Assessment of nuclear reaction cross section data for the production of radionuclides for medical applications

IAEA-CRP- on Nuclear data for charged particle monitor reactions and medical isotope production

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Highlights of First meeting

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Summary Report

First Research Coordination Meeting on

Nuclear Data for Charged-particle Monitor Reactions and Medical Isotope Production

IAEA Headquarters
Vienna, Austria

3 – 7 December 2012

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Guildford, UK

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IAEA Nuclear Data Section
Vienna, Austria

Table 3: Positron emitters

Cross sections	Decay data	Agreed responsibilities, and actions
$^{55}Mn(p,4n)^{52}Fe$	–	ACTION: Lahore (assess)
$^{nat}Ni(p,x)^{52}Fe$		ACTION: Lahore (assess)
$^{52}Cr(^{3}He,3n)^{52}Fe$		ACTION: Lahore (assess)
$^{58}Ni(p,\alpha)^{55}Co$	–	ACTION: Lahore (assess)
$^{54}Fe(d,n)^{55}Co$		ACTION: Lahore (assess)
$^{56}Fe(p,2n)^{55}Co$		ACTION: Lahore (assess)
$^{nat}Fe(p,x)^{55}Co$		ACTION: Kim (measure); ACTION: Lahore (assess)
$^{61}Ni(p,n)^{61}Cu$	–	ACTION: Jülich (measure and assess)
$^{64}Zn(p,\alpha)^{61}Cu$		ACTION: Lebeda (measure and assess)
$^{66}Zn(p,n)^{66}Ga$	–	ACTION: Lahore (assess)
$^{63}Cu(\alpha,n)^{66}Ga$		ACTION: Lahore (assess)
$^{68}Zn(p,n)^{68}Ga$	–	ACTION: Jülich (measure and assess)
$^{65}Cu(\alpha,n)^{68}Ga$		ACTION: Jülich (assess)
$^{93}Nb(p,x)^{90}Nb$	–	ACTION: Kim (measure and assess)
$^{89}Y(\alpha,x)^{90}Nb$		ACTION: Kim (measure and assess)
$^{89}Y(\alpha,x)^{89}Zr$		ACTION: Kim (measure and assess)
$^{nat}Ge(p,xn)^{72}As$	–	ACTION: Jülich (measure); ACTION: Lahore (assess)

Table 3: Positron emitters (cont'd)

Cross sections	Decay data	Agreed responsibilities, and actions
$^{75}As(p,3n)^{73}Se$	–	ACTION: Lebeda (measure); ACTION: Lahore (assess)
$^{72}Ge(\alpha,3n)^{73}Se$		ACTION: Lahore (assess)
$^{76}Se(p,n)^{76}Br$	–	ACTION: Jülich (measure); ACTION: Lahore (assess)
$^{77}Se(p,2n)^{76}Br$		ACTION: Jülich (measure); ACTION: Lahore (assess)
$^{75}As(\alpha,3n)^{76}Br$		ACTION: Lahore (assess)
$^{86}Sr(p,n)^{86}Y$	–	ACTION: Lahore (assess)
$^{88}Sr(p,3n)^{86}Y$		ACTION: Lahore (assess)
$^{85}Rb(\alpha,3n)^{86}Y$		ACTION: Lahore (assess)
$^{89}Y(p,n)^{89}Zr$	–	ACTION: ITA (assess)
$^{89}Y(d,2n)^{89}Zr$		ACTION: Lebeda (measure and assess)
$^{94}Mo(p,n)^{94}Tc^{m}$	–	ACTION: ITA (assess)
$^{92}Mo(\alpha,x)^{94}Tc^{m}$		ACTION: ITA (assess)
$^{110}Cd(p,n)^{110}In^{m}$	–	ACTION: Debrecen / VUB (assess)
$^{120}Te(p,n)^{120}I$	–	ACTION: Lahore (assess)
$^{122}Te(p,3n)^{120}I$		ACTION: Lahore (assess)

Overview of the task

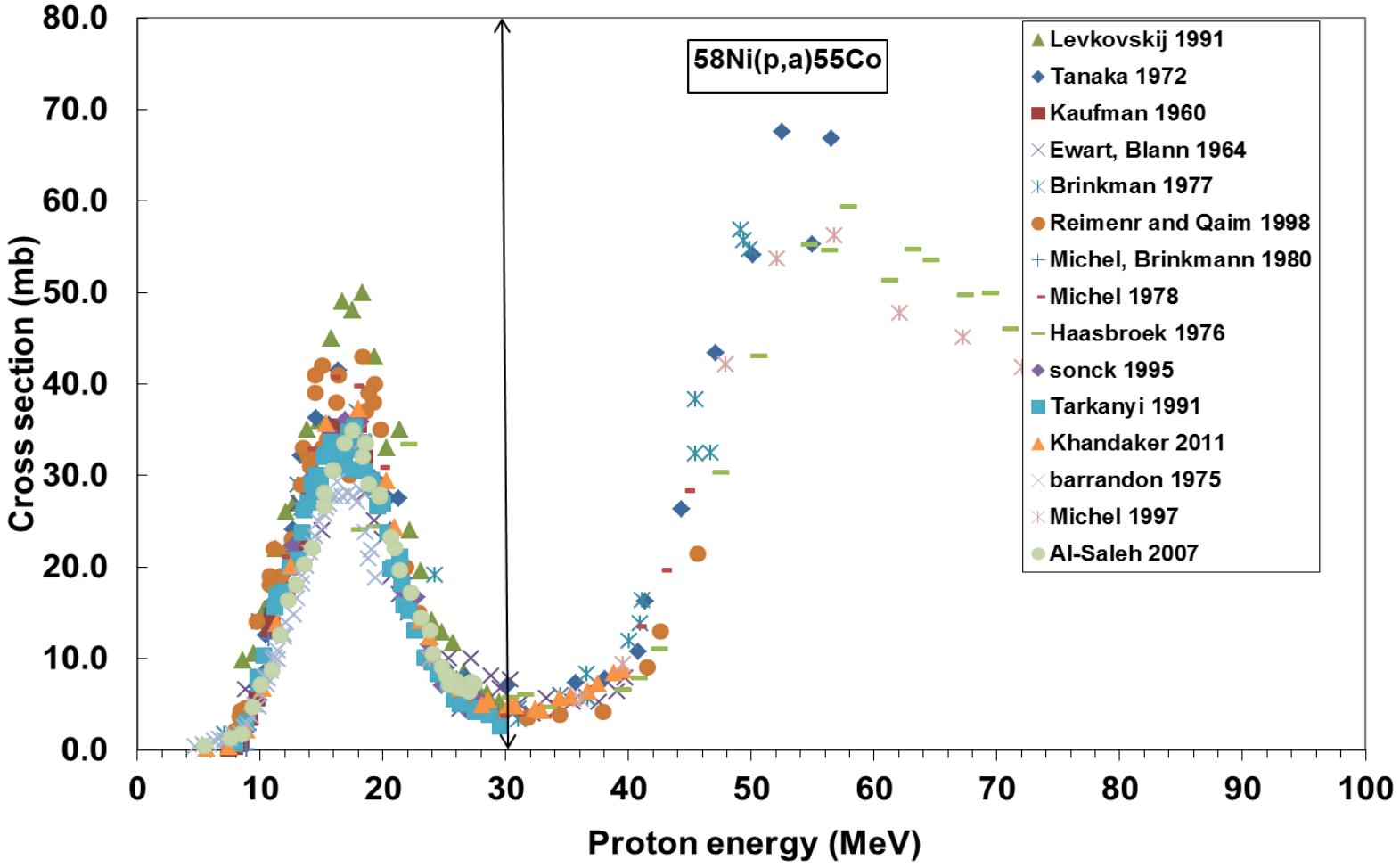
Assessment done

- ^{55}Co
- ^{66}Ga
- ^{72}As (deliverable)
- ^{73}Se (deliverable)
- ^{76}Br (Evaluation)
- ^{86}Y

Assessment in progress

- ^{52}Fe
- ^{120}I

^{55}Co from ^{58}Ni



Assessment

Author: V. N. Levkovskij
Title : Activation cross section nuclides of average masses (A=40-100)by protons and alpha-particles with average energies (E=10-50 MeV).
Refrence: Book: Levkovskij,Act.Cs.By Protons and Alphas,Moscow 1991 (1991) USSR
EXFOR: A0510061
Remarks: Normalized: By a factor of 0.8 on the baisi of difference in Monitor Reaction data.
Author: S. Tanak, M. Furukawa, M. Chiba
Title : Nuclear Reactions of Nickel with Protons Up to 56 MeV
Refrence: Journal of Inorganic and Nuclear Chemistry, Vol.34, p.2419 (1972) UK
EXFOR: B0020004
Remarks: Normalized by 1.065 on the basis of decay data
Author: S.Kaufman
Title : Reactions of Protons with Ni-58 and Ni-60.
Refrence: Physical Review, Vol.117, p.1532 (1960) USA
EXFOR: B0055005
Remarks: Normalized By a factor of 1.03 on the baisi of difference decay data.

Assessment continue-

Author: S. H.A.Ewart, M.Blann
Refrence: Private communication, Name.Ewart (1964)
EXFOR: C1012002
Remarks:
Author: G.A.Brinkman,J.Helmer,L.Lindner
Title : Nickel and copper fiols as monitors for cyclotron beam intensities
Refrence: Radiochemical and Radioanalytical Letters, Vol.28, p.9 (1977) Hungary
EXFOR: D0162012
Remarks: No normalization was done
Author: P.Reimer, S.M.Qaim
Title : Excitation function of proton induced reactions on highly enriched Ni-58 with special relevance to the production of Co-55 and Co-57
Refrence: Radiochimica Acta, Vol.80, p.113 (1998) Germany
EXFOR: D4078002
Remarks: No normalization was done
Author: R.MICHEL,G.BRINKMANN
Title : On the Depth-Dependent Production of Radionuclides ('A' BETWEEN 44 AND 59) By Solar Protons in Extraterrestial Matter.
Refrence: Journal of Radioanalytical Chemistry Vol.59, Issue.2, p.467 1980
EXFOR: A0145009
Remarks: No normalization was done
Author: R.Michel, H.Weigel, W.Herr
Title : Proton-Induced Reactions on Nickel with Energies Between 12 and 45 MeV.
Refrence: Zeitschrift fuer Physik A, Hadrons and Nuclei Vol.286, p.393
EXFOR: B0083005
Remarks: No normalization was done

Assessment continues

Author: M.Sonck,J.van Hoyweghen,A.Hermanne
Title : Determination of the external beam energy of a variable energy Multiparticle cyclotron
Refrence: Applied Radiation and Isotopes, Vol.47, p.445 (1996) UK
EXFOR: D0393002
Remarks: No normalization was done

Author: F.Tarkanyi,F.Szelecsenyi,P.Kopecky
Title : Excitation functions of proton induced nuclear reactions on natural nickel for monitoring beam energy and intensity
Refrence: Applied Radiation and Isotopes Vol.42, p.513 1991
EXFOR:D4002005
Remarks: No normalization was done

Author: M.U.Khandaker, K.S.Kim, M.W.Lee, K.S.Kim, G.N.Kim
Title : Excitation functions of (p,x) reactions on natural nickel up to 40 MeV
Refrence: Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.269, p.1140 (2011) Netherlands
EXFOR: D0162012
Remarks: No normalization was done

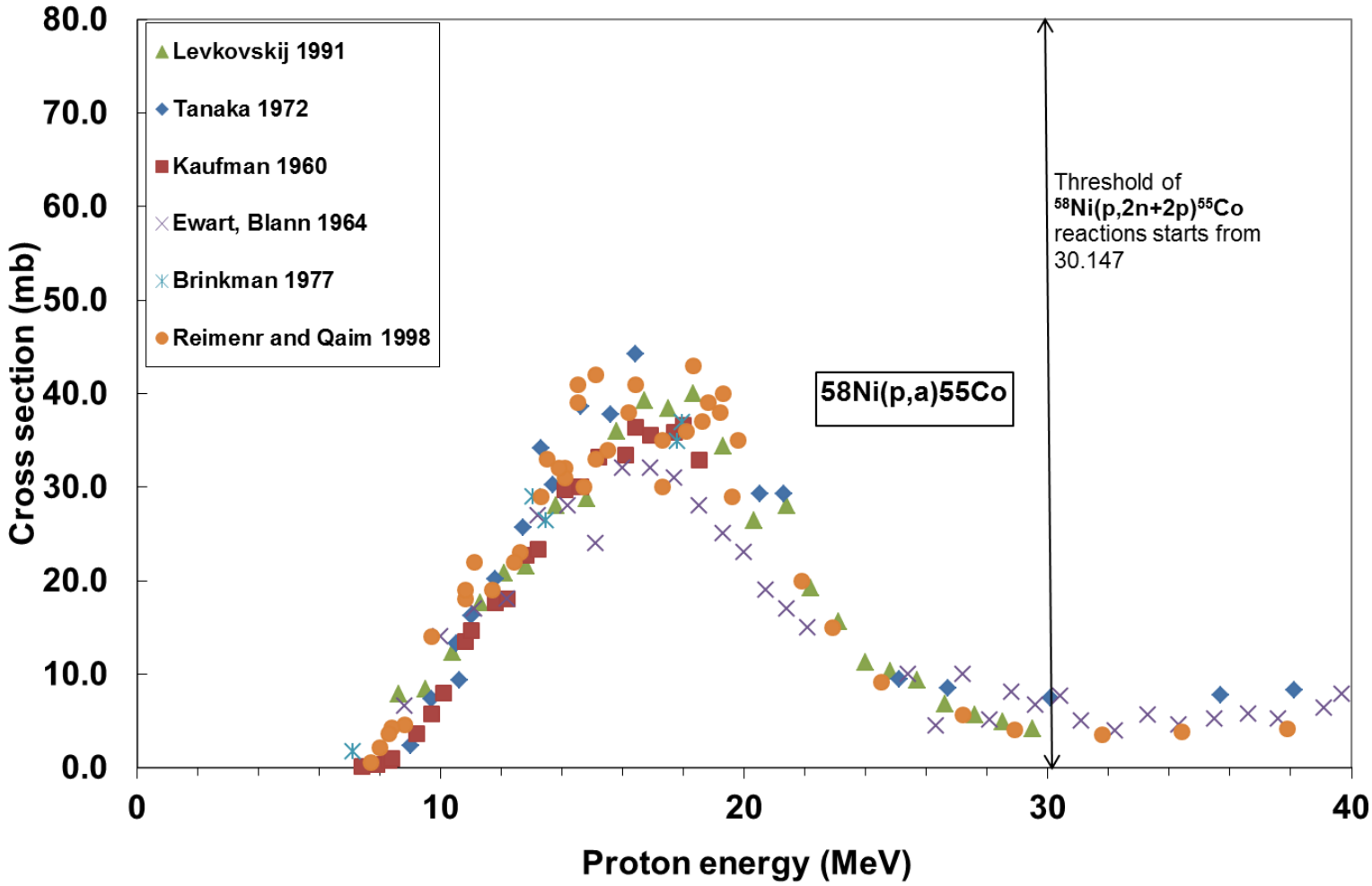
Author: J.N.Barrandon, J.L.Debrun, A.Kohn, R.H.Spear
Title : A Study of the Main Radioisotopes Obtained by Irradiation of Ti,V,Cr,Fe,Ni,Cu and Zn with Protons From 0 to 20 MeV.
Refrence: Nuclear Instrum.and Methods in Physics Res. Vol.127, p.269, 1975.
EXFOR: O0086009
Remarks: Normalized By a factor of 1.04 on the baisi of difference decay data.

Author: R.Michel, R.Bodemann, H.Busemann, R.Daunke, M.Gloris, H.-J.Lange, B.Klug, A.Krins, I.Leya, M.Luepke, S.Neumann, H.Reinhardt,
M.Schnatz-Buettgen, U.Herpers, Th.Schiekel, F.Sudbrock, B.Holmqvist, H.Conde, P.Malmborg, M.Suter, B.Dittrich-Hannen, P.-W.Kubik,
H.-A.Sinal, D.Filges.
Title : Cross sections for the production of residual nuclides by low- and medium-energy protons from the target elements
C, N, O, Mg, Al, Si, Ca, Ti, V, Mn, Fe, Co, Ni, Cu, Sr, Y, Zr, Nb, Ba and Au.
Refrence: Nucl. Instrum. Methods in Physics Res., Sect.B Vol.129, p.153, 1997.
EXFOR: O0276108
Remarks: No normalization was done

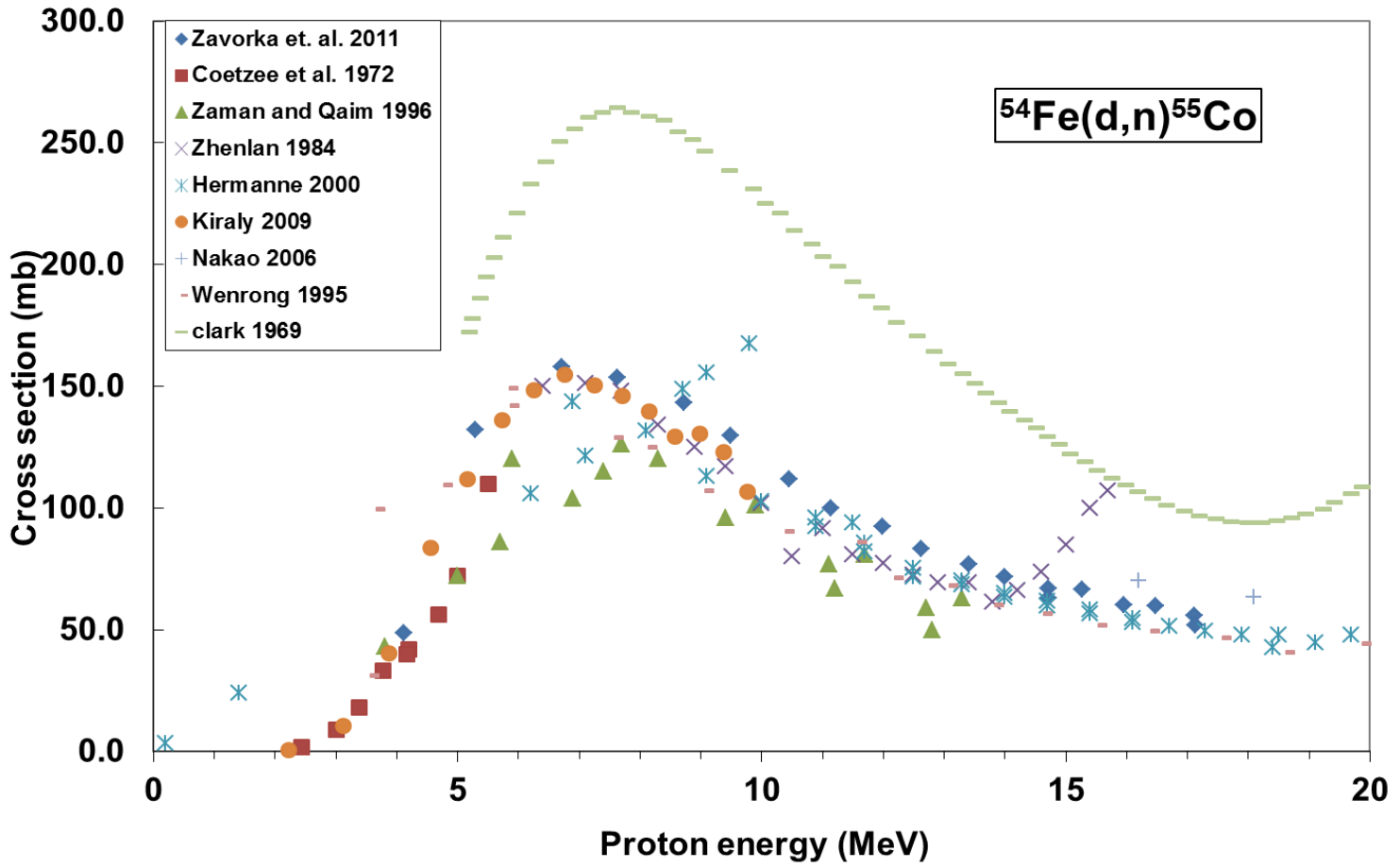
Author: F.S.Al-Saleh, K.S.AlMugren, A.Azzam
Title :Excitation functions of (p,x) reactions on natural nickel between proton energies of 2.7 and 27.5-MeV.
Refrence: Applied Radiation and Isotopes Vol.65, p.104, 2007.
EXFOR: O1503007
Remarks: No normalization was done

Author: G.A.Brinkman,J.Helmer,L.Lindner
Title : Nickel and copper fiols as monitors for cyclotron beam intensities
Refrence: Radiochemical and Radioanalytical Letters, Vol.28, p.9 (1977) Hungary
EXFOR: D0162012
Remarks: Haasbroek data is shifted toward the higher energies and this shift is increasing toward lower energies due to error propagation
Data was deselected

^{55}Co from ^{58}Ni



^{55}Co from ^{54}Fe



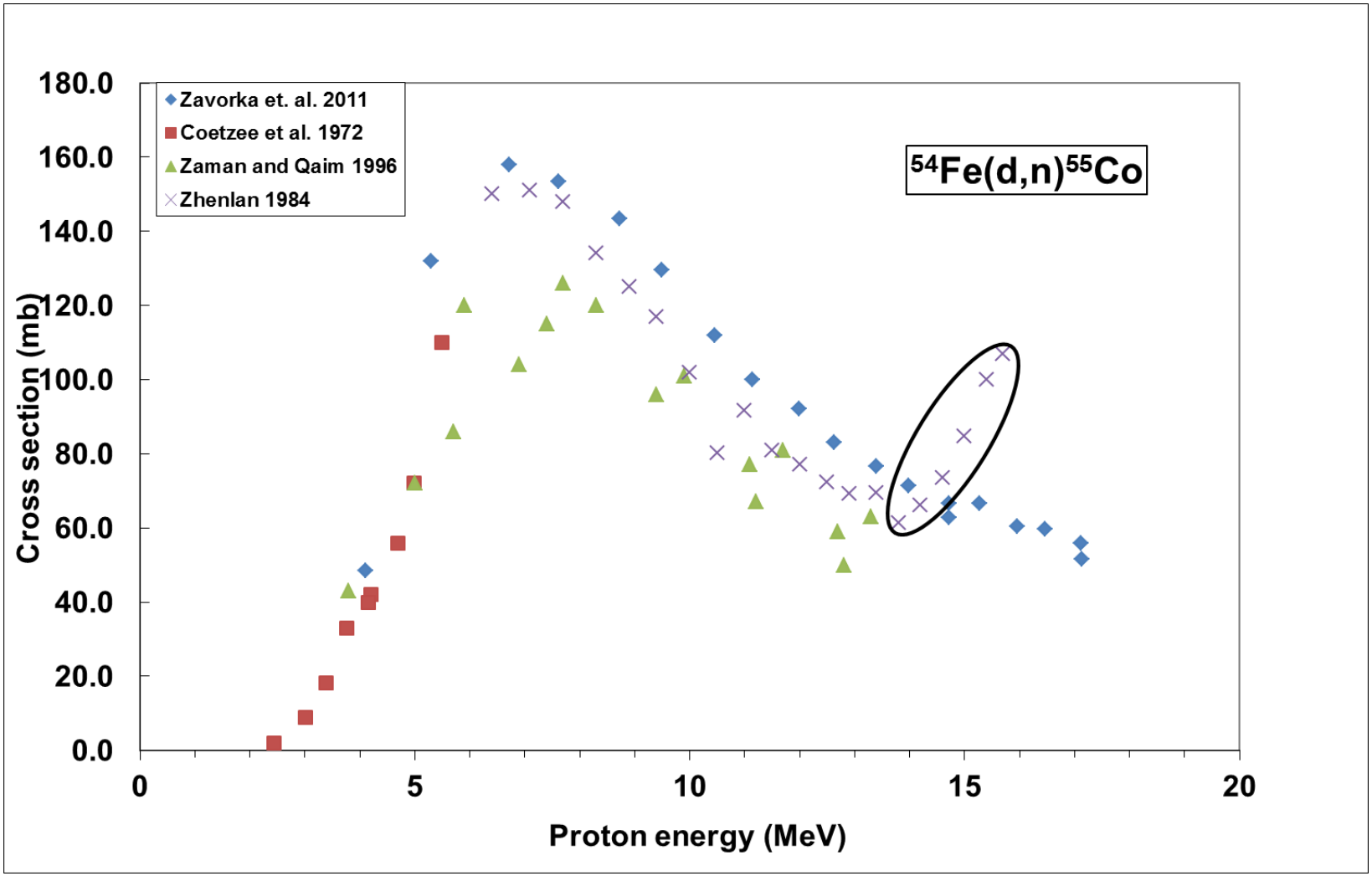
Assessment

Author: L.Zavorka, E.Simeckova, M.Honusek, K.Katovsky
Title : The Activation of Fe by Deuterons at Energies up to 20 MeV
Refrence: Journal of the Korean Physical Society Vol.59, p.1961, 2011.
EXFOR: D0672002
Remarks: No normalization was done
Author: M.R.Zaman, S.M.Qaim
Title : Nuclear Reactions of Nickel with Protons Up to 56 MeV
Refrence: Journal of Inorganic and Nuclear Chemistry, Vol.34, p.2419 (1972) UK
EXFOR: B0020004
Remarks: No normalization was done
Author: P.P.Coetzee, M.Peisach
Title : Activation cross sections for deuteron-induced reactions on some elements of the first transition series, up to 5.5 I
Refrence: Radiochimica Acta, Vol.17, p.1 (1972) Germany
EXFOR: B0055005
Remarks: Normalized: By a factor of 1.04 on the baisi of difference decay data.
Author: Tao Zhenlan,Zhu Fuying,Qiu Huiyuan,Wang Gongoing
Title : Excitation function of deuteron induced reactions on natural iron
Refrence: Atomic Energy Science and Technology, Vol.18, p.506 (1984) China
EXFOR: C1012002
Remarks:
Author: A.HERMANNE, M.SONCK, S.TAKACS, F.TARKANYI
Title : Experimental study of excitation function for some reactions induced by deuteron (10-50 MEV) on natural
Refrence: Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.161-163, p.178 (2000) Netherlands
EXFOR: D0162012
Remarks: No normalization was done
Author: B.Kiraly, S.Takacs, F.Ditroi, F.Tarkanyi, A.Hermanne
Title : Evaluated activation cross sections of longer-lived radionuclides produced by deuteron induced reactions
Refrence: Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.267, p.15 (2009) Netherlands
EXFOR: D4078002
Remarks: No normalization was done

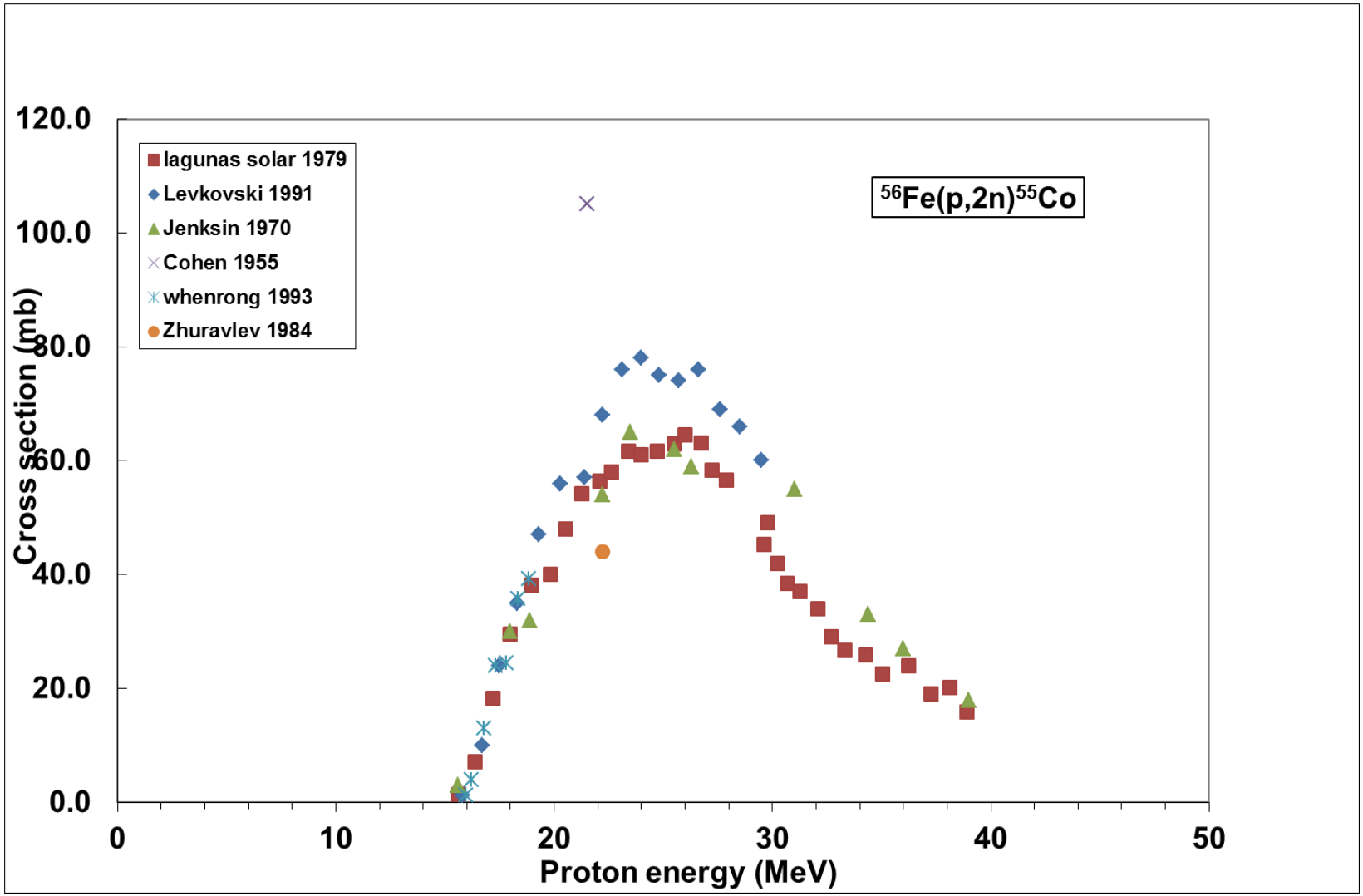
Assessment continue-

Author: M.Nakao, J.Hori, K.Ochiai, N.Kubota, S.Sato, M.Yamauchi, N.S.Ishioka, T.Nishitani
Title : Measurements of deuteron-induced activation cross-sections for IFMIF accelerator structural materials
Refrence: Nucl. Instrum. Methods in Physics Res., Sect.A Vol.562, Issue.2, p.785, 2006
EXFOR: E1988004
Remarks: No normalization was done
Author: ZhaoWenrong, LuHanlin, YuWeixiang, ChengJiantao
Title : Excitation functions for reactions induced by deuteron in iron
Refrence: Chinese J.of Nuclear Physics (Beijing). Vol.17, Issue.2, p.163 1995
EXFOR: S0044002
Remarks: No normalization was done
Author: J.W.Clark, C.B.Fulmer, I.R.Williams
Title : Excitation function for radioactive nuclides produced by deuteron-induced reactions in iron
Refrence: Physical Review Vol.179, p.1104, 1969
EXFOR: T0199007
Remarks: Data was deselected (not consistant even after normlization on the basis of decay data.)

^{55}Co from ^{54}Fe



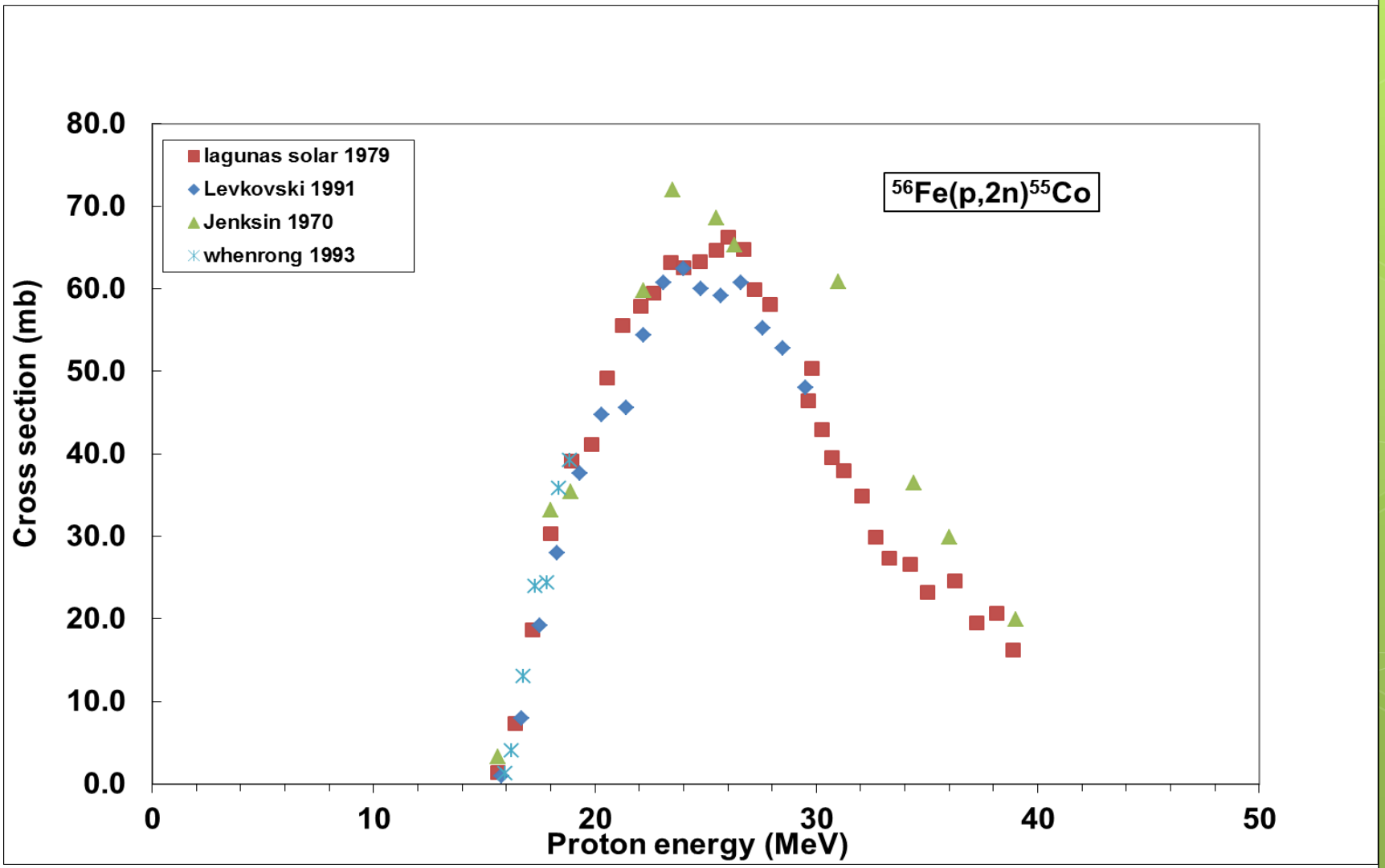
^{55}Co from ^{56}Fe



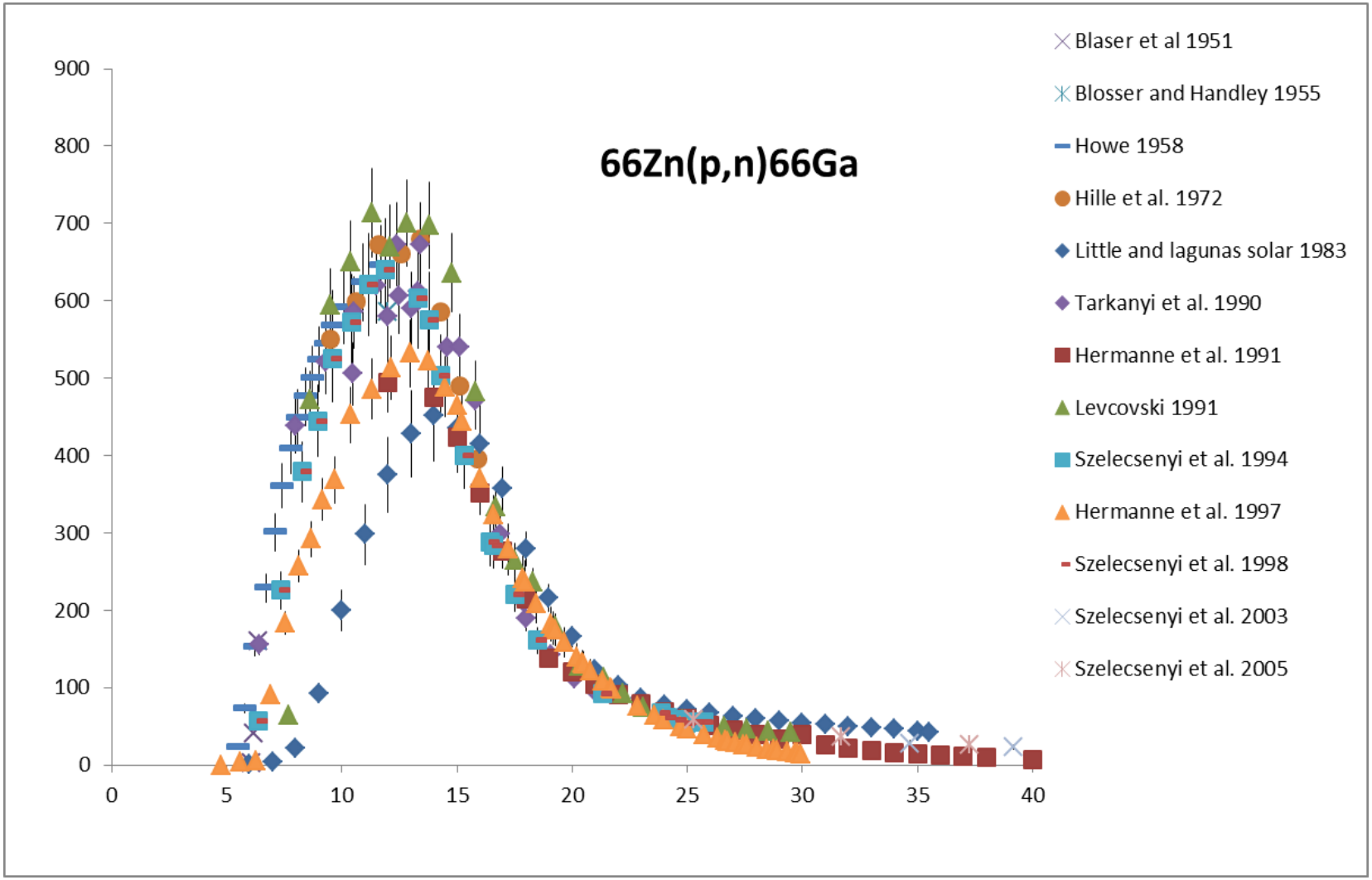
Assessment

Author: V. N. Levkovskij
Title : Activation cross section nuclides of average masses (A=40-100)by protons and alpha-particles with average energies (E=10-50 MeV).
Refrence: Book: Levkovskij,Act.Cs.By Protons and Alphas,Moscow 1991 (1991) USSR
EXFOR: A0510047
Remarks: Normalized: By a factor of 0.8 on the baisi of difference in Monitor Reaction data.
Author: ZhaoWenrong, LuHanlin, YuWeixiang
Title : Measurement of cross sections by bombarding Fe with protons up to 19 MeV
Refrence: Chinese J.of Nuclear Physics (Beijing). Vol.15, Issue.4, p.337, 1993
EXFOR: S0041003
Remarks: No normalization was done
Author: B.V.Zhuravlev, O.V.Grusha, S.P.Ivanova, V.I.Trykova, Yu.N.Shubin
Title : Analysis of neutron spectre in 22-MeV proton interactions with nuclei.
Refrence: Yadernaya Fizika Vol.39, p.264, 1984
EXFOR: A0271004
Remarks: Data was deselected Single point not consistant with other reported experimants
Author: I.L.Jenkins, A.G.Wain
Title : Excitation Functions For the Bombardment of Fe-56 With Protons
Refrence: Journal of Inorganic and Nuclear Chemistry Vol.32, p.1419, 1970
EXFOR: B0041004
Remarks: Normalized: By a factor of 1.107 on the baisi of difference in Decay data.
Author: B.L.Cohen, E.Newman
Title : (P,PN) And (P,2N) Cross Sections in Medium Weight Elements.
Refrence: Physical Review Vol.99, p.718, 1955
EXFOR: B0050006
Remarks: Data was deselected Single point not consistant with other reported experimants
Author: M.C.Lagunas-Solar, J.A.Jungerman
Title : CYCLOTRON PRODUCTION OF CARRIER-FREE COBALT-55.A NEW POSITRON-EMITTING LABEL FOR BLEOMYCIN
Refrence: Applied Radiation and Isotopes Vol.30, p.25, 1979
EXFOR: A0182004
Remarks: Normalized: By a factor of 1.055 on the baisi of difference in Decay data.

^{55}Co from ^{56}Fe



^{66}Ga from ^{66}Zn



Assessment

Author: J.P.Blaser, F.Boehm, P.Marmier, D.C.Peaslee
Title : Fonctions D'Excitation De La Reaction (P,N). I
Refrence: Jour: Helvetica Physica Acta, Vol.24, p.3 (1951), Switzerland
EXFOR: B0048004
Remarks: No normalization was done
Author: H.G.Blosser, T.H.Handley
Title : Survey of (P,N) Reactions at 12 MeV
Refrence: Physical Review, Vol.100, p.1340 (1955), USA
EXFOR: B0052007
Remarks: Normalized: By a factor of 1.09 on the baisi of difference decay data.
Author: H.A.Howe
Title : (P,N) Cross Sections of Copper and Zinc.
Refrence: Physical Review, Vol.109, p.2083 (1958), USA
EXFOR: B0060004
Remarks: Normalized: By a factor of 1.07 on the baisi of difference decay data.
Author: M.Hille, P.Hille, M.Uhl, W.Weisz
Title : Excitation Functions of (P,N) And (A,N) Reactions on Ni, Cu and Zn
Refrence: Nuclear Physics, Section A, Vol.198, p.625 (1972), Netherlands
EXFOR: B0058003
Remarks: Normalized: By a factor of 1.03 on the baisi of difference decay data.
Author: F.E.Little, M.C.Lagunas-Solar
Title : Cyclotron production of Ga-67. Cross sections and thick-target yields for the Zn-67(p,n) and Zn-68(p,2n) reactions.
Refrence: Applied Radiation and Isotopes, Vol.34, p.631 (1983), UK
EXFOR: A0321004
Remarks: Data were deselected due to significant energy shift
Author: F.Tarkanyi, F.Szelecsenyi, Z.Kovacs, S.Sudar
Title : Excitation functions of proton induced nuclear reactions on enriched 66Zn, 67Zn and 68Zn production of 67Ga and 66Ga.
Refrence: Radiochimica Acta, Vol.50, p.19 (1990), Germany
EXFOR: D4004001
Remarks: No normalization was done

Assessment continue-

Author: V.N.Levkovskij
Title : Activation cross section nuclides of average masses (A=40-100)by protons and alpha-particles with average energies (E=10-50 MeV).
Refrence: Levkovskij,Act.Cs.By Protons and Alphas,Moscow 1991, (1991), USSR
EXFOR: A0510087
Remarks: No normalization was done

Author: A.Hermanne, N.Walravens, O.Cicchelli
Title : Optimization of isotope production by cross section determination.
Refrence: Conf.on Nucl.Data for Sci.and Technol.,Juelich 1991, p.616 (1991), Germany
EXFOR: A0494004
Remarks: No normalization was done

Author: F.Szelecsenyi, T.E.Boothe, E.Tavano, M.E.Plitnikas, Y.Feijoo, S.Takacs, F.Tarkanyi, Z.Szucs
Title : New cross section data for 66-67-68 Zn+p reactions up to 26 MeV
Refrence: Conf.on Nucl.Data for Sci.and Techn.,Gatlinburg 1994, p.393 (1994), USA
EXFOR: D4025002
Remarks: No normalization was done

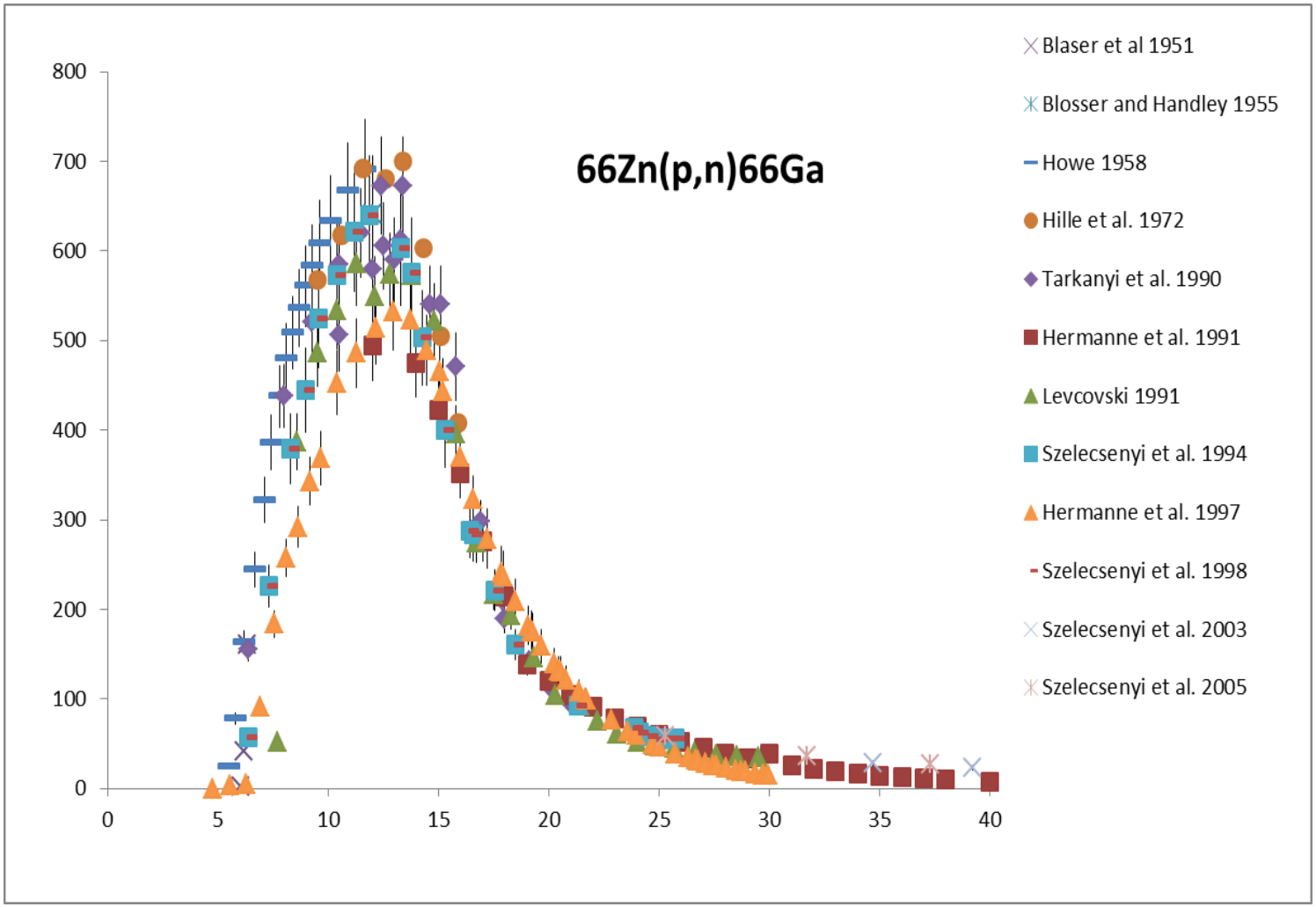
Author: A.Hermanne
Title : Evaluated cross section and thick target yield data of Zn+P processes for practical applications
Refrence: Priv.Comm: Hermanne (1997)
EXFOR: D4093004
Remarks: No normalization was done

Author: F.Szelecsenyi, T.E.Boothe, S.Takacs, F.Tarkanyi, E.Tavano
Title : Evaluated cross section and thick target yield data bases of Zn+p processes for practical applications
Refrence: Applied Radiation and Isotopes, Vol.49, p.1005 (1998), UK
EXFOR: C0506003
Remarks: No normalization was done

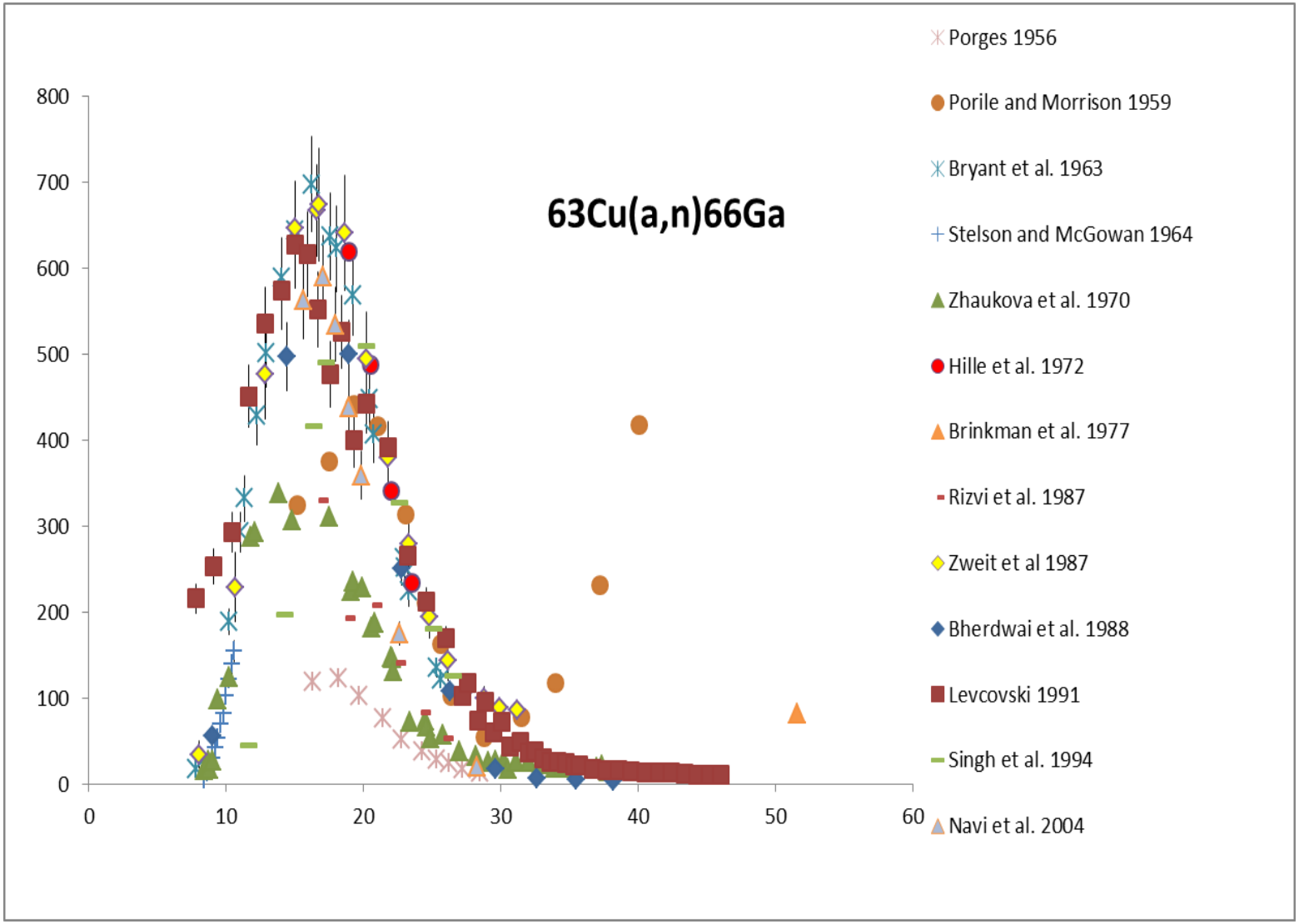
Author: F.Szelecsenyi, K.Suzuki, Z.Kovacs, M.Takei, K.Okada
Title : Investigation of the natZn(p,x)62Zn nuclear process up to 70 MeV: a new 62Zn/62Cu generator
Refrence: Applied Radiation and Isotopes, Vol.58, p.377 (2003), UK
EXFOR: D4117003
Remarks: No normalization was done

Author: F.Szelecsenyi, G.F.Steyn, Z.Kovacs, T.N.van der Walt, K.Suzuki, K.Okada, K.Mukai
Title : New cross-section data for the 66Zn(p,n)66Ga, 68Zn(p,3n)66Ga, natZn(p,x)66Ga, 68Zn(p,2n)67Ga and natZn(p,x)67Ga nuclear reactions up to 100 MeV
Refrence: Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.234, Issue.4, p.375 (2005), Netherlands
EXFOR: E1935003
Remarks: No normalization was done

^{66}Ga from ^{66}Zn



^{66}Ga from ^{63}Cu



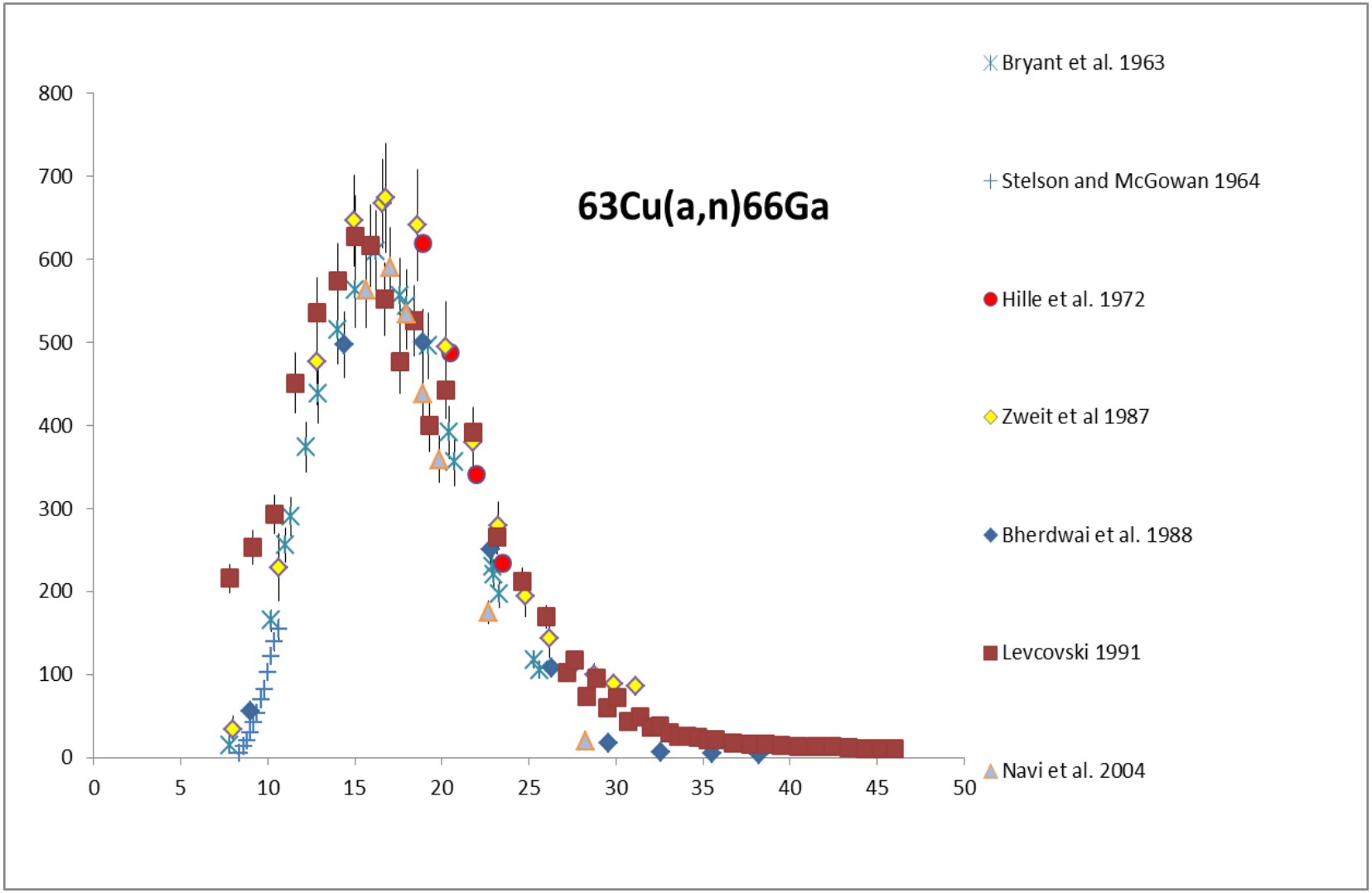
Assessment

Author: K.G.Porges
Title : Alpha excitation functions of silver and copper
Refrence: Jour: Physical Review, Vol.101, Issue.1, p.225 (1956), USA
EXFOR: R0039004
Remarks: Data were deselected; very Inconsistent results
Author: N.T.Porile, D.L.Morrison
Title : Reactions of Cu-63 and Cu-65 with Alpha Particles.
Refrence: Physical Review, Vol.116, p.1193 (1959), USA
EXFOR: B0156002
Remarks: Data were deselected due to significant energy shift
Author: E.A.Bryant, D.R.F.Cochran, J.D.Knight
Title : Excitation functions of reactions of 7 to 24 MeV He-3 ions with Cu-63 and Cu-65
Refrence: Physical Review, Vol.130, p.1512 (1963), USA
EXFOR: B0079016
Remarks: Normalized: By a factor of 0.874 on the baisi of difference decay data.
Author: P.H.Stelson, F.K.Mcgowan
Title : Cross sections for (alpha,n) reactions for medium weight nuclei.
Refrence: Physical Review, Vol.133, p.B911 (1964), USA
EXFOR: C0185013
Remarks: No normalization was done
Author: O.A.Zhukova, V.I.Kanashevich, S.V.Laptev, G.P.Chursin
Title : Excitation functions of reactions induced by alpha particles with maximum energy of 38 MeV on copper isotopes.
Refrence: Izvestiya Akademii Nauk KazSSSR,Ser.Fiz.-Mat., Vol.1970, Issue.4, p.1 (1970), Kazakhstan
EXFOR: A0647002
Remarks: Data were deselected; very Inconsistent results with significant energy shift
Author: M.Hille, P.Hille, M.Uhl, W.Weisz
Title : Excitation Functions of (P,N) And (A,N) Reactions On Ni, Cu and Zn
Refrence: Nuclear Physics, Section A, Vol.198, p.625 (1972), Netherlands
EXFOR: B0058006
Remarks: No normalization was done
Author: G.A.Brinkman, J.Helmer, L.Lindner
Title : Nickel and copper fiols as monitors for cyclotron beam intensities
Refrence: Radiochemical and Radioanalytical Letters, Vol.28, p.9 (1977), Hungary
EXFOR: D0162009
Remarks: Data were deselected; Inconsistent and also away from the interested region of the reaction

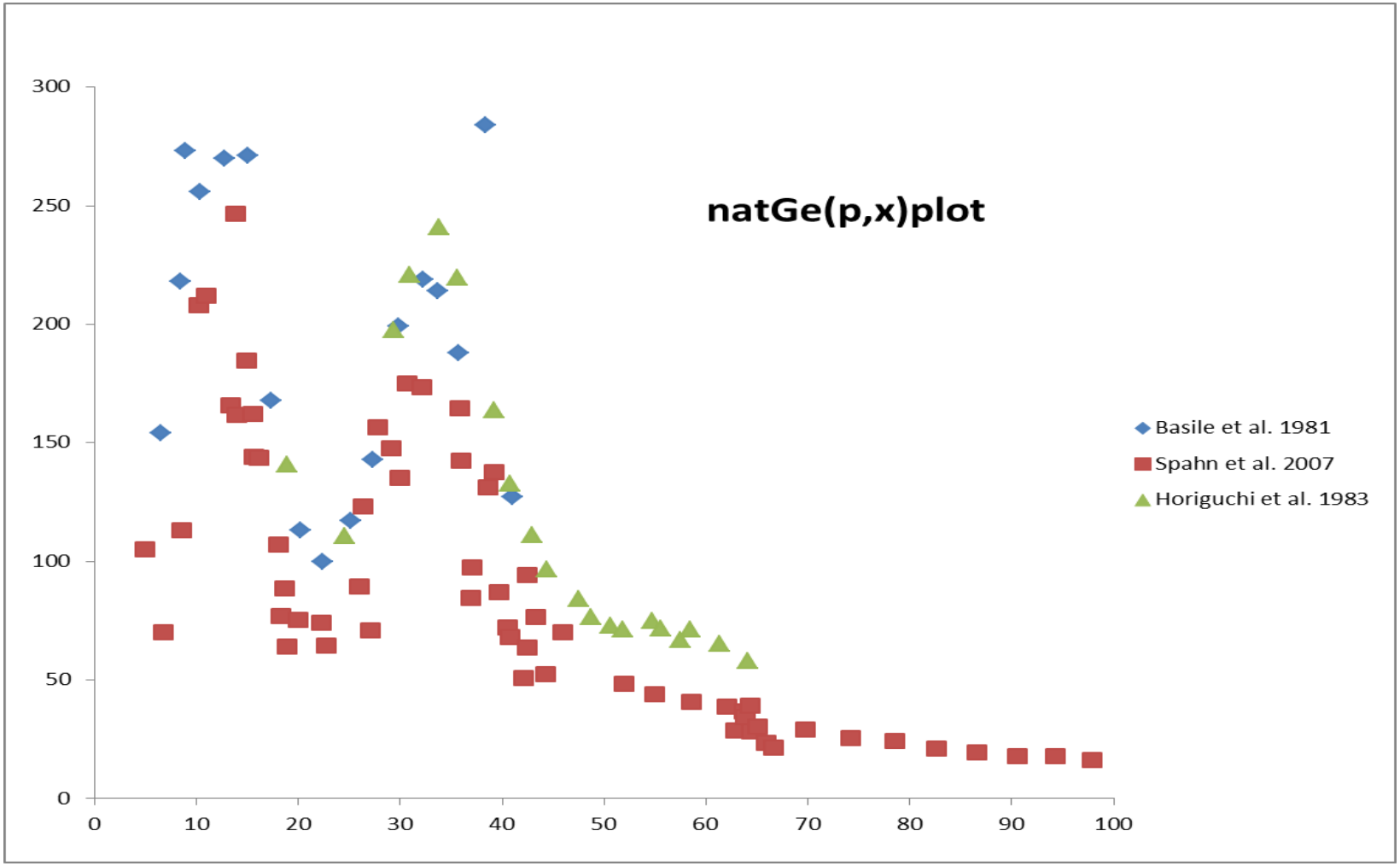
Assessment continues-

Author: I.A.Rizvi, M.Afzal Ansari, R.P.Gautam, R.K.Y.Singh, A.K.Chaubey
Title : Excitation function studies of (a,xpyn) reactions for 63,65Cu and pre-equilibrium effect
Refrence: Journal of the Physical Society of Japan, Vol.56, p.3135 (1987), Japan
EXFOR: D0090002
Remarks: Data were deselected; very Inconsistent results with significant energy shift
Author: J.Zweit, H.Sharma, S.Downey
Title : Production of Gallium-66, a short-lived, position emitting radionuclide
Refrence: Applied Radiation and Isotopes, Vol.38, p.499 (1987), UK
EXFOR: D0119002
Remarks: No normalization was done
Author: H.D.Bhardwaj, A.K.Gautam, R.Prasad
Title : Measurement and Analysis of Excitation Functions For Alpha-Induced Reactions in Copper.
Refrence: Jour: Pramana, Vol.31, p.109 (1988), India
EXFOR: A0465002
Remarks: No normalization was done
Author: V.N.Levkovskij
Title : Activation cross section nuclides of average masses (A=40-100)by protons and alpha-particles with average energies (E=10-50 MeV).
Refrence: Levkovskij,Act.Cs.By Protons and Alphas,Moscow 1991, (1991), USSR
EXFOR: A0510368
Remarks: No normalization was done
Author: N.L.Singh, B.J.Patel, D.R.S.Somayajulu, S.N.Chintalapudi
Title : Analysis of the excitation functions of (a,xnyp) reactions on natural copper
Refrence: Pramana, Vol.42, p.349 (1994), India
EXFOR: D0099004
Remarks: Data were deselected; Inconsistent results with significant energy shift
Author: A.Navin, V.Tripathi, Y.Blumenfeld, V.Nanal, C.Simenel, J.M.Casandjian, G.de France, R.Raabe, D.Bazin, A.Chatterjee, M.Dasgupta S.Kailas, R.C.Lemmon, K.Mahata, R.G.Pillay, E.C.Pollacco, K.Ramachandran, M.Rejmund, A.Shrivastava, J.L.Sida, E.Tryggestad
Title : Direct and compound reactions induced by unstable helium beams near the Coulomb barrier
Refrence: Physical Review, Part C, Nuclear Physics, Vol.70, Issue.4, p.044601 (2004), USA
EXFOR: D6021018
Remarks: No normalization was done

^{66}Ga from ^{63}Cu



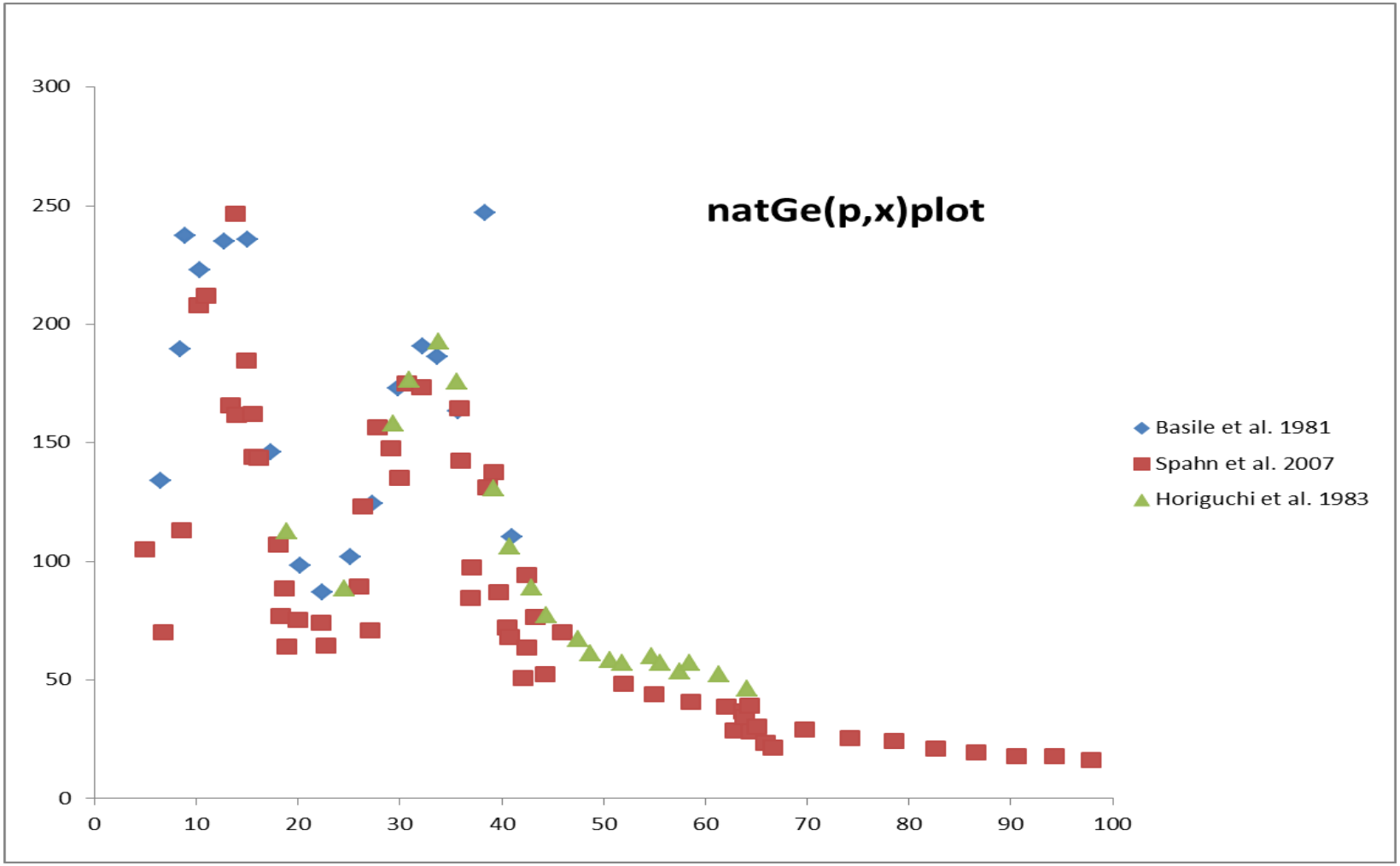
^{72}As from natGe



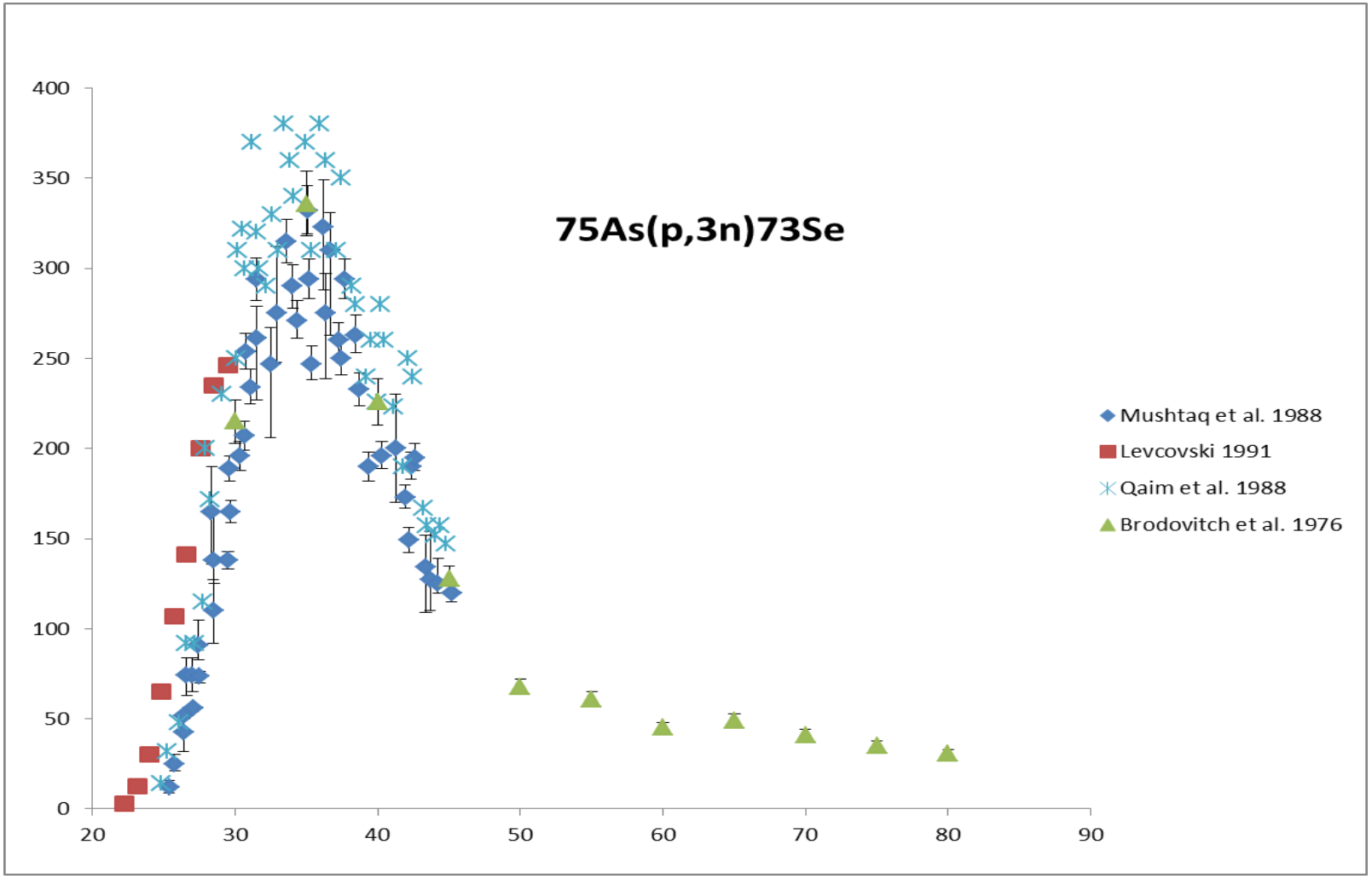
Assessment

Author: D.Basile, C.Birattari, M.Bonardi, L.Goetz, E.Sabbioni, A.Salomone
Title : Excitation Functions and Production of Arsenic Radioisotopes for Environmental Toxicology and Biomedical Purposes
Refrence: Applied Radiation and Isotopes, Vol.32, p.403 (1981), UK
EXFOR: A0190001
Remarks: Normalized by a factor of 0.87 due to the difference of decay data.
Author: T.Horiguchi, H.Kumahora, H.Inoue, Y.Yoshizawa
Title : Excitation Functions of Ge(p,xnyp) Reactions and Production of 68Ge
Refrence: Applied Radiation and Isotopes, Vol.34, Issue.11, p.1531 (1983), UK
EXFOR: E1968001
Remarks: Normalized by a factor of 0.80 on the baisi of difference in monitor reaction data.
Author: I.Spahn, G.F.Steyn, S.A.Kandil, H.H.Coenen, S.M.Qaim
Title :New nuclear data for production of 73As, 88Y and 153Sm: important radionuclides for environmental and medical applications
Refrence: Applied Radiation and Isotopes, Vol.65, p.1057 (2007), UK
EXFOR: D0454001
Remarks: No Normalized was done.

^{72}As from natGe



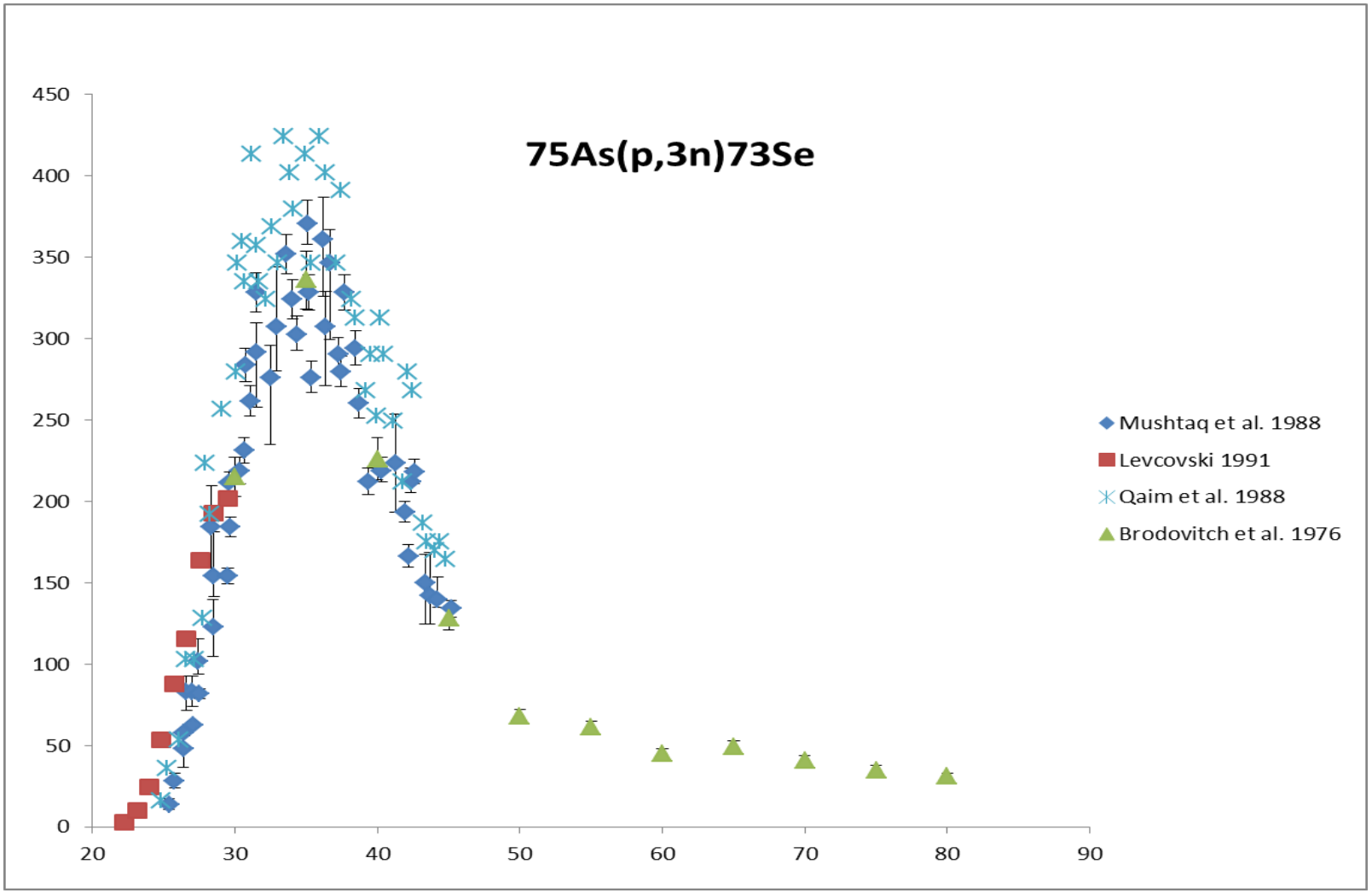
^{73}Se from ^{75}As



Assessment

Author: J.C.Brodovitch, J.J.Hogan, K.I.Burns
Title : The pre-equilibrium statistical model: comparison of calculation with two (p,xn) reactions
Refrence: Jour: Journal of Inorganic and Nuclear Chemistry Vol.38, p.1581 (1976).
EXFOR: C2016003
Remarks: No normalization was done
Author: A.Mushtaq, S.M.Qaim, G.Stocklin
Title : Production of 73Se via (p,3n) and (d,4n) Reactions on Arsenic
Refrence: Applied Radiation and Isotopes, Vol.39, p.1085 (1988), UK
EXFOR: A0467001
Remarks: Normalized by a factor of 1.117 on the baisi of difference in monitor reaction data.
Author: S.M.Qaim, A.Mustaq, M.Uhl
Title : Isomeric Cross-Section Ratio for the Formation of 73m,gSe in Various Nuclear Processes
Refrence: Physical Review, Vol.130, p.1512 (1963), USA
EXFOR: O1041001
Remarks: Normalized by a factor of 1.117 on the baisi of difference in monitor reaction data.
Author: V.N.Levkovskij
Title : Activation cross section nuclides of average masses (A=40-100)by protons and alpha-particles with average energies (E=10-50 MeV).
Refrence: Levkovskij,Act.Cs.By Protons and Alphas,Moscow 1991, (1991), USSR
EXFOR: A0510001
Remarks: Normalized by a factor of 0.82 on the baisi of difference in monitor reaction data.

^{73}Se from ^{75}As



Evaluation of ^{76}Br

- ^{77}Se(p,2n)^{76}Br
- ^{76}Se(p,n)^{76}Br
- ^{75}As(a,3n)^{76}Br

- M.N. Aslam, S. Sudár, **M. Hussain,** A.A. Malik, S.M. Qaim, **Evaluation of excitation functions of proton, ^{3}He and a-particle induced reactions for production of the medically interesting positron emitter bromine-76.** **(**Applied Radiation and Isotopes, **69**, 1490-1505, 2011).

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