Measures Against Uncontrolled Proton Beam Losses in HERA

F. Willeke, MHE
11.12.2003

- Problem description
- Magnet power supply reliability
- Beam loss simulations
- Measures being taken: PS reliability, early alarms from ps, detection of beam loss and orbit
- Summary and out look
- Conclusions

Problem

If a power circuit of low-β quadrupole magnet power of the proton ring trips, beam losses occur before the safety systems can dump the beam

Reason:

- The beam loss set in 2-20ms after the trip
- The alarm signals are passed to the safety systems via a slow PLC or relays (>20ms delay)
- The beam loss monitors integrate for 5ms
- The signal processing time from the source to the dump is about 1 ms

Reason for recent frequent occurrences:

- The number of critical power supply circuit was increased from 6 to 14 after the luminosity upgrade
- Due to unforeseen technical problems during the last shutdown the set up time for the power supplies was reduced to a minimum in order to mitigate the impact on the schedule

Critical Power Circuits

Before the Upgrade: QS, QR Circuits in HERA E,N,S

After the Upgrade: QS, QR Circuit in HERA E

GM, GN, GA, GB, QR Circuits in HERA S,N

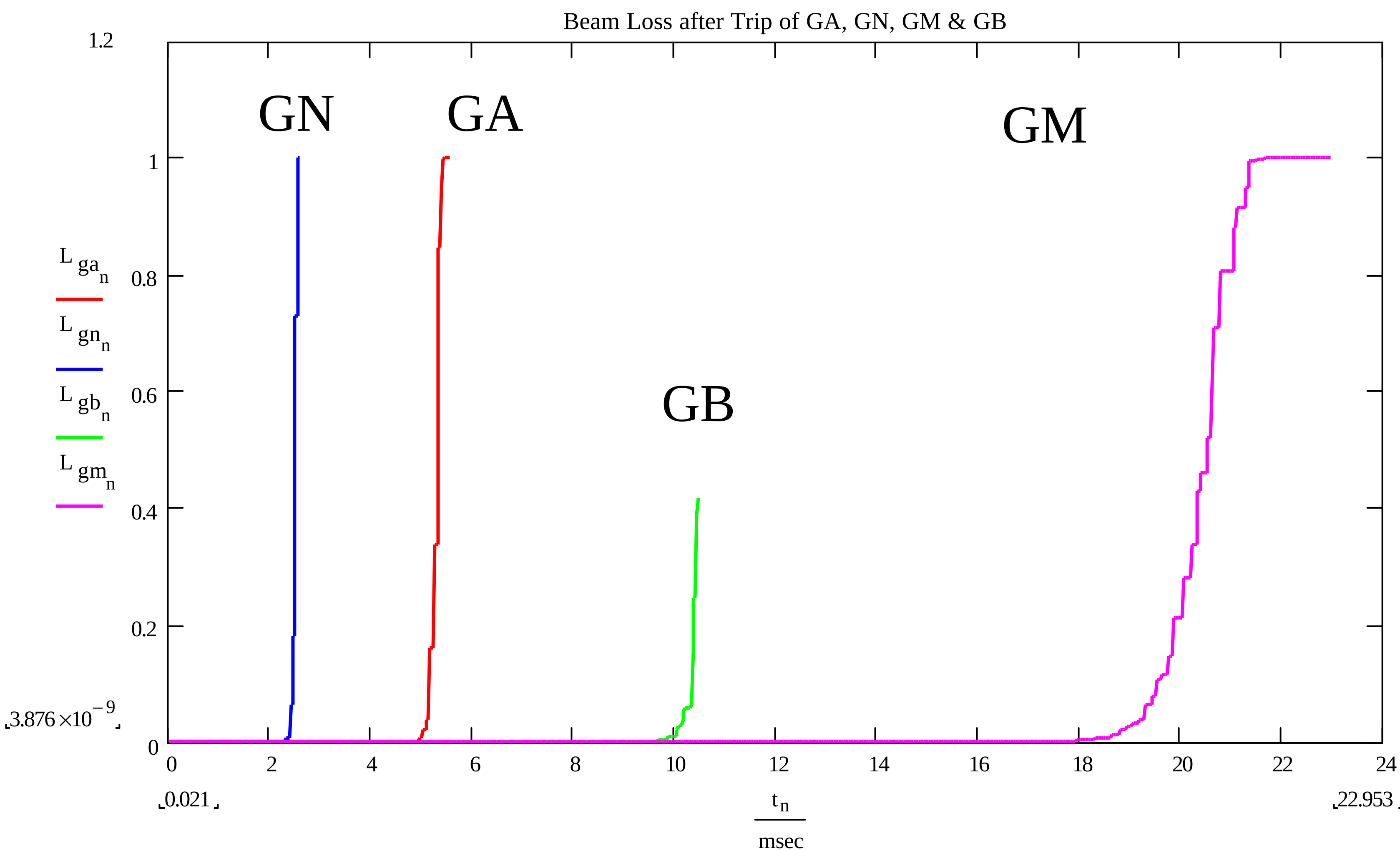
Power Circuit data **(Source W. Kook, MKK)**

Name	L/mH	R/mΩ	L/R/ms	MFBF/h*)	count	magnets
QS	1000	1446	691	10000	1	6 x QS+ 2 x QR
QR	1100	1223	899	10000	1	6 x QR
GM	400	387	1034	5000	2	4 x GM
GN	60	365	162	2104	2	6 x GN
GA	972	1854	524	6154	2	2 x GA + 4 x GB
GB	300	649	462	5000	2	2 x GB
QR10	400	868	460	5000	2	4 x QR
QR14	400	858	466	1818	2	4 x QR

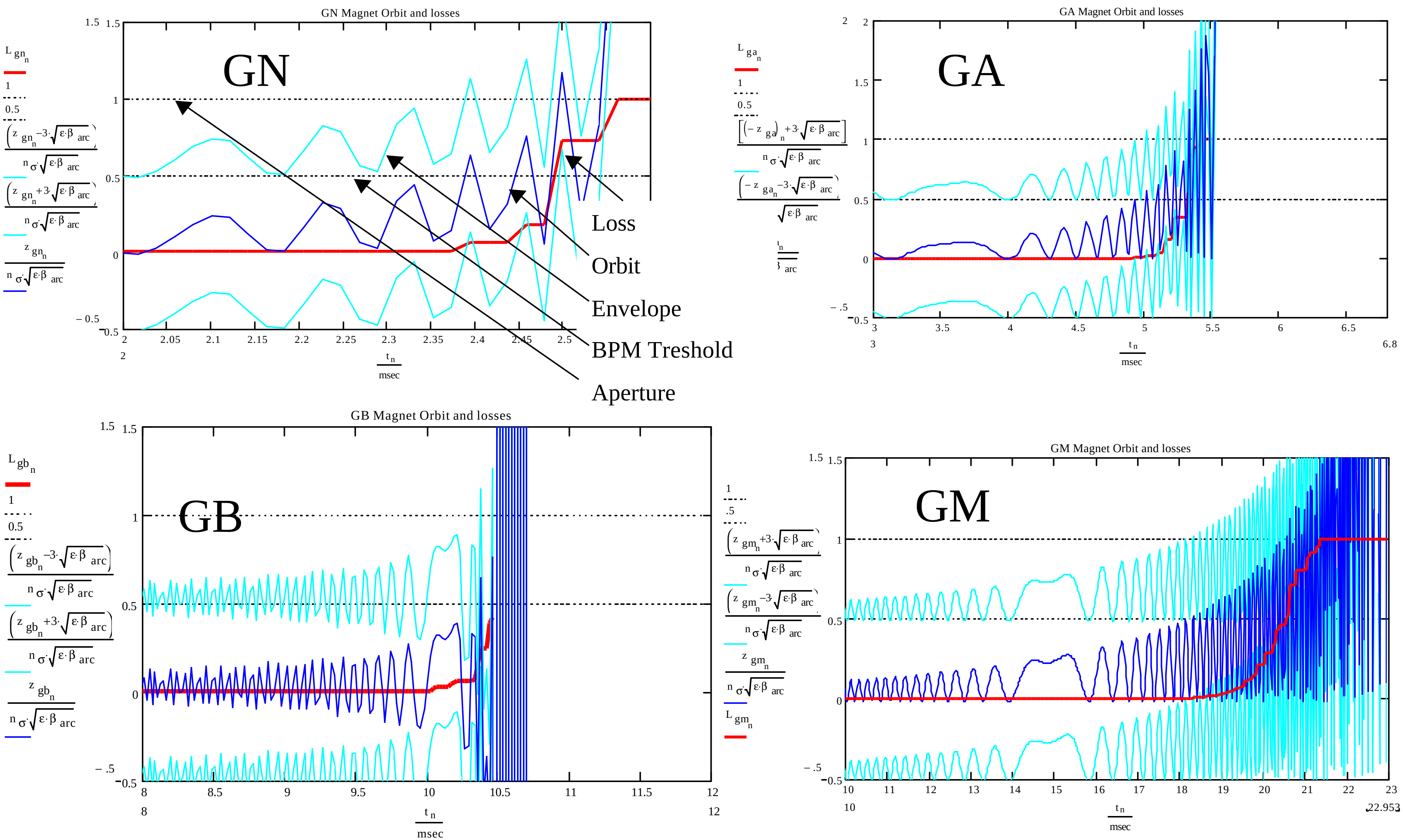
Total Trip Rate (*)averaged over Jan01-Nov03) : **1 / 265h ➔ 20 trips/year**

(vulnerable for 60% of the operation time of 300 days/year

Analysis of beam losses



Simulated Beam loss after trip for 6s aperture and 0.5 mm initial offset

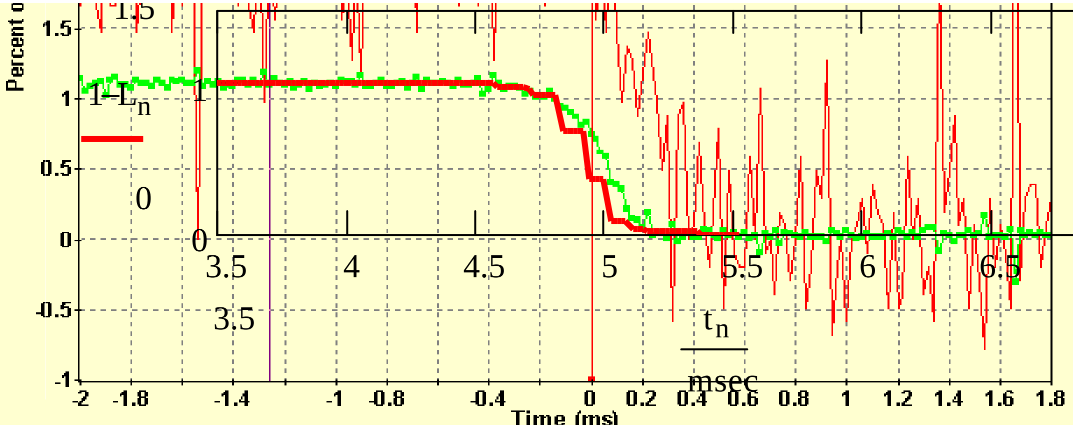


Measured and calculated loss after trip of GA

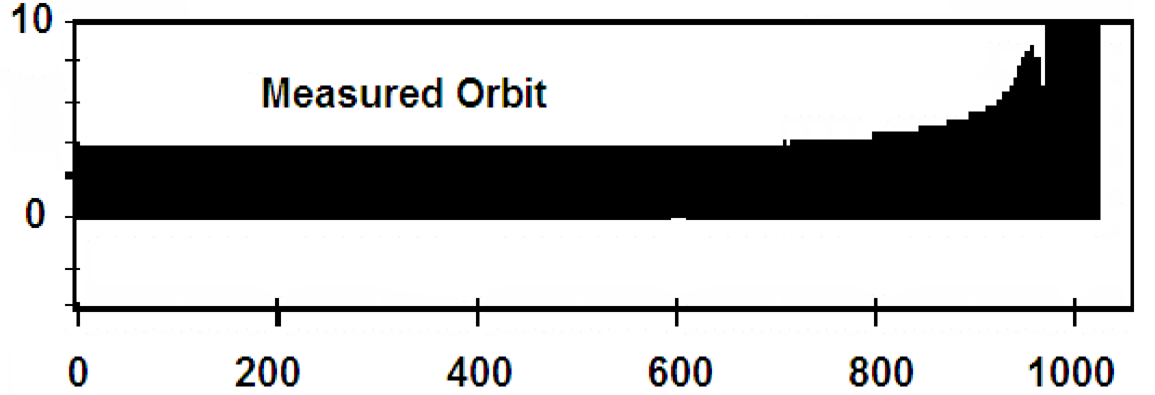
Green: Beam current monitor (Horn-type, sampled, ACCT)

Red: Calculations

Parameters assumed for calculation:
aperture limit at 7s,
initial orbit in magnets 0.3mm

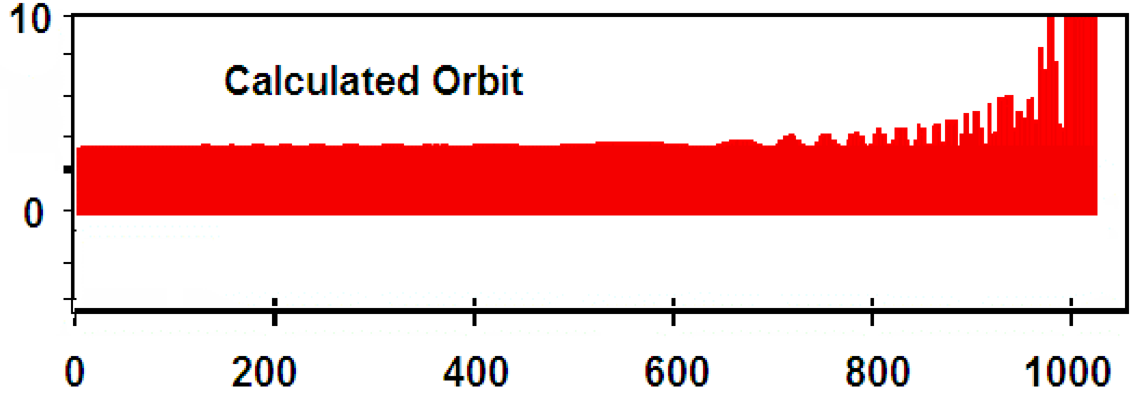


Comparison of measured and calculated beam loss after trip of GA circuit



Assumed initial offset

0.5mm

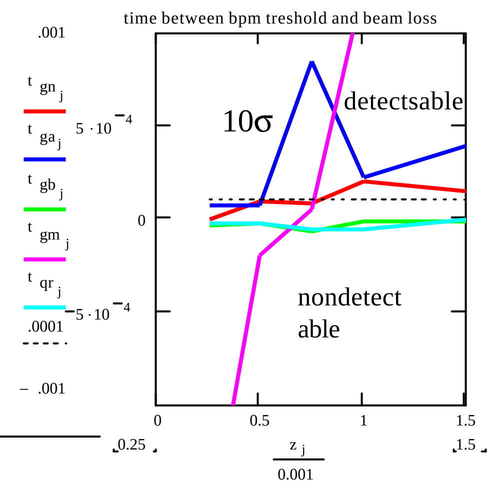


Synopsis Simulation

assuming BPM and BLM being complementary

BPM Alarms detectable 100µsec before loss

Z_{orb} [mm]	Trips detected	Probability
1.5	42%	42%
1.0	42%	22%
0.75	28%	15%
0.50	14%	17%
0.25	14%	4%



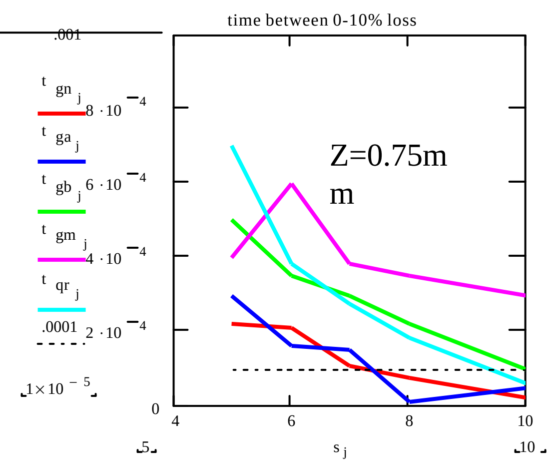
Threshold at 3mm

➔ 34 % of all trips detectable by BPM

BLM alarms detectable before loss >10%

a/σ	detected	P
10	28%	20%
8	43%	20%
7	100%	50%
6	100%	10%
5	100%	0%

➔ 75% of all trips detectable by BLM



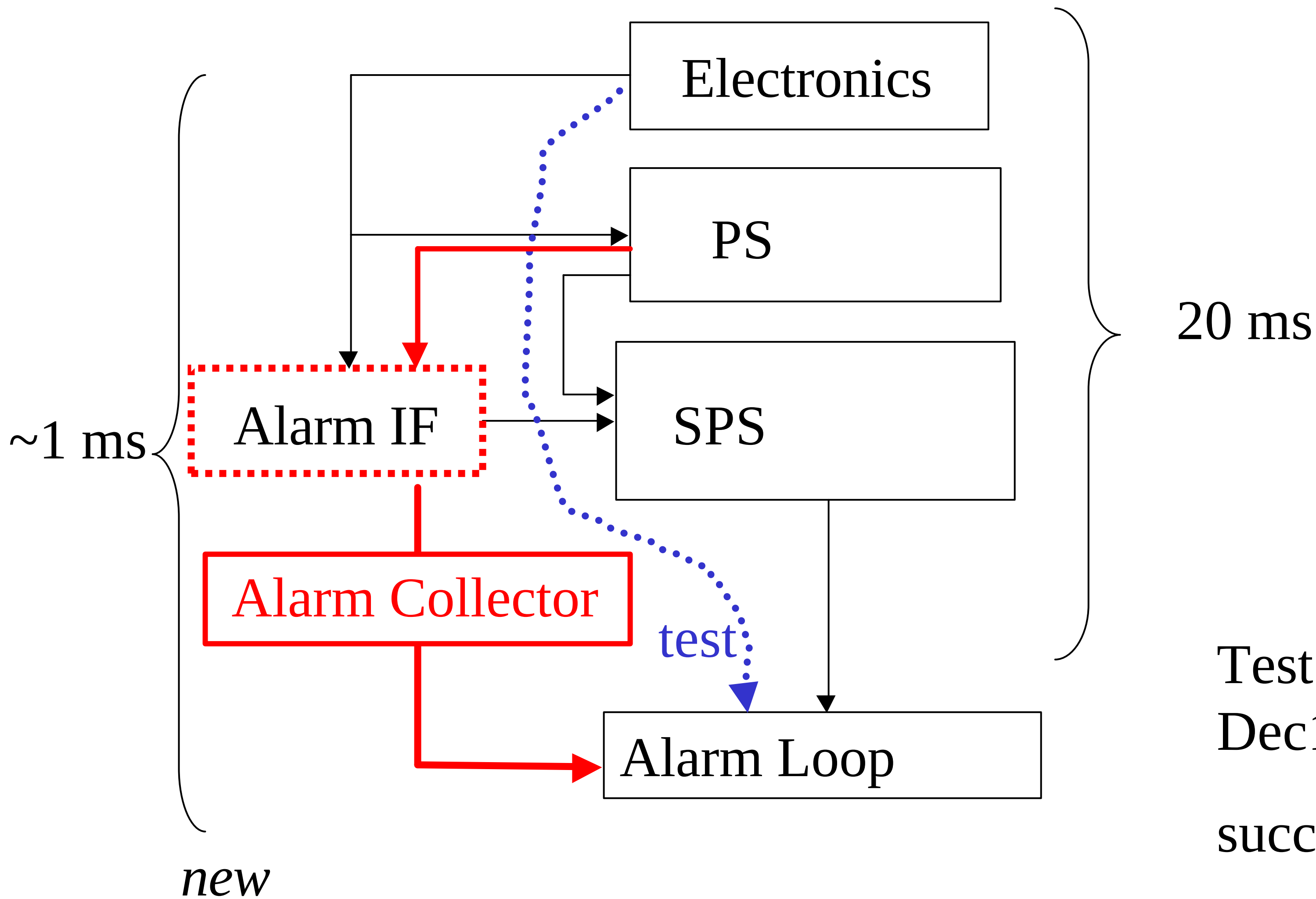
83% of all alarms detectable by combined BLM & BPM alarms

MKK Preventive Maintenance

- Checks 14 PS on maintenance days: mechanical anomalies, connections, measurement
- signals, sensitivity to mechanical tests (klopftests) done on Dec 4
- Check of water cooling system done on Dec 4
- Checks all ps after shutdown: mechanical abnormalities, connections, measurement-signals, sensitivity to mechanical tests (klopftests)
- Tightening screw terminal during upcoming maintenance days, repeat each shut down
- Check PS with infra-red camera once per year
- PS supply database will include data of failures, special incidents and activities
- Automatic redisplay of previous failures in case of a new failure at operator console
- Weekly checks of unusual noise, appearance by shift crew
- More time for maintenance after maintenance days and shut down needed!
- Logging of magnet PS performance data (voltages, etc) for early recognition of anomalies
- ALL Power supply regulations checked once per
- Regular checks of PSC by the service
- Improvements of PS regulation to reduce sensitivity to
- Prevent repeated resets without checks

Faster Power Supply Alarms

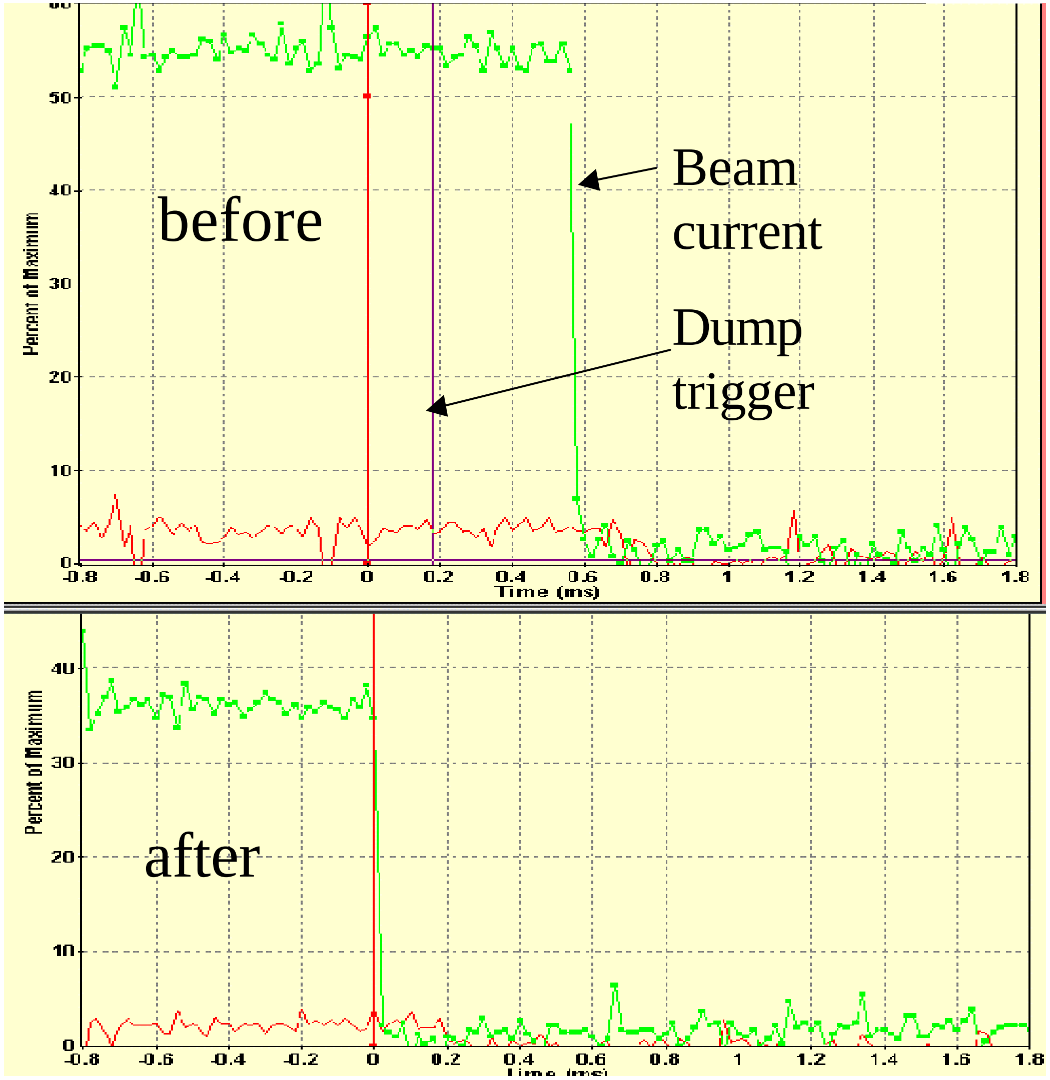
PS Alarm Paths



Test on Dec15

successful

Faster Dump by replacing slow electronics



Achieved by faster opto-coupler

Test of BPM Alarms

Thursday, Nov27, 2003

Test with 2mA Protons in 10 bunches at 920Gev using Luminosity Optics

Method: Switch of the GA-Power supply in HERA North (turning of pulse-control)

In each Quadrant 8 consecutive BPM's in both planes (hor. & vert.) activated

Test 1: 'Alarm Threshold 57 bit @ +6.5mm, -3.8mm

Test 2: 'Alarm Threshold 37 bit @ +3.5mm, -2.1mm

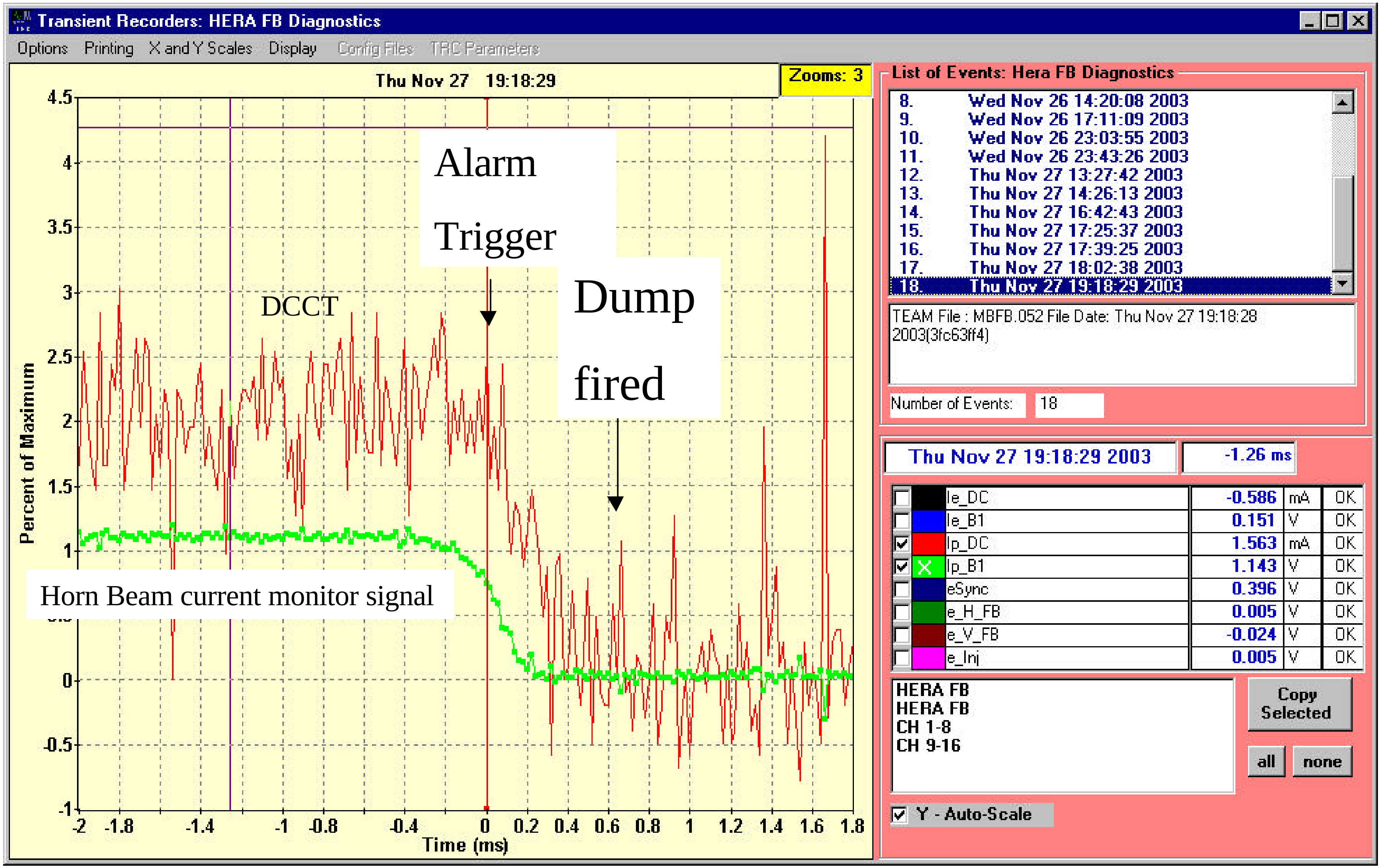
Orbit values in low β-Quadrupoles North: x = 2..4 mm

y = 1…3 mm

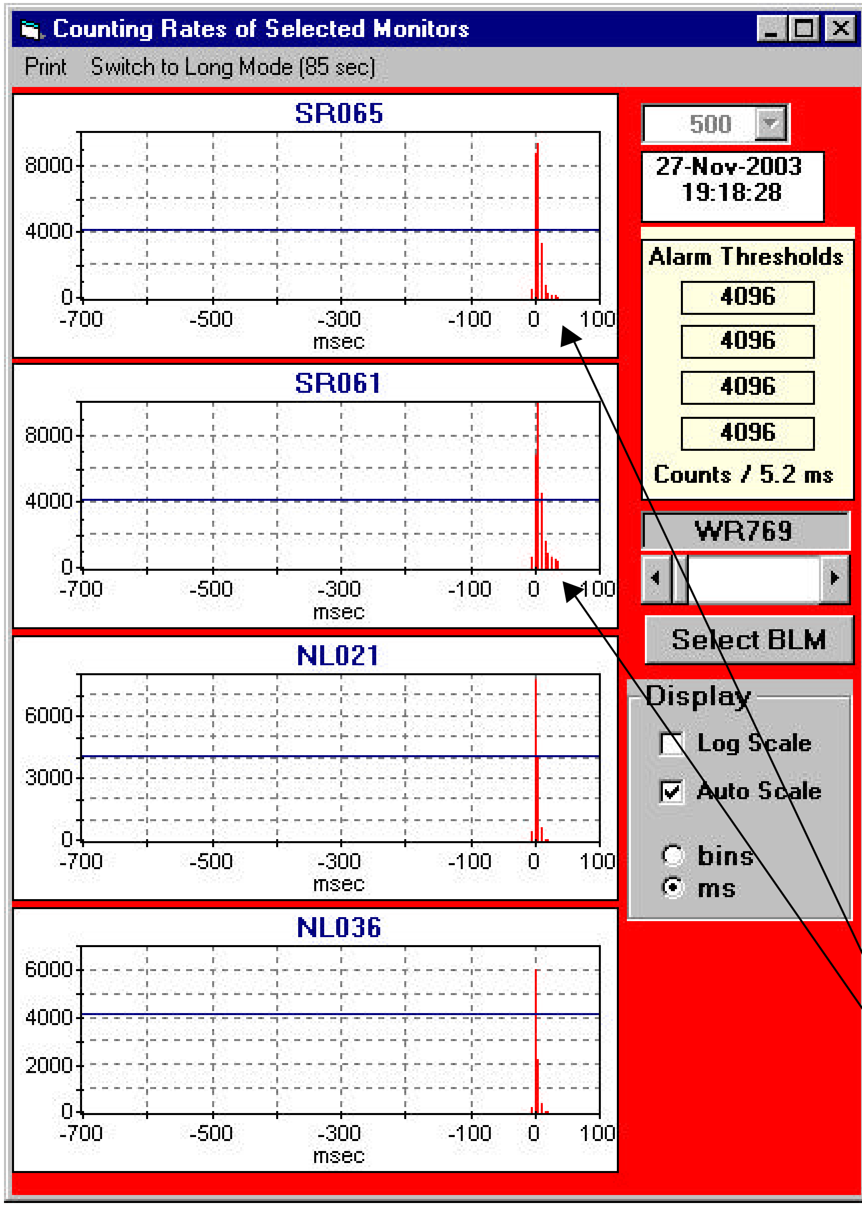
➔ kick ~0.1mr for 100% reduction in Magnet current @ 33mm orbit in the arc, 5mm orbit after 14% decay of magnet current

1st Test: Threshold at 6.5mm,-3.8mm : HERA-p Beam Current

red: DCCT, Green: Horn Monitor



1st Test



Archive Alarm Analysis

Print 3-D Chart Error List Help!?

Which BLMs Triggered The Alarm?

Start Search

BLMs Found: 19

Search/Test Criteria

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

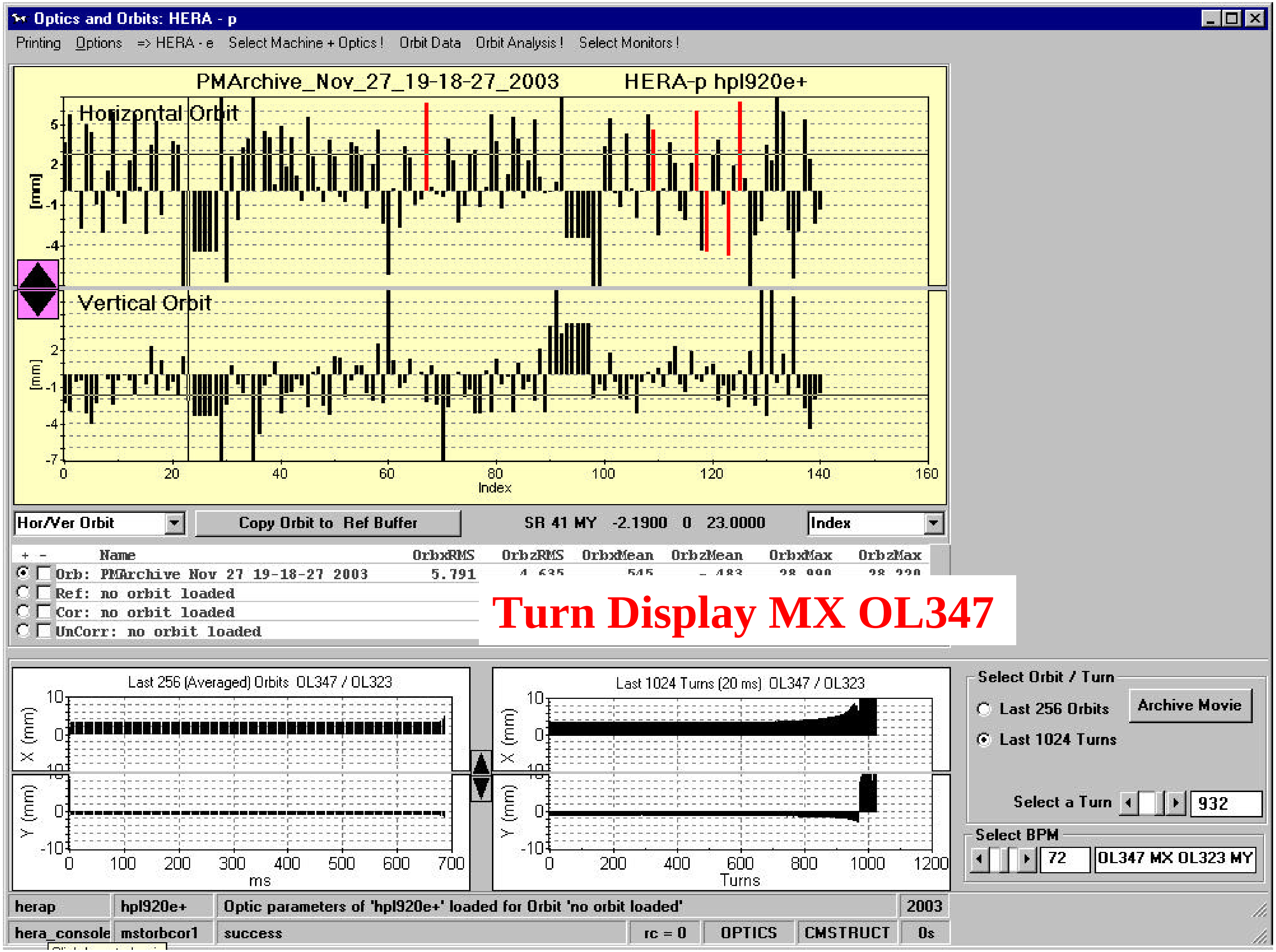
Threshold: Ratio of Test to ALRM Threshold 1.00

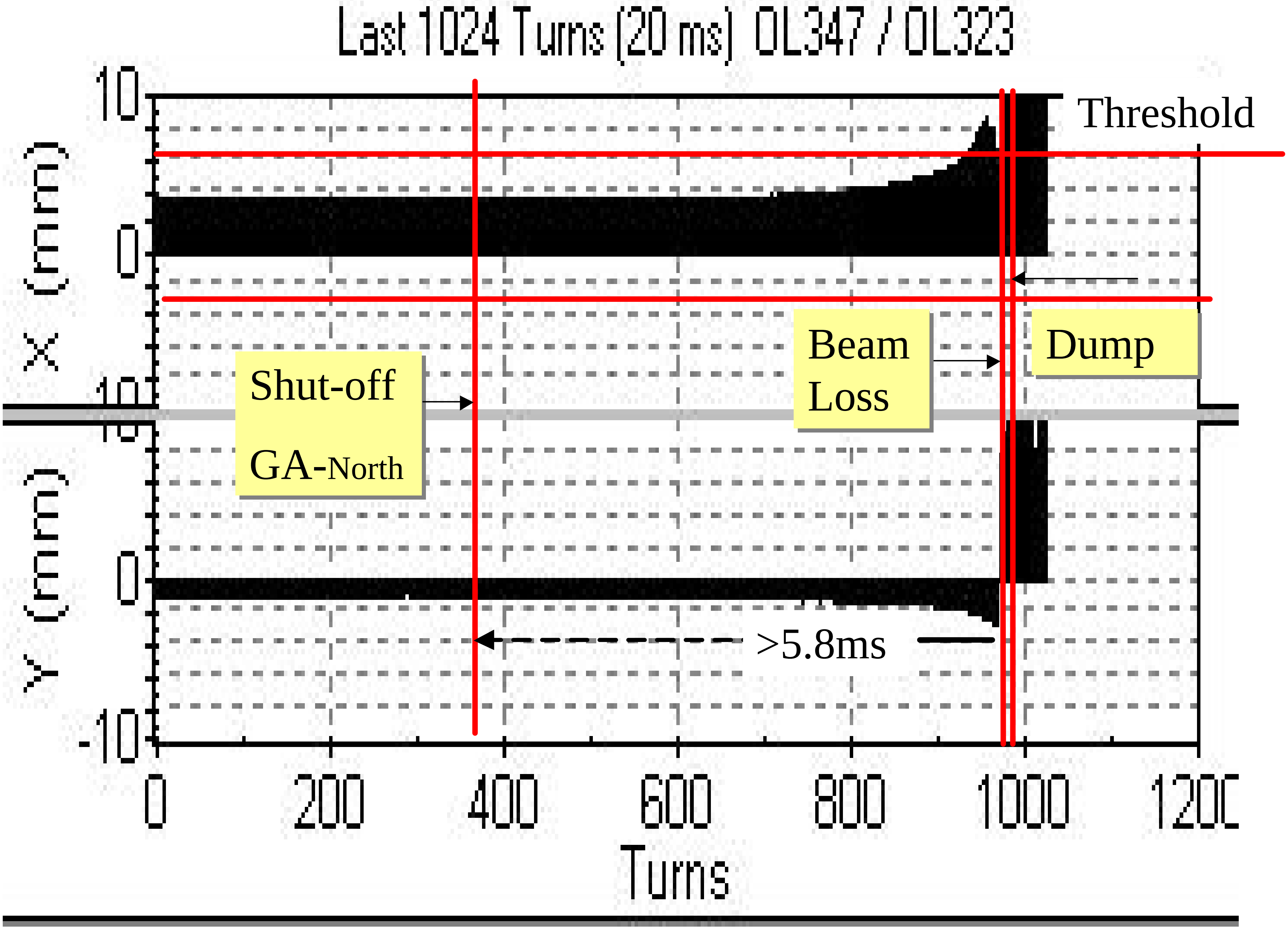
Archive: 27-Nov-2003 19:18:28 920 GeV

BLM	ALRM	-4	-3	-2	-1	Dump?	1
WR604	128	0	0	0	0	148	0
WR322	128	0	0	0	0	155	4
SR065	4096	0	0	0	548	8786	9385
SR061	4096	0	0	0	736	6868	1000[illegible]
SR048	4096	0	0	0	49	3759	9184
SR036	4096	0	0	0	0	2805	1057[illegible]
SR021	4096	0	0	0	0	3087	8973
SL021	4096	0	0	0	0	278	5572
SL274	128	0	0	0	0	261	23
SL369	128	0	0	0	9	149	0
NR061	4096	0	0	0	0	742	5033
NR021	4096	0	0	0	272	5071	1245
NL015	4096	0	0	0	137	3974	5480
NL021	4096	0	0	0	517	7788	4162
NL036	4096	0	0	0	295	6107	2278
NL274	128	0	0	0	0	171	10

Dirty dump with activations

Beam Orbit Summary immediately before Dump

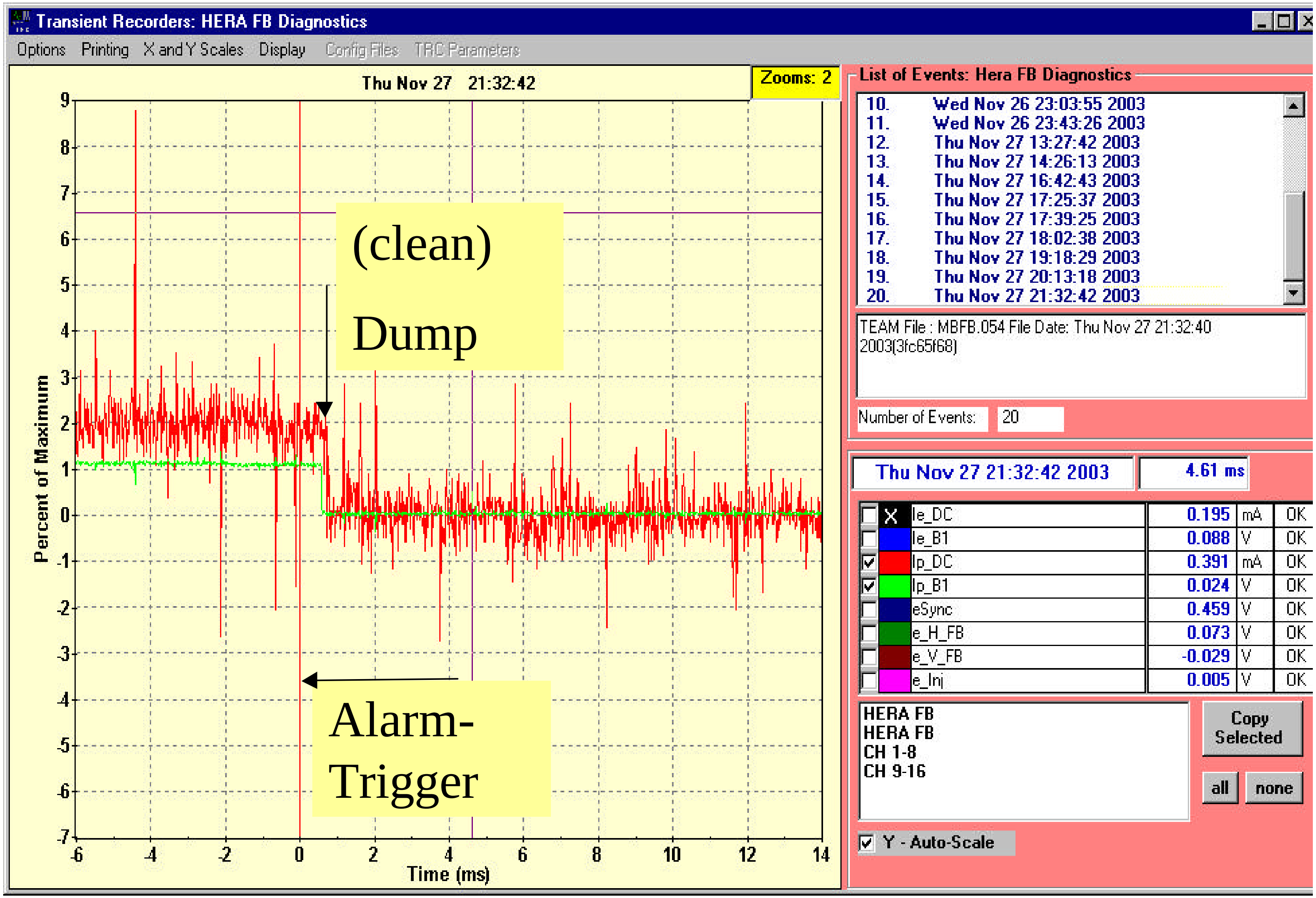


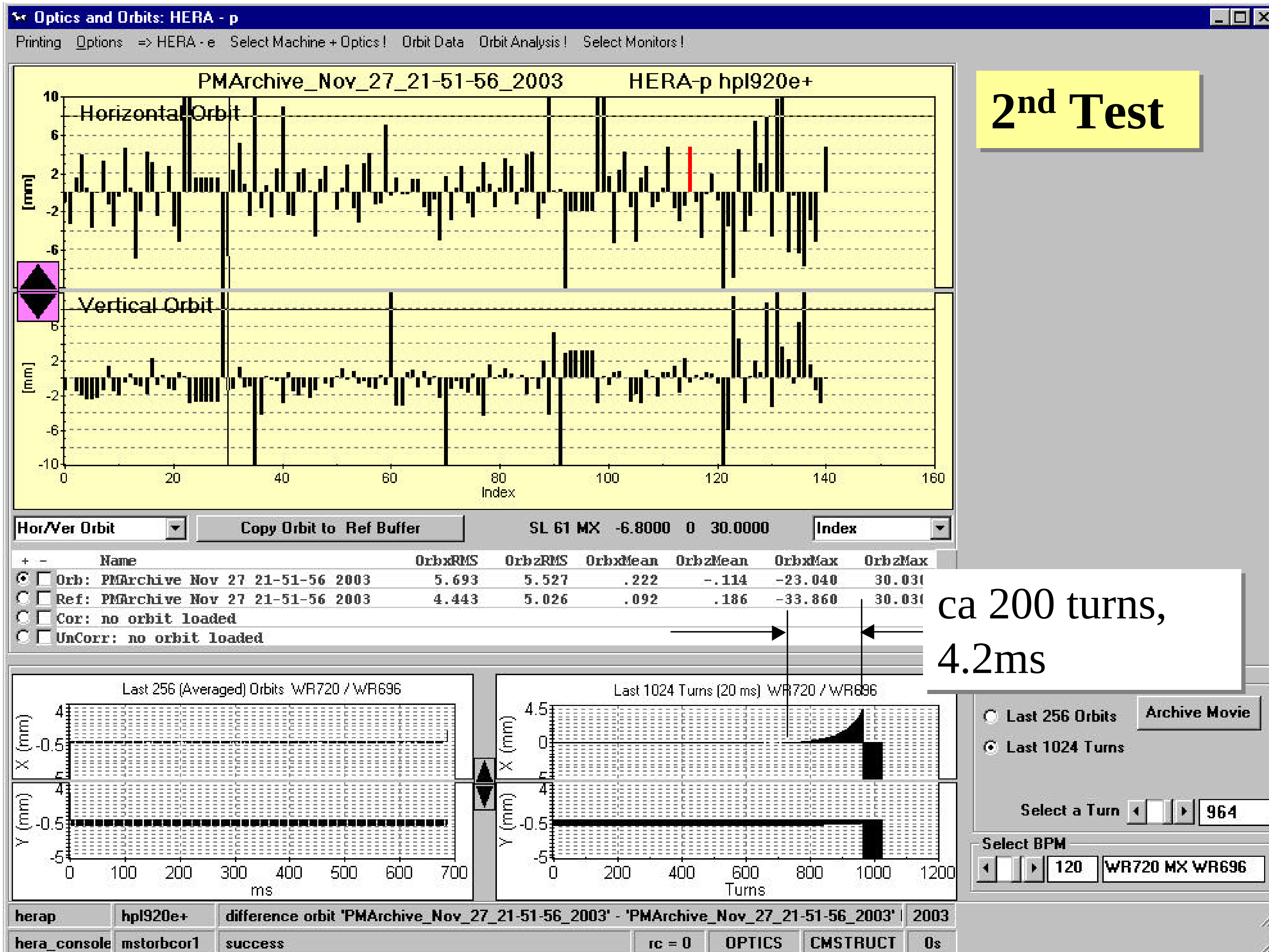


Last 1024 Turns (20 ms) OL347 / OL323
Threshold
Shut-off
GA-North
Beam Loss
Dump
>5.8ms
x (mm)
y (mm)
10
0
-10
0
200
400
600
800
1000
1200
Turns

2nd Test Threshold at 3mm,-2mm : HERA-p Beam Current

red: DCCT, Green: Horn Monitor




Optics and Orbits: HERA - p
Printing Options => HERA - e Select Machine + Optics ! Orbit Data Orbit Analysis ! Select Monitors !
PMArchive_Nov_27_21-51-56_2003 HERA-p hpl920e+
Horizontal Orbit
Vertical Orbit
[mm]
Index
2nd Test
Hor/Ver Orbit
Copy Orbit to Ref Buffer
SL 61 MX -6.8000 0 30.0000
Index
Name OrbxRMS OrbzRMS OrbxMean OrbzMean OrbxMax OrbzMax
Orb: PMArchive Nov 27 21-51-56 2003 5.693 5.527 .222 -.114 -23.040 30.03
Ref: PMArchive Nov 27 21-51-56 2003 4.443 5.026 .092 .186 -33.860 30.03
Cor: no orbit loaded
UnCorr: no orbit loaded
ca 200 turns, 4.2ms
Last 256 (Averaged) Orbits WR720 / WR696
Last 1024 Turns (20 ms) WR720 / WR696
X (mm)
Y (mm)
ms
Turns
Last 256 Orbits
Archive Movie
Last 1024 Turns
Select a Turn 964
Select BPM
120 WR720 MX WR696
herap hpl920e+ difference orbit 'PMArchive_Nov_27_21-51-56_2003' - 'PMArchive_Nov_27_21-51-56_2003' 2003
hera_console mstorbcor1 success rc = 0 OPTICS CMSTRUCT 0s

Fast Magnet Current Decay Alarm

Idea:

Measure PS voltage (expect large change in cae of a trip, large signal)
generate quasi-current decay signal by using an equivalent circuit
To replace the current decay measurement (small signals, large errors)

Status
:electronics design in progress
Electronics prototype in progress
First tests in January
Ready in February

Fast Beam Current Decay Monitors

Two versions:

ACCT monitor based (M. Werner)

Existing monitor for beam loss trigger system used

Has been observed for 2 weeks: no false alarms

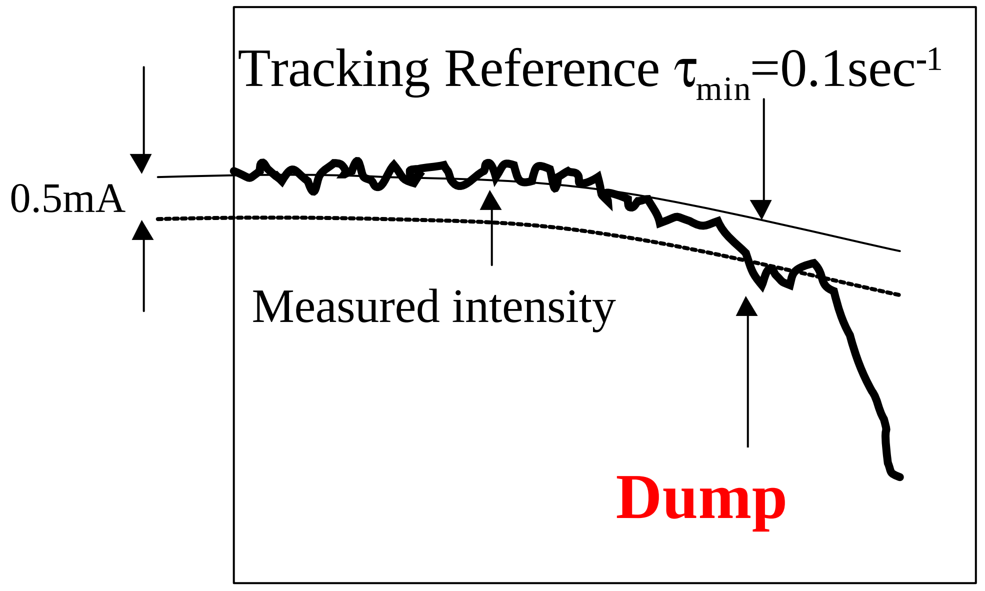
Monitor being tested in hall West

Expected to be available by Dec 17

DCCT Monitor based

(M. Wendt, J. Lund-Nielsen)

Tests in preparation



Measures Taken to avoid Uncontrolled Beam Loss

Measure	Status	Reduct. Incidents	available	comments
Preventive maintenance of PS	started, in progress	**2**	now	no trip for 1000h
Delay PS shut-off at failure	done	1.	now	5% of trips av.
Fast PS alarms bypassing plc	test in progress	4	Jan-Febr 04	
PS Current Decay Alarm	in preparation	2	Febr 04	
Speed up alarm loop 200µs	test in progress		Febr 04	
dump trigger 600→30ms	done		now	
Enable&integrate BPM alarm	**test done, integration in progr**.	**3***2	**Dec18/ Jan** 04	
Beam Current Loss alarm	**test in progress, enabled Dec 15**		Dec 18	
Fast Scintillator BLM HERA N	in preparation		March 04	
Shorter Integration time of BLM	canceled			
TTF- type beam loss monitors	canceled			
Collimators closer to the beam	preparations in progress	**1.2**	Dec 18	
Additional shielding N, S, E, W	under investigation	?	Nov 04	

Previous incident rate: **20 events / year**

Estimated incident rate per Dec 17 **3 events / year**

Estimated rate for Nov4 events (coll. Open) **1.5 event / year**

Estimated final incident rate 0.2 events / year

Conclusion

Incident rate of uncontrolled beam losses of protons increased by increased number of critical circuits, new power supplies and limited time allocated for maintenance

Reasons for these losses are well understood

Efforts are being made to avoid trips of the low beta quadrupole by an aggressive preventive maintenance program

Beam losses can be modeled and are in reasonable agreement with measurements.

Modeling of losses suggest that uncontrolled beam losses are best avoided by fast alarms of the power supply ➔ highest priority

Signals from beam measurements (BPMs, BLM) will provide additional safety in conjunction with the now speeded-up dump and alarm system.

Tight Collimator settings will help to get early beam loss signals

Additional shielding should help to reduce radiation dose in case an event occurs despite all efforts

➔ Propose to return to high intensity protons by Dec 17