Nuclear Science and Security Consortium
Virtual Scholar Showcase 2020

Statistical Nuclear Properties of ^{93}Sr for National Security Applications

June 2, 2020

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UC Berkeley

NUCLEAR SCIENCE and SECURITY CONSORTIUM

June 2 - 3, 2020

Introduction

Ph.D. Candidate, Department of Nuclear Engineering
University of California, Berkeley

Thesis:
"Constrained Nuclear Level Density and γ-Decay Strength for the ^{92}Sr(n,γ) Reaction"
Expected filing Summer 2020

Academic Advisor : Professor Jasmina Vujic
LLNL Mentor: Dr. Darren L. Bleuel

NSSC
NUCLEAR SCIENCE and SECURITY CONSORTIUM

Collaborative Mission Relevant Nuclear Physics

NNSA
National Nuclear Security Administration

Impact of neutron-induced reactions and β-decay in fundamental nuclear physics and applied science applications

- *U.S. Stockpile Stewardship Program (SSP)*
- *Nuclear Forensics*
- *Nuclear Energy*
- *Nuclear Astrophysics*
- *Nuclear Structure*

Lawrence Livermore National Laboratory

Dr. Nicholas D. Scielzo

Dr. Darren L. Bleuel

NSCL

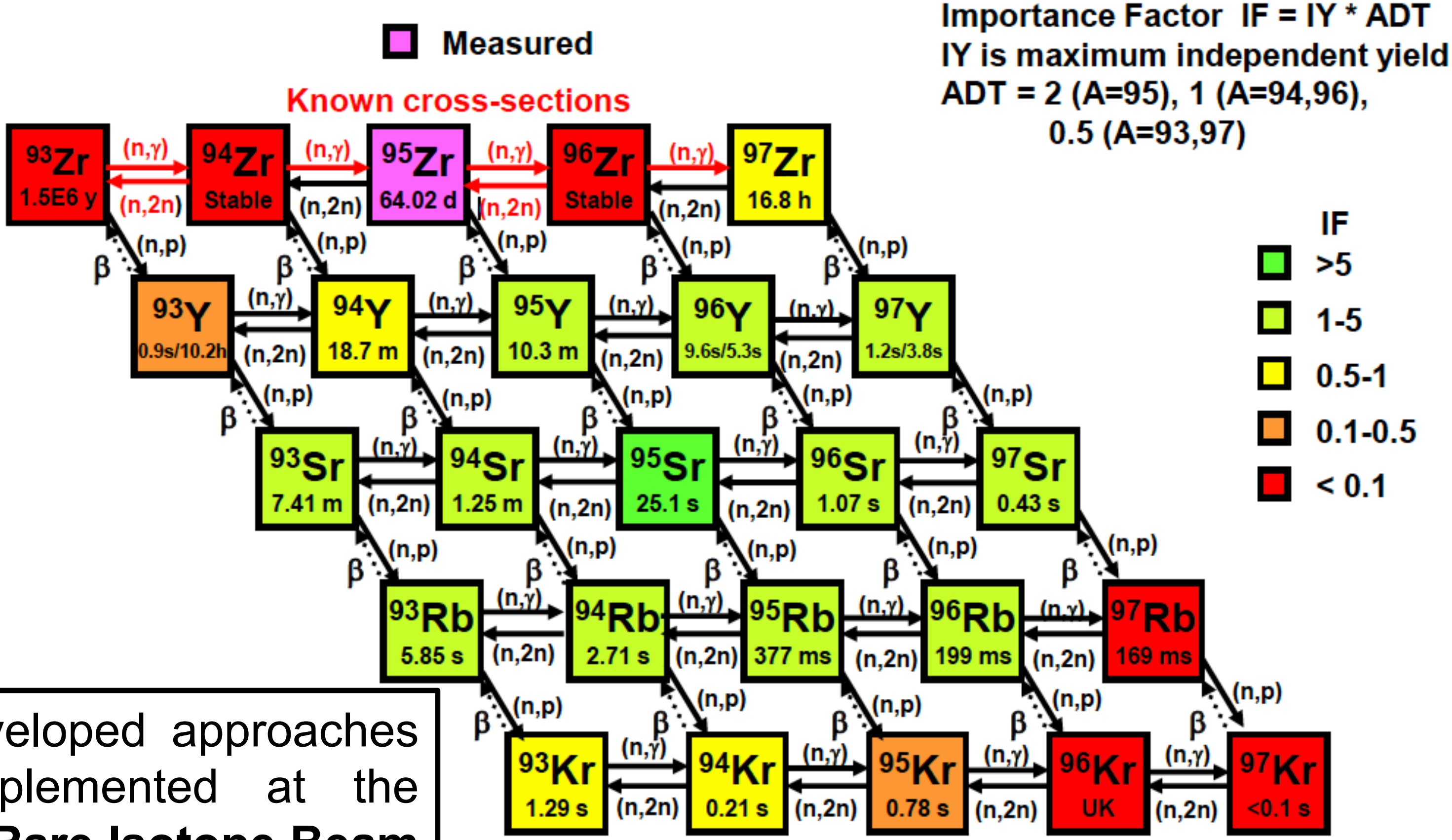
National Superconducting Cyclotron Laboratory

Dr. Artemis Spyrou

Dr. Sean N. Liddick

A~95 in a fission environment

Importance Factor IF = IY * ADT
IY is maximum independent yield
ADT = 2 (A=95), 1 (A=94,96), 0.5 (A=93,97)



Future: Developed approaches will be implemented at the **Facility for Rare Isotope Beam (FRIB)** to explore the limits of the known nuclides.

Meeting Isotope Needs and Capturing Opportunities for the Future: The 2015 Long Range Plan for the DOE-NP Isotope Program, *NSAC Isotopes Subcommittee,* July 20, 2015

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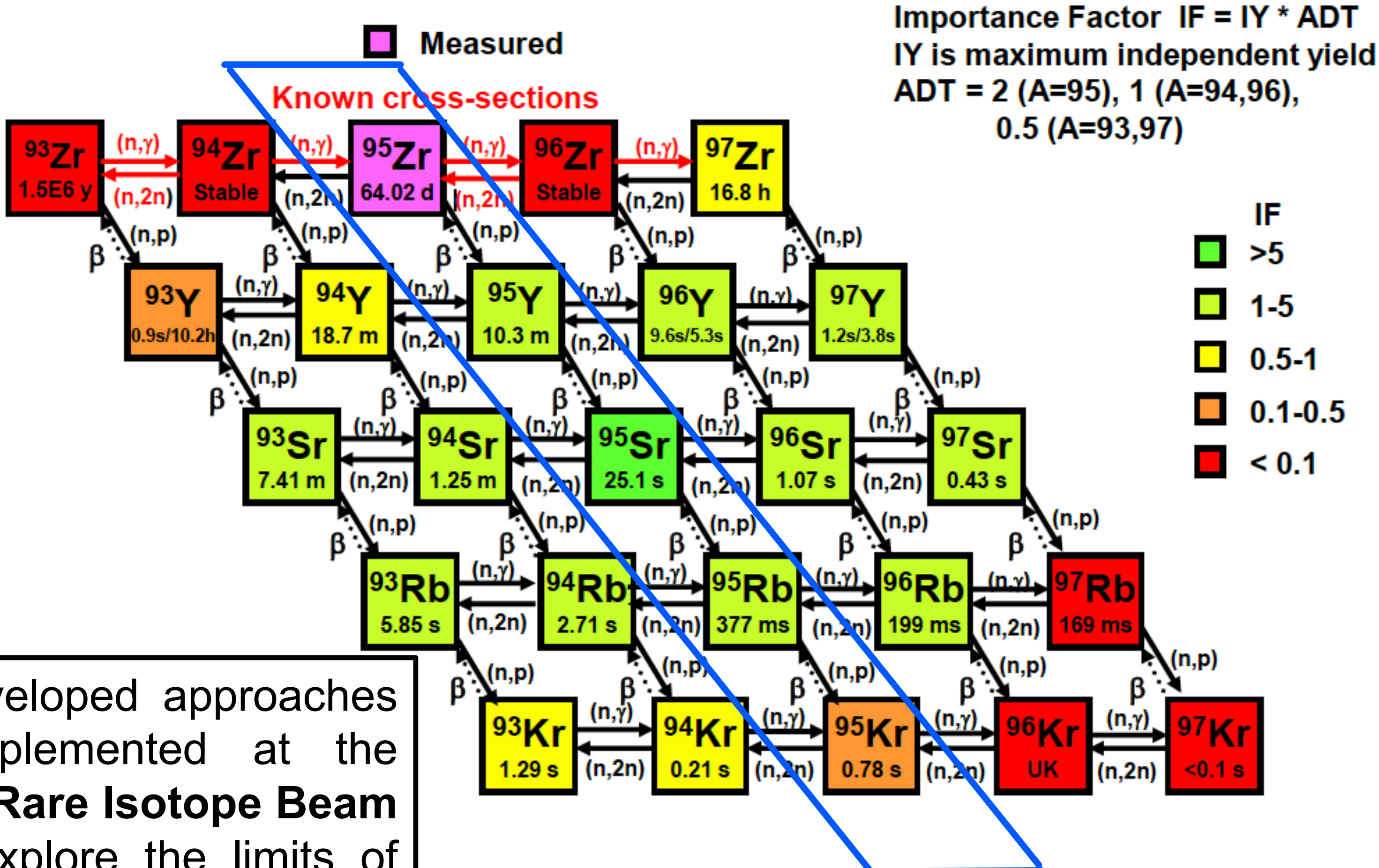

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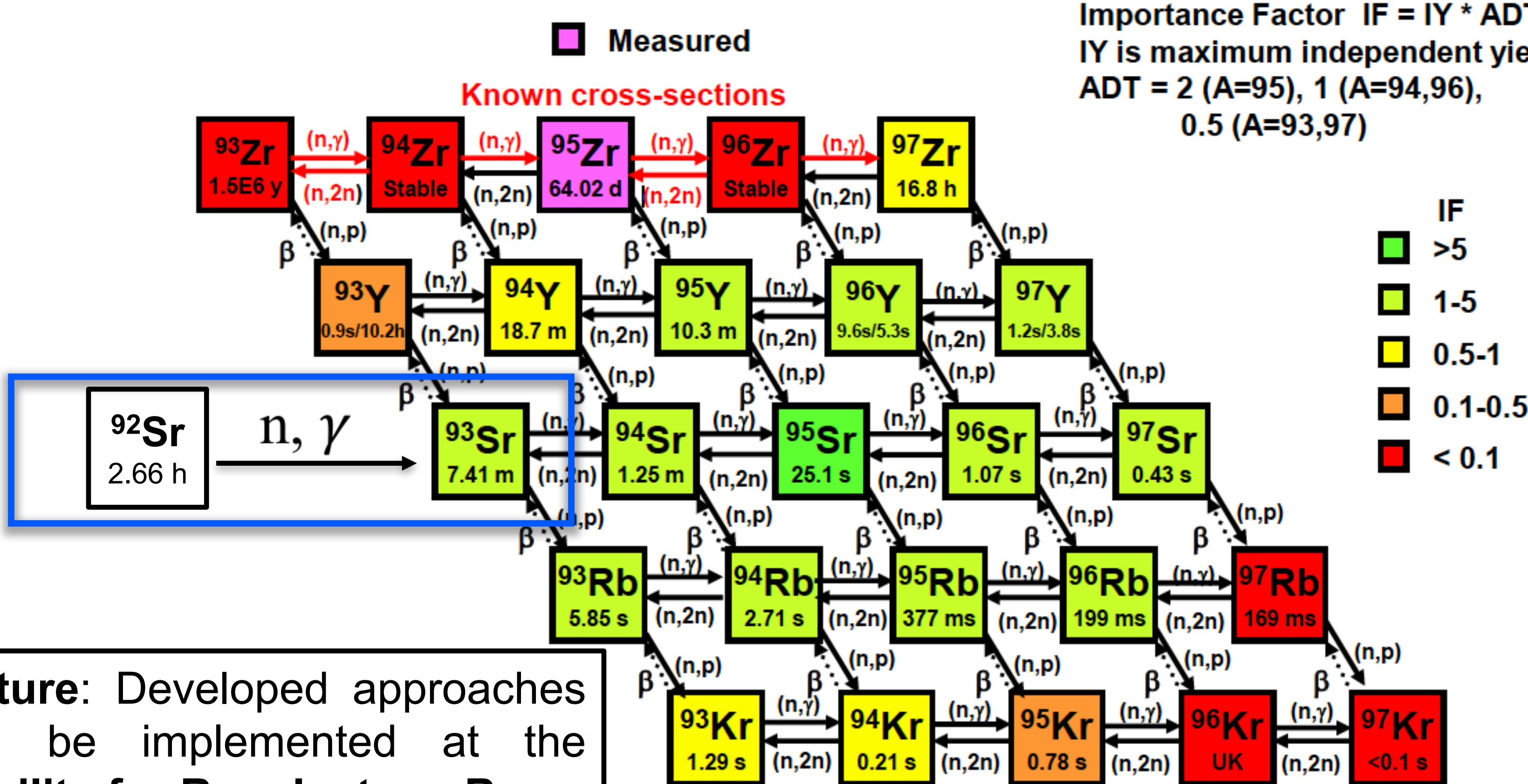

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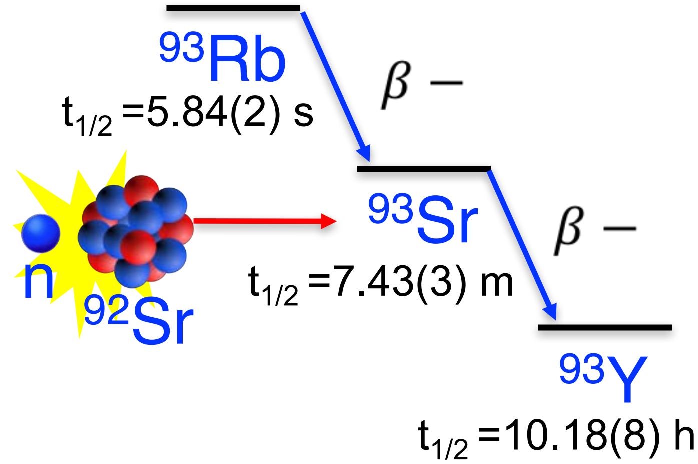
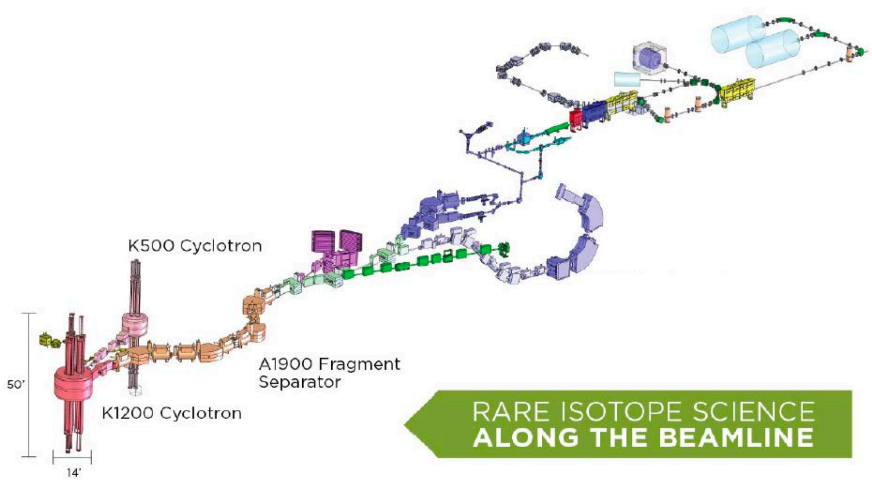
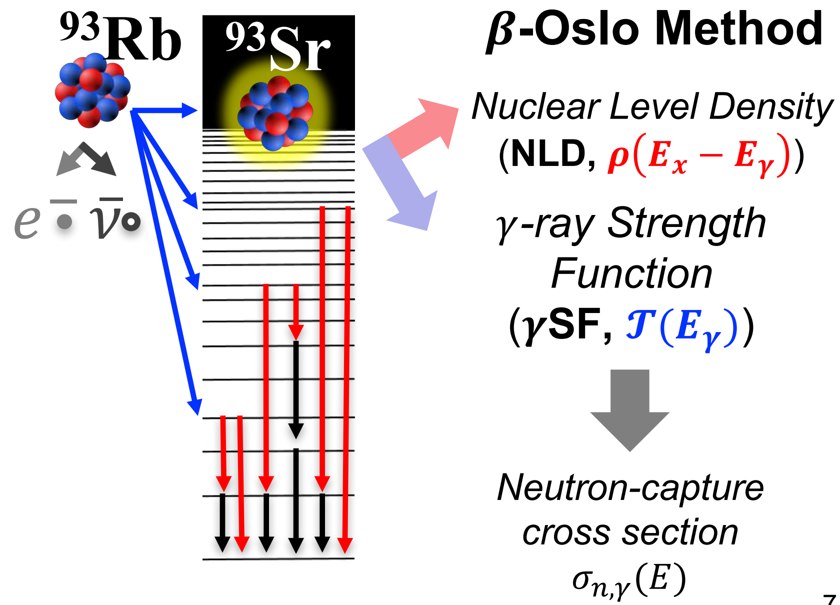
Indirect determination of the $^{92}Sr(n,\gamma)$ cross section

National Superconducting Cyclotron Laboratory (NSCL): Radioactive beam facility providing intense beam of decay parent ^{93}Rb

- Kinematics of the decay allows access to highly excited nuclear states of ^{93}Sr, i.e., $Q_\beta > S_n$
- Total absorption spectroscopy (TAS) enables simultaneous measurement of excitation energies and individual γ rays
- β-Oslo Method enables average nuclear properties to be extracted from measured γ-ray energies



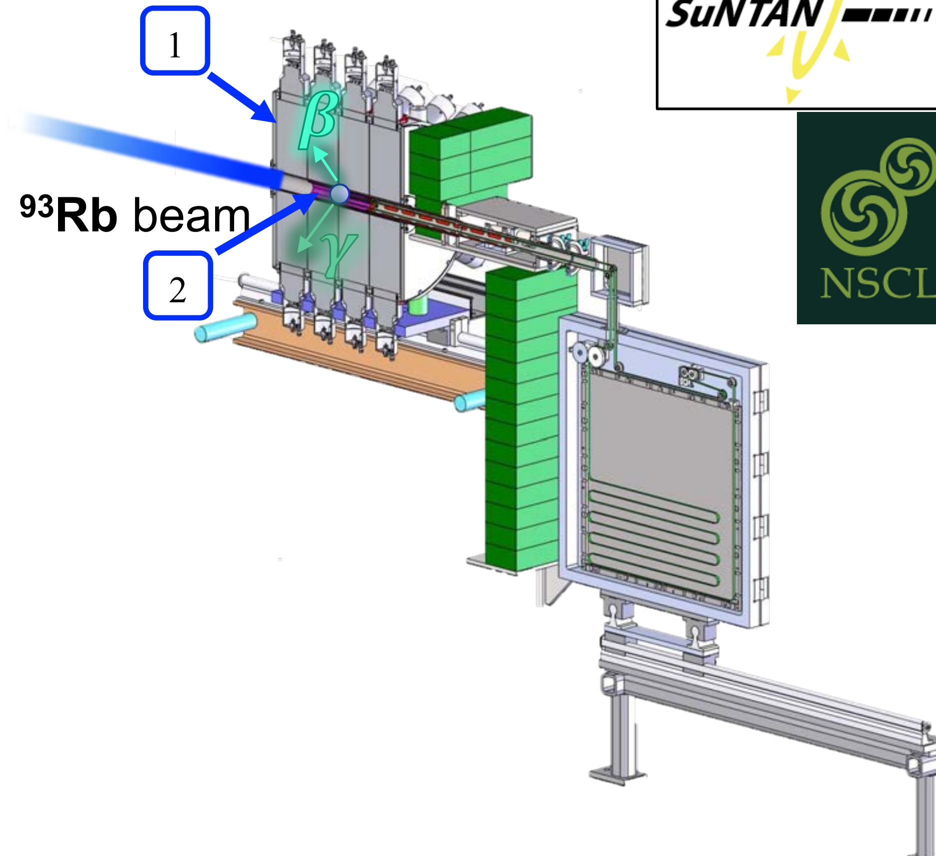




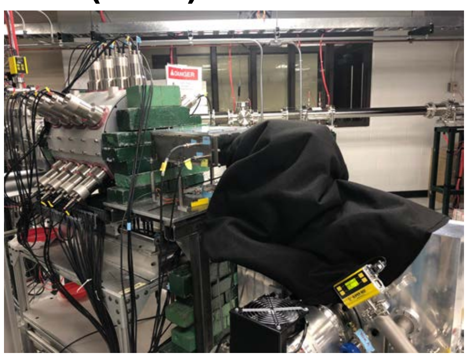
High efficiency TAS detector in conjunction with the β-Oslo Method

SuN+Tape Station for Active Nuclei (SuNTAN):

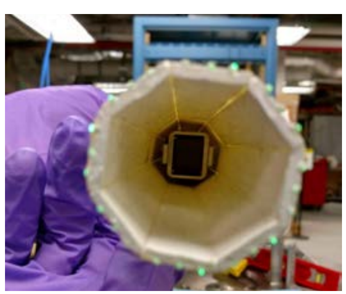
- Stopped beam of ^{93}Rb
- Implantation on 9-track tape for 60 s
- Contamination due to decay daughter ^{93}Sr
- Measured β-gated γ-ray energies analyzed using the β-Oslo Method



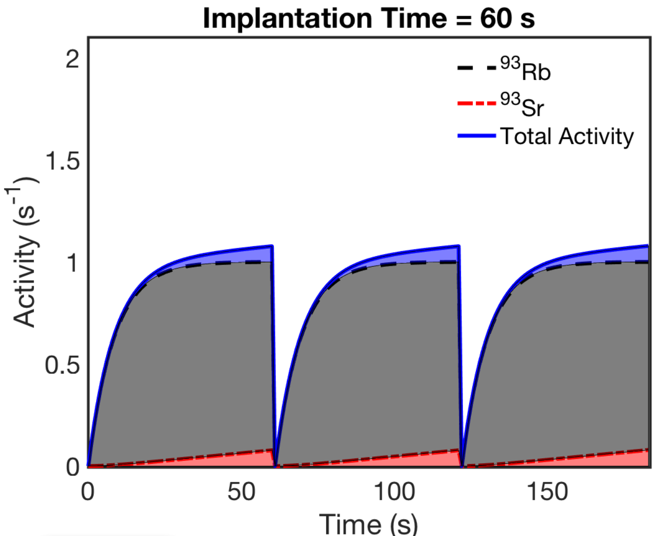
1 **Summing NaI(Tl) (SuN) Detector**



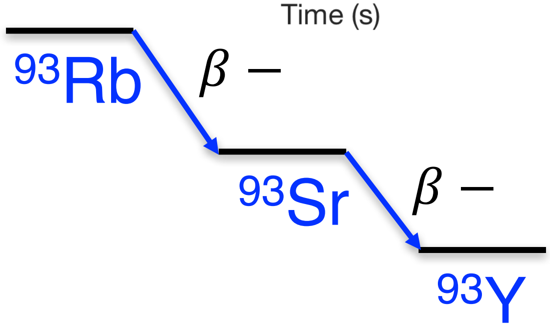
2 **Plastic Scintillator Barrel**

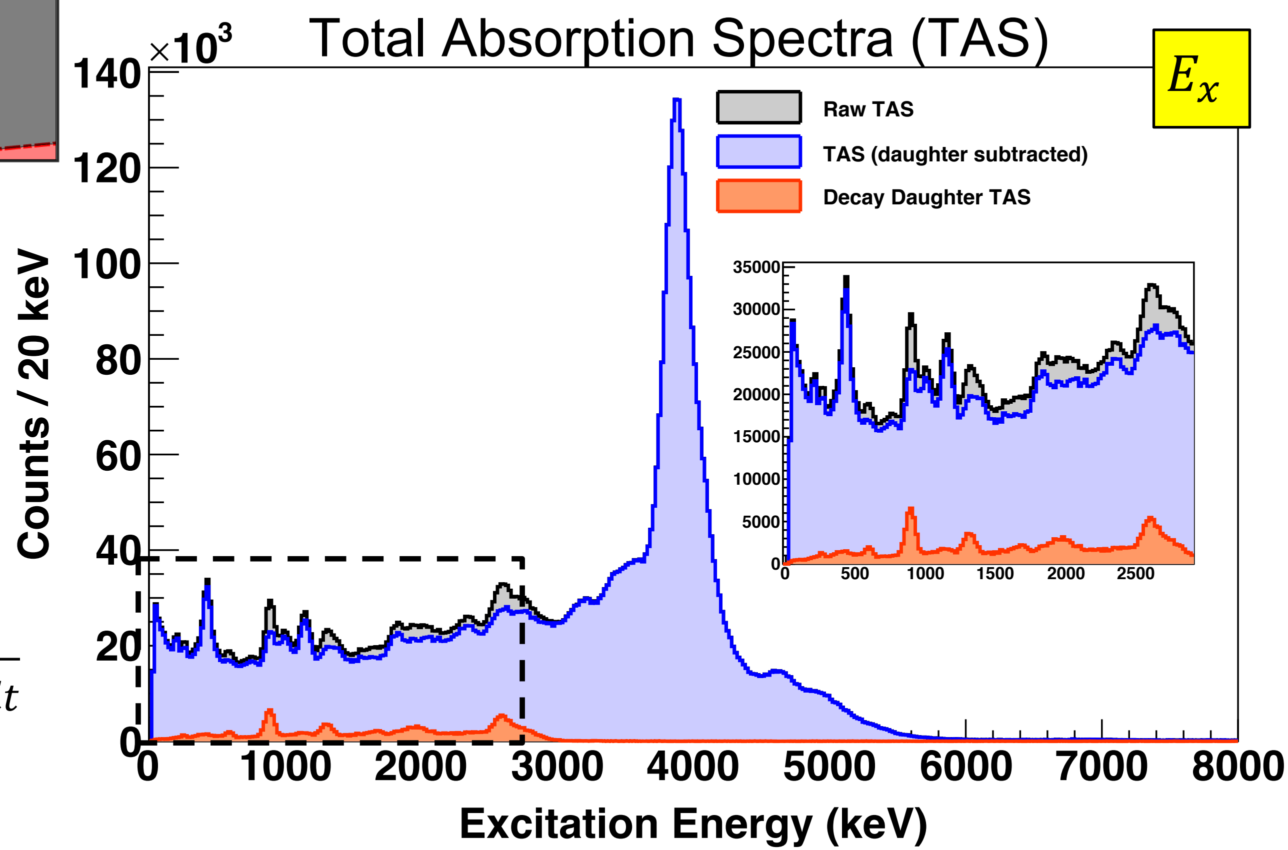


Analysis of experimental γ-ray spectra using the β-Oslo Method



Decay daughter as a contaminant: an implantation time of 60 s minimizes the impact of β decay of ^{93}Sr on measured γ rays while also maintaining high statistics.





Contamination level:

$$C = \frac{\int_0^{60} A_{^{93}Sr}(t)dt}{\int_0^{60} A_{^{93}Sr}(t) + A_{^{93}Rb}(t)dt}$$

$$C = 3.85\%$$

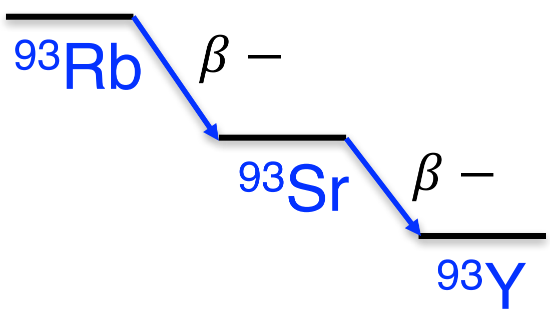
Analysis of experimental γ-ray spectra using the β-Oslo Method

Probability matrix: γ-ray energies as a function of excitation energy, $P(E_x, E_\gamma)$

TAS technique and β-γ coincidences are key to the β-Oslo Method. TAS measurements with SuN exploits several attributes:

- High efficiency detection of individual γ rays, 85(2)% for ^{137}Cs
- High summing efficiency, 65(2)% for ^{60}Co sum peak

Steps 1 & 2: Unfold and extract primary γ rays



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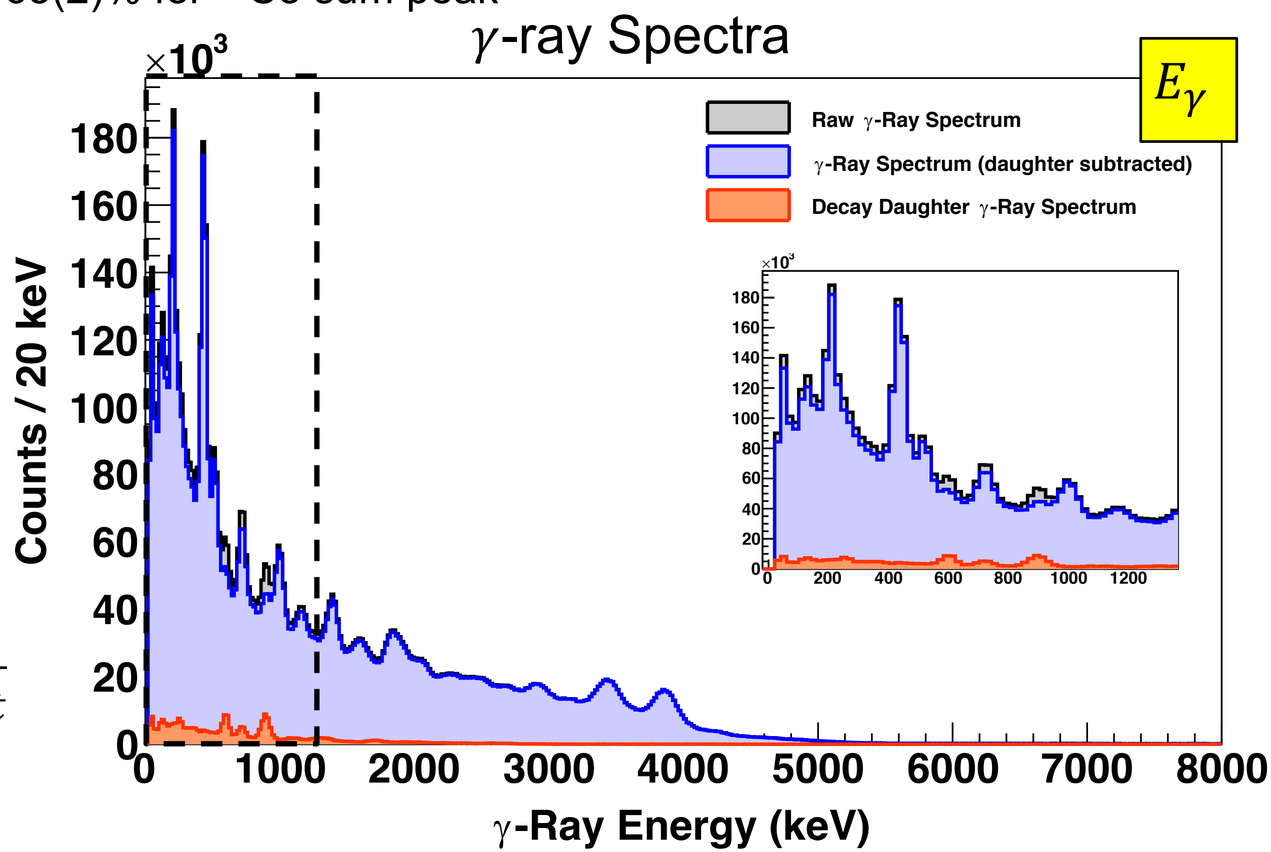
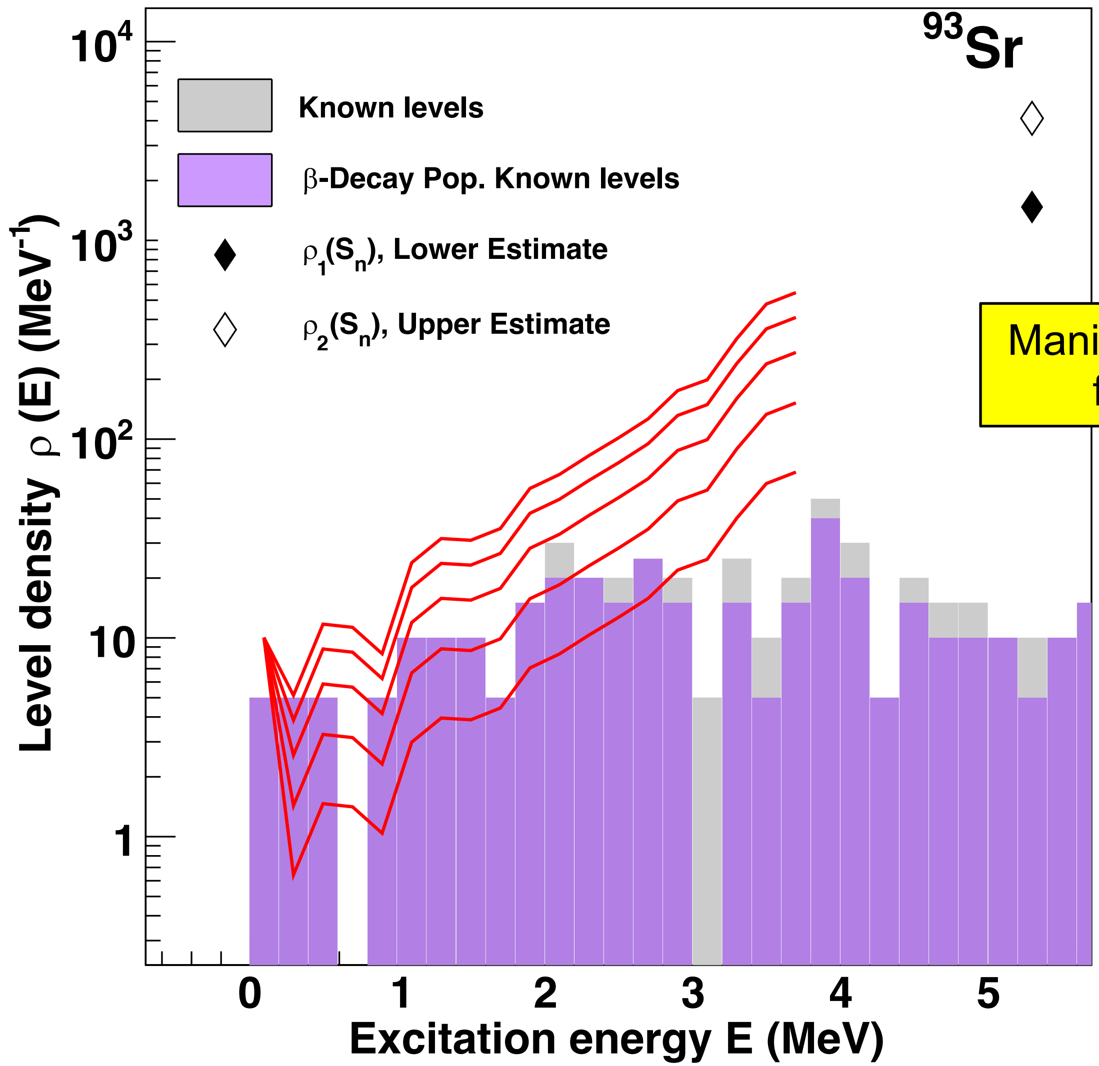


Normalizing the NLD

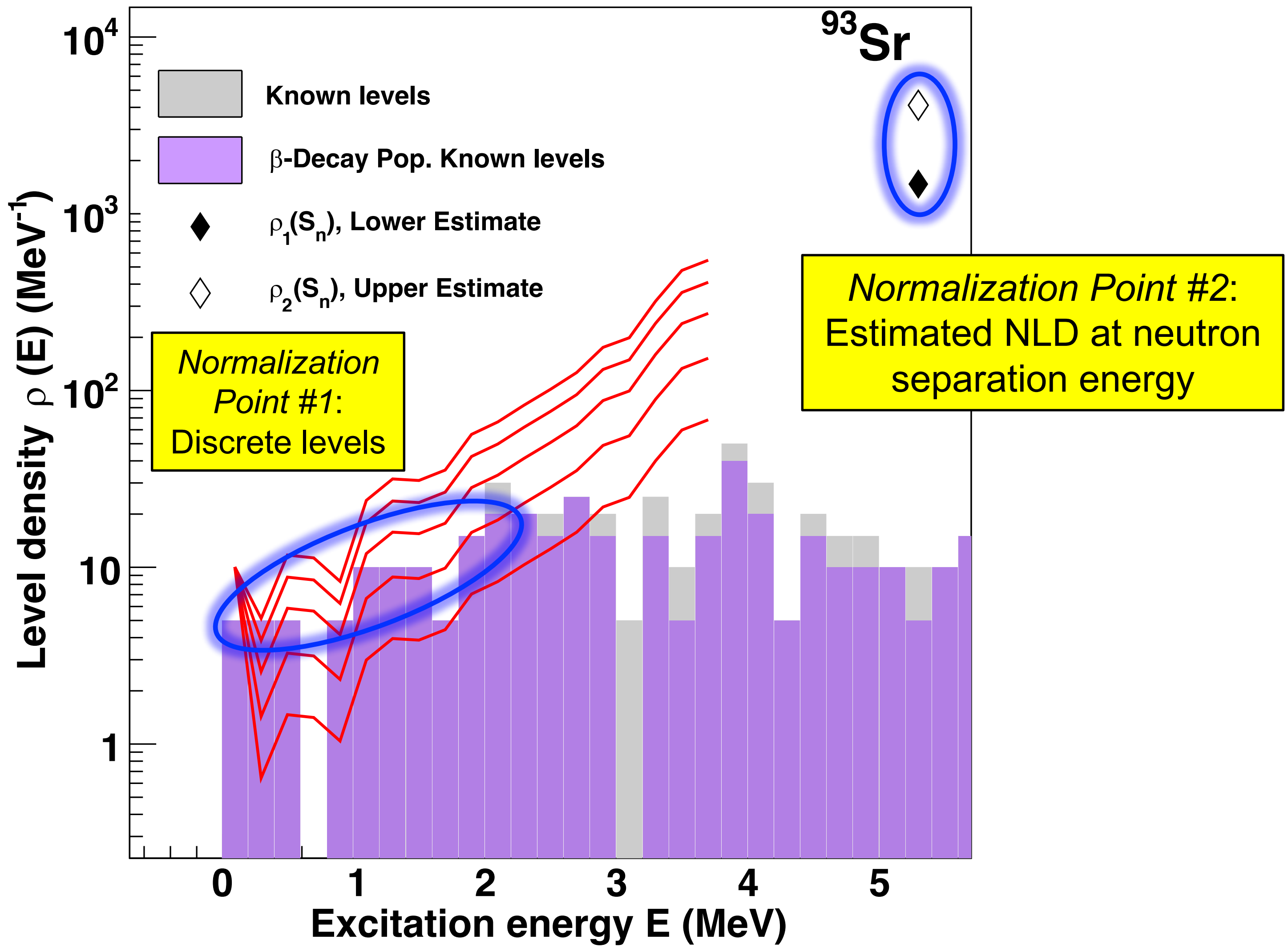
Steps 3 & 4: Extract & Normalize NLD



Manifold of solutions for the NLD

Normalizing the NLD

Steps 3 & 4: Extract & Normalize NLD



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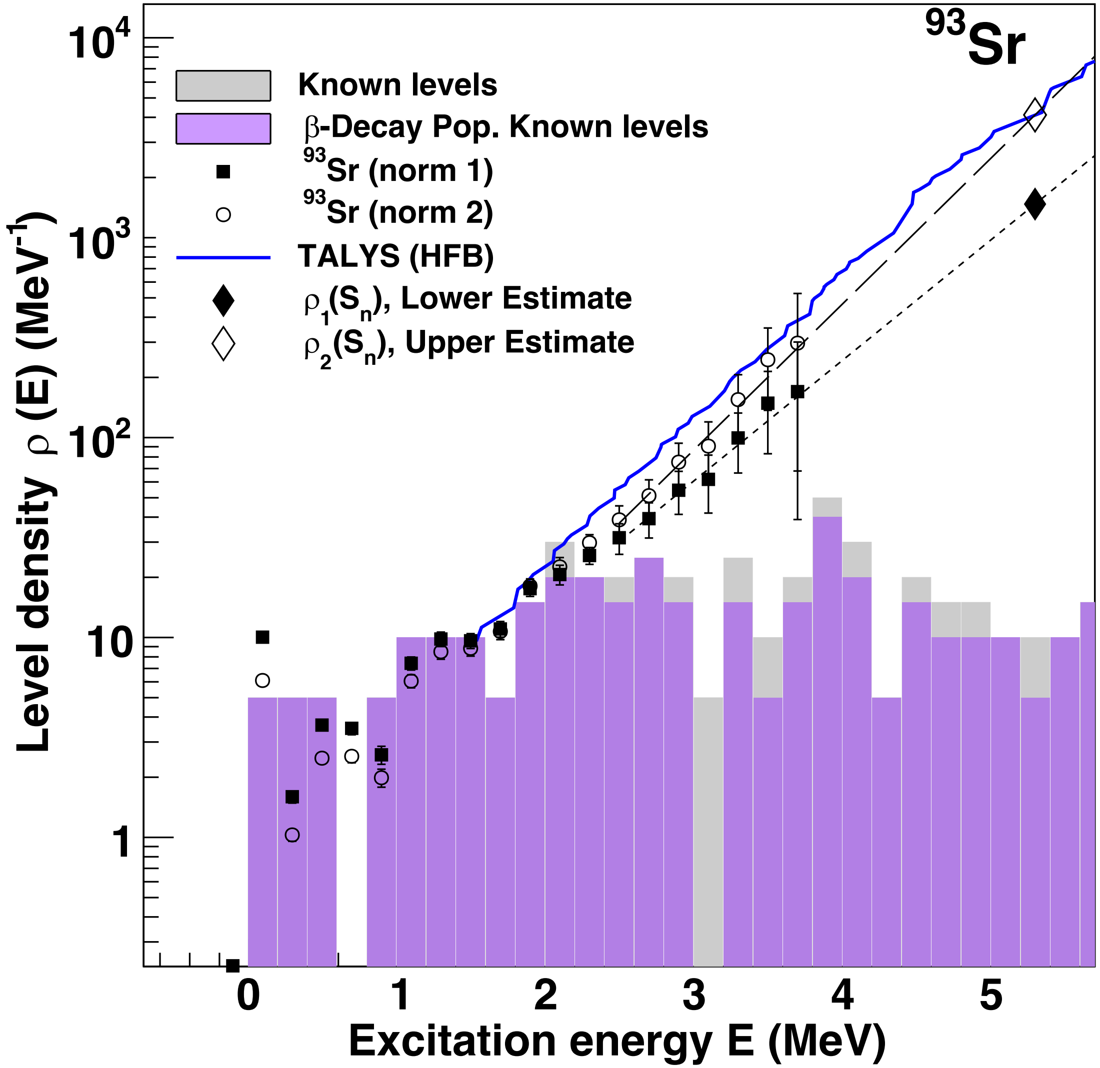


Normalizing the γSF

Steps 3 & 4: Extract & Normalize γSF

- Shape of the γSF depends on the slope of the NLD
  - NLD norm 1 = estimate from experimental data
  - NLD norm 2 = Hartree-Fock-Bogolyubov micro. Model
- Third (final) normalization point: avg. total radiative width & the avg. neutron resonance spacing

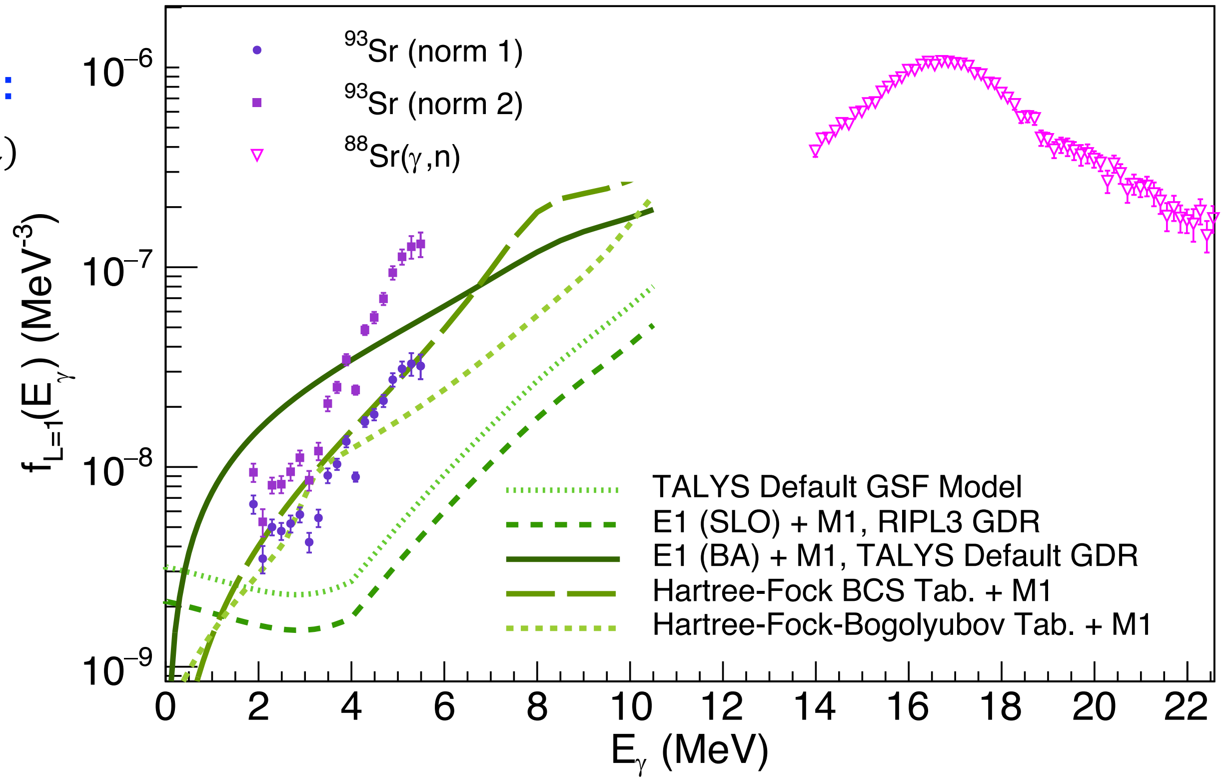
Estimated avg. total radiative width $\langle\Gamma\rangle$ from known widths of stable neighboring nuclei

Normalization parameters:

$$\tilde{\rho}(E - E_\gamma) = Ae^{\alpha(E-E_\gamma)}\rho(E - E_\gamma)$$

$$\tilde{\mathcal{T}}(E_\gamma) = Be^{\alpha E_\gamma}\mathcal{T}(E_\gamma)$$

$$f_{XL}(E_\gamma) = \frac{\mathcal{T}_{XL}(E_\gamma)}{2\pi E_\gamma^{2L+1}}$$



Constrained cross section & reaction rate

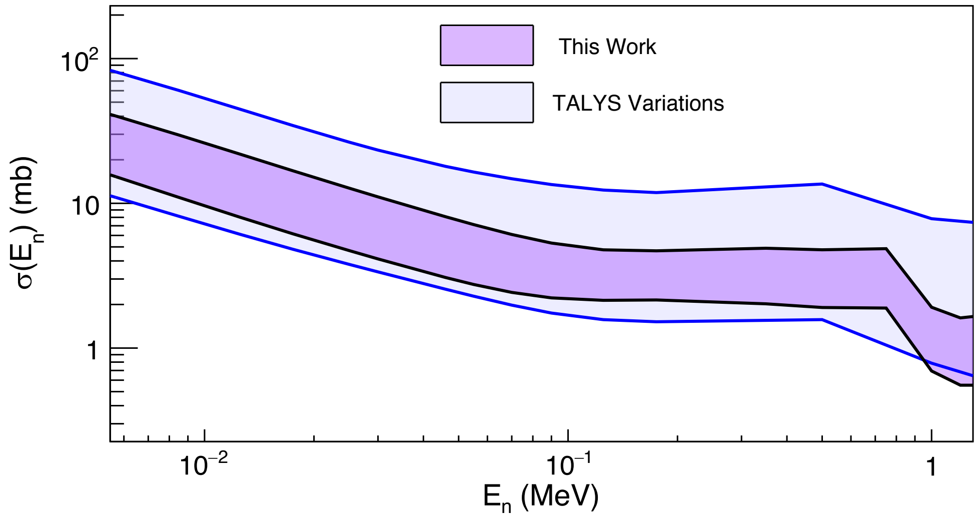
Step 5: Calculate cross section

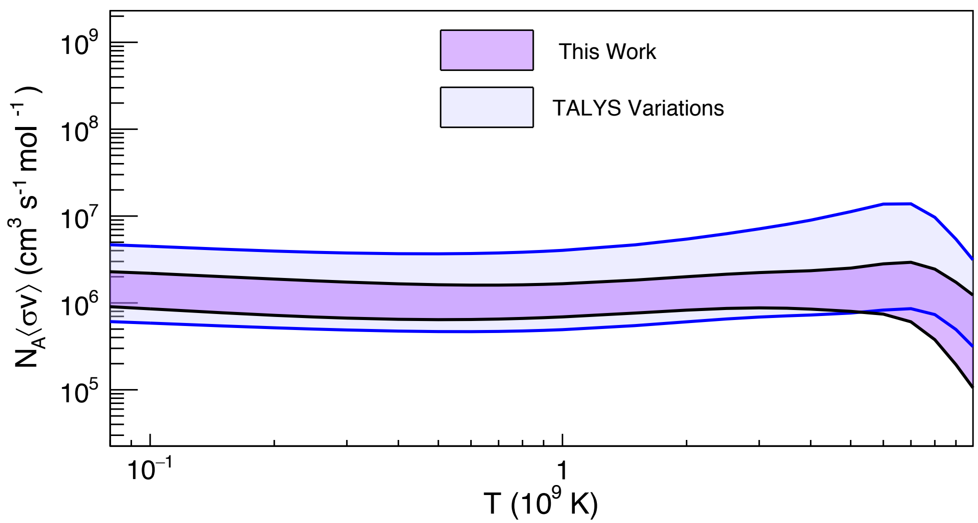
- Cross Section

  At low neutron energies, the cross section is constrained compare to TALYS upper/lower limits by a factor of 10 at low energies and a factor of 2-5 at E_n>0.440 keV.

- Astrophysical Reaction Rate

  Over the entire temperature range, the reaction rate is constrained compare to TALYS upper/lower limits by a factor of 4.





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University of Oslo
A. C. Larsen, M. Guttormsen, F. Zeiser

NSSC Experience

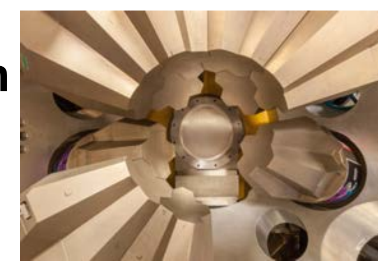
2016
Public Policy & Nuclear Threats Boot Camp

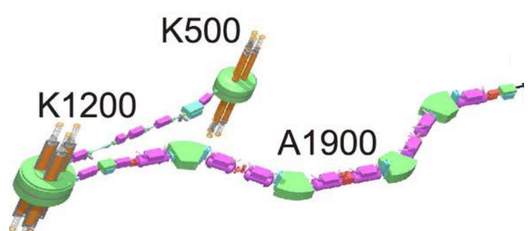
2014-2020
In-Residence Research at LLNL and LBNL

2016
Exotic Beam Summer School

Hands-on experiment:
In-beam γ-ray spectroscopy with GRETINA + S800 Spectrometer

Tools for improving knowledge of fundamental nuclear physics beyond theory





Acknowledgements

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