Post Mortem during Beam Operation

P. Duval*), M. Lomperski*), K. H. Mess

*) DESY

~~Post Mortem during Beam Operation~~

Oxymoron:

The machine is not dead during operation with beam!

Maybe:

The use of the "Post Mortem System" as an Event Driven Transient Recorder

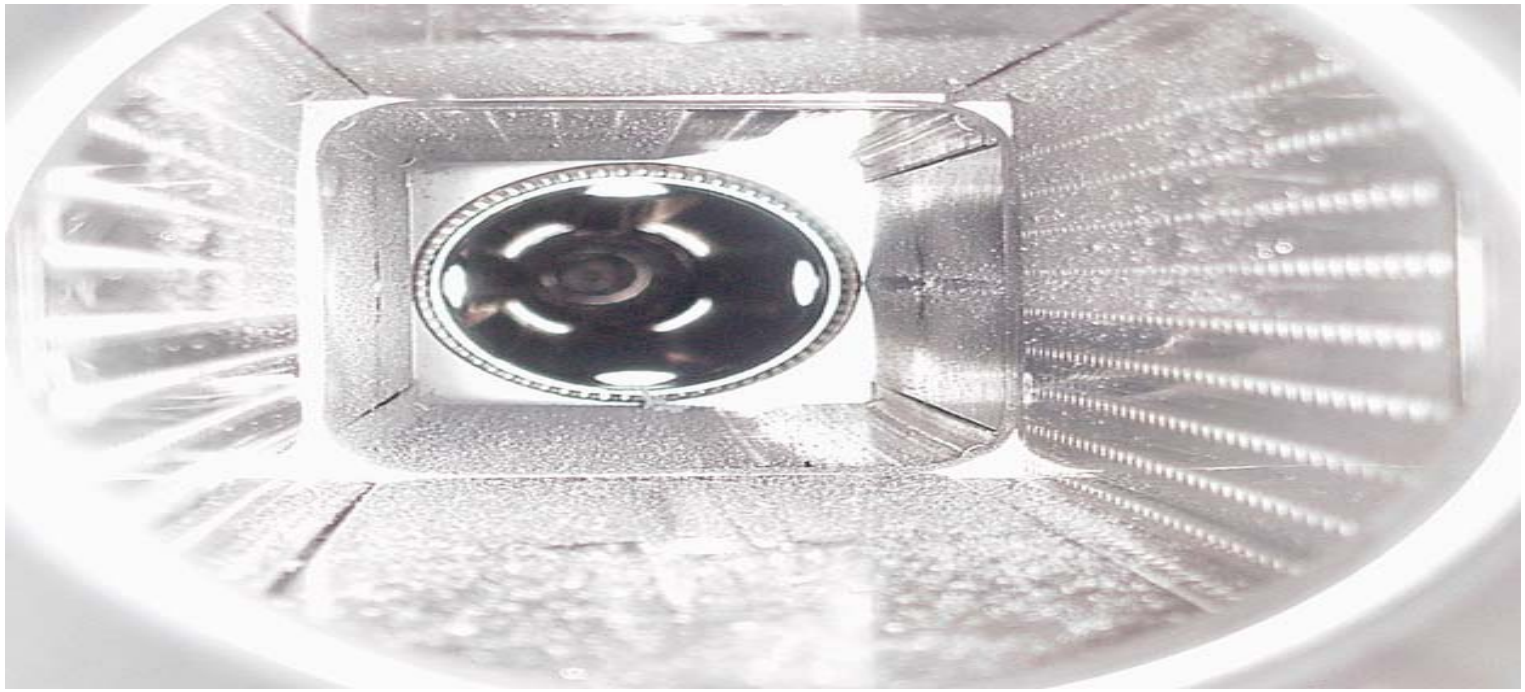
"Post Mortem"

- The first time I heard this expression was during the preparation of the HERA Proposal *)
- At that time (~24 years ago), memory chips were expensive, hence only very relevant systems were considered.
- As time passed and chips got cheaper, the "post mortem" at HERA developed to a "General Transient Recording System"
- Quoting M. Lomperski**):
- It is absolutely UNTHINKABLE that HERA would NOT have such a system - and not just as a "Software" system but that the hardware is able to deliver the goods (one of the biggest "holes" in the HERA concept is that the hardware for the electrons does NOT have the fast time scale data storage/retrieval as the protons do... And there are a few holes in the proton-hardware, too...).

*) DESY HERA 81/10, pg 220

**) priv. Communication

Insufficient “Post Mortem” of a Collimator



Jaws made of Tungsten-Alloy (DENSIMET)

- Channels gouged out of face of jaws (few mm wide and few mm deep)
- Channels start about 2 cm into jaw
- “Crumbs” (droplets?) stuck on all faces

“Explosive” events ? How did it happen?

Event Driven Transient Recorder

- Of course, an ideal, never failing, perfectly known machine can be operated without such a system.
- In reality we will need:
  - To iron out basic faults in the hardware
  - To identify and cure basic faults in the conception
  - To improve the knowledge of the machine
  - To improve operation efficiency
    - This implies to find the culprit in case of malfunctioning
    - Everybody is invited to prove his/her innocence by recording all relevant data
    - Event triggers (hardware and software or manual) have been defined (and armed).
    - Event triggers can also be "start of ramp", "squeeze", "quench", "beam loss above…", "RF voltage below.." etc, etc

Requirements (hardware)

- Time: As fast as practical; ms for "Quench", faster for "Beam Loss", Bunch spacing for BPM, RF… but synchronized
- Time span: sliding window of some 100 turns (BPM) up to seconds after a quench (to detect secondary quenches, or to measure the temperature and pressure)
- Signal types:
  - Analog values to a useful but affordable precision
  - Digital values (status bits), including "Alarms"

It is in the interest of everybody to provide as good and as telling data about his system as he/she can think of.

Consider "Alarms" and "Data Logging" as integral part of the system!

➔ Repetitive pattern:

- Often many analog sensors will have virtually identical signals and only a few show a different behavior. To sort that out, we need fast "pattern recognition" *).
- Digital status words at the time of the Event Trigger should all but one or a few show the "Valid" pattern. The software must in case of an event trigger automatically compare all bit pattern with a sat of template, valid for the type of operation before the event.
- Not normal conditions must be flagged
  - Not only in an event logger (alarm screen)
  - Also and in particular in a tree fashion, where a whole branch (system) becomes red. Clicking on it one can drill deeper and deeper, until all details are visible. (Preferentially in a pictorial way)

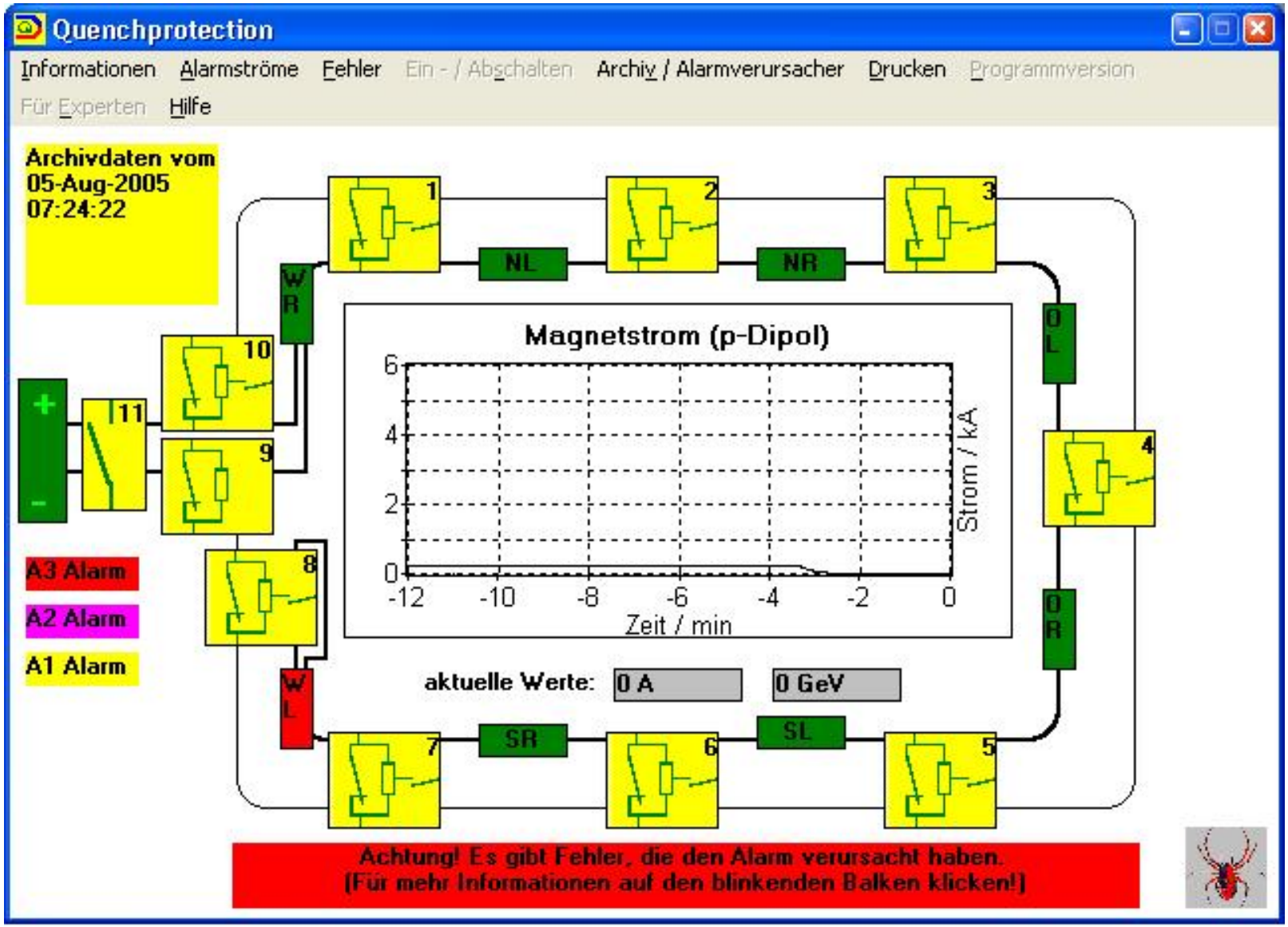
*) see F. Rodriguez Mateos, this review

Pitfalls

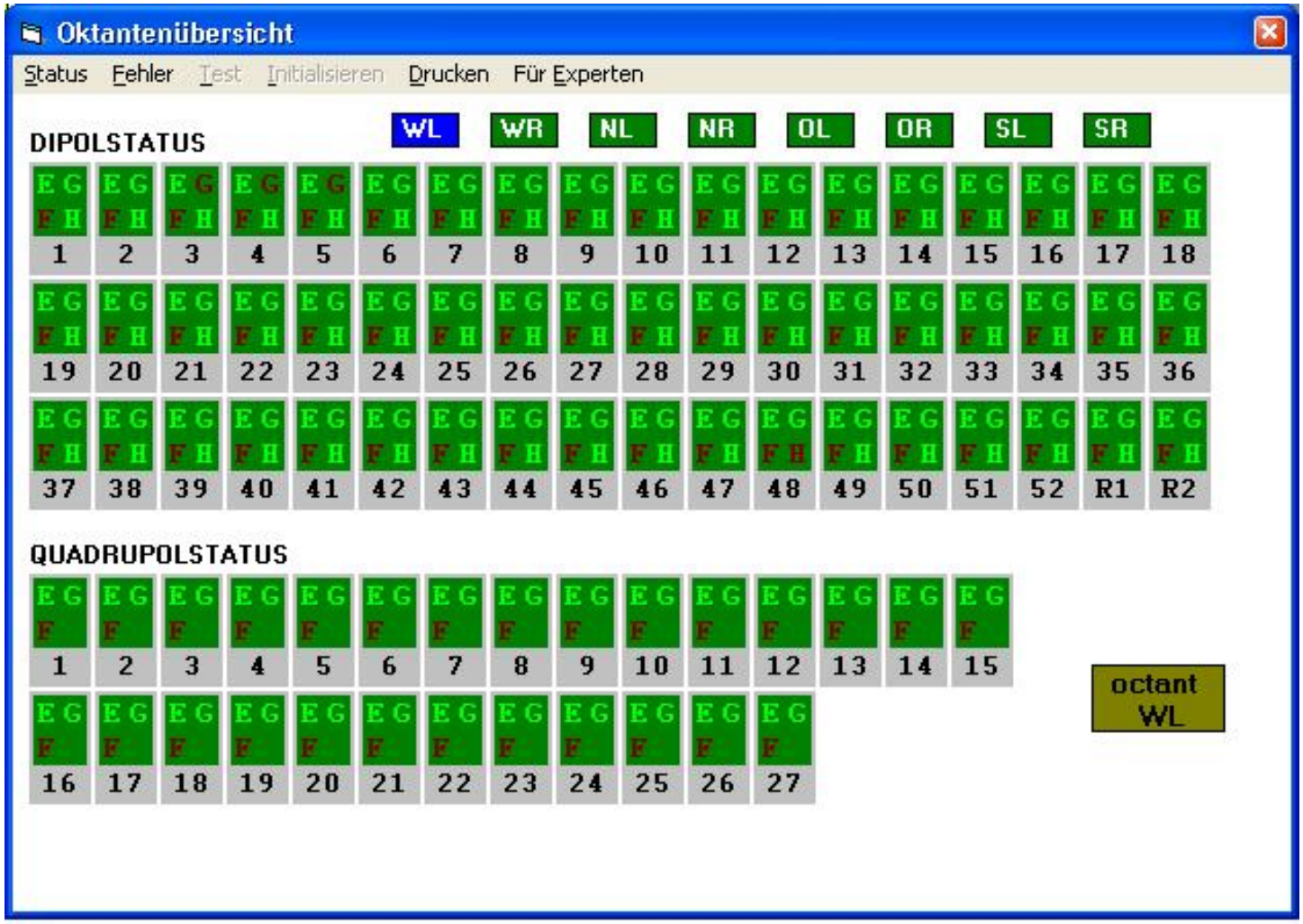
- In the beginning of HERA, only the quench protection system was equipped like sketched above.
- As eventually all serious situations resulted in a quench and as the quench protection system dutifully reported, the messenger was taken for the culprit.
- It must become the culture that
  - missing evidence for innocence

    is evidence for failure.

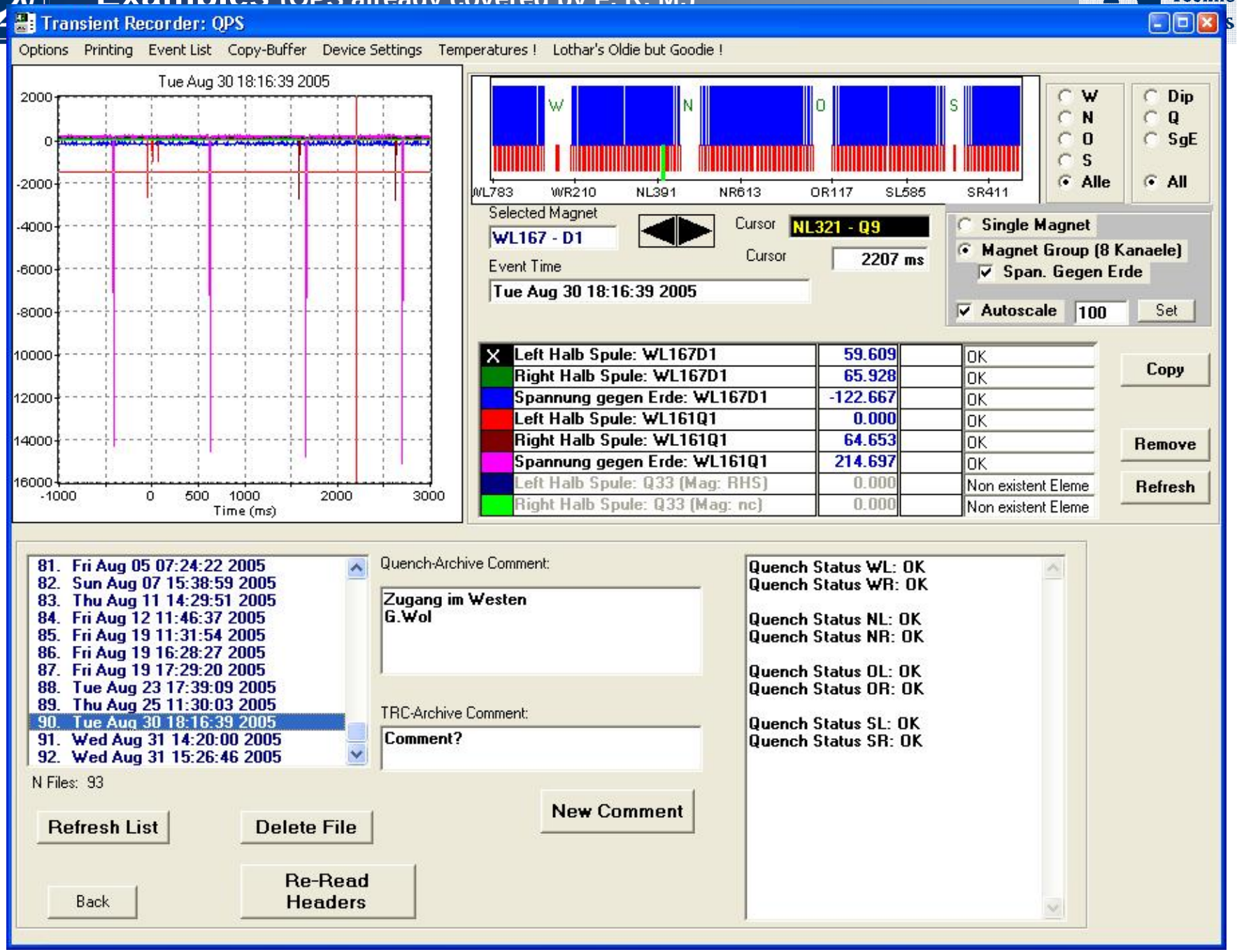
Examples (QPS already covered by F. R. M.)



Examples (QPS already covered by F. R. M.)



Examples (QPS already covered by F. R. M.)

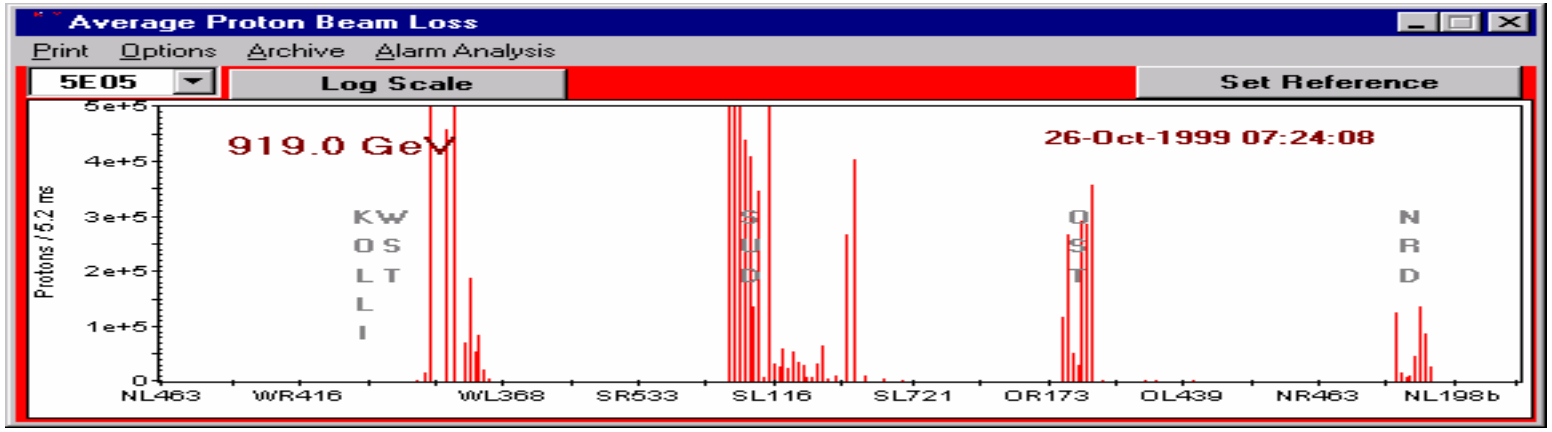


Examples (QPS already covered by F. R. M.)

➔ The best archive is useless unless you consequently and regularly try to find the reason for the fault and note it down:

Preferentially with an automatic transfer to the e-logbook

Basic Example from HERA



Dump during luminosity run

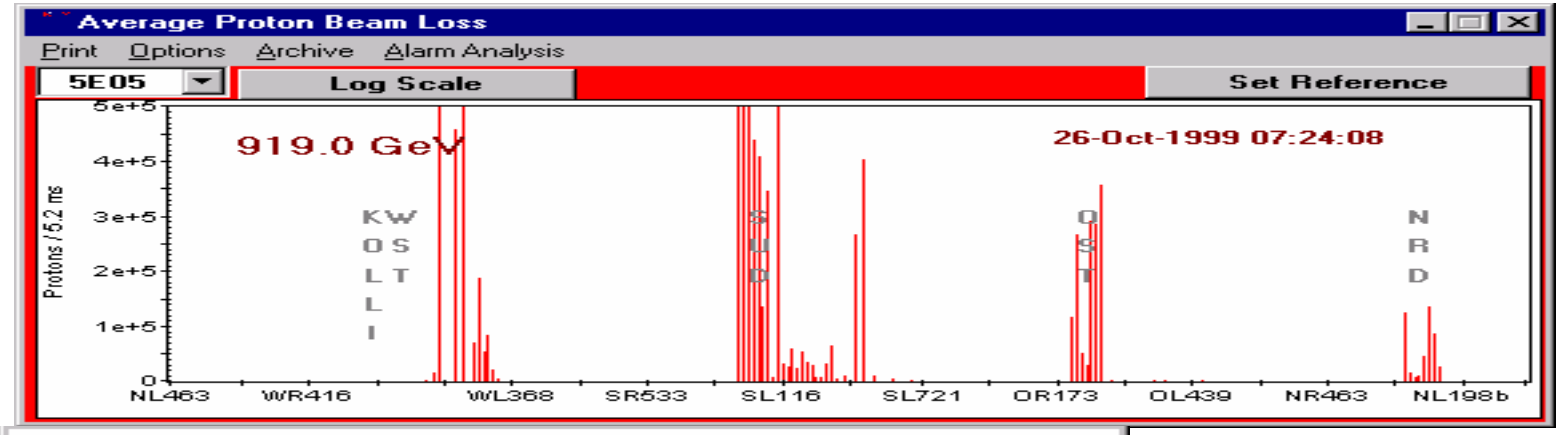
Overview of losses around ring: IPs - most in straight-section South, and near the Dump

(scaled from BLM Counts to lost protons, using efficiencies vs energy…)

Not so much help….

M. Lomperski

Basic Example from HERA



Which BLMs Triggered The Alarm?

Start Search

BLMs Found: 8

Search/Test Criteria

Start+Stop Bins:

Before Dump: 4

After Dump: 2

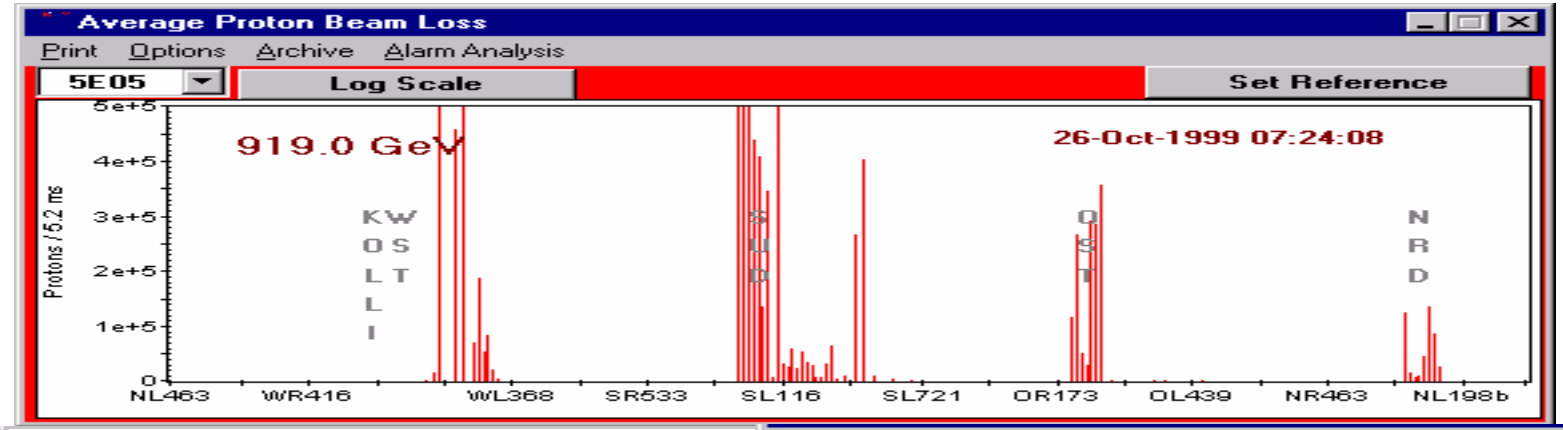
Threshold:

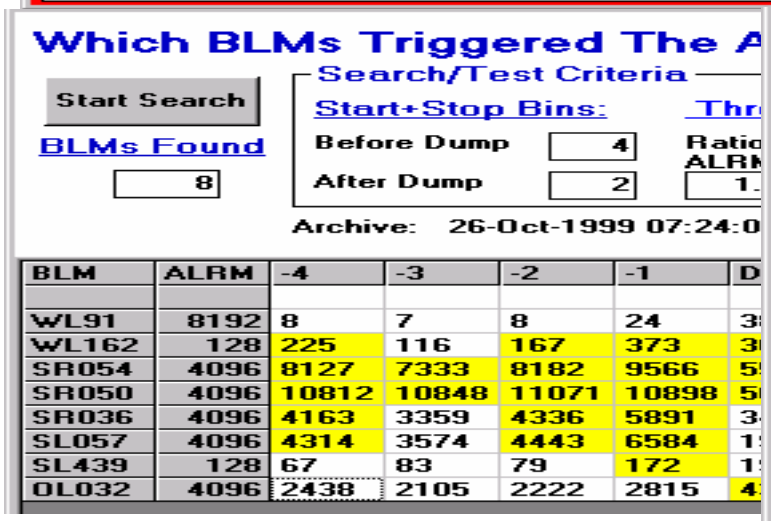
Ratio of Test to ALRM Threshold: 1.00

Archive: 26-Oct-1999 07:24:08 919 GeV

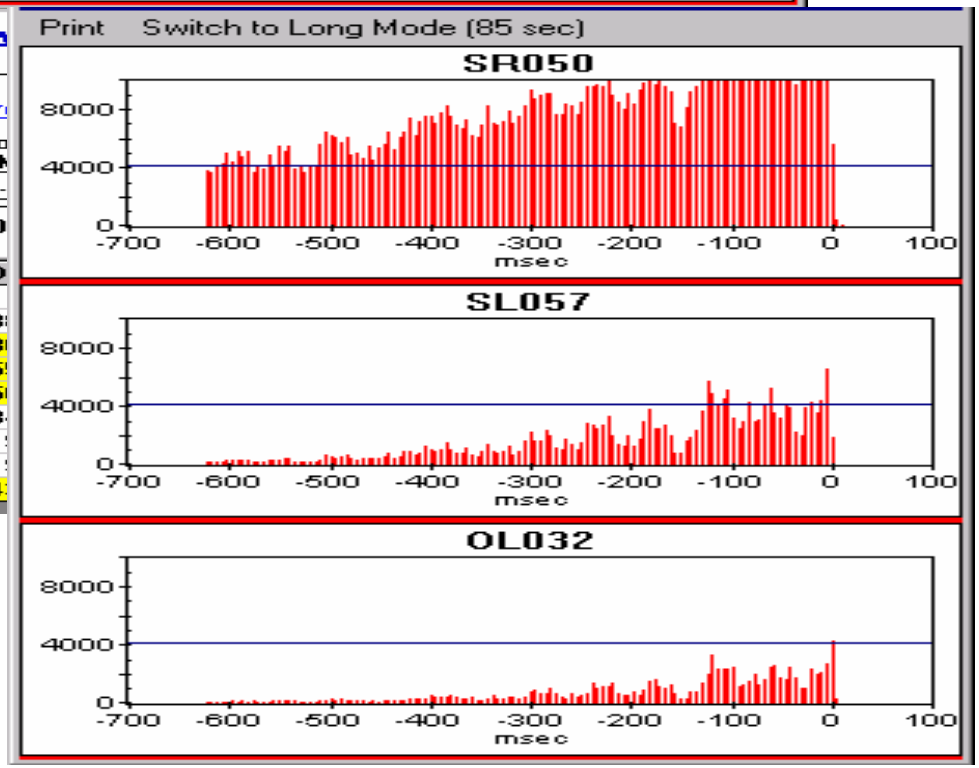
BLM	ALRM	-4	-3	-2	-1	Dump?	1	2
WL91	8192	8	7	8	24	3800	10837	10203
WL162	128	225	116	167	373	301	3	1
SR054	4096	8127	7333	8182	9566	5572	433	77
SR050	4096	10812	10848	11071	10898	5617	454	102
SR036	4096	4163	3359	4336	5891	3465	210	30
SL057	4096	4314	3574	4443	6584	1977	31	4
SL439	128	67	83	79	172	19	0	0
OL032	4096	2438	2105	2222	2815	4303	371	13

Basic Example from HERA

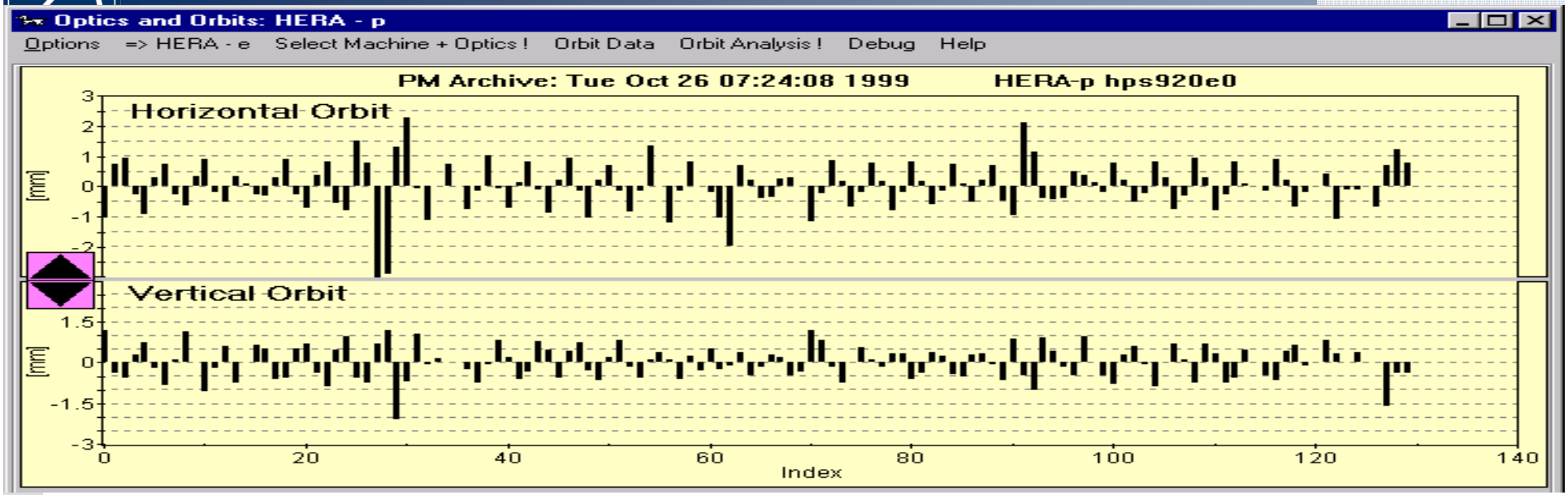




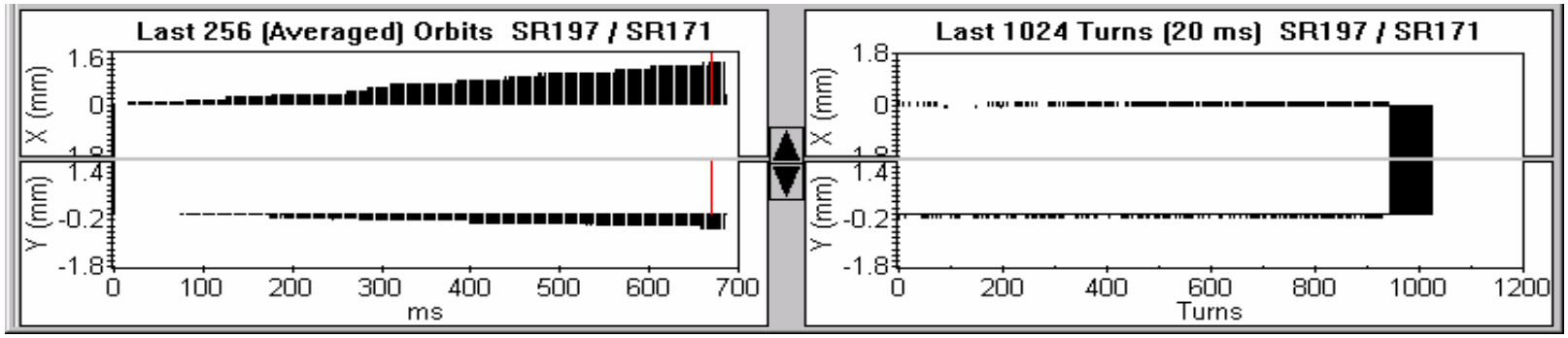
BLM	ALRM	-4	-3	-2	-1	D
WL91	8192	8	7	8	24	3
WL162	128	225	116	167	373	3
SR054	4096	8127	7333	8182	9566	5
SR050	4096	10812	10848	11071	10898	5
SR036	4096	4163	3359	4336	5891	3
SL057	4096	4314	3574	4443	6584	1
SL439	128	67	83	79	172	1
OL032	4096	2438	2105	2222	2815	4



Orbit Data

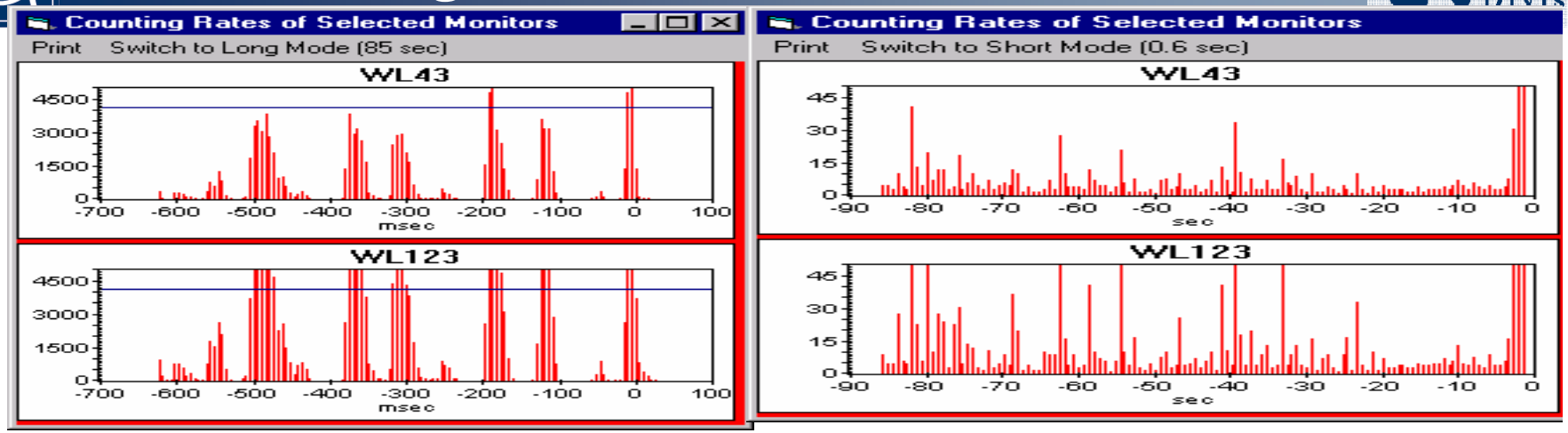


Difference Orbit: "beginning" and "end " of buffer;

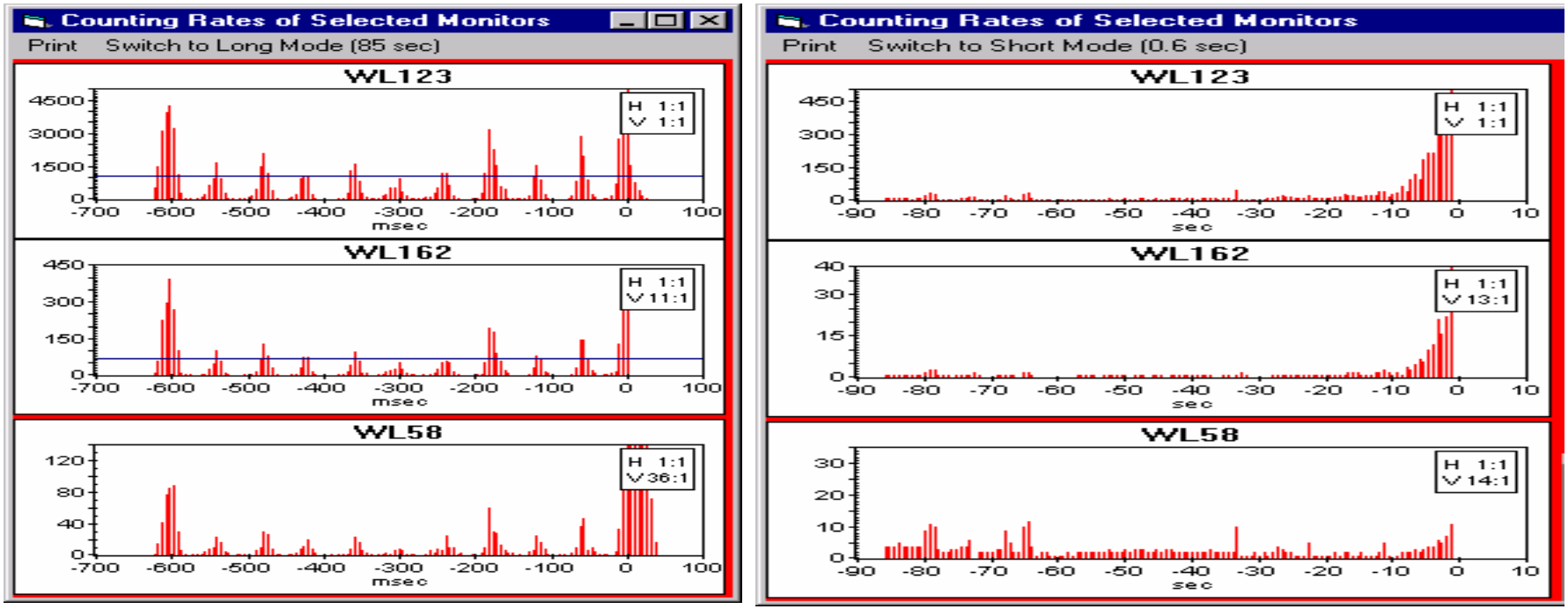


Selected Monitor: Time-Scale of Orbit-Change

Moving Collimator (12.Oct.98 10:08)

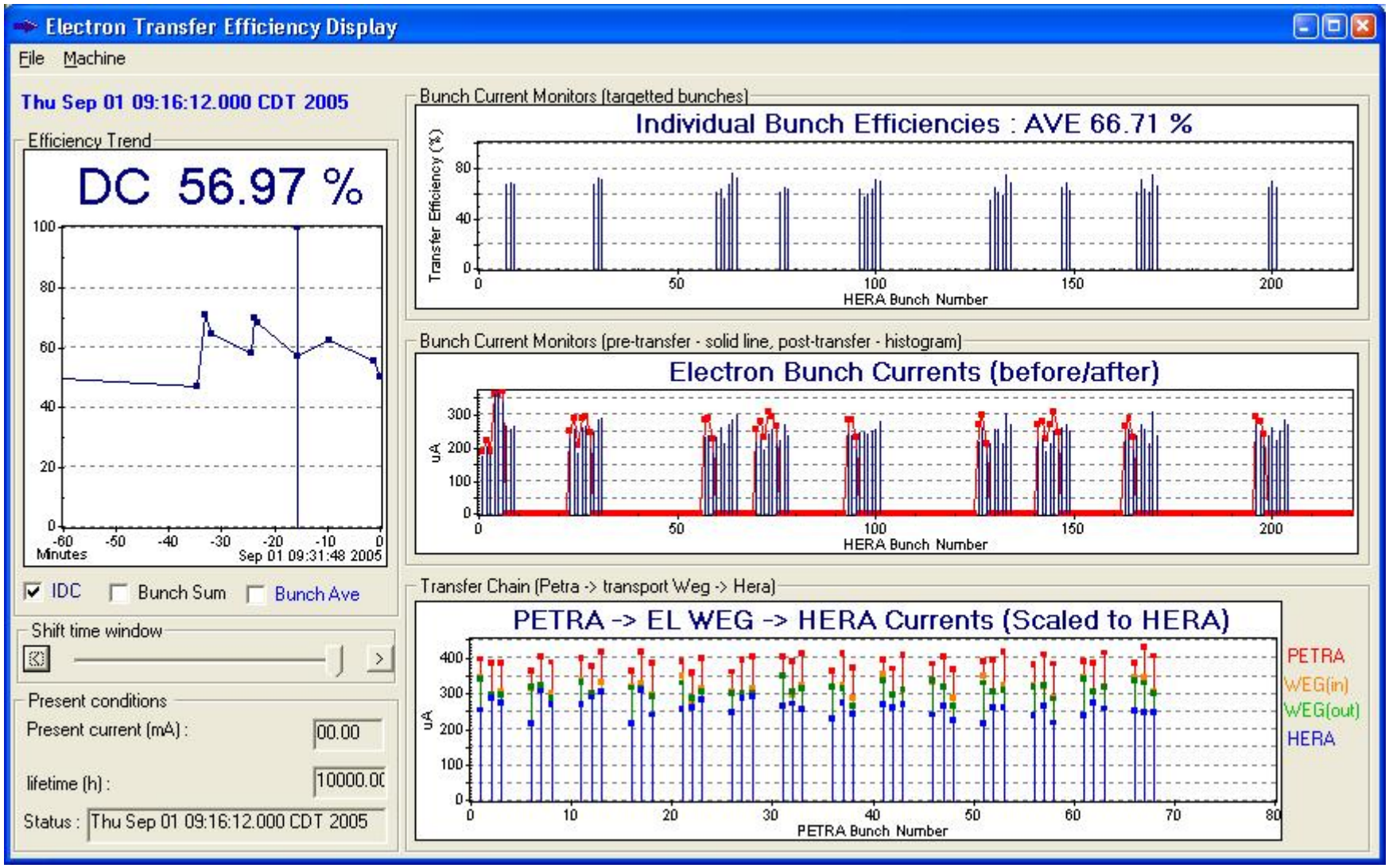


Cycling e-magnets (3.Sep.98 21:22)



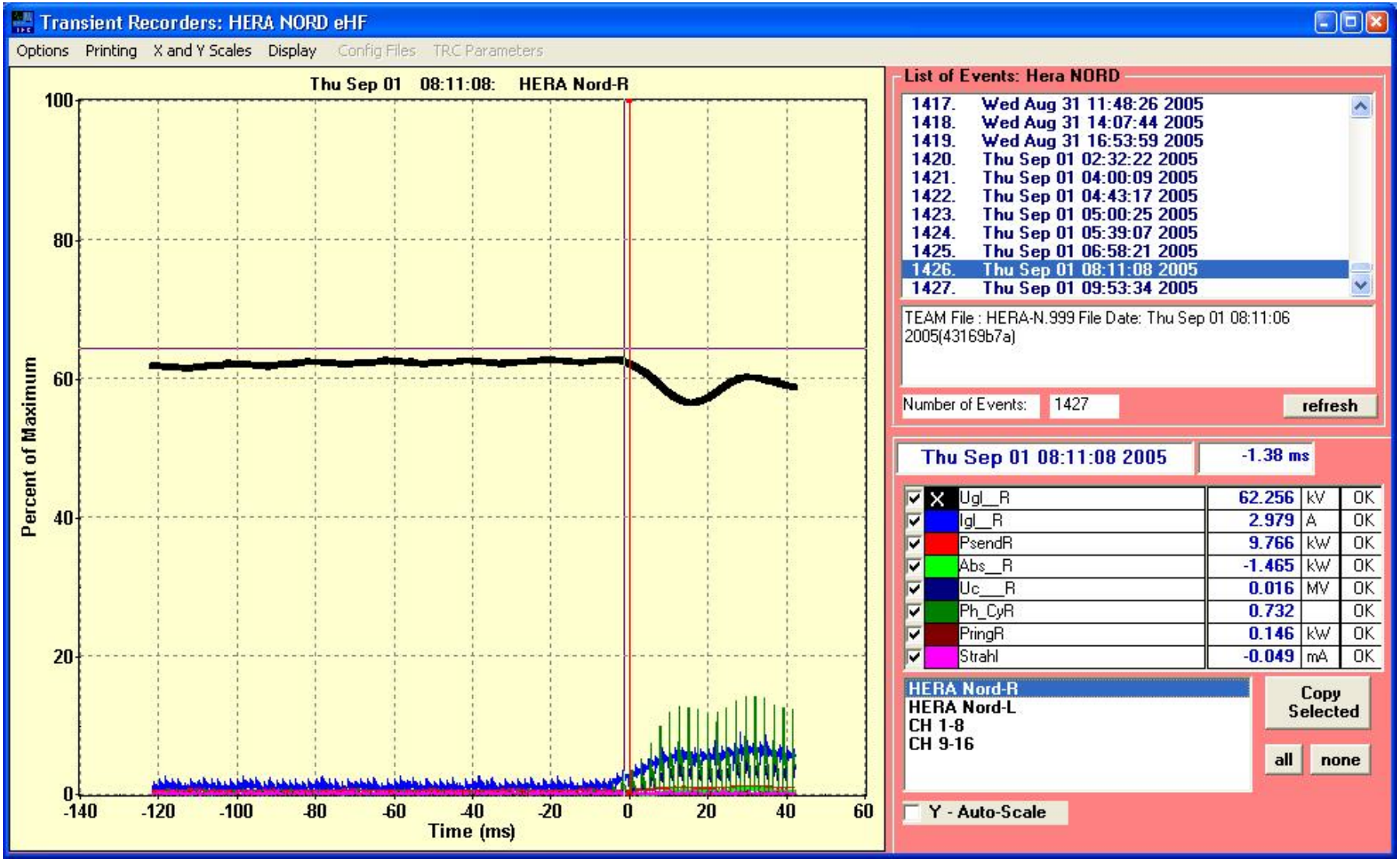
Orbit (electrons)

Injection efficiency (electrons)

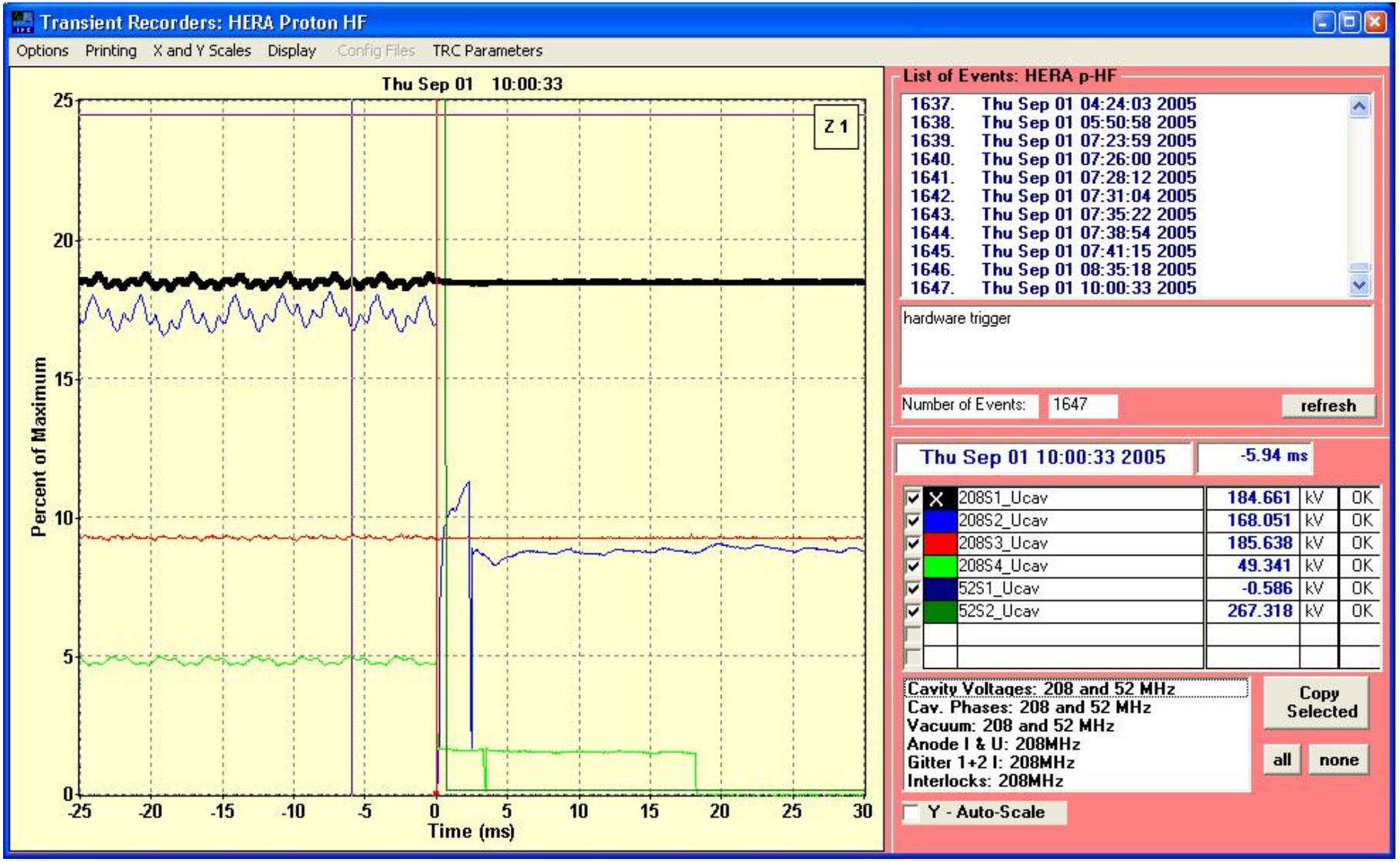


Injection efficiency (protons)

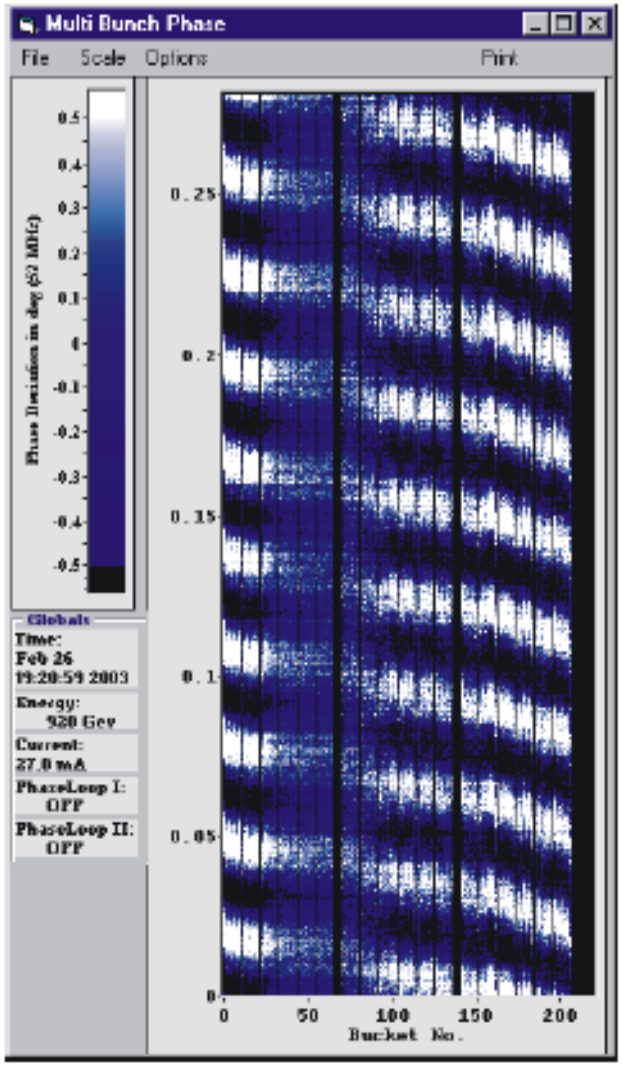
RF (electrons)



RF (protons)

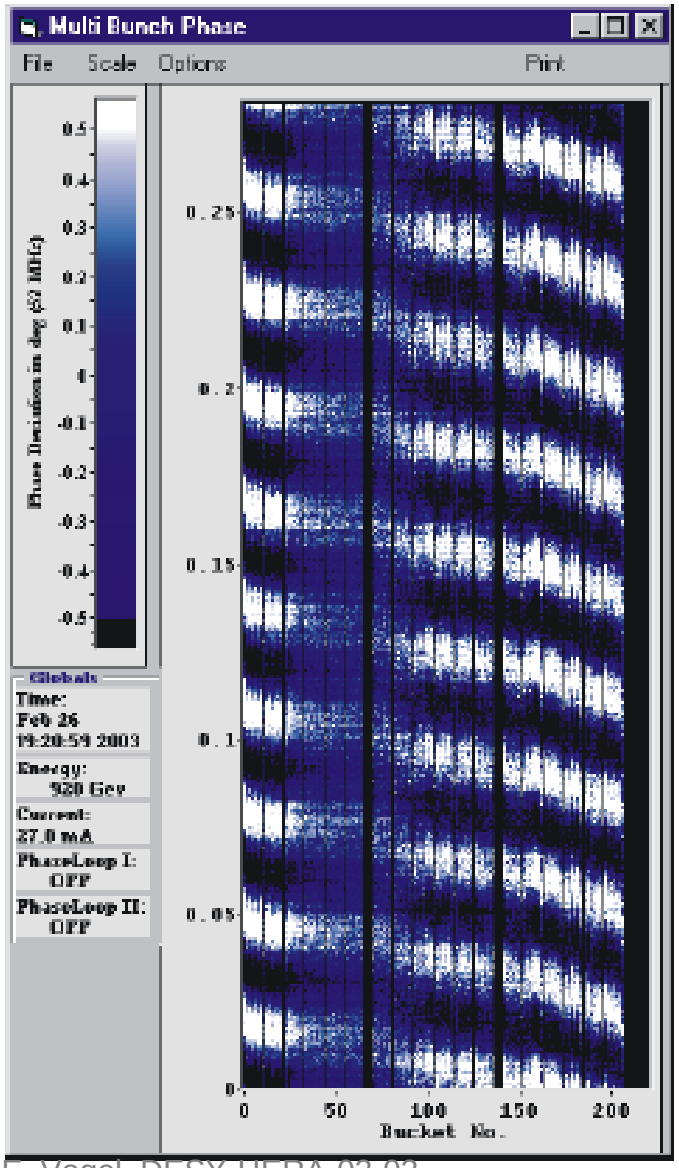

Transient Recorders: HERA Proton HF
Options
Printing
X and Y Scales
Display
Config Files
TRC Parameters
Thu Sep 01 10:00:33
Z 1
Percent of Maximum
Time (ms)
List of Events: HERA p-HF
1637. Thu Sep 01 04:24:03 2005
1638. Thu Sep 01 05:50:58 2005
1639. Thu Sep 01 07:23:59 2005
1640. Thu Sep 01 07:26:00 2005
1641. Thu Sep 01 07:28:12 2005
1642. Thu Sep 01 07:31:04 2005
1643. Thu Sep 01 07:35:22 2005
1644. Thu Sep 01 07:38:54 2005
1645. Thu Sep 01 07:41:15 2005
1646. Thu Sep 01 08:35:18 2005
1647. Thu Sep 01 10:00:33 2005
hardware trigger
Number of Events: 1647
refresh
Thu Sep 01 10:00:33 2005
-5.94 ms
208S1_Ucav 184.661 kV OK
208S2_Ucav 168.051 kV OK
208S3_Ucav 185.638 kV OK
208S4_Ucav 49.341 kV OK
52S1_Ucav -0.586 kV OK
52S2_Ucav 267.318 kV OK
Cavity Voltages: 208 and 52 MHz
Cav. Phases: 208 and 52 MHz
Vacuum: 208 and 52 MHz
Anode I & U: 208MHz
Gitter 1+2 I: 208MHz
Interlocks: 208MHz
Copy Selected
all
none
Y - Auto-Scale

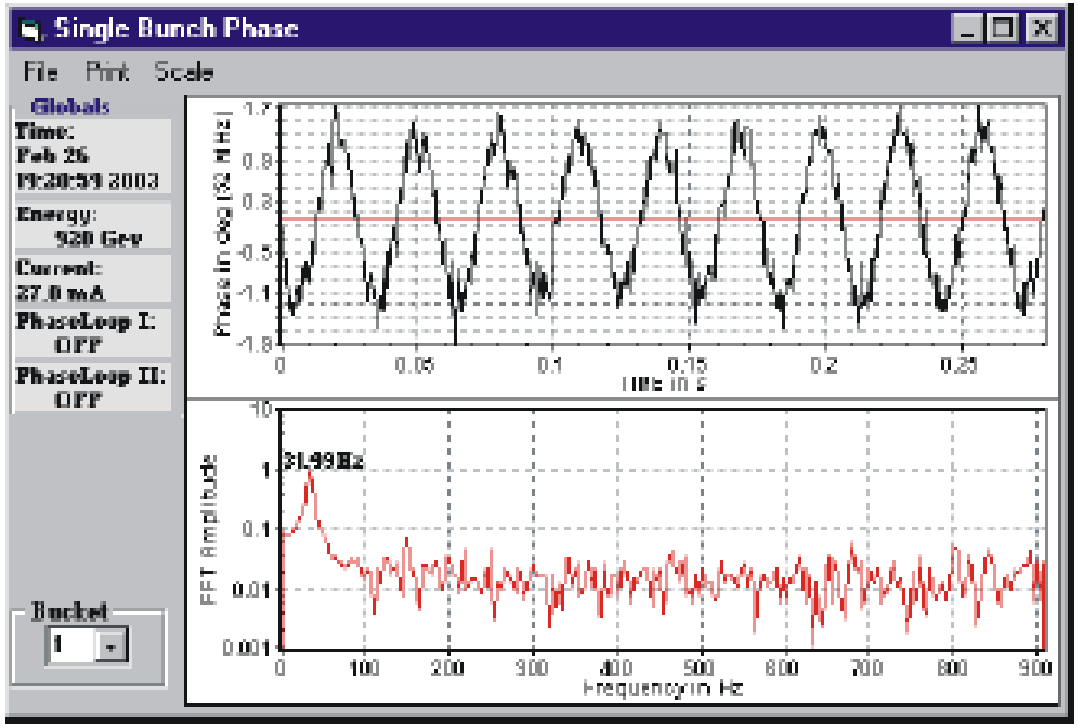
RF protons



E. Vogel, DESY-HERA-03-03

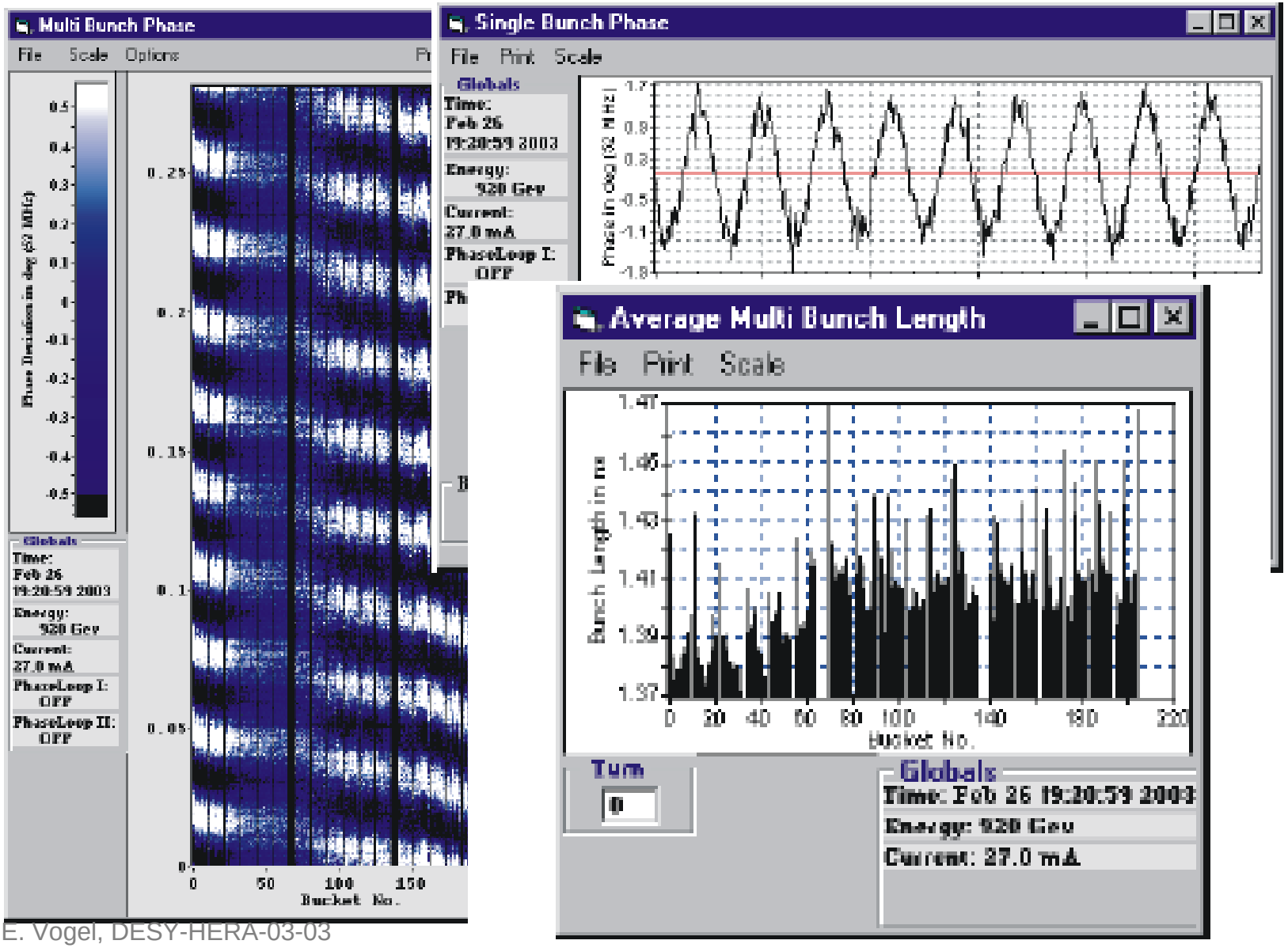
RF protons





E. Vogel, DESY-HERA-03-03

RF protons



E. Vogel, DESY-HERA-03-03

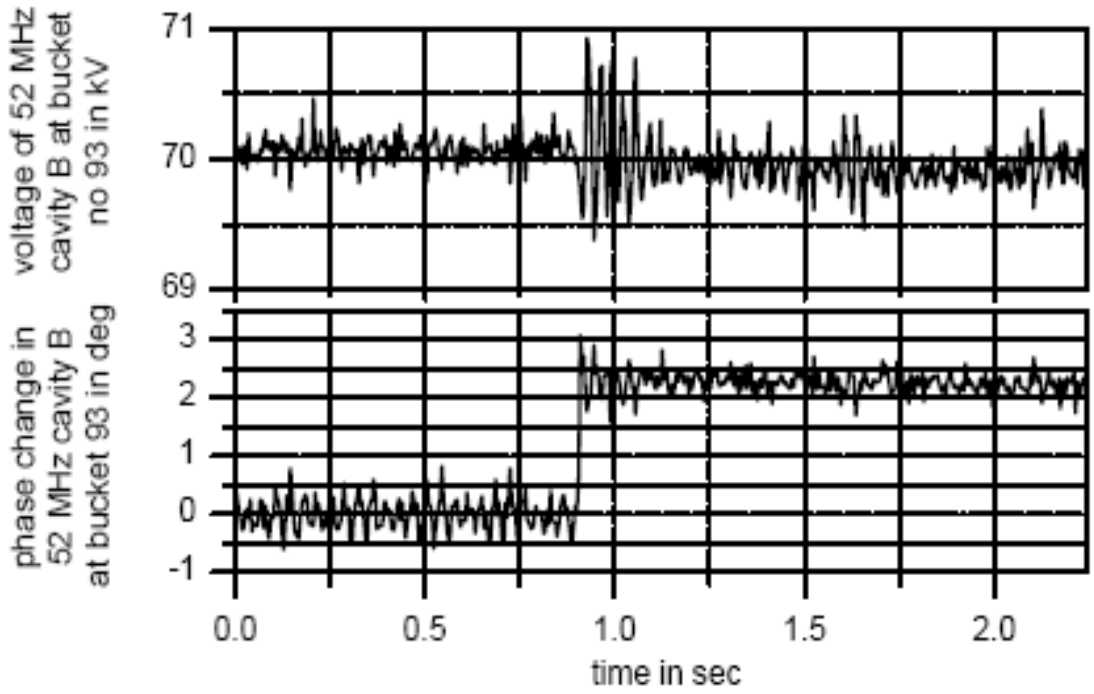


Figure 3.1: Transient changes of the RF in the 52 MHz cavity B due to the injection of the third bunch train (24th February 2003 at 00:08:10).

E. Vogel, DESY-HERA-03-03

RF protons

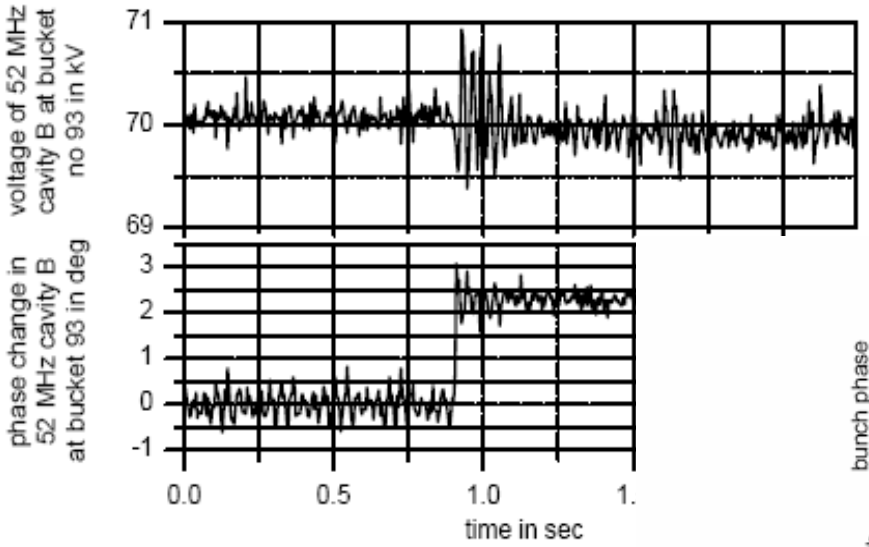


Figure 3.1: Transient changes of the RF in the 52 MHz cavity B bunch train (24th February 2003 at 00:08:10).

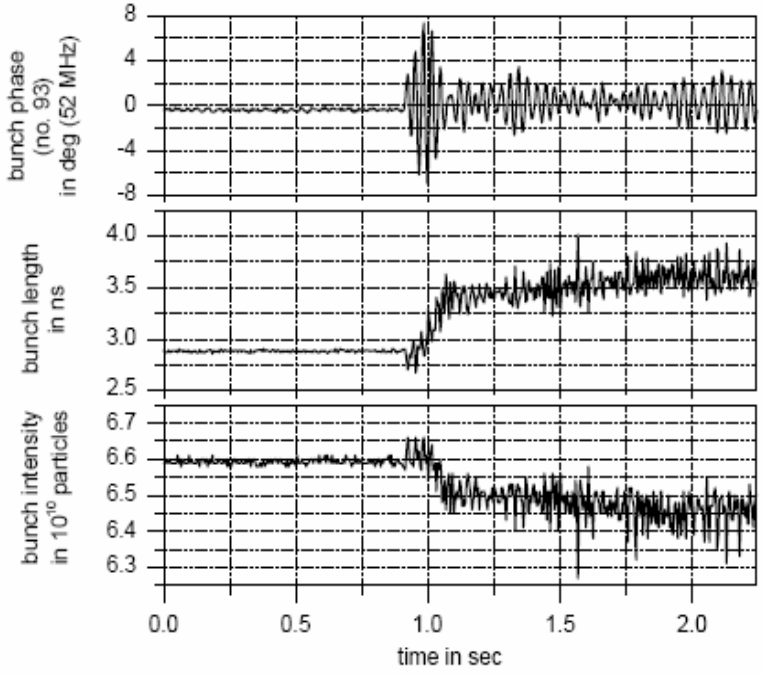
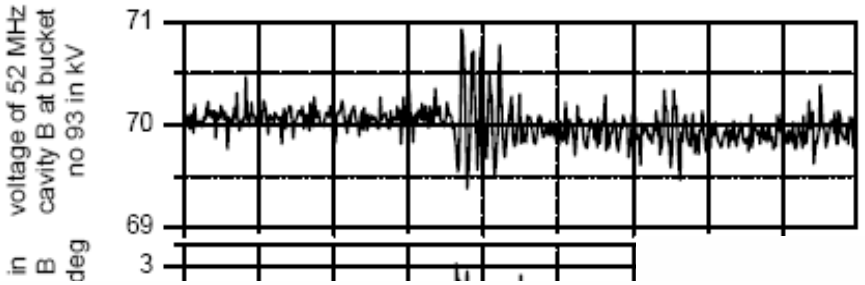
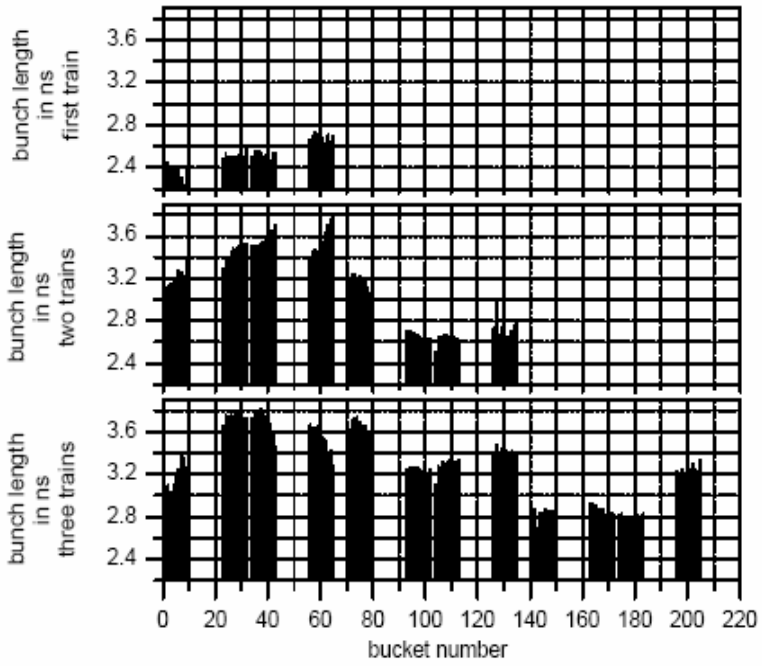


Figure 3.3: Oscillation of the already stored bunch at position 93, increase of its lengtl loss of intensity due to the injection of the third bunch train.

E. Vogel, DESY-HERA-03-03

RF protons





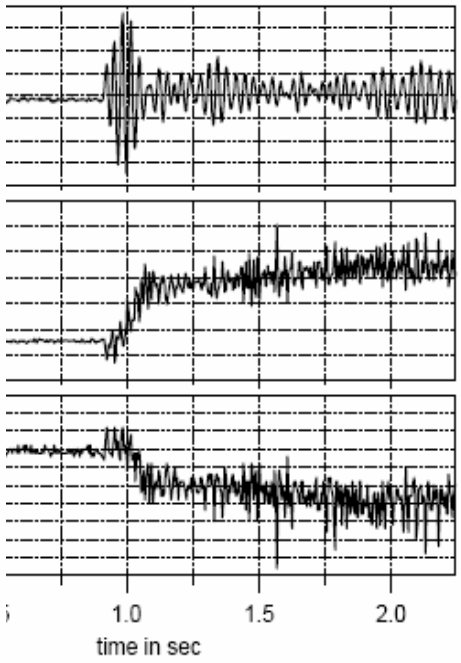
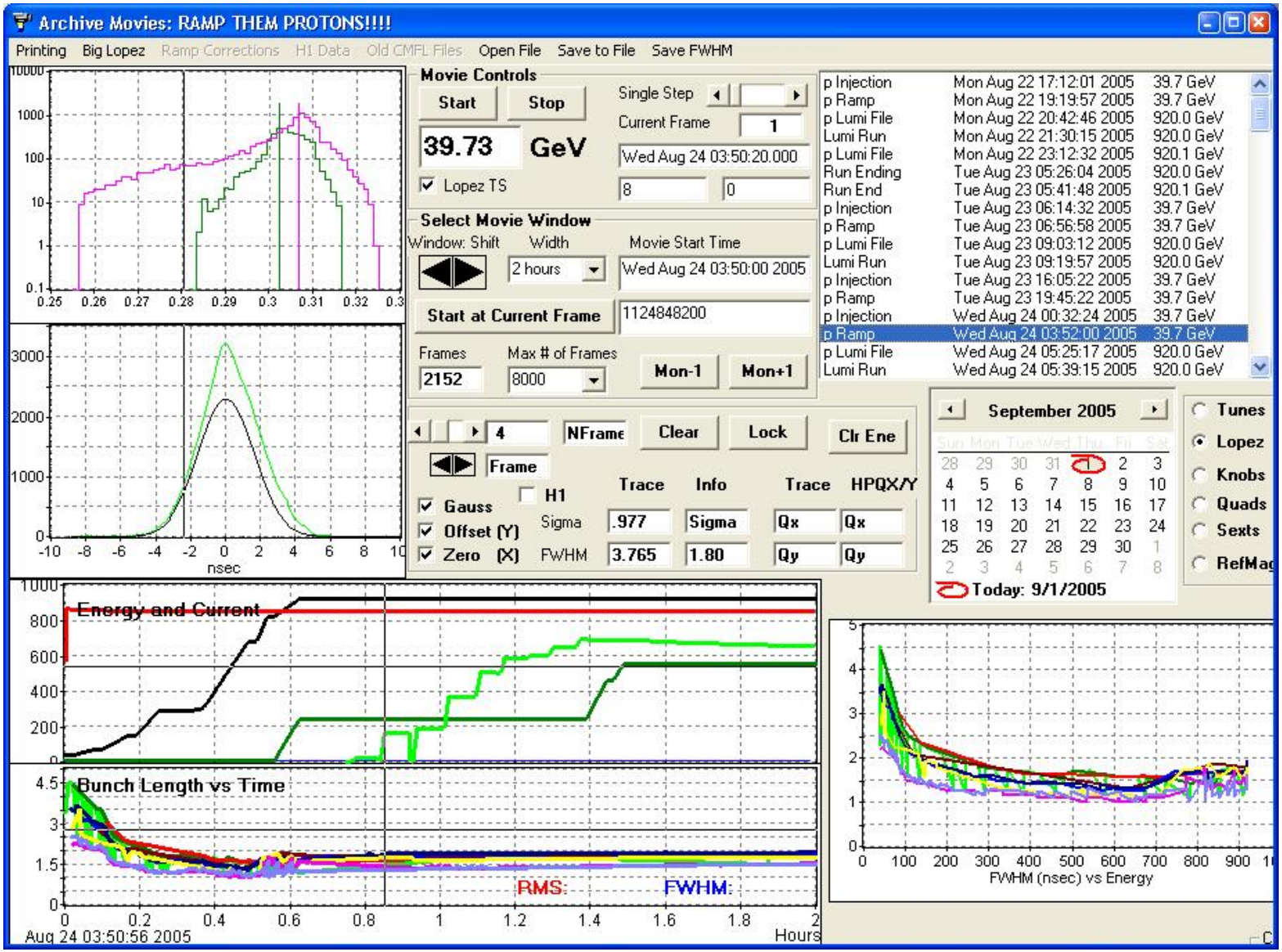


Figure 3.1: T
bunch train (

ed bunch at position 93, increase of its lengtl
e third bunch train.

Figure 3.4: Bunch length development due to transient beam loading, caused by subsequent injected trains of 40 bunches each. The beam current after the last injection was 69 mA. Data from 24th February 2003 starting at 00:00 AM.

Movie


Archive Movies: RAMP THEM PROTONS!!!!
Printing
Big Lopez
Ramp Corrections
H1 Data
Old CMFL Files
Open File
Save to File
Save FWHM
Movie Controls
Start
Stop
Single Step
Current Frame
39.73
GeV
Wed Aug 24 03:50:20.000
Lopez TS
Select Movie Window
Window: Shift
Width
2 hours
Movie Start Time
Wed Aug 24 03:50:00 2005
Start at Current Frame
1124848200
Frames
2152
Max # of Frames
8000
Mon-1
Mon+1
NFrame
Clear
Lock
Clr Ene
Frame
Gauss
Offset (Y)
Zero (X)
H1
Trace
Info
Trace
HPQX/Y
Sigma
.977
FWHM
3.765
1.80
nsec
p Injection Mon Aug 22 17:12:01 2005 39.7 GeV
p Ramp Mon Aug 22 19:19:57 2005 39.7 GeV
p Lumi File Mon Aug 22 20:42:46 2005 920.0 GeV
Lumi Run Mon Aug 22 21:30:15 2005 920.0 GeV
p Lumi File Mon Aug 22 23:12:32 2005 920.1 GeV
Run Ending Tue Aug 23 05:26:04 2005 920.0 GeV
Run End Tue Aug 23 05:41:48 2005 920.1 GeV
p Injection Tue Aug 23 06:14:32 2005 39.7 GeV
p Ramp Tue Aug 23 06:56:58 2005 39.7 GeV
p Lumi File Tue Aug 23 09:03:12 2005 920.0 GeV
Lumi Run Tue Aug 23 09:19:57 2005 920.0 GeV
p Injection Tue Aug 23 16:05:22 2005 39.7 GeV
p Ramp Tue Aug 23 19:45:22 2005 39.7 GeV
p Injection Wed Aug 24 00:32:24 2005 39.7 GeV
p Ramp Wed Aug 24 03:52:00 2005 39.7 GeV
p Lumi File Wed Aug 24 05:25:17 2005 920.0 GeV
Lumi Run Wed Aug 24 05:39:15 2005 920.0 GeV
September 2005
Today: 9/1/2005
Tunes
Lopez
Knobs
Quads
Sexts
RefMag
Energy and Current
Bunch Length vs Time
RMS:
FWHM:
Aug 24 03:50:56 2005
Hours
FWHM (nsec) vs Energy

Summary

- Hardware must provide the storage and readout possibility
- Event trigger must be configurable
- Synchronization is a must
- Storage must be available
- Software must
  - Be able to configure (arm/disarm) event trigger
  - Be able to plot various signals against time
  - Analyze automatically bit pattern and signals for known pattern
  - Be able to plot x-y plots, waterfall and movies
  - Be able to store comments and send plots to the logbook
  - Be able to provide data in a readable format for offline analysis

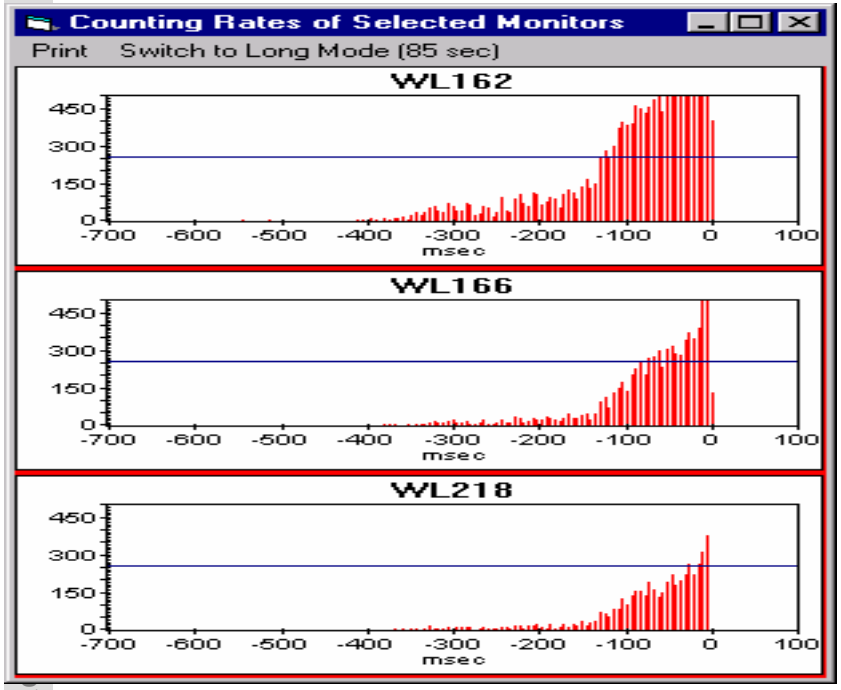
Final Word

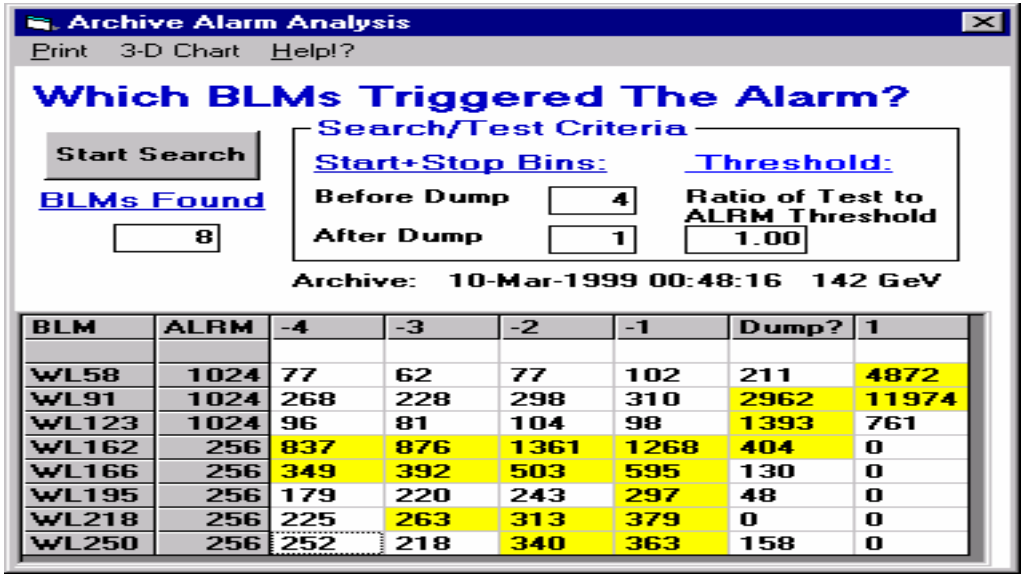
- A transient recording system is essential for a large and dangerous accelerator.
- I'm convinced that AB/CO acknowledges this.
- It is needed to avoid the repetition of mistakes or malfunctions.
- It is useful for "online" machine studies.
- It is handy for "offline" and dedicated machine studies.

For the discussion

BATMAN during the Ramp!

Head-Tail instability at 142 GeV





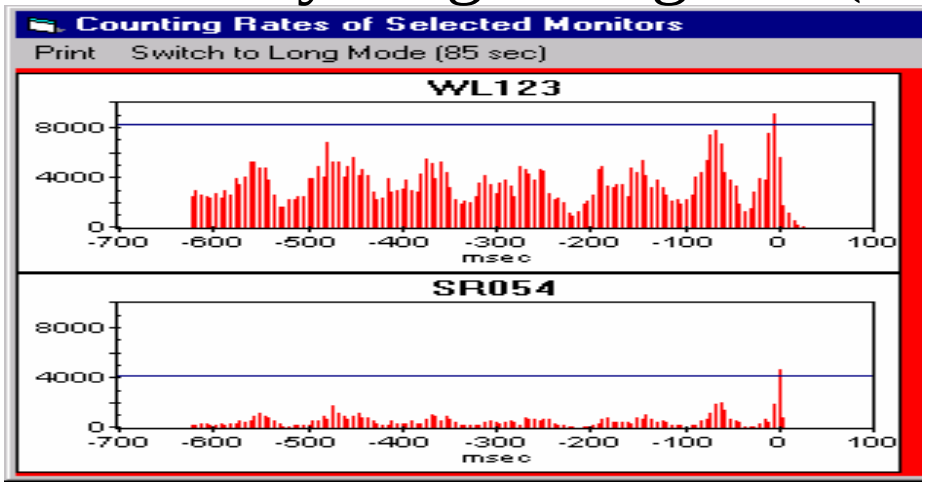
BLM	ALRM	-4	-3	-2	-1	Dump?	1
WL58	1024	77	62	77	102	211	4872
WL91	1024	268	228	298	310	2962	11974
WL123	1024	96	81	104	98	1393	761
WL162	256	837	876	1361	1268	404	0
WL166	256	349	392	503	595	130	0
WL195	256	179	220	243	297	48	0
WL218	256	225	263	313	379	0	0
WL250	256	252	218	340	363	158	0

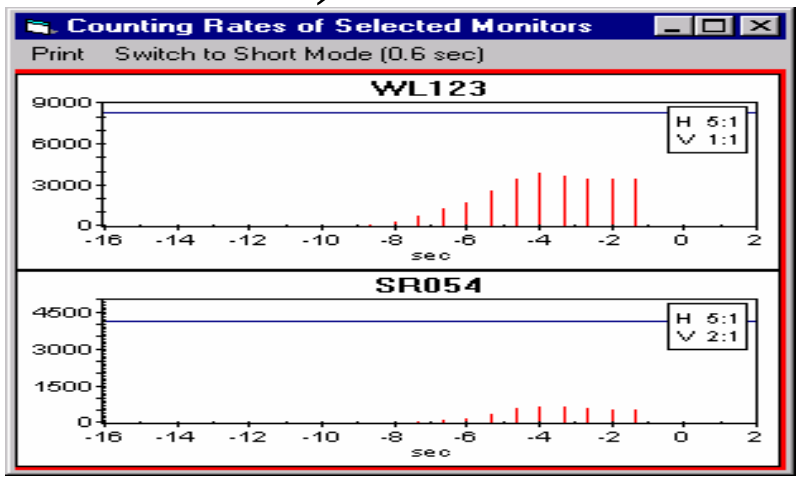
Losses visible for only 300 msec

No effect in orbit seen

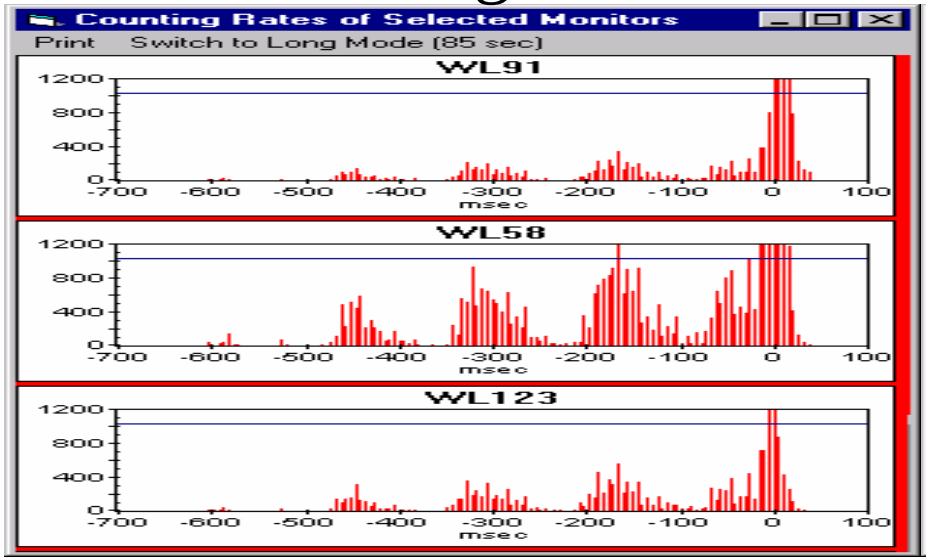
Losses are not always as “smooth” as one might expect…

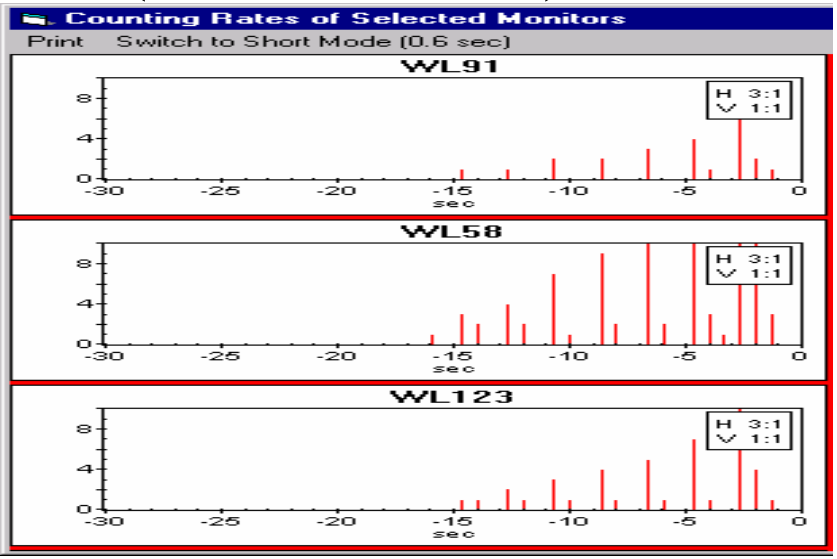
Cycling e-magnets (22.Jul.00 22:20)



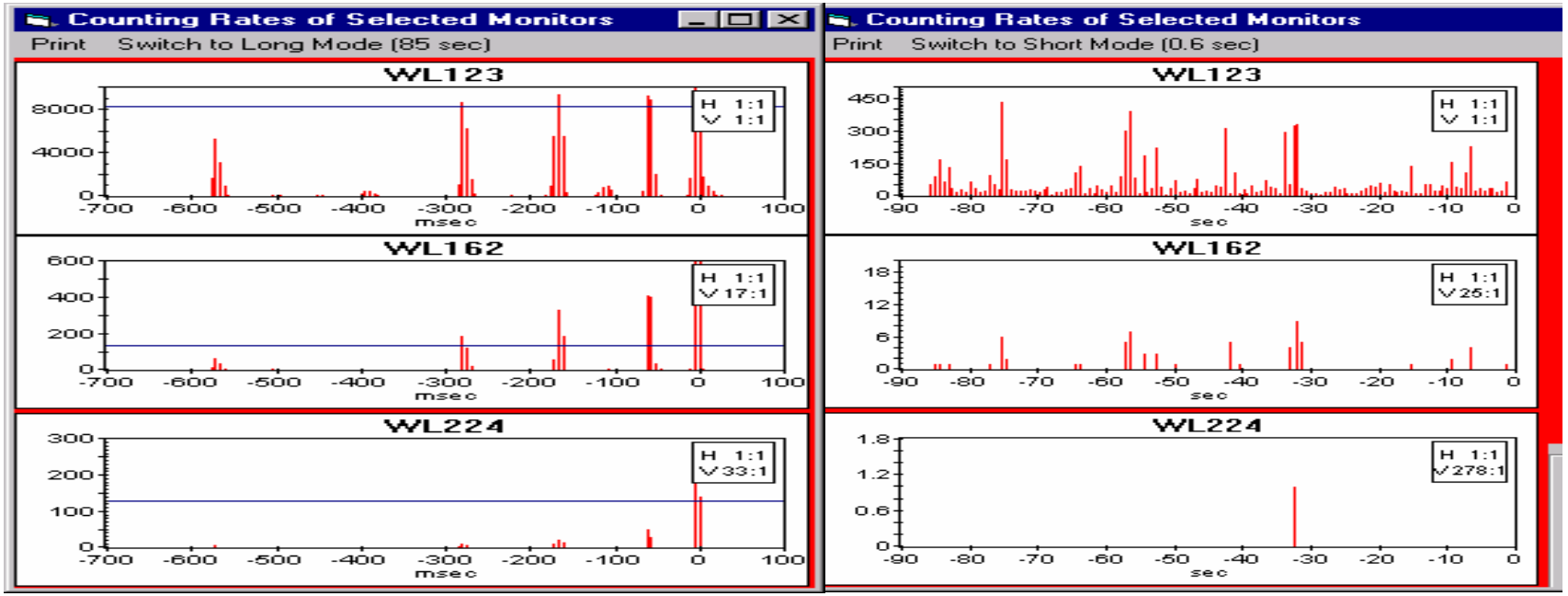


Moving Main Collimator (28.Jul.98 00:24)





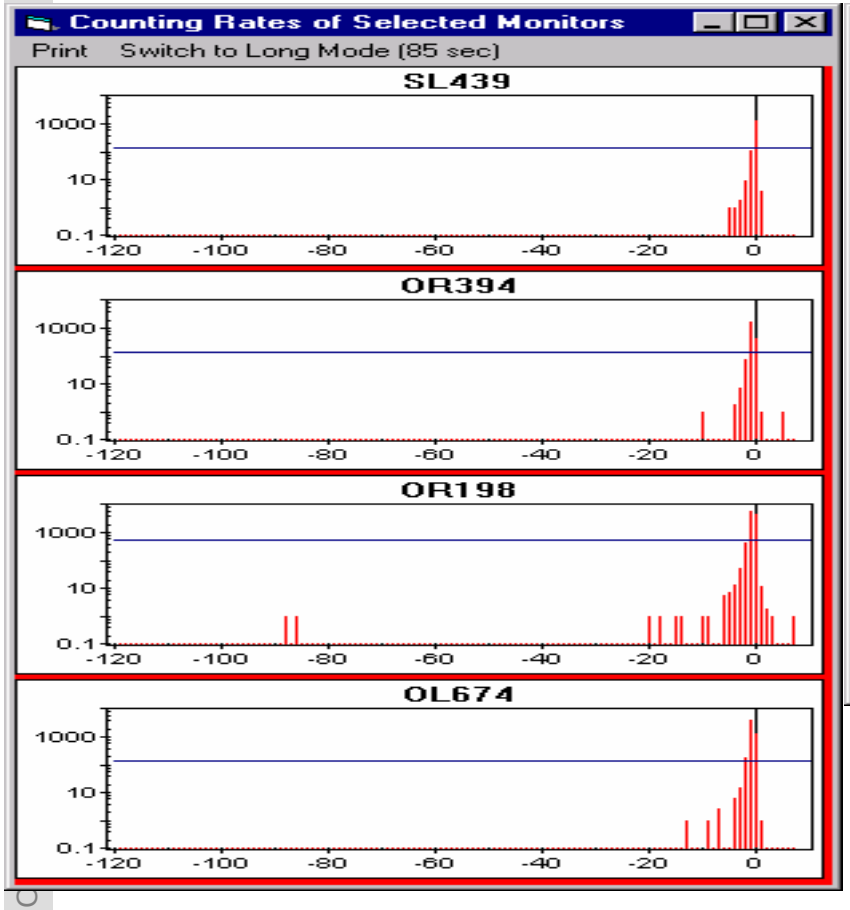
Stable p at 920 GeV 31.July.00



<u>Frequency of Oscillations</u>: 5 - 15 Hz

<u>Experience of HERA-B scraping Coasting (unbunched) Proton Halo with the Wire Target</u>: Violent rate fluctuations until the wire reaches the bunched part of the halo...

Careful reading too much into the losses...



Archive Alarm Analysis

Print 3-D Chart Help!?

Which BLMs Triggered The Alarm?

Start Search

BLMs Found: 13

Search/Test Criteria

Start+Stop Bins: Before Dump 5, After Dump 1

Threshold: Ratio of Test to ALRM Threshold 1.00

Archive: 21-Oct-1998 17:26:58 920 GeV

BLM	ALRM	-5	-4	-3	-2	-1	Dump?	1
WR675	128	0	0	1	13	184	102	0
WL58	4096	0	0	0	0	0	48	8860
WL91	4096	1	1	2	1	13	934	9196
SL439	128	1	1	2	10	115	1328	4
SL627	128	1	1	8	43	1012	665	2
OR580	128	0	1	4	30	491	1	0
OR394	128	0	2	8	81	1692	439	1
OR198	512	8	14	58	434	5862	4582	13
OL486	128	0	0	1	18	385	7	0
OL674	128	0	7	16	185	4083	1374	1
NR345	128	1	0	1	5	117	506	46
NR322	128	0	0	0	2	28	149	2
NR198	512	0	3	8	77	1467	451	0

(note log scale)

Fast losses (20 times the alarm level in 20 ms)

with **QUENCH** in the East Area…

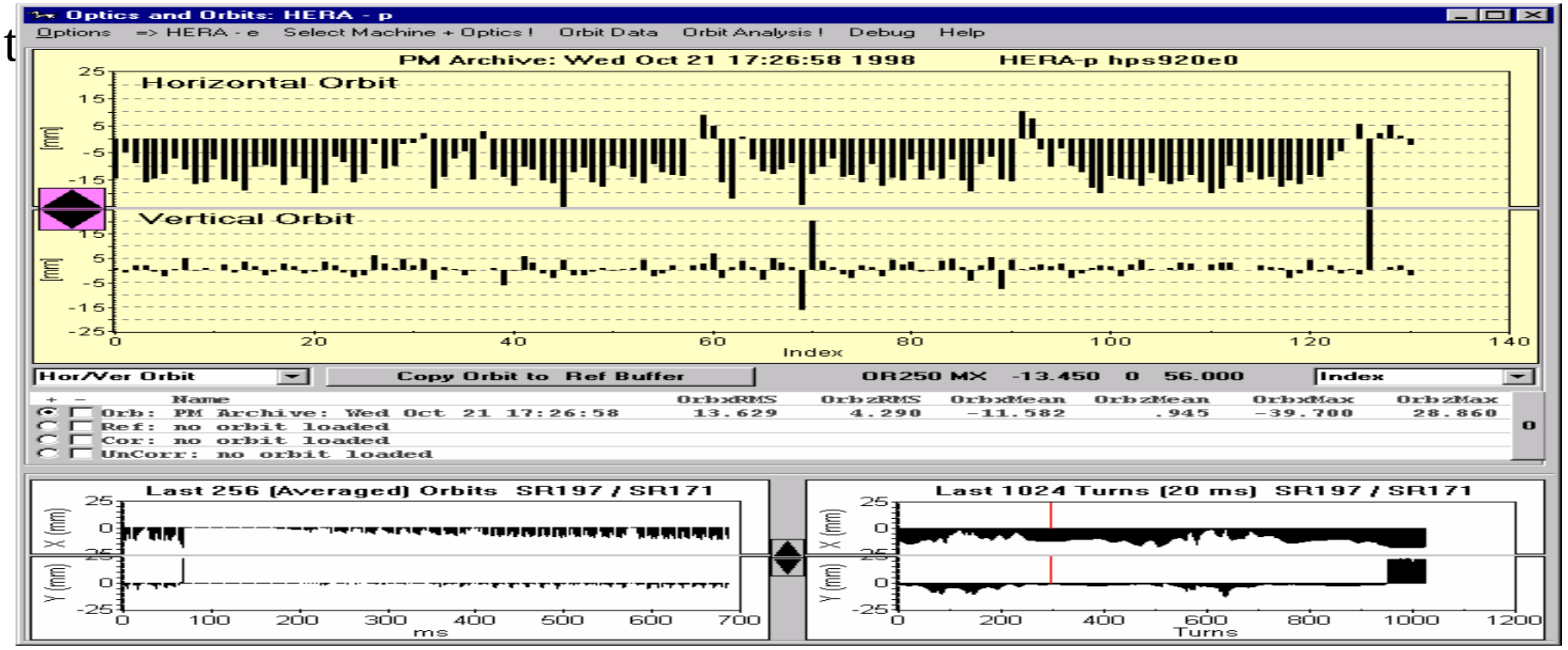
An RF Trip? But how can the losses be so **FAST**?

From the orbit data:

(1) Beam on a Dispersion orbit

(2) the RF tripped more than 0.5 sec before

t

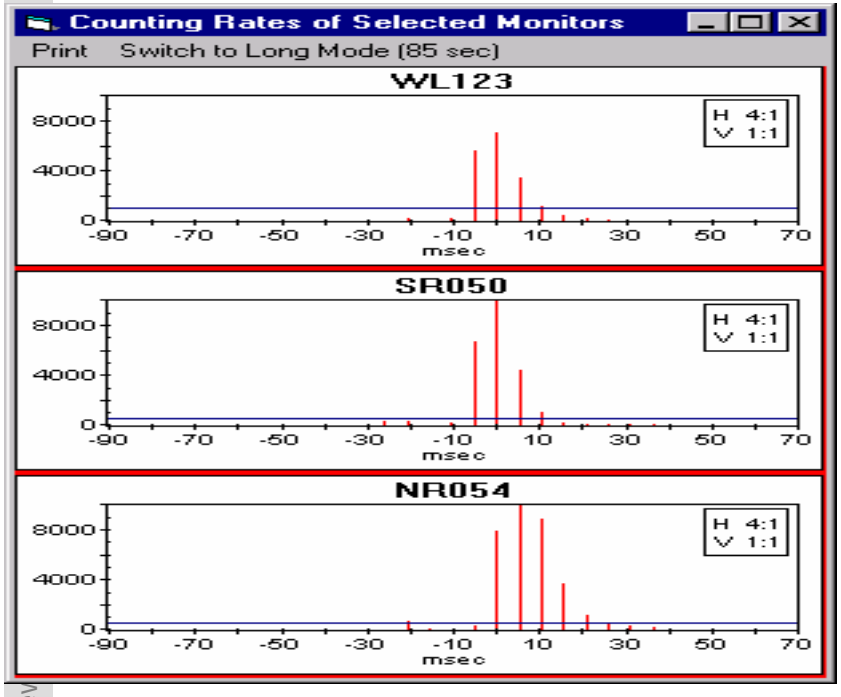


And the losses were too fast for the BLM System!

Quench!!!!

A (Nasty) Power Supply Trip:

A Quadrupole near an IP



Archive Alarm Analysis

Print 3-D Chart Help!?

Which BLMs Triggered The Alarm?

Start Search

BLMs Found: 96

Search/Test Criteria

Start+Stop Bins: Before Dump: 4; After Dump: 1

Threshold: Ratio of Test to ALRM Threshold: 1.00

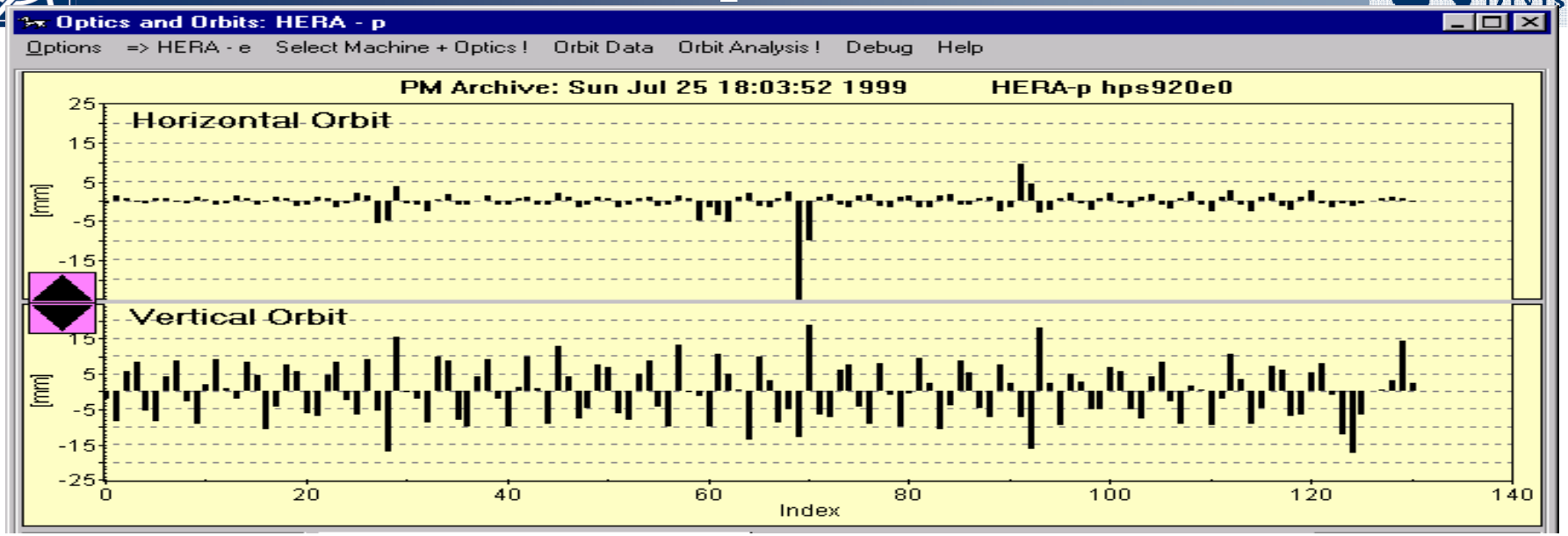
Archive: 25-Jul-1999 18:03:52 919 GeV

BLM	ALRM	-4	-3	-2	-1	Dump?	1
NL463	128	0	0	0	0	1259	8
NL486	128	0	0	0	1	688	5
NL697	128	0	0	0	0	218	1
NL768	128	0	0	0	0	346	6
WR769	128	0	0	0	404	21	4
WR745	128	0	0	0	12	181	2
WR698	128	0	0	0	0	541	0
WR604	128	0	0	0	1532	147	3
WR581	128	0	0	0	3	237	0
WR534	128	0	0	0	3	471	0
WR439	256	0	0	0	0	927	2
WR346	256	0	0	0	0	278	0
WR225	256	0	0	0	8	586	0
WR196	256	0	0	1	38	732	2
WR061	1024	0	0	0	122	5597	1734
WR040	1024	0	0	2	1123	3783	292
WR018	1024	0	0	5	906	4495	359

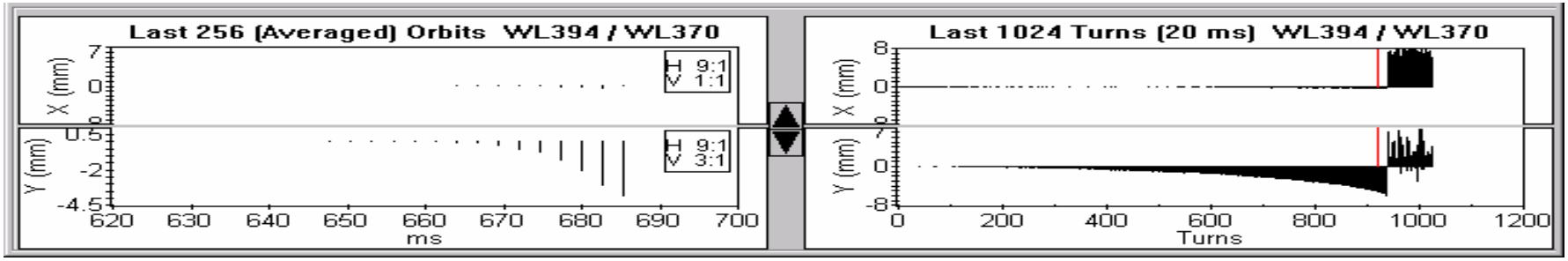
Heavy Losses Around the Ring

Massive Beam-Induced Quench

Orbit Data: Trip of QS10 - Ost



Difference Orbit: VERTICAL



Selected Monitor: Orbit Effect seen over 15 ms

Very Fast, Very Heavy Losses...
with Quench...

Not all “5-ms Quenches” have a clear cause….

- Both beams lost
- Proton losses < 5 ms
- No effect seen in orbit
- No tripped PS found

Archive Alarm Analysis

Print 3-D Chart Help!?

Which BLMs Triggered The Alarm?

Start Search

BLMs Found 49

Search/Test Criteria

Start+Stop Bins: Before Dump 4, After Dump 1

Threshold: Ratio of Test to ALRM Threshold 1.00

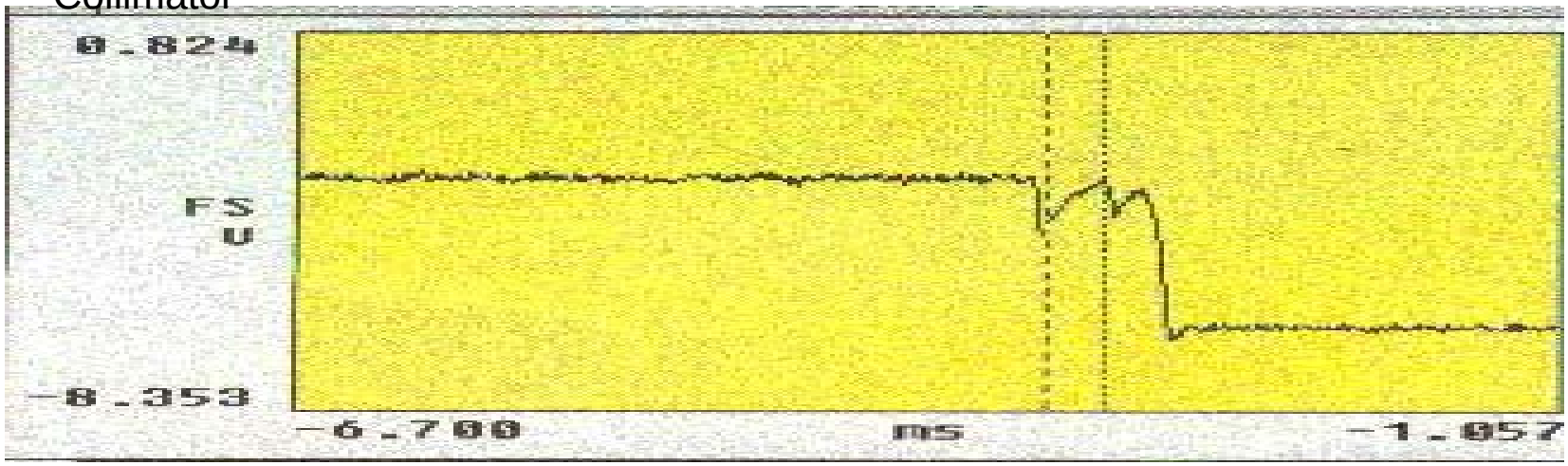
Archive: 04-Sep-1998 21:00:22 920 GeV

BLM	ALRM	-4	-3	-2	-1	Dump?	1
SL116	64	0	0	0	0	2435	19
SL146	64	0	0	0	2	3166	2
SL173	512	0	1	0	1264	2324	7
SL198a	512	0	0	0	1764	285	0
SL227a	64	0	0	0	652	1	0
SL251	64	0	0	0	76	203	0
SL274	64	0	0	0	1747	184	2
SL298	64	0	0	0	108	1	0
SL439	64	0	0	0	0	77	0
SL463	64	0	0	0	0	172	0
SL486	64	0	0	0	0	504	1
SL768	64	0	0	0	0	92	0
OR697	64	0	0	0	0	65	0
OR627	64	0	0	0	0	99	0
OR251	64	0	0	0	0	259	0
OR173	512	0	0	0	2073	1541	9
OL054	1024	1	0	0	0	1050	9
NR116	64	0	0	0	0	2272	1
NR057	1024	9	6	7	39	6203	1389

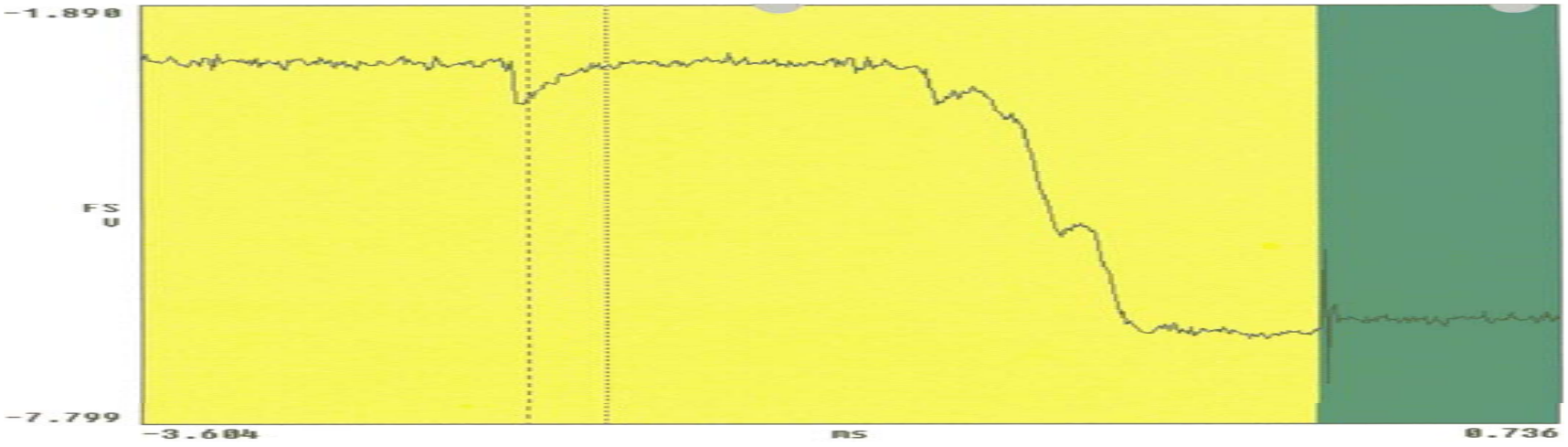
What happened during the 5 ms?

Transient-recorder outputs

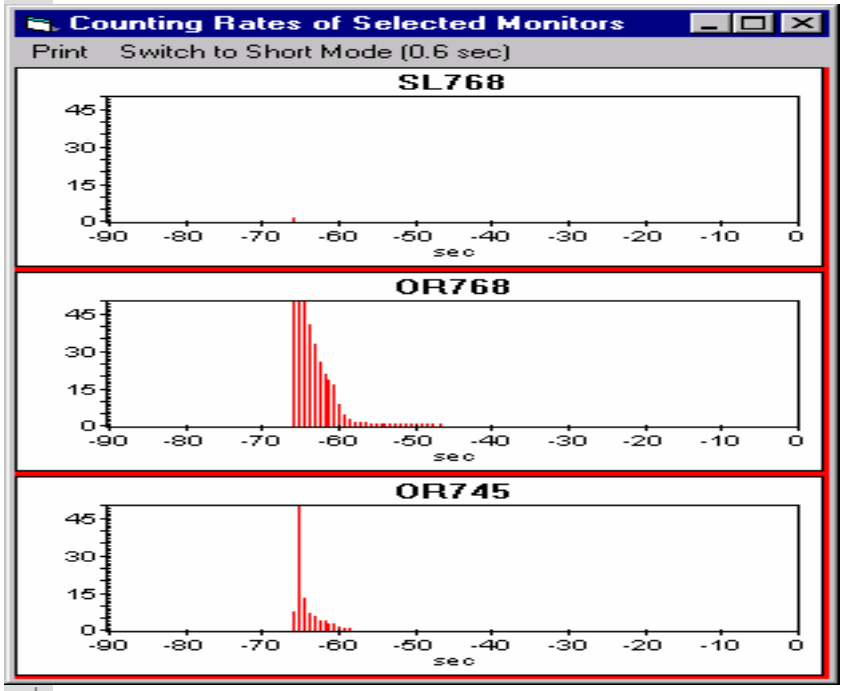
from two "**5 ms Quenches**" in 1996: Analog Output of a PIN Diode on the Main Collimator

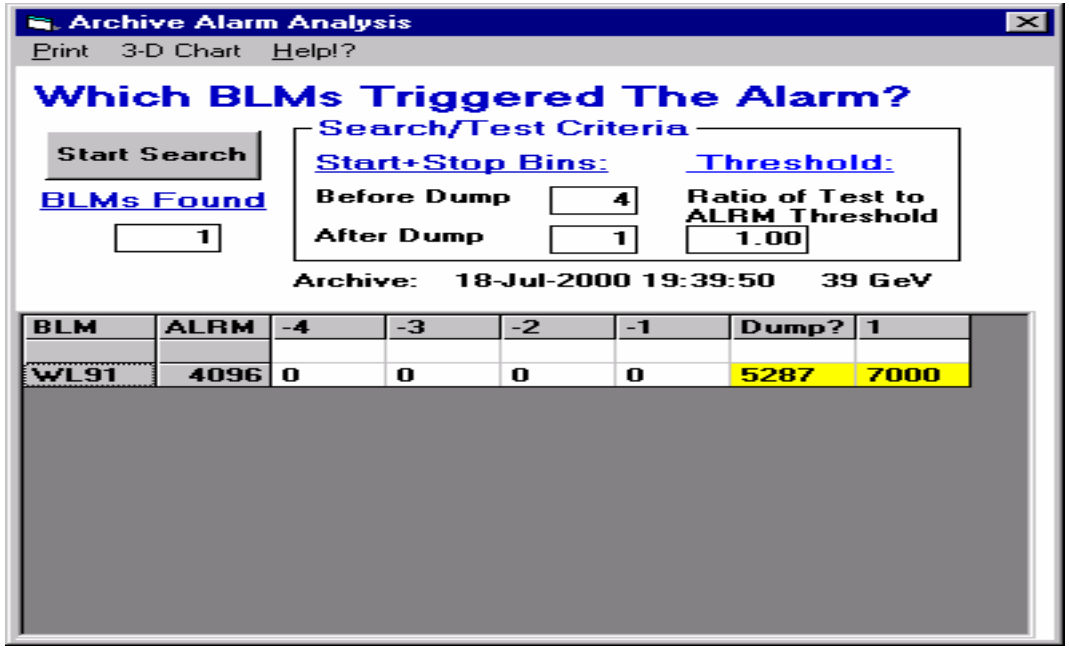


First spike: e-beam loss (?) [cursor Delta T: 0.2 ms]



Quench-alarm comes between beam transfers!





Losses observed **60 SECONDS** before the quench?

Beam-Transfer losses!!!

In the MIDDLE OF THE ARC???

A BUMP found its way into the Magnet-File

In the middle of the arc, NO BPM or LOSS MONITOR!