COMPASS
INSTITUTE OF PLASMA PHYSICS ASCR

Tomographic inversion of visible camera data for JT-60SA

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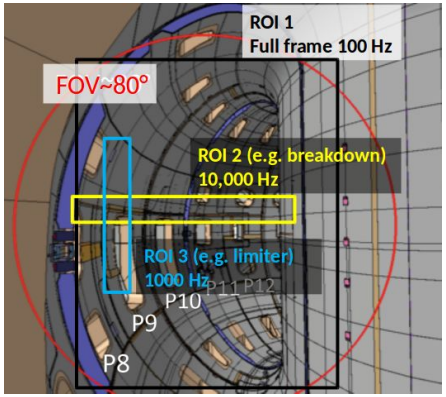
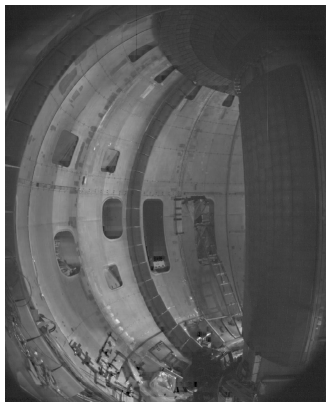
Aims of the proposed work

- **Limited number of diagnostics** in JT-60SA commissioning phase
  - ➢ Need to extract as many information from available ones

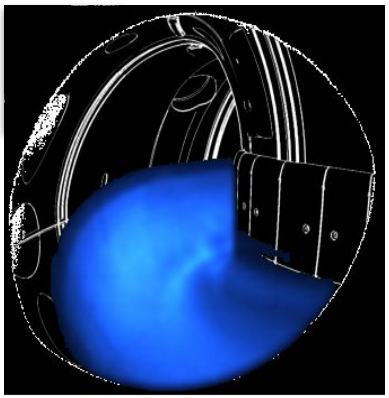
Proposal to support plasma **operation and modeling** by tomography assuming **toroidal symmetry** of EDICAM images

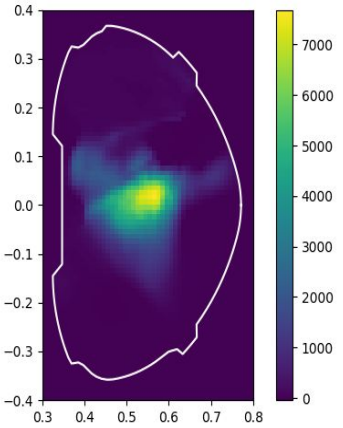
- **Outputs:**
  1. 2D poloidal light emissivity
  2. Comparison with electron cyclotron modelling (n_e & T_e radial profiles)
  3. Plasma contact with first wall (PFCs), plasma shape...





Edicam field of view at JT-60SA (actual picture)

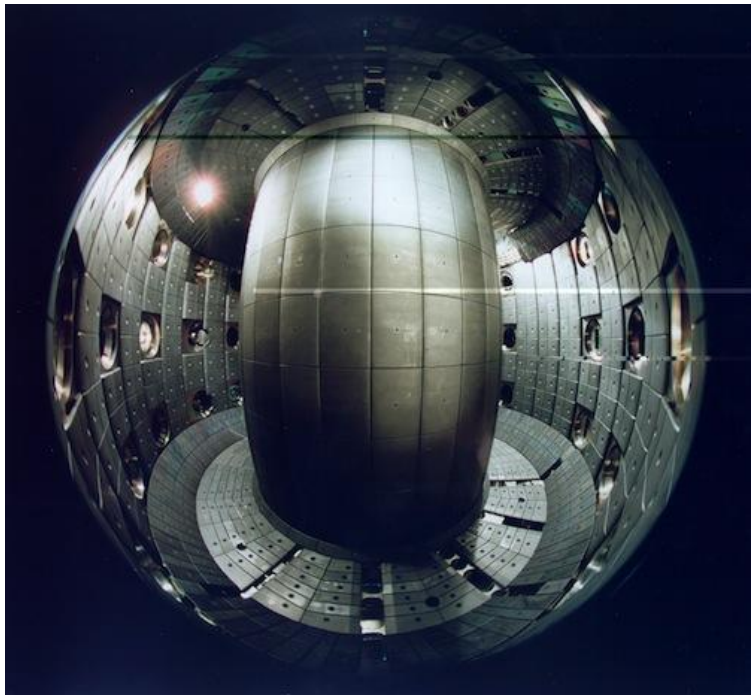


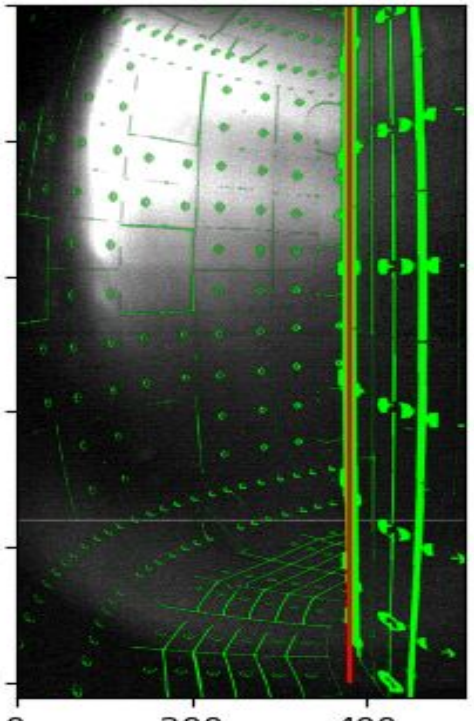


Tomographic inversion @COMPASS

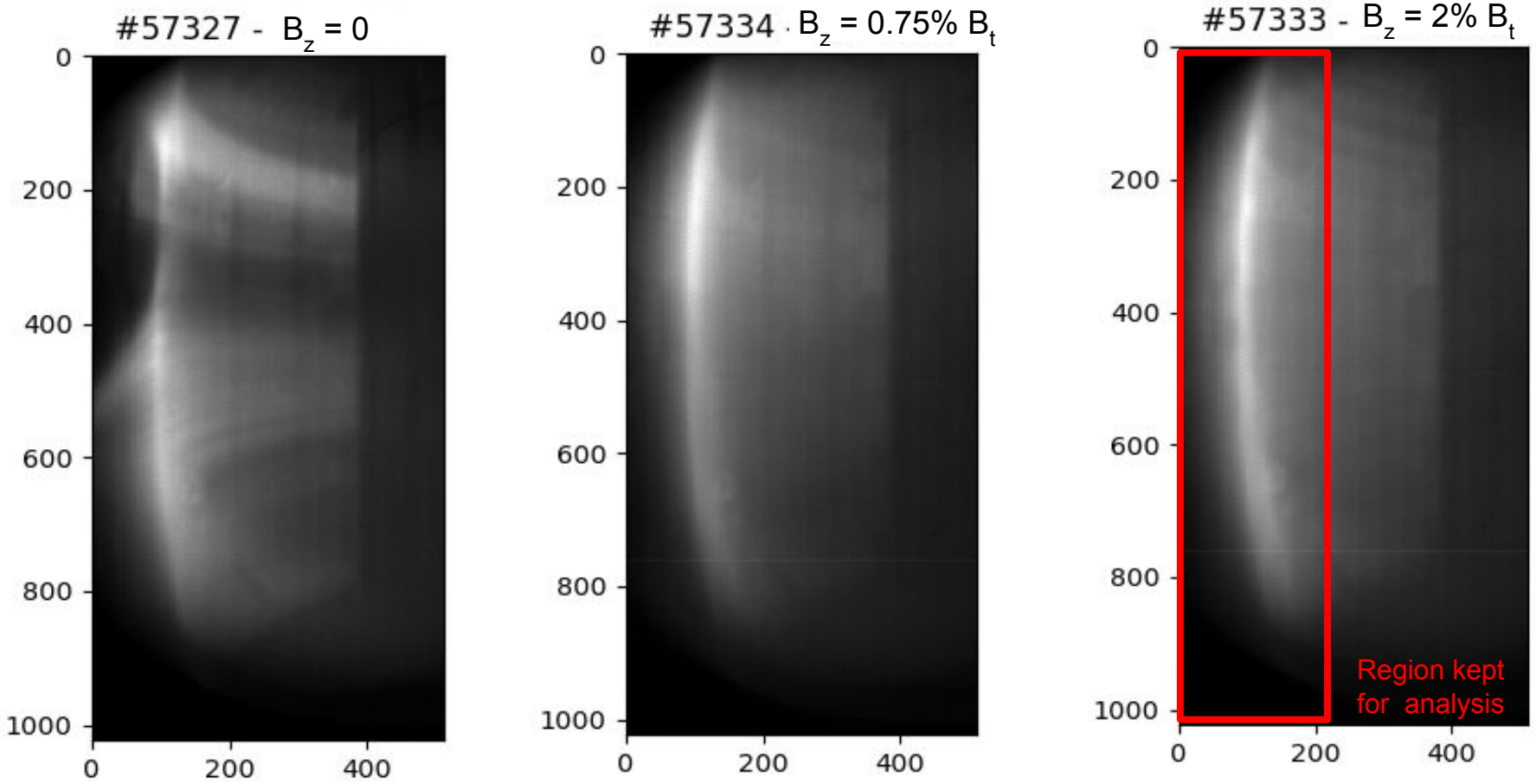
Illustrative example towards JT-60SA application

Tomography applied to TCV data
obtained from electron cyclotron plasmas





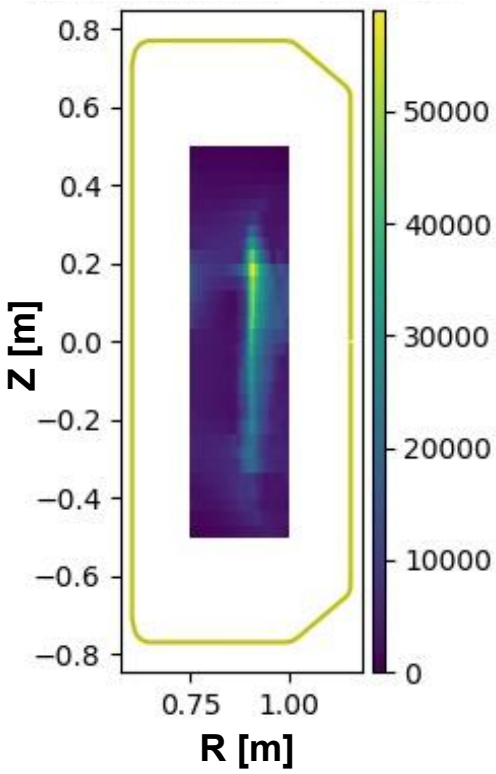
Camera observation of electron cyclotron plasmas for different vertical magnetic field on the TCV tokamak



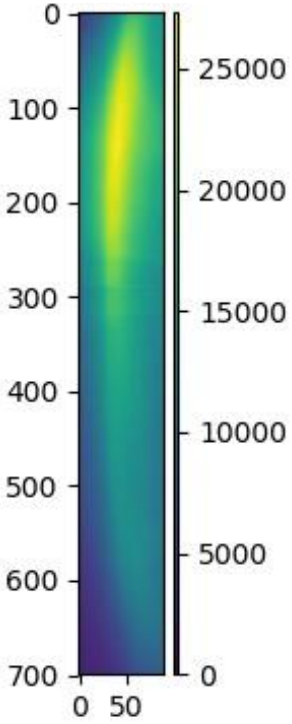
TCV tomography for #57334

- The signal had to be **cropped** significantly to avoid artefacts
- **Very good reconstruction** as seen on (signal-retrofit)

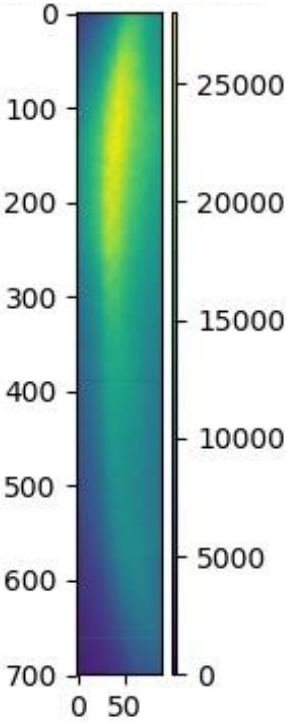
TCV poloidal plane



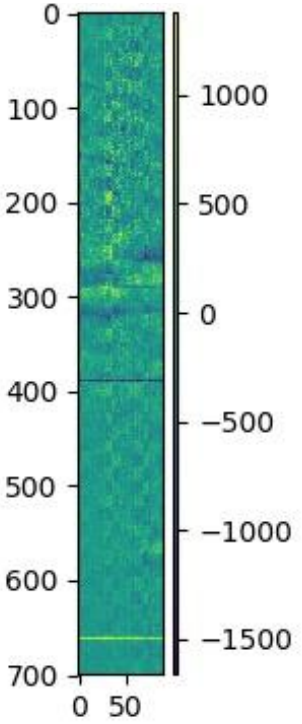
Retro fit



Raw signal



Signal - Retro fit



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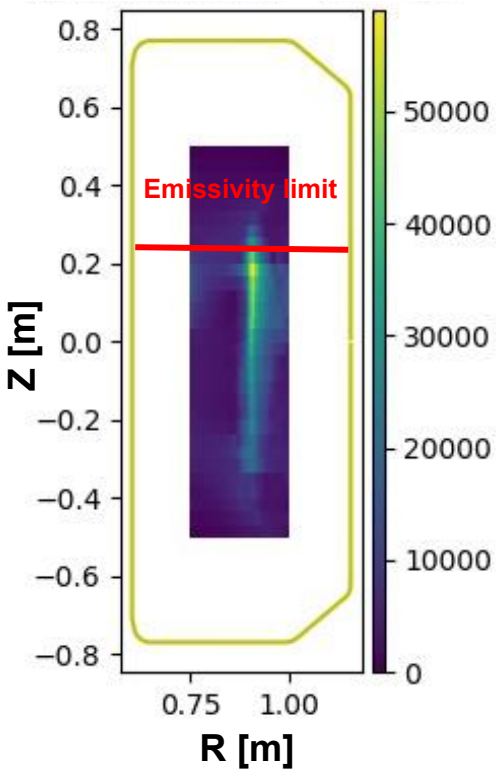
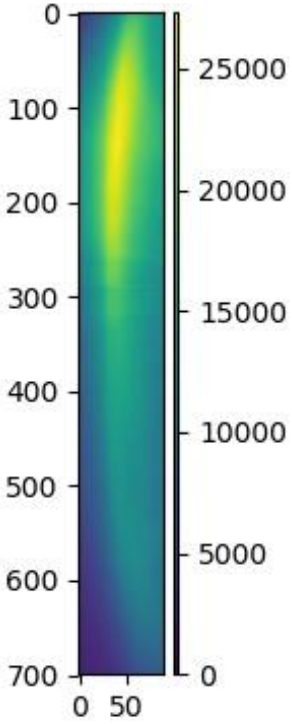
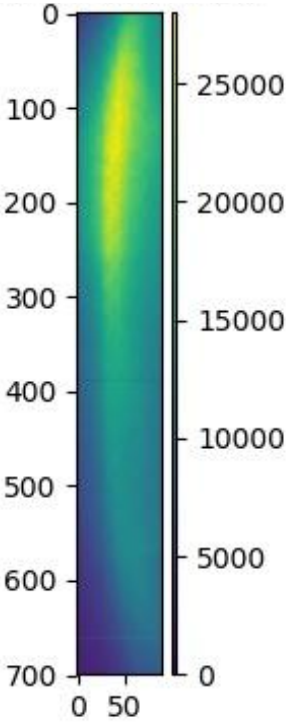


Retro fit



Raw signal



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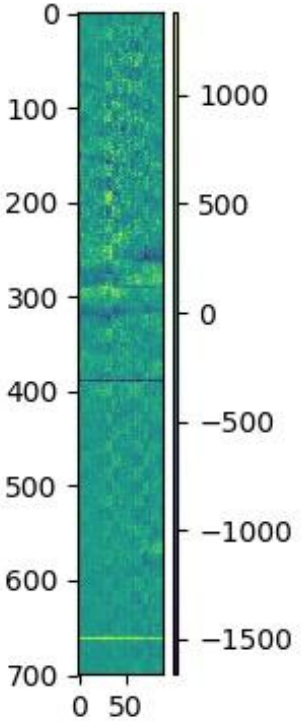
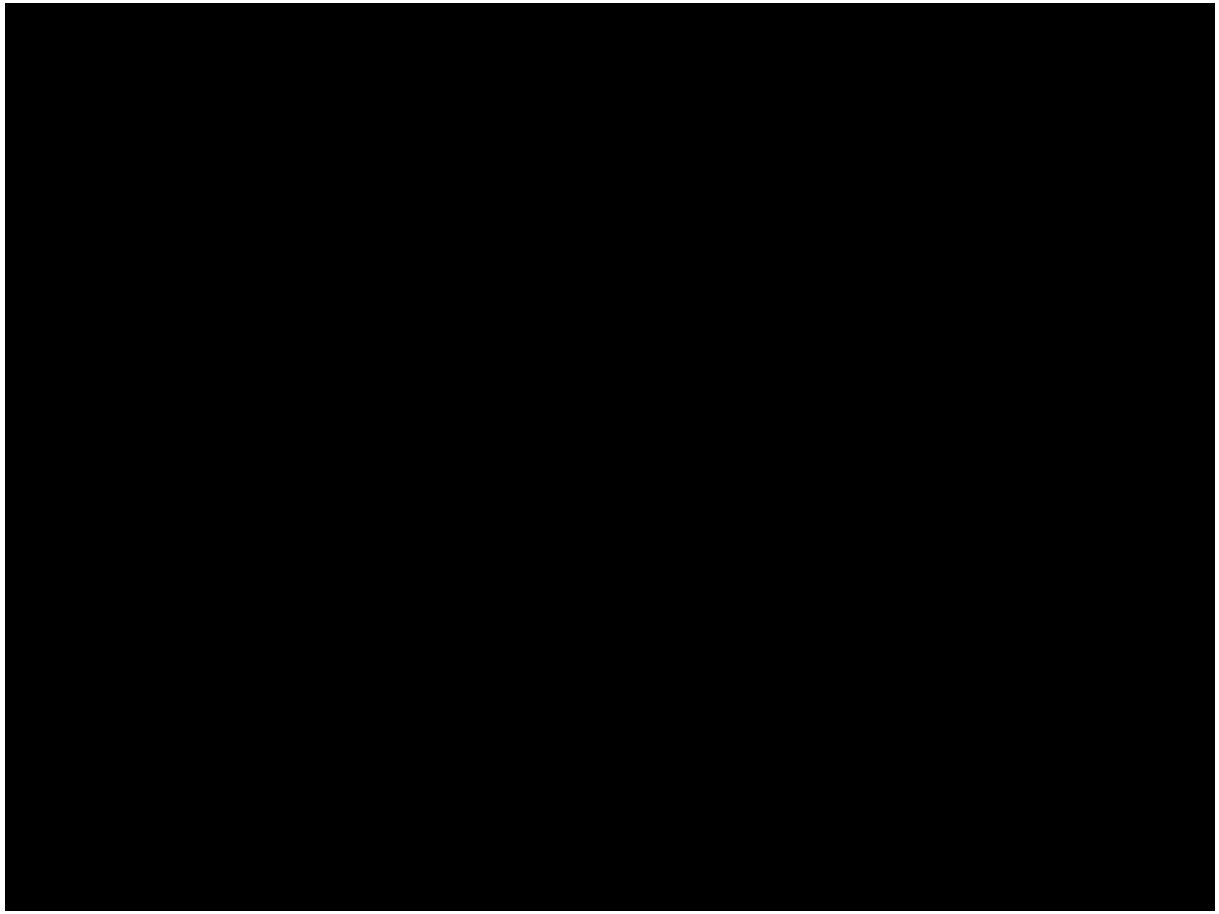


Electron cyclotron beam path at TCV

Courtesy T. Wauters

Camera probably
blind in the top part
(Z>0.2 m)



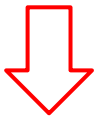
The reconstruction agrees very well with the electron cyclotron beam path

Comparison tomography and 1D code (tomator)

Courtesy T. Wauters

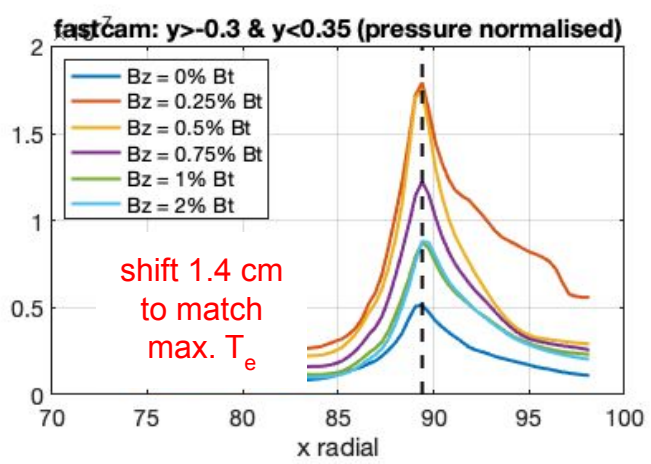
Graph description:

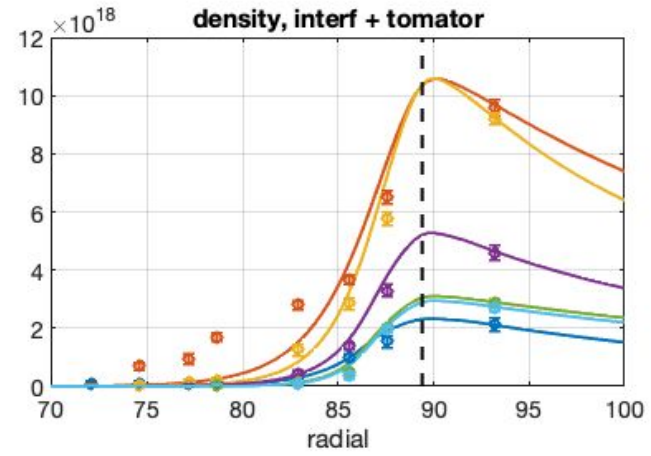
1. Radial light profile (averaged vertically, normalized to neutral pressure)
2. Radial density profile (experimental and model)
3. Temperature profile (model)

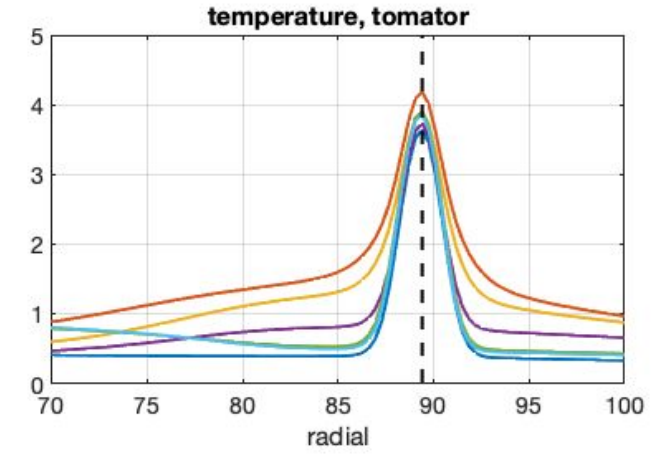


1. Maximum of light close to maximum of n_e and T_e
2. Relation between light and n_e and T_e

$$\text{Light} \propto n_0 * n_e * f(T_e)$$

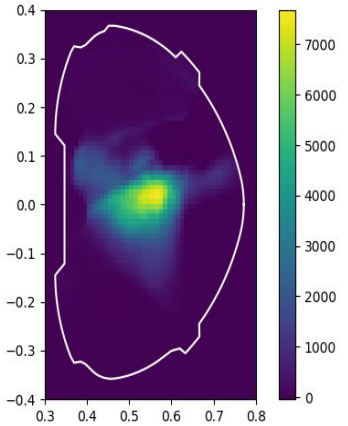


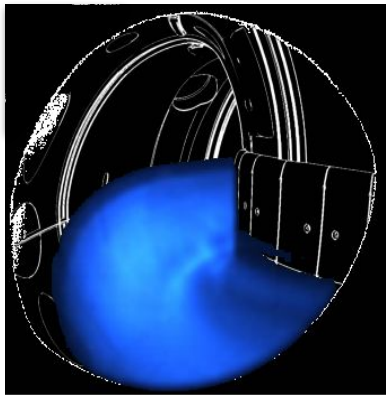




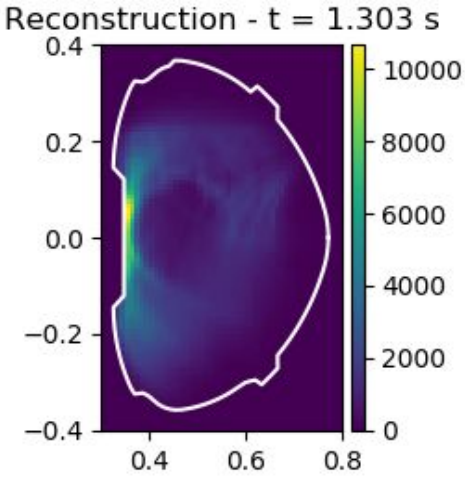
Other successful inversions @COMPASS

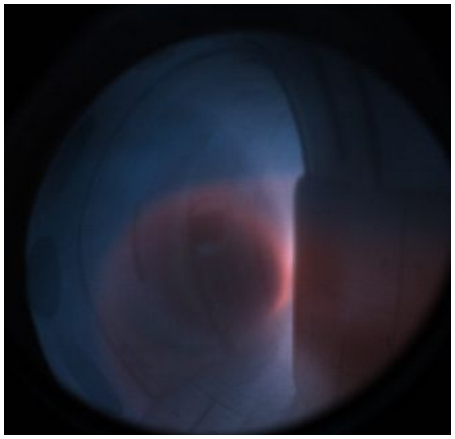
Tomographic inversion of a runaway beam



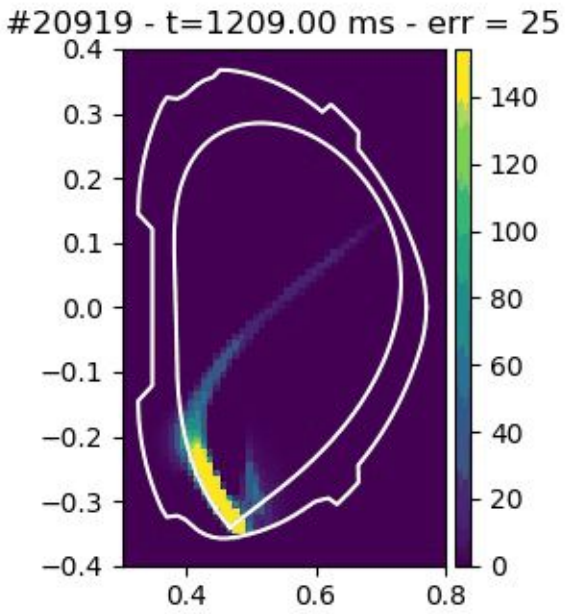


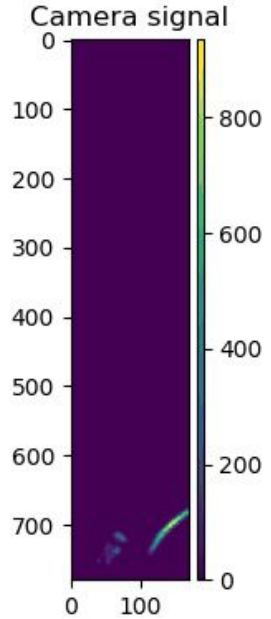
Tomographic inversion of a circular plasma





Tomographic inversion during detachment experiment



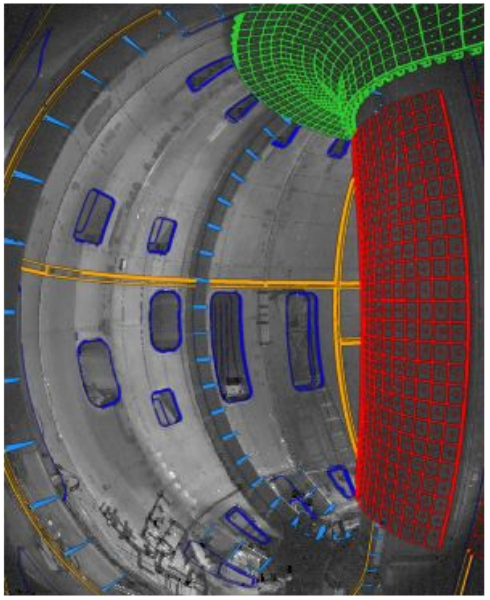


The inversion performs well for different plasma configurations

Work Plan in modeling (1/3)

- **2021: Achieved milestones**
  - Code development
    - Code calculating the geometrical matrix assuming toroidal symmetry
    - Implementing second algorithm (biorthogonal basis decomposition) to Python (more versatile)
    - Adapting code to be operational on JT-60SA servers
  - Benchmarking code**s**
    - COMPASS: Runaway electron beam, circular plasmas…
    - TCV: Electron cyclotron plasmas
  - Camera modelisation
    - Calcam calibration for EDICAM camera
- **2021: Achieved Deliverables**
  - Presentations
    - One presentation in front of EU side
    - One presentation in front of QST side
    - One presentation at the plasma team meeting
    - One presentation at the WPSA Project Planning Meeting

Got access to the QST servers (FOB, credentials, nomachine…)



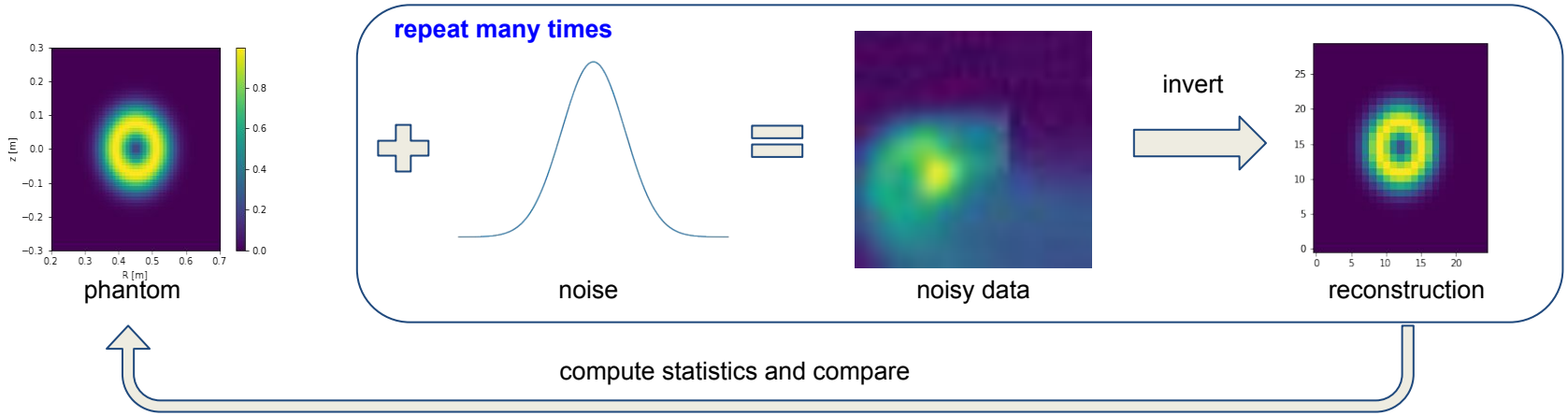
Tomography inversion algorithm ready to be applied to EDICAM data

Work Plan in modeling (2/3)

- **2021: Future milestones**
  - Code development
    - Make code run on JT-60SA servers (libraries…)
    - Testing further second algorithm (biorthogonal basis decomposition)
  - Camera modelisation
    - Calcam calibration for other cameras (at section P15)
- **2021: Future deliverables**
  - Comparison of tomography results with 1D electron cyclotron code

Work Plan in modeling (3/3)

- **2022 / 2023 / 2024 / 2025:**
  - **Possible milestones**
    - Combining different camera views
    - Raytraced geometry matrices
    - Improvements of current algorithms and/or implementation of new ones
    - Implement helicoidale symmetry (along field lines)
    - Test of robustness of algorithm
      1. Check precision and accuracy by Monte Carlo simulations
      2. Investigating the effect of reflections...
  - **Possible deliverables**
    - Improve robustness of the tomographic inversion
    - Continue comparison with plasma models

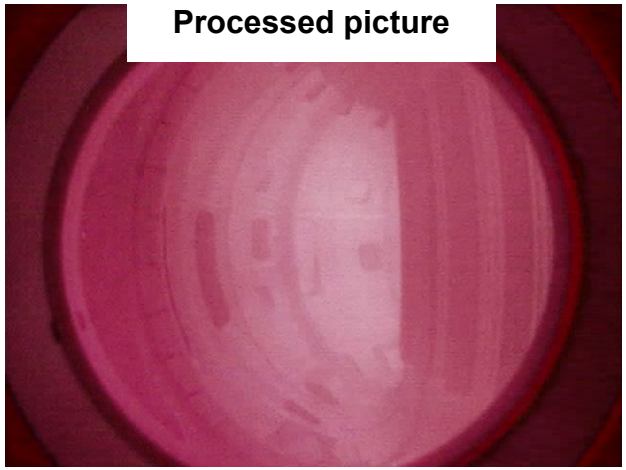


Work Plan for operation (1/2)

- **2021: Achieved milestones**
  - Image processing
    - Post processing of visible camera data located at section P15
- **2021: Milestones & Deliverables**
  - Apply tomography code to camera data
    - Electron cyclotron plasmas
    - Circular / D-shaped…
  - Help in general analysis of camera data
    - Experience from COMPASS (EDICAM)
    - Tools for post processing of tomographically inverted data

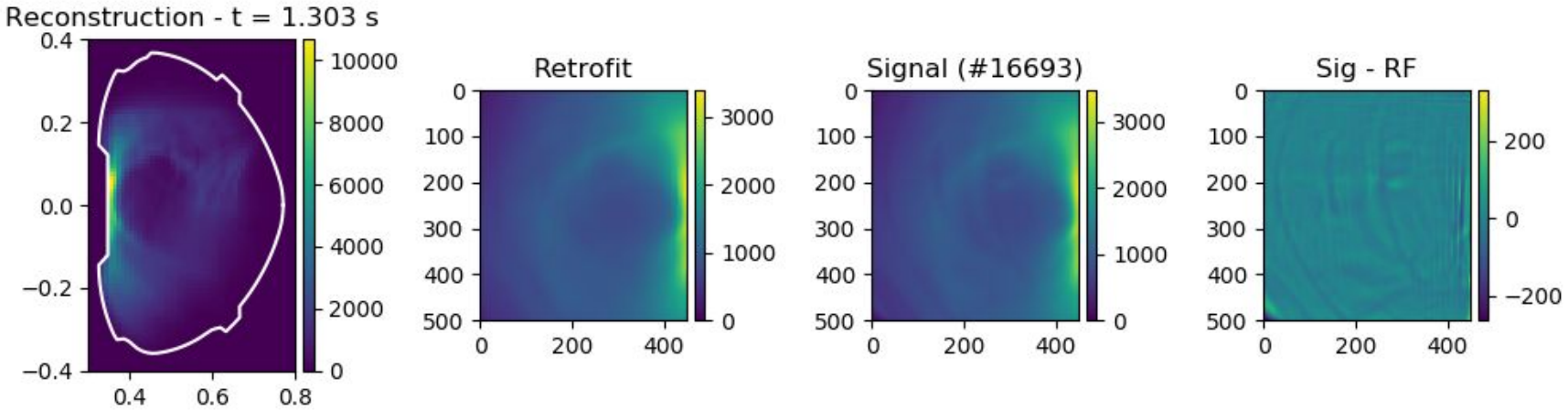
Raw picture from vis camera at P15

Processed picture



Work Plan for operation (2/2)

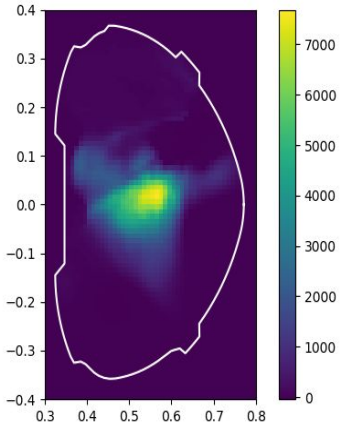
- **2022 / 2023 / 2024 / 2025:**
  - **Possible milestones**
    - Light observation with filters in front of the camera
    - Automatisation of algorithms (after shot results)
    - Possibility to go for real time analysis
  - **Possible deliverables**
    - Apply tomography for different plasma scenarios (not only electron cyclotron ones)
    - Development of new and improvements of existing post-processing tools
    - Provide feedback on plasma conditions as soon as possible

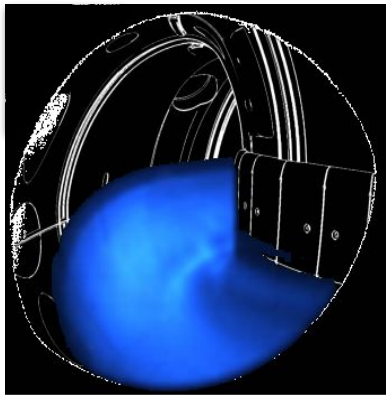


The algorithms could also be applied to circular plasmas, runaway beams… for instance

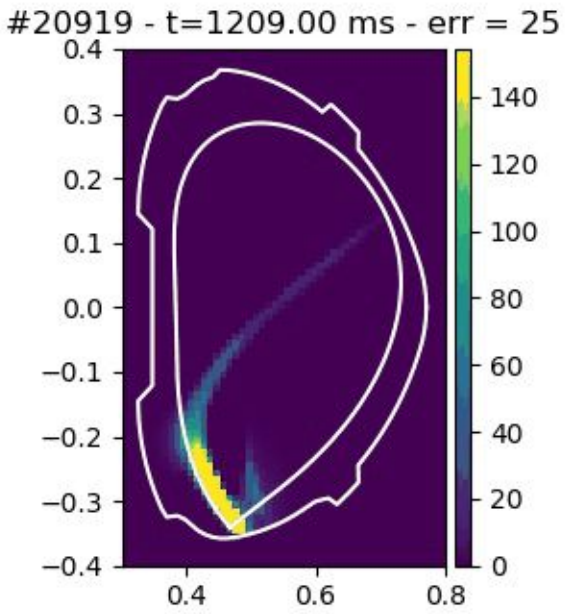
Summary of code capability

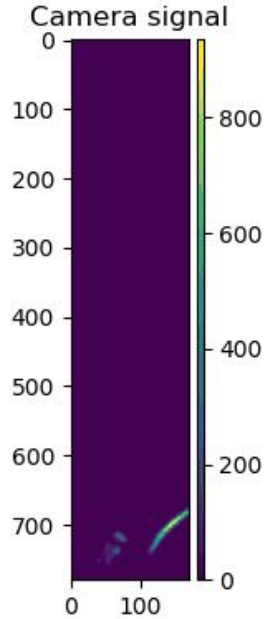
Tomographic inversion of a runaway beam @COMPASS



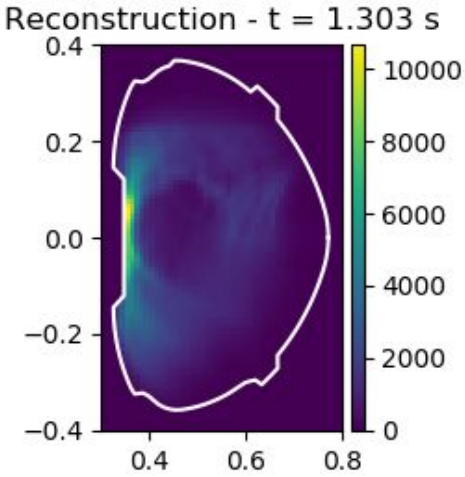


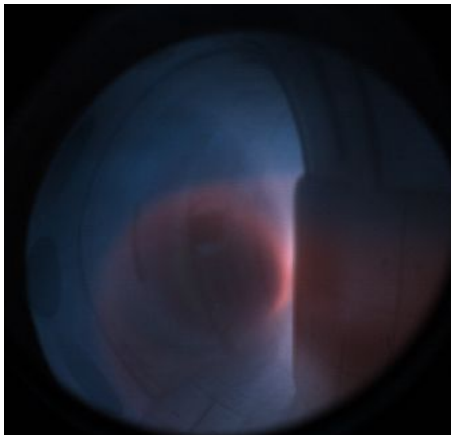
Tomographic inversion during detachment experiment @COMPASS





Tomographic inversion of a circular plasma @COMPASS





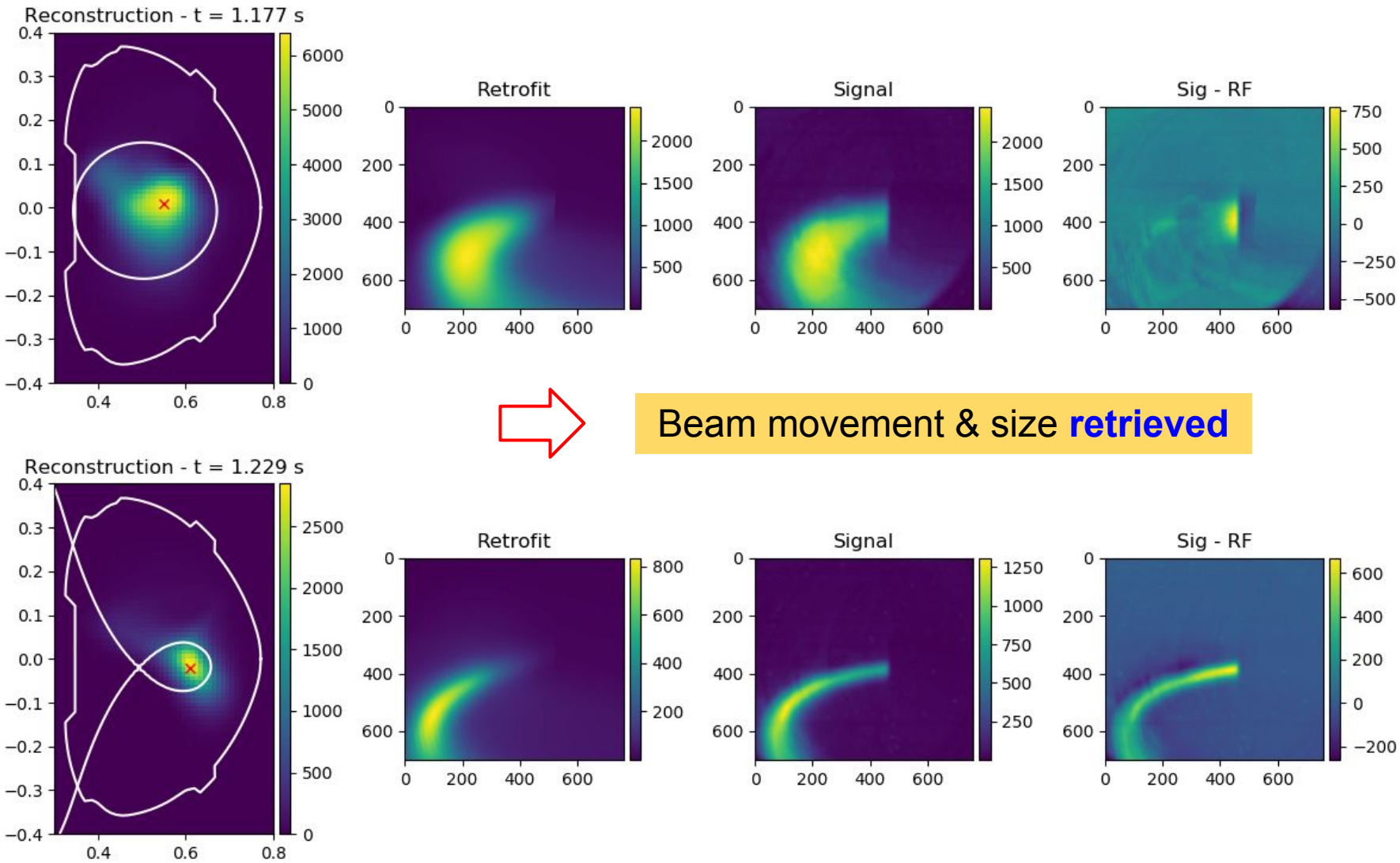
The inversion performs well for different plasma configurations

Agreed deliverables

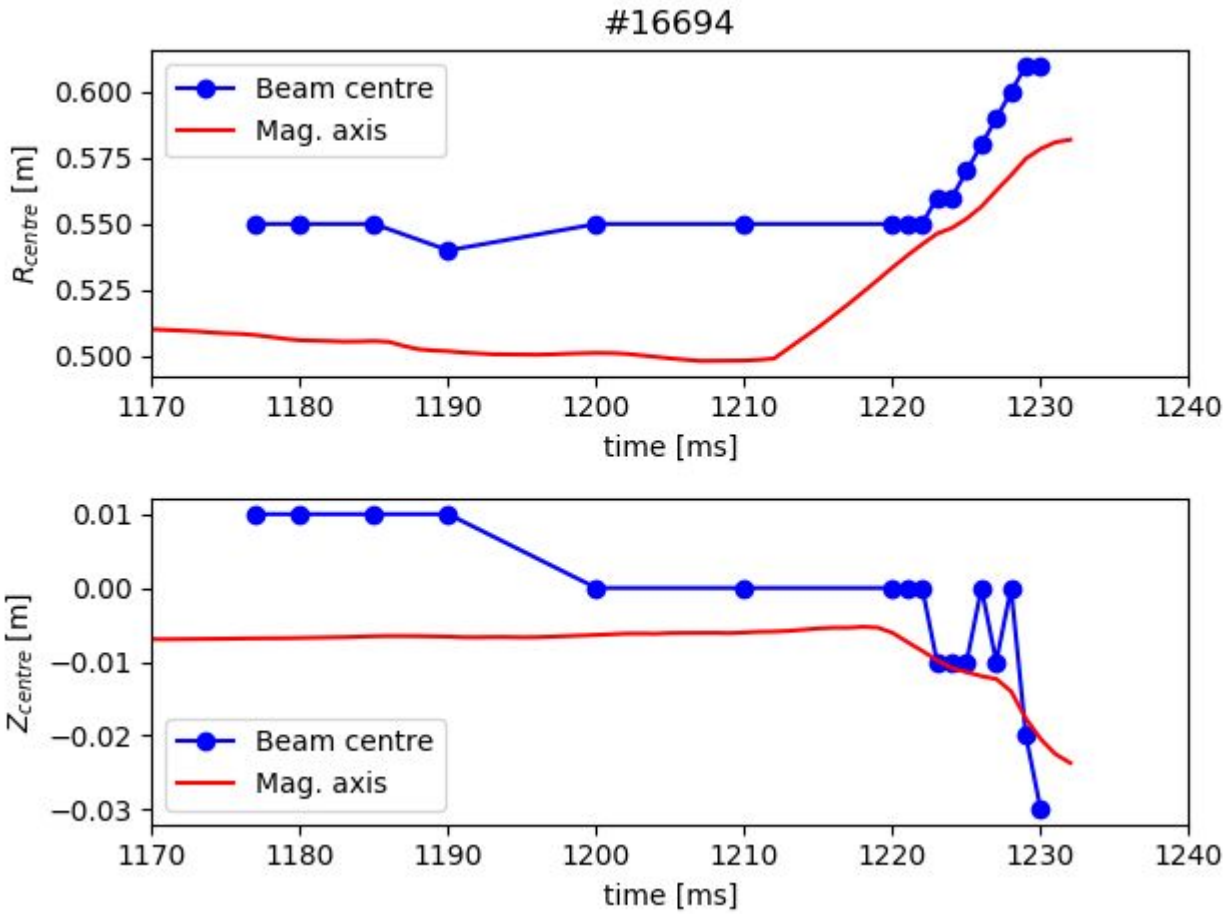
- **Operation**
  - **2021:**
    - Possible travel to QST
    - Apply code to data (hopefully)
    - Make a summary of achieved results (presentation / report)
- **Modelling**
  - **2021**:
    - Already many milestones achieved (see previous slide)
    - Code ready to be used by local user on QST server
  - **2022**:
    - Code available by general users (not locally only)
    - Comparison of tomography results with 1D electron cyclotron code

Back-up slides

Illustrative reconstructions of runaway electron beam (#16694)

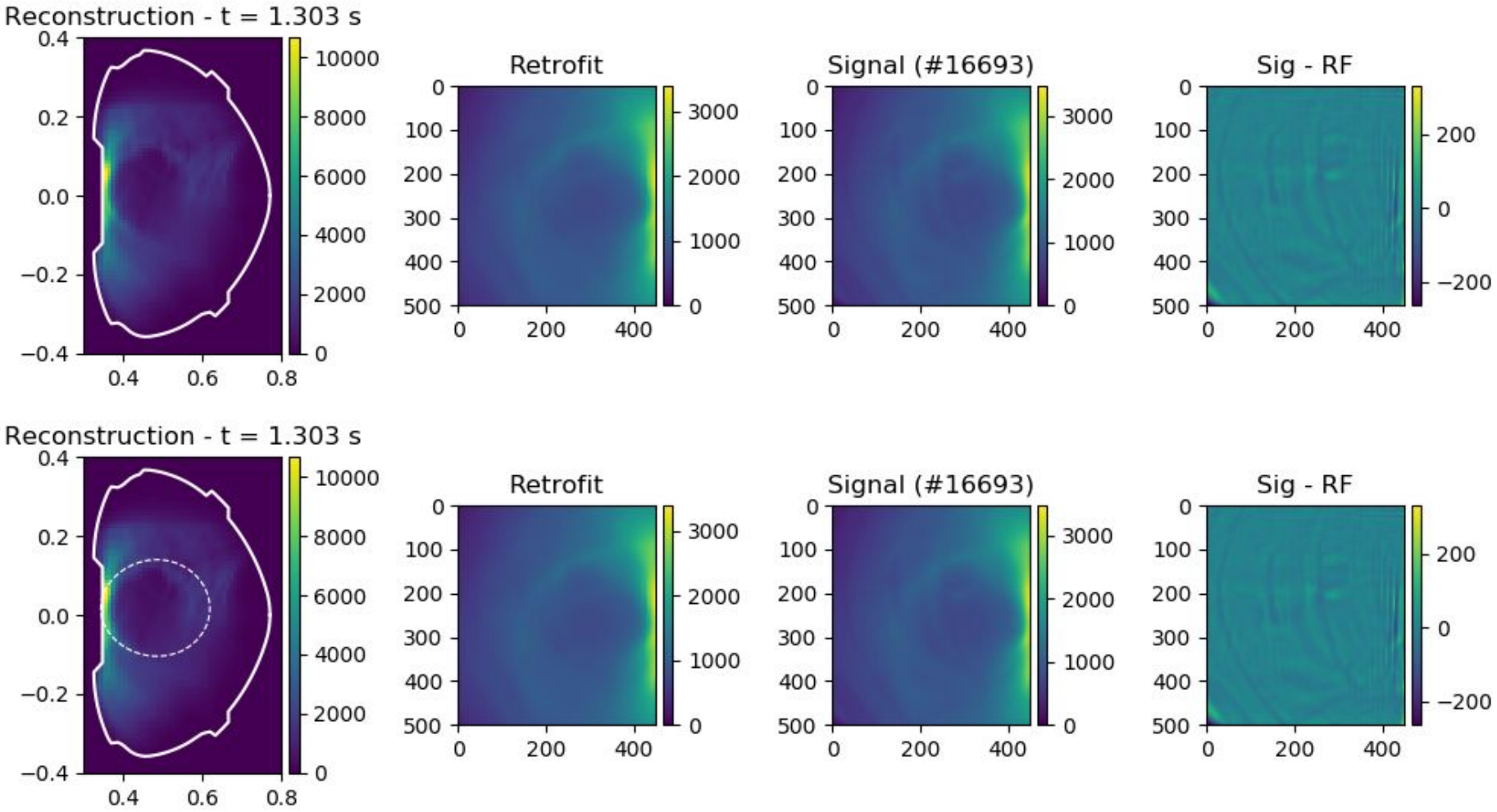


Runaway electron beam movement vs magnetic reconstruction



Plasma position and movement can be inferred = **promising for JT-60SA**

Circular plasma observation at COMPASS



Plasma shape and contact at high field side **retrieved**

Electron cyclotron beam path at TCV

- Camera probably **blind in the top part** (Z>0.2 m) → not seeing the first beam path
- The beam path explains the **asymmetry in Z**