

# EAF-2010 the last (best) of a generation

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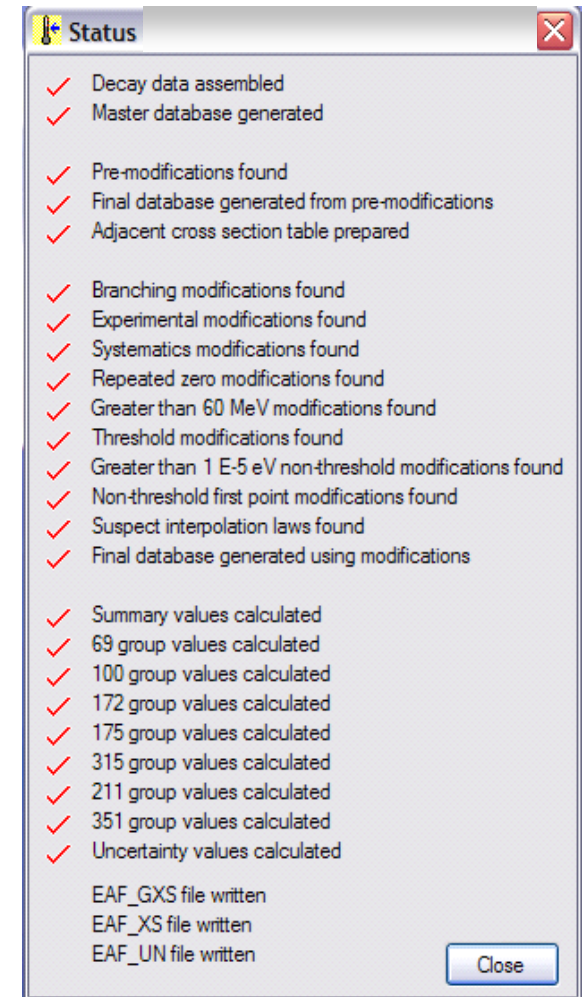
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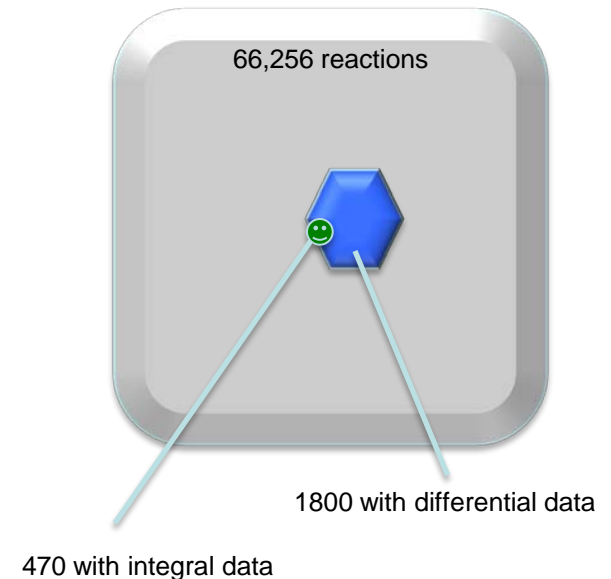
# Main comments on EAF-2010

- EAF-2010 has been completed in June 2010
- EAF-2010 is the last of the generation of EAF files
- It is the most complete and improved version of the EAF files – the best of a generation



# From EAF-2007 to EAF-2010

- Revision of all reaction channels (~1800) supported by experimental data using
  - visual comparison with EXFOR and updated Private EXFOR (most recent data not yet included in EXFOR) databases
  - SACS analysis
  - C/E analysis at reference energies (0.0253 eV, 30 keV, 14.5 MeV and RI's)
- Update and revision of capture data:
  - Extensive reviewing of all capture cross sections including the revision of applied XS systematic (in particular 30 keV)
  - Results are in detail presented at:  
<http://www.ccfе.ac.uk/EASY.aspx>
  - Update of the associated uncertainty data



# EAF-2007 to EAF-2010 threshold reaction data

- Update and revision of threshold reaction data:
  - Revision of  $(n,d)$  and  $(n,n'p)$  XS to improve the agreement with activation experiments for  $(n,d + n,n'p)$  cross sections
  - Revision of neutron emission channels  $(n,2n)$  and  $(n,3n)$  to compensate for competition with  $(n,f)$
  - Revision of XS based on the validation using integral measurements.
    - ✓ Decay power: a comprehensive experimental validation
    - ✓ Validation of EASY-2007 using integral measurements
    - ✓ Revisions and improvements of neutron capture cross sections for EAF-2010 and validation of TALYS calculations
    - ✓ Validation of EASY-2005 above 20 MeV

# EAFF-2007 to EAFF-2010 uncertainties

- Update and revision of uncertainty file, a major action undertaken:
  - Revision of non-threshold (Score = 0) reactions: new error factors introduced from XS systematics
  - Revision of non-threshold (Score > 0) reactions based on comparison with experimental information
  - Revision of all non-threshold reactions: new semi-quantitative approach used for error factors of  $1/v$  and <100 keV regions, based on error propagation of  $\sigma(0.0253 \text{ eV})$  and RI with corresponding C/E values.

# Statistical Analysis of Cross Sections (SACS)

**Cross section analysis**

Source: Final

Reaction: (n,p)

Min energy: 0.00E+00 eV

Include width data:

**y-axis**

- Maximum cross section
- Energy at maximum
- Width at maximum
- Skewness parameter
- Threshold
- Cross section at 25.3 meV
- Cross section at 30 keV
- Cross section at 14.5 MeV
- Cross section at 20 MeV
- Cross section at 30 MeV
- Cross section at 60 MeV

**x-axis**

- Mass (A)
- Number (Z)
- Asymmetry (s)
- aU parameter

**2nd reaction**

- None
- (n,n'p)
- (n,f)

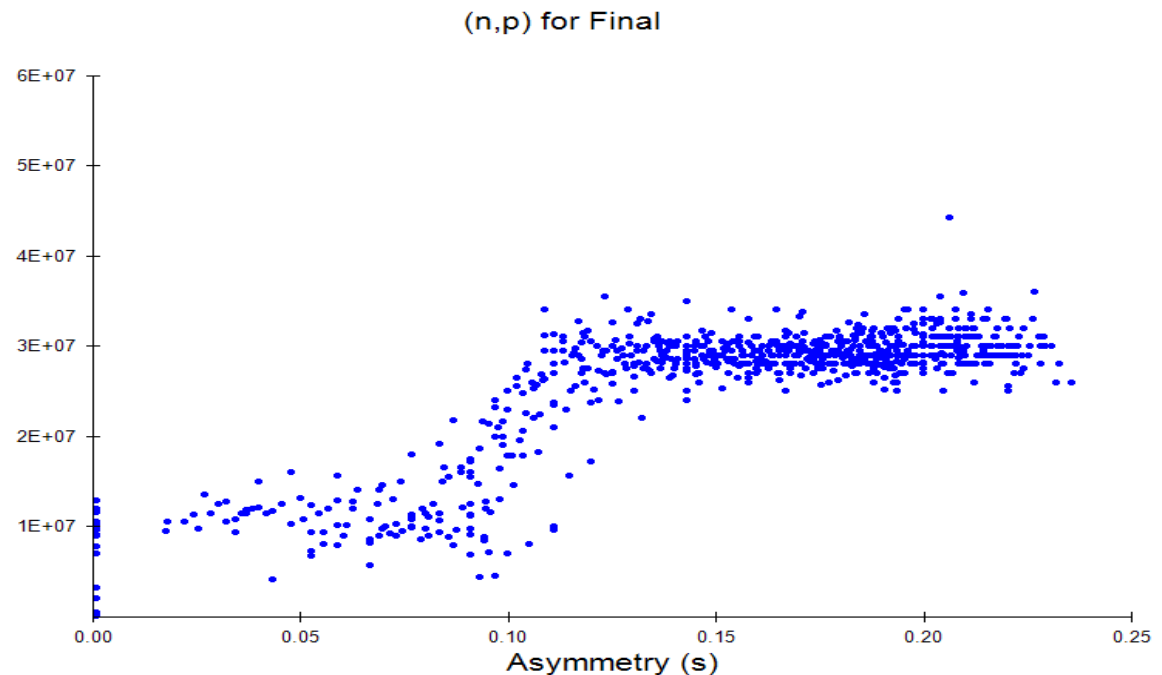
**Split Score**

- Min: {s,0}=0
- Max: {s,0}=s

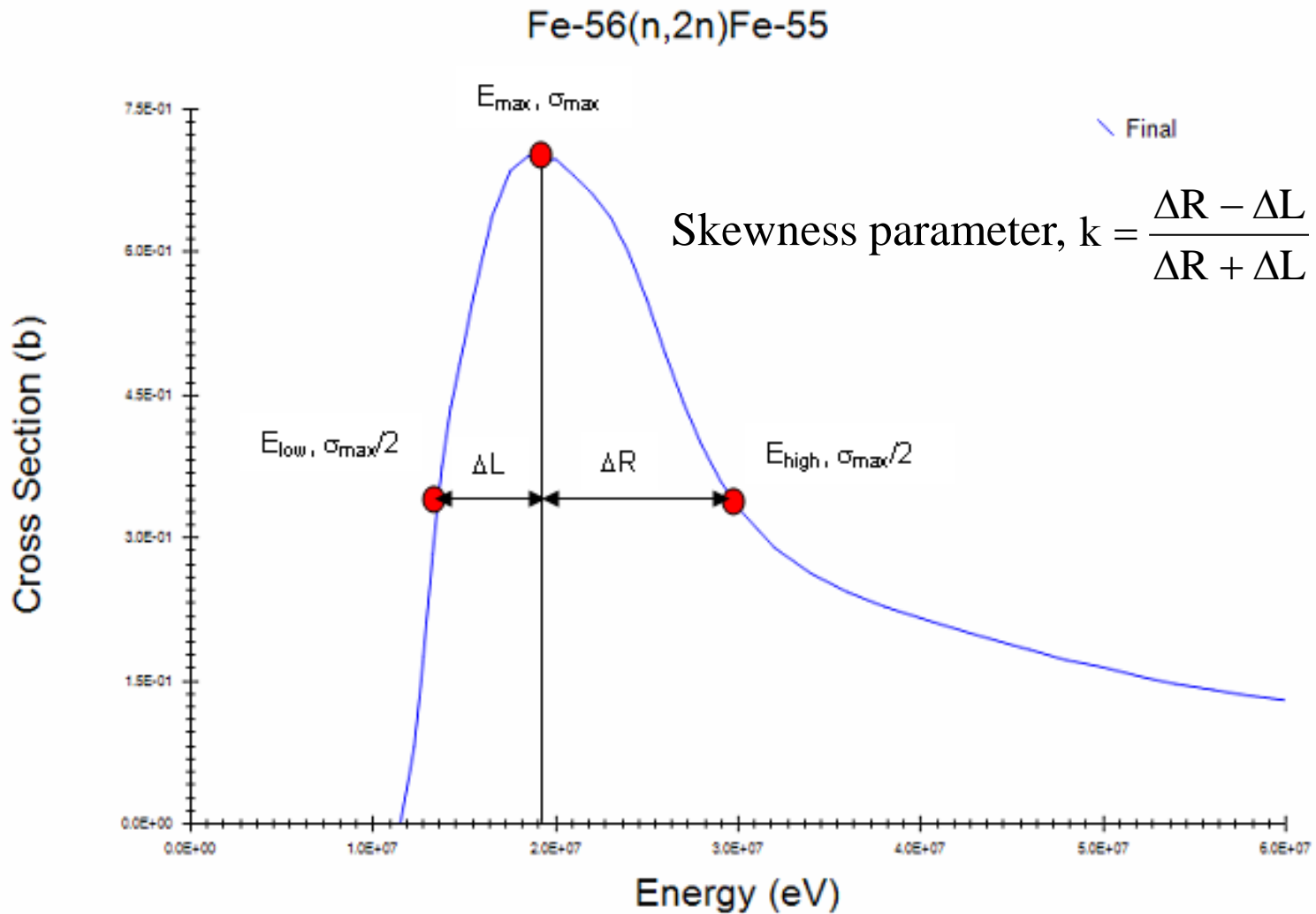
Plot

Validation...

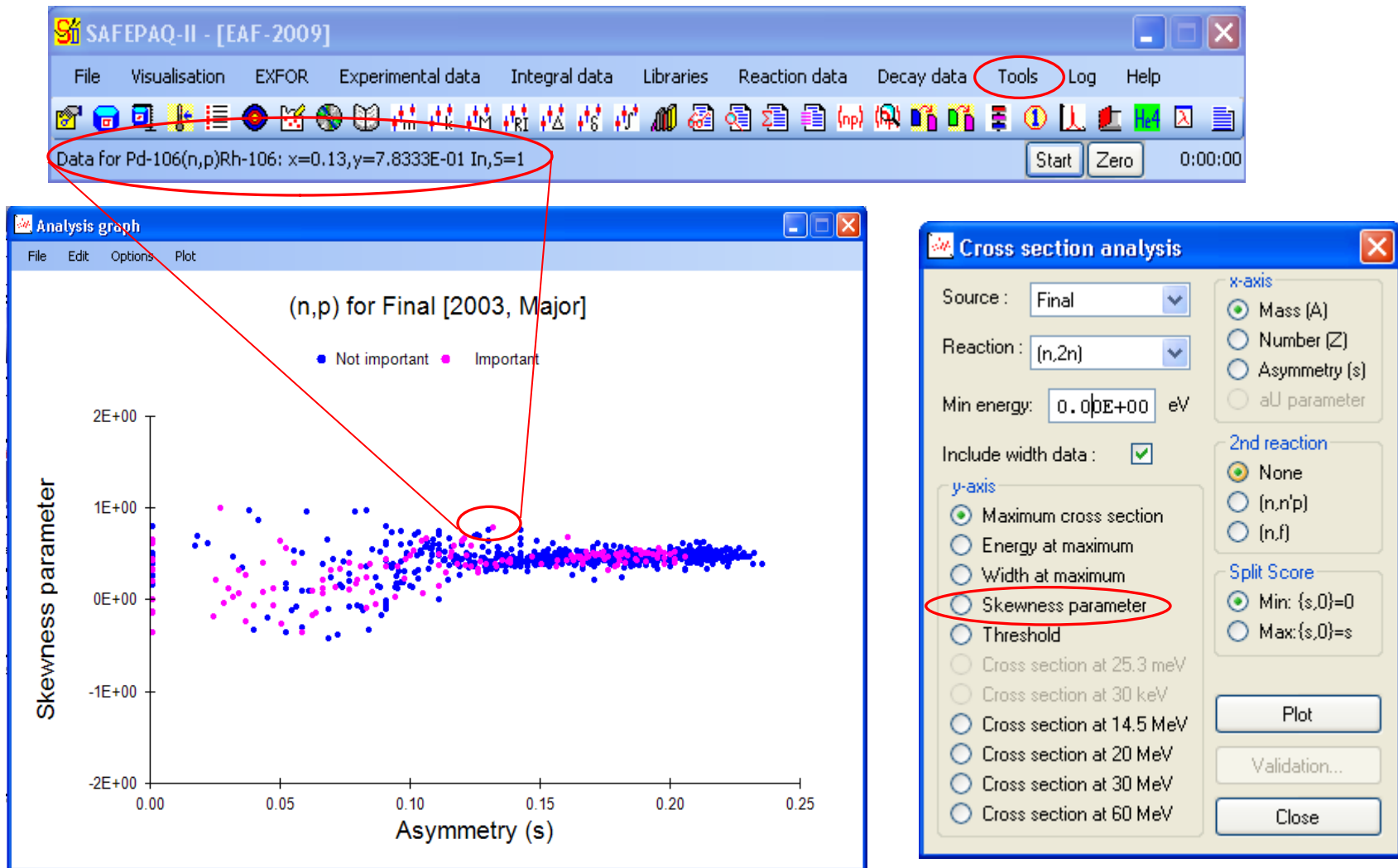
Close



# Defining skewness for threshold reactions



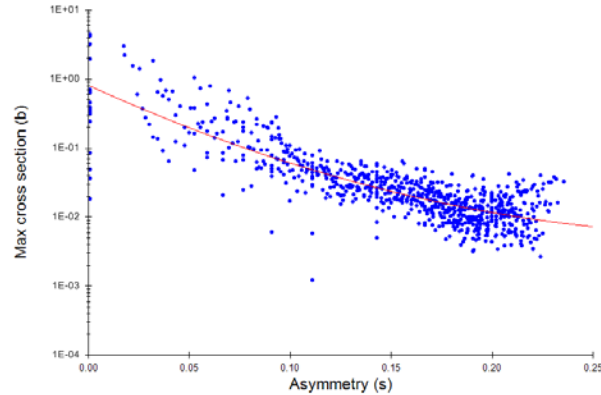
# SACS: Skewness parameter implementation



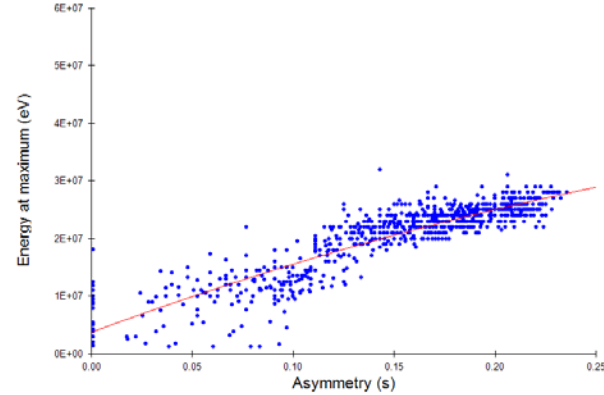


# Statistical analysis of cross sections plots

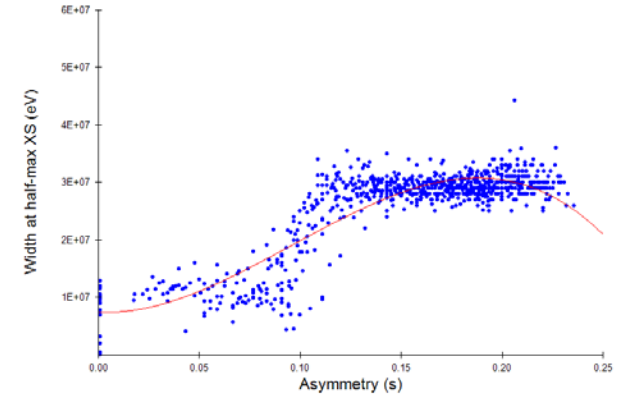
(n,p) for Final



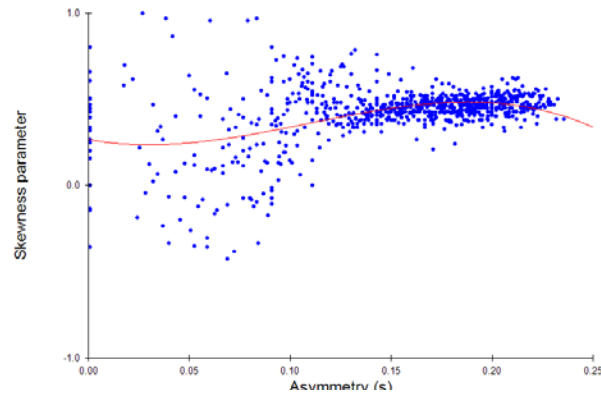
(n,p) for Final



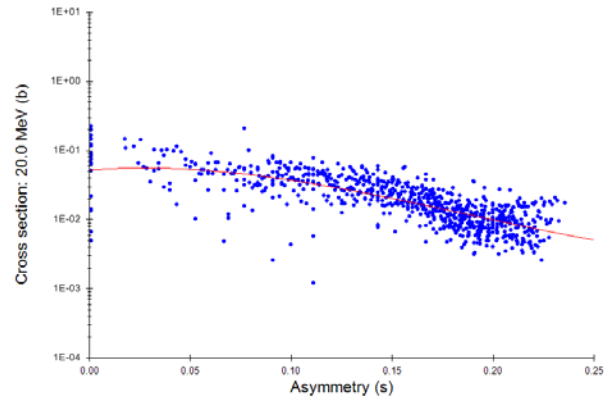
(n,p) for Final



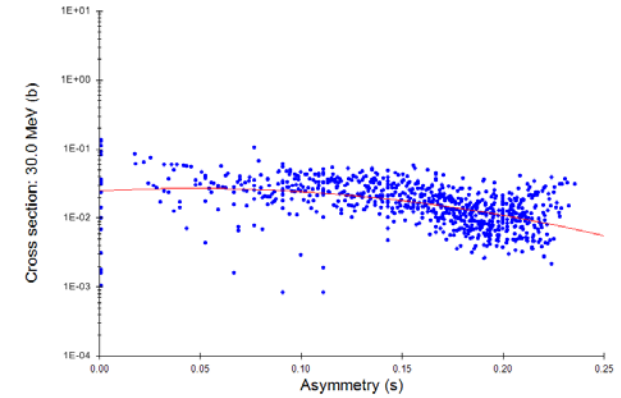
(n,p) for Final



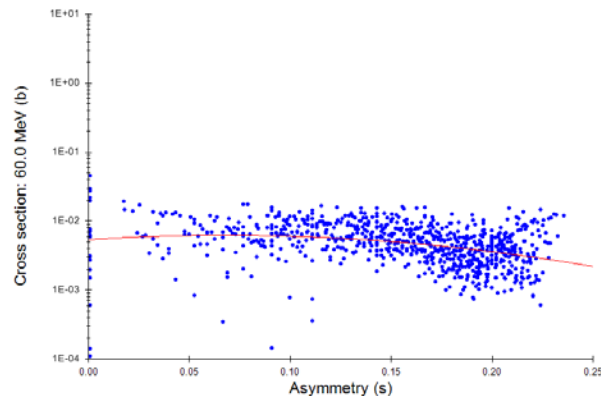
(n,p) for Final



(n,p) for Final



(n,p) for Final



- Extract (store) polynomial fit coefficients to each set of cross section statistical parameters (versus asymmetry) for a given reaction type.

# EAF-2010 – status, assembling

- Distribution started in June 2010
- Builds from EAF-2007 and 64,597 TALYS-5, -5a, -6 and -2009 channels above a few KeV
- Details:
  - 66,256 n-induced reactions ( $10^{-5}$  eV - **60 MeV**)
  - **816** Isotopes as targets
  - 66,864 d-induced reactions (EAF-2007  $\cong$  TALYS)
  - 67,925 p-induced reactions (EAF-2007  $\cong$  TALYS)
  - Decay data for 2,233 nuclides (includes the last UK data)
  - Uncertainty data for all n-induced reactions
  - Ingestion and inhalation indices
  - Part of European Activation SYstem-2010
- Documentation available on web site <http://www.ccfе.ac.uk/EASY.aspx>
- Cross section data > 20 MeV and d- and p- induced data  $\Rightarrow$  suitable for IFMIF

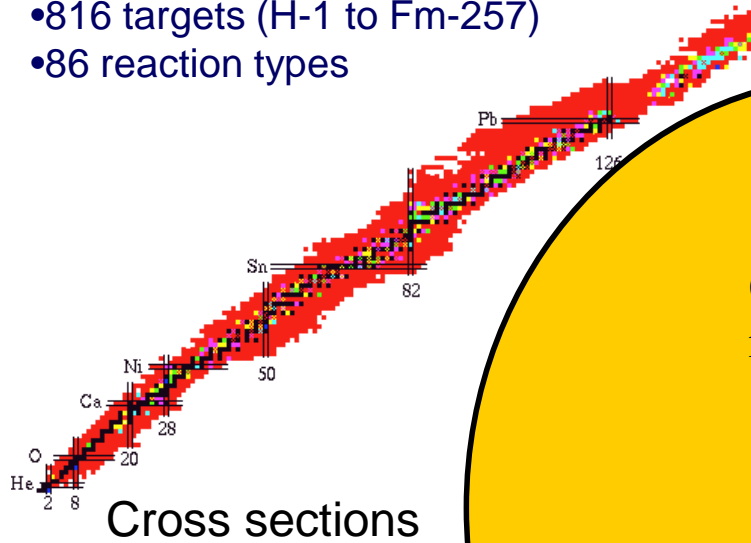
# EAF-2010 validation

- Validation of the EAF-2010 files:
  - A complete validation against all available differential measurements
    - By SACS analysis of all major reactions with  $Q < 20$  MeV
    - By C/E histogram analysis at major pertinent energies 0.0253 eV, 30 keV (n,g), 14.5 MeV and resonance integrals
    - The results are documented in EAF-Doc-5x series, by J. Kopecky
  - A complete validation against all available integral measurements experiments (FNS, FNG, REZ, etc...)
  - The validation reports are produced with emphasis on different nuclear applications (High energy, inertial and tokamak fusion, reactor types).

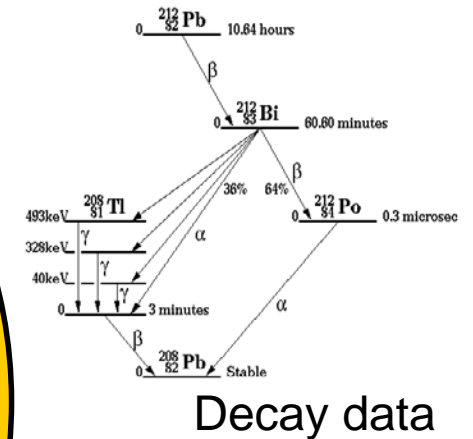
# European Activation File: n-induced

- 816 targets (H-1 to Fm-257)
- 86 reaction types

- 2,233 nuclides
- Stables and isomeric states ( $T_{1/2} > 1s$ )



**EAF-2010**  
66256 neutron induced reactions



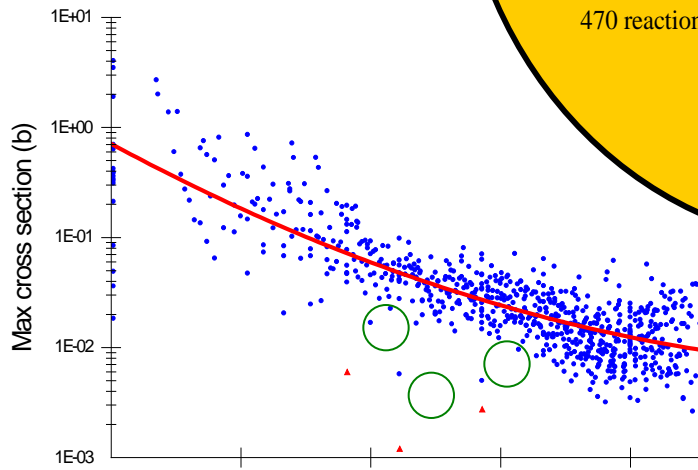
5096 important reactions

2265 major reactions

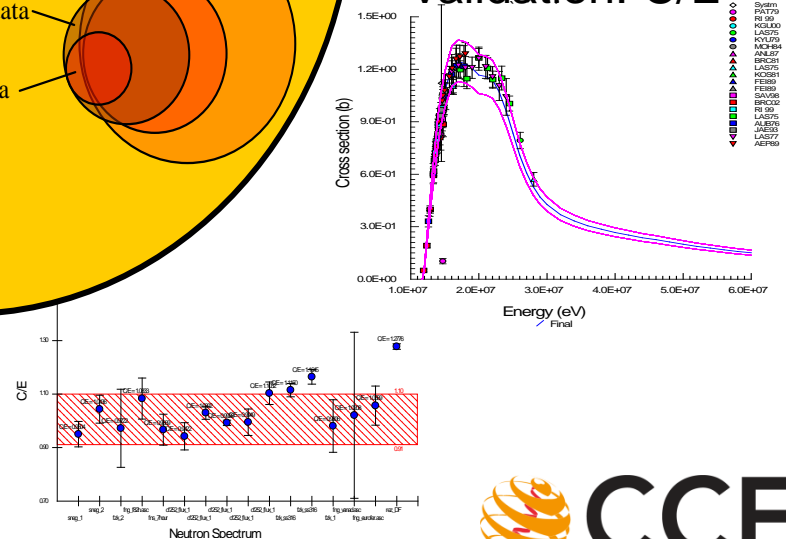
1728 reactions with any experimental data

470 reactions with integral data

## Validation: SACS



## Validation: C/E



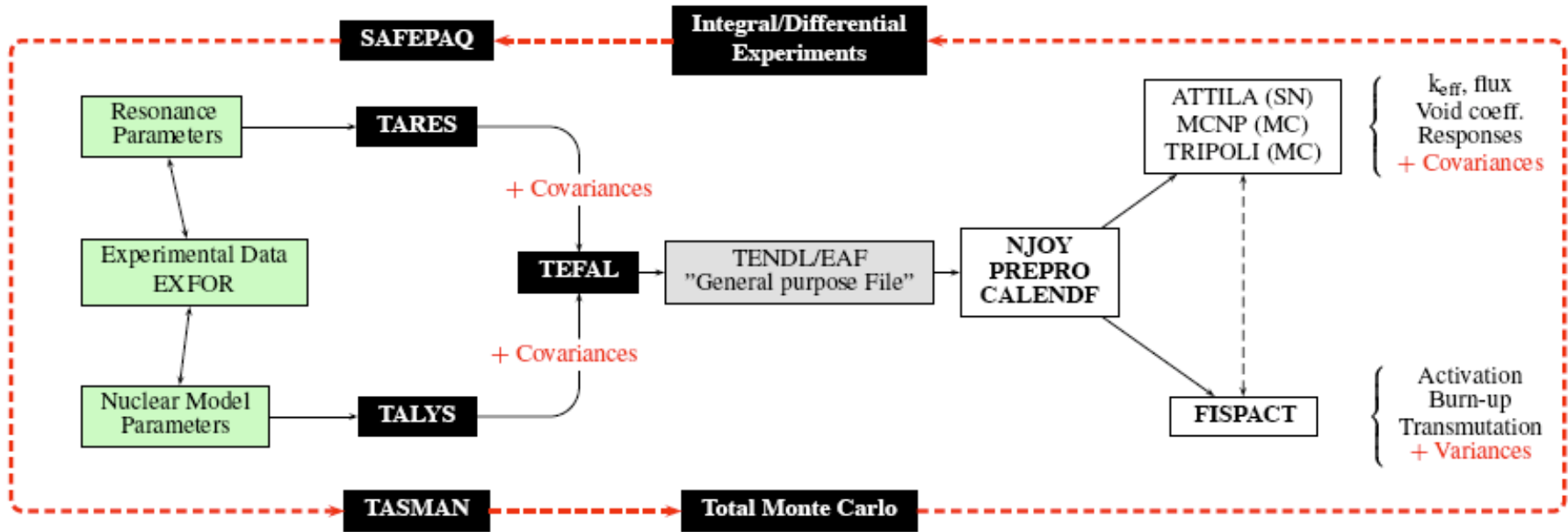
# EAF-2010 distribution

- In EAF format
  - As part of the European Activation System-2010
  - To all fusion association
  - Directly to other inventory code developer
    - ACAB, CINDER,..
- In ENDF-6 format, neutron only
  - Through the NDC: NEA, IAEA, BNL
  - EAF-2007 is already distributed that way

# Tomorrow goals

- ❖ Combined efforts to merge:
  - > validated EAF-2010 neutron activation cross section library
  - > with the TENDL-2010 neutron transport library
- to create a single but not unique truly general purpose file aimed at satisfying the radiation transport-dosimetry and activation-transmutation requirements for fusion and other devices
  - > Complete and consistent (internally and with transport library)
  - > Includes previous knowledge, know how of EAF evaluators
  - > Includes variances/covariances
- ❖ High Quality Assurance (reproducibility, verification, validation)
- ❖ Benchmarks with shielding (FNS, Oktavian, LLNL...), ICSBEP, ITER, and all fusion relevant experiments, but also fission
- ❖ Uncertainties tested with perturbation methods, Total Monte Carlo and FNS decay heat experiments

# Tools: an approach from basic nuclear data that includes benchmarking for fusion applications



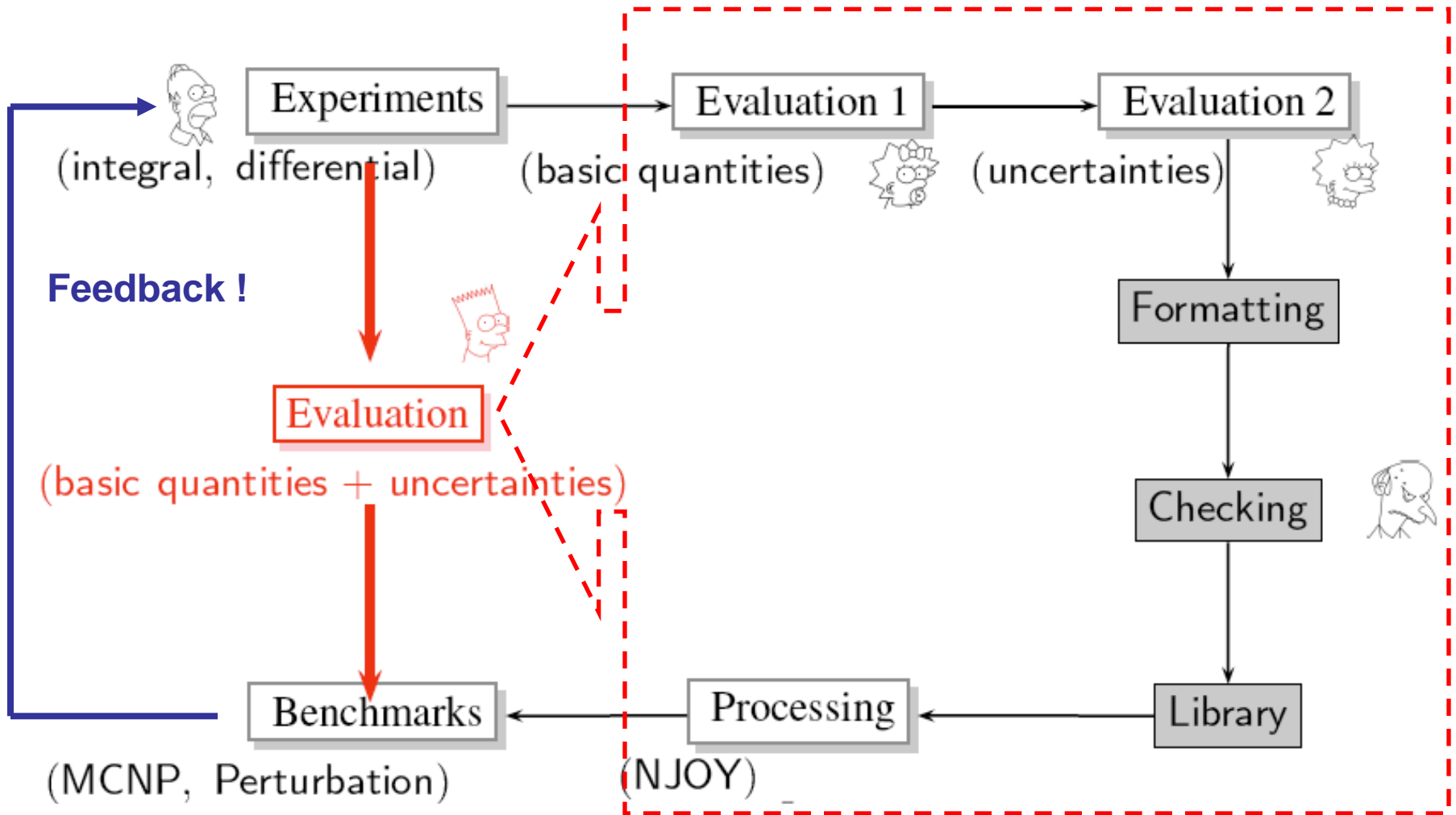
1. Theoretical nuclear model system: TALYS
2. Approach: activation-transmutation methodologies for fusion technology requirements: SAFEPAQ
3. Outcome 1: nuclear data evaluations (+ file production with associated uncertainty and covariances)
4. Outcome 2: library processing with NJOY, PREPRO and CALENDF

# Method – Knowledge/experience

- Knowledge on file production (automation, format, testing) from the transport and activation communities (TALYS & SAFEPAQ)
- Knowledge of previous EFF and EAF evaluations, EAF-2010. CCFE, NRG and CEA have considerable experience on nuclear data
- ❖ Total MC method already applied for Oktavian, FNS and LLNL benchmarks; Al, Si, Cu, Ti, Cr, Mn, Co, Fe, Mo, Zr, W, Mg
- ❖ Integral data V&V already applied and detailed in EAF validation reports
- ❖ Significant experience in running neutronics and other fusion shielding relevant calculations



# Method: No more delocalisation

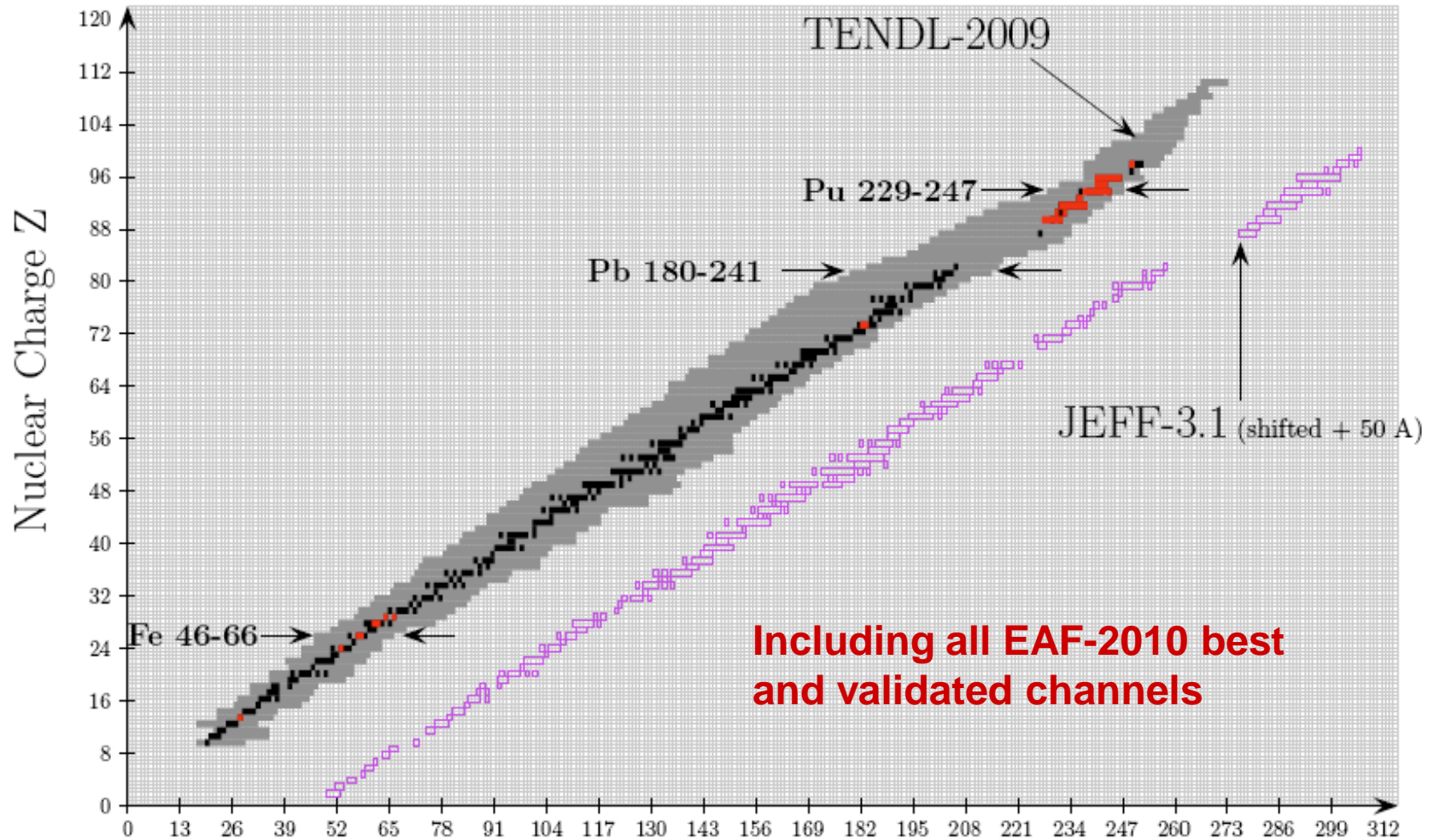


# Library content: $^{19}\text{F}$ – $^{281}\text{Ds}$ $T_{1/2} > 1$ second

Default Calculations

Medium Quality

Better Quality



# Method - Advantages

- ☺ This library arises from a unique source (TENDL & EAF-2010) that encompasses twenty years of European fusion related nuclear data research within the EAF and EFF projects
- ☺ For the first time, all fusion-related experimental, integral data and nuclear models will be transferred to technology in a consistent manner
- ☺ Includes other people's work (preferable with TALYS input files, but not necessarily), MF-2 from existing evaluation
- ☺ Automatic Benchmarking, Validation & Verification
- ☺ Only the essentials info for an evaluation are stored
- ☺ Feedback of extensive validation and benchmark activities will automatically be taken into account, repeatability
- ☺ Quality Assurance
- ☹ Needs discipline, team work and robust codes to (re) produce

# Schedule: welcome to the 21<sup>st</sup> century

- ✓ Generation and delivery of new neutron transport libraries for the Monte Carlo codes MCNP, TRIPOLI, SN code ATTILA and activation libraries for the FISPACT, ACAB code.
- ✓ In 2011: Unified activation and transport library based on EAF/TENDL, for more than 1000 isotopes
- ✓ Unique source (TENDL & EAF-2010), RR and URR from the best existing available source
- ✓ If required, inclusion of any other evaluation
- ✓ No targeting on a few materials: the method will be applied to all fusion-relevant materials at the same time !

A high quality library for all fusion-relevant materials is being produced