Ligand Binding Site Assessment

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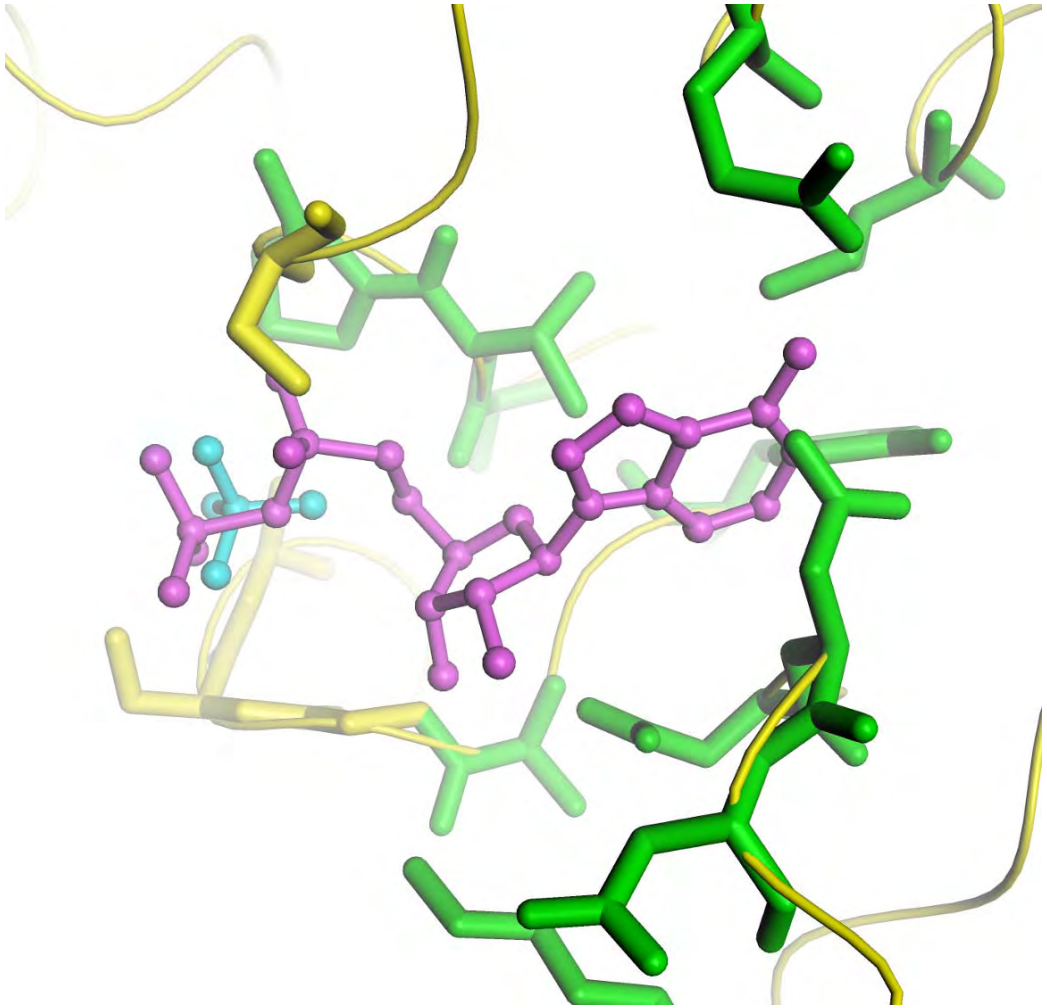
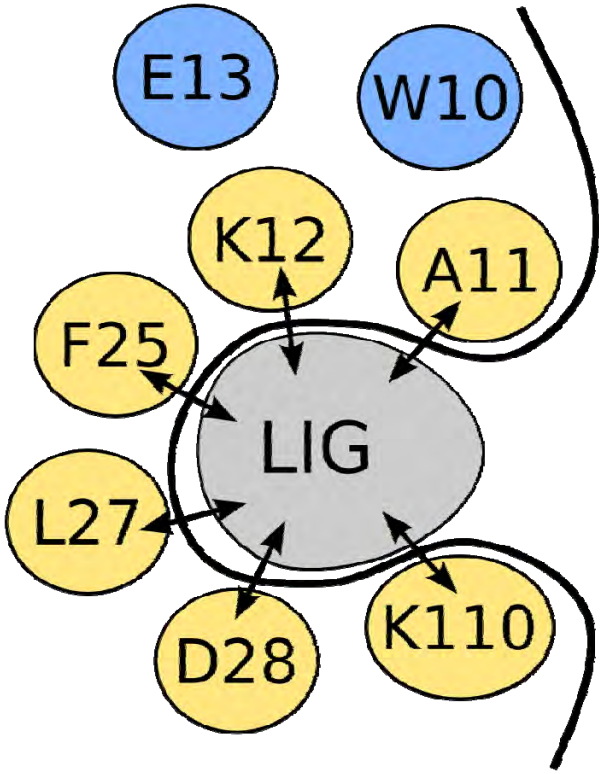
What exactly is the CASP LB question?

- Prediction of residues binding biologically relevant ligands in target proteins:





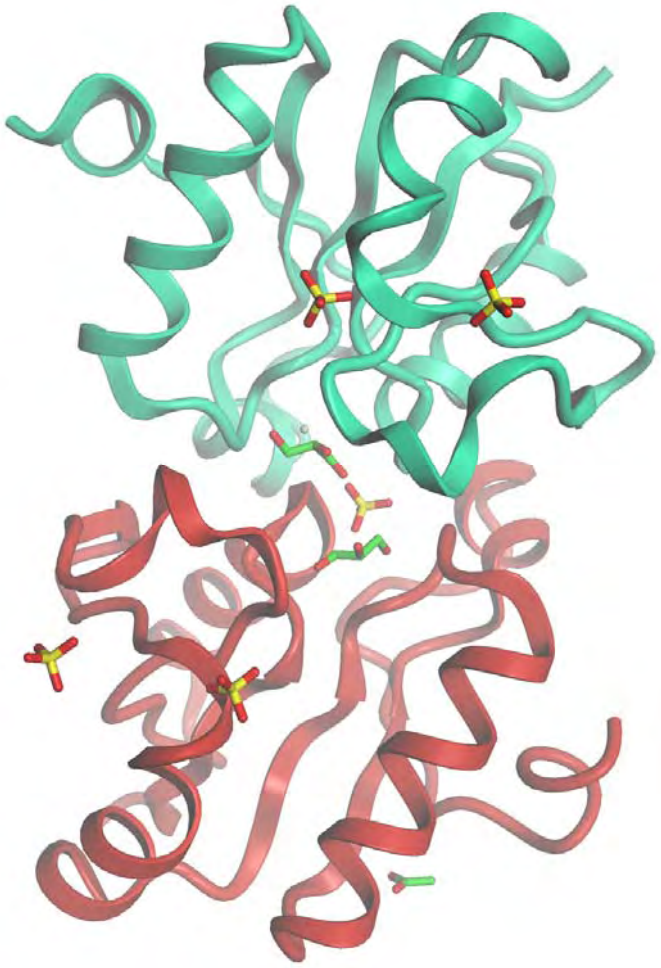
Binding site definition

- Residues with atoms within a certain distance to ***biologically relevant*** ligand atoms:

$$d_{i,j} \leq r_i + r_j + c \quad with \quad \left\{ \begin{array}{l} \mathrm{d_{i,j}} : \mathrm{distance} \\ \mathrm{r_x} : \mathrm{vdW\ \ radius} \\ \mathrm{c} : \mathrm{cutoff} \end{array} \right\}$$

- Assessment of biological relevance of ligands based on
  - SwissProt annotation
  - Scientific literature
  - Homologues structures
- Only structures with at least one biologically relevant ligand were used for scoring. (No "empty" targets).

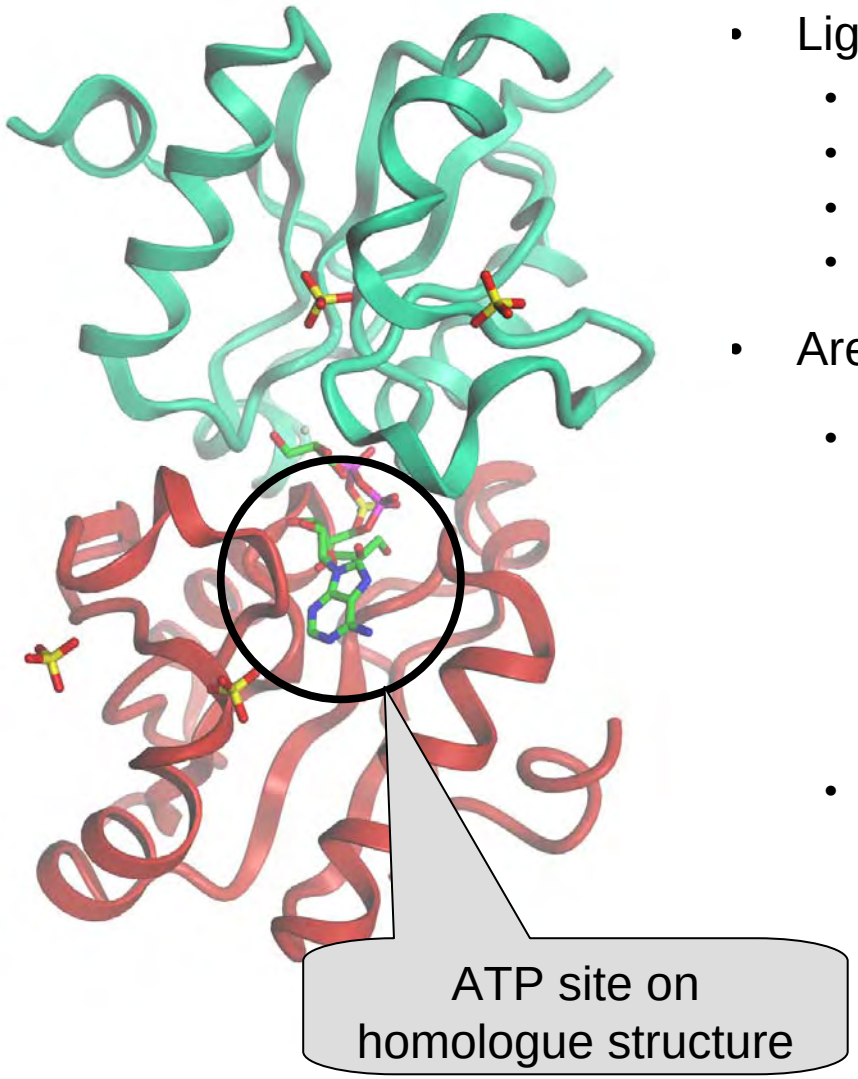
Binding site definition in detail ….



- Example: **T0622** (PDB: 3NKL)
- Ligands in experimental structure:
  - ACETIC ACID CH_3COOH
  - CHLORIDE ION Cl
  - GLYCEROL $C_3O_3H_8$
  - SULFATE ION SO_4
- Are any of these ligands biologically relevant?
  - UDP-D-Quinovosamine 4-Dehydrogenase from *Vibrio fischeri:*

    UDP-N-acetyl-D-glucosamine <=> UDP-2-acetamido-2,6-dideoxy-β-L-arabino-hex-4-ulose + H2O
  - Crystallization buffer: 0.2 M Ammonium sulfate, 0.1 M HEPES pH 7.5, 25 %w/v Polyehtlyene glycol 3,350

Binding site definition in detail ….



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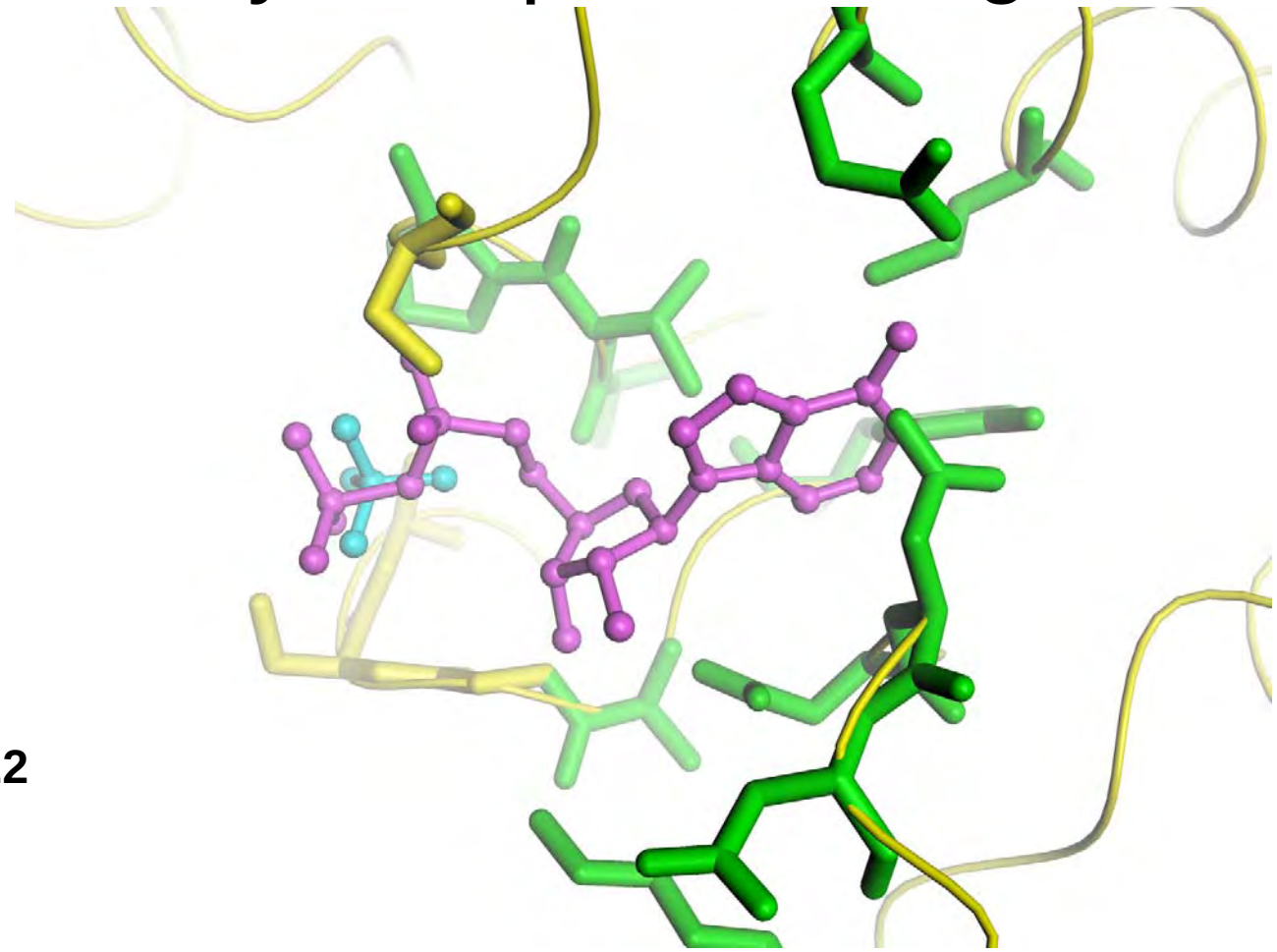
Partially occupied binding sites



T0622

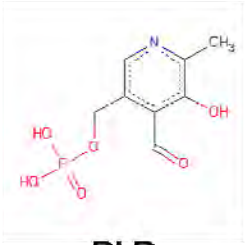
Ligand present in structure: SO_4 *(*cyan, ball & sticks)

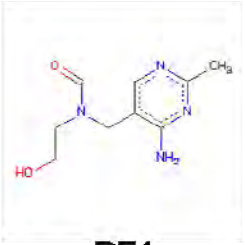
→ *partial binding site around SO_4 (*yellow, sticks)

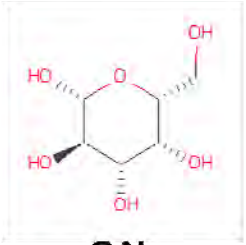
Biological relevant ligand: *NTP (*magenta, ball & sticks)

→ *extended binding site:* (yellow and green, sticks)

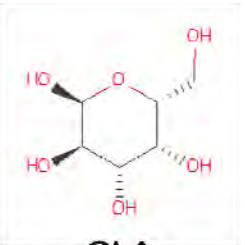
Ligands

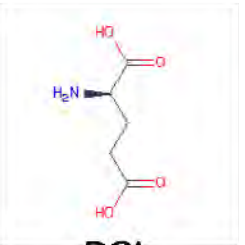

PLP

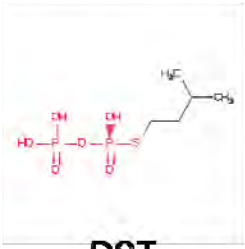

PF1

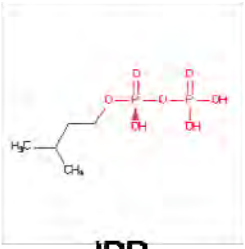

GAL

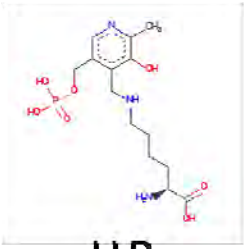

PEG


GLA

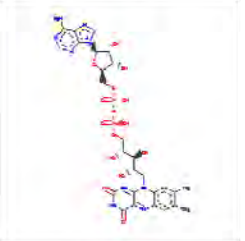

DGL


DST

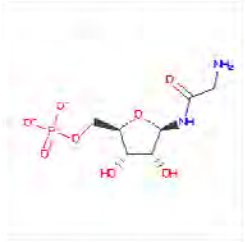

IPR

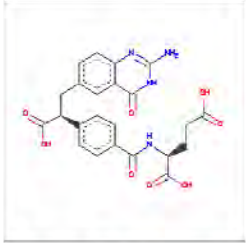

LLP

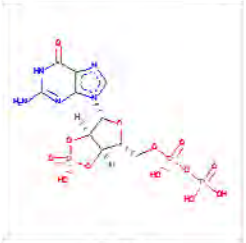

ANP

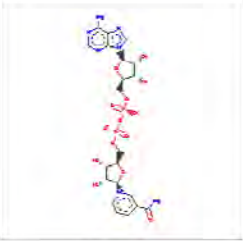

FAD

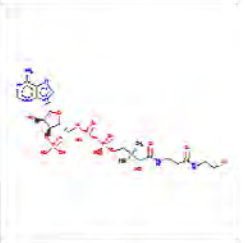

BES

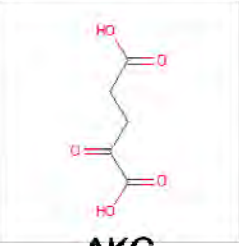

GAR

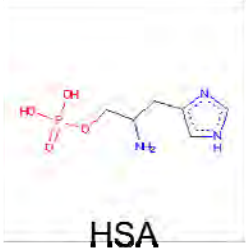

NHS


GPX

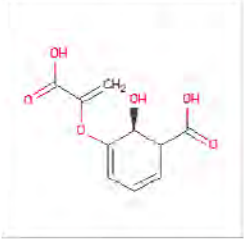

NAD

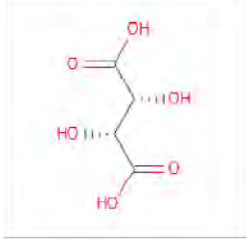

COA

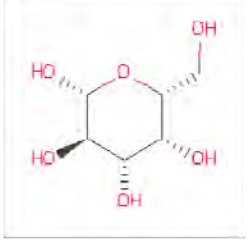

AKG

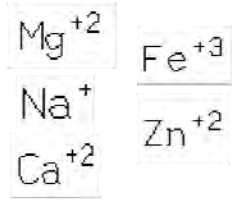

HSA


STE


ISC


TLA


GAL



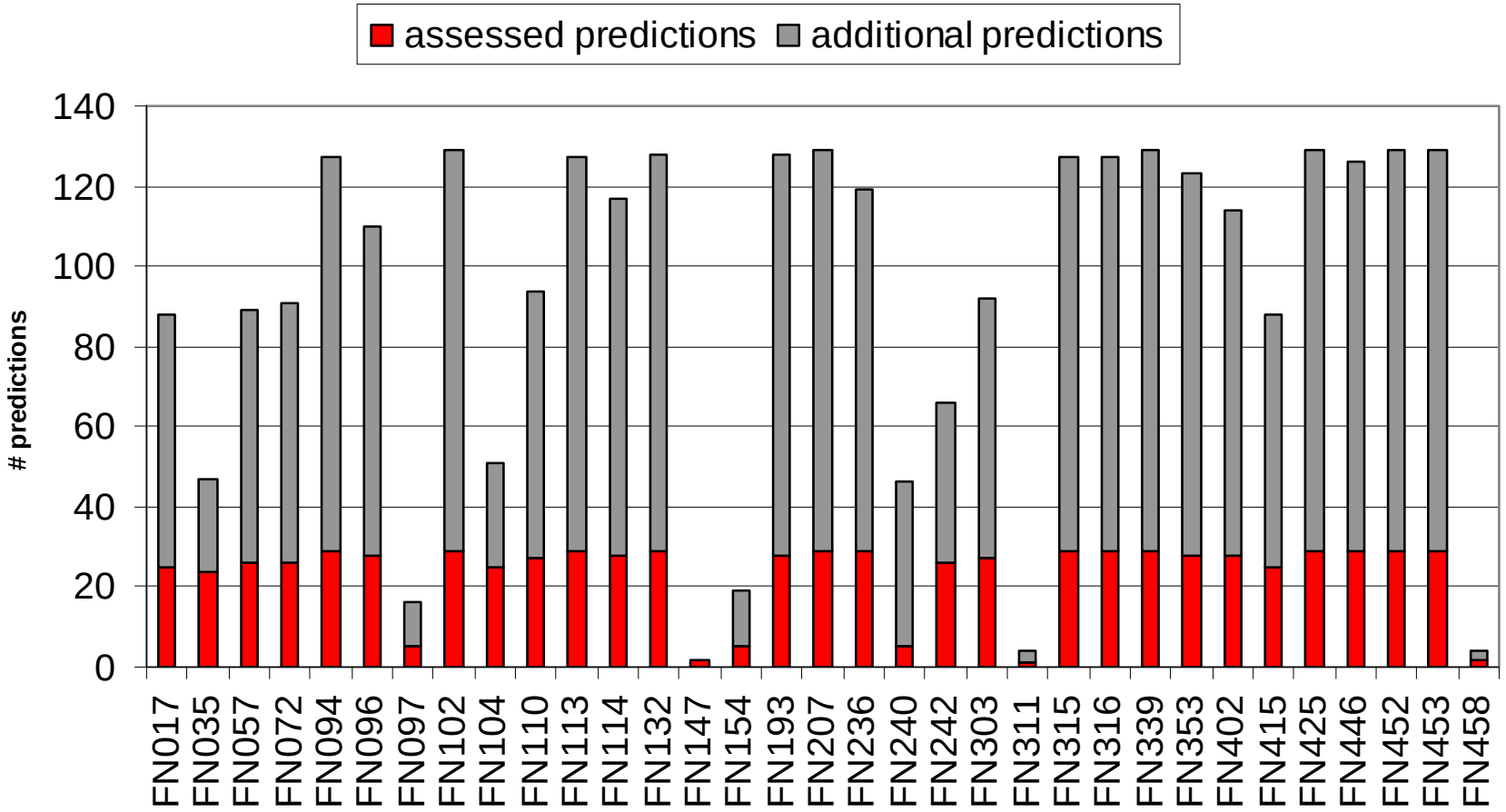
CASP9 LB in numbers

- 33 participating groups
  - 15 Server groups
  - 18 Human groups
- #1 predictions: 3'044
- 29 targets with ligands
  - 18 organic ligands (non-metal)
  - 8 metal ion ligands
  - 3 targets with both types
- Binding site type:
  - 22 ligands bound to single chain
  - 7 binding sites in protein-protein interfaces

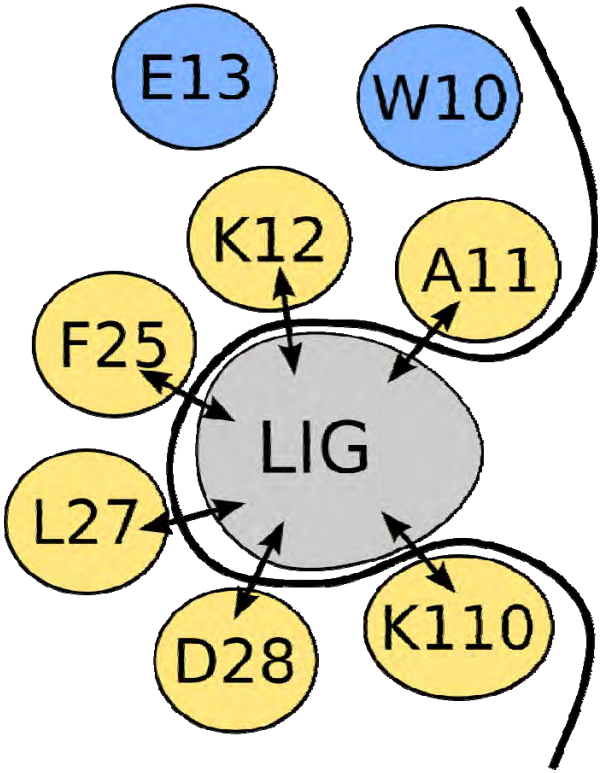
Target	PDB	Ligand	Full Ligand	Class	Interface	CASP Category
T0515	3MT1	SO4	PLP, LYS	Non-metal	A-B	TBM
T0516	3NO6	IMD	PF1	Non-metal		TBM
T0518	3NMB	NA		Metal		TBM
T0521	3MSE	CA, CA		Metal		TBM
T0524	3MWX	GOL	GAL	Non-metal		TBM
T0526	3NRE	PEG	GLA	Non-metal		TBM
T0533	3MWB	PHE		Non-metal	A-B	TBM
T0539	2L0B	ZN, ZN		Metal		TBM
T0547	3NZP	PLP	PLP, LYS	Non-metal	A-B	TBM
T0548	3NNQ	ZN		Metal		TBM
T0565	3NPF	CSA	DGL, ALA	Non-metal		TBM
T0570	3NO3	MG, GOL		Metal, Non-metal		TBM
T0584	3NF2	SO4	DST, IPR	Non-metal		TBM
T0585	3NE8	ZN		Metal		TBM
T0591	3NRA	LLP		Non-metal	A-B	TBM
T0597	3NIE	ANP		Non-metal		TBM
T0599	3OS6	SO4	ISC	Non-metal		TBM
T0604	3NLC	FAD		Non-metal		TBM / FM
T0607	3PFE	ZN	ZN, BES	Metal, Non-metal		TBM
T0609	3OS7	TLA	GAL	Non-metal		TBM
T0613	3OBI	EDO	GAR, NHS	Non-metal		TBM
T0615	3NQW	MN, SO4	MN, GPX	Metal, Non-metal		TBM
T0622	3NKL	SO4	NAD	Non-metal		TBM
T0625	3ORU	ZN		Metal		TBM
T0629	2XGF	FE, FE, FE, FE, FE, FE, FE		Metal	A-B-C	FM
T0632	3NWZ	COA		Non-metal	A-B-C	TBM
T0635	3N1U	CA		Metal		TBM
T0636	3P1T	AKG	HSA, PLP	Non-metal	A-B	TBM
T0641	3NYI	STE		Non-metal		TBM

CASP9 LB in numbers

- Number of predicted targets per group:



LB CASP format definition



Correct answer:

```
11, 12,      25, 27, 28,          110
```

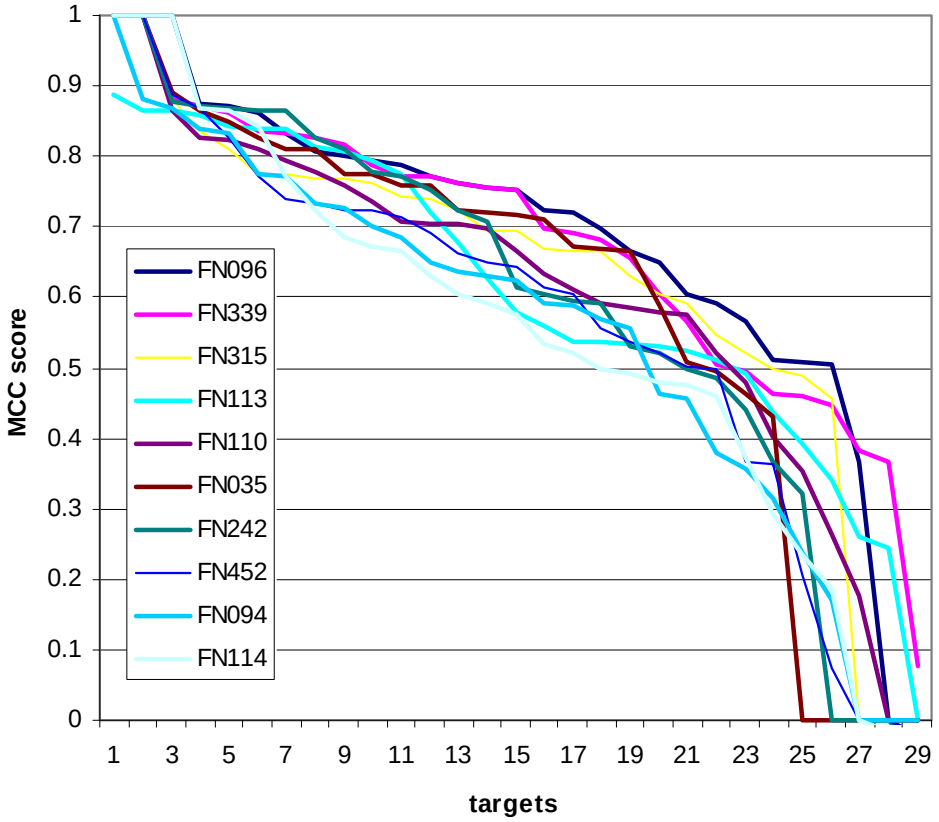
Example prediction:

```
11, 12, 13,      27, 28, 30, 31
```

→ **MCC Score**: `0.597`

MCC scores of top 10 groups

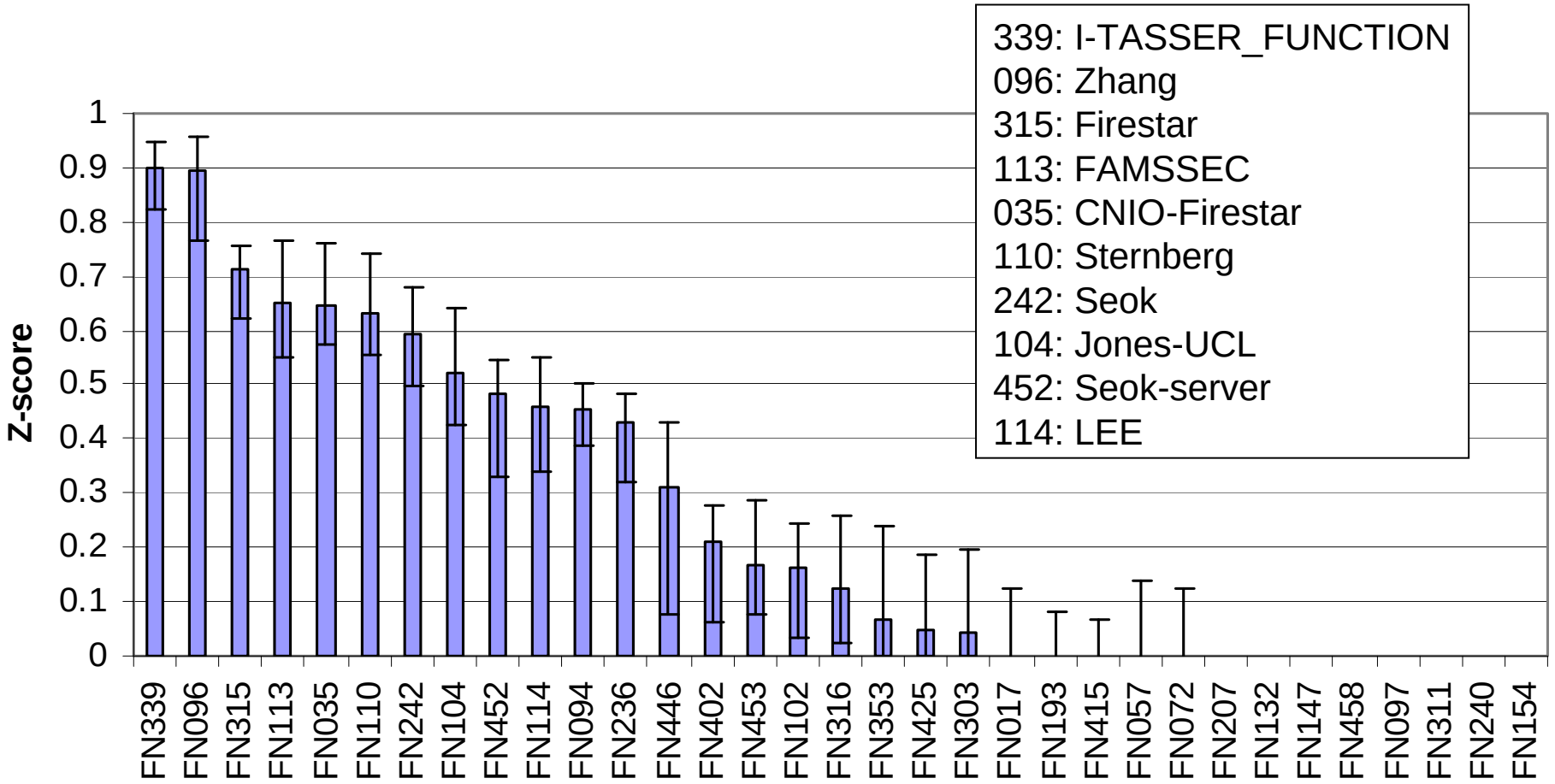
	FN339	FN096	FN315	FN113	FN035	FN110	FN242	FN104	FN452	FN114
T0515	0.68	0.65	0.74	0.58	0.71	0.58	0.60	0.78	0.74	0.66
T0516	0.84	0.87	0.72	0.84	0.00	0.18	0.72	0.63	0.72	0.48
T0518	0.38	-0.02	0.00	0.25	0.00	0.00	0.32	0.00	0.00	-0.02
T0521	0.08	0.67	0.52	0.53	0.76	0.57	-0.04	0.73	0.50	0.57
T0524	0.66	0.79	0.74	0.79	0.83	0.83	0.83	0.61	0.21	0.67
T0526	0.46	0.51	0.49	0.26	0.46	0.40	0.49	0.46	0.08	0.53
T0533	0.88	0.00	0.00	0.84	0.00	0.26	0.00	0.00	0.65	0.00
T0539	1.00	1.00	0.88	0.68	0.00	0.58	1.00	1.00	1.00	1.00
T0547	0.77	0.81	0.69	0.56	0.81	0.74	0.81	0.77	0.73	0.68
T0548	0.69	1.00	1.00	0.81	1.00	1.00	1.00	0.00	0.89	1.00
T0565	0.86	0.86	0.81	0.54	0.81	0.81	0.00	0.32	-0.03	-0.03
T0570	0.87	0.87	0.77	0.78	0.77	0.61	0.61	0.61	0.61	0.61
T0584	0.75	0.75	0.69	0.54	0.76	0.70	0.44	0.48	0.50	0.48
T0585	0.77	0.77	0.66	0.54	0.66	0.66	0.77	0.77	0.77	0.77
T0591	0.76	0.76	0.84	0.72	0.89	0.79	0.87	0.88	0.87	0.87
T0597	0.70	0.70	0.77	0.52	0.72	0.71	0.71	0.62	0.73	0.49
T0599	0.83	0.80	0.78	0.39	0.78	0.71	0.88	0.48	0.83	0.19
T0604	0.45	0.51	0.46	0.34	0.51	0.52	0.52	0.56	0.52	0.46
T0607	0.50	0.59	0.59	0.84	0.50	0.59	0.59	0.53	0.54	0.59
T0609	0.82	0.72	0.55	0.63	0.59	0.78	0.78	0.59	0.69	0.73
T0613	0.57	0.57	0.61	0.89	0.72	0.48	0.53	0.70	0.56	0.29
T0615	0.50	0.50	0.67	0.51	0.67	0.36	0.50	0.43	0.36	0.50
T0622	0.76	0.76	0.76	0.49	0.85	0.76	0.87	0.49	0.64	0.37
T0625	1.00	1.00	1.00	0.86	1.00	0.86	0.86	0.00	1.00	0.86
T0629	0.37	0.37	0.00	0.00	0.00	0.00	0.37	0.37	0.37	0.52
T0632	0.46	0.72	0.50	0.44	0.43	0.63	0.00	0.73	0.00	0.23
T0635	0.60	0.60	0.77	0.86	0.86	1.00	0.86	1.00	0.66	1.00
T0636	0.79	0.79	0.63	0.81	0.67	0.70	0.61	0.74	0.61	0.63
T0641	0.83	0.83	0.67	0.86	0.72	0.82	0.75	0.50	0.72	0.84
aver	*0.68*	*0.68*	*0.63*	*0.61*	*0.60*	*0.61*	*0.59*	*0.54*	*0.57*	*0.55*



Scoring Method

- Scores:
  - Matthews correlation coefficient (MCC)
  - Z-Scores based on MCC
- Averaging:
  - normalized by total number of targets with ligands
- Significance:
  - t-Test on MCC scores
  - 1/4 leave out boot strap

Mean MCC Z-scores for all targets



Scoring Stability & Significance

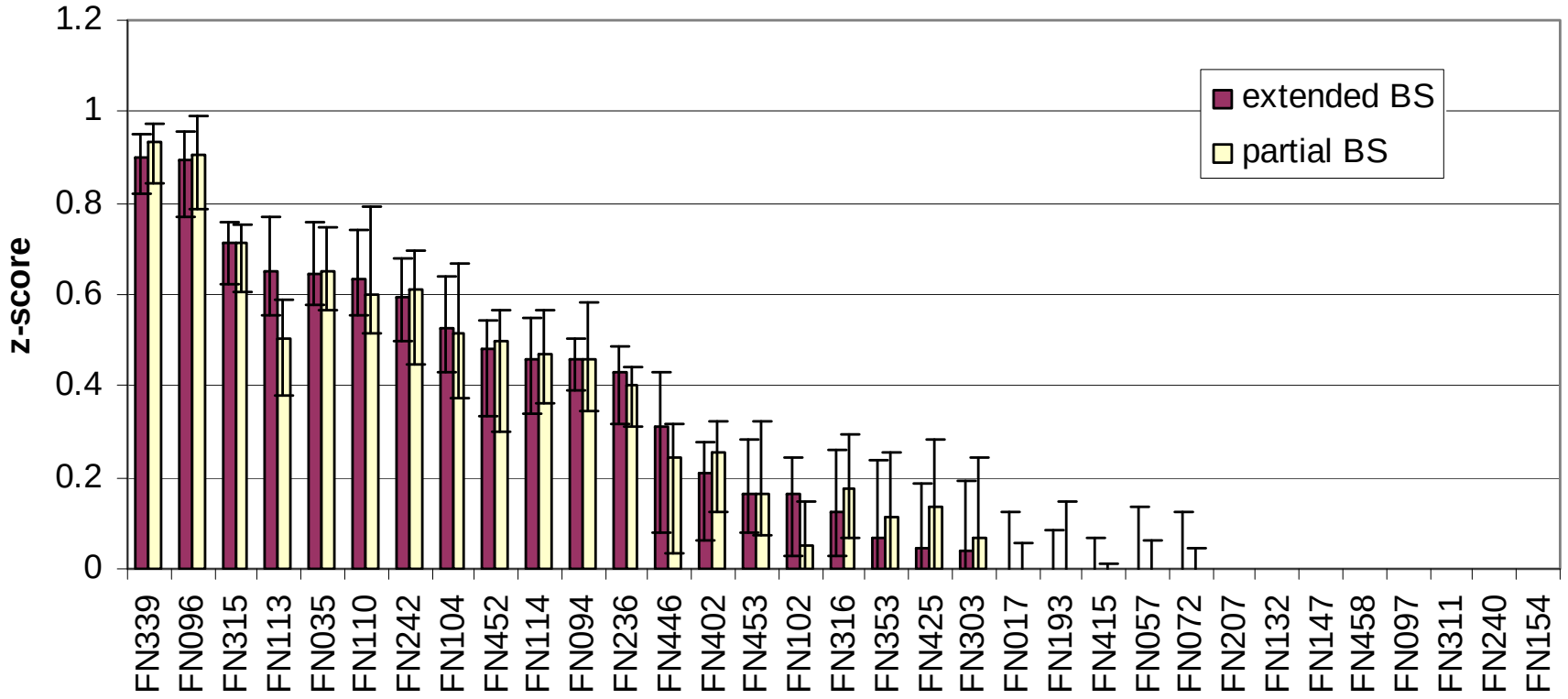
Ranking is "relatively" stable vs.

- Cut-off distance for inclusion of residues into binding site definition
- Assessment of full vs. partial binding site
- Binding site distance test ("McGuffin score")

But, ranking is not stable against:

- Target composition. In boot strap analysis, the top two groups are always ranking best, ranks of following groups may change +/- 6 ranks with different targets
- In t-Test, all differences insignificant.

Assessment of partial vs. extended sites

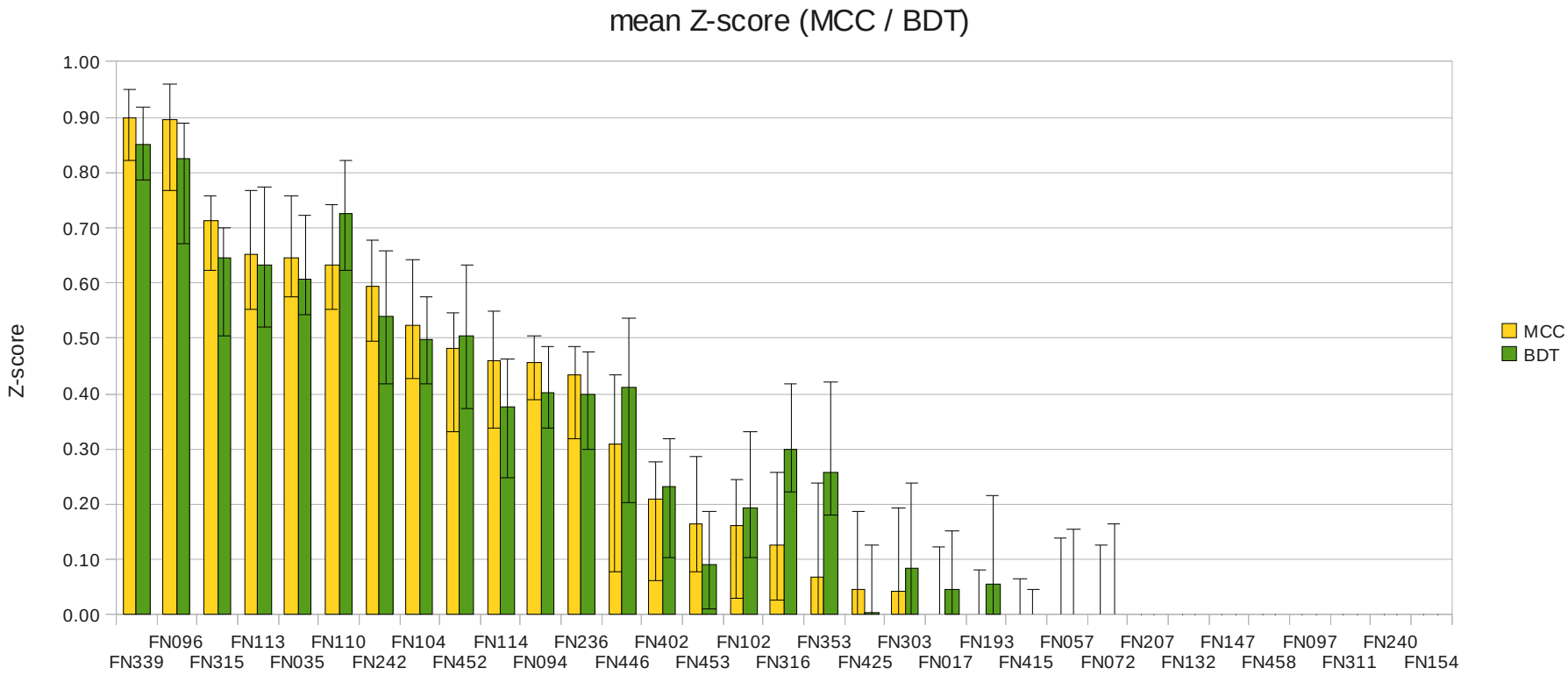


- No significant differences between partial binding site (blue) and full binding site (yellow)

Exact vs. "fuzzy" binding site scoring

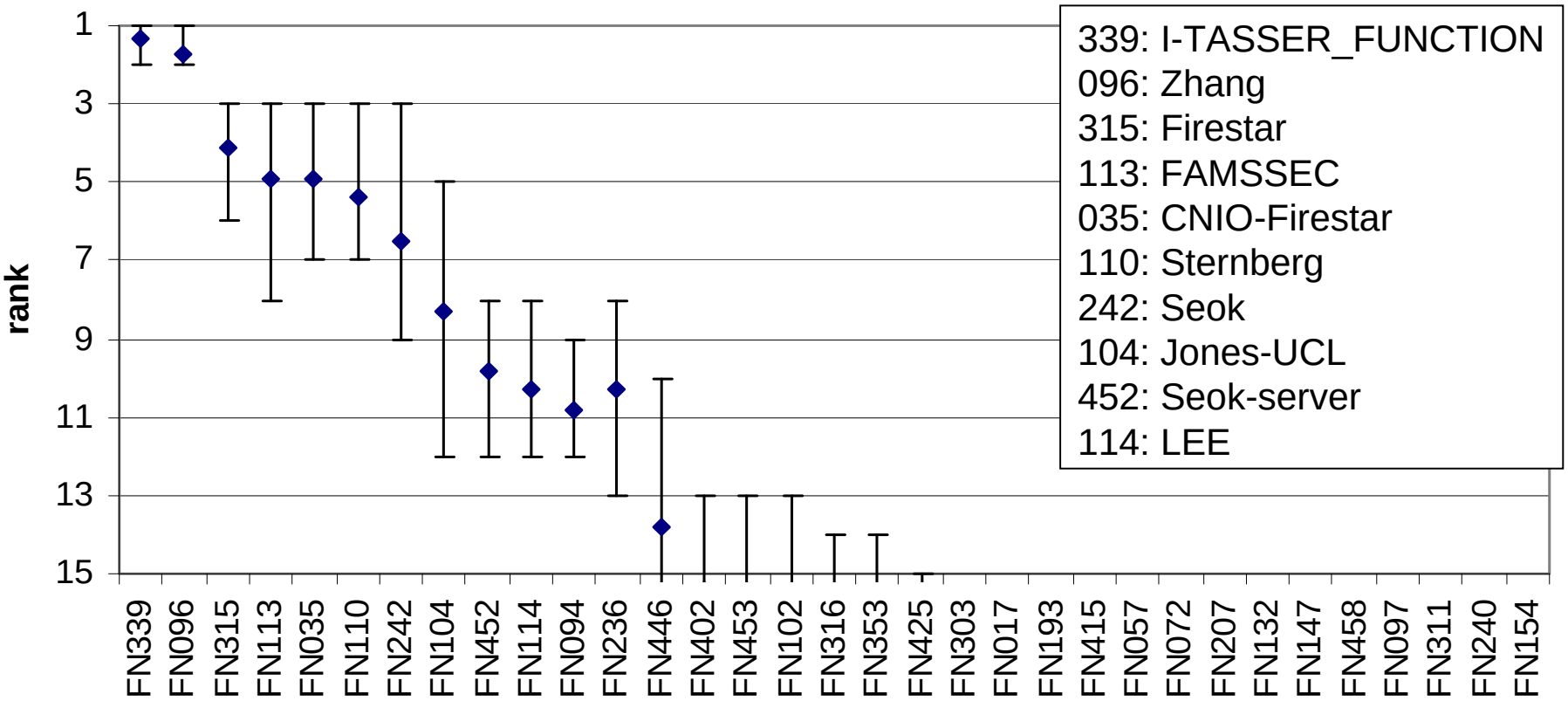
Binding site distance test (BDT) takes the relative distance to ligand binding site into account [1]

→ Not much difference



[1] D.B. Roche, S.J. Tetchner, L.J. McGuffin, The binding site distance test score, *Bioinformatics* (2010) 26(22): 2920-2921

Mean ranking of groups in bootstrap test



Error bars: min / max rank in boot strapped scoring

t-Test

(for MCC averaged over all targets)

	FN339	FN096	FN315	FN113	FN035	FN110	FN242	FN104	FN452	FN114	FN094	FN236	FN446	FN402	FN453	FN102	FN316	FN353	FN425	FN303	FN017	FN193	FN415	FN057	FN072	FN207	FN132	FN147	FN458	FN097	FN311	FN240	FN154
FN339		0.91	0.31	0.11	0.27	0.17	0.11	0.05	0.02	0.05	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN096	0.91		0.03	0.15	0.13	0.05	0.09	0.02	0.04	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN315	0.31	0.03		0.64	0.50	0.48	0.43	0.14	0.22	0.11	0.07	0.08	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN113	0.11	0.15	0.64		0.90	0.97	0.79	0.30	0.40	0.29	0.29	0.21	0.03	0.04	0.03	0.02	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN035	0.27	0.13	0.50	0.90		0.86	0.90	0.42	0.61	0.43	0.42	0.37	0.19	0.03	0.05	0.05	0.05	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN110	0.17	0.05	0.48	0.97	0.86		0.80	0.30	0.48	0.27	0.24	0.21	0.10	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN242	0.11	0.09	0.43	0.79	0.90	0.80		0.45	0.54	0.33	0.41	0.26	0.17	0.01	0.03	0.04	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN104	0.05	0.02	0.14	0.30	0.42	0.30	0.45		0.73	0.89	0.85	0.95	0.53	0.38	0.17	0.44	0.22	0.10	0.06	0.15	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN452	0.02	0.04	0.22	0.40	0.61	0.48	0.54	0.73		0.74	0.81	0.68	0.25	0.16	0.12	0.21	0.05	0.05	0.05	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN114	0.05	0.01	0.11	0.29	0.43	0.27	0.33	0.89	0.74		0.98	0.87	0.48	0.11	0.14	0.27	0.13	0.02	0.09	0.03	0.03	0.01	0.02	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN094	0.03	0.00	0.07	0.29	0.42	0.24	0.41	0.85	0.81	0.98		0.91	0.34	0.19	0.07	0.24	0.10	0.05	0.02	0.06	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN236	0.03	0.01	0.08	0.21	0.37	0.21	0.26	0.95	0.68	0.87	0.91		0.50	0.09	0.18	0.28	0.15	0.02	0.07	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FN446	0.01	0.01	0.05	0.03	0.19	0.10	0.17	0.53	0.25	0.48	0.34	0.50		0.71	0.47	0.74	0.42	0.29	0.22	0.27	0.06	0.05	0.03	0.04	0.04	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00
FN402	0.00	0.00	0.01	0.04	0.03	0.01	0.01	0.38	0.16	0.11	0.19	0.09	0.71		0.72	0.99	0.71	0.40	0.38	0.10	0.15	0.12	0.10	0.06	0.06	0.11	0.05	0.00	0.00	0.00	0.00	0.00	0.00
FN453	0.00	0.00	0.00	0.03	0.05	0.02	0.03	0.17	0.12	0.14	0.07	0.18	0.47	0.72		0.66	1.00	0.60	0.63	0.74	0.42	0.24	0.33	0.21	0.20	0.22	0.07	0.00	0.00	0.00	0.00	0.00	0.00
FN102	0.00	0.00	0.00	0.02	0.05	0.02	0.04	0.44	0.21	0.27	0.24	0.28	0.74	0.99	0.66		0.66	0.42	0.40	0.38	0.26	0.16	0.20	0.13	0.12	0.13	0.06	0.00	0.00	0.00	0.00	0.00	0.00
FN316	0.00	0.00	0.00	0.00	0.05	0.02	0.04	0.22	0.05	0.13	0.10	0.15	0.42	0.71	1.00	0.66		0.61	0.64	0.74	0.40	0.24	0.31	0.22	0.21	0.23	0.06	0.00	0.00	0.00	0.00	0.00	0.00
FN353	0.00	0.00	0.00	0.01	0.04	0.01	0.01	0.10	0.05	0.02	0.05	0.02	0.29	0.40	0.60	0.42	0.61		0.92	0.97	0.68	0.39	0.58	0.42	0.41	0.40	0.22	0.00	0.00	0.00	0.00	0.00	0.00
FN425	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.06	0.05	0.09	0.02	0.07	0.22	0.36	0.63	0.40	0.64	0.92		0.87	0.69	0.46	0.55	0.42	0.40	0.39	0.17	0.00	0.00	0.00	0.00	0.00	0.00
FN303	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.15	0.05	0.03	0.06	0.02	0.27	0.10	0.74	0.38	0.74	0.97	0.87		0.60	0.41	0.48	0.40	0.37	0.37	0.24	0.00	0.00	0.00	0.00	0.00	0.00
FN017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.01	0.02	0.06	0.15	0.42	0.26	0.40	0.68	0.69	0.60		0.61	0.14	0.44	0.37	0.43	0.27	0.00	0.00	0.00	0.00	0.00	0.00
FN193	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.05	0.12	0.24	0.16	0.24	0.39	0.46	0.41	0.61		0.79	0.99	0.97	0.86	0.62	0.00	0.00	0.00	0.00	0.00	0.00
FN415	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.01	0.03	0.10	0.33	0.20	0.31	0.58	0.55	0.48	0.14	0.79		0.70	0.63	0.59	0.39	0.00	0.00	0.00	0.00	0.00	0.00
FN057	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.04	0.06	0.21	0.13	0.22	0.42	0.42	0.40	0.44	0.99	0.70		0.74	0.83	0.54	0.00	0.00	0.00	0.00	0.00	0.00
FN072	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.04	0.06	0.20	0.12	0.21	0.41	0.40	0.37	0.37	0.97	0.63	0.74		0.86	0.59	0.00	0.00	0.00	0.00	0.00	0.00
FN207	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.01	0.05	0.11	0.22	0.13	0.23	0.40	0.39	0.37	0.43	0.86	0.59	0.83	0.86		0.75	0.00	0.00	0.00	0.00	0.00	0.00
FN132	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.07	0.06	0.06	0.22	0.17	0.24	0.27	0.62	0.39	0.54	0.59	0.75		0.00	0.00	0.00	0.00	0.00	0.00
FN147	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.62	0.67	0.76	0.30	0.12
FN458	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62		0.94	1.00	0.40	0.11
FN097	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.94		0.96	0.24	0.06
FN311	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.76	1.00	0.96		0.47	0.25
FN240	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.40	0.24	0.47		0.04
FN154	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.11	0.06	0.25	0.04	

P-value: <0.05 (white), <0.1 and >0.05 (gray), >0.1 (black)

Scoring Stability & Significance

➔ **Two methods (339: I-TASSER_FUNCTION, 096: Zhang) are always ranked top.**

➔ ***Not enough targets to make any clear distinction between the other groups' performance.***

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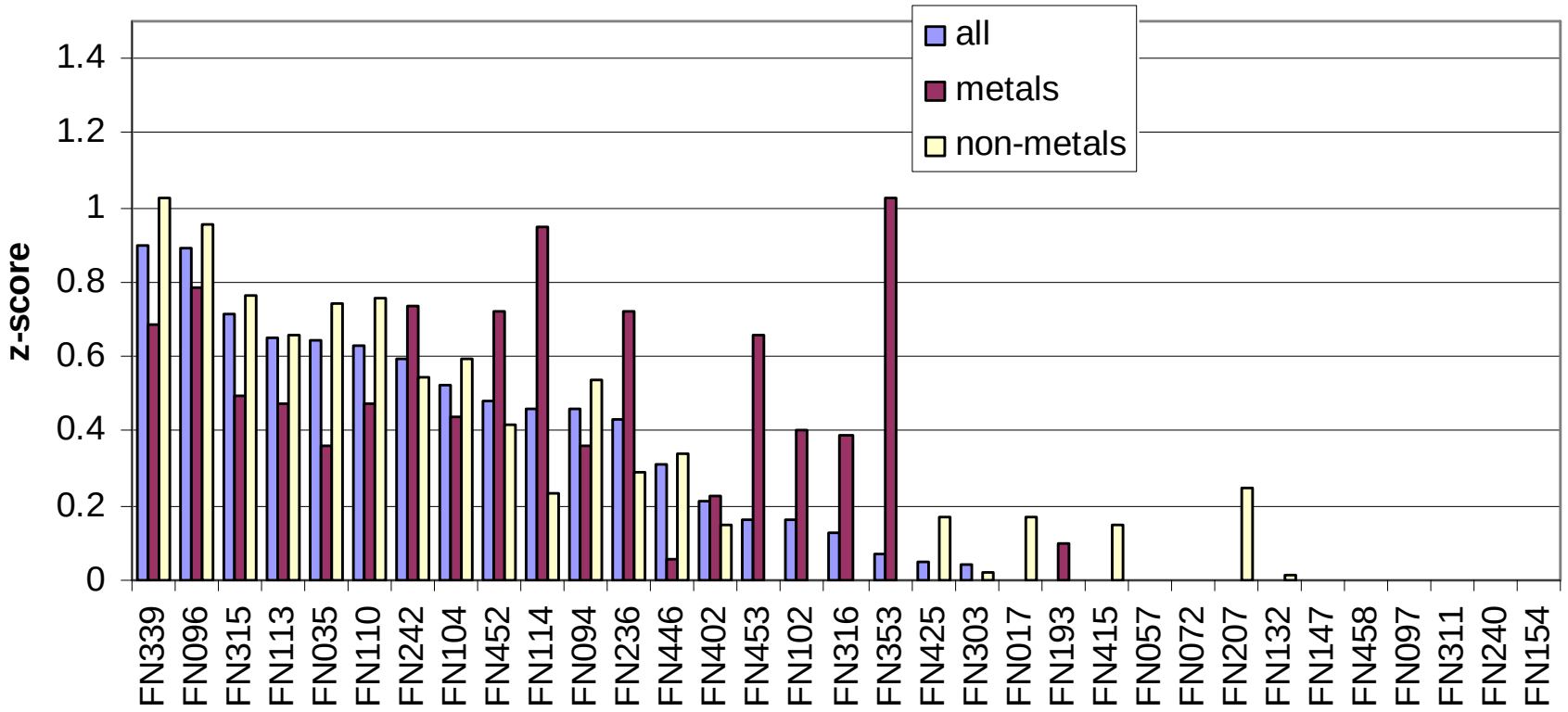
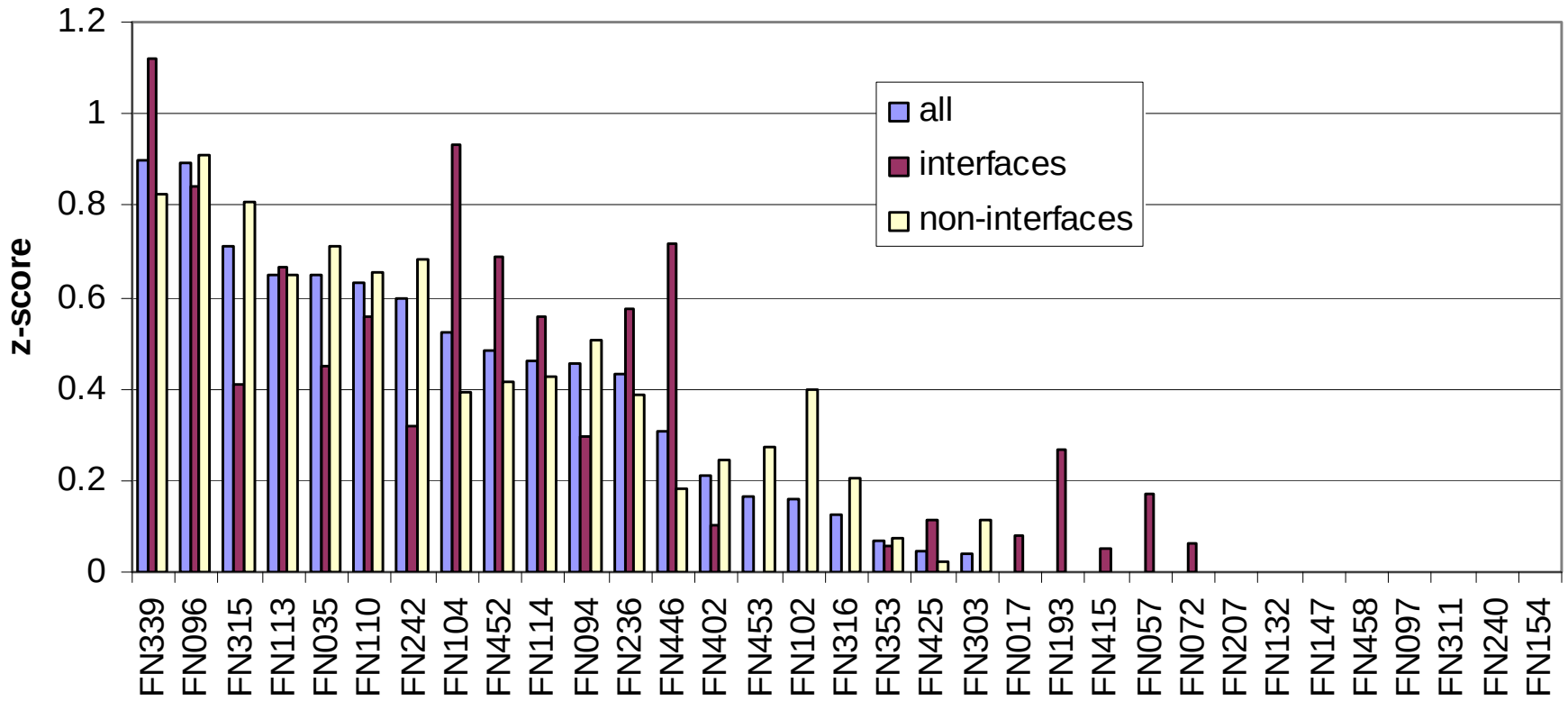
But are there some differences between groups …?

Prediction of Metal vs. Non-metal sites



Some groups (FN353, FN114) seem to perform "better" for metal ion binding sites (11).

Predictions of sites in interfaces



- Two groups (FN339, FN104) seem to perform "better" for predicting binding sites which are located at the interface of multiple chains (7).

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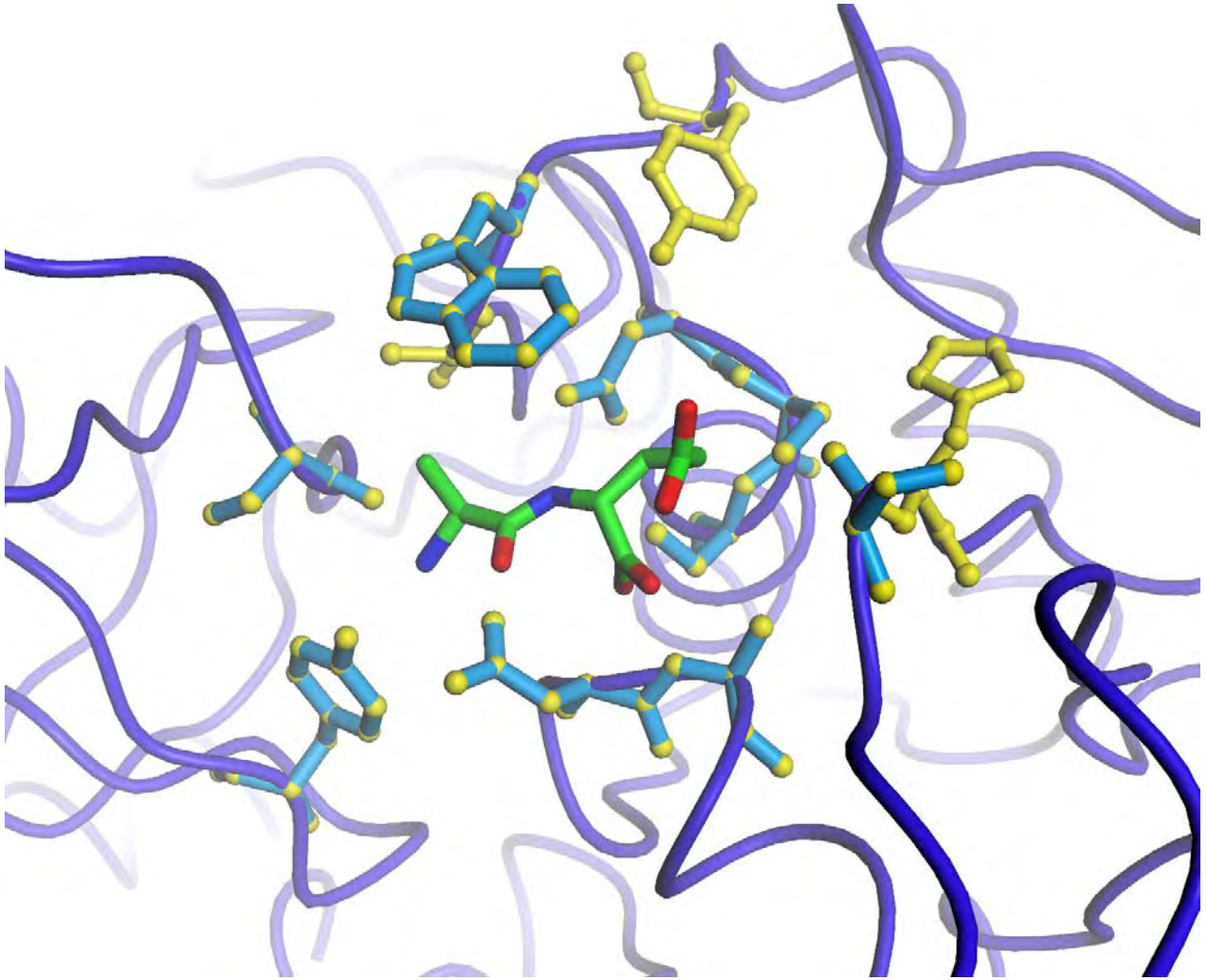
Examples

Example: T0565, FN096

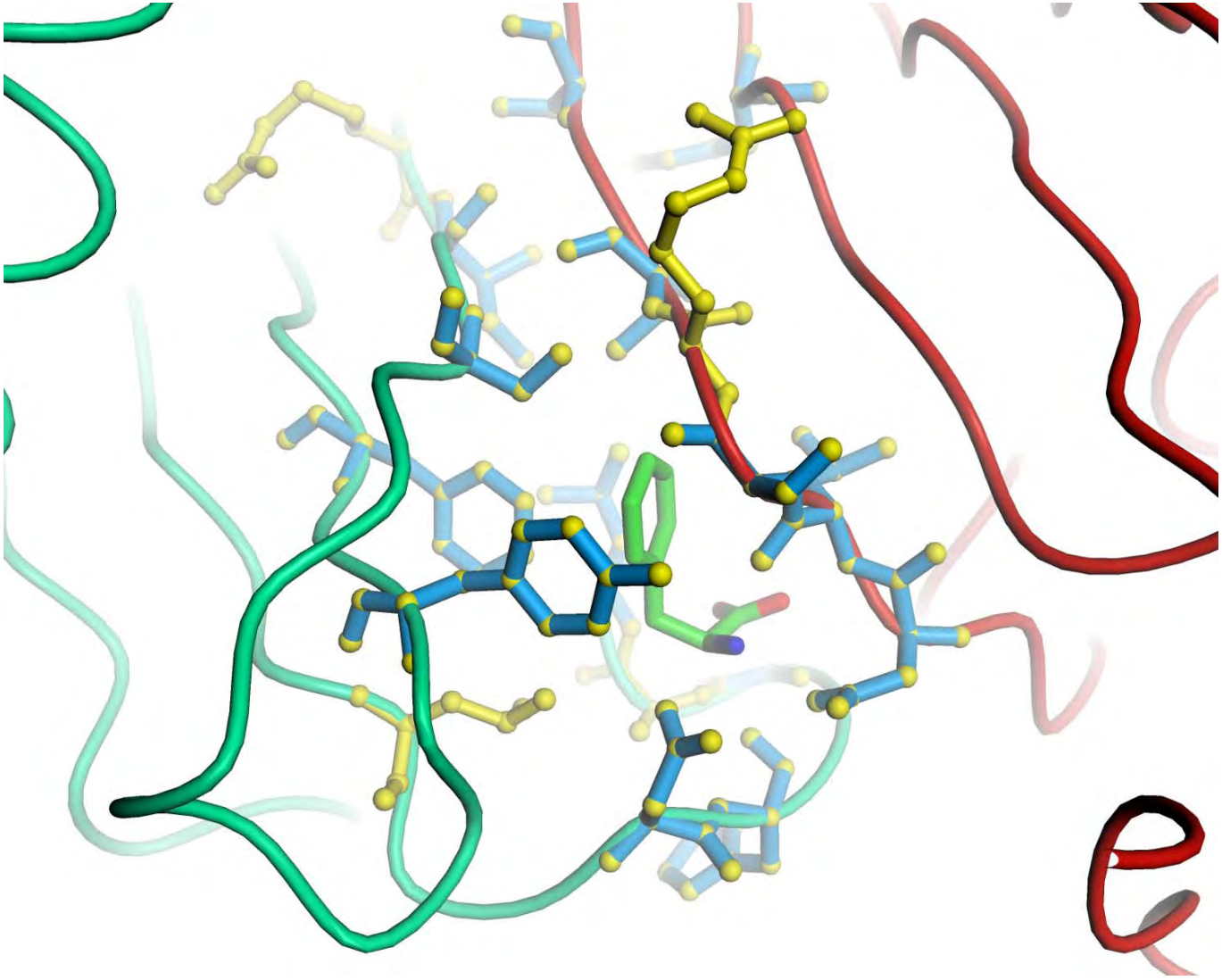
(cysteine endopeptidase with dipeptide ligand DGL,
MCC score: 0.86)



Ball&Stick: binding site definition (yellow), binding site prediction (blue)

Example: T0533, FN339

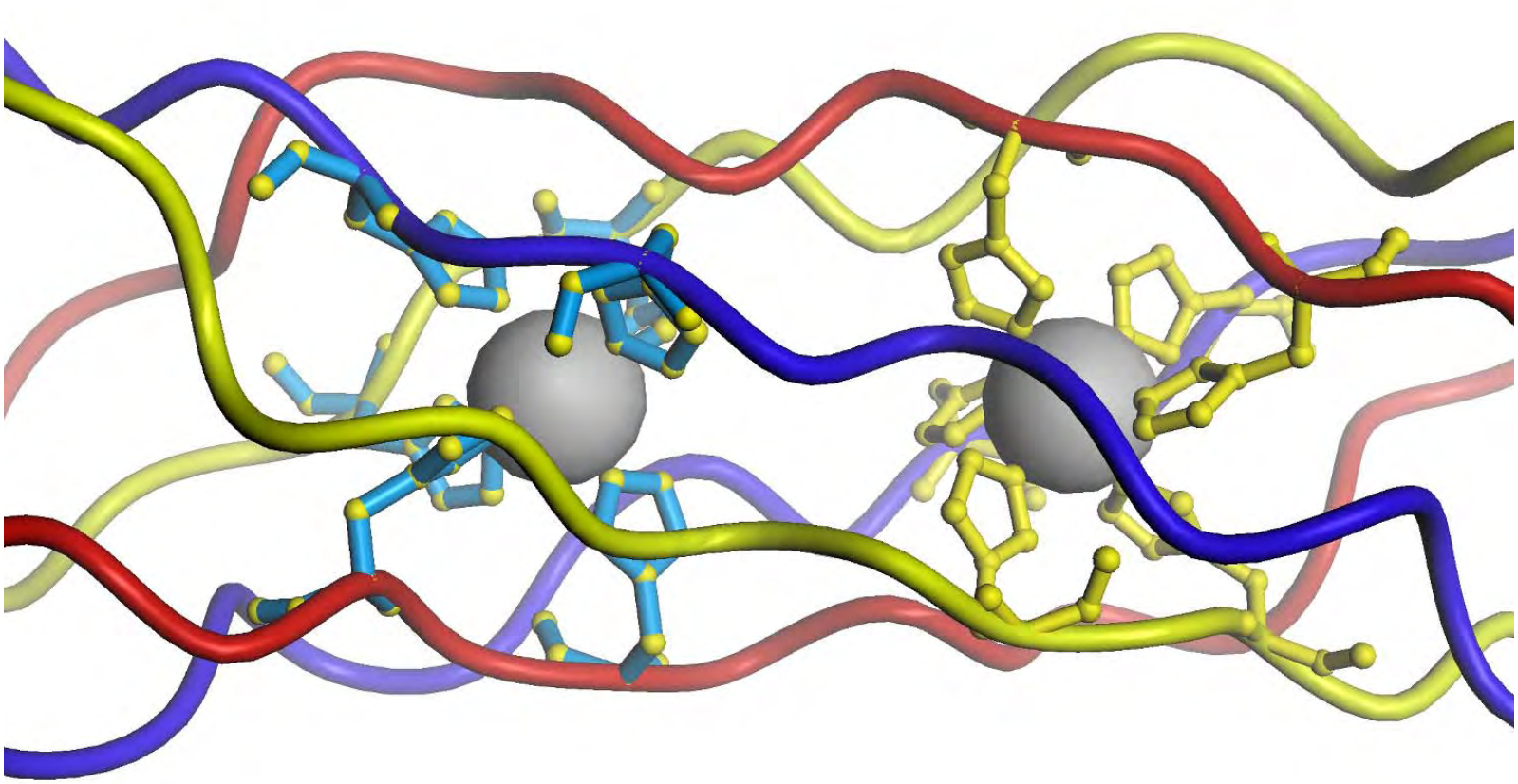
(dimeric structure where ligand binding site is located at the interface, MCC score: 0.88)



Ball&Stick: binding site definition (yellow), binding site prediction (blue)

Example: T0629, FN114

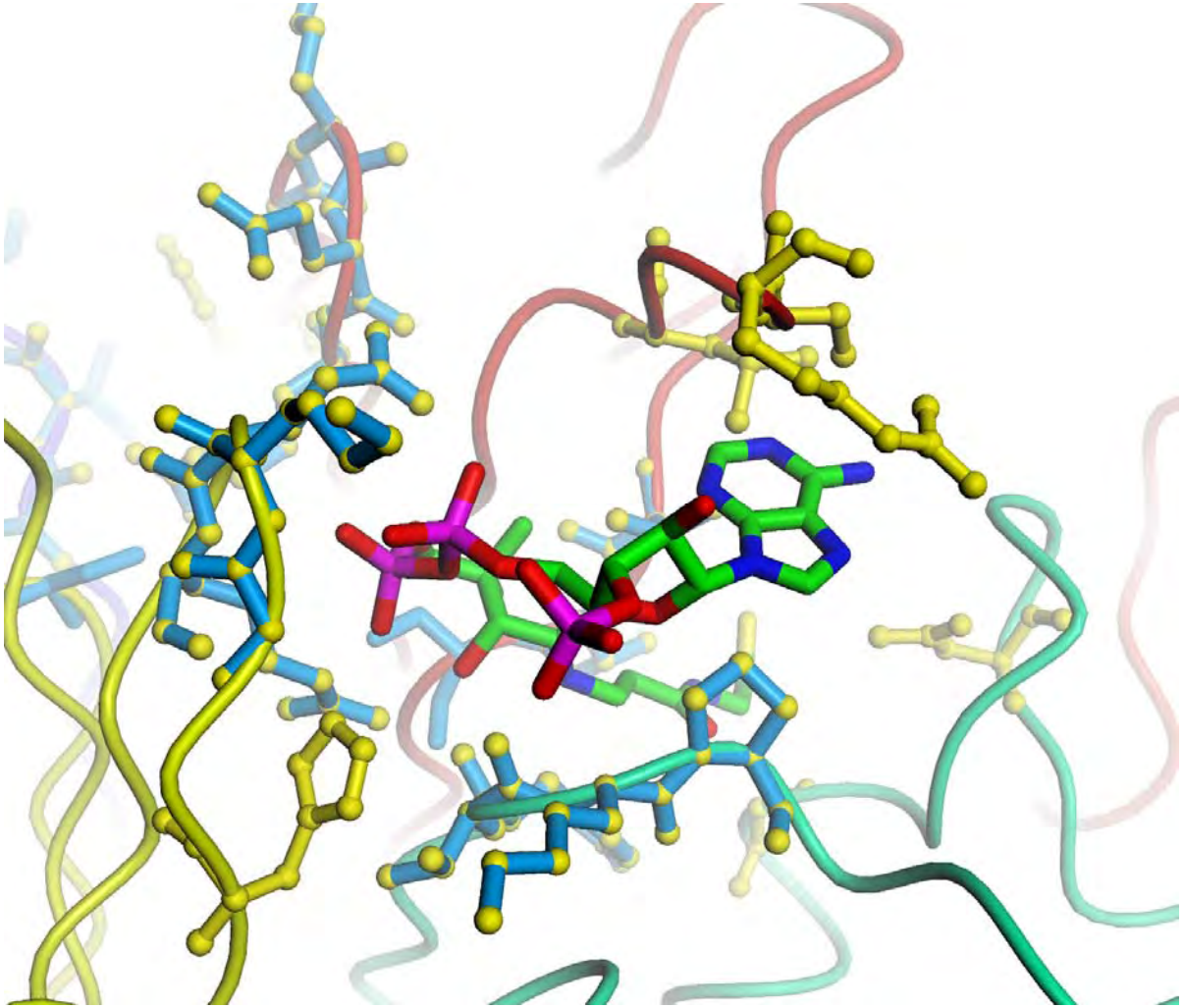
(challenging FM target with multiple metal binding sites, MCC score: 0.52)



Ball&Stick: binding site definition (yellow), binding site prediction (blue)

Example: T0632, FN104

(challenging target with ligand bound to 3 of 4 chains,
MCC score: 0.73)



Ball&Stick: binding site definition (yellow), binding site prediction (blue)

Acknowledgments

CASP9 LB predictors

Tobias Schmidt (Ligand Binding Site Assessment)

Jürgen Haas (Annotation Discussion)

Ursula Hinz (SwissProt, Annotation Discussion)

Tiziano Gallo Cassarino (Annotation Discussion)

CASP9 co-assessors: **Nick Grishin, Lisa Kinch, & Justin MacCallum**

CASP Organizers & Prediction Center: **John Moult, Anna Tramontano, Andriy Kryshtafovych, Krzysztof Fidelis**

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Round Table Discussion

Co-Chairs: Michael Sternberg & Torsten Schwede

Participants:

339: I-TASSER_FUNCTION / 096: Zhang

315: Firestar / 035: CNIO-Firestar

113: FAMSSEC

110: Sternberg

104: Jones-UCL (Interfaces)

114: LEE (metal binding sites)

Supplementary Material:

Binding site definition

Target	Partial bsite	Extended bsite
T0515	198, 199, 232, 233, 324	35, 37, 162, 198, 199, 230, 232, 233, 269, 273, 324, 328
T0516	44, 47, 48, 51, 113, 137, 141, 208, 211	44, 47, 48, 51, 113, 137, 138, 141, 167, 171, 174, 208, 211
T0518	132, 133, 134, 162, 164, 271, 273	132, 133, 134, 162, 164, 271, 273
T0521	48, 50, 52, 54, 59, 117, 121, 123, 128	48, 50, 52, 54, 59, 117, 121, 123, 128
T0524	73, 74, 177, 203, 230, 269, 271, 283	62, 63, 73, 74, 100, 101, 177, 203, 230, 269, 271, 283, 285
T0526	56, 83, 148, 173, 200, 241, 253	43, 56, 77, 83, 148, 173, 200, 241, 253
T0529	389, 390, 391, 533	389, 390, 391, 533
T0539	33, 36, 51, 53, 56, 59, 70, 73	33, 36, 51, 53, 56, 59, 70, 73
T0547	84, 86, 87, 132, 231, 233, 236, 273, 274, 320, 321, 322, 323, 483, 519	84, 86, 87, 132, 231, 233, 236, 273, 274, 320, 321, 322, 323, 452, 483, 484, 519
T0548	58, 62, 95, 98	58, 62, 95, 98
T0565	191, 193, 202, 203, 262, 263	54, 80, 191, 193, 194, 202, 203, 204, 221, 222, 262, 263
T0570	30, 59, 61, 123, 156, 158, 178, 222	30, 59, 61, 123, 156, 158, 178, 222
T0582	58, 60, 64, 94	58, 60, 64, 94
T0584	55, 58, 87, 104	55, 58, 87, 90, 91, 94, 103, 104, 155, 183, 184, 221, 248
T0585	13, 28, 82, 84, 115	13, 28, 82, 84, 115
T0591	109, 110, 111, 135, 185, 189, 217, 219, 251, 252, 260, 283	109, 110, 111, 135, 185, 189, 217, 219, 251, 252, 260, 283
T0597	36, 37, 38, 39, 40, 41, 42, 44, 57, 59, 73, 112, 114, 117, 120, 158, 160, 163, 174	36, 37, 38, 39, 40, 41, 42, 44, 57, 59, 73, 112, 114, 117, 120, 158, 160, 163, 174
T0599	213, 214, 215, 364, 377, 381	212, 213, 214, 215, 276, 304, 328, 347, 348, 362, 364, 377, 381
T0604	113, 114, 116, 117, 118, 137, 138, 166, 167, 170, 171, 172, 174, 175, 177, 178, 180, 241, 242, 243, 272, 273, 274, 277, 280, 352, 364, 365, 515, 516, 523, 524, 527	113, 114, 116, 117, 118, 137, 138, 166, 167, 170, 171, 172, 174, 175, 177, 178, 180, 241, 242, 243, 272, 273, 274, 277, 280, 352, 364, 365, 515, 516, 523, 524, 527
T0607	96, 129, 163, 190, 442	96, 129, 162, 163, 165, 190, 191, 205, 340, 410, 412, 413, 414, 442
T0609	67, 69, 108, 184, 288	67, 69, 80, 81, 108, 184, 245, 286, 288, 300
T0613	177, 178, 225, 229, 230	173, 174, 175, 176, 177, 178, 183, 192, 193, 194, 223, 225, 226, 229, 230
T0615	33, 36, 62, 63, 98, 102, 123, 127, 139, 147	26, 33, 36, 62, 63, 98, 102, 123, 127, 128, 130, 131, 139, 143, 147
T0622	10, 11, 12, 72	7, 9, 10, 11, 12, 33, 34, 35, 38, 69, 70, 71, 72, 77, 81
T0625	126, 143, 207	126, 143, 207
T0629	73, 75, 105, 107, 119, 121, 156, 158, 170, 172, 179, 181, 188, 190	73, 75, 105, 107, 119, 121, 156, 158, 170, 172, 179, 181, 188, 190
T0632	76, 83, 109, 110, 117, 118, 119, 120, 134, 136, 137, 138, 139, 164, 166, 167	76, 83, 109, 110, 117, 118, 119, 120, 134, 136, 137, 138, 139, 164, 166, 167
T0635	25, 27, 118	25, 27, 118
T0636	22, 47, 145, 172, 197, 301, 306, 313	22, 47, 75, 76, 145, 169, 171, 172, 194, 196, 197, 205, 206, 225, 301, 306, 313
T0641	30, 65, 66, 67, 96, 97, 127, 128, 129, 164, 166, 179, 204, 241, 272, 275, 279, 286	30, 65, 66, 67, 96, 97, 127, 128, 129, 164, 166, 179, 204, 241, 272, 275, 279, 286