1. OVERVIEW

This section summarizes the main things available to look at and tune in the e+ system. A step by step tuning procedure follows in the next section.

1. CONFIGURATIONS

These are the relevant configs for the e+ system and should always have gold configs loaded.

- Magnet configurations
  - Extracción line
  - EPOSLINE
  - CID-01
  - SRING

- Energy configurations
  - KEPOS
  - KSRING

- Timing configurations
  - TIMEPOS
  - TIMSRING

2. DIAGNOSTICS AVAILABLE

The following is a summary list of major tools available to look at or “tune on” to bring up the e+ yield.

- **PYIELD display**
  - Tabulates the yield and subyield throughout the e+ system.
  - Use this to immediately diagnose where we are losing the most yield.
  - Reference values for subyields are listed as a guide.

- **PYIELD correlation plot variables**
  - Allows you to put the PYIELD display values in a correlation plot to optimize a tuning parameter.
  - From the correlation plot acquisition panel, use the button macro “positron yields” to load all the pyield variables.

- **ETA foils and bunch length monitor scope**
  - Indicate the energy, energy spread, and amount of charge per bunch length.

- **BPM Orbits**
  - Indicate whether launch and steering in each subsystem are correct.

- **PROMonitor monitor screen EP01 185 (upstream of target)**
  - Jitter, tails, and energy spread in the scavenger beam are apparent.
**Sector 1 wire scanners**
measure the emittance and beta mismatch of positrons at the end of Sector 1

- scans only possible when S1 PLIC is very low
  S1 PLIC is optimized by longitudinal phase space tuning and by the optimizing the launch into S1

**SLTR Profile monitor**
PROF DR01 175
- at a high dispersion point so energy spread and tails are visible

**PLIC signal scope**
WTA-SDR indicates beam losses in S1 as well as SLTR and launch into ring
- see reference PLIC signal map to identify points along the beam line

**Positron Return Line PLIC**
4 x 6 PLIC

**SDR envelope monitor scope**
- shows the actual intensity at a BPM in the ring as a function of turn number in real time.
  tells you immediately if the knob you are turning has a strong effect on the SDR intensity, but it is misleading to tune on this only. The shape of the envelope indicates the rate of loss at injection

**SDR synchrotron feedback scope**
indicates longitudinal oscillations as beam launched into ring
- large oscillations if energy or phase badly matched
- oscillations grow if loop at fault or beam instability (pi mode)
  pi mode instability at present controlled by manual setting cavity tuners

**SDR synchrotron light spot**
indicates if ring is coupled
- round spot when emittances equal in each plane indicating tunes are coupled

**Tune measuring spectrum analyzer**
measures fractional tune in each plane
- frequency of each peak divided by 8.5 MHz gives fractional tune which should be 0.17 ± 0.01

**Turns monitor**
SDR BPM X, Y and TMIT as a function of turn number on a single bunch
- operated via a MATLAB program on a VAX terminal
  still an experimental tool
3. SCAVENGER BEAM TUNING

**scavenger beam steering**

Prof EP01 171 shows production and scavenger bunch at Horiz. Lambertson

- check for tails and correct kicker operation
- check extr. line kicker waveform monitor scope
- check kicker time and amplitude jitter

**scavenger beam energy**

set by feedback and feedforward loops

must match extr line magnets

- assigning knob EXT4 GEV mkb displays required scavenger energy in GeV

**scavenger beam energy spread**

influenced by phase ramp setting

- phase ramp usually set to give correct energy spread at the BSY

**target steering**

controlled by the set points of the target steering feedback loop

- optimize PT01 529 yield by scanning setpoints on either side of current settings if yield is more than 2% below 4.0

4. LONGITUDINAL PHASE SPACE TUNING TOOLS

**Sector 20 klystrons**

Note that these settings are strongly dependant on the beam intensity

**20-3 drive amplitude**

this is usually set at the maximum value after it was processed and should not be changed during routine tuning

**20-4 drive amplitude**

- tune to set the energy correctly on the ETA foils.
- In principle, it should also maximize Li01 831 yield and minimize S1 PLIC

Determines the energy of the e+ and hence how well they are captured in sector 1 rf bucket

**combined phase shifter**

- POS PHASE 34 knob tuned to optimize the energy spread on the ETA foils.
- This knob is frequently tuned and should also maximize Li01 831 yield and minimize S1 PLIC and minimize energy spread in the SLTR
changes phase of 20-3 and 20-4 in unison and hence also controls the energy and phase of the e+ reaching S1

20-3 and 20-4 phases

- in routine operation it is not normal to change the relative phases between the two klystrons
  Phase 20-3 is nominally set to maximize acceleration
  Phase 20-4 controls energy spread in EP02

Trombone

- tune to maximize Li01 831 yield and minimize S1 PLIC
  and minimize energy spread in the SLTR
  changing the e+ path length determines their arrival time at S1 and hence their phase w.r.t. S1. The phase in S1 in turn determines energy spread in the SLTR
**Sector 1 klystrons**

Klys 1-6 amplitude
- tune to correct energy in SLTR. This is difficult if e- are being co-accelerated in S1 because a simultaneous change must be made to e-energy in Li00
  - orbit in the SLTR reveals energy offsets at high dispersion points

**SLTR compressor**

klystron amplitude set at maximum
klystron phase set to leave the energy of the beam unchanged
- look at a difference orbit in the ring with the compressor on and off

**SDR station phase**

set to maximize capture in the ring, rarely needs changing
- the phase of the ring rf bucket is changed w.r.t. to the incoming beam phase

5. **TRANSVERSE PHASE SPACE TUNING**

**Launch optimization**

scavenger e- onto target
- use feedback setpoints

from PRL into WTA
- feedback correctors at end of PRL should maximize subyield in EP05 and also provide headroom for:

from WTA into S1
- 4 launch knobs (e.g. EP_X_MM.MKB etc.) should be used to maximize yield as far as Li01 835 only and should minimize S1 PLIC.

from S1 into SLTR
- 4 launch knobs to maximize yield to end of SLTR only

from SLTR into SDR
- 4 launch knobs to maximize SDR throughput and minimize first turn orbit difference with stored orbit.

**Steering**

Center beam in beam pipe. Beam should match gold ref orbit and PLIC minimized
- only attempted after upstream orbit and launch correct

All regions can be auto-steered using the mikado method with minimum corrector action. Consult an e+ physicist if you believe the SDR stored orbit steering is wrong.

Orbit bumps are used in specialized regions to move a short length of the orbit around.
- SDR septum bumps move the stored orbit around the septum blade. The launch and/or extraction orbit needs
reoptimization afterwards. Bifurcated bumps (B_SEPT_*.mkb) combine both these actions.
**Beta matching**

On the S1 wires the BMAG parameter should be close to 1 when the e+ emittances are measured

- 4 quadrupoles in the WTA are used to control this parameter using the online beta matching package (consult an e+ physicist)

BMAG is a parameter quantifying the mismatch of the transverse beam ellipse compared to the design beam.

**II. A TUNING RECIPE**

**Determine where upstream yield is starting to drop**

use special PYIELD display and compare subyields to gold subyields at each toroid

**Start with the upstream problems first**

**Use a serialized approach to increase yield**

only tune the yield up to the point of the next downstream toroid.

DO NOT tune an upstream parameter looking only at the SDR intensity

**Be sure gold configs are loaded and green**

DISPLAY RED on the gold config will also tell you if hardware is out of tolerance

1. **TARGET YIELD PT01 529**

   **Check profile monitor 185 (near target) for a small round stable spot**

   otherwise fix scavenger beam parameters first

   **Center the scavenger beam on the target**

   scan the feedback setpoints to either side of current value in steps of 0.2mm

2. **ETA YIELD EP02 812**

   **Check the ETA foils scope**

   CENTER the peak on the middle foil by controlling the energy with klystron drive 20-4

   MAXIMIZE the peak making it narrower by optimizing the energy spread with PHASE 30-4

   • tune for yield AND stability

   Iterate tuning on phase and drive knobs

   failure to restore yield may indicate that phases 90-3 and 90-4 are wrong, but be careful.

3. **PRL YIELD LI19 TO LI04**

   **Check orbits EP02 through Li01 in the return line**

   if autosteering is used ensure no bad BPMs are included

4. **WTA YIELD EP05 3152**
Check launch from PRL into WTA

slow feedback setpoints control launch

• check that correctors used at end of PRL are not at maximum
5. YIELD INTO S1 LI01 141

4 launch knobs use correctors at exit of the WTA

knobs can only be coarsely set at this toroid, fine tuning at next step

• S1 toroids don’t read out when e- co-accelerated at 60, 120Hz

6. S1 YIELD LI01 835

Tune to maximize yield and minimize PLIC

DO NOT change correctors in S1 away from configuration values
the orbit in S1 is a compromise for e+ and e- and will not benefit from further tuning!

Optimize launch from WTA
fine tune launch knobs from previous step

Optimize longitudinal tuning
optimize energy and phase of beam launched into S1

• fine tune energy with drive 20-4 and phase 30-4
• S1 toroids don’t read out when e- co-accelerated at 60, 120 Hz

Emittance and beta match check
this is not something to tune on, but a diagnostic if you suspect something is not right with the system
use S1 wires if PLIC low enough

• emittance should be around 2E-3 in each plane
• beta mismatch parameter BMAG should be less than 1.10
an online beta matching package exists, but please consult with a e+ physicist first
• if S1 PLIC too high for clean scans then energy collimate the beam using ETA collimators EP02 740, 741
move one jaw in until intensity drops ~25% then the other for a further 25% ensuring a symmetric reduction in energy spread

7. BEGINNING OF SLTR DR01 241

Optimize launch from S1
use 4 launch knobs

• make sure correctors at end of S1 not near maximum and
• if launch knobs generate S1 PLIC something else is wrong with S1 orbit so back up a step

Optimize energy spread
fine tune trombone

• putting in PROF DR01 175 is the only reliable way of verifying energy spread

8. SLTR YIELD DR01 1481

Optimize energy
use drive 1-6 to set energy to center orbit in SLTR
• unfortunately this also changes e- energy at and above 60 Hz
• so change e- energy simultaneously in Li00
Steer SLTR orbit flat
   can be autostered using mikado method, minimizing corrector strengths
   • pay attention to correctors near maximum and fighting each other
   loss along SLTR should not be more than 10%

Check phase of energy compressor
   look at a difference orbit in the ring
   • no change in orbit when compressor on/off

9. SDR THROUGHPUT DR03 71

Optimize launch
   4 launch knobs use correctors at end of SLTR
   • maximize ring throughput
   • 1st turn difference should then match stored orbit

Check energy
   if correct from previous step should not need changing
   • orbit should be symmetric about zero

Check stored orbit
   compare with gold orbit, especially near septa
   • scan septa bumps if orbit is suspect using bifurcated closed orbit bumps
   closed orbit bumps make only a local bump leaving the rest of the ring undisturbed (check that this is true). To maintain correct launch conditions from the SLTR or a correct orbit into the SRTL we use bifurcated bumps that also use correctors outside of the ring

Check synchrotron oscillation feedback scope
   should show small, damped oscillation
   • otherwise check SDR cavity tuning angle
   • SDR rf station phase may conceivably be wrong particularly if CID was recently retuned!

Check synchrotron light spot
   spot should be round indicating coupling
   • otherwise measure and correct tunes as necessary
   a tune knob for each plane controls quadrupoles in the SDR to change each tune by a predetermined amount

Check tunes
   good idea if sync light spot not round or orbit bumps not closing

Check extraction
   beam at PROF DR03 should be stable and not shadowed by septum
   SRTL orbit should match gold
   the SRTL orbit is crucial to good matching into the linac