Recommendation for Electron Cloud Mitigations in the ILC Damping Ring

ILC DR Working Group

October 13, 2010

Cornell University

Recommendation of Mitigations

As a group, we need to structure our discussion, and make decisions with a systematic approach

Give our recommendation and present the results as clearly as possible

Recommendation of Mitigations

We have been asked also to present a table with a list of mitigations, for each of the DR regions, and with mitigations listed in a ranked fashion

Mitigations ranking

ILC DR Mitigation Alternatives ranking

ILC DR	Drift	Quad	Dipole	Wiggler	Sext
Antechamber					
Solenoid Windings					
Al					
Cu					
TiN coating on Al					
Amorphous Carbon coating on Al					
Diamond Like Carbon on Al					
NEG coating on Al					
Rectangular Grooves w/TiN on Al					
Triangular Grooves w/TiN on Al					
Clearing Electrode					

Mitigations ranking

ILC DR Mitigation Alternatives ranking

ILC DR	Drift	Quad	Dipole	Wiggler	Sext
Antechamber	**No**				
Solenoid Windings	**Yes**				
Al	**-**				
Cu	**-**				
TiN coating on Al	**0.25**				
Amorphous Carbon coating on Al	**0.23**				
Diamond Like Carbon on Al	**-**				
NEG coating on Al	**0.27**				
Rectangular Grooves w/TiN on Al	**0.23**				
Triangular Grooves w/TiN on Al	**-**				
Clearing Electrode	**-**				

We should emphasize that although our systematic approach allows a “score table” for the various options for each item to be drawn up, our recommendations will be reached through structured discussion, and not by simply adding up the benefit and risk scores for the different options.

Antechambers need

Simulations strongly suggest that we need an antechamber design. The antechamber might not be part of the rating but it is assumed as required.

- In wigglers, the baseline assumption is that an antechamber of suitable efficiency is needed to
  - **Remove radiation power onto photon stop**
  - **Suppress the formation of photoelectrons and thus effectively reduce PEY**
- In the arcs, we propose to evaluate mitigations with the assumptions that an antechamber is present.

Solenoid windings

Solenoid windings are very efficient in drift sections and might be efficient in a weak quadrupole field. Solenoids are not efficient in bends and wigglers.

- We propose to evaluate mitigations with the assumptions that an antechamber **is present** in drift regions as a complement to coatings TiN, NEG or a-Carbon.
- Solenoids might complement also grooves.

Methodology

- Similar to the DR recommendation taken in 2006
- To make decisions as a group, we propose to use a **simplified adaptation** of the "Analytic Hierarchical Process" http://en.wikipedia.org/wiki/Analytic_hierarchy_process:
  - Decompose the problem into a hierarchy of criteria and alternatives.
  - A numerical weight is derived for each element of the hierarchy, allowing diverse elements to be compared to one another in a rational and consistent way.
  - Essence of the method is that expert's judgments, and not just the underlying information, can be used in performing the evaluations.
  - In the final step of the process, numerical priorities are calculated for each of the decision alternatives.

- Example on the Web

Recommendation for Mitigations

The criteria identified for the evaluation of mitigation are:

1) **Efficacy of mitigation**
2) **Costs**
3) **Risks**
4) **Impact on Machine Performances**

Efficacy of mitigation

- Photoelectric yield (PEY)
- Secondary emission yield (SEY)
- Ability to keep the vertical emittance growth below 10%

Costs

- Design and Manufacturing of mitigation
- Durability of mitigation
- Maintenance of mitigation
  - **Example: replacement of damaged power supplies for clearing electrodes**
- Operational costs
  - **Ex: Time for replacement of damaged power supplies for clearing electrodes**

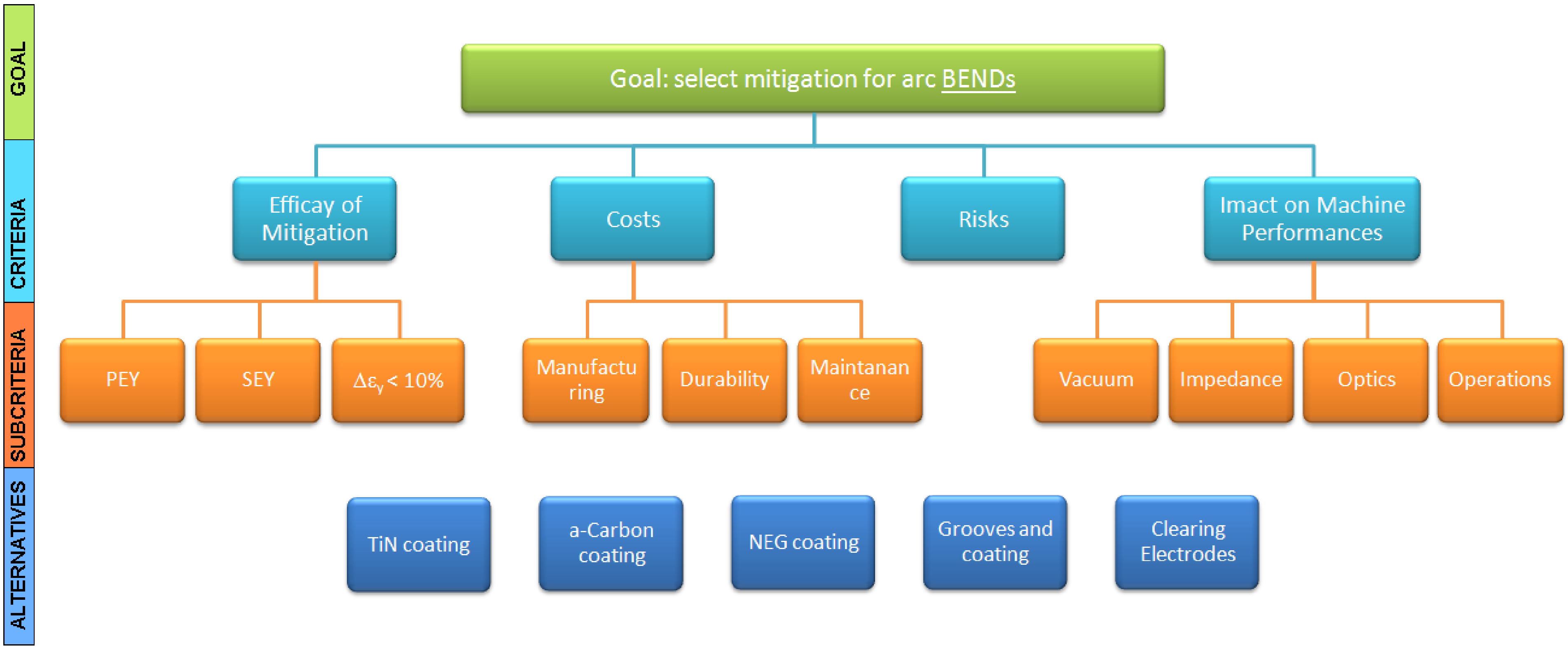
Risks

- Mitigation manufacturing challenges:
  - **Example: difficulty of manufacturing grooves of 1mm or less in a small aperture chamber**
  - **Ex: Difficulty of manufacturing of clearing electrode connectors**
- Missing experimental evidences yet
  - **Ex: aCarbon coating not tested yet under high radiation power conditions for long time**
- Operational risks
  - **Ex: Damage of clearing electrode feed-through**
  - **Ex: Failure of clearing electrode power supplies**
  - **Ex: Durability of coating**
- Reliability

Impact on Machine Performances

- Impact on vacuum performances
  - **Example: NEG pumping can have a positive effect**
  - **Ex: Larger grooves surface for pumping**
- Impact on machine impedance
  - **Ex: Impedance of grooves and of clearing electrodes**
- Impact on optics
  - **Ex: Generation of couplings with solenoids**
- Operational
  - **Ex: NEG re-activation after saturation**
  - **Ex: Availability**
  - **Ex: Time for replacement of damaged feed-trhough or power supplies**

Example: select mitigation for DR



First step: Ranking the Criteria

Assign a weighting factor to the criteria

(there is a long way and a short way to do this…)

	Weighting factor
Efficacy of mitigation	**0.6**
Costs	**0.08**
Risks	**0.12**
Impact on Machine	**0.20**
	1.000

2ns step: Evaluation of mitigation alternatives

Example: mitigation alternatives for DRIFT regions are:

1) TiN coating

2) amorphous-Carbon coating

3) NEG coating

4) Grooves with coating

Evaluation of mitigation alternatives

- To rank the alternatives, we compare them against each of the criteria using a scale from -4 to +4 summarized as:
  - **Negative values=detrimental**
  - **0 = no impact**
  - **Positive values = helpful**

Evaluation of mitigation alternatives

Example: evaluate electron cloud mitigation alternatives for DRIFT regions:

	Efficacy of mitigation	Costs	Risks	Impact on Machine
TiN coating	2	-1	0	0
C coating	2	-1	0	-1
NEG coating	1	-1	0	3
Grooves & coating	3	-1	0	-3

… DONE for DRIFT regions.

Finally, the matrix gets normalized and each value is factored by the weight of the respective criteria:

	Efficacy of mitigation 0.625	Costs 0.063	Risks 0.125	Impact on Machine 0.188	Total
TiN coating	0.16	0.02	0.03	0.05	0.253
C coating	0.16	0.02	0.03	0.04	0.241
NEG coating	0.13	0.02	0.03	0.09	**0.265**
Grooves & coating	0.18	0.02	0.03	0.01	0.242
					1.000

and a mitigation is selected for DRIFTs.

The rationale behind each assumption will be documented in the executive summary of this meeting.

Example:

Recommendation for mitigation in BENDs

Clearing electrodes is the recommended mitigation for the BENDs in the DR arcs, as shown in Table. TiN or amorphous are the possible alternative mitigations with good efficiency, low cost and low impact on the machine performances. Grooves are also a possible alternative if the manufacturing of small depth grooves for the small DR aperture dipole chambers will be demonstrated.

Since we aim at the smallest cloud density in magnet regions, TiN and Carbon coating should be preferred to NEG coating due to their SEY characteristic.

Select electron cloud mitigation in BENDs

• Efficacy of Mitigation

Measurements of the secondary electron yield of several coating and groove samples installed in situ in accelerator beam lines have been made. Typically the sample SEY is monitored before the installation in the beam line and after periods of beam conditioning. In field-free regions, TiN and a-Carbon thin film coatings show the measured secondary emission yield values just lower than unity after conditioning. NEG coating measured SEY values are slightly larger than unity after activation and conditioning. Rectangular grooves coated with TiN show SEY values well below unity and as low as 0.6.

• Costs

The costs of coating chambers either with TiN, Carbon or NEG should be relatively close. Chambers with a groove profile require additional costs while clearing electrodes are the most expensive in terms of design, manufacturing and installation. Durability of TiN is good as measured from stoichiometry ration from samples extracted from a vacuum chamber installed in a machine after 10 years of operation at high Ampere∢hour values. NEG coating requires re-activation cycles with additional costs.

•Risks

Chambers with small depth grooves in the mm scale to fit into the dipole chamber aperture might be challenging to manufacture. Clearing electrodes and interconnections might also be a manufacturing challenge for the > 2m long DR magnets.

•Impact on machine Performances

TiN coating has a low impact on machine performances with respect to vacuum, and impedance. Amorphous-carbon coating may impact vacuum by photo-desorption and outgassing with slightly larger presence of carbon oxides in high synchrotron radiation regions. NEG coating has pumping capability with a positive impact on vacuum performances but requires re-activation cycles after its saturation, which may imply additional maintenance periods.

We need to write down the comments …

Agenda

Working Group Meeting - October 13, 2010		
9:00	10:00	Discussion about the criteria for the evaluation
10:00	11:00	Complete the recommendation tables for DRIFTs
11:00	12:00	Complete the recommendation tables for BENDs
12:00	13:00	Lunch
13:00	14:00	Complete the recommendation tables for WIGGLERs
14:00	15:00	Complete the recommendation tables for QUADs
15:00	16:00	Look at the implications of the proposed operating scenarios and complete the tables for the recommendation
16:00	17:00	Formulate a statement about instability thresholds and incoherent emittance growth issues

- Back-up

First step: Ranking the Criteria

Assign a weighting factor to the criteria

A possible way of ranking the criteria, is to rate them on a scale of importance ranging for example from 0 – 10 and then normalize the results:

	Importance
Efficacy of mitigation	10
Costs	1
Risks	2
Impact on Machine	3

First step: Ranking the Criteria

Assign a weighting factor to the criteria

A possible way of ranking the criteria, is to rate them on a scale of importance ranging for example from 0 – 10 and then normalize the results:

	Importance	**Weighting factor ("Importance" normalized)**
Efficacy of mitigation	10	**0.63**
Costs	1	**0.06**
Risks	2	**0.13**
Impact on Machine	3	**0.19**
		1.000