Software For Accelerators

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Accelerator Activity Coordination Meeting

August, 2004

Topics...

- SDA: Making Accelerator data available to physicists, engineers and managers.. (S. Panacek, K. Genser, P. Lebrun)
- BLASTMAN: Magnet Database Project (D. Box, M. Fischler)
- Tevatron Instrumentation Projects (excluding BPM)
  - ➢ Real-time longitudinal emittance calculation for SBD (A. Para)
  - ➢ Tevatron Tune Fitter - 1.7 GHz, 21.4 MHz (P. Lebrun)
- Tevatron Orbit Cusp Finder and Beam Orbit Smoothing Tools
- Input to VAX-VMS migration project and improvement to Control System (R. Rechenmaker, S. Panacek, P. Lebrun)
- Outlook : what's next ?

SDA : Introduction

SDA is a system for acquiring, archiving and analyzing data from stores.

- *Slides borrowed from talk presented at ICAP04, summarized.*
- Objectives & Scope
- Data Acquisition and Archiving Aspect. (Skip!..)
- Analysis (SDA = Shot Data Analysis, for us)
  - Tools & computing aspects
  - Output
    - Web based
    - Summary table
    - Detailed information
    - Application Interfaces
- Analysis results:
  - Tevatron complex performance assessment via SDA

The Team

- ## SDA Group in Integration Department
  - K. Gounder, E. McCrory, V. Papadimitriou, J. Slaughter
  - Coordination, monitoring, analysis
- ## Controls Department
  - T. Bolshakov, M. McCusker, K. Cahill, B. Hendricks, J. Patrick and others
  - Infrastructure and applications
- ## Computing Division
  - K. Genser, P. Lebrun, S. Panacek
  - Analysis and applications

A collaboration between A/D Controls, Computing Division, A/D physicist, CDF/D0. The coordination is the responsibility of the Accelerator Integration Department

Ultimate Goal: More integrated luminosity usable by the experiments

- Allows correlation of information from multiple sources at specific times during the stores
- Information for day to day monitoring of stores
- Specialized studies
  - Long term trends
  - Investigate correlations
    - Luminosity vs. emittances, number of protons and anti-protons
  - Accelerator physics questions
    - Pbar Burn rate / total loss rate during HEP
    - Orbit changes
    - Unknow issues, hurdles yet to be discovered!
- The Tevatron complex includes the proton and antiproton sources, the Main Injector and the Recycler.

SDA – Computing

- Programming language : Java! … for data acquisition and analysis.
- Extensive use of high-level communication protocols, such as R.M.I.
- Multi-tier architecture: use of "servlets" applications to extract data
- Simple and straightforward use of relational database (SYBASE and MSQL) to hold the data.
- We rely on the Web for distribution of summary plots and tables (Excel or HTML), and API code distributions
- Coherent data access for both "sequenced" (triggered) and "periodic" (1 Hz -> 5 min) data.

SDA: Analysis Tools

- Data Browser on the web or standalone Java (SDAViewer)
- Report Writer for quick studies
- Tables built automatically every store
  - Supertable and EXCEL package
  - Derived tables and associated plotting tools
  - Short summary tables
  - Tables use corrected values
- Shots scrapbook
- OSDA (Offline Shot Data Analysis) - Suite of Java classes for user programs to directly access the data, apply corrections and calculate generally useful quantities like lifetimes (mostly S. Panacek)
- OSDAPhysics : Suite of Java class for beam physics studies (K. Genser, P. Lebrun,….)

Supertable

- One line per store
- Built automatically every store
- 130+ quantities of general interest
  - Dates, time on helix, length of store
  - How store ended
  - Luminosities, intensities at collision
  - Efficiencies at each stage from p, pbar sources to HEP
  - Emittances at each stage
  - Peak, average losses
  - Lifetimes, etc.
  - Averages over all bunches, for each quantity
- Web Accessible – HTML, EXCEL
  - analysis with plots, tables also on Web

SDA Edited Excerpt from Super Table

0 Store #	1 Date started shot set up	7 store length (hours)	8 how store ended	10 start stack	11 unstacking fraction	12 amount unstacked
3228	2/12/2004	0.22	Not Completed	135.19	0.88	119.2
3226	2/10/2004	33.31	Normal	160.39	0.86	138.6
3224	2/8/2004	36.92	Normal	149.39	0.87	129.6
3222	2/7/2004	40.18	Normal	177.19	0.81	144.2
3219	2/5/2004	31.09	Normal	173.79	0.85	147.6
3217	2/3/2004	27.98	Normal	204.19	0.8	163.4
3214	2/2/2004	33.89	Normal	208.19	0.75	156.4
3212	1/31/2004	31.37	Normal	175.19	0.78	136
3210	1/30/2004	14.65	Normal	189.39	0.62	118
3206	1/29/2004	15.1	TevQuench	80.59	0.94	75.4
3197	1/27/2004	32.38	Normal	120.39	0.9	108.6
3195	1/26/2004	2.68	Abort	145.39	0.91	131.6
3191	1/25/2004	17.9	Abort	103.79	0.93	96.2
3189	1/23/2004	35.76	Normal	142.39	0.88	125.2
3185	1/22/2004	26.41	Normal	133.19	0.9	120.4
3183	1/21/2004	23.59	Normal	120.39	0.85	102.6
3179	1/19/2004	27.76	Normal	163.19	0.86	140.4
3177	1/17/2004	22.27	Normal	172.39	0.81	140
3175	1/16/2004	25.07	Normal	176.39	0.7	123.6
3172	1/15/2004	21.48	Normal	159.99	0.51	81.2

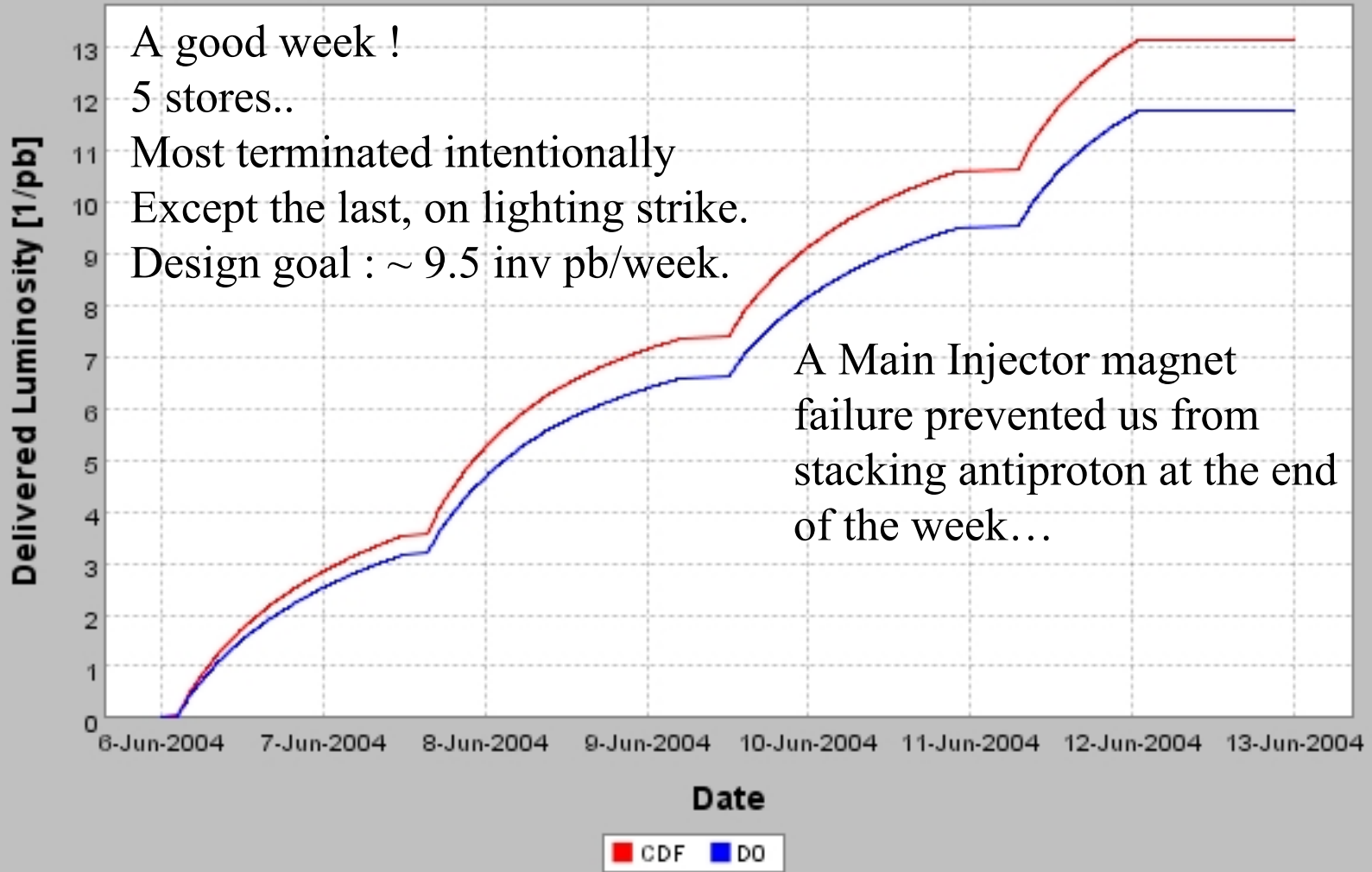# SDA Derived Tables- Bunch by Bunch Information

- Table per store – built automatically
  - All 6 emittances
  - Intensities
- Average and bunch by bunch information
- Use best algorithms to get physics quantities
  - Not always available directly from front-end.
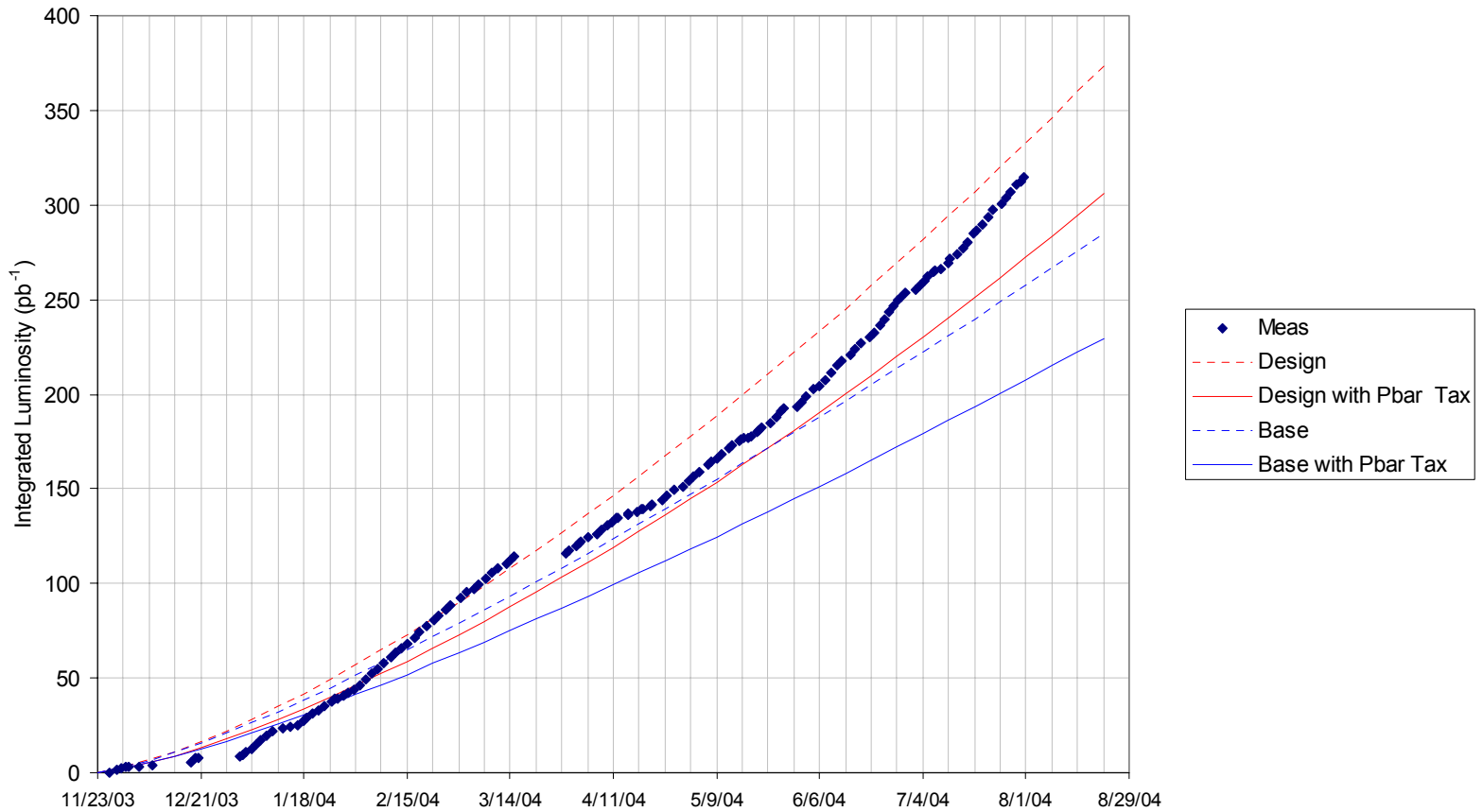- Interactive plotting interface

SDA Store Checker

- Purpose
  - Monitor instrumentation and DAQ
  - Monitor accelerator performance
- Checks SDA data for specified cases/sets
  - Min < device value < max
  - Min < (difference in time of 2 devices) < max
  - Min < (difference in value of 2 devices) < max
- Jobs run automatically every store
- "Standard" and "private" lists
- Results on WWW for "standard" list
- Lists on WWW
- Used to give email notification of initial luminosities

Integrated Luminosity Table and Plot

Tevatron Delivered Luminosity: Jun-06-2004 to Jun-13-2004

A good week !
5 stores..
Most terminated intentionally
Except the last, on lighting strike.
Design goal : ~ 9.5 inv pb/week.

A Main Injector magnet failure prevented us from stacking antiproton at the end of the week…
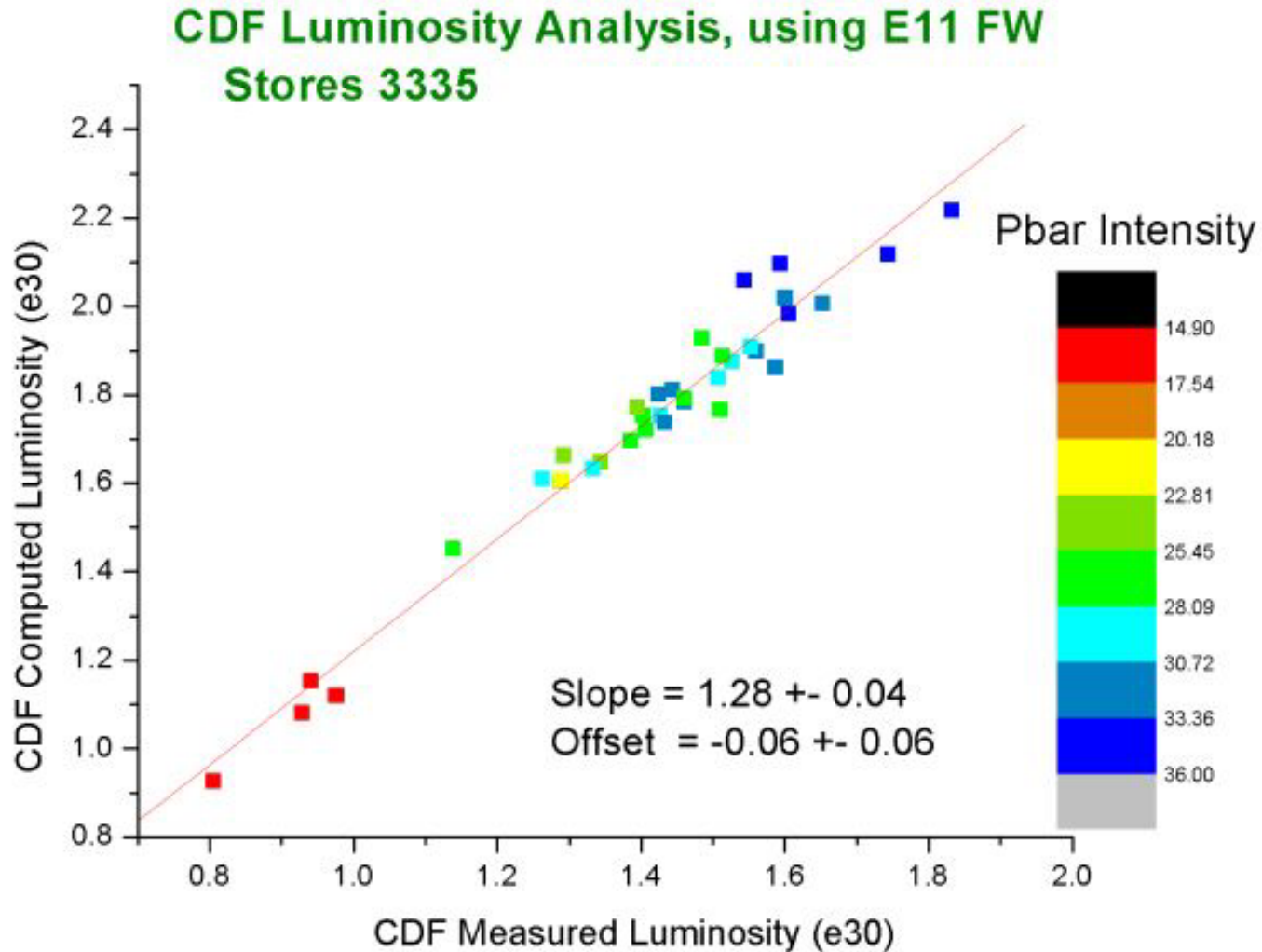
FY04 Integrated Luminosity

SDA Examples of Detailed Analysis

- These two plots described our overall performance. Improving performance requires meticulous analysis based on many data sources..
  - Is data acquisition reliable?
  - Is the instrumentation adequate?
    - Relative calibrations between devices and same devices in different machines
    - Systematic and statistical errors
- Let us go through a few examples of detailed analysis based on SDA tools and data sets:
  - Bunch by bunch Luminosity expectation (Skip)
 - Tevatron Transverse Emittances. (K. Genser)

SDA - Example of Analyses

CDF Luminosity Analysis, using E11 FW
Stores 3335

CDF Computed Luminosity (e30) vs CDF Measured Luminosity (e30)

Slope = 1.28 +- 0.04
Offset = -0.06 +- 0.06

Pbar Intensity

(black)	14.90
(red)	17.54
(orange)	20.18
(yellow)	22.81
(green)	25.45
(green)	28.09
(cyan)	30.72
(blue)	33.36
(blue)	36.00

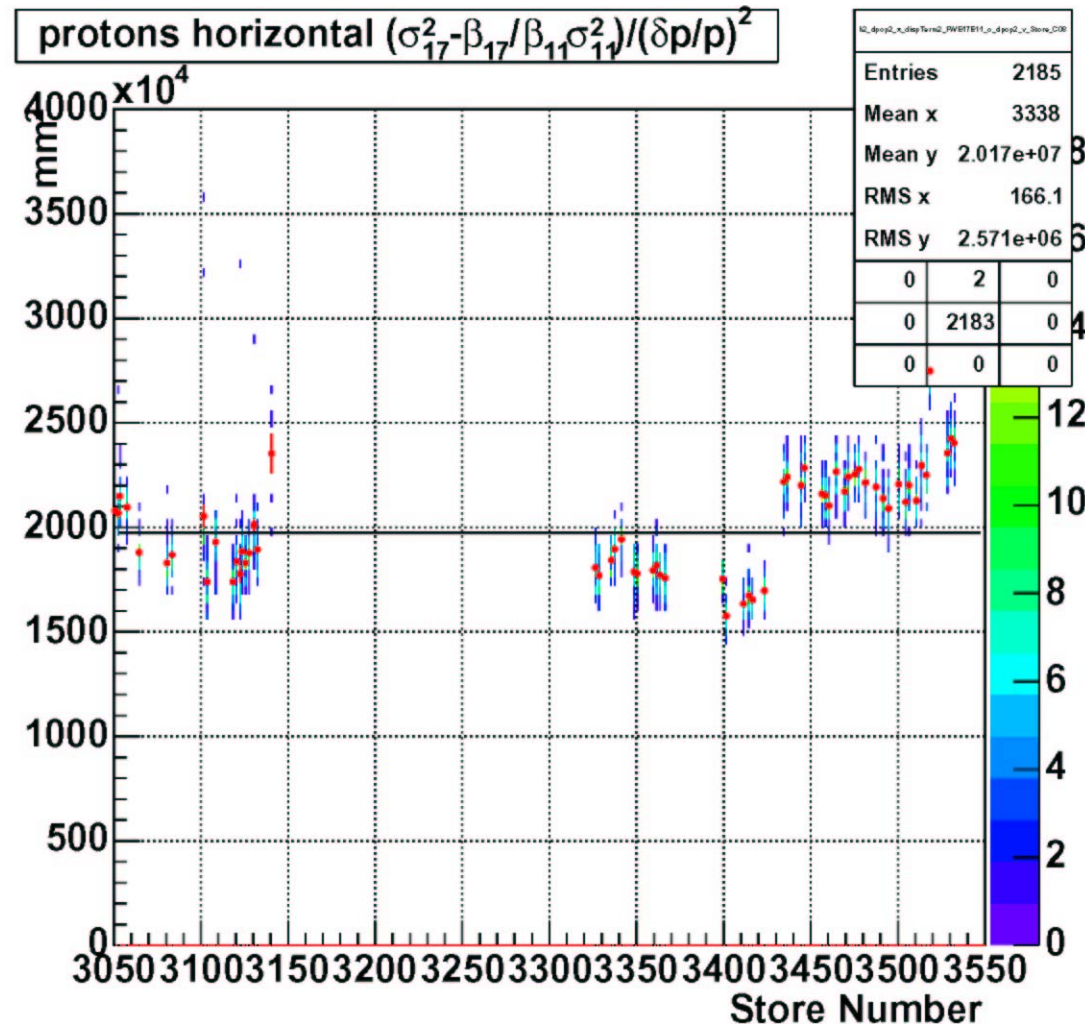# SDA : Tevatron Flying Wires and SyncLite

- Compare area of FW profile to FBI intensity
  - ➤ Very linear
  - ➤ Qualitative agreement given differences in gain and acceptance of the paddles
- Compare horizontal emittance as measured at E11 with E17 emittance, using SBD for dp/p
  - ➤ Anti-protons – ratio has slope of .97 and intercept of 1.25 – after fixing saturation
  - ➤ Protons – poor agreement, slope .41, intercept 14.5
- Compare area of SyncLite profile with FBI intensity
  - ➤ Better for anti-protons than for protons
- Compare flying wire emittances with SyncLite emittances
- Very sensitive to lattice parameters and dp/p
- Store to store variations
- ....

Compare FW Signal Intensity with FBI Intensity

FW E11 horizontal Signal Int.
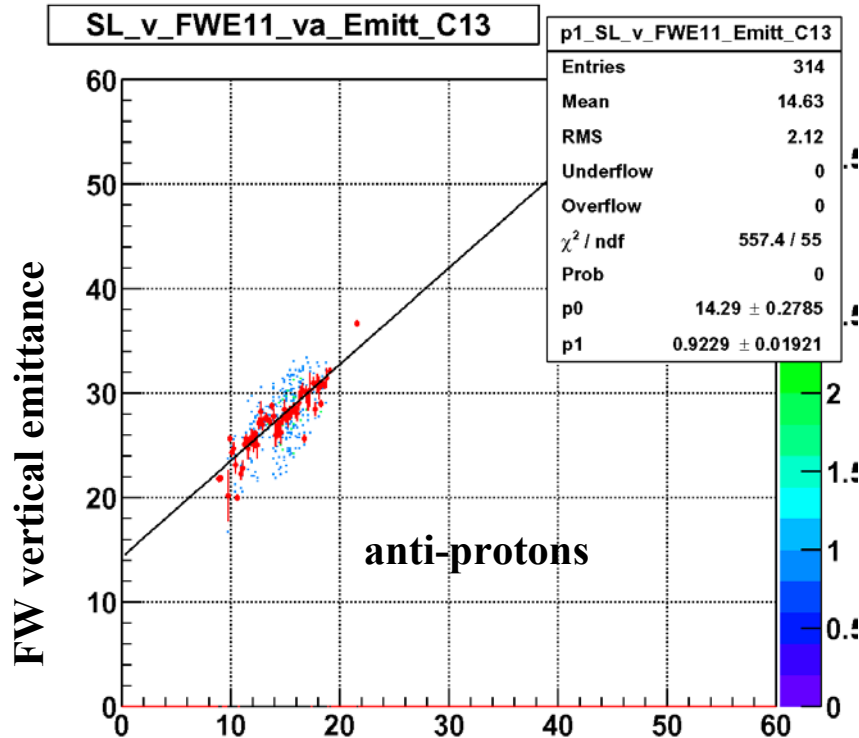
FW E17 Horizontal Signal Int.
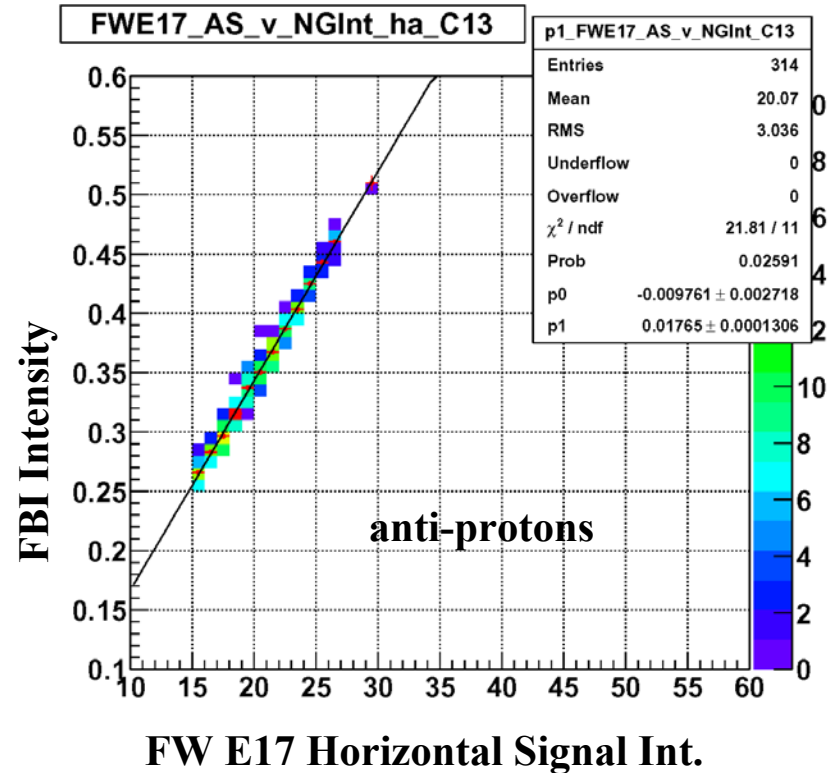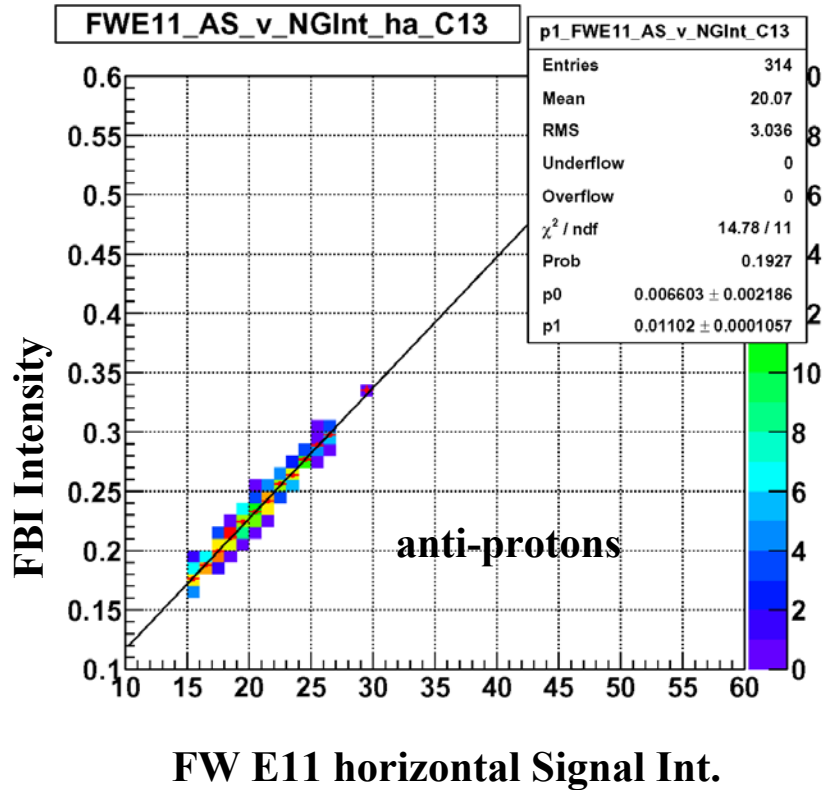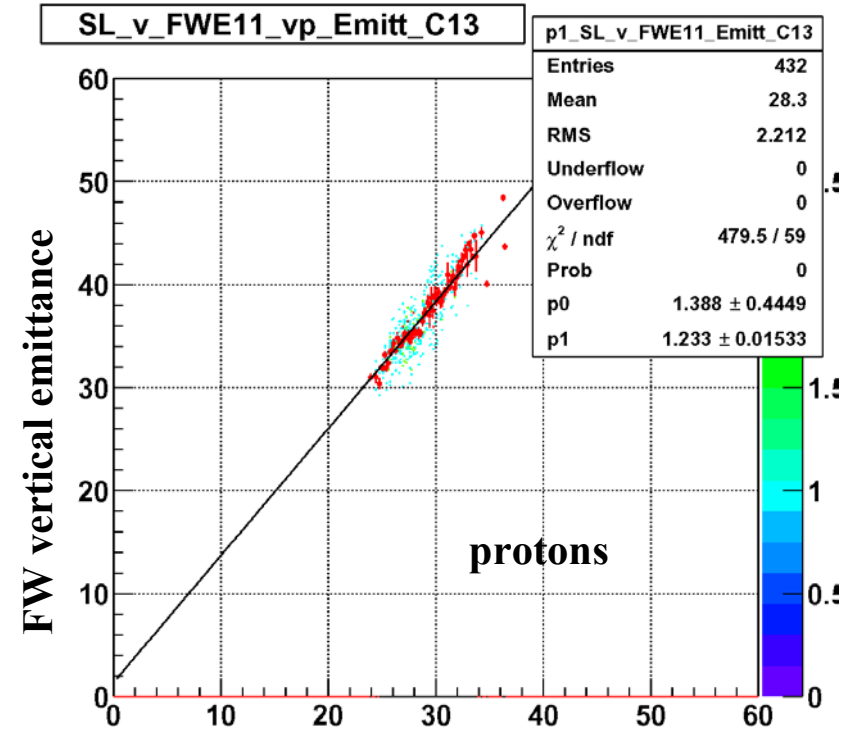
Compare E11 to E17 FW Horizontal Emittances

- This quantity is a fixed combination of the beta and dispersion function.

- Store 3424 lattice change is seen by horizontal Flying Wires;

- Proton detectors indicate another smaller change before store 3528 (due to RF change?) – we need to know the momentum spread to extract horizontal emittance

protons horizontal $(\sigma_{17}^2 - \beta_{17}/\beta_{11}\sigma_{11}^2)/(\delta p/p)^2$

Entries	2185
Mean x	3338
Mean y	2.017e+07
RMS x	166.1
RMS y	2.571e+06

0	2	0
0	2183	0
0	0	0

SDA : Compare SyncLite to FW – Vertical

anti-protons

SyncLite vertical Emittance

protons

SyncLite vertical Emittance

Outlook: The SDA meets new challenges.

Mixed Source Mode operation: The Main Injector takes antiproton from both the antiproton source and the Recycler. => SuperTable has recently been expanded. Further checks needed.

- Keep doing beam physics analysis. The machines have a life of their own!..
- Formalize standard Analysis, place them in ScrapBook…
- Better organization and maintenance of the software.
  - The osda/osdaphysics set of class grew without pre-conceived, "proper" OO design, originally. First phase of re-desing done, but could do better
  - Should be made easer to use..
  - Enhanced reliability of the D.A. and Analysis tools
- Integrated Calibration Databases (?)
- Data Schema Evolution for basic ACNET Variable (?)

Other Software projects...

- Magnet Database Project (D. Box, M. Fischler)
- Tevatron Instrumentation Projects (excluding BPM)
  - Real-time longitudinal emittance calculation for SBD (A. Para)
  - Tevatron Tune Fitter - 1.7 GHz, 21.4 MHz (P. Lebrun)
- Tevatron Orbit Cusp Finder and Beam Orbit Smoothing Tools
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"Magnet properties and alignment data are used for modeling and tuning Tevatron performance…..

For accelerator physicists who need to model and understand beam-magnet interactions, we propose to develop the Beams Lattice Alignment Survey Tracker for Modeling Accelerators Numerically (BLASTMAN) database. BLASTMAN will be a database of magnet locations, field strengths, calibrations and other magnet data that facilitate repeatable generation of lattices for modeling purposes…… "

Key Point: Critical Machine Data was kept by "experts"

And not easily shared..

➔ ***Create a proper database***

BLASTMAN: Status report from D. Box

- Equipment Inventory from M.E. /TeV (D. Augustine) into -> BLASTMAN.

- New Survey data from Alignment Management Group.

- Preliminary ER diagram for better integration of raw survey data

- N. Gelfand satisfied the BLASTMAN phase 1 is acceptable replacement for VAX MAGFIN db.. -> one old d.b. on the way to retirement..Need to finish maintenance tools.

Tevatron Instrumentation Support (I)

- **Sample Bunch Display (A. Para)**
  - ➤ Alvin Tollestrup came up with an algorithm to compute momentum spread and long. Emittance from pulse shape (time-wise) measurements, assuming constant phase space density along synchrotron motion.
  - ➤ and implemented it… in Mathematica..
  - ➤ Not suitable for Front-ends..
  - ➤ Rewritten in C and Lab-View, now integrated
 - ➤ We will need to re-commission this in the new SBD (better scope and front-end computer.)

Tevatron Instrumentation (II) : Tune Fitter

- Tune Fitters (P. Lebrun. ... *mostly.. Two years ago, ihad a bit of help from J Marraffino to get started with data conversion.*)

  - Motivation: Keep track of the betatron tunes while beams are circulating...

  - Front-end consist of VSA or digitizer cards + online computers running Fast Fourrier Transforms => freq spectra.

  - Must fit, "reliably" and often, such spectra, to extract "Tunes" and publish to ACNET.

  - Two of them, we have to type of Schottky devices (resonators) .. 21.4 MHz and 1.7 GZ => different tune fitters.

  - Details are http://www-ad.fnal.gov/tevtune/

Tevatron Tune Fitter : example of use

- Tuning at the beginning of the store.
- During stores.. When things go wrong..
- Studies..
  - Lattice studies ..
  - Beam-Beam studies….
- In use..

Store 3678: Flaky Sextupole Circuit….
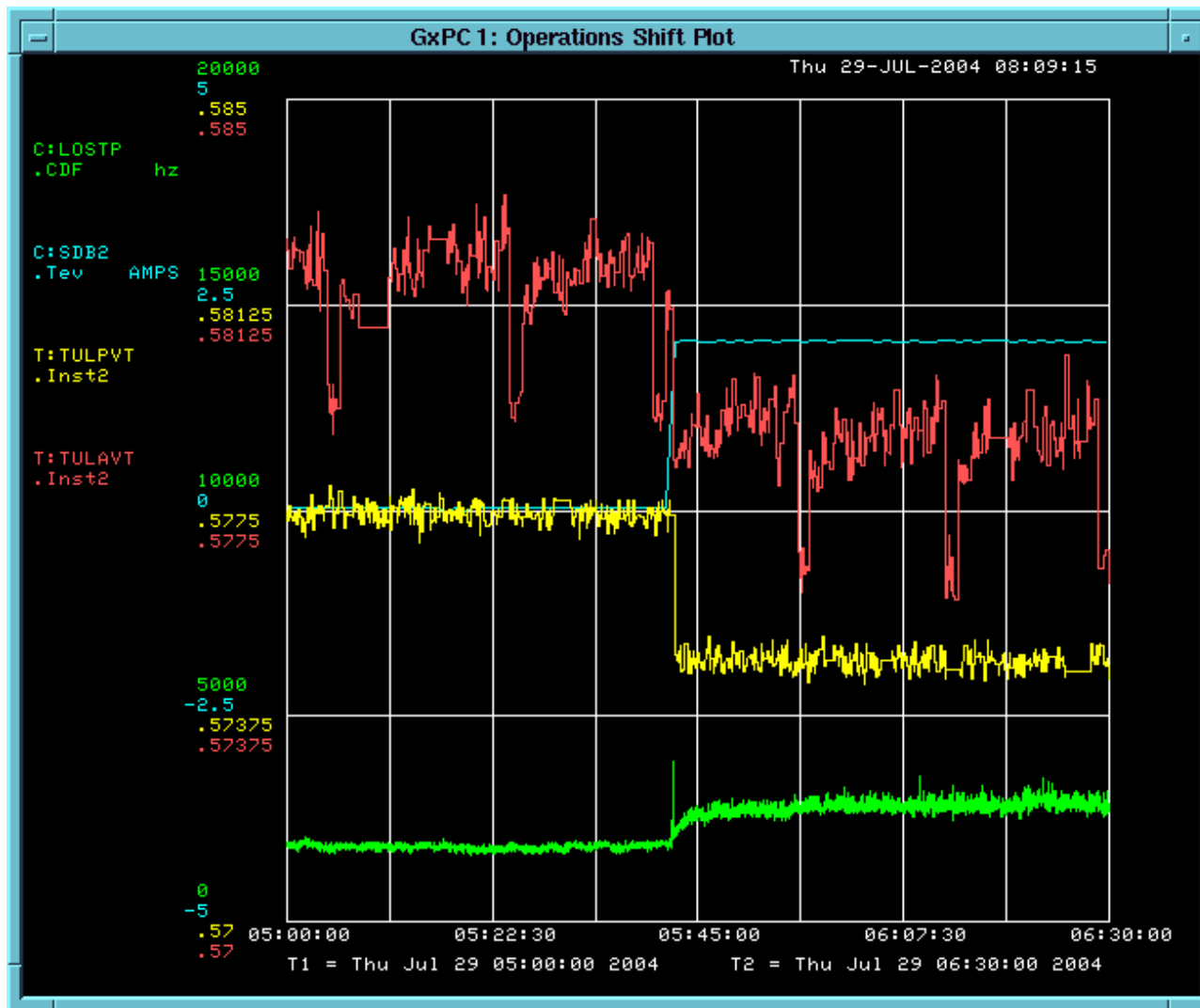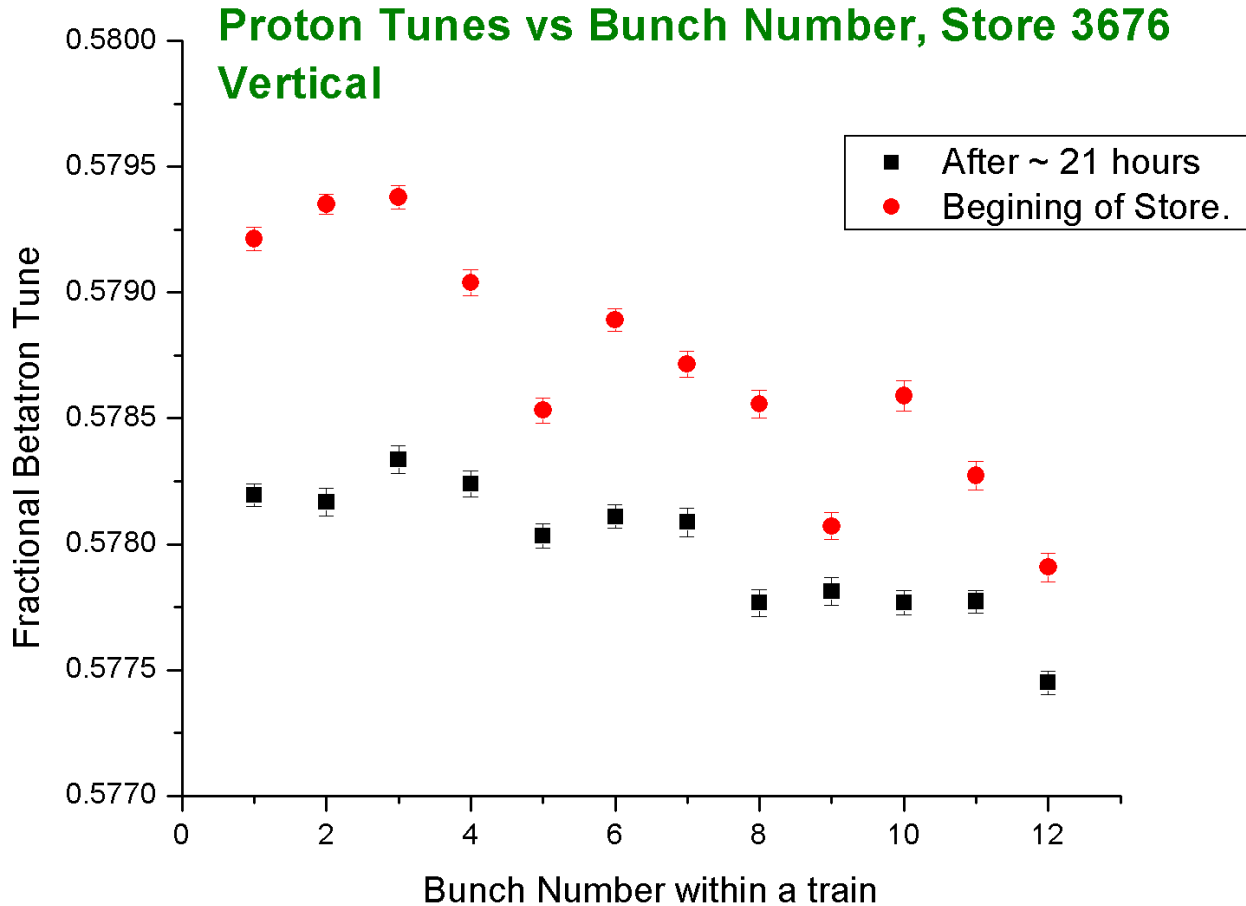

Proton tune very
   stable until.. ?

(Pbar tune changing
   because I kept
   changing the
   bunch gate every
   minute..)

Proton losses
   responded!

Tev expert looked at
   circuit.. SDB2
   turned on!

Vertical Proton Tune affected by Pbars:

Proton Tunes vs Bunch Number, Store 3676 Vertical

Legend:
- After ~ 21 hours
- Begining of Store.

X-axis: Bunch Number within a train
Y-axis: Fractional Betatron Tune

Software- Paul Lebrun – Accel. Activ. Coord. Meet

Tevatron Cusp Fitter:

- Team : Mark Fischler and John Marraffino
- Goal : Better (smoother) Tevatron beam orbit to maximize dynamic aperture.
- Input: BPM Readings, DFG settings, old orbit data
  - ➢ as a control system application
- Deduce the most likely combinations of magnetic field distortions (which cause "cusps" in the orbit) that would explain these readings.
- Useful in
  - ➢ Beam orbit smoothing
  - ➢ Understanding magnet changes

Tevatron Beam Orbit Smoother

- Goal : Same, additional utilities will be needed.
- Input: Existing orbit (BPM readings); target orbit
- Compute good DFG settings to smooth to the target orbit
- Enhancements over existing DFG applications:
  - ➢ Respecting the limitations on the DFG currects.
  - ➢ Avoiding two competing DFG's.
  - ➢ Minimizing current slew up the ramp in individual DFG's.

Controls & VAX VMS migration

- Three of us (Ron R., Suzanne P. and Paul L.) attend regularly the meeting of the task force on Controls & VAX VMS migration...

- Participate in the write-up on Java strategy. (Report will be out "soon")

- Wrote a nice tutorial for Java Application. (S. Panacek)
  - ➢ After consulting with AD/Controls
  - ➢ Presented to ~4 to 6 AD "students".
  - ➢ Has been used by a few newcomers..

Controls & VAX VMS migration

- Java is not the only answer... Current implementation has some deficiencies.

- Move (Vax-C -> ANSI C) of the core infrastructure to Linux has started, progressing well... The plans calls for starting to migrate end-users applications beginning FY05. Existing Java applications will be maintained and upgraded. New Applications? Well.. To be decided on a case by case basis.

- Need to integrate the C/(C++ ?) and the Java !!

A difficult project (we deal with a running machine!)
.... with real luminosity pay-off if successful !!!

Summary and Outlook

- Computing Division has delivered software to Accelerator Division. Quite a bit of it is in use.

- SDA is a working system, but it could be improved upon.

- We (AD + CD!) most definitely could do better in terms of D.A & Controls. Plenty of opportunities there. Integrated Luminosity = time * Luminosity. Better Control, less time wasted!