

Integrative Structure Validation Report ?

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The following software was used in the production of this report:

Integrative Modeling Validation Version 2.0

Python-IHM Version 1.8

MolProbity Version 4.5.2

PDB ID	9A76
PDB-Dev ID	PDBDEV_00000335
Structure Title	Integrative model of LEPA-CSHA by crosslinking MS and deep learning
Structure Authors	Kolja Stahl; Oliver Brock; Juri Rappsilber
Deposited on	2024-01-23

This is a PDB-IHM IM Structure Validation Report for a publicly released PDB-IHM entry.

We welcome your comments at helpdesk@pdb-ihm.org

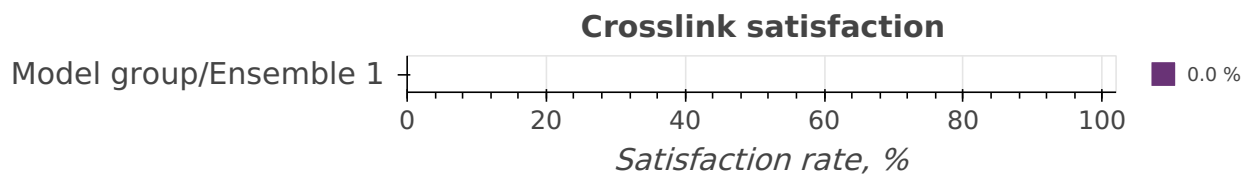
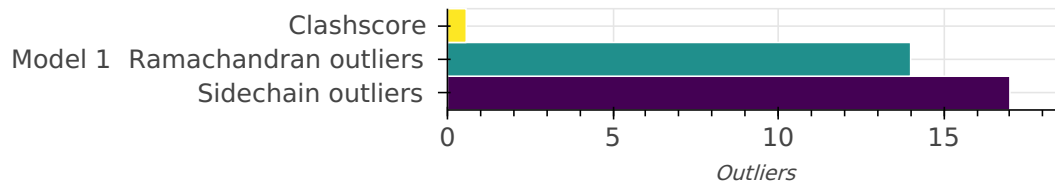
A user guide is available at https://pdb-ihm.org/validation_help.html with specific help available everywhere you see the ? symbol.

List of references used to build this report is available [here](#).

Overall quality ?

This validation report contains model quality assessments for all structures, data quality and fit to model assessments for SAS and crosslinking-MS datasets. Data quality and fit to model assessments for other datasets and model uncertainty are under development. Number of plots is limited to 256.

Model Quality: MolProbity Analysis



Ensemble information ?

This entry consists of 0 distinct ensemble(s).

Summary ?

This entry consists of 1 model(s). A total of 1 datasets were used to build this entry.

Representation ?

This entry has 1 representation(s).

ID	Model(s)	Entity ID	Molecule name	Chain(s) [auth]	Total residues	Rigid segments	Flexible segments	Model coverage/ Starting model coverage (%)	Scale
1	1	1	LEPA_BACSU	A	612	-	1-612	100.00 / 0.00	Atomic
		2	CSHA_BACSU	B	494	-	1-494	100.00 / 0.00	Atomic

Datasets used for modeling ?

There is 1 unique dataset used to build the models in this entry.

ID	Dataset type	Database name	Data access code
1	Crosslinking-MS data	PRIDE	PXD035508

Methodology and software ?

This entry is a result of 1 distinct protocol(s).

Step number	Protocol ID	Method name	Method type	Method description	Number of computed models	Multi state modeling	Multi scale modeling
1	1	AlphaLink2	AlphaLink2	None	1	False	False

There is 1 software package reported in this entry.

ID	Software name	Software version	Software classification	Software location
1	AlphaLink2	1.00	model building	https://github.com/Rappsilber-Laboratory/AlphaLink2

Data quality ?

Crosslinking-MS

At the moment, data validation is only available for crosslinking-MS data deposited as a fully [compliant](#) dataset in the [PRIDE Crosslinking](#) database. Correspondence between crosslinking-MS and entry entities is established using [pyHMMER](#). Only residue pairs that passed the reported threshold are used for the analysis. The values in the report have to be interpreted in the context of the experiment (i.e. only a minor fraction of in-situ or in-vivo dataset can be used for modeling).

Crosslinking-MS dataset is not available in the [PRIDE Crosslinking](#) database.

Model quality ?

For models with atomic structures, MolProbity analysis is performed. For models with coarse-grained or multi-scale structures, excluded volume analysis is performed.

Standard geometry: bond outliers ?

There are no bond length outliers.

Standard geometry: angle outliers ?

There are 84 bond angle outliers in this entry (0.71% of 11888 assessed bonds). A summary is provided below.

Chain	Res	Type	Atoms	Z	Observed (Å)	Ideal (Å)	Model ID (Worst)	Models (Total)
B	469	ASN	C-N-CA	10.07	139.83	121.70	1	1
B	482	ARG	C-N-CA	8.58	137.15	121.70	1	1
B	467	LYS	C-N-CA	7.52	135.23	121.70	1	1
B	474	TYR	C-N-CA	7.15	134.57	121.70	1	1
B	491	LYS	C-N-CA	6.75	133.85	121.70	1	1
B	155	ASP	CA-CB-CG	6.53	119.13	112.60	1	1
B	488	ARG	CD-NE-CZ	6.40	133.36	124.40	1	1
B	461	TYR	C-N-CA	6.35	133.14	121.70	1	1
B	488	ARG	C-N-CA	6.31	133.06	121.70	1	1
B	134	ASP	CA-CB-CG	5.95	118.55	112.60	1	1
B	463	GLY	C-N-CA	5.89	132.29	121.70	1	1
B	476	LYS	C-N-CA	5.79	132.12	121.70	1	1
B	490	GLN	C-N-CA	5.77	132.09	121.70	1	1
B	492	LYS	C-N-CA	5.76	132.07	121.70	1	1
B	23	PHE	CA-CB-CG	5.60	119.40	113.80	1	1
B	487	ASP	CA-CB-CG	5.53	118.13	112.60	1	1
B	470	ASN	O-C-N	5.45	114.27	123.00	1	1
B	486	GLY	C-N-CA	5.45	131.51	121.70	1	1
B	46	GLN	OE1-CD-NE2	5.43	117.17	122.60	1	1
B	461	TYR	CA-C-N	5.40	127.01	116.20	1	1
B	178	GLN	OE1-CD-NE2	5.29	117.31	122.60	1	1
B	465	LYS	C-N-CA	5.17	131.01	121.70	1	1
B	470	ASN	CA-C-N	5.17	126.54	116.20	1	1
B	461	TYR	O-C-N	5.14	114.78	123.00	1	1
B	239	GLN	OE1-CD-NE2	5.11	117.49	122.60	1	1
A	504	ASP	CA-CB-CG	4.99	117.59	112.60	1	1
A	396	ASN	OD1-CG-ND2	4.99	117.61	122.60	1	1
B	32	GLN	OE1-CD-NE2	4.99	117.61	122.60	1	1
A	612	GLN	OE1-CD-NE2	4.97	117.63	122.60	1	1
B	358	GLN	OE1-CD-NE2	4.96	117.64	122.60	1	1
A	342	GLN	OE1-CD-NE2	4.93	117.67	122.60	1	1
A	404	GLN	OE1-CD-NE2	4.89	117.71	122.60	1	1
B	145	ASN	OD1-CG-ND2	4.87	117.73	122.60	1	1

Chain	Res	Type	Atoms	Z	Observed (Å)	Ideal (Å)	Model ID (Worst)	Models (Total)
B	460	GLY	C-N-CA	4.86	130.45	121.70	1	1
B	473	SER	CA-C-N	4.83	125.86	116.20	1	1
B	475	ASP	N-CA-C	4.81	124.46	111.00	1	1
B	483	ARG	N-CA-C	4.79	124.42	111.00	1	1
B	210	GLU	C-N-CA	4.79	130.32	121.70	1	1
A	116	GLN	OE1-CD-NE2	4.68	117.92	122.60	1	1
A	121	GLN	OE1-CD-NE2	4.67	117.93	122.60	1	1
A	446	ASP	CA-CB-CG	4.64	117.24	112.60	1	1
A	511	HIS	CB-CG-CD2	4.61	125.20	131.20	1	1
B	488	ARG	CA-C-N	4.60	125.40	116.20	1	1
B	492	LYS	CA-C-N	4.54	125.29	116.20	1	1
B	6	GLN	OE1-CD-NE2	4.54	118.06	122.60	1	1
B	467	LYS	CA-C-N	4.54	125.27	116.20	1	1
B	379	GLN	OE1-CD-NE2	4.54	118.06	122.60	1	1
A	540	GLN	OE1-CD-NE2	4.51	118.09	122.60	1	1
B	481	ASP	C-N-CA	4.50	129.80	121.70	1	1
B	57	PHE	CA-CB-CG	4.45	118.25	113.80	1	1
B	477	LYS	N-CA-C	4.45	123.46	111.00	1	1
B	490	GLN	CA-C-N	4.38	124.96	116.20	1	1
A	468	GLN	OE1-CD-NE2	4.37	118.23	122.60	1	1
B	109	GLN	OE1-CD-NE2	4.36	118.24	122.60	1	1
B	475	ASP	C-CA-CB	4.35	101.84	110.10	1	1
B	165	ASP	CA-CB-CG	4.34	116.94	112.60	1	1
B	381	GLN	OE1-CD-NE2	4.34	118.26	122.60	1	1
B	380	GLN	OE1-CD-NE2	4.29	118.31	122.60	1	1
B	144	ASN	CA-CB-CG	4.29	116.89	112.60	1	1
B	463	GLY	CA-C-N	4.28	124.76	116.20	1	1
A	370	ASN	OD1-CG-ND2	4.26	118.34	122.60	1	1
B	320	GLN	OE1-CD-NE2	4.25	118.35	122.60	1	1
B	217	GLN	OE1-CD-NE2	4.24	118.36	122.60	1	1
A	16	ASN	OD1-CG-ND2	4.20	118.40	122.60	1	1
B	96	GLN	OE1-CD-NE2	4.20	118.40	122.60	1	1
A	335	GLN	OE1-CD-NE2	4.20	118.40	122.60	1	1

Chain	Res	Type	Atoms	Z	Observed (Å)	Ideal (Å)	Model ID (Worst)	Models (Total)
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A	113	ASP	CA-CB-CG	4.19	116.79	112.60	1	1
B	19	ASN	OD1-CG-ND2	4.18	118.42	122.60	1	1
A	49	GLN	OE1-CD-NE2	4.18	118.42	122.60	1	1
B	457	GLN	OE1-CD-NE2	4.18	118.42	122.60	1	1
B	481	ASP	N-CA-C	4.15	122.63	111.00	1	1
B	274	ASP	CA-CB-CG	4.15	116.75	112.60	1	1
B	114	GLN	OE1-CD-NE2	4.14	118.46	122.60	1	1
B	470	ASN	OD1-CG-ND2	4.13	118.47	122.60	1	1
A	132	ASN	OD1-CG-ND2	4.12	118.48	122.60	1	1
B	488	ARG	O-C-N	4.12	116.41	123.00	1	1
B	469	ASN	CA-C-N	4.12	124.43	116.20	1	1
B	490	GLN	OE1-CD-NE2	4.11	118.49	122.60	1	1
A	433	GLN	OE1-CD-NE2	4.10	118.50	122.60	1	1
B	469	ASN	O-C-N	4.09	116.46	123.00	1	1
A	364	ARG	CD-NE-CZ	4.09	130.12	124.40	1	1
B	224	GLN	OE1-CD-NE2	4.08	118.52	122.60	1	1
A	70	GLN	OE1-CD-NE2	4.03	118.57	122.60	1	1
B	144	ASN	OD1-CG-ND2	4.00	118.60	122.60	1	1

Too-close contacts ?

The following all-atom clashscore is based on a MolProbity analysis. All-atom clashscore is defined as the number of clashes found per 1000 atoms (including hydrogen atoms). The table below contains clashscores for all atomic models in this entry.

Model ID	Clash score	Number of clashes
1	0.57	10

There are 10 clashes. The table below contains the detailed list of all clashes based on a MolProbity analysis. Bad clashes are ≥ 0.4 Angstrom.

Atom 1	Atom 2	Clash(Å)	Model ID (Worst)	Models (Total)
B:75:ILE:HD11	B:143:LEU:HD22	0.67	1	1
A:378:PRO:HD2	A:603:LEU:HD11	0.62	1	1
A:275:VAL:HG13	A:329:LEU:HG	0.52	1	1

Atom 1	Atom 2	Clash(Å)	Model ID (Worst)	Models (Total)
B:486:GLY:CA	B:487:ASP:HB2	0.48	1	1
A:493:LYS:HE2	A:507:SER:HB3	0.44	1	1
A:300:LYS:HE2	A:332:SER:O	0.44	1	1
A:494:MET:HE1	A:515:ALA:O	0.44	1	1
B:302:ALA:HA	B:305:LEU:HD12	0.43	1	1
A:525:LYS:HZ2	A:606:ASP:CG	0.42	1	1
A:202:LYS:HE2	A:291:ALA:HB1	0.40	1	1

Torsion angles: Protein backbone ?

In the following table, Ramachandran outliers are listed. The Analysed column shows the number of residues for which the backbone conformation was analysed.

Model ID	Analysed	Favored	Allowed	Outliers
1	1102	1047	41	14

There are 14 unique backbone outliers. Detailed list of outliers are tabulated below.

Chain	Res	Type	Models (Total)
A	252	PRO	1
A	262	VAL	1
A	464	GLU	1
B	211	MET	1
B	459	GLY	1
B	468	SER	1
B	470	ASN	1
B	475	ASP	1
B	477	LYS	1
B	478	ARG	1
B	483	ARG	1
B	484	SER	1
B	487	ASP	1
B	493	SER	1

Torsion angles : Protein sidechains ?

In the following table, sidechain rotameric outliers are listed. The Analysed column shows the number of residues for which the sidechain conformation was analysed.

Model ID	Analysed	Favored	Allowed	Outliers
1	946	903	26	17

There are 17 unique sidechain outliers. Detailed list of outliers are tabulated below.

Chain	Res	Type	Models (Total)
A	46	MET	1
A	92	VAL	1
A	245	THR	1
A	252	PRO	1
A	278	THR	1
A	330	ASN	1
A	372	ASP	1
A	548	VAL	1
A	560	VAL	1
A	589	VAL	1
B	2	THR	1
B	163	ILE	1
B	257	LEU	1
B	385	GLU	1
B	406	LEU	1
B	474	TYR	1
B	481	ASP	1

Fit of model to data used for modeling ?

Fit of model(s) to crosslinking-MS data

Restraint types

Restraint types are summarized in the table below. Restraints assigned "*by-residue*" are interpreted as between CA atoms. Restraints between coarse-grained beads are indicated as "*coarse-grained*".

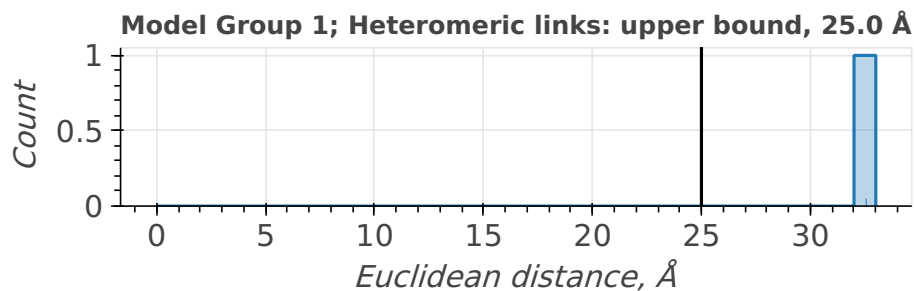
Restraint group represents a set of crosslinking restraints applied collectively in the modeling.

There are 1 crosslinking restraints combined in 1 restraint groups.

Linker	Residue 1	Atom 1	Residue 2	Atom 2	Restraint type	Distance, Å	Count
SDA	LYS	CA	LYS	CA	upper bound	25.0	1

Distograms of individual restraints

Restraints with identical thresholds are grouped into one plot. Only the best distance per restraint per model group/ensemble is plotted. Inter- and intramolecular (including self-links) restraints are also grouped into one plot. Distance for a restraint between coarse-grained beads is calculated as a minimal distance between shells; if beads intersect, the distance will be reported as 0.0. A bead with the highest available resolution for a given residue is used for the assessment.



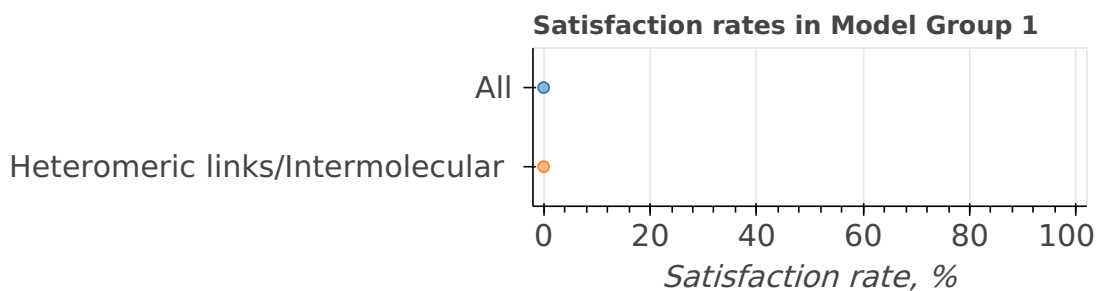
Satisfaction of restraints

Satisfaction of restraints is calculated on a [restraint group](#) (a set of crosslinking restraints applied collectively in the modeling) level. Satisfaction of a restraint group depends on satisfaction of individual restraints in the group and the conditionality (all/any). A restraint group is considered satisfied, if the condition was met in at least one model of the model group/ensemble. The number of measured restraints can be smaller than the total number of restraint groups if crosslinks involve non-modeled residues. Only deposited models are used for validation right now.

State group	State	Model group	# of Deposited models/Total	Restraint group type	Satisfied (%)	Violated (%)	Count (Total=1)
1	1	1	1/1	All	0.00	100.00	1
				Heteromeric links/Intermolecular	0.00	100.00	1

Per-model satisfaction rates in ensembles

Every point represents one model in a model group/ensemble. Where possible, boxplots with quartile marks are also plotted.



Fit of model to data used for validation ?

Validation for this section is under development.

The development of integrative model validation metrics, implementation of a model validation pipeline, and creation of a validation report for integrative structures are funded by NSF awards to the [PDB-IHM team](#) (DBI-1756248, DBI-2112966, DBI-2112967, DBI-2112968, and DBI-1756250) and awards from NSF, NIH, and DOE to the [RCSB PDB](#) (DBI-2321666, R01GM157729, and DE-SC0019749). The PDB-IHM team and members of the [Sali lab](#) contributed model validation metrics and software packages.

Dr. Jill Trewhella, Dr. Dina Schneidman, and members of the [SASBDB](#) repository are acknowledged for their advice and support in implementing SAS validation methods. Team members from the labs of Dr. Juri Rappsilber, Dr. Alexander Leitner, Dr. Andrea Graziadei, and members of [PRIDE](#) database are acknowledged for their advice and support in implementing crosslinking-MS validation methods. We are grateful to Dr. Shruthi Viswanath for discussions about uncertainty assessment of integrative structural models.

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