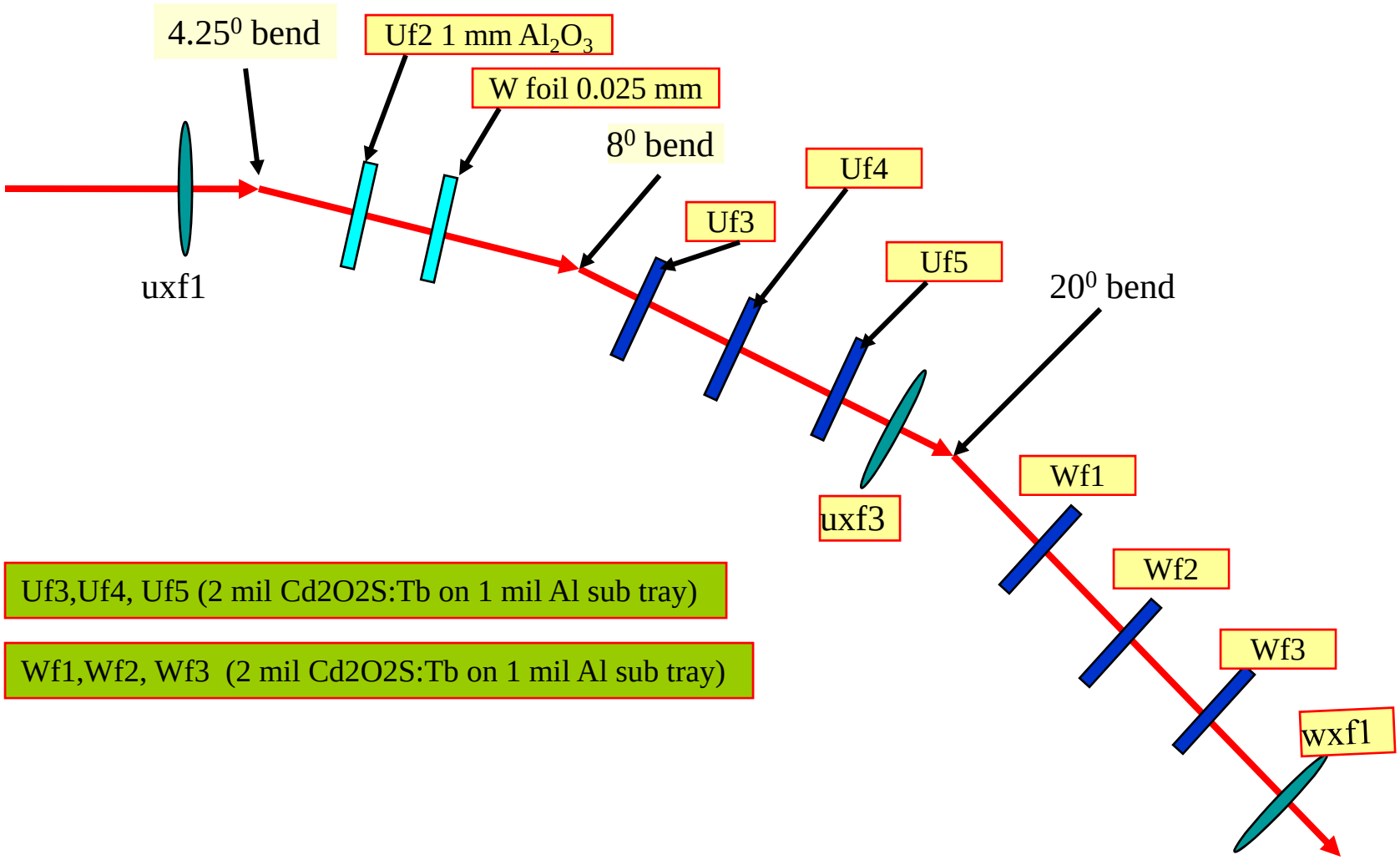
Proposed study in the AtR Line

- Type: Parasitic
- Why: To investigate non-linearities in the AtR combined function magnets.

N. Tsoupas, A. Jain, W. Glenn, W. W. MacKay, W. Meng, others…

Schematic arrangement of the U_line and W_line Flags that are used to measure the beam profiles



Uf3,Uf4, Uf5 (2 mil Cd2O2S:Tb on 1 mil Al sub tray)

Wf1,Wf2, Wf3 (2 mil Cd2O2S:Tb on 1 mil Al sub tray)

Why this Study?

Experimentally calc. Beam Parameters at Start of AtR

Theoretically calc. Beam Parameters at Start of AtR

Not always in agreement

Experimentally calc. Beam Parameters at Start of AtR Using U_line Flags

Experimentally calc. Beam Parameters at Start of AtR Using W_line Flags

- In an effort to explain the above observations we propose measurements to study the effects of non-linearities in the combined function magnets of AtR

In the rest of the presentation:

a) We show evidence of the allegations made above.

b) we provide proof that non-linearities in the combined function magnets of the AtR can actually cause these effects.

and:

c) MOST IMPORTANT:
Non-linearities in the magnets cause a miss-match of the injected beam in RHIC with the circulating beam

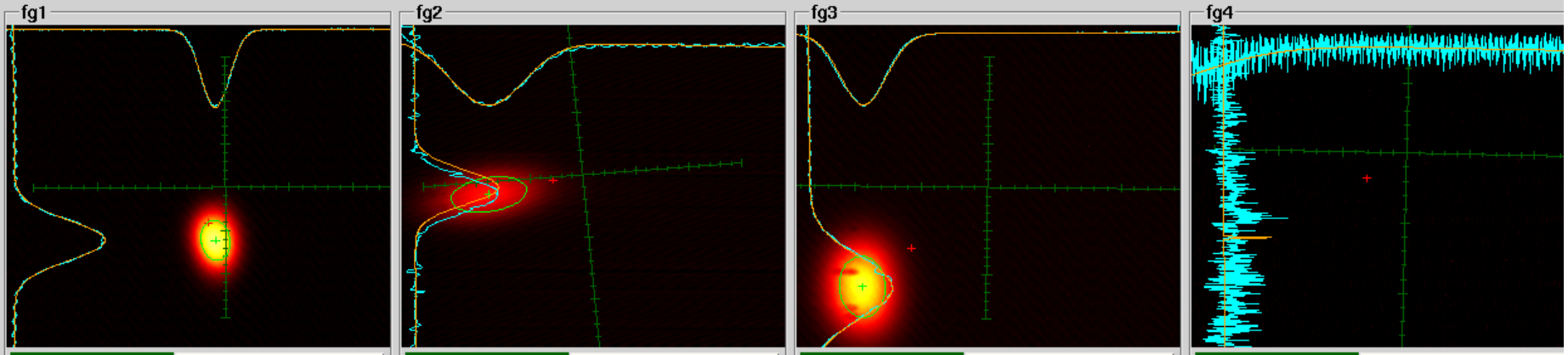
How we measure the beam parameters at the Start of the AtR? (next two slides)

Flag Profile Monitor

File Setup

Retract ATR Flags | Transformers | Flag Status | Open | Emit | Set U Flags | Set W Flags

ATR | SEB | HJET



	fg1	fg2	fg3	fg4
Flag	uf3	uf4	uf5	offLine
Plunger	In	In	In	Unknown
Lamp	Off	Off	Off	Off
Log Data	Enable	Enable	Enable	Disable

Intensity | Bkgd | ROI

Name	Value	+	−	Incr	fg1	fg2	fg3	fg4
Contrast					235	240	226	235
Brightness					115	115	65	115
Incr					1	1	1	1
					10	10	10	10
Xmission					0.68%	0.1292%	0.68%	100%

	fg1	fg2	fg3	fg4
Timestamp	15:47:43	15:47:43	15:47:43	15:38:36
Center [mm]	(−0.77327,−6.1254)	(−8.9887,−1.0249)	(−9.3375,−11.478)	(−24.218,−6.0223)
Sigma [mm]	(1.1208,2.3018)	(3.4512,1.3775)	(1.7207,3.4919)	(7.1127,0.042073)
Intensity	1223096	1538572	2591197	169112
Data Range	0 − 214	0 − 96	0 − 214	0 − 55

Warning -- Emit data exceeded table size, ignoring.
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Formalism to calculate the beam emittance and the beam parameters at the beginning of the AtR line

$$(\sigma_{11})_{out} = (R_{11})^2(\sigma_{11})_{in} + 2(R_{11})(R_{12})(\sigma_{12})_{in} + (R_{12})^2(\sigma_{22})_{in} + 2(R_{11})(R_{16})(\sigma_{16})_{in} + 2(R_{12})(R_{16})(\sigma_{26})_{in} + (R_{16})^2(\sigma_{66})_{in}$$

$$(\sigma_{33})_{out} = (R_{33})^2(\sigma_{33})_{in} + 2(R_{33})(R_{34})(\sigma_{34})_{in} + (R_{34})^2(\sigma_{44})_{in} + 2(R_{33})(R_{36})(\sigma_{36})_{in} + 2(R_{34})(R_{36})(\sigma_{46})_{in} + (R_{36})^2(\sigma_{66})_{in}$$

$$(\sigma_{11})_{out} = (R_{11})^2(\sigma_{11})_{in} + 2(R_{11})(R_{12})(\sigma_{12})_{in} + (R_{12})^2(\sigma_{22})_{in}$$
$$(\sigma_{33})_{out} = (R_{33})^2(\sigma_{33})_{in} + 2(R_{33})(R_{34})(\sigma_{34})_{in} + (R_{34})^2(\sigma_{44})_{in}$$

If the Location and the strength of the magnets in the AtR Line are known the calculated beam parameters and beam emittance depend on the measured “sigma’s” of the beam at the location of the flags.

$$\varepsilon_x = [\,(\sigma_{11})_{in}(\sigma_{22})_{in} - (\sigma_{12})_{in}^{\,2}\,]^{1/2}$$

$$(\beta_x)_{in} = [(\sigma_{11})_{in}] / [\,(\sigma_{11})_{in}(\sigma_{22})_{in} - (\sigma_{12})_{in}^{\,2}\,]^{1/2} = (\sigma_{11})_{in}/\varepsilon_x$$

$$(\alpha_x)_{in} = -[(\sigma_{12})_{in}] / [\,(\sigma_{11})_{in}(\sigma_{22})_{in} - (\sigma_{12})_{in}^{\,2}\,]^{1/2} = -(\sigma_{12})_{in}/\varepsilon_x$$

More details on What Prompted this Study

- Short term measurements yield same results on the calculated beam parameters from measured beam widths.
- Long term measurements may yield different results.
- The measured beam size depends on the location of the beam image on the flag. This affects the calculated emittance and beam parameters.

Short term measurements (~30 minutes time span)

#	bx(Strt) [m]	bx(Uf3) [m]	bx(Uf4) [m]	bx(Uf5) [m]	ax(Strt)	ax(Uf3)	ax(Uf4)	ax(Uf5)	sx(Uf3) [mm]	sx(Uf4) [mm]	sx(Uf5) [mm]	ex [pi.mm.mrad]	COMMENTS	Cntr
	37.5(5)	14.4(2)	50.6(11)	12.6(1)	-4.10(0.5)	1.20(0.3)	-1.94(0.4)	0.74(0.3)	1.73	3.24	1.62	15.1(2)	Theory	
	38.4	14.8	49.6	12.4	-4.19	1.23	-1.89	0.71	1.82	3.34	1.67	16.3	Fri Feb 18 2005 23:00	200(Uf4)
	37.9	14.6	51.4	12.5	-4.16	1.18	-1.95	0.75	1.75	3.29	1.62	15.3	Fri Feb 18 2005 23:00	200(Uf4)
	38.9	15.0	49.8	12.2	-4.27	1.23	-1.88	0.71	1.76	3.21	1.59	15.1	Fri Feb 18 2005 23:00	200(Uf4)
	35.1	13.5	55.9	13.4	-3.91	1.05	-2.15	0.87	1.66	3.37	1.65	14.7	Fri Feb 18 2005 23:00	200(Uf4)
	38.2	14.66	50.5	12.4	-4.18	1.21	-1.92	0.73	1.75	3.25	1.61	15.2	Fri Feb 18 2005 23:00	200(Uf4) Av
	35.6	14.9	44.9	13.0	-4.07	1.38	-1.80	0.61	1.67	2.90	1.56	13.6	Fri Feb 18 2005 23:00	195(Uf4)
	37.8	14.6	45.5	13.3	-3.98	1.36	-1.84	0.63	1.90	3.35	1.81	17.9	Fri Feb 18 2005 23:00	195(Uf4)
	41.8	16.1	44.8	11.7	-4.50	1.41	-1.68	0.59	1.94	3.23	1.65	16.9	Fri Feb 18 2005 23:00	195(Uf4)
	38.4	14.8	44.5	13.2	-4.03	1.39	-1.80	0.61	1.70	2.94	1.60	14.1	Fri Feb 18 2005 23:00	195(Uf4)
	38.1	14.6	53.0	12.4	-4.23	1.15	-1.98	0.78	1.81	3.44	1.66	16.2	Fri Feb 18 2005 23:00	200(Uf4)
	38.3	14.7	48.8	12.5	-4.15	1.25	-1.88	0.70	1.72	3.14	1.59	14.6	Fri Feb 18 2005 23:00	200(Uf4)

#	by(Strt) [m]	by(Uf3) [m]	by(Uf4) [m]	by(Uf5) [m]	ay(Strt)	ay(Uf3)	ay(Uf4)	ay(Uf5)	sy(Uf3) [mm]	sy(Uf4) [mm]	sy(Uf5) [mm]	ey [pi.mm.mrad]	COMMENTS	Cntr
	6.5(2)	52.4(4)	12.3(5)	51.5(10)	0.85(0.3)	-3.25(0.6)	0.41(0.2)	-2.31(0.4)	3.00	1.45	2.98	12.5(2)	Theory	
	9.4	30.9	14.7	87.3	1.70	-1.96	-0.06	-3.97	2.41	1.66	4.06	13.7	Fri Feb 18 2005 23:00	200(Uf4)
	9.2	30.7	15.9	90.1	1.73	-2.03	-0.04	-4.01	2.31	1.66	3.95	12.7	Fri Feb 18 2005 23:00	200(Uf4)
	9.6	29.9	15.2	90.6	1.76	-1.92	-0.09	-4.10	2.27	1.62	3.95	12.5	Fri Feb 18 2005 23:00	200(Uf4)
	9.8	30.1	14.4	89.3	1.75	-1.88	-0.10	-4.10	2.29	1.59	3.94	12.6	Fri Feb 18 2005 23:00	200(Uf4)
	9.5	30.3	15.0	89.4	1.74	-1.94	-0.08	-4.05	2.3	1.62	3.96	12.7	Fri Feb 18 2005 23:00	200(Uf4) Av
	11.1	29.8	12.6	91.2	1.84	-1.67	-0.20	-4.37	2.16	1.40	3.78	11.4	Fri Feb 18 2005 23:00	195(Uf4)
	10.3	30.2	13.3	88.6	1.76	-1.79	-0.14	-4.16	2.30	1.53	3.94	12.7	Fri Feb 18 2005 23:00	195(Uf4)
	10.6	30.2	12.9	89.1	1.78	-1.75	-0.17	-4.23	2.38	1.56	4.09	13.6	Fri Feb 18 2005 23:00	195(Uf4)
	10.3	29.8	13.6	89.9	1.78	-1.78	-0.15	-4.21	2.21	1.49	3.83	13.6	Fri Feb 18 2005 23:00	195(Uf4)
	9.6	30.1	14.8	89.5	1.75	-1.91	-0.09	-4.08	2.35	1.65	4.06	13.3	Fri Feb 18 2005 23:00	200(Uf4)
	9.7	29.7	14.9	90.8	1.78	-1.88	-0.10	-4.14	2.18	1.54	3.81	11.6	Fri Feb 18 2005 23:00	200(Uf4)
	9.6	30.8	14.3	87.3	1.70	-1.92	-0.08	-4.00	2.39	1.63	4.02	13.4	Fri Feb 18 2005 23:00	200(Uf4)
	10.0	30.7	13.6	87.1	1.72	-1.85	-0.11	-4.06	2.48	1.65	4.17	14.5	Fri Feb 18 2005 23:00	200(Uf4)

What Prompted this Study?

- Long term measurements may yield different results in the measurements of beam emittance and beam parameters.

Long term measurements (~Few months time span) pp06

Date	ε_x π[mm.mrad]	β_x [m]	α_x	ε_x π[mm.mrad]	β_x [m]	α_x
Feb. 07 06	15.8	24.1	-3.1	26.8	13.3	1.9
Mar. 17 06	15.9	42.8	-5.1	26.5	9.9	1.3

The measured beam emittance and beam parameters depend on the location of the beam image on the flags.

W_flags Run-pp06

DHT2 [mrad]	ε_x π[mm.mrad]	β_x [m]	α_x	ε_x π[mm.mrad]	β_x [m]	α_x
0.000	7.0	18.4	-2.3	11.0	5.5	1.05
0.025	8.0	16.9	-1.8	13.3	5.5	0.63
0.075	7.7	14.9	-1.85	13.0	6.7	1.26
0.125	6.2	24.8	-3.07	8.7	3.9	0.65
0.175	7.2	15.0	-1.71	12.3	5.7	0.90

Possible explainations on what may affect the measured beam emittance and beam parameters.

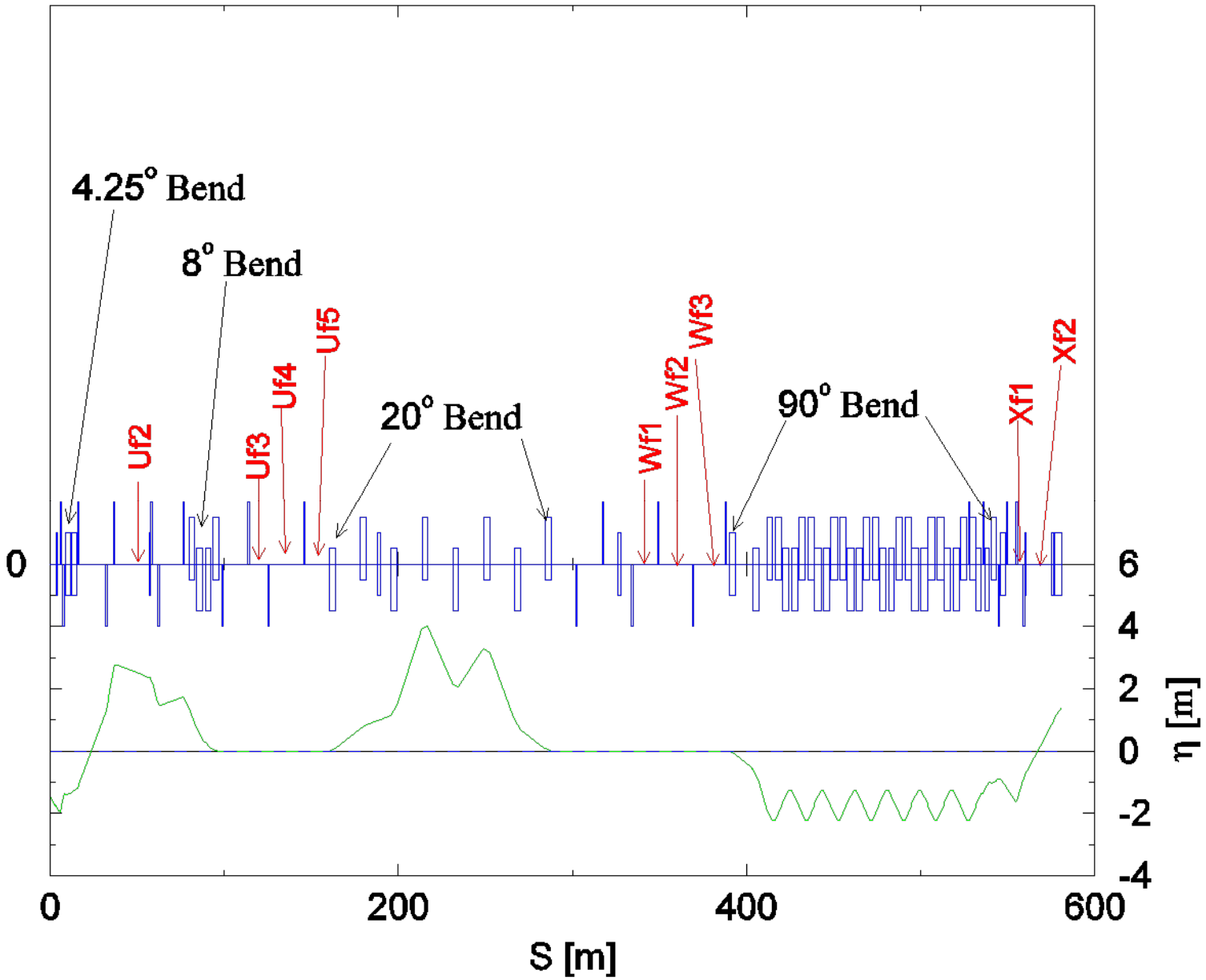
- The beam trajectory in the AtR line, under the assumption that the magnets are not “linear”. Mainly the Combined Function dipole magnets.

- Random errors in the magnetic field settings of the AtR magnets

- Misalignment of the AtR Magnets.

Effect of “K2 component” of the 8° bend on the beam parameters at the Start of the AtR (next six slides)

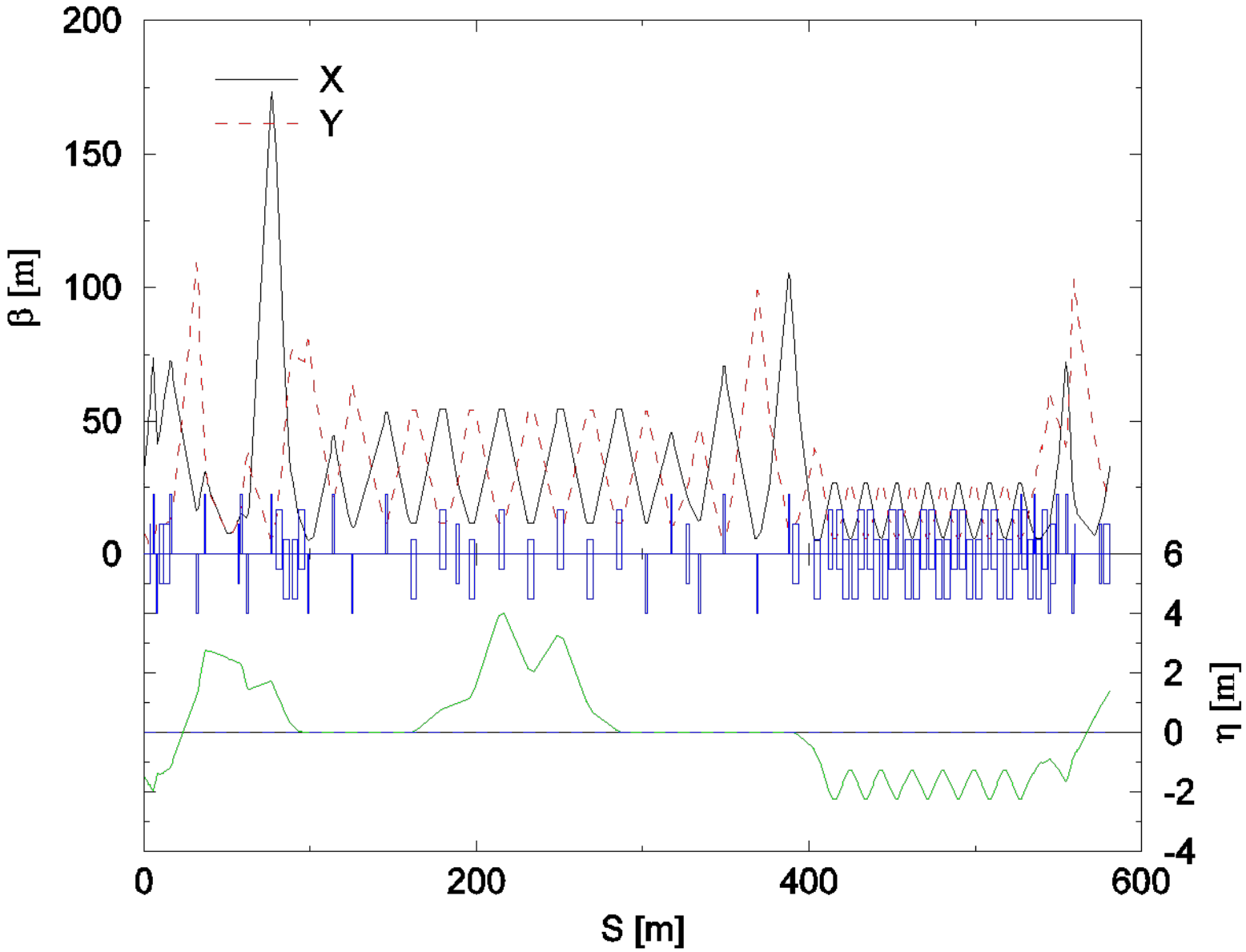
Location of the Combined Function Magnets and of the AtR Flags



Bends of the AtR line

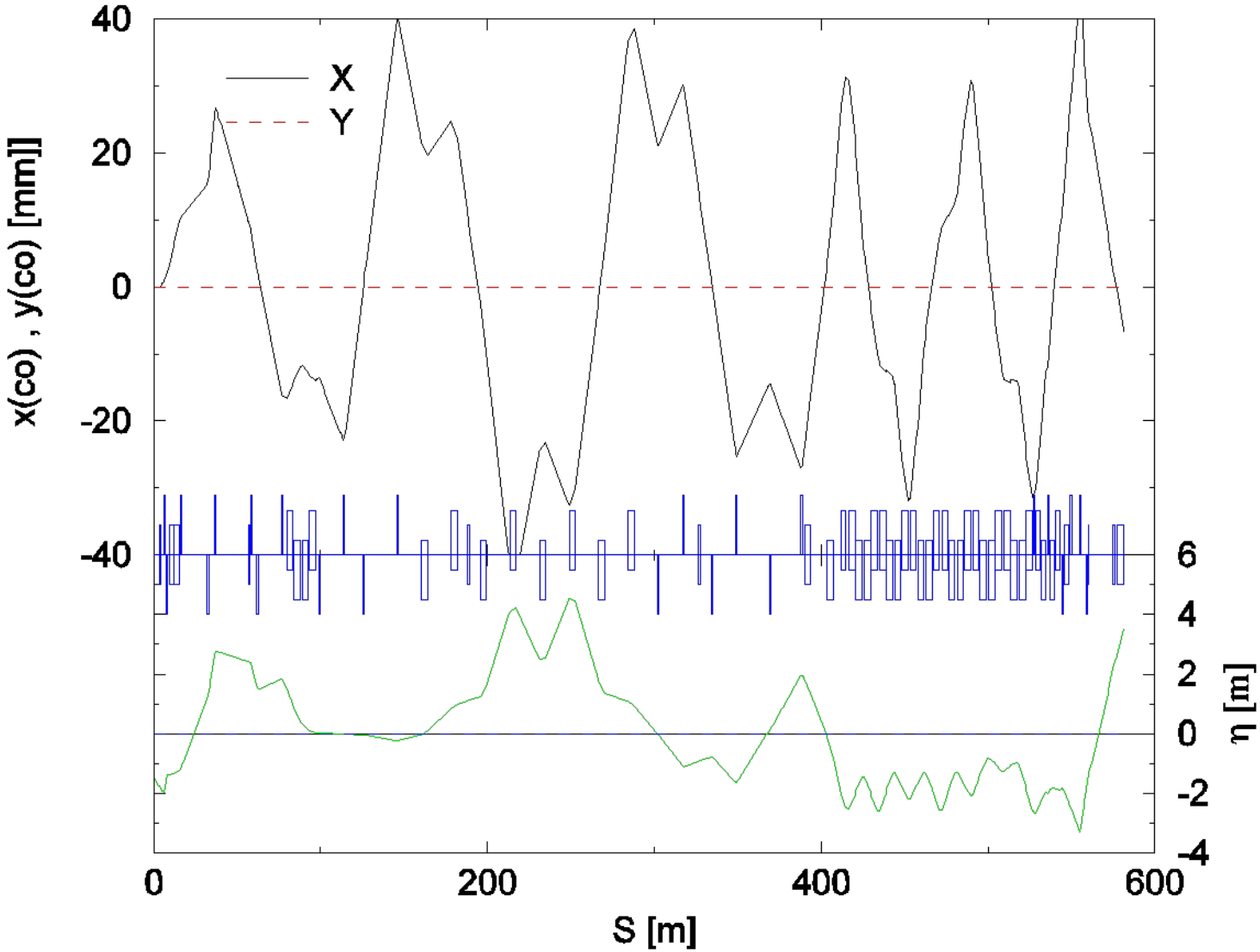
Bend Name	Angle[^{o}]	No of Mag.	Dipole type	Type	Gap [mm]	K0 [rad]	K1 [m^{-2}]	K2 [m^{-3}]
Four deg.	4.25^o	2	Uniform	A	38.5	0.0376	0.0000	0.00
Eight deg.	8°	4	Cf	C	39	0.0349	0.01882	??
Twenty deg.	20°	8	Cf	C	39	0.04363	0.02352	??
Ninety deg.	86.25^o	1	Uniform	Switch		0.04769	0.0000	0.00
		29	Cf	C	32	0.04815	0.03809	??
		1	Uniform	A	29	0.04280	0.0000	0.00

Beta and dispersion functions the AtR Line



Assume a value of $K2=0.015\ [m^{-3}]$ in the combined function magnets

X_{disp} with corrector UTH2 = +0.75 mrad



$\beta_{x,y}$, $\eta_{x,y}$, and σ_x as function of UTH2 strength

Flag	UTH2 [mrad]	β_x [m]	η_x [m]	σ_x [mm]	β_y [m]	η_y [m]	σ_y [mm]
Uf3	-0.75	16.573	0.048	1.314	77.275	0.000	2.837
UF3	0.00	13.048	0.000	1.166	56.593	0.000	2.428
Uf3	0.75	9.883	-0.040	1.015	41.573	0.000	2.081
Uf4	-0.75	36.418	0.160	1.951	13.445	0.000	1.183
Uf4	0.00	50.445	0.000	2.292	12.307	0.000	1.132
Uf4	0.75	70.500	-0.211	2.714	13.622	0.000	1.191
Uf5	-0.75	12.024	0.016	1.119	38.408	0.000	2.000
Uf5	0.00	12.664	0.000	1.149	51.375	0.000	2.313
Uf5	0.75	16.145	-0.045	1.297	70.419	0.000	2.708

Calculated beam emitances and beam parameters at AtR_Start for two different beam trajectories

UTH2 [mrad]	ε_x π[mm.mrad]	β_x [m]	α_x	β_y [m]	α_y	Flags
0.00	15.00	31.39	-3.04	7.92	0.99	U_line
0.75	15.01	24.43	-2.57	10.54	1.47	U_line
0.00	15.00	31.55	-3.06	7.96	0.99	W_line
0.75	16.90	29.95	-2.95	11.04	1.52	W_line

Effect of non-linearities of the 8° bend on the beam parameters at the Start of the AtR (next two slides)

Model one of the 8° combined function magnet (Whuzeng Meng) opera code.

The R_matrices of the 8° AtR bend are calculated for three possible AtR trajectories.

$\beta_{x,}$ at UF4 location as function of UTH2 strength

Flag	UTH2 [mrad]	β_x [m]	β_y [m]	Comments
Uf4	1.00	55.86	11.1	3Dcalc
Uf4	0.00	50.64	10.7	3Dcalc
Uf4	-100	27.34	10.1	3Dcalc

Effects of Random Magnet errors and Magnets misalignments on the measured beam emittance and beam parameters

Calculated emittances and beam parameters at the beginning of the AtR line with the calculated errors. The errors were caused by assuming a ±0.5% random error in the settings of the AtR magnets.

E_x π[mm.mrad]	β_x [m]	α_x	E_x π[mm.mrad]	β_x [m]	α_x
15.0±0.15	31.4±0.3	-3.04±0.03	15.0±0.2	7.9±0.1	0.99±0.02

Last but NOT least the effect of the non-ideal beam trajectory at the beam parameters and dispersion at the RHIC injection point

UTH2 [mrad]	β_x [m]	η_x [m]	σ_x	β_y [m]	α_y	Loc.
-0.75	36.8	-3.5	3.2	21.2	-0.02	XEND
0.00	33.3	1.4	2.1	18.6	0.02	XEND
0.75	28.4	6.1	4.6	15.7	0.06	XEND

Conclusions

- There is evidence of non-linearities in the combined function magnets of the AtR line
  - It affects the measured values of the beam parameters.
- Random magnets errors of ±0.5% in the settings of the AtR magnets does not affect significantly the measured values of the beam emittances and beam parameters.
- Same is true (no big effect) for magnet misalignments:
  - $\{\Delta x, \Delta y, \Delta S\} = \pm 0.75$ [mm]
  - $\{\Delta\theta, \Delta\phi, \Delta\psi\} = \pm 0.75$ [mrad]