Vertical Neutron Camera for JT-60SA Status report

11 July 2025

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UPPSALA UNIVERSITET

NARODOWE CENTRUM BADAŃ JĄDROWYCH ŚWIERK

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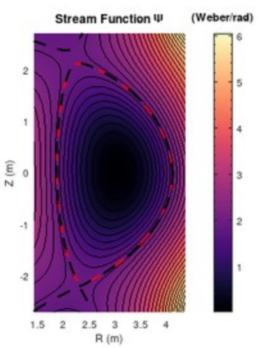
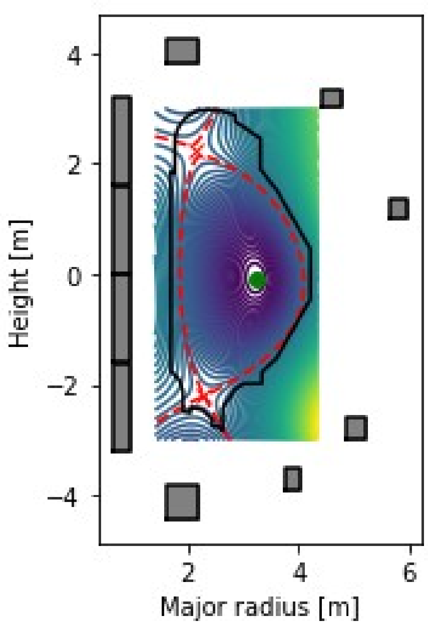
JT-60SA modeling in TRANSP/NUBEAM

- Neutron diagnostics (camera & spectrometer) design main driver
- Neutron emissivity from DRESS requires fast ions and fusion products (T burn-up) deposition and fully slowed down distribution position and velocity
- Workflow TRANSP/NUBEAM – DRESS well established and more under our control
- Full control on the simulation and its results (FI outputs)
- Study of the confinement of FIs, and representation in COM phase space
- What is needed is the NBI configuration used in the different scenarios as the only available data is the total NBI power but not how it is distribute among the various NBIs.

FreeGS equilibrium for S51

Initial test run carried out on an **equilibrium** calculated by the free boundary Grad-Shafranov solver **FreeGS** (with help of B. Dudson).





1.7e5, # Plasma pressure on axis [Pascals]
-2.3e6, # Plasma current [Amps]
-5.11, # vacuum f = R*Bt with R = 2.96 m, Bt = 1.72 T
alpha_m=4.0,
alpha_n=2.0,
Raxis = 2.97

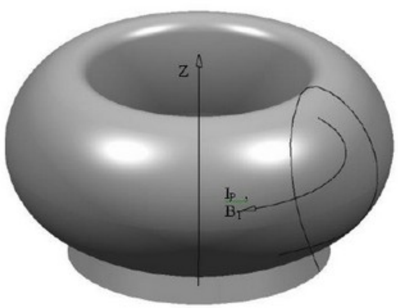
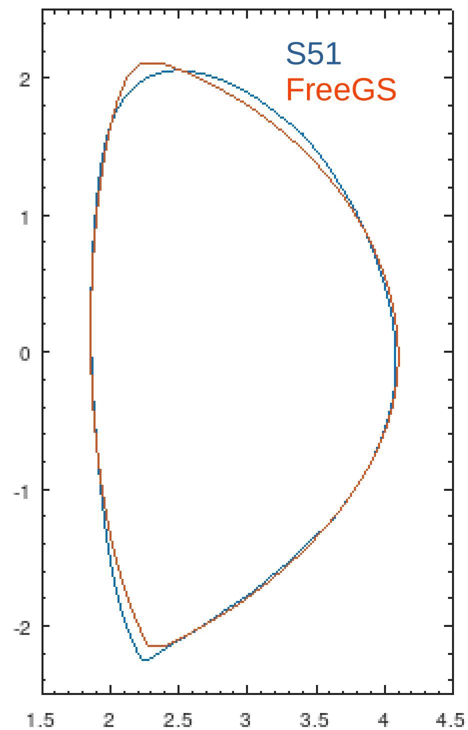
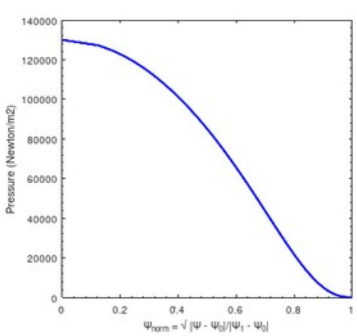
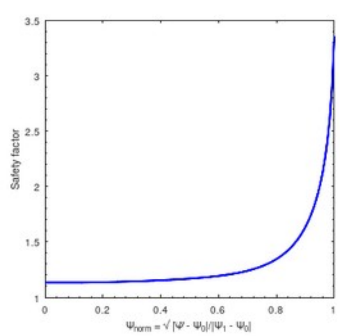
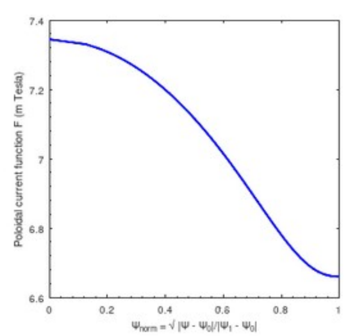


Figure 1.3-1 Plasma Current and Toroidal Field Direction



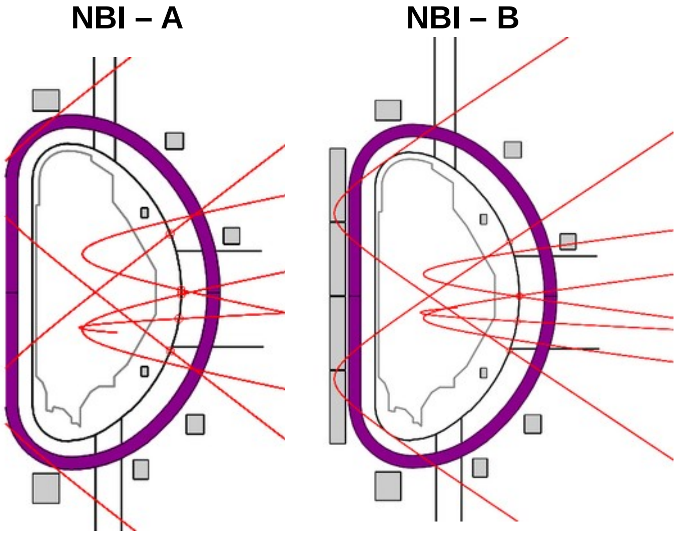






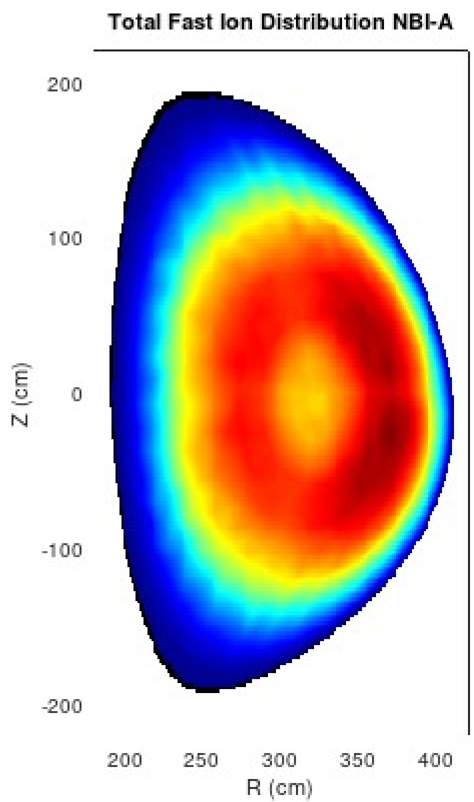
TRANSP/NUBEAM setup

- Simulation start time is at scenario flat-top, with NBIs turned on at the start of the simulation
- FreeGS generated gEQDSK **equilibrium** file converted to UFILES via scrunch2 for Ip = 2.36 MA, RBt = 5.11 mT with R = 2.96 m, Bt = 1.72 T
- Kinetic **profiles** from JINTRAC converted to UFILES, Z_{eff} = 2 flat radial profile
- Plasma rotation set to zero
- NLBCCW = NLJCCW = false (correct sign of Ip and Bt)
- No AFID
- NTPCLS = 5 x 10^4
- Medium fidelity, no FLR/GFLR correction
- Simulation time 1.5 s
- Profiles and equilibrium frozen (LEVGEO = 8)
- Runs for all P-NBIs and N-NBIs included
- FI output at 1.45 s (fully slowed down FI)
- Fusion products output
- $\beta + l_i/2$ exceeded default value (20): BLIP2MAX = 82 added to namelist (Marina G.)
- Descriptive runs



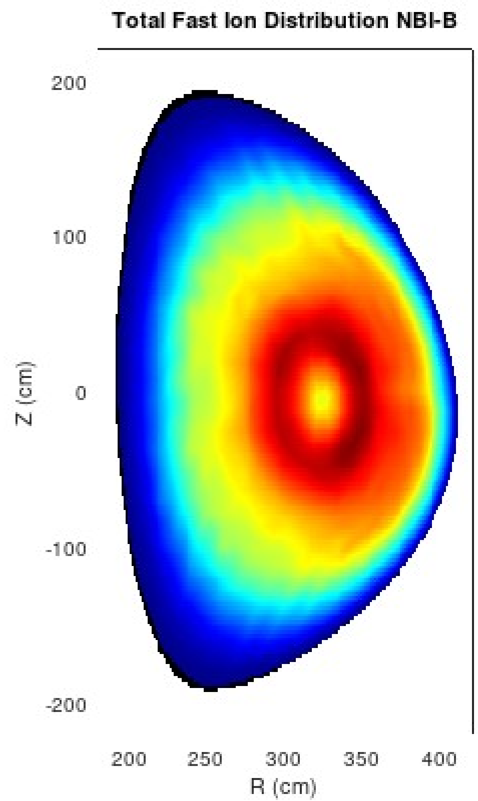
Total fast D ions distribution (all P & N NBIs)

$$\int f(R, Z, E, \lambda) dE d\lambda$$



$$t \in [0.145, 0.150] \text{ s}$$

$$\int f(R, Z, E, \lambda) dE d\lambda$$



$$t \in [0.145, 0.150] \text{ s}$$

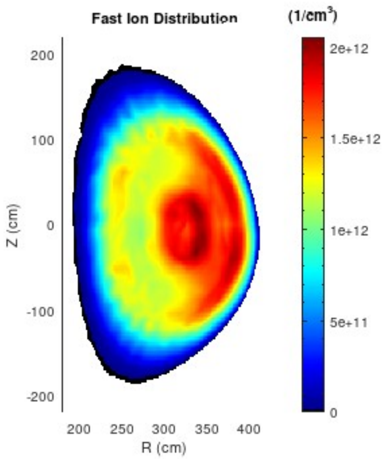
NBI-A: fast ions distributions

NBIs 1, 2, 3, 4

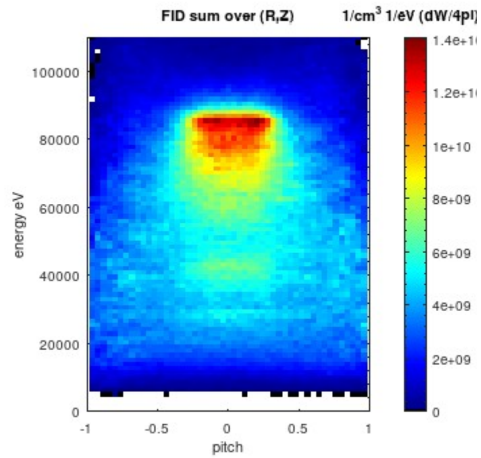
$t \in [0.145, 0.150]$ s

NBIs 9, 10, 13, 14

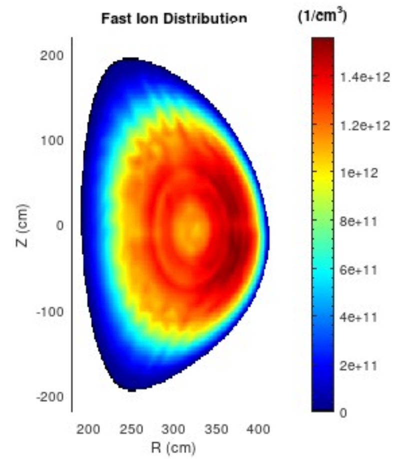
$\int f(R, Z, E, \lambda) dE d\lambda$



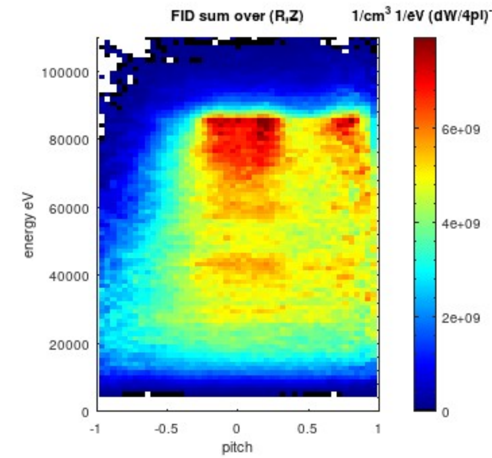
$\int f(R, Z, E, \lambda) dR dZ$



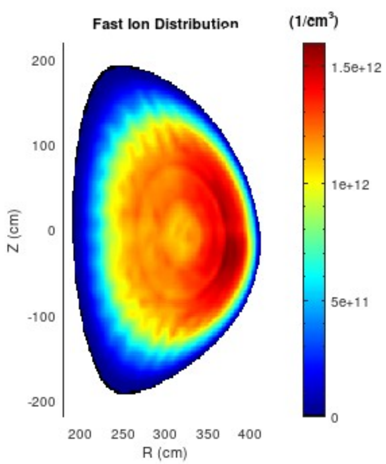
$\int f(R, Z, E, \lambda) dE d\lambda$

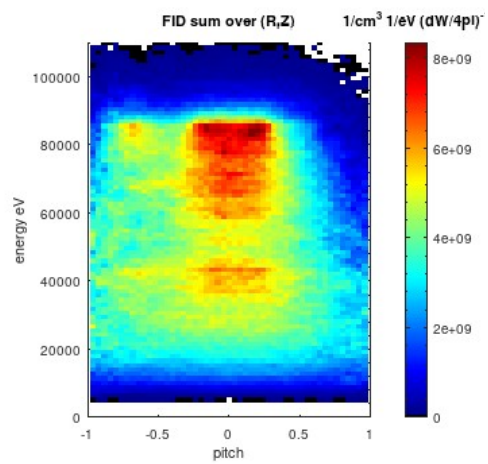


$\int f(R, Z, E, \lambda) dR dZ$

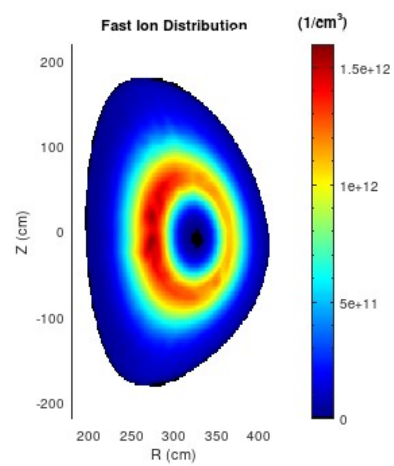


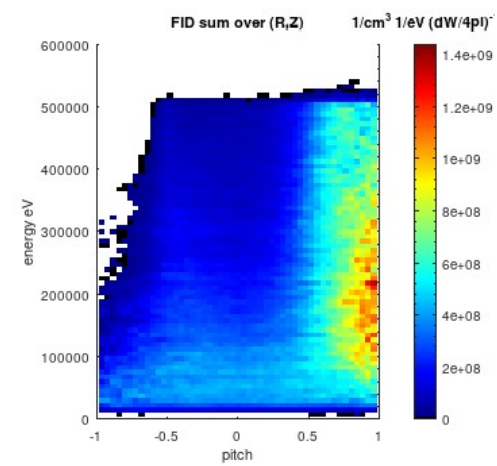
NBIs 5, 6, 7, 8



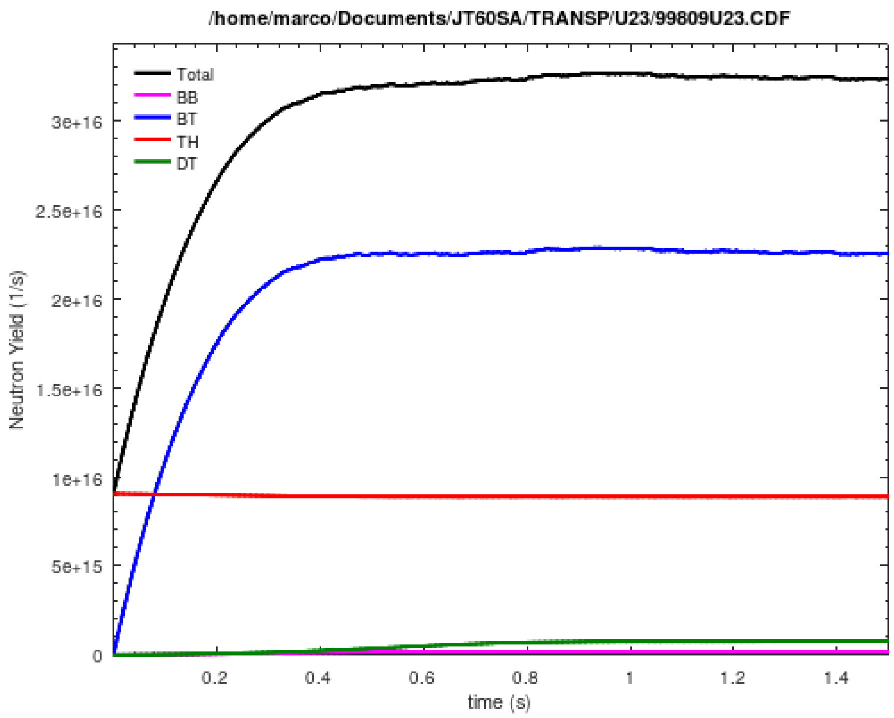


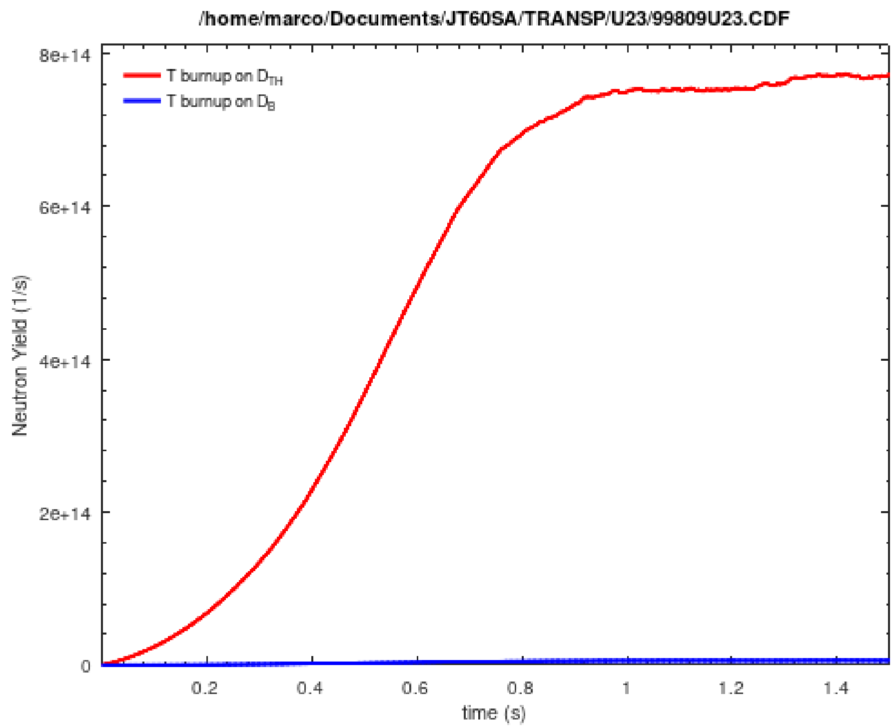
NBI 99





Neutron rates (including T burn-up)



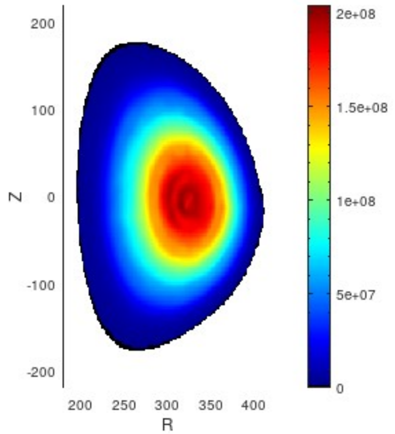


NBI-A #1 to # 4: fusion products distributions

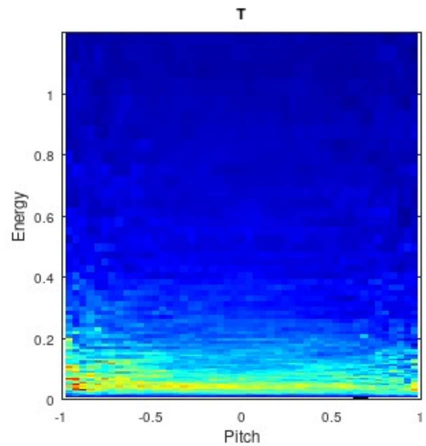
$t \in [0.145, 0.150]$ s

H (3.02 MeV)

$\int f(R,Z,E,\lambda)dEd\lambda$

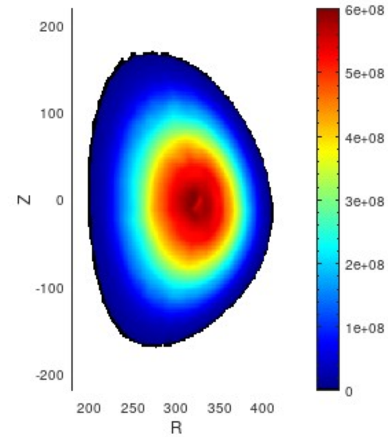


$\int f(R,Z,E,\lambda)dRdZ$

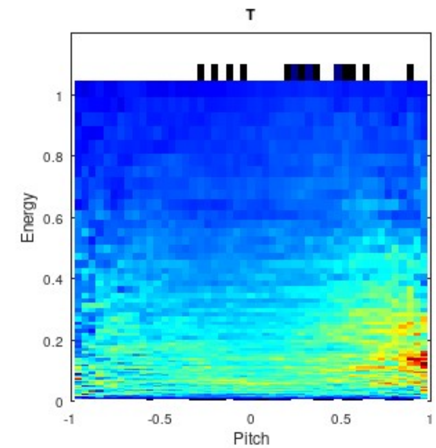


T (1.01 MeV)

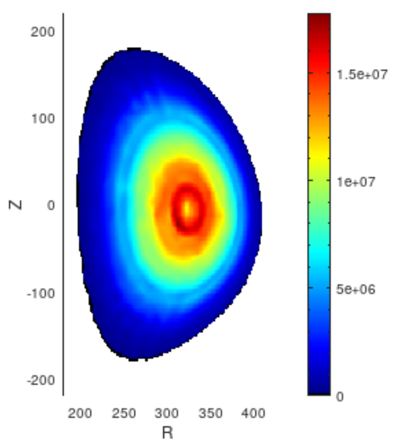
$\int f(R,Z,E,\lambda)dEd\lambda$

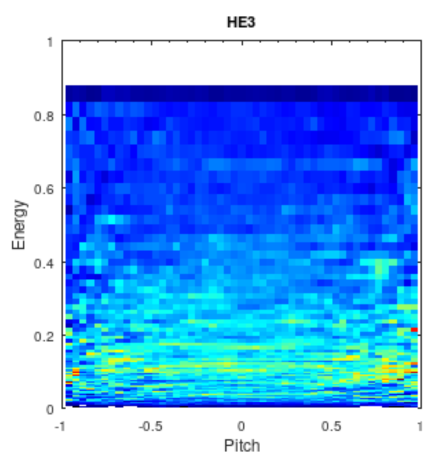


$\int f(R,Z,E,\lambda)dRdZ$

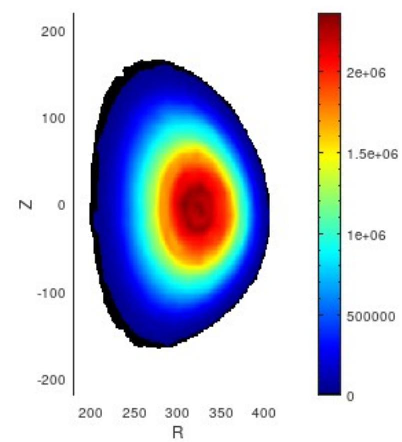


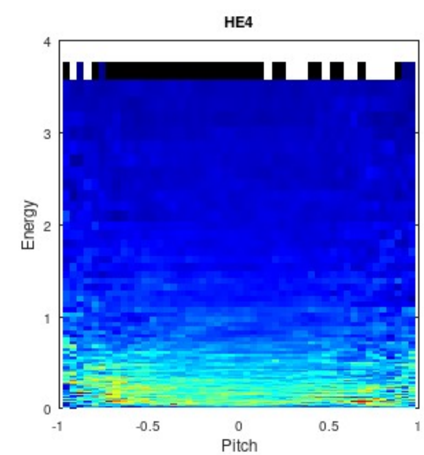
He3 (0.82 MeV)





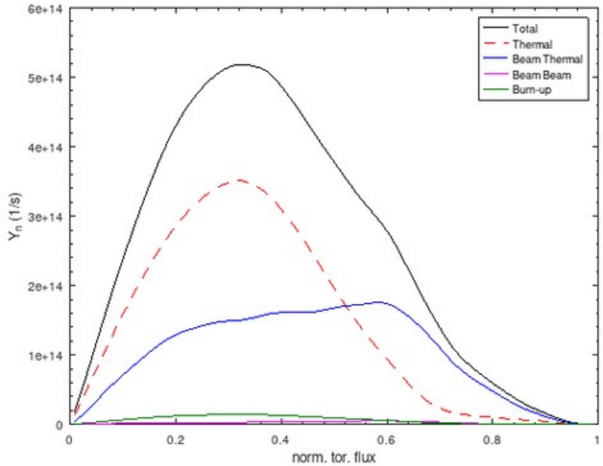
He4 (3.5 MeV)

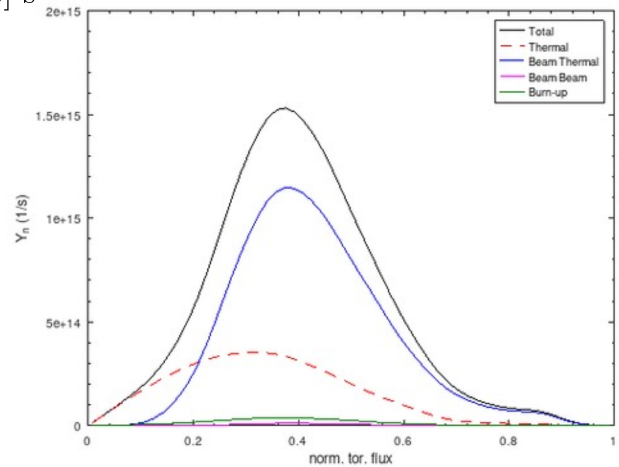


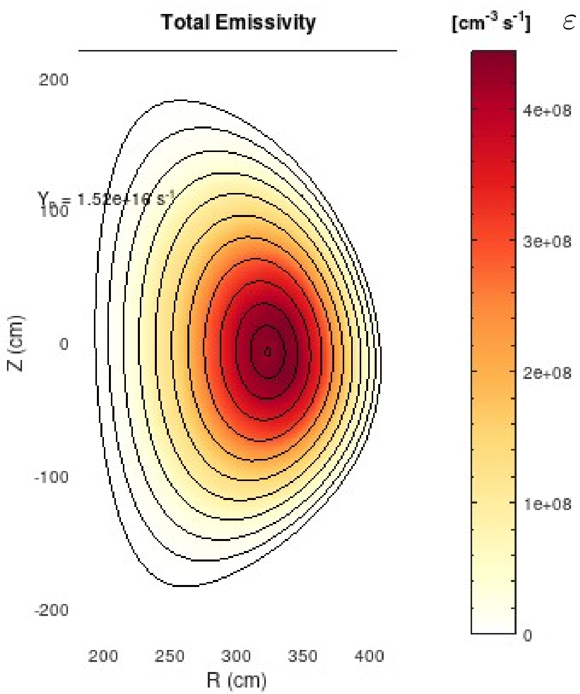


Neutron rate and emissivity

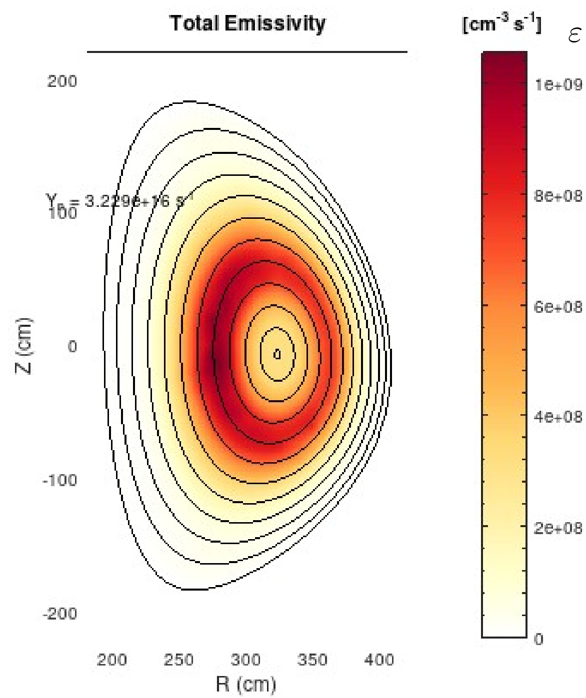
$t \in [0.145, 0.150]$ s







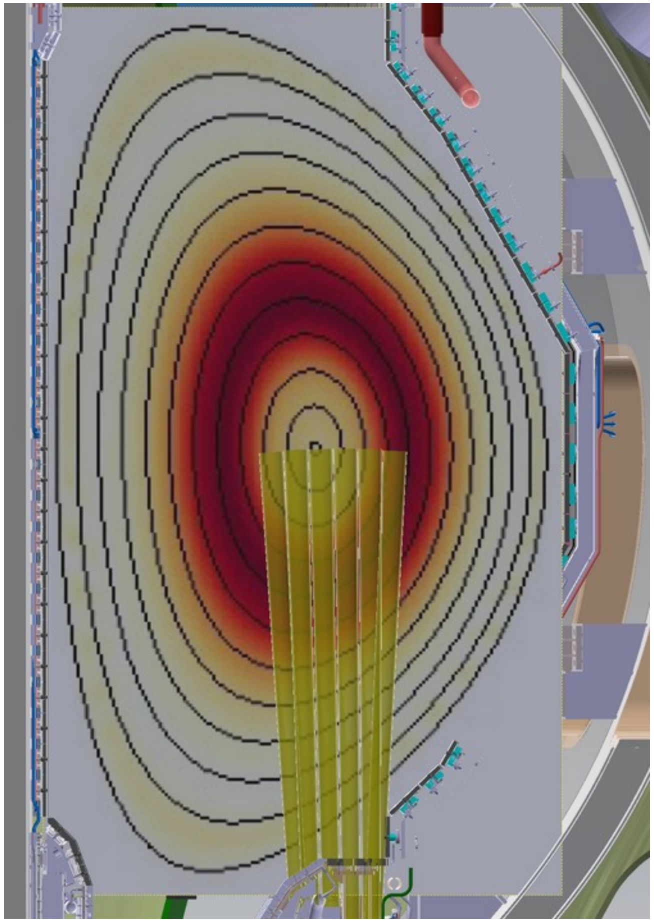
$\varepsilon(R, Z)$

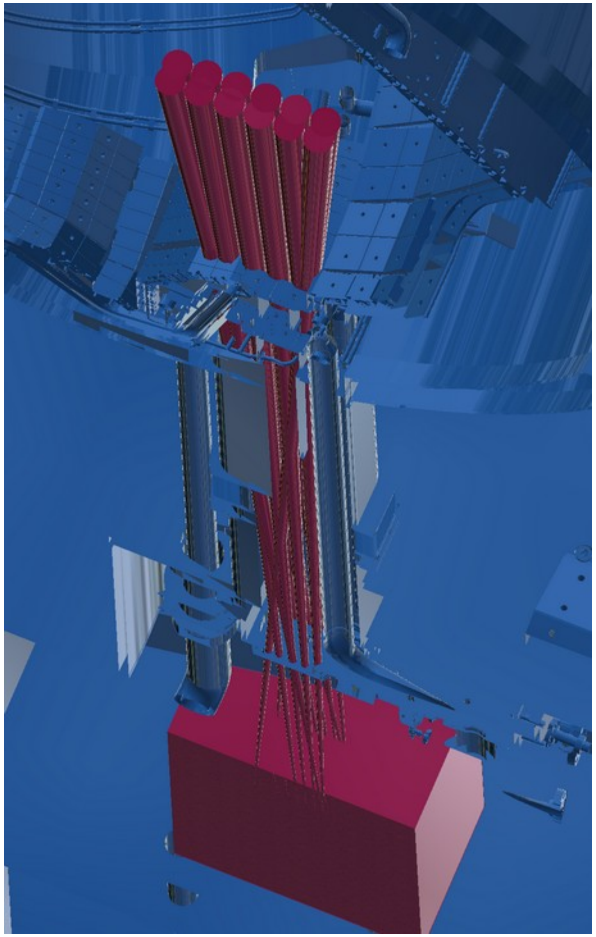


$\varepsilon(R, Z)$

VNC integration in P10

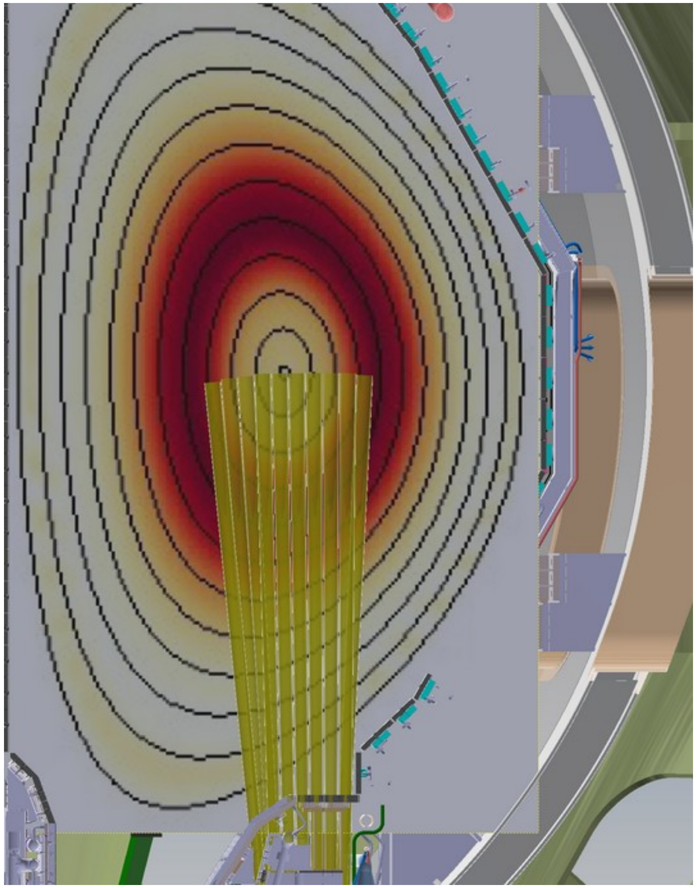
Collimators D10 – 2x6 detektors (2 rows) – wider field of view
Fitted in the P10 port and lower flange
Collisions with the Divertor

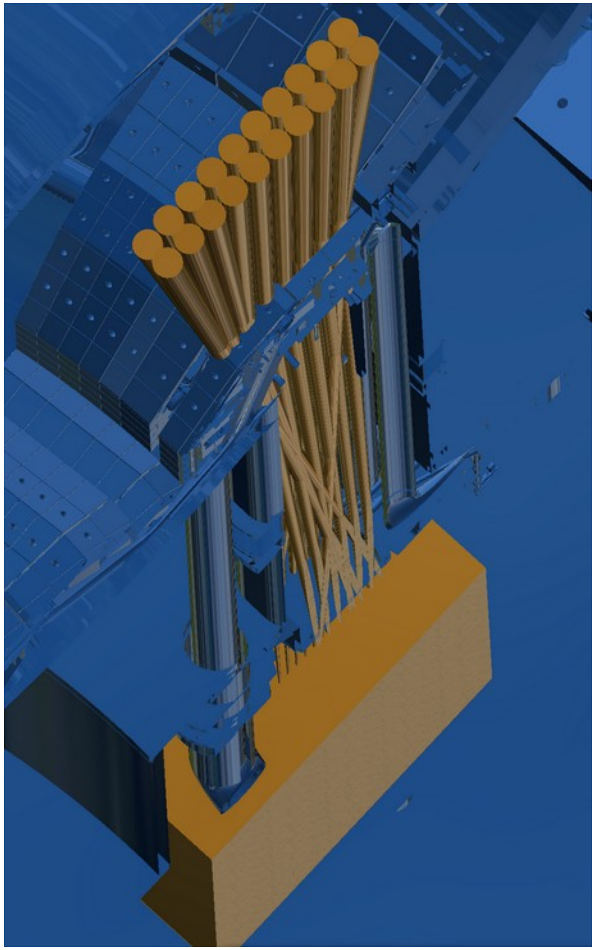


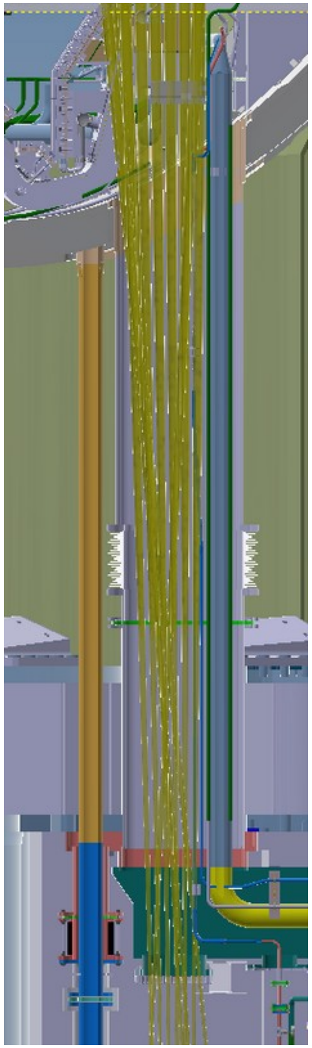


VNC integration in P10

Collimators D6,6 – 2x10 detektors (2 rows) – wider field of view
Fitted in the P10 port and lower flange
Collisions with the Divertor

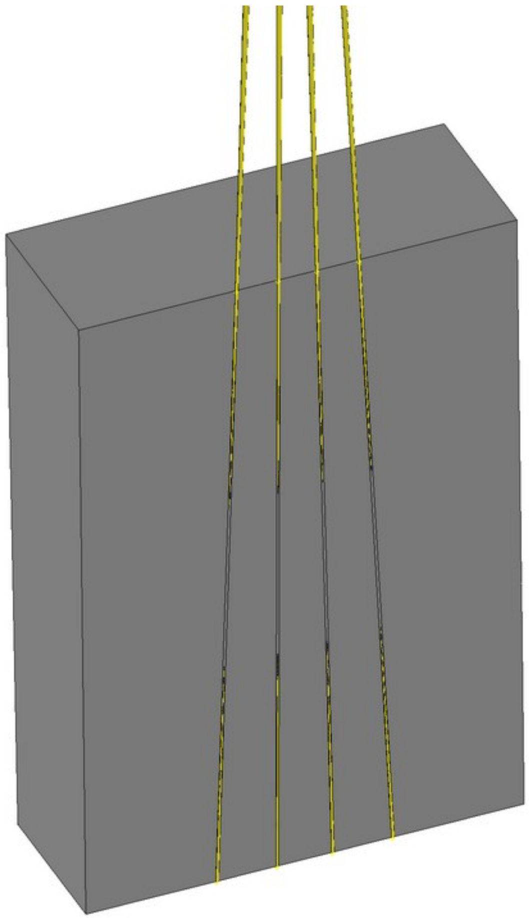


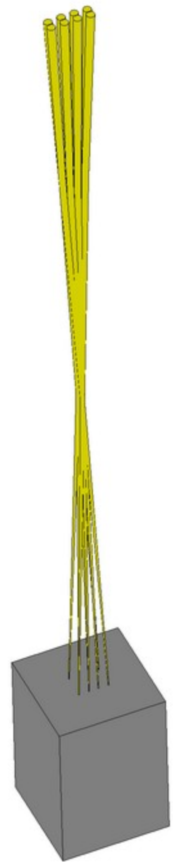


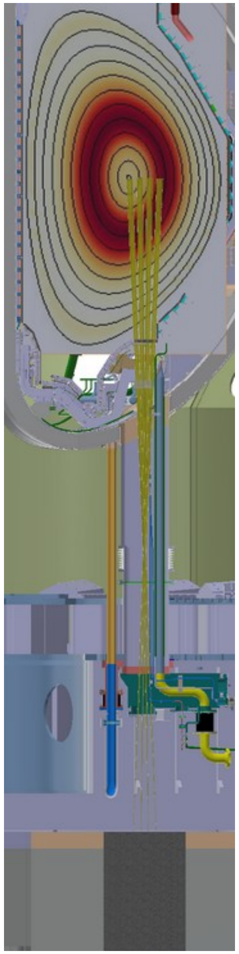


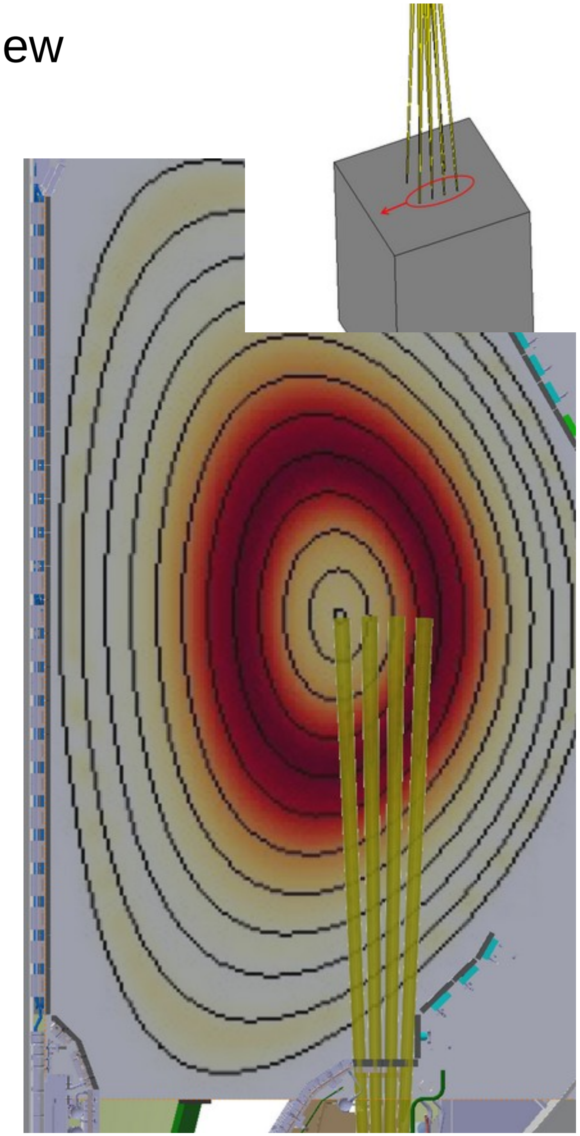
VNC integration in P10

Collimators D6,6 – 2x4 detektors (2 rows) – wider field of view
Fitted in the P10 port and lower flange









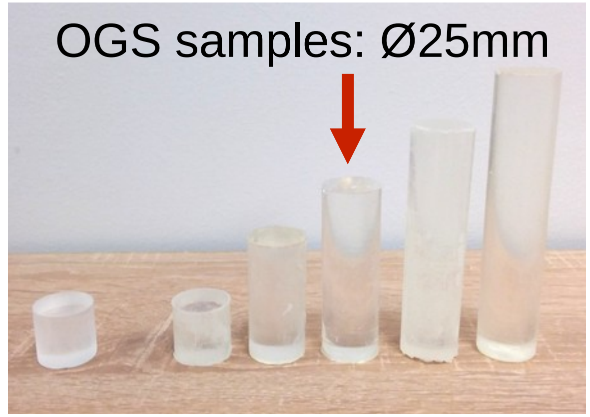
Alternative VNC detectors

- $LaCl_3$ scintillator coupled to a photomultiplier tube (see D. Rigamonti presentation)
- Doubles as γ-rays and neutron detector
- Similar performance of traditional liquid scintillators (EJ-301/EJ-309) but with the advantage of neutron spectrometry capabilities
- Same hardware requirements (HV power supplies, data acq): in fact, as easy as swapping a EJ-301 for a $LaCl_3$
- Very low own background radiation
- Slightly lower energy resolution than LaBr3s

Alternative VNC detectors

Organic Glass Scintillator
LY: 20 kph / MeV

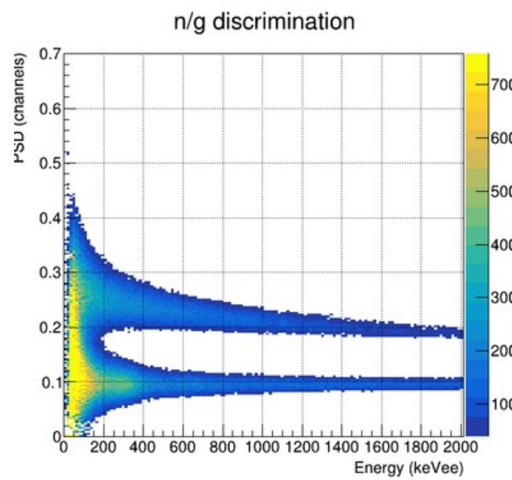
size: Ø25mm × 75mm

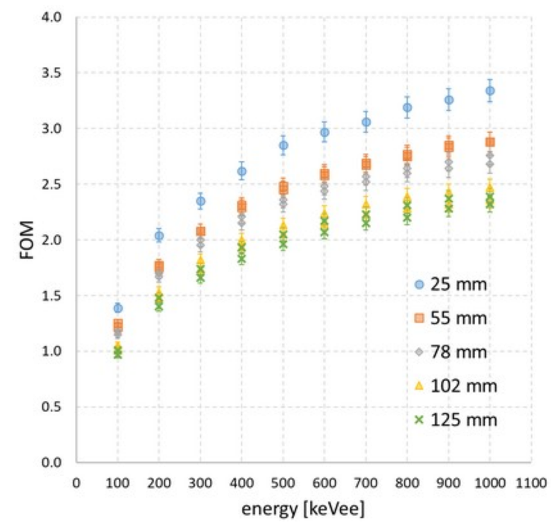


for 1:3 aspect ratio scintillator,

superb n/g discrimination

>200 keVee





det. dia	spat. res.	det. eff.	n emmis. scen. S5-1	dist	NR	det.CR	int.10ms
[cm]	[cm]	%	[n/(m3*s)]	[m]	[n/s]	[cps]	[counts]
1.0	6.8	20.0%	1.0E+15	9.5	5.0E+05	1.0E+05	1.0E+03

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Organic Glass Scintillator
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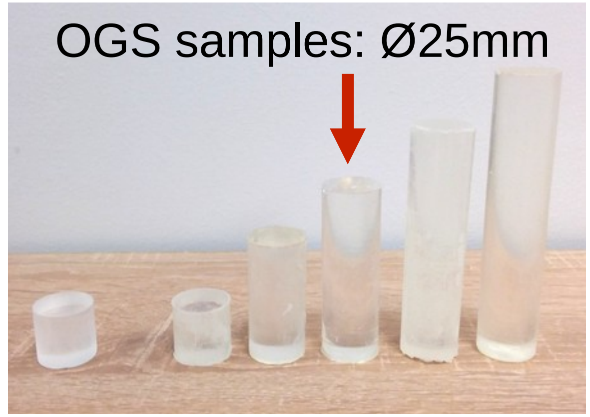

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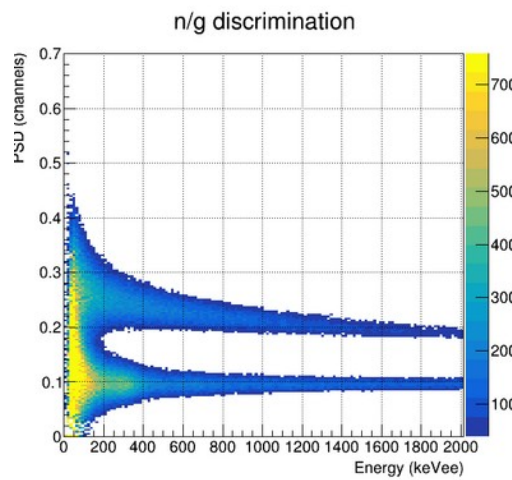

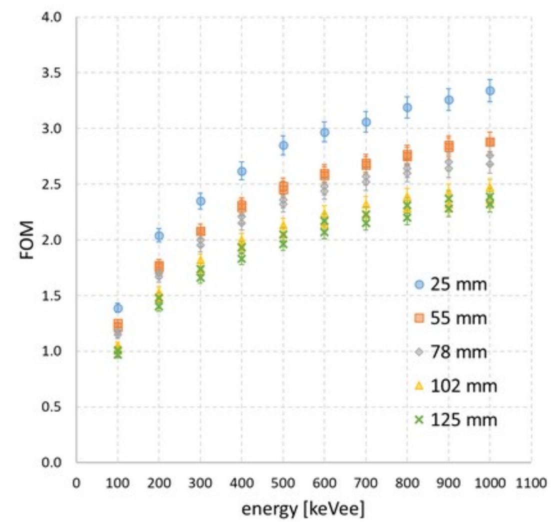

det. dia	spat. res.	det. eff.	n emmis. scen. S5-1	dist	NR	det.CR	int.10ms
[cm]	[cm]	%	[n/(m3*s)]	[m]	[n/s]	[cps]	[counts]
1.0	6.8	20.0%	1.0E+15	9.5	5.0E+05	1.0E+05	**1.0E+03**

Future activity

- Finalize design of VNC: number of LoS and geometry
- Submit TRANSP runs for Realistic equilibria from JINTRAC for S5 and S2
- Consider scenarios for 2nd Op. Phase (scaled down version of Advanced Inductive – Hybrid scenario #4-2)?
- Neutron spectra/fluxes from TRANSP/DRESS (i.e. with realistic collimated field of view) at the location of the neutron camera detectors (P10) and of the radial compact spectrometer (P12)
- Design and Assessment of detector performance
- Neutron source for MCNP for shielding optimization