24th Technical Meeting of the International Atomic and Molecular Data Centre Network

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# UPDATE ON ATOMIC, MOLECULAR AND PMI DATA ACTIVITY IN RUSSIA

P.R. Goncharov[1], A.B. Kukushkin[2,3]

[1] *Peter the Great Polytechnic University, 195251, St Petersburg, Russia*

[2] *NRC Kurchatov Institute, 123182, Moscow, Russia*

[3] *NRNU Moscow Engineering Physics Institute, 115409, Russia*

# Contributors

- **A.B. Kukushkin, A.B. Sivak**
  **NRC Kurchatov Institute**
- **Yu.M. Gasparyan, L.B. Begrambekov**
  **Moscow Engineering Physics Institute**
- **V.G. Kapralov, I.A. Sharov**
  **Peter the Great Polytechnic University**
- **M.N. Panov, N.N. Bakharev, V.I. Afanasyev, M.I. Mironov**
  **A.F. Ioffe Physico-Technical Institute**
- **V.P. Shevelko, I.Yu. Tolstikhina**
  **P.N. Lebedev Physical Institute**
- **A.S. Arakcheev**
  **G.I. Budker Institute of Nuclear Physics**

# Outline

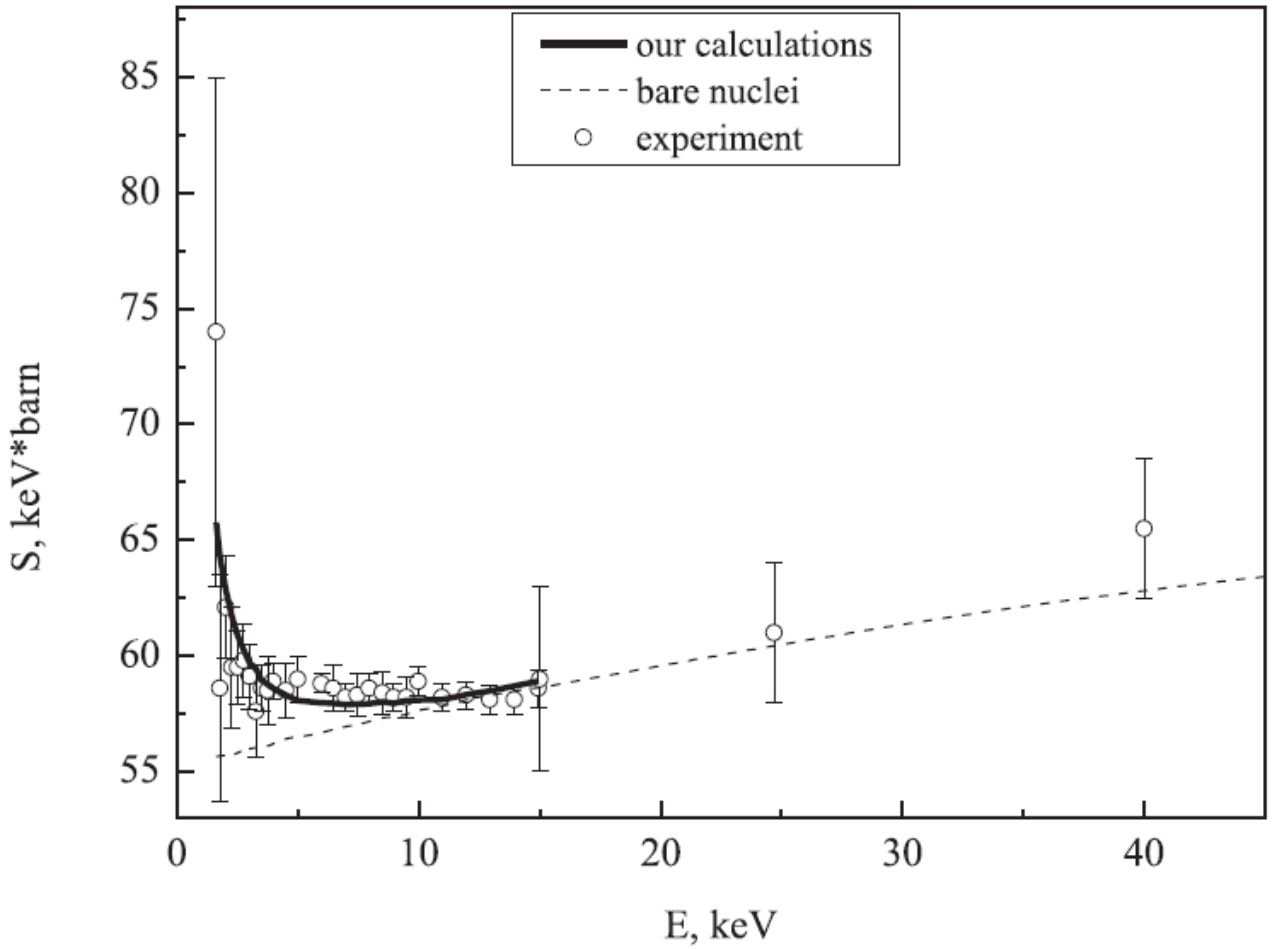
- Generation of atomic and molecular data for fundamental science and controlled nuclear fusion
- Use of atomic and molecular data in controlled nuclear fusion research
- Recent works on plasma-material interaction data
- Conclusions

# 1. Generation of atomic and molecular data for fundamental science and controlled nuclear fusion

| Process | Method | Data Source / Code | Publications | Verification / Application | Problem |
|---|---|---|---|---|---|
| **Screening of Coulomb potential in $D^+ + D$ reactions and other collisions** | Fitting of calculated data and use of theoretical considerations to make a simple formula for estimating the screening constant | *C.C. Lu, T.A. Carlson et al., Relativistic Hartree-Fock-Slater eigenvalues, radial expectation values, and potentials for atoms, $2 \leq Z \leq 126$ At. Data and Nucl. Data Tables, vol. 3, pp. 1-31 (1971)* | *A.N. Zinoviev, Interatomic potentials at high, medium and low collision energies, Proc. ISI-2017, vol. 1, p. 184*<br><br>*A.N. Zinoviev, Nucl. Instr. and Meth. in Phys. Res. B, vol. 406, Part B, pp. 465-469 (2017)*<br><br>*A.N. Zinoviev et al., Journal of Surface Investigation, vol. 10, pp. 576–578 (2016)* | Comparisons with experimental data | Precise knowledge of the cross-sections of nuclear fusion involving light elements is needed in modeling of nucleosynthesis in the Sun and stars. The presence of electrons affects the potential barrier shape and, hence, the tunneling probability. Astrophysical S-factor was obtained taking into account this effect. |

**Graph from**

*A.N. Zinoviev, Nucl. Instr. and Meth. in Phys. Res. B, vol. 406, Part B, pp. 465-469 (2017)*



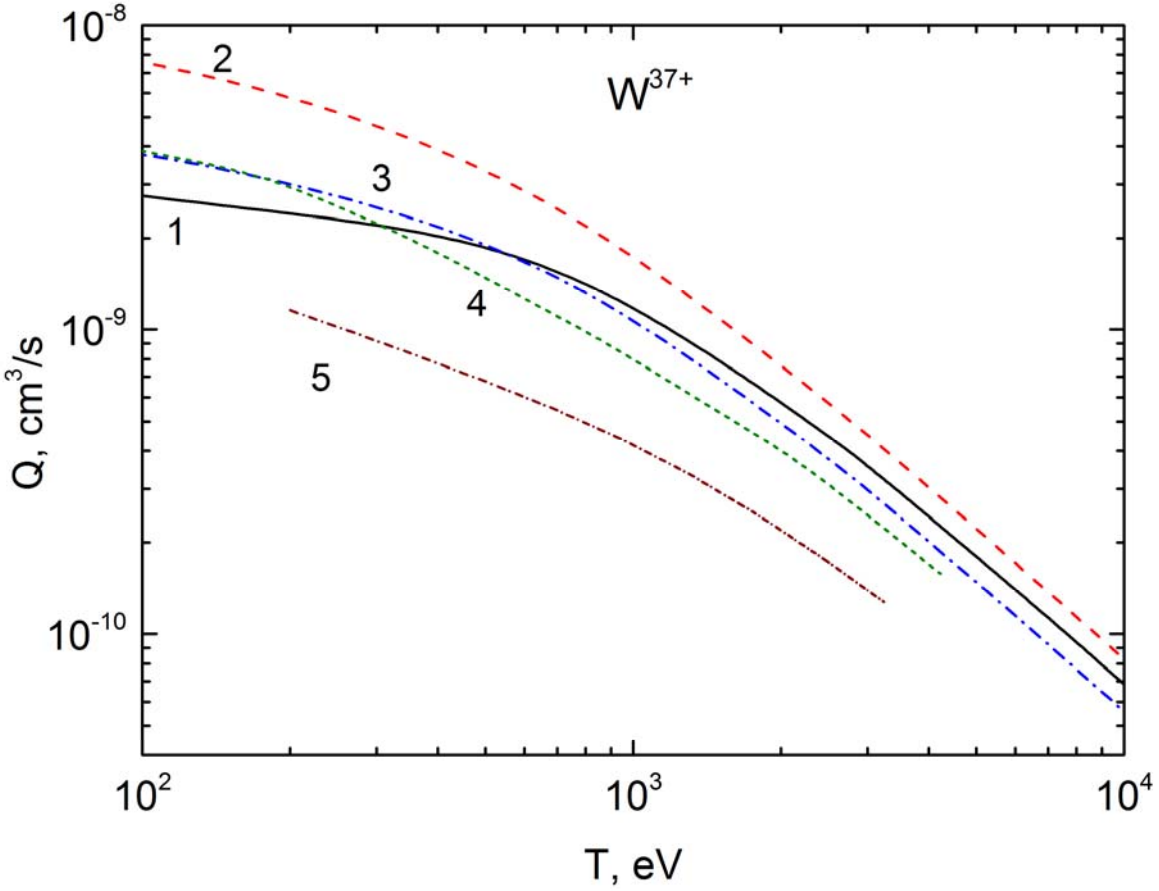

Astrophysical S-factor versus collision energy for $^{2}H(d,n)^{3}He$ reaction. Comparison with experimental data from *U. Greife et al., Z. Phys. A, vol. 351 pp. 107-112 (1995)*.

| Process | Method | Data Source / Code | Publications | Verification / Application | Problem |
|---|---|---|---|---|---|
| **Electron capture and electron capture with ionization of Ar by $He^{2+}$ ions**<br><br>**$He^{2+} + Ar \rightarrow He^{+} + Ar^{n+} + (n-1)e^{-}$**<br>**$n \geq 1$**<br><br>**and**<br><br>**$He^{2+} + Ar \rightarrow He^{0} + Ar^{n+} + (n-2)e^{-}$**<br>**$n \geq 2$** | Target atoms were supplied with an effusion gas jet. A collimated beam of $^{3}He^{2+}$ ions was used with energy in keV range. | Experimental setup described in *V.V. Afrosimov, A.A. Basalaev, G.N. Ogurtsov, M.N. Panov* ***Tech. Phys. 59*** *(2014) 642-648* | *V.V. Afrosimov, A.A. Basalaev, M.N. Panov* ***Tech. Phys. Lett. 43*** *(2017) 122-125* | Useful for checking the correctness of model potentials used in calculations of the interaction of H and He ions with multielectron atoms of impurities. Applicable in numerical modelling of physical processes in controlled fusion devices. | Plasma diagnostics, plasma heating and current drive. |

| Process | Method | Data Source / Code | Publications | Verification / Application | Problem |
|---|---|---|---|---|---|
| **Mechanism of radiation damage of amino acid molecules**<br><br>**$He^{2+} + Trp \rightarrow He^{(2-s)+} + Trp^{n+} + (n-s)e^{-}$**<br><br>**$He^{2+} + Gly \rightarrow He^{(2-s)+} + Gly^{n+} + (n-s)e^{-}$** | A collimated monokinetic beam of $^{3}He^{2+}$ ions with energy 4 keV/u intersected the effusive jet of molecules. | Experimental setup described in *V.V. Afrosimov, A.A. Basalaev, Yu.G. Morozov, M.N. Panov et al.* ***Tech. Phys. 58*** *(2013) 1243-1250* | *V.V. Afrosimov, A.A. Basalaev, V.V. Kuz'michev, M.N. Panov, O.V. Smirnov* ***Tech. Phys. 61*** *(2016) 342-348*<br><br>*V.V. Afrosimov, A.A. Basalaev, V.V. Kuz'michev, M.N. Panov, O.V. Smirnov* ***Tech. Phys. Lett. 43*** *(2017) 351-354* | Useful for probing the intrinsic properties of the molecules and tracing their chemical structure changes under the ion impact. | Studies of ionization and fragmentation of amino acids are due to their biological significance. Glycine was found in the interstellar space and in dust samples from comets. This stimulates studies of the role of extraterrestrial amino acids in the origination of life on Earth. Tryptophan is the metabolic precursor of serotonin, playing an important role in humans. |

| Processes | Method | Data Source \ Code | Publication | Verification / Application | Problem |
|---|---|---|---|---|---|
| **Charge-state evolutions of heavy-ion beams in matter** | A combination of semiclassical and quantum mechanical approaches | New **BREIT** code for calculating charge-state fractions of ion beams passing through matter<br><br>**RICODE**<br><br>**CAPTURE, ARSENY, DEPOSIT** | *N. Winckler et al., Nucl. Instr. and Meth. in Phys. Res. B, vol. **392**, pp. 67-73 (2017)* | ICF driven by heavy ion beams.<br><br>**F**acility for **A**ntiproton and **I**on **R**esearch (**FAIR**) in EU and **N**uclotron-based **I**on **C**ollider f**A**cility (**NICA**) in Russia | Energy losses of accelerated ions depend on their interaction cross sections with atoms and molecules of the residual gas in a wide energy range.<br><br>In heavy-ion therapy, the creation of the secondary electrons due to multiple ionization may be an important effect. |
| **Uranium ions stripping in molecular hydrogen** | | | *V.P. Shevelko et al., Nucl. Instr. and Meth. in Phys. Res. B, vol. **377**, pp. 77-82 (2016)* | | |
| **Multiple Electron Losses in Uranium Ion Beams** | | | *L. Bozyk et al., Nucl. Instr. and Meth. in Phys. Res. B, vol. **372**, pp. 102-108 (2016)* | | |

| Process | Method | Data Source / Code | Publications | Verification / Application | Problem |
|---|---|---|---|---|---|
| **Dielectronic recombination of heavy ions in plasmas** | Thomas-Fermi, Brandt-Lundquist, and Rost model of collective oscillations of atomic electron density | The statistical model of the dielectronic recombination | *D.S. Leontyev, V.S. Lisitsa, Contrib. Plasma Physics **56** (2016) 846-854*<br><br>*D. S. Leontyev, Problems At, Sci. & Techn. **40** (2017) 19-22*<br><br>*A. V. Demura et al, JETP **152** (2017) (in press)*<br><br>*A. V. Demura et al., EPJ Web Conf. 132, ( 2017)* | Comparison with<br><br>a) data from detailed level-by-level codes, and<br><br>b) experimental data | Integrated modeling of fusion experiments<br><br>Diagnostics of thermonuclear plasma |




1 - statistical model in Thomas-Fermi (TF) atoms [1];
2 - statistical model in TF atoms with account orbital momentum of atom [1];
3 - statistical model in Rost approach [1];
4 - data from FAC [4];
5 - data from ADPAC [5].

Dielectronic recombination rate coefficients $Q$ versus electron temperature $T$

[1] A.V. Demura, D.S. Leontyev, V.S. Lisitsa, V.A. Shurigyn, JETP, **152** (2017) in press.
[2] D. S. Leontyev, Problems At. Sci. & Techn., **40** (2017) 19-22.
[3] A. V. Demura, D. S. Leontyev, V. S. Lisitsa, V. A. Shurigyn, EPJ Web Conf. **132**, ( 2017) XXV-th Congress on Spectroscopy, 2016
[4] Wu Z., Fu Y., Ma X., Li M., Xie L., Jiang J., Dong C. — Atoms 2015, vol. 3, p. 474.
[5] K. Asmussen, K. B. Fournier, J. M. Laming, J. F. Seely, R. Dux, W. Engelhardt, and J. C. Fuchs, Asdex upgrade team, Nucl. Fusion 38, 967 (1998).

- **Researchers from 4 Russian institutions in Moscow, Tomsk and Snezhinsk are contributing to VAMDC activity**

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Journal of Physics B: Atomic, Molecular and Optical Physics
J. Phys. B: At. Mol. Opt. Phys. **49** (2016) 074003 (18pp)
doi:10.1088/0953-4075/49/7/074003

# The virtual atomic and molecular data centre (VAMDC) consortium*

M L Dubernet[1], B K Antony[2], Y A Ba[1], Yu L Babikov[3,4], K Bartschat[5], V Boudon[6], B J Braams[7], H-K Chung[7], F Daniel[8], F Delahaye[1], G Del Zanna[9], J de Urquijo[10], M S Dimitrijević[1,11], A Domaracka[12], M Doronin[1], B J Drouin[13], C P Endres[14], A Z Fazliev[3], S V Gagarin[15], I E Gordon[16], P Gratier[17,18], U Heiter[19], C Hill[20], D Jevremović[11], C Joblin[21], A Kasprzak[22], E Krishnakumar[23], G Leto[24], P A Loboda[15,25], T Louge[21], S Maclot[12,26], B P Marinković[27], A Markwick[28], T Marquart[19], H E Mason[9], N J Mason[29], C Mendoza[30], A A Mihajlov[27], T J Millar[31], N Moreau[1], G Mulas[21,32], Yu Pakhomov[33], P Palmeri[34], S Pancheshnyi[35], V I Perevalov[3], N Piskunov[19], J Postler[36], P Quinet[34,37], E Quintas-Sánchez[1], Yu Ralchenko[38], Y-J Rhee[39], G Rixon[40], L S Rothman[16], E Roueff[1], T Ryabchikova[33], S Sahal-Bréchot[1], P Scheier[36], S Schlemmer[41], B Schmitt[8], E Stempels[19], S Tashkun[3], J Tennyson[20], VI G Tyuterev[42], V Vujčić[11,43], V Wakelam[17,18], N A Walton[40], O Zatsarinny[5], C J Zeippen[1] and C M Zwölf[1]

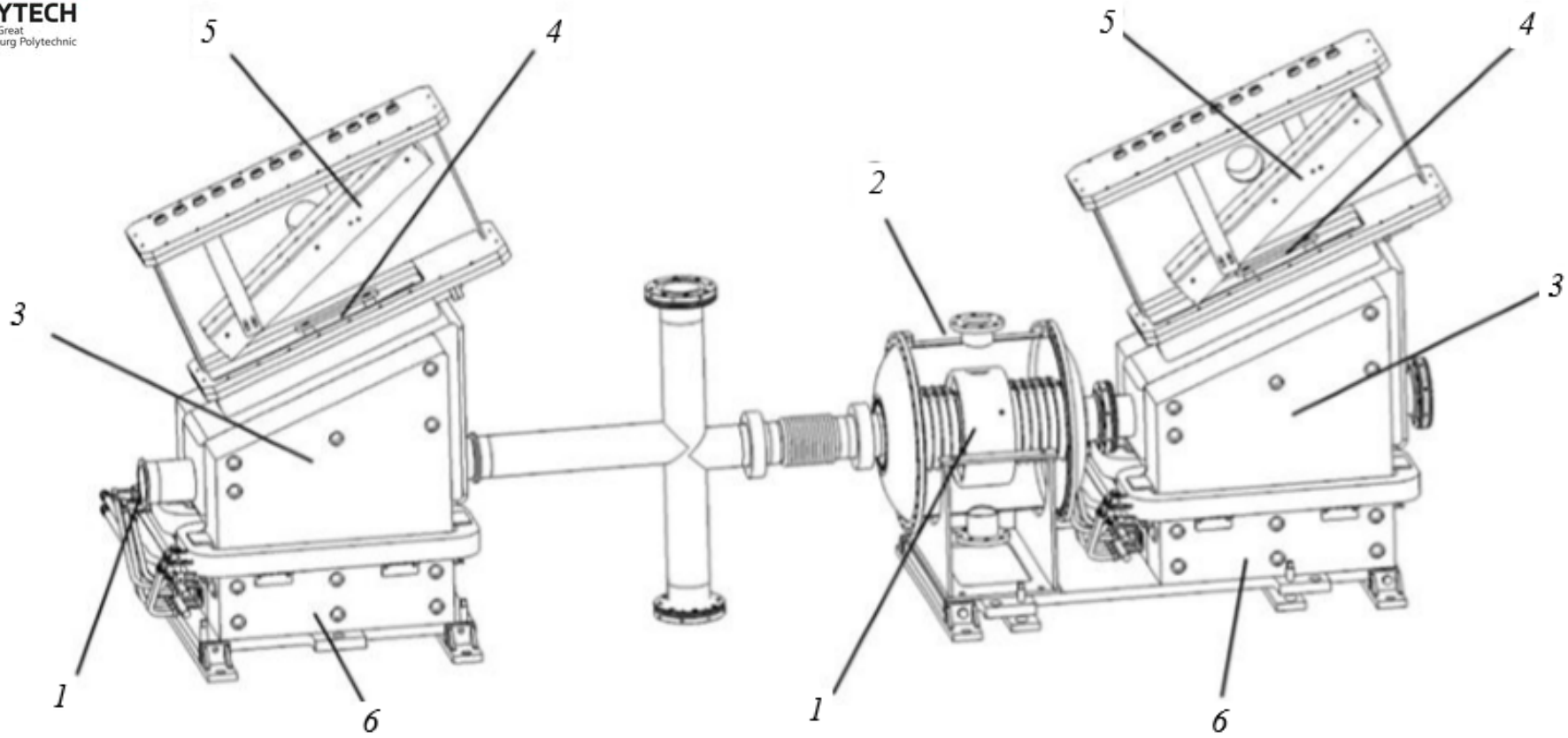
# 2. Use of atomic and molecular data in controlled nuclear fusion research

Peter the Great Polytechnic University and A.F. Ioffe Physico-Technical Institute

| Problem | Task | Publication | Processes | Data Source | Data Needs |
|---|---|---|---|---|---|
| **Numerical modelling and measurements of the ion distribution function on Globus-M and ITER** | Calculations of penetration of heating and diagnostic neutral beams into plasma.<br>Formation of the flux of escaping fast neutral atoms. | *S.Ya. Petrov, V.I. Afanasyev et al. Design features of neutral particle diagnostic system for ITER* ***Problems of Atomic Science and Technology, Series Thermonuclear Fusion 39*** *(2016) issue 1, pp. 68-80* | Charge changing reactions involving **H, D, T** | *R.K. Janev et al.* ***Nucl. Fusion 29*** *(1989) 2125-2140*<br>*S. Suzuki et al.* ***Plasma Phys. Control. Fusion 40*** *(1998) 2097–2111*<br>*R.K. Janev et al., Eds.* ***ATOMIC AND PMI DATA FOR FUSION****, Suppl. to Nucl. Fusion (IAEA 'green books')*<br>*and other published data* | Improved beam penetration model taking into account more impurity species |

# LENPA and HENPA for ITER

- Design and manufacturing by A.F. Ioffe Institute, numerical modelling by Peter the Great Polytechnic University

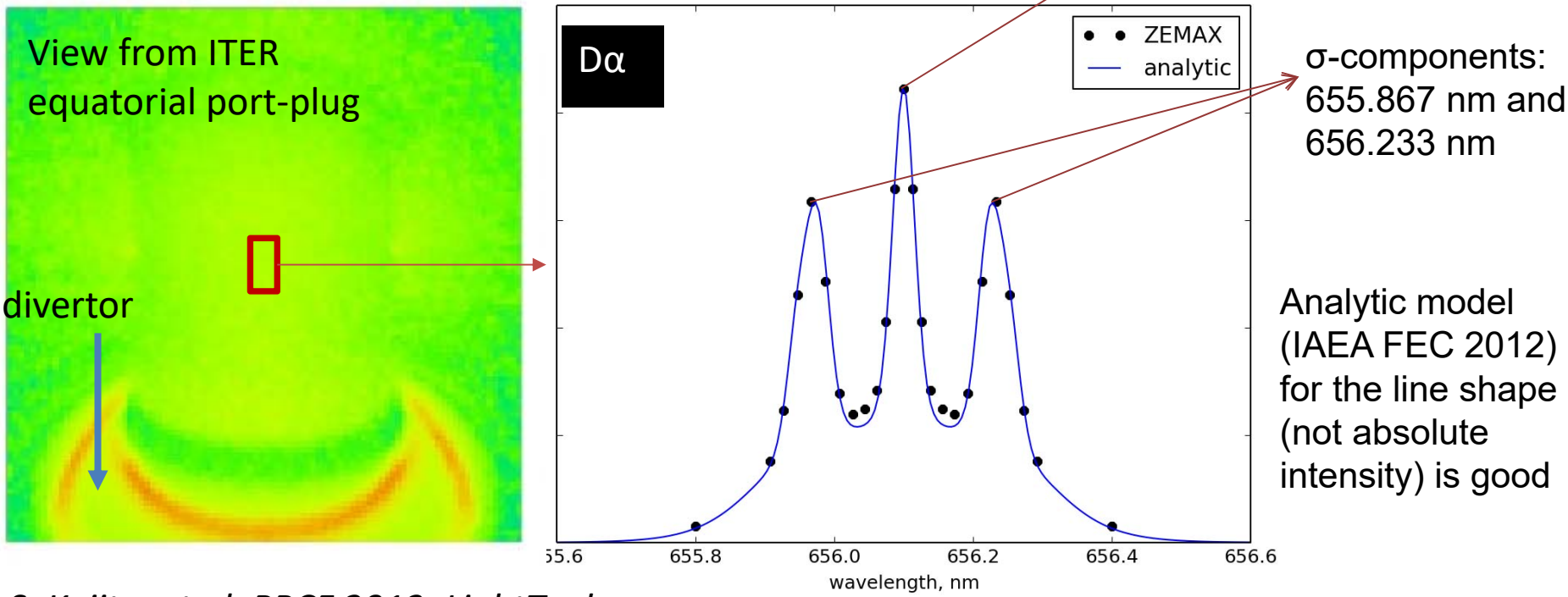



***1*** – stripping films; ***2*** – LENPA accelerator; ***3*** – electromagnets; ***4*** – plain capacitors; ***5*** – detector arrays; ***6*** – adjustable support

| Problem | Task | Publication | Processes | Data Source | Data Needs |
|---|---|---|---|---|---|
| **ITER main chamber H-alpha (and Visible Light) Diagnostic: "Synthetic Diagnostics" for error assessment and hardware optimization** | Measurement accuracy assessment, Divertor Stray Light (DSL) problem, optimization of optical dumps, ITER Measurement Requirement flow down | *A.B. Kukushkin, V.S. Neverov, A.G. Alekseev et al., Fusion Sci. Technol. **69** (2016) 628-642*<br><br>*E.N. Andreenko, A.G. Alekseev, A.B. Kukushkin et al. , Fusion Eng. Des., in press (2017)*<br><br>*S. Kajita, et al. Nuclear Fusion 2017 (accepted)* | All processes with $D_2$ and D<br><br>All processes with impurities (Be, W, etc.) | All for ITER<br>**B2-EIRENE (SOLPS4.3)**: background plasma in divertor+SOL<br>**EIRENE**: neutral D velocity distribution in SOL<br>**LightTools**: Balmer-alpha and Be DSL intensity<br>**ZEMAX**: Balmer-alpha DSL spectrum<br>**OSM+EIRENE+ DIVIMP**: Be emission<br>**ADAS**: in most of above codes | Beryllium ion transition probabilities in a strong magnetic field<br><br>Hydrogen isotope molecules dissociation with excited atoms as products<br><br>Beryllium hydride molecules |

# Stray light (SL) and optimization of optical dumps in ITER (Kurchatov Institute)

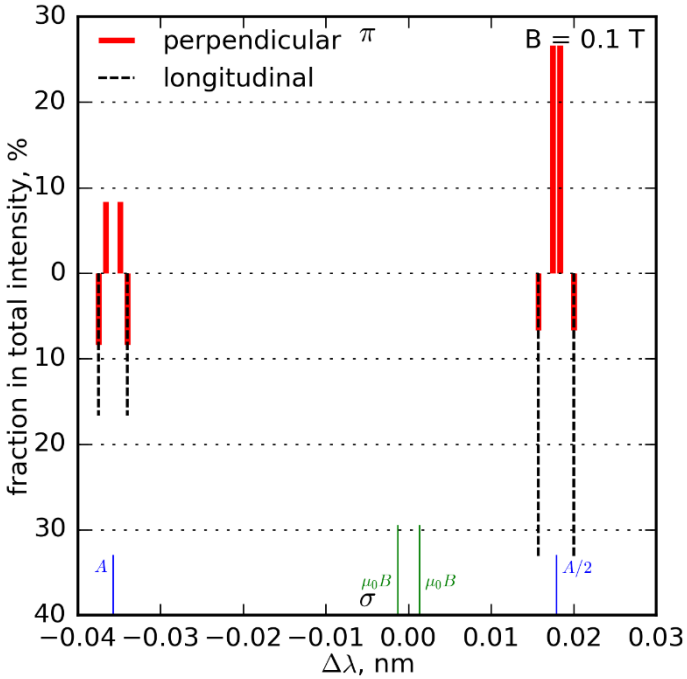
*scenario "d" (low dens. L-mode), λ = 656,1 nm*

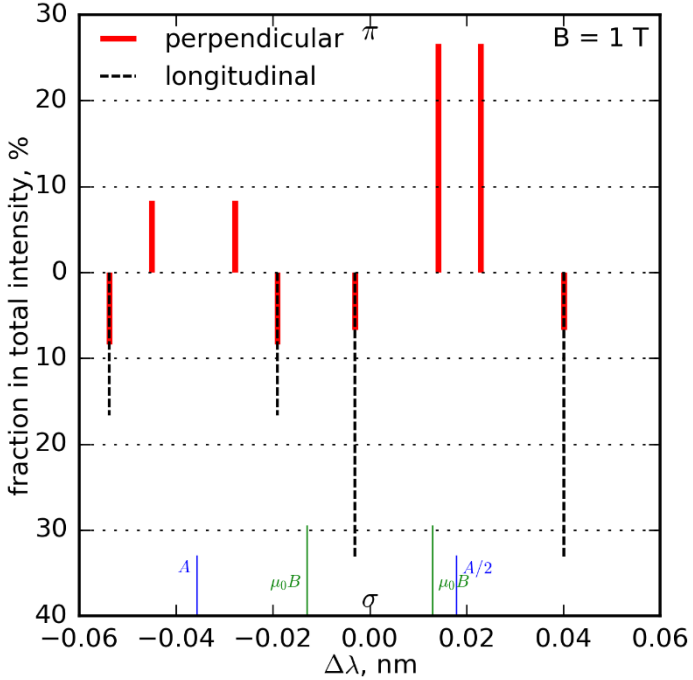


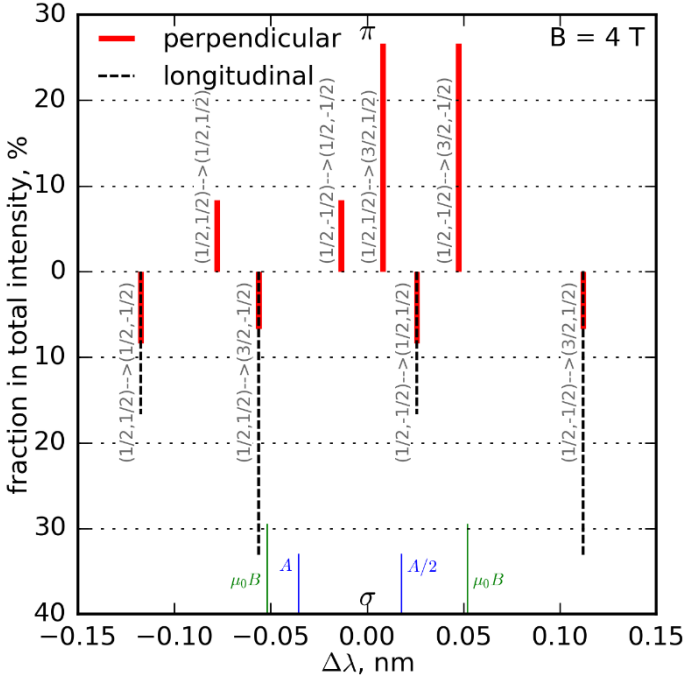

*S. Kajita, et al. PPCF 2013. LightTools code, SL intensity (integral in wavelength). Input: D-alpha emissivity from SOLPS (background SOL plasma), OSM-EIRENE-DIVIMP (SOL extended to first wall), ADAS (atomic data) (see Refs. in [1])*

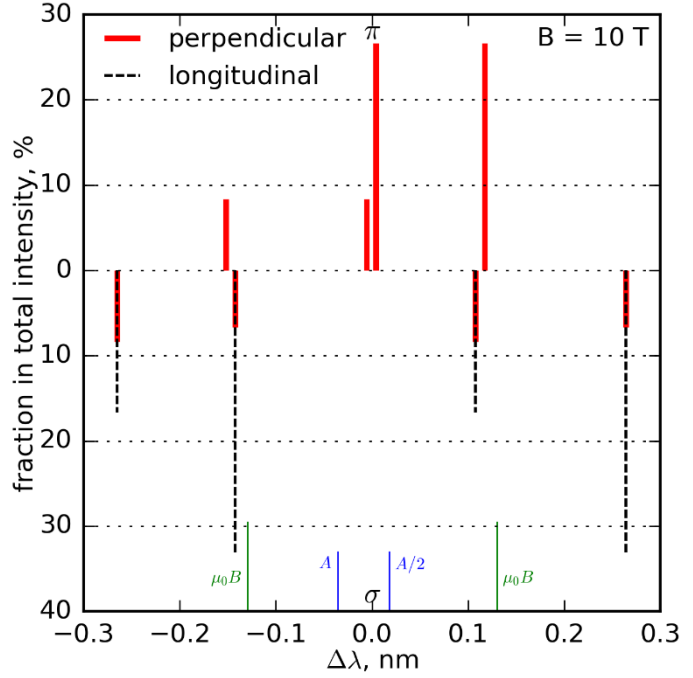
ZEMAX code, spectral line shape of the SL. Optimization of optical dumps in [1].


[1] E.N. Andreenko, A.G. Alekseev, A.B. Kukushkin, V.S. Neverov, S.W. Lisgo et al. , Fusion Engineering and Design (2017)



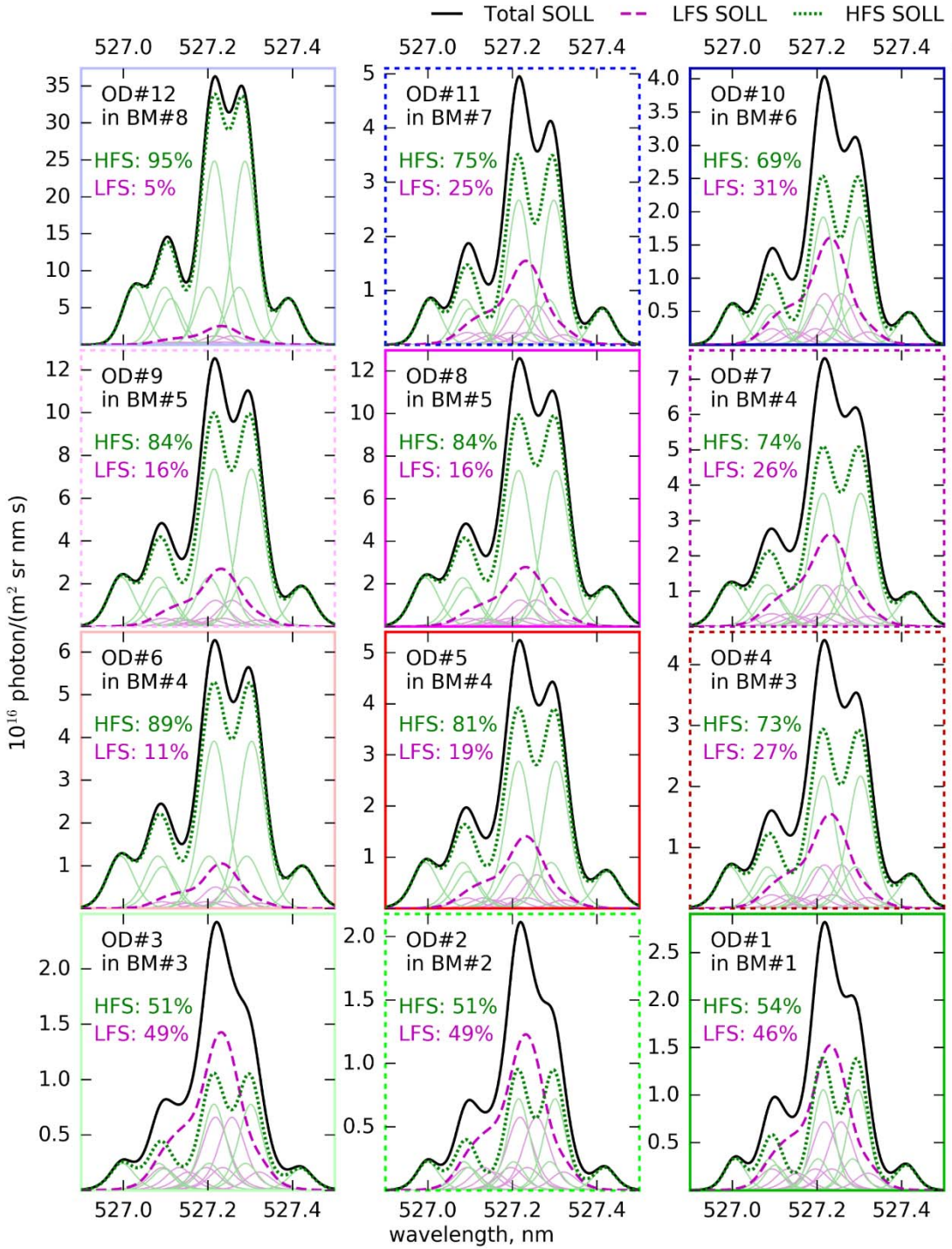



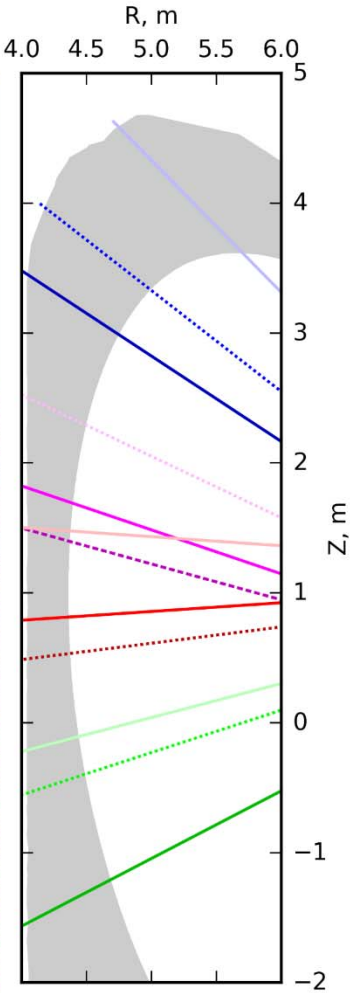




## Be II 527 nm

Fine structure of $1s^2 4s \rightarrow 1s^2 3p$ in magnetic field (0.1-10 T): fine structure splitting is comparable with Zeeman splitting in ITER

**DATA NEED:**
Transition probabilities in a strong magnetic field are **not** present in available databases and literature. Needed for high resolution spectroscopy of Be in ITER and JET.




Lines of sight:

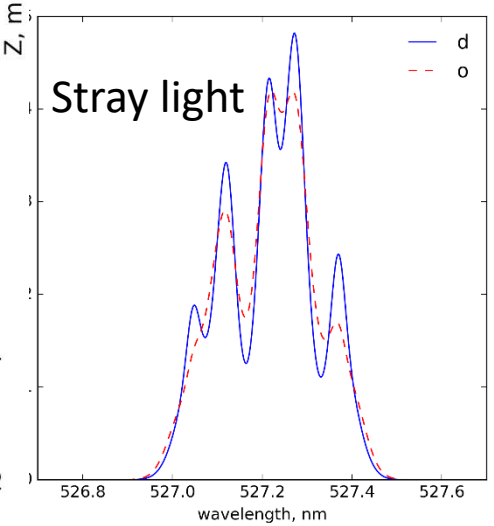
| top view | bottom view |
|---|---|
| OD#12 | OD#6 |
| OD#11 | OD#5 |
| OD#10 | OD#4 |
| OD#9 | OD#3 |
| OD#8 | OD#2 |
| OD#7 | OD#1 |

Scenario: d

# Be II 527 nm in ITER

Emissivity from OSM+EIRENE+ DIVIMP (S. Lisgo)

Line shapes from Kurchatov Inst. group

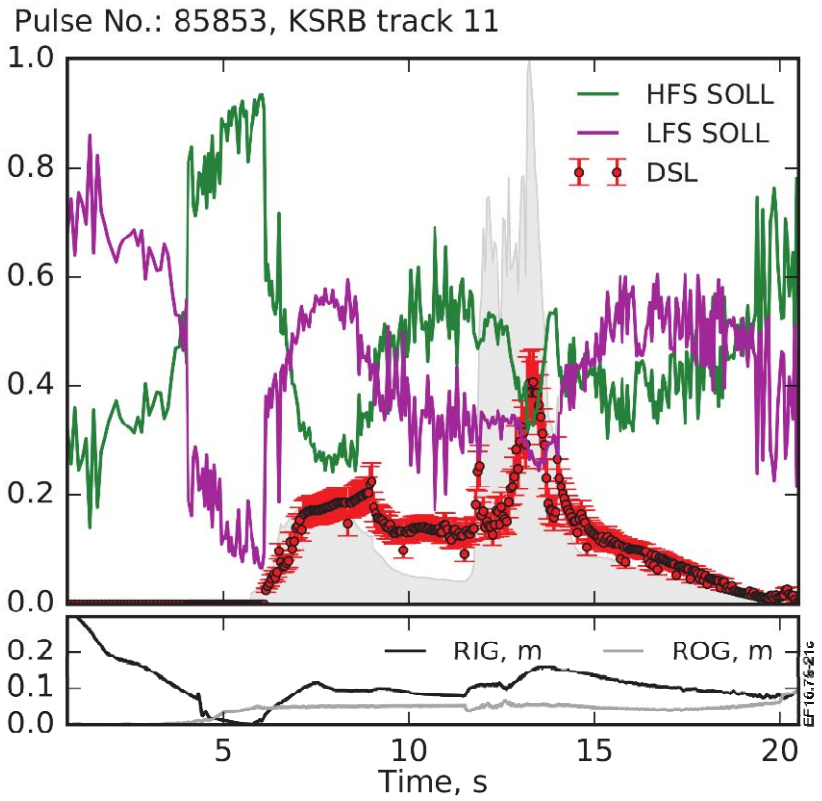


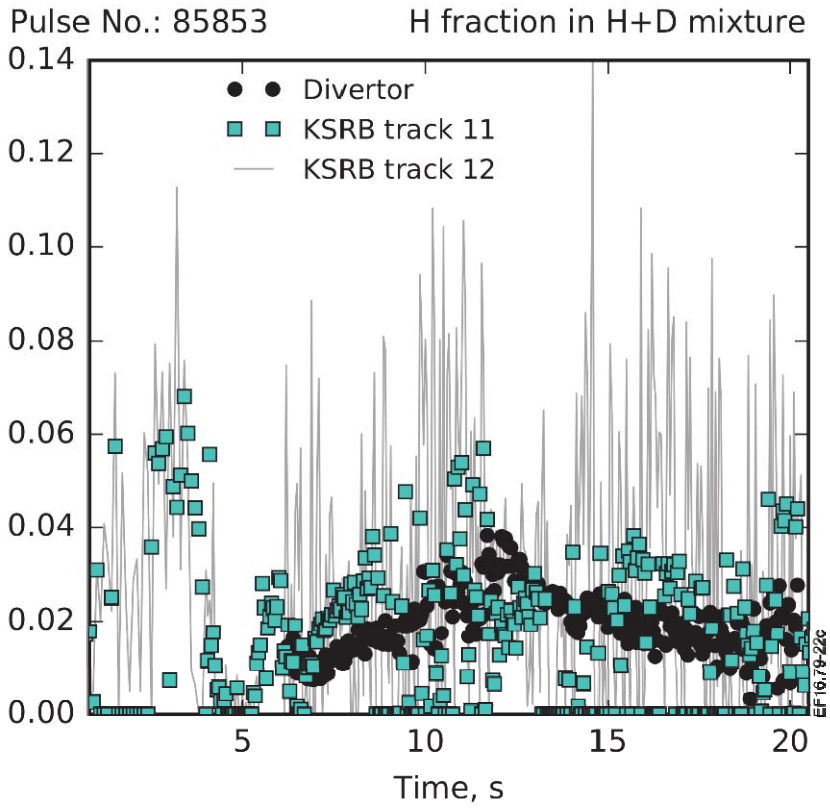

Stray light line shape is very close to that of HFS SOL light → high accuracy of atomic data is needed

| Problem | Task | Publication | Processes | Data Source | Data Needs |
|---|---|---|---|---|---|
| **H-alpha diagnostic in JET-ILW in support to ITER main chamber H-alpha (and Visible Light) Diagnostic** | Verification of H-alpha synthetic diagnostic for ITER in JET ITER-like Wall experiments<br><br>Isotope ratio monitoring in JET main chamber (with account of noticeable DSL) and divertor | *V.S. Neverov, A.B. Kukushkin, M.F. Stamp et al., Nucl. Fusion **57** (2017) 016031*<br><br>*V.S. Neverov, A.B. Kukushkin. KSRprocess software on JET* | All processes with D and H in SOL | Synthetic diagnostic for ITER A.B. Kukushkin, V.S. Neverov, et al. Fusion Sci. Tech., 2016, 69(3), 628-642 | Similar to needs for ITER, e.g. beryllium ion transition probabilities in a strong magnetic field |

# H-alpha high-resolution spectroscopy (HRS) on JET

**KSRprocess** code [V.S. Neverov, A.B. Kukushkin] is operating on **JET** data processing cluster for recovering the isotope ratio of hydrogen and deuterium in the SOL and divertor from high-resolution spectrum (HRS) of Balmer-alpha lines. **The HRS and respective atomic databases are critically needed** to separate useful signal (light from **LFS SOL** and **HFS SOL** on the lines of sight in main chamber, tracks 11 and 12 from equatorial ports) from background (divertor stray light, recovered from direct observation of divertor from the top).




*V.S. Neverov, A.B. Kukushkin, M.F. Stamp, et al., Nucl. Fusion **57** (2017) 016031*

# 3. Recent works on plasma-material interaction data

- Development of a fusion-fission hybrid system was mentioned among the priorities of Russian research programme on controlled nuclear fusion

  - E.A. Azizov et al.
    Update of Russian Federation Roadmap
    2nd IAEA DEMO Programme Workshop, 17-20 December 2013
  - B.V. Kuteev, Yu.S. Shpanskiy and DEMO-FNS Team
    Status of DEMO-FNS Development
    26th IAEA Int. Conf. on Fusion Energy, Kyoto, Japan, 17–22 October 2016
    Nucl. Fusion **57** (2017) 076039

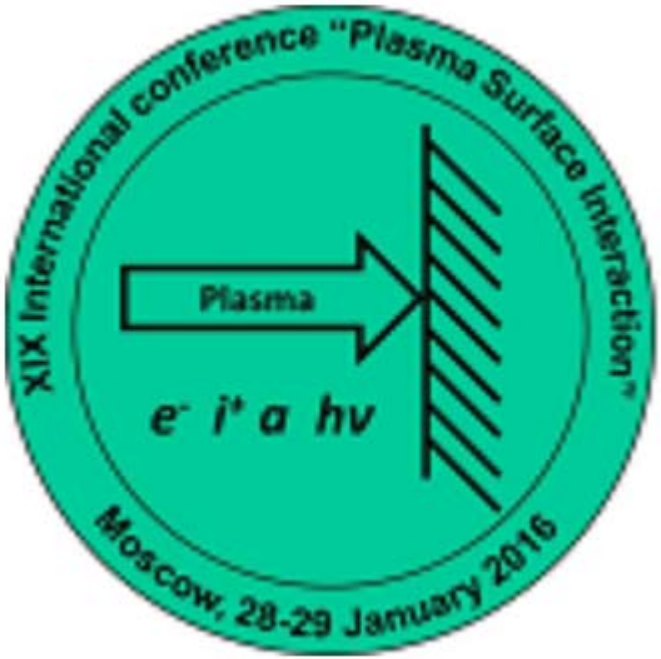
- This urges vigorous activity on the selection and testing of materials for steady state operation and studies of the underlying PMI processes

- **19th Russian Conference on Plasma-Surface Interaction**
  28-29 January 2016, Moscow, Russia http://plasma.mephi.ru/ru/psi2016en

- **20th Russian Conference on Plasma-Surface Interaction**
  26-27 January 2017, Moscow, Russia http://plasma.mephi.ru/ru/psi2017en

- **23rd International Conference on Ion-Surface Interactions ( ISI-2017 )**
  21-25 August 2017, Moscow, Russia http://isi2017.spbstu.ru/

- **5th International Symposium on Liquid Metals Applications for Fusion ( ISLA-5 )**
  25-27 September 2017, Moscow, Russia http://www.isla2017.mephi.ru/





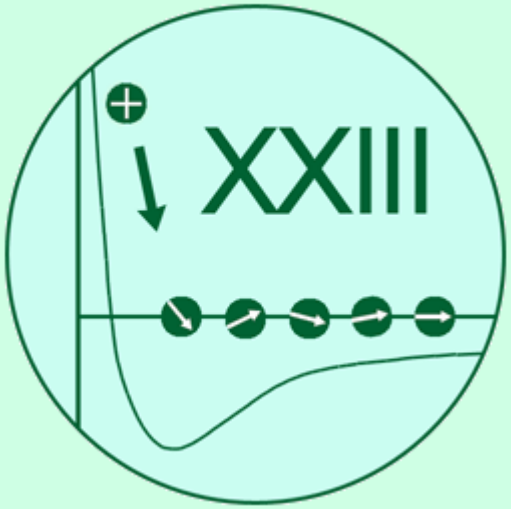
- Annual conference organized by Moscow Eng. Physics Institute

- **Russian Conferences on Plasma Surface Interaction** are mostly attended by domestic participants reporting on activities in Russia
- Selected papers from the **19th Conference** have been published in a special issue of Journal of Physics: Conference Series ( IOP ), vol. 748
- Materials of the **20th Conference** are not yet available in English. Selected papers are expected to appear in a journal later this year (presumably Journal of Physics: Conference Series).

| Processes | Method | Publication | Verification / Application | Problem |
|---|---|---|---|---|
| **Deuterium removal from radiation damage in tungsten by isotopic exchange with hydrogen atomic beam** | W samples were pre-irradiated with self-ions to create radiation-induced defects and then exposed to the $D^0$ beam. The deuterium removal was studied by isotopic exchange with $H^0$ beam. | *O.V. Ogorodnikova et al. Journal of Physics: Conference Series **748** (2016) 012007* | Controlled fusion research | The fuel removal methods from the wall materials need to be developed. One possible method is the isotope exchange. |
| **Surface modification and deuterium retention in reduced-activation steels under low-energy deuterium plasma exposure** | Reduced-activation ferritic/martensitic (RAFM) steelswere exposed to low energy D plasma (~20–200 eV per D). | *O.V. Ogorodnikova et al. Nucl. Fusion **57** (2017) 036010*<br><br>*O.V. Ogorodnikova et al. Nucl. Fusion **57** (2017) 036011* | -//- | Retention of Hydrogen isotopes in PFMs. |

| Processes | Method | Publication | Verification / Application | Problem |
|---|---|---|---|---|
| **Simulation of diffusion of hydrogen atoms in the lattice of tungsten** | Calculations using density functional theory (DFT) | *N.N. Degtyarenko, A.A. Pisarev, Journal of Physics: Conference Series **748** (2016) 012010* | Calculated temperature dependences of the diffusion coefficient were compared with experimental data from bibliography. | Behaviour of Hydrogen isotopes in PFMs. |
| **Plasma facing elements based on a liquid tin capillary pore system** | The corrosion resistance of Mo, Nb and W in pure liquid tin was investigated. at temperatures up to 1050°C. | I.E. Lyublinski et al. Journal of Physics: Conference Series 748 (2016) 012014 | It was found that Mo does not corrode in liquid Sn | Selection of alloy base material of the in-vessel tokamak elements based on liquid tin capillary pore systems. |

**Ion - Surface Interactions 2017**




**ISI 2017**

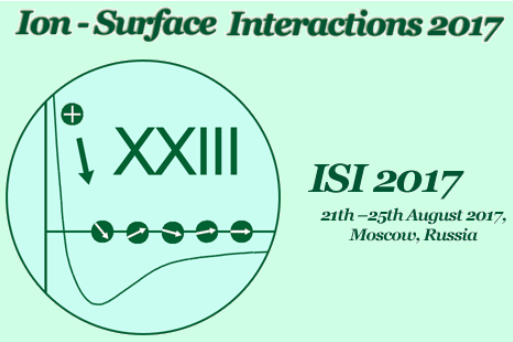
*21th –25th August 2017, Moscow, Russia*

- A biennial conference organized and sponsored by
  - Russian Academy of Sciences
  - Ministry of Education and Science
  - Moscow Eng. Physics Institute
  - Moscow State University
  - St. Petersburg Polytechnic University

  and other institutions

- Newest PMI activities in Russia and in the world were reported at the **23rd International Conference on Ion-Surface Interactions** ( ISI-2017, **21-25 August 2017, Moscow, Russia** )

- Selected papers will be published in special issues of
  - Bulletin of the Russian Academy of Sciences: Physics ( Springer )
  - Journal of Surface Investigation ( Springer )
  - Vacuum ( Elsevier )
  - Radiation Effects and Defects in Solids ( Taylor & Francis )

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MEPhI

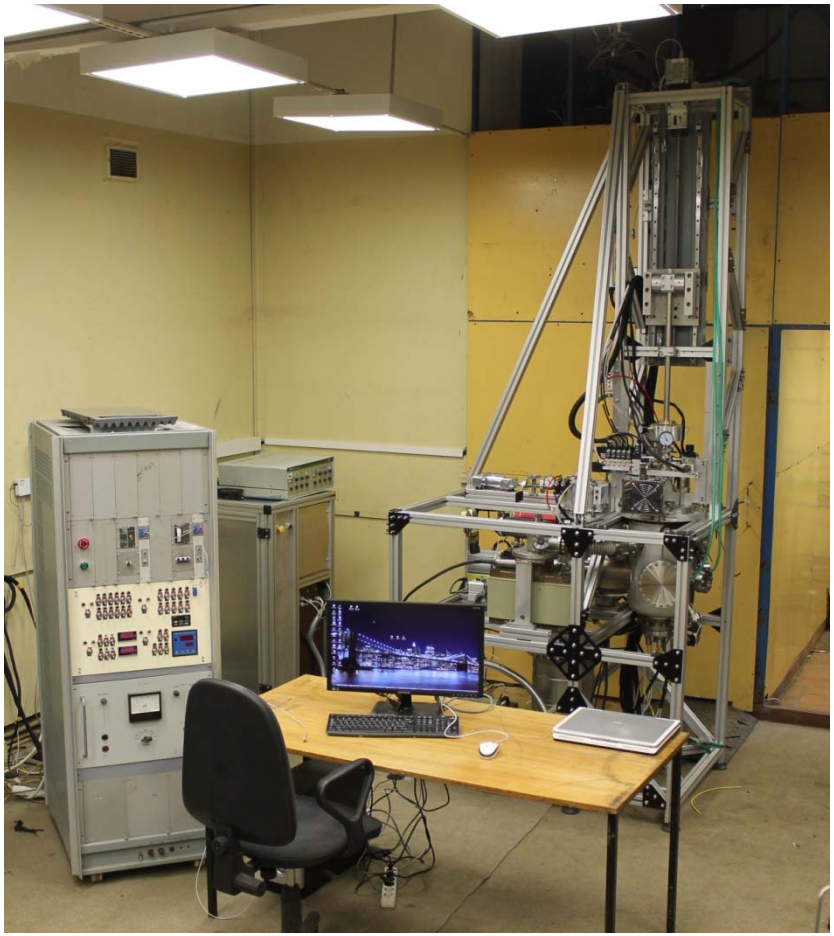
POLYTECH
Peter the Great St.Petersburg Polytechnic University

- More than 60 oral presentations, about 50% of them authored by researchers from Russia and others from EU, Japan, Korea, Norway, South Africa, UK, USA, and other countries
- About 130 poster presentations
- The scope of the conference is broad, covering fundamental science, controlled nuclear fusion, and industry, including 6 sections
  - Sputtering, surface structure, desorption
  - Ion scattering and propagation
  - Emission of ions, $e^-$, photons under ion-surface interaction
  - Ion implantation and surface modification
  - Ion-assisted processes in thin films and nanostructures
  - Physics and technology of plasma-surface interaction

# ISI-2017 Conference Reports relevant to Controlled Fusion

| Processes | Method | Publication | Verification / Application | Problem |
|---|---|---|---|---|
| **Hydrogen and helium retention in tungsten under ion irradiation** | Experiment | *Y. Gasparyan, Programme of ISI-2017, p. 12* | ITER, DEMO-FNS | W, Be, and C are being considered as PFMs. Retention is important in studies of plasma fueling and helium ash removal. |
| **Hydrogen trapping into and release from tungsten covered by beryllium/ aluminum oxide layer under plasma irradiation** | Experiment: Irradiation of tungsten and tungsten covered with Be/Al layers with 50 eV/at ions of $H_2$+1% $O_2$ plasma at 500 K | *L. Begrambekov, A. Kaplevsky, A. Evsin, S. Dovganyuk, A. Zakharov Programme of ISI-2017, p. 7* | ITER, DEMO-FNS | Sputtering of PFMs, transport of sputtered particles and subsequent deposition may lead to the appearance of coatings. Detritiation of W, Be, and Be-coated tungsten at low temperatures by irradiation with hydrogen plasma with oxygen addition. |
| **Removal of deuterium implanted into graphite by consequent irradiation by ions of hydrogen plasma** | Experiment: irradiation of surface with hydrogen atoms | A.A. Ayrapetov, L.B. Begrambekov, S.S. Dovganuk, A.S. Kapleuski, *Programme of ISI-2017, p. 12* | Laboratory plasma devices, controlled fusion research | Outgassing and detritization of graphite and boron carbide by plasma irradiation at low temperatures. |

# The Stand for film deposition and material irradiation



*L.B. Begrambekov, E.A. Azizov, O.I. Buzhinsky et al.* ***Proc. 25th IAEA Fusion Energy Conf.*** *(2014), MPT/P4-17*

**The goals of the Stand construction**

- Investigation of conditions of boron carbide (**$B_4C$**) coating deposition on tungsten;
- Testing of materials and thin films under thermal cycles and high power density ion and electron beam irradiation.

**The method of $B_4C$ coating deposition**

- The $B_4C$ coating is formed on tungsten substrate through deposition of boron and carbon atoms sputtered by plasma ions from boron and carbon targets

**The conditions of $B_4C$ deposition**

| | |
|---|---|
| Residual vacuum | ≤ $2\times10^{-8}$ Pa |
| Energy of sputtering ions | ≤ 20 KeV |
| Current of sputtering ions | ≤ 200 mA |
| Temperature | 500 - 900°C |

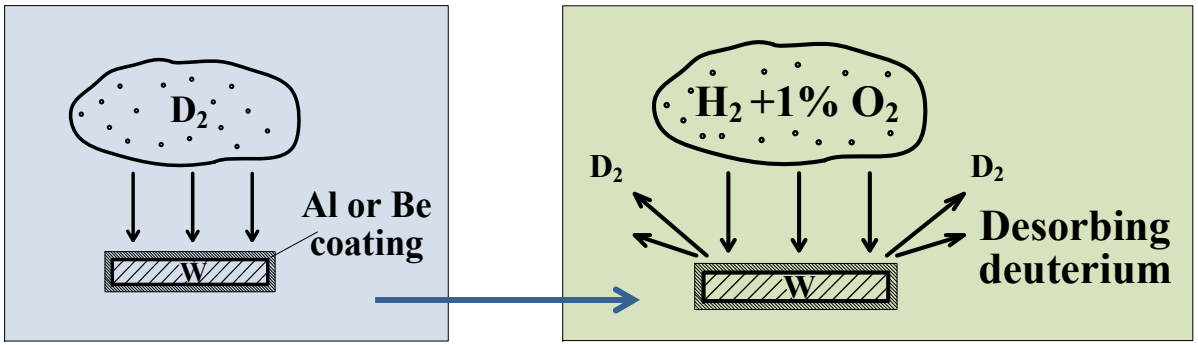
**The conditions of high heat load test**

| | |
|---|---|
| Quasy-stationary ion/electron beam with power density | ≤ 40 MW/m$^2$ |
| Testing cycle frequency | ≥ 1msec |
| Temperature of testing material | ≤ 2200°C |

Amounts of deuterium and hydrogen atoms in the tungsten samples without coatings (W) and with beryllium ($W_{Be}$) and aluminum ($W_{Al}$) layers after deuterium implantation and following irradiation by $H_2$ +1 % $O_2$ plasma.

| | Amount of deuterium atoms, $\times 10^{19}$ at/m$^2$ | | Amount of hydrogen atoms, $\times 10^{19}$ at/m$^2$ | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| Sample | Before irradiation with ions of $H_2$+1% $O_2$ plasma | After irradiation with ions of $H_2$+1% $O_2$ plasma | Before irradiation with ions of $H_2$+1% $O_2$ plasma | After irradiation with ions of $H_2$+1% $O_2$ plasma |
| **W** | 9.4 | 1.6 | 0.6 | 0.4 |
| **$W_{Be}$** | 16.0 | 3.1 | 6.5 | 4.1 |
| **$W_{Al}$** | 28.0 | 13.0 | 21.4 | 48.2 |

## Scheme of the experiments



# G.I. Budker Institute of Nuclear Physics

| Processes | Method | Publication | Verification / Application | Problem |
|---|---|---|---|---|
| **Study of plasma-surface interaction at the GOL-3 facility** | Experiments on GOL-3 | A.A. Shoshin, A.S.Arakcheev et al. Fusion Engineering and Design, vol. **114** (2017), pp. 157-179 (review paper) | Comparisons of different facilities for PSI studies are presented. | Experimental studies of PSI and behavior of materials under plasma loads in the multiple-mirror trap of the GOL-3 facility. The energy density in the extracted plasma stream varied from 0.5 to 30 $MJ/m^2$. |
| **In-situ imaging of tungsten surface modification under ITER-like transient heat loads** | A wide-area long-pulse electron beam was used for transient heating of tungsten. Sample surface was imaged with fast CCD cameras during the beam pulse. | A.A.Vasilyev, A.S.Arakcheev et al. Nuclear Materials and Energy, in press (available online 2016) https://doi.org/10.1016/j.nme.2016.11.017 | ITER and other controlled fusion research projects | A specialized test installation for research on material behavior under the impact of the powerful thermal shock was developed at the Budker Institute. It grants new capabilities for experimental simulation of transient heat loads corresponding to ITER-relevant ELMs type I. |

# Conclusions

- Generation of A-M data by experimental and computational methods in Russia in the past two years is reflected in a large number of publications in high-rank international journals
- Studies are motivated by astrophysics, biochemistry, fundamental science and controlled fusion research
- Development of ITER diagnostics in Russia reveals new data needs
- Strategic goals of Russian domestic research programme lead to vigorous activity on PMI data
- Generation of new PMI data was reported at several conferences hosted by Russian institutions and published in international scientific journals