Iota profile measurements on W7-X

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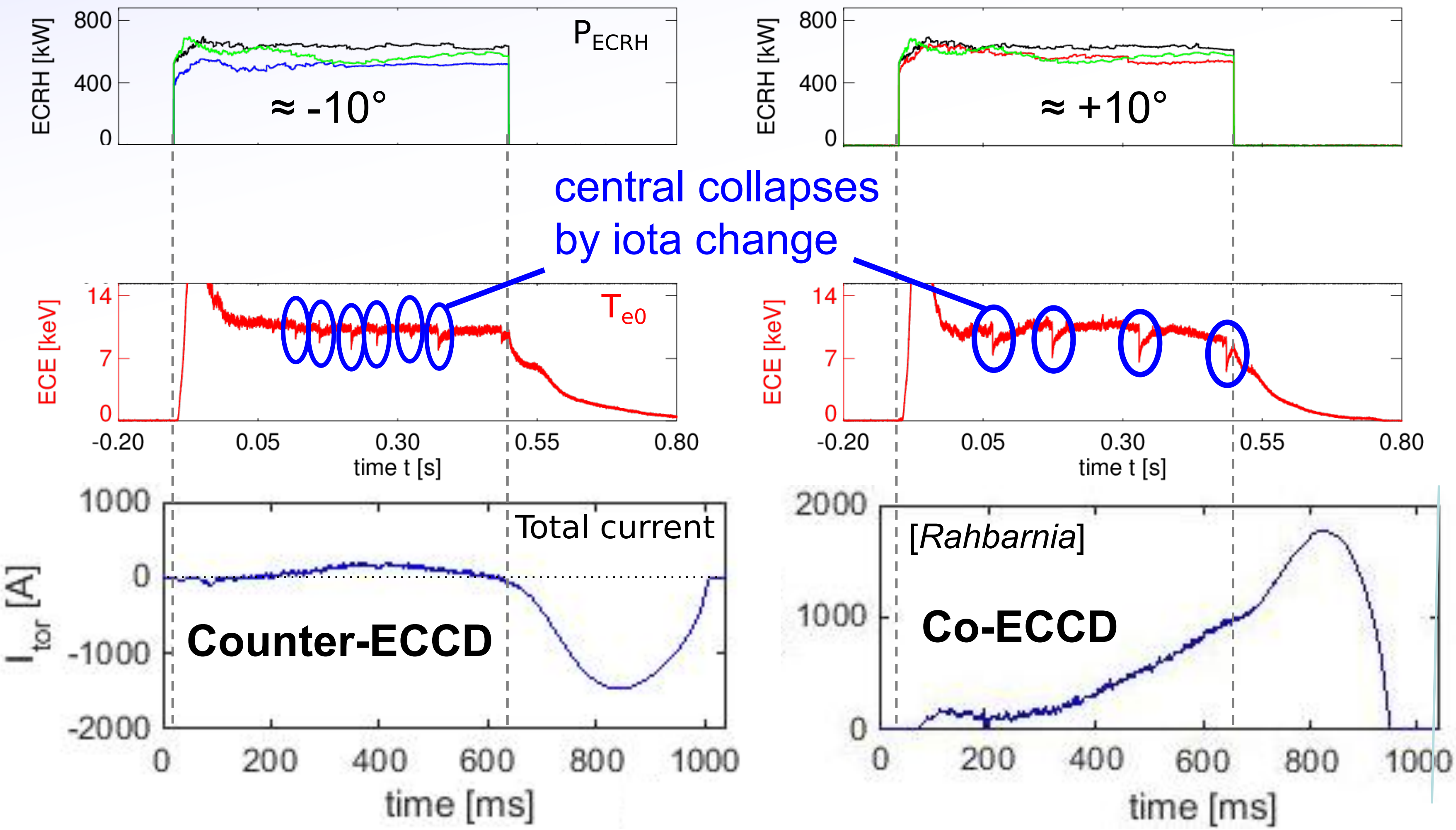
Iota profiles

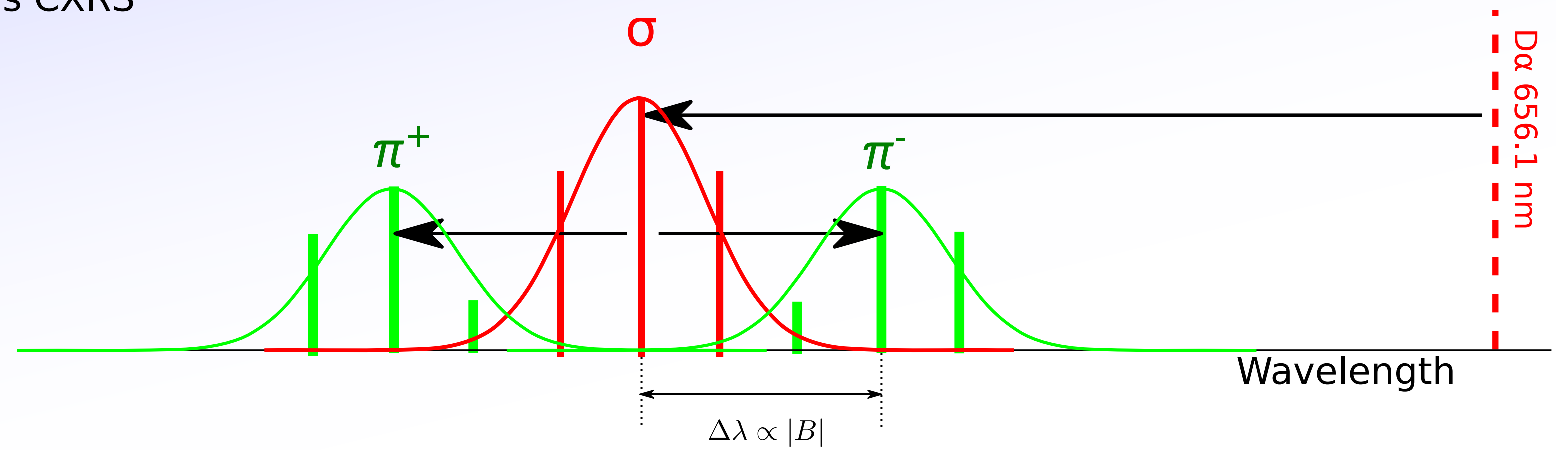
Iota profiles required for ECCD verification
- Where is exactly is current driven? how localised? shielding currents?
- Crashes - reconnection? Sawteeth like?



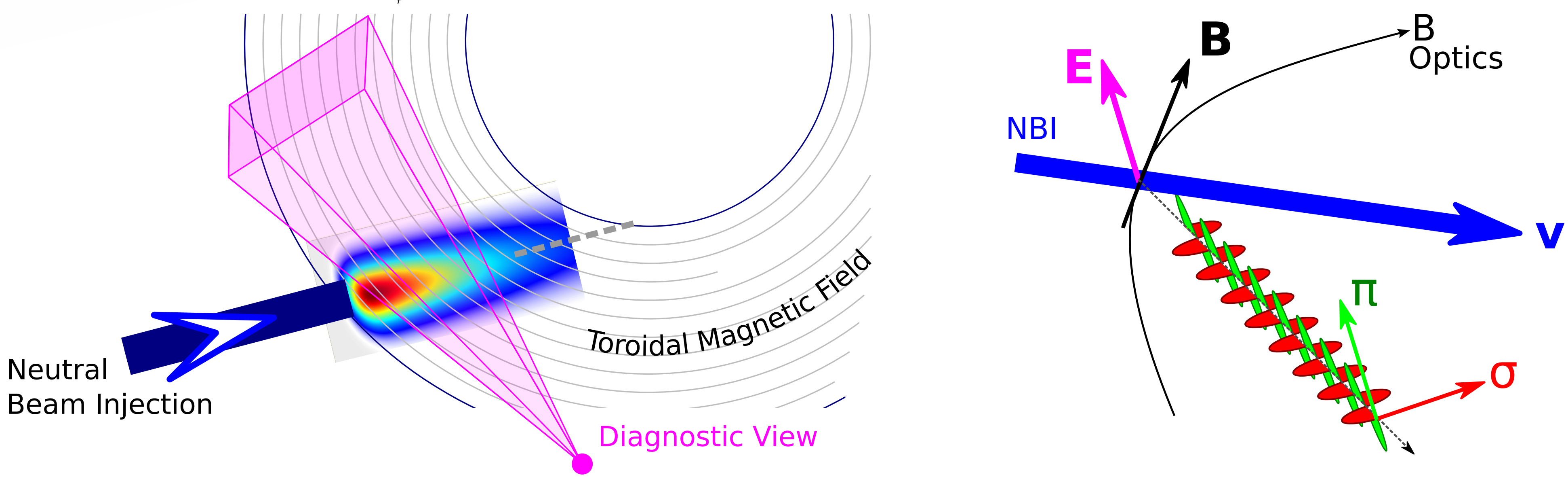
Motional Stark Effect

- Active beam spectroscopy gives internal measurements B through motional stark effect.
- Same optics/LOSs as CXRS

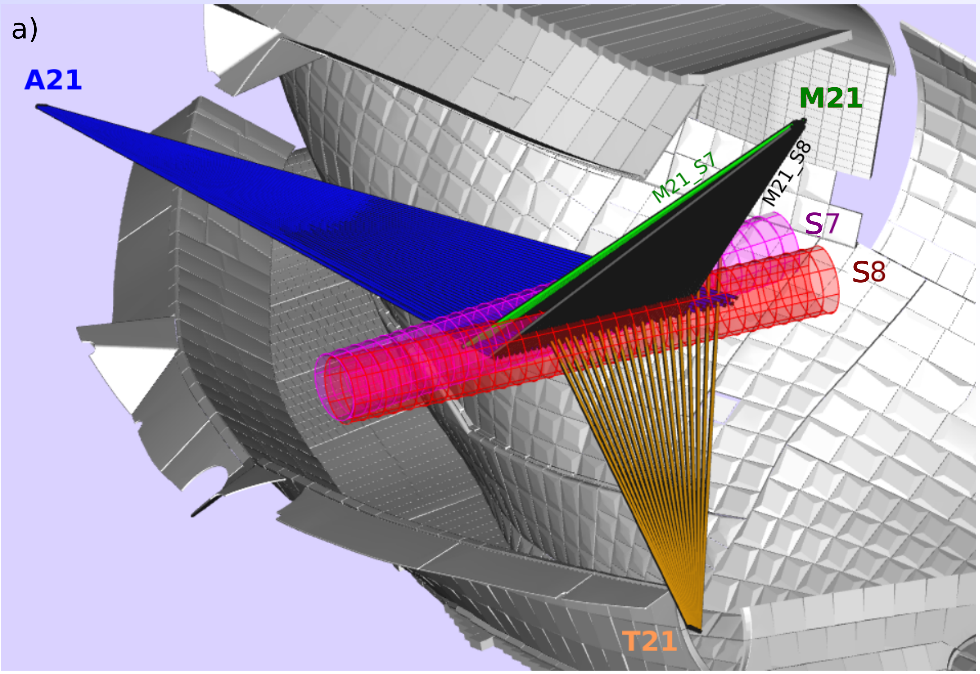
- Splitting: $\Delta\lambda \propto |B|$

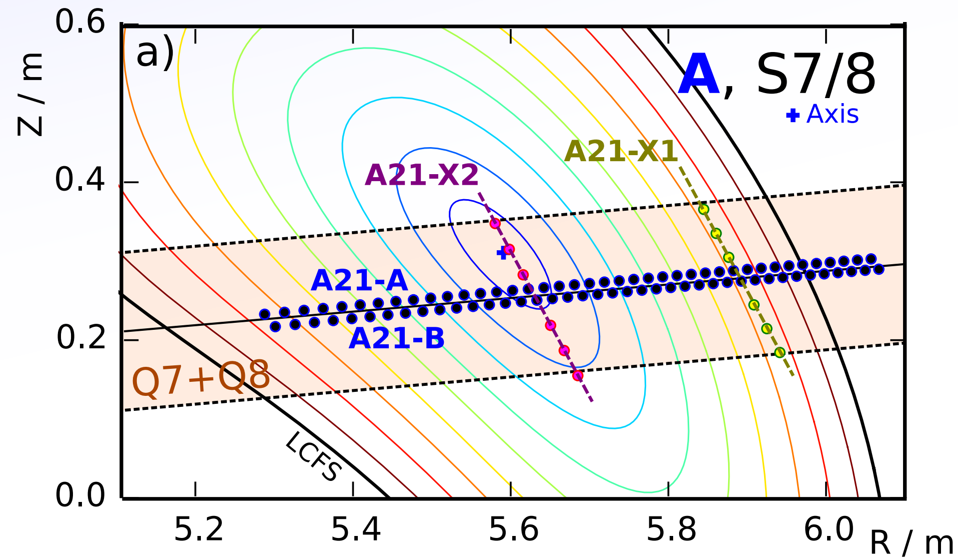


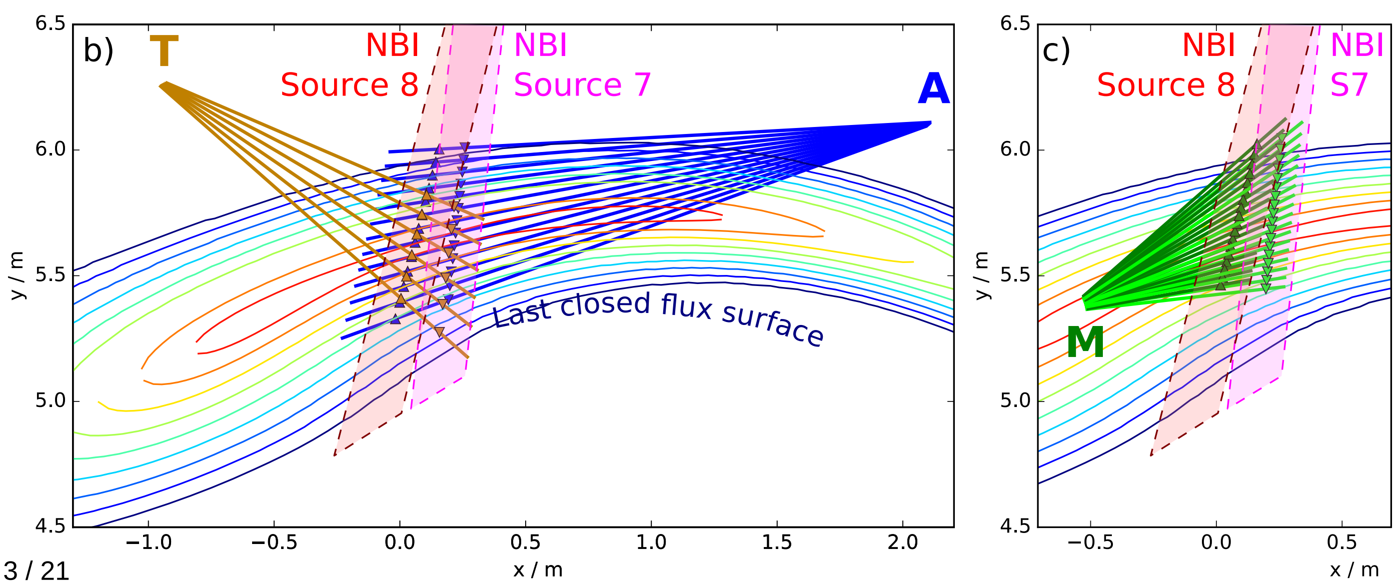
- Polarisation angle --> $\frac{B_z}{B_\phi}$



CXRS Optics


a)
A21
M21
M21_S7
M21_S8
S7
S8
T21

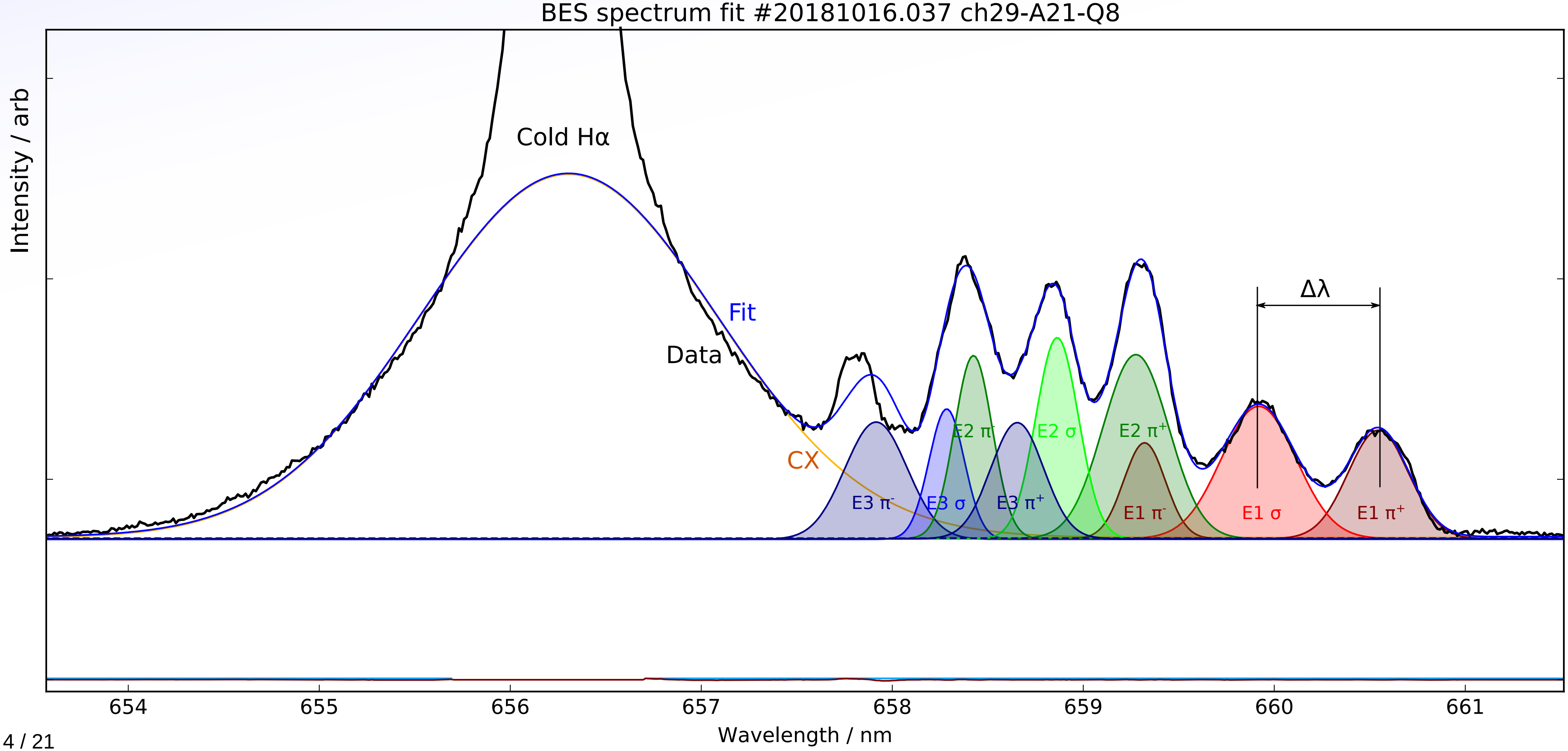

a)
A, S7/8
Axis
A21-X1
A21-X2
A21-A
A21-B
Q7+Q8
LCFS
Z / m
R / m
0.0
0.2
0.4
0.6
5.2
5.4
5.6
5.8
6.0


b)
T
NBI
Source 8
NBI
Source 7
A
Last closed flux surface
y / m
x / m
c)
NBI
Source 8
NBI
S7
M
4.5
5.0
5.5
6.0
6.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0

OP1.2b: BES |B| Measurements

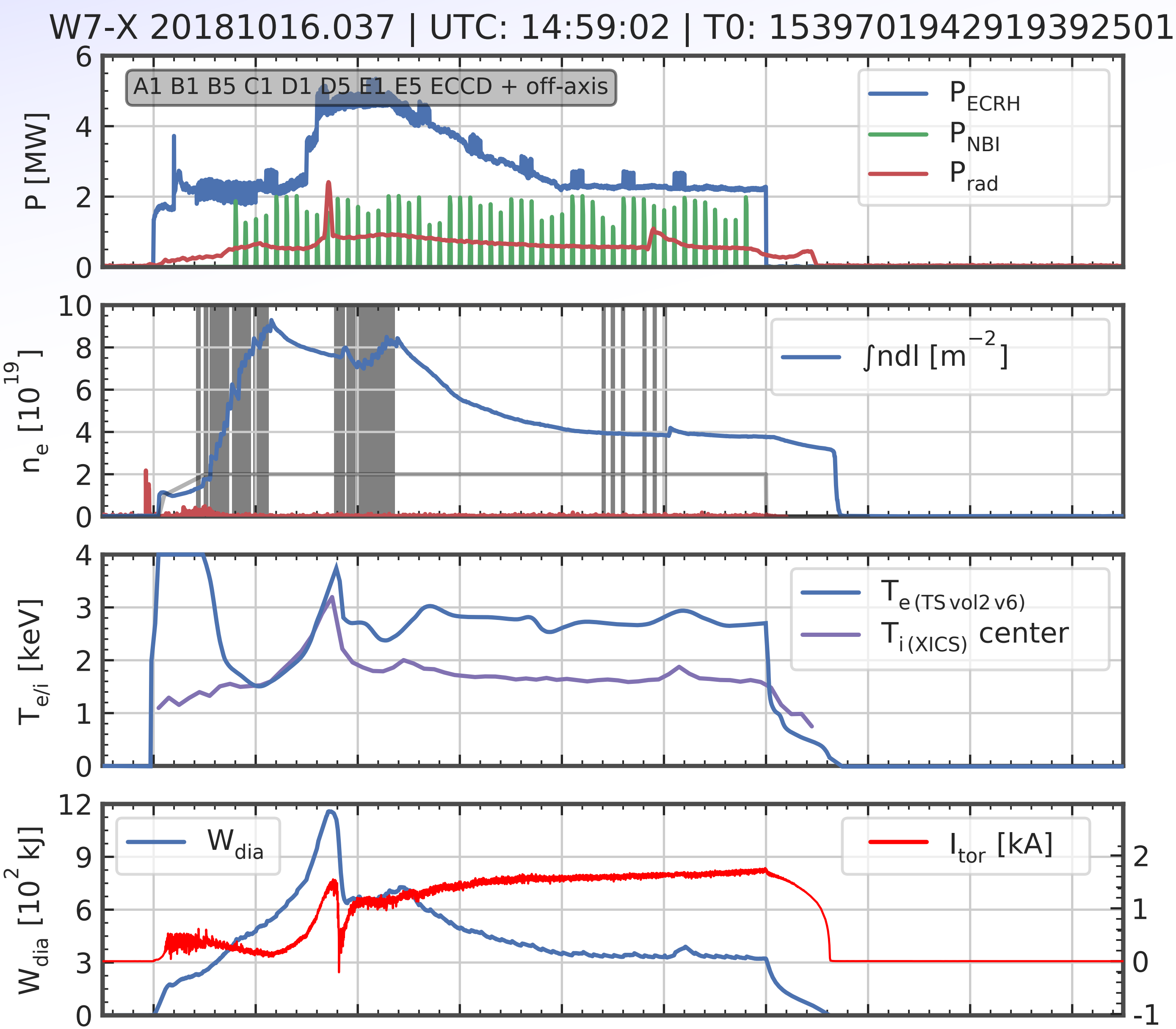
CXRS/BES (Beam Emission Spectroscopy) in OP1.2b measured Hα spectrum of beam for purpose of beam density + FIDA measurements.

Unexpectedly good signal allows accurate fitting of MSE E1 σ and π^+ components.
Possible to derive |B| from this:



OP1.2b: BES |B| Measurements

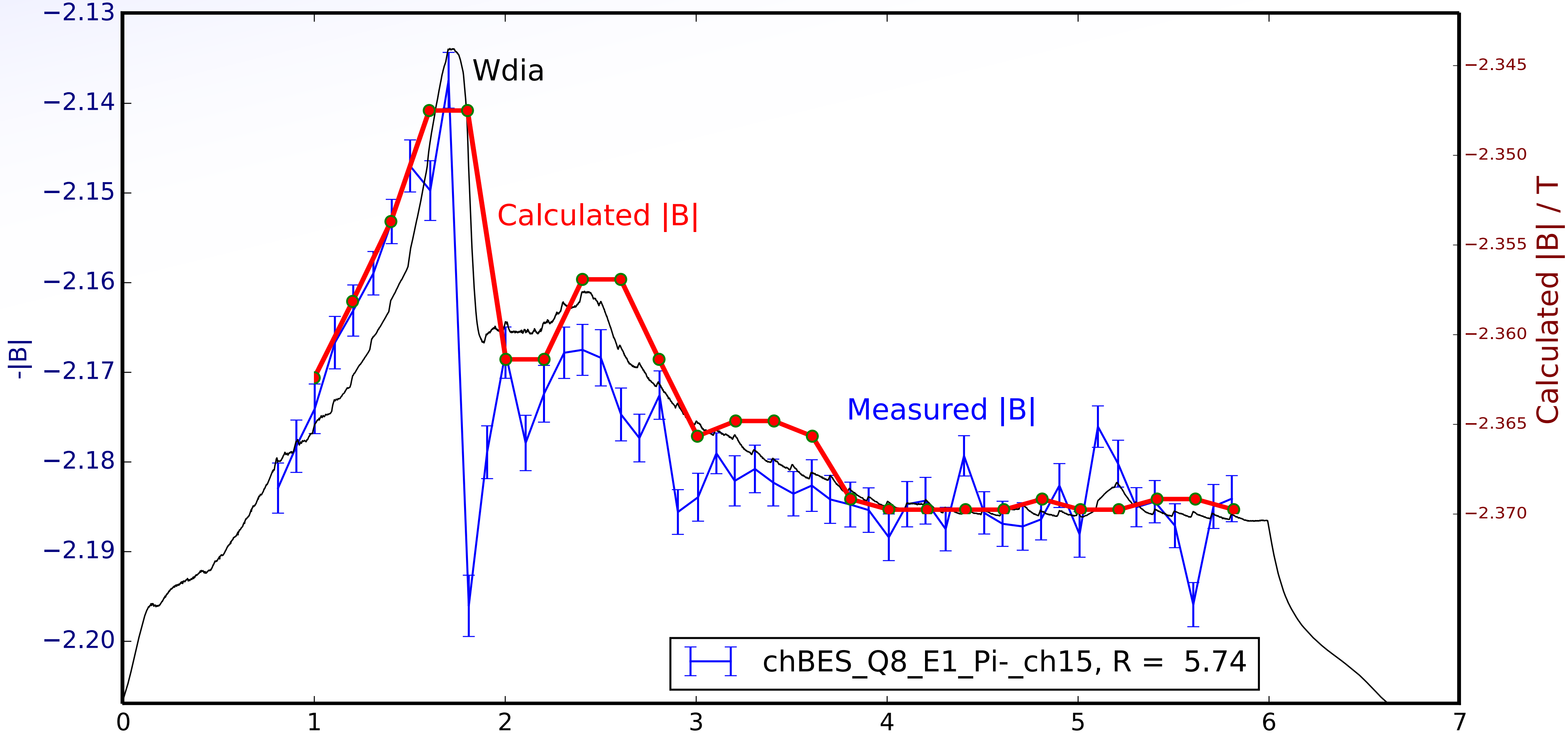
Only examined one shot so far: High-performance pellets discharge:



OP1.2b: BES |B| Measurements

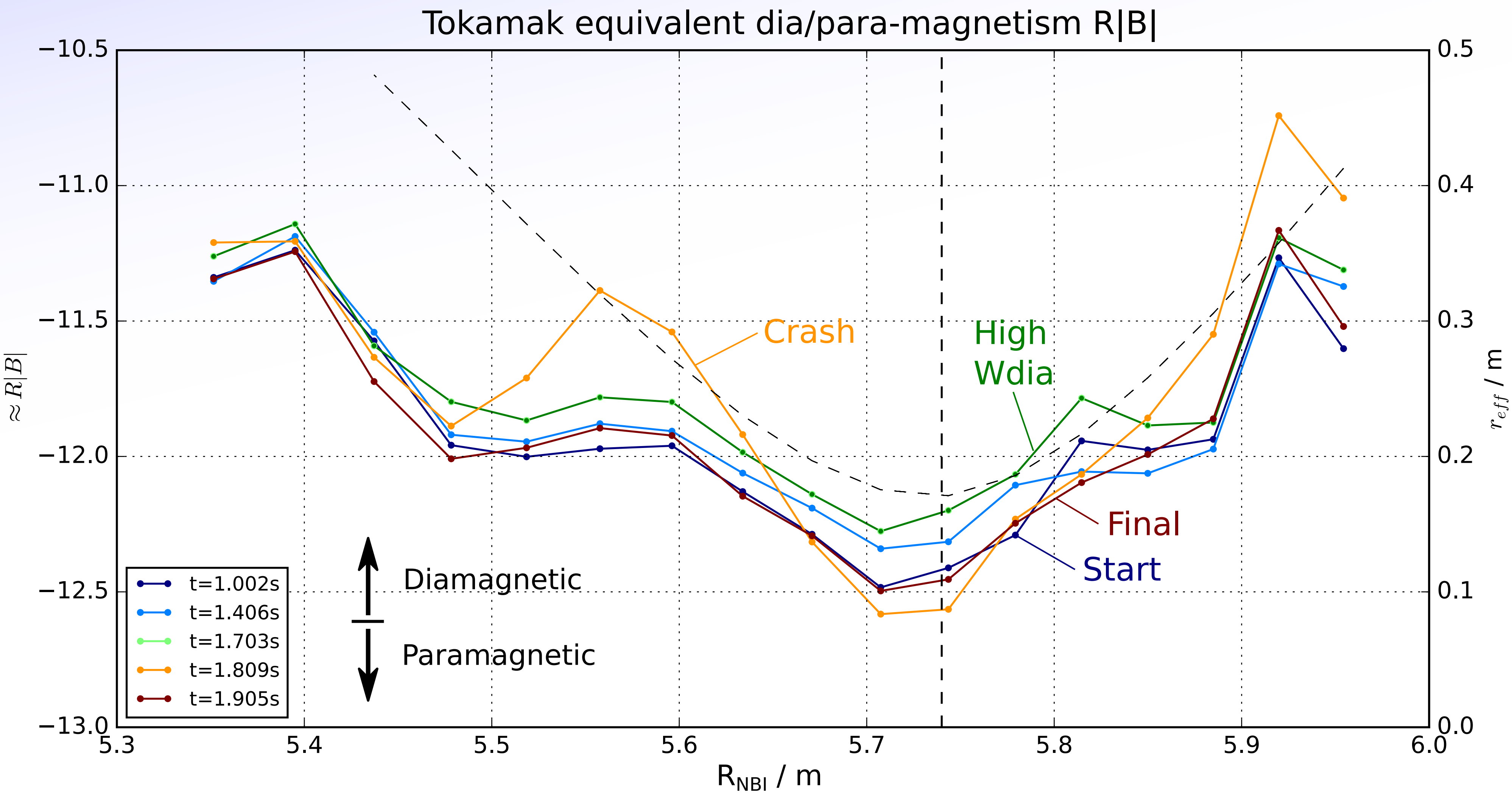
Only examined one shot so far: High-performance pelletrs discharge #20181016.037
- |B| Measurement mostly follows W_{dia} and |B| predicted by VMEC, apart from at crash.

(and a factor of 2 in variation, with arbitrary offset, for some reason)



OP1.2b: BES |B| Measurements

Full profile available:

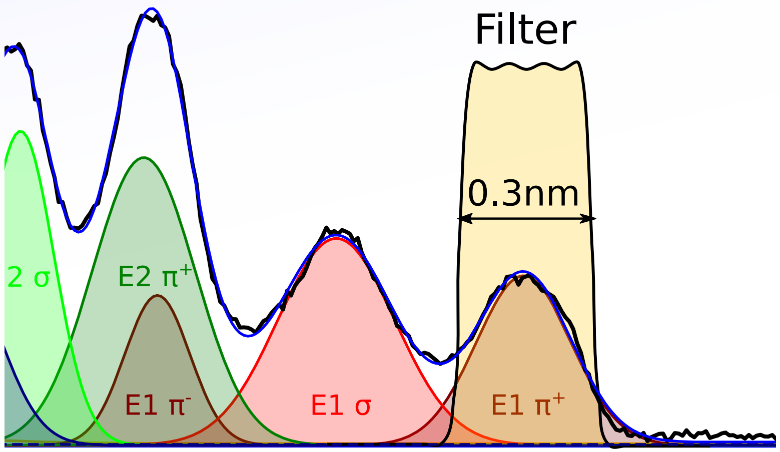


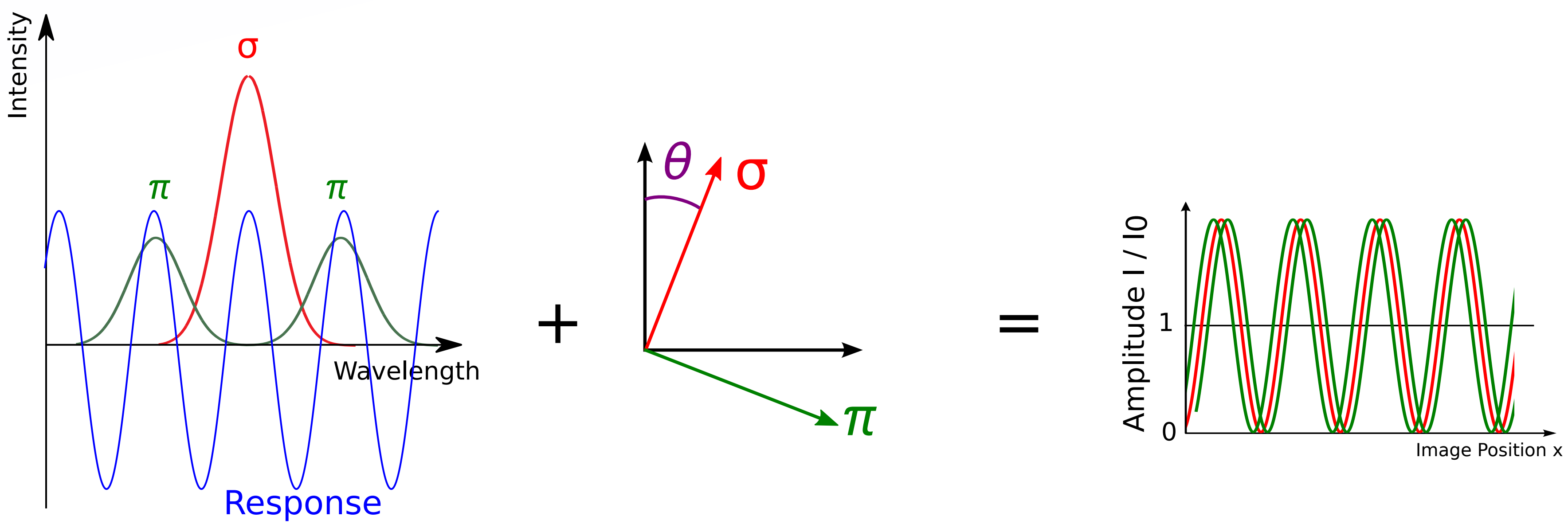
Polarisation

Polarisation measurements require more sophisticated hardware.

1) Filters and photo-elastic-modulators (PEMs)
    - Limited S/N and problems with systematics.
2) Imaging MSE
    - Works well at ASDEX Upgrade.

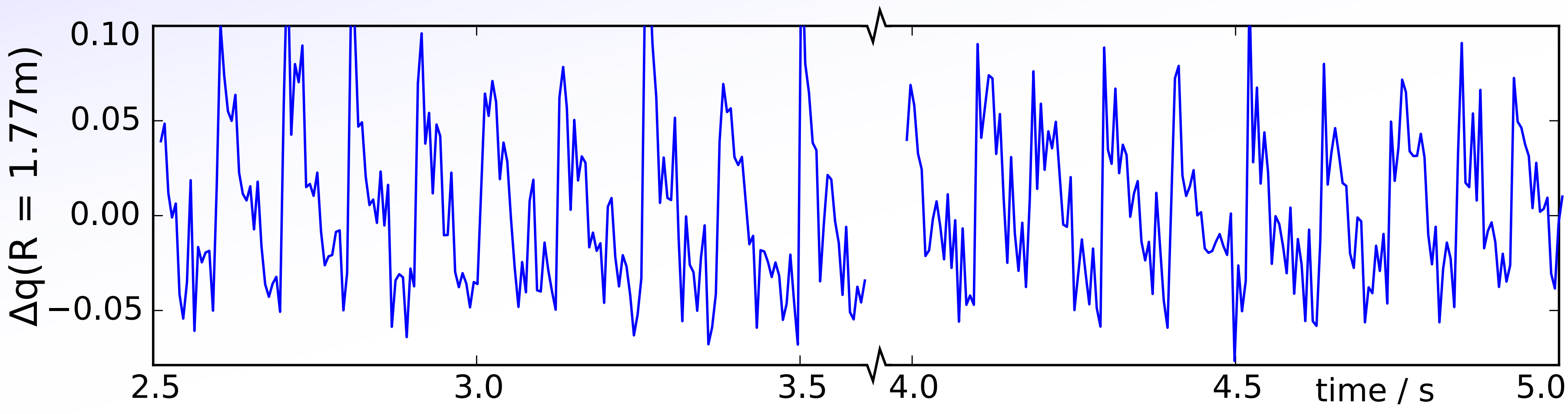
Same hardware as Doppler CIS (V. Perseo - E4) but use spectral separation to counteract polarisation orthogonality, allowing imaging with whole spectrum.

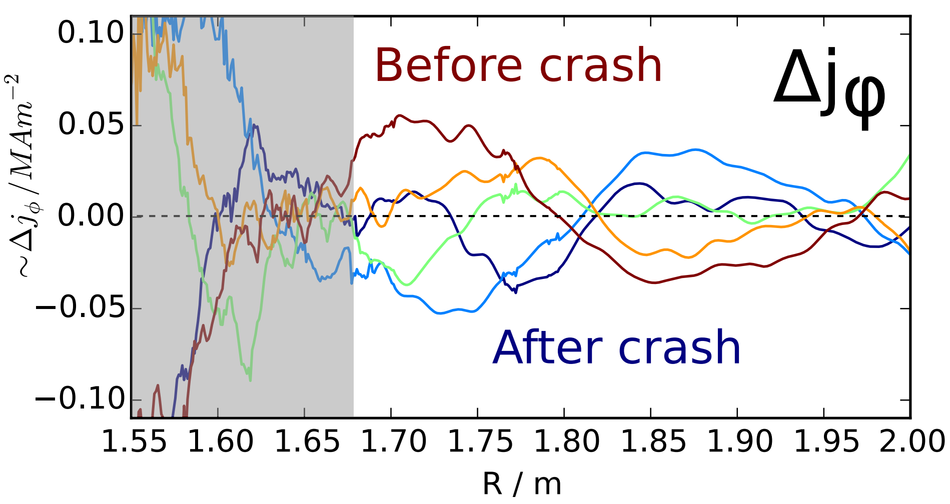


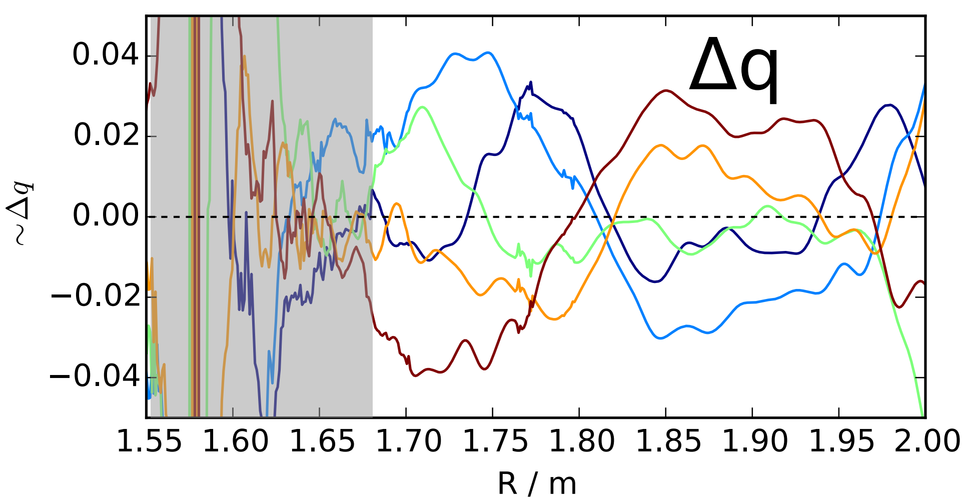


Imaging MSE

On ASDEX Upgrade, IMSE was able to produce unprecedented sensitivity to *q* profile **changes**:
- Calibration for absolute *q* however not yet reliable.
- Calibration against assumed vacuum configuration in W7-X would be much easier.

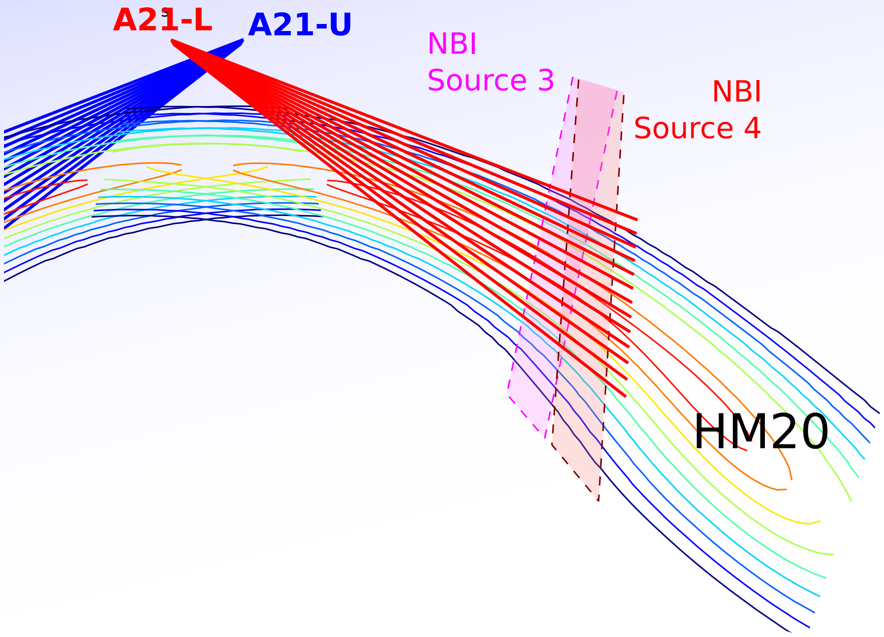


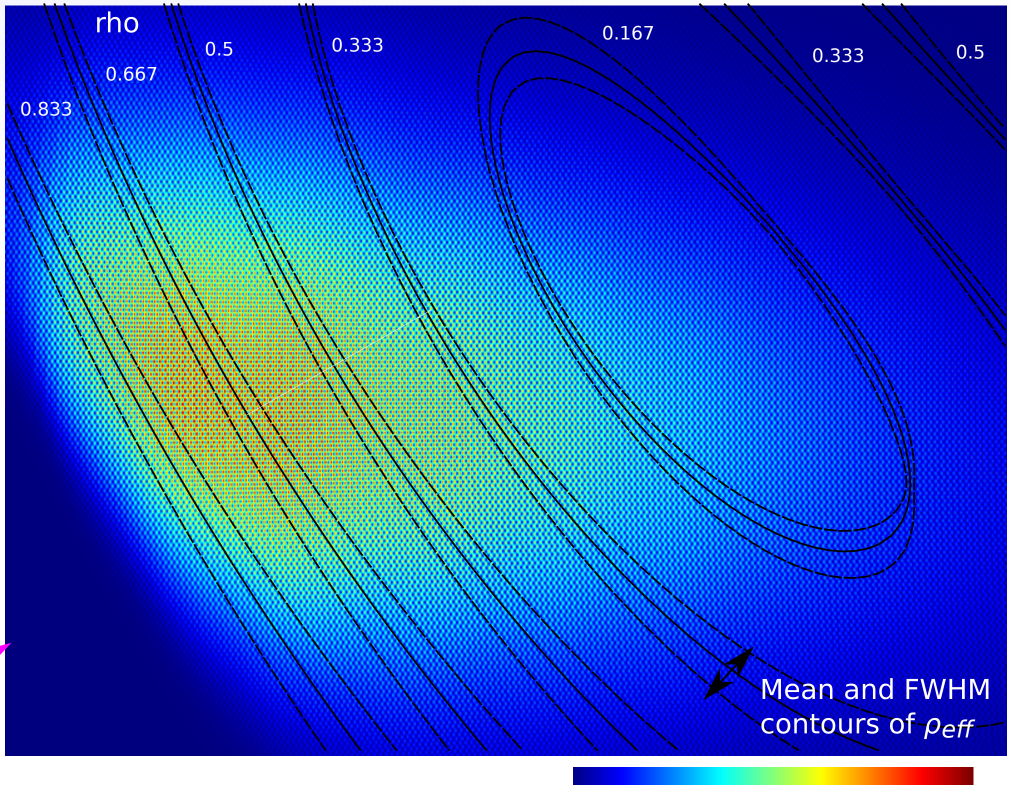


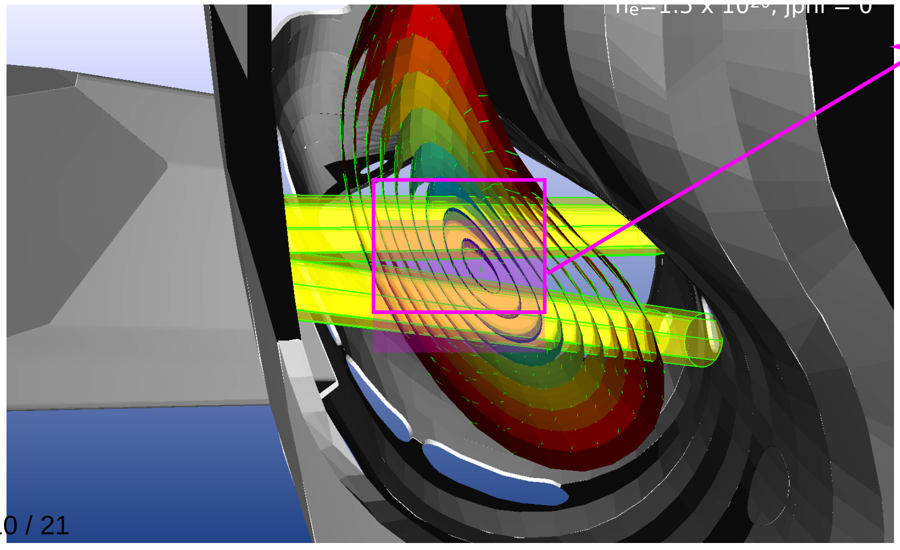


Imaging MSE

Some initial modelling done for IMSE on W7-X (ISHW 2012):

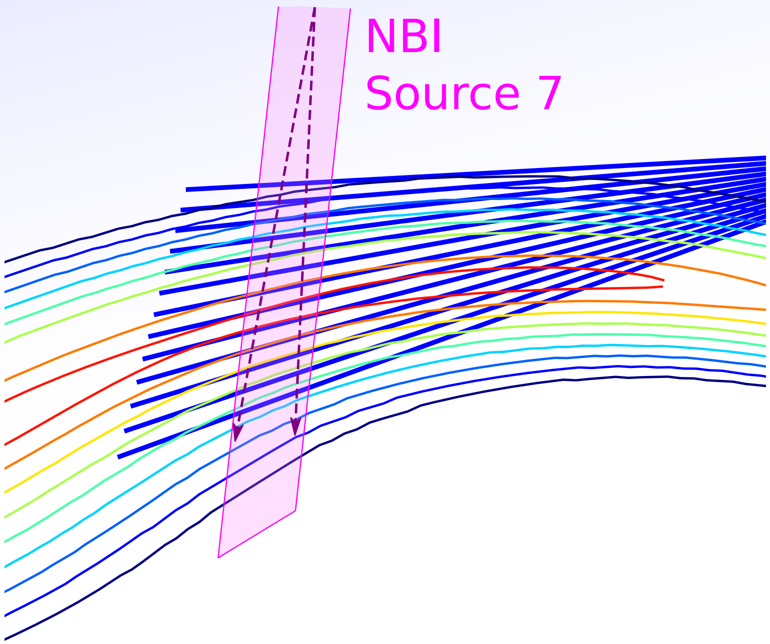


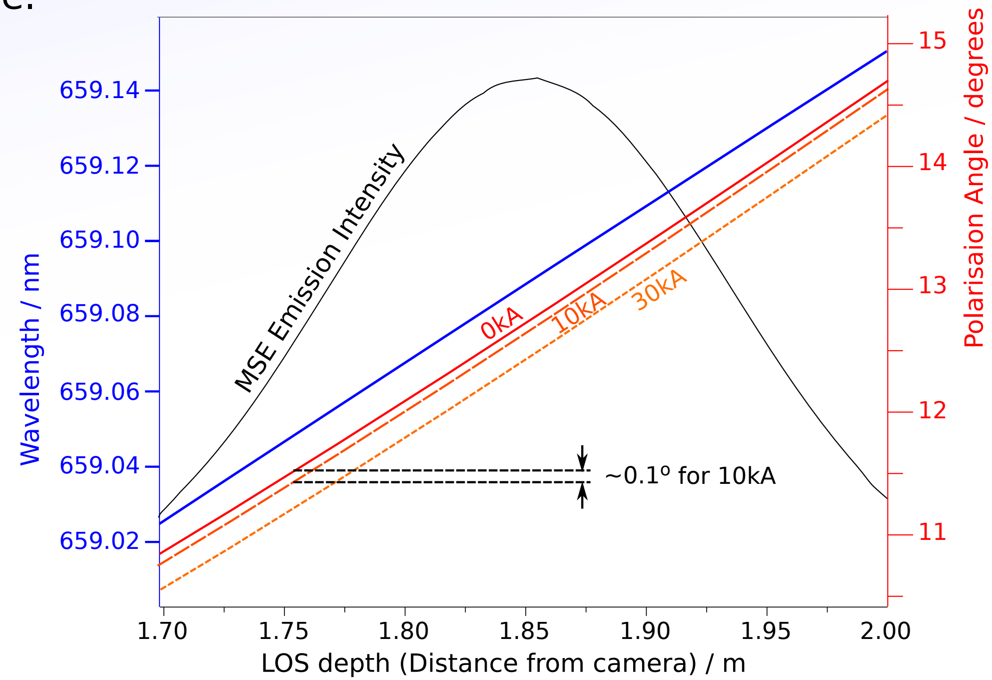




MSE Polarisation in Stellarators

- In Tokamak, view parallel to flux surfaces ensures no change in pitch over beam width.
- In Stellarator, the pitch changes strongly along a surface.
- Dopper shift also changes due to beam divergence.

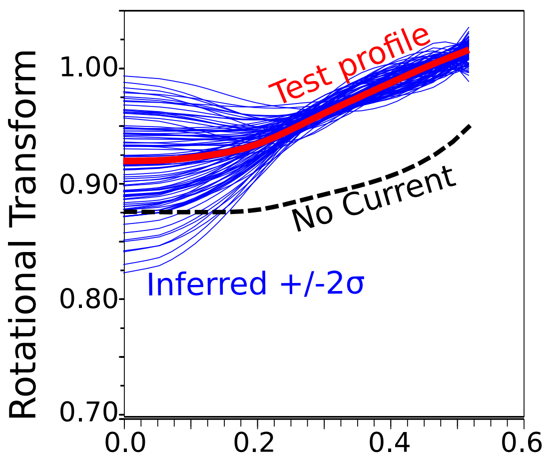


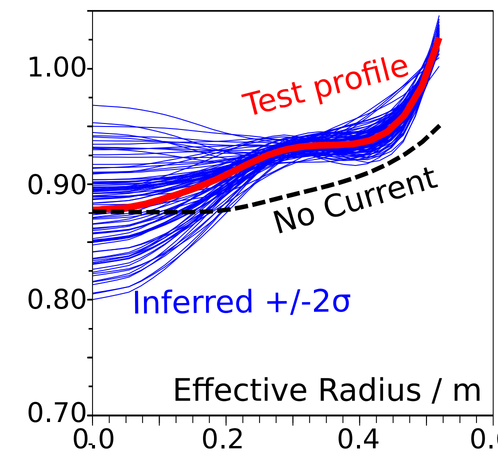


- Any small change in beam width / shape / attenuation etc. will lead to changes in the measured angle.

- Ignoring this, reconstruction ability should be good for mid-radius to edge.

- Iota/q is always hard in the very core!





Spectro-polarimetry

Simple approach:
- Measure spectrum through 4 polarisers
- Allows derivation of polarisation angle accross beam depth.

Used at LHD [K. Ida RSI. 2005]:

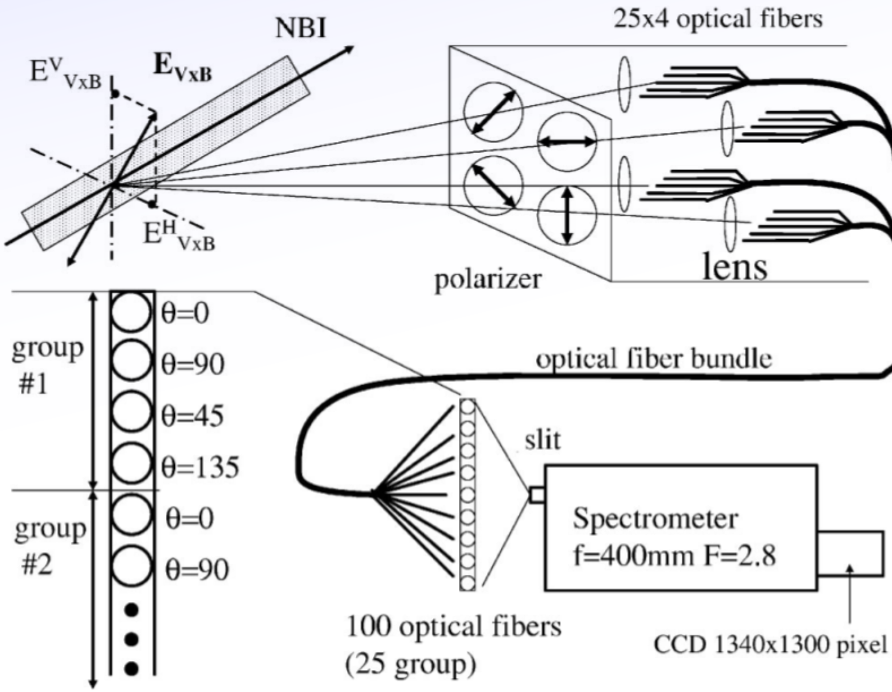
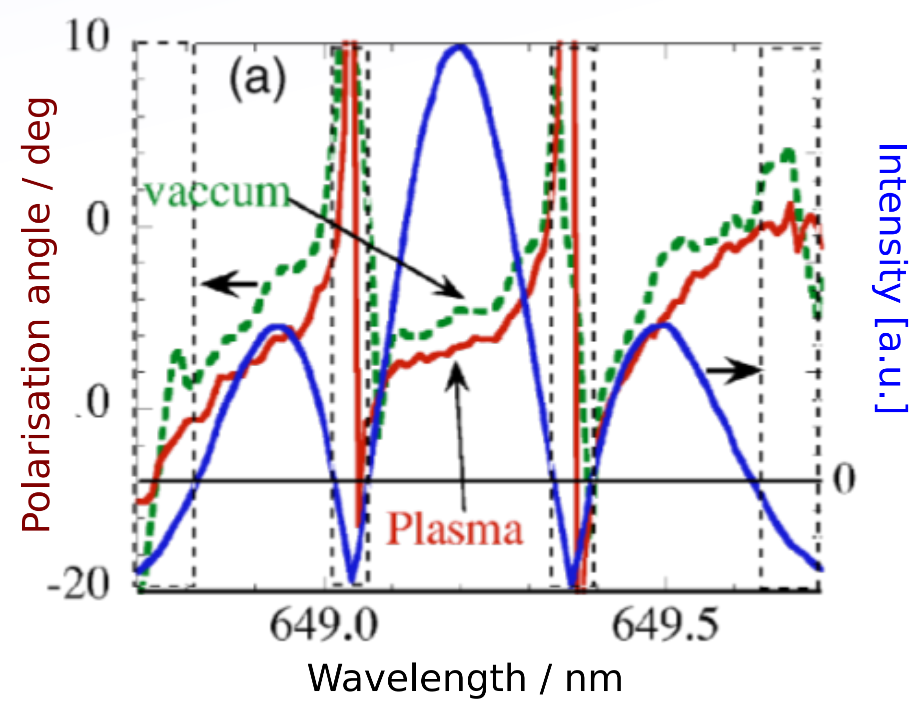


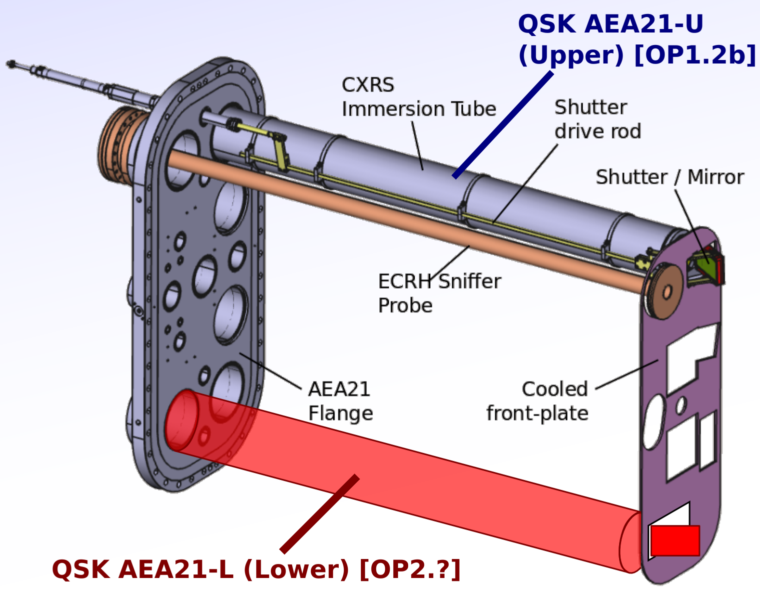
FIG. 1. Experimental setup for motional stark spectroscopy in LHD.

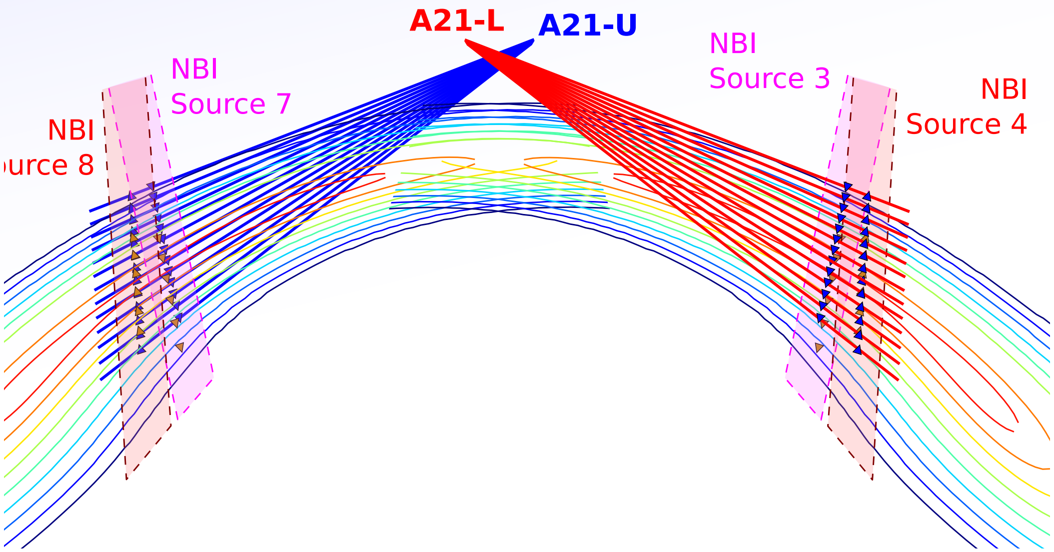


+ Low systematic error
+ Simple to implement, low cost
- Limited spatial resolution (4 channels per measurement)
- Limited time resolution

OP2 Possibilities

1) Add vacuum components for toroidal (A) observation of NI20:





- 10 - 15k€ for in-vacuum and barrier components.
- Optics can be decided later (and purchased).
- Could be shared (time or light) between:
  CXRS - But we would need more channels and spectrometers!
  CXRS CIS (Experimental)
  MSE / IMSE
  CIS (E4),
  Video (E4),
  BES (E5)

Summary

- Investigation/intention to measure iota profiles from Motional Stark Effect
- Will be implemented as part of CXRS / BES system.

1) |B| Measurements from BES
    - Already some data from OP1.2b - Looks promising
    - Easy to implement
    - May need to add extra fibres to CXRS for this (500€ / channel)

2) Polarisastion measurements
    - Needs careful modelling of best approach
    - Feasiblity study (Post-doc starting ~summer 2019)
    - Propose to install 2nd CXRS AEA21 Immersion tube in preparation for this.
    - IMSE prototype might be possible as temporary modification to E4's CIS system.

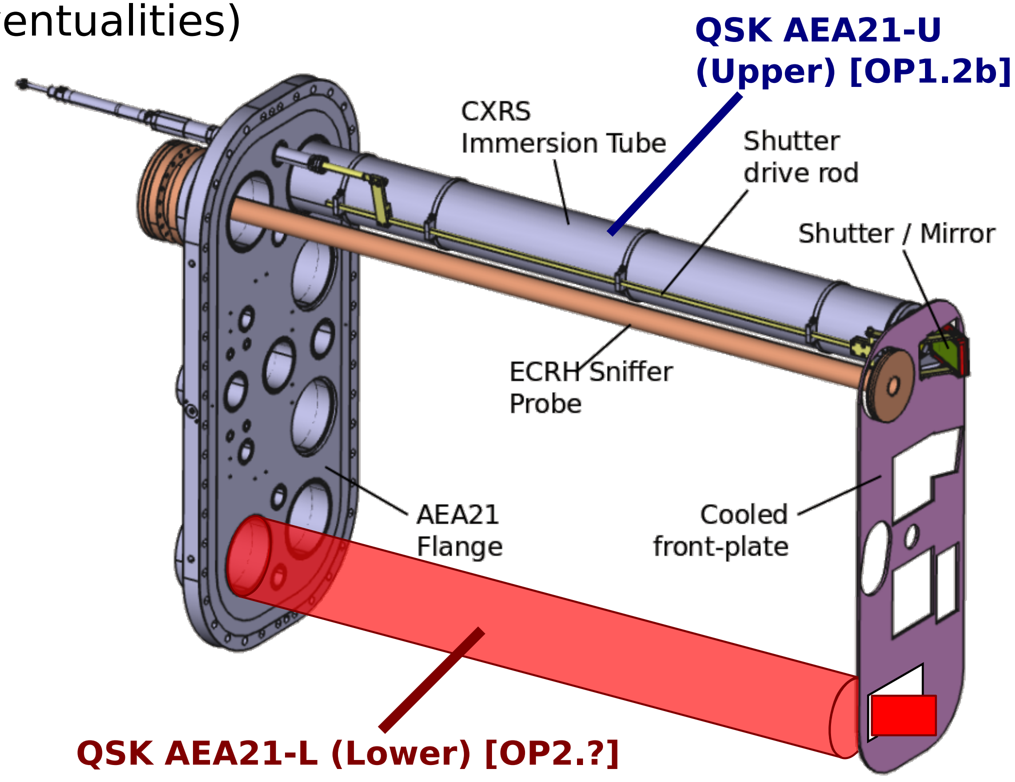
CXRS Immersion tube AEA21

- Several diagnostics require a high-etendué toroidal plasma view:
  - E3/QSK: CXRS on NBI for NI20
  - E4/QRI: Doppler CIS
  - E4/Q??: Fast Video (system??) (E4)
  - E3/QST: Motional Stark Effect
  - E5/Q??: Fluctuation Beam Emission Spectroscopy (US Collaboration??)

(E4/QRI and E4/Q??: AEQ21 in OP1, which may need replacement with pinhole.)

Proposal: Build 2nd immersion tube for CXRS.
- Vacuum interface components could be ready for OP2.1 (<15k€):
  - 9.3k€, repeat existing orders. (+5k€ eventualities)
  - One small TD Auftrag.
  - Minimal workload for E3-DIA, PK, QM.
  - Zero workload for DE, AS or CoDAC.

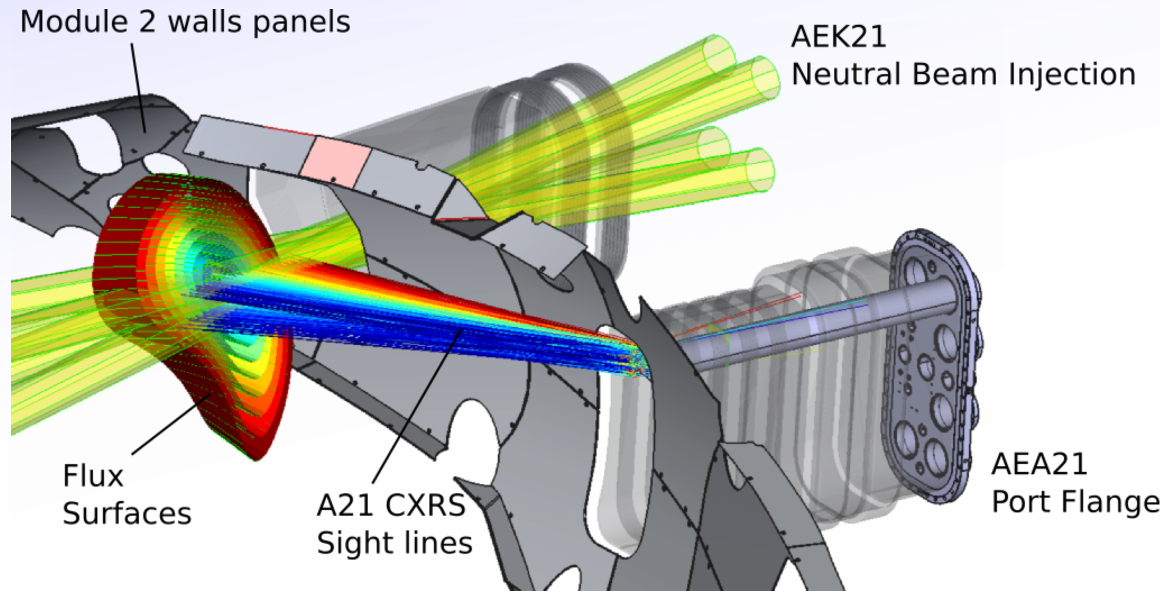
Disadvantages:
- Limited measurement period in 10MW long-pulse operation (~10secs)
- Optics need to be designed and built.

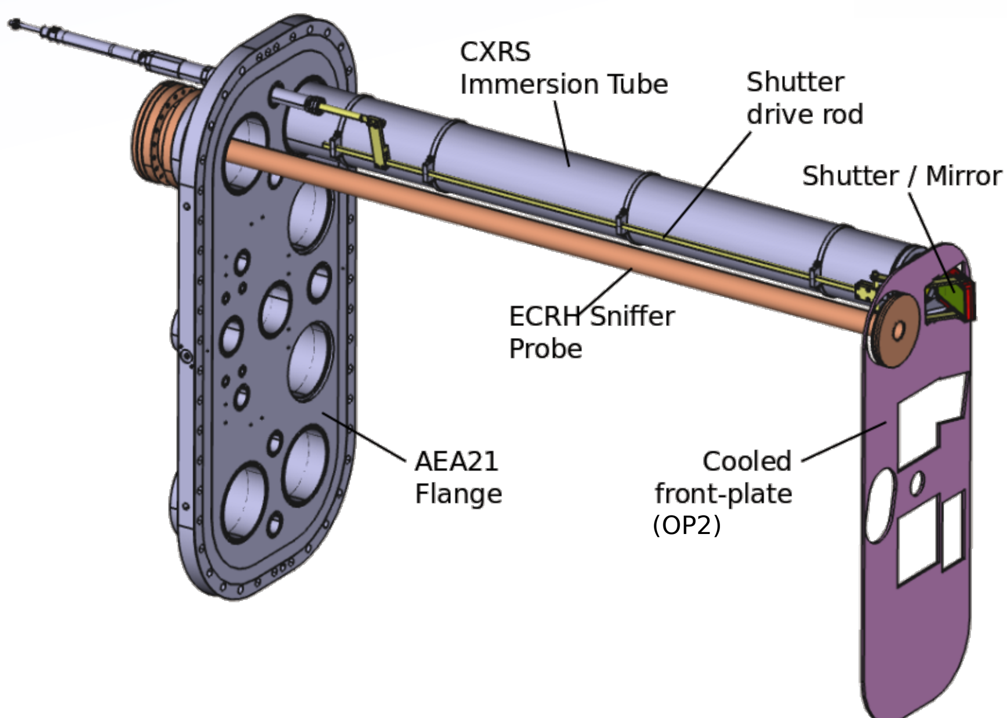


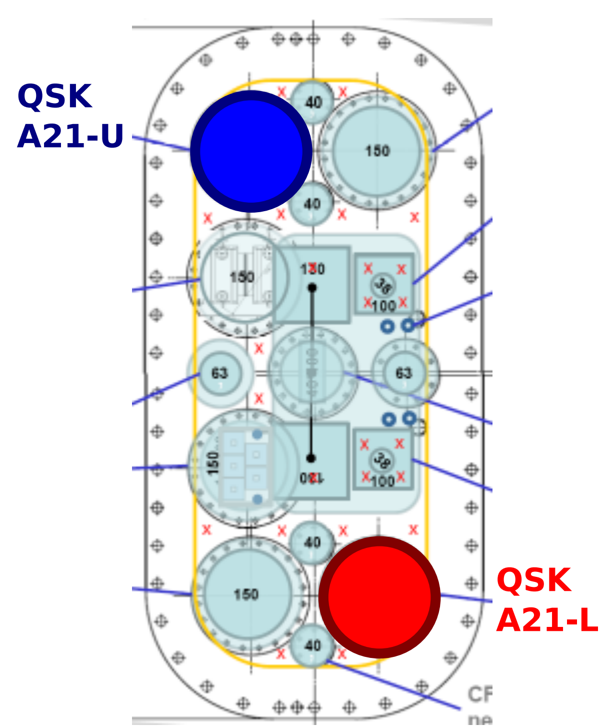
CXRS Immersion tube AEA21

- AEA21 plug-in tube viewing M21 installed and operated in OP1.2b.

- Daughter-flange was reserved for possible opposite system viewing M20.



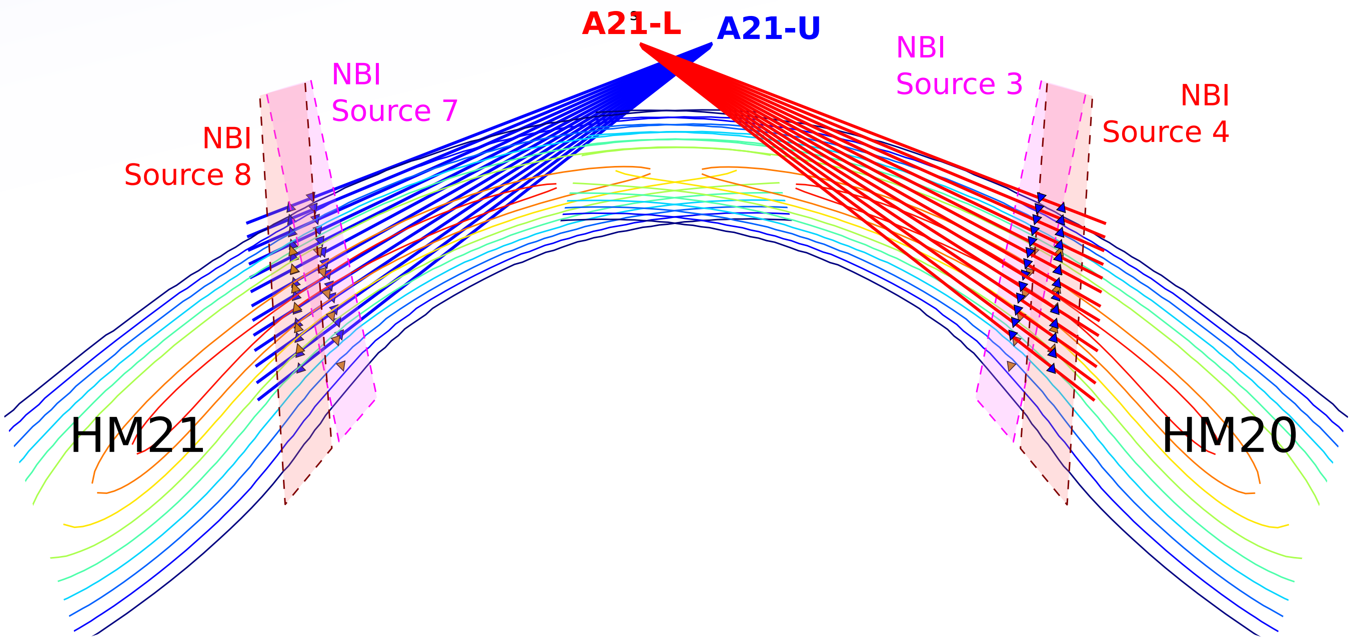




Approximate view (CXRS optics)

- System uses a in-vacuum mirror to view toroidally.
- Mirror can only be opened for ~10s periods at 10MW - **not steady state capable!**
  (This is the design safe estimate. Can probably be increased with some calculations)

- Shutter and tube cooling under development for OP2.1.
  Whatever the solution is, can be repeated for A21-L (budgeted 5k€ here).



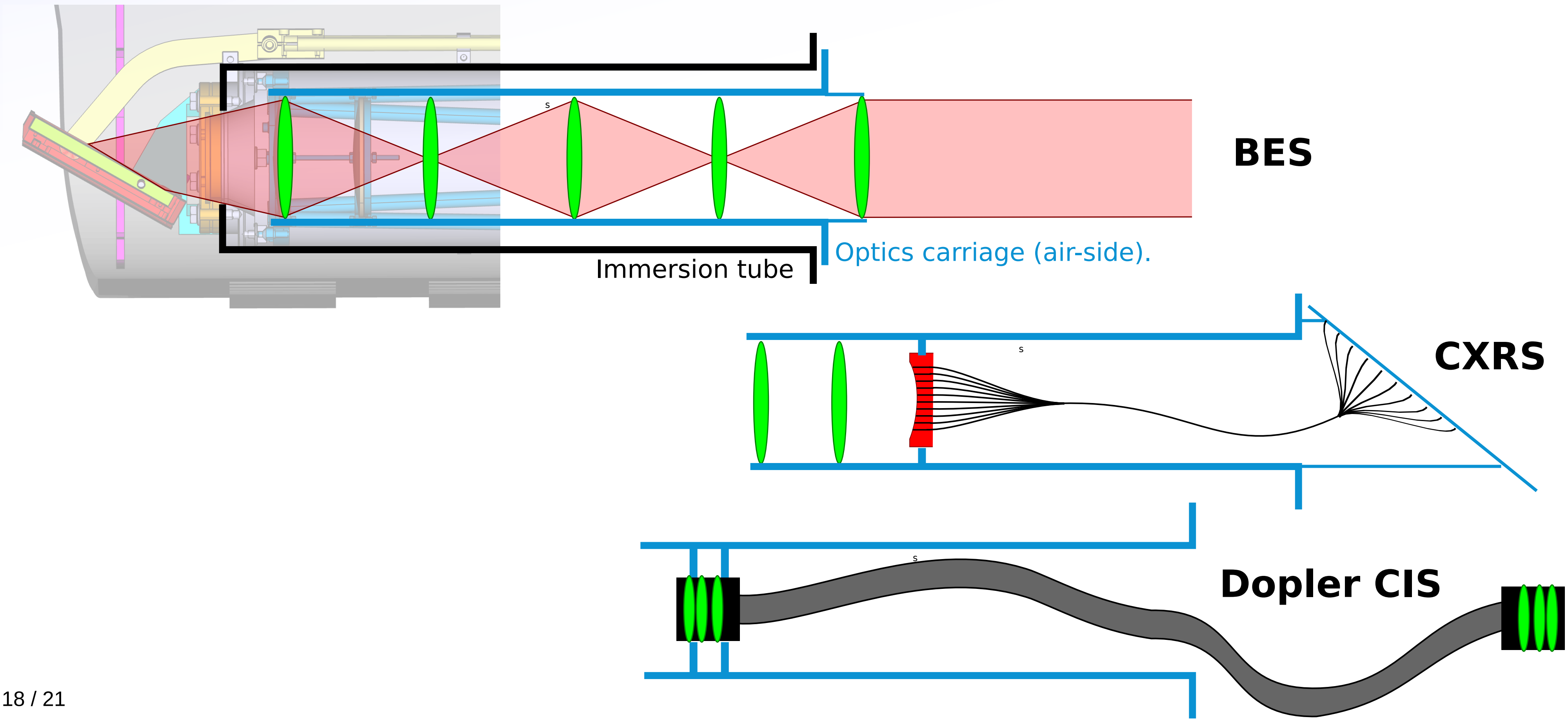
Optics / Usage

- Optics not covered in 15k€, but would need a redesign required anyway.
- Optics can be completed later (not vacuum-side).
- Could E4, E5, US or Hungary contribute optics?

Concept 1: Separate optic carriage for each diagnostic:

Preliminary, simple mechanical designs.

Time-share diagnostic port through-out campaigns.

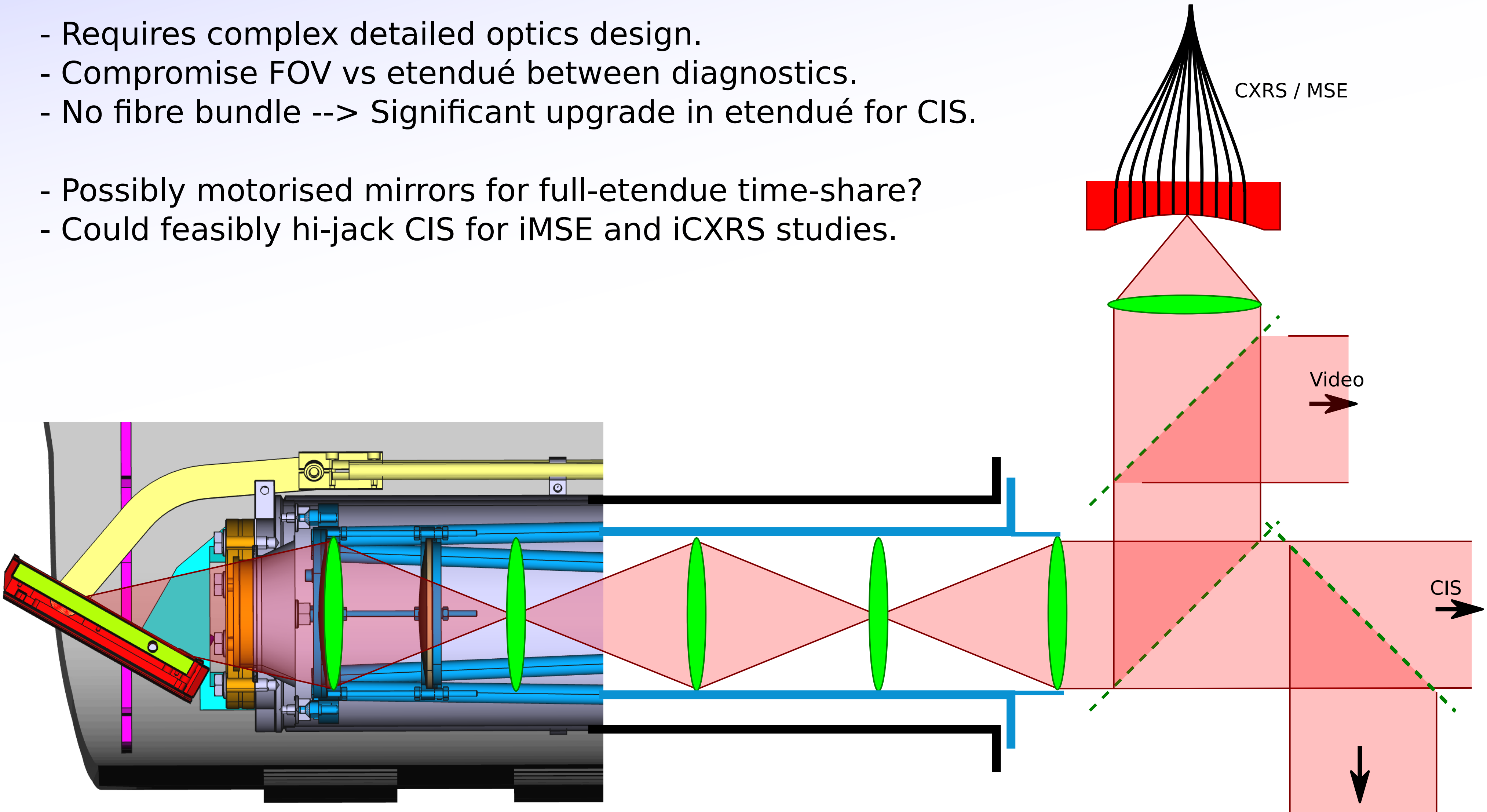


Optics / Usage

Concept 2: Image transfer and beam splitters.

- Requires complex detailed optics design.
- Compromise FOV vs etendué between diagnostics.
- No fibre bundle --> Significant upgrade in etendué for CIS.

- Possibly motorised mirrors for full-etendue time-share?
- Could feasibly hi-jack CIS for iMSE and iCXRS studies.



OP1.2b: BES |B| Measurements

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