Neutron-induced fission cross sections for $^{233,234,236,238}U$ up to 200 MeV

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Fission Experiments and Theoretical Advances (FIESTA)

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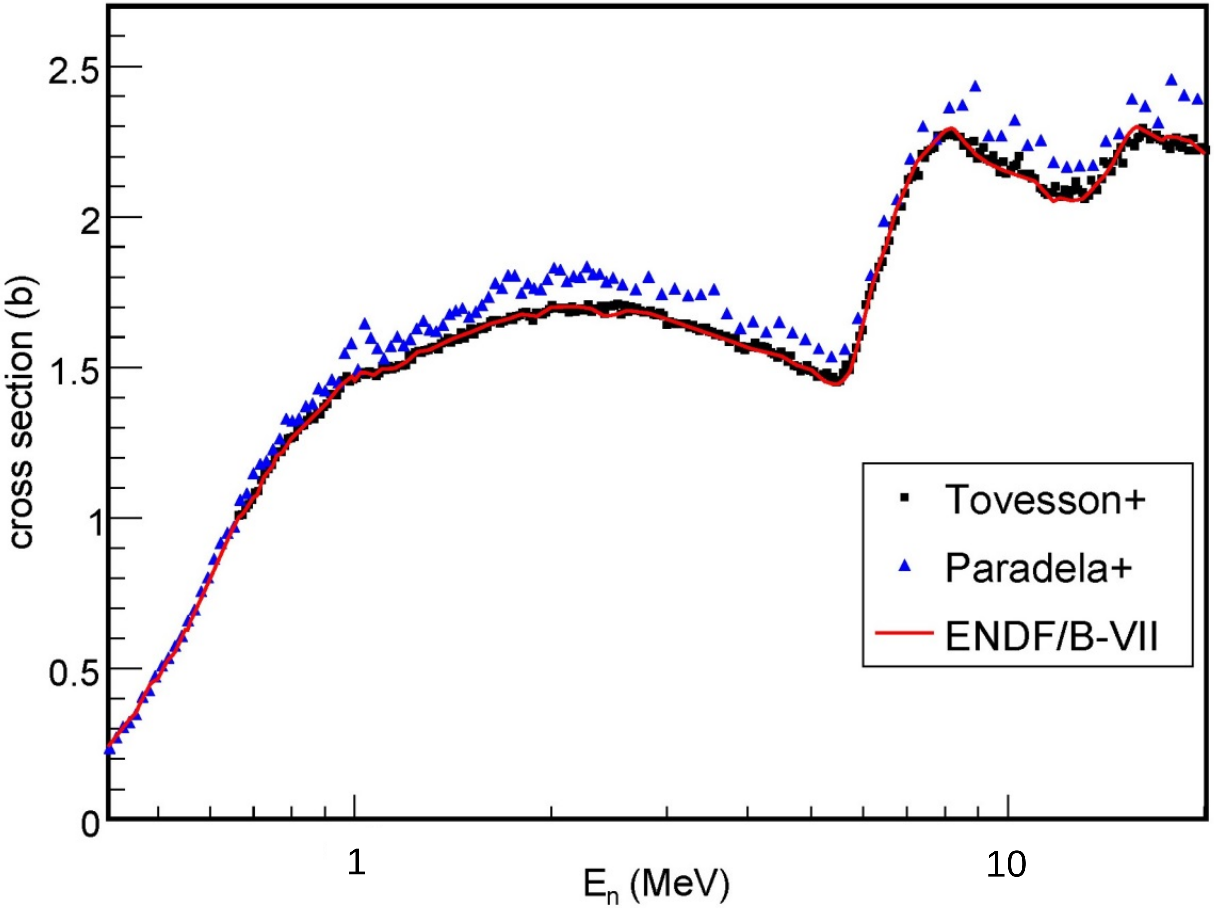
Outline

- Introduction
- The Los Alamos Neutron Science Center (LANSCE)
- Experiments and results
- Outlook

Introduction

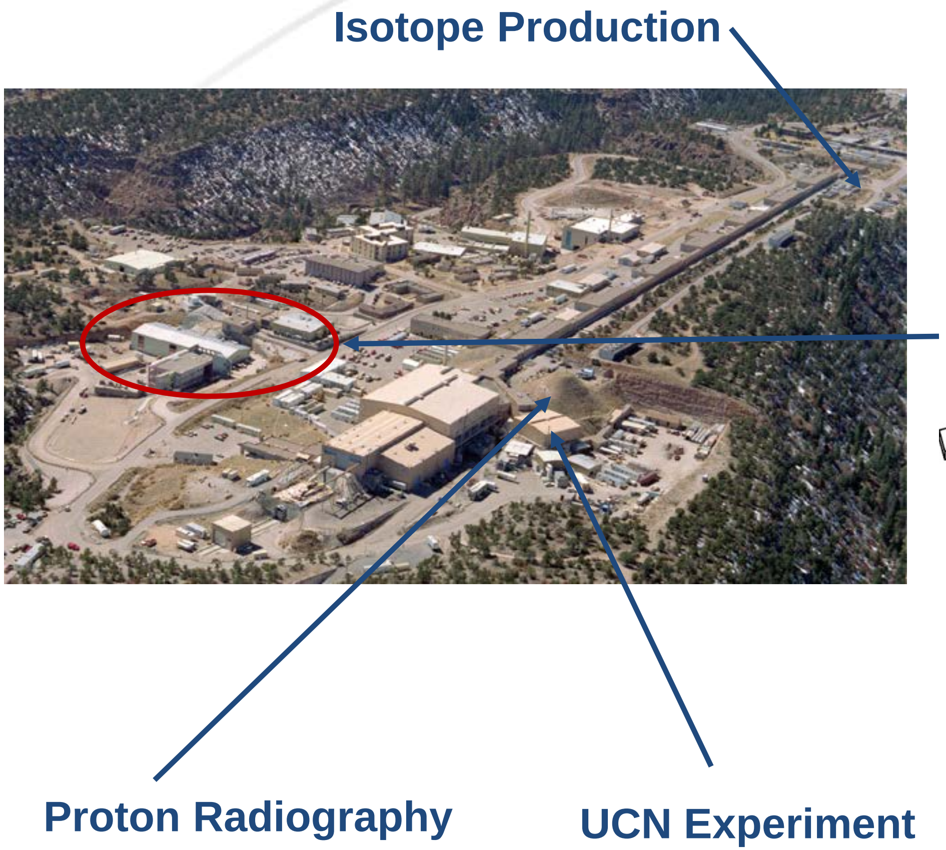
- **We still need new fission cross section measurements**
  - The cross sections of minor actinides play a more prominent role in fast reactors
  - Questions have been raised regarding the uncertainties in evaluations of major actinides
  - The U-238 and U-235 ENDF evaluations extend up to 200 MeV, very few measurements extend above 15 MeV
- **Traditional detector techniques provide reasonable high accuracy for fission cross sections**
  - Neutron sources such as LANSCE and n_TOF allows us measure over wide range of neutron energies
  - New types of detectors could further reduce uncertainties
- **The evaluation process benefits from systematic measurements**
  - Many isotopes
  - Wide range of neutron energies

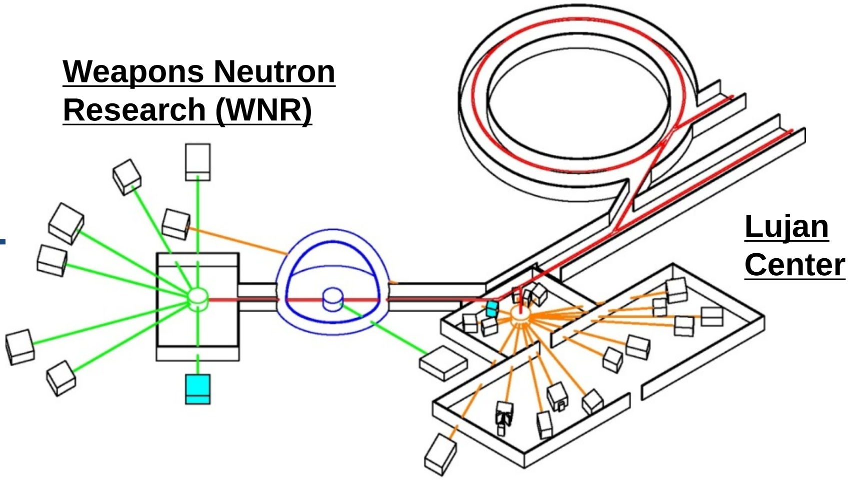
Recent measurements by different groups show discrepancies



- Np-237(n,f) was measured at LANL and n_TOF in recent years
- A 5% discrepancy above 1 MeV is observed
- Older measurements support he LANL result, recent Geel measurements support the n_TOF result

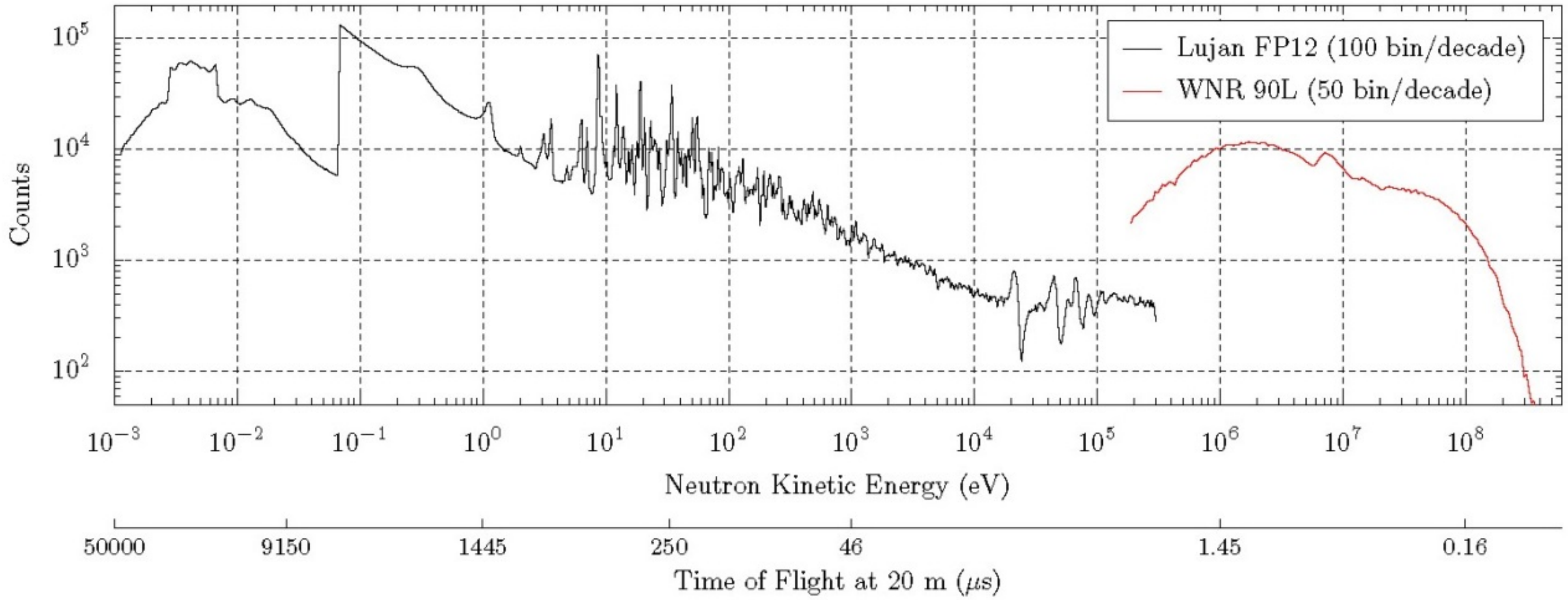
The Los Alamos Neutron Science Center (LANSCE)





- Spallation neutron source
- Moderated & un-moderated flight paths
- Neutron time-of-flight

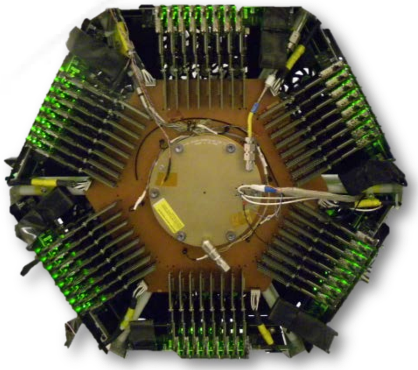
LANSCE provide neutrons from thermal to hundreds of MeV



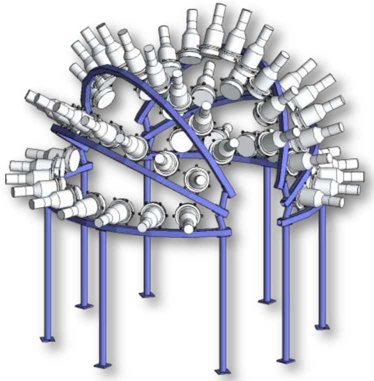
- High neutron flux over the full energy range
- Excellent resolution for fast neutrons, reasonable for slow neutrons

Nuclear Science Capabilities

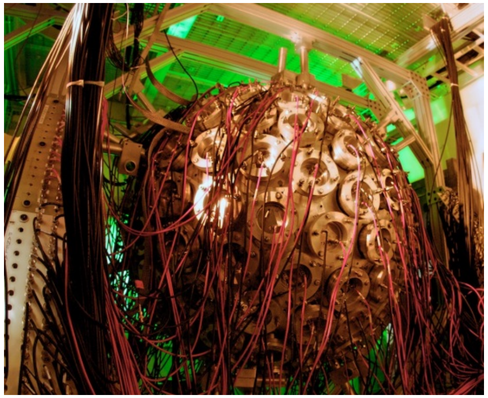
TPC
fission cross sections



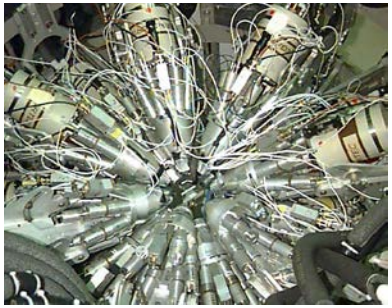
Ch-Nu
neutron output



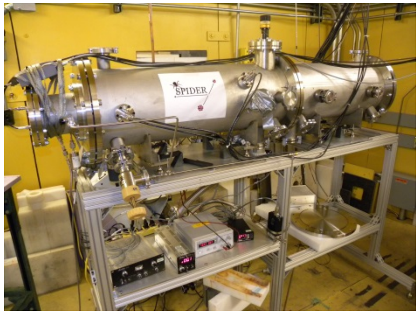
DANCE
neutron capture, fission ɣ-rays



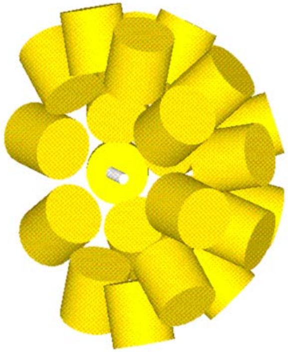
GEANIE
gamma production, Pu(n,2n)



SPIDER
fission yields

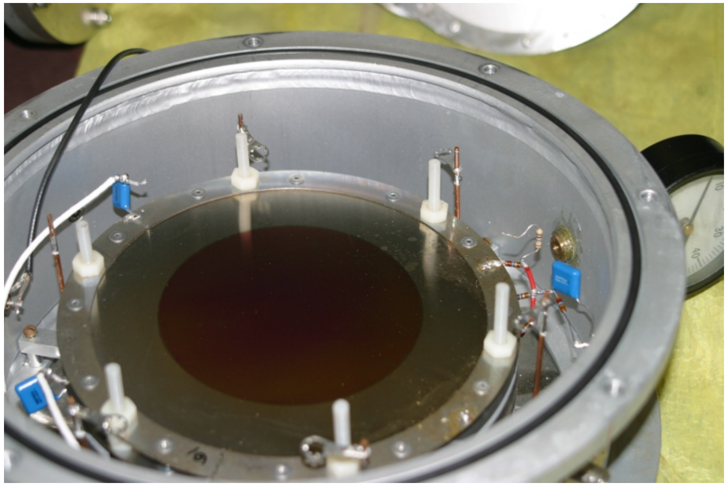


APOLLO
ɣ-rays for ion beam experiments



Fission cross section measurements at LANSCE

- **Fission counting with parallel plate ionization chamber**
  - Up to 4 foils per chamber
  - 12 mm cathode grid spacing: fragments does not range out
  - Energy deposition used to qualify fission events
- **Relative measurements**
  - Using the ^{235}U(n,f) standard
- **Neutron time-of-flight**
  - Wide neutron range measured in one experiment
  - Background due to frame-overlap and room return neutrons



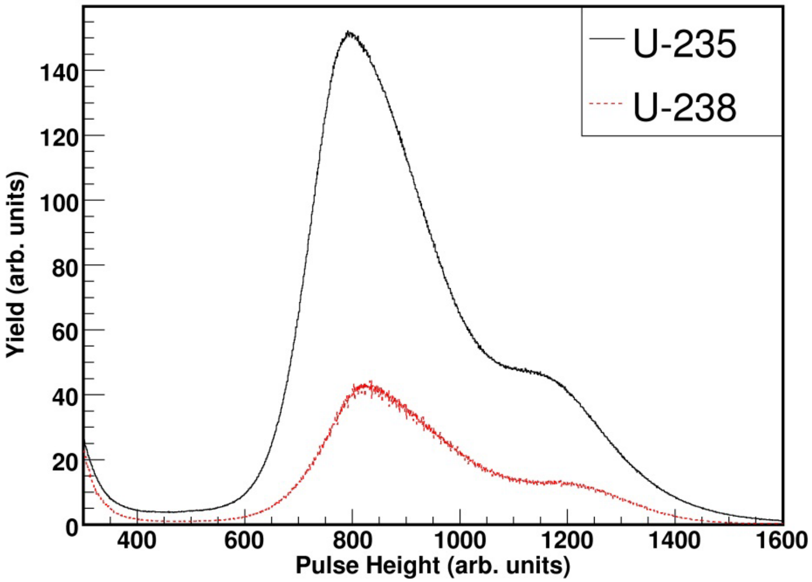
Measurement uncertainties are typically 3-5%

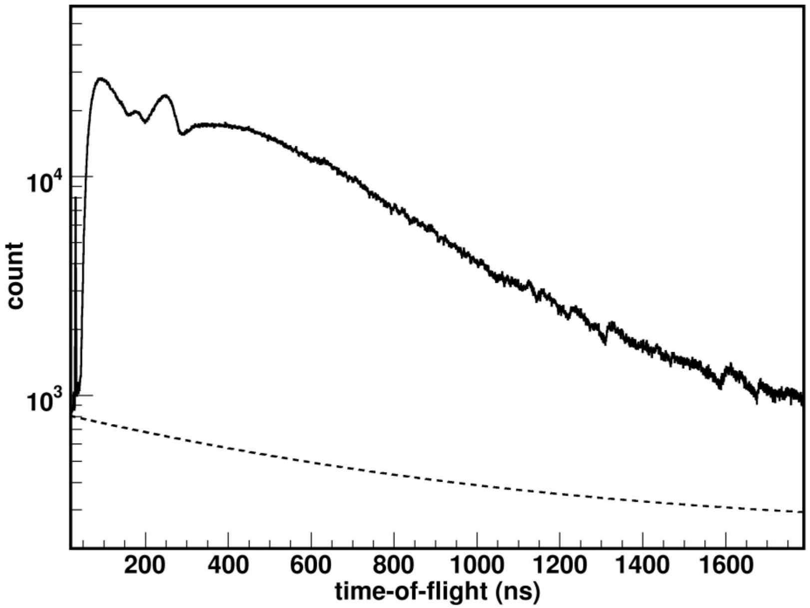
- **Neutron source**
  - Time-of-flight uncertainty 0.3%
  - Beam profile 2%
  - Neutron background 1%
- **Target**
  - Total number of atoms 0.5%
  - Uniformity of deposit 2%
  - Contaminants 0.1%
- **Fission detection**
  - Efficiency 0.5%
  - Dead-time 0.3%
  - Fission identification (background rejection) 1%
- **Normalization**
  - Accuracy of standard reaction 1%

$$\frac{\sigma_{Pu242}(E)}{\sigma_{U235}(E)} = \frac{N_{U235}}{N_{Pu242}} \cdot \frac{\epsilon_2(E)}{\epsilon_1(E)} \cdot \frac{\Phi_2(E)}{\Phi_1(E)} \cdot \frac{w_1^{-1}(E) \cdot C_1(E)}{w_2^{-1}(E) \cdot C_2(E) - C_2^b(E)} - \frac{N_{Pu239}}{N_{Pu242}} \cdot \frac{\sigma_{Pu239}(E)}{\sigma_{U235}(E)} - \frac{N_{Pu241}}{N_{Pu242}} \cdot \frac{\sigma_{Pu241}(E)}{\sigma_{U235}(E)}$$

Total uncertainty: 3%

Detector response

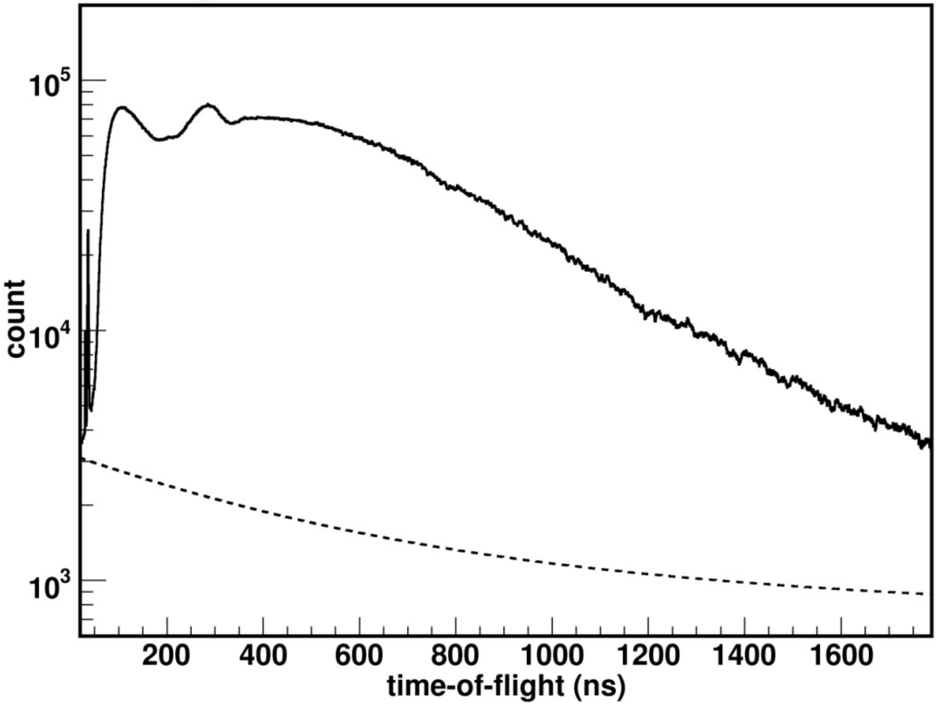




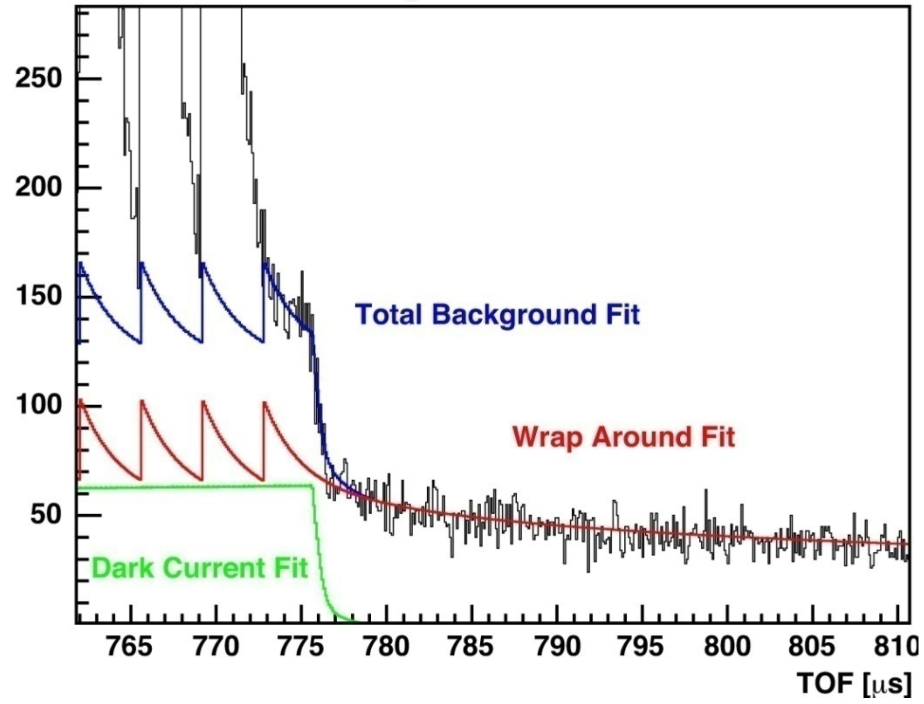
- The ionization chamber measures energy loss of particles in gas volume
- A fast time signal (~1 ns) is used to calculate neutron time-o-flight

Time-of-flight background is carefully corrected for

Short range, high resolution TDC



Long range, low resolution TDC



Accelerator-related background events are modeled and fitted to event rates between macro-pulses

^{233}U(n,f): no surprises here

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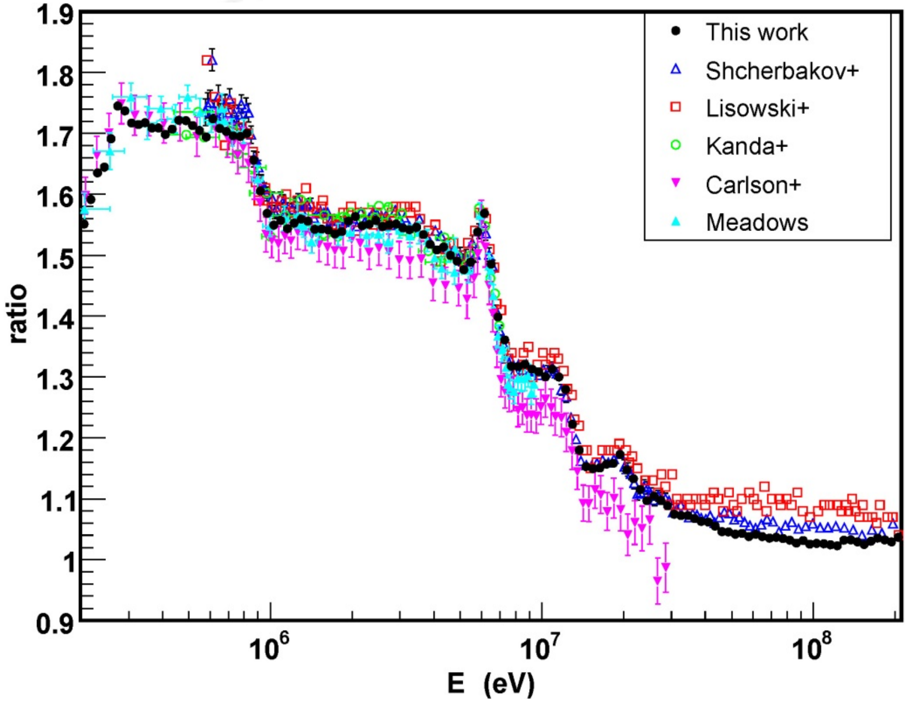
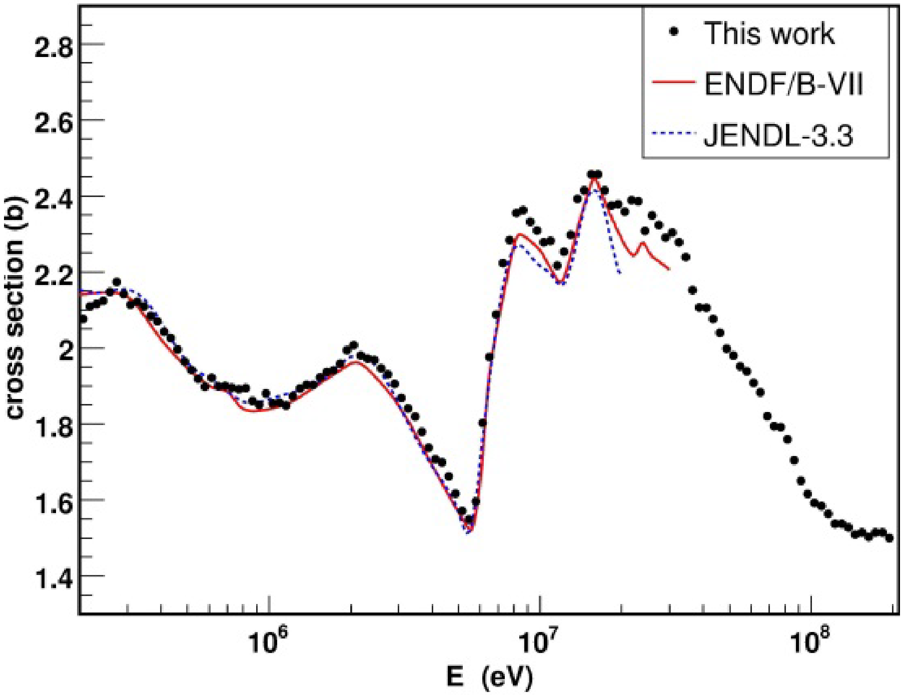
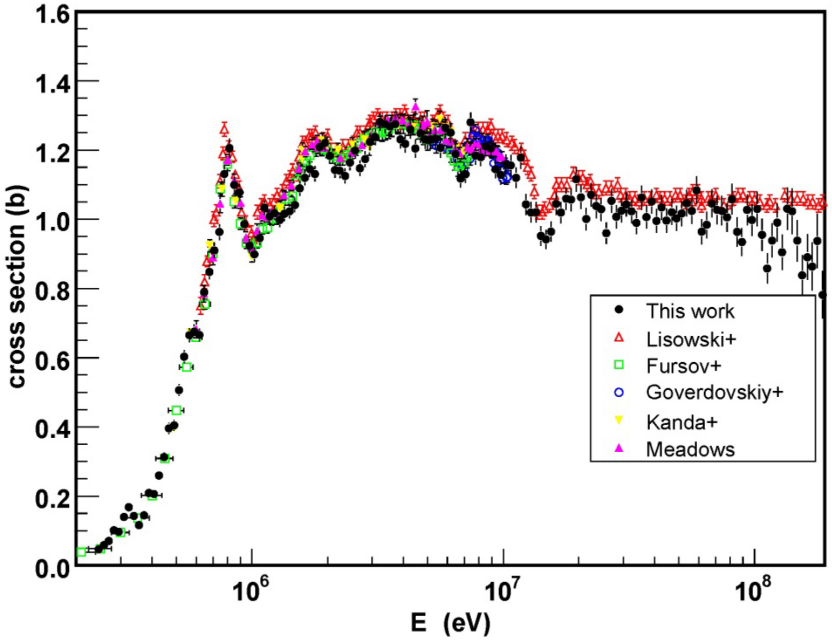


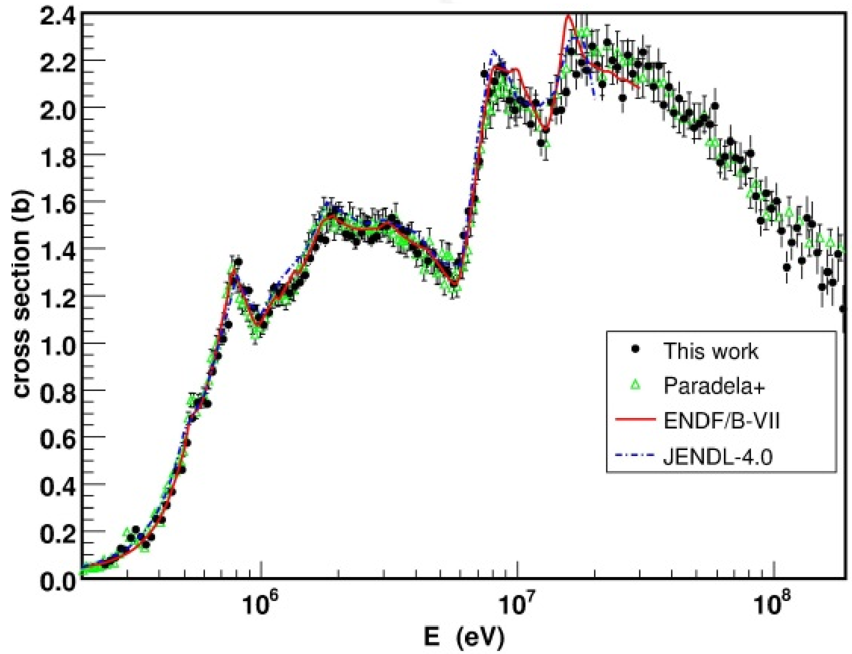


- U-233 is the fissile fuel in the Thorium fuel-cycle
- The current results is in good agreement with the result of Shcherbakov et al. above 20 MeV, but the cross section measured by Lisowski is about 5% higher

NNSA National Nuclear Security Administration

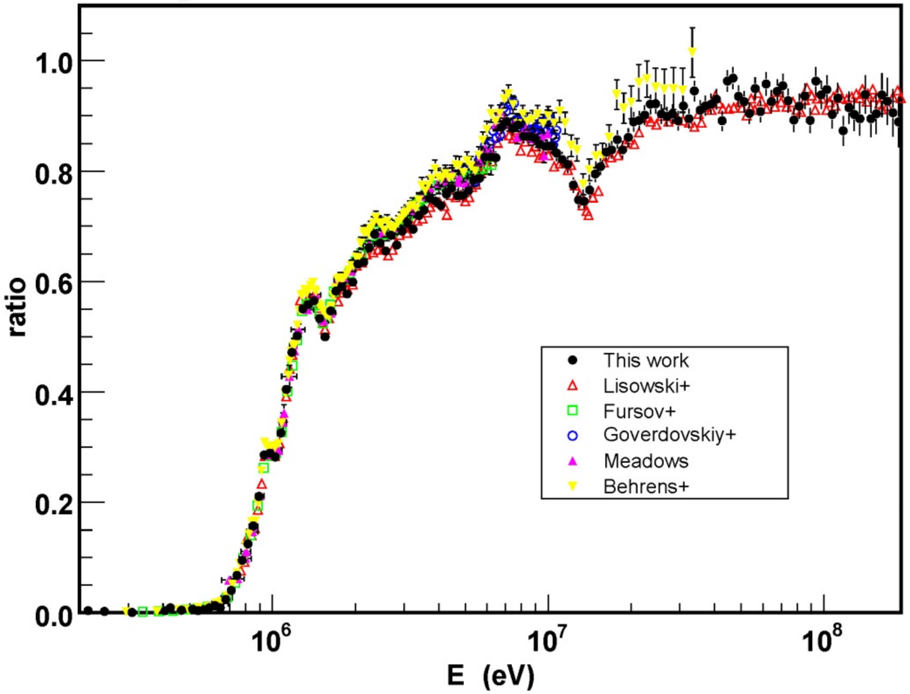
^{234}U(n,f): agreement with n_Tof

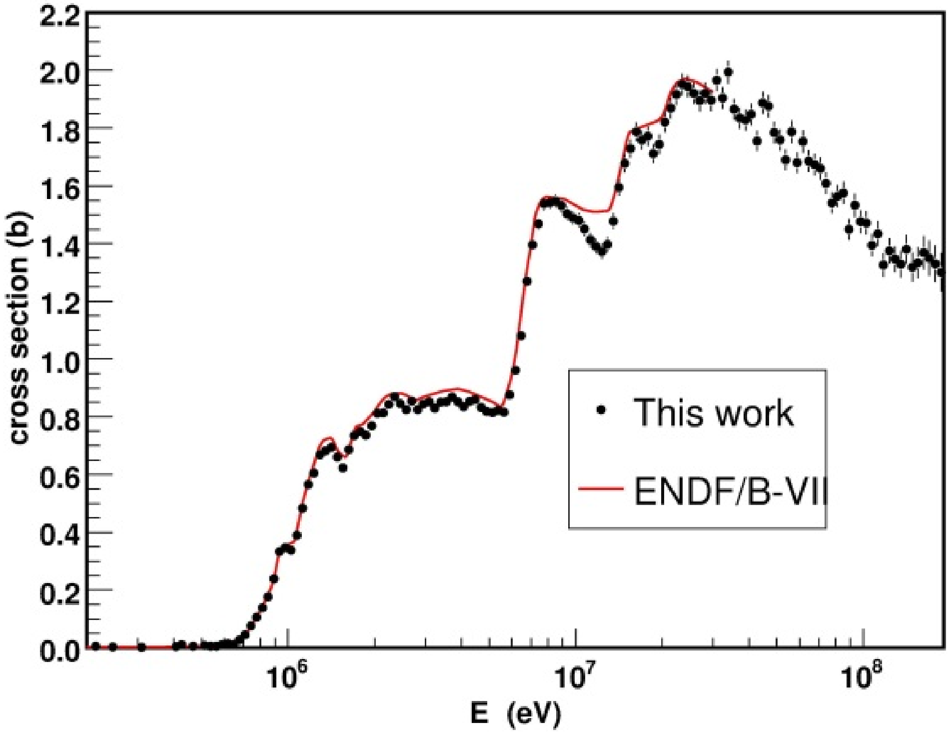




- The result for U-234 is consistent with the works by Lisowski and Paradela

$^{236}U(n,f)$: ENDF a little high?





- The current result agrees with Lisowski et al., and might indicate that the ENDF evaluation is slightly high

^{238}U(n,f): very close agreement with Lisowski et al.

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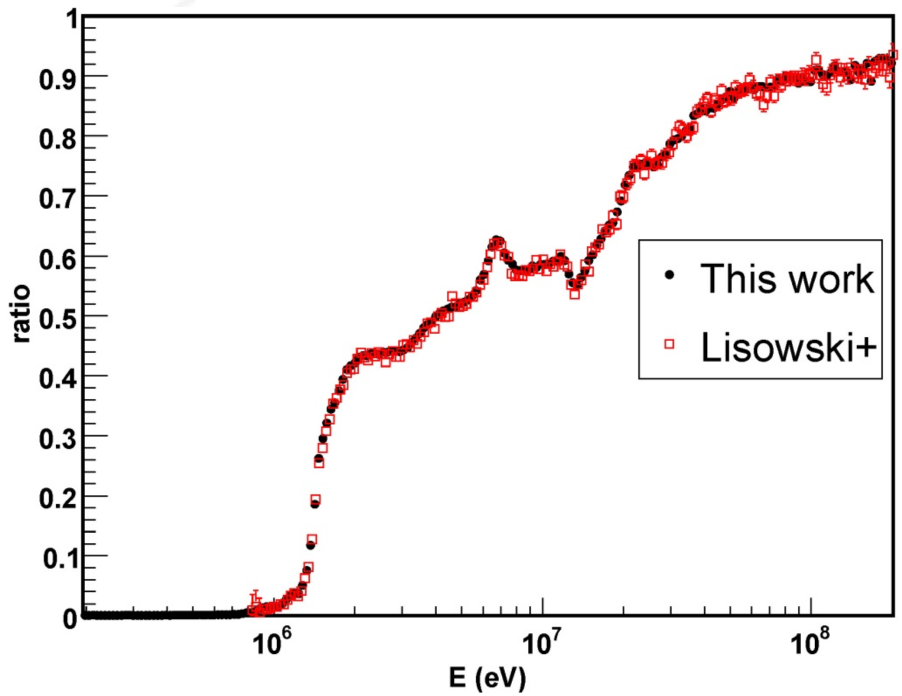
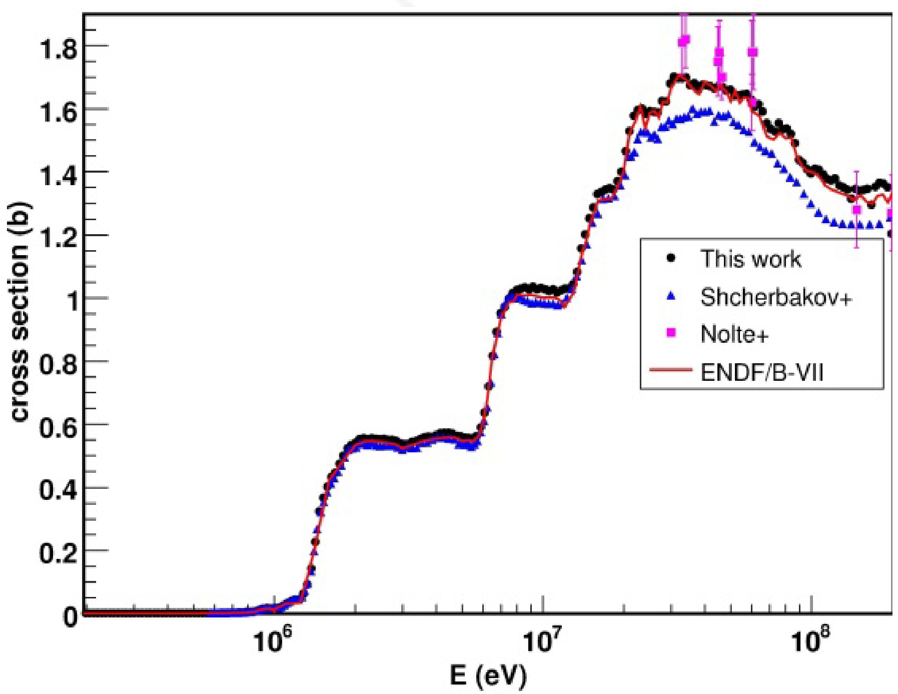


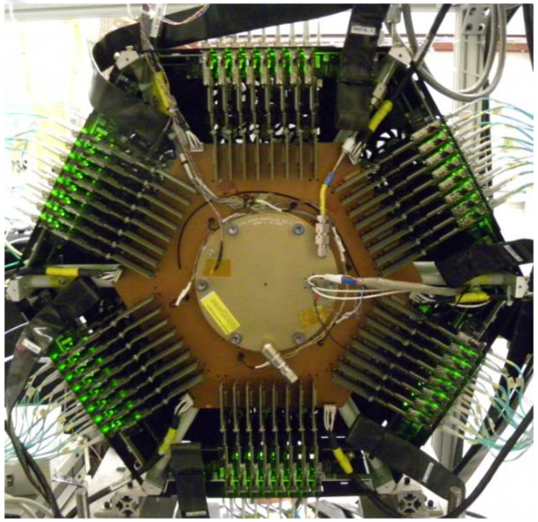


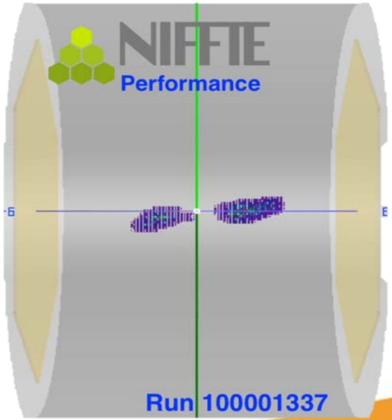
- The U-238/U-235 (n,f) ratio is important since both cross sections are standards
- Result is in close agreement with Lisowski et al., and significantly higher than the cross section by Shcherbakov

The TPC will reduce measurement uncertainties to 1%

- **Beam**
  - Time-of-flight uncertainty 0.3%
  - Beam profile 0.1%
  - Neutron background 0.2%
- **Target**
  - Total number of atoms 0.3%
  - Uniformity of deposit 0.3%
  - Contaminants 0.1%
- **Fission detection**
  - Efficiency 0.1%
  - Dead-time 0.2%
  - Fission identification 0.2%
- **Normalization**
  - Accuracy of standard reaction 0.3%

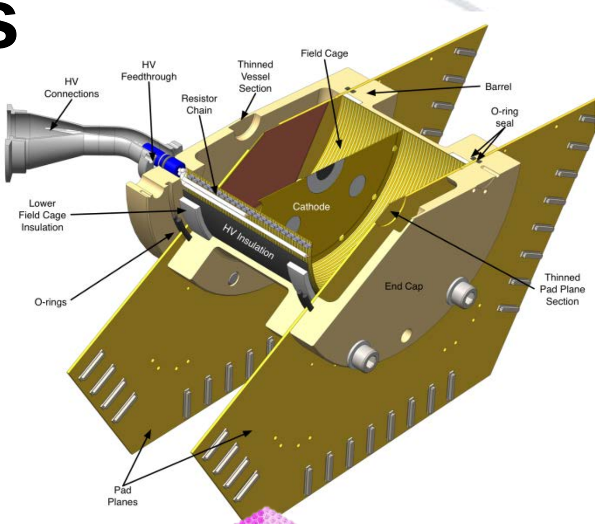
Total uncertainty: 0.7%

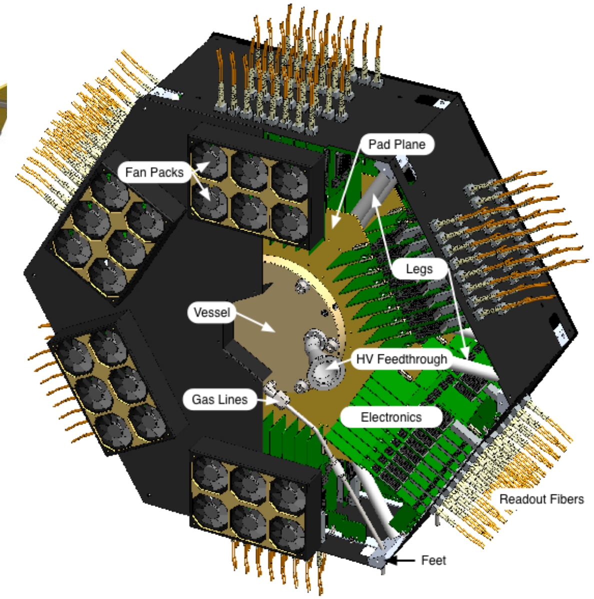


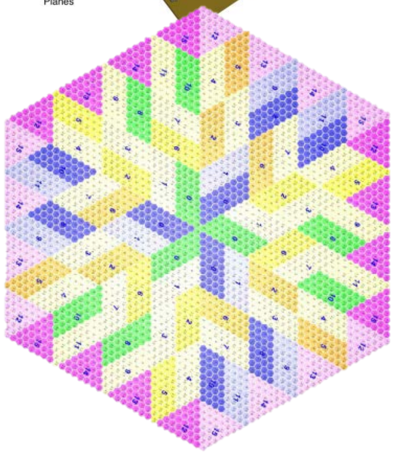


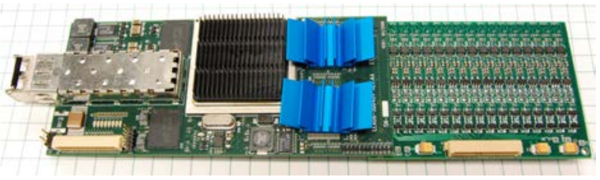
The fission TPC was scaled for fission studies

- ~4π solid angle coverage
- MICROMEGAS detector
  - 5952 readout pads
- Custom digital electronics
  - $55/channel, 30 MB/s sustained data rates
- Large dynamic range - designed for normalization to H(n,n)H
- Complete software suite includes remote online monitoring and detailed GEANT-based simulation









M. Heffner, D.M. Asner, R.G. Baker, *el al.*, *A Time Projection Chamber for High Accuracy and Precision Fission Cross Section Measurements*, **submitted to Nucl. Instr. and Meth**.

Summary & conclusions

- Fission cross sections are studied over a large range of excitation energies at LANSCE
- Total uncertainties are about 3% in current measurements
- We want the experimental data to impact evaluations
  - We need to provide detailed uncertainty budgets
  - Communicate with evaluators (good example of that: Chi-Nu)
- New measurement techniques will allow us to further reduce uncertainties to about 1%