Lawrence Livermore National Laboratory

USNDP – CSWEG update of LLNL experimental activities
Sante Fe, NM
November 2, 2010

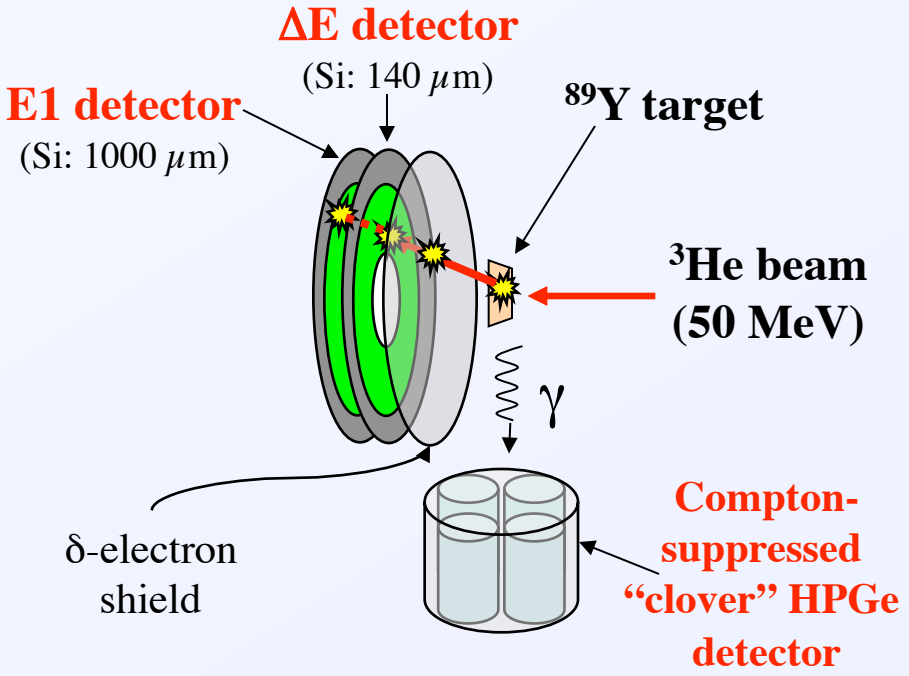
Jason T. Burke for LLNL and Collaborators

Lawrence Livermore National Laboratory, P. O. Box 808, Livermore, CA 94551

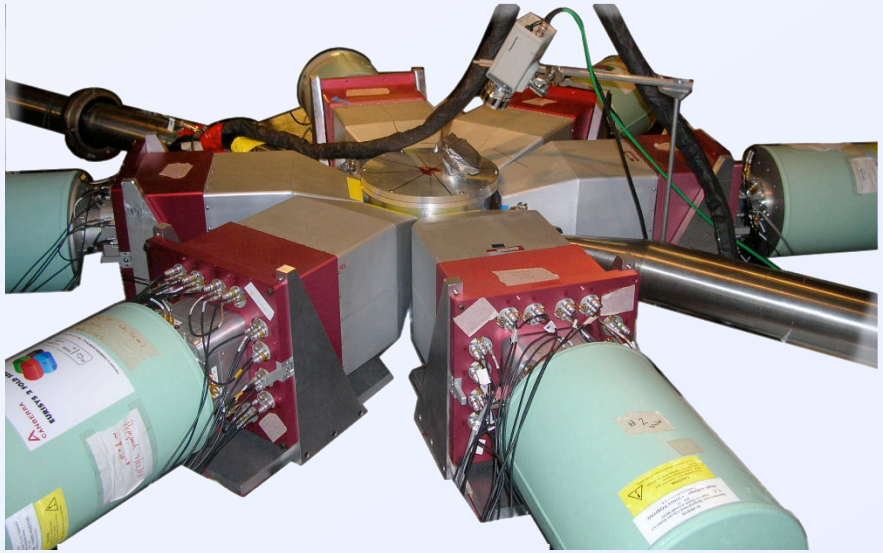
This work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

Experimental apparatus - STARS-LiBerACE now located in Cave 2 experimental hall @ 88Inch Cyclotron LBNL

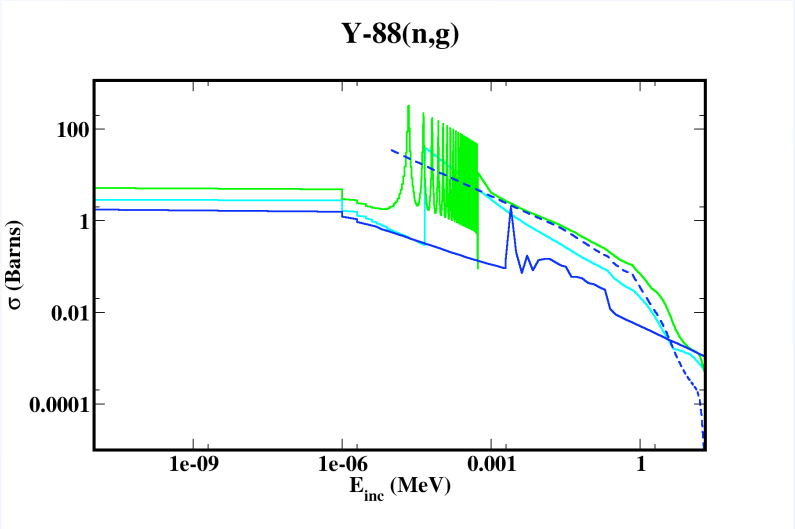
Detect scattered ^{3,4}He in segmented silicon detector array

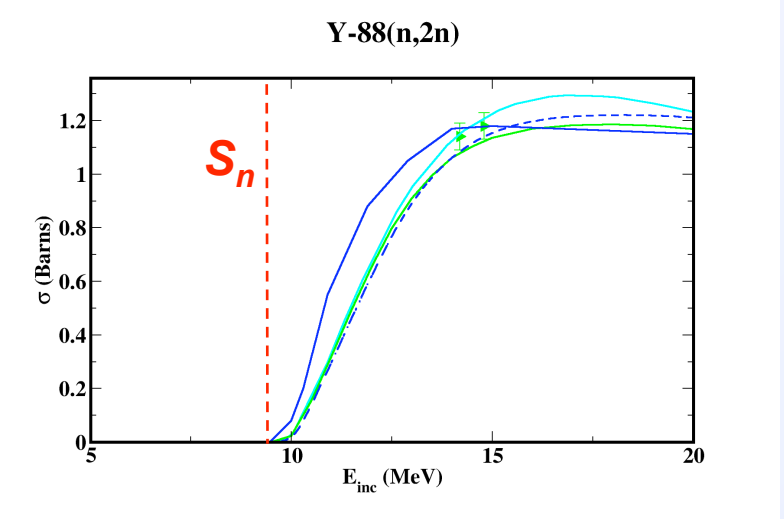


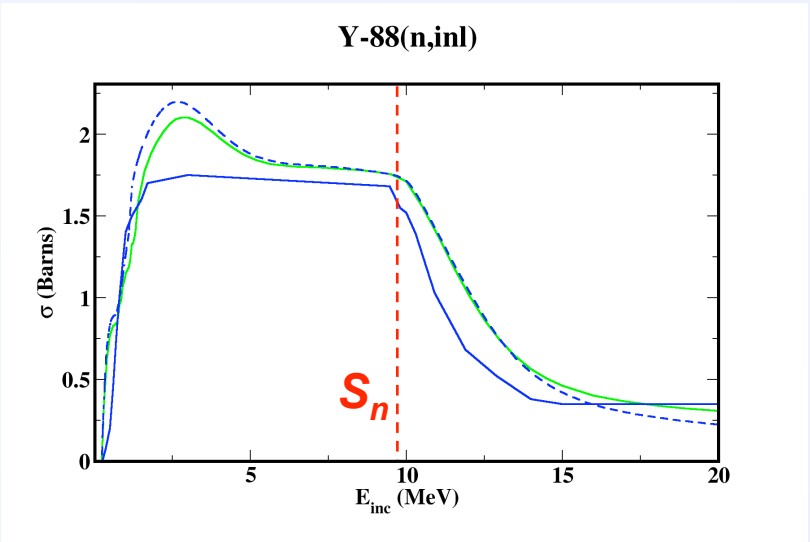
Coincident detection of characteristic γ-rays using an array of Compton-suppressed "clover" HPGe detectors



Evaluated cross sections for ^{88}Y







Figures courtesy of D. Brown, LLNL

Surrogate technique can determine many neutron-induced reactions…

Surrogate reaction

$^{89}Y(^{3}He,^{3}He')^{89}Y^{*}$ ←→ $^{88}Y + n$

Desired reaction

- $\gamma + {}^{89}Y^{*}$
- $n + {}^{88}Y^{*}$
- $2n + {}^{87}Y^{*}$
- $p + {}^{88}Sr^{*}$

compound nucleus

Main ^{88}Y creation and destruction reactions

Surrogate reaction

$^{89}Y(^{3}He,^{4}He')^{88}Y^{*}$ ←→ $^{87}Y + n$

Desired reaction

- $\gamma + {}^{88}Y^{*}$
- $n + {}^{87}Y^{*}$
- $2n + {}^{86}Y^{*}$
- $p + {}^{87}Sr^{*}$

compound nucleus

These channels are best identified by detecting γ rays in the de-excitation cascade

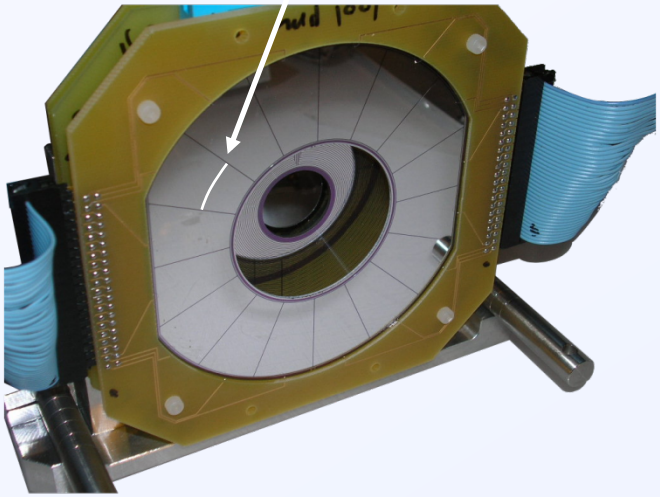
^{89}Y → stable (only stable Y isotope)

^{88}Y, ^{88m}Y → $t_{1/2}$ = 107 days, 13 hr

^{87}Y, ^{87m1}Y, ^{87m2}Y → $t_{1/2}$ = 3.3 days, 0.3 ms, 14 ms

Particle Detection example of ^{89}Y +^{3}He @ 50 MeV

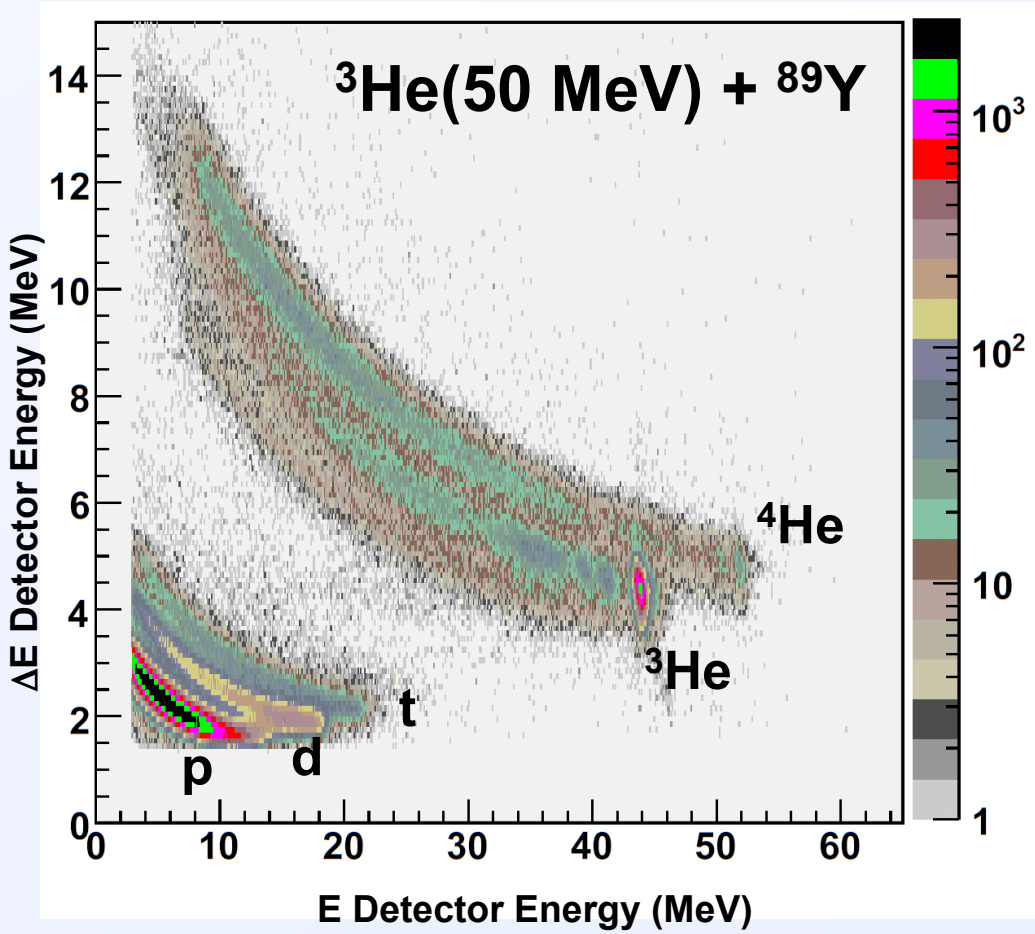
Individual “pixel”



Highly-segmented silicon array for particle identification and precise energy determination

Calibrated using ^{226}Ra α source (offline) and inelastic scattering off of discrete states in ^{12}C (online)

Detection positions allow “ray-tracing”

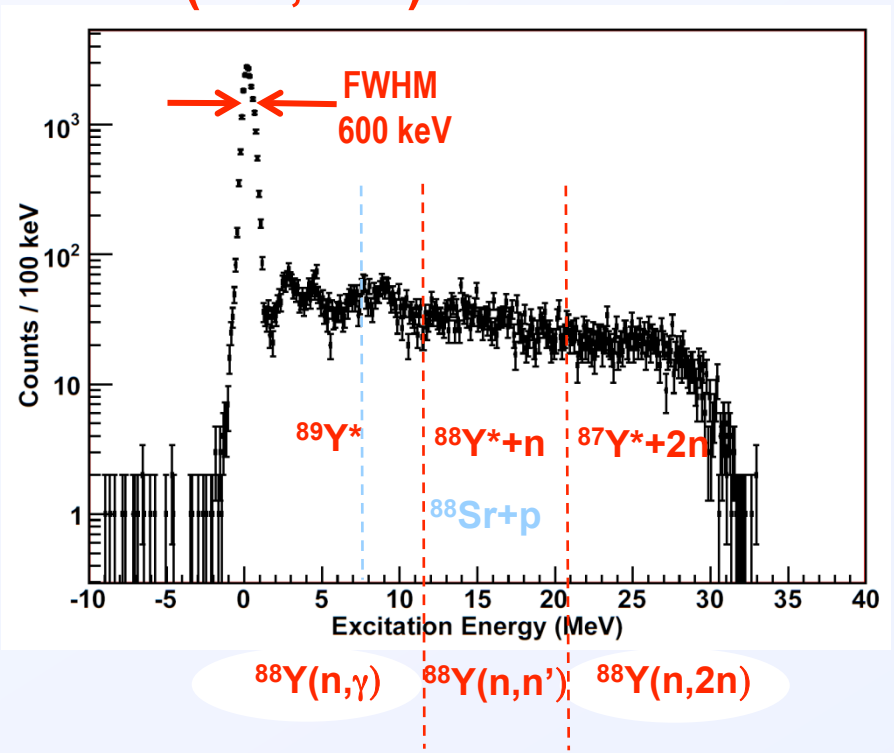


Determining $N_{(p,p')}$ Singles

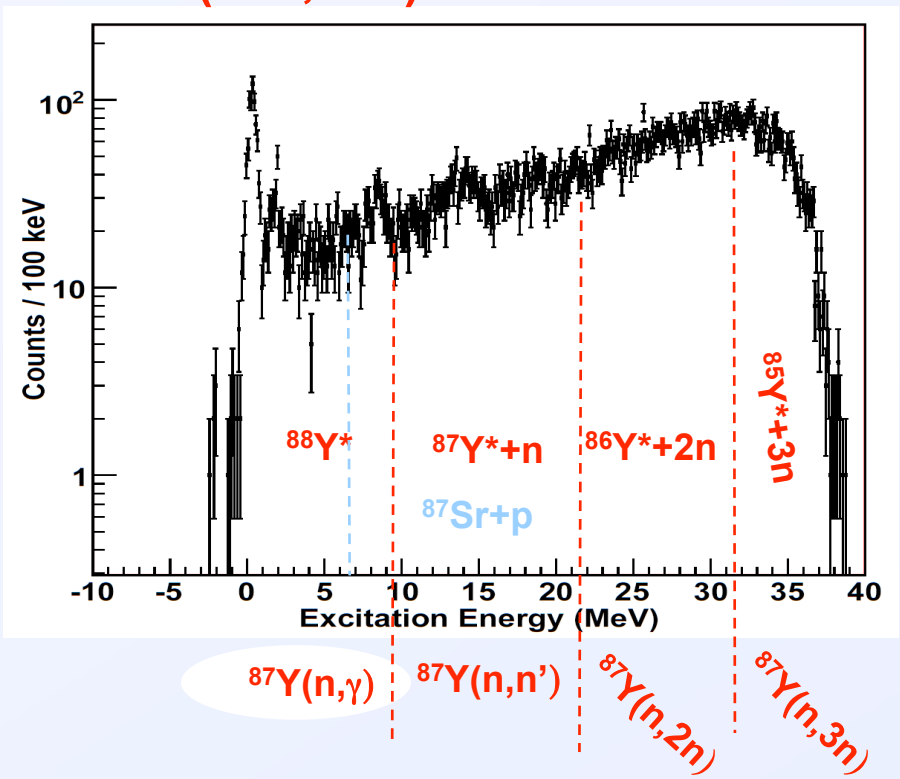
$$P_{(p,p\gamma)}(E_{ex}) = \frac{(1+\alpha_{IC})}{\varepsilon_\gamma f} \times \frac{N^{obs}_{(p,p\gamma)}(E_{ex})}{N^{obs}_{(p,p)}(E_{ex})}$$

Targets are self-supporting foil targets of pure monoisotopic ^{89}Y metal

^{89}Y(^{3}He,^{3}He')



^{89}Y(^{3}He,^{4}He)

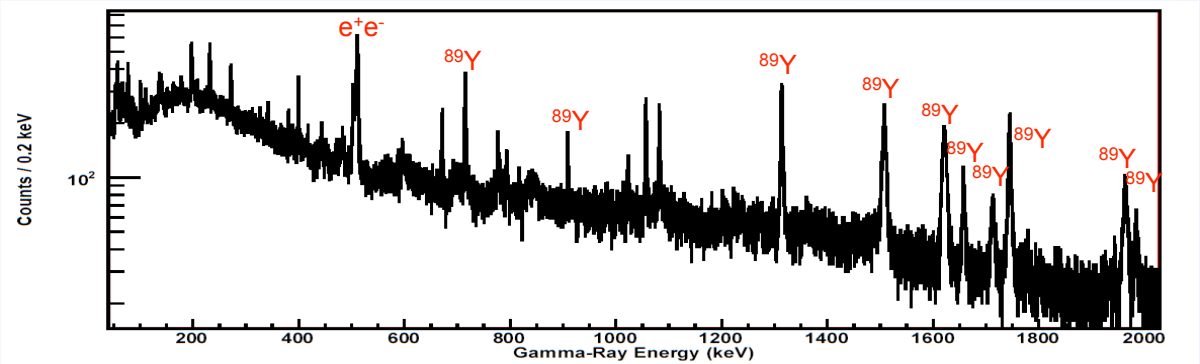


Equivalent energy range E_n = 0.3-21 MeV

Equivalent energy range E_n = 0.3-28 MeV

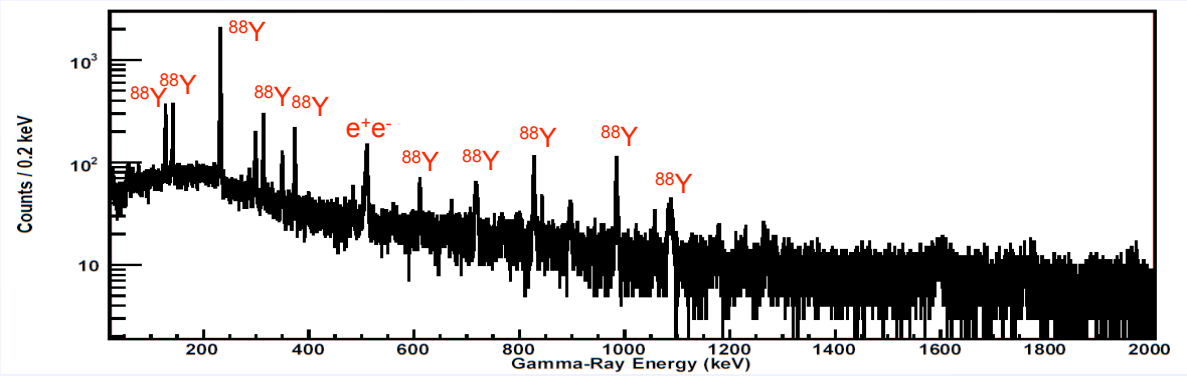
γ-ray cascade in coincidence with ^{3}He

$$P_{(p,p\gamma)}(E_{ex}) = \frac{(1+\alpha_{IC})}{\varepsilon_{\gamma} f} \times \frac{N^{obs}_{(p,p\gamma)}(E_{ex})}{N^{obs}_{(p,p)}(E_{ex})}$$



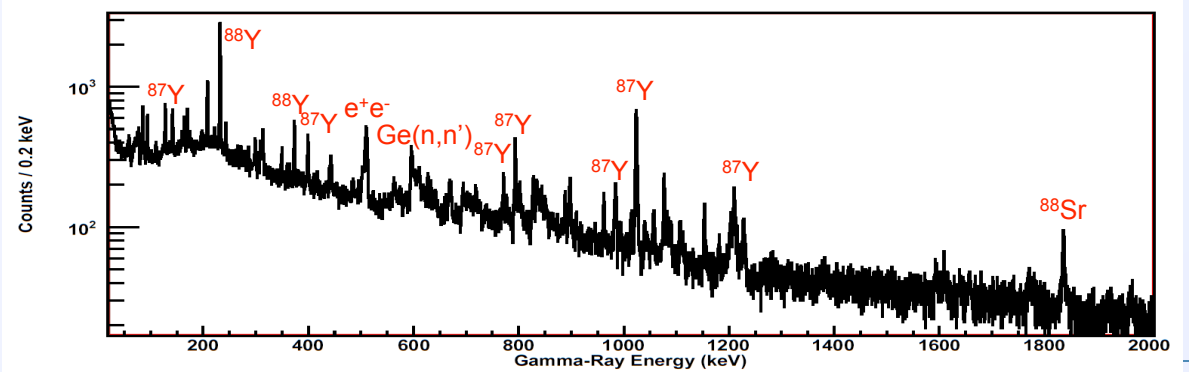
^{89}Y*

$0<E_{ex}<S_n$



^{88}Y*

$S_n<E_{ex}<S_{2n}$



^{87}Y*

$S_{2n}<E_{ex}<S_{3n}$

Nuclear Structure of ^{87,88}Y

SSAA Collaborators (C.W. Beausang of U. Richmond and others)

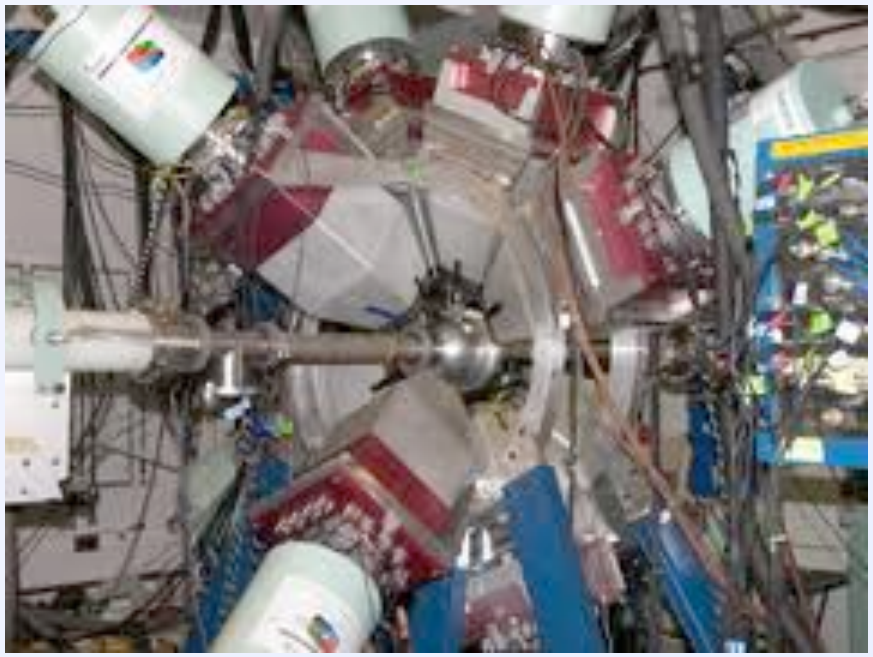
Experiment bombarding ^{89}Y target using ^{18}O beams at 60-90 MeV to tie down structure of ^{87,88}Y better

- Search for other transitions to ^{88m2}Y
- Existence of low-lying 7^+ state in ^{88}Y?
- Filling in of excited states and decay branching ratios

2 weeks of beamtime using WNSL's Van de Graaff accelerator and YRASTBALL

A.W. Wright Nuclear Structure Laboratory

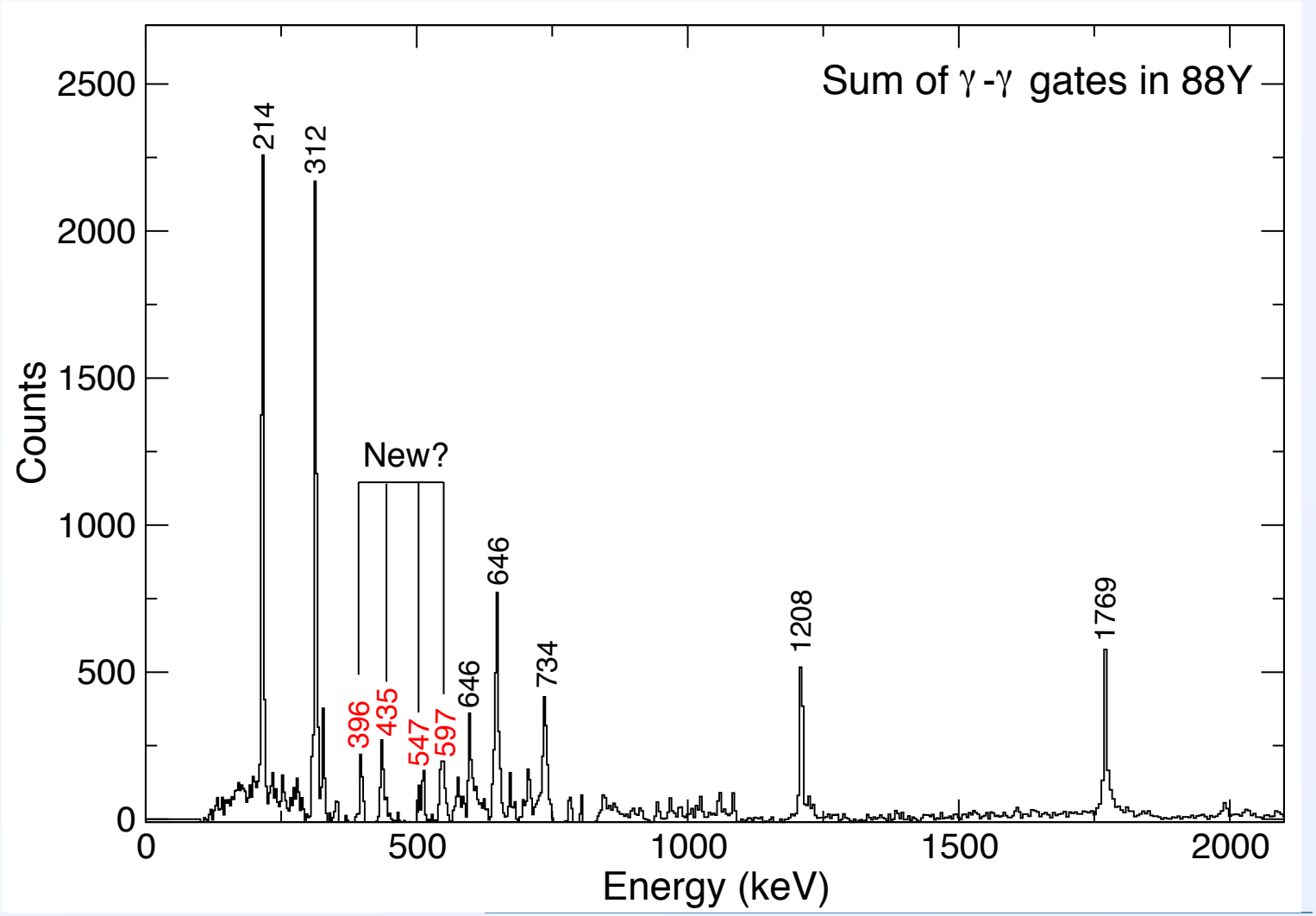
Yale University | PO Box 208120 | New Haven, CT 06520-8120



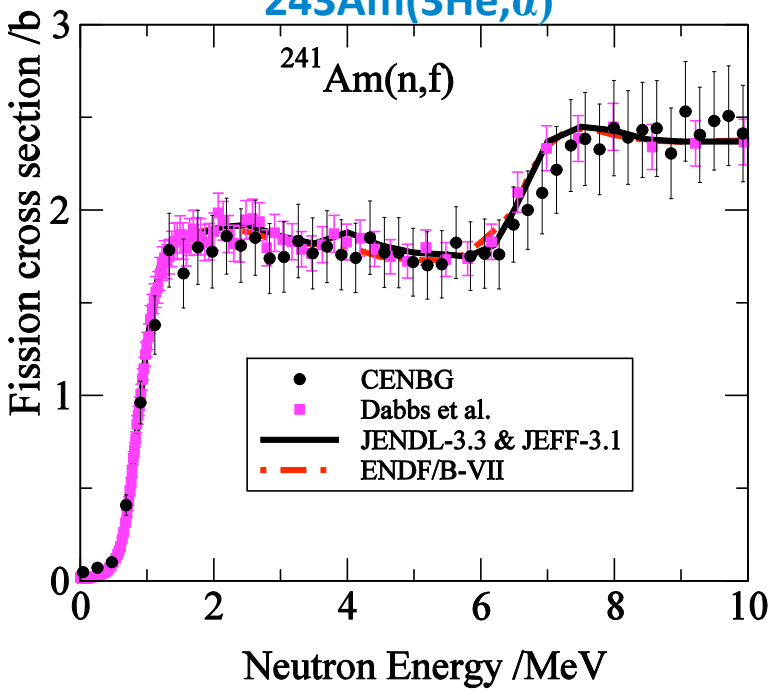
YRASTBALL → array of HPGe Clover detectors

Preliminary Analysis of ^{88}Y $\gamma-\gamma$ gates

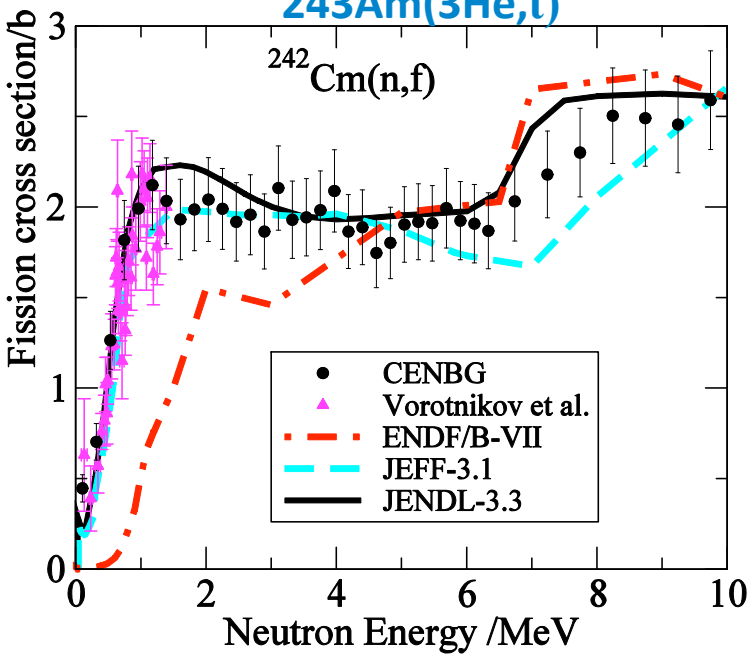
R. Hughes et al., Richmond and Surrey collaborators



243Am(3He,α)



243Am(3He,t)

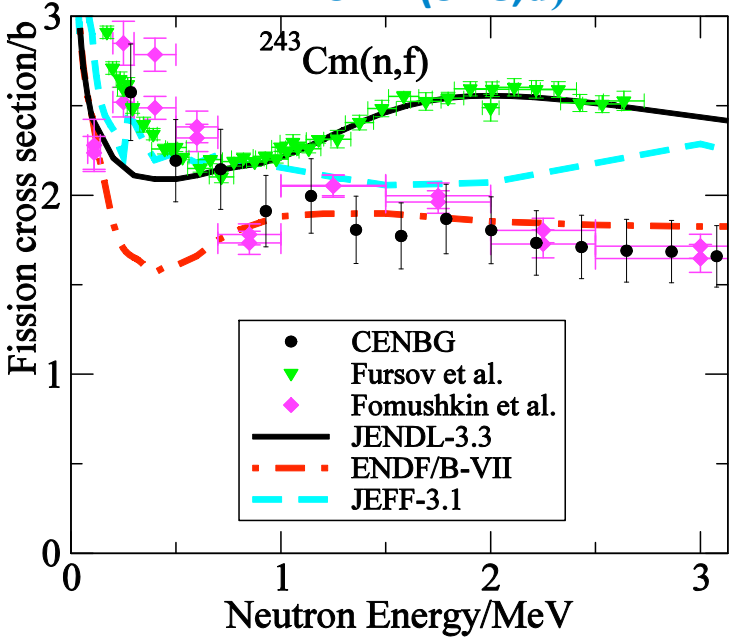


. Our surrogate 241Am XS is in very good agreement with the well known neutron-induced fission XS.

. For the first time, the 242Cm fission XS has been determined up to the onset of second-chance fission.

. New data for 243Cm with discrepancies with Fursov data but in good agreement with Formushkin data.

243Am(3He,d)

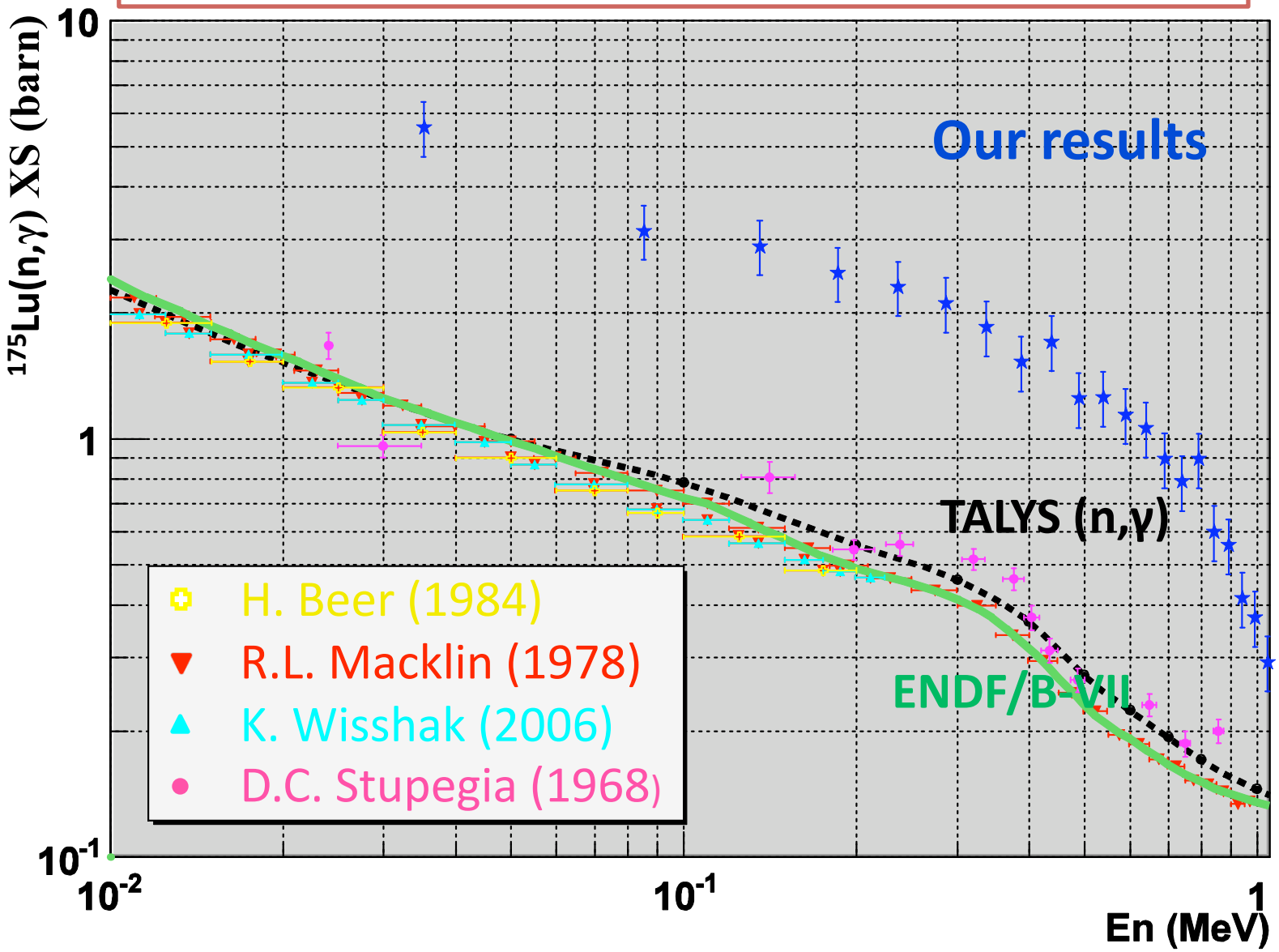


Phys. Lett. B, Volume 692, Issue 5, 13 September 2010, pages 297-301

Orsay Tandem measurement in collaboration with BIII, CENBG and LLNL

Feb. 2010 Courtesy Guillaume Boutoux CENBG

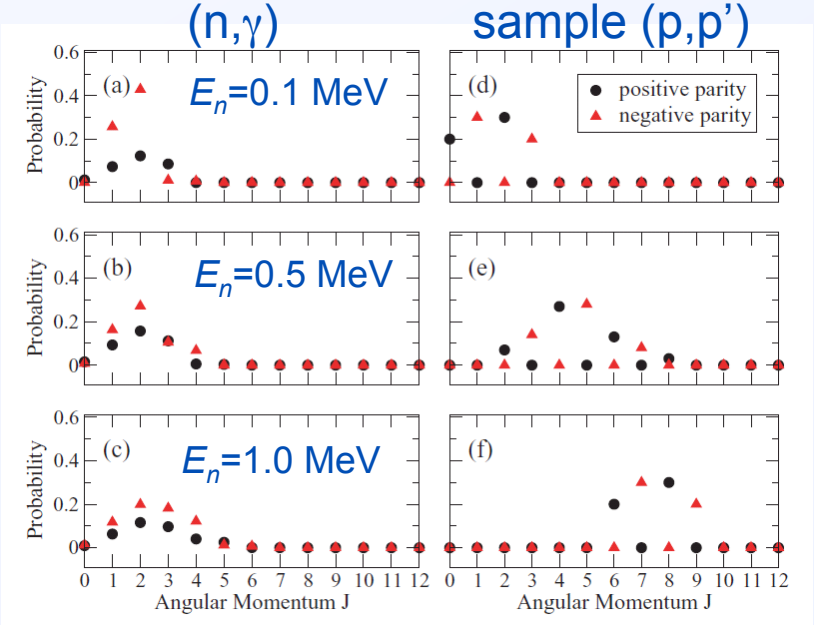
$^{174}Yb(^{3}He,p\gamma)^{176}Lu^{*}$ as surrogate reaction for $^{175}Lu(n,\gamma)$



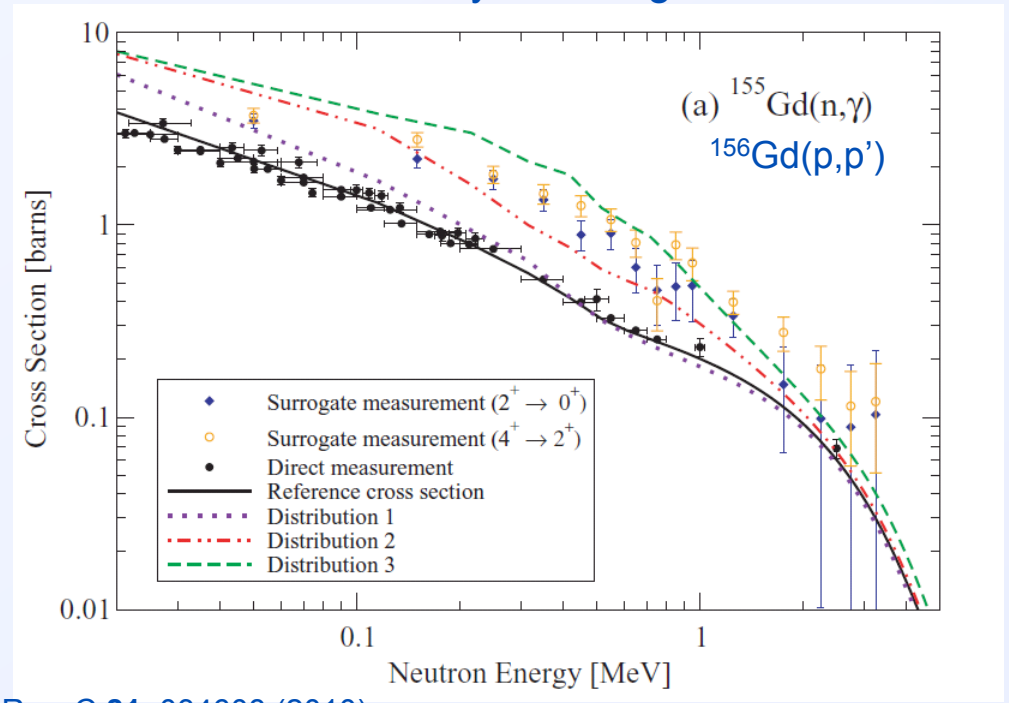
Benchmark measurements in nearby well-studied regions (Zr/Mo) are needed to guide theory

Tools under development for Gd to determine J^{π} of compound nucleus and correct for this effect in the cross sections will be used for Y

J^{π} distribution of surrogate reaction $\neq$ desired reaction

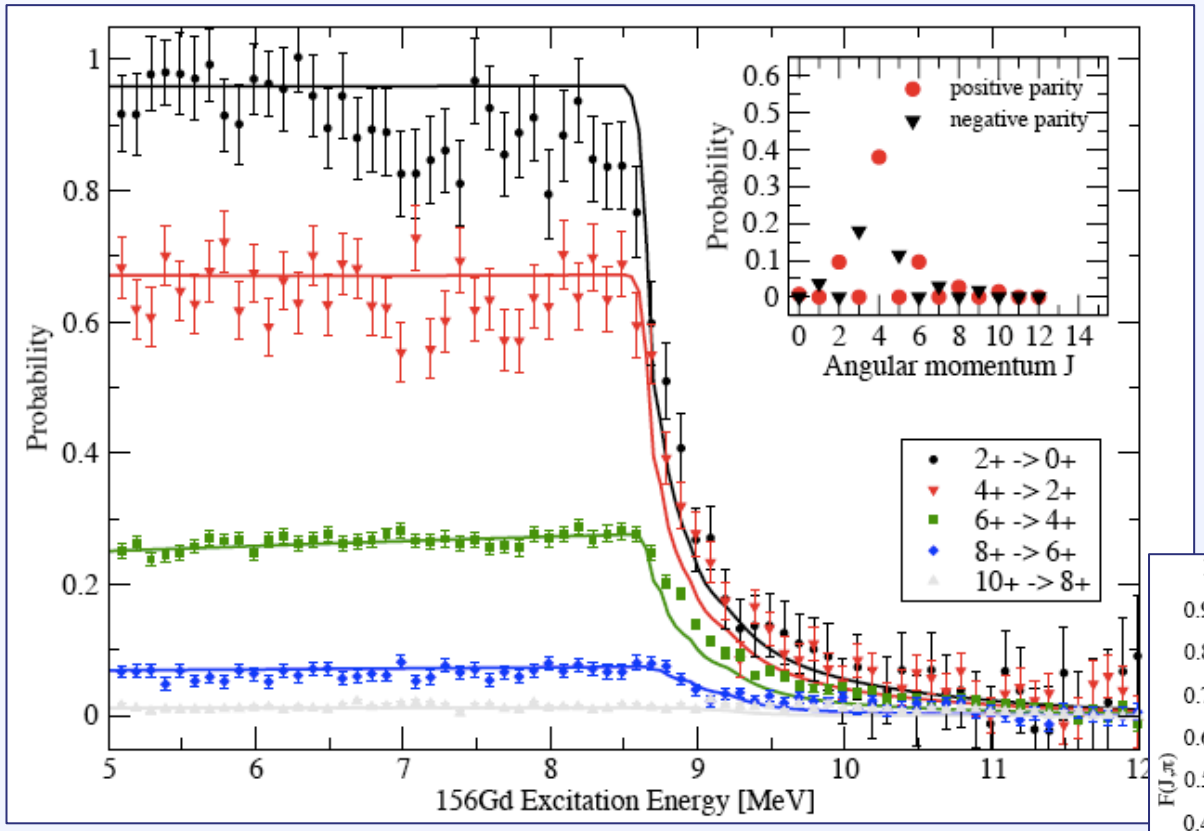


Experiment performed to determine ^{155}Gd(n,γ) cross section sensitivity to surrogate reaction J^{π}



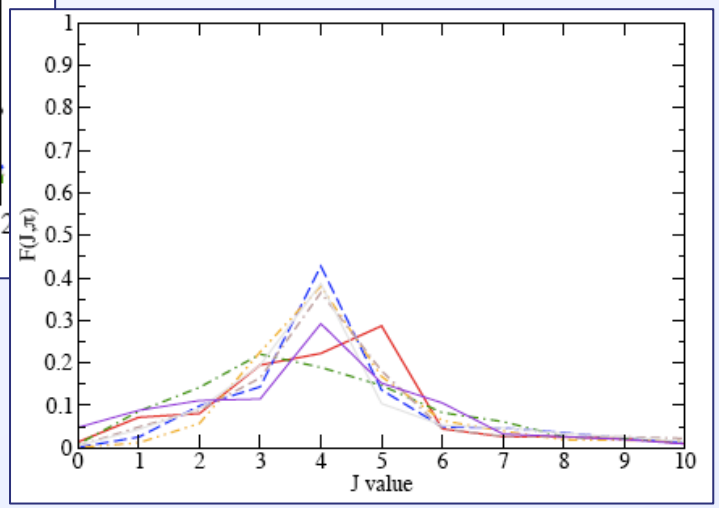
N.D. Scielzo *et al.*, Phys. Rev. C **81**, 034608 (2010)
J.E. Escher and F.S. Dietrich, Phys. Rev. C **81**, 024612 (2010)

Extracting the Surrogate (p,p') spin distribution: result for ^{156}Gd (Nick Scielzo and Jutta Escher)



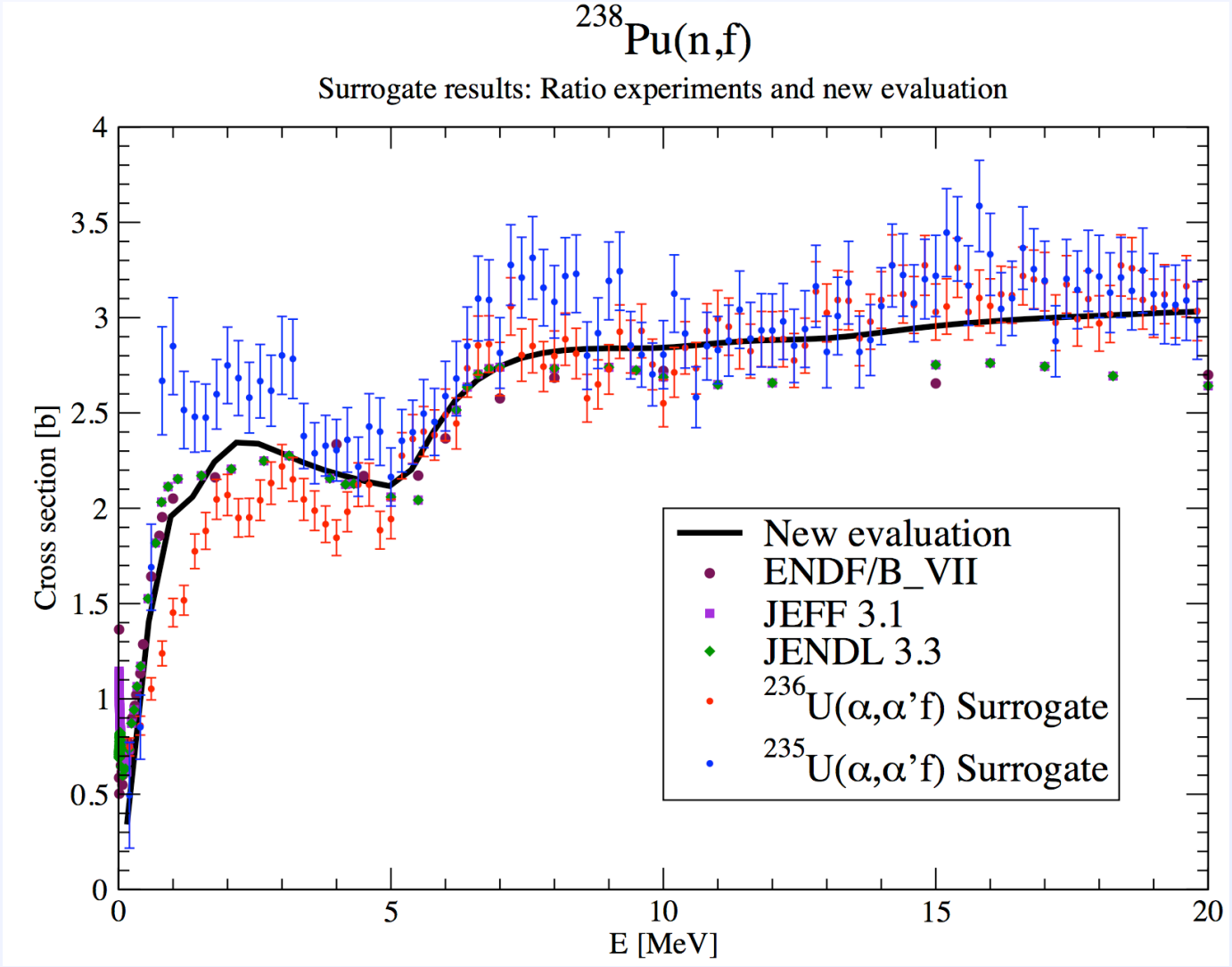
Cross sections determined once spin differences accounted for → also required for determination of reactions on isomers

Best-fitting spin distributions

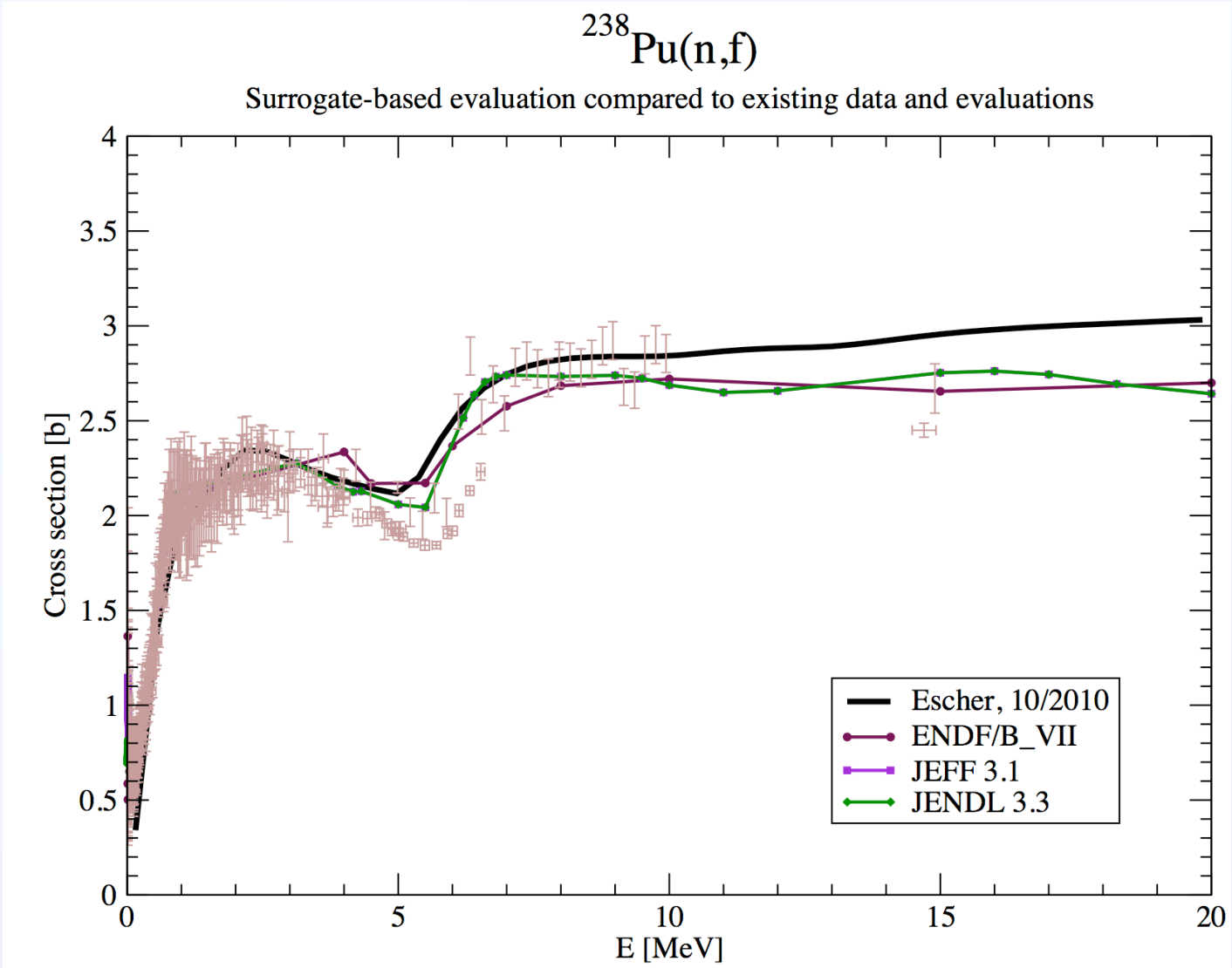


Results are being used to determine (n,γ) cross section for ^{153}Gd ($t_{1/2}$=242 day)

Surrogate ^{238}Pu(n,f) from ^{239}Pu(α,α') ratio measurement (Jo Ressler, Jutta Escher & Jason Burke)

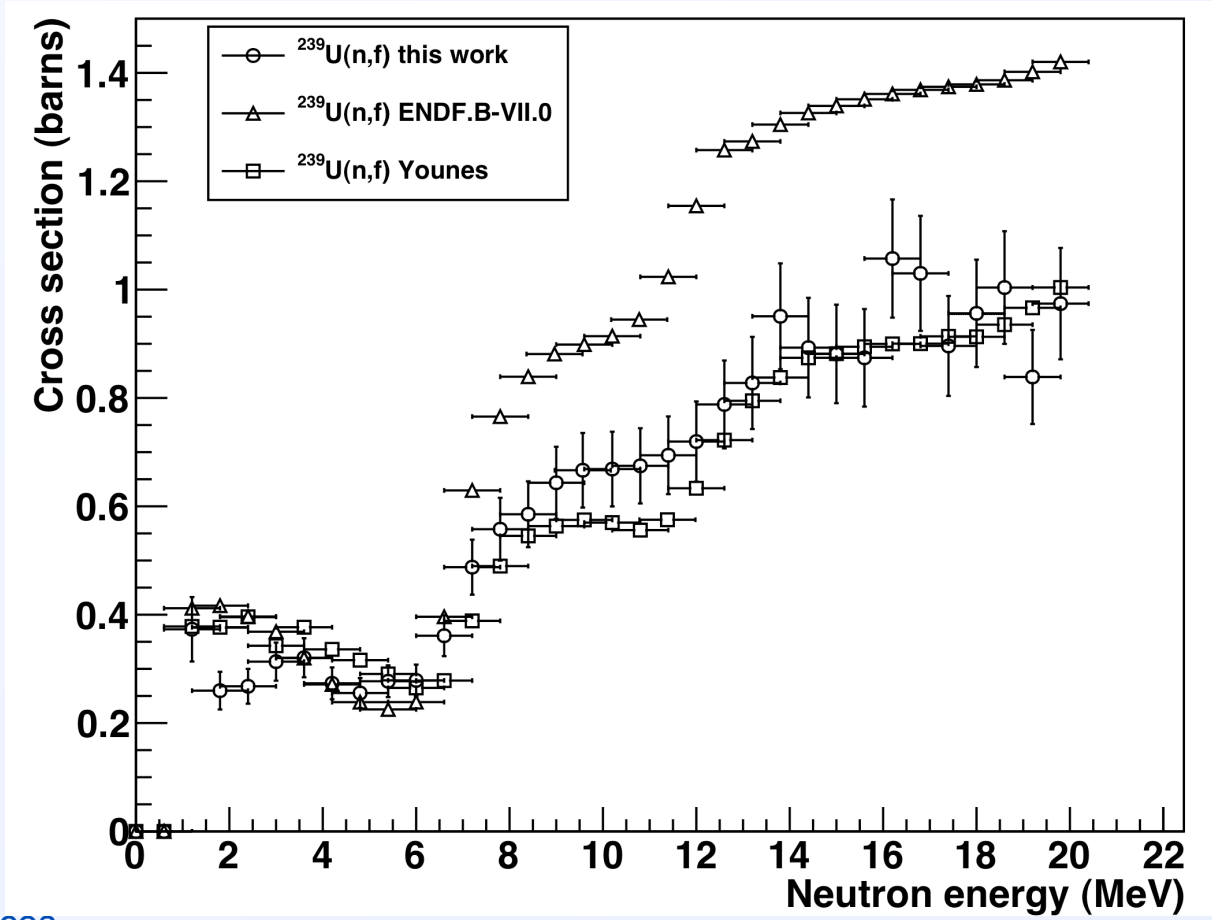


Current ^{238}Pu(n,f) data/evaluation

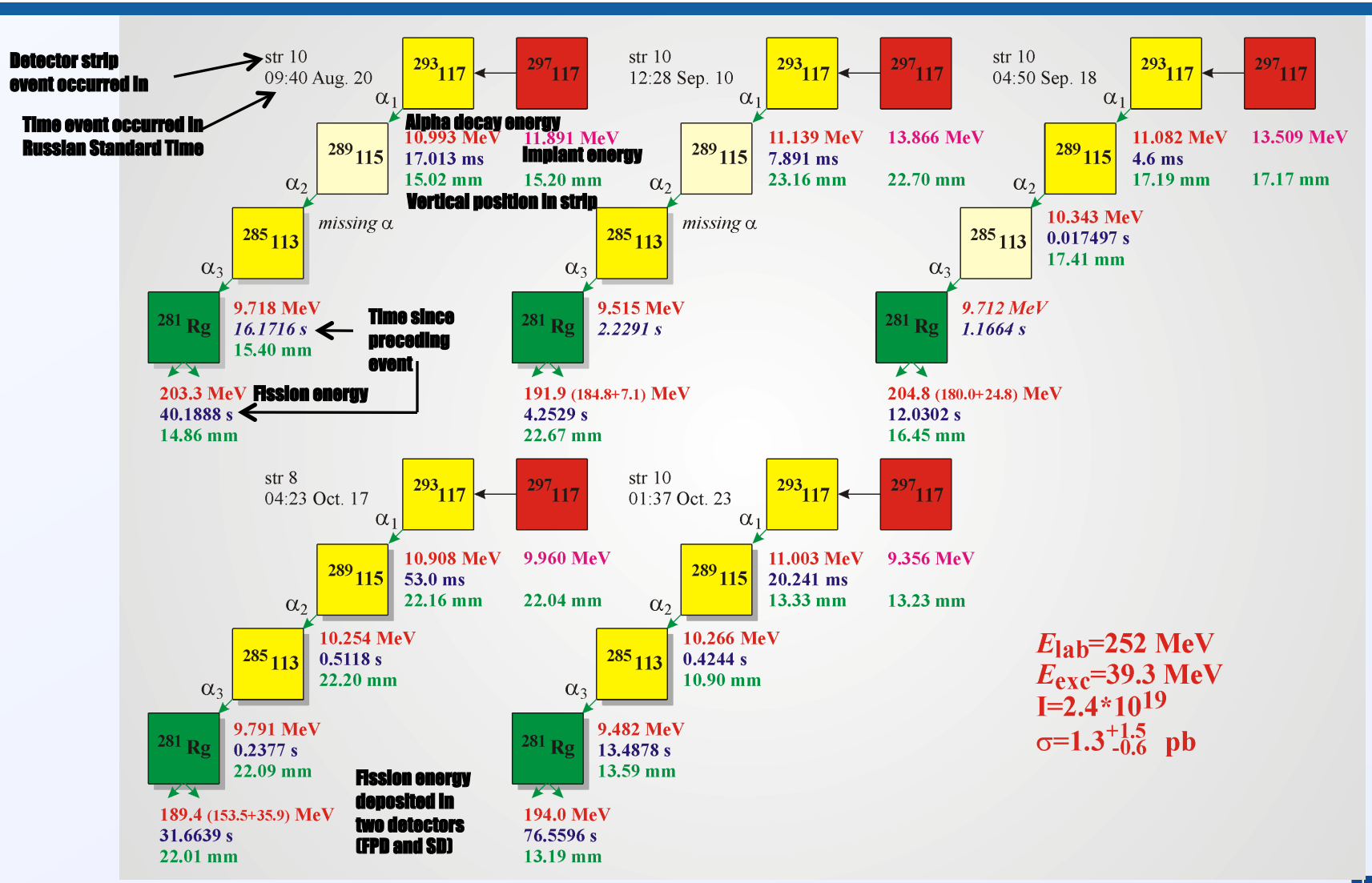


$^{239}U(n,f)$ ($\tau_{1/2}$=24minutes) determined from $^{238}U(^{18}O,^{16}Of)^{240}U$ and $^{234}U(^{18}O,^{16}Of)^{236}U$ (Burke & Escher)

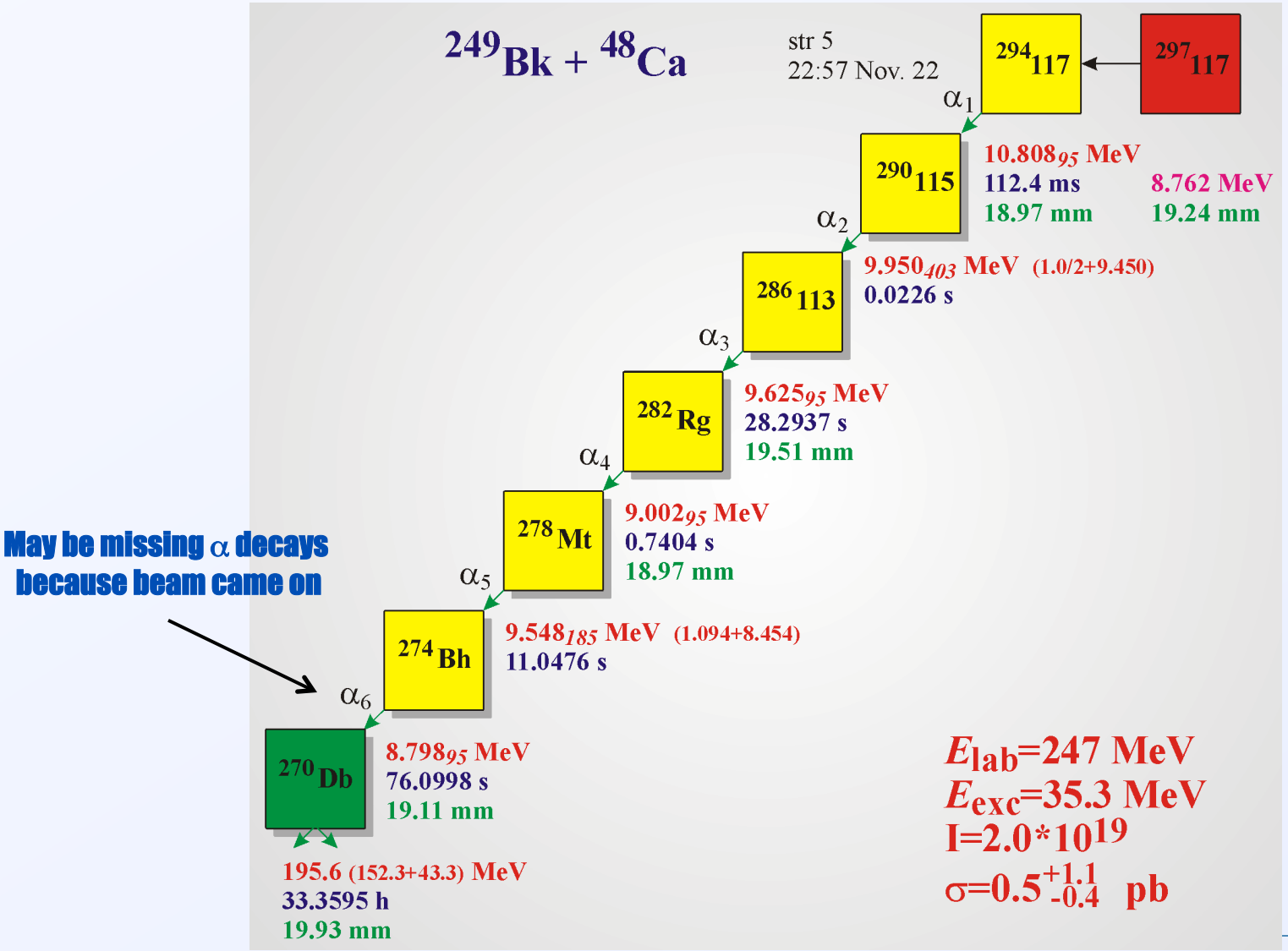
$$\sigma\left(^{239}U(n,f)\right) = \frac{N_{p-f}(^{238}U(^{18}O,^{16}Of))}{N_{p-f}(^{234}U(^{18}O,^{16}Of))} \times \sigma\left(^{235}U(n,f)\right)$$



Element 117: Five decay chains were observed during the initial run (Courtesy Mark Stoyer for LLNL team)

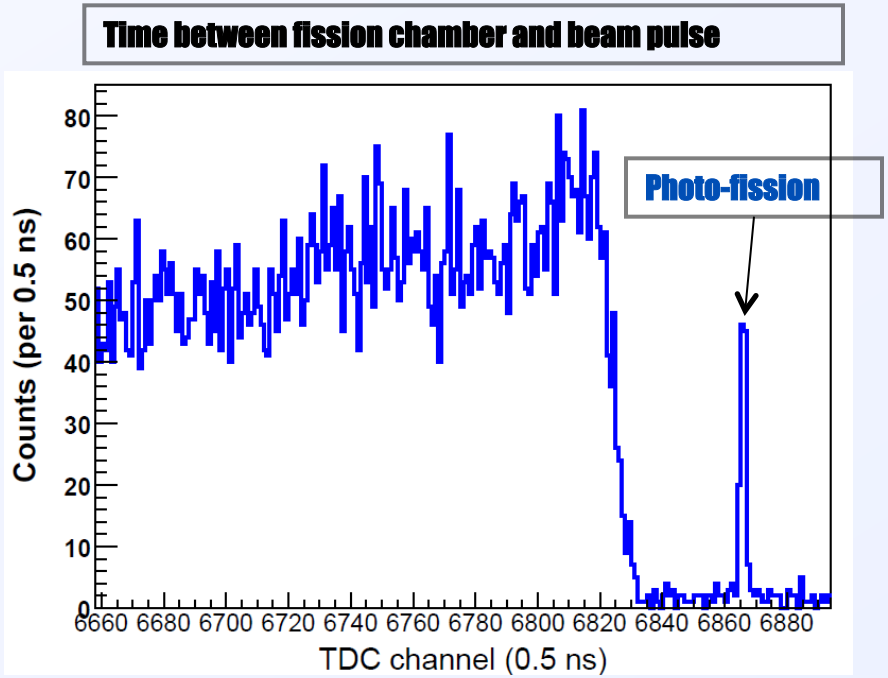


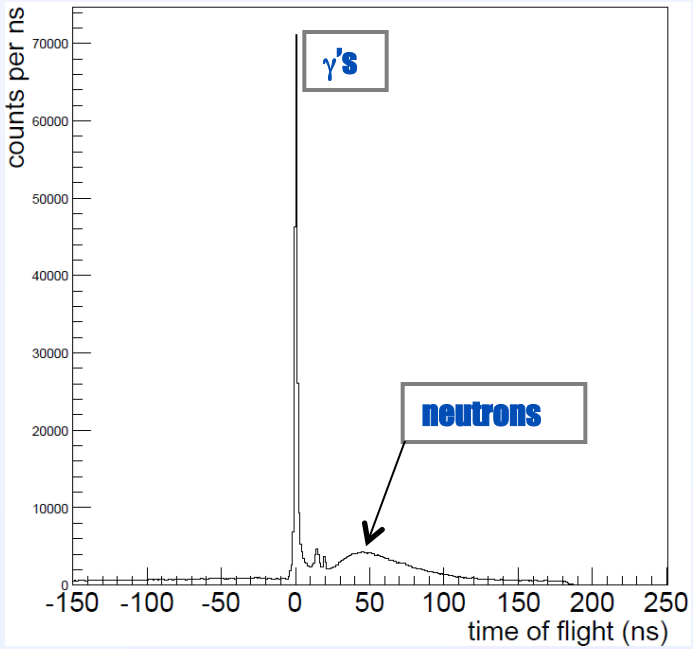
The beam energy was lowered and an additional, different decay chain, was observed



Fission neutron spectrum measurement (Courtesy C.Y. Wu)

- A 113 mg ^{235}U fission chamber was successfully assembled in LLNL and fielded in LANSCE/WNR together with Chi-Nu neutron detector array in 2010.
- Both liquid and ^{6}Li-glass scintillators were used for the neutron detection.
- Nanosecond time resolution was achieved and the data analysis in progress.
- A ^{239}Pu fission chamber will be assembled in 2011 for experiment.



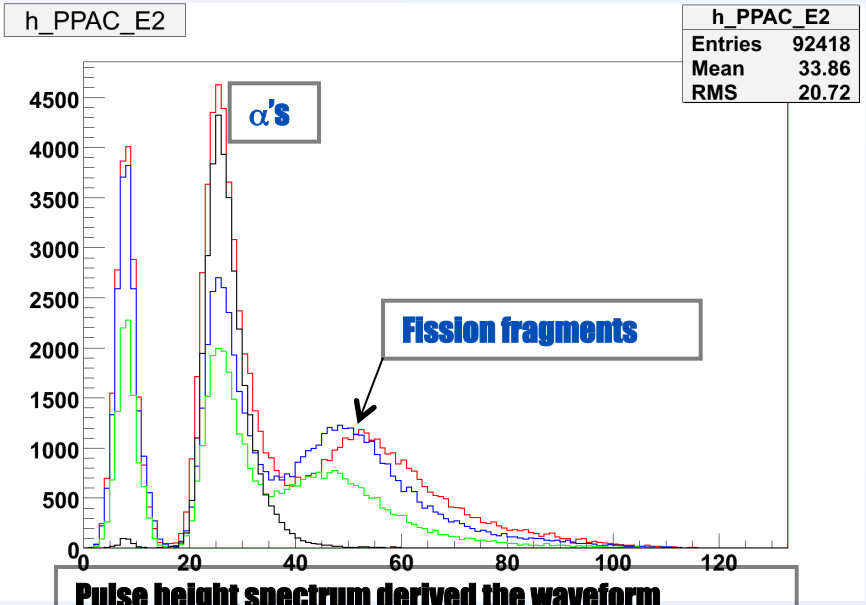


Time between fission chamber and liquid scintillator

Direct neutron-induced capture and fission measurement

- Measurements have been made for ^{239}Pu and ^{241}Pu using a newly LLNL designed fission chamber together with the DANCE array at LANSCE/Lujan center in 2010.
- Fission chamber works very well despite extreme radioactivity (~ 2 x 10^6 α /s for nearly one milligram ^{239}Pu and ~ 0.5 x 10^9 β /s for 147 μg ^{241}Pu). The data analysis is in progress.
- Measurements for ^{238}Pu and ^{235}U are planned for 2011.

Assembled fission chamber with the signal transmission line, protruded from the counter container.



Pulse height spectrum derived the waveform recorded for the fission chamber. Different colors represent the data from different runs.

Upcoming work on CS for FY10

-Continue to develop surrogate method reaction theory Ian Thompson & Jutta Escher

-Measure (n,gamma) and/or (n,2n) cross sections in Y/Zr region - LLNL

-Measure ^{238}Pu(n,2n) cross section over energy range of 0 to 20 MeV – LLNL

-Measure ^{23x}Np(n,f) cross section – UCB/Donuts

-Collaborate with French labs BRC/CENBG to measure ^{17x}Lu(n,gamma) cross sections using surrogate technique

-Start collaboration with Tokai group under Dr. S.Chiba – surrogate method

-New People coming to join the Collaboration:

-Richard Hughes- Post-Doc, University of Richmond/SSAA

Ultimate goal of the Surrogate Program is to be able to measure cross sections in inverse kinematics experiments at FRIB

Collaborators (students in red post-docs underlined)

L.A. Bernstein, D. Bleuel, J.T. Burke, F.S. Dietrich, J.E. Escher, R. Henderson, K. Moody, N.D. Scielzo, M. Stoyer, I. Thompson, and M. Wiedeking

Lawrence Livermore National Laboratory

L. Phair, M.S. Basunia, P.Fallon, R.M. Clark, I.Y. Lee, and A.O. Macchiavelli

Lawrence Berkeley National Laboratory

C.W. Beausang* and J.M. Allmond

University of Richmond

T. Ross

University of Surrey

J.J.Ressler* and J.A.Caggiano*

Pacific Northwest National Laboratory

J.A. Cizewski**, P.D. O'Malley and T. Swan

Rutgers University

E.B. Norman, R. Hatarik*, B.L. Goldblum, and C. Angell

University of California Berkeley

D. A. Meyer

Rhodes College

Now at LLNL

****Taking sabbatical at LLNL***

Talk LLNL, October 2010

Livermore - US

Neutron-induced cross sections via the surrogate method

G. Boutoux[1], B. Jurado[1], V. Méot[2], O. Roig[2], M. Aïche[1], A. Bail[2] ,
G. Barreau[1], E. Bauge[2], J.T. Burke[8] , N. Capellan [1], I. Companis[1], S.Czajkowski [1],
J.M. Daugas [2], X. Derkx[5] , T. Faul[2] , L. Gaudefroy [2], F. Gunsing[4], B. Haas[1],
G. Kessedjian[7],L. Mathieu[1], P. Morel[2], N. Pillet[2], P. Romain[2],
K.-H. Schmidt[1], O. Sérot[3] , J. Taieb[2], L. Tassan-Got[6], I. Tsekhanovich[1]

[1]Centre d'Etudes Nucléaires de Bordeaux Gradignan, CNRS/IN2P3, Université Bordeaux 1, FRANCE

[2]CEA – DAM – DIF

[3]CEA – Cadarache , DEN/DER/SPRC/LEPh

[4]CEA – Saclay , DSM/DAPNIA/SPhN

[5]Grand Accélérateur National d'Ions Lourds, CNRS/CEA

[6]Institut de Physique Nucléaire d'Orsay, CNRS/IN2P3

[7]LPSC Grenoble, CNRS/IN2P3

[8]Lawrence Livermore National Laboratory, California, USA

Personnel for neutron induced measurements

- LLNL: C.Y. Wu, A. Chyzh (PD), E. Kwan (PD), R. Henderson, J. Gostic (PD), J.A. Becker (LA)
- LANL (Chi-Nu): R.C. Haight, H.Y. Lee (PD), J. O'Donnell, A.B. Laptev (PD), R. Nelson, M. Devlin, J. Ullmann, N. Fotiades, D. Vieira, T. Bredeweg, M. Jandel
- LANL (DANCE): T.A. Bredeweg, A. Couture, M. Jandel, J. Ullmann, A.B. Laptev (PD)