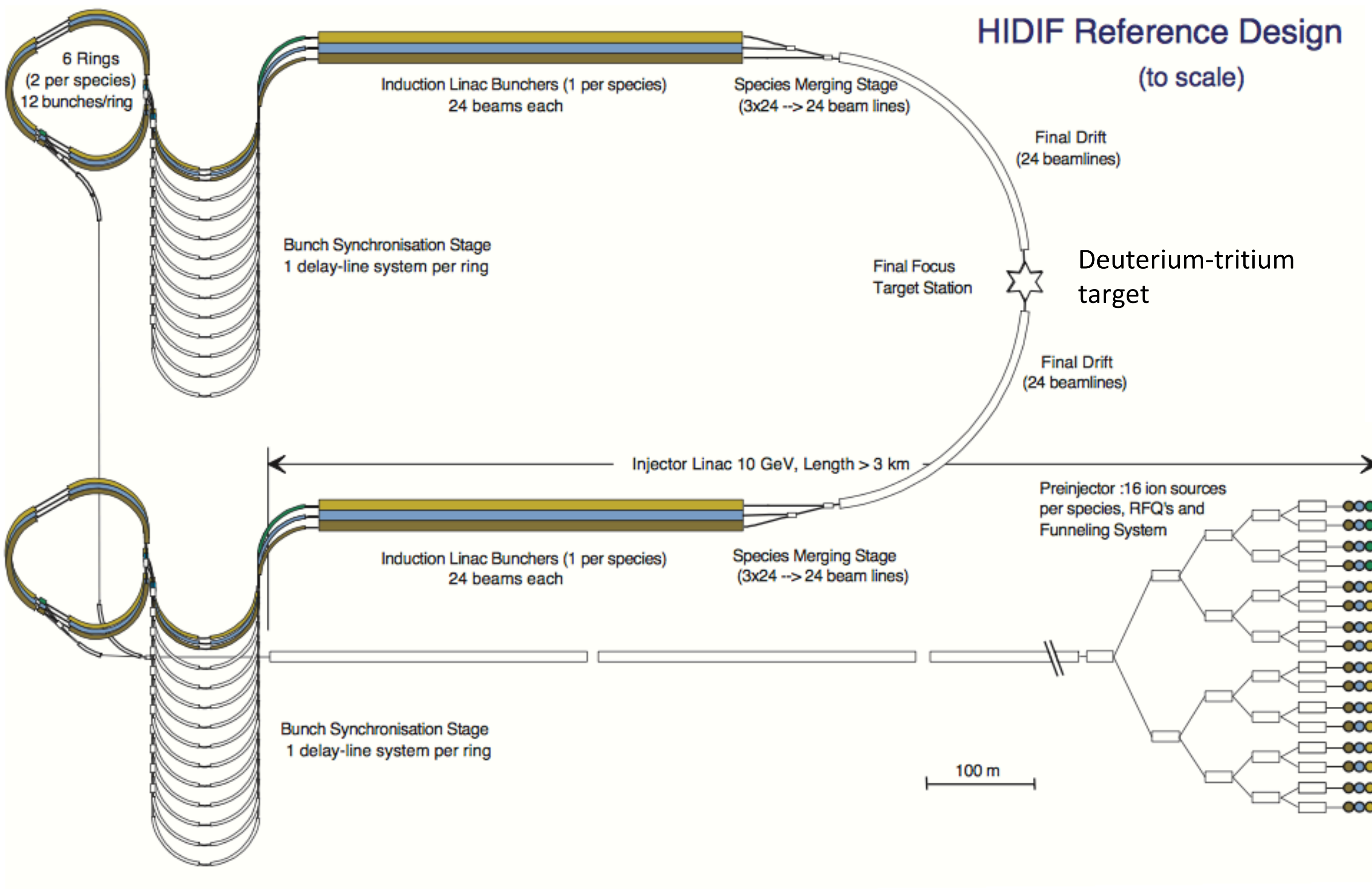
Sustainable fission energy: demonstrate the physics and technology of an Accelerator Driven System (ADS) for transmuting long-lived radioactive waste

Sustainable energy: development of fast spectrum reactor and fusion technology
Sustainable nuclear energy development requires the gradual transition of the current thermal spectrum reactor park to a fast spectrum reactor park. In order to reach this objective, innovative fuels and materials need to be tested and qualified for the future GEN IV fast reactor concepts. Also for the development of fusion energy the challenges lay to a large extent in the area of materials. The **development of materials and fuels** can only be performed **in an irradiation facility where fully controlled and representative experimental conditions** can be obtained.

http://myrrha.sckcen.be/en

Past ideas for energy production: HIDIF

C. Prior 1998

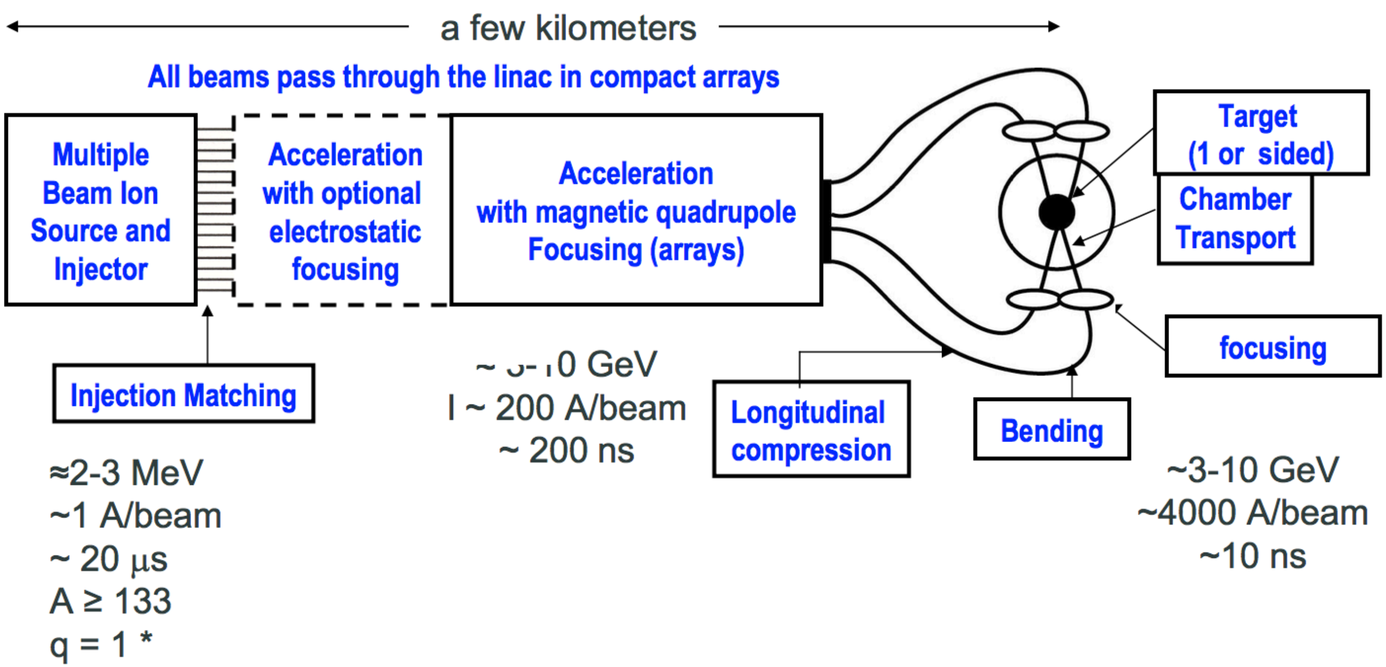


Ion kinetic energy (GeV)	10
Total beam energy per pulse (MJ)	3
Linac peak current (mA)	400
No. of storage rings	12
No. of stored bunches	144
Stored bunch length (ns)	250
No. of ion species (telescoping)	3
Final pulse length (ns)	6
Peak power (TW)	750
Total peak current (kA)	75
Focal spot size (mm)	1.7
Number of final beam lines	48
Number of target convertors	2

Total particles 2×10^{15}

Central ion Bi^{+1}

Multiple-beam induction linac driver for heavy ion fusion



Power amplification to the required 10 TW per beam is achieved by acceleration and longitudinal bunching of mildly-relativistic ions.

Slide 7

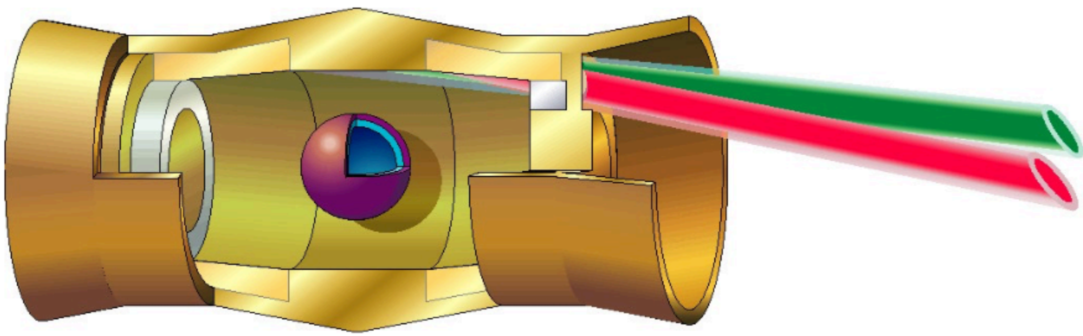
Heavy Ion Fusion Science Virtual National Laboratory

Grant Logan 2011

Indirect-drive, distributed radiator HIF target designs were developed in 2-D calculations at LLNL (1998 -2000)

Standard hohlraum-to-capsule radius ratio design (HCR = 2.1) Gain 60 @ 6 MJ

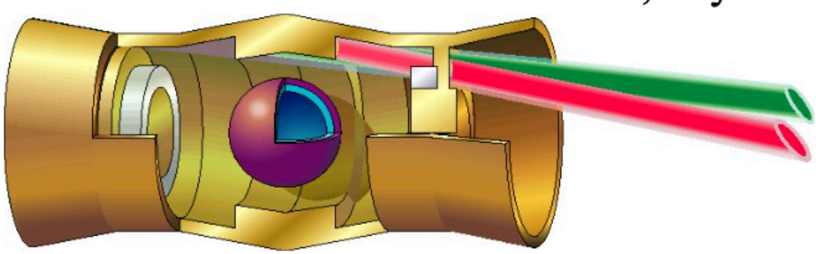
M. Tabak and D. Callahan-Miller, Phys. Plasmas **5** (1998)



(Drawn at same scale)

Close-coupled design (HCR = 1.6) Gain 130 at 3.3 MJ

D. Callahan-Miller and M. Tabak, Phys. Plasmas **7** (2000)



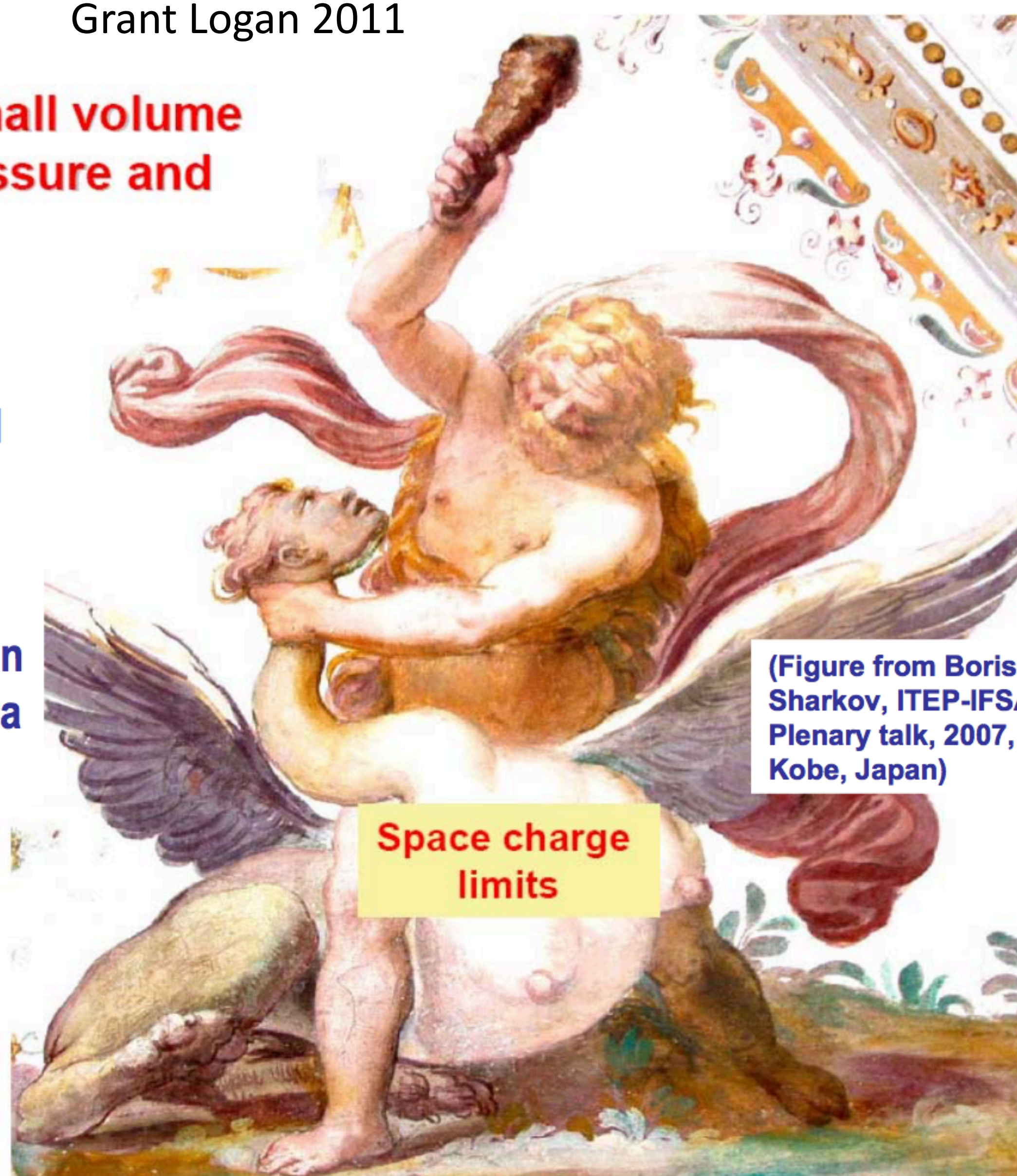
Hohlraum is smaller – requires smaller beam spots

Grant Logan
2011

Grant Logan 2011

An ion bunch must be compressed to a small volume against its thermal pressure and space charge forces

HIF targets require ~ 100 beams for pulse shape and symmetry. Each beam must be compressed to a few kA and focused to ~ 1mm radius spots on target. →100's of kV space charge potential @ initial 5 cm radius can be neutralized in chamber plasma before reaching the target.



(Figure from Boris Sharkov, ITEP-IFSA Plenary talk, 2007, Kobe, Japan)

Goal of HIF science :

explore limits to beam brightness that lead to lowest energy to drive targets !

Very Advanced Concepts

(19) Bundesrepublik Deutschland
Deutsches Patent- und Markenamt

(10) **DE 10 2006 007 824 A1** 2007.08.30

(12) **Offenlegungsschrift**

(21) Aktenzeichen: **10 2006 007 824.1**
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(43) Offenlegungstag: **30.08.2007**

(51) Int Cl.[8]: ***G21H 1/00*** (2006.01)

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(72) Erfinder:
gleich Anmelder

(56) Für die Beurteilung der Patentfähigkeit in Betracht gezogene Druckschriften:
Hossenfelder, Sabine, u.a.: Quasistable black holes at the Large Hadron Collider. In: Physical Review D66, 2002, 101502;
Dimopoulos, Savas und Landsberg, Greg: Black Holes at the Large Hadron Collider. In: Physical Review Letters, Vol. 87, No. 16, 2001, 161602;
Hawking, S.W.: Particle Creation by Black holes. In: Commun. Math. Phys., Vol. 43, 1975, S. 199-220;
Hossenfelder, Sabine, u.a.: Black hole relics in large extra dimensions. In: Physics Letters, Vol. B 566, 2003, S. 233-239;
Hossenfelder, Sabine: What Black Holes Can Teach Us. In: hep-ph/0412265;
Hossenfelder, Sabine: Dissertation, Universität Frankfurt am Main, 2003, Kap. 10.3;

Die folgenden Angaben sind den vom Anmelder eingereichten Unterlagen entnommen

Prüfungsantrag gemäß § 44 PatG ist gestellt.

(54) Bezeichnung: **Verfahren zur Energiegewinnung durch Umwandlung von Masse in Energie**

(57) Zusammenfassung: Die Erfindung betrifft ein Verfahren zur Energiegewinnung. Dabei wird ein Relikt eines Mini-Schwarzen Loches, z. B. ein LXD-BH-Relic (large extra dimension black hole relic) mit gewöhnlichen massebehafteten Teilchen, insbesondere mit Molekülen, Atomen, Atomteilchen bzw. mit Hawking-Strahlung oder deren primären, sekundären oder tertiären Zerfallsprodukten zur Kollision gebracht. Dadurch wird das Relikt des Mini-Schwarzen Loches, z. B. das LXD-BH-Relic, aus seinem stabilen Zustand in einen angeregten instabilen Zustand überführt, aus dem es unter Emission von Hawking-Strahlung wieder in den stabilen Zustand übergeht, wobei die emittierte Hawking-Strahlung oder ihre primären, sekundären oder tertiären Zerfallsprodukte direkt oder mittels eines Konverters, bspw. Fotozellen oder Brennstoffzellen, in

FFAG start in 1956 …

FFAG - recent

International Journal of High-Energy Physics

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Aug 19, 2008

The rise of the FFAG

Projects based on FFAG accelerators are beginning to flourish throughout the world.

Résumé.

L'essor des FFAG

Le concept des accélérateurs à gradients alternés et à champ fixe (FFAG) a été proposé au début des années 50 dans l'idée d'appliquer les méthodes de la focalisation forte et de la stabilité de phase à l'accélération des particules.

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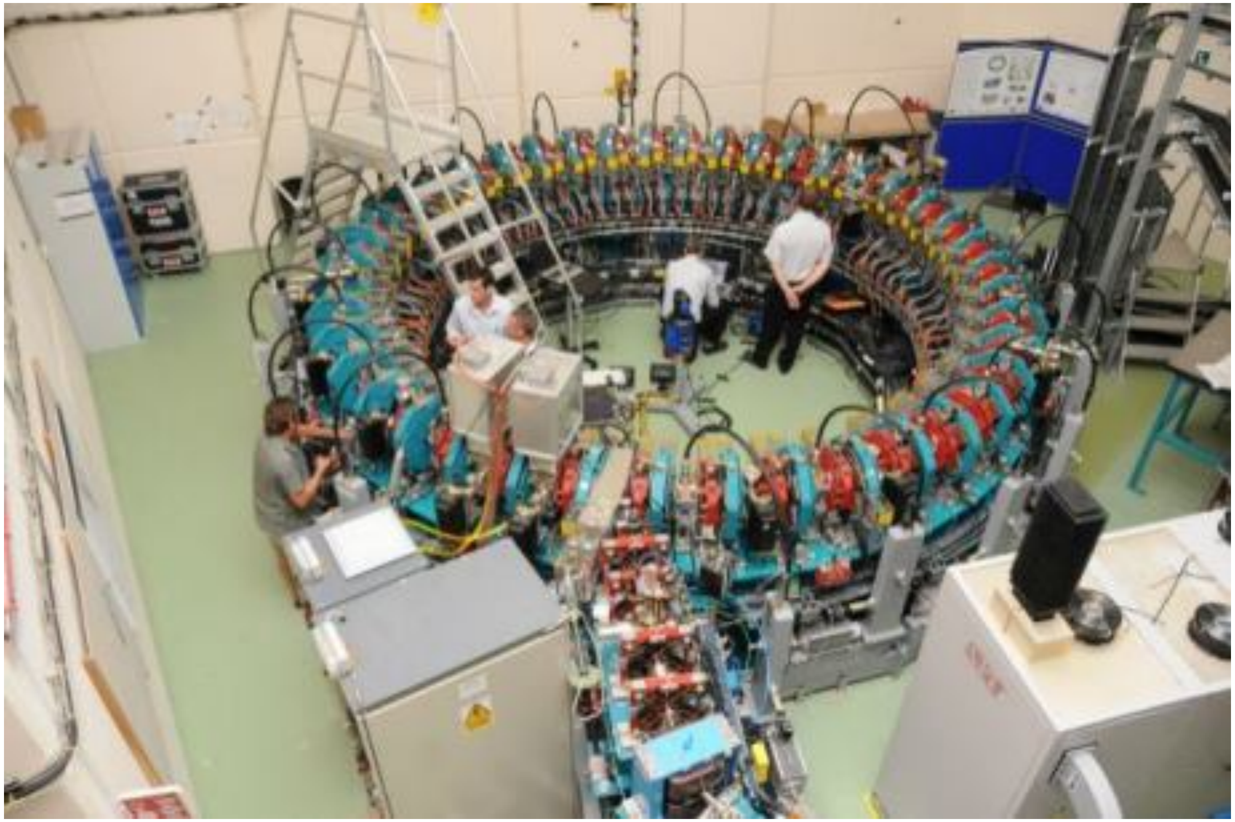
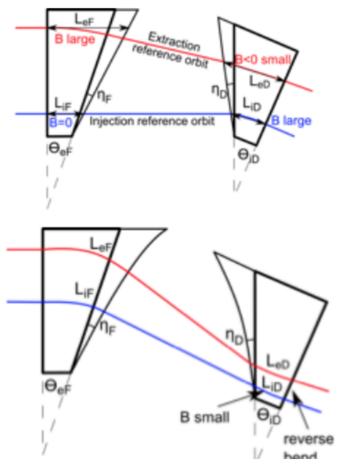
S.Machida et al.



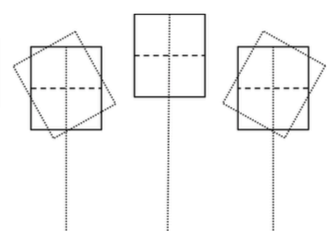
Special magnets



Radial designs with edge profiles
(C. Johnstone)

Tune-stable non-scaling FFAG designs have been developed

$$B_z = B_{z0}\left(\frac{r_0+r}{r_0}\right)^k = B_{z0}\left(1+\sum_{n=1}\frac{1}{n!}\frac{k(k-1)\cdots(k-n+1)}{r_0^n}r^n\right)$$

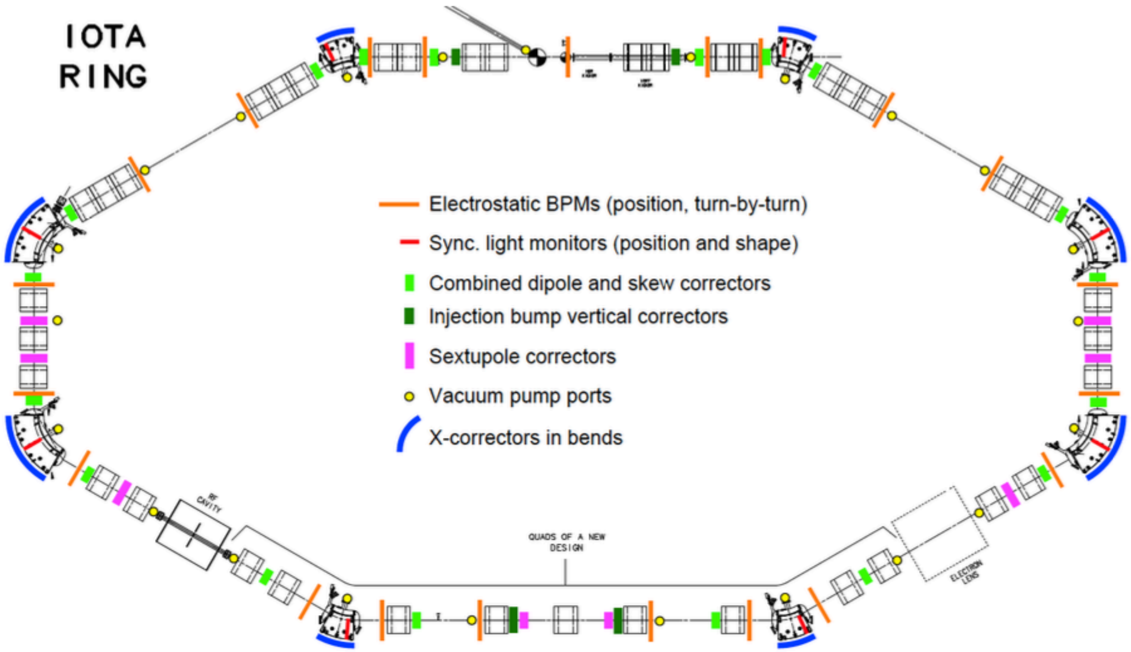


Rectangular magnets,
Simplified field profile
Higher stability region
(S. Machida, S. Sheehy)

Advanced optics in dynamics

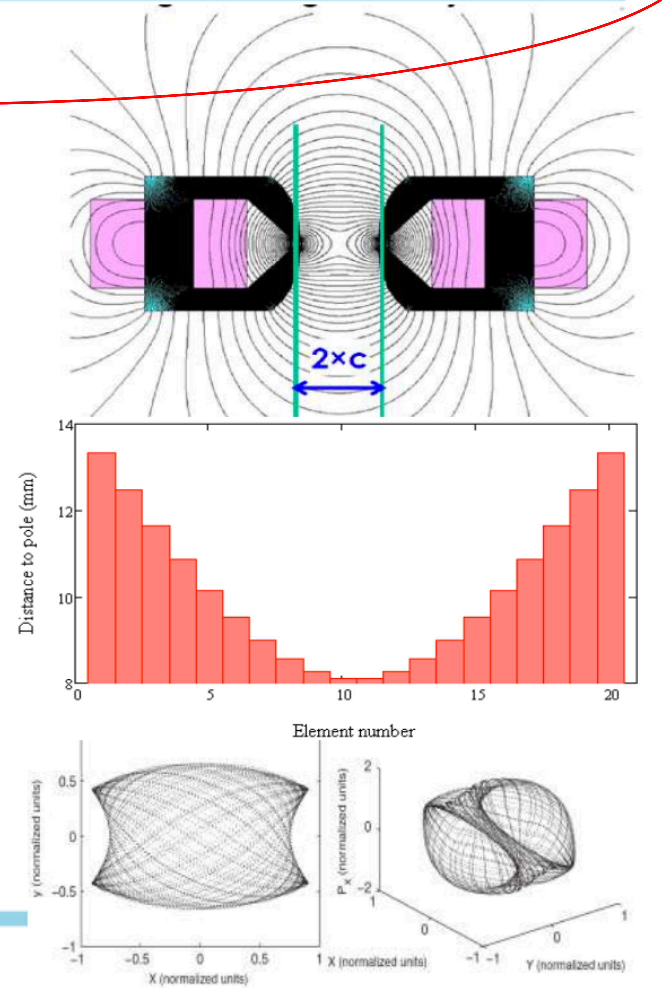
S. Nagaitsev, V. Shiltzev, S. Danilov, et al.

- *Integrable Optics*
  - *With strongly nonlinear magnets*
  - *With specially shaped electron beams in electron lenses*
- *Space Charge Compensation*
  - *With ~"Gaussian" electron lenses*
  - *With neutralizing "electron columns"*



Integrable Optics with Non-linear Magnets

- **Additional integrals of transverse motion possible:**
  - Special NL magnets →
  - Special optics of the ring (next slide)
  - Special longitudinal shape of the magnets (gap vs Z) →
  - Makes particle dynamics stable with very large tune-spread
    - Danilov, Nagaitsev, PRSTAB **13**, 084002 (2010) →



6 V.Shiltsev | IOTA, Plasma-based Colliders Workshop

Taming intensity

Flexible machines to store large emittance beams --> FFAG

New machines that exhibits integrable optics, or quasi-integrable optics

Electron lenses studies are on the way, but it has still to be proved that in practice they works

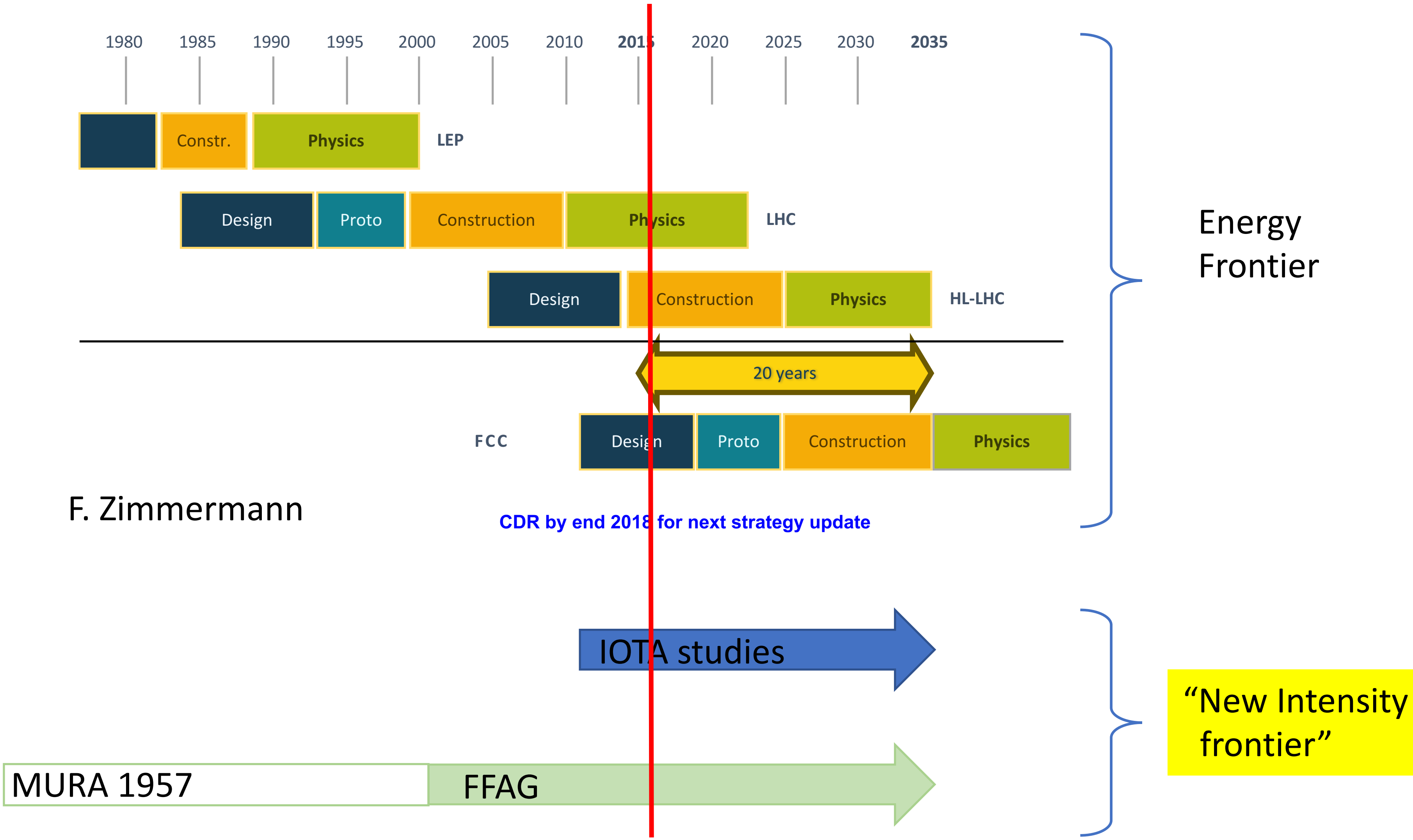
Fast, ultra-fast feed-back systems for instabilities suppression

Challenges

Technical → Creation of special magnetic or electric field configuration
Accelerator with special materials that mitigate impedances

Conceptual → new theoretical models to create nonlinear lattices integrable
especially: creating local quasi-integrable non-linear kicks

Trend & plans


1980
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Physics
LEP
Design
Proto
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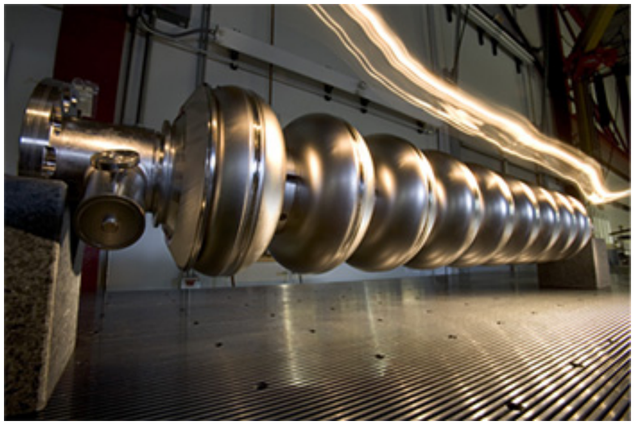
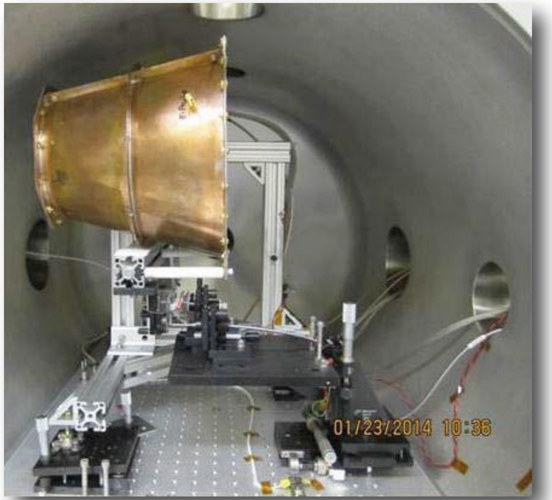
Physics
LHC
Design
Construction
Physics
HL-LHC
20 years
FCC
Design
Proto
Construction
Physics
F. Zimmermann
CDR by end 2018 for next strategy update
Energy Frontier
IOTA studies
MURA 1957
FFAG
"New Intensity frontier"

Advent of new synergies ?





Anomalous Thrust Production from an RF Test Device Measured on a Low-Thrust Torsion Pendulum

David A. Brady*, Harold G. White†, Paul March‡, James T. Lawrence§, and Frank J. Davies**
NASA Lyndon B. Johnson Space Center, Houston, Texas 77058

This paper describes the test campaigns designed to investigate and demonstrate viability of using classical magnetoplasmadynamics to obtain a propulsive momentum transfer via the quantum vacuum virtual plasma. This paper will not address the physics of the quantum vacuum plasma thruster (QVPT), but instead will describe the recent test campaign. In addition, it contains a brief description of the supporting radio frequency (RF) field analysis, lessons learned, and potential applications of the technology to space exploration missions.