ATF2 Ultra-Low β optics Studies.

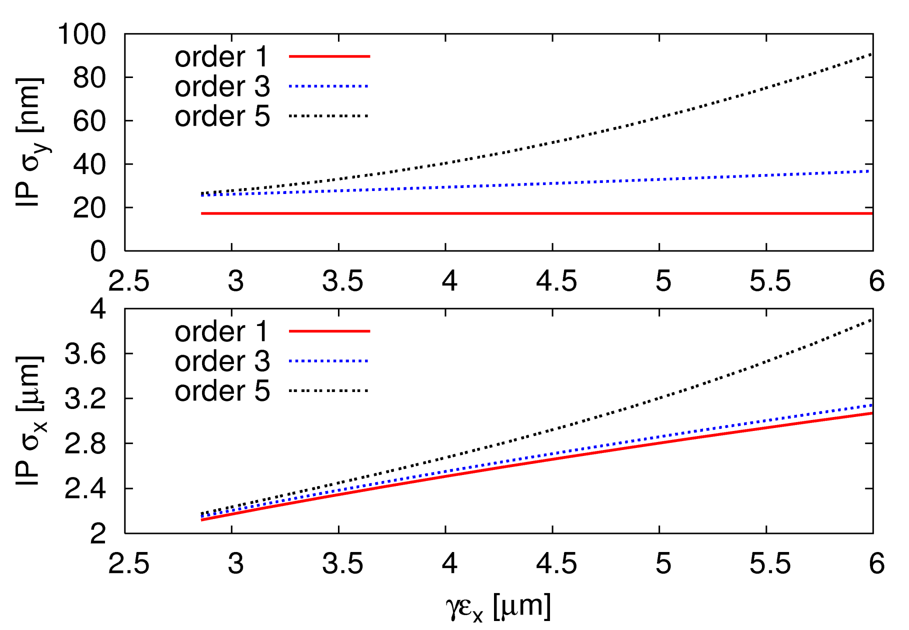
Collaborators: Philip Bambade, Brett Parker, Glen White, Rogelio Tomas, Yannis Papaphilippou

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

PLAN OF THE TALK

1. Can we realize the ATF2 Ultra-Low β^* optics at the present beam line ?
2. Possible Scenarios to achieve Ultra-Low β^* proposal:
    1. Replacing the NC QF1FF by a SC QF1FF.
        1. Multipoles components for the NC and SC QF1FF.
        2. Beam size using SC QF1FF before and after matching.
        3. Comparison between RMS, Gaussian and Shintake beam size.
    2. Inserting a Dodecapole magnet.
    3. Reducing the emittance from the DR inserting SC Wigglers.
    4. Minimizing the β_x at QF1.
3. Description of the ATF2 Ultra-Low β_y^* Lattice.
    1. Feasibility of the new lattice.
        1. Magnet aperture according to beam size .
        2. New currents required.
    2. Preliminary Tunning.
        1. Considered errors.
        2. Tuning results in terms of RMS, Gaussian and Shintake monitor.
4. Conclusions and Future Plans.

1. Can we realize the Ultra-Low β^* optics at the present line?



- Beta functions and beam size @ IP (no errors):
  - $\beta_x = 4.0$ mm $\sigma_x = 2.14$ μm
  - $\beta_y = 25.0$ μm $\sigma_y = 28.5$ nm
- Beta functions and beam size @ 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 the octupolar and dodecapolar skew component of QF1.

POSSIBLE SOLUTIONS:

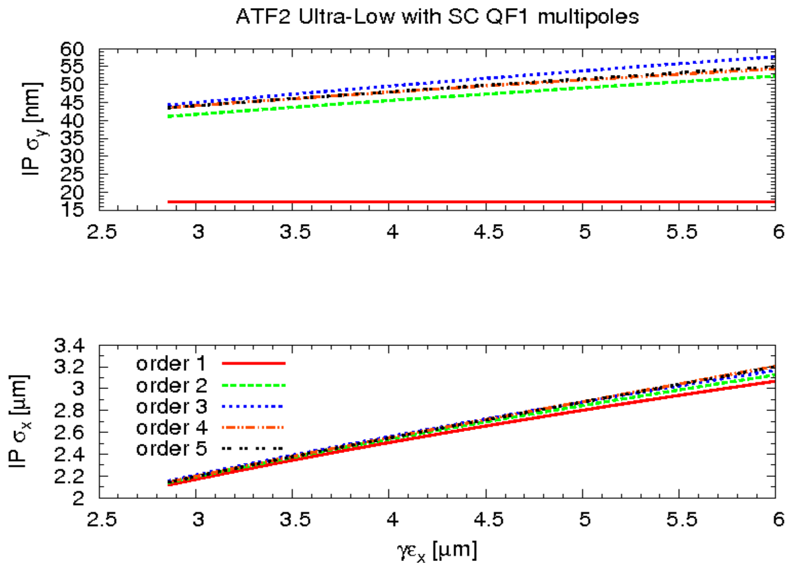
1. Using a Superconducting QF1FF instead of the NC QF1FF.
2. Implementing a Dodecapole magnet.
3. Reducing ε_x from the DR.
4. Developing a new lattice reducing β_x at QF1FF.

2.1.1. Multipoles components for the NC and SCQF1FF.

MAGNET NAME	SEXT/QUAD	OCT/QUAD	DECA/QUAD	DODE/QUAD	20-POLE/QUAD
NC Relative tol. @ 10 mm	< 0.03	< 0.025	< 0.01	< 0.05	< 0.12
NC QD0 (132 A)	**0.0255**	**0.00052**	**0.0070**	**0.0036**	**0.0027**
NC QF1 (77.5 A)	**0.0274**	**0.0058**	**0.0128**	**0.0036**	**0.0027**
SC QF1 Normal Comp.	**0.00013**	**-0.00009**	**0.00008**	**0.00002**	**0.00001**
SC QF1 Skew Comp.	**0.00013**	**-0.00005**	**0.00001**	**0.00001**	**0.00001**

Using a SC instead of NC QF1 the octupolar and dodecapolar component are reduced notably.

2.1.2. Beam size using SC QF1FF before and after matching.



The sextupole contribution, can be corrected by matching the sextupole's strengths and Tilts.

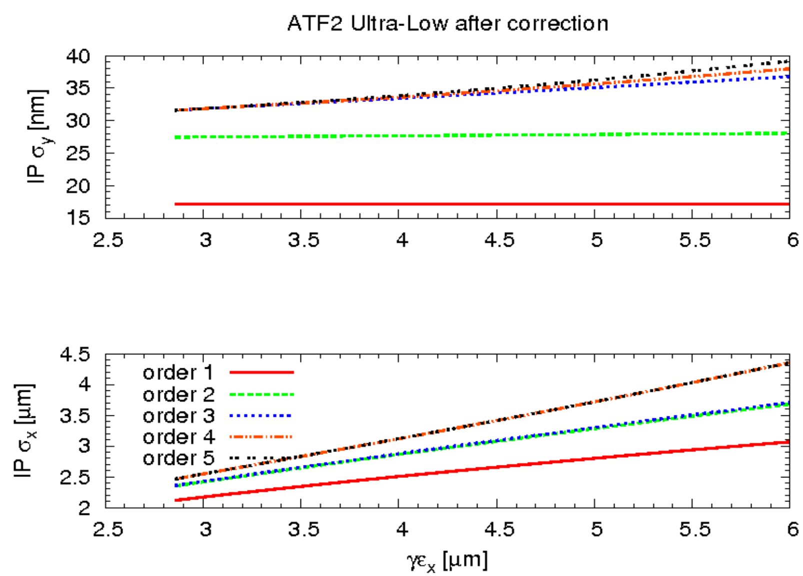
klsf6ff = 7.164693011 m^{-3}
klsf5ff = -1.89938836 m^{-3}
klsd4ff = 15.12204394 m^{-3}
klsf1ff = -2.501499369 m^{-3}
klsd0ff = 4.422272864 m^{-3}

sf6tilt = 0.042 rad
sf5tilt = 0.04 rad
sd4tilt = 0.038 rad
sf1tilt = 0.032 rad
sd0tilt = 0.0071 rad

IP beam sizes for ATF2 Ultra-Low β^* using a SC QF1

$\sigma_{y,\ high} = 39.2$ nm ; $\sigma_{x,\ high} = 4.4\ \mu m$ (RMS)

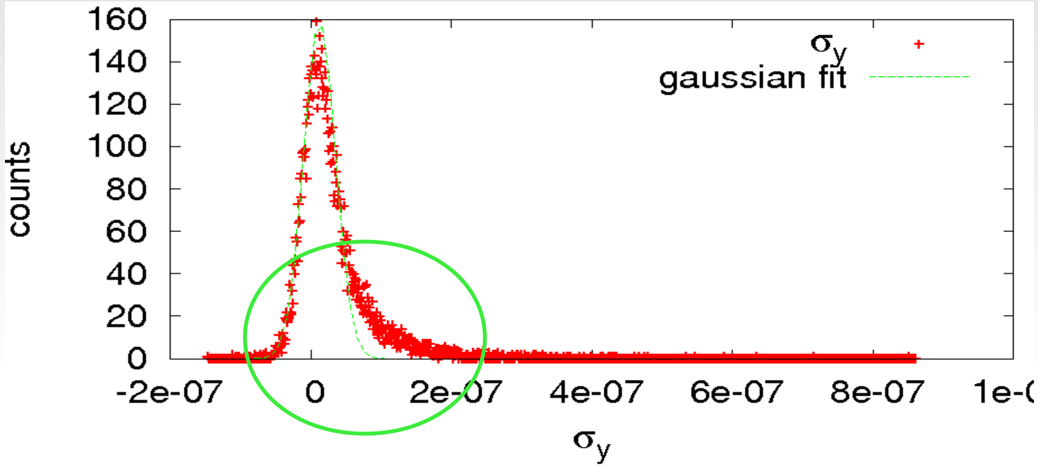
The octupole component needs to be decreased if we consider the RMS the as the criteria.



2.1.3. Comparison between RMS, Gaussian and Shintake beam size.

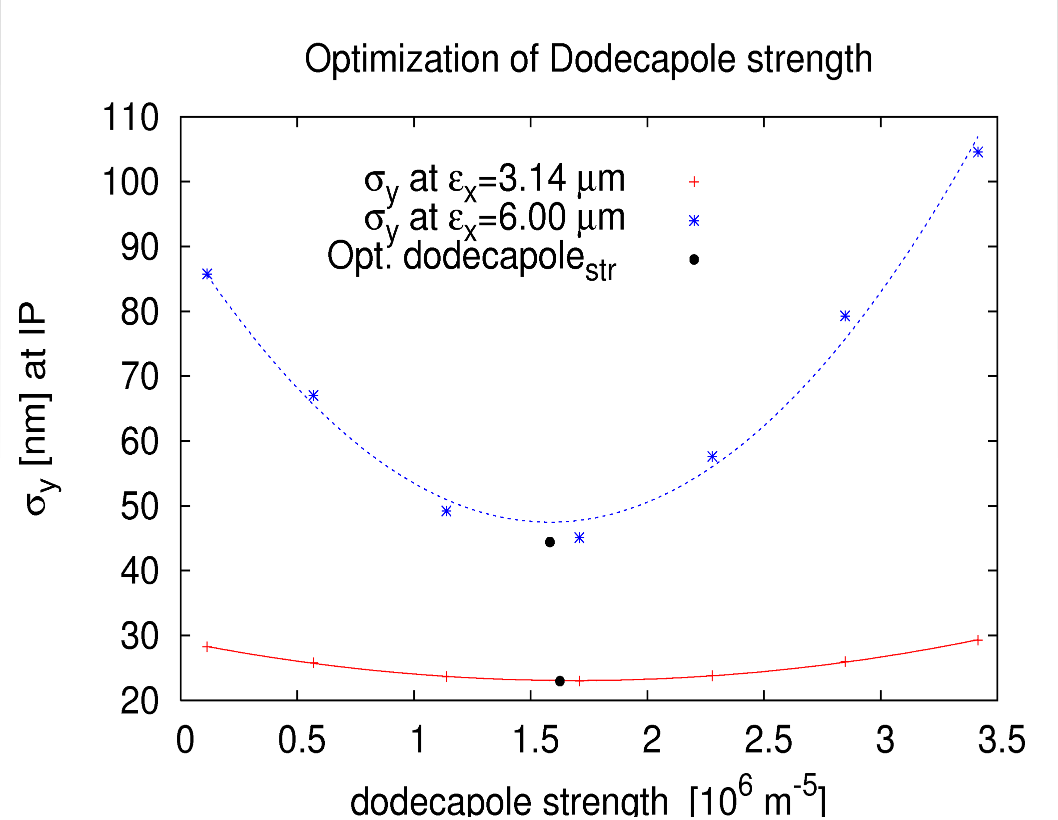
Tracking 10000 of particles through ATF2 Ultra-Low β^* considering a SC QF1

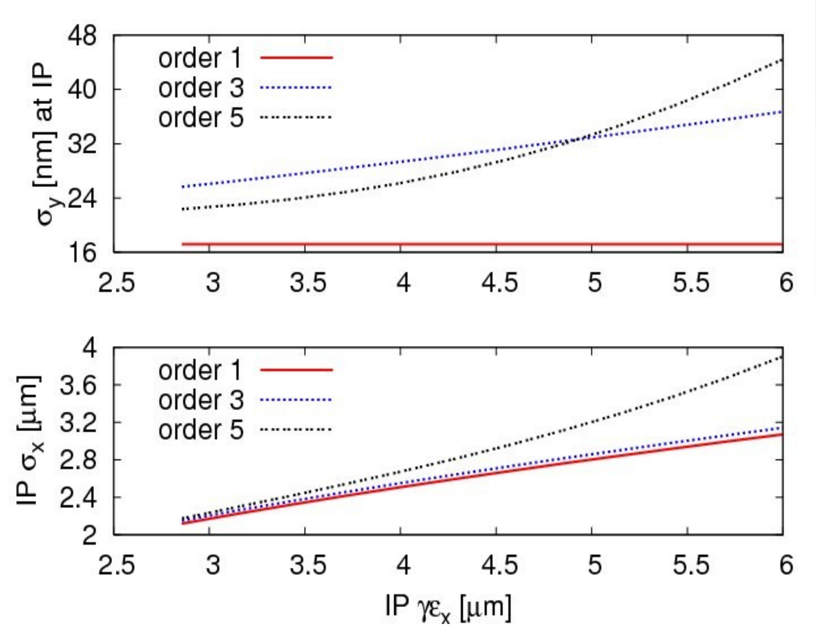
Need to define which is the criteria to follow in order to determine the tolerances for the multipoles.



RMS [nm]	Gaussian Fit [nm]	Particle within 1,2,3 Gaussian σ [%]			Shintake beam size [nm]	Particles within Shintake σ[%]
39.19	**21.83**	49	77	88	**26.52**	60

2.2. Dodecapole's Optimization





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

Optimum IP beam sizes @ IP (high ε):

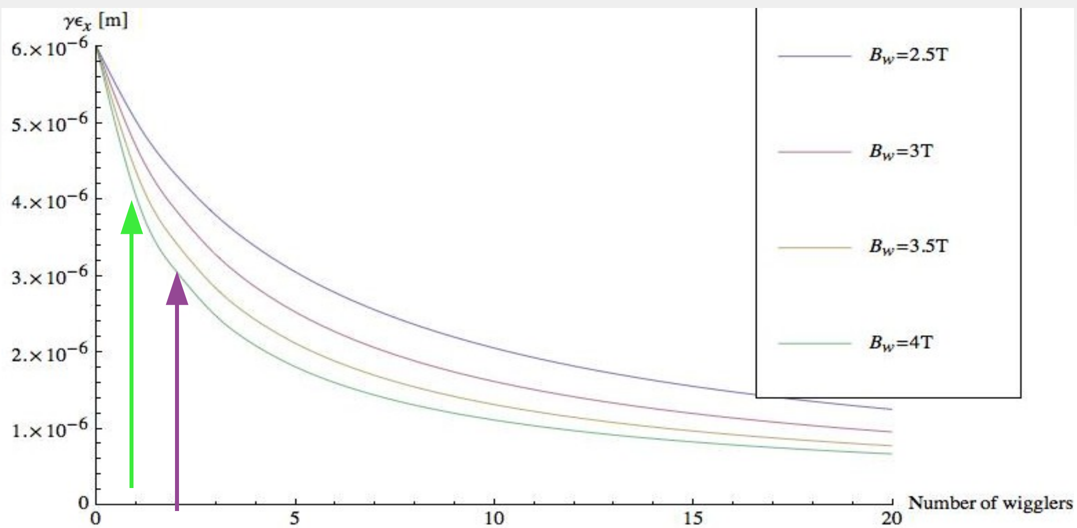
$\sigma_{y,\,high}$ = 44.4 nm ; $\sigma_{x,\,high}$ = 3.9 μm

2.3. Reduced ε_x from the DR.

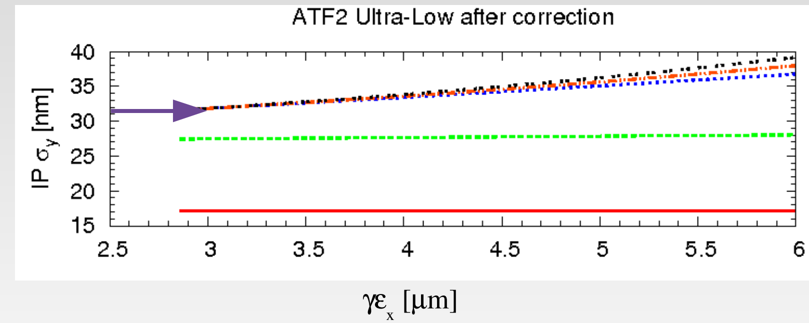
Introducing a SuperConducting Wiggler in the DR. 2 cases:

1 wiggler of 4 T reduces 30%

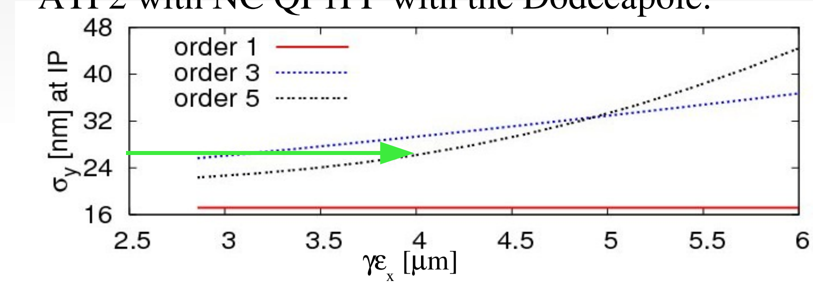
2 wigglers of 4 T reduces 50%



ATF2 with SC QF1FF after Correction:



ATF2 with NC QF1FF with the Dodecapole:



σ_y beam size @ IP for reduced ε_x:

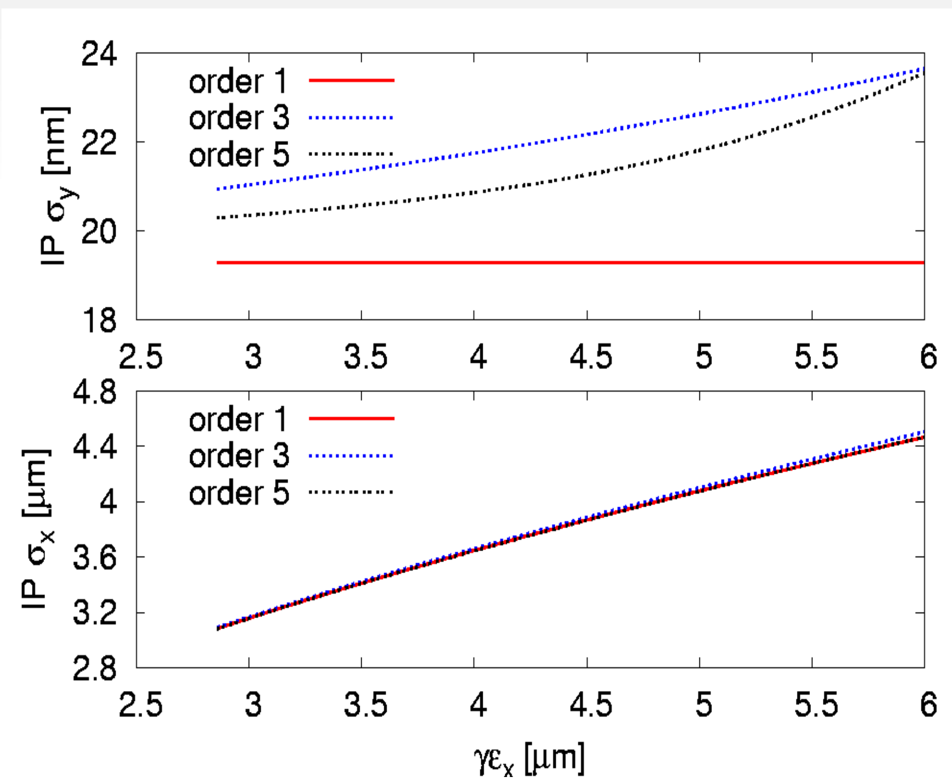
- ATF2 corrected: $\sigma_{y,\,50\%} = 31$ nm
- ATF2 with Dodecapole: $\sigma_{y,\,30\%} = 26$ nm

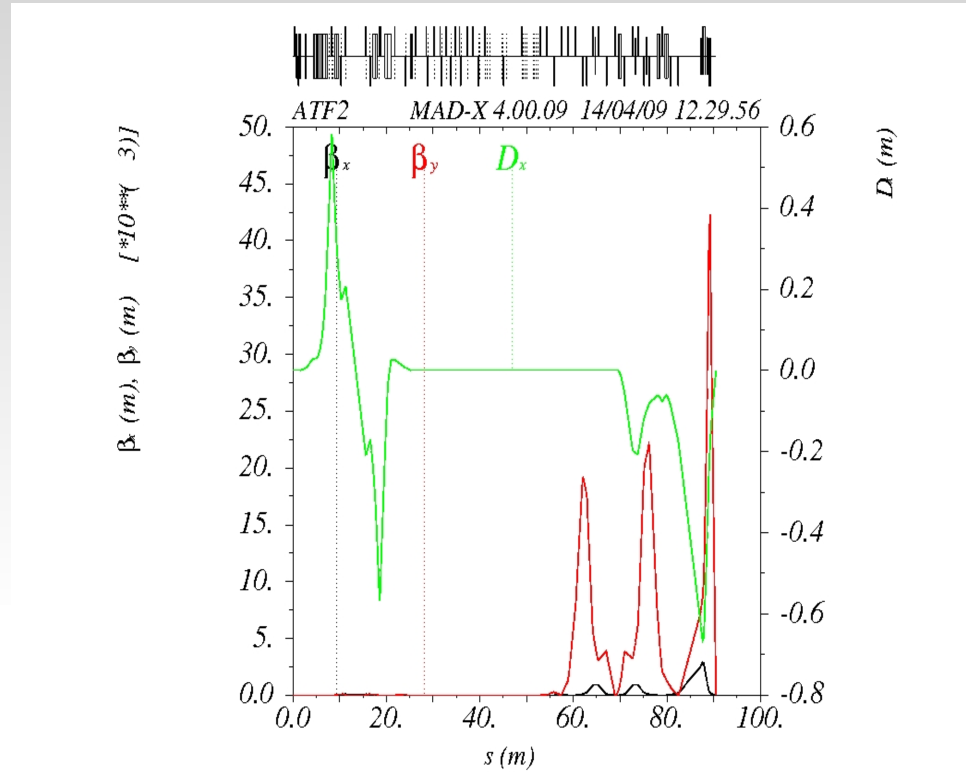
For further details see:

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

2.4 Minimizing the β_x function at QF1,

- Matching via Mad-x & Mapclass
  - Including Multipolar errors.
  - Constraints: increasing β_x @ IP
  - Variables: Quads & Sexts strengths & SF1 SD0 Tilts





Results:

- Beta functions @ IP:
  - β_x = 8.4608 mm ; β_y = 31.5727 µm
- Beam sizes @ IP (high ε_x):
  - σ_x = 4.4 µm ; σ_y = 23.8 nm

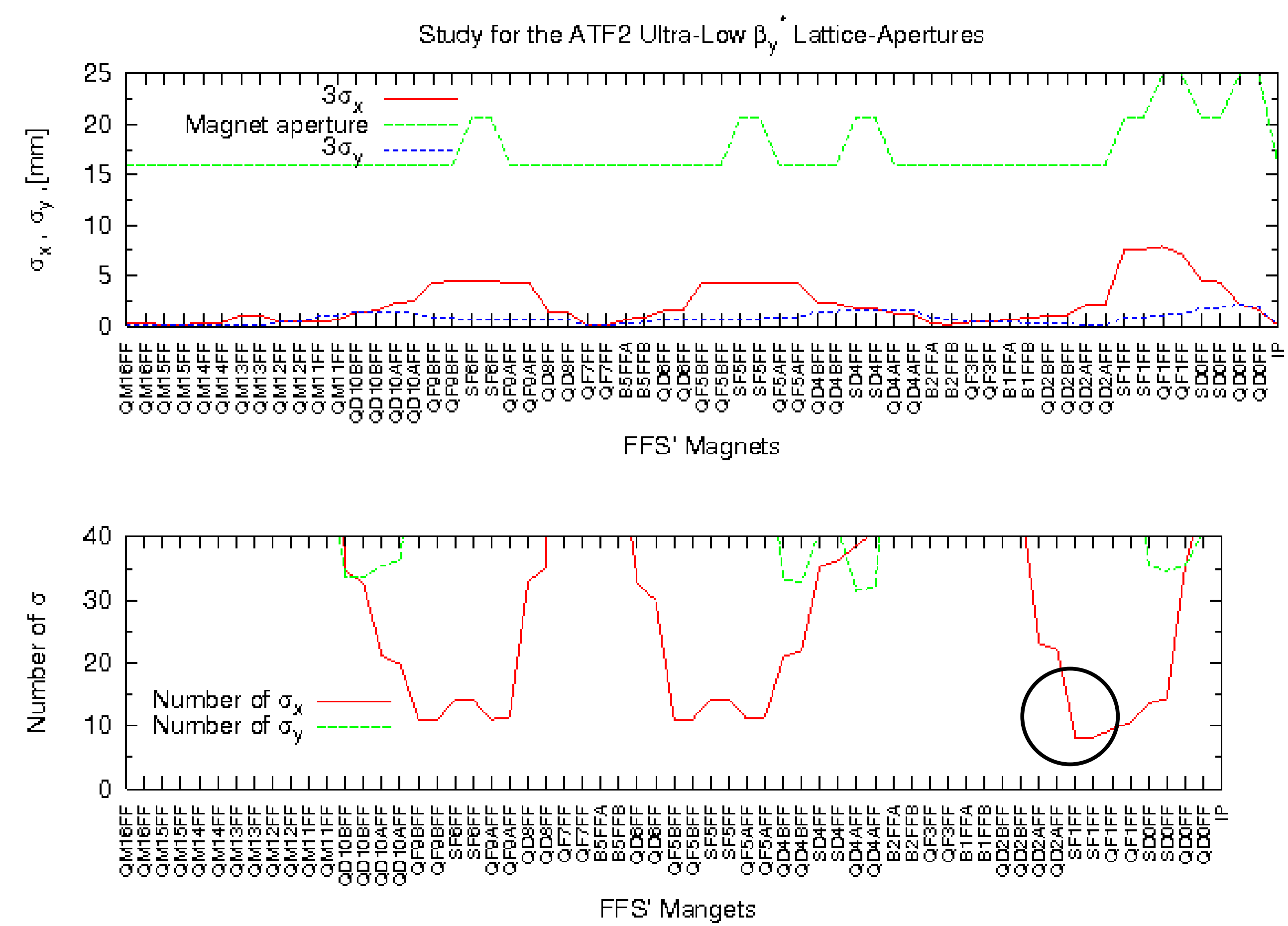
3.1.1. Magnet aperture according to beam Size

Radius of magnets:

Quads: 16mm.

Sexts: 20.6mm.

FD: 25mm.



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

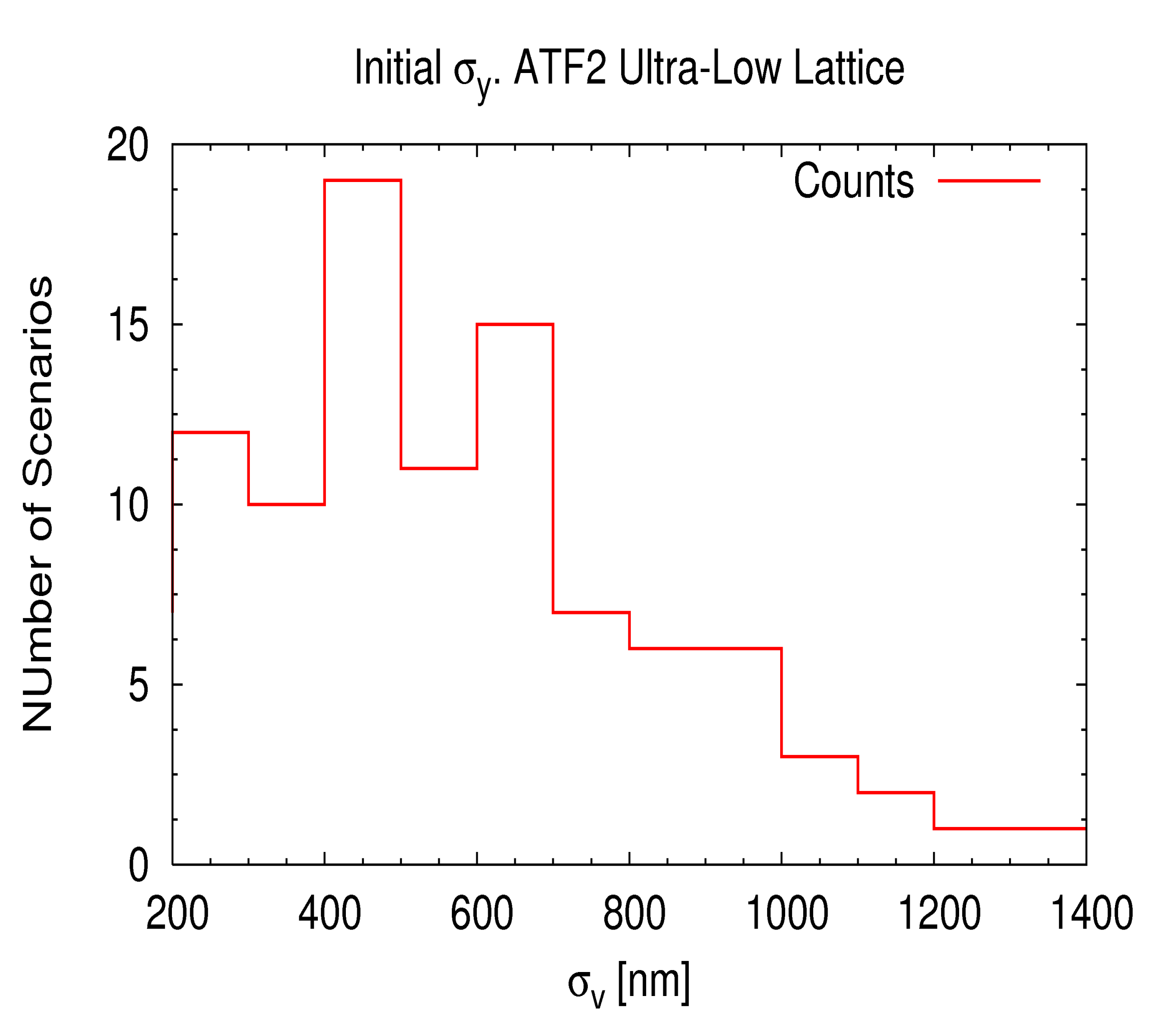
3.1.2. New currents required.

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

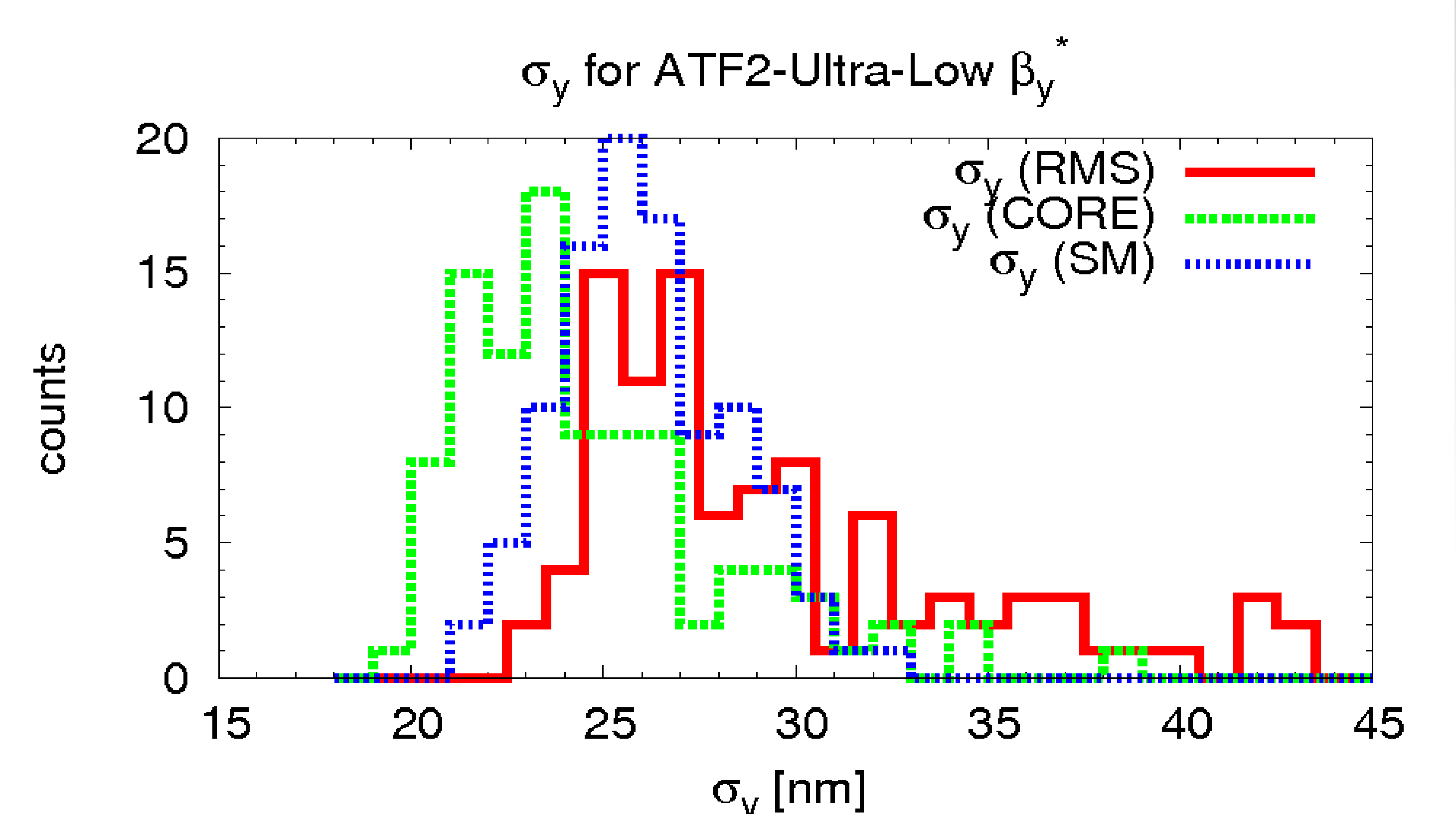
No significant changes are observed comparing with nominal values.

3.2.1. Considered errors in a preliminary Tuning.

- 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.



3.2.2. Tuning results in terms of RMS, Gaussian and Shintake.



RMS [nm]	Shintake [nm]	Gaussian [nm]
30 (73%)	**29 (88%)**	**27 (85%)**

4. CONCLUSIONS & FUTURE PLANS

- Using a SC QF1 the vertical beam size is reduced to 39 nm with respect to ~90 nm which correspond to nominal $\beta_x = 4$mm.
- Implementing a Dodecapole magnet reduces the vertical beam size to 44 nm.
- Inserting SC Wigglers reduce the emittances in such a way that both previous solutions satisfy the ATF2 Ultra-Low β^* goals.
- Combining SC QF1 with decreased β_x in QF1 expected to decrease σ_y much below 39 nm.
- Statistical preliminary Tuning Study shows that the 88% of the seeds reach a final vertical beam size $\sigma_y < 29$nm (Shintake Beam Size).

To be done...

- Study a combine solution with the SC QF1 and a reduced β_x at QF1.
- Study the impact of an Octupole magnet as a corrector for ATF2 with SC QF1FF.
- A more Realistic tuning, including: tilts, mispowerings, ground motion....