LLNL-PRES-668266

# Prompt Godiva Measurements

*Mark May, Craig Halvorson, John Scorby, Dan Bower,*

*Pat Lewis*

*Lawrence Livermore National Laboratory*

Lawrence Livermore National Laboratory

# Godiva

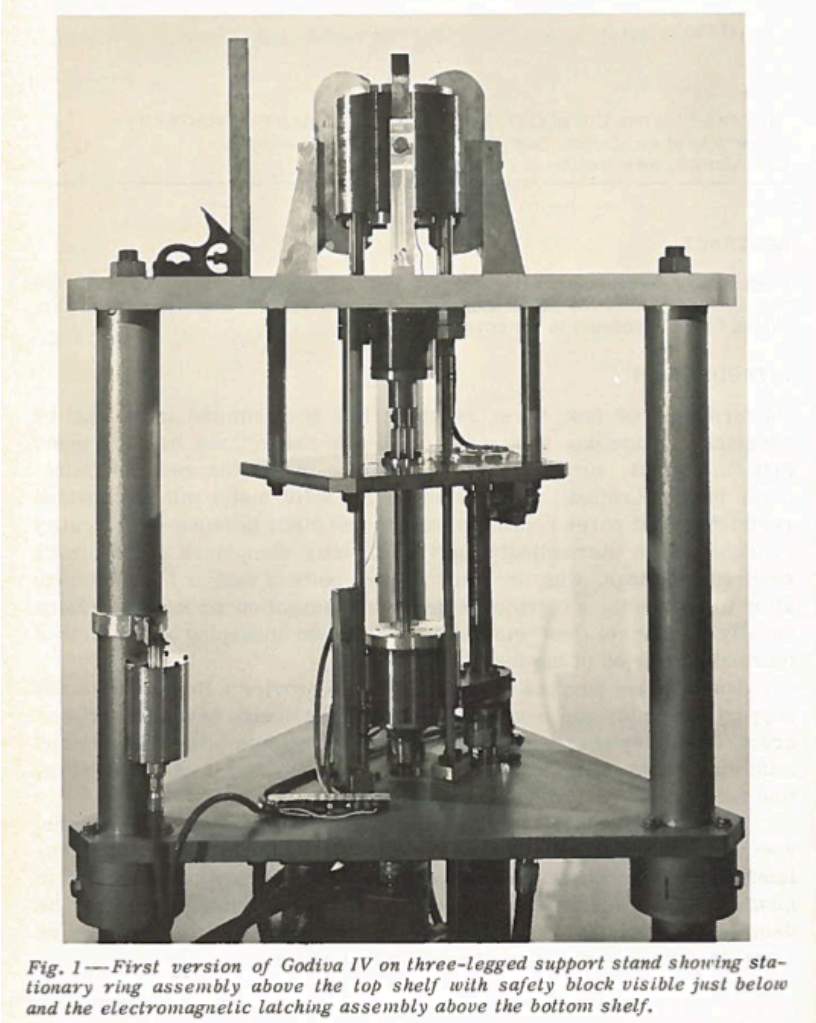
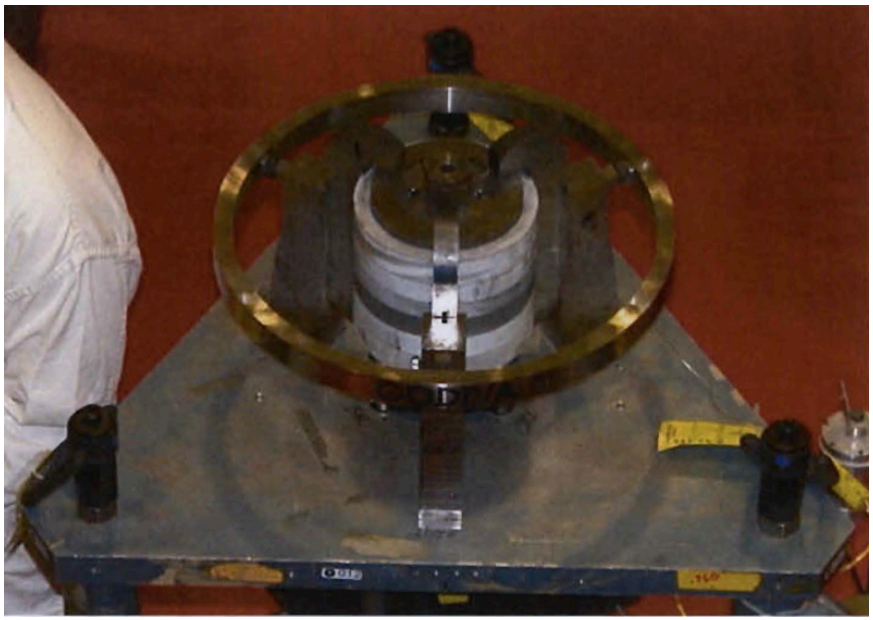


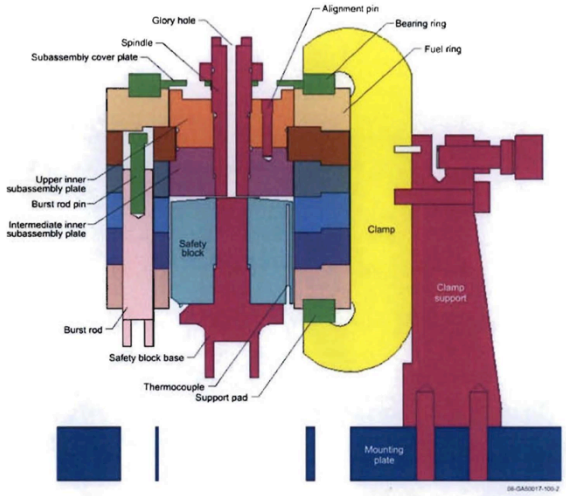
*Fig. 1—First version of Godiva IV on three-legged support stand showing stationary ring assembly above the top shelf with safety block visible just below and the electromagnetic latching assembly above the bottom shelf.*



*Top view of the Godiva-IV core and its restraints. (from LA-UR-09-01007)*

# Experimental Setup

*Schematic of the Godiva IV core*




Prompt Radiation Detector

4 Sensor Scintillator Photomultiplier /Photodiode

Cable ~100 ft

Recorders

Control Room

1.5 or 3 m from Godiva

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# Prompt Detector Measurement Summary

| Date | Godiva Burst # | Reactivity (Cents) | Delta T (°C) | LLNL Prompt Data |
|---|---|---|---|---|
| 4/15/2014 | 1977 | 102.0 | 75.4 | |
| 4/15/2014 | 1978 | 106.0 | 129.7 | Y |
| 4/16/2014 | 1979 | 111.0 | 236.9 | Y |
| 4/17/2014 | 1980 | 110.5 | 232.4 | recorded preburst |
| 5/27/2014 | 1990 | 111.3 | 229.9 | Y |
| 5/28/2014 | 1991 | 106.9 | 136.9 | Y |
| 5/28/2014 | 1992 | 102.0 | 69.2 | |
| 5/28/2014 | 1993 | - | 71.1 | |
| 5/29/2014 | 1994 | 102.0 | 68.5 | |

***Prompt Detector Data Recorded on 4 Godiva Bursts***

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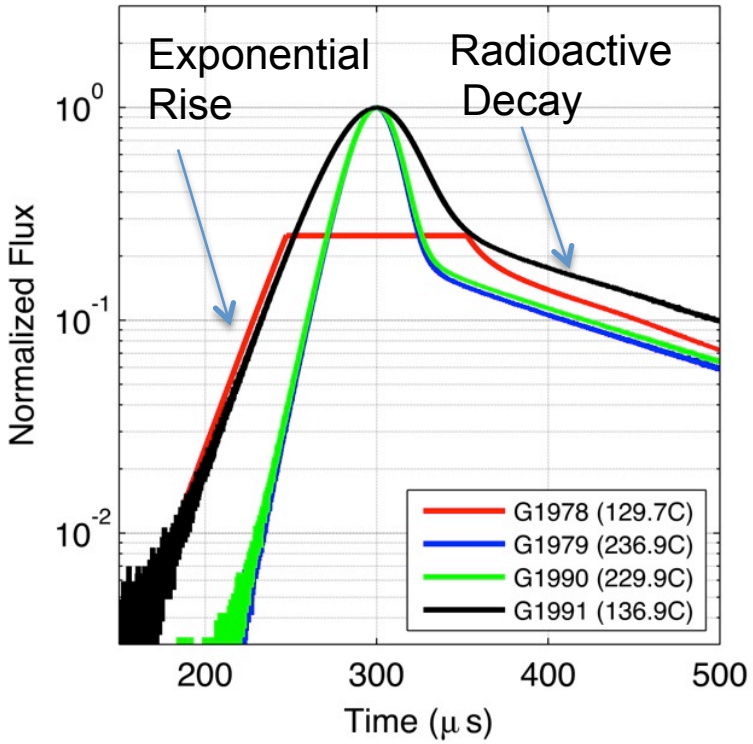
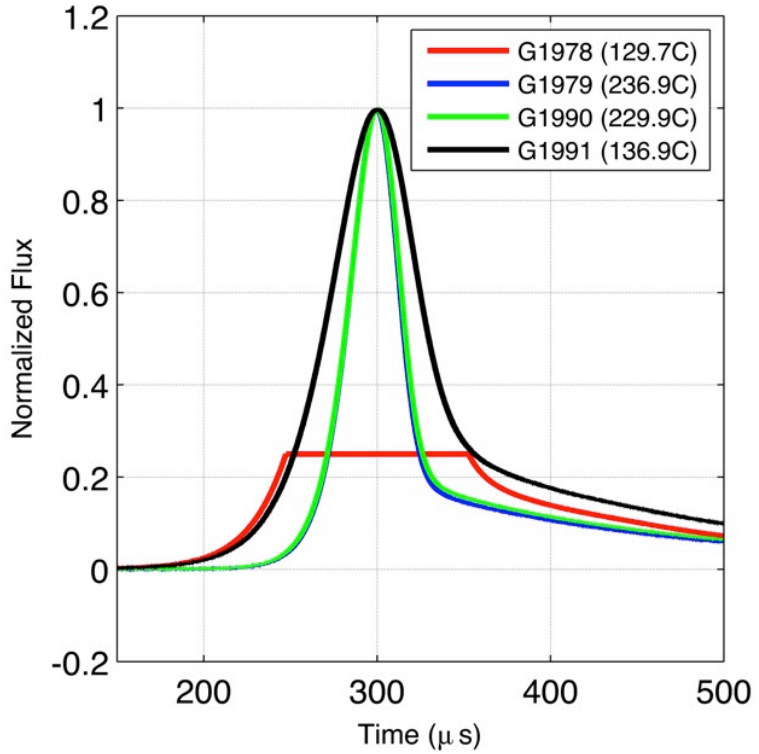
# Comparison of Prompt Peak Signals from Godiva Bursts.

## Photo Diode Signal Log Scale

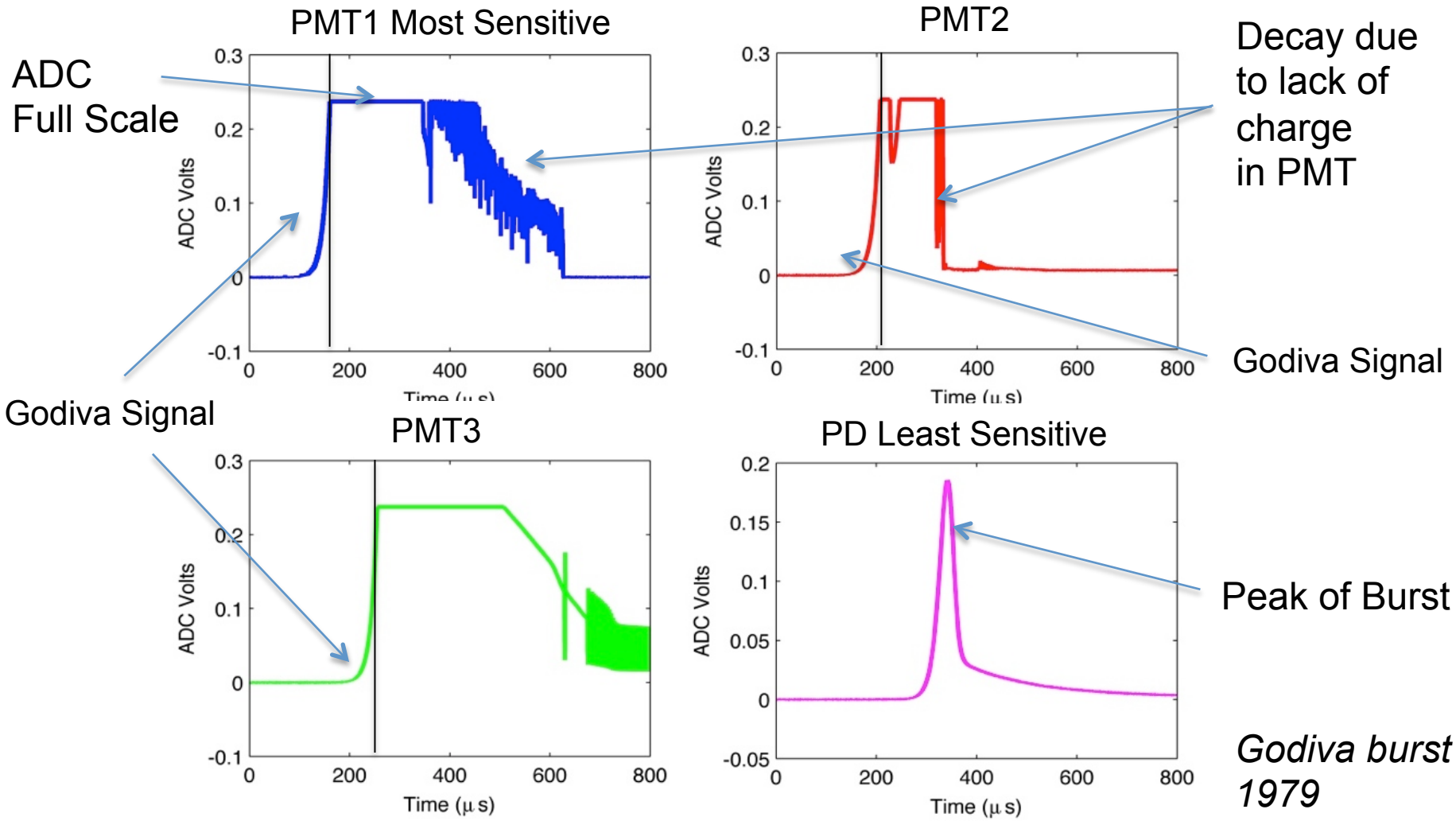



## Photo Diode Signal Linear Scale

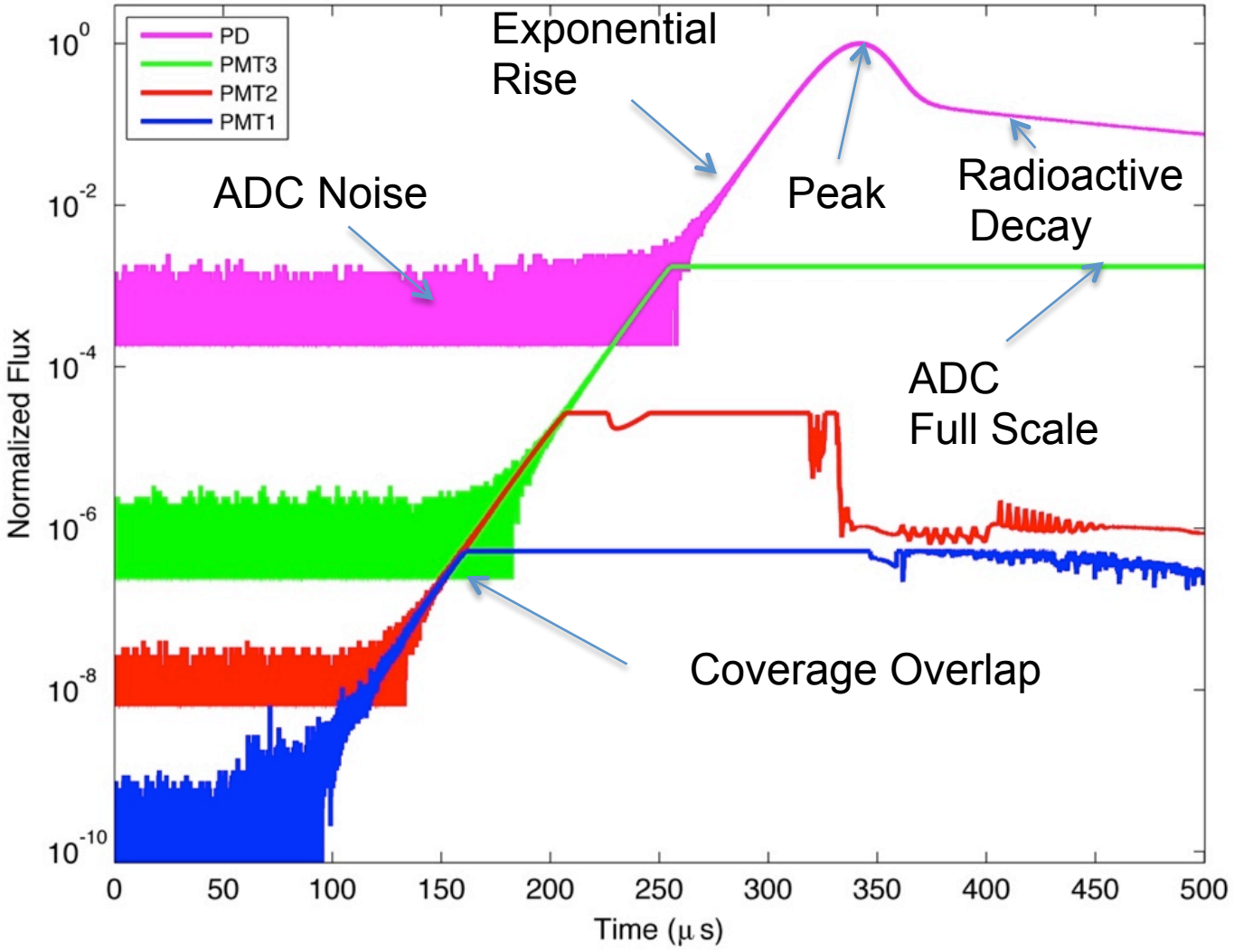



***Godiva Bursts are very repeatable***

# Raw Prompt Detector Data from a Godiva Burst



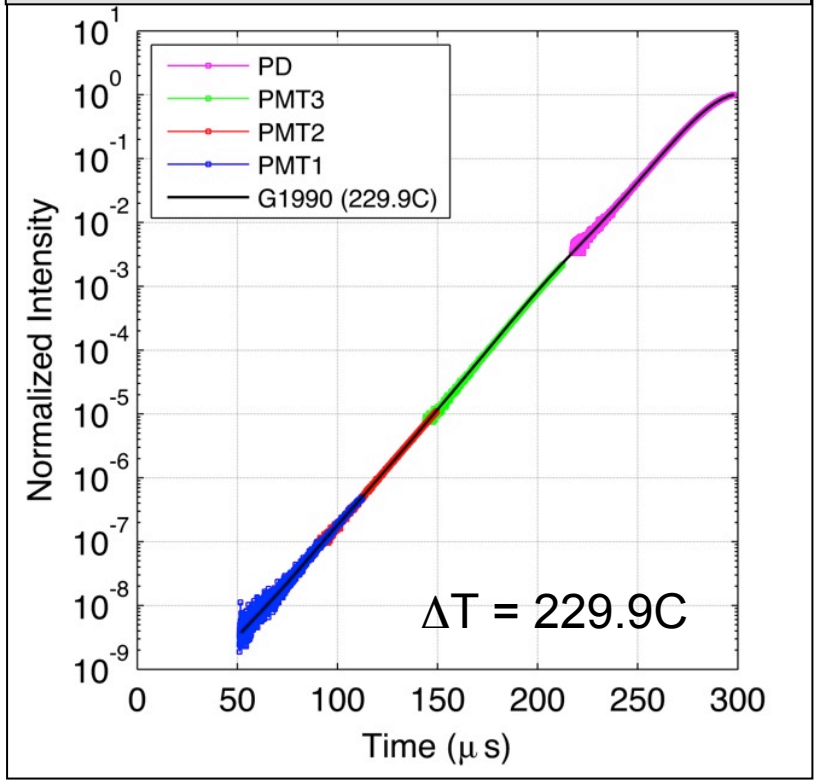
# Sample Prompt Detector Data from a Godiva Burst



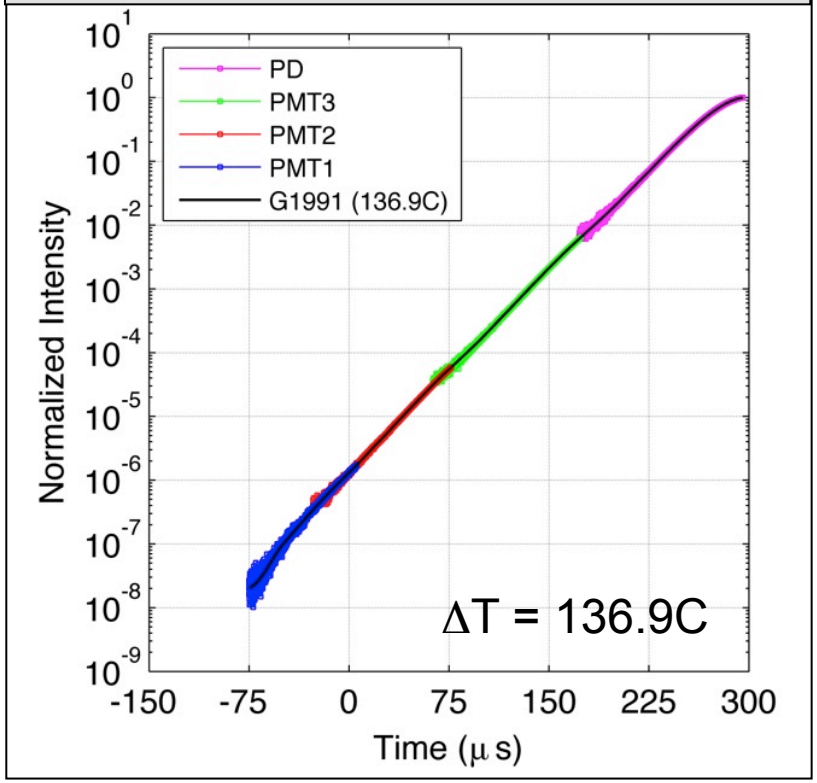

*Godiva burst*
*1979*
*$\Delta T$ = 236.9 C*

# Assembled Data for Godiva Bursts

## Godiva Burst 1990




## Godiva Burst 1991




**Assembled data from 4 sensors into one record using a least squares covariance fit.**

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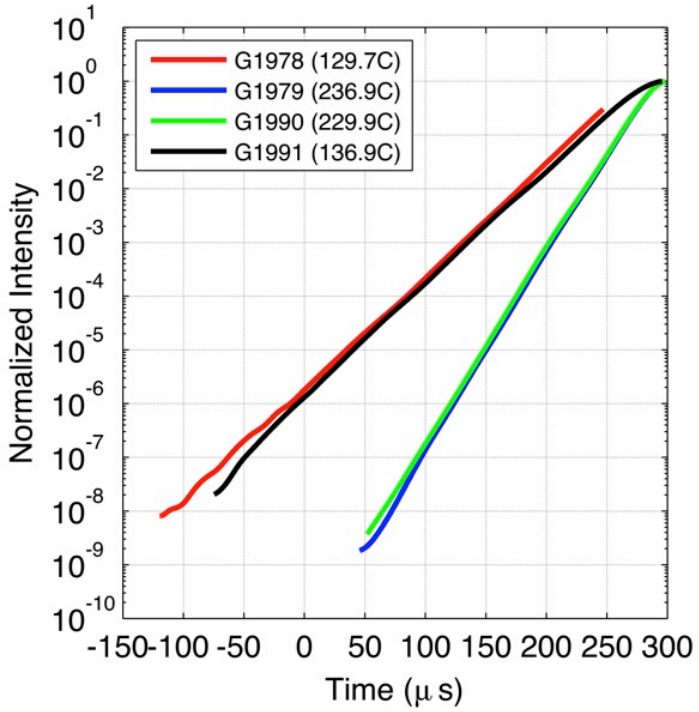
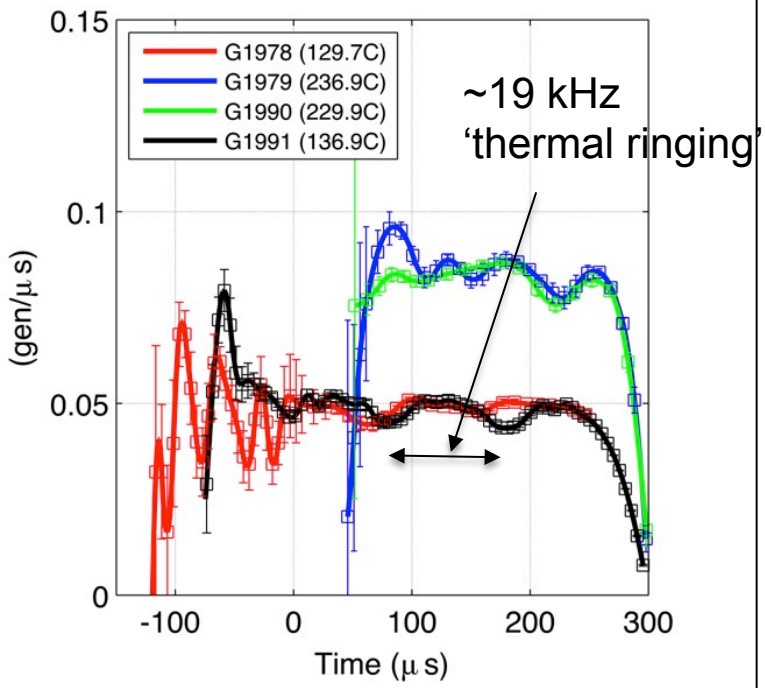
# Comparison of Godiva Intensities and Alphas

## Comparison of Prompt Intensities



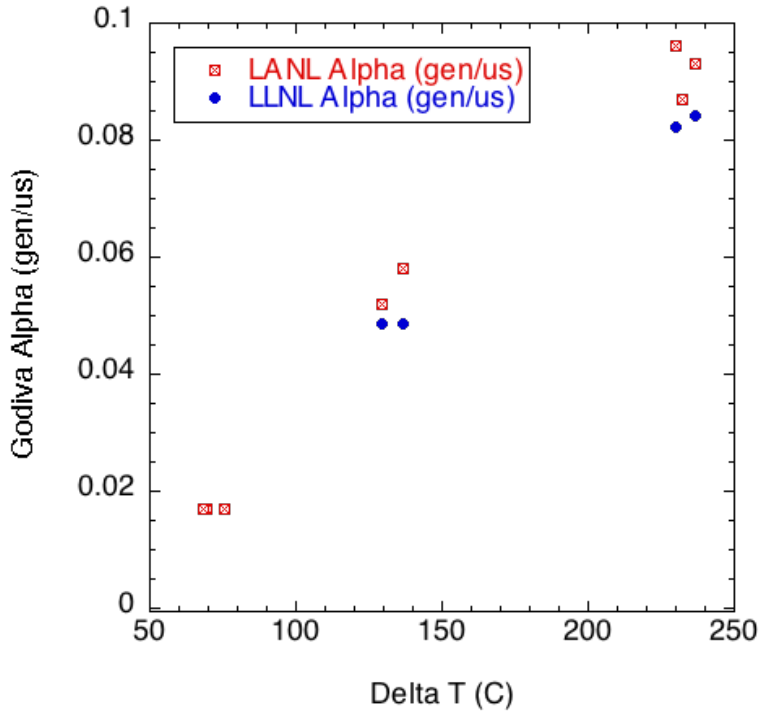

## Comparison of Prompt Alphas




***Time resolved Godiva Intensities and alpha are repeatable***

# Comparison of Godiva Alpha Measurements

## Comparison of Prompt Alphas




| Burst # | Rctvity (Cents) | Delta T (°C) | LANL α (gen/μs) | LLNL α (gen/μs) |
|---|---|---|---|---|
| 1977 | 102.0 | 75.4 | 0.017 | |
| 1978 | 106.0 | 129.7 | 0.052 | 0.0487 |
| 1979 | 111.0 | 236.9 | 0.093 | 0.0843 |
| 1980 | 110.5 | 232.4 | 0.087 | |
| 1990 | 111.3 | 229.9 | 0.096 | 0.0821 |
| 1991 | 106.9 | 136.9 | 0.058 | 0.0485 |
| 1992 | 102.0 | 69.2 | 0.017 | |
| 1993 | - | 71.1 | - | |
| 1994 | 102.0 | 68.5 | 0.017 | |

LANL: Single PD with lower S/N

LLNL: 4 Channels with high S/N and Sophisticated Algorithm

***LANL Alpha measurements are slightly higher than LLNL measurements***

# Determination of Fission Yields

- Correct the recorded energy flux on the prompt detector to total flux into $4\pi$.
  - room scattering is ignored.

- Detector recorded energy flux has contributions from both neutrons ($I_n$) and gammas ($I_\gamma$).

$$E_{Sensor} = C_n(E) * I_n + C_\gamma(E) * I_\gamma$$

$C_n$ - deposited energy by neutrons*: 0.2 MeV @ 2 MeV[1]
$C_\gamma$ - deposited energy by gamma rays*: 0.65 MeV @ 2 MeV[2]

- The number of fissions and leakage neutrons are related to the number gammas[2]:

$$I_F = I_\gamma / 0.42 \; ; \; I_n = 3.74 * I_\gamma$$

- Fission rate can be related to energy flux deposit in the detector.

$$I_F = I_\gamma / 0.42 = E_{Sensor} / (C_n * R + C_\gamma) / 0.42 = E_{Sensor} / 0.588$$

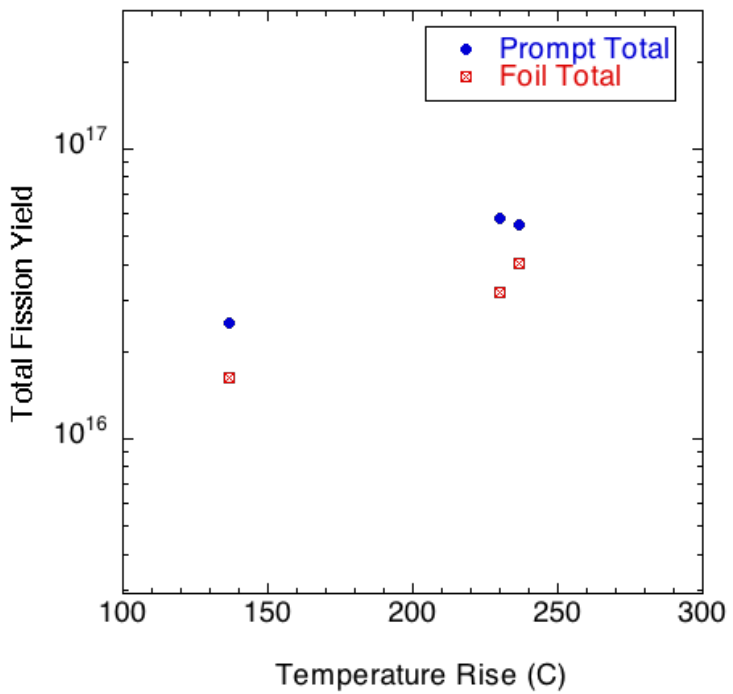
[1]T. F. Wimett, R. H. White, and R. G. Wagner, "Godiva IV," Proceedings of the National Topical Meeting on Fast Burst Reactors, Albuquerque, NM, pp. 95-104 (January 1969).

* Clark and Lent, "The Neutron and Gamma Sensitivities of Plastic Scintillators", UOPAD-75-20.

[2]T. Goorley (MCP)

# Summary of Fission Yields

## Total Number of Fissions




| Godiva Burst | 1979 | 1990 | 1991 |
|---|---|---|---|
| Delta Temperature (C) | 236.9 | 229.9 | 136.9 |
| Distance (m) | 3.15 | 3.15 | 3.15 |
| t(FWHM) (μs) | 34.47 | 35.43 | 61.34 |
| ($x10^{16}$) Total Fissions from Prompt | 5.45 | 5.77 | 2.50 |
| ($x10^{16}$) Total Fissions from Foils (Hickman and Heinrich) | 4.05 | 3.18 | 1.62 |

***Prompt Godiva Yields are in Fair Agreement to Yields from Foil Measurements***

# Godiva Conclusions

- Total fission yields estimates from prompt measurements are in fair agreement with foil measurements.
  - Improved total fission yield estimates possible with higher fidelity modeling.

- LLNL measured Godiva alphas are slightly lower than LANL measurements

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