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Instrumentation for ITER CXRS

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ADAS Workshop
Schloss Ringberg
Okctober 12007

1) Physics Issues versus Measurement Requirement Table and Budget

2) ITER partners

3) Sharing of physics tasks

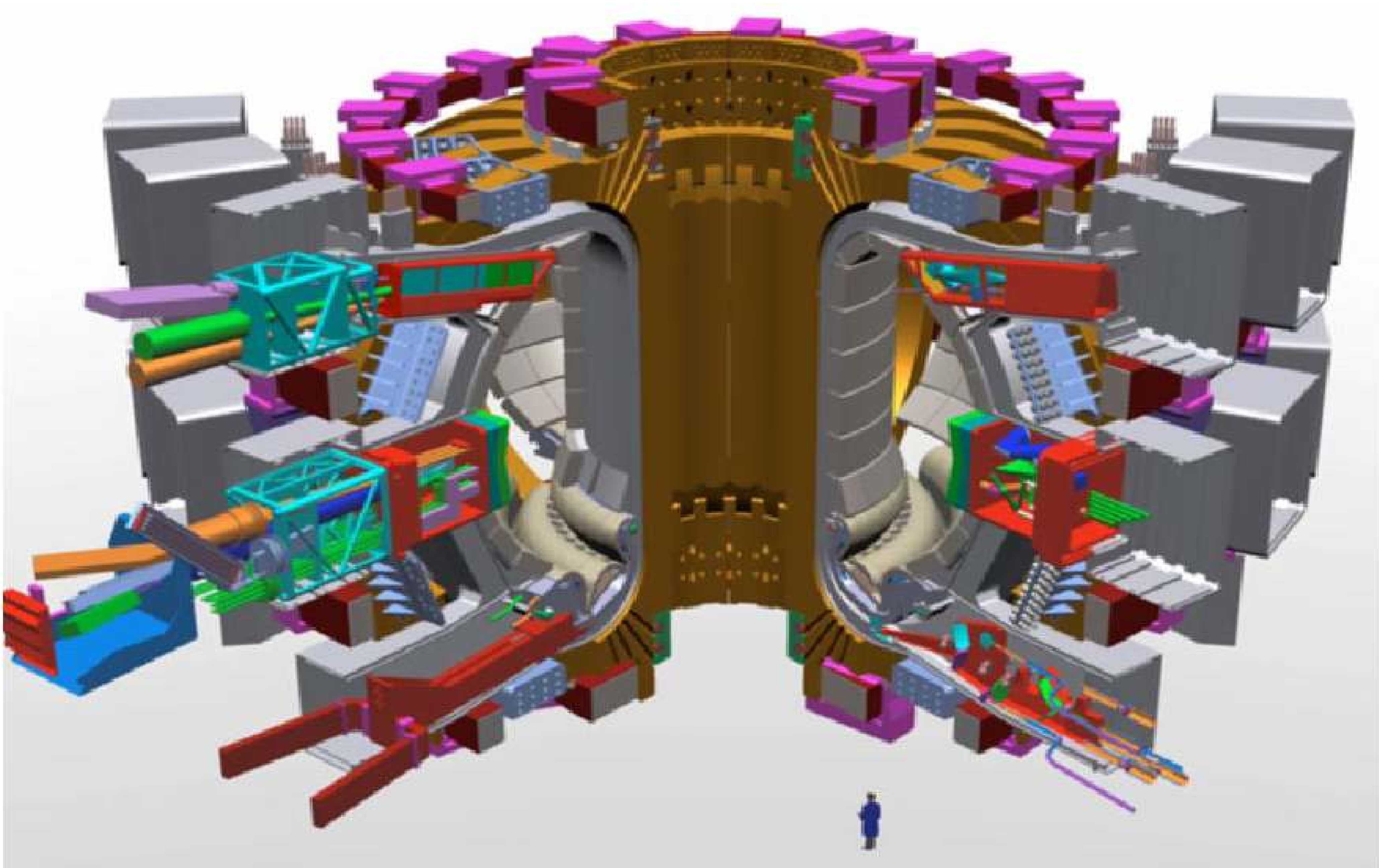
4) Sharing of Supporting Software

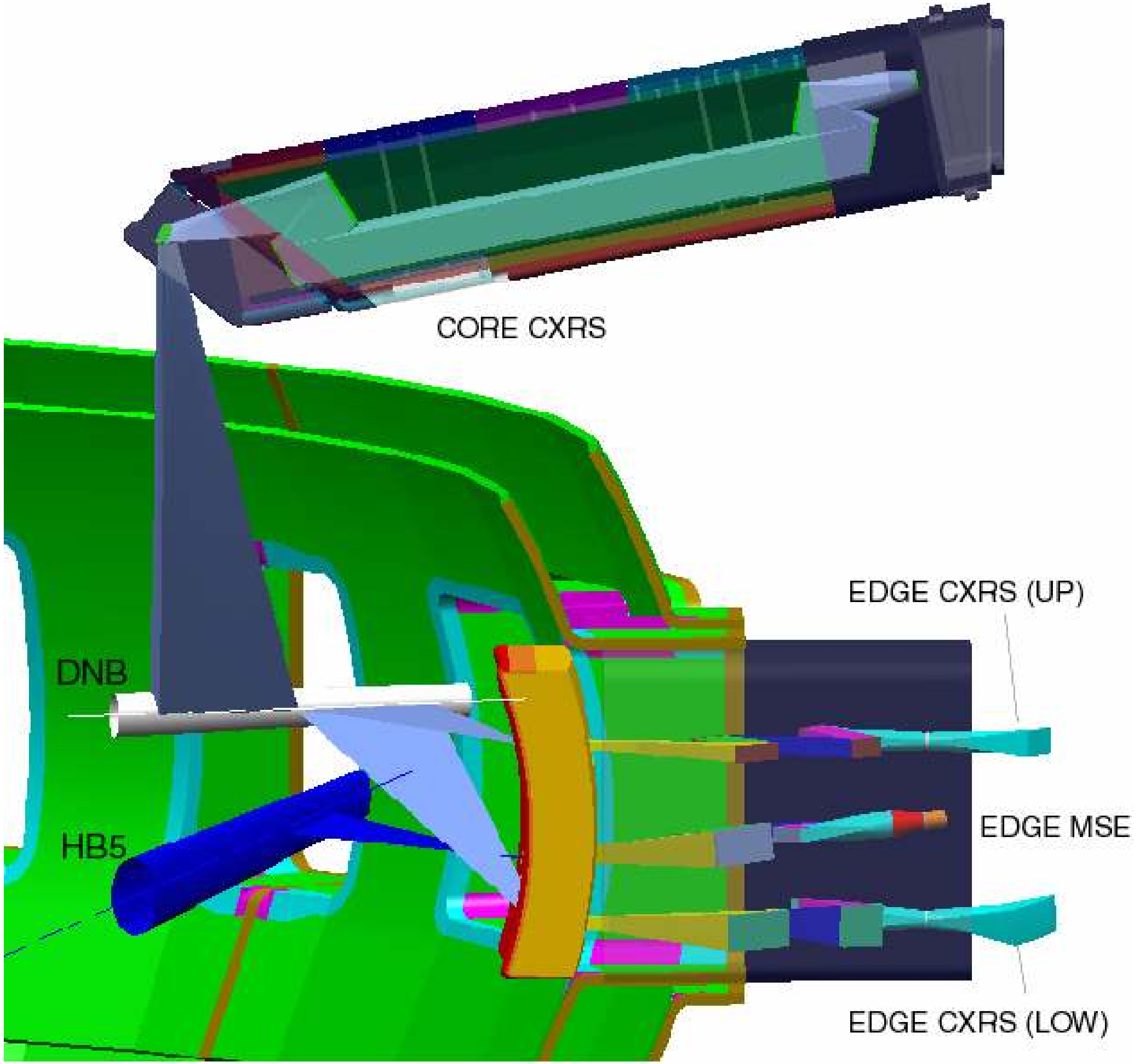
a) Simulation

b) Spectral Analysis ("CXSFIT")

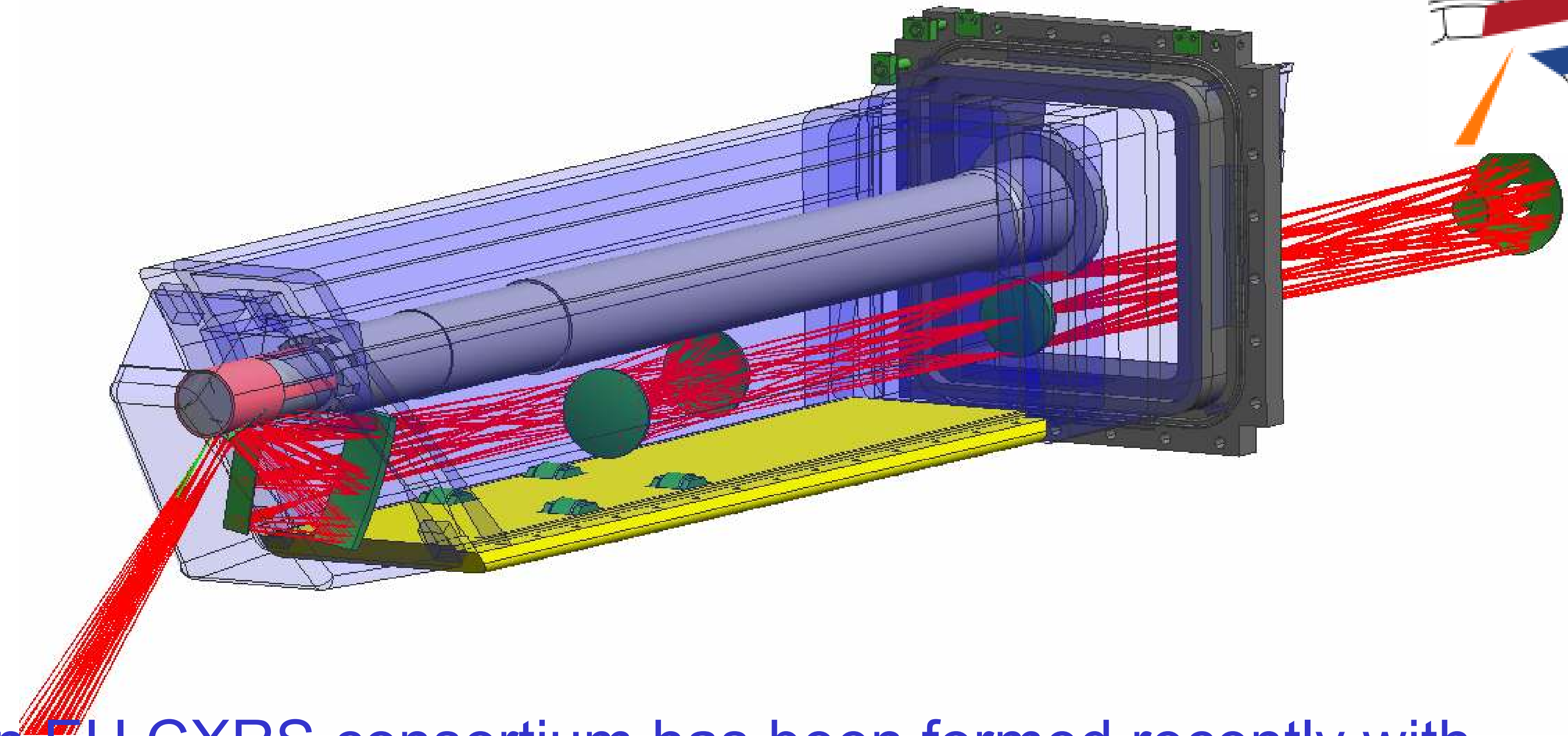
c) Data Evaluation ("CHEAP")

5) Optimisation of Instruments




CORE CXRS
EDGE CXRS (UP)
DNB
EDGE MSE
HB5
EDGE CXRS (LOW)

CXRS periscope , TNO Delft



An EU CXRS consortium has been formed recently with substantial commitments to CXRS port plug and instrumental developments

Project managers : W.Biel, FZ-Juelich, R.Jaspers, FOM

Consulting partners ,IPP Garching, UKAEA Culham, CEA Cadarache, ENEA Padua

raw data

wavelength calibration

identification of spectral features

absolute calibration

extraction of intensity width and position

localisation + magnetic mapping

local donor density

local impurity density

consistency checks

Spectral Prediction Code "CX-simulation"

Spectral analysis Code "CXSFIT"

CHarge Exchange Analysis Package

"CHEAP"

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Fusion Device

Impurity description

Target Plasma

Neutral Beam

Instrumentation

→

Prediction of active and passive
Spectral Features
Signal-To-Noise
Parameter retrieval

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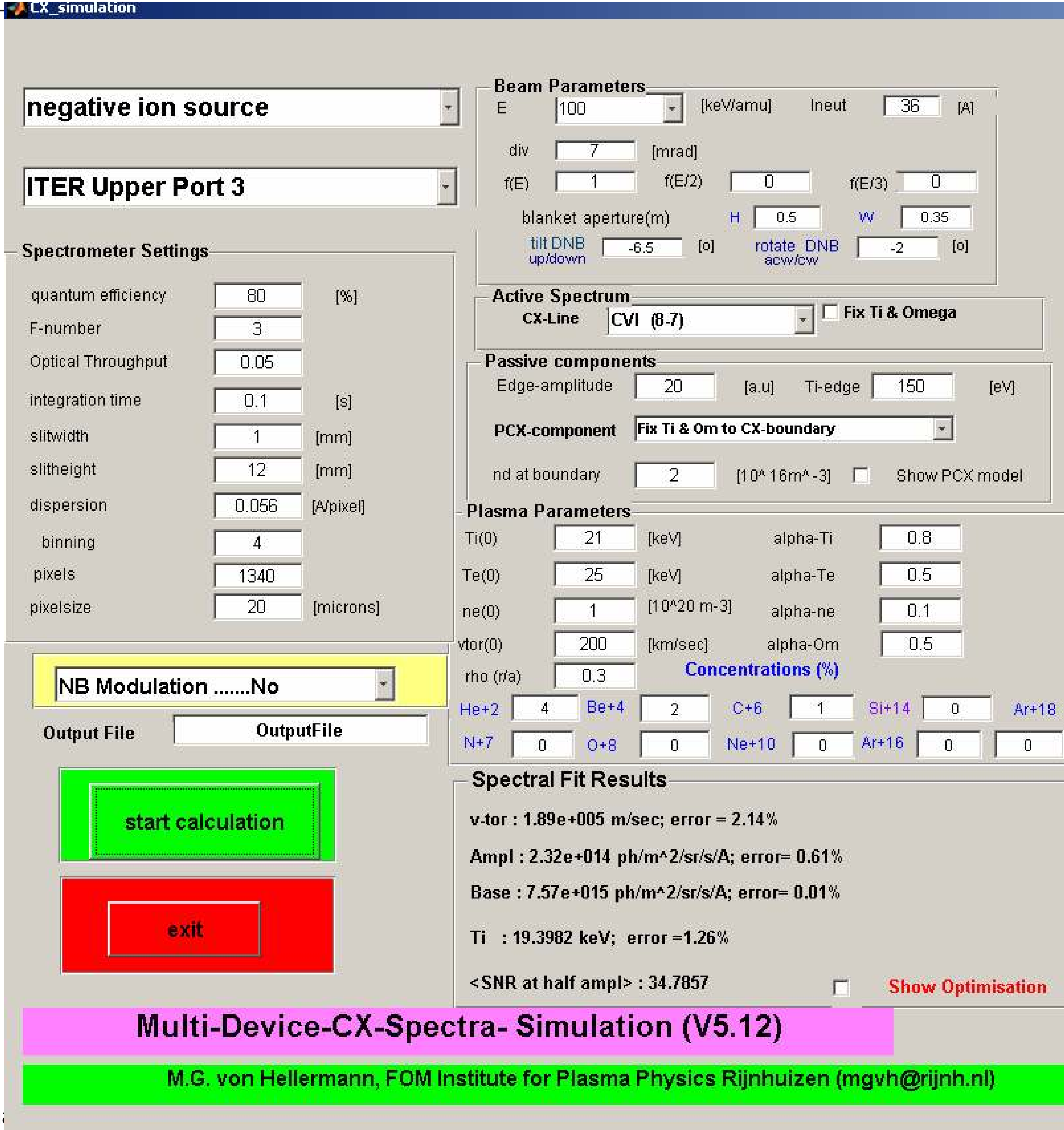
MATLAB simulation package includes presently:

1) ITER
2) JET
3) TEXTOR
4) ASDEX
5) Tore Supra
6) W7-X
7) HL-2A
8) HT-7
9) EAST
10) SST
11) RFXP


CX_simulation
negative ion source
ITER Upper Port 3
Spectrometer Settings
quantum efficiency 80 [%]
F-number 3
Optical Throughput 0.05
integration time 0.1 [s]
slitwidth 1 [mm]
slitheight 12 [mm]
dispersion 0.056 [A/pixel]
binning 4
pixels 1340
pixelsize 20 [microns]
NB Modulation ....No
Output File OutputFile
start calculation
exit
Beam Parameters
E 100 [keV/amu] Ineut 36 [A]
div 7 [mrad]
f(E) 1 f(E/2) 0 f(E/3) 0
blanket aperture(m) H 0.5 W 0.35
tilt DNB up/down -6.5 [o] rotate DNB acw/cw -2 [o]
Active Spectrum
CX-Line CVI (8-7) Fix Ti & Omega
Passive components
Edge-amplitude 20 [a.u] Ti-edge 150 [eV]
PCX-component Fix Ti & Om to CX-boundary
nd at boundary 2 [10^16m^-3] Show PCX model
Plasma Parameters
Ti(0) 21 [keV] alpha-Ti 0.8
Te(0) 25 [keV] alpha-Te 0.5
ne(0) 1 [10^20 m-3] alpha-ne 0.1
vtor(0) 200 [km/sec] alpha-Om 0.5
rho (r/a) 0.3
Concentrations (%)
He+2 4 Be+4 2 C+6 1 Si+14 0 Ar+18
N+7 0 O+8 0 Ne+10 0 Ar+16 0 0
Spectral Fit Results
v-tor : 1.89e+005 m/sec; error = 2.14%
Ampl : 2.32e+014 ph/m^2/sr/s/A; error= 0.61%
Base : 7.57e+015 ph/m^2/sr/s/A; error= 0.01%
Ti : 19.3982 keV; error =1.26%
<SNR at half ampl> : 34.7857
Show Optimisation
Multi-Device-CX-Spectra- Simulation (V5.12)
M.G. von Hellermann, FOM Institute for Plasma Physics Rijnhuizen (mgvh@rijnh.nl)

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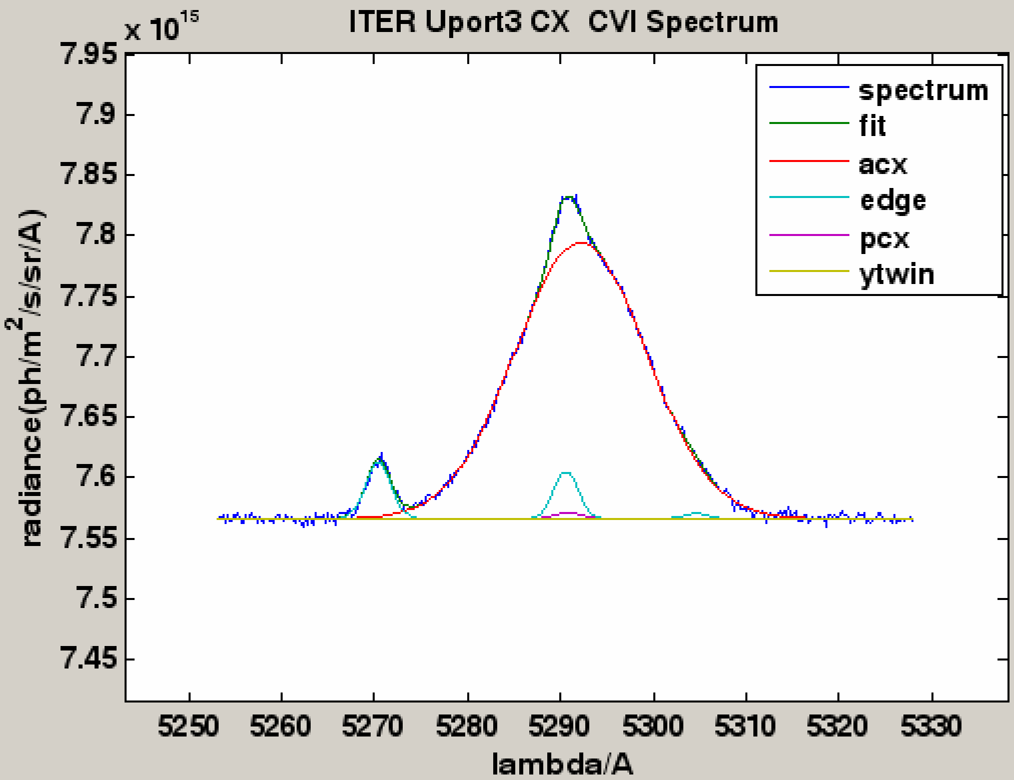
Calculated spectrum



☐ Show Raw Data

Description of components

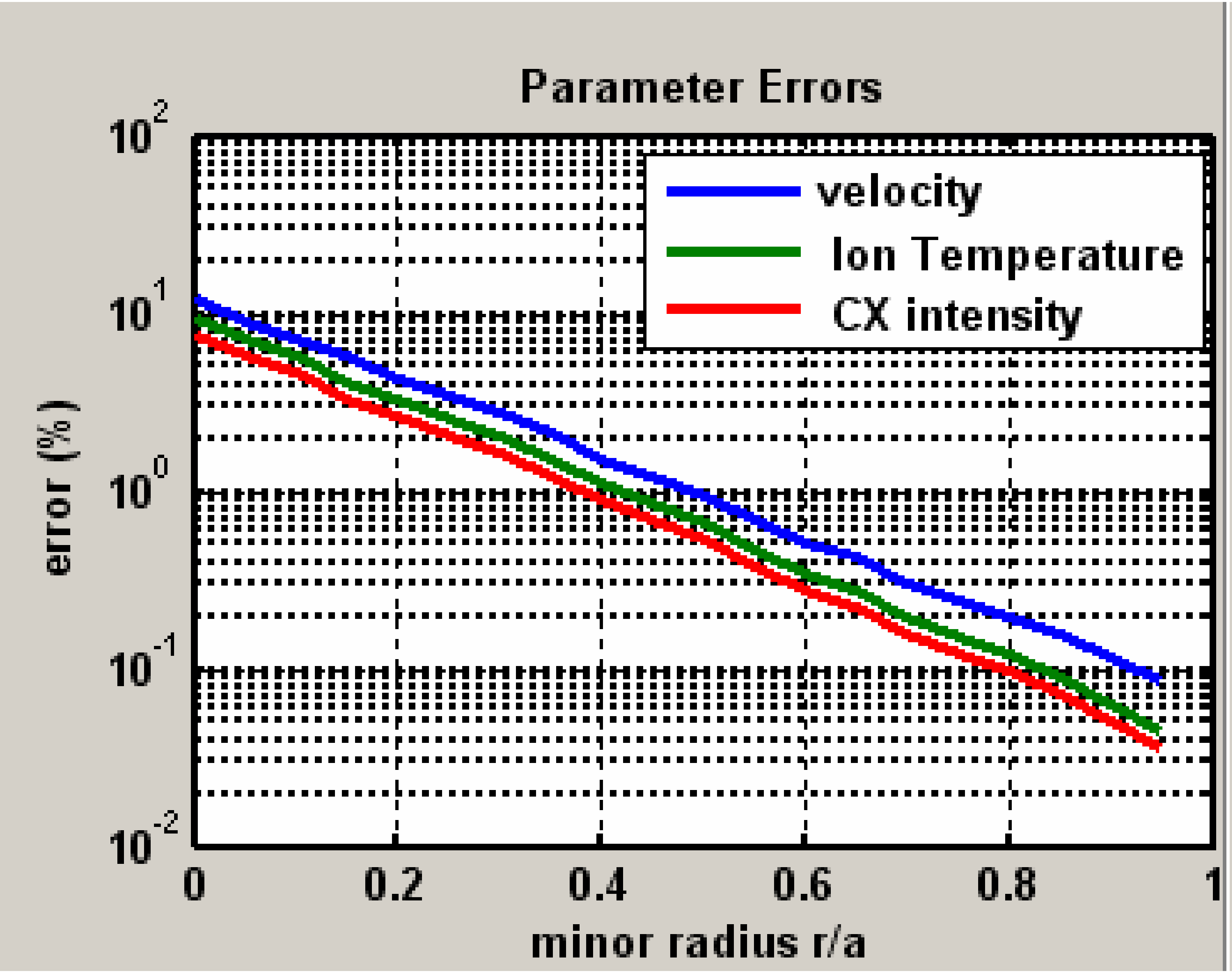
CVI-edge at 5290.59 CVI-CX at 5292.18

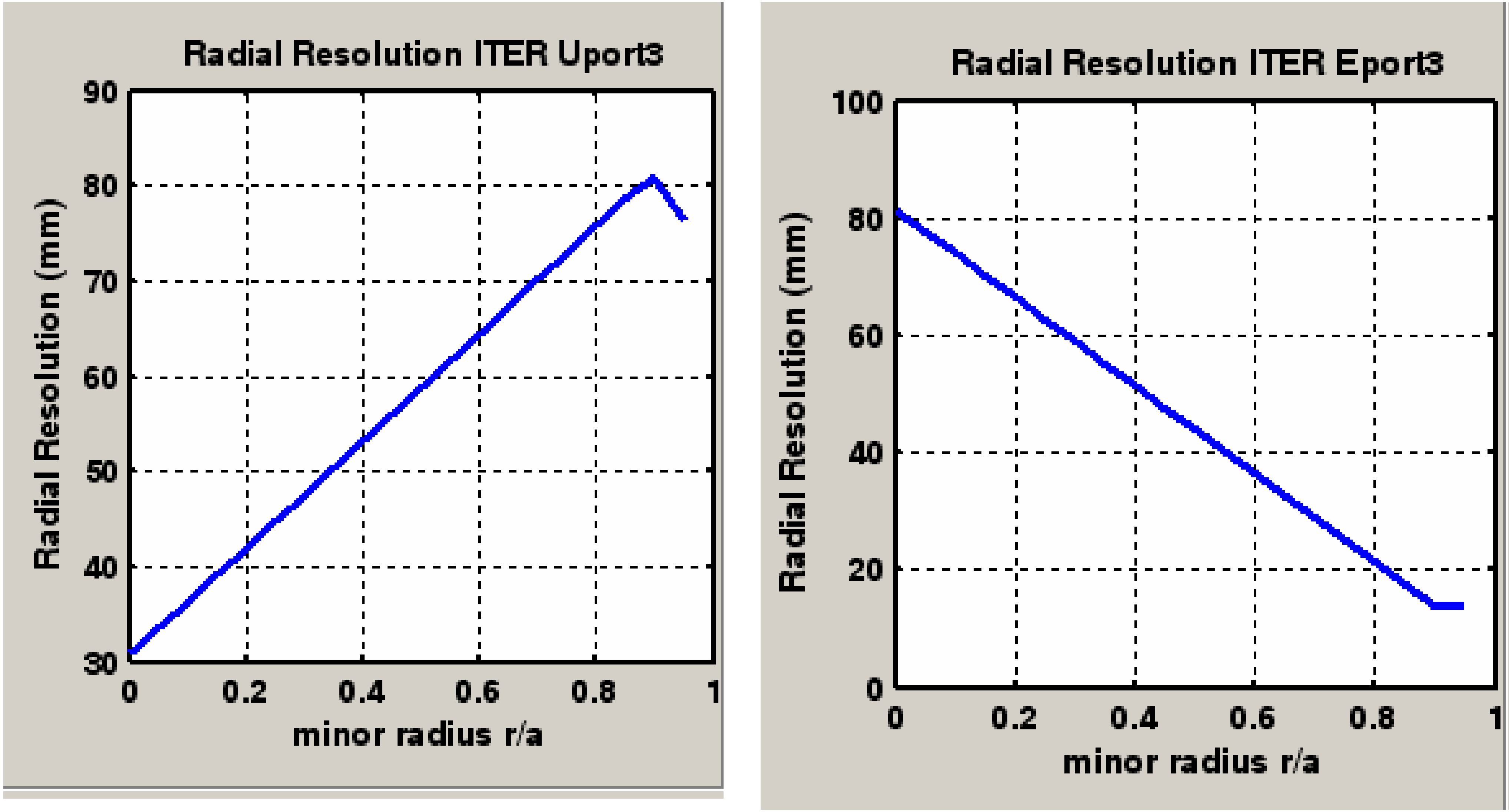
CVI-PCX at 5290.82 Ti-PCX: 0.92 keV

CIII:5304.62

BeII-edge: 5270.42

Error Analysis for CVI, U-port-2, τ=100ms




Radial Resolution ITER Uport3
Radial Resolution (mm)
90
80
70
60
50
40
30
0
0.2
0.4
0.6
0.8
1
minor radius r/a
Radial Resolution ITER Eport3
Radial Resolution (mm)
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
minor radius r/a

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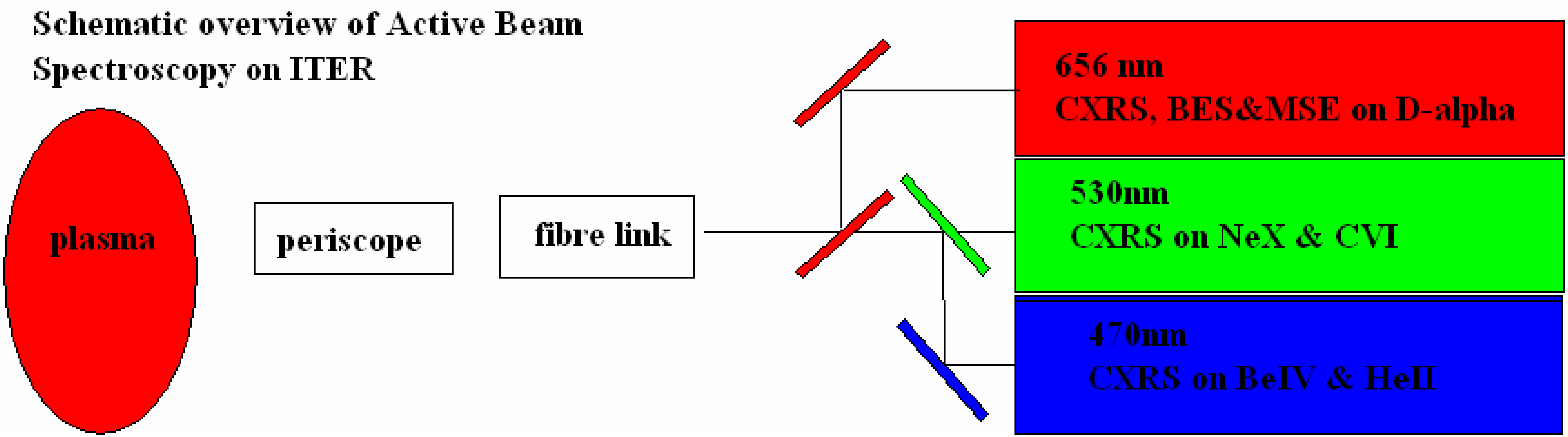
Parameter	*Range*	*Time Res*	*Space res*	*accuracy*
Vtor	5-200 km/s	10 ms	a/30	5km/s
Vpol	5-50 km/s	10 ms	a/30	5km/s
Ti, core (r/a<0.9)	0.5-40 keV	100 ms	a/10 (a/30)	10% (5%)
Ti, edge (r/a>0.9)	50eV-10 keV	100 ms	Tbd	10%
Core He density	1-10%	100 ms	a/10	10%

ITER CXRS measurement requirement table



Basic concept:
Multi-wavelength instrumentation for each radial chann

Special role of spectrometers for CXRS project

- Last optical element in the chain, outside the port plug, so a later construction/delivery or step-by-step implementation appears possible
- However probably by far the most expensive items, therefore quite relevant for the project plan
- Spectrometer specifications closely related to mirror labyrinth and fibres
- Feasibility of ITER core CXRS depends to a large extent on the development of a well-working spectrometer design

Spectrometer specifications:

Wavelength ranges which are to be monitored simultaneously

No.	Wavelength range λ / Å	Elements	Resolution / Å	Remark
1	4608 – 4736	He II, Be IV	2	Required
2	5189 – 5331	C VI, Ne X, Ar XVIII	1	Required
3	5629 – 5709	N VII	1	Optional
4	6028 – 6108	O VIII	1	Obsolete
5	6490 – 6630	BES band	1	Required India!

Note: „work horse“ type spectrometers inside ρ < 0.5;
more flexibility requested for ρ > 0.5

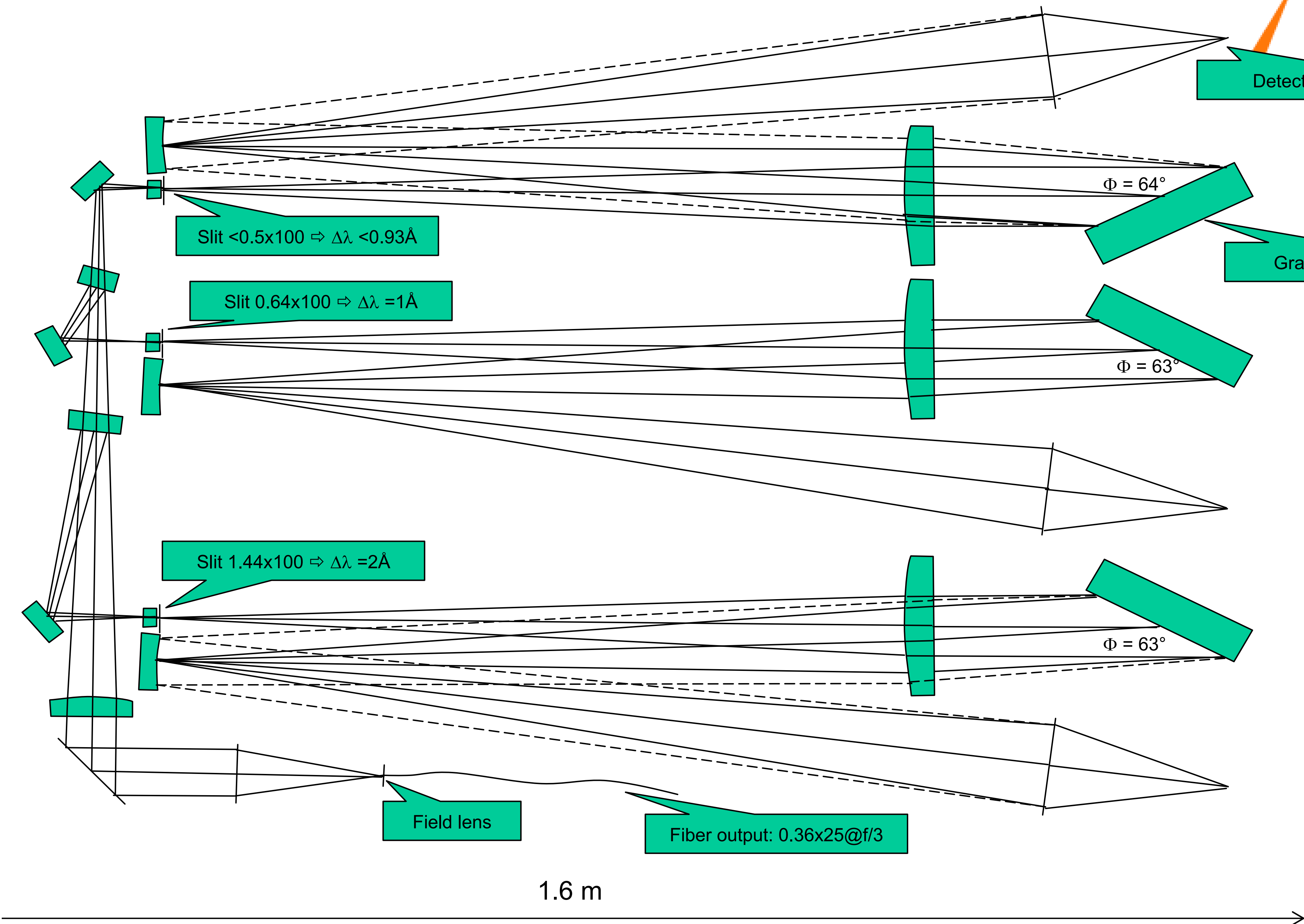
Spectrometer specifications (cont‘d):

- Spectrometer properties:
  - Etendue per spatial channel: 1 mm^2 sr
  - Transmission/efficiency: 0.6

- Fibre specifications:
  - Core diametre 0.2 mm
  - NA 0.22
  - Cladding/core ratio 1.1

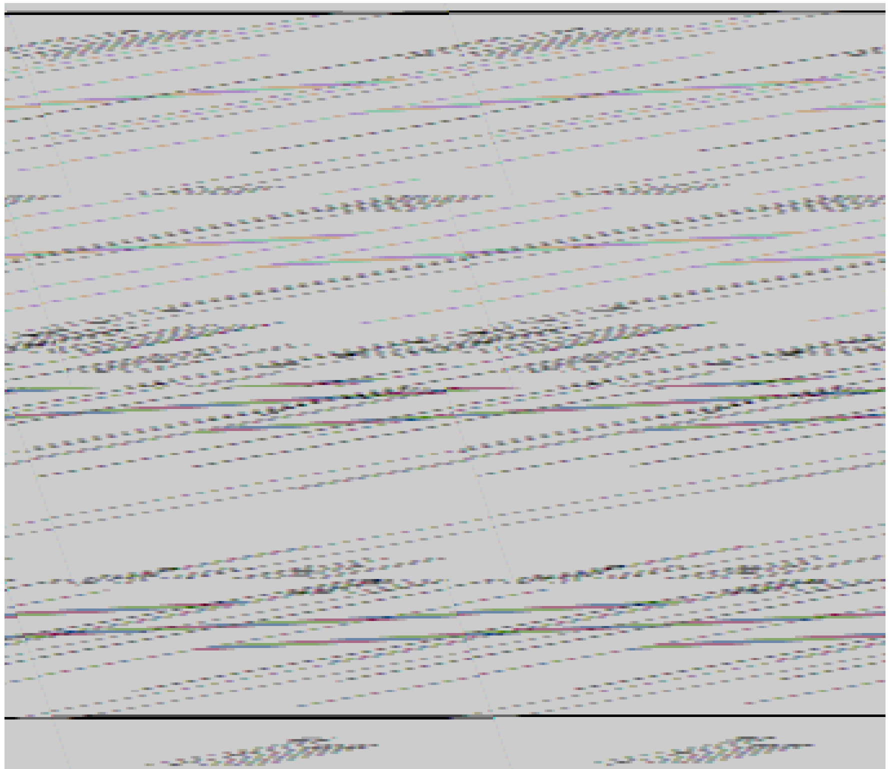
- Camera specifications:
  - Chip size suggested 26 mm x 6 mm
    (PI Acton PIXIS 400B)

Layout spectrometer (TNO) simultaneous 3-band detection

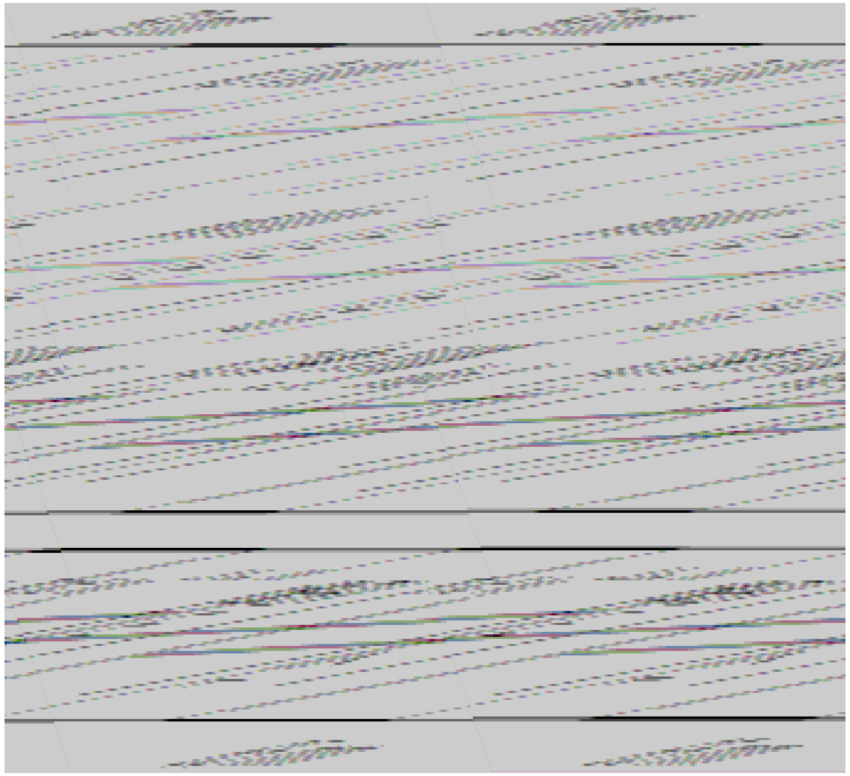


Echelle spectrometer with cross-disperser: arrangement of spectra on the detector

1:1 imaging ratio, option 1



1:1 imaging ratio, option 2



Problem: camera size (note the required time resolution of 100 frames/second)

Possible solution: Spectrometer with de-magnification ratio 1:2 or 1:3

Systematix spectrometer

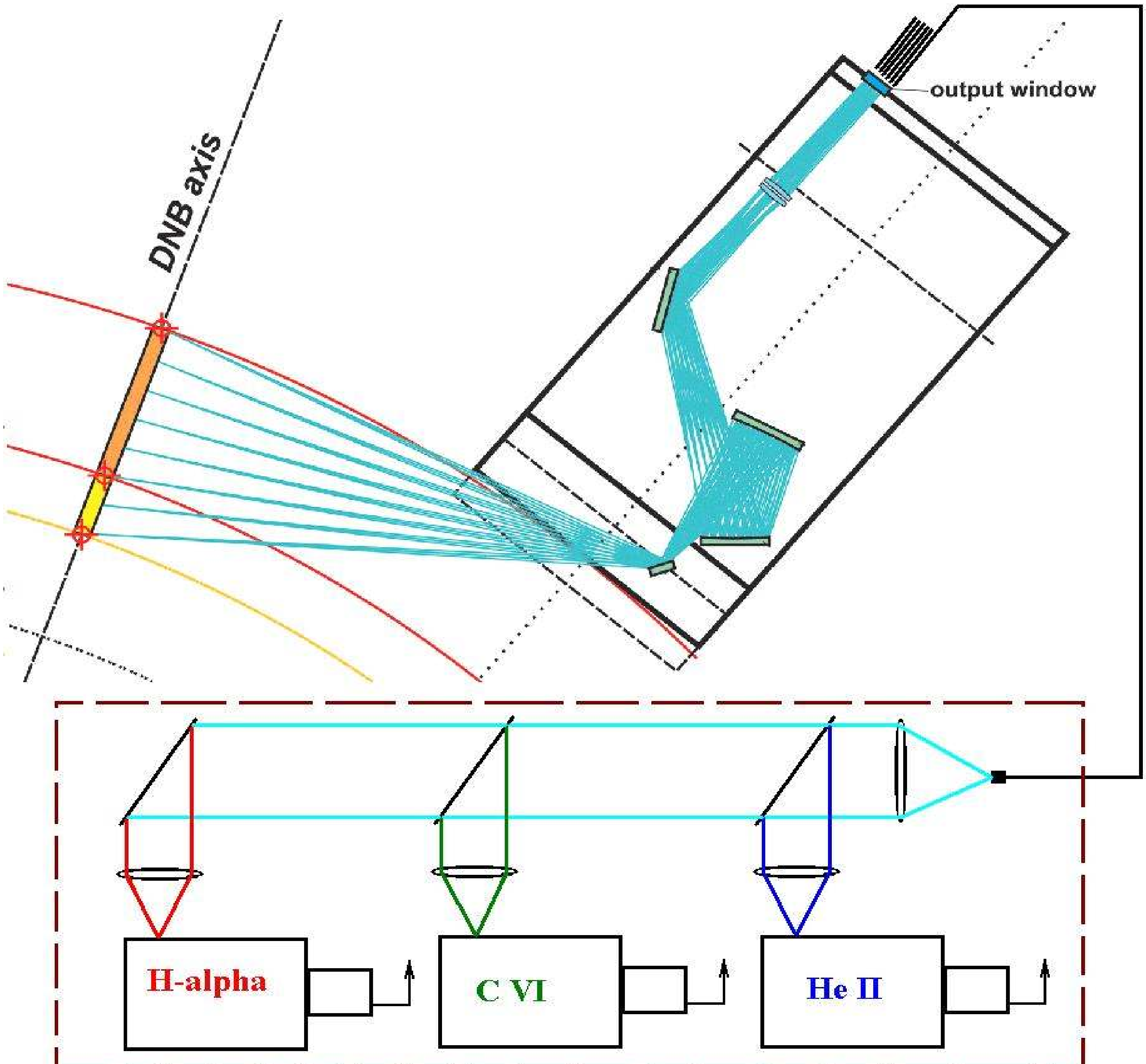
Special design Echelle spectrometer

(modified Pfund design)

with cross-disperser

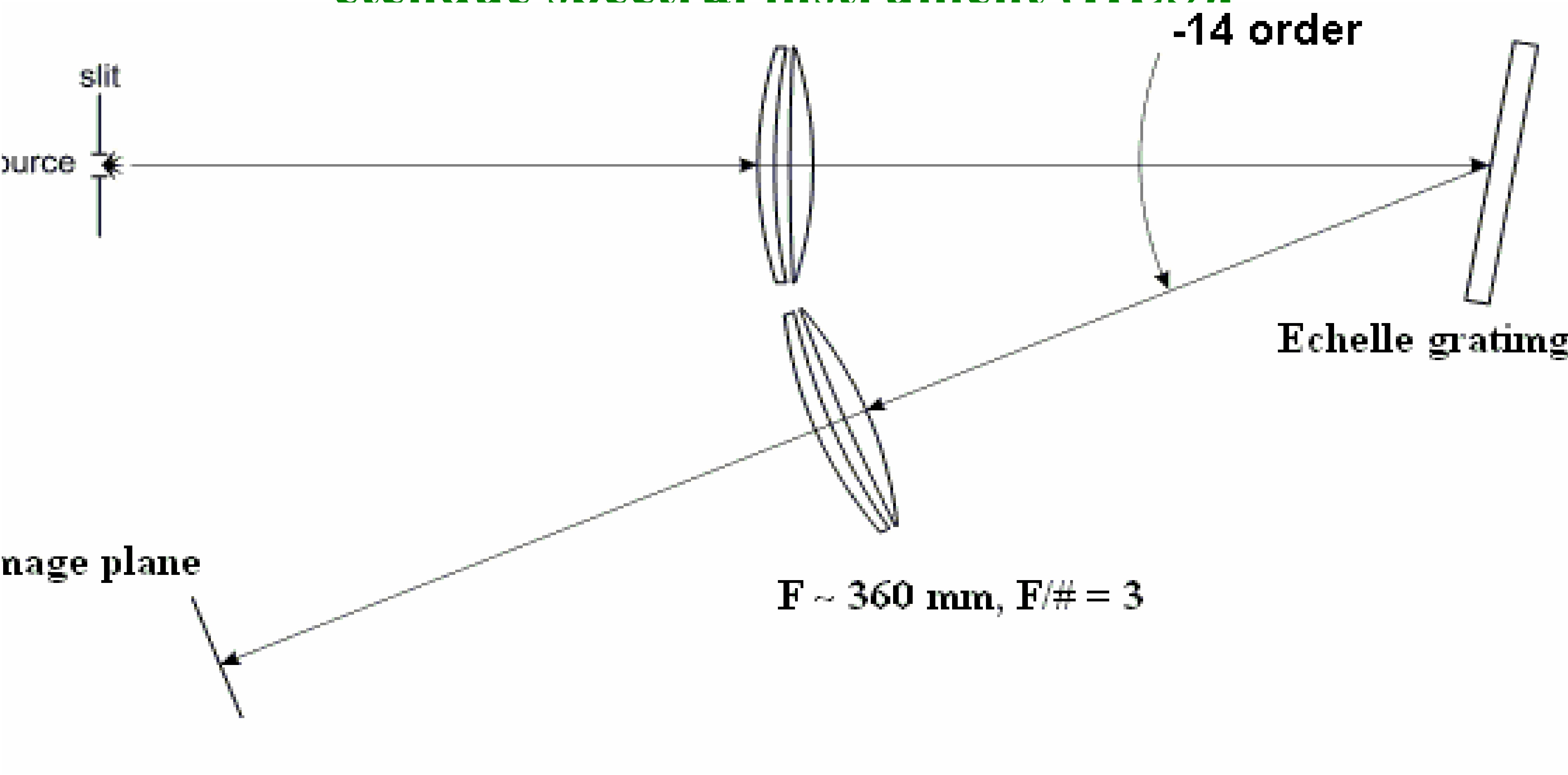
- **etendue 10^{-6} m^2 sr (but x 4 with MMA technique)**
- **f/2.9**
- **resolution 2.5 – 3 Å**
- **80 mm camera chip (but only 1/sec)**

CXRS experimental scheme of measurements.



RF-Edge-CXRS

Principle optical scheme of the high resolution high etendue spectral instrument (HES).



High etendue spectrometer (HES) design

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Summary

For optimum physics use for each radial channel a multi-wavelength Instrumentation is proposed including low-Z ions and bulk ions

Periscope optics and required time resolutions leave narrow margins for instrumentations

Several technical solutions are currently under discussion

Pilote studies are contracted out and will be evaluated in the near Future

The actual number of instruments is subject to budget and further negotiations between ITER partners