

NIC
National Ignition Campaign

**NTOF diagnostics and first DT, DD results from
NTOF20 detectors NIF**

Jac Caggiano
NIF Nuclear Diagnostics group
Computational Nuclear Physics group
LLNL

Lawrence Livermore National Laboratory


This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344



Collaborators

- LLNL
 - Scientists
 - Robert Hatarik
 - Mike Moran
 - Jim McNaney
 - Stephan Friedrich
 - Lee Bernstein
 - Wolfgang Stoeffl
 - Dieter Schneider
 - Ed Hartouni
 - D. Bleuel
 - Engineers
 - Todd Clancy
 - Rich Zacharias
 - Barb Quivey
 - Essex Bond
 - Jeff Haslam
 - “Others”
 - Dave Munro
 - Steve Hatchett
 - Siegfried Glenzer
 - Brian Spears
 - Many more...
- LLE / U. Rochester
 - James Knauer
 - Vladimir Glebov
 - Craig Sangster
 - Christian Stoeckl
 - Milt Shoup
 - Tom Busek
- LANL
 - Gary Grim
 - Doug Wilson
 - John Kline
- Sandia
 - Ray Leeper
 - Carlos Ruiz
- UNM
 - Gary Cooper
- Ohio U.
 - Carl Brune
- Colorado School of Mines
 - Uwe Greife
- General Atomics
 - Joe Kilkenny
- Consultants
 - Dick Fortner
 - Mark Eckart
 - Paul Weiss
 - Tom Phillips
 - Dick Lerche
- NSTECH
 - Vu Tran
 - Ken Moy


Dec. 9, 2010
Jac Caggiano - NHEP Project Review
National Ignition Campaign



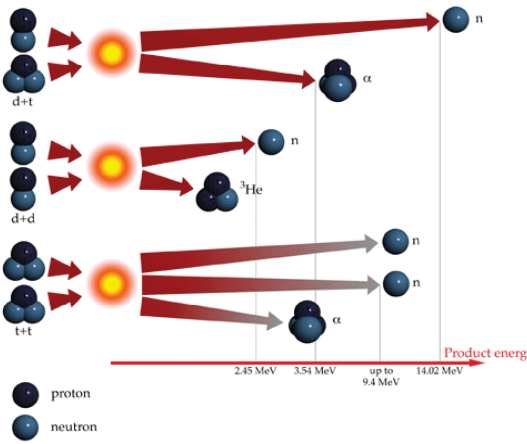
Outline

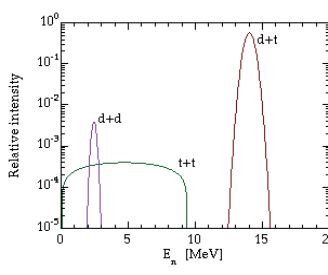
- NTOF intro
 - What, why, how
- First results
 - DD
 - DT
- Conclude

Mar. 14, 2011
Cagliano - London
National Ignition Campaign 3



Fusion Reactions

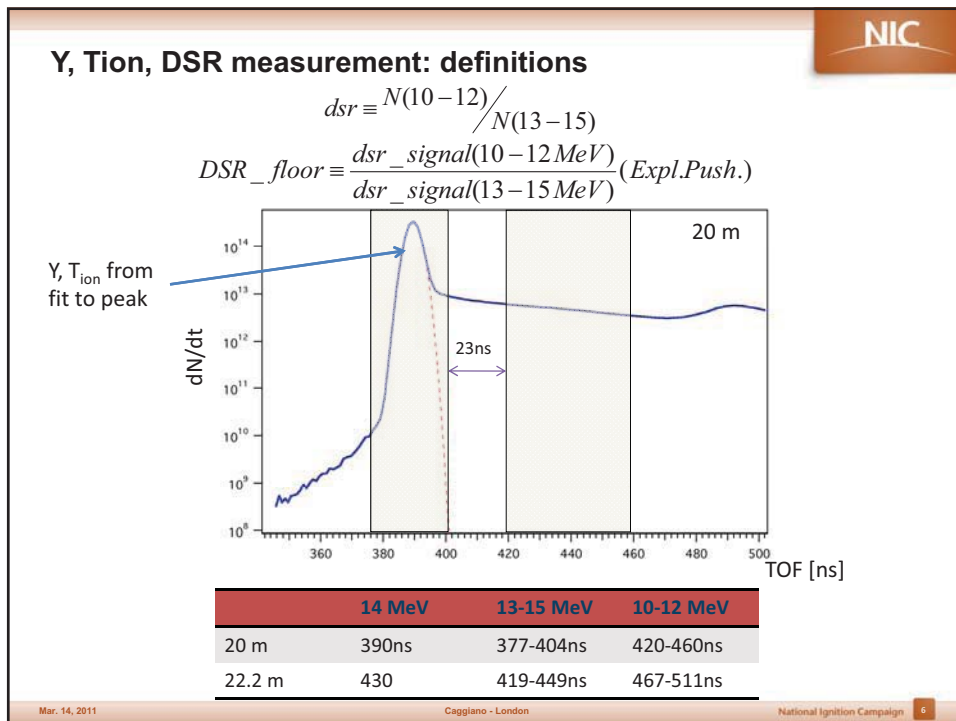
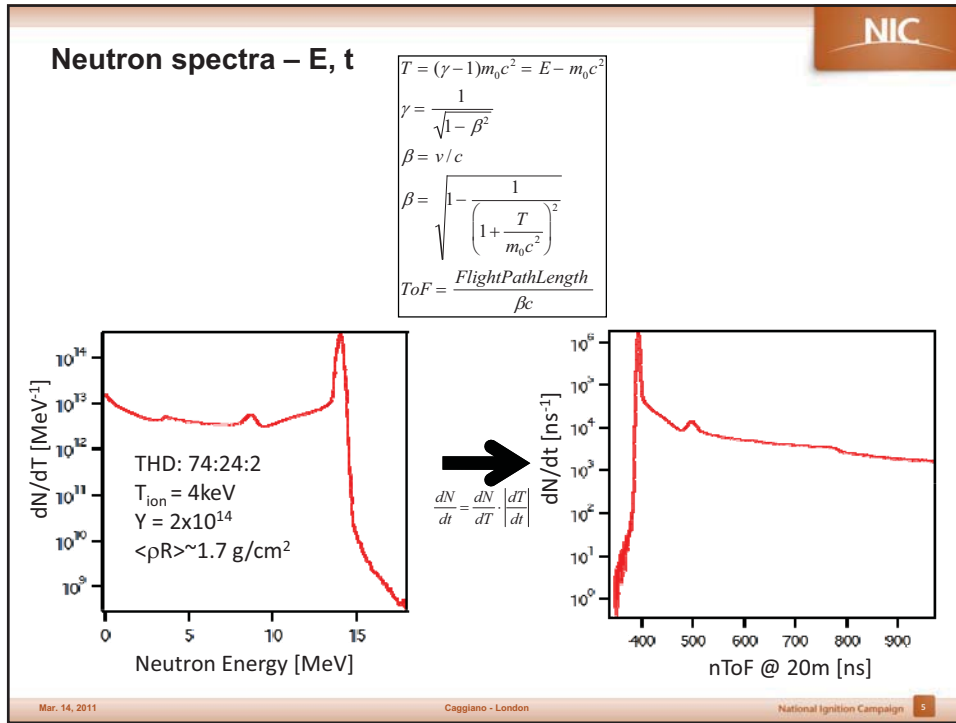




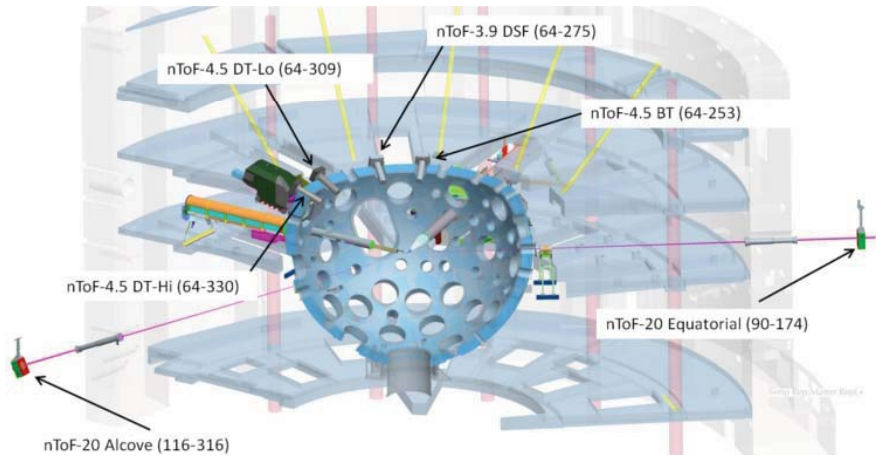
Reactions producing neutrons in fusion plasmas.

W.Stoeffl

Mar. 14, 2011
Cagliano - London
National Ignition Campaign 4



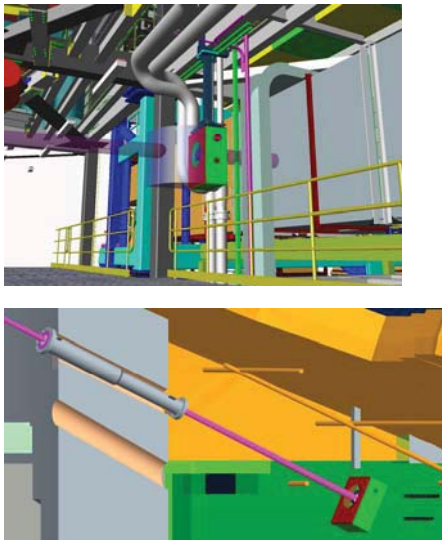
NTOF map @ NIF



A 3D schematic diagram of the National Ignition Facility (NIF) showing the locations of various Neutron Time-of-Flight (NTOF) detectors. The central feature is a blue spherical target chamber with a perforated surface. Six detectors are indicated by colored arrows and labels: nToF-3.9 DSF (64-275) in yellow, nToF-4.5 DT-Lo (64-309) in green, nToF-4.5 BT (64-253) in black, nToF-4.5 DT-Hi (64-330) in red, nToF-20 Equatorial (90-174) in purple, and nToF-20 Alcove (116-316) in blue. The detectors are positioned around the chamber, some pointing towards it and others away. The background shows the complex structure of the NIF building.

Mar. 14, 2011 Cagliano - London National Ignition Campaign 7

NTOF 20 locations



Two close-up photographs showing the physical locations of the NTOF-20 detectors. The top image, labeled "Equator", shows a detector mounted on a complex structure of pipes and metal supports. The bottom image, labeled "Alcove", shows a detector mounted on a wall, with a long, thin tube extending from it.

"Equator"

"Alcove"

Mar. 14, 2011 Cagliano - London National Ignition Campaign 8

Detectors and DAQ system

Liquid xylene+PPO+MSB, O₂ quenched

BC422Q

CVD diamonds:
-24x1mm
-2 10x1mm
-5x0.25mm

Coming up next:

MCP-PMT, 1 and 2-stage, and PD040

HV

Mar. 14, 2011

Caggiano - London

National Ignition Campaign 9

nToF20 "Spec"

- Scintillator:
 - Xylene, PPO, MSB
 - Chosen for low tail >40ns after peak
- Light readout
 - 1,2-stage MCP-based PMT
 - Photodiode ($\gamma > 10^{15}$)
- Data Acquisition
 - Tektronix DPO7104(1GHz)
 - FTD10000 (7GHz)
- Calibrated @ LLE/U.Rochester against other nToF detectors
 - Series tied back to $^{63}\text{Cu}(n,2n)^{62}\text{Cu}$ activation measurement
- Now calibrating in situ at NIF against
 - D. Bleuel's et al Cu, Zr, In NADs

Off the Shelf Metal Bellows

Fused silica windows

Design can accommodate an expansion chamber

Mounting holes on back of PMT mount similar to nToF20-IgnLo

PMT 240 Gain E6

Filter glass

Aluminum 6"/4" diameter x 2"/1" thick stainless steel cavity filled with Xylene

PMT 140 Gain E3

Two nToF20-Spec for NIF
One nToF20-Spec for OMEGA

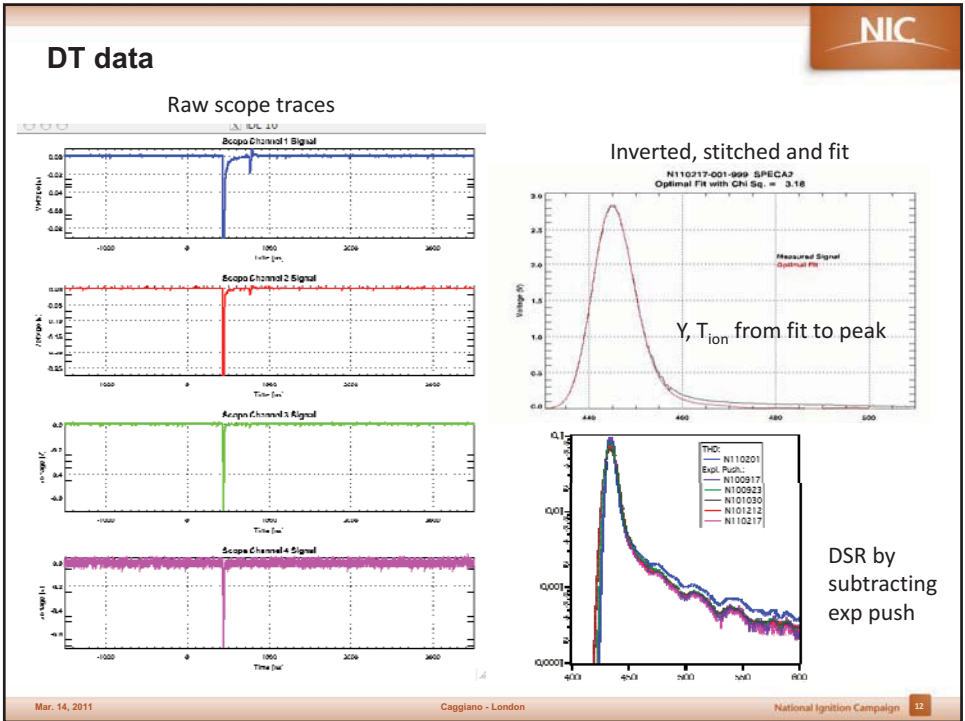
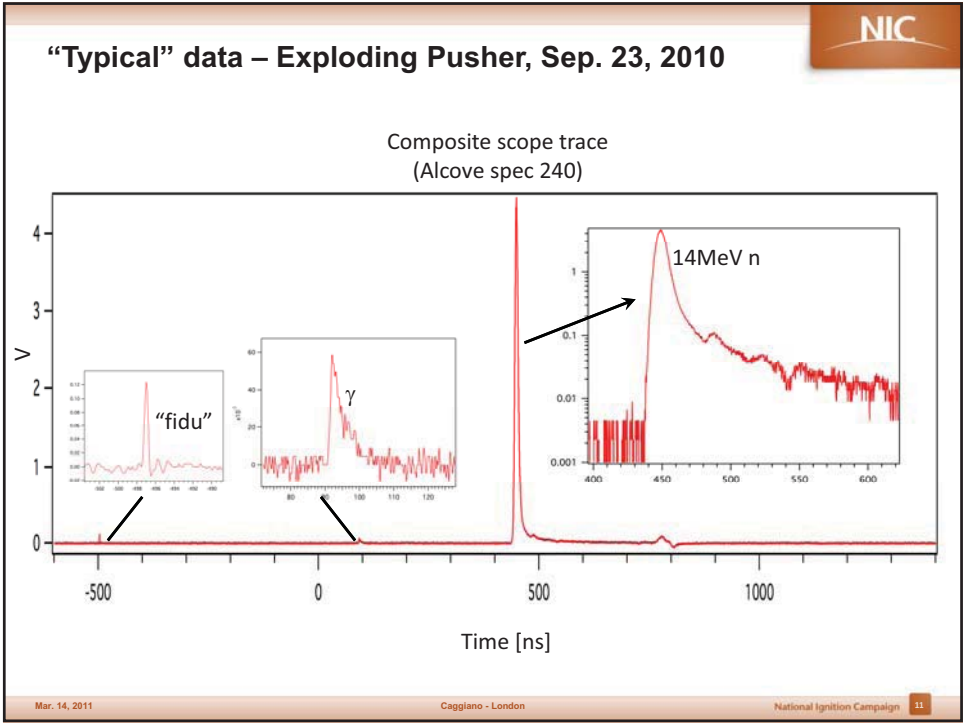
Amplitude [a.u.]

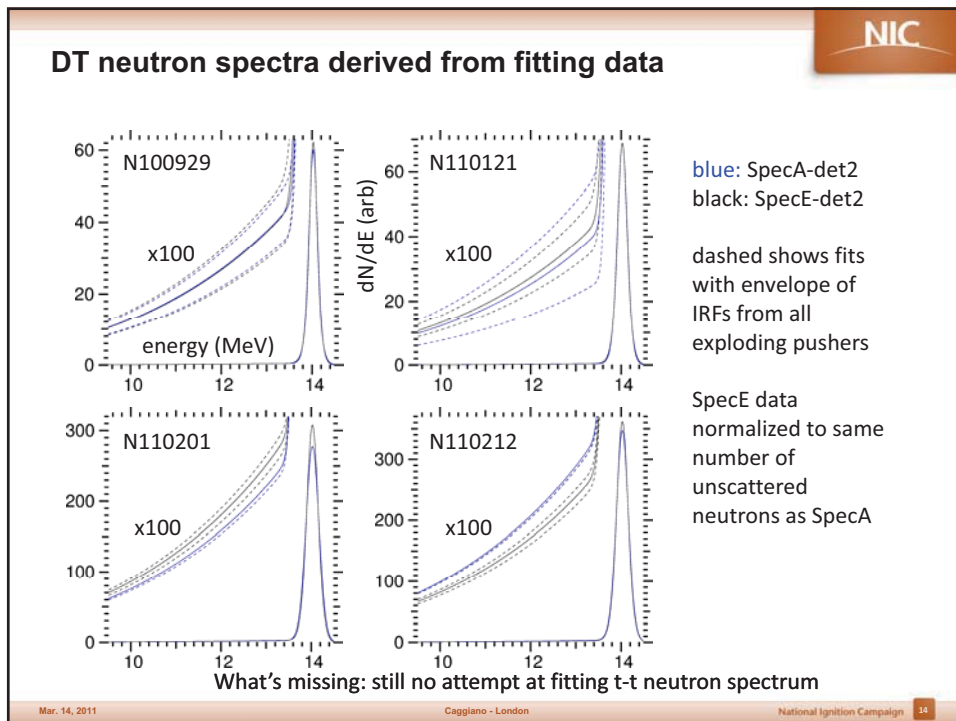
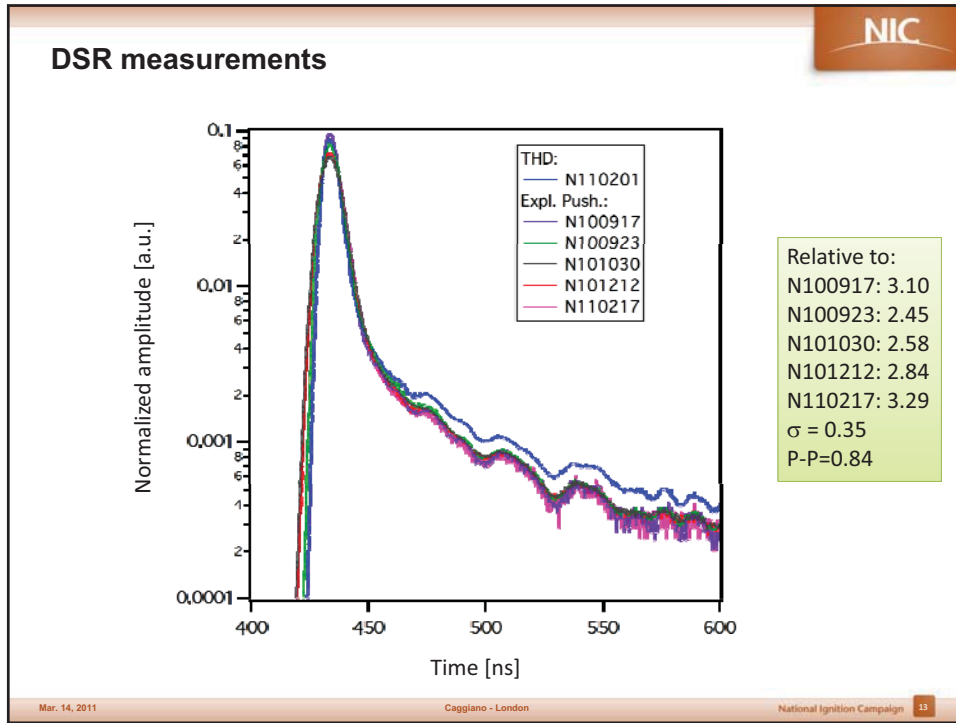
T [ns]

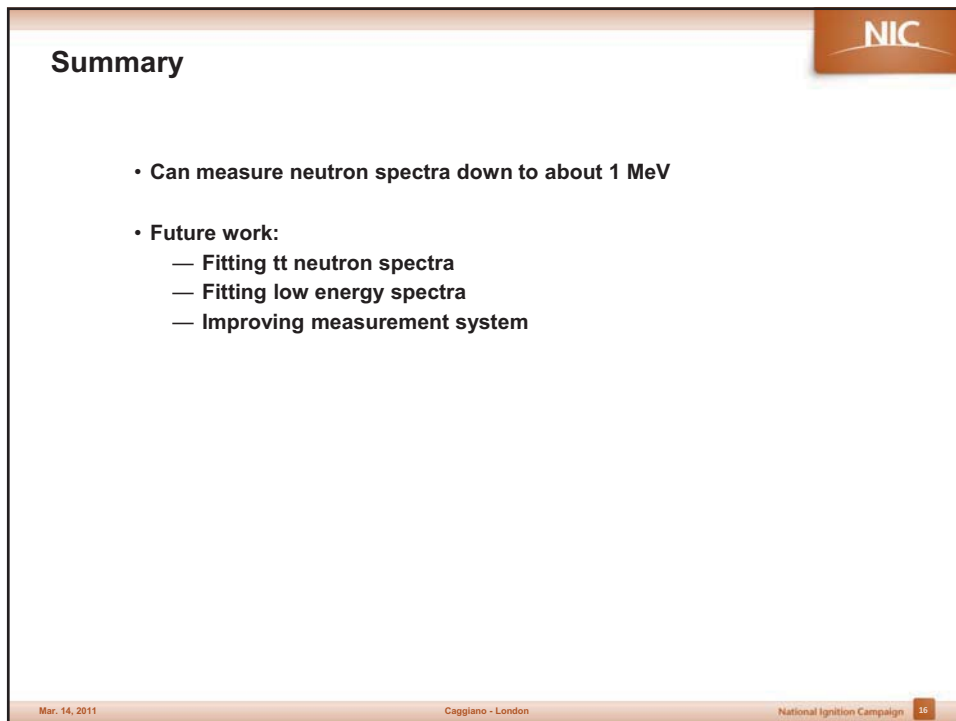
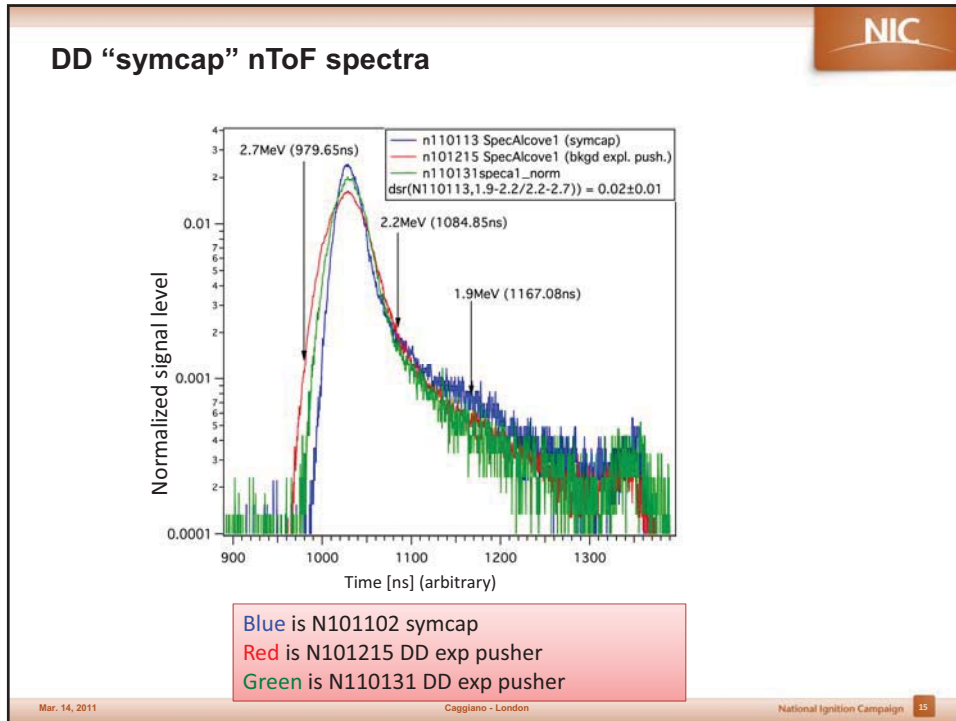
Mar. 14, 2011

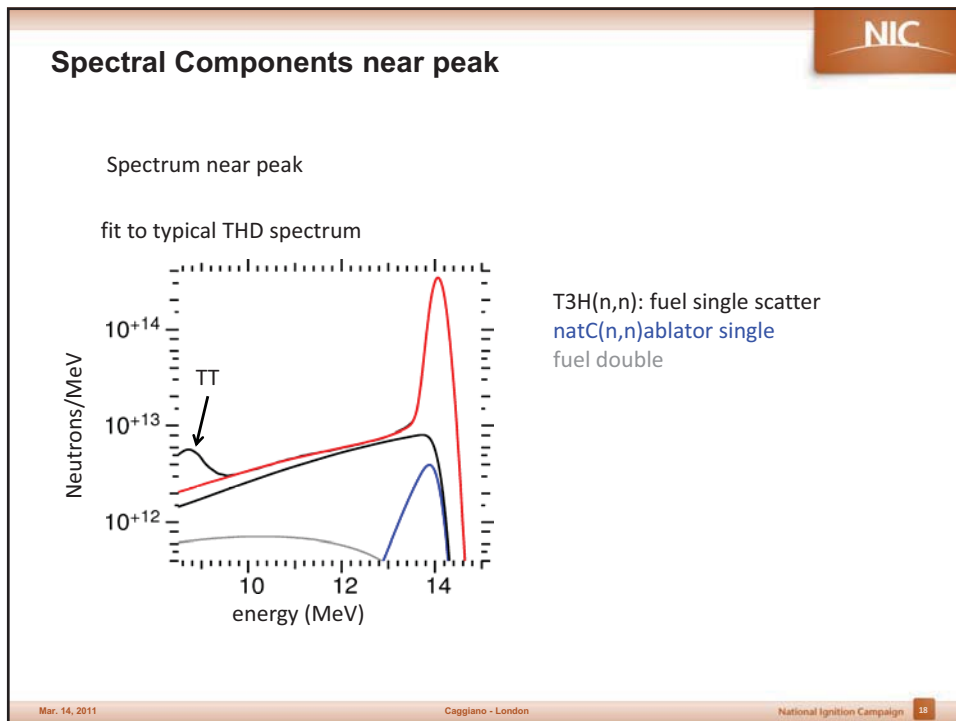
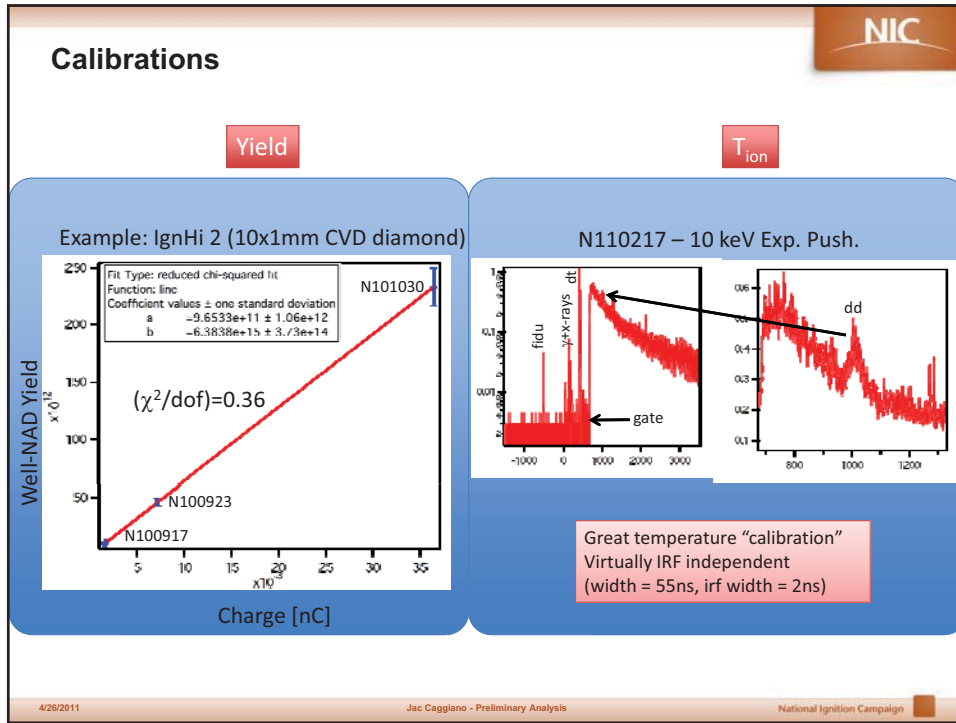
Caggiano - London

National Ignition Campaign 10 10









NIC

What is measured – voltage trace on scope

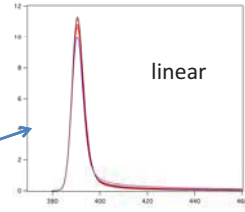
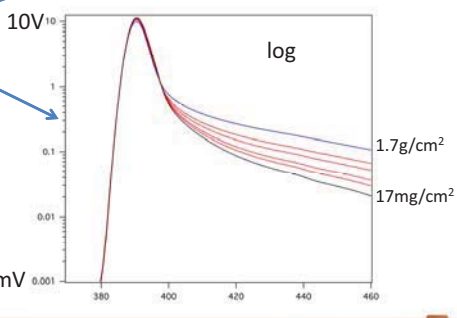
$$\frac{dN_e}{dt} = \frac{dN_n}{dt} \cdot \epsilon_{geom} \cdot P_{int} \cdot \frac{n_{hv}(E)}{n} \cdot \epsilon_{coll}^{scin} \cdot q \epsilon_{pc}(\lambda) \cdot g_{PM}$$

$$V(t) = IR = k_{coul} \cdot \frac{dN_e}{dt} \cdot 50\Omega$$

$V_{meas}(t) = V(t) \otimes IRF(t)$

IRF(t) includes:

- detector
- particle transit times
- cable
- scope
- PMT
- scattering backgrounds
- ...

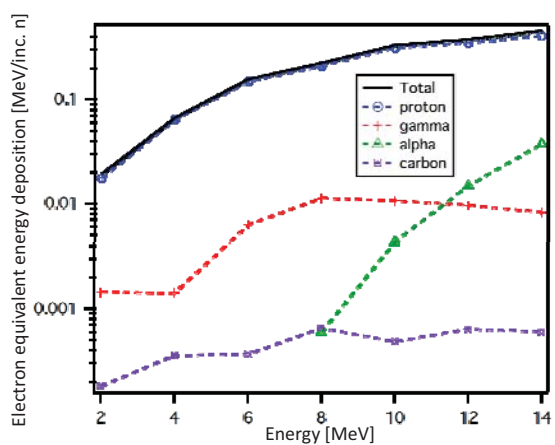



Mar. 14, 2011
Cagliano - London
National Ignition Campaign 19

NIC

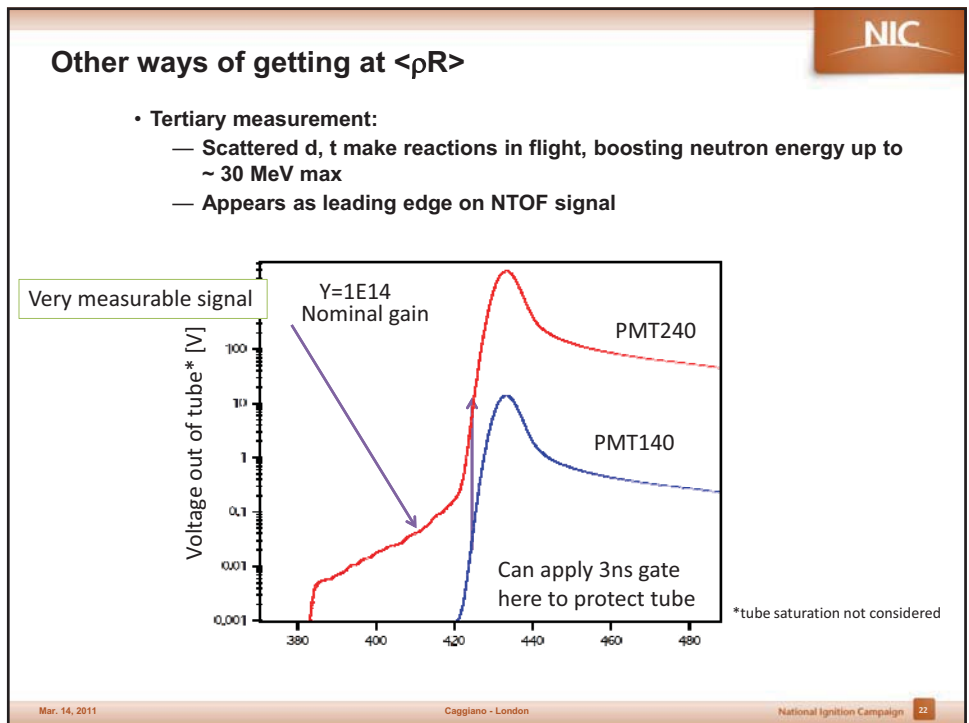
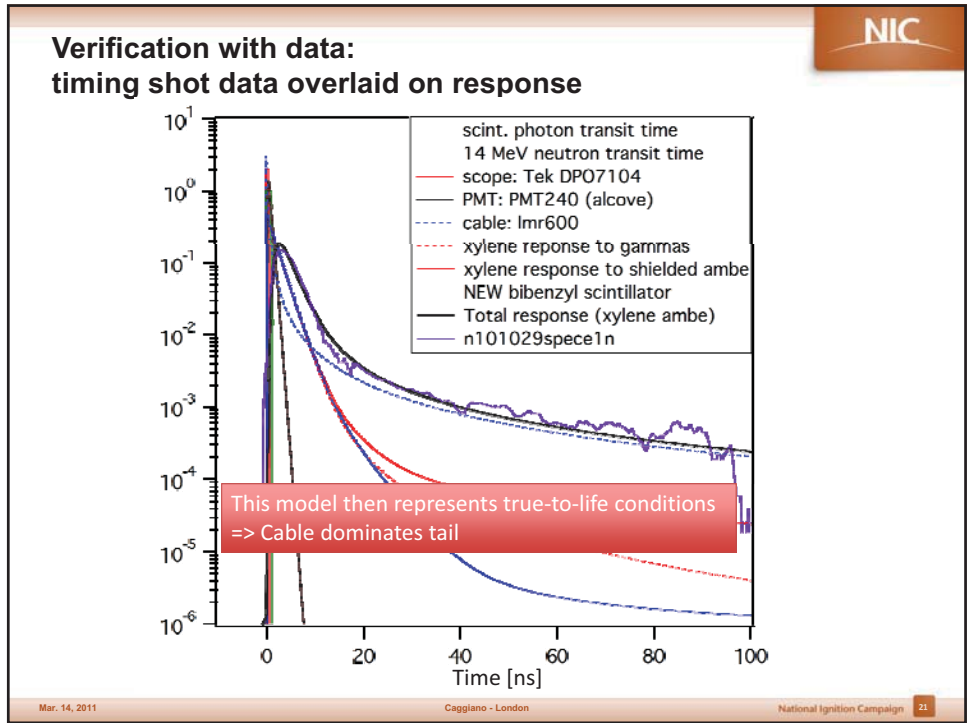
Spectrum modified by energy-dependent neutron sensitivity

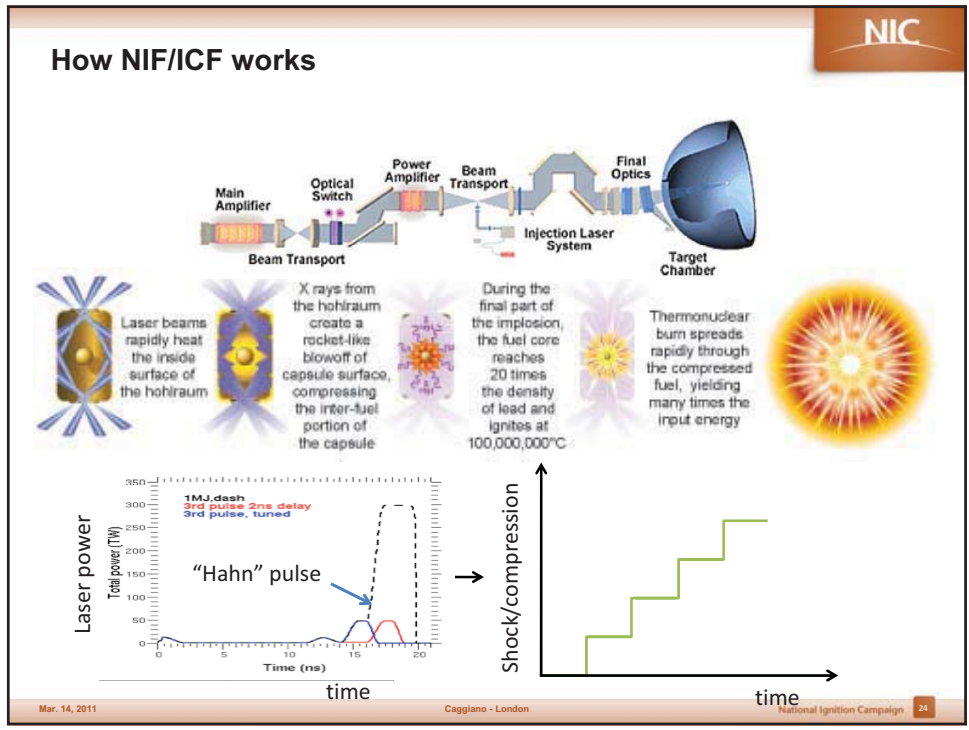
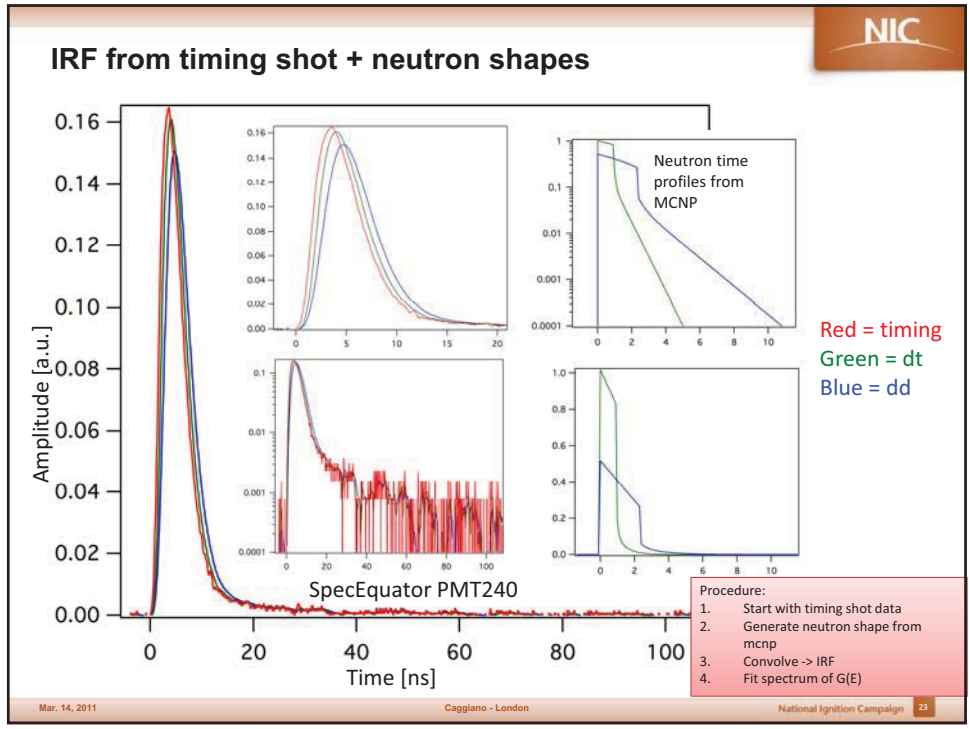
- C.Hagmann calculations, I supplied input geometry
 - Spec and ignlo detectors
 - Relative light output vs energy of incident neutron
- 86mm diameter beam (in reality, ~83mm)

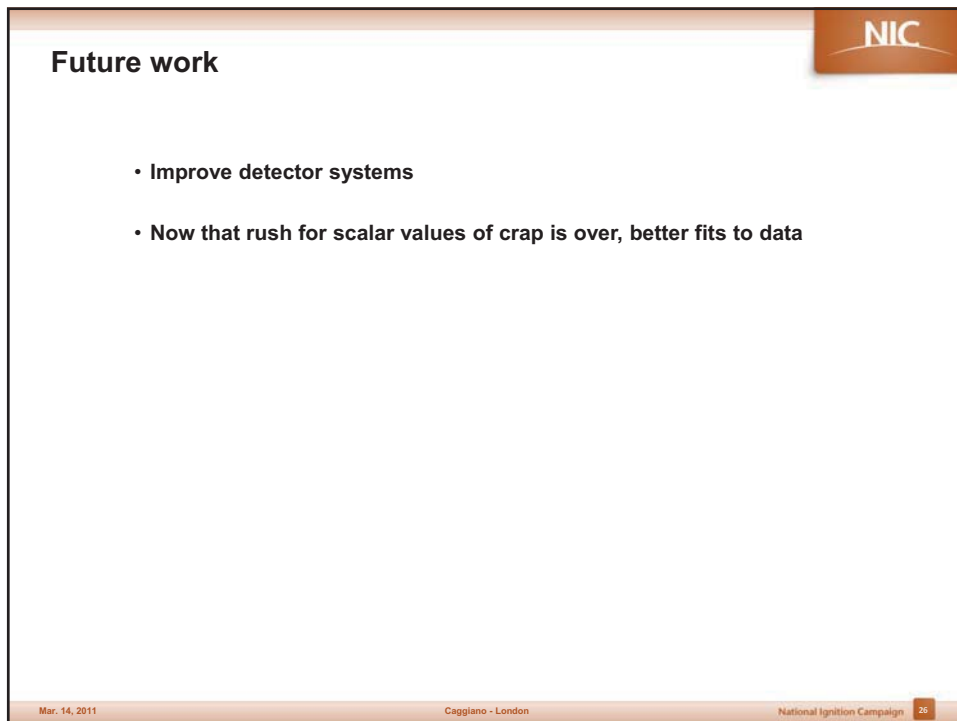
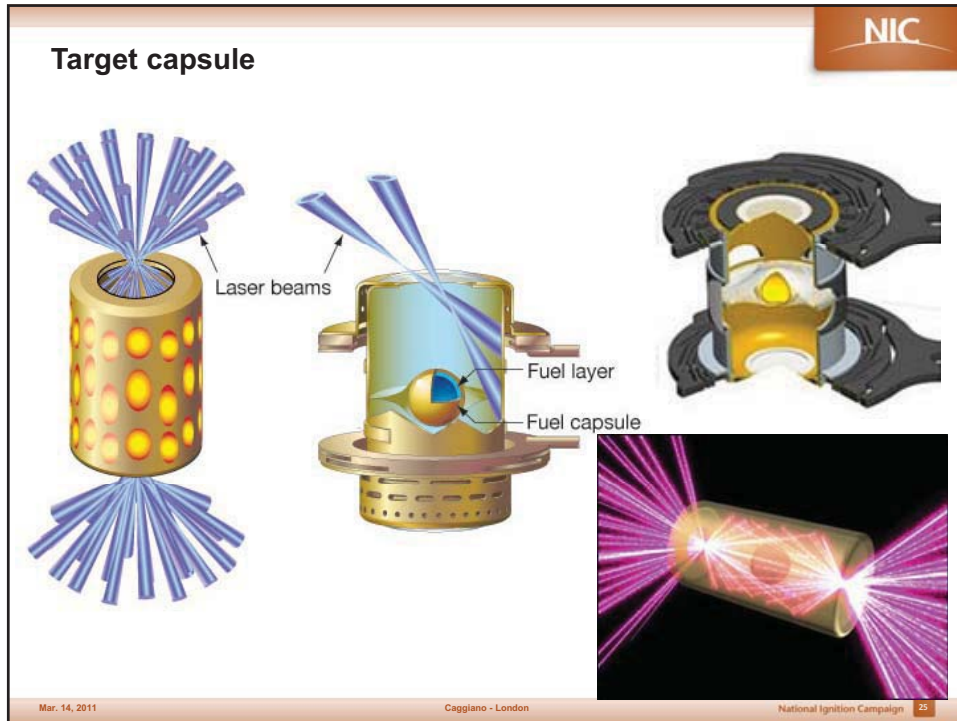



E [MeV]	Sensitivity [rel. to 14]
2	0.042
4	0.145
6	0.341
8	0.490
10	0.724
12	0.824
14	1.000

Mar. 14, 2011
Cagliano - London
National Ignition Campaign 20



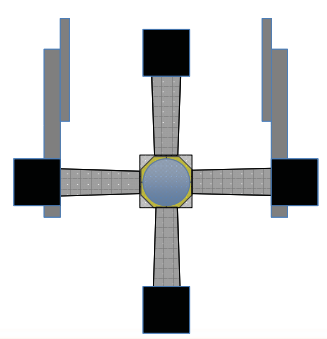




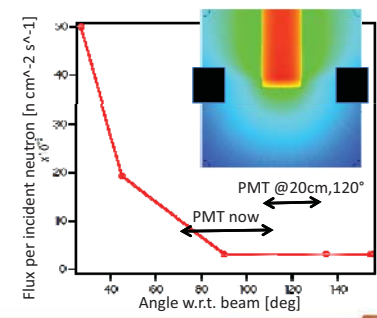


New system would improve background by 1200%

Contribution to dsr bkgd	Old	New	Improvement
Cable+scint	0.03	0.002	10x
Neutron scattering: TOTAL	0.03	0.003	10x
Neutron scattering: Local detectors	0.01	0.0001	100x
Neutron scattering: Housing/local mass	~0.02	0.002	10x
Total	0.06	0.005	12x



~30°



Flux per incident neutron [$\text{n cm}^{-2} \text{s}^{-1}$]

Angle w.r.t. beam [deg]

PMT @ 20cm, 120°

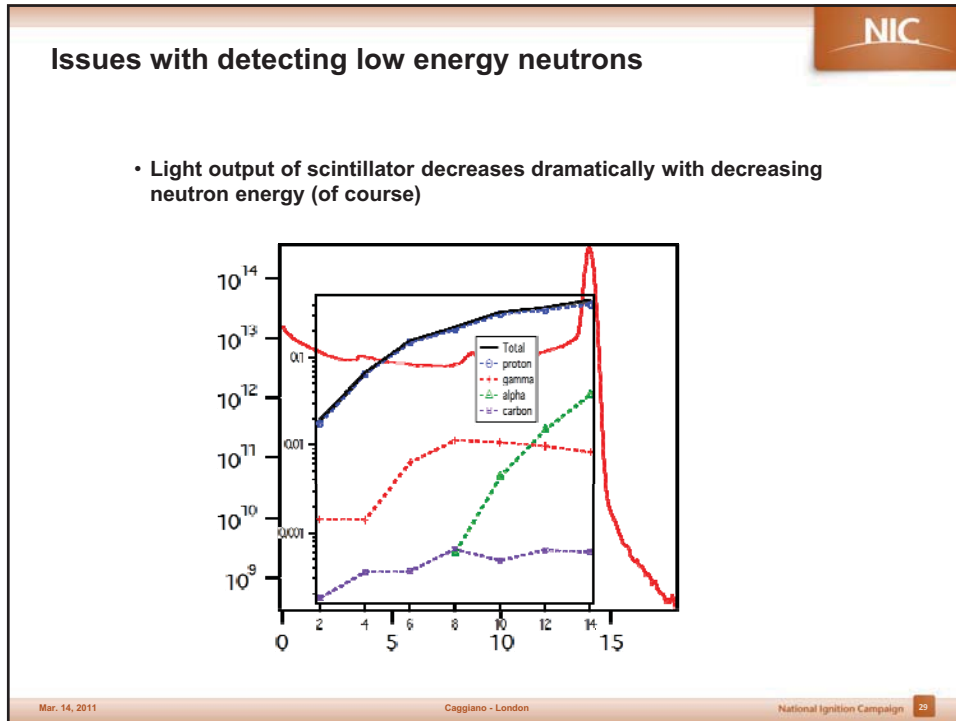
PMT now

Mar. 14, 2011
Cagliano - London
National Ignition Campaign 27



Backup slides

Mar. 14, 2011
Cagliano - London
National Ignition Campaign 28



NIC

So: what “should” neutron spectrum look like?

Reaction rate:

$$\langle \sigma v \rangle = \left(\frac{8}{\pi \mu} \right)^{1/2} \left(\frac{1}{kT} \right)^{3/2} \int \sigma(E) E e^{-E/kT} dE$$

$$\sigma(E) = S(E) \frac{1}{E} e^{-2\pi\eta}, \eta = \frac{Z_1 Z_2 e^2}{h v}$$

This is for a FIXED mean temperature, not necessarily a temperature distribution.
For a distribution in temperature, $f(T)$:

$$\langle \sigma v \rangle = \left(\frac{8}{\pi \mu} \right)^{1/2} \int dT \cdot f(T) \left(\frac{1}{kT} \right)^{3/2} \int \sigma(E) E e^{-E/kT} dE$$

What does this look like? Don't know...

Mar. 14, 2011 Cagliano - London National Ignition Campaign 30

NIC

“Brysk”* analysis

Compute cross section weighted kinetic energy for a single temperature:

$$\langle \sigma v \rangle = \left(\frac{8}{\pi \mu} \right)^{1/2} \left(\frac{1}{kT} \right)^{3/2} \int \sigma(E) E e^{-E/kT} dE$$

$$\langle E \rangle = \frac{\int E \cdot S(E) \cdot e^{b/\sqrt{E}} e^{-E/kT} dE}{\int S(E) \cdot e^{b/\sqrt{E}} e^{-E/kT} dE}$$

Compute moments of the distribution $\langle (E - \langle E \rangle)^{2i} \rangle$ and with $Q \gg T$, dist. is gaussian:

$$f(E) = \exp \left[\frac{-(E - \langle E \rangle)^2}{\frac{4 m_n kT \langle E \rangle}{m_n + m_\alpha}} \right]$$

Caveats:

- Done non-relativistically
- Dave Munro has refreshed this analysis relativistically, but outcome is generally the same

*H.Brysk, J. Plas. Phys. 15, p611-617(1973)

Mar. 14, 2011
Cagliano - London
National Ignition Campaign 31

NIC

All dsr results expressed as a percentage (neutron sensitivity correction(+25%) applied)

THD/EP	N10091	N10092	N10103	N10121	N11021	average	stddev	
SpecEq PMT140:	N10092	--	3.62	3.10	3.23	3.81	3.44	0.33
	N11012	--	2.97	2.45	2.58	3.18	2.80	0.34
	N11020	--	3.36	2.84	2.97	3.51	3.17	0.32
	N11021	--	2.61	2.30	2.42	2.96	2.57	0.29
SpecAI PMT140:	N10092	3.36	2.71	2.84	3.10	3.55	3.11	0.35
	N11012	2.84	2.20	2.33	2.58	3.07	2.60	0.36
	N11020	3.10	2.45	2.58	2.84	3.29	2.86	0.35
	N11021	3.09	2.40	2.58	2.88	3.33	2.86	0.37

Mar. 14, 2011
Cagliano - London
National Ignition Campaign 32