

# A Technique for Measuring the Time Response and Through-put Delay of Neutron Time-of-Flight Scintillation Detectors Using Cosmic Rays \*

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# nTOF Diagnostics

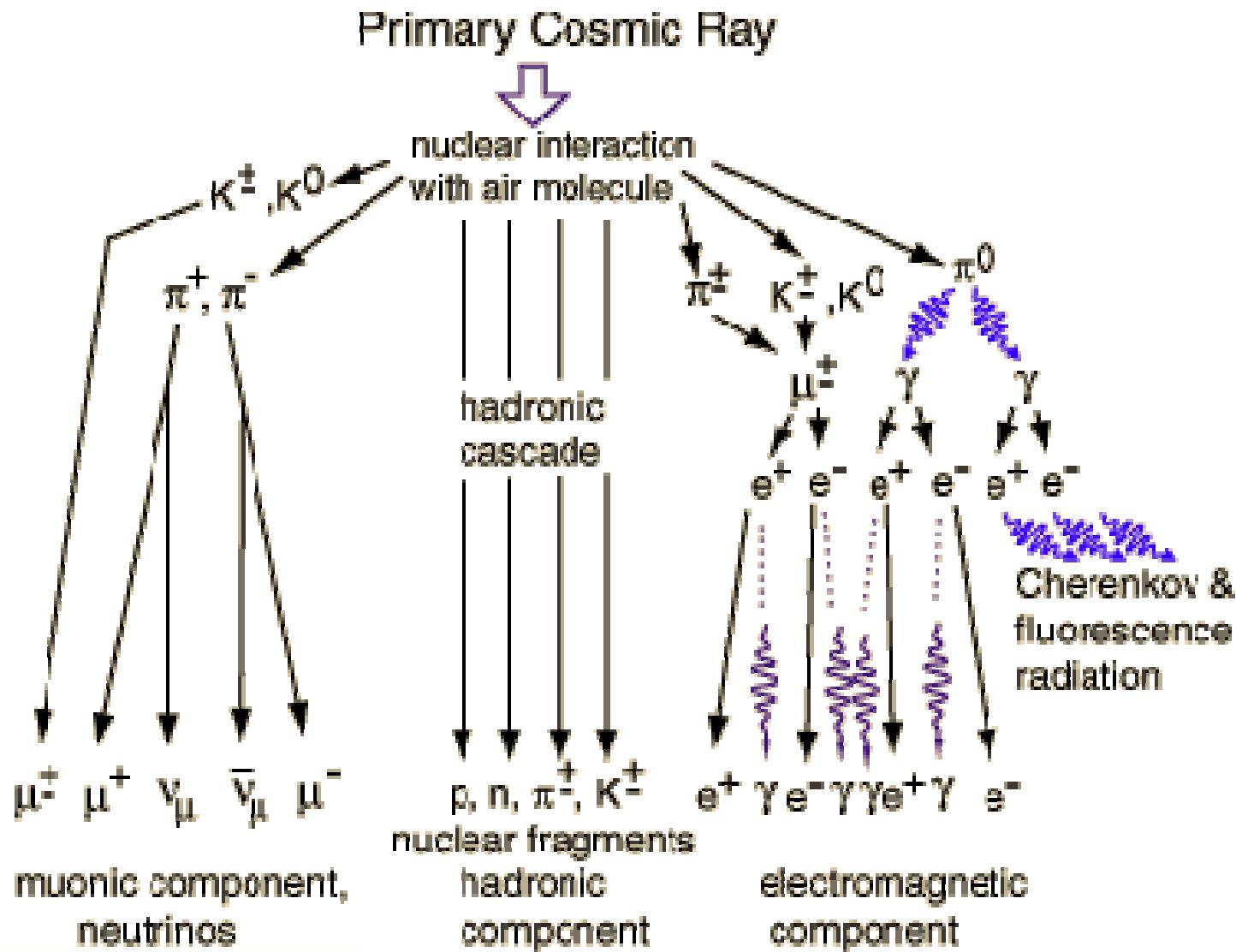
- Inertial Confinement Fusion Experiments at NIF, OMEGA and the Sandia Z Machine
- nTOF diagnostics are used to determine the neutron “bang” time and energy spectrum
- Requires the analysis of the nTOF output signal
- To provide accurate results, the nTOF detector time response and through-put must be unfolded from the nTOF output signal



# Determining the nTOF Time Response and Through-put Delay

- Usually requires accelerator-based photon beam experiments
- Expensive and resource intensive
- Possible to use cosmic radiation
- Chinese research utilized cosmic radiation
- Using cosmic radiation provides a bench-top capability for the determination of nTOF detector time response and through-put
- Would allow for the periodic re-evaluation of detectors

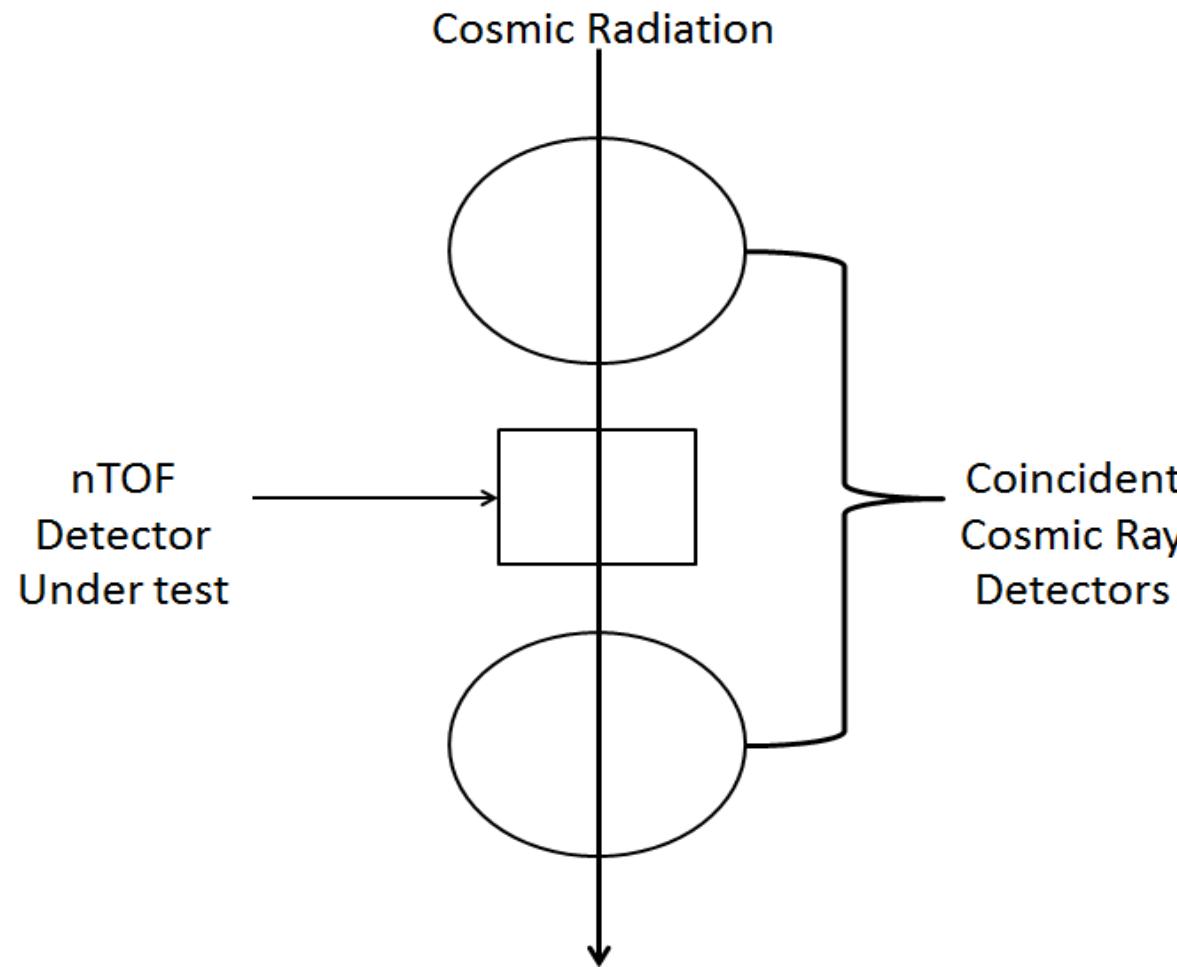
# Cosmic Radiation



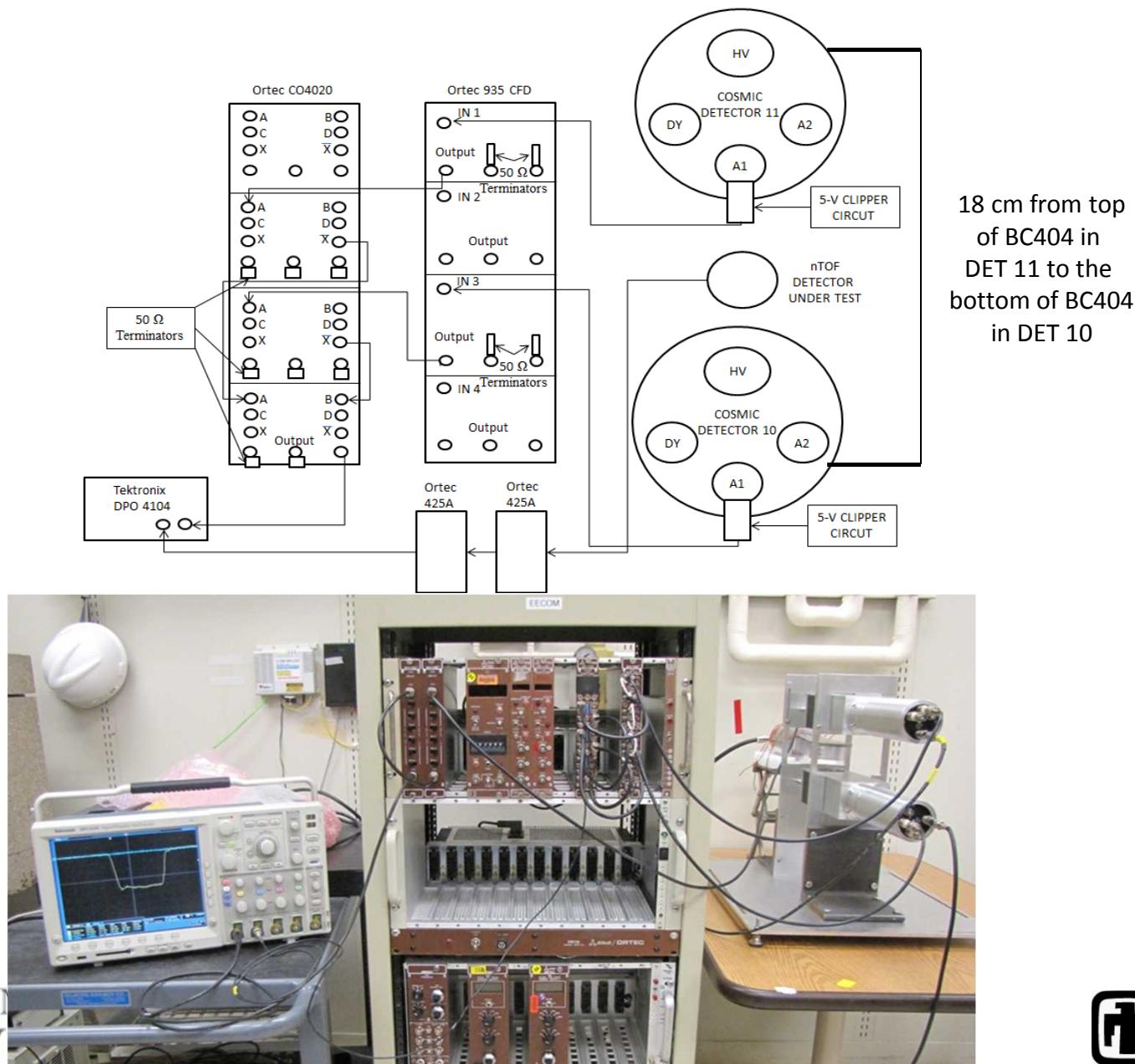
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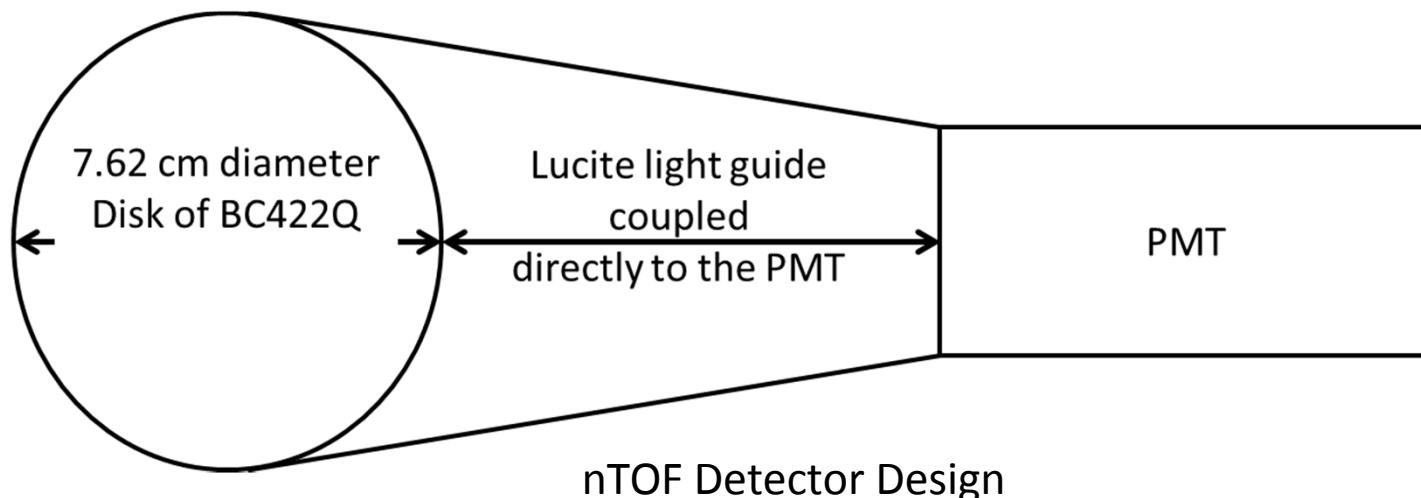
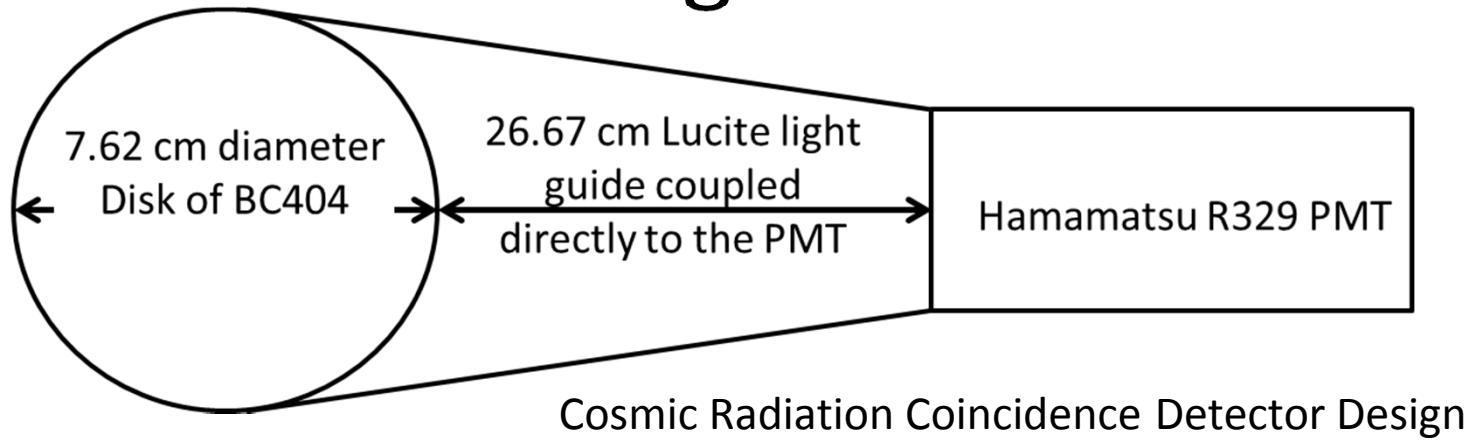
# General Cosmic Radiation Experimental System



# The Cosmic Radiation Experimental Set-up



# Cosmic Radiation and nTOF Detector Design



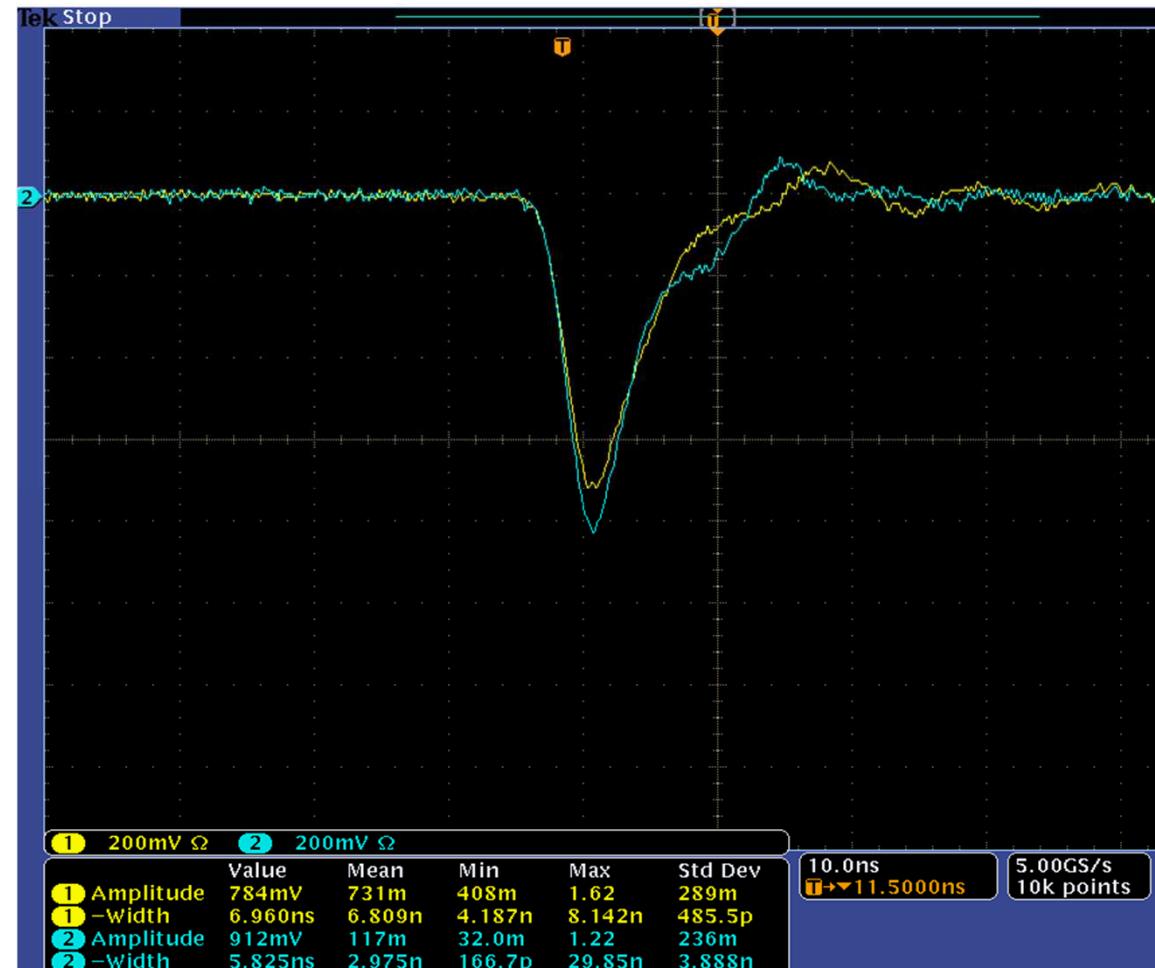
# Matching Pulse Shapes Between Cosmic Detectors 10 and 11

- To ensure that only coincidence events were counted, it was important to normalize the signals between Cosmic Detectors 11 and 10

- To do this, the bias applied to Cosmic Detector 10 was increased until the pulse shape matched

- The signal matching focused on the leading edge and the pulse shape

- To normalize the signals, the bias setting -1725 V for Cosmic Detector 11 and -1740 V for Cosmic Detector 10



# Cosmic Radiation Experiment

- Measure Time Response and Through-put Delay at -100 V intervals
- The intervals measured were between -1800 V to -2500 V
- Cosmic Radiation signals from the nTOF detectors below -1800 V were indistinguishable from background noise
- 20 measurements were taken for each interval
- The cosmic radiation experimental results were compared to accelerator experimental results for the same detector

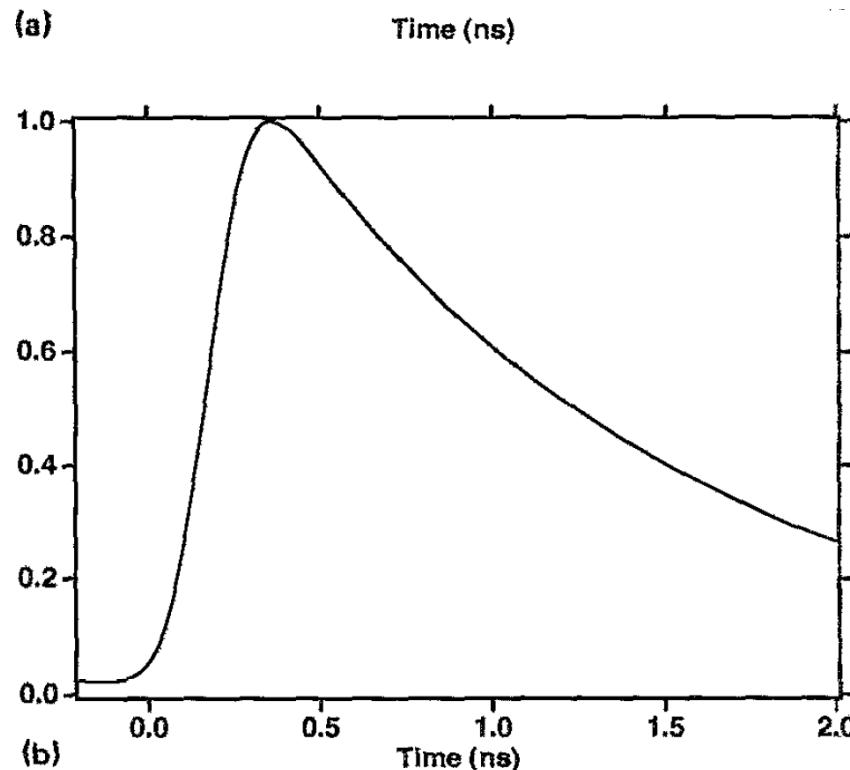


# The Idaho Accelerator Experiments

- Designed to measure the time response and through-put for nTOF detectors D1 and D2
- Conducted in 2006 at Idaho State Accelerator
- 44 MeV, 50 ps Short-Pulse Electron LINAC
- Electrons onto Tungsten Target, produces a 5 MeV, 50 ps pulse of photons
- Used a 20 GHz digitizer that produced average wave forms and no uncertainties



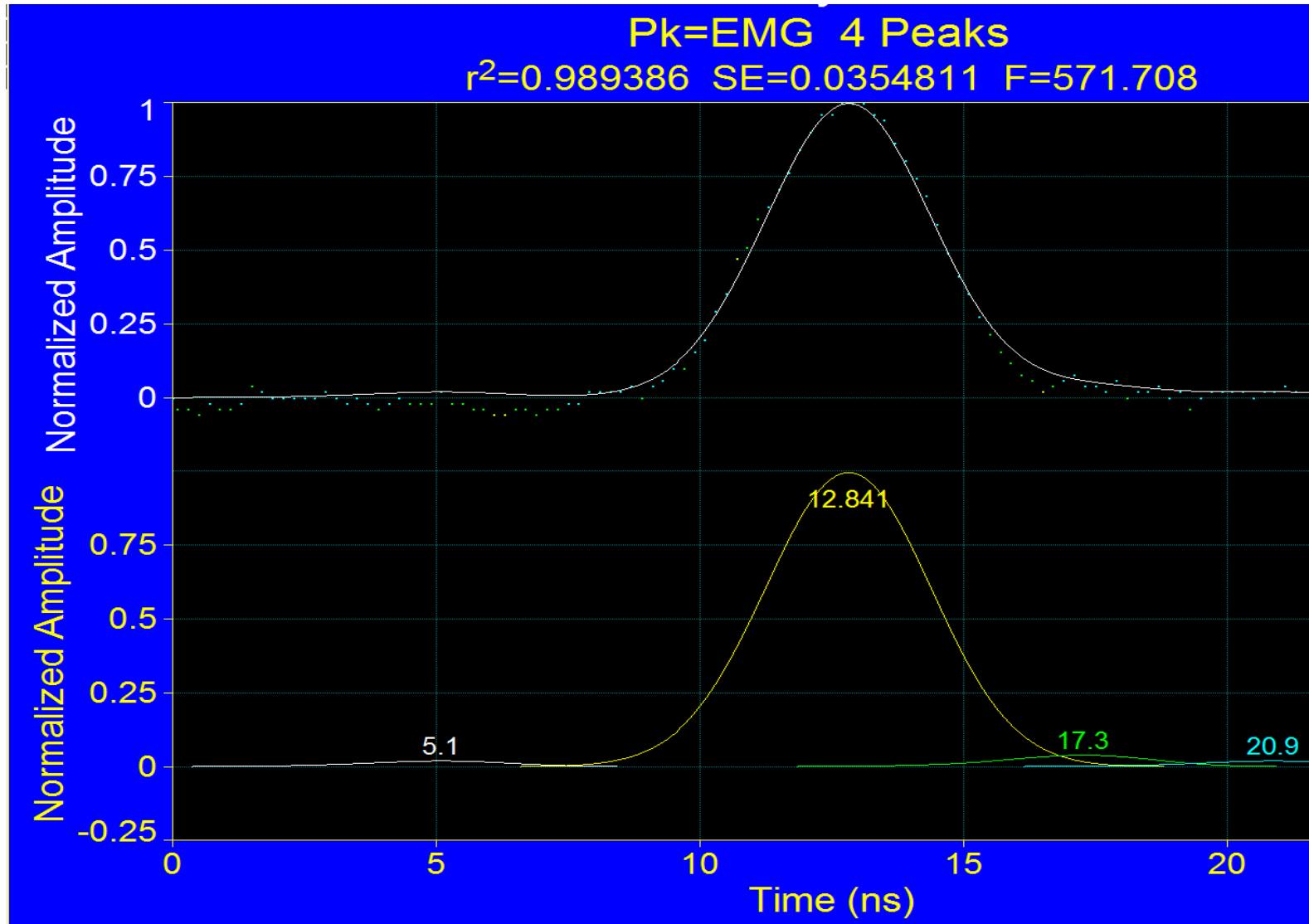
# Calculated Time Response Function: Exponentially-Modified Gaussian (EMG)



$$y(x; a, x_c, \sigma, \gamma) = \frac{a}{2\gamma} \exp\left(\frac{\sigma^2}{2\gamma^2} + \frac{x_c - x}{\gamma}\right) \left[ \operatorname{erf}\left(\frac{x - a}{\sigma\sqrt{2}} - \frac{\sigma}{\gamma\sqrt{2}}\right) + \frac{\gamma}{|\gamma|} \right]$$



# Exponentially Modified Gaussian Data Fit

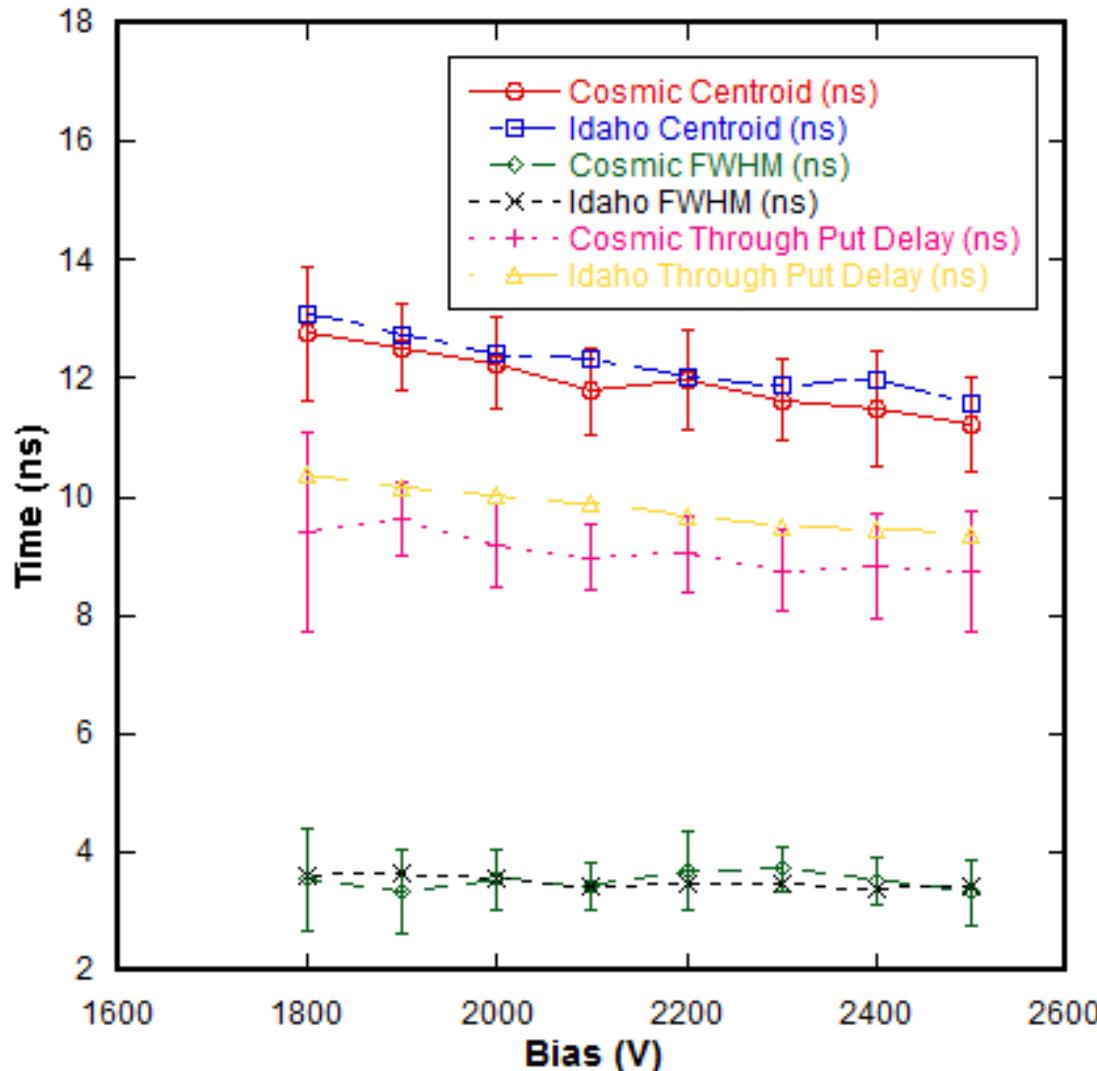


# Results for Detector D1 from -2500 V to -1800 V

Bias (V)	Centroid (ns)	FWHM (ns)	Through- Put at 10% Amplitude (ns)	$r^2$	SE
2500	$11.23 \pm 0.79$	$3.3 \pm 0.6$	$8.73 \pm 1$	$0.989 \pm 0.005$	$0.032 \pm 0.009$
2400	$11.5 \pm 0.98$	$3.498 \pm 0.39$	$8.8 \pm 0.9$	$0.999 \pm 0.009$	$0.037 \pm 0.011$
2300	$11.63 \pm 0.69$	$3.7 \pm 0.4$	$8.76 \pm 0.67$	$0.98 \pm 0.009$	$0.045 \pm 0.013$
2200	$11.97 \pm 0.84$	$3.68 \pm 0.67$	$9.03 \pm 0.63$	$0.965 \pm 0.024$	$0.06 \pm 0.019$
2100	$11.78 \pm 0.72$	$3.4 \pm 0.4$	$8.98 \pm 0.56$	$0.969 \pm 0.023$	$0.054 \pm 0.021$
2000	$12.26 \pm 0.78$	$3.54 \pm 0.5$	$9.19 \pm 0.70$	$0.91 \pm 0.05$	$0.092 \pm 0.039$
1900	$12.5 \pm 0.7$	$3.33 \pm 0.7$	$9.62 \pm 0.63$	$0.9 \pm 0.08$	$0.104 \pm 0.051$
1800	$12.75 \pm 1.1$	$3.54 \pm 0.853$	$9.4 \pm 1.7$	$0.847 \pm 0.145$	$0.182 \pm 0.208$



# Detector D1 Cosmic Experiment Data versus Idaho Experiment Data



# Comparison of D1 Detector Results Between the Cosmic Radiation Experiments and the Idaho Experiments

Bias (V)	Centroid (ns)	Idaho Centroid (ns)	FWHM (ns)	Idaho FWHM (ns)	Through- Put at 10% Amplitude (ns)	Idaho Through- Put at 10% Amplitude (ns)
2500	$11.23 \pm 0.79$	11.57	$3.32 \pm 0.56$	3.42	$8.73 \pm 1.01$	9.34
2400	$11.5 \pm 0.98$	11.98	$3.498 \pm 0.39$	3.36	$8.82 \pm 0.9$	9.46
2300	$11.63 \pm 0.69$	11.89	$3.71 \pm 0.36$	3.48	$8.76 \pm 0.67$	9.47
2200	$11.97 \pm 0.84$	12.02	$3.68 \pm 0.67$	3.48	$9.03 \pm 0.63$	9.65
2100	$11.78 \pm 0.72$	12.34	$3.41 \pm 0.40$	3.41	$8.98 \pm 0.56$	9.87
2000	$12.26 \pm 0.78$	12.42	$3.54 \pm 0.51$	3.55	$9.19 \pm 0.70$	10.04
1900	$12.52 \pm 0.72$	12.74	$3.33 \pm 0.72$	3.62	$9.62 \pm 0.63$	10.17
1800	$12.75 \pm 1.12$	13.099	$3.54 \pm 0.853$	3.59	$9.41 \pm 1.69$	10.39



# Conclusion

- The method is a valid technique for measuring the FWHM and through-put delay
- The results for the FWHM were consistent with the Idaho results
- The results for the through-put delay were mostly within one standard deviation of the Idaho results

# Future Work

- Establish a reference nTOF detector
- Use the through-put (10%) to establish that reference for the coincidence detectors and electronics because we are concerned with the through-put value
- Conduct additional studies to establish the effect of taking data over a longer time period

