IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

The PRINCESS Project:

An IRSN Project For Experimental Data Acquisition In The Frame Of Criticality Safety And Reactor Physics

ANS winter meeting
November 9, 2016

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Institut de Radioprotection et de Sûreté Nucléaire

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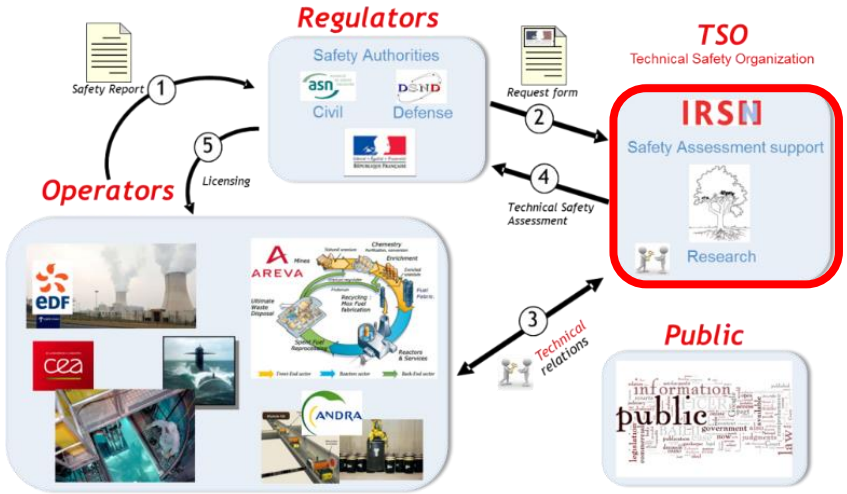
Outlines

- Context
- Areas of interest
- On-going collaborations and foreseen experiments
- Conclusion and perspectives

CONTEXT

IRS[N]: Technical Safety Organisation supporting nuclear regulators



- Research activities supporting safety
  - Reactor physics and Criticality department in charge of safety assessment and calculation codes development and validation
    - Since 50 years, more than 5000 criticality experiments were performed at CEA Valduc facility
      - To study criticality accidents (CRAC, SILENE, CALIBAN)
      - To support criticality codes validation (APPARATUS B, MARACAS, etc.)
        - More than 1000 experiments in CRISTAL French criticality calculation package and in the MORET Monte Carlo code validation database
        - More than 700 experiments in ICSBEP handbook

CONTEXT

October 2010 — April 2013 — December 2014 → 20XX

SILENE shutdown

SILENE

Refurbishment of the Valduc criticality facility

Collaboration IRSN/CEA/DOE-NNSA

Apparatus B Shutdown

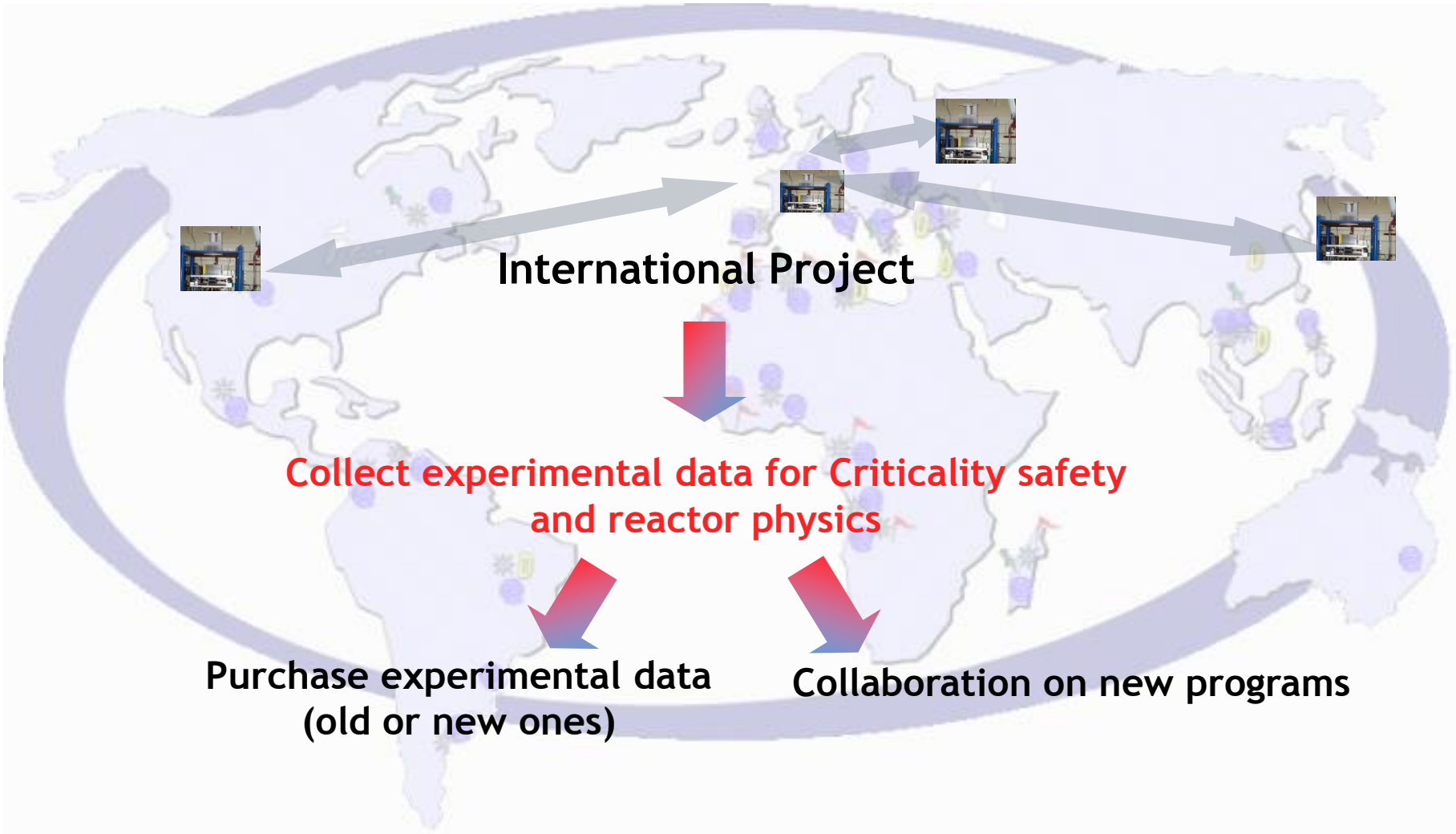
APPARATUS B

CALIBAN & PROSPERO Shutdown

CALIBAN

Context

PRoject for IRSN Neutron physics and Criticality Experimental data Supporting Safety



Context

PRoject for IRSN Neutron physics and Criticality Experimental data Supporting Safety

Why ?

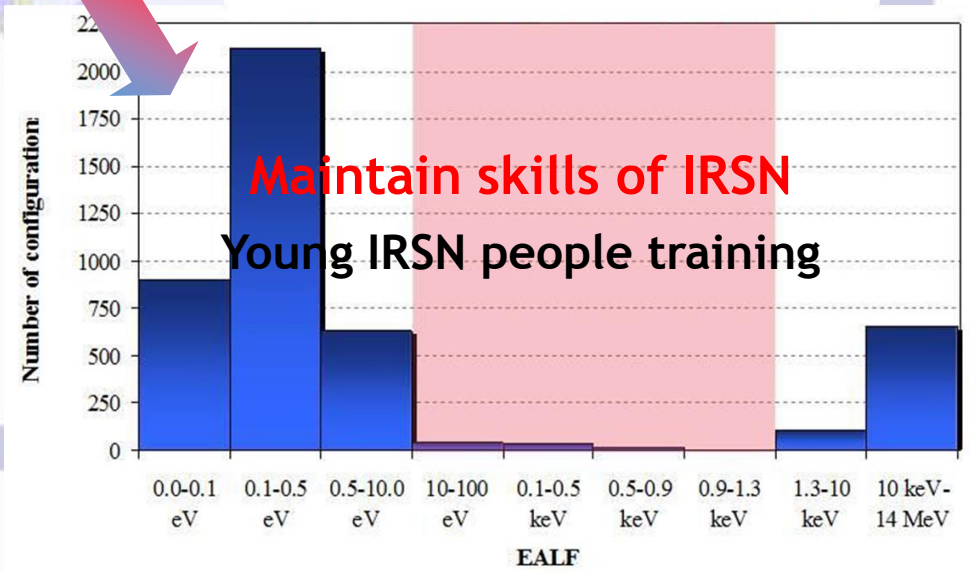
Still experimental needs

Epithermal range

New reactors

New materials ….

More accurate experimental data for ND feedback



Maintain skills of IRSN

Young IRSN people training

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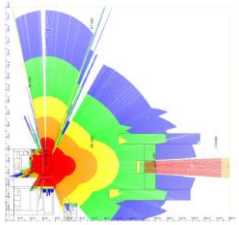
AREAS OF INTEREST

- **Criticality risk prevention**
  - Contribute to criticality calculation packages and nuclear data validation
  - Mainly sub-critical approaches extrapolated to critical conditions
    - Pool, split tables

- **Criticality accident**
  - Validation of radiation protection instrumentations (RPI) and doses estimation in the case of a criticality accident
  - Supercritical experiments
    - Fuel solutions or metallic reactors



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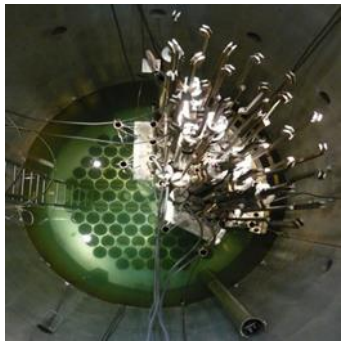
AREAS OF INTEREST

- **Validation of depletion calculation codes**
  - For reactor physics and criticality safety-studies for Burn-Up credit calculations
  - Post-irradiated Experiments (PIE)
    - Chemical analyses of irradiated fuel

- **Reactor physics**
  - Contribute to reactor calculation packages and nuclear data validation and qualification of instrumentation
  - Reactor mock-up experiments



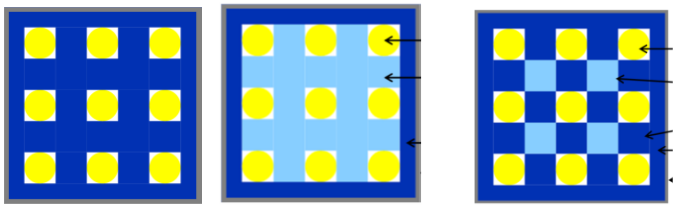
ON-GOING COLLABORATIONS AND FORESEEN EXPERIMENTS

SCK-CEN (Belgium)

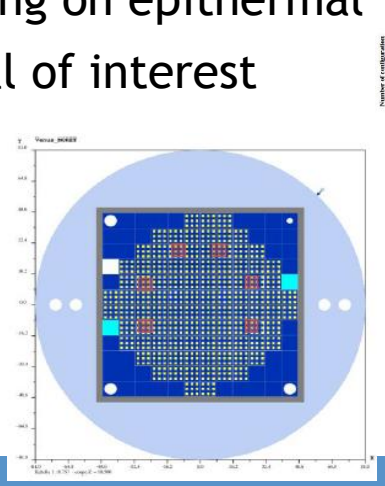
November 5th 2014: IRSN/SCK framework cooperation agreement

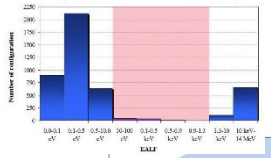
- Renewal for another 5 years of an on-going longstanding general collaboration initiated in 2008

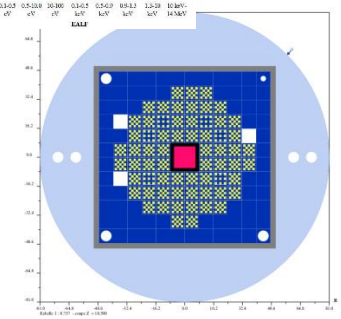
- Depletion calculations : Experimental data acquisition of the REGAL Program (PIE)
  - Characterisation of irradiated PWR fuel with Burnable poison (Gd)
- Criticality prevention and reactor physics: Feasibility study of experiments of interest in the VENUS-F reactor (HEU fuel (30% ^{235}U) - Lead reflected reactor)
  - Use of different rodlets allows varying the neutron spectra from fast (Lead) to thermal (graphite) focusing on epithermal
  - Use of central zone to test material of interest
  - Discussions in progress



VENUS-F assemblies







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ON-GOING COLLABORATIONS AND FORESEEN EXPERIMENTS

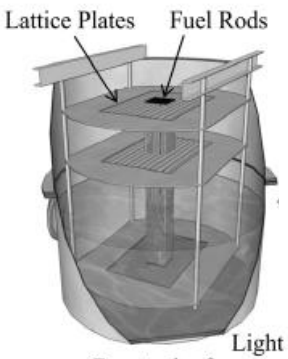
JAEA (JAPON)

April 26th 2016: Renewal for 5 years of an on-going longstanding general collaboration IRSN/JAEA

October 26th 2016: Implementing agreement dedicated to criticality issues

- A long term collaboration on experimental programs with technical exchanges on critical experiments performed in Apparatus B (Valduc) and in STACY and independent reviews of ICSBEP evaluation

- Criticality prevention: Restart of the STACY facility for fuel debris experiments ($U(4.95\%)O_2$ rods in water) following the Fukushima accident
  - Collaborating in the modified-STACY core design using advanced methods and in performance assessment
  - JAEA staff hosting at IRSN for 6 months in 2015 and one year in 2017
  - Start with Reference cores (« Zero experiments ») → Lattices of rods in water at different moderation ratios (until tightly packed lattices)
  - STACY first criticality planned beginning of 2019



Core tank of modified STACY

ON-GOING COLLABORATIONS AND FORESEEN EXPERIMENTS

- **DOE/NCSP**

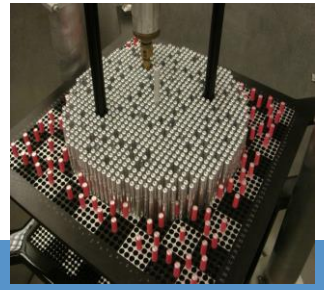
December, 12th 2014: Memorandum Of Understanding (MOU) established

- Bilateral agreements to be established with SNL, LLNL, LANL and ORNL

See Gary Harms previous presentation

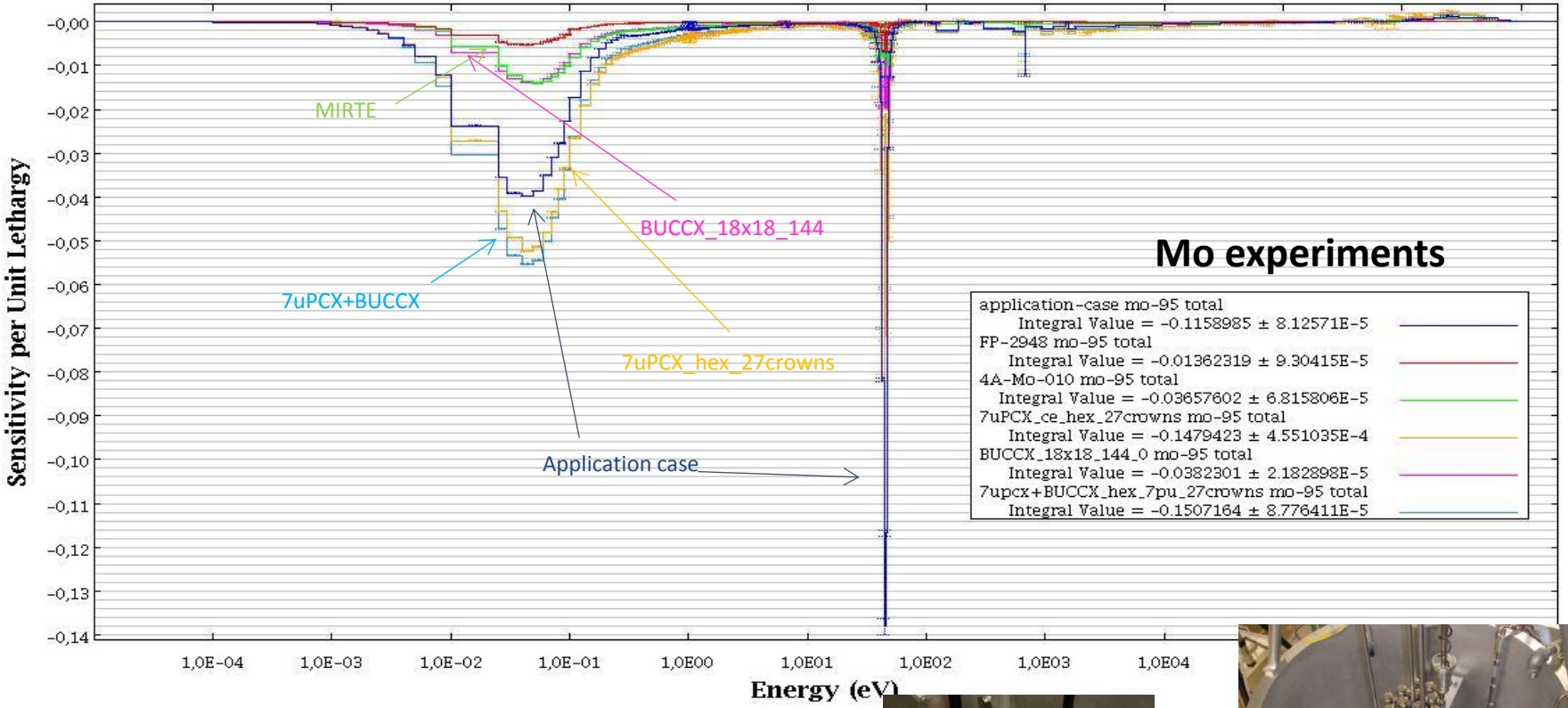
- Criticality prevention: SPRF/CX experiments with SNL
  - External review of ICSBEP evaluation of titanium experiments and others
  - IRSN leads two IER following CeD process
    - Molybdenum experiments using Mo sleeves surrounding 7uPCX rods with various pitches.
      - CED 1 report sent to Gary Harms, CED 2 in progress
    - Rhodium experiments using Rh foils in BUCCX rods or Rh solutions to improve ^{103}Rh sensitivity compare to LCT079
      - CED 1 report in progress

New accurate thermal experiments uncorrelated with French FP and MIRTE ones



ON-GOING COLLABORATIONS AND FORESEEN EXPERIMENTS

DOE/NCSP



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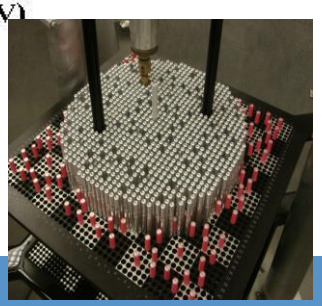
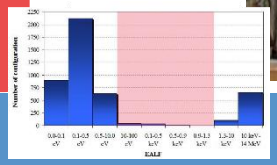


ON-GOING COLLABORATIONS AND FORESEEN EXPERIMENTS

- **DOE/NCSP** 
  - Criticality prevention: TEX experiments with LLNL
    - Experiments with U, Pu or U-Pu plates stacked with various moderators and diluents in PLANET or COMET
      - Participation in the CeD review process of TEX-Ta
        - Pu plates with CH_2 moderator and Tantalum as diluent
      - Participation in the CeD review process of TEX-Hf and Continuous Energy sensitivity calculations with MORET 5 IRSN home-made code and comparison with MCNP and SCALE
        - U-Mo plates (JEMINA plates) with CH_2 and Hf as diluent
      - IRSN leads the TEX-MOX program
        - U-Pu plates with various moderators (PE, Borated PE, Alumina) and Various Pu ratios and ^{240}Pu content
        - To be representative of low moderated MOX powder mixtures encountered in MOX fuel fabrication

New accurate experiments from fast to thermal energy range focusing in epithermal one



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ON-GOING COLLABORATIONS AND FORESEEN EXPERIMENTS

- **DOE/NCSP** 
  - Criticality accident: GODIVA and FLATTOP experiments
    - International Intercomparison Exercise for Nuclear Accident Dosimetry at the DAF using GODIVA-IV in May 2016

    - Ready (and happy!) to participate to the next experiments on GODIVA IV, FLATTOP, etc. in 2017+

See T. Miller previous presentation

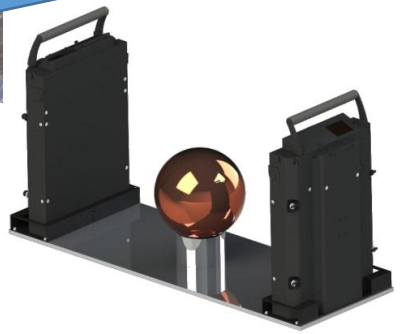
    - External reviewer of the OECD/NEA ICSBEP SILENE CAAS Benchmark (Pulses 2 and 3)
    - Common AWE-IRSN-LLNL-ORNL article at the ICRS13-RPSD 2016 conference on the Slide Rule Update

ICRS 13
RPSD 2016
October 3|6, 2016
Paris, France

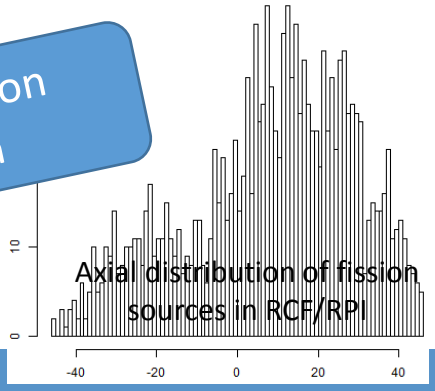
ON-GOING COLLABORATIONS AND FORESEEN EXPERIMENTS

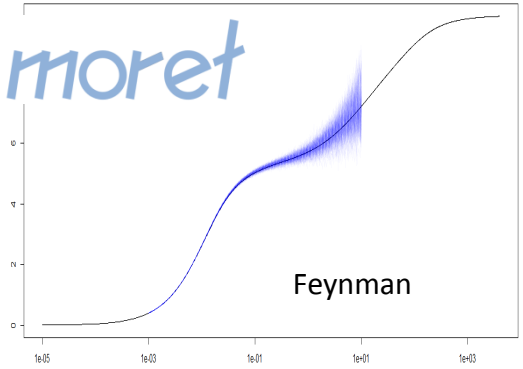
- **DOE/NCSP**
  - Noise measurement: subcritical experiments
    - External reviewer of the OECD/NEA ICSBEP Tungsten-reflected Plutonium-metal-sphere benchmark
    - Ready (and happy!) to participate to the next experiments:
      - Subcritical Copper-Reflected Plutonium-metal-sphere benchmark (Scrαp) (LANL)
      - ISSA Subcritical Multiplicity Benchmark (LLNL)
      - Critical and Subcritical 0-Power Experiment in RCP (Reactor Critical Facility) at Rensselaer (LANL et al)

See Jesson Hutchinson presentation



See this afternoon presentation





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CONCLUSION AND PERSPECTIVES

- Large variety of facilities: a lot of possibilities in terms of experiments
  - Wide energy range, various configurations and materials
  - Uncorrelated experiments → important for S/U analyses
- No plutonium solution experiments
- Bilateral agreements to be signed with DOE labs and SCK
- Some discussions to extend to reactor physics experiments

The strong and long term collaborations will provide an opportunity

- **To develop new techniques to address present and upcoming challenges in nuclear criticality safety and reactor physics**
- **To maintain high level of research driven by criticality safety assessment needs**

TO SUM UP ….

PRINCESS

DOE – NCSP

SCK

IPPE, KI

JAEA

BFS

LRO

PLANET

COMET

GODIVA

SPRF/CX

CALIBAN

VENUS

APPAREILLAGE B

SILENE

TRACY

STACY

Lattice Plates

Fuel Rods

Core tank of modified STACY

Preservation and dissemination

Preservation and dissemination

PRINCESS

International Handbook of Evaluated Reactor Physics Benchmark Experiments

IRPhE

International Handbook of Evaluated Criticality Safety Benchmark Experiments

ICSBEP

PRoject for IRSN Neutron physics and Criticality Experimental data Supporting Safety

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Enhancing nuclear safety

Thank you for your attention

Thanks to

JAEA

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U.S. DEPARTMENT OF ENERGY

Sandia National Laboratories

Lawrence Livermore National Laboratory

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OAK RIDGE National Laboratory

Special thanks for our Valduc colleagues