EUROfusion

Fusion Research in Europe

Tony Donné for EUROfusion

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 633053.
The views and opinions expressed herein do not necessarily reflect those of the European Commission.

EUROfusion officially launched in October 2014

29 Research Units (+ numerous Third Parties) in 27 European countries working together to achieve the ultimate goal of the Fusion Roadmap

8 Strategic Missions tackle all challenges in two main areas:

ITER Physics

- Risk mitigation for ITER
- JET, Medium Size Tokamaks, Plasma Facing Component devices

Back-up strategy

- Stellarator

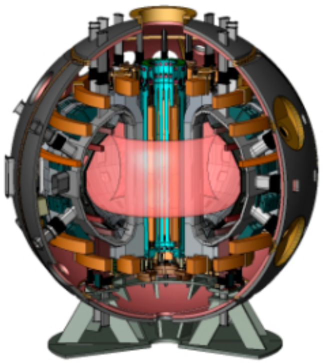
DEMO

- Conceptual design studies
- A single step to commercial fusion power plants
- Production of electricity with a closed fuel cycle

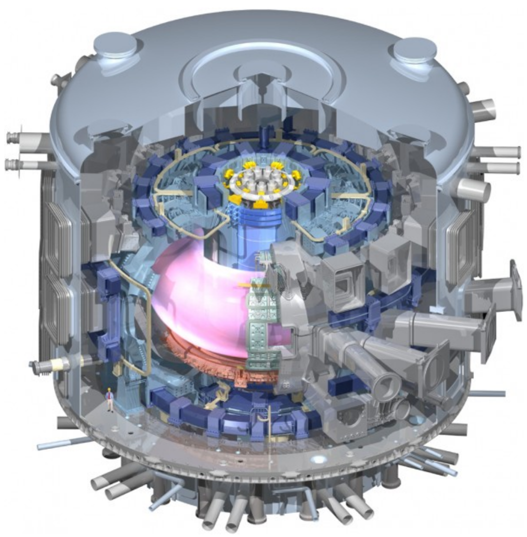
ITER Physics

Power Plant Physics & Technology

1: Plasma Regimes of Operation



High fusion performance by reducing energy losses by turbulence and by controlling plasma instabilities.



To achieve acceptable power depositions in the divertor, radiate as much as possible power from the plasma without having adverse effects on the performance

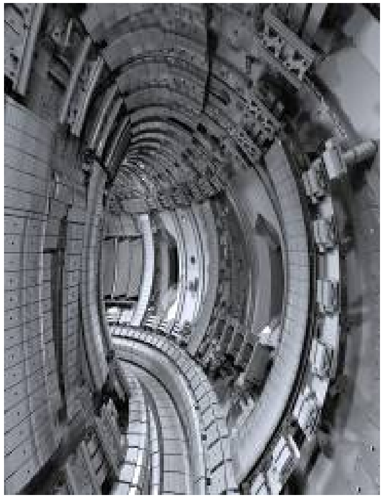
Develop active methods the state of divertor detachment

Try to achieve steady state conditions

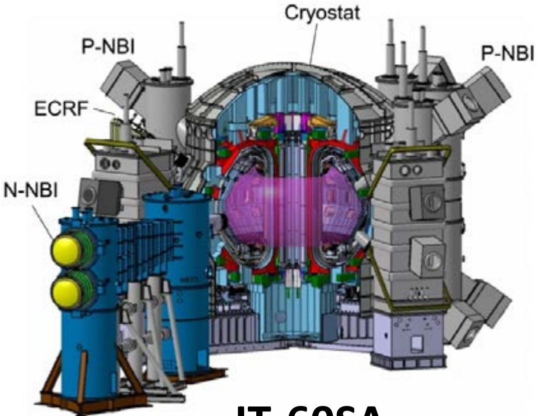
Main devices:

JET, AUG, TCV, MAST, JT-60SA, ITER

JET and Medium-Size Tokamaks

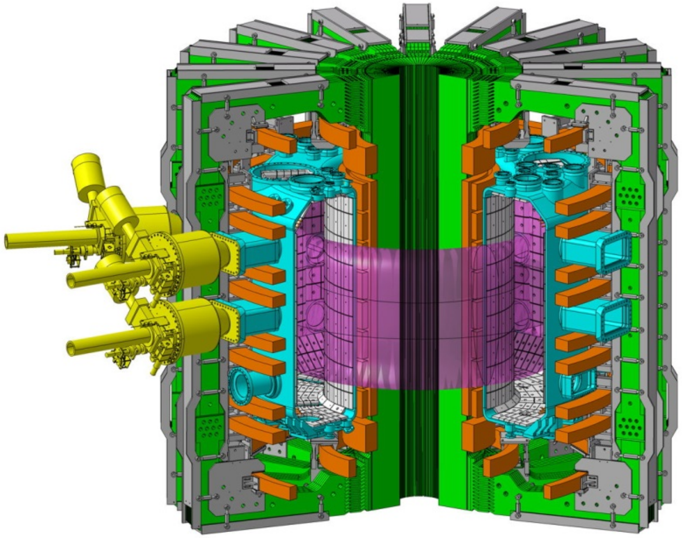


JET

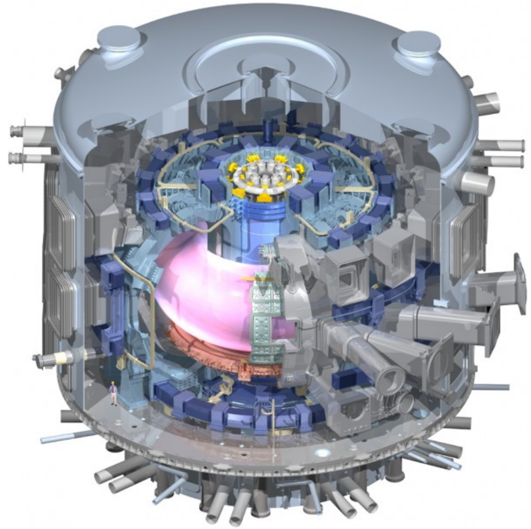


JT-60SA

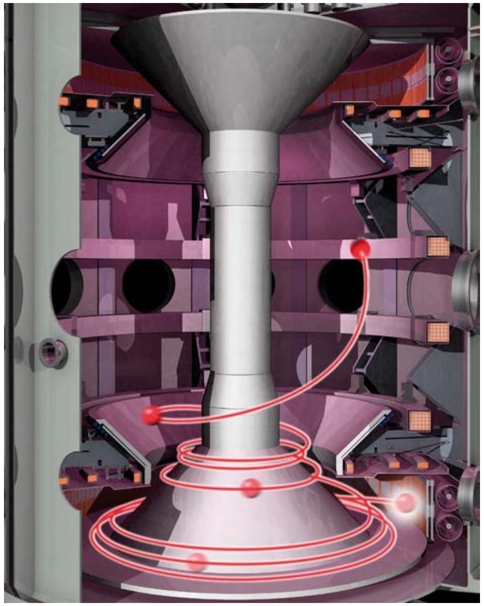
AUG



TCV

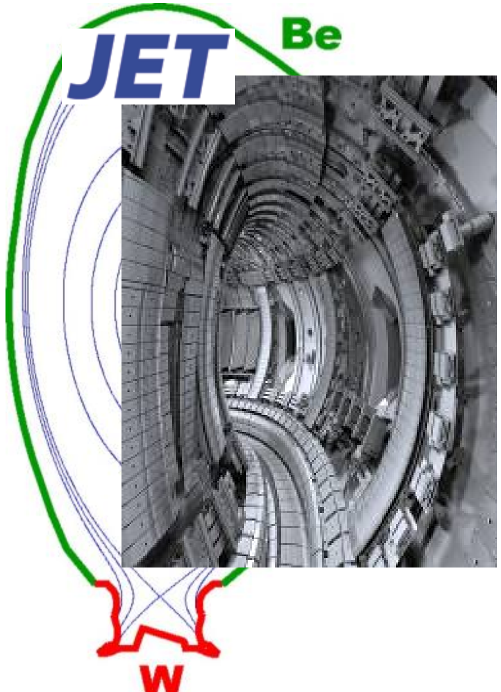


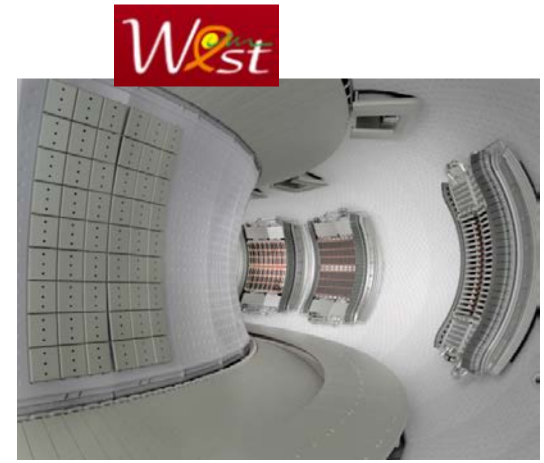
ITER



MAST Upgrade

EU Tokamak operation with a metallic wall



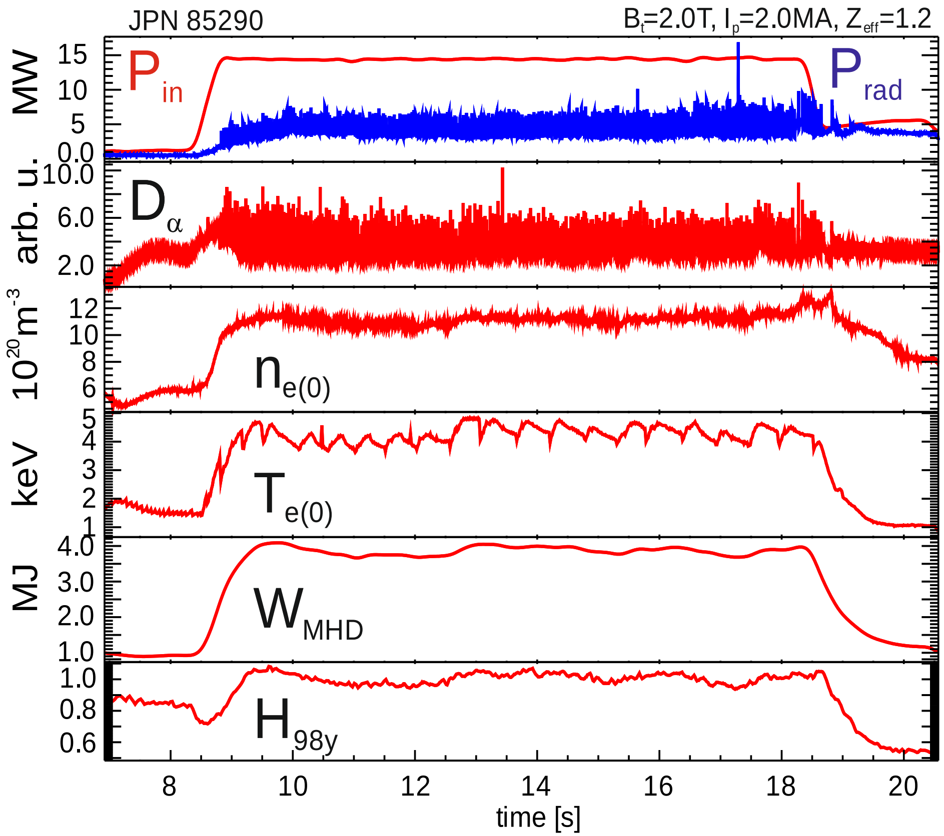


- **ASDEX Upgrade**:
  - conversion to all W PFCs complete Gradually over 7 years
  - in 2014 Massive outer W-divertor and Bare Steel Tiles and new divertor manipulator allowing large area sample insertion
- **JET**:
  - ITER-like Wall Be wall and W divertor change in one shutdown
  - Integrated test with DT scenario compatibility in 2017
- **Tore Supra→** WEST project (2016) :
  - from limiter to divertor configuration, from carbon to W environment,
  - Access to long pulse operation with actively cooled W-monoblocks components

Development of stationary H-mode for DT

Operational window narrower with JET-ILW

good confinement with strike-points close to pump duct entrance



- Stationary type I ELMy H-modes
  - ✓ **Gas fuelling**: to reduce W source
  - ✓ **Sufficient ELM frequency**: to flush W
  - ✓ **Central heating**: to avoid W peaking
  - ✓ **Heat exhaust control**

➢ **otherwise W-accumulation**

W concentration below $C_W \sim 5 \times 10^{-5}$

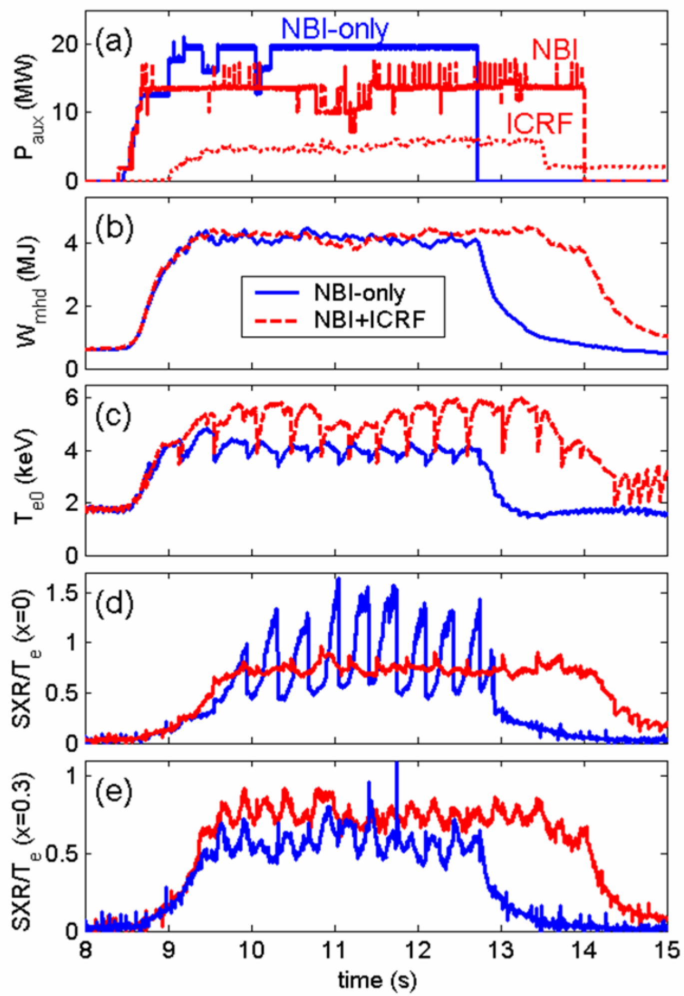
This confirms earlier work on AUG

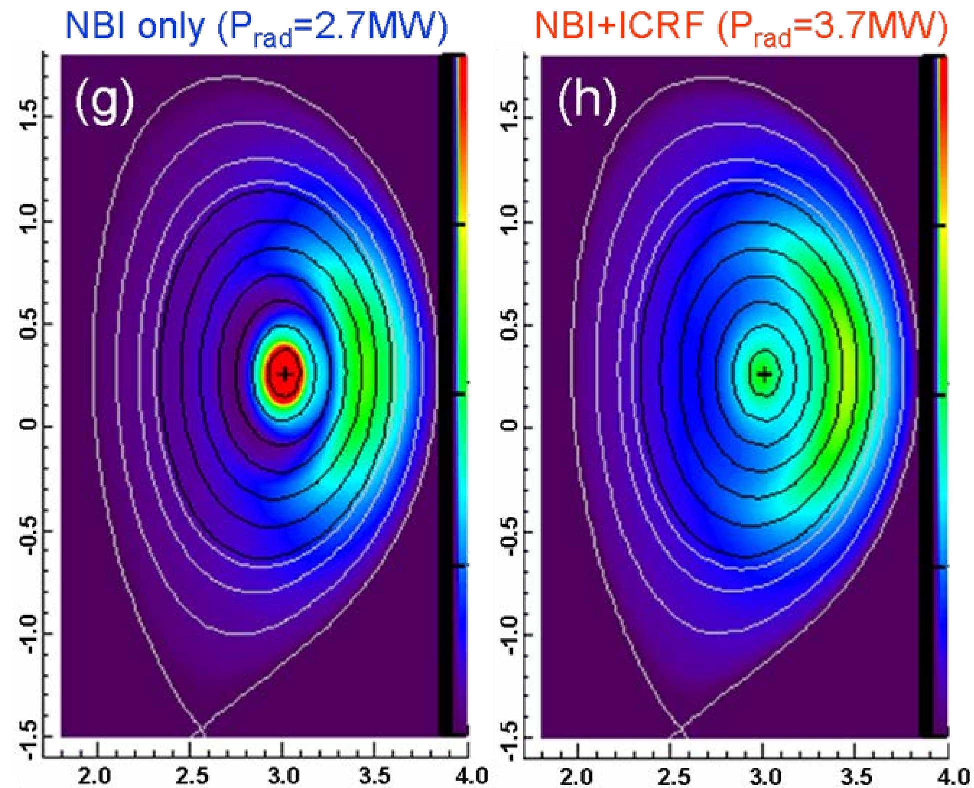
JET

I Nunes et al 25th IAEA FEC, St. Petersburg, Russia (2014)

Impurity screening: 2.5MA baseline H-mode at JET

H-modes @ 2.5MA/2.7T: 20MW NBI only vs. 14MW+6MW NBI+ICRF





- In the ICRF assisted discharge the central electron temperature is higher and the core SXR emission is mitigated (impurity screening)
- Somewhat larger total Prad with ICRH due to enhanced PWI (RF sheath effects)

E. Lerche, IAEA-FEC, 2014

E. Lerche, JSM, 8th December 2014

Sawtooth control and fast ions in JET

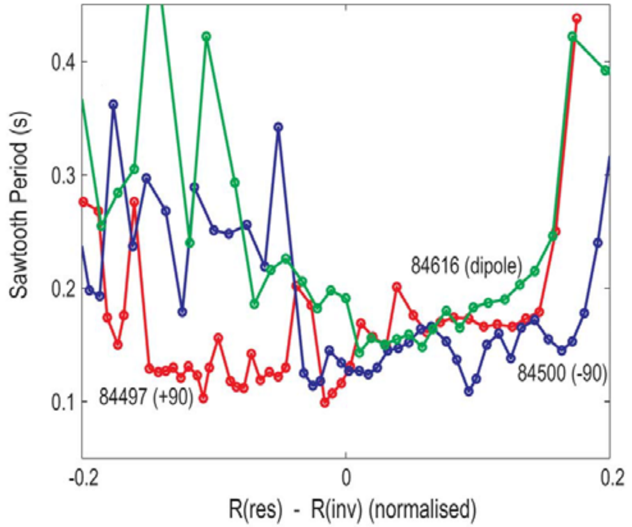
Experiments for 3 ICRH phasings

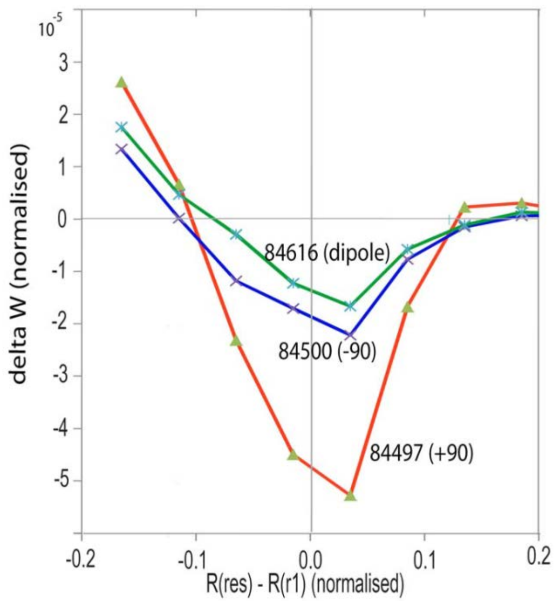
Modelling performed with

- SCENIC and SELFO for ICRH distribution
- HAGIS and MISHKA for stability calculations

Both experiment and modelling shows

- Sawtooth control is consistent with fast ion mechanism
  - depends on parallel velocity asymmetry of distribution, and large orbit width effects)
- Sawtooth stabilisation over fairly wide region of resonance location
- +90 phasing best
  - smallest sawteeth and widest region of control.
  - Asymmetry in the distribution is strongest with +90 phasing





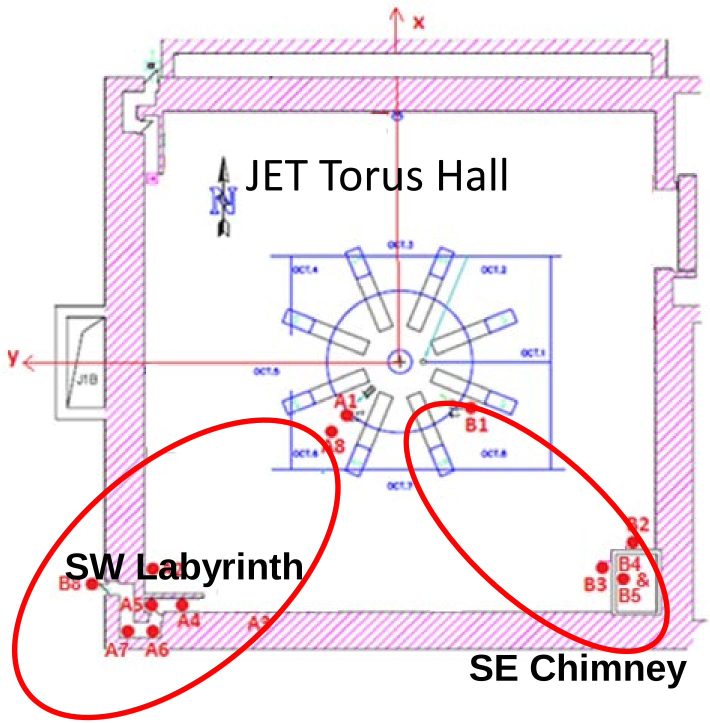
J. Graves, JSM, 8th December 2014

Neutron Streaming Experiment at JET (1/2)

- **Neutron fluence measured through large penetrations of JET Torus Hall biological shield up to ≈ 40 m from plasma source**

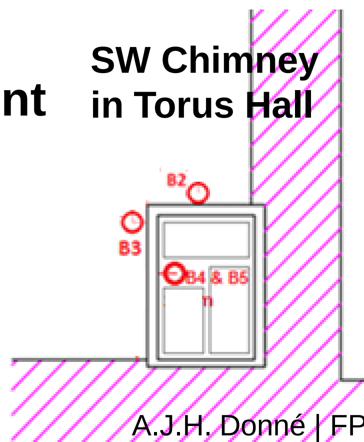
  Highly sensitive thermo-luminescent detectors individually calibrated in terms of kerma in air and neutron fluence

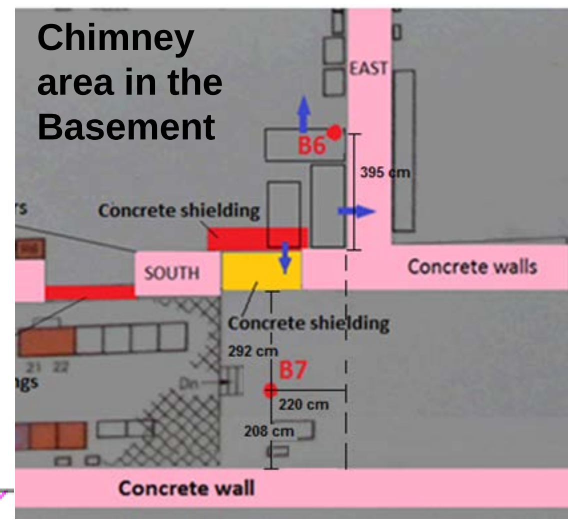
  Neutron and γ-ray components separated using pairs of ^{nat}LiF and ^{7}LiF detectors
  - ^{nat}LiF : Mg,Cu,P (MCP-N), 7.6% ^{6}Li
  - ^{7}LiF : Mg,Cu,P (MCP-7), (0.03% ^{6}Li)



- **Exposure to JET DD plasmas**
  - 22/9 – 11/10 2013, $Y_n = 2.76\times10^{18}$ neut
  - 22/6 – 6/9 2014, $Y_n = 9.90\times10^{18}$ neut

- **Validation in a real fusion environment of numerical tools used in ITER for calculating the neutron streaming in penetrations in large and complex volumes**

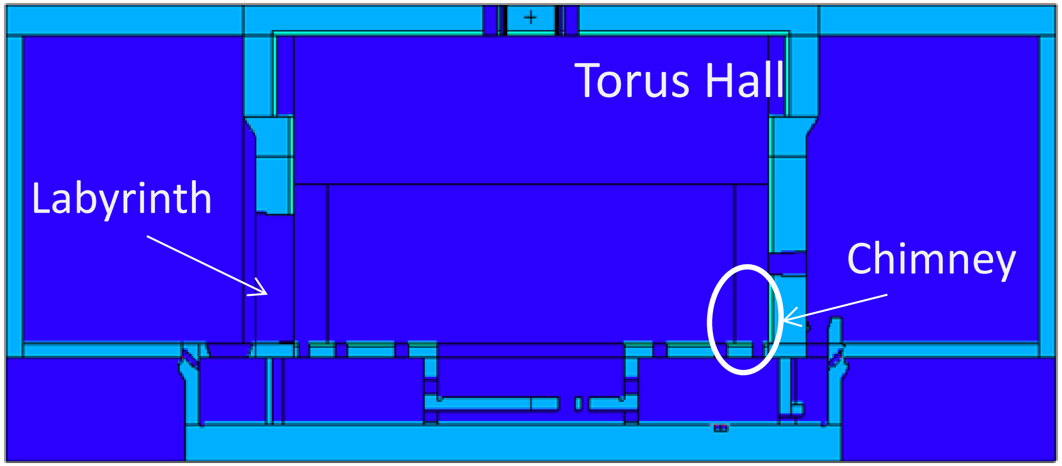


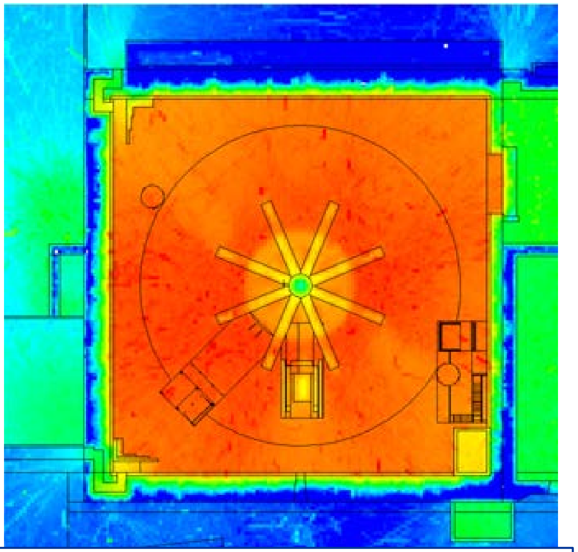


JET

P. Batistoni et al., to be sumbitted to NF

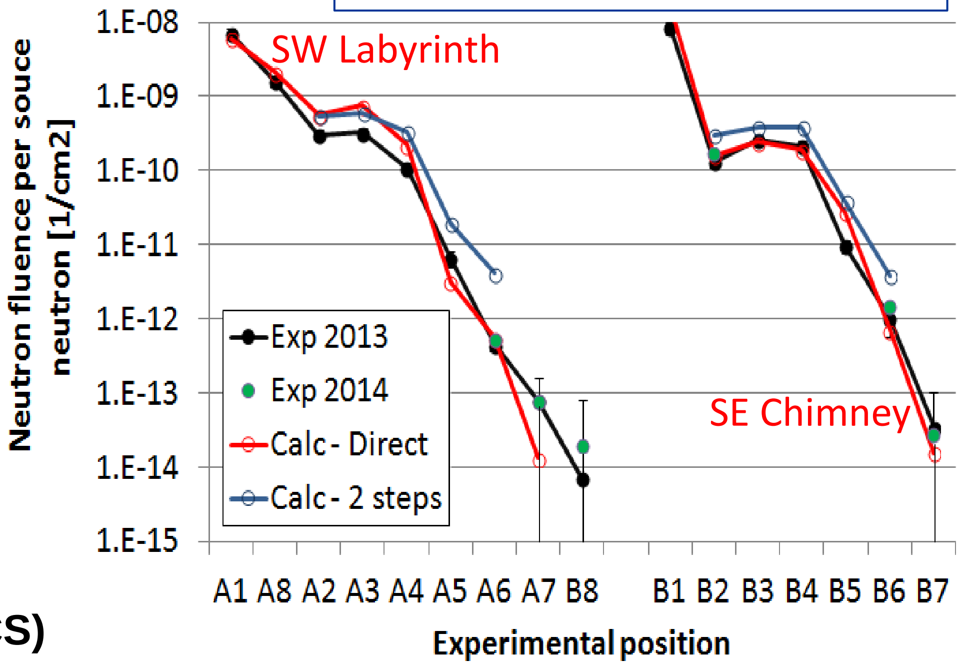
Neutron Streaming Experiment at JET (2/2)





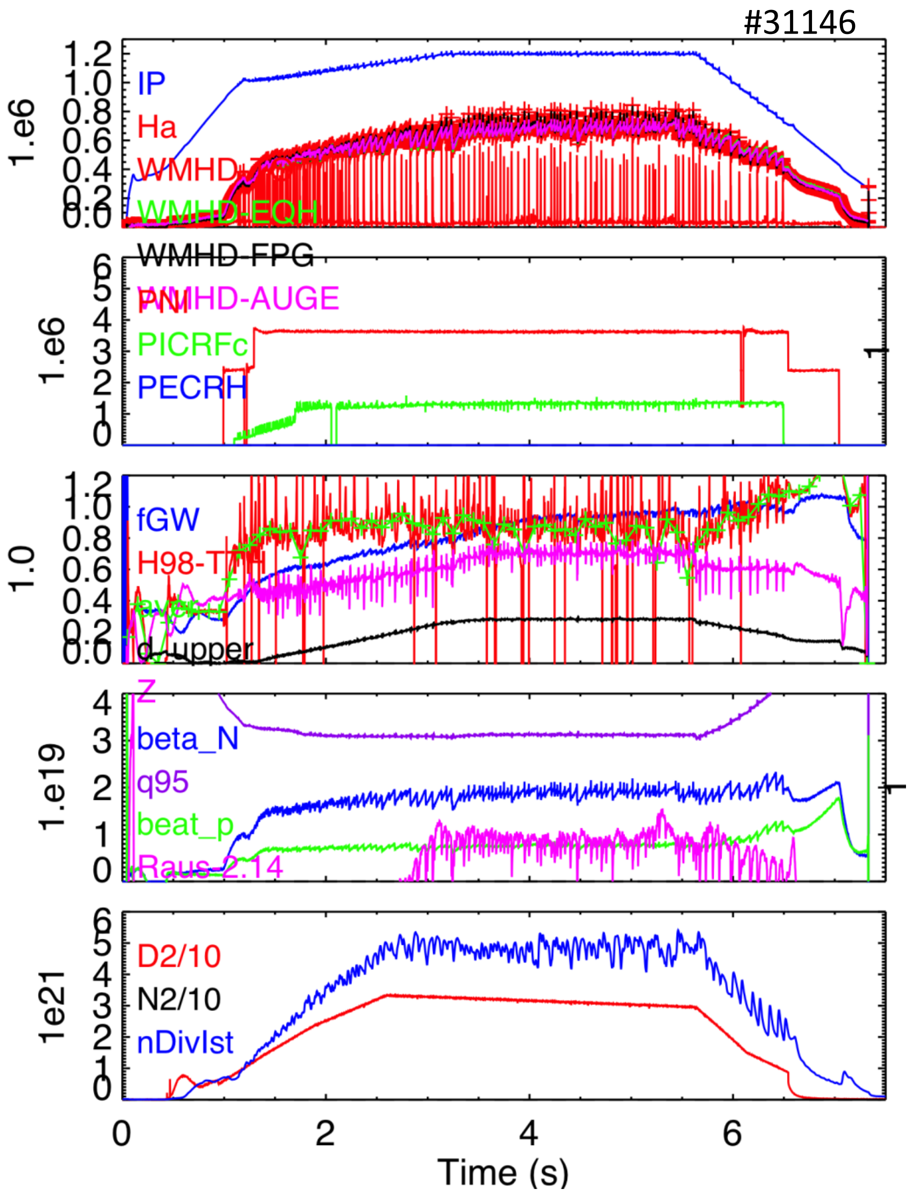
- **Calculations of neutron fluence and dose at TLDs using MCNP.5 – 6**
  Detailed model of JET machine
  Improved model of JET building with penetrations
  FENDL 2.1 neutron cross sections (ITER ref.)
- **Comparison of measurements and calculations: good agreement over up to 6 orders of magnitude variation of neutron fluence**
- Preparation for DTE2 in progress

P. Batistoni et al., to be sumbitted to NF



JET **(CCFE, ENEA, HELL, IPPLM, MESCS)**

MST1[2014] - ITER baseline in AUG



ITER goal:

H_{98}~1, β_N = 1.8, n/n_{gw}~0.85, q_{95}~3

Scenario achieved in 2014:

(1.2MA / 2.0T, 3.8 MW NBI + 1.8MW ICRH)

But need high gas puff level for stationarity

Issues 2014:

- Low confinement H_{98}~0.85
- Large ELMs
- High divertor heatload

Tried 2014:

- ELM mitigation: unsuccessful
- N seeding: promising
- scenario with q_{95}~3.6: promising

Goal for 2015:

- Alternative scenario with q_{95}~3.6
- Achieve ELM mitigation (RMP/pellets)
- Achieve tolerable heatload by mitigation with N_2 seeding

Josef Schweinzer/ Emanuel Joffrin / Marc Beurskens

MST1[2014] - Impurity seeding and shaping in AUG

Experiment in 2014 with impurity seeding in low and high triangularity plasmas showed:

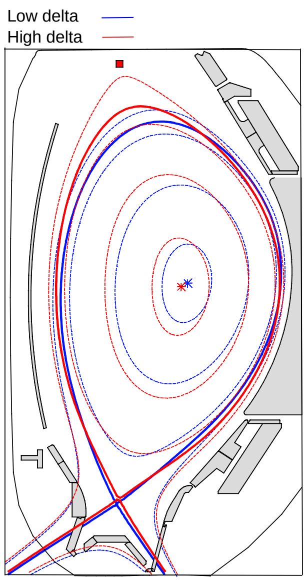
- Both Nitrogen and Carbon (CD_4) show similar confinement benefit
- This worked equally well for both low and high triangularity plasmas (unlike JET with N_2 seeding)
- The confinement benefit is a pedestal effect

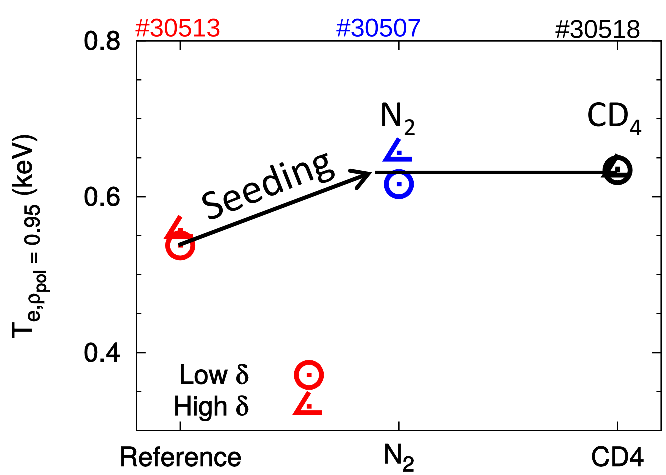
What did we learn?

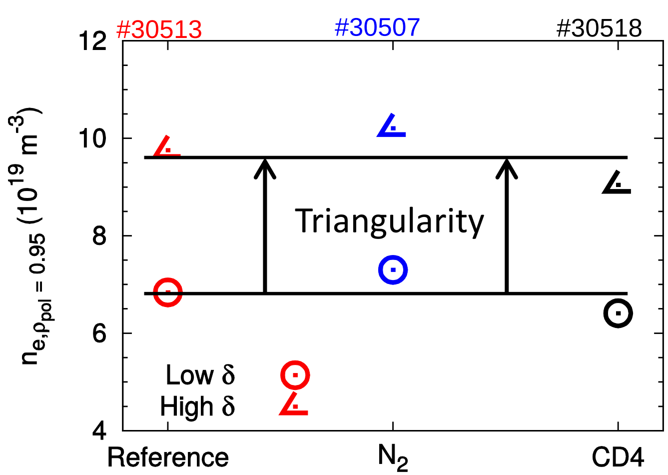
- Experiment shows that absence of C can (most likely) be replaced with N_2 in metal devices
- Role of seeding (raises T) and triangularity (raises n) are orthogonal.

Goals for 2015:

- Investigate power degradation of confinement in fuelled and seeded plasmas
- Optimising confinement in improved H-modes combined with heatload mitigation
- Study the Z-dependence (He, B, C, N, O, Ne, Ar, Kr)
- Provide link with JET-ILW experiments





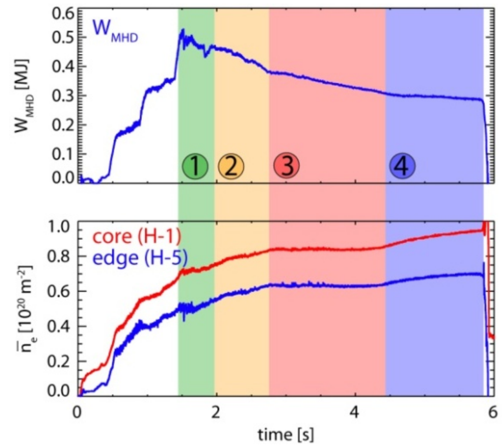


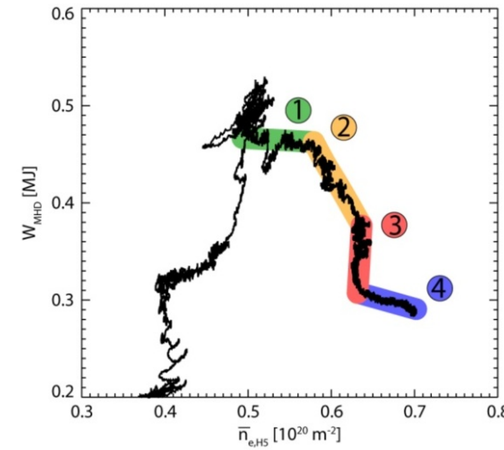
Mike Dunne / Lorenzo Frassinetti

4 distinct, quasi-stable regimes at the approach towards the H-mode density limit (HDL)

- Distinguished by evolution of plasma density & temperature and stored energy

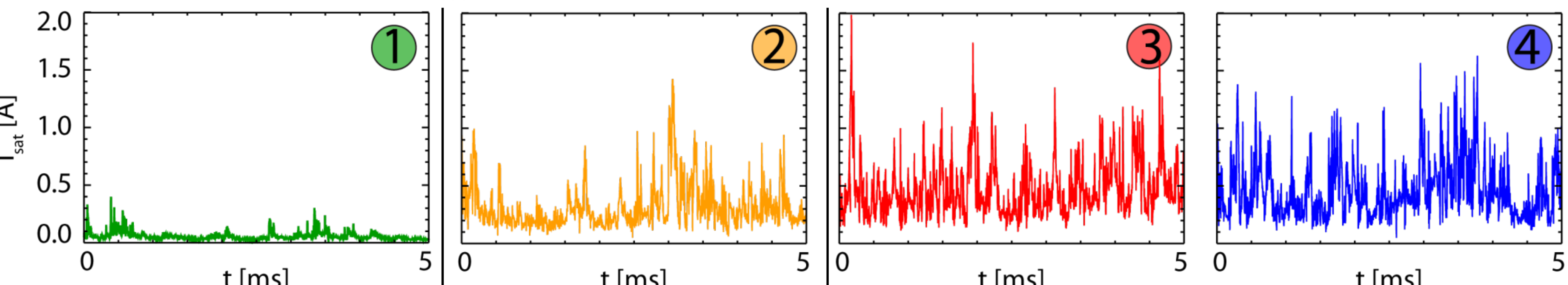
Characterized the SOL filament behaviour





① Stable H-mode	② Degrading H-mode	③ Breakdown of H-mode	④ L-mode
• density increases • pressure constant	• **density plateau in the SOL** builds up, core density fixed • stored energy (pressure) decreases	• overall **density profile constant** • stored energy drops • still H-mode, but ETB erodes	• density increases again • pressure almost constant

I_{sat} on fast reciprocating probe (far SOL, AUG #30586)



Only weak filaments
Low losses

More filaments
More losses

Strong filament appearance in phase 3 & 4
Increased transport losses

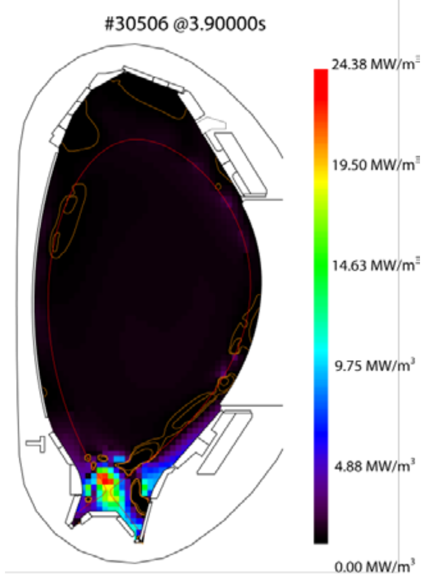
Matthias Bernert

Pronounced detachment achieved with N and Kr seeding

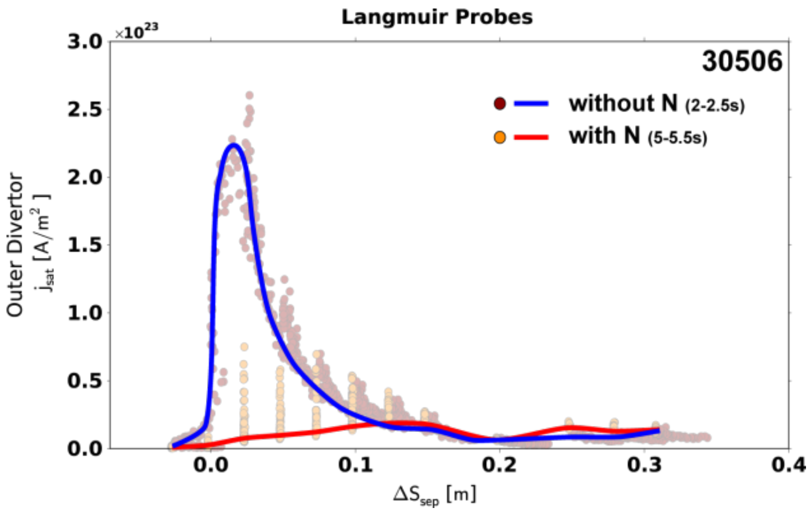
Nitrogen

Strong radiator at X-point, moving inside confined region

Quasi-stable operation, RT control possible



P_{sep}/R = 7-9.4 MW/m
$f_{rad} \leq$ 85%
f_{GW}=0.95
H98 = 0.9



2015

Increase heating power, reach $P_{sep}/R \approx$ 12 MW/m

Study X-point radiator

SC: Bernert & Lipschultz

Pronounced detachment achieved with N and Kr seeding

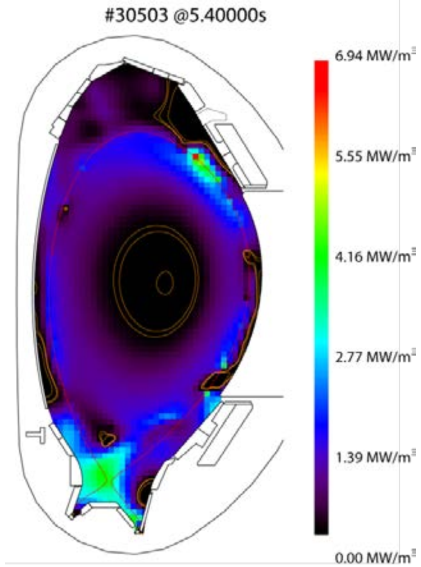
Krypton

Radiating ring at pedestal top

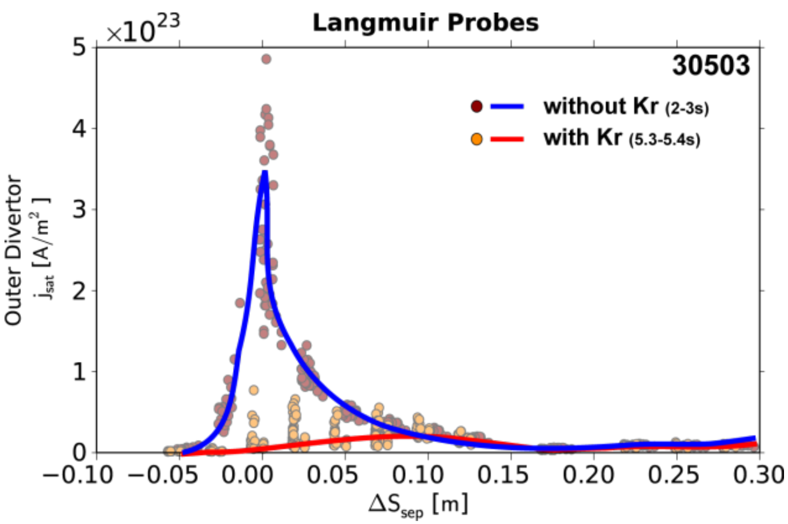
MARFE-like radiation condensation

insignificant reduction of confinement

ELM behaviour crucial (high frequent ELMs required)



$f_{rad} \leq 75\%$
$H98 \approx 0.95$

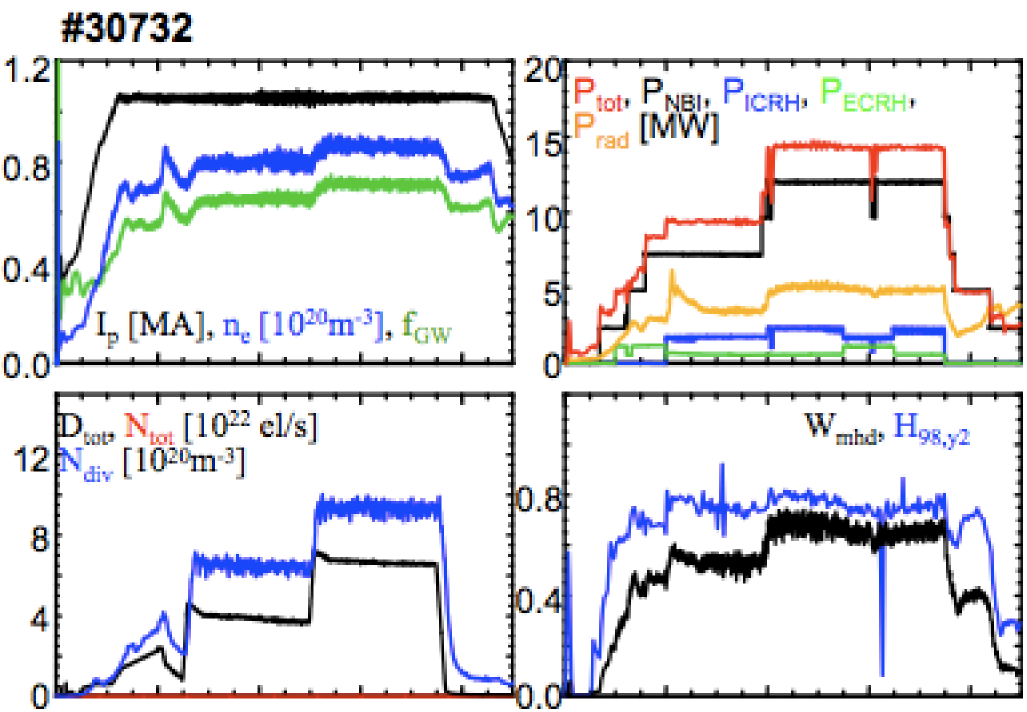


2015

Study mix of seed impurities

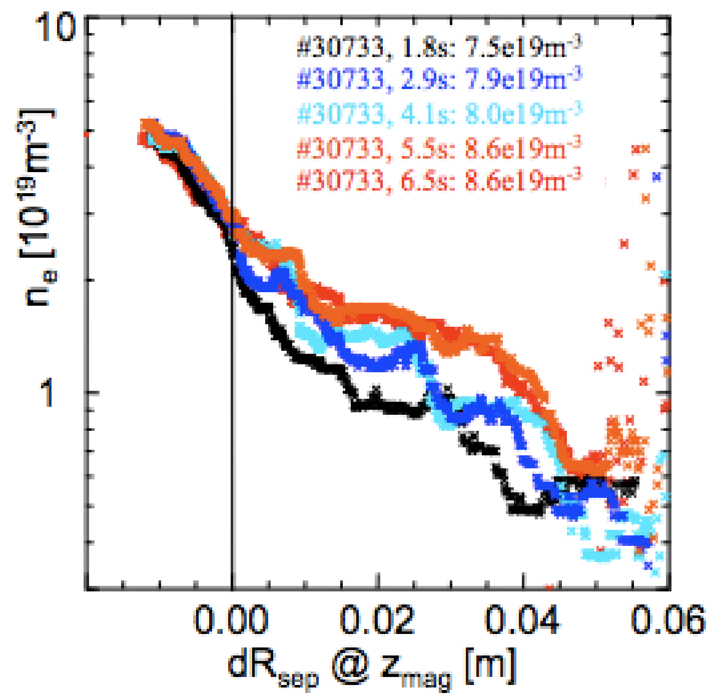
Analyse impact on dilution

SC: Bernert & Lipschultz



ITER relevant condition

- $P_{sep}/R < 7.3$ MW/m
- $f_{G < 0.8}$



✓ Midplane SOL shows increasing convective filamentary transport

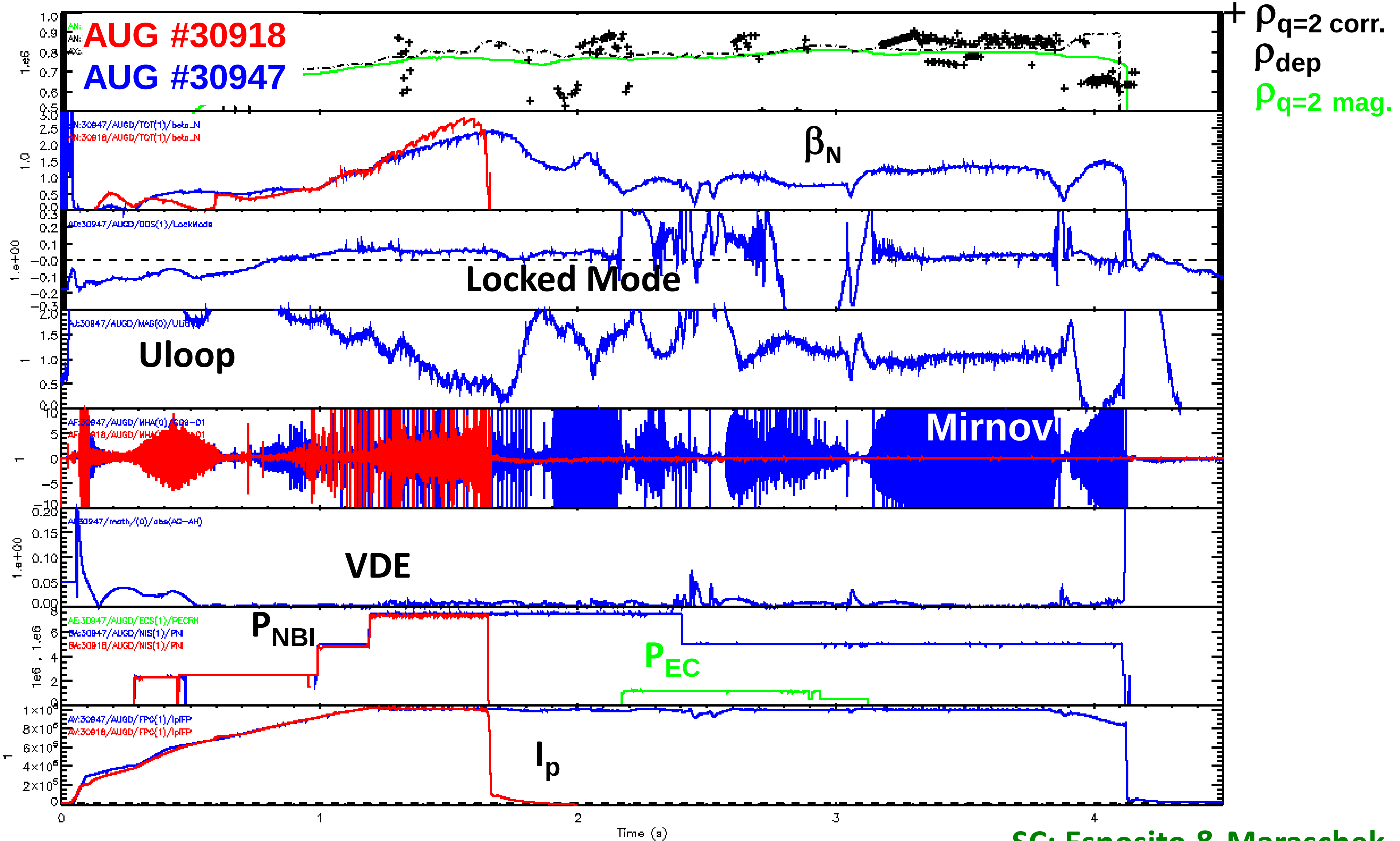
✓ Input for Modelling

✓ Combining Exp.+Modeling for first wall load estimate for large devices

SC: Vianello & Müller

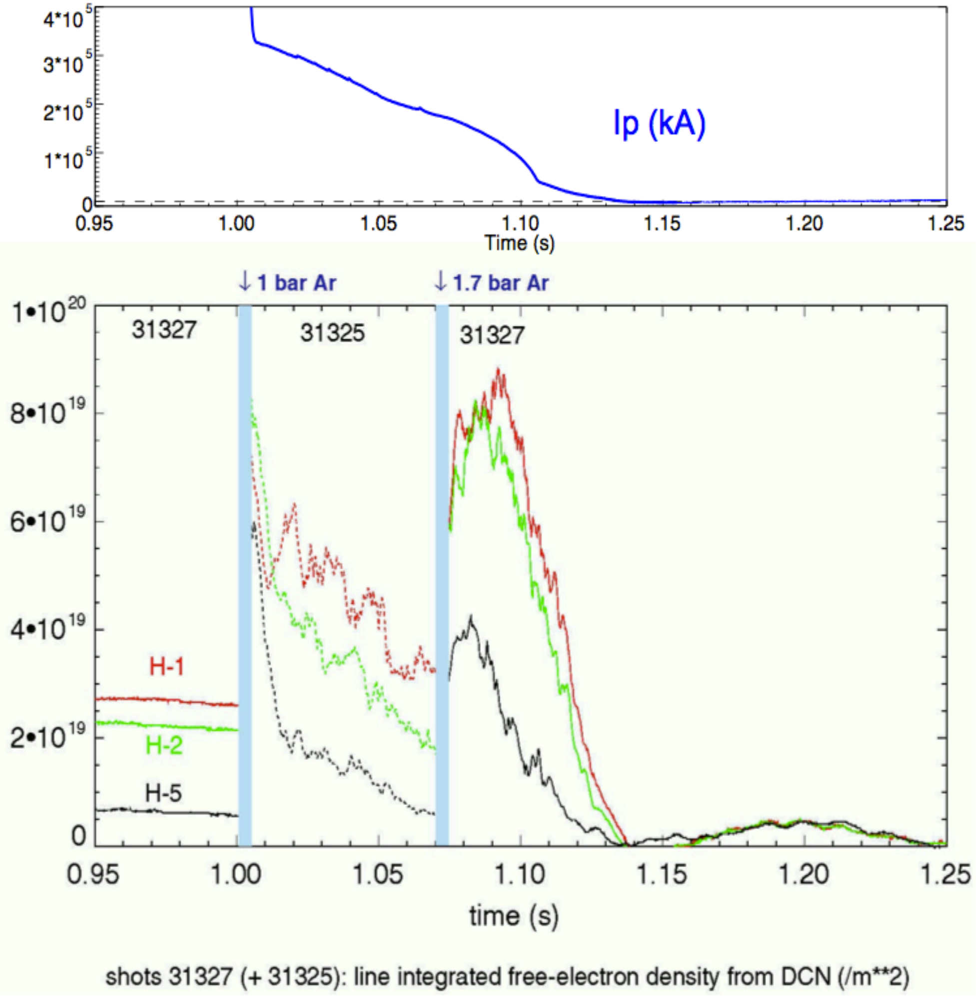
MST1[2014] - Disruption Avoidance

Disruption avoidance (ECCD) in high β-limit



SC: Esposito & Maraschek

- RE generation and dissipation with Ar MGI



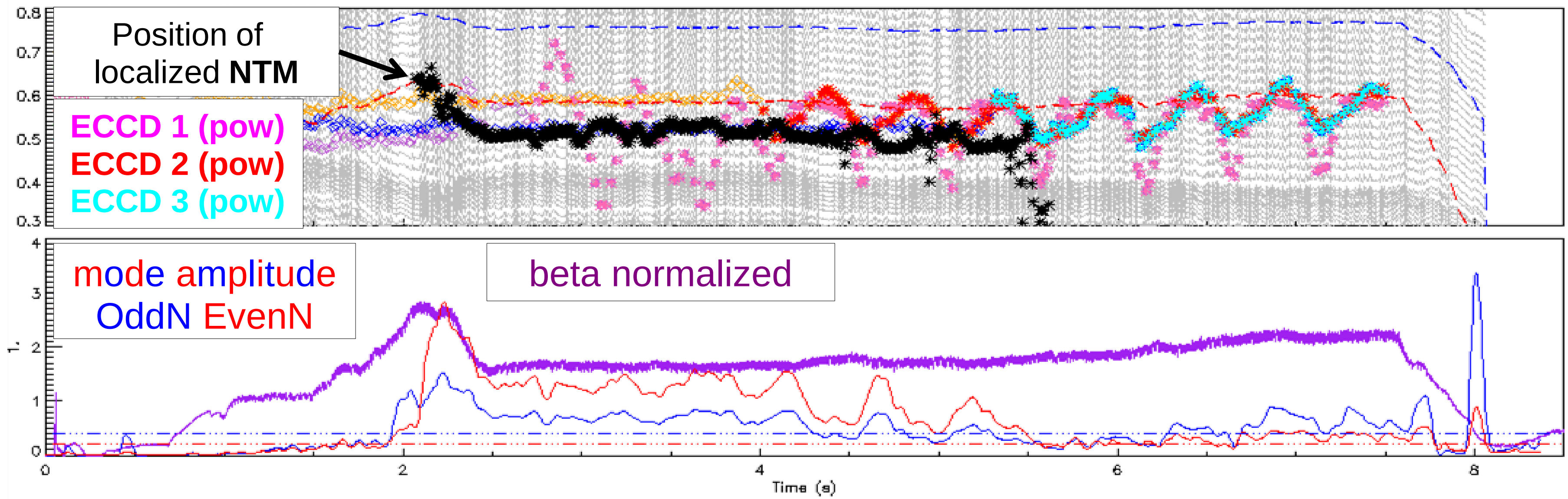
SC: Pautasso & Koslowski

MST1[2014] - ITER compatible RT-system for ECCD based NTM stabilization fully operational at ASDEX Upgrade

- **Real-time TORBEAM allows launcher control in Ψ-space (using RT-data)**
- **Closed feedback loop (in real-time operation) with latency below 100 ms**
- **Minimal set of required real-time diagnostics:**

  equilibrium, mode amplitudes, density profile

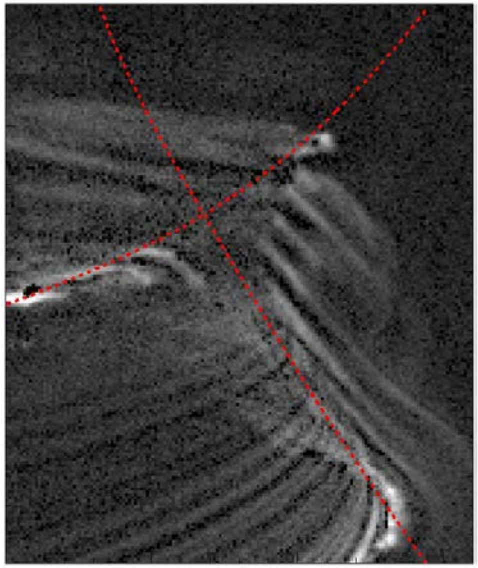
- **Sweeping across rational surface reduces deposition accuracy requirement**

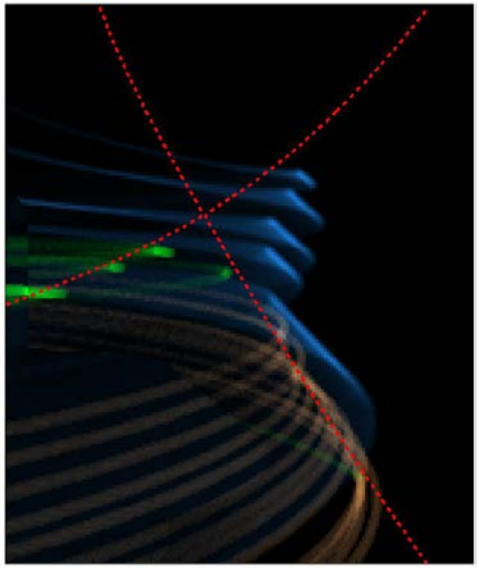


SC: Reich & Sauter

MST1[2014] - Three fluctuation regions identified in the MAST divertor

- Filaments in the main SOL: shape distorted by magnetic shear near the X-point
- Localised near the separatrix: small cross-field extent (~1cm), persist for ≤8μs frame time
- Filaments in the PFR
  - Strongest close to the separatrix at the inner leg ⟺ bad curvature region.
  - In agreement with *preliminary* BOUT++ calculations.

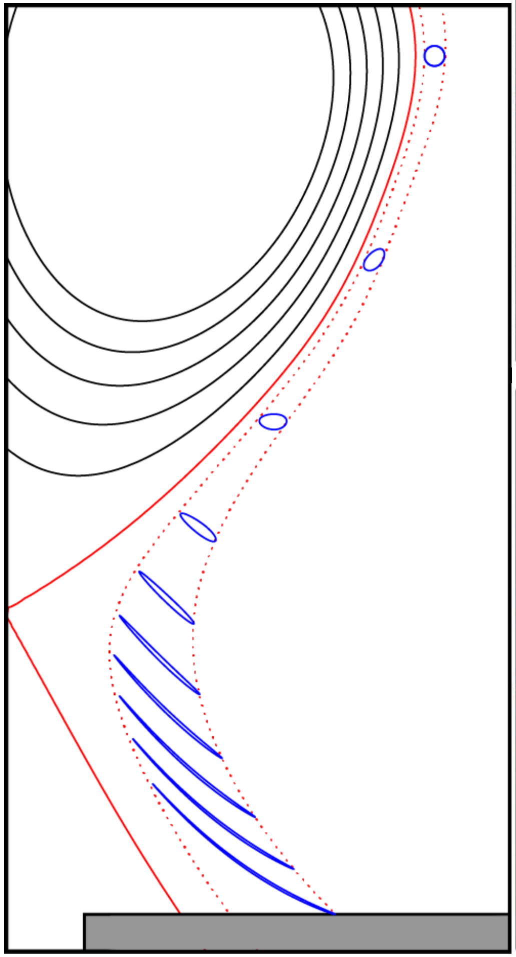


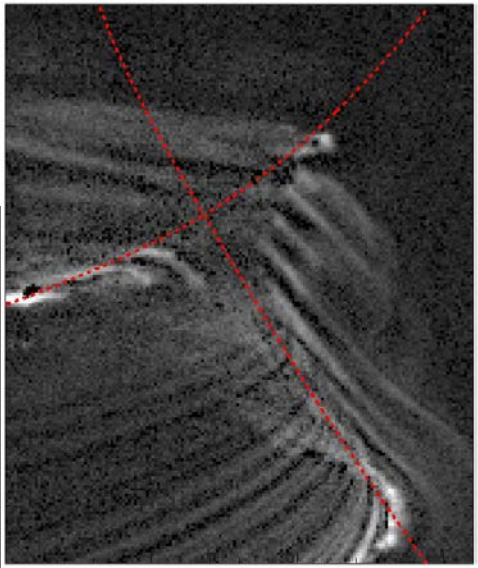


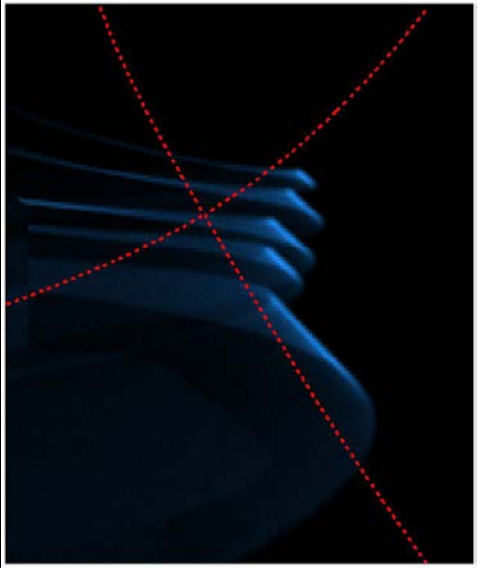
J.R. Harrison (CCFE), G. Fishpool (SC,CCFE), B. Dudson (U. York), N. Walkden (U. York)
APS invited to be submitted to Plasma Physics and Controlled Fusion

MST1[2014] - Three fluctuation regions identified in the MAST divertor

- Filaments in the main SOL: shape distorted by magnetic shear near the X-point







J.R. Harrison (CCFE), G. Fishpool (SC,CCFE), B. Dudson (U. York), N. Walkden (U. York)

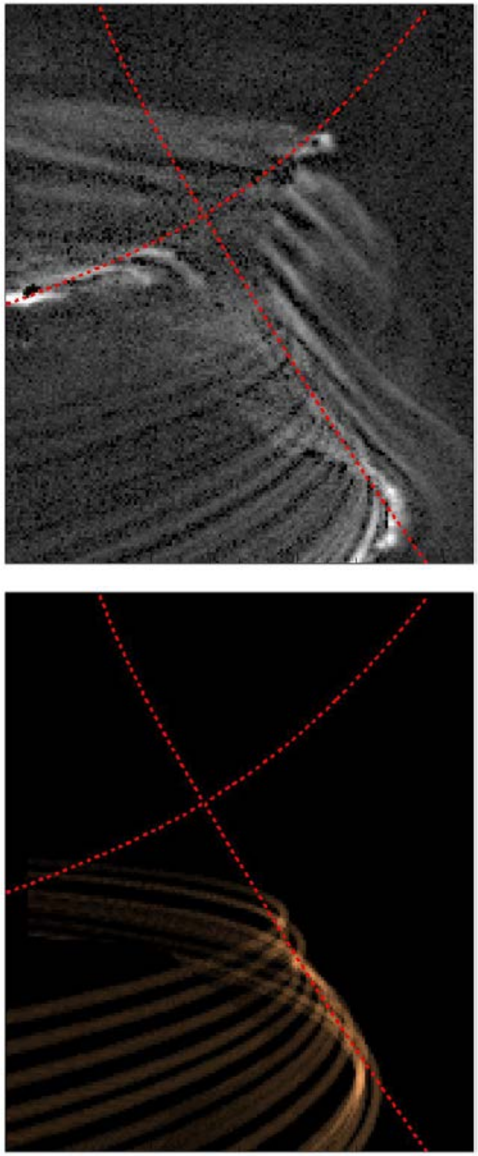
APS invited to be submitted to Plasma Physics and Controlled Fusion

CCFE
CULHAM CENTRE FOR FUSION ENERGY

MST1[2014] - Three fluctuation regions identified in the MAST divertor

- Filaments in the main SOL: shape distorted by magnetic shear near the X-point

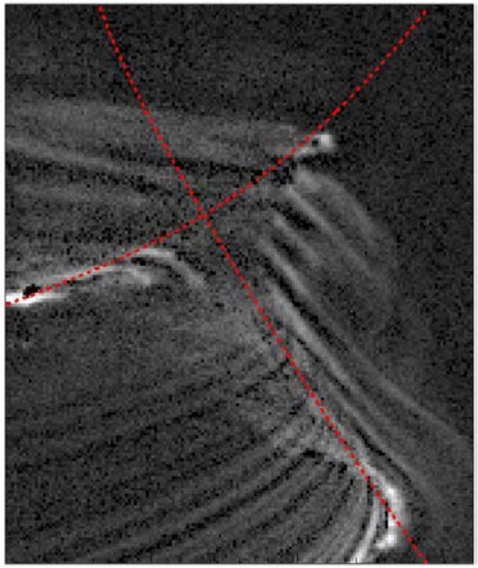
- Localised near the separatrix: small cross-field extent (~1cm), persist for ≤8μs frame time

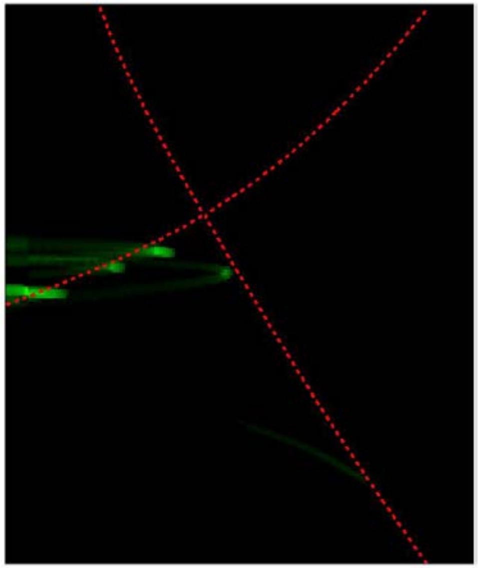


J.R. Harrison (CCFE), G. Fishpool (SC,CCFE), B. Dudson (U. York), N. Walkden (U. York)
APS invited to be submitted to Plasma Physics and Controlled Fusion

MST1[2014] - Three fluctuation regions identified in the MAST divertor

- Filaments in the main SOL: shape distorted by magnetic shear near the X-point
- Localised near the separatrix: small cross-field extent (~1cm), persist for ≤8μs frame time
- Filaments in the PFR
  - Strongest close to the separatrix at the inner leg ⟺ bad curvature region.
  - In agreement with *preliminary* BOUT++ calculations.



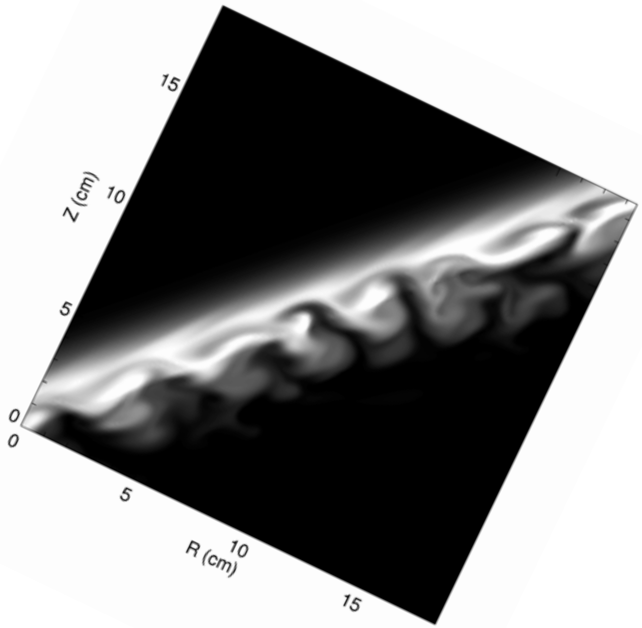


J.R. Harrison (CCFE), G. Fishpool (SC,CCFE), B. Dudson (U. York), N. Walkden (U. York)
APS invited to be submitted to Plasma Physics and Controlled Fusion

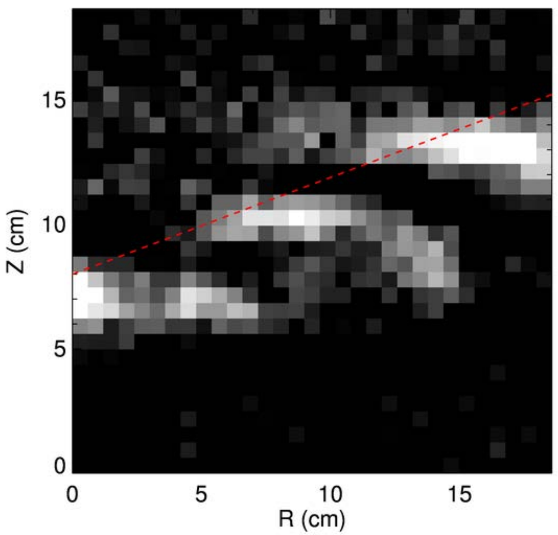
MST1[2014] - Three fluctuation regions identified in the MAST divertor

- Filaments in the PFR
  - Strongest close to the separatrix at the inner leg ⟺ bad curvature region.
  - In agreement with *preliminary* BOUT++ calculations.

BOUT++ (1 frame = 24μs)



Camera Data



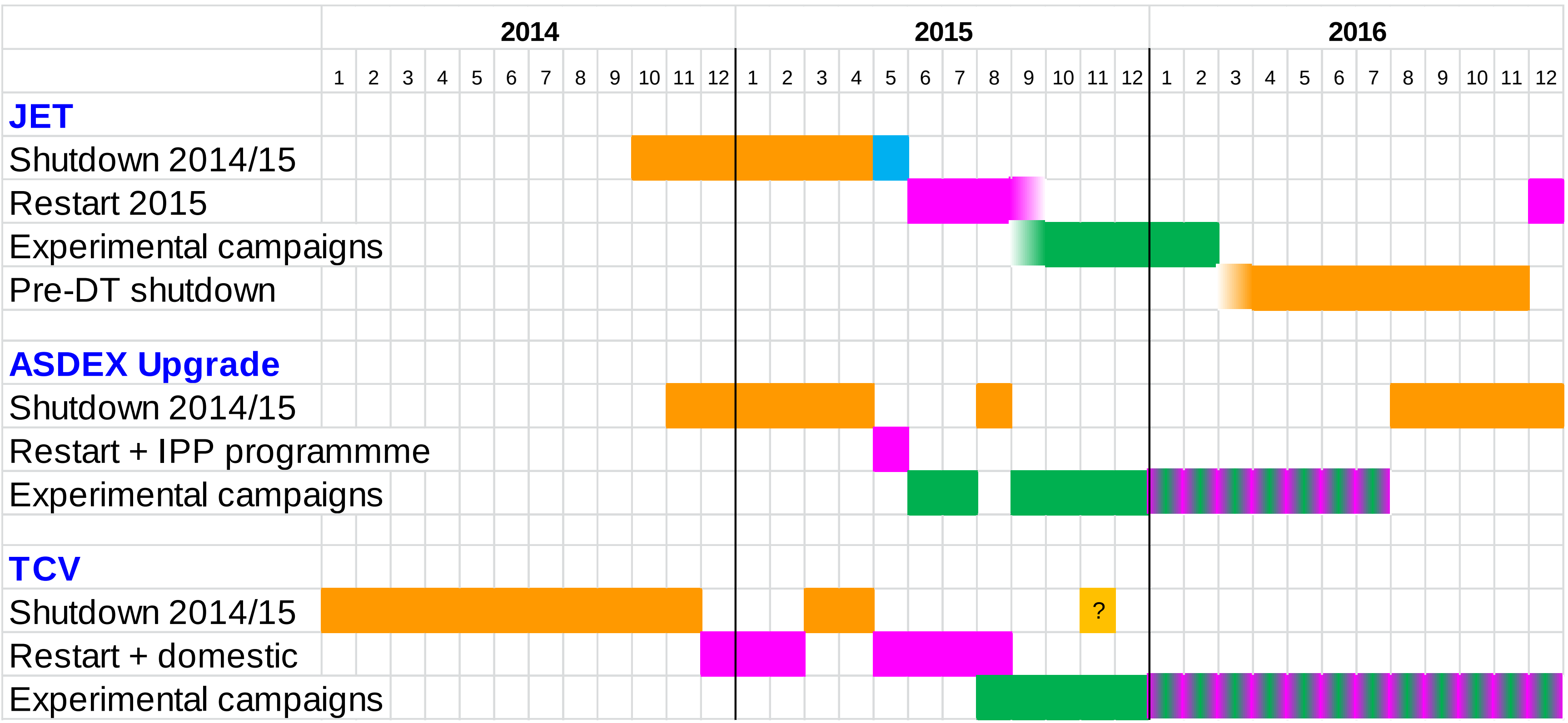
J.R. Harrison (CCFE), G. Fishpool (SC,CCFE), B. Dudson (U. York), N. Walkden (U. York)

APS invited to be submitted to Plasma Physics and Controlled Fusion

Planning JET, ASDEX-U and TCV

significant overlap in the experimental campaign: a tight coordination

JET and MST TFLs will draft an experimental programme to implement on each device: common General Planning Meeting early 2015 in Lausanne



8: Stellarator

Cons:

- behind tokamaks performance wise
- technically complicated

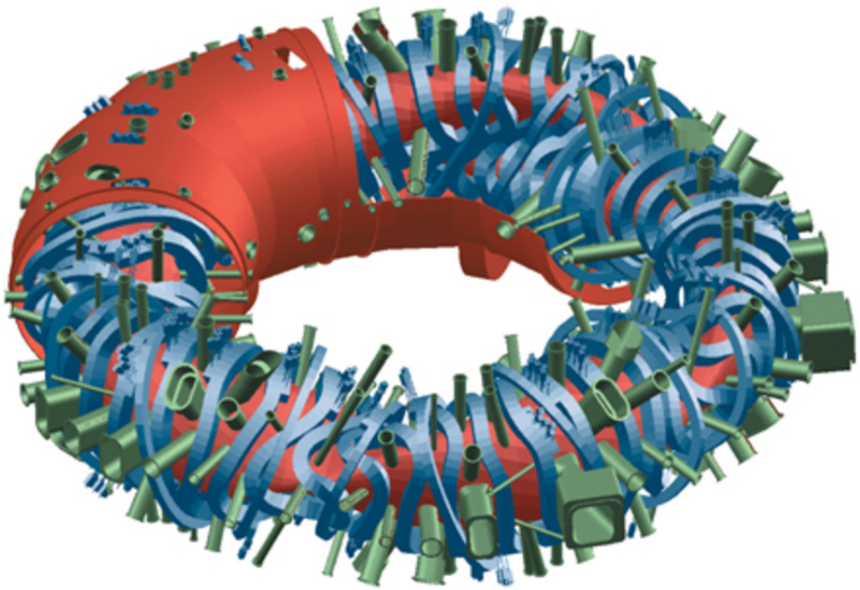
Pros:

- by definition stable and steady state
- a number of important advantages for a fusion reactor

Add-ons:

- Impact on the progress of the basic understanding of plasma physics in support of Mission 1 and 2 and in support of the ITER preparation

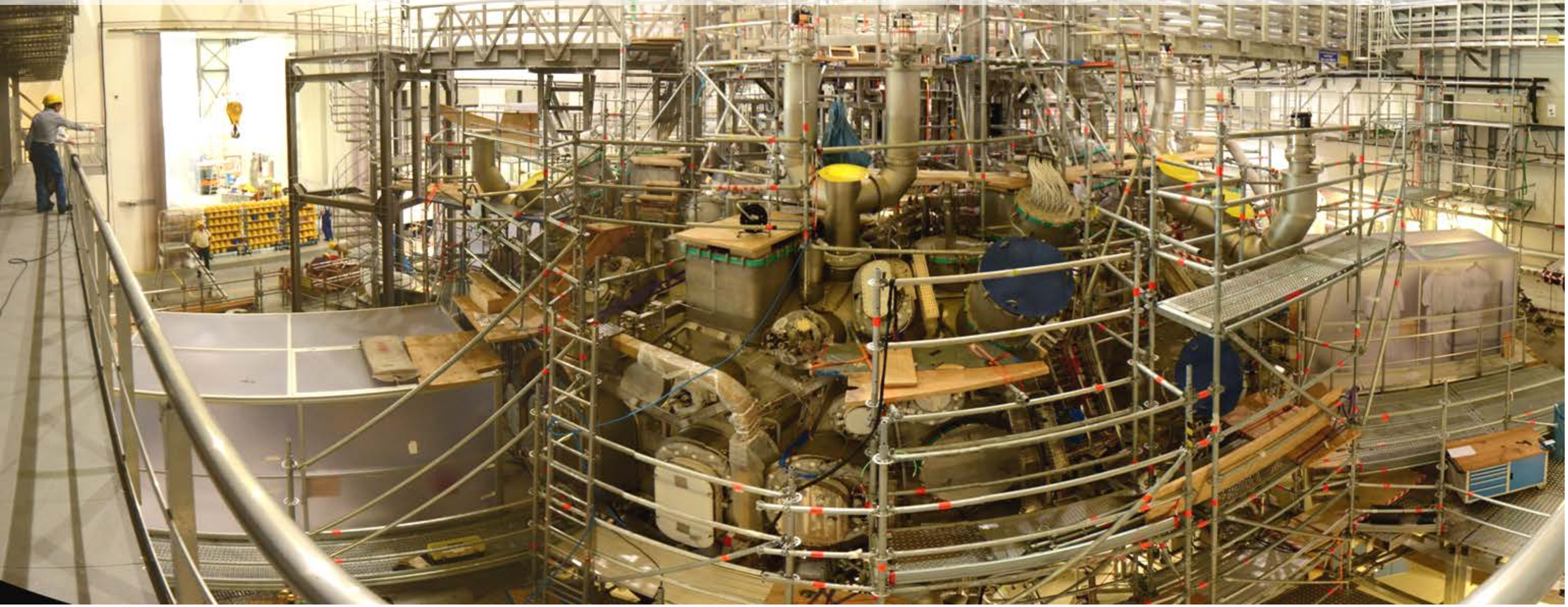
- Also contribution to PWI issues, diagnostics, ECRH, etc.



Main device: Wendelstein 7-X

Wendelstein 7-X: Status

Wendelstein 7-X Torus Hall (Greifswald, Germany, Aug. 2014)



- main-device assembly finished (May 2014) ✓
- device commissioning on track ✓
- **first plasma planned for summer 2015**

A. Dinklage for the W7-X Team 25th IAEA FEC, St. Petersburg, Russia (2014)

IPP

WENDELSTEIN 7-X

W7-X: bring the HELIAS line to maturity

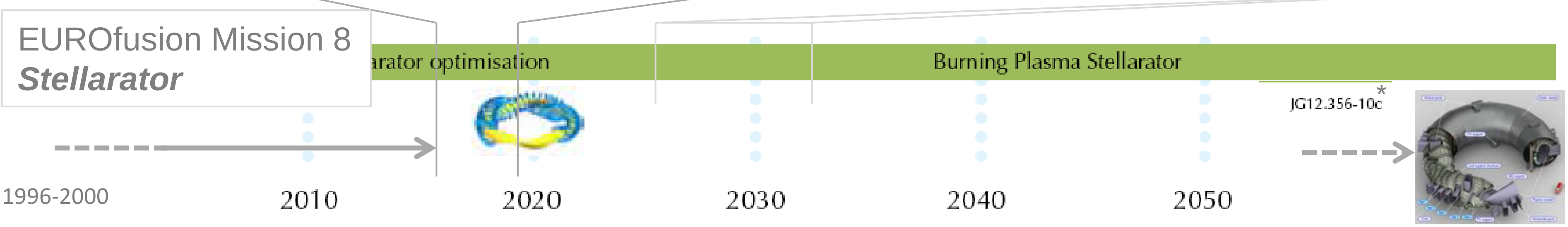
PFC-technology structures the way to reliable, steady-state, high $-nT\tau_E$ operation

uncooled C limiter	C uncooled divertor	actively-cooled divertor (CFC)	metal divertor ?
OP1.1	OP1.2	OP2	OP3 …
pulsed	pulsed operation	steady-state	

test-divertor assembly

water-cooled divertor assy

| 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | … |



Preparation for the actively cooled divertor is the primary target of the first phase.

Long term goal: Basis for a HELIAS FPP

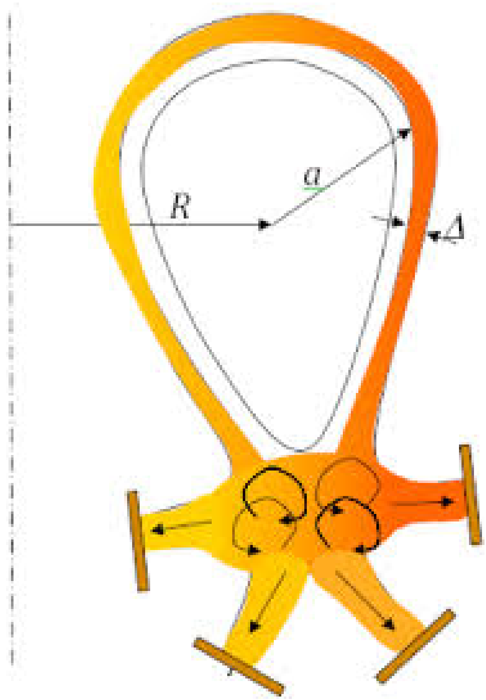
A. Dinklage for the W7-X Team 25th IAEA FEC, St. Petersburg, Russia (2014)

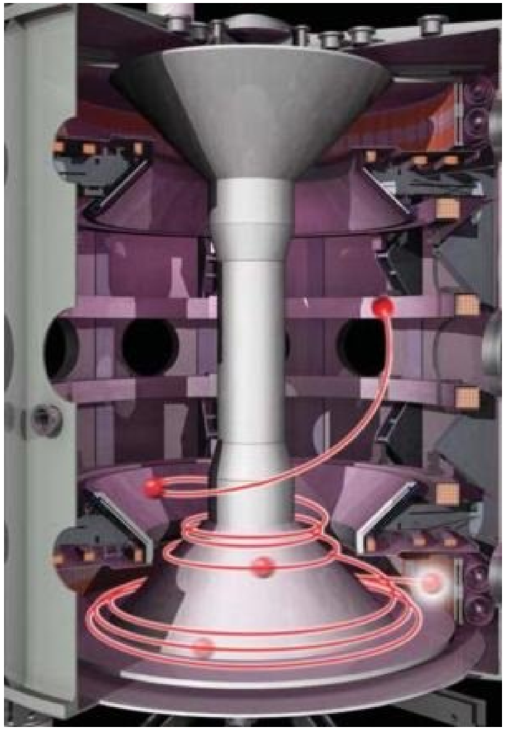
2: Heat Exhaust Systems

Research in alternative divertor solutions (Super-X, snowflake, liquid metal divertors)

Research in order to understand detached divertor conditions

Research to find more robust materials





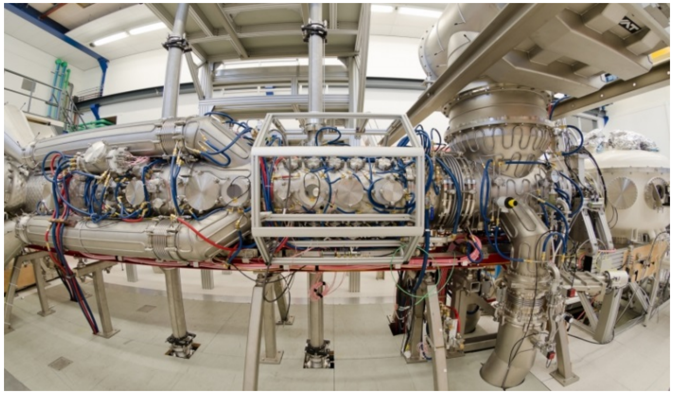
Main devices:

AUG, JET (conventional divertor)
MAST, TCV (advanced geometries)
WEST, W7-X (HHF components)
Linear devices (PWI)
Potentially a Divertor Test Tokamak

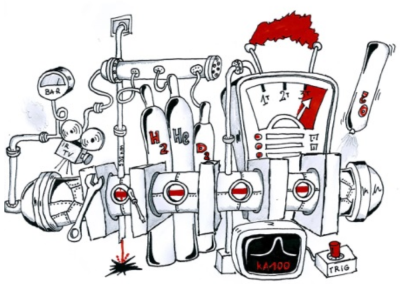
2: Heat Exhaust Systems

- Investigation of Plasma-Facing Components for ITER, Preparation of efficient PFC operation
- Assessment of alternative divertor & liquid metals PFCs
- Definition and design of the Divertor Tokamak Test facility

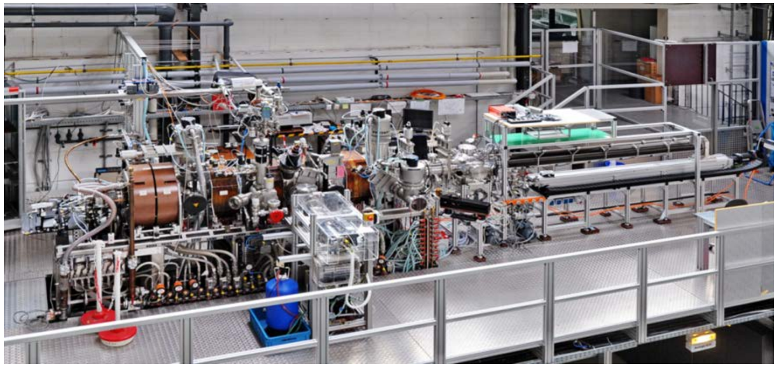
2: PFC Devices



Magnum-PSI



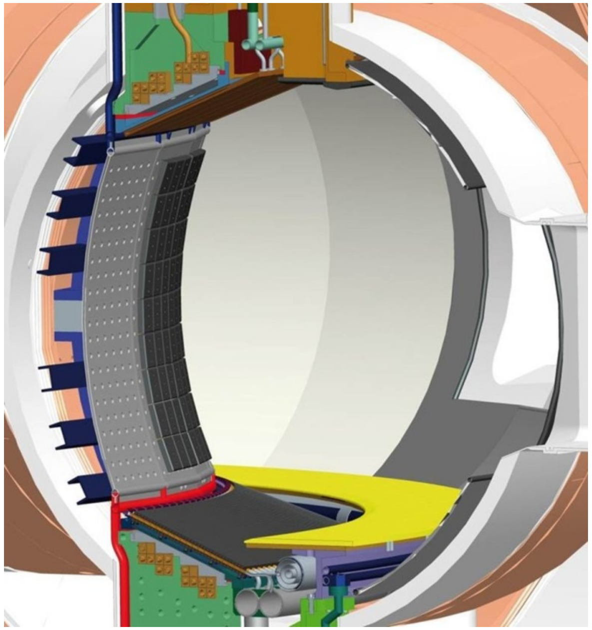
Pilot-PSI



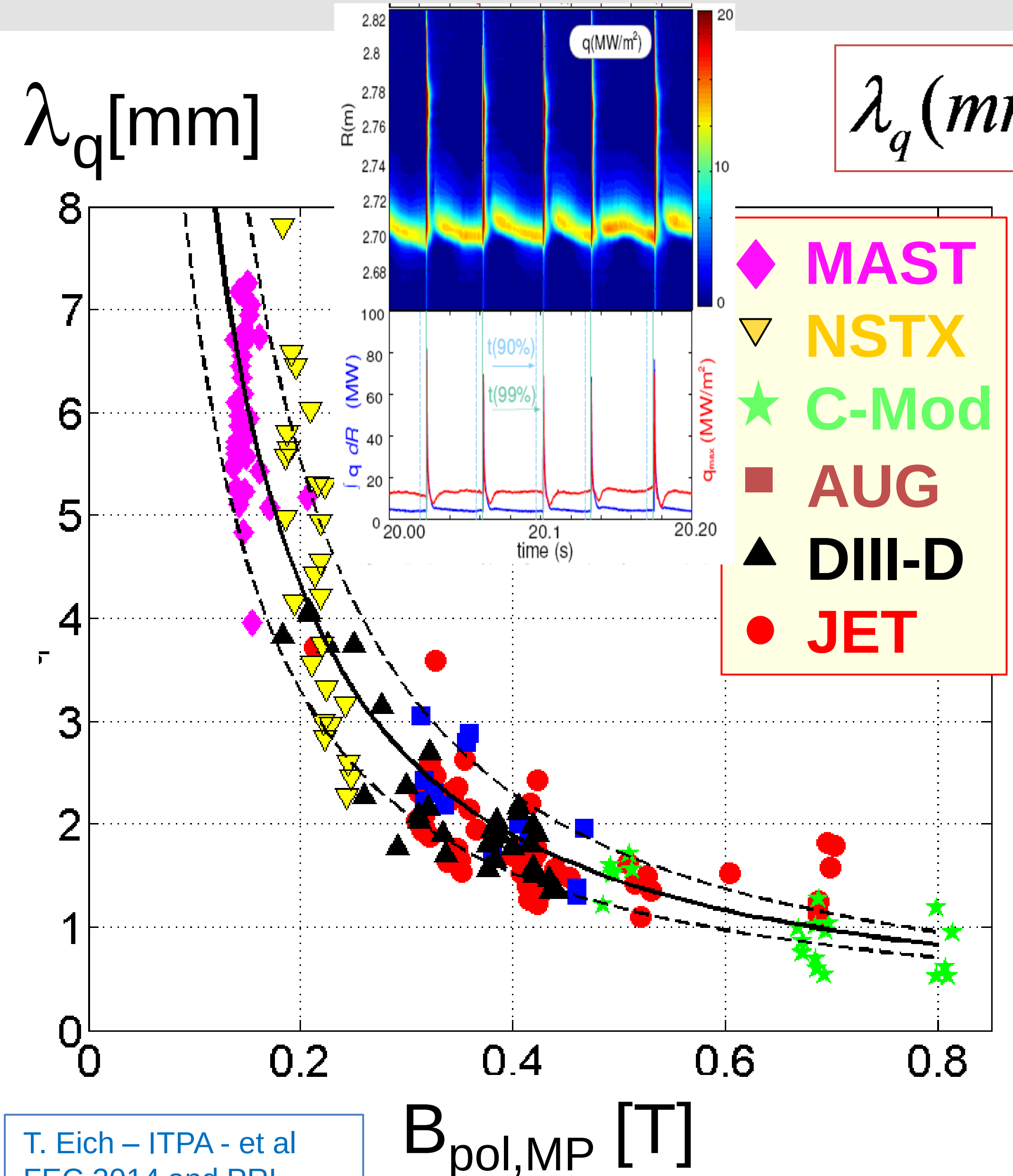
PSI-2

JUDITH-1/2

WEST



ITER power width ?



$$\lambda_q(mm) = (0.63 \pm 0.08) \times B_{pol,MP}^{-1.19}$$

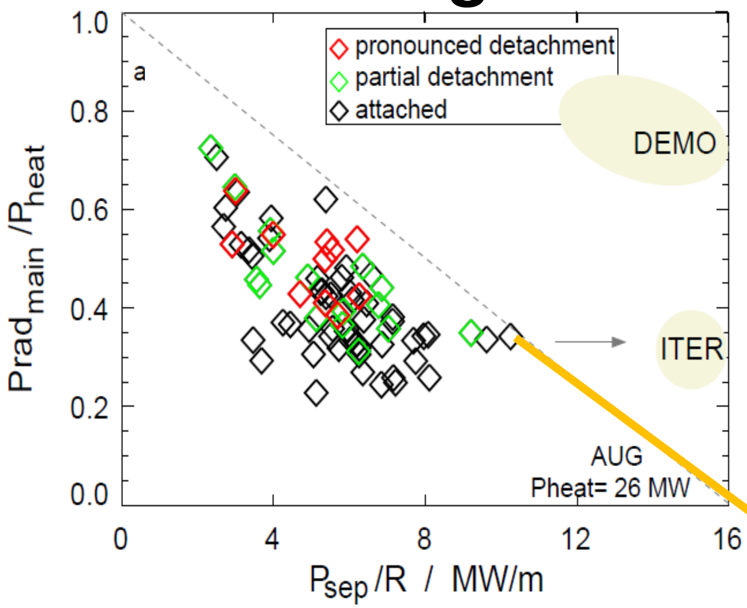
- $B_{pol,MP}$ the dominant scaling parameter ($I_p/a \propto B_{pol,MP}$)
- Extrapolation to ITER

  $\lambda_{q,ITER}$ = 0.9±0.3 mm

- Divertor power spreading and dissipation can produce acceptable target peak heat flux in ITER

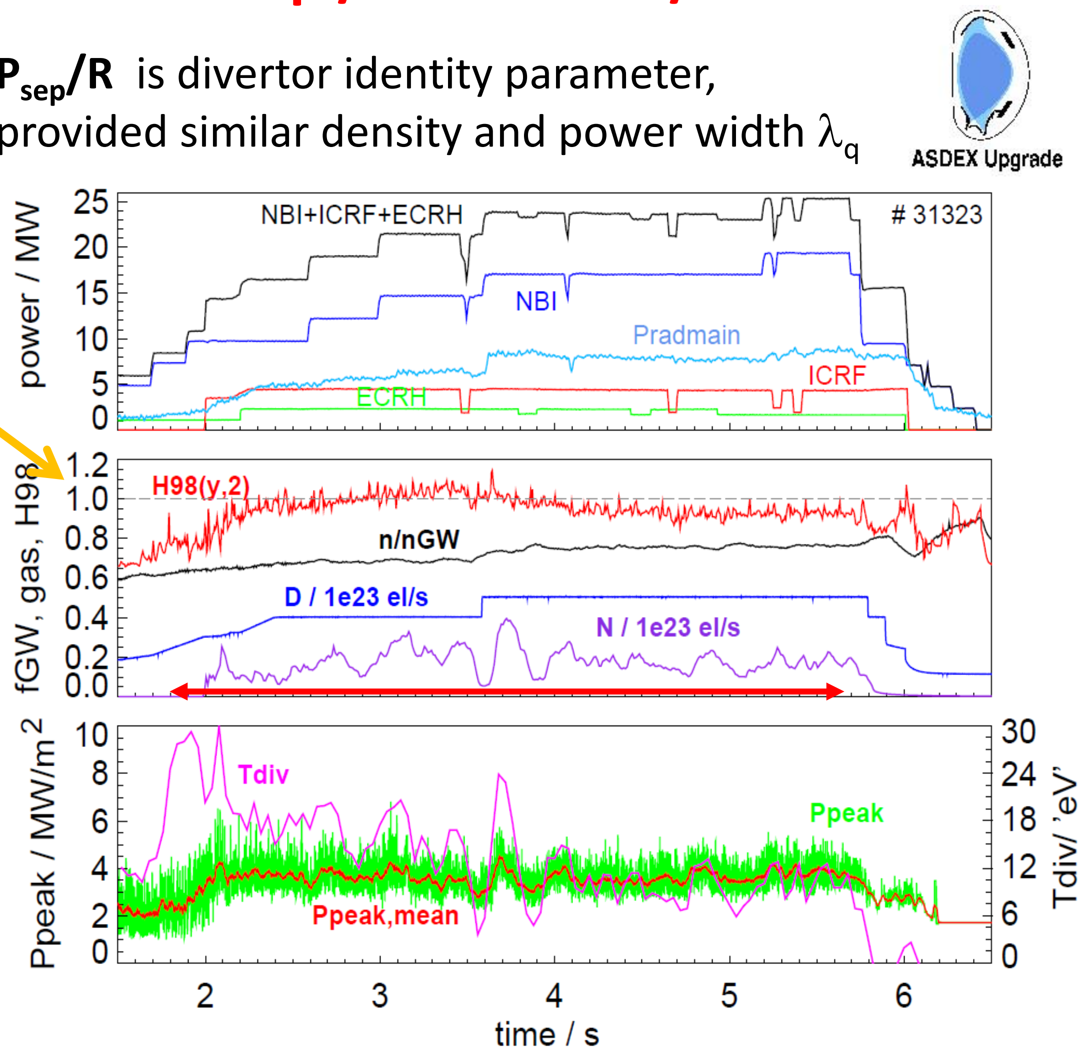
T. Eich – ITPA - et al FEC 2014 and PRL 2011

Nitrogen seeding on Asdex-Upgrade



Psep / R = 10 MW/m !

P_{sep}/R is divertor identity parameter, provided similar density and power width λ_q



Divertor detachment is a key to ITER mission.

Robust target power flux control schemes to be tested across machines for ITER

A. Kallenbach and H Zohm IAEA / FEC 2014

Tungsten dust-wall interaction and dust remobilization

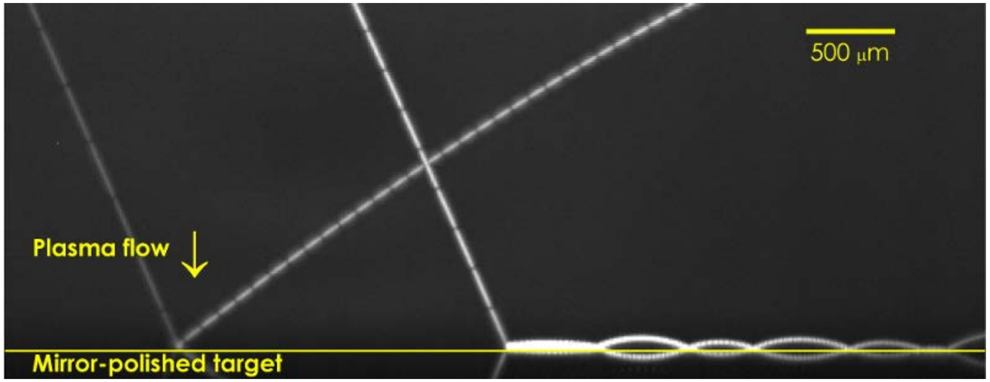
Dust-wall interaction: plays a crucial role in the formation of dust accumulation sites and dust remobilization under normal and transient conditions

Synergy of modeling and experimental efforts

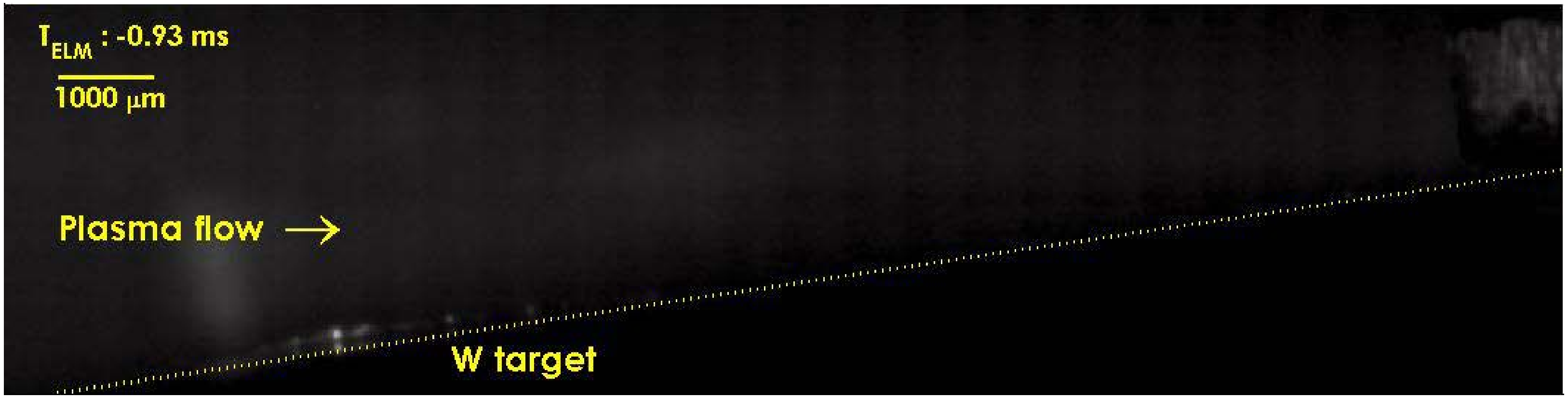
- **MIGRAINe** dust dynamics code including dust-wall interactions
- Highly controlled experiments in **Pilot-PSI**

L Vignitchouk et al, PPCF 56 (2014) 095005

Camera observations of dust motion in the sheath with unprecedented resolution are compared with model predictions to provide insight on the underlying phenomena.



P. Tolias et al., submitted to NF



WP14-ER-01/VR-01 S. Ratynskaia

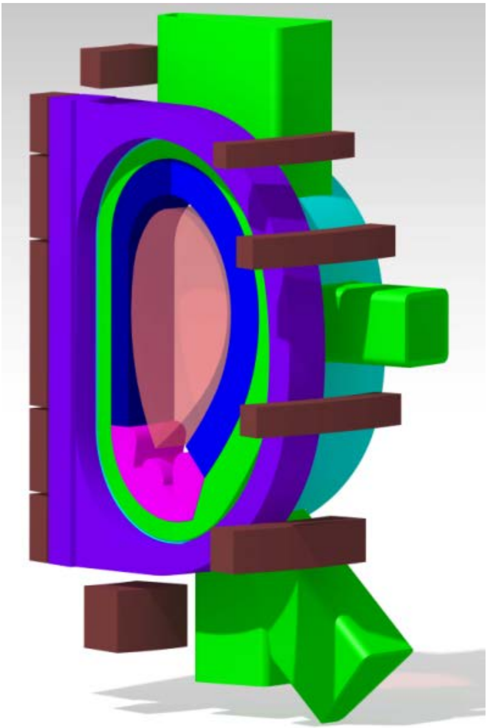
3: Neutron resistant materials

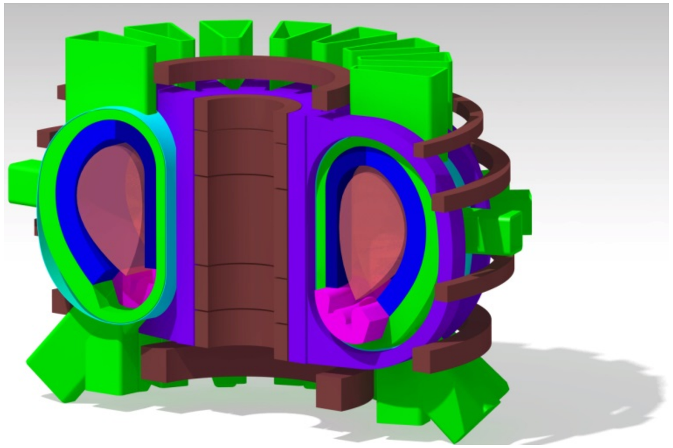
4: Tritium self-sufficiency

5: Intrinsic safety features

6: Integrated DEMO design and system development

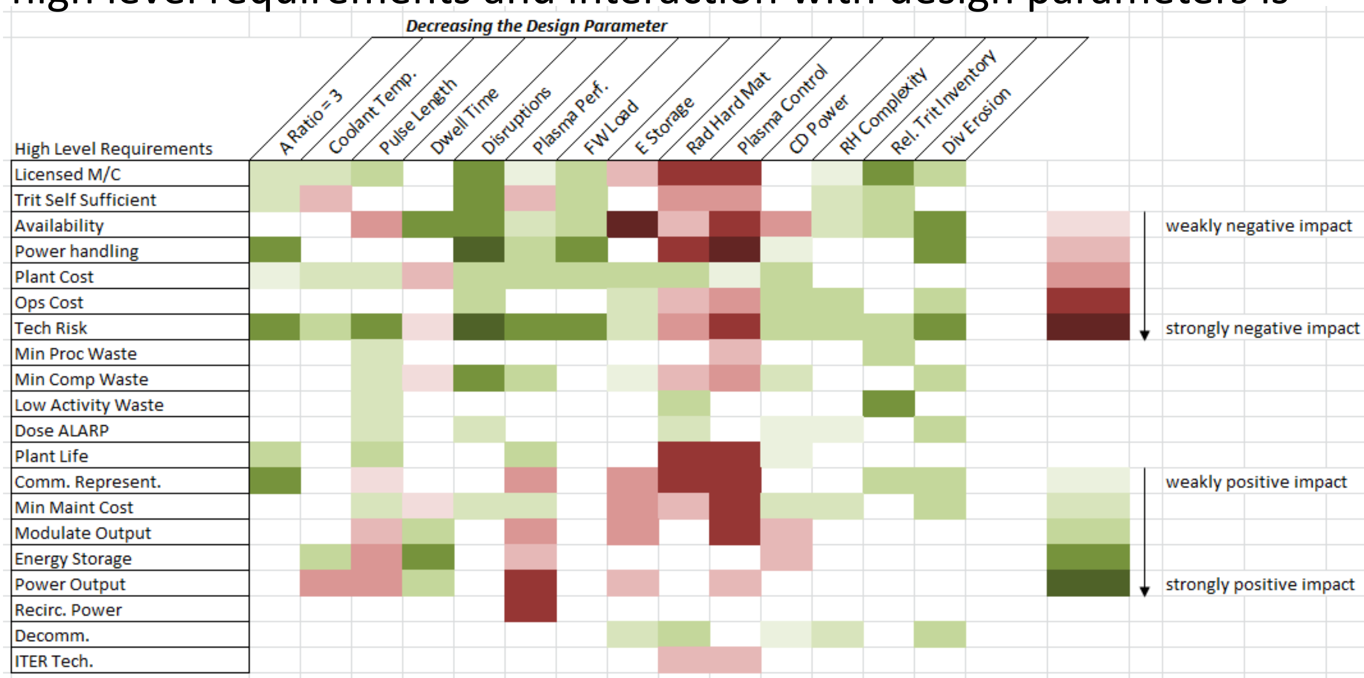
7: Competitive cost of electricity





WPPMI: Requirements Management & Stakeholder Highlights 2014

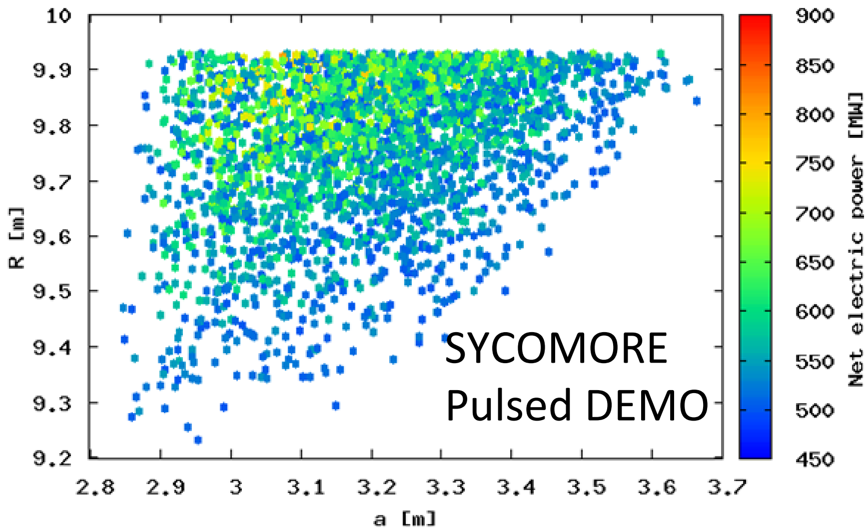
- Stakeholder engagement activity underway with meetings between PPPT and GEN IV Fission projects taking place to understand early phases processes (ASTRID held 28/11, MYRRAH 22/01/15)
- Analysis of high level requirements and interaction with design parameters is ongoing



- STAC recommendations have been incorporated into 2015AWP with respect to industrial involvement, additional planning support and decision making
- High Level Documents such as the Operational Concept Document and Plant Requirements Document have been issued for comment and revised

M. Shannon (PMU)

- PROCESS (CCFE)
  - Improved modules for radiation, pedestal, bootstrap current, TF coils, TF ripple, Costs, Availability,…
  - Advanced optimisation tools
  - Development towards a system code accounting for uncertainties
- SYCOMORE (CEA)
  - ✴ Relatively new system code based on ITM framework
  - ✴ Potential to develop features complementary to PROCESS (e.g. system code including a light transport code)



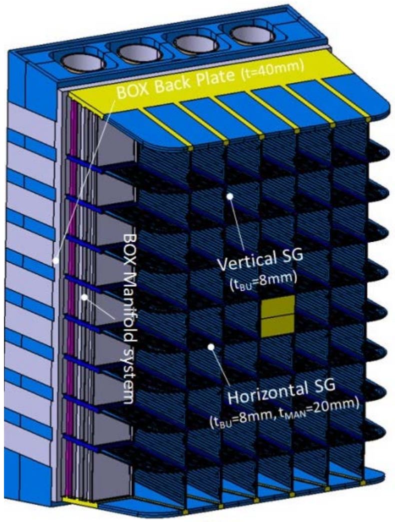
R. Wenninger (PMU) and WPPMI contributors

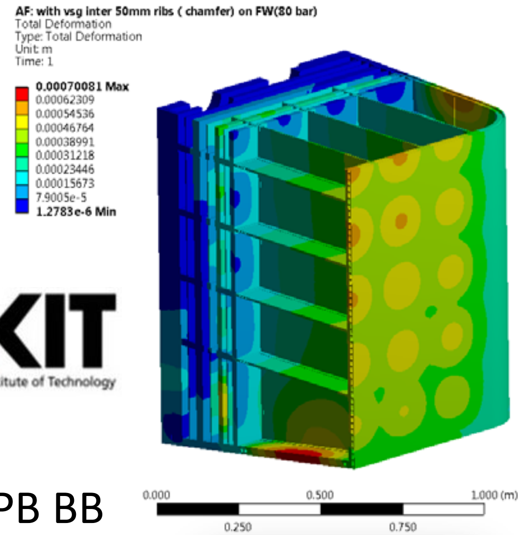
Advances of the DEMO Physics Basis

Area	Activities
Scenario Modelling	Initial studies of ramp-up and ramp-down, pellet fueling and related transport,…
Heating & Current Drive	Study of power requirements for NTM control
Transport	Investigations of bootstrap current, radiation effect on confinement, extrapolation of energy confinement time
MHD	Initial predictions of pedestal, global stability, vertical stability
Fast particles	Definition of investigation strategy
Specification of Wall Loads	Identification of relevant load types, investigations on loads due to radiation and thermal charged particles

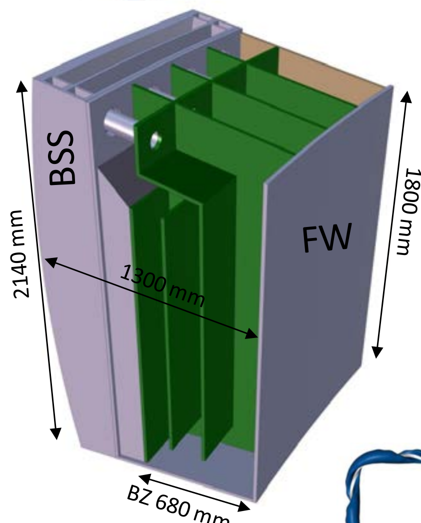
R. Wenninger (PMU) and WPPMI contributors

Highlights WPBB AWP 2014
BB Design

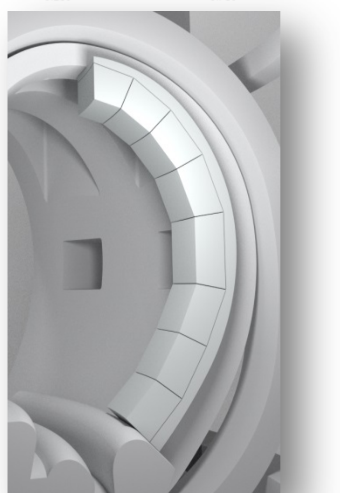




HCPB BB



DCLL BB

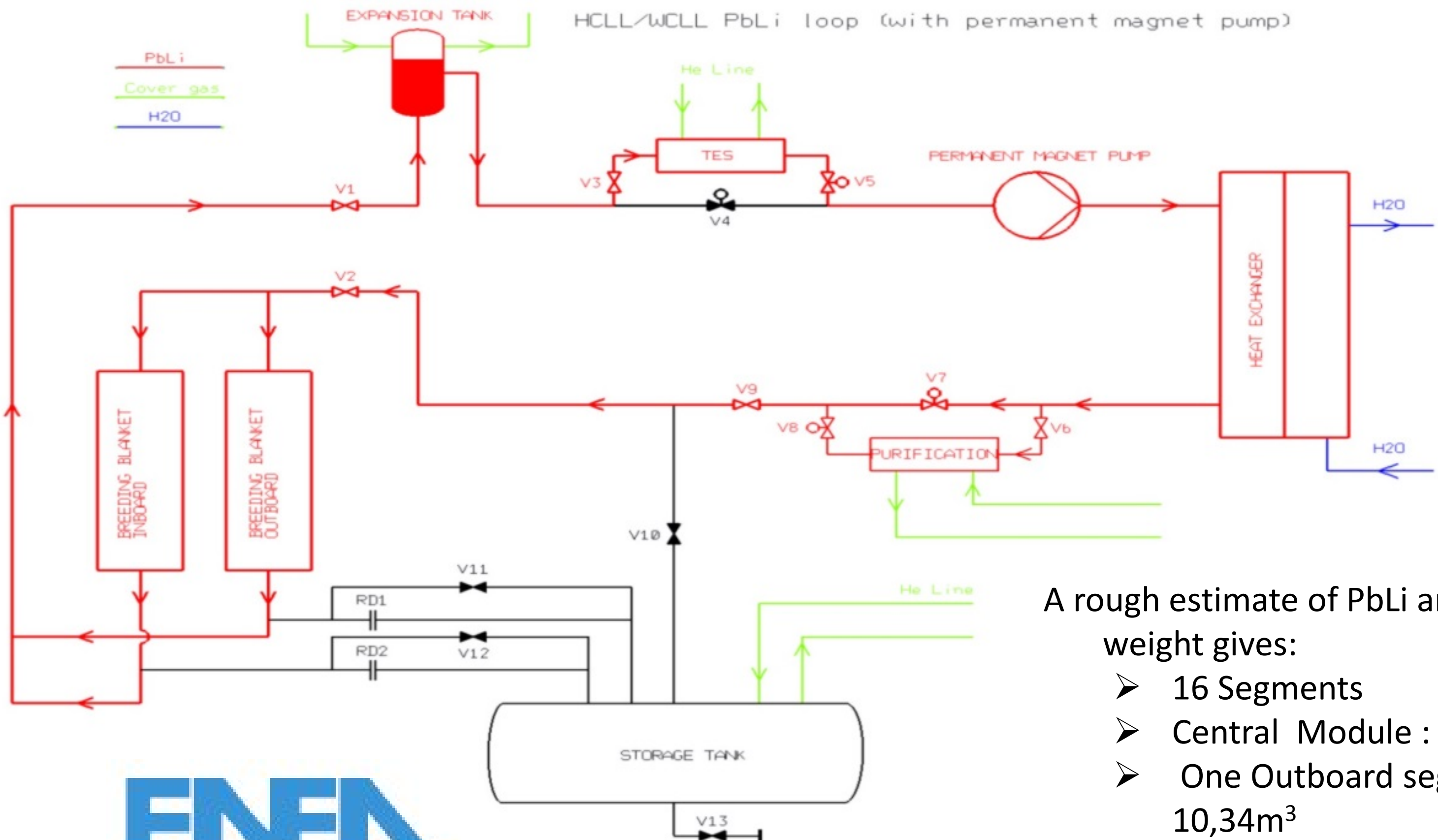


- The Breeding Blanket (BB) concept considered in PPPT have been adapted (e.g. HCPB and DCLL in the figure) at the current DEMO configuration.
- Neutronics, thermo-hydraulics and structural-mechanics performance were evaluated. Issues were identified in TBR and coolant performances.
- New design features have been evaluated and performances increased

Breeding Blanket Project in EUROFusion

L. Boccaccini (KIT) and WPBB Team

LiPb Technology



A rough estimate of PbLi amount in a segment's weight gives:

- 16 Segments
- Central Module : ~17,05m^3
- One Outboard segment (8 modules) : ~ 10,34m^3
- One Inboard segment (7 modules): ~ 5,21m^3

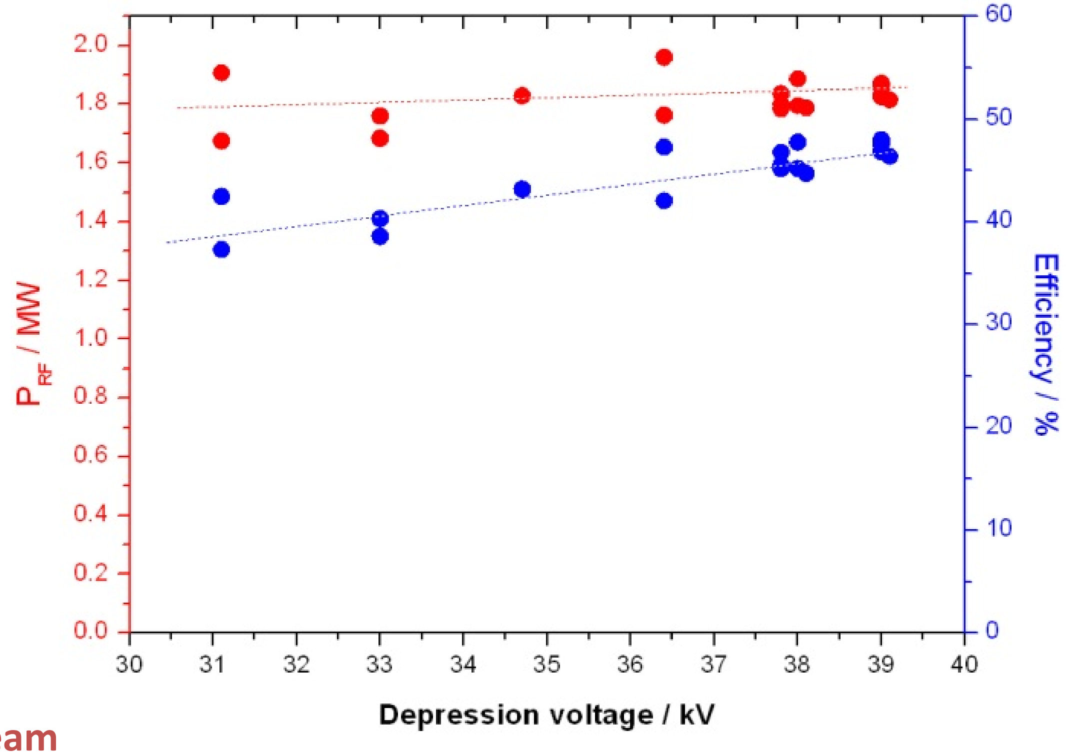
⇒ PbLi velocity ~ 0,005-0,01m/s
⇒ Mass flow rate/Segment: 52-78kg/s

- The first lay-out for the Pbli Loops for the Water Cooled Breeding Blanket were developed in 2014.

Breeding Blanket Project in EUROFusion

L. Boccaccini (KIT) and WPBB Team

- High frequency high power gyrotron development: Experiment with a 2 MW, 170 GHz, coaxial gyrotron with depressed collector: 170 GHz, **~1.9 MW**, total efficiency **~47%**, ~3ms

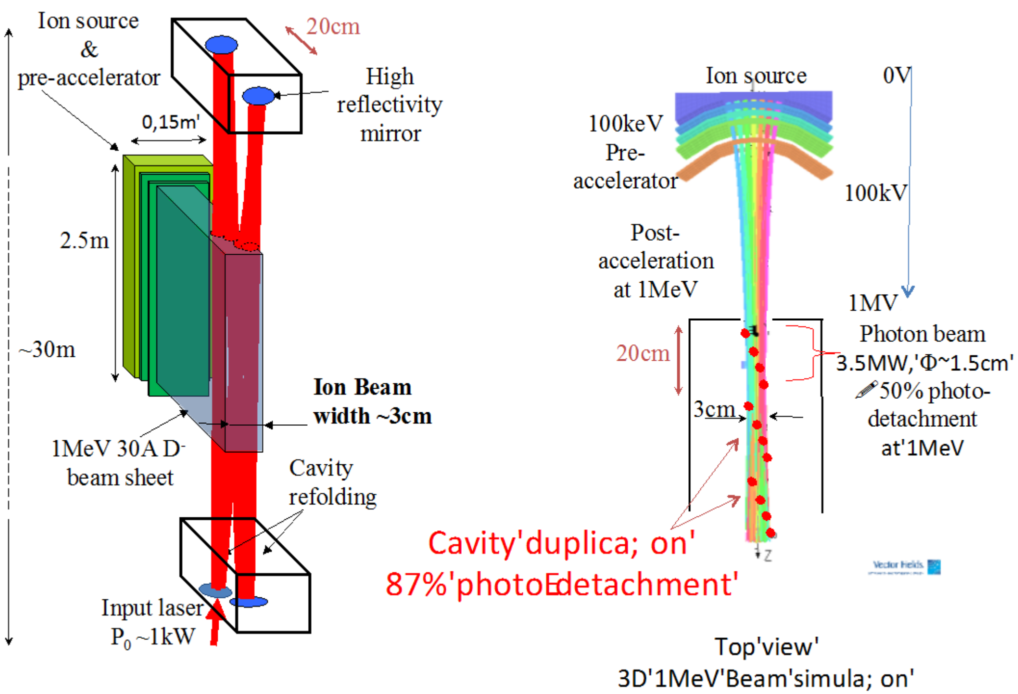


Karlsruher Institut für Technologie

M.Q. Tran (EPFL) and WPHCD Team

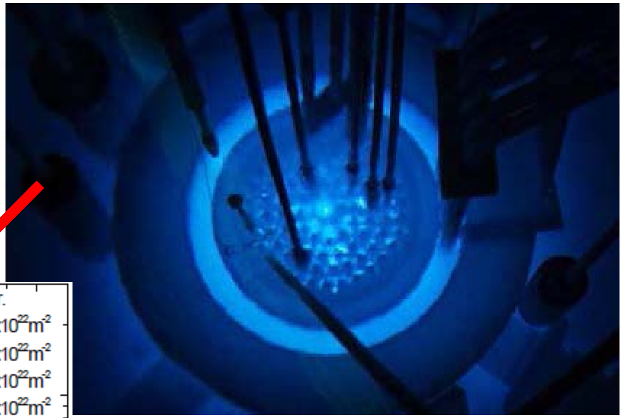
- Photoneutralisation as a method to increase 1 MeV NB efficiency. Feasibility study for DEMO with a milestone : end 2016

SIPHORE principle and Topology



M.Q. Tran (EPFL) and WPHCD Team

Advanced Magnet Technologies - HTS

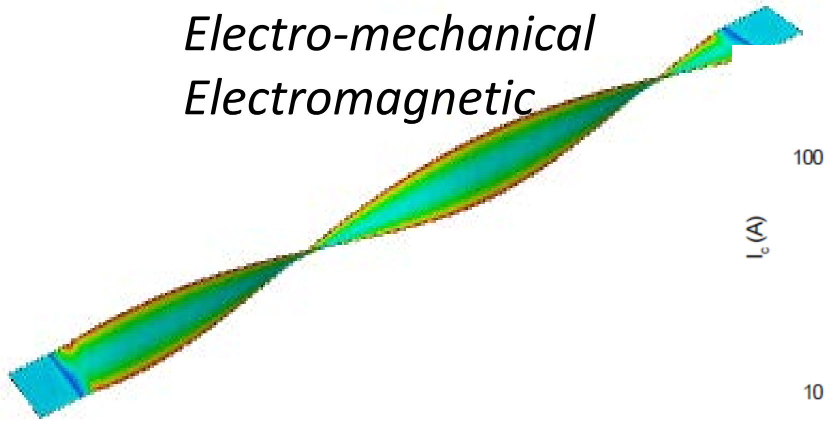


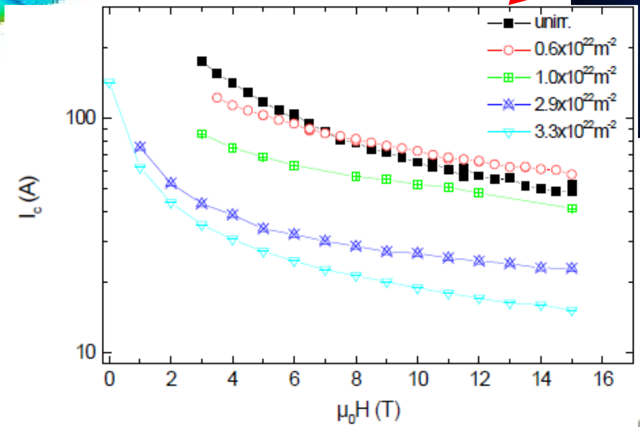
- **Several HTS Tapes tested & irradiated**

  comparative approach led to survey technology

- **Development of simulation models**

  Electro-mechanical
  Electromagnetic





- **Manufacture and tests of 2 cable concepts**

  Development of optimal samples design
  2 samples manufacture
  Good performances at T=4.2 K & high fields

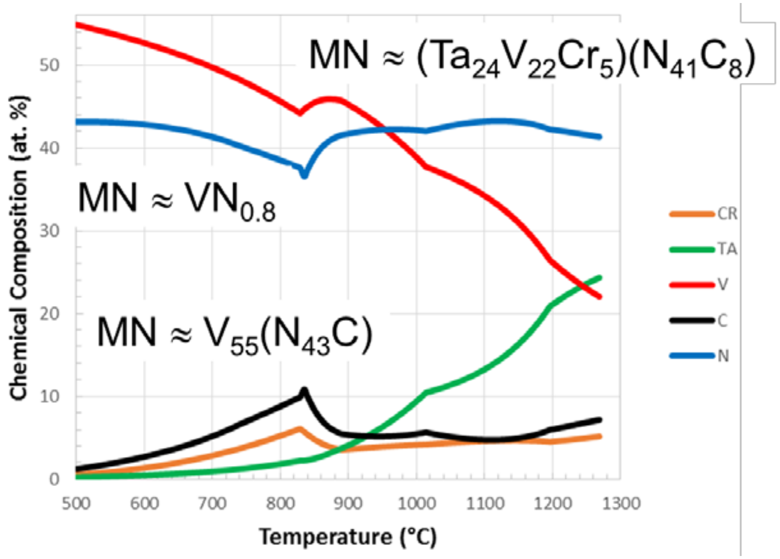
RACC cable

CORCcable

L. Zani (CEA) and WPMAG Team

Steel development based on thermodynamic calculations

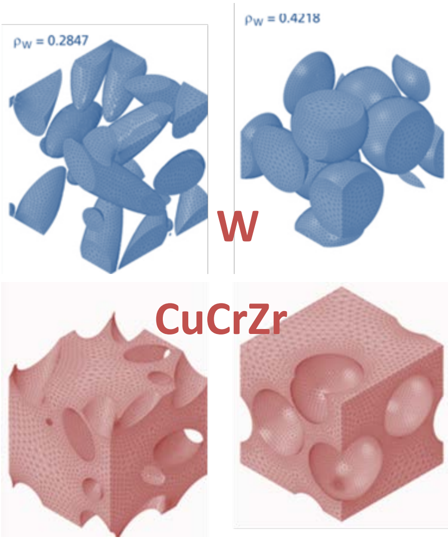
→ low temperature steel: **two** 80 kg batches produced
→ high temperature steel: **nine** 80 kg batches produced, **four** 100 kg batches in production
→ alternative ODS steel production: **23** lab-scale batches produced (250 – 550 g each)

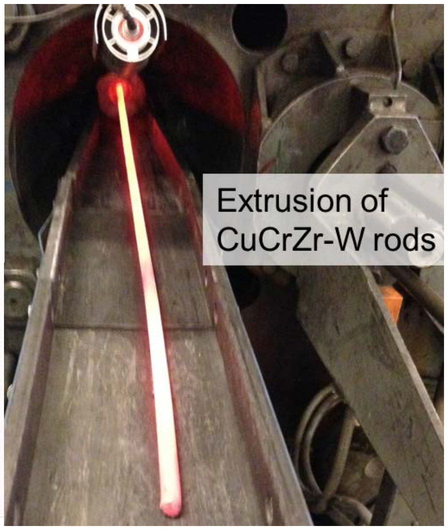


M. Rieth (KIT) and WPMAT Team

High Heat Flux Materials

W reinforced CuCrZr: simulation & production

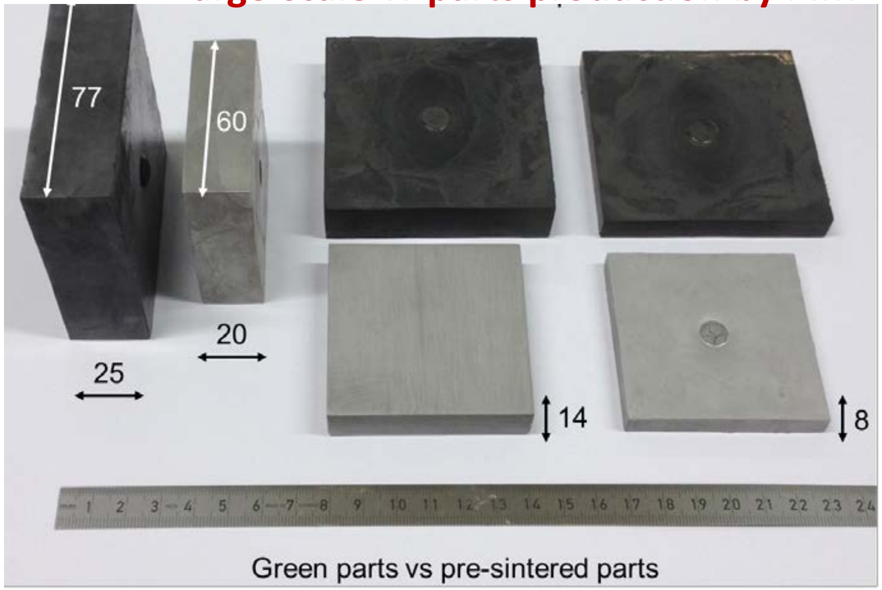




First batch: W fibre – W matrix composite fabrication

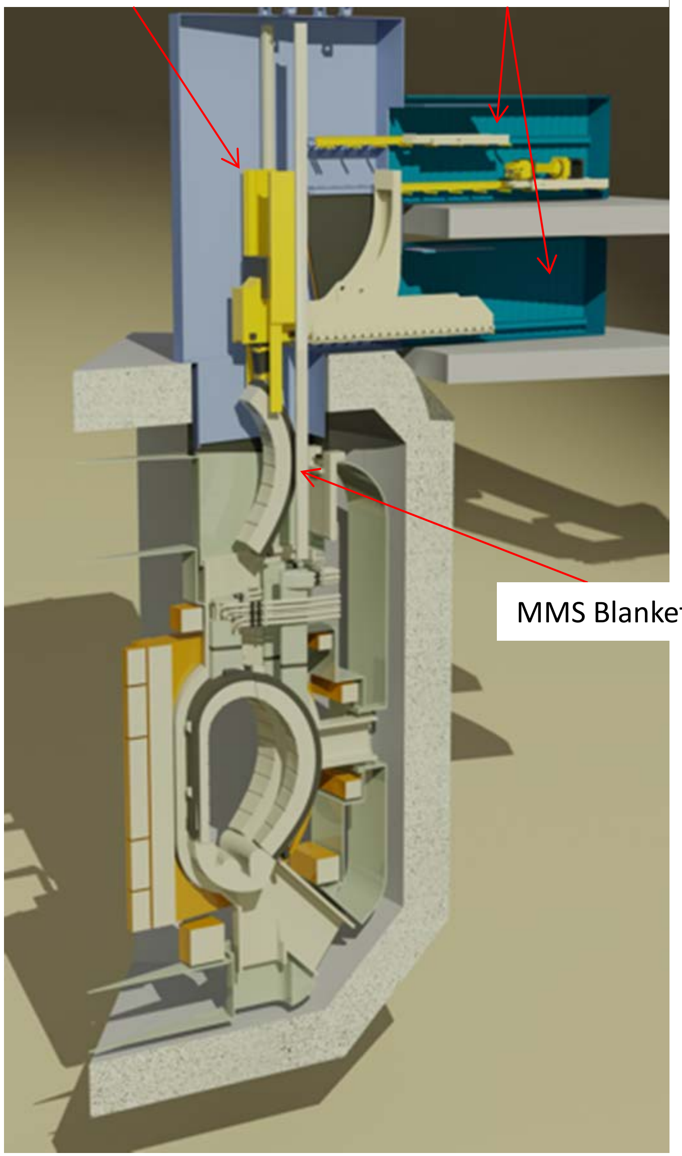
W laminated pipes in mockups for water and helium cooling

Large-scale W parts production by PIM



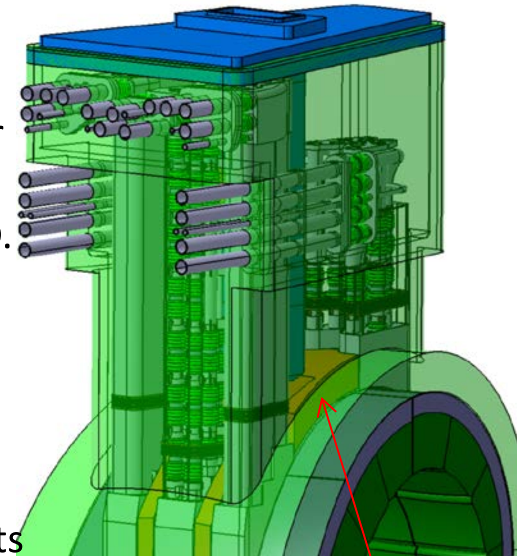
M. Rieth (KIT) and WPMAT Team

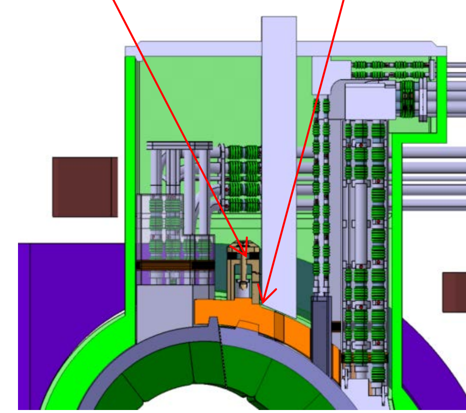
Remote Maintenance



Revaluation of the in-vessel remote maintenance:

- Improve flexibility allows for more cooling systems and access for diagnostics H&CD.
- Independent blanket and divertor maintenance
- Improved maintenance durations
- Near vertical lifts for blankets increase robustness of remote handling equipment
- Includes a neutron shield plug
- Independent port closure plate
- No in-vessel mover
- ITER-like cask transportation
- Improved unplanned single blanket maintenance

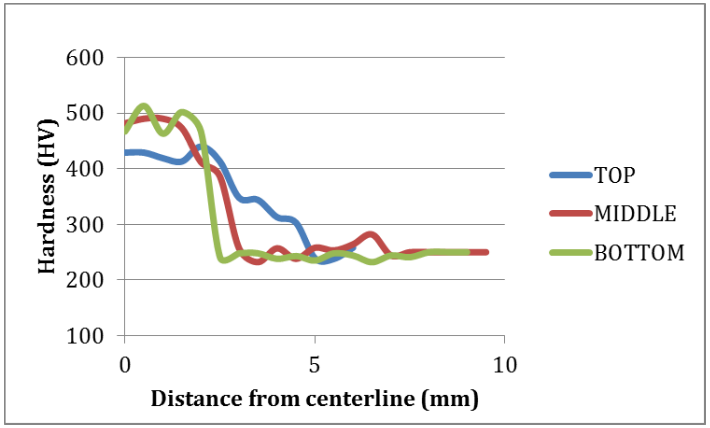


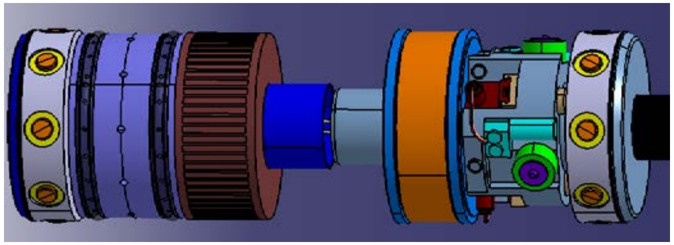


A. Loving (CCFE) and WPRM Team

Service Joint Technology

- 75% of blanket and divertor cassette maintenance duration is attributed to removal and installation of services
- Technology evaluation shows Laser to be favourable for in-bore cutting and welding
- Laser welding trials using P91 as a substitute for Eurofer have been undertaken
- Diffused laser has potential to provide extra heat input and can be used for post weld heat treatment





Concept tool design

Safety and Environment

- Draft **Plant Safety Requirements Document** written
  - Basic safety approach and principles set
  - Likely future regulatory regime considered
  - Requirements drafted in discussion with safety team and those working on DEMO design
  - Safety/Designers meeting held to discuss requirements and design choices and their impact
  - Confinement strategy proposed
- Improvements to codes and models for safety analysis
- Start of systematic studies to determine accident sequences for analysis
- Radioactive waste studies: selection of candidate techniques for detritiation of solid waste

N. Taylor (CCFE) and WPSAE Team

Proposal for risk mitigation of ITER

ITER has significant delays, possible solutions:

- ☞ Use contemporary fusion devices as risk mitigation for ITER
- ☞ Reduce the ITER non-active phase by proper preparation and training elsewhere

Proposal

- ☞ Establish an Int. Task Force to make a detailed proposal how present machines can be used to bring DT phase of ITER forward

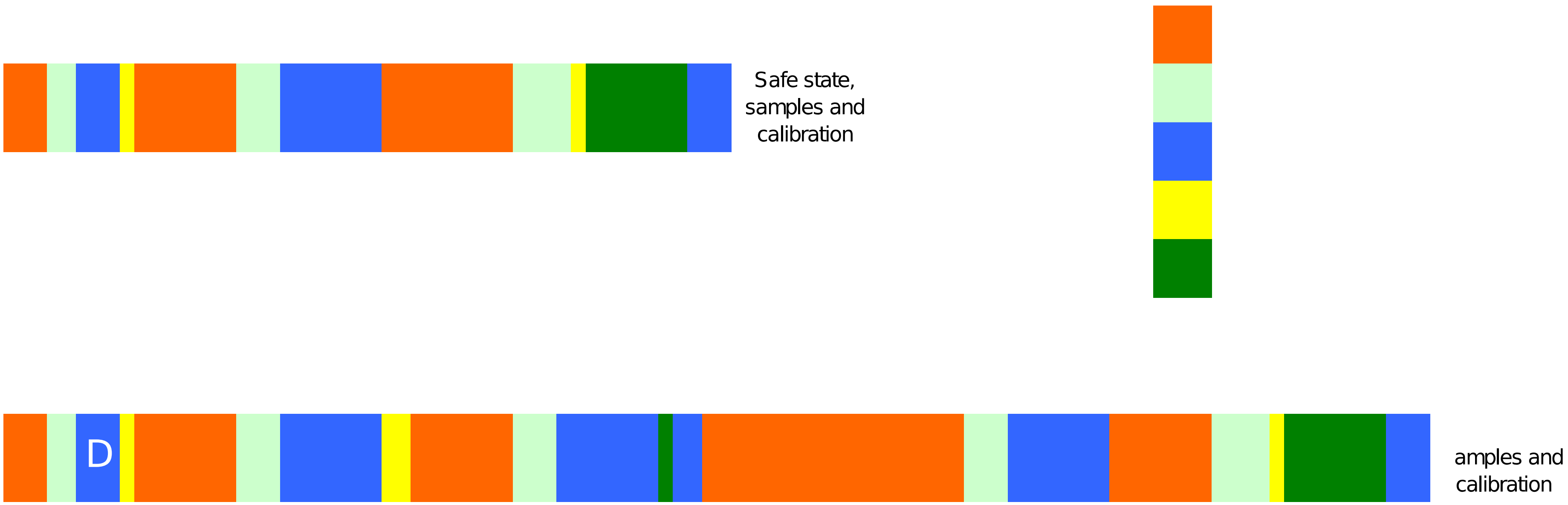
  This should include exploration of an ITER Q=10 baseline scenario at higher q_{95} based on 'improved H-mode' (AUG), 'Hybrid' (JET) or 'Advanced inductive' (DIII-D) scenarios

Specific JET contributions:

Only machine with DT, with ITER-like wall (Be-handling), full remote handling, organizing truly int. scientific campaigns, training

Future of JET - Internationalization

Long term JET plan depends on the success of the internationalization process (Wagner Panel on Strategic Orientation)



Details of the Alternative Scenario are not yet agreed

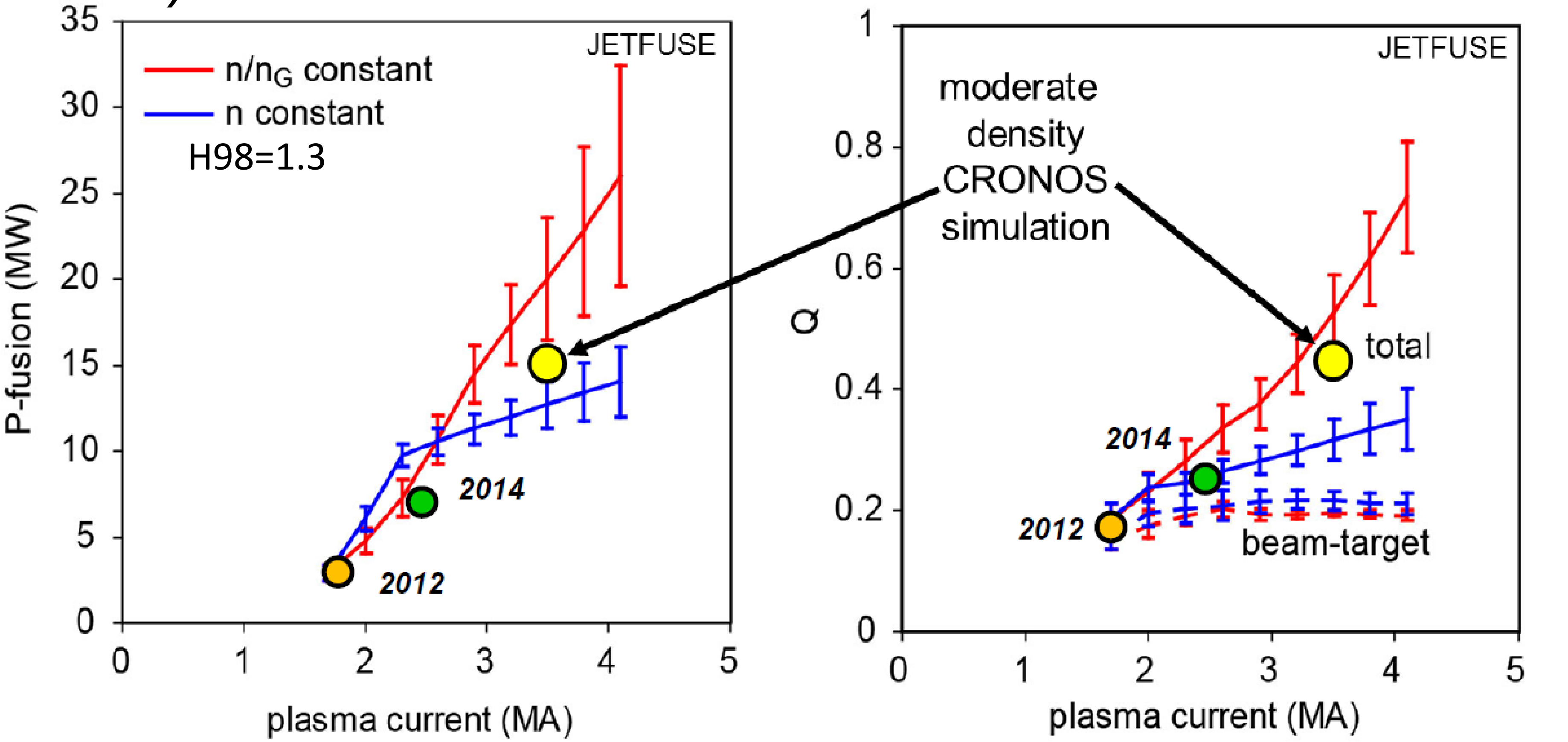
To 2025?

The feasibility of two further major enhancements (RMP Coils for ELM Control, ECRH) have been studied

Increase fusion performance in JET

Increase power (~40MW) to sustain (~5s) high β at high I_p/B_t (≥3.5MA/3.85T)

Develop heat exhaust control for divertor compatibility (sweeping, radiation)



The scientific case for DT operation in JET H. Weisen, A.C,C. Sips, C.D Challis, et al., Fusion Reactor Diagnostics Conf, 2013 (www.iop.org/Jet/fulltext/EFDC130406.pdf)

DT Campaign options

DT Campaign options		Full DT phase	DT phase ~DTE1	100% tritium only	Trace tritium
	14 MeV budget	**$1.7x10^{21}$**	**$2.5x10^{20}$**	**$5.0x10^{19}$**	**$5.0x10^{18}$**
ITER Scenarios in DT*	Baseline	20	8	200	
	Hybrid	40	2	200	
	Steady State	20	0	50	
Technology	Tritium retention				
	14 MeV calibration				
	Use 14 MeV Fluence				
Physics	Retention removal				
	Isotope scaling				
	α-particle effects				
	Fuelling & DT mix control				transport

**Number of high power (>25MW, 5s) pulses in DT (or 100% tritium) is indicated.*

ITER risk mitigation

	Impact of DT at JET
	Maximum
	Limited
	No

$1.7x10^{21}$ budget: Full exploitation of JET for mitigating the risks for ITER.

Epilogue

EUROfusion programme is in full swing

ITER Physics Programme:

- Strong programmatic approach
- Priorities discussed/selected EU wide
  - After that execution on device(s) best suited for specific study
- In 2015 simultaneous operation of JET, AUG and TCV
- In 2015 first operation of W7-X

Take home message:

It must be possible to optimize the ITER Research Plan by making proper use of contemporary fusion devices (e.g. training the team of ITER session leaders and operators in working with D-T, Be, Remote Handling, etc….., preferably using the ITER software)