Spoutání energie hvězd v pozemských podmínkách

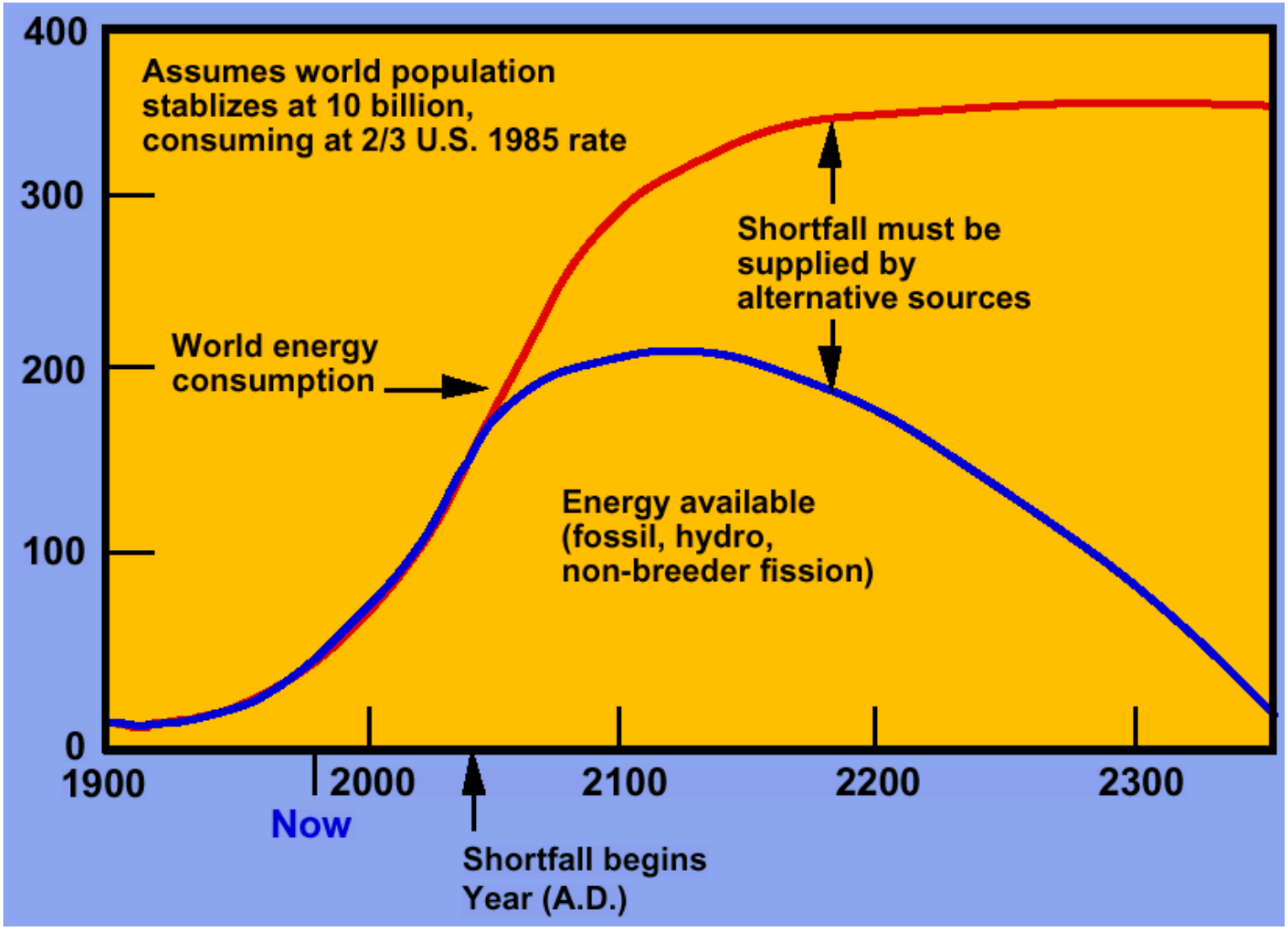
Vojtěch Svoboda

18. listopadu 2011

Outline of the talk

Obsah

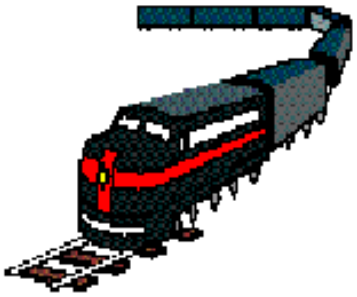
Energetické potřeby lidstva



Roční spotřeba 1GW elektrárny (zhruba Praha)

Coal

250 trains



Oil

11 super tankers

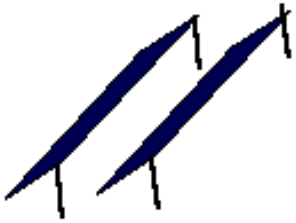
Fission

1.5 rail car load

Uranium Oxide

Solar

5000 acres of collectors
plus energy storage for
night and cloudy days

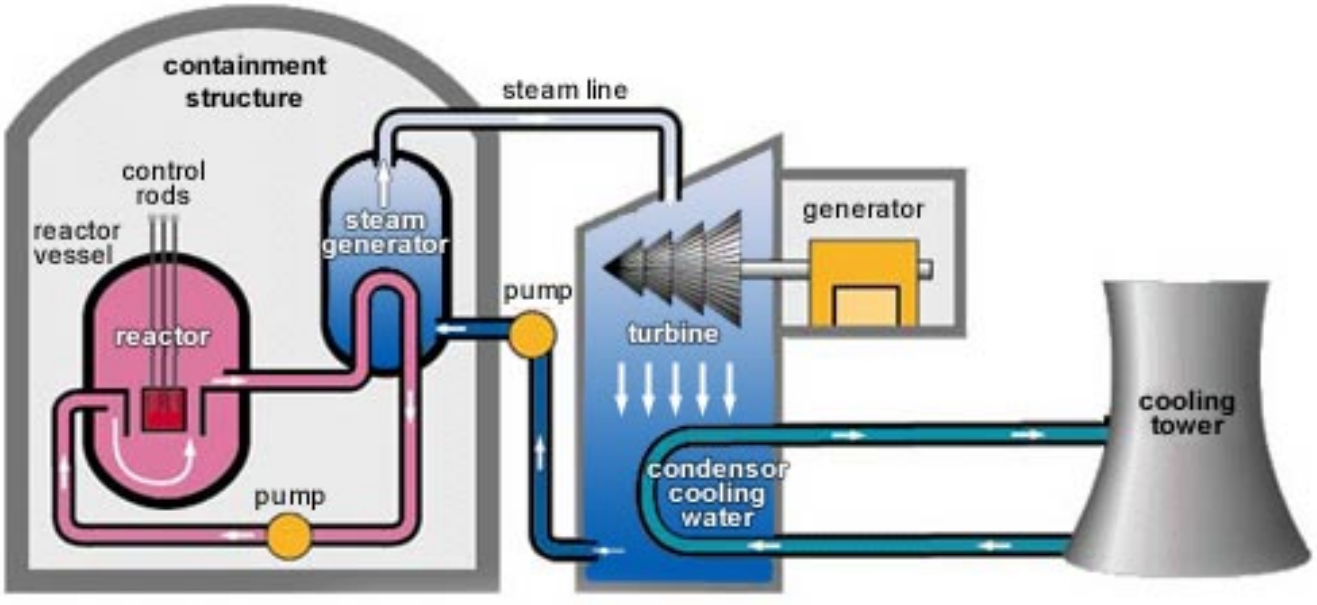


Fusion

1/2 ton pickup truck

Deuterium & Tritium

Základní princip tepelné elektrárny

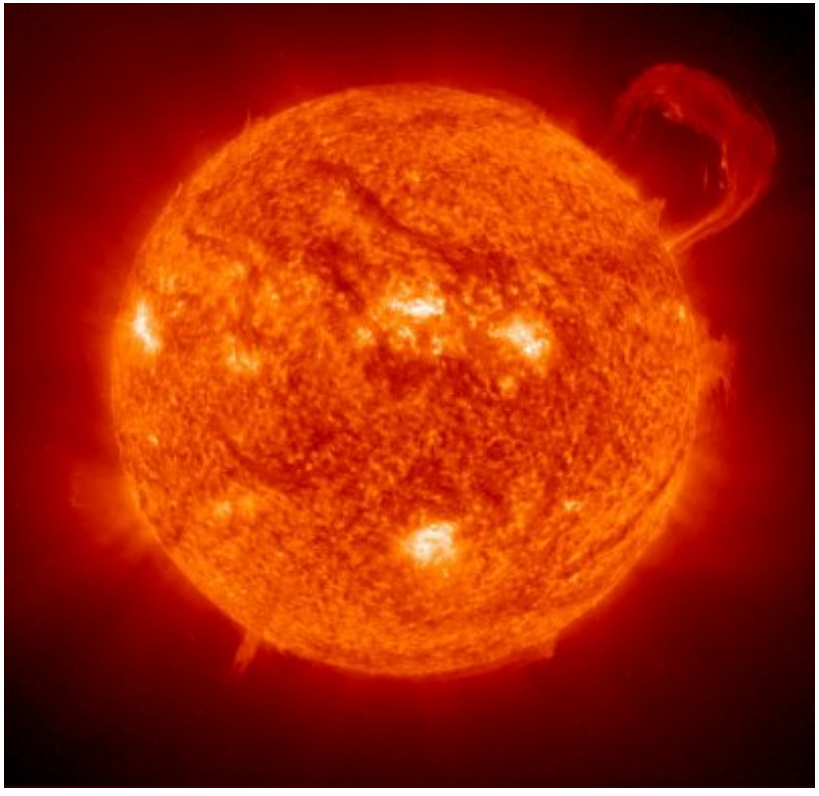


Otázka zní

?? ČÍM TOPIT ??

Obsah

Spoutání energie hvězd



Core Burning Stages in a 25 Solar Mass Star:

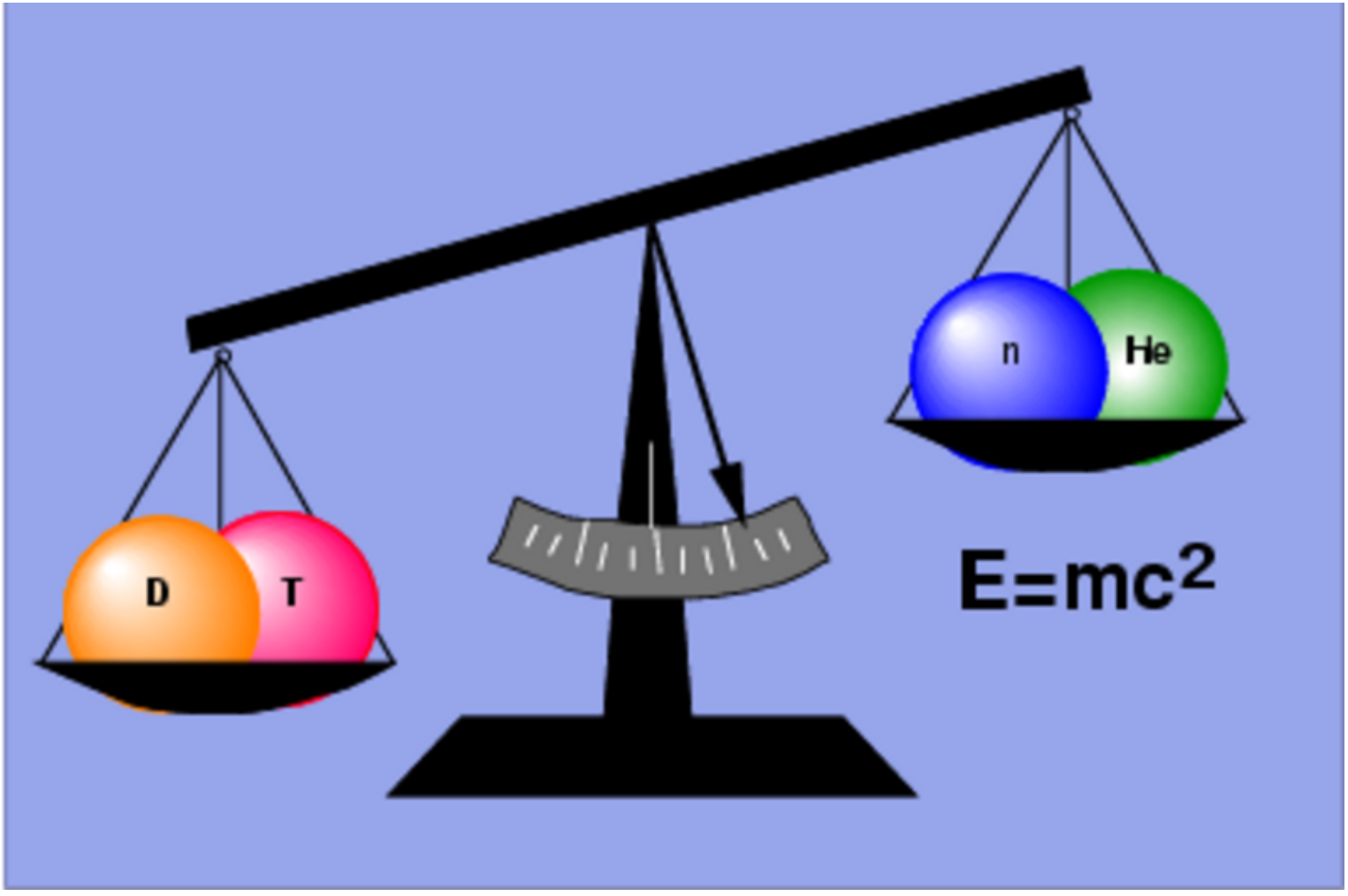
Fuel:	Products:	Temperature (K):	Minimum Mass:	Burning Period:
H	He	4×10^6	0.1	7×10^6 years
He	C, O	1.2×10^8	0.4	5×10^5 years
C	Ne, Na, Mg, O	6×10^8	4	600 years
Ne	O, Mg	1.2×10^9	~8	1 year
O	Si, S, P	1.5×10^9	~8	~0.5 years
Si	Ni - Fe	2.7×10^9	~8	~1 day

Nejvhodnější kandidát v pozemských podmínkách:

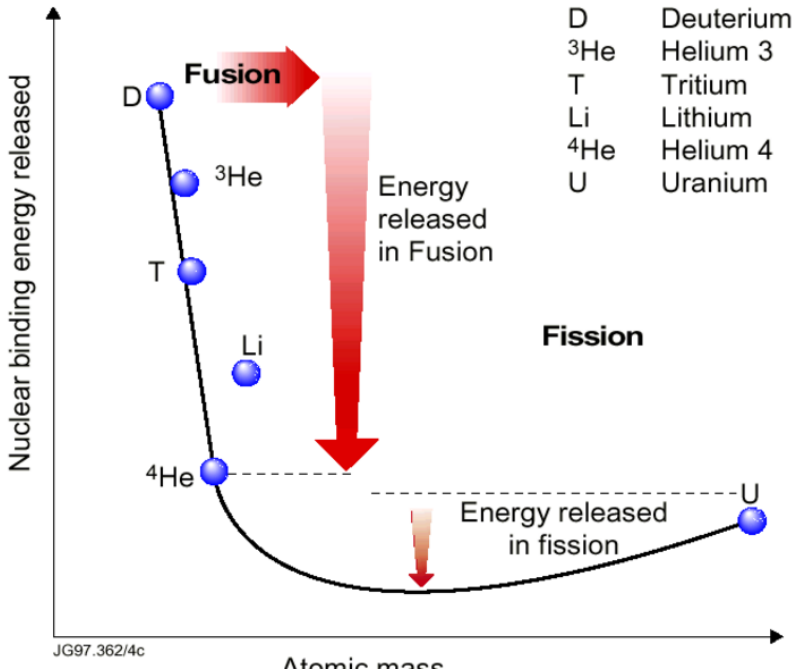
$$ {}^{2}_{1}\mathbf{D}_{(10\mathbf{keV})} + {}^{3}_{1}\mathbf{T}_{(10\mathbf{keV})} \Rightarrow {}^{4}_{2}\mathbf{He}_{(3.5\mathbf{MeV})} + \mathbf{n}_{(14.1\mathbf{MeV})} $$

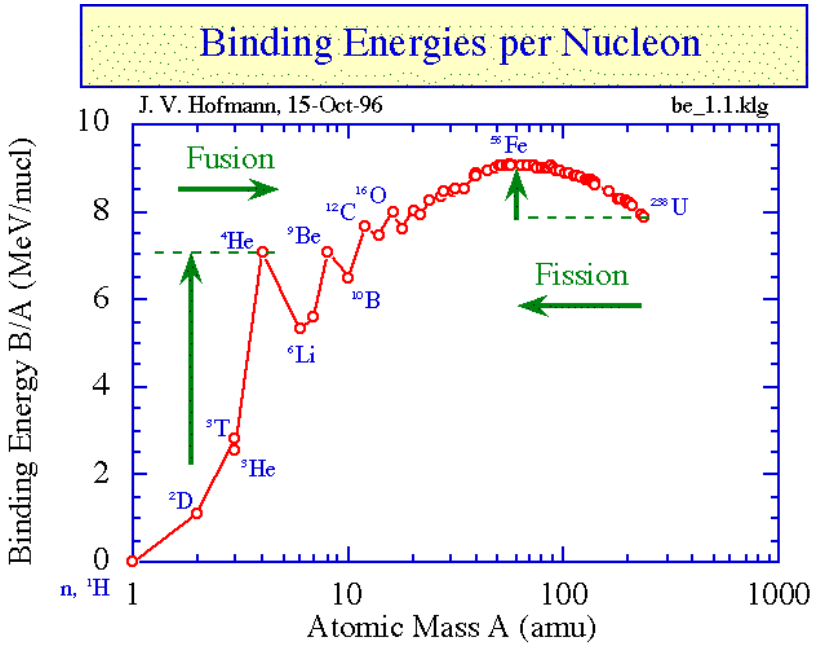
$\longrightarrow$ Udržet & Zapálit & Zahřát & Diagnostikovat $\longleftarrow$

Uvolnění vazebné energie I

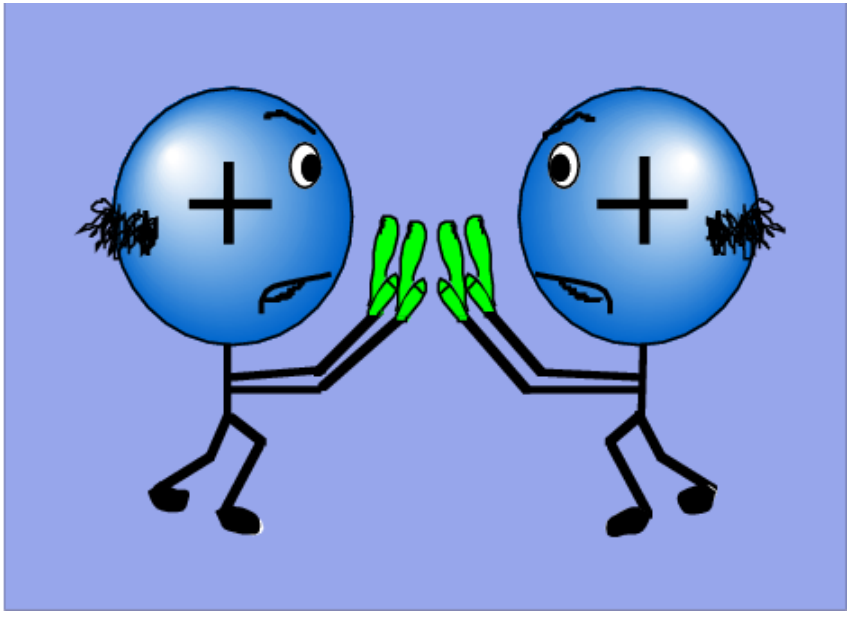


Uvolnění vazebné energie II





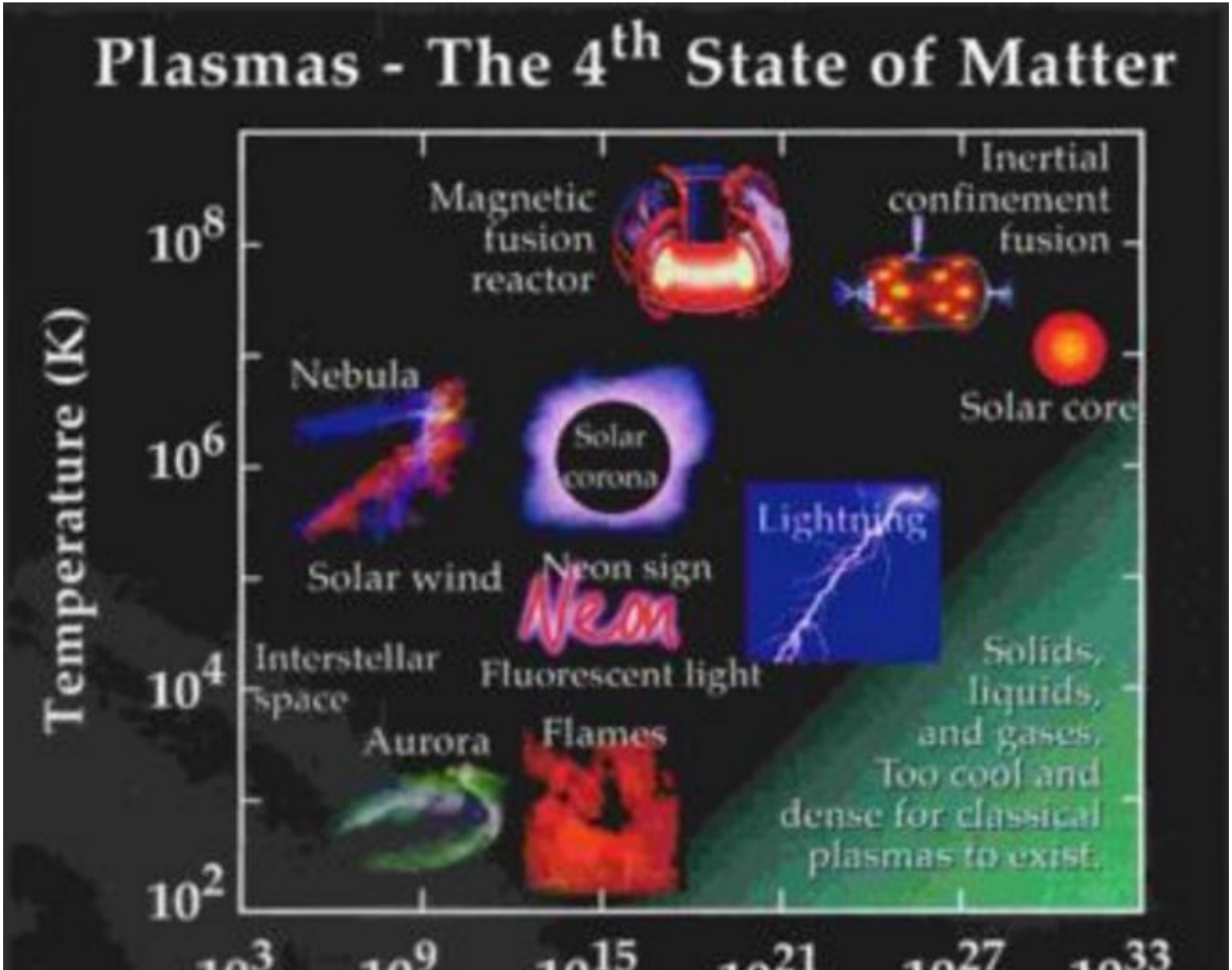
Problém: částice souhlasného náboje se odpuzují



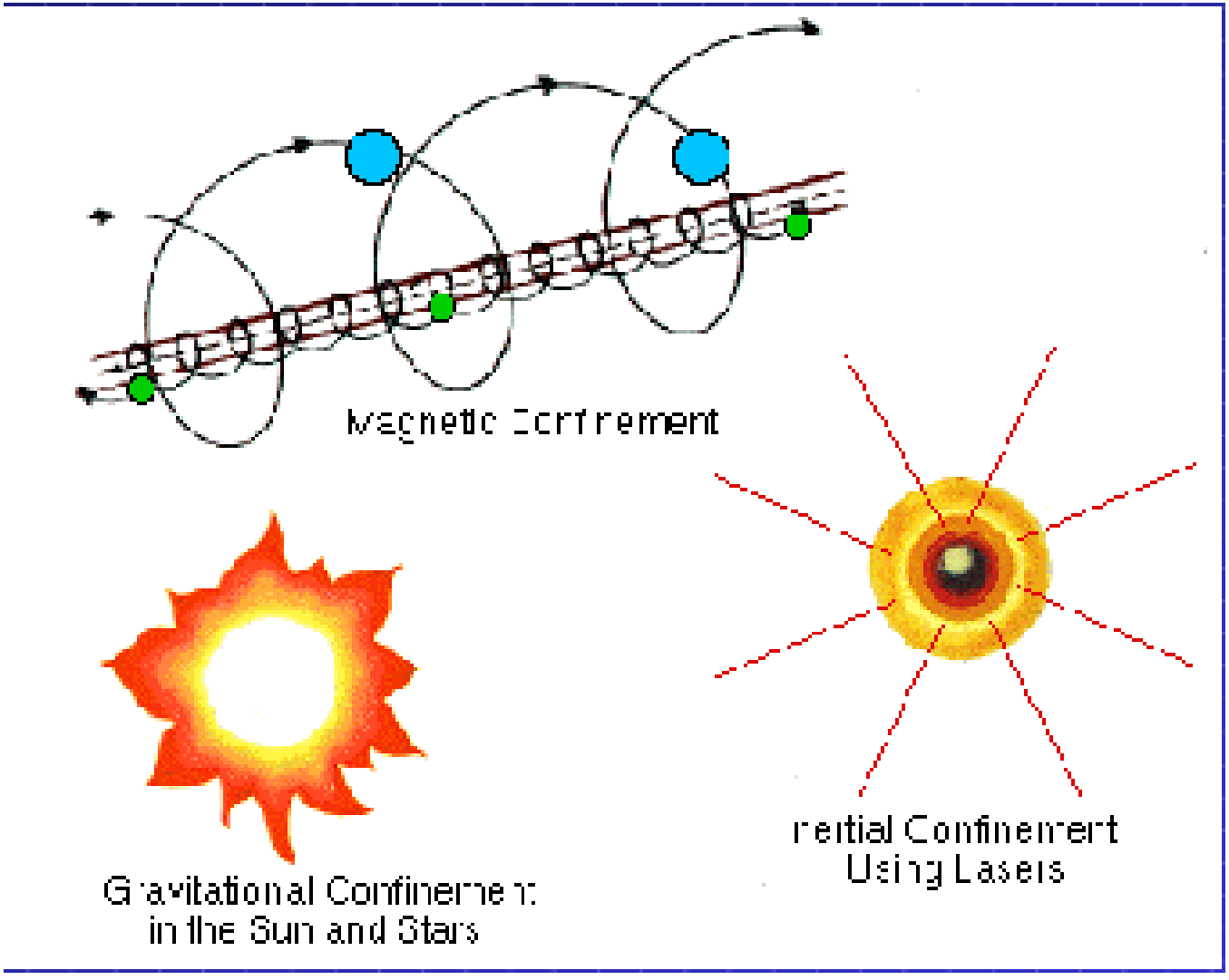
- Coulombův zákon:
  $F_E = \frac{1}{4\pi\epsilon_0}\frac{Q_1\ Q_2}{r^2}$

$$ {}^{2}_{1}\mathbf{D}_{(10\mathbf{keV})} + {}^{3}_{1}\mathbf{T}_{(10\mathbf{keV})} \Rightarrow {}^{4}_{2}\mathbf{He}_{(3.5\mathbf{MeV})} + \mathbf{n}_{(14.1\mathbf{MeV})} $$

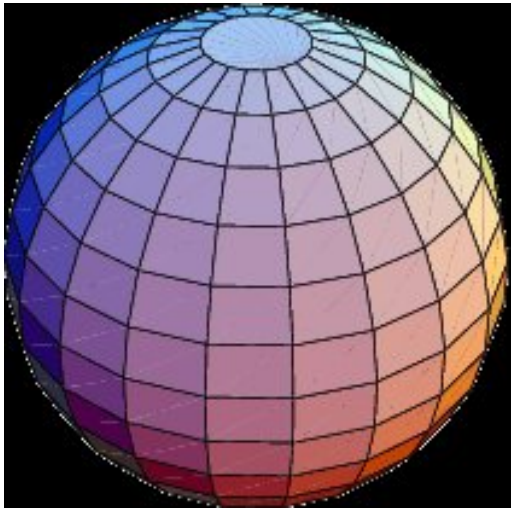
Plazma

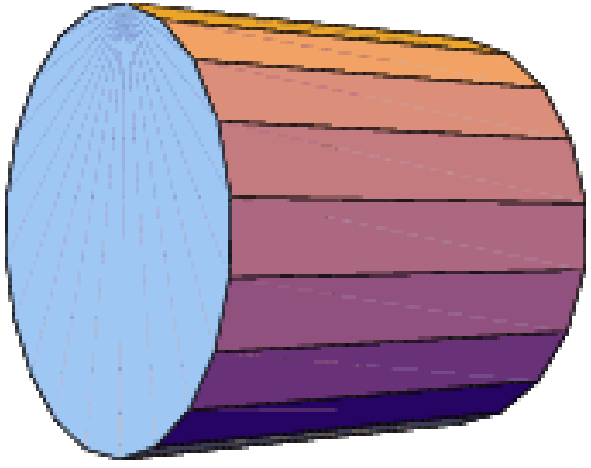

Plasmas - The 4th State of Matter
Temperature (K)
10^8
10^6
10^4
10^2
Magnetic fusion reactor
Inertial confinement fusion
Solar core
Nebula
Solar corona
Solar wind
Neon sign
Neon
Lightning
Interstellar space
Fluorescent light
Aurora
Flames
Solids, liquids, and gases. Too cool and dense for classical plasmas to exist.

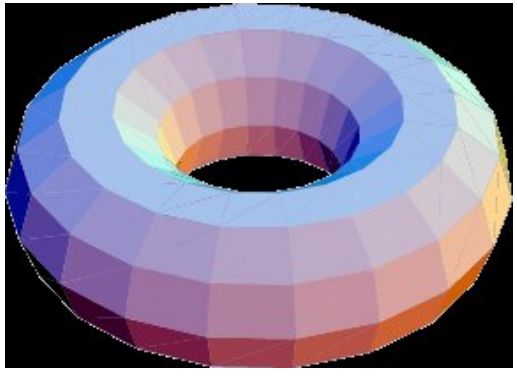
Tři způsoby udržení plazmatu



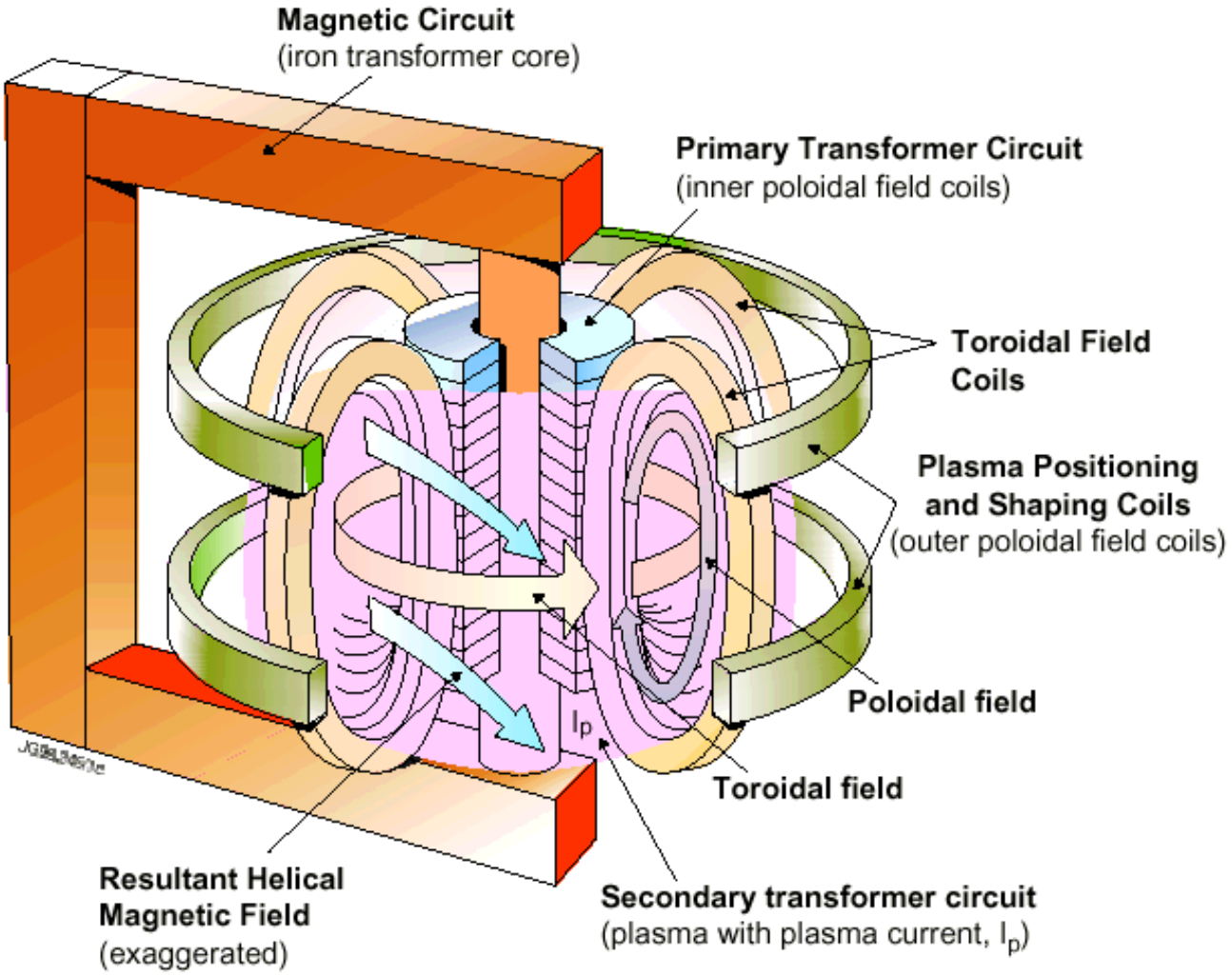
Geometrie udržení plazmatu



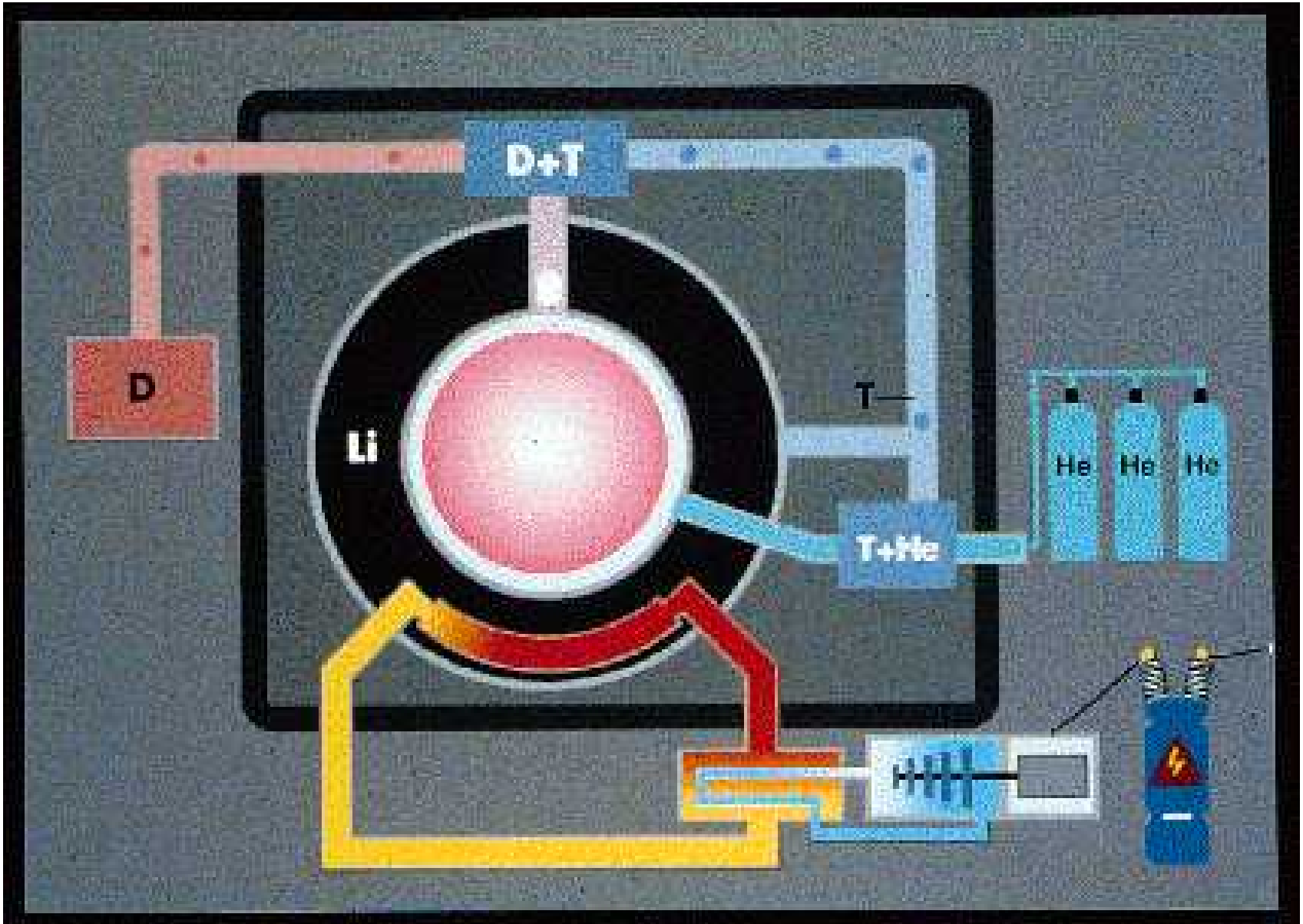




Magnetické udržení - Tokamaky



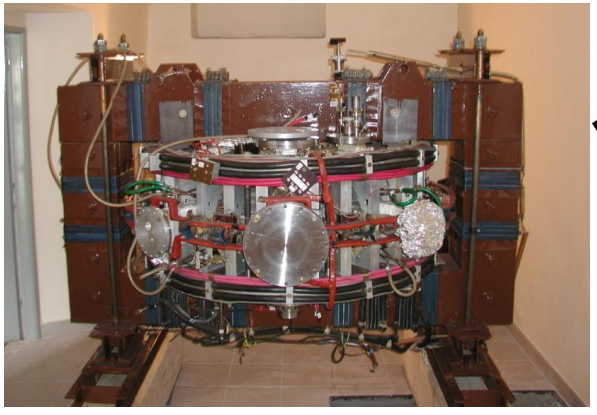
Budoucí reaktor



Obsah

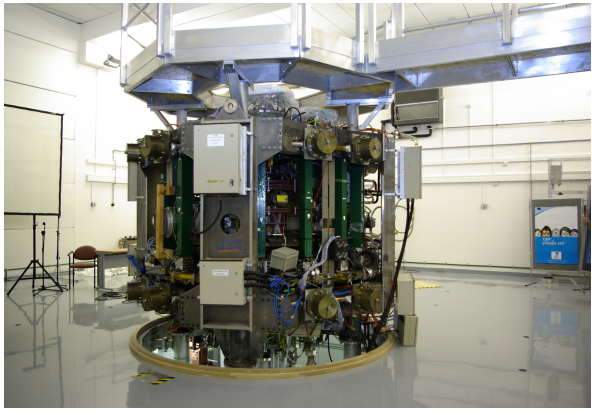
Tokamak GOLEM - historie

Kurchatov Institute near Moscow,
Soviet Union
1960: **TM1-MH**



1974

Culham Centre for Fusion Energy
Great Britain
1989: **COMPASS-D**



2006

Institute of Plasma Physics
Czech republic
CASTOR **COMPASS**

2008

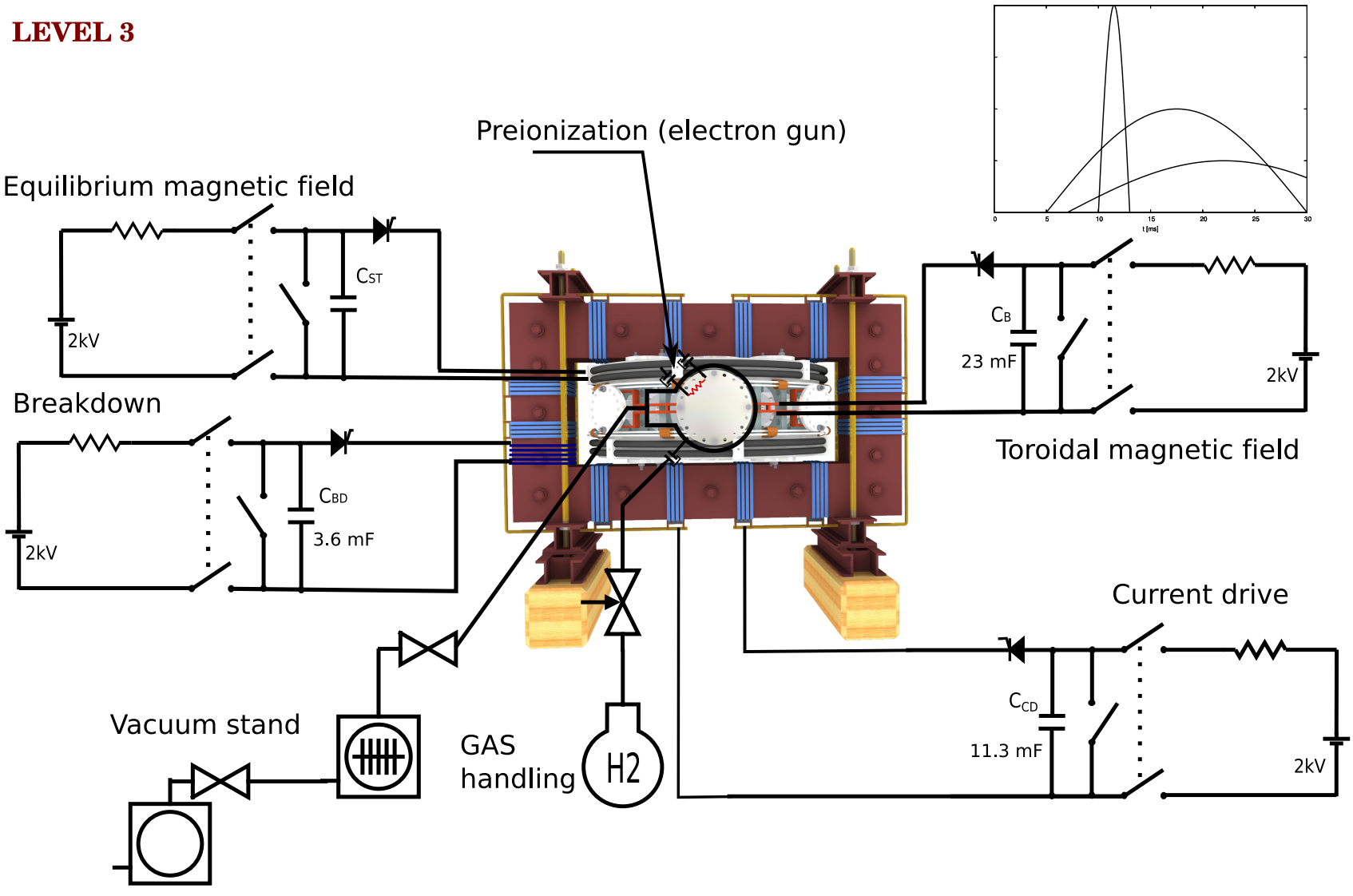
Czech Technical University Prague
Czech republic
GOLEM

2006: new curricula at FNSPE:
Physics and Technology of Thermonuclear Fusion

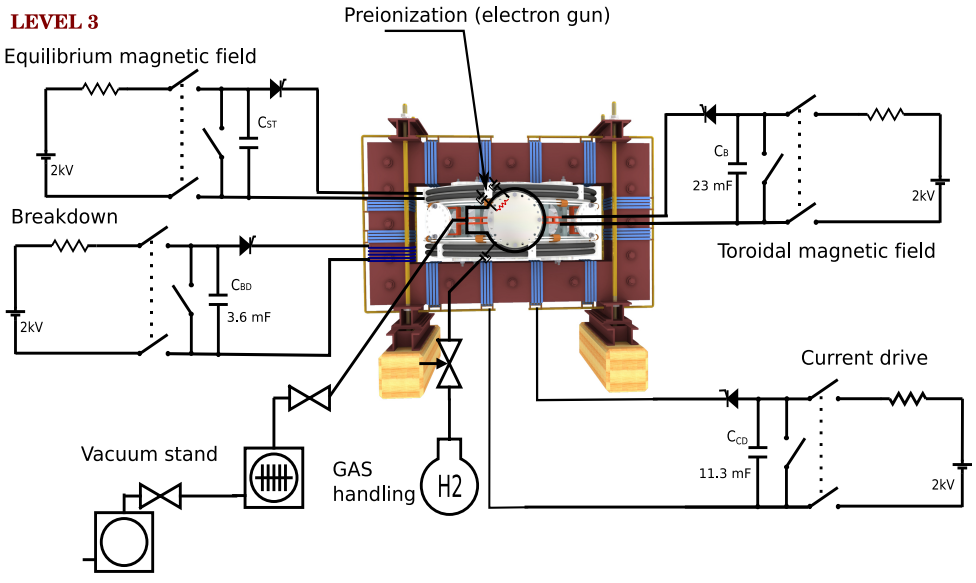
?virtual or real experiments?

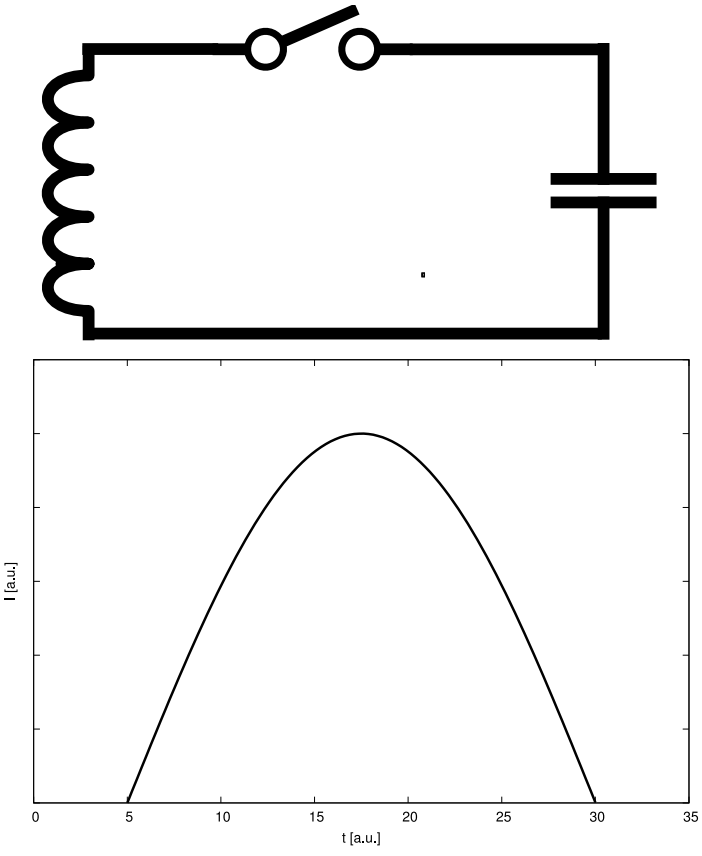
Tokamak GOLEM - inženýrské schéma

LEVEL 3



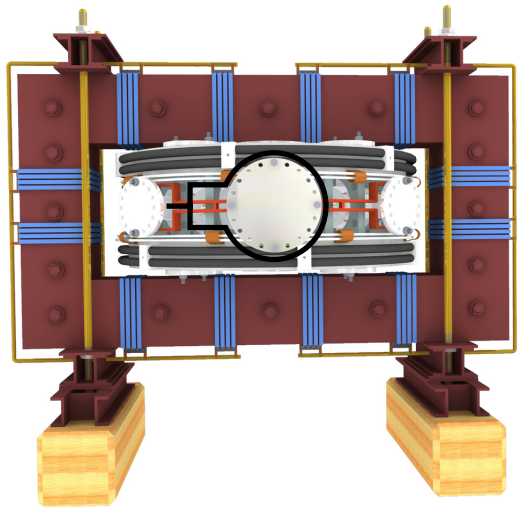
Vsuvka - LC obvod





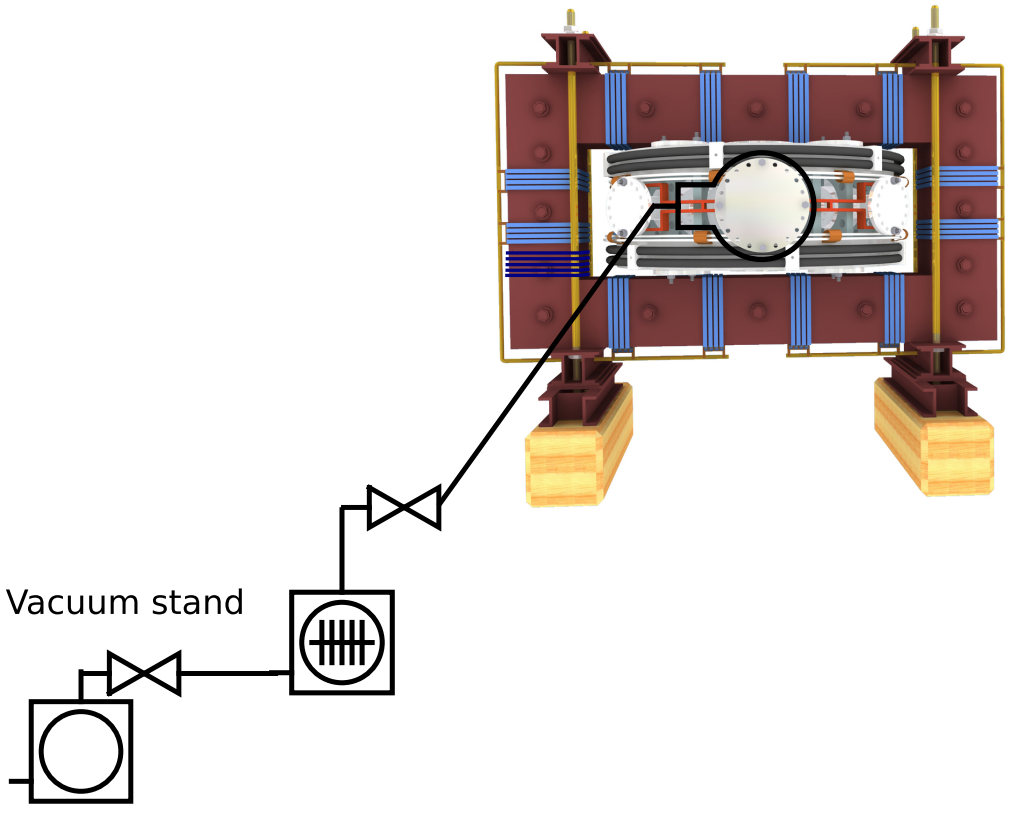
Tokamak GOLEM - základ

LEVEL 0



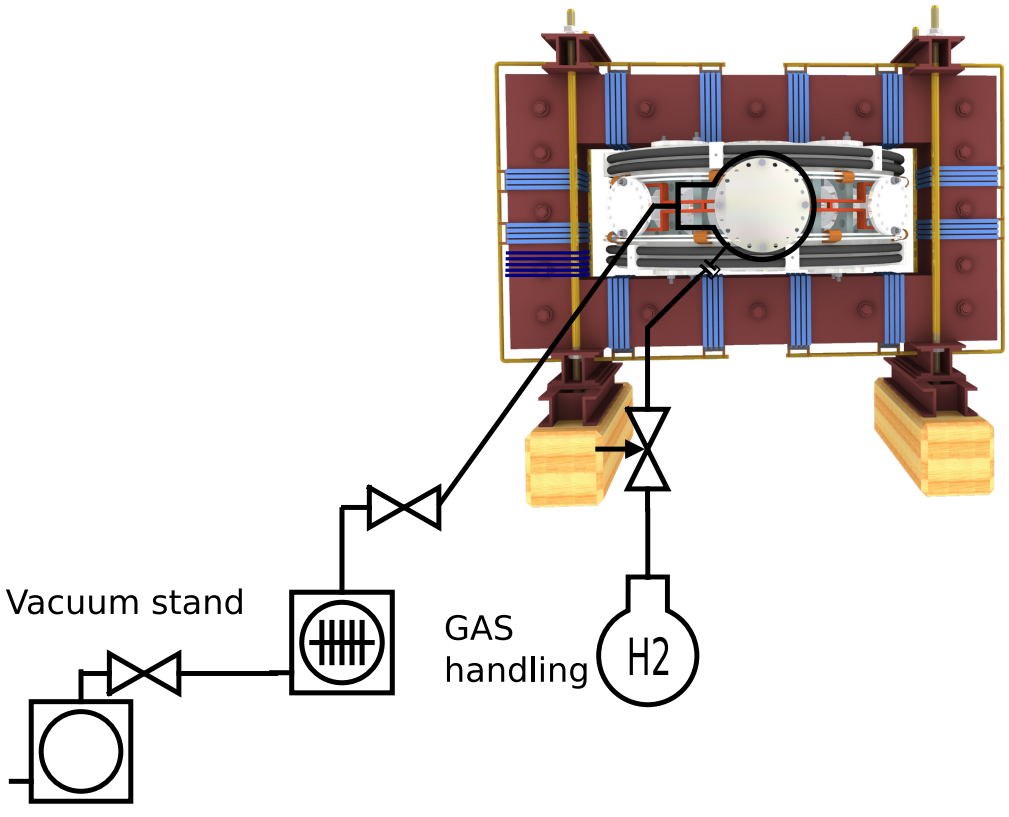
Tokamak GOLEM + čerpací systém (100 kPa $\rightarrow$ 1 mPa)

LEVEL 0



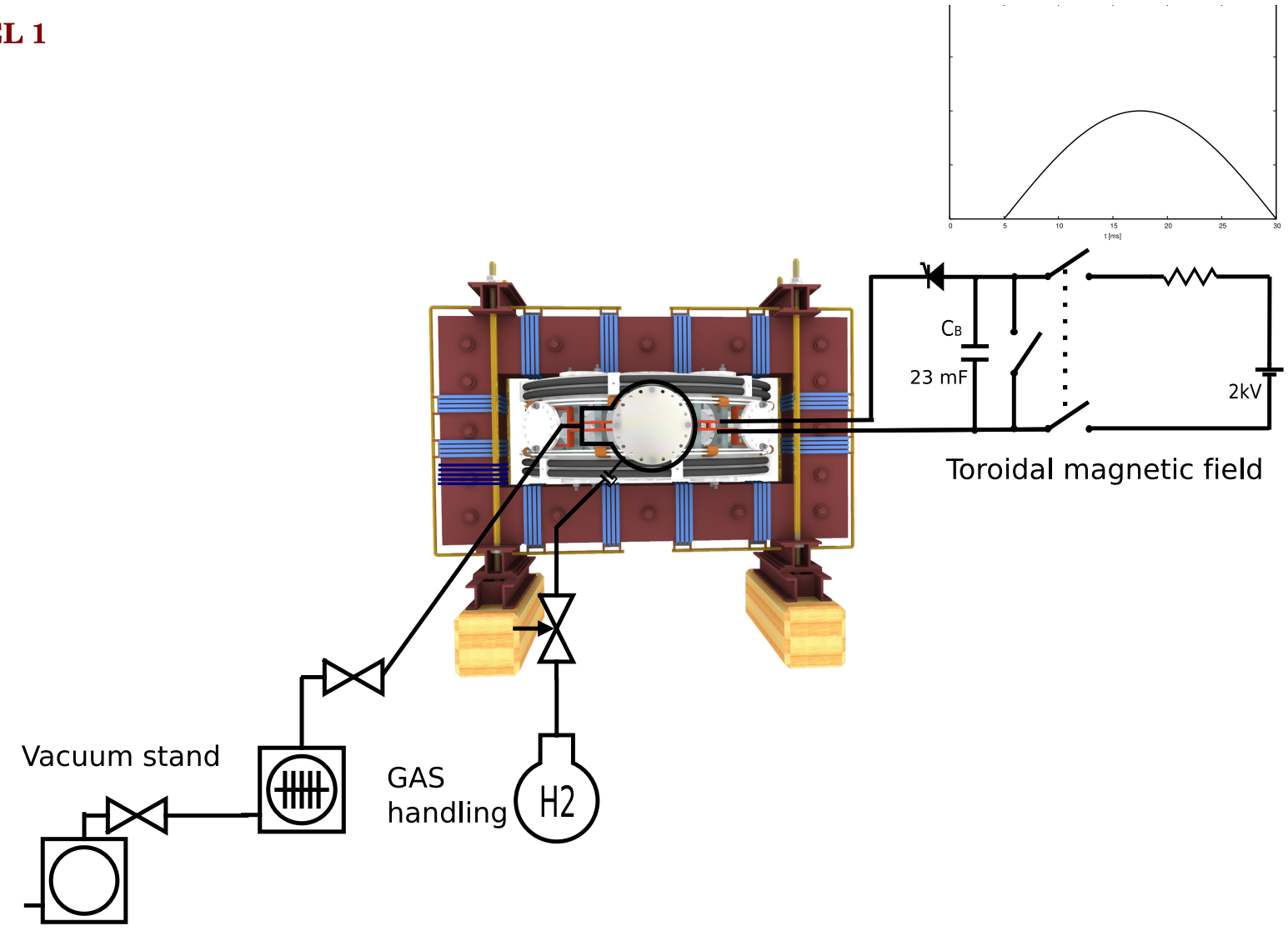
Tokamak GOLEM + napouštní pracovním plynem (H_2 či He)

LEVEL 0



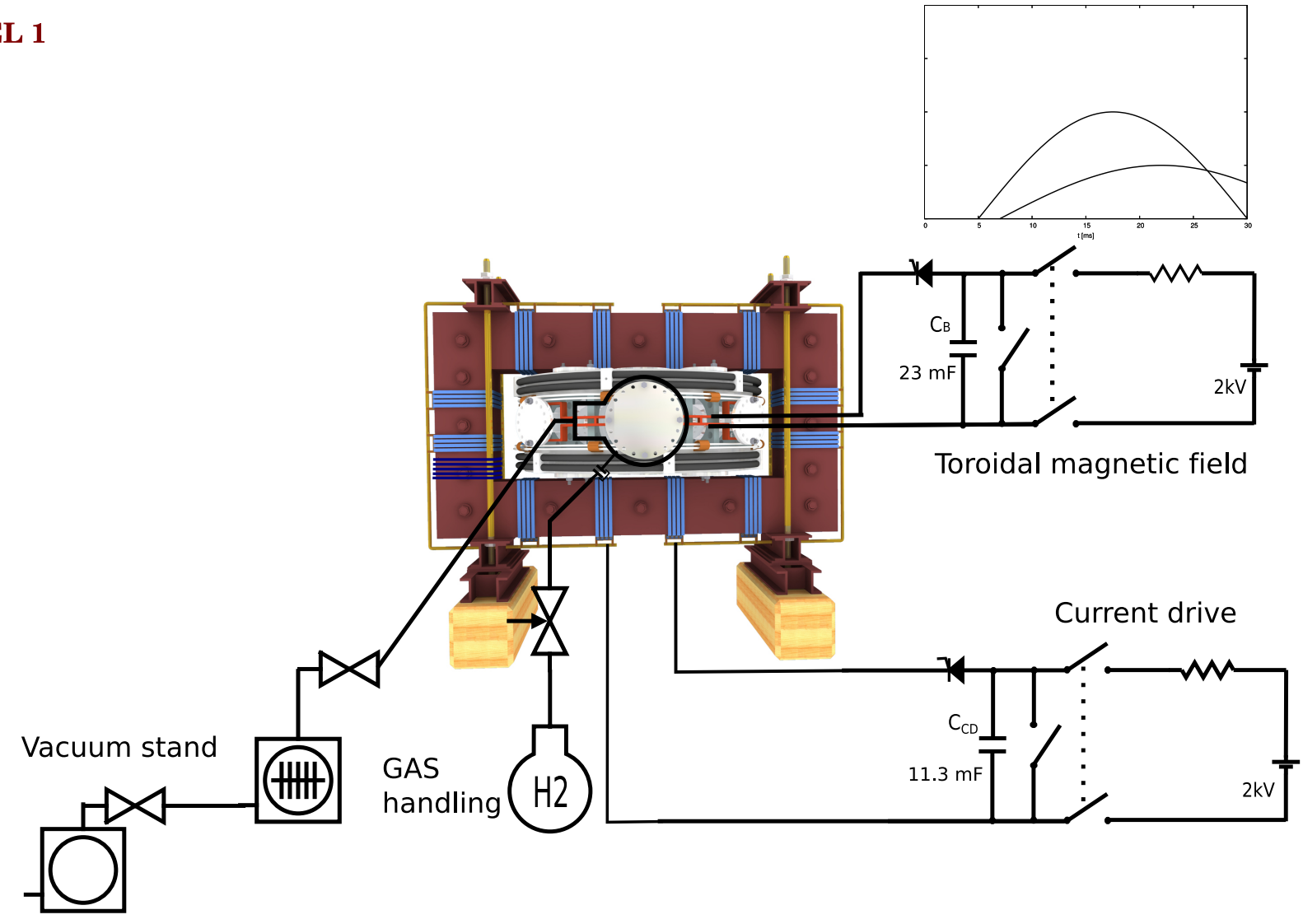
Tokamak GOLEM + B (toroidální magnetické pole)
Udržení plazmatu

LEVEL 1



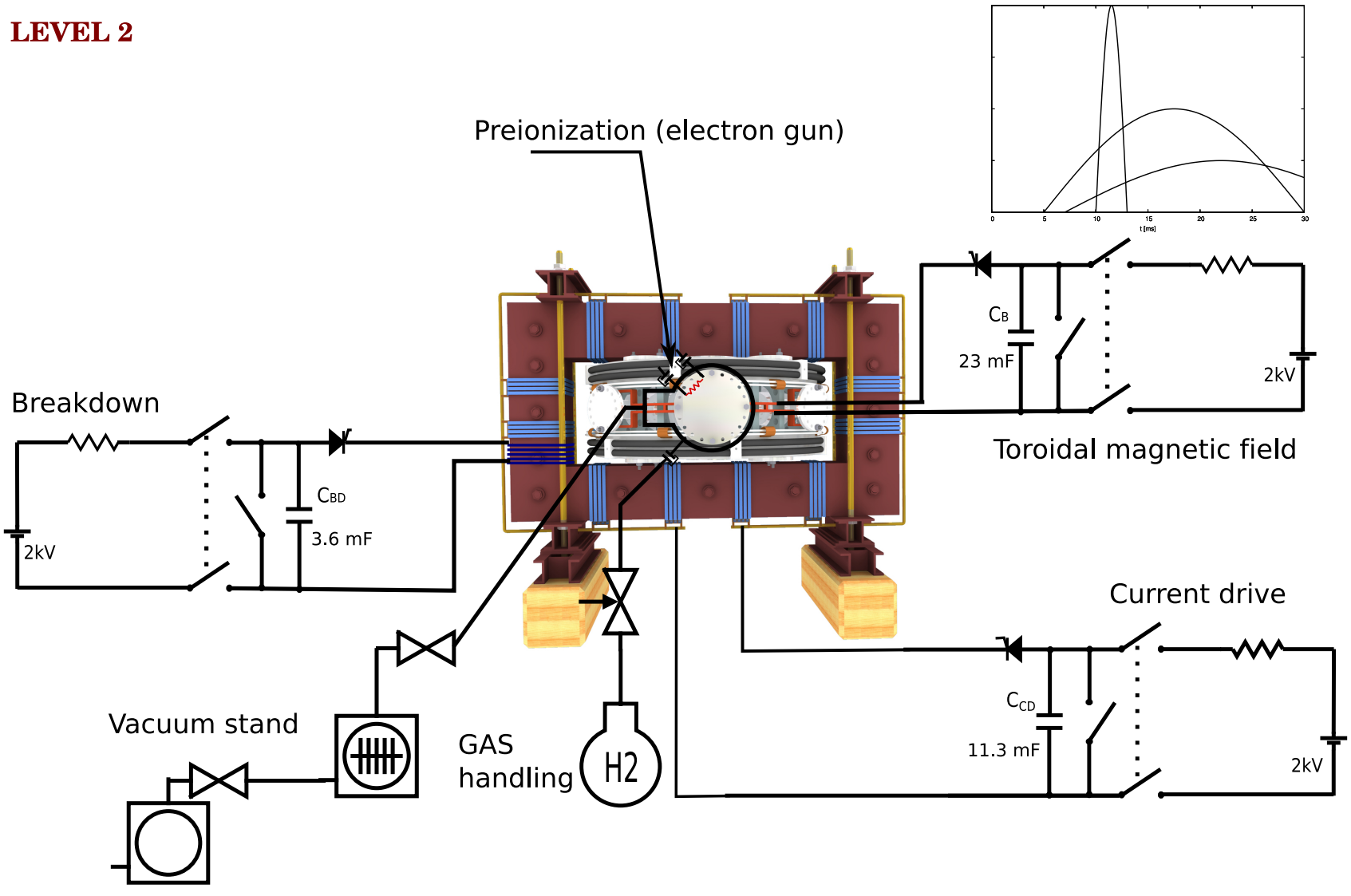
Tokamak GOLEM + CD (toroidální elektrické pole)
Ohřev plazmatu

LEVEL 1

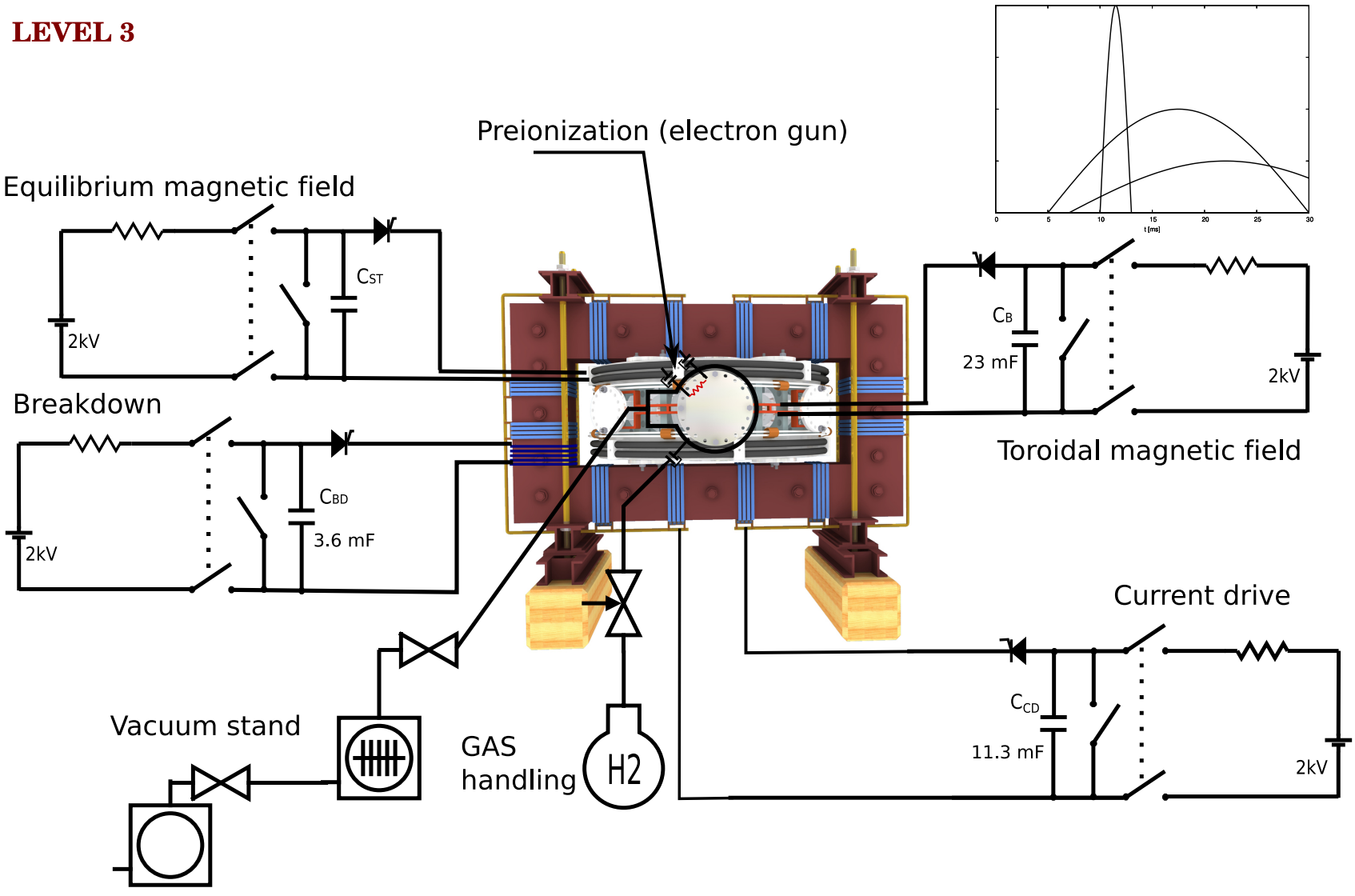


Tokamak GOLEM + pomoc průrazu neutrálního plynu **vytvoření plazmatu**

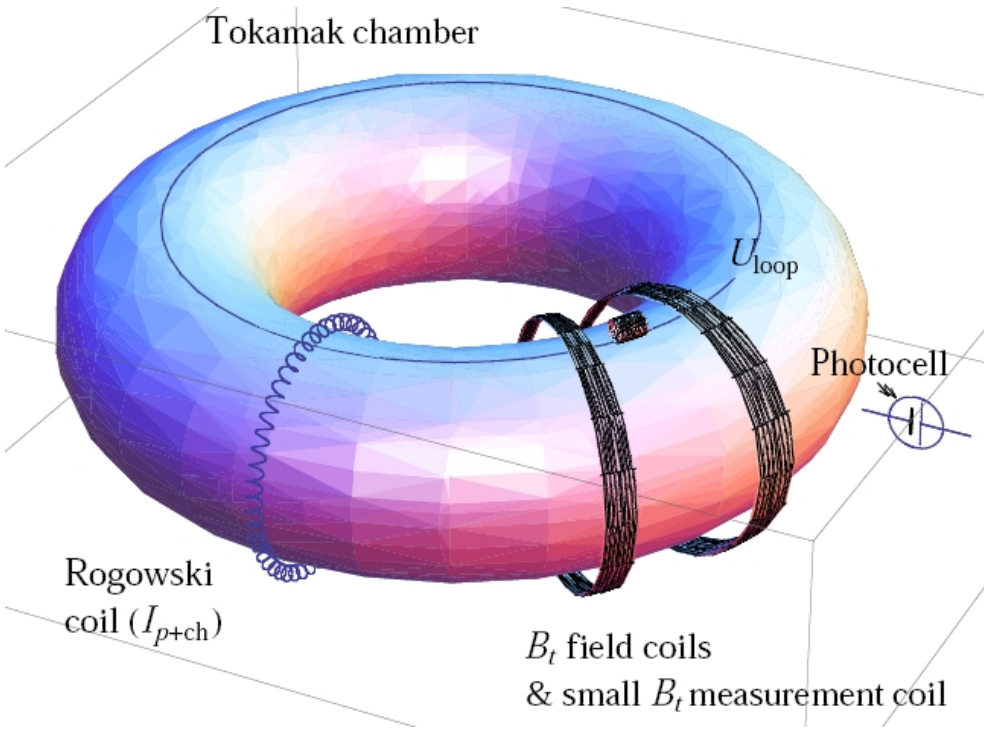
LEVEL 2

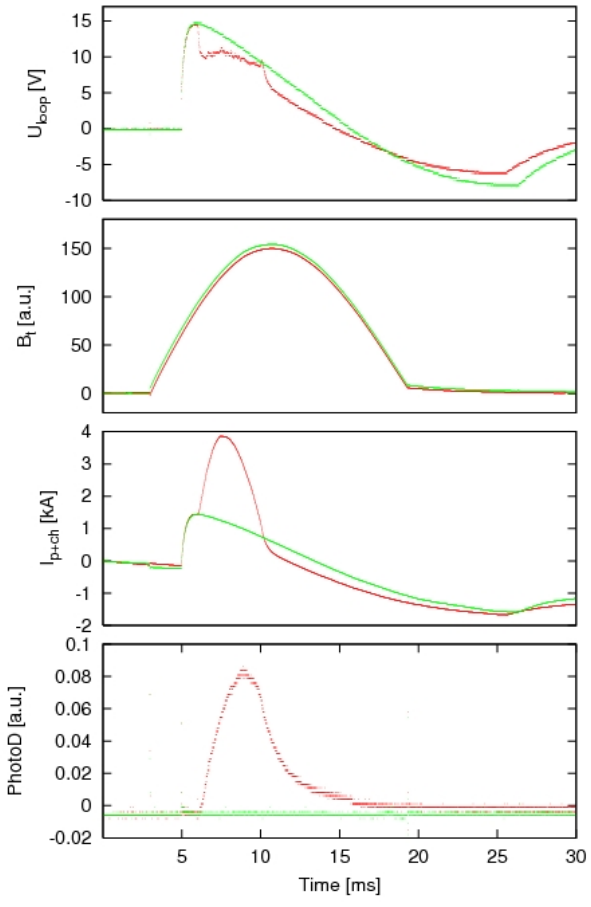


Tokamak GOLEM + základní stabilizace plazmatu vertikálním magnetickým polem



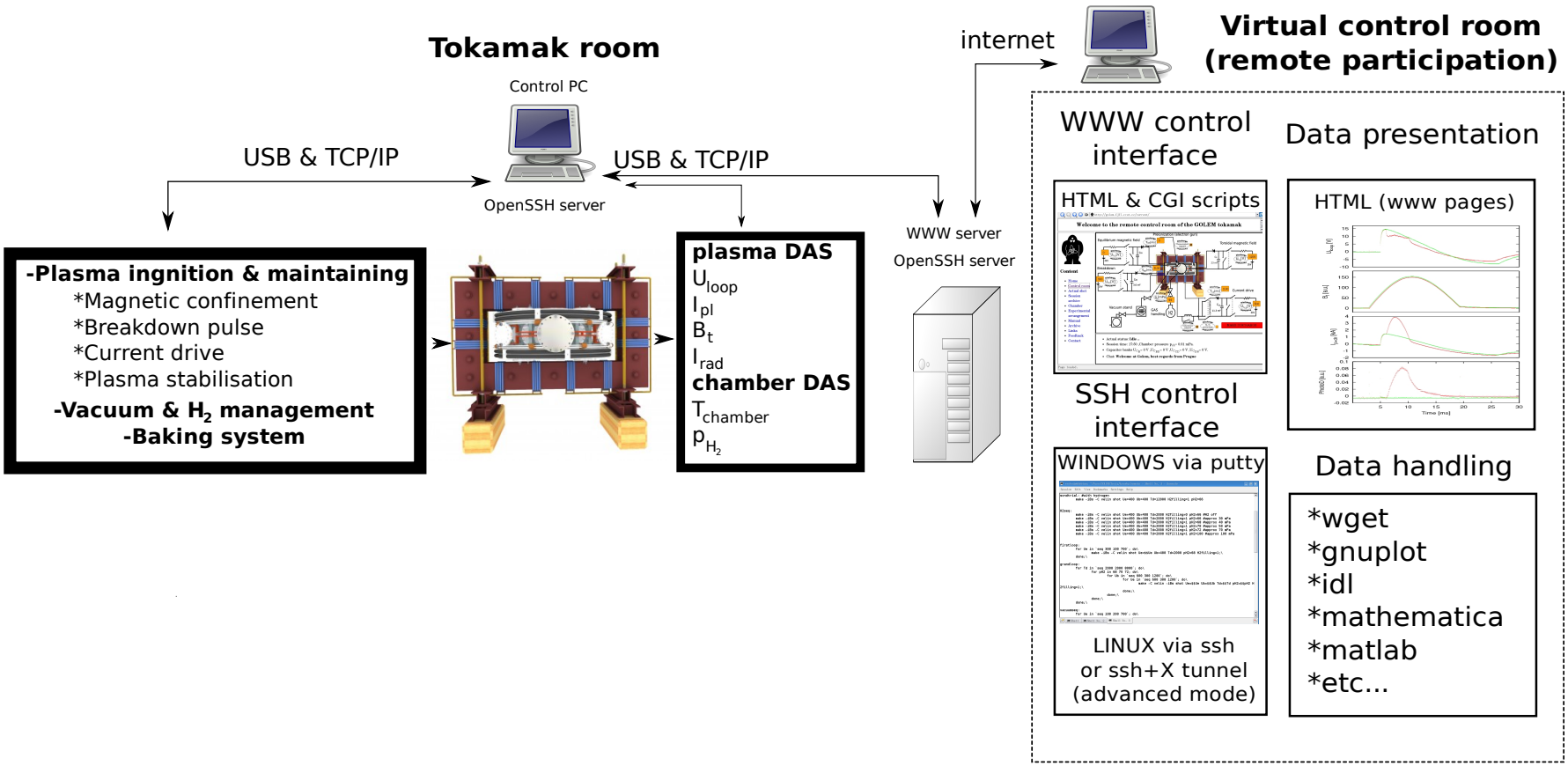
Diagnostika na tokamaku GOLEM





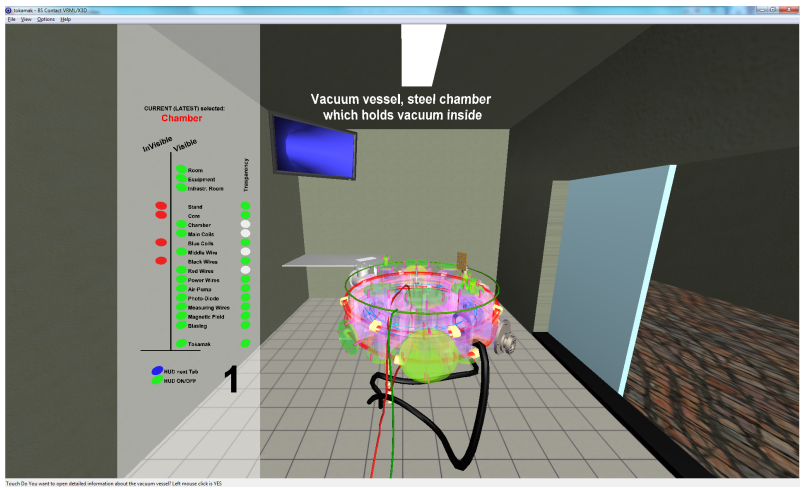
Diagnostika realizována s pomocí: NATIONAL INSTRUMENTS

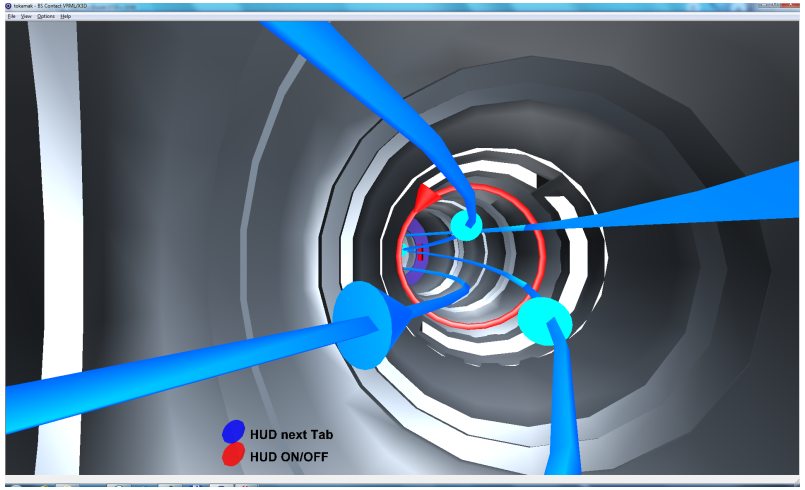
Napojení systému na internet



Virtuální model tokamaku GOLEM

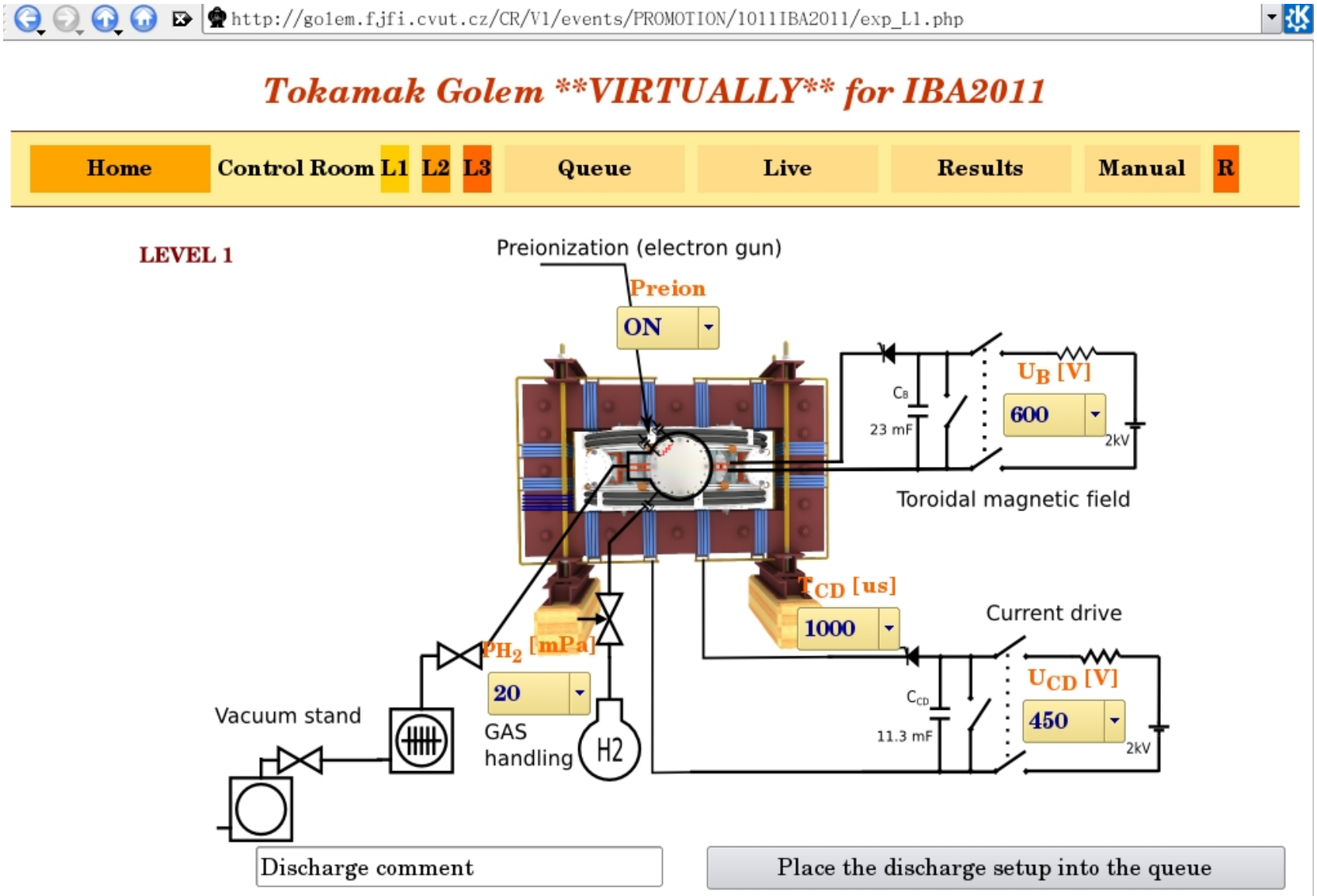
Tokamak & Kondenzátorovna





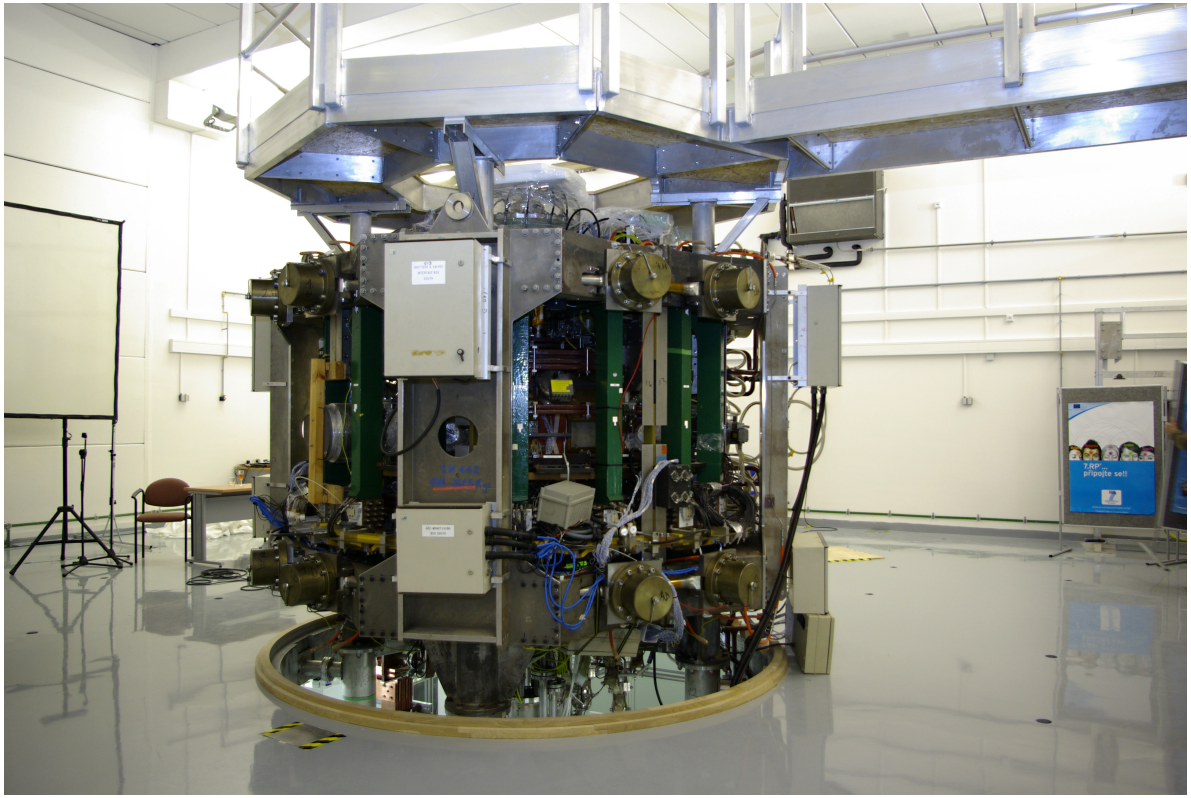
Rozklad do jednotlivých součástí & Pohled do komory

Virtuální velín tokamaku GOLEM

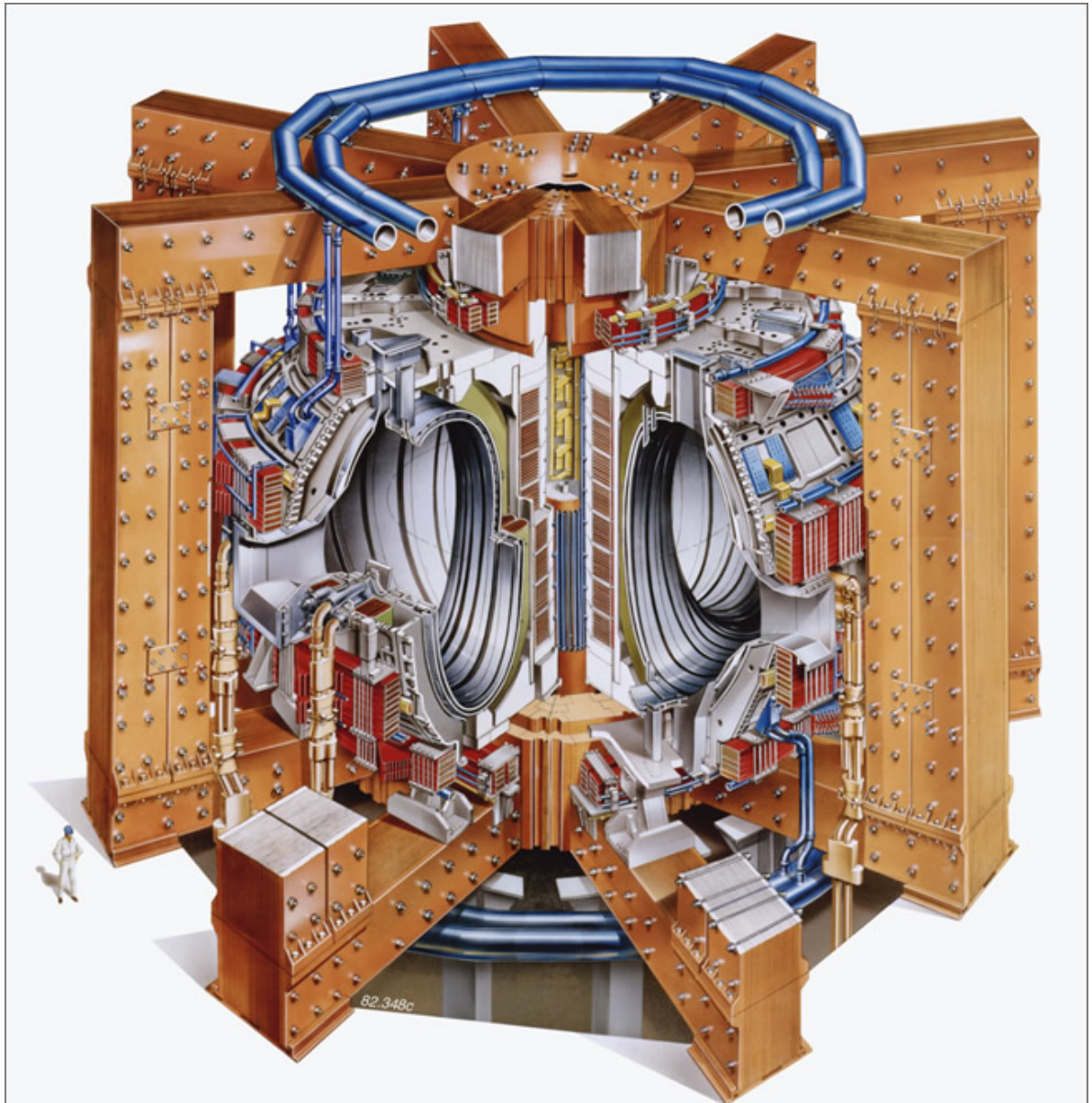


Obsah

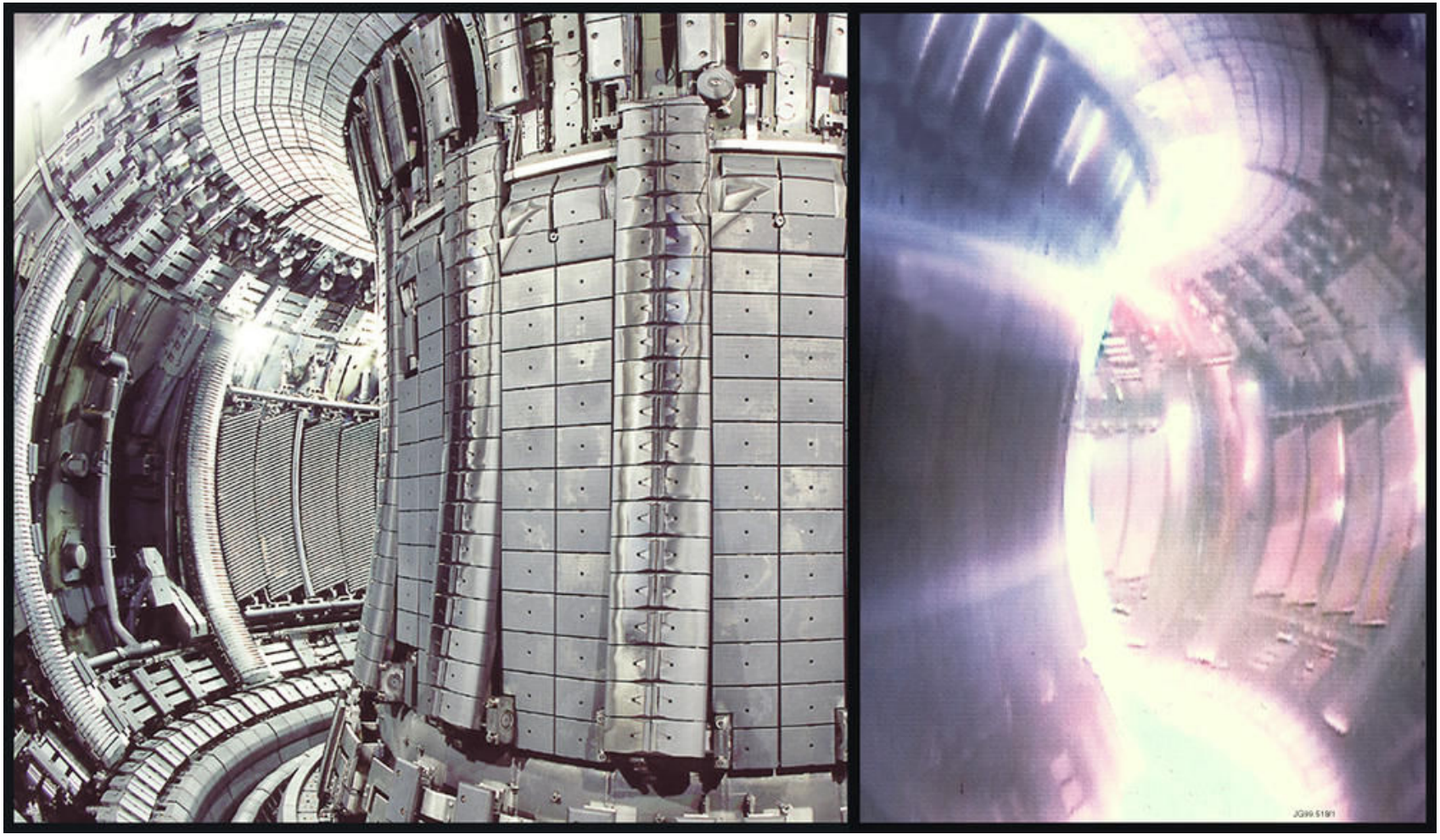
Compass



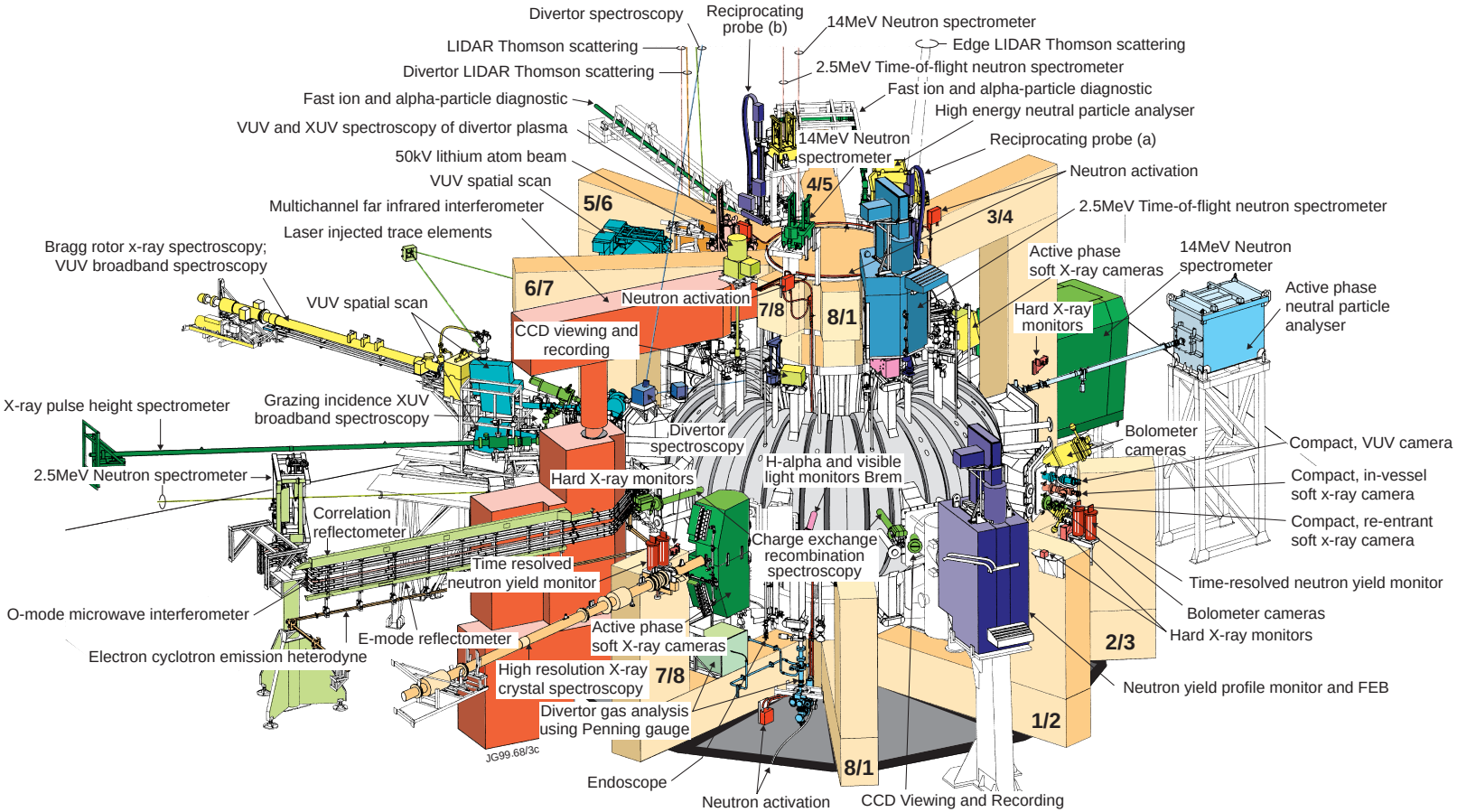
JET



Výboj v tokamaku



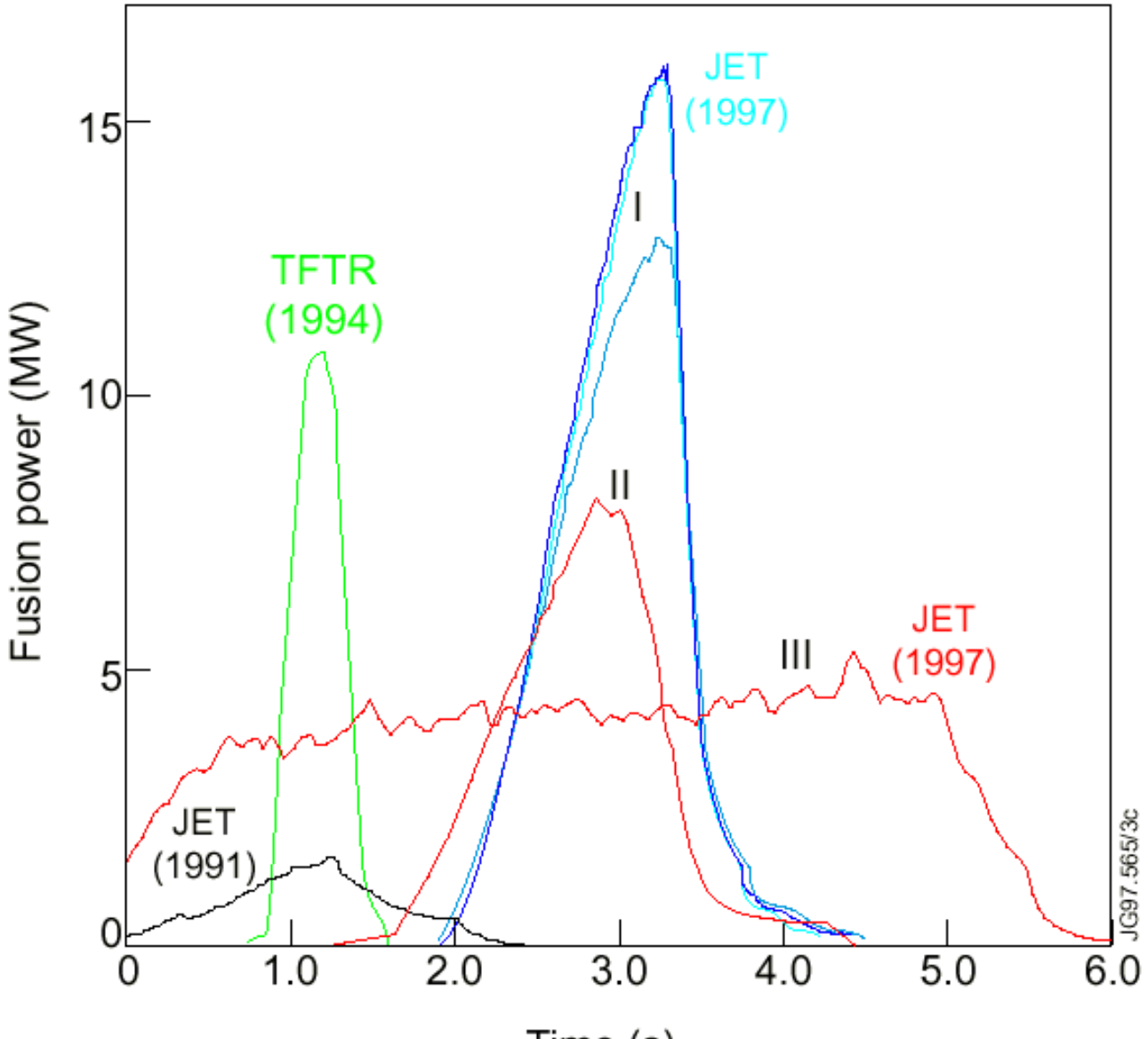
Joint European Torus (diagnostika)



The challenge of characterising extreme conditions of nuclear fusion plasmas both spatially and temporally has inspired JET to produce an impressive array of diagnostic techniques. Drawing from fields as diverse as neutronics, spectroscopy, lasers and microwaves, JET is a leader in the art of measurement."

Andrea Murari, Task Force Leader - Diagnostics.

Fúzní výkon JETu (DT palivo)



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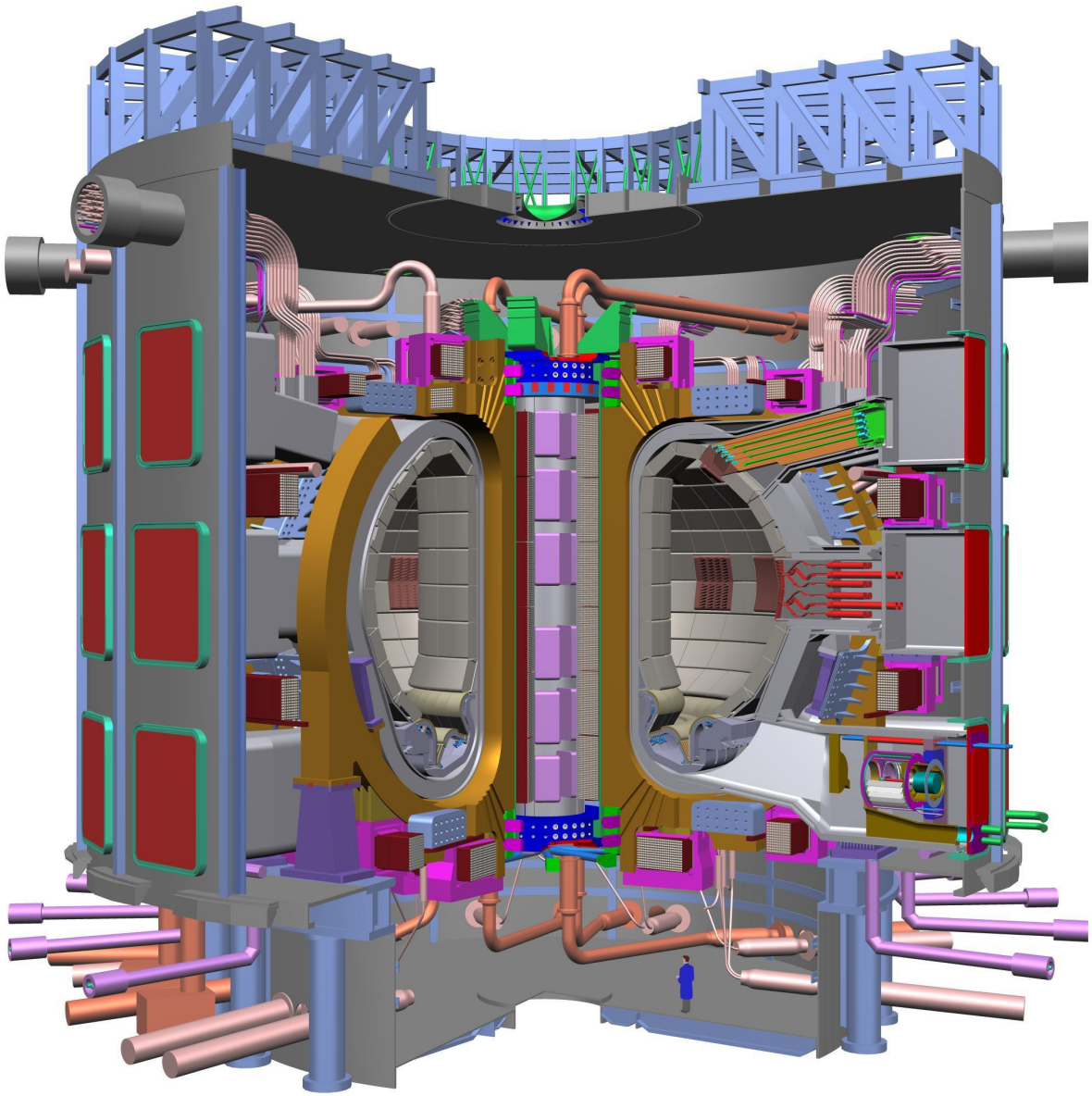
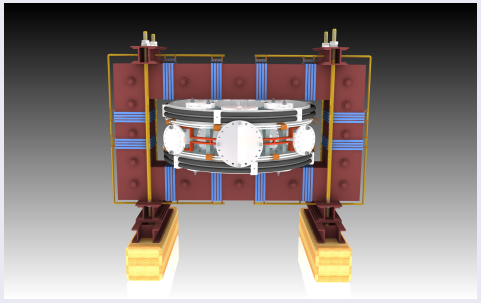


Tokamak.cz

Zimní škola fyziky plazmatu - Marianská 2011 (Tokamak, zřejmě COMPASS, s NBI)

Děkuji za pozornost



http://golem.fjfi.cvut.cz,
jste zváni