

Prompt γ rays in fission



Ching-Yen Wu

Lawrence Livermore National Laboratory

S&T Principal Directorate – Physical Life Science / Physics Division
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Outline

1. Motivation
2. DANCE and fission counter
3. Prompt γ 's for the spontaneous fission in ^{252}Cf
4. Status of deliverables
5. Workforce and budget
6. Summary





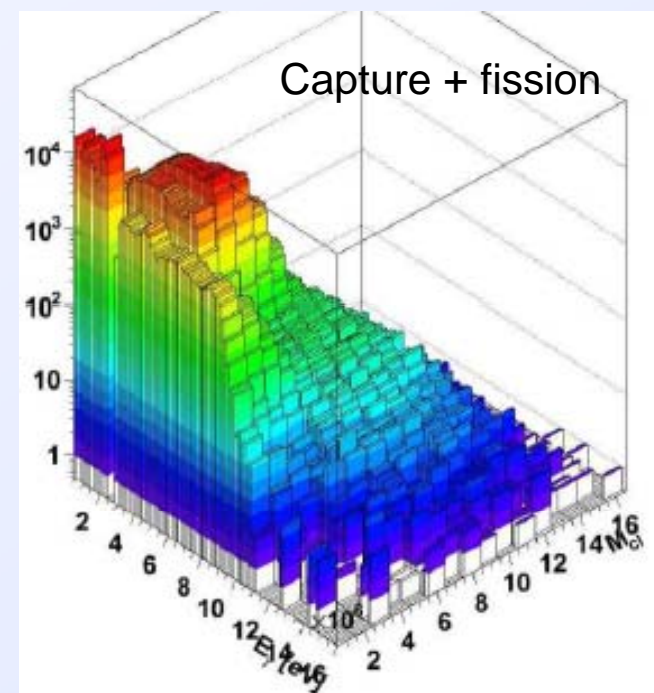
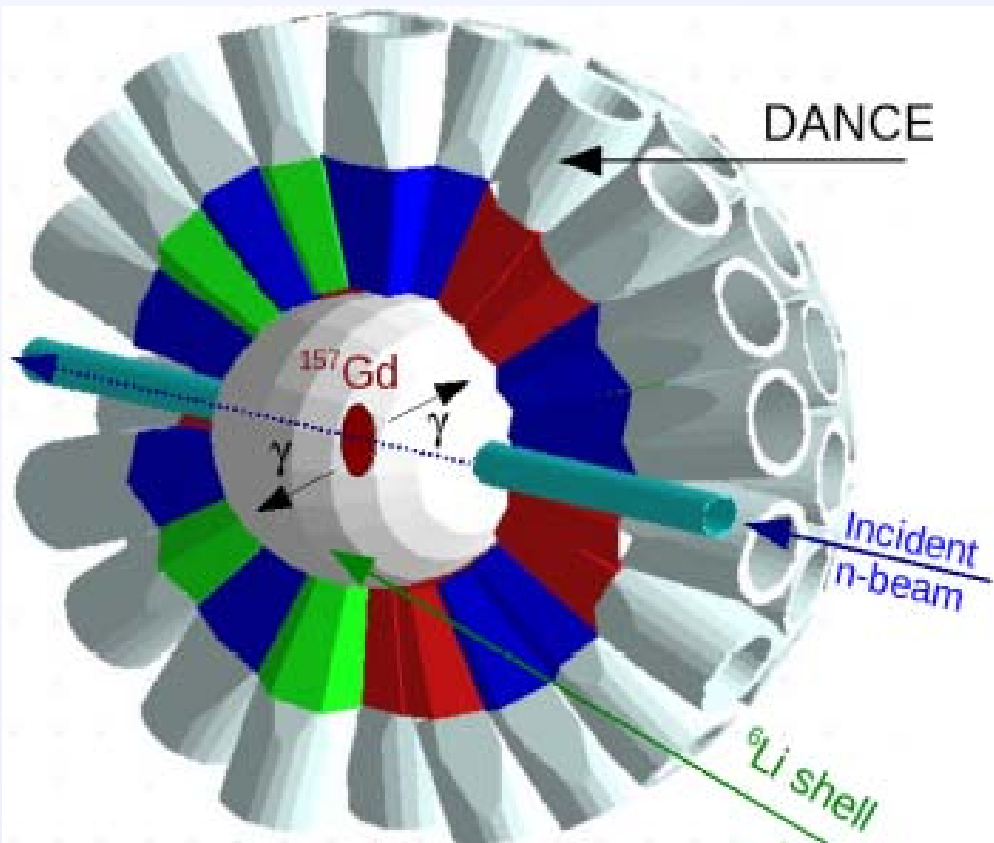
Motivation

- Prompt γ rays is the least known quantity in the study of the energy partition in fission
- Important applications in the Stockpile Stewardship, the advanced fuel cycle and so on



DANCE (Detector for Advanced Neutron Capture Experiments) for the γ -ray detection

- DANCE is a 4π γ -ray calorimeter and consists of 160 BaF₂ crystals with equal solid-angle coverage
- Many unique features: the nearly γ -ray energy independence of the detection efficiency, the photo-to-Compton ratio, and the multiplicity

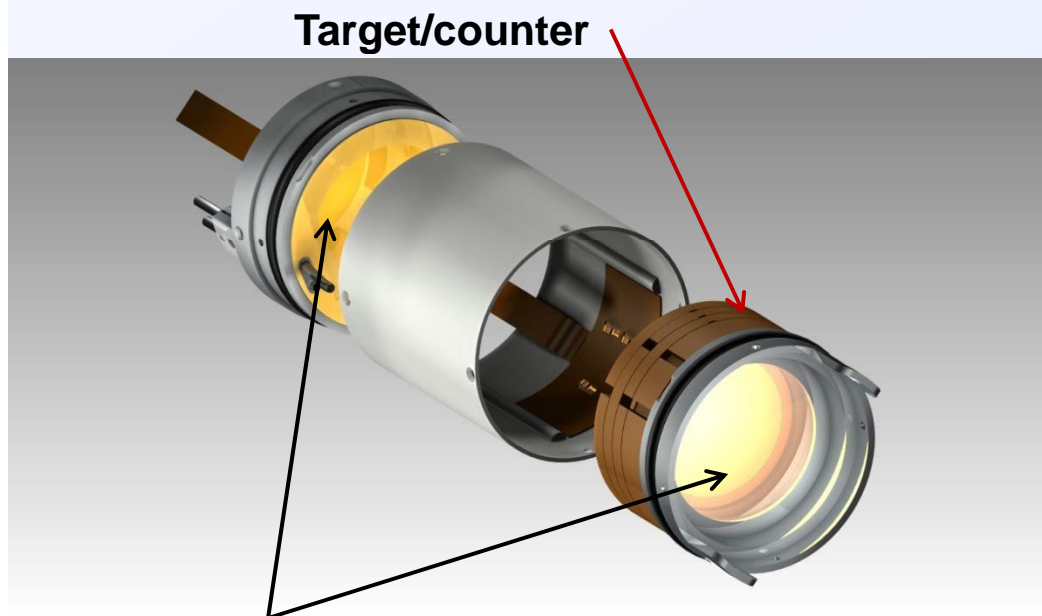


Total γ -ray energy vs. multiplicity distribution for ²⁴¹Pu

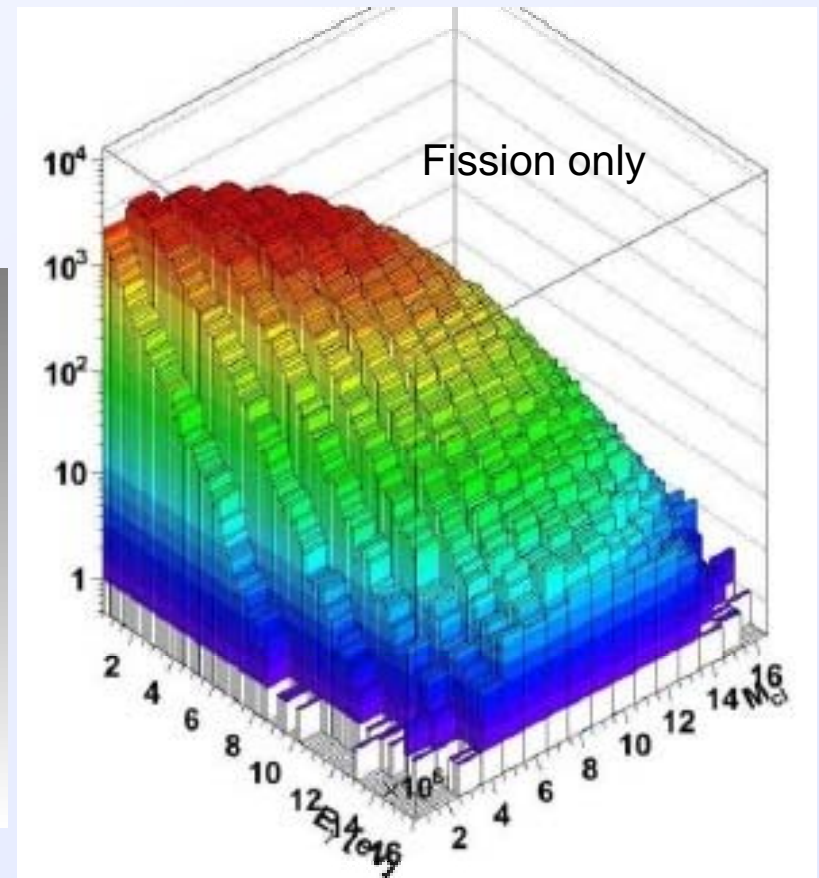


PPAC (Parallel-Plate Avalanche Counter) for the fission fragment detection

- PPAC is an ideal for the fission fragment detection
 - Resistance to the radiation damage
 - Tolerance to the high counting rate
 - Insensitive to the α 's



25.4 μm Kapton



Total γ -ray energy vs. multiplicity distribution for ^{241}Pu





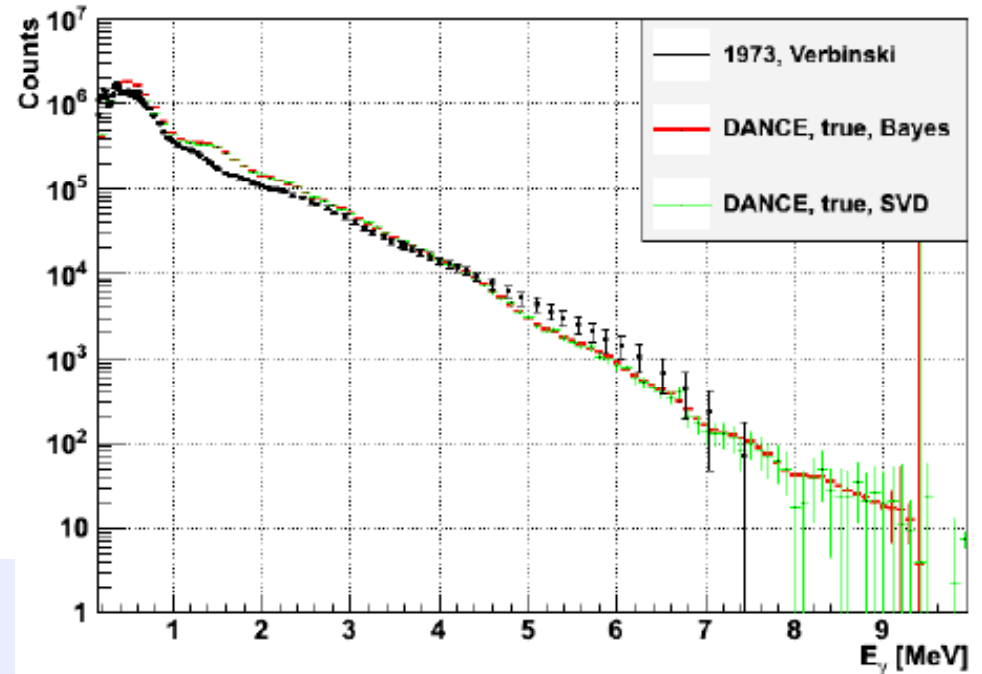
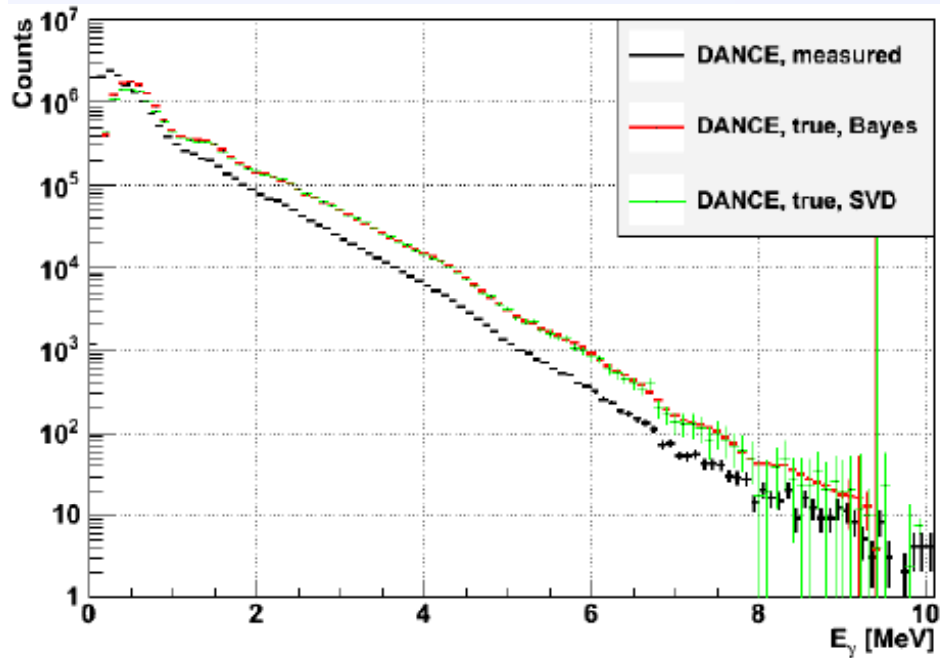
Prompt γ 's for the spontaneous fission in ^{252}Cf

- Measurement of the γ -ray energy and multiplicity distributions was carried out over a 5-day period in Jan 2011 with a source strength of $\sim 0.15 \mu\text{Ci}$
- The time resolution is ~ 2 ns between DANCE and PPAC, derived from the recorded waveforms of 500 Megasample/s Acqiris digitizers
- Both the γ -ray energy and multiplicity distributions were unfolded using the Bayesian approach and SVD (Singular Value Decomposition)
 - DANCE response was modeled by GEANT4 using the parameters validated with the calibration source, ^{22}Na , ^{60}Co , and ^{88}Y



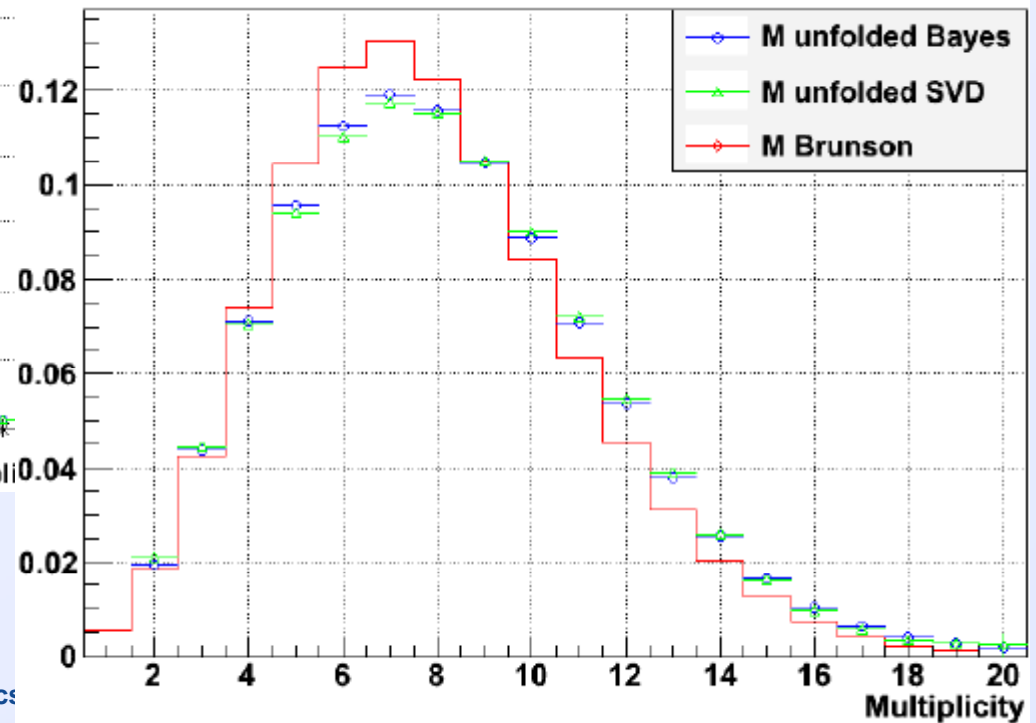
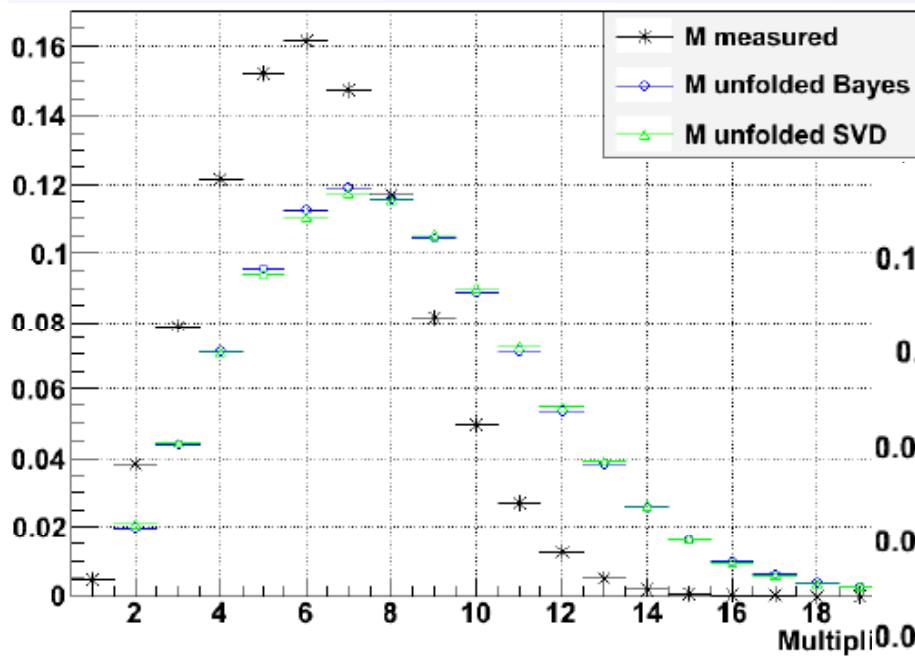
Prompt γ -ray energy distribution for the spontaneous fission in ^{252}Cf

- The γ -ray energy tapering off ~ 8 MeV was observed
- Both unfolded results agree with each other
- The discrepancy exists compared with the early results



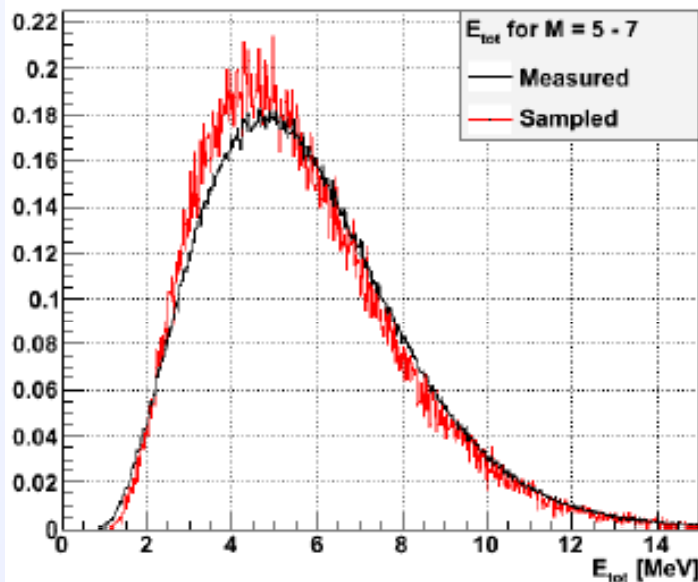
Prompt γ -ray multiplicity distribution for the spontaneous fission in ^{252}Cf

- The true prompt γ -ray multiplicity distribution in fission was derived for the first time
- The average multiplicity is higher than that of Brunson semi-empirical model



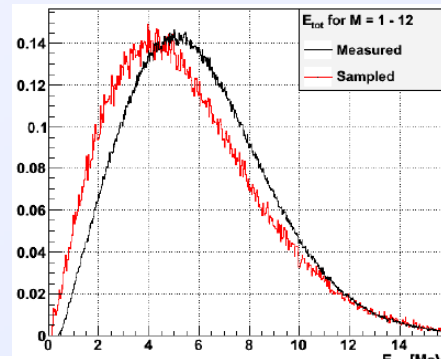
Stochastic aspect of prompt γ decays in fission

- Comparison of the total γ -ray energy between the measurement and the simulation by randomly sampling of both γ -ray energy and multiplicity distributions
- The total γ -ray distribution is well produced for the multiplicity between 5 and 7
 - Weak correlation between the γ -ray energy and multiplicity is evident
 - The averaging property of fission prompt γ decays can be described as stochastic process

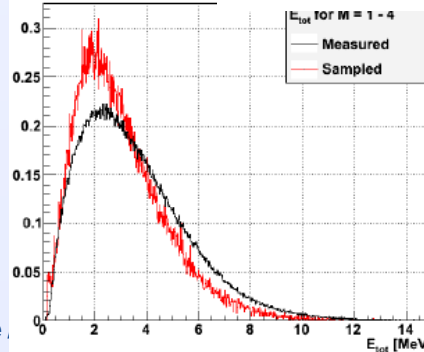


$M_\gamma = 5 - 7$

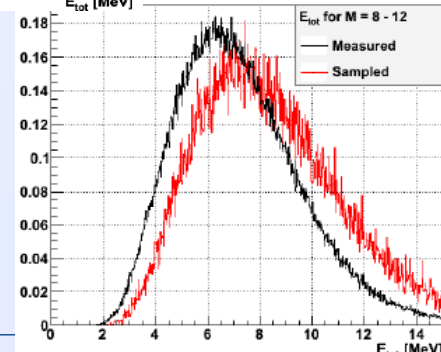
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$M_\gamma = 1 - 12$



$M_\gamma = 1 - 4$



$M_\gamma = 8 - 12$



Status of deliverables

1. $^{241}\text{Pu}(n, f \gamma)$
 - Experiment with a total mass of $\sim 147 \mu\text{g}$ was completed in Oct 2010
 - Preliminary data analysis was made
 - Final data analysis will be completed by Dec 2011 and the results will be published
2. $^{242\text{m}}\text{Am}(n, f \gamma)$
 - Data was collected in 2007
 - Abandoned due to the poor quality of data resulting from the poor performance of PPAC with an earlier design
3. $^{252}\text{Cf}(f, \gamma)$
 - Experiment with a source strength of $\sim 0.15 \mu\text{Ci}$ was completed in Jan 2011
 - The data analysis is completed
 - The results will be presented at CGS14 (invited talk) and published in the peer-reviewed journal



Workforce and budget

Home team: C.Y. Wu, A. Chyzh (PD), E. Kwan (PD), R. Henderson, J. Gositic (PD)

Wu, Chyzh, Kwan – target/counter development and assembling

Chyzh – data analysis

Henderson, Gostic – target fabrication and assembling

LANL collaborators: J. Ullmann, M. Jandel, T. Bredeweg, A. Couture, H.Y. Lee (PD), R. Haight, J. O'Donnell

Budget: \$84 K remaining as of Aug 6, 2011





Summary

- The unique combination of DANCE and PPAC allows one to study the proposed measurement of the prompt γ -ray energy and multiplicity distributions in fission.
- The unfolding of both distributions has been successfully carried out using Bayesian approach and SVD.
- A weak correlation between the γ -ray energy and multiplicity is evident and the stochastic aspect is identified for the averaging property in the prompt γ decays in fission
 - Important to the basic modeling and applications
- We will extend the current work to study the correlation between the total γ -ray energy and multiplicity in fission and its unfolded 2-D spectrum.
- It also is possible to extend the measurement to minor actinides relevant to the advanced fuel cycle.

