RHIC Experience:

Optics Measurements, Corrections, and Modeling

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Outline

OpticsCorrection

- RHIC Optics Design
  - Offline linear model design
  - Online implementation
- RHIC optics measurements status
- RHIC optics correction status
  - ORM approach
  - AC dipole measurement based
    - Summary of commissioning of SBST
- Future plans

RHIC Optics Design

OpticsCorrection

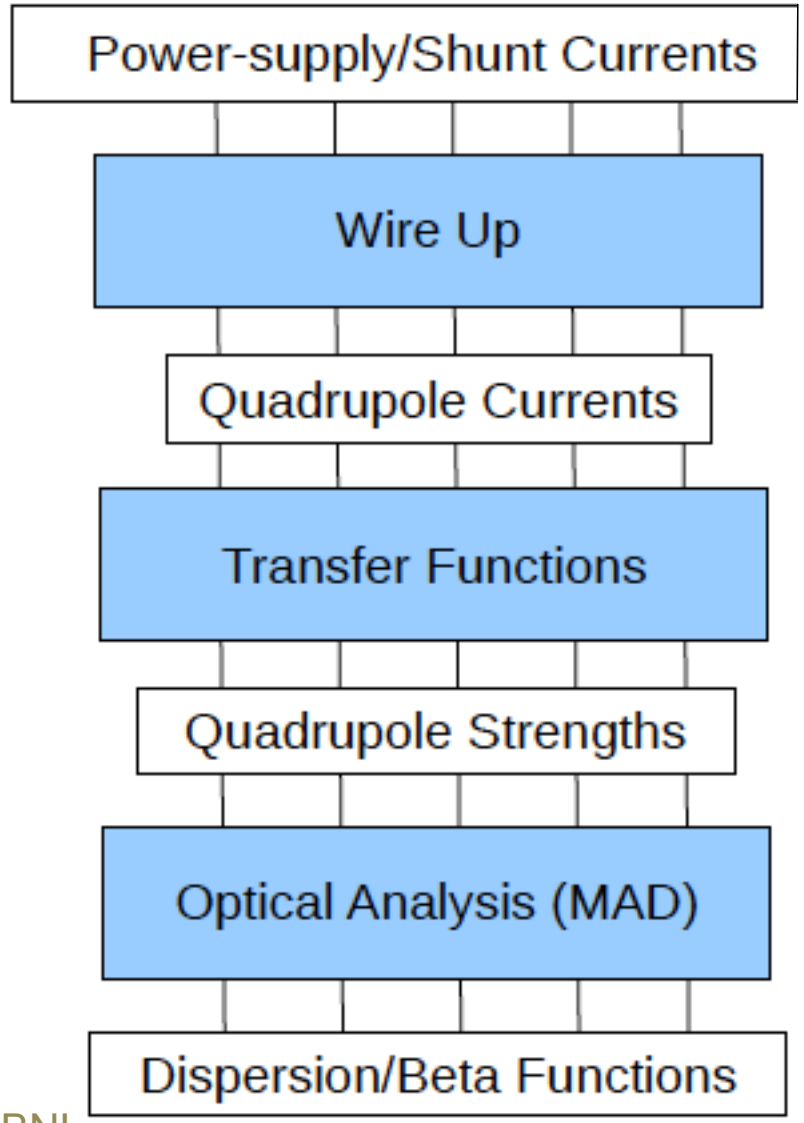
- Build linear model to fulfill desired optics functions for the entire ramp with the constraints/inputs of
  - Magnet transfer functions
  - RHIC power supply/shunt currents limit
  - RHIC magnets' wire-up scheme
  - Smooth changes of currents as function of beam energy

- This is done by MAD

Flowchart of RHIC optics design

OpticsCorrection

- Set the Power-supply/Shunt currents to get desired optics
  - Use an Optimizer to find the currents
  - Desired optics functions are the constraints
- Changing optics with beam (squeeze)
  - Requires smooth changes to the currents
- Weakest point: Magnet transfer functions



Courtesy of S. Tepikian, BNL

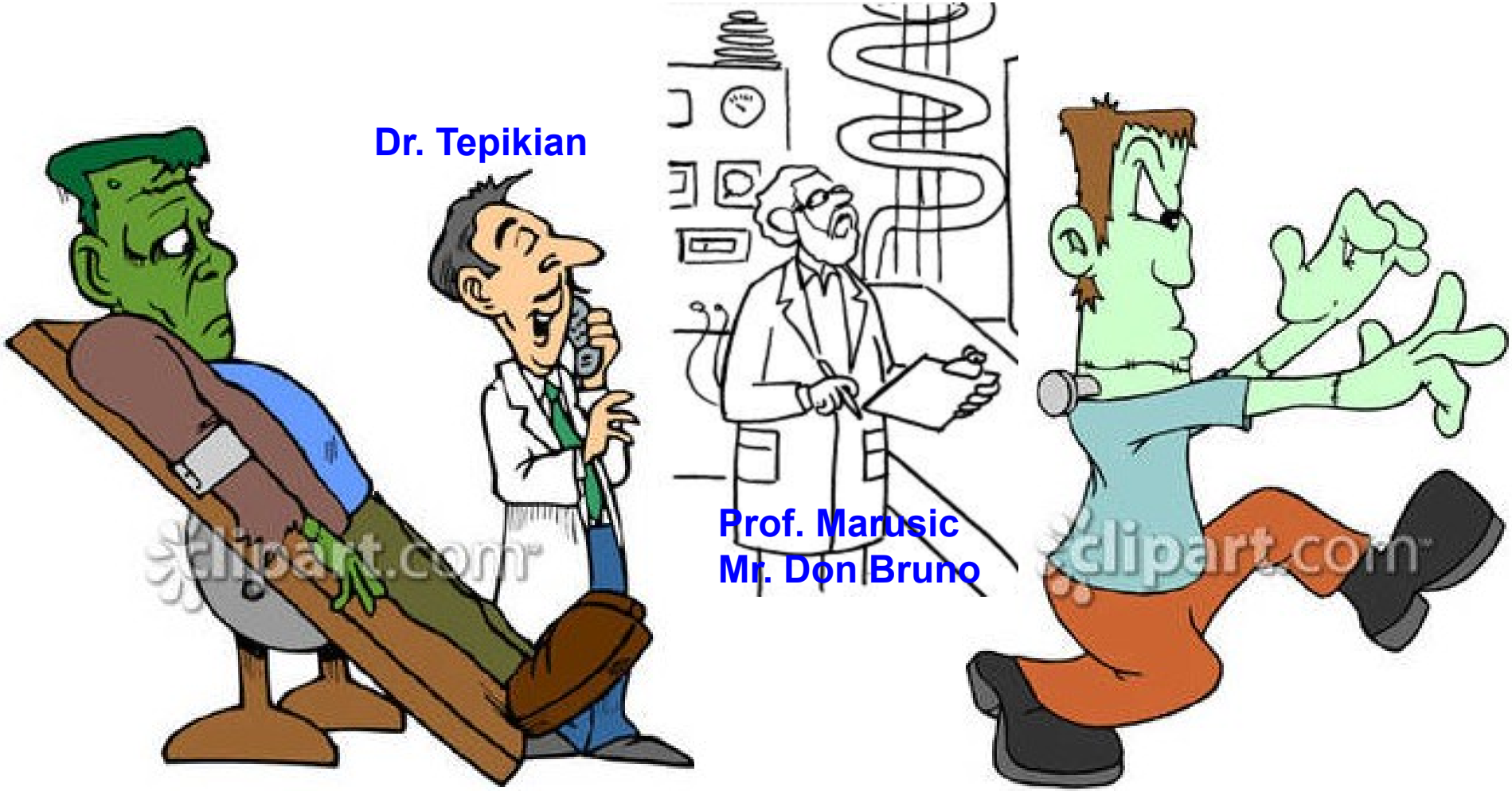
RHIC Optics Design

OpticsCorrection

- Build linear model to fulfill desired optics functions for the entire ramp
  - Output: magnet strength as function of beta*
- Handover the designed magnet strength as function of beta* to OptiCalc, RHIC online model
- OptiCalc then re-generates beta functions for the entire ramp for machine operation.
  - Mode details on RHIC online model are discussed by G. Robert-Demolaize tomorrow

"You complete me!"

OpticsCorrection



RHIC Optics Measurement Techniques

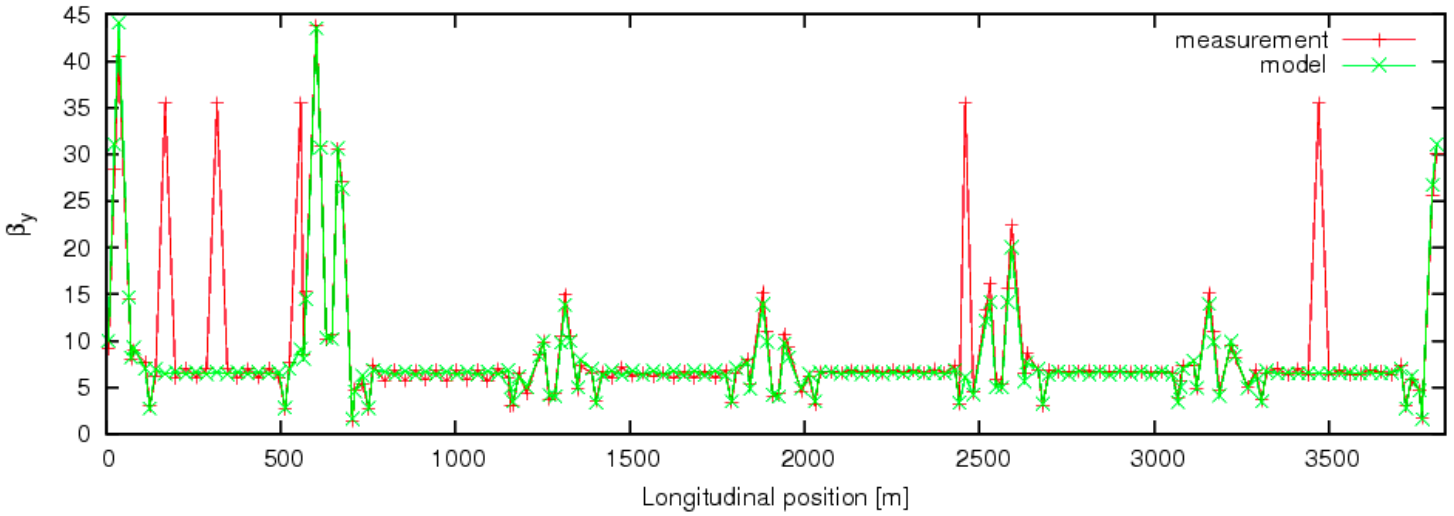
OpticsCorrection

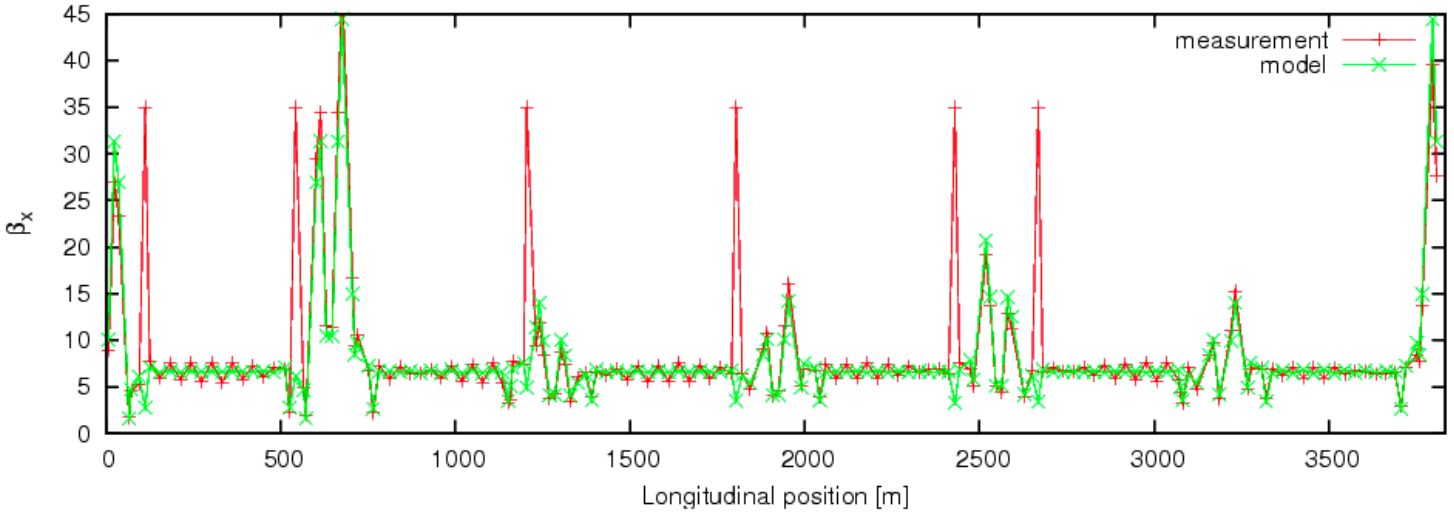
technique	Full ring	Beta*	Online data analysis	Request on beam conditions
AC dipole based	Yes	Yes	Yes	Minimize tune spread
Modulating triplet quadrupole	No	Yes	No	Minimize coupling
Orbit Response Matrix	Yes	Yes	No	N/A
Tune-meter based	Yes	Yes	No	Minimize tune spread

Status of RHIC Optics Measurement

OpticsCorrection

- Routine full ring beta/phase beat measurement using ac dipole for each operational lattice





each

%

Status of RHIC Optics Measurement

OpticsCorrection

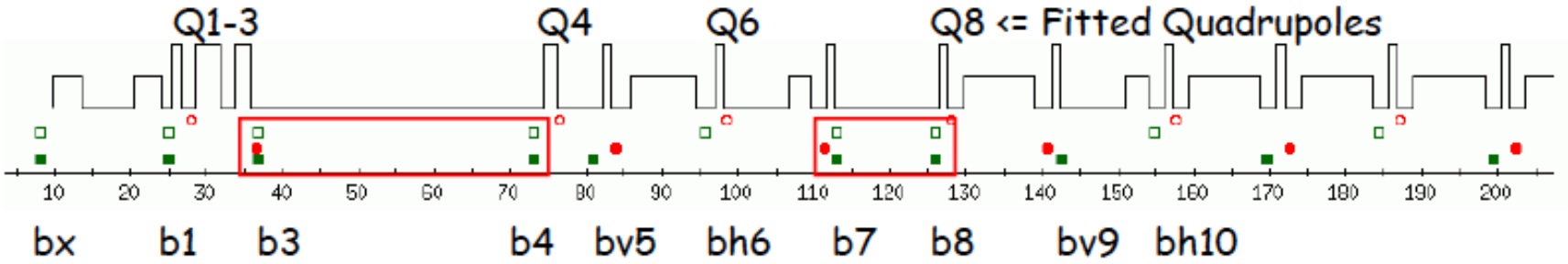
- Routine full ring beta/phase beat measurement using ac dipole for each operational lattice
- Routine ORM measurement
- Routine beta* measurement
  - using ac dipole
  - Modulating triplet quadrupoles
  - ORM

Method	β*(bh) [m]	β*(bv) [m]	β*(yh) [m]	β*(yv) [m]
mad	22.18	21.41	22.05	20.74
OptiCalc	22.24	20.25	21.88	19.25
quad tweak	19.3(1.4)	24.0(3.2)	21.0(2.2)	17.4(0.7)
AC dipole	22.75	21.00	21.82	19.77

Status of RHIC Optics Corrections

OpticsCorrection

- Focused on commissioning LOCO at RHIC before RUN10
  - Initiated by T. Satogata ~ 6 years ago
  - limited quadrupoles to avoid degeneracy problem
    - Lumped triplet quads, Q4,Q6,Q8. Dual bpms are available at these quadrupoles
    - The data analysis shows the fits should be available to correct 15~20% beta-beat
  - Application of ORM analysis to actual machine was a mixed results
    - BPM data quality



Status of RHIC Optics Corrections

OpticsCorrection

- Introduced SBST technique in RUN11 of pp
  - Glenn built similar SBST package for RHIC
    - scripts to adapt RHIC madx model, which only contains the design value of all magnets.
    - scripts to accommodate separate plane bpms
    - Compared the optics measurement results of using SUSSIX and using current RHIC online optics measurement application
  - Had ~ 8 hours of beam time during pp run to commission the technique in the Blue ring

Summary of SBST Commissioning

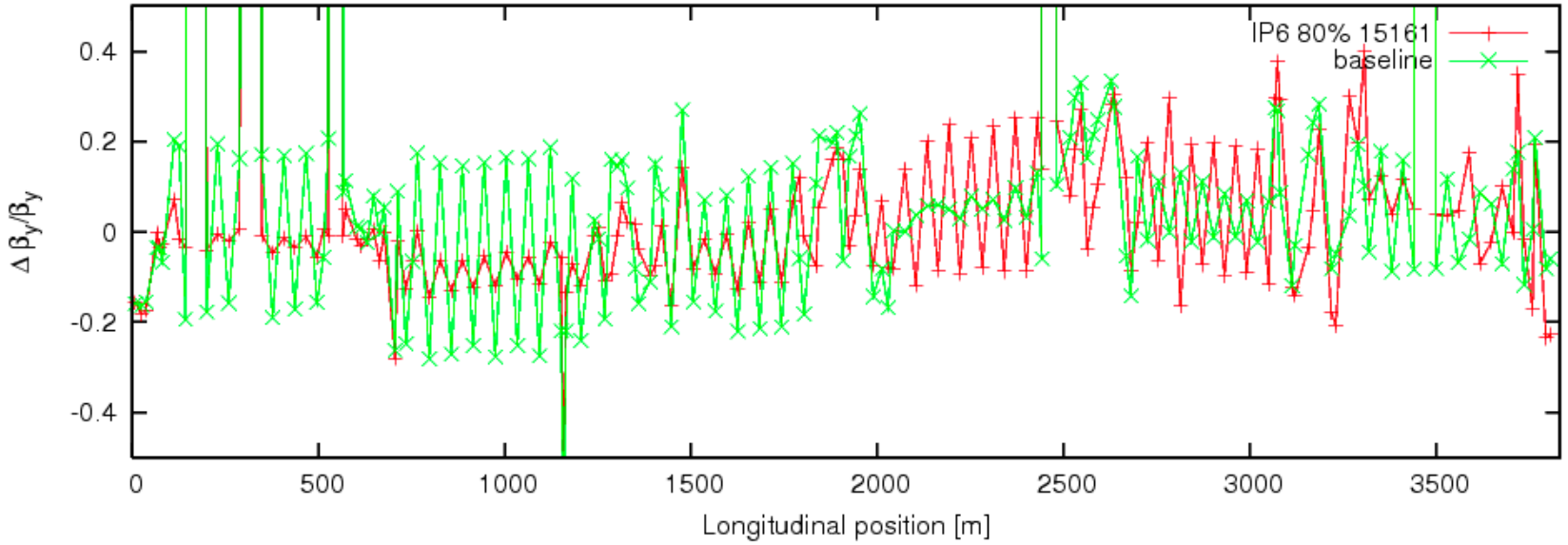
OpticsCorrection

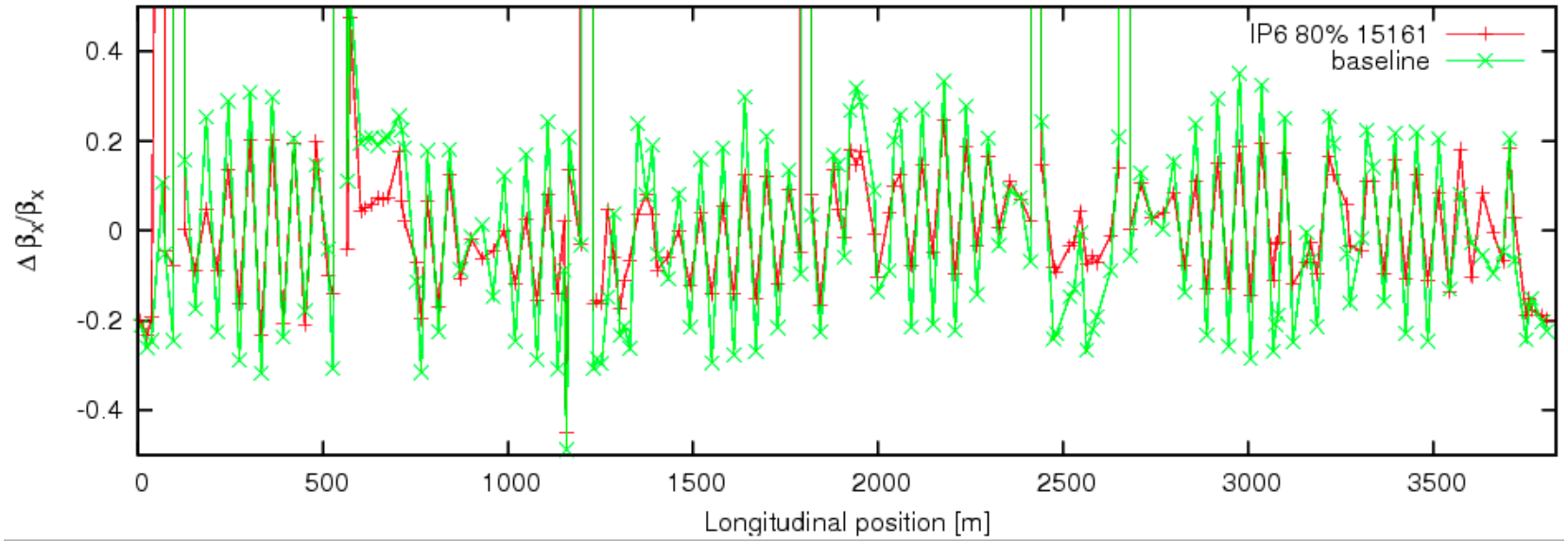
- Initial IP6 correction helped to reduce the vertical beta-beat except sector 12-1 and sector 2&3

Effect of IP6 Correction

OpticsCorrection

Fill15161





Effect of IP6 Correction

OpticsCorrection

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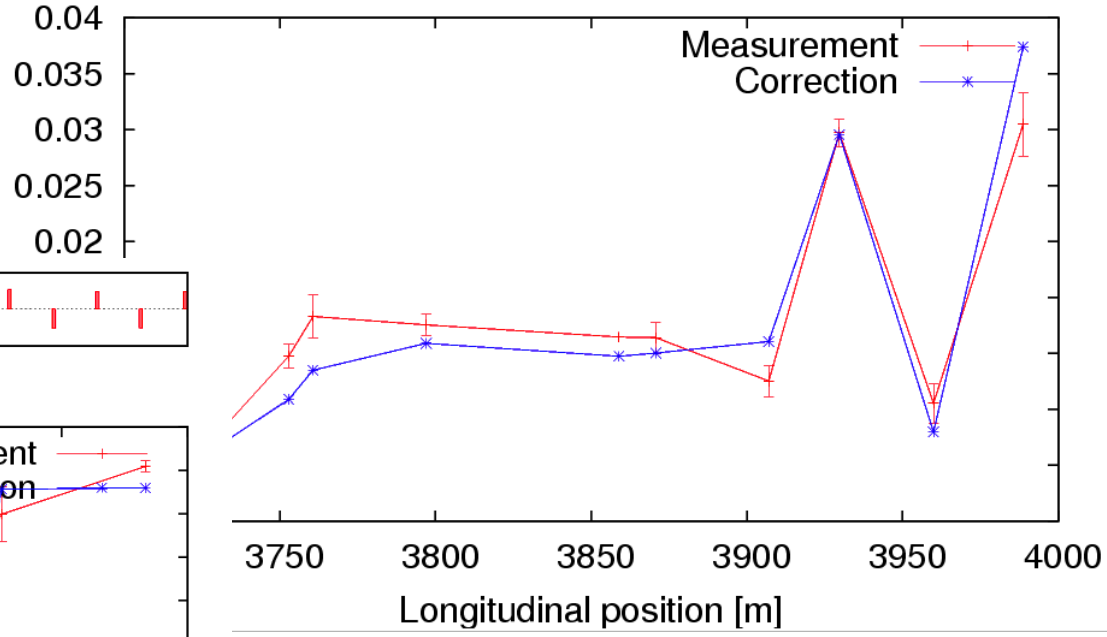
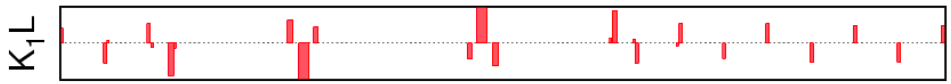
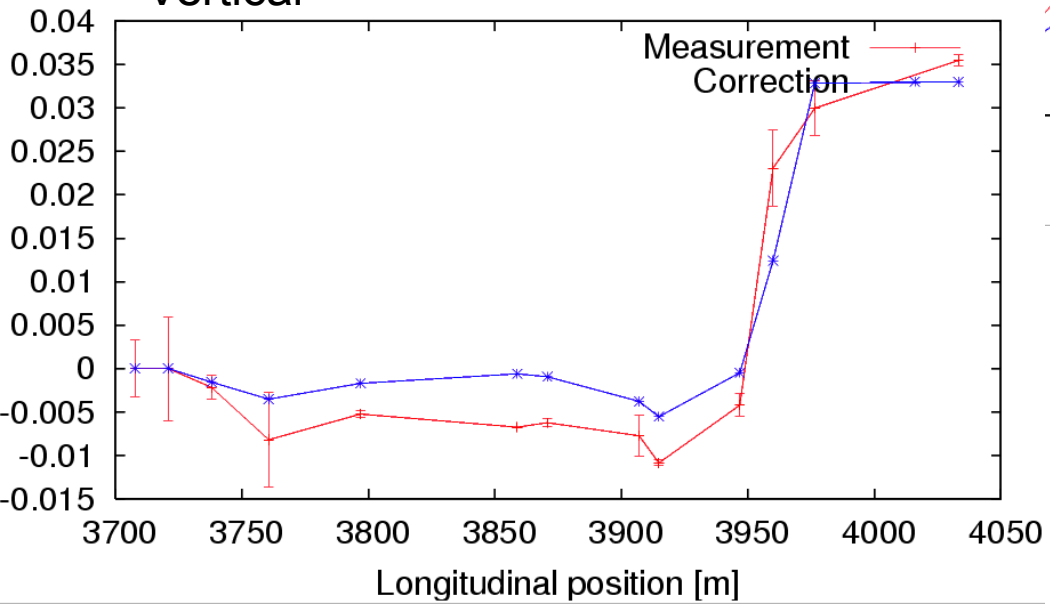
Calculated:
Q5I6, 0.95
Q5O6, 0.96

Horizontal





Vertical



Actual applied correction:

	design	trim
bi5-qf7	0.078881	0.00135248944
bo6-tq5	0.0211343	-0.0029438348

Summary of SBST Commissioning

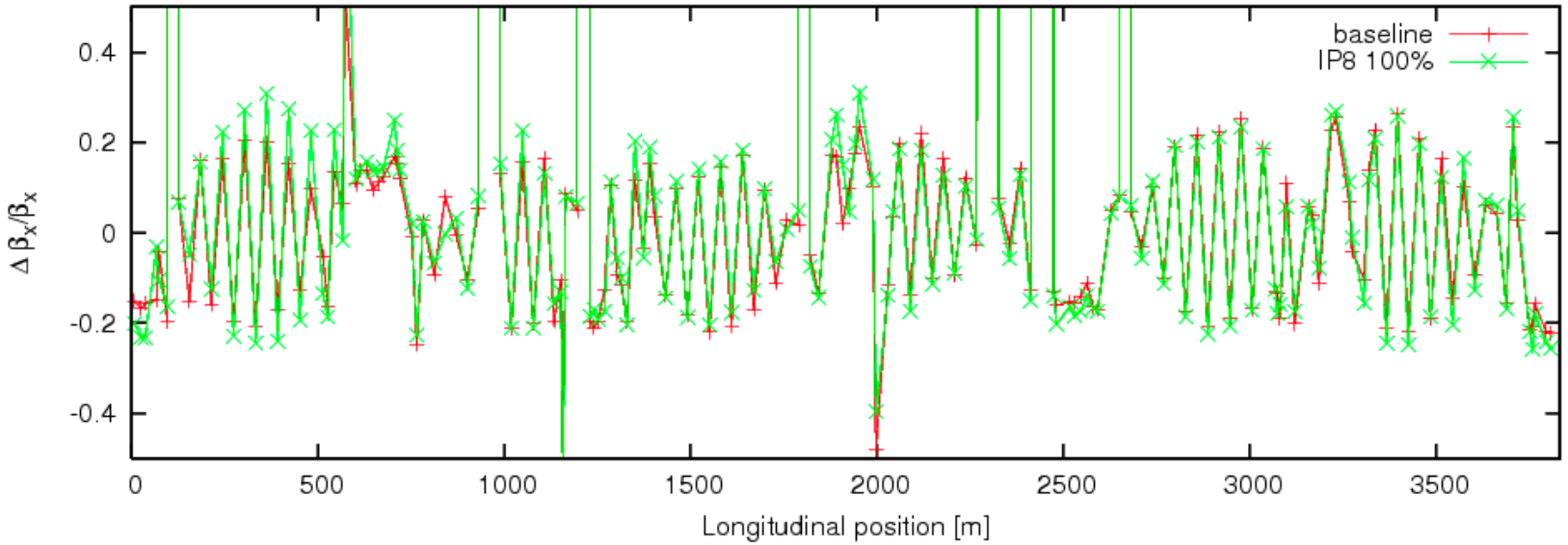
OpticsCorrection

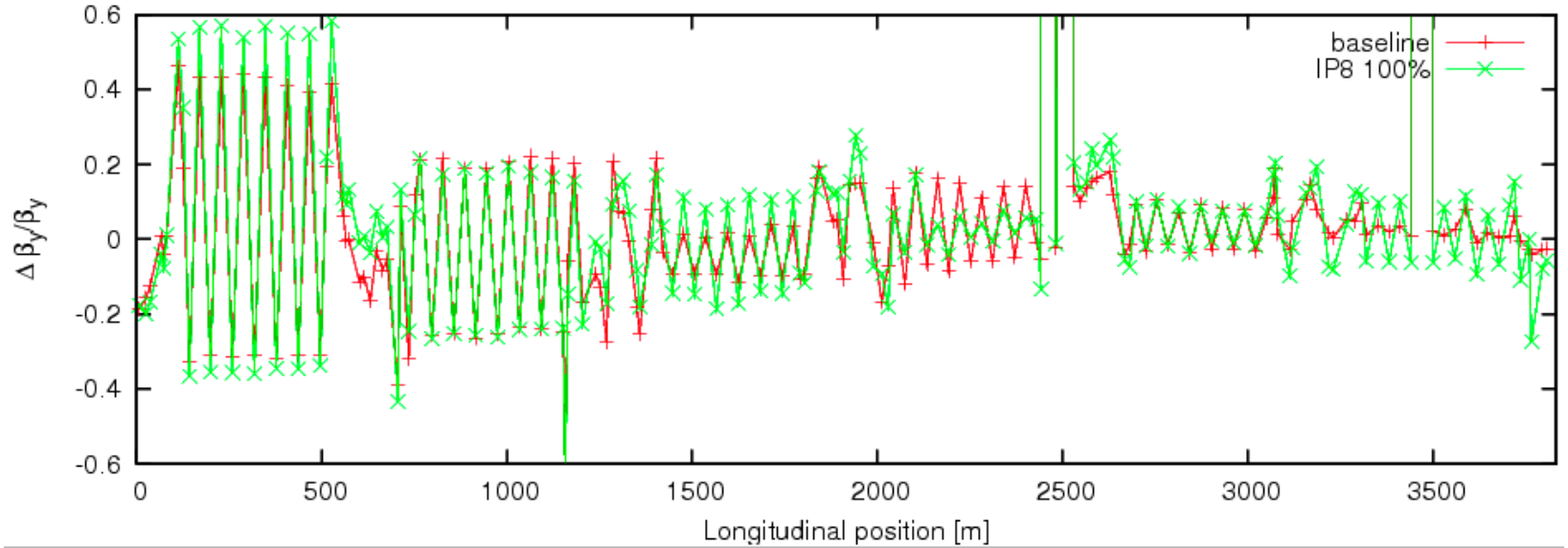
- Initial IP6 correction helped to reduce the vertical beta-beat except sector 12-1 and sector 2&3
- IP8 correction wasn’t effective in vertical. And it showed mixed effects on the horizontal beta-beat

Effect of IP8 Correction

OpticsCorrection

Fill15329



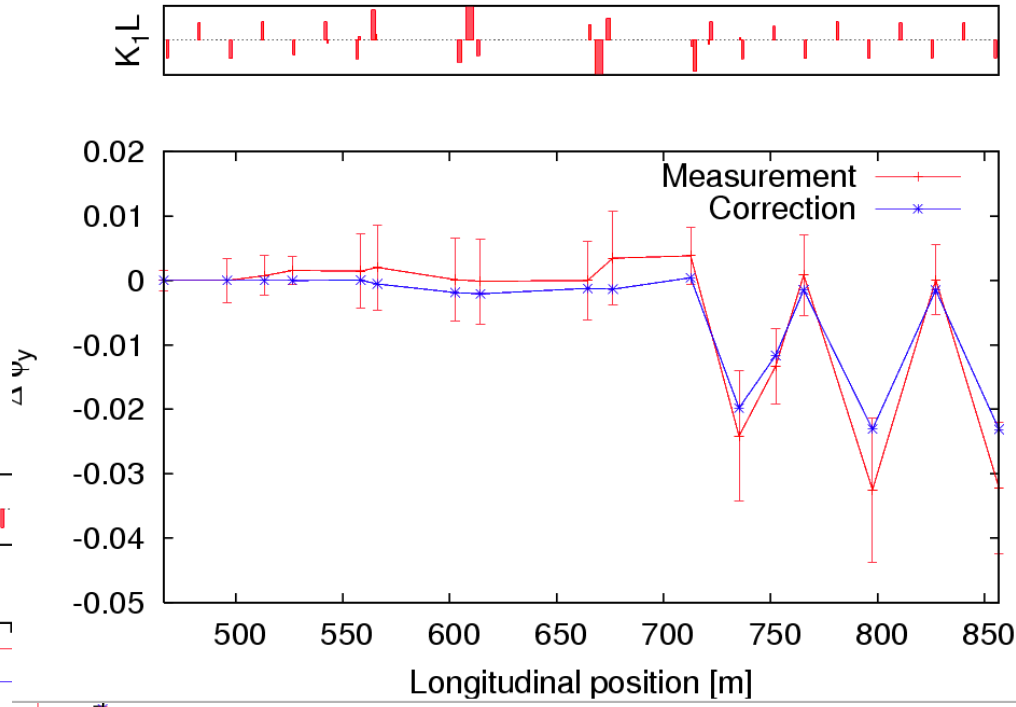


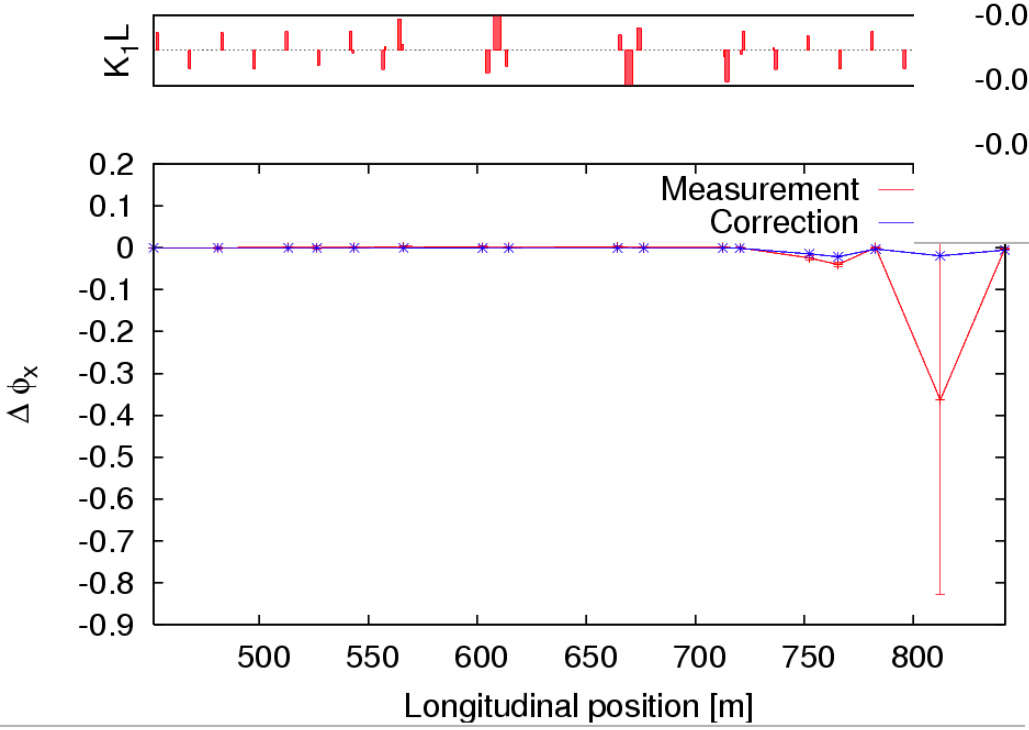
Effect of IP8 Correction

OpticsCorrection

Fill15329

Calculated:
Q6OT8,0.99
Q5OT8,0.9
Q3I8,1.0005
Q5IT8,0.98

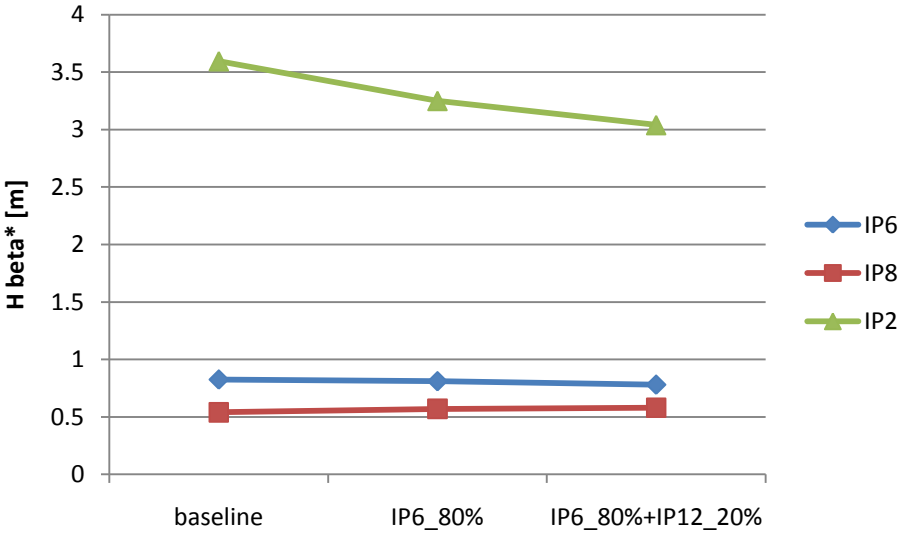


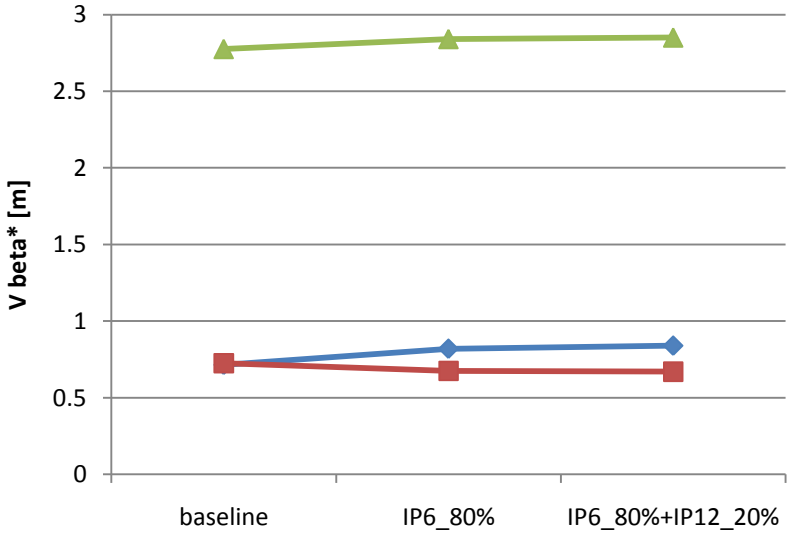


Summary of SBST Commissioning

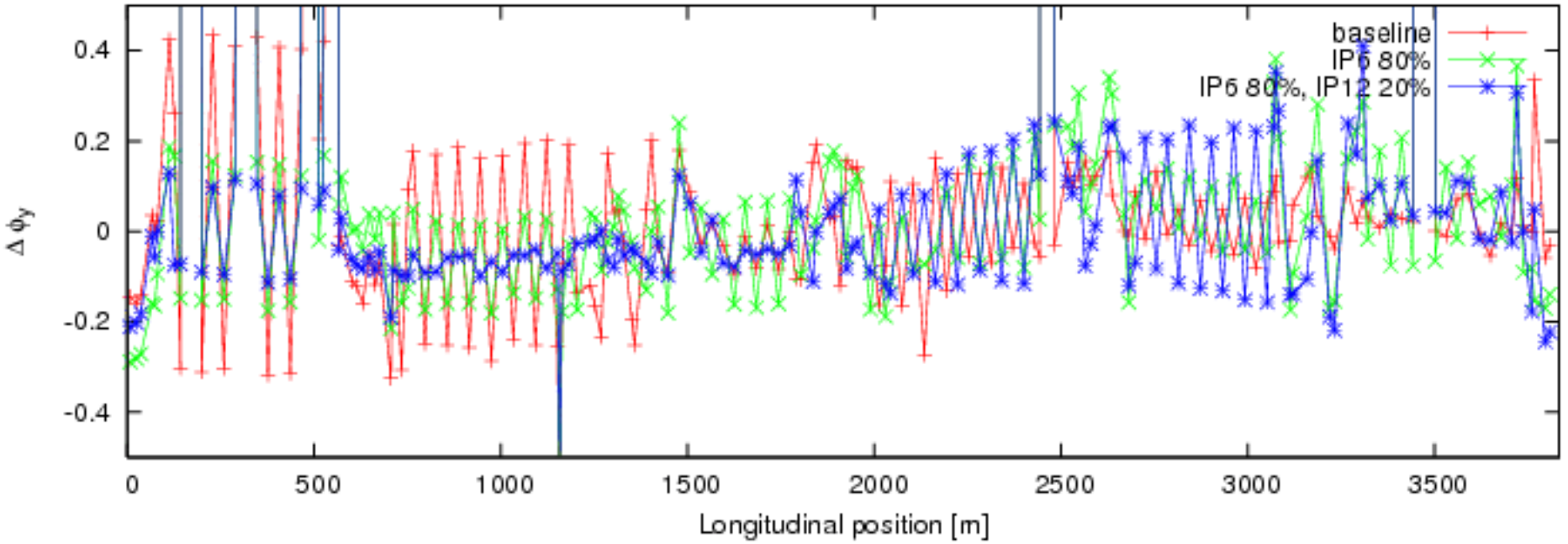
OpticsCorrection

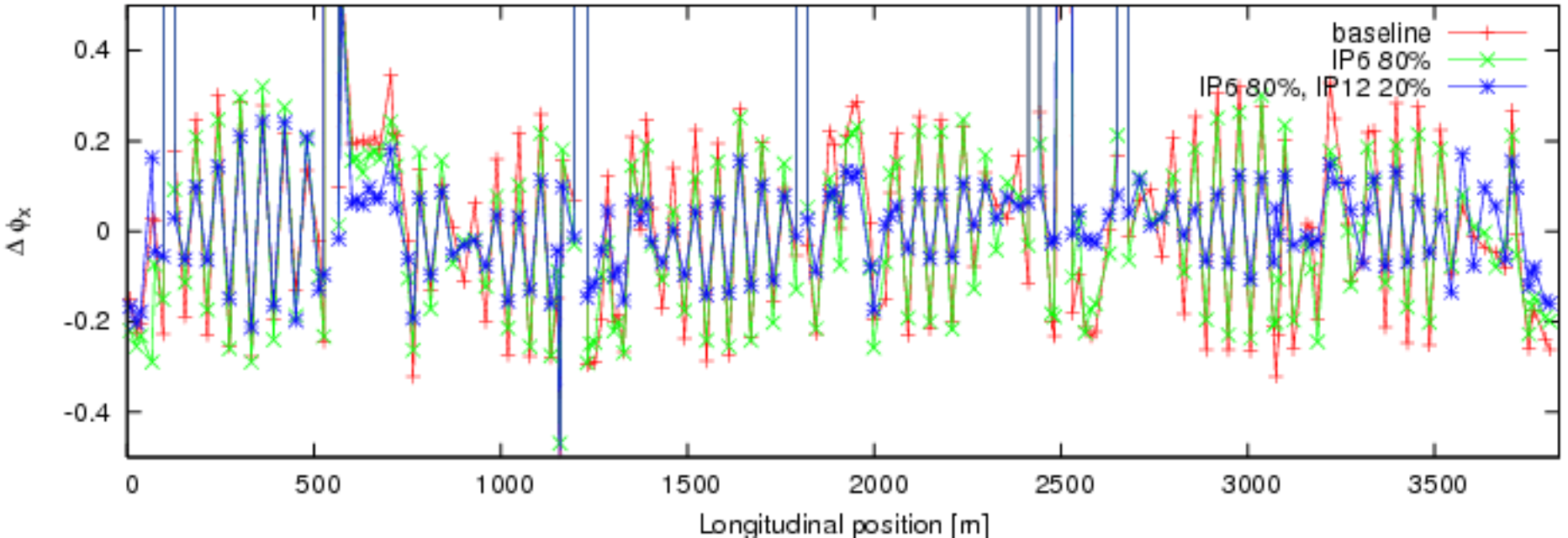
- Initial IP6 correction helped to reduce the vertical beta-beat except sector 12-1 and sector 2&3
- IP8 correction wasn't effective in vertical. And it showed mixed effects on the horizontal beta-beat
- Together with IP6 correction, IP12 correction shows moderate effect on horizontal beta-beat at the expense of vertical beta-beat. This solution also affected beta* at IP6 and IP8





Baseline, IP6, IP12+IP6

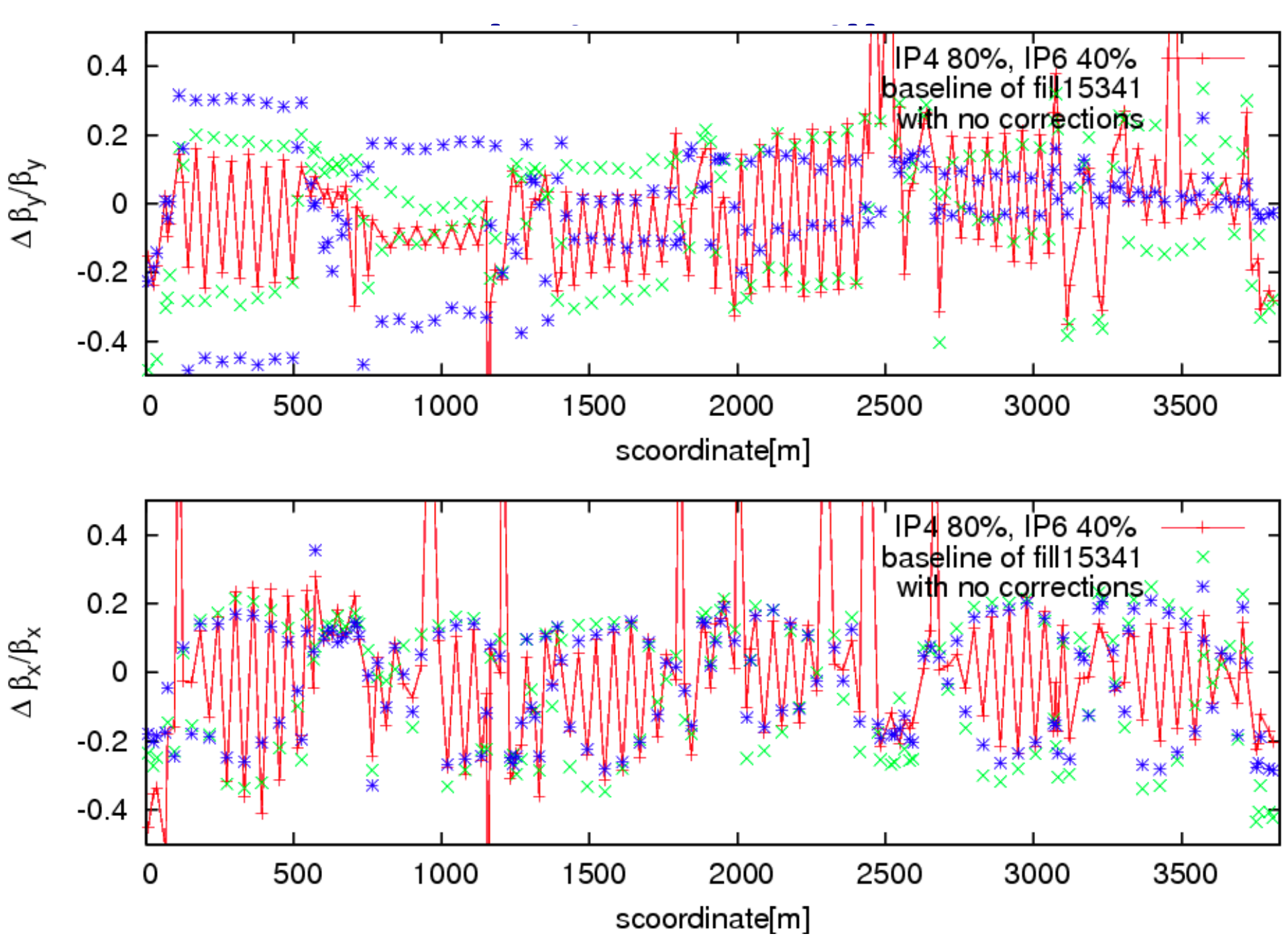




Summary of SBST Commissioning

OpticsCorrection

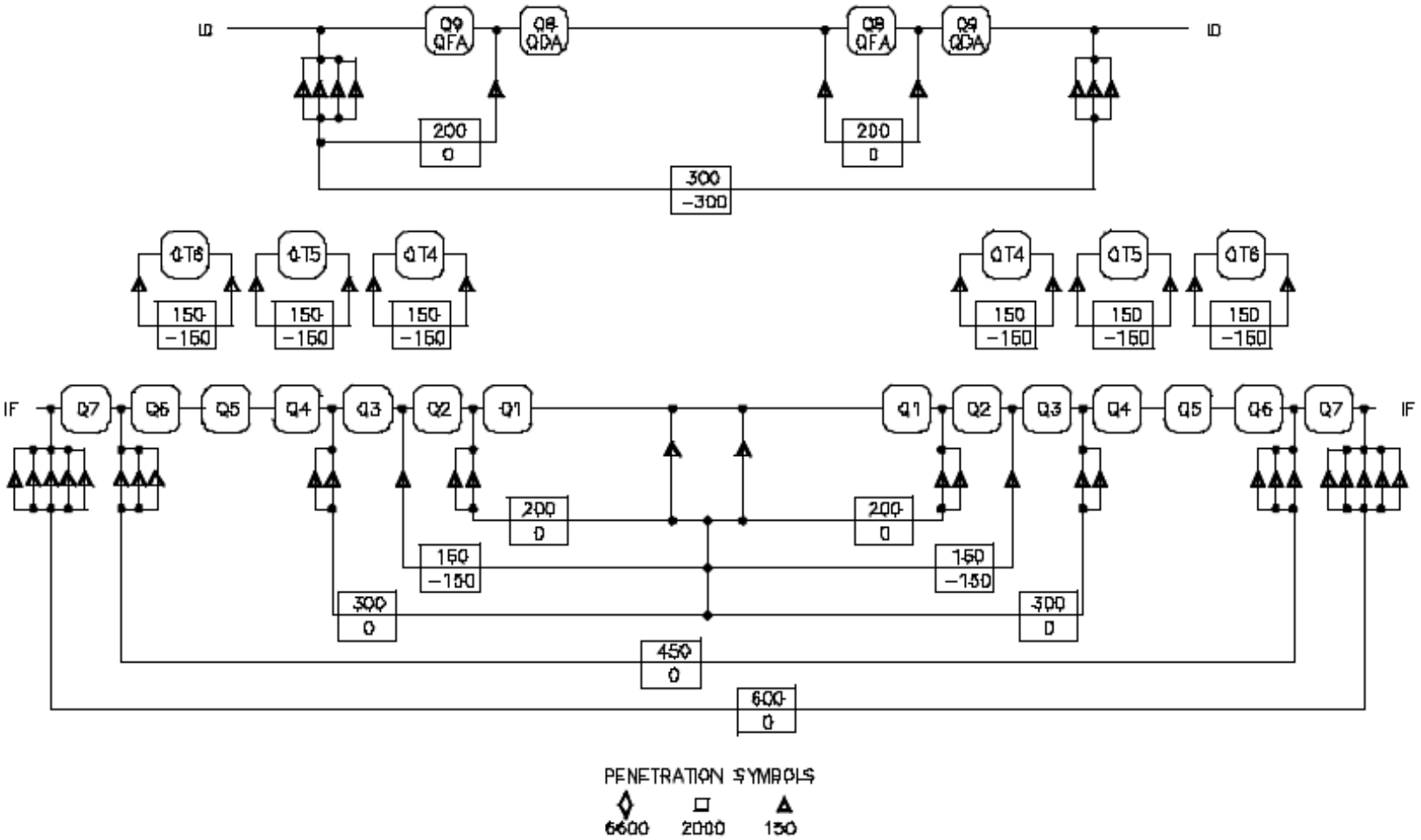
- Initial IP6 correction helped to reduce the vertical beta-beat except sector 12-1 and sector 2&3
- IP8 correction wasn't effective in vertical. And it showed mixed effects on the horizontal beta-beat
- Together with IP6 correction, IP12 correction shows moderate effect on horizontal beta-beat at the expense of vertical beta-beat. This solution also affected beta* at IP6 and IP8
- Together with reduced IP6 correction, IP4 correction shows moderate effect on vertical beta-beat except sector 6&7. No significant effect on horizontal beta-beat


IP4 80%, IP6 40%
baseline of fill15341
with no corrections
Δ βy/βy
scoordinate[m]
0.4
0.2
0
-0.2
-0.4
0
500
1000
1500
2000
2500
3000
3500
IP4 80%, IP6 40%
baseline of fill15341
with no corrections
Δ βx/βx
scoordinate[m]

Encountered Issues

OpticsCorrection

- Limited knobs
  - RHIC nesting power supply scheme



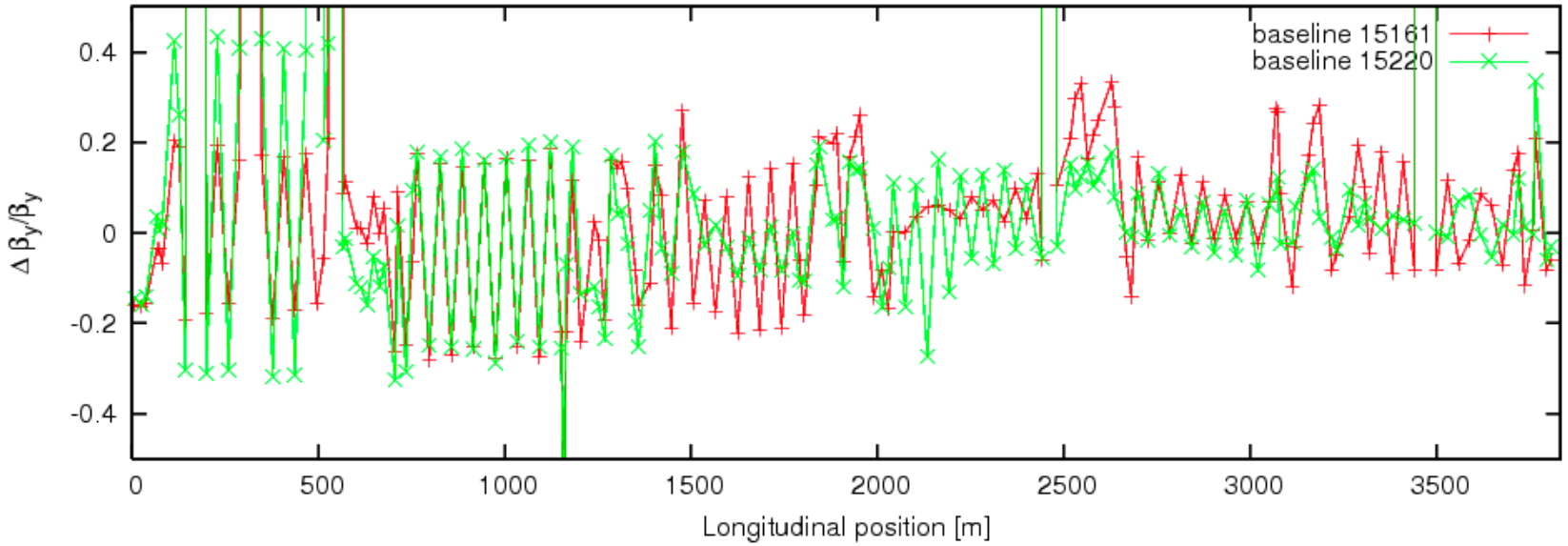
Encountered Issues

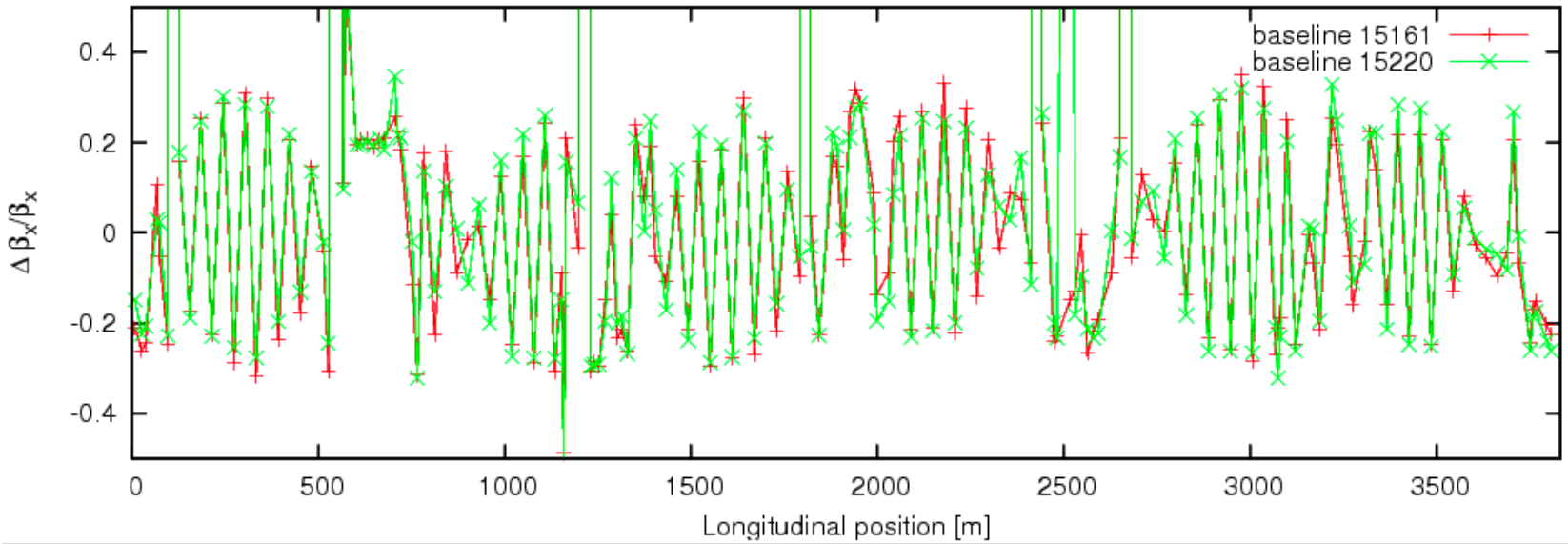
OpticsCorrection

- Limited knobs
  - RHIC nesting power supply scheme
    - limited independent knobs: trim quads at Q5, Q6
  - Power supply limit
- Reproducibility of optics

Reproducibility?

OpticsCorrection





Encountered Issues

OpticsCorrection

- Issues
  - Limited knobs
  - Reproducibility of optics
  - Complicated RHIC modeling infrastructure
    - Two model engines for RHIC: mad and online model(Opticalc)
      - They don't carry exact the same lattice, for instance, the crossing angles, local coupling corrections, etc.
    - Each model uses slightly different magnet transfer function
      - For mad, it assumes the same transfer function for the same type of magnets
      - For online model, the actual measured transfer function for each magnet is used

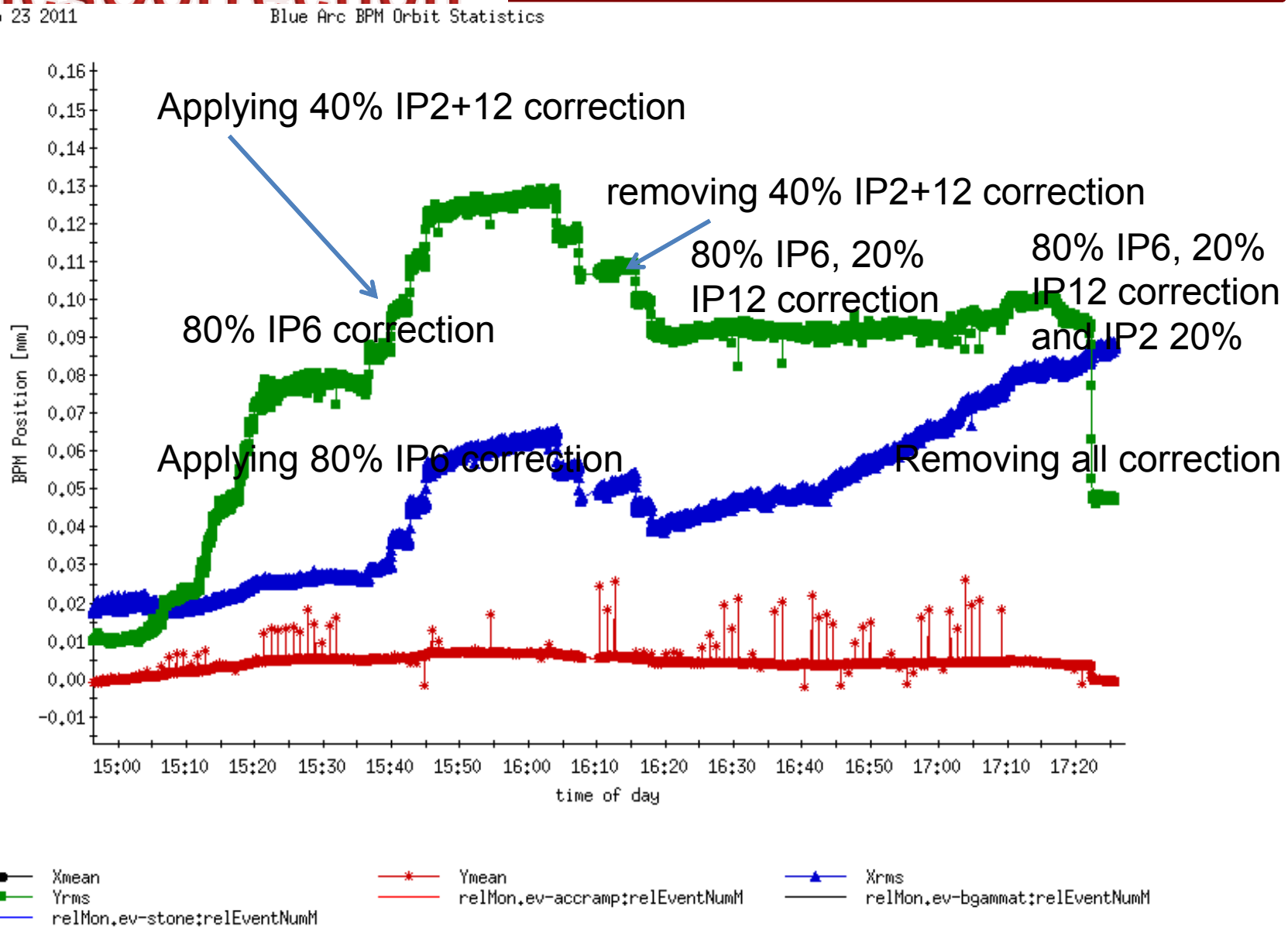
Future Plan

OpticsCorrection

- Systematically analyze the results from RUN11 to understand each IP's knob effect
- Integrate Glenn's SBST package with RHIC current online optics measurement application
  - Loptics was built based on ac dipole. It uses the turn by turn fitting to calculate the phase advances as well as beta functions
  - It is also based on RHIC online model
  - Implement the power-supply limit in the application
  - Include coupling as well as dispersion
- Commission the global optics correction (SVD)
  - Proof-of-principle in 2009 run

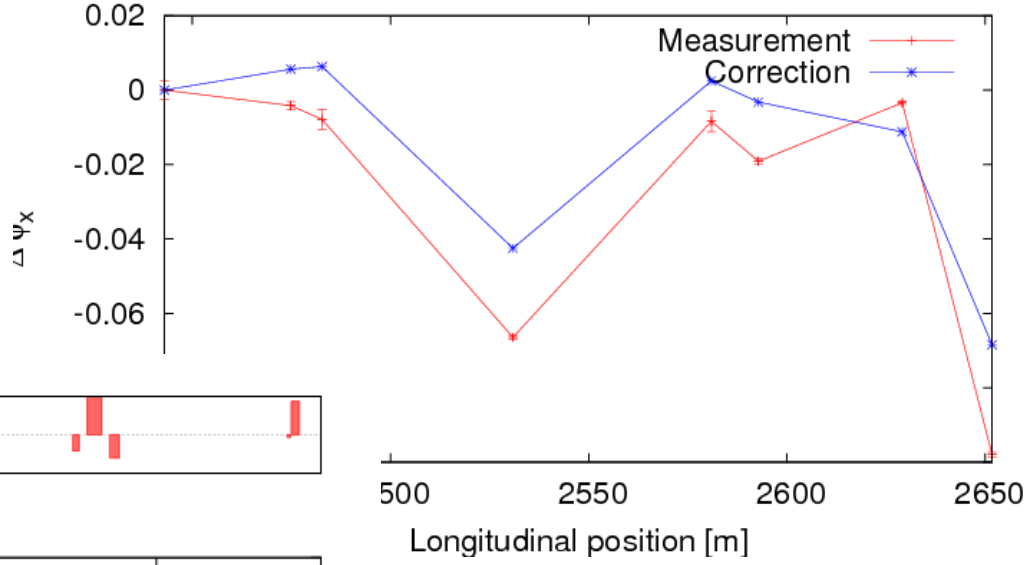
Beam not centered in Quads

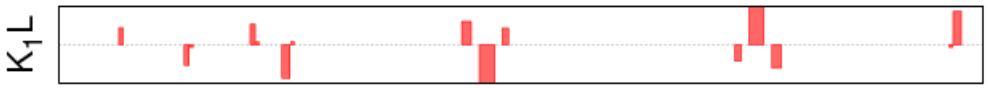
OpticsCorrection

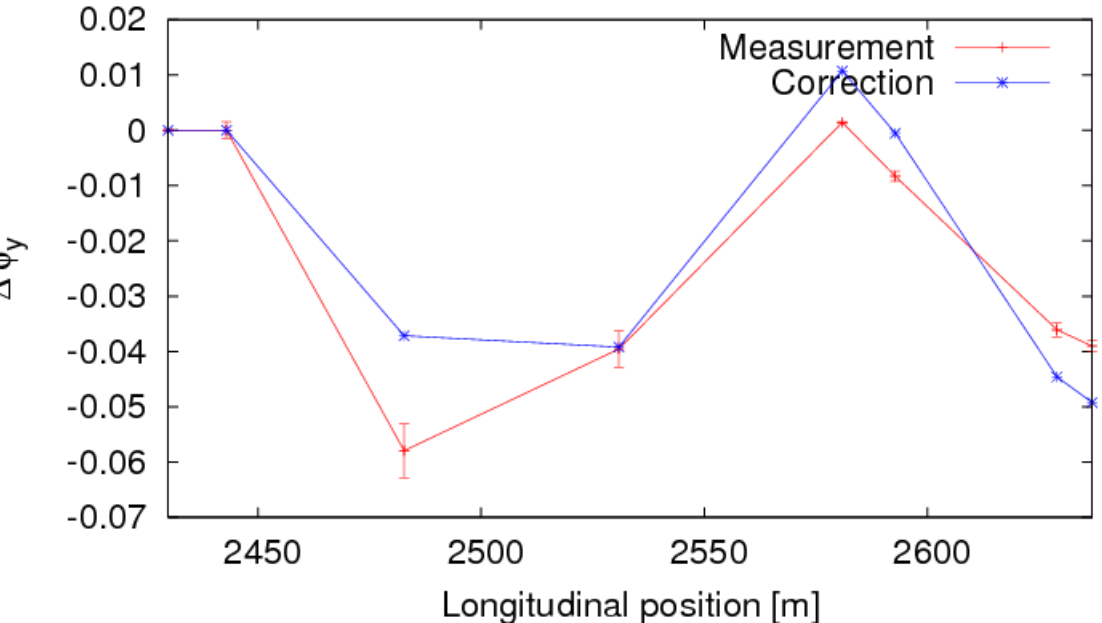


SBST Analysis IP2, Fill 15161

OpticsCorrection







Q5I2, 1.04
Q6I2, 1.1
Q4I2, 0.96
Q4O2, 1.05

In model,they change tune
Qx = 0.69 -> 0.7483
Qy= 0.68 -> 0.6757