LHCD simulation by ASTRA/FRTC of JET discharges Part I & 2

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Main aim of this activity

- ***Benchmark ASTRA/FRTC on JET discharges*** *by comparing simulation results with available experimental data:*
  - Edge ECE emission (down shifted ECE emission from relativistic electrons) (TF_6sept.2012)
  - q profile from EFIT / polarimetry or MSE
- ***The reasons for such benchmarking are:***
  - physical understanding of present experiments within the limit of the linear model
  - ***planning LHCD experiments in JET next campaign***

The focus here will be on

- **A qualitative comparison of the simulated $I_{LH}(t)$ signal with the edge ECE signal**

- **Comparison between the simulated q profile and the EFIT q-profile constrained to polarimetry and MSE**
- **Physical understanding concerns the role of Collisional Absorption (NRCA) of LH wave power**
  - ***Is NRCA important in JET plasma conditions ?***
  - ***Are there any conditions where it can play a role?***
  - ***Can it prevent LH power to enter into the plasma?***

Simulations Methodology

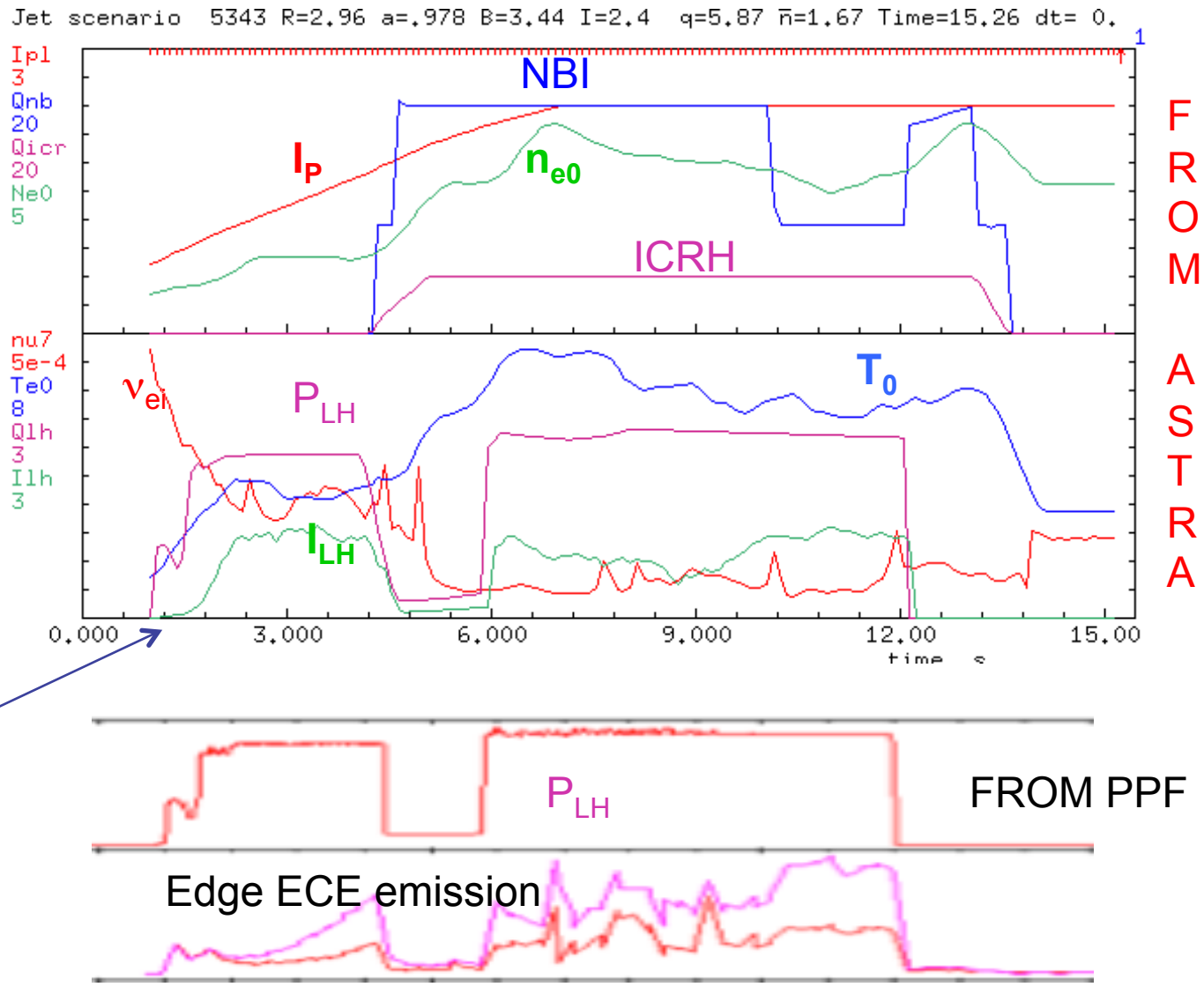
- Input data to ASTRA from TRANSP run
  - i.e. plasma parameters and H&CD sources *(different from LHCD)* from TRANSP
- Interpretative ASTRA run, except for
  - the current diffusion equation **(solved)**
  - LHCD profiles **calculated** self consistently **by FRTC** (Fast Standard Ray-Tracing Fokker Planck code)

Choice of JET shots to simulate

- Choice high density *"puzzling"* discharges
  - *where experimental LHCD effects into the plasma clearly change in time.*
- LHCD during the ramp up phase
  - 53430 ***(LHCD effects increase in time)***
  - 77601 ***(LHCD abruptly disappears)***
- LHCD during the main heating phase
  - 72835, 77893 ***(LHCD effects are mostly absent 1 s later the P_{LH}*** switch ***on)***

53430_simulation: time evolution

- Calculated I_{LH} has a delay ~2 sec with respect to the launched P_{LH}
- Clear correlation between I_{LH} increase and ν_{ei} decrease
- ***1.5 s DELAY of ILH in fair agreement with ECE emission signal***



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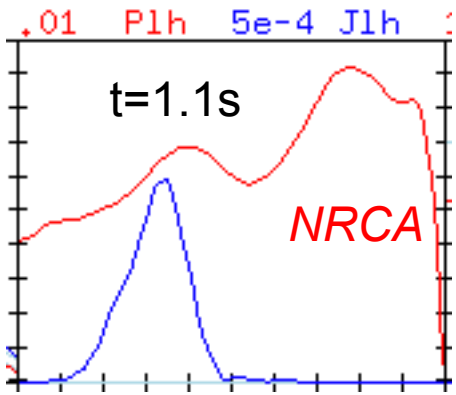
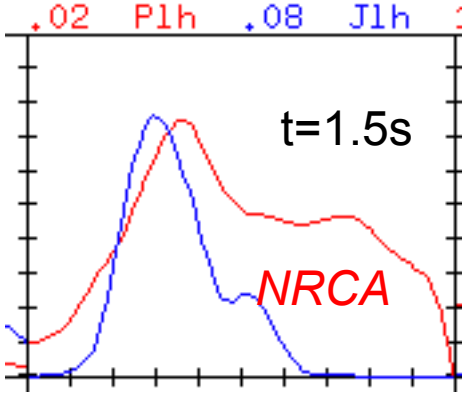
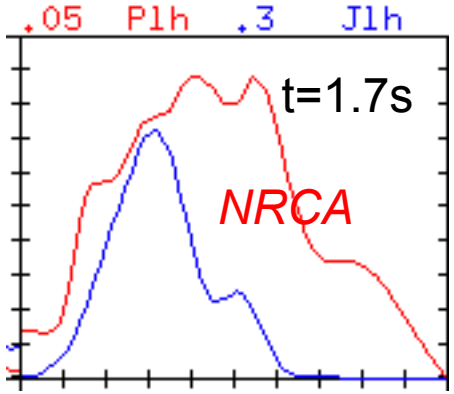
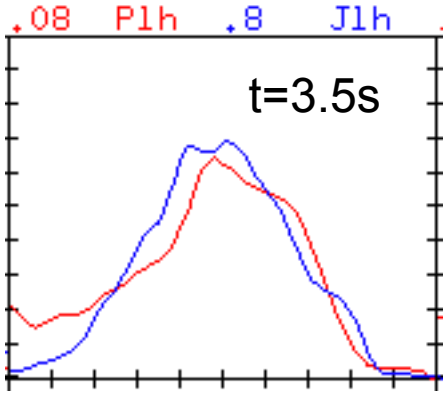
What the ILH delay is due to? NRCA is important in the early LH phase!

- P_{LH} and J_{LH} profiles are different
- Peripheral CA dominates at the beginning (first 3 times) avoiding LH current generation.

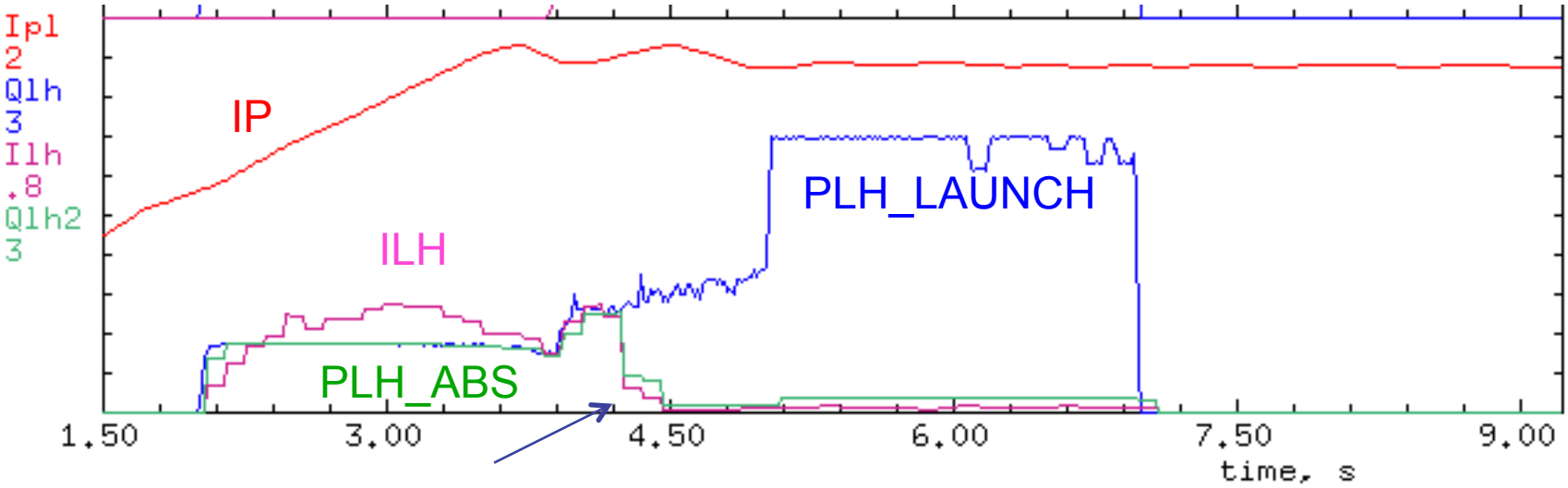






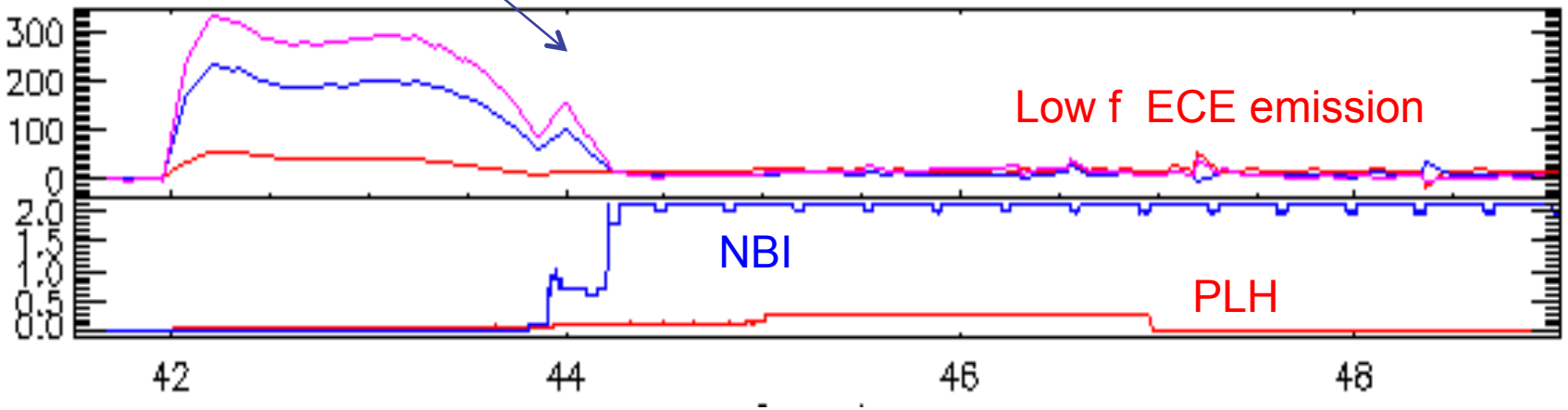


#77601 LHCD during the ramp: temporal evolution



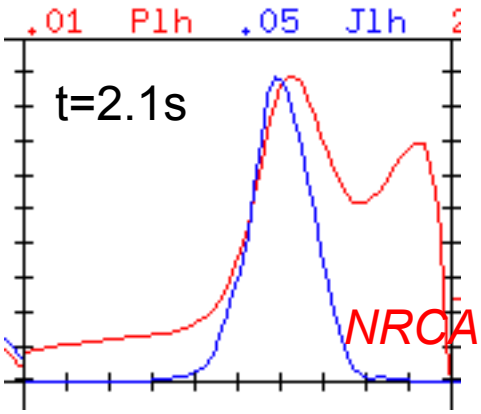
FROM ASTRA

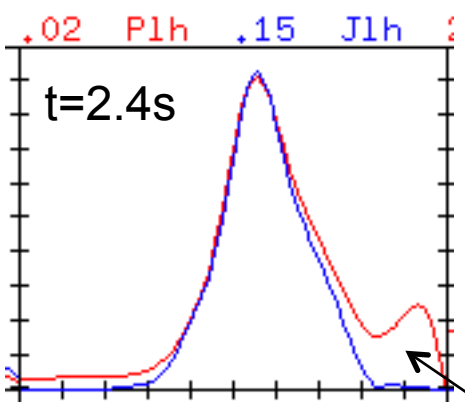
Lack of wave accessibility causes I_{LH} and P_{LH_ABS} to drop in temporal agreement with the ECE emission behaviour



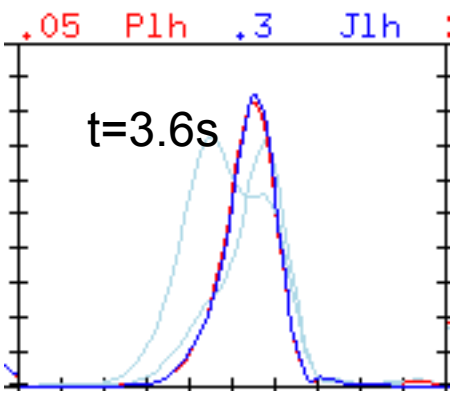
FROM PPF

77601: NRCA in the initial phase



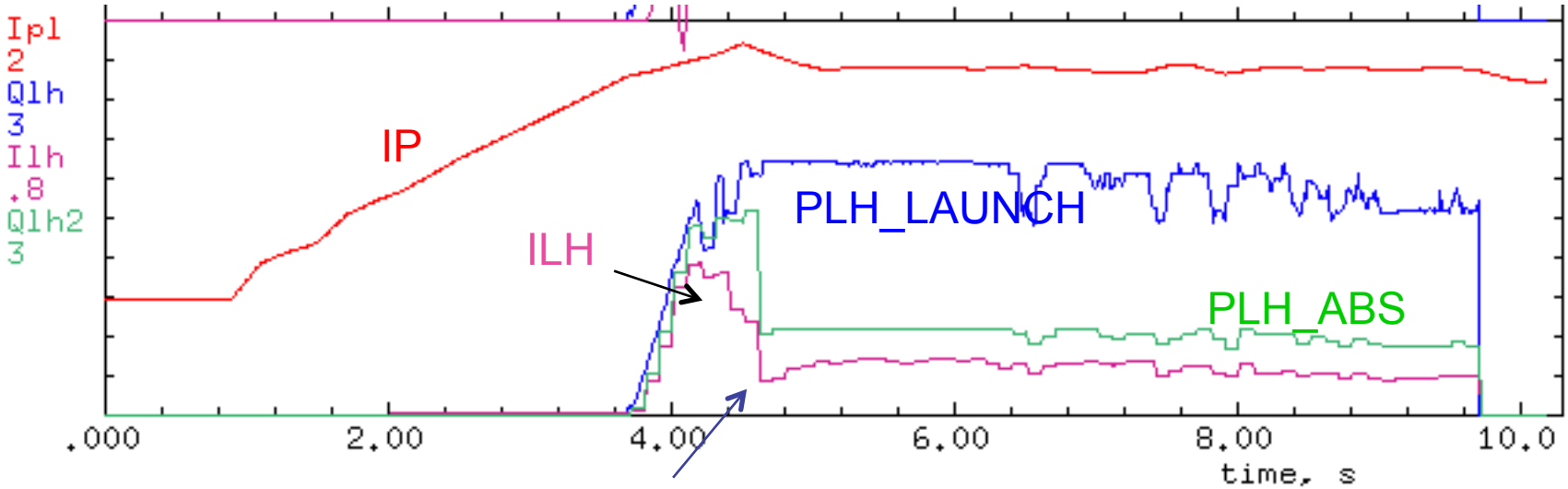


NRCA



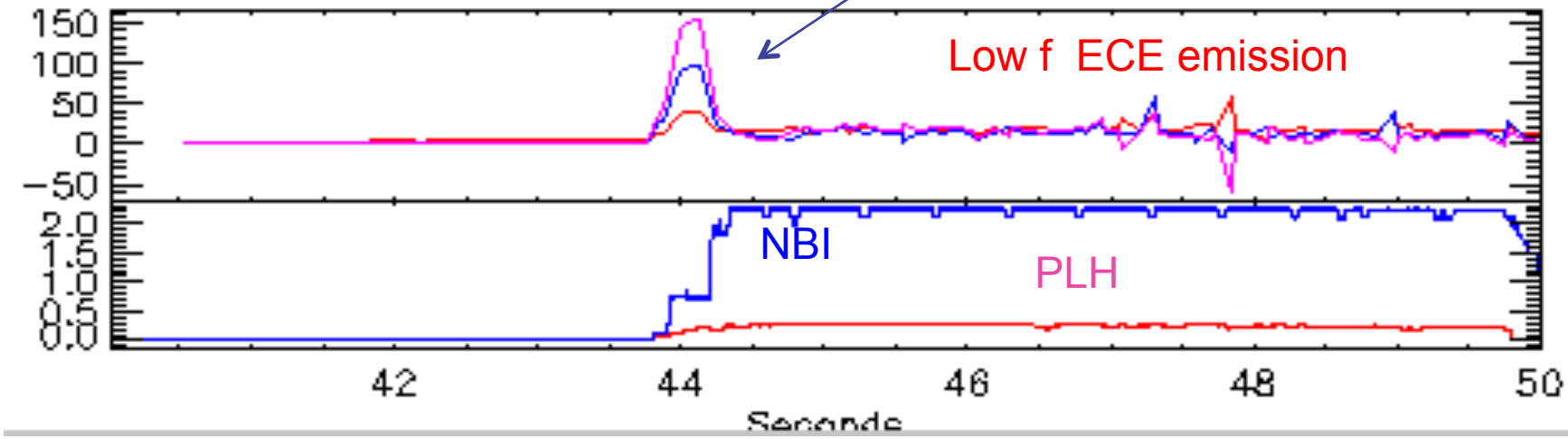
- *At t>4.5s a lack of wave-accessibility prevents the wave to enter into the plasma*

77893:time evolution. I_{LH} drops after 1 s to half of its value



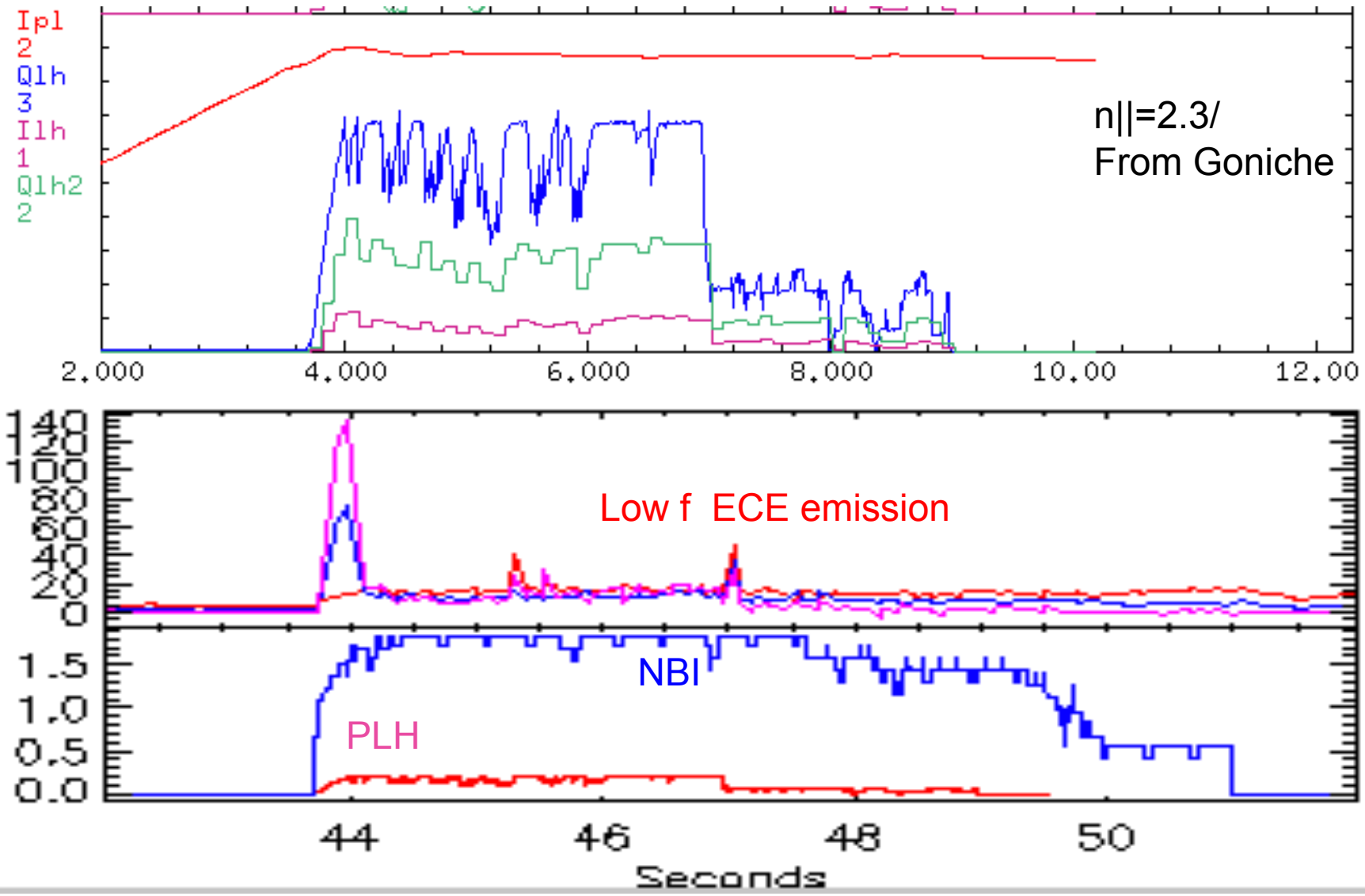
FROM ASTRA

Lack of wave accessibility causes I_{LH} and P_{LH_ABS} to drop in temporal agreement with the ECE emission behaviour



FROM PPF

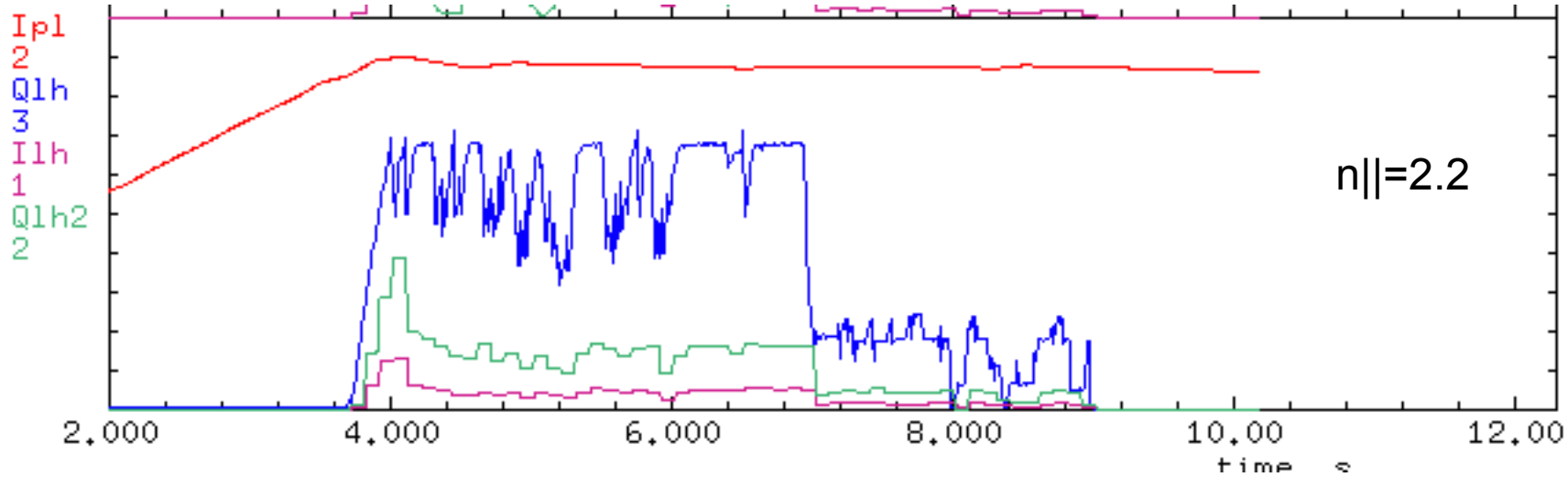
72835: temporal evolution

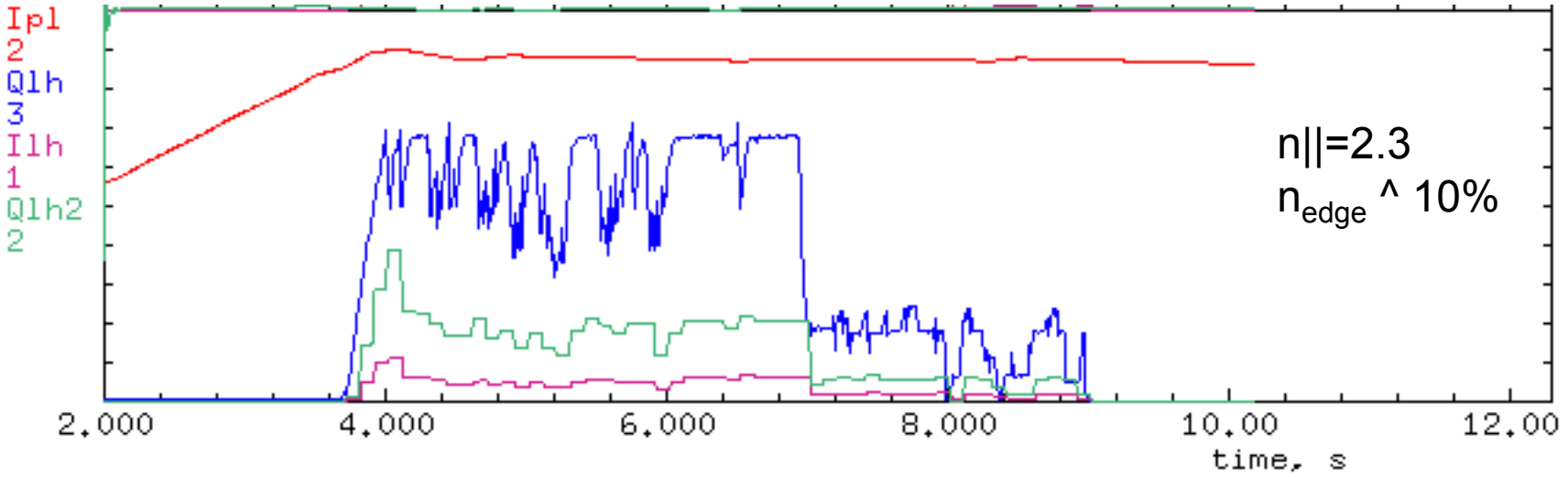


From ASTRA

From PPF

Lack of accessibility at n||=2.2 or if edge density just a 10% higher

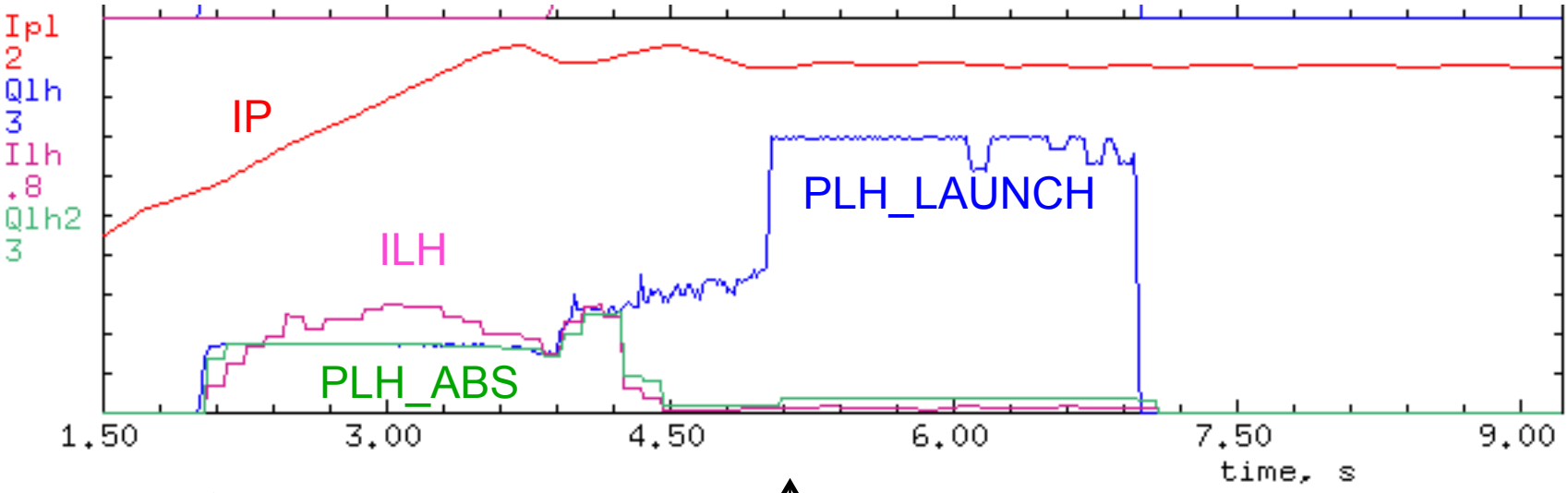




Conclusions (NRCA)

- **NRCA is "observed"** in LHCD JET discharges simulations *in the early phase of the current ramp up* (when the plasma is still collisional) in 2 discharges.
- **It accounts for the temporal delay of I_{LH}** (with respect to the launched power) experimentally documented by the DS ECE emission. NRCA stops as soon as ν_{ei} decreases and therefore it does not prevent LHCD to affect the current profile later on during the current ramp.
- Due to the "low JET plasma collisionality" **NRCA is negligible elsewhere** and cannot be responsible of the lack of penetration of LHCD in high density JET plasmas.
- In 2 of the high density discharges (77601,77893) analyzed so far, I_{LH} drops **due *to total or partial* lack of the accessibility** exactly at the time where the ECE drops. In 77601 the I_{LH} drop is total (as ECE). In 77893 the drop is partial (50%).
- ***Small variations of the density in the edge and of n|| spectrum could led to a partial lack of accessibility also in the case of 72835.***

#77601 LHCD during the ramp: q profile comparison

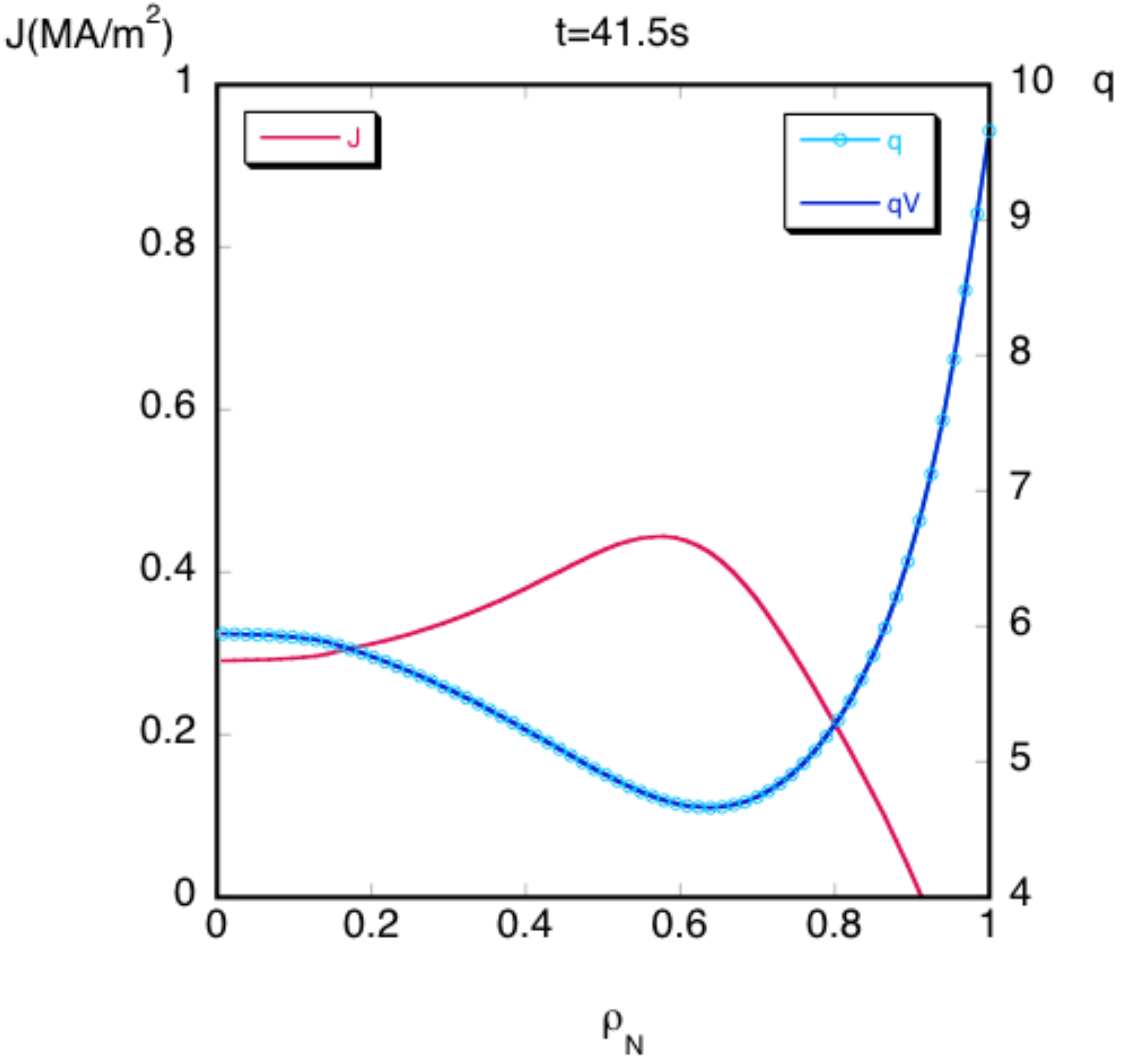


FROM ASTRA

t=41.5s t=42s t=43s t=45s t=49s

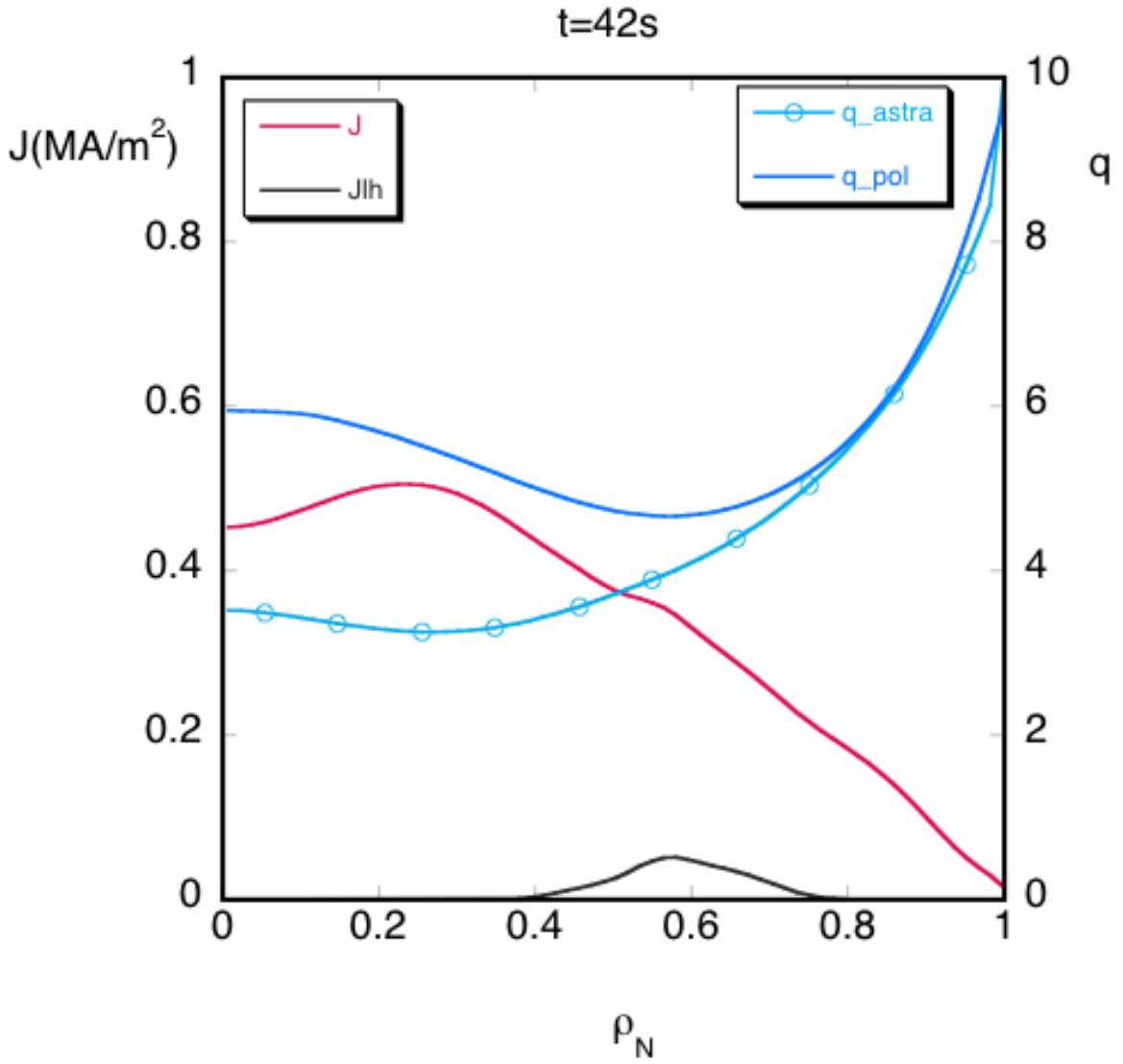
Times chosen for the comparison

Simulation/Polarimetry q_profile 77601 comparison: t=41.5s



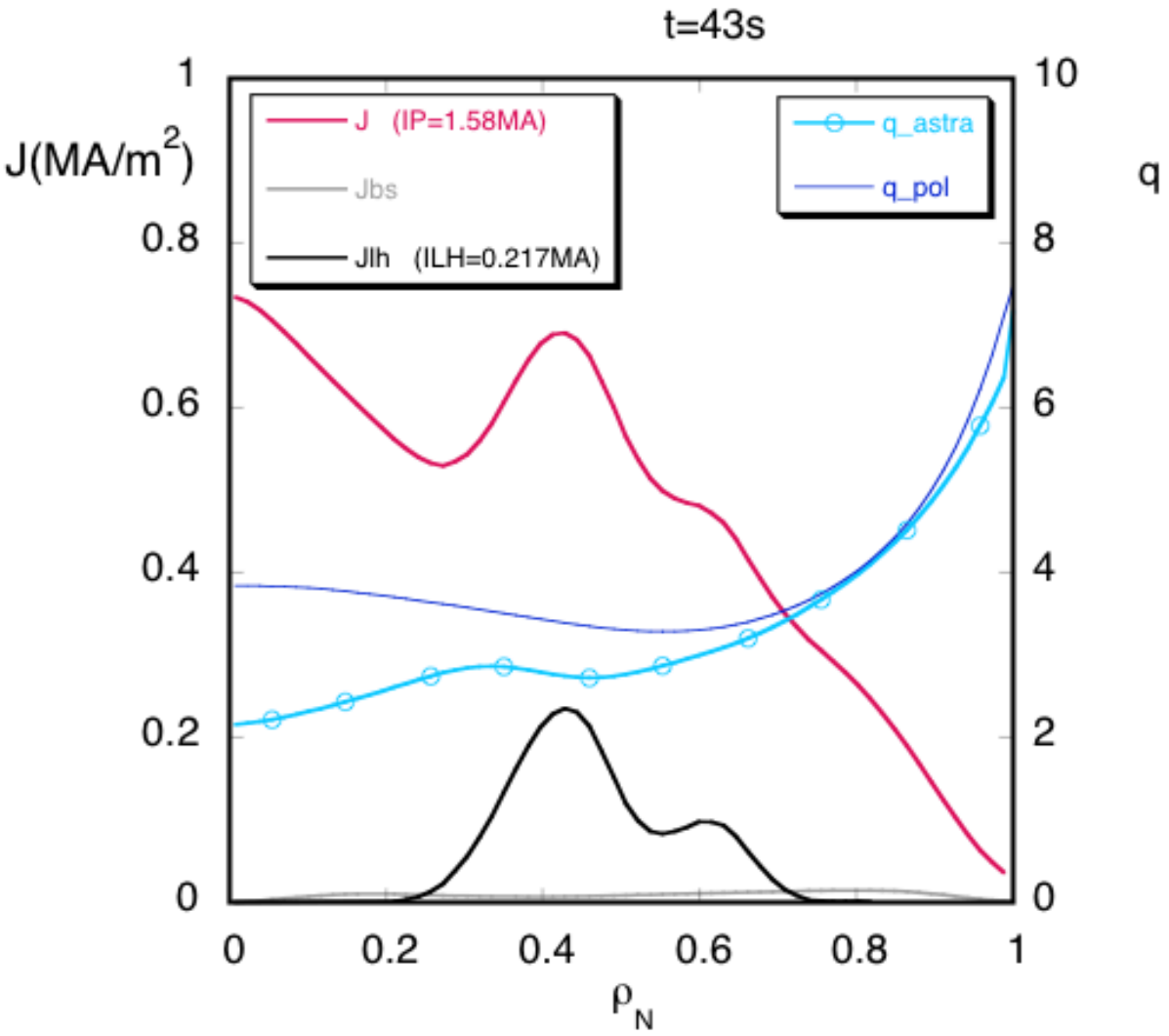
- *ASTRA starting q-profile taken from EFIT polarimetry measurement*
- *Reversal q profile*
- *Hollow J profile*

t=42 s: at the LHCD turn on



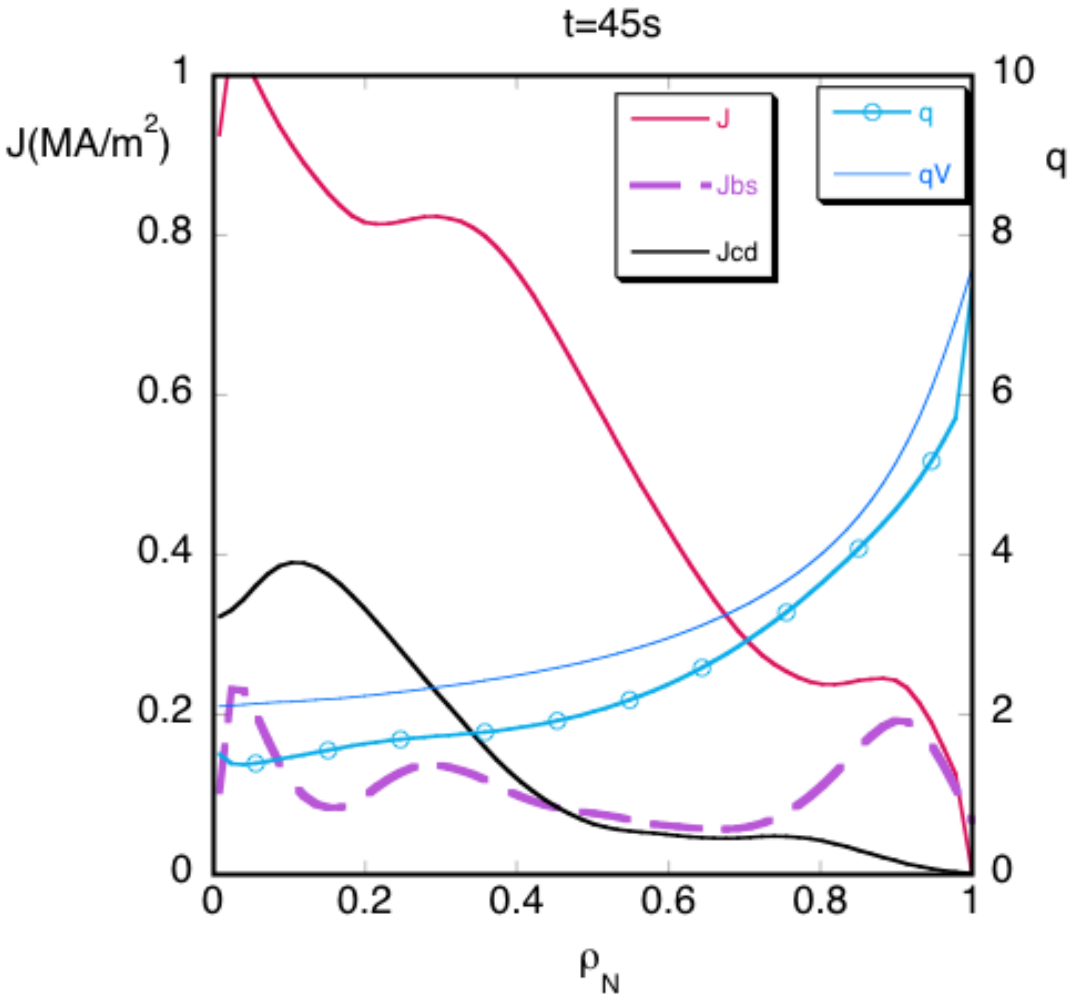
- *There is a remarkable difference in the simulated and measured q-profile 0.5 s after the start*
- *Neoclassical current diffusion much faster then measured during the current ramp.*

t=43 s : LH ON



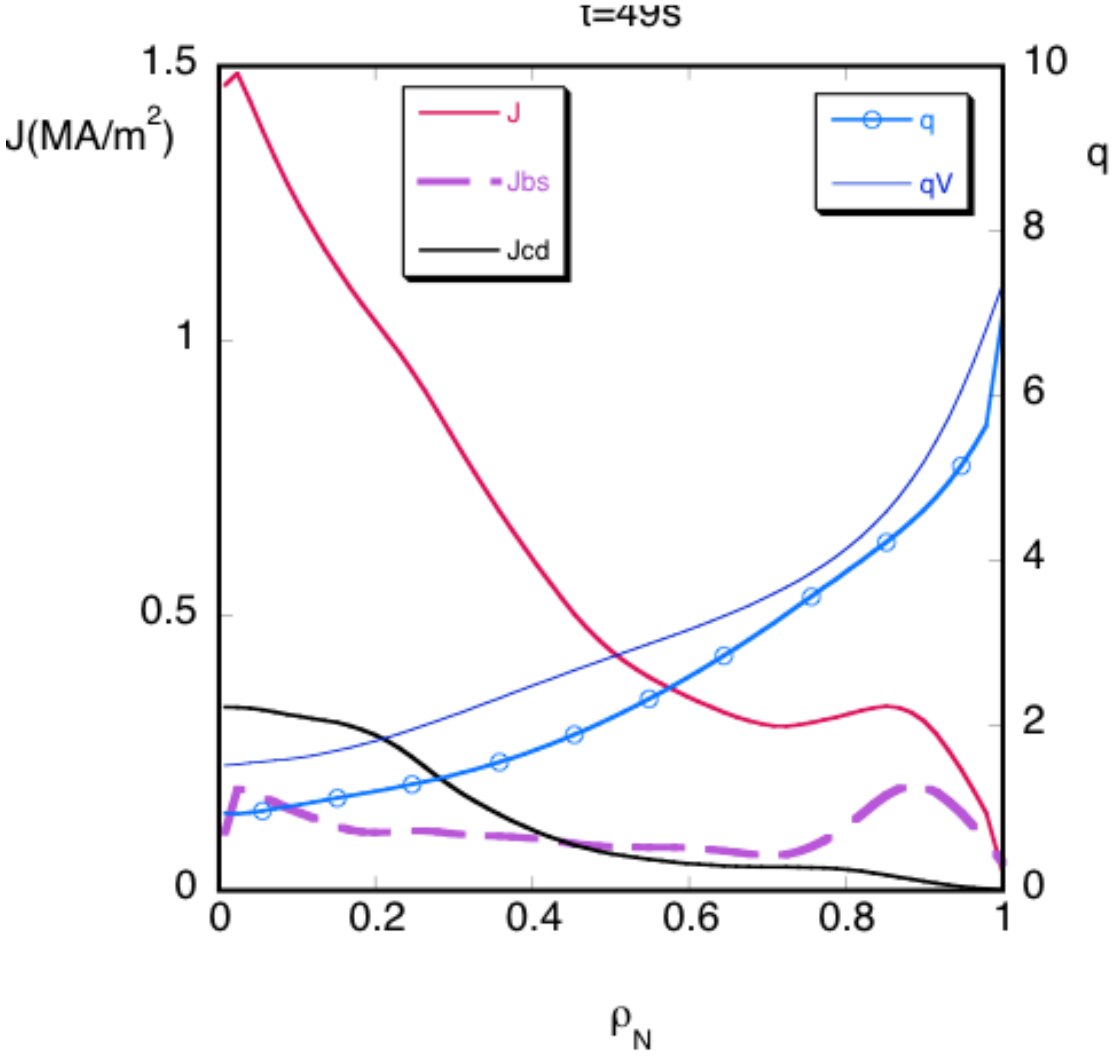
- *LHCD (271KA) induces a small shear reversal*
- *but OH central current much higher than measured*

t=45s at the NBI start



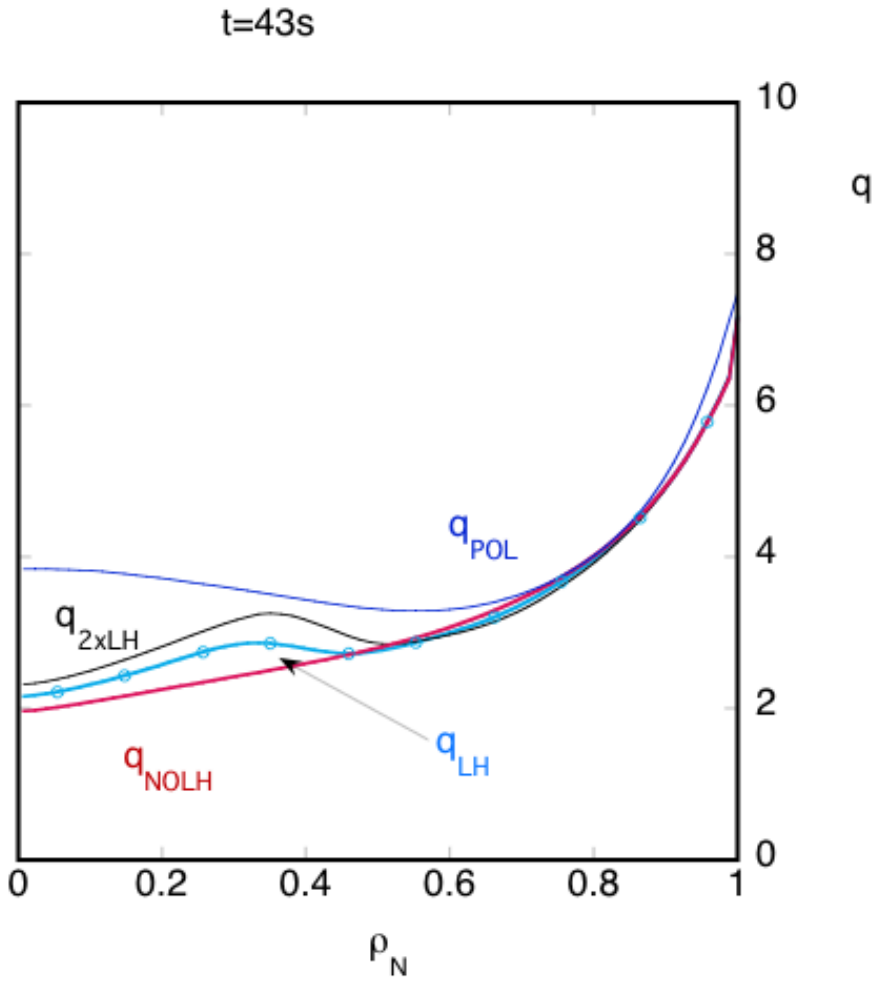
- I_{LH}=0, no accessibility
- I_{NBI}=0.315MA
- I_{BS}=0.433MA
- I_{PL}=1.74MA
- simulated and measured q_prof. have similar shapes
- *but edge boots. current seems higher in simulation ?*

t=49s



- *J is still peaking*
- *Simulated and measured q0 are still landing toward 1*
- *No ST observed in the expt.*

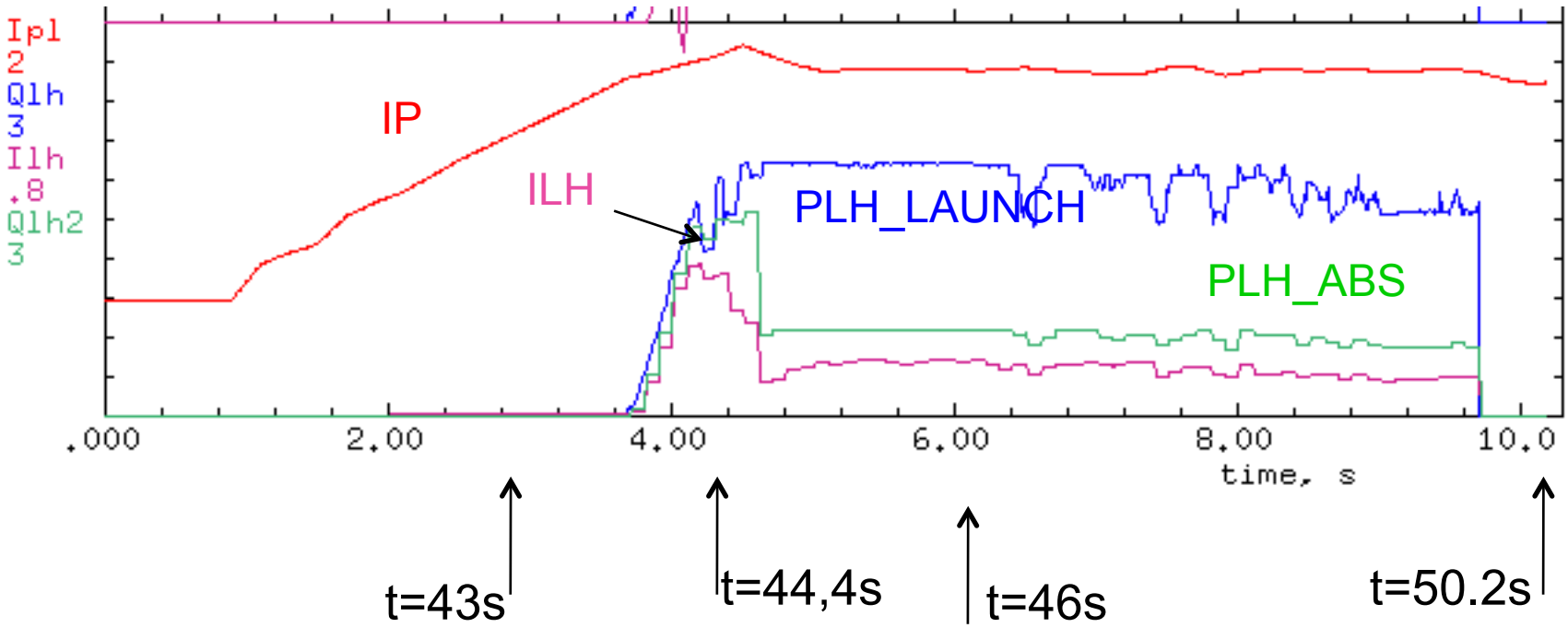
Exercise: changing the LHCD power



- *ASTRA runs*
- *at 2x P_{LH} (1MW)*
- *at P_{LH} (77601, 500kw)*
- *at P_{LH}=0*

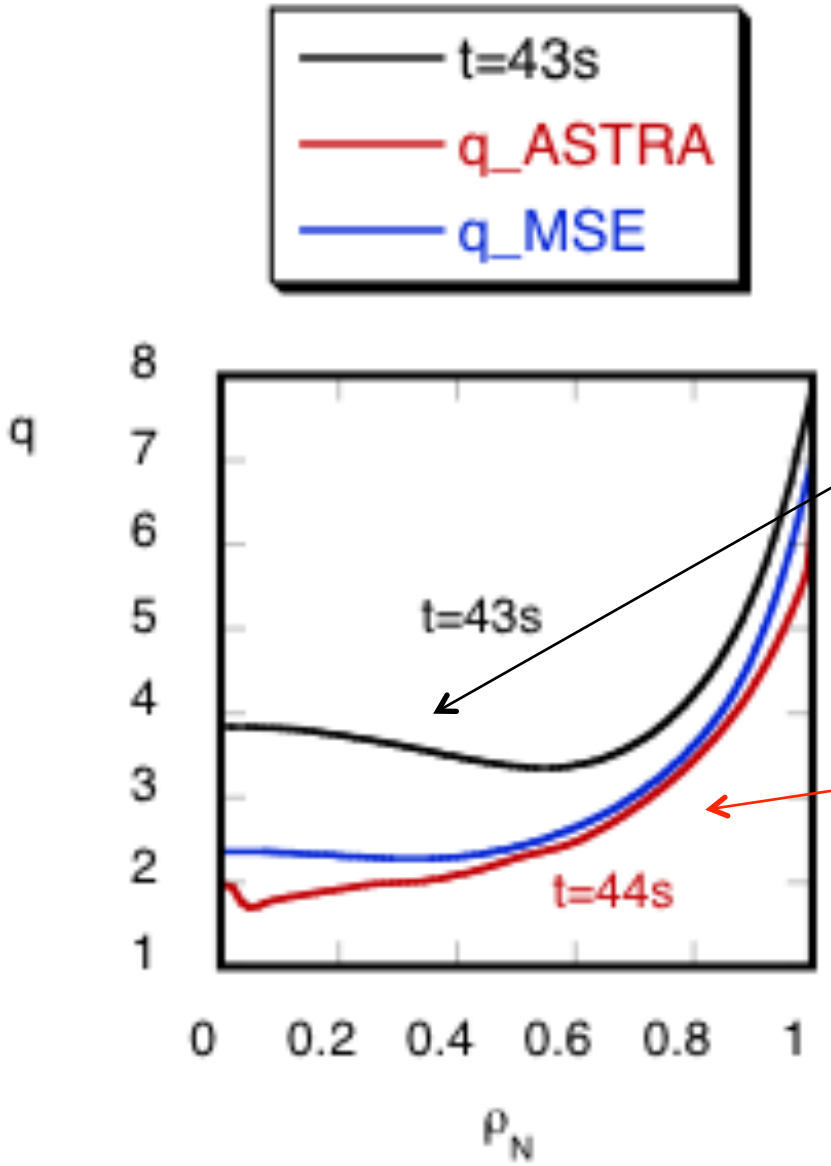
q_profile comparison in the main heating phase:#77893

FROM ASTRA



Times chosen for the comparison

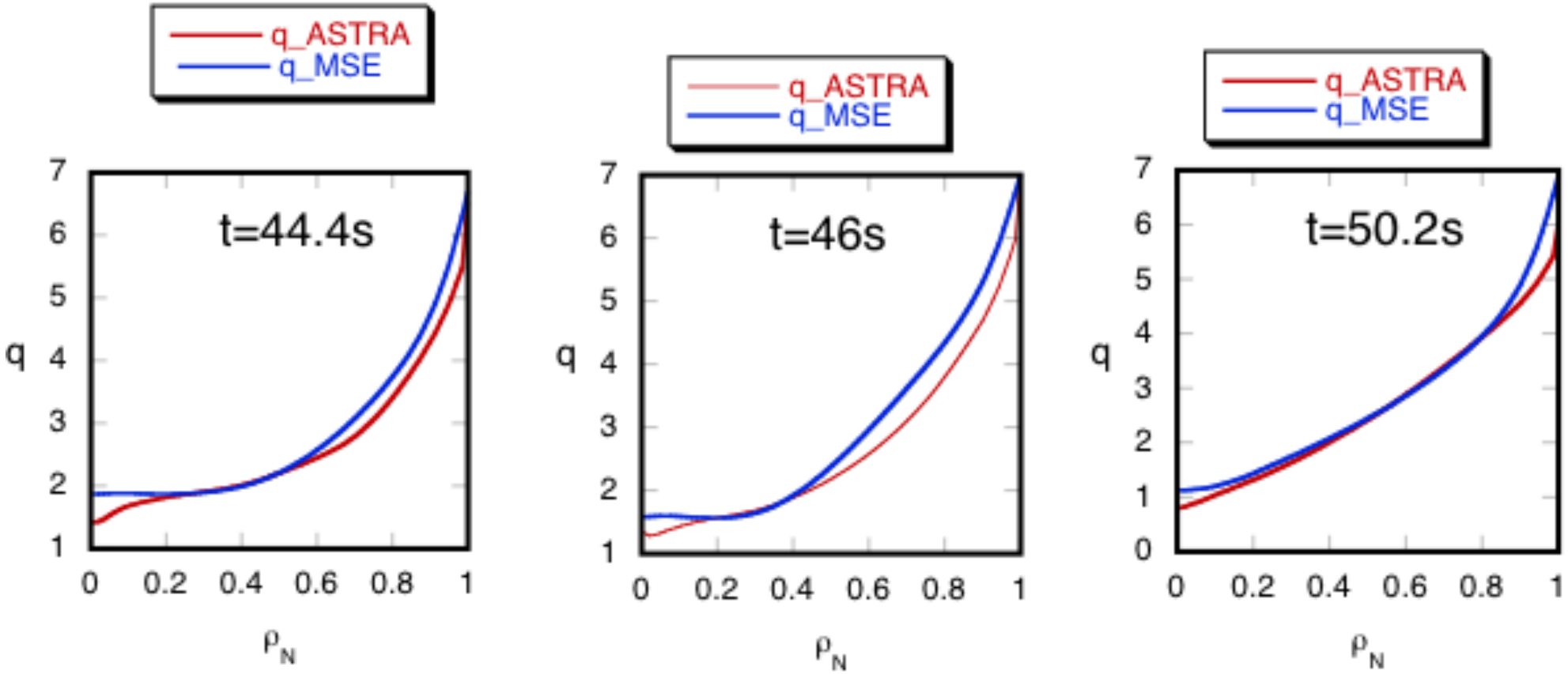
Simulation/measured q_profile 77893 comparison: t=43s & 44s



- *ASTRA starting q-profile taken from EFIT polarimetry measurement at t=43*
- *q_MSE & q_ASTRA*

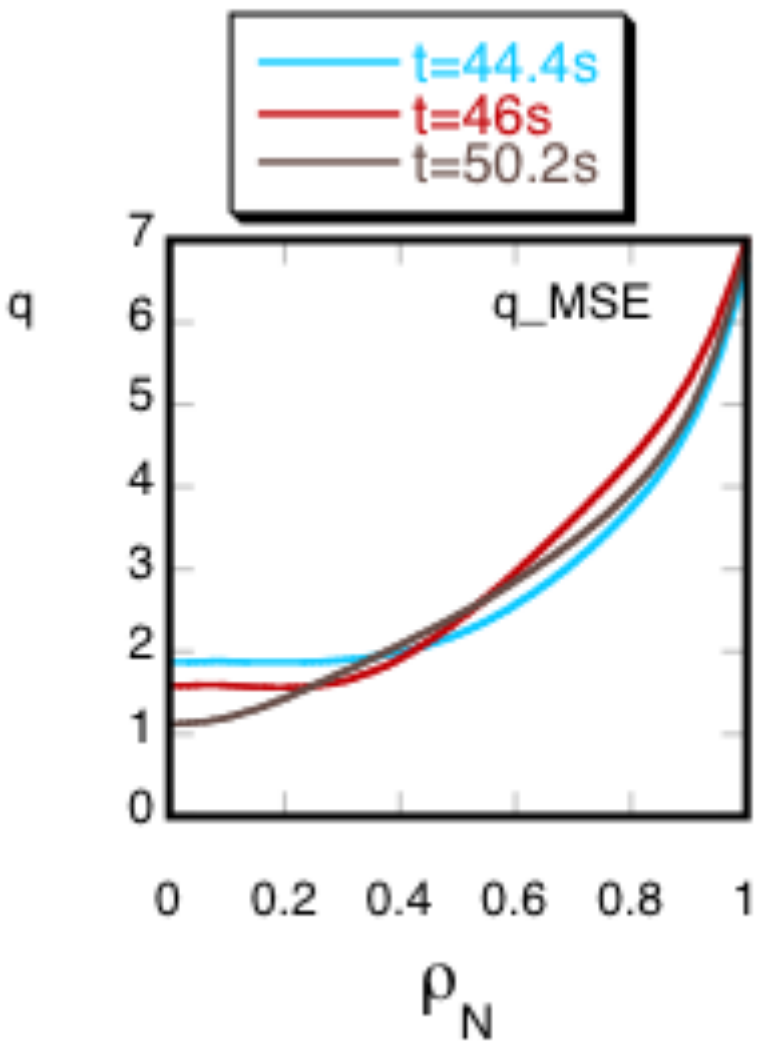
comparison at t=44

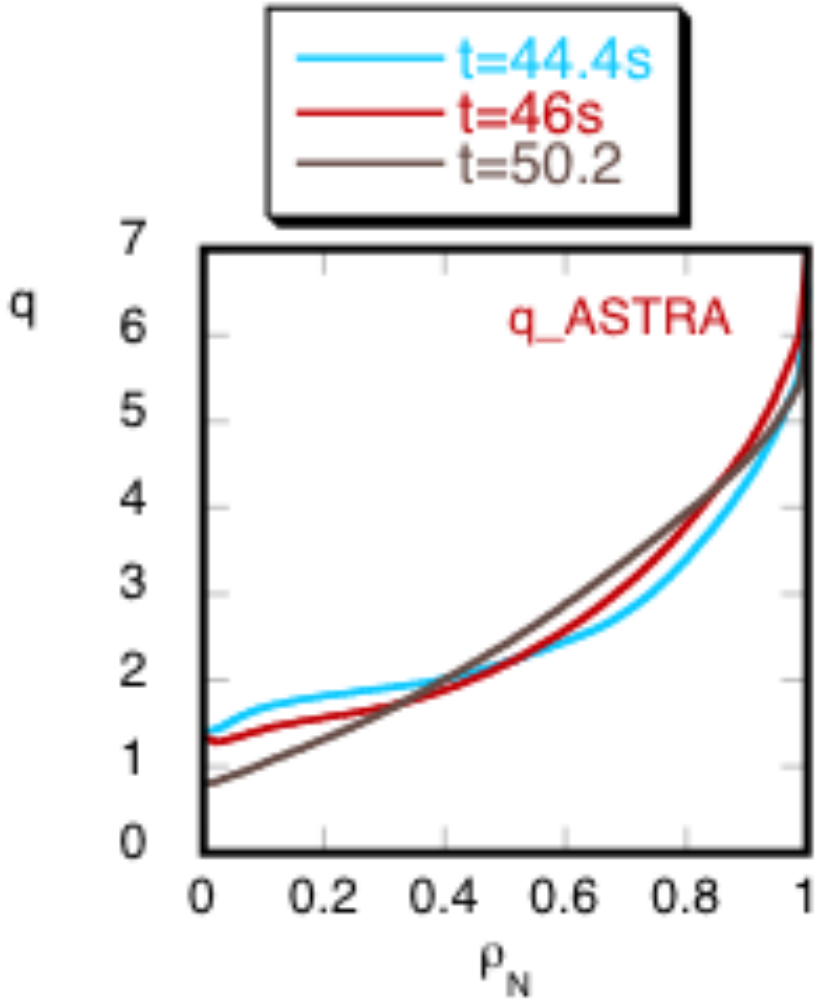
77893:comparison later on



- *General good agreement in the current flat-top*

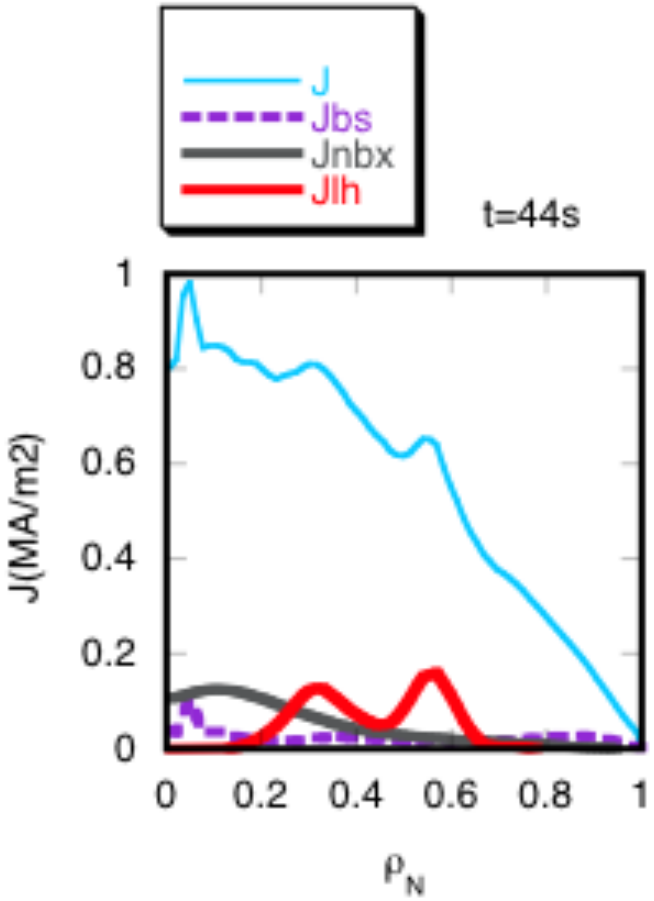
77893:Profile time evolution

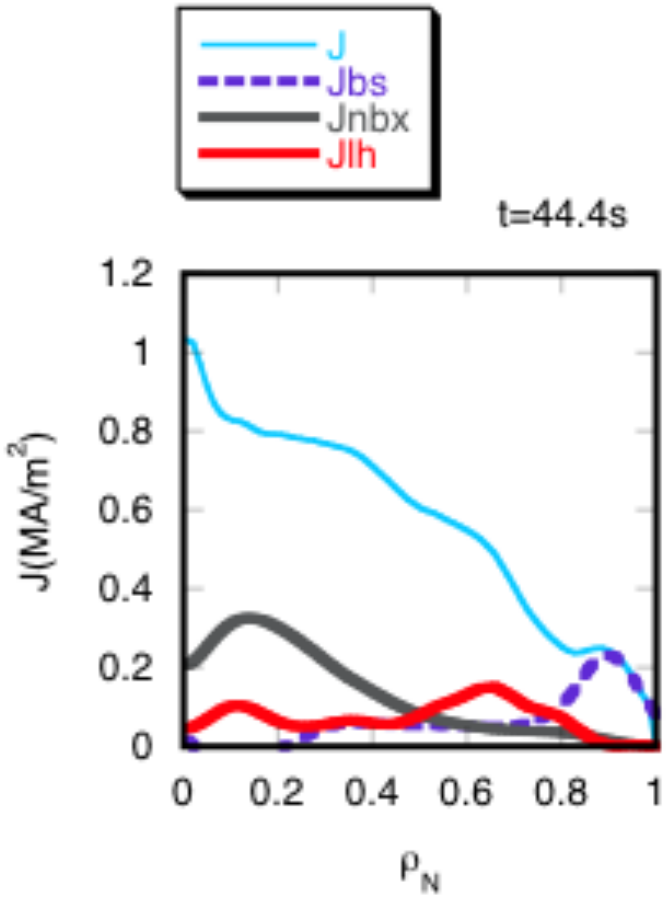


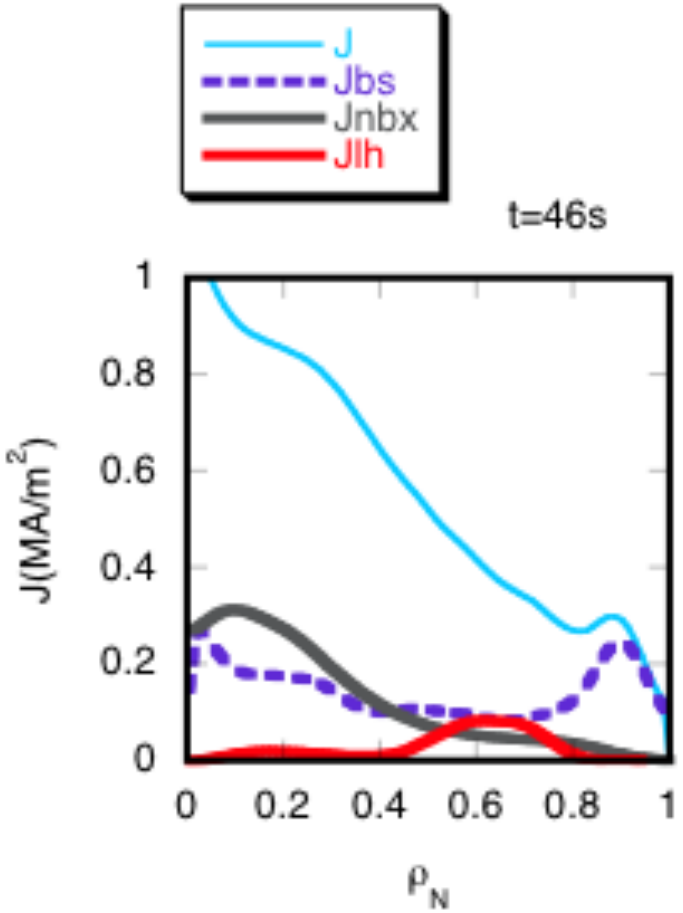


- *q_0 is always lower in the simulation*

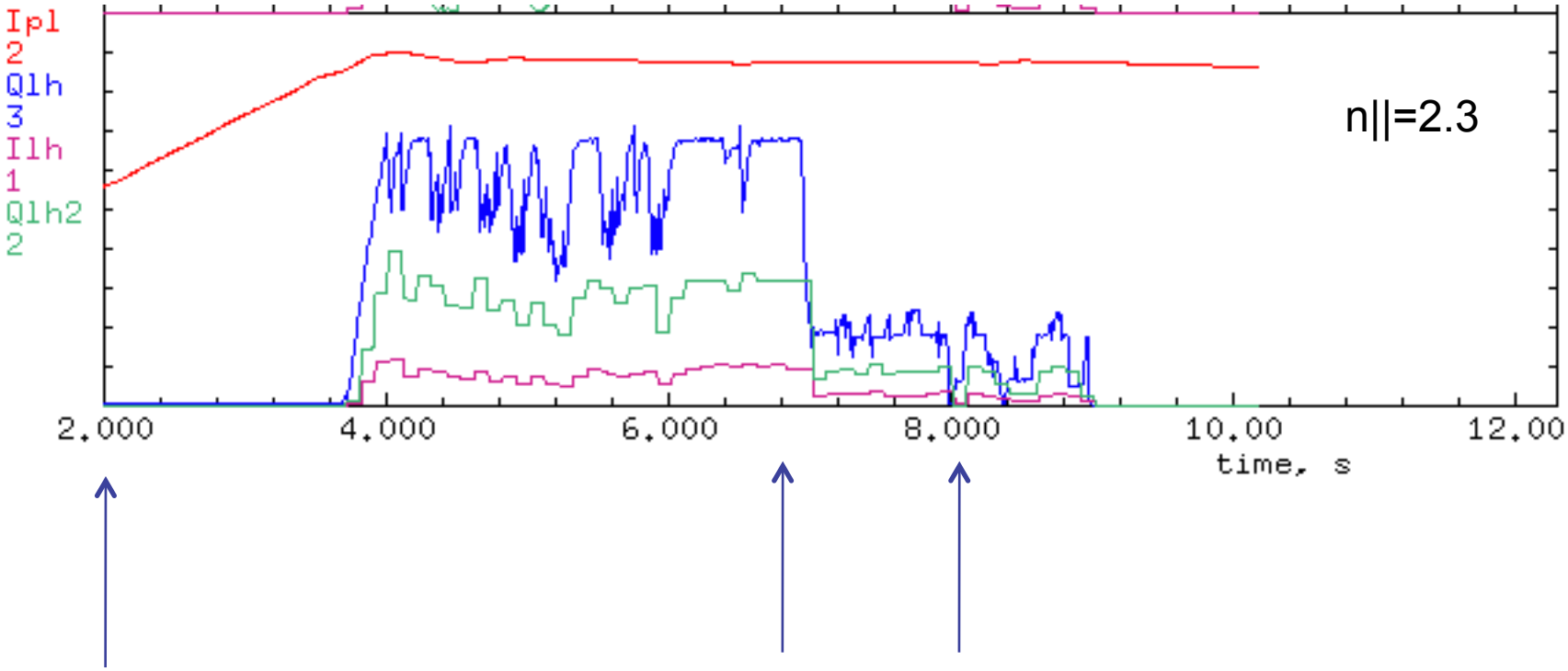
77893:J-profiles





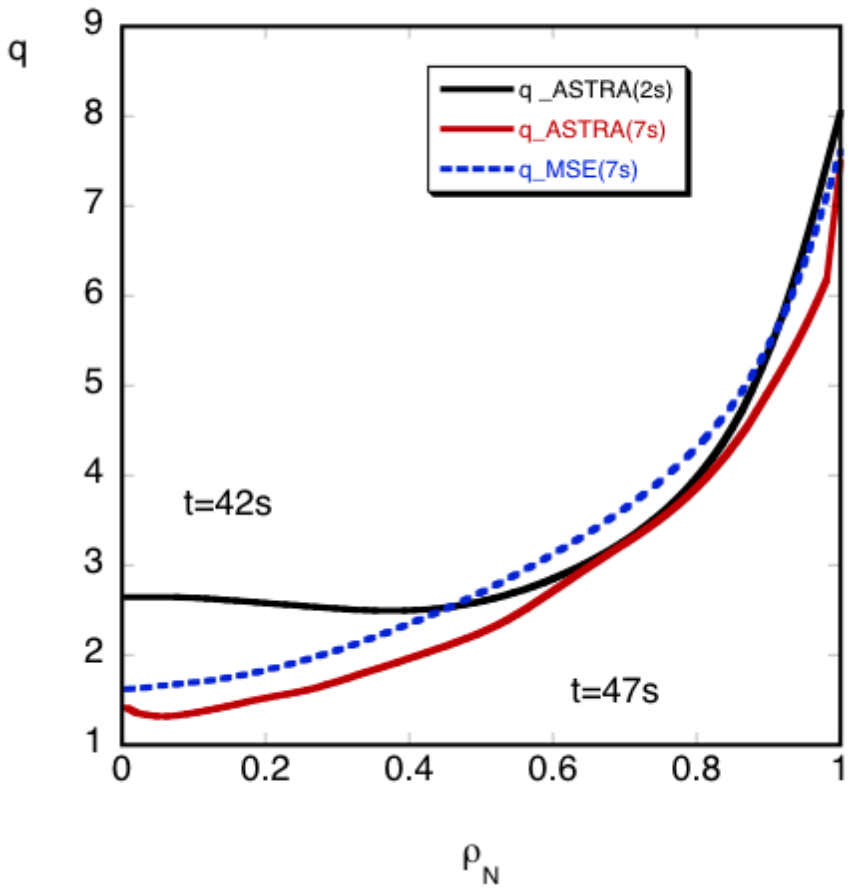


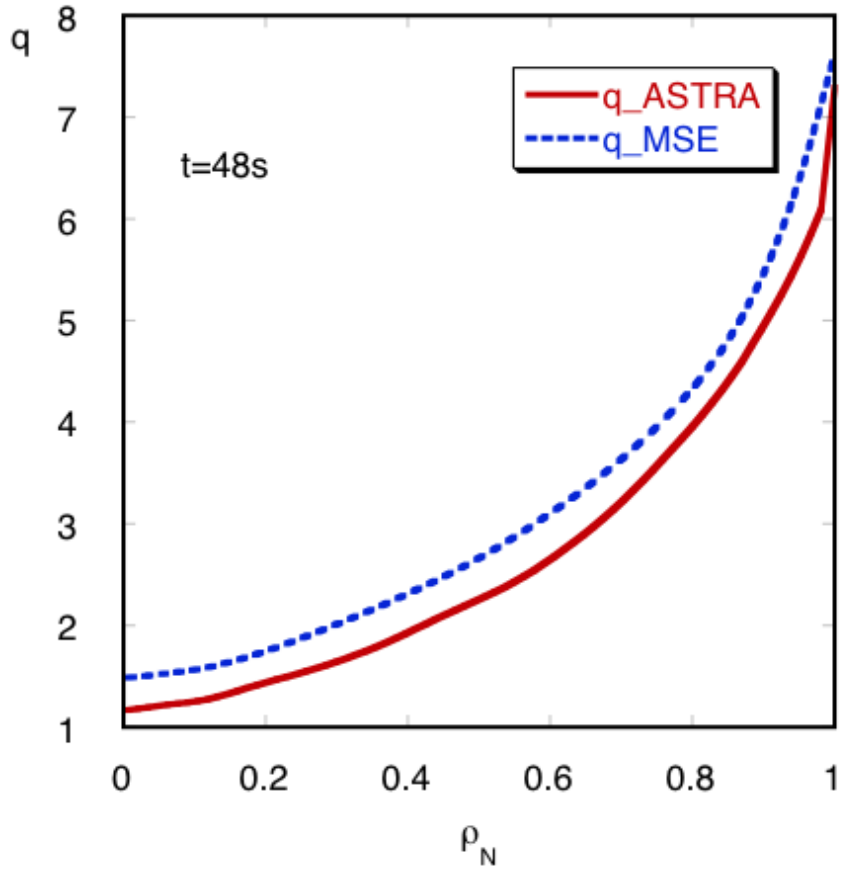
72835: main heating phase



From ASTRA

72835: q-pofile comparison

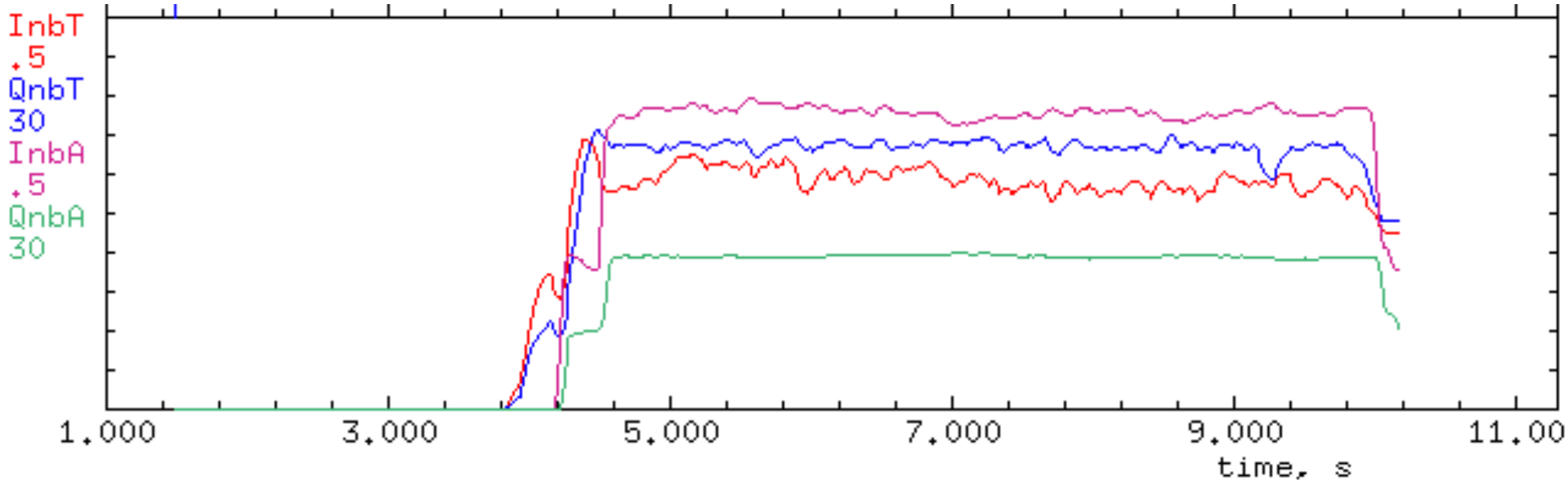




Conclusions (q-profile)

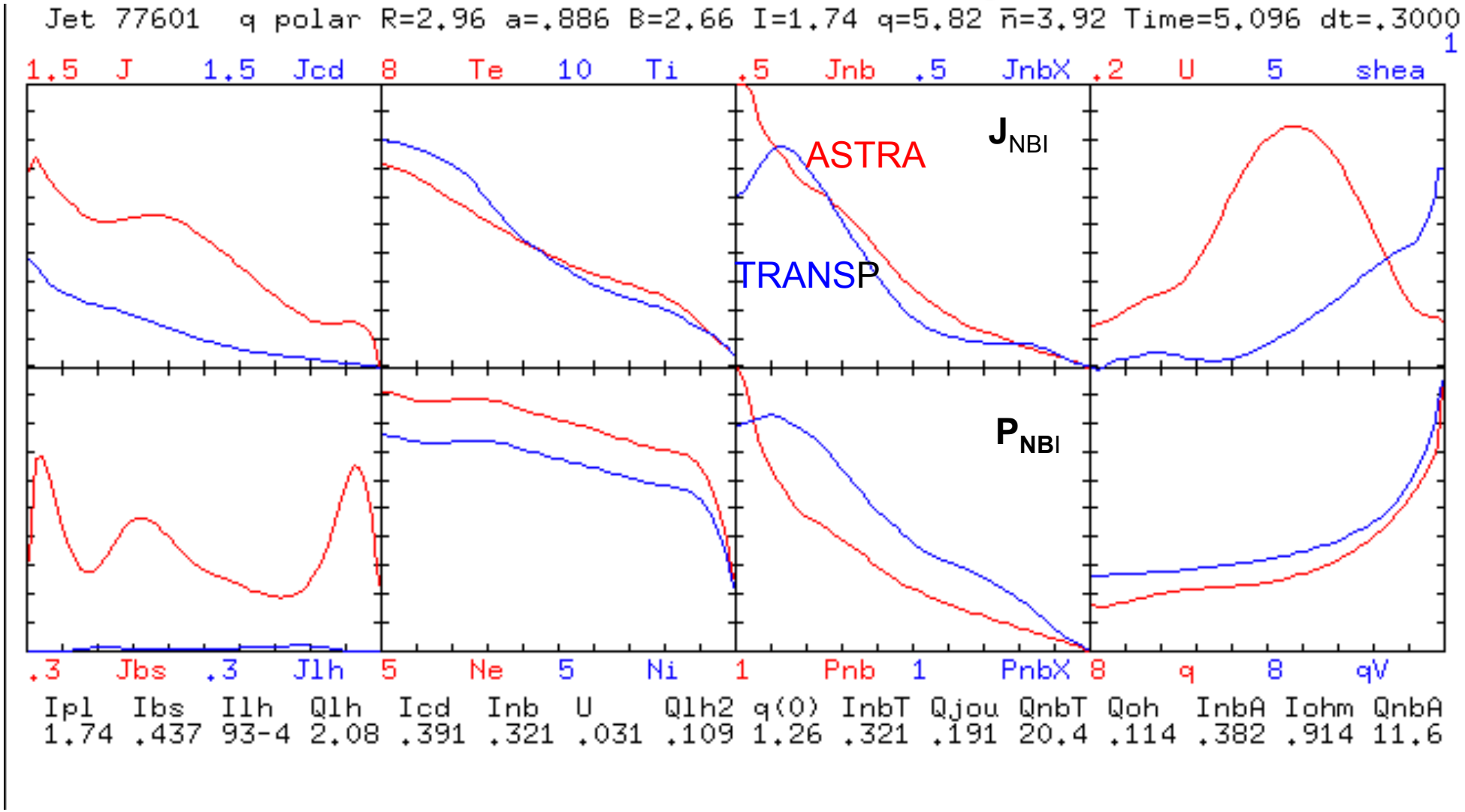
- *During the current ramp (≠77601) there is a remarkable difference in the simulated and measured q-profile 0.5 s after the start (where q profile are chosen equal)* indicating that *neoclassical current diffusion is much faster then measured during the current ramp.*
- *LHCD (271KA)induces a small shear reversal, but OH central current much higher than measured*
- On the contrary *during the current flat top, simulated and measured q profiles are in good* even though q_0 *is always lower in the simulation*

Comparison NBI ASTRA/TRANSP; temporal evolution #77601



- *Absorbed power by ASTRA is 60% of QNBI by TRANSP but driven currents are similar from both!*

Comparison NBI ASTRA/TRANSP; #77601 profiles

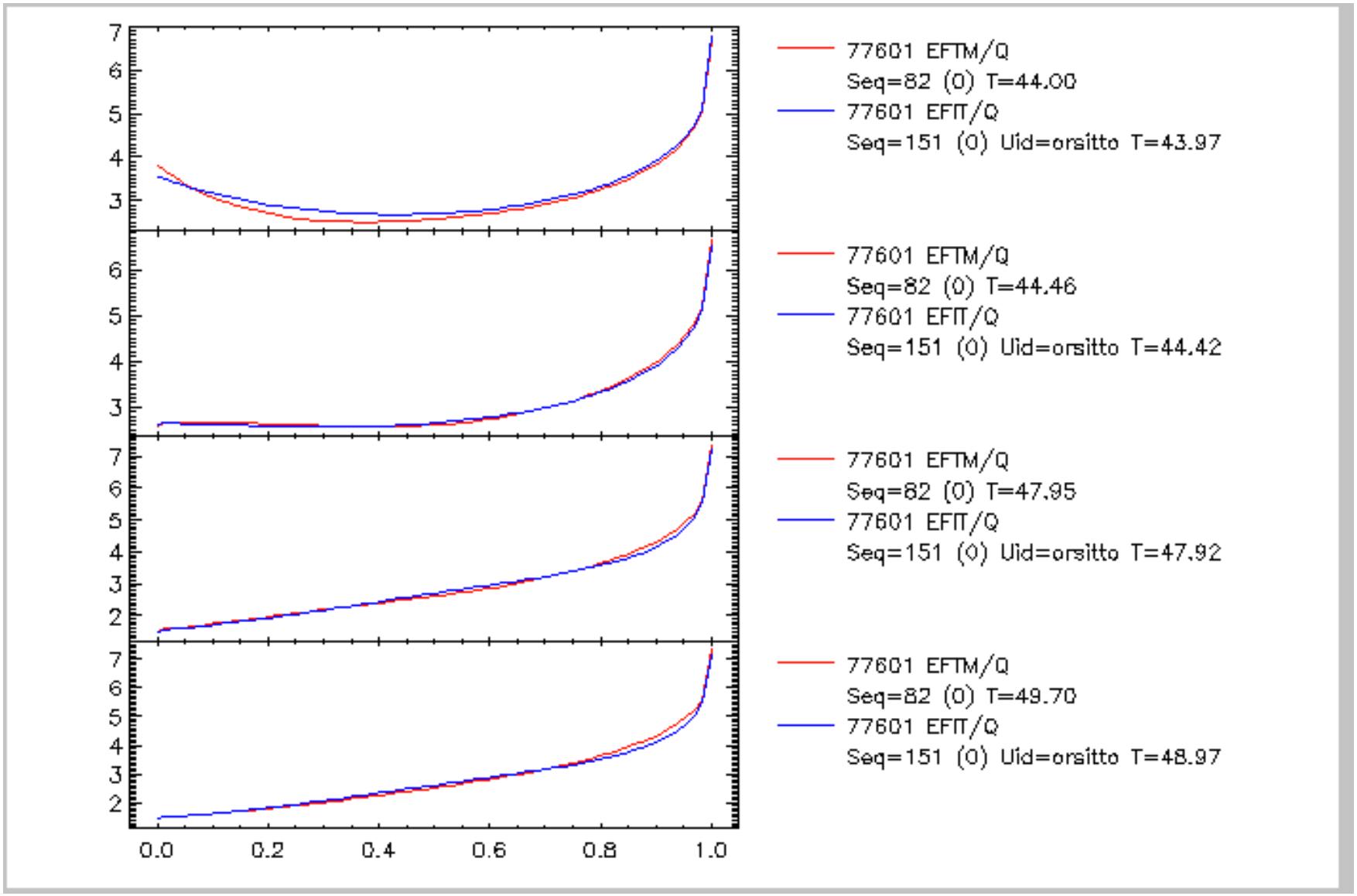


I_T=321kA, Q_T=20M , I_A=382KA, Q_A=12MW

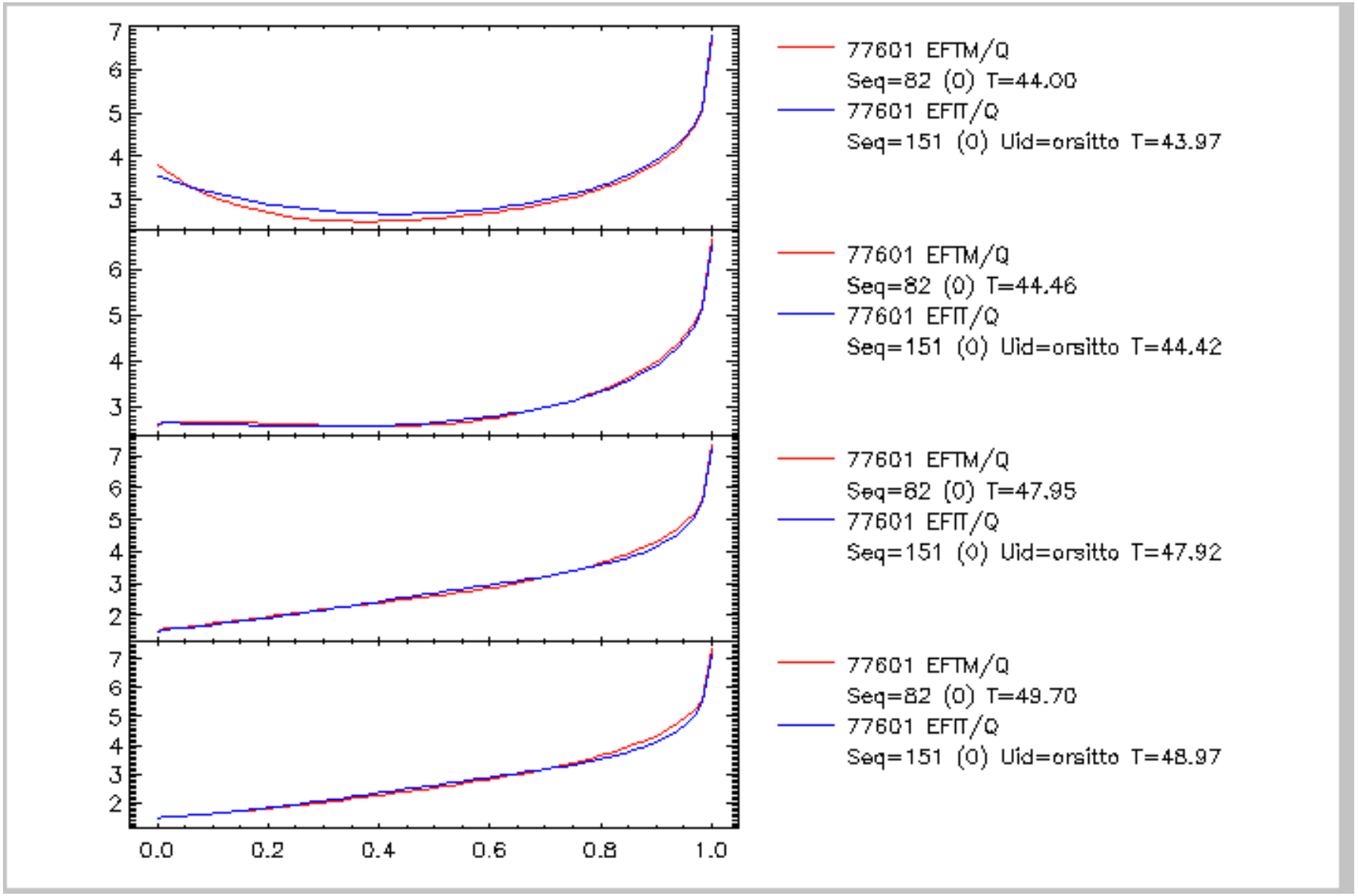
Future work

- Benchmarking activity on JET discharges is important for planning LHCD prelude experiments in the next campaign
- Run ASTRA/FRTC for #83328 to compare the simulated li and q prof. with the expt.data
- Run a discharge similar to 83328 but at higher LH power to enhance the LHCD effect on li and q.

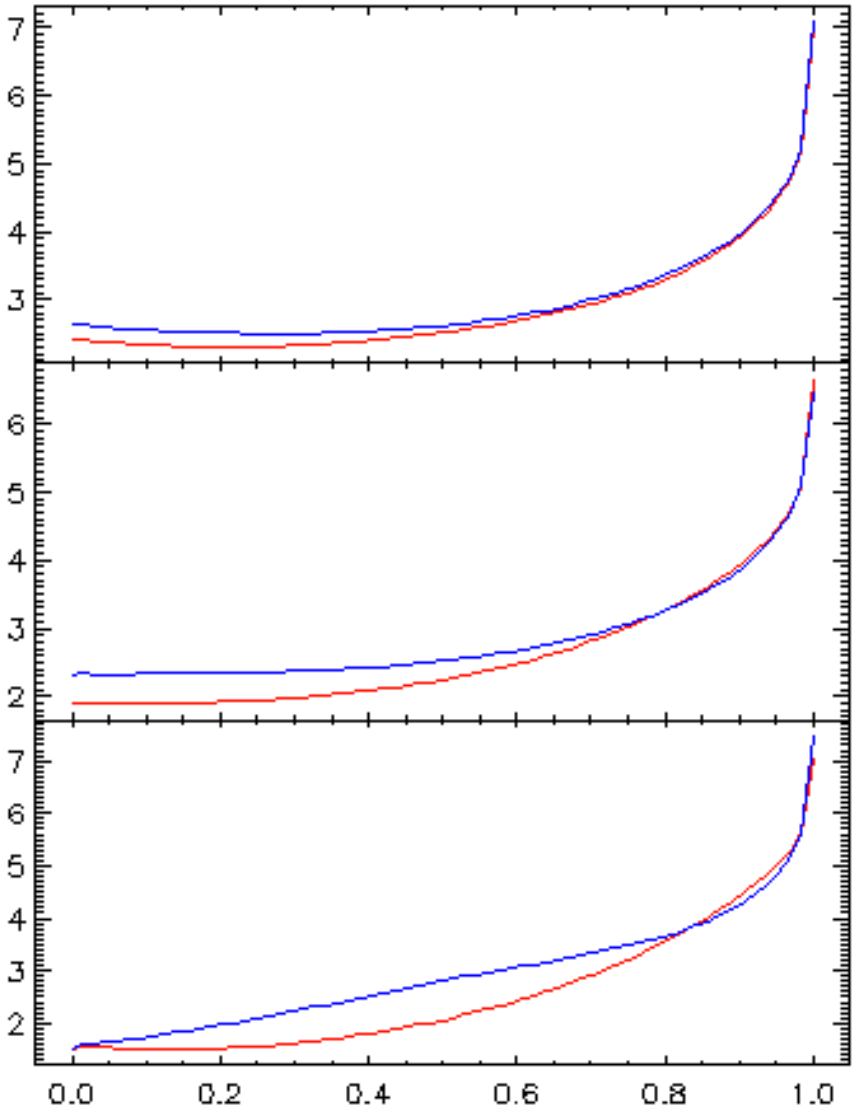
q data from MSE and polarimetry in good agreement for 77601



..and 72835


77601 EFTM/Q
Seq=82 (0) T=44.00
77601 EFIT/Q
Seq=151 (0) Uid=orsitto T=43.97
77601 EFTM/Q
Seq=82 (0) T=44.46
77601 EFIT/Q
Seq=151 (0) Uid=orsitto T=44.42
77601 EFTM/Q
Seq=82 (0) T=47.95
77601 EFIT/Q
Seq=151 (0) Uid=orsitto T=47.92
77601 EFTM/Q
Seq=82 (0) T=49.70
77601 EFIT/Q
Seq=151 (0) Uid=orsitto T=48.97
0.0
0.2
0.4
0.6
0.8
1.0

Some differences in 77893



77893 EFTM/Q
Seq=65 (0) T=43.96
77893 EFIT/Q
Seq=155 (0) Uid=orsitto T=43.92

77893 EFTM/Q
Seq=65 (0) T=44.26
77893 EFIT/Q
Seq=155 (0) Uid=orsitto T=44.37

77893 EFTM/Q
Seq=65 (0) T=46.25
77893 EFIT/Q
Seq=155 (0) Uid=orsitto T=46.27