Director's Review of the Project X Cost Range Estimate: MI/RR

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Project X Director's Review

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Outline

- Scope of Estimated Work
- Boundary Conditions /Assumptions
- Basis of Estimate/Total cost
- Technical Risks/Associated Cost Exposure
- RD@D costs/timeline
- Potential Technical Revisions
- Role of Outside Collaborators
- Summary

System Scope RR/MI

RR

- Accept the Linac beam and Inject into MI (bucket to bucket transfer) with good efficiency.
- Make the extra Linac cycles available for distribution at 8 GeV.

MI

- Accept beam from the RR in one turn.
- Provide 2MW of beam power from 60-120GeV by accelerating one Linac pulse of beam (1.6E14 protons).

Recycler Requirements

Description	Req.	Unit
Recycler		
Energy	8	GeV
Storage Efficiency	99.5	%
Average Recycler Beam Current	0.6	A
Availability	95	%
Injection Rate	5	Hz
Maximum Space Charge Tune Shift	0.05	
95% normalized transverse emittance	25	p-mm-mrad
r.m.s. normalized transverse emittance	13	p-mm-mrad
Bunching factor	2	
Longitudinal emittance per Bunch	0.5	eV-Sec
Cycle Time	1.4	sec
RF Frequency	53	MHz
Abort Gap Length	700	nsec
Peak Recycler Beam Current	2.356	A
Fast Extraction Rate	15	Hz
Fast Extraction Pulse Length	1.6	microsec

Second harmonic rf (500KV)

Longitudinal painting

53 MHz rf system (1MV)

MI Requirements

Description	Req.	Unit
Main Injector		
120 GeV cycle Time	1.4	sec
RF Frequency	53	MHz
Abort Gap Length	700	nsec
Acceleration Efficiency	99	%
Main Injector Beam Current	2.356	A
Final Energy	120	GeV
120 GeV Beam Power	2.1	MW
Availability	87	%
Injection Energy	8	GeV
Longitudinal emittance per Bunch	0.5	eV-Sec
Space Charge Tune Shift	0.05	0
95% normalized transverse emittance	25	p-mm-mrad
r.m.s. normalized transverse emittance	13	p-mm-mrad
Bunching factor	2	0

Second harmonic rf (1.5MV)

Technical Issues

- The current MI rf system does not have enough power to accelerate the beam. We currently have no second harmonic system in MI. Need a 53MHz rf system (including a second harmonic) for RR.
- The MI crosses transition.
- Electron cloud instabilities.
- Beam stability and losses.
- Recycler lattice modifications.

Total costs

WBS	Name	Start	Finish	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	Total Cost
1.4	MI/RR	10/1/08	8/3/16	$1,922,503	$4,342,700	$3,677,580	$2,450,800	$12,848,605	$28,674,016	$4,338,543	$3,425,610	$0	$0	$61,680,357
1.4.1	High Level RF Systems MI	8/2/13	2/4/14	$0	$0	$0	$0	$10,147,473	$21,719,277	$0	$0	$0	$0	$31,866,750
1.4.2	High Level RF System RR	8/2/13	2/4/14	$0	$0	$0	$0	$2,394,946	$5,126,054	$0	$0	$0	$0	$7,521,000
1.4.3	Installation Costs	10/13/14	10/9/15	$0	$0	$0	$0	$0	$0	$3,406,232	$93,768	$0	$0	$3,500,000
1.4.4	MI Beam Pipe Coating	10/1/15	3/31/16	$0	$0	$0	$0	$0	$0	$0	$907,296	$0	$0	$907,296
1.4.5	MI/RR RF Labor	8/2/13	8/3/16	$0	$0	$0	$0	$139,753	$864,114	$925,416	$852,412	$0	$0	$2,781,695
1.4.6	Gamma-t Jump	8/2/13	8/5/14	$0	$0	$0	$0	$90,776	$471,184	$0	$0	$0	$0	$561,960
1.4.7	Recycler Modifications	8/2/13	3/31/16	$0	$0	$0	$0	$75,657	$493,387	$6,895	$1,572,134	$0	$0	$2,148,073
1.4.8	MI/RR RD&D Plan	10/1/08	9/28/12	$1,922,503	$4,342,700	$3,677,580	$2,450,800	$0	$0	$0	$0	$0	$0	$12,393,583

All costs are in FY2009 dollars (direct cost only)

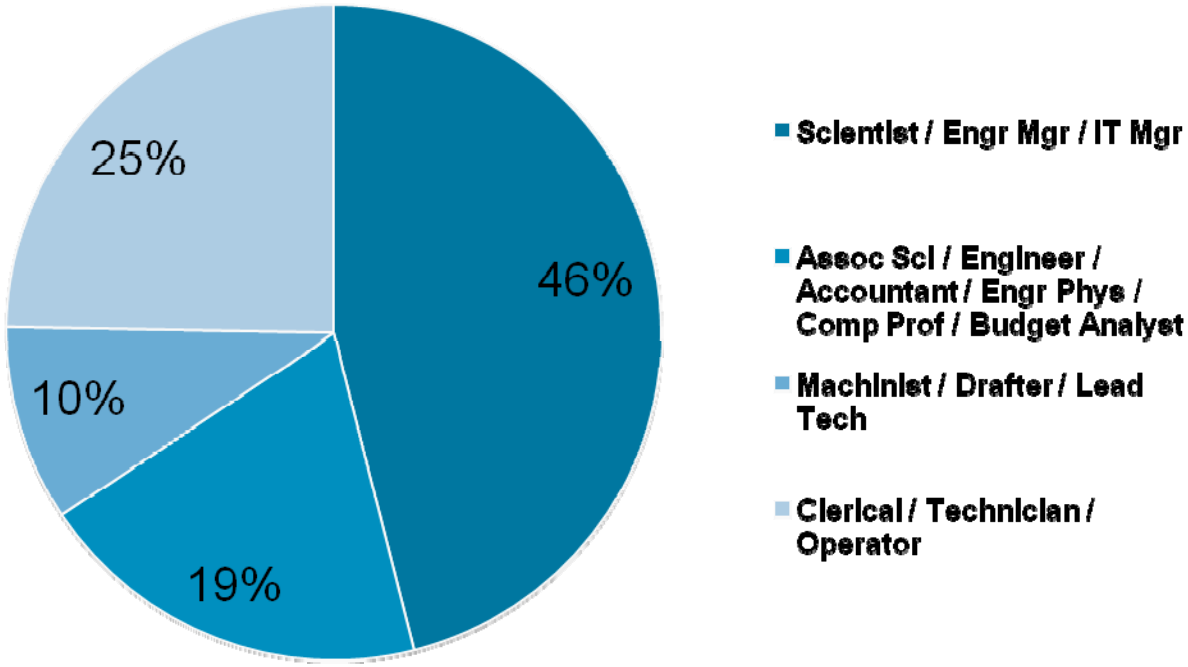
Technical Risks

- Completely new rf system for both RR and MI.
- Have to depend on simulations to determine the severity of electron cloud in both RR and MI.
- Coating of the MI pipe has to happen in situ.
- Loss mechanisms have to be understood and losses have to be controlled.
- We have and extensive RD@D Plan to address these risks
  - Design and test cavity prototypes.
  - Bench mark electron cloud generation codes against MI/RR beam data.
  - Determine the feasibility of MI beam pipe coating.
  - Simulations and measurements of space charge effects
  - Have a design for a gamma-t jump

Project X Breakdown of RD@D Costs

	FY09 $ and FTEs										
		FY09		FY10		FY11		FY12		Total	
		M&S	Labor	M&S	Labor	M&S	Labor	M&S	Labor	M&S	Labor
1.40	MI/RR	$446	10.00	$2,200	16.25	$1,420	19.40	$600	14.00	$4,666	59.65
1.4.1	High Level RF Systems MI	$220	0.00	$1,750	0.00	$1,020	0.00	$350	0.00	$3,340	0.00
1.4.2	High Level RF System RR	$0	0.00	$0	0.00	$0	0.00	$0	0.00	$0	0.00
1.4.3	Installation Costs	$0	0.00	$0	0.00	$0	0.00	$0	0.00	$0	0.00
1.4.4	MI/RR RF Labor	$0	3.60	$0	8.60	$0	11.10	$0	4.75	$0	28.05
1.4.5	Gamma-t Jump	$0	0.00	$0	0.00	$0	0.00	$0	0.00	$0	0.00
1.4.6	Recycler Modifications	$0	1.75	$150	4.25	$150	4.25	$150	4.25	$450	14.50
1.4.7	Physics Design & Modelling	$226	4.65	$300	3.40	$250	4.05	$100	5.00	$876	17.10

Labor Type Distribution for RD@D Plan



Goals and Timeline for RD@D (1)

- FY09
  - Develop and install two new RFA detectors. Develop and install permanent set-up for microwave e cloud measurements. Compare e cloud signals in the field free region for coated (TiN), un-coated pipes.
  - Compare e cloud generation code (PONSIT) with beam measurements. Compare also with another generation code. Start beam dynamics simulations.
  - Learn about TiN coatings (DC sputtering vs. magnetron sputtering). Examine coated pipes with both methods.
  - Update the 53 Mhz design for a higher R/Q. Run cavity software simulations (include LLRF stability). Model perpendicular biased tuner. Complete a paper design of second harmonic cavity.

Goals and Timeline for RD@D (2)

- FY10
  - Run beam dynamic simulations with e cloud and space charge. Evaluate the effect on the beam. Can broadband dampers have an effect?
  - Install ECLOUD1-SEY station in MI and measure the effect of beam conditioning on the SEY of various coatings.
  - Proceed with a TiN coating set-up at Fermilab. Experiment with coatings of straight beam pipes. Develop cathode targets for elliptical MI beam pipe.
  - Schedule 53MHz cavity review. Finalize cavity and tuner design. Order major components for a prototype construction. Finish second harmonic cavity design.
  - Complete lattice design for Recycler.

Goals and Timeline for RD@D (3)

- FY11
  - Experiment with coating of MI pipes inside dipoles. Investigate the effect of remnant fields.
  - Evaluate the severity of the electron cloud problem in both RR and MI. Use measured SEY for both coated and un-coated pipes.
  - Finish assembling first prototype cavity and tuner. Start low level testing of complete prototype cavity. Schedule second harmonic cavity review. Order parts for second harmonic cavity prototype. Design/specify rf power source for second harmonic.
  - Complete Instrumentation requirements for both MI and RR.

Goals and Timeline for RD@D (4)

- FY12
  - Test first harmonic cavity with high power in test station. Implement any necessary changes or upgrades. Install and test with beam. Assemble and test second harmonic with low power. Test second harmonic power source.
  - Present the results of the beam coating studies. Determine what it would take to coat the beam pipe in each ring.
  - Review the whole electron cloud medication strategy for both rings.
  - Finalize magnet and power supply requirements for new Recycler lattice.

Potential Technical Revisions

- The whole RR beam pipe will have to be replaced if coating is needed.
- If the MI beam pipe cannot be coated in situ the whole MI beam pipe will have to be replaced.
  - It would like reinstalling MI all over again.
  - The clearing electrodes can be considered as solution also.
- Alternative rf frequencies will be considered for in order to minimize electron cloud effects.
  - Will affect current MI and RR instrumentation.
  - Current choice of rf frequency is close to optimum for the MI rf requirements.

Collaborators

- BNL
  - Provide coated samples and technical support.
  - Collaboration on rf systems.
- SLAC
  - Provide coated samples and technical support.
  - Cavity field modeling and LLRF beam stability simulations.
  - Compare different generation codes and start beam dynamic simulations.
  - Provide test stands for electron cloud measurements (ECLOUD1).
- LBNL
  - Collaborate on e cloud microwave measurements.
  - Electron cloud simulations with PONSIT.
  - Modeling of low losses due to space charge.

Summary

- We have identified all the technical elements required for the MI/RR operation.

- The new MI/RR rf system dominates the total cost.

- We have developed an extensive RD@D program in order to address the technical issues/risks.
  - We have already established collaborations with 3 other labs.