

This was written using OpenOffice 1.10. I've never figured out how to mix portrait and landscape in it. Since the tables work better in landscape, everything is. If you know how to mix orientations, email me.

This is my biased summary of the meeting held Friday, August 5, 2005, 1330-1510. Feel free to send your biased changes to all its recipients.

Attendees: Armstrong, Benesch, Bogacz, Chao, Freyberger, Hutton, Kazimi, Paschke, Tiefenback

Improvements are needed in beam quality before HAPPEX-Hydrogen begins mid-October. Changes can be tested and backed out in the region through cavity R034 in August and September because that region won't change with energy. The remaining 12 injector cavities, 3 skew quads and 13 normal quads will change.

Agenda

1. Define the problem

It was agreed that the goal was to eliminate 4-space (x, x', y, y') coupling throughout the machine. This is expected to result in minimization of helicity dependent position differences from cathode to hall as one of the consequences of eliminating coupling. Eliminating x-y coupling as excited by PZT is **NOT** the goal.

2. Define a conceptual framework for solving the problem. In particular, can it be segmented?

Chao expressed the belief that [separating CU & CM will not make the procedure any easier, since we still need to respond to coupling in the second half of CM with energy change, with only 3 skew quads and insufficient \(actually no\) BPM's to characterize transport. Separating 100 keV \(or a, b below\), 5-60 MeV, and the remainder is more natural in terms of measurability & modularity.](#) Everyone else felt that improvements could and should be made within segments even if this precluded a global optimization near term due to hardware limitations. Skew quads, normal quads and correctors can be added in September and BPMs in January if these will assist in optimization of segments and the full injector. Segments cited were:

- a. cathode to chopper (0I02A)
- b. chopper to A4 (0I02A to 0I07)
- c. quarter and 5 MeV (0I07 to 0L03)
- d. cryomodes and matching (0L04 to 0L10)
- e. injector chicane to IPM1L02

All but Chao felt (c) was the worst offender for coupling. He said (c) and (d) are equal [based on beam based measurements](#). I guesstimated one-sixth for (a+b), half for (c) and a third for (d+e). YMMV.

Among the other things that came up during this part of the discussion that I don't have a good spot for elsewhere:

- I. Mike T. suggested that x-y coupling can be checked at 0L10 with a viewer and an upstream quad. If the spot changes smoothly from, say, a vertical ellipse to a horizontal one as the quad is varied, without any tilting, x-y coupling is minimal. If it rotates, there's coupling.

- II. Wien quads are coupling suspects. Most of the measurements in 100 keV have been done with them off. Can purity of the Wien quads be improved by making new ones or beam line changes to accommodate cleaner ones if there's no space now? Decision: wait on this.
- III. To investigate via PARMELA and experimentally: Does orbit through the quarter affect coupling.
- IV. additional correctors are needed in 5 MeV region. One additional skew quad is needed to give enough (8) to independently decouple segments (c) and (d); this might go between the cryomodules. There should be enough normal quads, since there are eight within 0L01-0L06 girders.

3. *Define at least two intermediate milestones.*

- August 12 ATLI submission for additional correctors and skew/normal quads. Numbers, if not exact locations. **OK**
- August 17 draft plan for adequate partial solution of problem to meet needs of HAPPEX-hydrogen beginning October 14.
- August 31 most computer modeling complete **OK**
- September 2 finalize location of magnets for installation following week
Reza has an ATLI task locating three additional corrector pairs. Chao has agreed that two extra skew quads in the 5 MeV region, in the vicinity of regular quads 2A and 3A, are desirable. Exact locations TBD. There may not be enough available trim card channels. Steve said 7 are available and Ron thought 5.
- September 8 plan for tests at end of restoration. (if too many are on vacation, September 12)
- Sept 20 finalize plan for meeting needs of HAPPEX

4. *What modeling can profitably be done? All of these are to include sensitivity checks via successive single parameter variation.*

- a. PARMELA simulation of the solution Chao dropped in July 15. Compare with the data he took.
- b. PARMELA simulation of the solution Chao didn't try July 15
- c. PARMELA simulation of coupling in the quarter and the skew quads
- d. compare PARMELA matrix for quarter to Chao's measured matrix
- e. determine sensitivity of optics/coupling to orbit offsets and orbit angles through quarter
- f. determine sensitivity of optics/coupling to changes in relative phase of 0R27 and 0R28.
- g. PARMELA simulation of effect of reducing all beams to a third their present size via a change in "steering lens". Concern is what this will do to B and C. A will end up ~0.5 mm, the old standard size, but B and C will be a third the usual size.

5. *What empirical (beam) tests can be made and backed out easily?*

- a. can x-y coupling in the quarter be cut by adjustment of skew quads 0I07 through 0L03, which aren't set by lemi?
- b. Wien quad x-y coupling measurement
- c. determine sensitivity of optics/coupling to orbit offsets and orbit angles through quarter
- d. determine sensitivity of optics/coupling to changes in relative phase of 0R27 and 0R28.

6. *should weekly? PZT data be taken to track changes?*

not discussed, but since it's only 15 minutes a week, why not?

7. other thoughts

Chao had a few concerns not covered above, including getting PZT upright; increasing beam pipe diameter in 5 MeV region or adding correctors there; suspect 0L06 quad; unknown in chicane-NL region; phase locking of PZT 30 Hz to 30 Hz BPM screens so the latter work with the PZT; higher stability BPM's for Halls A/C to allow more real time monitoring.

8. question from Andrew: what did we learn from the July 15 test? Answer from Chao:

- a. reduced PZT response two pass to C a factor of five from prior response, 30 uA CW
- b. could run 30 uA CW (max. allowed) C beam to Hall C, the only hall available during test.
Could run CW A beam to Hall A with currents of 10's of uA (60?). Exact number needs be confirmed from ELOG search around 07/15.
- c. could not run both A and C CW to inline dump - beam loss trips as steering incompatible for two beams
- d. beams were big in 5 MeV
- e. setup was very sensitive to chopper setup (Andrew: not acceptable as chopper drifts)
- f. coupling wasn't measured due to time limit. Decoupling of XY to <1% level from 100 keV to 60 MeV was confirmed during 03/04 MD under same matching procedure.

9. Segmentation redux

Andrew and I emphasized that the way the machine is run is that the stuff from the cathode to the middle of the first cryomodule is invariant with energy and the rest changes with energy. It is therefore necessary to segment any coupling solution into at least two pieces of the injector, energy invariant and energy variant.

This was again discussed by Chao and Jay 1700 Monday 9/12 and in the B team meeting 9/13. Chao and Jay agreed that two more skews in the 5 MeV region were desirable. Mike Tiefenback suggested at the B team meeting the possible utility of adding quads to the 0L05 girder between cryomodules to create a doublet or triplet. It was agreed that some modeling was needed to determine best location of the new quads, including at least one attempt to decouple x-y with eight skews and eight normal quads, with injector viewed as either one module or two. Looking at the song sheet after the meeting, I'm not sure how one could fit a second quad on the 0L05 girder.

10. Extreme interventions in the long term for Q-Weak and HAPPEX-lead

Inspired by segmentation, I pointed out that there is a cryomodule being refurbished and that a skew quadrupole could be installed mid-module. This module could then be installed in the injector instead of NL04, hurting fault rate but perhaps improving beam quality. Andrew said he had spent lunch trying to persuade SRF folks to build a cryo unit with the new cavities which don't couple x to y. This would totally eliminate the issue for the quarter. I suggested putting one new cavity into the spare quarter cryostat instead. It would only have to sustain ~7 MV/m. I later talked to Mark Wiseman about this option.

Looking at the side of helium vessel, from the left waveguide to the start of the right end dish assembly is ~97 cm. Exact dimension needs layout. The new seven cell cavity is 100 cm exactly. A slanted waveguide (rather than a dogleg) would be needed to make up the ~3 cm. A long

stainless beam pipe would bridge the ~50 cm gap to the left end dish assembly beamline flange. Ceramic HOM loads could be placed in circular waveguides in lieu of the capacitively coupled coax HOM extractors or each new-style HOM coupler could be cabled to an HOM load strapped to the inside of the helium vessel. Recall that CEBAF heat load to 2K per HOM load is ~25 mW at 200 uA. Old style tuner would be adapted with longer rods. And so on.

Retrofitting the spare quarter in this fashion would still be expensive but likely less than a third the cost of an entirely new quarter. (Jay's cost WAG). All of the cryostat components would be reused. The savings in using only one cavity apply to either Andrew's idea or mine.

Action items:

1. modeling as defined above - Yuhong **complete**
2. additional correctors - Reza first cut now and revised locations after Yuhong's modeling **complete**
3. plan - Arne, since no one volunteered and seconded Andrew on the need
4. improve tables which follow: everyone

Checks of proposed solution to be made computationally before writing test plan to download and check

Property	Figure of Merit	Tolerance	Comment
Decoupled transport from 100 keV to 60 MeV	Off-diagonal elements in 4D transfer matrix	0	On paper this is not too difficult.
Non-singular transport from 100 keV to 60 MeV	SVD condition number in X & Y M11/M33 as measure of singularity	SVD: 250 M11/M33: 1.0	
Match of PZT-defined Twiss into 60 MeV line	Courant Snyder mismatch parameter in X & Y	10	Advisory rather than absolute
PZT amplitude reduction from 100 keV to 60 MeV	Amplitude peak & RMS	Peak: >10 RMS: >10	Advisory rather than absolute
Spot size from 5 MeV to 60 MeV	Spot size everywhere	TBD	
Match of beam spot into 60 MeV line	Courant Snyder mismatch parameter in X & Y	10	Advisory rather than absolute
Estimate apparent emittance growth from coupling			
Skew quad strength	BDL	5 MeV: <20 G All else: <40 G	To avoid inaccuracy and misalignment kicks
Quad strength	BDL	Physical limit	
Adequate beam stay-clear			
Beta max (m)			
Acceptable sensitivity to errors			
Identify magnets most sensitive to errors (tweaked first to match model and machine)			
Evaluate sensitivity to input conditions			
Define technique to match input conditions adequately			
Define quantitative measure of coupling			

After download, measure:

Property	Method	Figure of Merit / Tolerance	Comment
Decoupled transport from 100 keV to 60 MeV	100 keV FOPT measurement	Off-diagonal/on-diagonal determinant ratio of 4D transport $\leq 1\%$	Extremely elaborate procedure
Non-singular transport from 100 keV to 60 MeV	100 keV FOPT measurement	SVD condition number ≤ 250	Extremely elaborate procedure
Propagation of Cathode displacement	30 hz PZT throughout	Amplitude reduction from 100 keV to target hall.	10 minutes when all else is in place.
Transportability	Maximum deliverable CW current for all halls simultaneously	μA / whatever is within envelope	Need all halls (A/C at least) to be available.
Beam spot	All viewers from OL01 to North Linac	Qualitative inspection	
Beam spot	Emittance measurements at 100 keV, 5 MeV, 60 MeV, Hall A/C	Emittances	Minimum 3 hours.
Measure coupling, compare to expectations			
Determine if beam stay-clear is adequate	30 Hz aperture		
Tweak most sensitive elements to optimize optics and coupling			