# NDPCI Progress report: Nuclear Data Activities in India 2016-2017


**On behalf of NDPCI**

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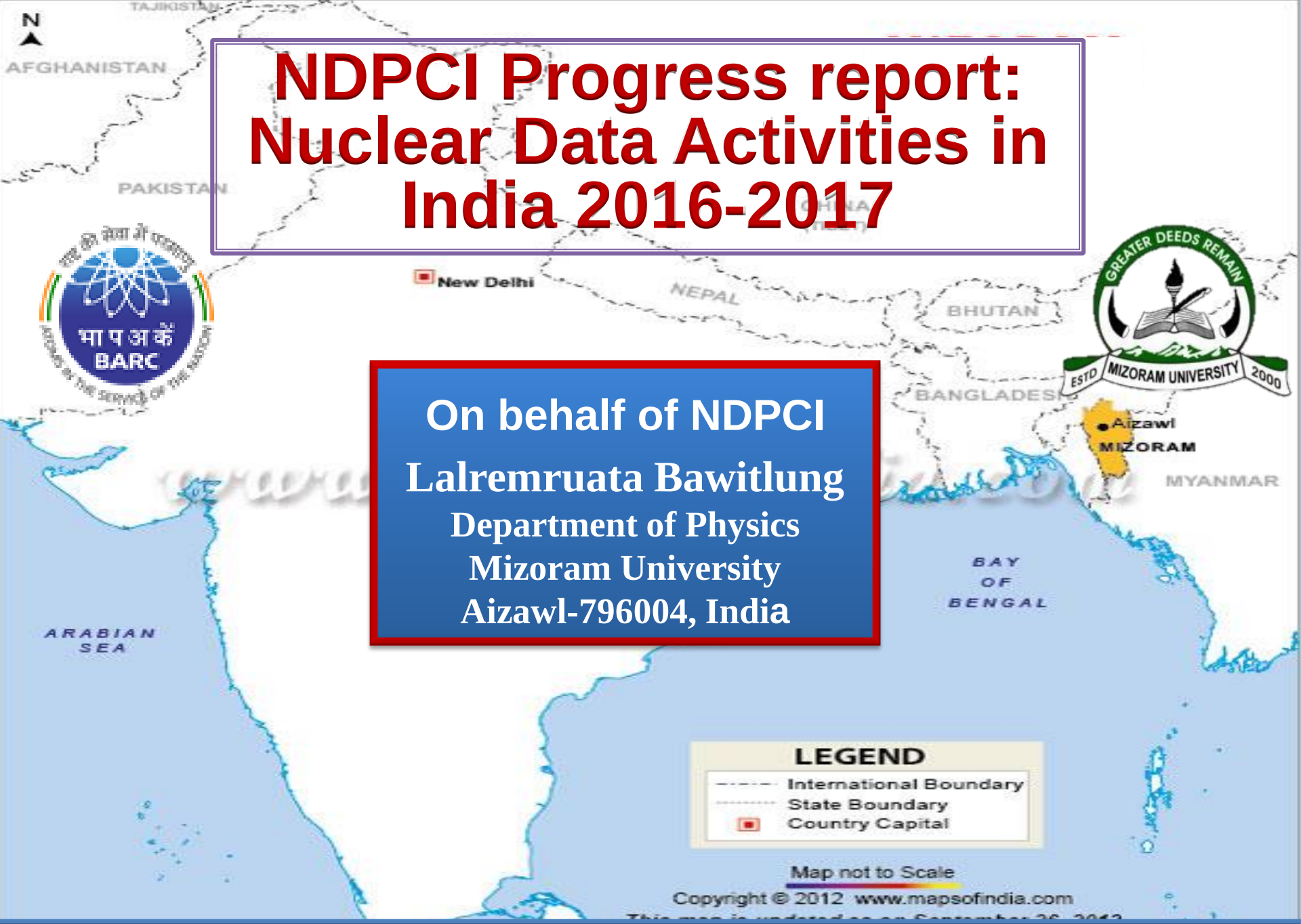




*NRDC-2017, IAEA's Headquarters, Vienna 23 to 26th May 2017.*

# CONTENTS

I. Conference organized(NDPCI Specific)

II. EXFOR Compilation activities

III. Other developments(Nuclear Data Measurements, Softwares, EXFOR-I)

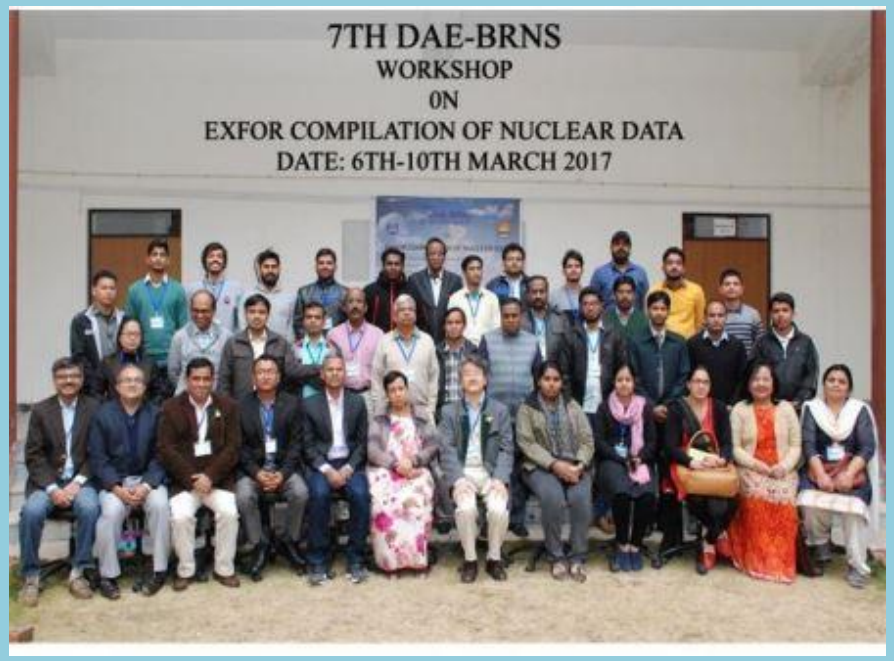
# I. Conference organized

1. Nuclear Reaction and Applications, BARC, 2-12th November 2016

2. 7th DAE-BRNS Workshop on Compilation of Experimental Nuclear Reaction Data(EXFOR-2017), NEHU, Shillong, India 6-10th March 2017

3. Error Propagation in Nuclear Reaction Data Measurement (EPNRDM-2017), Mizoram University, Aizawl, 13-14th March 2017.

## EXFOR-2017

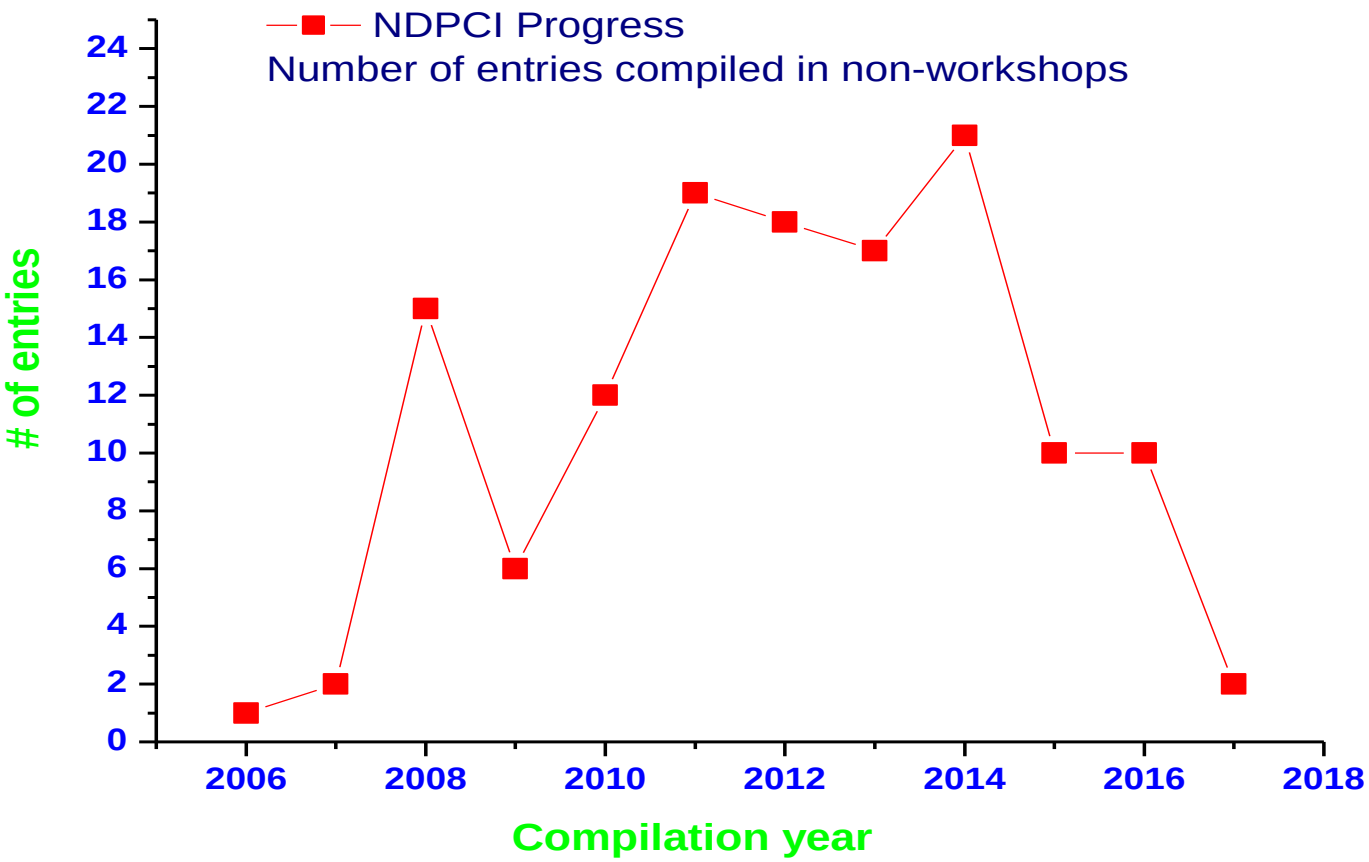



## EPNRDM-2017

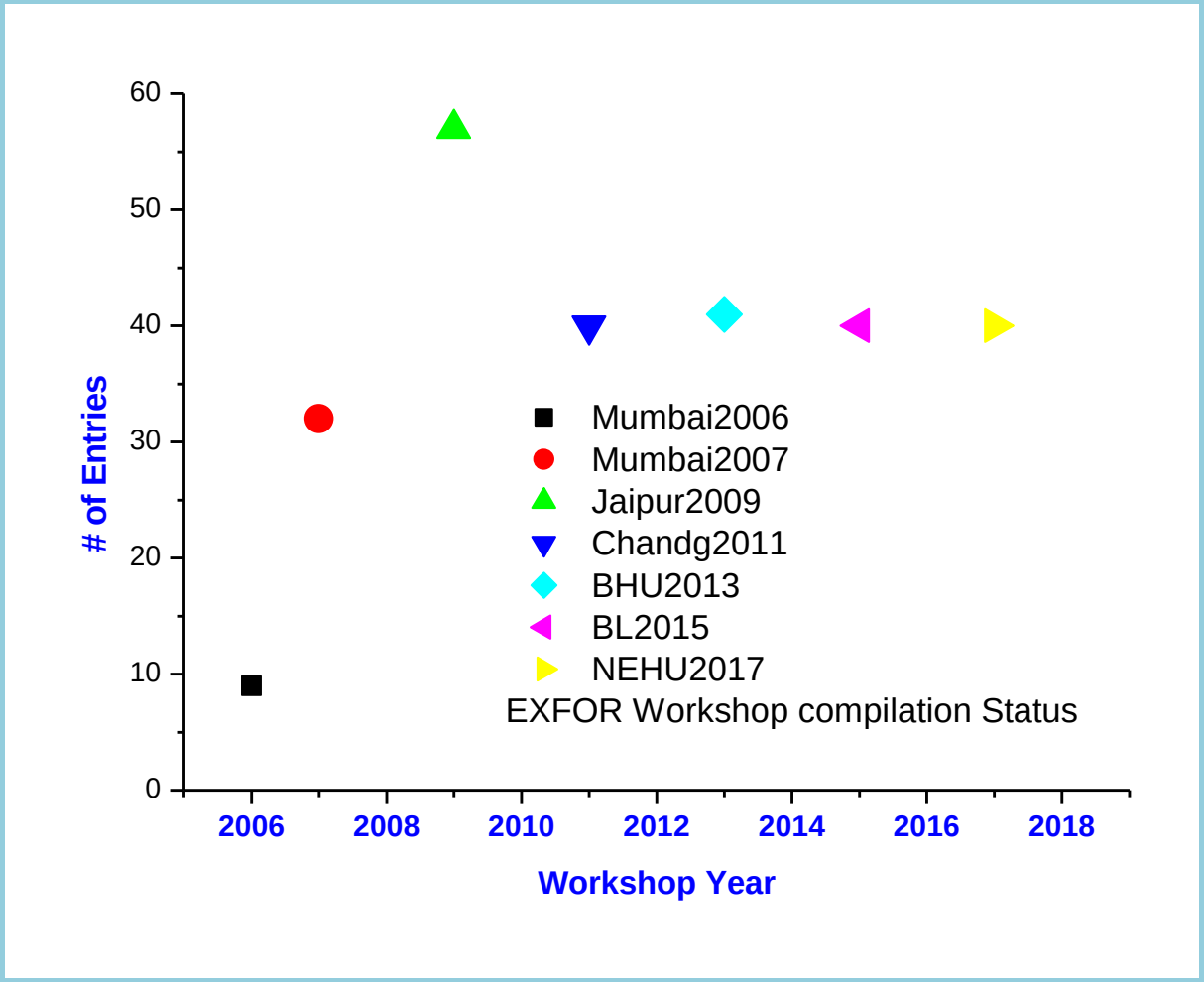
***The Fourth DAE-BRNS Theme Meeting on Generation and use of Covariance Matrices in the Applications of Nuclear Data****

***December 09-13, 2017***

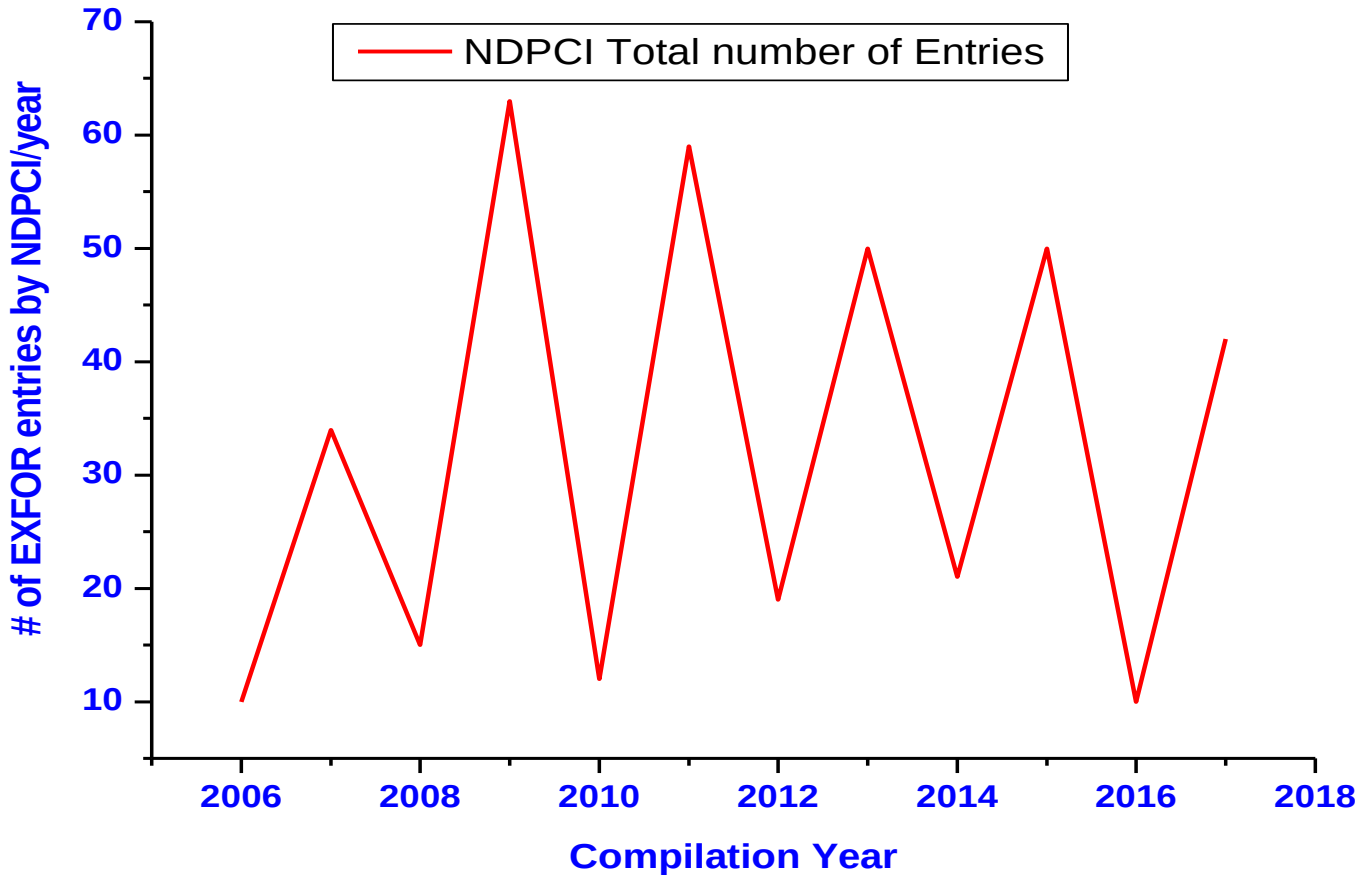
# Total number of entries for non workshop/regular activity since 2006



# Total number of entries for workshop since 2006



# Total number of entries since 2006 = 385 including 2017 workshop which is 1.7% of entries in EXFOR database



During 2016-2017, NDPCI submitted **52** entries to NDS

From Regular compilation activity = 23%

Charged particle induced = 34 Entries

Neutron induced reactions = 18 Entries

From EXFOR workshop = 77 %

About 90% entries are recent publications.

All new articles published till 2016 are completed, few old articles from Vidya's scanning remains

# III. Other developments(Nuclear Data Measurements, Softwares, EXFOR-I)

## III. 1. Nuclear Data Measurements

**Neutron Induced Cross section Measurement:**

| En(MeV) | Reaction | Facility | Source | Group |
|---|---|---|---|---|
| 0.5 – 2 MeV | $^{70}Zn(n,g)^{71}Zn^{m}$ | FOTIA,BARC | $^{7}Li(p,n)^{7}Be$ | MZU |
| 2 - 15 MeV | $^{232}Th(n,g)^{233}Th$<br>$^{232}Th(n,2n)^{231}Th$<br>$^{238}U(n,g)^{239}U$<br>$^{238}U(n,2n)^{237}U$ | CCW,BARC | D-D,D-T | BARC |
| 6 – 13 MeV | 92-U-238(N,F)ELEM/MASS,CUM,FY<br>92-U-238(N,F)MASS,CHN,FY<br>92-U-238(N,F),SEC,AP,LF<br>92-U-238(N,F),SEC,AP,HF | 14 UD Pelletron | $^{7}Li(p,n)^{7}Be$ | BARC |
| Thermal | 56-BA-138(N,G)56-BA-139,,SIG<br>56-BA-138(N,G)56-BA-139,,RI<br>59-PR-141(N,G)59-PR-142,,SIG<br>59-PR-141(N,G)59-PR-142,,RI | Am-Be | | Manipal Univ. |
| 7 – 20 MeV | 26-FE-55(N,X)1-H-1,,SIG | 14 UD Pelletron | 6Li beam | IPR/BARC |
| 1 – 5 MeV | 25-MN-55(N,G)25-MN-56,,SIG | 14 UD Pelletron | $^{7}Li(p,n)^{7}Be$ | MSU/BARC |

# Charged particle and Heavy ion induced reactions

28-NI-64(3-LI-7,EL)28-NI-64,,DA,,RTH
28-NI-64(3-LI-7,NON),,SIG,,,DERIV
78-PT-198(6-C-12,FUS),,SIG,ER

13-AL-27(D,HE3)12-MG-26,PAR,DA

28-NI-64(3-LI-7,2N)31-GA-69,IND,SIG
28-NI-64(3-LI-7,3N)31-GA-68,,SIG
28-NI-64(3-LI-7,3N)31-GA-68,,SIG
28-NI-64(3-LI-7,X)30-ZN-69,IND,SIG
28-NI-64(3-LI-7,X)30-ZN-68,IND,SIG
41-NB-93(3-LI-7,EL)41-NB-93,,DA
41-NB-93(3-LI-7,X)3-LI-7,PAR,DA
41-NB-93(3-LI-7,X+T)2-HE-4,,DA,T+A
41-NB-93(3-LI-7,X)3-LI-6,PAR,DA
41-NB-93(3-LI-7,X)4-BE-8,PAR,DA
41-NB-93(3-LI-7,X)2-HE-4,,SIG
41-NB-93(3-LI-7,X)4-BE-8,PAR,SIG
41-NB-93(3-LI-7,X)3-LI-6,PAR,DA
41-NB-93(3-LI-7,X)3-LI-7,PAR,DA

41-NB-93(3-LI-7,5N)44-RU-95,,SIG
41-NB-93(3-LI-7,X)43-TC-96,,SIG
41-NB-93(3-LI-7,X)43-TC-95,CUM?,SIG
41-NB-93(3-LI-7,X)42-MO-93-M,,SIG

6-C-12(6-C-12,X)3-LI-6,,DA
6-C-12(6-C-12,X)3-LI-7,,DA
6-C-12(6-C-12,X)4-BE-7,,DA
6-C-12(6-C-12,X)4-BE-9,,DA
6-C-12(6-C-13,X)3-LI-6,,DA
6-C-12(6-C-13,X)3-LI-7,,DA
6-C-12(6-C-13,X)4-BE-7,,DA
50-SN-112(3-LI-6,X)3-LI-6,PAR,DA
50-SN-112(3-LI-6,X+D)2-HE-4,,DA,D+A
50-SN-112(3-LI-6,EL)50-SN-112,,DA,,RTH
50-SN-112(3-LI-6,X)3-LI-5,,DA
50-SN-112(3-LI-6,X)4-BE-8,,DA
50-SN-112(3-LI-6,X)2-HE-4,,SIG
50-SN-112(3-LI-6,X)3-LI-6,PAR,SIG
50-SN-112(3-LI-6,X+D)2-HE-4,,SIG
50-SN-112(3-LI-6,X)3-LI-5,,SIG
50-SN-112(3-LI-6,X)4-BE-8,,SIG

# Charged particle and Heavy ion induced reactions continued ->

28-NI-58(6-C-12,X)ELEM/MASS,,DA
28-NI-58(6-C-12,X)4-BE-8,PAR,DA
26-FE-56(6-C-12,X)ELEM/MASS,,DA
26-FE-56(6-C-12,X)4-BE-8,PAR,DA
28-NI-58(6-C-12,EL)28-NI-58,,DA,,RTH
28-NI-58(6-C-12,NON),,SIG,,,DERIV

70-YB-174(8-O-16,FUS),,SIG,ER
70-YB-176(8-O-16,FUS),,SIG,ER

65-TB-159(9-F-19,4N)74-W-174,,SIG
65-TB-159(9-F-19,5N)74-W-173,,SIG
65-TB-159(9-F-19,6N)74-W-172,,SIG
65-TB-159(9-F-19,X)73-TA-173,IND,SIG

69-TM-169(14-SI-28.F),,DA,FF,RSD
70-YB-176(14-SI-28,F),,DA,FF,RSD
71-LU-175(14-SI-28,F),,DA,FF,RSD
72-HF-180(14-SI-28,F),,DA,FF,RSD
73-TA-181(14-SI-28,F),,DA,FF,RSD
74-W-182(14-SI-28,F),,DA,FF,RSD
69-TM-169(14-SI-28.F),,SIG
70-YB-176(14-SI-28,F),,SIG
71-LU-175(14-SI-28,F),,SIG
72-HF-180(14-SI-28,F),,SIG
73-TA-181(14-SI-28,F),,SIG
74-W-182(14-SI-28,F),,SIG

65-TB-159(8-O-16,2N)73-TA-173..SIG
65-TB-159(8-O-16,X)72-HF-173,(CUM),SIG
65-TB-159(8-O-16,3N)73-TA-172,,SIG
69-TM-169(8-O-16,2N)77-IR-183,,SIG
90-TH-232(5-B-10,SCT)90-TH-232,PAR,DA,,RTH
90-TH-232(5-B-11,SCT)90-TH-232,PAR,DA,,RTH
90-TH-232(5-B-10,NON),,SIG,,,DERIV
90-TH-232(5-B-11,NON),,SIG,,,DERIV

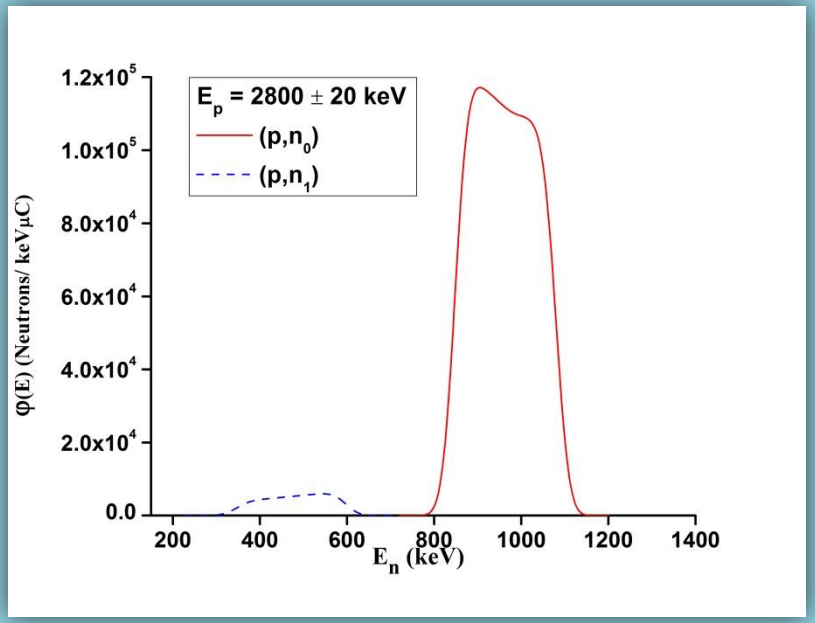
# III. 2. Software Developments- EPEN

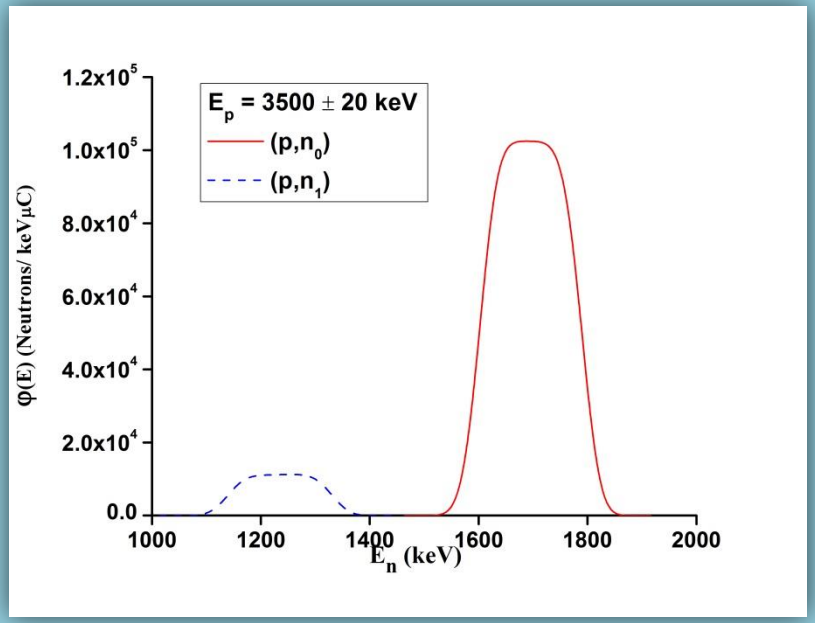
$^{7}Li(p,n)^{7}Be$ neutron spectrum code(EPEN) from threshold to 4 MeV have been developed in collaboration with NDS, IAEA.

In India, the FOTIA(Folded Tandem Ion Accelerator) and 14 UD Pelletron Facility at TIFR, Mumbai are the facility used for performing neutron induced cross section measurement using $^{7}Li(p,n)^{7}Be$ as neutron source.

However, due to the continious beam structure and low flux, ToF technique can not be employed for neutron energy-flux spectrum for data reduction procedure. Experimentalist therefore has to reply on simulated neutron spectra.

# EPEN neutron energy spectrum at $E_p$ = 2800 ± 20 keV and 3500 ± 20 keV



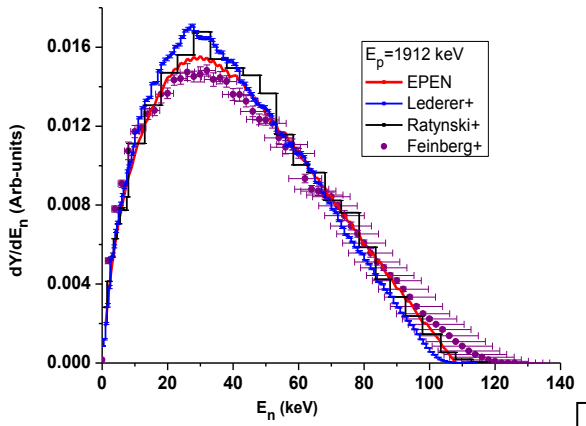

**$\langle E_{p,n0} \rangle$ = 0.96 MeV**

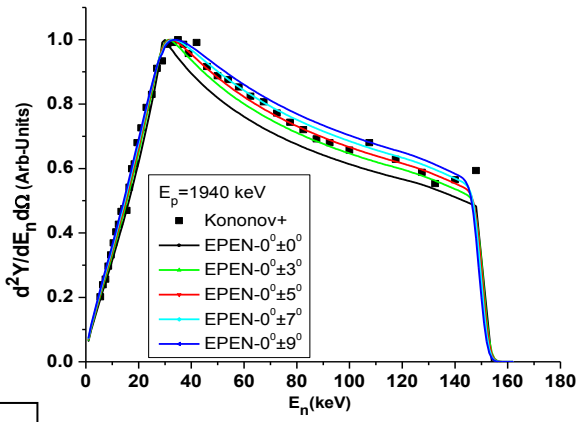
**$\langle E_{p,n1} \rangle$ = 1.69 MeV**

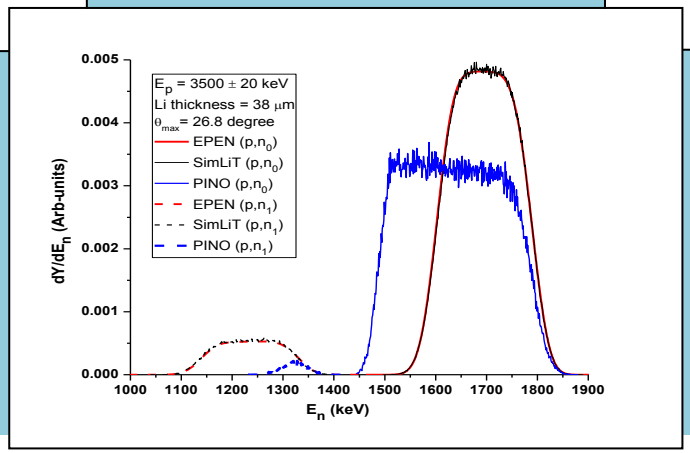
**Such neutron spectra are utilized for experimental data analysis and for background neutron simulations using Monte Carlo codes**

# Validation

**EPEN reproduces experimental spectra well**

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ANS

## Thick and Thin Target $^{7}Li(p,n)^{7}Be$ Neutron Spectra Below the Three-Body Breakup Reaction Threshold

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[b]*International Atomic Energy Agency, Nuclear Data Section, Division of Physical and Chemical Sciences, Department of Nuclear Sciences and Applications, Wien A-1400, Austria*

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Accepted for Publication January 13, 2017

**Abstract** — *Recently, we measured the $^{70}Zn(n,\gamma)^{71}Zn^{m}$ activation cross sections using the $^{7}Li(p,n)^{7}Be$ neutron source for 2.0 MeV < $E_p$ < 3.7 MeV. Since the time-of-flight and multiple foil activation techniques*

PHYSICAL REVIEW C **95**, 024619 (2017)

# Measurements of neutron capture cross sections on $^{70}$Zn at 0.96 and 1.69 MeV

L. R. M. Punte,[1] B. Lalremruata,[1,*] N. Otuka,[2] S. V. Suryanarayana,[4] Y. Iwamoto,[3] Rebecca Pachuau,[1] B. Satheesh,[1] H. H. Thanga,[1] L. S. Danu,[4] V. V. Desai,[4] L. R. Hlondo,[1] S. Kailas,[4] S. Ganesan,[5] B. K. Nayak,[4] and A. Saxena[4]

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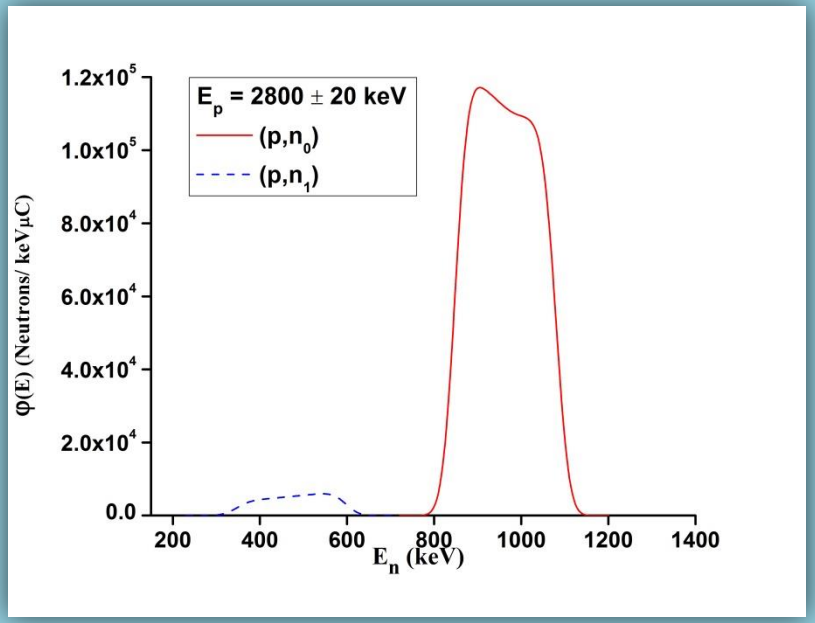
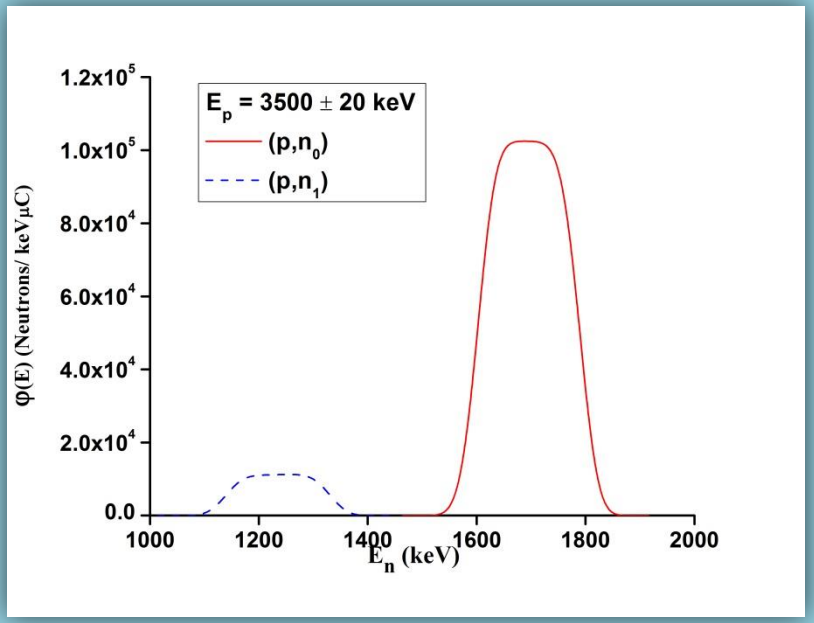
[5]*Reactor Physics Design Division, BARC, Mumbai-40085, India*

(Received 24 November 2016; revised manuscript received 10 January 2017; published 28 February 2017)




**$<E_{p,n0}>$ = 0.96 MeV**

**$<E_{p,n1}>$ = 1.69 MeV**

PHYSICAL REVIEW C **95**, 024619 (2017)

## Measurements of neutron capture cross sections on $^{70}$Zn at 0.96 and 1.69 MeV

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# III. 2. Software Developments- EXFOR-I

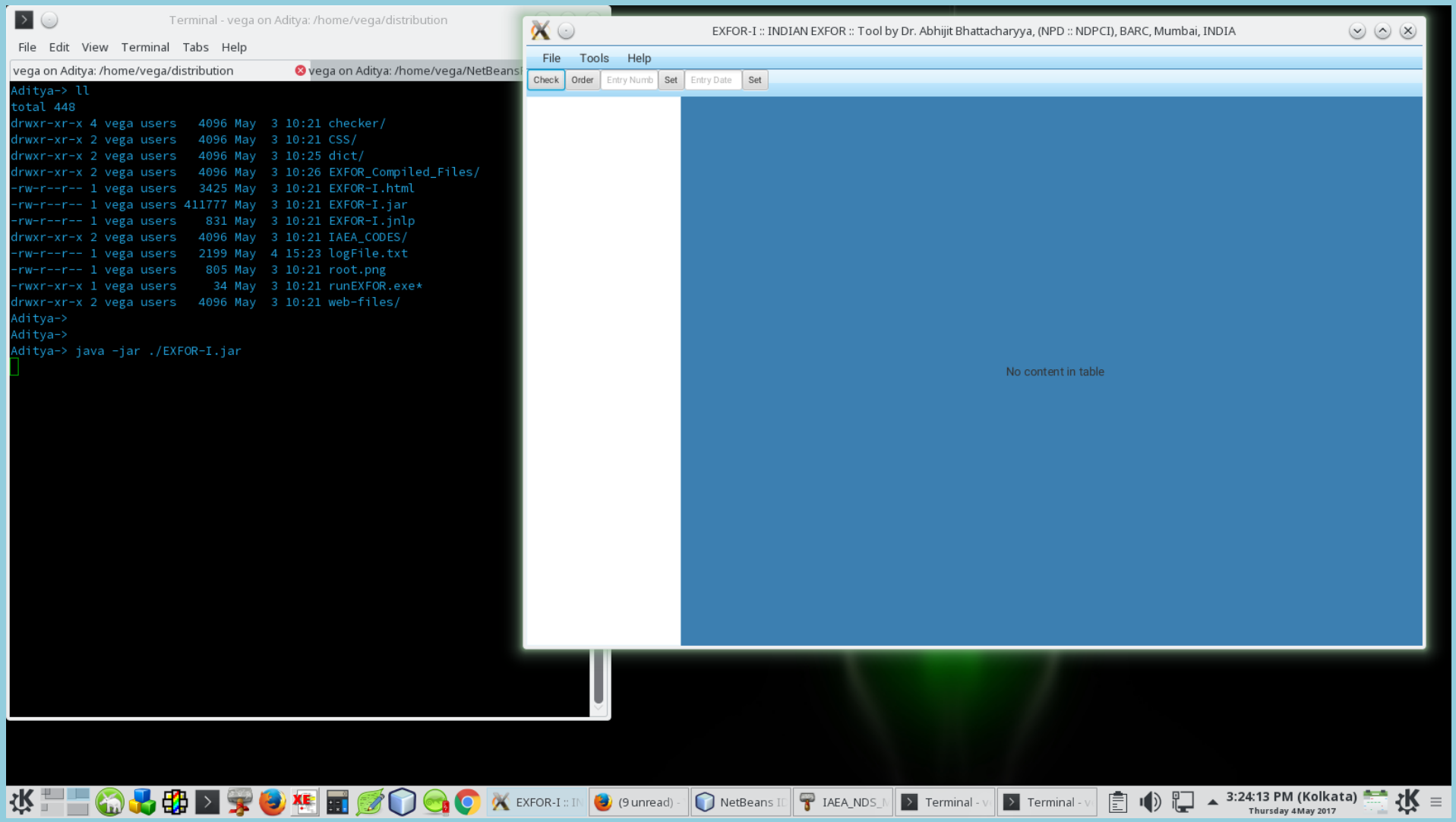
## "EXFOR-I" Editor

Being developed and tested by Abhijit Bhattacharyya

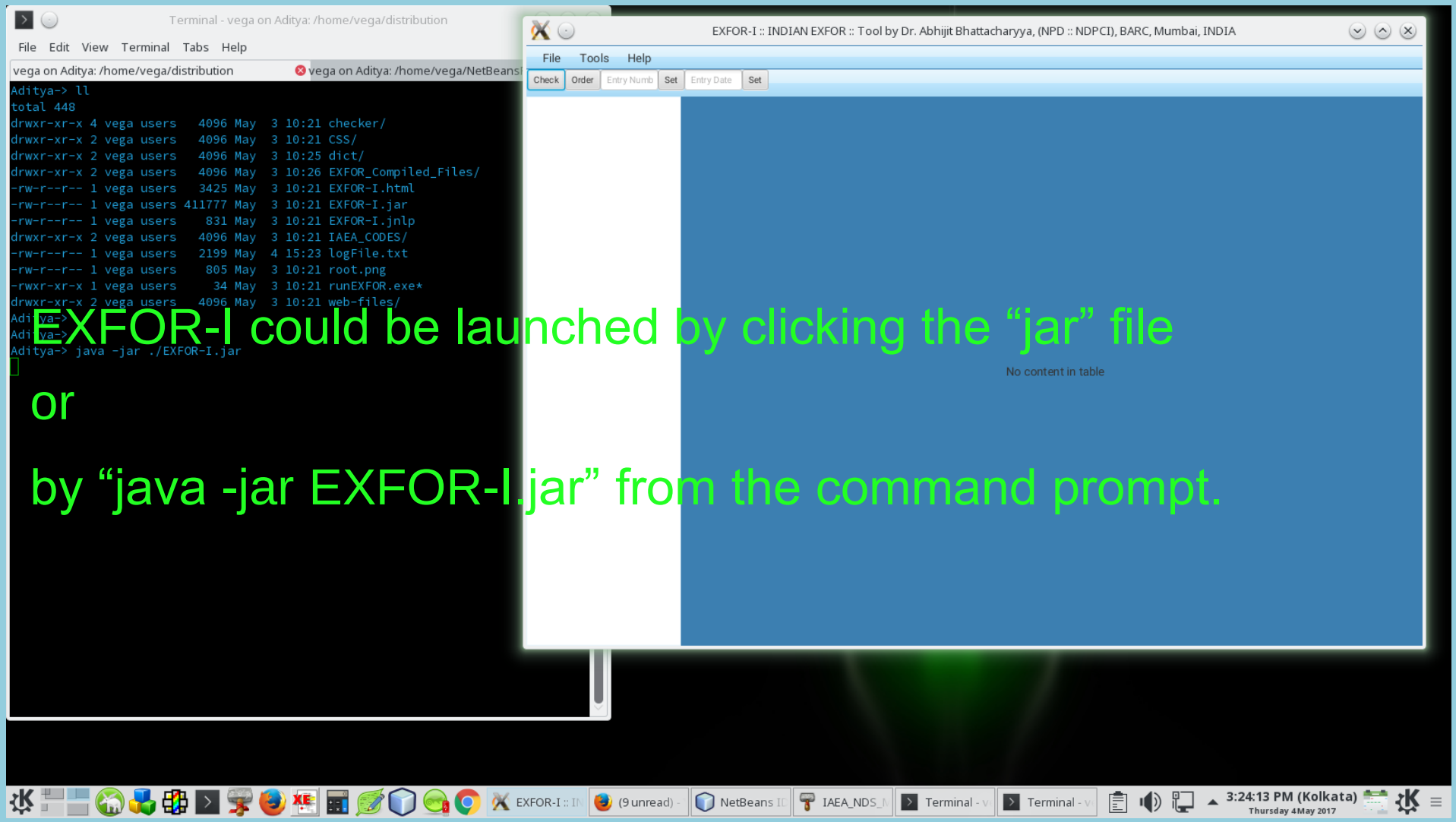
- Nuclear Data Physics Centre (NDPCI)
- Bhabha Atomic Research Centre
- Mumbai
- INDIA

- EXFOR-I is an Indian initiative like Russian and Japanese.
- EXFOR-I is platform independent, offline, simple and minimalist software.
- EXFOR-I automates simple jobs.
- EXFOR-I provides handles for CHEX and JANIS checker besides it's own simple checker.
- EXFOR-I will provide live hints for possible error during compilation.
- EXFOR-I uses IAEA dictionaries without any further modification for the code resulting in easy update

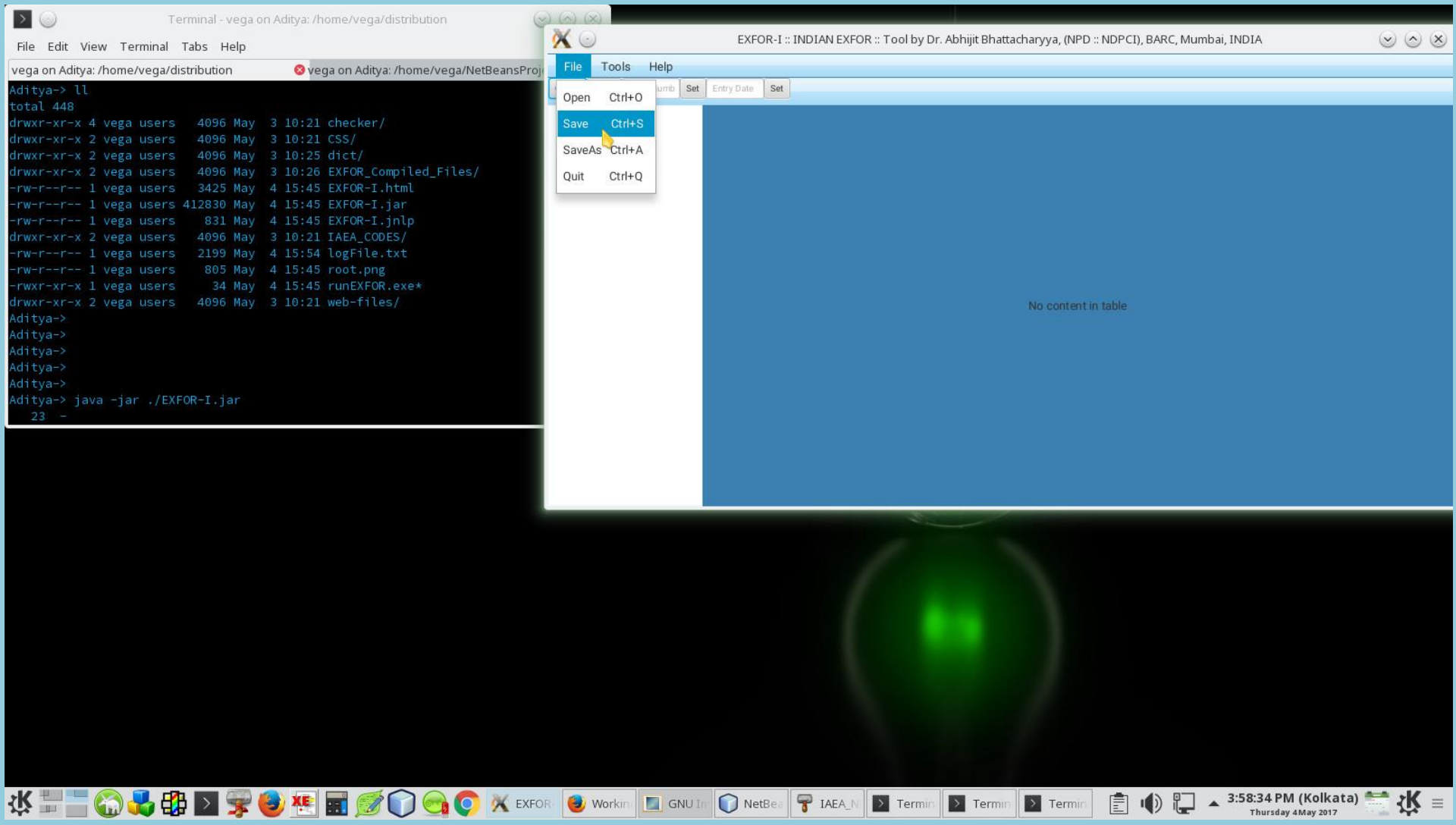
# EXFOR-I (Launch)



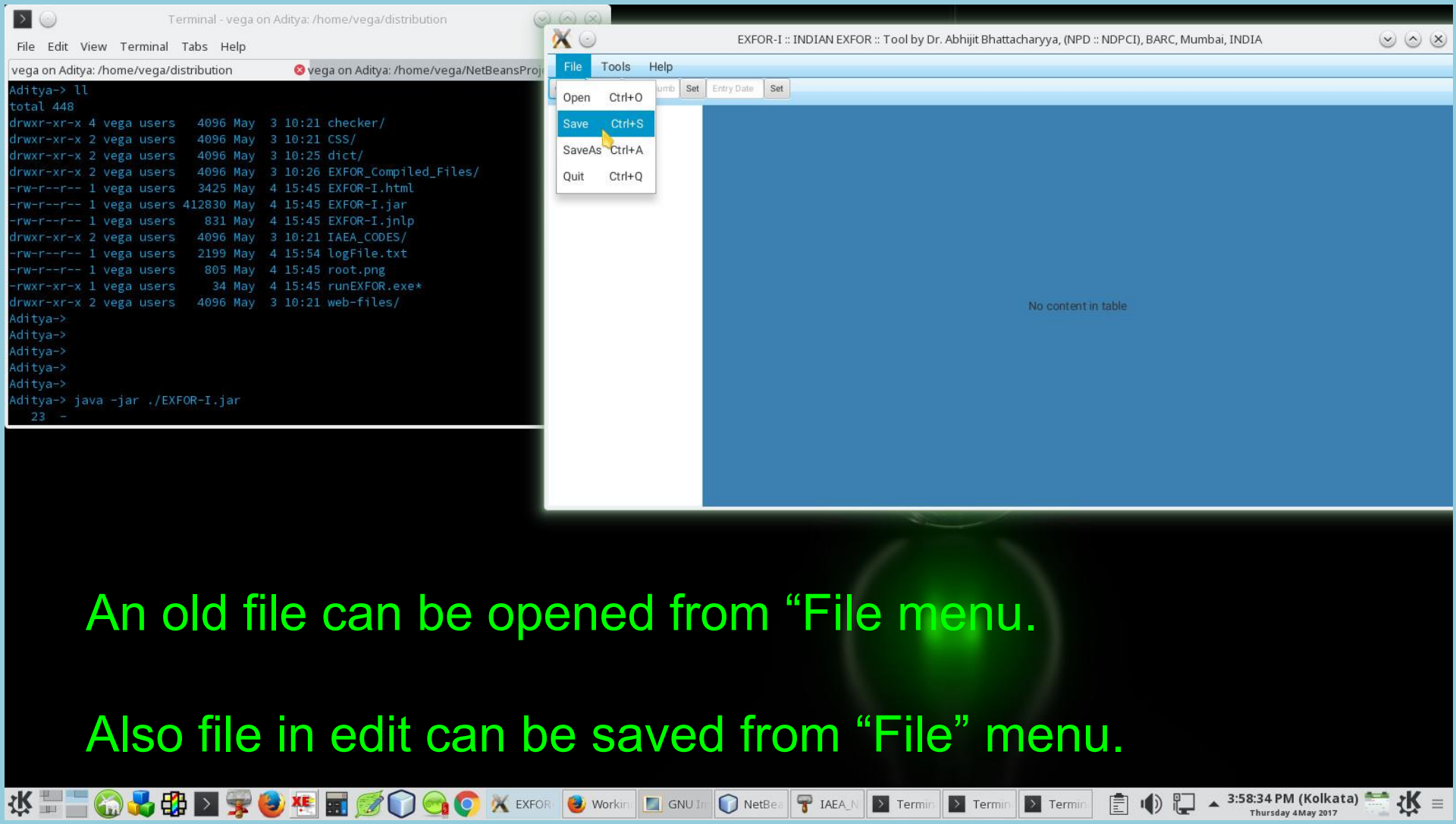
# EXFOR-I (Launch)



# EXFOR-I (File Menu options)



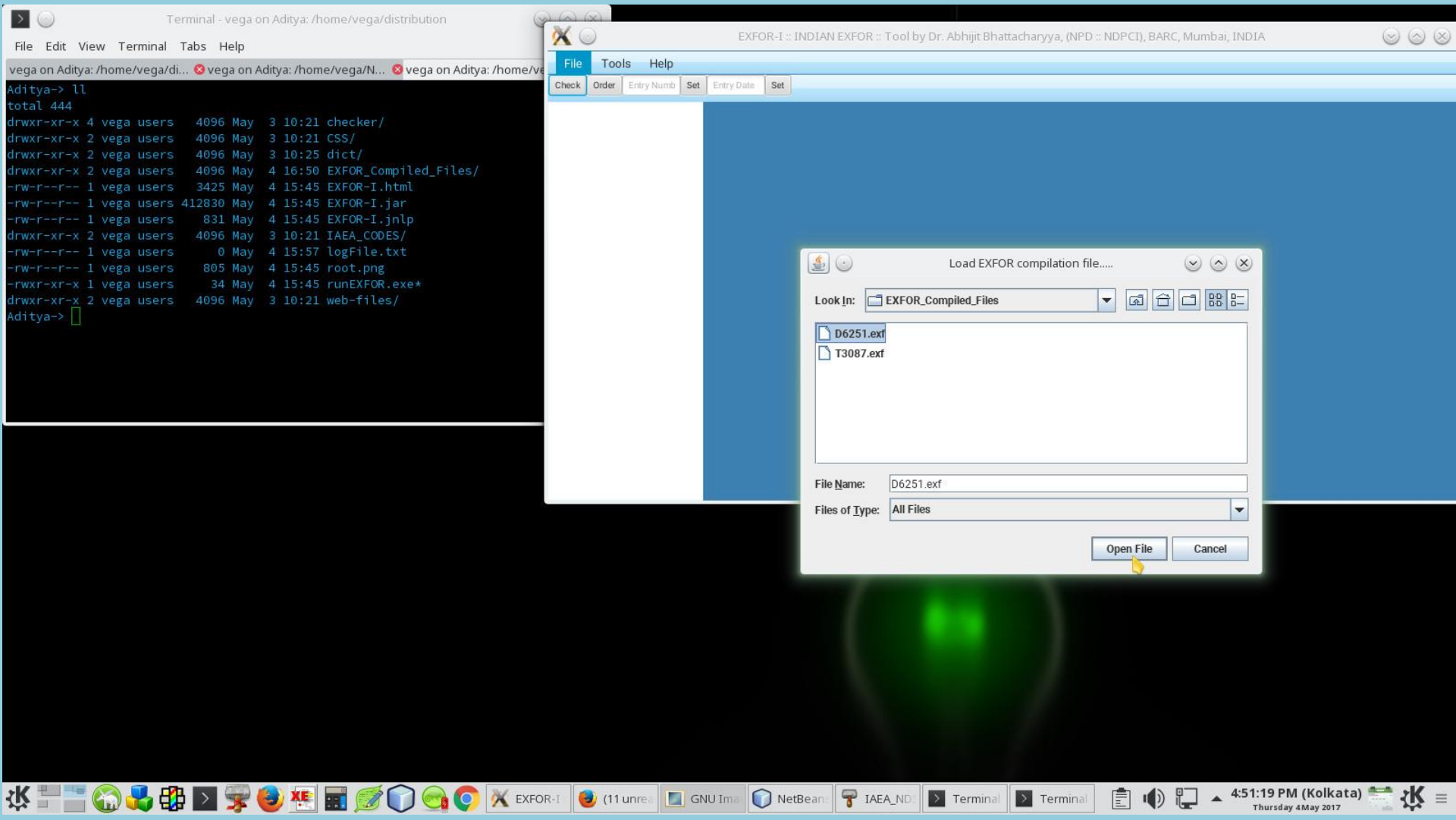
# EXFOR-I (File Menu options)




An old file can be opened from “File menu.

Also file in edit can be saved from “File” menu.

# EXFOR-I (File open dialog)



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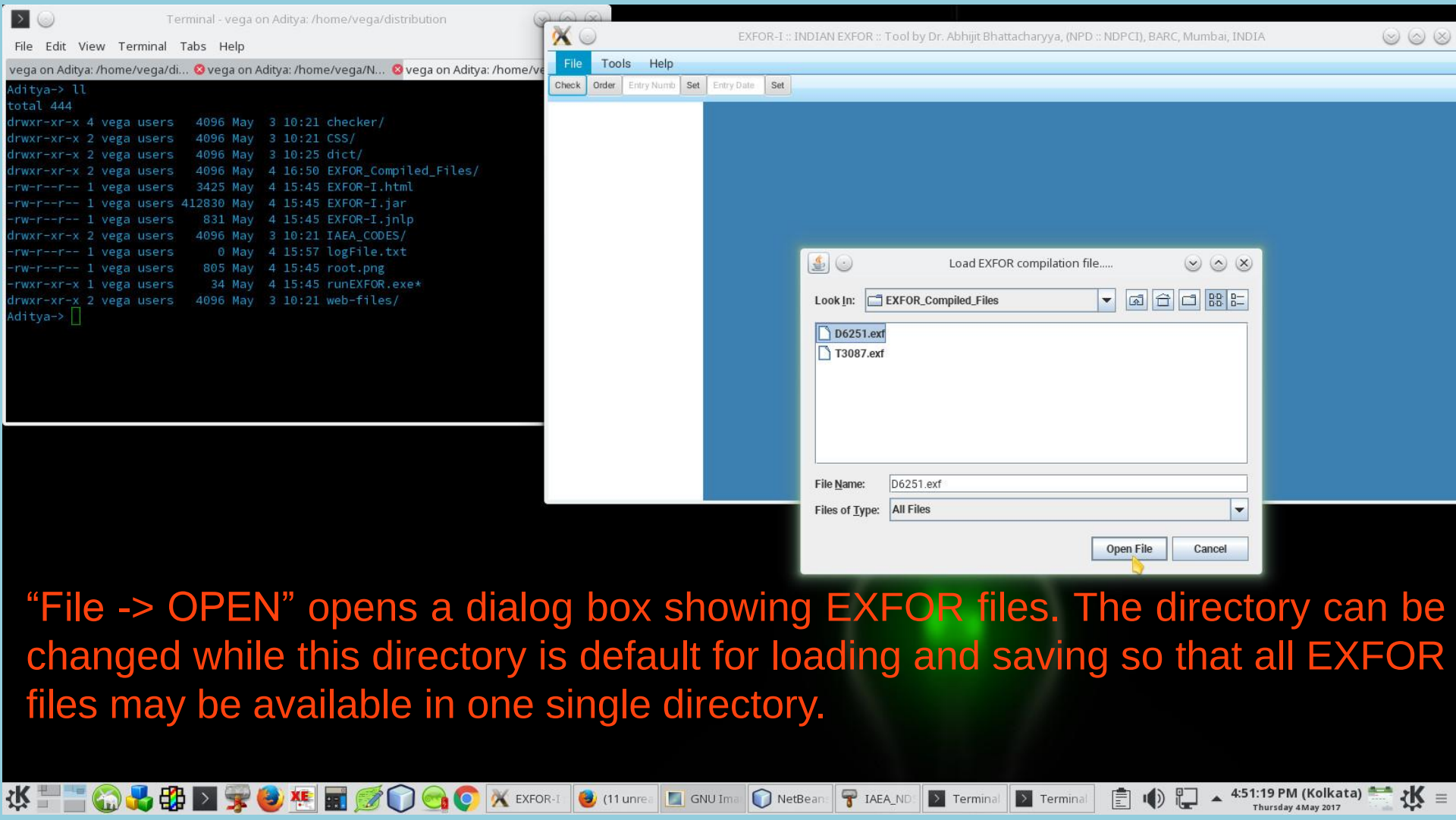
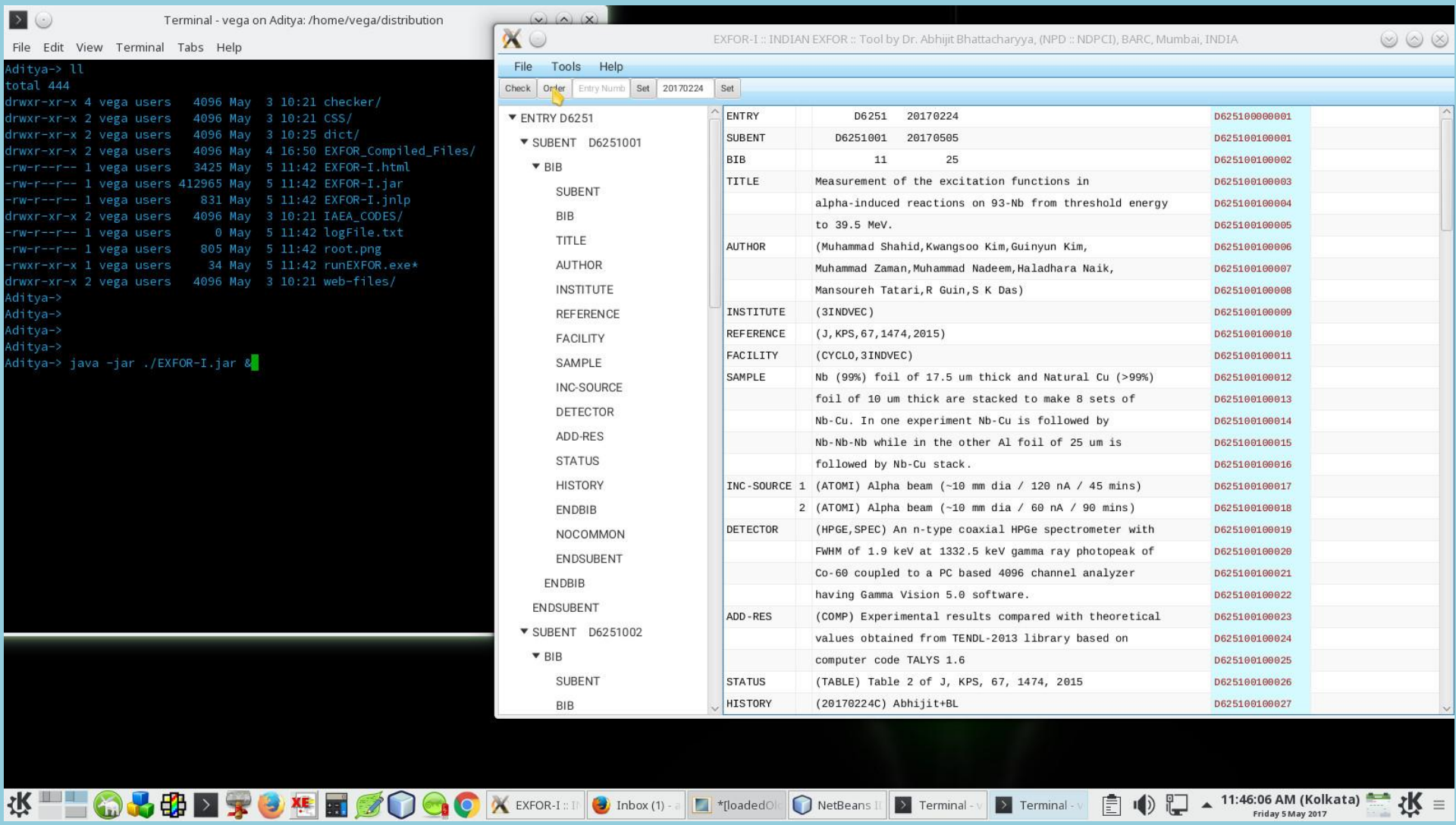


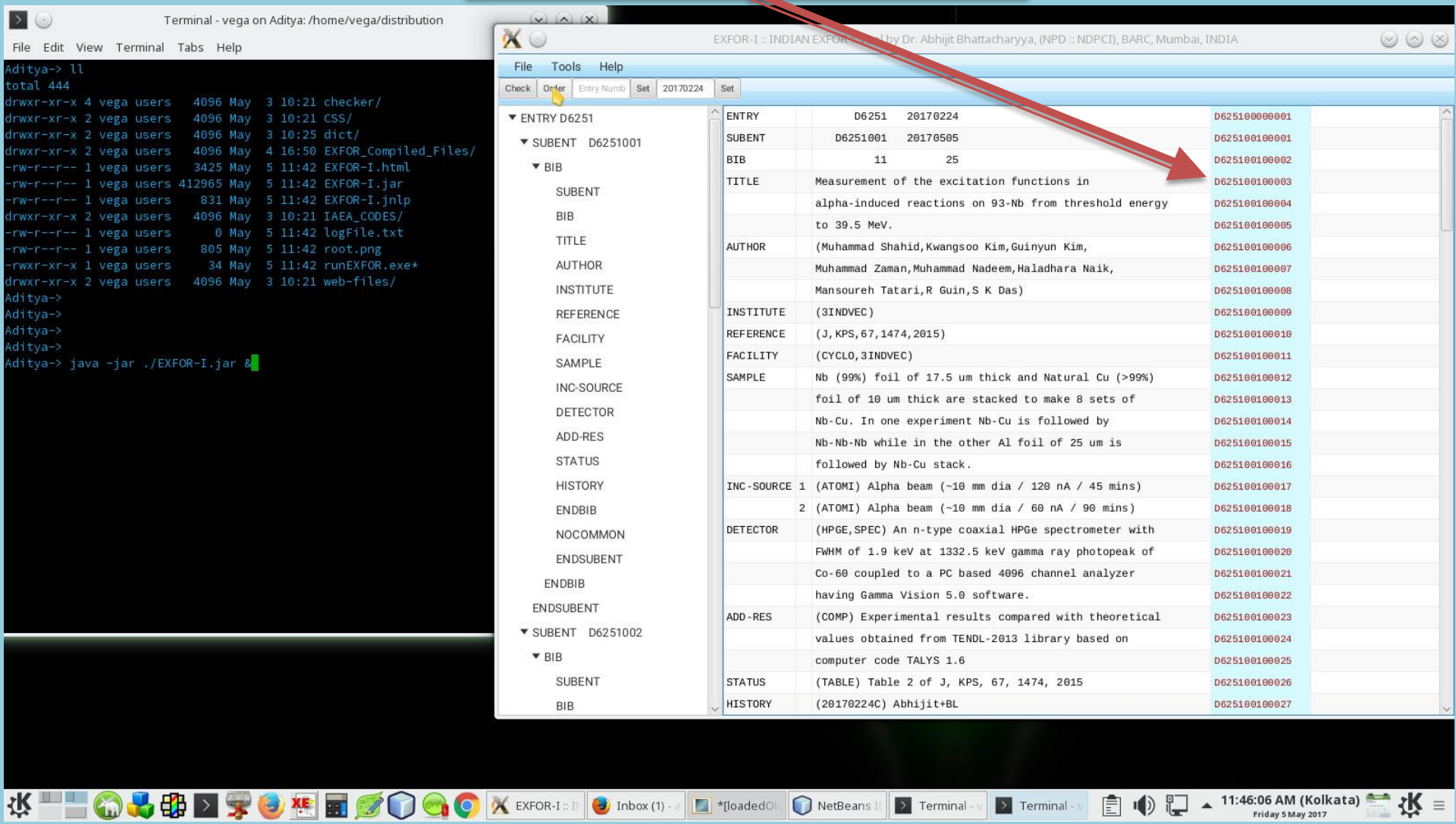

"File -> OPEN" opens a dialog box showing EXFOR files. The directory can be changed while this directory is default for loading and saving so that all EXFOR files may be available in one single directory.

# EXFOR-I (Loaded file ordered)



# EXFOR-I (Loaded file ordered)

**Loaded file has been ordered**



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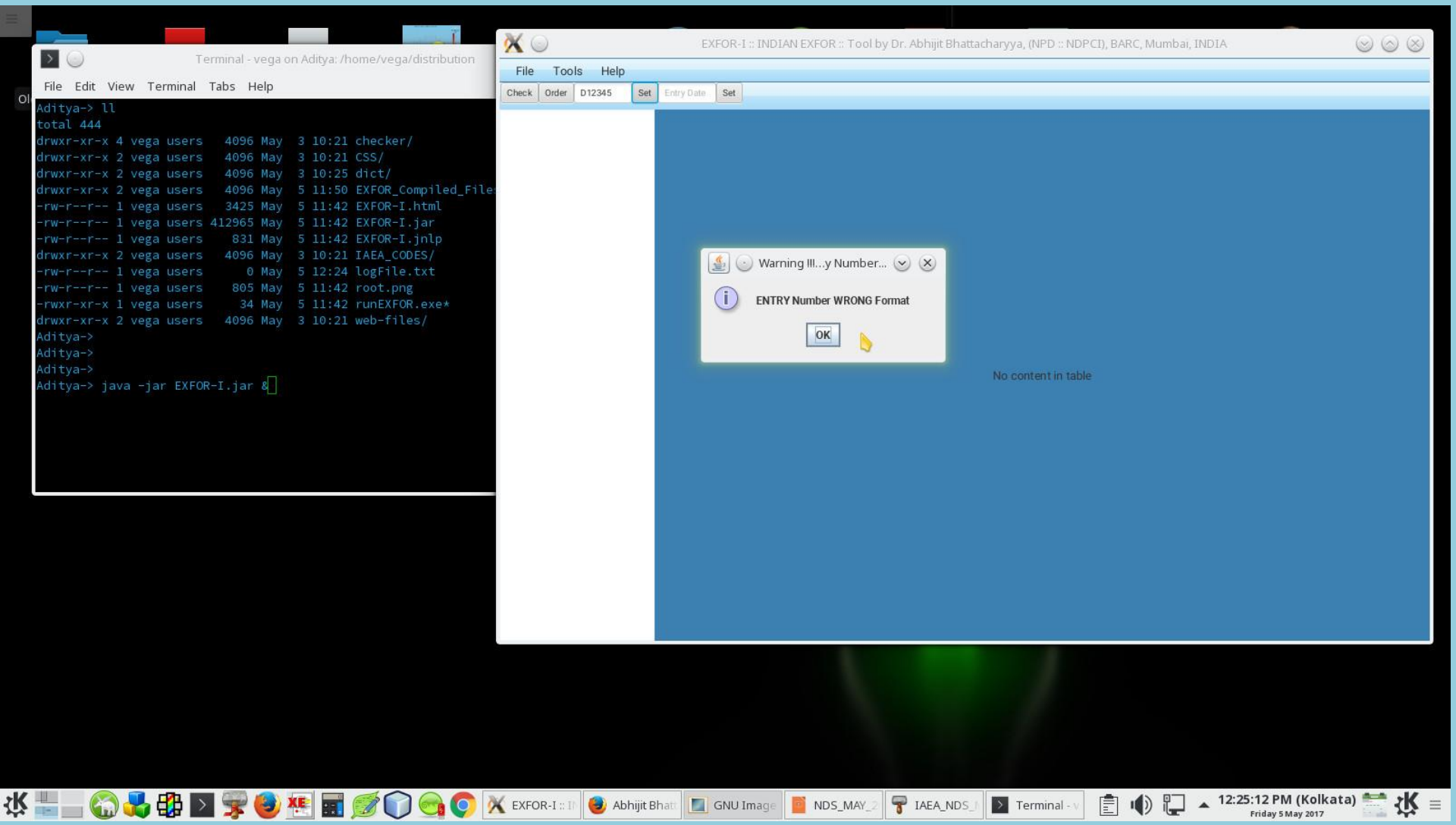

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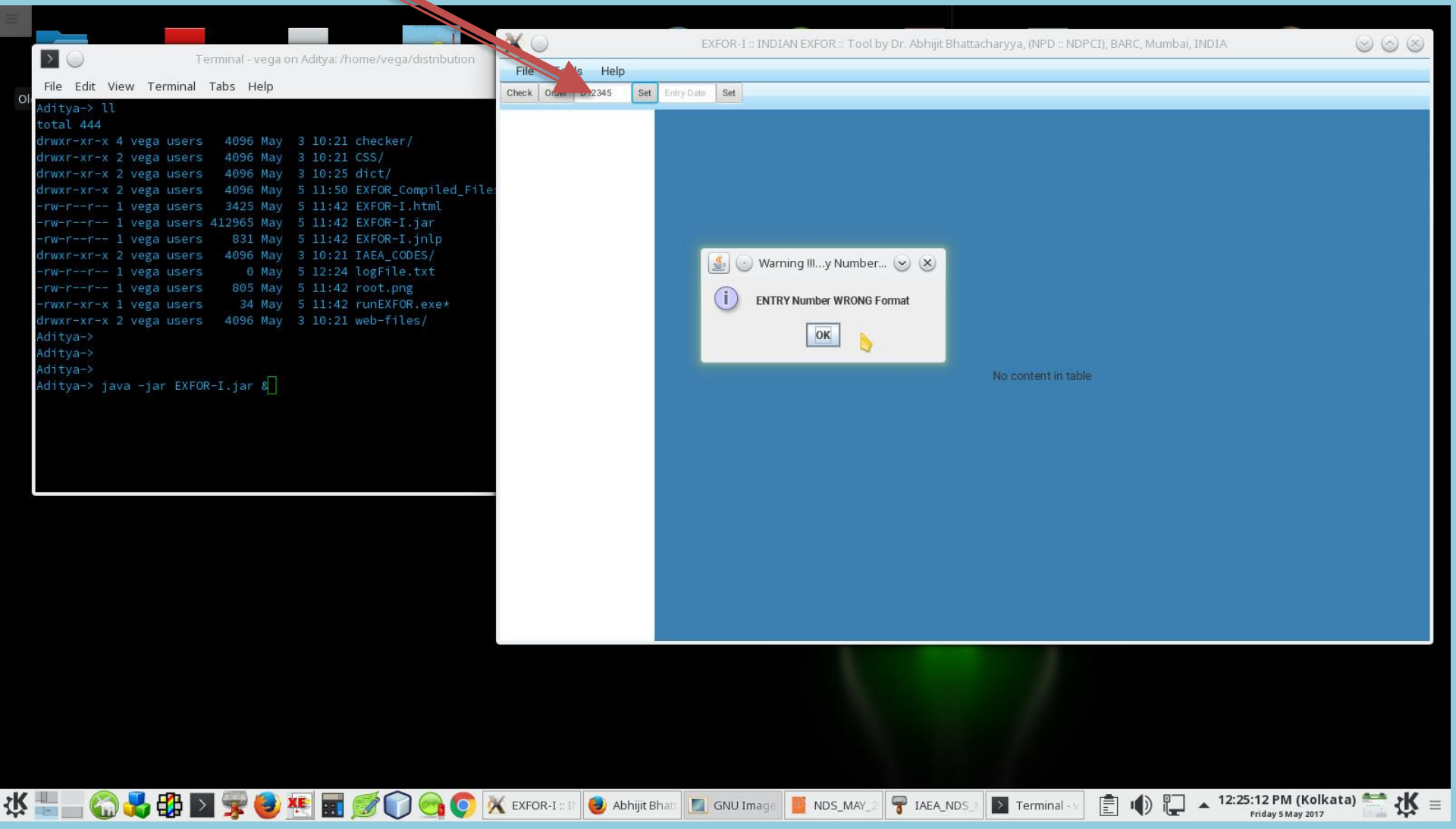
Enter the ENTRY NUMBER in BOX



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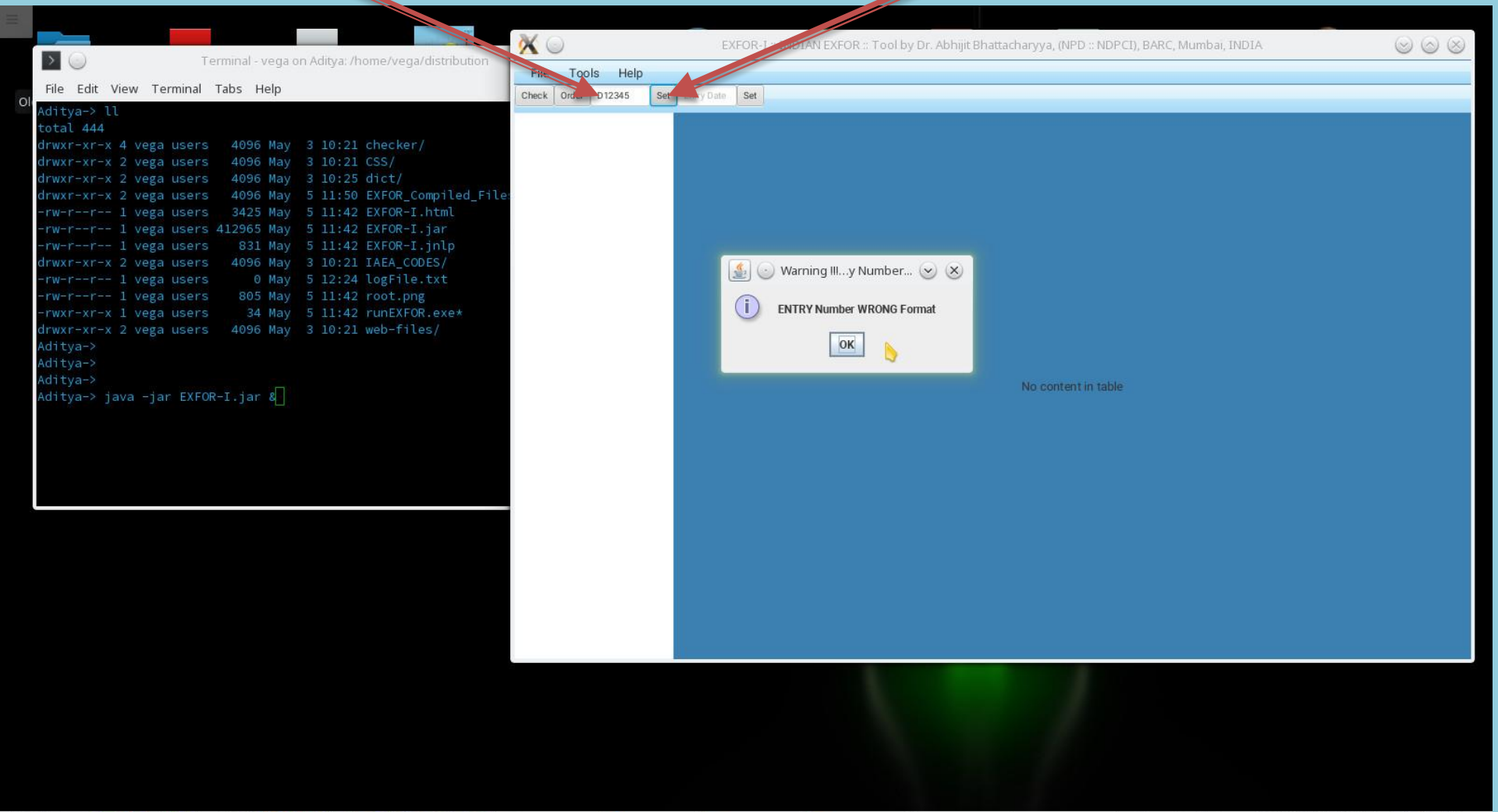
Enter the ENTRY NUMBER in BOX

**Click SET**

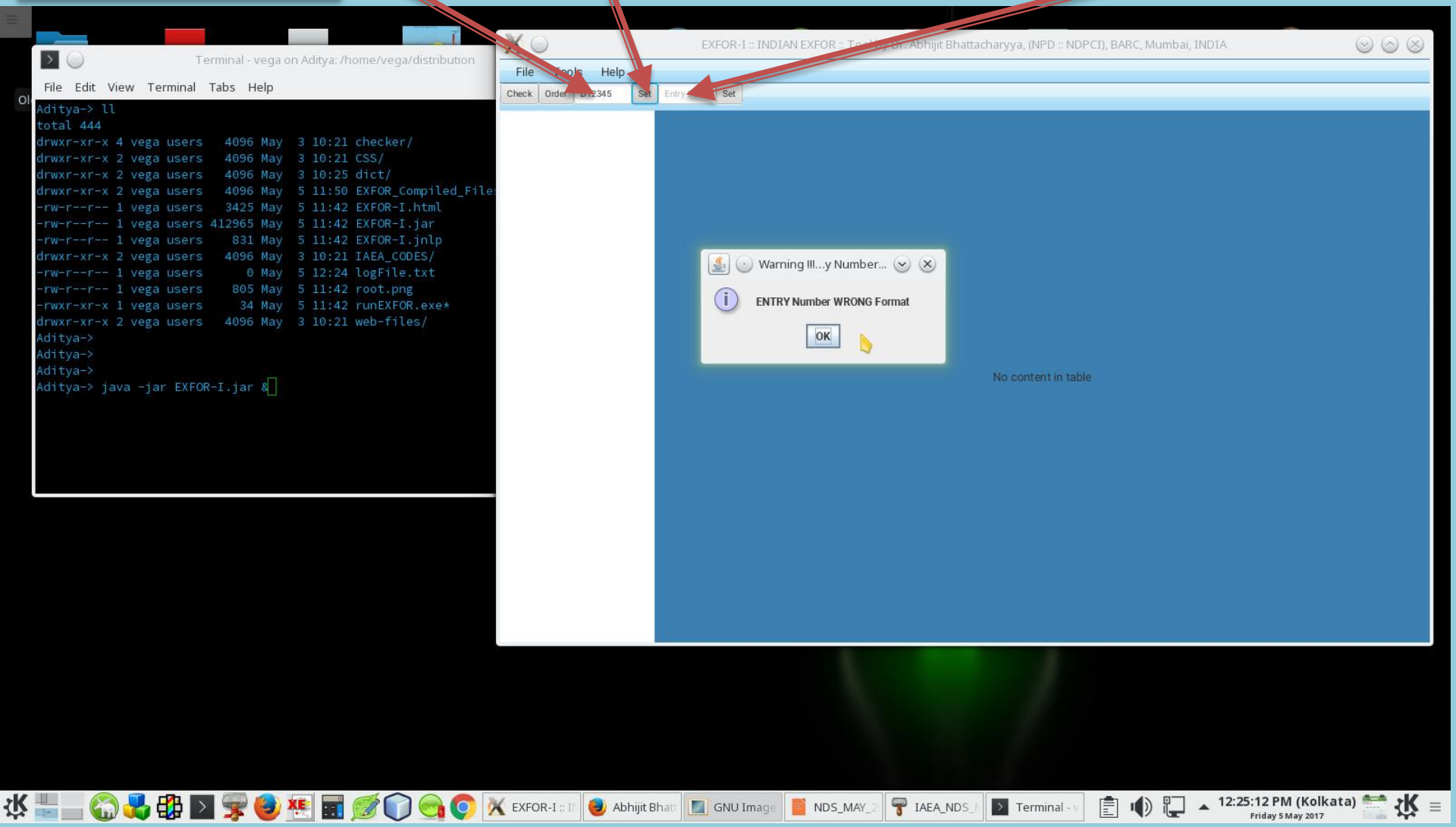


# EXFOR-I (Type entry number to create new EXFOR file)

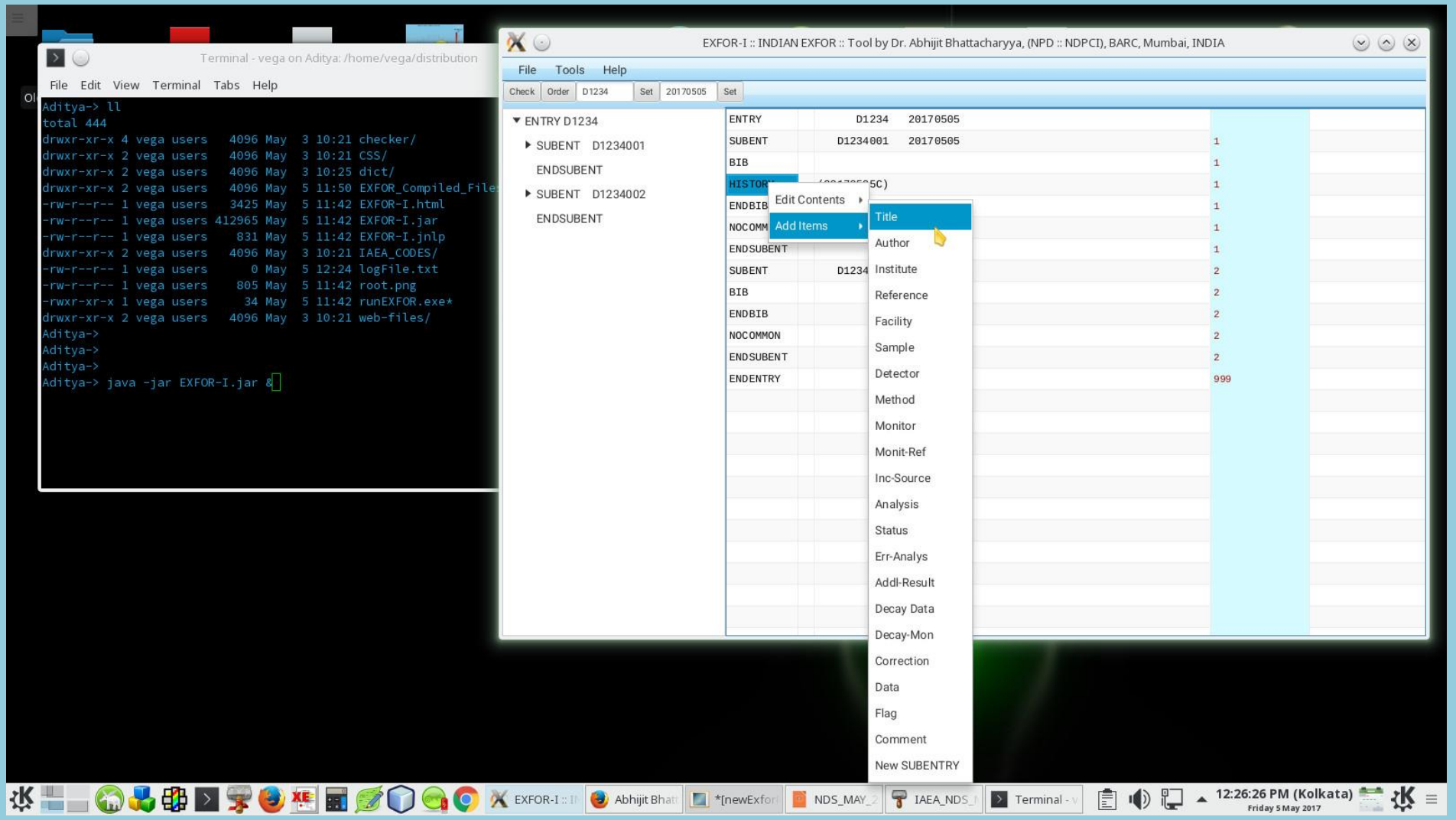
Enter the ENTRY NUMBER in BOX

Click SET

System DATE would be set automatically

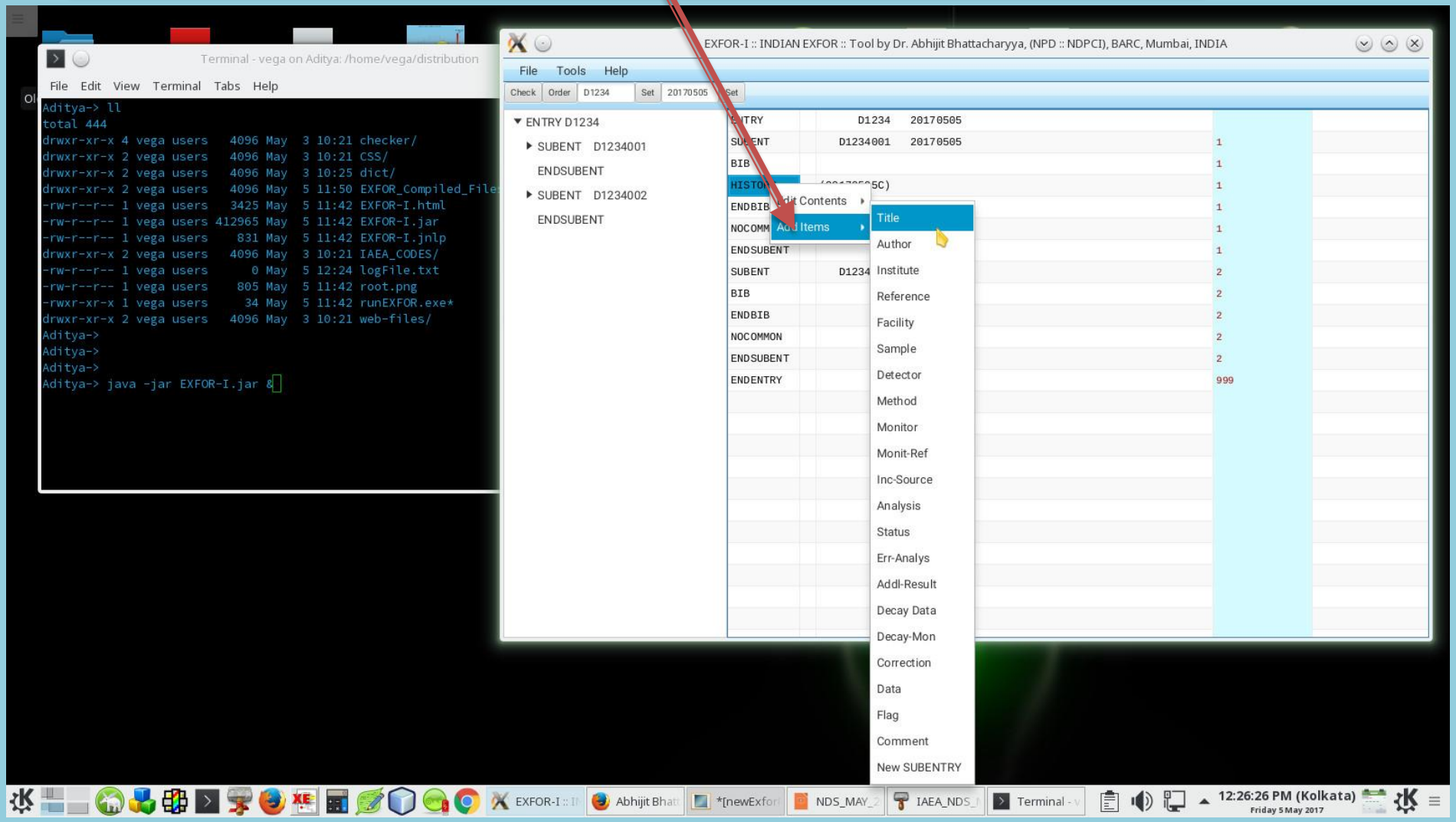


# EXFOR-I (Right-Click shows headers to be added)



# EXFOR-I (Right-Click shows headers to be added)

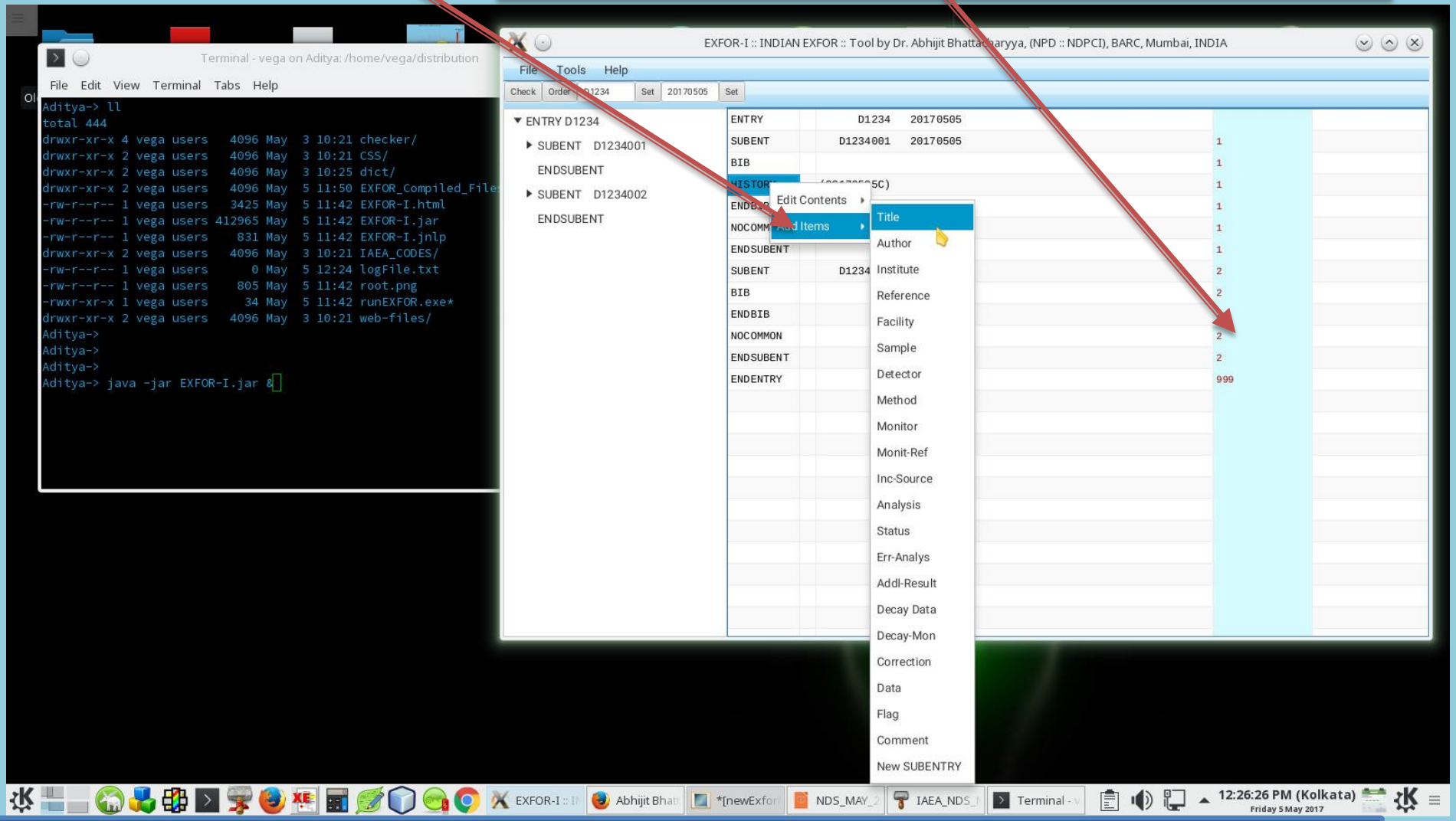
**Right click shows add/Edit sub menu while add shows headers**



# EXFOR-I (Right-Click shows headers to be added)

Right click shows add/Edit sub menu while add shows headers

Un-ordered entry shows SUBENT which would be ordered



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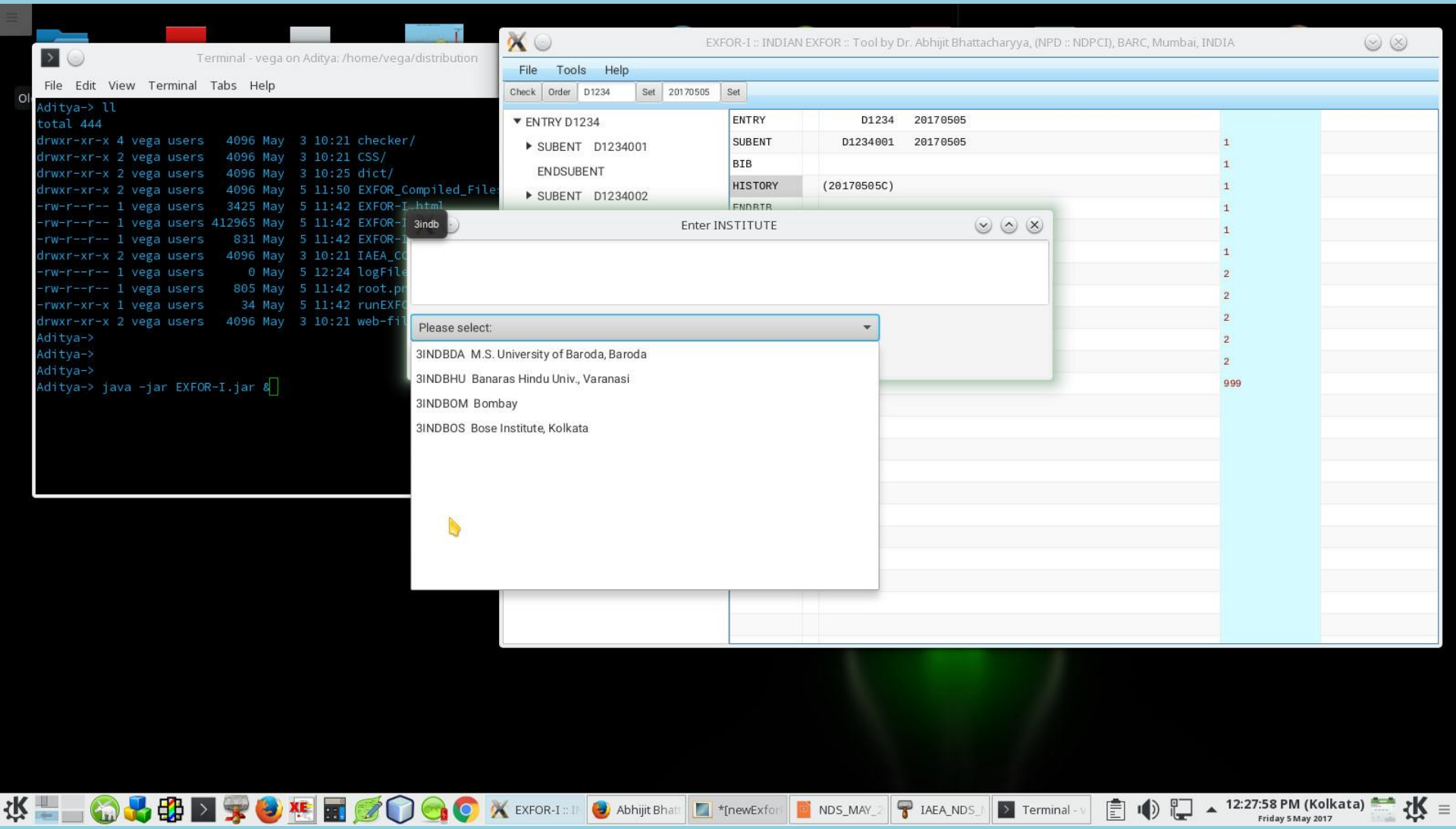
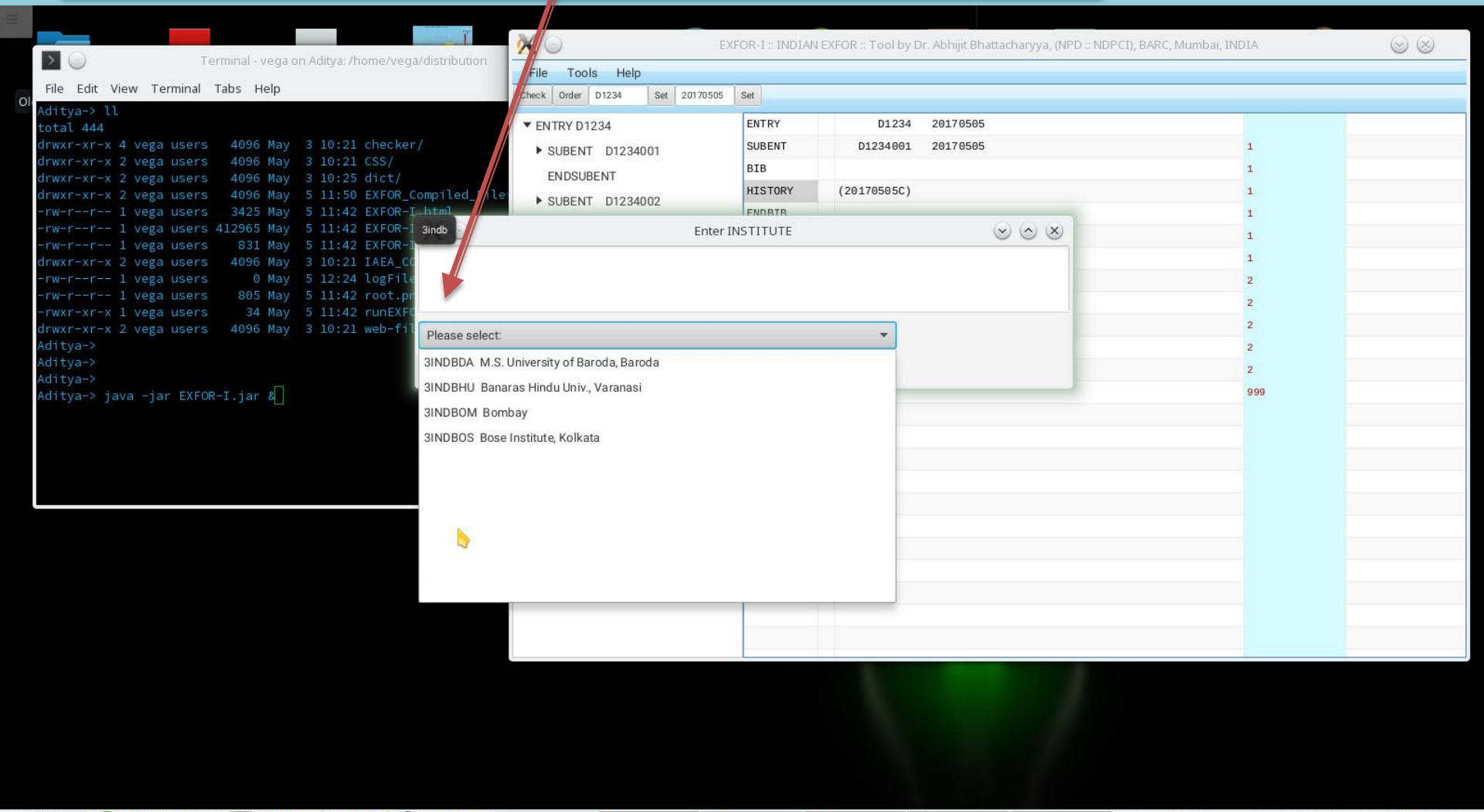
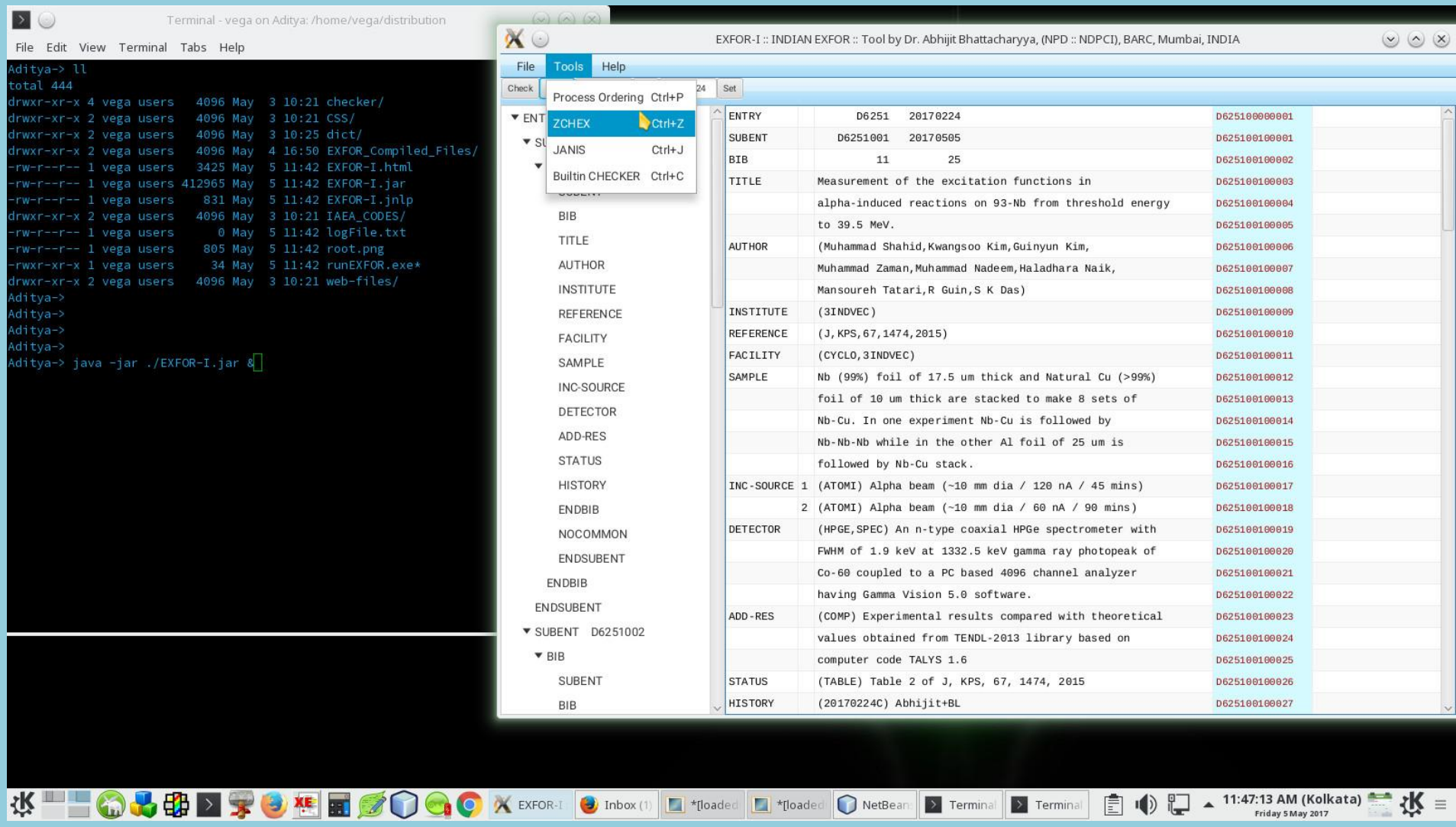


# EXFOR-I (Intelligent search)

Start typing keyword to narrow down. No need to scroll

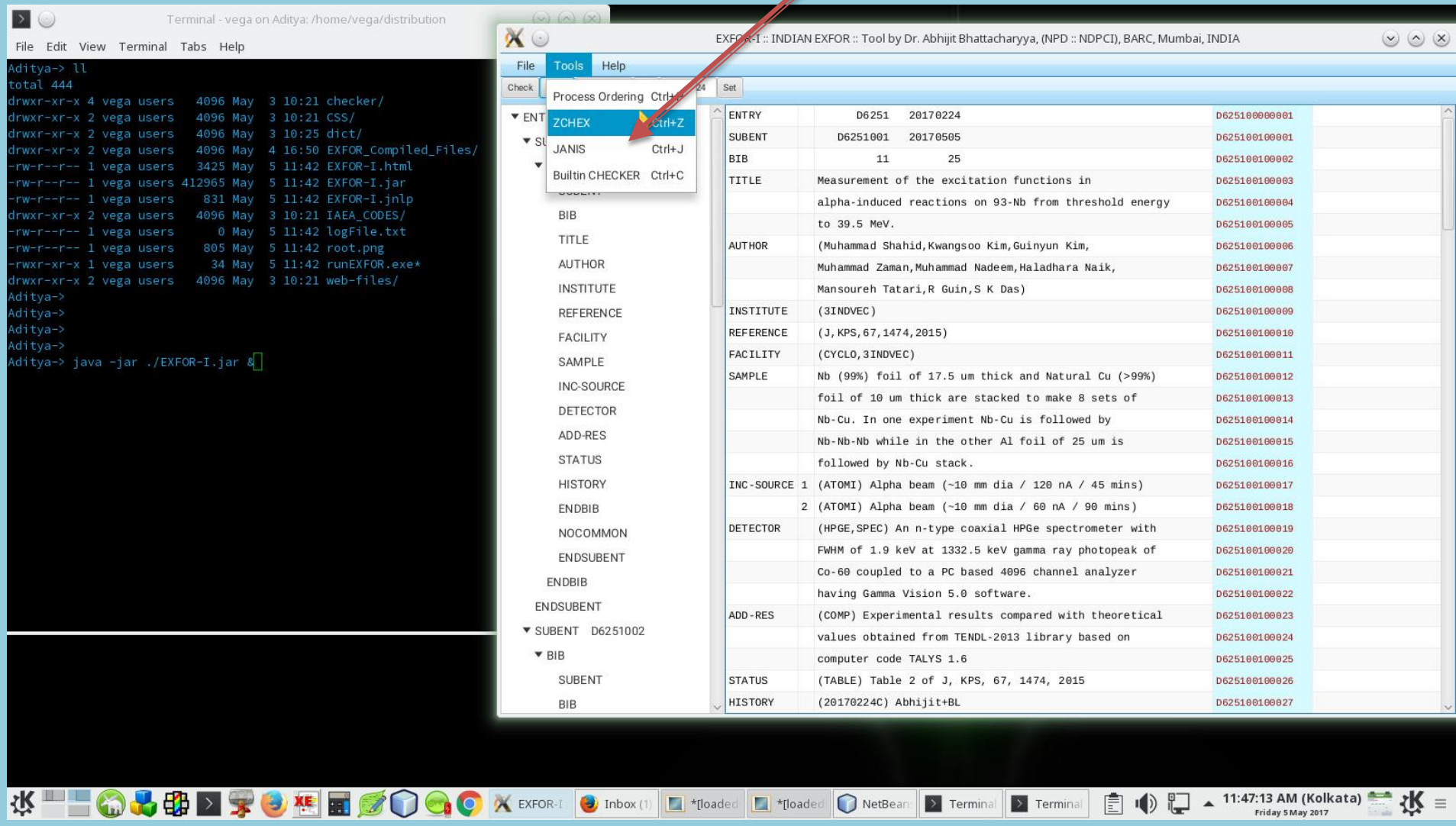


# EXFOR-I (tools)

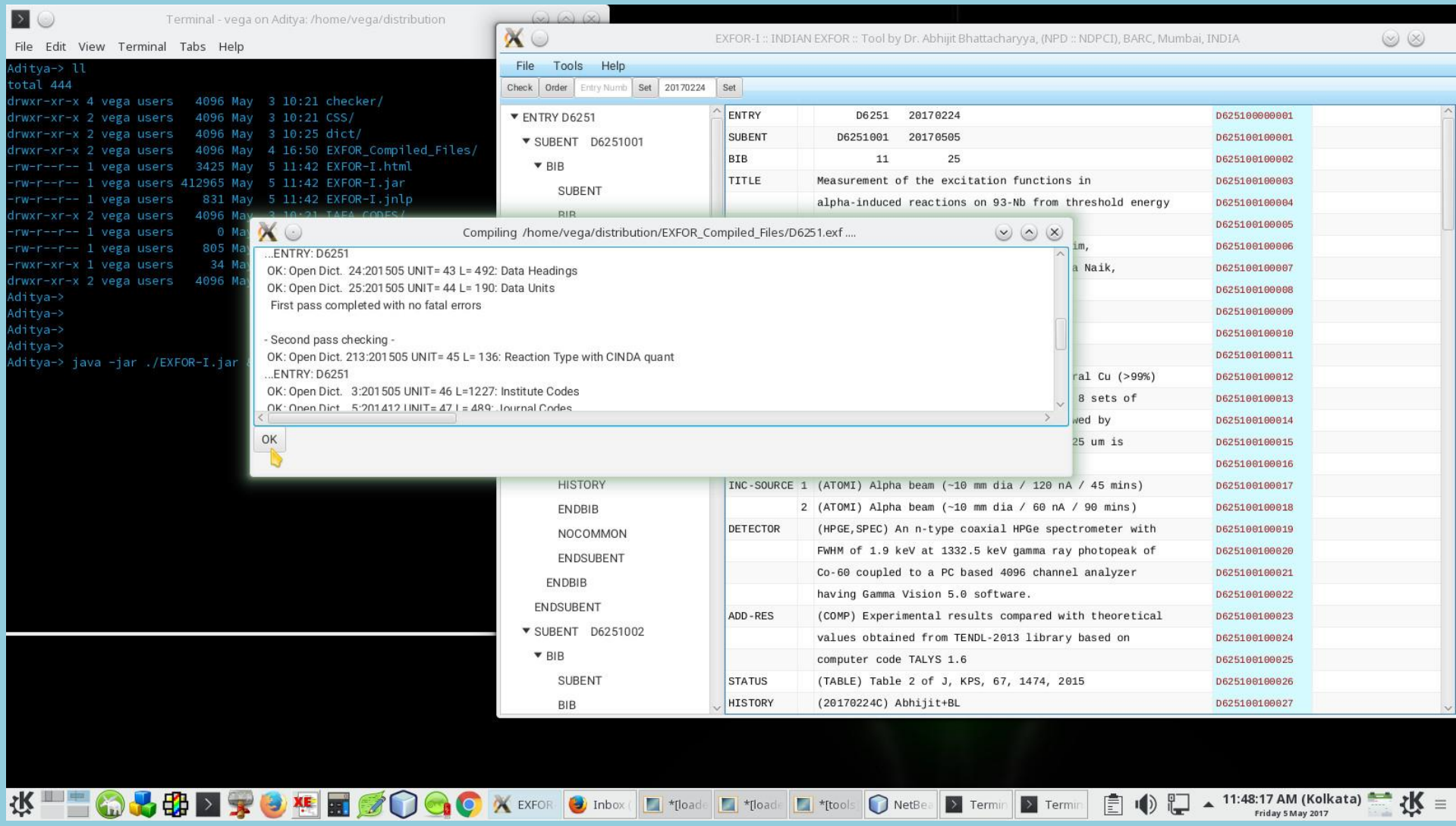


# EXFOR-I (tools)

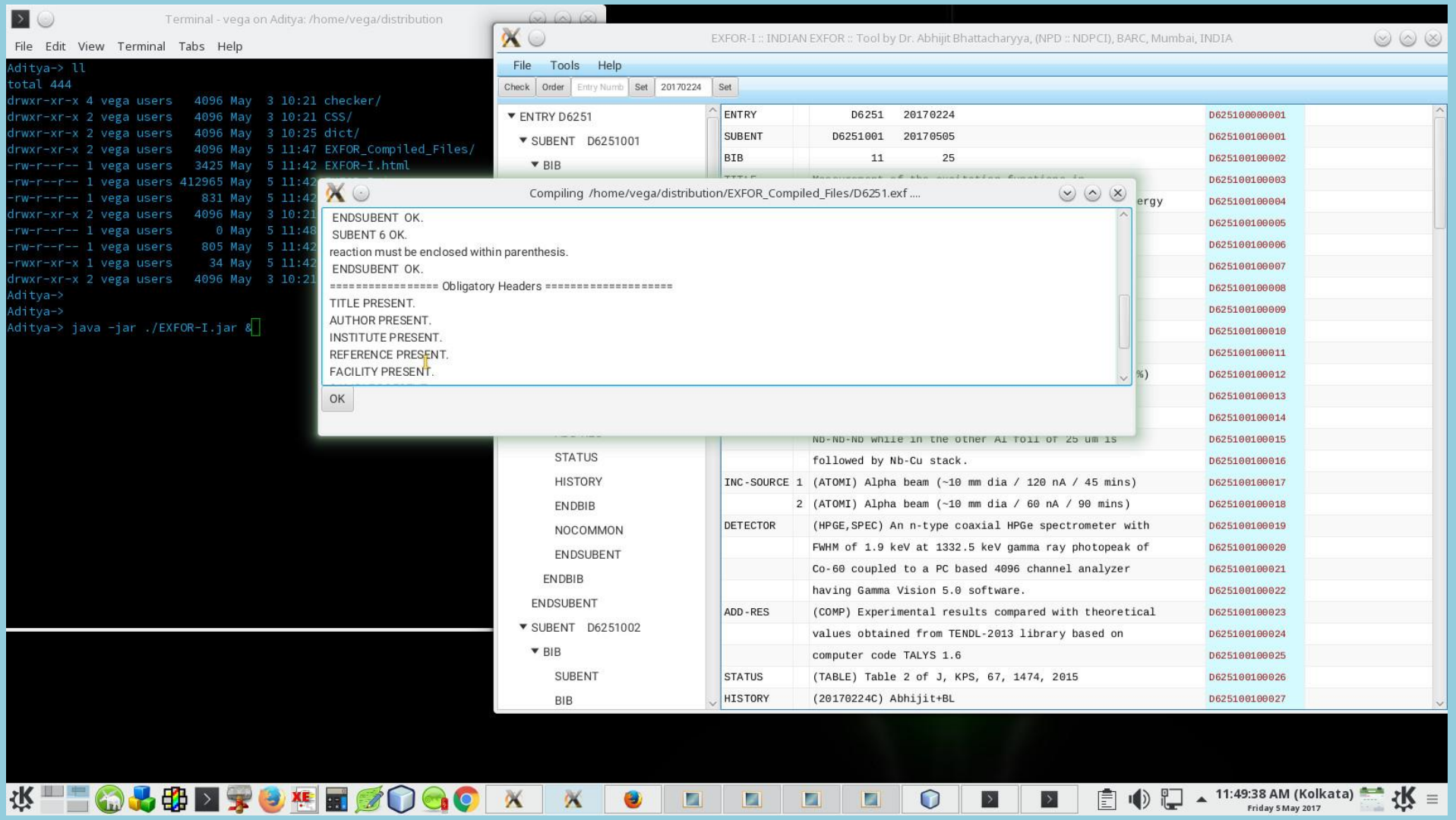
Ordering, checking by CHEX, JANIS and by EXFOR-I CHECKER



# EXFOR-I (CHEX dialog)



# EXFOR-I (own checker)



## EXFOR-I : I => India :: I => Intelligent Interface

- EXFOR-I: demands continuous input from users for continuous evolution in the line of user-friendliness, automated correction etc.
- EXFOR-I : *requests NDS to think on modification of grammers to implement proper English language grammer specially punctuation, spaces etc.*
- *Entries tested : 33087, D6191, D6196, D6199, D6211 and D6251.*

# -: Acknowledgement :-

Naohiko Otsuka

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# THANK YOU
# FOR YOUR ATTENTION!!