How to lose 10^8 protons in 1 ms and keep it under control?

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for Quench Test Strategy WG
(including experts from BE/CO, BE/BI, MPP, MPE, BE/BI, RF, ABT/BTP, Collimation, ABP, … - common effort)

MPP, 2012/12/14

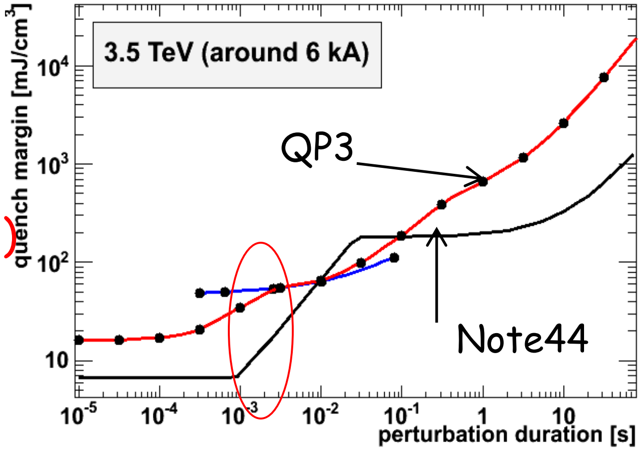
Outlook

1. What we want to do?
2. Previous millisecond-scale test.
3. Last MD summary.
4. How many protons to quench?
5. UFOs and neutral particles peak.
6. ADT team proposal.
7. Intensity and emittance measurements at ultra-low intensity.
8. Fast QPS measurement.

The goal

Measurement of the quench limit of arc magnet for UFO-timescale.

1. Controlled generation of UFOs not possible.
2. The differences between UFO loss pattern and our experiment one will be taken into account by FLUKA/G4 simulations, but it is better to reproduce UFO conditions as well as possible.
3. Experiment will validate QP3 code.
4. There is controversy concerning helium impact on quench level at millisecond timescale (factor 5).
5. With validated QP3 we can trust its prediction of quench limit at 6.5-7 TeV
6. Predictions of UFO-generated quenches (LS1)
7. Fine-tuning of BLM thresholds (LS1)



Wire scanner quench test (2010)

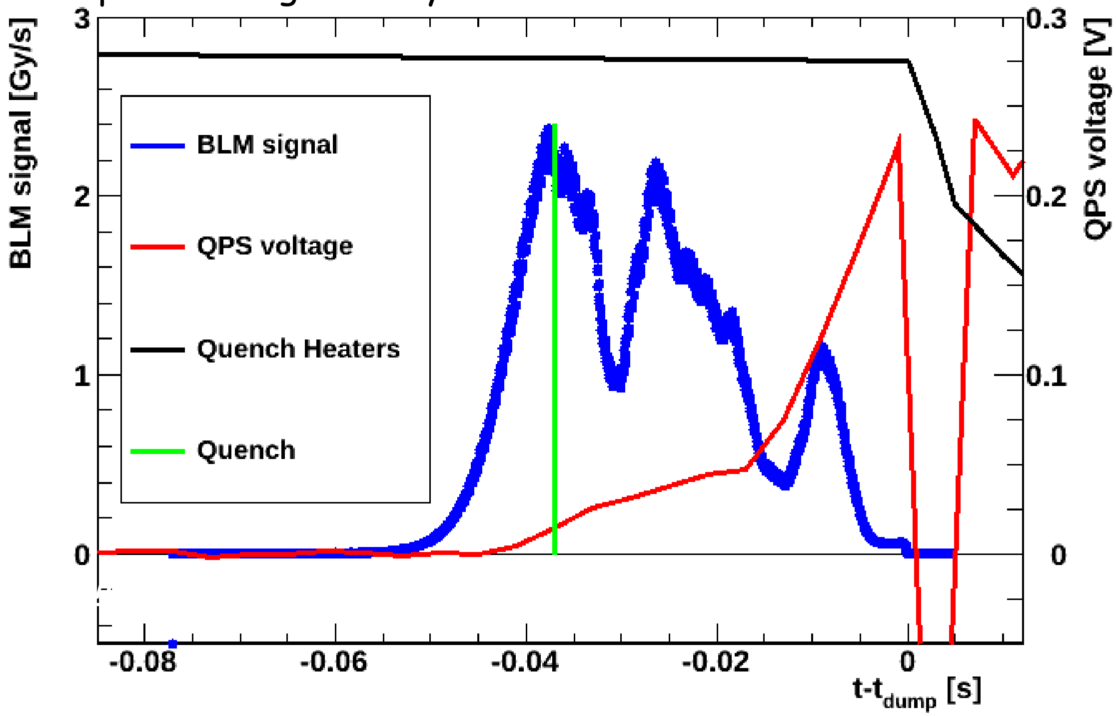
Experience in performing and data analysis of a similar test.

- beam energy: 3.5 TeV
- magnet MBRB (4.5K)
- loss duration ~ 20 ms
- UFO-like loss type but particular geometry

- number of protons going through the wire: ~ $1.4 \cdot 10^{14}$
- number of hard interactions: ~ 10^{10}
- maximum energy density at quench:

FLUKA: 19 mJ/cc

QP3: 32 mJ/cc



Remarks:

- QP3 uses input from FLUKA (radial energy deposit)
- both values have large errors

Loss continues after the quench, QPS resolution enough to determine N_{prot}

MDs on October 13 and June 22, 2012

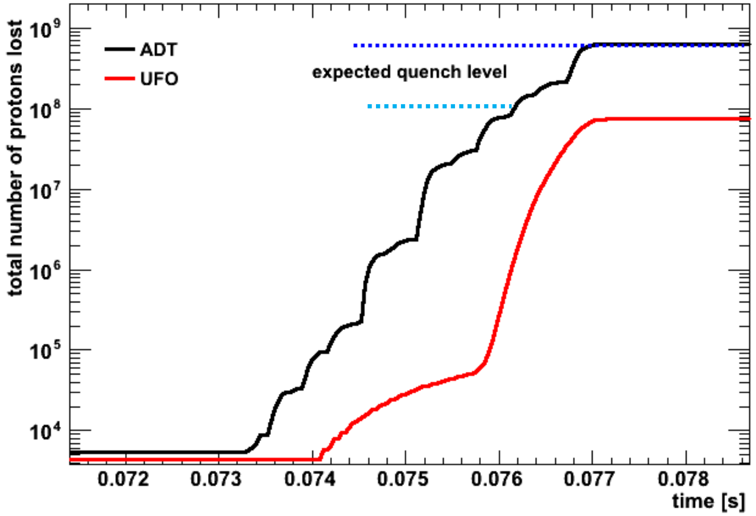
1. Main worry was:

   how to generate 1 ms losses without use of Wire Scanner?

2. The test conditions were reproduced but beam was aiming at collimator not magnet (magnetic field will have impact on timing!)

3. The best conditions:

   - Maximum damper gain with flipped sign (anti-damping) and sample hold
   - Octupoles to 0
   - Chromaticity = 2 (small)
   - MKQ gave initial kick

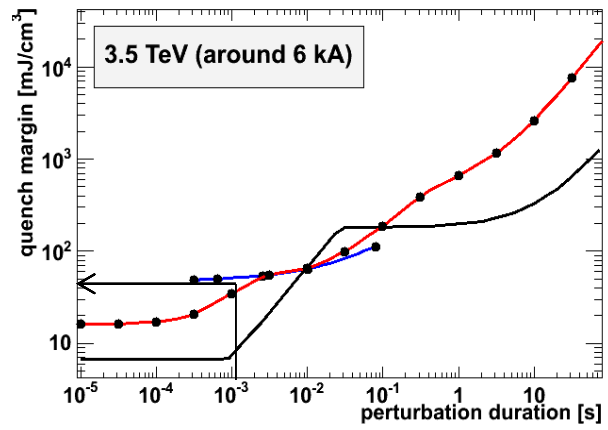


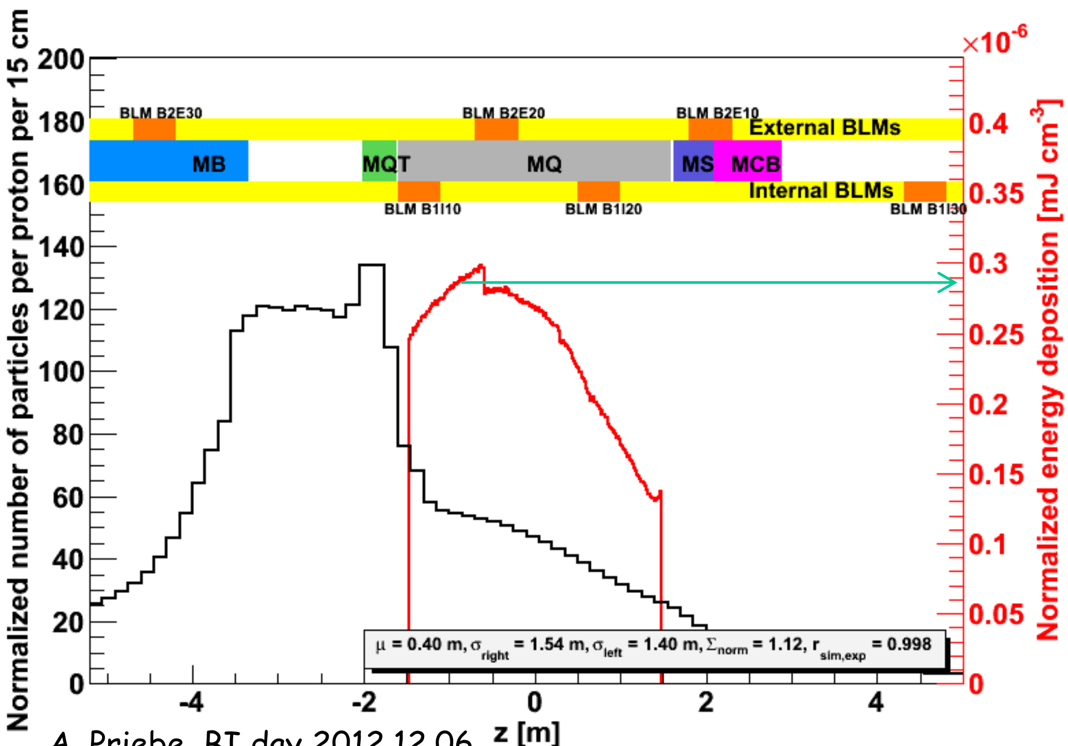
MQ quench test and simulations

- beam energy: 3.5 TeV
- magnet MQ (1.9K)
- orbital bump loss scenario
- vertical loss

- one lost proton: ~ $0.29 \cdot 10^{-6}$ mJ/cc
- quench limit (QP3):

30-40 mJ/cc





A. Priebe, BI day 2012.12.06

Protons needed to quench:

$N_{prot} \geq 10^8$

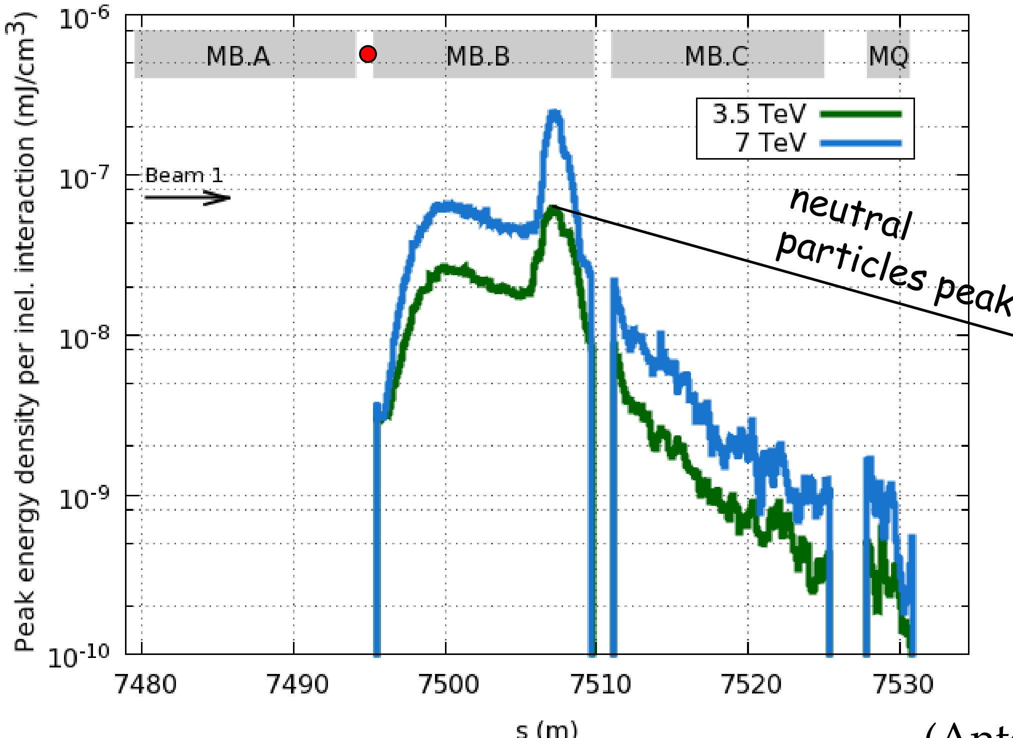
Simulation was done for very small beam in horizontal plane.

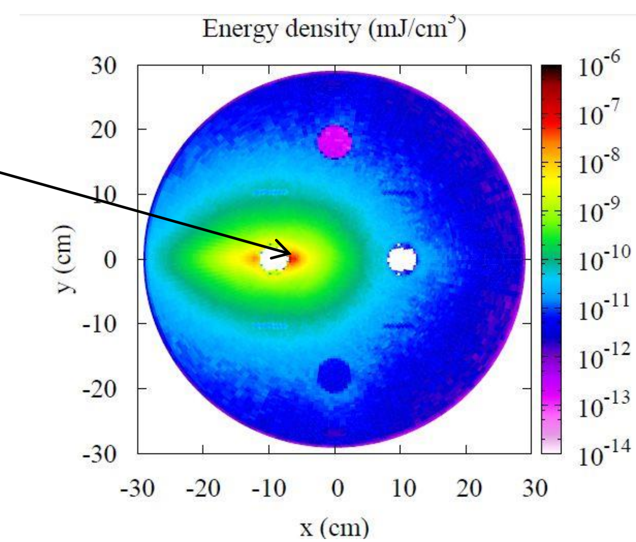
UFO case

- $5 \cdot 10^{-8}$ mJ/cc
  (versus $3 \cdot 10^{-7}$ mJ/cc for orbital bump)
- magnet MB and MQ (1.9K)
- horizontal loss (magnetic field and geometrical)

One inelastic interaction with UFO produces 5-10 less energy in the coil than orbital bump.

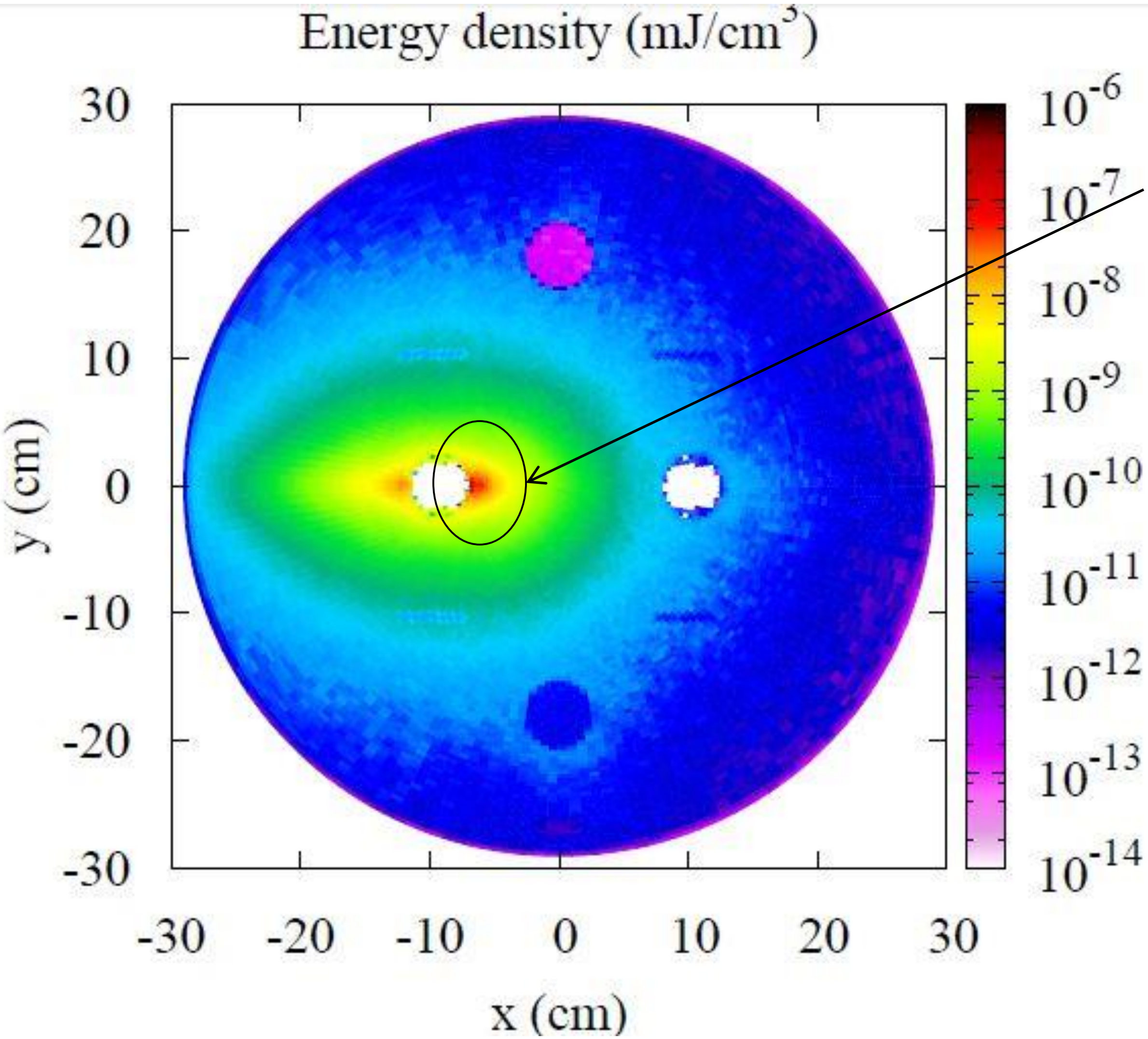
(ratio between BLM signal and coil energy does not change much)





(Anton simulations)

Neutral particles peak



Vertical size of the impact area of neutral particles is larger than vertical beam size.

(to be quantified)

To reproduce this condition:

vertical blow up.

Additional advantage: energy deposition more diluted so more protons needed to quench.

ADT team proposal

Wolfgang, Daniel

1. accelerate 10 small pilots (each 5×10^9 p) to 4 TeV
2. use new damper settings with ultra-low sensitivity
   (factor 2 more sensitive than current low intensity settings, D.V.)
3. reduce bunch intensity by gated vertical blow-up/loss until target intensity reached
4. apply procedure with flipping sign of H damper proceeded by Q-kick as tested   if no quench: scrape less next bunch

testing before hand:

1. ultra low intensity settings → 2 h
2. test kick procedures and blow-up at 450 GeV → 2 h
3. calibrate intensity / losses → 2 h
   (intensity of bunch estimated by ADT sum signal and
   integrated losses at primary collimator during V- blowup, see Stefano)

How to measure 10^8 ?

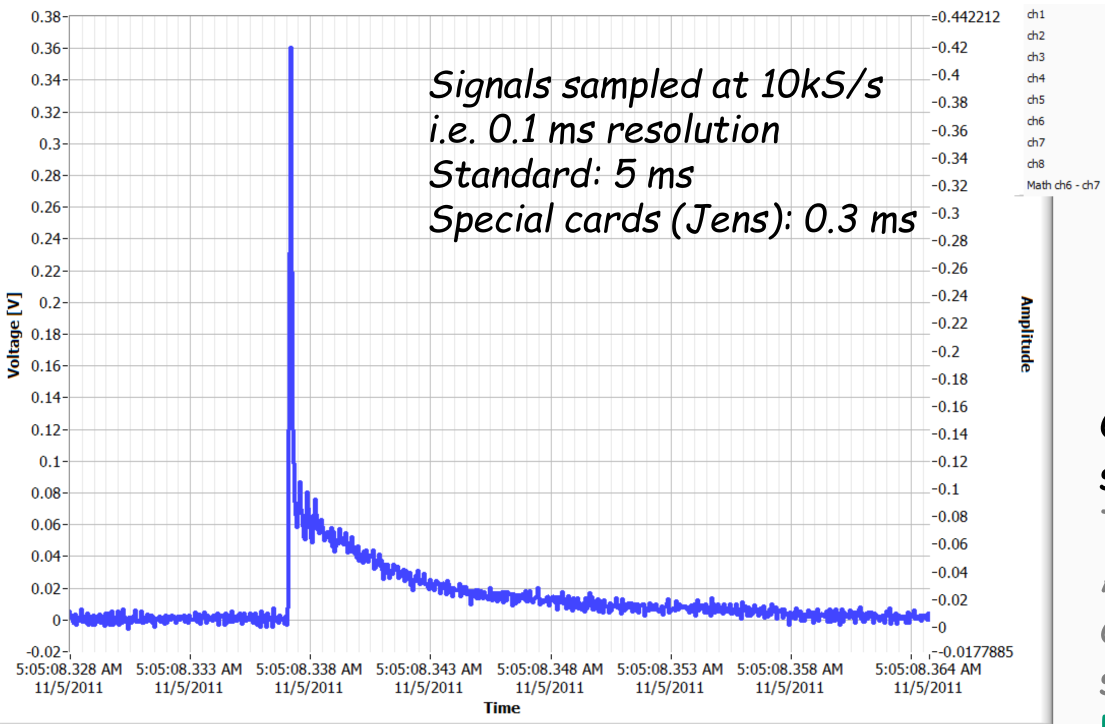
Intensity:

1. Longitudinal Density Monitor can measure down to 10^7 protons (5 min integration time) – at least one bunch measurable by Fast BCT needed. Accuracy 5%.
2. We have BLM calibration from other tests (also the other foreseen test, Steady State with orbital bump) so we could estimate number of lost protons from BLM signal. But this is post-loss method.
3. Fast BCT can go down to 10^8 protons – discussion ongoing with experts
4. The ADT sum signal can also give an indication of the bunch intensity -> to be tested with low intensity bunch

Emittance:

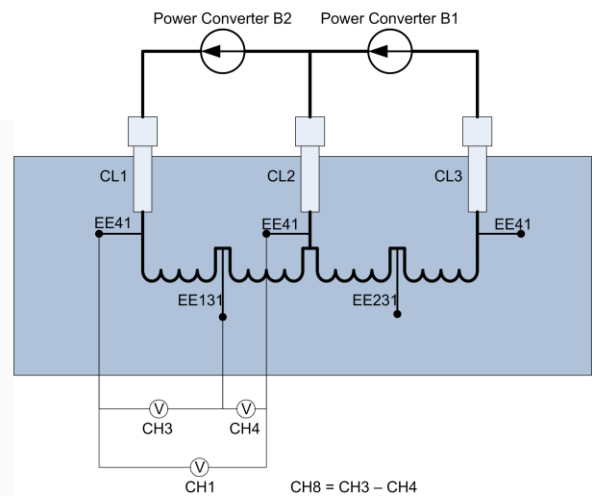
1. Wire scanner probably could work (although never tested combination of gain and filter)
2. BSRT should work as well (Federico)

Can we rely on fast QPS measurement to determine the moment of quench?
Measurements during Q6 quench test look promising
but there are doubts…



Signals sampled at 10kS/s
i.e. 0.1 ms resolution
Standard: 5 ms
Special cards (Jens): 0.3 ms

by Mateusz



CH8 corresponds to the signal seen by the quench detector.
The same voltage taps are used. All the inductive voltages are cancelled, only the resistive signal is seen, unless…
Unless there are some signals appearing only on EE131 - these can be seen as well…

This time we will have diamond detector on scope input, so no problem to synchronize with losses.

Conclusions

1. A baseline, complete proposal presented
2. Needs 6 hours of beam at injection for testing
3. Tools to measure seem to be in place (and redundant)
4. Some interlocks must be disables (IP6 BPMs)
5. Quench expected to happen between 10^8 and 10^9 lost protons
6. EDMS document will be prepared
7. Beam screen issue to be discussed in January (MPP? QTSWG?)
8. Is there another way to go?