**Nuclear Science and Security Consortium**
**NPP/ND Review**

# Nuclear Data Measurements at LANL and LBNL

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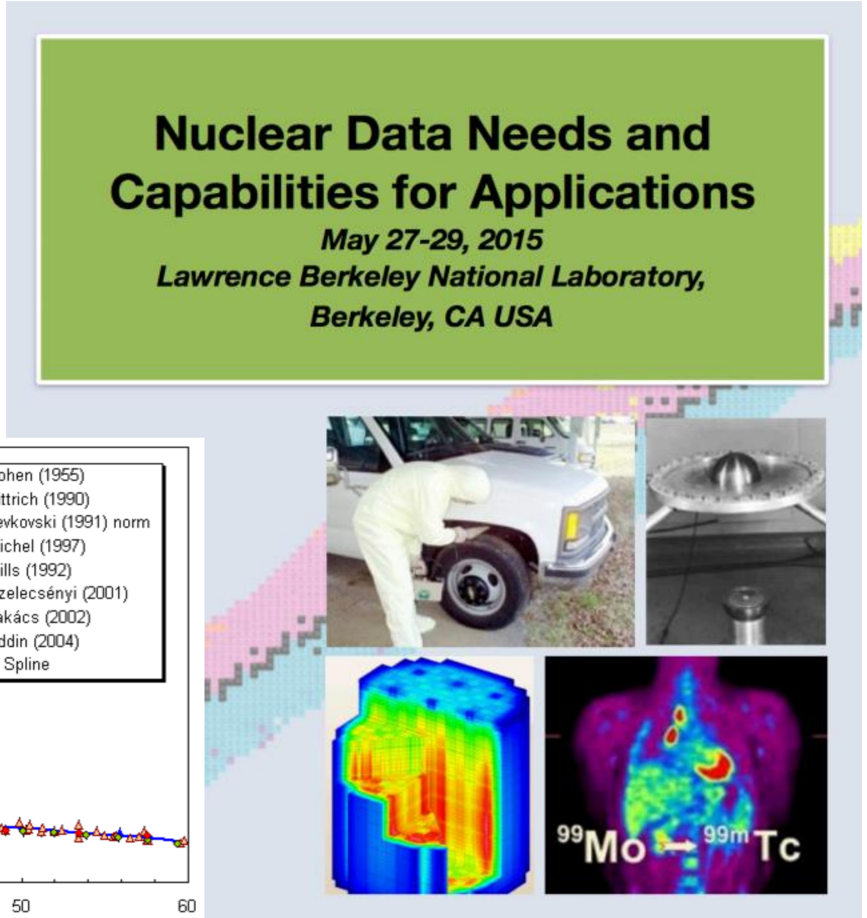
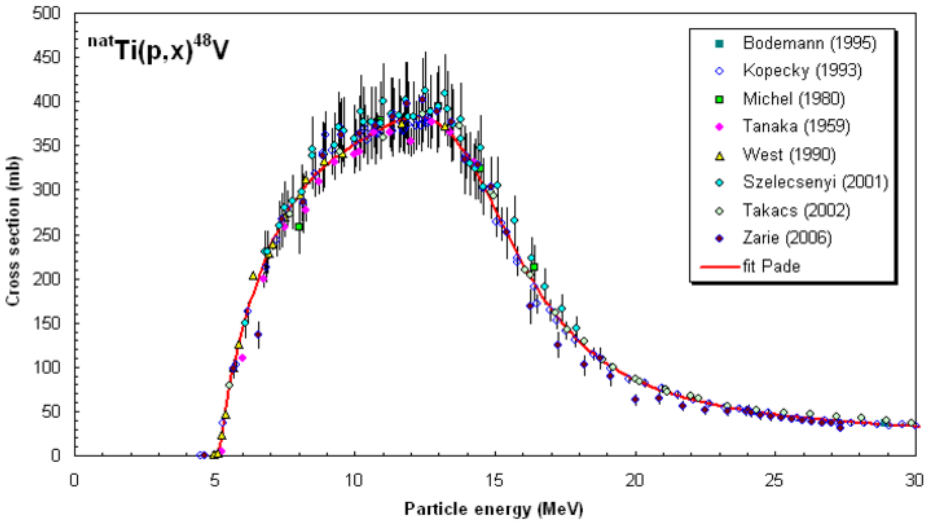
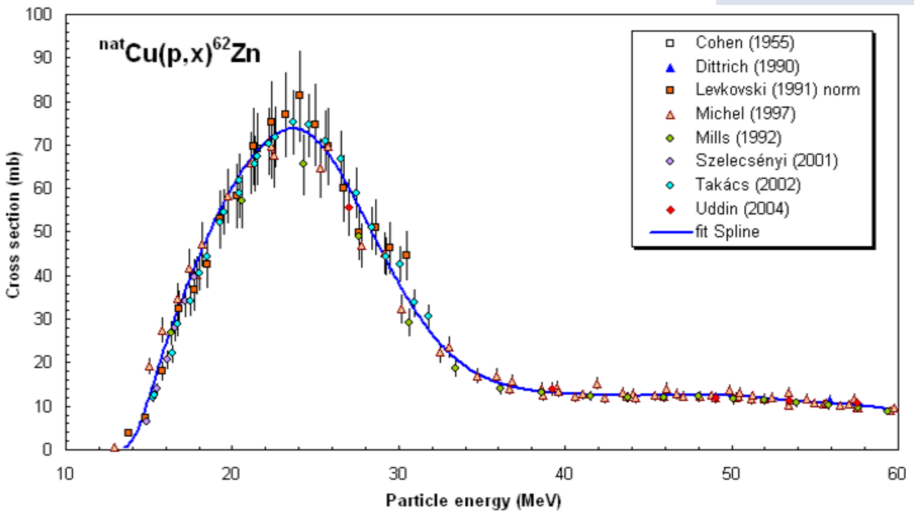
# Measurements @ LANL – Nb(p,x)

- Dosimetry was the top cross-cutting need in the NDNCA whitepaper
  - Vital for robust determination of fluence, energy for charged-particle measurements
  - Current data is deficient above ~30 MeV/A



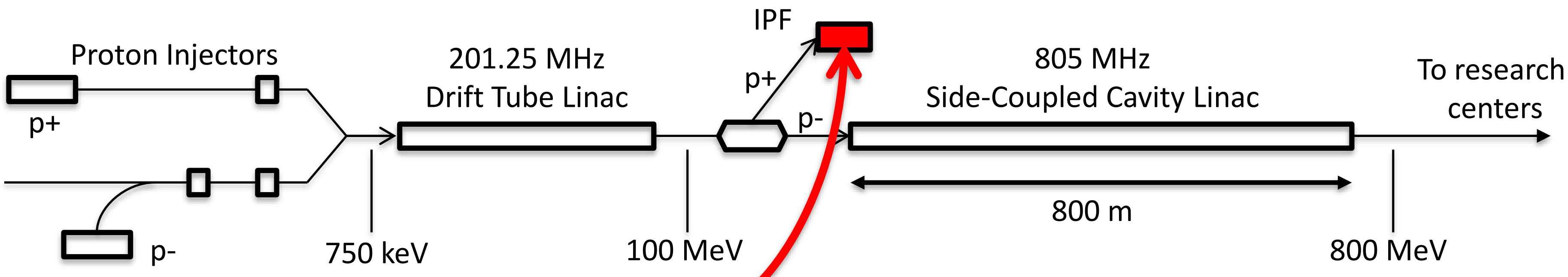



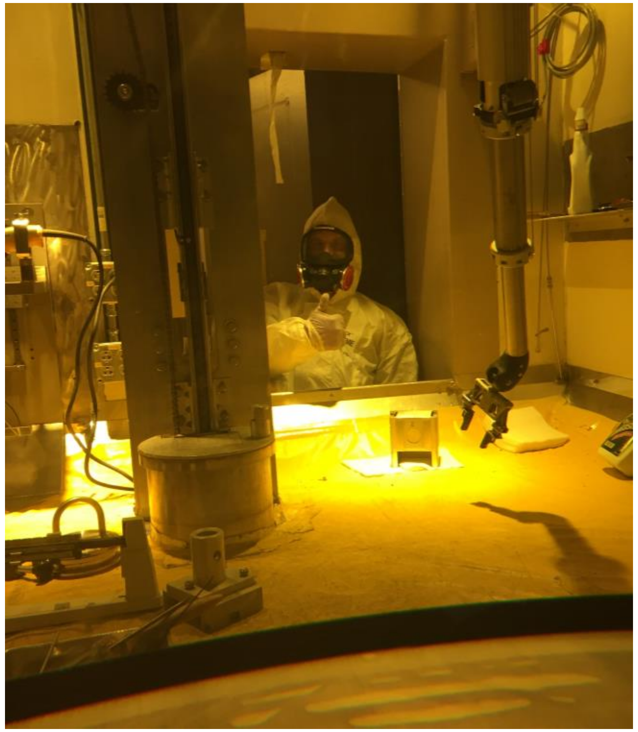




nds.iaea.org/medical/monitor_reactions.html

# Measurements @ LANL – Nb(p,x)

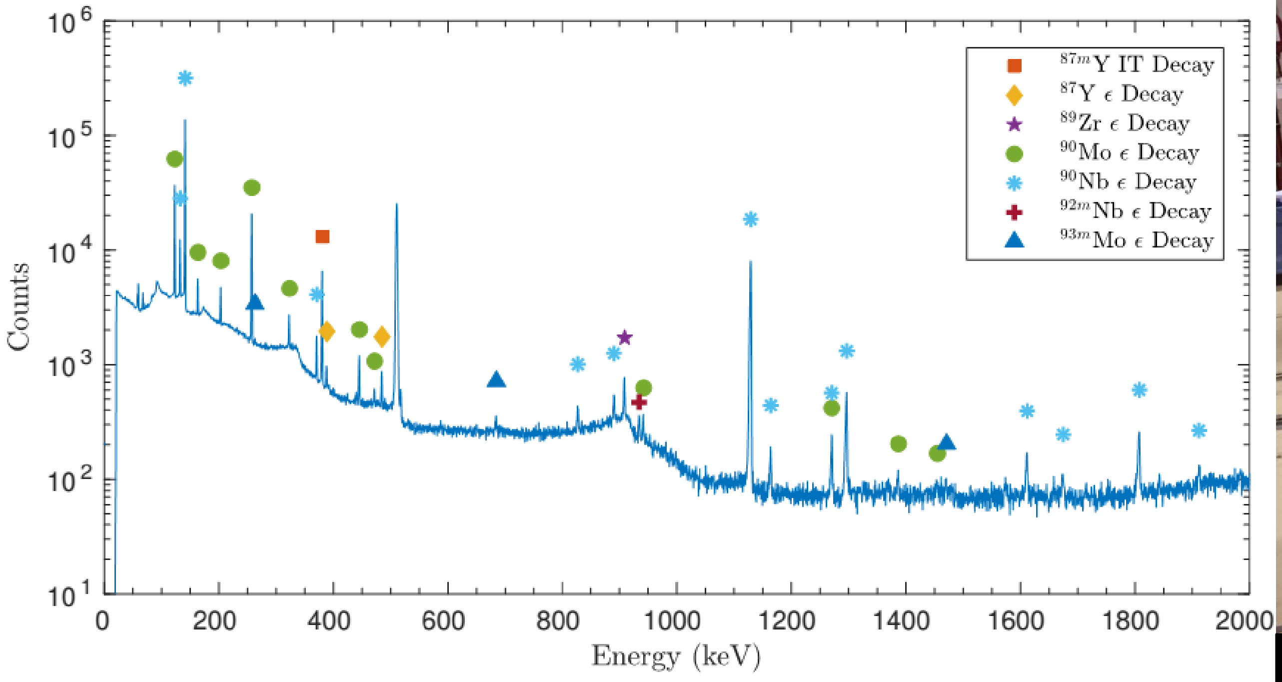
Measurement performed in Jan-Feb 2017 at LANSCE-IPF (100 MeV proton beam)



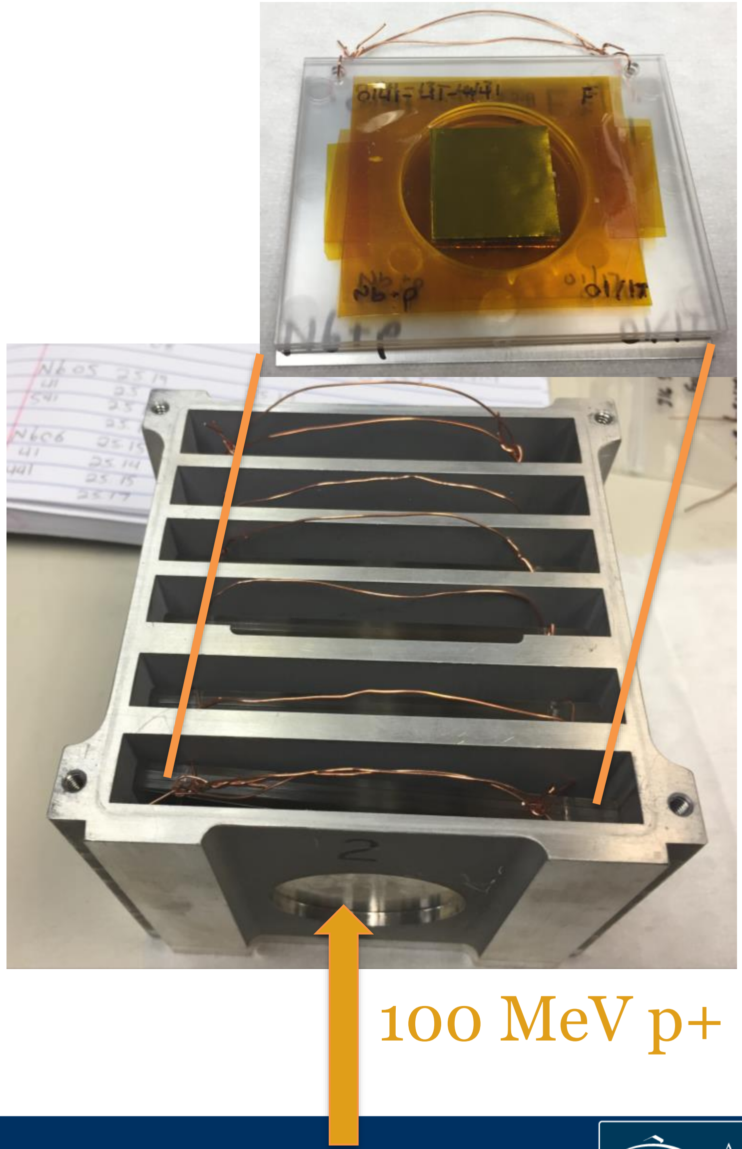



# Measurements @ LANL – Nb(p,x)

- $^{nat}Nb(p,4n)^{90}Mo$ is a high-priority objective as a new proton beam dosimetry standard for $E_p \approx 40 - 200$ MeV
  - Desired for use at facilities such as LANSCE-IPF, BLIP (BNL), iTHEMBA, etc.
  - Produced additional emerging radionuclides: $^{82m}Rb$, $^{86}Y$, $^{89}Zr$, $^{90}Nb$

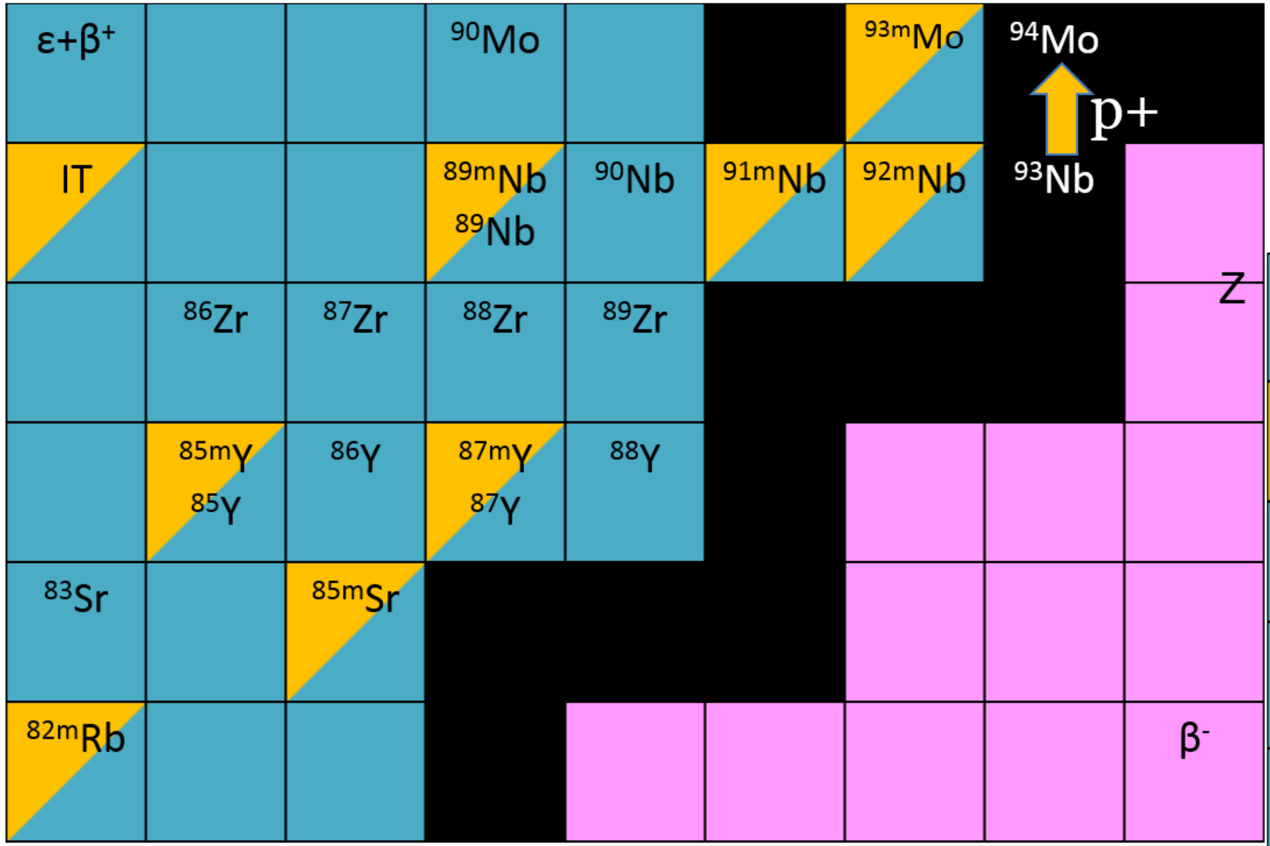


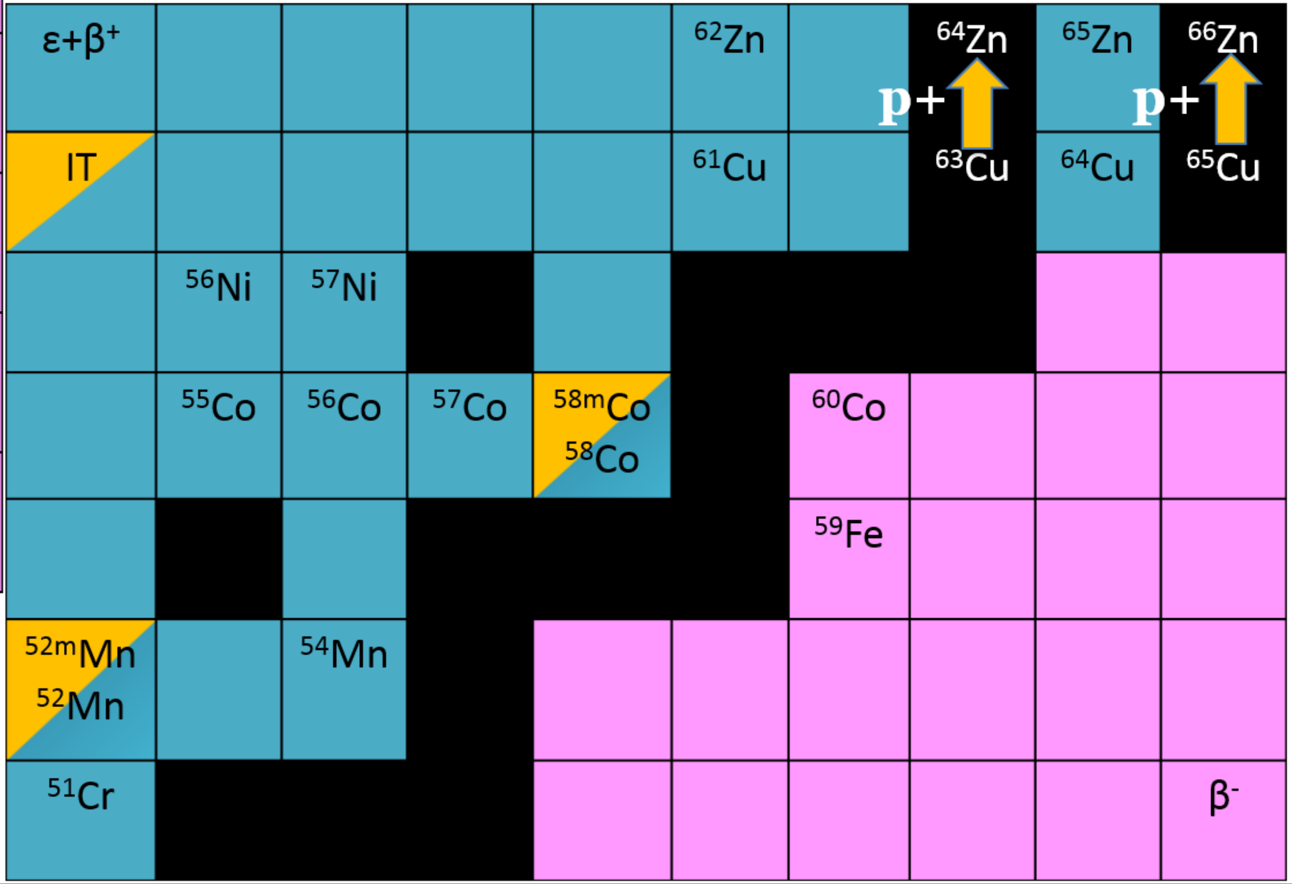

M. Nortier



100 MeV p+

# Measurements @ LANL – Nb(p,x)

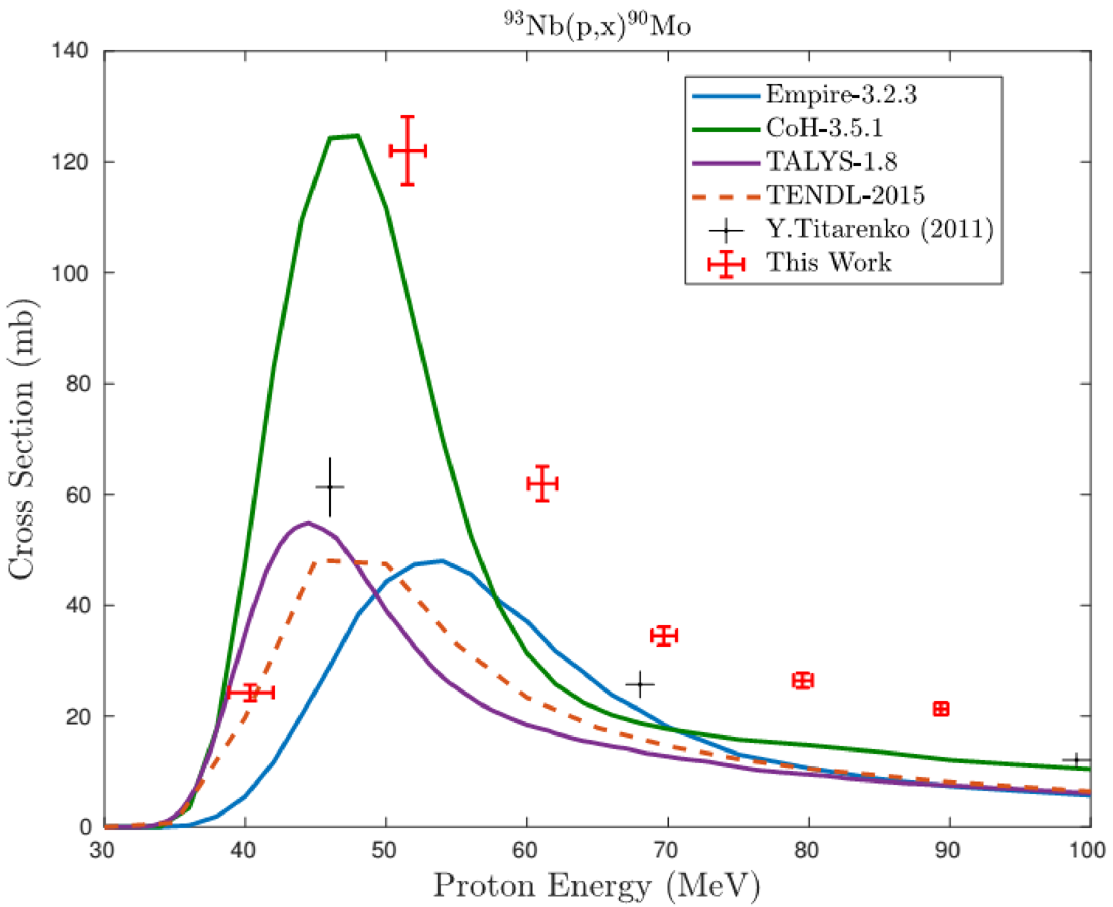


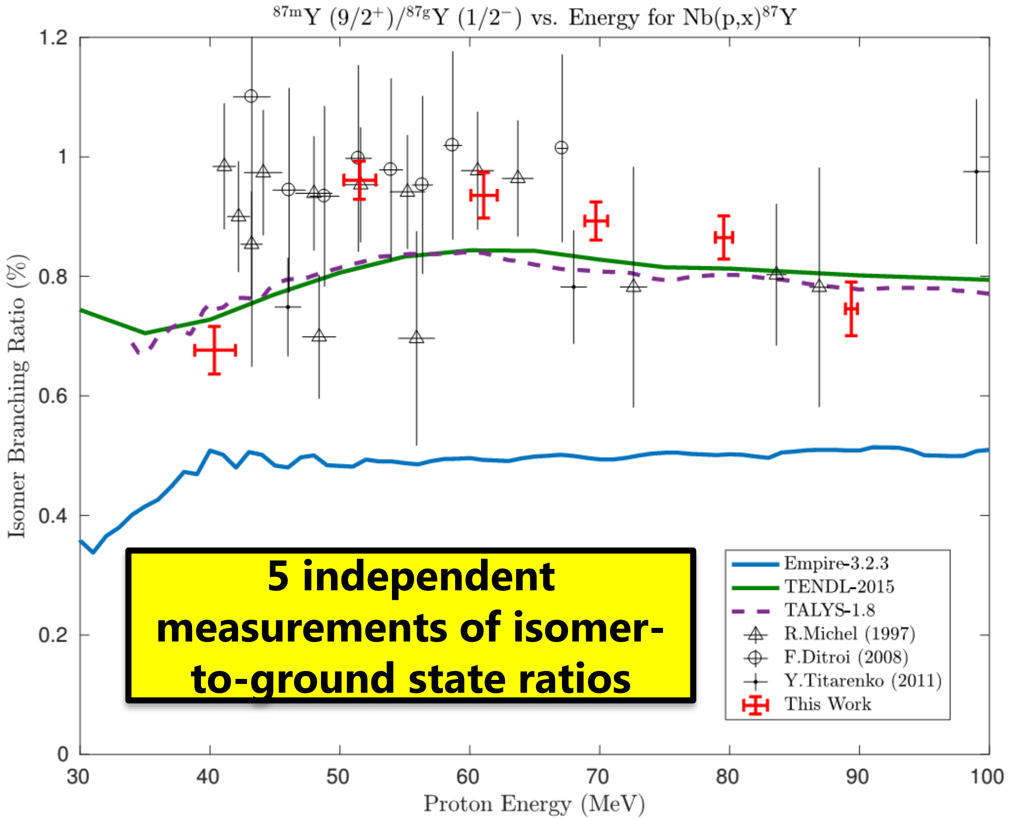




**Measurements of 38 cross-sections for $^{93}$Nb(p,x) and $^{nat}$Cu(p,x)**


[1] A.S. Voyles, NIM B (2018)

# Measurements @ LANL – Nb(p,x)



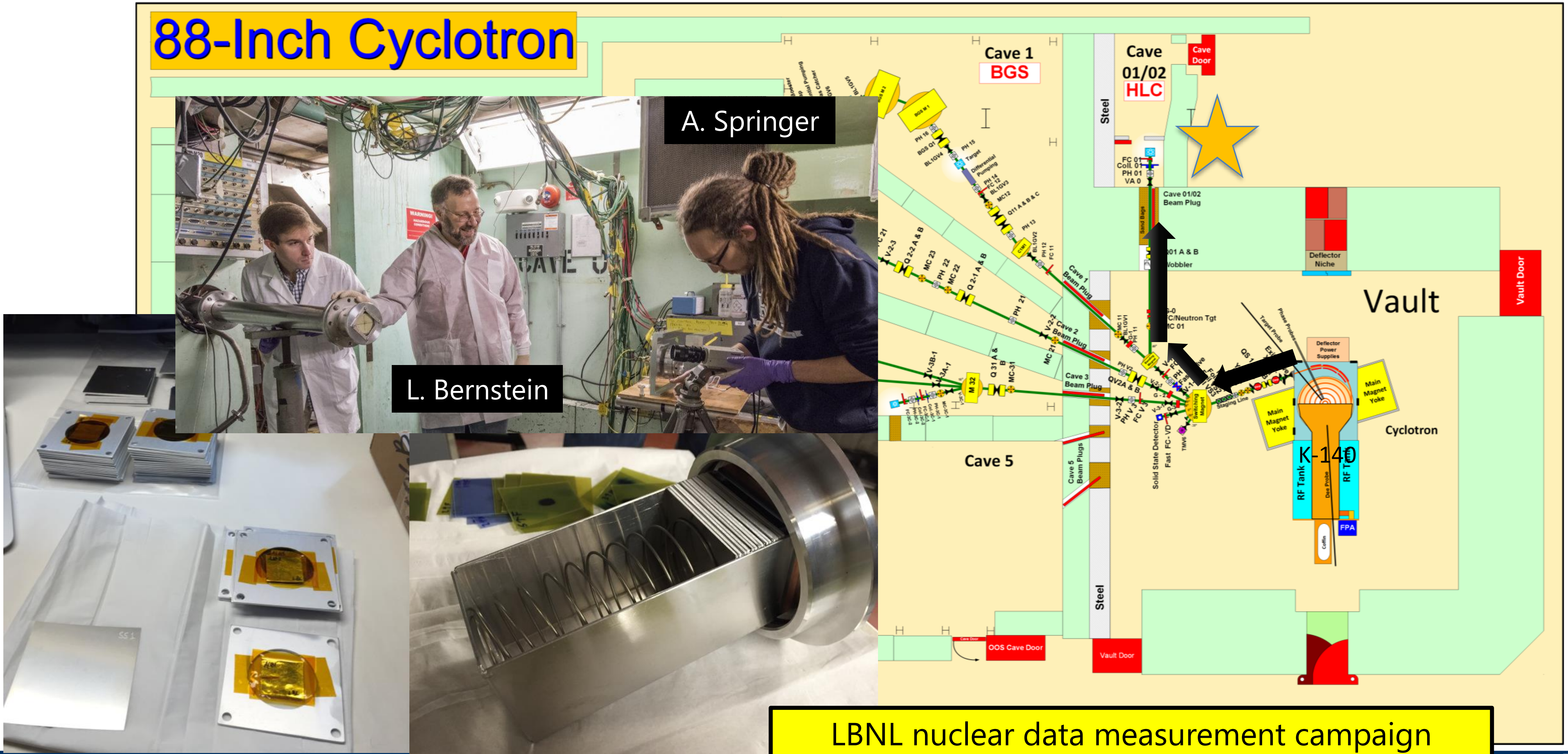

**5 independent measurements of isomer-to-ground state ratios**

***A.S. Voyles et al., "Excitation functions for (p,x) reactions of niobium in the energy range of $E_p$ = 40–90 MeV", NIM B, 429 (2018) 53–74. http://dx.doi.org/10.1016/j.nimb.2018.05.028***

**Results have been published, and are currently being compiled into EXFOR!**

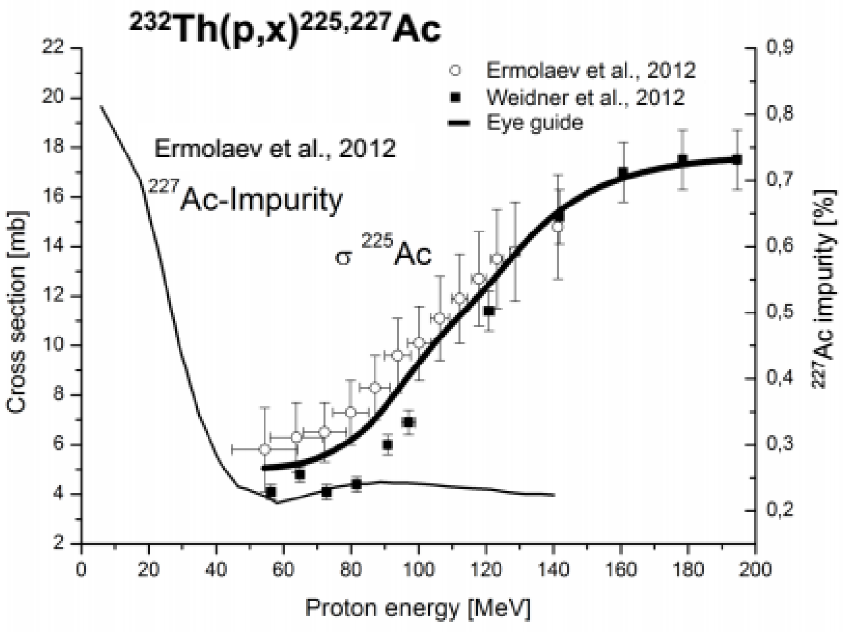
**Next step: extend to 200 MeV**

# Stacked-target Charged Particle Excitation Functions




LBNL nuclear data measurement campaign started in Q2 2016, in collaboration with LANL

# $^{140}La(p,6n)^{134}Ce$ - a PET analogue for $^{225}Ac$




**$^{232}Th(p,x)^{225}Ac$**

$E_p$ = 140 → 60 MeV

$^{225}Ac$ yield:

4 MBq/μAh

**$^{226}Ra(p,2n)^{225}Ac$**

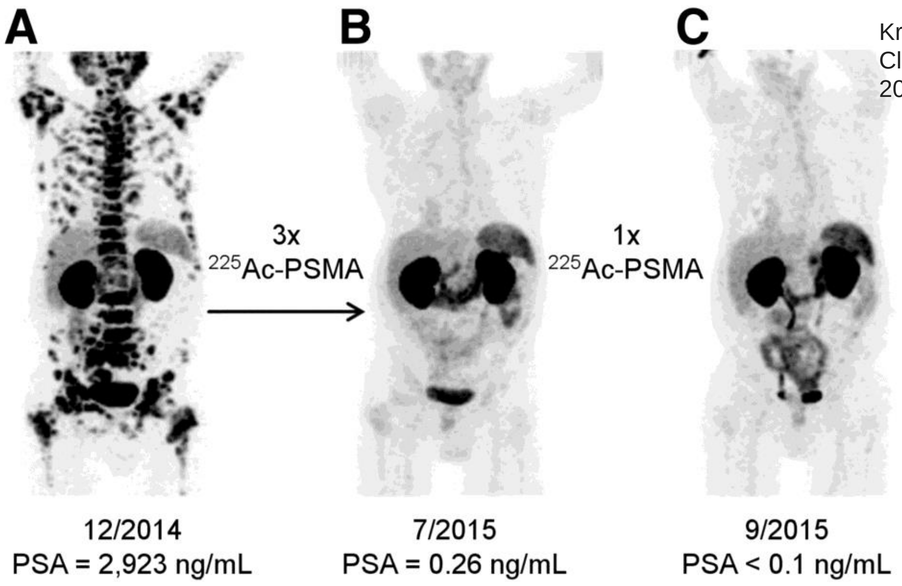
$E_p$ = 22 → 10 MeV

$^{225}Ac$ yield:

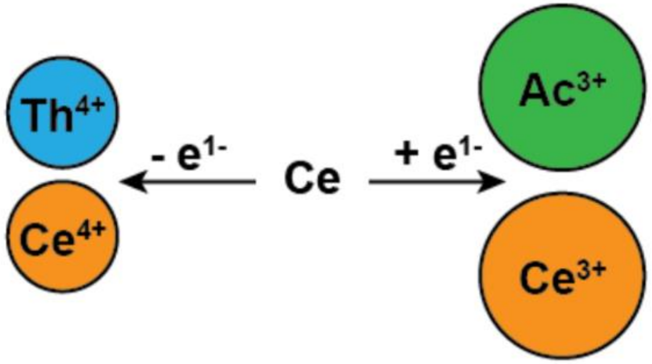
7 MBq/μAh

**(radioactive target)**

The La/Ce project is a joint venture between LBNL/UCB (Abergel, Bernstein), LANL (Kozimor) and U. of Wisconsin (Engle)




Kratochwil, Clemens, et al., 2016

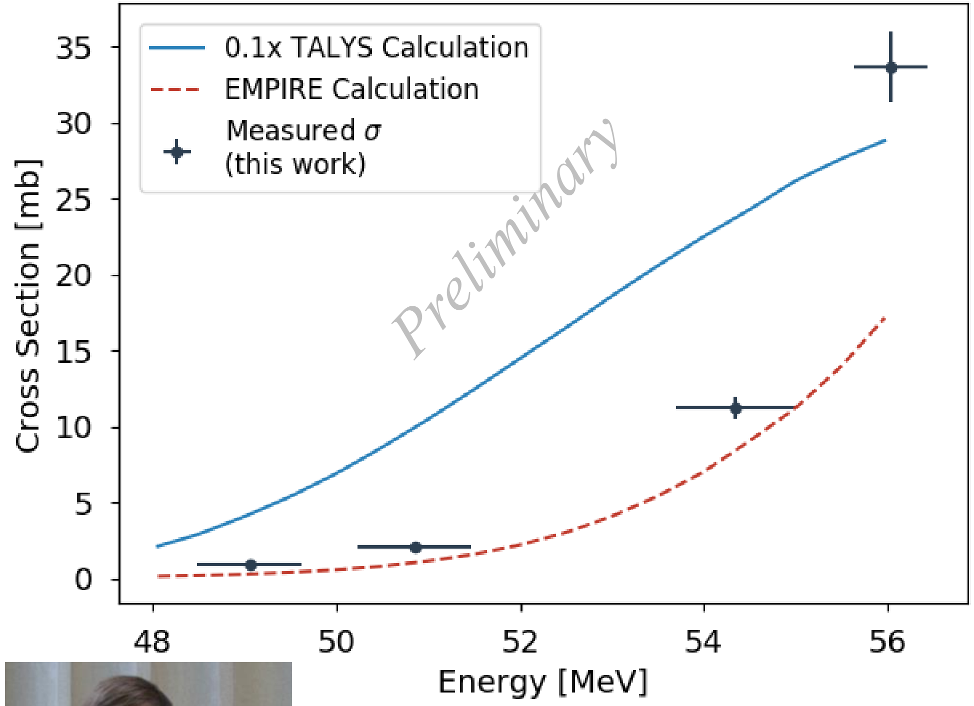



**$^{134}Ce$ as a $^{227}Th$ mimic**

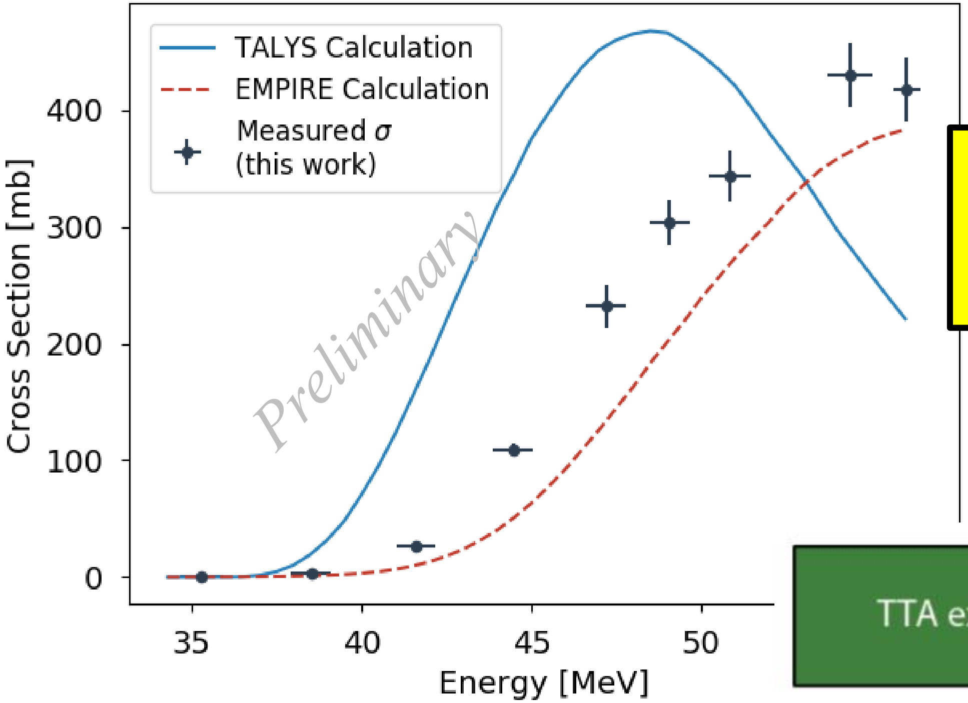
**$^{134}Ce$ as an $^{225}Ac$ mimic**

# $^{140}$La(p,6n)$^{134}$Ce - a PET analogue for $^{225}$Ac

$^{140}$La(p,6n)$^{134}$Ce Cross Section




$^{140}$La(p,5n)$^{135}$Ce Cross Section




**$^{135}$Ce is a contaminant isotope: higher-energy beam required for clean production of $^{134}$Ce**

**Step 1**
TTA extraction of $Ce^{IV}$ from $La^{III}$

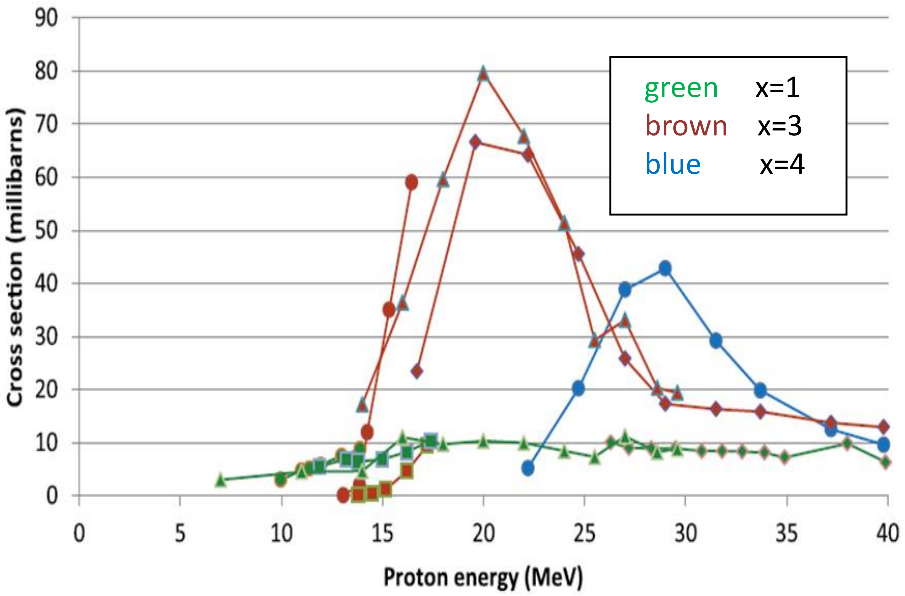
**Step 2**
Anionic exchange to remove residual $^{139}$La target material

**Step 3**
Generation of oxidation state pure $Ce^{III}$ or $Ce^{IV}$ stock solutions

Jon Morrell

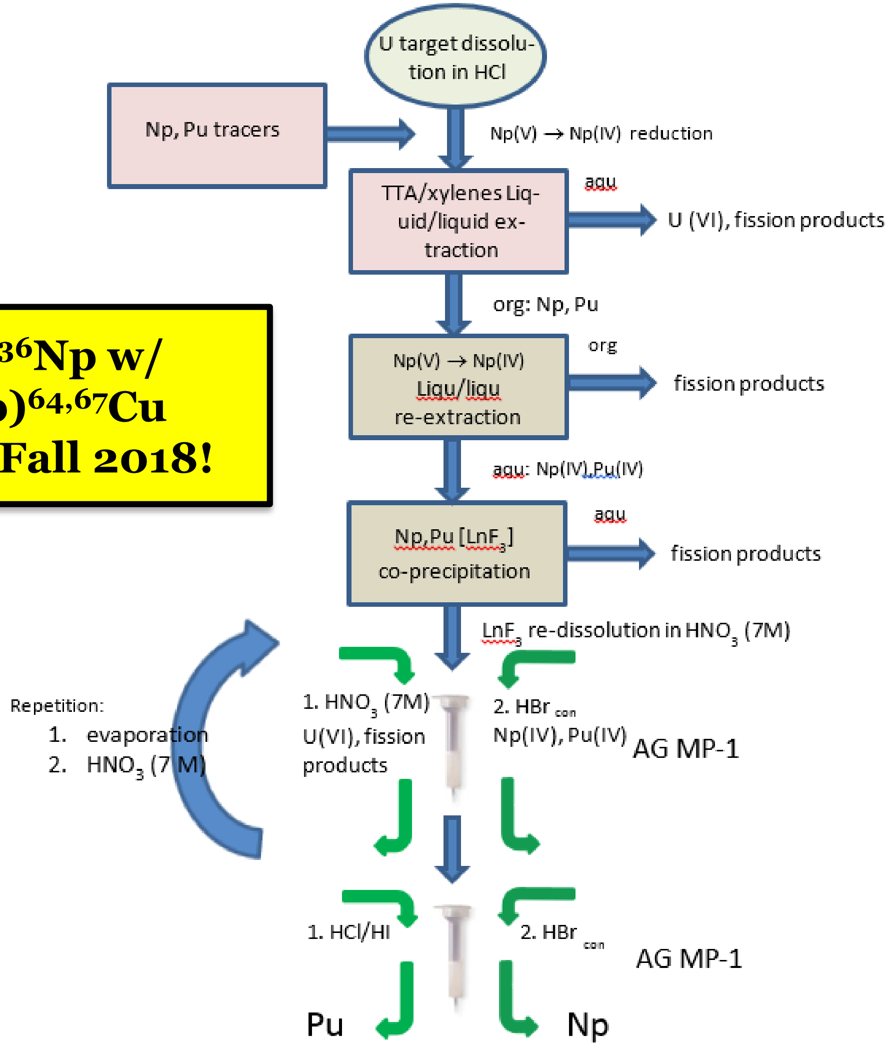
**Next steps:**
- **Extension of data up to 100 MeV**
- **Design of LANL production target**
- **Collaborative development of radiochemical workup and uptake studies between LBNL / LANL**

# $^{238}U(p,xn)^{236,237}Np$ and $^{235}U(d,x)^{236}Np$ Production*




Literature reaction cross sections for $^{238}U(p, xn)$

**$^{235}U(d,n)^{236}Np$ w/ $^{64,67}Zn(n,p)^{64,67}Cu$ planned for Fall 2018!**




**Vital mass-spec "spike" for nonproliferation**

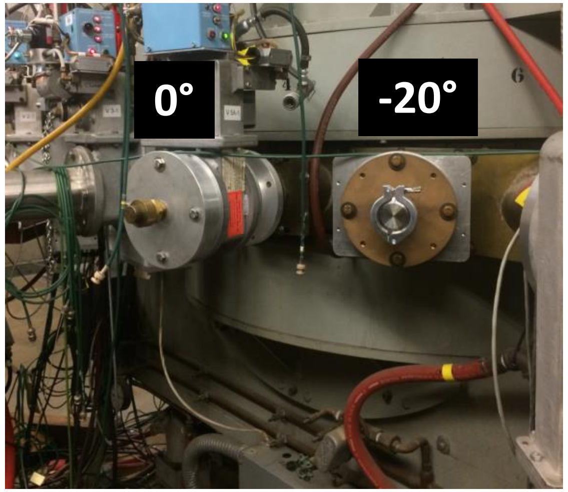
**Provide radiochemical expertise to UCB, for potential skills transfer to IPF!**



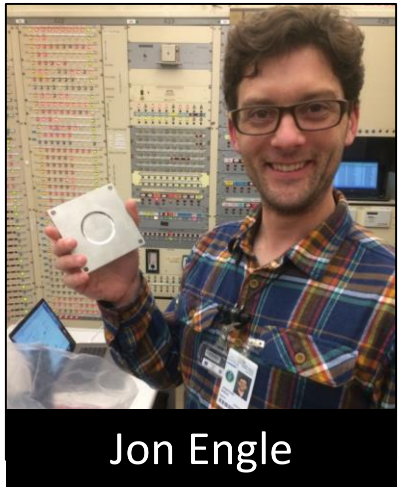

*Funded under the first Interagency Nuclear Data Working Group FOA in FY18

# $^{7}$Li(p,n) "Quasi-Monoenergetic" Neutron Source

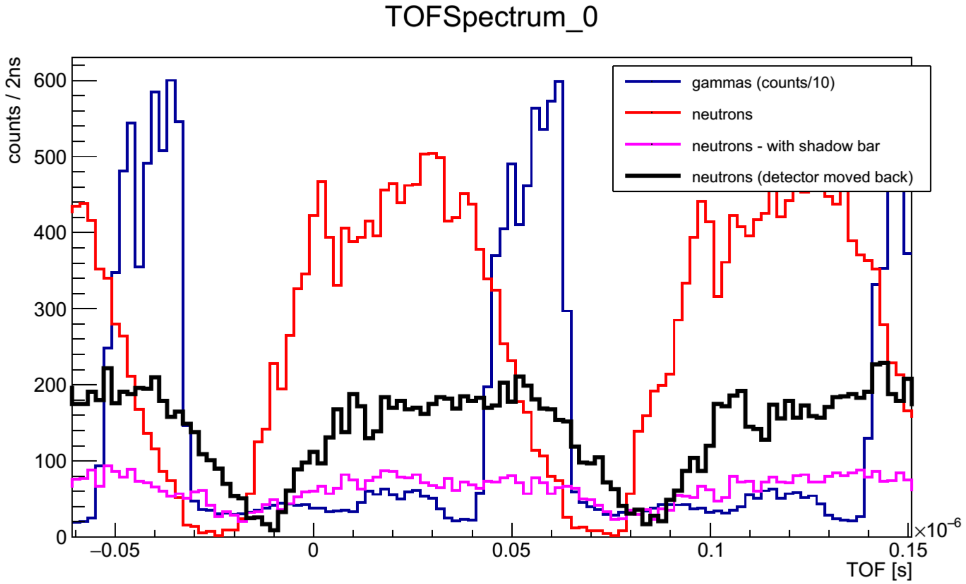
Vault-based irradiation

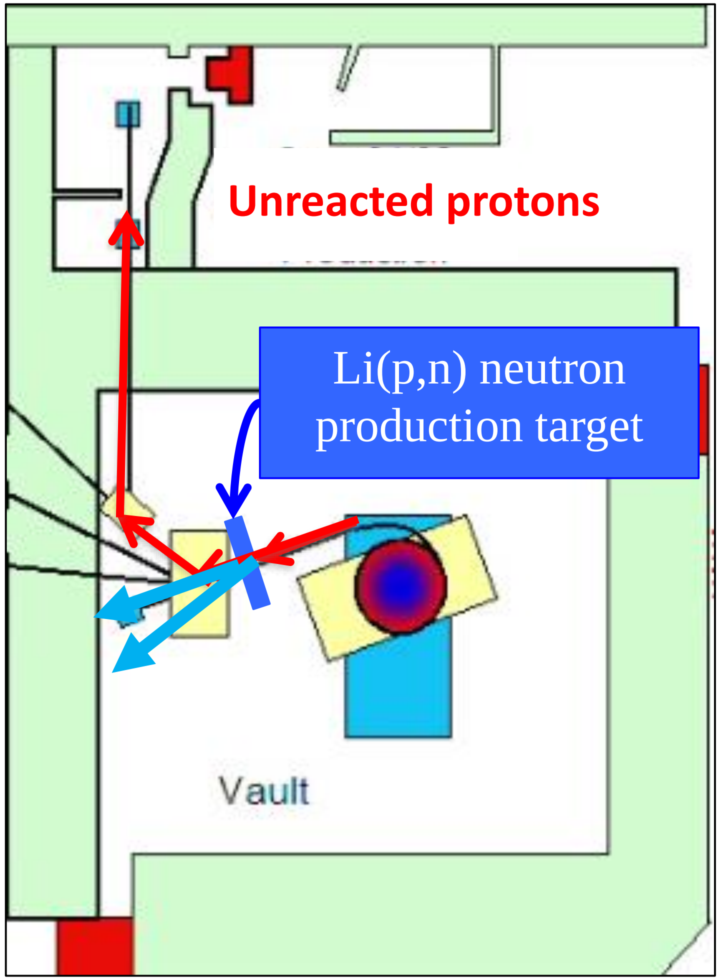



Inconel-clad Li targets(LANL LDRD)




- Neutrons from 0-***60*** MeV
- Y, Co, Al, In, Zr, Au samples irradiated in the vault
- Flux from $10^{6\text{-}4}$ /MeV/sr/s (decreases w/$E_n$)




**First experiments took place in April 2018**