

Results of recent beam-beam simulation studies

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1 COLLISION optics

1.1 Conditions for tracking

- version 6.5 at collision; Sixtrack with beam-beam
- tune range (0.3 – 0.33) along a line parallel to the diagonal: split $Q_x - Q_y = 0.01$; step $\Delta Q_x = 0.0005$
- nominal beam-beam in ALL β^* cases; $N_p = 1.15 \times 10^{11}$; 10^6 turns
- bb only – no triplet err. (*no seeds: disregard “min”*)
- increase β^* and vary crossing angle

1.2 Matching

- match β^* and crossing angle α in IP1 and IP5 for both beams
- removed IP offset
- keep tune across each IR for each beam
- max strengths as in db; k_{qx} changed for 2m; antisymmetry respected for $k_{qx,4,5,6}$

1.3 What is shown:

- section names = β^* [m], full crossing angle 2α [mrad] and sep. value $d[\sigma]$ as found from scaling: $d = d_0 \frac{\alpha}{\alpha_0} \sqrt{\frac{\beta^*}{\beta_0^*}}$
for example: 0.55 0.285 d=9.4
- Chaos border and Dynamic Aperture (DA) as functions of unperturbed tune Q_x for 17 init. angles in $x - y$ plane
- separation plotted at all HO + LR crossings in IR1 in units of weak-beam sigma;
- Luminosity L in units 10^{33} (see next page) ;
- footprint: from 0 to 6σ

$$L = \frac{1}{4\pi\beta^*\epsilon} N_p^2 k_b f \gamma F(\alpha, \beta^*) 10^{-4}; \quad F(\alpha, \beta^*) = \frac{1}{\sqrt{1 + (0.077 \frac{\alpha}{\sqrt{\beta^*\epsilon}})^2}}$$

α is half of the crossing angle in rad;

β^* is beta at IP;

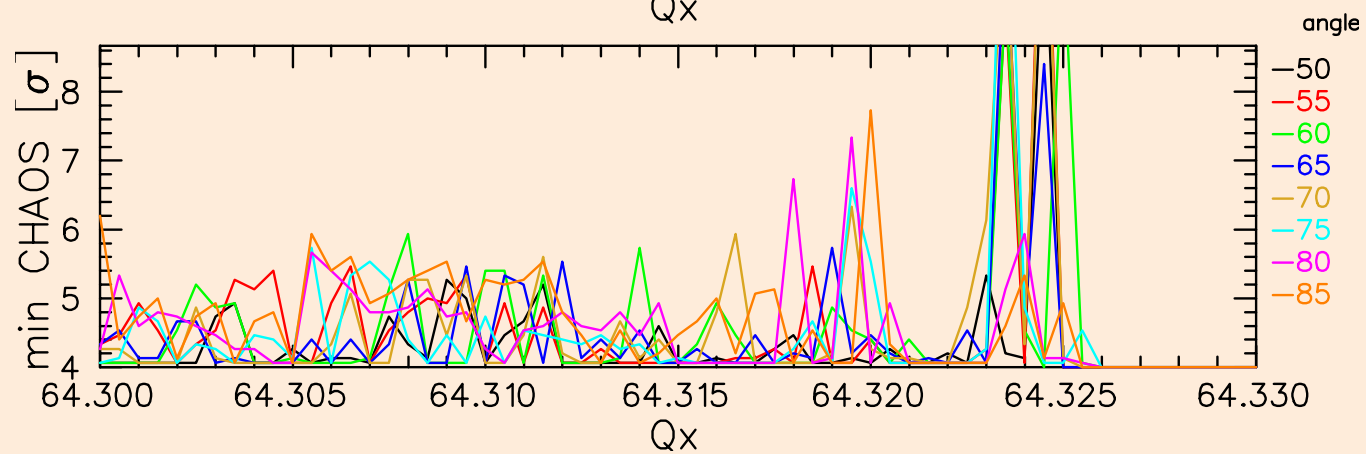
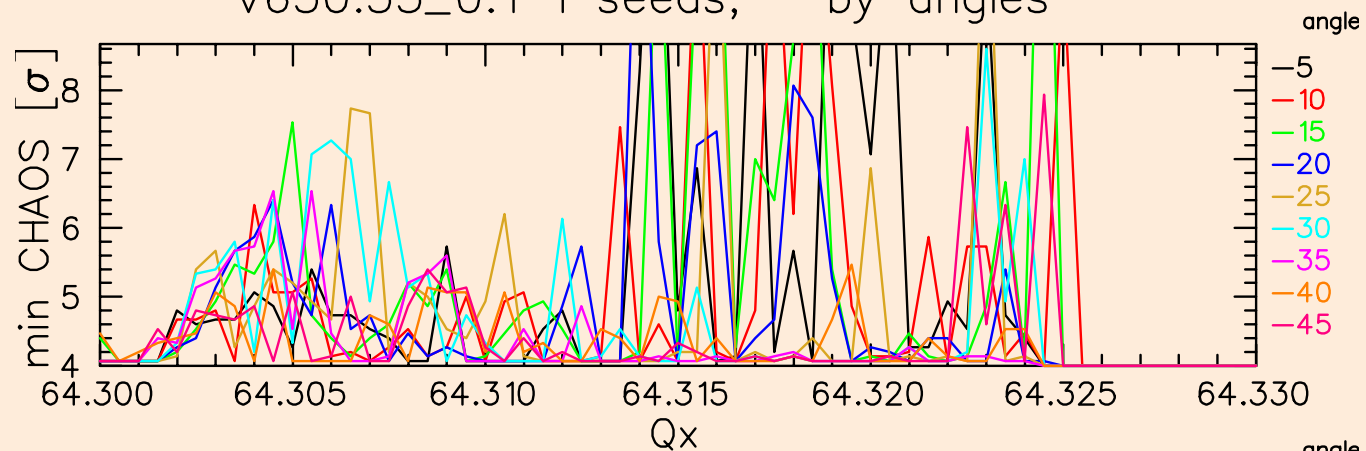
$$N_p = 1.1510^{11}, \quad f = 11245.5, \quad k_b = 2835, \quad \epsilon = 3.7510^{-6}/\gamma$$

$$\gamma = 7000/0.938.$$

2 0.55m 0.2 d=6.6

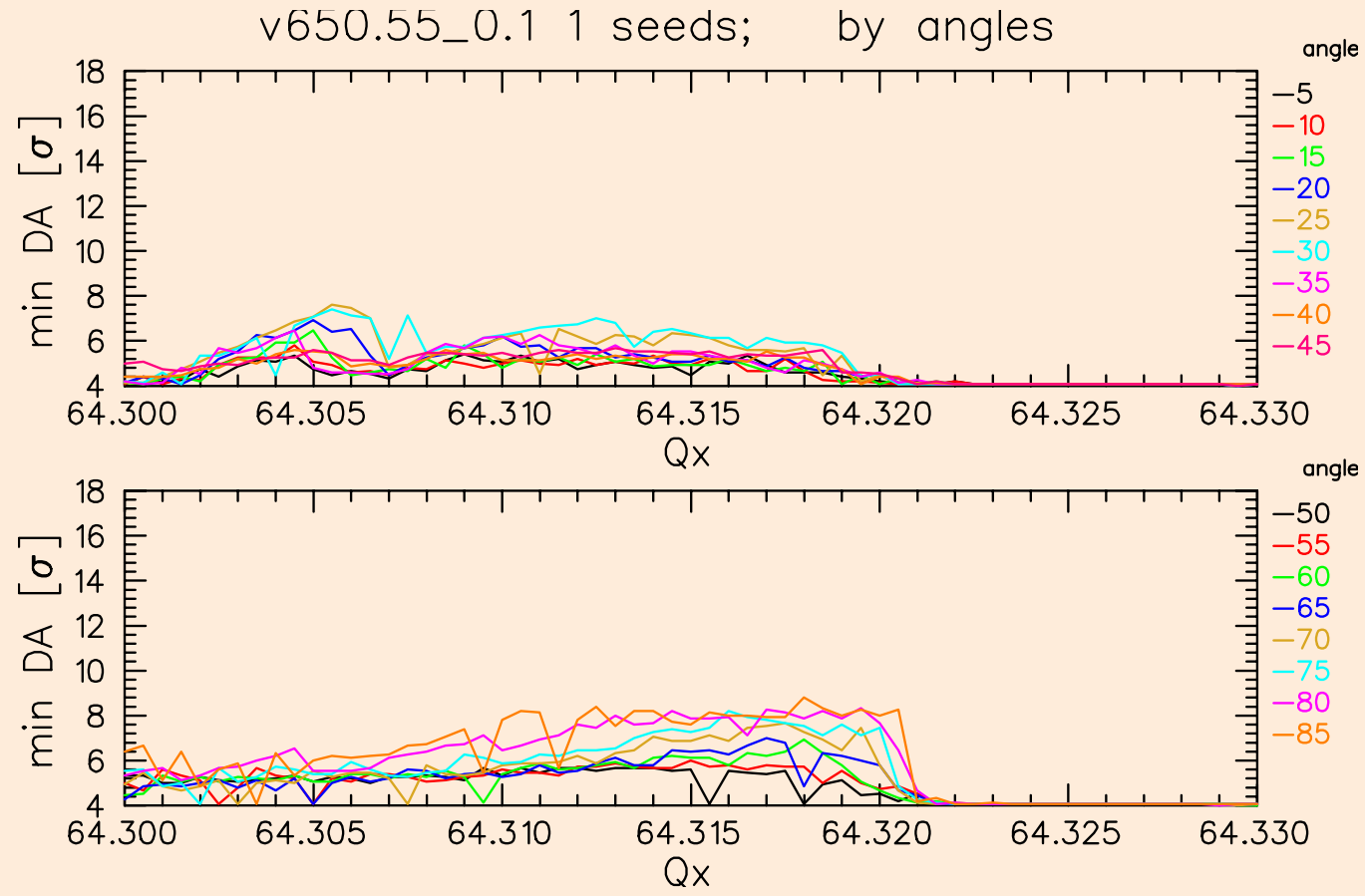
2.1 Chaos

v650.55_0.1 1 seeds; by angles

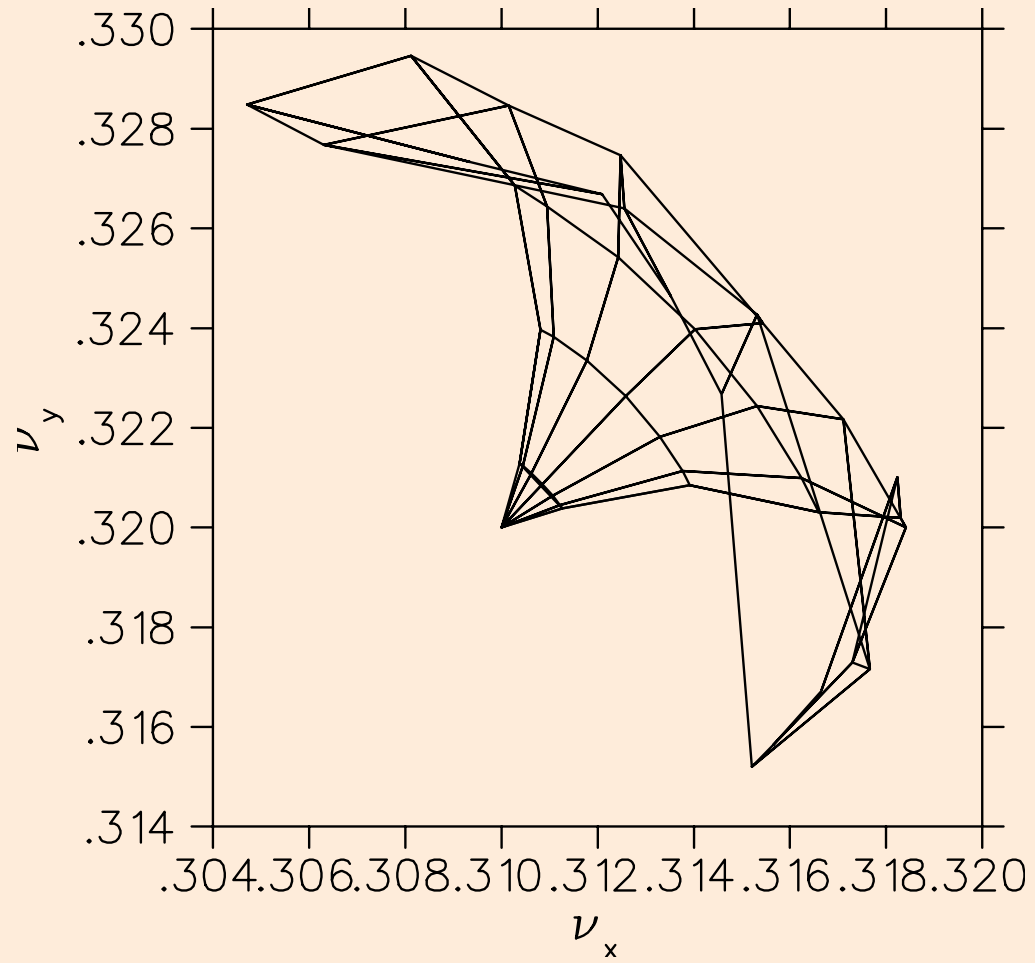


get eps

2.2 DA; d=6.6

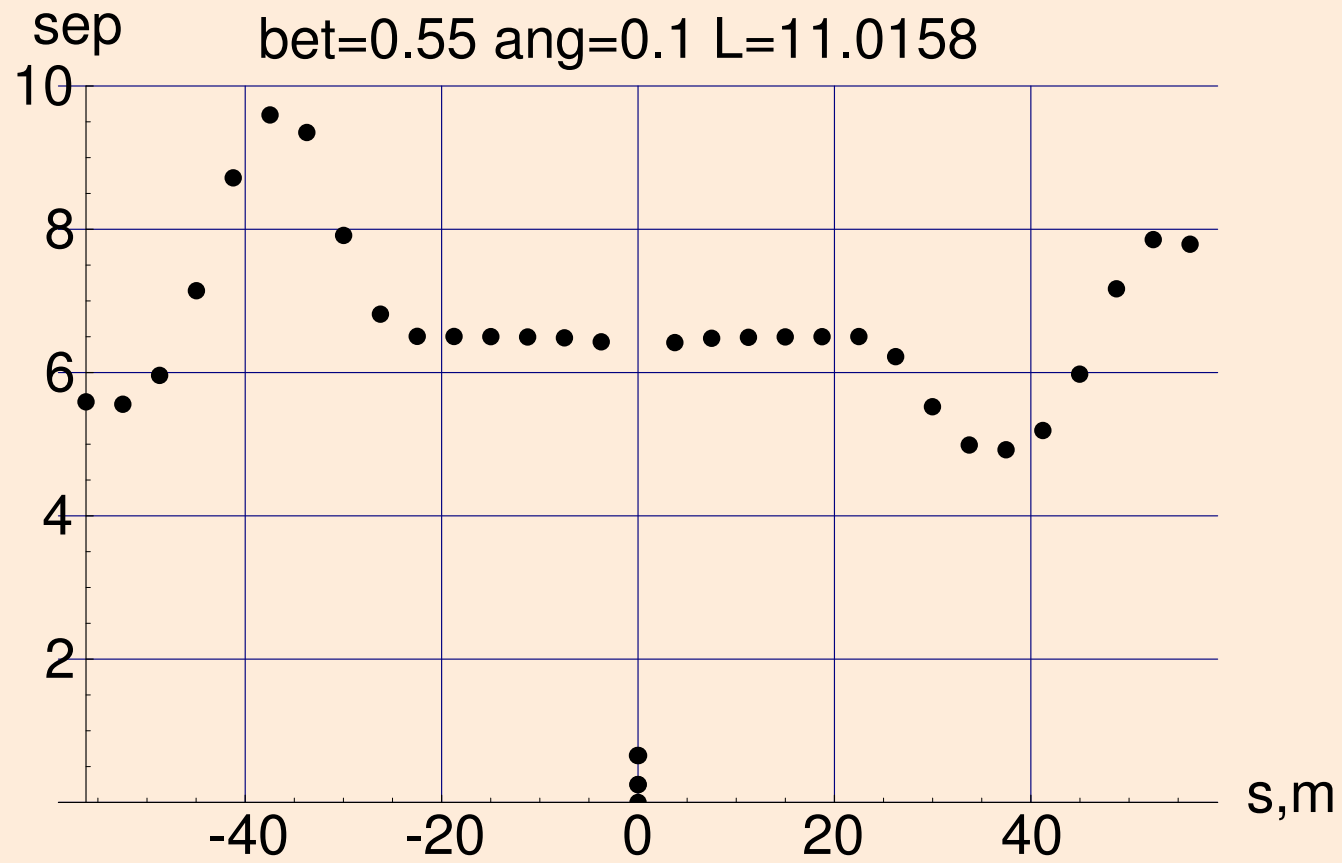


2.3 foot



get eps

2.4 separation



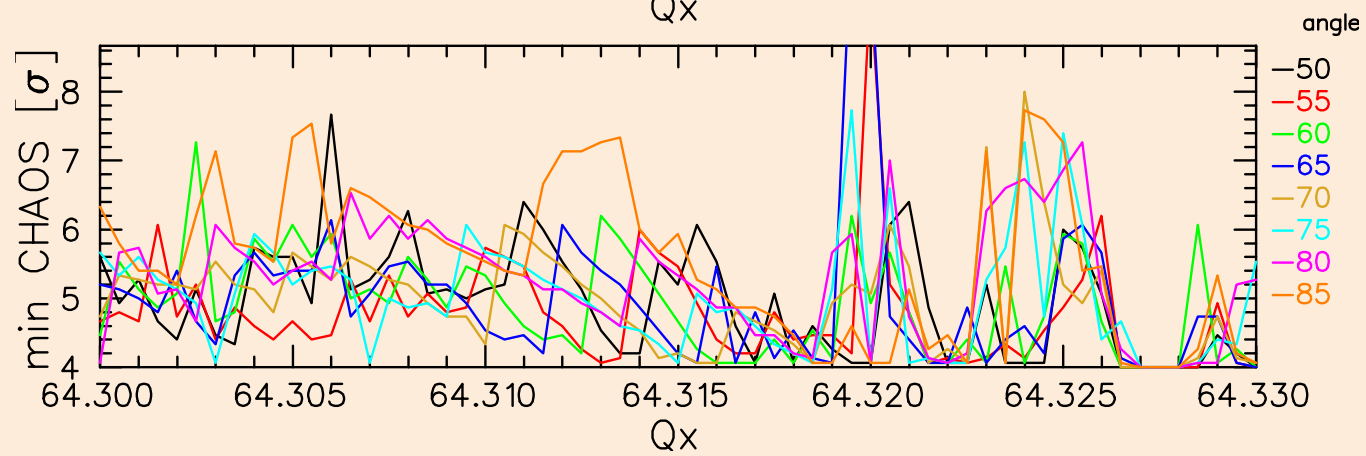
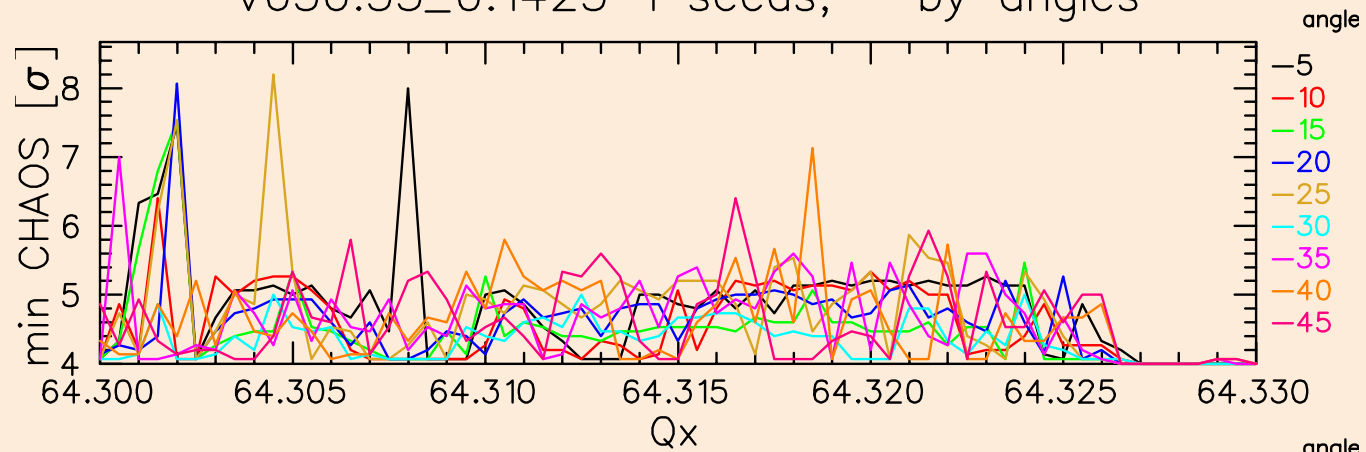
get eps

2 0.55m 0.2 d=6.6

3 0.55m 0.285 d=9.4

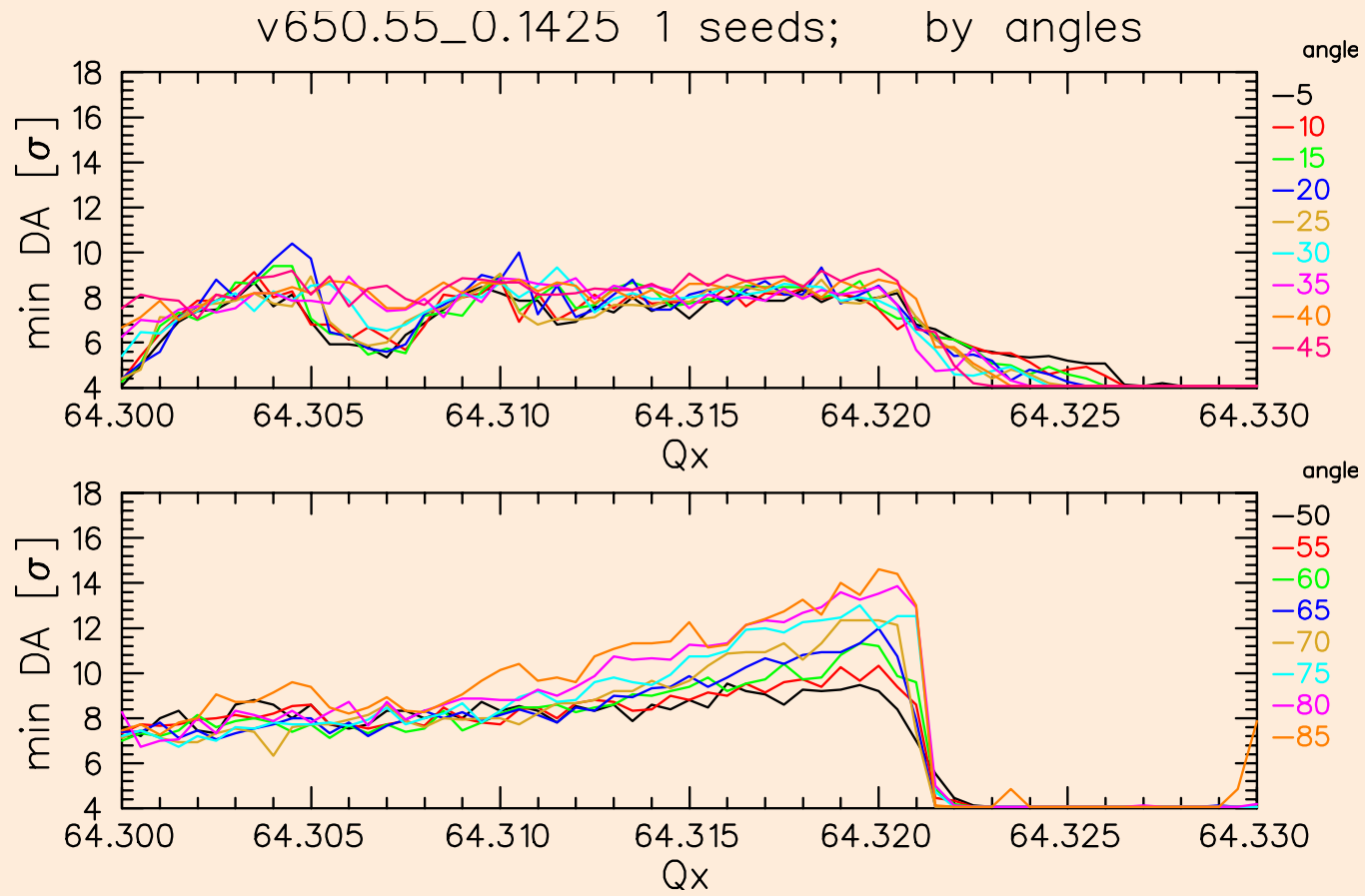
3.1 Chaos

v650.55_0.1425 1 seeds; by angles

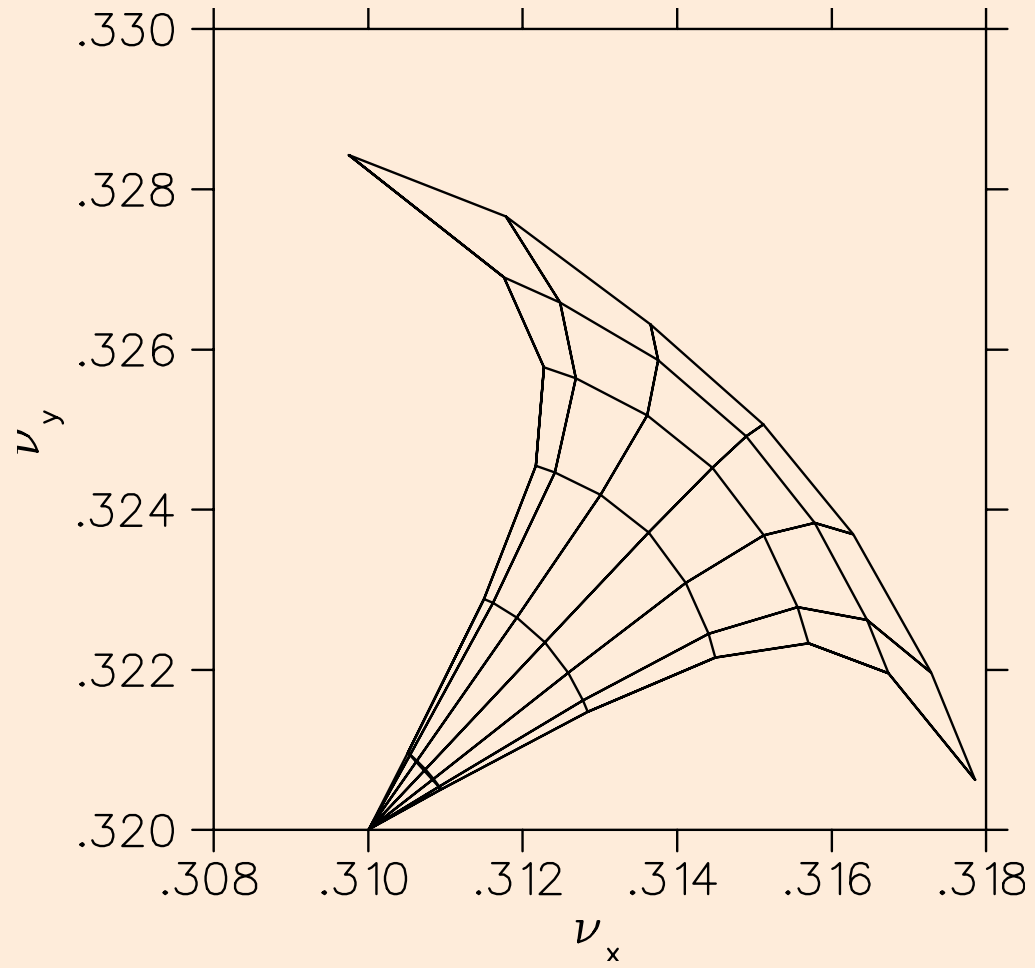


get eps

3.2 DA; d=9.4



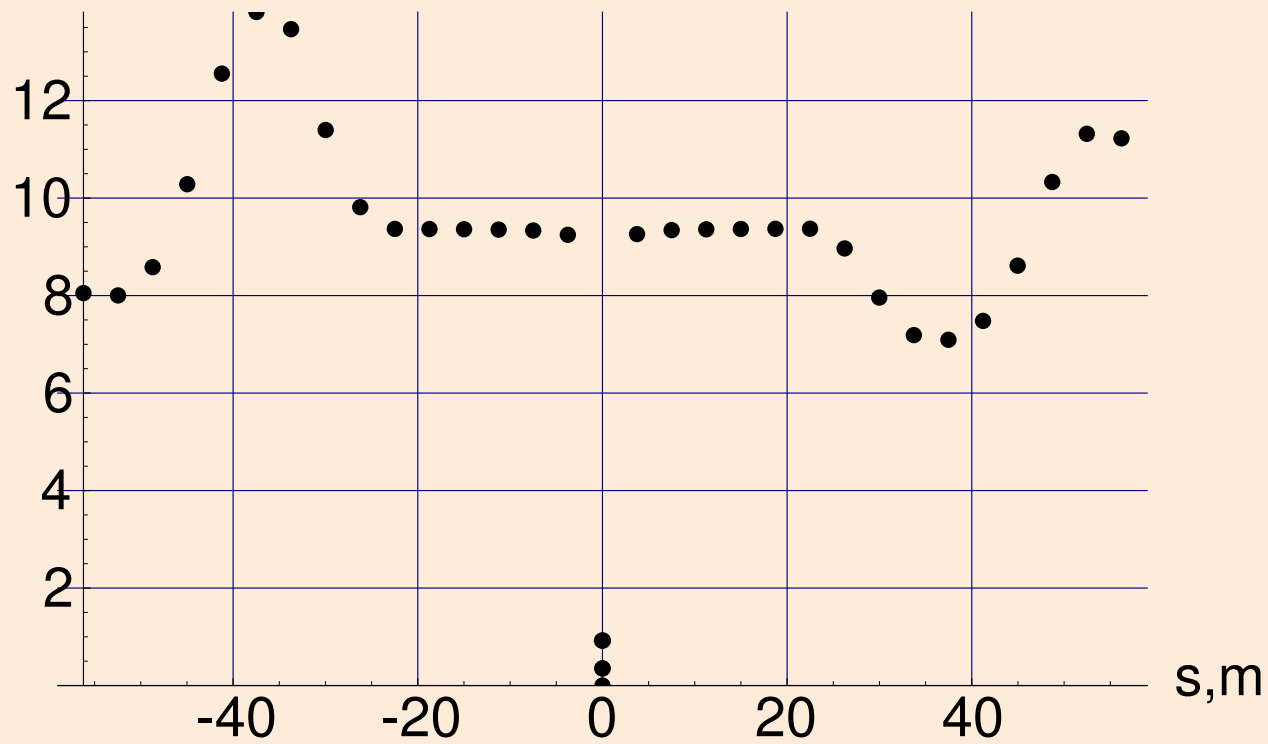
3.3 foot



get eps

3.4 separation

sep [sgm] bet=0.55 ang=0.1425 L=10.1321

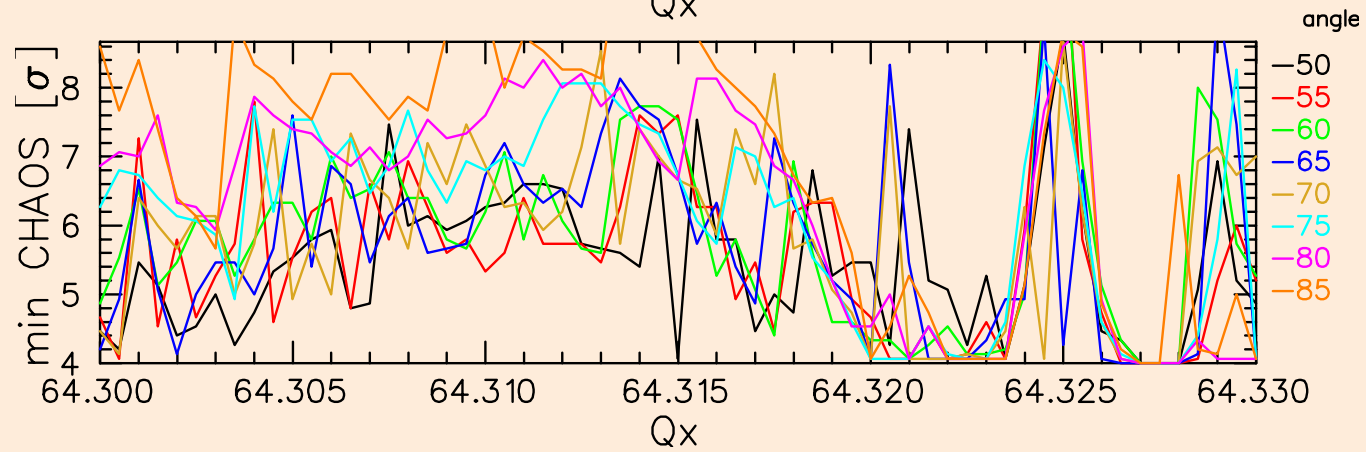
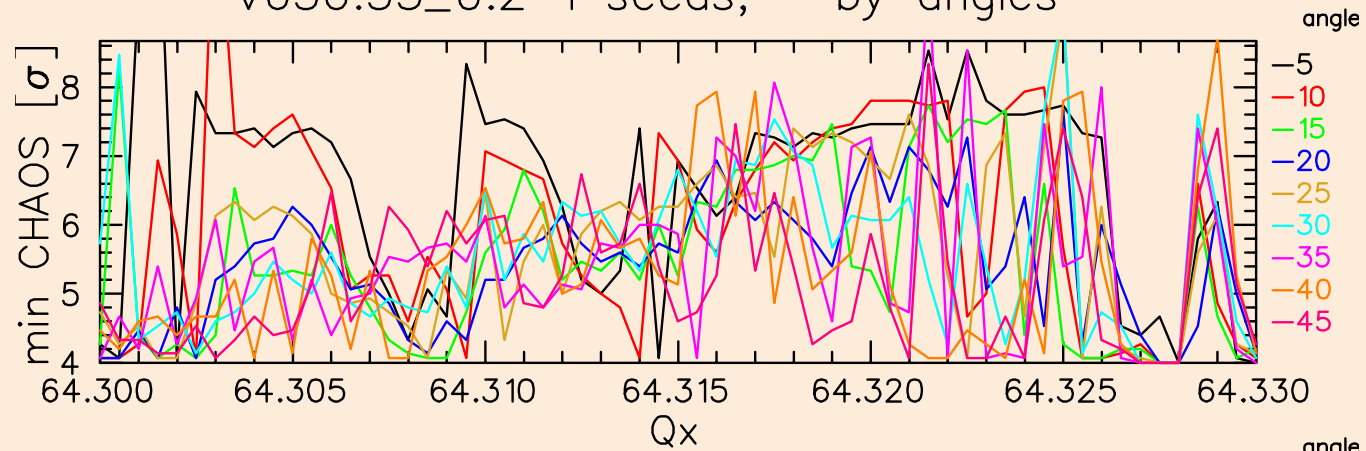


get eps

4 0.55m 0.4 d=13.2

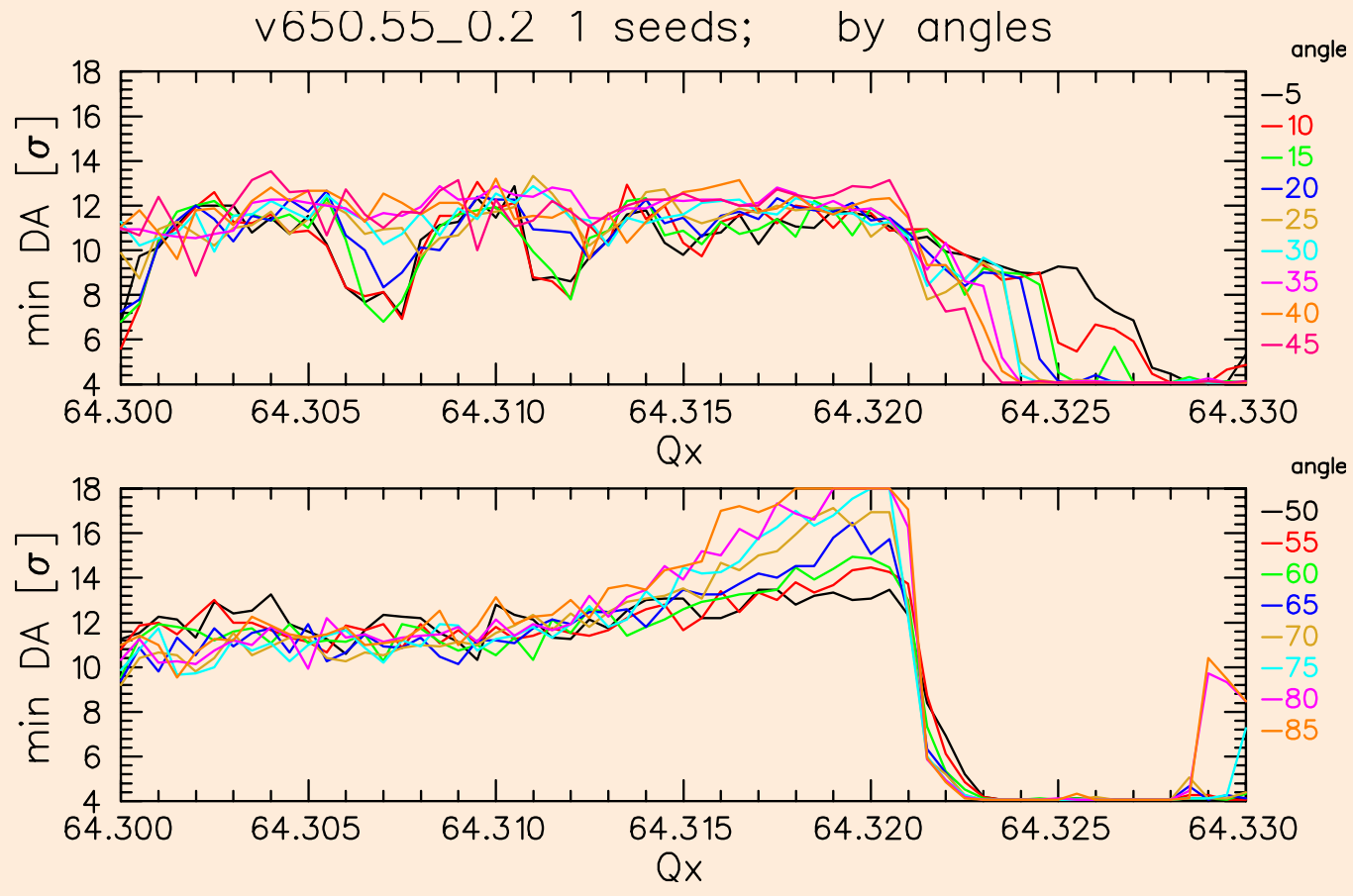
4.1 Chaos

v650.55_0.2 1 seeds; by angles

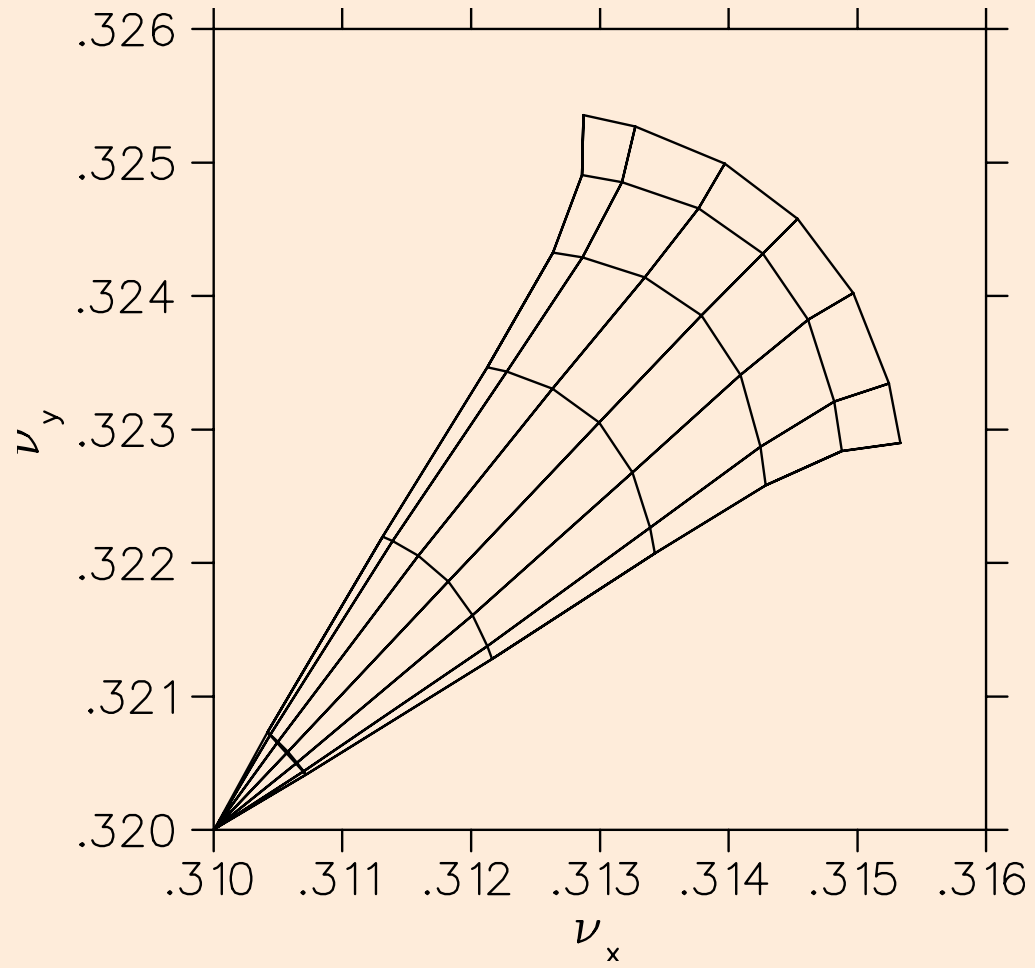


get eps

4.2 DA; d=13.2



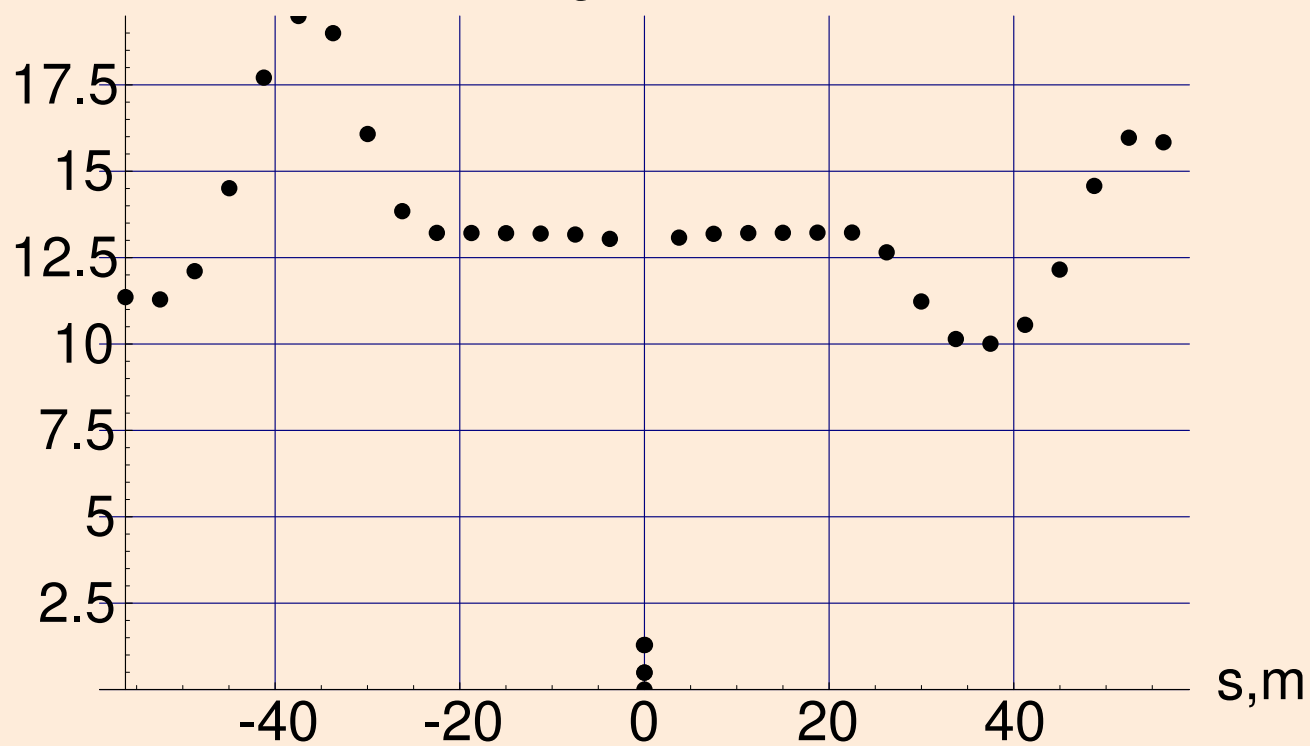
4.3 foot



get eps

4.4 separation

sep [sgm] bet=0.55 ang=0.2 L=8.90601



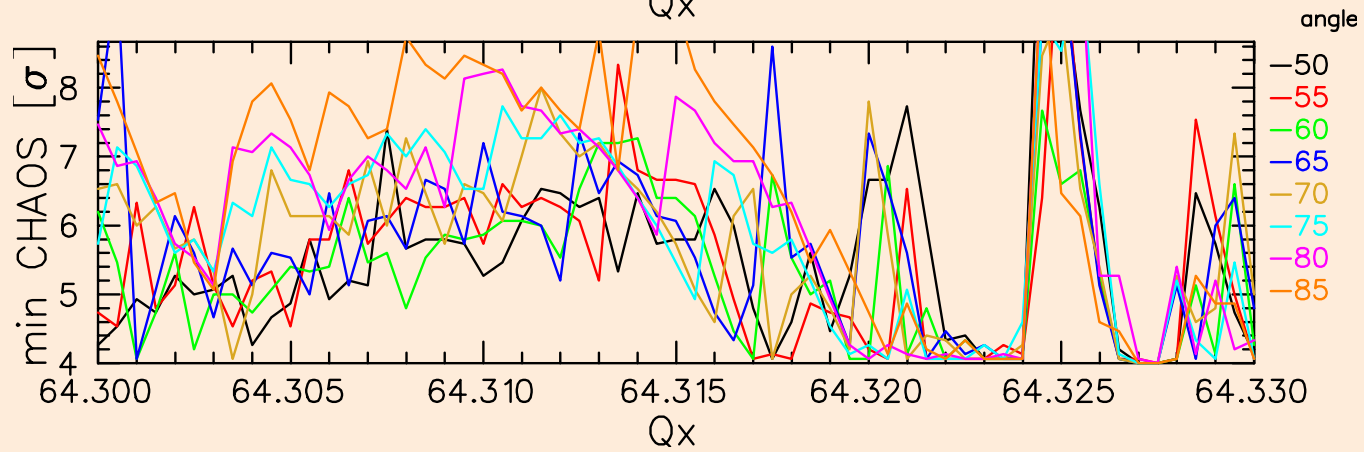
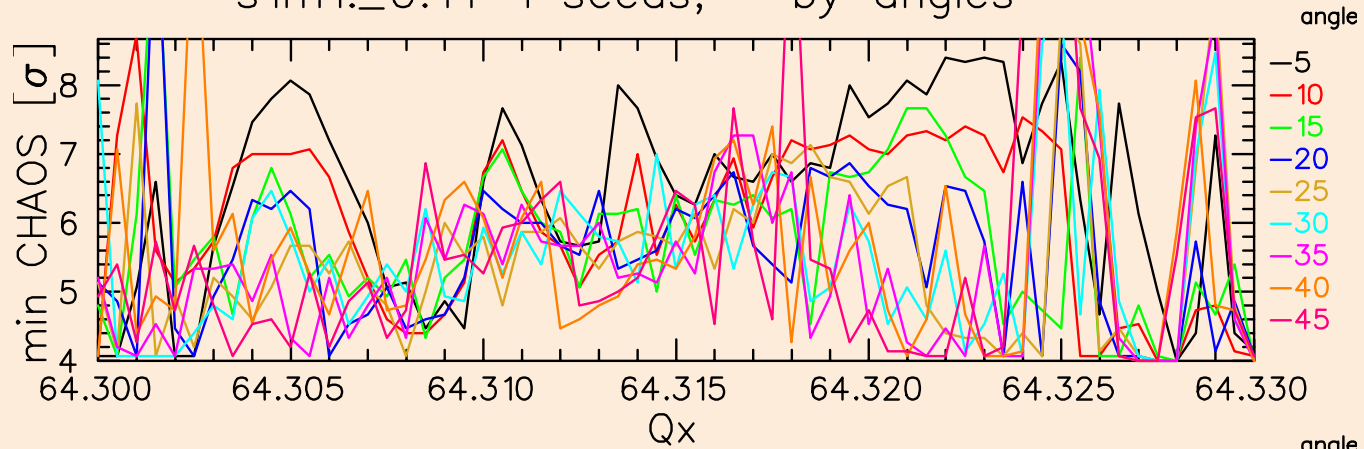
get eps

4 0.55m 0.4 d=13.2

5 1m 0.28 d=12.5

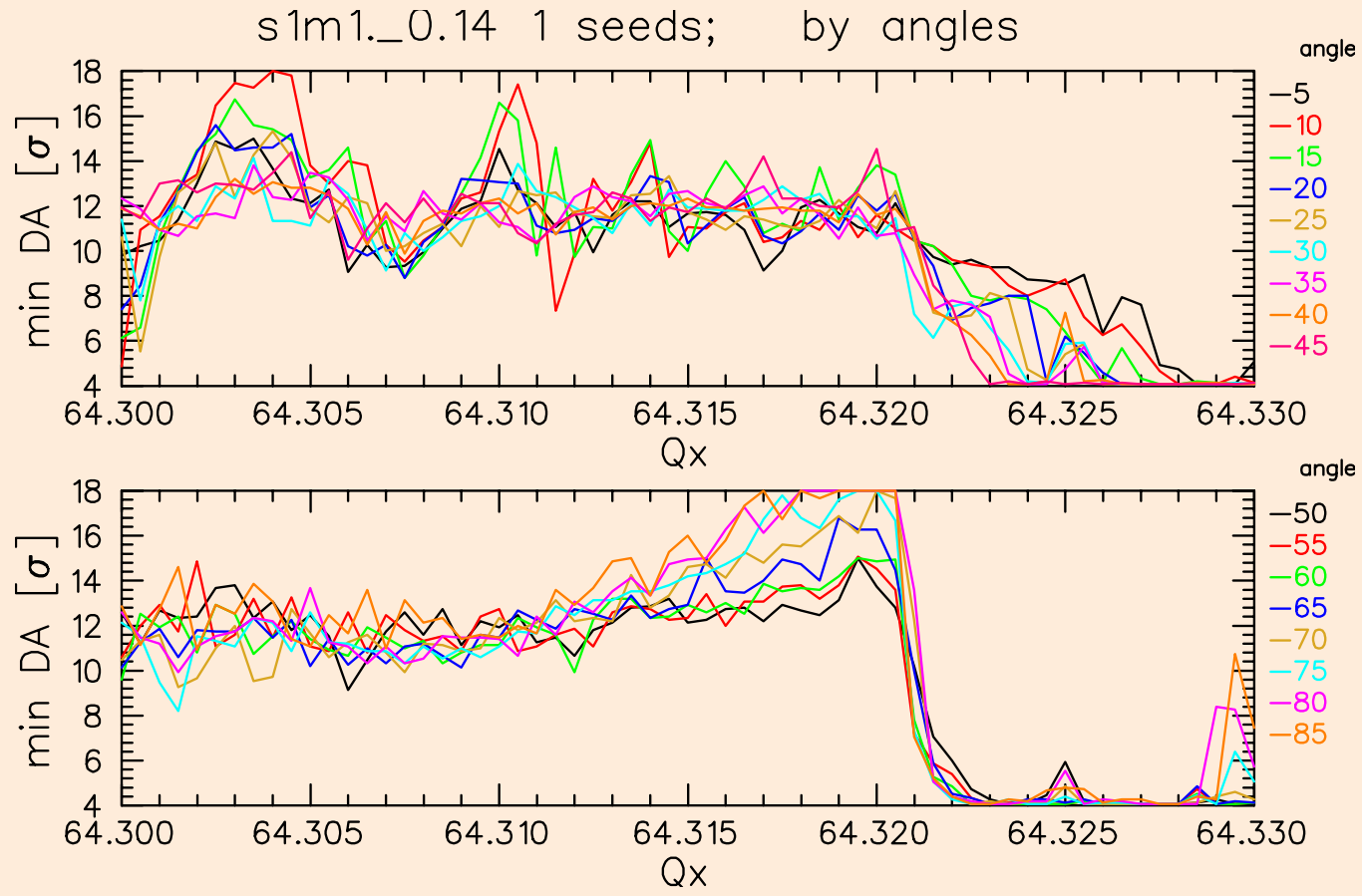
5.1 Chaos

s1m1_0.14 1 seeds; by angles

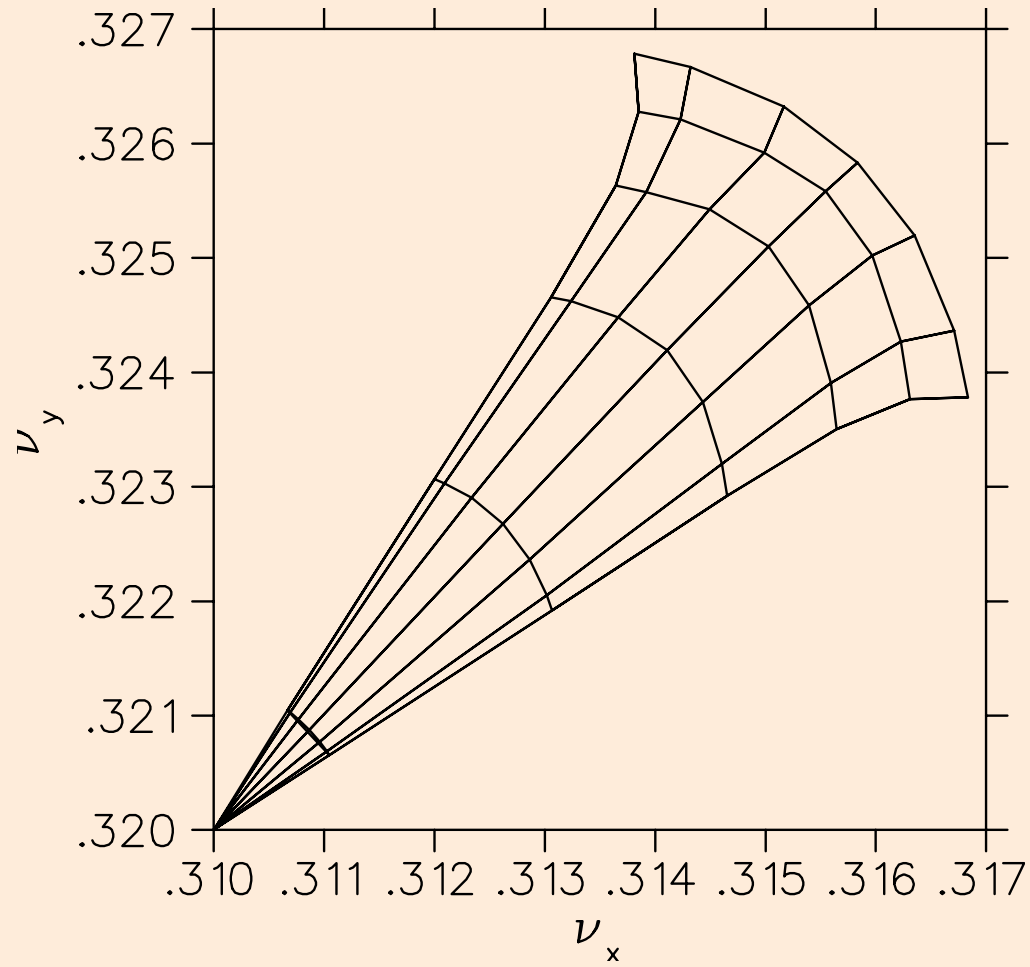


get eps

5.2 DA; d=12.5

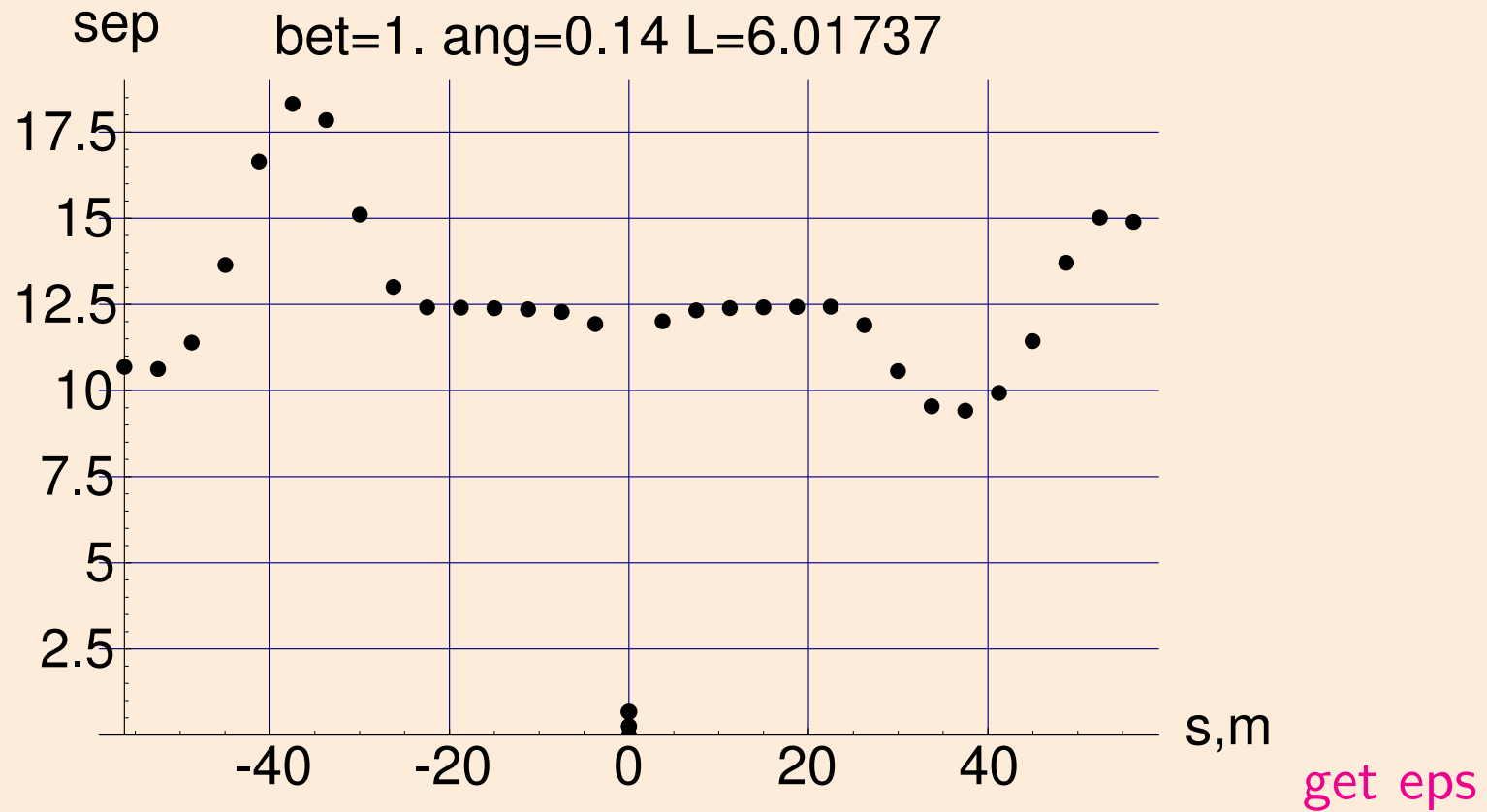


5.3 foot



get eps

5.4 separation

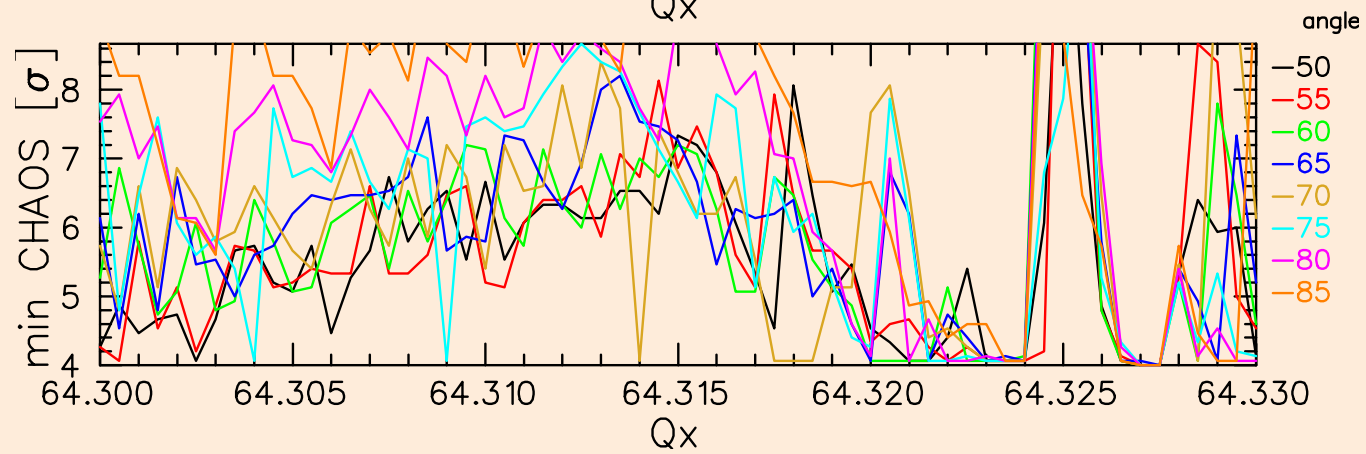
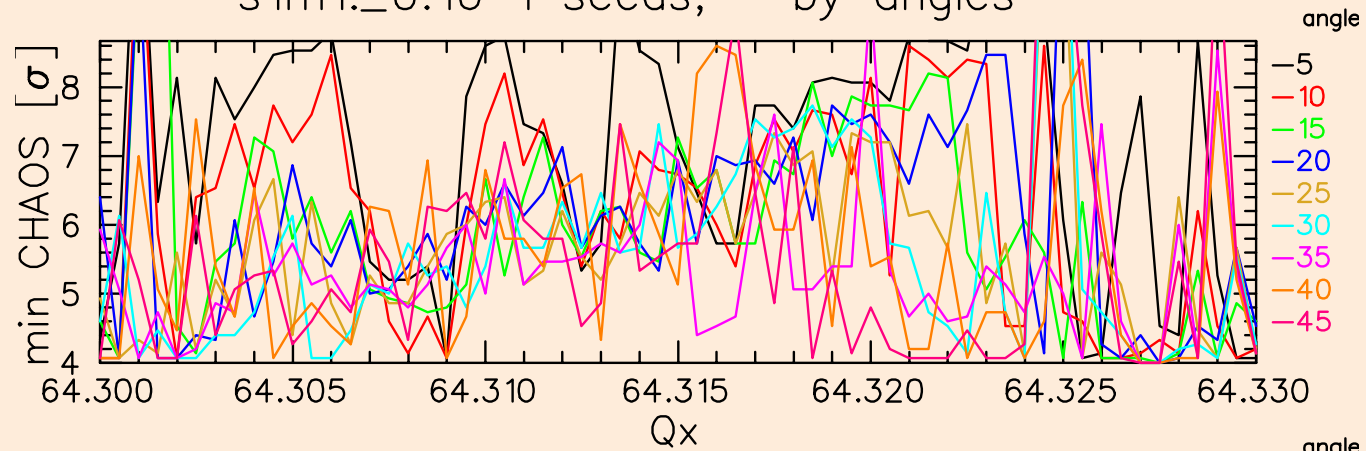


5 1m 0.28 d=12.5

6 1m 0.32 d=14.3

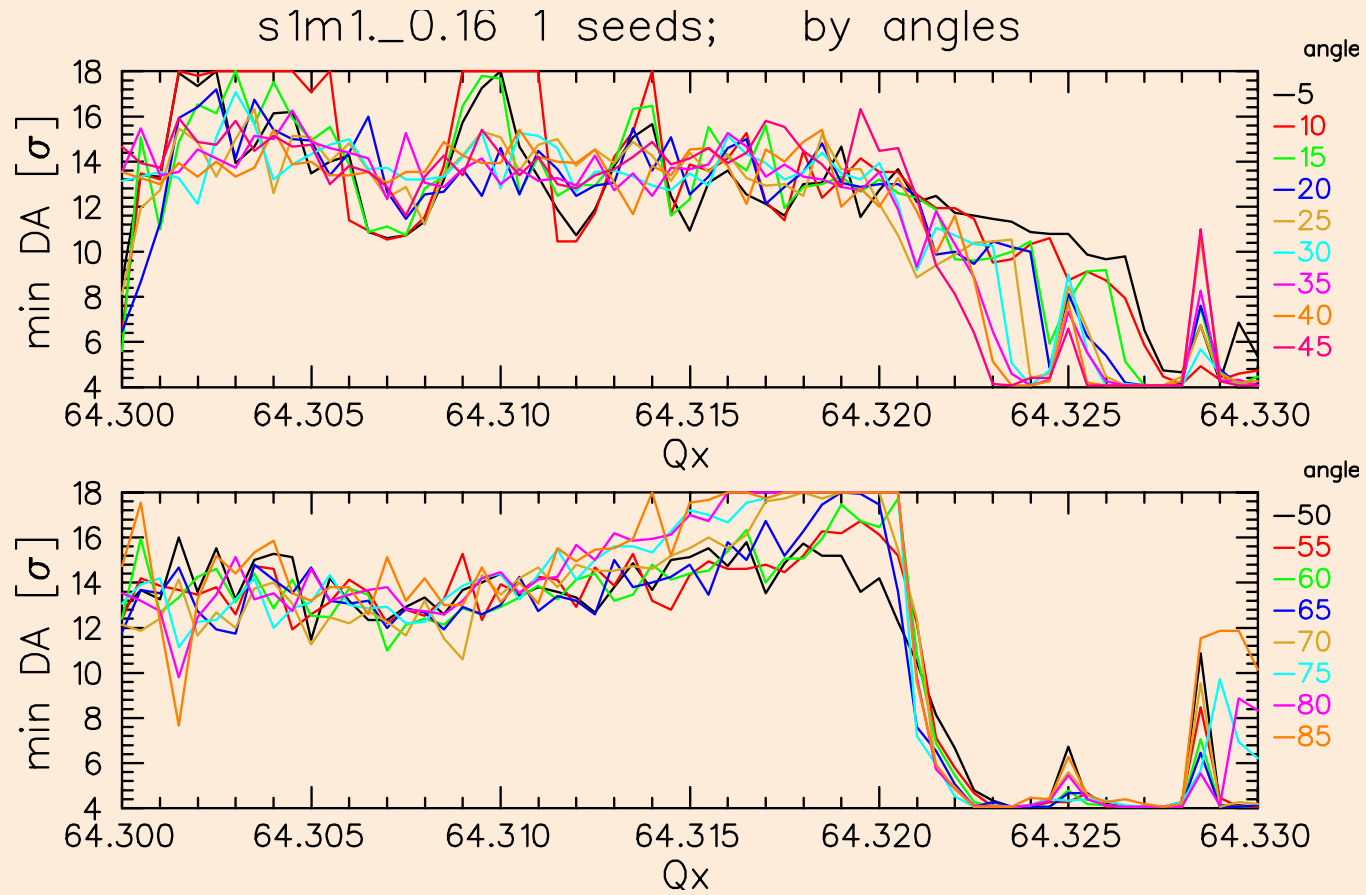
6.1 Chaos

s1m1._0.16 1 seeds; by angles

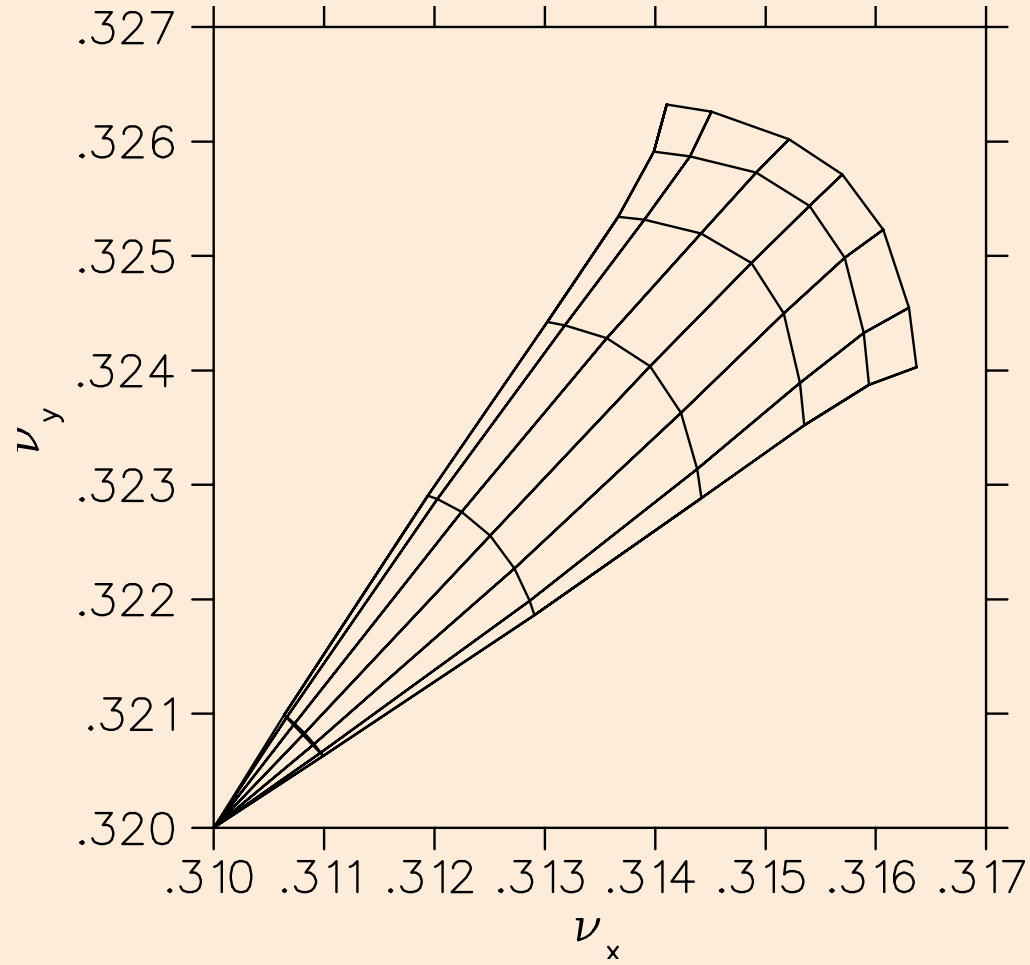


get eps

6.2 DA; d=14.3

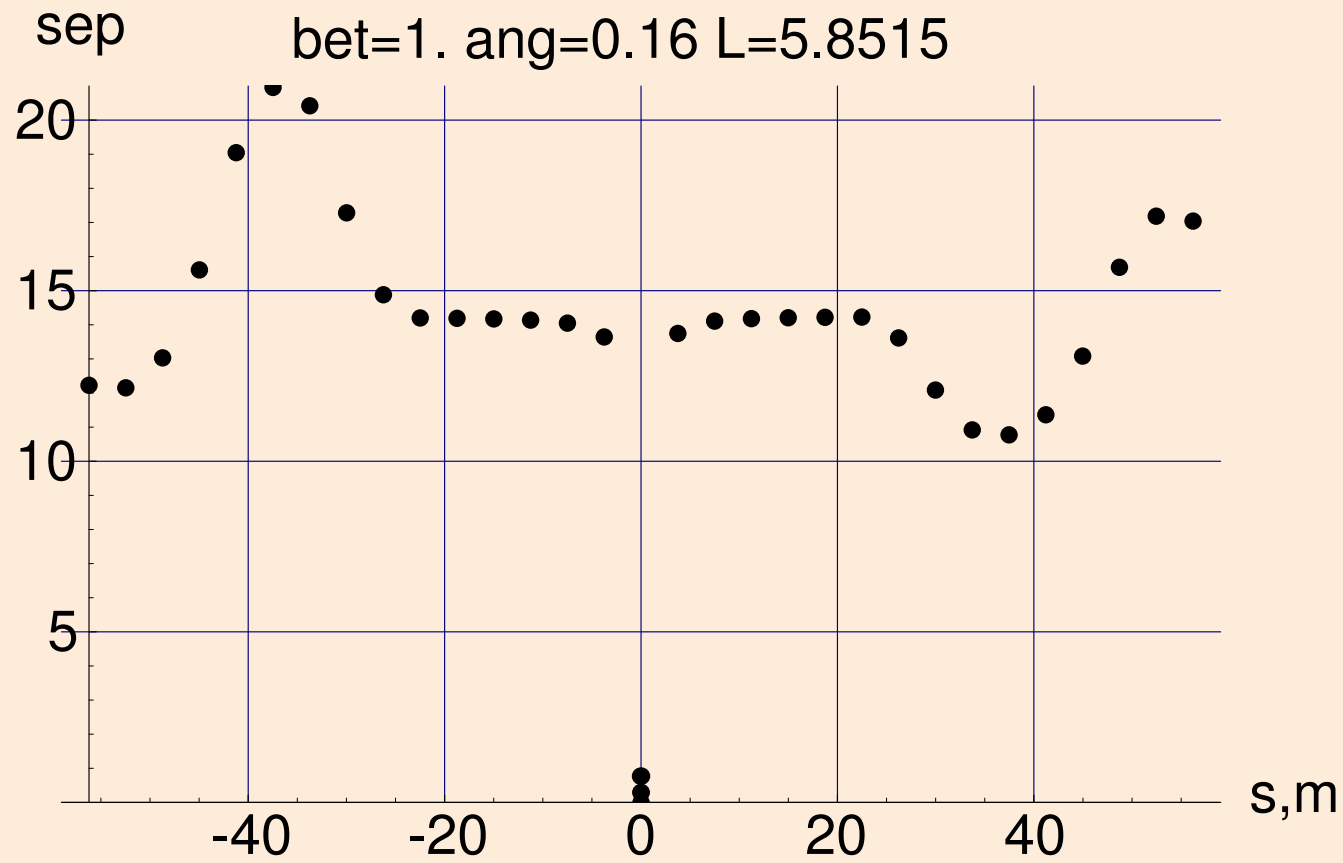


6.3 foot



get eps

6.4 separation



get eps

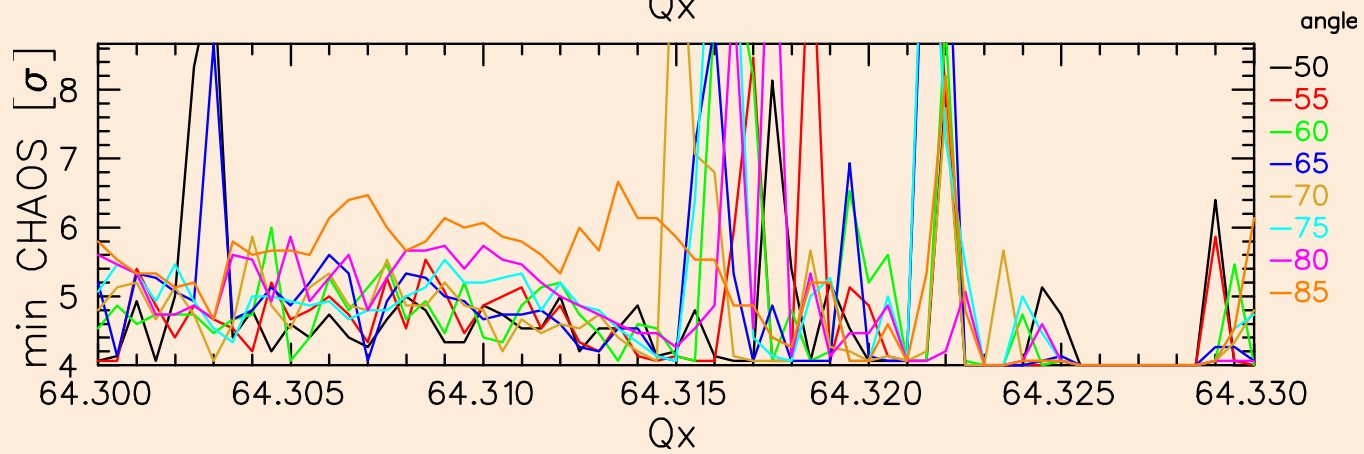
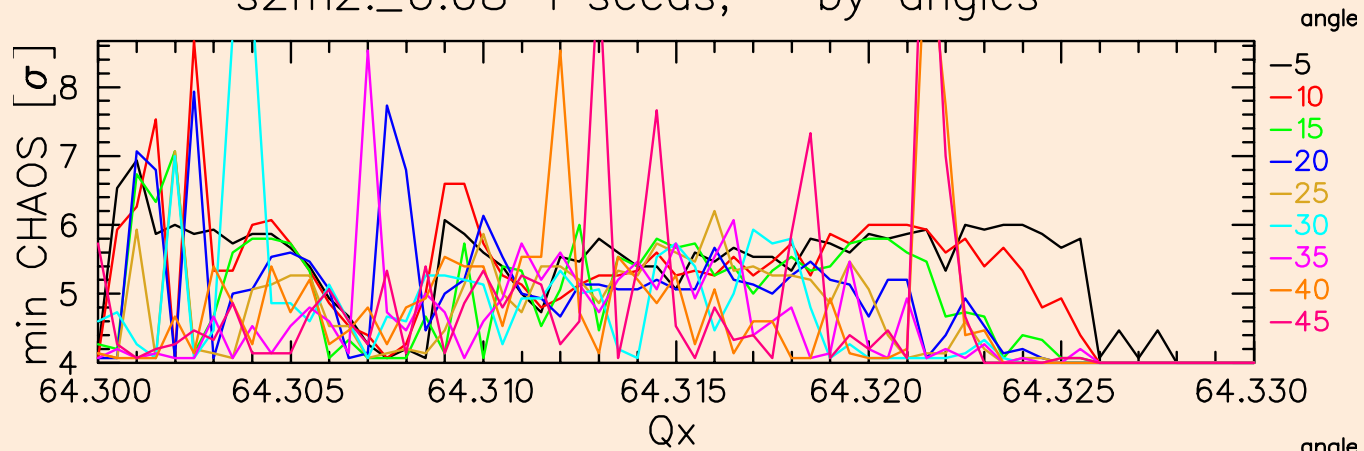
6 1m 0.32 d=14.3

40

7 2m 0.16 d=10.1

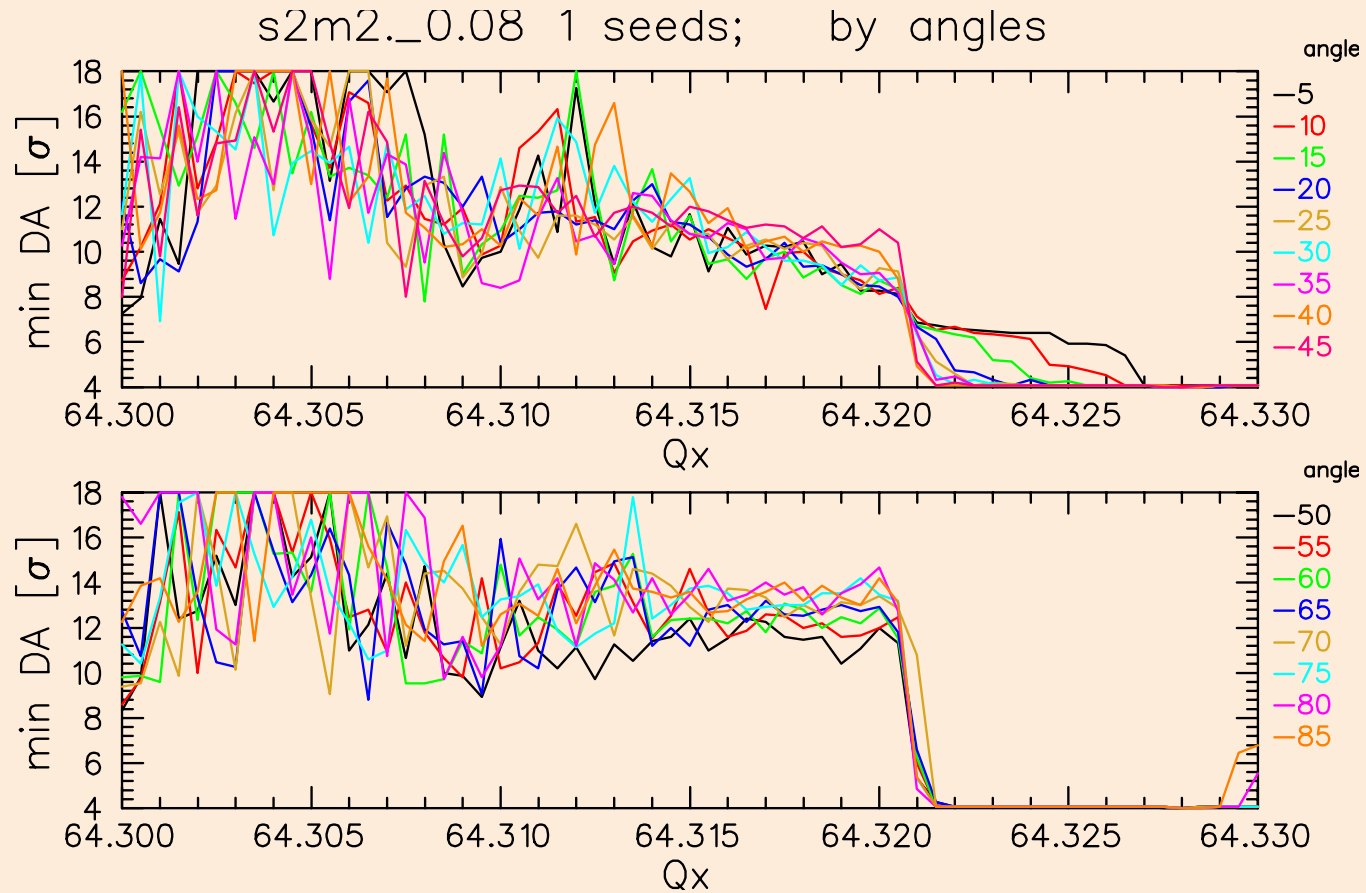
7.1 Chaos

s2m2._0.08 1 seeds; by angles

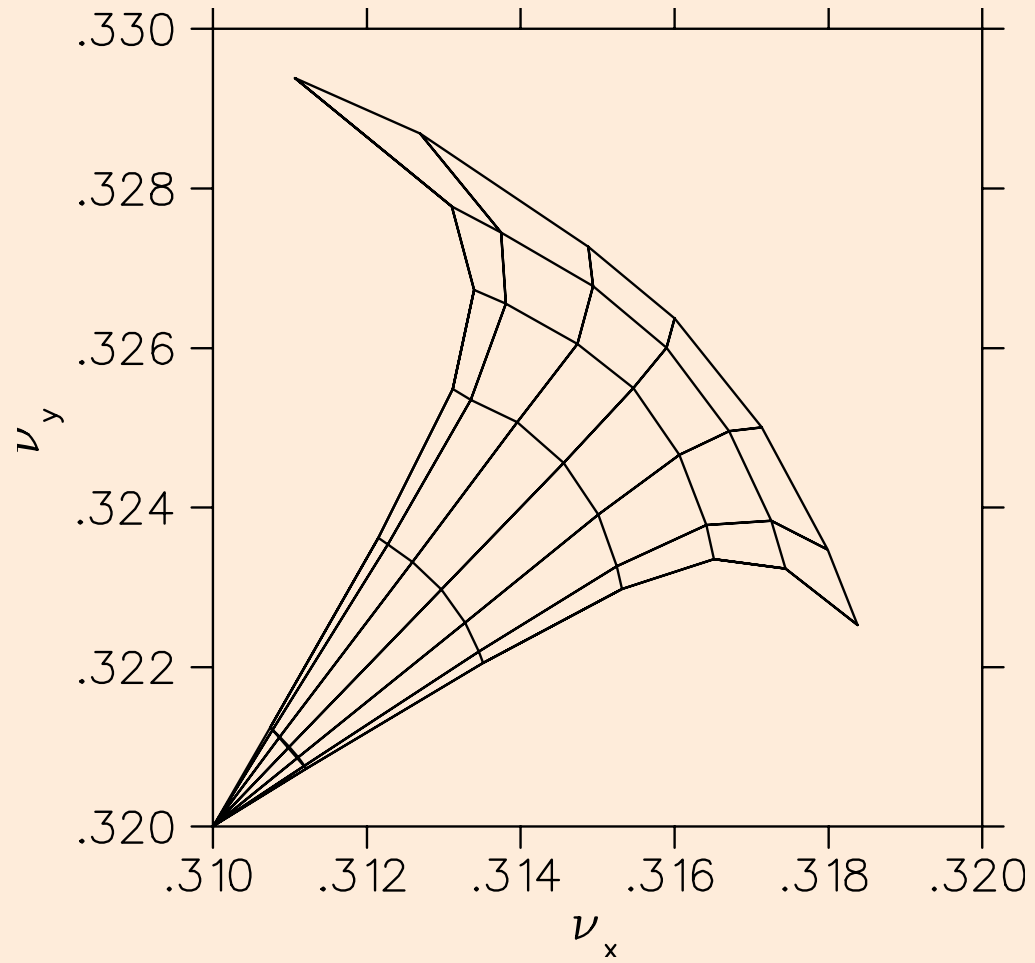


get eps

7.2 DA; d=10.1

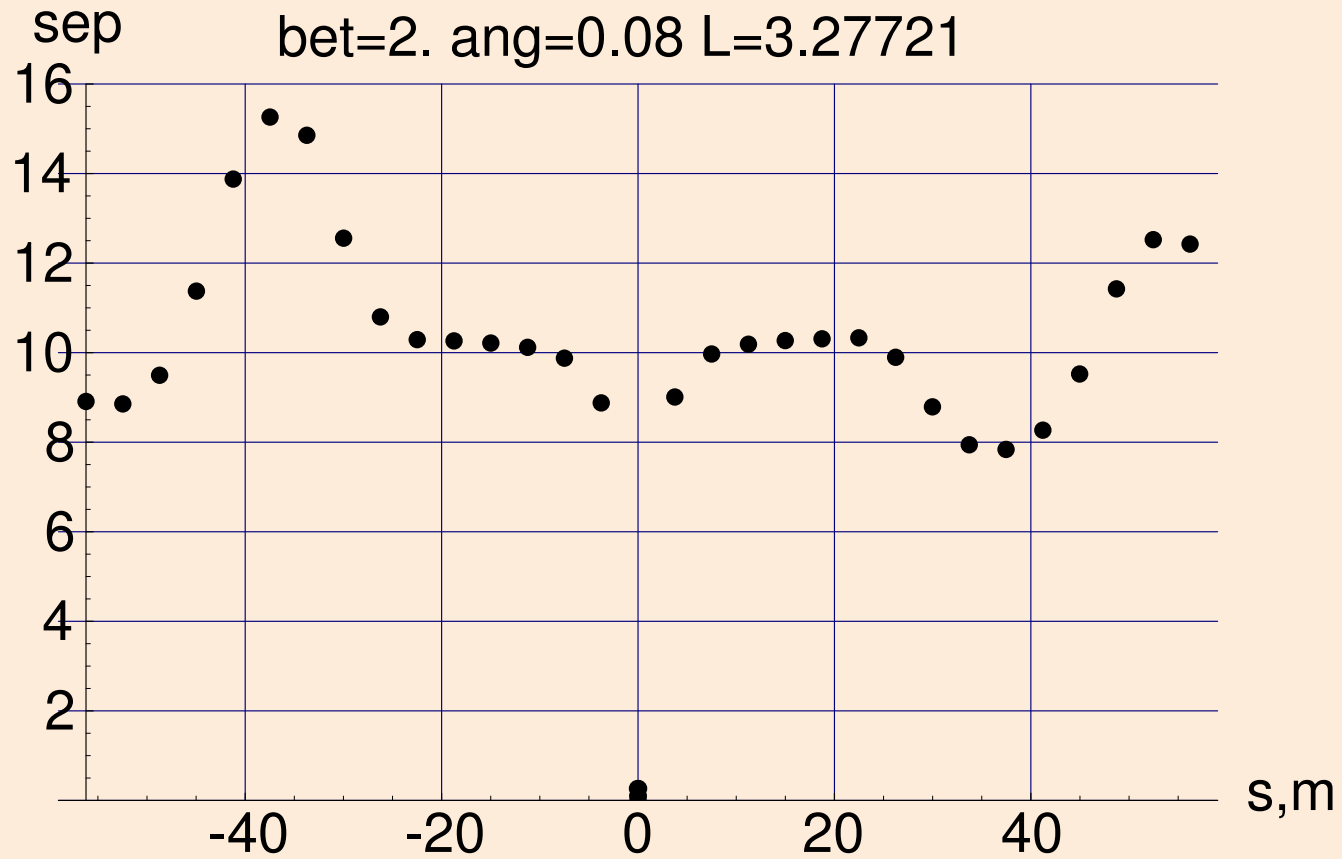


7.3 foot



get eps

7.4 separation



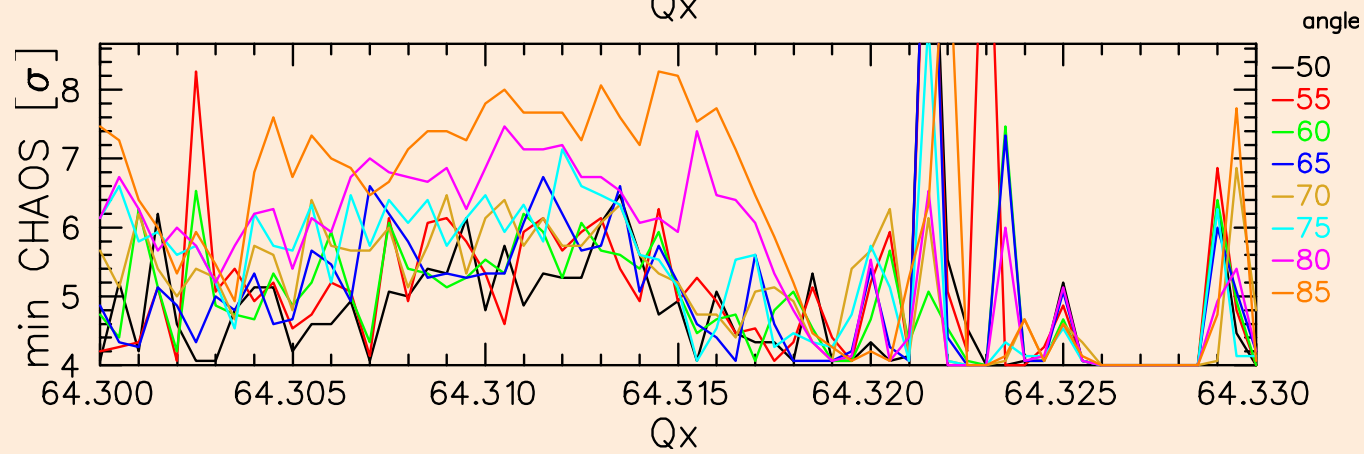
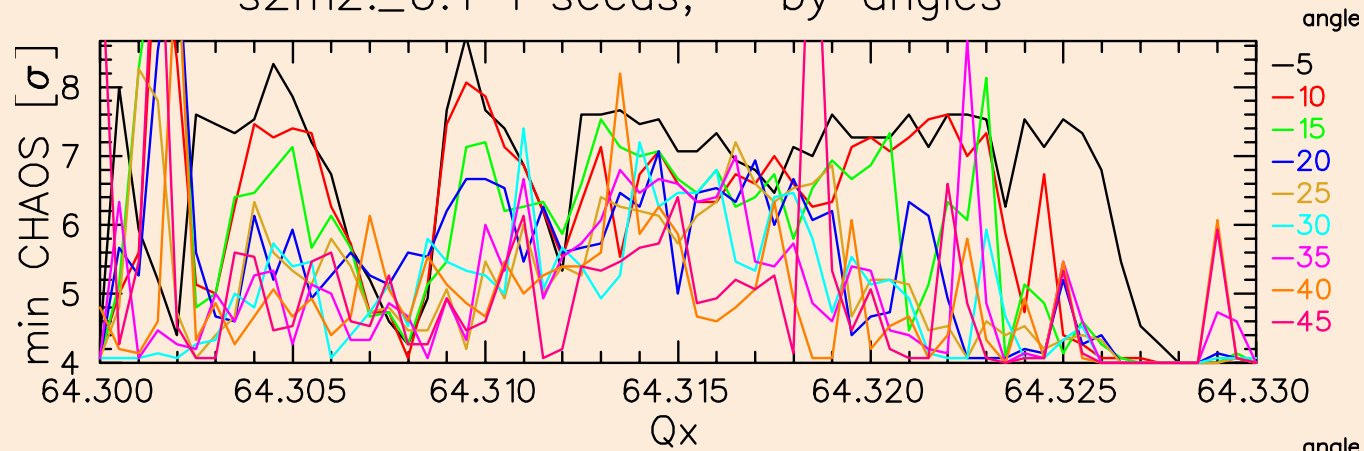
get eps

7 2m 0.16 d=10.1

8 2m 0.2 d=12.6

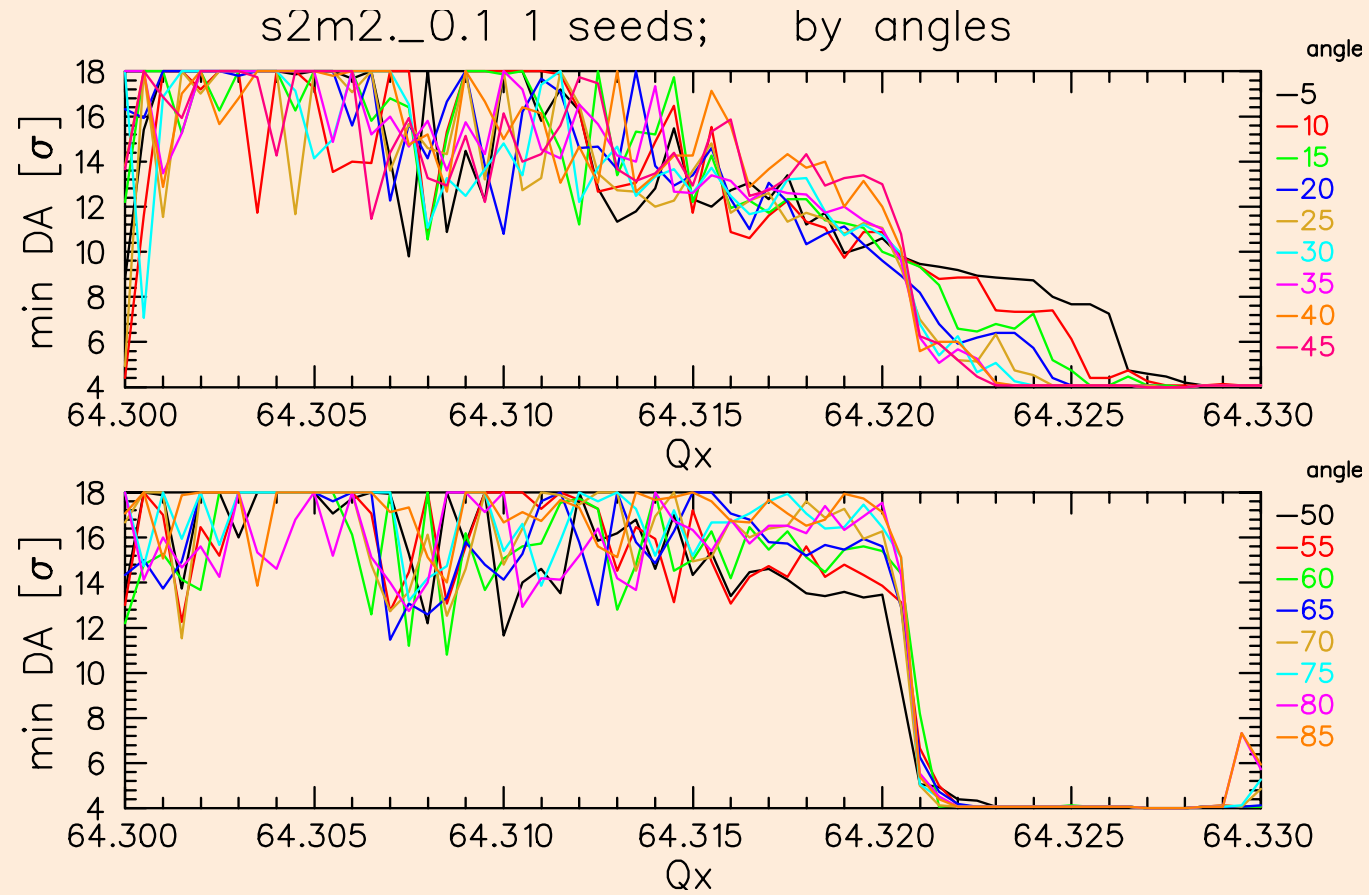
8.1 Chaos

s2m2._0.1 1 seeds; by angles

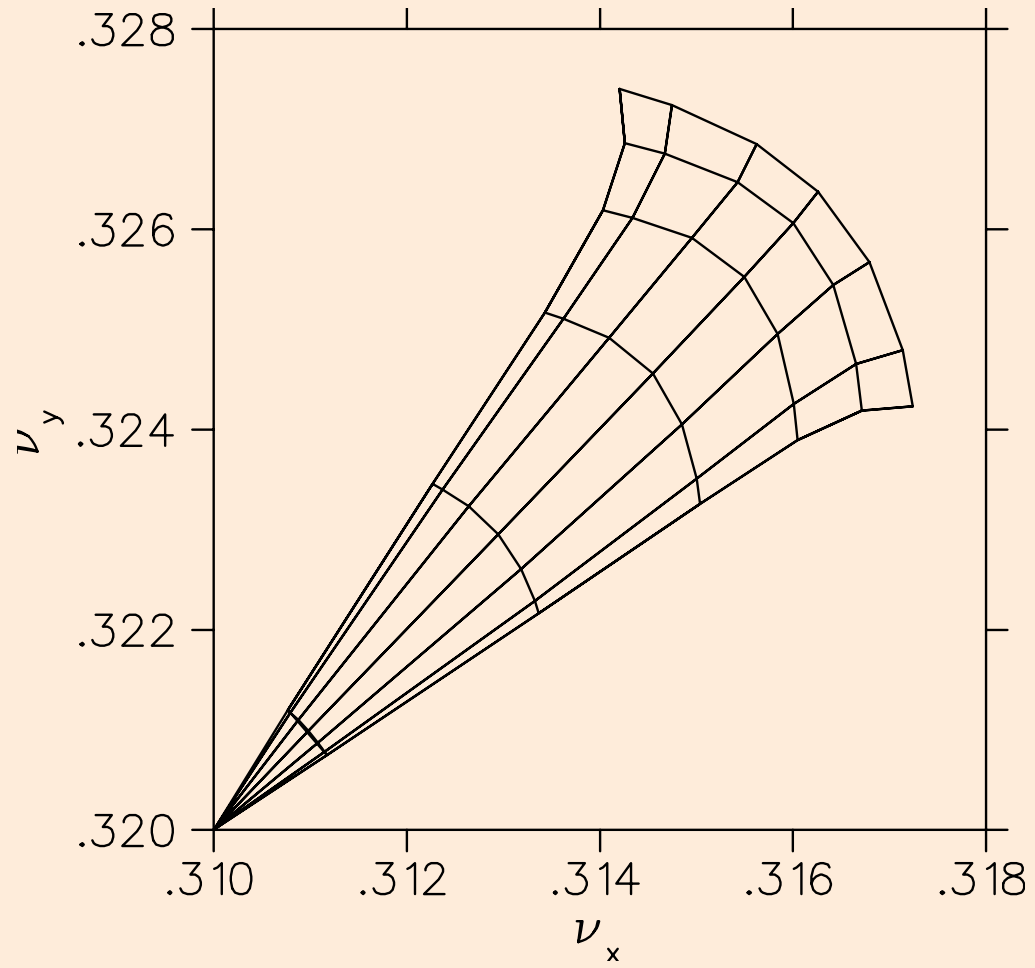


get eps

8.2 DA; d=12.6

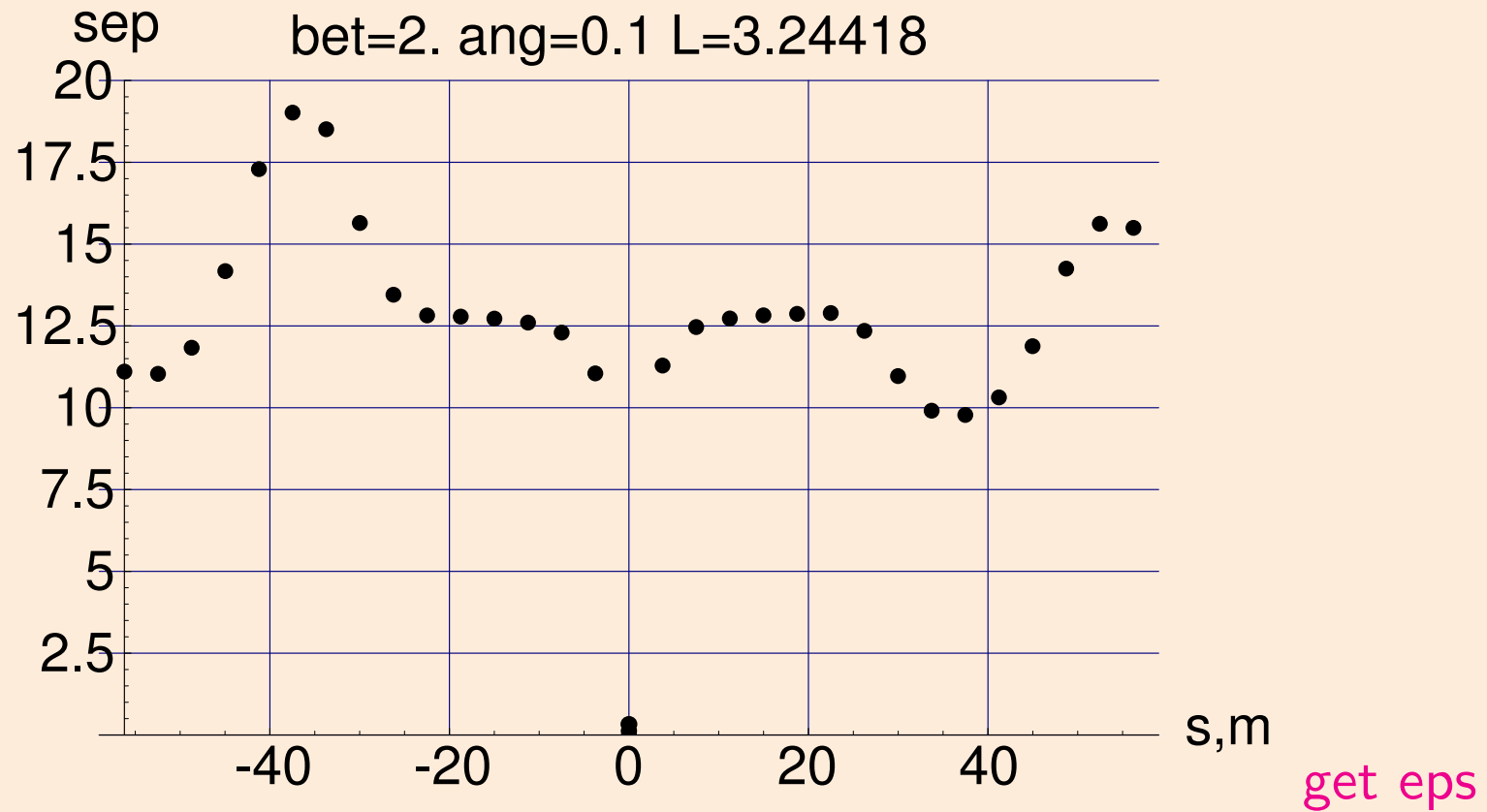


8.3 foot



get eps

8.4 separation



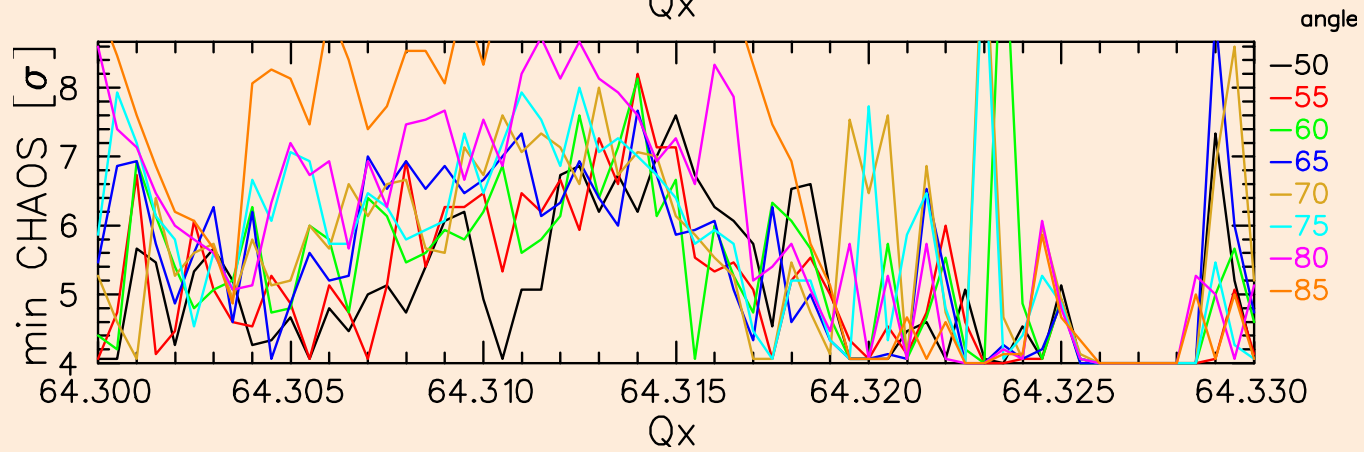
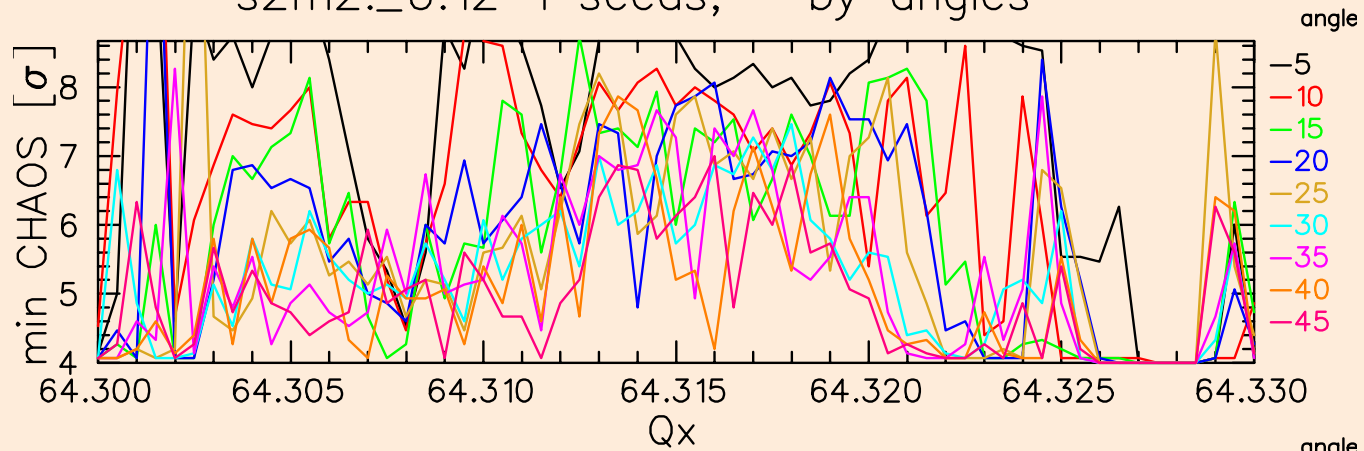
8 2m 0.2 d=12.6

50

9 2m 0.24 d=15.1

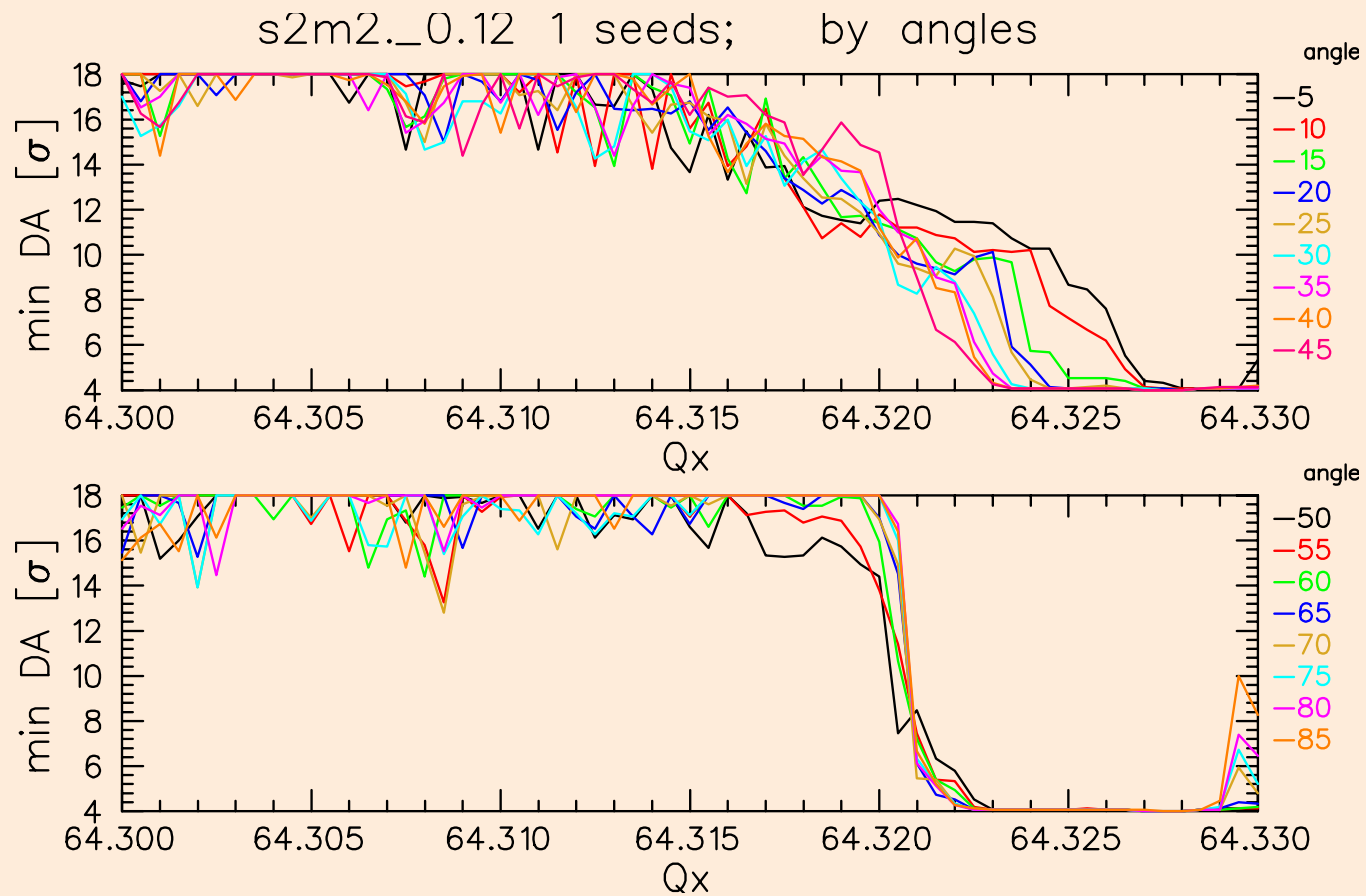
9.1 Chaos

s2m2._0.12 1 seeds; by angles

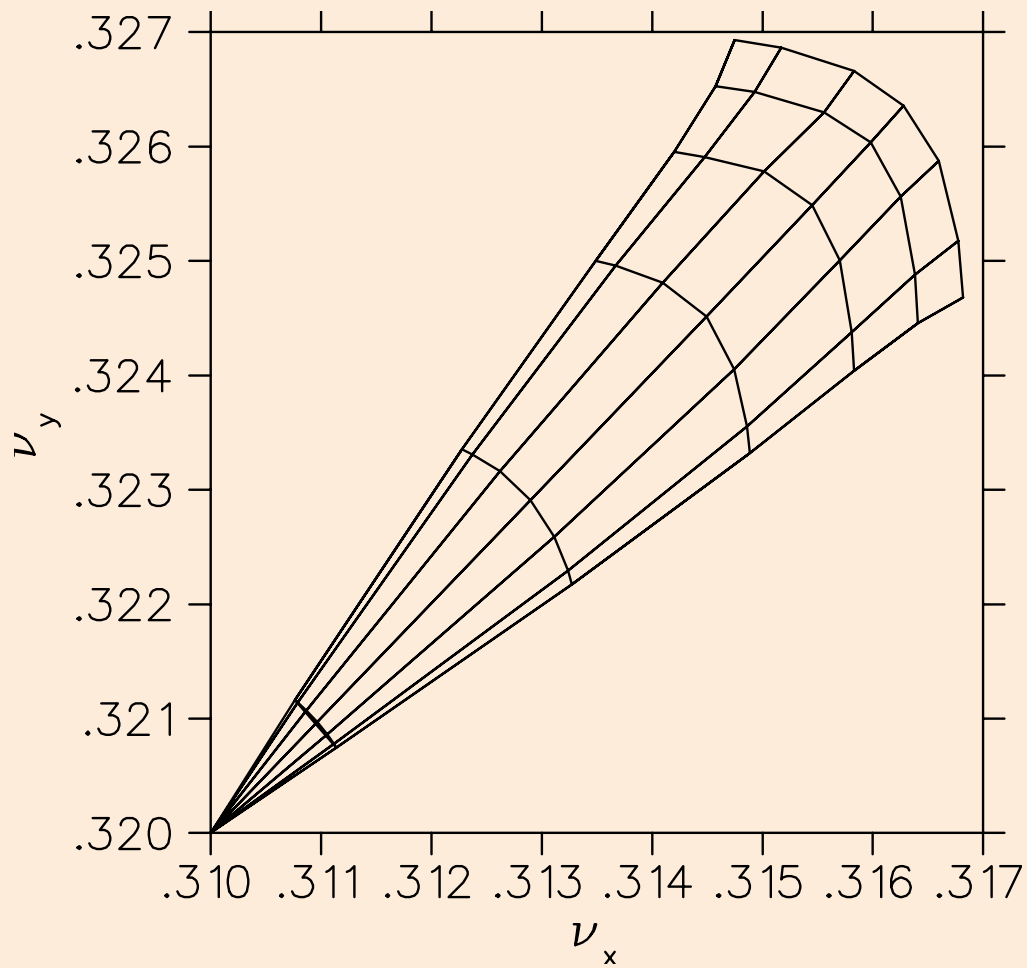


get eps

9.2 DA; d=15.1

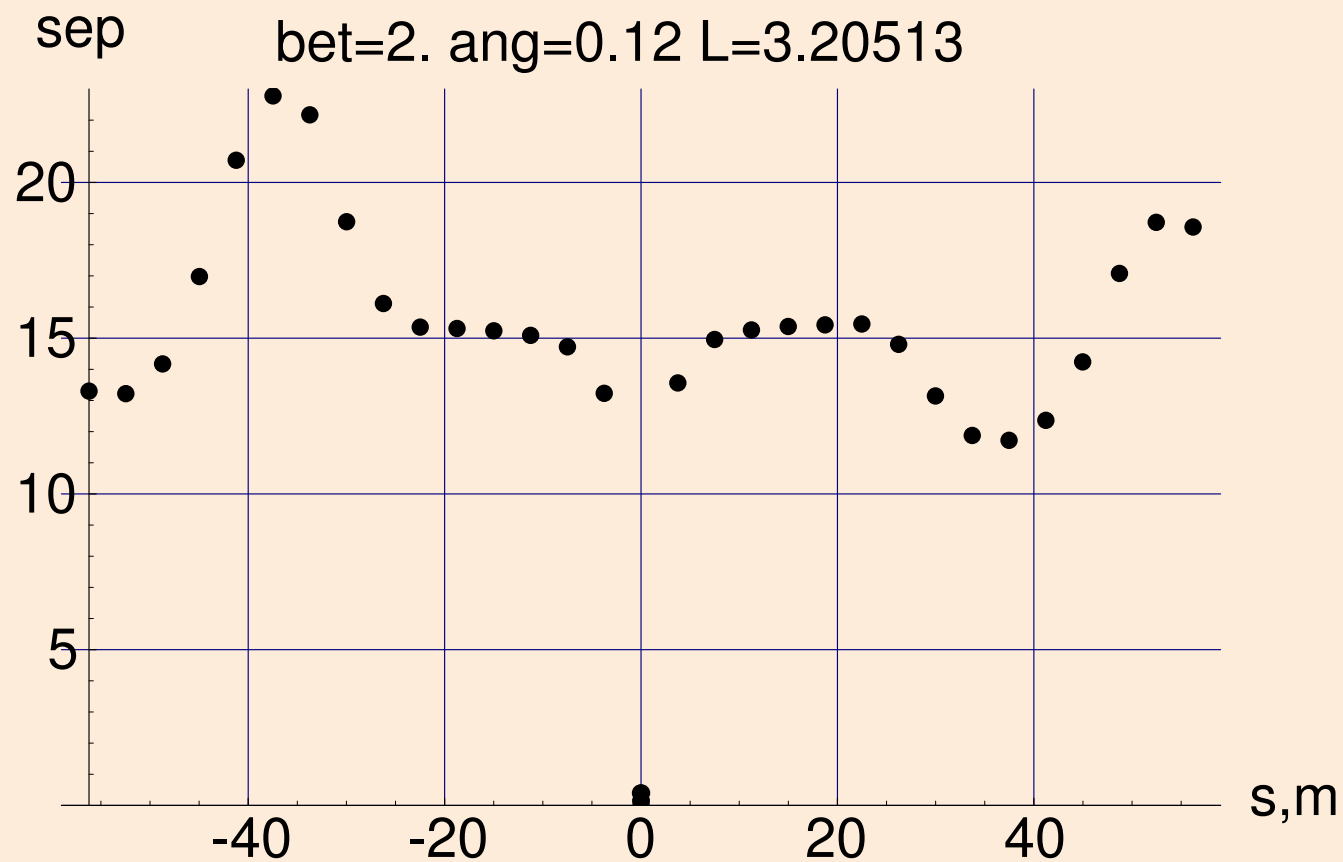


9.3 foot



get eps

9.4 separation

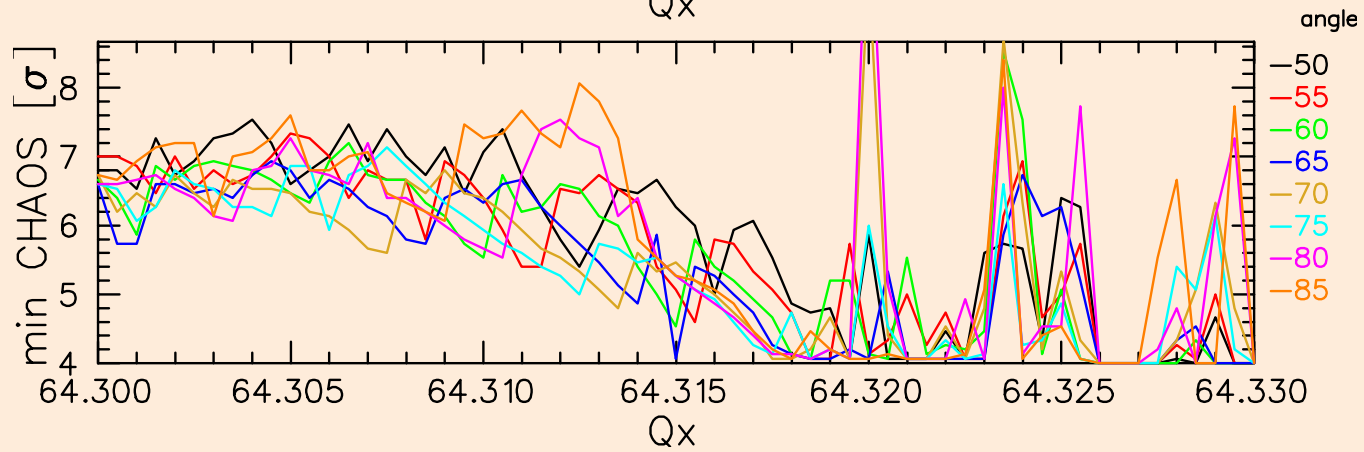
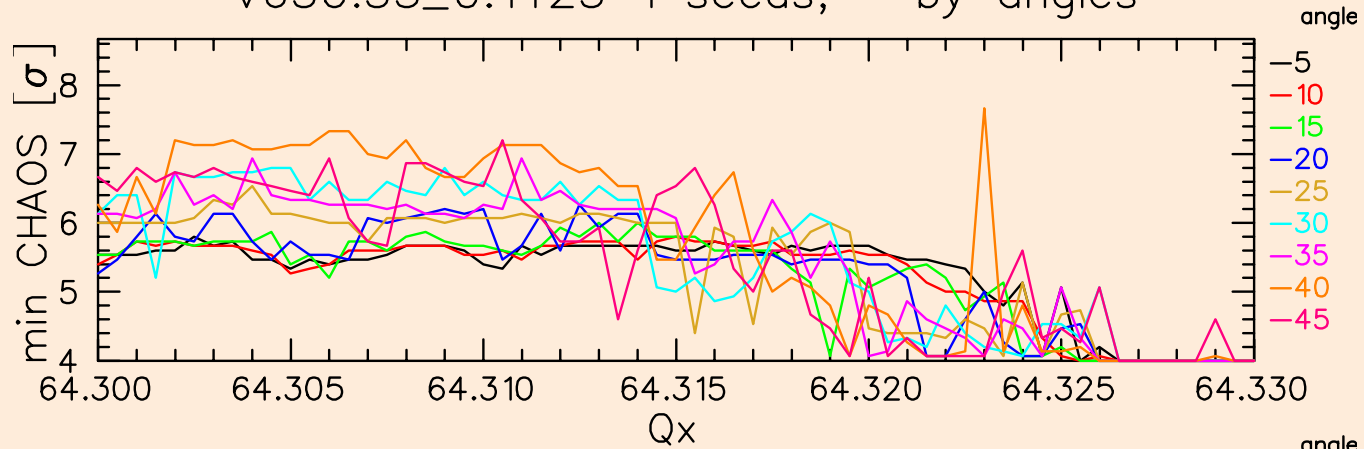


get eps

10 0.55m 0.285 d=9.4 (only long range)

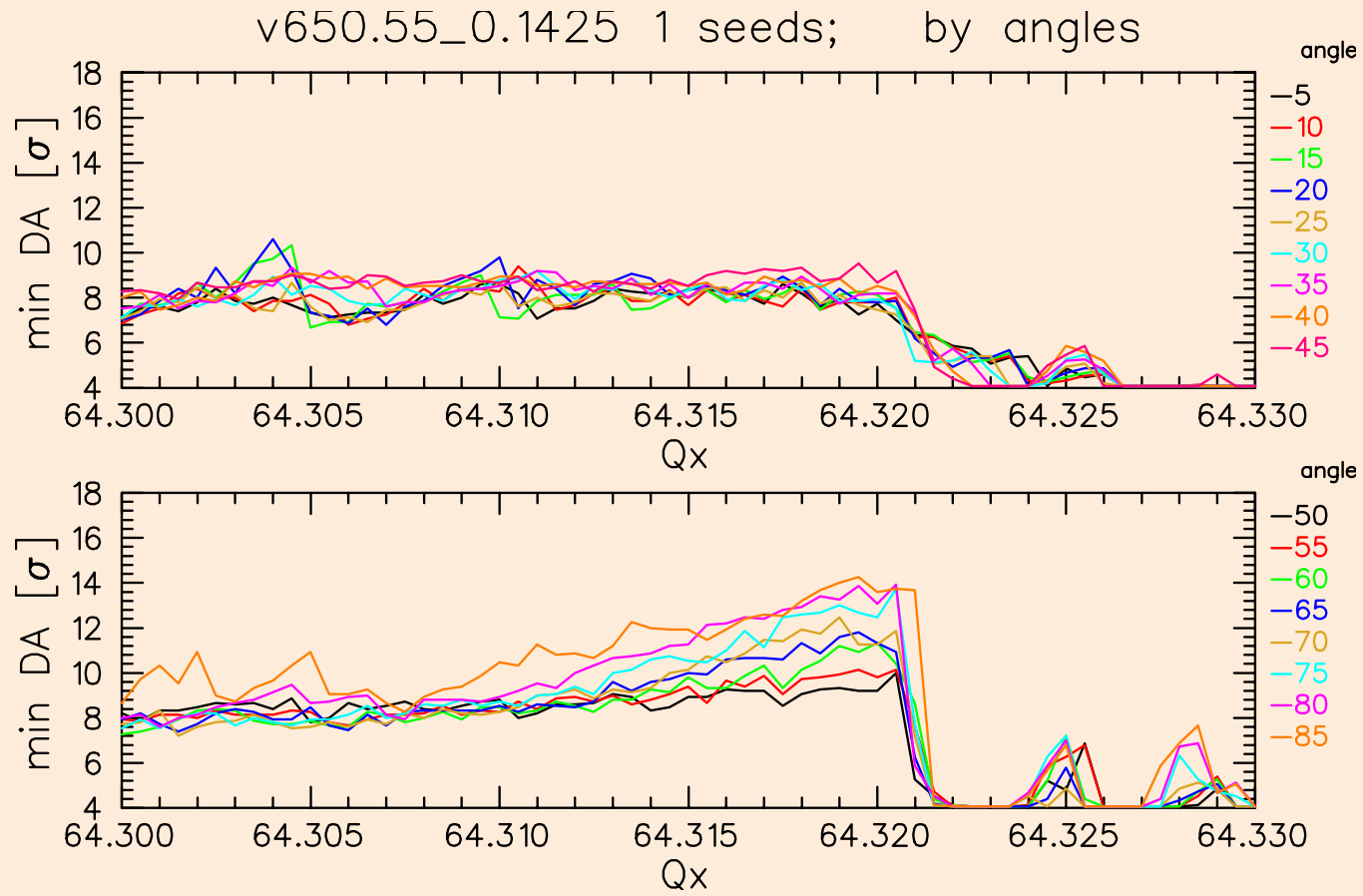
10.1 Chaos

v650.55_0.1425 1 seeds; by angles

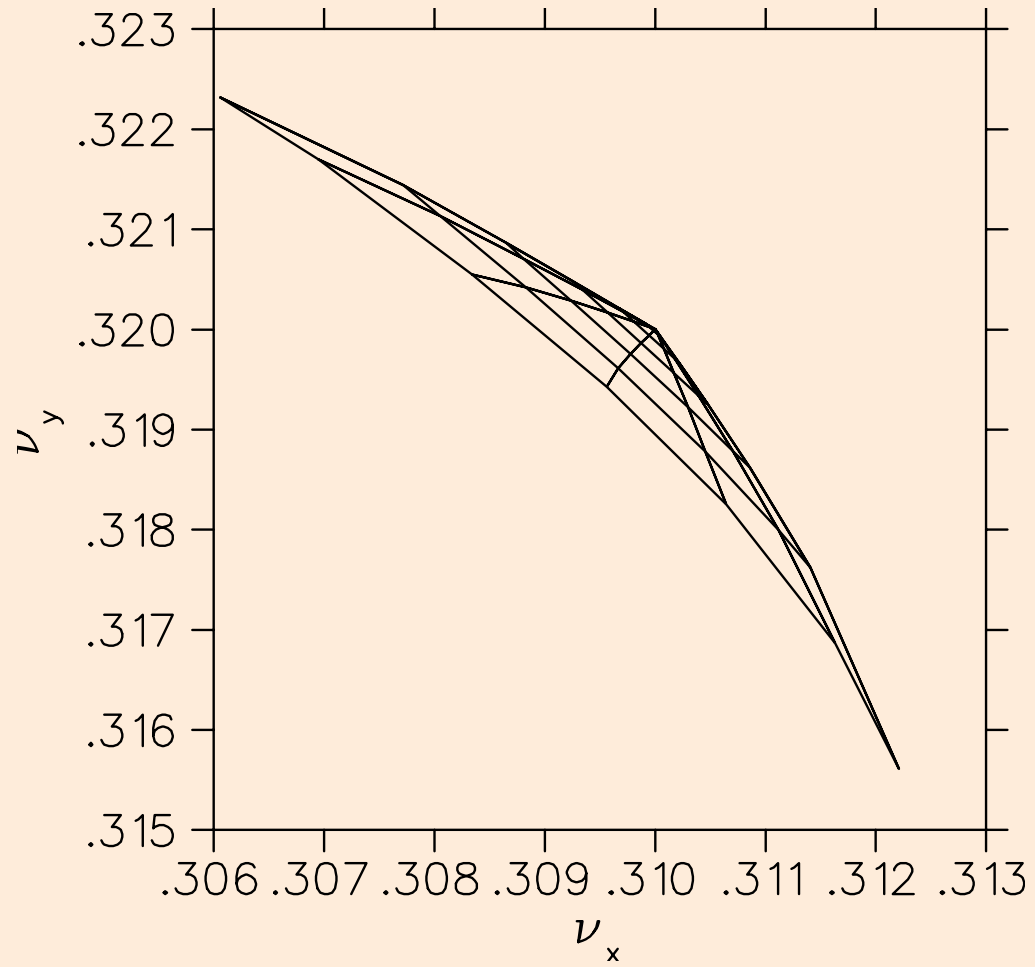


get eps

10.2 DA; d=9.4 (only long range)

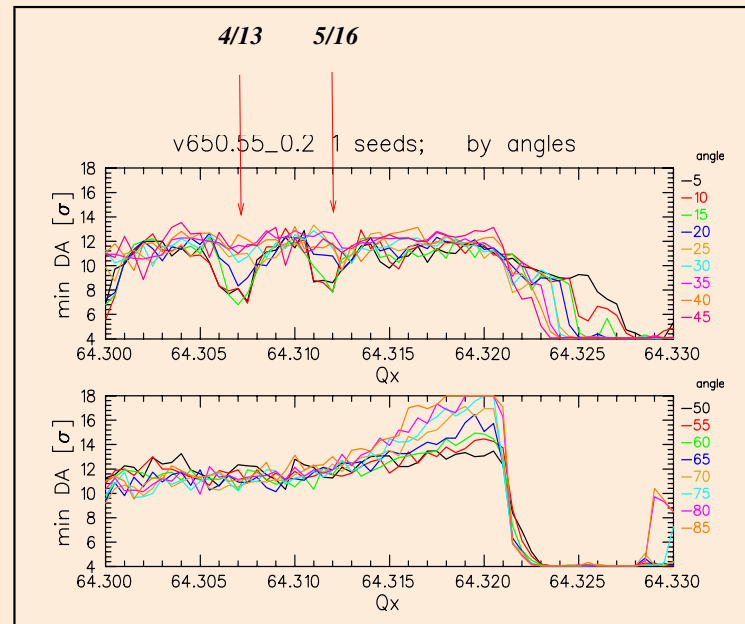


10.3 foot



get eps

11 BB resonances cause two dips in DA:



Betatron invariant computed with first ord. pert. theory and shows that:

4/13 can be canceled by $\pi/2$ phase diff. IP5-IP1

5/16 can not (because 16 is divisible by 4)

12 Summary (collision)

- Even with these **full** head-on + long range collisions and **pessimistic (high)** $N_p = 1.15 \cdot 10^{11}$ taking $\beta^* > 1m$ already gives $DA \approx 8 - 10 \sigma$.
For example (1 m, 0.28 mrad) or (2 m, 0.2 mrad) $\rightarrow DA \approx 10\sigma$.
- If $\beta^* > 0.55m$, DA roughly obeys: $DA \sim d$
- that's, **except near resonances**: The two dips persist in **horiz plane**; caused by **head-on (?)** BB. **In theory**, $\pi/2$ horiz. phase between the two IPs would cancel the left one, but needs a tight constraint on phase: $\sim 0.01 - 0.02$

13 INJECTION optics

13.1 Conditions for tracking and what is shown

- version 6.5 at 450 GeV; Sixtrack with beam-beam
- head-on only; $N_b = 0.4 \times 10^{11}$; 60 seeds; 10^5 turns
- different optics settings: 6 m , 11 m , 17 m
- Chaos border and Dynamic Aperture (DA):
average (black) and **minimum (red)**

14 Flags: (err,a2,a2c,D1D2,BB)

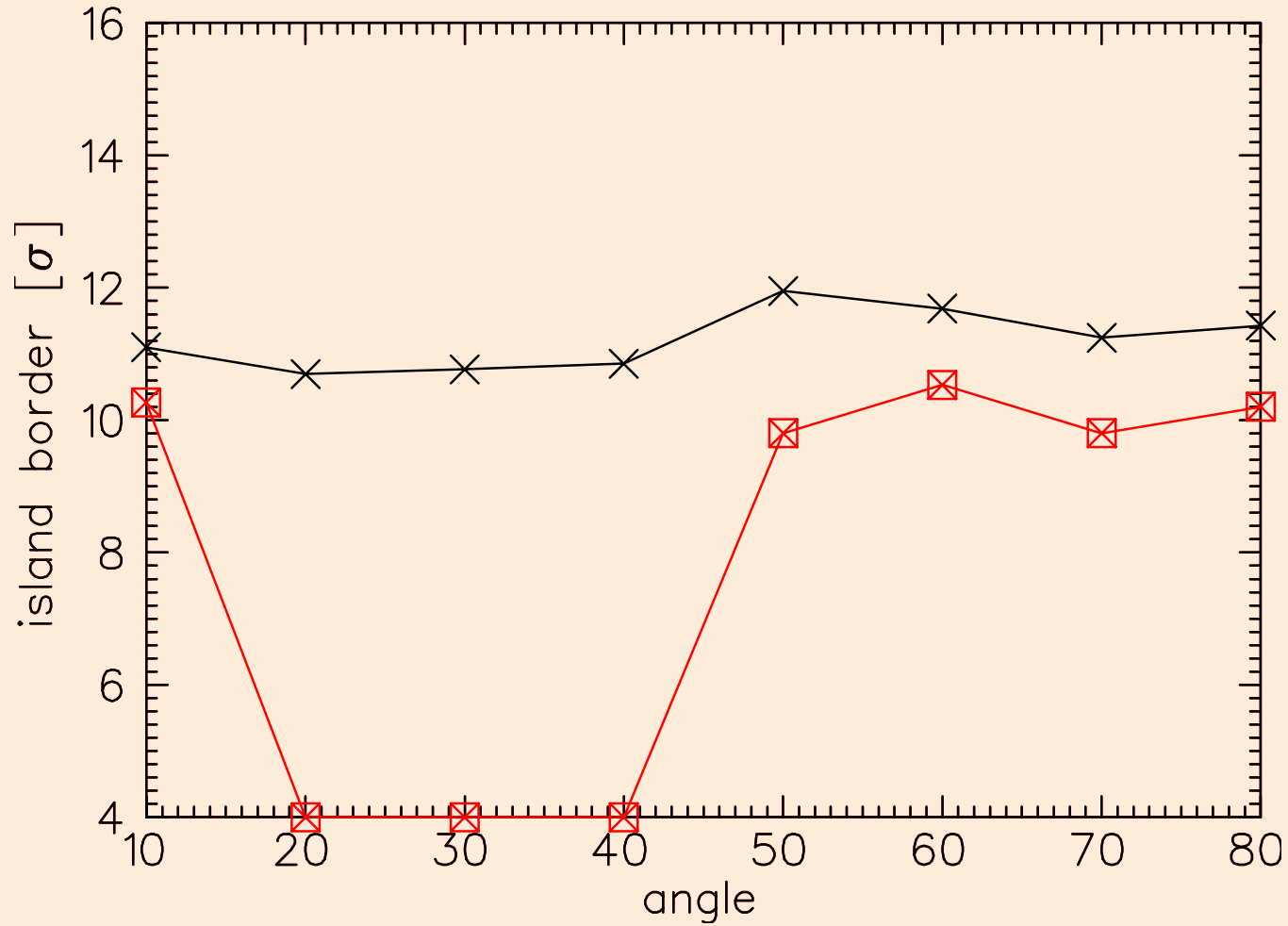
All errors as in MG's 17m sample job (2006),
but for the 6 and 11 m I've switched off the D1-D4 x-alignment.
I've introduced some on/off flags:

- **err** high order field errors
- **a2**
- **a2c** coupling correction
- **D1D2** D1-D4 alignment and field err.
- **BB** beam-beam

15 17m (1,1,1,1,0)

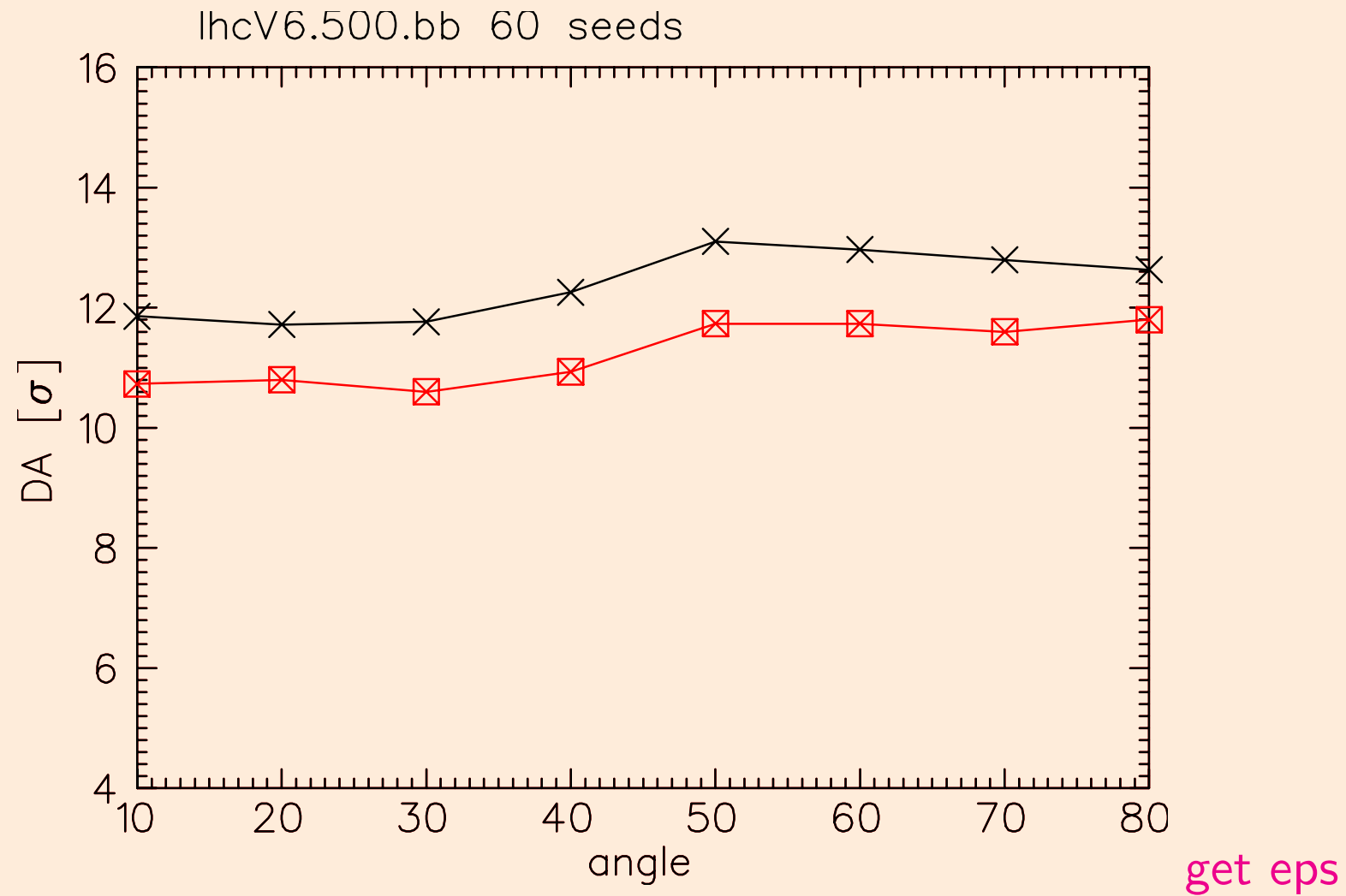
15.1 Chaos

lhcV6.500.bb 60 seeds



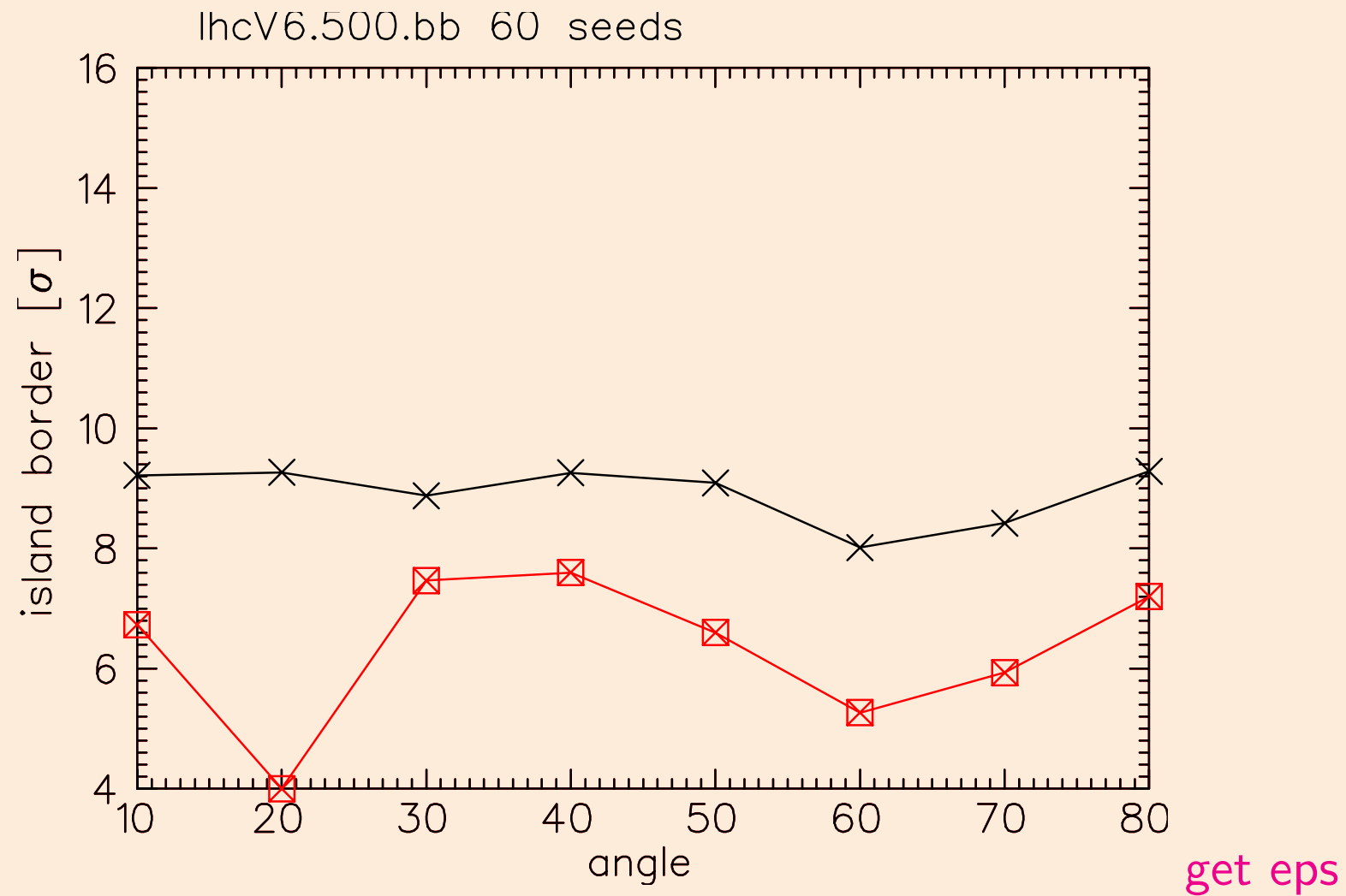
get eps

15.2 DA

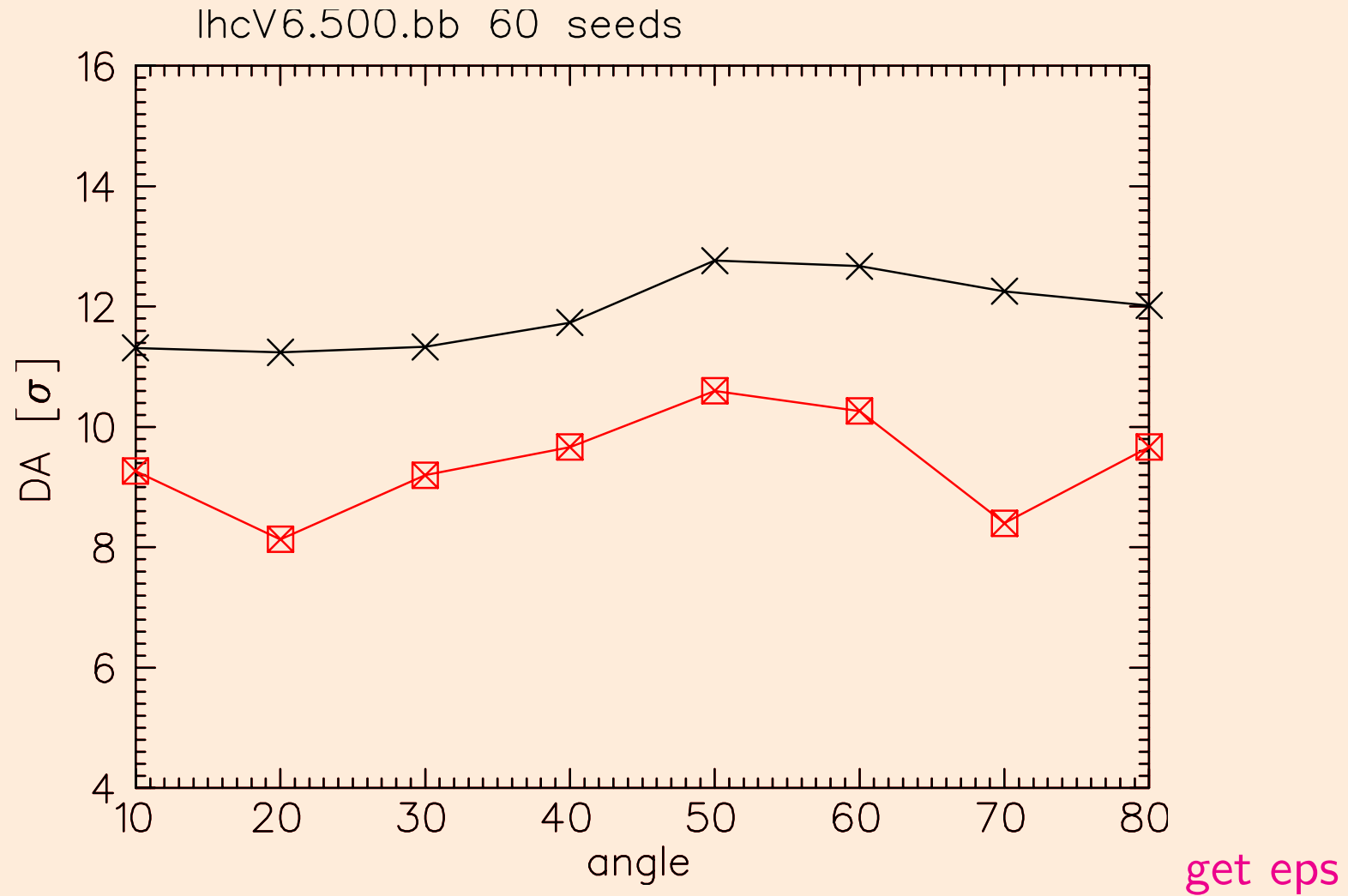


16 17m (1,1,1,1,1)

16.1 Chaos

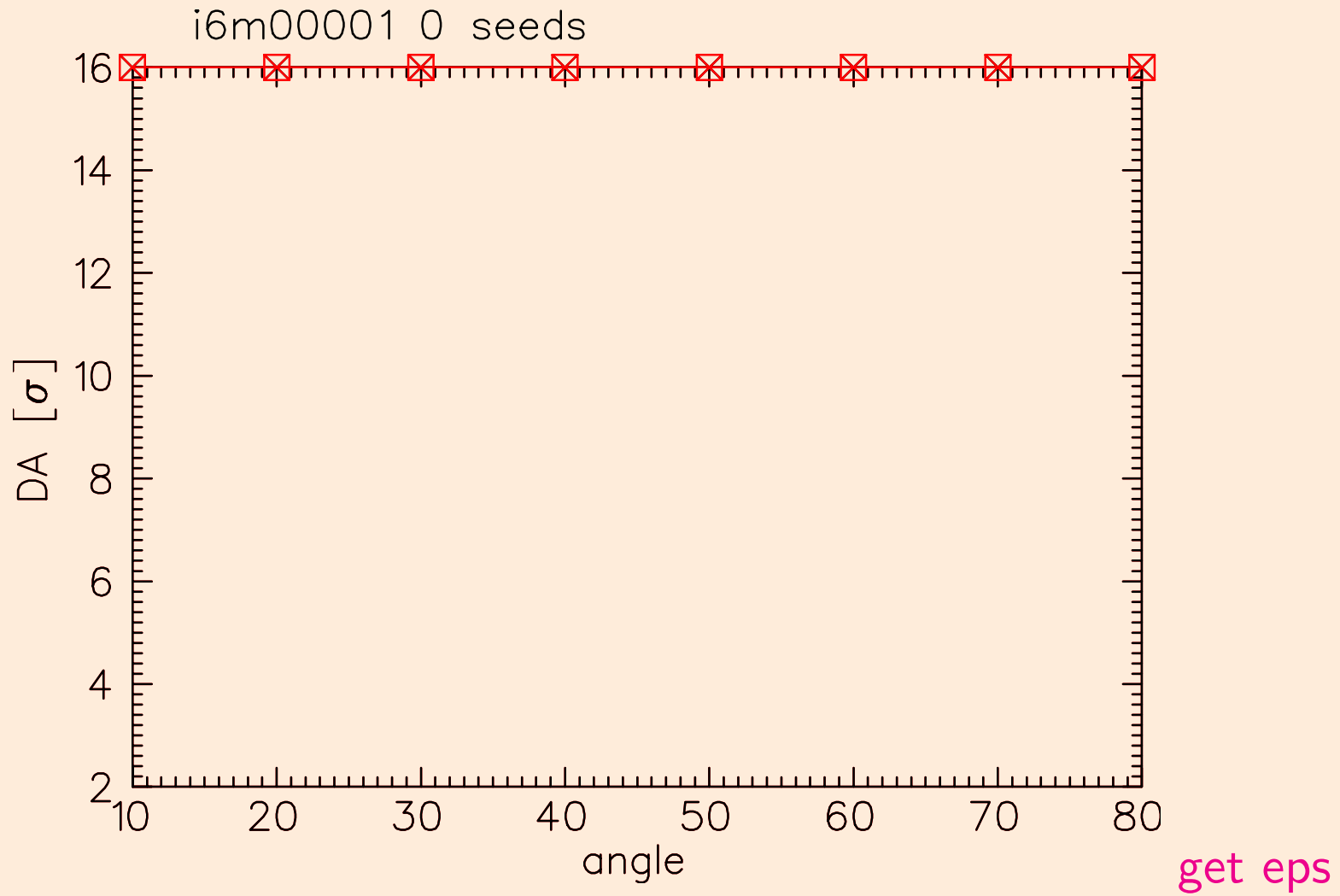


16.2 DA

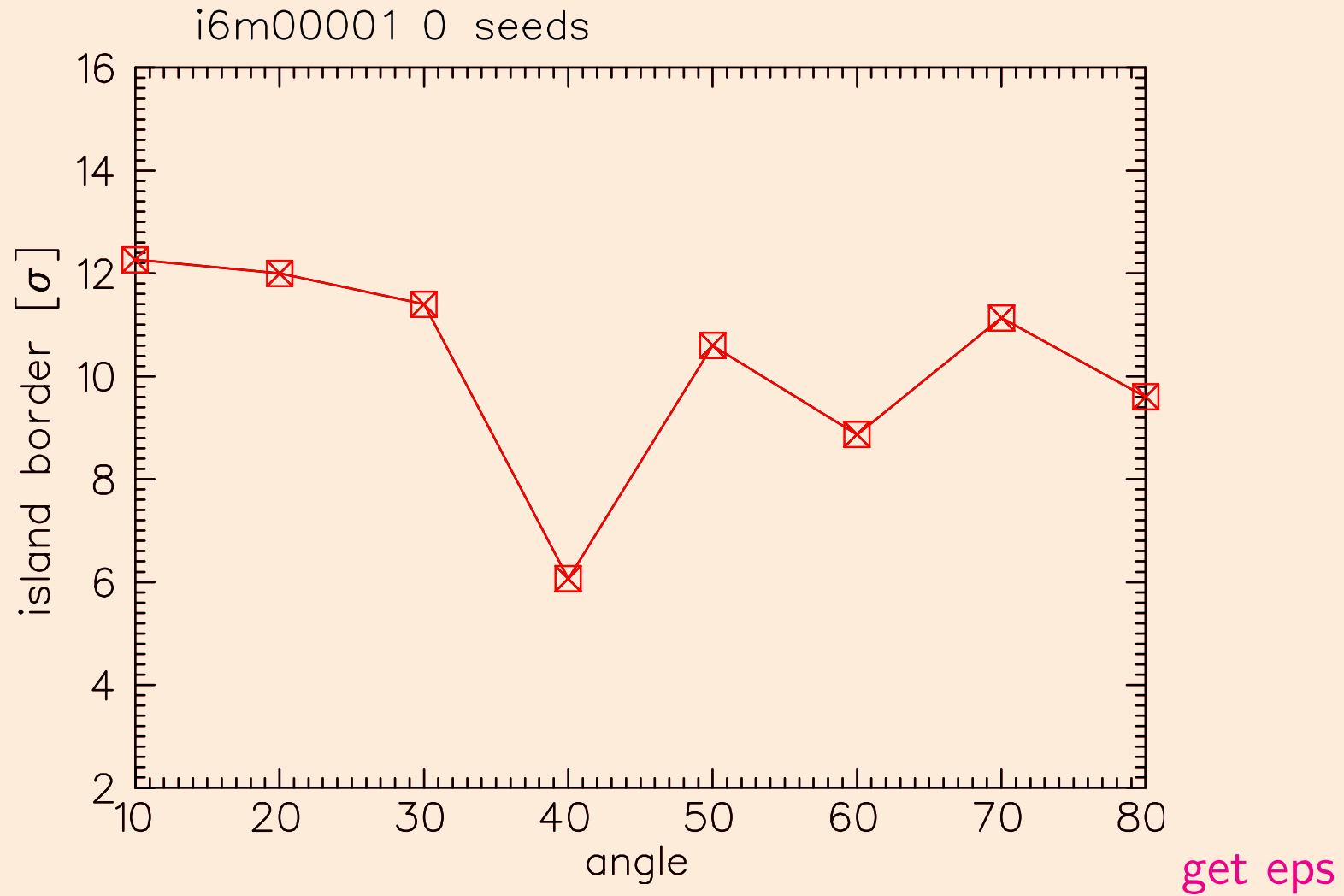


17 6m (0,0,0,0,1)

17.1 DA



17.2 Chaos



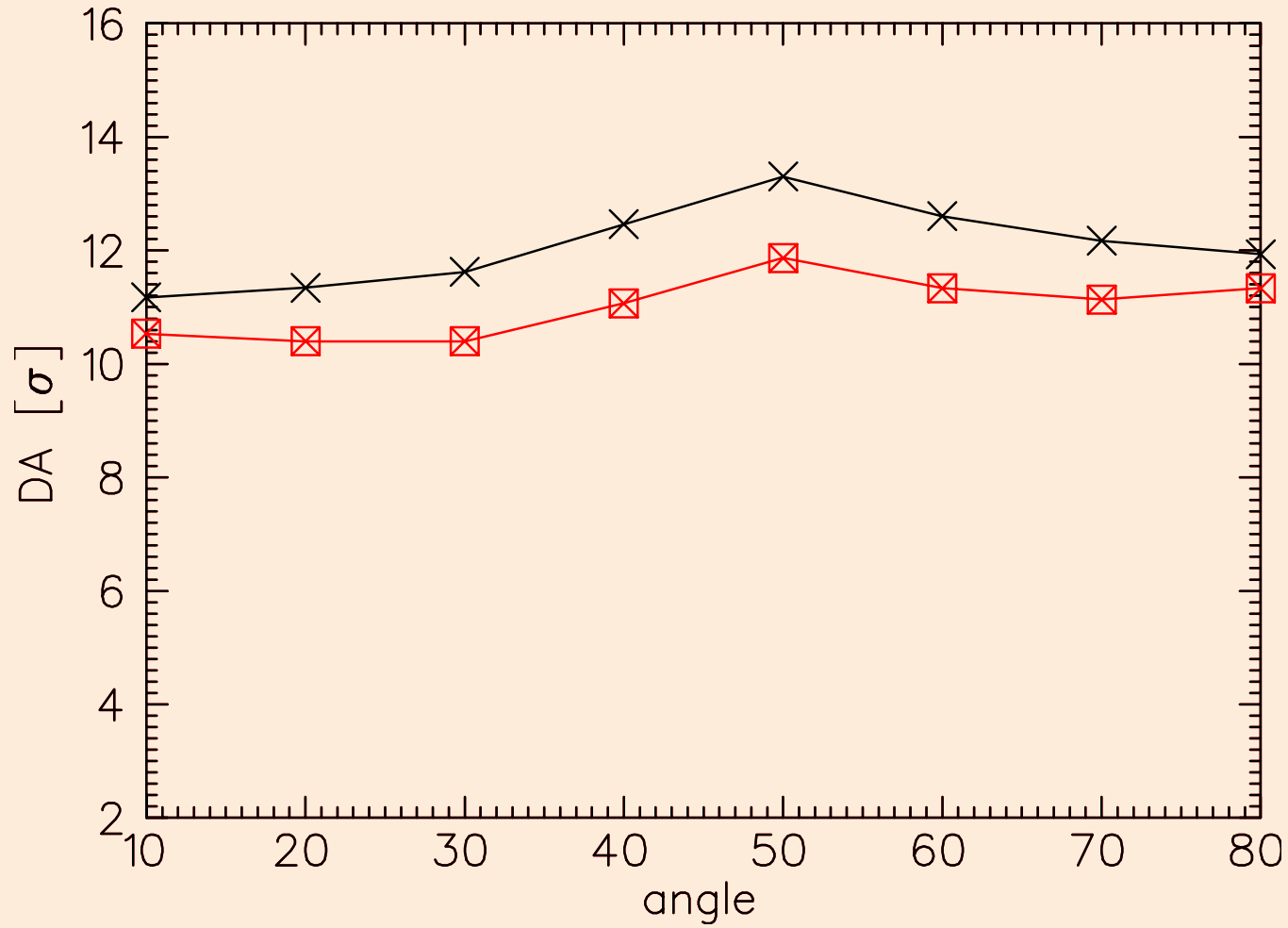
17 6m (0,0,0,0,1)

73

18 6m (1,0,0,0,1)

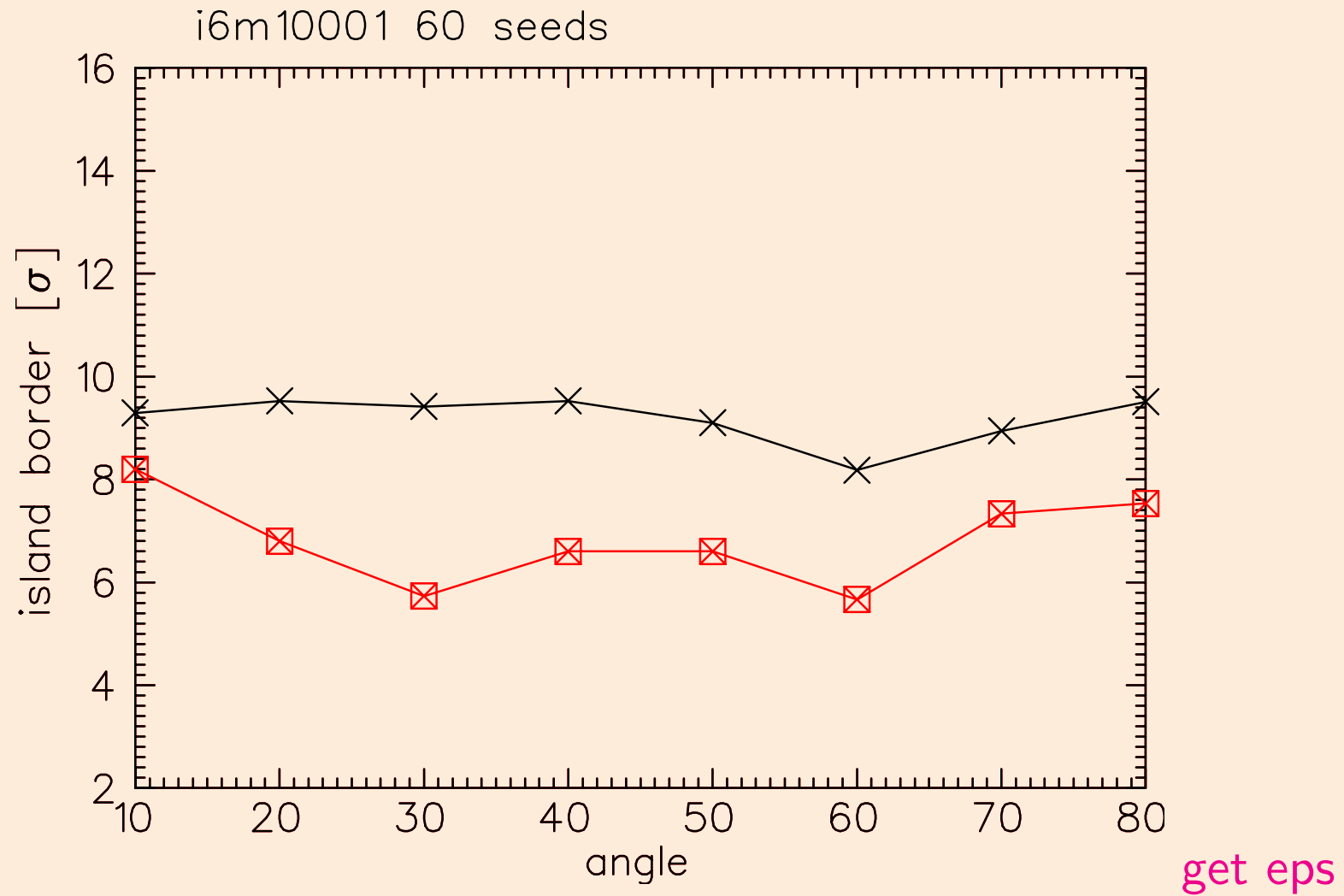
18.1 DA

i6m10001 60 seeds



get eps

18.2 Chaos

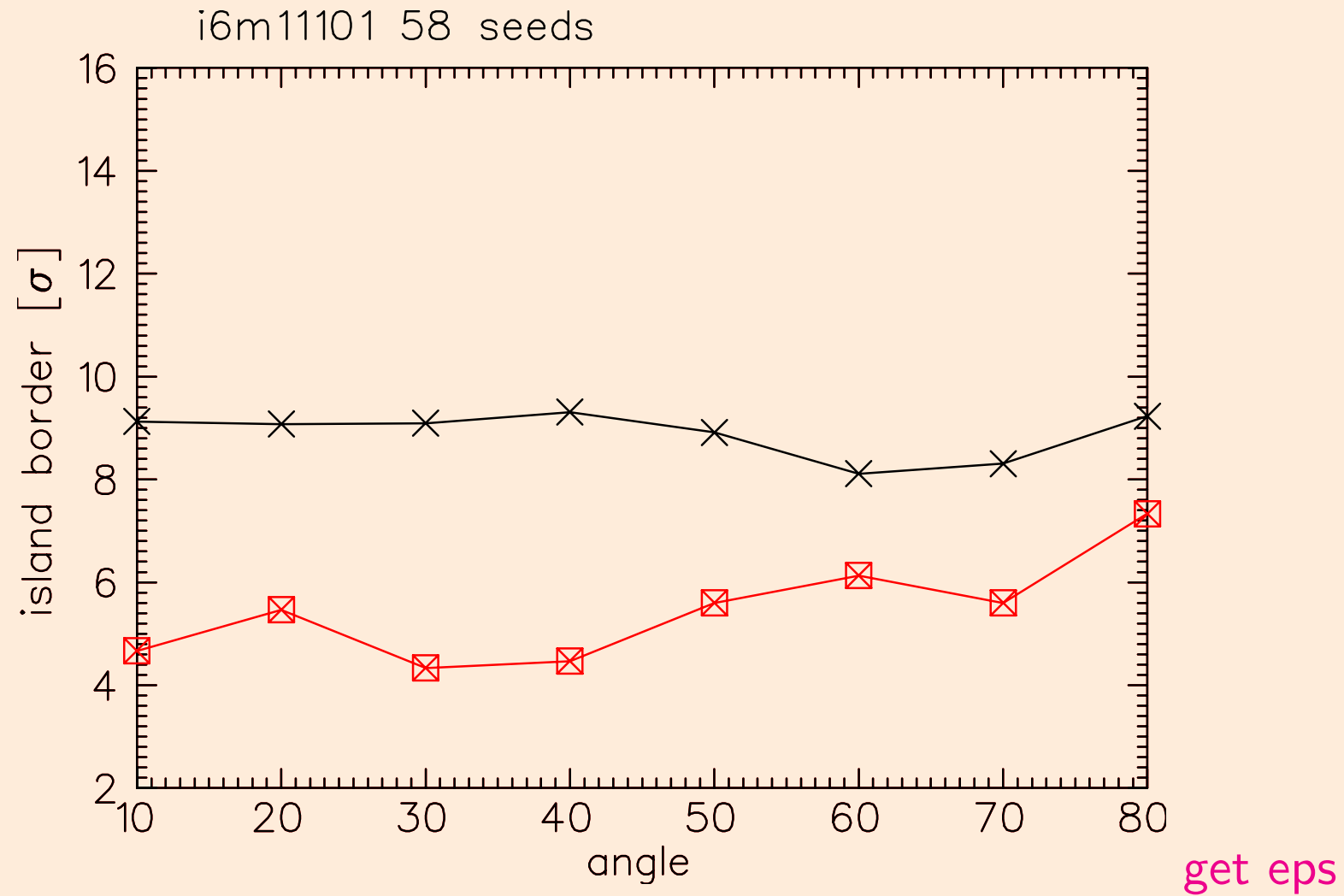


18 6m (1,0,0,0,1)

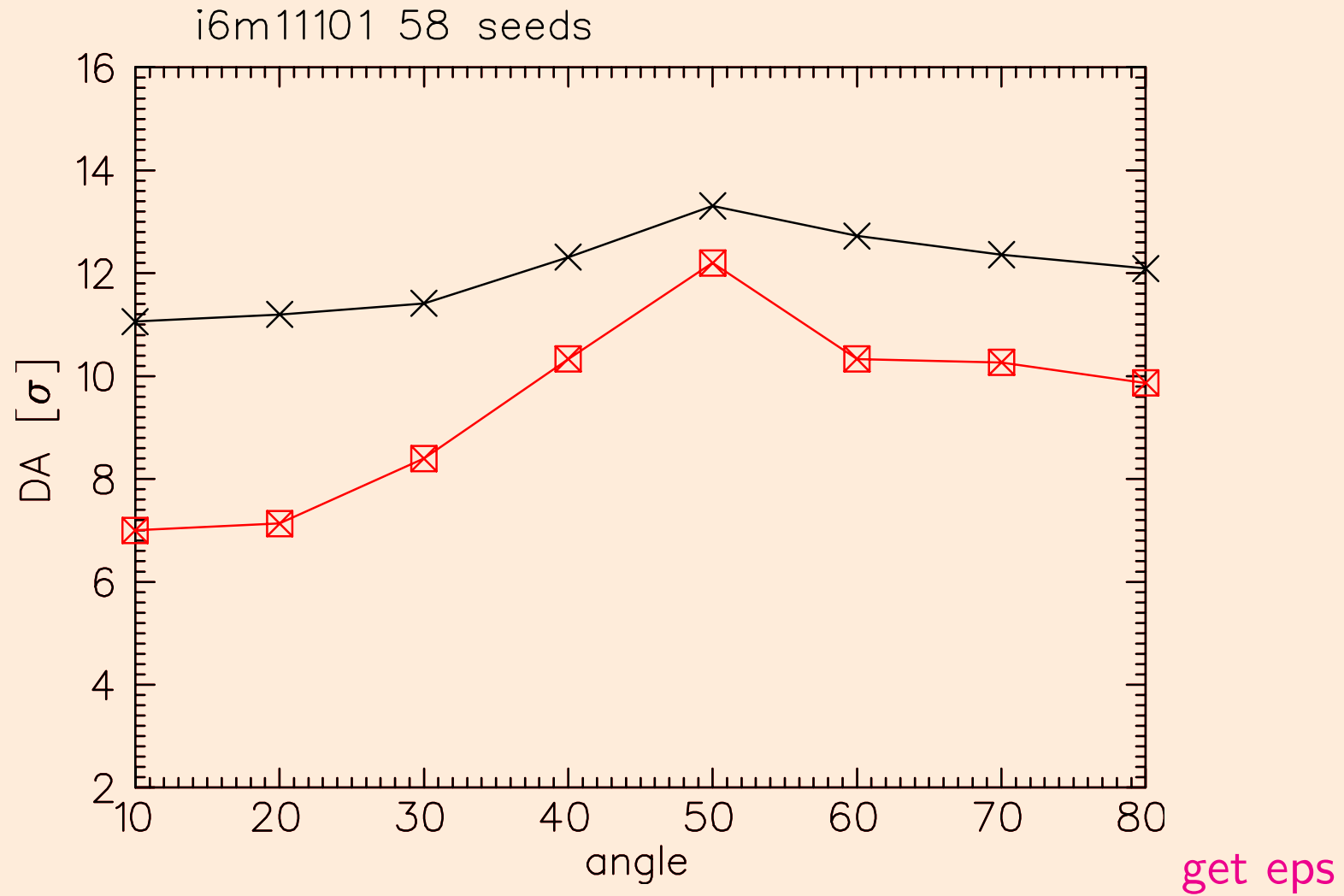
76

19 6m (1,1,1,0,1)

19.1 Chaos

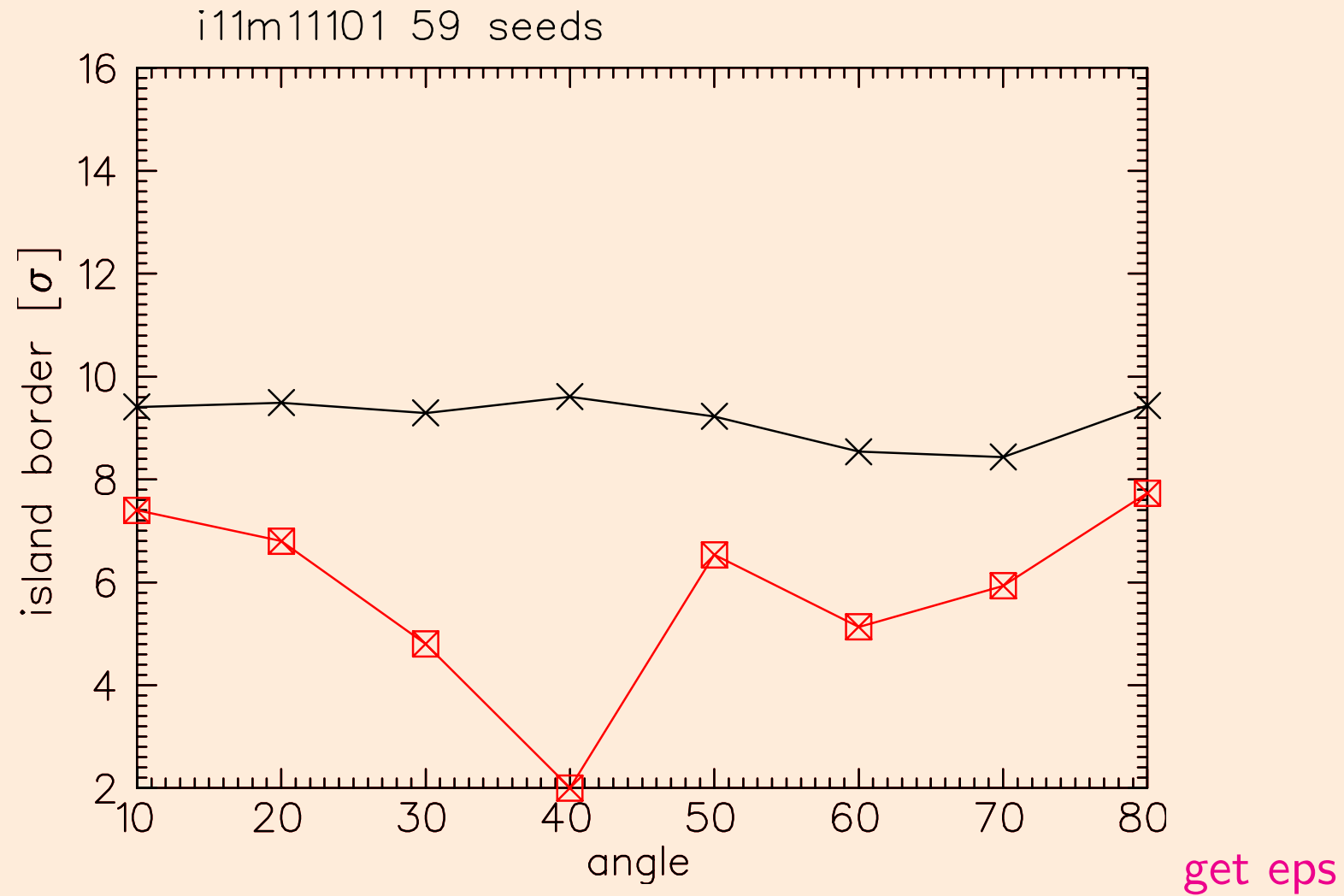


19.2 DA

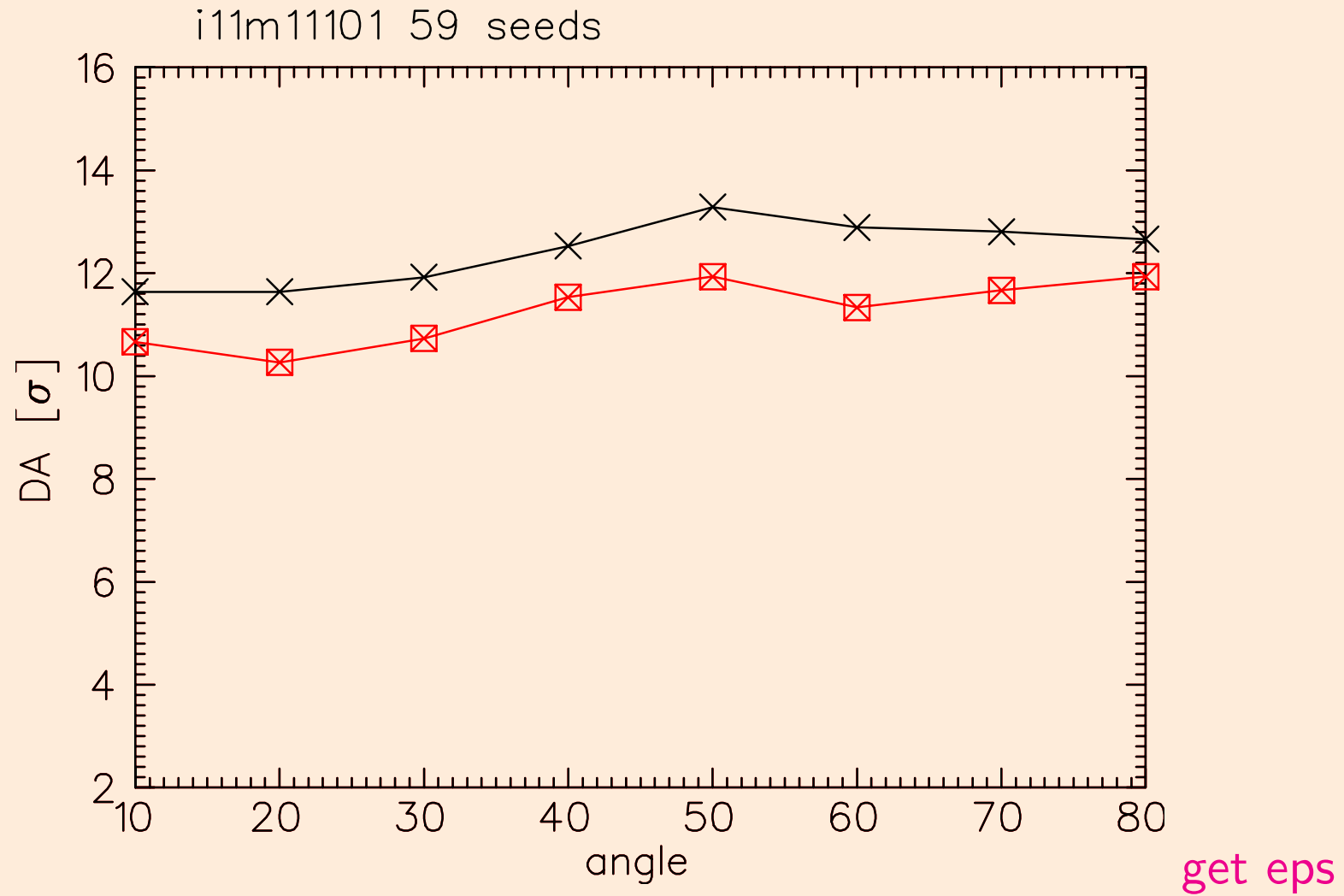


20 11m (1,1,1,0,1)

20.1 Chaos



20.2 DA



21 Summary (450 GeV)

For HO collisions IP1+IP5, 10^5 turns, $N_b = 0.4 \times 10^{11}$, with $\beta^* = 17\text{m}, 6\text{m}, 11\text{m}$.

- $\beta^* = 17\text{m}$, min DA = 8 sigma
- With 6m and 11m “beam-beam only” causes no particle loss, while with field err., corrected coupling and bb
(but no D1-D4 align.):
 $\beta^* = 6\text{m} \rightarrow \text{min DA} = 7 \sigma$ (near hor plane)
(and 10σ without the a2)
 $\beta^* = 11\text{m} \rightarrow \text{min DA} = 10 \sigma$
- *BOINC admin. is being moved to UK – causes delays at the moment (CPSS and lxplus are available)*