Status of the
ATF2 Ultra-Low β FFS.

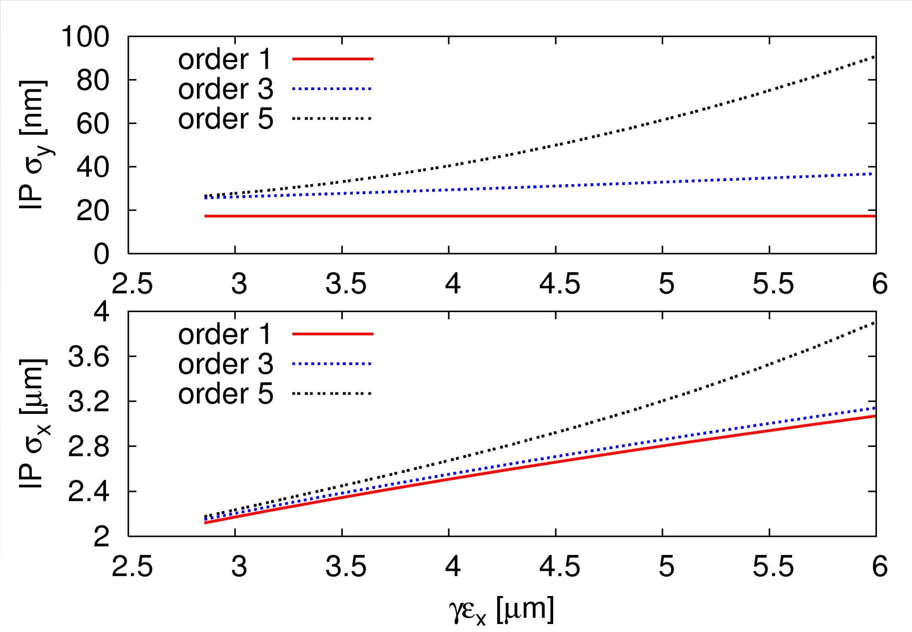
Presenter: **Edu Marin**
eduardo.marin.lacoma@cern.ch

Acknowledgments : Brett Parker, Glen White,
Cherrill Spencer and Yannis Papaphilippou.

PLAN OF THE TALK

1. ATF2 Ultra-Low β^* Lattice problem (multipoles of QF1).
2. Possible Solutions:
    1. Reducing emittance by a SC Wiggler in DR.
    2. Correction by a Dodecapole magnet.
    3. Replacing QF1 by a SC Q.
    4. Designing a new ATF2 Ultra-Low β_y^* lattice.
3. Feasibility of ATF2 Ultra-Low β_y^* Lattice.
    1. Beam Size along the beam line.
    2. New current values for the magnets.
4. Tuning the ATF2 Ultra-Low β_y^* Lattice.
    1. Horizontal and Vertical Misalignments.
    2. KNOBS for β-functions, Dispersion and coupling.
    3. Strategy for the first Tuning.
5. Results for the First Tuning Study.
    1. Results for σ_y obtained via RMS beam size.
    2. Results for σ_y obtained via a Gaussian fit.
6. Conclusions and Future Plans.

1. BEAM SIZE DEPENDENCE ON ε_x FOR ULTRA-LOW β^* LATTICE.



- β functions and beam size $(\gamma\varepsilon_x = 6\mu m)$ @ IP (no errors):
  - $\beta_x = 4.0$ mm $\sigma_x = 2.14$ μm
  - $\beta_y = 25.0$ μm $\sigma_y = 22.8$ nm
- β functions and beam size $(\gamma\varepsilon_x = 6\mu m)$ @ IP (with errors):
  - $\beta_x = 4.0$ mm $\sigma_x = 3.9$ μm
  - $\beta_y = 25.0$ μm $\sigma_y = 92.8$ nm

Due to multipolar components measurements of QF1:

QF1_Octopole = 0.0056 % @ r_o=10mm

QF1_Dodecapole = 0.035 % @ r_o=10mm

POSSIBLE SOLUTIONS:

1. Reducing ε_x from the DR.
2. Implementing a Dodecapole magnet.
3. Using a Superconducting for the QF1 with smaller errors.
4. Developing a new lattice reducing β_x at QF1.

For further details see: Mechanical measurements of ATF2 Final Doublet magnets. Cherrill Spencer. ATF2 weekly meeting, October 2008.

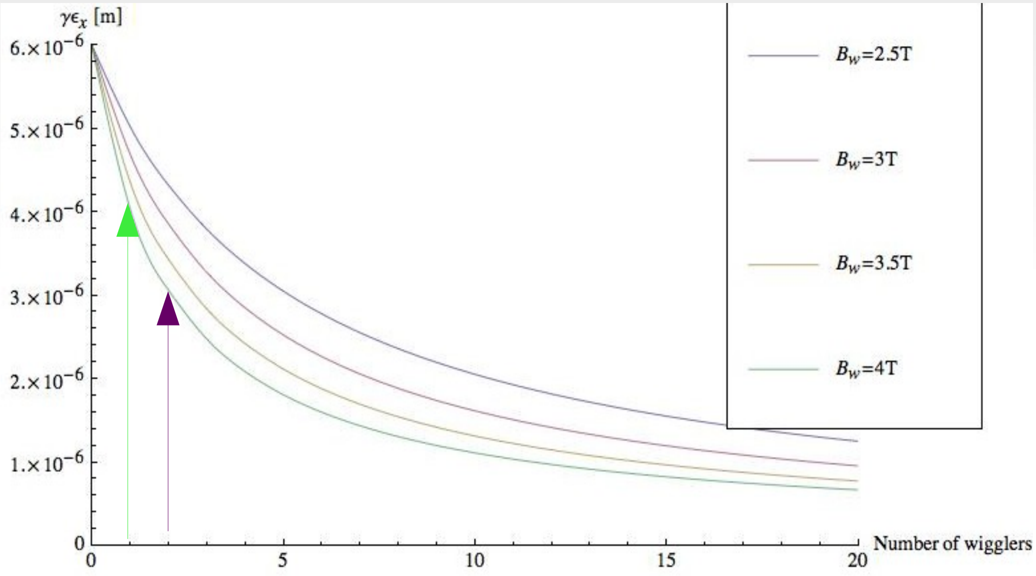
2.1. Reduced ε_x from the DR.

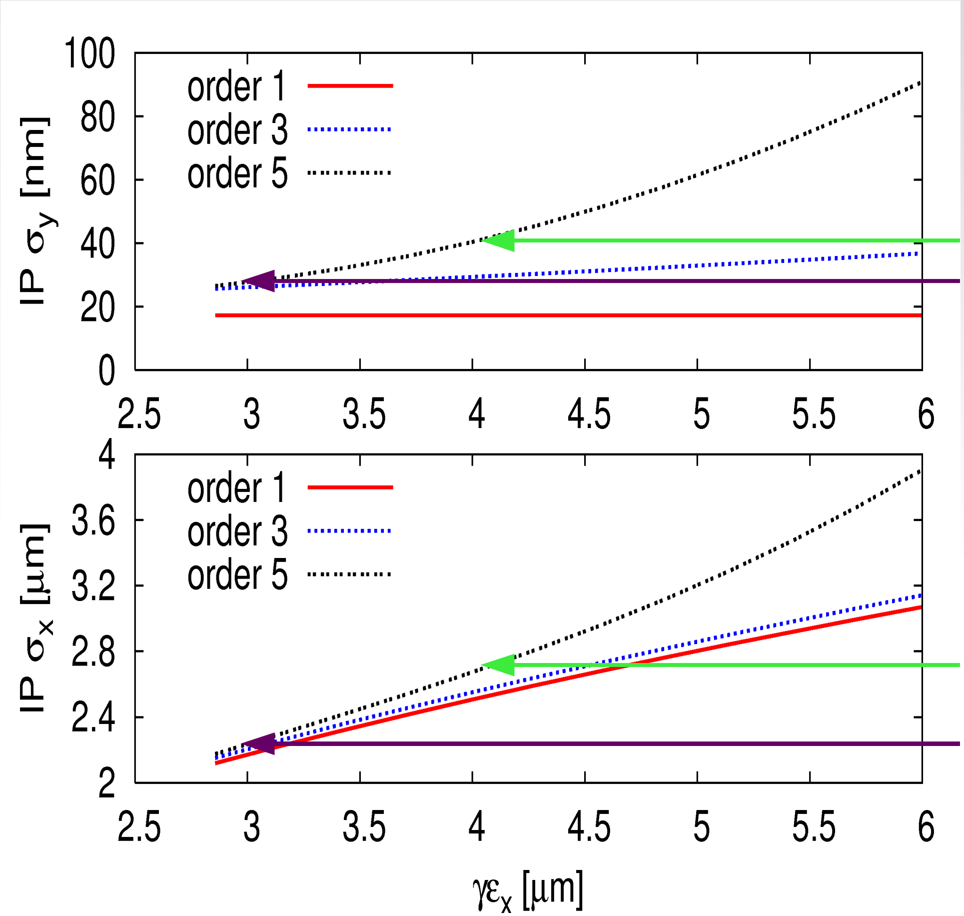
Introducing a SuperConducting Wiggler

in the DR. 2 cases:

1 wiggler of 4 T reduces 30%

2 wigglers of 4 T reduces 50%





2 SC Wiggler needed

IP beam sizes for new $\gamma\varepsilon_x$:

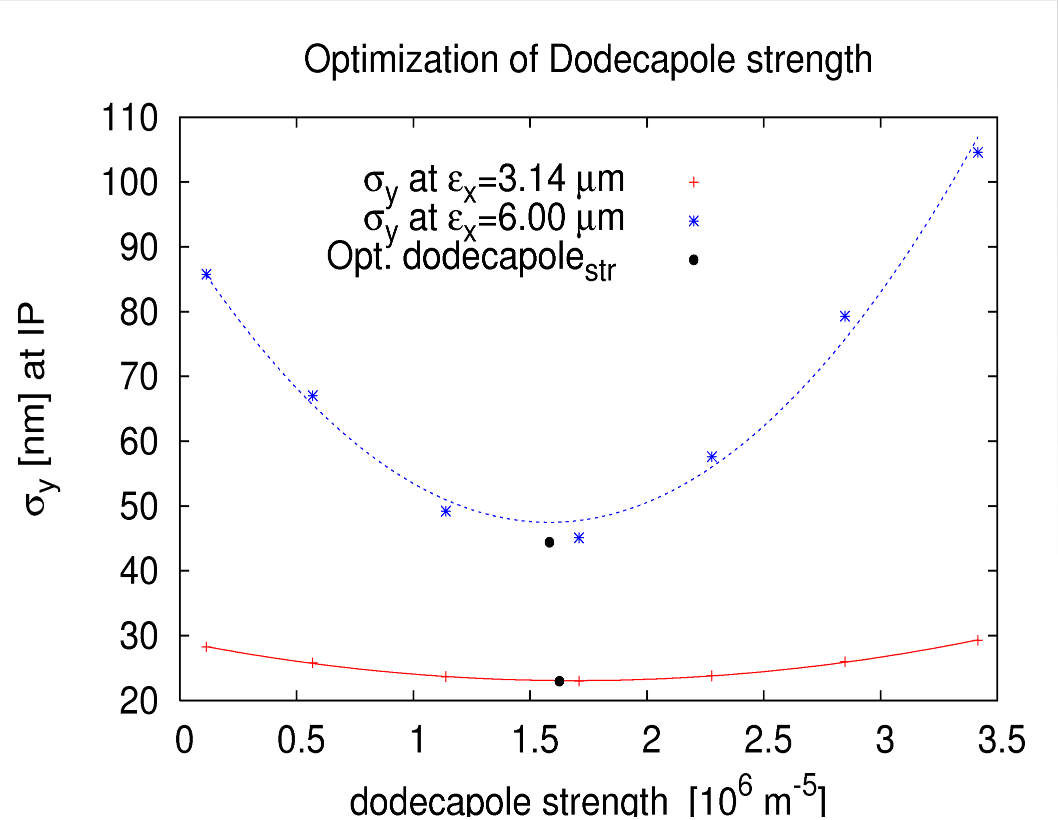
$\sigma_{y,\,30\%}$ = 40 nm ; $\sigma_{x,\,30\%}$ = 2.7 µm

$\sigma_{y,\,50\%}$ = 28 nm ; $\sigma_{x,\,50\%}$ = 2.2 µm

For further details see:

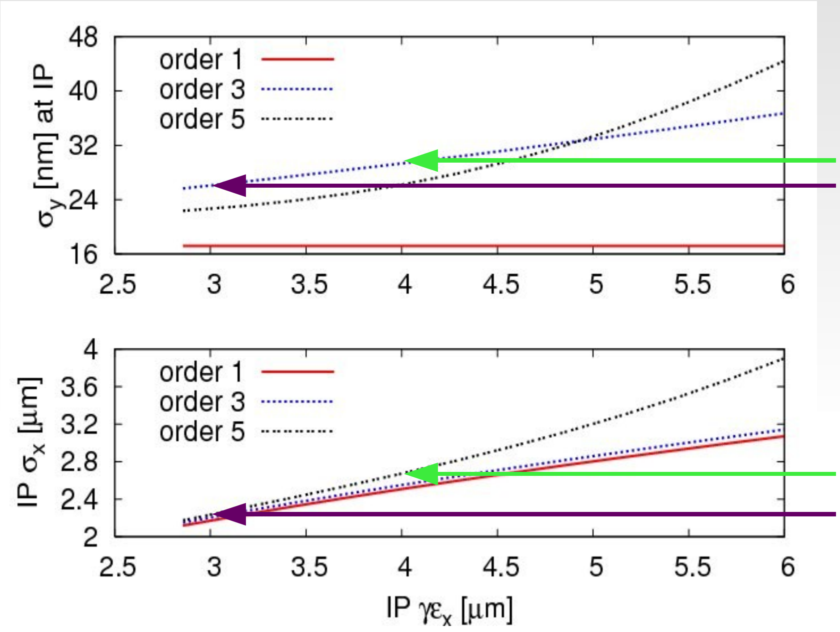
Emittance reduction by a SC wiggler in the ATF-DR. Y. PAPAPHILIPPOU. ATF2 weekly meeting, September 2009.

2.2 Dodecapole's Optimization



Optimum IP beam sizes $(\gamma\varepsilon_x=6\mu m)$:

$\sigma_{y,\ high}$ = 44.4 nm ; $\sigma_{x,\ high}$ = 3.9 μm



IP beam sizes for reduced $\gamma\varepsilon_x$:

$\sigma_{y,\ 30\%}$ = 29 nm ; $\sigma_{x,\ 30\%}$ = 2.7 μm

$\sigma_{y,\ 50\%}$ = 26 nm ; $\sigma_{x,\ 50\%}$ = 2.3 μm

Optimum Dodecapole strength $=1.58\cdot10^6\ m^{-5}$

Only a dodecapole is not sufficient.

2.3 Using a Superconducting FD.

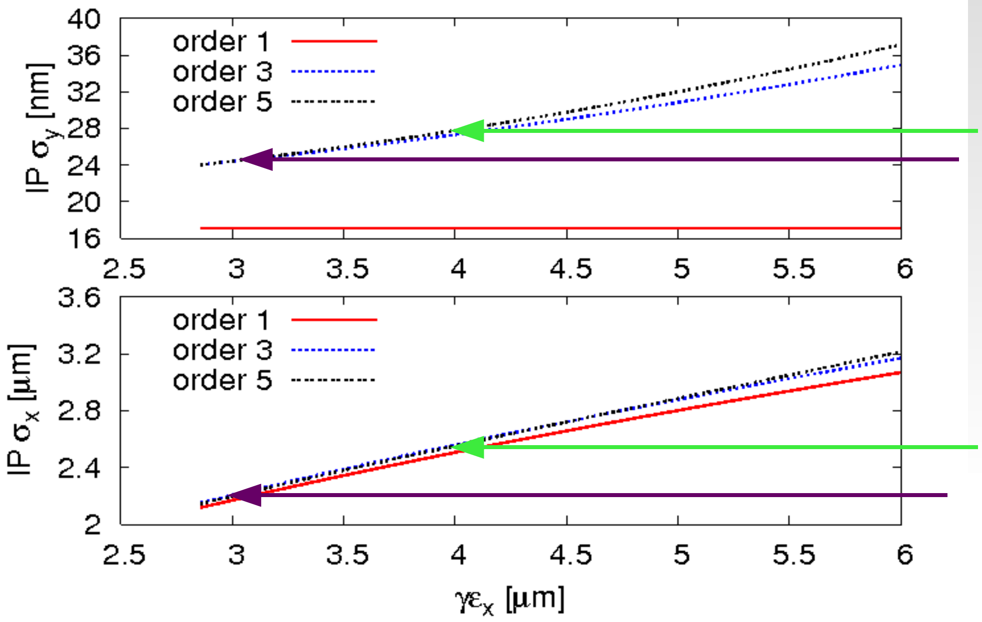
Using a SC Q, a relative octopolar and dodecapolar components are introduced about 2 parts of 10000 at $r_o = 28mm$.

$$QF1\_Multipole = 0.02\%$$

Comparing with the NC ones at $r_o = 28mm$,

$$QF1\_Octopole = 0.04\%$$

$$QF1\_Dodecapole = 2.2\%$$



IP beam sizes for $\gamma\epsilon_x = 6\mu m$

$\sigma_y = 37.13$ nm ; $\sigma_x = 3.21\ \mu m$

IP beam sizes for reduced $\gamma\epsilon_x$:

$\sigma_{y,\ 30\%} = 27.76$ nm ; $\sigma_{x,\ 30\%} = 2.55\ \mu m$

$\sigma_{y,\ 50\%} = 24.83$ nm ; $\sigma_{x,\ 50\%} = 2.25\ \mu m$

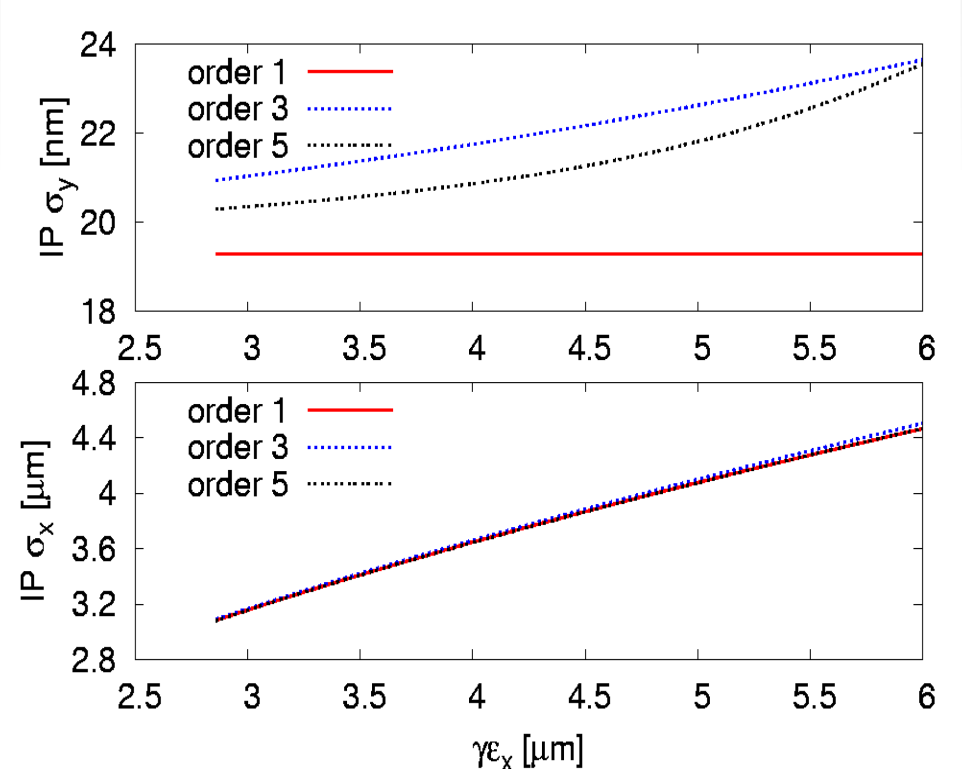
A SC Q helps but not enough.

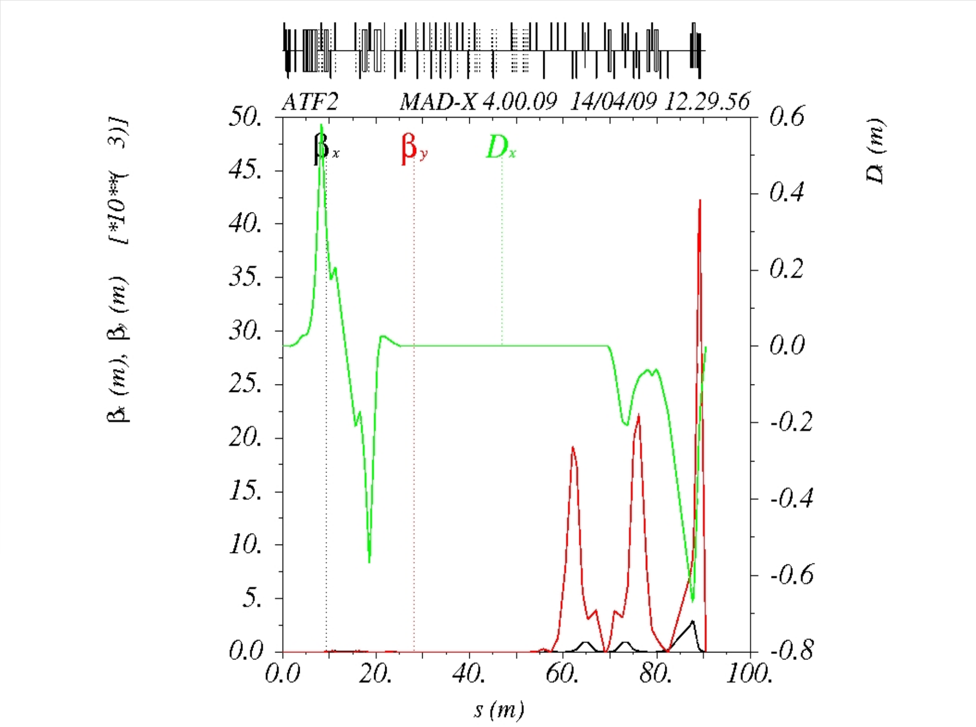
For further details see: Specification/Parameters of SC Q and Cryogenics. Brett Parker. ATF2 weekly meeting, September 2009.

2.4 Matching for a new Ultra Low β_y^* Lattice.

- Matching via Mad-x & Mapclass
  - Including Multipolar errors.
  - Constraints: increasing β_x @ IP
  - Variables: Quads & Sexts strengths

    & SF1 SD0 Tilts





Results:

- Beta functions @ IP:
  - $\beta_x = 8.4608$ mm ; $\beta_y = 31.5727$ μm
- Beam sizes @ IP ($\gamma\epsilon_x = 6\mu m$) :
  - $\sigma_x = 4.4$ μm ; $\sigma_y = 23.8$ nm

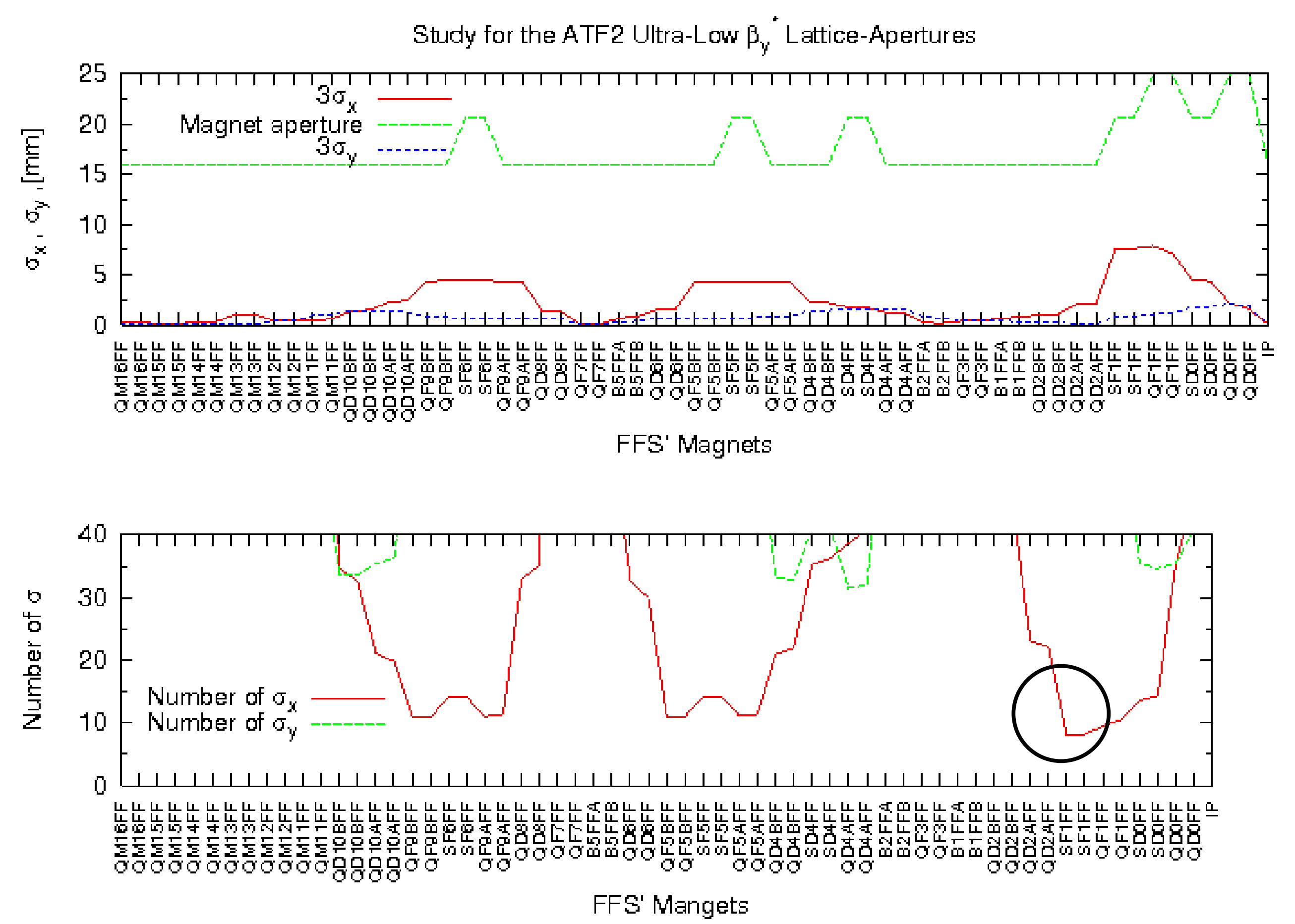
3.1.1 Beam Size along ATF2 Ultra-Low β_y^*.

Radius of magnets:

Quads: 16mm.

Sexts: 20.6mm.

FD: 25mm.



Minimum number of sigmas equals to 8.1 corresponding to σ_x at SF1.

3.1.2 Beam Size along ATF2 Ultra-Low β^* Lattice

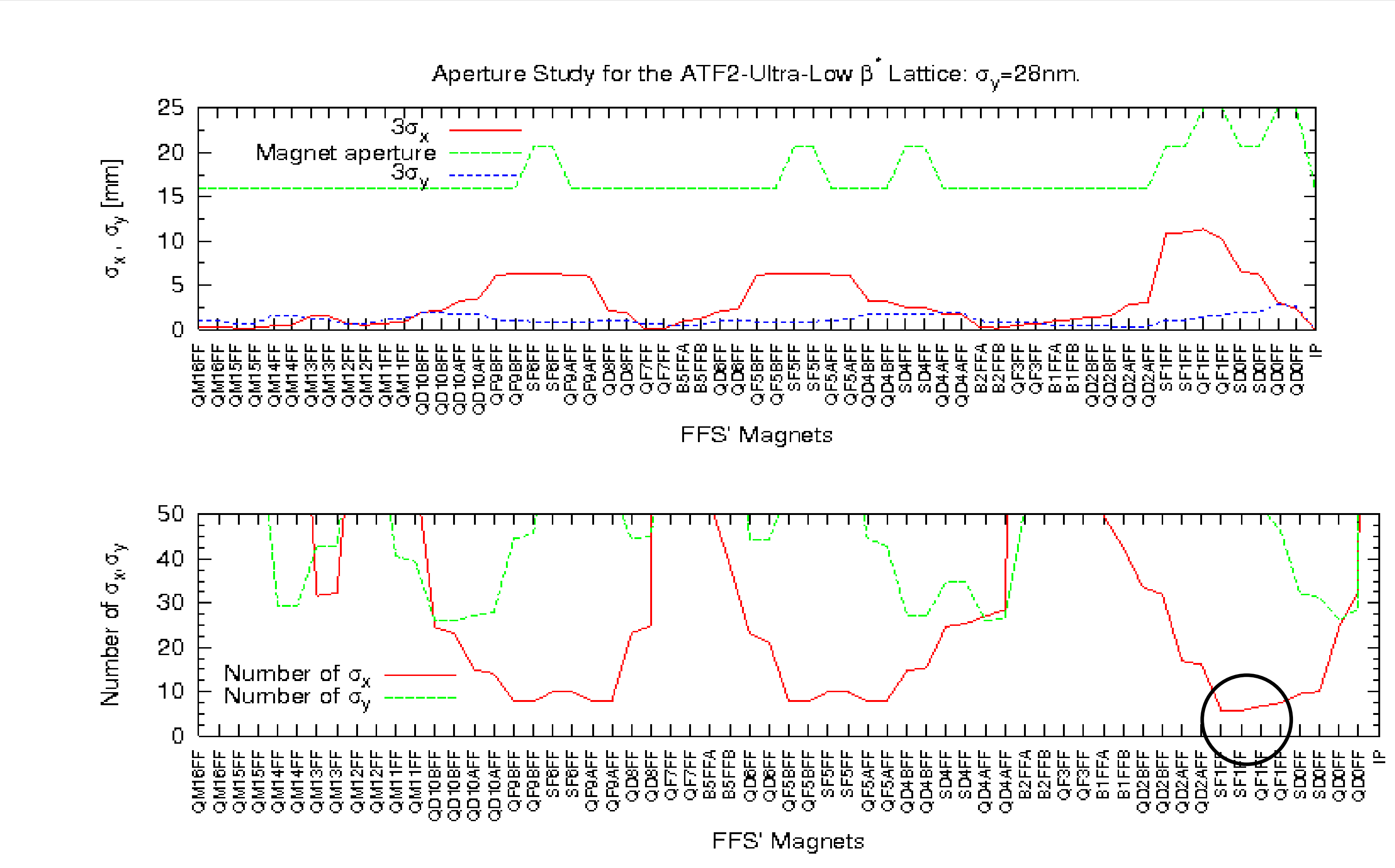
Radius of magnets:

Quads: 16mm.

Sexts: 20.6mm.

FD (NC): 25mm.

FD (SC): 28mm



Minimum number of sigmas equals to 5.7 corresponding to σ_x at SF1.

For SC Q the Number of σ_y increases up to 6.4.

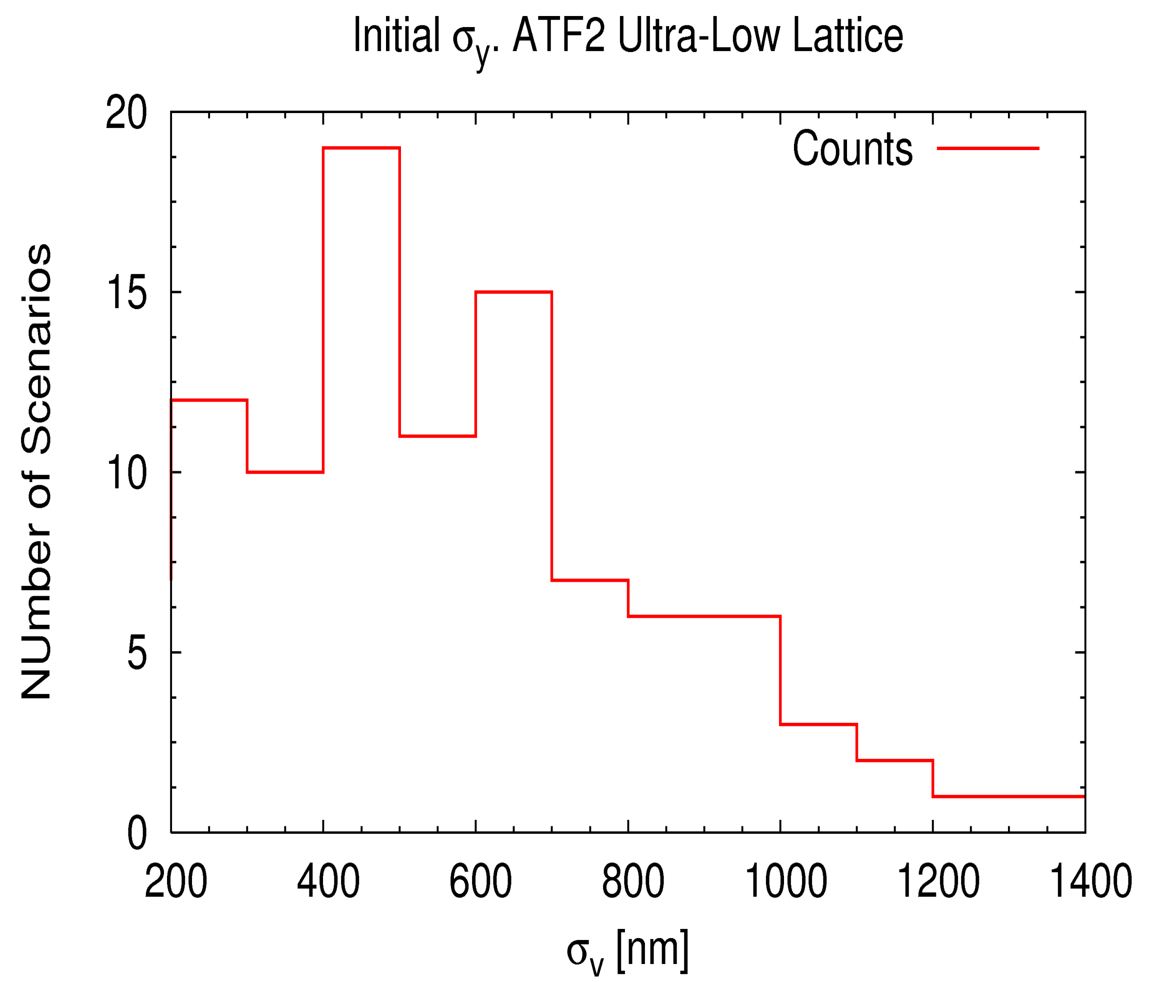
3.2. New current values for the Magnets

Magnet	Nom. Strength	New Strength	ratio	Nom. Current	New Current	Max. current
[FFS]	[m-3]	[m-3]		[A]	[A]	[A]
SF6FF	8.565	6.581	0.77	15.548	11.947	50
SF5FF	-0.791	-2.165	2.74	1.404	3.843	50
SD4FF	14.910	15.813	1.06	27.498	29.163	50
SF1FF	-2.578	-2.538	0.98	3.819	3.760	50
SD0FF	4.312	4.441	1.03	6.348	6.538	50
	[m-2]	[m-2]				
QM16FF	0.582	0.468	0.80	27.080	21.774	150
QM15FF	-0.320	0.576	1.80	14.880	26.826	150
QM14FF	-1.120	-1.349	1.20	52.510	63.257	150
QM13FF	0.911	0.938	1.03	42.600	43.868	150
QM12FF	0.336	0.314	0.94	15.630	14.620	150
QM11FF	0.000	0.000		0.000	0.000	150
QD10FF	-0.290	-0.290	1.00	13.500	13.494	50
QF9FF	0.379	0.379	1.00	17.620	17.620	50
QD8FF	-0.604	-0.604	1.00	28.120	28.106	50
QF7FF	0.550	0.481	0.88	25.590	22.391	50
QD6FF	-0.602	-0.582	0.97	28.030	27.093	50
QF5FF	0.376	0.375	1.00	17.500	17.458	50
QD4FF	-0.297	-0.298	1.00	13.810	13.849	50
QF3FF	0.553	0.576	1.04	25.710	26.785	50
QD2BFF	-0.199	-0.265	1.34	9.230	12.323	50
QD2AFF	-0.290	-0.239	0.82	13.480	11.099	50
QF1FF	0.742	0.739	1.00	71.630	71.386	100
QD0FF	-1.364	-1.365	1.00	131.800	**131.864**	150

No significant changes are observed comparing with nominal values.

4.1. Horizontal and Vertical Misalignments

- Random Gaussian distribution within 30 µm, for the initial transversal displacements to all Quads & Sext:
- Initial σ_y [0.2 µm , 1.4 µm]
- Tuning via MAD-X & MAPCLASS using Simplex algorithm
- Statistical Study formed by 100 different seeds.



4.2. Knobs for the β-functions, Dispersion and coupling.

Displacing sextupoles in the transverse plane, we construct the knobs.

Displacing horizontally the sextupoles we have obtained the knobs, whose controls β- functions and the horizontal dispersion. →

	SF6_dx [nm]	SF5_dx [nm]	SD4_dx [nm]	SF1_dx [nm]	SD0_dx [nm]
β_x	44.25	88.41	-0.57	14.95	1.12
β_x	-1.06	31.94	27.15	-49.38	-76.18
α_y	-41.29	-89.61	0.75	-16.06	-2.49
α_y	-0.49	31.46	25.85	-49.52	-76.74
δ_x	32.77	-80.68	0.87	48.43	-8.37

	SF5_dy [nm]	SD4_dy [nm]	SF1_dy [nm]	SD0_dy [nm]
<x,y>	-69.6	-64.35	9.96	-30.25
<px,y>	74.14	60.61	-8.72	27.44
<x,py>	-70.43	-59.09	14.53	-36.55
<px,py>	-65.2	63.14	27.66	-31.58
δ_y	-49.6	36.43	-3.84	-78.73

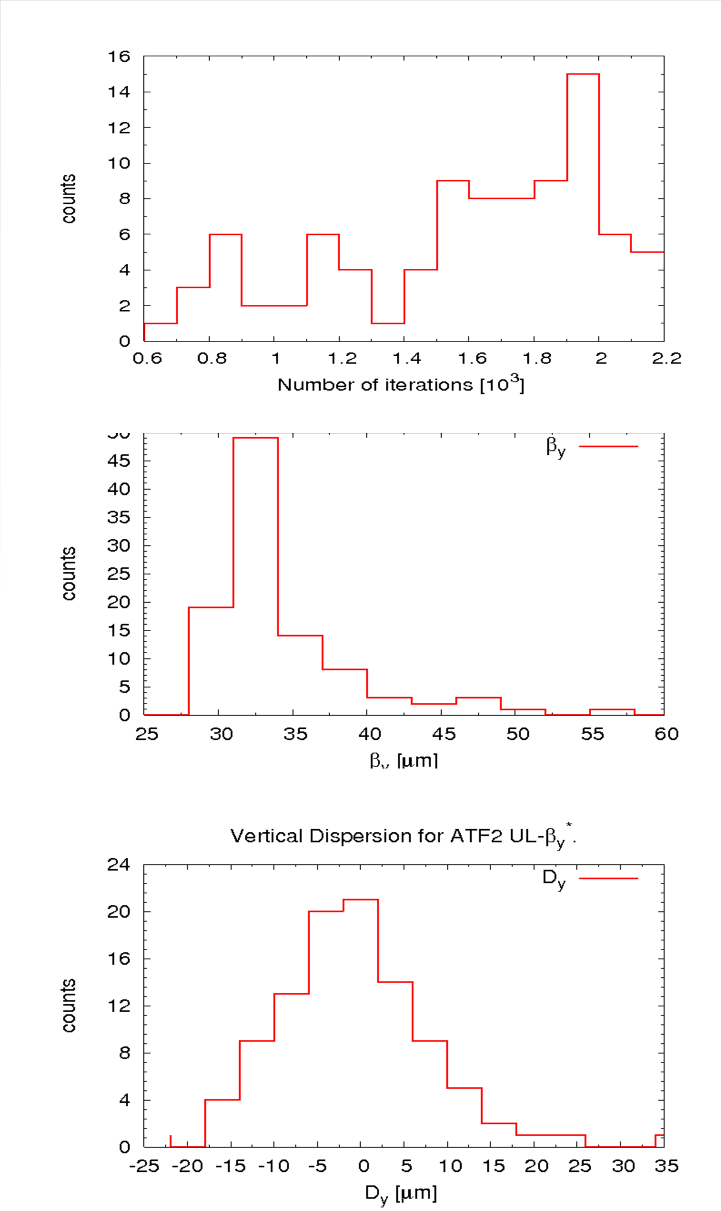
← Displacing vertically the sextupoles we have obtained the knobs, whose controls the couplings and the vertical dispersion.

4.3. Strategy of the First FFS Tuning.

- Assumptions.
  - Including:
    - Multipolar errors.
    - Measurement error: σ_x(1µm), σ_y(2nm)
  - Constraint: minimize σ_y
  - Variables: Transversal Misalignments of Quads & Sext.

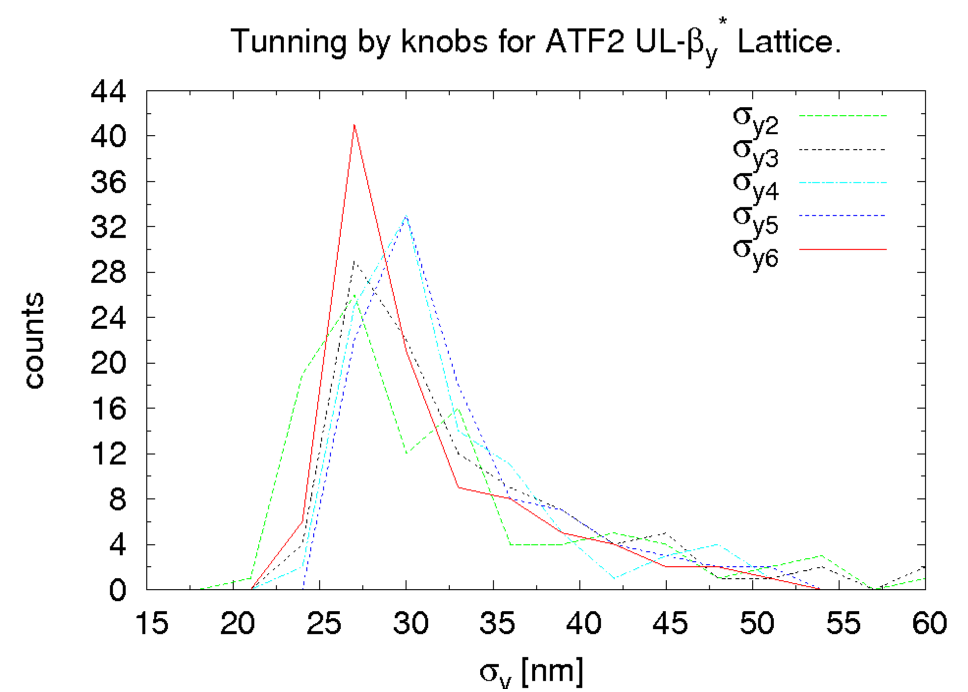
- Tuning via Mad-x & Mapclass using the Simplex algorithm.
  - Horizontal and Vertical displacement of Quadrupoles and Sextupoles.
  - Implementation of horizontal knob to reduce β_y function.
  - Implementation of vertical knobs to reduce the coupling $<p_x,y>$ and vertical dispersion.

5.1. Results of σ_y in terms of RMS beam size.

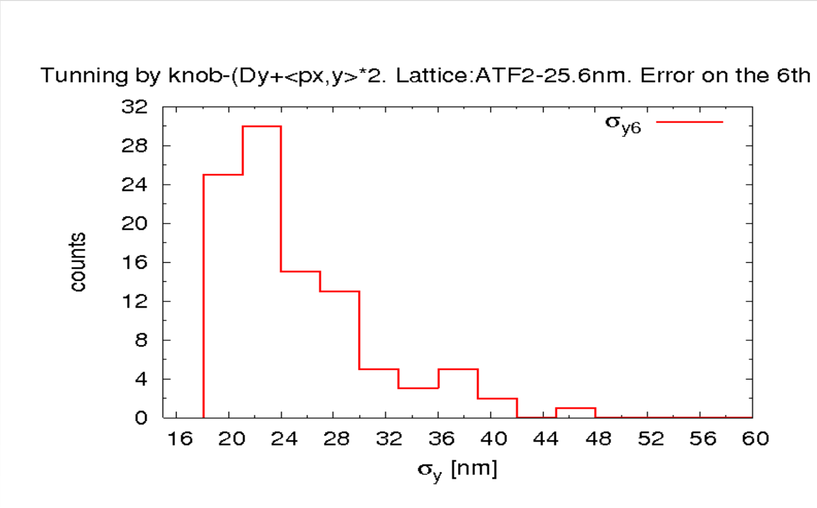


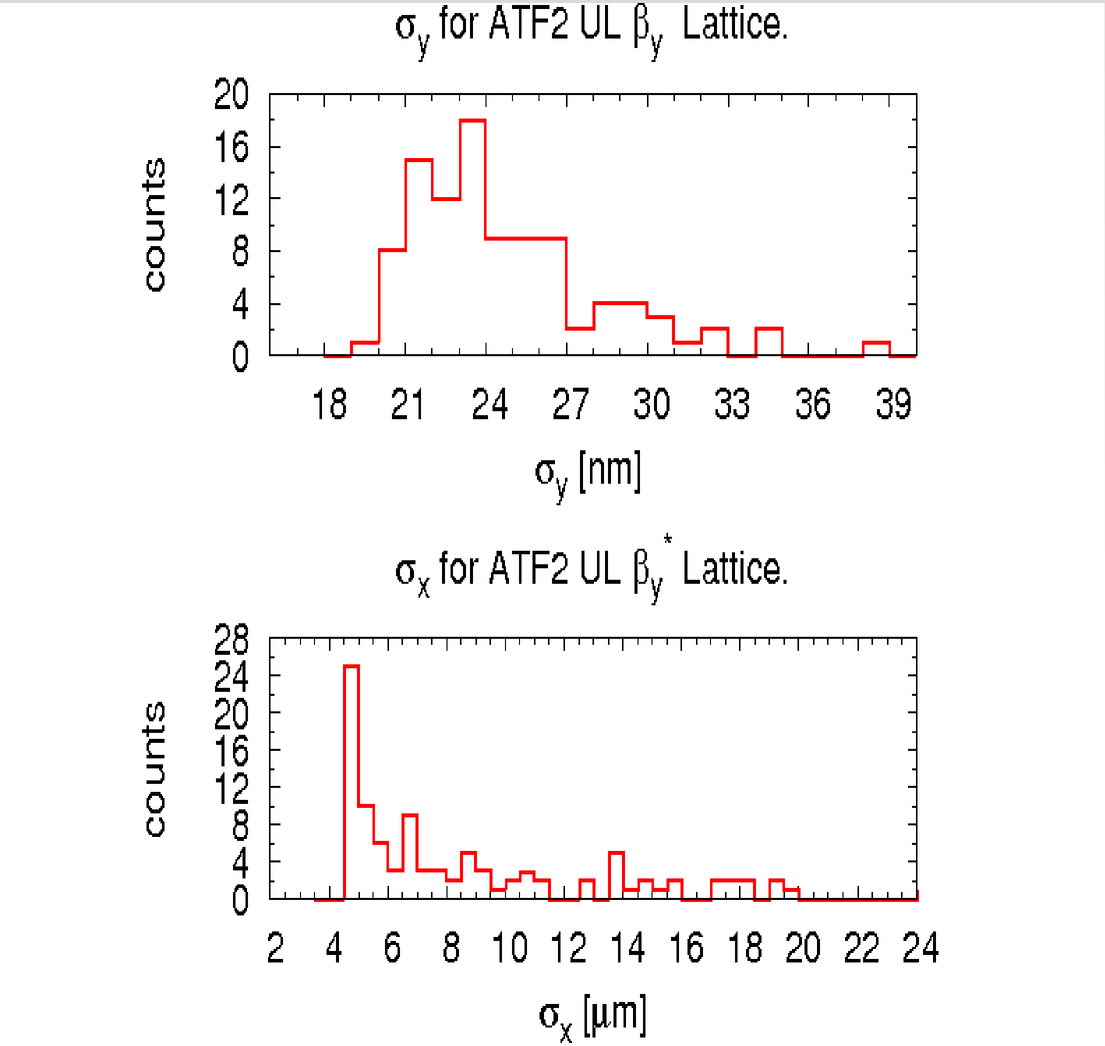
Values obtained via MAPCLASS code after MADX tuning.

83% of seeds have a σ_y value < 30 nm (RMS value)


Tunning by knobs for ATF2 UL-β_y^* Lattice.

5.2. Results for σ_y obtained for the CORE Beam Size.





- A Gaussian distribution is fitted for the 10000 tracked particles .
- 83% of the scenarios have a final $\sigma_y < 28$ nm. (Gaussian Fit)

6. CONCLUSIONS & FUTURE PLANS

- Possible strategies to achieve ATF2 Ultra-Low β^* Lattice:

  a) 2 SC Wigglers of 4T
  $\sigma_y = 28$ nm

  b) 1 (2) SC W + Dodecapole magnet
  $\sigma_y = 29$ nm ($\sigma_y = 26$ nm)

  c) 1 (2) SC W + SC Q
  $\sigma_y = 27$ nm ($\sigma_y = 25$ nm)

  d) Reducing β_x @ QF1
  $\sigma_y = 23.8$ nm

- Statistical Tuning Study shows 83% of the seeds reach $\sigma_y < 28$ nm (Gaussian Fit).

To be done...

- Inserting an Octopole magnet.
- Evaluate the beam size as the Shintake Monitor does.
- A more Realistic tuning, including: tilts, mispowerings, ground motion....
- Study at intermediate Vertical Beam Size stages.