RHIC beam-dump (*problem*)

Dumping a 250GeV high intensity proton beam quenches magnets downstream of the dump absorber.

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describe the problem:

- RHIC dump geometry
- Sooner or later as we raise the energy and intensity, protons will “routinely” quench downstream magnets (Q4)... apparently now.
- Should this be a surprise? (no)
- is this really something else going on? (no evidence)
- what (if anything) we are doing about it.

Start of the internal dump: the beam dies between the rings, and just upstream of the beam's Q4 magnet – not enough longitudinal space (kicker to absorber) to get significantly away from the beam pipe with reasonable kickers. The "hole" in the absorber (aka the beam pipe) provides secondaries created in the absorber with a low material path downstream.

figure from Alan Stevens" tech note Erwin Rogers sketch)(see below)

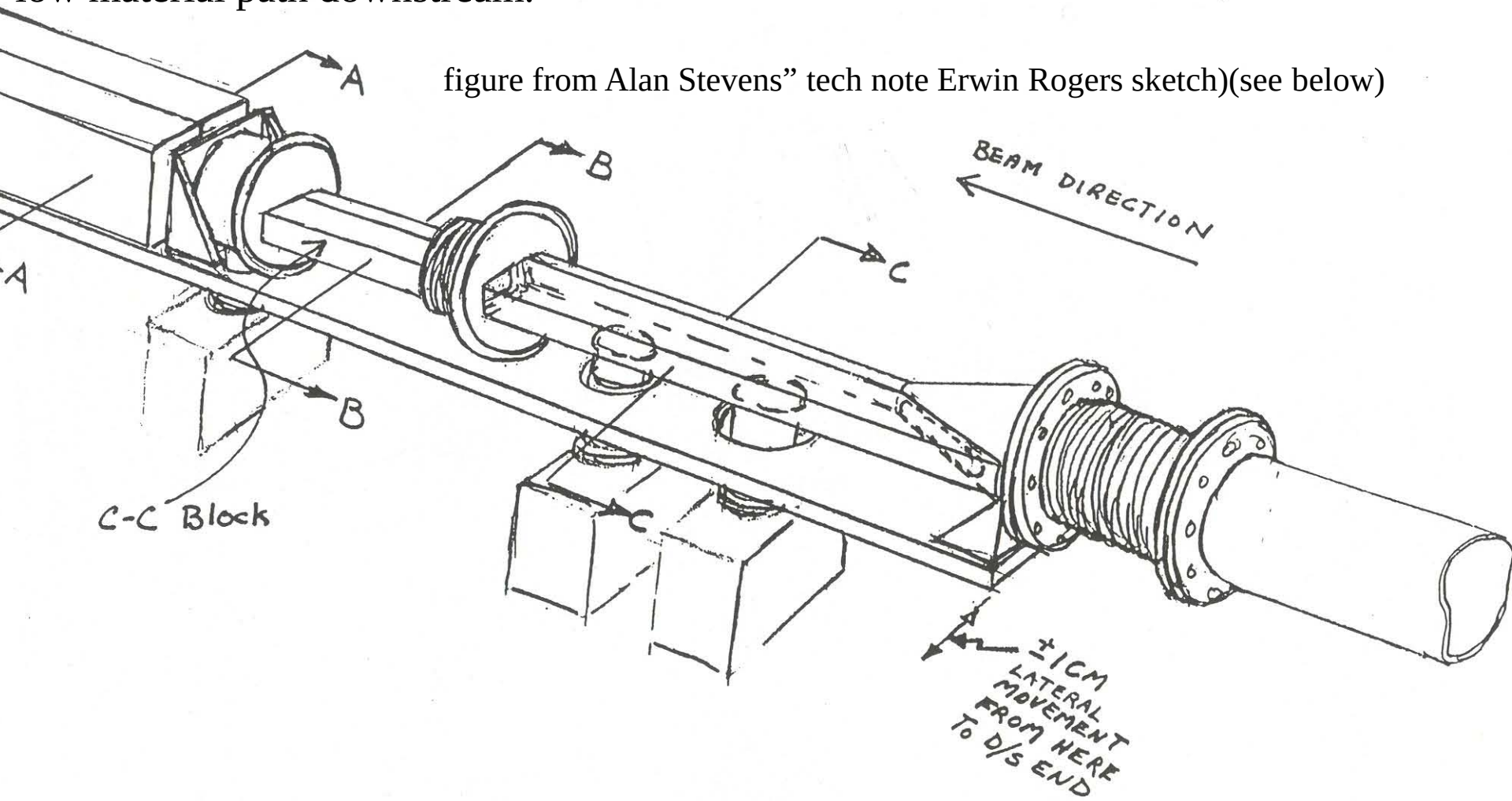
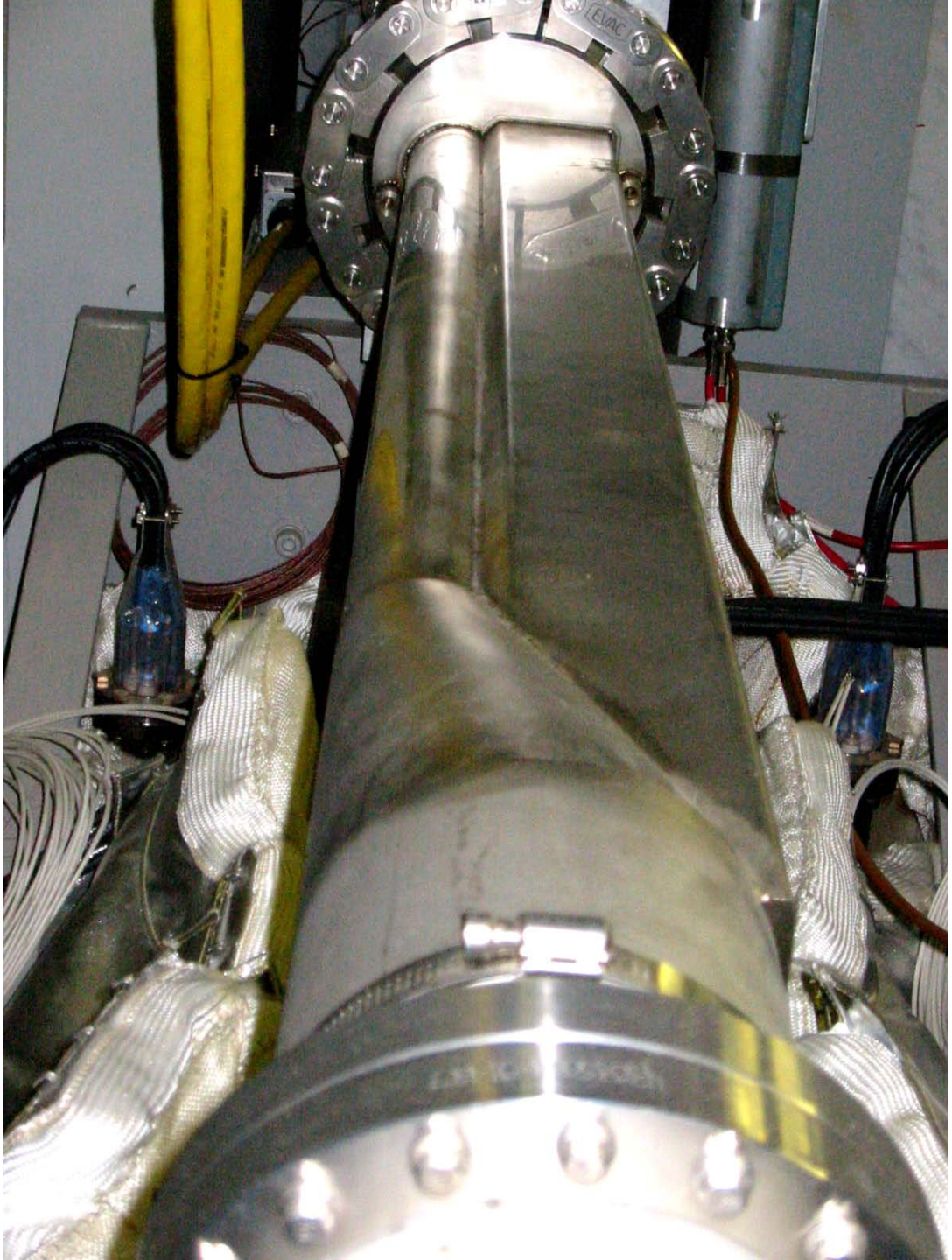


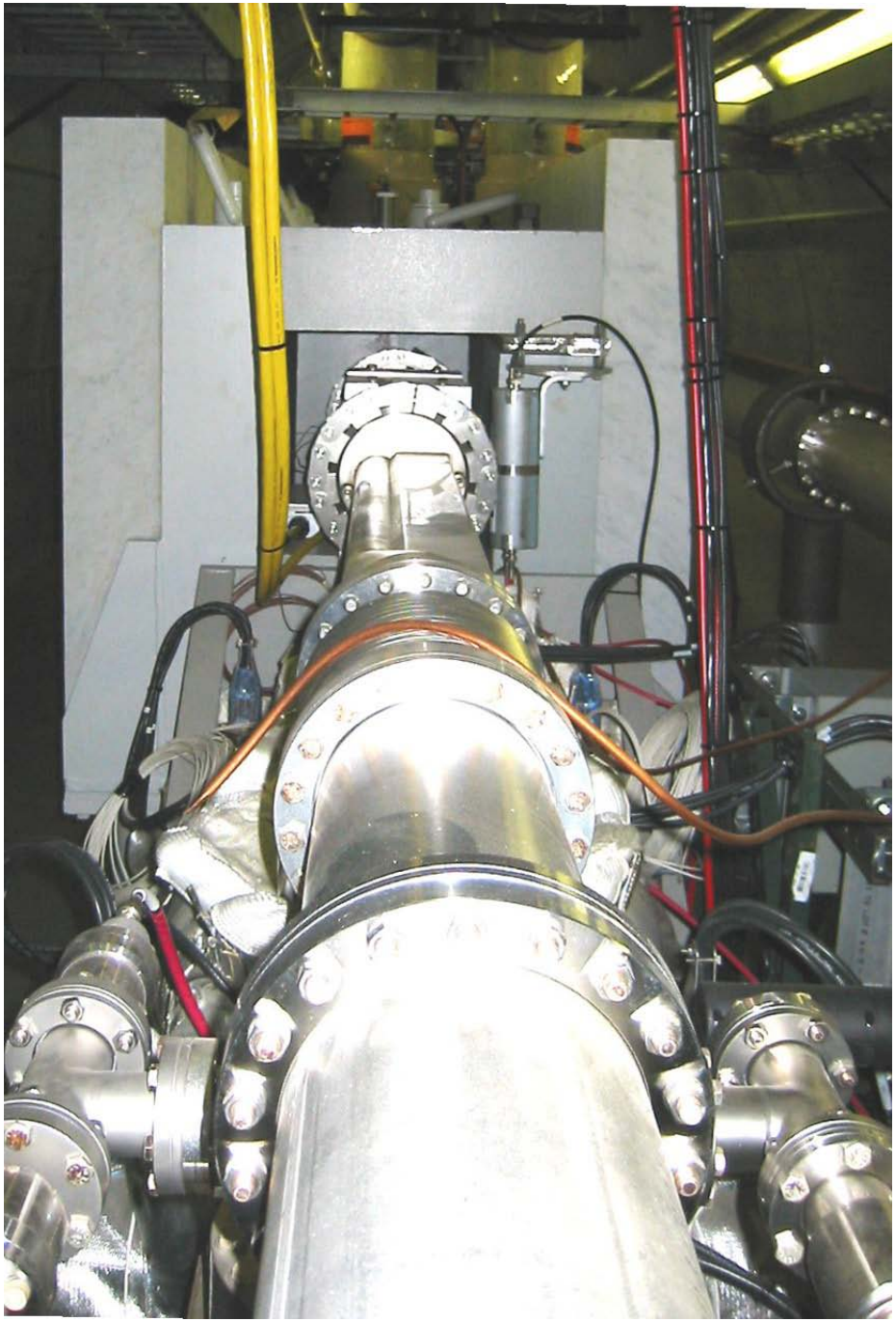
Fig. 1 Preliminary Engineering Sketch of the Dump Region Near its Upstream End. The "dump core" (see Ref [2]) has some lateral adjustment as shown. The "boxes" below the beam pipe indicate vacuum pumps. In the design studied, the most downstream

implementation in Blue ring.

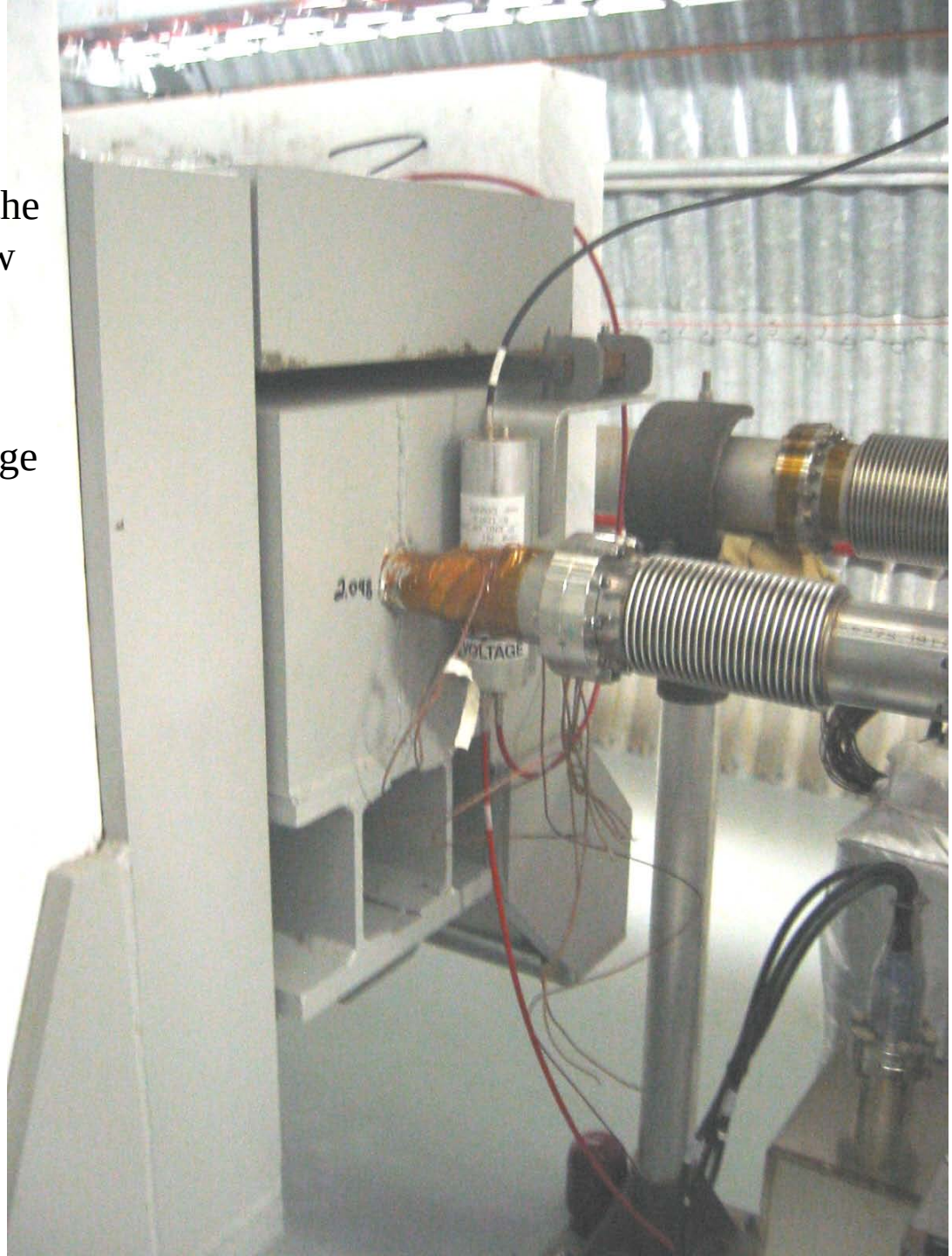
The circulating beam is in the tube on the left (also beam left)



Same but stepping upstream a bit. (The blue beam is going away from us, yellow just visible to right)



the problem end: looking at the downstream end of the yellow dump. Yellow beam travels to the right. The first superconducting magnet is just off edge of the picture.



During late March and early April it was observed that permit pulls (due to beam losses) consistently resulted in magnet quenches with the magnets downstream of the dumps involved.

Further this behavior correlated with highest intensities and occurred in both rings (though more often in Yellow than Blue).

Some confusion from reported quenching magnets: in yellow: y9-Q6 and in blue b10-Q4. We learned from Don Bruno that (Q4,5,and 6) share a common voltage tap, and the reporting is frugal – and in this case misleading to one without this inside knowledge (can we fix this?) So observations are consistent with Q4 always being the magnet suffering.

Immediate response: increase kick strength to normal max (had reduced due to prefires).

Widen abort gap (make timing less critical)

Shift widened abort gap to remove the two weakest kicks.

Apparently these changes did not eliminated the problem, but the experiment ended.

spreadsheet with some numbers associated with the quenches

intensities associated with quencher: yellow 121e11 blue 128e11. Also here loss monitor responses for monitors downstream of the dumps and some information about how the beam was lost.

			yellow			blue				permit	quench		
date	time	energy	intensity	g9-lm5	g9-lm6	intensity	g10-lm5	g10-lm6					
29-Mar-09	743		114	14000	2780	113	13000	2860			yellow Y9Q6		
30-Mar-09	800		109	13700	2700	74	10000	1900		9 o'clock snake	yellow Y9Q6		
31-Mar-09	542		87			78				9 o'clock snake	none	gap widened 2 bunches, ramp early	
31-Mar-09	1943		78	10900	2480	97	12000	2480		9 o'clock snake	none		one bunch
3-Apr-09	605		76	10600	1930	106	12700	2650		9 o'clock snake	none		
3-Apr-09	746		117	2580	380	115	7550	1820		early in ramp?			
6-Apr-09	647	250	85	11500	2200	105	12800	2700	?	9 o'clock snake	none		
6-Apr-09	807	242	118	14100	2800	124	13800	3000		9 o'clock snake	none	4th stone from end of ramp	
6-Apr-09	918	242	121	14350	2850	132	14400	3200			yellow Y9Q6	4th+ stone from end of ramp	
6-Apr-09	1115	250	116	14200	2830	128	14350	3200			yellow Y9Q6	blue B10Q4	3rd+ stone from end
												ramp shifted early the second bunch	
6-Apr-09	1545		103	13100	2560	117	13500	2960					
7-Apr-09	1102		80	11100	2100	103	12660	2650		9 o'clock snake	none	(probably)	endOfStore
7-Apr-09	1218		119	14100	2825	125	13800	3030		5e-ps2llm	none	4th stone from end of ramp	
9-Apr-09	809		80	10900	2050	109	12900	2760			mains		essentially end of store
											snake would have pulled but "quench" already had.		

The idea behind these configuration changes was that a stronger kick will increase the intensity "head room" before quenching by moving the beam transversely away from the beam pipe.

Aside from the timing shift (can gain no more that way) we can: increase the voltage (trivial to turn up the wick but probably increases the number of prefires – any further development here?)

Other changes are much more expensive:

add another kicker module

add more shielding one way or another

redo the abort to morph from an internal dump into an external dump (new Q4 with a hole for the aborting beam, and a downstream septum to bend away).

The results from previous simulation of the dumping:

(AD/RHIC/RD-97 Energy Deposition Downstream of the Internal Dump A.J.Stevens Dec 1995)

Alan's conclusions (a bit of which are shown on the next slide) were that we had maybe x2 headroom before routinely quenching with 57 1e11 protons at 250GeV, (and with an uncertainty in the calculation of a factor of 2).

Our intensities exceeded the headroom factor of two. Maybe his estimate was spot on.

quench at 2mJ/g

With these modest enhancements, the energy density values, converted to mJ/g at design intensity, is shown in Table 3 below.

Table 3 Maximum Energy Densities in mJ/g at Design Intensity

Geometry	Trim Coil	Main Coil
1.25 mm pipe	2.00 ± 0.27	1.01 ± 0.19
3.00 mm pipe	0.78 ± 0.13	0.40 ± 0.11

The errors in Table 3 are simply the estimate of statistical error from Fig. 4; no error on the enhancement factors is included.

IV. Discussion of Results

The thicker beam pipe appears to offer a significant improvement, and should be implemented if possible. The most difficult problem in calculations such as those described here is evaluating the systematic error. The primary sources for such error are believed to be inaccuracy in the physics simulation in CASIM and inadequate representation of the details of the geometry. An attempt has been made to minimize the latter by simulating the current engineering implementation of the dump design. Based on primarily FNAL experience, a factor of 2 to 3 is considered to be reasonable agreement between CASIM predictions and observations in a geometry as complicated as that considered here. The thick beam pipe geometry gives a safety factor somewhat greater than this for the main coil in this worst-case situation.[7] Although not explicitly discussed in this note, the energy density is very sensitive to the transverse displacement on the C-C block achieved by the kickers,[1] so that meeting the kicker specification is critically important.

email from Alan Stevens to Ahrens and Kin Yip, 18Nov03

In addition to (vaguely) remembering the calculation, I remember some 'what if' discussions with Mike Harrison. Given a large systematic error, as well as - at the time - an imperfect (to say the least) knowledge of what the distribution of bunches on the face of the dump would actually be, it seemed sensible to wait and see when (or if) we actually got into trouble, i.e., at what intensity would Q4 routinely quench on a beam abort. Among the possible solutions to this would be (a) [perhaps] an improved kicker, since escaping energy is very sensitive to the distribution on the face of the dump, (b) a thicker beam pipe (as you mentioned), and (c) a custom version of Q4, which has a lead liner. Any of these were believed to be capable of 'buying' a factor of 3 or so tolerance.

One reason for waiting was that at the time of the design, it was believed that it might be very desirable (at a cost of approximately $10M) to have an external dump. This was to be achieved by replacing the Q4 (and Q5?) region with a special cryostat configuration (an extraction 'hole' thru the cryostat) and adding an extraction septum downstream of the kickers. There is an inherent problem with the internal dump. For it to survive, carbon is needed in the beginning. But the presence of carbon makes it easy for energy to escape in the beam channel and therefore to affect downstream magnets. This inherent problem surely sets a limit somewhere.

cheers - Alan

What are we doing?

Alan Stevens pointed toward a strong sensitivity in the robustness against quenching to the transverse distance of impact at the face of the dump. Kin Yip is overseeing a revisit to the work done by Alan to get a quantitative prediction for what there is to be gained going this way – increasing the distance from the circulating beam of the initial impact on the fact of the C-C absorber.

Answering for example the questions how much would running at 30kV – or adding one more kicker – buy us in intensity headroom.