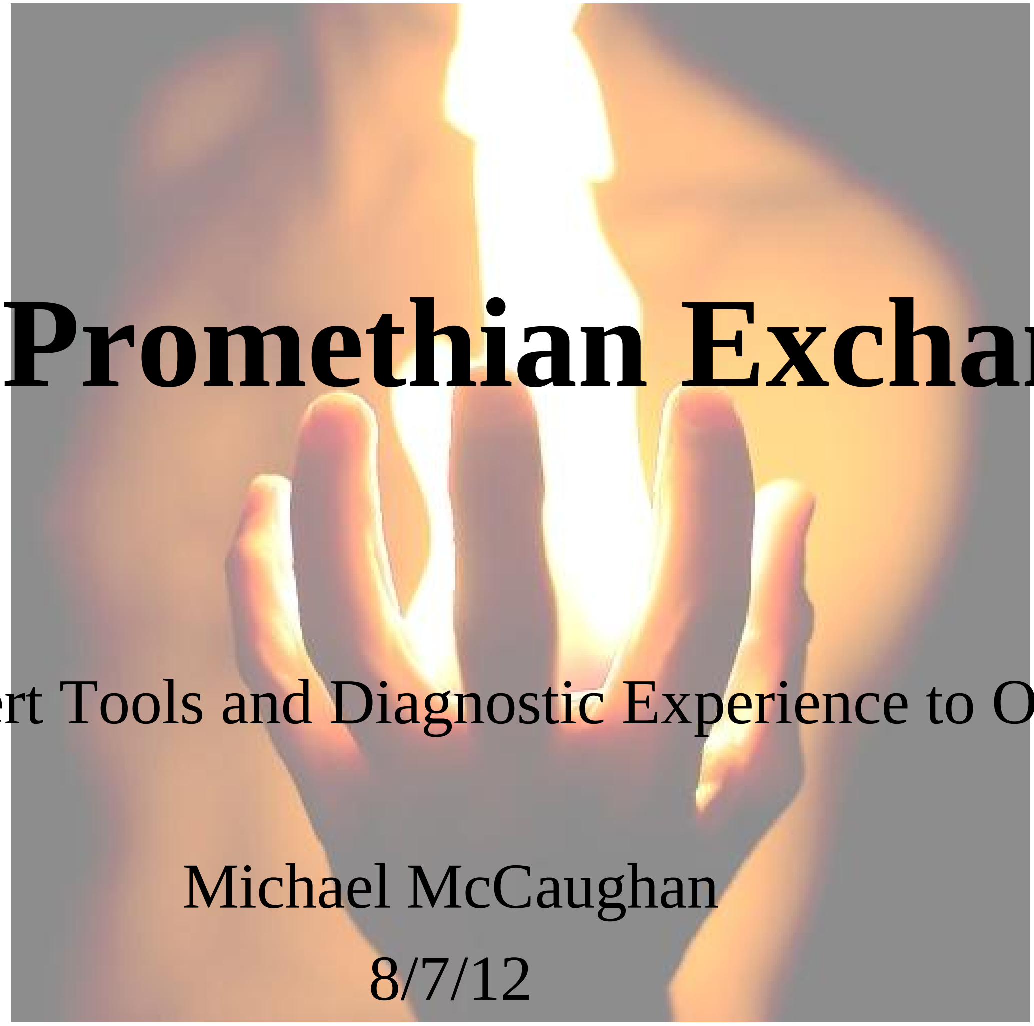


The Promethian Exchange:

Bringing Expert Tools and Diagnostic Experience to Operations

Michael McCaughan

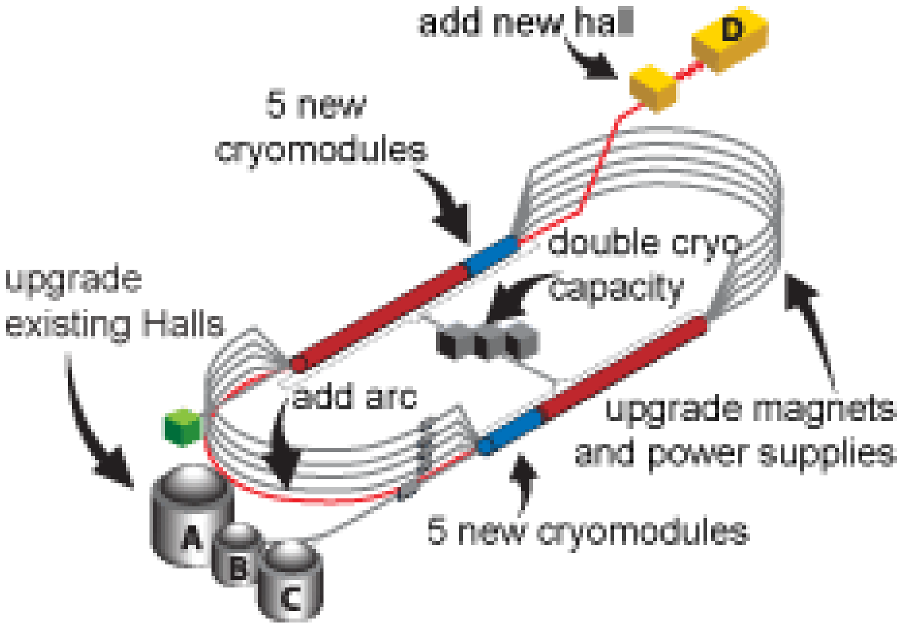
8/7/12

Forward

Operators need a variety of diagnostic tools in order to make their lives easier. Sometimes it becomes necessary to add, improve, or modify the suite of diagnostics in order to do new or different jobs, or to improve upon existing methods in one's accelerator.

This talk will attempt to outline various methods by which specific diagnostic improvements have been achieved in the CEBAF accelerator at Jefferson lab and abstract methods of process which can be applied to any lab/setting.

CEBAF



CEBAF

Cryomodule

CEBAF Example: Emittance Measurements

Existing method of measurement:

The wire scanner is used to scan beam profile one scan at a time while varying the strength of an upstream quadrupole over a known/deterministic range. This data is transmitted to an accelerator physicist who analyzes it to determine the Twiss parameters at this location. The accelerator model (in Optim/Elegant) is then used to determine what quad changes (if any) are required to constrain the Twiss parameters (or the beam envelope) at the desired location.

Emittance (Review)*

158 5 Particle Beams and Phase Space

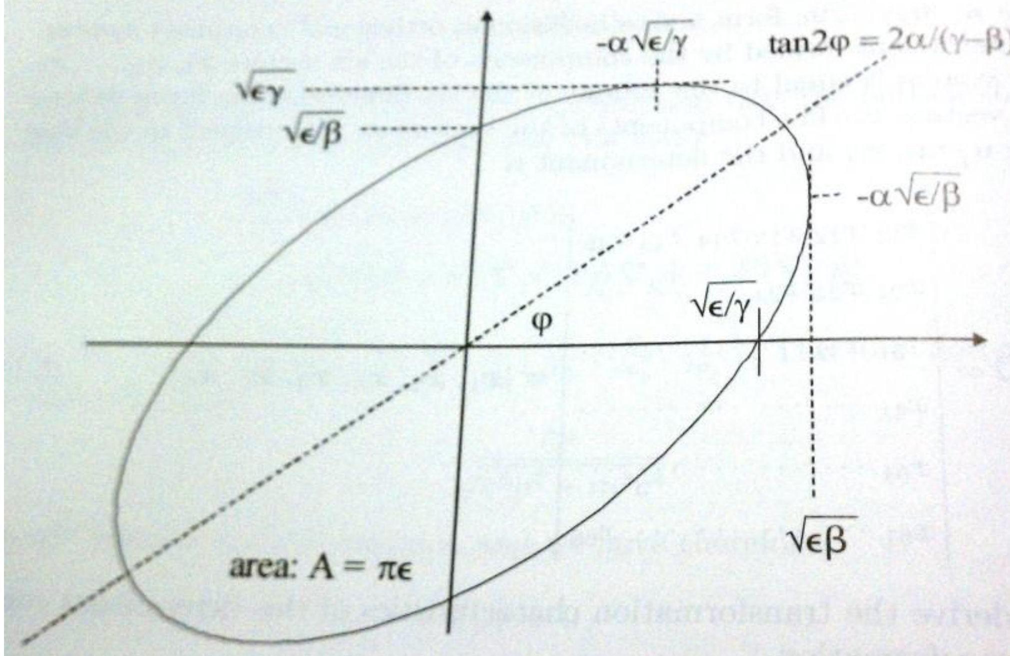


Fig. 5.2. Phase space ellipse

It has become customary to surround all particles of a beam in phase space by an ellipse called the phase ellipse (Fig. 5.2) described by

$$\gamma x^2 + 2\,\alpha\,x\,x' + \beta\,x'^2 = \epsilon, \tag{5.18}$$

where α, β, γ, and ϵ are ellipse parameters. The area enclosed by the ellipse is called the beam emittance[1] ϵ defined by

[1] The literature is not always uniform in the representation of numerical values for the beam emittance. Often the beam emittance is quoted in units of π–mm–mrad

*Particle Accelerator Physics, 3rd ed. Wiedemann

Twiss Parameters/Beam Envelope*

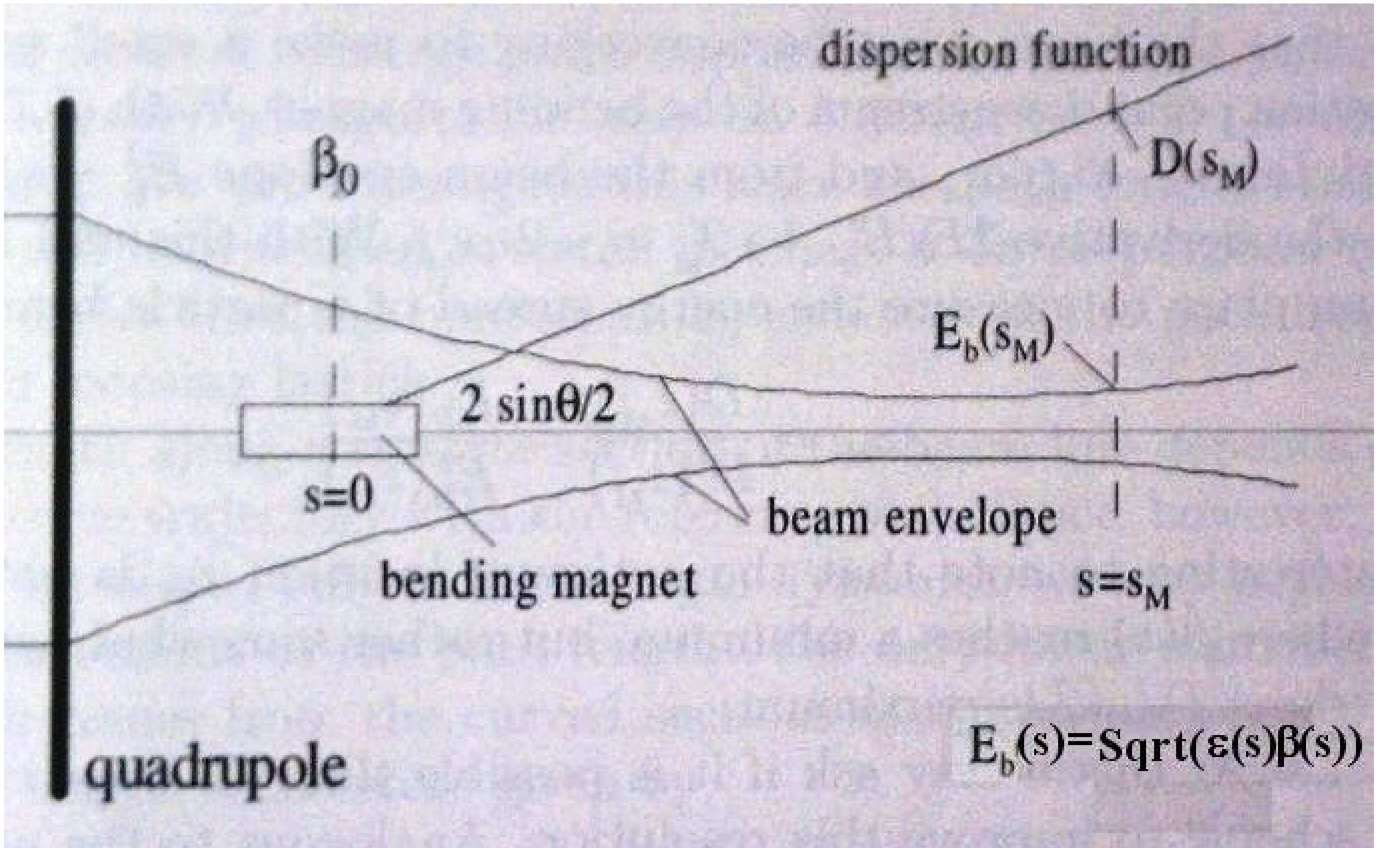


Fig. 5.15. Measurement of the energy spectrum

*Particle Accelerator Physics, 3rd ed. Wiedemann p. 185

Wire Scanner

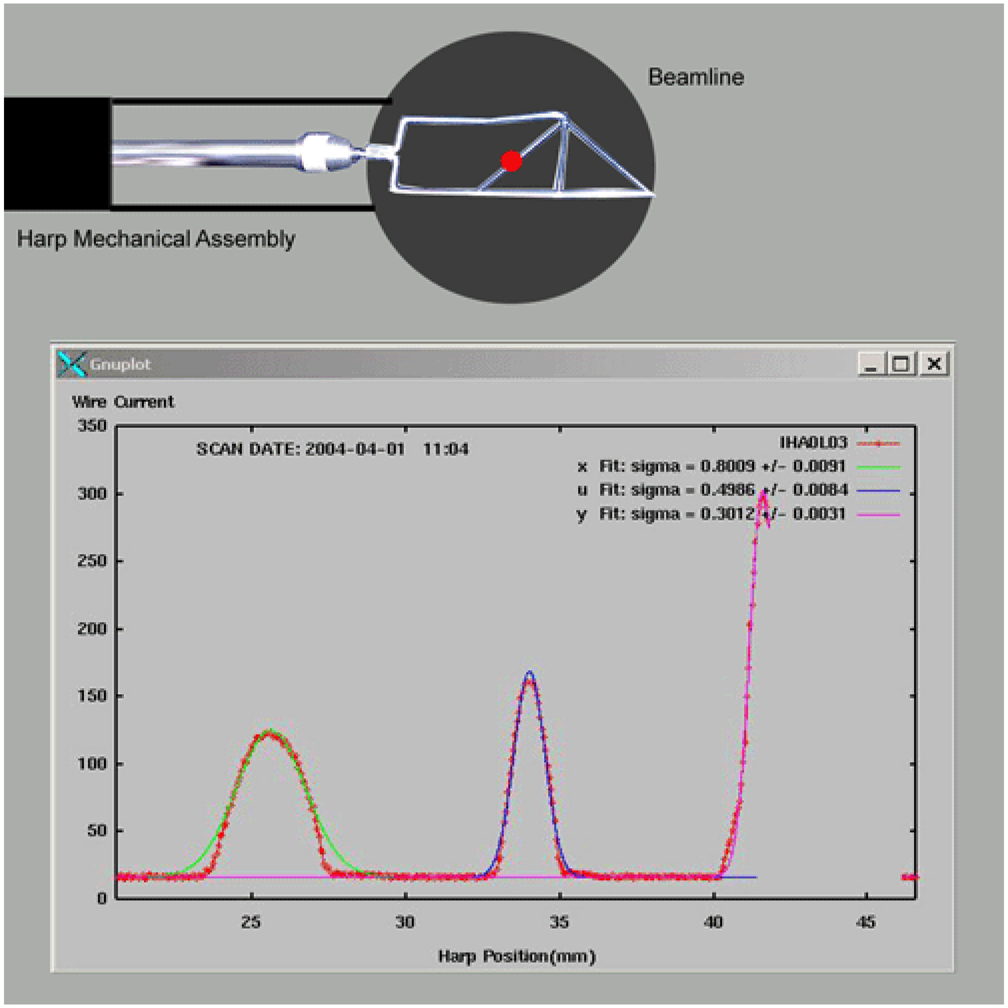
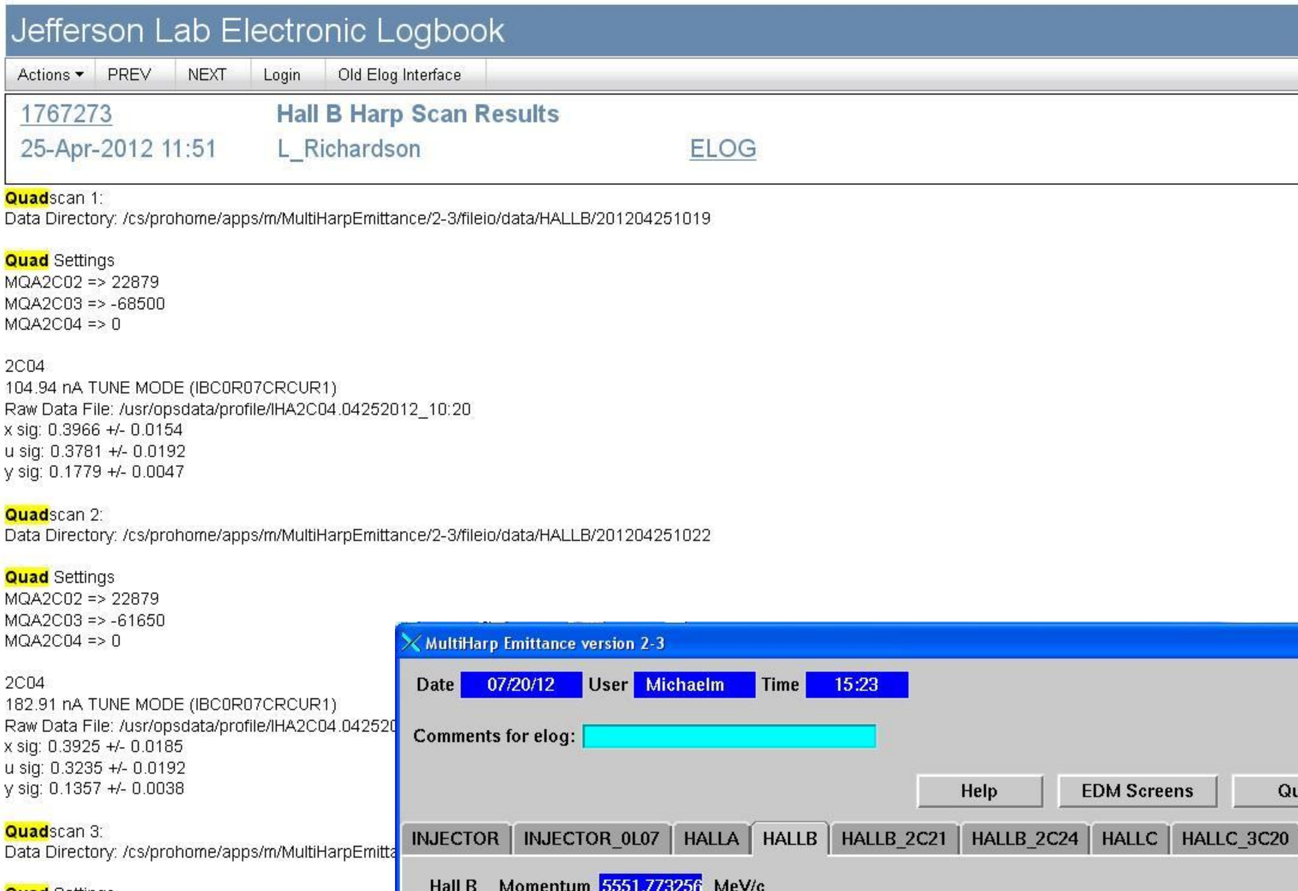


*Image by Tony Dela Cruz

Microsoft Office Excel

Data Collection Automated



Jefferson Lab Electronic Logbook

Actions ▾ | PREV | NEXT | Login | Old Elog Interface

1767273 Hall B Harp Scan Results
25-Apr-2012 11:51 L_Richardson ELOG

Quadscan 1:
Data Directory: /cs/prohome/apps/m/MultiHarpEmittance/2-3/fileio/data/HALLB/201204251019

Quad Settings
MQA2C02 => 22879
MQA2C03 => -68500
MQA2C04 => 0

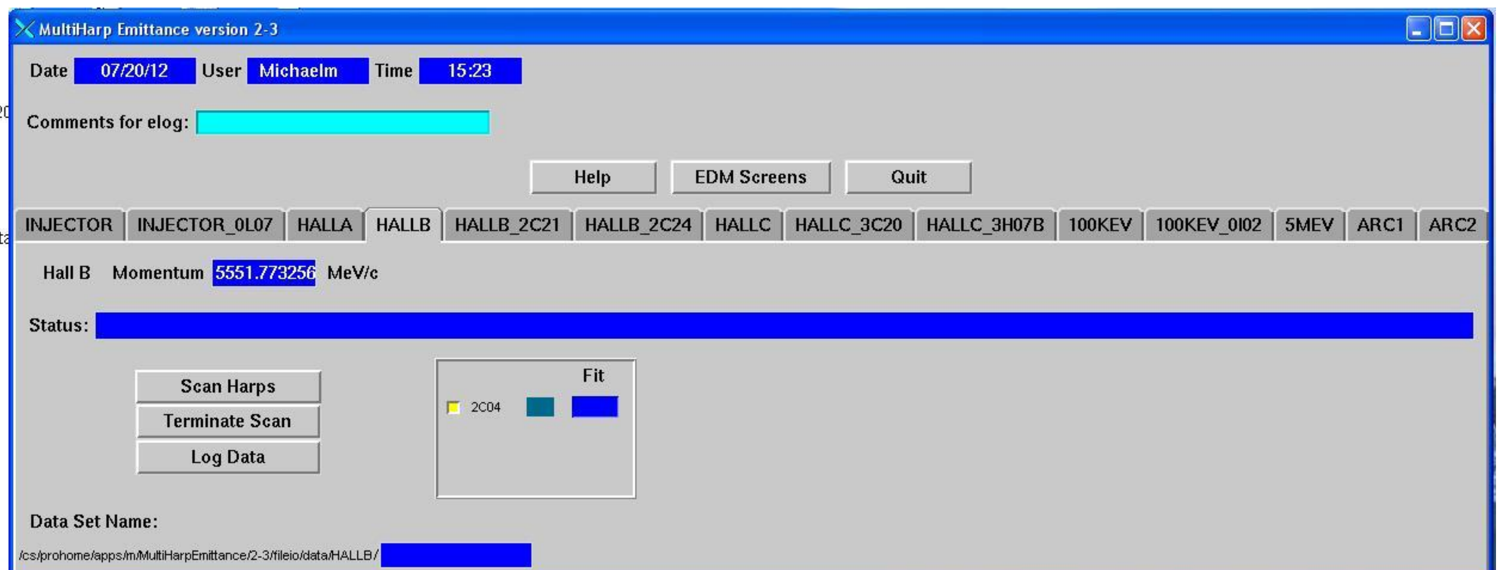
2C04
104.94 nA TUNE MODE (IBC0R07CRCUR1)
Raw Data File: /usr/opsdata/profile/IHA2C04.04252012_10:20
x sig: 0.3966 +/- 0.0154
u sig: 0.3781 +/- 0.0192
y sig: 0.1779 +/- 0.0047

Quadscan 2:
Data Directory: /cs/prohome/apps/m/MultiHarpEmittance/2-3/fileio/data/HALLB/201204251022

Quad Settings
MQA2C02 => 22879
MQA2C03 => -61650
MQA2C04 => 0

2C04
182.91 nA TUNE MODE (IBC0R07CRCUR1)
Raw Data File: /usr/opsdata/profile/IHA2C04.042520
x sig: 0.3925 +/- 0.0185
u sig: 0.3235 +/- 0.0192
y sig: 0.1357 +/- 0.0038

Quadscan 3:
Data Directory: /cs/prohome/apps/m/MultiHarpEmitta



Scripts written to extract Twiss parameters

```
File  Edit  View  Search  Terminal  Help
[4] michaelm@opsl07 > convertMultiHarp -area=INJECTOR -dataset=201111141931

Next Step: calcEmittance -sddsfile=/a/opsuser/michaelm/INJECTOR.XY.multiharp.sdds -location=IPM0L06

[5] michaelm@opsl07 > calcEmittance -sddsfile=/a/opsuser/michaelm/INJECTOR.XY.multiharp.sdds -location=IPM0L06
LATTICE: LATTICE=HASH(0xac78308)


GOOD FITS         EMITTANCE                          BETA                              ALPHA
 per 100             (m)                              (m)
=================================================================================================
X  100   3.851398e-09  +/- 9.054713e-12    4.798691e+01  +/- 1.699023e-01    -4.182476e+00 +/- 1.463783e-02
         5.704557e-09                      9.959065e+01                      -7.702563e+00

Y  100   4.525185e-09  +/- 8.709658e-12    1.234184e+01  +/- 2.960817e-02    1.219522e+00  +/- 2.950041e-03
         5.704557e-09                      1.059235e+01                      -2.064242e-01

DATE:        2011-11-14 19:31:00
LOCATION:          IPM0L06
MOMENTUM: 31.6800000000000033 MeV

ETAX: 0.00m ETAY: 0.00m  DPP: 0
SCANS USED:  19/19


NEXT STEP: matchElegant -segment=INJ -emitx=3.851398e-09 -betax=4.798691e+01 -alphax=-4.182476e+00 -emity=4.525185e-09 -betay=1.234184e+01 -alphay=1.219522e+00 -mar
ker=MKMATCHINJ -beamline=MATCHINJ -optimize

[6] michaelm@opsl07 > matchElegant -segment=INJ -emitx=3.851398e-09 -betax=4.798691e+01 -alphax=-4.182476e+00 -emity=4.525185e-09 -betay=1.234184e+01 -alphay=1.2195
22e+00 -marker=MKMATCHINJ -beamline=MATCHINJ -optimize


==============================
OPTIMIZING MKMATCHINJ

MKMATCHINJ OPTIMIZATION COMPLETE
   OPTIMIZATION FUNCTION: 0
   OPTIMIZATION VALUES and DIFFERENCES
   MQD0L06.K1:   1.480982596098669e+00    5.336198609866938e-02
   MQD0L07.K1:  -1.182039113280749e+00   -8.833276328074913e-02
   MQD0L08.K1:   2.020141313307178e+00    4.581573307178122e-03
   MQD0L09.K1:  -1.611988828166625e+00    4.183181833375293e-03
   MQD0L10.K1:   1.821117527450723e+00   -1.231815254927660e-02


"MKMATCHINJ"  beta x (m)  beta y (m)  alpha x   alpha y
==============================================================
   DESIGN      16.4770     7.5405     -4.0289    1.6501
  MEASURED     21.0072     6.0753     -5.1059    0.9626
  MATCHED      17.3720     8.0098     -3.9473    1.5716

QUAD VALUES:    NOW       DIFF    SUGGESTED    DESIGN
=======================================================
MQD0L06.BDL     237.67      8.88    246.55 (   234.05)
MQD0L07.BDL    -182.08    -14.71   -196.79 (  -222.69)
MQD0L08.BDL     335.55      0.76    336.31 (   394.12)
MQD0L09.BDL    -269.06      0.70   -268.36 (  -266.47)
MQD0L10.BDL     305.23     -2.05    303.18 (   322.06)
[7] michaelm@opsl07 >
```

Script written to analyze against CEBAF model (Elegant)

Data File
Data File

1767347	**HALLB MATCHING RESULTS at IPM2C05**
25-Apr-2012 12:56	J_Benesch

Elog Backlink: hall B matching choices

```
matchElegant  -segment=HALLB -emitx=3.721046e-10 -betax=5.283022e+01 -alphax=4.381245e+00 -emity=5.558937e-10 -betay=4.60
==============================
OPTIMIZING MKMATCHHALLB

MKMATCHHALLB OPTIMIZATION COMPLETE
   OPTIMIZATION FUNCTION: 7.1168309618923e-13
   OPTIMIZATION VALUES and DIFFERENCES
   MQA2C01.K1:  -1.663507851382638e-01    2.961513486173620e-02
   MQA2C02.K1:   5.110671432404837e-01    9.849231324048374e-02
   MQA2C03.K1:  -6.990038735364688e-01    3.067464635312378e-04
   MQA2C04.K1:   4.925631692454748e-01    6.060649245474836e-03


"MKMATCHHAL"  beta x (m)  beta y (m)  alpha x   alpha y
==============================================================
   DESIGN      18.0410    33.0809     3.2242   -5.7225
  MEASURED     80.8648    64.5977     7.8856   -8.9356
  MATCHED      18.0410    33.0809     3.2242   -5.7225

QUAD VALUES:    NOW        DIFF     SUGGESTED     DESIGN
=======================================================
MQA2C01.BDL  -10867.13   1642.28  -9224.85 (-10867.13)
MQA2C02.BDL   22879.00   5461.81  28340.81 ( 22874.74)
MQA2C03.BDL  -38779.70     17.01 -38762.69 (-38779.17)
MQA2C04.BDL   26978.60    336.09  27314.69 ( 26978.24)
```

Command line interface functional, but obtuse to some…

Procedure created to detail script/tool usage for non-experts

Jefferson Lab **DRAFT**

Multi-Harp Emittance Matching Procedure

Document Number: Document Number—TBD

Revision Number: Rev. 1b2; **DRAFT**

Technical Custodian: Mike McCaughan

Estimated Time to Perform: ?????

Procedure Overview

This procedure describes how to, first, use the Multi-Harp Emittance Tool to gather harp data in a specific region, and then, invoke the **convertMultiHarp** script to analyze the data and provide a new matching solution. As it scans the harps in the region, the Multi-Harp Emittance Tool varies upstream quadrupole strengths, creating a data set for analysis. The **convertMultiHarp** script analyzes that data and provides a set of recommended quadrupole settings to improve the match at the end of the region. Optics checks in the downstream region confirm whether or not the new matching solution was successful.

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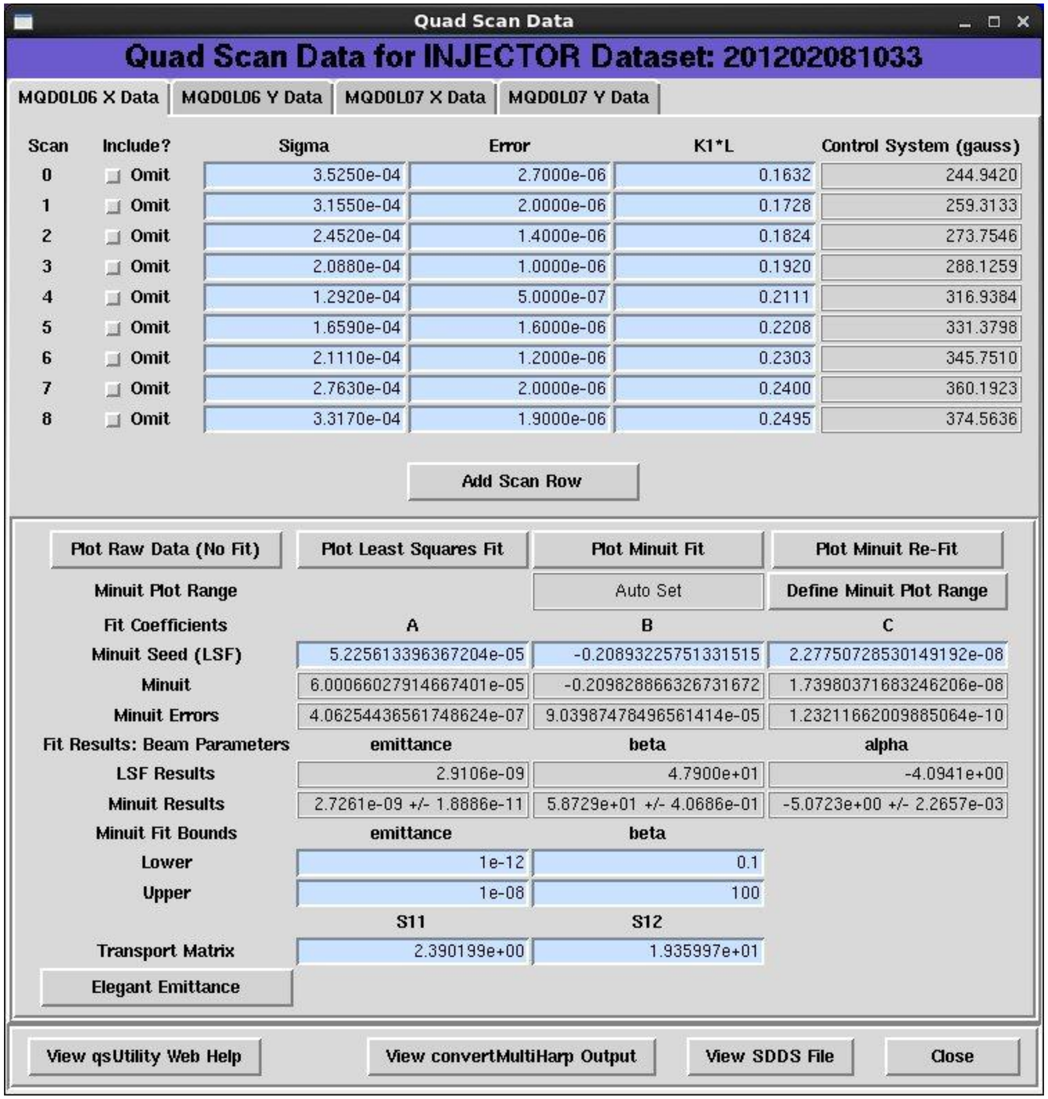
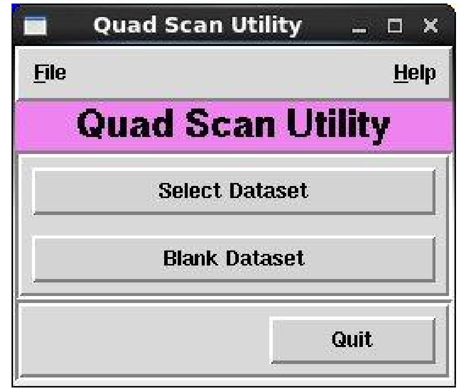
Prerequisites

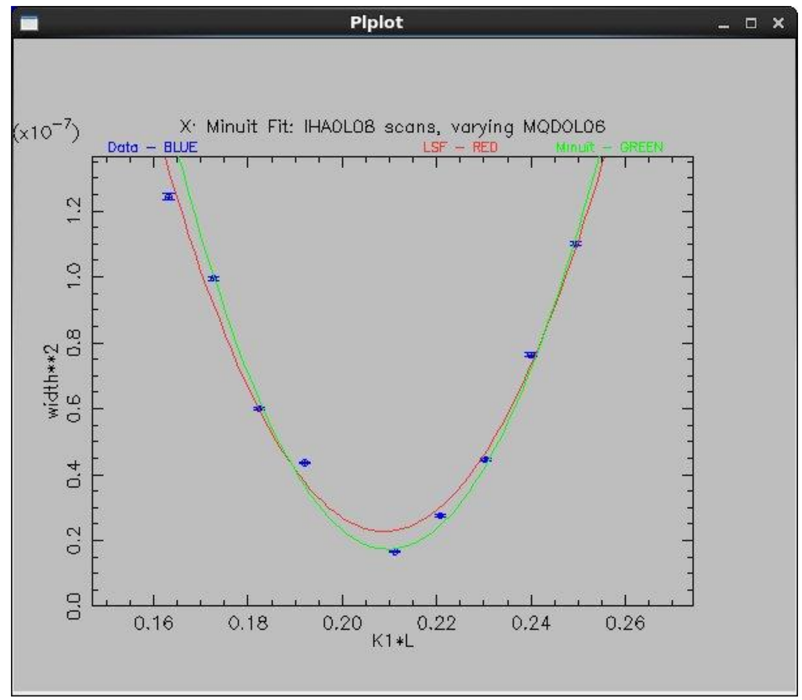
1. The Optics Restoration and Finalization Procedure (ORFP) should be complete for all beamline upstream from where the harp scans will be made (i.e., if matching to Hall A, ORFP should be complete through the accelerator and the transport line to the hall).
2. The accelerator setup must be in line with the accelerator model. This is typically the case, but Optics On-call will be able to tell you if it is not.
3. Crew Chief permission is required before beginning this procedure.
4. Optics On-call must give permission before any new matching solution is actually

Operations working in concert with software group / accelerator physicists

More Intuitive Software (qsUtility)
(Allows for better analysis/error correction)

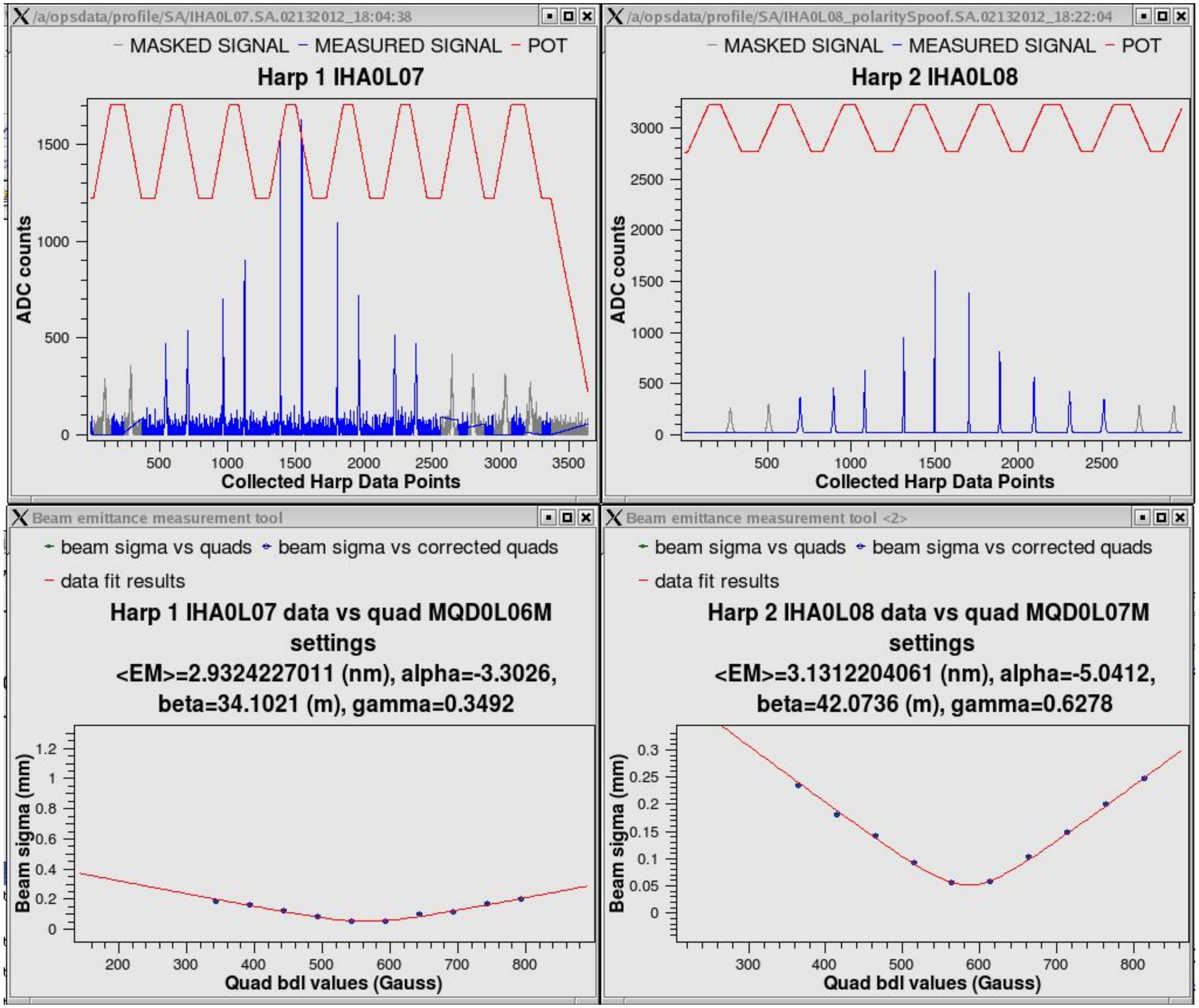






Development by High Level Apps group with Ops feedback

Change in Data Collection Method (Zig-Zag)
(Faster Data Collection)



Development by Crew Chief working with HLA under guidance of an Accelerator physicist

Related: Analysis of downtime (4/29/11)

The Director of Operations met with an Accelerator Physicist, the Operability coordinator, and his deputy to discuss a summary of two years worth of unscheduled tuning time.

Out of 273 hours over two years of unscheduled tune time, 91% of the lost time was divdided into 11 different categories. The list below summarizes this:

- **Hall B Beam size: 83**
- Dispersion/optics drift, cycle the world events: 53
- Hall A&C Backgrounds, including Compton: 47
- Extraction BLM trips/setup: 23
- Injector transmission: 15
- Hall A&C beam size: 12
- Path length maintenance: 6
- ILM0R04 trips (does not include Jan 2011 event): 4
- Shunt troubles / Lambertson stripes: 3
- Ion chamber trips: 2
- Other: 25

Total: 273 hours

(83/273 = ~30%)

Results of Analysis

Considerations: Hall B beam size & breathing ***83 hours (FY 09/10)***

Faster matching data acquisition vs. multiharp would make it easier for Ops to insist on actual matching vs. using SmartKnobs or other quads empirically.

Faster acquisition/matching programs in works. Additionally, moved 2C23 CW/Yag:Ce viewer to 2C24 girder (requiring modification of the stand and vacuum cross) after ensuring the change will survive through both the energy upgrade and the upcoming experiment (HD-Ice) at the direction of the APEL (Accelerator Physics Experimental Liaison). Allows for faster empirical match at desired location as viewer easier to tune against then wire scanner (You can watch your change immediately instead of waiting for wire scan.)

60 Hz current variation can be due to injector laser phase or scraping. The latter is generally at extraction. Reduction in injector 60 Hz would help.

Training on Injector setup and Separation. Sleuthing for noise sources with spectrum analyzer/o'scopes. Careful setup by Injector group and investigation by source group…

Beam orbit in accelerator drifts when hall B is the high pass hall.

More sensitive orbit locks envisioned for lower current beam following energy upgrade

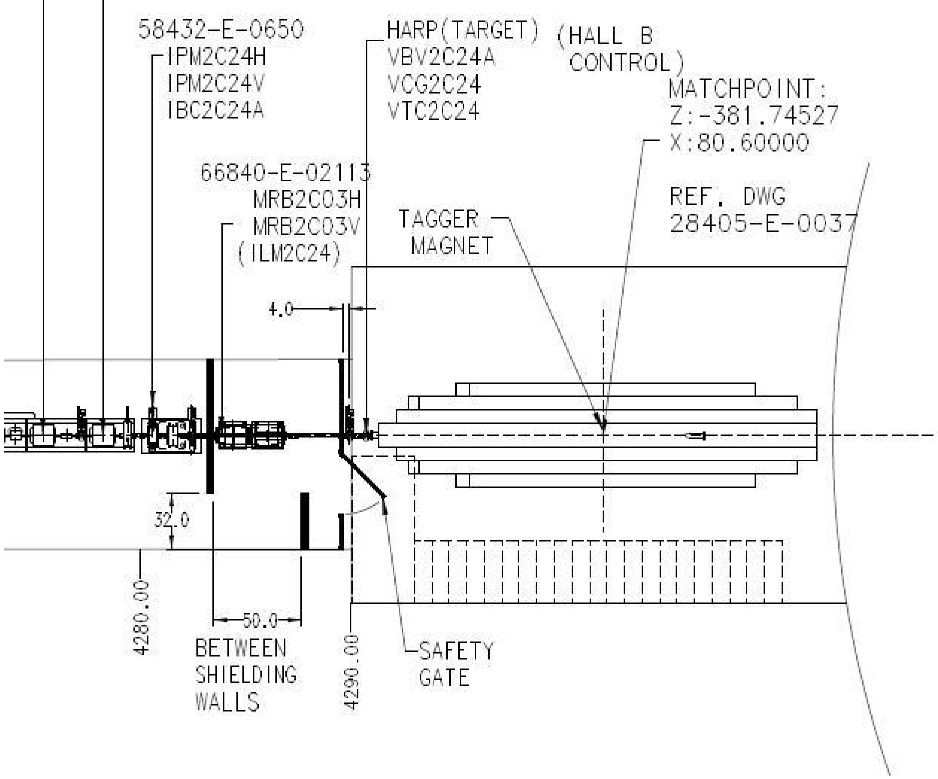
Beam shoulders are generally sourced in injector and shouldn't simply be hidden "within" the central distribution via hall B quad changes.

Experimental Hall doesn't care to first order… not showing up profoundly in data.

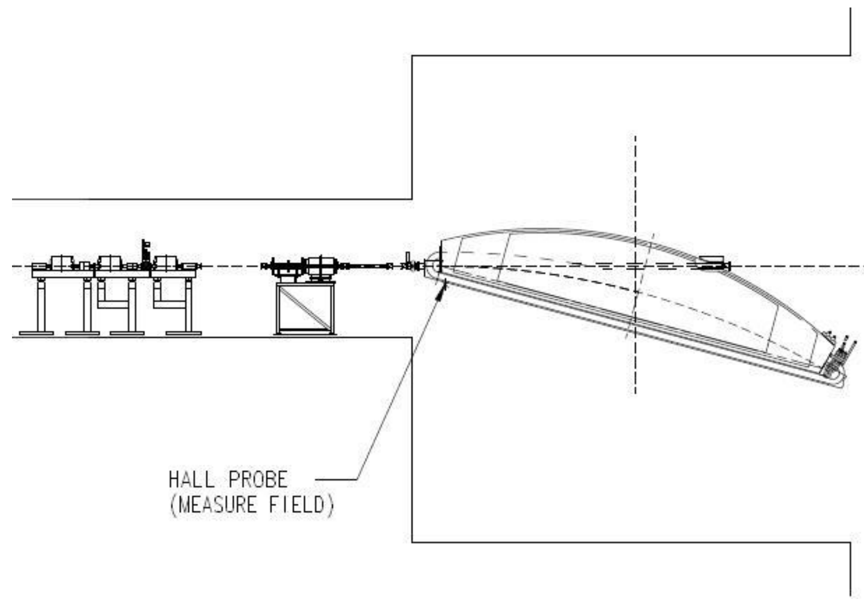
Change of Viewer position

ZONE	REV	DES
	-1	INITIAL LAYOUT
	-2	SEE ELEMENT CONTROL REVISION -5 FOR REV
	-3	MOA2C22 CHANGED TO CHANGED TO MOY2C23, TO MOK2C24
	-4	ADDED AREA DESIGNAT REMOVED NOTE 7. ADD NOMENCLATURE TABLE.

Match point differed from Diagnostic location



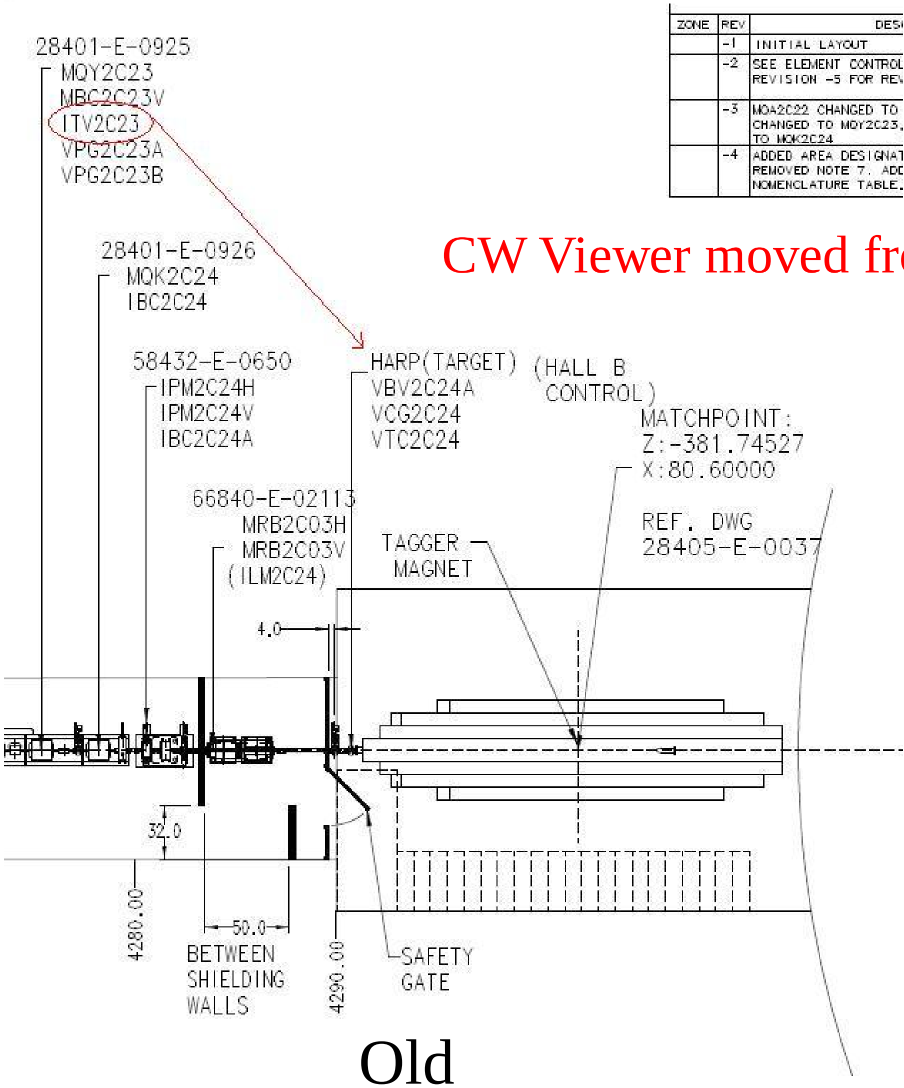
From Above



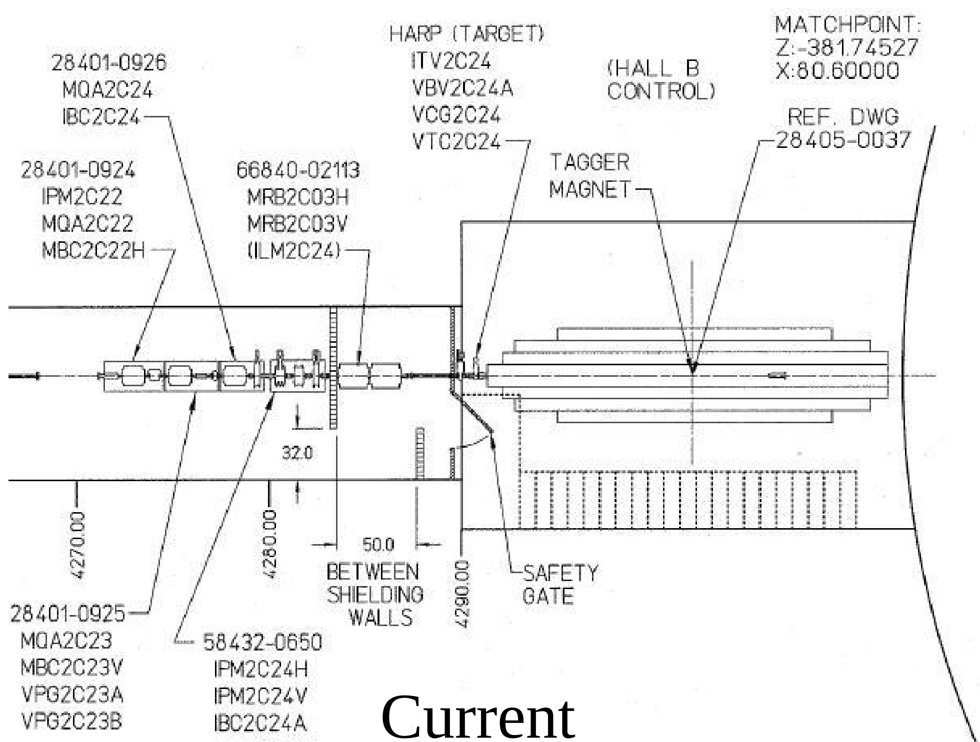
Side View

Movement existing diagnostic hardware (Breaking Vacuum)

CW Viewer moved from ~7m out to a few cm from wire scanner



Old



Current

Speed of empirical beam tuning greatly increased

MATCHPOINT:
Y:103.34326m

Incremental Improvements

Incremental improvements:

Initial improvement:

- Automating data collection
- Creation of Linux shell scripts (Former accelerator operator aggravated with doing data analysis by hand wrote shell scripts to do it for her)
- Automation of data processing
- Create procedures to make usage of software more transparent

Secondary improvements/refinements:

- qsUtility (GUI uses shell script algorithms but allows for error reduction through de-selection of points in the data set) (In-progress)
- Change in wire scanner operation- Straight insert/extract to Zig-zag protocol while varying quad strength; this allows for faster data taking. (5 minutes instead of 20-30 minutes) (In-progress)
- Revise procedures as necessary.
- Better/different hardware where it has the most impact

Abstraction

Identifying your problems/short falls

How?

- Operational experience (That's you guys)
- Analysis of archived signals/data
- Analysis of unplanned accelerator down times and what is causing/contributing to them and looking for patterns.
- The #*(@ thing is broken…
- Diagnostics, Engineering, and Software group ideas/modification/new hardware/software
- Can we do things in a better way than we currently are? (The optimization problem…)
- Conduct Experimentation/Proof of concept
- Physics Division input (Are we trying to meet a goal or design specification for a new experiment?)
- Management and other input

Planning and Assessing Resources

- Identify the players it affects (directly or indirectly): Operations, Diagnostics, Software, Opticians/Physicists, etc.
- Will you solution cause more or less down time to your experimenters than the problem? (Is there a significant benefit for this exchange?)
- Determine the constraints of your system:
  - Are you able throw money at it once and make it go away for good? (Usually the answer here is no, as there is little to no money save for labor OR the problem is more complicated)
  - Can one affect a hardware solution or a software solution (or both… what's cheapest/most effective)
- Resource assessment: people, equipment, hardware/software, special pots of money (Accelerator Improvement Projects (AIP) $ from the DOE); things don't have to be done all at once…
- Engaging your resources… people work better when they are self motivated

Formulating Solutions

- Do cost-benefit analysis… show the downtime the problem is generating is costing the Lab more than trying to effect a solution. This can translate into $ for a solution.
- Identify Problems/Shortfalls and define the scope of work. Hold to this because scope creep can kill projects by making them miss deadlines and run over budget.
- Can we do it a better way? (The optimization problem)
- Incremental Improvements are good; don't be afraid of them. Much easier to make a number of small gradual changes rather then large substantial changes. (Less people will make waves for you)
- Assign a project manager and form a committee of those interested to work on problem… sometimes this is 3 people, sometimes it's 30…

Practical Questions

- How does operations get involved early enough to get diagnostics which they want and which are useful/usable?

  Let Operators work with other groups (either in rotation or in accordance with their wishes) during shutdowns and assign specific liaison to important groups/experiments. Allow them to continue with this work if desired when not on shifts.

- How to interface with appropriate parties to develop useful diagnostics?

  Talk to them… most of getting what you need is building a rapport with the group you need it from. Try and understand where they are coming from, what their system is / how it works, and what compromise you can come to which will help you both to affect solutions in the future. Engineers/Programmers are not magic robots you hit in the head when you want something… don't treat them like they are…

Practical Questions (continued)

- What do you do when you have the right diagnostics in the wrong location and vice-versa?

  Create process to motivate diagnostic improvements / modifications (analyzing down time, suggest solutions, offer cost-benefit analysis…)

- What should you do when the tool is too complicated and/or obtuse for operations to use? / What do you do when the tool/diagnostic you get is klugey/does not work right?

  Either someone must learn to live with it and then write procedures/train the rest of the group

  OR

  Talk with tools creator and work with them to see what you can do to make it more user friendly. Easy cosmetic changes for them may help you dramatically… like putting all the buttons in the order you must hit them for your procedure.

  OR

  Accept some tools are broken and at an opportune time (ie. A shutdown) may need to be rewritten. Work with tool maker to form requirement document for the next version/upgrade of the tool. Eventually most tools must be rewritten due to software/OS upgrades, changes in libraries or programming languages, etc. Have your changes made during one of these already cumbersome rewrite periods when large bodies of code already must be changed.

Thanks!

- Dept. of Operations: Arne Freyberger
  - Ops: Noel Okay, Terry Carlino, & Dennis Turner
  - Operability: Steve Suhring, Randy Michaud, & Tom Oren
- Accelerator Physicists:
  - Jay Benesh, Mike Tiefenback, & Mike Spata
- Software / High level apps groups:
  - Marie Keesee & Michele Joyce
- Engineering: Ron Lauze
  - EES-IC: Keith Cole, Tony Dela Cruz, & Brad Cumbia
- Mechanical Engineering: Rick Wolfley
- Injector Group: Yan Wang
- Source Group: Riad Suleman

Questions / Thoughts?