# IR2 squeeze for 3.5 TeV update

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# IR2 squeeze background

- Injection optics in IR2 is highly constrained
  - Injection phase advance constraints
  - Aperture limitations ($n_1$ criterion)
  - Solution found (by T. Risselada) requires high value of (normalised) gradient, in triplet quadrupoles, must be reduced for 7 TeV.
- For Pb-Pb operation at $7Z$ TeV, the squeeze to β*=0.5 m requires a *pre-squeeze*, in which injection constraints are relaxed at constant β*=10 m and triplet gradient is reduced.
  - Pre-squeeze takes additional time.
- Squeeze then proceeds at constant triplet K1.
- For 3.5 Z TeV, p p operation mostly at β*=10 m but a squeeze to β*=3 m is requested.
  - Pre-squeeze no longer necessary/wanted and could be suppressed to save time in operation.
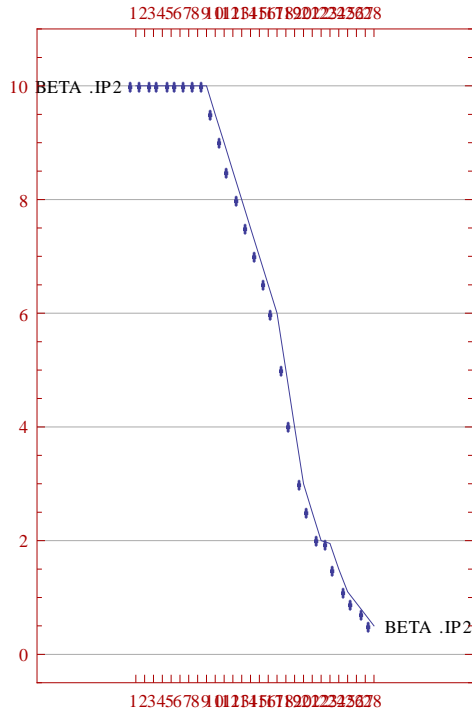
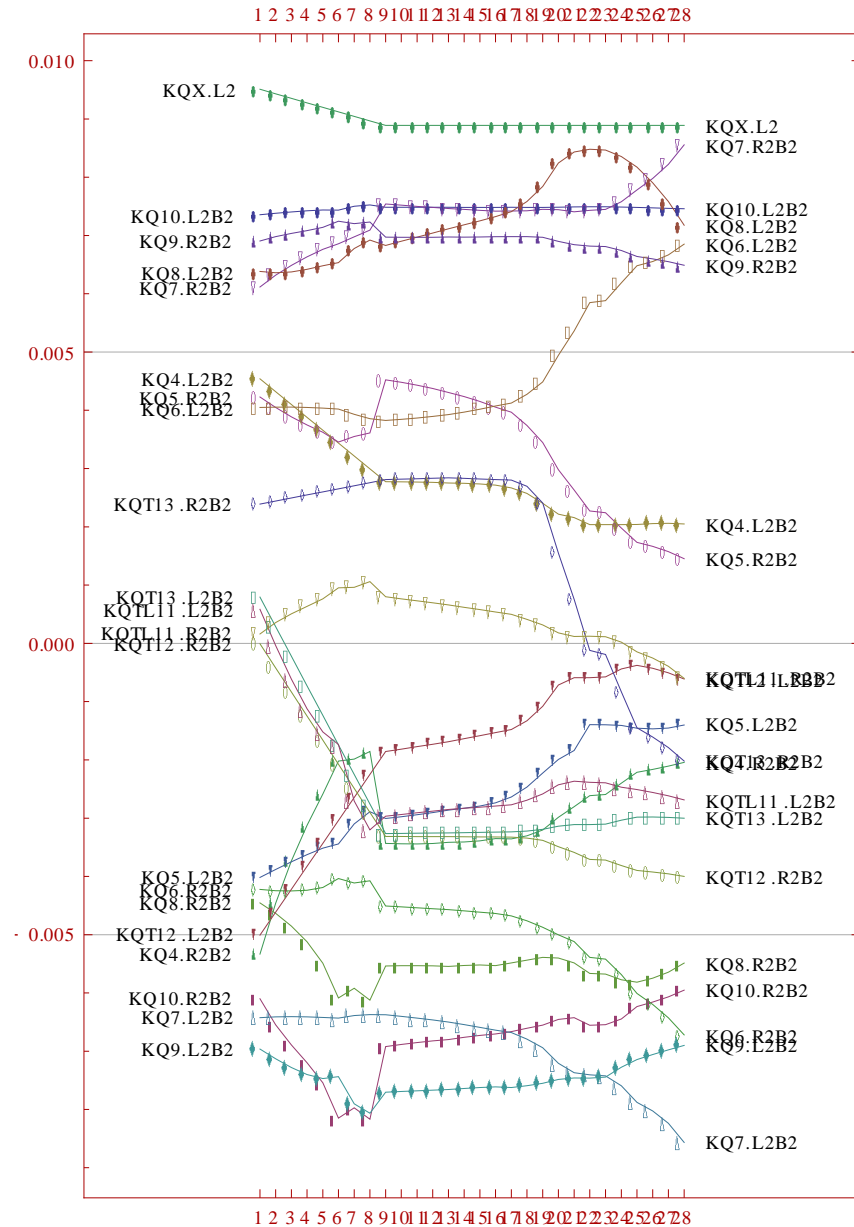# Present squeeze with pre-squeeze
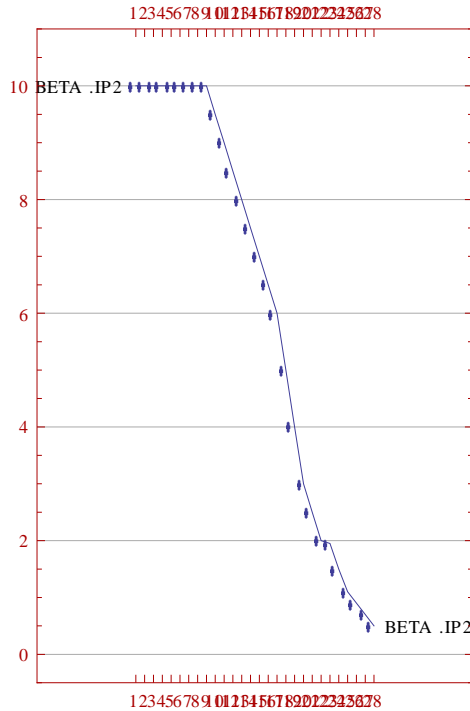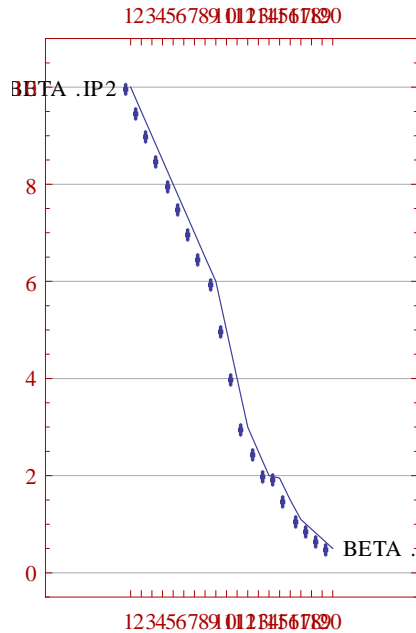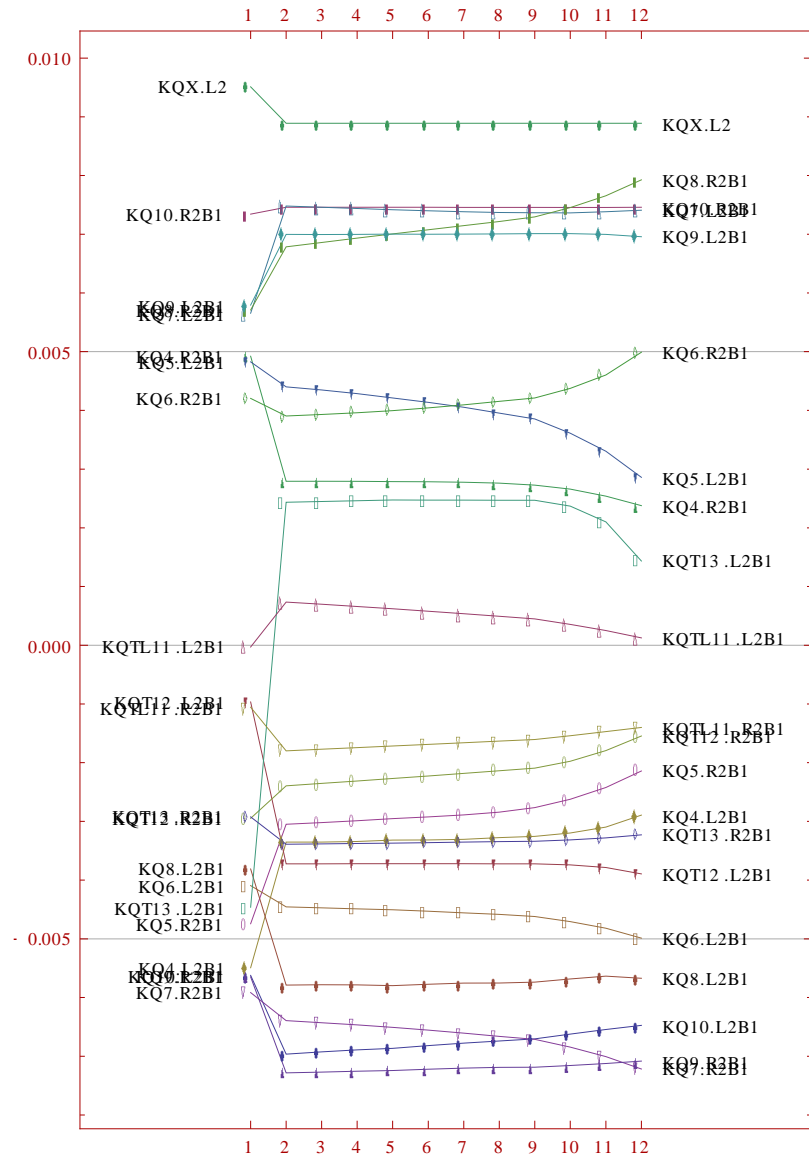
Beam 1

28 steps, some awkward variations of trim quads
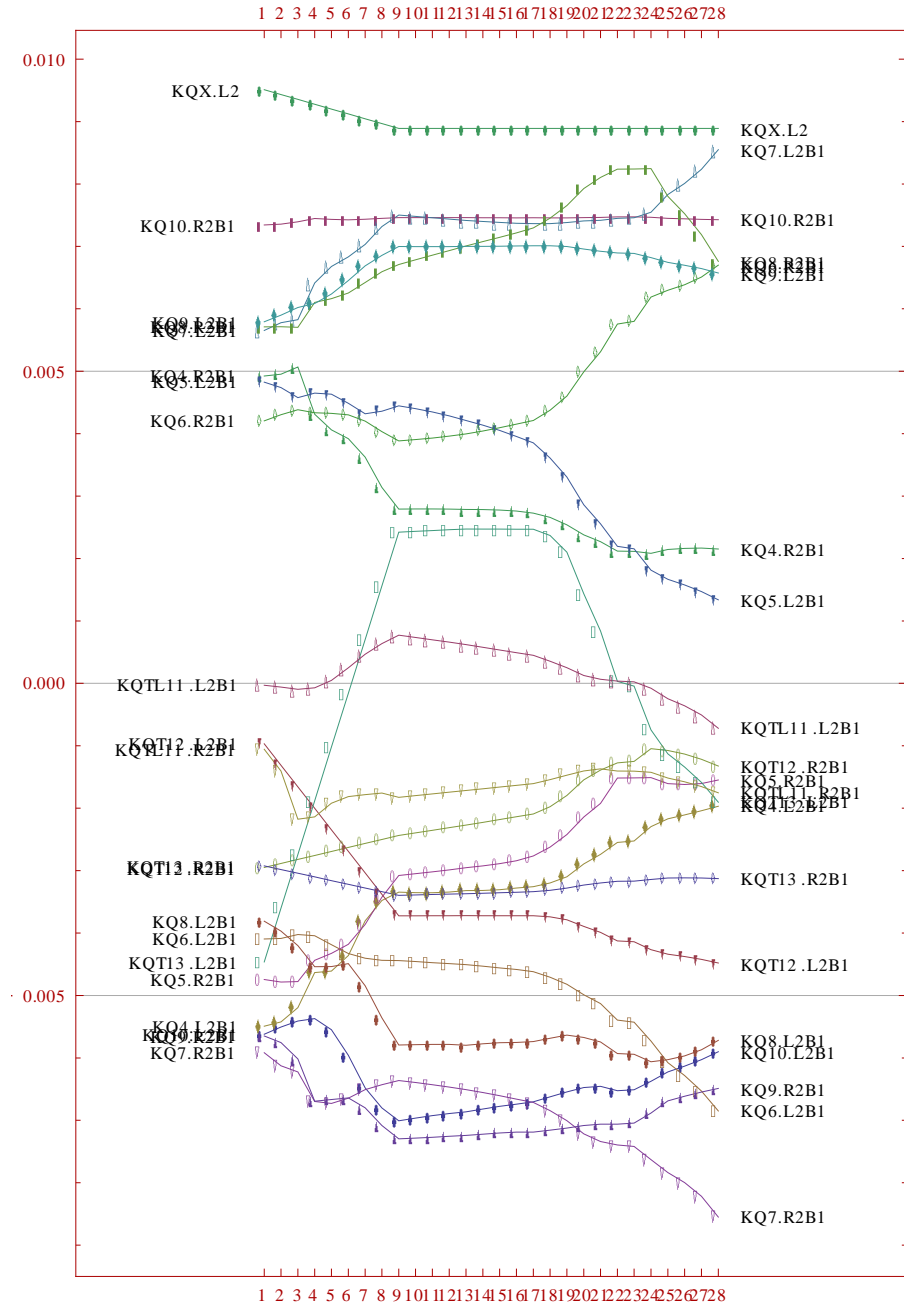
# Present squeeze with pre-squeeze



Beam 2

# Simple removal of pre-squeeze



Beam 1

20 steps, big jumps of quads in first step to β*=9.5 m but OK later.

# Beta-beating in 4 arcs



ARC.12.B1 — $\beta_x/\beta_{x0} - 1$

ARC.12.B1 — $\beta_y/\beta_{t0} - 1$

$$\left\{ \quad , \quad , \quad \begin{pmatrix} 0.056853 & 0.168219 \\ 0.274039 & 0.262124 \end{pmatrix} \right\}$$

ARC.23.B1 — $\beta_x/\beta_{x0} - 1$

ARC.23.B1 — $\beta_y/\beta_{t0} - 1$

$$\left\{ \quad , \quad , \quad \begin{pmatrix} 0.0371711 & 0.172039 \\ 0.0532329 & 0.2622132376778434 \end{pmatrix} \right\}$$

ARC.34.B1 — $\beta_x/\beta_{x0} - 1$

ARC.34.B1 — $\beta_y/\beta_{t0} - 1$

$$\left\{ \quad , \quad , \quad \begin{pmatrix} 0.0367854 & 0.170251 \\ 0.0535135 & 0.262372 \end{pmatrix} \right\}$$

ARC.45.B1 — $\beta_x/\beta_{x0} - 1$

ARC.45.B1 — $\beta_y/\beta_{t0} - 1$

$$\left\{ \quad , \quad , \quad \begin{pmatrix} & 0. \\ & 0.0535 \end{pmatrix} \right.$$
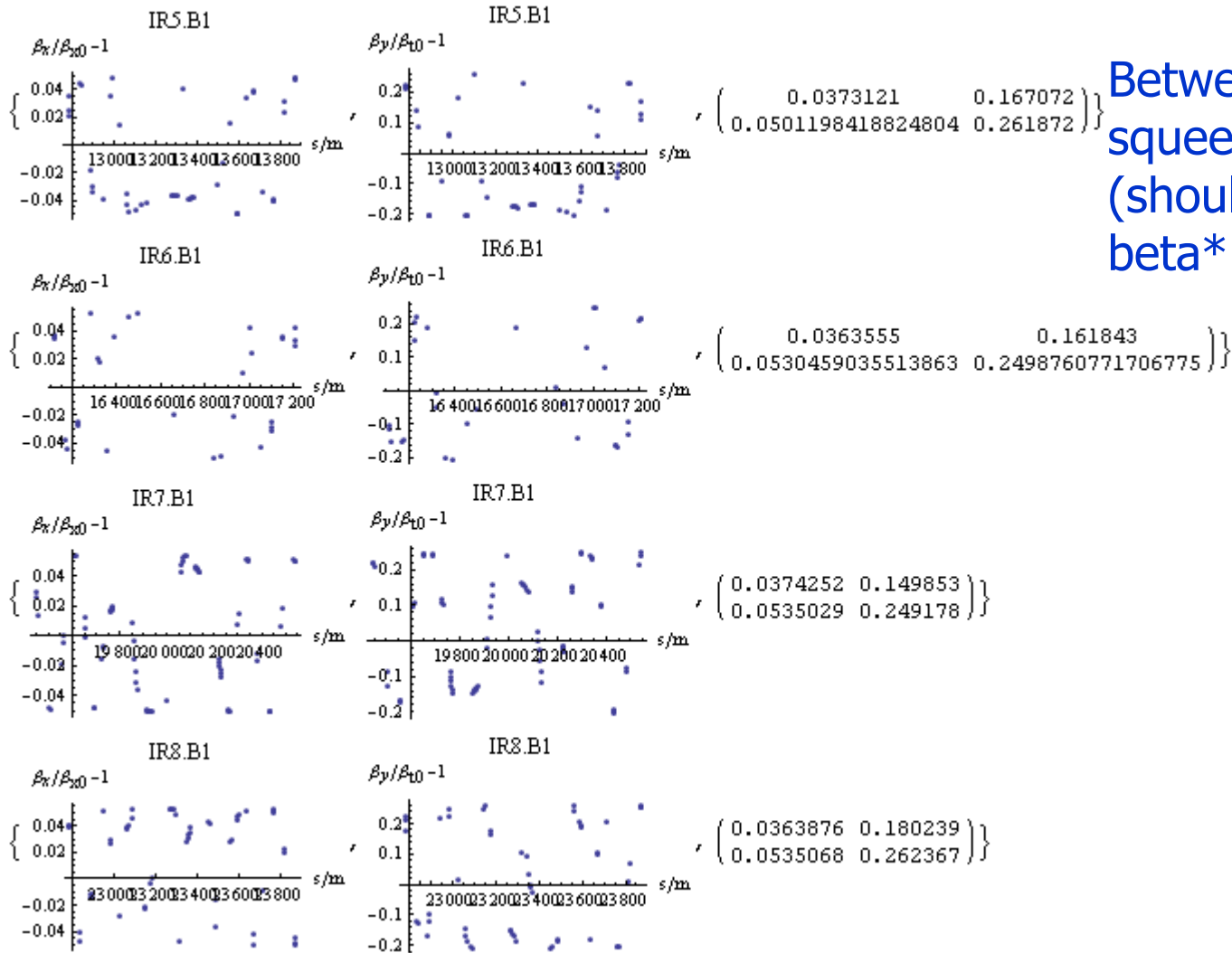
Between first two squeeze points (should be beta*=9.75 m)
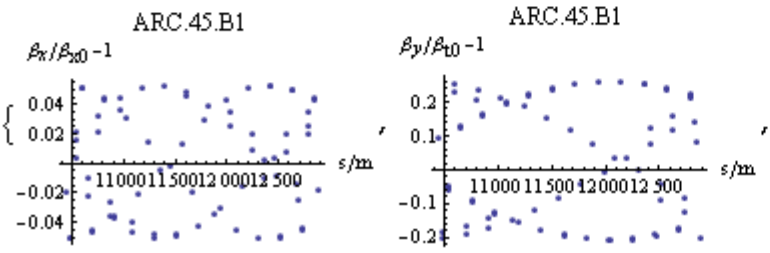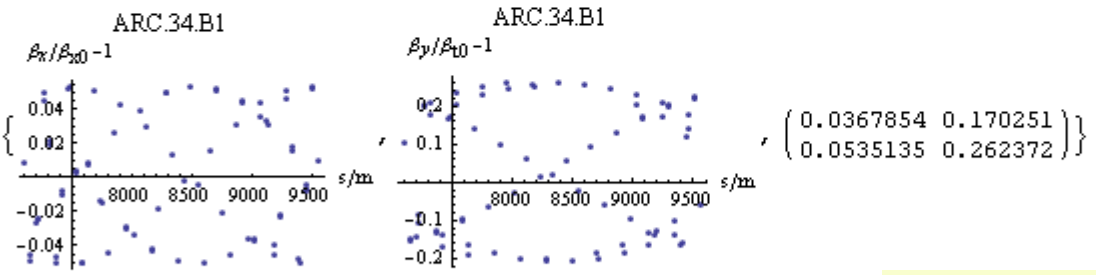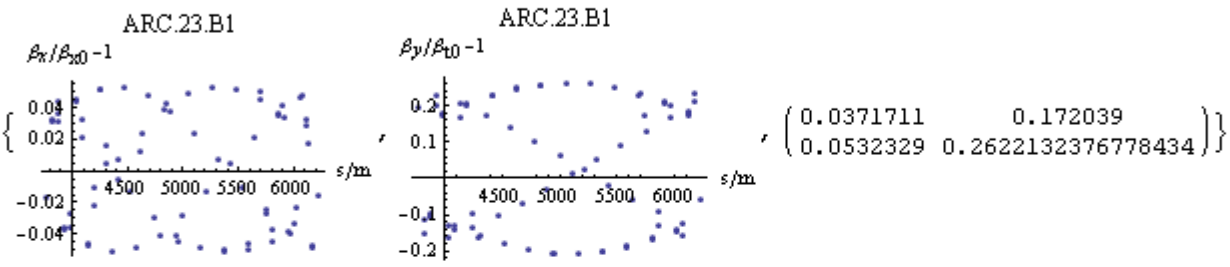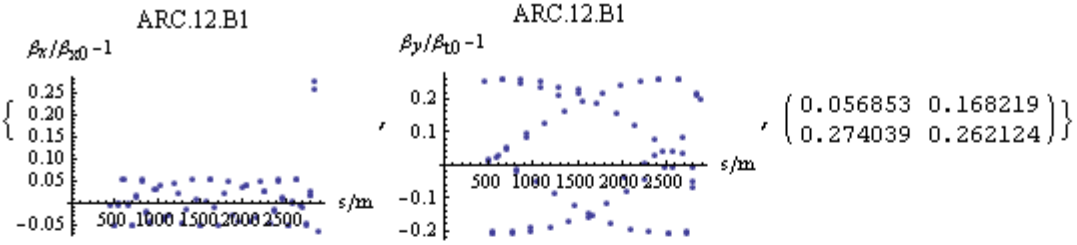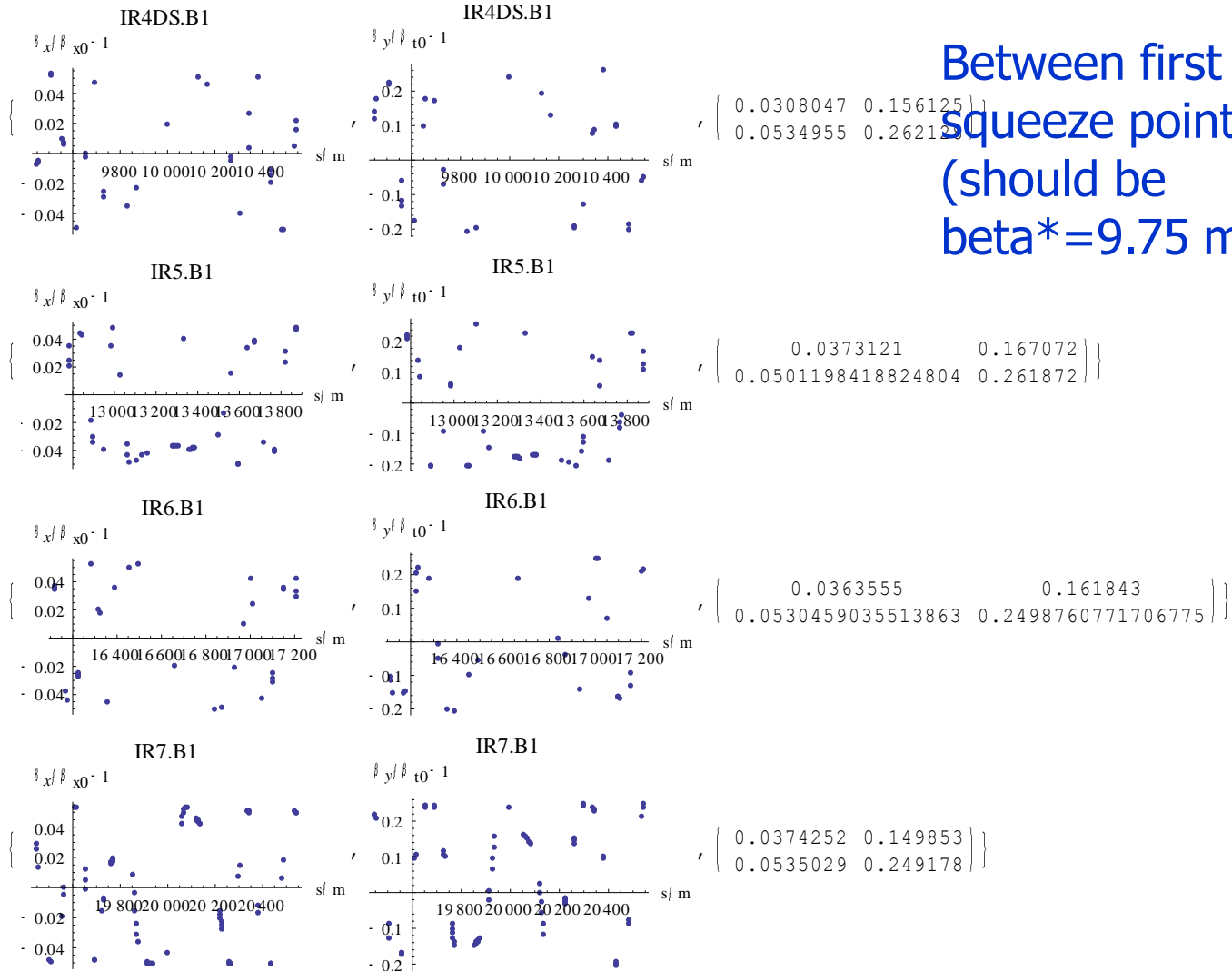
$$\left\{ \begin{matrix} \left( \dfrac{\beta_x}{\beta_{x0}} - 1 \right)_{\text{RMS, Quadrupoles}} & \left( \dfrac{\beta_y}{\beta_{y0}} - 1 \right)_{\text{RMS, Quadrupoles}} \\[2em] \max\left( \left| \dfrac{\beta_x}{\beta_{x0}} - 1 \right| \right)_{\text{Quadrupoles}} & \max\left( \left| \dfrac{\beta_y}{\beta_{y0}} - 1 \right| \right)_{\text{Quadrupoles}} \end{matrix} \right\}$$

# Beta-beating in 4 more arcs



IR5.B1 — $\beta_x/\beta_{x0}-1$, $\beta_y/\beta_{t0}-1$

$$\left\{\begin{pmatrix} 0.0373121 & 0.167072 \\ 0.0501198418824804 & 0.261872 \end{pmatrix}, \right.$$

IR6.B1 — $\beta_x/\beta_{x0}-1$, $\beta_y/\beta_{t0}-1$

$$\left. \begin{pmatrix} 0.0363555 & 0.161843 \\ 0.0530459035513863 & 0.2498760771706775 \end{pmatrix}\right\}$$

IR7.B1 — $\beta_x/\beta_{x0}-1$, $\beta_y/\beta_{t0}-1$

$$\left. \begin{pmatrix} 0.0374252 & 0.149853 \\ 0.0535029 & 0.249178 \end{pmatrix}\right\}$$

IR8.B1 — $\beta_x/\beta_{x0}-1$, $\beta_y/\beta_{t0}-1$

$$\left. \begin{pmatrix} 0.0363876 & 0.180239 \\ 0.0535068 & 0.262367 \end{pmatrix}\right\}$$

Between first two squeeze points (should be beta*=9.75 m)

# Beta-beating in some LSS



Between first two squeeze points (should be beta*=9.75 m)

$$\left(\begin{array}{cc} 0.0308047 & 0.156125 \\ 0.0534955 & 0.262123 \end{array}\right)$$

$$\left(\begin{array}{cc} 0.0373121 & 0.167072 \\ 0.0501198418824804 & 0.261872 \end{array}\right)$$

$$\left(\begin{array}{cc} 0.0363555 & 0.161843 \\ 0.0530459035513863 & 0.2498760771706775 \end{array}\right)$$

$$\left(\begin{array}{cc} 0.0374252 & 0.149853 \\ 0.0535029 & 0.249178 \end{array}\right)$$

# New squeeze for 3.5 TeV

- Previous presentation showed that it is difficult to make a smooth transition from injection optics to later points in the existing squeeze

- Trying another approach: inserting just one additional squeeze point between 10 m and 9.5 m
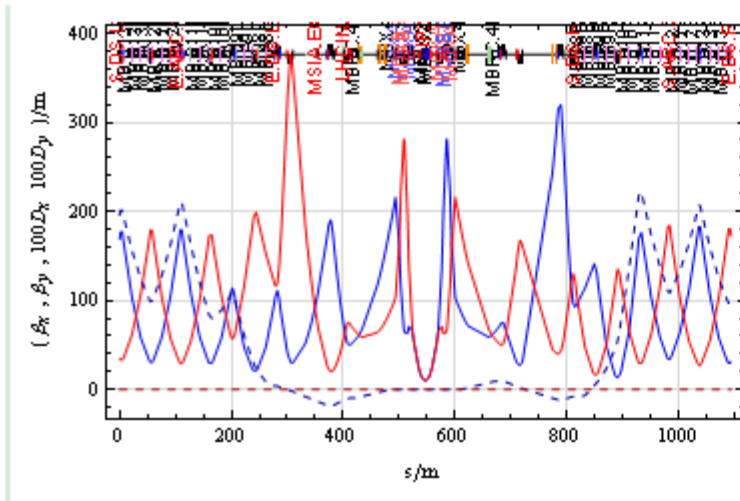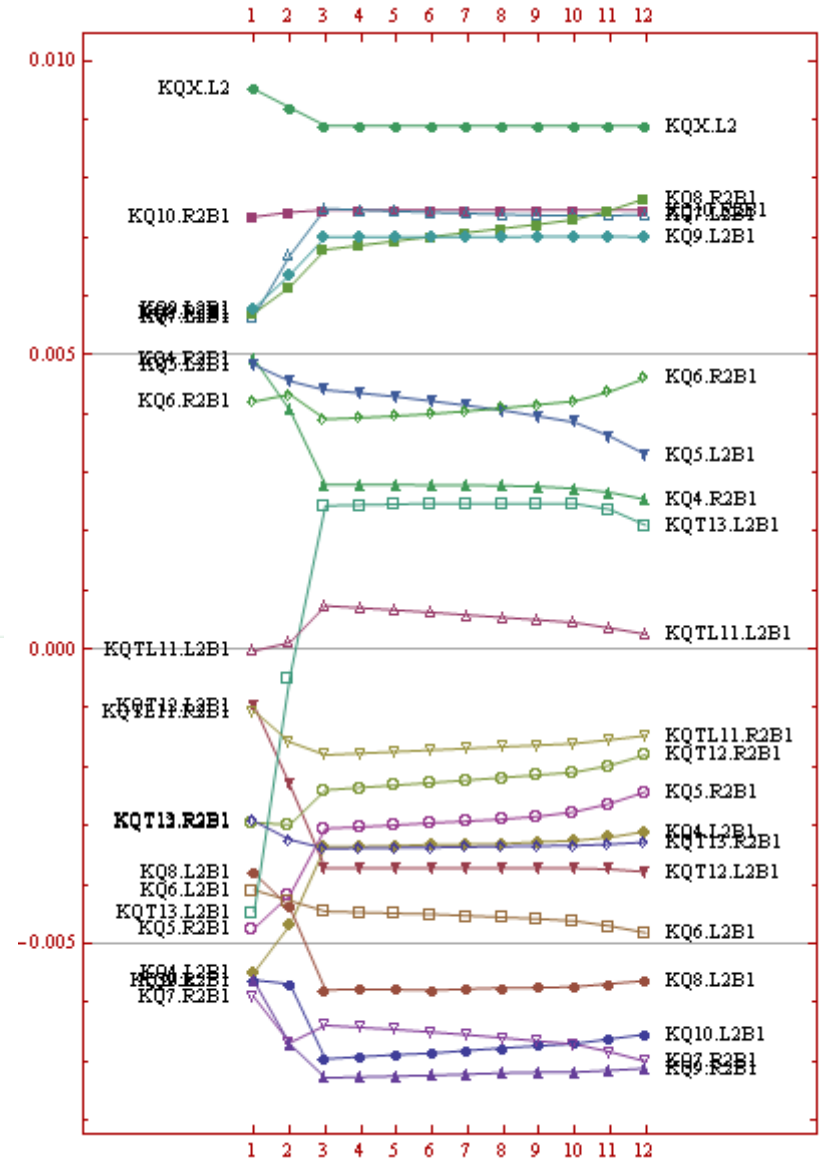
$$\beta^* = 9.75 \text{ m}$$
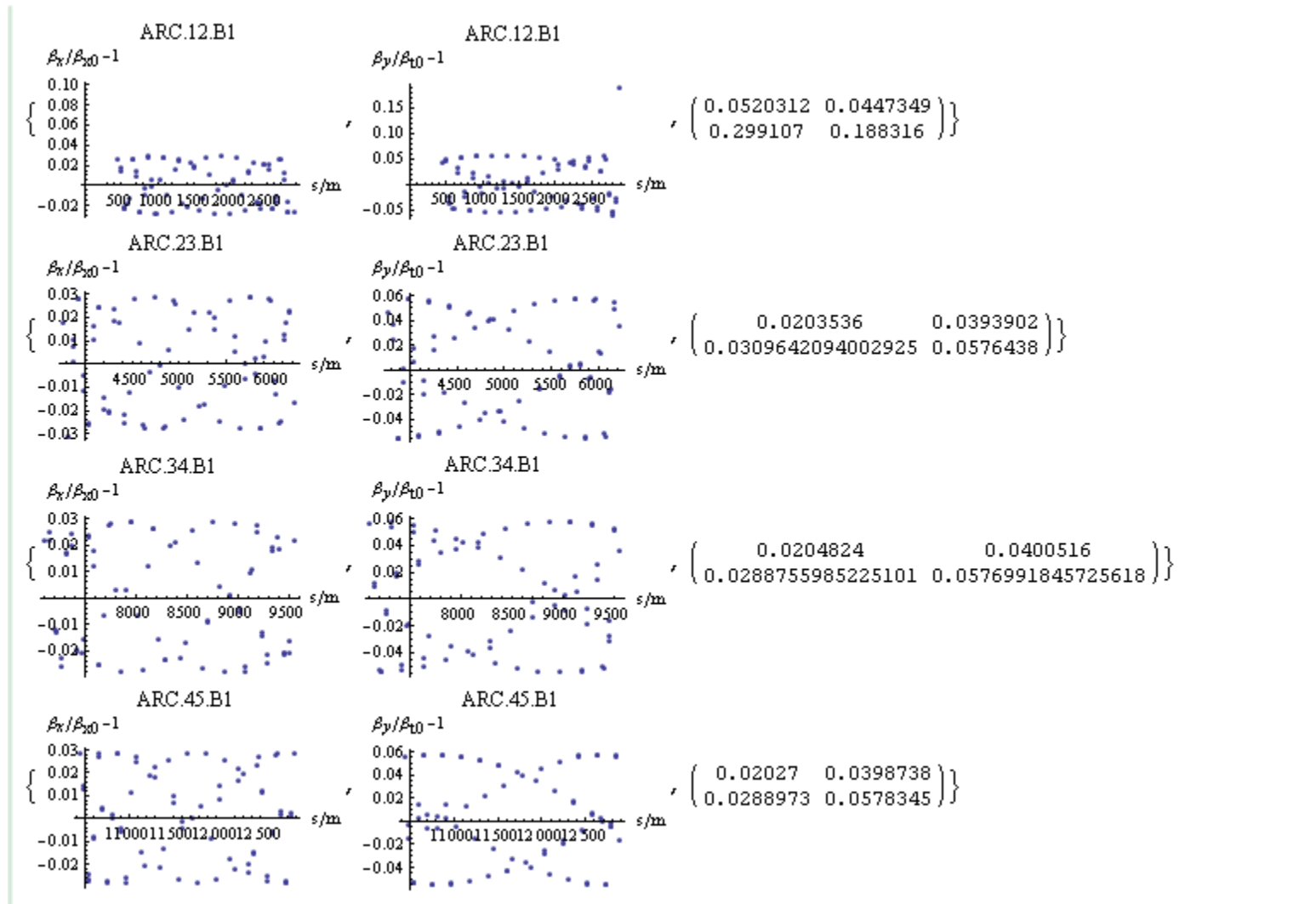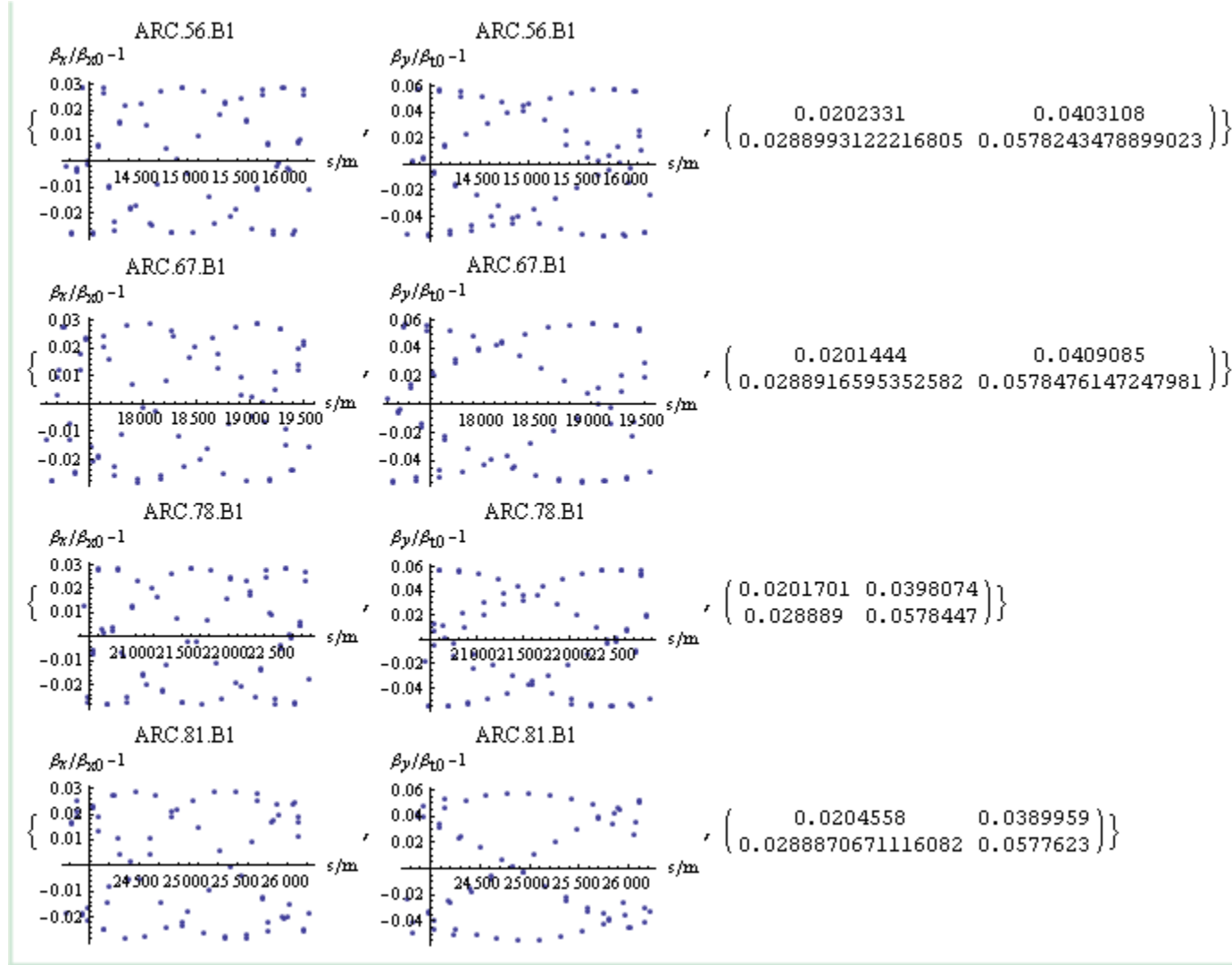
# Squeeze with additional point
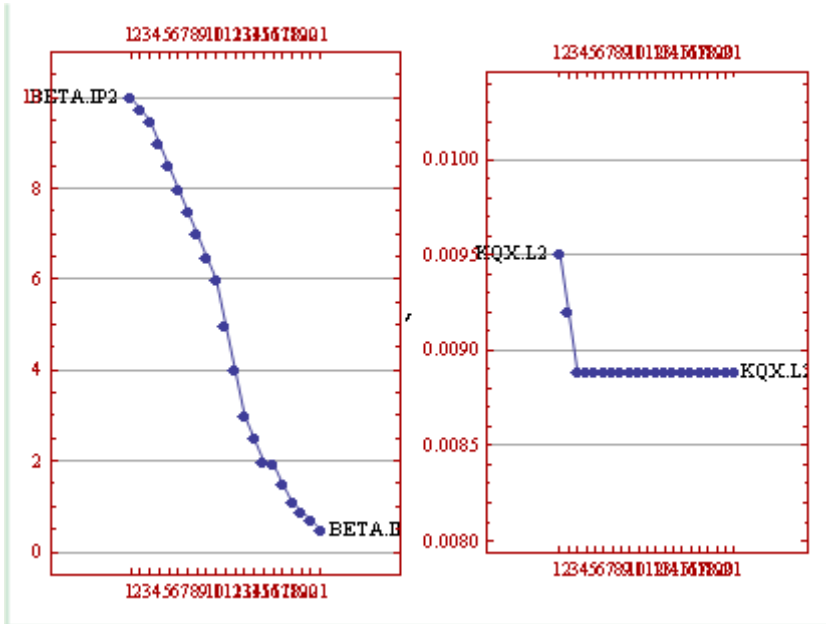


Similarly for Beam 2

It was possible to find a pretty good match at beta* = 9.75 m, starting from an interpolation of 10 m and 9.5 m.

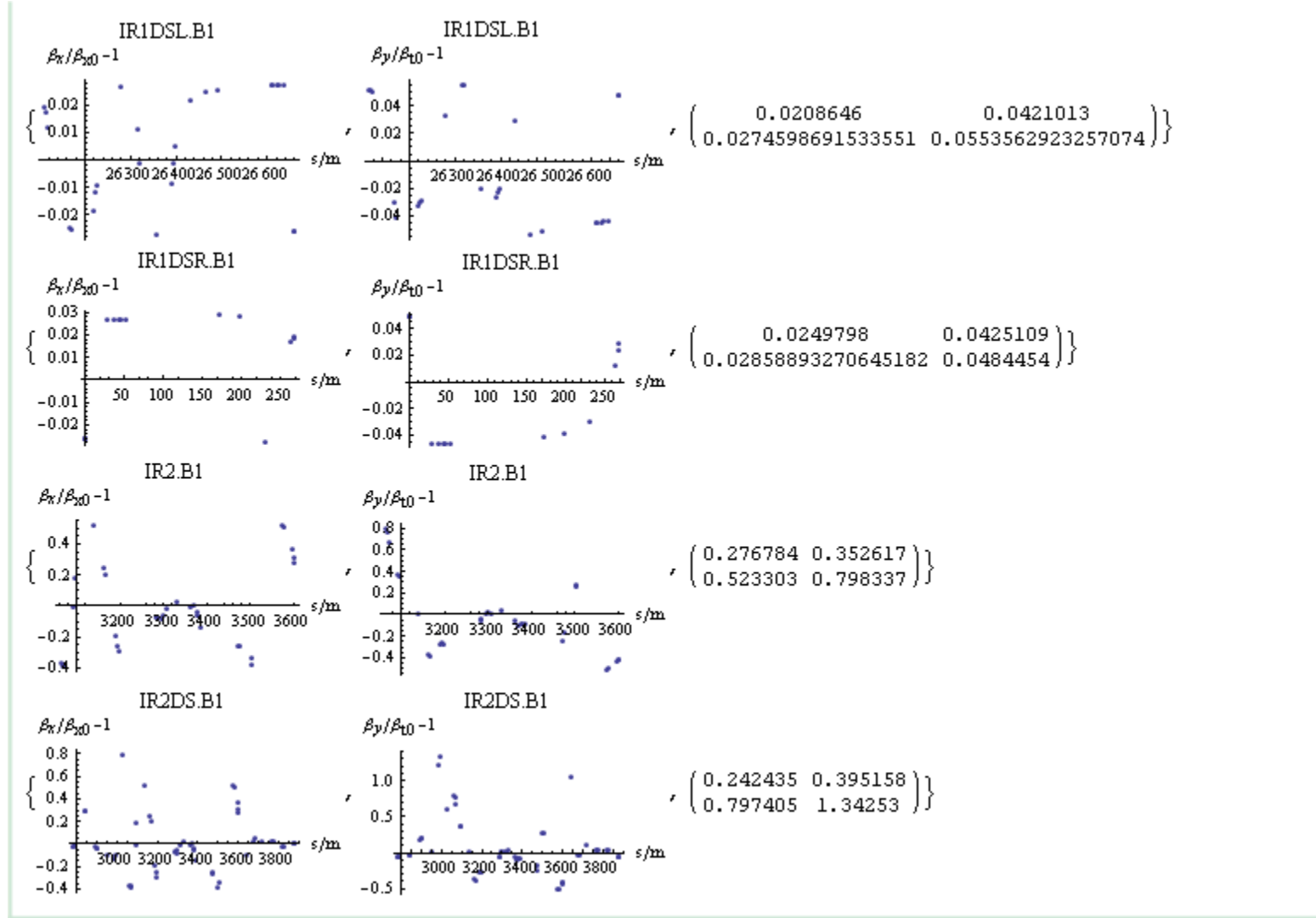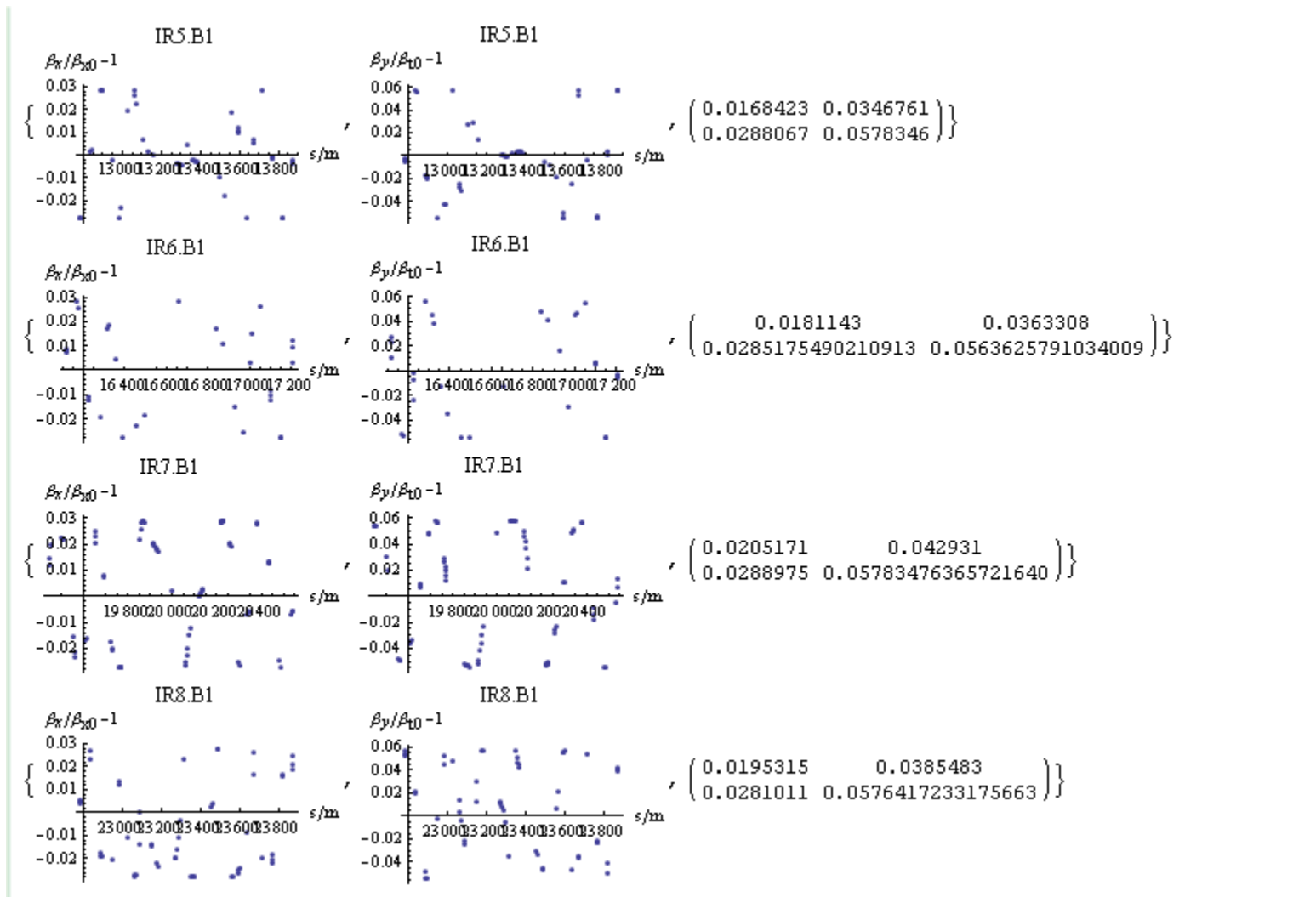# Beta-beating in 4 arcs

# Beta-beating in 4 more arcs

# Beta-beating in some LSS

# Beta-beating in more LSS

# Summary

- Tried many things …
- Latest approach seems to produce an acceptable squeeze for IR2
- One extra step (wrt short-circuiting pre-squeeze) but smaller variations of quadrupole strengths
- Potentially forms basis of a better full-energy squeeze where squeeze is started in ramp
- Bumps to be matched