JCPRG

Development of Nuclear Reaction Data File for Astrophysics (NRDF/A)

OTUKA Naohiko for JCPRG

Nuclear Reaction Data Centre, Hokkaido University (JCPRG)
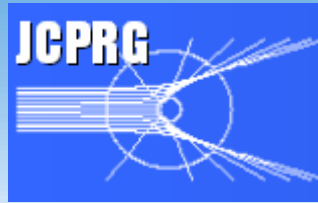
Nuclear Data Center, Japan Atomic Energy Agency (JAEA)

http://www.jcprg.org/

Co-authors

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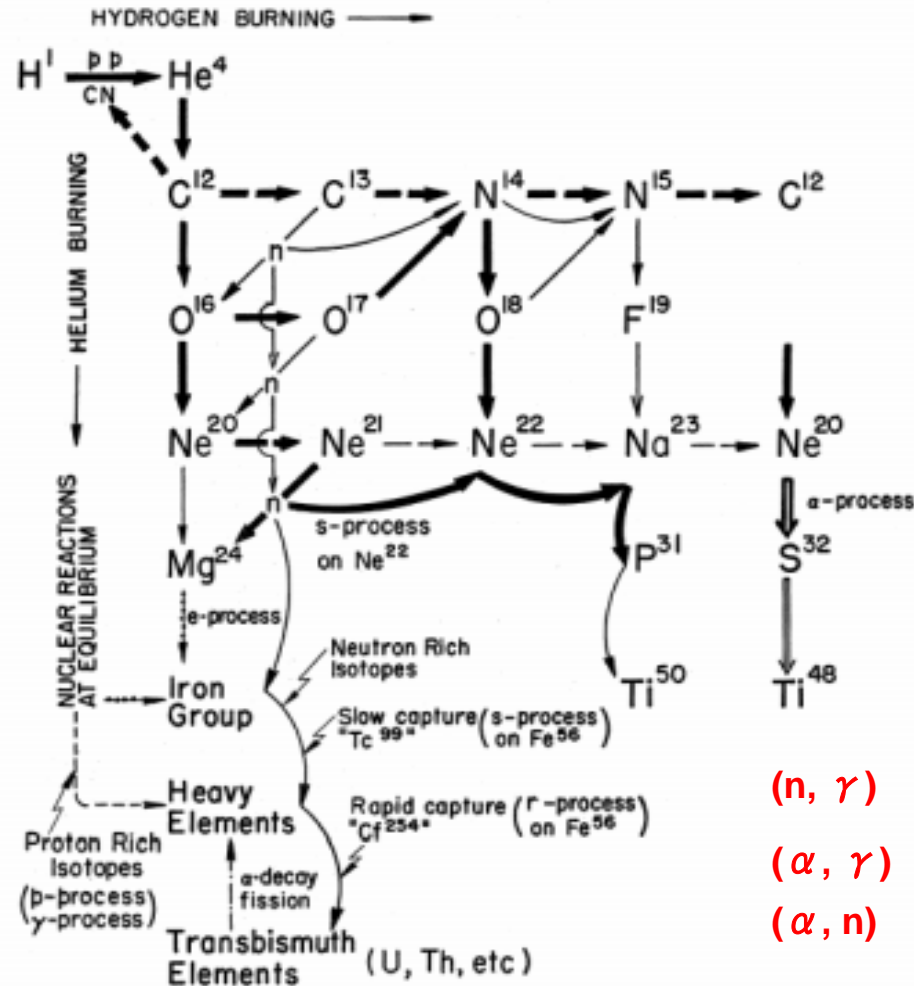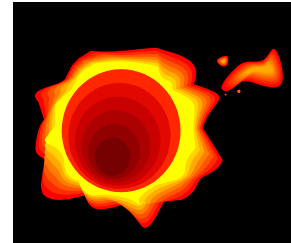 **(Faculty of Science + JCPRG, Hokkaido Univ.)**

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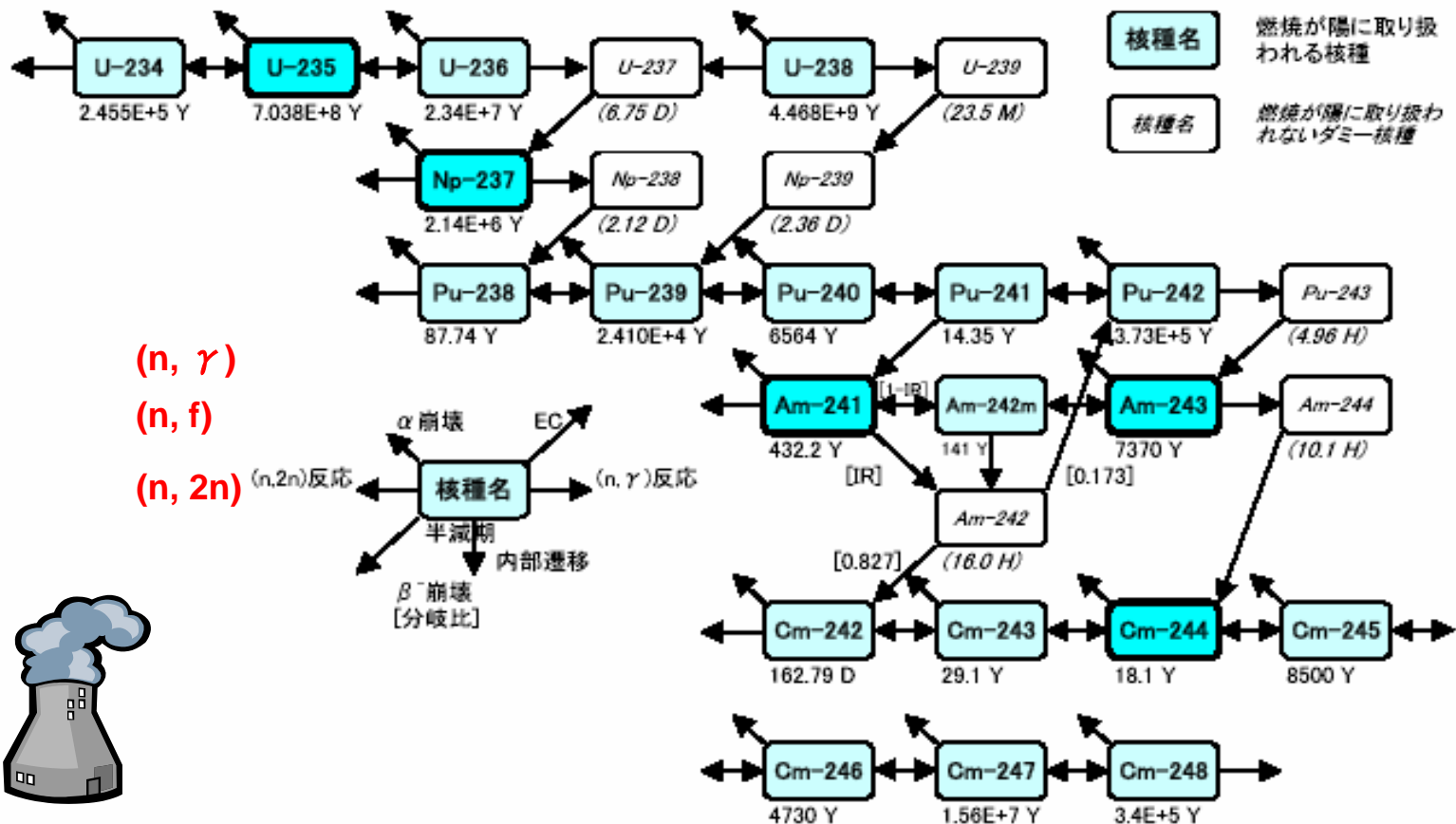
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1. Data Compilation for Nuclear Science and Technology

Network in Astronuclearphysics

(n, γ)

(α, γ)

(α, n)

Schematic diagram of nuclear process in stars - E. M. Burbidge et al., (B^{2}FH) Rev.Mod.Phys.29(1957)
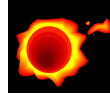
Network in Reactor Physics

Burning chain in fast breeder reactor *JOYO* - Sugino (2007), private communication

Nuclear Reaction Data are Utilized in ...

Science

- **Astronuclear physics**
- **Nuclear physics**

Technology

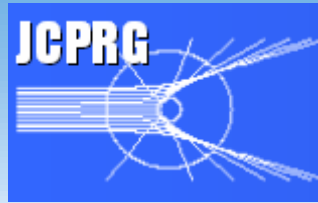- **Nuclear energy (fission, fusion, ADS)**
- **Medical isotope production (diagnosis, therapy)**
- **Shielding**
- **Ion-beam material analysis**

Common resource in science and technology

- **etc.** → **Experimental database for general purpose**

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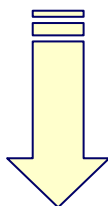# 2. Data Compilation Activity in Japan and the World

JCPRG?

Japan Charged-Particle Nuclear Reaction Data Group (*JCPRG*)
日本荷電粒子核反応データグループ
**(1974.4~ founded by H. Tanaka)**

Hokkaido University Nuclear Reaction Data Centre (*JCPRG*)
北海道大学大学院理学研究院附属原子核反応データ研究開発センター
(*2007.4~*, Head: K. Katō)
- **Compilation and international exchange of nuclear reaction data**
- R&D contraction for nuclear data with RIKEN Nishina Center
- Collaborative nuclear data education with JAEA Nuclear Data Center

Compilation of Experimental Data

Input of bibliography
experimental condition
(~1 week after publication)

RIKEN
CNS
RCNP
JAERI
NIRS
CYRIC
KEK
…

Numerical data
from Experimenters
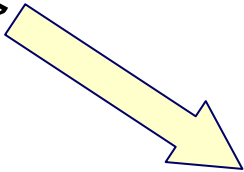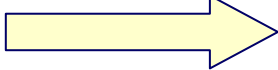
Data Compiler

- Checking
- Author proof
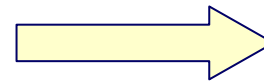
Release
(~6 months
after
publication)

Digitization if data is not available
(old data, silent authors…)

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International Experimental Data Exchange

EXFOR:
    EXchange FORmat for nuclear reaction data

NEA-DB (e.g. Karsruhe)

BNL-NNDC (CSISRS)

EXFOR

Russia
China
Hungary
Ukraine
...

IAEA-NDS (Coordinator)

JCPRG (NRDF)
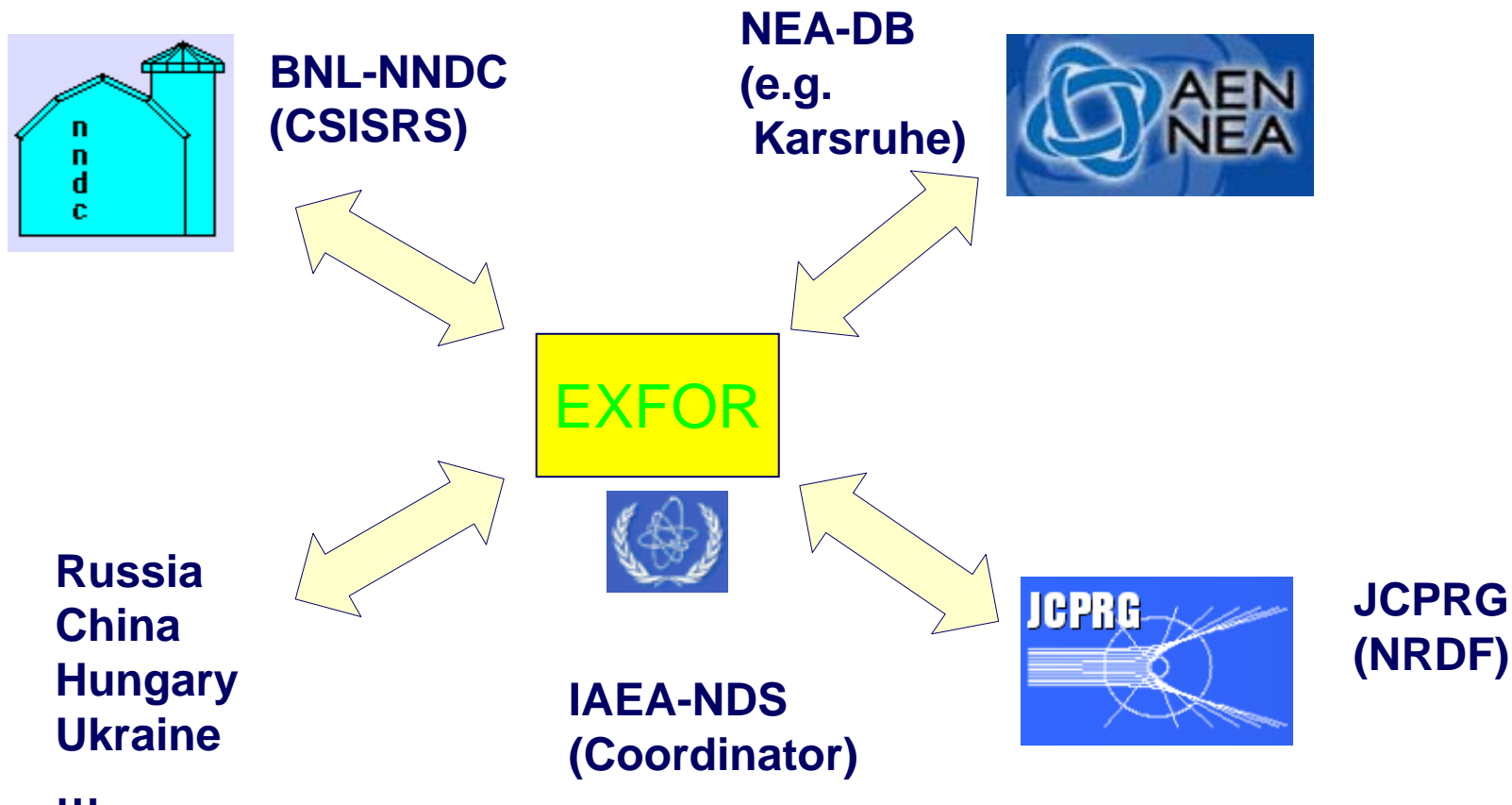
Nuclear Reaction Data Centre Network (NRDC)
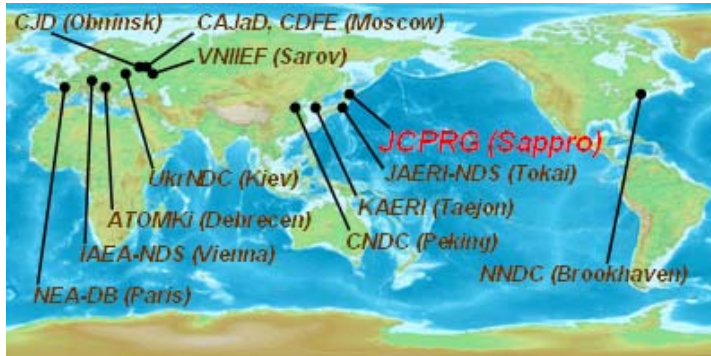
Coordinated by IAEA-NDS
(Nuclear Data Section)

- 🇺🇸 **NNDC**
- 🇪🇺 **NEA-DB**
- 🇺🇳 **IAEA-NDS**
- 🇷🇺 **CJD, CAJaD, CDFE, CNPD**
- 🇭🇺 **ATOMKI**
- 🇺🇦 **UkrNDC**
- 🇯🇵 **JCPRG JAEA-NDC** — *Asian Centres*
- 🇮🇳 **BARC**
- 🇨🇳 **CNDC**
- 🇰🇷 **KAERI-NDEL**

• Centres are responsible for data compilation of their area.
• JCPRG and IAEA-NDS also check data files from the world.(format, physics)

JCPRG

Compilation Statistics
(EXFOR, 2003-2006)

Neutron induced
reaction data (1050 works)

Compilation Statistics (Neutron)

CJD (4)
9%

IAEA-NDS (3)
8%

US
NNDC (1)
28%

NEA-DB (2)
55%

**EU +
Japan**

Compilation Statistics (CPND)

NNDC (T)
4%

CAJaD (A)
5%

CNDC (S)
0%

NEA-DB (O)
30%

US
NNDC (C)
22%

JCPRG (J)
0%

Japan

IAEA-NDS (D)
15%

Sarov (F)
13%
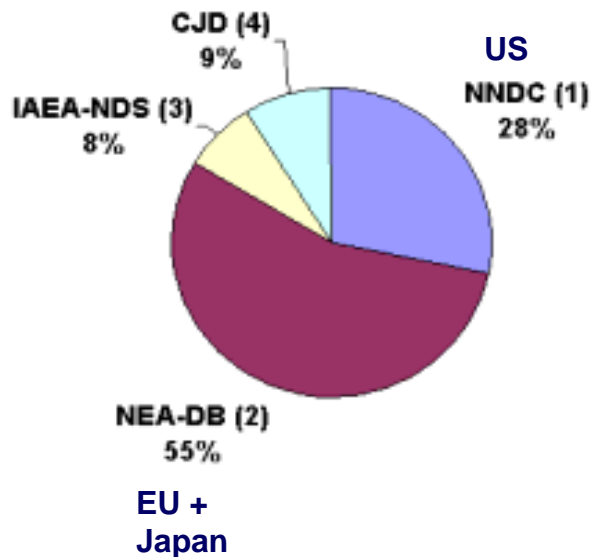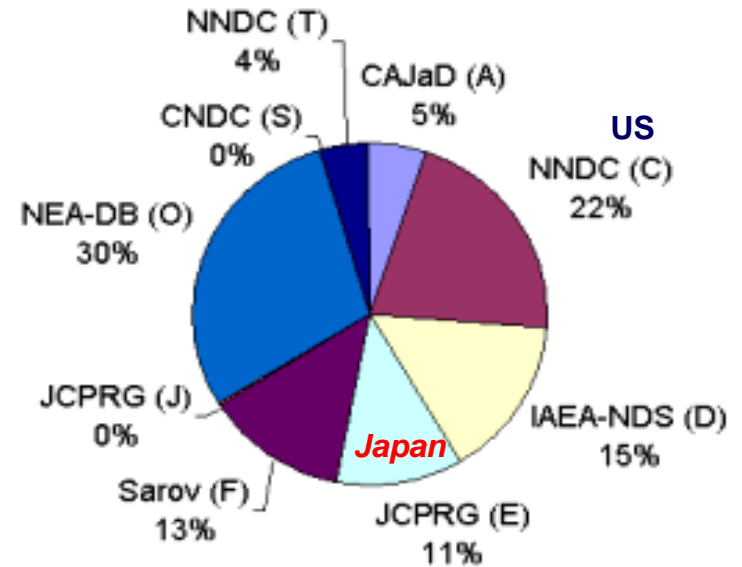
JCPRG (E)
11%

Charged-particle induced reaction data
(3000 works, of which 10% is from JCPRG)

Photo-nuclear data (138 works)

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Access to EXFOR

JCPRG   IAEA-NDS   NNDC   NEA-DB

80,000~90,000 searches / year

CD and Book are also available.

(CINDA: A Bibliographical data
base for nuclear reaction works)

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3. Nuclear Reaction Data File for Astrophysics (NRDF/A)

Format of General Purpose File

NRDF format

```
¥¥DATA,1;
INC-ENGY-CM=0.3125[3.0375MEV;
THTC=180DEG;
¥DATA;
INC-ENGY-CM DSIGMA/DOMEGA DELTA-DSIGMA/DOMEGA'19'
(MEV) (MB/SR) (MB/SR)
0.3125  434.1   +-23.5
0.3375  371.2   +-21.4
0.3625  321.8   +-18.9
```

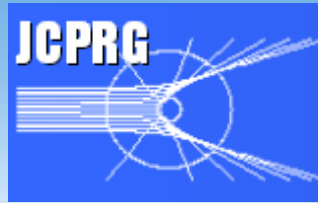← $^1H(^{11}C,^{11}C)^1H$ dσ/dΩ by CNS

EXFOR format

```
    BIB                  4          7          E180300200002
    REACTION   (1-H-1(6-C-11,EL)1-H-1,,DA)                E180300200003
    STATUS     (TABLE)Data sent by T.Teranishi by e-mail, E180300200007
               corresponding figure is Fig.1, p30         E180300200009
    ENDBIB               7          0          E180300200010
    NOCOMMON             0          0          E180300200011
    DATA                 3        105          E180300200012
    EN-CM       DATA-CM     ERR-S              E180300200013
    MEV         MB/SR       MB/SR              E180300200014
     0.3125      434.1       23.5              E180300200015
     0.3375      371.2       21.4              E180300200016
     0.3625      321.8       18.9              E180300200017
```

Format must be *flexible* for various kind of quantities.

→ Derived files of specific quantities would be helpful for evaluators.

Derived File for Evaluators (Neutron Data)

"*Computational Format*" (C4)

developed at IAEA Nuclear Data Section, available at IAEA-NDS and NNDC.

(Z,A) Beam	Target	ENDF quantity MF	MT	Incident Energy (eV)	Cross section and error (barn)	(barn)	Author name and publication year	Data ID number	
...									
2004	6013	3	4	649790.0	2.2148-7	2.0514-9	S.E.KELLOGG,ET.AL. (89)	C0517	2
2004	6013	3	4	600120.0	7.1917-8	1.0480-9	S.E.KELLOGG,ET.AL. (89)	C0517	2
2004	6013	3	4	549940.0	2.0182-8	4.765-10	S.E.KELLOGG,ET.AL. (89)	C0517	2
2004	6013	3	4	499970.0	4.5420-9	1.857-10	S.E.KELLOGG,ET.AL. (89)	C0517	2
2004	6013	3	4	449930.0	7.682-10	6.741-11	S.E.KELLOGG,ET.AL. (89)	C0517	2
2004	6013	3	4	767000.0	2.6000-6	1.0400-7	S.Harissopulos, (05)	F0786	4
2004	6013	3	4	786000.0	3.3000-6	1.3200-7	S.Harissopulos, (05)	F0786	4
2004	6013	3	4	807000.0	5.1000-6	2.0400-7	S.Harissopulos, (05)	F0786	4
2004	6013	3	4	826000.0	7.2000-6	2.8800-7	S.Harissopulos, (05)	F0786	4
...									

- All data points of specific reaction/quantity from various measurements are in one file.

- Easy to read by Fortran and other computer languages

- Special purpose file for low energy neutron induced reaction data evaluation
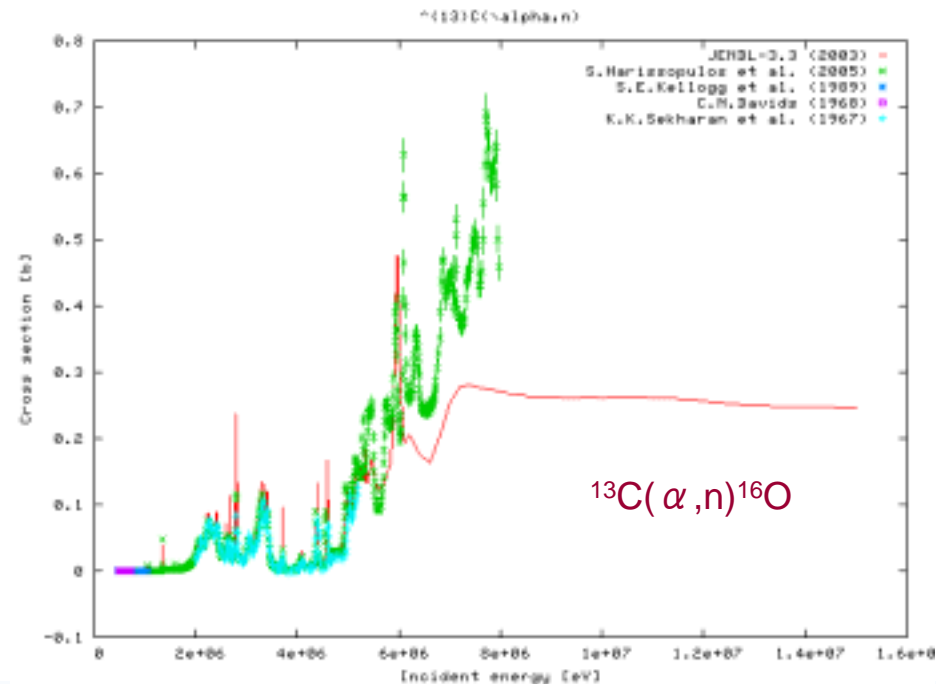
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Derived File for Evaluators (Astronuclear Data)

NRDF/A : Compilation for astrophysical data of
31 reactions - (n, γ), (α, γ), (α,n) - derived from EXFOR

```
¥¥BIB;
D#        A0005
DATE      2006-12-09
RCT       13C(A,N)16O
PHQ       SIGMA
REF       [HA2005] S.Harissopulos et al., Phys.Rev.C72(2005)062801
REF       [KE1989] S.E.Kellogg et al., Bull.Am.Phys.Soc.34(1989)1192(E10.5)
REF       [DA1968] C.N.Davids, Nucl.Phys.A110(1968)619
REF       [SE1967] K.K.Sekharan et al., Phys.Rev.156(1967)1187
COM       EXFOR A0613.003 (EN-CM vs SIGMA) should be added.

¥¥DATA;
EN-MIN     EN-MAX    SIGMA      ERR-T      ERR-S     REF
EV         EV        B          B          B
 7.6700E+05 7.6700E+05 2.6000E-06 1.0400E-07 -        HA2005
 7.8600E+05 7.8600E+05 3.3000E-06 1.3200E-07 -        HA2005
 8.0700E+05 8.0700E+05 5.1000E-06 2.0400E-07 -        HA2005
 8.2600E+05 8.2600E+05 7.2000E-06 2.8800E-07 -        HA2005
 8.4600E+05 8.4600E+05 1.0800E-05 4.3200E-07 -        HA2005
 8.6600E+05 8.6600E+05 1.4300E-05 5.7200E-07 -        HA2005
 8.8600E+05 8.8600E+05 2.0200E-05 8.0800E-07 -        HA2005
 9.0600E+05 9.0600E+05 2.8700E-05 1.1480E-06 -        HA2005
 9.2500E+05 9.2500E+05 3.8400E-05 1.5360E-06 -        HA2005
 9.4500E+05 9.4500E+05 5.3200E-05 2.1280E-06 -        HA2005
 9.6500E+05 9.6500E+05 8.0100E-05 3.2040E-06 -        HA2005
 9.7500E+05 9.7500E+05 8.9300E-05 3.5720E-06 -        HA2005
 9.8500E+05 9.8500E+05 1.0100E-04 4.0400E-06 -        HA2005
 9.9400E+05 9.9400E+05 1.1600E-04 4.6400E-06 -        HA2005
 1.0050E+06 1.0050E+06 1.5200E-04 6.0800E-06 -        HA2005
 1.0160E+06 1.0160E+06 1.6400E-04 6.5600E-06 -        HA2005
 1.0250E+06 1.0250E+06 1.8900E-04 7.5600E-06 -        HA2005
 1.0300E+06 1.0300E+06 2.0900E-04 8.3600E-06 -        HA2005
 1.0460E+06 1.0460E+06 4.6100E-04 1.8440E-05 -        HA2005
 1.0500E+06 1.0500E+06 8.5000E-04 3.4000E-05 -        HA2005
 1.0520E+06 1.0520E+06 2.0300E-03 8.1200E-05 -        HA2005
 1.0530E+06 1.0530E+06 4.5300E-03 1.8120E-04 -        HA2005
 1.0540E+06 1.0540E+06 8.7700E-03 3.5080E-04 -        HA2005
```
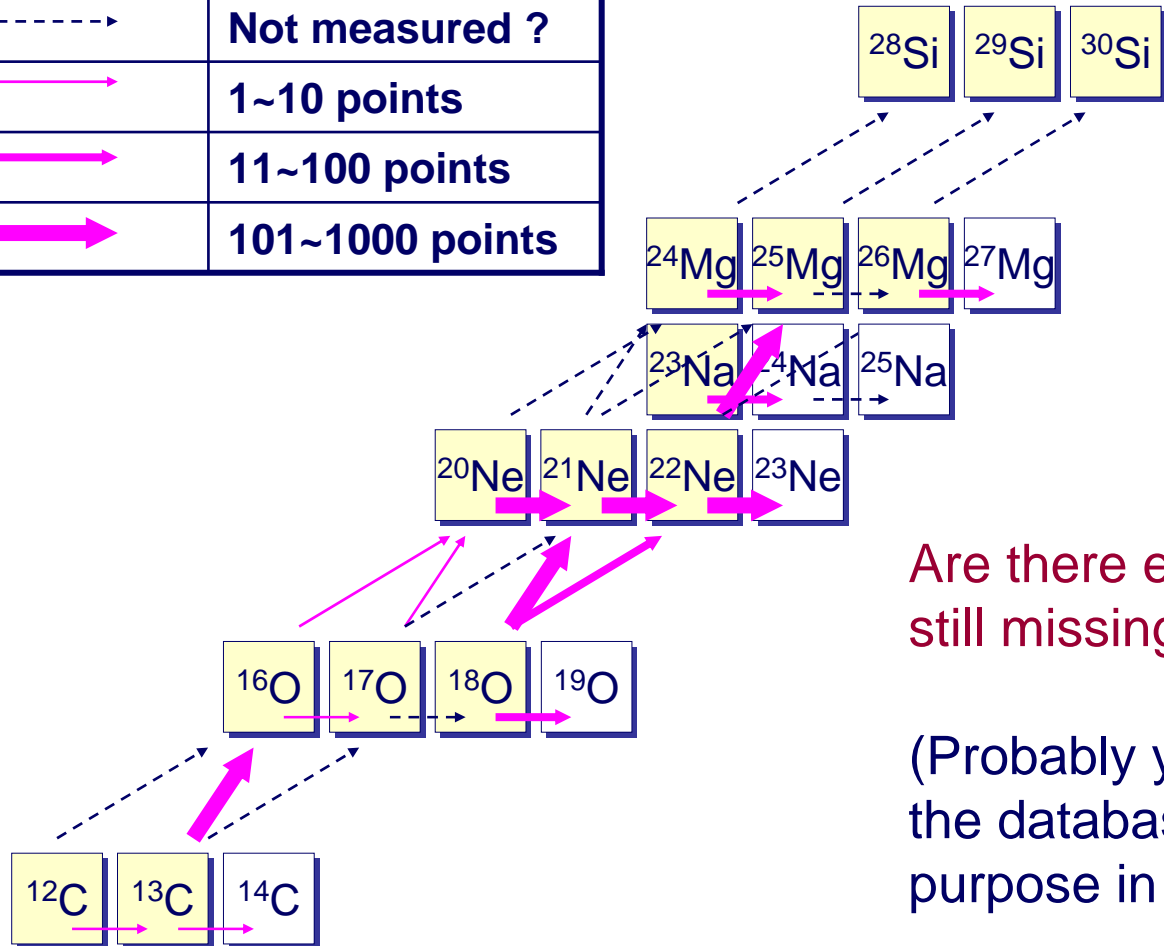

$^{13}C(\alpha,n)^{16}O$

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Scope of NRDF/A in 1st Year
(Cross section - C to Si)

- - - →	**Not measured ?**
→	**1~10 points**
⟶	**11~100 points**
⟹	**101~1000 points**

^{28}Si ^{29}Si ^{30}Si

^{24}Mg ^{25}Mg ^{26}Mg ^{27}Mg

^{23}Na ^{24}Na ^{25}Na

^{20}Ne ^{21}Ne ^{22}Ne ^{23}Ne

^{16}O ^{17}O ^{18}O ^{19}O

^{12}C ^{13}C ^{14}C

Are there experimental data still missing in EXFOR?

(Probably yes, EXFOR *was* the database for energy purpose in the early stage.)

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5. Conclusion

Conclusions

- **Nuclear reaction data base:**
  Basic infrastructure in physics and engineering
  We do not set special purpose on the database.

- **International network of data compilation is working very well.**

- **General purpose file → Derived files (energy, astro,...)→ Users**

- **We did a trial to develop a derived experimental data file (NRDF/A) for astronuclear reaction data evaluation.**

- **Completeness of astronuclear data in the primary database (NRDF/EXFOR) must be checked.**

- **Thanks for all experimentalists who provide us numerical data!!**

- **Citation and acknowledgement to our databases are appreciated. (Resource of budget and man power is poor.)**

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Members of JCPRG and NRDC

- **Hokkaido University Nuclear Reaction Data Centre (JCPRG)**

  NRDF Advisory Committee：
  Y. Abe (RCNP), Y. Akaishi (RIKEN), Y. Aoki (Tsukuba), M. Baba (Sendai), J. Chiba (TUS),
  A. Hasegawa (NEA-DB), K. Hatanaka (RCNP)), M. Ishihara (RIKEN), K. Kato (Sapporo),
  J. Katakura (JAEA), M. Kawai (Fukuoka), S. Kubono (CNS), S. Morinobu (RCNP), T. Noro (Fukuoka),
  T. Motobayashi (RIKEN), T. Nagae (Kyoto), K. Okamoto (JAIF), H. Ohnuma (TIT),
  H. Orihara, (Sendai), T. Saito (Sendai), H. Sakurai (RIKEN), H. Tanaka (Sapporo),
  H. Utsunomiya (Konan)

  NRDF Steering Committee：
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  Y. Hirabayashi (Hokkaodo U.), T. Katayama (Hokusei Gakuen U.), H. Masui (Kitami Inst. Tech.),
  H. Noto (Hokusei Gakuen U.), A. Ohnishi (Hokkaido U.), S. Okabe (Hokkaido U.)

  Compilation, Digitization, System development:
  T. Ashizawa (Hokkaido U.), H. Matsumiya (Hokkaido U.), T. Murakami (Hokkaido U.),
  R. Suzuki (Hokkaido U.), T. Togashi (Hokkaido U.), K. Tsubakihara (Hokkaido U.),
  H. Yoshida (Hokkaido U.), T. Yoshida (Hokkado U.)

- **Nuclear Reaction Data Centers Network (NRDC)**

  Active compilers:
  O. Schwerer (IAEA-NDS, Vienna), S. Dunaeva (IAEA-NDS, Vienna), S.Y. Babykina (CAJaD, Moscow),
  S. Maev (Obninsk), M. Mikhaylyukova (IPPE-CJD, Obninsk), N.Otuka (JAEA/JCPRG, Tokai),
  S. Takacs (ATOMKI, Debrecen), H. Henriksson (OECD-NEA, Paris), N.Klimova (UkrNDC, Kiev)