PAUL SCHERRER INSTITUT

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Status Report
100 keV DC Gun Test Stand

May 17, 2006

What Happened Since the MAC Meeting

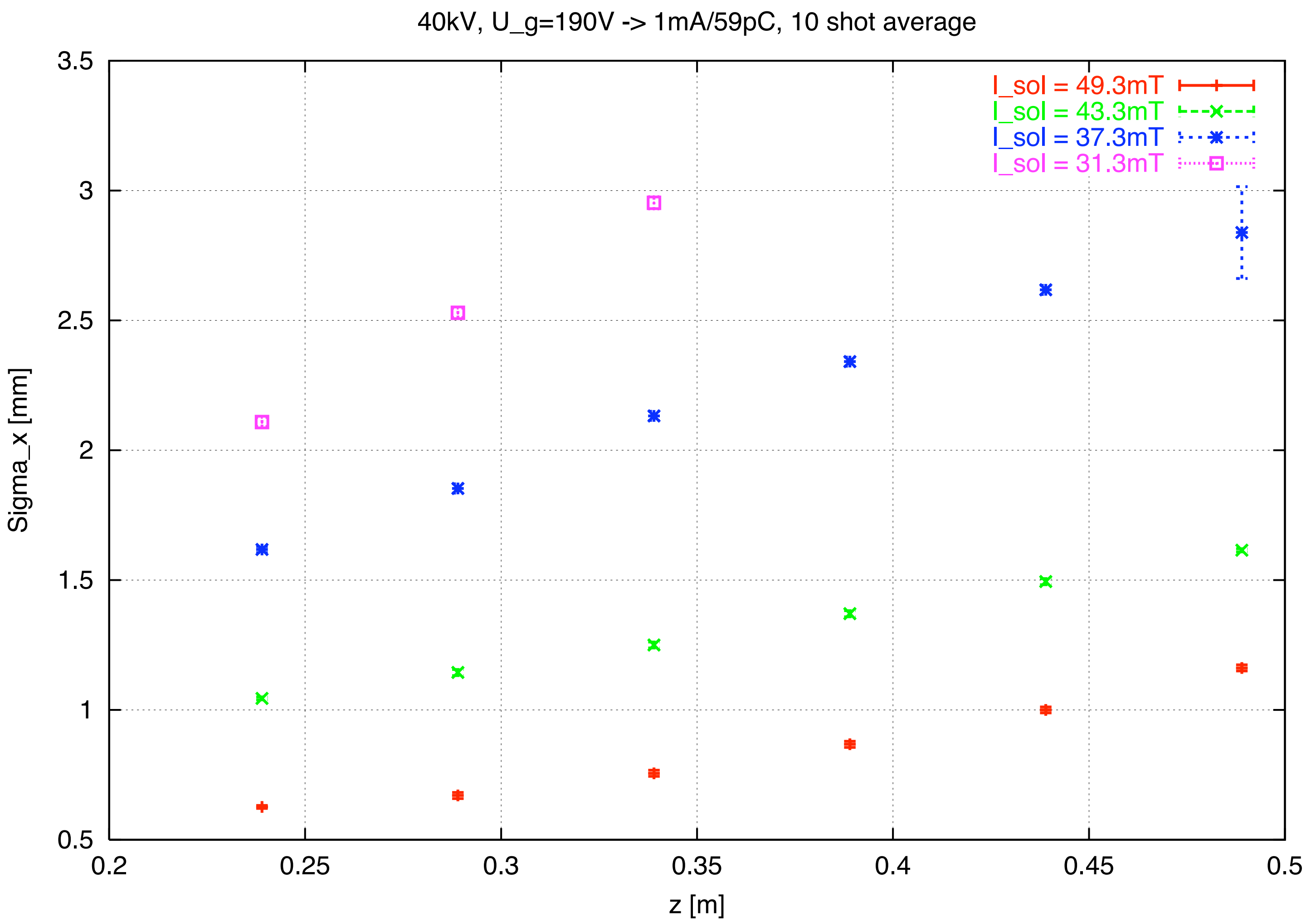
- The short (and miserable) life of SRI-1257C
  - Maximum emission no higher than ~300 μA and ~5 pC
  - Bad pulse shape
  - Lots of discharges from tips to gate → can cause HV breakdown
  - Gradual decrease of ohmic resistance between tips and gate (from > 2 MΩ down to ~ 55 kΩ)
  - Bridged → no emission → R.I.P.
- Inserted new FEA (SRI-1257B)
  - Stable operation possible up to ~2 mA and ~80 pC
  - Decent pulse shape
  - More emission possible by further increasing gate voltage → however, this causes sporadic discharges from tips to gate → avoid such operation due to risk of HV breakdown

What Can Be Measured at Low Intensity

- No transverse single-shot measurements possible (SNR of P43!)
- No obstructive transverse measurements possible (slits, pepper-pot)

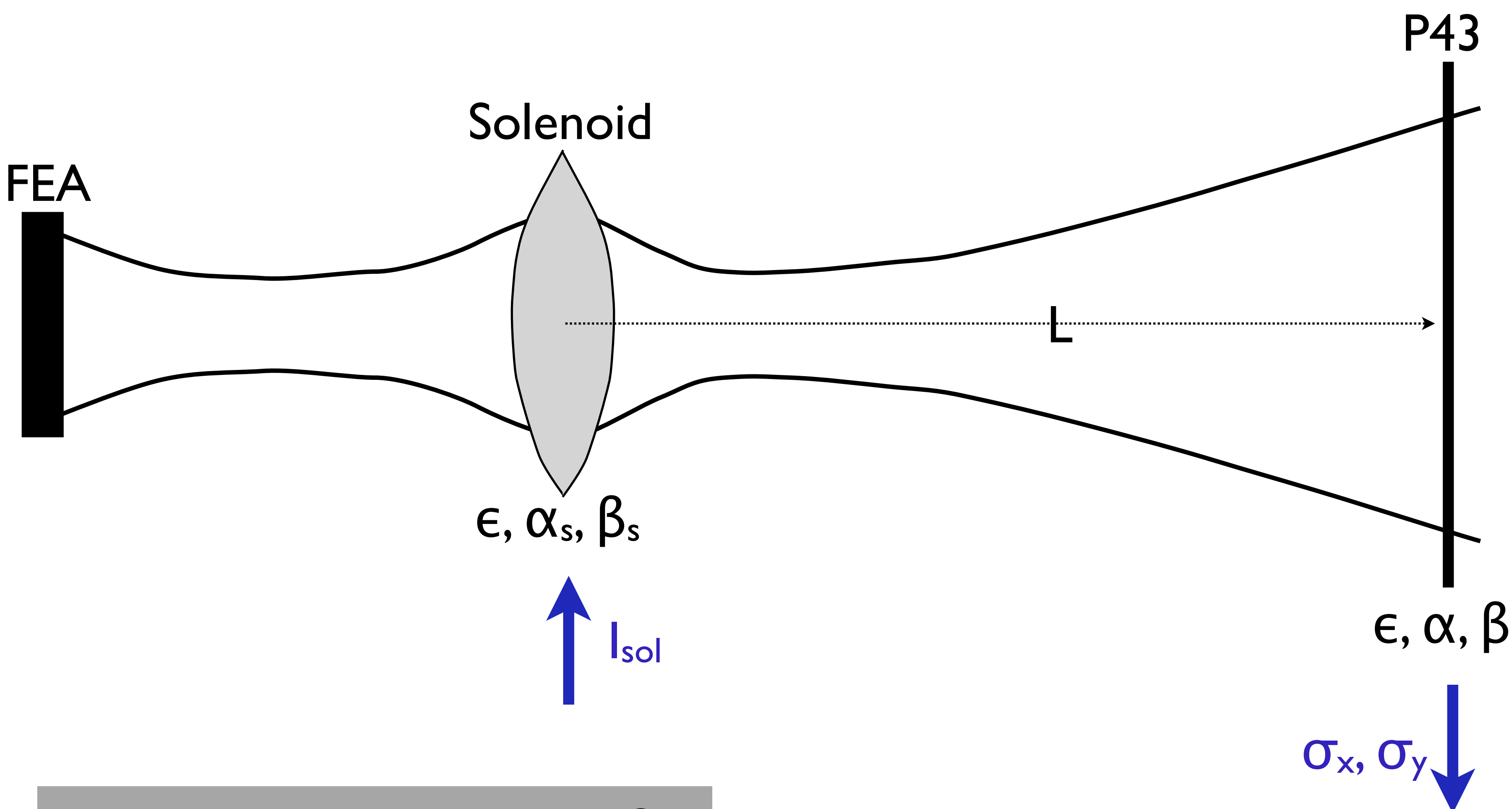
→ Integrate over several shots in order to increase signal level

→ Minimize noise level (no ambient light sources, narrow shutter time)



Emittance Measurement

- Can emittance still be derived without obstructive measurements?
- Yes! Theoretical understanding of solenoid focussing → "Solenoid Scan"



$$\sigma_{x,y}^{(i)} = f(I_{sol}^{(i)}, \epsilon, \alpha_s, \beta_s)$$

Solenoid Scan Measurement Method (I)

- Solenoid is a focussing element and a rotator → if measurement is rotationally symmetric, treat solenoid as pure focussing element in both transverse planes

$$\mathcal{M} = \mathcal{M}_S \, \mathcal{M}_L = \begin{pmatrix} 1 - L \cdot kl & L \\ -kl & 1 \end{pmatrix} \quad \text{where } k = \left(\frac{(\int B ds)/l_{eff}}{2 \, p/e} \right)^2$$

- Use thin lens approximation and calculate transformation of Twiss parameters from transfer matrix

$$\begin{pmatrix} \beta \\ \alpha \\ \gamma \end{pmatrix} = \begin{pmatrix} C^2 & -2CS & S^2 \\ -CC' & CS' + C'S & -SS' \\ C'^2 & -2C'S' & S'^2 \end{pmatrix} \begin{pmatrix} \beta_s \\ \alpha_s \\ \gamma_s \end{pmatrix}$$

$$\sigma^2 = \varepsilon\beta = C^2 \varepsilon\beta_s - 2SC\varepsilon\alpha_s + S^2 \varepsilon\gamma_s$$

Solenoid Scan Measurement Method (2)

- Beam size can be expressed as a function of k

$$
\begin{aligned}
\sigma^2 &= \varepsilon\beta = C^2\varepsilon\beta_s - 2SC\varepsilon\alpha_s + S^2\varepsilon\gamma_s \\
&\vdots \\
&= k^2 \underbrace{\left(L^2 l^2 \varepsilon\beta_s\right)}_{c_2} + k \underbrace{\left(2L^2 l\varepsilon\alpha_s - 2Ll\varepsilon\beta_s\right)}_{c_1} + \underbrace{\left(\varepsilon\beta_s - 2L\varepsilon\alpha_s + L^2\varepsilon\gamma_s\right)}_{c_0}
\end{aligned}
$$

- Parabolic fit for $\sigma^2(k)$ → c_i → Twiss parameters

$$
\begin{aligned}
\varepsilon^2 &= \frac{c_0 c_2 - c_1^2/4}{L^4 l} \\
\beta_s &= \frac{1}{\varepsilon}\frac{c_2}{L^2 l^2} \\
\alpha_s &= \frac{1}{\varepsilon}\left(\frac{c_1}{2L^2 l} + \frac{c_2}{L^3 l^2}\right) \\
\gamma_s &= \frac{1}{\varepsilon}\left(\frac{c_0}{L^2} + \frac{c_1}{L^3 l} + \frac{c_2}{L^4 l^2}\right)
\end{aligned}
$$

Solenoid Scan Measurement Method (3)

- Derive source properties by backtracking from solenoid through drift space

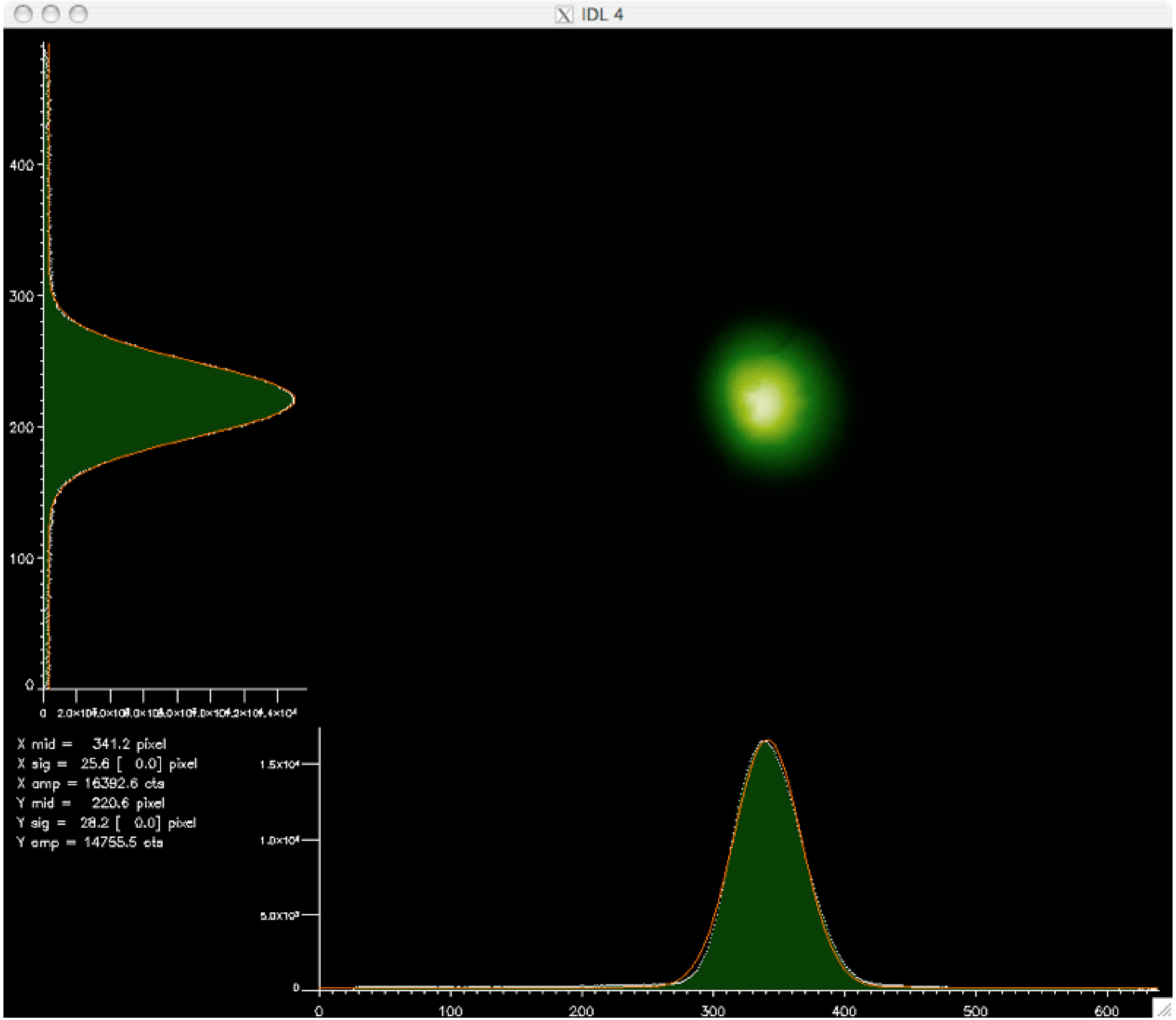
$$\beta = \frac{1}{\gamma} = \frac{1}{\gamma_s}$$

$$\sigma = \sqrt{\varepsilon\beta} = \sqrt{\frac{\varepsilon}{\gamma_s}}$$

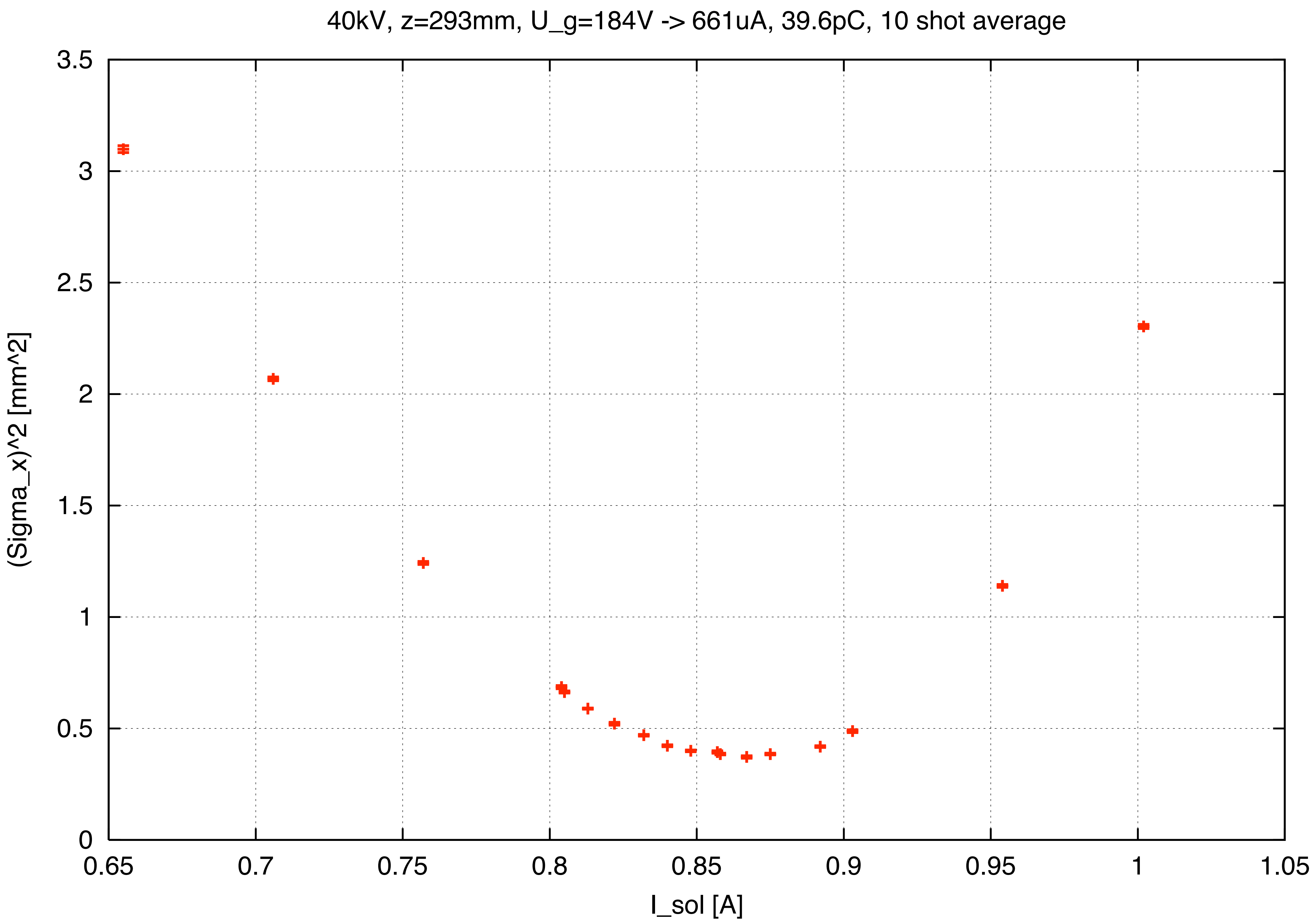
$$\Delta s = \frac{-\alpha_s}{\gamma_s}$$

- Implemented application *SOLSCAN* that takes raw measurement data, transforms I_{sol} to k values, plots measurement data, fits the parabola, calculates the optical parameters and outputs them together with the phase space ellipse

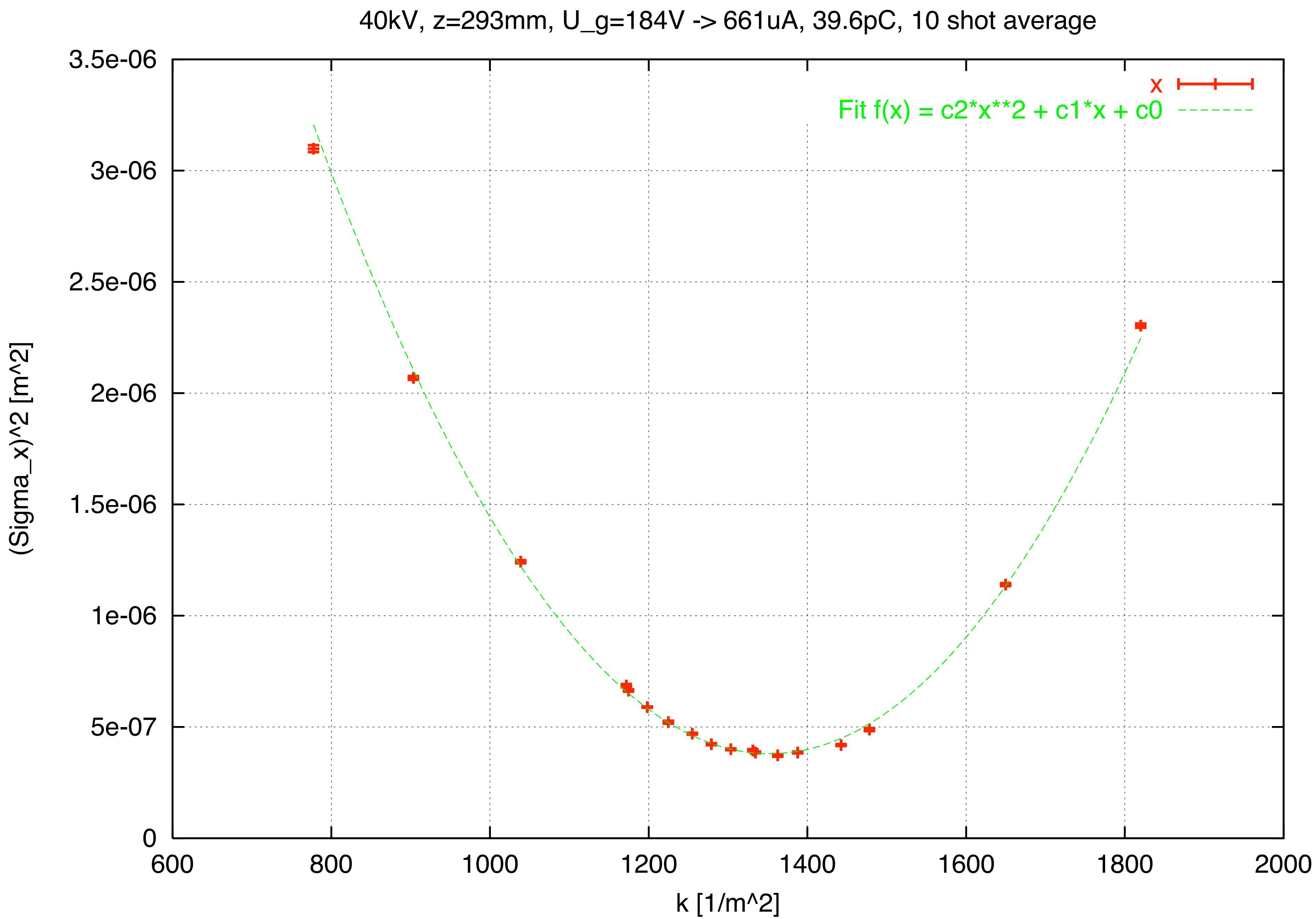
Example Solenoid Scan Measurement (1)



Example Solenoid Scan Measurement (2)

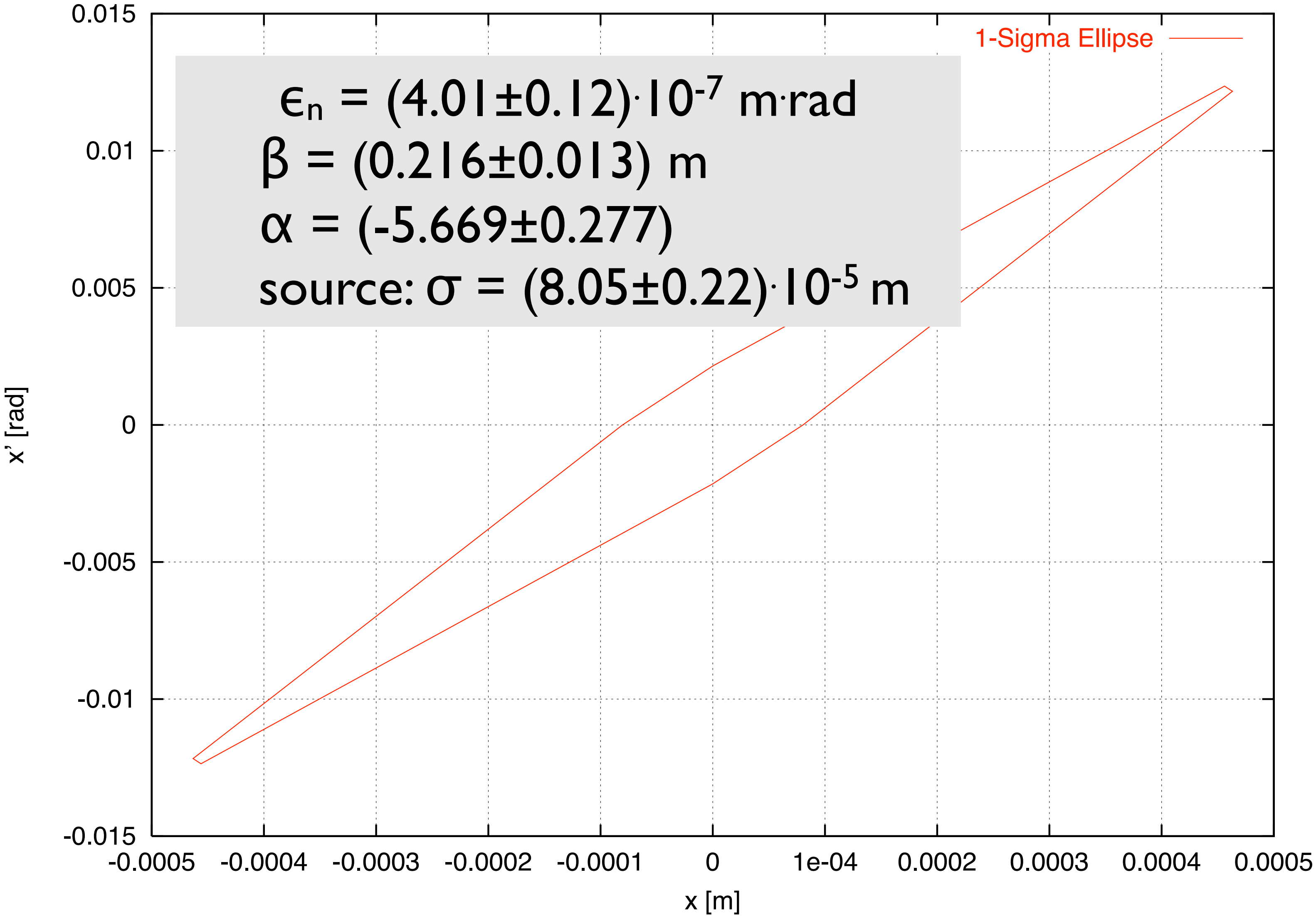


Example Solenoid Scan Measurement (3)

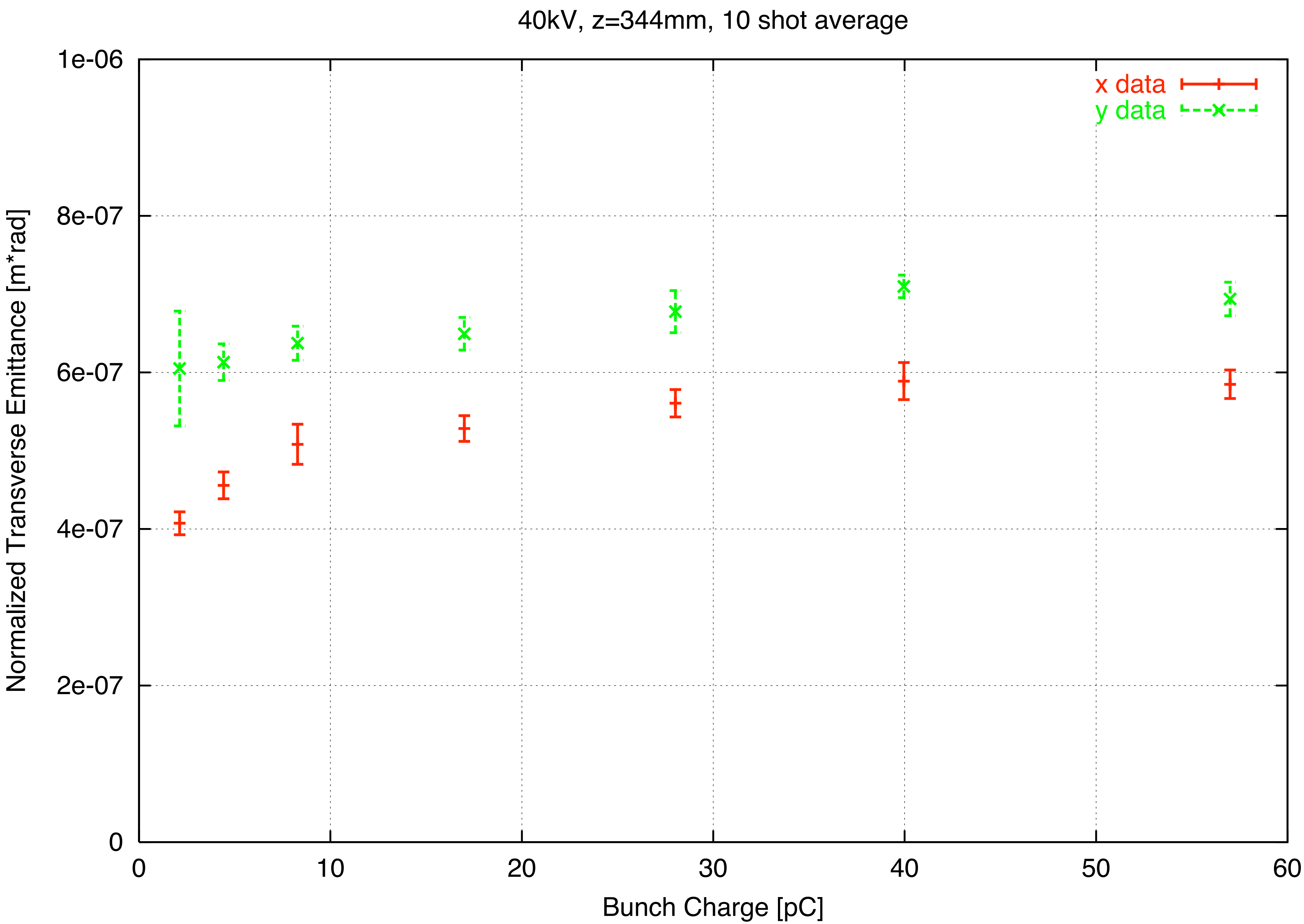


Example Solenoid Scan Measurement (5)

```
[pc5202 SRI-1257B]
[bash SLSBASE=/prod]$ solscan.sh

c2 =  8.5519e-12
d_c2 =  9.5410e-14
c1 =  -2.3135e-08
d_c1 =  2.5590e-10
c0 =  1.6026e-05
d_c0 =  1.7160e-07
c01 = -0.99400
c12 = -0.99300
c02 = 0.97400

d2 =  1.2004e-11
d_d2 =  1.5700e-13
d1 =  -3.1769e-08
d_d1 =  4.2390e-10
d0 =  2.1397e-05
d_d0 =  2.8500e-07
d01 = -0.99800
d12 = -0.99700
d02 = 0.99100

Eacc = 40000
L = 0.28700
d_L = 0.0030000
l = 0.022000
d_l = 0.00050000

*** from x data ***
eps =  9.9421e-07
d_eps =  3.0755e-08
_rel = 0.030934
epsn =  4.0100e-07
d_epsn =  1.2405e-08
_rel = 0.030934
epsbeta =  2.1451e-07
d_epsbeta =  1.0996e-08
_rel = 0.051261
epsalpha =  -5.6361e-06
d_epsalpha =  2.1301e-07
_rel = 0.037794
epsgamma = 0.00015269
d_epsgamma =  4.9115e-06
_rel = 0.032167
beta = 0.21576
d_beta = 0.012918
_rel = 0.059871
alpha = -5.6689
d_alpha = 0.27686
_rel = 0.048839
gamma = 153.58
d_gamma = 6.8538
_rel = 0.044627
beta0 = 0.0065113
d_beta0 = 0.00029058
_rel = 0.044627
sigma0 =  8.0459e-05
d_sigma0 =  2.1845e-06
_rel = 0.027150
s0 = 0.036912
d_s0 = 0.0024420
_rel = 0.066158
```



Application: Emittance vs. Bunch Charge



Outlook

- Non-linear fit, thick lens evaluation of measurement data
  → Improve emittance measurement
  → Verify if current results are correct (thin lens approximation!)

- Obstructive measurements (slits, pepper-pot) with max. beam intensity
  (or with a different FEA type which emits a decent amount of charge!)
  → Improve emittance measurement
  → Reconstruction of phase space density, not just Twiss parameters
  → Single-shot measurement
  → Measure emittance at any solenoid setting

- Compare/benchmark these different measurement techniques

- Try to calibrate MAFIA model to experimental data