



# TRANSP run using EFIT equilibrium

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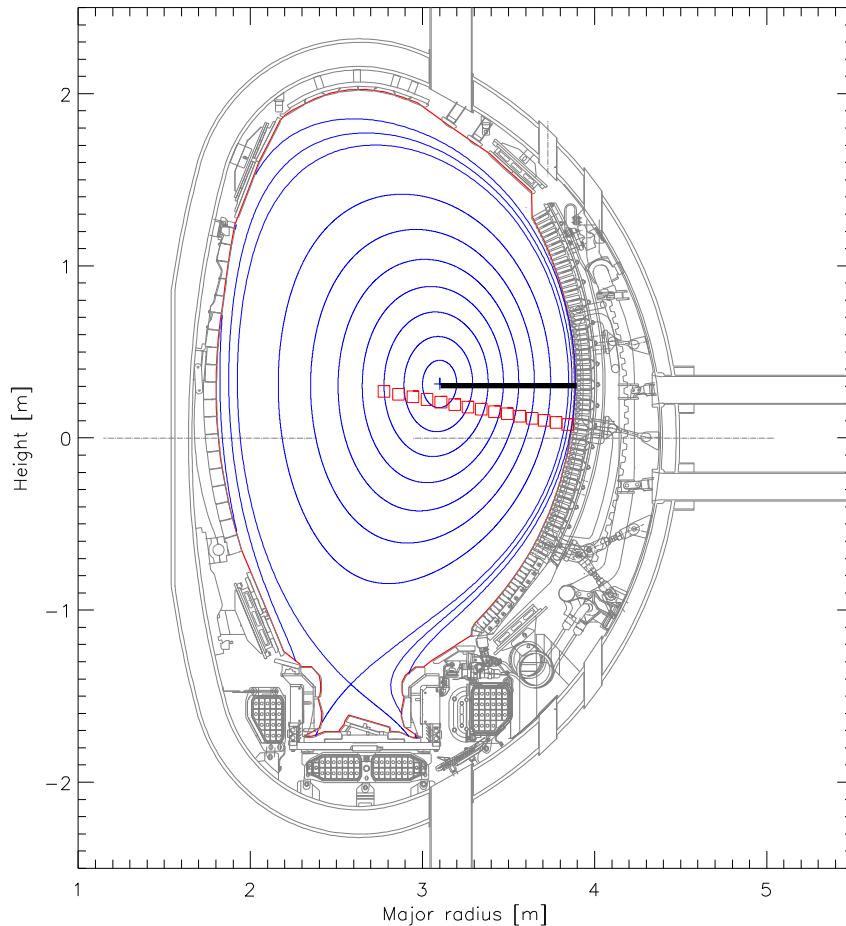
1. Motivation
2. MHD equilibrium and Poloidal Field Diffusion Equation (PDE) in TRANSP
3. Comparison of TRANSP results using EFIT equilibrium
4. How to run TRANSP using EFIT

# Line of sight of CXRS measurement



#77154 at 46s

SURF Lx201.2



The Input data for TRANSP run must be the profile on the mid-plane i.e. from magnetic axis to boundary surface at low field side.

However, CX data is measured along the line of sight, which is deviated from the mid-plane.

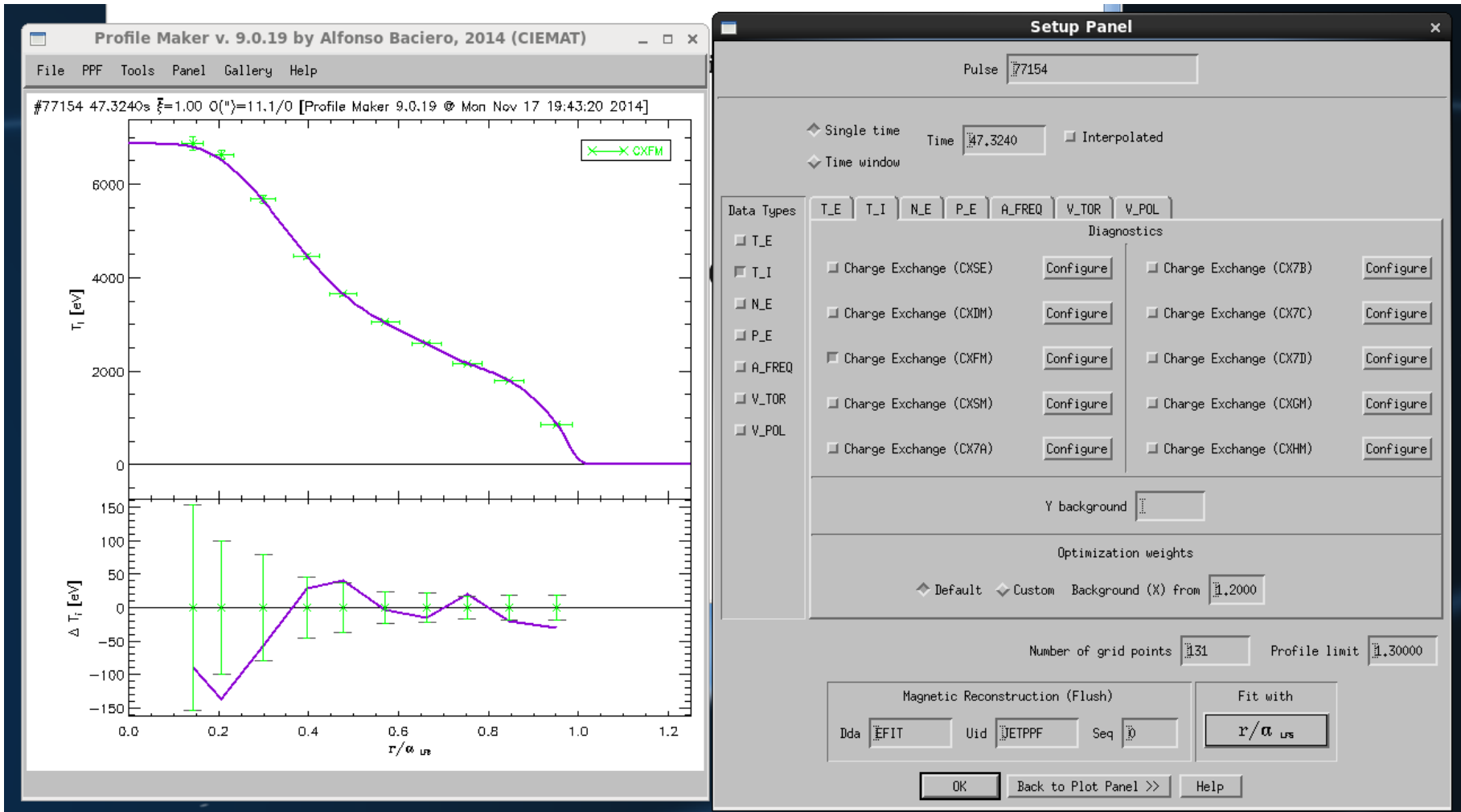
This requires mapping process of the measured data.

— #77154/JETPPF/EFIT/0 t=45.992199

— ks5 (Mk2HD-) **CXRS**

— Mid-plane

# Input data is mapped with EFIT



However, TRANSP internal equilibrium can be different with EFIT.

# MHD Equilibrium



Numerical solution to Grad-Shafranov equation :-

$$-\mu_0 R^2 \frac{dp}{d\psi} - \mu_0 F \frac{dF}{d\psi} = \Delta^* \psi(R, z) \equiv R^2 \nabla \cdot \left( \frac{\nabla \psi(R, z)}{R^2} \right) \longrightarrow \text{to find } \Psi \text{ in real space}$$

R and z coordinate.

where

$\Psi$  = Poloidal Flux Function

$F = RB_T \times$  Poloidal current outside constant  $\psi$  surface

$p$  = plasma pressure

$R$  = Major Radius

$B_T$  = toroidal angle

$RB_T$  is measured, and  $p$  come from measurements and modelling

Boundary of plasma is obtained from EFIT.

# Poloidal field Diffusion Equation (PDE)



$$-\frac{\partial \vec{B}(\sqrt{\Phi_N}, t)}{\partial t} = \frac{1}{\mu_0} \nabla \times (\eta \nabla \times \vec{B}(\sqrt{\Phi_N}, t))$$

where

$\eta$  = plasma resistivity

$\sqrt{\Phi_N}$  is sqrt of normalized toroidal flux

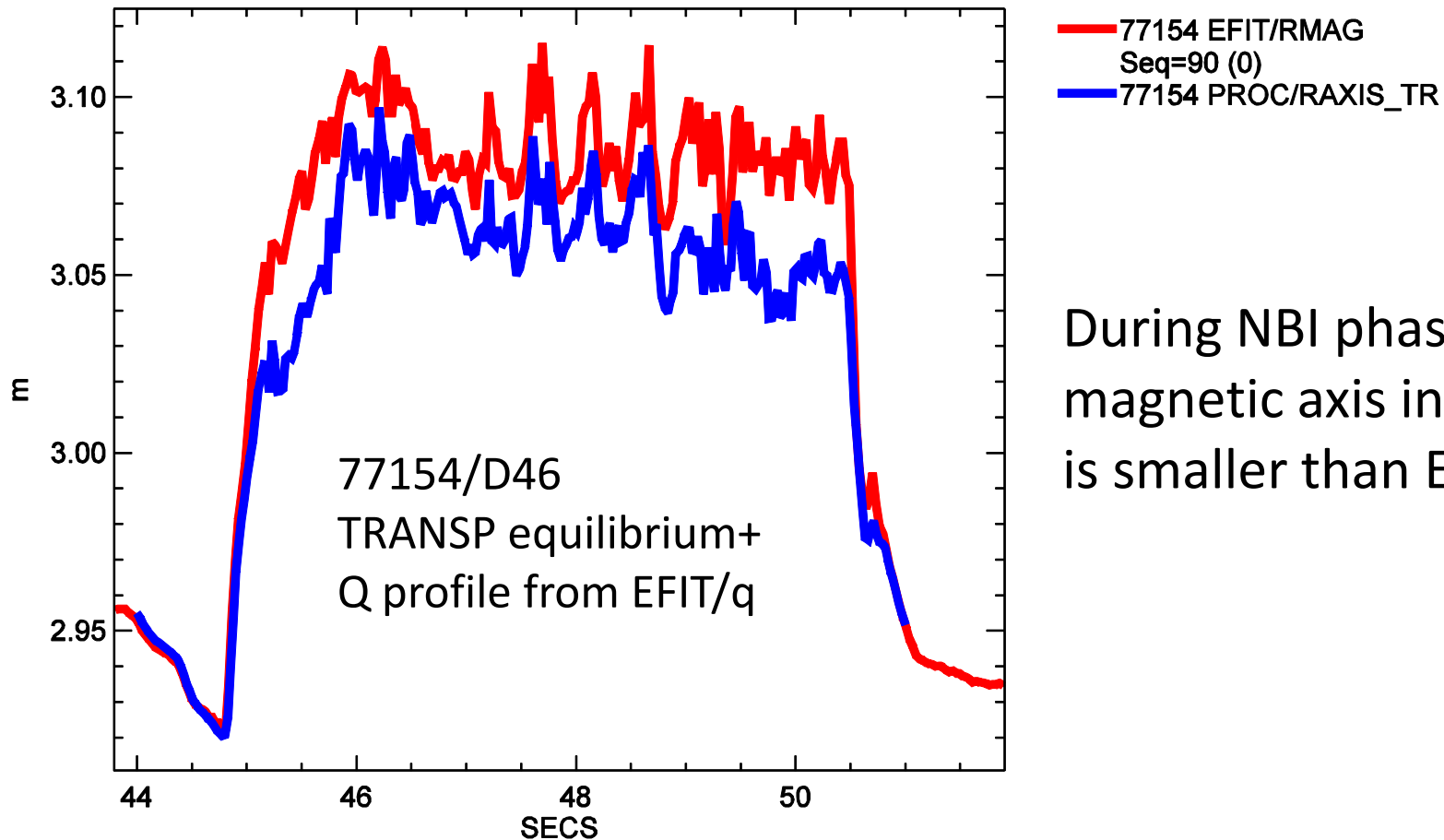
Method 1.  $q$  is calculated by solving PDE.

$$\eta = \eta_{spitzer}(T_e, Z_{eff}) \rightarrow \vec{B}(\sqrt{\Phi_N}, t) \rightarrow \Psi(\sqrt{\Phi_N}, t) \rightarrow \frac{d\Phi}{d\Psi} = q(\sqrt{\Phi_N}, t)$$

Method 2.  $q$  is prescribed from EFIT/ $q$ .

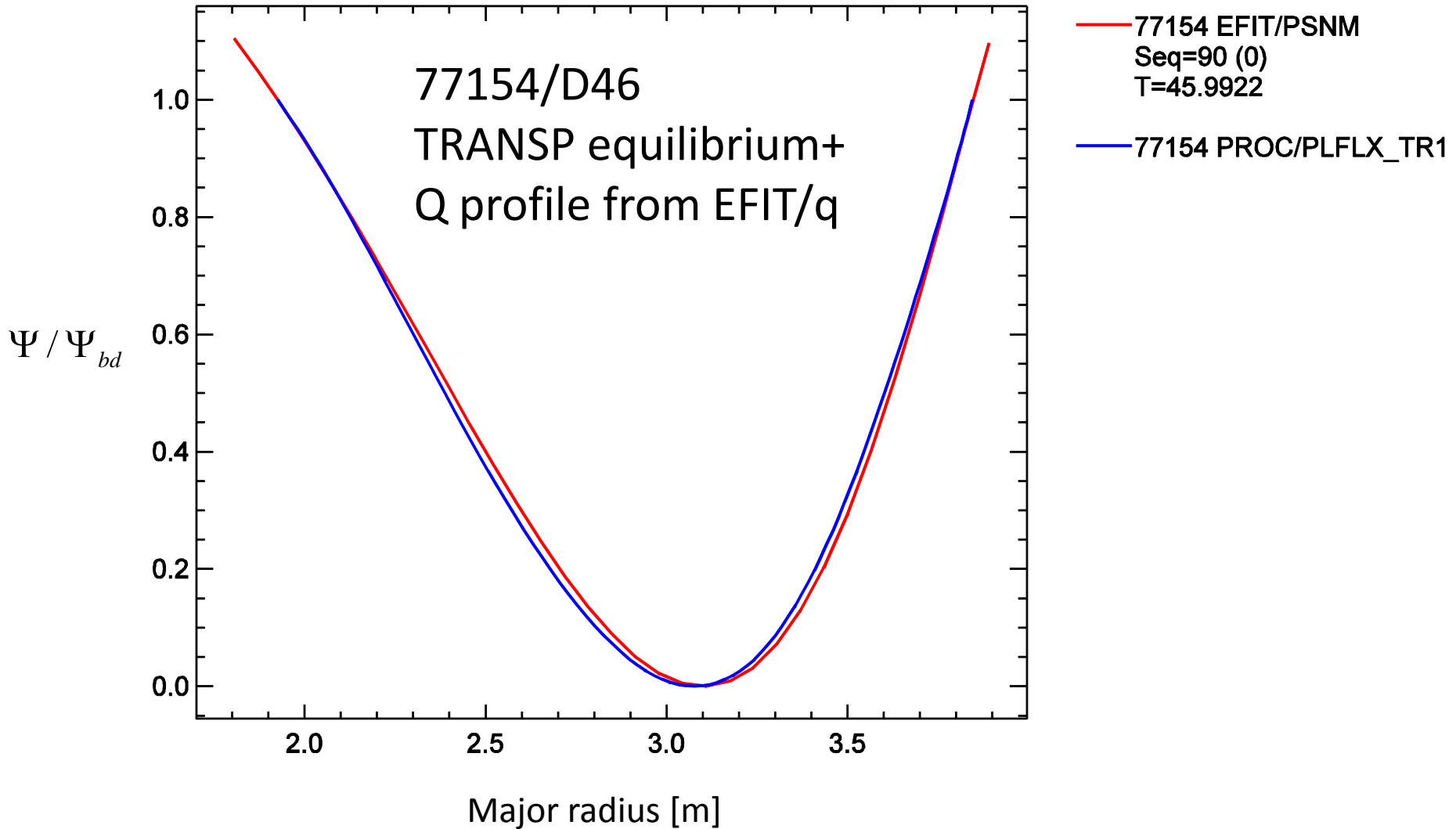
$$q(\Psi, t) = \frac{d\Phi}{d\Psi} \rightarrow \Psi(\sqrt{\Phi_N}, t) \rightarrow \vec{B}(\sqrt{\Phi_N}, t) \rightarrow \eta$$

# Magnetic axis: EFIT and TRANSP



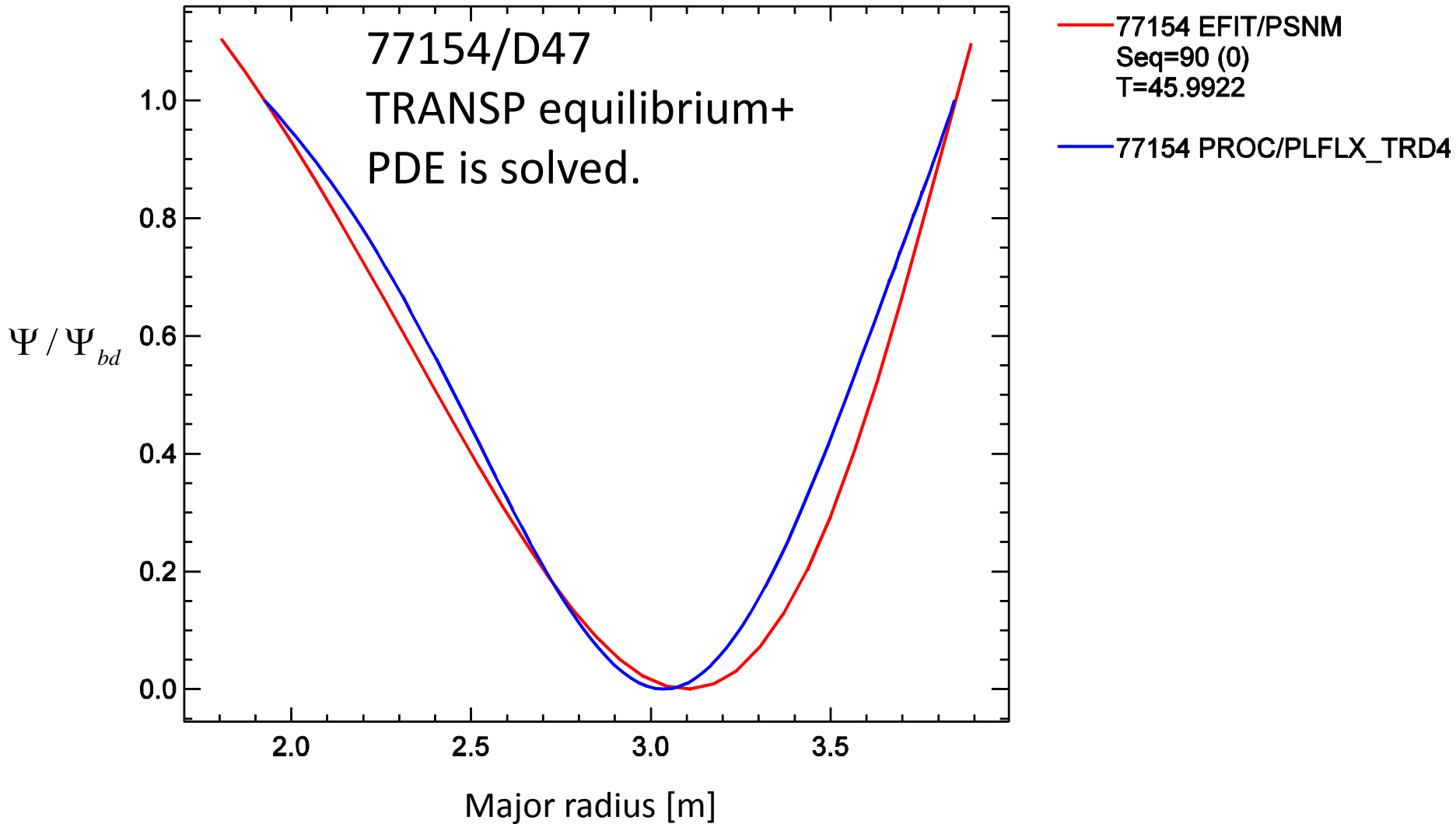
During NBI phase,  
magnetic axis in TRANSP  
is smaller than EFIT.

# Normalized psi: EFIT and TRANSP

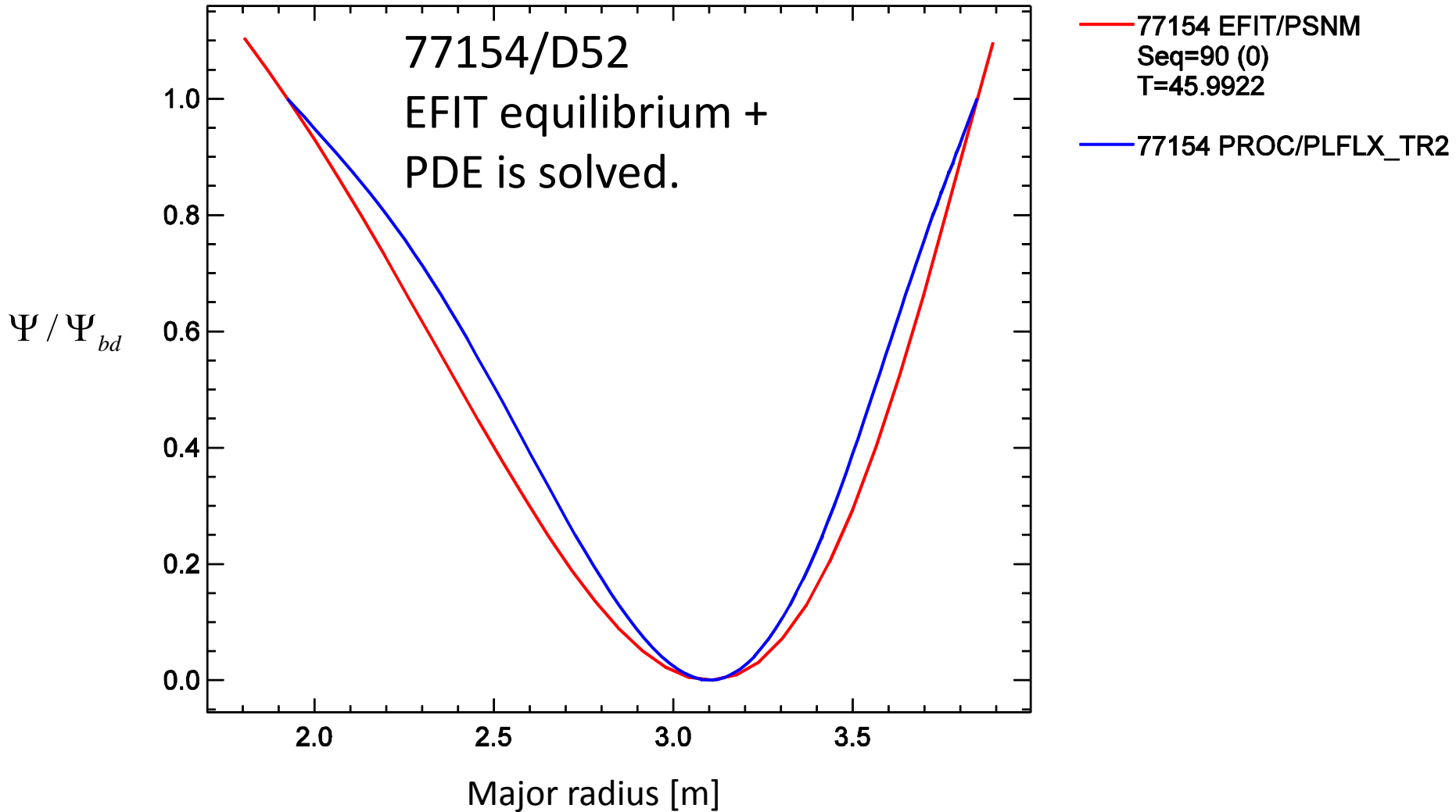




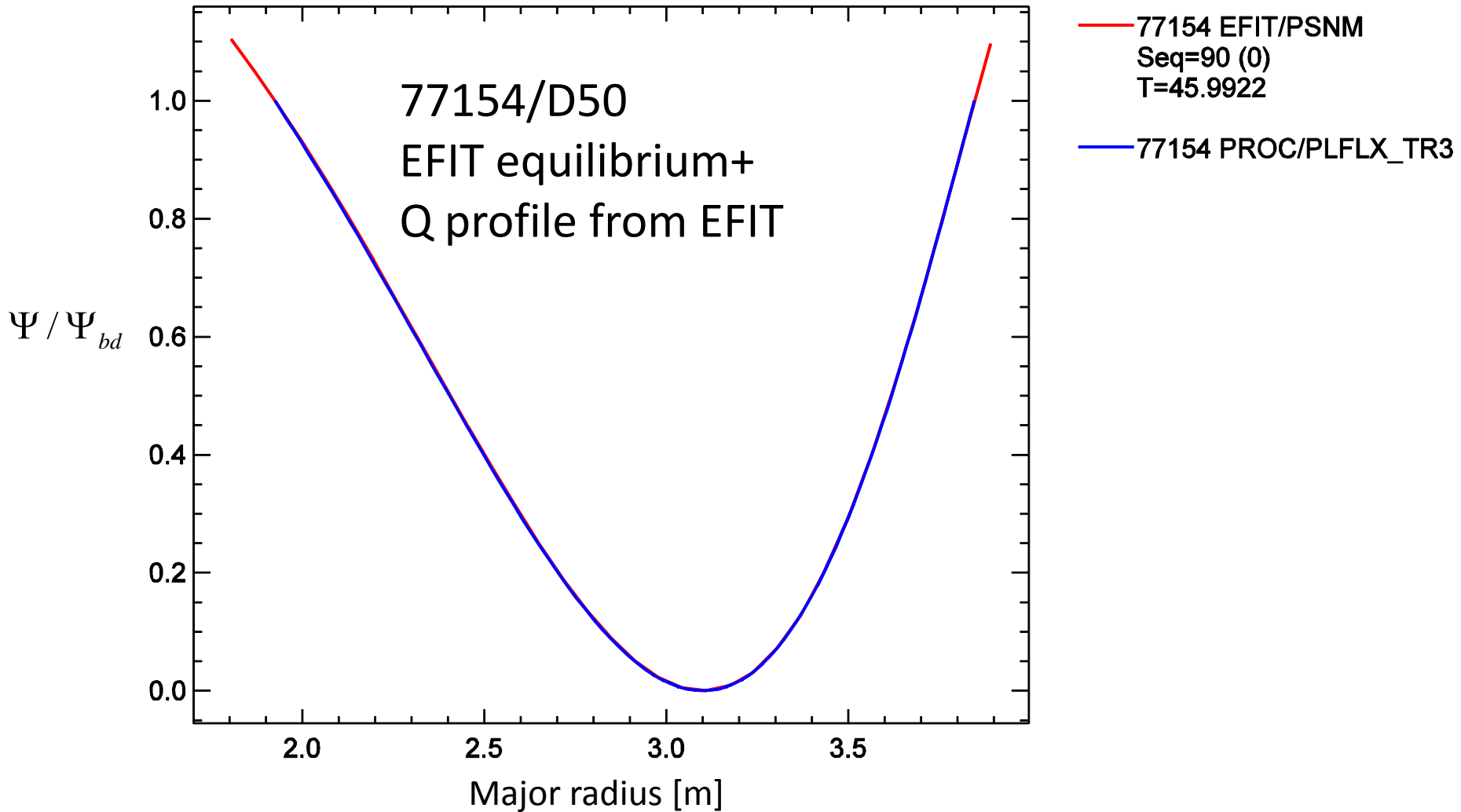
# Normalized psi: **EFIT** and **TRANSP**



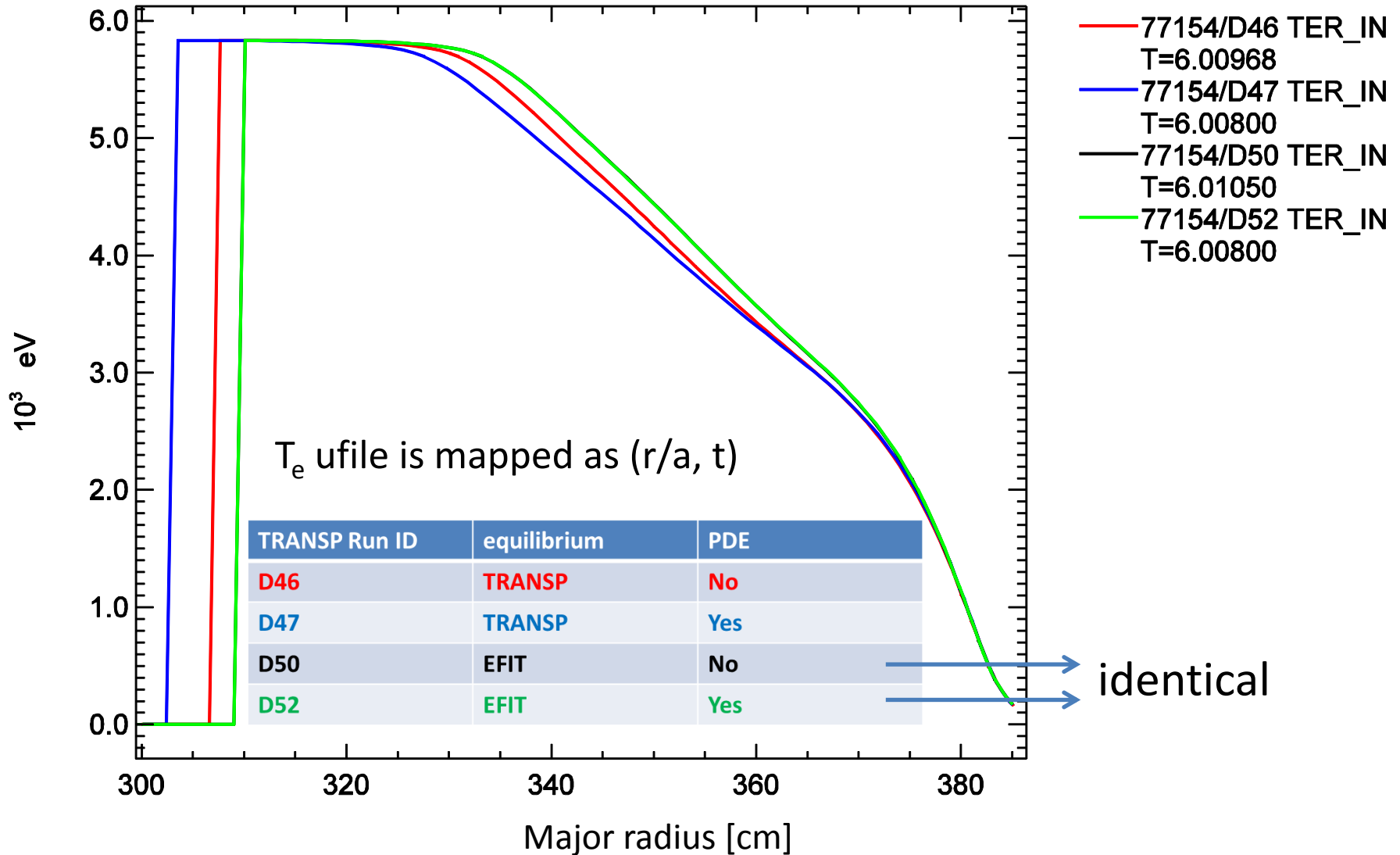
# Normalized psi: EFIT and TRANSP



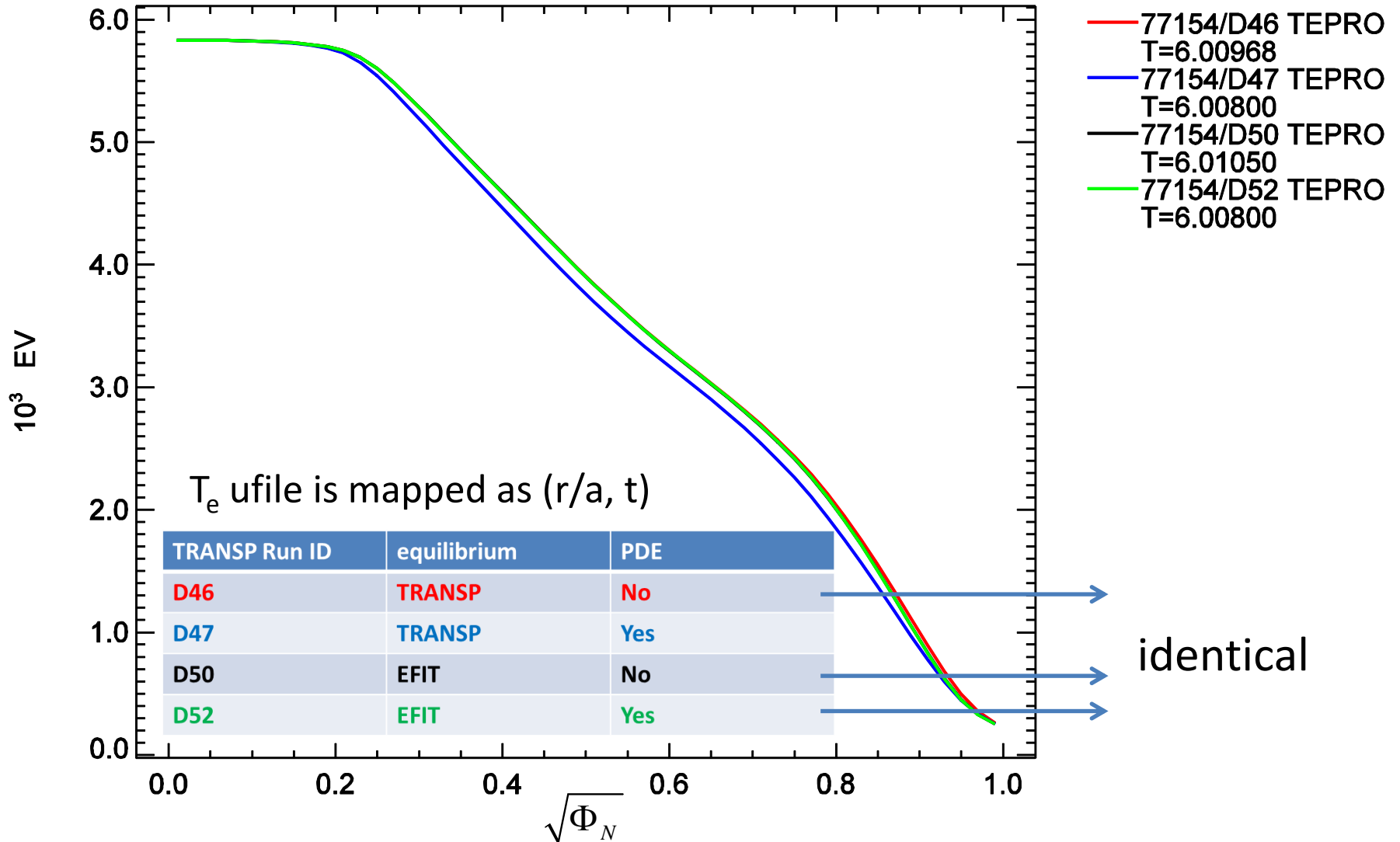
# Normalized psi: EFIT and TRANSP



# TER\_IN: TER data as input



# TEPRO: INPUT $T_e$ PROFILE



# How to run TRANSP using EFIT equilibrium



1. Open TRANSP window and set \$SDD for a new run
2. Create gfiles folder in \$SDD  
(e.g. \$SDD/gfiles= /common/transp\_shared/Data/data/JETdirs/77154/gfiles)
3. Copy and paste g eqdisk files and index.dat into the gfiles folder  
(e.g. /home/jec2020/runs/transp\_test/77154/efit.0/gfiles/index.dat → \$SDD/index.dat)
4. Reduce the timeslices in index.dat, and save it as index.dat\_2
5. Run Scrunch2 using the index.dat\_2 in \$SDD/gfiles, produce MMX ufile  
(e.g. \$SDD/gfiles/EQD77154.MMX), and copy it into \$SDD (e.g. \$SDD/EQD77154.MMX\_0000)
6. Run TRANSP and modify the namelist file (e.g. 77154D46TR.DAT) during the step config

# 1. Open TRANSP window and set \$SDD for a new run



- Open TRANSP window

```
hkim@jac-15:~  
File Edit View Search Terminal Help  
hkim@jac-15> ~pshare/transp_window pro
```

- Set \$SDD (Standard data directory) for a new run e.g. 77154

```
=====  
settrn2 -S- Login completed  
  
>>>> Grid Proxy active  
timeleft : 263:50:49 (11.0 days)  
  
TrDir::ShowDfRun      -U-  
                    -- Default Run is 77154D54 TWD is defined as /common/transp_shared/Data/wor  
k/hkim/,@runs/JET_62_28151  
%JETtransp 77154D54 new names 77154D50 config mdstree new
```

## 2. Create gfiles folder in \$SDD



- %cd \$SDD
- %mkdir gfiles

```
%pwd
/common/transp_shared/Data/data/JETdirs/77154
%ls
77154          EDG77154.FLW_0081  #err#"          HRTS77154.NE_0177  HRTS77154.TE_0183  MAGN77154.FLX_0003"  MG277154.XLM_0062"  PNBI77154.NBL_0175  TIN77154.RNT_0189"
77154"        EDG77154.FLW_0081"  ~filfix.pro    HRTS77154.NE_0183  HRTS77154.TE_0186  MAGN77154.ITOR_0003  MG377154.VPA_0062  _scruncher_      TrFile.PtoU
BOL077154.TOBU_0051  EFIT77154.Q_0090  GASH77154.MAJR_0129  HRTS77154.NE_0186  HRTS77154.TE_0203  MAGN77154.ITOR_0003"  MG377154.VPA_0062"  _scruncher_"    TrFile.PtoU"
BOL077154.TOBU_0051"  EFIT77154.Q_0177  GASH77154.MAJR_0129"  HRTS77154.NE_0203  KS377154.ZEFV_0165  MG277154.BET_0062  MSCR77154.MRY_0170  scruncher_170.log
CXFM77154.AFCR_0205  EFIT77154.Q_0186  GASH77154.MAJR_0186  HRTS77154.TE_0157  KS377154.ZEFV_0179  MG277154.BET_0062"  MSCR77154.MRY_0170"  scruncher.log
CXFM77154.TICR_0205"  EFTM77154.Q_0206  gfiles         HRTS77154.TE_0157"  KS377154.ZEFV_0195  MG277154.XIP_0062  out              TIN77154.RNT_0163
CXFM77154.TICR_0242  EFTM77154.Q_0238  HRTS77154.NE_0157  HRTS77154.TE_0157""  KS377154.ZEFV_0195"  MG277154.XIP_0062"  PNBI77154.NBI_0169  TIN77154.RNT_0176
CXFM77154.ZFCX_0205  #err#           HRTS77154.NE_0157"  HRTS77154.TE_0177  MAGN77154.FLX_0003  MG277154.XLM_0062  PNBI77154.NBI_0169"  TIN77154.RNT_0189
%[]
```

Create gfiles folder in \$SDD



### 3. Copy and paste g eqdisk files and index.dat into the gfiles folder



- `%cd /home/jec2020/runs/transp_test/77154/efit.0/gfiles`
- `%cp g* $SDD/gfiles`
- `%cp index.dat $SDD/gfiles.`

g eqdisk files

```
g_p77154_t42.845 g_p77154_t45.235 g_p77154_t47.625 g_p77154_t50.
g_p77154_t42.855 g_p77154_t45.245 g_p77154_t47.635 g_p77154_t50.
g_p77154_t42.865 g_p77154_t45.255 g_p77154_t47.645 g_p77154_t50.
g_p77154_t42.875 g_p77154_t45.265 g_p77154_t47.655 g_p77154_t50.
g_p77154_t42.885 g_p77154_t45.275 g_p77154_t47.665 g_p77154_t50.
%pwd
/home/jec2020/runs/transp_test/77154/efit.0/gfiles
%cp g* $SDD/gfiles
```

## 4. Reduce the timeslices in index.dat



- `%nedit index.dat` # of timeslices. 2627 is too many!

```
index.dat - /common/transp_shared/Data/data/JETdirs/77154/gfiles/
File Edit Search Preferences Shell Macro Windows
ntimes=2627
path="/home/jec2020/runs/transp_test/77154/efit.0/gfiles"
time=40.505 filename=g_p77154_t40.505
time=40.515 filename=g_p77154_t40.515
time=40.525 filename=g_p77154_t40.525
time=40.535 filename=g_p77154_t40.535
time=40.545 filename=g_p77154_t40.545
time=40.555 filename=g_p77154_t40.555
time=40.565 filename=g_p77154_t40.565
time=40.575 filename=g_p77154_t40.575
time=40.585 filename=g_p77154_t40.585
time=40.595 filename=g_p77154_t40.595
time=40.605 filename=g_p77154_t40.605
time=40.615 filename=g_p77154_t40.615
time=40.625 filename=g_p77154_t40.625
time=40.635 filename=g_p77154_t40.635
time=40.645 filename=g_p77154_t40.645
time=40.655 filename=g_p77154_t40.655
time=40.665 filename=g_p77154_t40.665
time=40.675 filename=g_p77154_t40.675
time=40.685 filename=g_p77154_t40.685
time=40.695 filename=g_p77154_t40.695
time=40.705 filename=g_p77154_t40.705
time=40.715 filename=g_p77154_t40.715
```

## 4. Reduce the timeslices in index.dat



- Reduce the number of timeslices. (errors can occur with too many time slices.)
- 10~ 20 time slices per second is recommended as other input data.

```
index.dat_2 - /common/transp_shared/Data/data/JETdirs/77154/gfiles/
File Edit Search Preferences Shell Macro Windows
ntimes=73
path="/home/jec2020/runs/transp_test/77154/efit.0/gfiles"
time=43.995 filename=g_p77154_t43.995
time=44.005 filename=g_p77154_t44.005
time=44.105 filename=g_p77154_t44.105
time=44.205 filename=g_p77154_t44.205
time=44.305 filename=g_p77154_t44.305
time=44.405 filename=g_p77154_t44.405
time=44.505 filename=g_p77154_t44.505
time=44.605 filename=g_p77154_t44.605
time=44.705 filename=g_p77154_t44.705
time=44.805 filename=g_p77154_t44.805
time=44.905 filename=g_p77154_t44.905
time=45.005 filename=g_p77154_t45.005
time=45.105 filename=g_p77154_t45.105
time=45.205 filename=g_p77154_t45.205
time=45.305 filename=g_p77154_t45.305
time=45.405 filename=g_p77154_t45.405
time=45.505 filename=g_p77154_t45.505
time=45.605 filename=g_p77154_t45.605
time=45.705 filename=g_p77154_t45.705
time=45.805 filename=g_p77154_t45.805
time=45.905 filename=g_p77154_t45.905
time=46.005 filename=g_p77154_t46.005
```

- Save the modified index.dat as index.dat\_2

## 5. Run Scrunch2 using index.dat\_2 in \$SDD/gfiles, and produce MMX ufile



execute scrunch2  
in \$SDD/gfiles

```
%pwd
/common/transp_shared/Data/data/JETdirs/77154/gfiles
%scrunch2
*** SCRUNCH2 *** 3/3/2010 version (dmc)

default is to input from tokamak EFIT MDS+ data;
alternatives:
enter "INDEX" here to use an "EFIT INDEX" file.
enter "TRANSP" here to read from TRANSP archive.
enter "TSC" here to use a TSC "movie.cdf" file.
enter "Q" to quit.

[OLD VALUE: " "]
enter 3 or 4 character TOKAMAK id code, e.g. "NSTX":
[fggetline; no command line editing available]
```

# 5. Run Scrunch2 using index.dat\_2 in \$SDD/gfiles, and produce MMX ufile



```
%scrunch2
*** SCRUNCH2 *** 3/3/2010 version (dmc)

default is to input from tokamak EFIT MDS+ data;
alternatives:
enter "INDEX" here to use an "EFIT INDEX" file.
enter "TRANSP" here to read from TRANSP archive.
enter "TSC" here to use a TSC "movie.cdf" file.
enter "Q" to quit.

[OLD VALUE: " "]
enter 3 or 4 character TOKAMAK id code, e.g. "NSTX":
[fggetline: no command line editing available]
INDEX
%enter "q " or "Q " to skip index file...
%unixfile: enter a complete, literal unix file specification,
or "r " or "R " to set up a directory path (with environment
variable name translation) and then specify a relative file
specification.

[OLD VALUE: "..."]
unixfile (scrunch2 (G-Eqdk index file)); enter file spec or "r":
index.dat_2
%scrunch2: EFIT INDEX file OK.
...please provide labeling information...
[OLD VALUE: " "]
tokamak id (3 or 4 characters e.g. "MAST"):
JET
[OLD VALUE: " 0"]
shot number (non-negative integer,le.999999):
77154
%get_tokyr: subroutine jetyr.for: tokamak JET shot 77154 => shot year: 2009
tokamak: JET shot: 77154
shot year: 2009
enter "Y" to verify:
```

Switch to use  
a index file

The name of index file  
to be used

JET

Shot number

Y if okay

# 5. Run Scrunch2 using index.dat\_2 in \$SDD/gfiles, and produce MMX ufile



```
shot year: 2003
enter "Y" to verify:
Y
EFIT_INDEX timebase contains 73 time points covering the range
t= 4.39950E+01 to t= 5.10050E+01 seconds.

-----
STANDARD mode
-----

Time options: process all available times (no tmin,tmax).
No interior time exclusion intervals.
--> no. of Fourier moments: 16
--> no. of radial points: 41
--> no. of poloidal points: 100
boundary minimum curvature ratio: crat = 8.0000E-02
crat = [min.curvature]/[plasma-half-width]
is used to avoid a "too-kinked" bdy near
a separatrix. The bdy is adjusted inward
to satisfy the "crat" condition.
maximum relative Grad-Shafranov error gs_errmax: 2.5000E-01
used to check accuracy of EFIT G-Eqdisk data
in region well inside plasma boundary.
maximum relative variation in |det(J)| for R w/in 10% of Rmax: 5.0000E-01
check on numerical behavior of equilibrium geometry.

NOTE: not all EFIT Psi(R,Z) datasets can be processed.
Datasets lacking well behaved level contours trigger a variety of
error detectors in the "nscrunch" data processing routines.

options:
D -- change MODE of operation ...
R -- start over (reset parameters to default values).
A -- accept these parameter settings.
Q -- quit (go get a different shot).
T -- reset time options.
S -- specify time smoothing of results.
E -- change gs_errmax (accuracy check parameter).
C -- change crat (bdy curvature parameter).
L -- change number of poloidal points.
M -- change number of moments (min 3 max 16).
I -- option to infer I(t) and q(rho,t) from Psi(t,R,Z) (currently: F)
X -- Psi(t,R,Z) output option (currently: F)
Y -- {R,Z}(t,theta,x) output option (currently: F)
   T-> equal arc theta; F-> "VMEC" theta; nmoms reset.
N -- change number of radial points.
J -- change max |det(J)| variation for R w/in 10% of Rmax.

scr2_options: processing option:
```

Several options for producing MMX ufile are available.

'A' → produce MMX ufile with g eqdisk files as they are.



# 5. Run Scrunch2 using index.dat\_2 in \$SDD/gfiles, and produce MMX ufile



```
estimated relative GS error in data: 1.433765187445431E-02
=====> scr2_execute: time = 50.8050003
estimated relative GS error in data: 1.082841163322985E-02
=====> scr2_execute: time = 50.9049988
estimated relative GS error in data: 1.109558284604982E-02
=====> scr2_execute: time = 51.0050011
estimated relative GS error in data: 6.700016077383597E-03

-----
EFIT/xplasma processing completed.

scr2_execute: 0 errors processing the data.
scr2_execute: successfully processed 73 time points.

Elapsed cpu time (seconds):      19.09
Elapsed wall clock time (seconds): 20.00

directions of toroidal B field & current:
      EFIT      scrunch2_output_file
Btor: -1        -1
Itor: -1        -1
(+1 means "counter-clockwise viewed from above").
( 0 means unknown or unspecified).

scr2_examine options:
I -- plot EFIT q(x,t) (q) profile evolution.
G -- plot EFIT g(x,t) (R*Bt) profile evolution.
P -- plot EFIT P(x,t) (pressure) profile evolution.
C -- plot total plasma current vs. time (if computed).
M -- plot equilibrium at fixed time.
N -- plot time evolution of flux surface at fixed x.
A -- plot R at the magnetic axis, vs. time.
B -- plot boundary surface midplane R,Z and a vs. time.
V -- plot volumes enclosed by flux surfaces.
E -- plot relative GS error vs. time. (EFIT only)
J -- plot edge det(J) vs. poloidal angle, time.
K -- compare min(det(J)) and max(det(j)) vs. time.
F -- plot enclosed poloidal flux vs. time.
O -- plot flux difference (PF0), R=0 to magnetic axis.
R -- REPROCESS data, removing some time points...
S -- change sign of B or I for output file.
U -- get sign of B and I from existing Ufile.
T -- plot enclosed toroidal flux vs. time.
Q -- quit plotting options.
L -- plot axisymmetric limiter contour.
```

Plotting option is available.

Q → go to the next step.



```
scr2_examine: enter plotting option:
```

# 5. Run Scrunch2 using index.dat\_2 in \$SDD/gfiles, and produce MMX ufile



Y → write MMX ufile

P → create prefix name of the MMX ufile  
i.e. EQD → EQD77154.MMX  
(default prefix name is AA)

```
scr2_examine: enter plotting option:  
0  
scr2_examine: write the data to Ufiles? (Y/N):  
Y  
Ufile path: current directory.  
-->Ufile prefix: "AA"  
Psi(poloidal) vs. t Ufile suffix: "PLF"  
Psi(toroidal) vs. t Ufile suffix: "TRF"  
delta(Psi(poloidal)) (machine axis to mag. axis) vs. t Ufile suffix: "PF0"  
P profile Ufile suffix: "PRS"  
G profile Ufile suffix: "GRB"  
Q profile Ufile suffix: "QPR"  
moments data Ufile suffix: "MMX"  
limiter data Ufile suffix: "LIM"  
...data to be written in MKS mode.  
  
P -- modify Ufile prefix  
S -- modify Ufile suffixes  
D -- modify directory path  
T -- set output mode (TRANSP or MKS)  
  
0 -- (zero): restore default settings  
W -- WRITE the data and exit  
Q -- quit without writing.  
  
scr2_write: enter option code letter:  
P  
[OLD VALUE: "AA      "]  
prefix for all Ufiles:  
EQD  
Ufile path: current directory.  
-->Ufile prefix: "EQD"  
Psi(poloidal) vs. t Ufile suffix: "PLF"  
Psi(toroidal) vs. t Ufile suffix: "TRF"  
delta(Psi(poloidal)) (machine axis to mag. axis) vs. t Ufile suffix: "PF0"  
P profile Ufile suffix: "PRS"  
G profile Ufile suffix: "GRB"  
Q profile Ufile suffix: "QPR"  
moments data Ufile suffix: "MMX"  
limiter data Ufile suffix: "LIM"  
...data to be written in MKS mode.  
  
P -- modify Ufile prefix  
S -- modify Ufile suffixes  
D -- modify directory path  
T -- set output mode (TRANSP or MKS)  
  
0 -- (zero): restore default settings  
W -- WRITE the data and exit  
Q -- quit without writing.  
  
scr2_write: enter option code letter:
```



# 5. Run Scrunch2 using index.dat\_2 in \$SDD/gfiles, and produce MMX ufile



W → EQD77154.MMX  
Is produced in \$SDD/gfiles.

Q → Finish scrunch2

```
scr2_write: enter option code letter:
W
NAMED FILE: EQD77154.PLF
NAMED FILE: EQD77154.PF0
NAMED FILE: EQD77154.TRF
NAMED FILE: EQD77154.PRS
NAMED FILE: EQD77154.QPR
NAMED FILE: EQD77154.LIM
NAMED FILE: EQD77154.GRB
NAMED FILE: EQD77154.MMX
default is to input from tokamak EFIT MDS+ data;
alternatives:
enter "INDEX" here to use an "EFIT INDEX" file.
enter "TRANSP" here to read from TRANSP archive.
enter "TSC" here to use a TSC "movie.cdf" file.
enter "Q" to quit.

[OLD VALUE: " "]
enter 3 or 4 character TOKAMAK id code, e.g. "NSTX":
Q
%  
|
```

- copy the produced MMX ufile into \$SDD  
`%cp EQD77154.MMX $SDD/EQD77154.MMX_0000`

## 6. Run TRANSP and modify the namelist file (e.g. 77154D46TR.DAT) during step config



- %JETtransp step config
- Modify the namelist file as shown below
  - LEVGEO= 8 !To use an equilibrium ufile, LEVGEO=11 is to use TRANSP equilibrium solver (TEQ)
  - LFIXUP=2 !For automatic unit conversion and time axes swapping. Note, the units labels must be correct. LFIXUP=0 is default.
  - PREMMX='EQD'
  - EXTMMX='MMX\_0000 UFL:3:tranppf:0:\$SDD' !Equilibrium ufile is specified to be read.
  - !PREMRY='MSCR'
  - !EXTMRY='MRY\_0170 UFL:2:tranppf:0170:\$SDD:EFIT/170/JETPPF'  
!Equilibrium boundary condition is no more required.
- After all these steps TRANSP should run with EFIT equilibrium.