Status and plan of Beta-matching in Extraction line

200812

Kiyoshi Kubo

Goal and task members

- Goal is to set correct (designed) Twiss parameters at the exit of EXT (entrance of FF). But,
  - It is not clear how fine the optics should be matched.
- The first beam test in December (we have a half shift) ?
- Members

  K.Kubo, M. Pivi, (M. Woodley ?),,,,,?

Possible procedure of beta matching

1. Measure Twiss parameters around the extraction kicker in Damping Ring. : Measurement of tunes changing quadrupole strengths around the kicker. Probably DR optics should not be changed after low emittance tuning in the ring.
2. Calculate a proper setting of quadrupole magnets in the extraction line and set it.
3. Measure emittance and Twiss parameters in the extraction line.: Multi-wire measurement and/or Q-scan methods.
4. Calculate a proper setting of quadrupole magnets in the extraction line and set it. Changing strength of quadrupole magnets in up stream region is better for checking the result.
5. Perform 3 again to confirm the matching.
6. Iterate 4 and 5 if necessary.

To be carefully considered

- Strength of QM7R (Extracted beam goes through off axis of this magnet.)
  - What is quadrupole field component?
  - Effects of multi-pole components?
- Error of beam size measurement
  - Performance of wire scanners
  - Effects of beam jitter

On QM7R quad field error

- Extracted beam goes through off axis of QM7R
  - Quadrupole component is smaller at off axis.
  - Optics was designed for on axis quad field

Requirement:

- Designed Twiss parameters at the FF entrance
- Zero dispersions in the straight section of EXT
- Cancellation by two-kicker system

If the field is known,

- Correction by changing Damping Ring optics is possible (M.Woodley and M.Pivi)
- Correction by changing quadrupole of upstream part of EXT is also possible (K.Kubo)

But, beam orbit at QM7R is not accurately known. → field strength is not well known.

Non linear field cannot be compensated.

→ This magnet is still a big problem

Simulation of beta-matching

- Preliminary simulations have been performed.
- Use perfect EXT beam Line
- Set initial mismatch
  - At entrance of EXT, set beta and alpha
- Simulate emittance and beam (Twiss) parameter measurement by wire scanners
  - Multi-wire and
  - Quad scan
- Change quads in EXT line for matching at FF entrance and look at
  - B_mag (measure of beta-matching)
  - Beam size at IP (with perfect FF line).

Simulation of multi-wire measurement

- By tracking 40000 macro-particles using SAD
- 5 wires (MW0X ~ MW4X)
- Error of beam size measurement
  - Absolute + relative

$$a_{x(y)} + r_{x(y)}\sigma_{x(y)}$$

$$\text{standard}: \; a_{x(y)} = 1\,\mu\text{m}, \quad r_{x(y)} = 0.03$$

- Dispersion at each wire is set by hand

$$\text{standard}: \eta_x = 10\,\text{mm}, \; \text{error of} \; \eta_x = 3\,\text{mm}$$

$$\eta_y = 3\,\text{mm}, \; \text{error of} \; \eta_y = 1\,\text{mm},$$

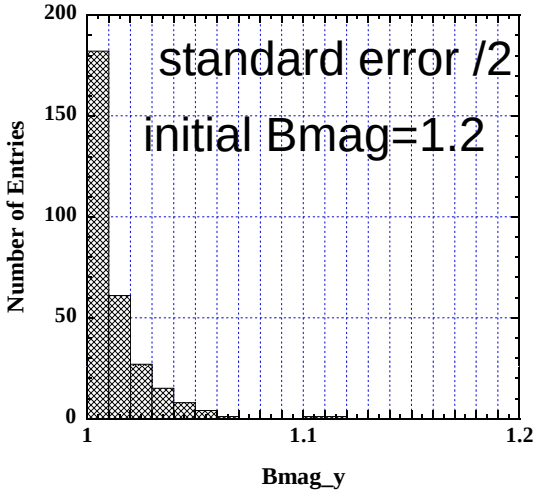
- “Error factor” is multiflied to the each error
- 100 random seeds for errors
- Emittance and Twiss-parameters are fitted.

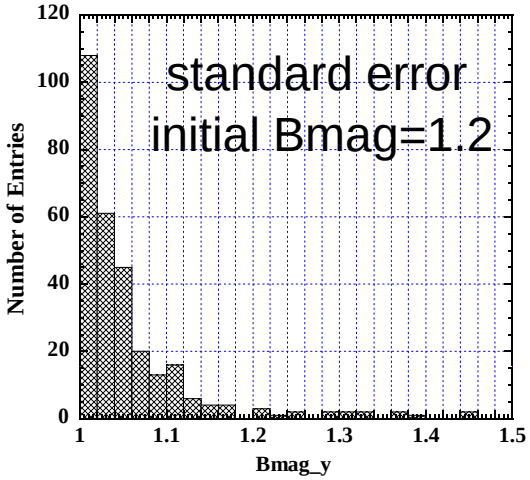
Set Quads for matching

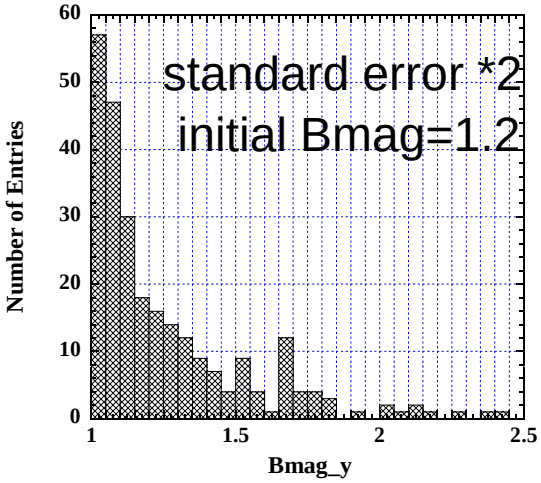
- From fitted beam parameters, calculate strengths of QF9X ~ QD14X for matching at the end of EXT line (entrance of FF line)
- Command “fit” of SAD is used.
- Set calculated strength and perform tracking.

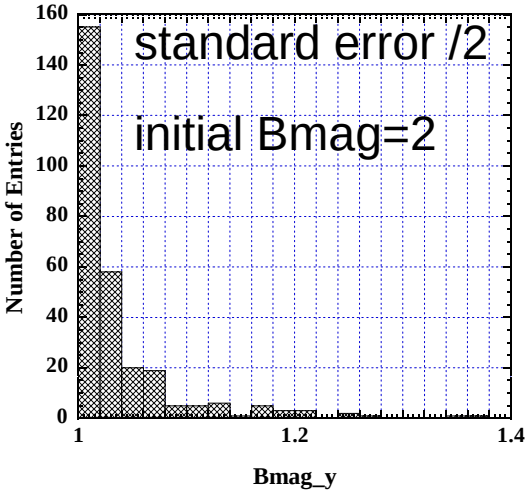
Result of multi-wire simulation

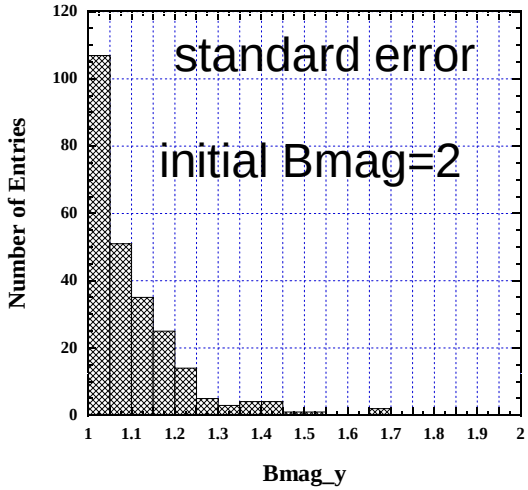
Distribution of Bmag after matching correction





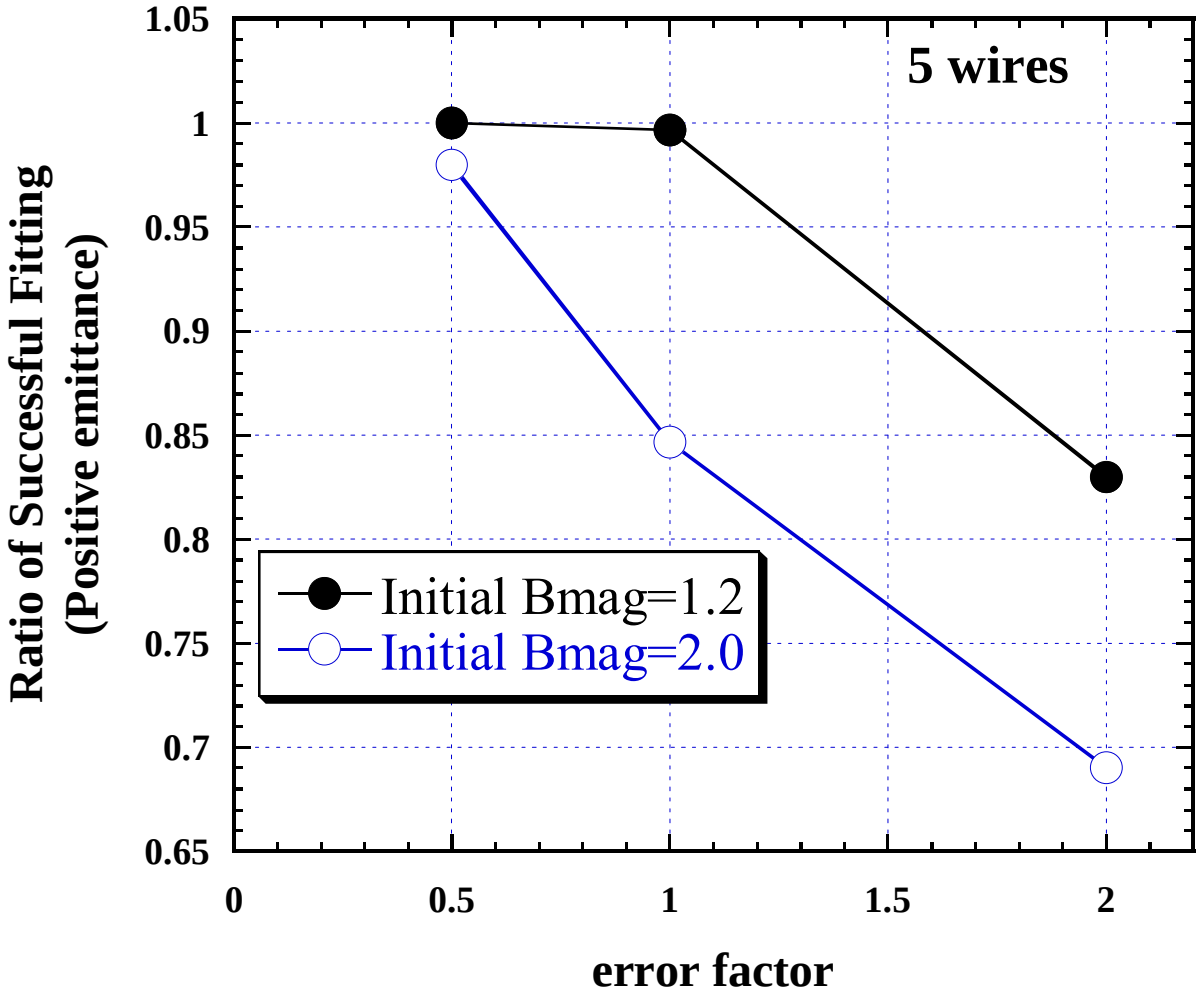




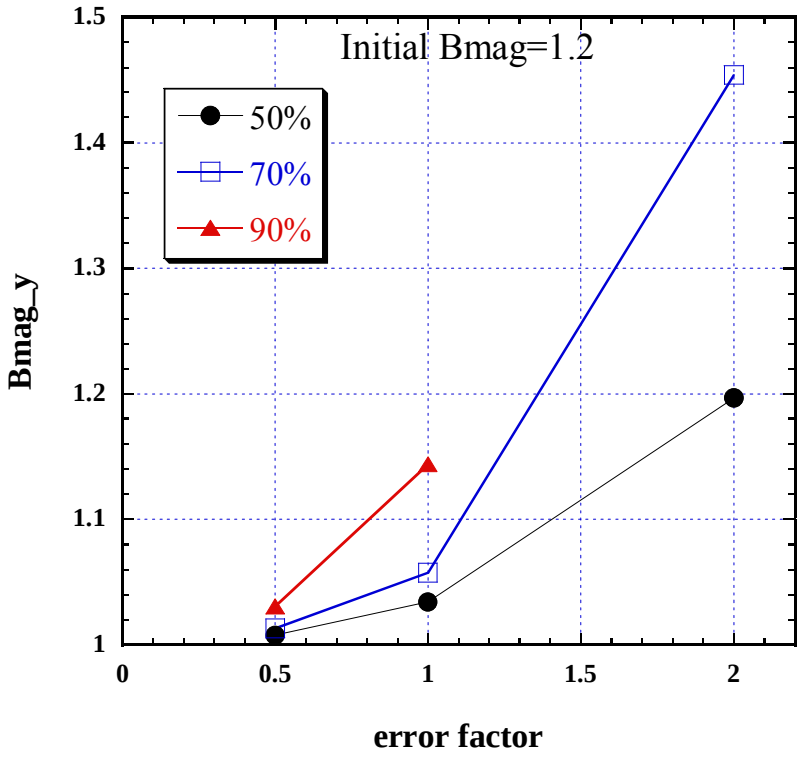


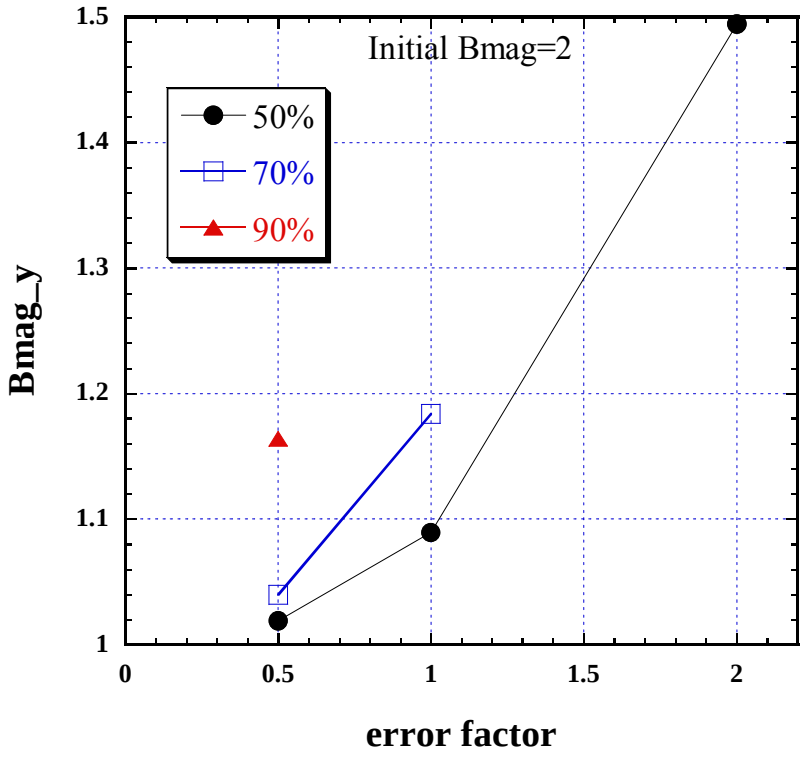
Fitting deos not give
positive emittance
for some random seeds,
in the large error cases.

Ratio of successful fitting



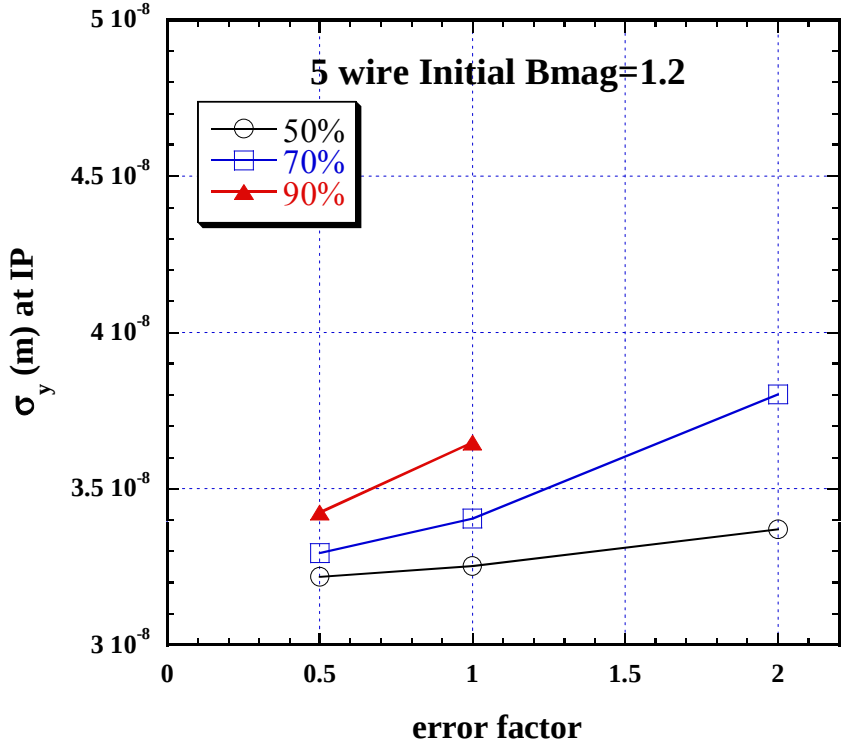
Bmag_y after matching correction (5-wires)

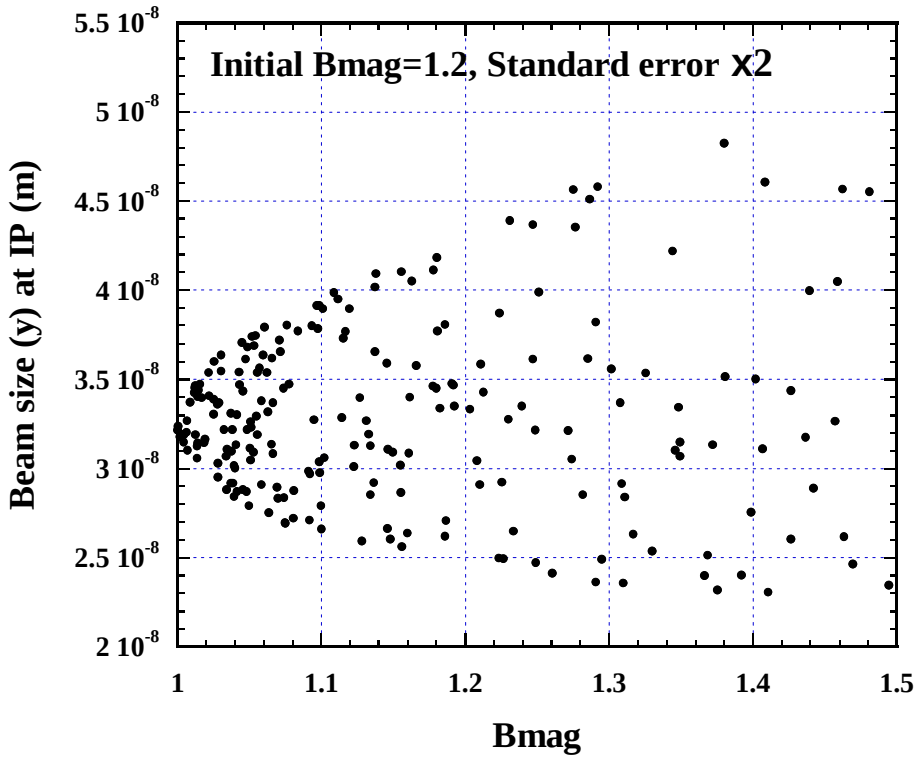




Standard error seems too large. 1/2 seems fine.

Beam size at IP after matching correction (5-wires), Perfect FF line



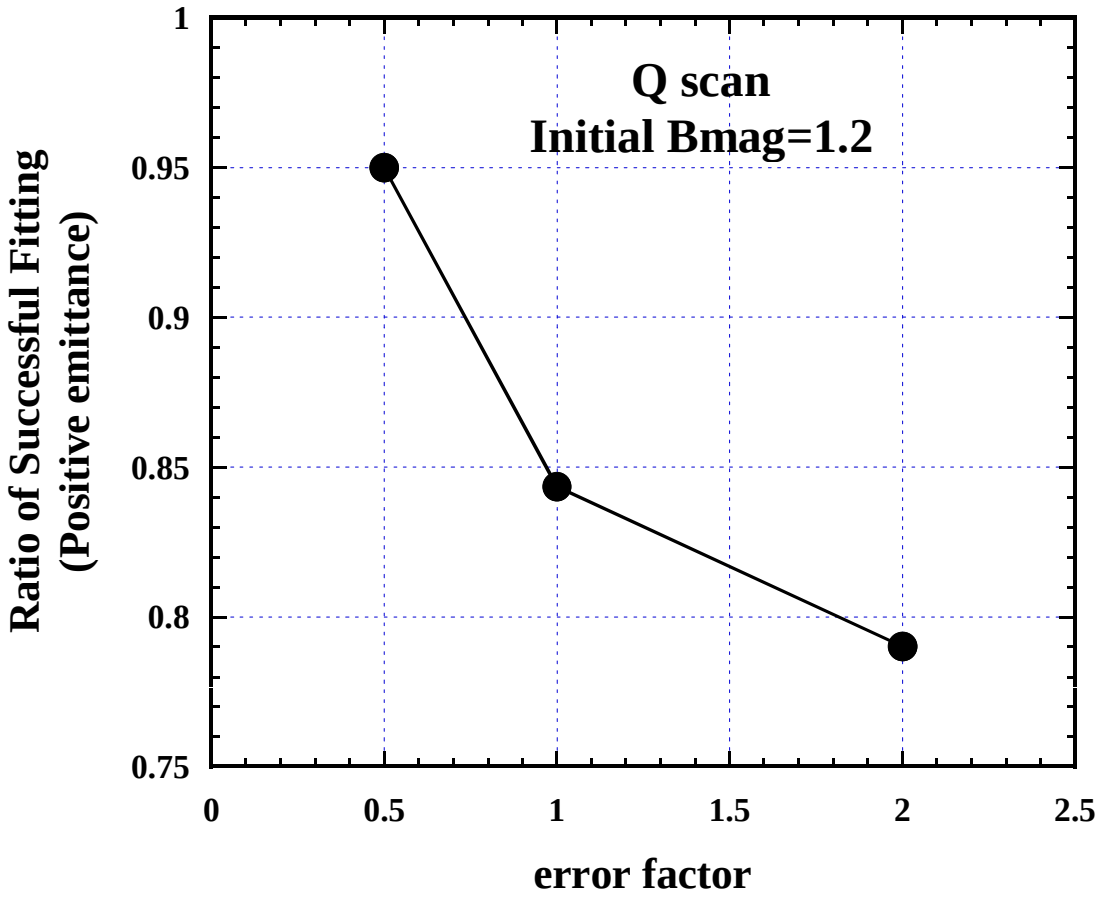


Designed FF line without IP tuning.
Tuning will change the result.
Requirement for beta-matching is not clear.

Simulation of Quad scan measurement

Performance looks similar to multi-wire method (a little worse)

Ratio of successful fitting



Summary of the preliminary simulation

Simulation of beta-matching was performed:

- Multi-wire method (5 wire scanners)
- Quad scan method

- Bema size resolution ~<0.5 micron is desirable
  - For poor resolution, the data cannot be fitted.
- Both methods will be fine for good bema size resolution. But multi-wire method is less sensitive to beam size error.

Accurate beam size measurement is critical for beta matching correction.

More simulations of beta-matching

IF necessary,

- Include “standard” (realistic) errors. Probably we may use the assumption, which Glen White used.
- Realistic error of beam size monitors should be carefully considered.
- Limit of magnet strength, etc. should be taken into account.
- Integrated study
  - Include all basic corrections: orbit, dispersion, (and maybe coupling).
  - Effects to IP beam size with tuning

We will need iterations of simulations and beam test.

For experiment and operation

- Emittance and betafunction measurement tool is exist (old one, modified for new beam line).
  - Wire scanner measurement and fitting. (both multi-wire and q-scan)
- Analysis are done off-line.
  - It seems fine, at least for a moment

SUMMARY

- It is not clear how fine the beta-function should be matched.
  - Look at effect to IP tuning (?)
- Preliminary simulation showed that we need good beam size measurement.
  - ~0.5 micron resolution is desirable, 2 micron is not acceptable.
- First beam test will be performed soon.
  - Iteration of experiment and theory (simulations) will be necessary.

back up

Initial mismatch

- Two cases of B_mag
  - B_mag=1.2 and B_mag=2

$$2B_{mag} = \beta_0\gamma + 2\alpha_0\alpha + \gamma_0\beta$$

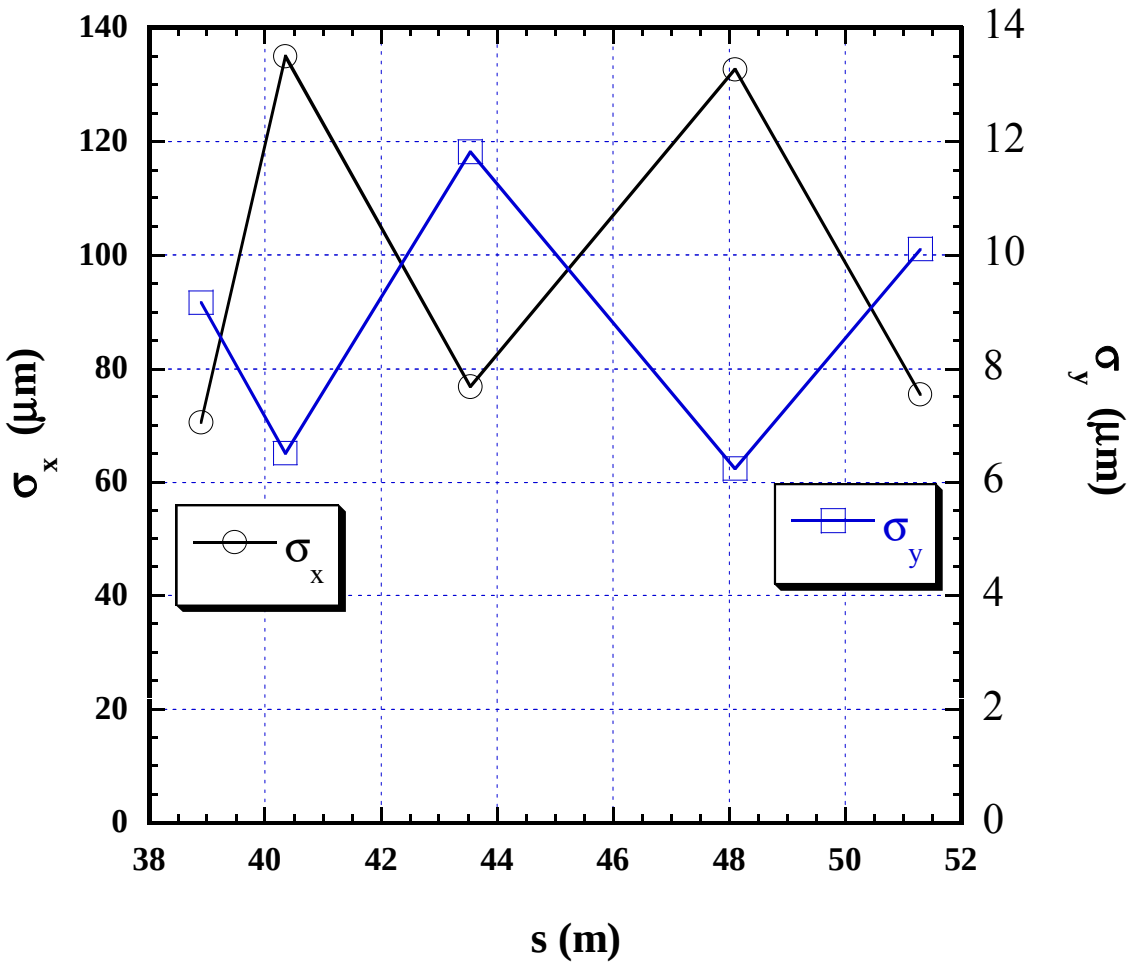
$$= (\beta_0 < x'^2 > +2\alpha_0 < xx' > +\gamma_0 < x^2 >)/\varepsilon$$

  - Three cases for each Bmag

$$\beta = \beta_0, \quad \beta = \beta_0(B_{mag} \pm \sqrt{B_{mag} - 1})$$

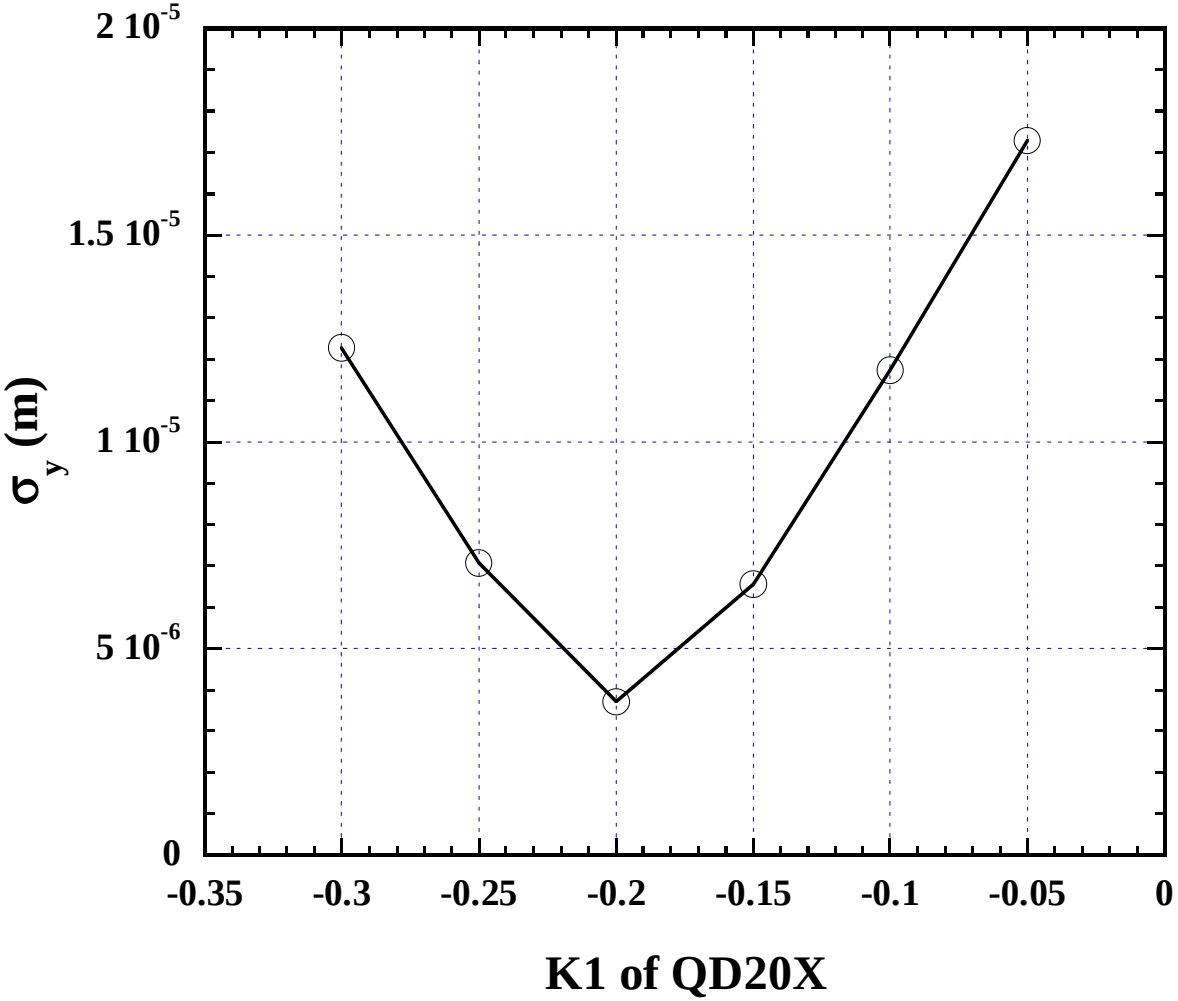
This may not be realistic. (?)

Beam size at wires, no error

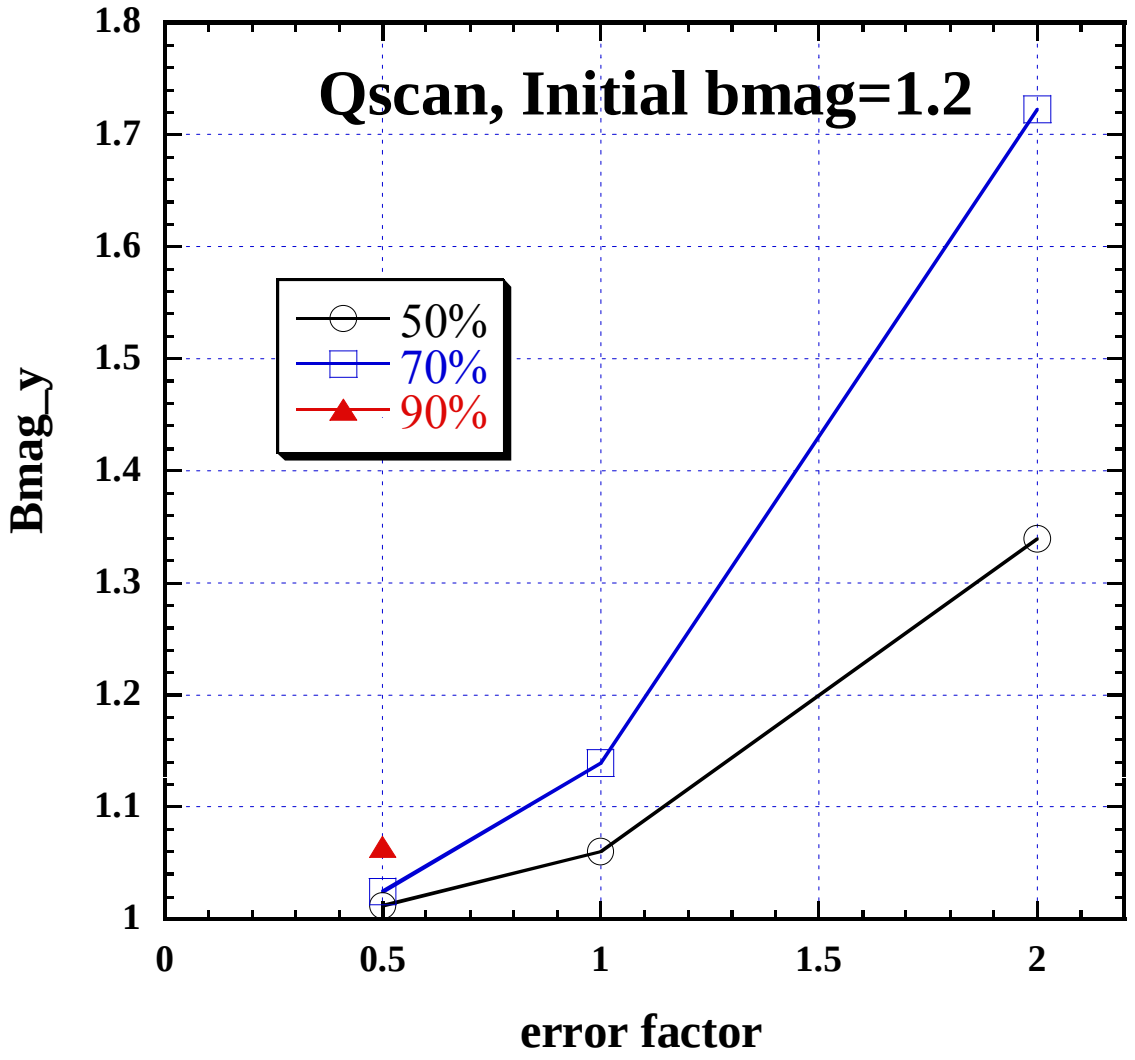


Quad scan measurement

Without errors



Bmag_y after matching correction (Q scan)



Beam size at IP
after matching correction (Q-scan),
Perfect FF line