IAEA
International Atomic Energy Agency
Atoms for Peace and Development

IAEA Technical Meeting on Nuclear data for Reactor Antineutrinos and applications

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Nuclear Data Section
International Atomic Energy Agency

International Atomic Energy Agency

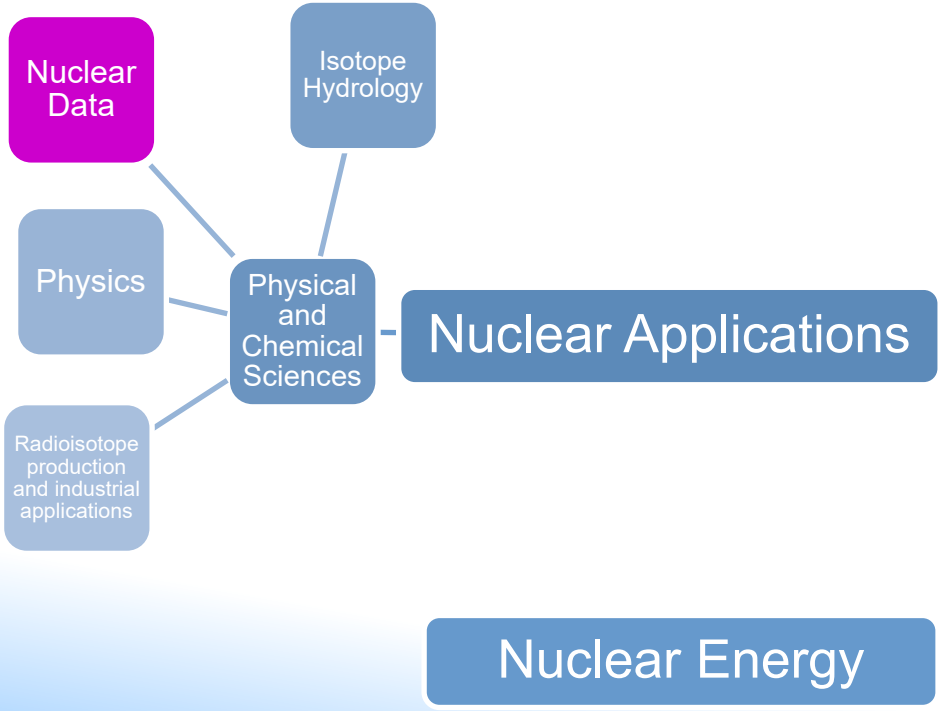
The world centre for cooperation in the nuclear field since 1957

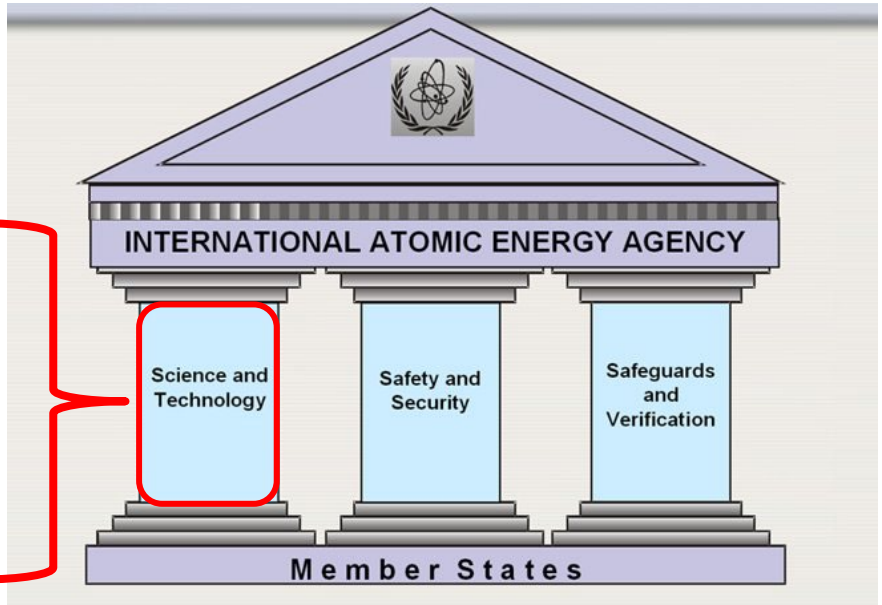
Promotes the safe, secure and peaceful use of nuclear technologies

Total of 177 Member States

About 2500 personnel

Promoting and supporting safe, secure and peaceful application of nuclear technologies





Nuclear Data Section

IAEA

NSDD
Nuclear Structure & Decay Data Network

NRDC
Nuclear Reaction Data Center Network

INDEN
International Network of Nuclear Data Evaluators

Develops nuclear data through data development projects and international networks

Promotes research through international coordinated research projects & technical meetings

Reference Database for beta-delayed neutrons

Photonuclear Data and Photon Strength Functions

Fission Yield Data

Decay Data for Antineutrino Spectra and Applications

ICTP The Abdus Salam International Centre for Theoretical Physics

IAEA

Enhances capacity building via training workshops and mentoring schemes

Provides services in dissemination of databases, web tools and technical documents

LiveChart of Nuclides
Interactive Chart of Nuclides
Mobile App: Isotope Browser

Isotope Browser for mobile

Medical Isotopes
Accelerator simulations

Beta-delayed neutrons
Reference Database for Beta-Delayed Neutron Emission

Joint ICTP-IAEA Workshops on:

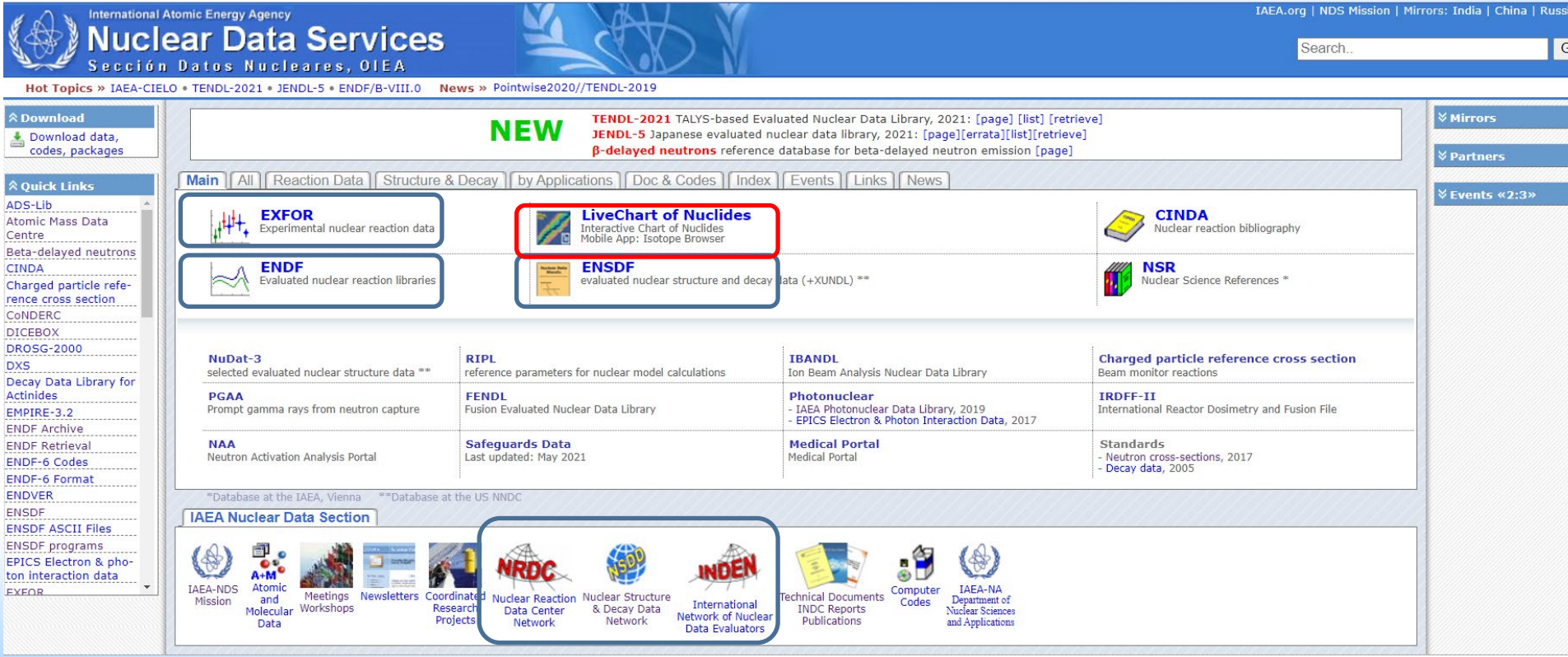
Nuclear Structure and Decay Data

Nuclear Data Measurements for Science and Applications

Nuclear Reaction data for Applications

Nuclear Data Services

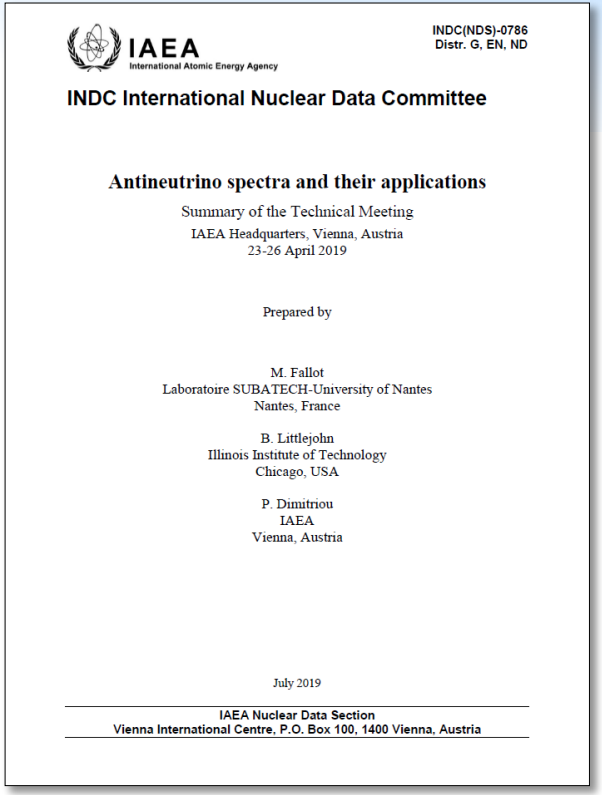
https://www-nds.iaea.org/



Background

1st IAEA Technical Meeting on Antineutrino spectra and their applications, 23-26 April 2019

- 37 participants from 11 countries
- Topics
  - Reactor antineutrino measurements for basic science and applications
  - Flux and spectrum modeling
  - Nuclear data and reactor data needs
- Summary report: INDC(NDS)-0786



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INDC(NDS)-0786
Distr. G, EN, ND

INDC International Nuclear Data Committee

Antineutrino spectra and their applications

Summary of the Technical Meeting
IAEA Headquarters, Vienna, Austria
23-26 April 2019

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July 2019

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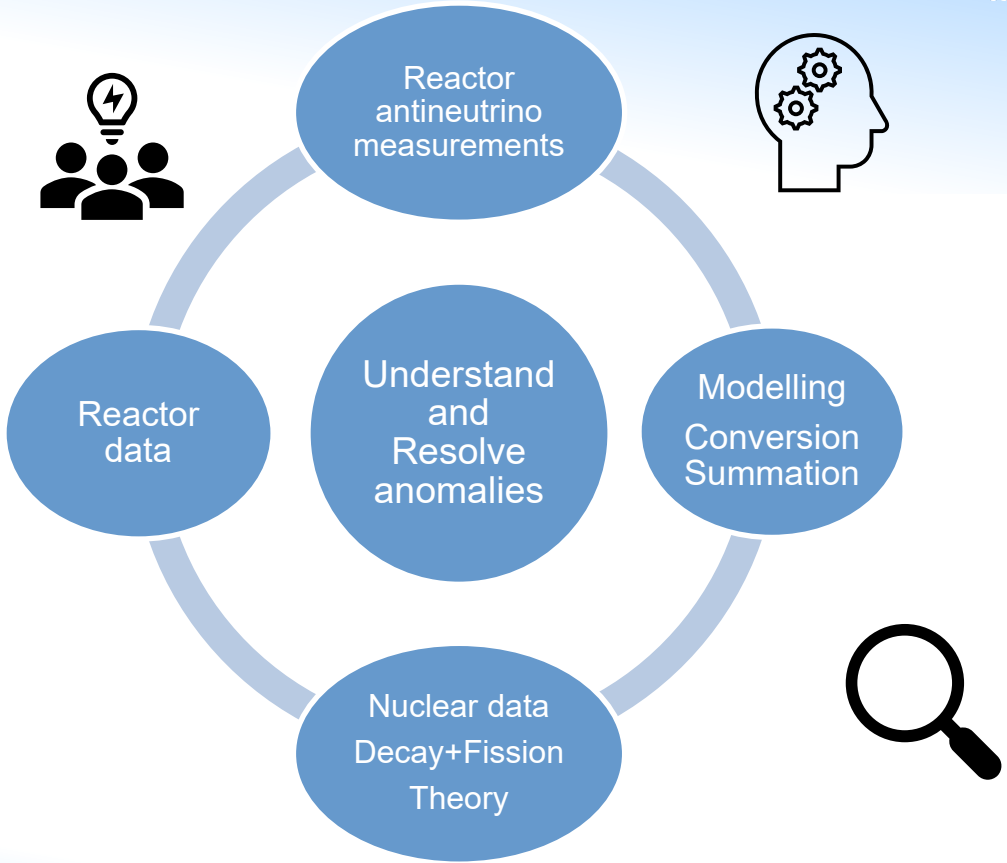
Inter-disciplinary

- Presentations – Q&A
- Roundtable discussions
- Recommendations
- Common statements - Report

New ideas
New collaborations
New meetings



Follow-up:2nd IAEA Technical Meeting on Reactor Antineutrino spectra and applications, 16 – 20 January 2023

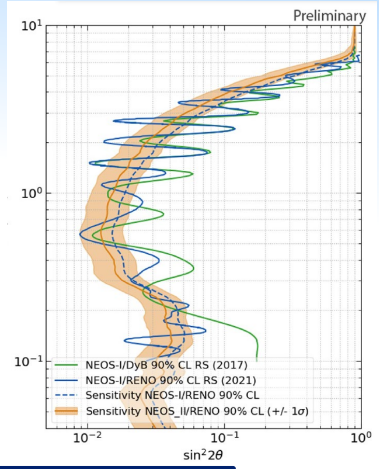
- Purpose:
  - follow up on progress
  - revise status and data needs
  - address data preservation and dissemination
  - needs for coordination
- Participants: 56 registered; 18 in person
- Countries: China, France, Germany, Korea, Poland, Spain, Russia, US
- Report: in preparation

https://conferences.iaea.org/event/337/

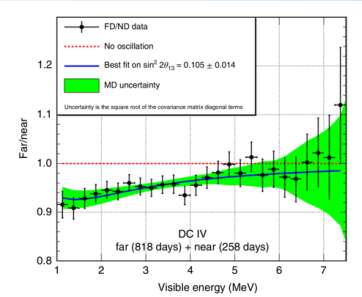
Reactor antineutrino experiments

- **Highlights**
  - Sterile neutrino phase space have been narrowed down – not entirely ruled out
  - ILL beta spectra measurements could be root cause of RAA – supported by DB fuel evolution measurements
  - Spectral distortion is not yet understood
  - Number of experiments in the final stages of analysis and further joint analysis planned
  - On-surface and mobile detectors are being developed
- **Future**
  - Improve uncertainties in short-baseline experiments
  - Coordination and collaboration btw different experiments and joint analyses (see DB/PROSPECT; PROSPECT/STEREO)
  - Correlated HEU/LEU measurements
  - JUNO/TAO results expected
  - Expert guidance on different reactor types needed

NEOS II : sterile neutrino search



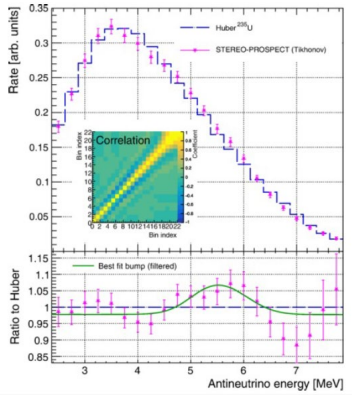
Double CHOOZ : $\sin^2 2\theta_{13}$



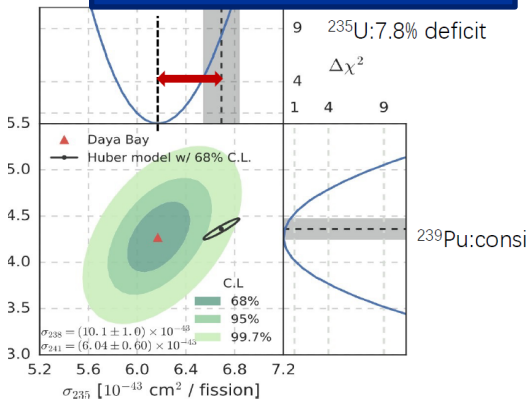
$\sin^2(2\theta_{13}) = 0.102 \pm 0.011\,(\text{syst.}) + 0.04\,(\text{stat.})$

PROSPECT/STEREO Joint Spectrum Analysis

Bump excess has 2.4σ significance

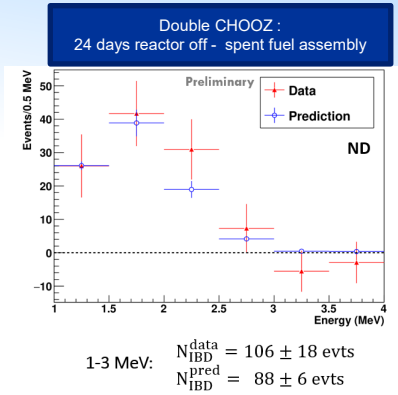


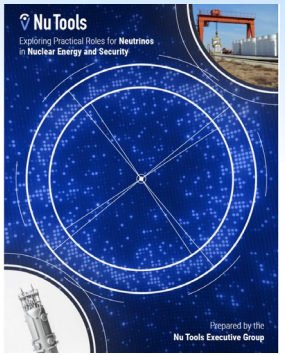
Daya Bay: data point to ^{235}U as main responsible for RAA

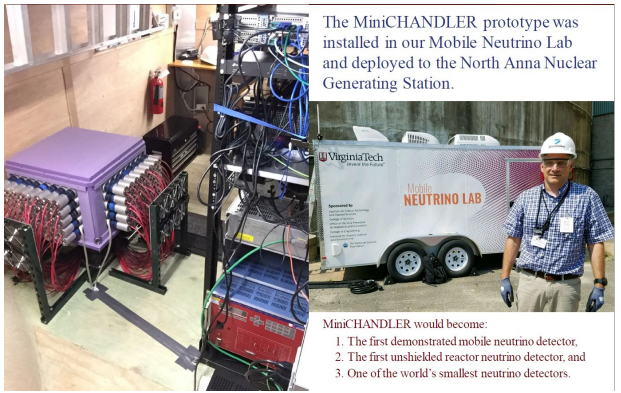


Antineutrino applications: reactor monitoring, spent fuel

- **Antineutrino applications: reactor monitoring, spent fuel**
  - Clear observation of residual antineutrinos (Double CHOOZ)
  - Nu Tools report: discussion of the utility of actual uses cases in the US – engagement with end-users
  - Antineutrino detectors as on/off monitors demonstrated
  - Detector technology and prototypes that have the potential to meet requirements and boundary conditions
  - New detector materials - potentially at industrial level
- **Challenges**
  - Backgrounds – too high
  - There is no clear use case – mostly tied to cost and effort associated with it
  - "Nu Tool" scoping studies outside the US?
  - Resources (funding)
- **Future**
  - Continue to develop use cases
  - R&D on demonstrating technology
  - Measurements in different reactors (for basic science, for nuclear data, for operations) AND different detector at same reactor to understand systematics
  - Open channels of communication with reactor physicists



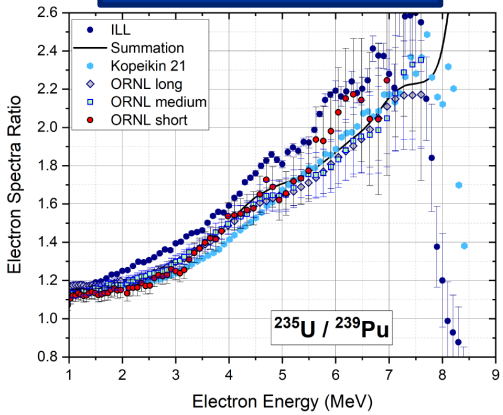




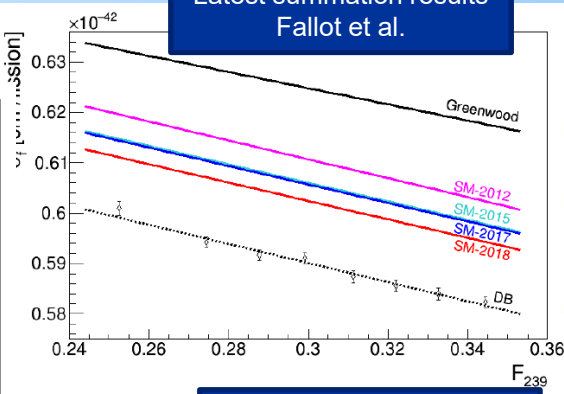
Modeling flux and spectrum

- **Modeling flux and spectrum**
  - Significant progress in summation calculations: agree with flux evolution from Daya Bay
  - New Kurchatov Inst. U235/Pu239 measurement
  - Steps towards quantifying uncertainties
  - New open computational tools -ConFlux
- **Challenges**
  - Uncertainty quantification
  - Better input data: decay data, fission yields, covariances, long range correlations
  - Access to standardised experimental data formats
- **Future**
  - New and improved input data (fission yields with covariances)
  - Inter-comparison of summation models
  - Theoretical predictions (nuclear)
  - Calculated spectra for new/other reactor types
  - Shared open computational tools – easy to validate input data and enhance exchanges btw groups

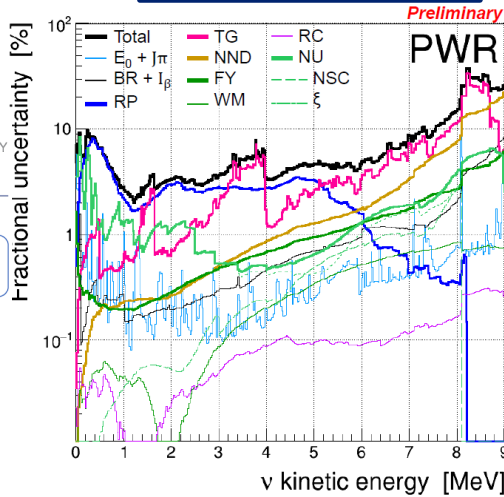
New beta spectra, Sonzogni et al.



Latest summation results Fallot et al.

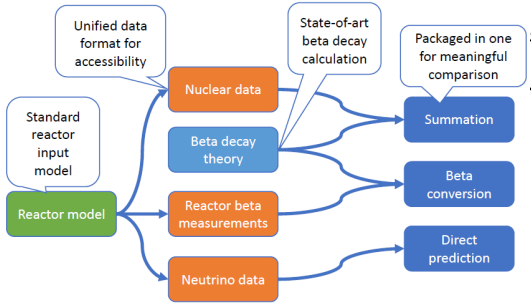


Summation with uncertainty budget, Perisso et al.



Xianyi Zhang et al.

CONFLUX



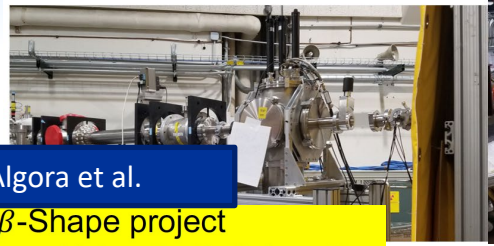
Nuclear data

- **Highlights**
  - New TAGS measurements – improved decay data
  - Improved treatment of non-unique forbidden transitions
  - Recommended isomeric fission yield ratios
- **Challenges**
  - TAGS data related to high E part of spectrum are difficult to measure
  - Beta delayed neutron spectra to compare with JUNO/TAO
  - Disentangle isomers and grounds state spins
  - Covariance matrices associated with the measurements
  - Fission yields, isomeric ratios: ongoing effort
- **Future**
  - Integral beta measurements - new measurements to compare with ILL
  - Individual beta spectra measurements
  - Incorporate new evaluated fission yields with uncertainties
  - Improve beta shapes – consider microscopic nuclear models
  - Measurements to include contributors to high energy region of spectrum
  - Complete TAGS measurements and perform High Resolution Spectroscopy measurements where needed
  - Mass measurements/Q values, for identification of isomers

Rykaczweski et al.

MTAS at CARIBU

- Beams of ^{252}Cf fission products after a high-r
- Utilized Multi-Reflection Time-of-Flight (MR-TOF) separator to get isotopically purified beams
- Beam diagnostic cross and β-counter next the tape implantation point (UTK) added.
- Two Ge detectors at the collection point in coincidence with β-counter

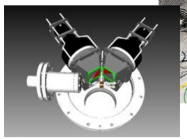


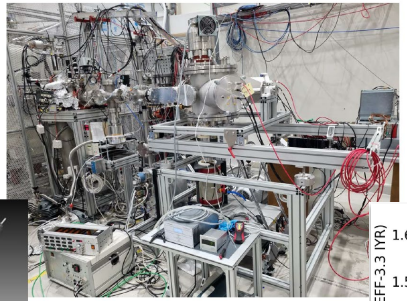
Algora et al.

β-Shape project
Nantes-Surrey-Valencia Collaboration

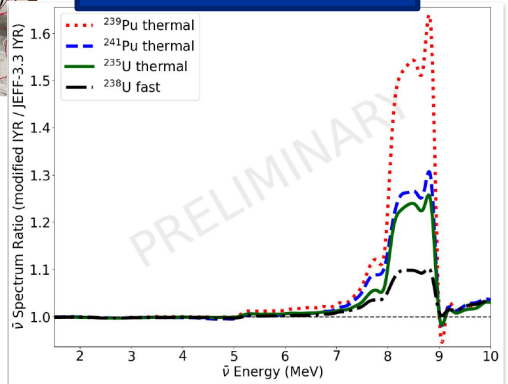
$\Delta E - E$ telescopes to measure the beta spectrum of selected decays using isotopically pure beams at Jyväskylä

Si and plastic detectors





Mattera et al.



Data preservation and dissemination

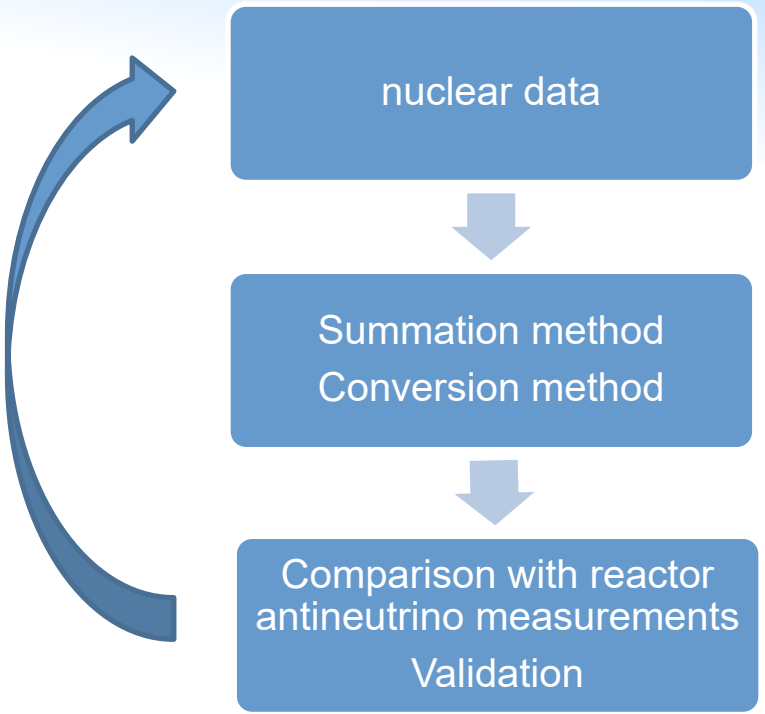
Research data management requirements have created NEW needs for standardization and formats, data management plans, and repositories

- **Status**
  - There is progress in making more and more data available in publications and supplementary material
  - Daya Bay has established a “good practice” in sharing data
  - Joint analyses (PROSPECT/DB; PROSPECT/STEREO)
- **Challenges**
  - What information can be archived for future analysis?
  - Standardization
  - Infrastructures [platforms, search engines, metadata] and repositories
  - Resources and coordination
- **Future**
  - Collaborations should provide both antineutrino spectrum and additional information (unfolded spectrum and covariance matrices)
  - Community should determine unified format (e.g. binning)
  - Need to archive reactor data in addition to neutrino data
  - Agree on a standard repository

U.Of Vienna - RDM

Reactor antineutrinos and their applications

- Nuclear data needs
  - What nuclear data are relevant
  - What nuclear data need to be improved
  - Priorities
- Validation of nuclear data
  - Use reactor antineutrino data as integral benchmarks to validate nuclear data

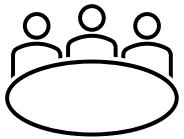


Conclusions - final recommendation

- Basic science goals: high precision data - almost there
- Applications: identify use cases – R&D needed – resources
- Modeling: improve nuclear theory – open computational tools
- Nuclear data: improve nuclear data – uncertainties – beta spectra
- Data preservation and dissemination: standardisation – sharing of data following FAIR principles

Progress limited by available resources – coordination is needed

Recommendation: form a Working Group under the auspices of the IAEA



Role: to coordinate and provide advice
Membership: international

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Thank you!