

# From Batch to Interactive: Interactive analysis workbench

-- Making Cluster Resources Accessible Anytime and Anywhere

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On Behalf of the INK Team



# Interactive a**N**alysis wor**K**bench



- 1** Motivation
- 2** Design and Development
- 3** Current Status and Next Steps
- 4** Summary

# HEP Analysis Way is Deeply Changed

- **Traditional way**

Debug on login node → **Batch task on cluster**

- **New development tools:**

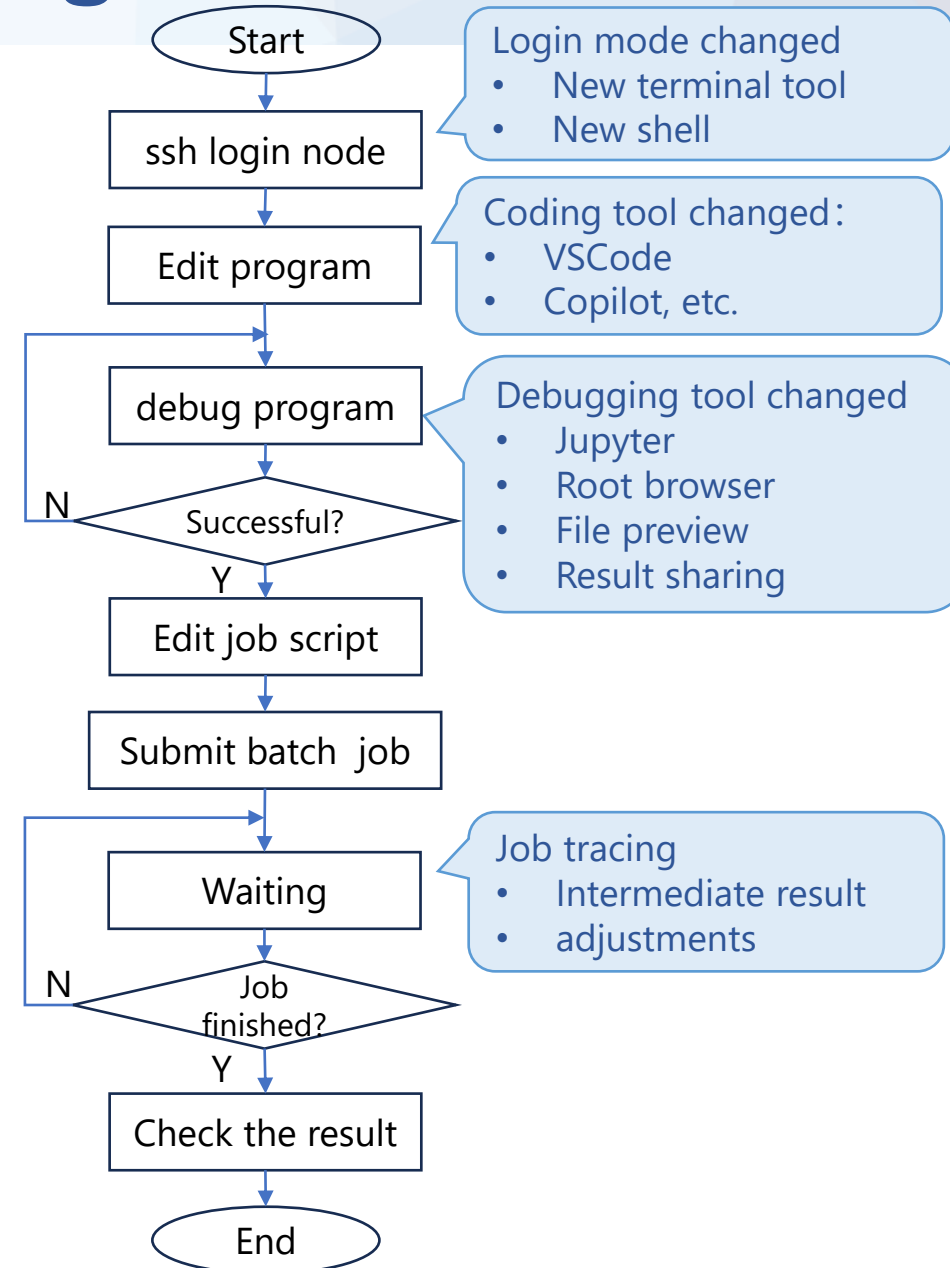
- Features-rich IDE (VSCode, JetBrains), Interactive Programming Environment (JupyterLab), etc..

- **New coding assistance:**

- Copilot, ROOT Browser, file preview, etc..

- **New Demand for debugging & execution**

- Online plotting and result sharing
- Simplified, on-demand runtime environment setup (esp. for new comer)
- Runtime environments switching on demand



# HEP Data Processing Requirements Collected

- **From Users:**

- IDE (such as vscode) is hard to use with SSH remote mode login farm
  - Extra burden to the login node – more and more slowly
  - Disconnection happened frequently
- X-forwarding always gets stuck, when drawing figure or using root browser.
- Forbidden port forwarding due to the security reason, cannot use Jupyter Lab easily outside campus

- **From HEP Software Developers:**

- Computing resource environment is hard to deploy and use.
- No way to access file from the developer's own machine

- **Analysis Facility**

- Loosely definition: infrastructure and services that provide integrated data, software and computational resources to execute on or more elements of analysis workflow
- Batch system: infrastructure of AF
  - **Transition from “Closed & Backend” to “Open & Frontend”**

# Solution: Interactive Platform

- **Core Concept**

- Run **interactive tools** (VSCode, Jupyter, etc.) **as cluster jobs**, delivered via web.
- Provide users with **secure API interfaces** for cluster job management and file access

- **Key Benefits**

- No Lag – Tools run in cluster node, zero client-side load
- No dependency on ssh – Used without any additional ssh login
- Guaranteed Resources – Dedicated memory/storage, no login node strain
- Dev-Friendly – Build & integrate custom apps with cluster APIs

- **Web-First Access**

- 🌐 Zero Setup – Browser-only,
- 📁 FileOps Simplified – Upload/download/view/share files directly
- 🔗 Easy Integration – Unified APIs for lab software/web services

# INK: Interactive aNalysis worKbench

- **Visionary goal**

- **Scientific research with just a network connection**

- Shift backend / offline computing and storage resources to the frontend / interactive for enhanced accessibility
    - Enable flexible integration of resources and applications
    - Provide customized interactive tools for HEP experiments
    - Offer plus-and-play deployment solution for the HEP computing sites

- **Immediate goal**

- Scientific research with just a web page

- Provide web-based interactive analysis tool based on HTCondor cluster

- Leverage web technologies : VSCode, Jupyter, Rootbrowse, VNC, Enode
    - Run on the dedicated HTCondor job slot : no interference each other

- Enable external file system access

- Files could be accessed via web page directly
    - Upload / Download / View

- Provide API interfaces for cluster job submission and file access for the workflow of the experiment

# Exploring INK: User Dashboard

The dashboard is titled "INK" and is accessed via the URL `ink.ihep.ac.cn/panel`. It features a navigation bar at the top with links for Home, Dashboard, Eshell, Files, Ink Jobs, Help, and a user profile for "shijy".

**Navigation Bar**: Located at the top of the page, containing navigation links and user information.

**Services**: A section containing icons for Monitor, Dashboard, Eshell, DAQ Shift, and Jobs. A callout "Customized App for Specific Experiment" points to the Monitor icon.

**Applications**: A section showing the operating system (AlmaLinux9) and icons for Compile, VScode, Jupyter, Root Browse, and E-Node.

**Ink Job Overview**: A section titled "Ink Jobs Statistics" showing "Current Interactive Jobs" as 89. It includes a "Statistics of Interactive Jobs" bar chart and a legend for job types: Enode 1, Jupyter 3, Vscode 72, Rootbrowse 6, Vnc 7.

**User Job Info**: A table titled "My Ink Jobs" listing active jobs:

Operation	Job Type	Job ID	OS For Job	Job Status
Connect	vnc	35384	AlmaLinux9	RUNNING
Connect	jupyter	35383	AlmaLinux9	RUNNING
Connect	compile	35267	AlmaLinux9	RUNNING

**IHEP Computing Overview**: A section titled "Platform Overview" showing "Running Jobs" and "Queueing Jobs" as stacked bar charts over a 24-hour period. The legend for both charts includes: atlas, cms, combination, dqmjuno, dyw, gecam, herd, higgs, hxmt, juno, junodc.

# Exploring INK: Cluster Files Manager

The screenshot shows the INK Cluster Files Manager interface. The address bar at the top displays 'ink.ihep.ac.cn/files'. Below the address bar, there are navigation tabs for 'Home', 'Dashboard', 'Eshell', 'Files', 'Ink Jobs', and 'Help'. The 'Files' tab is active. A search bar and several action buttons ('Goto', 'Upload', 'Create Dir', 'Create File', 'Download Files') are visible. The main content area shows a file listing table with columns for Name, Perms, Owner, Group, Size, Last Modified Time, and Operation. The current directory is '/home/cc/shijy/Ink'. Callouts highlight various features: 'Address Bar' points to the URL; 'Upload/Create File/Directory' points to the action buttons; 'Current Directory' points to the breadcrumb path; 'Preview' points to the preview icon; 'Path copy' points to the path copy icon; 'Share' points to the share icon; 'Download' points to the download icon; and 'Delete' points to the delete icon.

**Address Bar**

**Upload/Create File/Directory**

**Current Directory**

**Preview**

**Path copy**

**Share**

**Download**

**Delete**

Name	Perms	Owner	Group	Size	Last Modified Time	Operation
RawData	drwxr-xr-x	shijy	u07	4 KB	2025-09-24 23:15:28	Preview Path copy Share
testjobs	drwxr-xr-x	shijy	u07	4 KB	2025-09-24 23:15:43	Preview Path copy Share
2月11日.mp4	-rw-r--r--	shijy	u07	11.42 MB	2026-02-11 10:23:07	Download Preview Path copy Share Delete
4月住宿发票.pdf	-rw-r--r--	shijy	u07	127.92 KB	2026-02-11 03:27:57	Download Preview Path copy Share Delete
BESIII_Detector.jpeg	-rw-r--r--	shijy	u07	383.05 KB	2025-09-24 23:15:01	Download Preview Path copy Share Delete
Data_ana_1.root	-rw-r--r--	shijy	u07	770.52 KB	2025-06-05 02:03:43	Download Preview Path copy Share Delete
Ink_v1.zip	-rw-r--r--	shijy	u07	11.53 MB	2026-02-11 15:25:28	Download Preview Path copy Share Delete
JUNO_DISPLAY.png	-rw-r--r--	shijy	u07	527.09 KB	2025-04-02 16:45:51	Download Preview Path copy Share Delete
JUNO_oscillation.png	-rw-r--r--	shijy	u07	2.02 MB	2025-04-02 16:45:38	Download Preview Path copy Share Delete
PhysRevLett.110.252001.pdf	-rw-r--r--	shijy	u07	365.55 KB	2025-04-02 16:45:25	Download Preview Path copy Share Delete
SVM.png	-rw-r--r--	shijy	u07	256.97 KB	2025-04-02 16:45:17	Download Preview Path copy Share Delete
Zc3900.png	-rw-r--r--	shijy	u07	36.18 KB	2025-06-26 06:45:45	Download Preview Path copy Share Delete
mos2_nopt_corr_img_fill(3).fts	-rw-r--r--	shijy	u07	2.10 MB	2025-06-04 08:06:46	Download Preview Path copy Share Delete
output.mp4	-rw-r--r--	shijy	u07	13.87 MB	2026-02-11 10:26:44	Download Preview Path copy Share Delete

# Exploring INK: EShell

SSH to login node in webpage terminal by one click.

```
hanx at lxlogin003 in ~
$ ssh
hanx at lxlogin003 in ~
$ bash -c 'cat /etc/motd'
*****
Welcome to lxlogin003.ihp.ac.cn, AlmaLinux release 9.4 (Seafoam Ocelot)
* User Manual: http://fnappily.ihp.ac.cn/cchelp/
*****
hanx at lxlogin003 in ~
$ ls
afs          CE          cron.sh     DIRAC       HPC          ink-test    junofa      LoginNodeActivitybackup  nginx.conf  PKI          sleep.py    TencentCloud  Untitled1.ipynb  uploadfile.py
backup      cron_new.sh cron_task.sh HERD         ink          ISO         lnk_guide   mon                private     scratchfs   startup     test.sh      Untitled4.ipynb  vim.txt
besfs      cron_old.sh cvafs       herdfs      ink_guide   LoginNodeActivity  my_project  Other-study  public      scripts     tra         Untitled1.ipynb  works
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hanx at lxlogin003 in ~
$ cd ink
hanx at lxlogin003 in ~/ink
$ ls
app_443.conf  app_login.info  hep_jupyter-lab.err.3956036.0  hist.png  ink-rootbrowse  jupyter.log  rootbrowse_hanx.cxx  start-vnc.sh.out  vscode.log
app_check2.py  fastink-dev    hep_jupyter-lab.err.6338211.0  ipacc.ipynb  ipacc.ipynb      rb2.py       rootfiles            start-vscode.sh  write_in_rootbrowse.cxx
app_check3.py  fimpilot.py   hep_jupyter-lab.out.3956036.0  import_ROOT_test.ipynb  jobs-20280109-085329  rb3.py       sample.ipynb        test.py
app_check.py  firestorm.desktop  hep_jupyter-lab.out.6338211.0  ink         juno-event-display  rb.py        sample.pdf          traffic.json
app_check.sh  hep_jupyter-lab  hist.pdf                    ink-front   jupyterlab.sh    rootbrowse   start-vnc.sh        Untitled1.ipynb
hanx at lxlogin003 in ~/ink
$ cd rootfiles
hanx at lxlogin003 in ~/ink/rootfiles
$ pwd
/home/cc/hanx/ink/rootfiles
hanx at lxlogin003 in ~/ink/rootfiles
$ ls
1| 19.4% 17| 20.7% 33| 5.9% 49| 8.9%
2| 100.0% 18| 1.8% 35| 7.7% 50| 3.9%
3| 3.0% 19| 1.8% 35| 7.1% 51| 7.2%
4| 3.0% 20| 1.2% 36| 3.5% 52| 1.8%
5| 2.9% 21| 1.8% 37| 11.4% 53| 14.3%
6| 6.5% 22| 3.0% 38| 4.1% 54| 20.5%
7| 18.2% 23| 9.5% 39| 7.7% 55| 7.7%
8| 1.2% 24| 6.6% 40| 3.6% 56| 3.9%
9| 3.6% 25| 2.4% 41| 7.2% 57| 3.6%
10| 1.8% 26| 0.6% 42| 2.4% 58| 2.4%
11| 3.0% 27| 100.0% 43| 94.6% 59| 5.3%
12| 3.6% 28| 3.0% 44| 1.8% 60| 1.8%
13| 7.7% 29| 2.4% 45| 7.2% 61| 18.3%
14| 4.8% 30| 1.8% 46| 100.0% 62| 8.9%
15| 13.7% 31| 100.0% 47| 5.4% 63| 6.0%
16| 2.4% 32| 6.0% 48| 1.8% 64| 4.1%
Mem[ 81.3C/251C] Tasks: 2359, 5755 thr, 1093 kthr, 0 running
Swp[ 0K/0K] Load average: 13.83 18.48 19.53
Uptime: 13 days, 00:50:13

PID USER      NLWP PRI  NI  VIRT  RES  SHR  S  CPUN  W%MEM  TIME+  Command
3362489 tengli  1 20 0 839M 352M 221M R 100.5 0.1 13:26.07 python devrun.py --seed 181655938 --nev
3559606 luoxj    75 20 0 11.7C 790M 52736 R 100.5 0.3 0:22.05 python /afs/ihp.ac.cn/users/l/luoxj/Dat
3426102 tengli  1 20 0 997M 550M 290M R 99.9 0.2 9:05.31 python devrun.py --seed 181655938 --nev
3187442 giudm    1 20 0 1044M 598M 292M I 99.3 0.2 28:00.52 python3 /works2/herd/giudm/herdos/herdo
3508657 wangnanyan 128 20 0 12.0C 318M 12644 R 93.9 0.1 3:11.60 python l.test.generate_top.py 16 ad IOS
3558100 wuzy    6 20 0 1148M 510M 166M S 53.5 0.2 0:09.61 softwarew/softwara2.0/diectrigger /eos
3560319 chenweizhen 2 20 0 374M 80032 18944 S 25.6 0.0 0:01.47 /cvmsf/lhcb.cern.ch/lhcbdirac/versions/v
3536124 chenhuoyi 1 20 0 1336M 985M 125M R 24.4 0.4 0:56.68 /dybfs2/users/liji16/Libs/root-6.32.08-i
5391 cvafs    21 20 0 17.5C 154M 2048 S 23.2 0.1 2d19h53m /usr/bin/eosxd /eos/user -o rw,system_mount,fsnam
3559503 huangzhiha 18 20 0 900M 179M 79872 D 19.0 0.1 0:02.69 python l.py
2971959 zhangfz   1 20 0 231M 14948 3584 S 17.2 0.0 7:01.16 http -u zhangfz
3541061 hanx   1 20 0 4519M 413M 5120 S 11.3 0.2 1h45:50 /usr/bin/cvmsf2 -o rw,system_mount,fsnam
3541061 hanx   1 20 0 230M 15872 4096 R 10.7 0.0 0:05.68 http
4367 root    61 10 -10 5098M 2146M 10240 S 5.4 0.8 1d03h50m /usr/bin/eosxd /eos/user -o rw,fsname=us
2832040 xuwei    5 20 0 988M 636M 3816 S 3.6 0.0 0:02.18h37:46 bta
3535222 xpzhang  1 20 0 2147M 9188 5632 S 4.8 0.0 0:07.19 sshd: xpzhang@notty
3535223 xpzhang  1 20 0 223M 4608 4096 S 4.8 0.0 0:07.83 rsync -server -sender -logDtype.llfs
348919 xuejingqin 12 20 0 41.4C 311M 5692 S 4.2 0.1 41:25.47 /workfs2/juno/xuejingqin/.vscode-server/
4159 cvafs    2 20 0 36108 13616 5120 S 3.6 0.0 2h55:36 /usr/bin/cvmsf2 --cachmgr_ - 10 11 429
3122703 zhangyihan 1 20 0 20244 8060 5632 S 3.6 0.0 1:14.81 sshd: zhangyihan@notty
3560429 chenshiqia 1 20 0 215M 1536 1536 S 3.6 0.0 0:00.06 sleep 10s
3440525 cvafs    21 20 0 12.5C 265M 8192 S 3.0 0.1 47:25.63 /usr/bin/cvmsf2 -o rw,system_mount,fsnam
4097848 root    61 10 -10 7391M 116M 12800 S 3.0 0.0 3:08h55m /usr/bin/eosxd /eos/hhazo -o rw,fsname=c
2472 root    58 20 0 83140 28700 0 S 2.4 0.0 5h24:20 /usr/share/filebeat/bin/filebeat -c /etc/cron_old.sh ink
1157816 root    61 10 -10 6307M 935M 14336 S 2.4 0.4 19h38:10 /usr/bin/eosxd /eos/hhazo -o rw,fsname=ch
3122704 zhangyihan 1 20 0 9792 7680 5120 S 2.4 0.0 0:47.70 /usr/libexec/openssh/sftp-server
353953 xuejingqin 14 20 0 43.4C 730M 9788 S 1.8 0.3 54:05.17 /workfs2/juno/xuejingqin/.vscode-server/
2279139 root    55 10 -10 716M 188M 15360 S 1.8 0.1 1h31:15 /usr/bin/eosxd /eos/wcda -o rw,fsname=wc
1490495 root    61 10 -10 2524M 632M 12800 S 1.2 0.2 2h59:55 /usr/bin/eosxd /eos/argo -o rw,fsname=ar
3069955 root    1 20 0 0 0 0 I 1.2 0.0 0:02:88 kworker/u129:6-events_unbound
3505890 root    1 20 0 0 0 0 I 1.2 0.0 0:00:55 kworker/u129:2-flush-afs-l
1 root      1 20 0 183M 8184 3072 S 0.6 0.0 4h06:25 /usr/lib/systemd/systemd nofb --switched

hanx at lxlogin003 in ~
$ cat /etc/motd
*****
Welcome to lxlogin003.ihp.ac.cn, AlmaLinux release 9.4 (Seafoam Ocelot)
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besfs      cron_old.sh cvafs       herdfs      ink_guide   LoginNodeActivity  my_project  Other-study  public      scripts     tra         Untitled1.ipynb  works
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app_check3.py  fimpilot.py   hep_jupyter-lab.out.3956036.0  import_ROOT_test.ipynb  jobs-20280109-085329  rb3.py       sample.ipynb        test.py
app_check.py  firestorm.desktop  hep_jupyter-lab.out.6338211.0  ink         juno-event-display  rb.py        sample.pdf          traffic.json
app_check.sh  hep_jupyter-lab  hist.pdf                    ink-front   jupyterlab.sh    rootbrowse   start-vnc.sh        Untitled1.ipynb
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3426102 tengli  1 20 0 997M 550M 290M R 99.9 0.2 9:05.31 python devrun.py --seed 181655938 --nev
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3508657 wangnanyan 128 20 0 12.0C 318M 12644 R 93.9 0.1 3:11.60 python l.test.generate_top.py 16 ad IOS
3558100 wuzy    6 20 0 1148M 510M 166M S 53.5 0.2 0:09.61 softwarew/softwara2.0/diectrigger /eos
3560319 chenweizhen 2 20 0 374M 80032 18944 S 25.6 0.0 0:01.47 /cvmsf/lhcb.cern.ch/lhcbdirac/versions/v
3536124 chenhuoyi 1 20 0 1336M 985M 125M R 24.4 0.4 0:56.68 /dybfs2/users/liji16/Libs/root-6.32.08-i
5391 cvafs    21 20 0 17.5C 154M 2048 S 23.2 0.1 2d19h53m /usr/bin/eosxd /eos/user -o rw,system_mount,fsnam
3559503 huangzhiha 18 20 0 900M 179M 79872 D 19.0 0.1 0:02.69 python l.py
2971959 zhangfz   1 20 0 231M 14948 3584 S 17.2 0.0 7:01.16 http -u zhangfz
3541061 hanx   1 20 0 4519M 413M 5120 S 11.3 0.2 1h45:50 /usr/bin/cvmsf2 -o rw,system_mount,fsnam
3541061 hanx   1 20 0 230M 15872 4096 R 10.7 0.0 0:05.68 http
4367 root    61 10 -10 5098M 2146M 10240 S 5.4 0.8 1d03h50m /usr/bin/eosxd /eos/user -o rw,fsname=us
2832040 xuwei    5 20 0 988M 636M 3816 S 3.6 0.0 0:02.18h37:46 bta
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3535223 xpzhang  1 20 0 223M 4608 4096 S 4.8 0.0 0:07.83 rsync -server -sender -logDtype.llfs
348919 xuejingqin 12 20 0 41.4C 311M 5692 S 4.2 0.1 41:25.47 /workfs2/juno/xuejingqin/.vscode-server/
4159 cvafs    2 20 0 36108 13616 5120 S 3.6 0.0 2h55:36 /usr/bin/cvmsf2 --cachmgr_ - 10 11 429
3122703 zhangyihan 1 20 0 20244 8060 5632 S 3.6 0.0 1:14.81 sshd: zhangyihan@notty
3560429 chenshiqia 1 20 0 215M 1536 1536 S 3.6 0.0 0:00.06 sleep 10s
3440525 cvafs    21 20 0 12.5C 265M 8192 S 3.0 0.1 47:25.63 /usr/bin/cvmsf2 -o rw,system_mount,fsnam
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3122704 zhangyihan 1 20 0 9792 7680 5120 S 2.4 0.0 0:47.70 /usr/libexec/openssh/sftp-server
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2279139 root    55 10 -10 716M 188M 15360 S 1.8 0.1 1h31:15 /usr/bin/eosxd /eos/wcda -o rw,fsname=wc
1490495 root    61 10 -10 2524M 632M 12800 S 1.2 0.2 2h59:55 /usr/bin/eosxd /eos/argo -o rw,fsname=ar
3069955 root    1 20 0 0 0 0 I 1.2 0.0 0:02:88 kworker/u129:6-events_unbound
3505890 root    1 20 0 0 0 0 I 1.2 0.0 0:00:55 kworker/u129:2-flush-afs-l
1 root      1 20 0 183M 8184 3072 S 0.6 0.0 4h06:25 /usr/lib/systemd/systemd nofb --switched

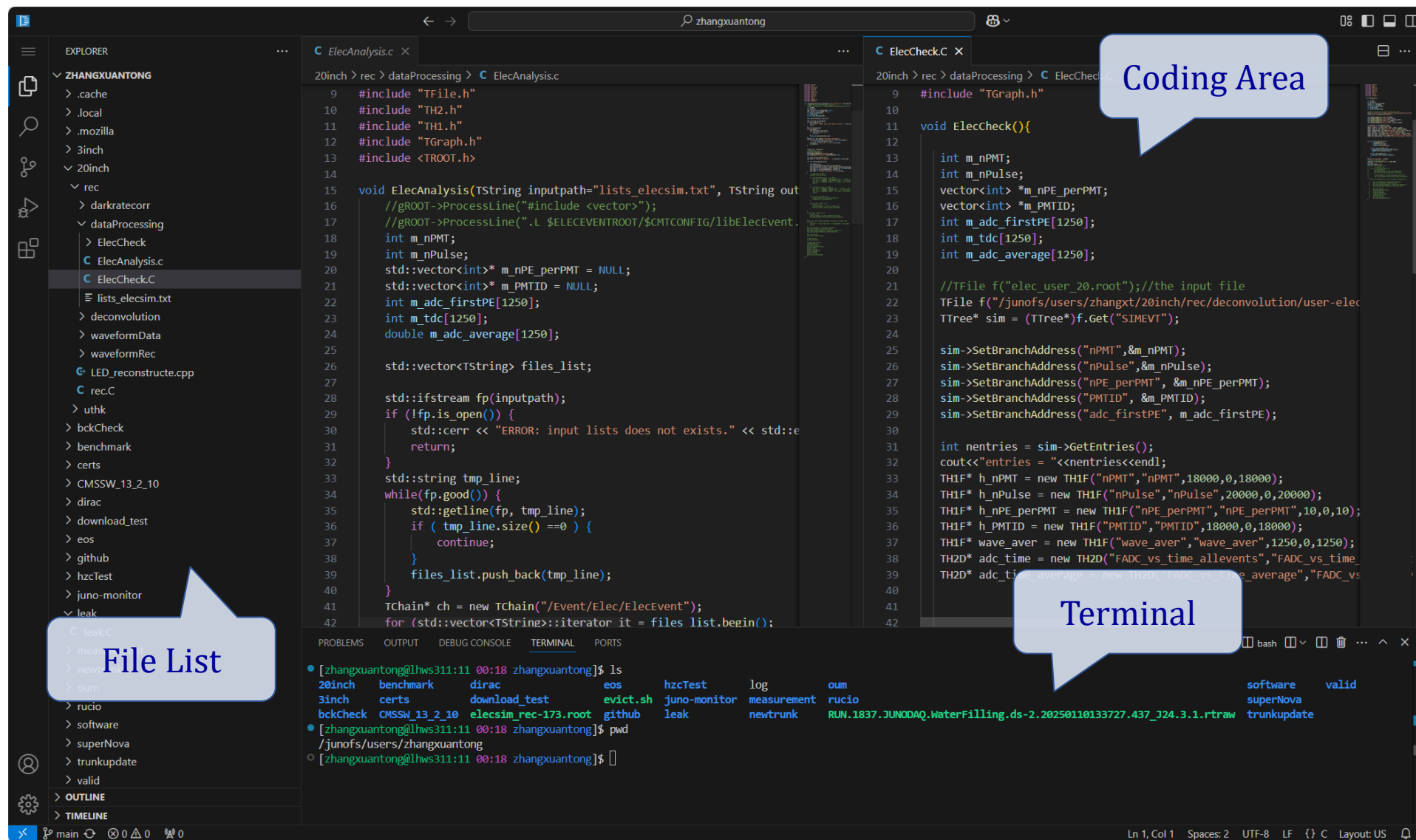
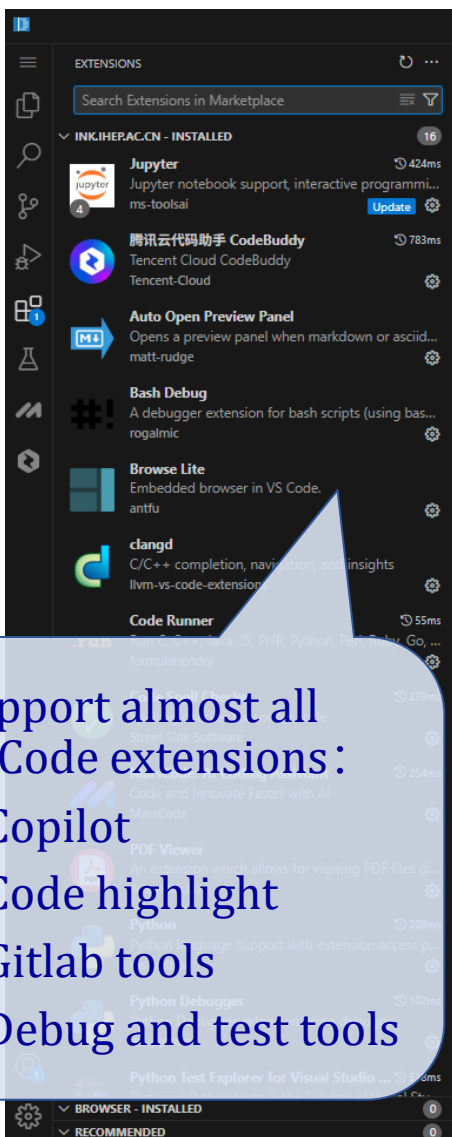
hanx at lxlogin003 in ~
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*****
Welcome to lxlogin003.ihp.ac.cn, AlmaLinux release 9.4 (Seafoam Ocelot)
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$ ssh
hanx at lxlogin003 in ~
$ bash -c 'cat /etc/motd'
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hanx at lxlogin003 in ~
$ ls
afs          CE          cron.sh     DIRAC       HPC          ink-test    junofa      LoginNodeActivitybackup  nginx.conf  PKI          sleep.py    TencentCloud  Untitled1.ipynb  uploadfile.py
backup      cron_new.sh cron_task.sh HERD         ink          ISO         lnk_guide   mon                private     scratchfs   startup     test.sh      Untitled4.ipynb  vim.txt
besfs      cron_old.sh cvafs       herdfs      ink_guide   LoginNodeActivity  my_project  Other-study  public      scripts     tra         Untitled1.ipynb  works
hanx at lxlogin003 in ~
$ ls
afs          CE          cron.sh     DIRAC       HPC          ink-test    junofa      LoginNodeActivitybackup  nginx.conf  PKI          sleep.py    TencentCloud  Untitled1.ipynb  uploadfile.py
backup      cron_new.sh cron_task.sh HERD         ink          ISO         lnk_guide   mon                private     scratchfs   startup     test.sh      Untitled4.ipynb  vim.txt
besfs      cron_old.sh cvafs       herdfs      ink_guide   LoginNodeActivity  my_project  Other-study  public      scripts     tra         Untitled1.ipynb  works
hanx at lxlogin003 in ~
$ cd ink
hanx at lxlogin003 in ~/ink
$ ls
app_443.conf  app_login.info  hep_jupyter-lab.err.3956036.0  hist.png  ink-rootbrowse  jupyter.log  rootbrowse_hanx.cxx  start-vnc.sh.out  vscode.log
app_check2.py  fastink-dev    hep_jupyter-lab.err.6338211.0  ipacc.ipynb  ipacc.ipynb      rb2.py       rootfiles            start-vscode.sh  write_in_rootbrowse.cxx
app_check3.py  fimpilot.py   hep_jupyter-lab.out.3956036.0  import_ROOT_test.ipynb  jobs-20280109-085329  rb3.py       sample.ipynb        test.py
app_check.py  firestorm.desktop  hep_jupyter-lab.out.6338211.0  ink         juno-event-display  rb.py        sample.pdf          traffic.json
app_check.sh  hep_jupyter-lab  hist.pdf                    ink-front   jupyterlab.sh    rootbrowse   start-vnc.sh        Untitled1.ipynb
hanx at lxlogin003 in ~/ink
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hanx at lxlogin003 in ~/ink/rootfiles
$ pwd
/home/cc/hanx/ink/rootfiles
hanx at lxlogin003 in ~/ink/rootfiles
$ ls
1| 19.4% 17| 20.7% 33| 5.9% 49| 8.9%
2| 100.0% 18| 1.8% 35| 7.7% 50| 3.9%
3| 3.0% 19| 1.8% 35| 7.1% 51| 7.2%
4| 3.0% 20| 1.2% 36| 3.5% 52| 1.8%
5| 2.9% 21| 1.8% 37| 11.4% 53| 14.3%
6| 6.5% 22| 3.0% 38| 4.1% 54| 20.5%
7| 18.2% 23| 9.5% 39| 7.7% 55| 7.7%
8| 1.2% 24| 6.6% 40| 3.6% 56| 3.9%
9| 3.6% 25| 2.4% 41| 7.2% 57| 3.6%
10| 1.8% 26| 0.6% 42| 2.4% 58| 2.4%
11| 3.0% 27| 100.0% 43| 94.6% 59| 5.3%
12| 3.6% 28| 3.0% 44| 1.8% 60| 1.8%
13| 7.7% 29| 2.4% 45| 7.2% 61| 18.3%
14| 4.8% 30| 1.8% 46| 100.0% 62| 8.9%
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Mem[ 81.3C/251C] Tasks: 2359, 5755 thr, 1093 kthr, 0 running
Swp[ 0K/0K] Load average: 13.83 18.48 19.53
Uptime: 13 days, 00:50:13

PID USER      NLWP PRI  NI  VIRT  RES  SHR  S  CPUN  W%MEM  TIME+  Command
3362489 tengli  1 20 0 839M 352M 221M R 100.5 0.1 13:26.07 python devrun.py --seed 181655938 --nev
3559606 luoxj    75 20 0 11.7C 790M 52736 R 100.5 0.3 0:22.05 python /afs/ihp.ac.cn/users/l/luoxj/Dat
3426102 tengli  1 20 0 997M 550M 290M R 99.9 0.2 9:05.31 python devrun.py --seed 181655938 --nev
3187442 giudm    1 20 0 1044M 598M 292M I 99.3 0.2 28:00.52 python3 /works2/herd/giudm/herdos/herdo
3508657 wangnanyan 128 20 0 12.0C 318M 12644 R 93.9 0.1 3:11.60 python l.test.generate_top.py 16 ad IOS
3558100 wuzy    6 20 0 1148M 510M 166M S 53.5 0.2 0:09.61 softwarew/softwara2.0/diectrigger /eos
3560319 chenweizhen 2 20 0 374M 80032 18944 S 25.6 0.0 0:01.47 /cvmsf/lhcb.cern.ch/lhcbdirac/versions/v
3536124 chenhuoyi 1 20 0 1336M 985M 125M R 24.4 0.4 0:56.68 /dybfs2/users/liji16/Libs/root-6.32.08-i
5391 cvafs    21 20 0 17.5C 154M 2048 S 23.2 0.1 2d19h53m /usr/bin/eosxd /eos/user -o rw,system_mount,fsnam
3559503 huangzhiha 18 20 0 900M 179M 79872 D 19.0 0.1 0:02.69 python l.py
2971959 zhangfz   1 20 0 231M 14948 3584 S 17.2 0.0 7:01.16 http -u zhangfz
3541061 hanx   1 20 0 4519M 413M 5120 S 11.3 0.2 1h45:50 /usr/bin/cvmsf2 -o rw,system_mount,fsnam
3541061 hanx   1 20 0 230M 15872 4096 R 10.7 0.0 0:05.68 http
4367 root    61 10 -10 5098M 2146M 10240 S 5.4 0.8 1d03h50m /usr/bin/eosxd /eos/user -o rw,fsname=us
2832040 xuwei    5 20 0 988M 636M 3816 S 3.6 0.0 0:02.18h37:46 bta
3535222 xpzhang  1 20 0 2147M 9188 5632 S 4.8 0.0 0:07.19 sshd: xpzhang@notty
3535223 xpzhang  1 20 0 223M 4608 4096 S 4.8 0.0 0:07.83 rsync -server -sender -logDtype.llfs
348919 xuejingqin 12 20 0 41.4C 311M 5692 S 4.2 0.1 41:25.47 /workfs2/juno/xuejingqin/.vscode-server/
4159 cvafs    2 20 0 36108 13616 5120 S 3.6 0.0 2h55:36 /usr/bin/cvmsf2 --cachmgr_ - 10 11 429
3122703 zhangyihan 1 20 0 20244 8060 5632 S 3.6 0.0 1:14.81 sshd: zhangyihan@notty
3560429 chenshiqia 1 20 0 215M 1536 1536 S 3.6 0.0 0:00.06 sleep 10s
3440525 cvafs    21 20 0 12.5C 265M 8192 S 3.0 0.1 47:25.63 /usr/bin/cvmsf2 -o rw,system_mount,fsnam
4097848 root    61 10 -10 7391M 116M 12800 S 3.0 0.0 3:08h55m /usr/bin/eosxd /eos/hhazo -o rw,fsname=c
2472 root    58 20 0 83140 28700 0 S 2.4 0.0 5h24:20 /usr/share/filebeat/bin/filebeat -c /etc/cron_old.sh ink
1157816 root    61 10 -10 6307M 935M 14336 S 2.4 0.4 19h38:10 /usr/bin/eosxd /eos/hhazo -o rw,fsname=ch
3122704 zhangyihan 1 20 0 9792 7680 5120 S 2.4 0.0 0:47.70 /usr/libexec/openssh/sftp-server
353953 xuejingqin 14 20 0 43.4C 730M 9788 S 1.8 0.3 54:05.17 /workfs2/juno/xuejingqin/.vscode-server/
2279139 root    55 10 -10 716M 188M 15360 S 1.8 0.1 1h31:15 /usr/bin/eosxd /eos/wcda -o rw,fsname=wc
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app_443.conf  app_login.info  hep_jupyter-lab.err.3956036.0  hist.png  ink-rootbrowse  jupyter.log  rootbrowse_hanx.cxx  start-vnc.sh.out  vscode.log
app_check2.py  fastink-dev    hep_jupyter-lab.err.6338211.0  ipacc.ipynb  ipacc.ipynb      rb2.py       rootfiles            start-vscode.sh  write_in_rootbrowse.cxx
app_check3.py  fimpilot.py   hep_jupyter-lab.out.3956036.0  import_ROOT_test.ipynb  jobs-20280109-085329  rb3.py       sample.ipynb        test.py
app_check.py  firestorm.desktop  hep_jupyter-lab.out.6338211.0  ink         juno-event-display  rb.py        sample.pdf          traffic.json
app_check.sh  hep_jupyter-lab  hist.pdf                    ink-front   jupyterlab.sh    rootbrowse   start-vnc.sh        Untitled1.ipynb
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PID USER      NLWP PRI  NI  VIRT  RES  SHR  S  CPUN  W%MEM  TIME+  Command
3362489 tengli  1 20 0 839M 352M 221M R 100.5 0.1 13:26.07 python
```

# Exploring INK: VSCode



Support almost all VSCode extensions:

- ✓ Copilot
- ✓ Code highlight
- ✓ Gitlab tools
- ✓ Debug and test tools

# Exploring INK: JupyterLab

The screenshot displays the JupyterLab Launcher interface. On the left is a file browser with a search bar and a list of files and folders. The main area is divided into three sections: Notebook, Console, and Other. The Notebook section contains seven kernel options, with 'JUNO\_PYTHON' circled in red. The Console section contains seven kernel options. The Other section contains six file type options: Terminal, Text File, Markdown File, Julia File, Python File, and Show Contextual Help. A menu bar at the top includes File, Edit, View, Run, Kernel, Tabs, Settings, and Help. The bottom status bar shows 'Simple' mode, 0 kernels, 0 files, and a notification bell.

File Edit View Run Kernel Tabs Settings Help

Filter files by name

Name Modified

Desktop 4mo ago

Documents 4mo ago

Downloads last mo.

firefox 3mo ago

kr5 9mo ago

milvus 3mo ago

music 4mo ago

photos 2mo ago

Pictures 4mo ago

Public 4mo ago

temp 3mo ago

Templates 4mo ago

venv 3mo ago

Videos 4mo ago

cm\_agent yesterday

dirac03.rescan.log yesterday

dirac03.tar.gz yesterday

files.log 8mo ago

firefox-136.0.4.t... 3mo ago

log 2mo ago

remove.sh 2mo ago

test.py 8mo ago

Untitled1.ipynb 3mo ago

Untitled1.txt 3mo ago

Untitled2.ipynb 2mo ago

Untitled2.ipynb 2mo ago

x509up\_u10664 3mo ago

Launcher

Notebook

Python 3 (ipykernel)

fermiPy 1.4.0

Julia 1.11.5

JUNO\_PYTHON

Python (LCG 107)

Python 3.12 with ROOT v6.34.04

ROOT C++ v6.34.04

Console

Python 3 (ipykernel)

fermiPy 1.4.0

Julia 1.11.5

JUNO\_PYTHON

Python (LCG 107)

Python 3.12 with ROOT v6.34.04

ROOT C++ v6.34.04

Other

Terminal

Text File

Markdown File

Julia File

Python File

Show Contextual Help

Jupyter Plugins

File Lists

Jupyter Kernels:

- ✓ Python3/ROOT/Julia/FermiPy
- ✓ Experiment customized environment

Some popular editors:

- ✓ Terminal
- ✓ Text editor
- ✓ Markdown editor

# Exploring INK: ROOT Browser

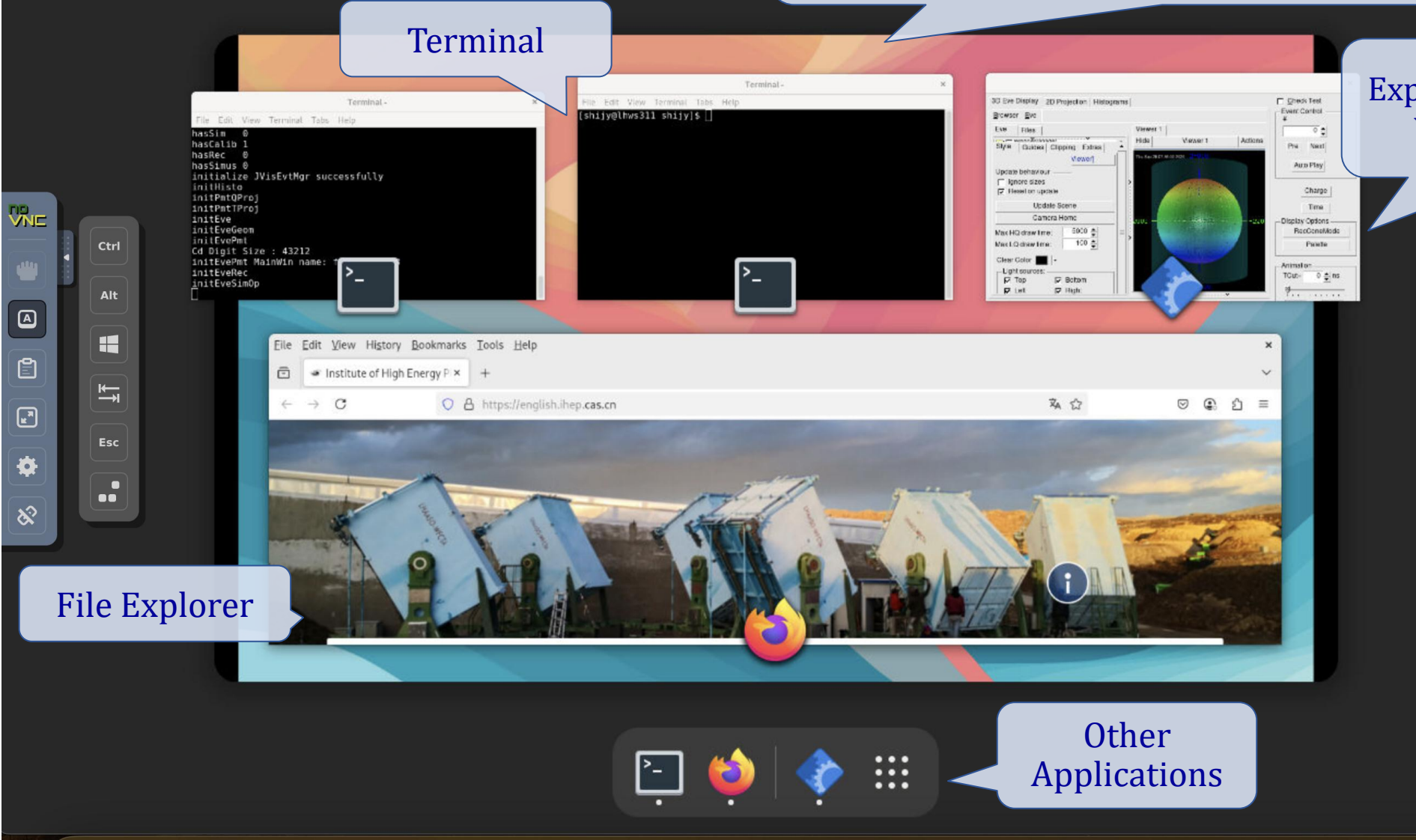
The screenshot displays the ROOT 7 browser interface. On the left, a file tree shows the path `hanx > ink > ink-rootbrowse > sample.root`. A table lists files with their names and sizes. A blue callout bubble labeled "File Path" points to the file list, and another labeled "ROOT File Contents" points to the file details.

The main area contains two histograms. The left histogram, titled "ximass", shows a distribution of mass values. A blue callout bubble labeled "Interaction with ROOT Objects" points to a data point on the histogram. A tooltip for this point shows: `ximass bin = 51 x = [1.321, 1.322] entries = 18159`. A summary box for the "ximass" histogram displays: `Entries 121612 Mean 1.321 Std Dev 0.004413`. The right histogram, titled "lammass", shows a similar distribution. A summary box for the "lammass" histogram displays: `Entries 121612 Mean 1.116 Std Dev 0.002702`.

At the bottom, a command line interface shows the following text: `ximass ximass bin = 51 x = [1.321, 1.322] entries = 18159 307,314`. Below this is a prompt `Enter command ...` and a list of ROOT objects: `root [1] h1002->Show() [IncrementalJIT] addModule() failed: Duplicate definition of symbol 'ZN21_ROOT_SpecialObjects5h1002E' =====> EVENT:-1 Xim = 0 xi0 = 0 vmass = 0 umass = 0 mxi = 0 chisqm = 0 chisq = 0`. A blue callout bubble labeled "ROOT Command Line Interface" points to this area.

# Exploring INK: VNC

VNC works as a cloud desktop, running in IHEP job cluster.  
Has perfect network connection and zero I/O delay



Terminal

Experiment Customized Visualization App

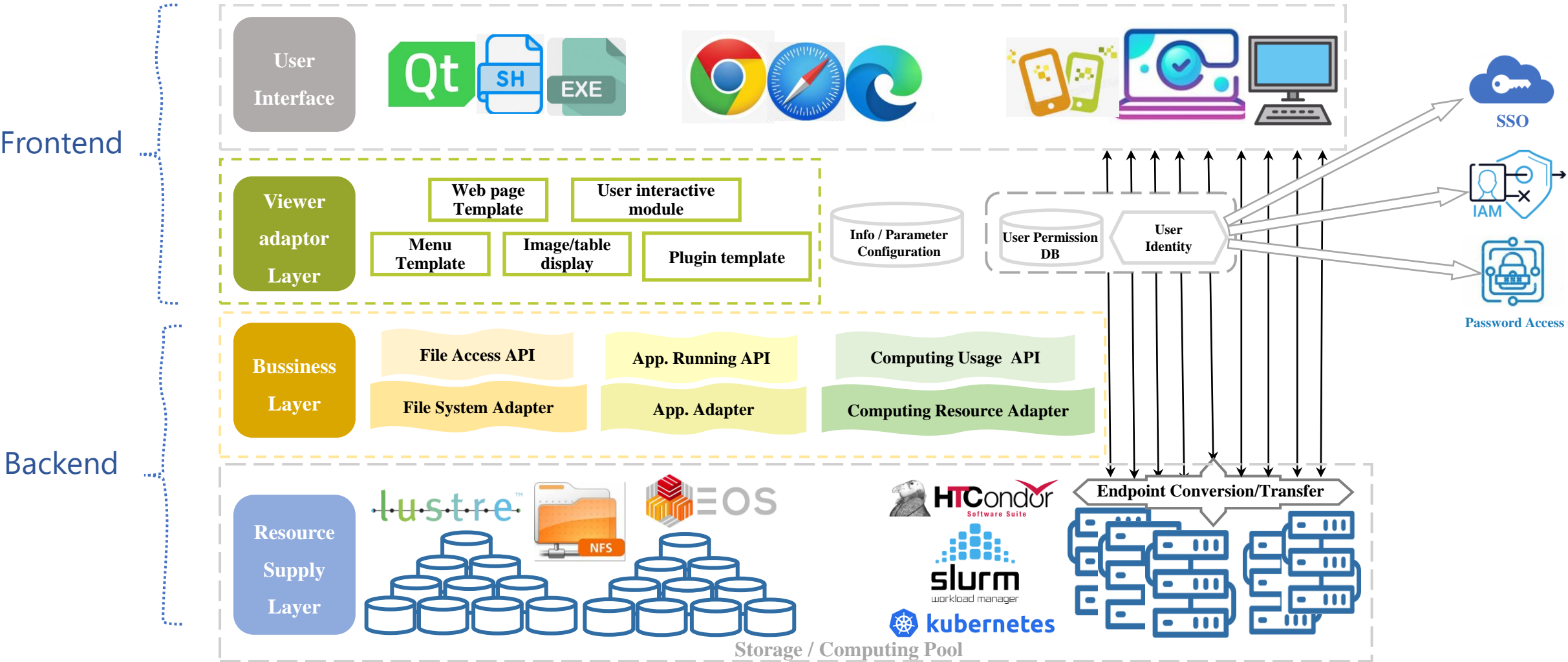
File Explorer

Other Applications

# Key Development Challenges

- **Loose and flexible software architecture**
  - Customizable: each HEP experiment configure its own resource and applications
  - Configurable: resources allocation, applications, default settings
  - Ready-to-use deployment for site
- **Secure authentication & authorization**
  - Support diverse methods (SSO, token, passwd, commercial account)
  - Secure for the computing and storage resource usage
    - Maintain consistent access policies for external/internal users
- **Seamless resource & application integration**
  - Various resources integration: HTCondor, Slurm, Kubernetes, EOS, Lustre etc.
  - Flexible application integration mechanism

# Loose and Flexible Architecture



INK Modular Architecture

# INK Modular Architecture

- Hierarchical layers structure
- Separation of frontend and backend
  - Frontend:
    - User interface layer: user way to connect resource
      - Web-based portals
      - User software
    - Viewer adapter layer: user portal generator
  - Backend:
    - Business logic layer: standardized API for the frontend interaction
    - Adapter layer: integrates diverse resources (compute, storage, applications)

# Authentication and Authorization

## ● Authentication

- INK leverages the cluster's existing authentication mechanism(SSO, IAM, Password etc.)
- Mutual trust established among INK components

## ● Authorization

- Dedicated INK user permission database governs
  - Available resources
  - Allowed Applications
  - Resources access rights

# INK Authentication and Authorization at IHEP

## ● IHEP cluster authentication

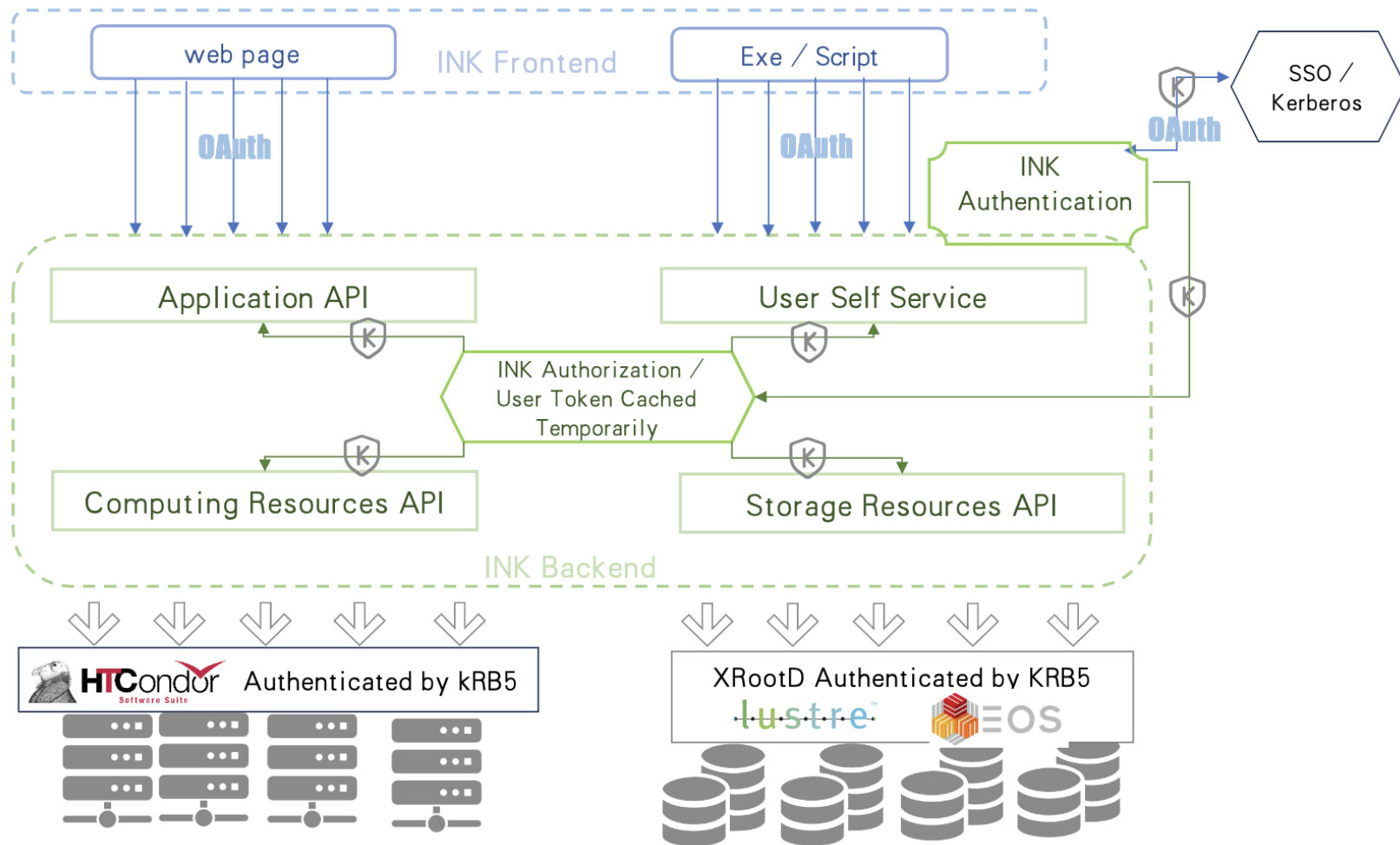
### ● Kerberos 5

- user authentication
- Computing & storage usage
  - HTCondor & XRootD

## ● OAuth for INK frontend/backend authentication

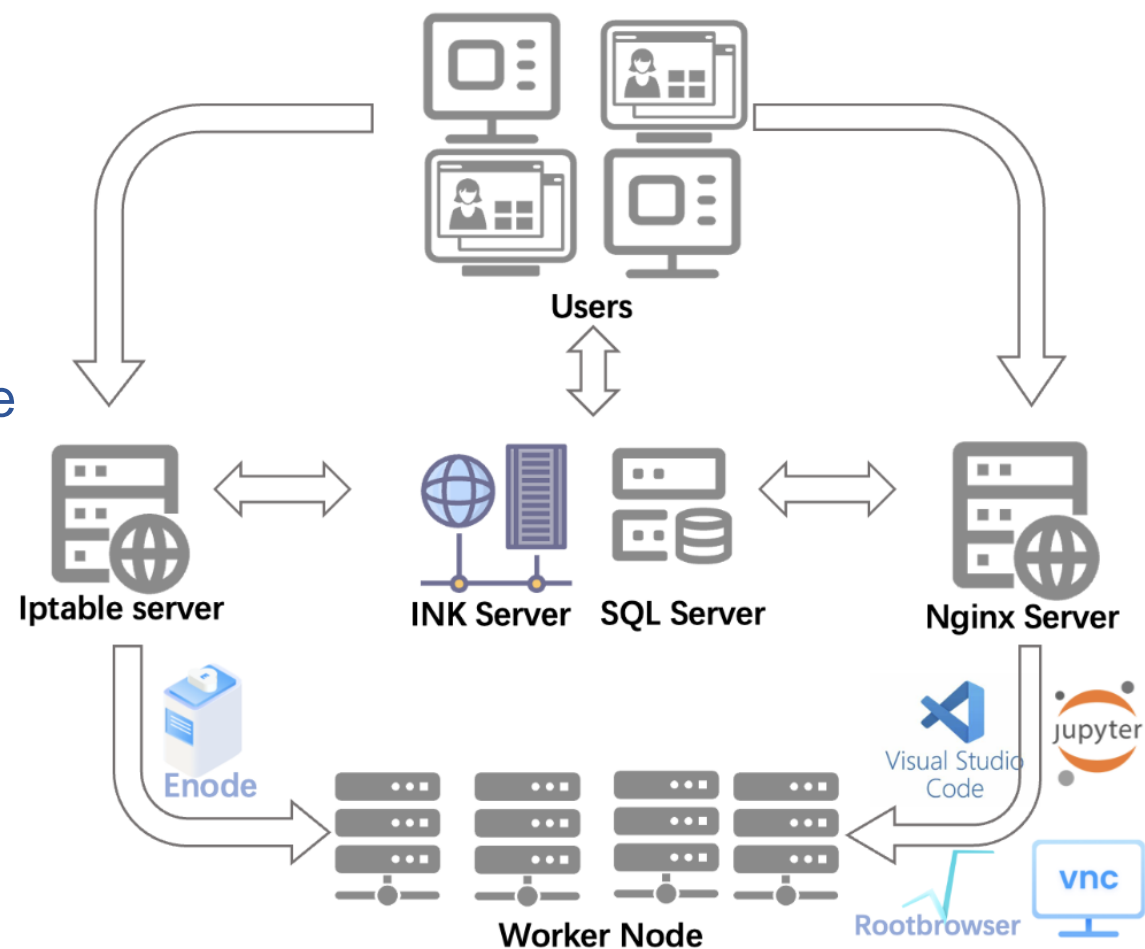
## ● A authorization mechanism developed

- Kerberos 5 service provides short-term user ticket
- INK caches and refreshes user tokens during the job execution



# Run Application ON Worker Node

- **Connecting to applications running on worker nodes via port forwarding**
  - Nginx Server: handle port forwarding for VSCode, Jupyter, VNC, and Rootbrowser
  - Iptable Server: handle port forwarding for Enode
- **File stream connection between file storage and frontend**
  - For file upload / download
  - Files viewer running inside browser
    - Fits files
    - Root files



Port forwarding for application running at worker node

# Customization for Experiments & Plugin Mode for New App

- Resources and applications database records:

- **Experiment-specific configuration**

- Resources of the experiments
    - Applications of the experiments

Each experiments has its own INK web page

- **User-specific configuration**

- Personalized resources and applications permission →

Each user has his own INK web page

- Plugin mode to integrate new app

- A way for users to develop their own App
  - INK provide job slot to run the app
  - INK provide authentication

User's own interactive app could be integrated

# Current Status

- Publicly accessible at <https://ink.ihep.ac.cn>
  - Test release: Feb. 2025
  - First official release: Mar. 2025
  - Open source: Nov. 2025
- IHEP user access the web page directly without any extra work
  - 1 CPU core with 6GB memory for each job slots
  - Limit 24 hours wall time for the INK job
  - Each user can run one of each job type
  - Provide special job slots for some special exp. user
    - Bigger memory
    - More CPU cores
  - Several customized application for dedicate Exp.
    - Alicpt DAQ monitor
    - LHAASO GPU analysis
- **Quite positive user feedback received!**

# Next Plan – Job Tracing Based on eBPF

## ● eBPF (extended Berkeley Packet Filter)

- Safely run "microkernel modules" in the operating system kernel
- Executing in a secure sandbox environment does not affect kernel stability.
- With eBPF, custom logic can be dynamically and securely injected into the critical execution paths of the operating system kernel for observing or handling various kernel events.

## ● Tracing job process based on eBPF

- The eBPF program is triggered and executed when a specific event occurs
- The event-driven model ensures the high performance and low overhead characteristics of eBPF
- Metrics collection of the process in milli-second level



# Next Plan - Create an Agent-ready Computing Ecosystem

- **MCP & Skills: Foundation for Agent Interaction**

- MCP (Model Context Protocol) standardizes service communication, while SKILL packages specific platform capabilities for easy invocation by agents.

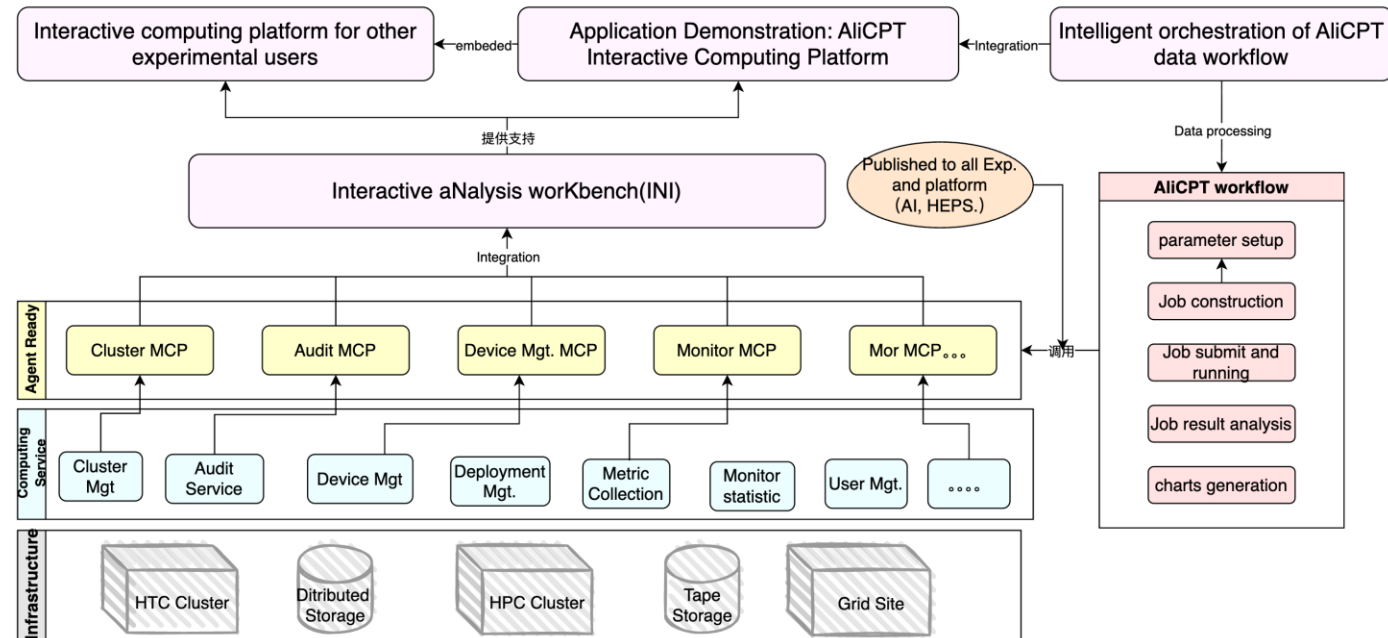
- **MCP & Skills Based Intelligent Computing Platform Infrastructure**

- Transform computing platform infrastructure into MCP-enabled intelligent services
- allow direct and simplified access for external AI agents

- **INK Integration for Unified Access**

- **AliCPT as a Demonstration Agent**

- Demonstrate how AliCPT can autonomously submit jobs, access data, and monitor status,
- highlighting the simplicity and efficiency of the agent-ready ecosystem



# Summary

- **Traditional batch system face limitations (Offline, closed and backend) for HEP data analysis now**
- **INK focus on providing an interactive usage of the cluster**
  - Provides users with a “frontend usage” for “backend resources”
  - It supports global security credentials, enabling seamless and password-free access to all resources.
  - By bridging backend resources and frontend display, it allows interactive tools like VSCode to be presented via web pages.
  - Received positive feedback from users since the first release published
- **Further development is ongoing based on the HEP requirements**
  - Job tracing based on eBPF
  - Create an agent-ready computing ecosystem

# Thank You!

# Questions?

