NJOY Processing (con't) and Criticality Validation

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ICTP/IAEA WORKSHOP ON THE EVALUATION
OF NUCLEAR DATA FOR APPLICATIONS

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Outline

- A brief summary of NJOY i/o for creating ACE files (con't)
  - .t (thermal scattering law) – **second lecture starts here…**
  - .y (dosimetry)
- A brief summary of NJOY's plotting capability
  - Cross Sections
  - Angular distributions
  - Secondary emission spectra
- Criticality Validation and Cross Section Data Testing
  - International Criticality Safety Benchmark Evaluation Project (ICSBEP).
- Some NJOY references

Creating an MCNP ACE .t File

MCNP ACE .t - I

Differences between ENDF and ACE (A Compact ENDF) …

- ENDF:
  - A thermal kernel evaluation may include data to represent "coherent" elastic or "incoherent" elastic, and always contains "incoherent" inelastic scattering (i.e., S(α,β)) at an evaluator supplied discrete set of temperatures.
- ACE .t:
  - Coherent elastic is a linearly interpolable (E_i,σ_i) array.
  - Incoherent elastic is the same, or may contain σ_i/E.
  - Incoherent inelastic energy-angle probability distributions.
  - Can only be created at one of the input tape defined temperatures.

NJOY Sequence for ACE .t

- MODER/RECONR/BROADR – as before, if want “free gas” scattering for that isotope.
- (LEAPR, optional) – create a tsl tape from user defined α and β mesh, temperature(s), and the molecular phonon spectrum (*not covered in this Workshop*).
- THERMR – create coherent and incoherent scattering cross sections and scattering matrices, from one of (i) LEAPR output, or (ii) an evaluated thermal scattering library (tsl) file.
- ACER – create mcnp thermal (.t) file.

NJOY "THERMR" module - I

- What does THERMR really do?
  - Produces pointwise neutron scattering cross sections in the thermal range.
    - Works with legacy, ENDF/B-III, or ENDF/B-VI and later thermal data.
    - Inelastic scattering and energy-transfer matrices for free and bound scatterers are determined from ENDF $S(\alpha,\beta)$ scattering functions.
    - Incoherent elastic scattering cross sections from non-crystalline materials (e.g., polyethylene, ZrH) are generated from ENDF/B-VI (or later) data or internal data.
    - Coherent elastic scattering cross sections from crystalline materials (e.g., graphite) are also generated from ENDF/B-VI (or later) data or internal data.

NJOY "THERMR" module - II

- **nendf, nin, nout must be the same mode.**
- **THERMR card 2 input has changed from NJOY99 to NJOY2012 and later.**
  - **iin S(α,β) option is 2 (is 4 in NJOY99).**
  - **iform is new (iform=0 is typical).**
- **Use matde=0 when computing free gas scattering for matdp.**
- **nbin = 20 is typical, but a new continuous representation option in acer makes this obsolete.**

```
Input …
 - card 1:  nendf,nin,nout
   - nendf = input, endf, tape with mf=7 data
   - nin   = input pendf tape number
   - nout  = output tape number

 - card 2:  matde,matdp,nbin,ntepm,iin,icoh,
            iform,natom,mtref,iprint
   - matde = material from nendf tape
   - matdp = material from nin (pendf) tape
   - nbin  = number of equiprobable angles
   - ntemp = number of temperatures (1)
   - iin   = inelastic options
             [0/1/2 = none/free gas/S(α,β)]
   - icoh  = elastic options
             [0/1 = none/use ENDF6], or if
             processing earlier formats, see the
             NJOY manual
   - iform = inelastic output format
             [0/1 = E-E'-μ (MF6 special), or
                    E-μ-E' (MF6/Law7).
```

NJOY "THERMR" module - III

- **mtref+1 is automatically assigned for elastic scattering.**
- **See NJOY manual, Table 4 for a list of ENDF/B moderator materials and recommended "mtref" values.**
- **tempr must match that on nendf.**
- **tol = 0.1% is typical**
- **emax = 10 eV is typical; there is no harm in specifying a value that exceeds the maximum tsl input tape energy.**
- **THERMR may be executed multiple times in the same NJOY job.**
- **For example, a job sequence might process "free gas" ^{1}h, h-h_2o, and h-ch_2.**

```
Input (con't) …
 - card 2:  matde,matdp,nbin,ntemp,iin,icoh,
            iform,natom,mtref,iprint
   - natom  = number of principal atoms
   - mtref  = inelastic reaction mt (must be
              between 221 and 250)
   - iprint = print option (0/1/2 = minimum/
              maximum/maximum + intermediate
              results) (0)
 - card 3:  temperatures (°K)
   - tempr = list of ntemp temperatures

 - card 4:  tol,emax
   - tol    = reconstruction tolerance
   - emax   = maximum energy for thermal treatment
              (for free gas and T > 3000, emax and
              the energy grid are scaled)
```

NJOY “ACER” module - I

- What does ACER really do?
  - Creates an ACE (A Compact ENDF) format file for MCNP.
    - “fast” (continuous energy); thermal; dosimetry; photo-atomic; photo-nuclear;
    - Can write files in ascii (type 1) or binary (type 2) format;
      - We recommend that users create ascii formatted files for ease of portability.
    - Creates an “xsdir” record;
    - Performs rudimentary data checks.

NJOY "ACER" module - II

- What does ACER really do … in NJOY's own words:

```
!    --- thermal data ---
!
! The data from the pendf tape as prepared by the thermr module is read in.  Inelastic and
! incoherent elastic cross sections are stored directly.  Coherent elastic cross sections are
! converted to a cumulative "stair step" form and stored.  The angular representation for incoherent
! elastic is stored directly.  None is needed for coherent elastic.  The incoherent inelastic energy
! distributions are converted into probability bins with the equally probable angles left unchanged.
! The bins can have equal probabilities or variable probabilities.  In the latter case, outlying bins with
! smaller probabilities are provided to extend the sampling to rare events.  A new tabulated option
! uses a continuous tabulated probability distribution (pdf/cdf) (requires a MCNP5.1.50 or later) and
! provides extended plotting.
```

NJOY "ACER" module - III

- **We recommend accepting all default options.**
- **Card 2 iopt = 2 to create a ".t" ACE file.**
- **Card 2 itype = 1 for an ascii file.**
- **Card 2 suff is easily changed at any time via text editor.**
- **Card 2 nxtra is obsolete. Set to zero and there is no card 4.**

```
Input …
 - card 1:  nendf,npend,ngend,nace,ndir
   - nendf = input endf tape
   - npend = input pendf tape (from previous job)
   - ngend = unit for multigroup photon data
             (obsolete)
   - nace  = output (ace) file
   - ndir  = xsdir information

 - card 2:  iopt,iprint,itype,suff,nxtra
   - iopt = ace file type (1/2/3/4/5/7/8 = fast/
            thermal/dosimetry/photo-atomic/photo-
            nuclear/read type 1/read type 2
            (iopt<0 for mcnpx format)
   - iprint = (0/1) = min/max print
   - itype  = (1/2) = ace output type
   - suff   = mcnp zaid suffix (default = .00)
   - nxtra  = number of (iz,aw) pairs to read (0)

 - card 3:  hk
   - hk = descriptive character string
          (≤ 70 characters)
```

NJOY "ACER" module - IV

- **Thermal values such as mti, nbint and mte must be consistent with those used in the previous THERMR job.**

```
Input …
 *** Cards 8,8a,9 for thermal (iopt=2) output ***
 - card 8:  matd,tempd,tname
   - matd  = material id
   - tempd = temperature (°K, 300)
   - tname = thermal zaid (≤ 6 characters,
             default is za

 - card 8a:
   - iza01 = moderator component za value
   - iza02 = moderator component za value (0)
   - iza03 = moderator component za value (0)

 - card 9:  mti,nbint,mte,ielas,nmix,emax,iwt
   - mti   = mt value for thermal incoherent data
   - nbint = number of bins for incoherent sct
   - mte   = mt for thermal elastic data
   - ielas = 0/1=coherent/incoherent elastic flag
             - get this from mf=7/mt=2 LTHR flag
               (but not the specific LTHR value!)
   - nmix  = number of atom types in mixed
             moderator (1/2 = not mixed/mixed)
   - emax  = max energy for thermal
   - iwt   = (0/1/2 = variable/const/tabulated)
             weighting option
             - use iwt=2 for latest method
```

Creating an MCNP ACE .y File

NJOY Processing of IRDFF Data Sets

```
--
-- NJOY processing of the IRDFF dosimetry file into ACE format
-- - IRDFF is one large file with many materials
--   - use moder to extract the material of interest
--     - make two copies for ACER
--
moder
 1 -21
 'IRDFF v1.02 for mat xxx'
 20 xxx
 0/ end of moder
--
-- make a second copy of this material
moder
 -21 -22
--
-- acer/dosimetry processing
acer
 -21 -22 0 31 32/                          card 1
 3 1 1 .10/                                card 2
 'IRDFF v1.02 data for material xxx'/ card 3
 xxx 300./                                 card 10
--
-- end of job
stop
```

NJOY input script to create an MCNP dosimetry file … replace "xxx" with the appropriate material number.

Nonlinear interpolation is allowed in MCNP Dosimetry files (NJOY99, p. XVII-29); NJOY2012, p. 513,514).

LANL has run this input deck for all v1.02 IRDFF data sets.

We used a pre-release version of NJOY2012, but NJOY99.364 or 99.393 processes ^{109}Ag (material 4731) and all other data sets.

This slide taken from LANL's presentation at the 1st RCM for Improving the IAEA International Dosimetry Library for Fission and Fusion.

Visualizing Nuclear Data with NJOY

Visualizing Nuclear Data - I

- NJOY produces postscript formatted plots.
  - Use the “PLOTR” module to create a plot command file.
  - Use the “VIEWR” module to create a .ps file.
- The minimum input to PLOTR is (i) an output tape number (ascii) and an input card specifying the pendf tape (ascii or binary), matn, mf, mt and temperature of the data to be plotted.
- The only input to VIEWR is the PLOTR output tape number and VIEWR’s output tape number (ascii).

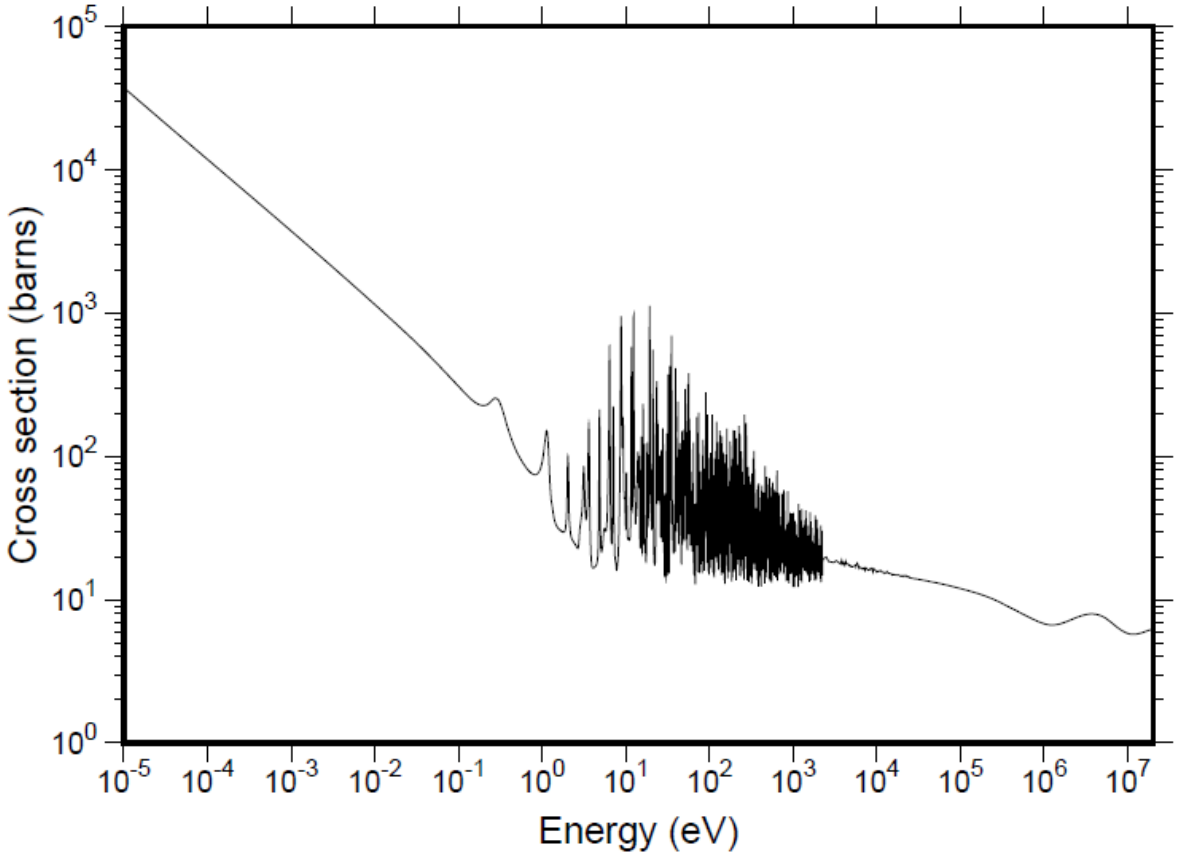
Visualizing Nuclear Data - II

- What does PLOTR really do … in NJOY's own words:

```
! plot cross sections
!
! Handles ENDF data, PENDF or GENDF data at specified temperatures, or experimental input
! data.  Several plots can be given on each set of axes, with both left and right scales.  Also,
! several graphs can be given on each page or display.  Error bars may be included for input
! data.  Flexible titles and legend blocks are allowed.  All standard combinations of log and
! linear axes are supported, either grids or tick marks can be requested, and scales can be
! chosen automatically or set by the user.  In some cases, the x axis is thinned.  In other cases,
! extra points are added so that, for example, linear-linear data plots correctly on a log-log
! graph.  A limited capability for 3-d plots of angle and energy is included, and the ENDF-6
! File 6 format is supported.  Percent difference and ratio plots can be requested.
!
! Plotr writes plot commands on an output file for later use by the viewr module or an external
! graphics program.
```

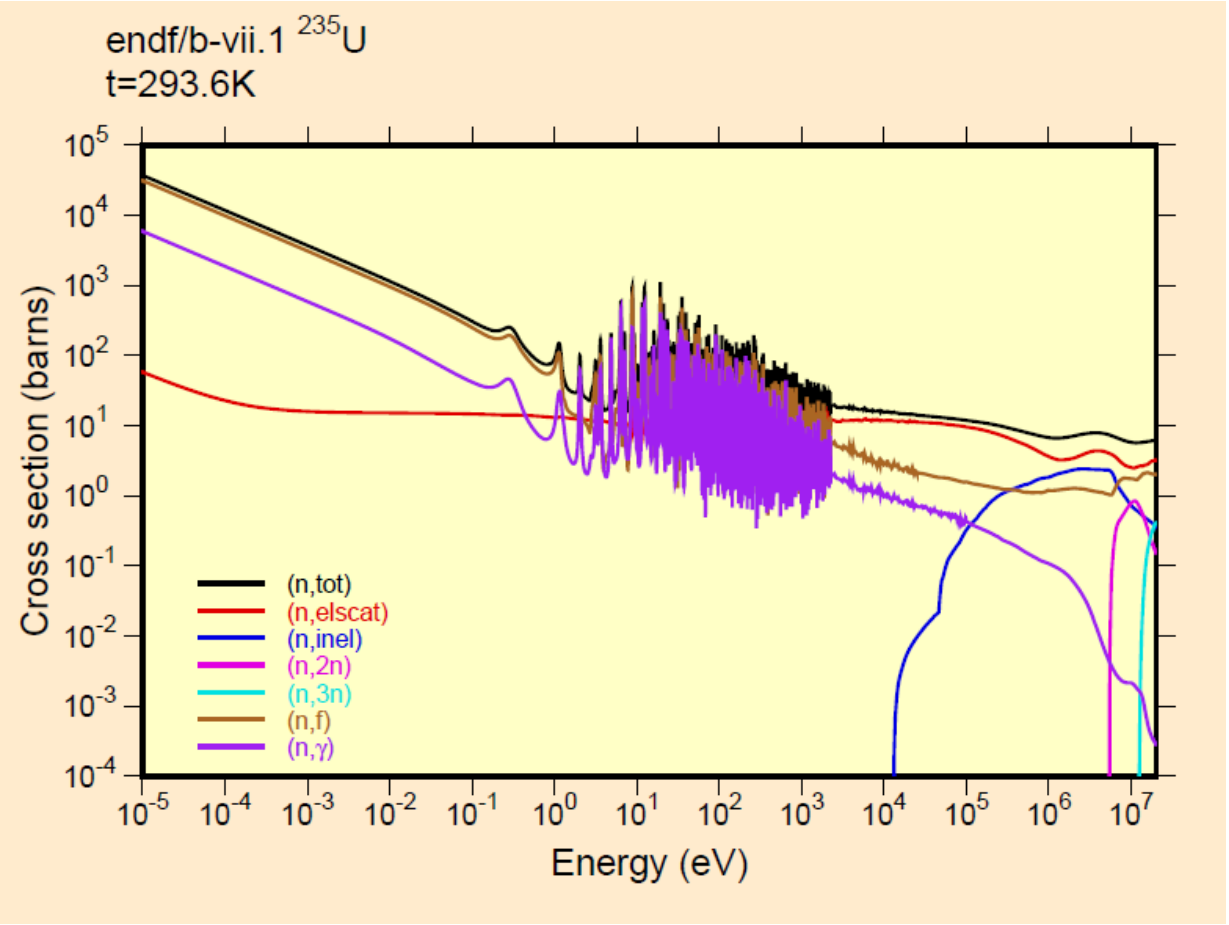
Visualizing Nuclear Data - III

- A plot with minimal user input …
- matn = 9228
- mf = 3
- mt = 1
- temper = 293.6 °K



Visualizing Nuclear Data - IV

- With a little more user input …
  - Something more suitable for impressing your boss, ☺.



NJOY "PLOTR" module - I

- **PLOTR reads plot commands from nplt0 or user input and creates a plot command file on nplt to be interpreted by VIEWR.**
- **Refer to the PLOTR section of the NJOY manual for a summary of PLOTR input commands.**
  - **Numerous PLOTR examples are provided throughout this chapter.**
- **Refer to the VIEWR section of the NJOY manual for special command sequences to generate greek letters and to create subscript and/or superscript characters in text strings.**
- **Other NJOY modules creating a plot command file include HEATR, ACER, GROUPR, and COVR.**

```
Input …
 - card 0:  nplt,nplt0
   - nplt  = output file
   - nplt0 = input file (0)

 - card 1:  lori,istyle,size,ipcol
   - lori   = page orientation
              (0=portrait/1=landscape).
   - istyle = character font (1=roman/2=swiss).
   - size   = character size (+=page unit;
              -=fraction of subplot (+0.3).
   - ipcol  = page color (0 = white).

 *** Repeat cards 2 thru 13 for each curve ***
 - card 2:  iplot,iwcol,factx,facty,xll,yll,
            ww,wh,wr
   - iplot = plot index (1 = new axes, new page).
   - iwcol = window color (default to ipcol).
   - factx = x-axis scaling (1.0)
   - facty = y-axis scaling (1.0)
   - xll,yll = lower left corner of plot area
               (0.0,0.0).
   - ww,wh,wr = window width, height & rotation
                angle (default is one plot/page).
```

NJOY "PLOTR" module - II

- **PLOTR reads plot commands from nplt0 or user input and creates a plot command file on nplt to be interpreted by VIEWR.**
- **Refer to the PLOTR section of the NJOY manual for a summary of PLOTR input commands.**
  - **Numerous PLOTR examples are provided throughout this chapter.**
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- **Other NJOY modules creating a plot command file include HEATR, ACER, GROUPR, and COVR.**

```
Input …
 * cards 3 through 7 for iplot = +1 or -1 only *

 - card 3:  t1
   - t1 = up to 60 character title (line 1)
          (default is blank).

 - card 3a:  t2
   - t2 = up to 60 character title (line 2)
          (default is blank).

 - card 4:  itype,jtype,igrid,ileg,xtag,ytag
   - itype = 1/2/3/4 = linx-liny/linx-logy/
             logx-liny/logx-logy axes.
   - jtype = 0/1/2 = none/linear/log
             alternate y or z axis.
   - igrid = 0/1/2/3 = grid & tic mark control;
             none/grid/tic outside/tic inside.
             -=fraction of subplot (+0.3).
   - ileg  = 0/1/2 = legend options;
             none/yes/yes with pointer.
   - xtag  = legend upper left x value
   - ytag  = legend upper left y value
             (default is upper left corner).
```

NJOY "PLOTR" module - III

- **PLOTR reads plot commands from nplt0 or user input and creates a plot command file on nplt to be interpreted by VIEWR.**
- **Refer to the PLOTR section of the NJOY manual for a summary of PLOTR input commands.**
  - **Numerous PLOTR examples are provided throughout this chapter.**
- **Refer to the VIEWR section of the NJOY manual for special command sequences to generate greek letters and to create subscript and/or superscript characters in text strings.**
- **Other NJOY modules creating a plot command file include HEATR, ACER, GROUPR, and COVR.**

Input …
 * cards 3 through 7 for iplot = +1 or -1 only *

- card 5: el,eh,xstep
  - el = plot E_{min} (remember, ENDF is eV).
  - eh = plot E_{max}.
  - xstep = x-axis step for tic marks.
  - default is automatic scales; if el & eh are given with linear scaling xstep is required.

- card 5a: xlabl
  - xlabl = x-axis label (up to 60 characters, default = ***Energy (eV)***).

- card 6: yl,yh,ystep
  - yl = lowest value of y-axis.
  - yh = highest value of y-axis
  - ystep = y-axis step for tic marks.
  - default is automatic scales; if yl & yh are given with linear scaling ystep is required.

- card 6a: ylabl
  - ylabl = y-axis label (up to 60 characters, default = ***Cross section (barns)***).

NJOY "PLOTR" module - IV

- **PLOTR reads plot commands from nplt0 or user input and creates a plot command file on nplt to be interpreted by VIEWR.**
- **Refer to the PLOTR section of the NJOY manual for a summary of PLOTR input commands.**
  - **Numerous PLOTR examples are provided throughout this chapter.**
- **Refer to the VIEWR section of the NJOY manual for special command sequences to generate greek letters and to create subscript and/or superscript characters in text strings.**
- **Other NJOY modules creating a plot command file include HEATR, ACER, GROUPR, and COVR.**

```
Input …
 * cards 3 through 7 for iplot = +1 or -1 only *
 * cards 7 and 7a for jtype > 0 only *

 - card 7:  rbot,rtop,rstep
   - rbot  = lower secondary (or z) axis limit.
   - rtop  = upper secondary (or z) axis limit.
   - rstep = axis step for tic marks.
   - default is automatic scales.

 - card 7a:  rl
   - rl = alternate y-axis or z-axis label (up to
          60 characters, default = blank).
```

NJOY "PLOTR" module - V

- **PLOTR reads plot commands from nplt0 or user input and creates a plot command file on nplt to be interpreted by VIEWR.**
- **Refer to the PLOTR section of the NJOY manual for a summary of PLOTR input commands.**
  - **Numerous PLOTR examples are provided throughout this chapter.**
- **Refer to the VIEWR section of the NJOY manual for special command sequences to generate greek letters and to create subscript and/or superscript characters in text strings.**
- **Other NJOY modules creating a plot command file include HEATR, ACER, GROUPR, and COVR.**

```
Input …
 *** card 8 is always present ***

 - card 8:  iverf,nin,matd,mfd,mtd,temper,
            nth,ntp,nkh
   - iverf = endf version (0=user input on cards
             12 & 13 plus ignore the remaining
             parameters on this card; 1=gendf).
   - nin   = input endf/pendf/gendf… tape #.
   - matd  = material id.
   - mfd   = material file.
   - mtd   = material section.
   - temper = temperature (degK, default = 0.).
   - nth,ntp,nkh = control parameters for special
                   plots (default = 1,1,1).  See
                   the NJOY manual for details.
```

NJOY "PLOTR" module - VI

- **PLOTR reads plot commands from nplt0 or user input and creates a plot command file on nplt to be interpreted by VIEWR.**
- **Refer to the PLOTR section of the NJOY manual for a summary of PLOTR input commands.**
  - **Numerous PLOTR examples are provided throughout this chapter.**
- **Refer to the VIEWR section of the NJOY manual for special command sequences to generate greek letters and to create subscript and/or superscript characters in text strings.**
- **Other NJOY modules creating a plot command file include HEATR, ACER, GROUPR, and COVR.**

```
Input …
  *** cards 9 & 10 are used for 2D plots ***

 - card 9:  icon,isym,idash,iccol,ithick,ishade
   - icon = 0/-i/i = plot symbol and connection
            (default = points connected, no
             symbols).
   - isym = plot symbol code (see manual 0=none).
   - idash = line type (see manual, 0=solid).
   - iccol = curve color (see manual, 0=black).
   - ithick = curve thickness (1).
   - ishade = shade pattern (0=none).  A somewhat
              obsolete option from days when b&w
              printers ruled the day.

 *** card 10 is required when ileg ≠ 0 ***
 - card 10:  aleg
   - aleg = legend or curve title (up to
            60 characters, default = blank).

 *** card 10a is required when ileg = 2 ***
 - card 10a:  xtag,ytag,xpoint
   - xtag,ytag = x,y position of title
   - xpoint    = x position of pointer (≤ 0 to
                 omit the pointer).
```

NJOY "PLOTR" module - VII

- **PLOTR reads plot commands from nplt0 or user input and creates a plot command file on nplt to be interpreted by VIEWR.**
- **Refer to the PLOTR section of the NJOY manual for a summary of PLOTR input commands.**
  - **Numerous PLOTR examples are provided throughout this chapter.**
- **Refer to the VIEWR section of the NJOY manual for special command sequences to generate greek letters and to create subscript and/or superscript characters in text strings.**
- **Other NJOY modules creating a plot command file include HEATR, ACER, GROUPR, and COVR.**

```
Input …
  *** card 11 is used for 3D plots ***

 - card 11:  xv,yv,zv,x3,y3,z3
   - xv,yv,zv = coordinates of view point
                (default = 15.,-15.,15).
   - x3,y3,z3 = side of "work box"
                (default = 2.5,6.5,2.5).

 *** cards 12 & 13 are required when iverf=0 ***
 - card 12:  nform
   - nform = input data format code.
           = 0 = free form input (this is the
                 only option at present).

 - card 13:  xdata,ydata,yerr1,yerr2,xerr1,xerr2
   - xdata = x-axis data
   - ydata = y-axis data
   - yerr1,yerr2 = lower & upper y value limit
   - xerr1,xerr2 = lower & upper x value limit
   - repeat card 13 until an empty (/) record is
     read.
   - yerr1,yerr2,xerr1,xerr2 defaults are zero.
```

NJOY “VIEWR” module - I

- **VIEWR reads plot commands from the “infile” input tape and creates a postscript formatted output tape.**
- **The “infile” input can be generated by one of HEATR, ACER, GROUPR, COVR or PLOTR.**
- **Refer to the VIEWR section of the NJOY manual for special command sequences to generate greek letters and to create subscript and/or superscript characters in text strings.**
  - **… or review the comments provided in the viewr.f90 source code.**

```
Input …
 - card 1:  infile,nps
   - infile = input tape with plot commands
   - nps    = output file containing postscript
              (.ps) formatted plots.
```

Criticality Validation and Cross Section Data Testing

… Cross Section Data Testing

- The comments and suggestions that follow are not rigorous rules that users must follow …
- … rather they represent observations based upon personal experience from working in reactor core design and criticality safety environments.
- Workshop attendees should feel free to adapt or ignore these comments, consistent with their own institutional requirements.

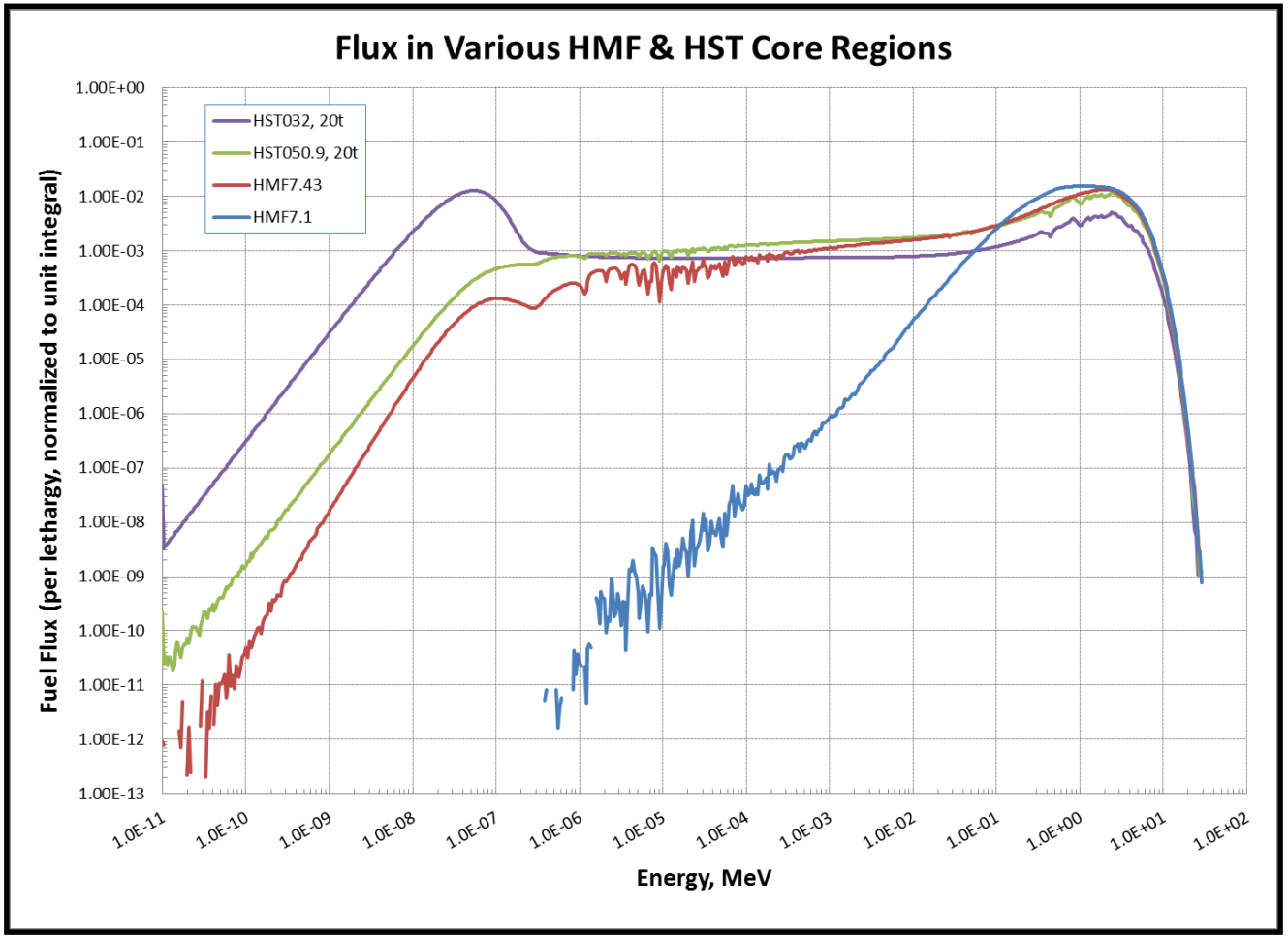
… Cross Section Data Testing

- Some key words and phrases include …
  - Verification – a process to determine that the design specifications have been met.
    - For a computer code this means verifying that if the equation $E = mc^3$ (!) is specified by the analyst, that is what was coded by the programmer.
  - Validation – a process to determine the level of accuracy.
    - For a computer code this means determining the level of accuracy for quantities calculated by that code.
    - The level of accuracy is often determined by calculating a suite of "benchmark" experiments.
      - A "benchmark" experiment is generally a precise measurement of a simple system that includes a well defined and small uncertainty.

… Cross Section Data Testing

- Some key words and phrases include …
  - Margin of Safety (MoS) – in the field of criticality safety this is an extra level of criticality applied to any calculated eigenvalue.
    - If the calculated system k_{eff} is less than unity after application of the institutionally accepted MoS then the process is deemed safe.
  - Range of Applicability (RoA) – when using the results from a suite of critical benchmark experiments to validate a new design the key attributes of those benchmarks must match the design attributes.
    - The neutron flux spectrum is often a key parameter.
    - It is not practical to apply a design bias based upon calculations of a fast reactor system to a light water reactor.

… Cross Section Data Testing



Proper benchmark selection allows for data testing over energy intervals of many decades.

Sample fuel region flux spectra for a selection of highly enriched uranium critical systems (taken from the ICSBEP Handbook – see next slide).

This slide taken from LANL's contribution to the IAEA CM on Compensating Effects due to Nuclear Reaction and Material Cross Correlations in Integral Benchmarks.

… Cross Section Data Testing

- Testing of ENDF/B-x libraries has been a CSEWG activity for decades. Similar efforts by JEFF, JENDL, …
  - Data testing has focused on criticality …
    - ENDF-230, "Benchmark Testing of ENDF/B-IV.
    - ENDF-311, "Benchmark Testing of ENDF/B-V.
    - ENDF/B-VI.x – various CSEWG meeting minutes throughout the 1990s.
    - Chadwick *et al*, "ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology," *Nuclear Data Sheets* **107**, 2931 (2006).
      - Also van der Marck, "Benchmarking ENDF/B-VII.0," *Nuclear Data Sheets* **107**, 3061 (2006).
    - Kahler *et al*, "ENDF/B-VII.1 Neutron Cross Section Data Testing with Critical Assembly Benchmarks and Reactor Experiments," *Nuclear Data Sheets* **112**, 2997 (2011).
      - Also van der Marck, "Benchmarking ENDF/B-VII.1, JENDL-4.0 and JEFF-3.1.1 with MCNP6," *Nuclear Data Sheets* **113**, 2935 (2013).

… Cross Section Data Testing

- An important source of evaluated critical benchmark experiments is the International Criticality Safety Benchmark Evaluation Project (ICSBEP)
  - see http://icsbep.inel.gov/ , or https://www.oecd-nea.org/science/wpncs/icsbep/handbook.html
- Some ICSBEP info …
  - Initiated in 1992 by the US DOE Defense Programs (CSBEP).
    - Expanded to become an international activity in 1994.
  - Evaluations are defined in terms of fissile material (^{239}Pu, ^{235}U (and enrichment), ^{233}U) , material composition (metal, compound, solution) and spectrum (fast, intermediate, thermal).
    - Ex. HEU-MET-FAST-001 = Highly enriched uranium, metal, fast spectrum. More simply called HMF1.
  - ***Caution … Users should read the benchmark model description and develop their own input decks.***

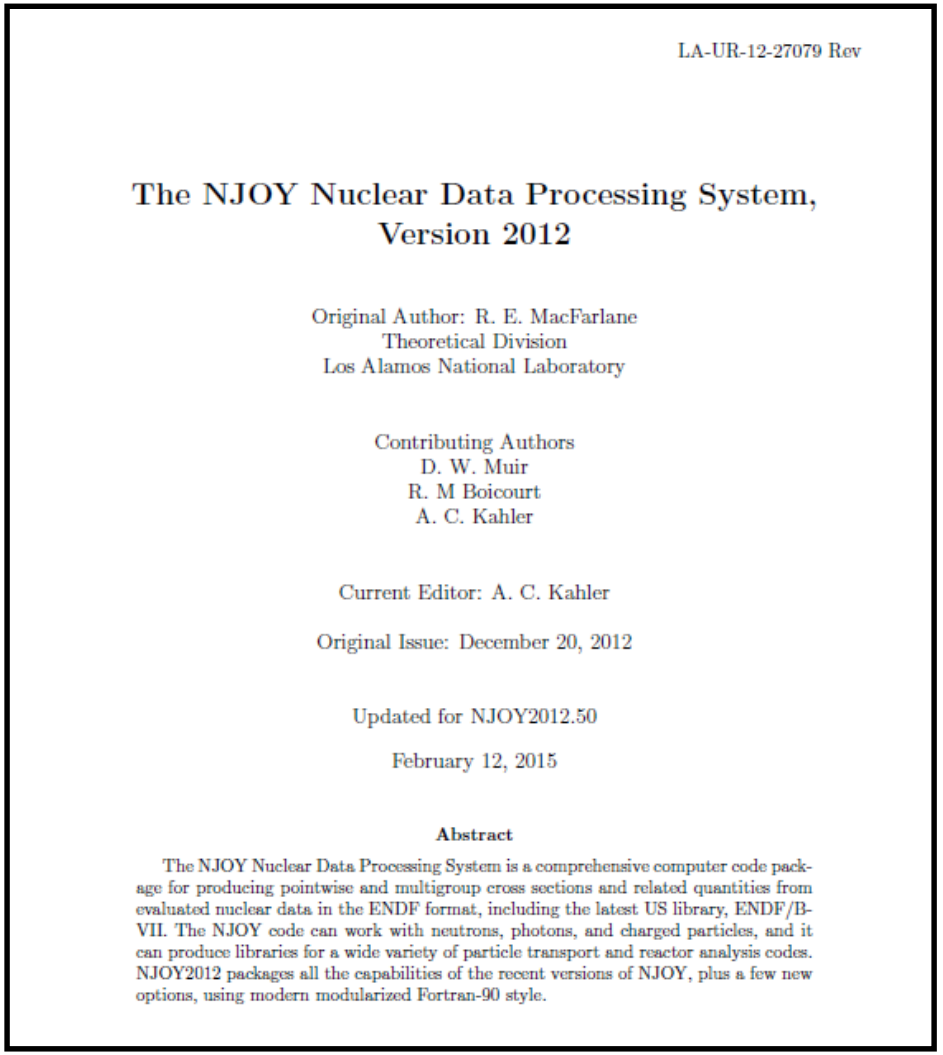
… Cross Section Data Testing

- How do you find the “correct” benchmarks?
  - Today … learn how to use the new tools described by other speakers during this workshop.
  - But also keep in mind some basic (common sense!) rules …
    - Critical Assemblies with simple geometry and a minimal number of well characterized materials.
      - LANL assemblies … Godiva, Jezebel, Flattops, Big-10
    - A suite of assemblies with minimal geometry and/or material changes that yield a wide variation in a relevant parameter of interest.
      - HMF7 = HEU with varying amounts of CH_2.
      - PMFx = metal ^{239}Pu core with various reflectors.
      - HMFx = metal HEU with various interstitial and/or reflector materials.
      - LCTx = UO_2 lattice with varying pitch or varying soluble poison content.

some NJOY Reference Material

NJOY Documentation - I

- hyperlinked NJOY2012 and NJOY2016 manuals are available in pdf format …
- http://t2.lanl.gov/nis/codes/NJOY12/NJOY2012.82.pdf
- https://github.com/njoy/NJOY2016-manual/blob/master/njoy16.pdf



LA-UR-12-27079 Rev

The NJOY Nuclear Data Processing System, Version 2012

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Abstract

The NJOY Nuclear Data Processing System is a comprehensive computer code package for producing pointwise and multigroup cross sections and related quantities from evaluated nuclear data in the ENDF format, including the latest US library, ENDF/B-VII. The NJOY code can work with neutrons, photons, and charged particles, and it can produce libraries for a wide variety of particle transport and reactor analysis codes. NJOY2012 packages all the capabilities of the recent versions of NJOY, plus a few new options, using modern modularized Fortran-90 style.

NJOY Documentation - II

Title page from a recent NJOY paper …

Available online at www.sciencedirect.com
ScienceDirect
Nuclear Data Sheets 111 (2010) 2739–2890
Nuclear Data Sheets
www.elsevier.com/locate/nds

Methods for Processing ENDF/B-VII with NJOY

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The NJOY Nuclear Data Processing System is widely used to convert evaluations in the Evaluated Nuclear Data Files (ENDF) format into forms useful for practical applications such as fission and fusion reactor analysis, stockpile stewardship calculations, criticality safety, radiation shielding, nuclear waste management, nuclear medicine procedures, and more. This paper provides a descrip-

NJOY Documentation - III

- Data Processing references included in the MCNP Documentation …
  - LA-UR-13-20137, “Continuous Energy Neutron Cross Section Data Tables Based Upon ENDF/B-VII.1”
  - LA-UR-12-00800, “Release of Continuous Representation for S(α,β) ACE Data”.

- Additional reports on “NJOY Data Processing” can be found under the “Nuclear Data and Physics” category in the MCNP Reference Collection.

NJOY Documentation - IV

- … and from Europe:
  - "A Validated MCNP(X) Cross Section Library based upon JEFF 3.1" (http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/42/097/42097803.pdf).
  - "Processing of the JEFF-3.1 Cross Section Library into a Continuous Energy Monte Carlo Radiation Transport and Criticality Data Library", NEA/NSC/DOC(2006)18 (https://www.oecd-nea.org/dbprog/Njoy/Cabellos-report_mcjeff31-v36.pdf).
- … and other JEF documents issued through the OECD Nuclear Energy Agency.