EUROfusion

Determination of Runaway Electron Distribution Parameters from Synchrotron Radiation Measurements

C. Monti[1], G. Ghillardi[1], C. Barcellona[2], B. Esposito[1], M. Hoppe[3], J.R. Martin Solis[4]

[1]ENEA, Frascati, Italy
[2]Università degli Studi di Catania, Catania, Italy
[3]Chalmers University of Technology, Gothenburg, Sweden
[4]Universidad Carlos III de Madrid, Leganes, Spain

ENEA
Italian National Agency for New Technologies, Energy and Sustainable Economic Development

SICILIAE STVDIVM GENERALE 1434

AVANCEZ 1829
CHALMERS

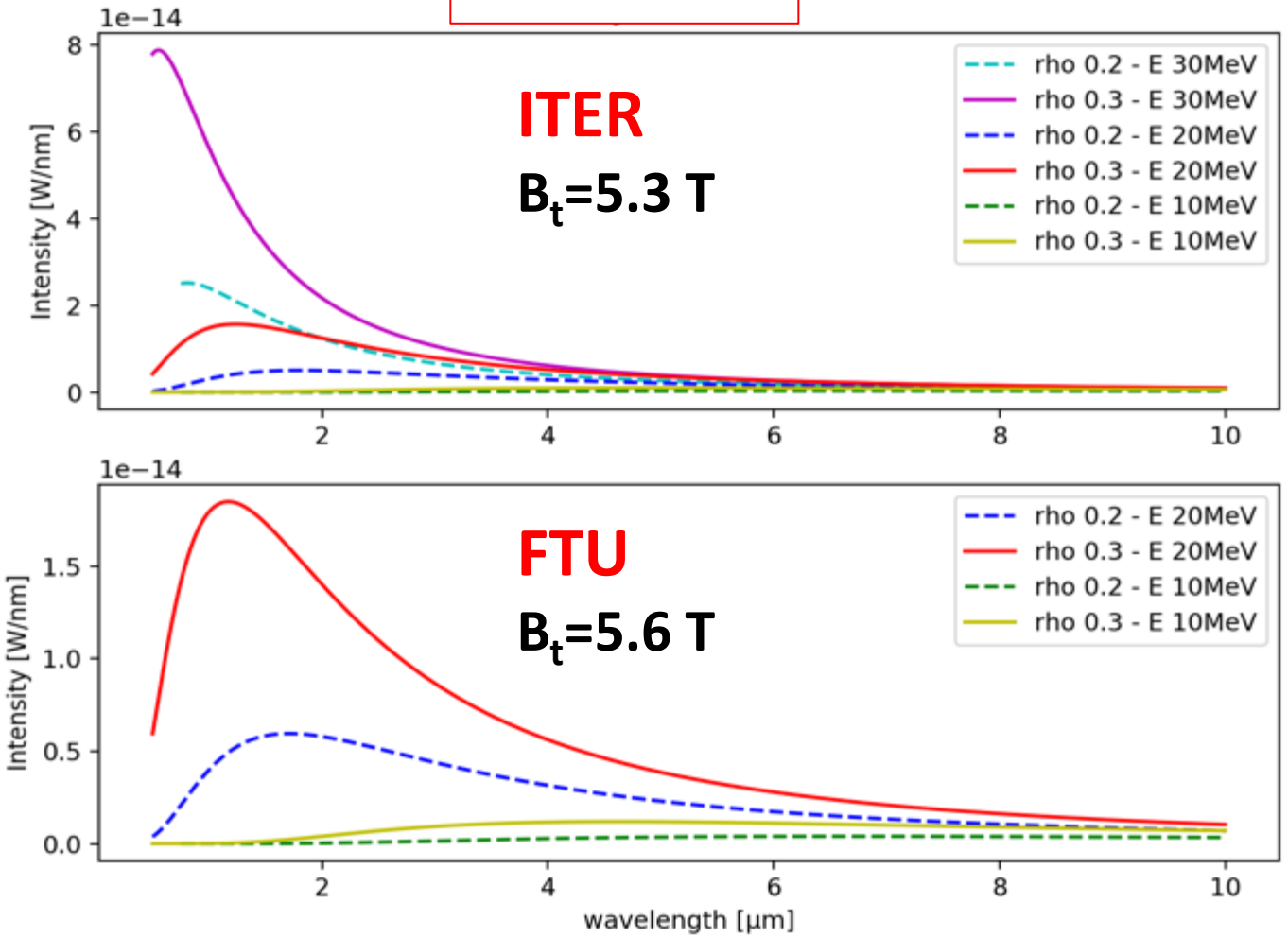
UNIVERSIDAD CARLOS III DE MADRID

Outline

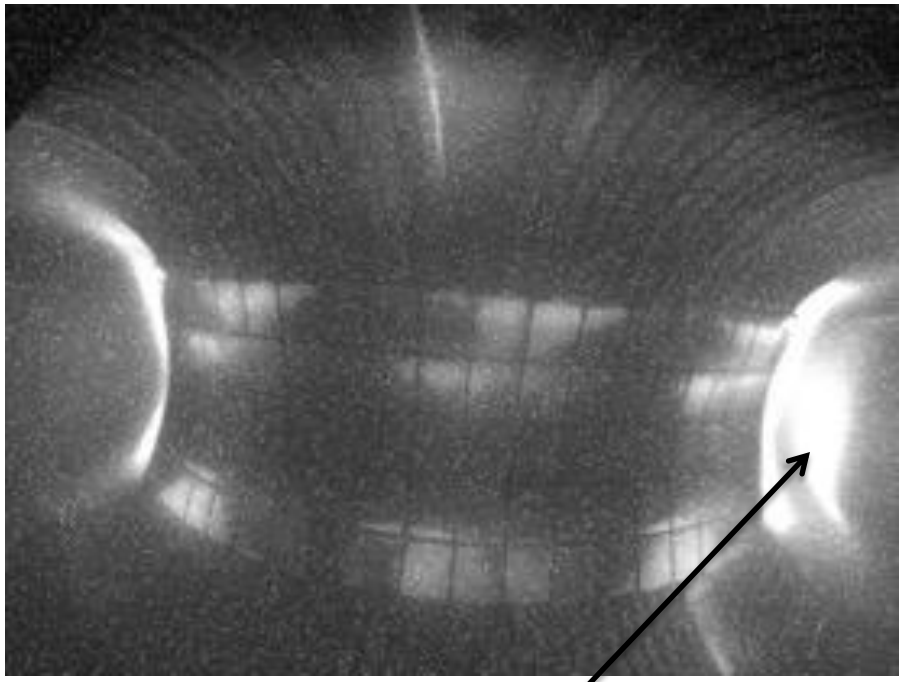
- **Runaway Electron** (RE) beams, forming after disruptions, are one of the main concerns for ITER operations since their impact onto the plasma facing components may cause damages
- **Synchrotron radiation** emitted by RE is a powerful tool to infer information on their dynamics
- A portable **Runaway Electron Imaging and Spectroscopy (REIS)** system has been developed by ENEA and used in FTU, AUG, TCV and COMPASS.
- An upgrade of the original system (REIS-Extended) now covers the wavelength range 0.4-5 μm
- Comparison between experimental and simulated synchrotron images and spectra (simulation by means of SOFT: Synchrotron-detecting Orbit Following Toolkit) leads to the estimates of RE parameters:
  - pitch angle
  - maximum energy
  - radial density profile
  - number

Synchrotron Emission from RE

SPECTRA



IMAGES

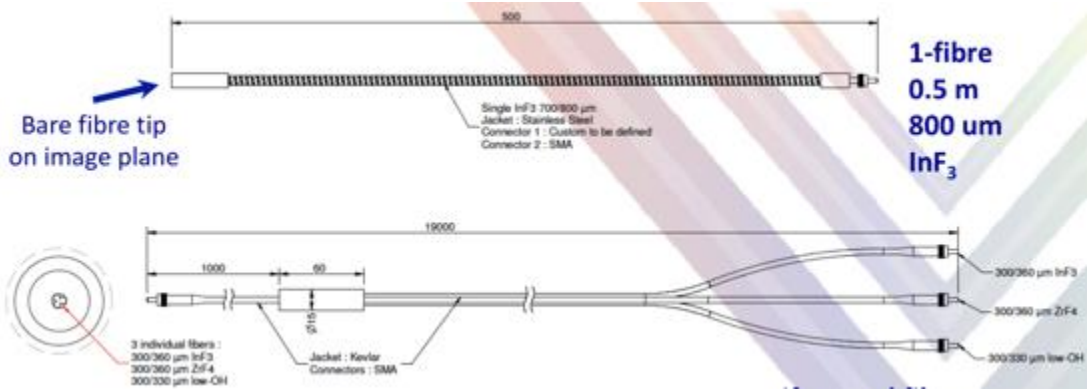


RE synchrotron emission
(**FTU #43654**, t=370 ms)

REIS Components

2 wide-angle objective lenses coupled to the 2 fibers, one for **forward (FW) view** and one for **backward (BW) view**, and with a CCD camera

2 fibers for FW & BW view



Trifurcated fiber for the 3 spectrometers (FW view)

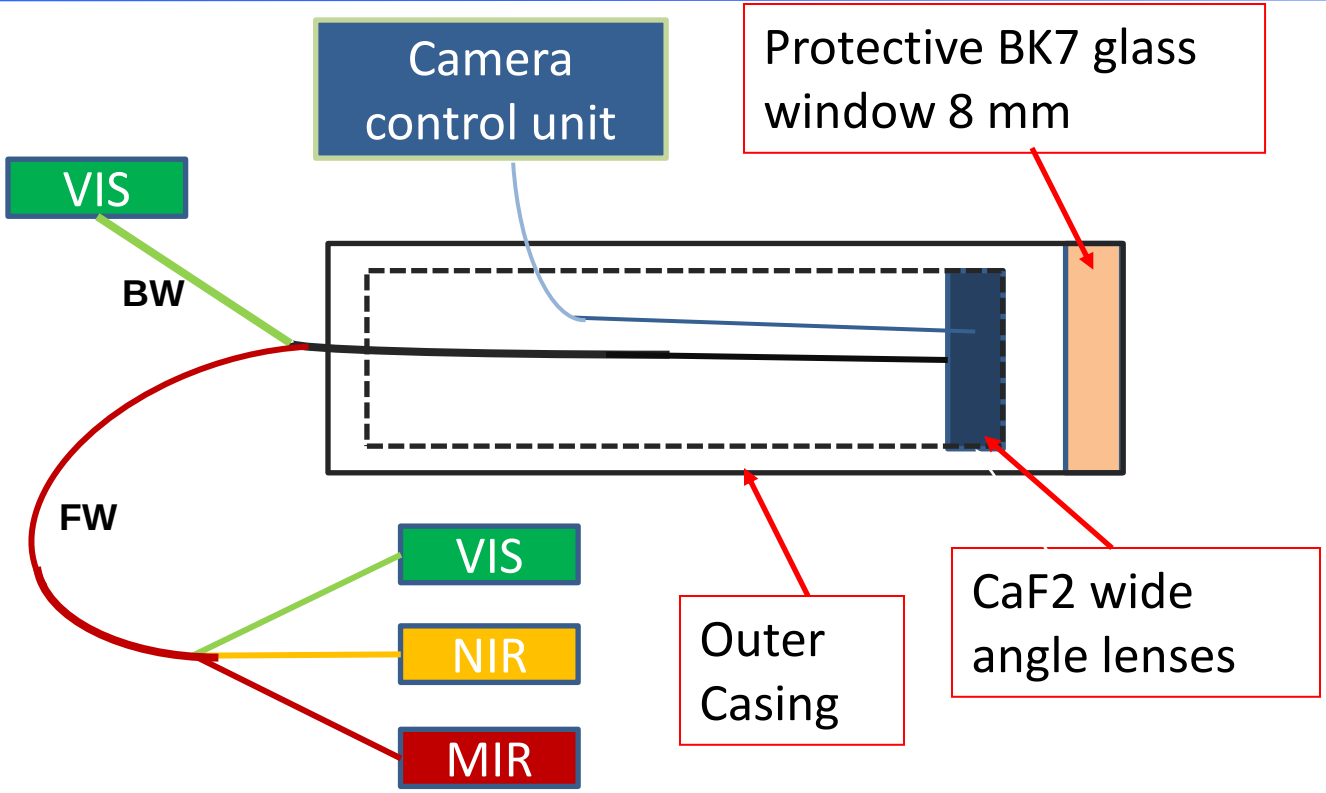
Fast JAI CCD camera (120 frames per second)

VIS range spectrometers (FW & BW views) 400-800 nm

NIR range spectrometer 900-2500 nm

MIR range spectrometer 1400-5000 nm

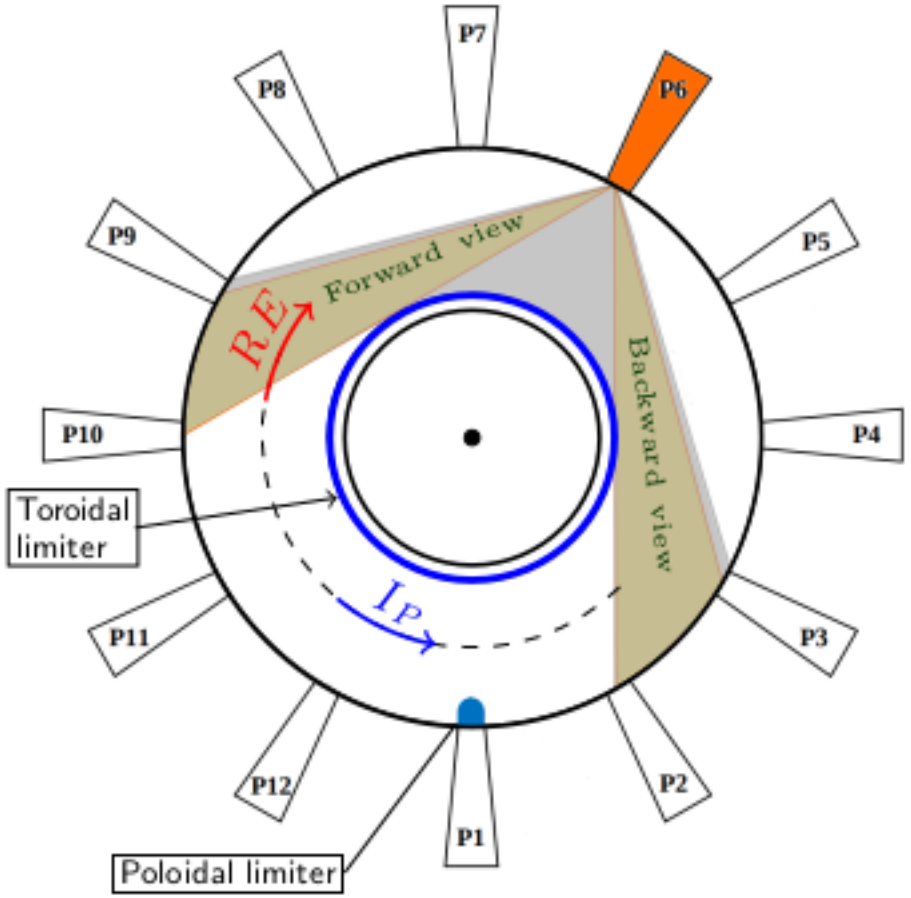
REIS Set-Up



Fibers length: 19 m

Calibration performed considering all the components combined in the system using blackbody sources

FTU midplane cross section. CCD camera and spectrometers field of view (FOV) are shaded, respectively, in gray and brown.



Analysis Method

SPECTRA SIMULATIONS

- Fixed pitch
- Mono-energetic
- Flat radial distribution (r/a=0-0.99)

Loop on pitch angle and energy

Comparison between simulation and data (least squared minimization)

Information on energy and number of RE

IMAGES SIMULATIONS

- Exponential pitch
- Mono-energetic (selected from spectra)
- Flat radial distribution (r/a=0-0.99)

Loop on pitch angle

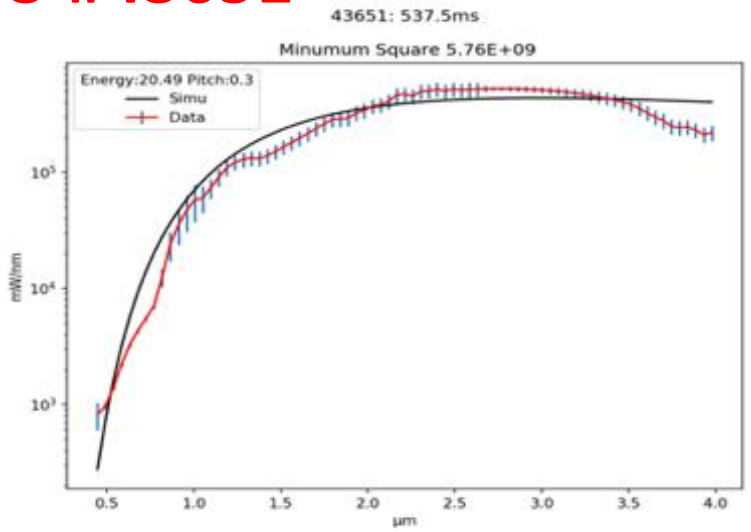
Comparison between simulation and data (least squared minimization)

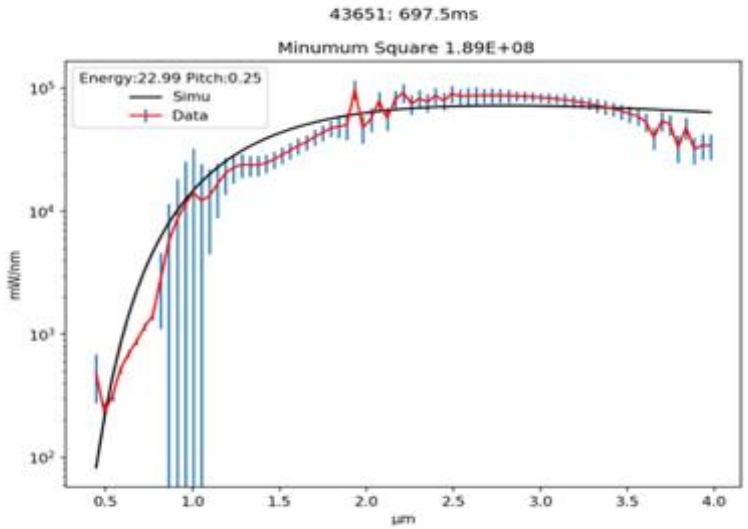
Information on pitch angle and radial profile

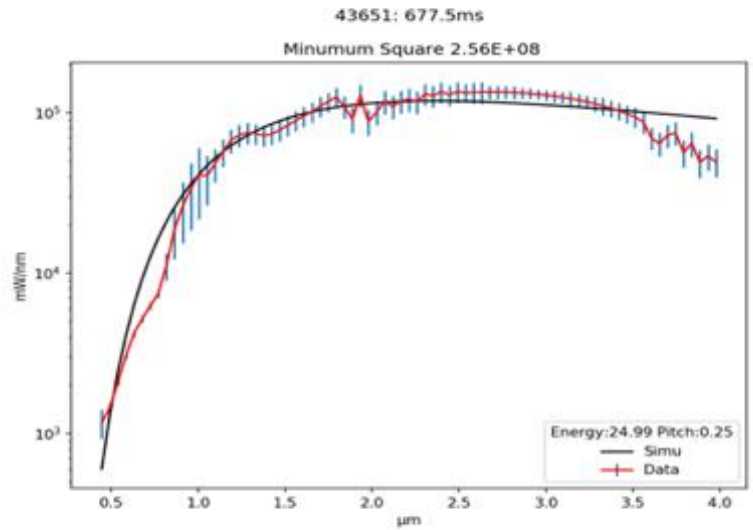
- Simulation **using SOFT software developed by Chalmers University**
- Method applied for each time of the acquisition.
- Monoenergetic distribution function found to be slightly better than exponential distribution.

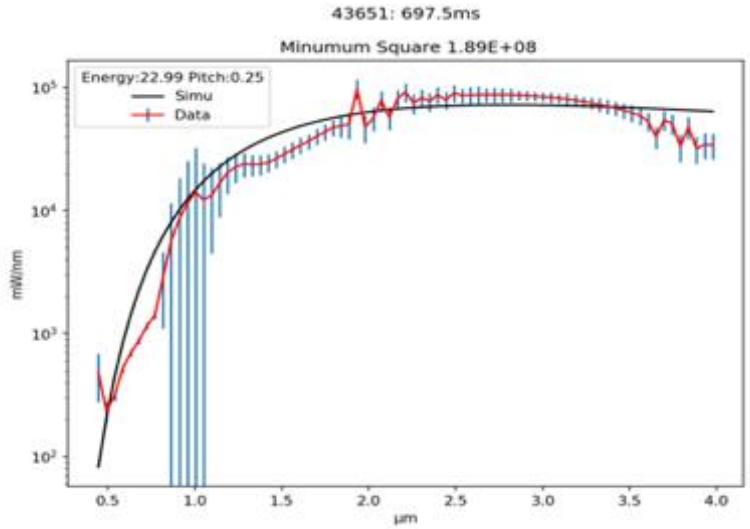
SPECTRA: experimental (red) vs SOFT reconstruction (black)

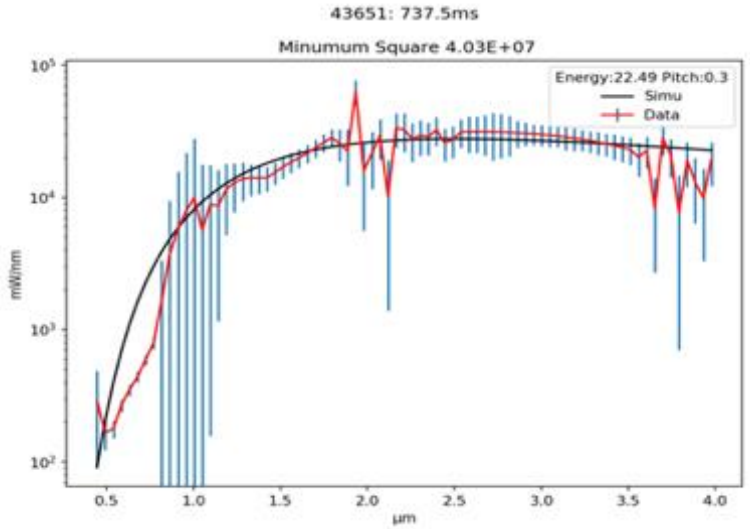
FTU #43651

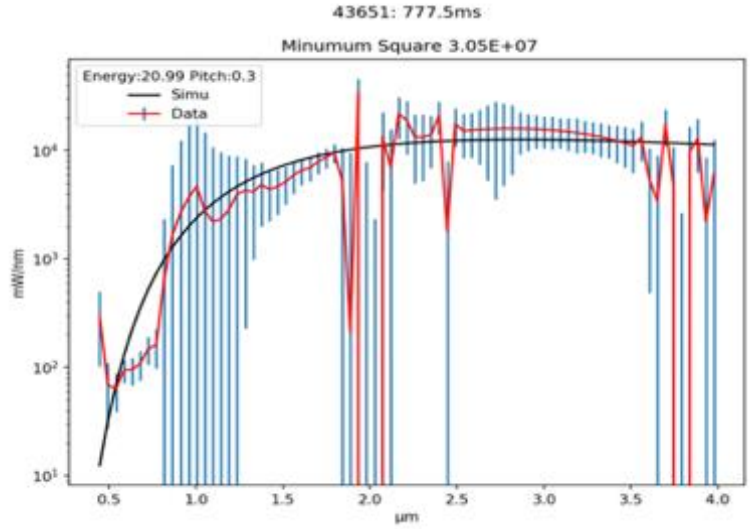






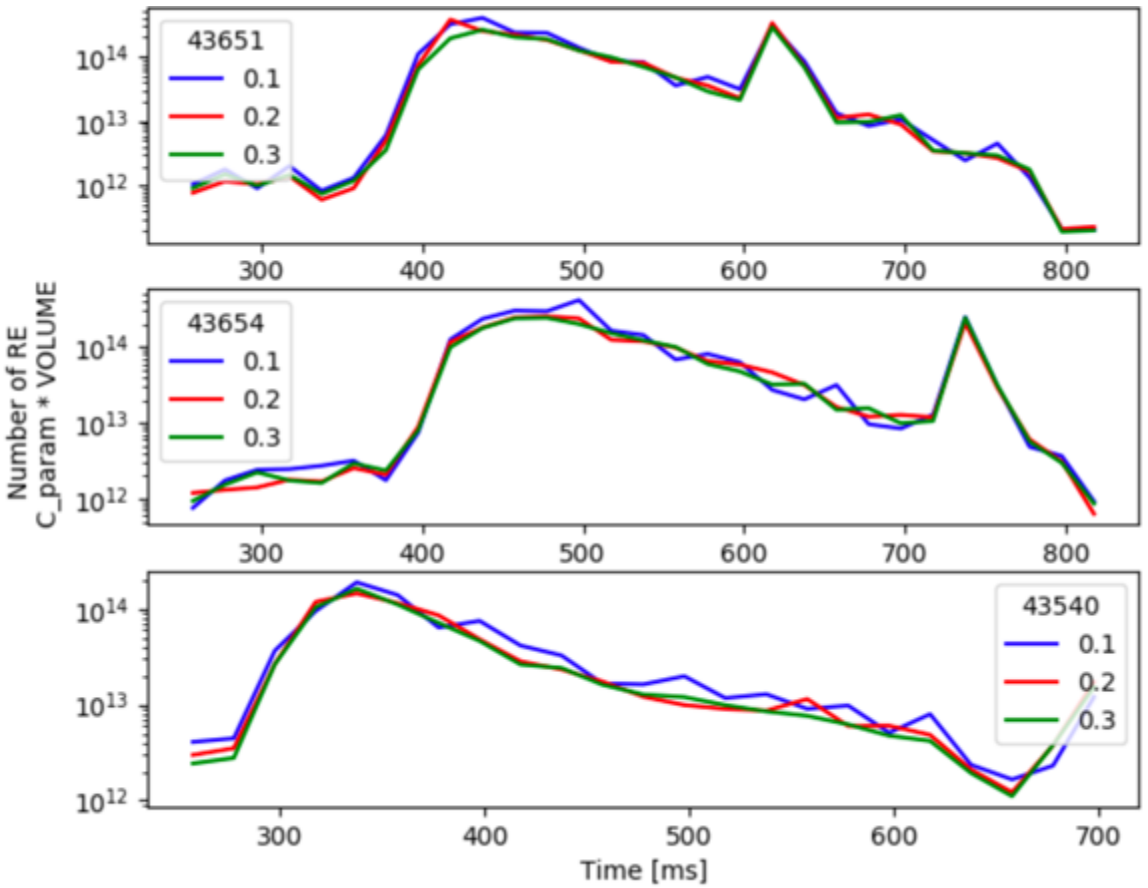




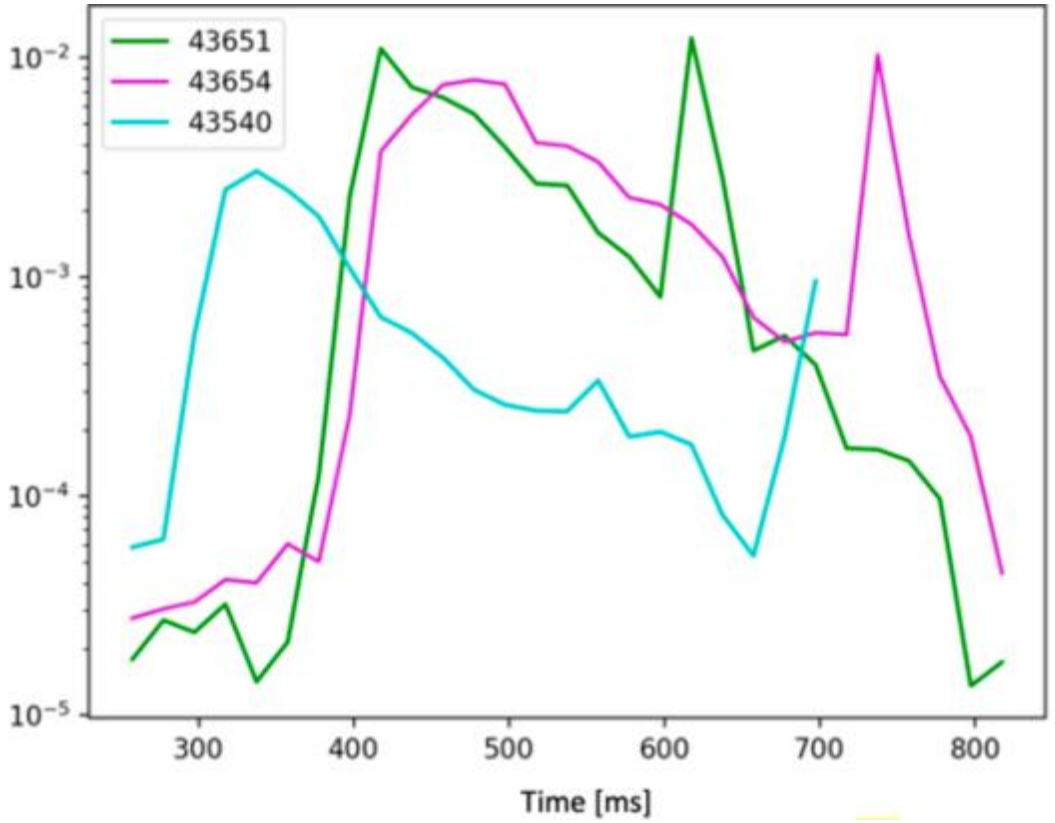


RE Number

RE number as determined by best match of SOFT simulated spectra to experimental spectra



Estimated RE Current fraction of total Current



IMAGES: experimental (left) vs SOFT reconstruction (right)

FTU #43651

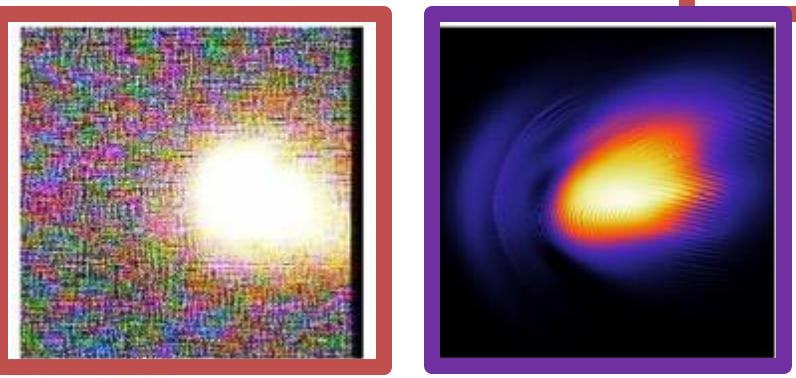
Real image from camera

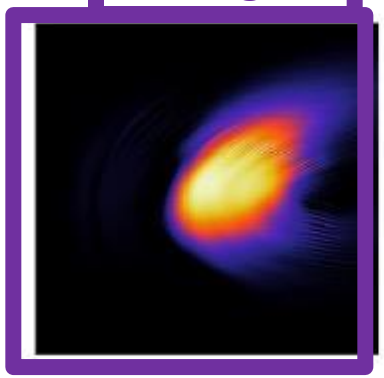
Best synthetic image

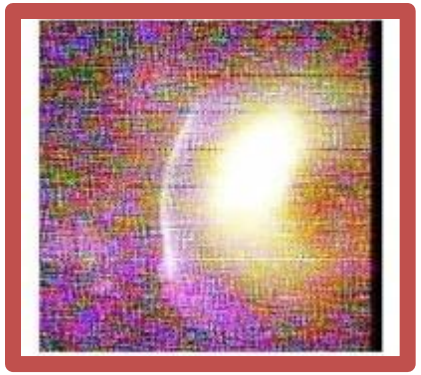
540 ms

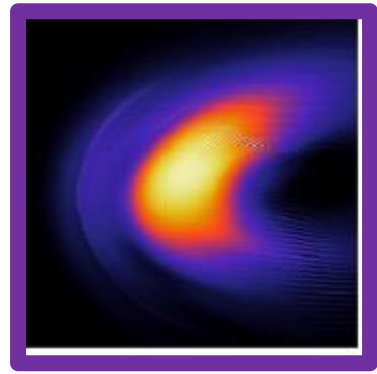
580 ms

660 ms





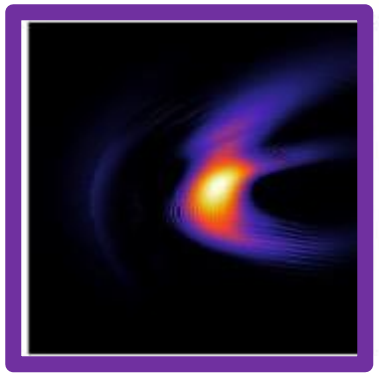




700 ms

740 ms

780 ms

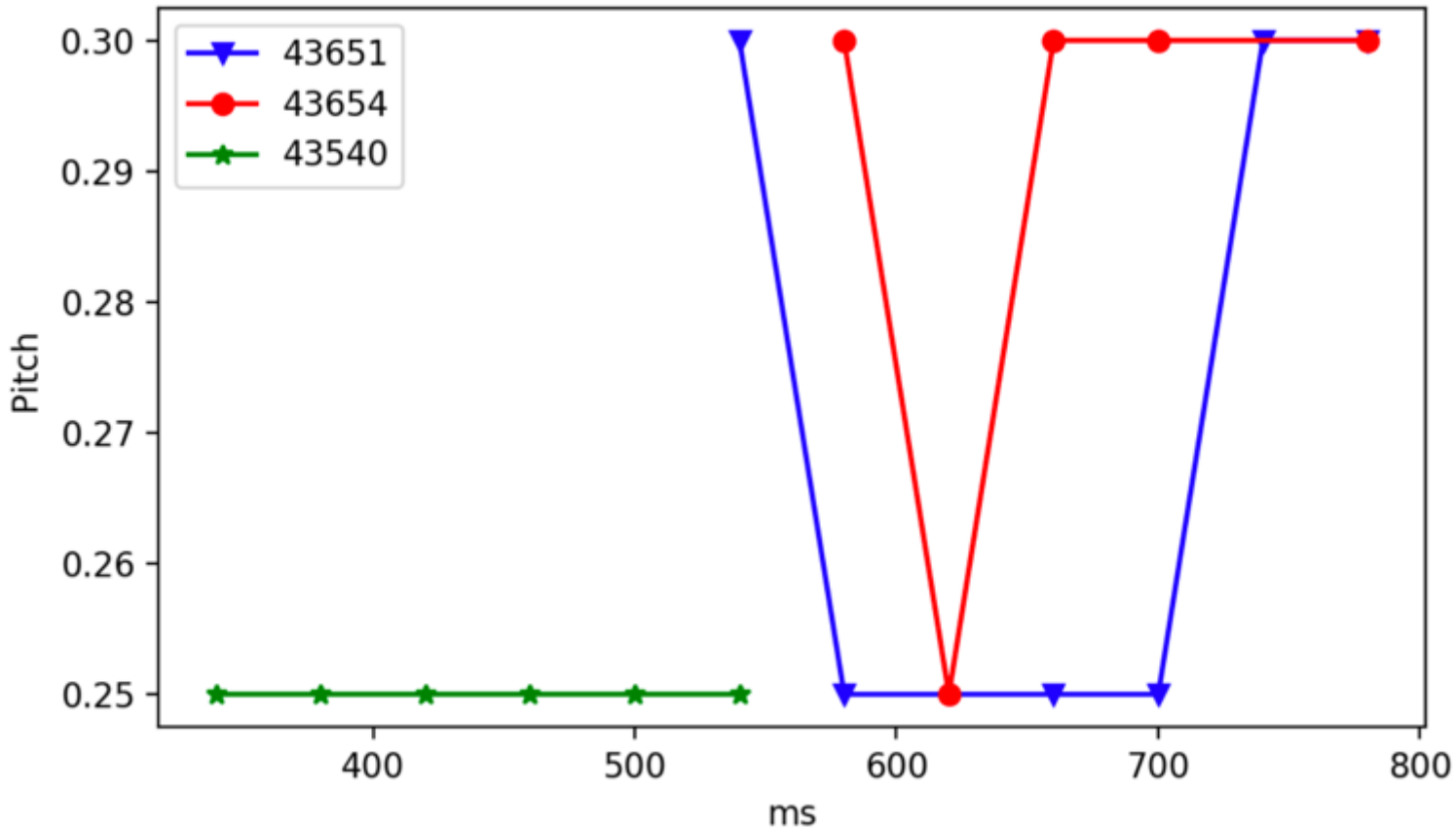


BEST Pitch Angles = [0.3, 0.25, 0.25, 0.25, 0.3, 0.3]

RE Pitch Angle

Images are more sensitive to pitch angle than Spectra

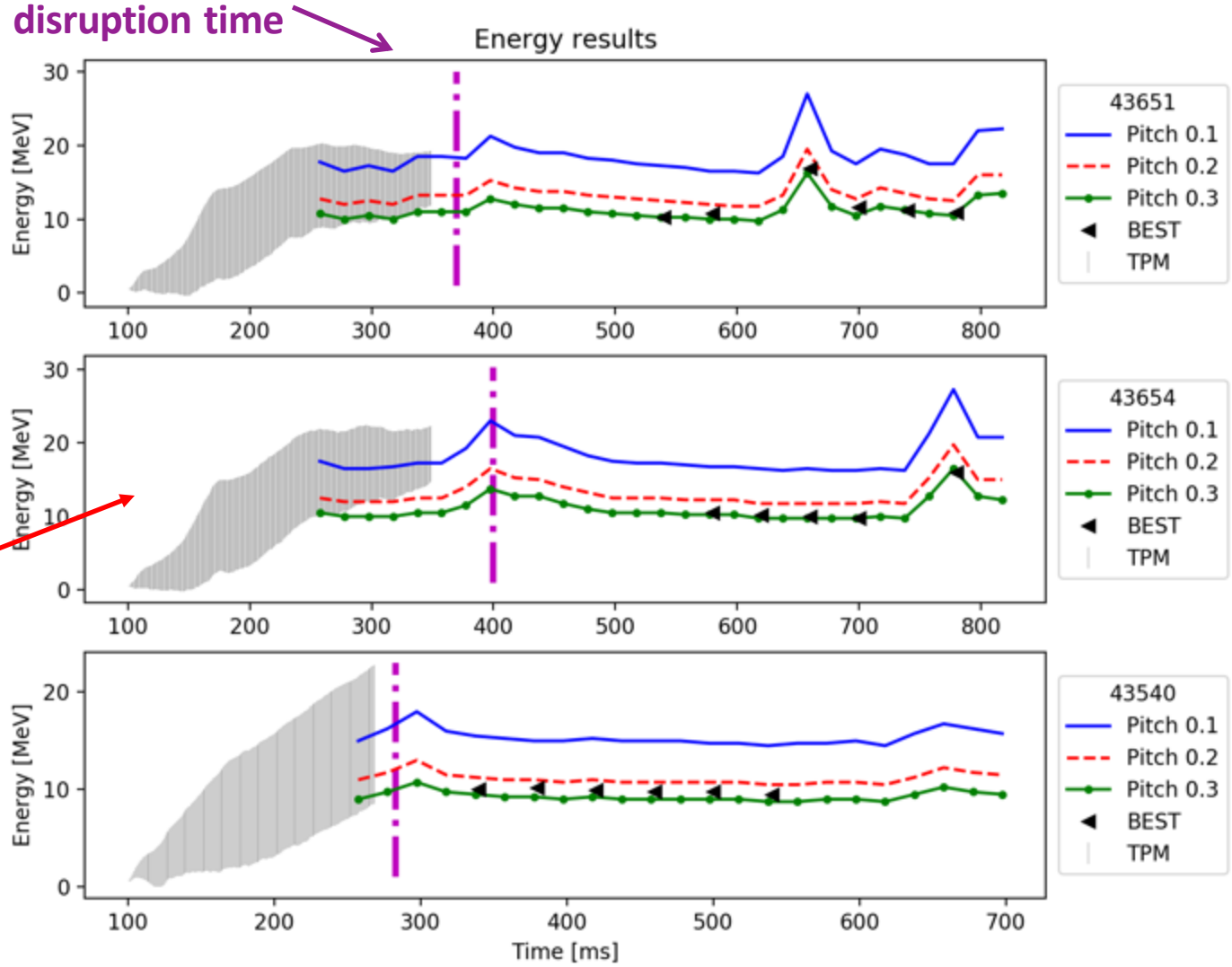
Showing pitch angles determined from Images (see previous slide) for 3 FTU RE discharges



RE Maximum Energy

'BEST' corresponds to values obtained using pitch angle derived from Images

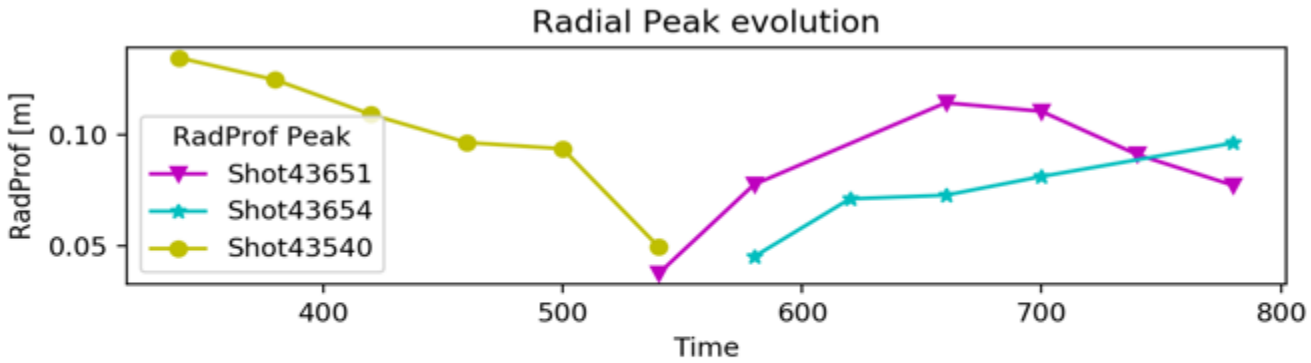
In plasma current ramp-up time interval no REIS data are available (low RE synchrotron emission) **simulation using Test Particle Model has been performed**
→ based on experimental measurements (density and loop voltage)
→ good match with experimental data

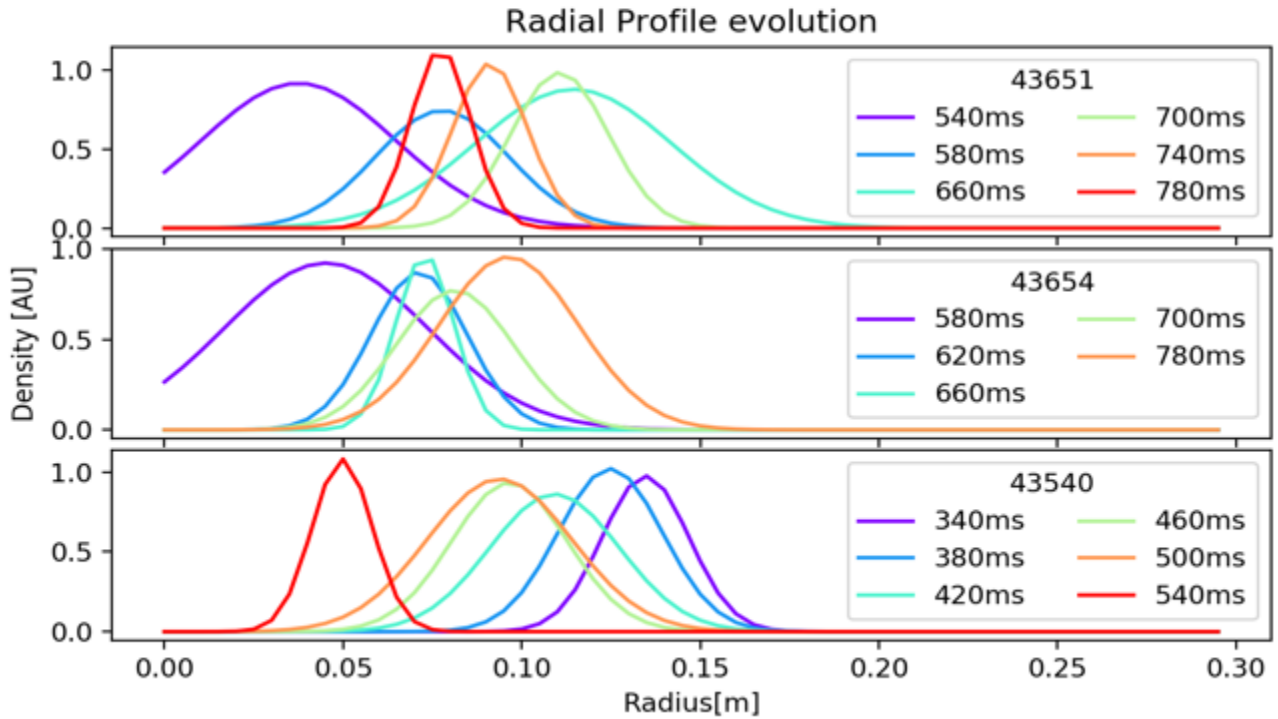


RE Radial density profiles

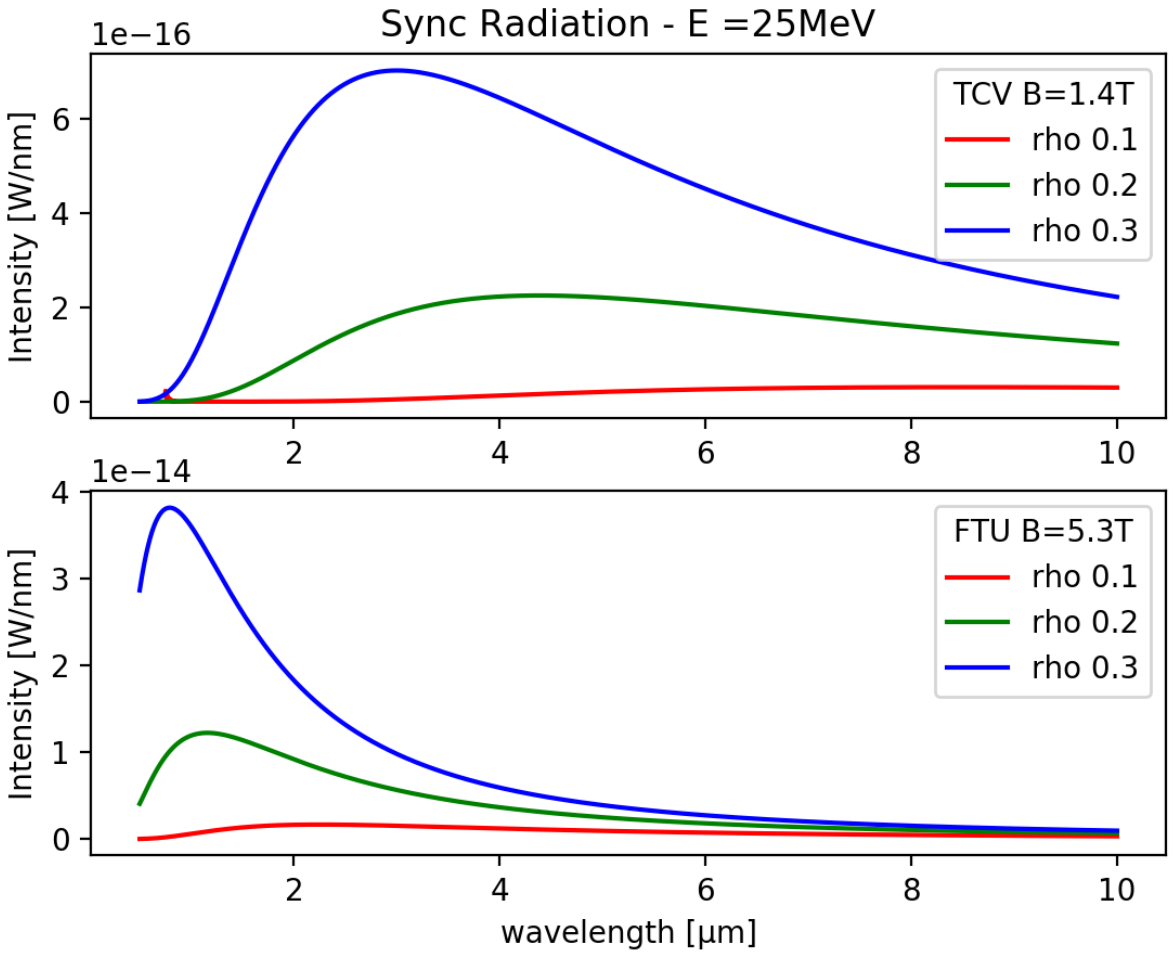
Radial profiles are derived comparing simulated images and experimental ones.

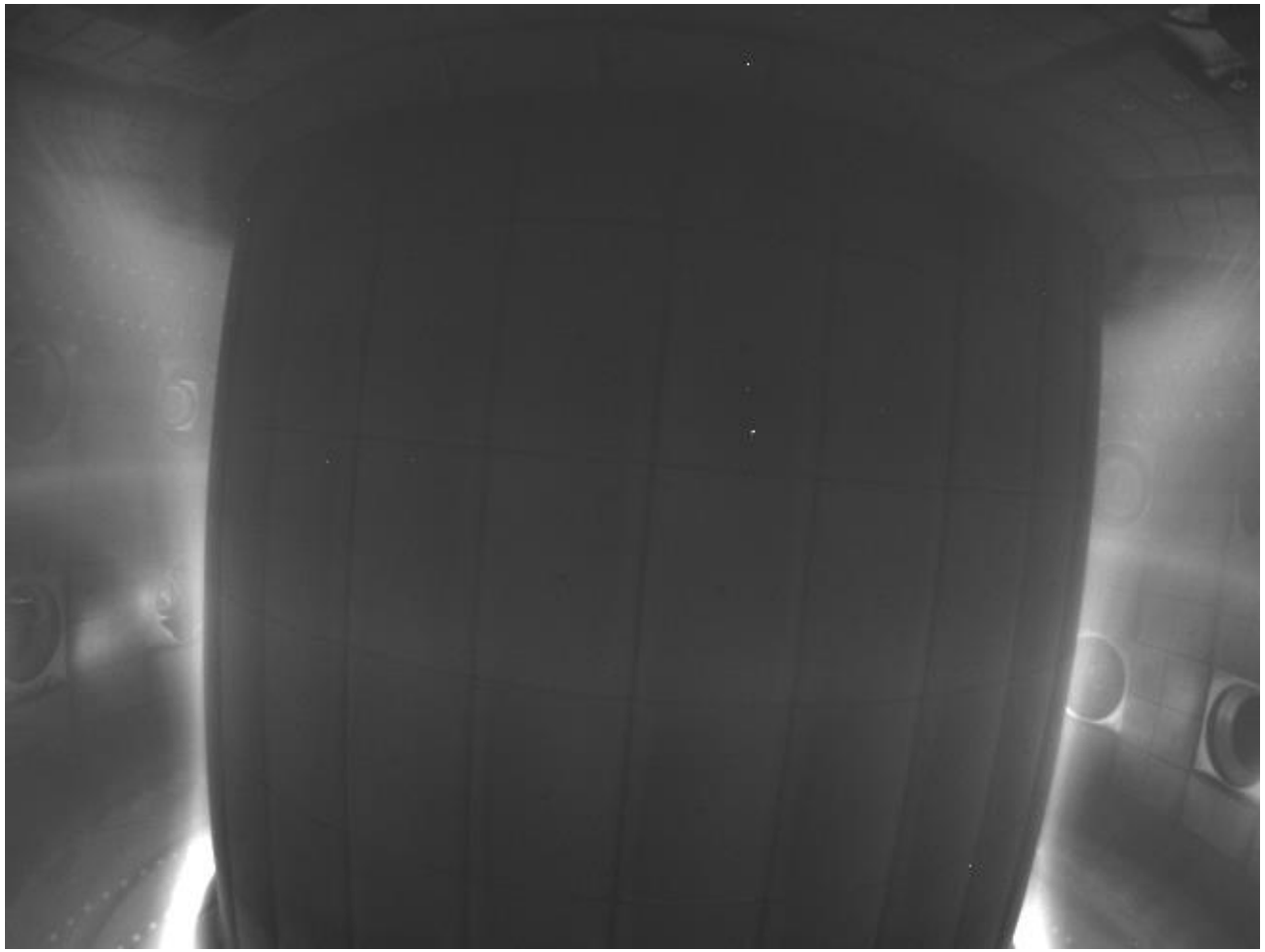
An algorithm determines the radial profile maximizing the similarity between the two images.



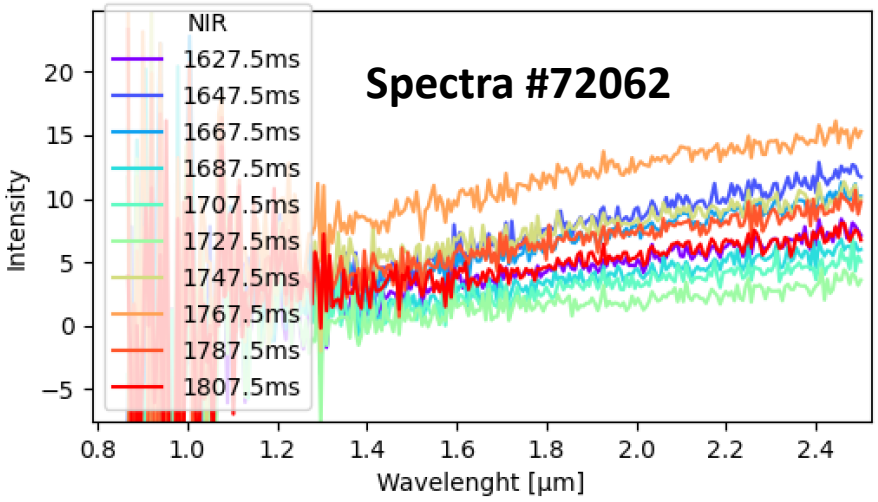


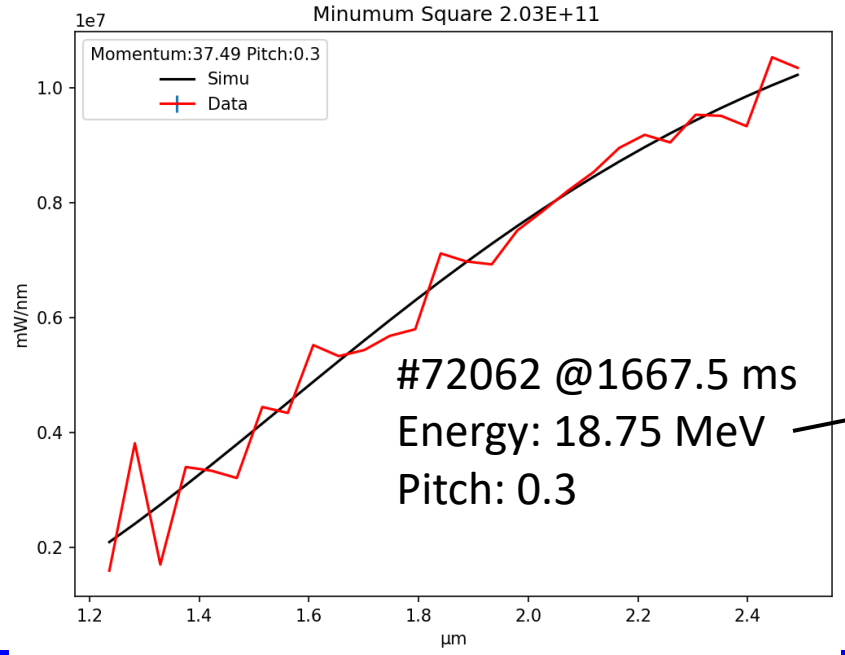
Synchrotron Emission from RE in TCV



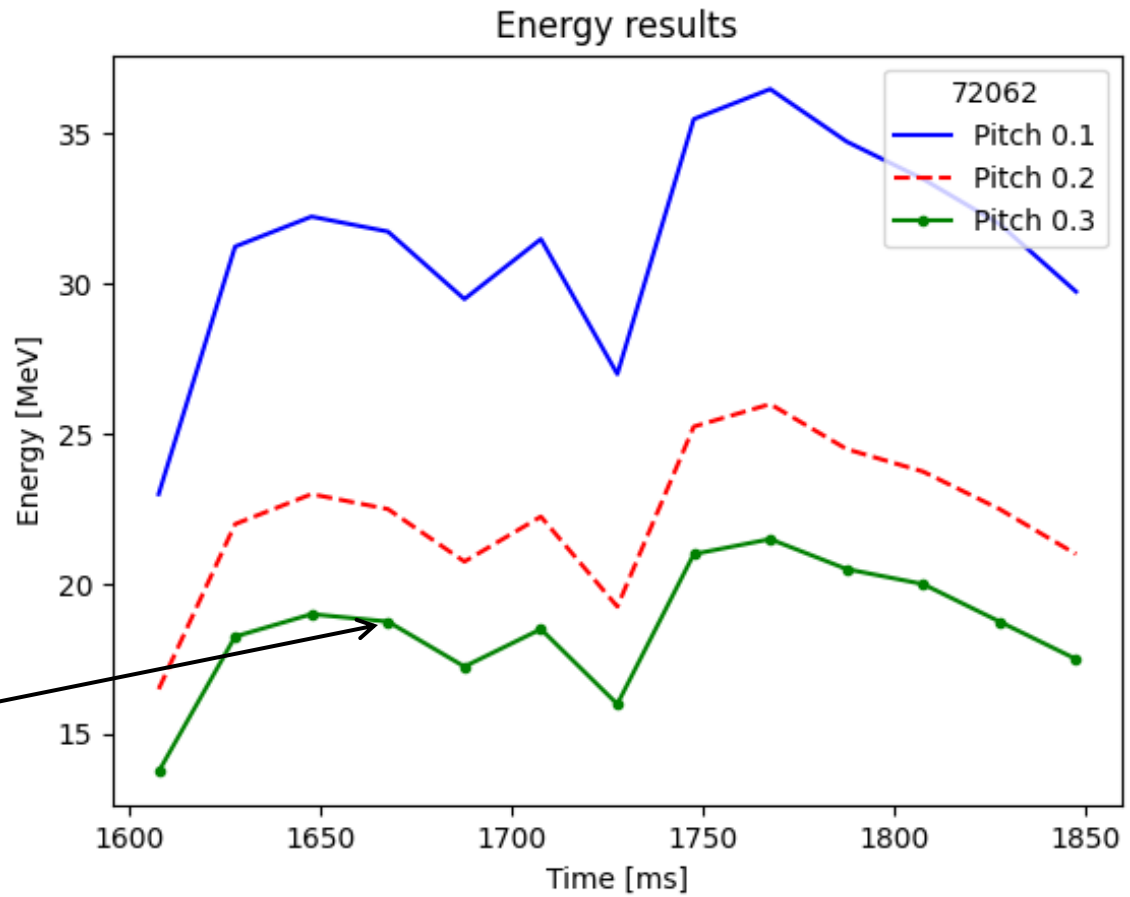


SPECTRA and ENERGY from RE in TCV

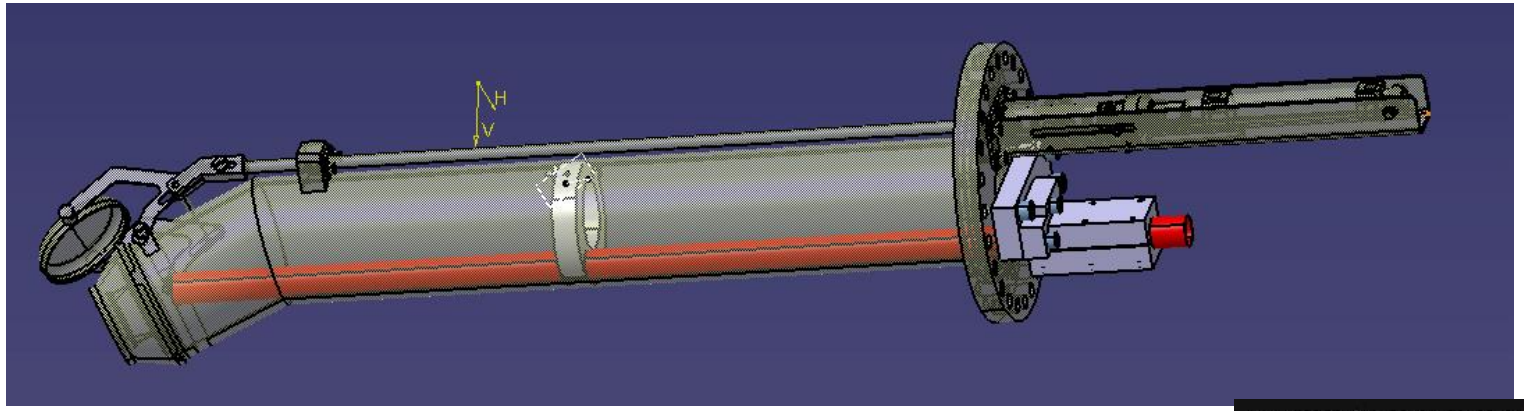




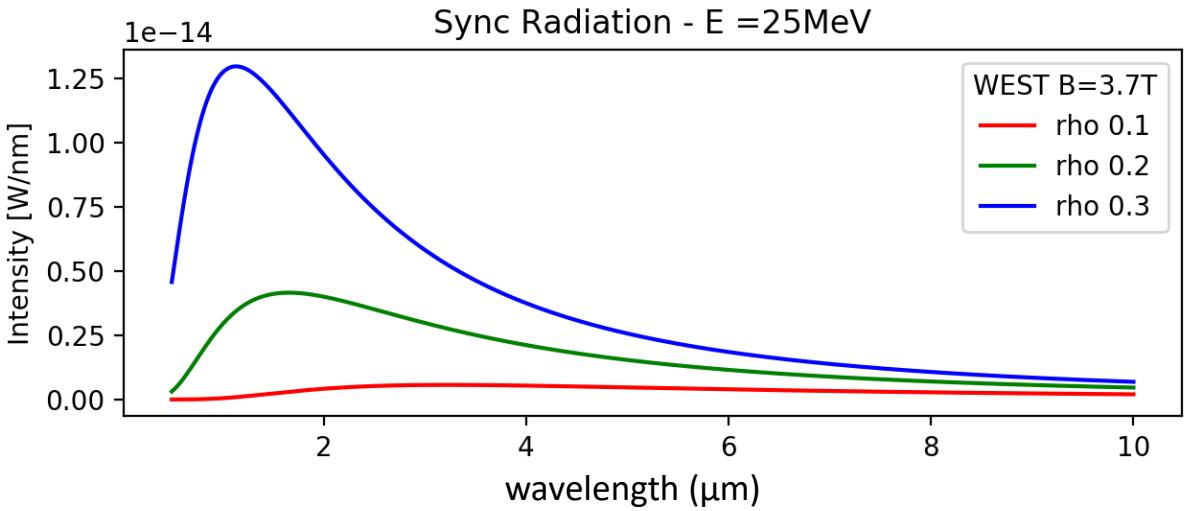
#72062 @1667.5 ms
Energy: 18.75 MeV
Pitch: 0.3

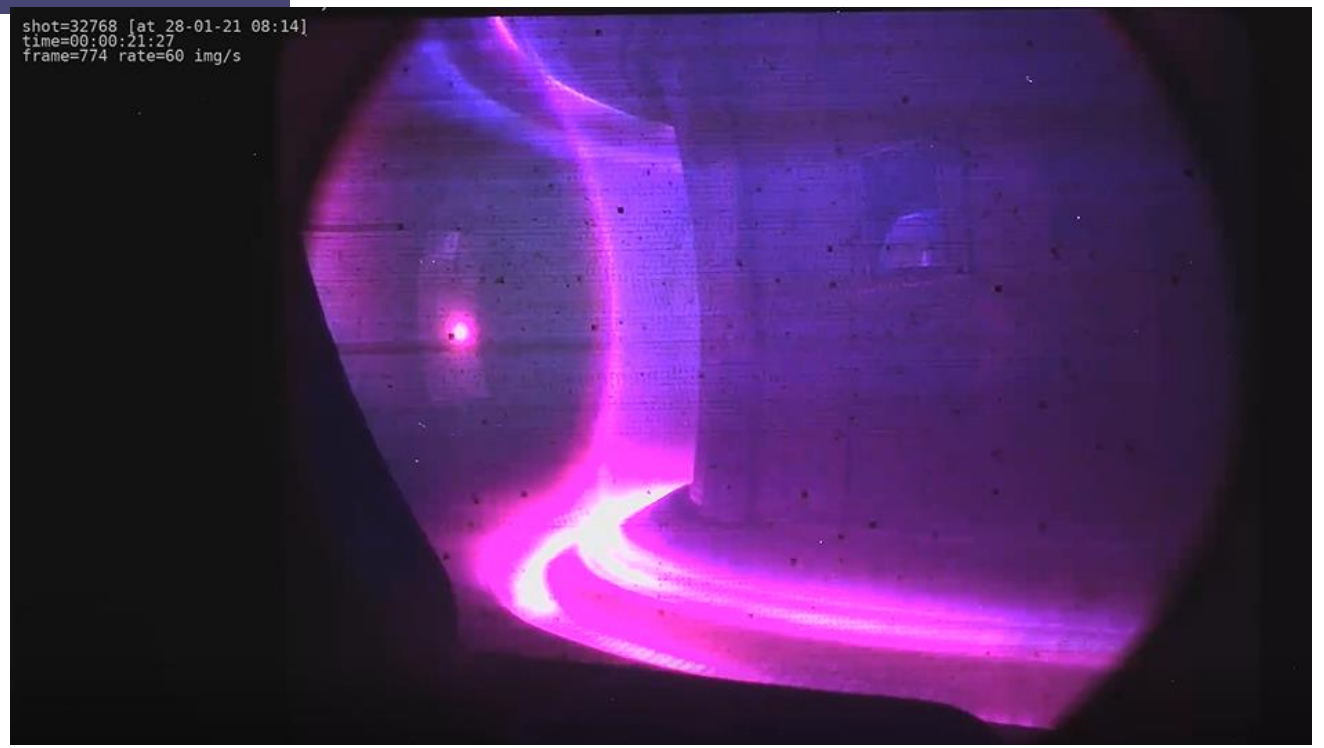


Future installation on WEST (2022)



Spectra from REIS + images from WEST fast visible camera





Outcomes and Prospects

- REIS-E successfully **calibrated**, **tested,** and **installed** so far on **FTU, COMPASS** and **TCV**
- Demonstrated the potential of combining spectra and images for **RE dynamics reconstruction** with determination of time evolution of RE parameters
- Work results contained in “Overview of the FTU results”, OV/P-2 (IAEA 2020).

Future applications:

- Planned installation on WEST in March 2022
- Future use of the diagnostic for DTT device
- Planned development: real-time version

Thanks for your attention