DE LA RECHERCHE À L'INDUSTRIE

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IRFM

TORE SUPRA

18-22 July 2012

www.cea.fr

Why not include TOKAMAKS in the quest of exotic particles?

Outline

I/ Tokamak and Magnetic fusion

II/ What is Tore Supra?

III/ Tore Supra and the Axions or ALPs

IV/ Tore Supra and Solar Chameleons

V/ Conclusion

Tore Supra and What else ?
Tore Supra and the WEST projet

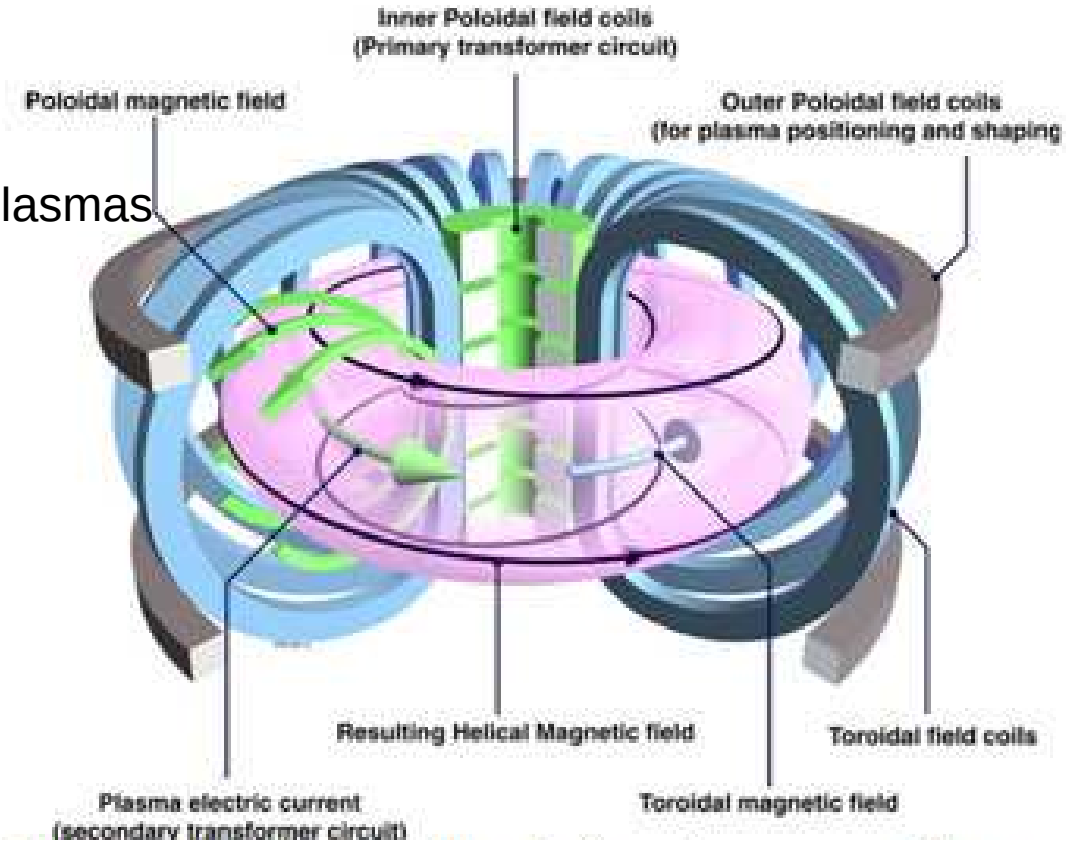
What is a Tokamak?

Tokamak : Russian acronyms
- Toroidal Chamber
- Magnetic field
- Current

Aiming at confining thermonuclear plasmas

Developed during the ’50 by
A. Sakharov, B. Kadomtsev,
L. Artsimovitch, V.Shafranov
Soviet Academicians
Breaking results IAEA conf. ’68
Tokamak – T3

$$\nabla p = \vec{J} \times \vec{B}$$



$$nT_i\tau_E \sim 10^{21}\ m^{-3}.keV.s$$

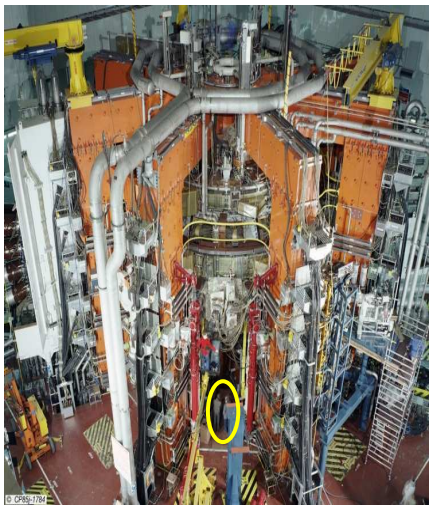
$$\tau_E \ \alpha \ a^2/D$$ (a length of the confinement box
D diffusion coefficient)

$$D_{Coll} \ \alpha \ \nu\rho_i \qquad \sim 10^{-2} m^2/s$$
$$D_{Neoclass} \ \alpha \ q^2\varepsilon^{1/2}D_{coll} \qquad \sim 10^{-1} m^2/s$$
$$D_{Turb} \ \alpha \ \nabla T/T_c \qquad \sim 1\text{-}10\ m^2/s$$

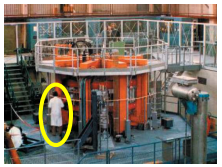
What next? Confinement of alpha particles?

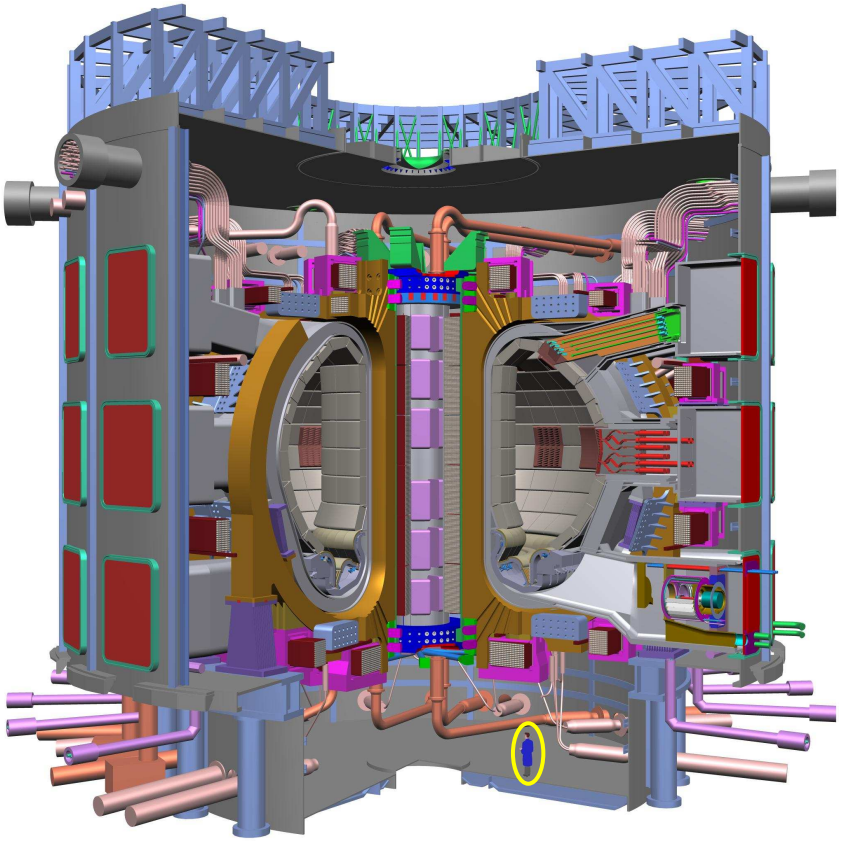
$$D \nearrow \quad a^2 \nearrow$$

Bigger and Bigger Tokamaks



JET
80 m³





T3
~ 0.3 m³

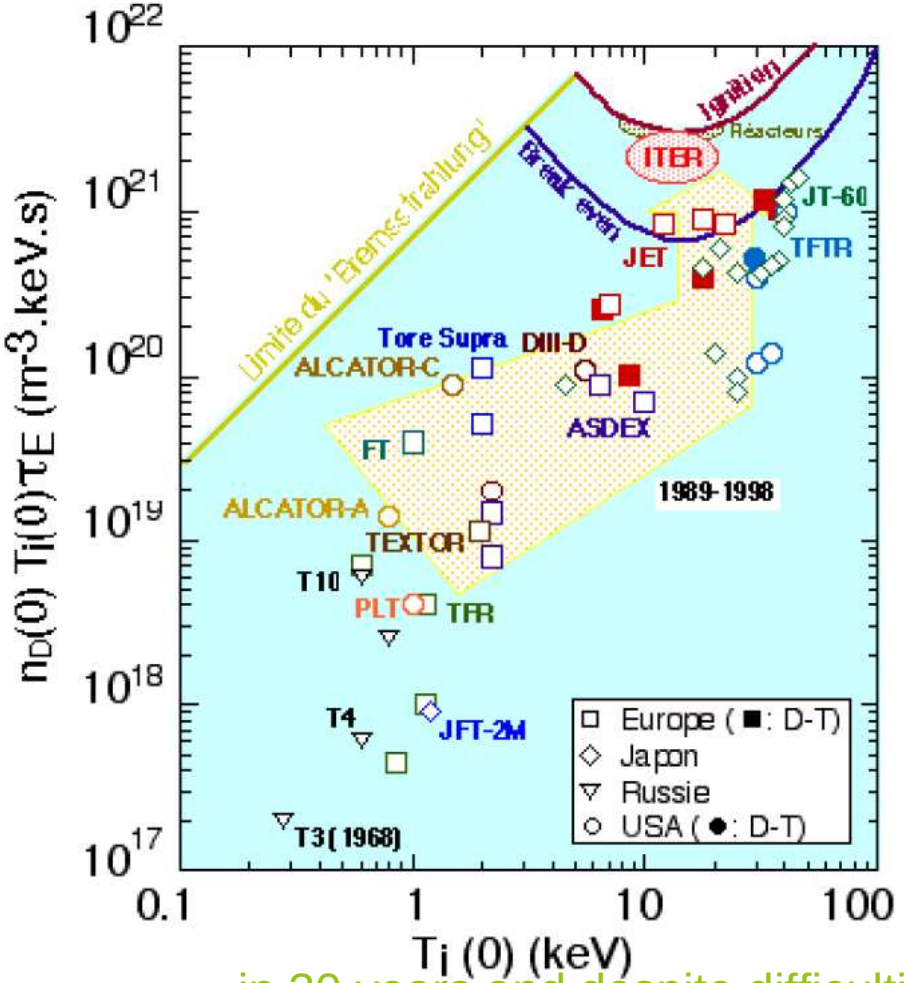
TFR
PLT
0.5-1m³

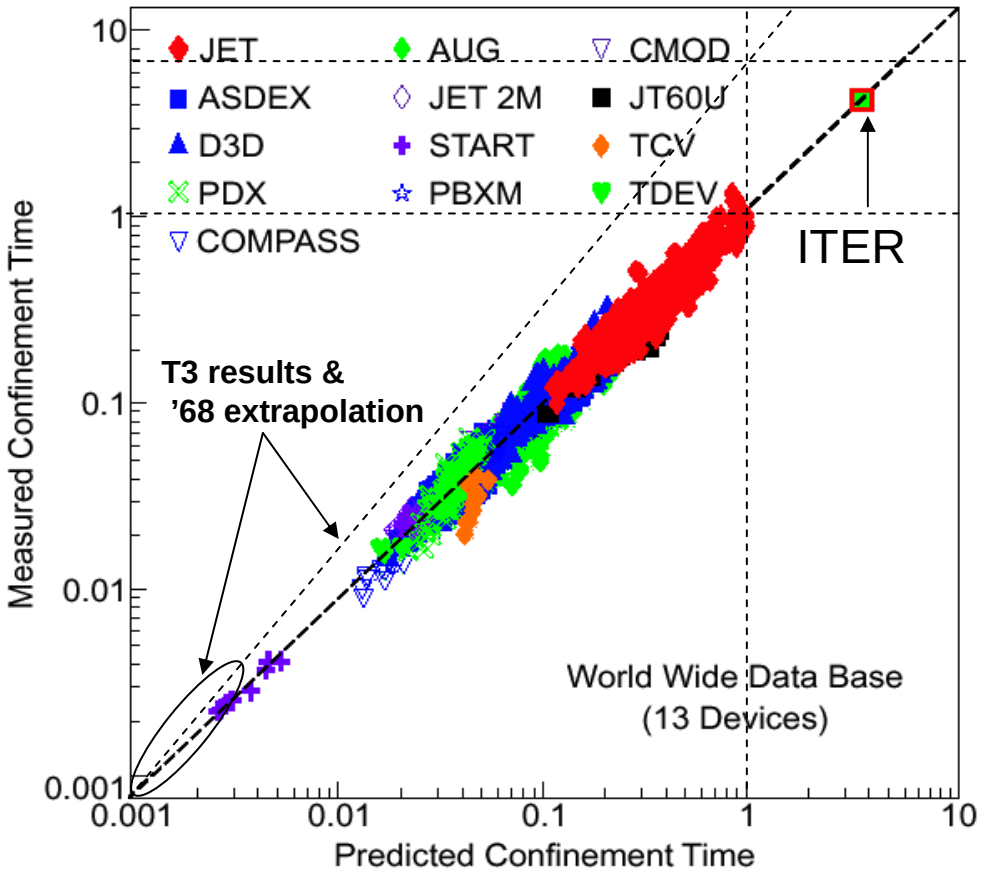
Tore Supra
TFTR
25-30 m³

ITER
800m³

1960 1970 1980 1990 2000 2010 2020 2030 2040

Steady progress towards thermonuclear conditions



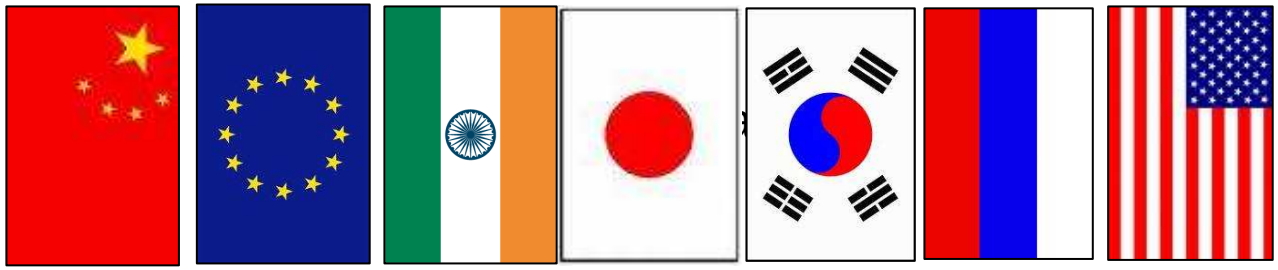


in 30 years and despite difficulties $nT_i\tau_E$ increased steadily by a factor 10^4

(as fast as the Moore low for semiconductors)

Still a factor 3-5 needed with ITER!!

ITER Project
International Thermonuclear Experimental Reactor



Iter:*lat.* ''the way'' *(prononced like iterate)*

Partnership:

55 % of mankind

70% of the mondial PIB

Cost: 10 G€ construction

5 G€ operation

Decision
Reagan/Gorbatchev
Reykjavik, 1985

Engineering
Design
Activities
1990-2003

R. Aymar (EDA)
P.H. Rebut (CDA)
CEA/DSM

Sites
Competition
2003-2005

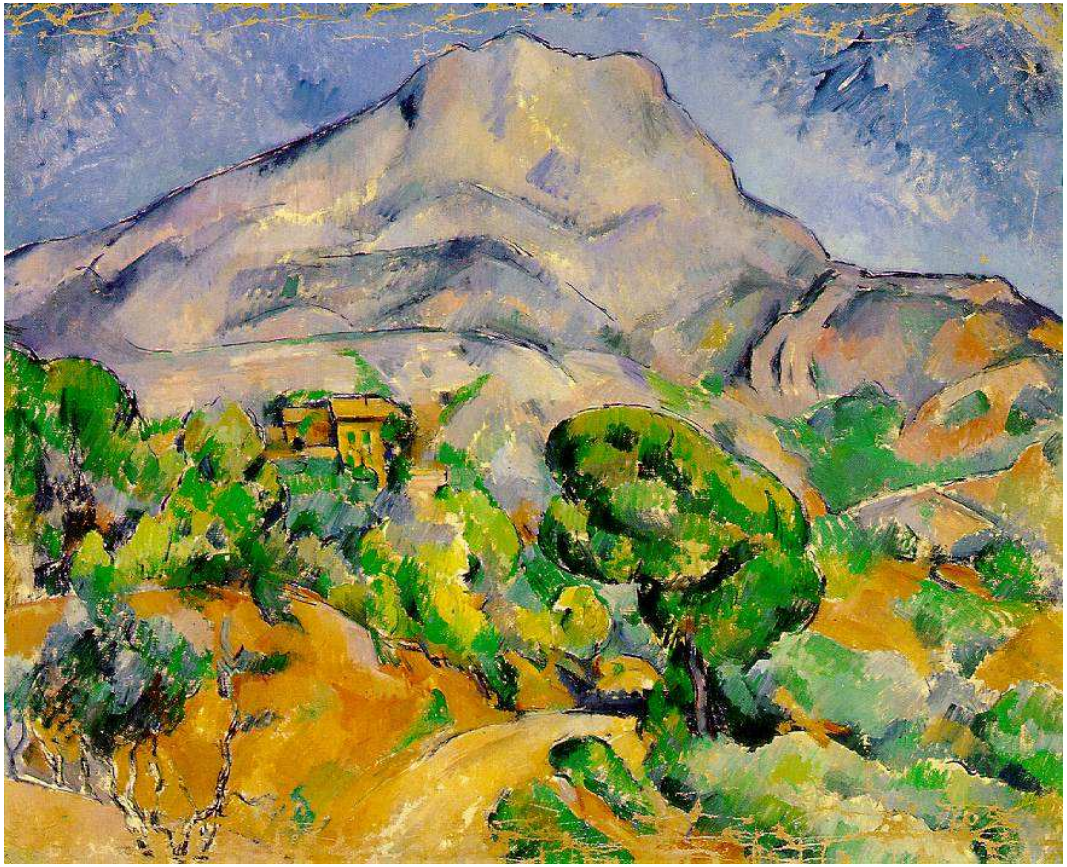
Site prep.
& licensing
2005-2007

Construction
2007-2020

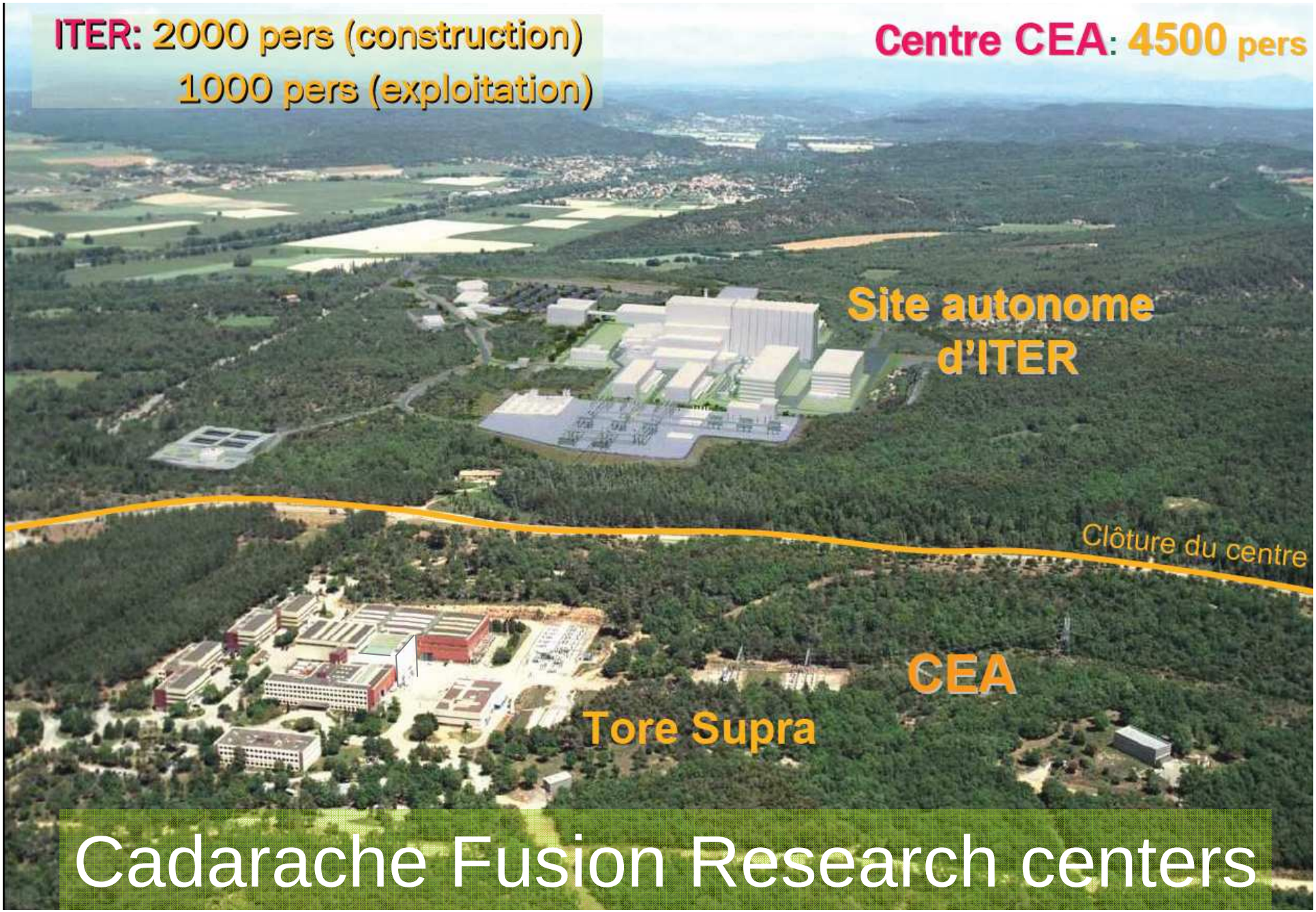
O. Motojima
K. Ikeda

Operation
2020 - 2027 - 2040
H2-D2 - DT

Where is Cadarache ?



Paul Cézanne, Montagne Sainte Victoire, Summer 1900

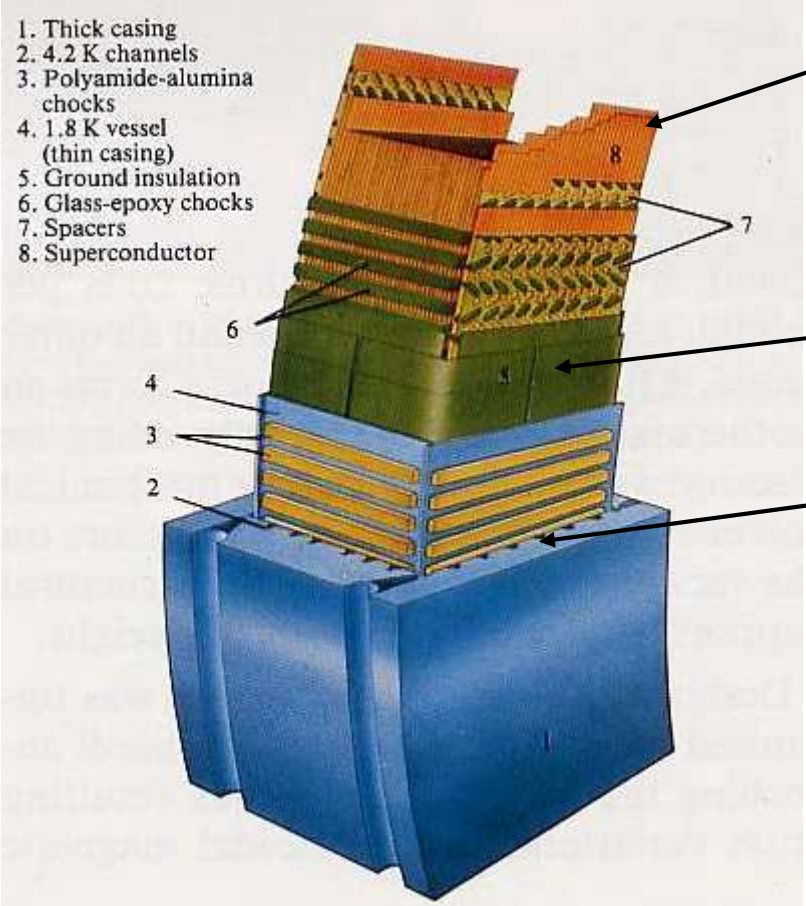


Cadarache Fusion Research centers

What is Tore Supra ?


ADC

Tore Supra Toroidal Field coils



Tore Supra TF coil structure

bare conductors in superfluid helium !

Superfluid helium (1.8 K) in thin casing

50 Tons

Supercritical helium (4.5 K) in thick casing channels

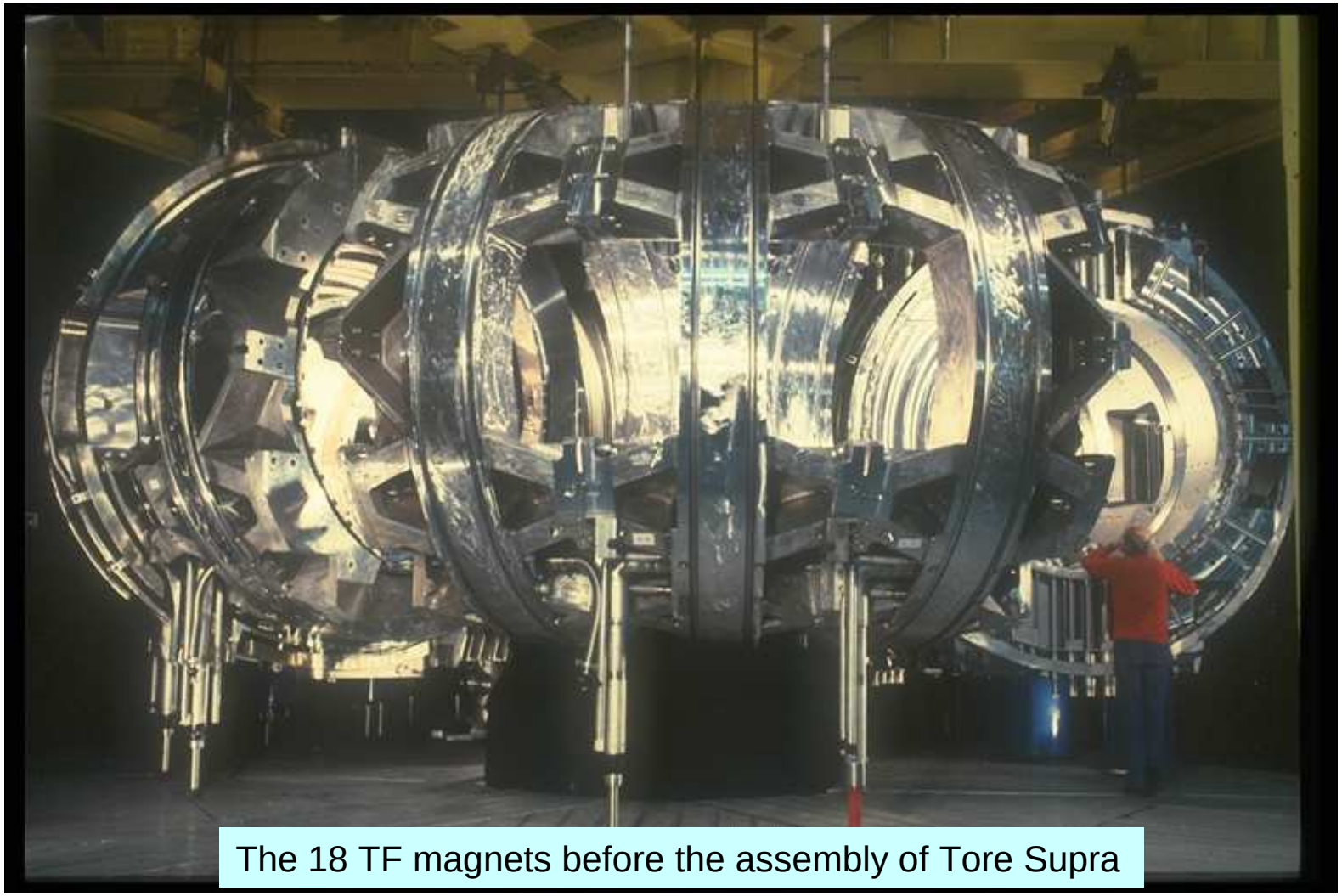
120 Tons

+

Thermal screens (80 K) 20 Tons

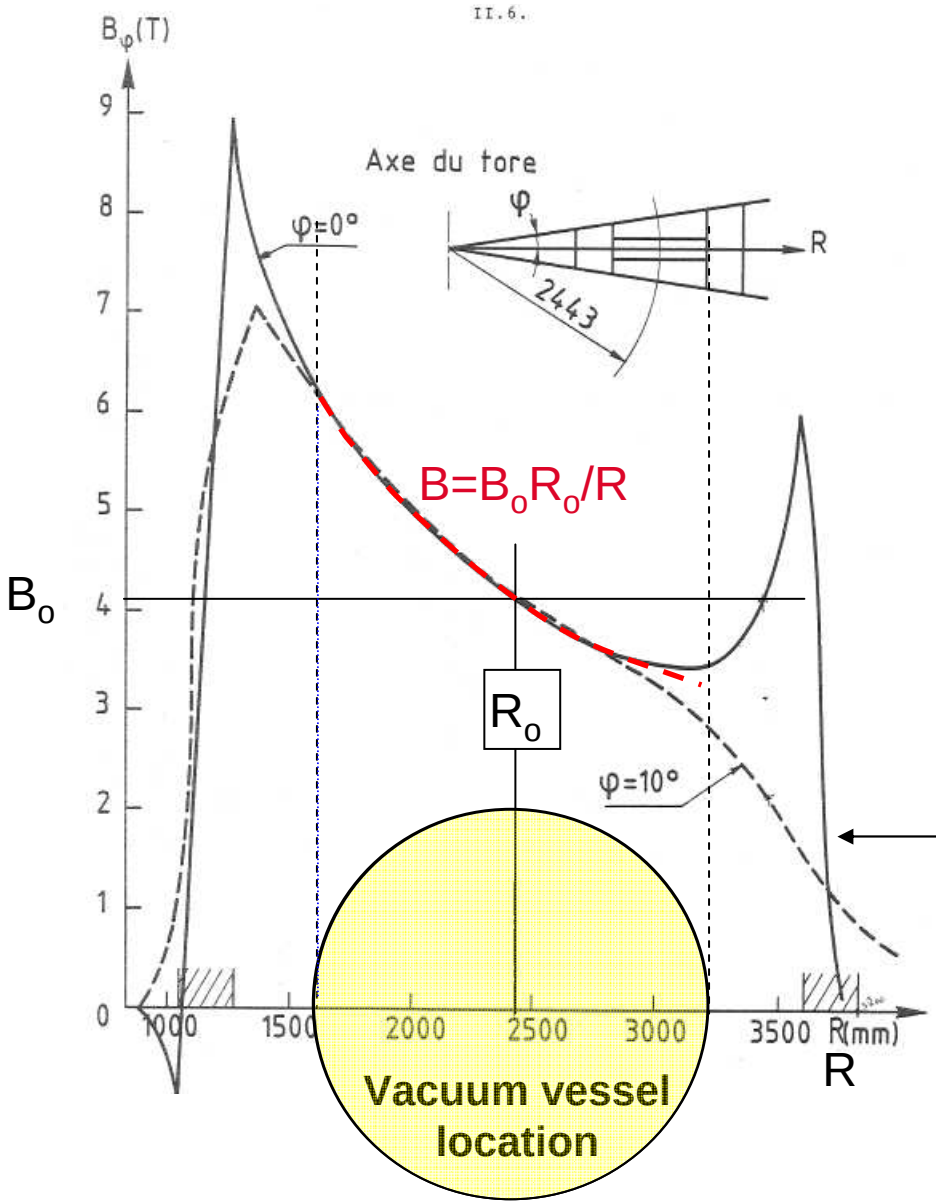
Pioneering LHC technologies

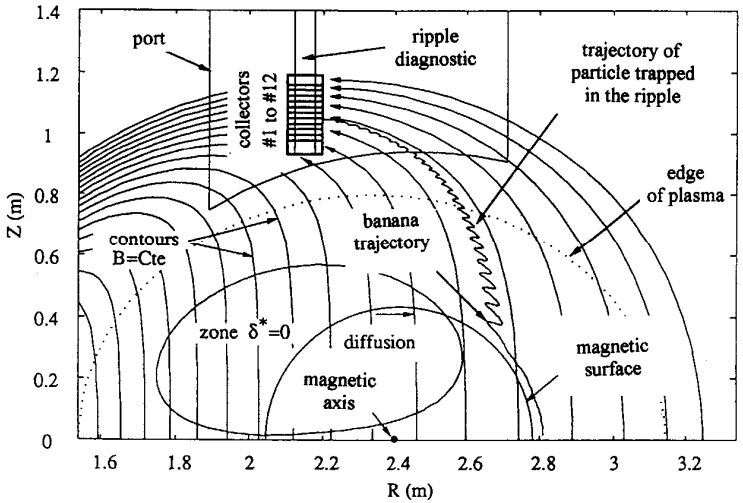
Tore Supra magnetic field system



The 18 TF magnets before the assembly of Tore Supra

Tore Supra Toroidal magnetic field





IsoB$_T$ in the R,Z plan

Toroidal magnetic field intensity

- On the axis of one TF coils
- In between two adjacent coils

Distribution at full current (1450 A, 4,5 T on axis)
Now magnetizing current limited to 1250 A (3,85 T on axis)

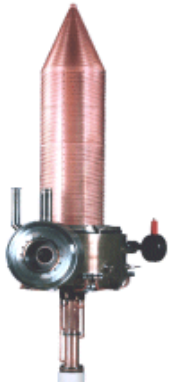
Tore Supra Main Parameters

TORE SUPRA	
start of operation (y)	**1988**
Ro (m)	2,4
a (m)	0,8
BTo (T)	3,85
Vessel volume (m3)	35

Pressure	10e-5 Pa *Gyrotron 118 GHz*
Temperature	120℃

Torus Hall : 30 m x 30 m x10 m
(ITER: 80x80x80)
Manhole for Access 65x55 cm

RF Heating Systems:
47-54 MHz : 12 MW x 40s
3.7 GHz : 8 MW cw
118 GHz : 1 MW x 5s



118Ghz antenna & gyroton,
propagation HE11 corrugated waveguide L=25m

Tore Supra
and
relic Axions

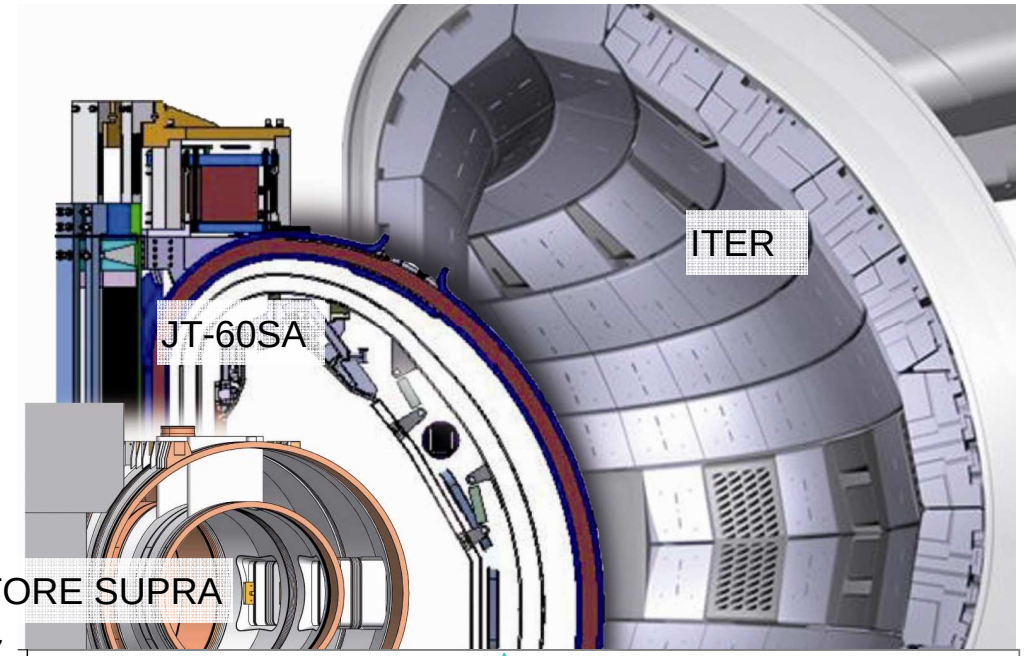
Axions search with Tokamaks
Tore Supra & the next

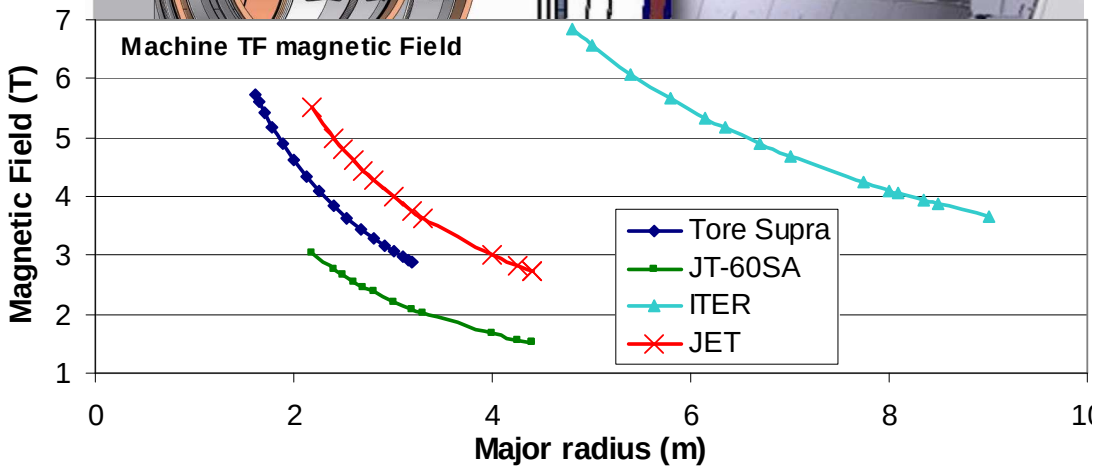
Dedicated existing experiments

Param. / Units		CAST-I	ADMX
B	T	9	7.5
L	m	9.26	1
A	m^2	0.003	0.2
B^2V	T^2m^3	**2.25**	**12**

Large superconducting tokamaks

Param. / Units		TS	JT-60SA	ITER
B	T	4	2.25	5
$L=2\pi R_o$	m	15	19	38
A	m^2	2	7	35
B^2V	T^2m^3	**480**	**700**	**30000**
Starting date		**1988**	**2019**	**2022**
Location		**Cadarache**	**Naka**	**Cadarache**

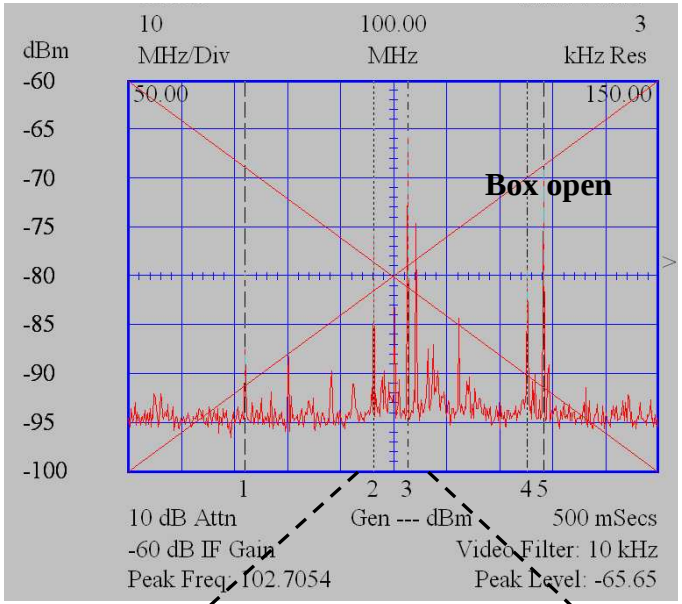


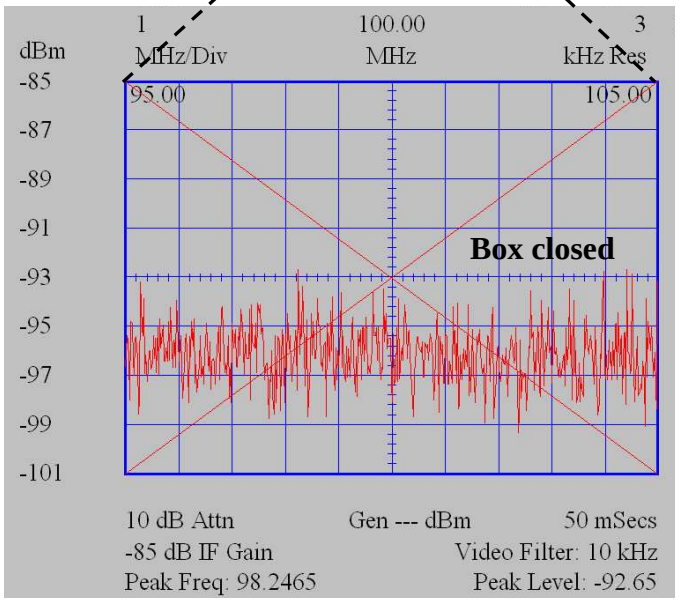


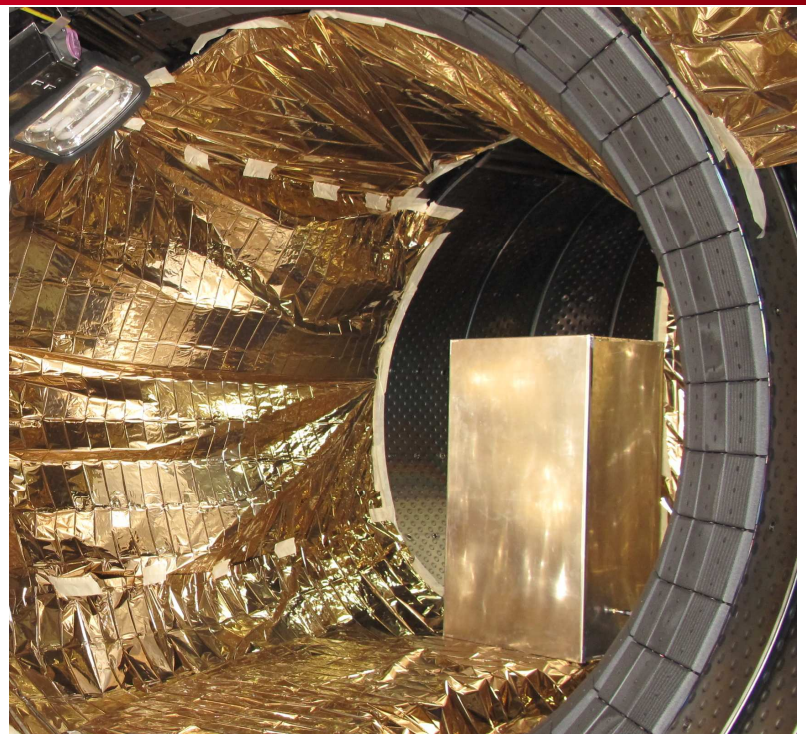
ITER* and JT-60SA directorates aware of and interested by Konstantin's request

*See : http://www.iter.org/newsline/227

Tore Supra and the Axions search (at low frequencies<1GHz)







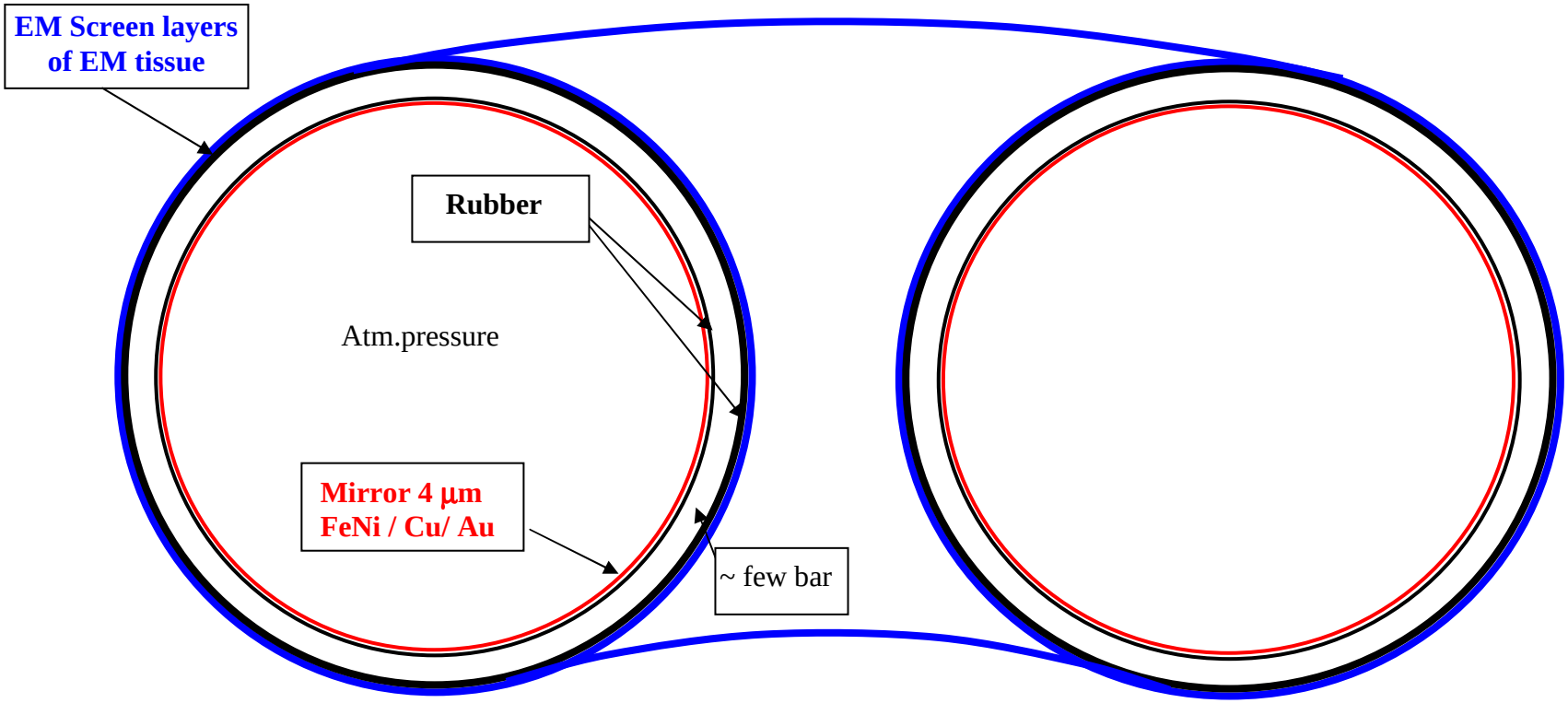
Possible Concept EM noise screening:

box-in-a-box concept.

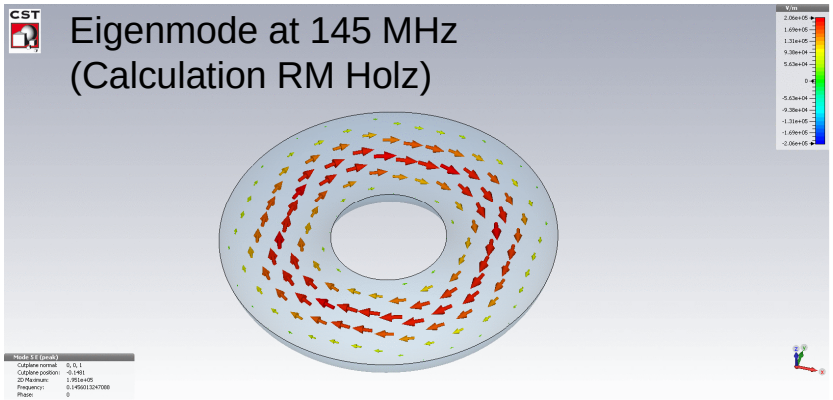
Insert a metal coated inner tube in Tore Supra. (inflatable structures and multi layers RF protective textiles). Make available the whole volume and accessible the full 480 T^2m^3.

Collaboration with F. Caspers,CERN

A concept for 140 - 200 MHz Pneumatic resonator inserted in Tore Supra for CDM axion search



Double shell pneumatic resonator for 100 MHz-2 GHz CDM Axion search in Tore Supra



Similar mechanical concerns for the Chicago Pile N°1 CP1 and its “cubical” balloon 1942 !

A 100dB RF screen for Tore Supra

YSHIELD GmbH & Co. KG
Am Schulplatz 2
94099 Ruhstorf
GERMANY

Phone: 0049-8531-31713-8
Fax: 0049-8531-31713-5
Email: info@yshield.com
Internet: www.yshield.com

YSHIELD
EMR - PROTECTION

Miscellaneous shielding products 2/8

Metallized polyester netting HNG100 (HF+LF)

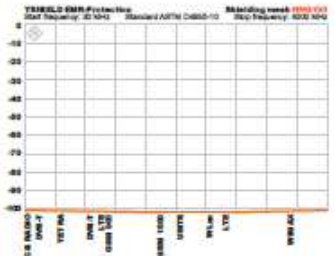
Characteristics

HNG100 is a compact woven, **heavy metallized polyester netting for shielding of high-frequency radiation (HF) and low-frequency electric fields (LF).**

Maximum shielding product with over 100 dB. This professional product is typically used for ministries of defence, banking houses, laboratories, etc. Typical application **for bonding interior** on walls, ceilings, floors, as intermediate layer, for **drywall constructions**, loosely laid, etc.

Technical data

- **Width: 145 cm**
- **Length: By the meter / 20 m roll**
- **Attenuation: 100 dB at 1 GHz**
- Weight: 140 g/m²
- Material thickness: 0.08 mm
- Color: Anthracite / Brown
- Tensile strength: Very good in both directions, 220 N/mm
- Materials: Polyester, copper, nickel, protection coating
- Surface conductivity: 0.003 ohm (square resistance R□)



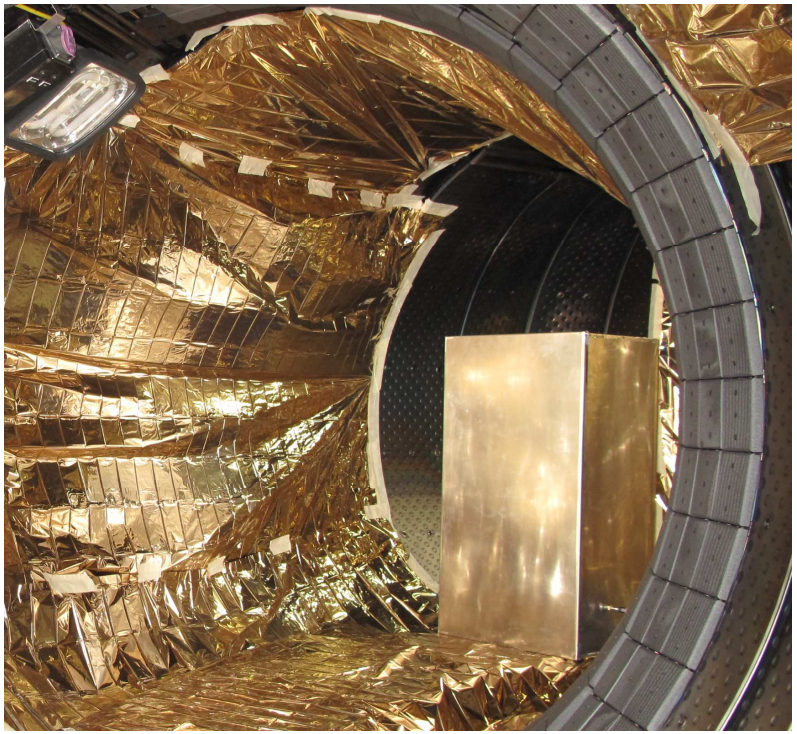
Typical metalized tissue for RF shielding of Tore Supra :
Manufactured by **YSHIELD**

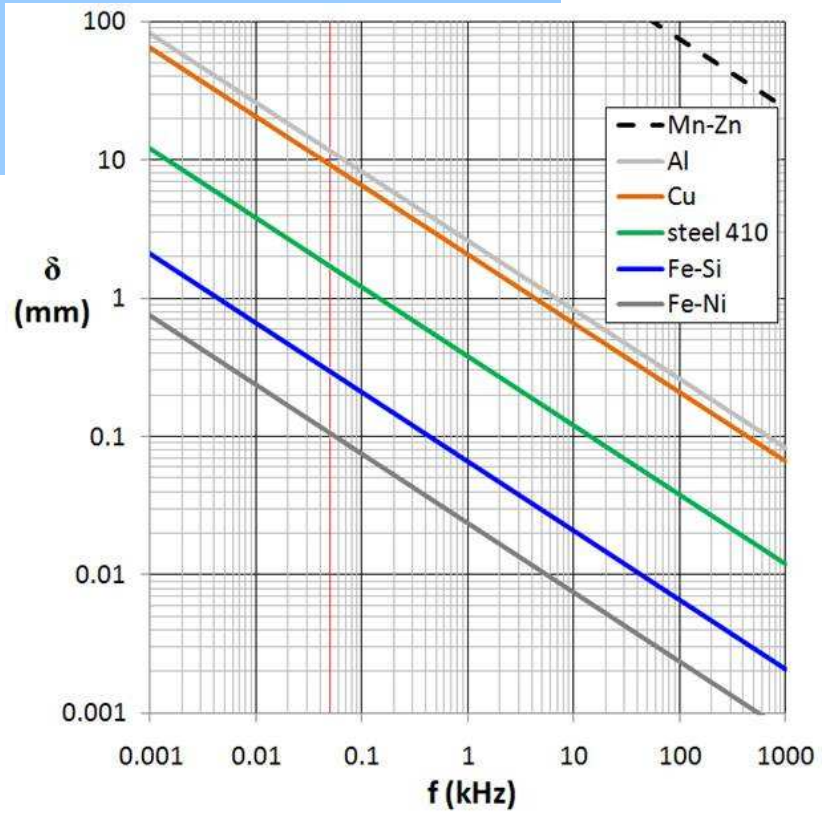
6 or 8 layers if so required.
Cheap: < 30 €/m²

Tore Supra and the ALPs search (at High Frequencies >10 GHz)

Only things to do :

1) Improve the reflection coefficient of the wall (hanging the wall with improved golden thermal blankets)
2) turning the magnetic field on
3) wait for a signal in a cavity of $480 T^2 m^3$…





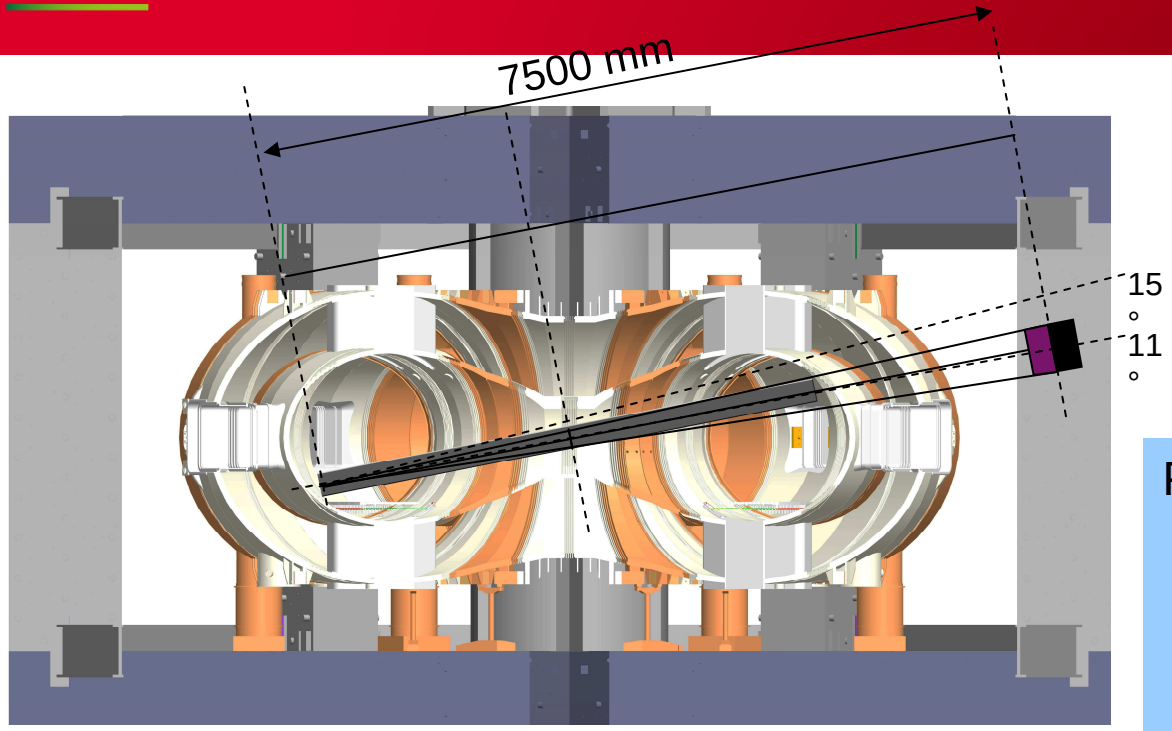
Reflective mirror thickness : 2-3 skin depths

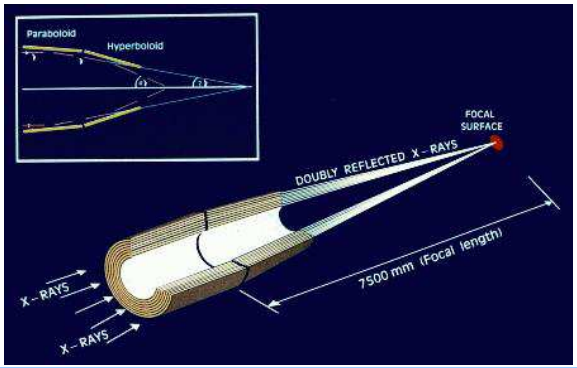
1 µm @ 4GHz for Al or Cu

20 nm @100GHz for Al or Cu

TORE SUPRA
and
Solar Chameleons

Tore Supra & Solar Cameleon search

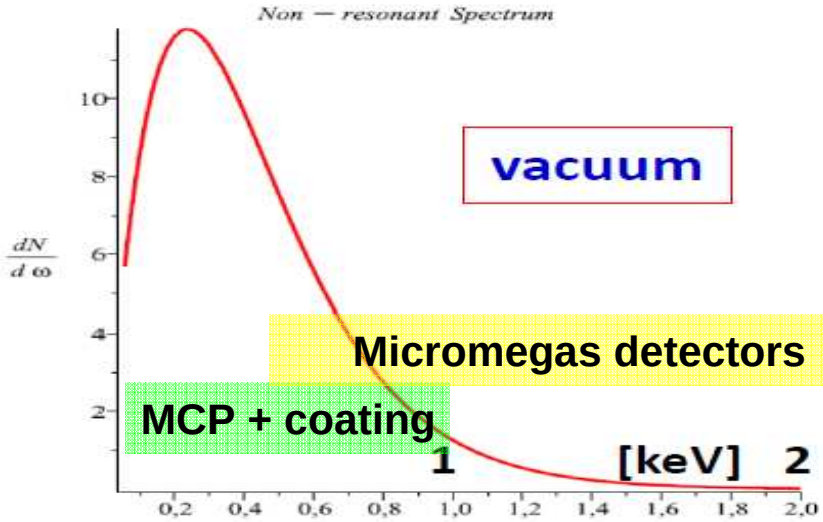


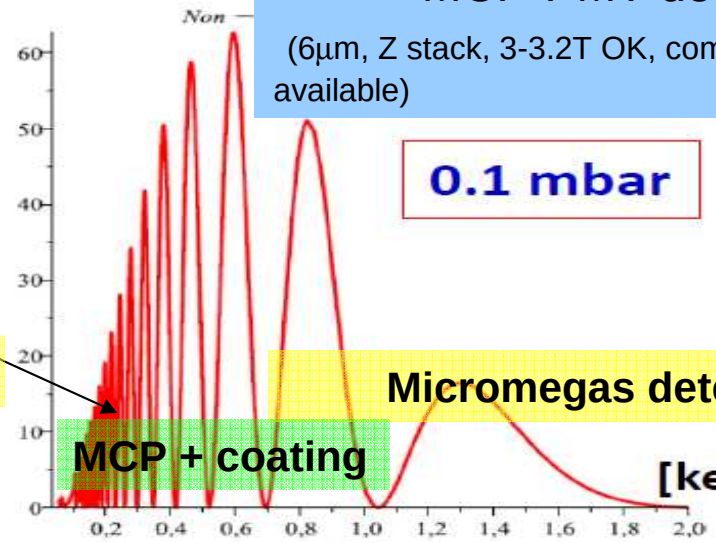


Possible Concept for Chameleon search

Tore Supra (few 10^{-5} Pa)
+ XMM
+ MCP-PMT detectors

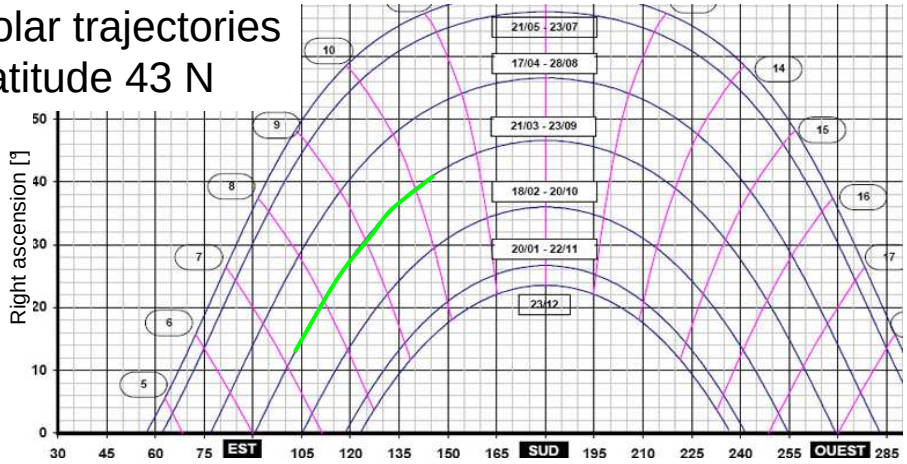
(6µm, Z stack, 3-3.2T OK, commercially available)

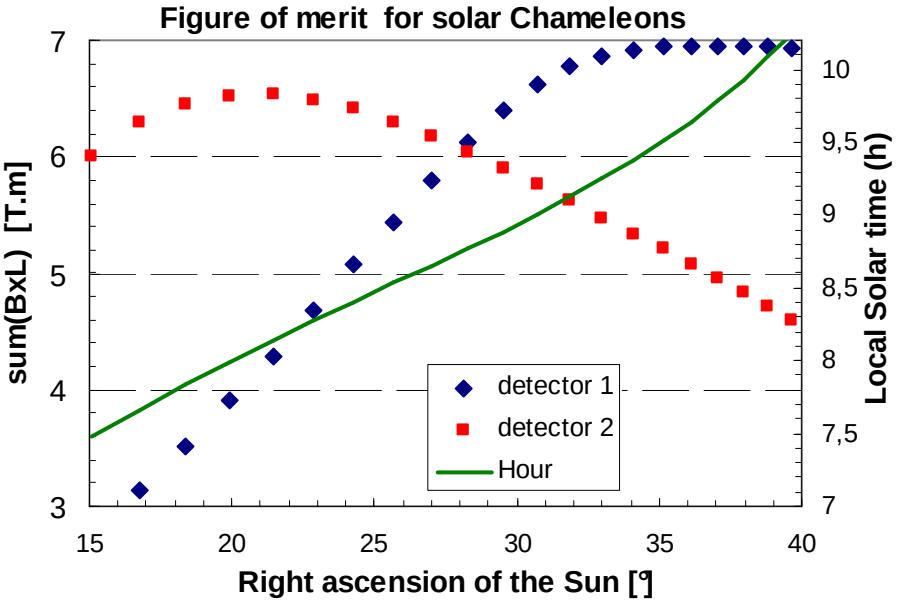


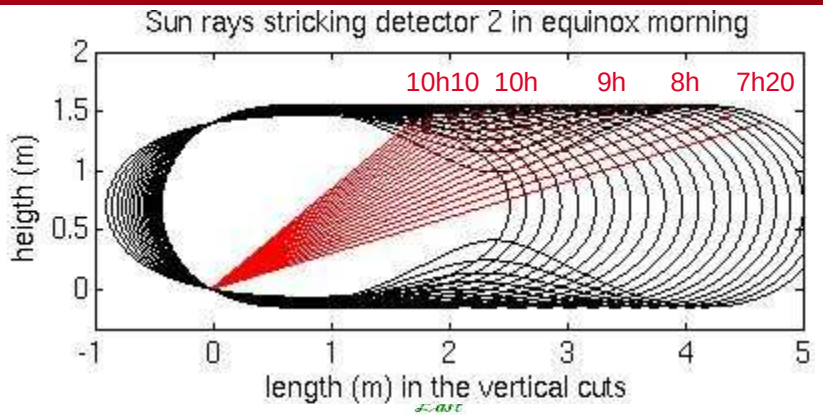


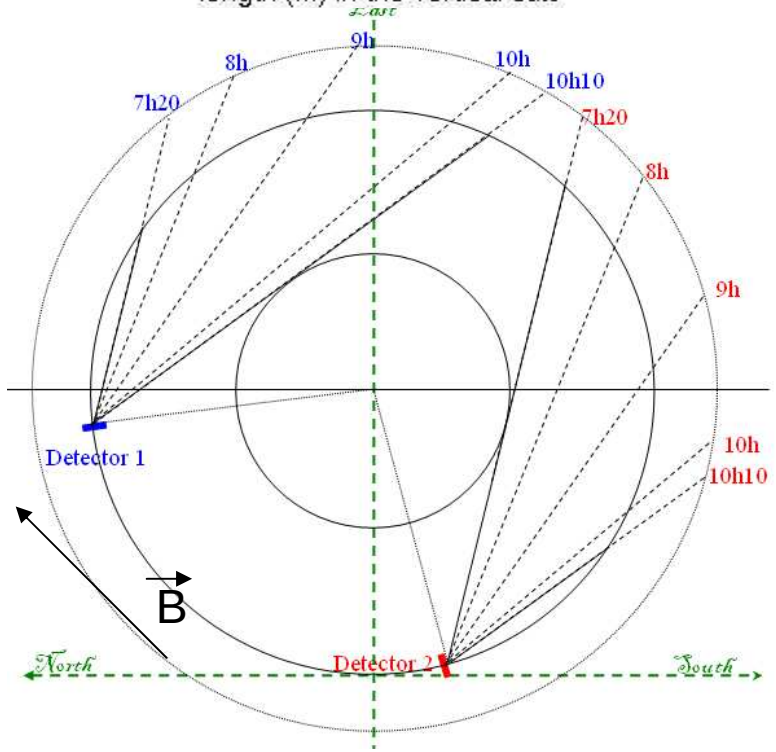
Location of MCP detectors and figures of merits in Tore Supra for solar chameleons search

Solar trajectories
Latitude 43 N









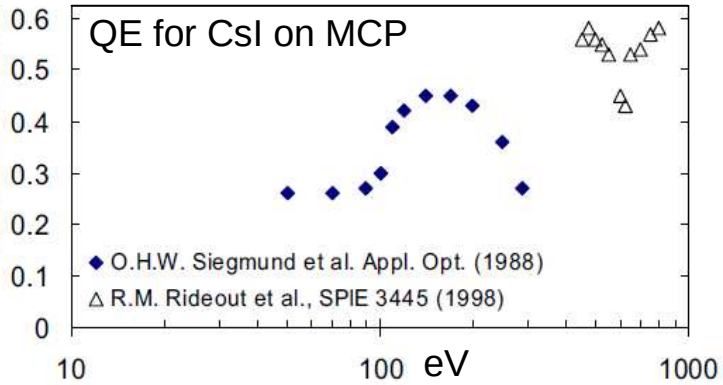
Tore Supra: the only fixed helioscope in the world, the Sun doest all the job

Micro Channel Plate Detectors (MCP-PMT)

New results from **PHOTONIS** presented* recently at the 12th Pisa-Meeting on Advanced Detectors
http://www.pi.infn.it/pm/2012/

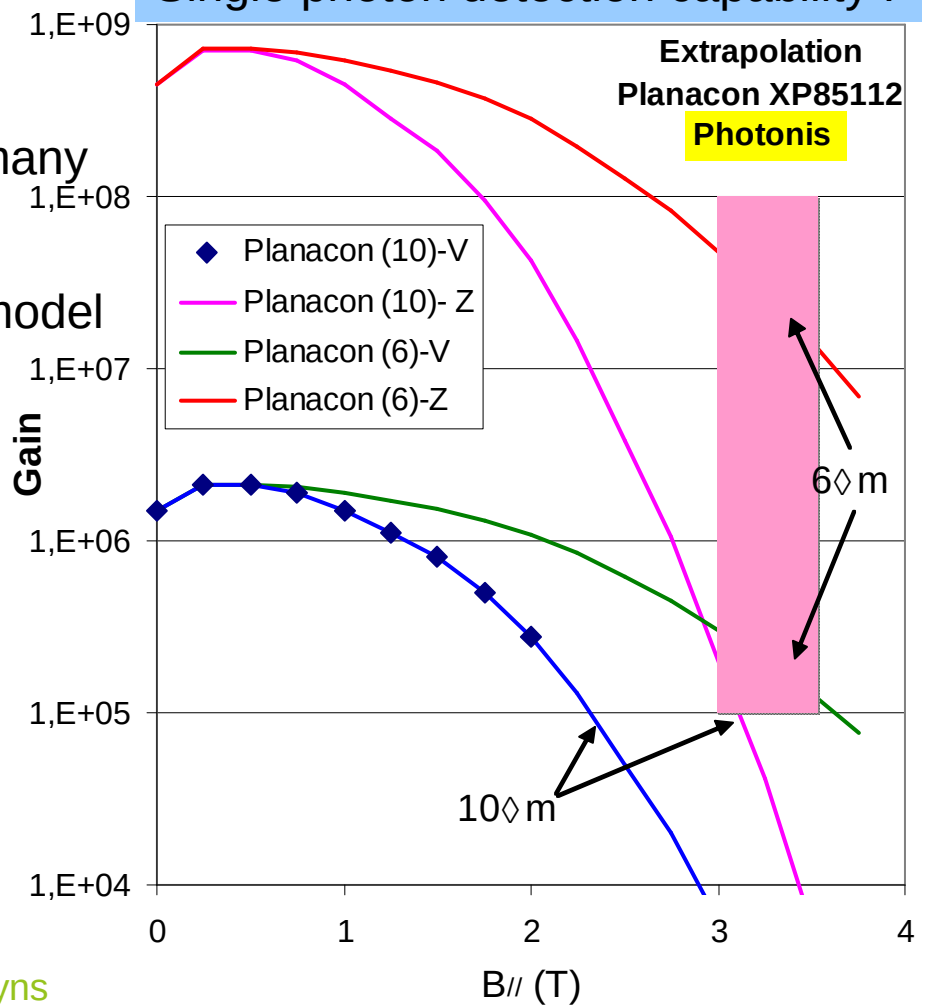
Development of Planacon XP85112
for PANDA Experiment at FAIR, GSI, Germany
http://www.photonis.com/en/ism/63-planacon.html

Results Extrapolation from G.W. Fraser's model
Nuc. Inst.& Meth; in Phys. Research, A291 (1990), p.595



A.Tremsin & O.Siegmund, in Proc of SPIE 59200 I-1

Single photon detection capability !



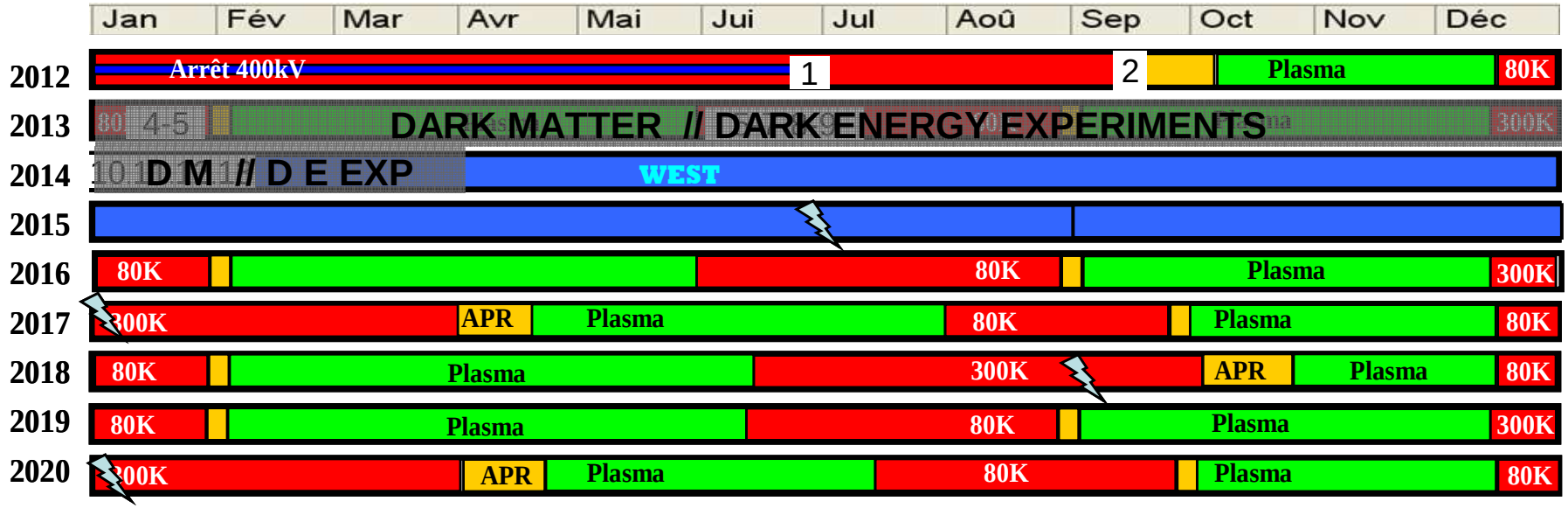
+ development cost for V or Z stack 6 µm
Photonis: Brive-la-Gaillarde, France, Courtesy E. Schyns

(*) http://agenda.infn.it/getFile.py/access?contribId=37&sessionId=9&resId=0&materialId=slides&confId=4148

New ideas discussed during the meeting Generation/Fragmentation/Detection

Seems feasible
To be elobrated further
Using the Tore Supra Heating sources
(to be analyzed in more details)
easy but not straightforward for 118 GHz
possible also at 48-57 MHz
3.7 GHz not sure (structure of the TS antenna)
probably: remove the antenna and utilize
only one klystron (500kW cw)
coupled to a dedicated waveguide
Or Using lasers
Detectors/ mirrors/…

Tore Supra Schedule 2012-2020
an opportunity and a constraint



Possible time slots before the start of the WEST project

1) test of the background noise (magnet at room temperature, atm.pressure): 1 week spring 2012
2) 2nd EM background measurements: 2 days September 2012
3) first experimental session: 2 weeks end of January 2013
4) second experimental session: 6 weeks beginning june 2013- mid july 2013
5) third experimental session beginning 2014: 6-8 weeks

Updated

(in the case WEST project be slightly delayed, more accuracy expected end 2012).

After the completion of the WEST project, access to the high field side slightly reduced

If there is an interest of using Tore Supra: one should be fast

=> the WEST project design phase is a unique opportunity to access to Tore Supra for a while

Conclusions

A possible Schedule :

- A unique opportunity offered by the WEST project
  (after 2014 Tore Supra West very busy)

Concepts for

- ALPS search above 10 GHz
- CDM Axion search around 150 MHz
- Chameleon Search/ Chameleon Generation
- ….

Be fast and reactive for

- Finding sponsors/Founding projects
- Setting collaborations/organization
- Developing
  - Resonator/reflector for Axions
  - MCP sensors for solar chameleons/ Collaboration for XMM
  - Chameleon generators
  - …
  - Tore Supra operation team for these activities

Thanks for your Attention

Commissariat à l'énergie atomique et aux énergies alternatives
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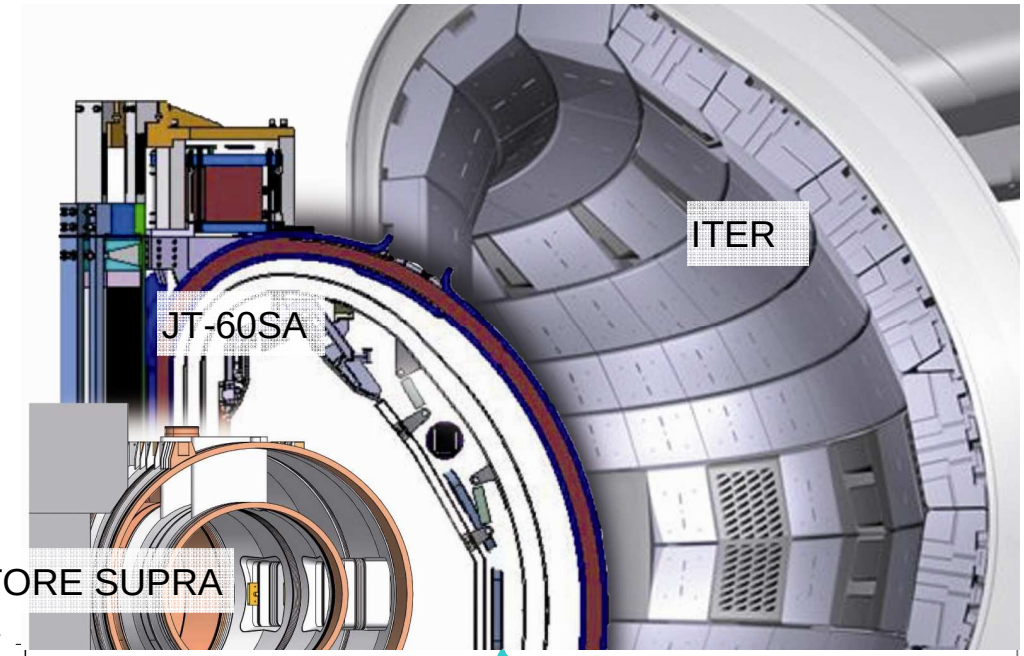
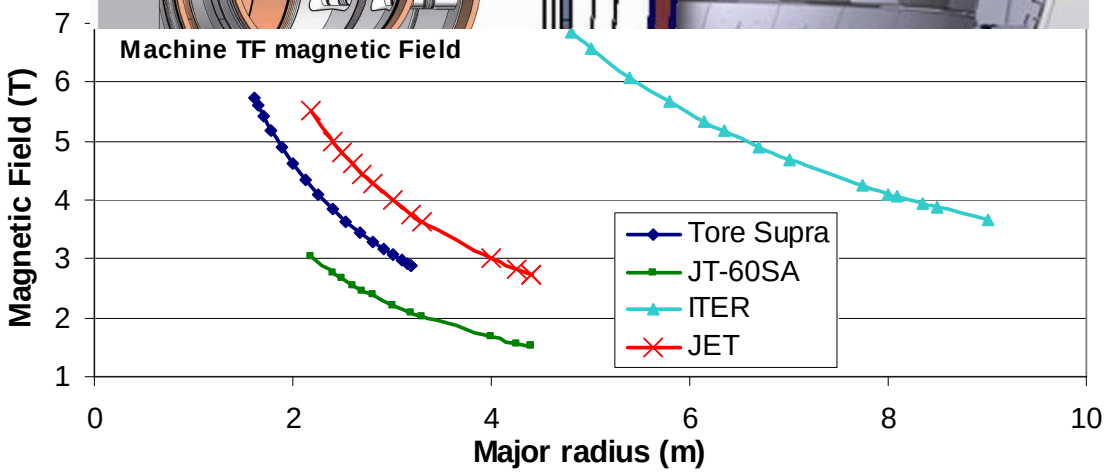
DSM
IRFM
DIR

Etablissement public à caractère industriel et commercial | RCS Paris B 775 685 019

Tore Supra and what next (or what else) ?

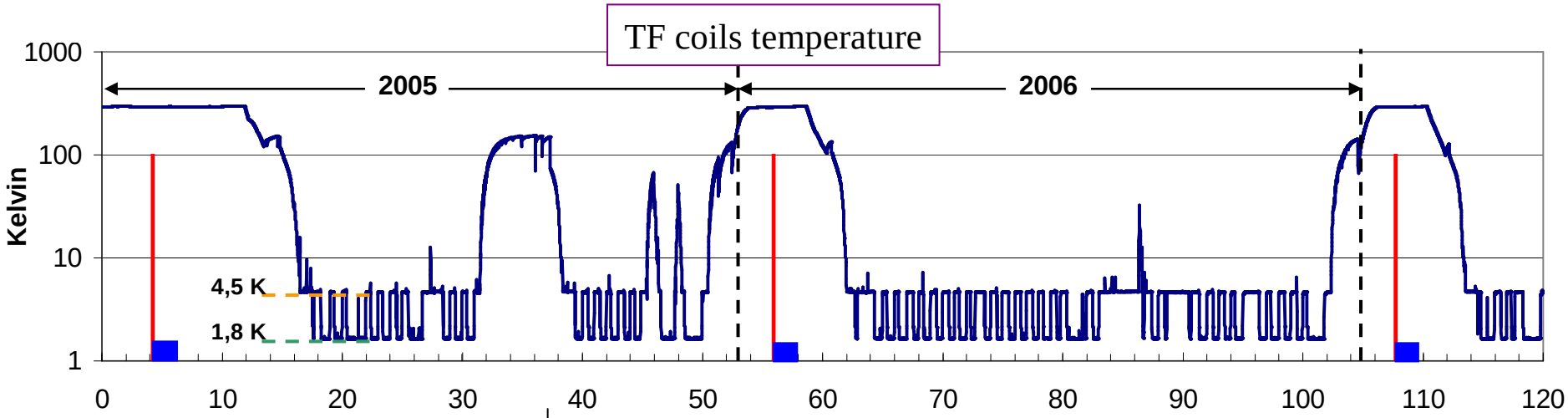




	TS	JET*	JT-60SA	ITER
start of Operation (y)	**1988**	**1983**	**2019**	**2022**
Ro (m)	2,4	3,4	2,96	6,2
a (m)	0,8	1,1	1,18	2
b (m)	0,8	2,2	2,31	4
Bto (T)	3,85	4	2,25	5,3
Vessel volume (m3)	35	150	140	1000
B2V (T2m3)	500	2240	708	30000

*JET: activated & pulsed machine
(TF on ~5 mn/h)

Tore Supra Operation Rhythm



Heavy maintenances
~ 3 months per year
Regulatory controls
Cryogenic, CWS,
Tore Supra Configuration

Plasma Operation rhythm ~ 40 hours a week
4 days a week : TF magnet at 1.8K
3 days at 4.2K w.e. and maintenance day (Monday)

A mutation of the Tore Supra Facility is proposed

WEST : W Environment in Steady-state Tokamaks

Proposal: Turn Tore Supra into a Test Bed besides ITER, dedicated mostly to tungsten (W) actively cooled PFCs *(requires an X-point configuration)*

Motivation:

- Risk minimisation (manufacturing and operation) on ITER relevant technology
- Unique capability within the decade
- Key for ITER, but also for EAST,JT60-SA, W7X...

Feasability study achieved in 2010, welcomed by high level international panel; conceptual study underway

Dedicating Tore Supra to ITER preparation and risk minimisation

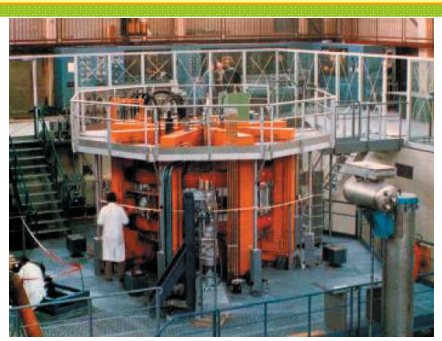
European Context of magnetic fusion research

1960-1985 : Pioneering studies ⇨ tokamak configuration

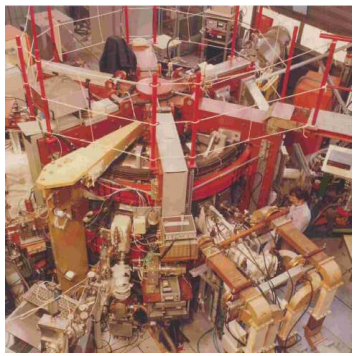
march 25th, 1957:
Signature of the
EURATOM treaty in Rome

Association
EURATOM-CEA

TFR Team at CEA Fontenay aux Roses



Petula and Wega Team at CEA Grenoble



Key results

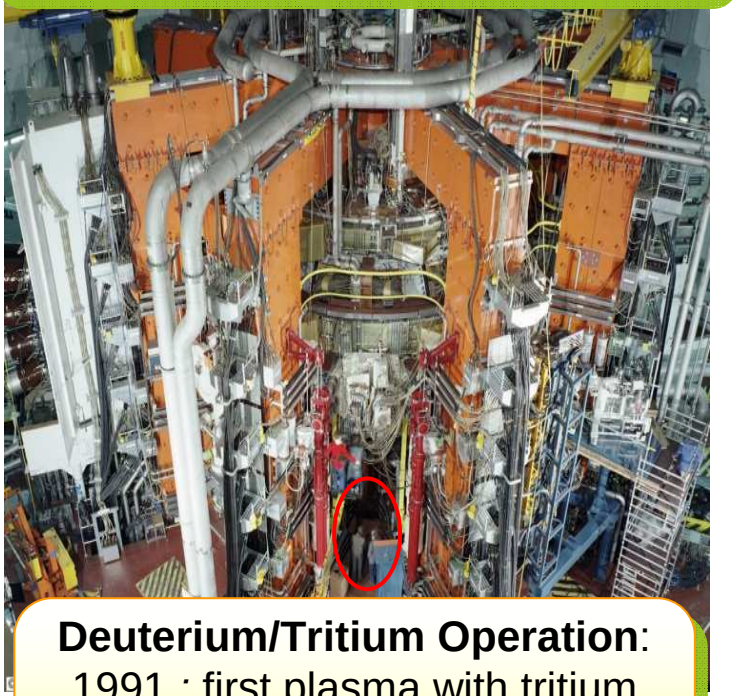
Decision to build

JET & *Tore Supra*

P.H Rebut *R. Aymar*

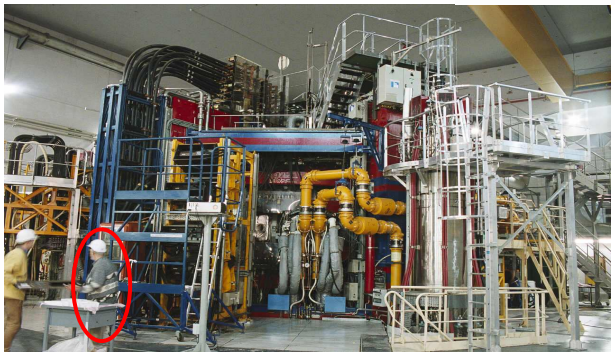
European Context of magnetic fusion research

JET (Euratom) :
Size& Nuclear Performances
1983 : first plasma



Deuterium/Tritium Operation:
1991 *:* first plasma with tritium
1997 : 16 MW Fusion (peak)
2011: **W-Be Wall**

Tore Supra (France-CEA):
Innovative technologies for ***Long Plasma Pulse:***
1) Supraconductivity
2) Active cooling (plasma facing components)
3) Non inductive current drive
1988 : first plasma



1996 *:* 2 minute-long pulses
2002 : **fully cooled plasma facing components**
2003 : world record 6'30 and 1 GJ injected
2010: **Increased Cur.Drive capability** (>6 MW LHCD)
2012-> towards 1000s a few GJ

ITER
2005-2040