SDA Time Intervals

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LAFS workgroup
What is SDA?

- Sequenced Data Acquisition
- Backed up with **Hierarchical** Data Logging System.
<table>
<thead>
<tr>
<th>ID</th>
<th>Date/Time</th>
<th>Description</th>
<th>Case</th>
<th>Set</th>
<th>Collection</th>
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<td>Before Ramp</td>
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<td>HEP</td>
<td>05/07/2005 14:44:49</td>
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<td>Pause HEP</td>
<td>05/08/2005 12:02:28</td>
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<td>Inject Protons: Booster to MI</td>
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<td>Abort</td>
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<td>Conditions</td>
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<td>Set up</td>
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<td>1</td>
<td>1</td>
<td>0 shot 2667 shot index 25704 owned PbarTransferShot</td>
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<td>Unstack pbars</td>
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<td>Transfer pbars from Accum to MI</td>
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<td>2667 shot index 25704 owner PbarTransferShot</td>
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<td>Coalesce Pbars in the MI</td>
<td>05/07/2005 13:59:30</td>
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<td>2667 shot index 25704 owner PbarTransferShot</td>
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<td>05/07/2005 14:03:02</td>
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<td>403 shot index 25706 owner RecyclerShot</td>
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<td>403 shot index 25706 owner RecyclerShot</td>
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<td>05/07/2005 14:03:12</td>
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<td>10</td>
<td>0</td>
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<td>shot index 25641</td>
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</table>
What is SDA?

- Sequenced Data Acquisition
- Backed up with Hierarchical Data Logging System.
- Based on rules and driven by events
- Terms: Event, Device, Collection, Shot, Case, Set.
ACNET Events

- 256 Tclk events + delay
- Absolute and Relative Time events, delays.
- State variable changes.
- Changes of ACNET special device readings (category of devices).
What is SDA?

- Sequenced Data Acquisition
- Backed up with Hierarchical Data Logging System.
- Based on rules and driven by events
- Terms: Event, Device, Collection, Shot, Case, Set.
- Numerous tools, tables, applications..
Summary tables

- **Intensities and Emittances**, averages and bunch by bunch for both Collider Shot and Pbar Transfers from Accumulator to Recycler.

- "Supertables" for both Collider Shot and Pbar Transfers from Accumulator to Recycler.

- Performance plots.

- Luminosity plots.

- OSDA API for reading SDA data.

- Physicists named SDA Shot Data Analysis.
### Recomputed Emittances Table

<table>
<thead>
<tr>
<th>Store # 4100</th>
<th>Proton Vertical [pm-mm-mm]</th>
<th>Proton Horizontal [pm-mm-mm]</th>
<th>Proton Longitudinal [eV-sec]</th>
<th>Proton Vertical [pm-mm-mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accumulator</td>
<td>.</td>
<td>.</td>
<td>2.0</td>
<td>.</td>
</tr>
<tr>
<td>Recycler</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
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<tr>
<td>MI 8 GeV</td>
<td>12.7</td>
<td>13.9</td>
<td>5.3</td>
<td>.</td>
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<tr>
<td>MI 150 GeV</td>
<td>12.2</td>
<td>13.3</td>
<td>4.9</td>
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<tr>
<td>Proton Injection</td>
<td>16.7</td>
<td>14.2</td>
<td>3.3</td>
<td>.</td>
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<tr>
<td>Pb for Injection</td>
<td>16.8</td>
<td>15.3</td>
<td>3.2</td>
<td>.</td>
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<tr>
<td>IM 100 GeV</td>
<td>12.3</td>
<td>14.5</td>
<td>3.0</td>
<td>.</td>
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</tbody>
</table>

- **#138 TeV p bunch length at 150, before helix opened (ns):** 2.58
- **#139 TeV p bunch length at Remove Halo (ns):** 2.72
- **#140 pbar bunch length (hours):** 1.65
- **#141 p bunch growth (hours):** -22.39
- **#142 pbar bunch growth (hours):** -66.46
- **#143 time on helix (minutes):** 45.12
- **#144 pbar lifetime at 150 (hours):** 36.95
- **#145 pbar lifetime 1st 2 hours into store (hours):** 21.67
- **#146 pbar lifetime, 1st 2 hours into store (hours):** 151.46
- **#147 pbar lifetime, 1st 2 hours into store (hours):** 21.49

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**Integrated Luminosity 1310.57 (1/pb)**
What is SDA?

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- Backed up with **Hierarchical** Data Logging System.
- Based on rules and driven by events
- Terms: Event, Device, Collection, Shot, Case, Set.
- Numerous tools, tables, applications.
- Defines common language for different workgroups.
- Used during Fermilab Collider Run II for **fine tuning** of accelerator complex.
What is SDA?

SDA was vital for fine tuning of Fermilab Accelerator complex during Collider Run II.
How Fermilab SDA is organized?

There are several types of Shots. Each has a rule for starting a shot (an event) and a rule for stopping a shot (another event).

Shot has collections. Each type of collection has rules with starting and stopping events too.

Inside collection there are event-based rules for devices.

Type of collection defines a Case. Different devices are collected during "Inject Pbars" and "Remove Halo" cases.

Flat Datalogger is considered as database table with fields: device_name, timestamp, device_value.
Example of Time Intervals / Collections.

- Example times:
  - $t_1, t_2, t_3, t_4, \ldots$

- Event times:
  - $v_1, v_2, v_3, v_4, \ldots$

- "Flat" UTC - timestamped database table

- Time intervals:
  - Proton Injection Porch
  - Proton Injection Tune Up
  - Bunch 1
  - Bunch 2

- Timeline:
  - Collider Shot
SDA on Collections.

ColliderShot # 5592
- Proton Injection Porch
  - Collection #1
- Proton Injection Tune Up
  - Collection #2 - Set 1
  - ...
  - ...
  - Inject Pbars
    - Collection # 120 - Set 1
    - Collection # 121 - Set 2
    - Collection # 122 - Set 3
    - ...
  - Before Ramp

Recycler Shot # 3855
- Setup
  - Pbar Transfer Shot From RR to MI
  - Collection # 1 - Set 1
  - Collection # 4 - Set 2
  - ...
  - Accelerate Pbars In MI
    - Collection # 2 - Set 1
    - ...
    - Coalesce Pbars in the MI
      - Collection # 3 - Set 1
      - ...

Why redesign?

LAFS (LHC At Fermilab Software) group was formed in Fermilab in Autumn 2006.

LAFS Goal - share experience & software with CERN and learn from new CERN control system.

SDA was one of the initial project.

"Proof of design" SDA version based on XML DB was implemented.

Our collaborators did not like it:

- XML DB is not common (boosts support cost).
- Huge initial time investment (device rules).
- No integration with time - based datalogger.
Initial time investment.

To define Fermilab-like SDA one needs to define shot start/stop rules, collection rules and device reading rules.

Some collections have up to 350 devices reading rules.

It may be unclear which devices to include.

The set of collection types is rather clear from the beginning.
SDA Time Intervals (TI) provides a solution of these problems and enriches Fermilab SDA with Temporal Logic.

The idea is to get rid of individual device-related rules, but leave all the Collection-related rules. Collections become "empty", so they are renamed to Time Intervals.

Time Intervals are stored in a relational database. The TI table can be used in SQL queries to "flat" time-based datalogger table, providing "filtering" and "tagging".
Implementation - SQL Tables.

CREATE TABLE ti(
    owner INT not null,
    shot INT not null,
    theCase INT not null,
    theSet INT not null,
    file_idx INT not null,
    coll_idx INT not null,
    success TINYINT DEFAULT 1,
    tStart Timestamp not null,
    tStop Timestamp not null
)

cREATE UNIQUE INDEX ti1 ON ti( owner, file_idx, coll_idx )
CREATE INDEX ti2 ON ti( owner, shot, theCase, theSet )
CREATE INDEX ti_tstart ON ti( tStart )
CREATE INDEX ti_tstop ON ti( tStop )
Implementation - Filtering

Read values of Device during Pbar Injection #2

Growth of Emittance of Bunch #3 during second Pbar Injection.
Implementation - Filtering

```
SELECT A.ts, A.value
FROM flat_dl A, ti B
WHERE
    A.ts >= '01/01/2006' AND A.ts <= '01/01/2007'
    AND
    A.device = "Device" AND
    B.owner = ColliderShot AND
    B.theCase = InjectPbars AND
    B.theSet = 2 AND
    B.success = 1 AND
    A.ts >= B.tStart AND A.ts <= B.tStop
ORDER BY
    A.ts
```
Implementation - Data Tagging

How reading of Device changed throughout shot?

Emittance of Bunch #3 during the shot.
Implementation ï Data Tagging

```
SELECT A.ts, A.value, B.theCase, B.theSet
FROM flat_dl A, ti B
WHERE
  A.device = "Device" AND
  B.owner = ColliderShot AND
  B.shot = 5592 AND
  B.success = 1 AND
  A.ts >= B.tStart AND A.ts <= B.tStop
ORDER BY A.ts
```
Implementation - Temporal Logic

How much time was spent between shots throughout the year (average)? And between HEP (Collisions mode)?

How many transfers from Accumulator to Recycler was done during ColliderShot #5592?

How much time was spent in shot setup is comparing to total HEP time?

List all the time intervals of Pbar Injection? And Proton Injection? And throughout last 3 year? Does it grow?
public class SdaTimeInterval {
    private long start, stop;
    private List<SdaTimeInterval> children;
    private SdaTimeInterval parent;

    private int[] logicCoords; // owner/shot/case/set
    private int[] uniqueCoords; // unique keys
    private String[] names; // owner and case names
    private boolean valid = true;

    public boolean includes(SdaTimeInterval interval);
    public boolean overlaps(SdaTimeInterval interval);
    public boolean before(SdaTimeInterval interval);
    public boolean after (SdaTimeInterval interval);
    public boolean insideOf(SdaTimeInterval interval);
}
SDA TI was implemented in Fermilab in Spring 2007.

It is actively used since.
What is not covered by TI?

Fermilab SDA allows for saving bunch of high frequency data collected at necessary time, TI cannot provide it.

Fermilab SDA collections provides all the information about a given stage - physicist can look at all the relevant devices.

Data, collected on event are always more precise then data read on time.
Thank you for attention.