JET 1999-2002: dal Michelson ECE al Real Time Control

WIP 04 Aprile 2022, Frascati

PROLEGOMENON:
ciclo informativo WIP’s

- Risultati diagnostiche THz, Enabling Research, collaborazione Clarendon *(fatto: Febbraio 2020)*
- Collaborazione con DIII-D San Diego (*fatto: 21 Febbraio 2022*)
- *JET 1999-2002: dal Michelson ECE al Real Time Control (oggi)*

......surfing the years......

- 1999 end of JET Joint Undertaking: JET EFDA
- Long (3yrs) JOC secondments from Associations (laboratories) (1999-2003)
- *ECE KK2/KK1 (Polycromator, Michelson)*
- *ECE KK5 (Fast rotating mirror from Frascati) (C. Centioli)*
- *Long secondment 2005-2009 (note: 4 years)*
- *Experimental campaigns 2016+ (Eurofusion)*
- *DCO*
- *Validazione temperatura elettronica ECE/Scattering (L. Senni, FP Orsitto)*
- *KK3 Real Time (M. Cappelli)*

Electron Cyclotron Emission

Electron Kinetics Group

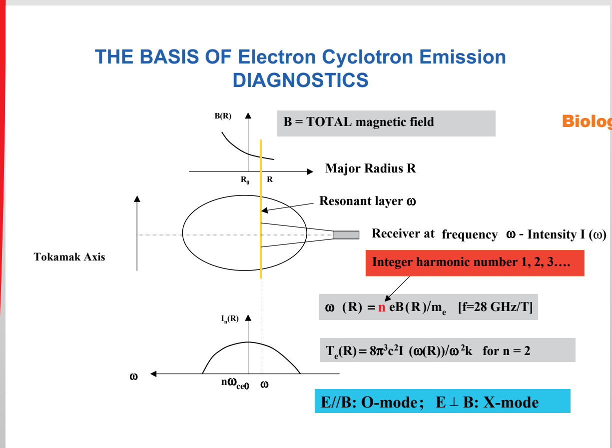
Purpose

Measurement of electron temperature: Basis of experimental technique.

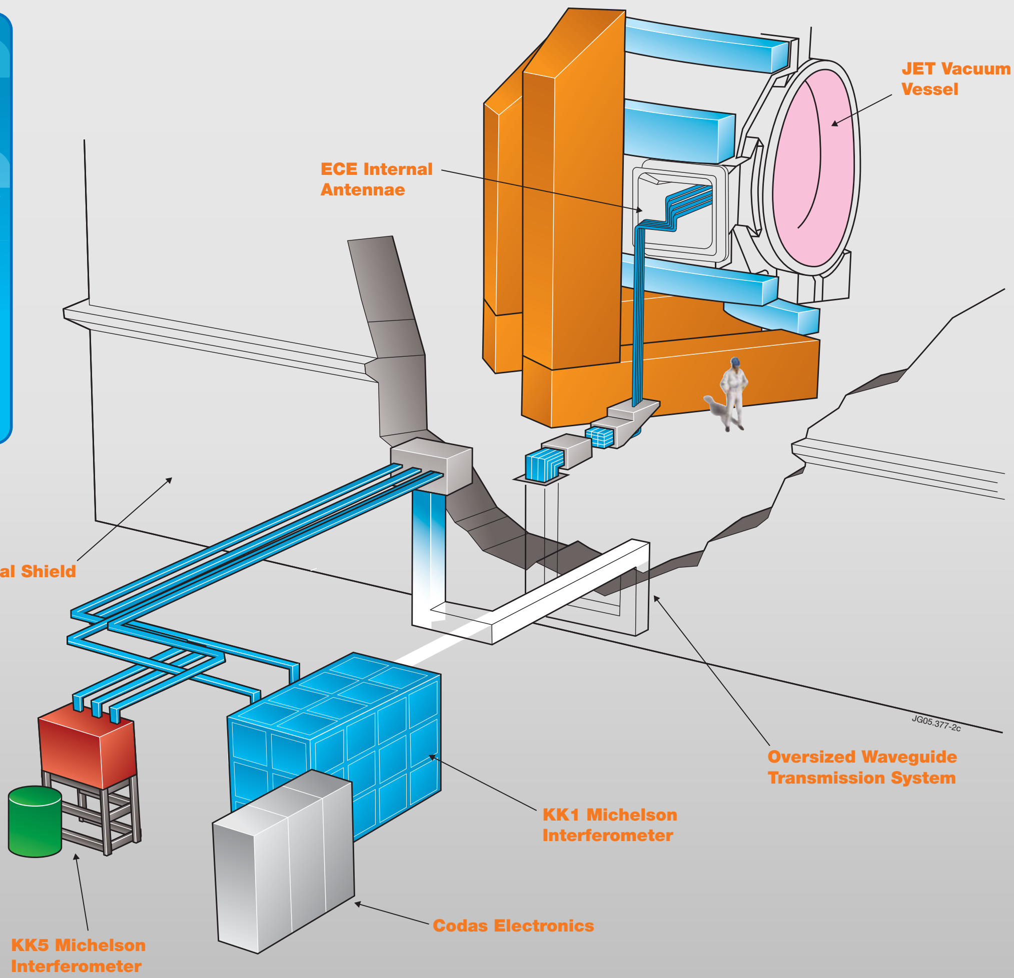
Principle

In a tokamak plasma, the electrons orbit or gyrate around the lines of the confining magnetic field and as a consequence emit radiation - "Electron Cyclotron Emission (ECE)". Under certain conditions the intensity of this radiation can be used to determine the electron temperature.

The ECE occurs at the frequency of gyration and its low harmonics. As these frequencies are determined by the local value of the magnetic field, which is precisely known in a tokamak, the emission at a particular frequency can be related to a specific position in the plasma. Thus by measuring the intensity of radiation at different frequencies, the electron temperature can be determined at various positions in the plasma.



The radiation from the electron cyclotron emission is collected by an array of five antennas mounted in the vacuum vessel.
The collected radiation is transmitted to the Diagnostic Hall where it is analysed using various instruments.



PARAMETERS SUMMARY

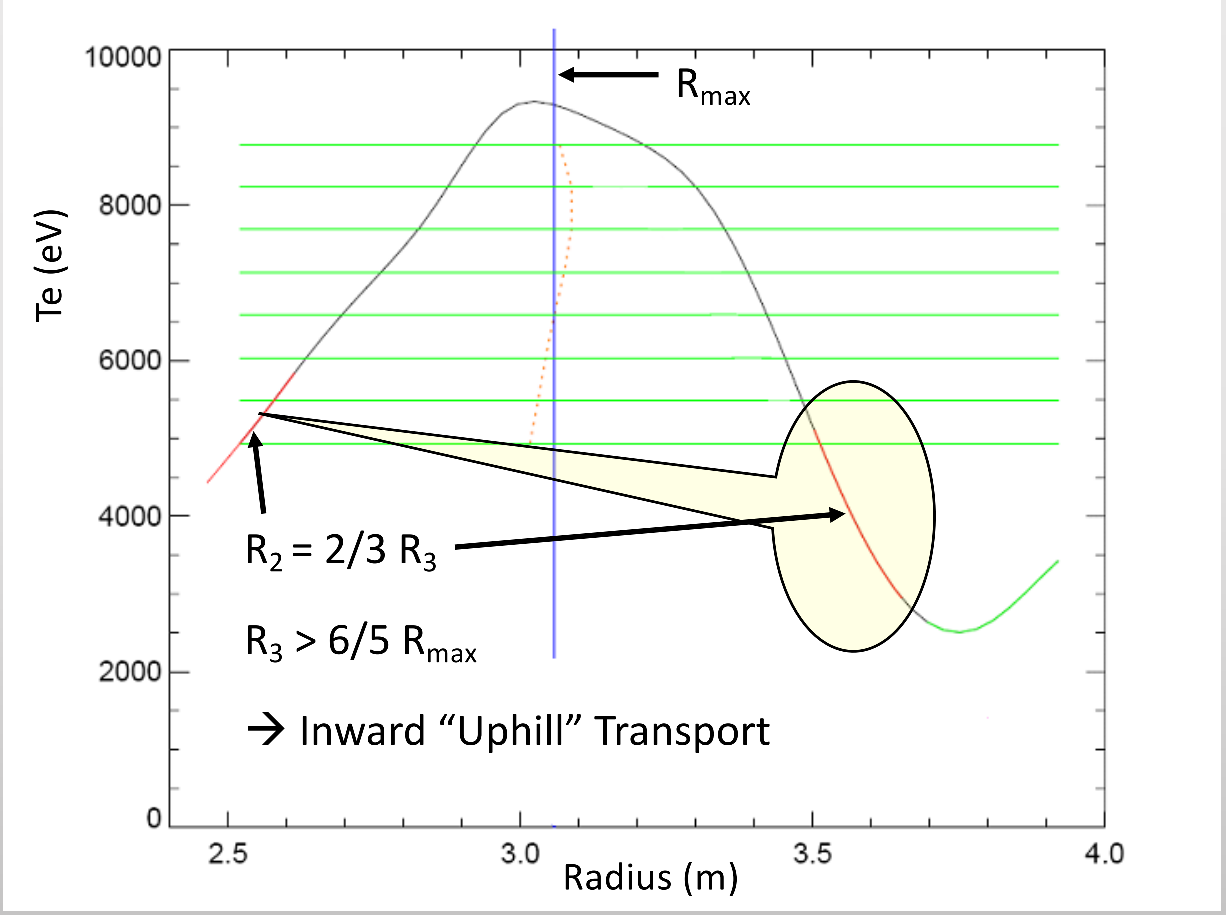
	KK1	M1 - FTU	KK5
Time resolution	17 ms	5 ms	10 to 5 ms
Maximum path difference	2.5 cm	4 cm	5 cm
Scanning speed	1.8 m/s	8 m/s	10 m/s
Spectral range (Ghz)	80- 500	100- 800	100- 800
Spectral resolution (GHz)	12	7.5	6
Radial space resolution(*)	20 cm	2.5 cm	10 cm
Electrical bandwidth (approx.)	1 - 5 KHz	3 - 30 KHz	3 - 30 KHz

(*) depending on the magnetic field configuration and value; 3T for Jet.

ITER DIAGNOSTIC

With an appropriate design of modulator size, shape and mechanics, the rotating mirror FTS's can provide broadband absolutely calibrated ECE measurements, with 1 ms time resolution and spectral performances suitable for measuring electron temperature profiles with less than 5 centimeter space resolution. These characteristics, together with exceptionally high reliability and time stability make this type of instrument the best candidate for ECE measurements in the next step large size fusion experiments. Thus we are planning to provide in the near future a detailed proposal and design of a FTS for ITER.

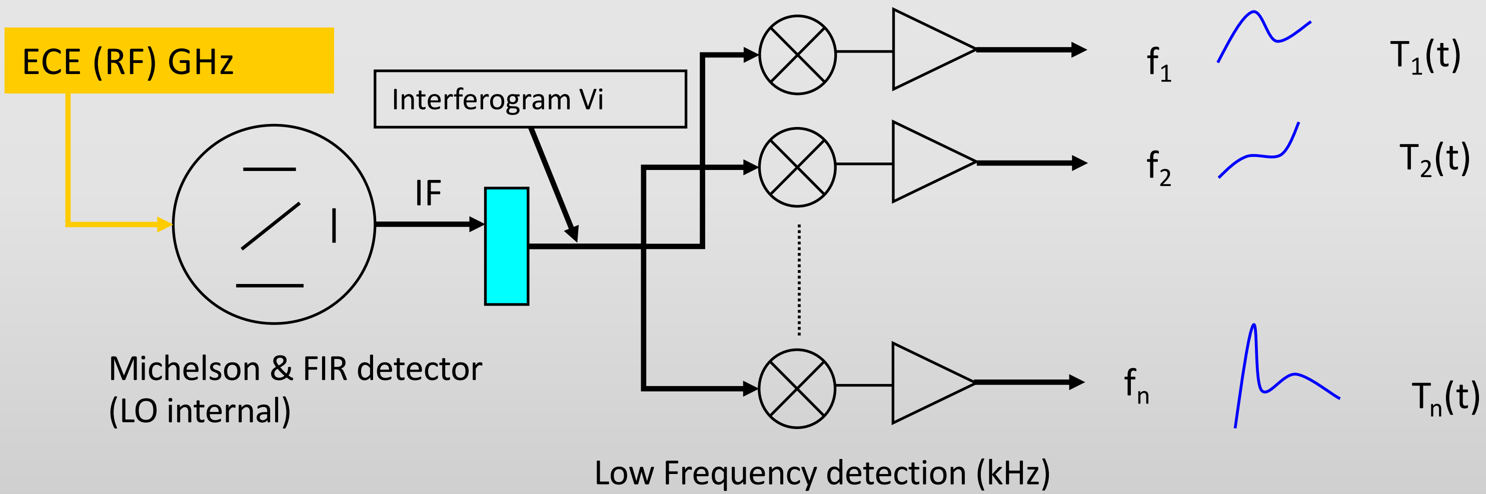
Energy Flow between Harmonics



For high Te (>5 KeV) and high density, good ECE absorption coefficient and favourable transport conditions can enhance the inter-harmonic inward transport effect.

A SuperHeterodyne Interferometer

If V_{scan} is ***constant***, the low (or ***electric***) frequency components of the Michelson AM output (interferogram) can be Heterodyne analysed. Or, given the low frequency (kHz), using a high-Q filter to extract the amplitude of the desired component. This multistage, hybrid receiver is a Superheterodyne Interferometer.

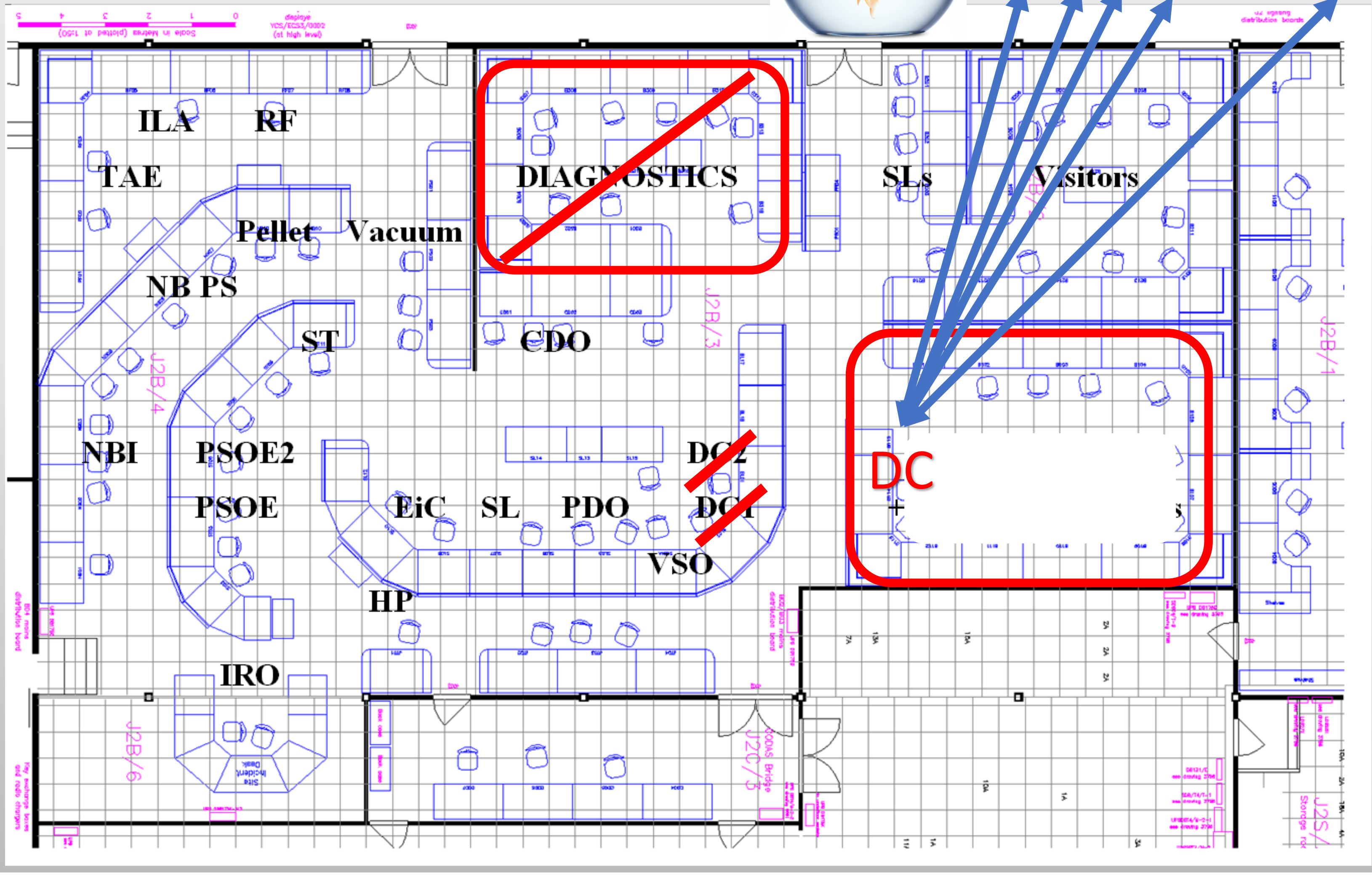


This method offers better time resolution of the traditional Fourier Transform analysis: a few wave cycles are sufficient to "clip" the ECE emission amplitude.

Control room layout (from DT reharsal 25/8/2020)

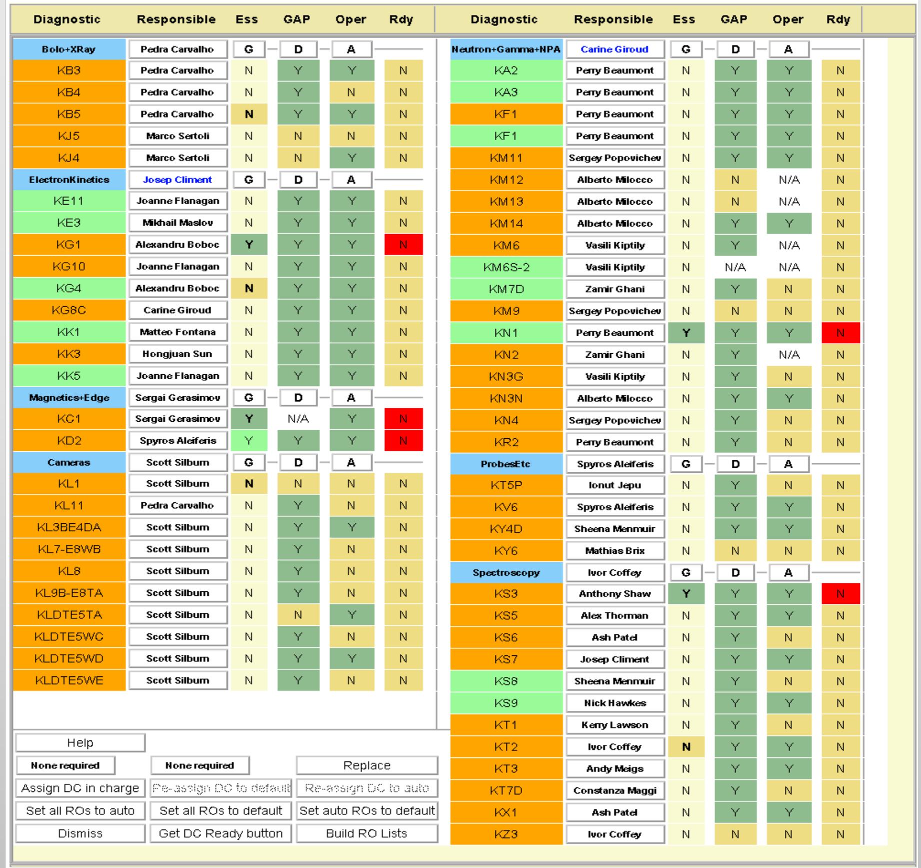
What we have?

Diagnosticians & SC



AC/DC (from DT reharsal 25/8/2020)

AC/DC allows monitoring the status of all diagnostics. They are categorized in groups, following the Diagnostic Request System (DRS).



Diagnostic	Responsible	Ess	GAP	Oper	Rdy
Bolo+XRay	Pedra Carvalho	G	D	A	
KB3	Pedra Carvalho	N	Y	Y	N
KB4	Pedra Carvalho	N	Y	N	N
KB5	Pedra Carvalho	N	Y	Y	N
KJ5	Marco Sertoli	N	N	N	N
KJ4	Marco Sertoli	N	N	Y	N
ElectronKinetics	Josep Climent	G	D	A	
KE11	Joanne Flanagan	N	Y	Y	N
KE3	Mikhail Maslov	N	Y	Y	N
KG1	Alexandru Boboc	Y	Y	Y	N
KG10	Joanne Flanagan	N	Y	Y	N
KG4	Alexandru Boboc	N	Y	Y	N
KG8C	Carine Giroud	N	Y	Y	N
KK1	Matteo Fontana	N	Y	Y	N
KK3	Hongjuan Sun	N	Y	Y	N
KK5	Joanne Flanagan	N	Y	Y	N
Magnetics+Edge	Sergai Gerasimov	G	D	A	
KC1	Sergai Gerasimov	Y	N/A	Y	N
KD2	Spyros Aleiferis	Y	Y	Y	N
Cameras	Scott Silburn	G	D	A	
KL1	Scott Silburn	N	N	N	N
KL11	Pedra Carvalho	N	Y	N	N
KL3BE4DA	Scott Silburn	N	Y	Y	N
KL7-E8WB	Scott Silburn	N	Y	N	N
KL8	Scott Silburn	N	Y	N	N
KL9B-E8TA	Scott Silburn	N	Y	N	N
KLDTE5TA	Scott Silburn	N	N	Y	N
KLDTE5WC	Scott Silburn	N	Y	N	N
KLDTE5WD	Scott Silburn	N	Y	Y	N
KLDTE5WE	Scott Silburn	N	Y	N	N

Diagnostic	Responsible	Ess	GAP	Oper	Rdy
Neutron+Gamma+NPA	Carine Giroud	G	D	A	
KA2	Perry Beaumont	N	Y	Y	N
KA3	Perry Beaumont	N	Y	Y	N
KF1	Perry Beaumont	N	Y	Y	N
KF1	Perry Beaumont	N	Y	Y	N
KM11	Sergey Popovichev	N	Y	Y	N
KM12	Alberto Milocco	N	N	N/A	N
KM13	Alberto Milocco	N	N	N/A	N
KM14	Alberto Milocco	N	Y	Y	N
KM6	Vasili Kiptily	N	Y	N/A	N
KM6S-2	Vasili Kiptily	N	N/A	N/A	N
KM7D	Zamir Ghani	N	Y	N	N
KM9	Sergey Popovichev	N	N	N	N
KN1	Perry Beaumont	Y	Y	Y	N
KN2	Zamir Ghani	N	Y	N/A	N
KN3G	Vasili Kiptily	N	Y	N	N
KN3N	Alberto Milocco	N	Y	Y	N
KN4	Sergey Popovichev	N	Y	N	N
KR2	Perry Beaumont	N	Y	N	N
ProbesEtc	Spyros Aleiferis	G	D	A	
KT5P	Ionut Jepu	N	Y	N	N
KV6	Spyros Aleiferis	N	Y	Y	N
KY4D	Sheena Menmuir	N	Y	Y	N
KY6	Mathias Brix	N	N	N	N
Spectroscopy	Ivor Coffey	G	D	A	
KS3	Anthony Shaw	Y	Y	Y	N
KS5	Alex Thorman	N	Y	Y	N
KS6	Ash Patel	N	Y	N	N
KS7	Josep Climent	N	Y	Y	N
KS8	Sheena Menmuir	N	Y	N	N
KS9	Nick Hawkes	N	Y	Y	N
KT1	Kerry Lawson	N	Y	N	N
KT2	Ivor Coffey	N	Y	Y	N
KT3	Andy Meigs	N	Y	Y	N
KT7D	Constanza Maggi	N	Y	N	N
KX1	Ash Patel	N	Y	Y	N
KZ3	Ivor Coffey	N	N	N	N

Hovering the mouse above buttons will provide clear statement of the status of each.

Manuale DCO: *a disposizione per chi lo desidera*

- **A pratical DCO Manual**
  - *M. Zerbini - ENEA Frascati*

1 Avant-propos

- This document has been created to summarize sundry important information about DCO duties and functions, reflecting my views, impression and direct experience.
- The document is being continuously modified during sessions, adding, removing or changing information based on occurring events. It is not an official manual and does not replace the official reference documents. The official source for the information are the the DCO WIKI page, and related (which are not always kept up to date):

ECE Real-Time project (Zerbini, Cappelli)

- Ripreso dal vecchio progetto “legacy” del 2002

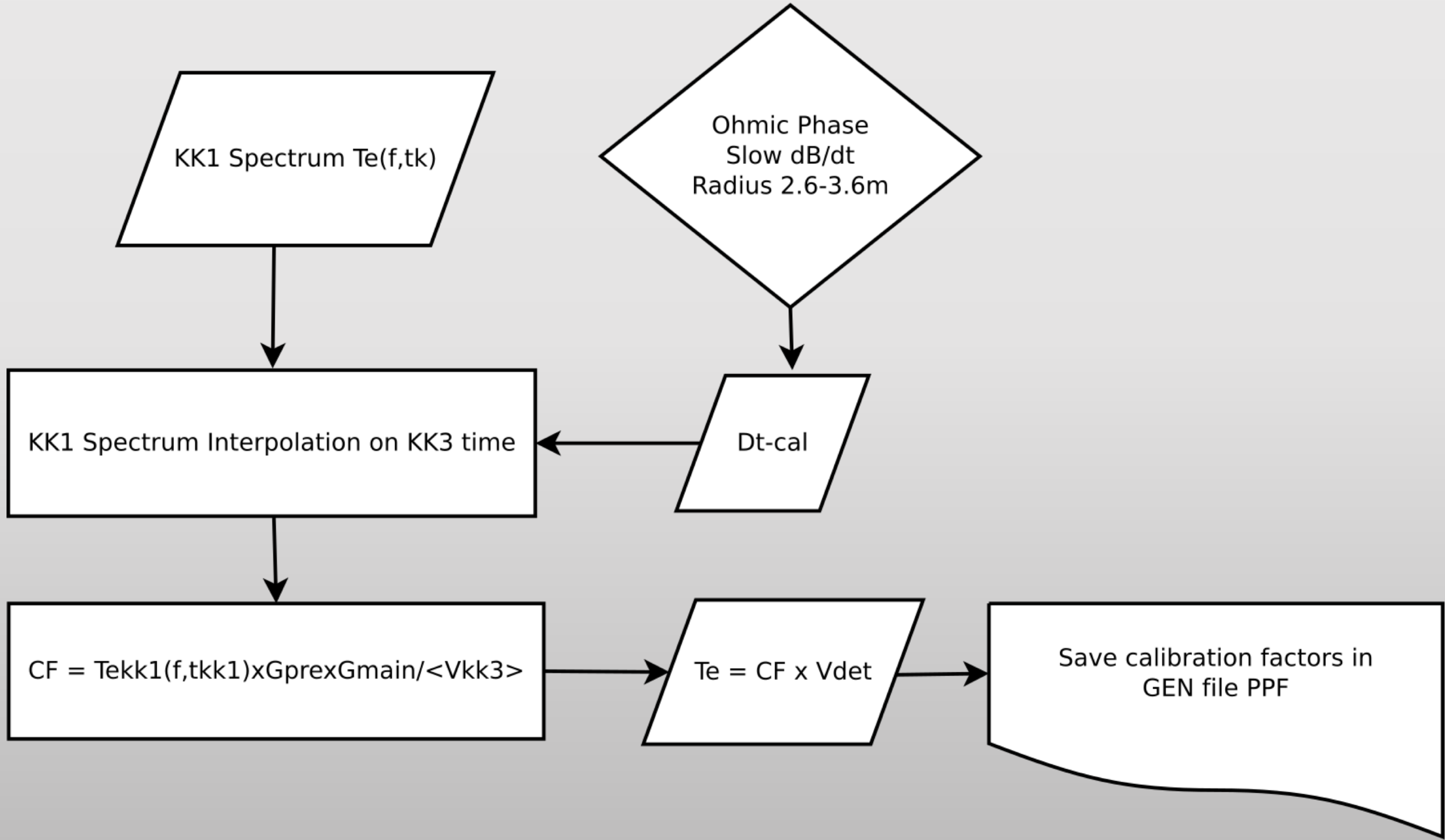
- Calibrare e validare l’ECE KK3 (heterodyne) in “real-time”, per interventi di protezione macchina sul plasma, e feedback sui regimi

- Report Eurofusion cleared. Disponibile (43 pagine!)

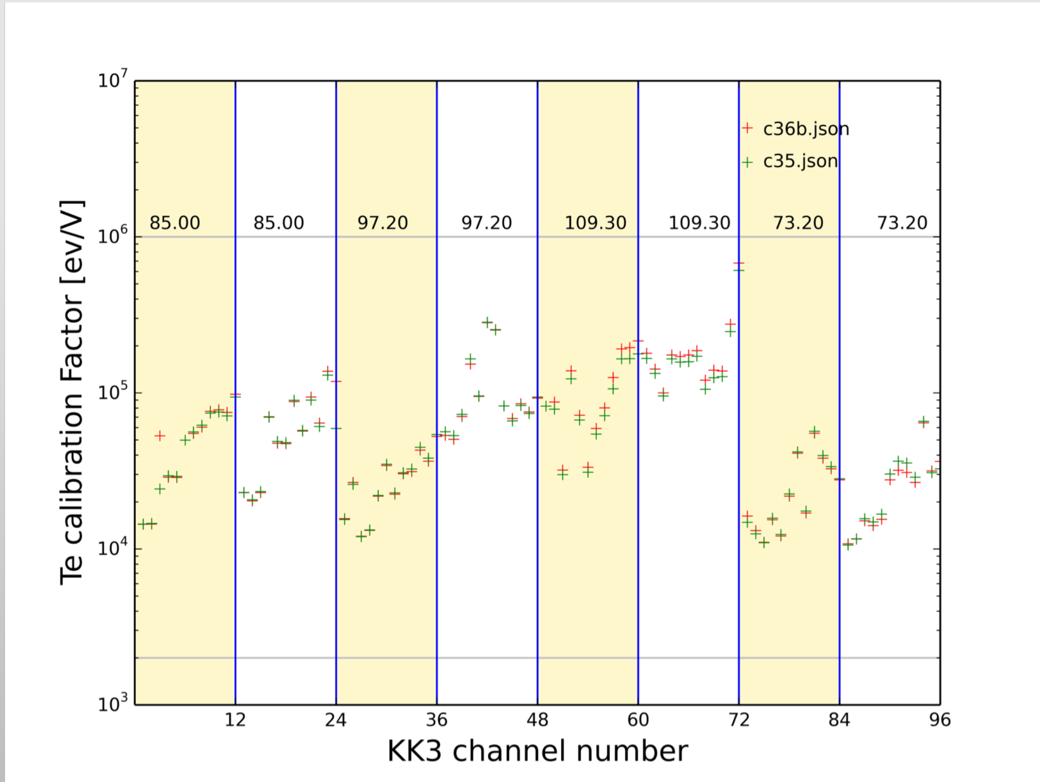
(e’ un sommario completo delle diagnostiche ECE e correlate, i principii, i numeri e l’implementazione sul JET)

The new JET KK3 Real Time Project: Table of Contents

ECE Real-Time workflow

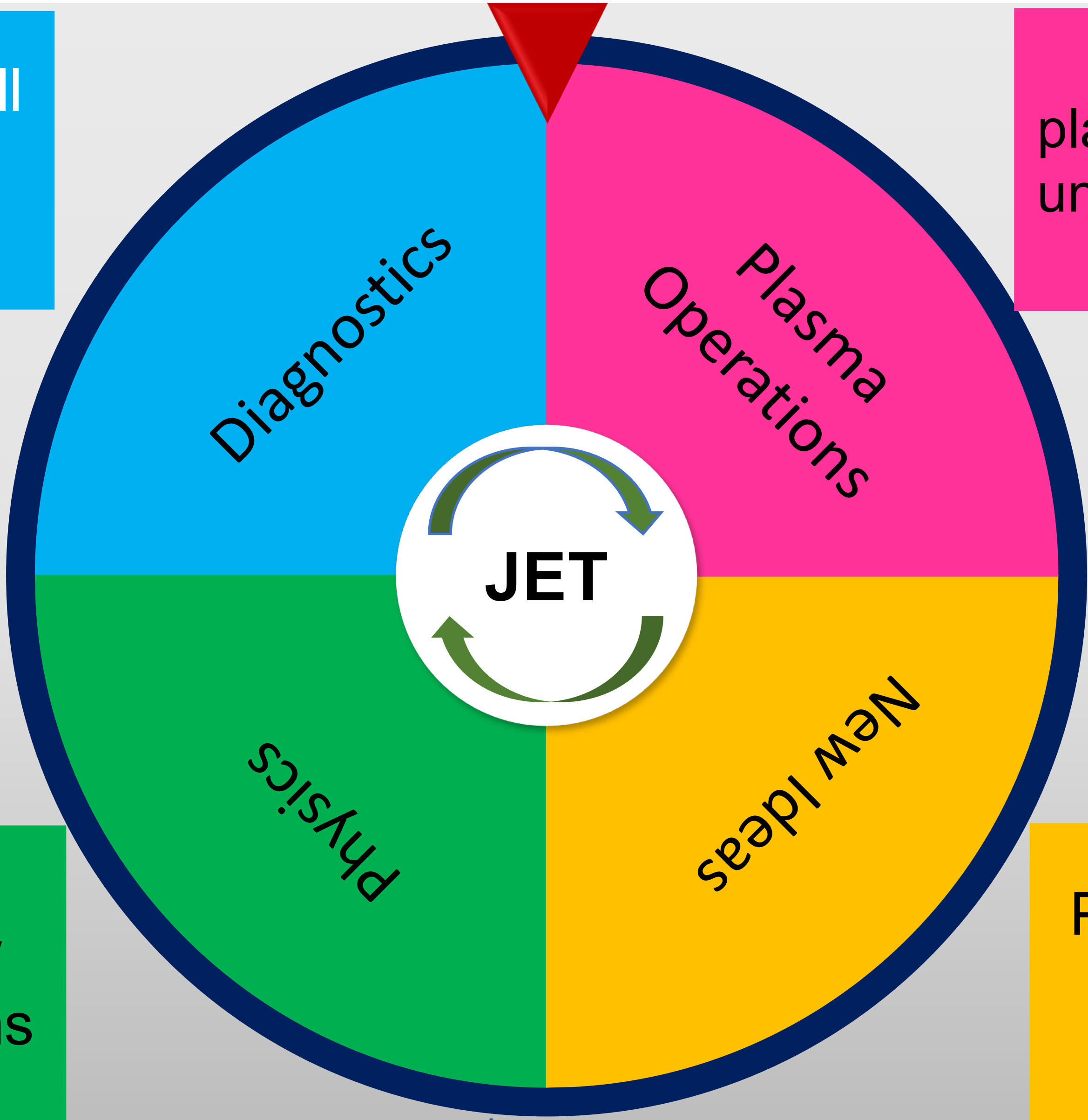


Calibration factors JET campaign C35 (89013-89472) and C36 (92200-92500) by kk3gen.py.
8 IF sub-bands A1-A2-B1-B2... etc. made of 12 channels each, are marked by the vertical bands.
The corresponding value of LO frequency in GHz is indicated for each one of them.
Statistically set "safe" range $2 \times 10^3 < CF < 1 \times 10^6$
calibration factors from the two sets of pulses (green and red symbols) are remarkably overlapping.
Within each IF band a local (mainly upward) trend in CF vs. frequency (i.e. channel number)



Not new, but well built and managed

2 shifts and pre-planning good, more understandable than DIII-D



Focus on a few specific programs

Planning method different than DIII-D

qualche opinione personale, per concludere

Nell'insieme il JET ha dimostrato di reggere lo shock post-Euratom del 1999, soprattutto grazie all'ottimo supporto logistico ed ingegneristico pre-esistente

La struttura attuale, ri-modificata di recente, funziona, ma e' inevitabilmente burocratizzata, e rallentata dalla presenza di molti "attori"

Assoluta necessita' di utilizzare il JET per il training (*dal vero!*) di nuovi e meno-nuovi arrivati su macchine di larga scala

Real time: linea da sviluppare e valorizzare