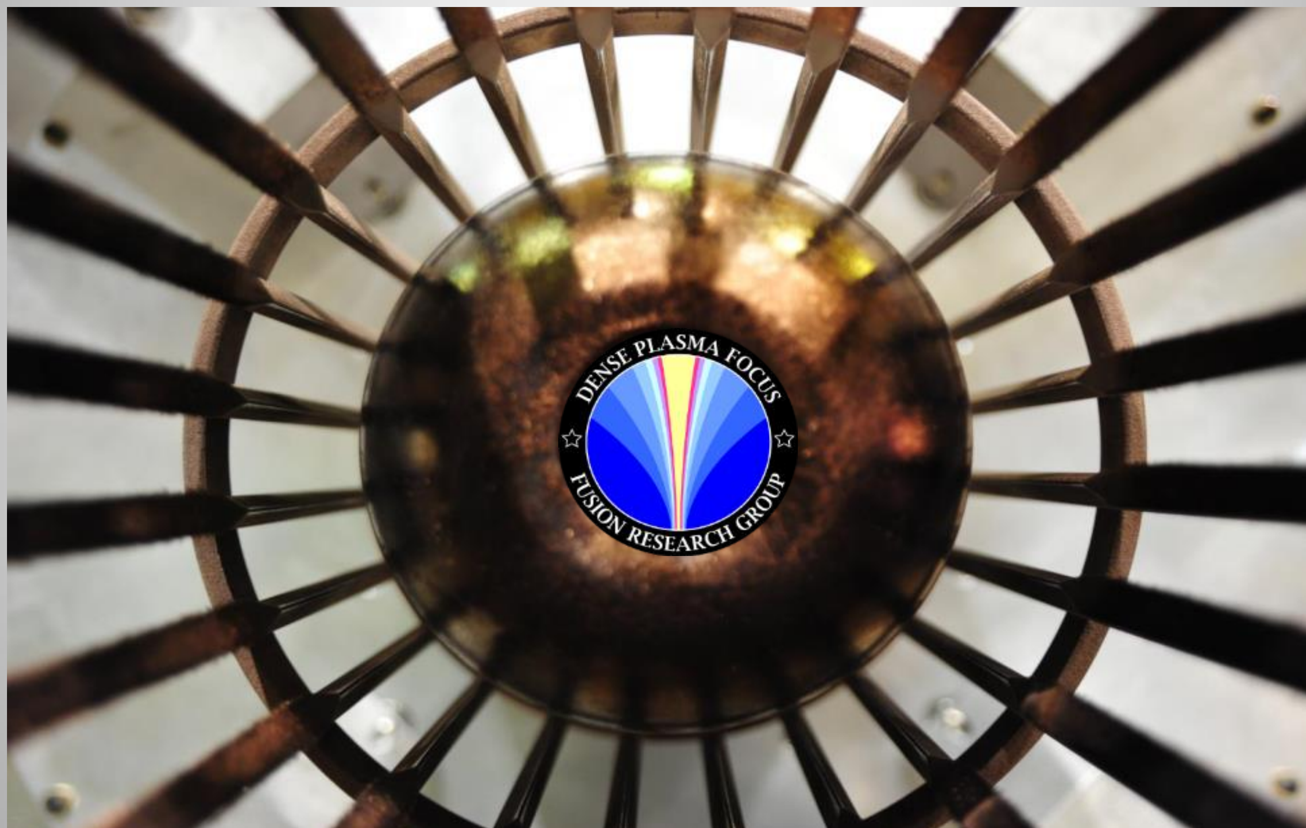
DOE/NV/25946--2147

The NSTec Dense Plasma Focus Laboratories – An Overview



This work was done by National Security Technologies, LLC, under Contract No. DE-AC52-06NA25946 with the U.S. Department of Energy

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Daniel Lowe, PhD

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Outline

- **What is a DPF?**
- **What programs the DPF support**
- **What we have done in the past**
- **DPF diagnostic tools**
- **Where we are going**
- **What we can improve upon**

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What is a Dense Plasma Focus?

- A pulsed power machine that typically drives a $H_2/D_2/T_2$ plasma down an anode and radially collapses the gas to produce a Z pinch
- Stored energy ranges from J to MJ
- Sizes range from tabletop to 3 story buildings
- Rep rates from 1 per day to 100 hz
- Neutron yields from 1e5 DD to 1e14 DT

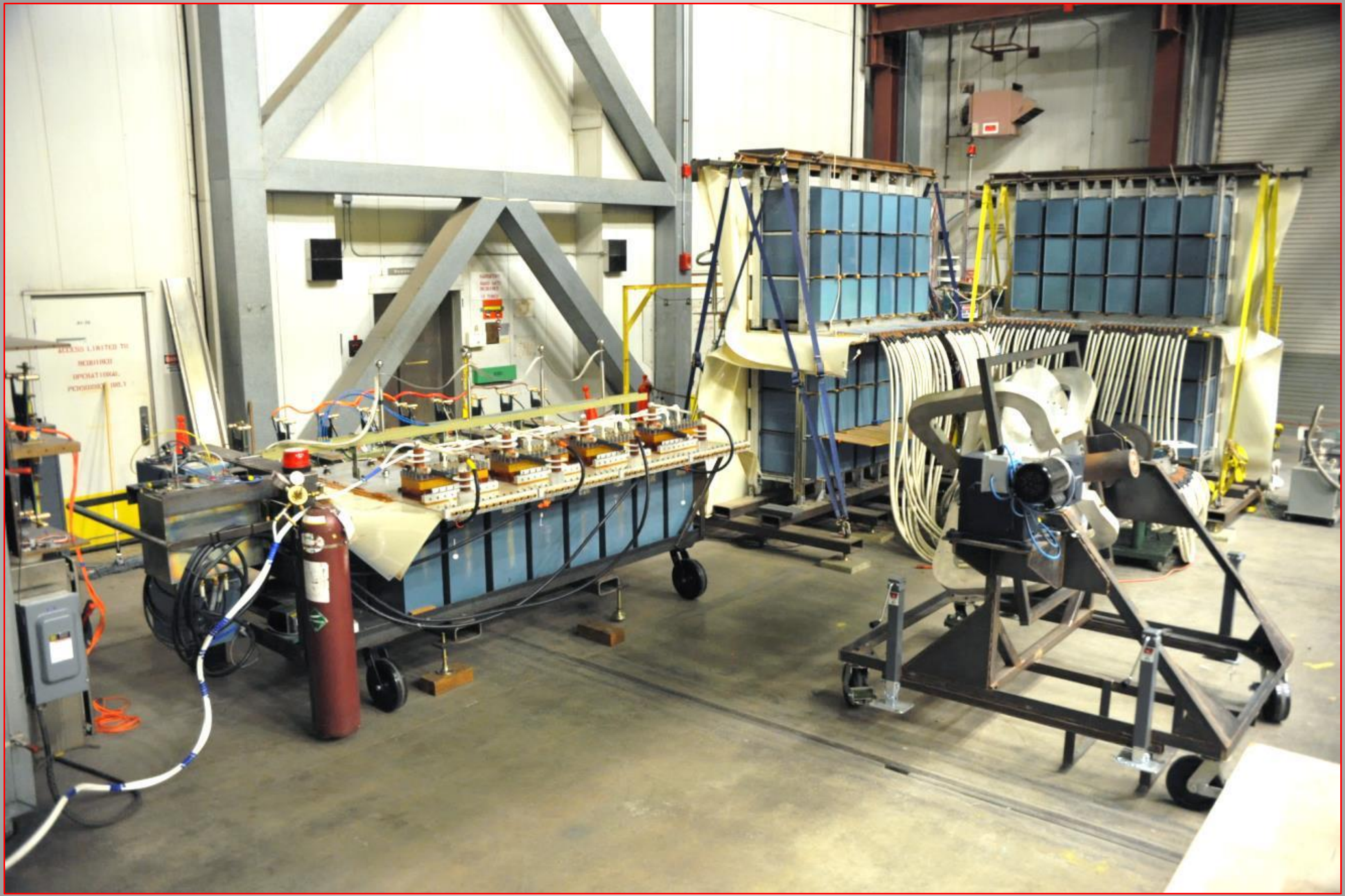
What is a Dense Plasma Focus?

x07rho_slice.mov

What is a Dense Plasma Focus?

DPF_Test2.wmv

What is a Dense Plasma Focus?



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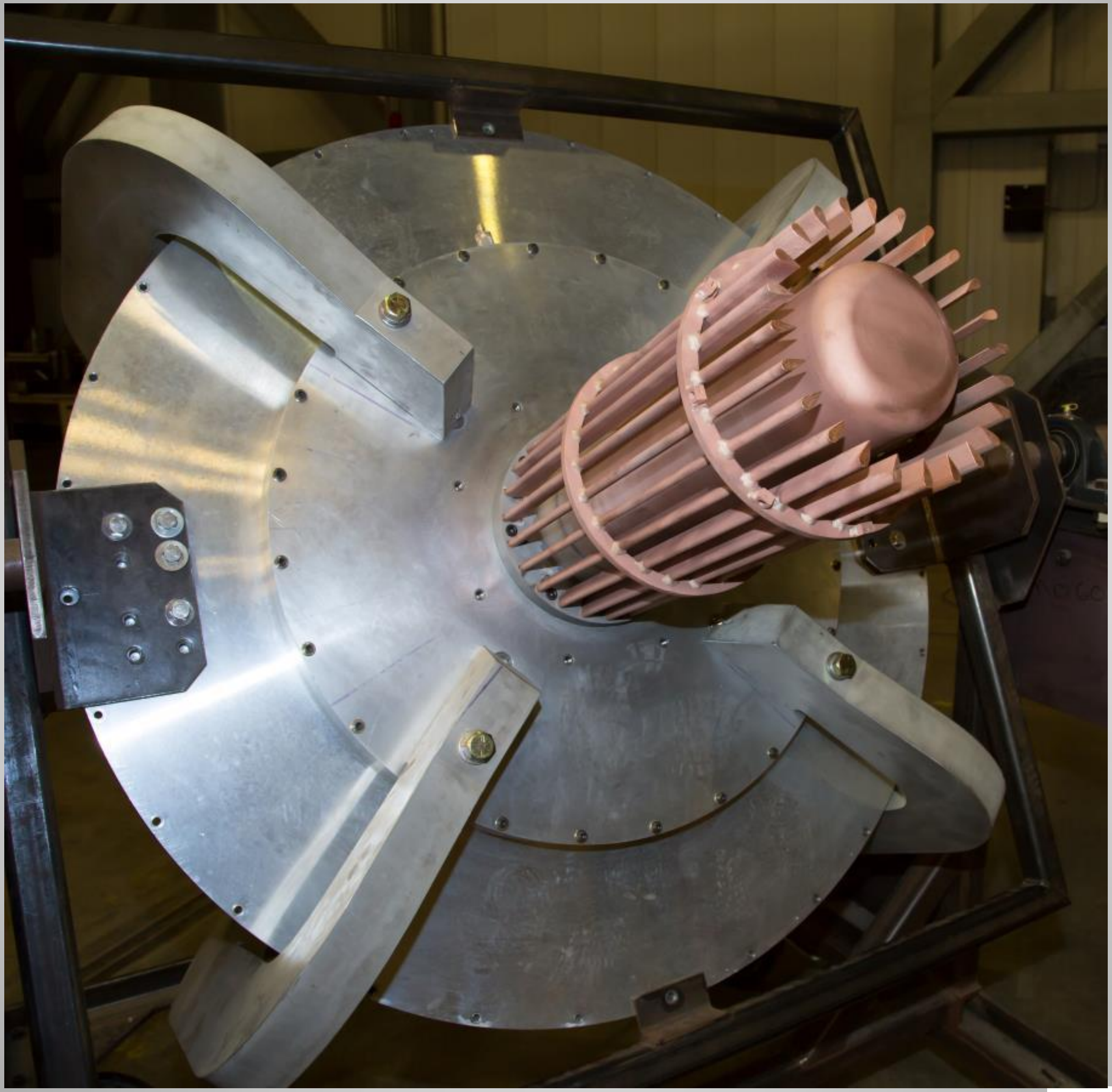
What is a Dense Plasma Focus?



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- What is a DPF?
- **What programs the DPF support**
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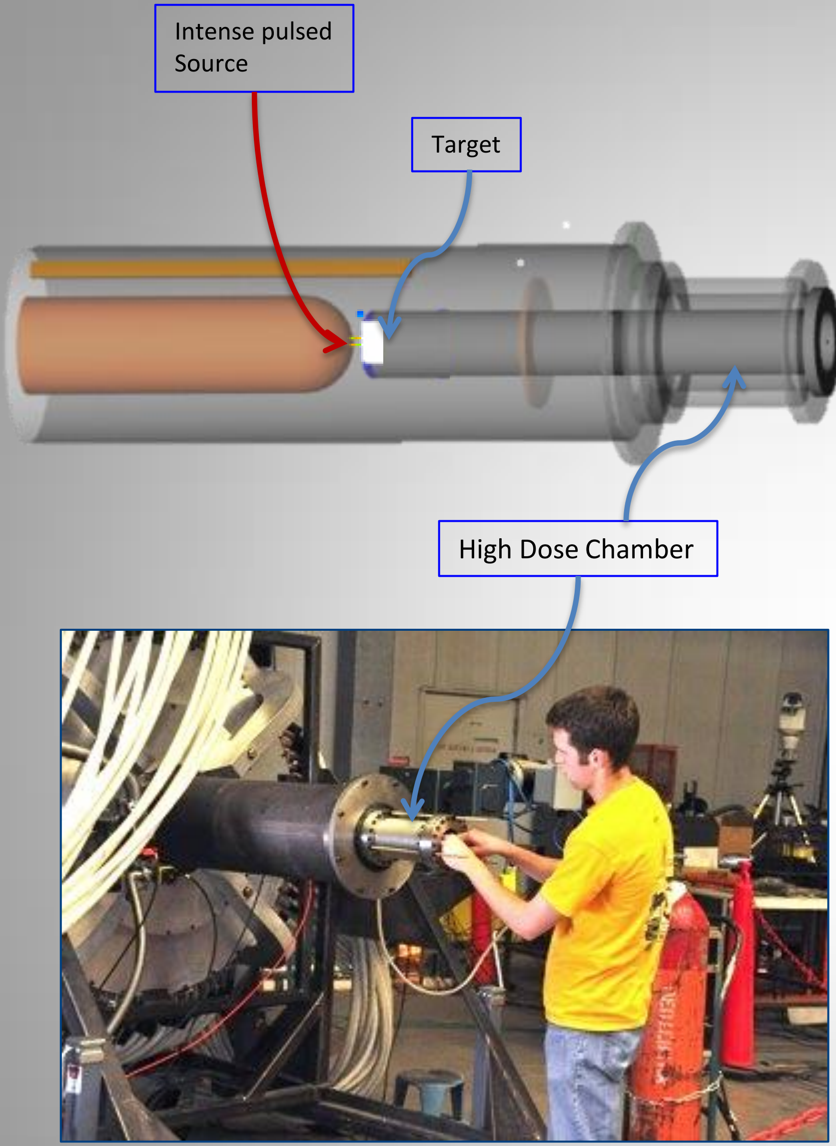
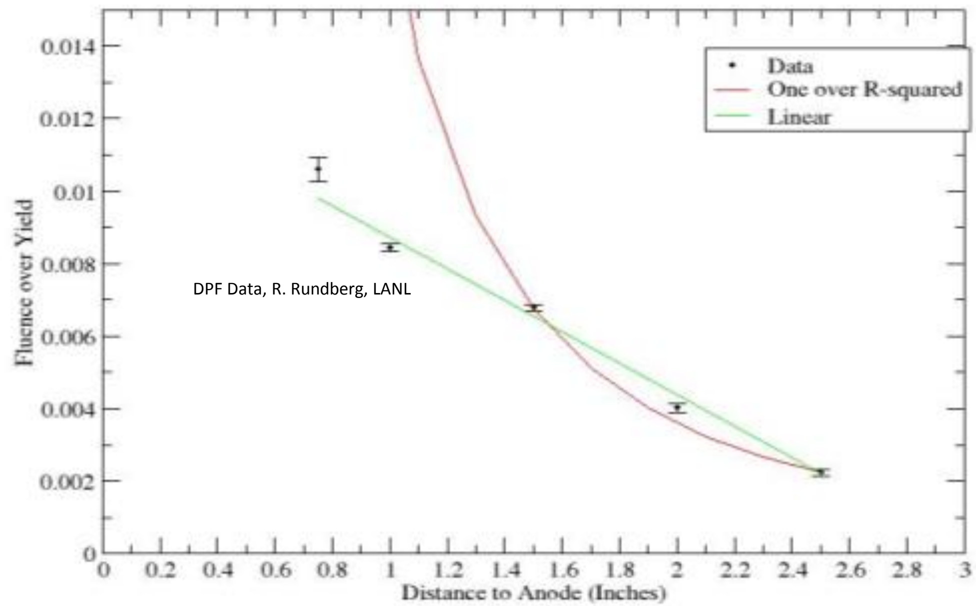
Programs the DPF support…

- NDSE (Neutron Driven Subcritical Experiments)
  - Measuring k_{eff} on an imploding object with a pulsed neutron source
- NRS (Neutron Resonance Spectroscopy)
  - Shock front temperature measurements within opaque materials
- Flash Neutron Radiography
  - Pulsed radiograph/shadowgraphs using neutrons
- Nuclear Forensics
  - Material activation using mono-energetic fusion neutrons, EMP studies, detector calibrations, Teller light

Ultra-High Dose Chamber

- Radiate with pure fusion neutrons
- Radiate with { fission – fusion } spectrum
- Surrogate source
- Generate moderated beam





Single Pulse DD Fluences

1×10^{11} neutrons/cm2

(> 10 times a day)

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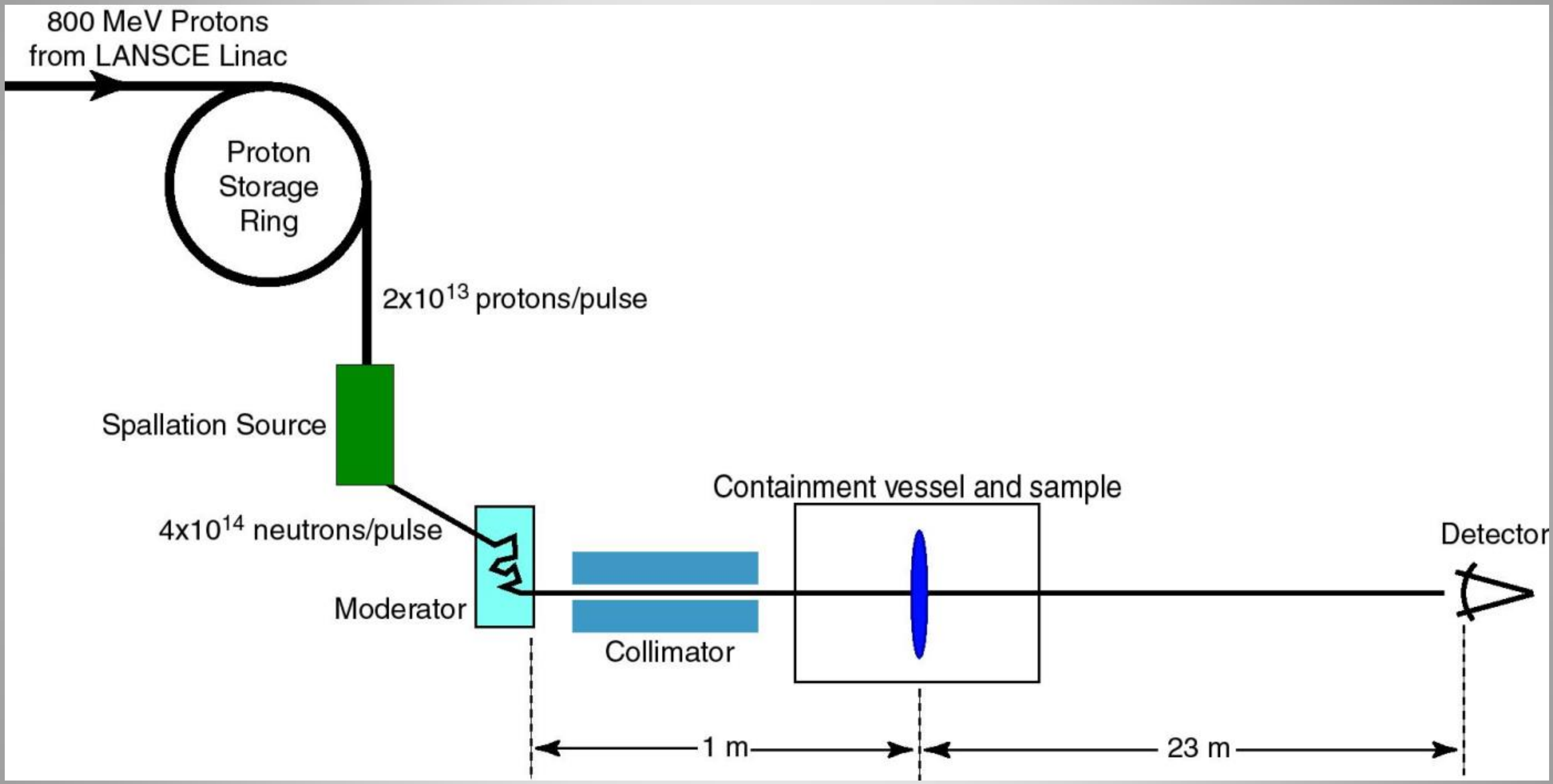
DANGER
480
VOLTS

NRS slides


800 MeV Protons
from LANSCE Linac
Proton
Storage
Ring
2x10^13 protons/pulse
Spallation Source
4x10^14 neutrons/pulse
Moderator
Collimator
Containment vessel and sample
Detector
1 m
23 m

NRS slides

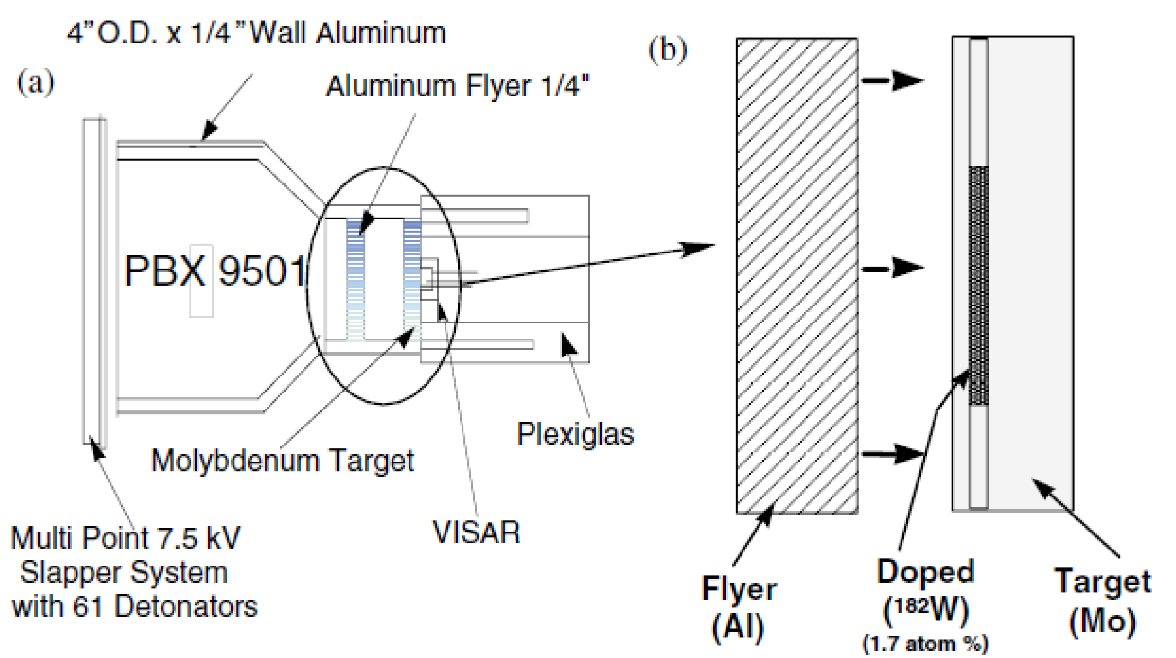


FIG. 1 (color). (a) A schematic of the launcher-target assembly. (b) A magnified view of the portion with the aluminum flyer and the target.

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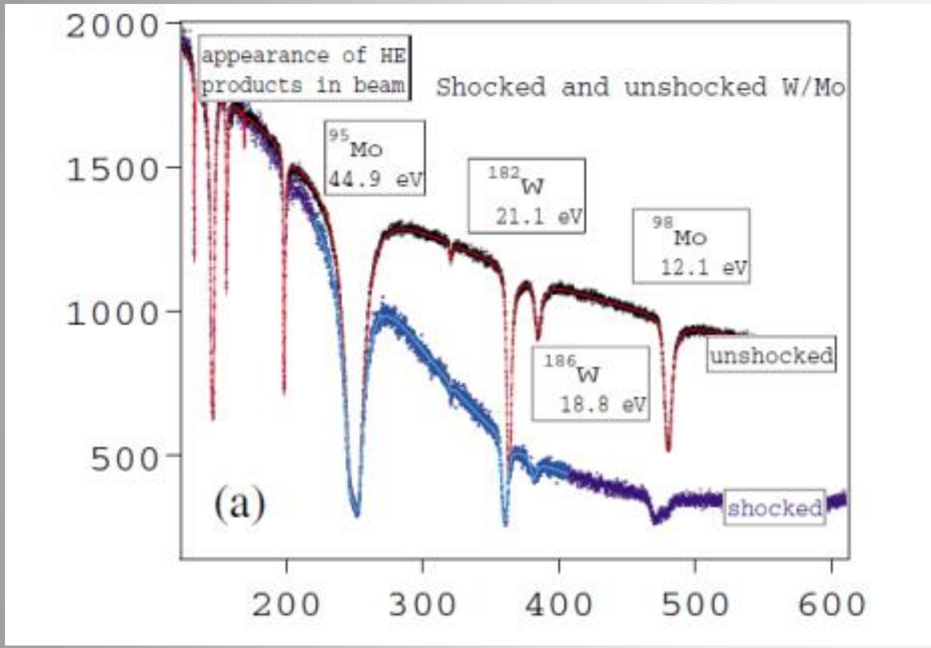
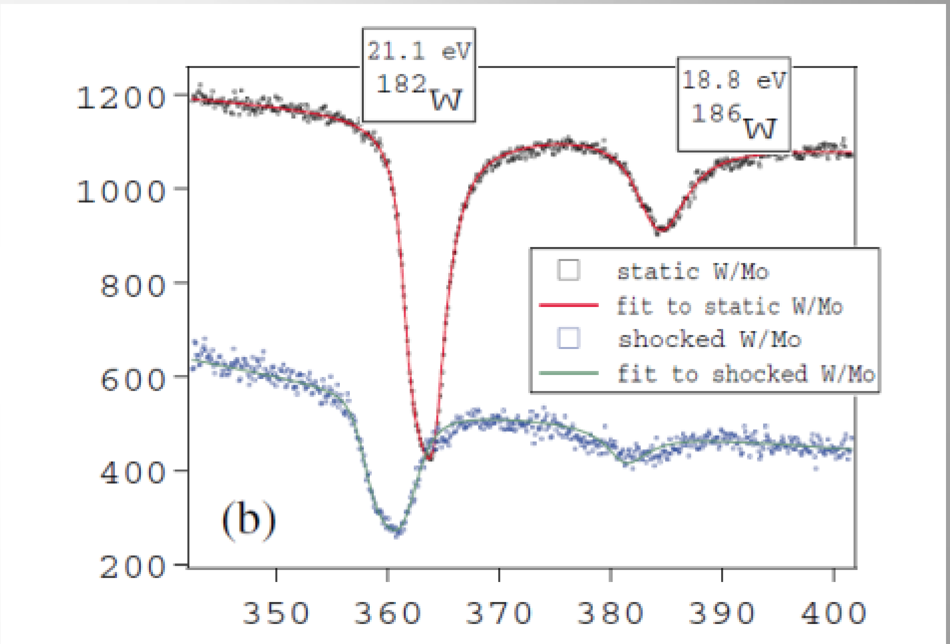
NRS slides

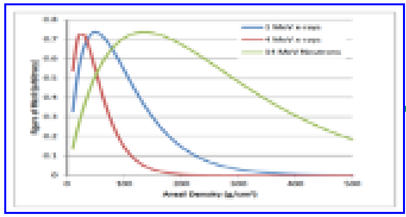


2000
1500
1000
500
200
300
400
500
600
appearance of HE products in beam
Shocked and unshocked W/Mo
95 Mo 44.9 eV
182 W 21.1 eV
98 Mo 12.1 eV
186 W 18.8 eV
unshocked
shocked
(a)



21.1 eV 182 W
18.8 eV 186 W
1200
1000
800
600
400
200
350
360
370
380
390
400
static W/Mo
fit to static W/Mo
shocked W/Mo
fit to shocked W/Mo
(b)

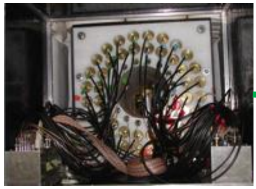
NDSE Overview



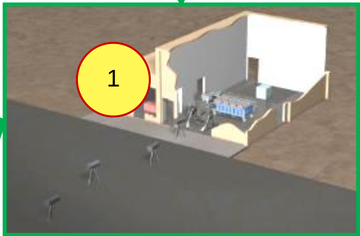
LANL system and component characterization

DT DPF Source

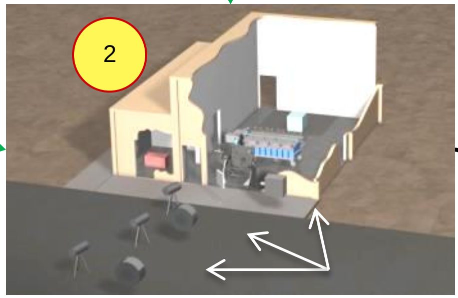
DT DPF



$K_{effective}$ Detector Systems



Keff ***DT Source*** Tests
Source Characterization

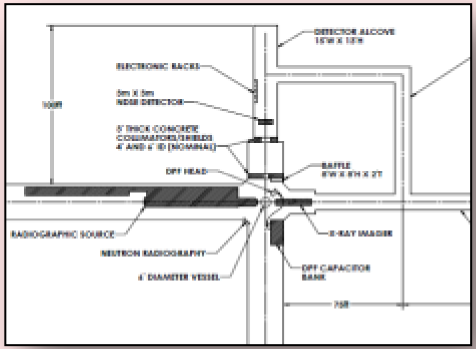


Keff ***System Component*** Tests

Keff DT Facility
SNM Static System Optimize

U1a

NDSE – Radiography Facility



AB for SNM

Targets/Systems

Static Test Facility Preparation

Static Test With SNM
Δ

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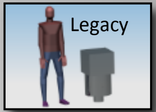
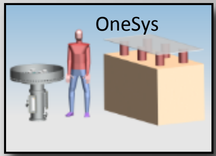
Short NSTec DPF History … (with Results)

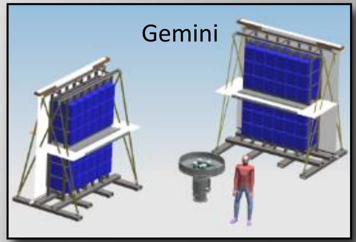
- **Existing Small DPF source**
  - **(From LANL) used for detector development [c 1990]**



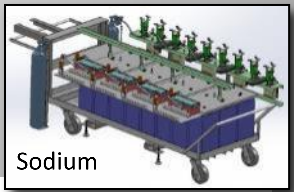
- **First "Build a DPF requirement" was to provide a short-pulsed neutron source for a Keff diagnostic on Unicorn. Shaft Shot, 4' hole. [2002]**
  - Small "Legacy" source used to set operating point
    - Shot with DD and **DT [2002]**
      - ***DT/DD Yield ratio measured***, used to size Unicorn DT source
  - **133 kJ DT source designed**; Our first NSTec design and built source
    - single stage bank, ***new*** source made with Pegasus capacitors, hardware.
    - Tested in North Las Vegas, **[March 2004]**
    - ✓ **November 1, 2007 achieved Unicorn goals of >1e12 n/p and << 100ns FWHM**



- **500 kJ source followed, "TallBoy" [2008]**
  - Marx bank
    - ✓ **70 kV erected**
- **1 MJ "Gemini" source built to investigate yield scaling issues. [2009]**
  - Now most powerful and
  - largest energy storage capacity operating DPF in world, with
  - highest DD neutron yield of
    - ✓ **> 1 x 10^{12} DD neutrons per pulse.**



- **350 kJ DT DPF system (to upgrade 133 kJ Onesys) [2012]**
  - In early **D-T** startup, February 2014: Achieved Design Yield > **1 x 10^{13} DT**
  - Operability, Pulse width, Pulse shape.



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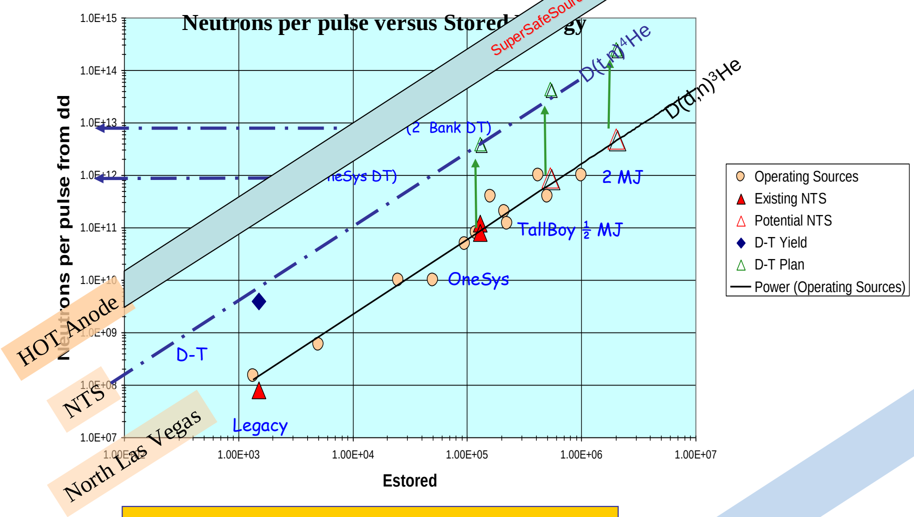
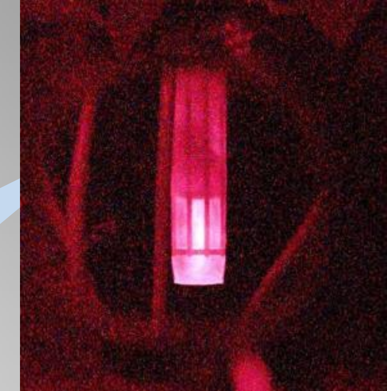
Path forward: DPF – NLV and NTS Sources



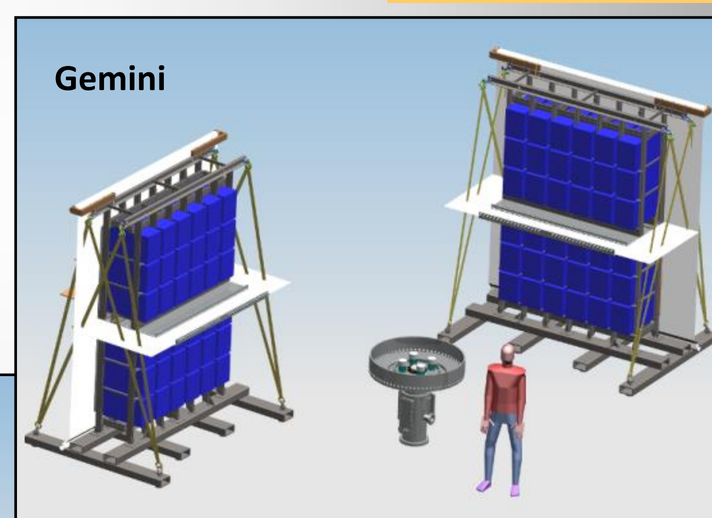
NSTec is steadily executing plan for needed neutron systems and sources.



to the

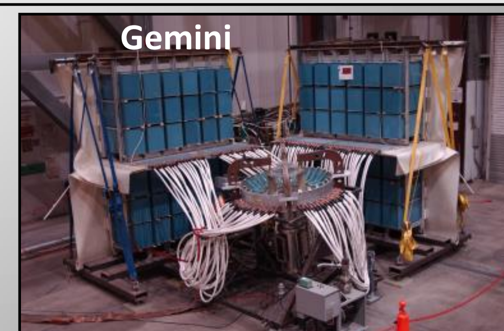
- ***state of the art,***
- 1 Megajoule stored

DD_2009
Purpose: > 3 MA
1 MJ, Yield Scaling investigations



DD_2008
Purpose:
Test HV operations

TallBoy

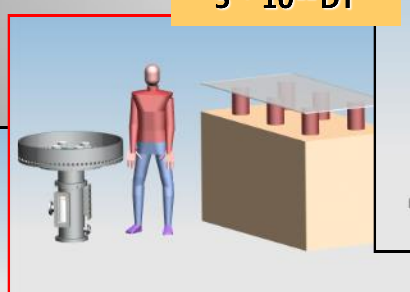


From:

- ***Legacy***

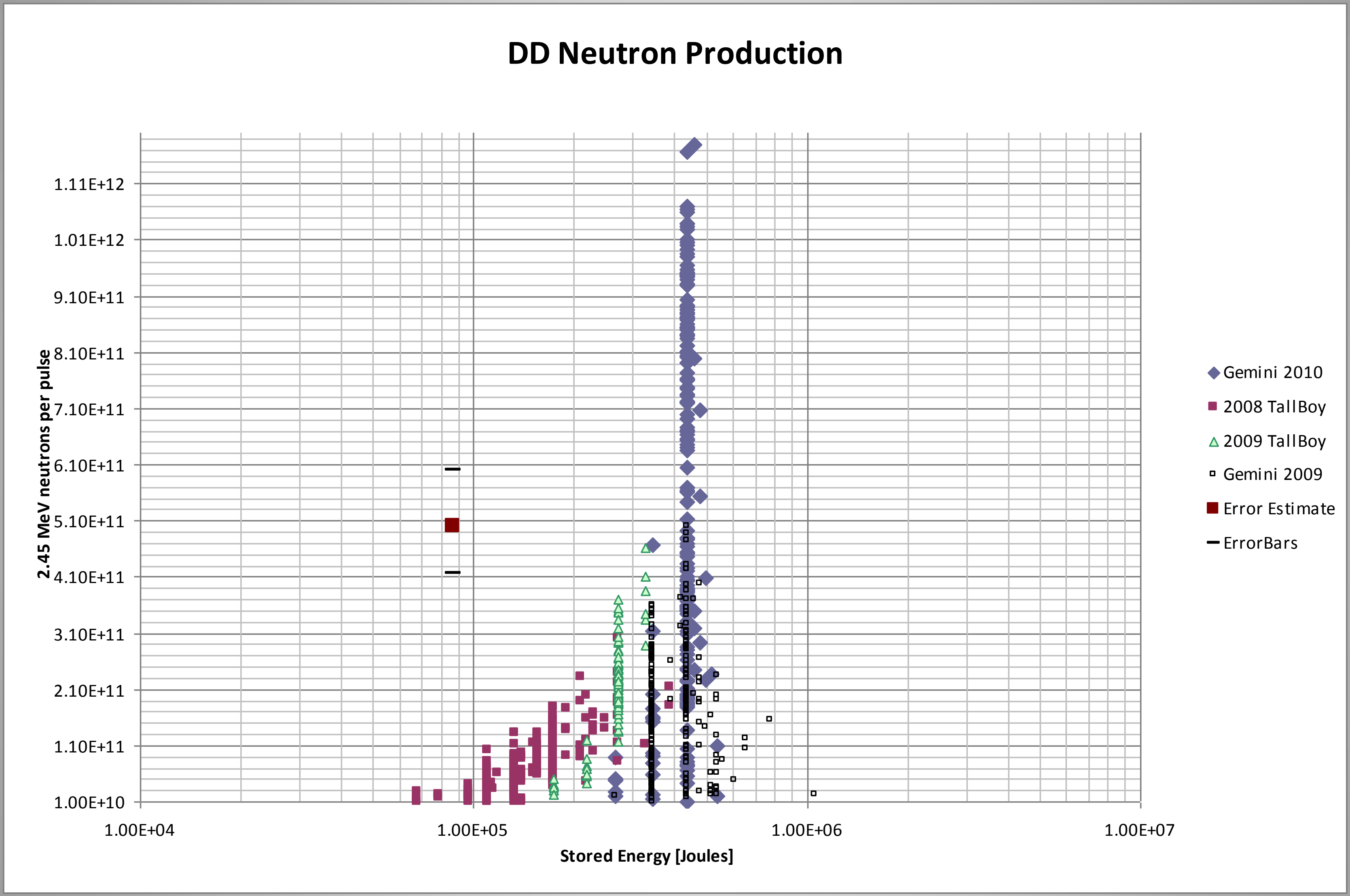
DD_2004

DT_2007
Purpose:
~ 5 * 10^{12} DT



OneSys (NTS DT)

NSTec DPF Experimental Results



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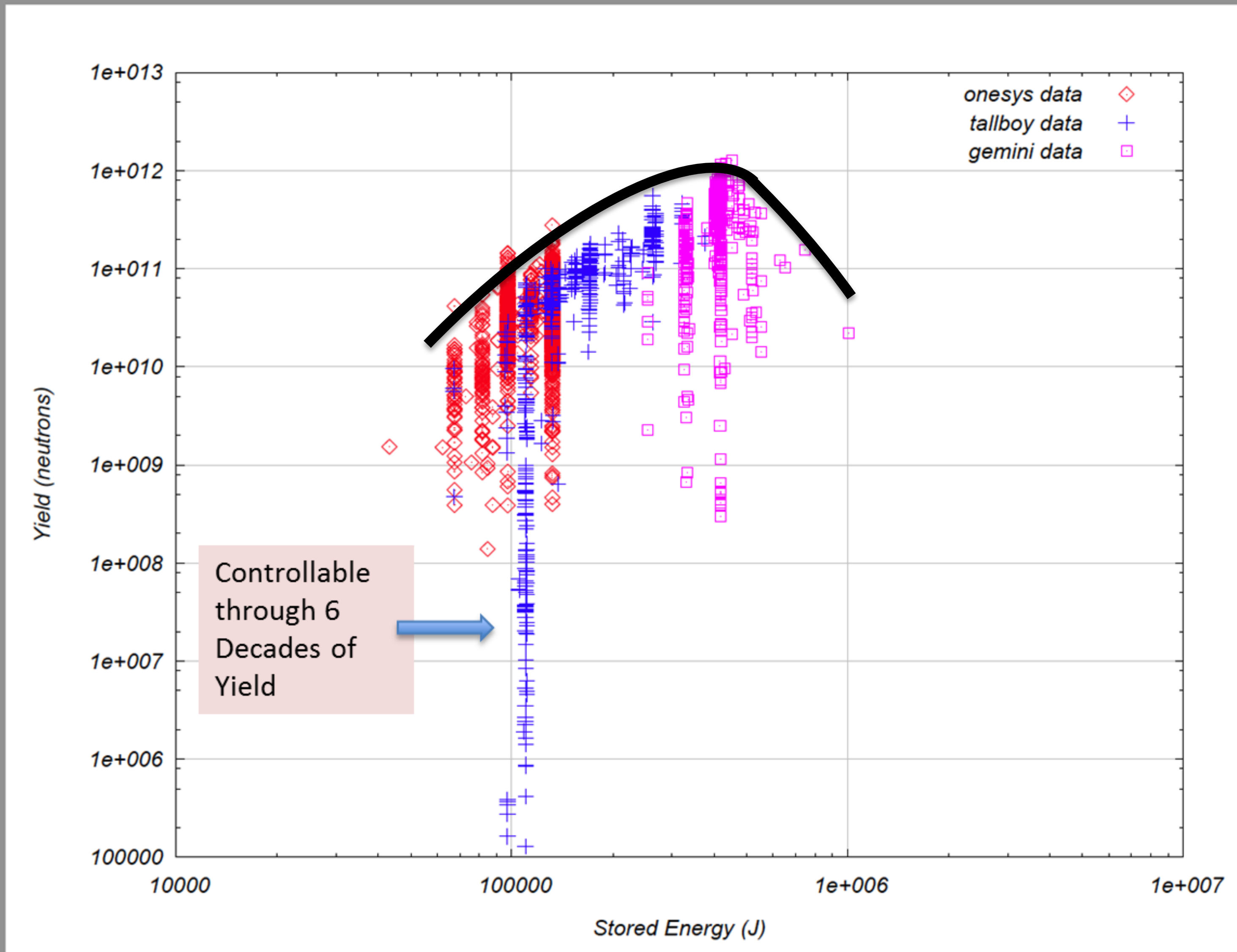
Yield Cessation @ 1E12



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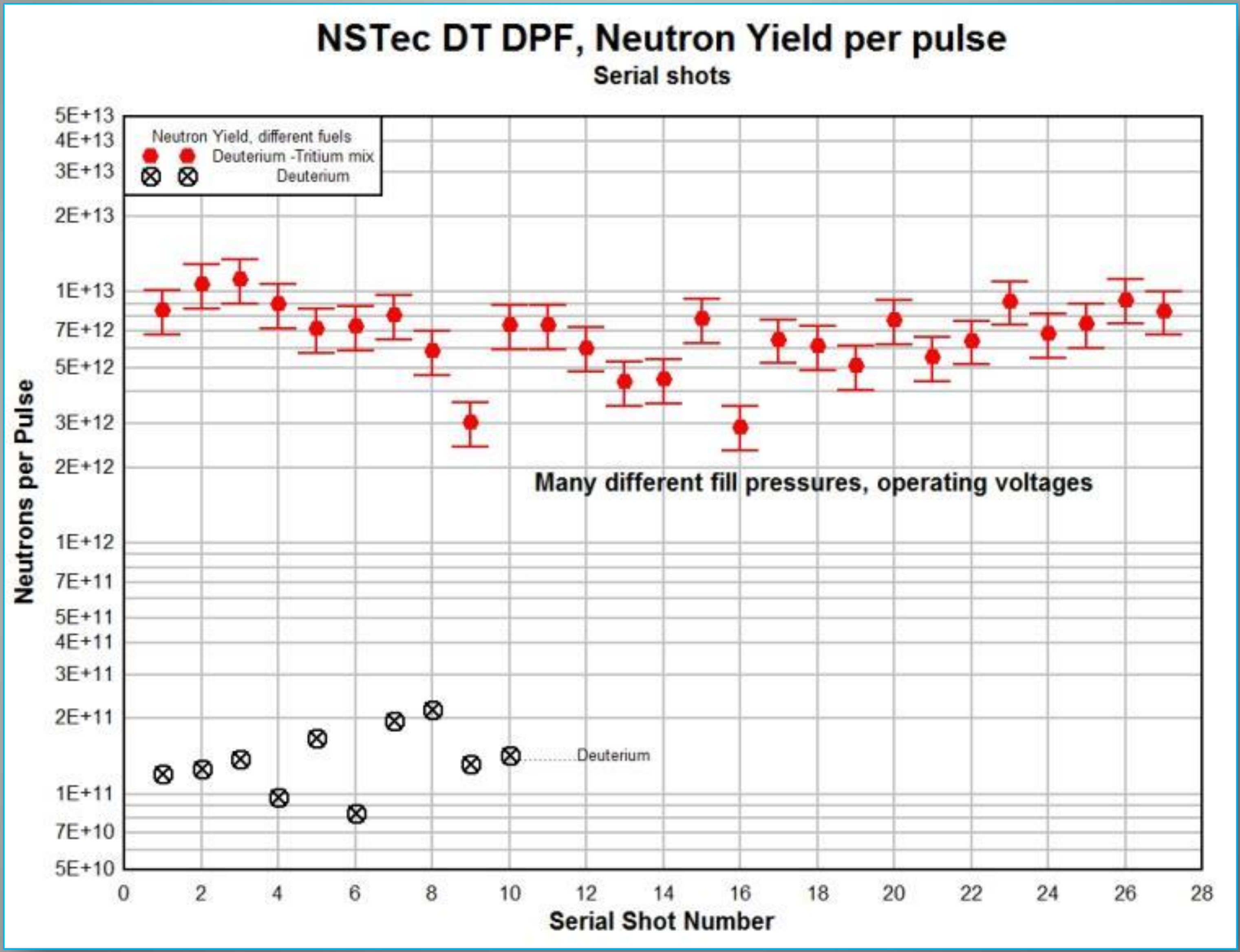

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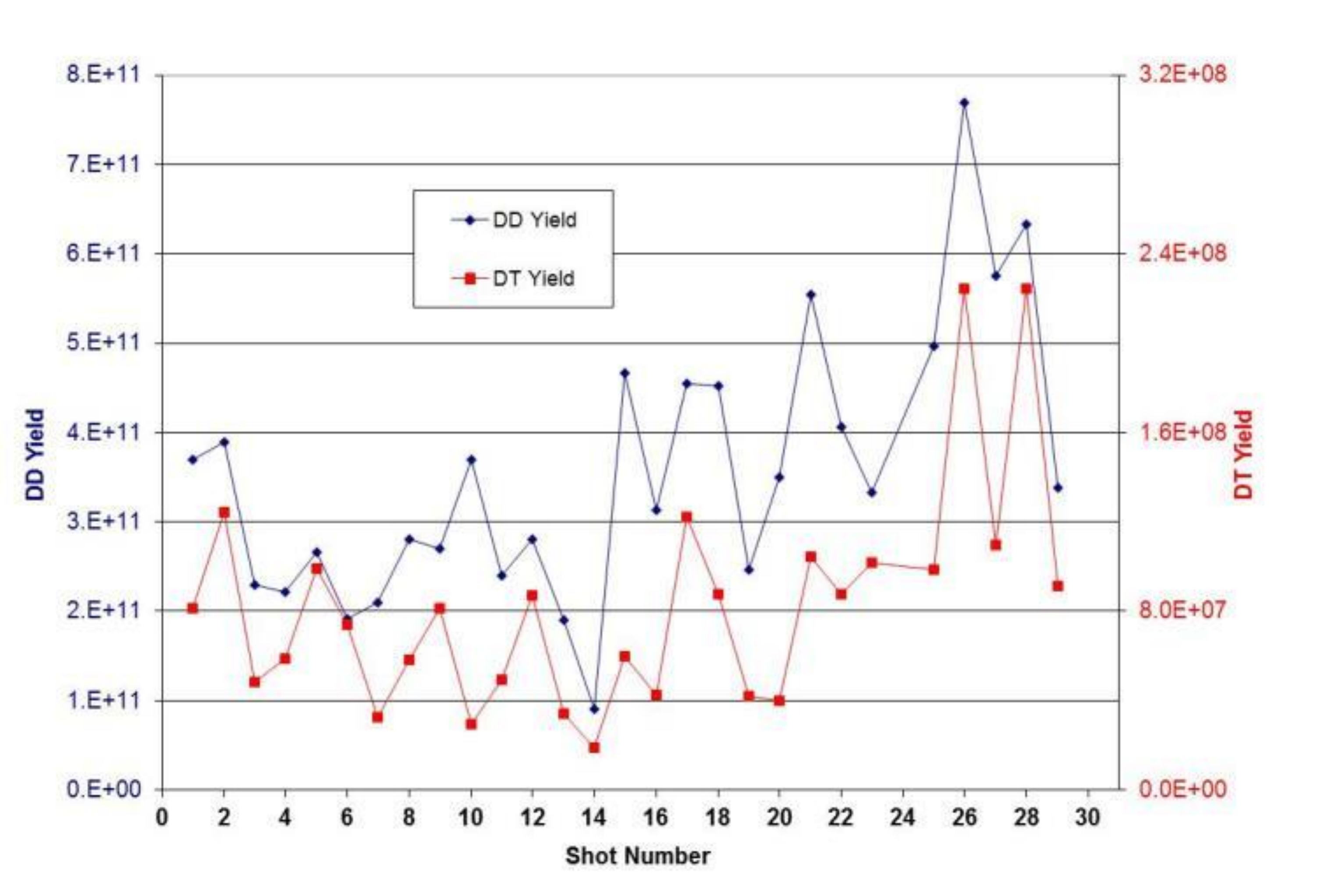
DD/DT yield in MJ DD source



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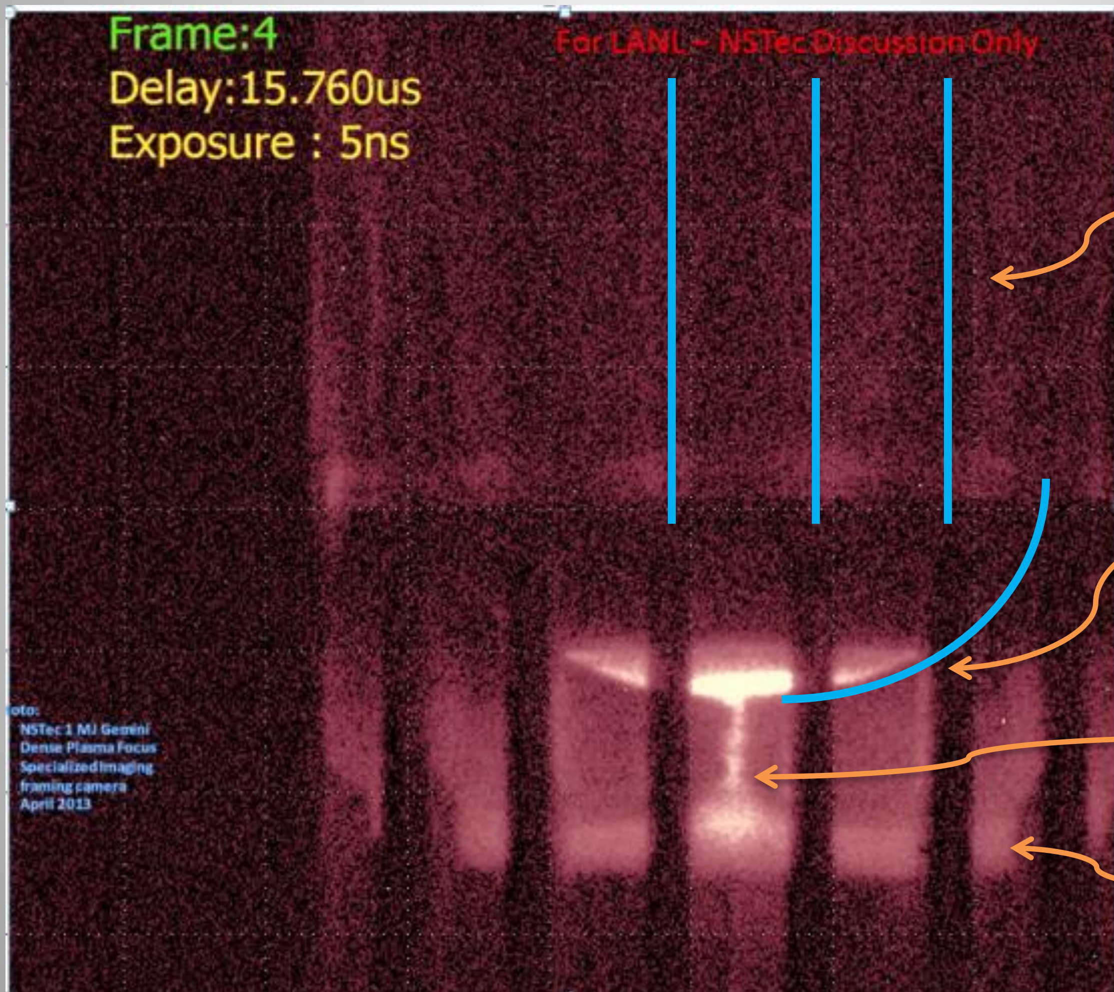
DPF Pinch

5 ns exposure, optical



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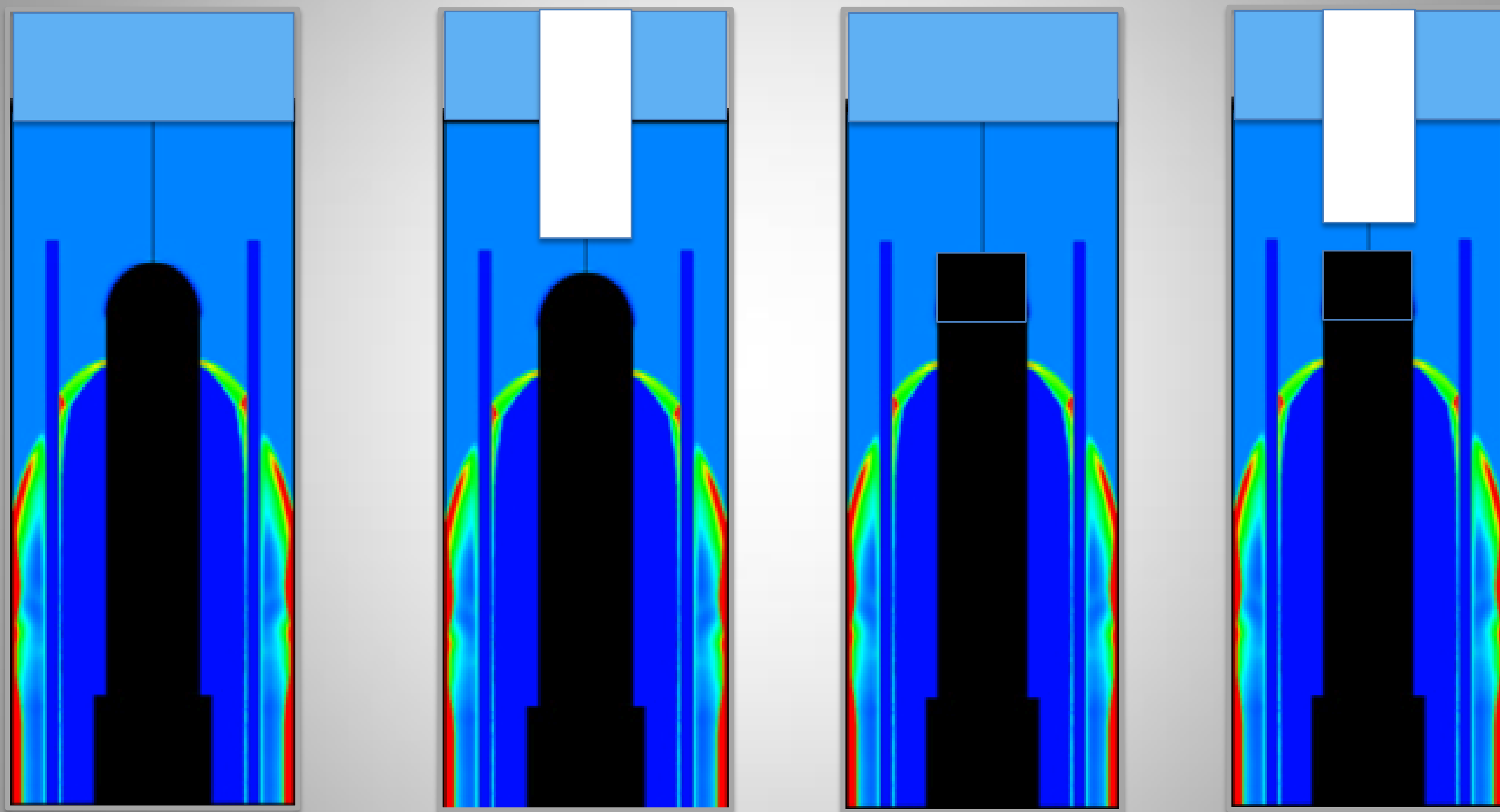

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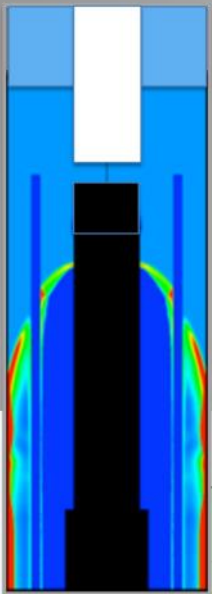
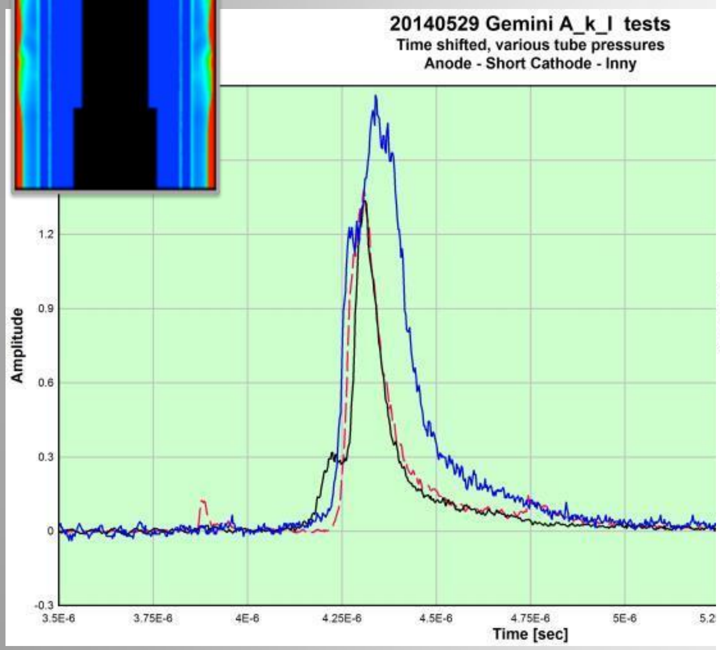
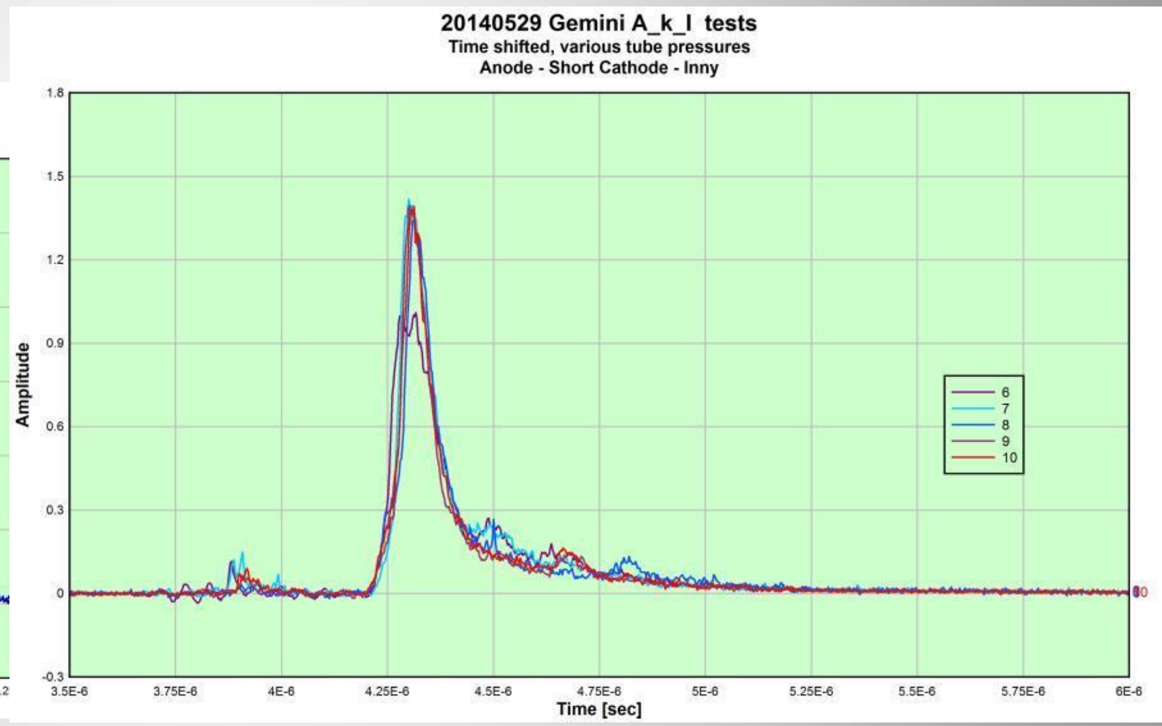
FlatTop + Inny, Short Cathode

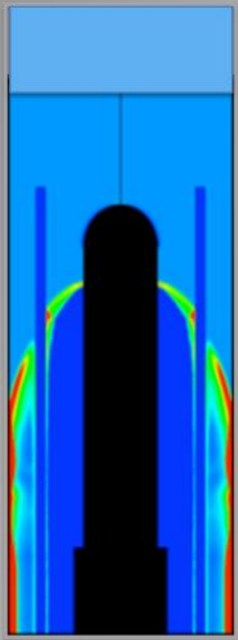


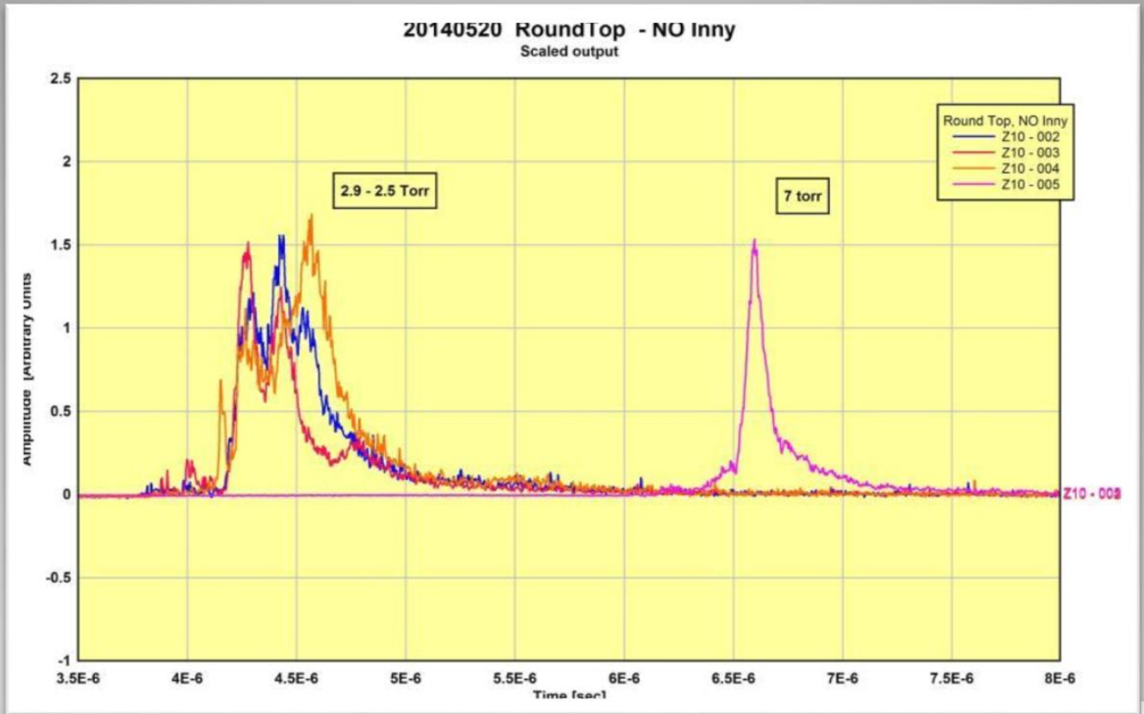


Old FlatTop

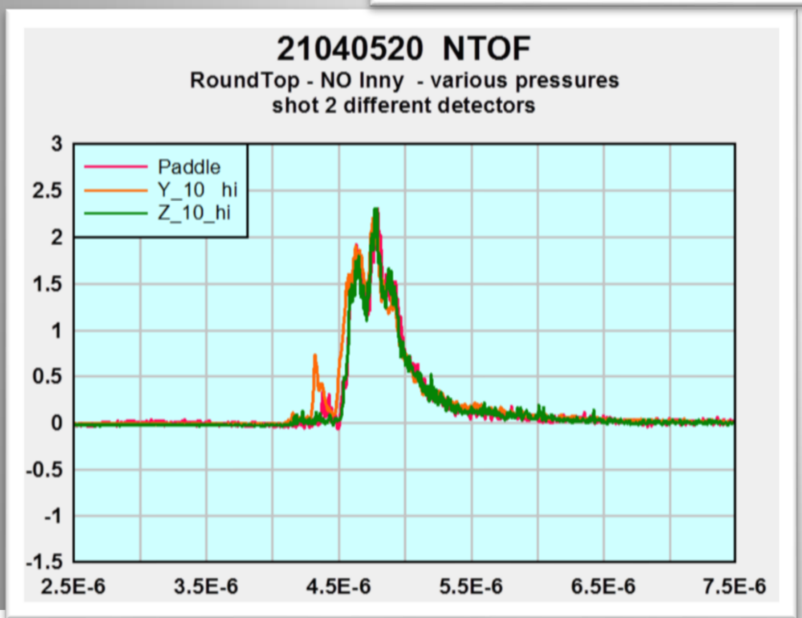


New FlatTop

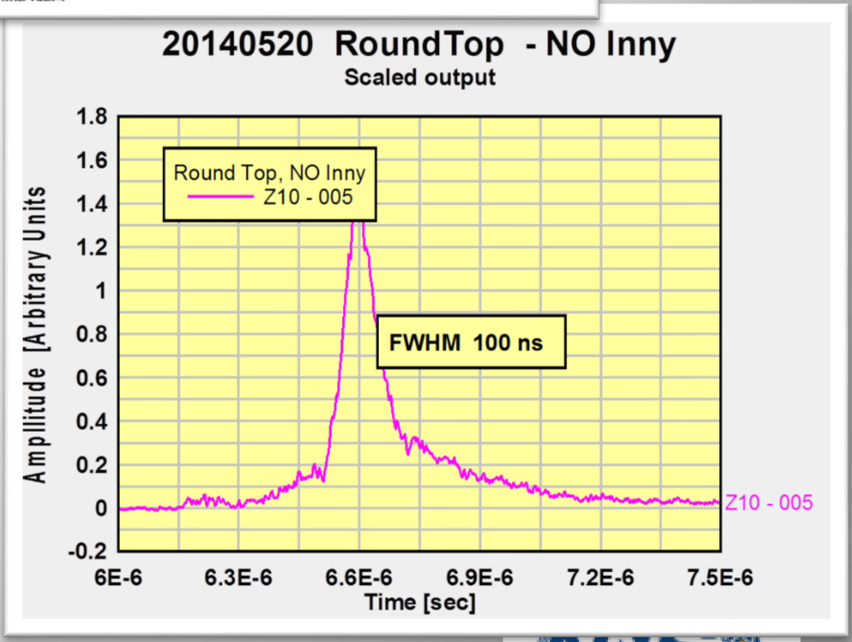




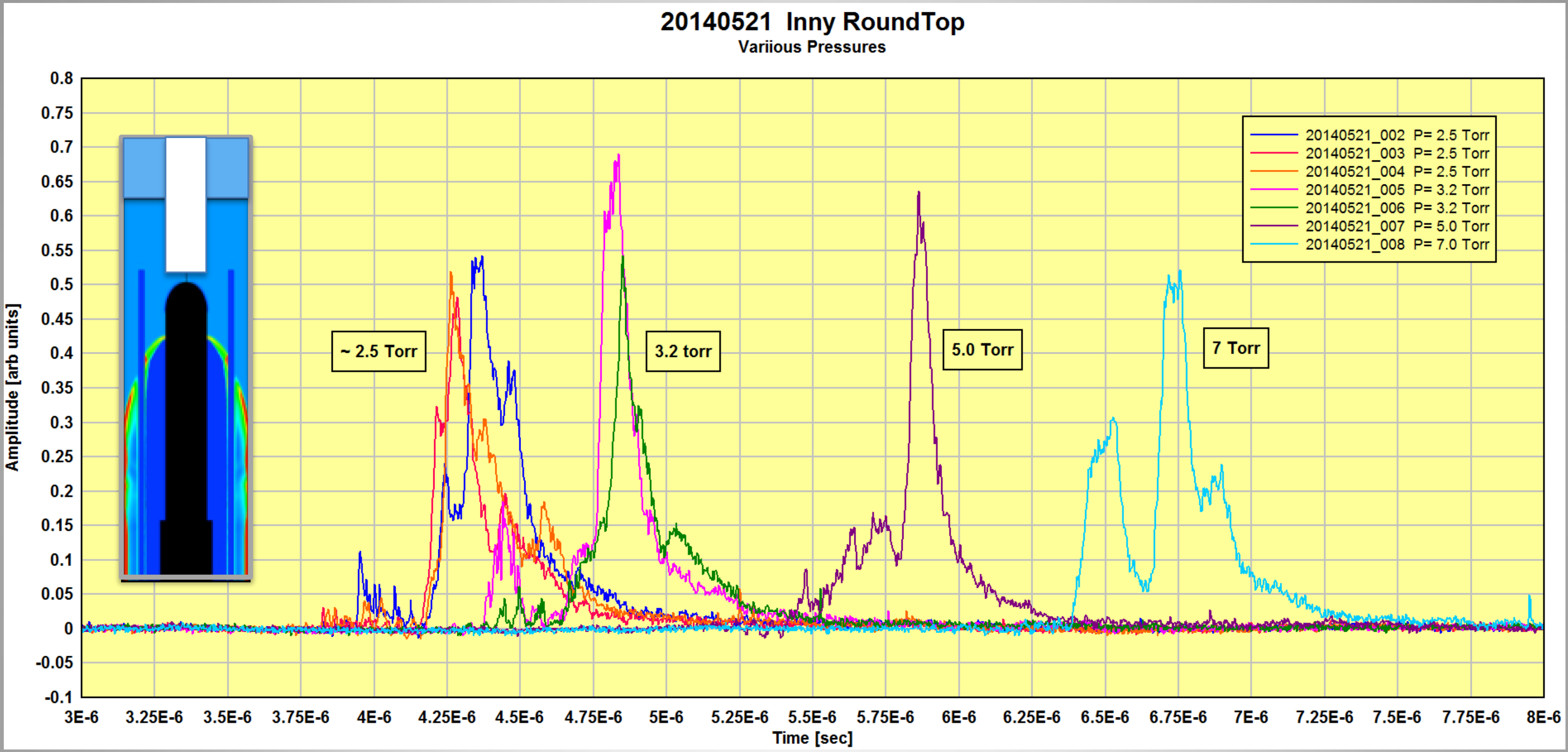
20140520 RoundTop - NO Inny
Scaled output
2.9 - 2.5 Torr
7 torr
Round Top, NO Inny
Z10 - 002
Z10 - 003
Z10 - 004
Z10 - 005
2.5
2
1.5
1
0.5
0
-0.5
-1
3.5E-6
4E-6
4.5E-6
5E-6
5.5E-6
6E-6
6.5E-6
7E-6
7.5E-6
8E-6



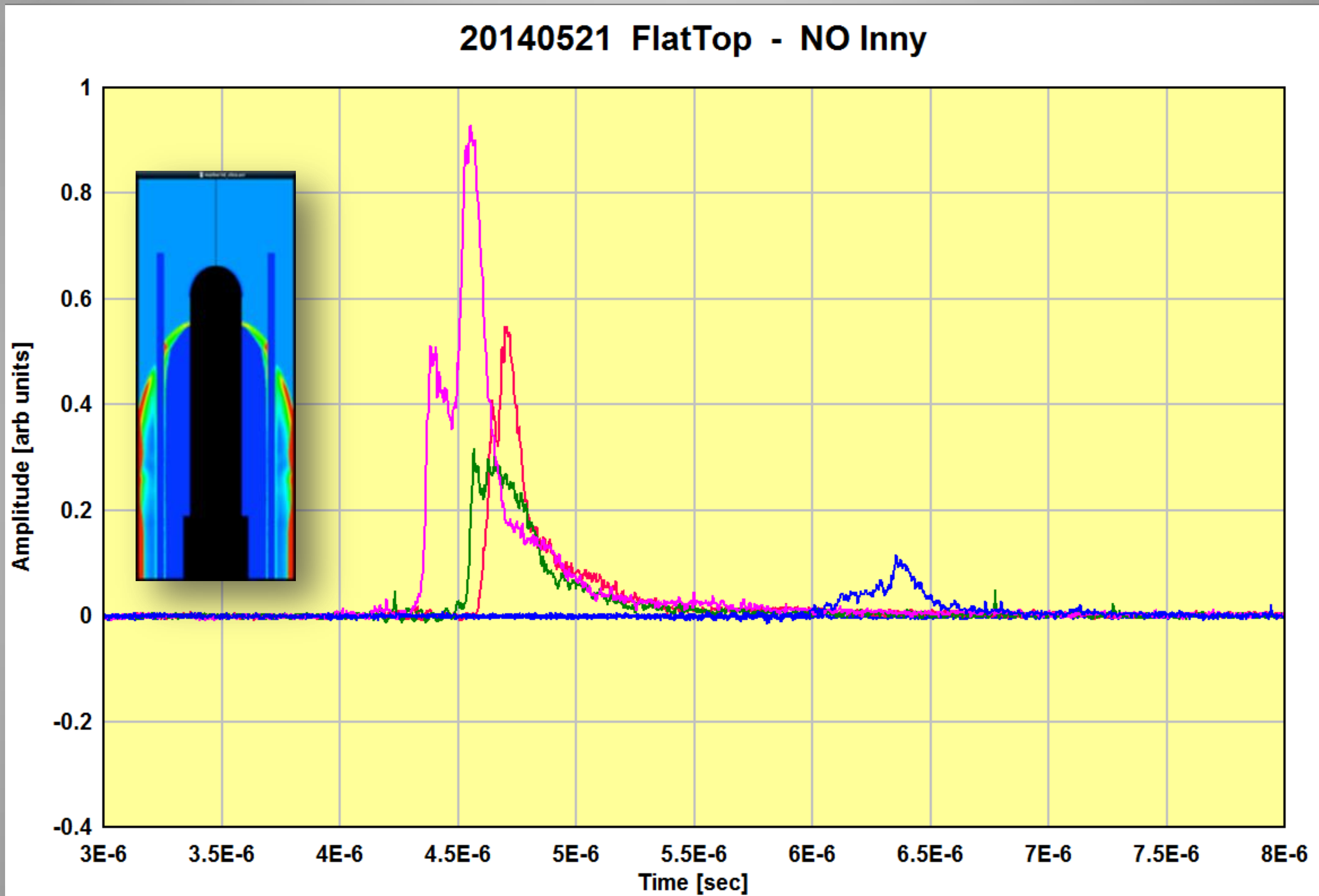
21040520 NTOF
RoundTop - NO Inny - various pressures
shot 2 different detectors
Paddle
Y_10 hi
Z_10_hi
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
2.5E-6
3.5E-6
4.5E-6
5.5E-6
6.5E-6
7.5E-6



20140520 RoundTop - NO Inny
Scaled output
Round Top, NO Inny
Z10 - 005
FWHM 100 ns
Amplitude [Arbitrary Units]
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
Z10 - 005
6E-6
6.3E-6
6.6E-6
6.9E-6
7.2E-6
7.5E-6
Time [sec]

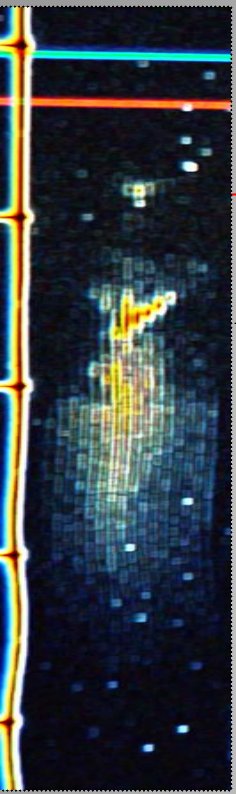


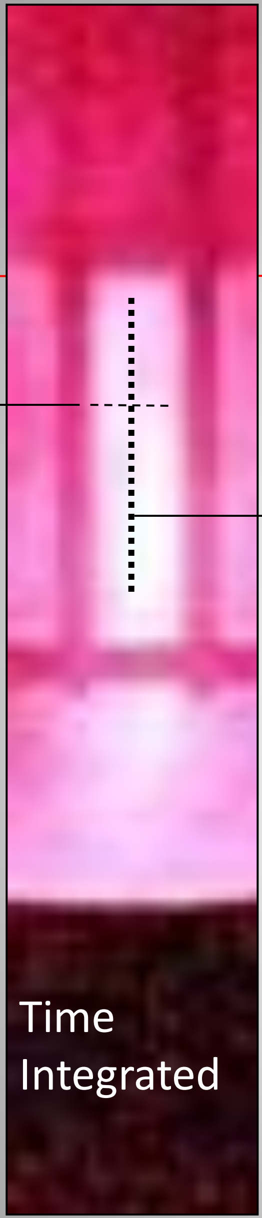
20140521 Inny RoundTop
Variious Pressures
Amplitude [arb units]
Time [sec]
~ 2.5 Torr
3.2 torr
5.0 Torr
7 Torr
20140521_002 P= 2.5 Torr
20140521_003 P= 2.5 Torr
20140521_004 P= 2.5 Torr
20140521_005 P= 3.2 Torr
20140521_006 P= 3.2 Torr
20140521_007 P= 5.0 Torr
20140521_008 P= 7.0 Torr

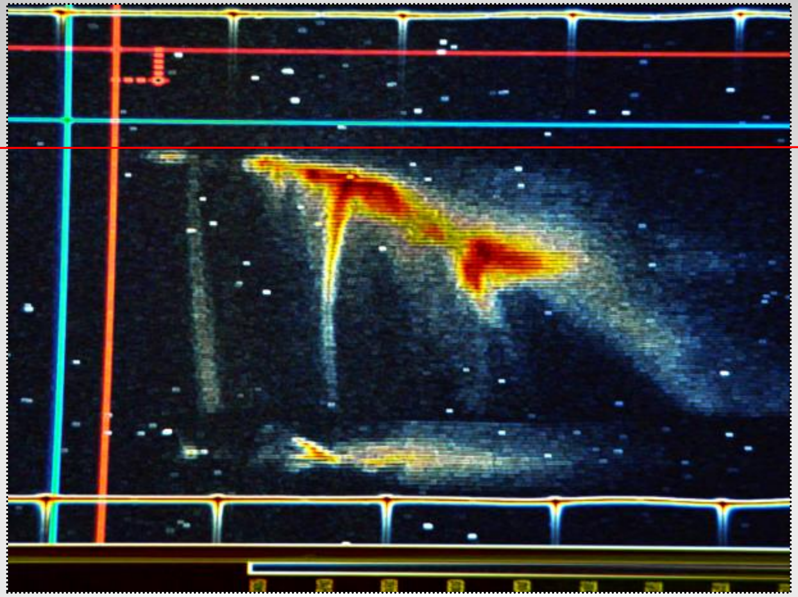


E. Chris Hagen, NSTec

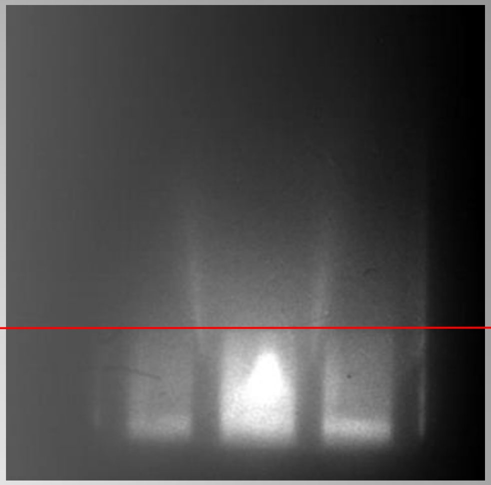
Soft X-rays







Time



10 ns Frame

DPF Imaging

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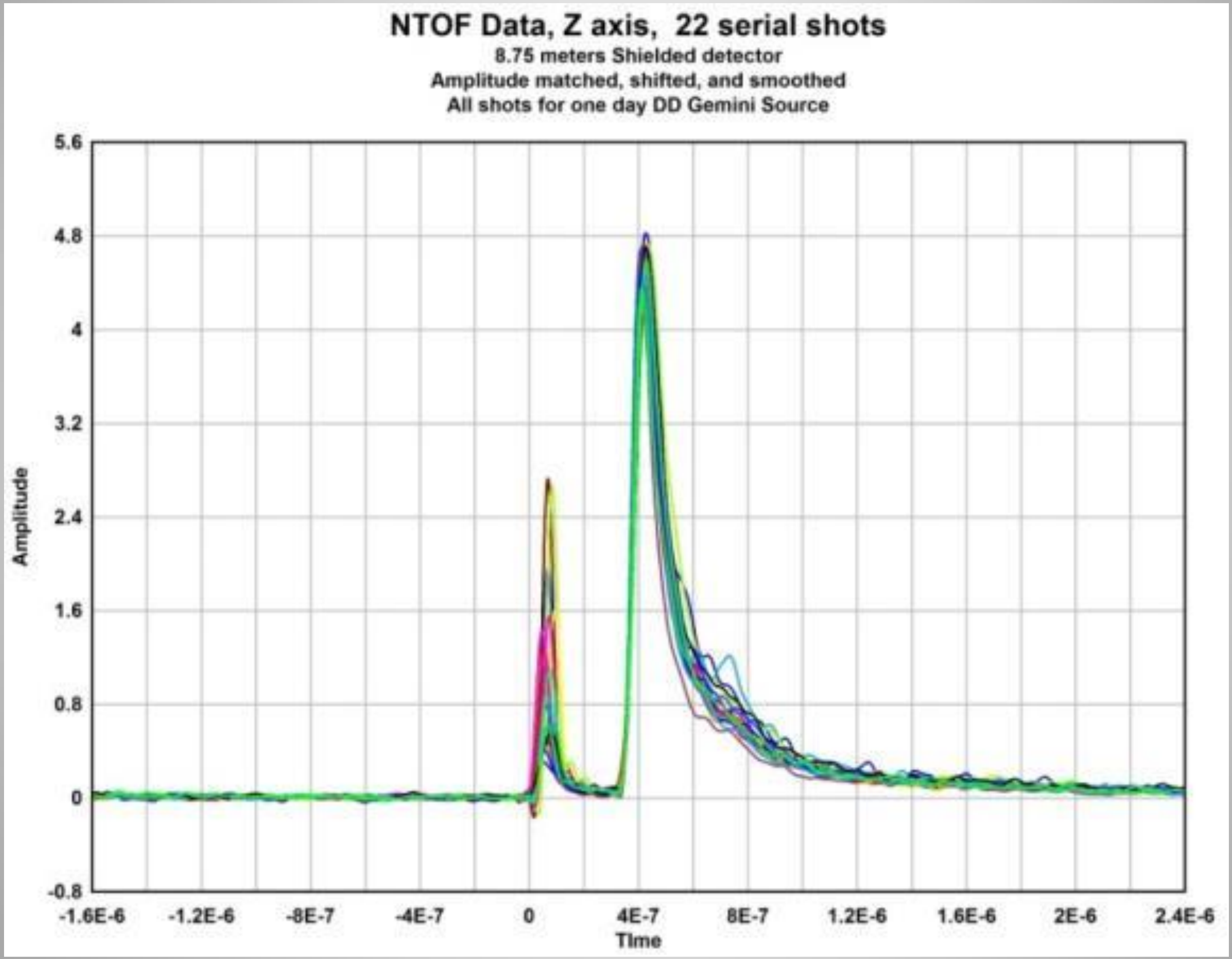
Repeatability



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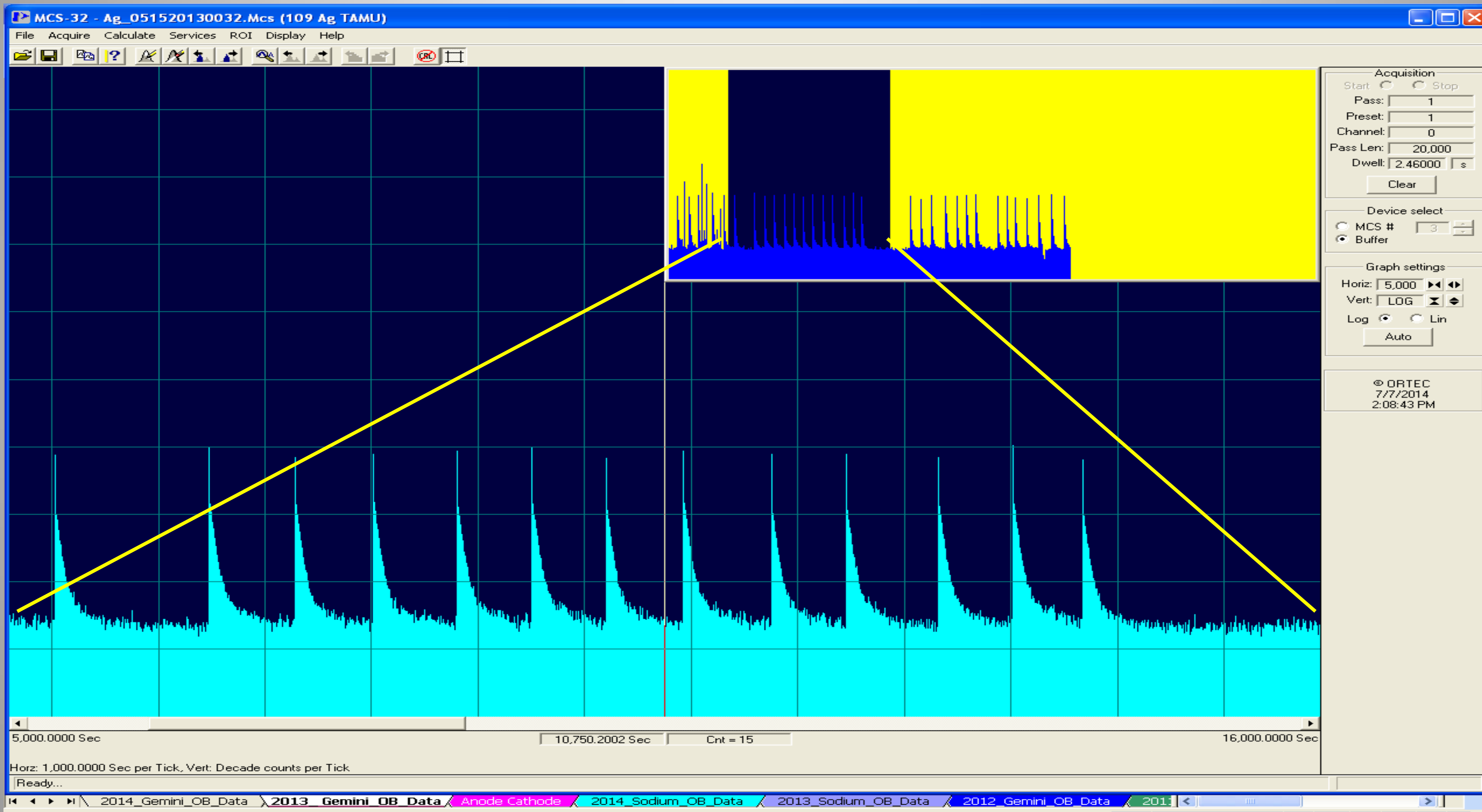
Measurements of DPF

- Total current vs time (faraday or rogowski)
- Voltage vs time (1000x voltage probe, 100 mhz)
- Neutrons/Sec (NTOF)
- Optical Data of pinch formation and evolution
- Total neutron yield (2.45 and 14 MeV)
- Neutron energy versus angle (NTOF)
- Gamma output (SNL)
- RF output (SNL RSL)
- Yield Ratio   DT/DD
- Integrated optical spectra

^{109}Ag activation data (DD)

All Day, 32 Shots



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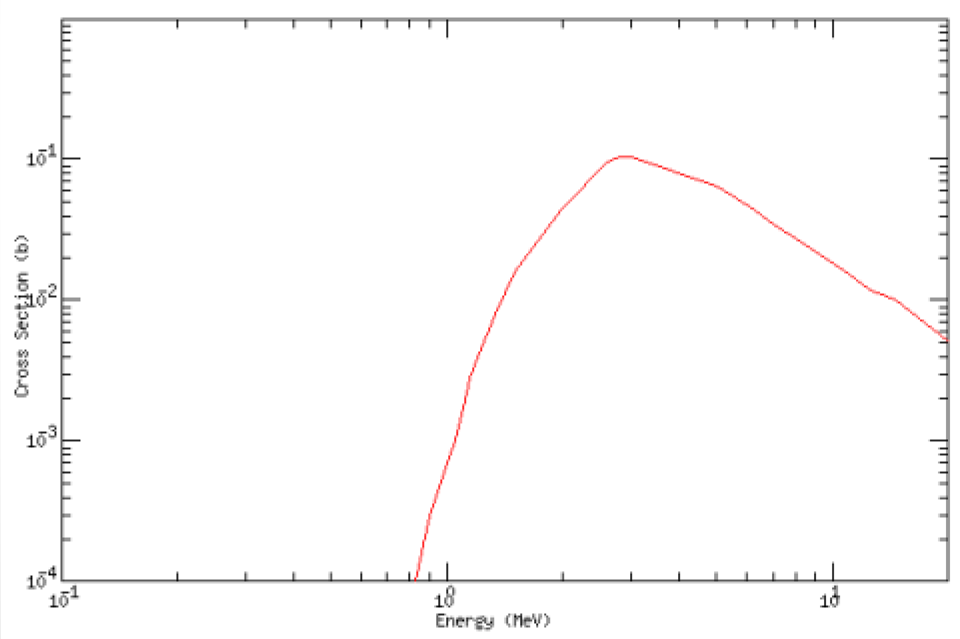
Be Activation Detectors

- Be rods in plastic scintillators
- Be rods in liquid scintillator*
- Be foil sandwich



Pr Activation Detectors

Praseodymium activation detector for measuring bursts of 14MeV neutrons

B. T. Meehan ; E. C. Hagen ; C. L. Ruiz ; G. W. Cooper

[+] Author Affiliations

Proc. SPIE 7449, Hard X-Ray, Gamma-Ray, and Neutron Detector Physics XI, 744912 (September 11, 2009); doi:10.1117/12.830039

Text Size: A A A

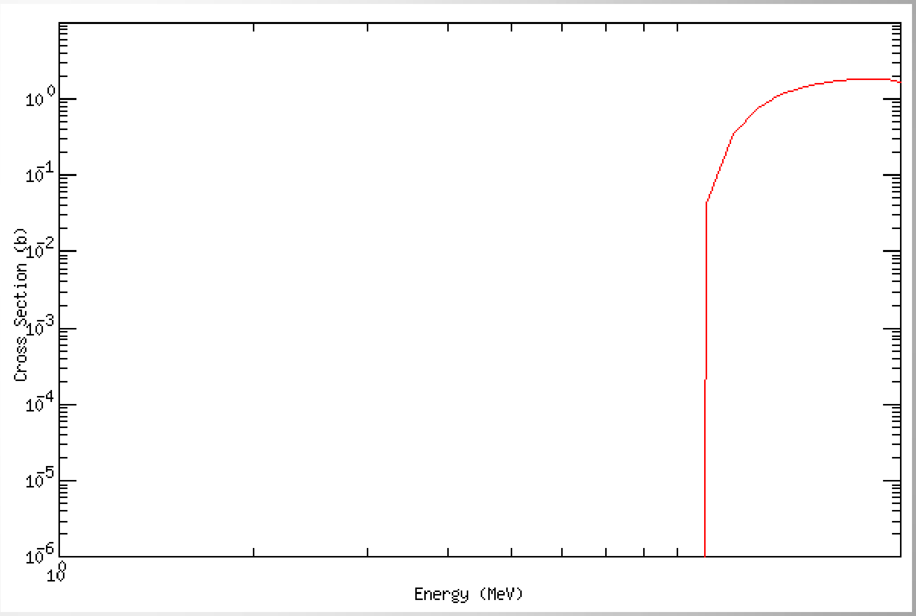
From Conference Volume 7449

Hard X-Ray, Gamma-Ray, and Neutron Detector Physics XI
Ralph B. James; Larry A. Franks; Arnold Burger
San Diego, CA | August 02, 2009

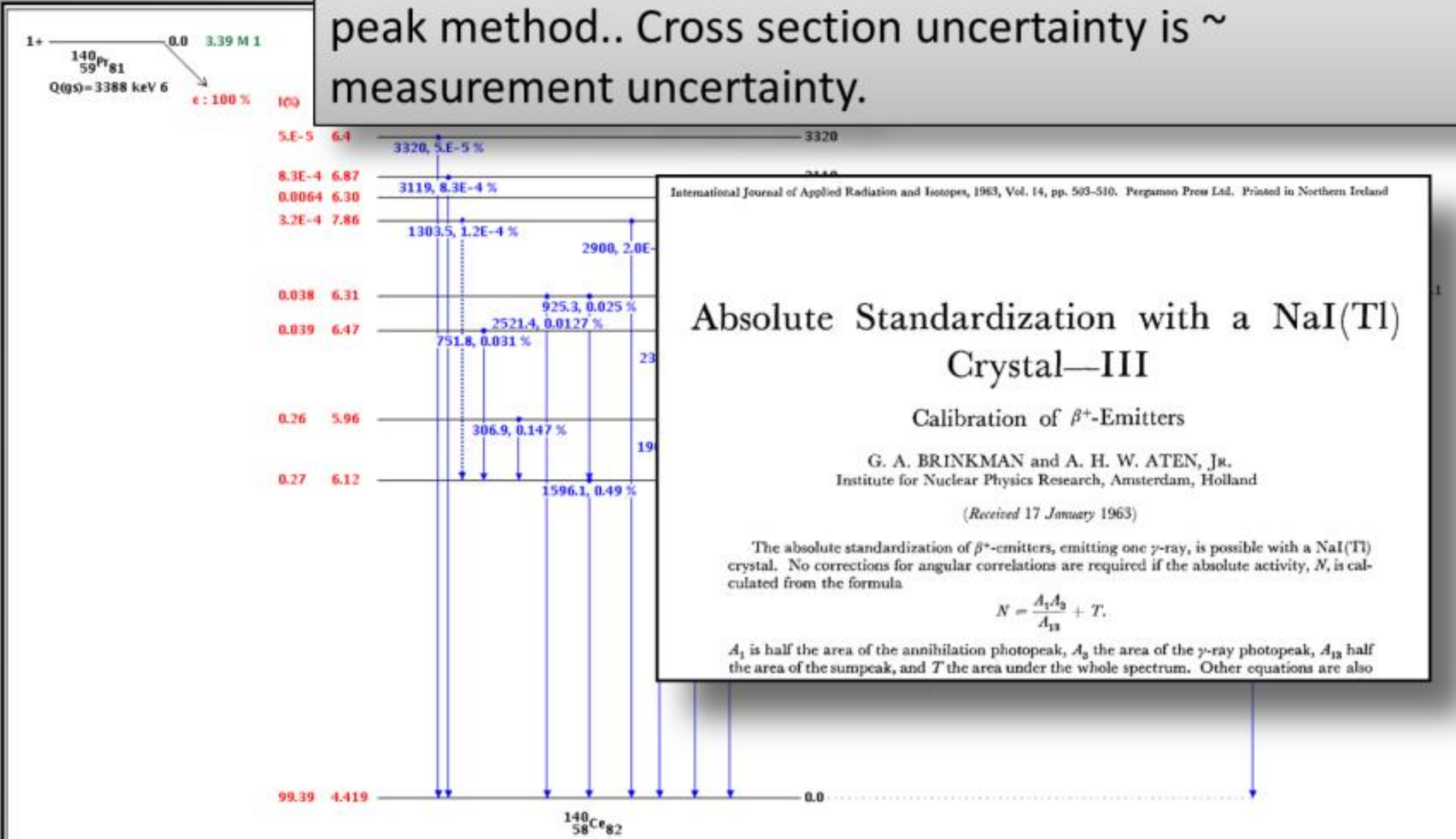
Abstract References

abstract

A new, accurate, neutron activation detection scheme for measuring pulsed neutrons has been designed and tested. The detection system is accurate and sensitive to neutrons with energies above 10 MeV; importantly, it is insensitive to gamma radiation and to lower-energy (e.g., fission and thermal) neutrons. It is based upon the use of praesodymium, an element that has a single, naturally occurring isotope (Pr-141), a significant (n,2n) cross section, and decays by positron emission. Neutron fluences are measured by using the sum-peak method to count gamma-ray coincidences from the annihilation of the positron decay product. The system was tested using 14 and 2.45 MeV neutron bursts produced by NSTec Dense



Annihilation Radiation counted. Yields from use of sum peak method.. Cross section uncertainty is ~ measurement uncertainty.



International Journal of Applied Radiation and Isotopes, 1963, Vol. 14, pp. 503–510. Pergamon Press Ltd. Printed in Northern Ireland

Absolute Standardization with a NaI(Tl) Crystal—III

Calibration of β^+-Emitters

G. A. BRINKMAN and A. H. W. ATEN, JR.
Institute for Nuclear Physics Research, Amsterdam, Holland

(*Received* 17 *January* 1963)

The absolute standardization of β^+-emitters, emitting one γ-ray, is possible with a NaI(Tl) crystal. No corrections for angular correlations are required if the absolute activity, N, is calculated from the formula

$$N = \frac{A_1 A_3}{A_{13}} + T.$$

A_1 is half the area of the annihilation photopeak, A_3 the area of the γ-ray photopeak, A_{13} half the area of the sumpeak, and T the area under the whole spectrum. Other equations are also

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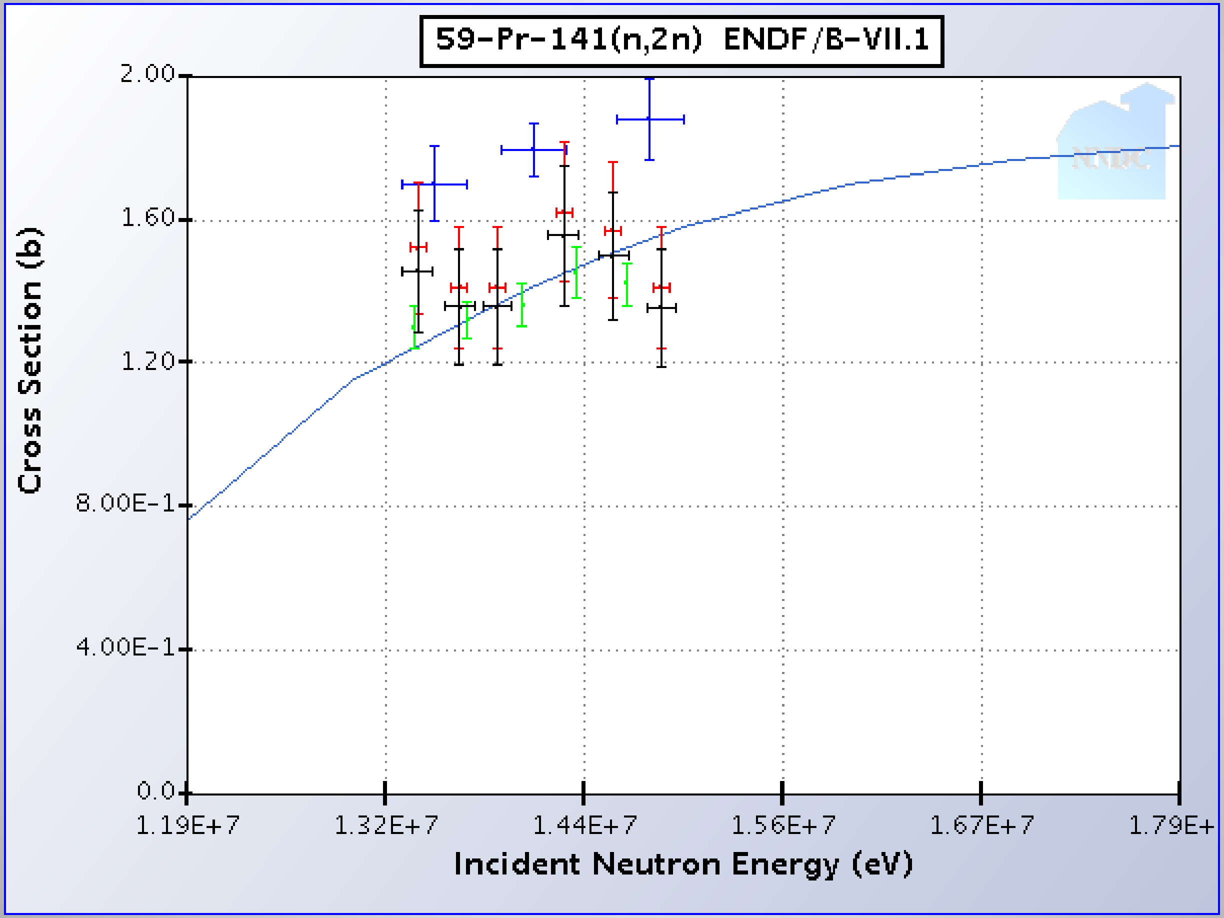
Pr Activation Detectors



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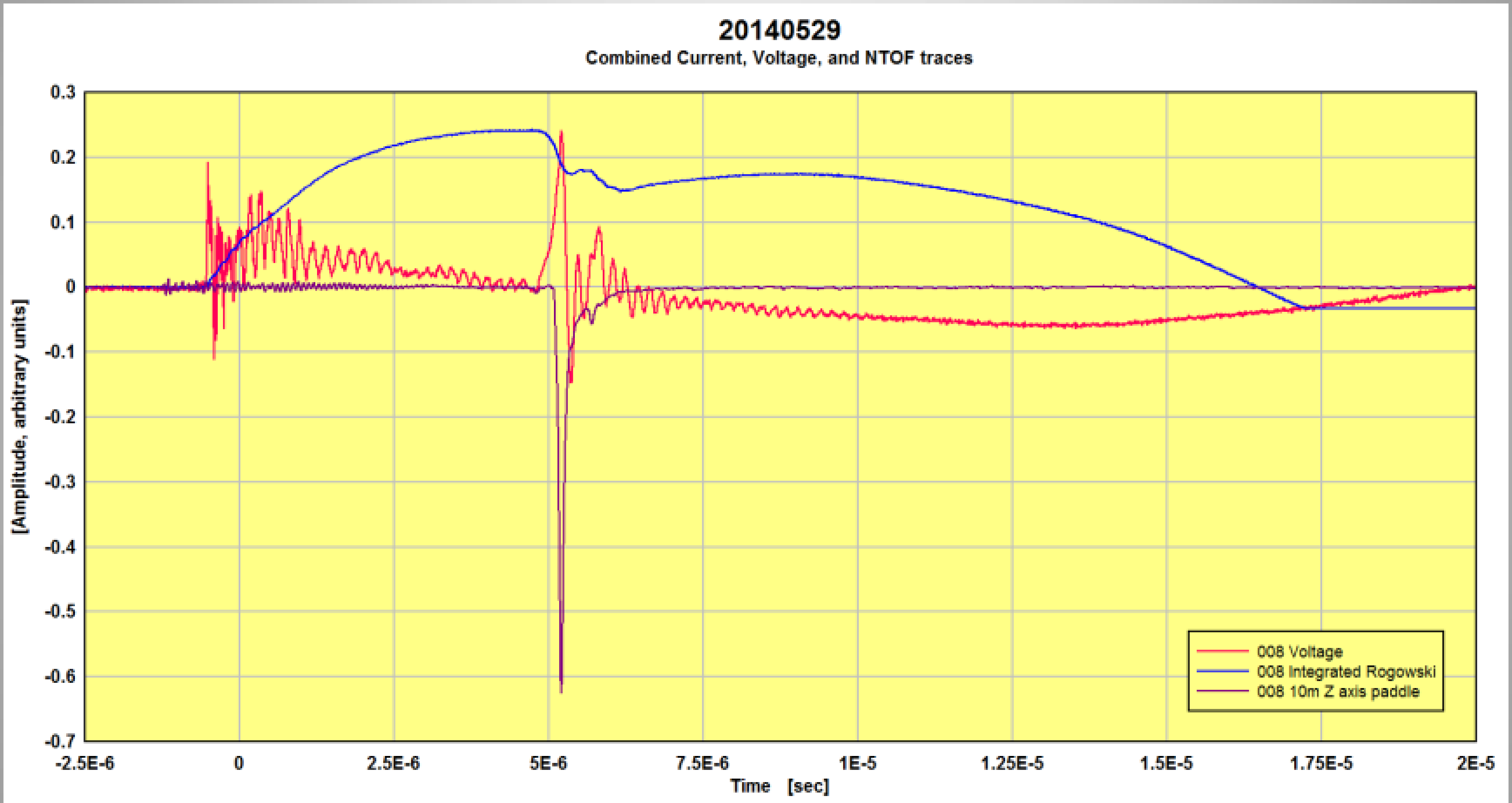
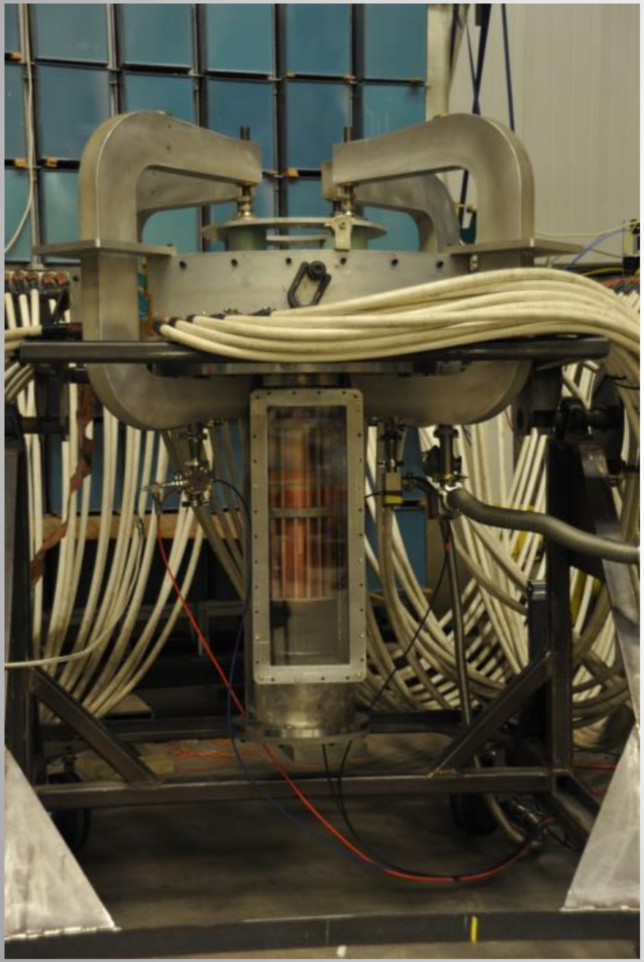
DPF Machine Diagnostics



Framing Camera



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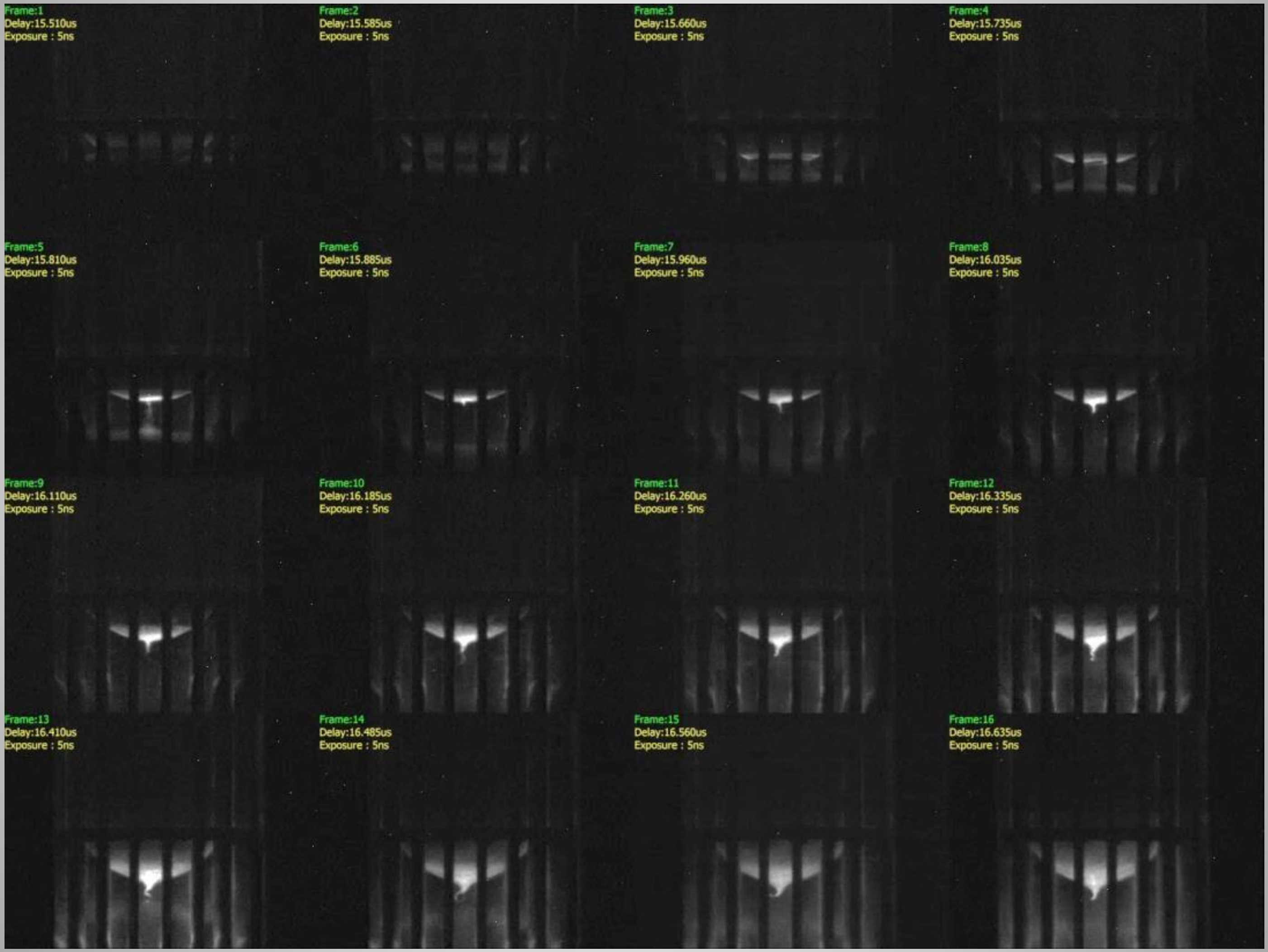
Framing Camera



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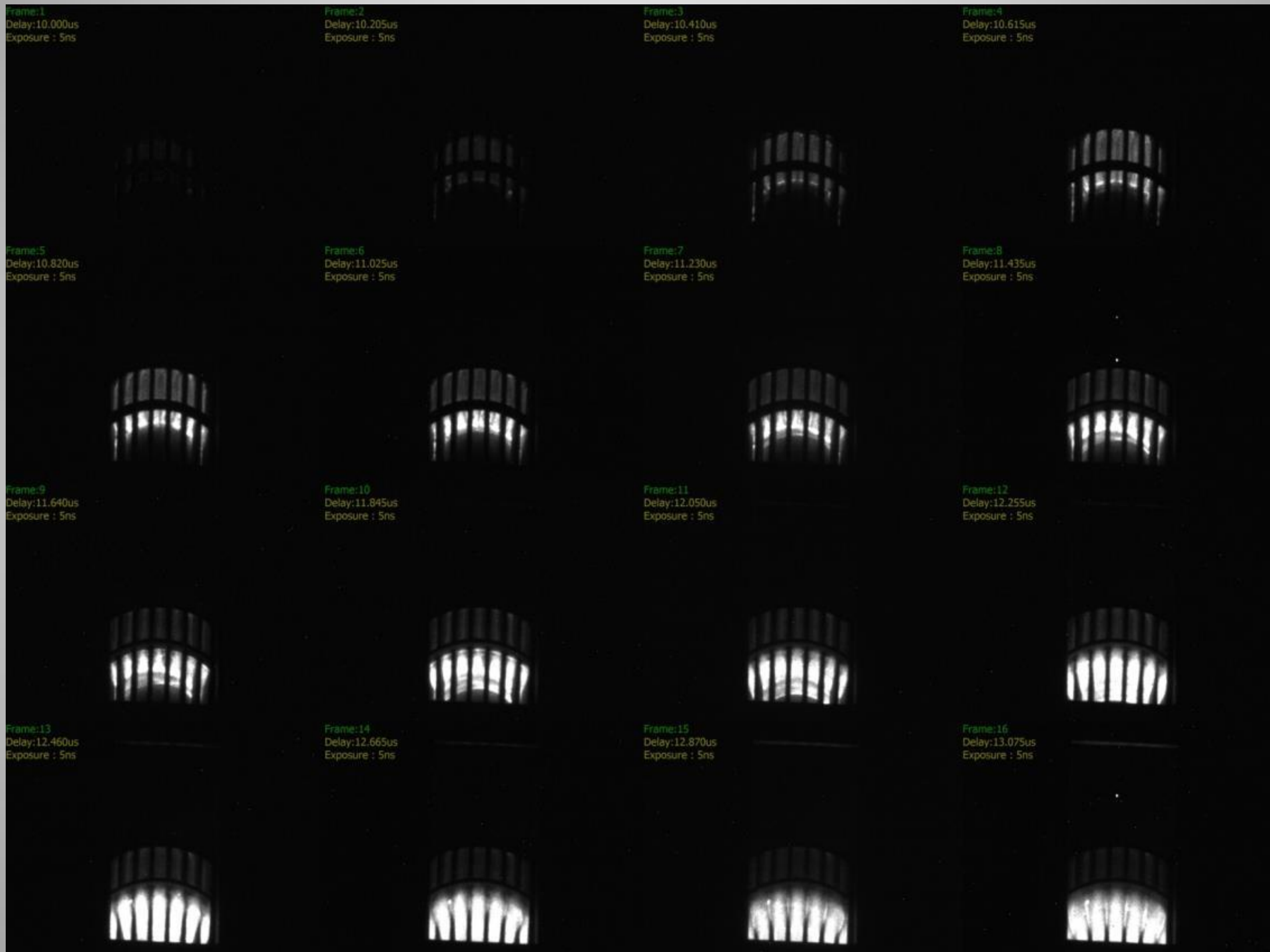
Framing Camera



NTOF Detectors

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- What is a DPF?
- What programs the DPF support
- What we have done in the past
- DPF diagnostic tools
- **Where we are going**
- Potential areas of collaboration

Current and Future Work

- Supporting applied physics experiments is the core mission
  - NDSE drives most of the DPF work for the next 5 years
    - Pulse width (short as possible)
    - Number of pulses (strive for single)
    - Yield (high as possible with single pulse)

- Remaining (R&D to improve the capability and capacity we will use to do future applied physics)
  - Gas Puff Nozzles
  - Plasma Diagnostics
  - Modelling efforts
    - ALLEGRA, GORGON, LSP, MACH, SCAT
  - Forensics
  - Neutron Radiography

- What is a DPF?
- What programs the DPF support
- What we have done in the past
- DPF diagnostic tools
- Where we are going
- **Potential areas of collaboration**

Collaboration

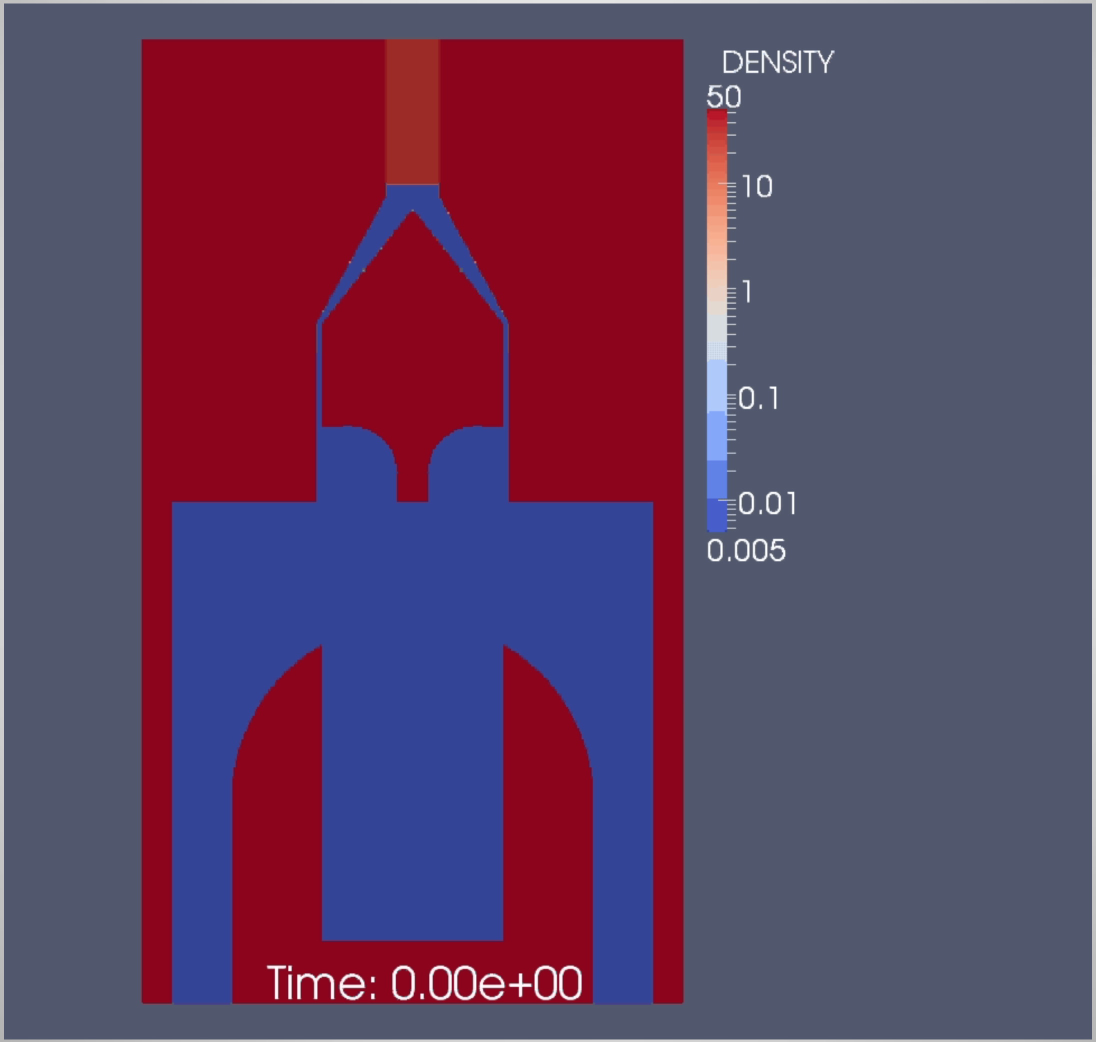
- **Student related research on DPF related topics**

  - **Gas puff**
    - **Design**
    - **Verification**
    - **Modeling**
  - **Plasma diagnostics**
    - **Electron**
    - **Ion**
    - **Optical**
    - **IR/UV**

- **Machine Diagnostics**
  - **dV/dt**
  - **dI/dt**
  - **EMI/EMP**

- **Detectors**
  - **Activation**
  - **Prompt**
  - **Gamma blind, fast**

Gas Puff Nozzles



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Questions/Comments?