Coordinated Research Project on Updating/Improving Nuclear Level Densities for Applications: introduction

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Goal of the CRP

Provide updated recommended nuclear level densities based on new experimental data and models

- Ground-state total level densities
- Fission saddle point level densities
- Average resonance spacings (D_0, D_1)

CM on Nuclear Level Densities, 26 – 28 June 2023, INDC(NDS)-0883

Goal cont'd

Update RIPL-3 segment on Densities

Level Densities Segment

Total Level Densities

Back-Shifted Fermi Gas Model (BSFG)

Level density parameters for the BSFG model obtained by fitting the Fermi-gas model formula to the recommended spacings of s-wave neutron resonances and to the cumulative number of low-lying levels.

Data File (34.3kB) README File (2.2kB)

Gilbert-Cameron Model

Level density parameters for the Gilbert-Cameron model obtained by fitting the Fermi-gas model formula to the recommended spacings of s-wave neutron resonances and by matching the corresponding level density to discrete levels.

Data File (42.8kB) README File (2.4kB)

Enhanced Generalized Superfluid Model (EGSM)

Level density parameters for the Enhanced Generalized Superfluid Model (EGSM), which takes into account collective enhancement of the nuclear level density in addition to shell and superfluid effects. The parameters were obtained by fitting the corresponding model formulas to the recommended spacings of s-wave neutron resonances and by matching level densities to discrete levels.

Data File (26.1kB) README File (2.4kB)

Z Systematics:
Data File (1.3kB) README File (1.3kB)

Retrieval of Total Level Density Parameters

Atomic number (Z)
Mass number (A)
(blank for all mass numbers)
retrieve reset

Plot of Total Level Density Parameters (a-parameters)

Select one of below and input no.:
Atomic number (Z)
Mass number (A)
Neutron number (N)
X-axis: A
plot reset

Plot of Total Level Densities

HFB Total Level Densities

The data files (*.dat) contains the HFB plus combinatorial nuclear level densities at ground state deformations[1]. The nuclear level density
the basis of the single-particle level scheme and pairing energy derived at the ground state deformation based on the BSk14 Skyrme
phenomenological level density parameters ctable and ptable are tabulated in files (*.cor) by fitting the HFB calculated curve to the RIPL II
s-wave neutron resonances D0 and to the cumulative number of low-lying levels.

References:
[1] S. Goriely, S. Hilaire, A.J. Koning, Improved microscopic nuclear level densities within the Hartree-Fock-Bogoliubov plus combinat
C78 (2008) 064307
[2] S. Goriely, M. Samyn, J.M. Pearson, Phys. Rev. C75 (2007) 064312

HFB Data Files (total 486.6MB) HFB README File (3.1kB)

HFB corrections File (30kB) HFB corrections README File (2kB)

Introduction | MASSES | LEVELS | RESONANCES | OPTICAL | DENSITIES | GAMMA | FISSION | CODES | Contacts

Average Resonance Spacings Segment

Average Spacings of Neutron Resonances

296 average spacings for s-wave neutron resonances and 82 average spacings for p-wave neutron resonances.

References:
[1] Sukhoruchkin, S.I. et al. in Low Energy Neutrons and their Interaction with Nuclei and Matter. Ed. H.Schopper, Springer-Verlag, Berlin, 2000, v.16B.
[2] Ignatyuk A.V. Contribution to the Second CRP Meeting on RIPL-2 (Verenna, June 2000).

Data File with s-wave Resonances (22kB)
Data File with p-wave Resonances (9.4kB)
README File (5.1kB)

Retrieval of Average Spacings of Neutron Resonances

Atomic number (Z)
Mass number (A)
(blank for all)
retrieve reset

Plot of Average Spacings of Neutron Resonances in Function of Mass Number (A)

Atomic number (Z)
(blank for all)
s- or p-wave s-wave
plot reset

Level Densities at Saddle Points Calculated within HFB

The files contains the HFB plus combinatorial nuclear level densities at saddle and isomer deformations[1]. The nuclear level density is coherently obtained on the basis of the single-particle level scheme and pairing energy derived at the saddle point deformation or shape isomer deformation. The same BSk14 Skyrme force[2] is used to estimate the fission saddle and isomeric points.

References:
[1] S. Goriely, S. Hilaire, A.J. Koning, Phys. Rev. C (2008) in press
[2] S. Goriely, M. Samyn, J.M. Pearson, Phys. Rev. C75 (2007) 064312

Data Files README File (4.0kB)

Retrieval of Level Densities at Saddle Points

Atomic number (Z)
Mass number (A)
retrieve reset

Research Objectives I

Low-lying discrete states: IAEA-NDS, Yi Xu

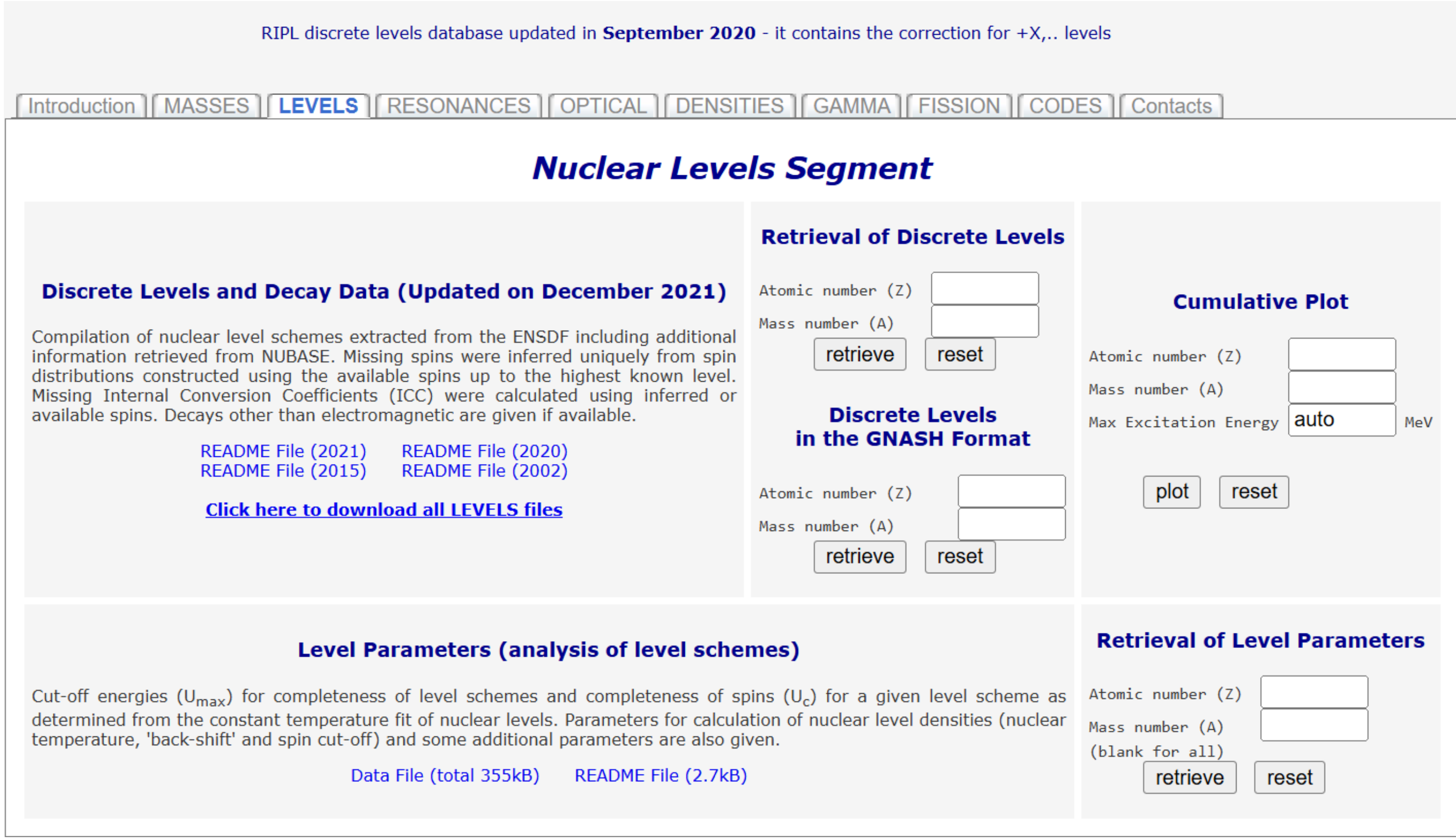
a) Update low-lying states in the RIPL database

b) Empirical determination of completeness of levels

c) Investigate the possible assignment of spin and parities for unknown cases

d) Review the method to assign spin-cutoff on low-lying states

e) Low-lying discrete levels for exotic nuclei



Research objectives II

Average Resonance Spacings: Milan Krticka, Anatoly Ignatyuk?, Arjan Koning,….

- Comprehensive compilation of average resonance spacings
- Update of RIPL-3 evaluation using RIPL-3 evaluation method (296 s-wave; 82 p-wave)
- New evaluations with new methods
- Uncertainty quantification for all methods
- Comparison of different evaluations
  - Provide D_0 for (l+1/2) and D_0 for (l-1/2) if available and possible

Pre-requisite:

- Database of measured resonances or resonance parameters (ENDF/B, JEFF, JENDL…)
- Known experimental conditions – quality of measured resonances

Research objectives II cont’d

Other average resonance quantities

- Average neutron widths?
- Average neutron strength S
- Average gamma width $\Gamma\gamma$

RIPL-3

```
#                 Resonance data for s-wave resonances
# Z El  A   Io     Bn         D0        dD      S0    dS    Gg    dG
Com.
#                 [MeV]      [keV]     [keV]   [1E-4][1E-4][meV] [meV]
&Ref
#==================================================================
======
 11 Na  23  1.5   6.960  1.00E+02  2.00E+01   0.25  0.15    -     -
*07I
 12 Mg  24  0.    7.331  4.80E+02  7.00E+01   0.00  0.00    -     -
*07I
 12 Mg  25  2.5  11.094  5.00E+01  1.00E+01   0.00  0.00    -     -
*07I
 12 Mg  26  0.    6.446  2.10E+02  8.00E+01   0.00  0.00    -     -
*07I
 13 Al  27  2.5   7.725  5.50E+01  6.00E+00   2.30  0.50  1600   400
07I
 14 Si  28  0.    8.474  3.32E+02  3.50E+01   0.50  0.24    -     -
07I
 14 Si  29  0.5  10.609  1.93E+02  2.20E+01   0.00  0.00    -     -
*07I
 14 Si  30  0.    6.587  2.25E+02  3.00E+01   0.00  0.00    -     -
*07I
 15 P   31  0.5   7.937  5.00E+01  1.20E+01   0.42  0.20  2000   400
```

Research objectives III

Experimental data: Vetle Ingeberg, Mathis Wiedeking, Thibault Laplace, Kgashane Malatji, Peter von Neumann-Cosel, Alexander Voinov, Kaushik Banerjee, Milan Krticka, Pär-Anders Söderström, Gustavo Nobre

- Compilation of experimental derived level densities [Oslo method, Shape method, inelastic scattering, evaporation spectra,…]
- Comparison of results from different measurement techniques
- Comprehensive uncertainty analysis (including model uncertainties)
- Review of the existing data (e.g., re-adjust to updated normalization data, assign quality indicator);
- Recommendation of experimental derived nuclear level density data

Research objectives IV

Model development (global, semi-global): Cenxi Yuan, Stephane Goriely, Stephane Hilaire, Ruirui Xu, Yuan Tian, Osamu Iwamoto, Yi Xu

- New phenomenological (Gilbert-Cameron, Fermi Gas, Enhanced Generalized Superfluid Model)
- New Microscopic (Comb.+Boson expansion, Shell Model, HFB+comb., Relativistic HFB, ..)
- Comparison with experimental data: Ncum, D0, and experimentally derived NLDs
- Uncertainty quantification

Research objectives V

Validation of models and evaluations – Extensive comparisons with different nuclear reaction codes (CCONE, EMPIRE, TALYS, UNF): Iwamoto, Koning, Nobre, Pomp, Xu, et al.

- Reaction data (e.g. standards, (n,n’), (n,p), neutron spectrum, prompt fission -spectra)
- Isomeric cross section ratios and (n,n’γ) cross section data
- Multi-step cascade gamma spectra
- Average radiative widths
- Maxwellian-Averaged Cross Sections (MACS)
- Isomeric fission yield ratios
- To be considered: D_0 for (l+1/2) and D_0 for (l-1/2)

Research objectives VI

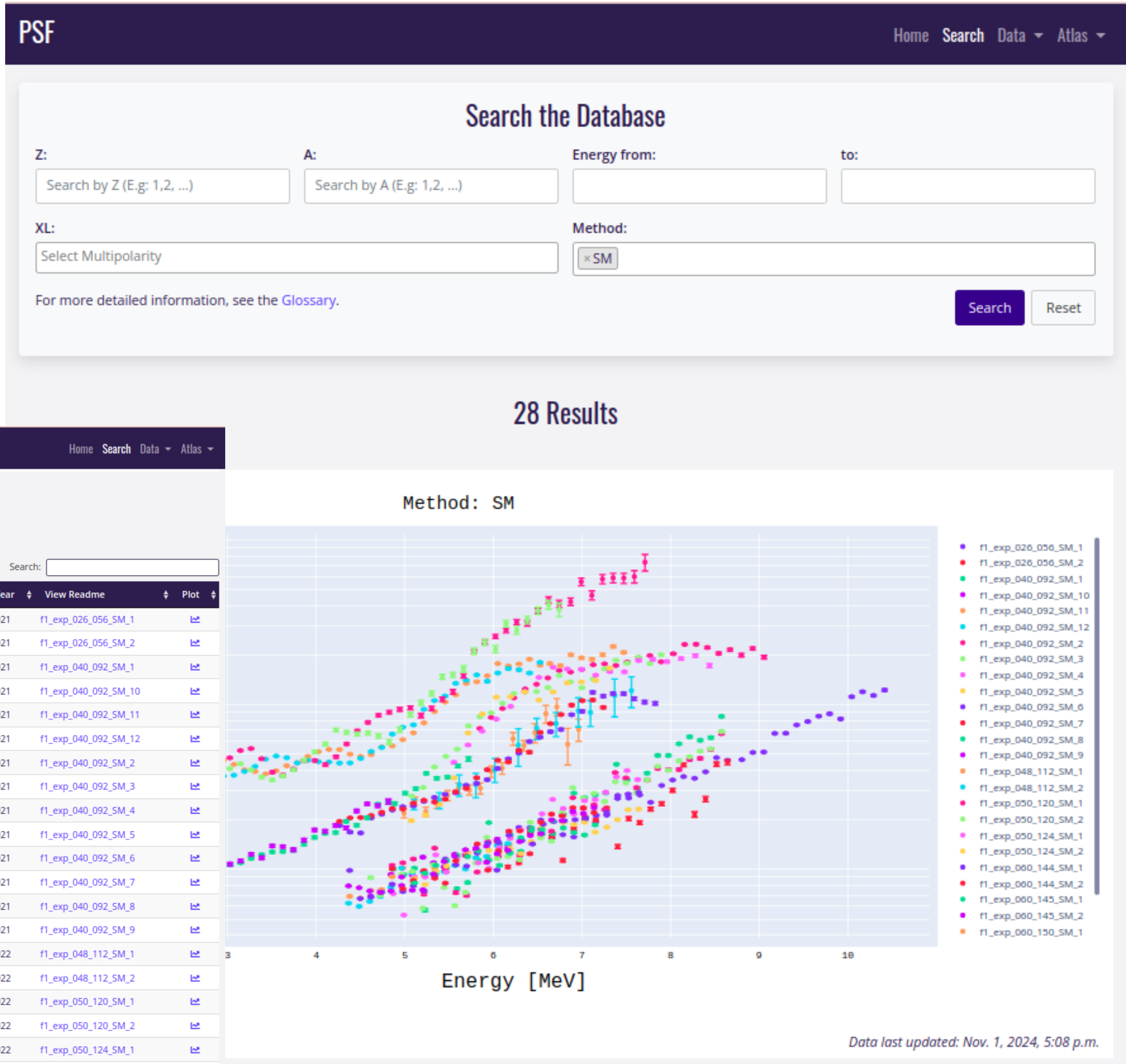
Theoretical developments to guide practical calculations and improve understanding: Cenxi Yuan, Yi Xu, ..

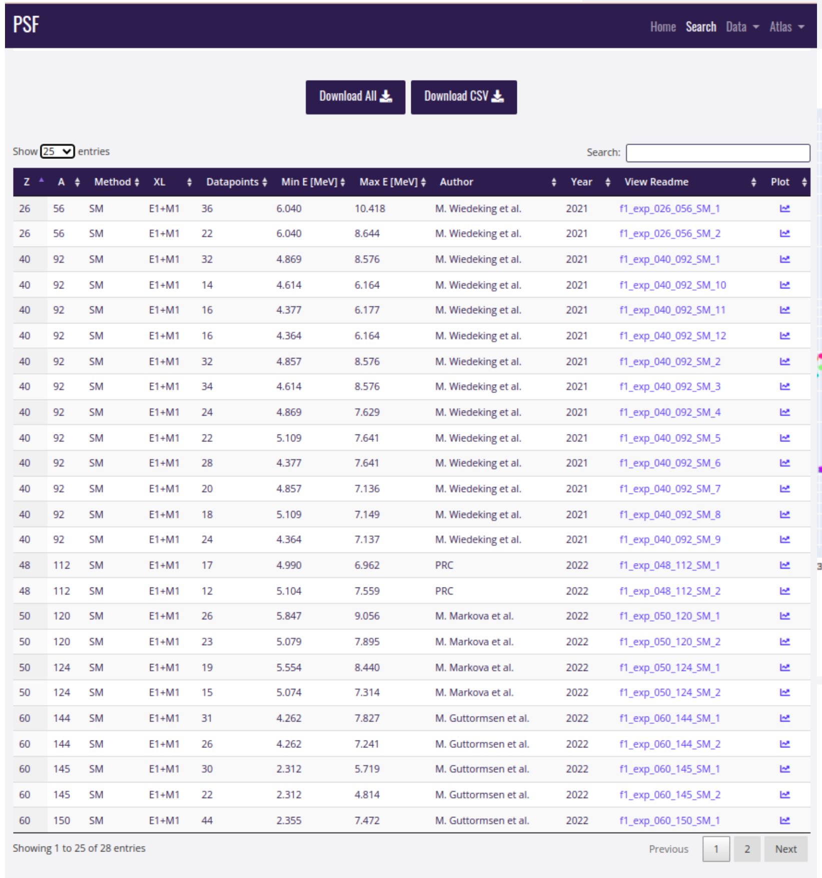
- Spin distribution
- Parity distribution
- Damping of shell and collective effects
- Deformation (fission)

Research Objectives VII

Dissemination: IAEA-NDS

- Open repository (GitHub)
- Interactive interface
- Web-based API
- Publications




PSF

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Z	A	Method	XL	Datapoints	Min E [MeV]	Max E [MeV]	Author	Year	View Readme	Plot
26	56	SM	E1+M1	36	6.040	10.418	M. Wiedeking et al.	2021	f1_exp_026_056_SM_1	
26	56	SM	E1+M1	22	6.040	8.644	M. Wiedeking et al.	2021	f1_exp_026_056_SM_2	
40	92	SM	E1+M1	32	4.869	8.576	M. Wiedeking et al.	2021	f1_exp_040_092_SM_1	
40	92	SM	E1+M1	14	4.614	6.164	M. Wiedeking et al.	2021	f1_exp_040_092_SM_10	
40	92	SM	E1+M1	16	4.377	6.177	M. Wiedeking et al.	2021	f1_exp_040_092_SM_11	
40	92	SM	E1+M1	16	4.364	6.164	M. Wiedeking et al.	2021	f1_exp_040_092_SM_12	
40	92	SM	E1+M1	32	4.857	8.576	M. Wiedeking et al.	2021	f1_exp_040_092_SM_2	
40	92	SM	E1+M1	34	4.614	8.576	M. Wiedeking et al.	2021	f1_exp_040_092_SM_3	
40	92	SM	E1+M1	24	4.869	7.629	M. Wiedeking et al.	2021	f1_exp_040_092_SM_4	
40	92	SM	E1+M1	22	5.109	7.641	M. Wiedeking et al.	2021	f1_exp_040_092_SM_5	
40	92	SM	E1+M1	28	4.377	7.641	M. Wiedeking et al.	2021	f1_exp_040_092_SM_6	
40	92	SM	E1+M1	20	4.857	7.136	M. Wiedeking et al.	2021	f1_exp_040_092_SM_7	
40	92	SM	E1+M1	18	5.109	7.149	M. Wiedeking et al.	2021	f1_exp_040_092_SM_8	
40	92	SM	E1+M1	24	4.364	7.137	M. Wiedeking et al.	2021	f1_exp_040_092_SM_9	
48	112	SM	E1+M1	17	4.990	6.962	PRC	2022	f1_exp_048_112_SM_1	
48	112	SM	E1+M1	12	5.104	7.559	PRC	2022	f1_exp_048_112_SM_2	
50	120	SM	E1+M1	26	5.847	9.056	M. Markova et al.	2022	f1_exp_050_120_SM_1	
50	120	SM	E1+M1	23	5.079	7.895	M. Markova et al.	2022	f1_exp_050_120_SM_2	
50	124	SM	E1+M1	19	5.554	8.440	M. Markova et al.	2022	f1_exp_050_124_SM_1	
50	124	SM	E1+M1	15	5.074	7.314	M. Markova et al.	2022	f1_exp_050_124_SM_2	
60	144	SM	E1+M1	31	4.262	7.827	M. Guttormsen et al.	2022	f1_exp_060_144_SM_1	
60	144	SM	E1+M1	26	4.262	7.241	M. Guttormsen et al.	2022	f1_exp_060_144_SM_2	
60	145	SM	E1+M1	30	2.312	5.719	M. Guttormsen et al.	2022	f1_exp_060_145_SM_1	
60	145	SM	E1+M1	22	2.312	4.814	M. Guttormsen et al.	2022	f1_exp_060_145_SM_2	
60	150	SM	E1+M1	44	2.355	7.472	M. Guttormsen et al.	2022	f1_exp_060_150_SM_1	

Showing 1 to 25 of 28 entries | Previous 1 2 Next

Outputs

- Recommended NLD models and parameters
- Recommended NLD tables (for both phenomenological and microscopic):
  a. Provide renormalization parameters on low-lying states and D_0
  b. Provide adjustment procedure for tabulated NLDs for practical calculations
- Recommended tables of average resonance spacings D_0,D_1, $\Gamma\gamma$, Strengths
- Compilation of experimental data (derived NLD, resonances, and validation data)
- GitHub repository; interactive interface
- Publication(s) describing technical work and recommendations

Timeline

Duration: 2024 - 2028

RCM 1 : 24-28 March 2025

RCM-2: Q4 2026

RCM-3: Q4 2027→ final outputs and outline of final CRP publication

Consultant Meetings: in between as needed

RCM 1

Agree on individual work plans and additional actions

Assign working group conveners:

WG 1: Low-lying discrete levels

WG 2: Resonances

WG 3: Experimental data

WG 4: Models

WG 5: Validation

WG 6: Theory

WG 7: Dissemination

Outputs need to be discussed in detail:

What (are we able to produce)

Who (has the expertise and time)

How (format)

When (deadlines)

Participants

Name (CSI)	Country
Kaushik Banerjee, Pratap Roy	VECC, India
Stephane Goriely, Wouter Ryssens	ULB, Belgium
Stephane Hilaire, Sophie Peru	CEA, France
Vetle Ingeberg, Sunniva Siem, Anne-Cecilie Larsen	Univ. Oslo, Norway
Osamu Iwamoto	JAEA, Japan
Milan Krticka	Charles Univ. , Czech R.
Thibault Laplace, Mathis Wiedeking, Kgashane Malatji	Univ. California Berkeley and LBNL, USA
Gustavo Nobre, Dave Brown	BNL, USA
Stephan Pomp, Andreas Solders, Ali al-Adili	Uppsala Univ., Sweden
Alexander Voinov	Ohio Univ., USA
Peter von Neumann-Cosel, Johan Isaak et al.	Univ. Darmstadt, Germany
Ruirui Xu, Yuan Tian	CIAE, China
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Cenxi Yuan, Shengli Chen, et al.	Sun Yat-sen University

IAEA

Thank you!

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