Linac and Booster Beam Diagnostics

Proton Source Workshop

December 7 and 8, 2010

Craig Drennan

Beam Diagnostic Systems

- Beam Position Monitors, BPM
- Beam Loss Monitors, BLMs
- Beam Emittance Measurement
- Beam Current Toroids
- Beam Intensity Profile Measurement
- Beam Velocity Measurement
- Beam Bunch Length Measurement
- Not Included: Beam Phase

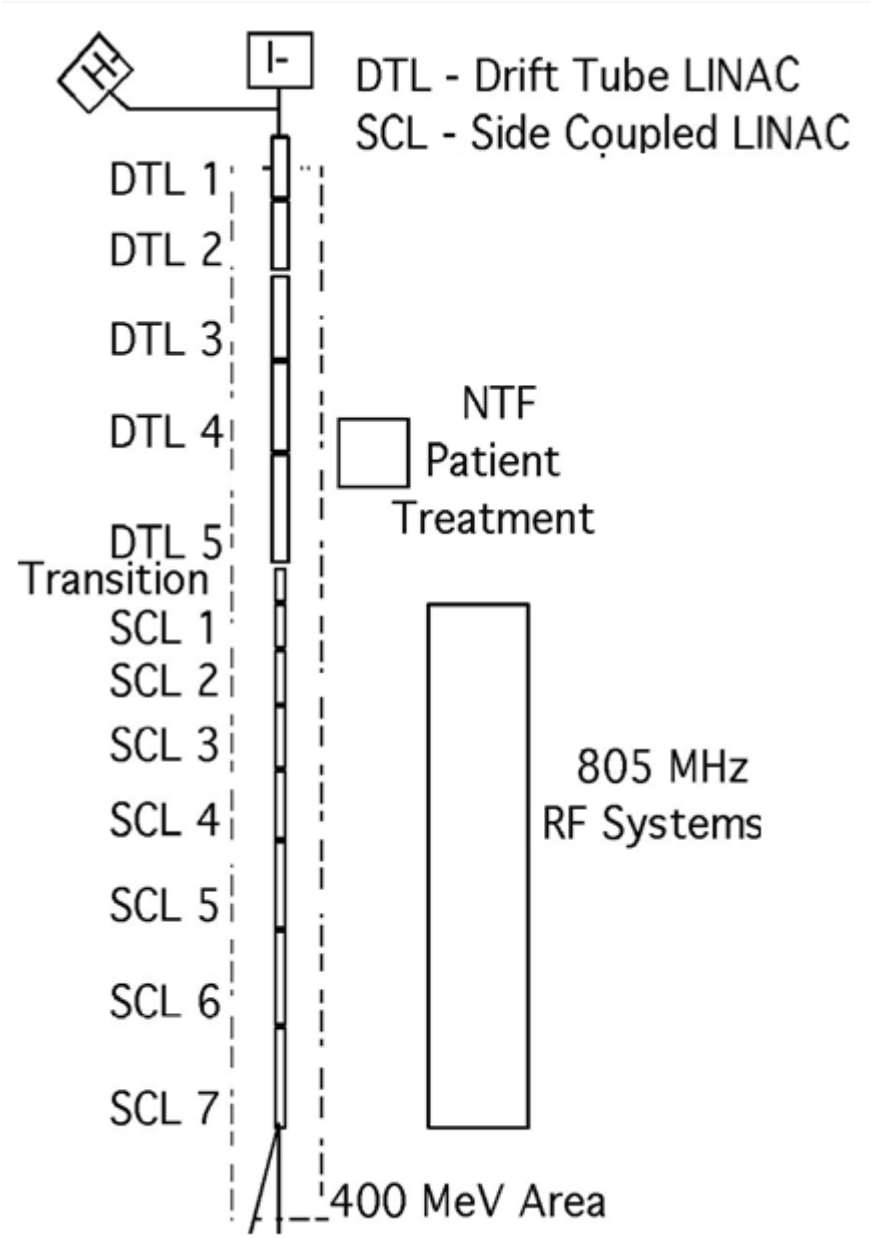
To Be Discussed

- Brief inventory of the diagnostic systems
  - Their purpose and importance to operations
  - Current maintenance issues
  - Current efforts towards improvement
- Group discussion of these systems
  - Questions, comments and correction on the presentation
  - Possible next steps

Preface

- Almost all of the beam diagnostics in the Linac and the Booster have the same main issue. They all have obsolescent components that can no longer be procured.
- The distinction between different systems is how critical they are to operations and/or how much time is reasonable to repair or replace the diagnostic.
- There are a few areas we hope to increase the reliability and quality of beam delivered by improving the performance and calibration of the beam diagnostics.

Linac


H-
I-
DTL - Drift Tube LINAC
SCL - Side Coupled LINAC
DTL 1
DTL 2
DTL 3
DTL 4
DTL 5
Transition
SCL 1
SCL 2
SCL 3
SCL 4
SCL 5
SCL 6
SCL 7
NTF
Patient
Treatment
805 MHz
RF Systems
400 MeV Area

Linac Beam Position Monitors

Daily

RF Module:

Linac Low Energy,

Dwg # EE-60820, R.C. Webber 1987

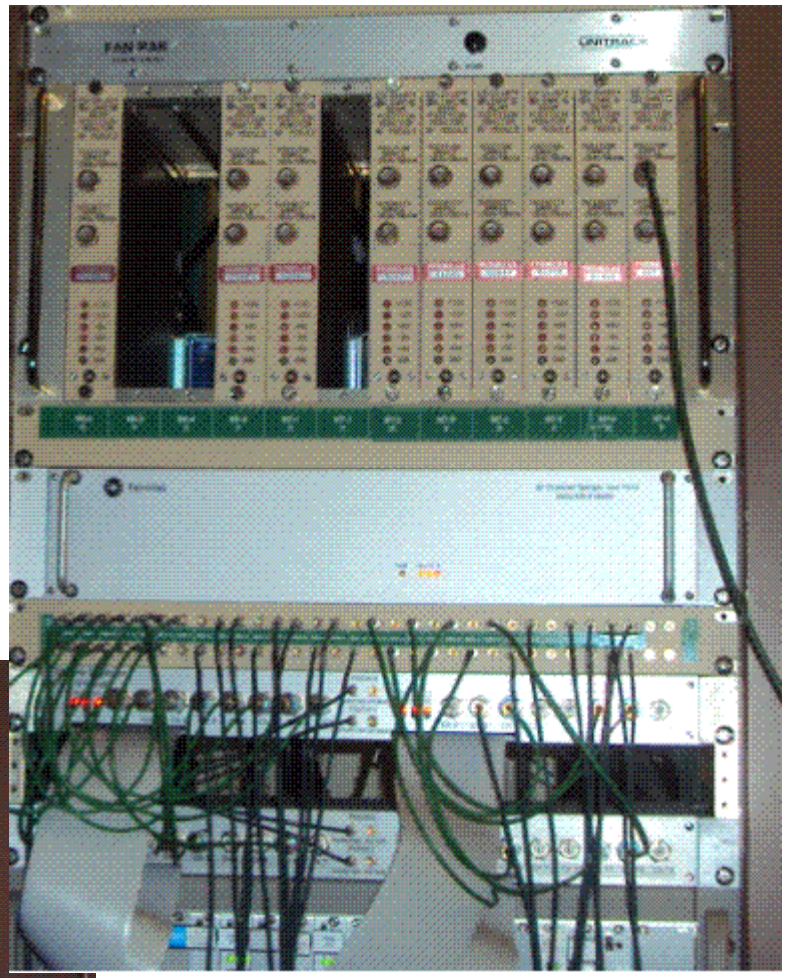
Linac High Energy,

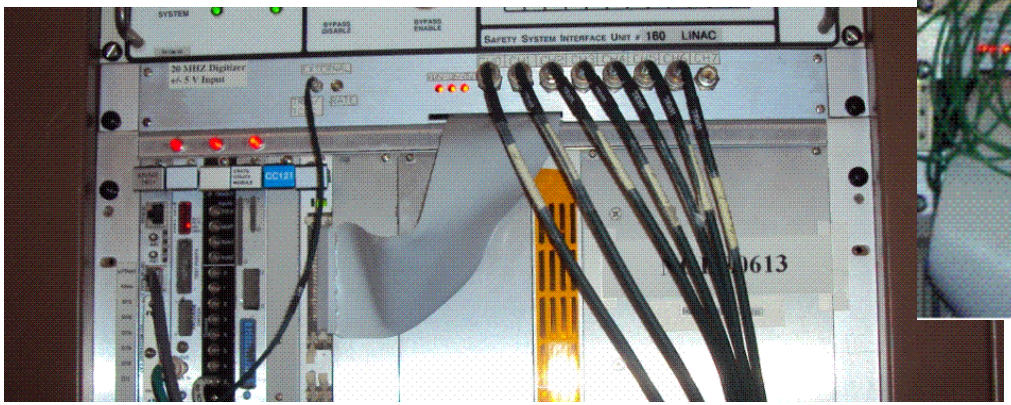
Dwg # ED-281074, J. Arthur 1993

Digitizer and DAQ:

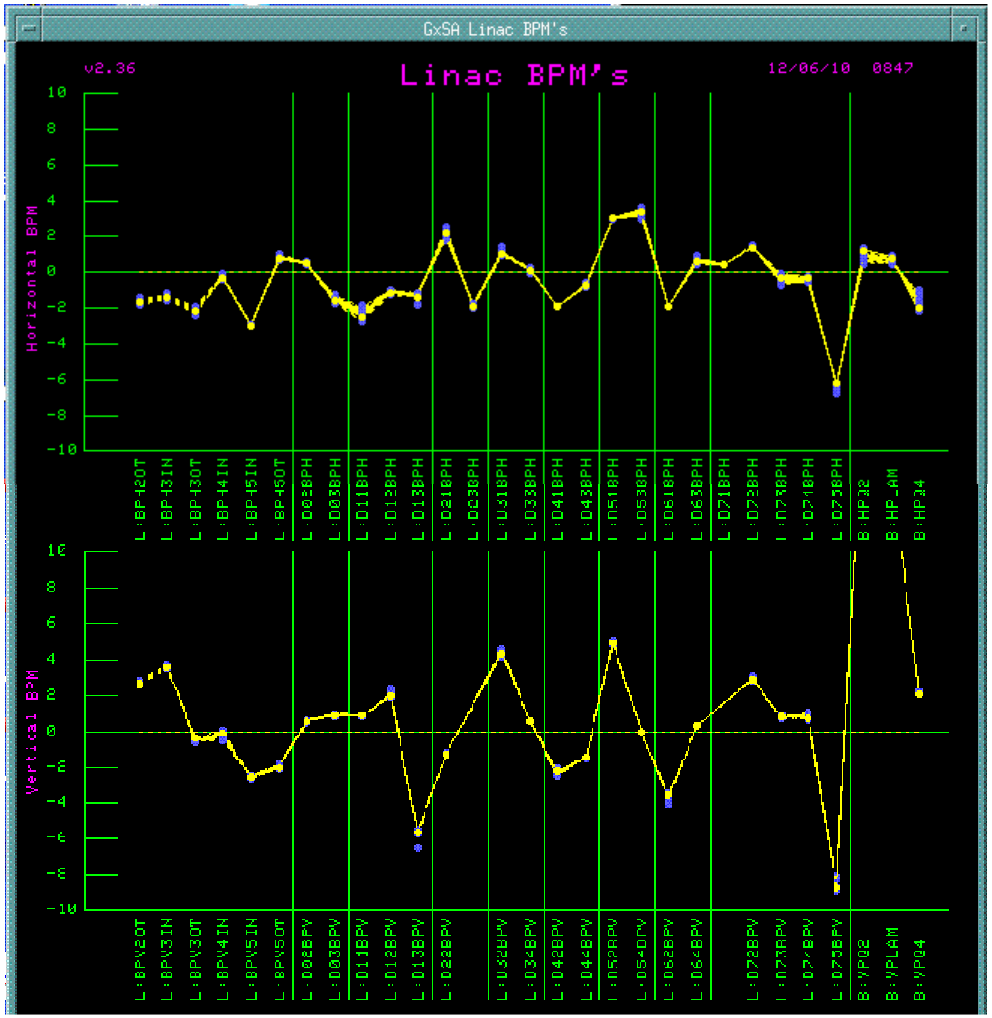
8 Channel, 20 MHz Digitizers tied into

Linac front-end VME crates





Linac Beam Position Monitors



-Beam position calibration needs improvement.

-There is no online calibration for the current Linac BPM RF Modules.

-It is important that the new BPM electronics be linear with beam intensity in order for steering programs to work properly.

-Desired position resolution of +/- 0.25mm

-NTF 's calibration needs should be considered in any upgrade.

Linac Beam Position Monitors

- Linac BPM Electronics Upgrade.
  - Linac BPM positions
    - Low Energy Linac, 14
    - High Energy Linac, 68 (20 not used)
    - 400MeV plus 200 MHz Booster Injection, 51
  - New electronics are like MTA BPMs.
  - Prototype installation expected in Spring 2011.

Continuously

Linac Beam Loss Monitors

- 62 BLMs using Main Ring style log integrators
  - All BLM integrators and DAQ are concentrated in racks just South of the Linac Diagnostics room (all but one).
  - BLM integrators are simply sampled at a fixed time offset from start of beam.
  - Baseline measurement and subtraction are performed in the VME front end processor.

Daily

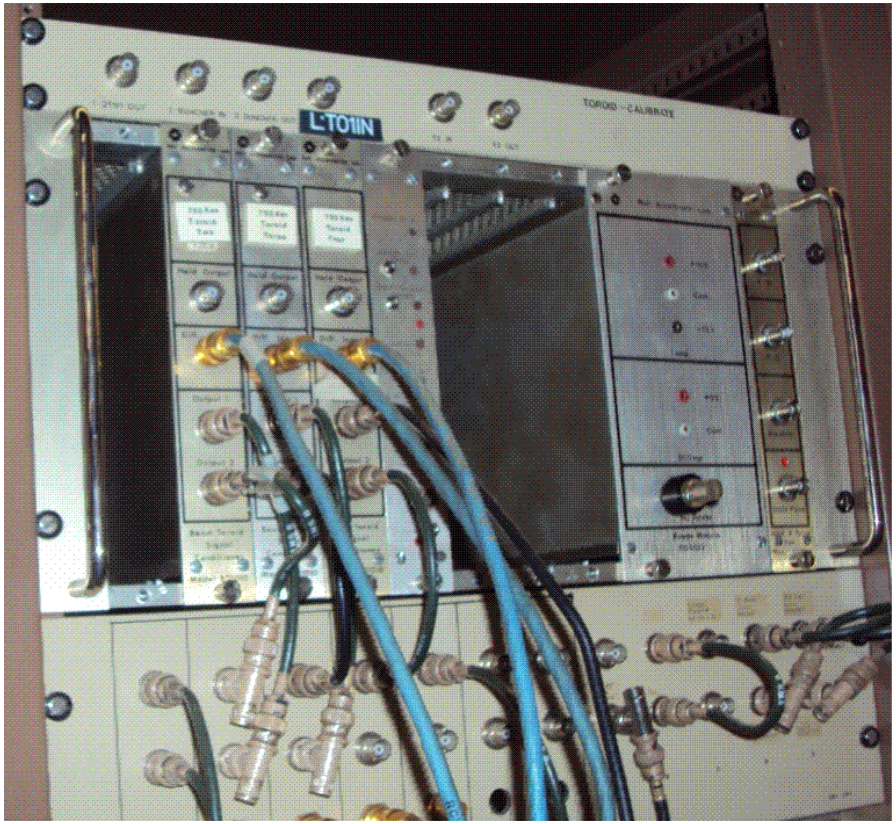
Long, Total Loss Monitors

- Total Loss Monitors are ion chambers several meters long.
  - Currently Linac has to TLM's at Linac Module 3. One on each side (ACNET=> L:TLMDR, L:TLMDH).

Daily

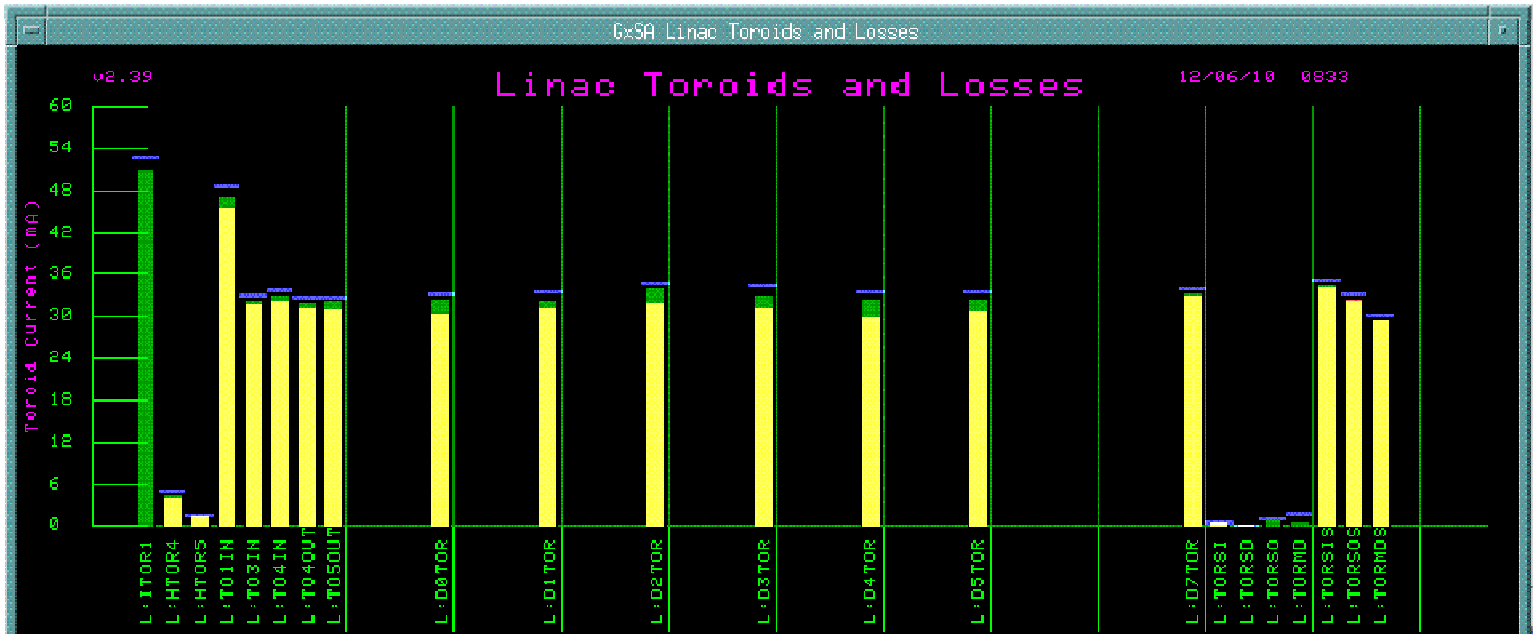
Linac Beam Current Measurements

Photo of one type of toroid and
The current NIM electronics.



Linac Beam Current Measurements

- Linac Toroids and Wall Current Monitors
  - The proton source uses 35 toroids total. All of the toroid systems have been considered for either partial or complete upgrade.



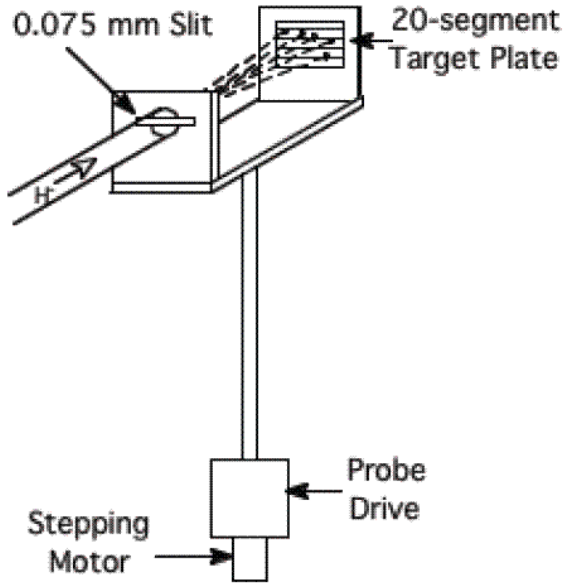
Linac Beam Current Measurements

- New toroids, and measurement and calibration electronics are on there way for the new RFQ at the Linac front end and at the momentum dump.

The new toroid procured for Installation near the Momentum Dump.

750 keV Line Emittance Probes

- Emittance probes are used in the 750 keV transport lines and will be important in bringing up the new RFQ based injector.
  - The maintenance of the electronics and motor controls must continue.
  - New analysis and display software applications will be requested.

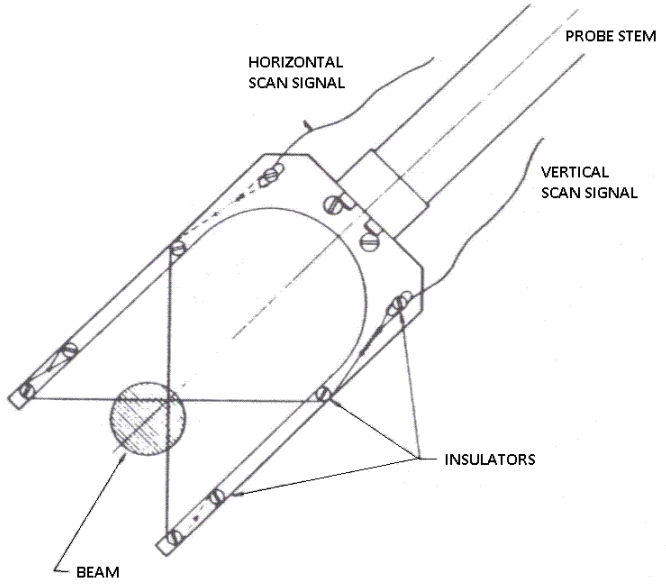


Linac Wire Scanners

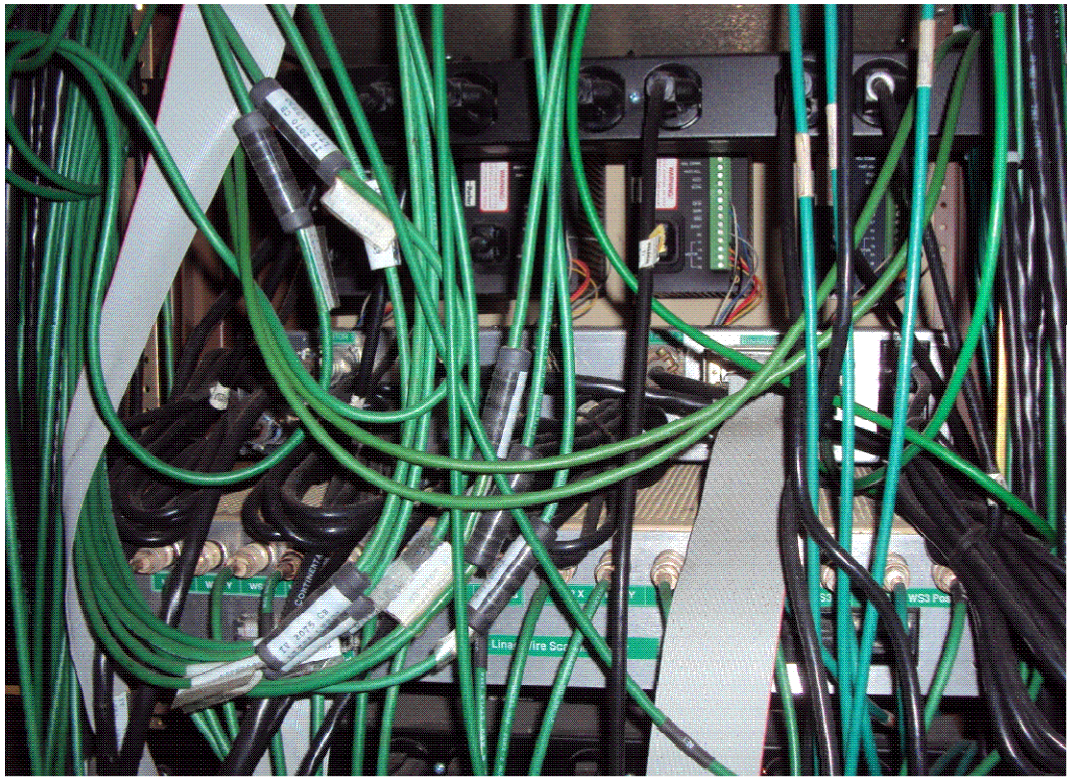
- 750 keV line has 2 wire scanners
- Low Energy Linac, 3
- High Energy Linac, 16
- Dump lines, 12

A new ACNET application could make these wire scanners easier to use.

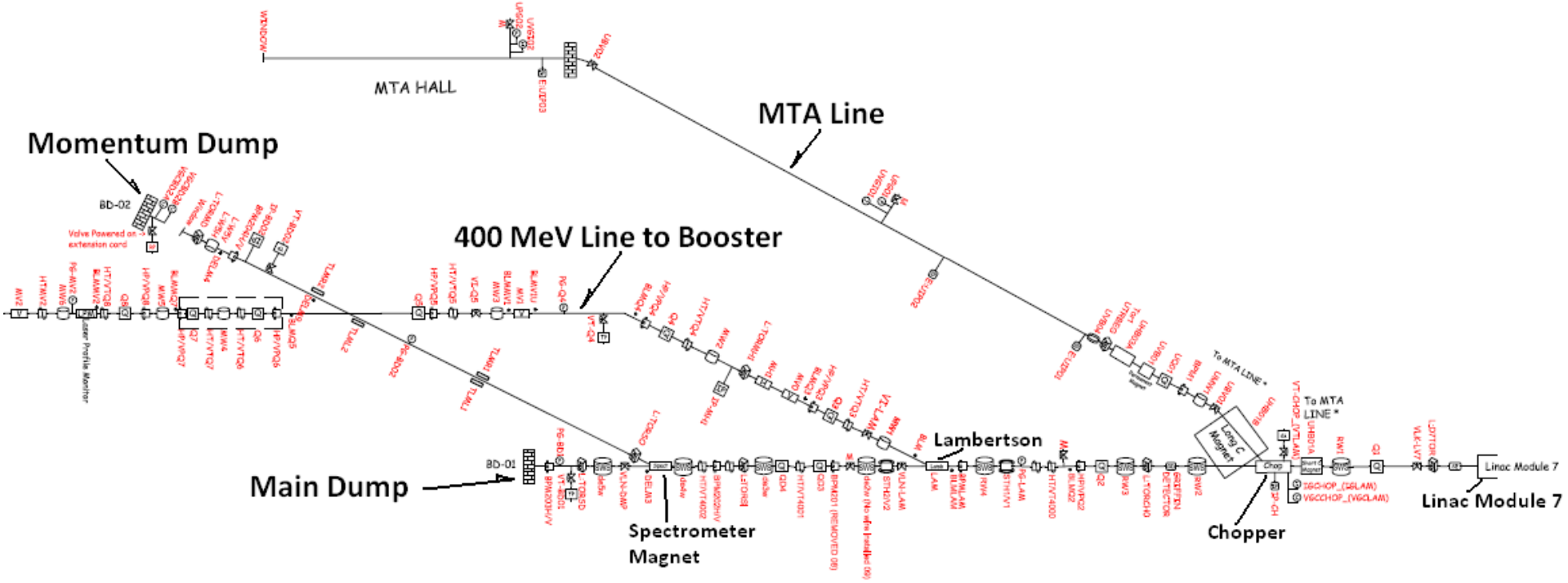
The application would run the wires, collect the data, and compute and display the profile mean and sigma's.



Linac Wire Scanners



400 MeV and Dump Lines



http://www-ad.fnal.gov/proton/booster/BoosterLayout.pdf

Daily

400MeV Beam Position Monitors

RF Module:

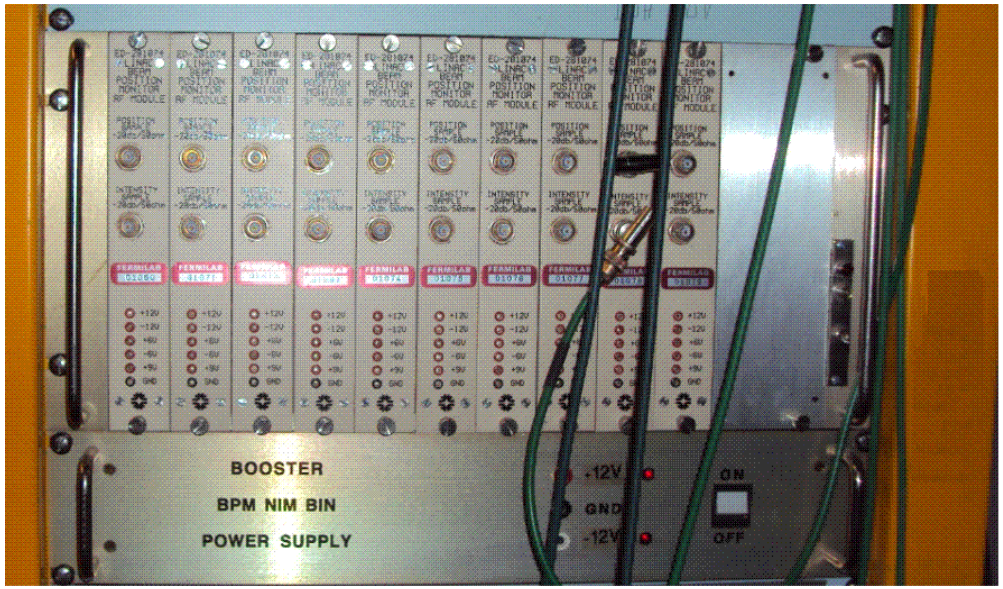
Dwg # ED-281074, J. Arthur 1993

Digitizer and DAQ:

Omnibyte, 5 MHz, “Comet” VME Beams-doc-3013-v2, S. Lackey 2008

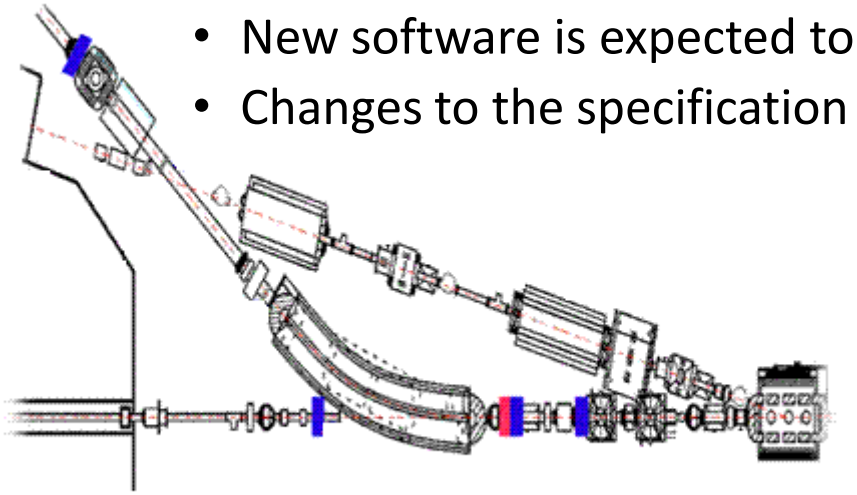
For Description of gating see Beams-doc-3696-v1, C.C. Drennan 2010

400 MeV BPM electronics will be upgraded with the Linac BPM’s.



New Spectrometer Multi-Wires

- New multi-wires are being engineered for upstream and downstream of the Linac spectrometer.
  - Upstream: Standard ceramic split multi-wire as used in the MI-8 line.
  - Downstream: New multi-wire currently being designed
    - 5.5 inch (140 mm) aperture with 98 wires on a 1.45 mm wire spacing (the two end wires are grounded).
    - New software is expected to be written to display 96 wire profiles.
    - Changes to the specification should be voice right away.



400 MeV Line Multi-Wires

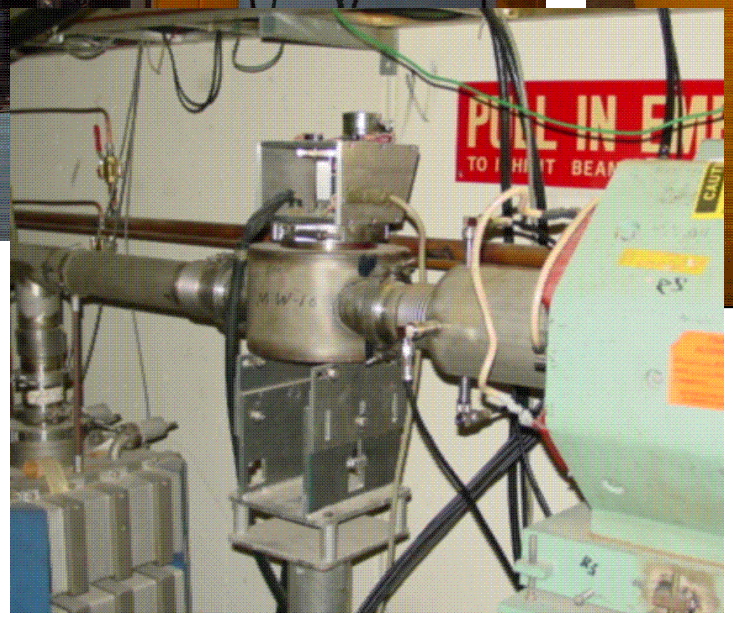
Daily

- 12 multi-wire profile monitors in the 400 MeV line are currently supported by the Booster.

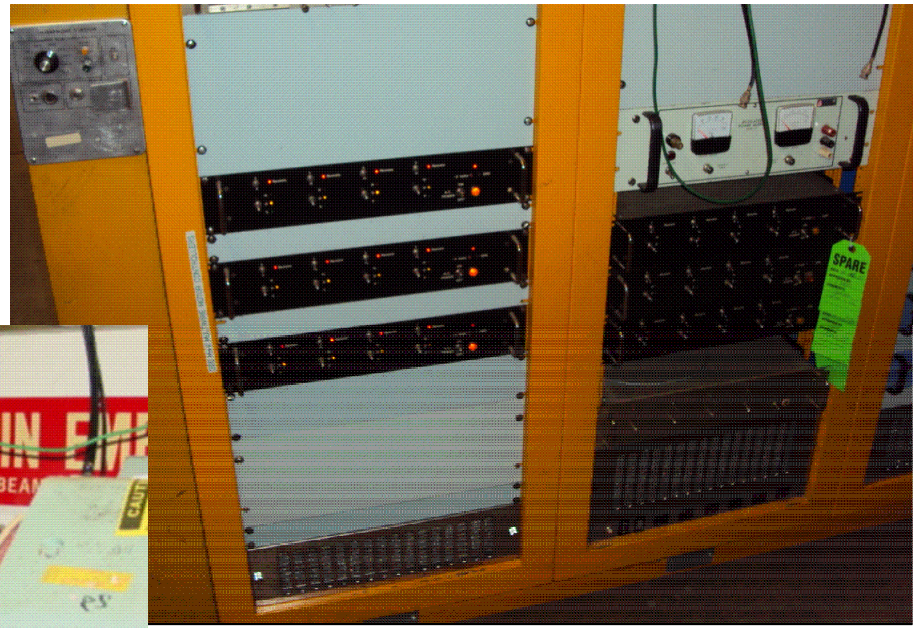
- Electronics
  - NIM motor controller
  - NIM multiplexed integrator
  - CAMAC C192 Multi-Wire Digitizer

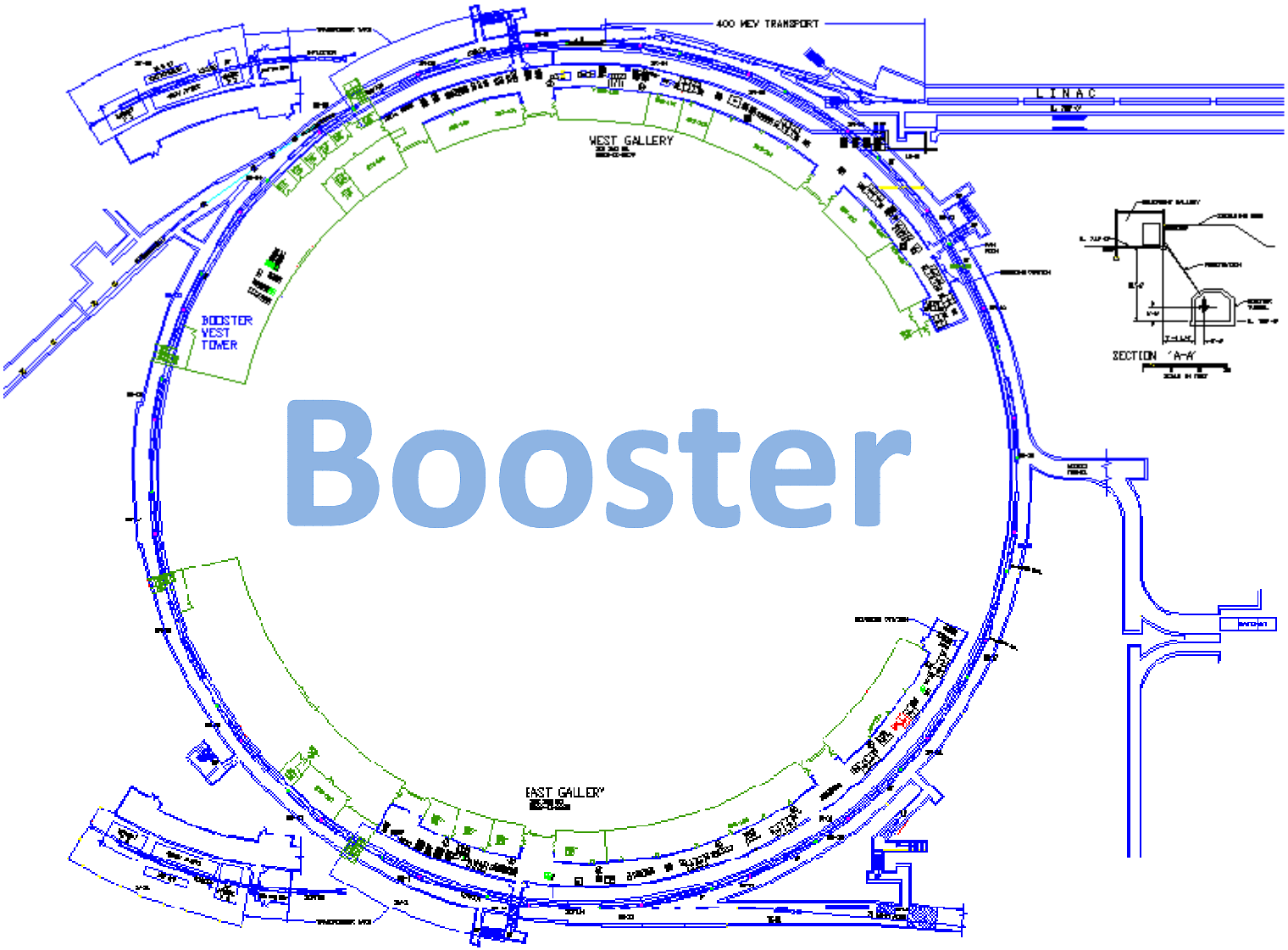
- Just prior to 2008, these wires were used every 2 to 3 months.
  - There is a special concern for the multi-wire located in the 400 MeV chute (MW4).

400 MeV Line Multi-Wires



Multi-wire electronics currently supported by Booster group.



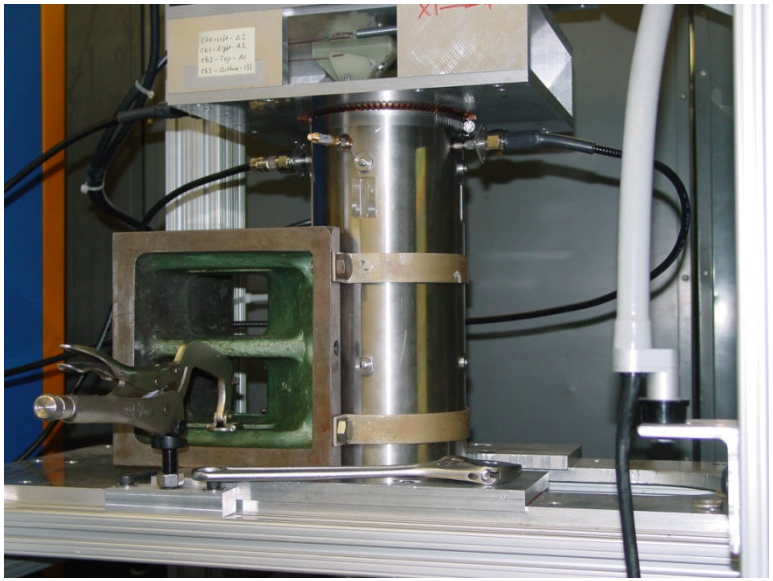

400 MEV TRANSPORT
LINAC
WEST GALLERY
BOOSTER
VEST
TOWER
SECTION 'A-A'
EAST GALLERY

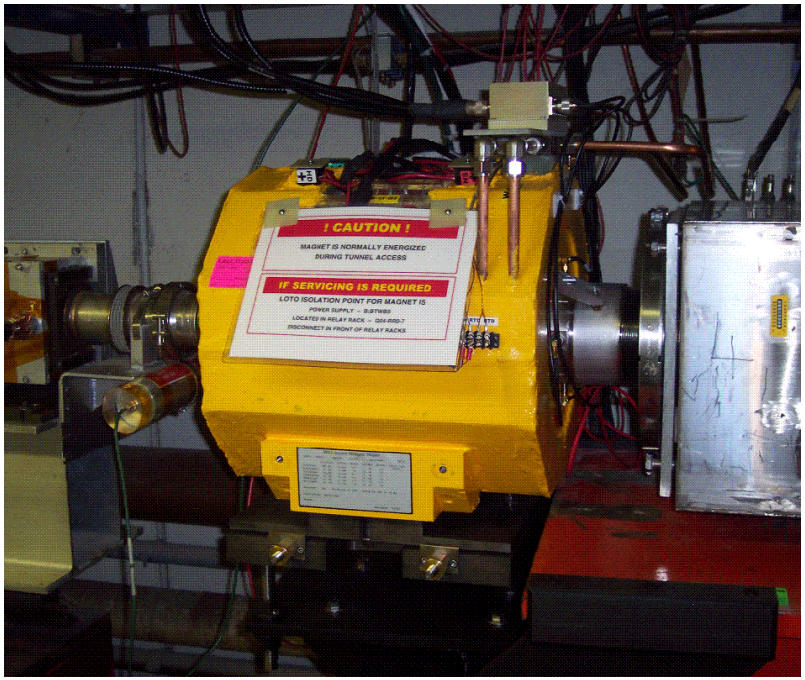
Booster

Daily

Booster Beam Position Monitors

- New Booster BPM detectors were installed recently with the corrector magnet upgrade
  (J.L. Crisp, Beams-doc-2221-v1; J. Fitzgerald, Beams-doc-3376-v1)
- Original Heliax cabling from enclosure to gallery





Booster Beam Position Monitors

102 Position Measurements

References ========

RF Module:

Dwg # EE-37626, R.C. Webber 1986

Digitizer and DAQ:

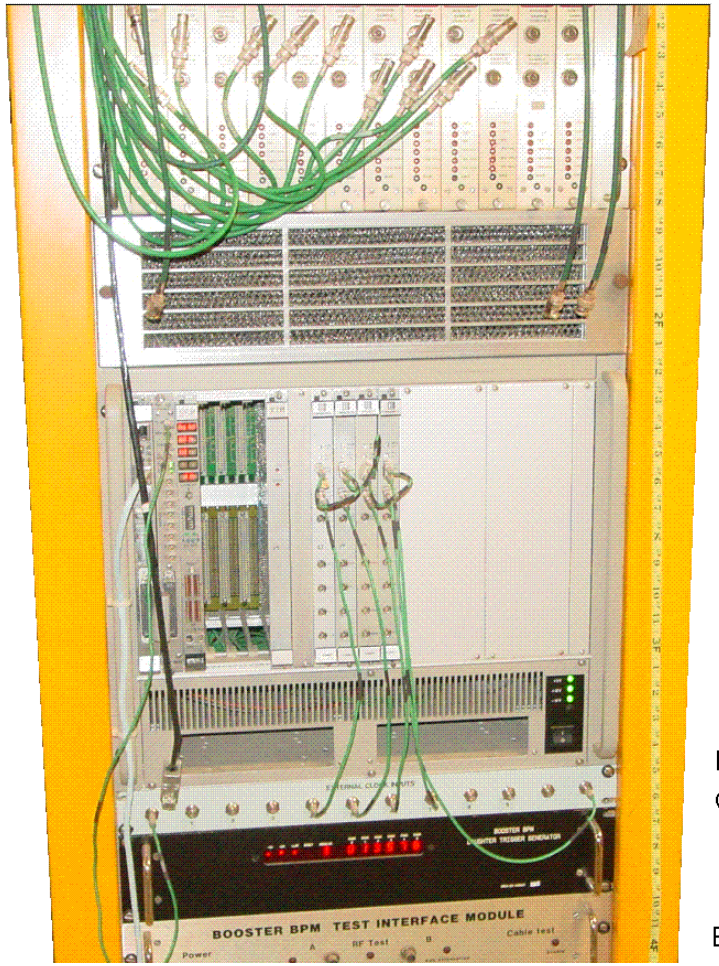
Omnibyte, 2 MHz, “Comet” VME

Beams-doc-3013-v2, S. Lackey 2008

Gating and Turn-by-Turn Sampling :

DTG Dwg# ED-21837 Rev B, 1991

Beams-doc-3696-v1, C.C. Drennan 2010



RF Modules

VME Omnibyte Digitizers

Daughter Trigger Generator

BPM Test Interface

Continuously

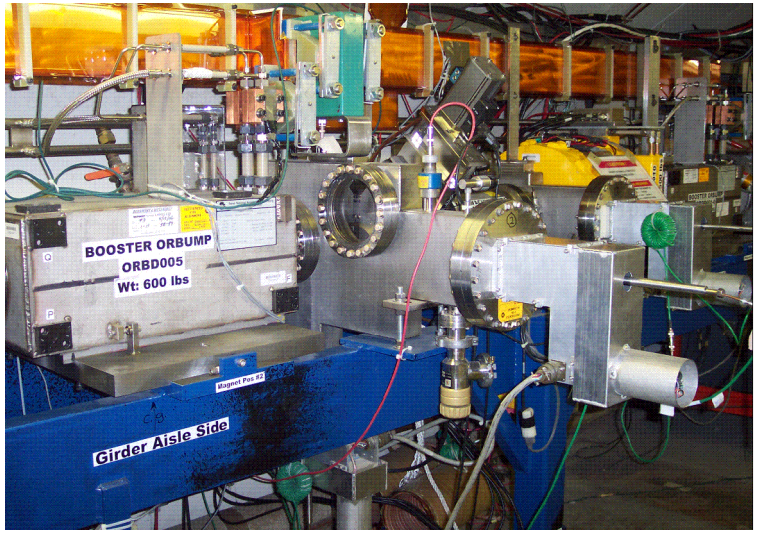
Booster Beam Loss Monitors

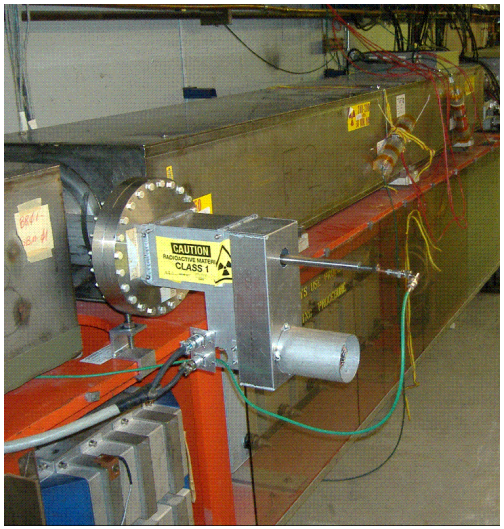
- 92 BLMs using modified Main Ring style log integrators
  - Currently read back with a combination of MADCs and IRM digitizers.
  - Upgrade to newer Tevatron and Main Injector style VME Integrator Digitizers is in the works.

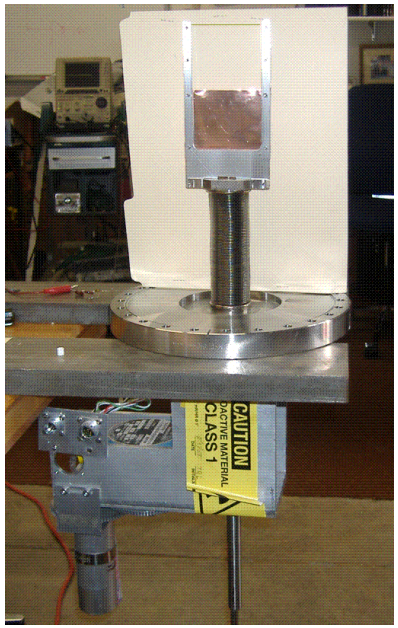
    (Beams-doc-3723-v1, C.C. Drennan)

Booster Injection Single Wire Scanners

- There are 4 single wire scanners on the Booster injection girder.
- There is 1 single wire scanner known as the “Neutral Beam Scanner” used for studies of the electron stripping foils. (Beams-doc-3642-v1 C.C. Drennan)

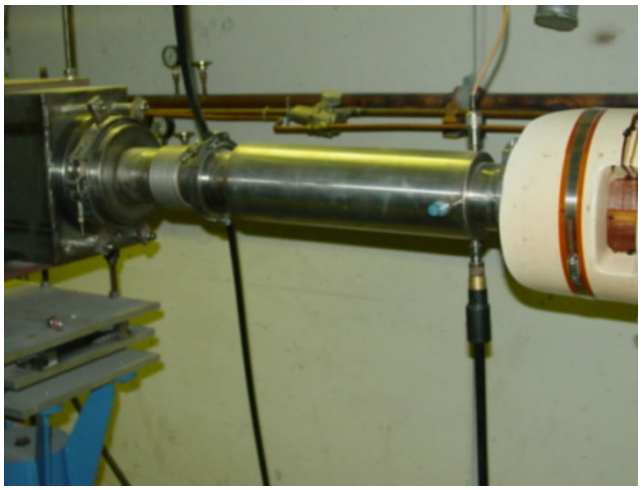


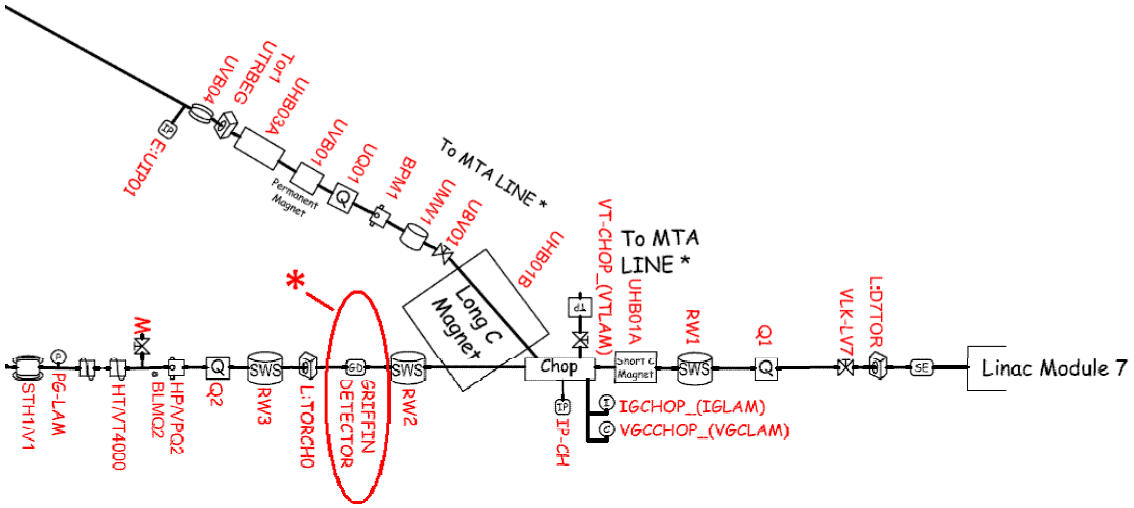


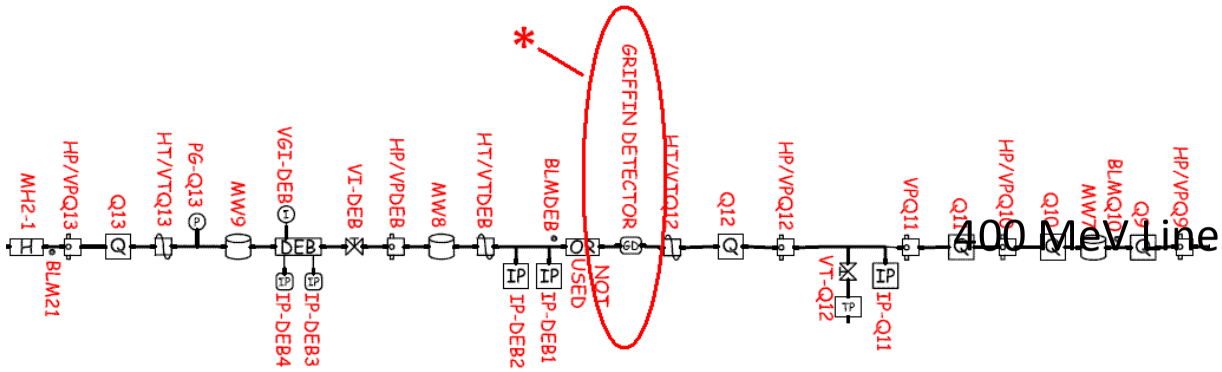


Griffin Detector Beam Pickup

Used for Velocity and Bunch Length Measurement







Continuously

Linac Velocity and Bunch Phase Variation

- Linac Velocity and Bunch Phase Variation
  - The RF phase between the signals from each of the two Griffin Detectors is measured to determine relative Linac beam velocity into the Booster.
  - Linac average velocity is read back by IRM node 61F and used in a Linac regulation loop.

Beam to Debuncher drive showing bunch to bunch phase variation.

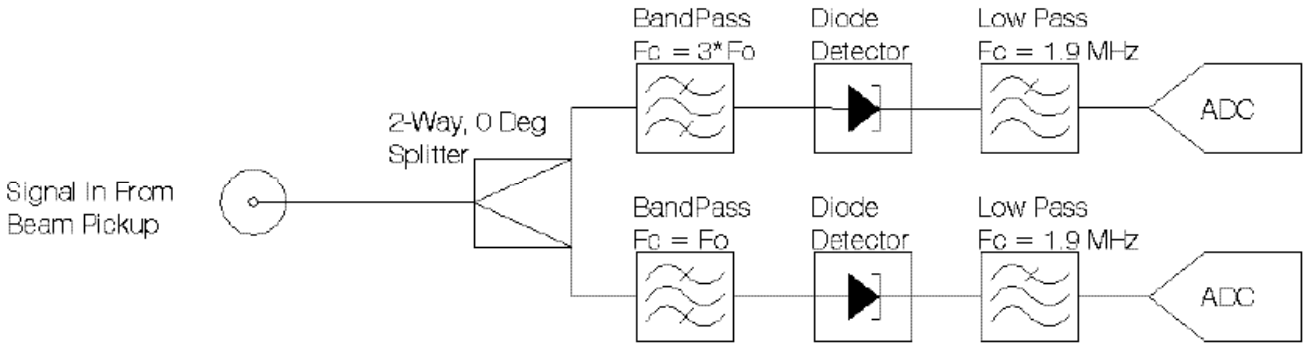
Linac velocity measurement

Horizontal Position at Q4 (400 MeV)

Daily

Bunch Width Measurement

- Booster Injection Bunch Width Measurement



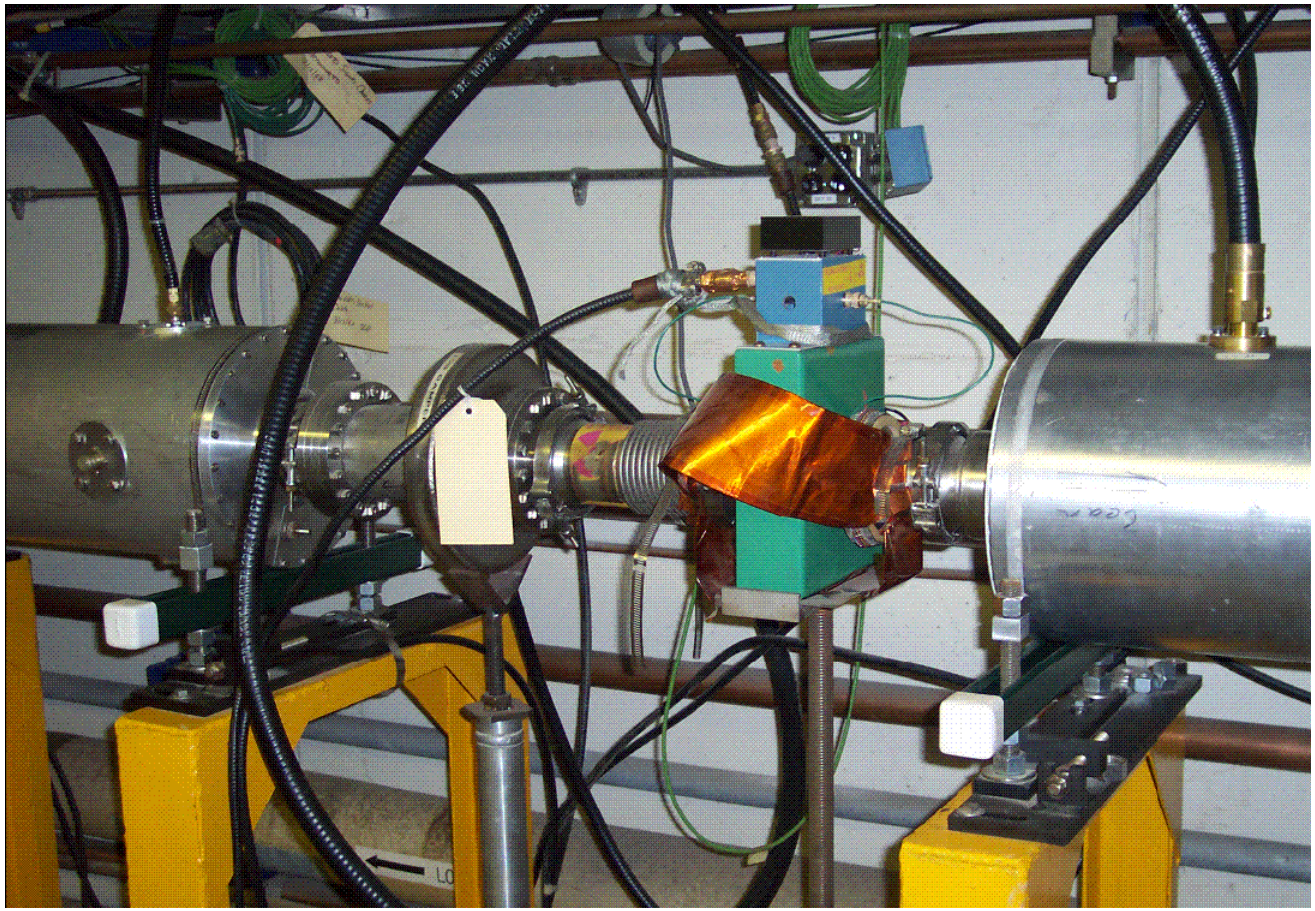
$$\sigma_t = 0.027 \cdot \mathrm{T}_0 \cdot \sqrt{\left(P_{dBm}(\omega_0) - P_{dBm}(3\omega_0)\right)}$$

Beams-doc-3214-v2, C.C. Drennan

Continuously

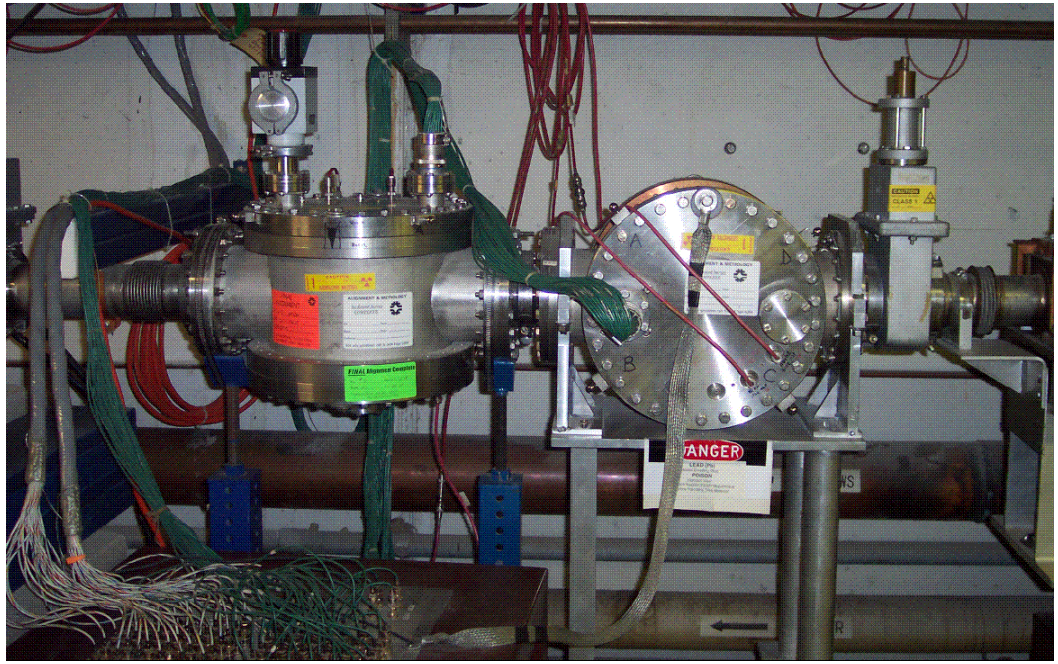
Booster Beam Current, B:CHG0

- Beam Current Toroid at period 20



Booster Ion Profile Monitor

- IPM is a non-destructive profile monitor in the Booster.
  - Currently needs to have the micro channel plates replaced in both units. This requires breaking vacuum.



The End

AD-Instrumentation Department
List of Activities (Status: Dec 2010)

Proton Source

Support, maintenance, soft-and firmware, controls integration, modifications, upgrades, new installations for the following beam and non-beam instrumentation & diagnostics systems:

(M-Maintenance//U-Upgrade//I-Issues//C-Commissioning)

[System Owner]

Linac	805 MHz modulators (klystron section) 7x [Prieto] BPM, 2 per tank, 2 different styles (M) [Olson] New low-cost PPD-style BPM/TOF read-out electronics (U) [Eddy] Toroids (with integrator electronics) 7x (M) [Fellenz] Wall current monitors (WCM) 7x(M) [Fellenz] New SEM multiwires for the dump-line (U) [Tassotto/Schoo]
400 MeV Beam-line	Toroid,3x (M)[Aisha/Dallas] BPM 12x (C) [Eddy] BLM 12x (C) [Olson] Ionization profile monitors (IPM), new requested installation [Zagel] Laser Wire Profile Monitor (LWPM), new requested installation [Zagel]
MTA Beam-line (new equipment, to be commissioned)	BPMs, read-out system (in collaboration with PPD), 10x BLMs, 12x (M) [Olson] Toroids, 3x (M)[Aisha/Dallas] Multiwires, 7x
Booster	Stripline BPM pickups (new installation), 96x(U) [Fitzgerald] BLMs (partial support) (M) [Olson] WCM, 3x(M) [Fellenz] BCHG0 Toroid (M)[Aisha/Dallas] Toroid, 1x(M) [Aisha/Dallas] IPM, 2x [Zagel] Total loss monitors (TLM), MiniBoone Tr. damper system 2x(I) [Crisp, Eddy, Fellenz]
MI-8 Beam-line	BPMs, analog front-end & Echotek based read-out system, 50x [Prieto] BLMs, 50x, plus collimator BLMs (M) [Olson] Toroids, 3x(M)[Aisha/Dallas/Charlie] Mulitwires, 8x, Fermilab & Texas style

The AD-Instrumentation Department provides support for temperature and humidity measurement systems in most areas.

```
L8   TRANS. & MOD. 1-7 LOSS MONITORSET     D/A   A/D  Com-U ◆PTools◆
-<FTP>+ *SA◆ X-A/D  X=T:IRING  Y=T IRING ,T:C4TP3D,T:A1TPUL,T B1TRQ0
COMMAND ---X Eng-U  I= 0       I= 0      , 240    , 240    , 5
-< 1>+  One+ AUTO   F= 4000    F= 20000  , 280    , 280    , 25
tuning  wires   bpm/lm   trims   quads  LOSSMON  bpms   vacuum
 L:D00LM      M0-0 Sampld Loss Monitor              .113   CNT
 L:D0VLM      MV-V Sampld Loss Monitor              .073   CNT

 L:D11LM      M1-1 Sampld Loss Monitor              .137   CNT
 L:D12LM      M1-2 Sampld Loss Monitor              .275   CNT
 L:D13LM      M1-3 Sampld Loss Monitor              .104   CNT
 L:D14LM      M1-4 Sampld Loss Monitor              .006   CNT

 L:D21LM      M2-1 Sampld Loss Monitor              .842   CNT
 L:D22LM      M2-2 Sampld Loss Monitor             -.027   CNT
 L:D23LM      M2-3 Sampld Loss Monitor              .269   CNT
 L:D24LM      M2-4 Sampld Loss Monitor             -.15    CNT

 L:D31LM      M3-1 Sampld Loss Monitor              .403   CNT
 L:D32LM      M3-2 Sampld Loss Monitor              .009   CNT
 L:D33LM      M3-3 Sampld Loss Monitor             -.012   CNT
 L:D34LM      M3-4 Sampld Loss Monitor              .143   CNT

 L:D41LM      M4-1 Sampld Loss Monitor              .134   CNT
 L:D42LM      M4-2 Sampld Loss Monitor              .18    CNT
 L:D43LM      M4-3 Sampld Loss Monitor              .061   CNT
 L:D44LM      M4-4 Sampld Loss Monitor             -.037   CNT

 L:D51LM      M5-1 Sampld Loss Monitor              .281   CNT
 L:D52LM      M5-2 Sampld Loss Monitor              .137   CNT
 L:D53LM      M5-3 Sampld Loss Monitor              .009   CNT
 L:D54LM      M5-4 Sampld Loss Monitor              .027   CNT

 L:D61LM      M6-1 Sampld Loss Monitor              .012   CNT
 L:D62LM      M6-2 Sampld Loss Monitor             -.049   CNT
 L:D63LM      M6-3 Sampld Loss Monitor             -.058   CNT
 L:D64LM      M6-4 Sampld Loss Monitor              .171   CNT

 L:D71LM      M7-1 Sampld Loss Monitor              .333   CNT
 L:D72LM      M7-2 Sampld Loss Monitor              .049   CNT
 L:D73LM      M7-3 Sampld Loss Monitor             -.024   CNT
 L:D74LM      M7-4 Sampld Loss Monitor              .632   CNT


 L:D7LMSM     Sum of Loss Monitors                 3.906       .
 !=============================================!
-L:62ET06     Sample&Hld Trig LossMon0     2344   * 2344    US
-L:62ET07     Sample&Hld Trig LossMon1     2144   * 2144    US
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L8   TOTAL LOSSES & 400MEV BLMS    SET     D/A   A/D  Com-U ◆PTools◆
-<FTP>+ *SA◆ X-A/D  X=T:IRING  Y=T IRING ,T:C4TP3D,T:A1TPUL,T B1TRQ0
COMMAND ---X Eng-U  I= 0       I= 0      , 240    , 240    , 5
-< 2>+  One+ AUTO   F= 4000    F= 20000  , 280    , 280    , 25
tuning  wires   bpm/lm   trims   quads  LOSSMON  bpms   vacuum

 ! *** TOTAL LOSSES.................................
 L:D0TLM      Loss Mon: Averag Modul 0                .092   MV
 L:D1TLM      Loss Mon: Averag Modul 1                .128   MV
 L:D2TLM      Loss Mon: Averag Modul 2                .232   MV
 L:D3TLM      Loss Mon: Averag Modul 3                .134   MV
 L:D4TLM      Loss Mon: Averag Modul 4                .085   MV
 L:D5TLM      Loss Mon: Averag Modul 5                .113   MV
 L:D6TLM      Loss Mon: Averag Modul 6                .018   MV
 L:D7TLM      Loss Mon: Averag Modul 7                .244   MV
 L:TLTMPE     Total Loss Module 3 East                .479   levl
 L:TLTMPW     Total Loss Module 3 West                .082   levl
 ! *** 400 MEV LOSS MONITORS.......................
 L:DELM1      Loss Mon: Lambertson Out                .211    mV
 L:DELM2      Loss Mon: Spectrometr In                .473    mV
 L:DELM3      Loss Mon: Straight Dump                 .943    mV
 L:DELM4      Loss Mon: Momentum Dump                6.9      mV
 L:DELM5      Loss Mon: Extra 400MeV                 2.353    mV

 L:DELM6      Loss Mon. Lambertson US                 .314    CNT
 L:DELM7      Loss Mon. DLQ1                          .51     CNT
 L:DELM8      Loss Mon. DLQ2                          .089    CNT
 L:DELM9      Loss Mon. SPEC dwnstream                .328   ct*1
 L:DELM10     Loss Mon. Griffen Det.                 -.439    CNT
 L:DELM11     Loss Mon. Chopper upstm                -.015    CNT
 L:DELM12     Loss Mon. Chopper dwnstm                .046    CNT

 ! *** BEAM DUMP #2 - TOTAL LOSS MONITORS.........
 L:TLML1      Spec TLM   Upstream East               730     levl
 L:TLMR1      Spec TLM   Upstream West              6.132    levl
 L:TLML2      Spec TLM Downstream East             82.87     levl
 L:TLMR2      Spec TLM Dowsntream West             16.54     levl

-L:TLMDR      LINAC DUMP TLM RESET        .001  *  .001     mS
-L:TLMDRE     LINAC DUMP TLMReset Evnt    00AA    *00AA
-L:TLMDH      LINAC DUMP TLM HOLD          10     * 10       mS
-L:TLMDHE     LINAC DUMP TLMHold Event    00AA    *00AA

 ! *** POWER LOSS ..............................
 L:D7POWL     Total Beam Power Lost               * 7.248
 L:D7POWL     Total Beam Power Lost               * 7.248
 L:D7APWL     Average Linac power lost            *  .006
 L:D7LMSM     Sum of Loss Monitors                  3.906       .
```

```
L8   RADIATION MONITORS              SET     D/A   A/D  Com-U ♦PTools♦
-<FTP>+ *SA♦ X-A/D  X=T:IRING  Y=T IRING ,T:C4TP3D,T:A1TPUL,T B1TRQ0
COMMAND ---X Eng-U  I= 0       I= 0      , 240    , 240    , 5
-< 3>+  One+ AUTO   F= 4000    F= 20000  , 280    , 280    , 25
tuning  wires   bpm/lm   trims   quads  LOSSMON  bpms   vacuum

 ! *** RADIATION MONITORS.........................

 L:T12CHP     T1 T1 2 RAD MONITR                    * 5.061   MRH
 L:T2CHIP     T2 PENTRA RAD MONR                    * 3.872   MRH
 L:T3CHIP     T3 PENTRA RAD MONR                    * 3.597   MRH
 L:T4CHIP     T4 PENTRA RAD MONR                    * 3.658   MRH
 L:T5CHIP     T5 PENTRA RAD MONR                    * 3.11    MRH
 L:T6CHIP     T6 PENTRA RAD MONR                    * 4.36    MRH
 L:T7CHIP     T7 PENTRA RAD MONR                    * 4.024   MRH
 L:T8CHIP     T8 PENTRA RAD MONR                      0       MRH
 L:T9CHIP     T9 PENTRA RAD MONR                      0       MRH

 L:T3SCAR     TK3 TUNNEL RAD MON                    *  .188   R/H
-L:TUNRAD      TUNING RAD MONITR          70.19       147.4   mR/h
-L:TK1RAD      TANK 1 RAD MONITOR         -.098       13.18   mR/h

 L:400SCA      LABYRINTH RAD MON                        .118   R/hr

 G:RD2047     LIN 400 MeV Air Mon.                      0      Cpm
 G:RA2047     LIN 400 MeV Air Mon.                      0      Cpm
 G:RA2040     400 MeV, Labrth, leg2                    69      mRem

 G:RA2031     Linac Encl, TL#1                         2.1     mRem
 G:RD2031     Linac Encl, TL#1                         3.9     mRem

L8   TANK 5 LOSS MONITORS            SET     D/A   A/D  Com-U ♦PTools♦
-<FTP>+ *SA♦ X-A/D  X=T:IRING  Y=T IRING ,T:C4TP3D,T:A1TPUL,T B1TRQ0
COMMAND ---X Eng-U  I= 0       I= 0      , 240    , 240    , 5
-< 4>+  One+ AUTO   F= 4000    F= 20000  , 280    , 280    , 25
tuning  wires   bpm/lm   trims   quads  LOSSMON  bpms   vacuum

 ! *** TANK 5 LOSS MONITORS.....................

 L:TK5LM1     Tank 5 Loss Monitor 1                 *  0      CNT
 L:TK5LM2     Tank 5 Loss Monitor 2                 *  0      CNT
 L:TK5LM3     Tank 5 Loss Monitor 3                 *  0      CNT
 L:TK5LM4     Tank 5 Loss Monitor 4                 *  0      CNT
 L:TK5LM5     Tank 5 Loss Monitor 5                 *  0      CNT
 L:TK5LM6     Tank 5 Loss Monitor 6                 *  0      CNT
 L:TK5LM7     Tank 5 Loss Monitor 7                 *  0      CNT
 L:TK5LM8     Tank 5 Loss Monitor 8                 *  0      CNT
```

```
L8   D7LMSM Loss Monitors            SET     D/A   A/D  Com-U ♦PTools♦
-<FTP>+ *SA♦ X-A/D  X=T:IRING  Y=T IRING ,T:C4TP3D,T:A1TPUL,T B1TRQ0
COMMAND ---X Eng-U  I= 0       I= 0      , 240    , 240    , 5
-< 5>+  One+ AUTO   F= 4000    F= 20000  , 280    , 280    , 25
tuning  wires   bpm/lm   trims   quads  LOSSMON  bpms   vacuum

 !*** These LMs contribute to the D7LMSM calculatio

 L:TK5LM1     Tank 5 Loss Monitor 1                 *  .067   CNT
 L:TK5LM2     Tank 5 Loss Monitor 2                 *  .055   CNT
 L:TK5LM3     Tank 5 Loss Monitor 3                 * -.146   CNT
 L:TK5LM4     Tank 5 Loss Monitor 4                 * -.076   CNT
 L:TK5LM5     Tank 5 Loss Monitor 5                 *  .021   CNT
 L:TK5LM6     Tank 5 Loss Monitor 6                 *  .07    CNT
 L:TK5LM7     Tank 5 Loss Monitor 7                 * -.058   CNT
 L:TK5LM8     Tank 5 Loss Monitor 8                 *  .006   CNT

 L:D00LM      M0-0 Sampld Loss Monitor                 .046   CNT
 L:D0VLM      MV-V Sampld Loss Monitor                 .174   CNT
 L:D11LM      M1-1 Sampld Loss Monitor                 .119   CNT
 L:D12LM      M1-2 Sampld Loss Monitor                 .192   CNT
 L:D13LM      M1-3 Sampld Loss Monitor                 .204   CNT
 L:D14LM      M1-4 Sampld Loss Monitor                 .192   CNT
 L:D21LM      M2-1 Sampld Loss Monitor                 .815   CNT
 L:D22LM      M2-2 Sampld Loss Monitor                 .107   CNT
 L:D23LM      M2-3 Sampld Loss Monitor                 .217   CNT
 L:D24LM      M2-4 Sampld Loss Monitor                -.012   CNT
 L:D31LM      M3-1 Sampld Loss Monitor                 .15    CNT
 L:D32LM      M3-2 Sampld Loss Monitor                -.012   CNT
 L:D33LM      M3-3 Sampld Loss Monitor                 .116   CNT
 L:D34LM      M3-4 Sampld Loss Monitor                -.003   CNT
 L:D41LM      M4-1 Sampld Loss Monitor                 .015   CNT
 L:D42LM      M4-2 Sampld Loss Monitor                 .18    CNT
 L:D43LM      M4-3 Sampld Loss Monitor                 .104   CNT
 L:D44LM      M4-4 Sampld Loss Monitor                 .128   CNT
 L:D51LM      M5-1 Sampld Loss Monitor                 .07    CNT
 L:D52LM      M5-2 Sampld Loss Monitor                 .168   CNT
 L:D53LM      M5-3 Sampld Loss Monitor                -.11    CNT
 L:D54LM      M5-4 Sampld Loss Monitor                -.079   CNT
 L:D61LM      M6-1 Sampld Loss Monitor                -.067   CNT
 L:D62LM      M6-2 Sampld Loss Monitor                 .116   CNT
 L:D63LM      M6-3 Sampld Loss Monitor                -.085   CNT
 L:D64LM      M6-4 Sampld Loss Monitor                 .232   CNT
 L:D71LM      M7-1 Sampld Loss Monitor                 .247   CNT
 L:D72LM      M7-2 Sampld Loss Monitor                 .18    CNT


 L:D7LMSM     Sum of Loss Monitors                    3.357
```

```
L8   TOROIDS OVERVIEW              SET     D/A   A/D  Com-U ♦PTools♦
-<FTP>+ *SA♦ X-A/D  X=T:IRING  Y=T IRING ,T:C4TP3D,T:A1TPUL,T B1TRQ0
COMMAND ---X Eng-U  I= 0       I= 0      , 240    , 240    , 5
-< 9>+  One+ AUTO   F= 4000    F= 20000  , 280    , 280    , 25
tuning  wires   bpm/lm   trims   quads  LOSSMON  bpms   vacuum

 ! *** 750 LINE.....................................
 L:ITOR1      I  TOROID  1                          * 51.82   mA

 L:HTOR4      H  TOROID  4                            53.5    mA
 L:HTOR5      H  TOROID  5                          * 48.89   mA

 ! *** LE LINAC.....................................
 L:TO1IN      T1 TOROID IN                          * -.278   mA

 L:TO2IN      T2 TOROID IN                          *  0      mA
 L:TO2OUT     T2 TOROID OUT                         *  0      mA

 L:TO3IN      T3 TOROID IN                          *  0      mA
 L:TO3OUT     T3 TOROID OUT                         *  0      mA

 L:TO4IN      T4 TOROID IN                          *  .04    mA
 L:TO4OUT     T4 TOROID OUT                         * -.113   mA

 L:TO5OUT     T5 TOROID OUT                         *  0      mA

 ! *** HE LINAC.....................................
 L:D0TOR      Transition Out Toroid                 *  0      mA
 L:D1TOR      Module 1 Out Toroid                   *  0      mA
 L:D2TOR      Module 2 Out Toroid                   *  0      mA
 L:D3TOR      Module 3 Out Toroid                   *  0      mA
 L:D4TOR      Module 4 Out Toroid                   *  0      mA
 L:D5TOR      Module 5 Out Toroid                   *  0      mA
 L:D6TOR      Module 6 Out Toroid                   *  0      mA
 L:D7TOR      Module 7 Out Toroid                      0      mA

 ! *** SPECTROMETER AREA............................
 L:TORSD      Toroid - ST dump                      *  0      mA
 L:TORSI      Toroid - Spect IN                     *  0      mA
 L:TORSO      Toroid - Spect OUT                    *  0      mA
 L:TORMD      Toroid - Mom. Dump                    *  0      mA
 L:TORMDS     Mom Dump Toroid Sample                * 31.05   mA
 L:TORSIS     Spect In Toroid Sample                  35.94   mA
 L:TORSOS     Spect Out Toroid Sample                 33.74   mA
 G:LMDEFF     Momentum dump efficiency              * 91.12   %
```

```
L8   400 MEV WIRES                  SET      D/A    A/D   Com-U ♦PTools♦
-<FTP>+ *SA♦ X-A/D   X=T:IRING   Y=T IRING ,T:C4TP3D,T:A1TPUL,T B1TRQ0
COMMAND ---X Eng-U   I= 0        I= 0       , 240     , 240     , 5
-< 1>+  One+ AUTO    F= 4000     F= 20000   , 280     , 280     , 25
tuning  WIRES   bpm/lm   trims   quads  lossmon  bpms   vacuum
 ! ************ UPSTREAM LAMBERTSON *********** !
-L:DE1WPX       POSX    MAX  IN IN  OUT     <       > -31.49   MM  0.
 L:DE1WSX       WIRE SCANNER X                   *  .008    V
-L:DE1WPY       POSY    MAX  IN IN  OUT     <       >* 31.49   MM  0.
 L:DE1WSY       WIRE SCANNER Y                   *  .006    V

 ! REMOVED FROM TUNNEL DUE TO MOM. DUMP VACUUM
-L:DE2WPX       POSX    MAX  IN IN -158.5   <       >*-112.2   MM  0*
 L:DE2WSX       WIRE SCANNER X                   *  .027    V
-L:DE2WPY       POSY    MAX  IN IN  158.3   <       >* 112.1   MM  0*
 L:DE2WSY       WIRE SCANNER Y                   *  .009    V

 ! ************ DOWNSTREAM QD4 ***************** !
-L:DE3WPX       POSX    MAX  IN IN  OUT     <       > -33.43   MM  0.
 L:DE3WSX       WIRE SCANNER X                   *  .005    V
-L:DE3WPY       POSY    MAX  IN IN  OUT     <       >  33.43   MM  0.
 L:DE3WSY       WIRE SCANNER Y                   *  .003    V

 ! ************ UPSTREAM SPECTROMETER MAGNET ** !
-L:DE4WPX       POSY    MAX  IN IN  OUT     <       > -45.41   MM  0.
 L:DE4WSX       WIRE SCANNER X                   *  .01     V
-L:DE4WPY       POSY    MAX  IN IN  OUT     <       >* 45.42   MM  0.
 L:DE4WSY       WIRE SCANNER Y                   * -.017    V

 ! ************ STRAIGHT AHEAD DUMP *********** !
-L:W4HPOS       E W4     LOC REM  I -35.47   <       > -36.92   MM   0 .
 L:W4H          E W4 HORZ SIGNAL                 *  0       V
-L:W4VPOS        E W4    LOC REM  I  35.52   <       >  36.97   MM   0 .
 L:W4V          E W4 VERT SIGNAL                 *  0       V

 ! ************ MOMENTUM DUMP ****************** !
-L:W5HPOS       E W5     LOC REM  I -4.885   <       > -4.968   CM   0 .
 L:W5H          E W5 HORZ SIGNAL                 *  0       V
-L:W5VPOS       E W5     LOC REM  IN OUT     <       >* 18.55   CM   0 .
 L:W5V          E W5 VERT SIGNAL                 *  0       V



 ! ********************************************** !
 ! *** Sample and hold timer for the wire scanner !
 ! *** Originally was 1995 usc (06/18/2010)   *** !
-L:62ET04       Sample&Hold Trig, Motor0     1998   * 1998    US
```

```
L8   WIRE SCANNERS D81-83           SET      D/A    A/D   Com-U ♦PTools♦
-<FTP>+ *SA♦ X-A/D   X=T:IRING   Y=T IRING ,T:C4TP3D,T:A1TPUL,T B1TRQ0
COMMAND ---X Eng-U   I= 0        I= 0       , 240     , 240     , 5
-< 2>+  One+ AUTO    F= 4000     F= 20000   , 280     , 280     , 25
tuning  WIRES   bpm/lm   trims   quads  lossmon  bpms   vacuum
 ! ************ UPSTREAM CHOPPER *************** !
-L:D81WPX*.01 Wire Scanner X Position      <       >*-21.5    MM  0  .
 L:D81WSX      Wire Scanner X signal                * -.032   V
 L:D81WSY      Wire Scanner Y Signal                * -.02    V
 L:D81WSU      Wire Scanner U Signal                *  .013   V

 ! *********** DOWNSTREAM CHOPPER (REMOVED) *** !
-L:D82WPX*.01 Wire Scanner X Position      <       >* 214.9   MM  0  *
 L:D82WSX      Wire Scanner X signal                * -.009   V
 L:D82WSY      Wire Scanner Y Signal                * -.001   V
 L:D82WSU      Wire Scanner U Signal                *  .004   V

 ! *********** UPSTREAM Q2 ******************** !
-L:D83WPX*.01 Wire Scanner X Position      <       >*-29.43   MM  I  .
 L:D83WSX      Wire Scanner X signal                * -.05    V
 L:D83WSY      Wire Scanner Y Signal                * -.052   V
 L:D83WSU      Wire Scanner U Signal                * -.063   V
```

```
L8   HE WIRES MODULE 0-4          SET     D/A   A/D  Com-U ◆PTools◆
-<FTP>+ *SA◆ X-A/D  X=T:IRING  Y=T IRING ,T:C4TP3D,T:A1TPUL,T B1TRQ0
COMMAND ---X Eng-U  I= 0       I= 0      , 240     , 240     , 5
-< 4>+  One+ AUTO   F= 4000    F= 20000  , 280     , 280     , 25
tuning  WIRES   bpm/lm   trims   quads  lossmon  bpms   vacuum
 ! *********** MODULE 0 ************ !
-L:D03WPX     Wire Scanner X Position     <      > -48.07   MM  0  .
 L:D03WSX     Wire Scanner X signal              *  .002   V
-L:D03WPY     Wire Scanner Y Position     <      >  15.86   MM
 L:D03WSY     Wire Scanner Y Signal              * -.008   V
-L:D03WPU     Wire Scanner U Position     <      >  45.23   MM
 L:D03WSU     Wire Scanner U Signal              *  .013   V

 ! *********** MODULE 1 ************ !
-L:D13WPX     Wire Scanner X Position     <      > -51.77   MM  0  .
 L:D13WSX     Wire Scanner X signal              *  .005   V
-L:D13WPY     Wire Scanner Y Position     <      >  19.02   MM
 L:D13WSY     Wire Scanner Y Signal              * -.001   V
-L:D13WPU     Wire Scanner U Position     <      >  50.06   MM
 L:D13WSU     Wire Scanner U Signal              *  .008   V

 ! *********** MODULE 2 ************ !
-L:D23WPX     Wire Scanner X Position     <      > -47.61   MM  0  .
 L:D23WSX     Wire Scanner X signal              *  .003   V
-L:D23WPY     Wire Scanner Y Position     <      >  15.06   MM
 L:D23WSY     Wire Scanner Y Signal              *  .004   V
-L:D23WPU     Wire Scanner U Position     <      >  44.33   MM
 L:D23WSU     Wire Scanner U Signal              *  .006   V

 ! *********** MODULE 3 ************ !
-L:D33WPX     Wire Scanner X Position     <      > -46.54   MM  0  .
 L:D33WSX     Wire Scanner X signal              *  .01    V
-L:D33WPY     Wire Scanner Y Position     <      >  15.51   MM
 L:D33WSY     Wire Scanner Y Signal              *  .006   V
-L:D33WPU     Wire Scanner U Position     <      >  43.89   MM
 L:D33WSU     Wire Scanner U Signal              *  .009   V

 ! *********** MODULE 4 ************ !
-L:D43WPX     Wire Scanner X Position     <      > -47.97   MM  0  .
 L:D43WSX     Wire Scanner X signal              *  .007   V
-L:D43WPY     Wire Scanner Y Position     <      >  15      MM
 L:D43WSY     Wire Scanner Y Signal              *  .002   V
-L:D43WPU     Wire Scanner U Position     <      >  44.53   MM
 L:D43WSU     Wire Scanner U Signal              *  .007   V


-L:62ET04     Sample&Hold Trig, Motor0     1998   * 1998    US
```

```
L8   HE WIRES MODULE 5-7          SET     D/A   A/D  Com-U ◆PTools◆
-<FTP>+ *SA◆ X-A/D  X=T:IRING  Y=T IRING ,T:C4TP3D,T:A1TPUL,T B1TRQ0
COMMAND ---X Eng-U  I= 0       I= 0      , 240     , 240     , 5
-< 5>+  One+ AUTO   F= 4000    F= 20000  , 280     , 280     , 25
tuning  WIRES   bpm/lm   trims   quads  lossmon  bpms   vacuum
 ! *********** MODULE 5 ************ !
-L:D53WPX     Wire Scanner X Position     <      > -47.72   MM  0  .
 L:D53WSX     Wire Scanner X signal              * -.027   V
-L:D53WPY     Wire Scanner Y Position     <      >  15.4    MM
 L:D53WSY     Wire Scanner Y Signal              * -.049   V
-L:D53WPU     Wire Scanner U Position     <      >  52.63   MM
 L:D53WSU     Wire Scanner U Signal              * -.037   V

 ! *********** MODULE 6 ************ !
-L:D63WPX     Wire Scanner X Position     <      > -47.17   MM  0  .
 L:D63WSX     Wire Scanner X signal              *  .005   V
-L:D63WPY     Wire Scanner Y Position     <      >  16.17   MM
 L:D63WSY     Wire Scanner Y Signal              *  .006   V
-L:D63WPU     Wire Scanner U Position     <      >  44.79   MM
 L:D63WSU     Wire Scanner U Signal              *  .013   V

 ! *********** MODULE 7 ************ !
-L:D73WPX     Wire Scanner X Position     <      > -46.39   MM  0  .
 L:D73WSX     Wire Scanner X signal              *  .005   V
-L:D73WPY     Wire Scanner Y Position     <      >  15.45   MM
 L:D73WSY     Wire Scanner Y Signal              *  .003   V
-L:D73WPU     Wire Scanner U Position     <      >  43.75   MM
 L:D73WSU     Wire Scanner U Signal              *  .005   V
```

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Booster IPM Notes

Has

- Horizontal and Vertical Operational
- Electrostatic collection of Ions with up to 8KV Clearing Field
- 64 Anode strips spaced at 1.5mm
  - Approximately 60% copper, 40% space between strips.
- 30 channels instrumented in each plane (64 total)
  - with 60db gain amplifier
  - ~ 300KHz
- Samples once per turn throughout Booster cycle
  - ~19900 samples
- Applications page on B77

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Booster IPM Notes 2

Needs to be Determined

- Can use either the 30KV electrostatic units from MI or a new magnetic design specifically for booster.
- Beam Specs in NOVA Era
- ~10mm sigma at injection. 400MeV
- ~4mm sigma at extraction. 8GeV
- ~0.5 e12 particles per batch per turn minimum
  - In general we can see and make good measurements at 2 turns
  - (this is the minimum, have run as many as 18 turns)
  - Typical 10-12 turns for NuMI and P-Bar Stacking.
- Can use magnets to contain electrons.

  (Has been modeled by Alan Hahn and Andreas Jansson and will be updated.)

Linac Beam Current Measurements

- Linac Toroids and Wall Current Monitors
  - The proton source uses 35 toroids. All of the toroid systems have been considered for either partial or complete upgrade. We expect five locations would get a new Pearson CT model 3100 1.0 V/A.
  - The electronics would be placed at three different locations along the LINAC.
  - The toroid system would consist of
    1) MVME5500 Processor acting as crate controller. Timing board.
    2) Calibration boards with 8 independent analog outputs.
    3) Digitizer Down-Converter boards to handle up to 10 toroid signals and calibration signals.
    4) VME64X crate

    Cabling consisting of two 3/8 inch heliax cables per toroid system, one for calibration and one for signal.

    The crate would display raw data and processed data via ACNET.