Non-local solenoid compensation, vertical emittance, beam-beam, polarization

K. Oide (UNIGE/CERN/KEK)

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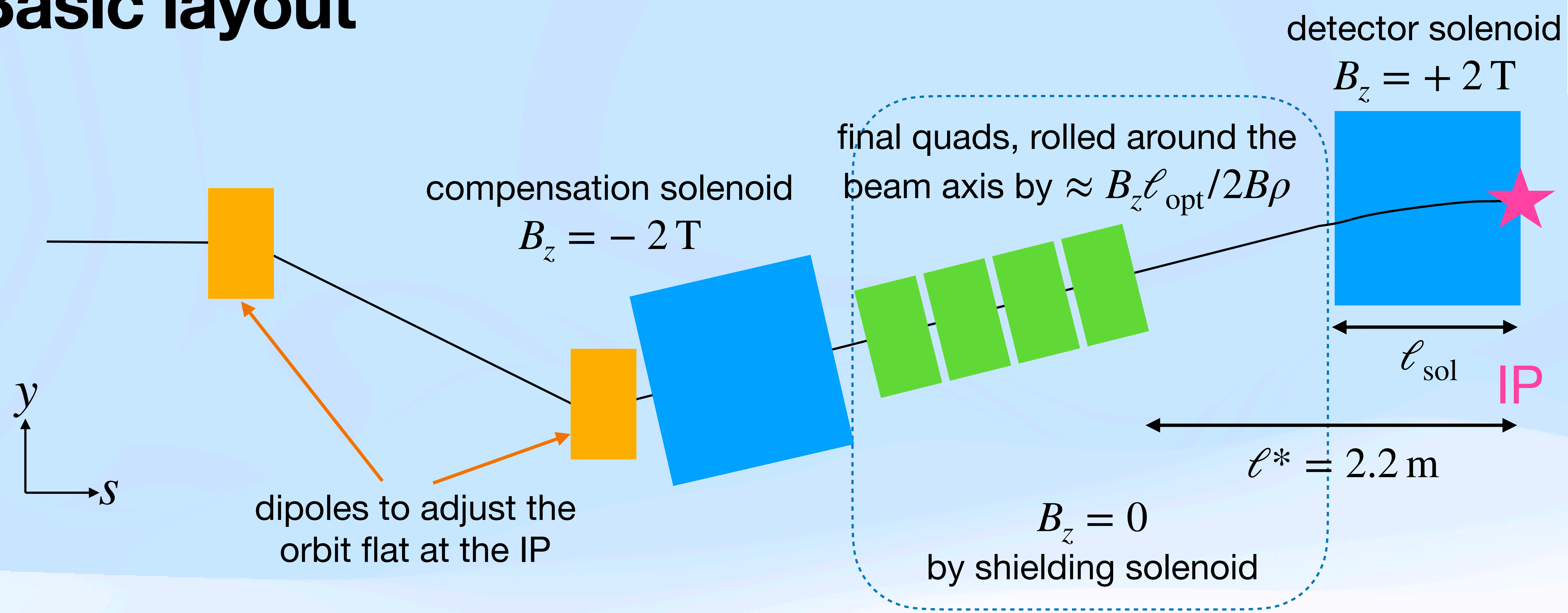
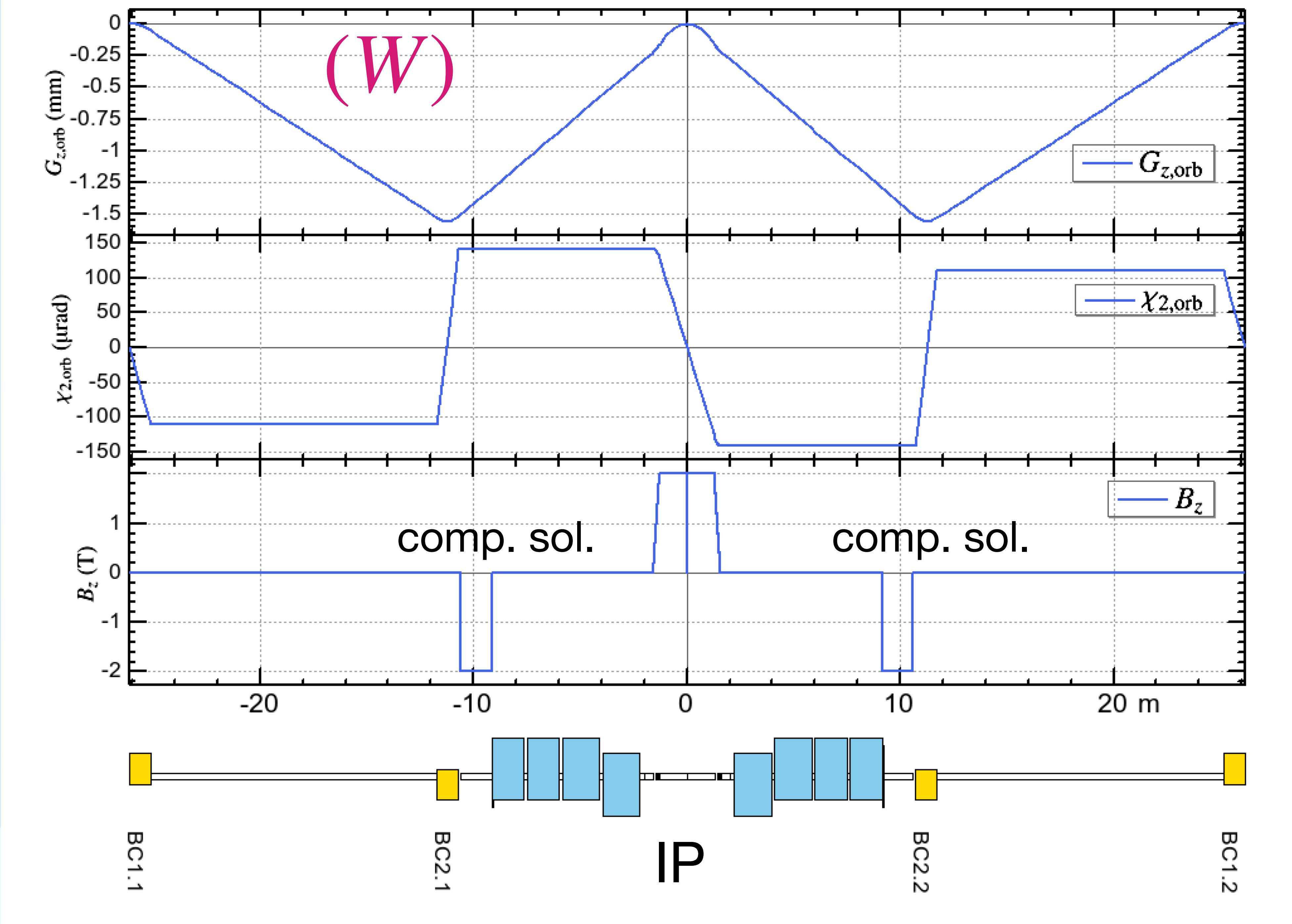
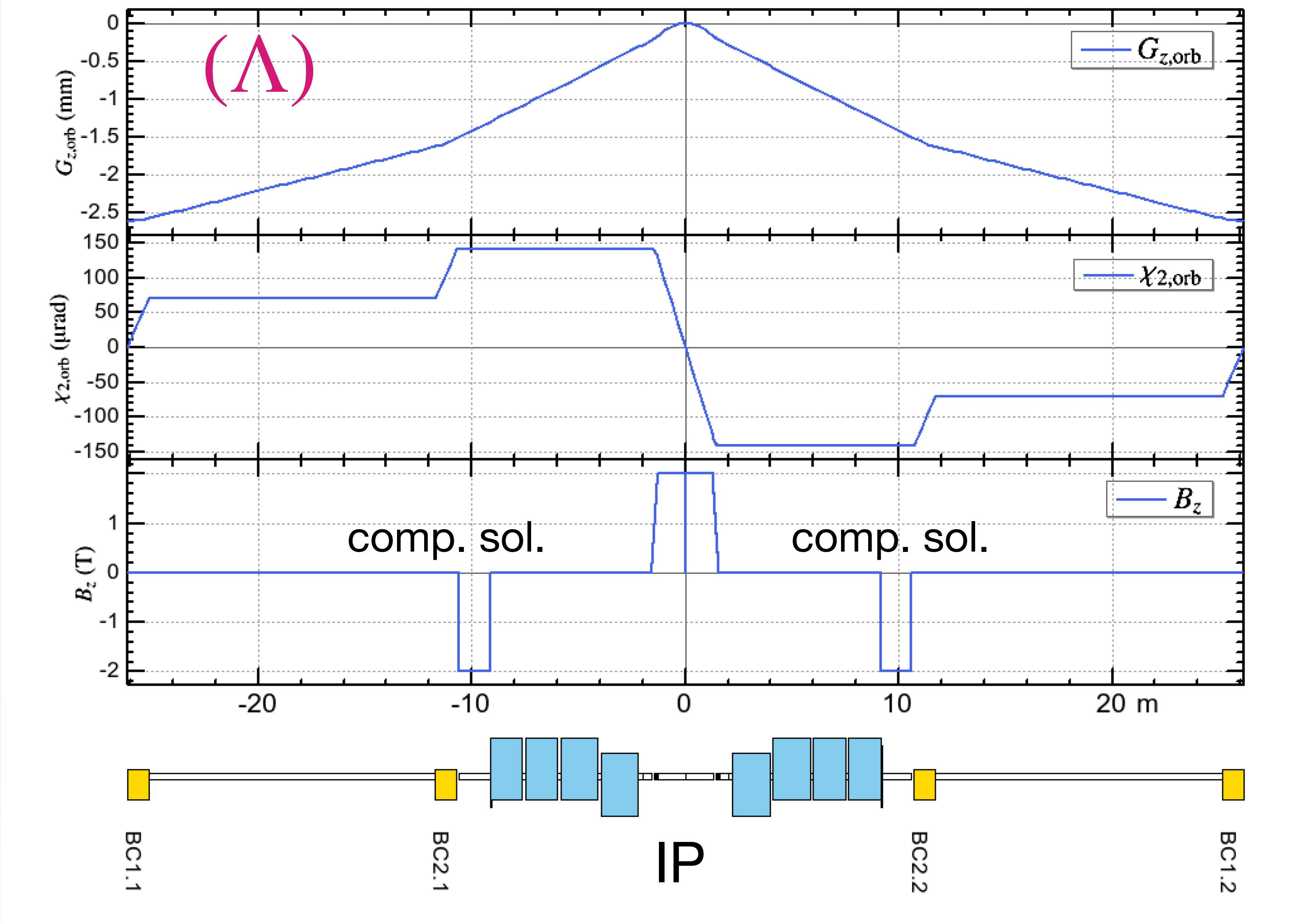
Basic layout

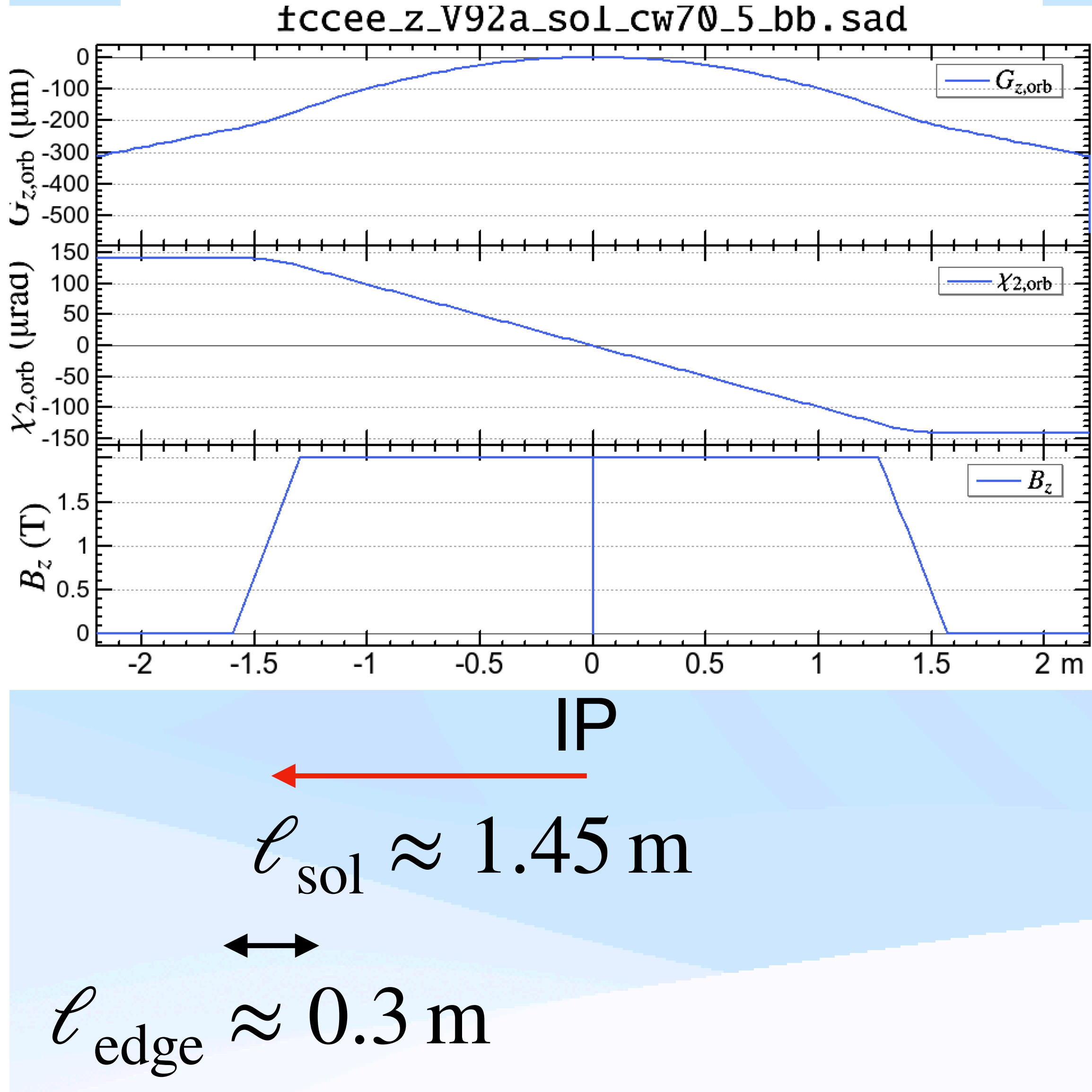


- The orbit is bent vertically by the detector solenoid.
- The final quads followed by the compensation solenoid are aligned along the beam axis.
    - This prevents additional orbit/dispersion deviation.
- Right after the detector solenoid region, the solenoid filed is completely shielded by the shielding solenoid, up to ℓ_{sol} from the IP.
    - The final quads sit in the field-free region.
- The vertical bend angle is corrected outside the compensation solenoid by two dipoles/side.

Basic layout: two types of the vertical bump





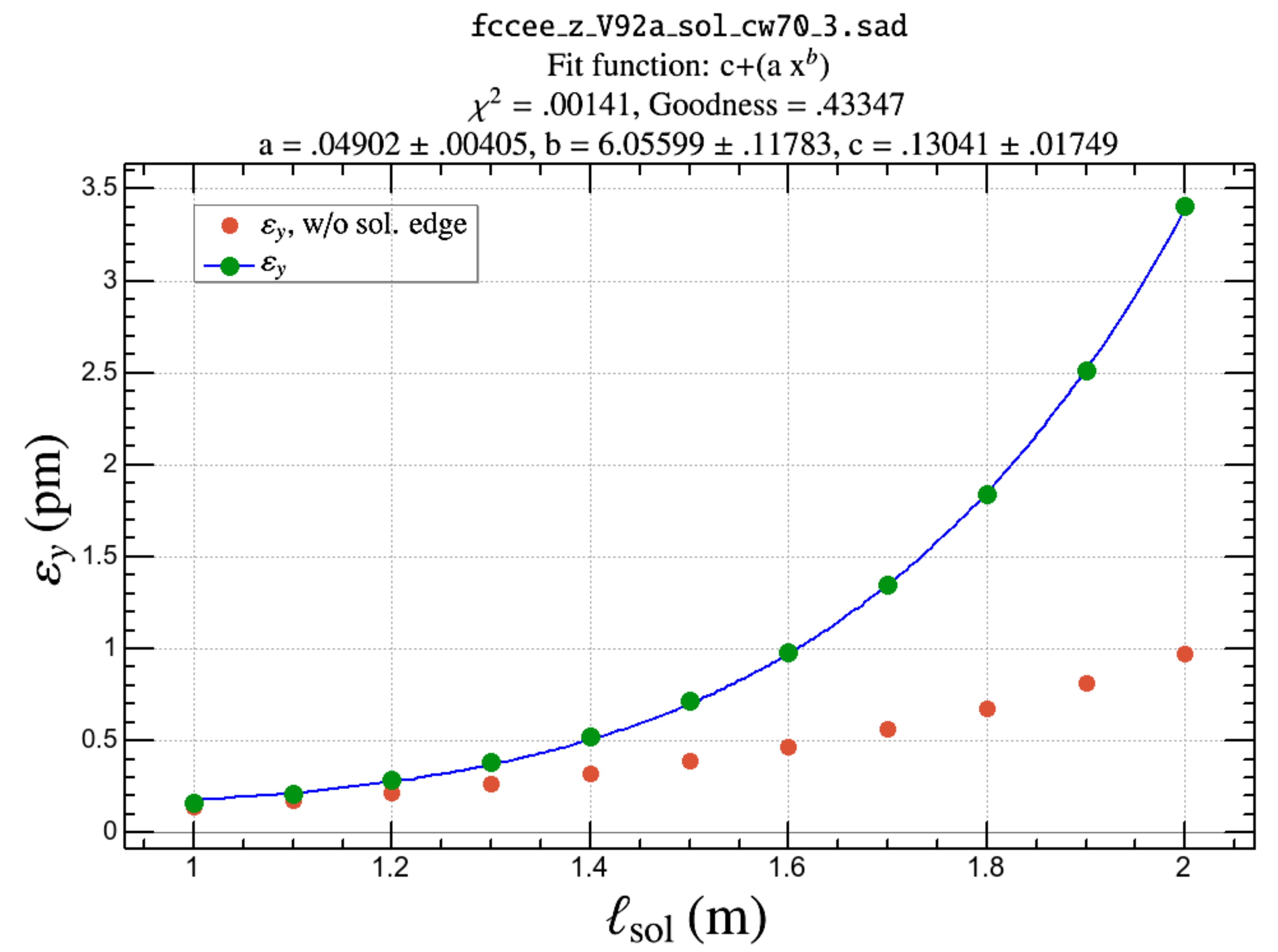


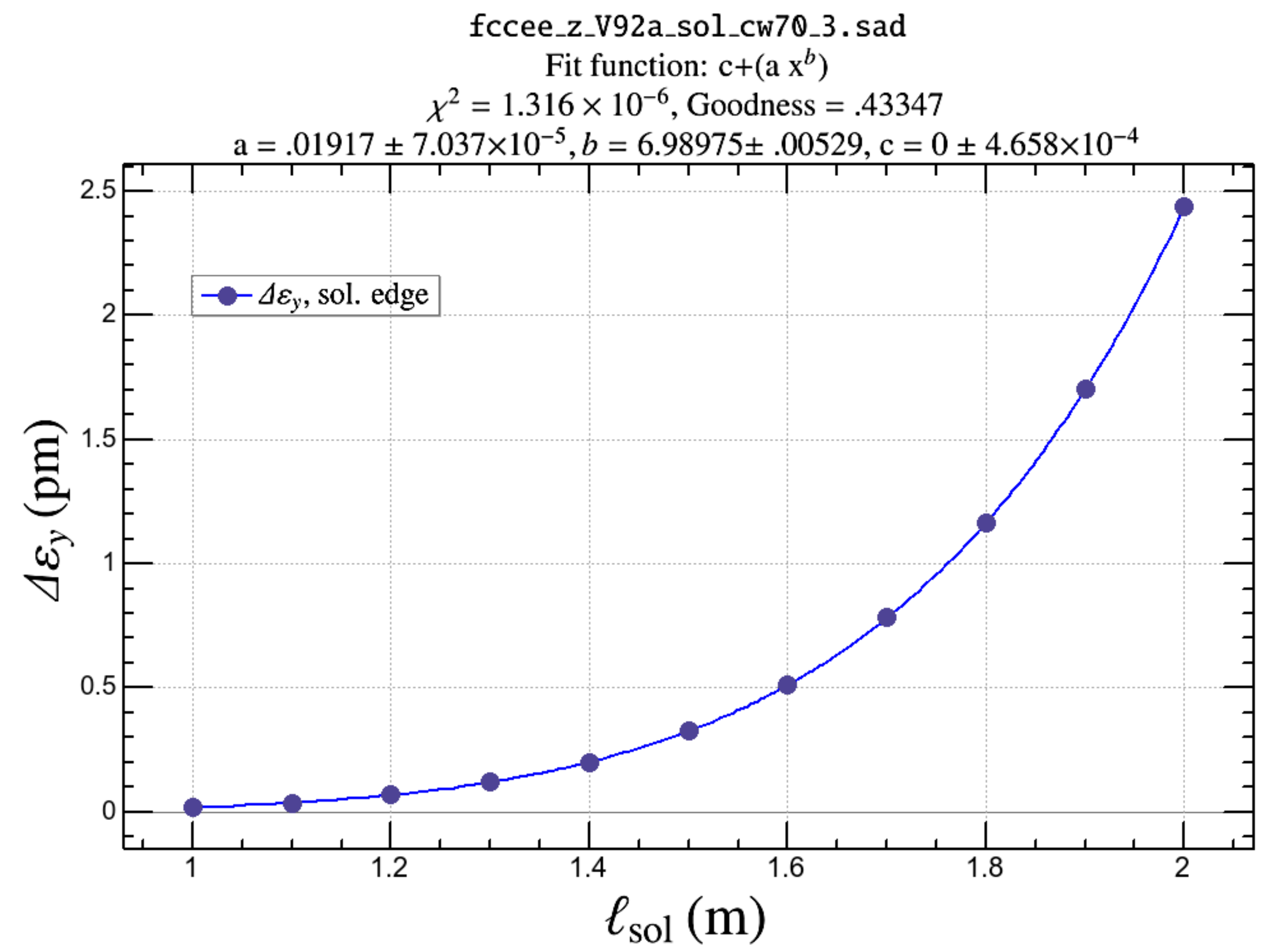
$\ell_{\text{sol}} = 1.45\,\text{m}$

- Two types of the vertical bump orbits have been tried:
  - Type W (left): the IP is on the same plane as the arc.
  - Type Λ (right): the IP has a vertical offset relative to the arc. In the case of $\ell_{\text{sol}} = 1.45\,\text{m}$, about 2.6 mm higher.
- Different vert. emittances and beam-beam performance.
  - The type W has better beam-beam blowup & lifetime.

Type	W		Λ	
ℓ_{sol}(m)	**1.0**	**1.45**	**1.45**	**1.7**
ℓ_{edge} (m)	0.1	0.3	0.3	0.6
ε_y (pm)	0.16	0.36	0.22	0.28
$\varepsilon_{y,\text{BB}}$ (pm)	1.4	1.4	2.2	2.4
τ (s)	16000	16000	550	550
$p(\%)$	-	0.99±0.05	-	0.43±0.03

Vertical emittance (type W)

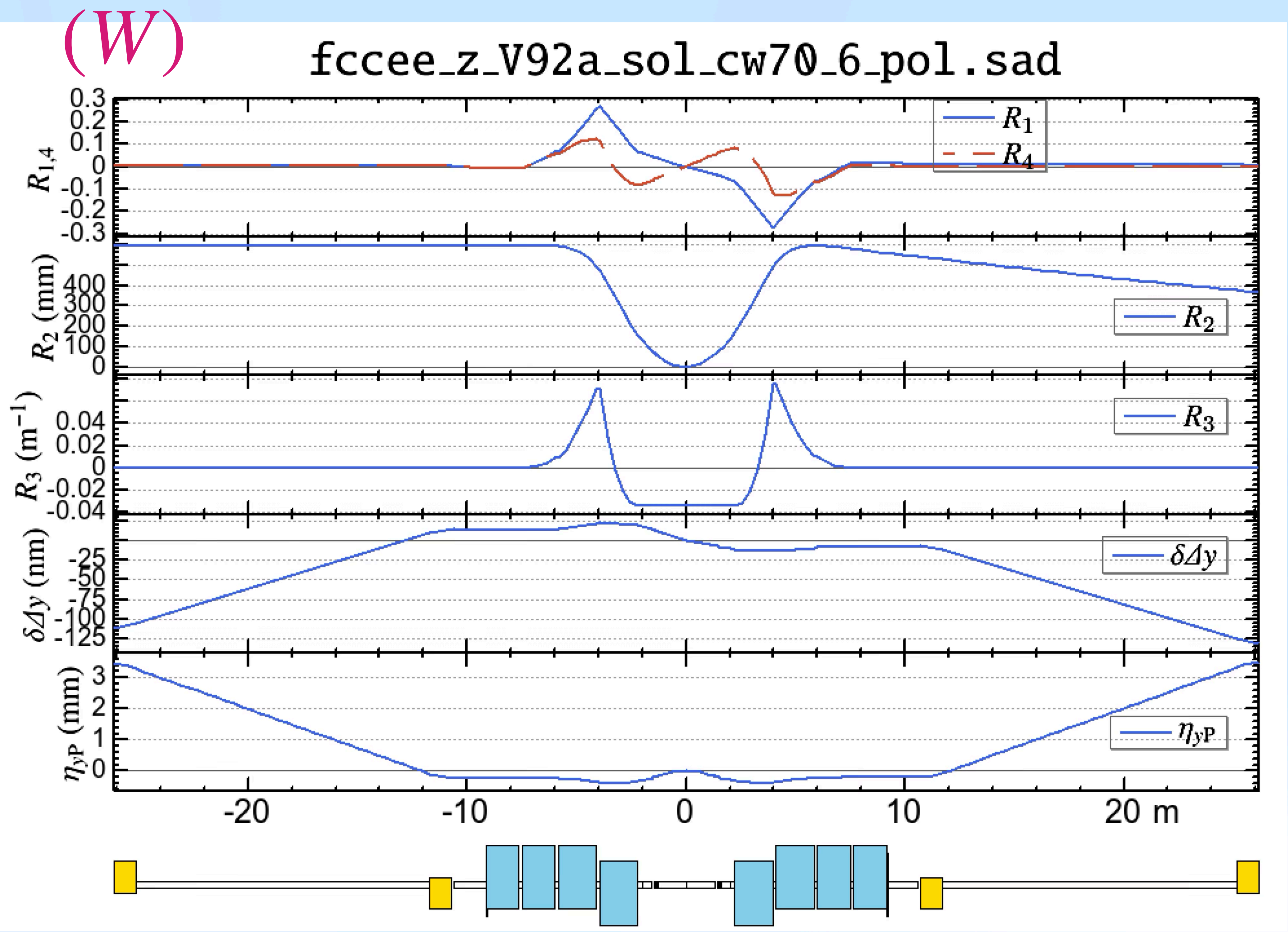


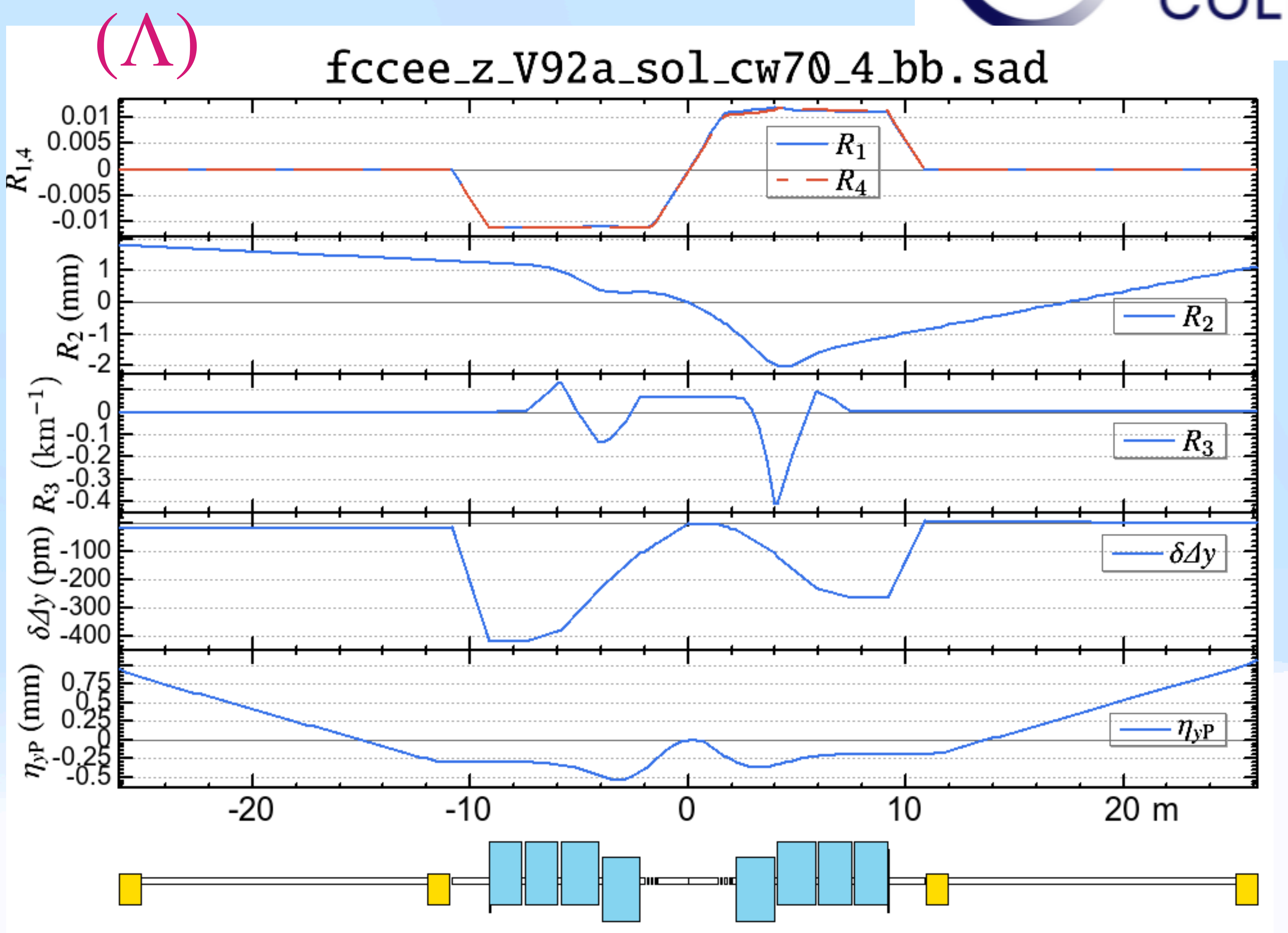


- The generated vertical emittance of this scheme is plotted as a function of ℓ_{sol} .
- The total (green dots, left) has a strong dependence on ℓ_{sol} , showing the 6th power of ℓ_{sol}.
- The red dots on the left plot shows the emittance without the solenoid edge.
  - The solenoid edge has the major contribution.

- The emittance from the solenoid edge, plotted on the right, shows the 7th power of ℓ_{sol} .
  - This is due to the dependence $\Delta\varepsilon_y \propto \beta_y \eta_y'^2 / \rho^3 \propto \ell_{sol}^7$.
  - **This emittance from the edge is optics-independent; $\Delta\varepsilon_y$ does not depend on the optics outside $\pm\ell_{sol}$.**
- Here the length of the fringe of the edge is assumed 10 cm.

X-y coupling and vertical dispersion (type Λ)



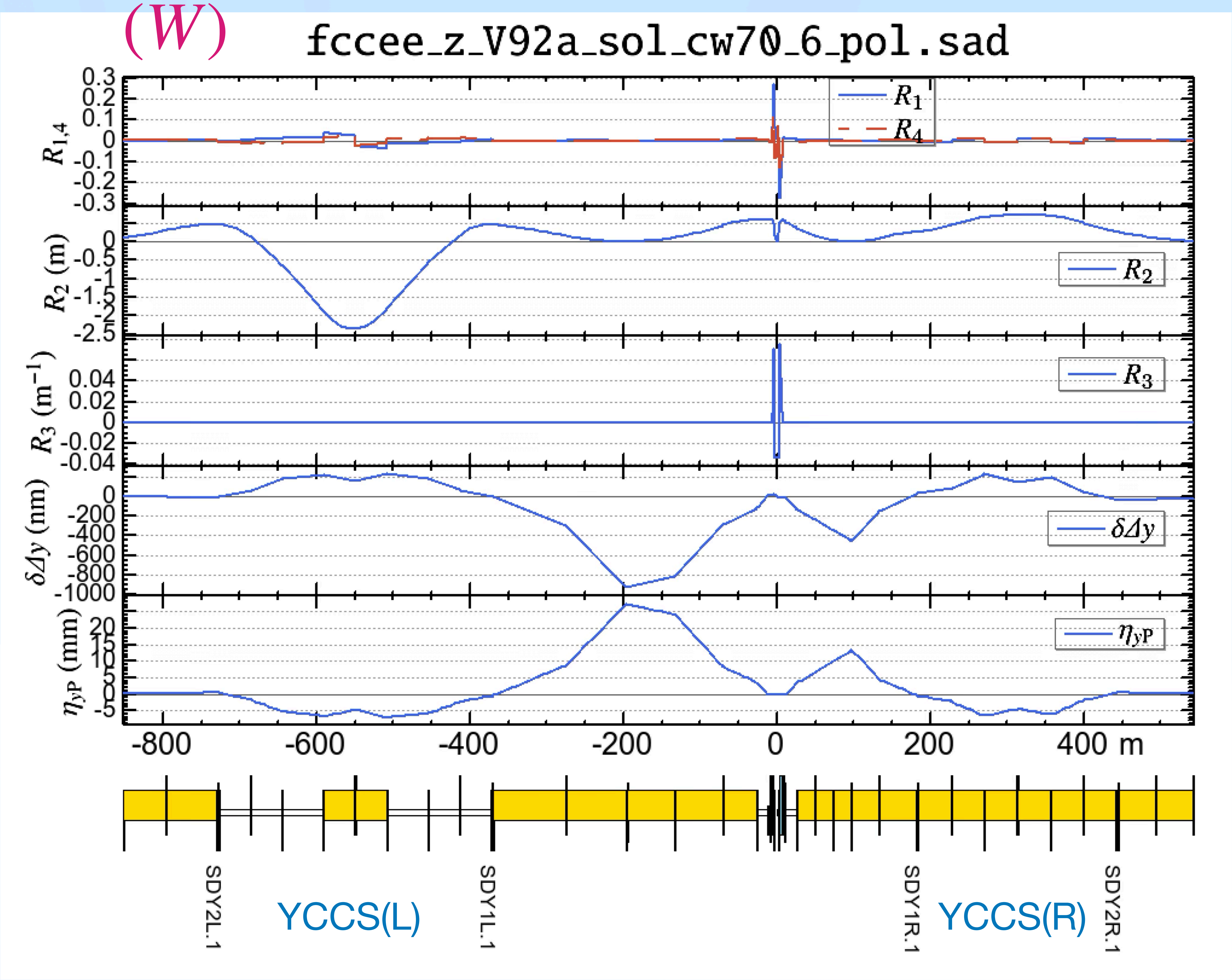


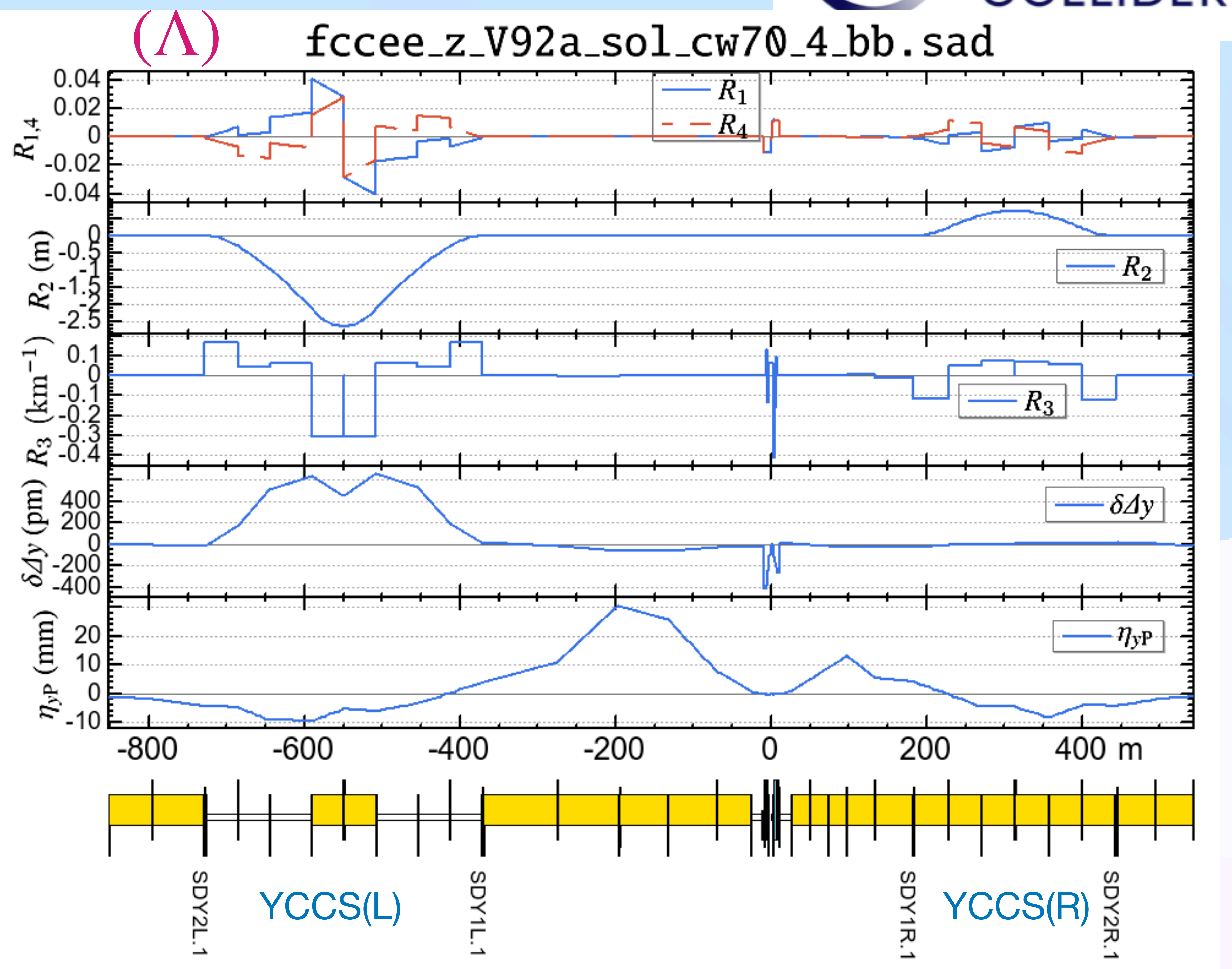
- The x-y coupling parameters $R_{1,2,3,4}$ are well confined within the compensation solenoid region as shown above.
- However, the vertical dispersion leaks toward outside.
- The profile of $R_{1,2,3,4}$ looks different for W and Λ. W has better symmetry around the IP.

$$\mathrm{R} = \begin{pmatrix} \mu \mathrm{I} & \mathrm{J} \mathrm{r}^T \mathrm{J} \\ \mathrm{r} & \mu \mathrm{I} \end{pmatrix} = \begin{pmatrix} \mu & . & -\mathrm{R4} & \mathrm{R2} \\ . & \mu & \mathrm{R3} & -\mathrm{R1} \\ \mathrm{R1} & \mathrm{R2} & \mu & . \\ \mathrm{R3} & \mathrm{R4} & . & \mu \end{pmatrix}$$

X-y coupling and vertical dispersio (type W)

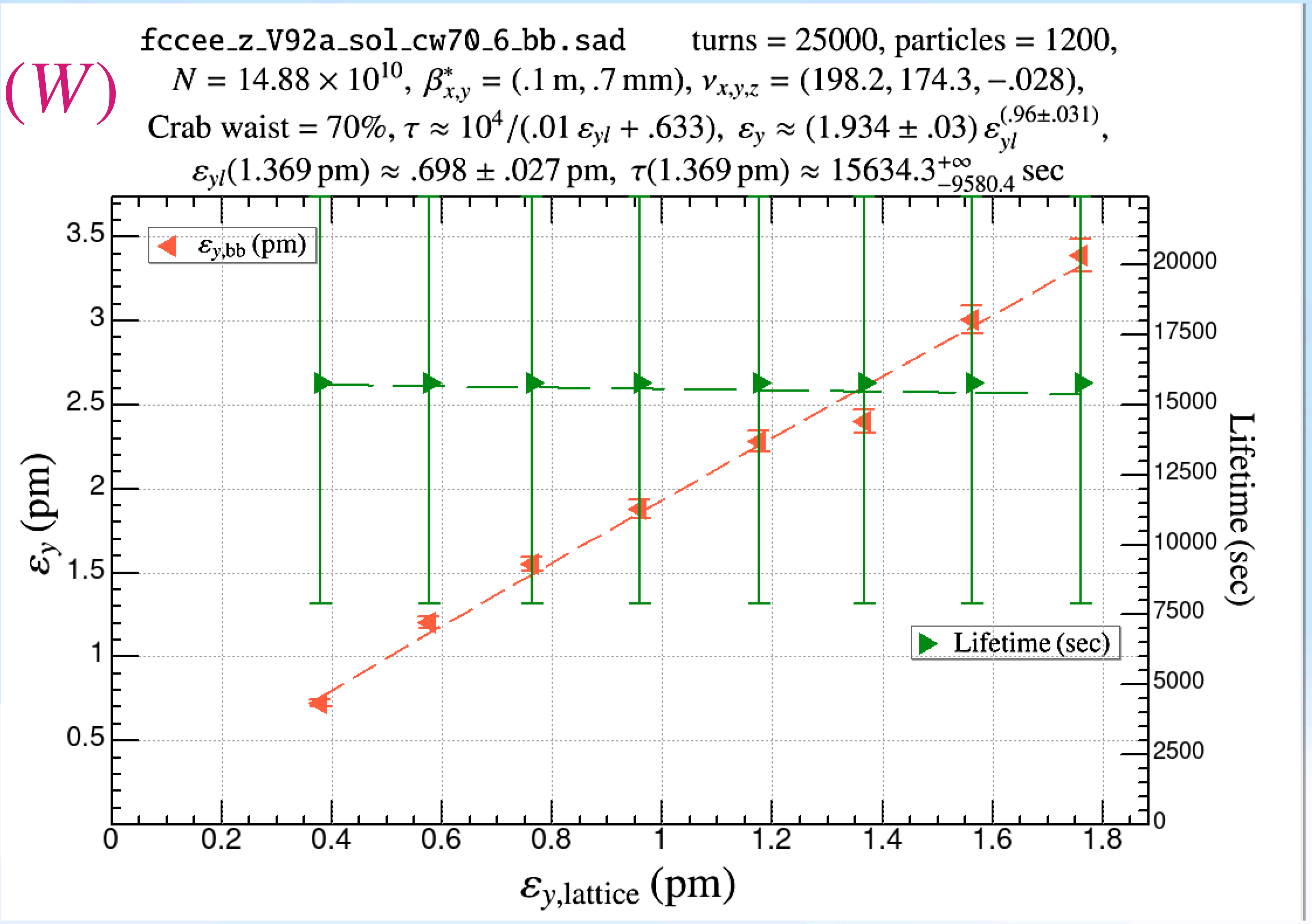
FUTURE CIRCULAR COLLIDER

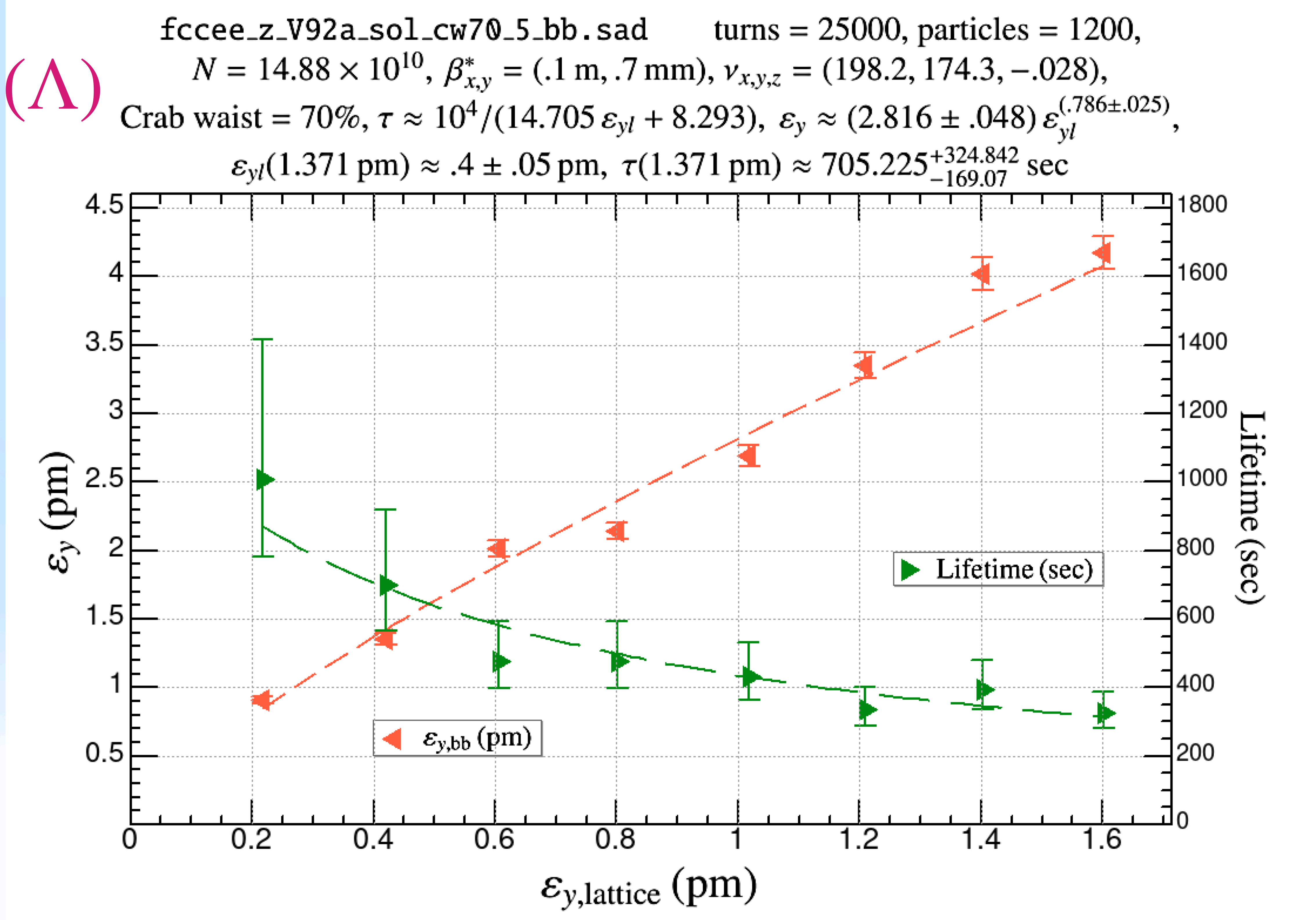




- Here we absorb the vertical dispersion by putting skew quadrupole components on the YCCS sexts.
  - This is straight-forward as generated x-y coupling is confined in the YCCS region.
- The type W (left) has better suppression of the vertical dispersion outside the YCCS.

Beam-beam performance

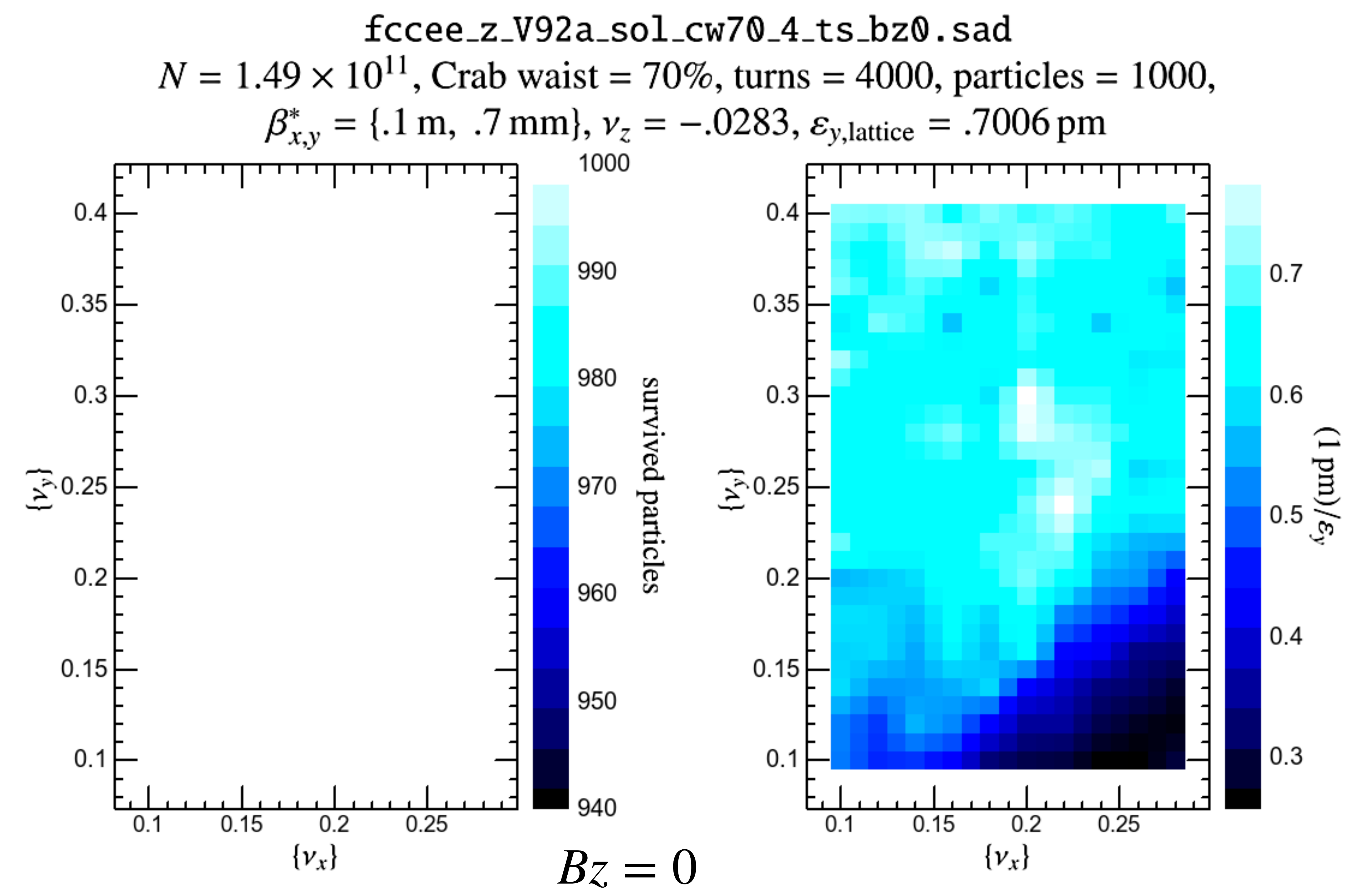


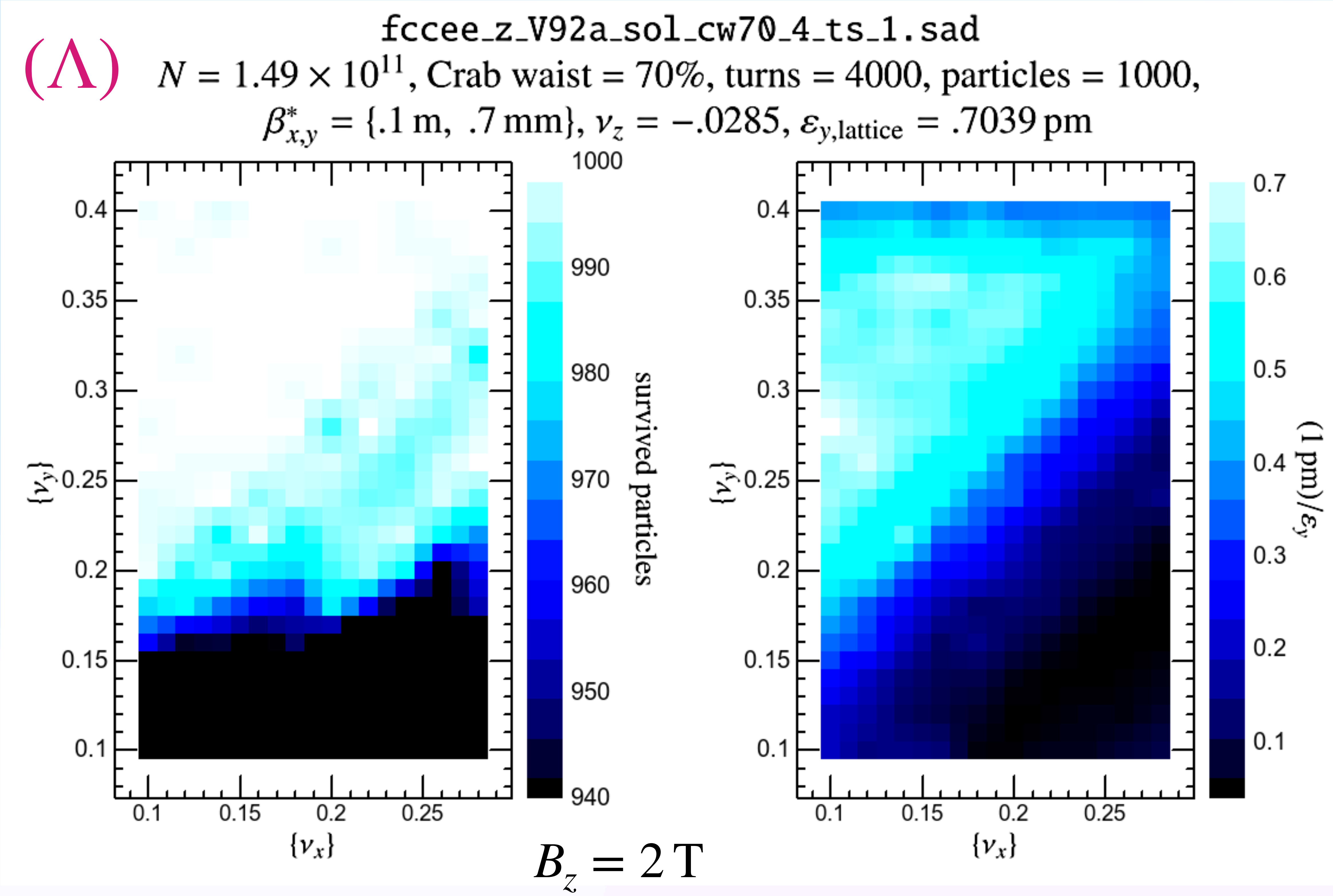


$\ell_{\mathrm{sol}} \approx 1.45\,\mathrm{m}$

- The beam-beam performance with $\ell_{\mathrm{sol}} \approx 1.45\,\mathrm{m}$ looks poorer for type Λ (right), having 1/30 lifetime and x1.5 stronger blowup of the vertical emittance, compared to type W (left).

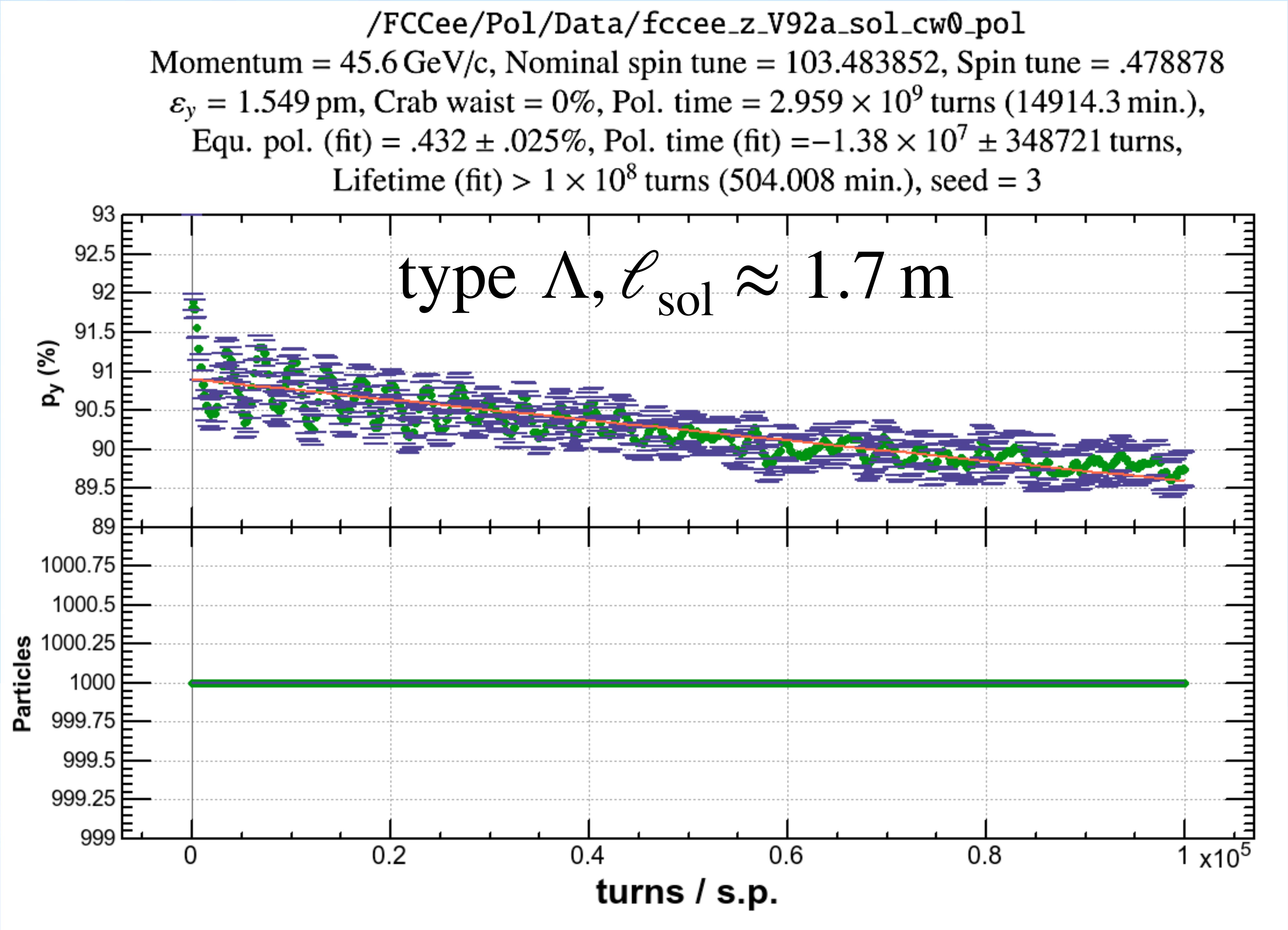
Beam-beam tune survey

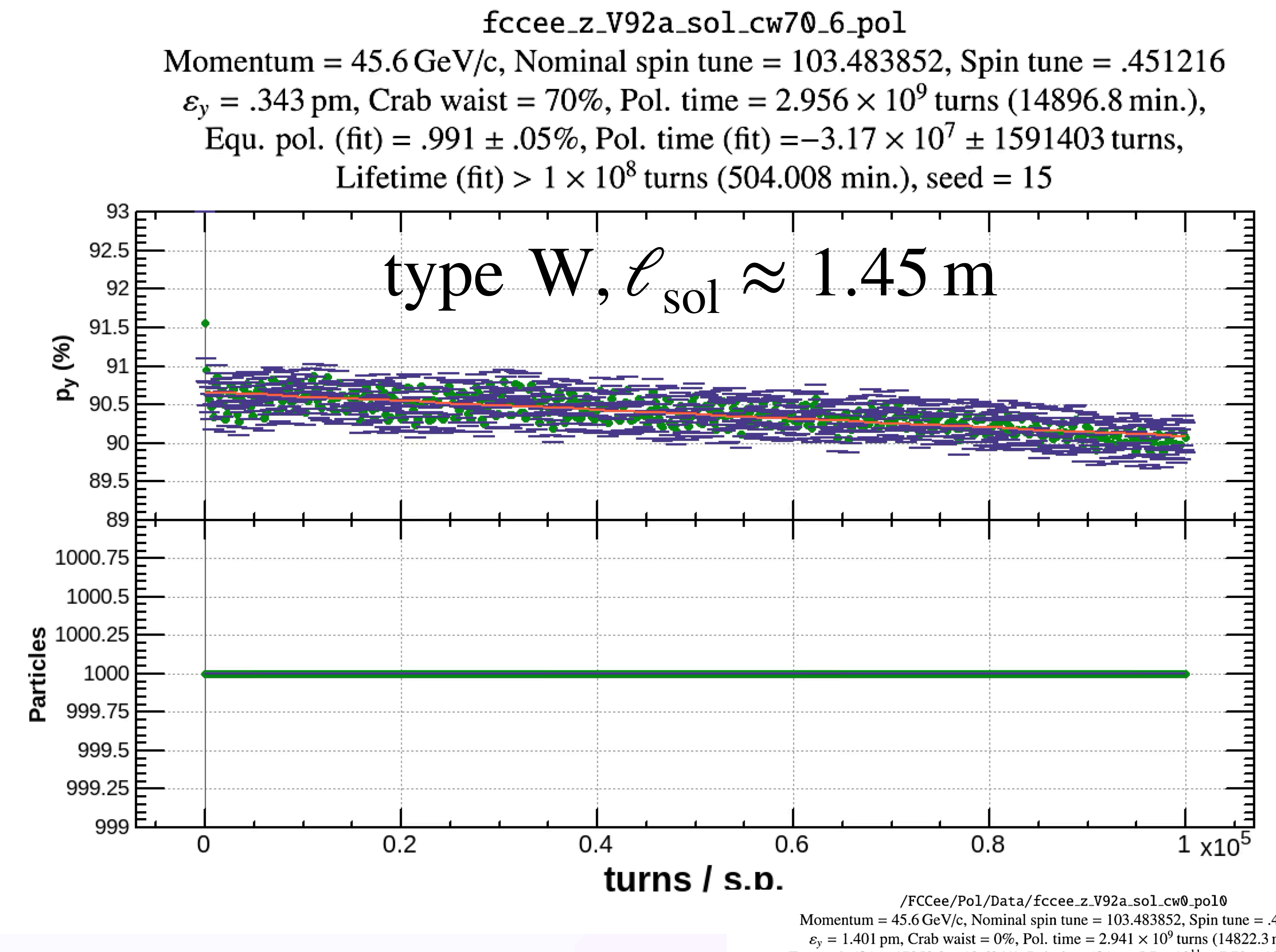




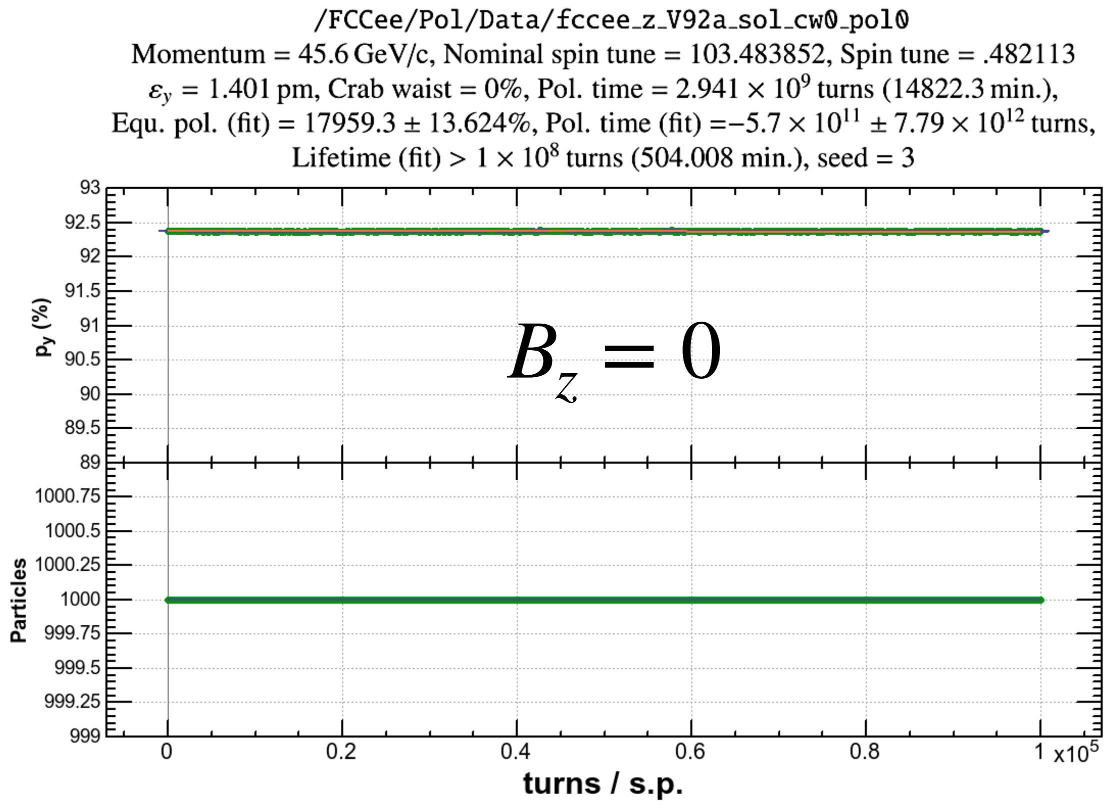
- The tune survey for $B_z = 2\,\text{T},\ \ell_{\text{sol}} \approx 1.7\,\text{m}$, type Λ (right) shows an existence of a large blowup area around the $\{\nu_x\} = \{\nu_y\}$ resonance.
- The degradation in the lifetime is also seen.
  - No loss has been seen for $B_z = 0$ in the entire tune space.

Polarization





- The spin tracking shows a significant depolarization for type W, $\ell_{\text{sol}} \approx 1.7\,\text{m}$ (left), and type Λ, $\ell_{\text{sol}} = 1.45\,\text{m}$ (right)
  - Tracking starts at Sokolov-Ternov polarization.
  - The equilibrium polarization may decay to 0.43% (left) and 0.99% (right), by assuming the observed depolarization speeds.
- No depolarization is seen for $B_z = 0$ (right low).
- Some polarization bump tunings will be necessary.



Summary (preliminary)

- Examined a non-local solenoid compensation scheme.
  - Two types, W and Λ, of the vertical bump around the IP have been tried:

Type	W		Λ	
ℓ_{sol}(m)	**1.0**	**1.45**	**1.45**	**1.7**
ℓ_{edge} (m)	0.1	0.3	0.3	0.6
ε_y (pm)	0.16	0.36	0.22	0.28
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τ (s)	16000	16000	550	550
p(%)	-	0.99±0.05	-	0.43±0.03

- The type W with $\ell_{\mathrm{sol}} = 1.45\,\mathrm{m}$ seems usable, except for the polarization.
  - A polarization tuning such as vertical bump in the arc is necessary.