



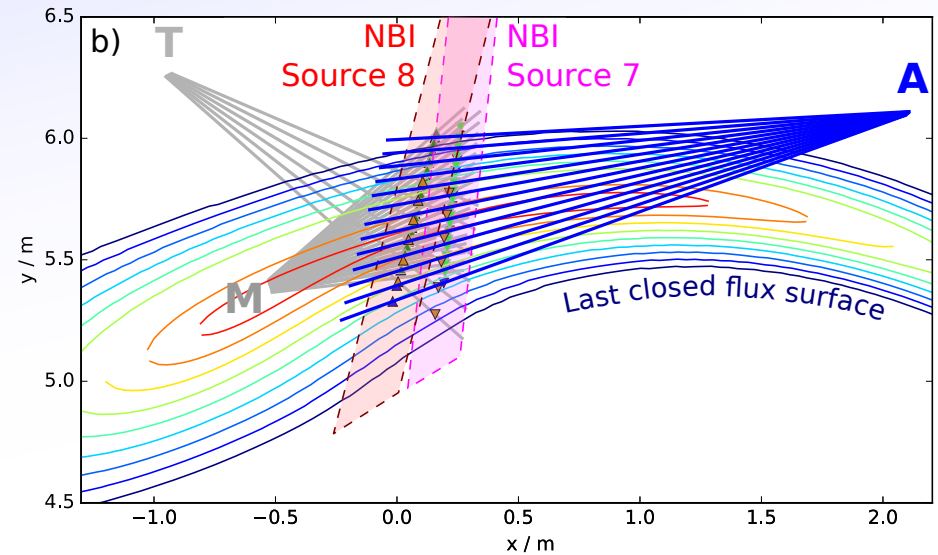
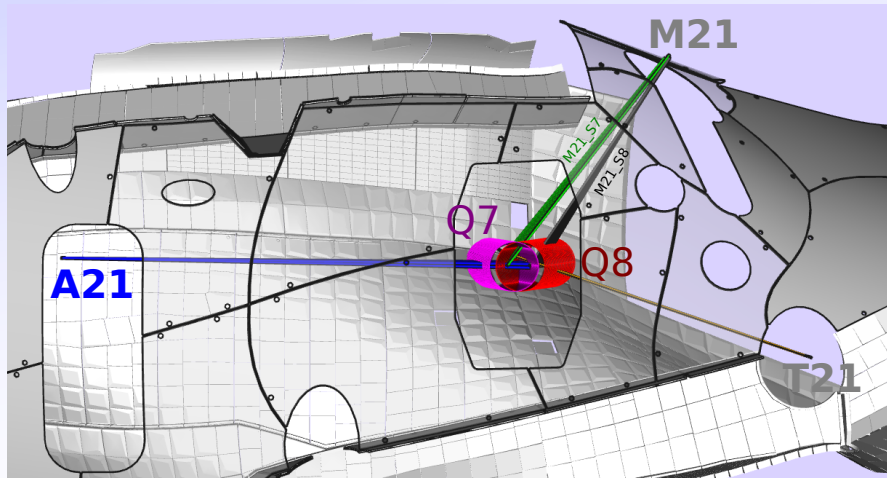
CXRS at W7-X - Current status and OP2 plans

O. P. Ford¹, L. Vano¹, T.W.C Neelis², C. Biedermann¹, R. Wolf¹

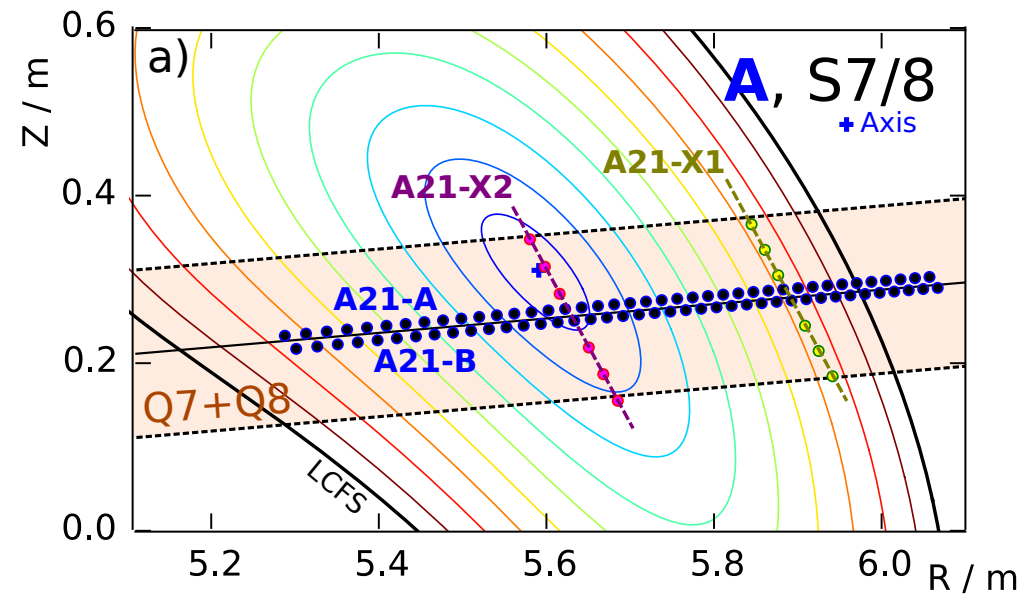
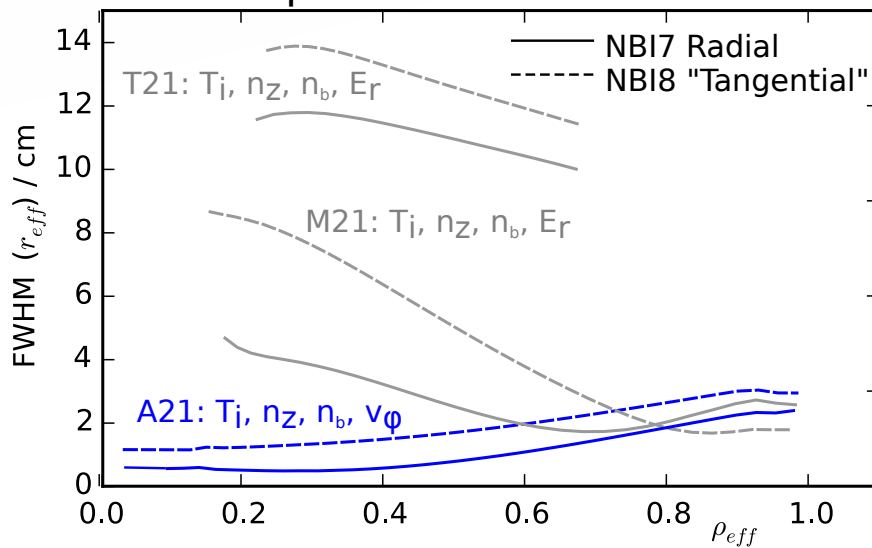
1: Max-Planck Institut für Plasmaphysik, Greifswald, Germany

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Observation Systems



Spatial resolution



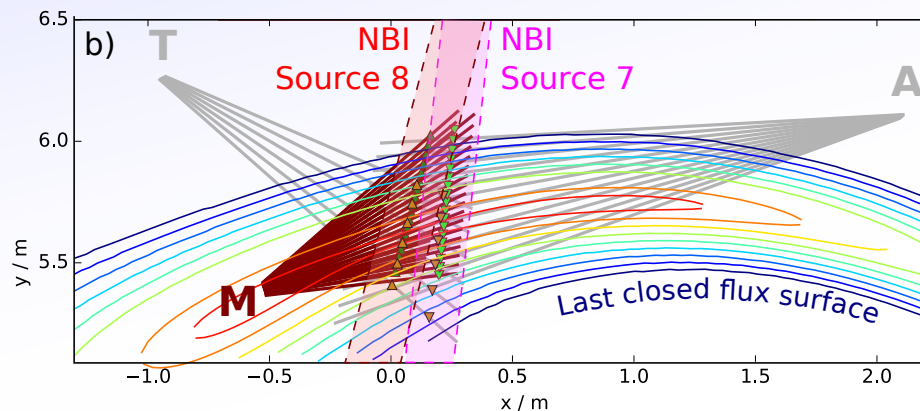
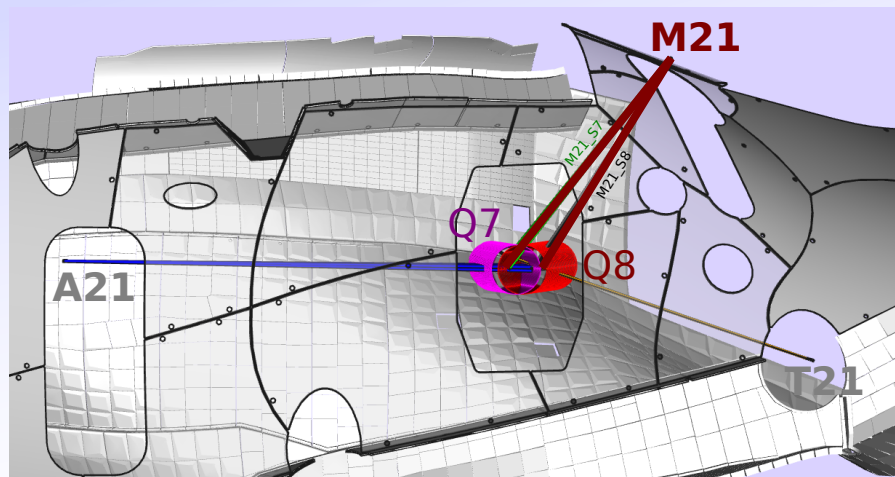
AEA21: High resolution, toroidally viewing system.

AEM21: 45° to toroidal. Primarily for Er.

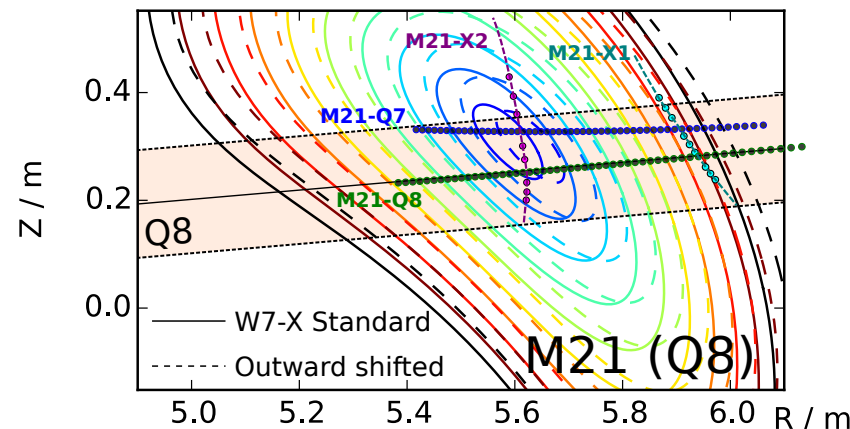
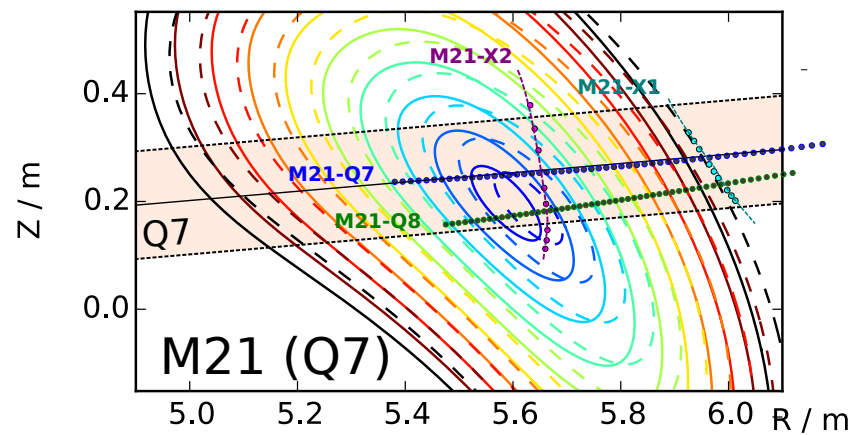
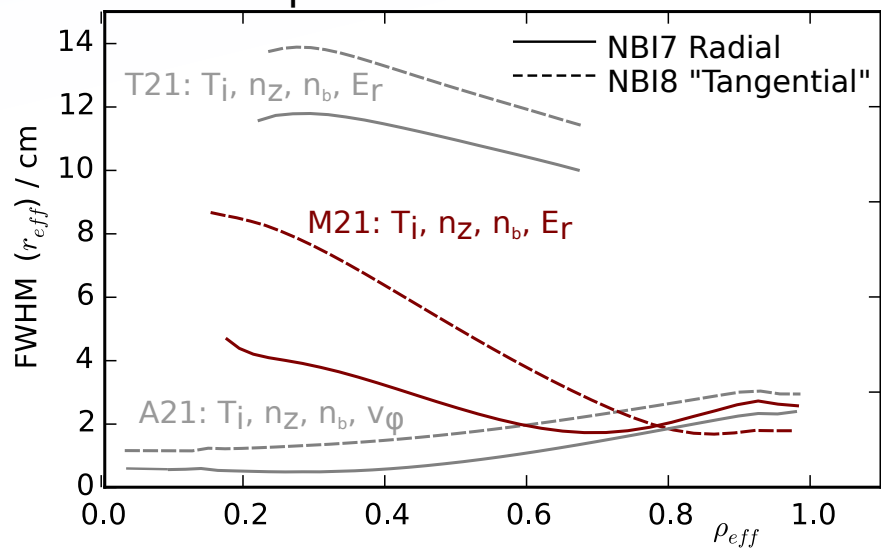
AET21: Low resolution overview/cross-check. -45° to toroidal.



Observation Systems



Spatial resolution

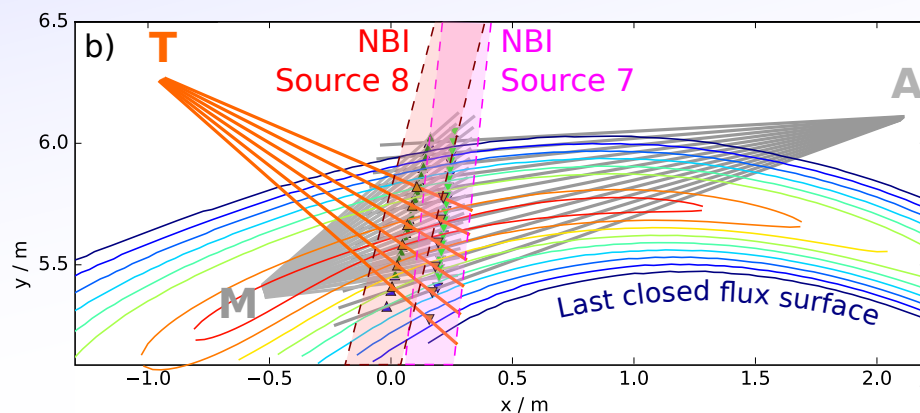
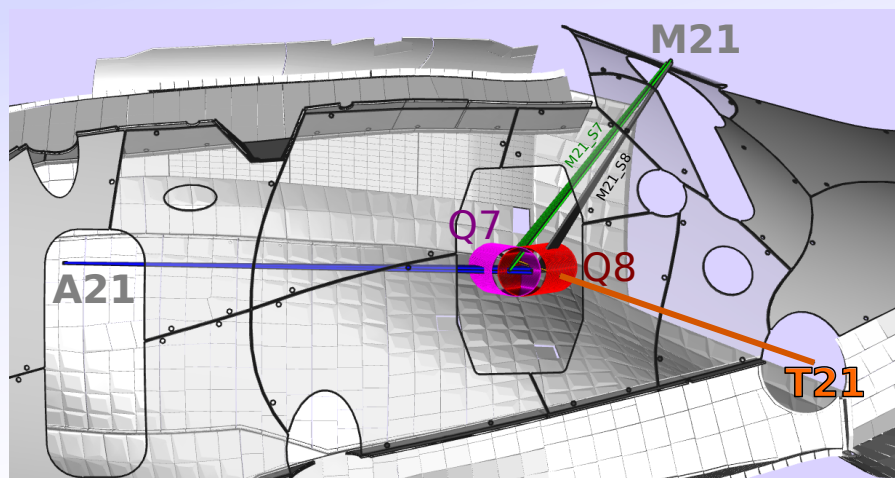


AEA21: High resolution, toroidally viewing system.

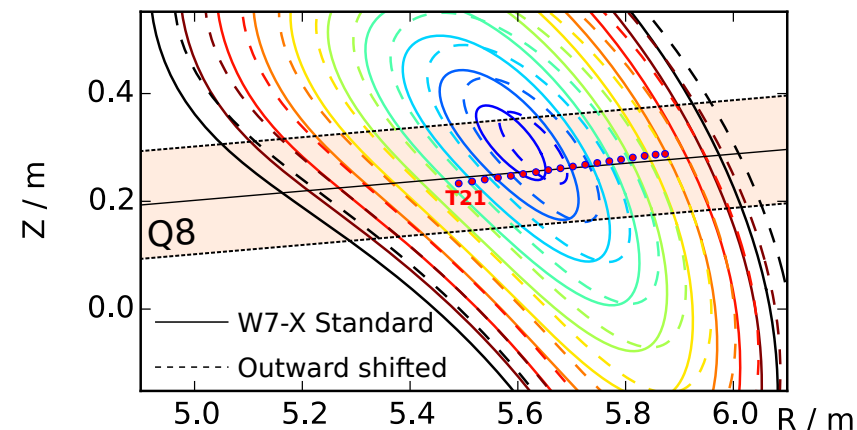
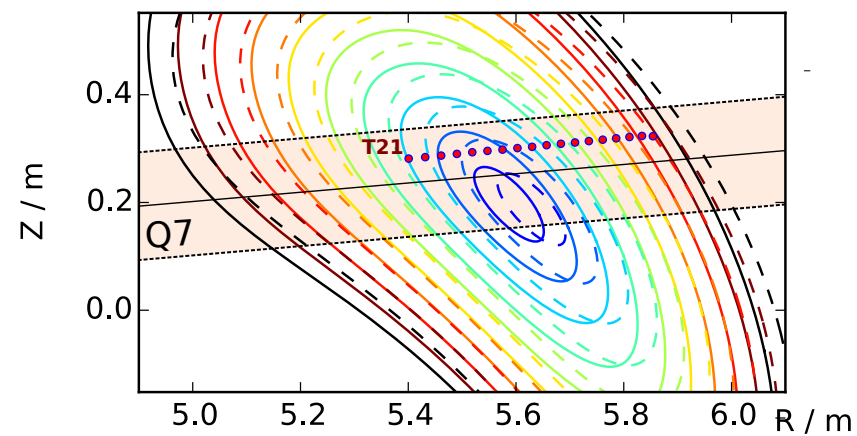
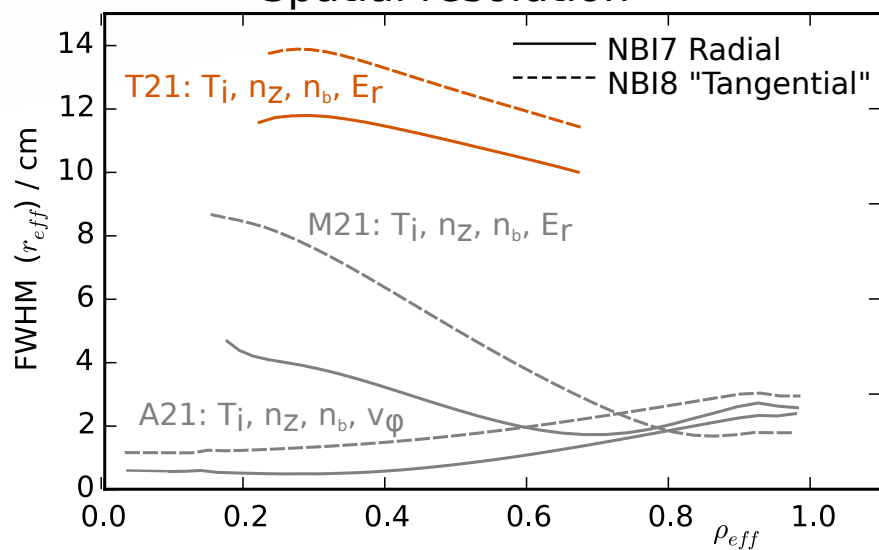
AEM21: 45° to toroidal. Primarily for Er.

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Observation Systems



Spatial resolution



AEA21: High resolution, toroidally viewing system.

AEM21: 45° to toroidal. Primarily for Er.

AET21: Low resolution overview/cross-check. -45° to toroidal.



Spectrometers

5 Spectrometers provide 300 measurements, each a mix from A, M and T ports:

ITER-Like Spectrometer (ILS) - Base system, **52 channels**:

Red (H α) --> n_b and FIDA, maybe one day T_H , n_H , n_e

Green (529nm) --> T_i , n_C , E_r

Blue (468nm) --> n_{He}

Always available

AUG1 - Secondary impurities 1: **43 channels**

Mainly n_O , n_B , n_C and more T_i , E_r .

Variable settings

AUG2 - Secondary impurities 2: **37 channels**

Injected impurities: B, N, Fe²³⁺, Fe²⁴⁺, Ar

NIFS He/H - **30 channels**.

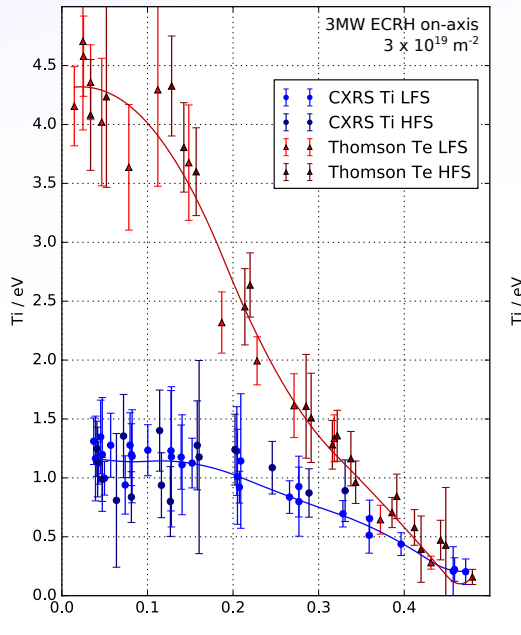
High resolution H α for He/H ratio.

But also for BES --> n_b , FIDA, n_H , T_H ...

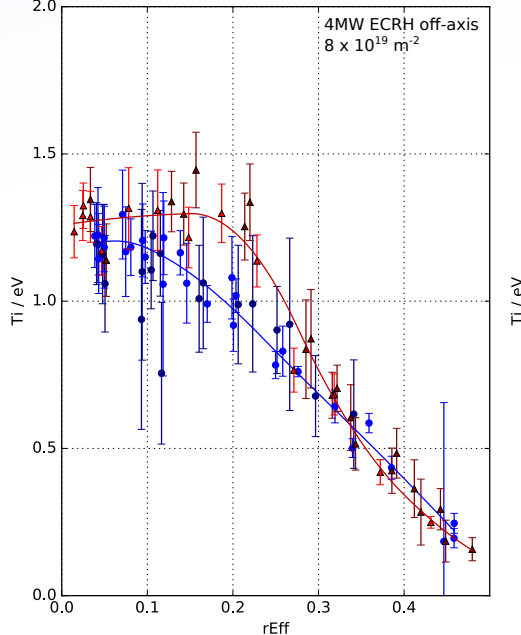
Ti Profiles

- Ti profiles now available for almost all OP1.2b NBI shots.
- Generally good agreement with Thomson Scattering and expectations.
- Processed with simple Gaussian fitting program.
- Good for blips but long NBI shots difficult.
- Only forward modelling of whole profiles will solve this --> Minerva

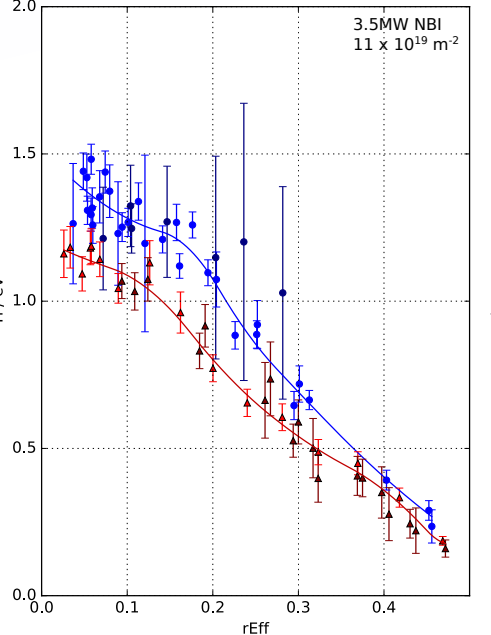
T_i, T_e profiles. CX: ILS_Green-21_DualGauss, TSVer=31
#20180822.014, <(8.450 < t < 8.513)>, VMEC: w7x_ref_179



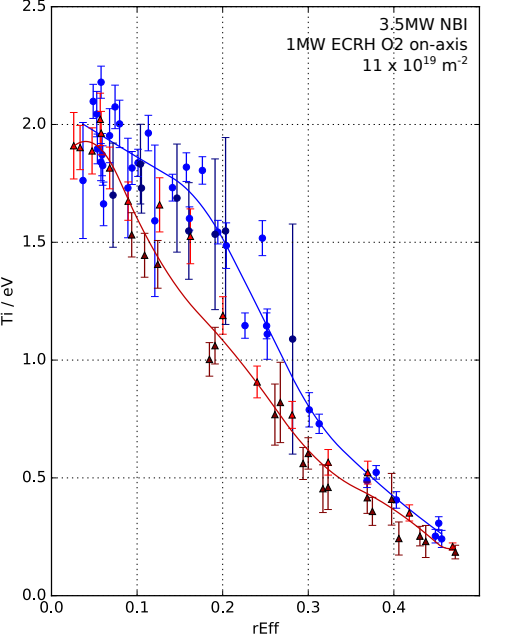
T_i, T_e profiles. CX: ILS_Green-21_DualGauss, TSVer=31
#20180822.022, <(6.430 < t < 6.506)>, VMEC: w7x_ref_179



T_i, T_e profiles. CX: ILS_Green-21_DualGauss, TSVer=28
#20181009.034, <(2.750 < t < 2.850)>, VMEC: w7x_ref_27



T_i, T_e profiles. CX: ILS_Green-21_DualGauss, TSVer=28
#20181009.034, <(3.150 < t < 3.250)>, VMEC: w7x_ref_27

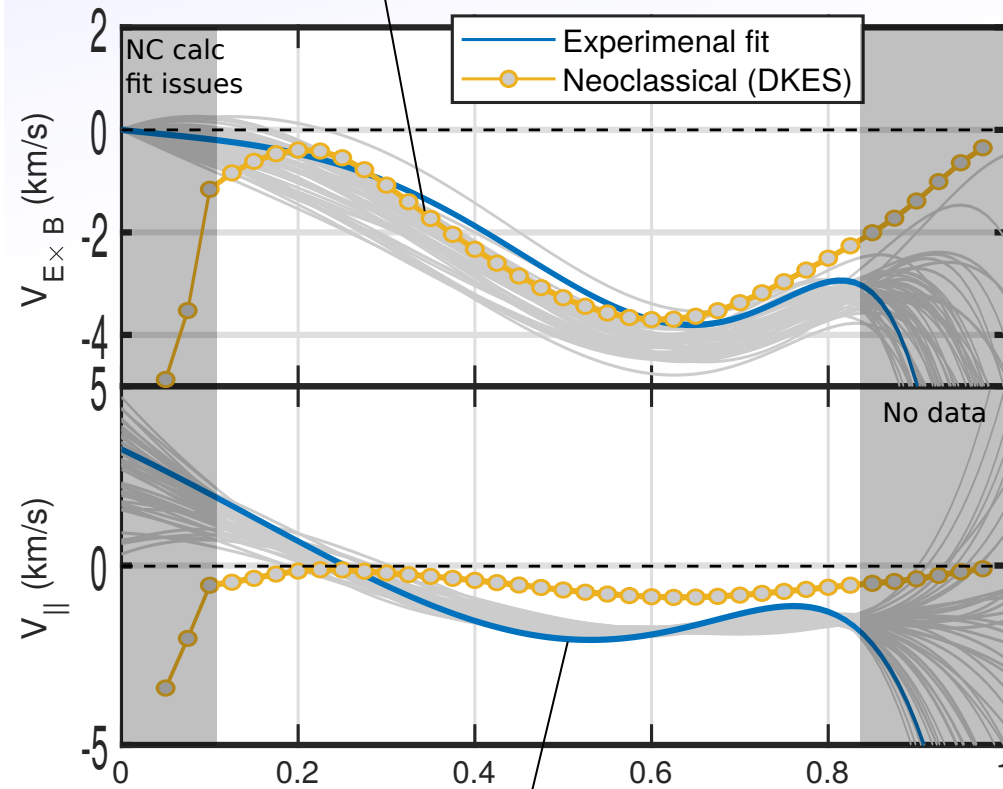


- Good quality profiles produced for normal uses.
- Special mode for high resolution gradient measurements (all spectrometers on C_VI)

E_r Profiles (A. Alonso)

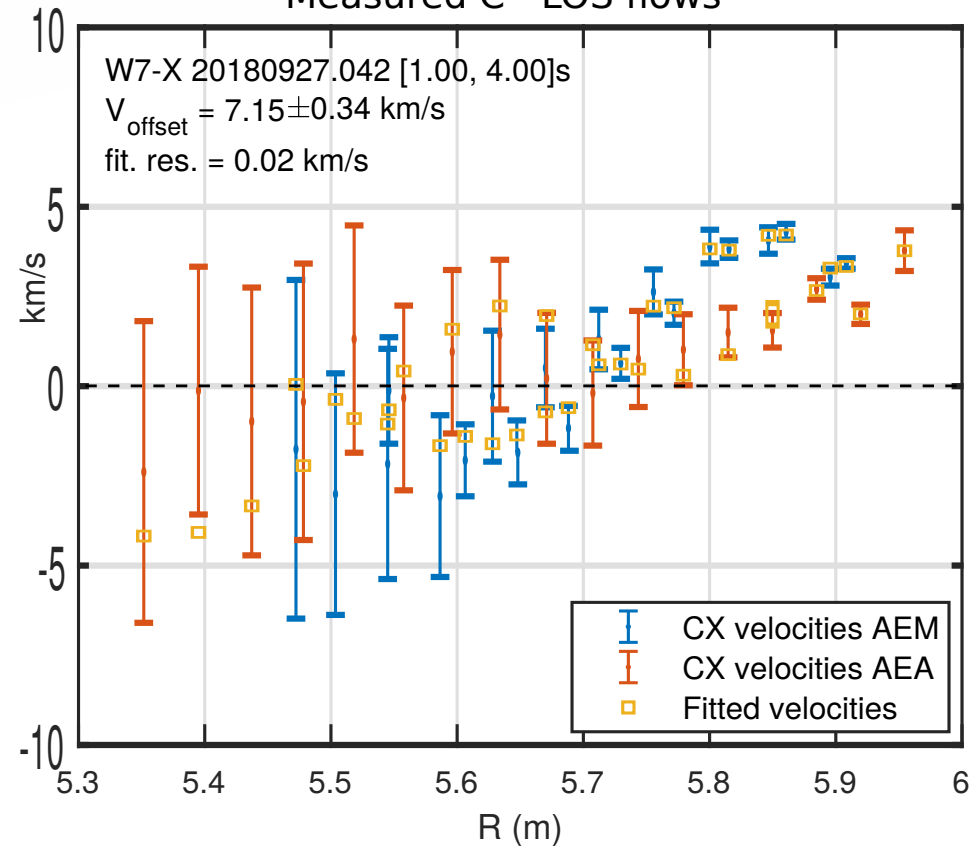
- Work is on-going to produce E_r profiles (A. Alonso):
- Measured flows into magnetic coordinates --> Potential + Toroidal flow
- Correction of CX cross-section effects and finite lifetime orbit effects

NC predicted E_r strongly affected
by choice of fits of profiles



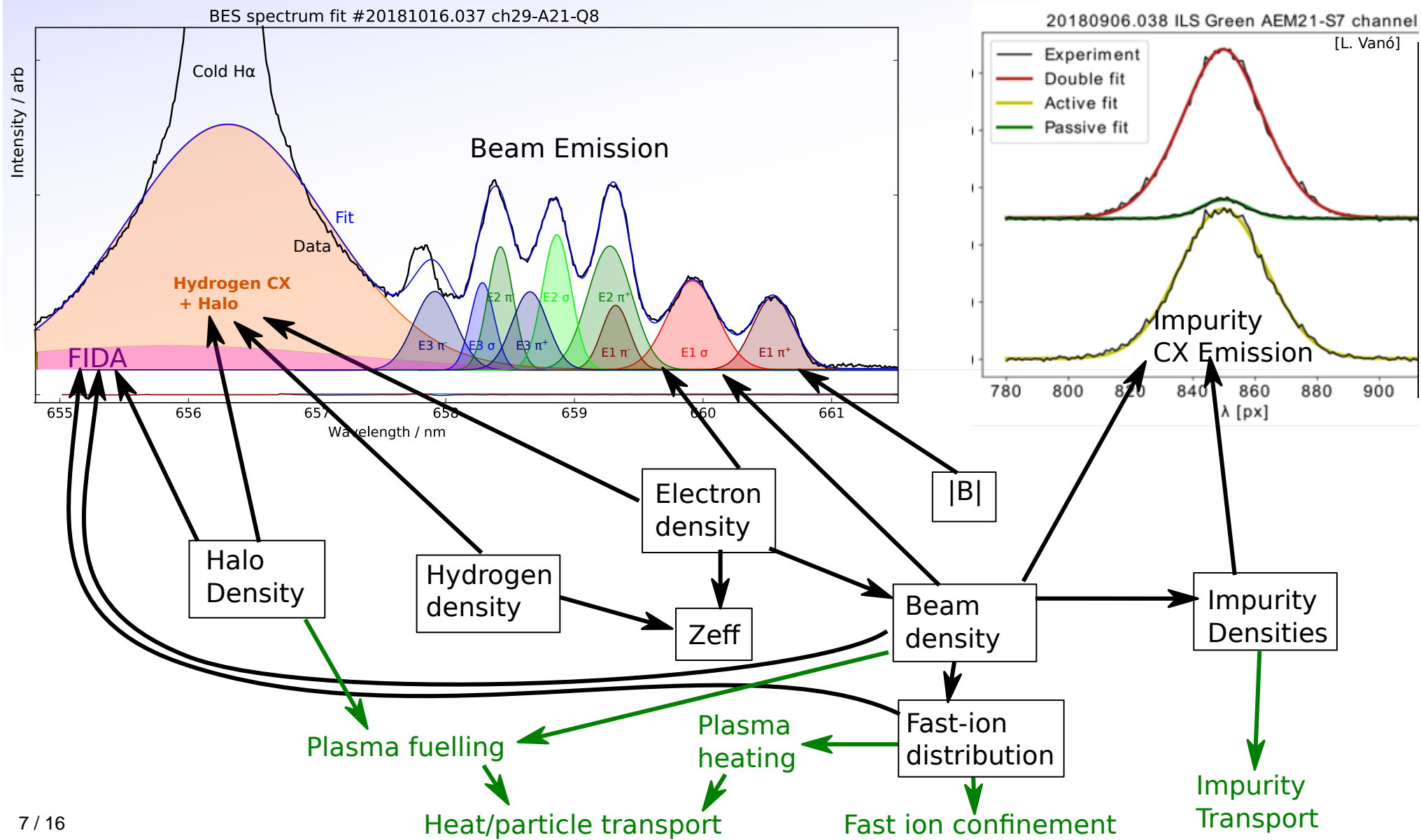
Parallel flows strongly affected by assumed
NBI energy component fractions.

Measured C^{VI} LOS flows



OP1.2b: BES Measurements

BES (Beam Emission Spectroscopy) and Halpha spectrum can deliver lots of information



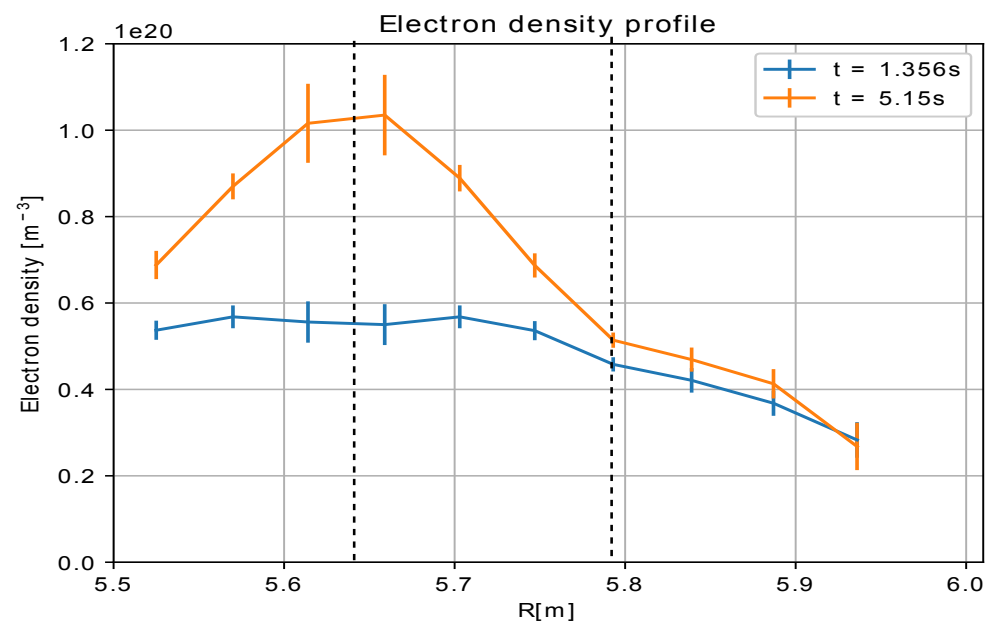
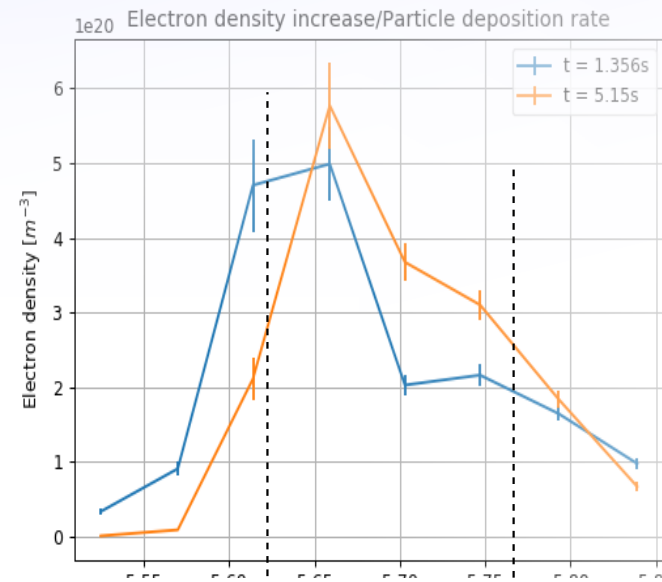
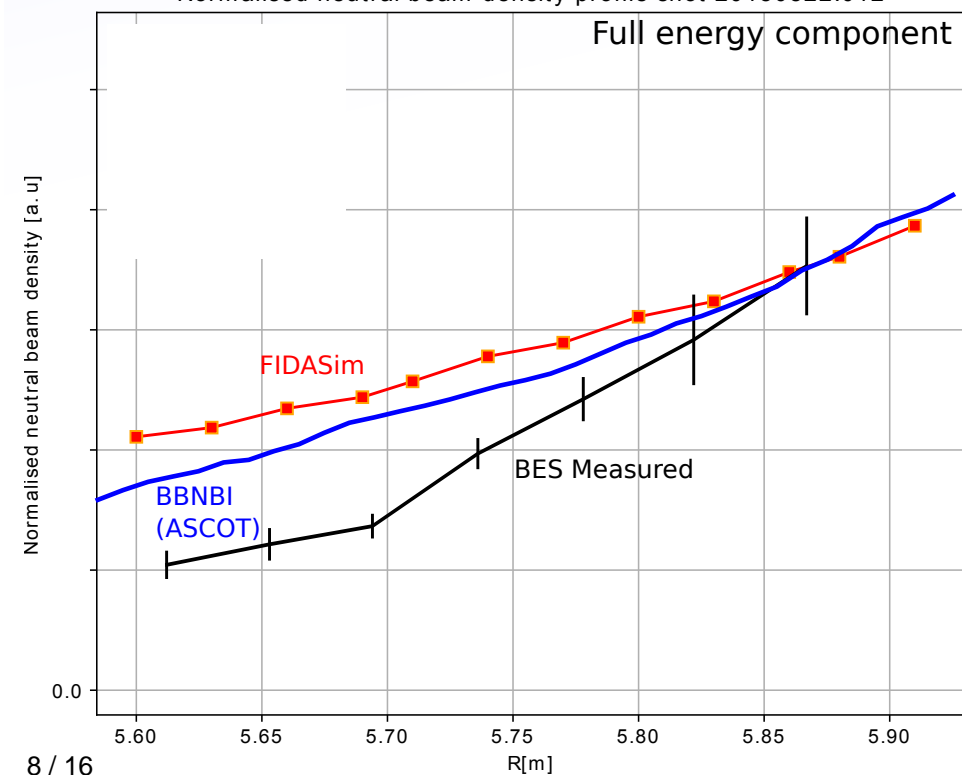
Beam deposition (T.W.C.Neelis)

Measured beam deposition (ignoring Halo CX broadening) now calculated.

- Comparison to models (see talk S. Äkäslompolo)
- Fast ion birth profile
- Particle source profile

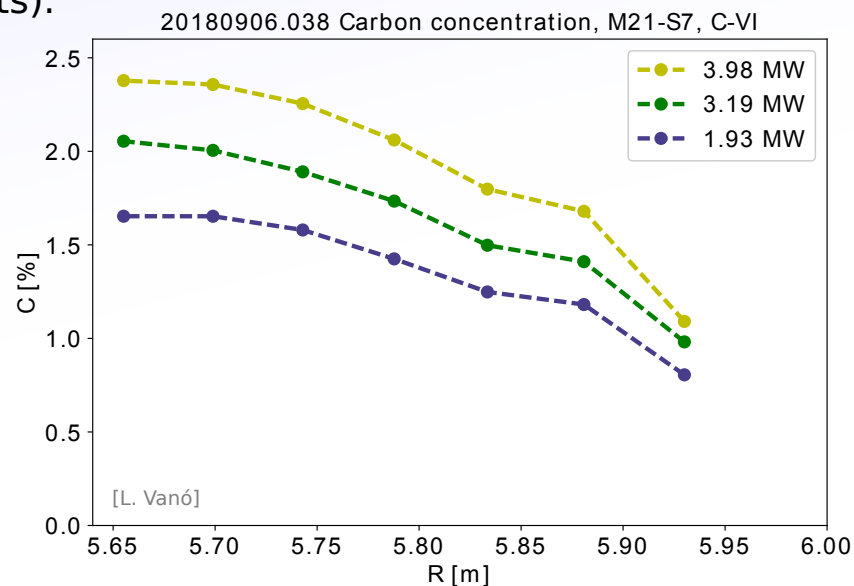
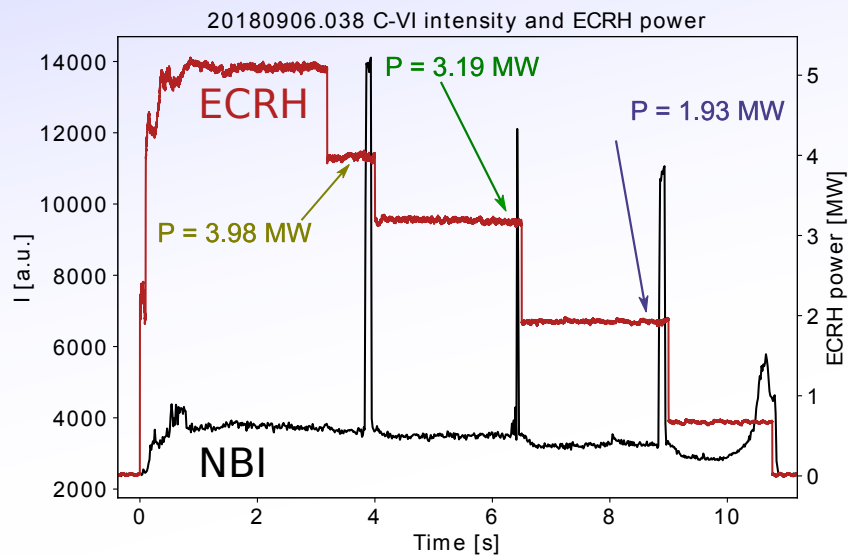
Normalised neutral beam density profile shot 20180822.012

Full energy component

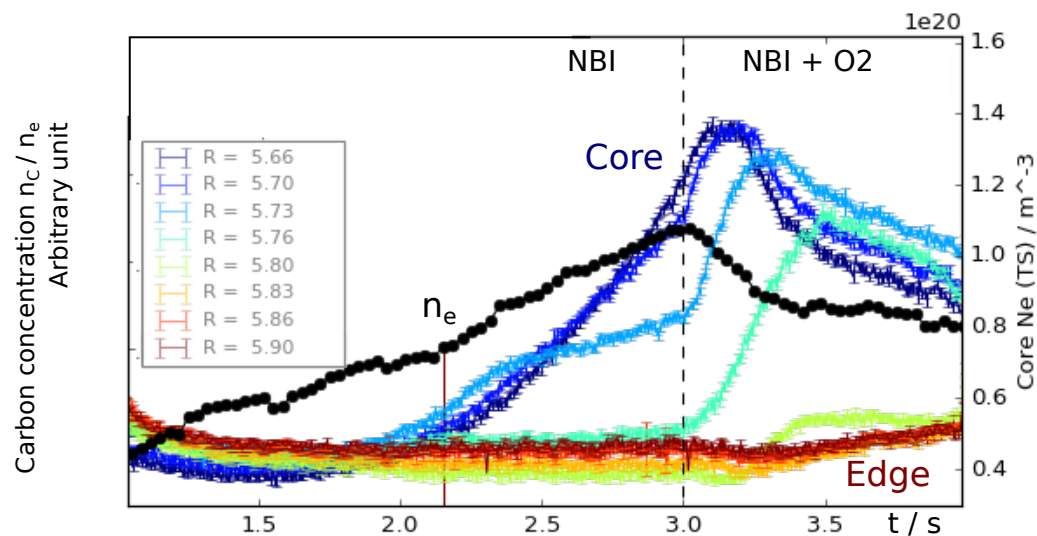
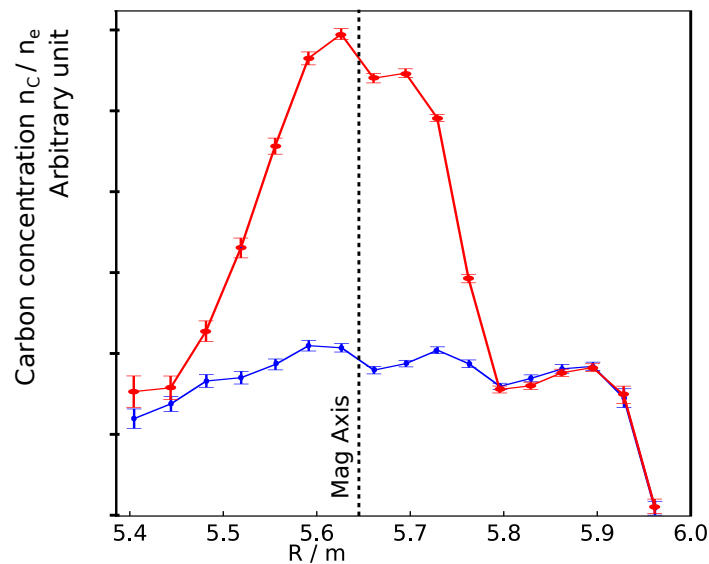


Carbon Profiles (L. Vanó)

- Now able to produce carbon concentration profiles for NBI blips.
- Very soon somewhat routinely (Requires accurate BES fits).



Strongly peaked carbon concentrations seen in pure NBI shots:



OP1.2b: FIDA

- FIDA Measurements planned with 'AUG' variable wavelength spectrometers:
Unsuccessful due to insufficient dynamic range but ILS H α channel fortunately sees FIDA signal very well.

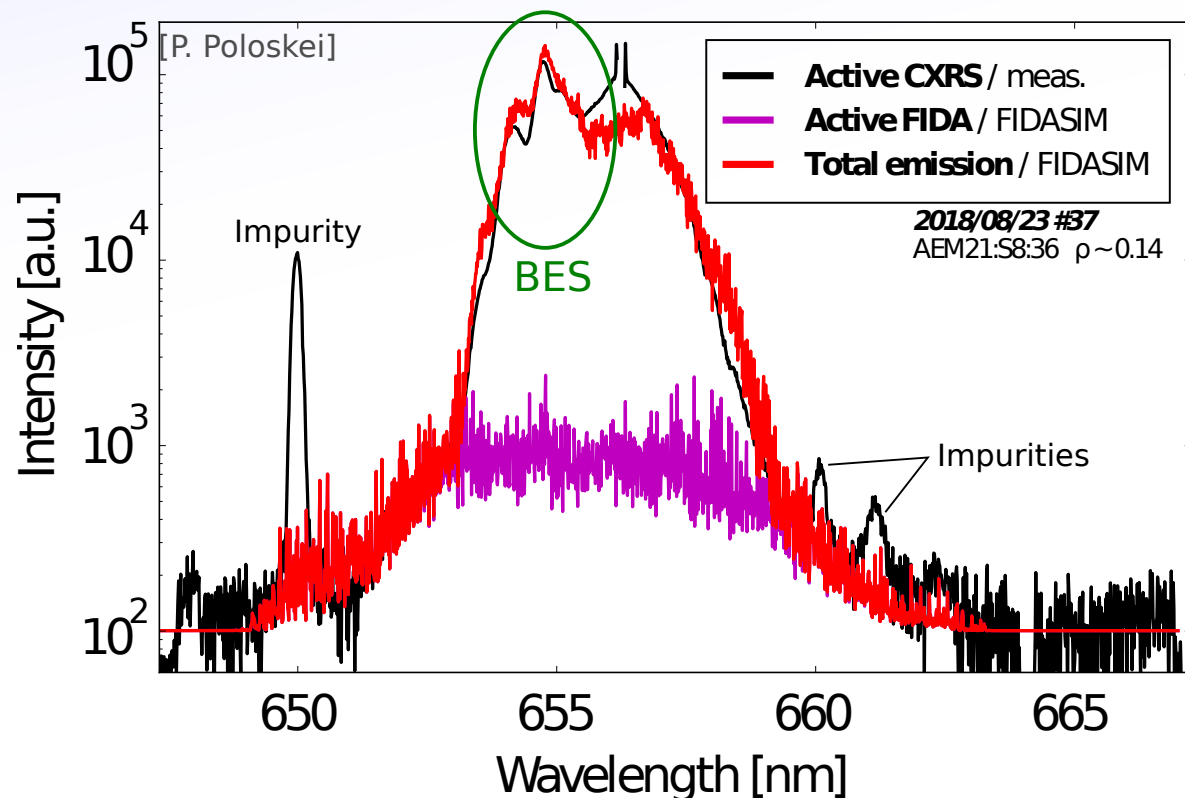
- Comparisons with ASCOT / FIDASIM underway
(P. Poloskei, S. Äkäslompolo)

- Bachelor Student (~Summer, with S. Bozhenkov) to look systematically at data and consider FIDA options for OP2.

- Dedicated spectrometer?, but unlikely to improve on ILS.

- ILS H α can be optimised for much higher speed (~2ms)

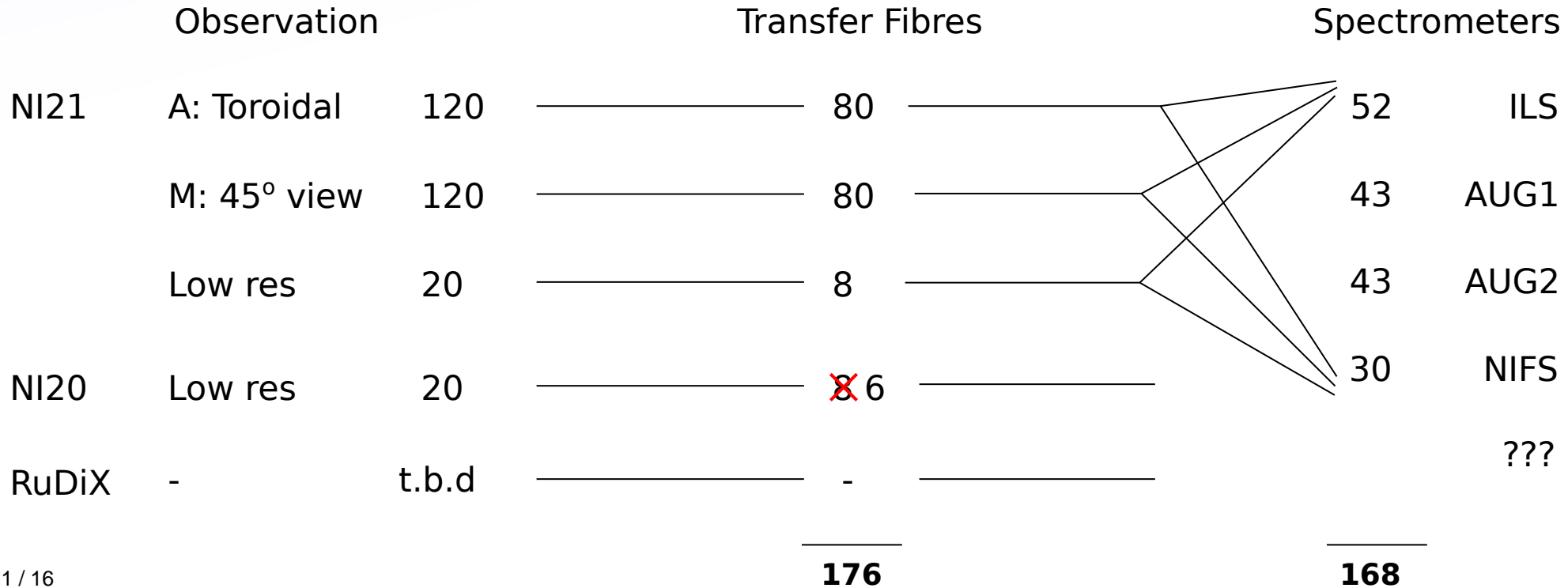
- Offered use of very high speed spectrometer for OP2 (~ μ s, but 1-channel) for FIDA from Garching (B. Geiger, A. v. Vuuren). Passive FIDA measurements planned.





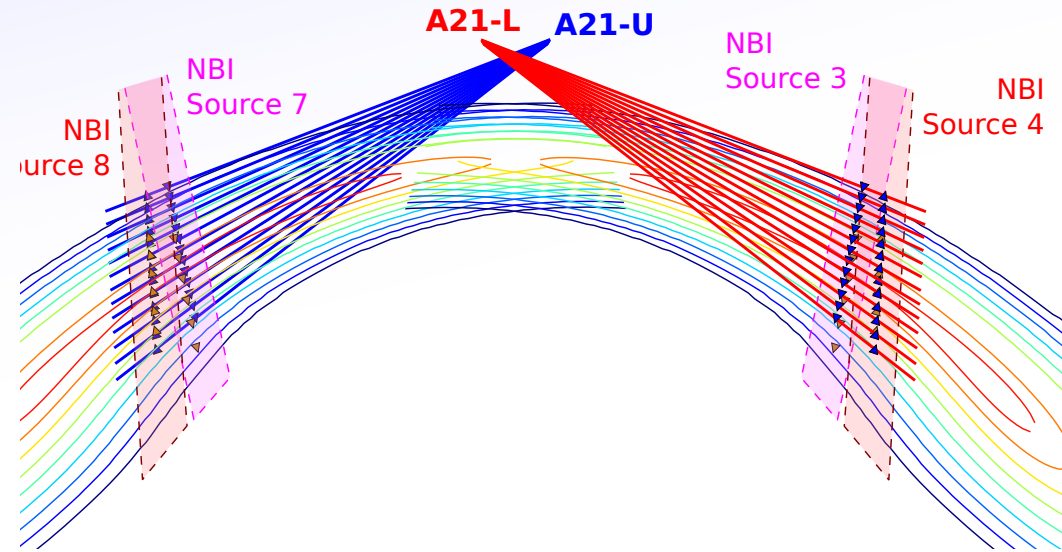
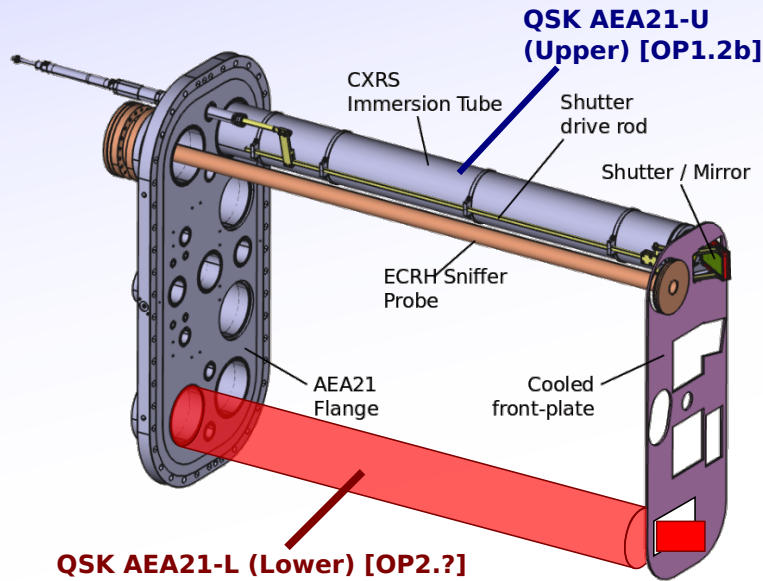
OP2 Plans

- CXRS produces good high resolution data up to 2.5keV and $1.5 \times 10^{20} \text{ m}^{-2}$,
 - **No upgrades in coverage or resolution are planned** (or budgeted).
- Front-end optics need cooling to meet OP2 requirements:
 - In-progress and expecting to be ready for OP2 vacuum closing.
- Currently only 6-channels available on NI20 box using T-port (low resolution). Upgrade here will require more fibres (~400€ / channel)
- We can add/upgrade spectrometers at the back-end at any time (i.e. right up to start of OP2.1).



OP2 Possibilities

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



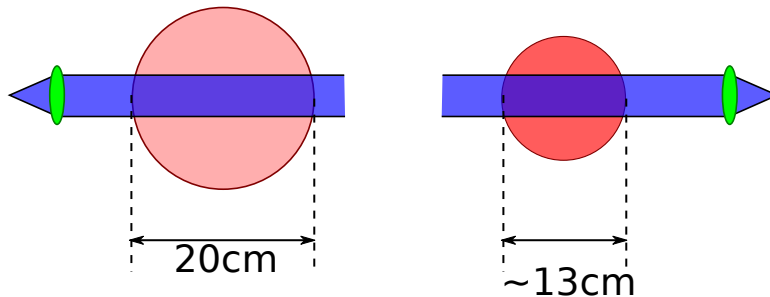
- 10 - 15k€ for in-vacuum and barrier components.
- Optics can be decided later (and purchased).
- Could be shared (time or light) between:
 - CXRS - But we would need more channels and spectrometers!
 - CXRS CIS (Experimental)
 - MSE / IMSE
 - CIS (E4),
 - Video (E4),
 - BES (E5)

OP2 Possibilities

2) CXRS on RuDiX

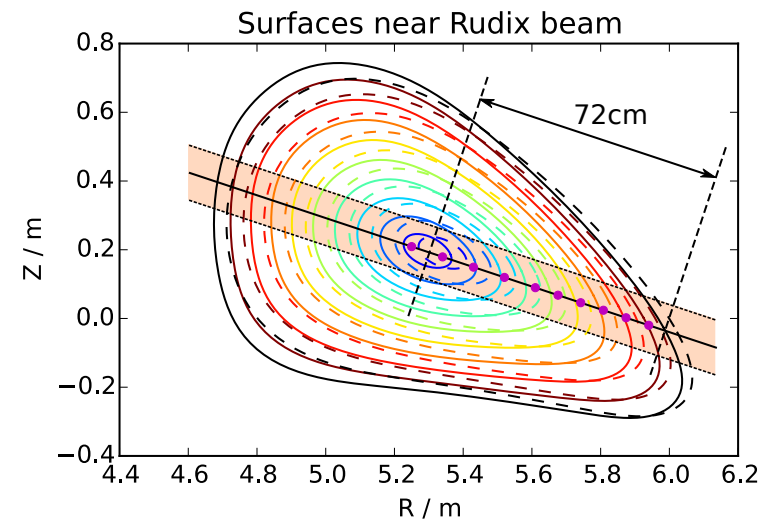
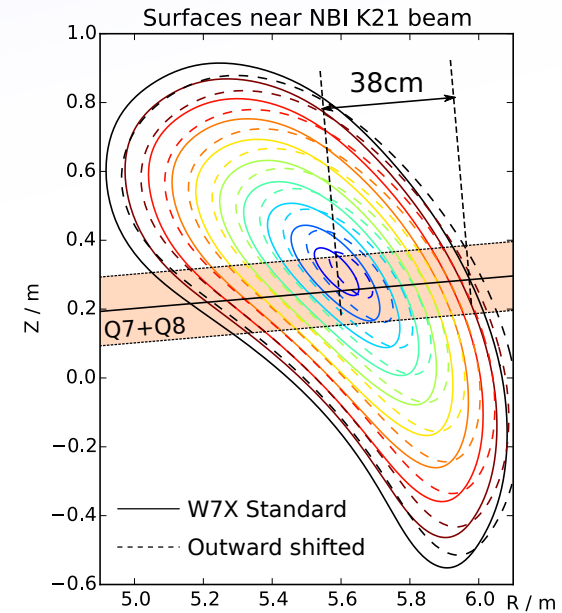
- CXRS on RuDIX baseline design currently limited (12 channels, f/6 spectrometer, no CCDs!)
- If RuDIX is installed, we could move large part of transfer/back-end over to RuDIX easily, but...

Beam	NBI	RuDIX
Current	25 A	2.2 A
Diameter	20cm	13cm
Power	1.8MW	360kW
Energy	55 kV	60 kV
Divergence	0.8°	0.7°
Plasma 1/2 width	40cm	90cm
Signal (edge)	125 Am⁻¹	17 Am⁻¹ (14%)
Signal (core)	60 A/m⁻¹	4 Am⁻¹ (6%)



Much lower core S/N due to:

- 1) Lower beam current (8%)
- 2) Longer path in plasma (stronger attenuation)



OP2 Possibilities

2) CXRS on RuDiX

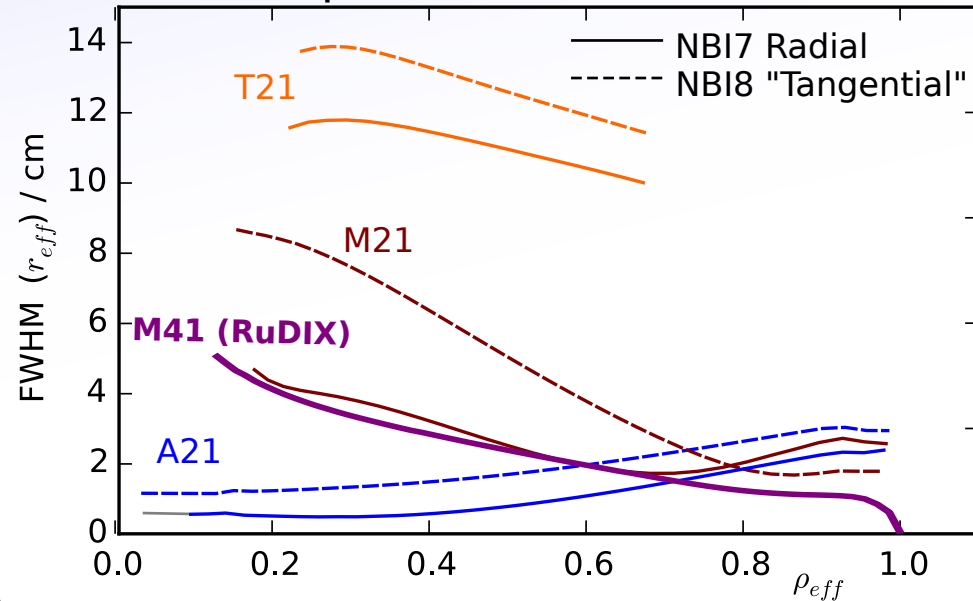
- Resolution same as poloidal system in core, better than both at edge.

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Resolution (c)	1 cm	5 cm
Resolution (e)	3 cm	1 cm

Pros:

- More than 10sec coverage.
(Do we require CXRS in long pulse experiments?)
- Less perturbative
(Lower power, no current drive)
- Better edge resolution

Spatial resolution



Cons:

- Resources / reliability (see talk P. McNeely)
- No toroidal flow measurement
- Much lower S/N
- Lower core resolution



Summary

- Very successful campaign for CXRS. Good data available or expected for: T_i , E_r , v_ϕ , n_C , n_O , n_b
- Need good strategy for exploiting BES data and dealing with CXRS passive background:
 - Minerva would be very powerful here - Student in Minerva group?
 - *Possibility* of 3cm resolution $\Delta t \sim 10\text{ms}$ n_H/n_e profile information! (P. Poloskei, FIDASIM)
- **No changes/upgrade to base system planned.**
 - Do we want more spectrometers (e.g. for Spectral-MSE, CXRS)?
 - Would need more transfer fibres to match.
- FIDA: Explore possibilities with existing hardware? Dedicated spectrometer?
- Proposal: Install 2nd immersion tube for OP2.1:
 - Low cost, low effort, opens possibilities for OP2 diagnostic development.
- Do we need RuDIX?
 - CXRS looks to be worse on RuDIX.
 - Do we really need long pulse measurements?
 - Is NPA good enough reason alone to have it?