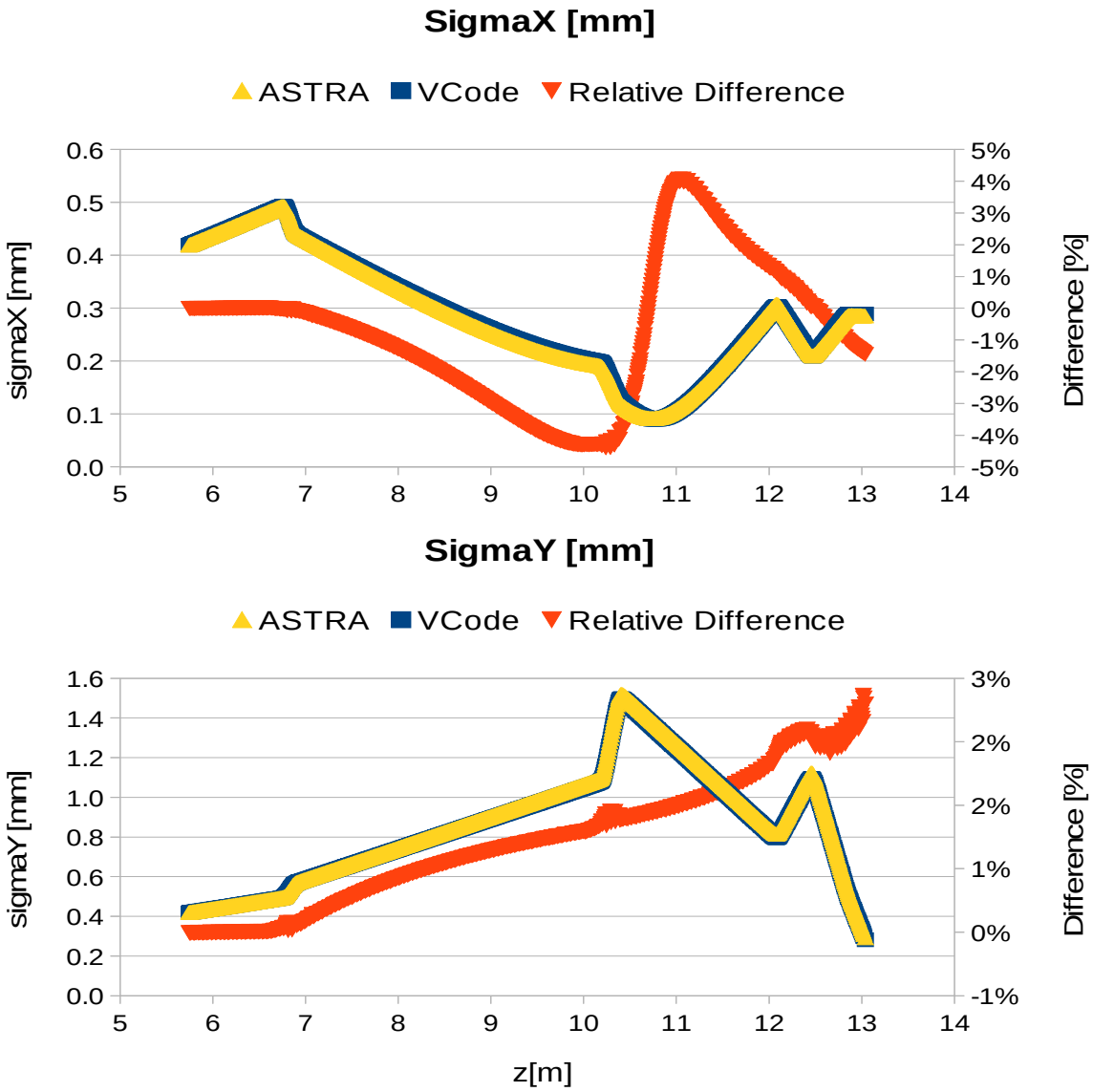
ASTRA Vs. VCode
(Vs. MAD) in the matching section

PPS 24.10.13

G. Kourkafas

NO SPACE CHARGE TRACKING - MATCHING FROM MEASUREMENT

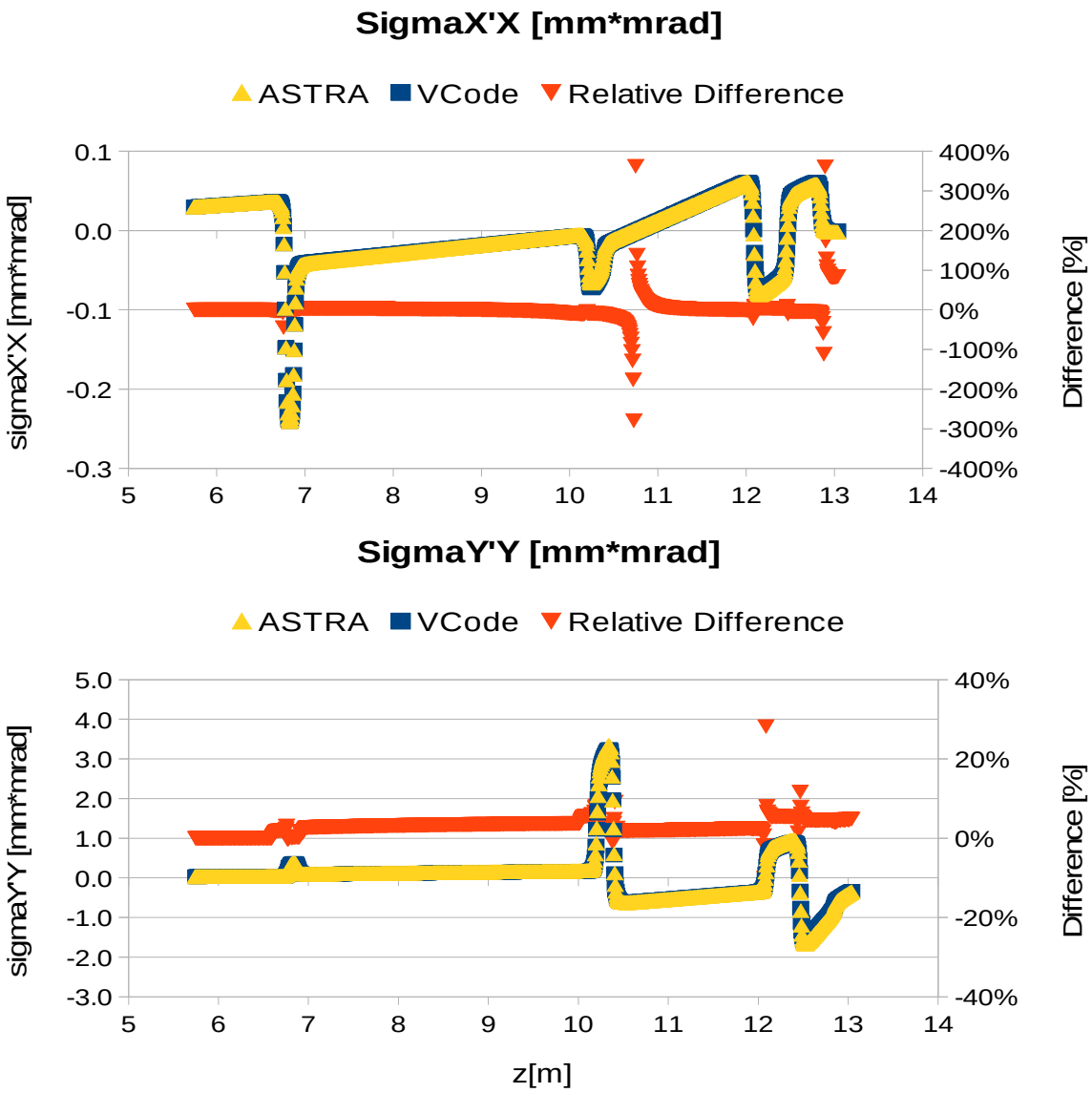
Beam size from EMSY1 to PST.Scr2



~-2% difference at PST (0.285/0.289)

~3% difference at PST (0.290/0.282)

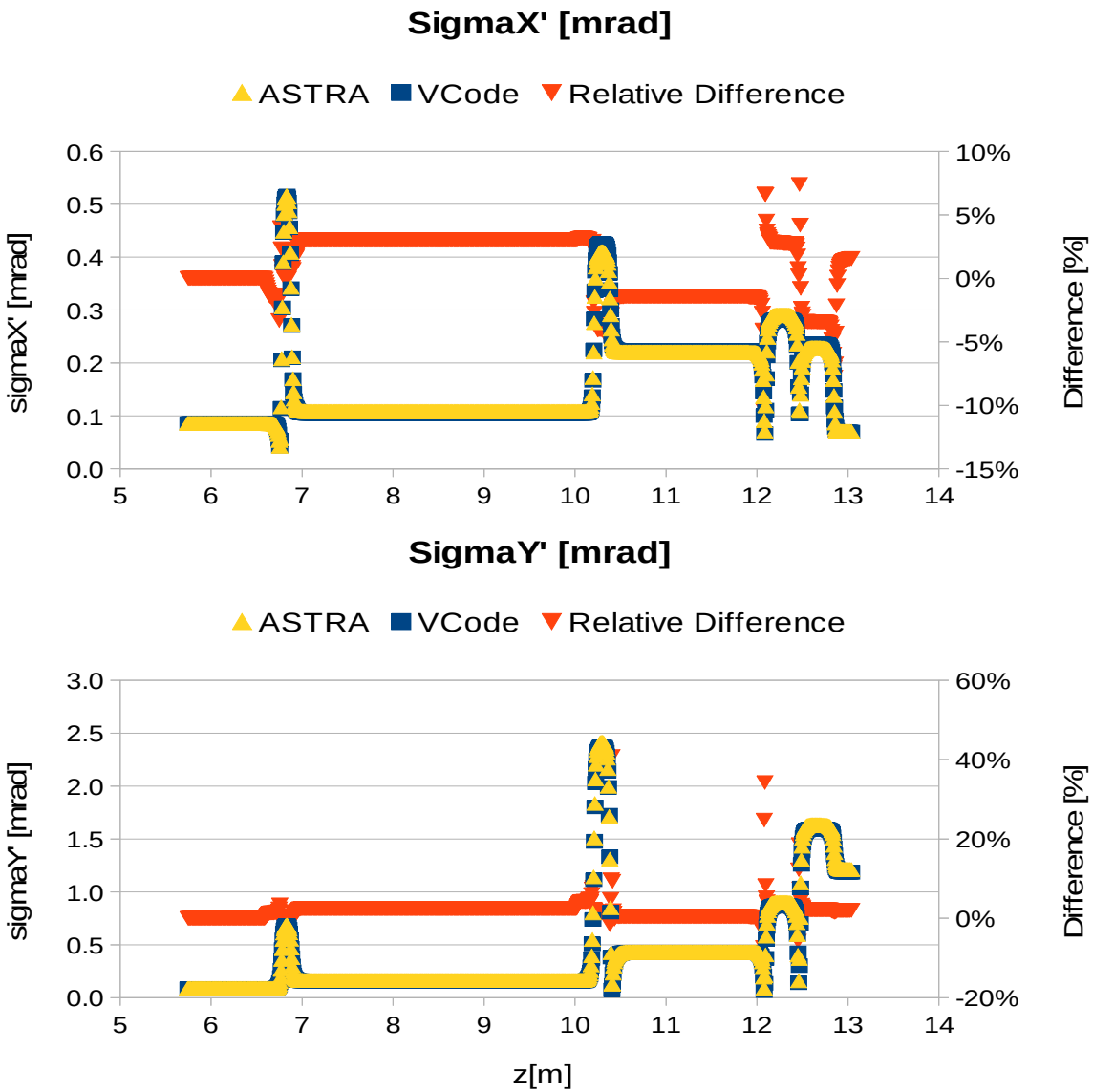
Covariance from EMSY1 to PST.Scr2



~84% difference at PST (-0.002/0.000)

~5% difference at PST (-0.351/-0.334)

Divergence from EMSY1 to PST.Scr2

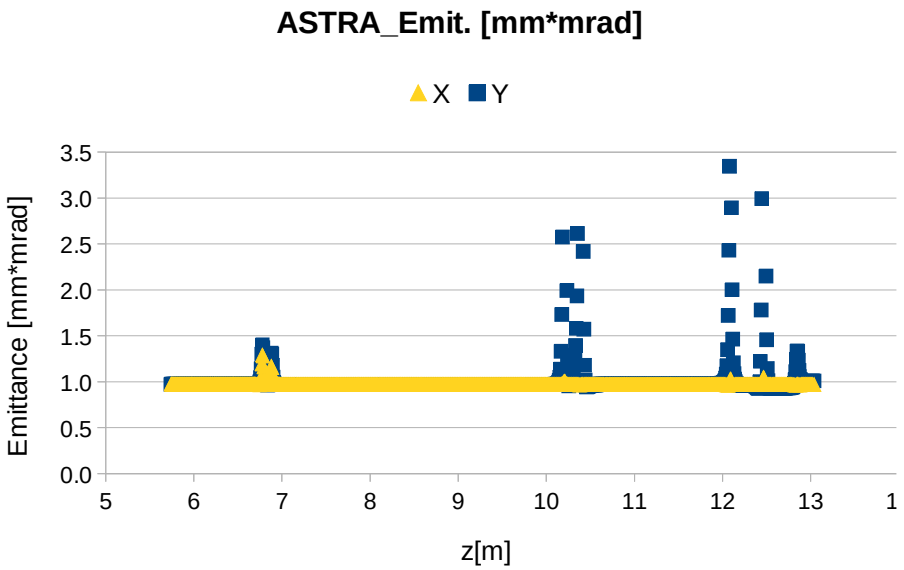


~2% difference at PST (0.071/0.070)

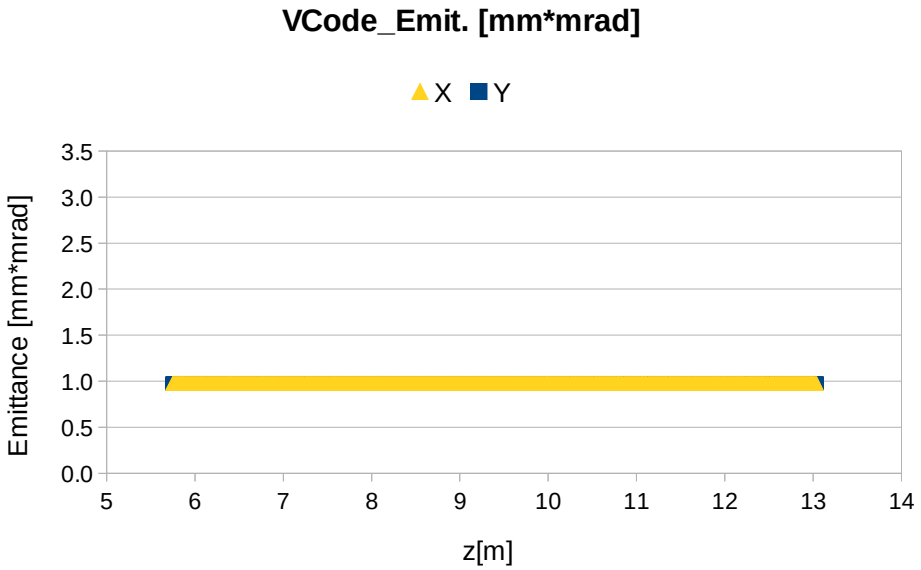
~2% difference at PST (1.210/1.185)

Emittance

@PST.Scr2:
X=0.969 / Y=1.009 mm*mrad



@PST.Scr2:
X=0.972 / Y=0.972 mm*mrad



- **Emittance stays (almost) constant in both codes**
- **Which is the reason for the small increase in ASTRA for Y-plane? Why do the emittance jumps in the quadrupoles differ for each plane? Is it due to the coupling terms?**

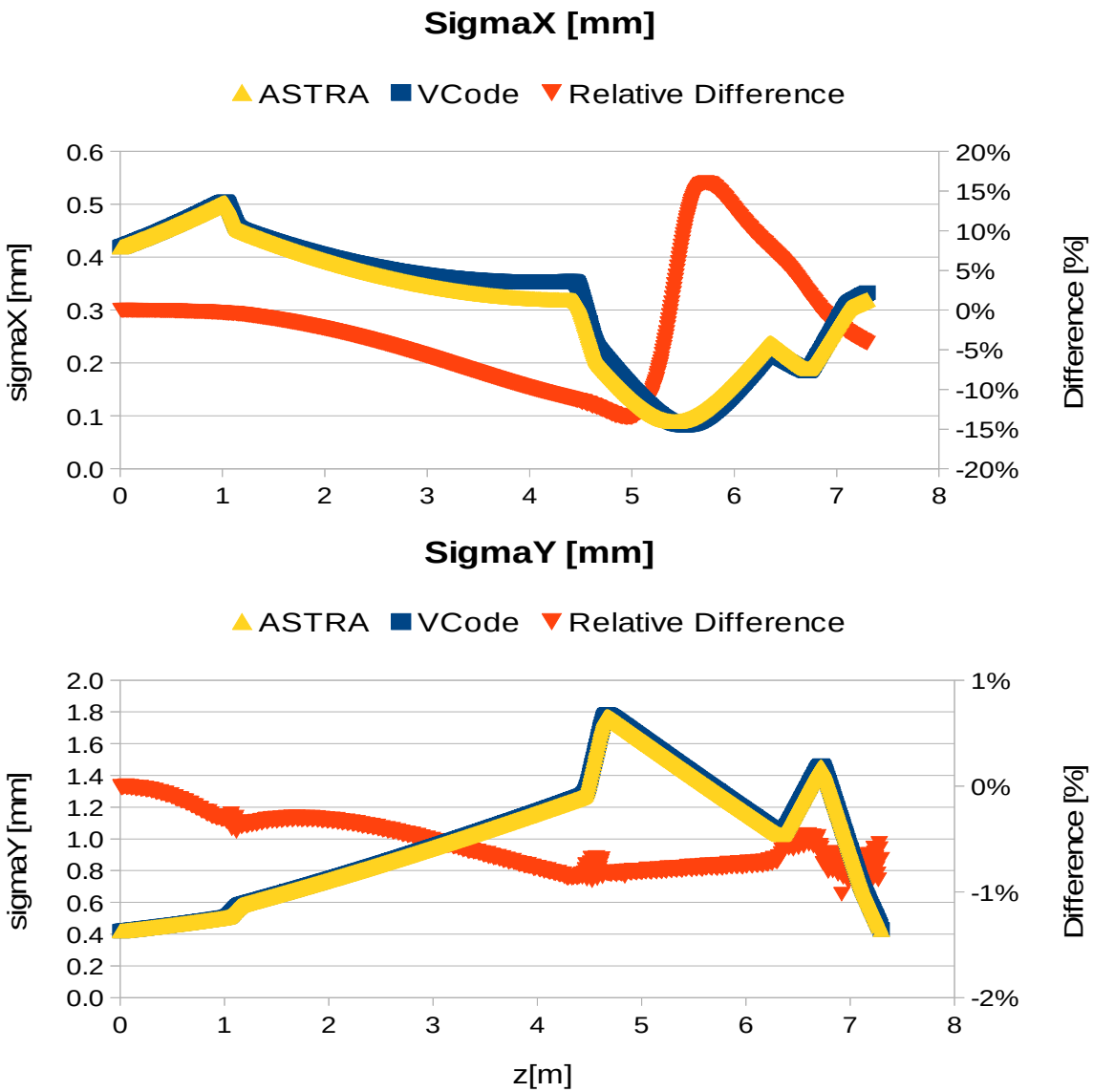
Errors w.r.t. ASTRA (no sp. charge)

	ASTRA Vs. VCode	ASTRA Vs. MAD
xx	-2% (0.285/0.289)	6% (0.285/0.269)
x'x	84% (-0.002/0.000)	-265% (-0.002/-0.007)
yy	3% (0.290/0.282)	17% (0.290/0.241)
y'y	5% (-0.351/-0.334)	15% (-0.351/-0.297)
$beta_x$	-3% (4.045/4.149)	11% (4.045/3.600)
$alpha_x$	84% (0.098/0.016)	-270% (0.098/0.363)
$beta_y$	2% (4.033/3.949)	29% (4.033/2.879)
$alpha_y$	1% (16.765/16.563)	12% (16.765/14.752)

- **VCode results (rough 2nd order tracking) are closer to ASTRA than MAD results → reason: thick quadrupoles?**

TRACKING WITH SPACE CHARGE - MATCHING FROM MEASUREMENT

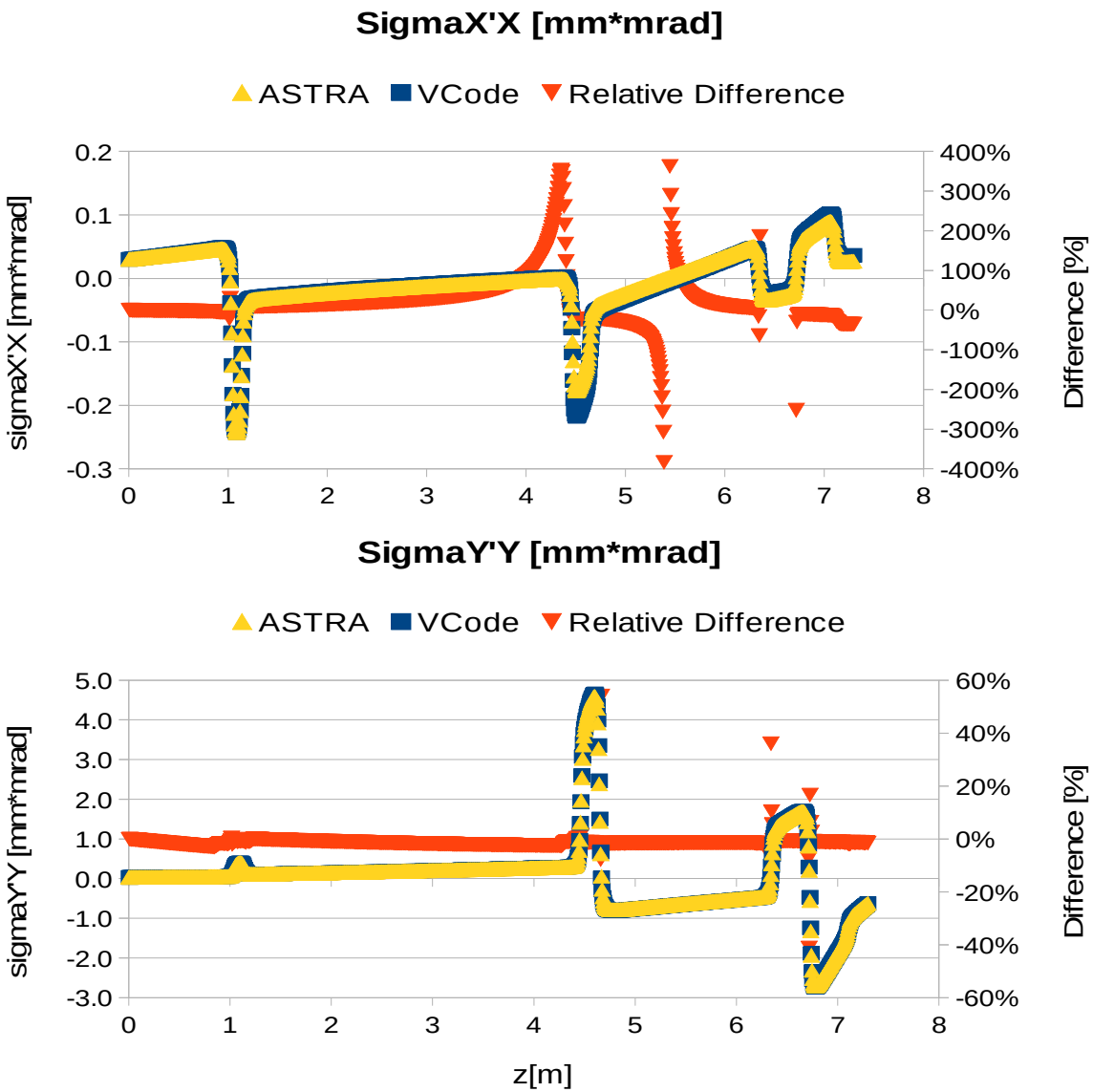
Beam size from EMSY1 to PST.Scr2



~-4% difference at PST (0.320/0.333)

~-1% difference at PST (0.427/0.429)

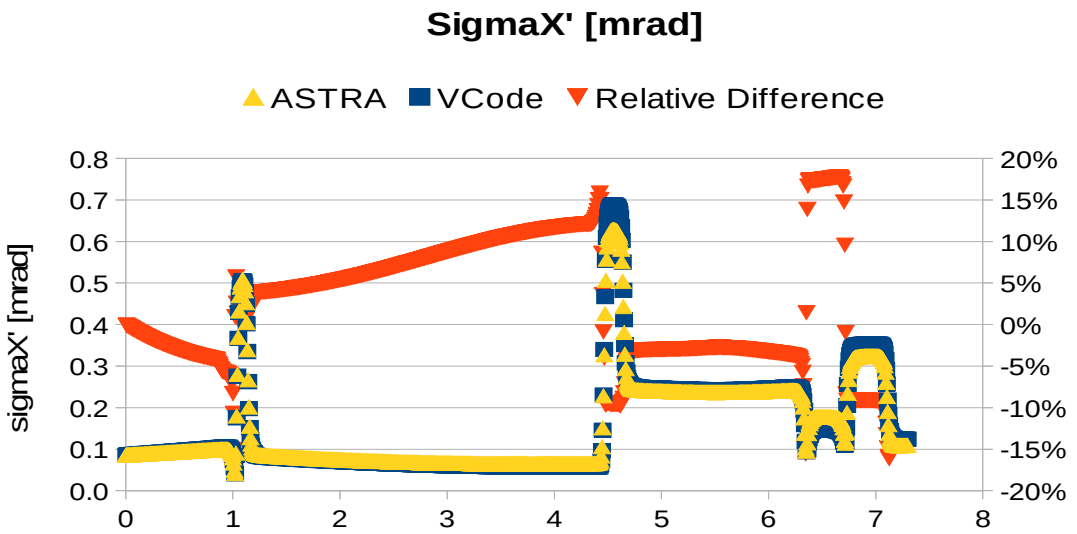
Covariance from EMSY1 to PST.Scr2

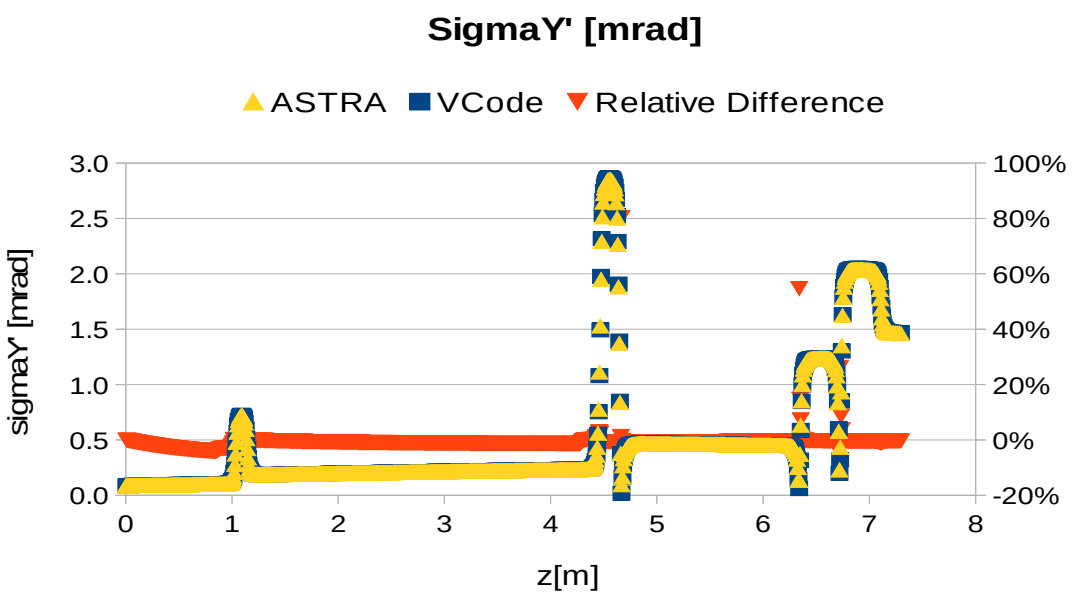


~-35% difference at PST (0.027/0.036)

~-2% difference at PST (-0.620/-0.629)

Divergence from EMSY1 to PST.Scr2



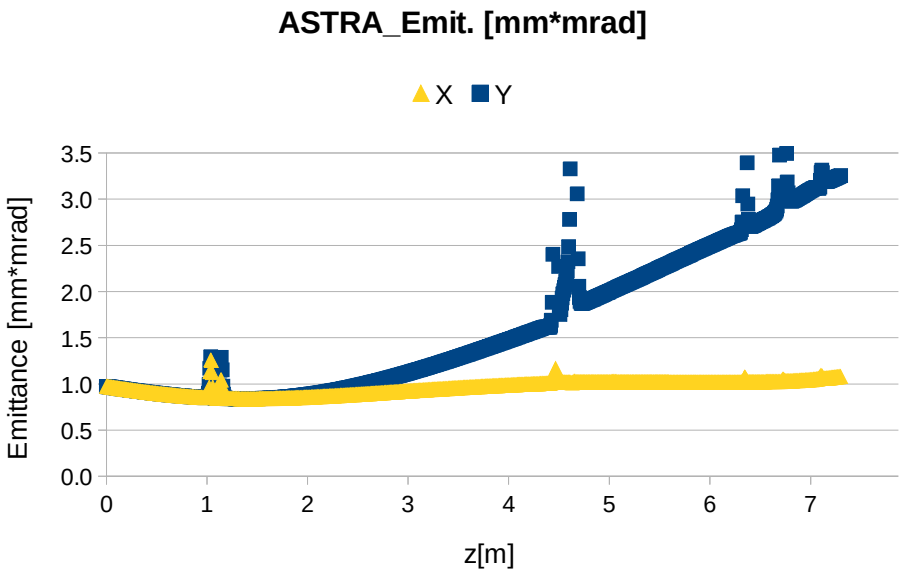


~-14% difference at PST (0.109/0.125)

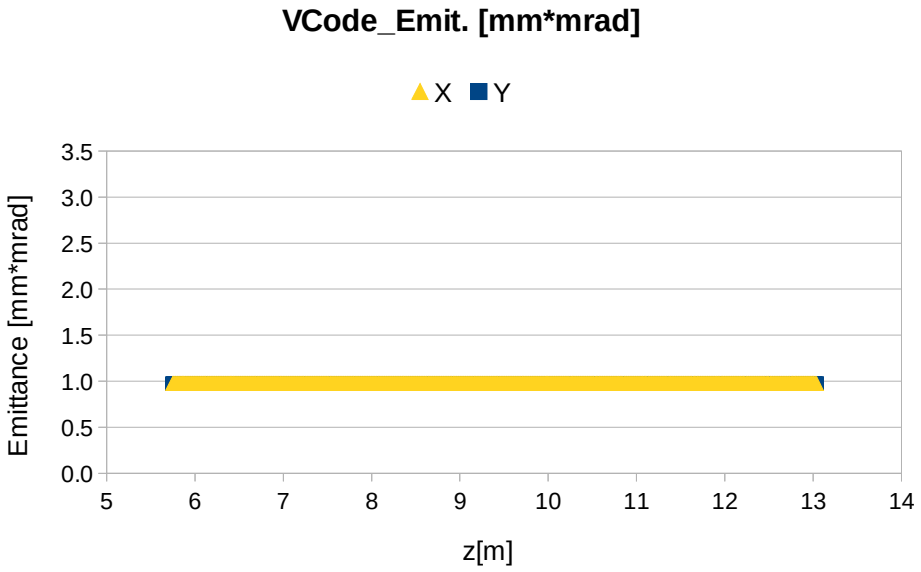
~0% difference at PST (1.459/1.465)

Emittance

@PST.Scr2:
X=1.081 / Y= 3.256 mm*mrad



@PST.Scr2:
X=0.972 / Y=0.972 mm*mrad



- **Big emittance increase in ASTRA**
- **Constant emittance in Vcode**
  (slight emittance increase in VCode when considering the moments up to 4th order: up to 1.1 mm*mrad)

Errors w.r.t. ASTRA (sp. charge ON)

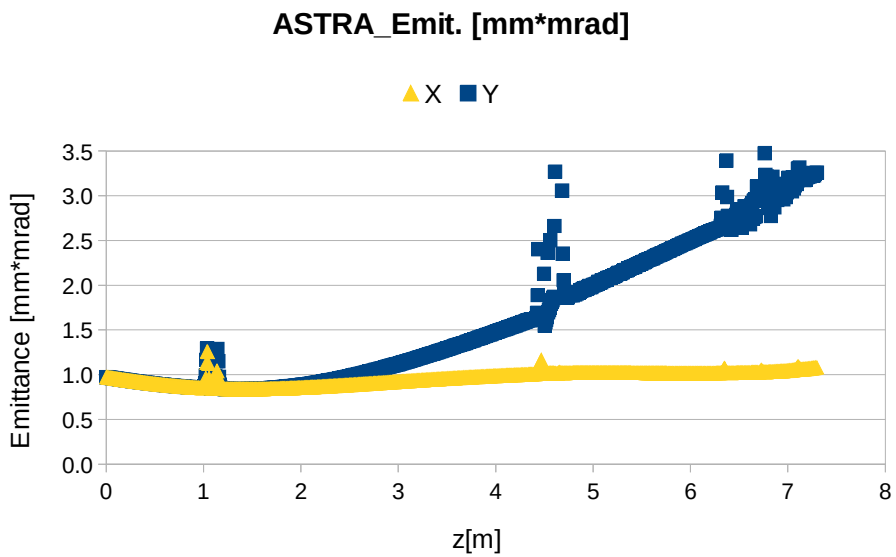
	ASTRA Vs. VCode	ASTRA Vs. MAD
xx	-4% (0.320/0.333)	16% (0.320/0.269)
x'x	-35% (0.027/0.036)	126% (0.027/-0.007)
yy	-1% (0.427/0.429)	44% (0.427/0.241)
y'y	-2% (-0.620/-0.629)	52% (-0.620/-0.297)
$beta_x$	-21% (4.561/5.500)	21% (4.561/3.600)
$alpha_x$	-51% (-1.195/-1.798)	130% (-1.195/0.363)
$beta_y$	-239% (2.703/9.152)	-7% (2.703/2.879)
$alpha_y$	-240% (9.184/31.213)	-61% (9.184/14.752)

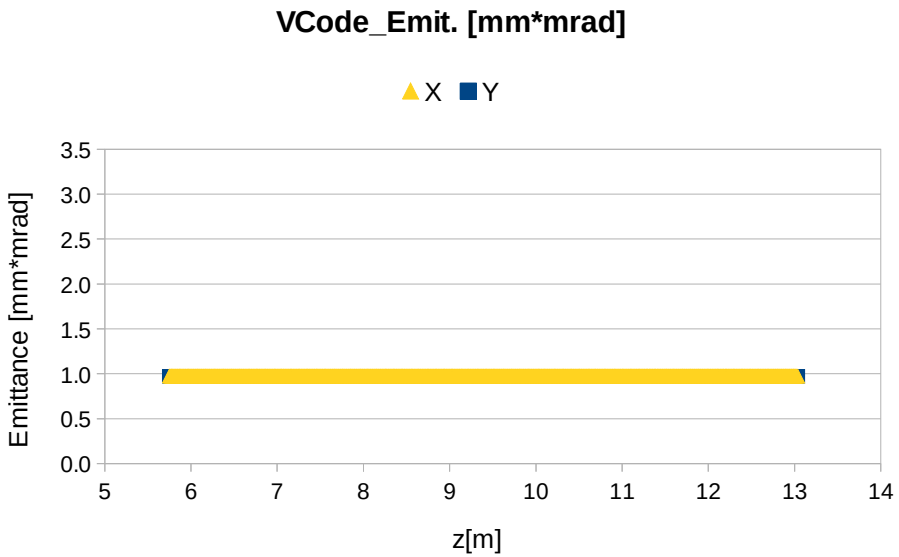
- **In terms of moment tracking VCode is closer to ASTRA than MAD but due to the Y-emittance discrepancy VCode fails to deliver similar Twiss parameters**

HOWEVER…

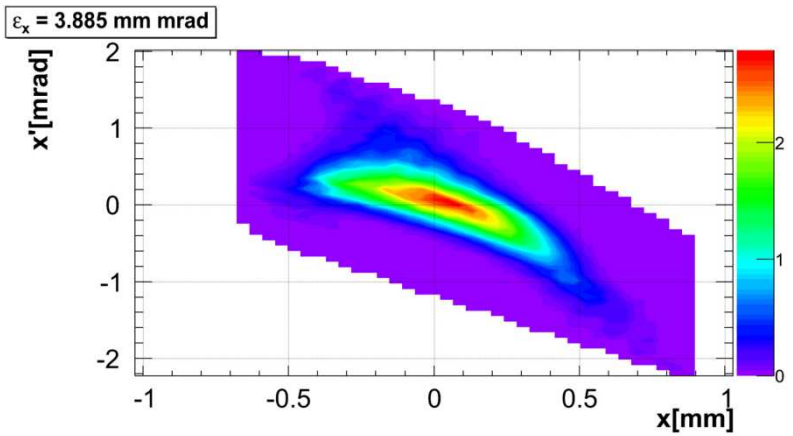
Measured emittance Vs. simulated

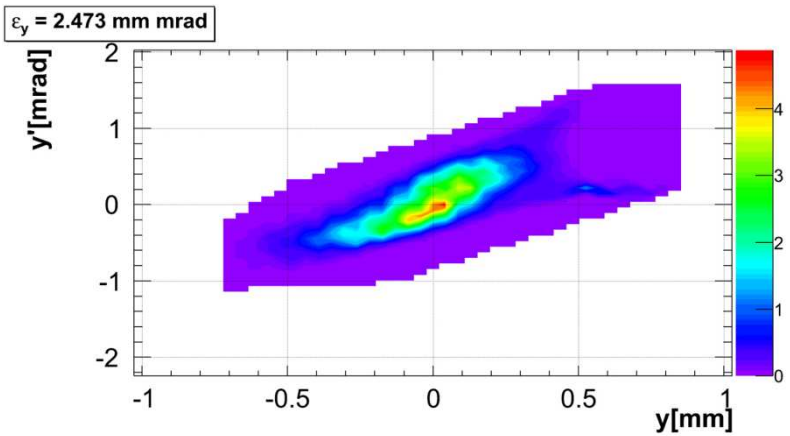
Simulated

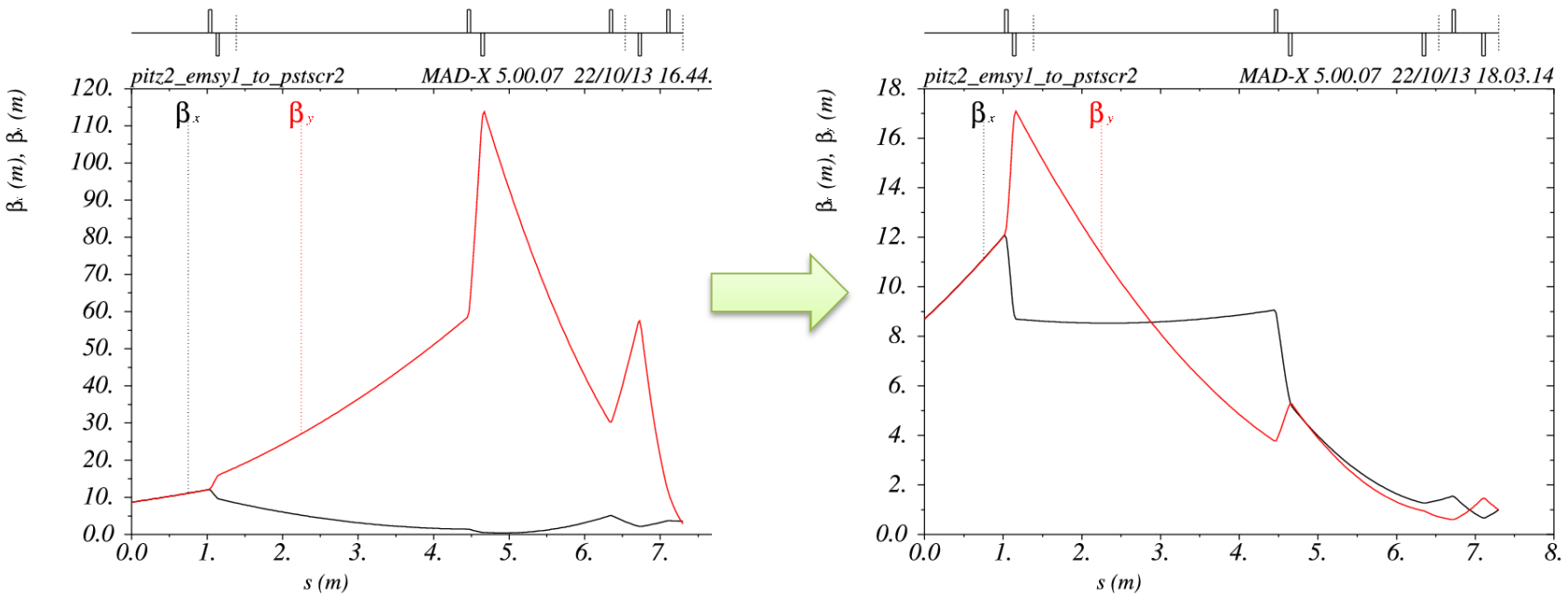




Measured



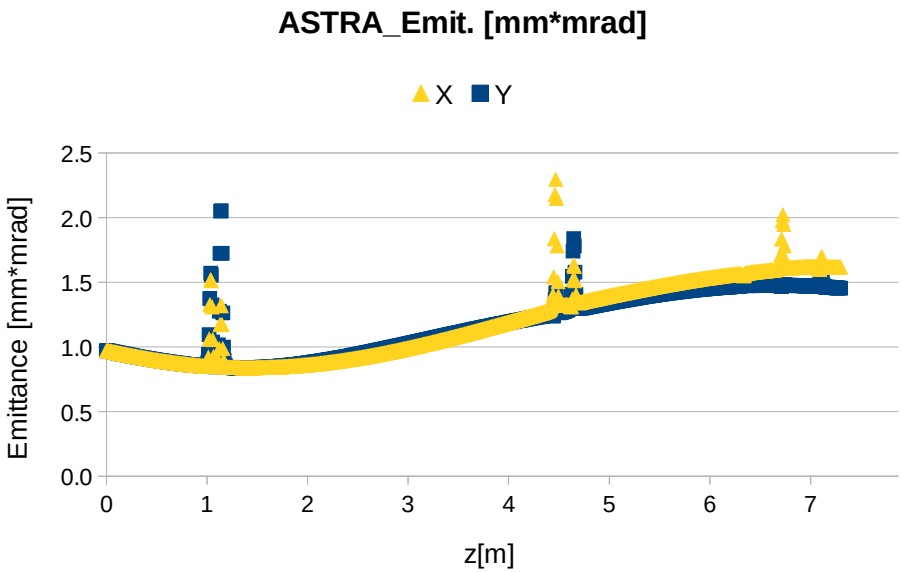




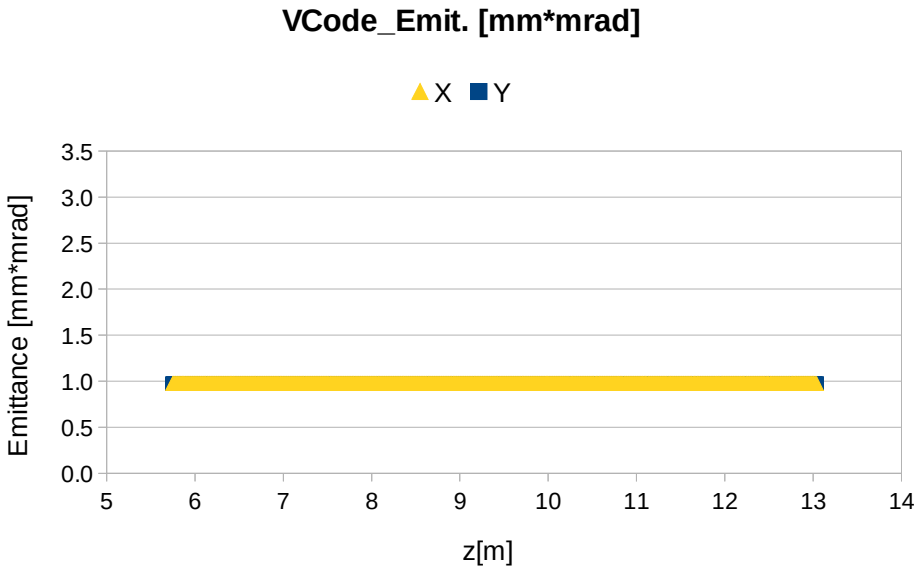
TRACKING WITH SPACE CHARGE - SYMMETRICAL MATCHING

Emittance

@PST.Scr2:
X=1.617 / Y= 1.454 mm*mrad



@PST.Scr2:
X=0.972 / Y=0.972 mm*mrad



- **Symmetrical emittance increase observed in ASTRA**
- **Constant emittance in VCode (even with the 4th-order-moments tracking)**

Errors w.r.t. ASTRA (sp. charge ON)

	ASTRA Vs. VCode	ASTRA Vs. MAD
xx	-8% (0.425/0.460)	16% (0.425/0.269)
x'x	-14% (0.128/0.145)	126% (0.128/-0.007)
yy	7% (0.234/0.218)	44% (0.234/0.241)
y'y	8% (-0.127/-0.117)	52% (-0.127/-0.297)
$beta_x$	-95% (5.381/10.494)	81% (5.381/0.999)
$alpha_x$	-89% (-3.813/-7.211)	70% (-3.813/-1.125)
$beta_y$	-30% (1.815/2.356)	45% (1.815/0.999)
$alpha_y$	-38% (4.212/5.820)	73% (4.212/1.125)

- **Again, in terms of moment tracking VCode is closer to ASTRA than MAD, but not concerning the Twiss parameters**

Comparison Conclusions

- In terms of the beam's statistical moments VCode gives a better agreement to ASTRA than MAD, but…
- … as the optical parameters depend on the emittance, no better agreement in Twiss is observed comparing to MAD
- Neither ASTRA nor VCode can estimate the correct emittance in the PST region
- No apparent improvement from MADX was observed

Outlook

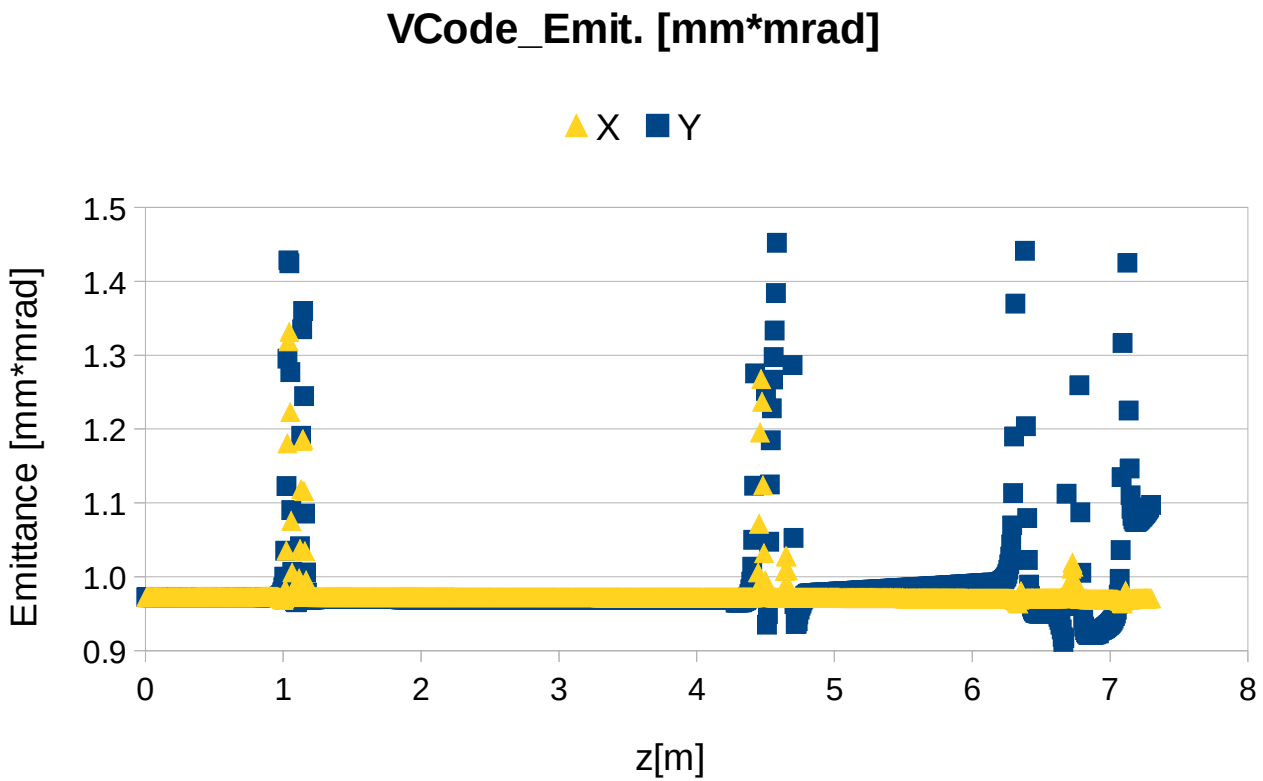
- Minimize uncertainty:
  - Repeat matching after measuring at EMSY 2
  - Try 5 projections (tomo section: better understood)
- Try to get conditions for (a) easier and (b) symmetric matching :
  a) $\alpha>0$ ($\rightarrow \beta\downarrow$) @ EMSY 1
  b) $\alpha=0$ (beam waist) @ HIGH1.Q3 (first matching quad)
  → Big laser spot size and weak solenoid focusing → ~460um, ~370A for 1nC, 24.5MeV/c (+ High1.Q1,2??)
- Measure emittance evolution along the matching section for these conditions (EMSY 2 + multiscreen @ High1.Sc3,4,5? using VCode to include linear sp.ch. ??)

THANKS FOR YOUR ATTENTION ☺

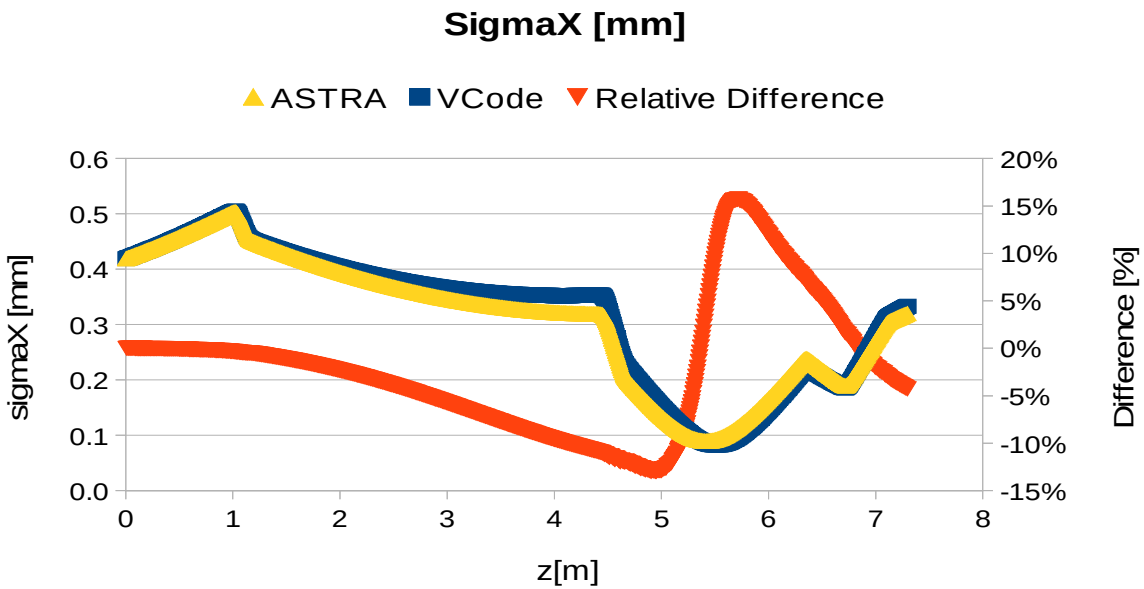
BACKUP SLIDES

DETAILED 4TH ORDER VCODE TRACKING (E-6 TIME STEP, E-4 STEP WIDTH)

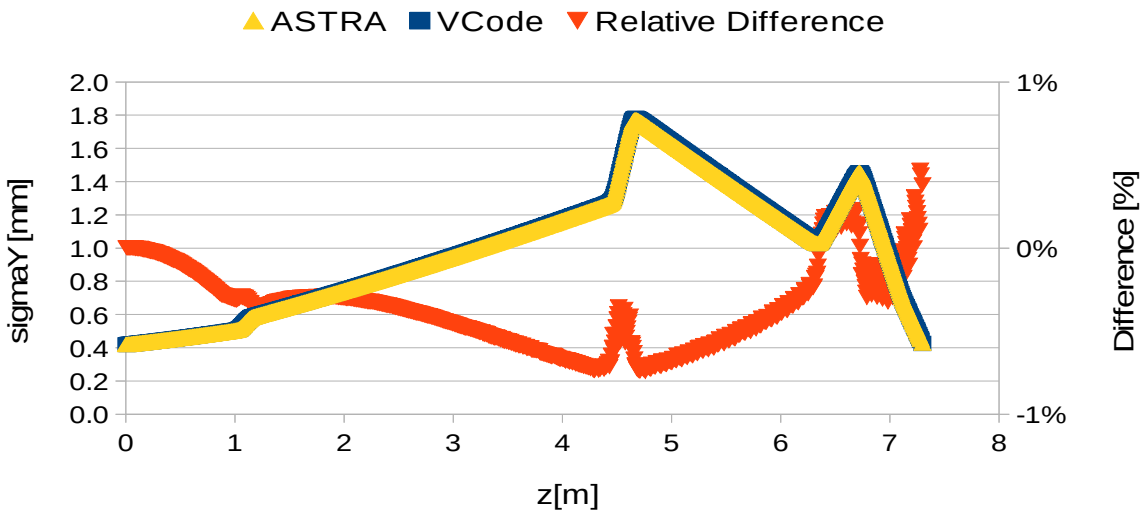
VCode Emittance from EMSY1 to PST.Scr2



Beam size from EMSY1 to PST.Scr2

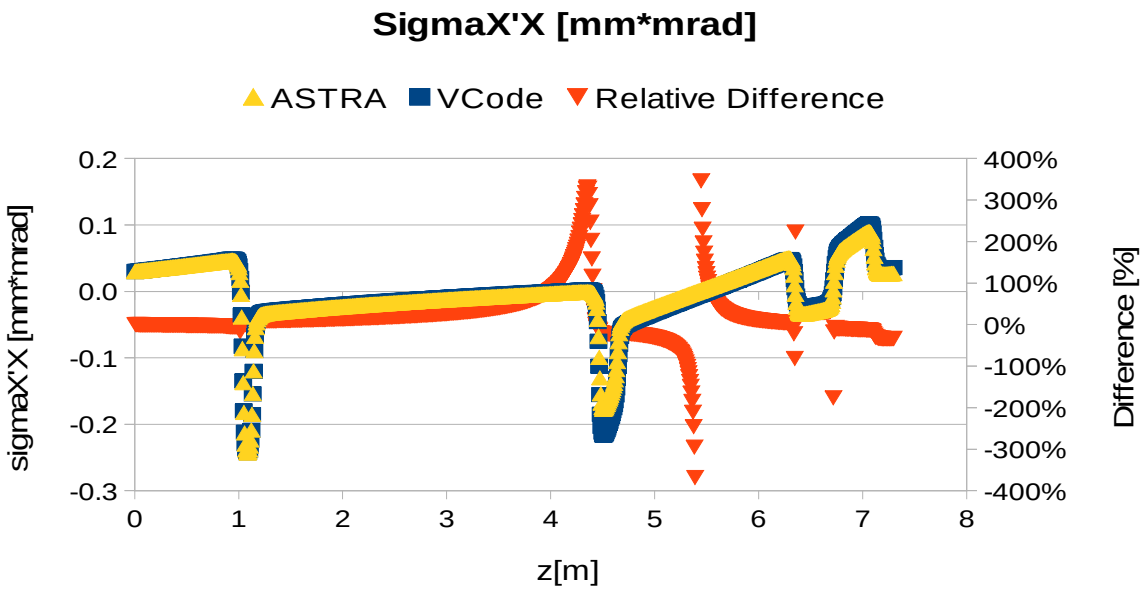


~-4% difference at PST

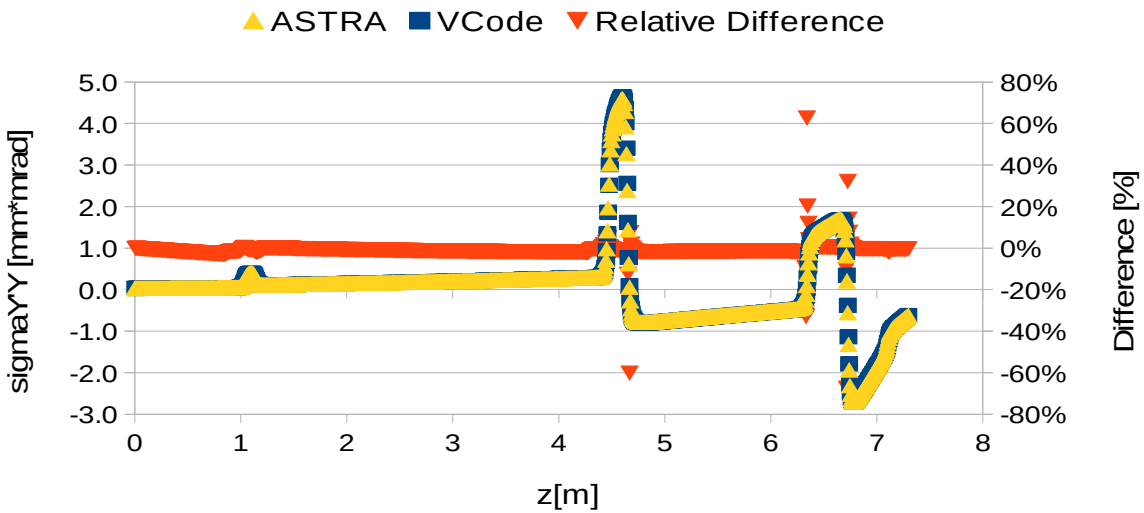


~0% difference at PST

Covariance from EMSY1 to PST.Scr2

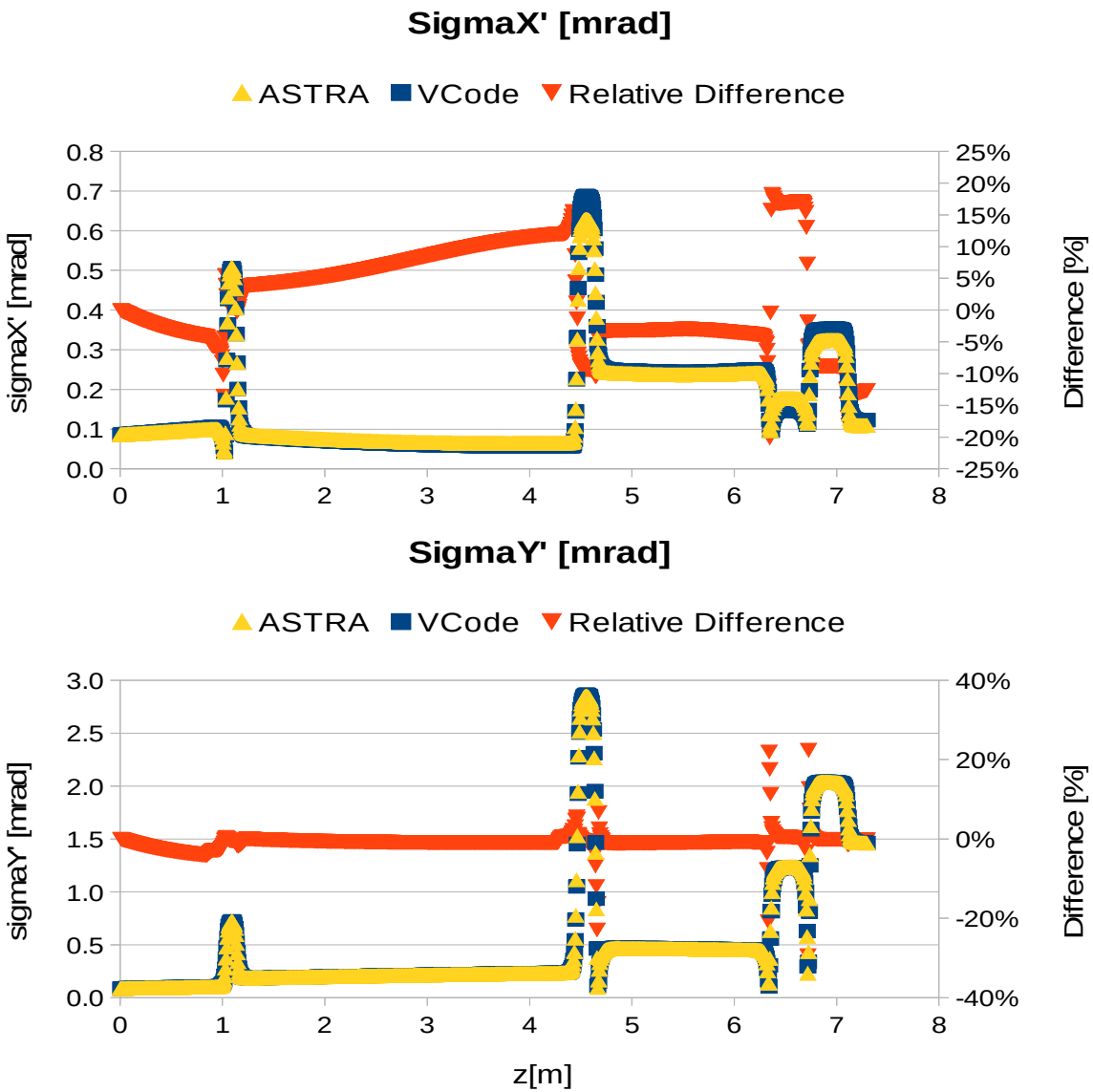


~-33% difference at PST



~0% difference at PST

Divergence from EMSY1 to PST.Scr2



~-13% difference at PST

~0% difference at PST

Influence of tracking precision in VCode

- Results are practically the same (<1% dif) up to 1mm tracking step (no emittance increase for the 2nd order moments)
- Results differ up to 10% for <1mm tracking step (where the emittance increases for the 2nd order moments)
- The deviation is smaller when the 2nd order moments are considered
- 1mm tracking step -> precise & fast

Influence of order of moments in VCode

- VCode emittance increases when the 4^{th} order moments are used (regardless of the precision), but remains stable for the 2^{nd} order
- Results up to 2% different (closer to ASTRA) when considering the moments up to 4^{th} order instead of the 2^{nd}
- Approximately double/triple the simulation time for 4^{th} order (~3 sec instead of ~1).

Influence of quadrupoles

- 7% max difference between ASTRA and VCode without quads (compared to 33% with quads)
- No emittance increase in VCode

Influence of different input beams

- Similar match of the moments for the minimum emittance case (a) and a big emittance case (b):
  a) X: -2%, -15%, -7% / Y: 2%, 3%, 1%
  b) X: -1%, -23%, -19% / Y: 1%, -1%, -1%
- Better matching for Y (why?? bigger beam size along the lattice -> weaker space-charge effect?)

Vcode Conclusions

- The tracking step precision has negligible effect when larger than 1mm (-> fast tracking)
- The improvement in the tracking of the moments is small when higher order modes are considered
- Emittance increase is also observed by VCode when higher orders are considered

VCode errors in terms of Twiss

- Moments
  xx= -4%, x'x=-33%
  yy= 1%, y'y= 0%

- Twiss
  $beta_x$= -21%, $alpha_x$= -49%
  $beta_y$= -193%, $alpha_y$= -197%

- Y climbs up to 240% on 2nd-order tracking

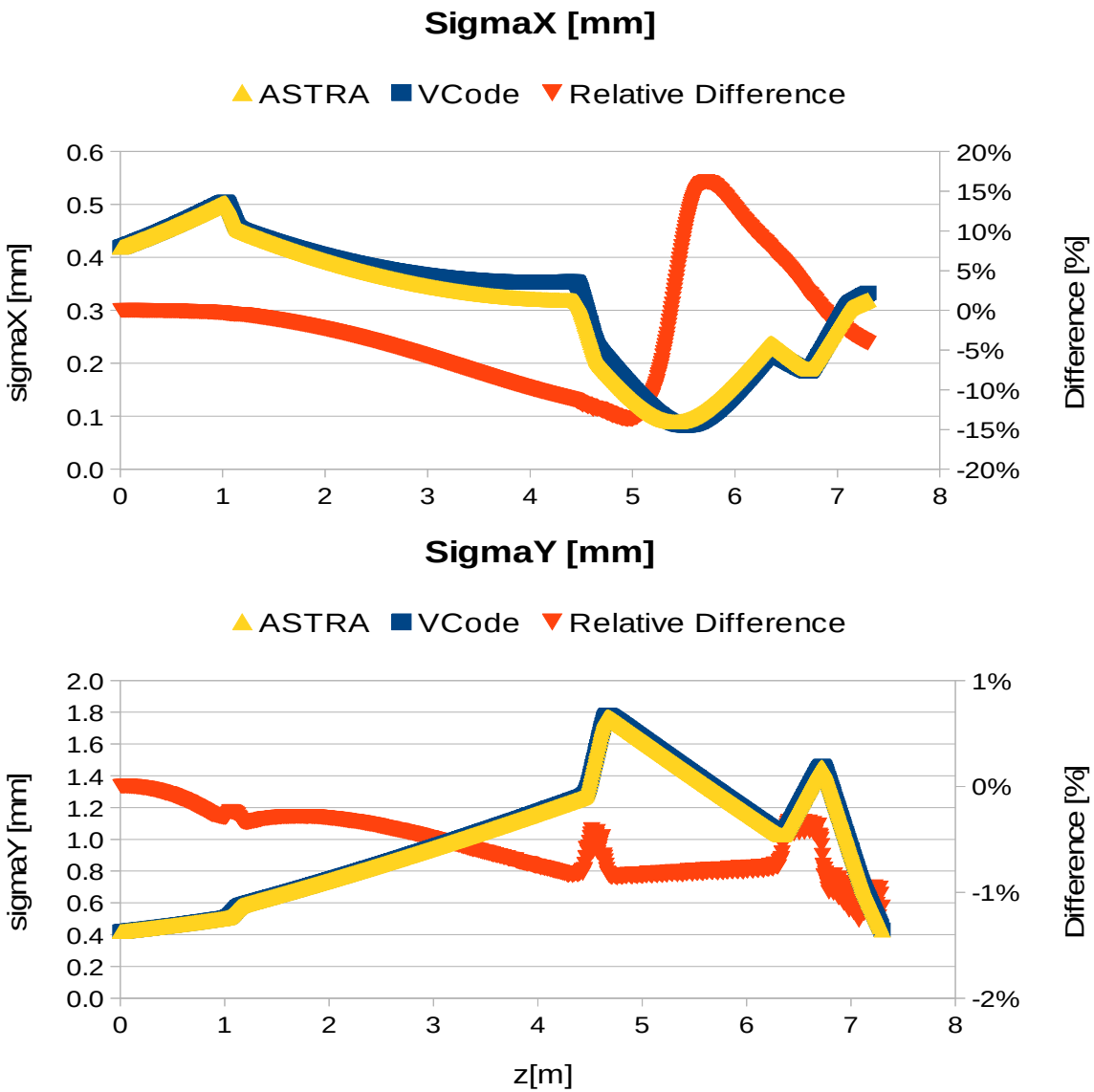
MAD errors w.r.t. ASTRA

- Moments
  xx= 16%, x'x=127%
  yy= 44%, y'y= 52%

- Twiss
  $beta_x$= 21%, $alpha_x$= 130%
  $beta_y$= -7%, $alpha_y$= -61%

DETAILED 2ND ORDER VCODE TRACKING (E-6 TIME STEP, E-4 STEP WIDTH)

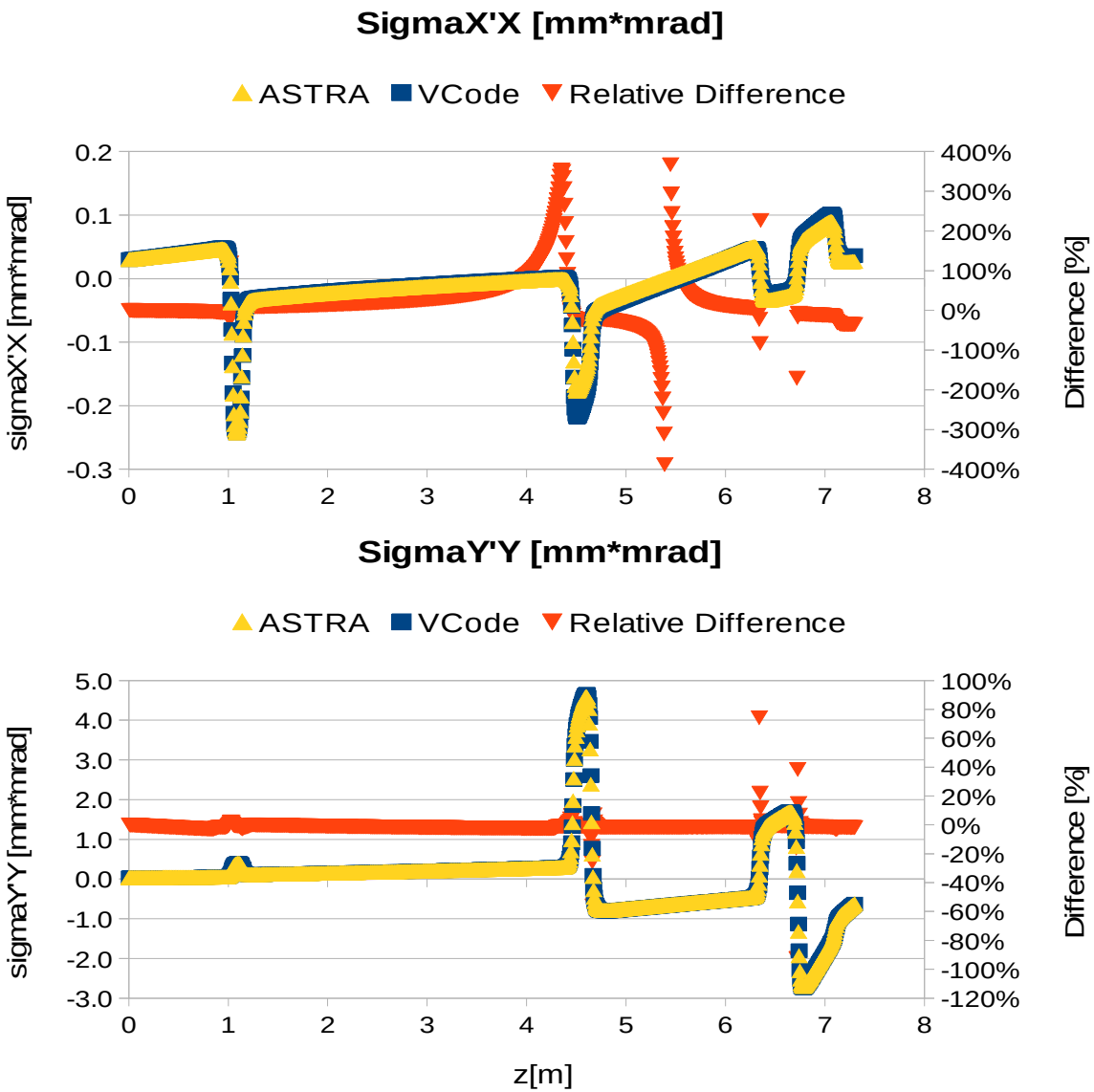
Beam size from EMSY1 to PST.Scr2



~-4% difference at PST

~-1% difference at PST

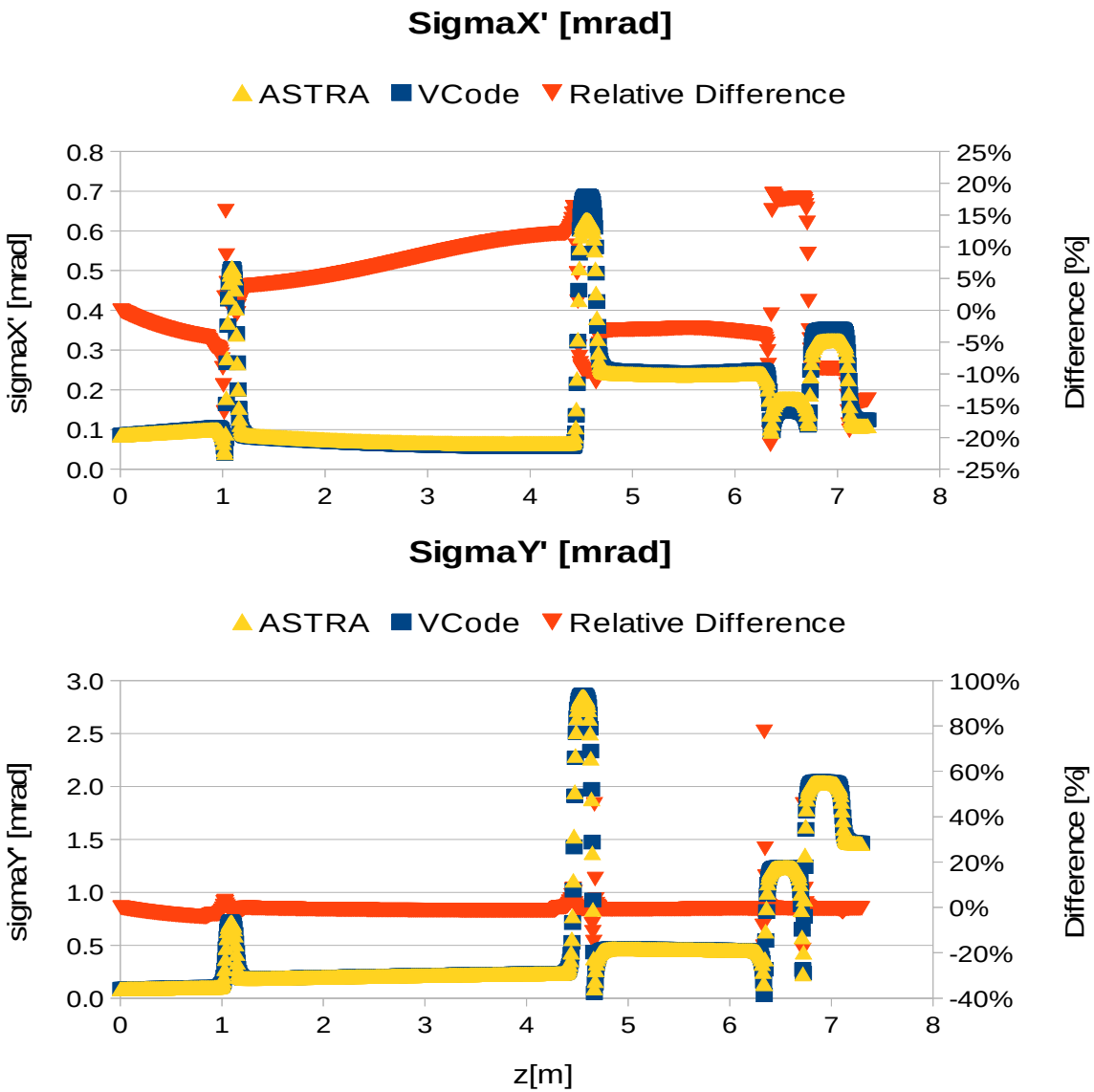
Covariance from EMSY1 to PST.Scr2



~-35% difference at PST

~-2% difference at PST

Divergence from EMSY1 to PST.Scr2

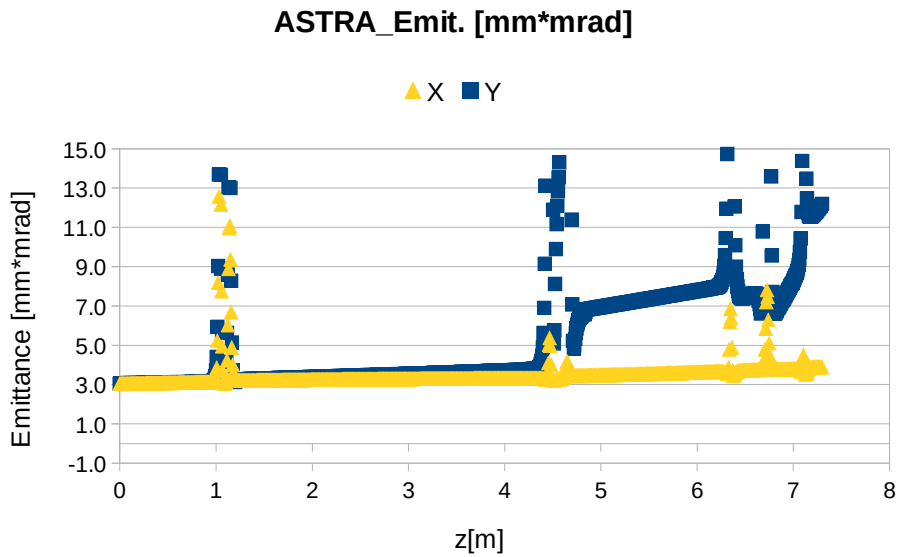


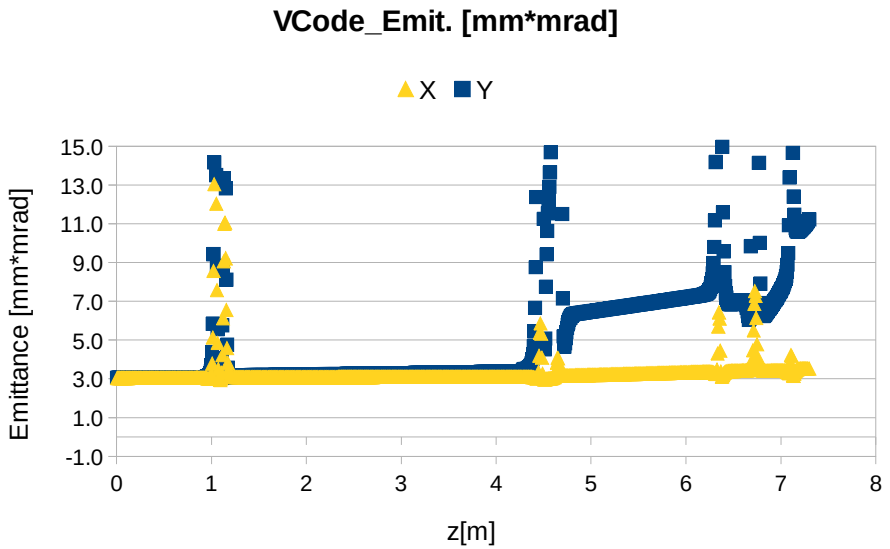
~-14% difference at PST

~0% difference at PST

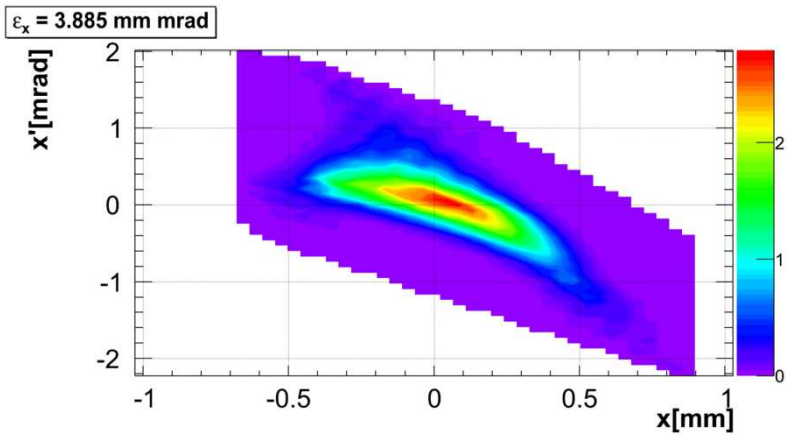
Big emittance beam – case (b)

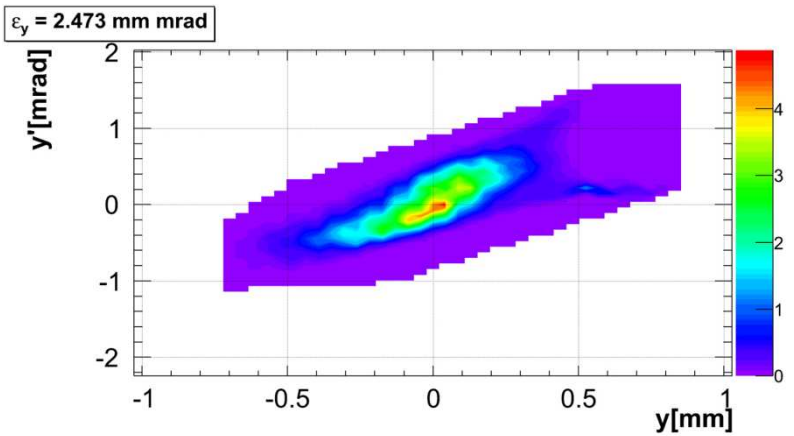
Simulated





Measured





VCode errors in terms of Twiss (b)

- Moments
  xx= -1%, x'x=-23%
  yy= 1%, y'y= -1%

- Twiss
  $beta_x$= -12%, $alpha_x$= -36%
  $beta_y$= -8%, $alpha_y$= -9%

- Y climbs up to 300% on 2nd-order tracking

MAD errors w.r.t. ASTRA (b)

- Moments
  xx= 4 %, x'x= 107 %
  yy= 16 %, y'y= 13 %

- Twiss
  $beta_x$= -17%, $alpha_x$= -109%
  $beta_y$= 180%, $alpha_y$= -249%