Validation of Zr evaluated reaction cross section data

A. Trkov, M. Herman, R. Arcilla
National Nuclear Data Center
Brookhaven National Laboratory

Mini-CSEWG Meeting, Montauk, New York, June 21-23, 2011

BROOKHAVEN NATIONAL LABORATORY
a passion for discovery

U.S. DEPARTMENT OF ENERGY | Office of Science

Objectives

- Compare and test new evaluations
- Check the root cause of possible overprediction of reactivity in integral benchmarks

Scope

- Consider libraries:
  - ENDF/B-VI.8
  - ENDF/B-VII.0
  - ENDF/B-VII.1-beta3
  - New NNDC-BNL evaluation
  - JENDL-4
- Consider criticality benchmarks from the ICSBEP Handbook
  - 37 identified
  - 21 actually used

Transport cross sections

	Thermal cross section			Resonance integral		
	Total [barns]	Elastic [barns]	Capture [barns]	Total [barns]	Elastic [barns]	Capture [barns]
ENDF/B-VII.0	6.97	6.79	0.182	122	121	1.07
ENDF/B-VII.1b3	6.99	6.80	0.190	123	121	1.07
BNL	6.99	6.80	0.190	123	121	1.07
JENDL-4	6.58	6.38	0.196	118	117	1.00
ENDF/B-VI.8	6.56	6.38	0.185	120	118	0.95

(For detals see report)

Activation cross sections: 90Zr(n,2n)

^{90}Zr(n,2n)

Measured	IRDFF	BNL
0.221 b +/- 2.9 %	0.217 b +/- 5.2 %	0.219 b +/- 5.1 %

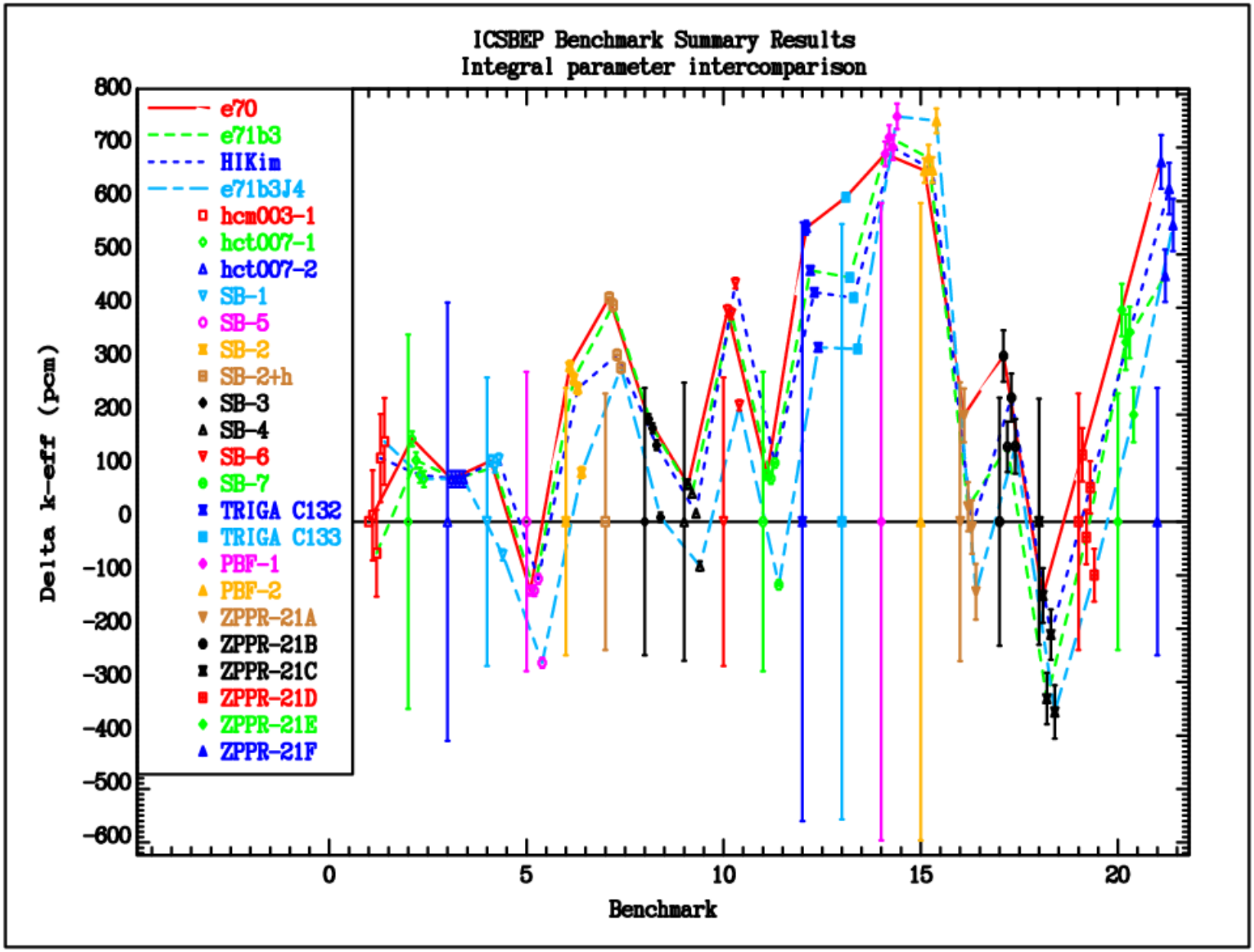
(Uncertainty from ^{252}Cf fission spectrum)

Activation cross sections: $^{94}Zr(n,\gamma)$

^{94}Zr	σ_0 [barns]	Diff. [%]	RI [barns]	Diff. [%]
IUPAC	0.051 b ±1.8 %	Ref.	0.27 b±3.8 %	Ref.
ENDF/B-VII.0	0.0497 b	-1.8 %	0.314 b	17 %
JENDL-4	0.0507 b	-0.2 %	0.285 b	5.7 %
BNL	0.0497 b	-1.8 %	0.314 b	17 %

Activation cross sections: $^{96}Zr(n,\gamma)$

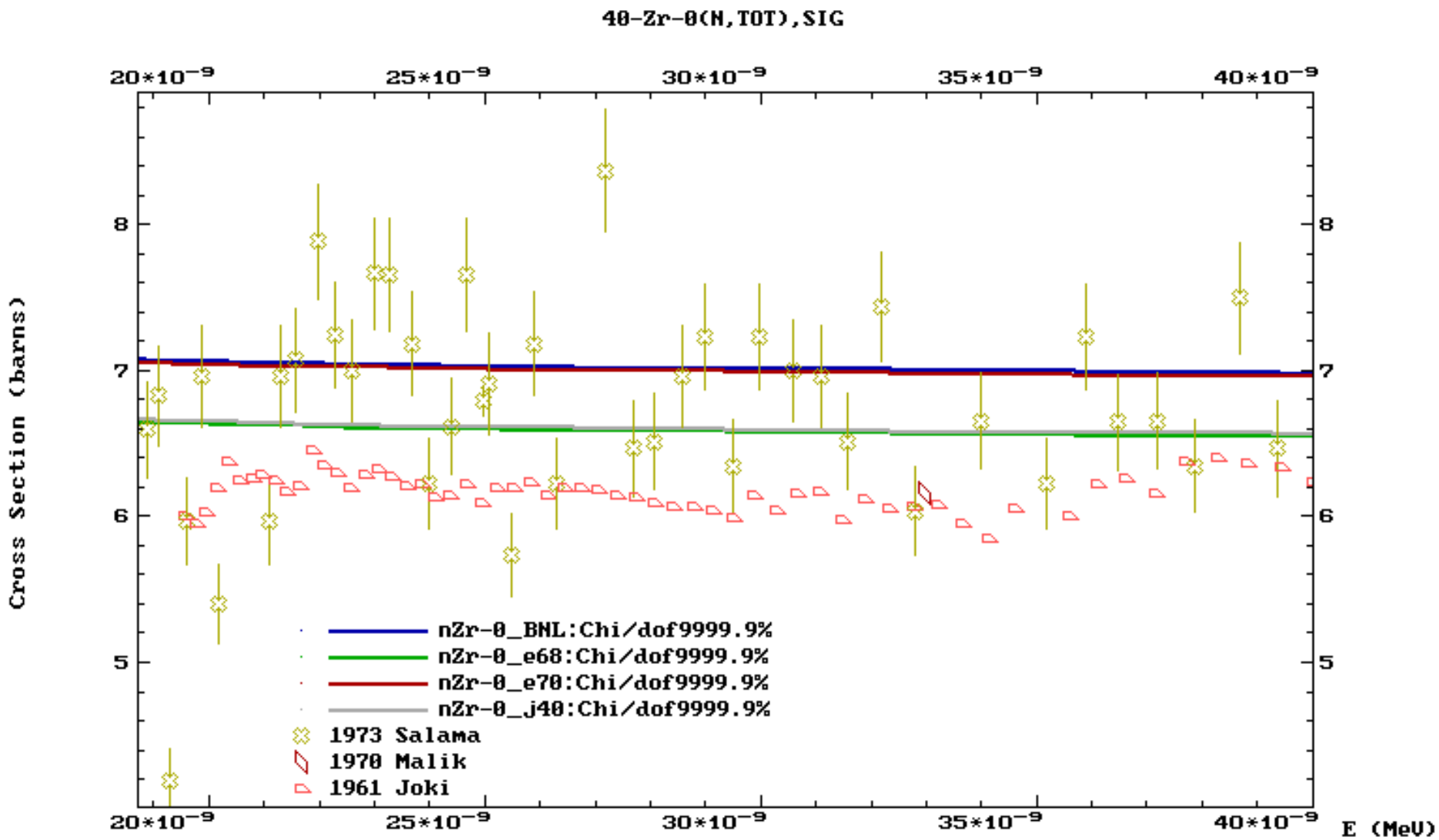
^{96}Zr	σ_0 [barns]	Diff. [%]	RI [barns]	Diff. [%]
IUPAC	0.0197 b ±3.8%	Ref.	4.96 b±3.5 %	Ref.
ENDF/B-VII.0	0.0228 b	16 %	5.16 b	4.1 %
JENDL-4	0.0203 b	3.2 %	4.23 b	-15 %
BNL	0.0228 b	16 %	5.16 b	4.1 %

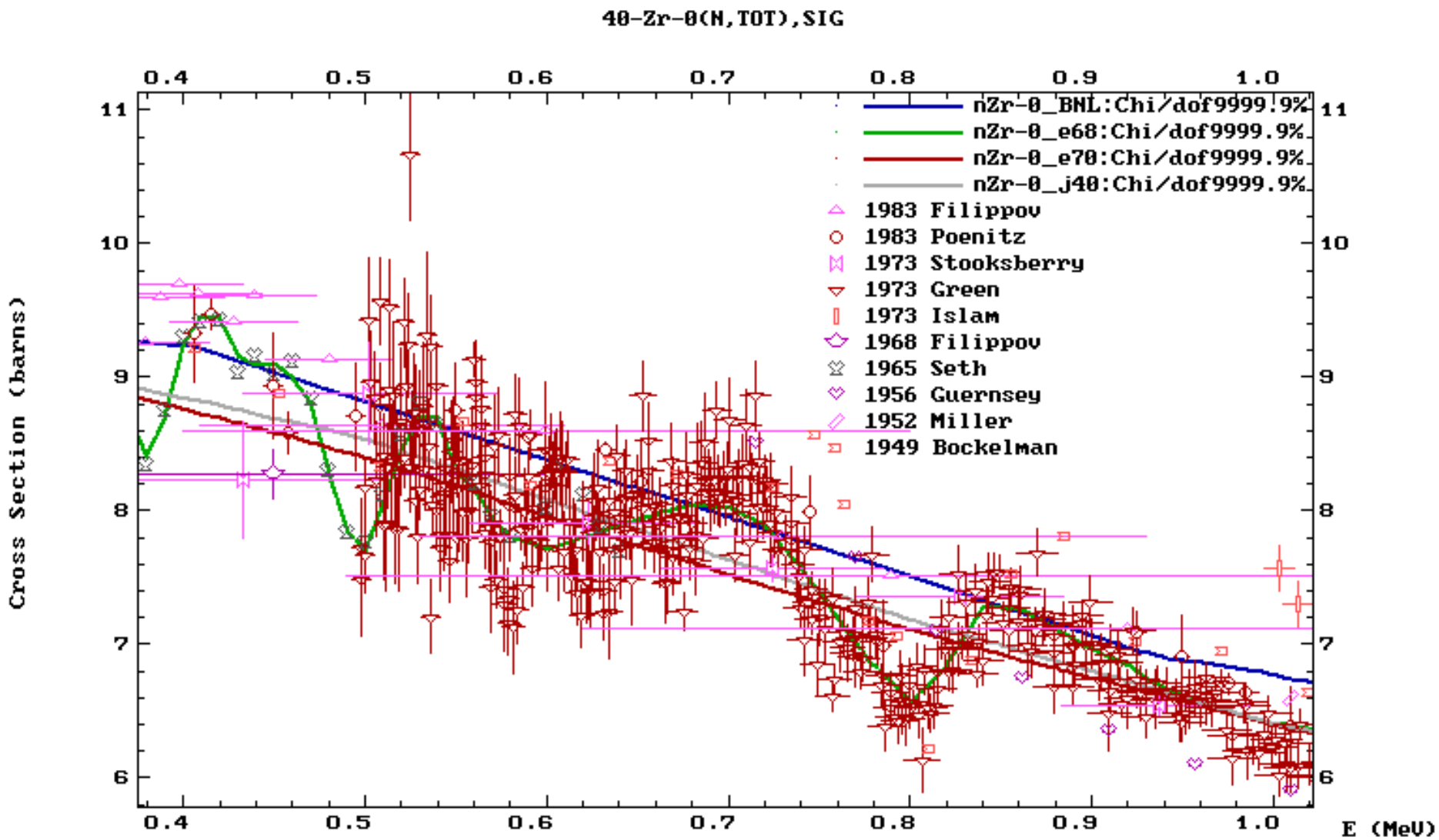

ICSBEP Benchmark Summary Results
Integral parameter intercomparison
Delta k-eff (pcm)
Benchmark
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
0
5
10
15
20
e70
e71b3
HIKim
e71b3J4
hcm003-1
hct007-1
hct007-2
SB-1
SB-5
SB-2
SB-2+h
SB-3
SB-4
SB-6
SB-7
TRIGA C132
TRIGA C133
PBF-1
PBF-2
ZPPR-21A
ZPPR-21B
ZPPR-21C
ZPPR-21D
ZPPR-21E
ZPPR-21F

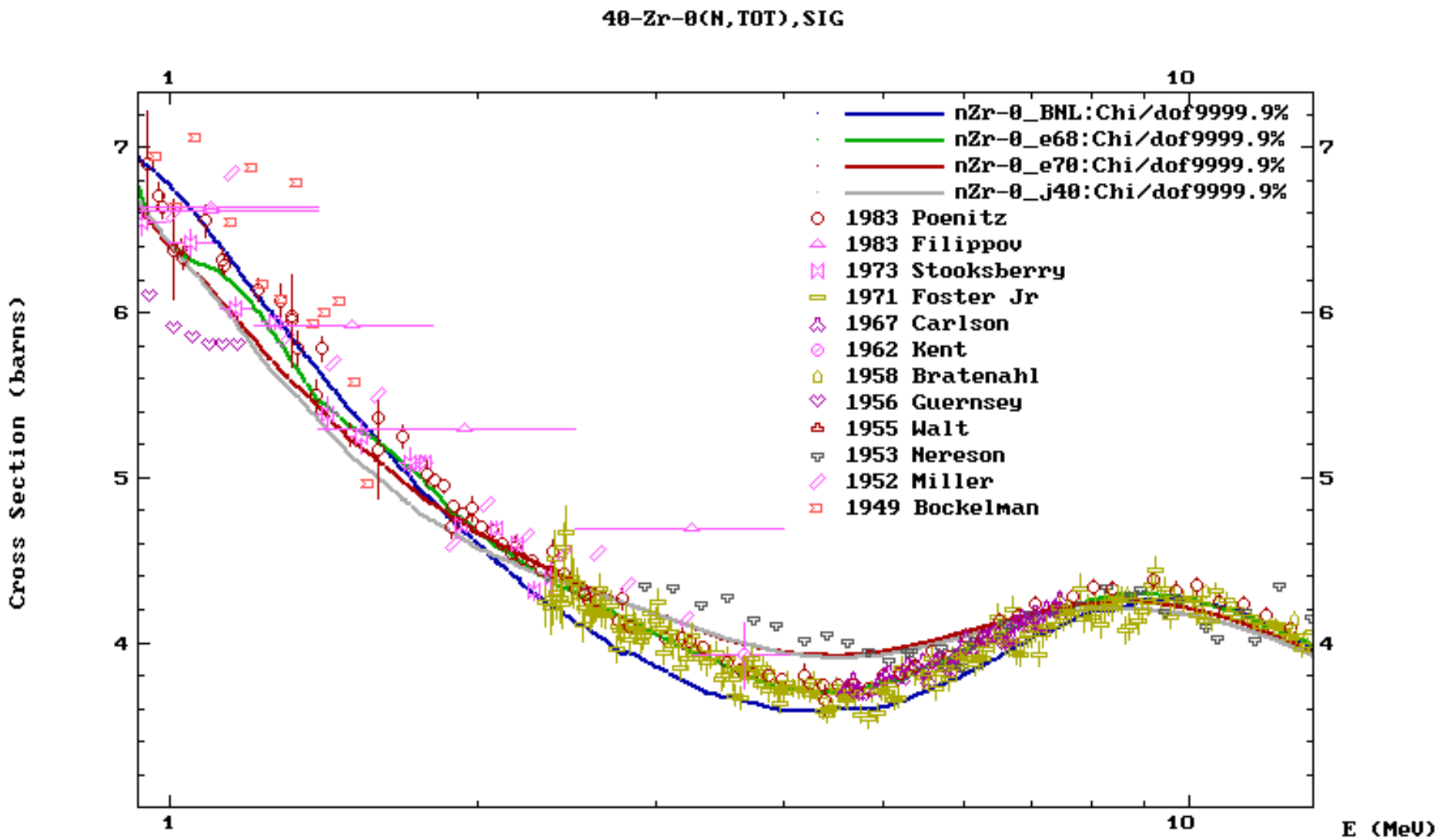
Conclusions

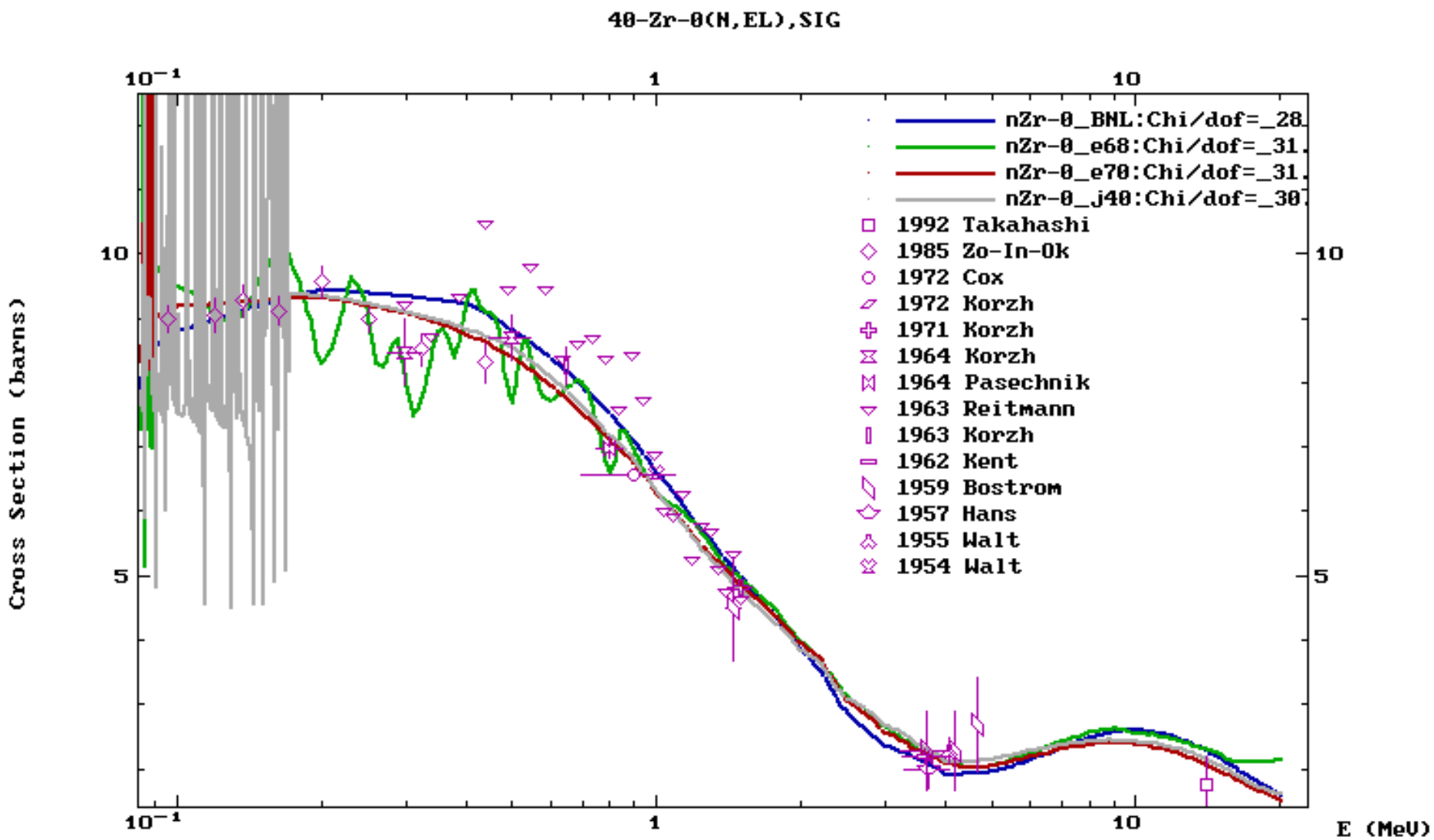
Transport cross sections

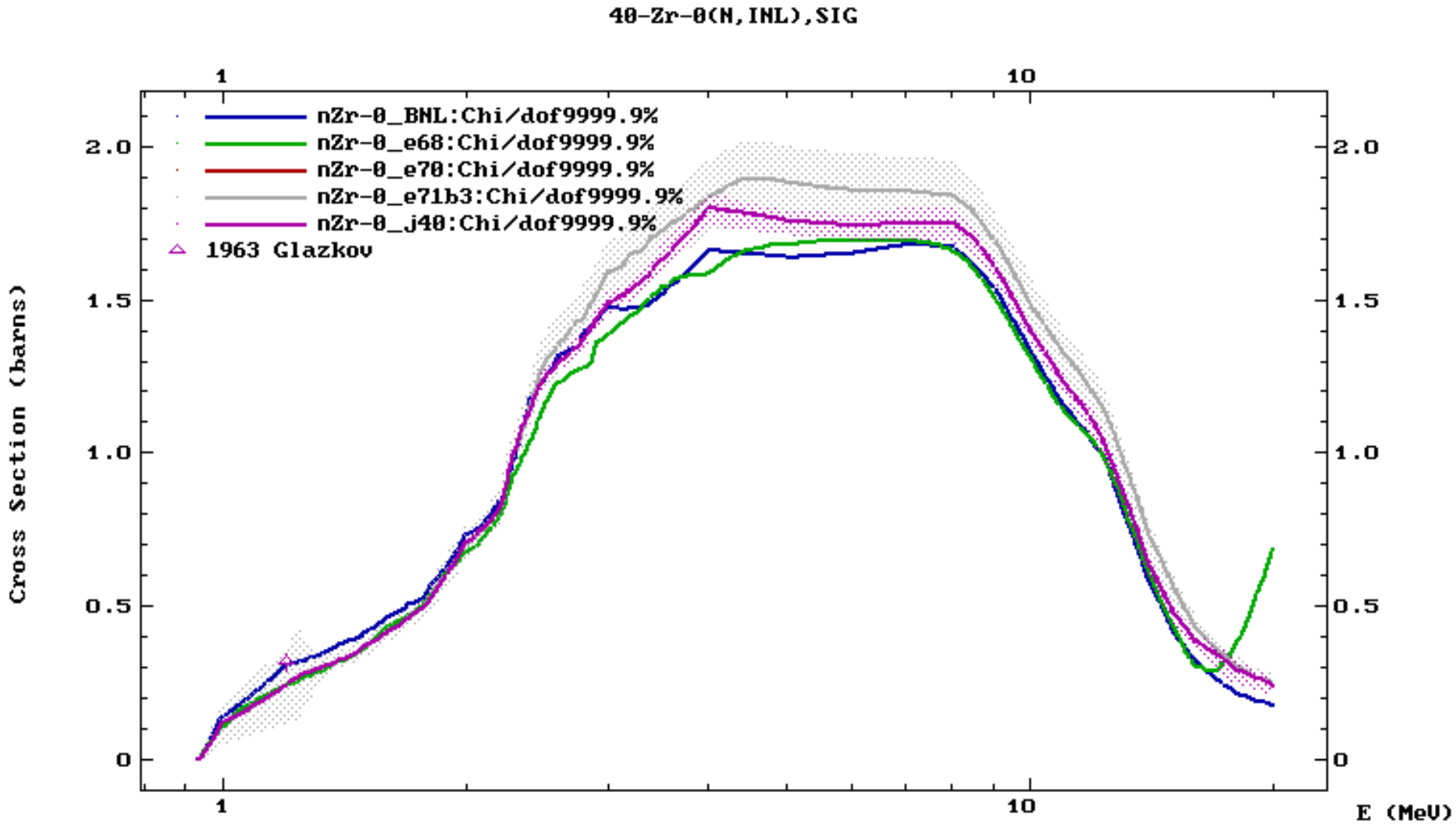
- Fast reactors
  - single series of benchmarks – no conclusion
- Thermal reactors
  - Possible over-estimation of reactivity
  - Sensitivity on scattering cross section
  - New BNL or JENDL-4 data provide some improvement
- Activation reactions
  - ^{90}Zr(n,2n) BNL consistent (possible problems ~20 MeV)
  - ^{94}Zr(n,γ), ^{96}Zr(n,γ) need improvement in all files

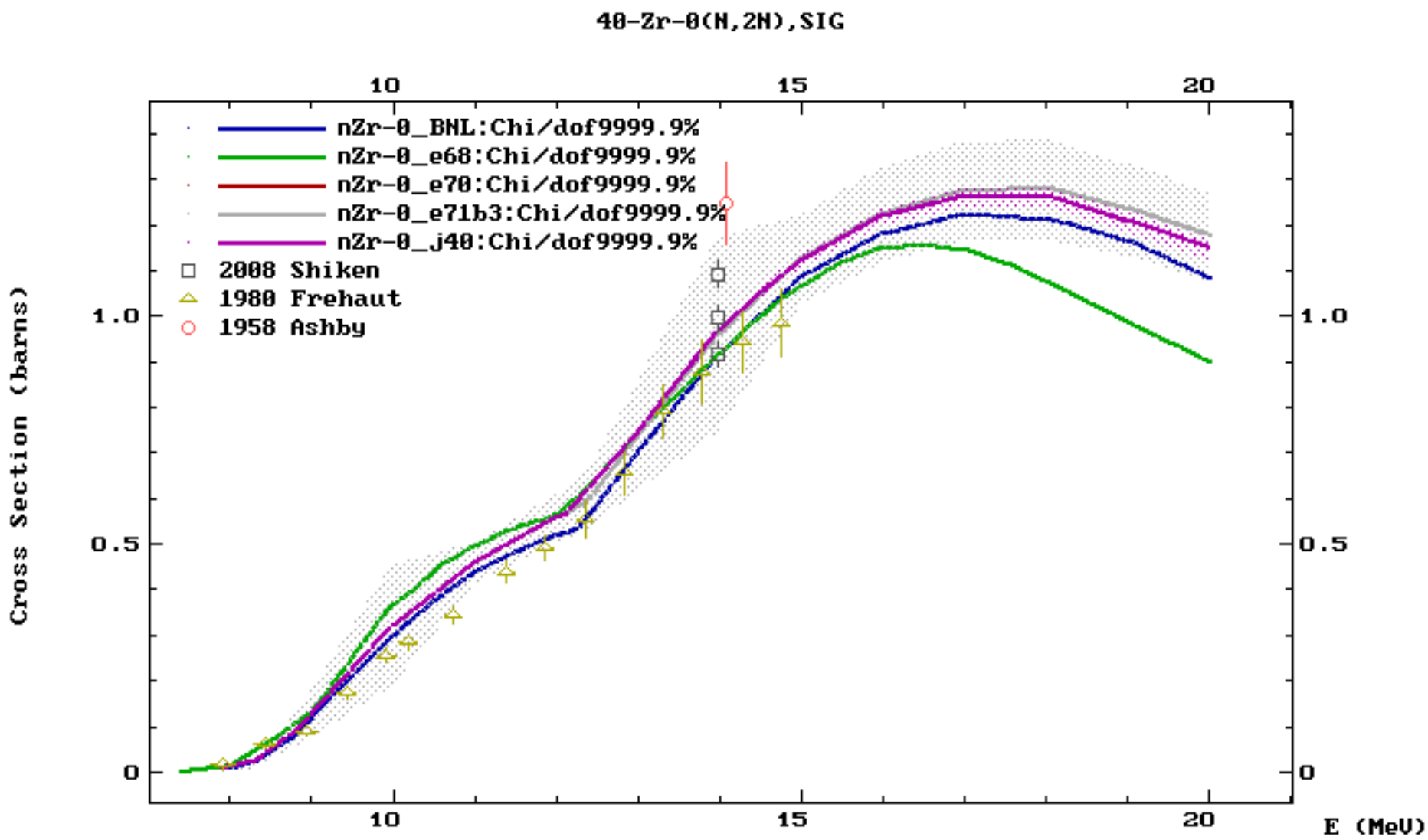

40-Zr-0(N,TOT),SIG
Cross Section (barns)
E (MeV)
20*10⁻⁹
25*10⁻⁹
30*10⁻⁹
35*10⁻⁹
40*10⁻⁹
5
6
7
8
nZr-0_BNL:Chi/dof9999.9%
nZr-0_e68:Chi/dof9999.9%
nZr-0_e70:Chi/dof9999.9%
nZr-0_j40:Chi/dof9999.9%
1973 Salama
1970 Malik
1961 Joki

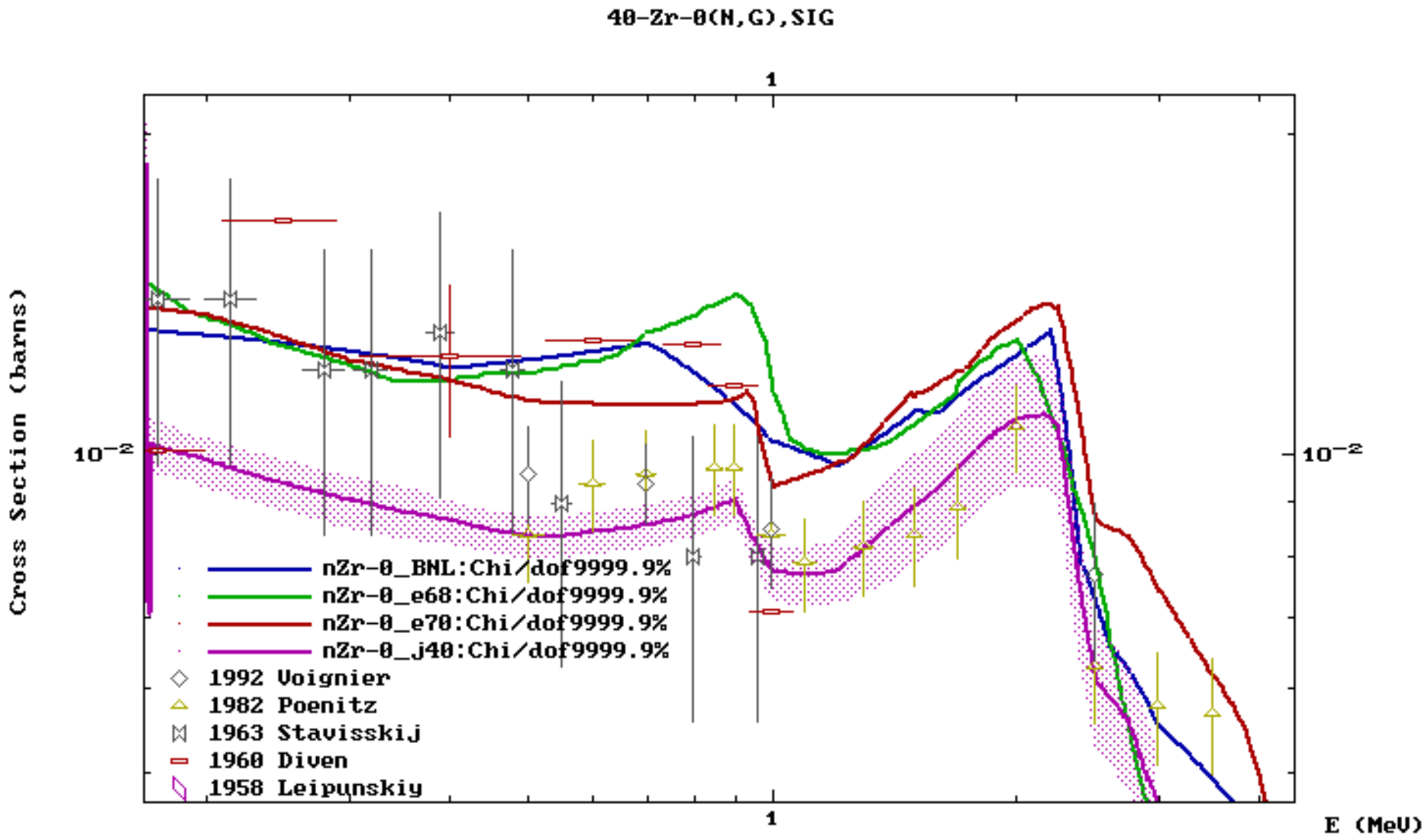

40-Zr-0(N,TOT),SIG
nZr-0_BNL:Chi/dof9999.9%
nZr-0_e68:Chi/dof9999.9%
nZr-0_e70:Chi/dof9999.9%
nZr-0_j40:Chi/dof9999.9%
1983 Filippov
1983 Poenitz
1973 Stooksberry
1973 Green
1973 Islam
1968 Filippov
1965 Seth
1956 Guernsey
1952 Miller
1949 Bockelman
Cross Section (barns)
E (MeV)
0.4
0.5
0.6
0.7
0.8
0.9
1.0
6
7
8
9
10
11

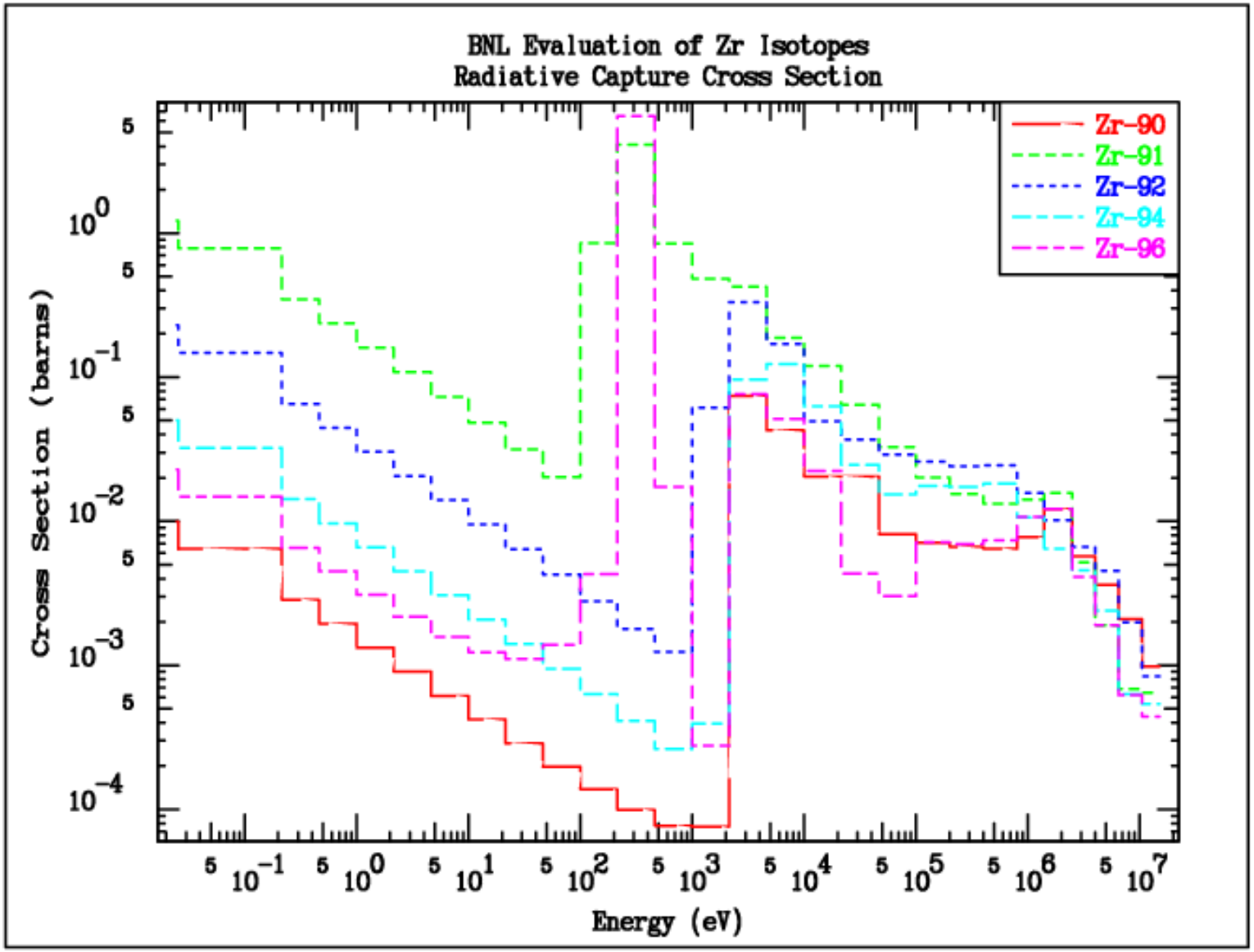

40-Zr-0(N,TOT),SIG
nZr-0_BNL:Chi/dof9999.9%
nZr-0_e68:Chi/dof9999.9%
nZr-0_e70:Chi/dof9999.9%
nZr-0_j40:Chi/dof9999.9%
1983 Poenitz
1983 Filippov
1973 Stooksberry
1971 Foster Jr
1967 Carlson
1962 Kent
1958 Bratenahl
1956 Guernsey
1955 Walt
1953 Nereson
1952 Miller
1949 Bockelman
Cross Section (barns)
E (MeV)
1
10
4
5
6
7

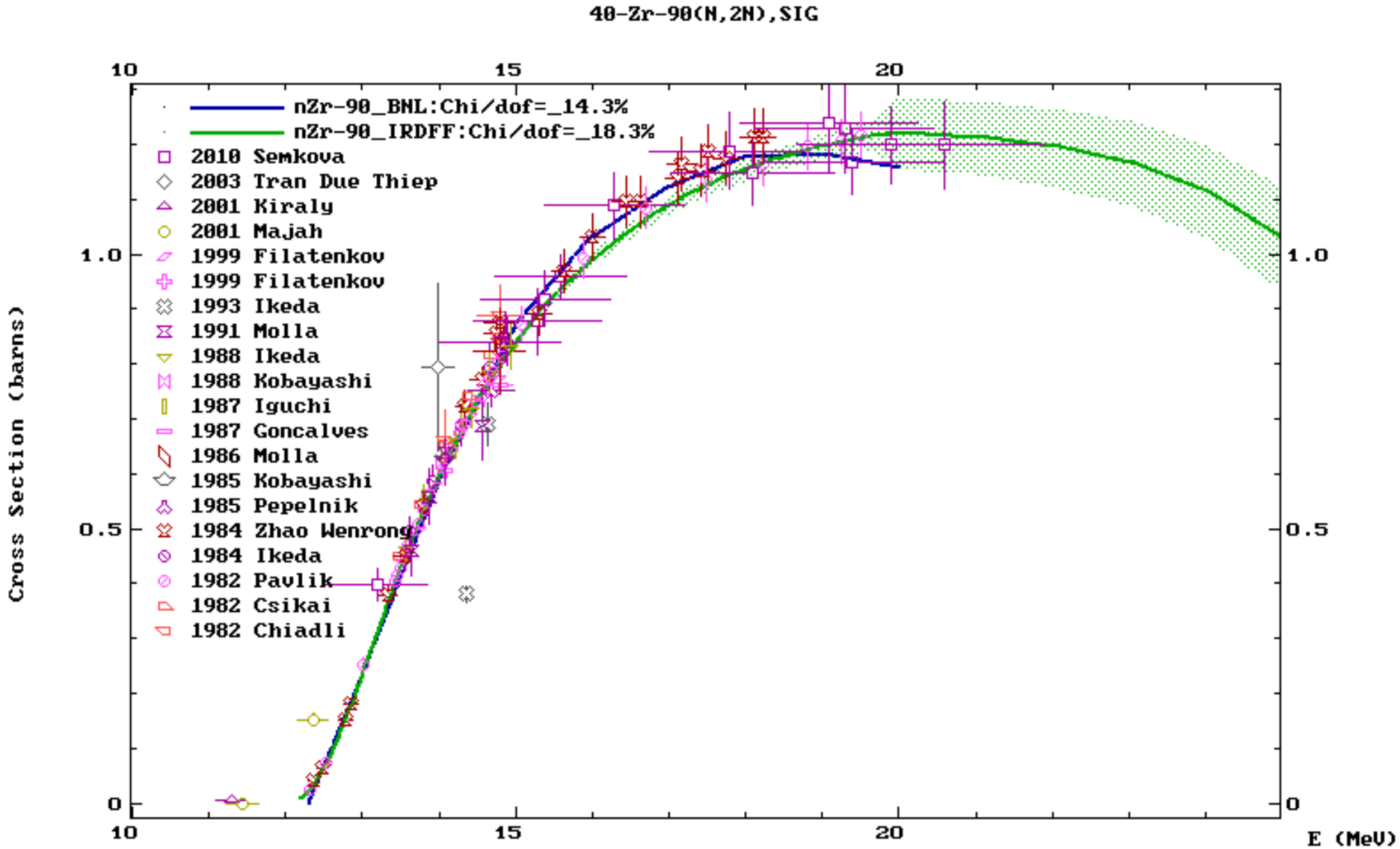

40-Zr-0(N,EL),SIG
nZr-0_BNL:Chi/dof=_28.
nZr-0_e68:Chi/dof=_31.
nZr-0_e70:Chi/dof=_31.
nZr-0_j40:Chi/dof=_30.
1992 Takahashi
1985 Zo-In-Ok
1972 Cox
1972 Korzh
1971 Korzh
1964 Korzh
1964 Pasechnik
1963 Reitmann
1963 Korzh
1962 Kent
1959 Bostrom
1957 Hans
1955 Walt
1954 Walt
Cross Section (barns)
E (MeV)
10⁻¹
1
10
5


40-Zr-0(N,INL),SIG
nZr-0_BNL:Chi/dof9999.9%
nZr-0_e68:Chi/dof9999.9%
nZr-0_e70:Chi/dof9999.9%
nZr-0_e71b3:Chi/dof9999.9%
nZr-0_j40:Chi/dof9999.9%
1963 Glazkov
Cross Section (barns)
E (MeV)
1
10
0
0.5
1.0
1.5
2.0


40-Zr-0(N,2N),SIG
nZr-0_BNL:Chi/dof9999.9%
nZr-0_e68:Chi/dof9999.9%
nZr-0_e70:Chi/dof9999.9%
nZr-0_e71b3:Chi/dof9999.9%
nZr-0_j40:Chi/dof9999.9%
2008 Shiken
1980 Frehaut
1958 Ashby
Cross Section (barns)
E (MeV)
0
0.5
1.0
10
15
20


40-Zr-0(N,G),SIG
1
10^{-2}
10^{-2}
1
Cross Section (barns)
E (MeV)
nZr-0_BNL:Chi/dof9999.9%
nZr-0_e68:Chi/dof9999.9%
nZr-0_e70:Chi/dof9999.9%
nZr-0_j40:Chi/dof9999.9%
1992 Voignier
1982 Poenitz
1963 Stavisskij
1960 Diven
1958 Leipunskiy


BNL Evaluation of Zr Isotopes
Radiative Capture Cross Section
Zr-90
Zr-91
Zr-92
Zr-94
Zr-96
Cross Section (barns)
Energy (eV)


40-Zr-90(N,2N),SIG
nZr-90_BNL:Chi/dof=_14.3%
nZr-90_IRDFF:Chi/dof=_18.3%
2010 Semkova
2003 Tran Due Thiep
2001 Kiraly
2001 Majah
1999 Filatenkov
1999 Filatenkov
1993 Ikeda
1991 Molla
1988 Ikeda
1988 Kobayashi
1987 Iguchi
1987 Goncalves
1986 Molla
1985 Kobayashi
1985 Pepelnik
1984 Zhao Wenrong
1984 Ikeda
1982 Pavlik
1982 Csikai
1982 Chiadli
Cross Section (barns)
E (MeV)
10
15
20
0
0.5
1.0