Level density, experimental data status, problems

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Topics for discussion:

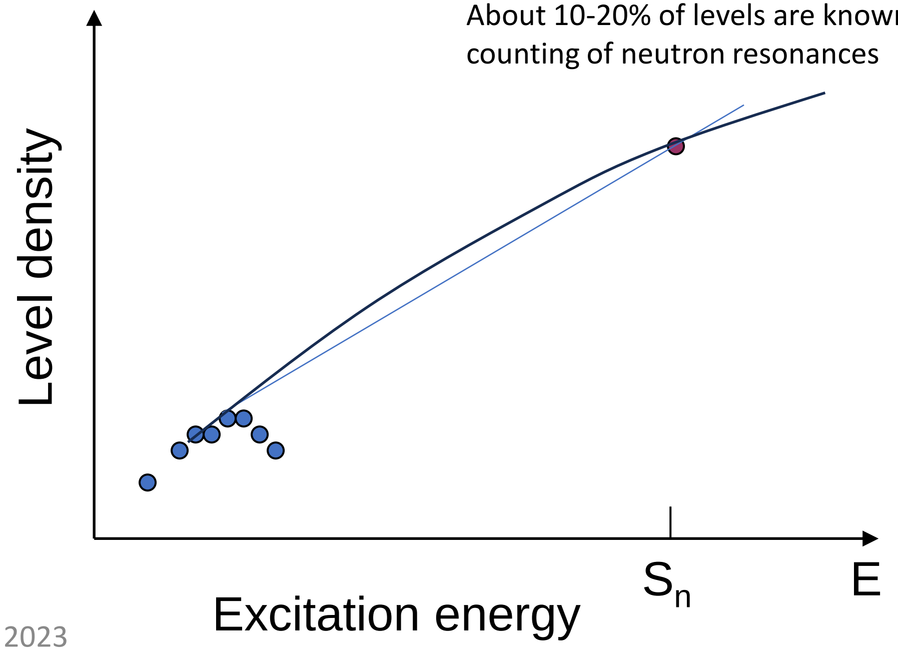
1. Neutron resonance data
2. Oslo data
3. Particle evaporation
4. What needs to be done

Source of uncertainties of current level density models

All current models rely on data on neutron s-wave neutron resonance spacings !!!

Neutron resonance spacings have very limited information about the nuclear level density

1) they are known at the neutron separation energy S_n only (about 7-10 MeV of excitation energy)
2) they are known in very limited spin interval (target spin I±1/2)



Neutron s-wave resonance data are very limited to constrain level density models !!!

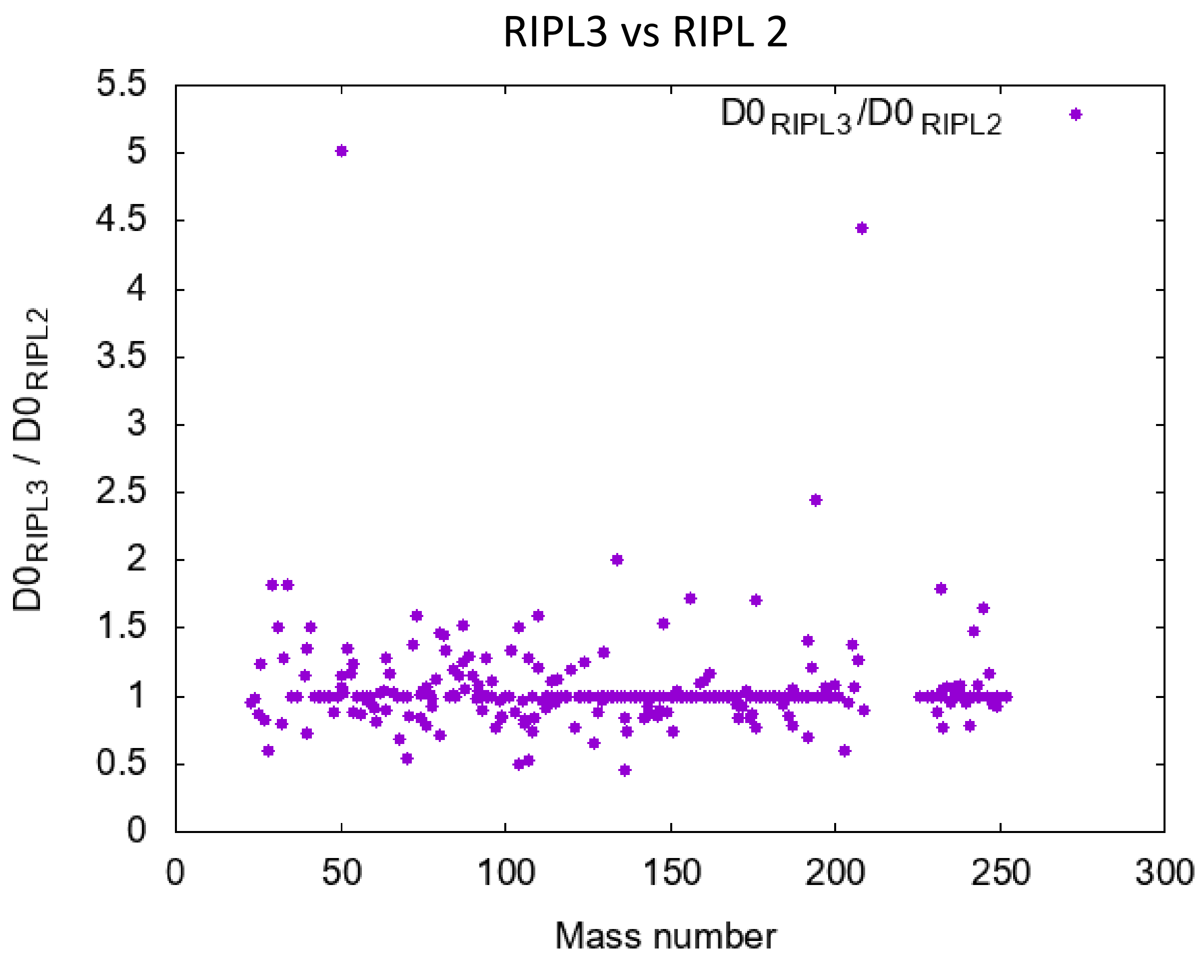
How reliable are neutron resonance data ?

Neutron resonance data

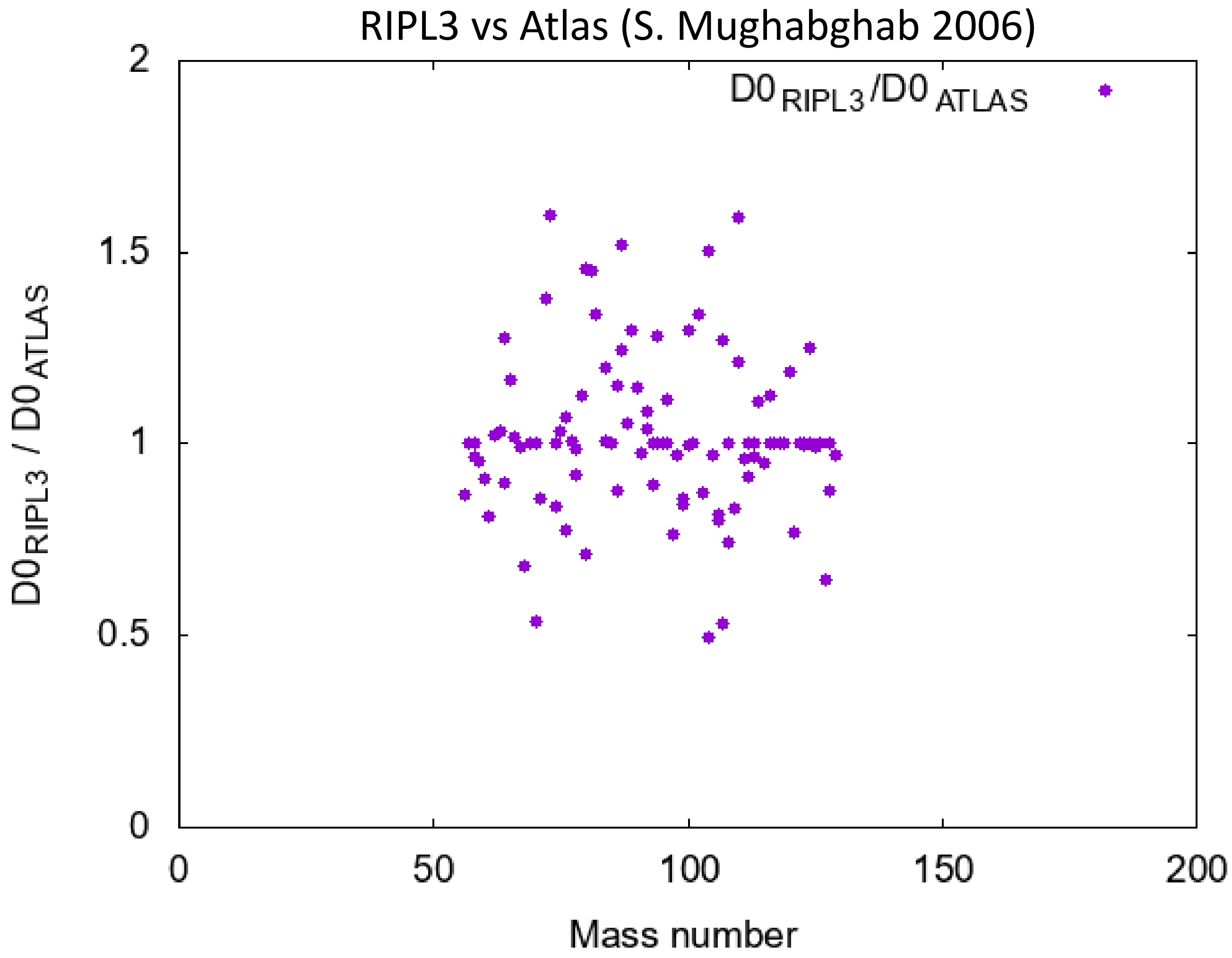
how well do we know resonance spacings data ?

1. RIPL2
2. RIPL3
3. S. Mughabghab atlas

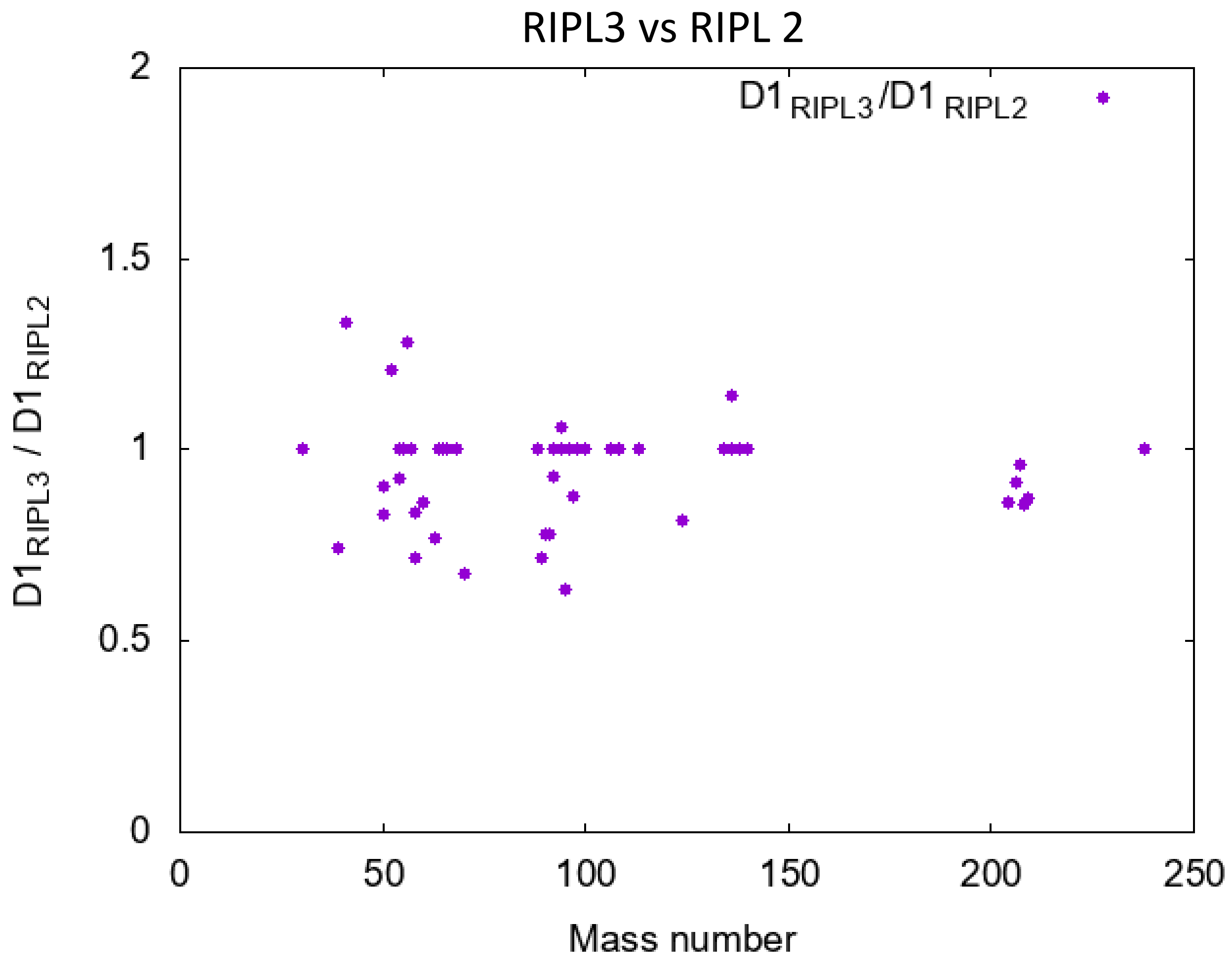
s-wave resonance spacings (D_0)



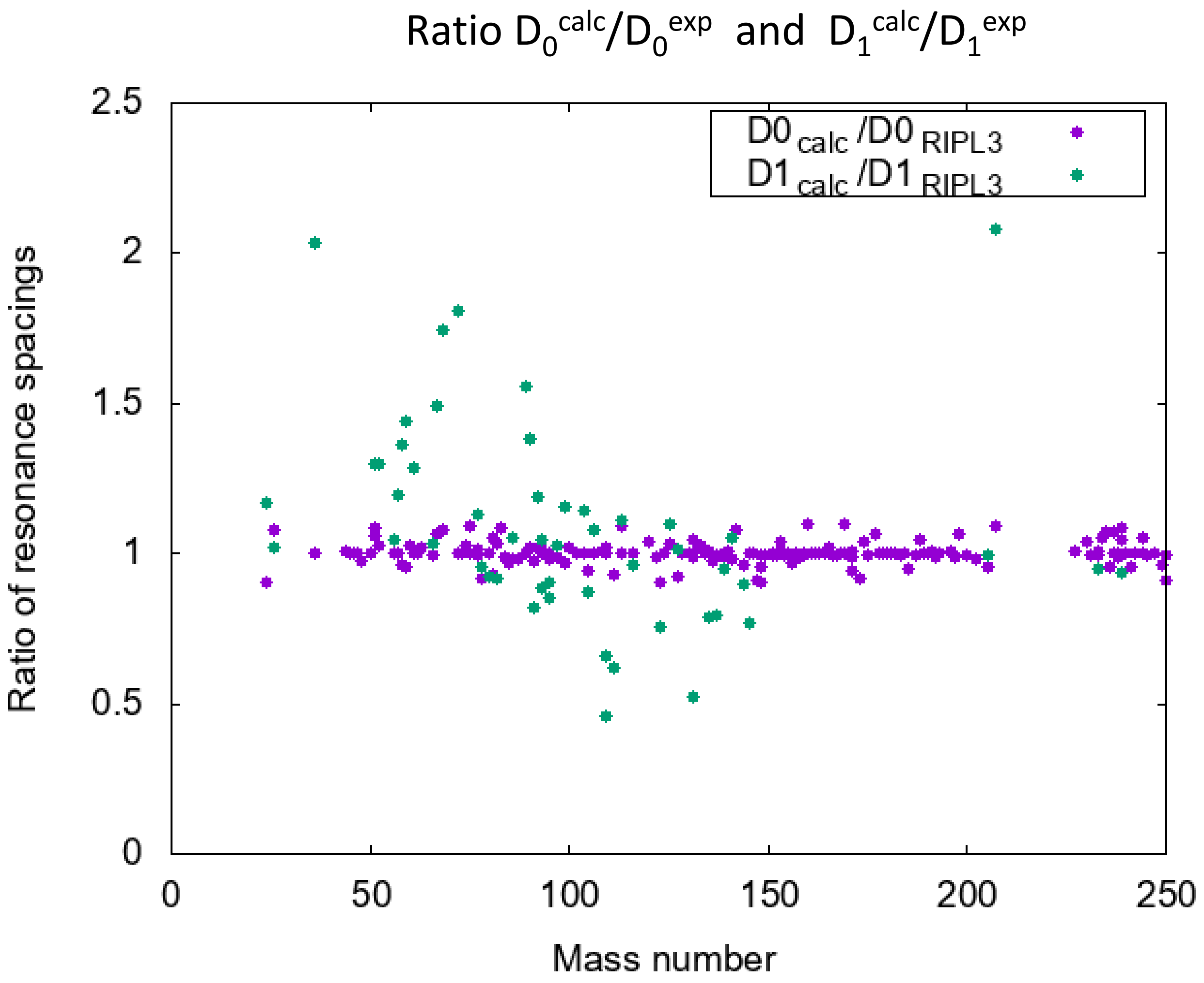
s-wave resonance spacings (D_0)



p-wave resonance spacings (D_1)



Results of D_0 and D_1 model calculations



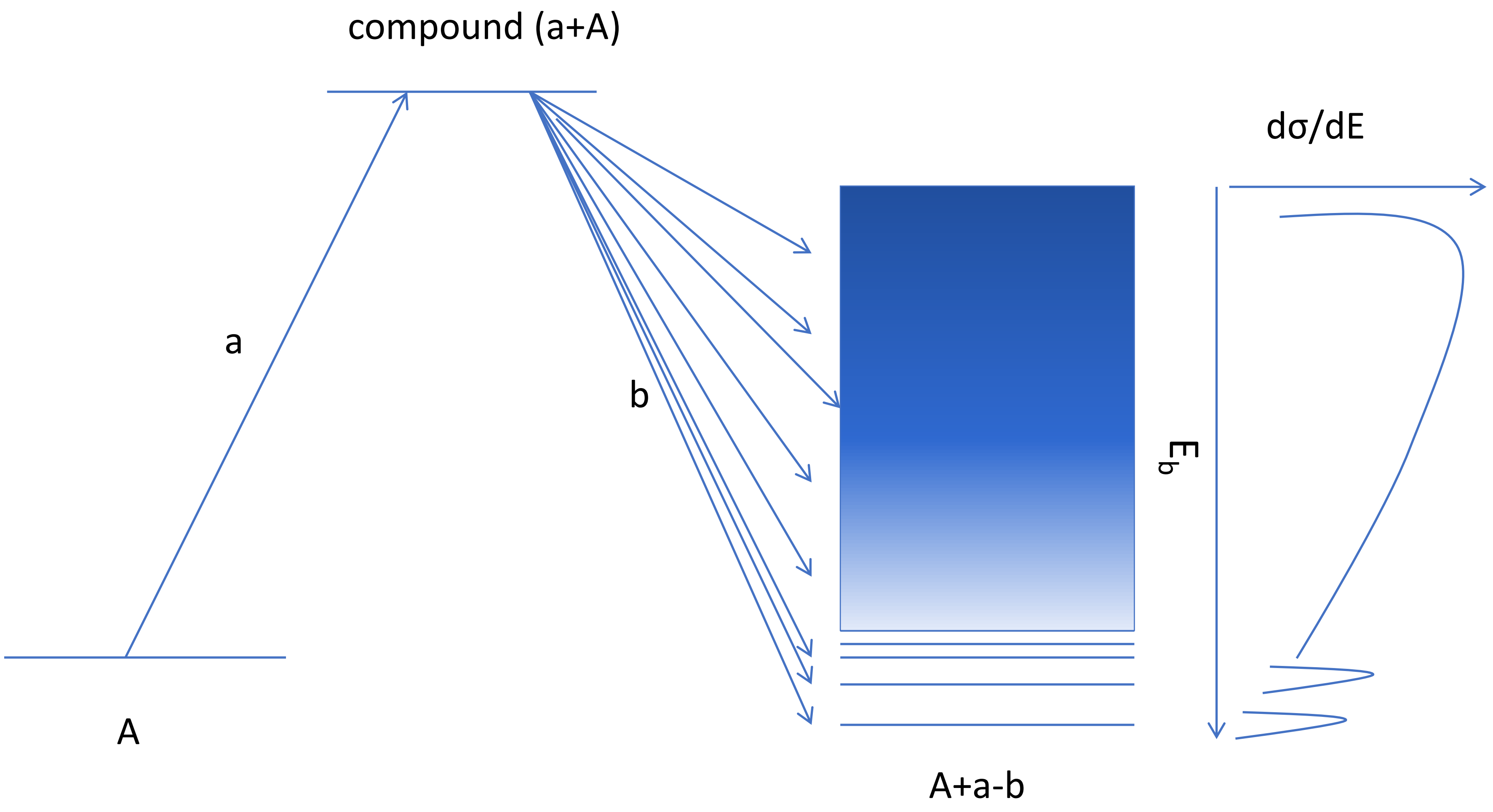
Calculations are with BSFG model
with parameters from BSFG RIPL3 data file

Density of p-wave resonances
is underestimated in the range 50-100
and overestimated in the range 100-150
by model calculations !!!

Level density from Oslo experiments

1. Uses s-wave resonance data for absolute normalization and bear uncertainties associated with them. (including spin and parity distribution uncertainties)
2. The shape method is promising but there are little data on it, still under investigation
3. Oslo data are good to look into systematic behavior on the BSFG/CT level density energy dependence. It might improve predictive power of the empirical models.

Level densities from evaporation spectra measurements



$$\frac{d\sigma(E)}{dE} \sim \sigma_C(E)\frac{T_{out}(E')\rho_f(E^*)}{\sum_i T_{out\,i}}$$

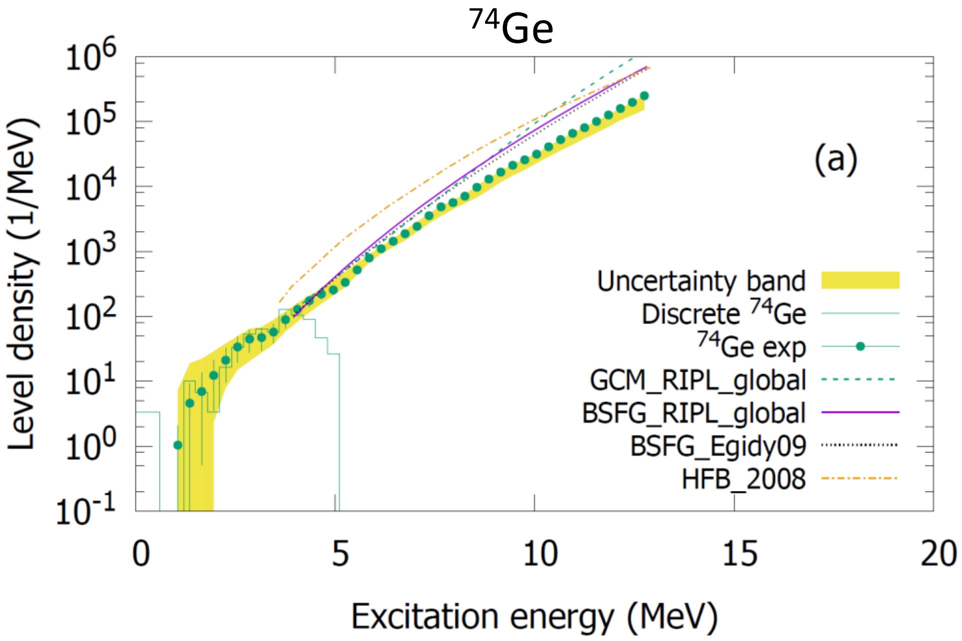
The experimental LD is obtained with a renormalization procedure:

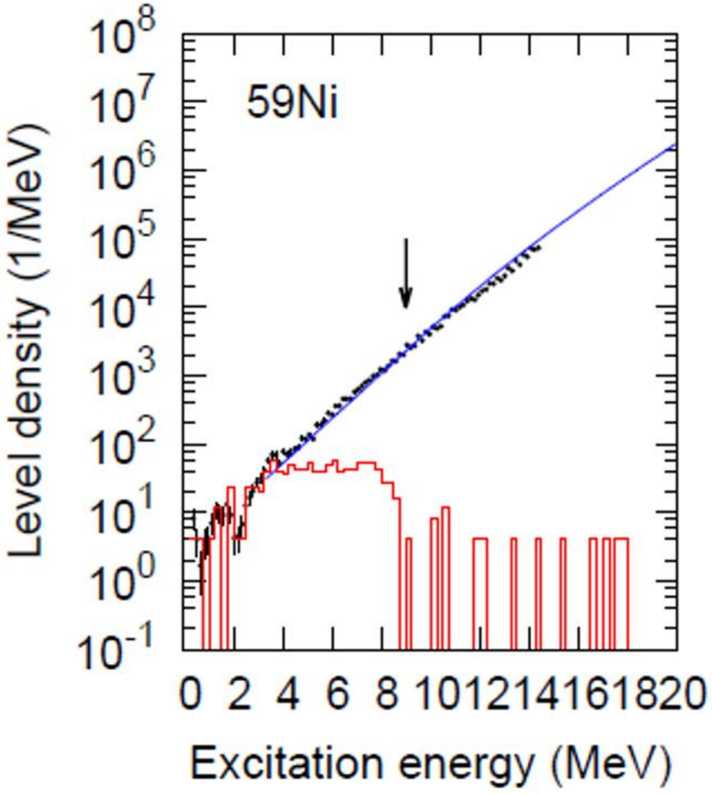
$$\rho(E)^{exp} \propto \frac{d\sigma}{dE}^{exp} \Big/ \frac{d\sigma}{dE}^{cal} \times \rho(E)^{cal}$$

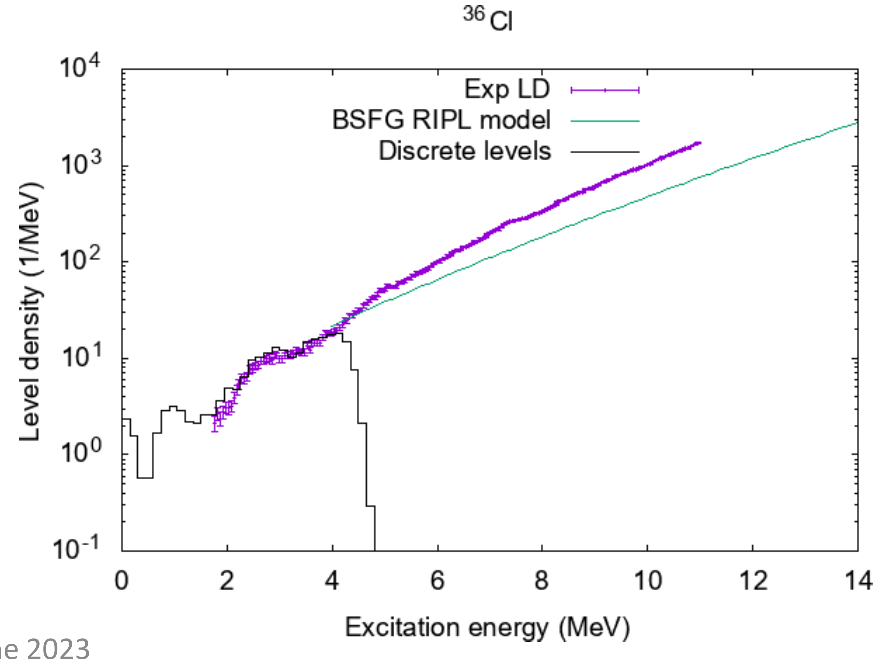
Level densities from particle evaporation spectra

- Independent method, does not rely on neutron resonance data
- Potentially provides information about the level density in a wide range of spins
- Available data sometime show an inconsistency with model estimates based on s-wave resonance spacing data

Level density predictions based on s-wave resonance data
vs one from evaporation spectra measurements







Data base on LD from evaporation technique

~ 120 entries found

Goal:

- LD data evaluation
- LD independent model parameter systematics
- consistency check with models based on resonance spacings

ID	Nucleaus	Z	A	Emin	Emax	Reaction	Method	Reference
1019	37Cl	17	37				Evaporation	
860	44Sc	21	44	2	8	3he,a	Evaporation	A.V. Voinov et al. PRC 77, 034613 (2008)
867	47Ti	22	47	4	13	3he,p	Evaporation	A.V. Voinov et al. PRC 77, 034613 (2008)
868	47V	23	47	2	7		Evaporation	B.V. Zhuravlev et al. PAN 74, 335 (2011)
869	48V	23	48	2	6		Evaporation	B.V. Zhuravlev et al. PAN 74, 335 (2011)
870	49V	23	49	2	10		Evaporation	B.V. Zhuravlev et al. PAN 74, 335 (2011)
874	51Cr	24	51	6	16		Evaporation	S. Grimes et al, PRC 3, 645(1971)
878	53Cr	24	53	4	8		Evaporation	R. Fischer et al. PRC 30, 72 (1984)
877	52Mn	25	52	2	6		Evaporation	A.P.D. Ramirez et al. PRC 92, 014303 (2015)
879	53Mn	25	53	2	9		Evaporation	B.V. Zhuravlev et al. PAN 74, 335 (2011)
880	54Mn	25	54	2	6		Evaporation	A.P.D. Ramirez et al. PRC 92, 014303 (2015)
881	54Mn	25	54	2	8		Evaporation	B.V. Zhuravlev et al. PAN 74, 335 (2011)
886	56Fe	26	56	2	24		Evaporation	C.C. Lu et al, NP A190,229(1972)
894	57Fe	26	57	9	17		Evaporation	B. Oginni PhD Thesis OU 2009
890	57Fe	26	57	2	8		Evaporation	R. Fischer et al. PRC 30, 72 (1984)
889	57Fe	26	57	4	10		Evaporation	A.V. Voinov et al. PRC 76, 044602 (2007)
888	57Fe	26	57	6	11		Evaporation	A.P.D. Ramirez et al. PRC 92, 014303 (2015)
882	55Fe	26	55	5	12	dp	Evaporation	A.P.D. Ramirez et al. PRC 92, 014303 (2015)
1012	56Fe	26	56			dn	Evaporation	A. Voinov et al, PRC 74, 014314(2006)
901	59Co	27	59	3	8		Evaporation	K. Tsukada et al, NP 78 369(1966)
883	55Co	27	55	3	8		Evaporation	A.P.D. Ramirez et al. PRC 92, 014303 (2015)
914	61Co	27	61	8	16		Evaporation	B. Oginni PhD Thesis OU 2009
895	57Co	27	57	2	10		Evaporation	A.P.D. Ramirez et al. PRC 92, 014303 (2015)
896	57Co	27	57	6	11	pn	Evaporation	V. Mishra et al. PRC 49, 750 (1994)
897	57Co	27	57	2	7		Evaporation	M.I. Svirin PAN 37, 475 (2006) [data from other pa
900	59Co	27	59	0	19		Evaporation	C.C. Lu et al, NP A190,229(1970)
905	60Co	27	60	6	17		Evaporation	B. Oginni et al. PRC 80, 034305 (2009)
906	60Co	27	60	2	10		Evaporation	A.V. Voinov et al. PRC 76, 044602 (2007)
887	56Co	27	56	0	6		evaporation	B.V. Zhuravlev et al. AIP Conf. 769, 931 (2005)
898	57Co	27	57	1	9		evaporation	B.V. Zhuravlev et al. AIP Conf. 769, 931 (2005)
924	64Ni	28	64	5	16		Evaporation	A.V. Voinov et al. EPJWebConf 21, 05001 (2012)
916	61Ni	28	61	8	16		Evaporation	B. Oginni PhD Thesis OU 2009
926	64Ni	28	64	10	19		Evaporation	B. Oginni PhD Thesis OU 2009
921	63Ni	28	63	0	13		Evaporation	A.V. Voinov et al. EPJWebConf 21, 05001 (2012)
920	63Ni	28	63	9	22		Evaporation	B. Oginni et al. PRC 80, 034305 (2009)
902	59Ni	28	59	0	14		Evaporation	A.V. Voinov et al. EPJWebConf 21, 05001 (2012)
903	59Ni	28	59	3	7	pn	Evaporation	B.V. Zhuravlev et al, BRASP, 63 5 764(1999) [BRASP
904	59Ni	28	59	6	16		evaporation	S. Grimes et al, PRC 3, 645(1971)
918	62Ni	28	62	3	17		Evaporation	A.V. Voinov et al. EPJWebConf 21, 05001 (2012)
908	60Ni	28	60	2	12		Evaporation	A.V. Voinov et al. PRC 76, 044602 (2007)
915	61Ni	28	61	0	13		Evaporation	A.V. Voinov et al. EPJWebConf 21, 05001 (2012)
911	60Ni	28	60	3	16		Evaporation	A.V. Voinov et al. EPJWebConf 21, 05001 (2012)
912	60Ni	28	60	1	23		Evaporation	C.C. Lu et al, NP A190,229(1972)
919	62Ni	28	62	2	19		Evaporation	C.C. Lu et al, NP A190,229(1970)

What to do (long term project)

- Revise evaluations of neutron resonance parameters, document how evaluations are done and make documentations accessible for researchers.
- Understand the difference of the model parameterizations based on s-wave and p-wave resonances.
- Oslo LD data are suggested to be analyzed for the BSFG vs CT LD energy dependence to see if any systematic behavior can be found
- Create a data base for LD studied with particle evaporation technique. Do data evaluations, produce level density parameter systematics, compare them with that based on neutron resonance spacings to see possible similarity and inconsistency.

Possible deliverable on a short-term time scale

LD data for set of nuclei for which consistent (!!!) data are obtained from different experimental techniques. This would enhance data reliability.
(example is ^{59}Ni: resonance s-wave and particle evaporation data are totally consistent)