STAR detector:
- Operating since 1999 (till 2025)
- 22 subsystems and growing
- Detector Control System is EPICS-based, having over 60k process variables
- Data taking rate: ~2kHz (started at 1Hz!)
- Colliding species: AuAu, CuCu, pp

STAR Collaboration:
69 institutions from 14 countries, with a total of ~680 collaborators.
My current responsibilities

• STAR Databases
  - Online: Conditions, RTS, RunLog, Shifts
  - Offline: Calibrations, Geometry (+API)
  - FileCatalog
  - Software Infrastructure

• STAR Services
  - MIRA: SCADA Framework
  - SKM: SSH Key Management
  - PhoneBook: Collaboration Record Keeping
  - Shift Signup & Accounting
  - Experiment's RunLog
  - Online Event Display

• Misc Tools and Interfaces
  - DB Interfaces: Monitor, Browser, Explorer
  - Author tools: author lists (LaTeX, Inspire)
  - Online Service Aggregator
  - jobStat: nightly tests UI
  - dbPlots: Conditions DB archive viewer
  - dbSlice: db readiness checker
  - talkstats / simstats
  - Online-to-Offline data migration scripts & monitoring tools
  - Drupal modules: STAR papers, meeting, conference etc
"Online" Databases: used during data taking, optimized for fast writes, not fully structured. MySQL: two master servers containing four independent db instances, four slave servers. Each replica contains all online databases. New RTS database is a three-node MongoDB cluster.
"Offline" Databases: Calibrations and Geometry Databases used during data production. Highly structured and optimized for fast reads. Replicated setup: single MySQL master, 15 MySQL slaves (three groups). Load Balancer is built into the client DB API (StDbLib, cpp). Database is not a file lookup service but data distribution service (+descriptors). Highly optimized for performance: peak load of 150k queries per second was handled without interruptions. Routine average load is ~20k queries per second.
Offline Databases: format & API

STAR DB stores Data and IOV!

- Every data bit has its own Validity Range
- Data is requested via Event Timestamp + /full/path/to/the/entry
- Three time tags: beginTime, entryTime, deactivateTime
- Complete reproducibility: constrain entryTime and get db state as it was at time X

2019-05-24
Offline DB: clusters & clouds

**KEY FEATURES:**
- Easy to maintain: just one service to maintain – MySQL master + N replicas. No separation between file servers and IOV servers. Maintainable by just one person bottom up (online to production).
- MySQL replication allows near-perfect horizontal scalability, so if performance is a bottleneck, just add more servers to the pool to accommodate for the increased load. Commodity hardware is fine, no need for a super-beefy servers.
- Client-based load balancing allows simple local LB configuration setups
- MySQL Query Cache is the only cache, and it is update-aware, no cache expiration time inconsistencies, ~95% efficiency

**CLUSTERS:**
- MySQL is fairly easy to setup (incl. replication), so new cluster setup is not too complicated. Instant replication ensures 100% real-time data propagation across servers;
- Load is not an issue: add as many db replicas as needed in no time;

**CLOUDS:**
- (from STAR experience) Bring DB server along with your jobs, use it as local server.. One year of STAR db data is ~5GB, no exascale-sized db needed if properly maintained ;)

2019-05-24
"FileCatalog" Databases: contain locations of all BNL-hosted files (HPSS, XROOTD, Distributed Disks) MySQL, one master, two replicas, optimized for frequent updates.

"SoFi" Databases: various Software Infrastructure databases. Loggers, monitoring, web services, SKM, file statistics, user activity stats etc. MySQL, several pairs of “one master, one replica” setups.
MIRA: SCADA Framework

Messaging Interface and Reliable Architecture

- Features:
  - Scalable architecture
  - Inter-operable, low-overhead protocol
  - Payload-agnostic messaging
  - Quality of Service regulation
- Originally designed to implement better meta-data collection (archiver) and provide basic service messaging bus
- Implemented using Message-Queuing service bus - AMQP, later MQTT
- Supports Complex Event Processing (CEP)
- With time, expanded to the Control System realm and Alarm Handling

MIRA: Archive Viewer

ETOF Temperatures

CLICK HERE to set plot range, or CLICK ON

Time, ES
Board: Board

2019-05-24
Experiment's PhoneBook
https://www.star.bnl.gov/pnb/client/

- MySQL database backend (EAV model, schema-free) which has detailed historical information on every member of STAR collaboration, back to y1998. New fields could be configured on the fly without any interruption of service or database schema updates.
- Modern user interface, which is more than just interface. Its HTML5 frontend is a client app, written in JavaScript.
- Server core, exposing RESTful API (single source of data) for all possible clients: PhoneBook, ShiftSignup, Disk Space allocators etc..

RESTful API over HTTPS
User Interface
Admin Interface
ShiftSignup

DB
MySQL
Server Core
Web Server

Clients: cpp, php, js, python

2019-05-24
# PhoneBook UI


## PhoneBook 2.0

### Intro

**ADD FIELD**

<table>
<thead>
<tr>
<th>id</th>
<th>weight</th>
<th>Fixed name</th>
<th>Description</th>
<th>Group</th>
<th>is required?</th>
<th>is enabled?</th>
<th>Privacy mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>name_first</td>
<td>Firstname</td>
<td>username</td>
<td>Yes</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>name_initials</td>
<td>Initials</td>
<td>username</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>name_last</td>
<td>Last Name</td>
<td>username</td>
<td>Yes</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>name_latex</td>
<td>Latex Last Name</td>
<td>username</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>name_unicode</td>
<td>Unicode Last Name</td>
<td>username</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>inspire_id</td>
<td>Inspire ID</td>
<td>username</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>gender</td>
<td>Gender</td>
<td>username</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>address_line_1</td>
<td>Address Line 1</td>
<td>user address</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>address_line_2</td>
<td>Address Line 2</td>
<td>user address</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>address_line_3</td>
<td>Address Line 3</td>
<td>user address</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>city</td>
<td>City</td>
<td>user address</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>state</td>
<td>State/Region</td>
<td>user address</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>country</td>
<td>Country</td>
<td>user address</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>13</td>
<td>13</td>
<td>postcode</td>
<td>Postcode/Zipcode</td>
<td>user address</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td>institution_id</td>
<td>Home Institution</td>
<td>user address</td>
<td>Yes</td>
<td>Yes</td>
<td>public</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>extra_institution_id</td>
<td>Additional Home Institution(s)</td>
<td>user address</td>
<td>No</td>
<td>Yes</td>
<td>public</td>
</tr>
</tbody>
</table>
Shift Signup & Accounting

https://online.star.bnl.gov/ShiftSignup/

• **Features:**
  • Highly-configurable Shift Signup and Accounting tool. Integrated with STAR phonebook. Provides detailed overview of STAR shift crews and Online QA shifts, contains expert list.

• **Administrative Features:**

• **Accounting Features:**
  • Automatic checks for BNL mandatory shifter trainings, statistics of shift dues per institution, special shift dues calculations for experts
### Shift Signup & Accounting UI

**https://online.star.bnl.gov/ShiftSignup/**

#### Shift Signup Run 19

1. **To Signup:** First select your Institution and Name, then choose a signup sheet.
2. **To view schedules:** Choose a signup sheet.

**--- Institutions ---**

<table>
<thead>
<tr>
<th>Institution</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of California - Davis</td>
<td>Daniel Cebra</td>
</tr>
<tr>
<td>Brookhaven National Laboratory</td>
<td>Zilong Chang</td>
</tr>
<tr>
<td>Rutgers University</td>
<td>Joel Mazor</td>
</tr>
<tr>
<td>University of California - Davis</td>
<td>Todd Kimbom</td>
</tr>
<tr>
<td>Shanghai Institute of Applied Physics</td>
<td>Xiaohai Jin</td>
</tr>
<tr>
<td>University of California - Riverside</td>
<td>David Kapukhyan</td>
</tr>
<tr>
<td>Central China Normal University</td>
<td>Dingwei Zhang</td>
</tr>
<tr>
<td>Central China Normal University</td>
<td>Zhenzhen Yang</td>
</tr>
<tr>
<td>Kent State University</td>
<td>Yue Liang</td>
</tr>
</tbody>
</table>

**--- People ---**

<table>
<thead>
<tr>
<th>Institution</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Texas at Austin</td>
<td>Jan Vanek</td>
</tr>
<tr>
<td>Nuclear Physics Institute, The Czech Academy of Sciences</td>
<td>Lukas Kramarik</td>
</tr>
<tr>
<td>Czech Technical University in Prague</td>
<td>Maria Stefanakis</td>
</tr>
<tr>
<td>Warsaw University of Technology</td>
<td>Rongxiang Wu</td>
</tr>
<tr>
<td>National Laboratory</td>
<td>Matthew R. Johnson</td>
</tr>
<tr>
<td>University of California - Davis</td>
<td>Todd Kimbom</td>
</tr>
<tr>
<td>Shanghai Institute of Applied Physics</td>
<td>Xiaohai Jin</td>
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<td>Central China Normal University</td>
<td>Zhenzhen Yang</td>
</tr>
<tr>
<td>Kent State University</td>
<td>Yue Liang</td>
</tr>
</tbody>
</table>

#### Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Institution</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb 26th - Mar 5th</td>
<td>0:30-7:30</td>
<td>University of California - Davis</td>
<td>Daniel Cebra</td>
</tr>
<tr>
<td></td>
<td>7:30-16:30</td>
<td>Brookhaven National Laboratory</td>
<td>Zilong Chang</td>
</tr>
<tr>
<td></td>
<td>16:30-0:30</td>
<td>University of California - Riverside</td>
<td>David Kapukhyan</td>
</tr>
<tr>
<td>Mar 5th - Mar 12th</td>
<td>0:30-7:30</td>
<td>University of California - Davis</td>
<td>Daniel Cebra</td>
</tr>
<tr>
<td></td>
<td>7:30-16:30</td>
<td>Brookhaven National Laboratory</td>
<td>Shuai Yang</td>
</tr>
<tr>
<td></td>
<td>16:30-0:30</td>
<td>University of California - Riverside</td>
<td>David Kapukhyan</td>
</tr>
</tbody>
</table>

---

*Week 1 Subshops: compact view*
Experiment's RunLog
https://online.star.bnl.gov/RunLog/

- Features:
  - Extensive web interface for all STAR runs, taken during RHIC data taking Runs.
  - Provides run statistics (time, events, triggers, files etc) filtering, monitoring logs, conditions overview and other information
  - Collects and organizes information from a variety of sources: Run-Time System, DAQ, Conditions, Slow Controls etc;
  - Composed of a ~dozen services, three database instances and a web interface.
  - Archived annually, to provide historical records for past Runs
  - Web Interface was fully re-written from scratch in 2010 as Model-View-Controller application

[RunLog interface screenshot]
SSH Key Management
https://www.star.bnl.gov/starkeyw/

• Features:
  • Completely automatic SSH key management across mid-sized Linux cluster (online domain).
  • Allows to satisfy CyberSecurity requirements for sensitive domain access.
  • Enables user fingerprinting via personal SSH keys.
  • Eliminates the need for password-protected shared accounts (aka sticky-note passwords)

• Administrative Features:
  • User, Host, Public Key or Public-Private Key management.
  • Assign user keys to accounts, enable/disable offending users or hosts, receive notifications of new requests, approve requests.

[Diagram showing the flow of data between nodes and services]
SSH PUBLIC KEY MANAGEMENT CONSOLE: STAR

HOME :: HELP

ADMIN ACCESS: show pending requests :: show pending re-pub requests :: account and host management :: expired associations :: show hosts :: show host tags :: show users :: show admins :: show keys :: show config parameters :: account scan :: private/public key pair management :: show blacklisted keys

(Re)Upload Public Key
Public key file in OpenSSH format: Browse... No file selected.

Upload Public Key File
This will "replace" any previously uploaded key. Key replacement takes up to 10 minutes to propagate to the client nodes.

Contact E-mail
Current E-mail: arkhipkin@bnl.gov
Change E-mail to:
Change E-mail:

Request for account association
Host: Select Host...
Account: Select Account...
Host Restriction: *:star.bnl.gov
Reason for this association: ex: subsystem expert

Request Account @ Host Association for Your Key
This is "not" instantaneous — all associations must be approved by an administrator before becoming active.

Association status list

2019-05-24
# SSH Key Management


## List of hosts

<table>
<thead>
<tr>
<th>HOST</th>
<th>STATUS</th>
<th>DESCRIPTION</th>
<th>VERSION</th>
<th>ACCOUNTS</th>
<th>USERS</th>
<th>LAST HEARTBEAT</th>
<th>LAST UPDATE</th>
<th>TOGGLE STATUS</th>
<th>DELETE HOST</th>
</tr>
</thead>
<tbody>
<tr>
<td>barbados2.starp.bnl.gov</td>
<td>ACTIVE</td>
<td>barbados2.starp.bnl.gov (SL6, x86_64) (Slow Controls)</td>
<td>2nd gen. / 2.0.5</td>
<td>16</td>
<td>9</td>
<td>2019-02-18 20:05:50</td>
<td>2019-02-15 17:15:22</td>
<td>❌</td>
<td>❌</td>
</tr>
<tr>
<td>beatrice.starp.bnl.gov</td>
<td>ACTIVE</td>
<td>beatrice (BMC node), SL6.x, x386</td>
<td>2nd gen. / 2.0.6</td>
<td>5</td>
<td>4</td>
<td>2018-06-19 18:10:01</td>
<td>2019-02-18 20:10:24</td>
<td>❌</td>
<td>❌</td>
</tr>
</tbody>
</table>

Showing 1 to 10 of 91 entries

---

2019-05-24

19/29
Event Display handles full event lifecycle: from raw DAQ data to the fully reconstructed and visualized event in 3D. Client: web browser. Used during RHIC runs by STAR, RHIC MCR, and also for public outreach (DOE events, Universities).

Fully reconstructed TPC tracks, EMC hits
Online Event Display: track reco

1. Raw Hits import: 3D spacepoints from DAQ. Conversion from HW coordinates to x,y,z – T0 applied

2. Pattern Recognition / Seed Finding via triplets + fast KD tree search

3. Track Candidate Following & Fitting (circle fit, sz fit → fully reco'ed momentum

4. Vertex Seed Finding
   Centroid found by projecting tracks to DCA(POC) to z-axis

Performance: 0.5s to reconstruct central event with ~5000 tracks

C++11:
   kdfinder.hpp
   nanoflann.hpp
Online Event Display: Web UI v1

https://online.star.bnl.gov/display/

EVD: STAR Control Room, RHIC Control Room
EIC Event Display, sPHENIX Event Display
Event Display Web UI v2

https://www.star.bnl.gov/~dmitry/gide_new/

- Geometry Input Format:
  - latest GDML version supported
- Event Input Format: JSON
- Geometry Shapes:
  - 100% coverage of GDML/G4, TGeo, VecGeom
- Interactivity:
  - Subselection of volumes
  - Automatic volume positioning
- Physical Objects
  - Tracks: helix, set of points
  - Hits: 3d points a-la TPC, calorimetric hits
- Extensively used by ITPC experts: debugging!

[Image of the Event Display Web UI v2 interface]

https://www.star.bnl.gov/~dmitry/gide_new/
Custom monitoring tool, specialized for large replicated MySQL setups. Monitors all STAR databases, Provides extensive automatic inventory, replication status and performance tuning hints.
Custom database browsing tool. Provides generic database viewer capability, and specialized database viewing for EMC and EEMC subsystems.
DB Explorer
https://online.star.bnl.gov/dbExplorer/

Auto-documentation system for STAR Offline Databases and API. Provides web-based interface for database schema and structure, provides samples for DB read and DB write for each table.
jobStat: nightly tests
https://online.star.bnl.gov/jobStat/

Web interface to STAR nightly tests system. Provides fast plotting capabilities for all nightly tests.
Drupal Development

• Features:
  • Drupal is modular, easy to extend content management system
  • Provides STAR with web-based document management, blogs, calendar of events, conferences, STAR paper/note archive and many more since 2003.

• Custom modules:
  • STAR conference and meeting
  • STAR publications and notes
  • STAR presentations and thesis
  • STAR simulation requests
  • STAR news and polls
Summary

● Current Duties:
  – All STAR databases – maintenance, support, backups, performance tuning, development for 30+ servers, 50+ MySQL instances, 3 MongoDB instances

● Major RHIC Run Tasks:
  – Online Databases, migration scripts, RunLog service, ShiftSignup service, MIRA services (data collectors), Event Display service

● Major Out-of-Run Tasks:
  – Offline Databases, StDbLib (DB API), FileCatalog databases, DB-related software upgrades, Drupal development and maintenance, R&D development (not mentioned here)

● Commonly-used Languages and Techs:
  – C++, JavaScript, PHP, shell, SQL, RPC, XML, JSON, HTML, CSS etc.