Targeted Modification of the NIF Neutron Energy Spectra for National Security Applications

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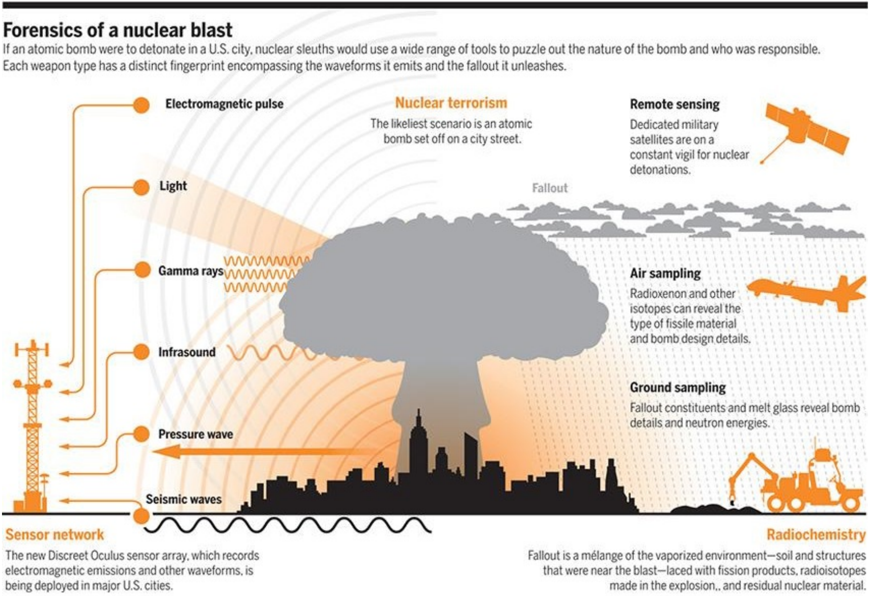
Berkeley
UNIVERSITY OF CALIFORNIA

Outline

- A tailored neutron spectrum is needed to produce *realistic* samples for post-detonation nuclear forensics
- Current neutron sources do not have *spectra* or *intensities* relevant to nuclear forensics thereby
  - Limiting the quality and efficacy of the sample
  - Requiring man-power intensive corrections to be made
  - Locking in legacy analysis methods
- NIF is the only facility capable of providing a prompt, >1E15 14 MeV neutron pulse needed for this measurement
- Our approach combines developed 14 MeV NIF neutron sources and platforms with the ETA
- ETA design was tested on the 88" cyclotron at LBNL

Motivation: Attribution of a Nuclear Detonation



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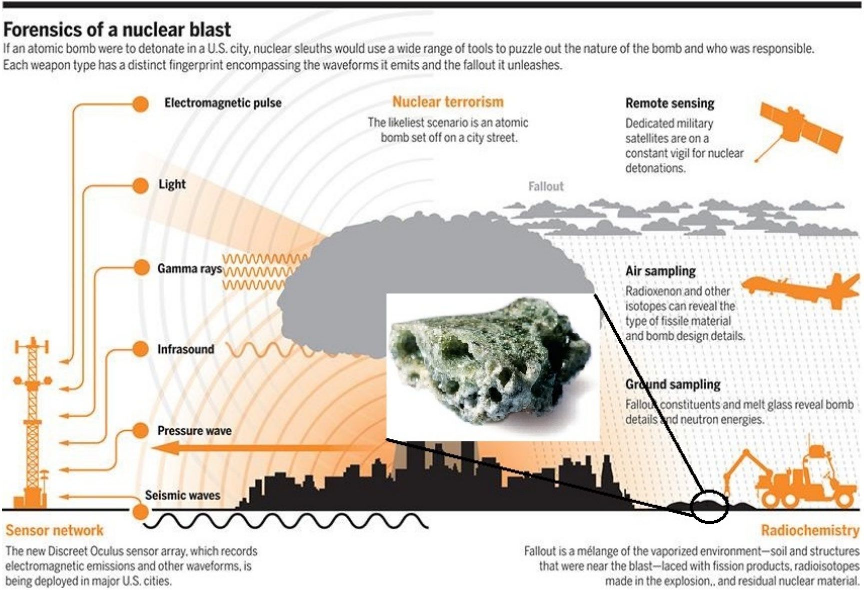
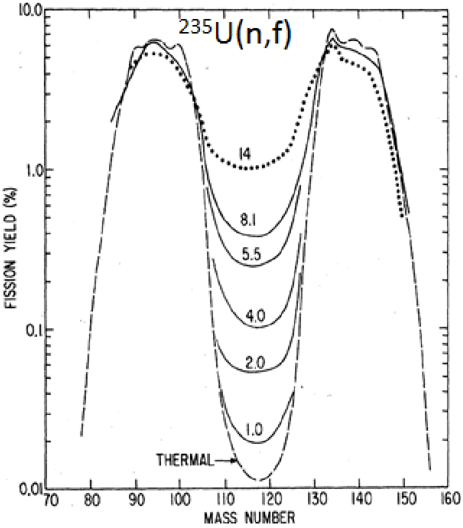


Data and models are inadequate to predict FP yields from exposure to a NW spectrum



[1]

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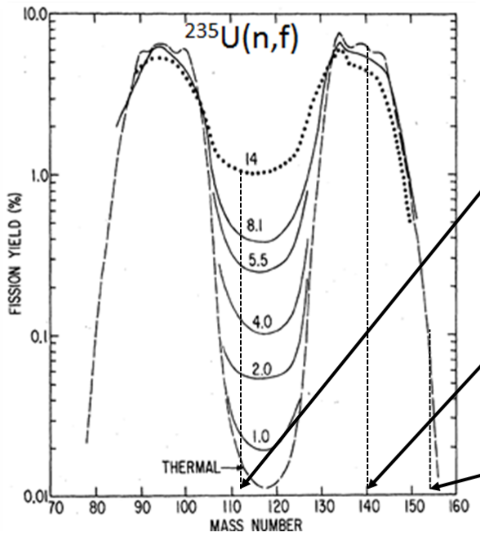

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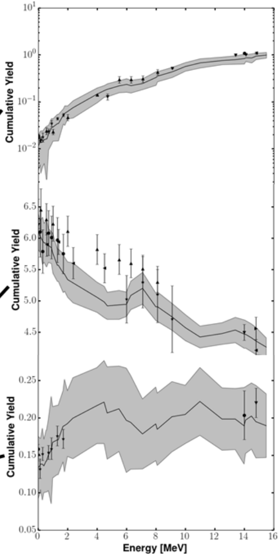
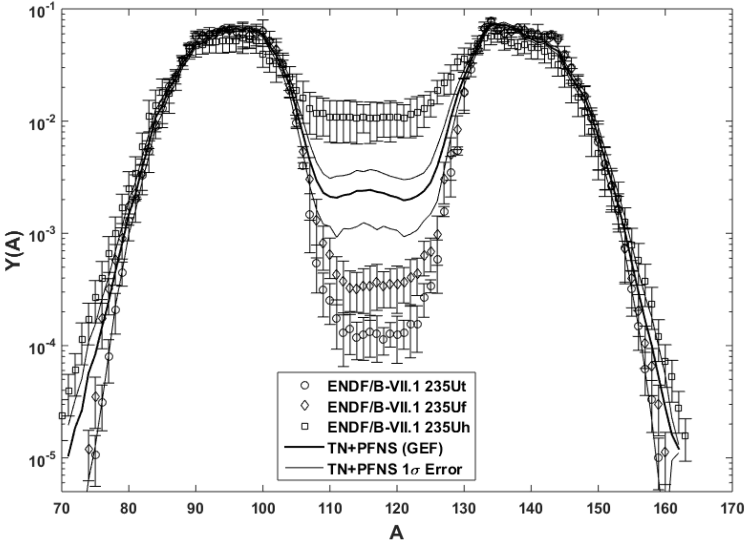


Current approach uses limited mass chains and ENDF data resulting in large errors in FP yields



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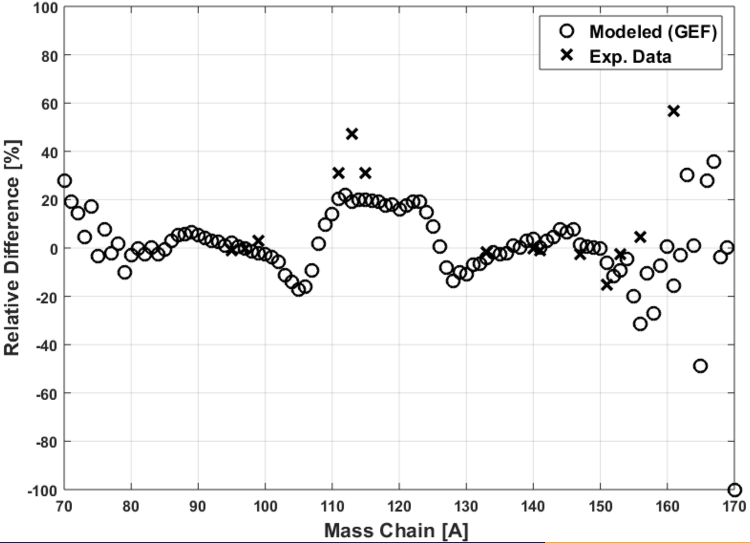
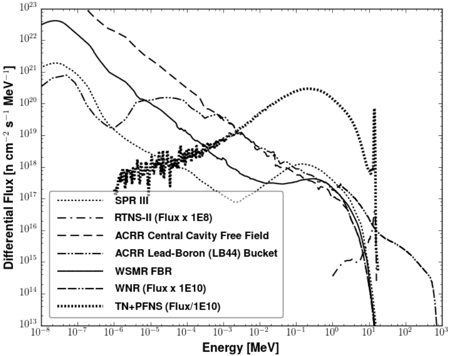


Problem Statement

Problem: U.S. lacks broad spectrum neutron source capable of combining the 14.1 MeV D-T fusion and the Watt fission spectrum (TN+PFNS) necessary to produce realistic detonation fission products and debris



Nuclear Weapons Effects National Enterprise Neutron Facilities [3]–[15]

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This limits the

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- Ability to train the next generation on a diverse array of realistic unknown samples [2]
- Ability to develop modern techniques capable of meeting shifting attribution challenges and contemporary EH&S requirements [2]

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Proposed Solution: Application of spectral shaping techniques using Coeus optimization package to create tailored neutron spectra

Source Selection: Why NIF?

Goal: Develop an energy tuning assembly (ETA) to generate TN+PFNS

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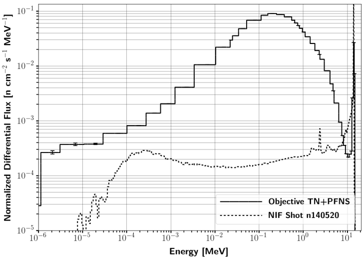

NIF Starting vs Objective Neutron Spectra [12]–[14], [16], [17]

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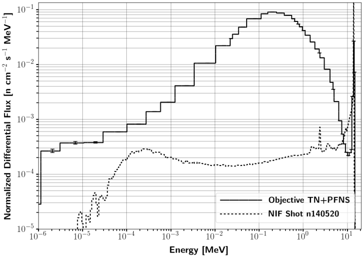
  - $\sim 10^{16}$ neutrons/pulse ($\sim$100x greater than OMEGA)
  - $\sim$200 ps pulse length



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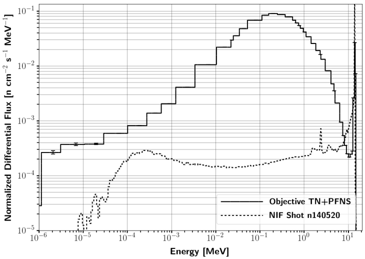

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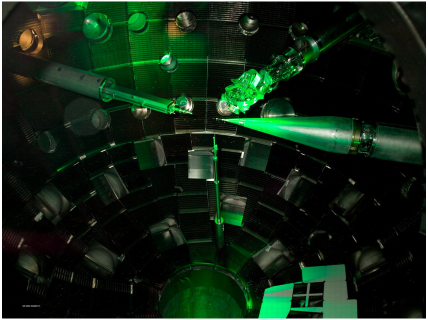

NIF Target Chamber (TC) [18]

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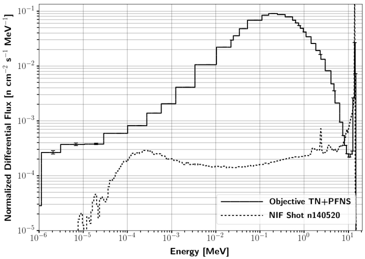
  - On-site radio-chemistry facilities



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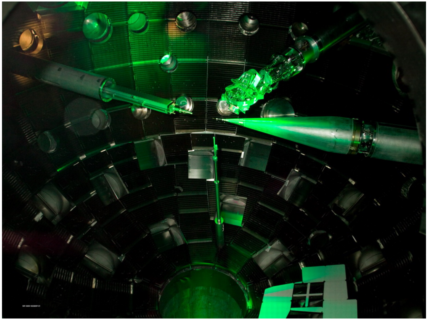
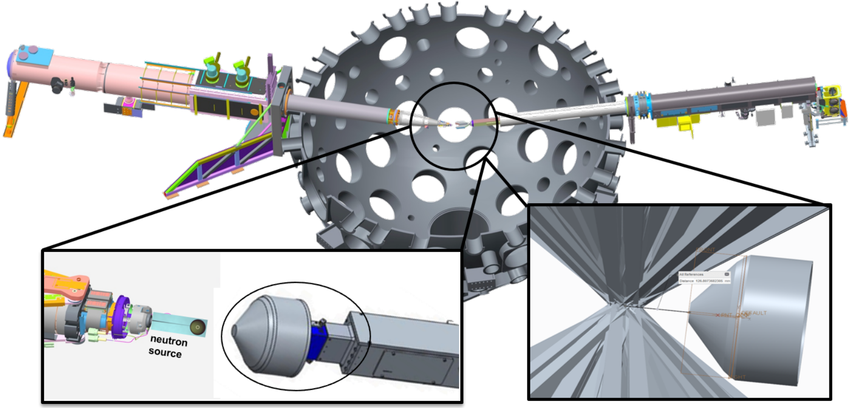


NIF Target Chamber (TC) [18]

Research Development: NIF ETA Concept



ETA will be a new snout using the high-strength NSA pin-mount

Stand-off distance is 12.7 cm w/ 10 mm PDXP 1ω clearance

ETA is installed in TANDM 90-124 for use with a PDXP neutron source on Tarpos 090-239.

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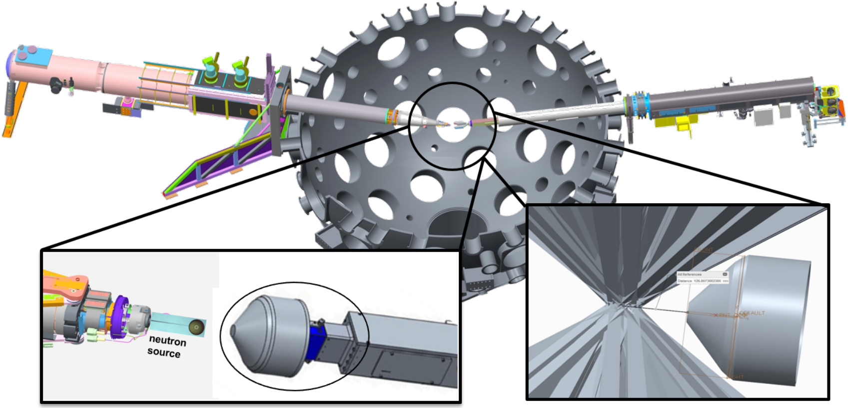

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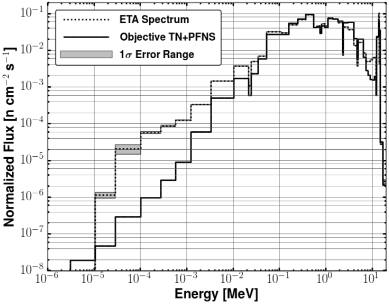
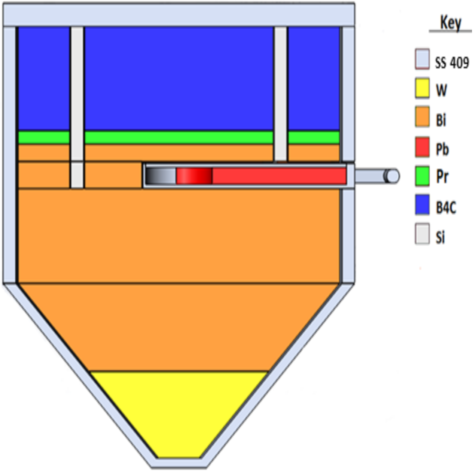
Research Development: ETA Design

Constraints

$\sim$ 70 kg

1.6×10^9 Fissions





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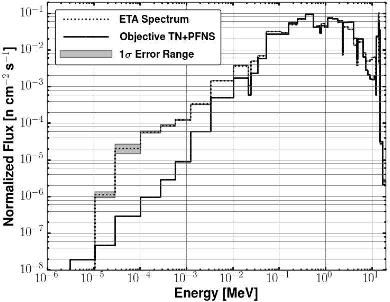
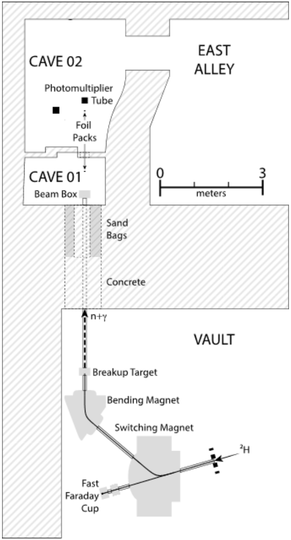
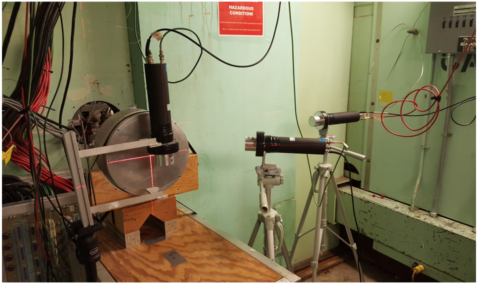
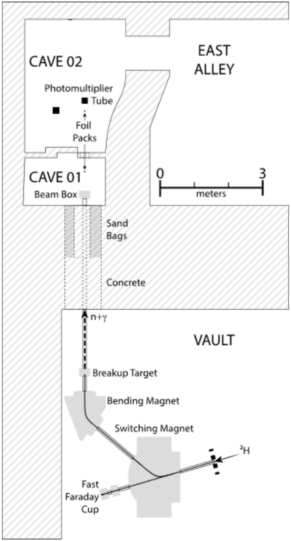


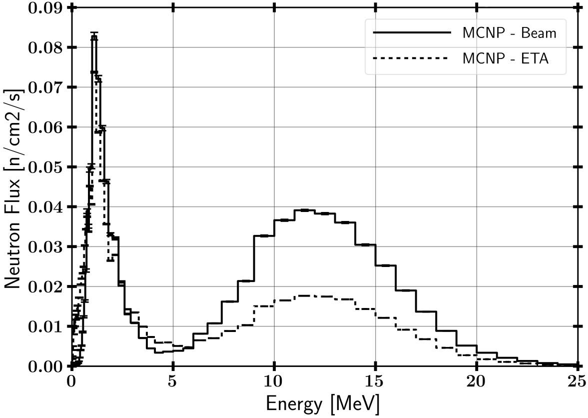
Research Development: ETA fielded at 88"



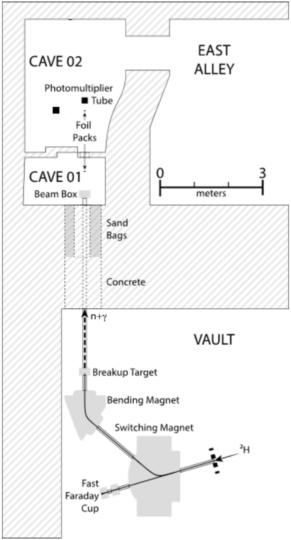


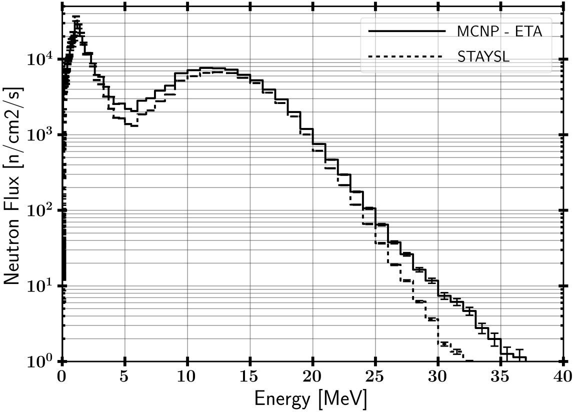
88" experiments tested modeling capability and developed measurement methodology





Research Development: 88" Method Development





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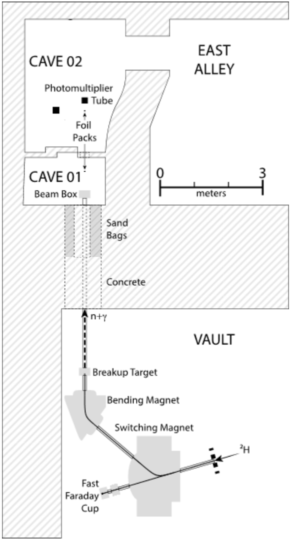

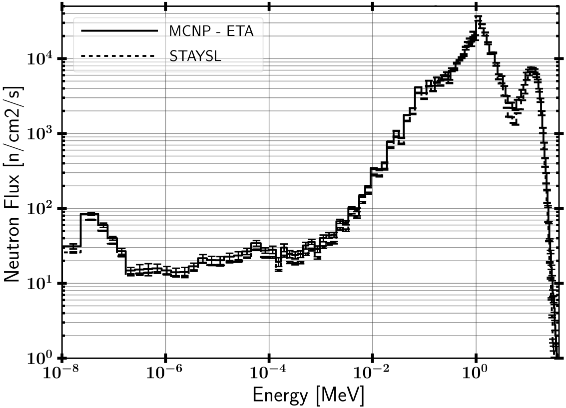

Research Team & Sponsors

AFIT:

- Jason Stickney

University of California, Berkeley:

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- *Bethany Goldblum*
- Josh Brown
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- Will Kable
- Ethan Boado
- Sandra Bogetic
- Youdong Zhang
- Zach Sweger
- Ninad Munshi

Lawrence Berkeley National Lab:

- ***Lee Bernstein***

Lawrence Livermore National Lab:

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- *Eugene Henry*
- *Charles Yeamans*
- *Kim Christensen*
- *Dawn Shaughnessy*
- Darren Bleuel
- Brent Blue
- Walid Younes
- Joe Bauer
- Narek Gharibyan
- Don Jedlovec

Conclusions

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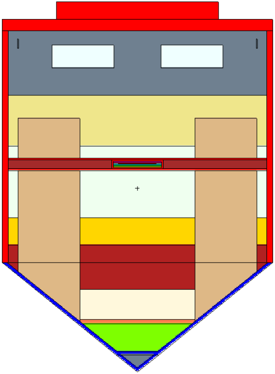
Backups

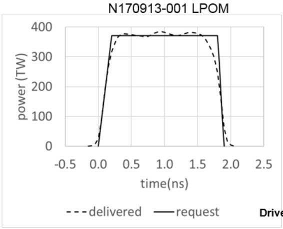
Research Development: ETA Design

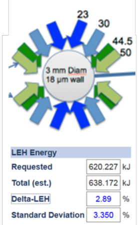
- Coeus & Gnowee completed
- General optimization tools for designing custom neutron spectra
- Finalized NIF TNF ETA design



Research Development: NIF Neutron Source

Laser (28.6 % cone fraction)

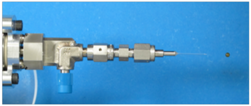




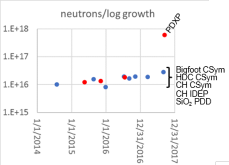
Drive ~1.0e15 W/cm² at capsule

Target

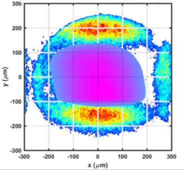
Material: CH (GDP)
Outer diameter: 2.9 mm
Thickness: 18 microns
Gas fill: 65:35 DT, 8 atm (1.6 mg/cc)
warm



	N170913-001	**Preshot simulation**
Y_n DT	3.0 ± 0.1 x 10^{15}	HYDRA: 1-3 x 10^{15} ARES: 4-9 x 10^{15}
T_{ion} (keV) NTOF	10.9 ± 0.2	ARES: 11-12keV
T_e (keV) TiDFS		ARES: gas peak average 5keV
DSR (%)	<0.2%	
BT x-ray (ns)	2.56 ± 0.08	ARES: 2.45-2.65 ns
BT nuclear (ns)	2.38 ± *	ARES: 2.4-2.65ns
Burn width x-ray (ps)	329 ± 40	
Burn width g (ps)	**	
Neutron P0 (um)	205 ± 7	
Neutron P2 (%)	-30% ±1 %	
Neutron M0 (um)	209 ± 3	
Neutron M2 (%)	2%	



N170913-001 PDXP source



CNXI 90-315 x-ray (MATLAB jet) with primary neutron image (purple-blue cool) overlaid.

Research Development: NIF Experimenmtal Config

Target Positioner	Tarpos
Driver Pulse Shape	2 ns nearly-square pulse
Number of Beams	192
Energy/Peak Power	360 TW, 620 kJ
Phase Plates Needed	Standard
Backlighter Beams	None
Backlighter Beams	None
Target Design	Polar direct drive exploding pusher
Fill	65:35 DT, 8 atm
Mandrel OD	2.9 mm
Ablator Thickness	18 microns
Hohlraum	N/A

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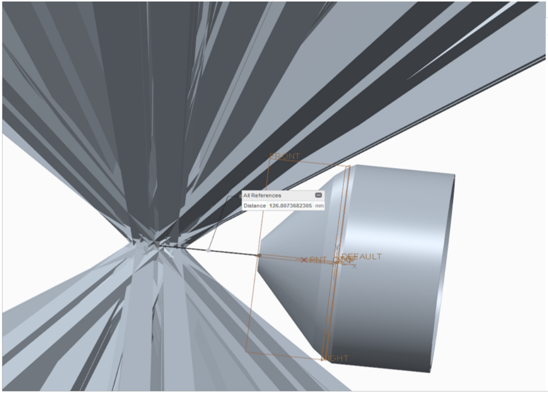

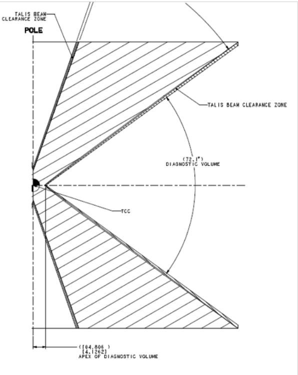

ETA closest approach is on equatorial plane at a standoff of 12.7 cm from TCC: trailing edge of ETA cone clears PDXP 1w with 10 mm clearance.

Cone angle on equator from SAA12-101128 is 72.1°.

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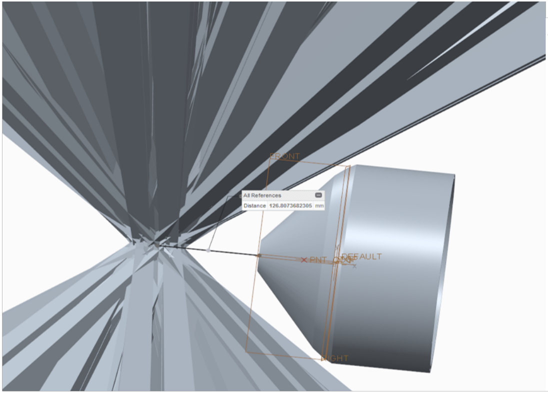

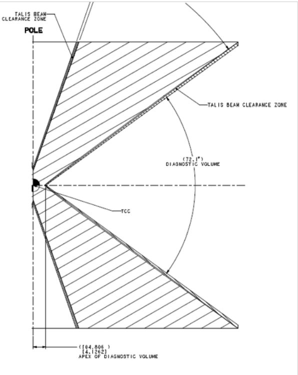

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Research Development: Modeled Spectrum

Energy Range	TN+PFNS Fractional ϕ	ETA Fractional ϕ
0-3 keV	7.23×10^{-5}	$6.20 \pm 0.23 \times 10^{-4}$
3-100 keV	3.80×10^{-2}	$5.02 \pm 0.01 \times 10^{-2}$
0.1-6 MeV	8.03×10^{-1}	$7.65 \pm 0.01 \times 10^{-1}$
6-10 MeV	3.33×10^{-2}	$4.01 \pm 0.01 \times 10^{-2}$
10-20 MeV	1.26×10^{-1}	$1.44 \pm 0.01 \times 10^{-1}$

Research Development: Modeled FP Yields

FP	Objective	ETA
$^{95}_{40}Zr$	6.17 ± 0.09	6.15 ± 0.09
$^{97}_{40}Zr$	5.75 ± 0.09	5.74 ± 0.09
$^{111}_{47}Ag$	0.25 ± 0.01	0.26 ± 0.01
$^{115}_{48}Cd$	0.25 ± 0.01	0.26 ± 0.01
$^{133}_{53}I$	6.41 ± 0.13	6.38 ± 0.14
$^{140}_{56}Ba$	5.71 ± 0.07	5.68 ± 0.07
$^{147}_{60}Nd$	2.12 ± 0.03	2.11 ± 0.03
$^{151}_{61}Pm$	0.47 ± 0.02	0.47 ± 0.02
$^{153}_{62}Sm$	0.18 ± 0.01	0.18 ± 0.01

Research Development: Modeled Foil A_0

Foil	Reaction	A_0 [Bq]
Zirconium	^{90}Zr(n,2n)^{89}Zr	1724
Nickel	^{58}Ni(n,2n)^{57}Ni	398
	^{58}Ni(n,p)^{58}Co	330
Indium	^{115}In(n,n')^{115m}In	6.97×10^4
	^{115}In(n,g)^{116m}In	6.18×10^4
Gold	^{197}Au(n,2n)^{196}Au	3547
	^{197}Au(n,g)^{198}Au	578
Aluminum	^{27}Al(n,p)^{27}Mg	4224
	$^{27}Al(n,\alpha)^{24}Na$	31.3

References I

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