GALILEE: A nuclear data processing system for transport, depletion and shielding codes

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Introduction

**GALILEE Project**

- **CEA Nuclear Data Processing System** for Transport, Depletion and Shielding Codes (application codes)

- Part of a CEA global development program dedicated to fine modelling of nuclear systems.
  - Other projects contributing to this aim:
    - APOLLO3 (deterministic transport)
    - TRIPOLI-4 (Monte Carlo transport)
    - DARWIN3 (all fuel cycle problems)

- **GALILEE aims:**
  - To provide to application codes a tool-box allowing a consistent processing for nuclear data coming from any evaluation given in ENDF/B6 format,
  - To carry out an automatic chain for creating application libraries,
  - To provide consistent application libraries for modelling a nuclear system.
GALILEE project context

GALILEE project must be carried out in synergy
- with application codes in order to be able to share “data” but also “tools”
- with codes creating evaluations (CONRAD) in order to be able to share physical models

Introduction
Why a processing system

Nuclear Data stored in evaluations cannot be directly used in application codes
- Cross-Sections given by resonance parameters in Resonance Range
- Angular transfer laws given by Legendre polynomials decomposition (max. P64) at various incident energies
- ...

Processing step requires
- Physics: cross-section reconstruction thanks to nuclear formalisms
- Numerical methods: Multigroup parameters calculations thanks to integration techniques
- Computing: Library creation with a given format

Process depends on:
- Kind of information stored in an evaluation
- Physical problem studied
- Models used in application codes
**GALILEE Project Steps**

**GALILEE-V0**

- Reinforce our experience in Nuclear Data Treatment
  - ~20 know-how years
- Perpetuate our specific processing tools

**GALILEE-Vn, n ≥ 1**

- **Carry out a new** Nuclear Data processing system
- Ensure consistency with evaluation data production
- Insert Nuclear Data processing as one of the major components of a nuclear system modelling
- Have a processing system at the same “Quality Level” as the new Physics Core or Criticality Codes
  - APOLLO3 (CEA)
  - TRIPOLI-4 (CEA)
  - DARWIN3 (CEA)
- Introduce a « modularity » between nuclear data treatment and application codes
GALILEE-V0 Description

Elaboration of an integrated chain producing automatically consistent libraries for APOLLO2 and TRIPOLI-4

- Processing chain GALILEE-V0-1
- In β-tests at CEA/SPRC since January 2008

Based on:

- NJOY99: Los Alamos Nuclear Data processing system (USA)
- CALENDF-2005: CEA Nuclear Data processing code
  - Probability Tables
- PREPANJ99
  - data for NJOY and CALENDF
- LIBNJ90
  - Convivial access to ENDF, PENDF and GENDF NJOY formats
- N2A2
  - interface between NJOY and CALENDF output files and APOLLO2 libraries
- Scripts written in PERL
2008 planned developments

- Introduce ECCO/ERANOS-2 library creation in GALILEE-V0 chain
- Create a verification tool allowing us, when a new library coming from a new evaluation is produced, to test
  - Data consistency and completeness
  - The impact of the new evaluation on a set of calculations
    - Core Physics
    - Criticality
    - Depletion
    - Shielding
    - ...
GALILEE-V0-1 Chain

- **File**
- **Code**

**Evaluation**

- **NJOY/RECONR**
- **NJOY/BROADR**

**PENDF**

- **NJOY/HEATR**
- **NJOY/THERMR**
- **NJOY/UNRESR**

**PENDF**

- **NJOY/THERMR**

**TRIPOLI-4**

**TP**

- **CALENDF**

**N2A2**

**NJOY/GROUPR**

**GENDF**

- **APIOLLO2**

Workshop on processing tools for evaluated nuclear data libraries

November 18, 2008 Issy les Moulineaux, France
Library effect on an UO2 depletion cell calculation

- JEF-2.2 versus JEFF-3.1
- BVII.0 versus JEFF-3.1
- New 016 & New Zr91 and Zr96 versus JEFF-3.1

From S. MENELLE
GALILEE-V1: Why a new Nuclear Data Processing System? (1)

Nuclear Data Processing activity (capability & skill) is essential at CEA

GALILEE-V1 aims:

• Provide fully **mastered tools**
  - Renewed and standardised
  - That can be parameterised
  - Able to create **all** the application code libraries

• Provide a **processing system** with two complementary running ways
  - An **integrated** way to create, with a convivial and automatic chain, consistent libraries for all the application codes
    - consistent global modelling of a nuclear system.
  - An **open** way to provide processing tools for application codes
Nuclear Data Processing activity (capability & skill) is essential at CEA

- GALILEE-V1 could provide a shared platform for nuclear data treatment
  - CEA/IRSN
    - R&D
    - Use of a common tool
    - Possible co-developments if an agreement is found for property/diffusion rights
  - Interest shown by OCDE for a European nuclear data processing system, open, linked to JEFF3 (IRSN proposal at November 2007 JEFF meeting)
  - Durable teams involved in GALILEE
    - Associated to new code development sustained by industrials or by safety authority
To develop our own nuclear data processing tools allows us to master the modelling carried out in application codes

- Nuclear data processing depends on the use of the data in the application codes

Full mastering of processing tools allows to choice:

- What kind of nuclear data a given application takes into account
  - Scattering reaction
    - total
    - elastic & total inelastic
    - elastic & each inelastic level
- Processing accuracy and interpolation laws (reconstruction)
- Nuclear Data Representation
  - Standard ones (PENDF, GENDF, PT)
- Data format
R&D Activities

• Improve some nuclear data process
  - Unresolved range
  - Anisotropy
  - Thermal range
  - Uncertainties

• Define new nuclear data representation
  - Anisotropy
Cross-section reconstruction in unresolved resonance range
Groupwise Anisotropy calculation

$^1\text{H} : $ Transfer from (15-17MeV) to (7.79-10MeV)

From C. JOUANNE & C.M. DIOP
Uncertainty propagation

- EVALUATIONS
- Groupwise cross-sections
- Depletion solver
- Material Balance
- Filiation chain

Statistics on results

No intrusive method
Global modelling of a nuclear system needs several application codes which data must be fully consistent

- Code to code comparisons are often used
  - To validate an industrial calculation scheme versus a reference calculation scheme
  - To validate a reduced depletion chain used in a transport code versus a complete one used in a depletion code

Modelling effects in application codes begin smaller and smaller

\[ \Rightarrow \] Process inconsistencies appear

**GALILEE-V0**: Integrated system ensuring consistent libraries for TRIPOLI-4 and APOLLO2/CRONOS2

**GALILEE-V1**: Integrated system ensuring consistent libraries for all the codes used in the global modelling of a nuclear system

- Neutronics, criticality, fuel cycle, shielding
- GEN II, GEN III, GEN IV, ITER, ...
GALILEE-V1 - Open and modular processing system (1)

Application code libraries are no longer “static” ones
• with a collection of given isotopes
• processed once and for all
• on a given temperature grid
• on a given energy mesh

Part of the processing can be done during a neutronics calculation
• In a neutronics/thermo-hydraulics coupling, temperature distribution varies and cross-sections have to be broadened dynamically (already possible in TRIPOLI-4)
• Cross-section description can be calculated on a refined energy mesh thanks to a specific tool creating a fitted energy mesh which is under progress at CEA

GALILEE-V1:
- will provide a dynamic interface with application codes
- will gather modular and parameterised tools
**GALILEE-V1 - Open and modular processing system (2)**

**Aim**: Global modelling of a nuclear system

- **GALILEE-V1**: Tool box for application codes
- **APOLLO3**
- **TRIPOLI-4**
- **DARWIN3**
**GALILEE-V1 - Implementation**

- New processing system
  - Conceived in a modular and parameterised way
  - With an automatic and integrated way of running

- Based on **CALENDF-2005** for physical models
  - Renewed for all computational aspects
    - Modern computer language (C++)
  - Completed
    - Provide all NJOY functionalities needed for core physics
      - Comparison between several processing tools
      - Inter-Validation

- Ensuring consistent models with codes that create nuclear evaluations
  - CONRAD
GALILEE-V1 - Validation/Qualification

Build a test collection
- Ensuring the quality of the data provided to application codes
- Ensuring that there is no regression when a component is changed
- Allowing to measure the impact, on representative core physics situations, of changing an isotope evaluation, a model, ...

Benchmarks participation
- ICSBEP (criticality)
- SINBAD (shielding)
- DICKENS, AKYIAMA (residual power)
- Benchmarks AEN/OCDE (depletion)
- ...

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Conclusion

Nuclear Data Processing at CEA

- Major activity
- One fundamental component of nuclear system global modelling
- Nuclear Data Processing System GALILEE
  - Is in phase with the new generation of reactor physics codes
  - Brings consistency and representation flexibility to nuclear data used in application codes
  - Is unified, integrated or open, and validated
  - Allows R&D activity
  - Ensures consistency with models used to create evaluations (CONRAD)