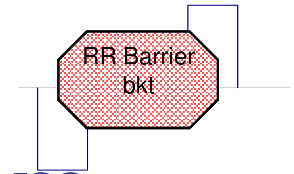


Cooling the Hot Momentum Beam after the Tev Shots

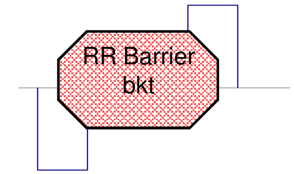
(preliminary)

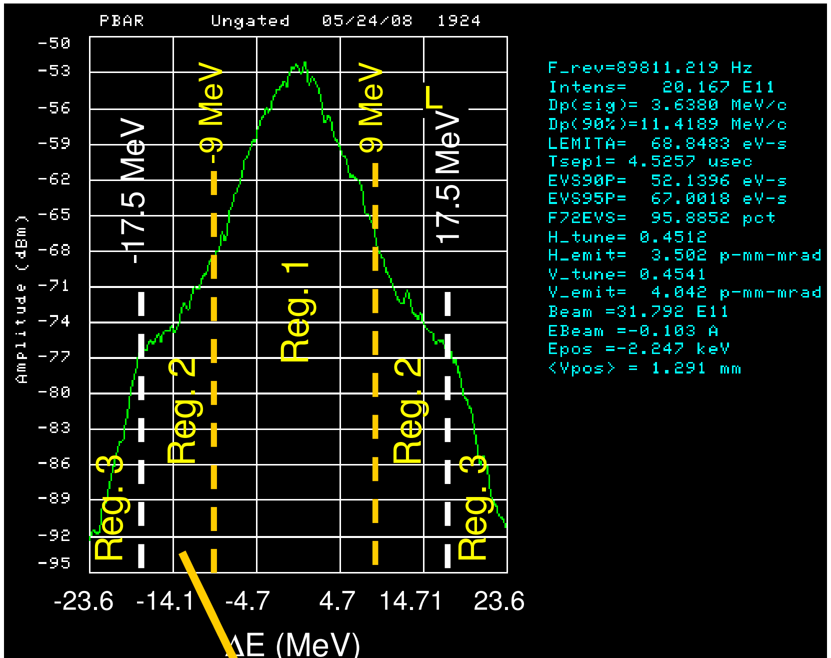
Chandra Bhat and Lionel Prost

RR Meeting
May 28, 2008

- Primary Goal: Cool the leftover hot momentum pbars in the Recycler more efficiently with our cooling systems.
- Investigate possibility of cooling the large off momentum antiprotons in the Recycler using e-cool (off energy and on axis)

Momentum Mining & Beam in hot momentum bucket



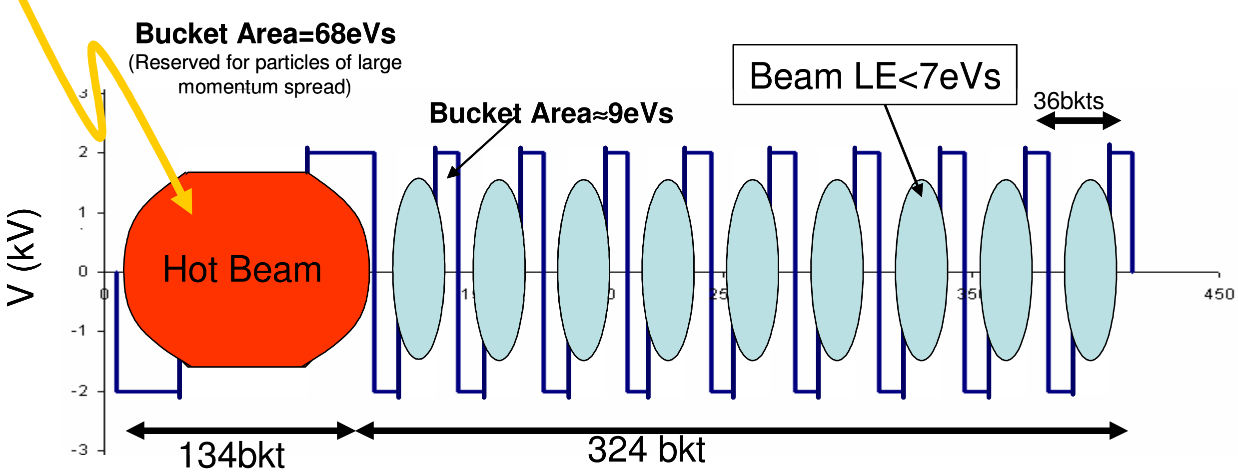


Particles with ΔE in

- -- Reg. 1 are sent to the Tevatron
- -- Reg. 2 end up in the high Momentum bkt.
- -- Reg. 3 are DC beam

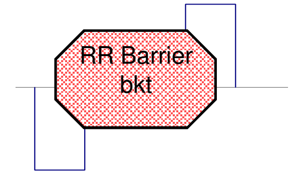
Typically <4% of the beam will be left back after the Tev shots with

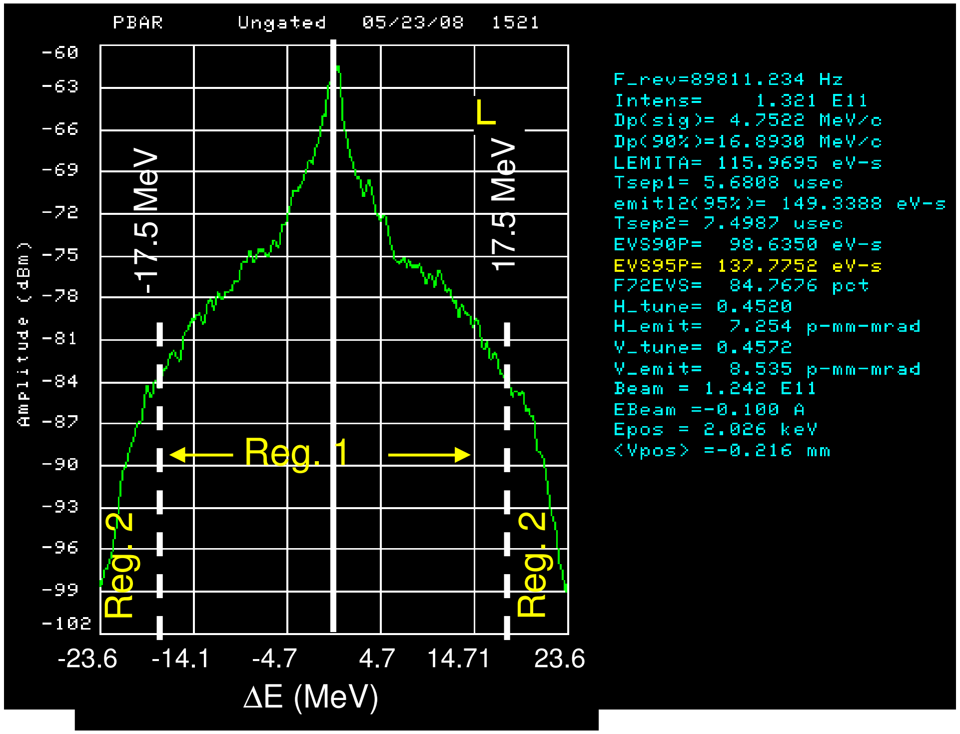
- -- RMS Momentum spread ~ 5 MeV/c
- -- Large LE (95%)
- -- Large Transverse Emittance



Chandra Bhat

Beam in the hot momentum bucket





Rectangular Barrier Bucket

$$\varepsilon_l = T_2 \Delta \hat{E} + \frac{\pi|\eta|}{3\omega_o \beta^2 E_o eV_o} \Delta \hat{E}^3$$

Barrier Pulse height

95% width from Schottky data

Bucket length

After expanding the hot momentum bucket to 300 bkts, for this beam

-- RMS Momentum spread ~ 5 MeV/c

-- 95% width from Schottky data >23 MeV

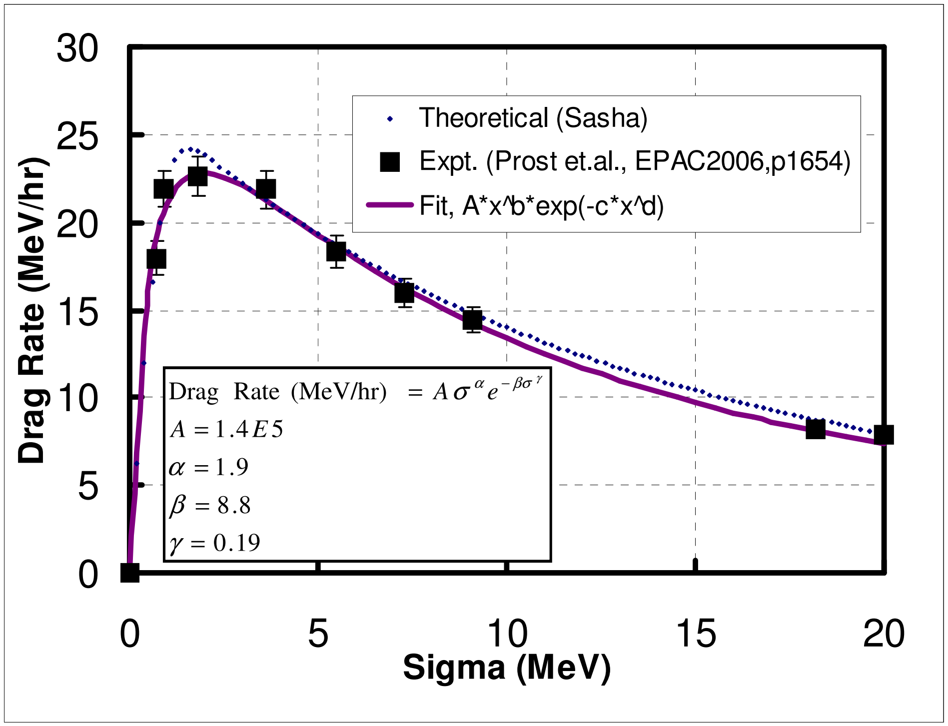
-- LE (95%) ~149 eVs

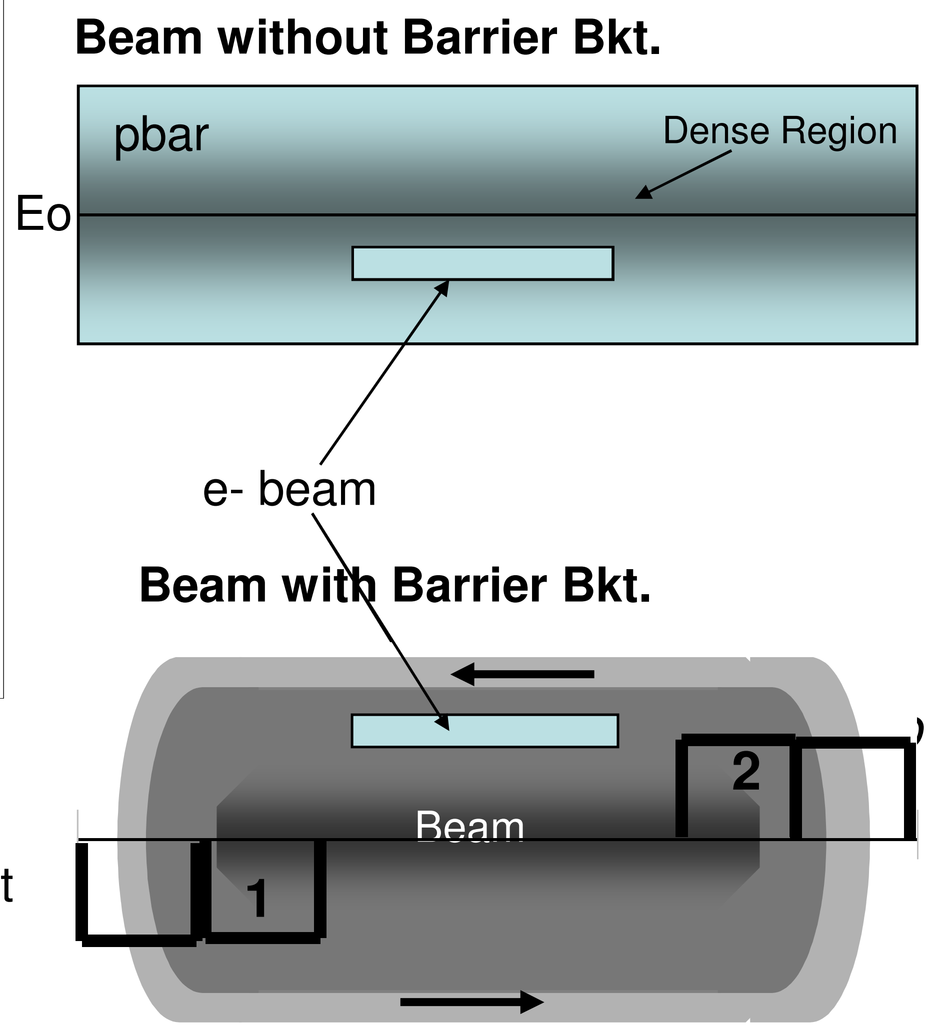
-- Transverse Emittance ~ 8 pi

Currently, the beam is cooled using stochastic as well as e-cool for about half hour before AR→RR pbar transfer. But, within the bandwidth of longitudinal stochastic cooling system (.5-1 GHz) the particle in Reg. 2 and higher end of Reg. 1 are less affected. This happens even during regular cooling.

Can we cool the beam efficiently? And what we have learnt from this study?

Drag-rate Measurements
(Prost et. al. EPAC2006, 1654)
& Inferences from Drag-rate data



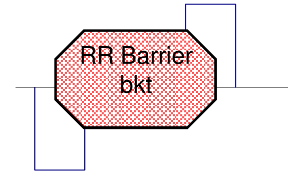


In the current case by adding two standard rf barrier pulses we can increase the bucket height from **17.5 MeV → 24.8 MeV** which captures all DC beam.

Experiments

- Capturing all dc beam particles below +/-25 MeV (by widening the barrier pulses)
- Transverse Cooling on/off
- Longitudinal cooling on/off
- 0.1 Amp of e-beam on axis
- e-beam energy varied from ±9kV to 0kV in certain fashion
  - To drag the pbars from about ±20 MeV towards the core
  - Keep e-energy for a longer time on high ΔE-pbars and for a shorter time on the low ΔE-pbars

(Transverse and longitudinal cooling:) I used the stochastic cooling parameters were set by Lionel

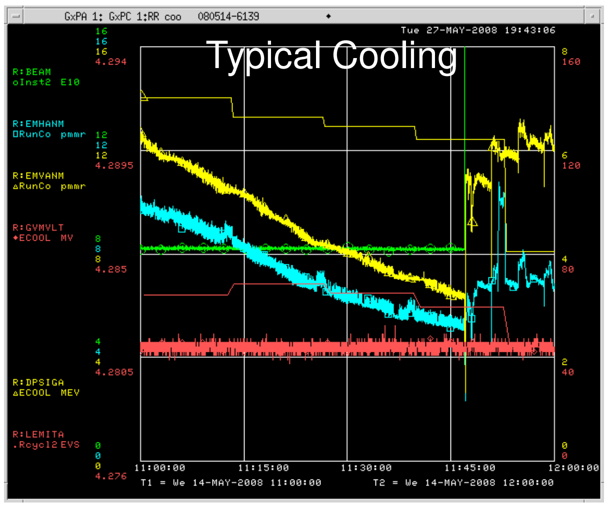


R:GVMVLT and Schottky Data

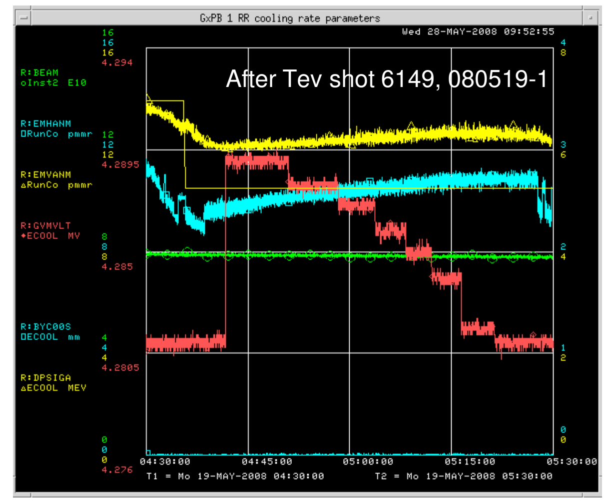
Standard Cooling
→Normal T & L – stochastic cooling
→e-beam on energy and on axis

Special cooling study
→T-stochastic cooling on
→L-stochastic cooling off
→e-beam on axis and energy is changed in 1kV step

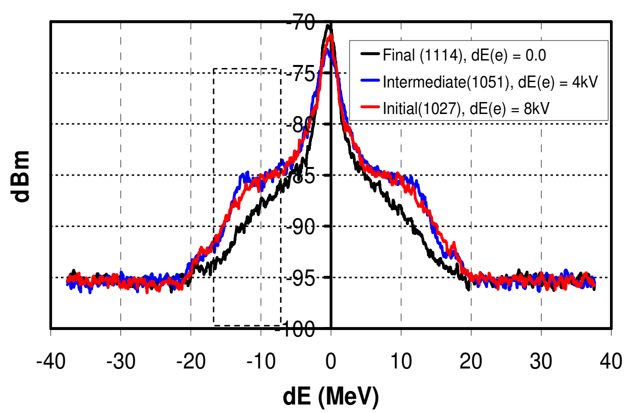
Special cooling study
→T&L-stochastic cooling off
→e-beam on axis and energy is changed in 1kV steps

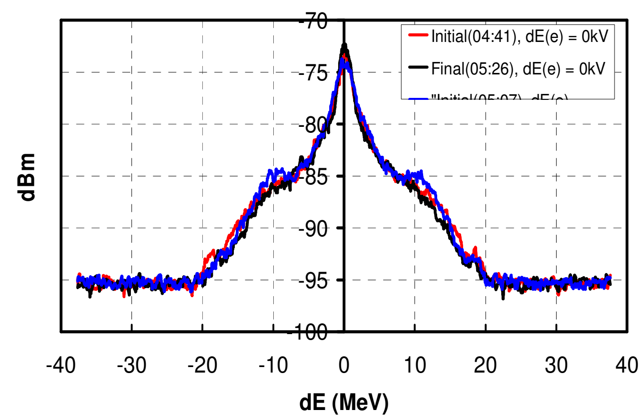


rr-schottky-hi-mmnt-cooling-080518.xls



rr-schottky-hi-mmnt-cooling-080519.xls





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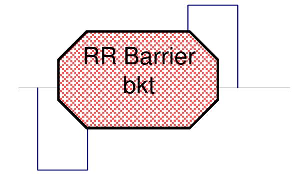
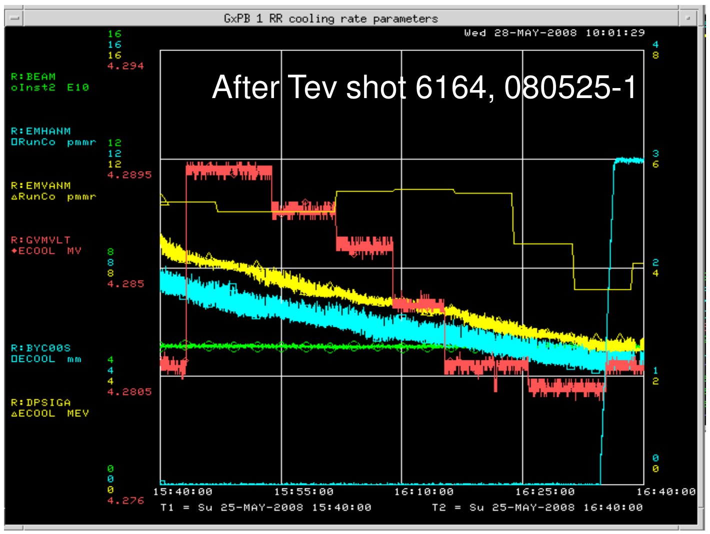
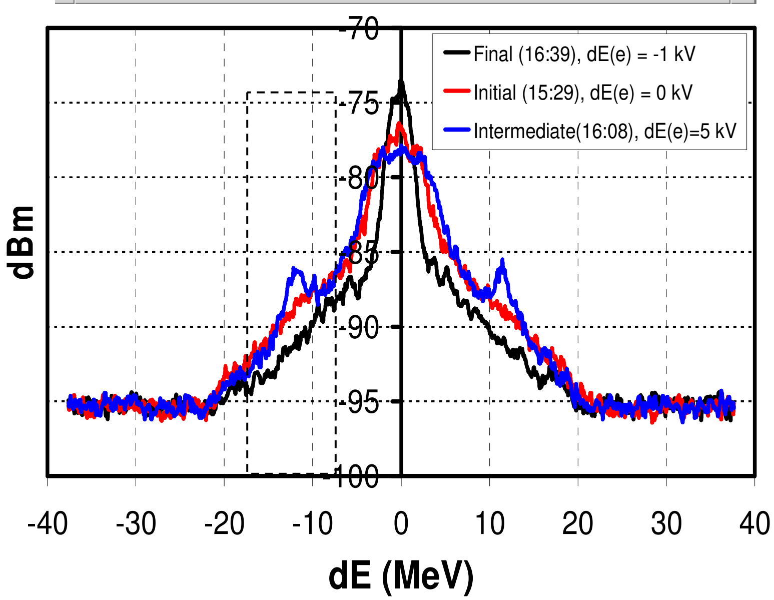


R:GVMVLT and Schottky Data (cont.)

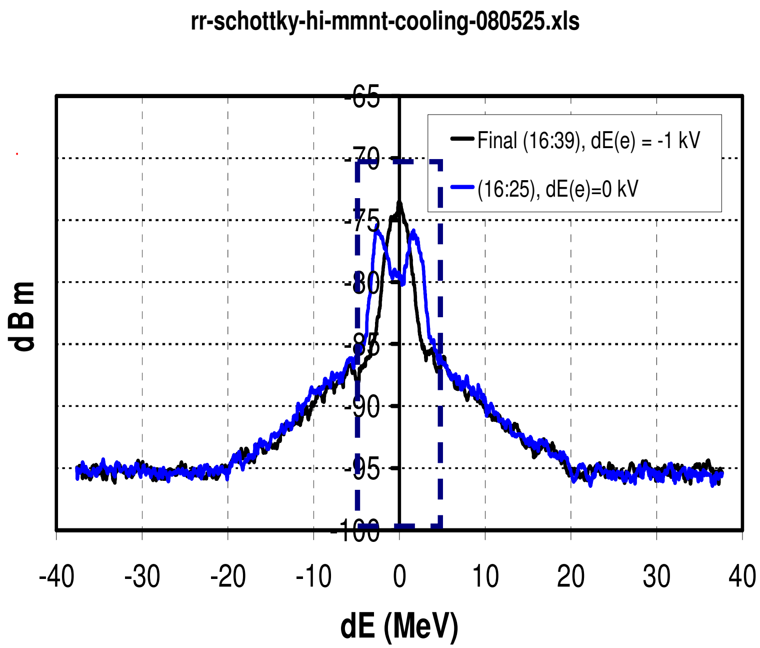




Special cooling study
→T-stochastic cooling on
→L-stochastic cooling off
→e-beam on axis and
energy is changed with varying step

- **Conclusions**
  - Without stochastic cooling and with e-cooling alone, the dragging of high momentum pbars was very slow.
  - With transverse stochastic cooling on, L- cooling off, the dragging of the high momentum pbars was noticeable. About 25% of the beam were dragged in about 30 min.

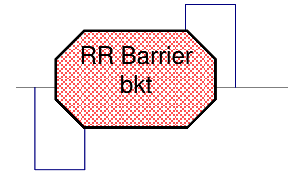
Future Plans



- **Apply similar e-cooling technique for dragging high momentum particles into the core between two AR→RR pbar transfer with**
  - Transverse stochastic cooling on
  - Longitudinal stochastic cooling off
  - 0.1 Amp of e-beam on axis
  - e-beam energy varied from -9kV to 0 kV in about 30 min.

  → **This would help reducing the shoulder in Schottky data.**
- **Investigate possibility of using e-beam on axis but slightly off energy, so that the longitudinal phase space density is always lower than instability limit**
- **Try increasing the e-beam intensity while cooling**

Stochastic cooling parameters set by Lionel Prost




```
PB R20 COOLING PARAMS
R20  OPS RR TUNING PAGE        (CE) SET    D/A    A/D   Com-U *PTools*
-<FTP>+ *SA* X-A/D  X=TIME     Y=R:GVMVLT,R:LEMITA,R LMVSA ,R EMITHN
COMMAND ---- Eng-U  I= 0       I= 4.276  , 0       , 0       , 0       6
-<26>+  One+ AUTO   F= 3600    F= 4.294  , 200     , 6       , 60
.5-1ghz  1-2ghz h2-4ghz v2-4ghz swchtre GENERAL peanuts testdev

 ! FRONT-END ATTENUATORS (LEAVE ALONE)
-R:P1PA21      0.5-1 GHz Mom F-E Atten      13        13       dB
-R:P2PA21      1-2 GHz Horz F-E Atten       13        13       dB
-R:H4PA21      2-4 GHz Horz F-E Atten       18        18       dB
-R:V4PA21      2-4 GHz Vert F-E Atten       6       * 6        dB

 ! BACK-END ATTENUATORS
-R:P1PA11      0.5-1 GHz Mom B-E Atten      3         3        dB
-R:P2PA11      1-2 GHz Horz B-E Atten       15        15       dB
-R:H4PA11      2-4 GHz Horz B-E Atten       4         4        dB
-R:V4PA11      2-4 GHz Vert B-E Atten       4         4        dB

 ! COLD BUCKET MANIPULATION (SEE<99> FOR MORE)
 R:LNCBKT      Cold bucket length                     300      Bkts
 # R:LNCBKT / 52.511                                  5.713    Bkts
-R:TSEP1       DP TRUE SIGMA 'A'            5.681     5.681    usec
-R:FARBP6      ARB6 bp0=start Cool p  108         108          BKTS
-R:FARBP7      ARB7 bp1=end Cool pos  456         456          BKTS
-R:FXFERP      Xfer bucketPos Delta  -243       * 0            BKTS

 ! BEAM HEALTH
 R:BEAM        Recycler Beam Current                  5.177    E10
-R:LIFE        Pbar 1-hour Lifetim   .579   .403      .403     Hour
-R:DPSIGA      DP True sigma 'A'            5.206     5.206    MEV
-R:LEMITA      LONG EMMITANCE 90% 'A'       129.6     129.6    EVS
-R:AVEMIT      RR Avg. VSA Emmittenc        6.09      6.09     Pmmr
-R:EMITHA      RR VSA Horz emmittence       5.723     5.723    Pmmr
-R:EMITVA      RR VSA Vert emmittance       6.458     6.458    Pmmr
-R:AVDNST      RR Avg. VSA beam density      .006      .006    N/Vh
-R:HDNSTY      RR VSA Horz beam density      .006      .006    N/Vh

 ! E-COOL (SEE <24> FOR MORE)
 R:DCCT        ECool DCCT BEAM CURRENT              * -.101    AMP
-R:BIASV       Bias Voltage                 20        20.01    KV
 R:BYC00S      Cool C00 V (slow)                   -.0007523   mm
-R:TPSTRV      TPS TrvV     4.2809534  4.28901   09.28         MV
 R:GVMVLT      TPS GvmV terminal V                4.2891936    MV
 ! PBAR STACKING
 A:IBEAM       ACC 1ma=10**10pbar               * 83.347187    mA
 A:STCKRT      Pbar Stacking Rate                     20.1     mA/h
```