EUROfusion

WDEV-1: status, plans, and future prospects

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ENEA
ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

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Status of WDEV-1

WDEV-1: Linear MHD stability chain for energetic particles and non-linear codes for fast-ion MHD interaction

- The Niched Pareto Genetic Algorithm (NPGA) has been implemented to perform the fit of the numerically obtained energetic particles distribution functions using a *parametric distribution function* in term of constants of motion, w (kinetic energy per unit mass), $\lambda=\mu/w$ (the generalized pitch angle), P_ϕ (the canonical toroidal momentum).
- The parametrised distribution function has been implemented in the hybrid MHD-Gyrokinetic code HYMAGYC
- The adaptation of input reading of CASTOR-K from CPOs to IMAS is under way.
- the HALO code is now able to obtain part of its inputs in the IMAS frame

Status of WDEV-1

Project/TF:	CD		
Activity Title:	**Task WDEV-1: Linear MHD stability chain for energetic particles and non-linear codes for fast-ion MHD interaction**	**Activity**	CD.WDEV-1
Activity Owner:	*PL: Michele Romanelli (CCFE)*	**Issue:**	*1*

Start Event:	*PB PMP approval*	**Planned Start Date:**	*1 January 2019*
End Event:	*All task deliverables met*	**Planned End Date:**	*31 Dec. 2020*
Activity Manager:	*TC: Gregorio Vlad (ENEA_Frascati)*	**Date:**	

Inputs required:

Task deliverables:

D1: Implement the parametrised distribution functions fitted from H&CD modelling codes in the non-linear code HYMAGYC for fast-ion MHD interaction and make it IMAS compliant
D2: Release linear MHD stability workflow for energetic particles using parametrised distribution functions fitted from H&CD modelling codes with documentation

WP Outputs:
Workflow release

Management Information

Human Resources: *e.g. Person days - Professional Staff, Technical, Staff, Support Staff, Others*

RU	Name	Workplan	2019 ppy	2020 ppy
ENEA Frascati	G. Vlad, G. Fogaccia, S. Briguglio Francesco Napoli Claudio Di Troia	Provide a genetic algorithm using the Pareto dominance criterion to perform the fit of the distribution function without any human bias. Implement the Niched Pareto Genetic Algorithm (NPGA) to perform the fit of the proposed parametric distribution function and make it available as an automatic tool able to interface gyrokinetic or H&CD modelling codes. Release the linear MHD stability workflow using the parametrised distribution functions above.	0.8	0.8
CCFE	James Cooke	Make the HALO Workflow IMAS / EU-IM compliant. Clearly define eigenmode and distribution data representations based on existing IMAS data structures (if they exist or develop them if they don't) and document the conventions used in order to adapt HALO to read and write those data representations.	0.4	0.4
IST	Rui Coelho Paulo Rodriguez	Complete the work of including CASTOR-K as part of the MHD stability chain for energetic particles. Support the release of the linear MHD stability workflow for energetic particles.	0.3	0.3

Research Unit	2019 ppy	2020 ppy
ENEA	0.8	0.8
CCFE	0.4	0.4
IST	0.3	0.3
Total	1.5	1.5

Other resources: controlled by PL/TFL – i.e. use of common facilities
Gateway cluster

Status of WDEV-1:

FIT OF THE FAST PARTICLE DISTRIBUTION FUNCTION

F. Napoli, C. Di Troia – ENEA

A parametric Equilibrium Distribution Function (EDF) for describing the Energetic Particles

- The proposed EDF is obtained from the most probable distribution function once:
  - the interactions are conservatives: w is constant
  - The motion of charges is described through the non-perturbative guiding center transformation: μ is constant
  - The system is axysimmetric: P_ϕ is constant
  - The set of (w, μ, P_ϕ) determines the stationary orbits
  - The libration angle between the magnetic moment direction and the guiding center velocity is oscillating following a gaussian behavior

- The pdf for finding an orbit is e.g.:

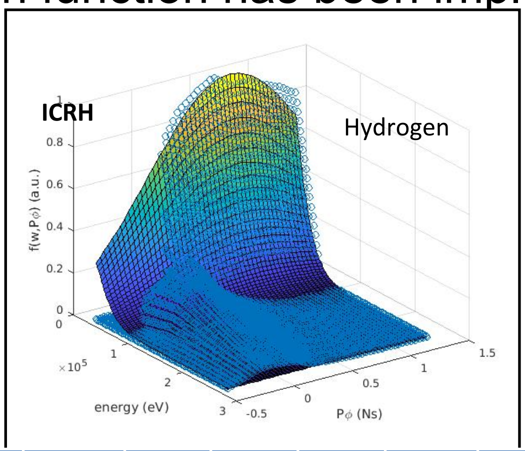
$$f_{\rm eq} = \mathcal{N}\frac{[1+(\mu/w)/\lambda_0](w/T_w)^{\alpha w}}{\sqrt{2\pi}}\frac{\mathrm{H}(w_b-w)}{w^{3/2}+w_c^{3/2}}\exp\left[-\frac{(\mathcal{P}_\phi-\mathcal{P}_{\phi 0})^2}{\Delta^2_{P_\phi}}\right]\exp\left\{-\frac{w}{T_w}\left[\frac{(\mu/w)-\lambda_0}{\Delta_\lambda}\right]^2\right\}.$$

Status of WDEV-1:

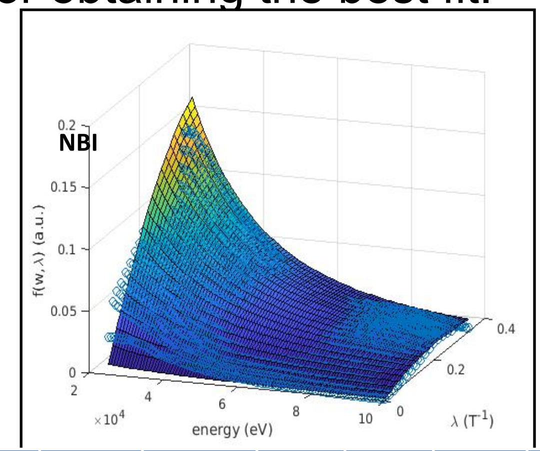
FIT OF THE FAST PARTICLE DISTRIBUTION FUNCTION

F. Napoli, C. Di Troia – ENEA

- Analysed several datasets from ASCOT (NBI) and FIDO (ICRH);
- The most of the distribution function defined over the full 3D domain (w, λ, P_φ) has been successfully fitted;
- A MATLAB code able to perform a global multi-trial fitting of the parametrized distribution function has been implemented for obtaining the best fit.



α_w	T_w (eV)	λ_0 (T^{-1})	$\Delta\lambda$ (T^{-1})	$P_{\phi 0}$ (Ns)	ΔP_ϕ (Ns)	N
2.99	13880.03	0.32	0.26	0.73	0.99	1.00



α_w	T_w (eV)	λ_0 (T^{-1})	$\Delta\lambda$ (T^{-1})	$P_{\phi 0}$ (Ns)	ΔP_ϕ (Ns)	N
-0.47	22446.20	1.66 10^-6	0.63	0.0024	0.29	80.28

NEXT STEPS:

1. a fully IMAS-compliant implementation and integration with the Kepler environment;
2. a multi-objective optimization on the moments of the distribution function;
3. a Chi-squared hypothesis test to evaluate the goodness of the fit;
4. a complete command-line interface and an intuitive GUI for the MATLAB end-user.

Status of WDEV-1:

HYMAGYC development and IMAS compliance

G. Vlad, G. Fogaccia, S. Briguglio – ENEA

- HYMAGYC has been updated to use the parallel MHD solver (PARMHD, developed within PARFS/PARFS2 HLST projects)
- Full FLR effects have been tested, “real device” geometry, nonlinear run (saturation observed)
- The parametrised distribution function has been implemented

AUG n=1 non-linear simulations for monotonic and non-monotonic EP density profile

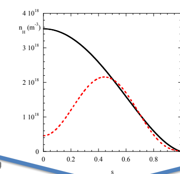
Monotonic EP density profile, full FLR and $\delta A_\perp$ effects retained

- $n_{H0}/n_{i0} \simeq 0.207$, $T_H = 0.093$MeV

Linear phase:

$\gamma_{lin}/\omega_{A0} \approx 0.026$; $\omega_{lin}/\omega_{A0} \approx +0.113$

$\gamma_{lin} \approx 127923[s^{-1}]$; $\omega_{lin} \approx +88.4$ [kHz]



Non-monotonic EP density profile, full FLR and $\delta A_\perp$ effects retained

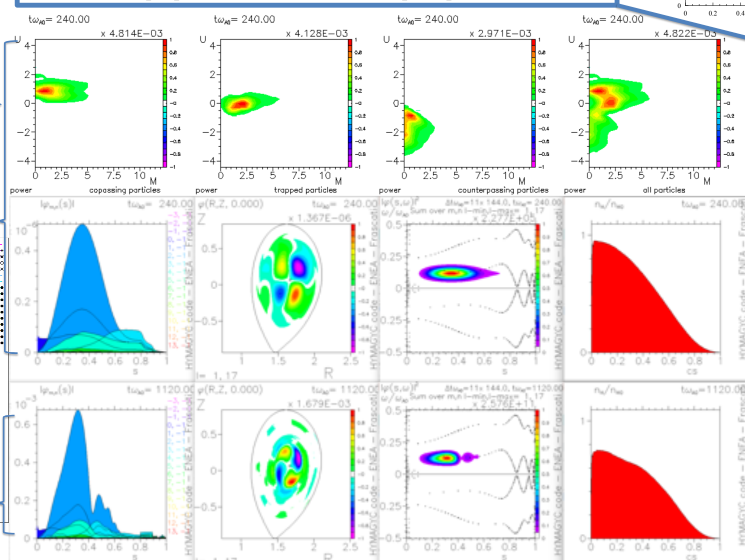
- $n_{H0}/n_{i0} \simeq 0.0267$, $T_H = 0.093$MeV

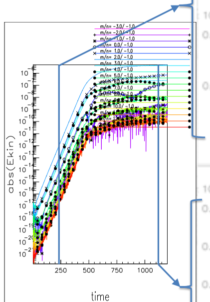
Linear phase:

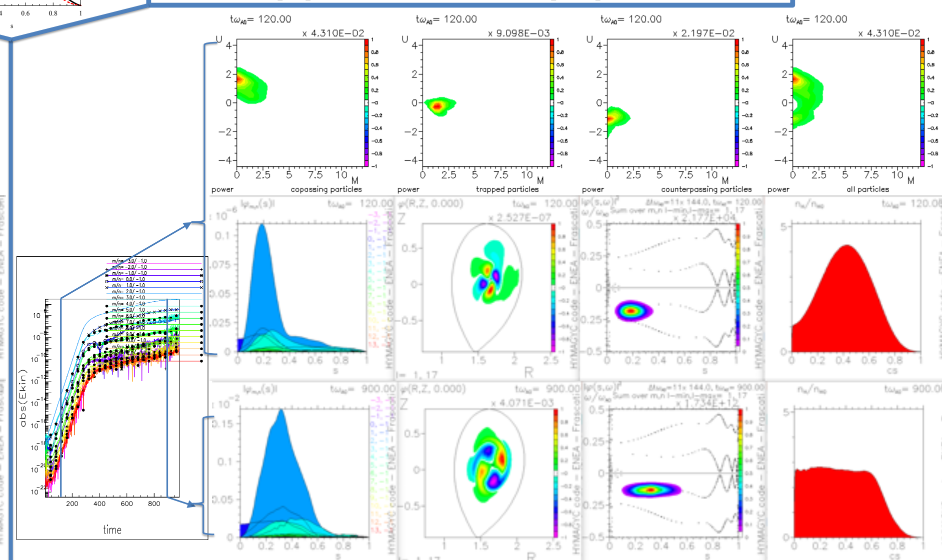
$\gamma_{lin}/\omega_{A0} \approx 0.044$; $\omega_{lin}/\omega_{A0} \approx -0.187$

$\gamma_{lin} \approx 215624[s^{-1}]$; $\omega_{lin} \approx -147.03$ [kHz]

Wave-particle power exchange during linear phase in the (μ,u) plane (co-passing, trapped, counter-passing, all)







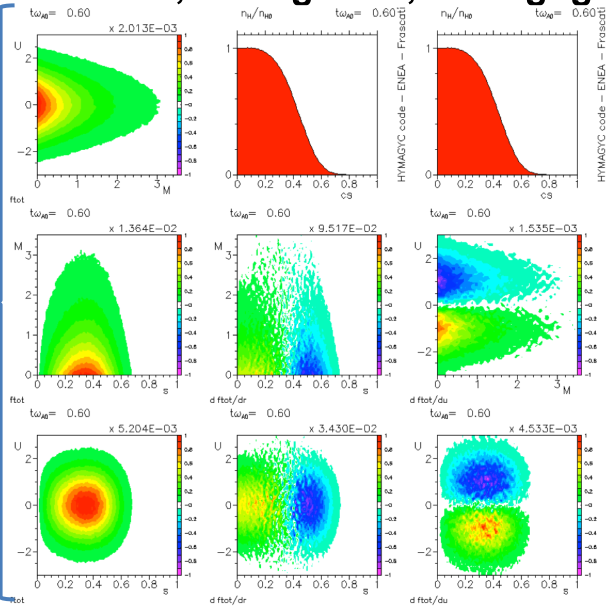
The mode driven by the monotonic EP radial density profile rotates clockwise, is located at mid radius close to the maximum EP radial gradient and to the minimum of the q profile, and just below the toroidal gap lower continuum (RSAE).The mode driven by the non-monotonic EP radial density profile rotates, on the contrary, in the opposite direction (counter-clockwise), being located radially more internally, where the radial density gradient has opposite sign, and within the toroidal gap in frequency. Both the modes saturates while flattening the EP radial profile in the radial region where the modes are located.

Status of WDEV-1:
HYMAGYC development and IMAS compliance

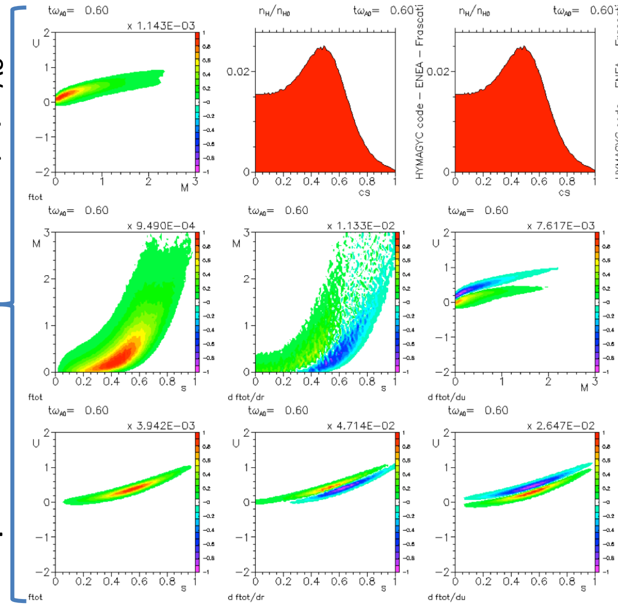
G. Vlad, G. Fogaccia, S. Briguglio – ENEA

See Movies…

“Standard” Maxwellian, $t/\tau_{A0}=0$

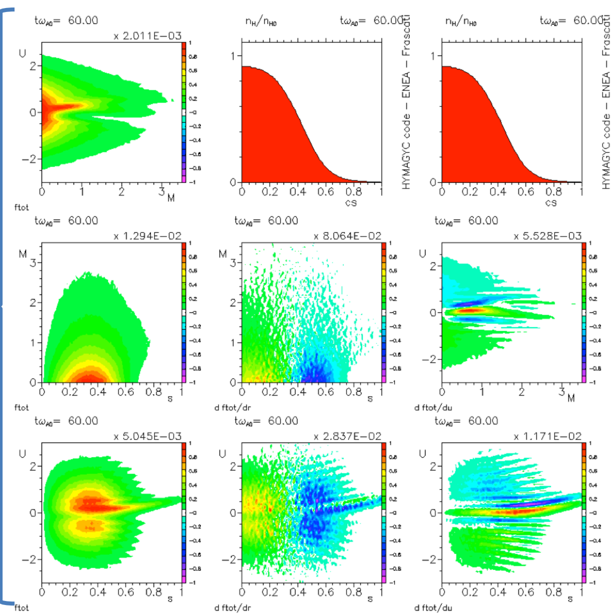


Equilibrium Distr. Funct., $t/\tau_{A0}=0$

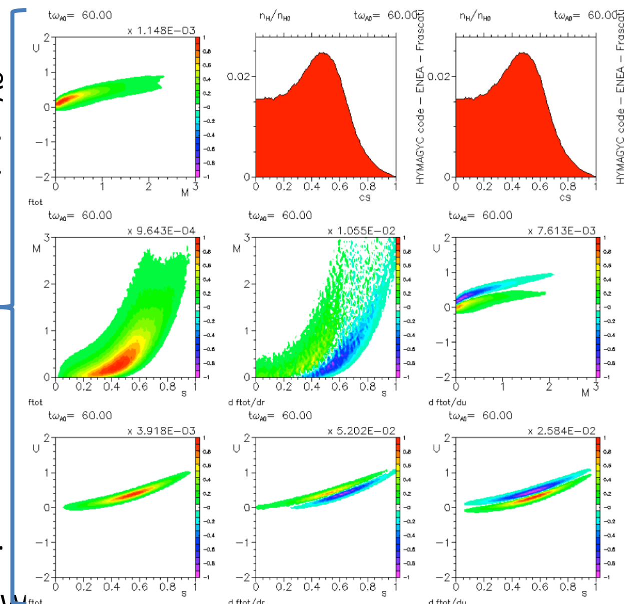


$f(w, \lambda, P_\phi)$

“Standard” Maxwellian, $t/\tau_{A0}=60$



Equilibrium Distr. Funct., $t/\tau_{A0}=60$



Status of WDEV-1:
CASTOR-K

R. Coelho, P. Rodrigues (FPT-IST: D. Borba, R. Coelho, J. Ferreira, F. Nabais, P. Rodrigues)

- Tested input reading of CASTOR-K with CPOs building on previous work already done (adaptation to IMAS is trivial).
- Equilibrium and MHD structured data from HELENA and ILSA tested successfully and yielding the same result as using native standalone code.
- Work still to be done: interfacing to distributions and filling an output mhd object. Should address the most recent IMAS DD where changes in mhd_linear were introduced.

Status of WDEV-1:

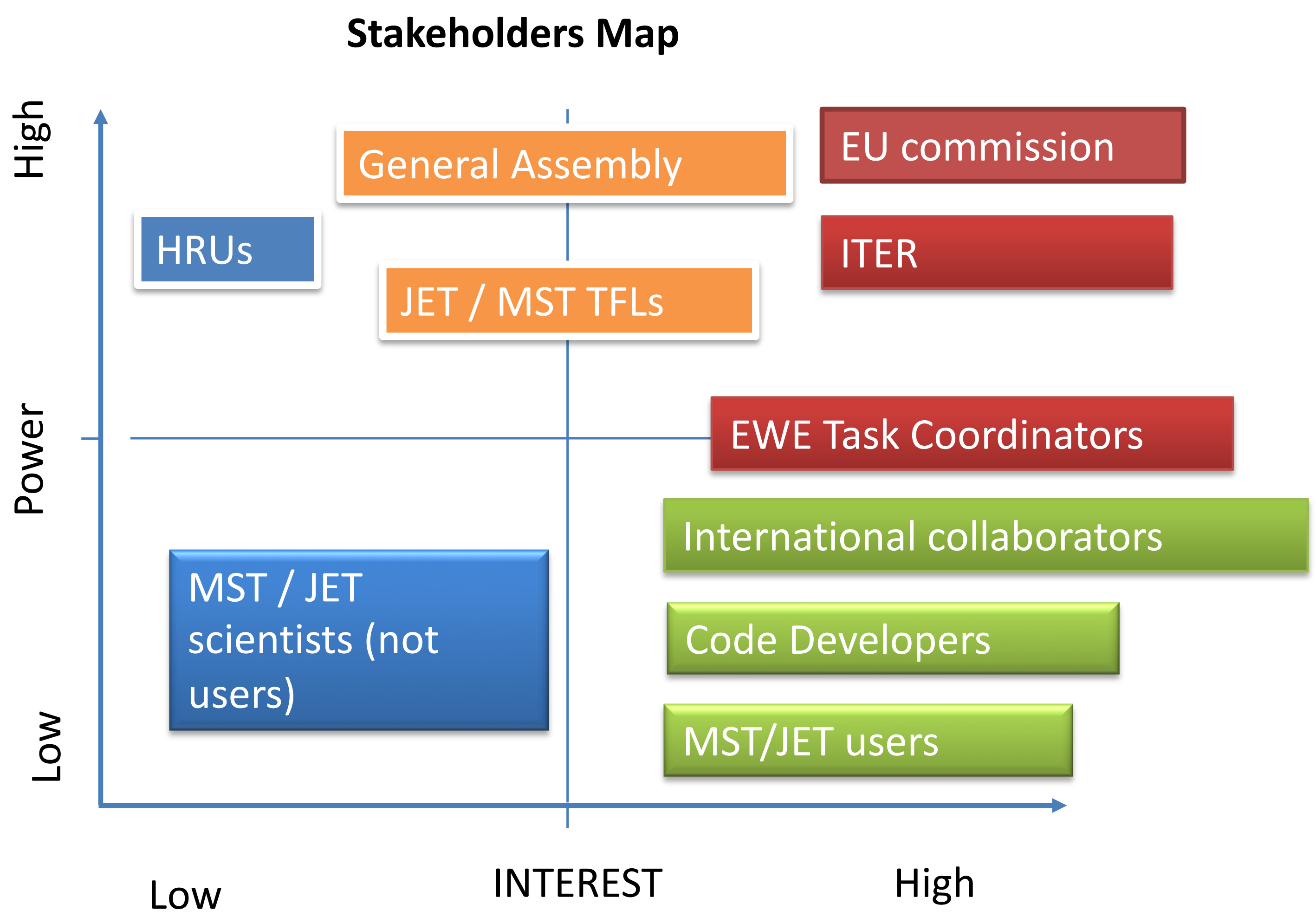
HALO (HAgis LOcust)

M. Fitzgerald, J. Cooke

- HALO on the ITER cluster can now read:
  - Density profile IDS
  - Temperature profiles IDS
  - Equilibrium IDS
- The remaining IMAS inputs required for HALO to run are:
  - Fast ion distribution function (currently generated by ASCOT, TRANSP and SELFO only)
  - Linear perturbation (currently generated by MISHKA only)
- Some test data are still lacking on IMAS:
  - linear perturbation (=>EQ&STABIL workflow)
  - equilibrium distribution function (Jarie Varie from ASCOT team has a script which takes a CoM distribution function in text file format and translates in IMAS/GGD format (Generalized Grid Description)

Plans for 2020

Identification of Key Stakeholders for Task EWE-5



Plans for 2020

Requirements of Key Stakeholders for your Task

Key Stakeholder 1

- Requirement 1
- Requirement 2
- ….
- ….
- ….

Key Stakeholder 2

- Requirement 1
- Requirement 2
- …..
- …..
- …..

Timeline for 2020

2020 Timeline for your task

	Jan	Feb	Mar	Apr	May	Jun
C. Di Troia, F. Napoli						Read numerical distribution function from IMAS Database
S. Briguglio, G. Fogaccia, G. Vlad						make HYMAGYC IMAS compliant
R. Coelho, P. Rodrigues						make CASTOR-K IMAS compliant
M. Fitzgerald, J. Cooke						no commitment for 2020

Timeline for 2020

2020 Timeline for your task

	Jul	Aug	Sep	Oct	Nov	Dec
C. Di Troia, F. Napoli						Provide an intuitive GUI interface for the end-users
S. Briguglio, G. Fogaccia, G. Vlad						Insert HYMAGYC in a MHD&EP workflow...
R. Coelho, P. Rodrigues						Insert CASTOR-K in a MHD&EP workflow...
M. Fitzgerald, J. Cooke						no commitment for 2020