# RF System LSD Work

## William Merz

LSD Re-Baseline Review Jefferson Lab November 16, 2012

Page 1 Office of Science

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Thomas Jefferson National Accelerator Facility





### Outline

#### What I will talk about –

- 12 GEV RF power system installation and commissioning
- R100 installation
- 6 GEV RF system recovery
- 6 GEV RF maintenance

#### What I won't talk about –

- C100 installation and commissioning
- RF Separator work plans
- New C50 module
- Helium processing
- Gradient recovery





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### **12 GEV RF Installation Status**



| Location | НРА                   |  |              |  |  | LLRF   |          |              |                       |  |  | Tunne  | Status        |                       |  |              |  |
|----------|-----------------------|--|--------------|--|--|--|----------|--------------|-----------------------|--|--|--|---------------|-----------------------|--|--------------|--|
| SL24     | $\checkmark$          | <ul> <li>✓</li> </ul>  | <            | <ul> <li>✓</li> </ul>  | <ul><li>✓</li></ul>  | <ul> <li>✓</li> </ul>  | ✓        | $\checkmark$ | $\checkmark$          | <ul> <li>✓</li> </ul>  | <ul> <li>✓</li> </ul>  | <ul> <li>✓</li> </ul>  | ✓             | <ul> <li>✓</li> </ul> | <  | ✓            |  |
| SL25     | <ul> <li>✓</li> </ul> | <ul> <li>Image: A second s</li></ul> | <b>V</b>     | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | <b>~</b> | <b>√</b>     | <ul> <li>✓</li> </ul> | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A set of the set of the</li></ul>  | $\checkmark$  | <b>√</b>              | <ul> <li>Image: A second s</li></ul> | ✓            |  |
| SL23     | <ul> <li>✓</li> </ul> | <ul> <li>Image: A second s</li></ul> | $\checkmark$ | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | <b>~</b> | <b>~</b>     | <ul> <li>✓</li> </ul> | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | $\checkmark$  | <b>√</b>              | <ul> <li>Image: A second s</li></ul> | 1            |  |
| SL22     | $\checkmark$          | <ul> <li>Image: A second s</li></ul> | <b>V</b>     | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | <b>~</b> | <b>√</b>     | $\checkmark$          | <ul> <li>Image: A second s</li></ul> | ×  | <ul> <li>Image: A second s</li></ul> | $\checkmark$  | $\checkmark$          | <ul> <li>Image: A second s</li></ul> | <b>√</b>     |  |
| SL26     | <ul> <li>✓</li> </ul> | <ul> <li>Image: A second s</li></ul> | <b>V</b>     | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | -        | <b>√</b>     | <ul> <li>✓</li> </ul> | -  | <ul> <li>Image: A second s</li></ul> | <ul> <li>Image: A second s</li></ul> | -             | <b>√</b>              | -  | -            |  |
| NL22     | I                     | <ul> <li>Image: A second s</li></ul> | <b>V</b>     | <ul> <li>Image: A second s</li></ul> | 50%  | <ul> <li>Image: A set of the set of the</li></ul>  | 75%      | <b>√</b>     | $\checkmark$          | <ul> <li>Image: A second s</li></ul> | ×  | <ul> <li>Image: A second s</li></ul> | -             | $\checkmark$          | <ul> <li>Image: A second s</li></ul> | _            |  |
| NL23     | I                     | <ul> <li>Image: A second s</li></ul> | <b>V</b>     | <ul> <li>Image: A second s</li></ul> | 50%  | <ul> <li>Image: A set of the set of the</li></ul>  | -        | -            | -                     | -  | -  | -  | -             | $\checkmark$          | -  | -            |  |
| NL24     | -                     | <ul> <li>Image: A second s</li></ul> | 1            | ×  | 50%  | <ul> <li>Image: A second s</li></ul> | -        | Ι            | -                     | -  | -  | -  | -             | 1                     | <ul> <li>Image: A second s</li></ul> | -            |  |
| NL25     | -                     | <ul> <li>Image: A set of the set of the</li></ul>  | $\checkmark$ | <ul> <li>Image: A second s</li></ul> | 35%  | <ul> <li>Image: A second s</li></ul> | -        | -            | -                     | -  | -  | -  | -             | <b>√</b>              | -  | -            |  |
| NL26     | I                     | <ul> <li>Image: A second s</li></ul> | 75%          | <ul> <li>Image: A second s</li></ul> | -  | <ul> <li>Image: A second s</li></ul> | -        | -            | -                     | -  | -  | -  | -             | $\checkmark$          | -  | -            |  |
|          | Klystron              | Pedestal   | Card<br>Cage | LCW  | Wave<br>Guide  | Cathode<br>PS  | Wiring   | FCC          | HPA<br>Controls       | Stepper<br>Chassis   | Piezo<br>Tuner   | Interlock<br>Chassis   | Wave<br>Guide | Cable                 | Cryo<br>Module   | Commissioned |  |

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## 12 GEV RF Plan- FY12 Installation & Testing



### **The Other RF Work**

#### **Completing the 12 GEV Machine**

- The upgrade requires a solid base to build upon
- Several System upgrades and part of the recovery process is "off the project" but necessary

#### Additional RF system work

- Injector RF upgrades R100 Cavity and RF System
  - New RF Controls
  - New Klystron
  - Upgraded Cathode Power Supply
- "Old" RF System Recovery
  - Re-characterize the 6 GEV RF cavities following temperature cycle to room temperature (Emax and Q, etc.)
  - Helium Process low gradient cavities
  - Thorough PM, re-hab and check out of RF power systems

# A schedule supporting this work is developed and consistent with meeting the 12 Gev schedule





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# **R100 Work – Project Charter**

| Objectives                  | Redesign 0L04 to allow for a full energy injector intended to help achieve<br>12Gev using a newer LLRF system and Hybrid CPS/HPA   |  |  |  |  |  |  |  |
|-----------------------------|--|--|--|--|--|--|--|--|
| Deliverables                | <ul> <li>Replace C25 Cryomodule with a higher gradient Cryomodule (R100).</li> <li>Design a new interface chassis to be placed between the 12Gev HPA chassis and the hybrid CPS/HPA system.</li> <li>Replace the entire RF control system with the newer 12GeV hardware.</li> <li>Replace old Vacuum system with the newer 12GeV system. This includes all new HV cabling to meet today's new standards.</li> <li>Commission and re-certify 0L04.</li> </ul> Provide a system to allow full-energy injector for 12 GeV era (123.5 MeV) |  |  |  |  |  |  |  |
| Constraints                 | The R100 has already been installed and aligned. This system needs to be completed by Nov 2013 for 1 pass beam.  |  |  |  |  |  |  |  |
| Assumptions                 | Use of R100 Cryomodule and that it is ready by Nov 13'; Engineering<br>and Operations support available for installation and commissioning<br>phase. Also that the 8KW Klystrons are ordered and delivered on time.<br>Also that the new hybrid CPS/HPA system will fit into the existing<br>cabinet.  |  |  |  |  |  |  |  |
| Special JLab<br>Commitments | None that I can think about.   |  |  |  |  |  |  |  |
| Budget                      | The budget is \$535K for this project but if you include the 49% GSA that increases the total to \$983K.   |  |  |  |  |  |  |  |

#### Labor: 46 m-w total – 4 m-w EE, 42 m-w Coordinator, ED and ET





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## **R100 Work - Schedule**

| Schedule           | Already installed the R100 Cryomodule                                     |
|--------------------|---|
|                    | Alignment of the R100 is completed.                                       |
|                    | Dec 12° – Have the Klystrons on order.                                    |
|                    | Dec 12' - Have the long lead12GeV Vacuum equipment ordered.               |
|                    | Dec 12' - Have the network equipment purchased.                           |
|                    | Dec 12° - Locate all of the components that have been purchased to make   |
|                    | the CPS/HPA hybrid system.  |
|                    | Feb 13' - Make sure we don't need any changes to the PSS system           |
|                    | Feb 13' - Have a design in place for the interface chassis to go between  |
|                    | the HPA chassis and the CPS/HPA.  |
|                    | Feb 13' – Have new cabling identified and on order                        |
|                    | Feb 13' - Have a CAD design for the CPS/HPA and start on its              |
|                    | Mar 13 <sup>2</sup> Install waveguide                                     |
|                    | Mar 13 - Instan waveguide   |
|                    | Mar 13 – Order up all of the 12GeV chassis.                               |
|                    | Mar 13° – Build the interface chassis.                                    |
|                    | May 13' – Install the LLRF chassis and cabling.                           |
|                    | June 13' – Test the system into shorts.                                   |
|                    | July 13° – Start commissioning.   |
|                    | Oct 13' - Replace the 5KW Klystrons with the newer 8KW units.             |
| Controls/Reporting | The requirements will be reviewed by the head of the operations           |
|                    | department. Monthly status reports will be provided to the controls group |
|                    | leader and head of the operations department.                             |

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### **Recovery Schedule**

| ID     | Task Name                      | Duration        | Janu      | ary              | 4.000   | February          | 004 07         | Ma           | rch       | -     |          | April   | 404     | 4000   | ET  | May  | Ello La | ene l | am 1 | Ju  |
|--------|--------------------------------|-----------------|-----------|------------------|---------|-------------------|----------------|--------------|-----------|-------|----------|---------|---------|--------|-----|------|---------|-------|------|-----|
| 1      | Injector Cryomodules @ 2K      | 1 day           | 1/6   1/1 | 3 1/20<br>9-Inje | 1/2/    | 2/3 2/10 2/17     | 2/24 3/3       | 3/10         | 3/1/ 3    | 124 3 | 31 4/    | 4/14    | 4/21    | 4/28   | 5/5 | 5/12 | 5/19 5  | /26   | 6/2  | 6/9 |
| 2      | North Linac Cryomodules @ 2K   | 1 day           | 8-4       | lorth Lin        | ac Cry  | omodules @ 2K     | SS             |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 3      | South Linac Cryomodules @ 2k   | 1 day           |           | 8-               | South   | Linac Cryomodul   | es @ 2K        |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 4      | PSS Certification              | 5 days          |           | PSSC             | ertific | ation             | 200            |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 5      | RF PM1 0L02                    | 2 days          | R         | BFMI             | OLO2    |                   |                |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 6      | RF PM1 2L02                    | 2 days          | 9         | PIRE PM          | 1 21.02 | 2                 |                |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 7      | RF Checkout 0L02               | 3 days          |           | BE               | - Che   | eckout 0L02       |                |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 8      | Commission 0L02                | 7 days          |           | III-S            | 9       | Commission OL02   |                |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 9      | RF PM1 0L03                    | 2 days          | R         | REPMI            | OL03    |                   |                |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 10     | RF PM1 2L11                    | 2 days          | 9         | REAL PM          | 1 21.11 | 1                 |                |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 11     | RF Checkout 0L03               | 3 days          |           | <b>B</b>         | e Che   | eckout 0L03       |                |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 12     | Commission 0L03                | 7 days          |           | H                | 44      | Commissio         | OLD3           |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 13     | RF PM1 1L02                    | 2 days          | R         | REPM1            | 11.02   |                   |                |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 14     | RF PM1 1L03                    | 2 days          | 9         | PER PM           | 1 11.03 | 3                 |                |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 15     | RF Checkout 1L02               | 3 days          |           |                  | F Che   | eckout 1L02       |                |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 16     | Commission 1L02                | 7 days          |           | H-H              |         |                   | ommissio       | n 1L02       |           |       |          |         |         |        |     |      |         |       |      |     |
| 17     | RF Checkout 1L03               | 3 days          |           |                  | Real    | F Checkout 1L.03  | and an area    |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 18     | Commission 1L03                | 7 days          |           |                  | TT-     |                   | Com            | mission      | 1L03      |       |          |         |         |        |     |      |         |       |      |     |
| 19     | RF PM1 1L04                    | 2 days          |           |                  |         | RH PM1 1L04       |                |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 20     | RF Checkout 1L04               | 3 days          |           |                  | 19      | Checkout          | 1L04           |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 21     | Commission 1L04                | 9 days          |           |                  |         |                   |                | Çon          | mission   | 1L04  | L .      |         |         |        |     |      |         |       |      |     |
| 22     | RF PM1 1L05                    | 2 days          |           |                  |         | RRH PM1 1LC       | 5              | -            |           |       |          |         |         |        |     |      |         |       |      |     |
| 23     | RF Checkout 1L05               | 3 days          |           |                  |         | GREAT Che         | ckout 1L0      | 5            |           |       |          |         |         |        |     |      |         |       |      |     |
| 24     | Commission 1L05                | 9 days          |           |                  |         |                   | Carana Connect | -            | Cor       | nmiss | ion 1L0  | 5       |         |        |     |      |         |       |      |     |
| 25     | RF PM1 1L06                    | 2 days          |           |                  |         |                   | 11 1L06        |              |           |       |          |         |         |        |     |      |         |       |      |     |
| 26     | RF Checkout 1L06               | 3 days          |           |                  |         | <b>ARE</b>        | F Checkou      | t 1L06       |           |       |          |         |         |        |     |      |         |       |      |     |
| 27     | Commission 1L06                | 9 days          |           |                  |         | -                 | -              |              |           |       | Commis   | sion 1L | 06      |        |     |      |         |       |      |     |
| 28     | RF PM1 1L07                    | 2 days          |           |                  |         | 4 R               | REPM1 1        | _07          |           | П     |          |         |         |        |     |      |         |       |      |     |
| 29     | RF Checkout 1L07               | 3 days          |           |                  |         | q                 | REFE CH        | eckout       | 1L07      |       |          |         |         |        |     |      |         |       |      |     |
| 30     | Commission 1L07                | 7 days          |           |                  |         |                   |                |              | 0001200-5 | -     | -        | ommis   | sion 1L | .07    |     |      |         |       |      |     |
| 31     | RF PM1 1L08                    | 2 days          |           |                  |         |                   | RRI            | PM1 1L0      | 18        |       |          |         |         |        |     |      |         |       |      |     |
| 32     | RF Checkout 1L08               | 3 days          |           |                  |         |                   | 9085           | F Che        | ckout 11  | .08   |          |         |         |        |     |      |         |       |      |     |
| 33     | Commission 1L08                | 7 days          |           |                  |         |                   |                | 1            |           | -     |          | ç       | ommis   | sion 1 | L08 |      |         |       |      |     |
| 34     | RF PM1 1L09                    | 2 days          |           |                  |         |                   | 9              | RRIP         | M1 1L09   |       |          | 1000    |         |        |     |      |         |       |      |     |
| 35     | RF Checkout 1L09               | 3 days          |           |                  |         |                   |                | 9 <b>8</b> 4 | F Check   | out 1 | L09      |         |         |        |     |      |         | _     |      |     |
|        |                                | Task            |           |                  |         | Cutomal Milact    |                | ~            |           | 1     | Manual   | C       | o Pollu | 2      |     |      |         |       |      |     |
|        |                                | Calif           |           |                  |         | g External Wilesa | AIC .          | ~            |           |       | Manuar   | Summa   | ry ronu |        | _   | _    | 1000    |       |      |     |
|        |                                | Split           |           |                  |         | Inactive Lask     |                | -            |           | _     | Manuai   | Summa   | ry      | -      |     |      | -       |       |      |     |
| Projec | ct: RF Support Activities CY13 | Milestone       | •         |                  |         | Inactive Milesto  | ne             | $\odot$      |           |       | Start-on | У       |         | L      |     |      |         |       |      |     |
| Date:  | Wed 11/14/12                   | Summary         | -         |                  |         | Inactive Summ     | ary            |              |           |       | Finish-o | nly     |         | 3      |     |      |         |       |      |     |
|        |                                | Project Summary |           |                  | -       | Manual Task       | 12             | E            | _         | -     | Progres  | 5       |         |        | _   |      |         |       |      |     |
|        |                                | External Tacks  |           |                  |         | Duration only     | 83             |              |           | -     | Deadlin  |         |         | л      |     |      |         |       |      |     |
|        |                                | CAUCITIAN LASKS | 0000000   |                  |         | Buradon-only      |                |              |           |       | Seaun    | -       |         | ~      |     |      |         |       |      |     |

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Thomas Jefferson National Accelerator Facility Page 8



### **RF Recovery Schedule: Expanded View**



### **Recovery Notes**

#### **PSS Functional Certification**

• Mid January for most zones, gets HV turned on

#### **RF PM1: Initial Checks**

- Perform basic electronic checks
- Inspect and service as required
- Generally should take about 2 days per zone but likely to vary

#### **RF Checkout**

- Recover and tune RF system so it will operate up to cavity limitations or max system capability
- When complete, ready to perform SRF re-commission measurements
- Allocated 3 days for optimization per zone

#### Work Plan

- A team of 2 people in each Linac
- Working on two zones in each Linac in parallel
- Major problems will be bypassed in order to move to the next zone to stay ahead of the SRF team if necessary
- Major PM effort (PM2) deferred until after SRF recovery and more resources are available following the completion of 12 GEV commissioning

• Proposed schedule supports SRF plan, completion in May 2013



Thomas Jefferson National Accelerator Facility Page 10



## **RF Work - Details**

| RF PM's Part 1  | RF Checkout  | RF PM's Part 2  |  |  |  |  |  |
|---|--|---|--|--|--|--|--|
|   | Low Level RF System:   |   |  |  |  |  |  |
| Replace defective Conformable Cables, Buffer cables, etc.                   | Isolate RF Control Module problems in machine                |   |  |  |  |  |  |
| Isolate & resolve Interface Chassis to Cryomodule cabling/connection proble | I Isolate Arc, IR Waveguide Vacuum Interlock problems in mac | nine  |  |  |  |  |  |
| Verify proper operation of the LLRF Power Supply Air Flow Sensor            | Verify proper LO/IF levels at each RFCM                      |   |  |  |  |  |  |
| Measure RF Module Power Supply DC output voltages and AC ripple             | Verify proper Driveline Heaters/Controllers operation        |   |  |  |  |  |  |
| Measure Interface Chassis Power Supply DC output voltages and AC ripple     |  |   |  |  |  |  |  |
| Measure MOPS DC voltages, AC ripple & verify proper cryomodule heater ou    | tputs  |   |  |  |  |  |  |
|   | High Power RF System:  |   |  |  |  |  |  |
|   | <u>CPS:</u>  |   |  |  |  |  |  |
| Replace defective/cracked 50 Ohm Resistors (cathode resistors)              | Verify proper HV operation                                   | Perform physical PMs  |  |  |  |  |  |
| Verify proper interlock operation   |  | Replace/repair HV wiring with corroded connectors                                     |  |  |  |  |  |
| Verify proper metering operation  |  | Replace corroded hardware   |  |  |  |  |  |
|   |  | Realign & stablize HV transformer bobbins to prevent HV arc failures                  |  |  |  |  |  |
|   | HPA:   |   |  |  |  |  |  |
| Replace defective waveguide air hoses                                       | Isolate and resolve 2 1/2 watt amp & p/s problems            | Perform physical PMs  |  |  |  |  |  |
| Adjust waveguide air pressure system for proper operation                   | Isolate and resolve klystron filament operational problems   | Replace defective Klystron Connection Board cabling/hardware                          |  |  |  |  |  |
| Replace defective LCW hoses   | Isolate and resolve klystron mod anode operational problems  | Upgrade waveguide air pressure interlock  |  |  |  |  |  |
| Verify operation of the LCW flowmeter and adjust, as necessary              | Isolate and resolve klystron operational problems            | Replace suspect LCW hoses   |  |  |  |  |  |
| Measure 2 1/2 Watt Amp Power Supplies DC output voltages and AC ripple      |  | Run klystron Miram curves and adjust fillament voltages for proper klystron operation |  |  |  |  |  |
| Remove & replace defective fiber optic cables                               |  | Remove & replace defective waveguide circulator loads                                 |  |  |  |  |  |





Thomas Jefferson National Accelerator Facility Page 11



### **Back-Up Slides**





Thomas Jefferson National Accelerator Facility Page 12

