IAEA 60 Years
Atoms for Peace and Development

Nuclear Data for Ion Beam Analysis Applications

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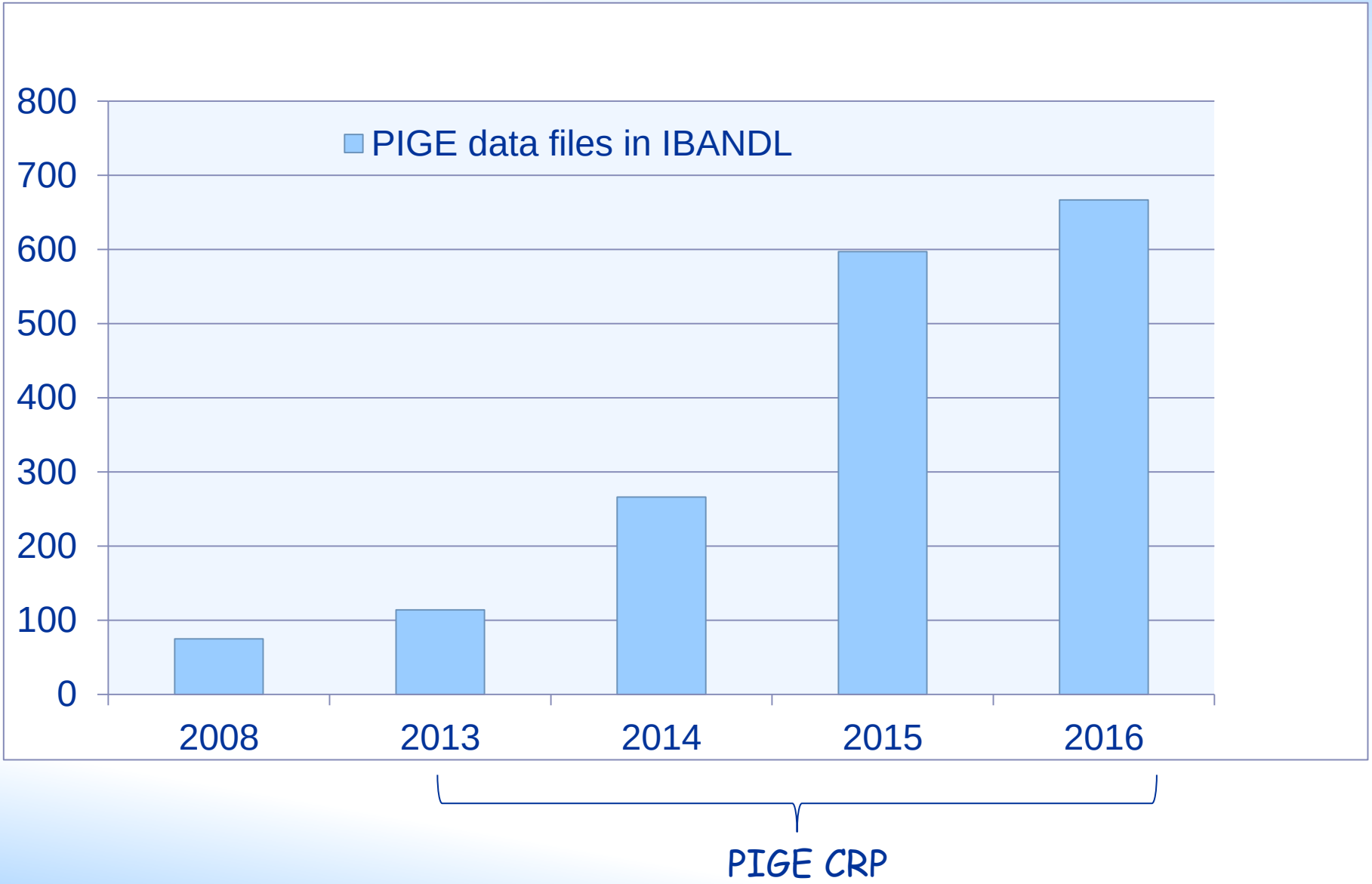
Outline

- History
- Results from last CRP on PIGE
- Status of IBANDL – new features
- Recent efforts
- Future

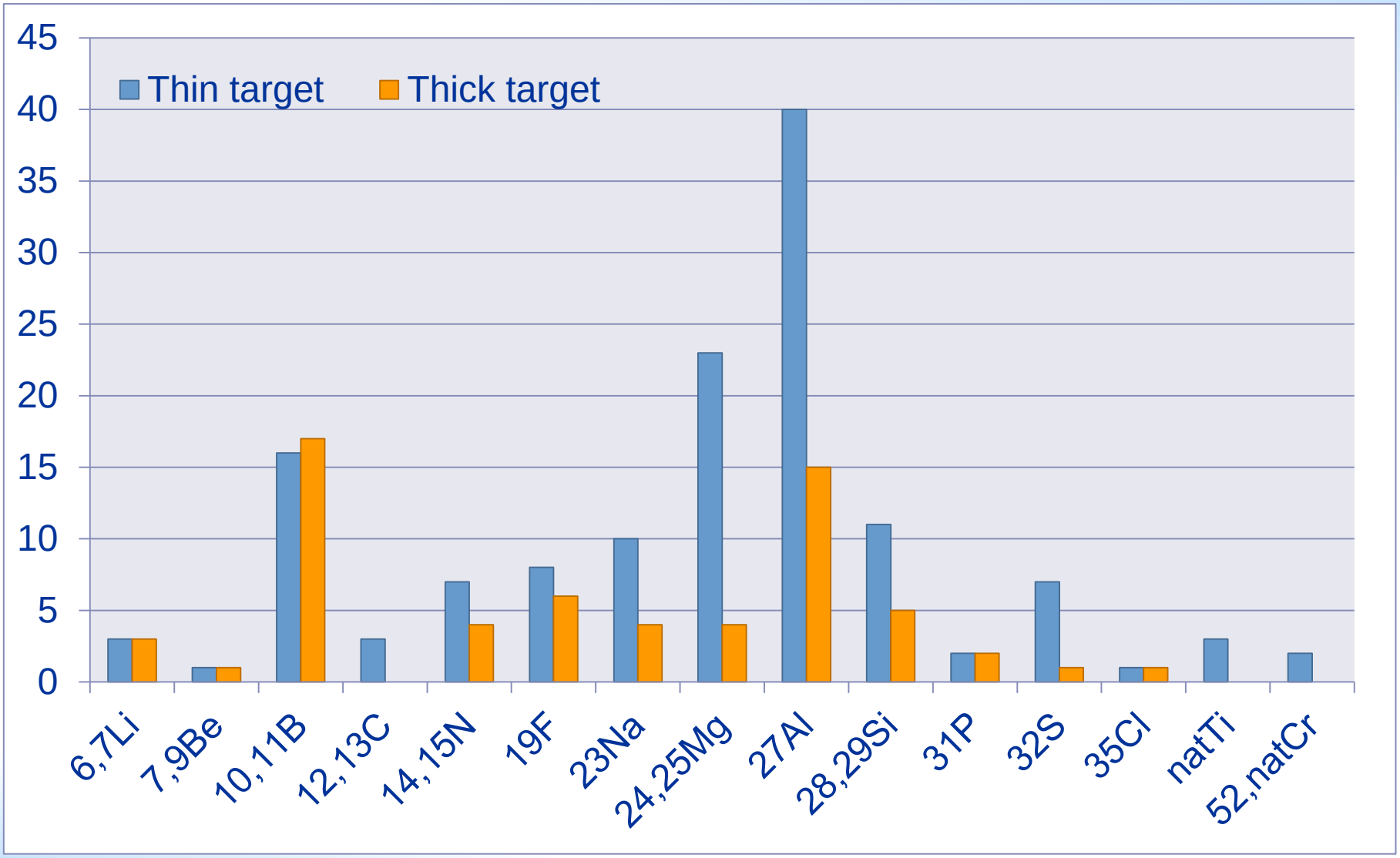
Historical Overview

- Year 2003: IAEA-NDS Technical Meeting
  - Creation of Ion Beam Analysis Nuclear Data Library on NDS server: merging of Sigmabase and NRA database
- Years 2005-2009: CRP on Development of Reference Database for Ion Beam Analysis (IAEA-TECDOC 1780)
  - Development of IBANDL: interface, database structure, graphical viewer
  - New Measurements of EBS, NRA cross sections
  - Evaluation: SigmaCalc (A. Gurbich, IPPE) made available through IBANDL
- Years 2011-2015: CRP on Development of Reference Database for Particle-Induced Gamma-ray Emission spectroscopy (PIGE)
  - Review literature for relevant data
  - New measurements of PIGE cross sections to fill gaps or resolve discrepancies
  - Development of software for standardless PIGE
  - Evaluation (INDC(NDS)-0660)

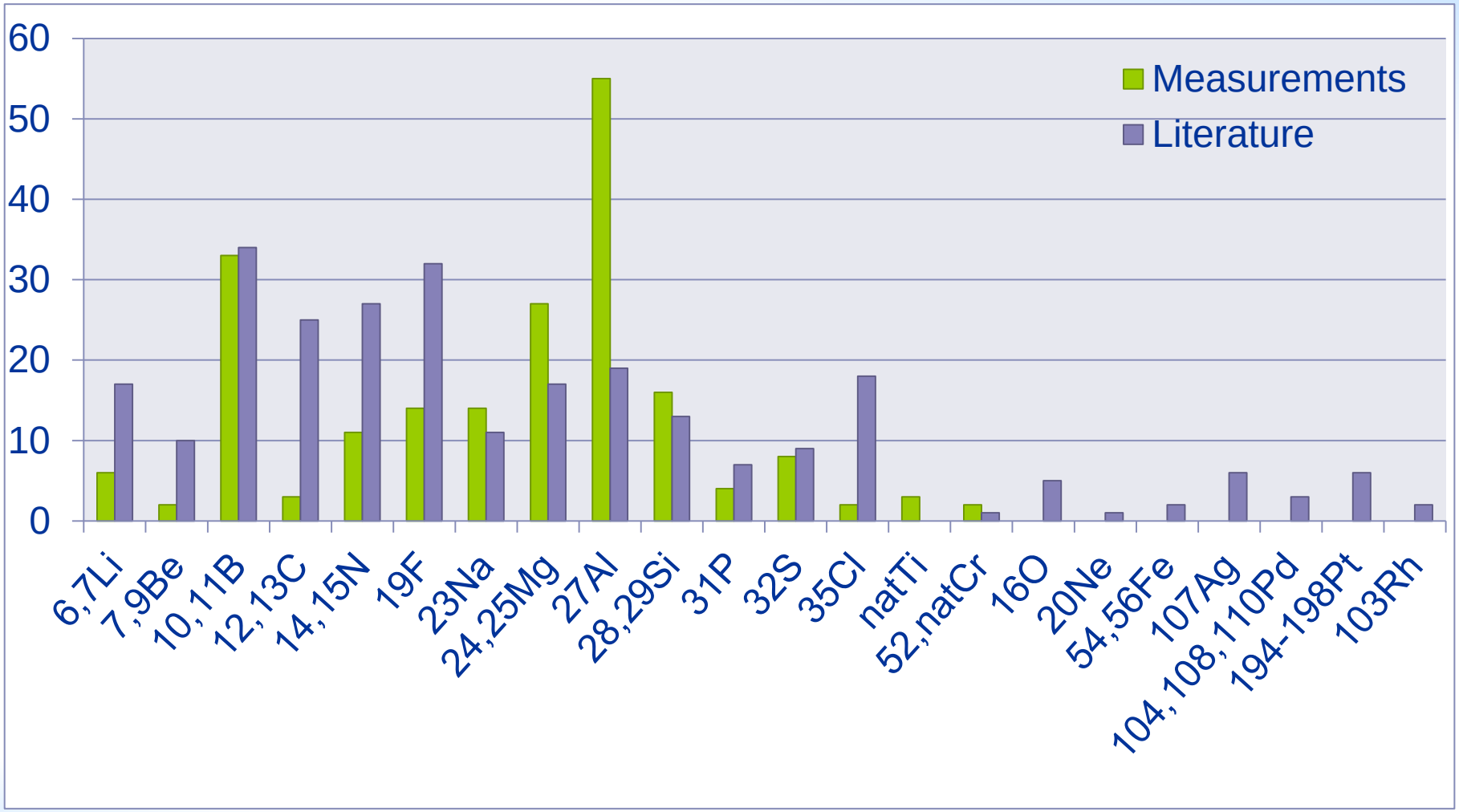
PIGE CRP 2011-2015 (Final report in preparation)



PIGE CRP: Measurements

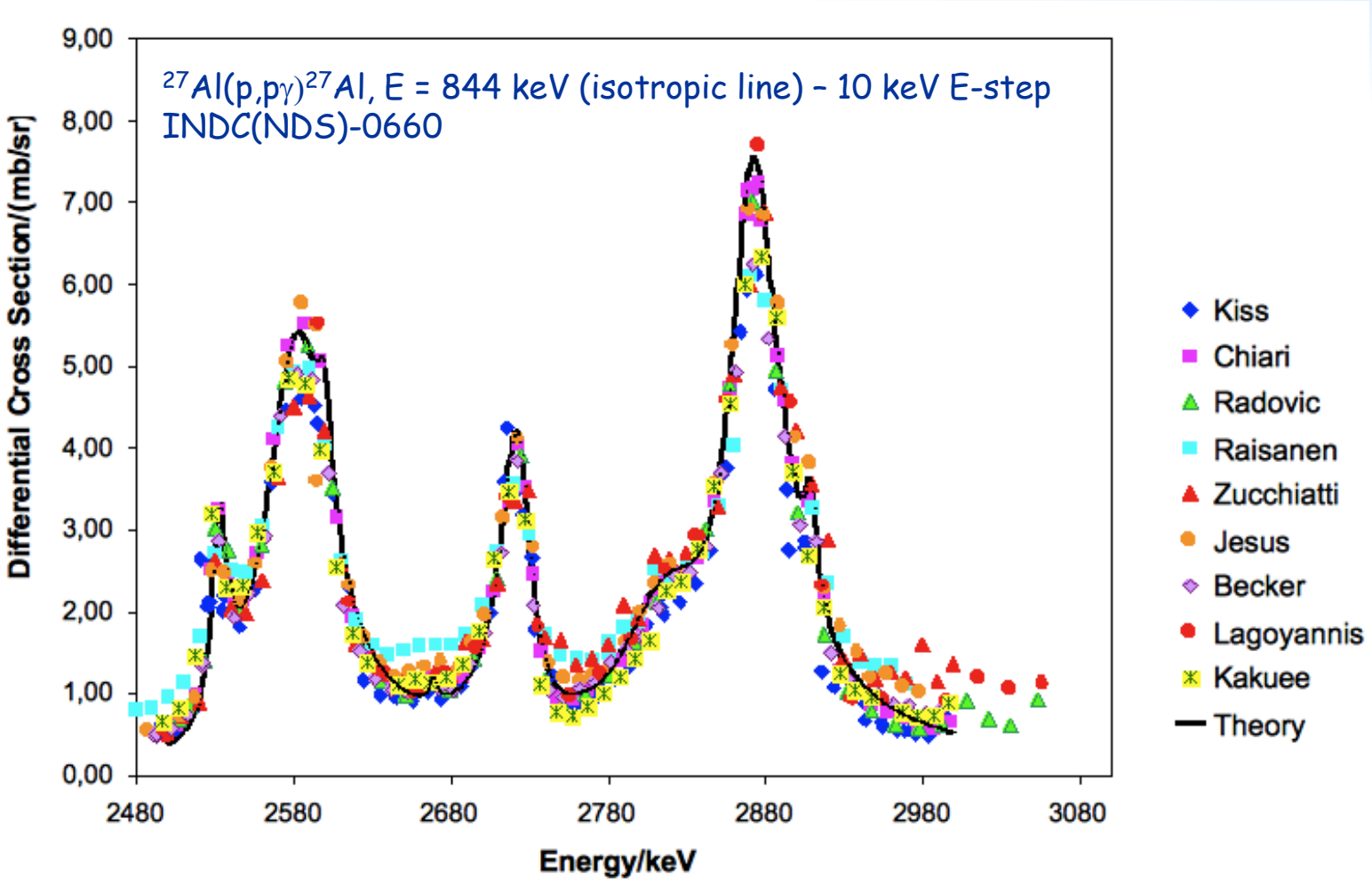


PIGE CRP: Literature Search



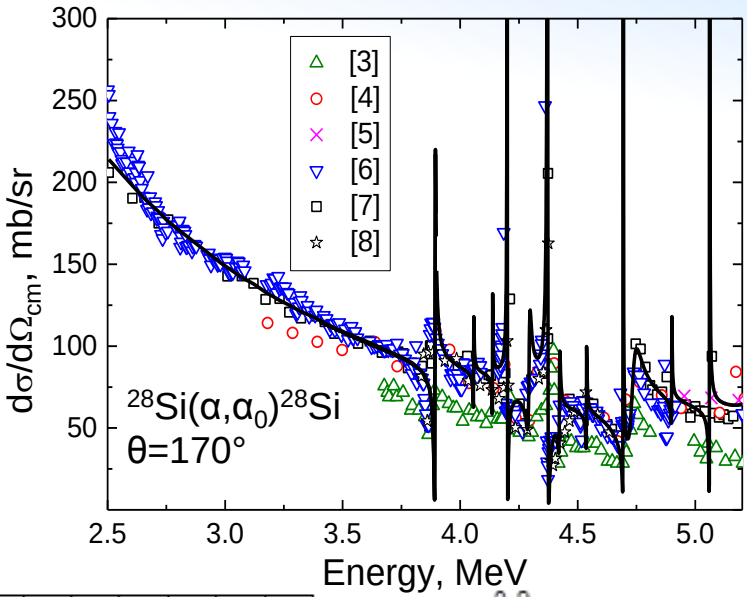
Coordinated Cross-Section Measurement

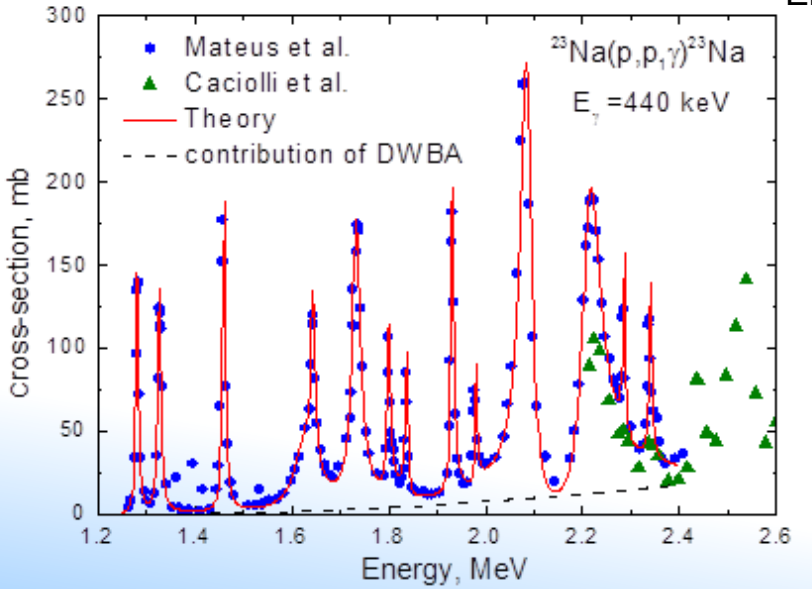
To assess systematic problems with thin-target measurements at different facilities and check Quality Assurance

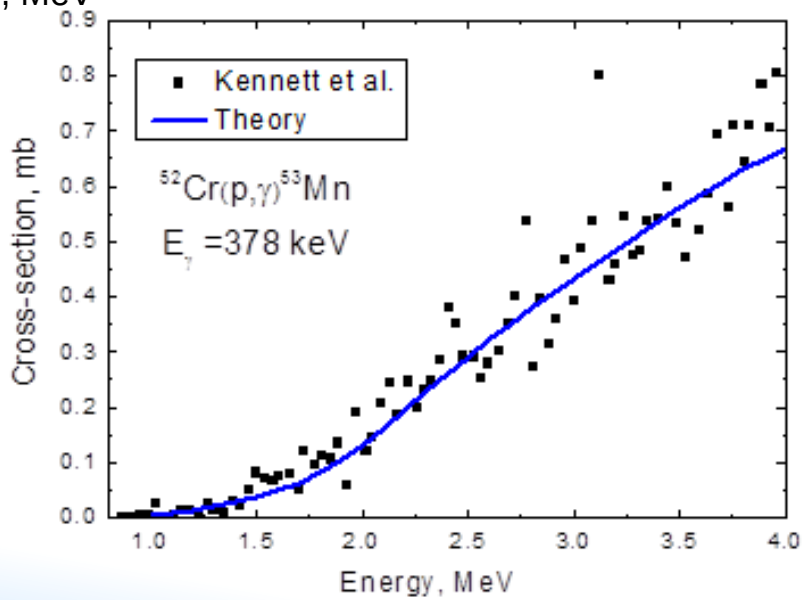


Evaluations

- SigmaCalc (A. Gurbich, IAEA Contracts) at http://sigmacalc.iate.obninsk.ru/



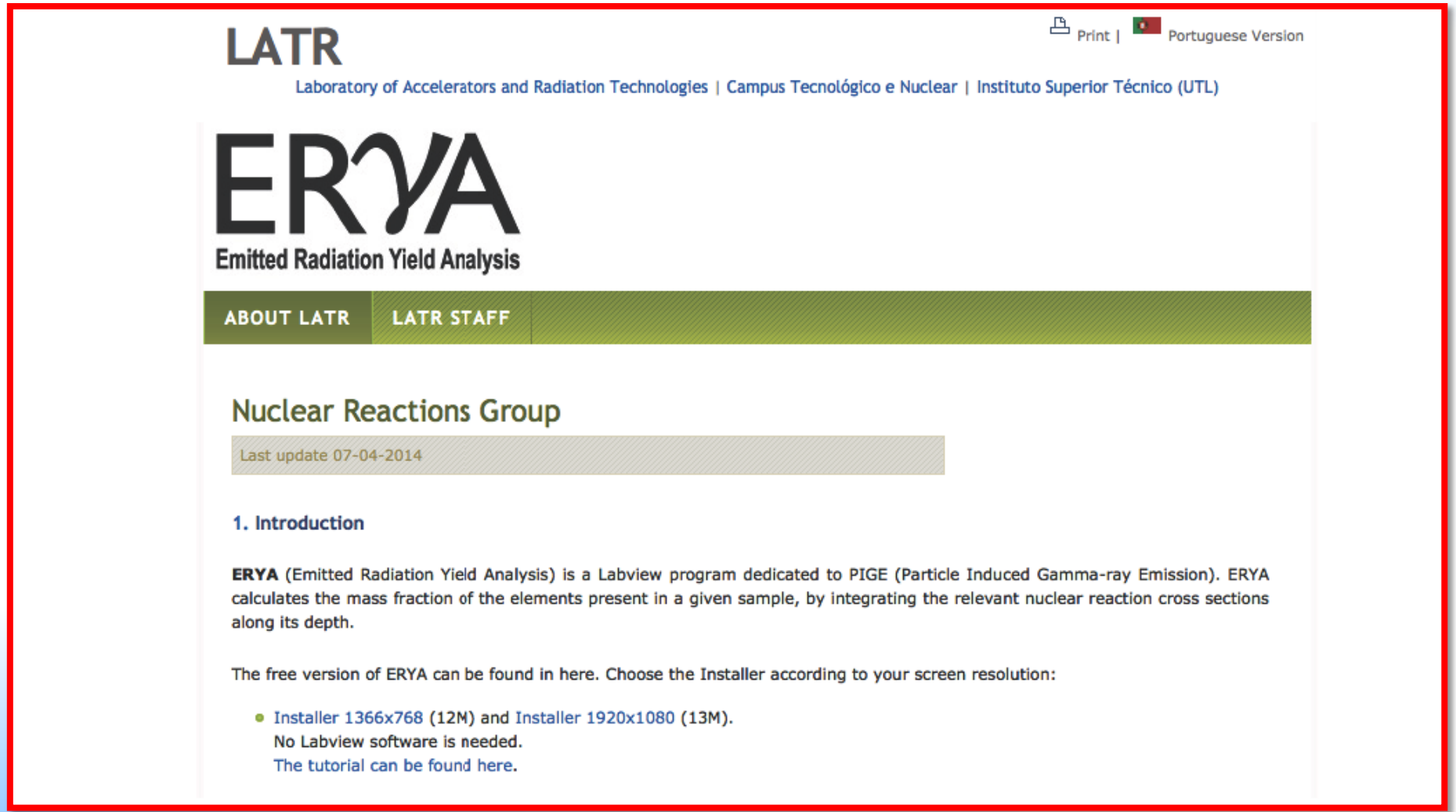




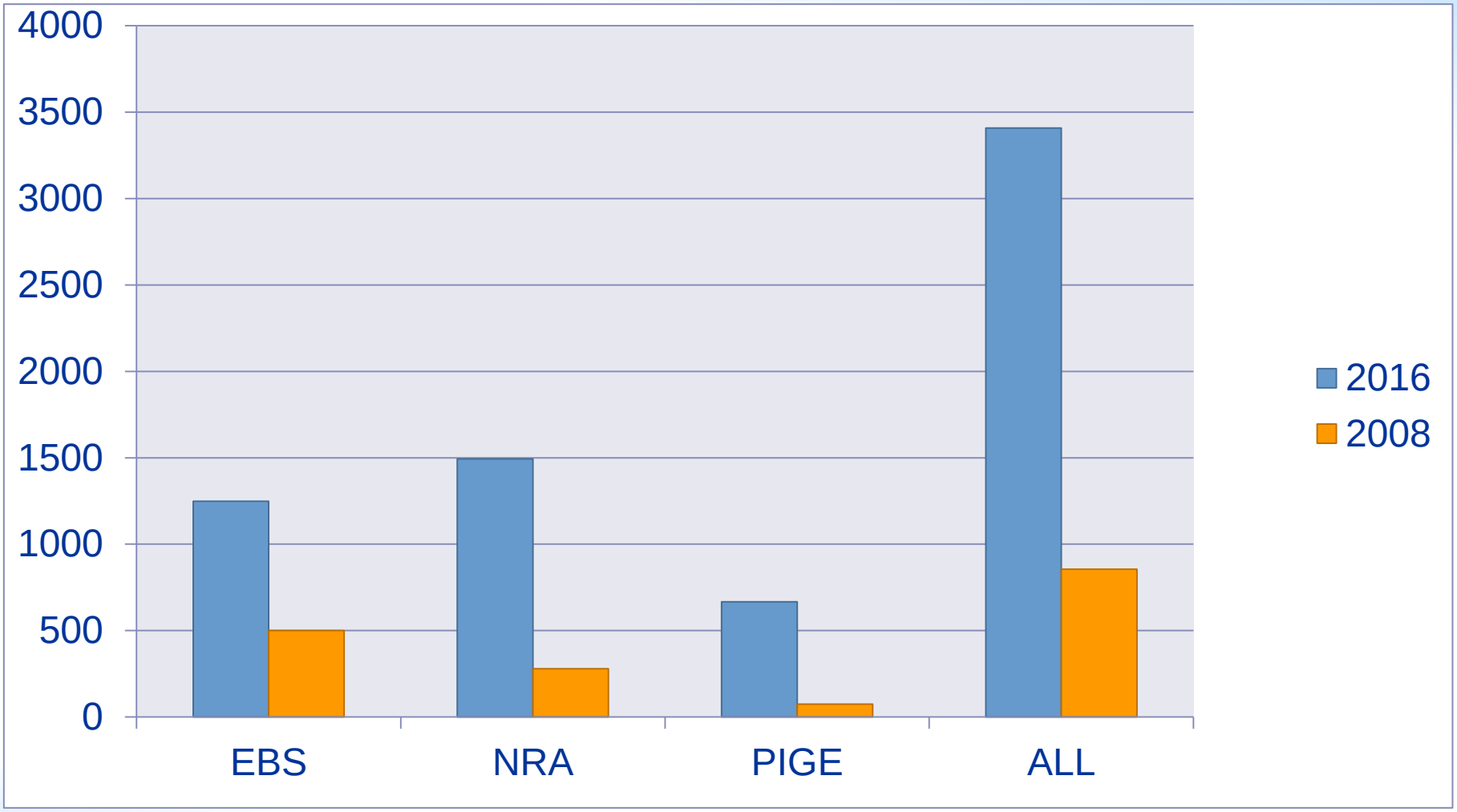
Figures: IAEA Report INDC(NDS)-0660, Vienna, June 2014

Bulk Analysis – Standardless PIGE

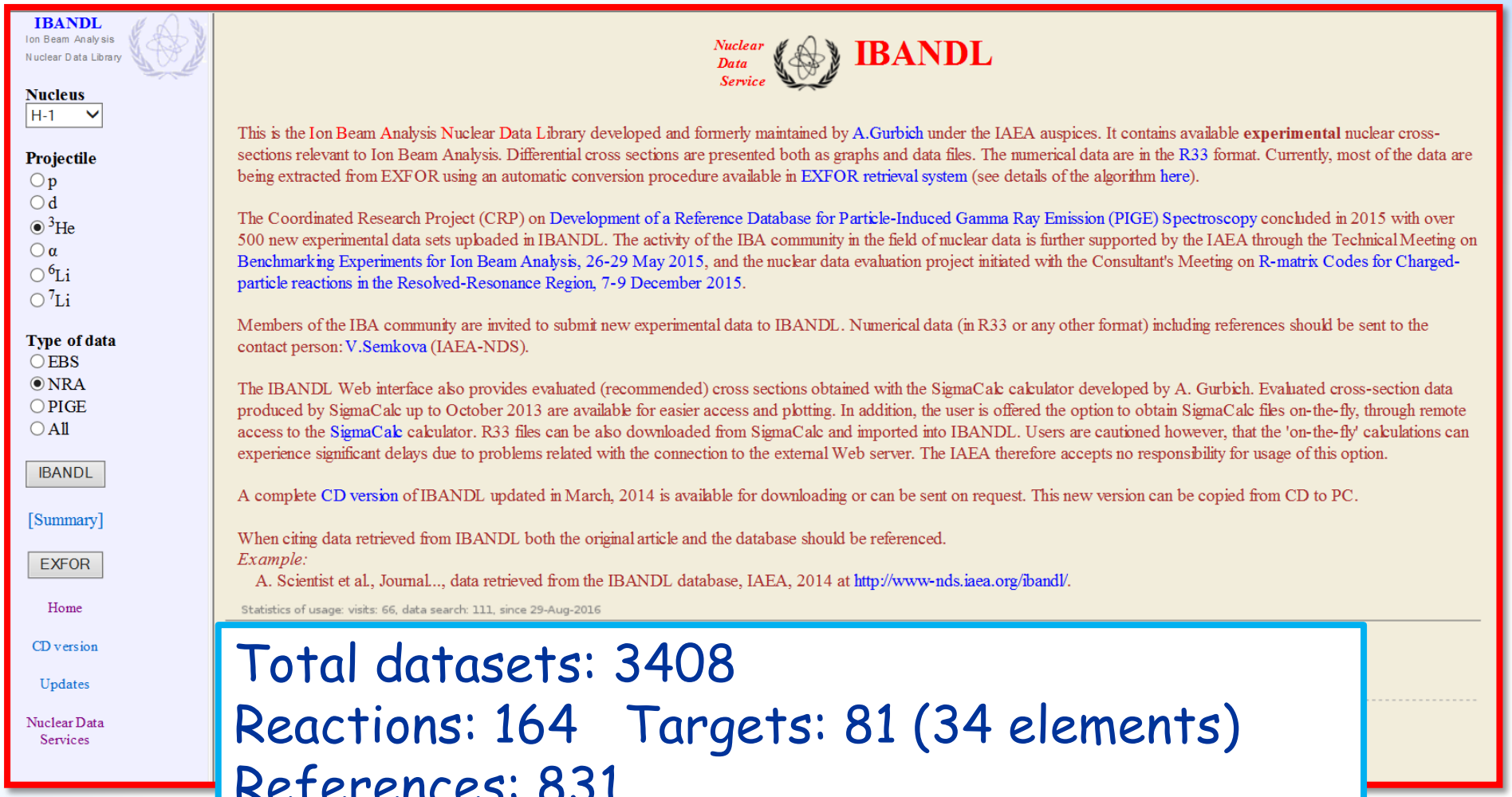
- ERYA code for testing standardless PIGE bulk analysis: calculates mass fraction of the elements in a given sample by integrating relevant nuclear reaction cross sections along its depth
- Distributed to CRP members for testing/Upgraded for PIGE depth profiling



IBANDL after CRPs



Ion Beam Analysis Nuclear Data Library



Total datasets: 3408
Reactions: 164 Targets: 81 (34 elements)
References: 831
SigmaCalc data: 44

IBANDL: features

- IBANDL: development and maintenance by NDS since 2013
  - Web and Database Programming (Viktor Zerkin)
  - Data Compilation (Valentina Semkova)
  - Supervision in collaboration with IBA community

- Major effort to link IBANDL to EXFOR database:
  more information on IBANDL datasets and related references in EXFOR can be accessed through links

- New features:
  - Conversion between units
  - Graphical comparison with User-supplied dataset
  - Cross sections in Inverse kinematics

- Current version of IBANDL can be downloaded directly (https://www-nds.iaea.org/cdroms/)

- Evaluated cross sections available through link to SigmaCalc (http://sigmacalc.iate.obninsk.ru/)

Example: Conversion of units in IBANDL

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IBANDL
Ion Beam Analysis Nuclear Data Library

Nucleus
C-12

Projectile
- (•) p
- ( ) d
- ( ) ^{3}He
- ( ) α
- ( ) ^{6}Li
- ( ) ^{7}Li

Type of data
- (•) EBS
- ( ) NRA
- ( ) PIGE
- ( ) All

IBANDL

[Summary]

EXFOR

Home

CD version

Updates

Nuclear Data Services

^{12}C + p

Type of data: EBS View: [x] extended [ ] inverted Convert units for plotting: ( ) no ( ) rr->mb/sr (•) mb/sr->rr Plots: [reset]

No.	Reaction	Angle	Energy(keV)	Pts	Update	X4	Reference	File	Plot
1	^{12}C(p,p$_0$)^{12}C	179	360-7100	349	2012-01-01		Evaluated data from SigmaCalc archive (A.Gurbich, 2011)	View Save	[ ] mb
							Evaluated data from current version of [SigmaCalc] >>> Calculate (timeout=5min)		
2	^{12}C(p,p$_0$)^{12}C	179.2°	4000-6600	55	2006-06-23	X4	M. Tosaki et. al. Nucl. Instr. Meth. B168 (2000) 543 »	View Save	[ ] mb
3	^{12}C(p,p$_0$)^{12}C	178°	490-2500	61	2011-09-02	X4^{+}	A.R.Ramos+(2002), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.190, p.95 »	View Save	[ ] rr
4	^{12}C(p,p$_0$)^{12}C	170°	700-2500	29	2006-06-23	X4^{-}	E.Rauhala Nucl.Instrum.Methods B12 (1985) 447 »	View Save	[x] mb
5	^{12}C(p,p$_0$)^{12}C	170°	2700-3100	5	2006-06-23	−	Yang Guohua et al. Nucl.Instr.& Meth. v.B61 (1991) 175 »	View Save	[x] rr
6	^{12}C(p,p$_0$)^{12}C	170°	1600-1790	22	2006-06-23	X4^{+}	R.Salomonovic, Nucl. Instr. Meth. v.B82 (1993) 1 »	View Save	[x] mb
7	^{12}C(p,p$_0$)^{12}C	170°	990-3500	78	2006-06-23	+	Amirikas,, R., Jamieson, D.N. and Dooley, S.P. (1993) Nucl. Instr. and Meth. B77, 110. »	View Save	[x] rr
8	^{12}C(p,p$_0$)^{12}C	170°	290-720	24	2006-06-23	+	Z.Liu et al. Nucl. Instr. Meth. v.B74 (1993) 439 »	View Save	[x] rr
9	^{12}C(p,p$_0$)^{12}C	170°	710-2970	37	2006-06-23	+	Z.Liu et al. Nucl. Instr. Meth. v.B74 (1993) 439 »	View Save	[x] rr
10	^{12}C(p,p$_0$)^{12}C	170°	290-2970	60	2006-06-23	+	Z.Liu et al. Nucl. Instr. Meth. v.B74 (1993) 439 »	View Save	[x] rr
11	^{12}C(p,p$_0$)^{12}C	170°	340-3000	123	2006-06-23	X4^{+}	S. Mazzoni et al., Nucl. Instr. Meth. B136-138 (1998) 86 »	View Save	[x] mb
12	^{12}C(p,p$_0$)^{12}C	170°	2690-7000	71	2011-04-05	X4^{+}	D.Abriola+(2011), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol269, p.2011 »	View Save	[x] mb
13	^{12}C(p,p$_0$)^{12}C	168.2°	380-4360	180	2007-08-21	X4^{+}	H.L.Jackson+(1953), Jour. Physical Review, Vol89, p.365 »	View Save	[ ] mb
14	^{12}C(p,p$_0$)^{12}C	165°	340-3000	123	2006-06-23	X4^{+}	S. Mazzoni et al., Nucl. Instr. Meth. B136-138 (1998) 86 »	View Save	[ ] mb

Conversion of units

IAEA 60 Years Atoms for Peace and Development

IBANDL
Ion Beam Analysis Nuclear Data Library

Nucleus
C-12

Projectile
- p
- d
- ^{3}He
- α
- ^{6}Li
- ^{7}Li

Type of data
- EBS
- NRA
- PIGE
- All

IBANDL

[Summary]

EXFOR

Home

CD version

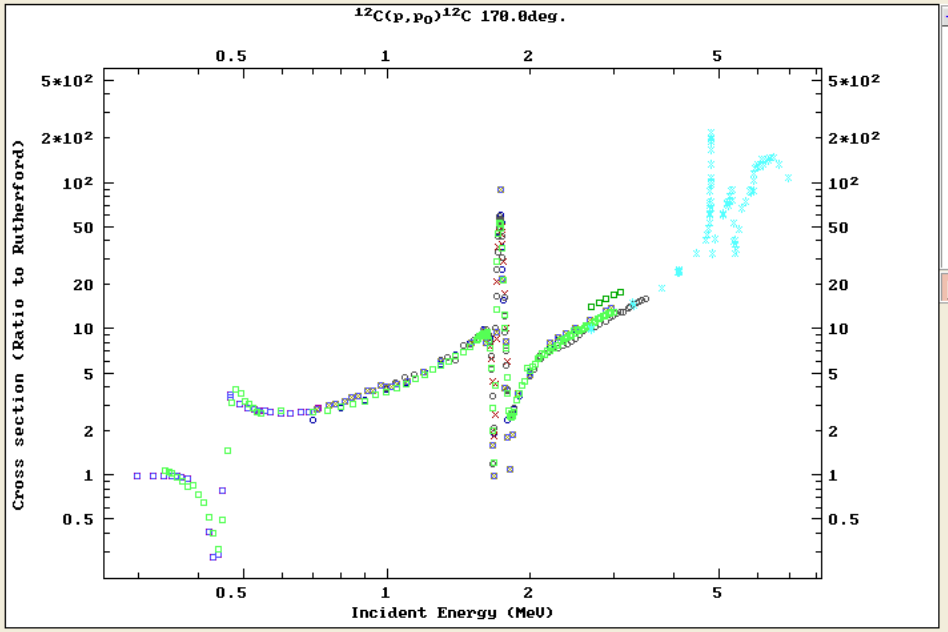
Updates

Nuclear Data Services

Welcome to Web-ZVView!

Interactive plotting of IBANDL and SigmaCalc data

1) θ=170° E_1=0.7-2.5MeV Source: E.Rauhala Nucl.Instrum.Methods B12 (1985) 447
2) θ=170° E_1=2.7-3.1MeV Source: Yang Guohua et al. Nucl.Instr.& Meth. v.B61 (1991) 175
3) θ=170° E_1=1.6-1.8MeV Source: R.Salomonovic, Nucl. Instr. Meth. v.B82 (1993) 1
4) θ=170° E_1=1-3.5MeV Source: Amirikas,, R., Jamieson, D.N. and Dooley, S.P. (1993) Nucl. Instr. and Meth. B77, 110.
5) θ=170° E_1=0.3-0.7MeV Source: Z.Liu et al. Nucl. Instr. Meth. v.B74 (1993) 439
6) θ=170° E_1=0.7-3MeV Source: Z.Liu et al. Nucl. Instr. Meth. v.B74 (1993) 439
7) θ=170° E_1=0.3-3MeV Source: Z.Liu et al. Nucl. Instr. Meth. v.B74 (1993) 439
8) θ=170° E_1=0.3-3MeV Source: S. Mazzoni et al., Nucl. Instr. Meth. B136-138 (1998) 86
9) θ=170° E_1=2.7-7MeV Source: D.Abriola+(2011), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.269, p.2011



Select data for plotting [all] [none]
- 1) 170deg c2pp0a.r33 12C(p,p0)12C
- 2) 170deg c2pp0i.r33 12C(p,p0)12C
- 3) 170deg c2pp0j.r33 12C(p,p0)12C
- 4) 170deg c2pp0n.r33 12C(p,p0)12C
- 5) 170deg c2pp0p.r33 12C(p,p0)12C
- 6) 170deg c2pp0q.r33 12C(p,p0)12C
- 7) 170deg c2pp0r.r33 12C(p,p0)12C
- 8) 170deg c2pp0x.r33 12C(p,p0)12C
- 9) 170deg c2pp0__a.r33 12C(p,p0)12C
- 10) Use my data [example]

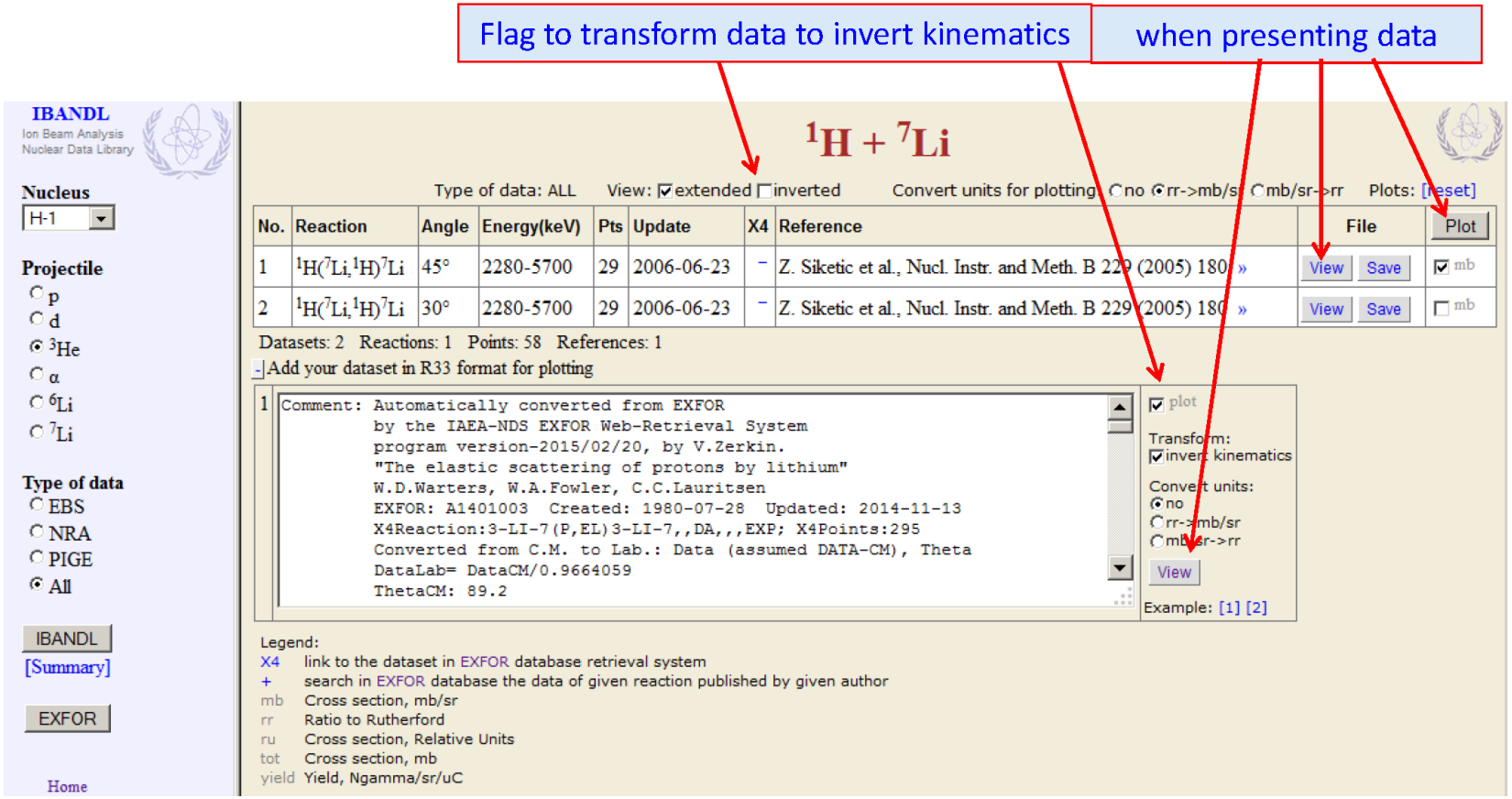
See: plotted data (17Kb)

Log: XY X Y Lin: XY X Y Auto-range: XY X Y Page: >> << Zoom: <> >< Grid: VH 0 V H Pts: Txt Box PL

Reset Repaint Legend Authors Info+ PostScript Manual options:[+] Clipboard: Copy Paste

Shift legend:x=0 y=0 Split:0 1:xy;2:y Plot data or ratio:0 0:data; 1:ratio to dataset-1; 2:ratio to 2-nd, etc.

Example: Inverse Kinematics in IBANDL



IBANDL contains angular distributions $d\sigma/d\Omega(\theta,E)$ for incident charged particle reactions

Inverse Kinematics in IBANDL

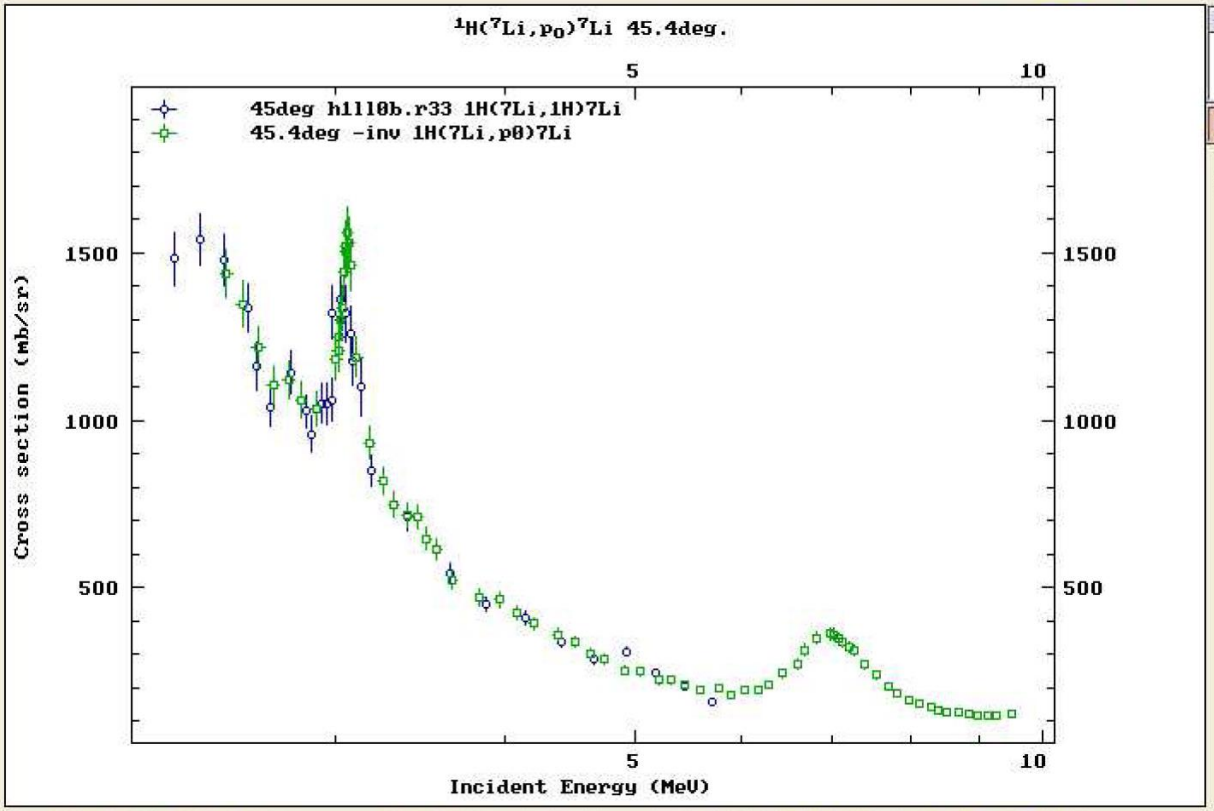
60 Years

Welcome to Web-ZVView!

Interactive plotting of IBANDL and SigmaCalc data

1) θ=45° E_1=2.3-5.7MeV Source: Z. Siketic et al., Nucl. Instr. and Meth. B 229 (2005) 180 +

2) θ=45.4° E_1=2.5-9.5MeV Source: W.D.Warters+(1953), Jour. Physical Review, Vol.91, Issue.4, p.917 [inv] Original: ^{7}Li(p,p_0)^{7}Li E_1=0.4-1.4MeV φ=45.4° θ=81.1° +



- Select data for plotting [all] [none]
  - 1) 45deg h1l10b.r33 1H(7Li,1H)7Li
  - 2) 45.4deg -inv 1H(7Li,p0)7Li
- + 3) Use my data [example]

See: plotted data (6Kb)

Details of calculations

Log: XY X Y Lin: XY X Y Auto-range: XY X Y Page: >> << Zoom: <> >< Grid: VH 0 V H Pts: Txt Box PL Print

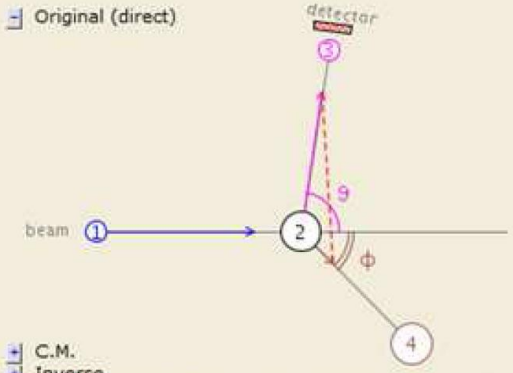
Reset Repaint Legend Authors Info+ PostScript Manual options:[+] Clipboard: Copy Paste

Shift legend:x=0 y=0 Split:0 1:xy;2:y Plot data or ratio:0 0:data; 1:ratio to dataset-1; 2:ratio to 2-nd, etc.

Data for plotting: ZVD (4Kb), send to ZVView; download ZVView; upload and plot your ZVD file

Inverse Kinematics in IBANDL

Original (direct)



C.M.
Inverse
Result: inverse-kinematics data presented in R33 format

Original (direct)
Reaction: $^{7}Li(p,p_0)^{7}Li$ Qvalue=0 nPoint:71
M1: Incident p M_1=1.007825 E_1=1367.0keV
M2: Target 7Li M_2=7.0160046
M3: Scattered p M_3=1.007825 E_3=1070.6keV θ=81.1° σ(θ)=45.1053mb/sr±5.0%
M4: Recoil 7Li M_4=7.0160046 E_4=296.4keV φ=45.4°

Result: inverse-kinematics data presented in R33 format
Reaction: $^{1}H(^{7}Li,p_0)^{7}Li$ Qvalue=0 nPoint:71
M1: Incident 7Li M_1=7.0160046 E_1=9516.4keV
M2: Target 1H M_2=1.007825
M3: Ejectile p M_3=1.007825 E_3=2061.1keV θ=45.4° σ(θ)=122.484mb/sr±5.0%
M4: Residual 7Li M_4=7.0160046 E_4=7455.3keV φ=8.2°

Calculations

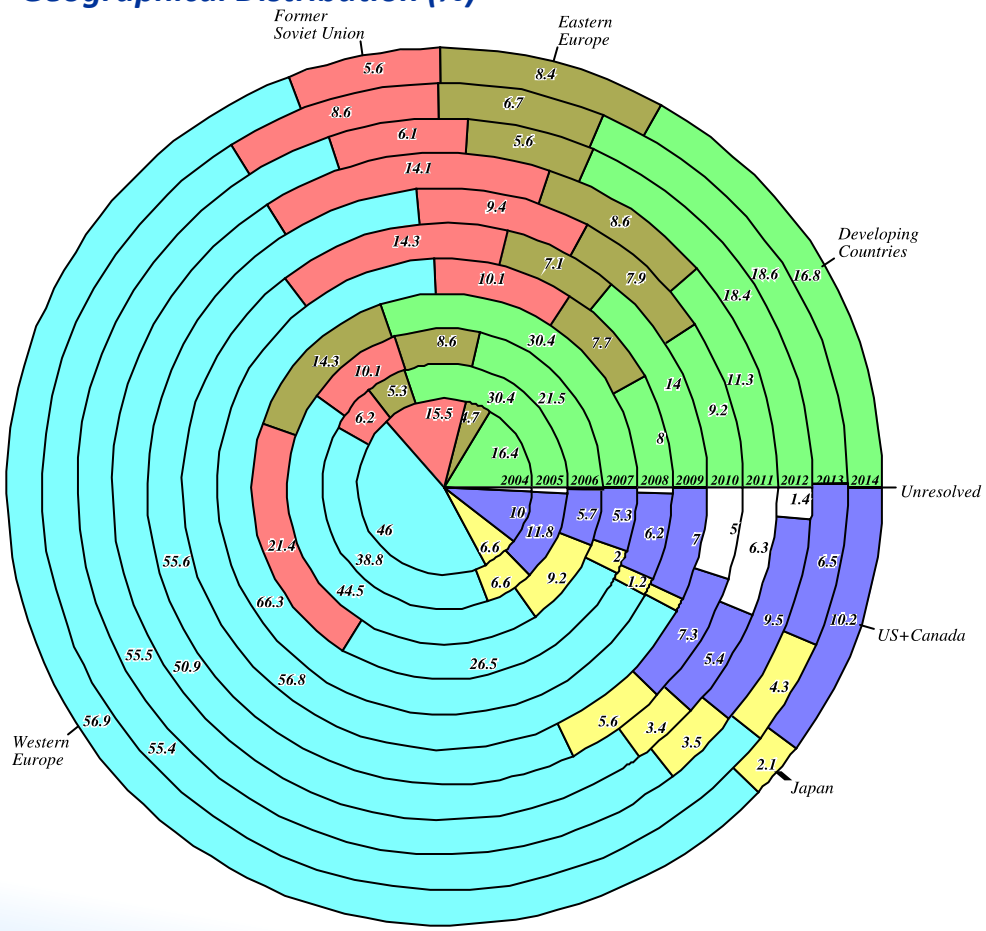
	Original (lab.): $^{7}Li(p,p_0)^{7}Li$ Q=0							Center of mass								Inverse kinematics						
#	E_1, keV	θ°	σ(θ), mb/sr	φ	σ(φ)	E_3	E_4	E'_{cm}	θ'	φ'	σ'(θ')	E'_1	E'_2	E'_3	E'_4	E_2"	φ"	σ"(φ")	θ"	σ"(θ")	E_3"	E_4"
1	358.6	81.1	529.741	45.4	4.35366e6	280.851	77.7494	313.558	89.3	90.7	511.914	274.174	39.3842	274.174	39.3842	2496.4	45.4	1438.52	8.2	164261.	541.3	1955.2
2	368.3	81.1	497.427	45.4	4.08809e6	288.447	79.8525	322.04	89.3	90.7	480.687	281.591	40.4495	281.591	40.4495	2563.9	45.4	1350.77	8.2	154241.	555.9	2008
3	378.5	81.1	450.076	45.4	3.69894e6	296.436	82.064	330.959	89.3	90.7	434.93	289.389	41.5698	289.389	41.5698	2634.9	45.4	1222.18	8.2	139559.	571.3	2063.6
4	388.2	81.1	407.779	45.4	3.35132e6	304.033	84.1671	339.441	89.3	90.7	394.056	296.805	42.6351	296.805	42.6351	2702.5	45.4	1107.33	8.2	126444.	585.9	2116.5
5	398.4	81.1	413.26	45.4	3.39637e6	312.021	86.3786	348.359	89.3	90.7	399.353	304.604	43.7553	304.604	43.7553	2773.5	45.4	1122.21	8.2	128143.	601.3	2172.1
6	407.1	81.1	391.875	45.4	3.22062e6	318.835	88.2649	355.967	89.3	90.7	378.687	311.256	44.7108	311.256	44.7108	2834	45.4	1064.14	8.2	121512.	614.5	2219.6
7	417.8	81.1	382.085	45.4	3.14016e6	327.215	90.5848	365.323	89.3	90.7	369.227	319.437	45.886	319.437	45.886	2908.5	45.4	1037.55	8.2	118476.	630.6	2277.9
8	432.2	81.1	435.468	45.4	3.57888e6	338.493	93.7069	377.914	89.3	90.7	420.813	330.446	47.4675	330.446	47.4675	3008.8	45.4	1182.52	8.2	135029.	652.3	2356.4
9	433.7	81.1	445.21	45.4	3.65895e6	339.668	94.0321	379.226	89.3	90.7	430.227	331.593	47.6322	331.593	47.6322	3019.2	45.4	1208.97	8.2	138050.	654.6	2364.6
10	434.2	81.1	461.032	45.4	3.78898e6	340.059	94.1405	379.663	89.3	90.7	445.517	331.976	47.6872	331.976	47.6872	3022.7	45.4	1251.94	8.2	142956.	655.4	2367.3
11	435.1	81.1	480.354	45.4	3.94778e6	340.764	94.3357	380.45	89.3	90.7	464.189	332.664	47.786	332.664	47.786	3029	45.4	1304.4	8.2	148948.	656.7	2372.2
12	437	81.1	493.156	45.4	4.05299e6	342.252	94.7476	382.111	89.3	90.7	476.56	334.116	47.9947	334.116	47.9947	3042.2	45.4	1339.17	8.2	152917.	659.6	2382.6

IBANDL Web Statistics

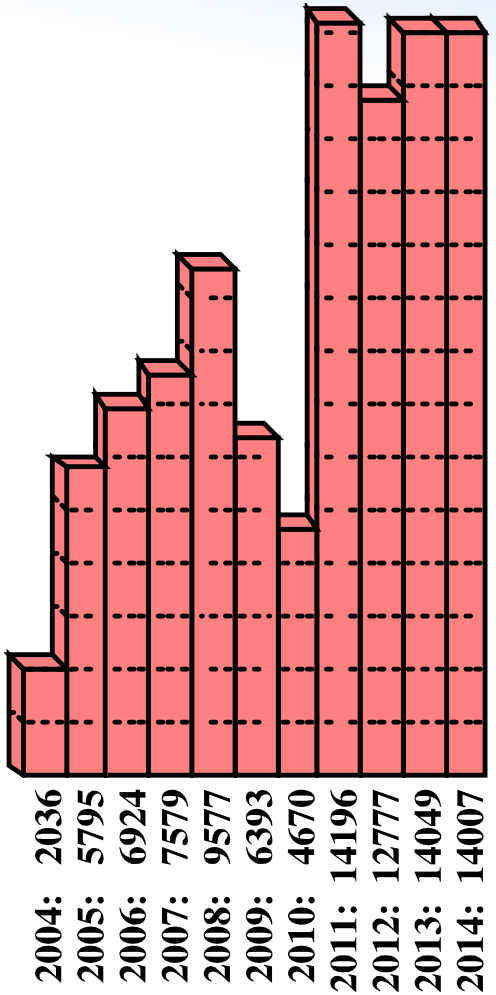
IAEA 60 Years Atoms for Peace and Development

2004-2014

Geographical Distribution (%)



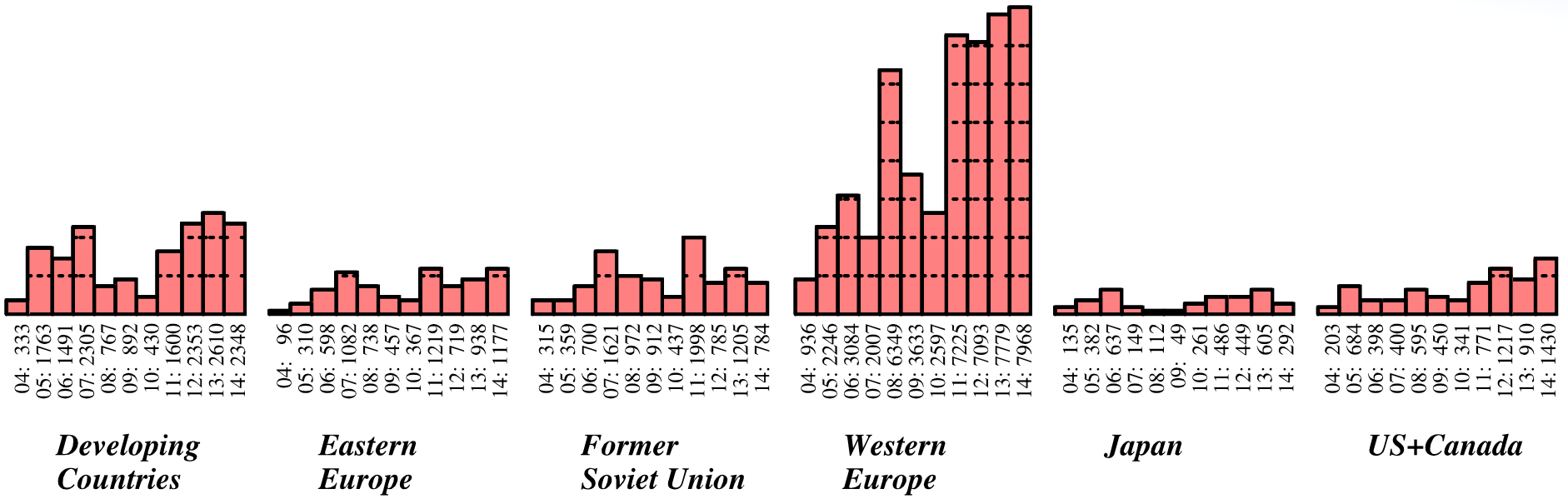
Total per Year*



Prepared by V.Zerkin, IAEA-NDS, 20-Apr-2015

IBANDL Web Statistics

Total per Year by Areas*



Prepared by V.Zerkin, IAEA-NDS, 20-Apr-2015

IBA Benchmarking Measurements

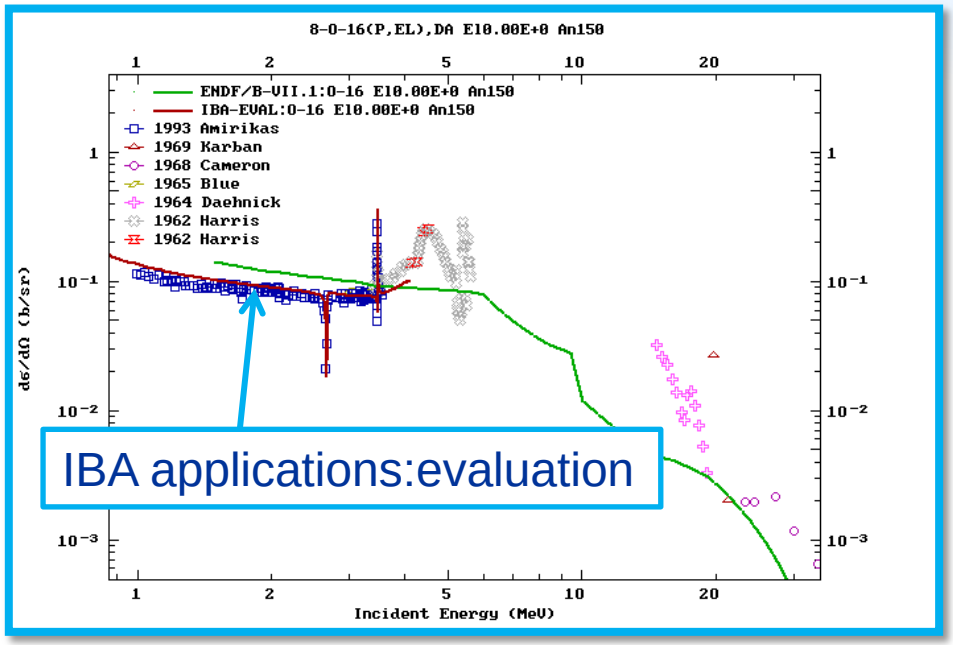
- IAEA Technical Meeting, 26-29 May 2015

Purpose

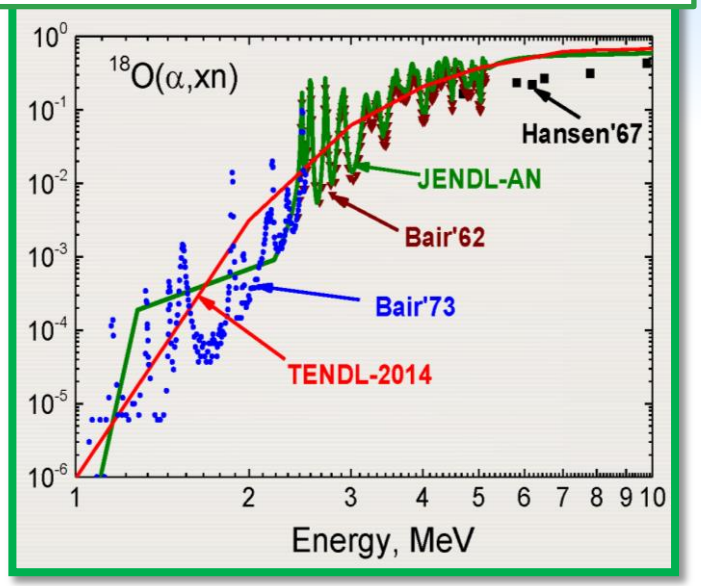
- Define methodology for benchmarking measurements
- Proposed Guidelines for EBS, NRA and PIGE
- Describe a Proficiency Benchmarking Measurement for EBS
- Produce a list of priority benchmark experiments for EBS, NRA and PIGE
- Data dissemination: benchmark data in IBANDL + calculational tools to produce thick-target spectra on-the-fly

Report: INDC(NDS)-0690

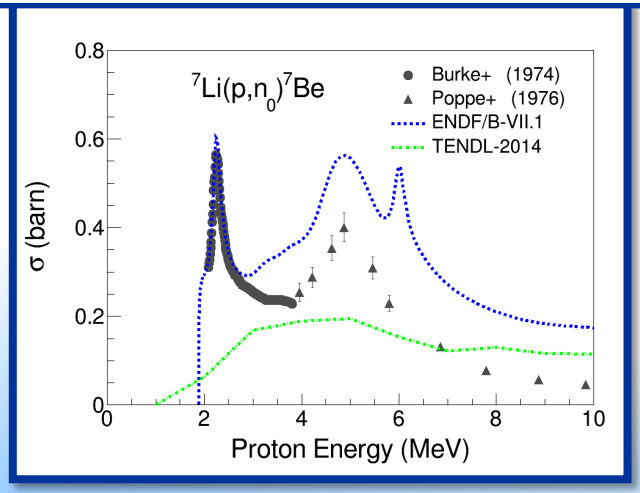
R-matrix Codes for Evaluation

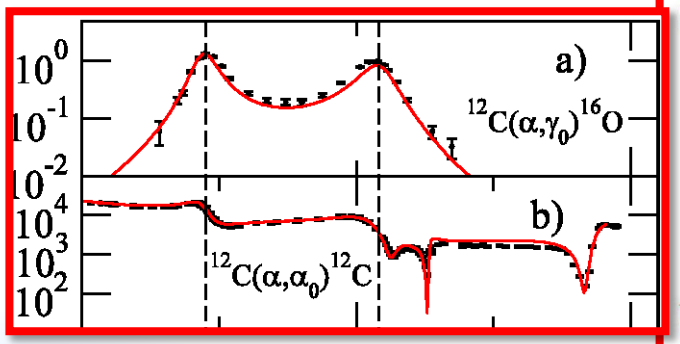


Spent fuel management: neutron production

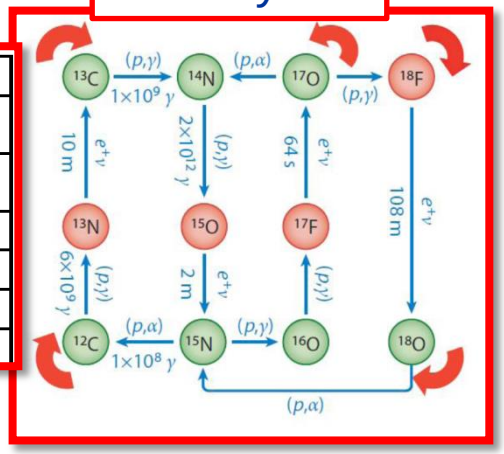


^{7}Li(p,n)^{7}Be reaction is a promising candidate for neutron source, e.g., BNCT, in a resonance range





CNO cycles



R-matrix Codes for Evaluation

- IAEA Consultant Meeting on R-matrix codes for Charged-particle Reactions in the Resolved Resonance Region, 7-9 Dec. 2015 (INDC(NDS)-0703)

Purpose

- Compare existing R-matrix codes used in different fields of nuclear sciences (nuclear data evaluation, nuclear astrophysics, Ion Beam Analysis etc)
- Define a common platform for all the codes: input/output resonance parameters can be understood and used by all codes
- Propose a methodology for evaluation of cross-sections in the resolved resonance region followed by PIGE)
- Produce evaluated cross sections in ENDF-6, R33 and simple format for users in specific and broader scientific community
- Data dissemination

Presentations

#	Author	Title	Link
1	P. Dimitriou	Motivation-Background information; p+^{27}Al using SAMMY	PDF
2	R.J. deBoer	AZURE2: An R-matrix Code for Nudear Astrophysics	PDF
3	M. Paris	R-Matrix Analysis of Multichannel REaction Data with EDA	PDF
4	I.J. Thompson	Widening the Scope of R-matrix Methods	PDF
5	L. Leal	Brief descriptions about the SAMMY Code	PDF
6	A. Trkov	Charged-Particle Resonance Data in ENDF-6 Format	PDF
7	S. Kunieda	Present status of R-matrix code AMUR and analysis for ^{8}Be and ^{17}O systems	PDF

Future

- 2nd CM on R-matrix codes for charged-particle reactions in the resolved resonance region, Dec. 2016

  - R-matrix codes: common platform for using input/output resonances
  - Evaluation methodology: statistical treatment, uncertainties
  - Evaluated data files: frozen version will be produced and made available (in various formats: R33, ENDF-6, ascii files)

- Thick-target yields from Benchmarking measurements:
  - Data will become available in IBANDL
  - On-the-fly calculations of thick-target yields for comparison

- Continuous maintenance and development of IBANDL

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Thank you!