Interpretation of FLASH measurements: 16th of June 2011

1 Measurements

FLASH Logbook **Thursday 16. June 2011 Afternoon**

shift summary

Tech. coord.	Run Coordinator(s)	Operators	Other Persons
* Goerler, Max	* Kammering, Raimund	* Jahn, Hans-Joachim * Heuck, Kim * Rothenburg, Jens * Seebauer, Oliver * Behrens, Christopher	* Edwards, Schneidmiller, Wesch
Photon coordinator(s)	**Photon Operators**	**LLRF coordinator**	**Users**
*	*	*	*

Goal * Compression studies and SASE with 3.9 module

Achievements
* set up on crest phases by C Schmidt using his time of flight tool. Worked well.
* Turned off BC3 and changed Acc4/5 to on crest for this condition
* Used LOLA to make compression measurements for Acc1/Ac39 phase change measurements of 1:1 and 1:3
* Changed phases from no to full compression To first order looked like matched prediction quite well. Needs analysis

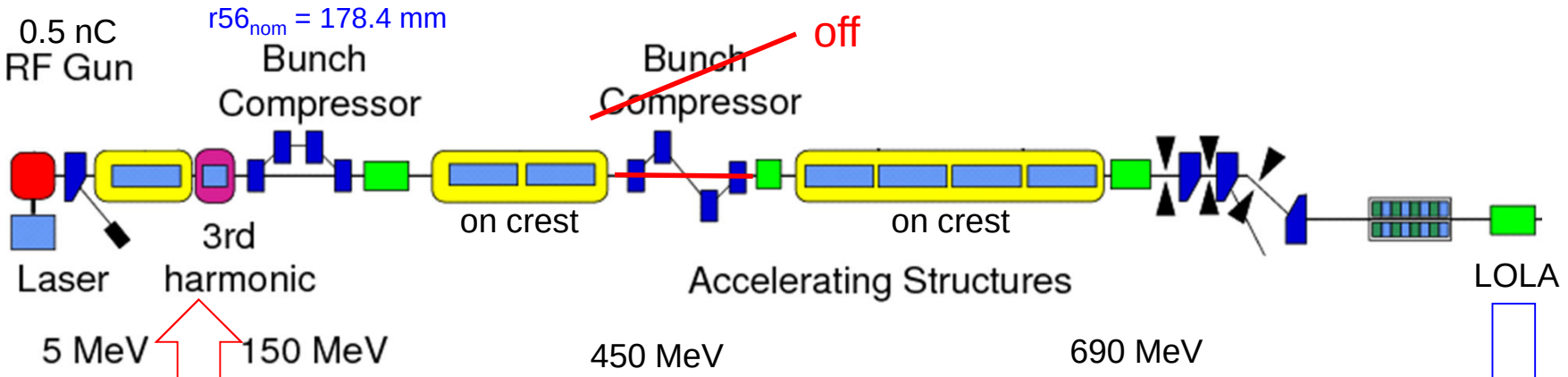
→ s2E seminar, June, 20, 2011:

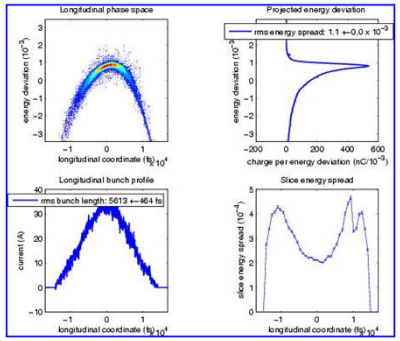
Compression Studies
June 16, 18, 2011
Preliminary report

C Behrens, H Edwards,
E Schneidmiller, S Wesch,
C Schmidt

1 Measurements

setup



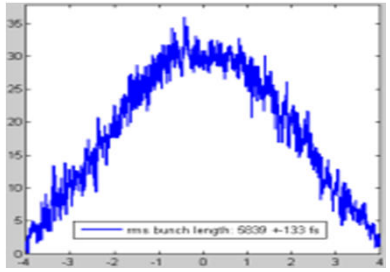


carefull phasing (BAM) before measurements
in the following: each measurement with index (from -30 to 61)
but not each index with measurement!

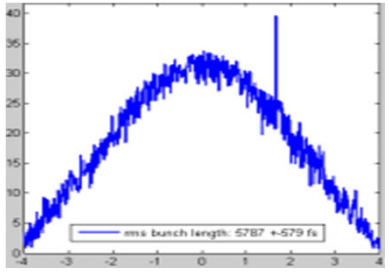
1 Measurements

current profiles

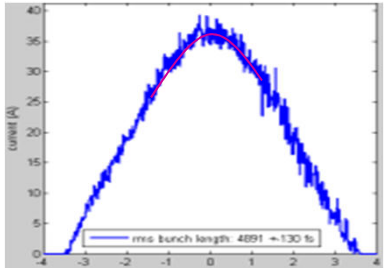
-30(0deg)



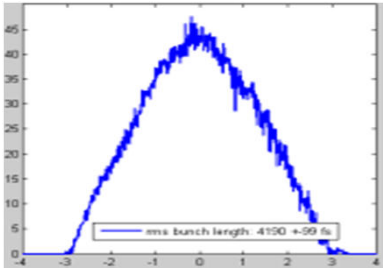
-20(1deg)



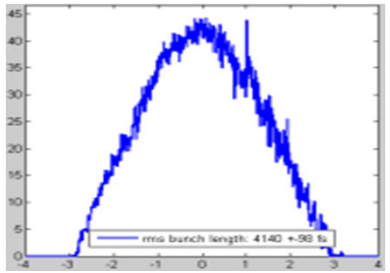
-15(2deg)



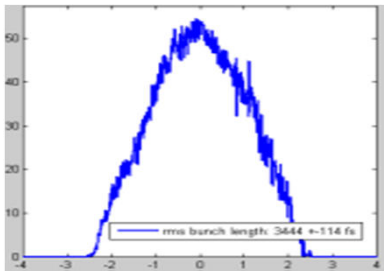
-12(3deg)



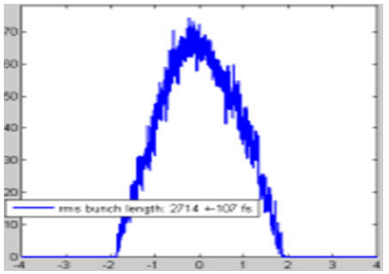
-10(?3deg)



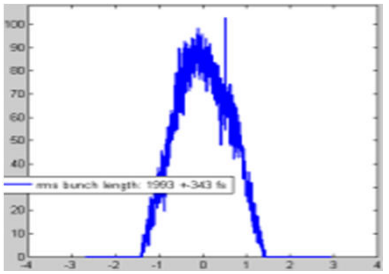
0(?4deg)



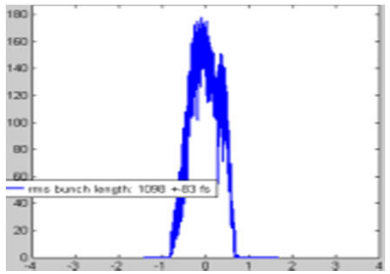
10(5deg)



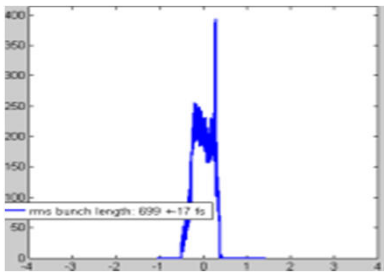
15(6deg)



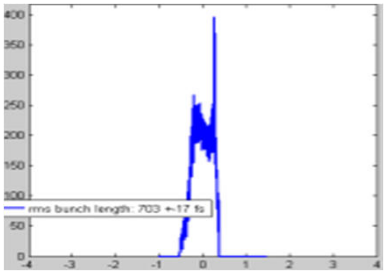
20(7deg)



29(7.5deg)



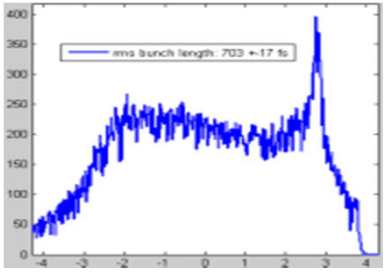
30(7.5deg)



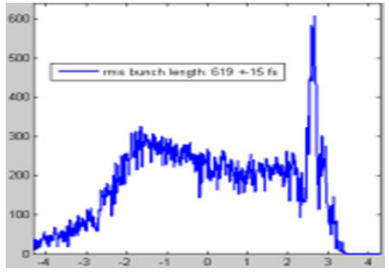
1 Measurements

current profiles

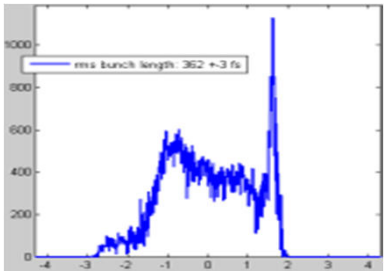
30(7.5deg)



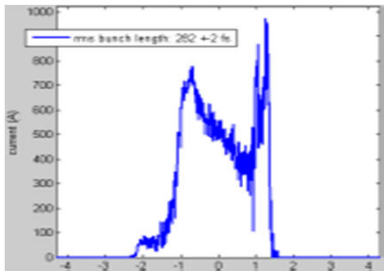
40(7.6deg)



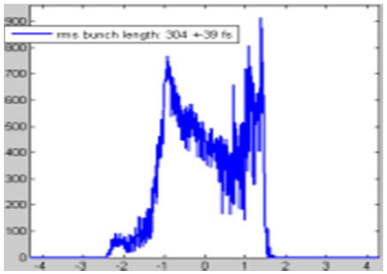
50(7.9deg)



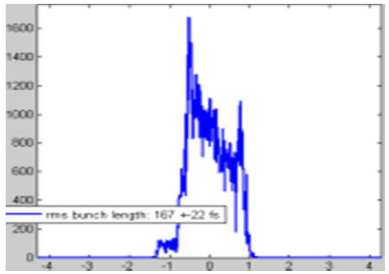
51(?)



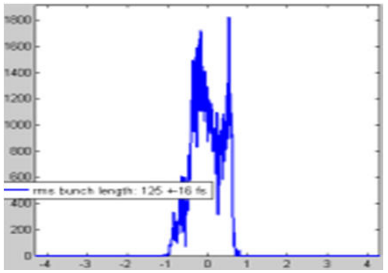
52(8.0deg)



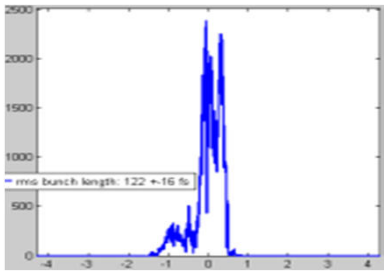
53



54

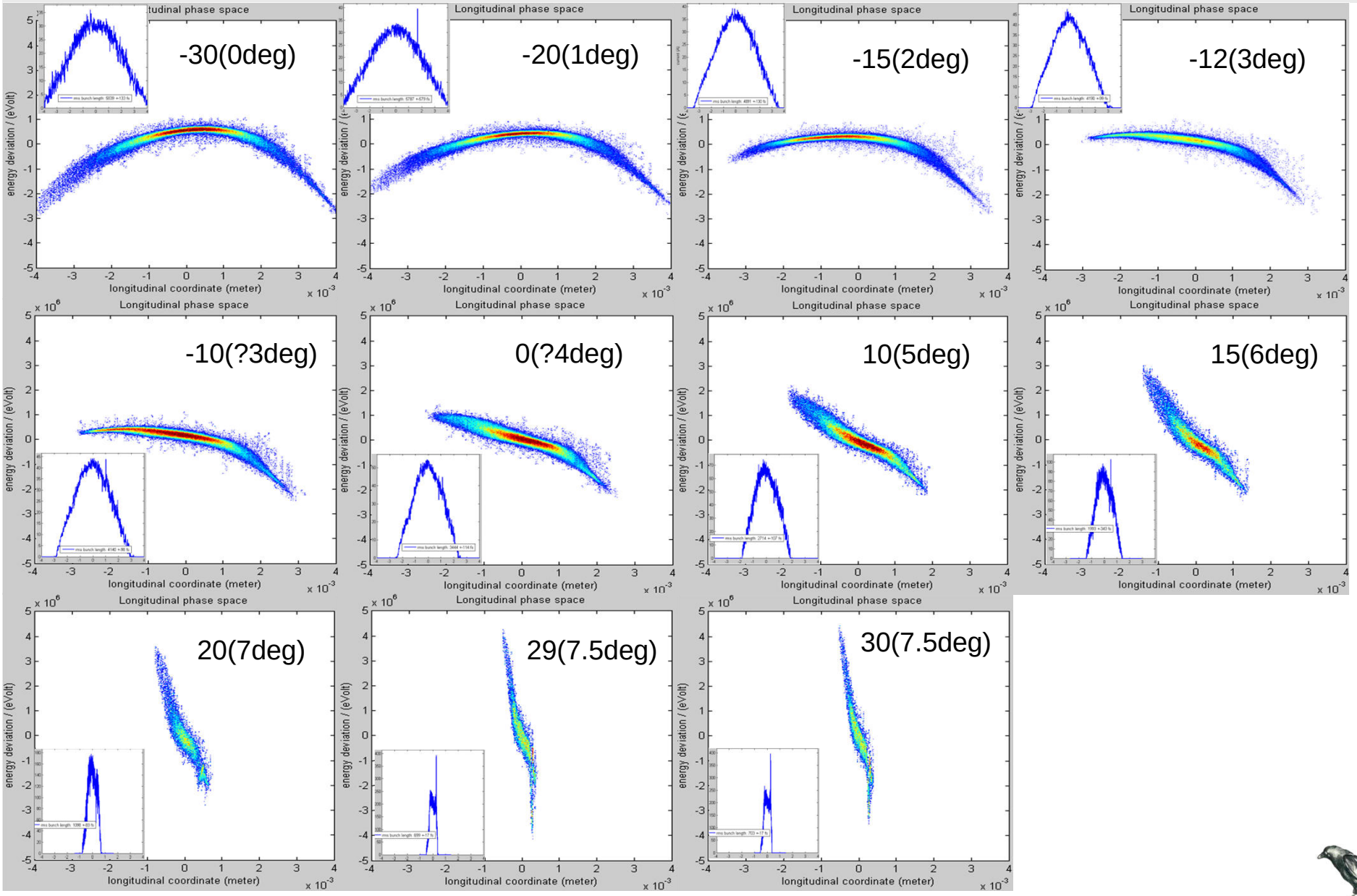


55



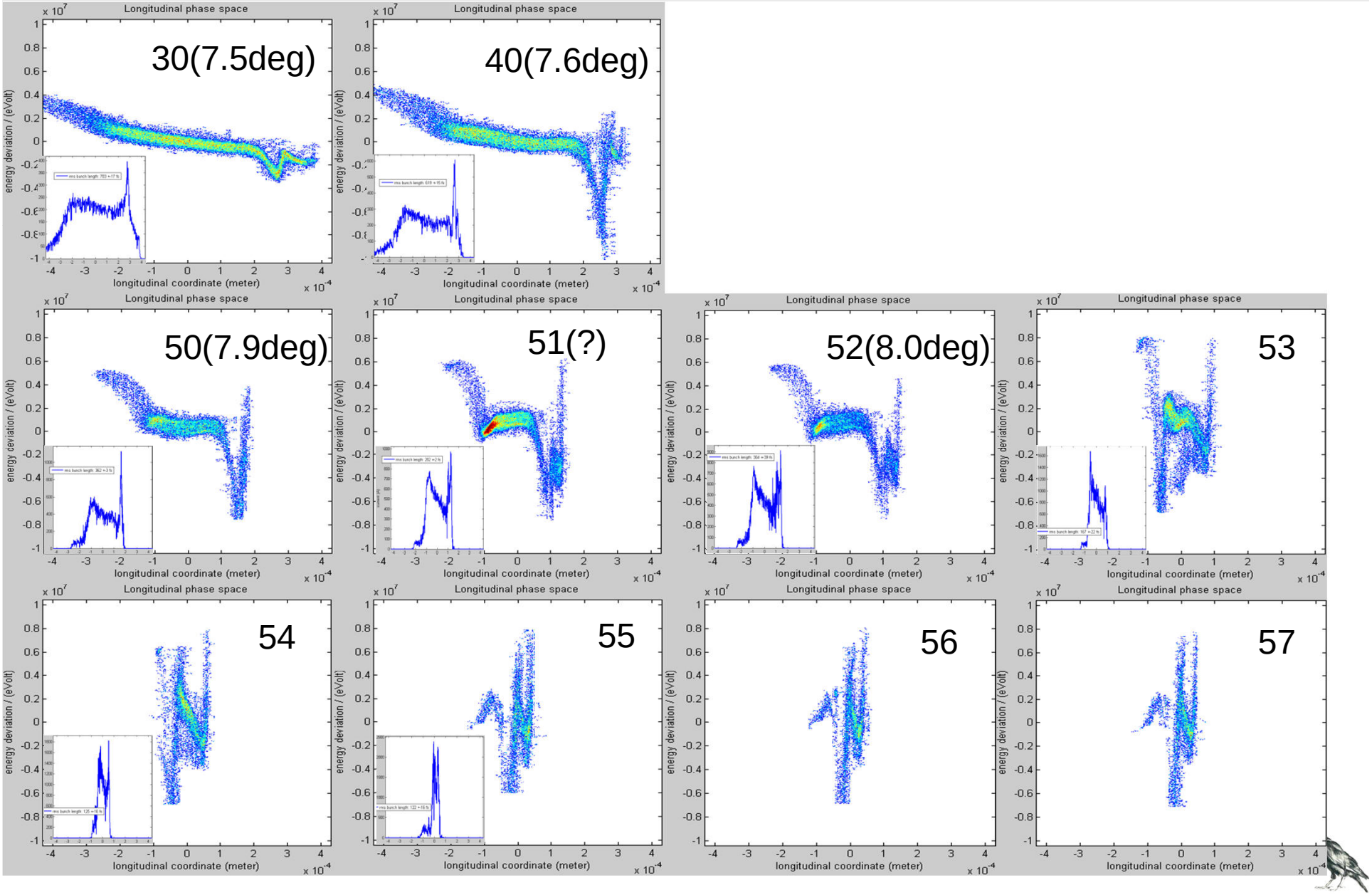
1 Measurements

LOLA screen, recalculated → constant scale (energy vs. length)



1 Measurements

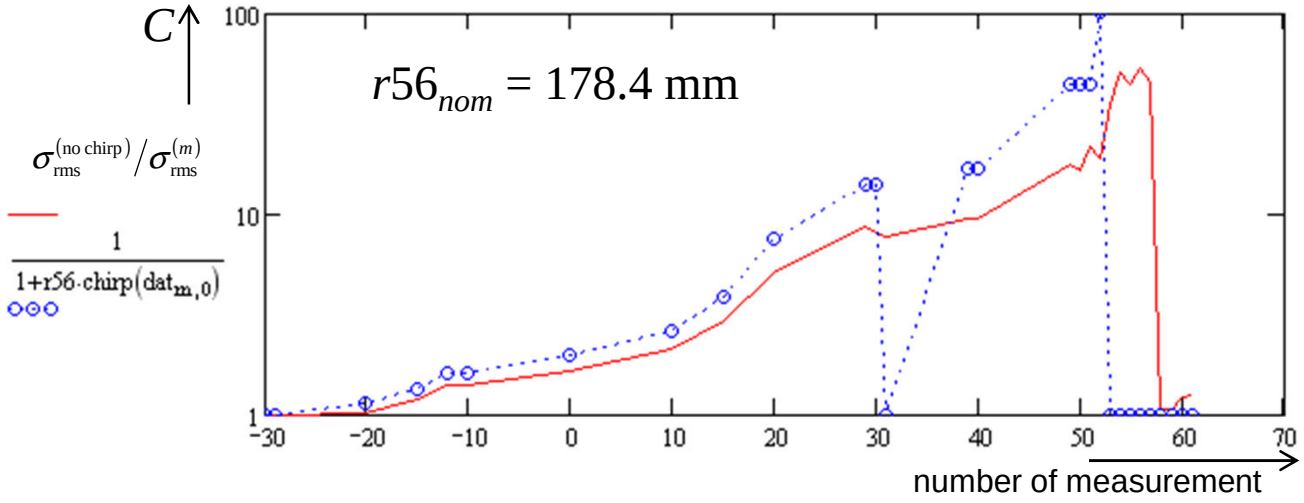
LOLA screen, recalculated → constant scale (energy vs. length)



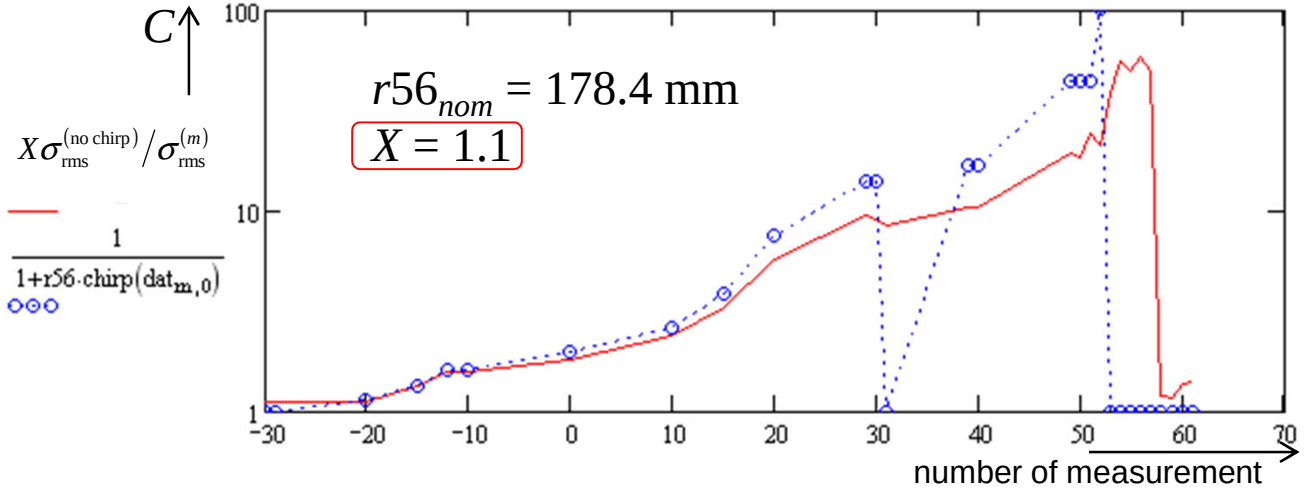
2 Analysis - Compression Factor

no self effects

comparison measurement (rms), compr{chirp(nominal rf-setting)*(nominal r56)}

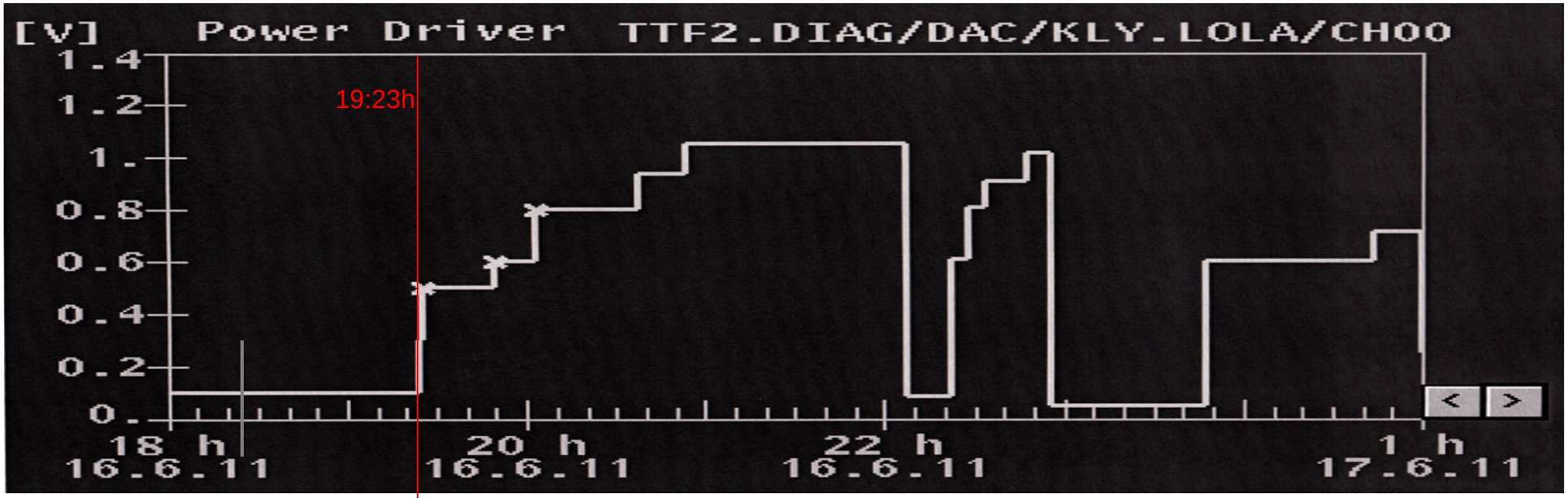


systematic error of rms-length without chirp; (inconsistent calibration)



2 Analysis - Compression Factor

LOLA time calibration: klystron history

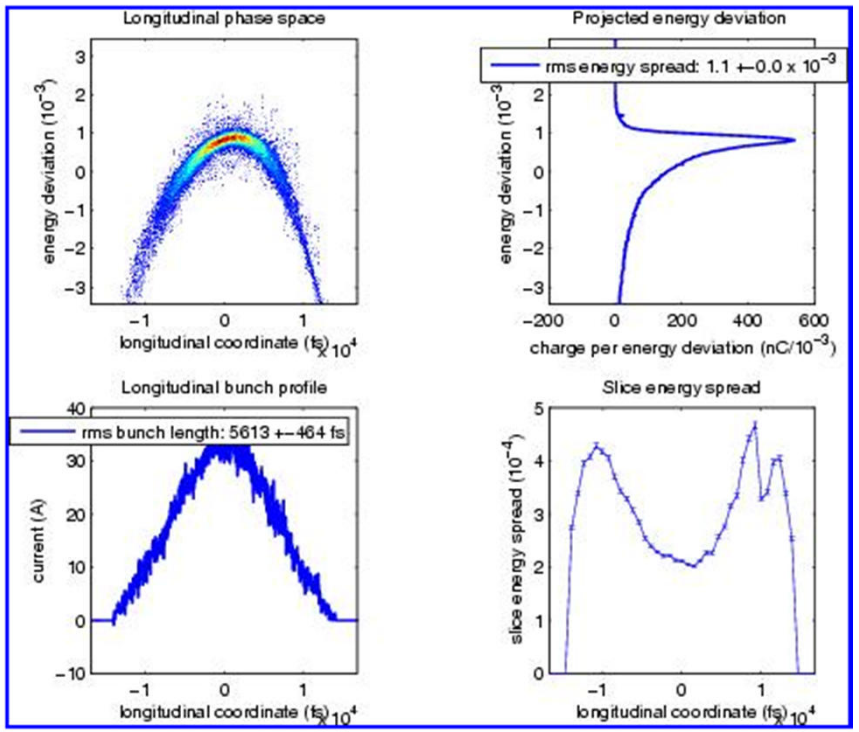


mess		time rf-set	**time T-calib**	time data	A1 MV	P1 Deg	A39 MV	P39 Deg	Len_step um/pix	Ene_step keV/pix
-30		17:37	**18:23**	18:32	163.80	0.00	18.2	0.00	11.44	15.15
-20		19:06	**19:05**	19:10	163.80	1.00	18.2	-1.00	12.45	15.2
-15		19:13	**19:12**	19:17	163.90	2.00	18.2	-2.00	11.97	15.19
-12		19:24	**19:25**	19:29	164.00	3.00	18.2	-3.00	10.8	15.11
-10	?	19:37	**19:25**	19:38	164.10	4.00	18.2	-4.00	10.8	15.11

2 Analysis - Compression Factor

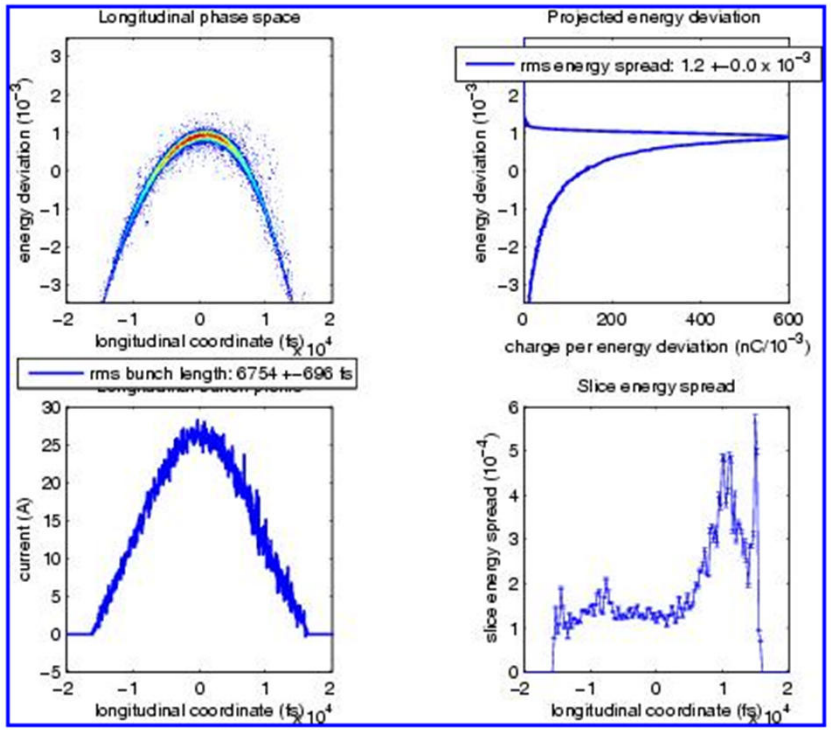
LOLA time calibration: comparison with later measurement

16.06.2011 18:30 ttflinac tpb1cbc7f4_8238_4769_b4ad_31ff8993da31



rms = 5.63 psec
(1.7 mm)

16.06.2011 23:07 ttflinac tp5777a96e_

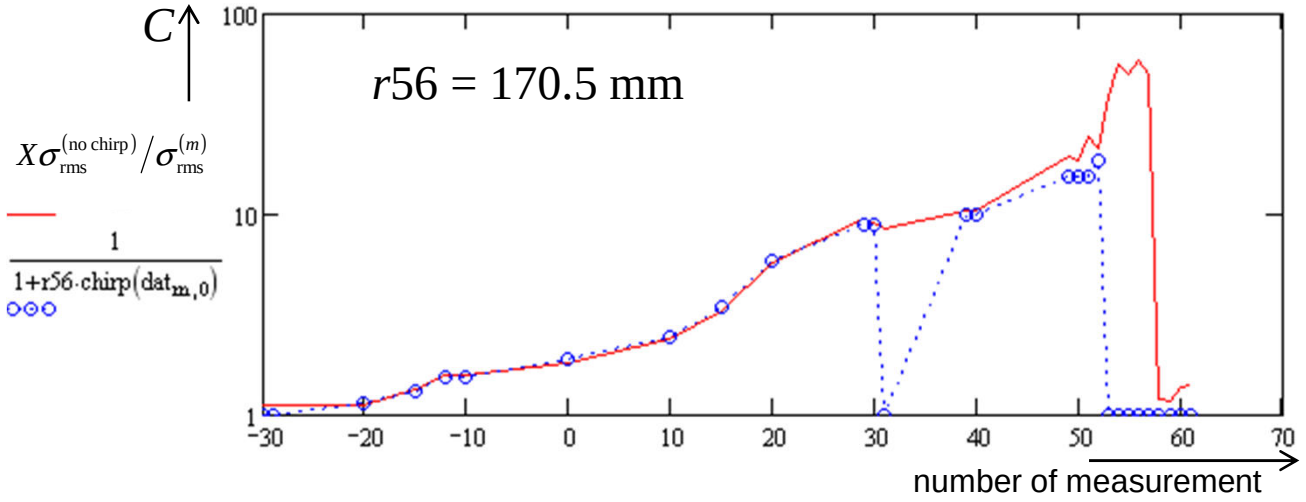


rms = 6.75 psec
(2.0 mm)

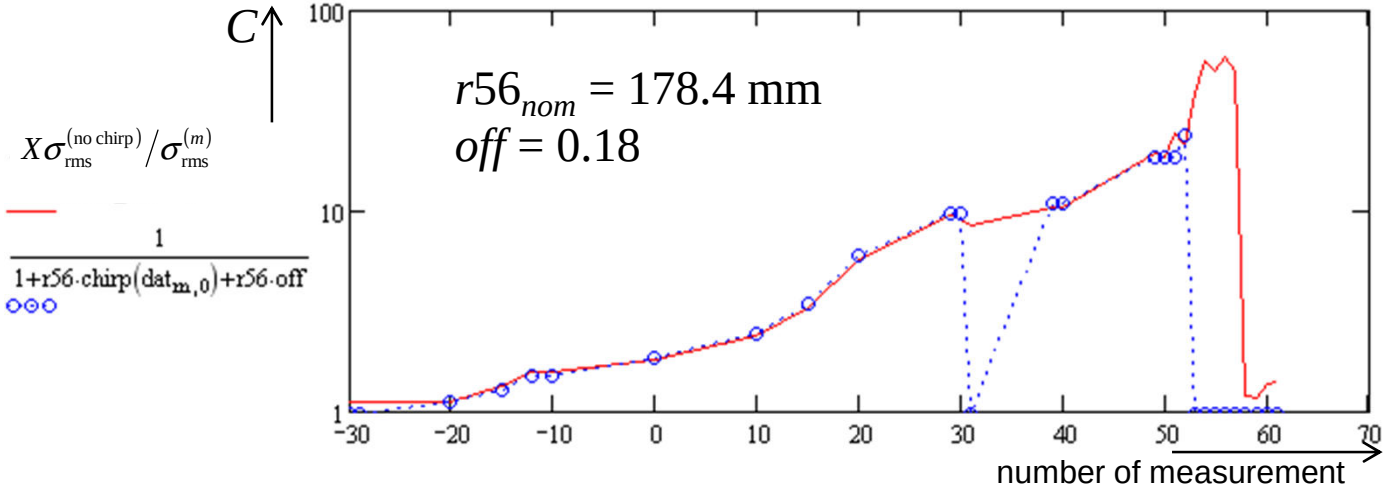
2 Analysis - Compression Factor

no self effects

wrong r56 ?

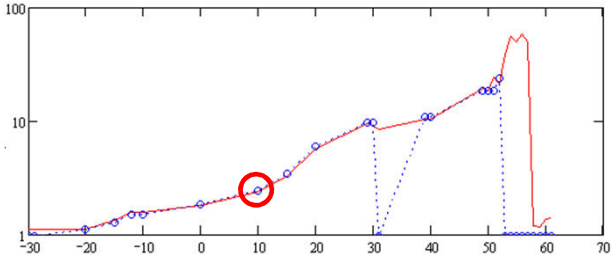


additional chirp (from initial condition)



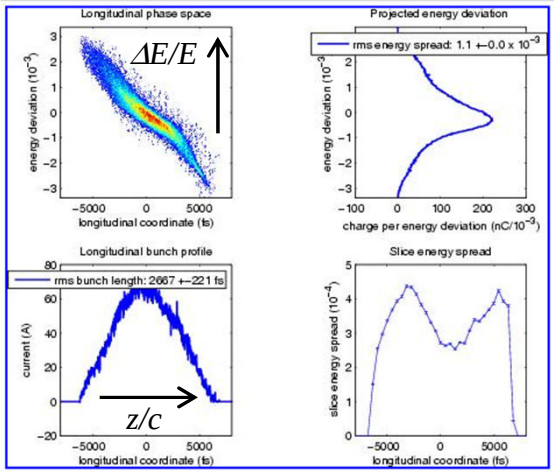
3 LOLA Measurements

index = 10



log-book:

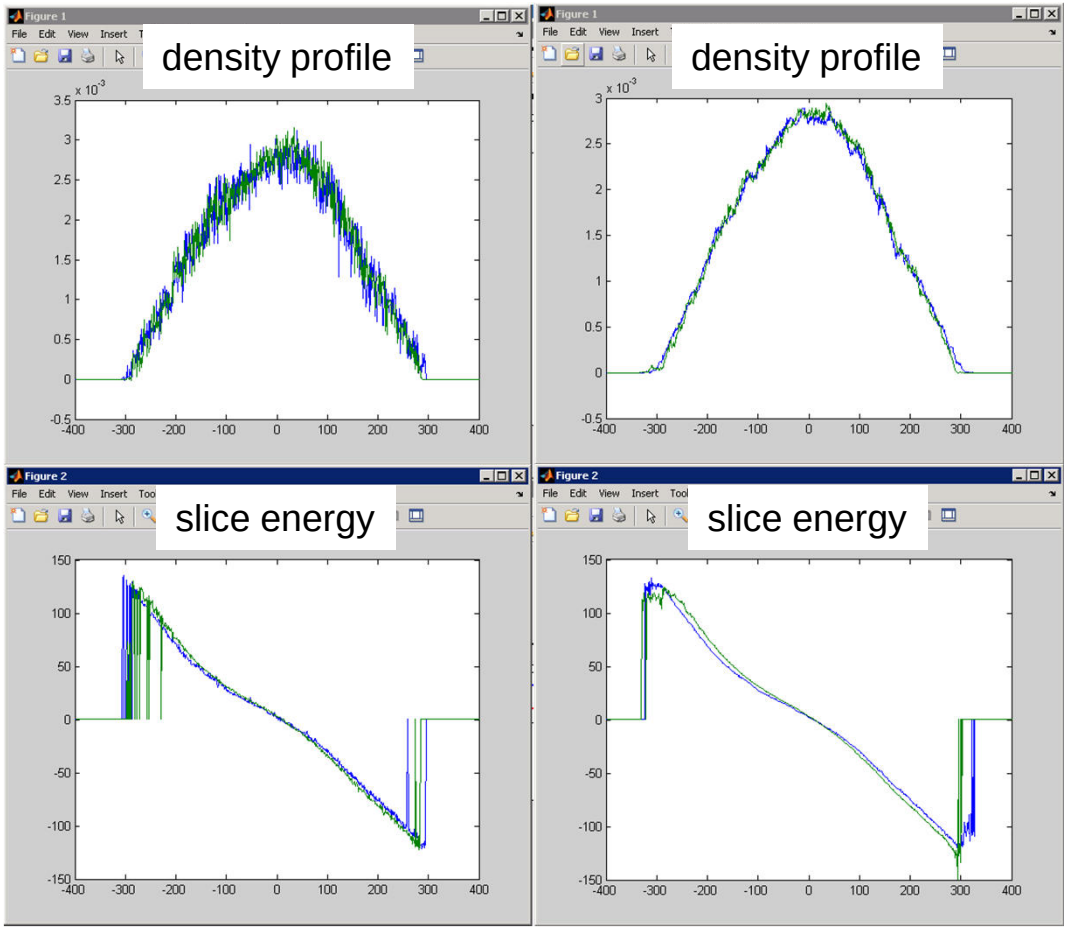
16.06.2011 19:55	ttflinac	tp2c99b905_d98f_4011_926a_1308318b535d.ps



slope 1 slope 2 (z-flipped)

single measurement 20 measurements averaged

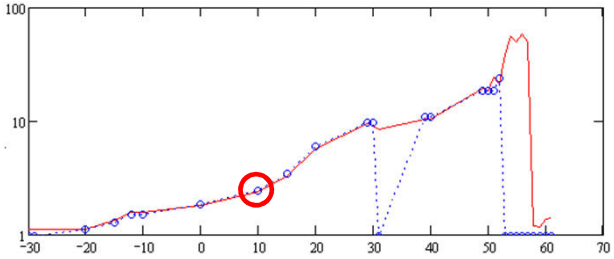
z



E

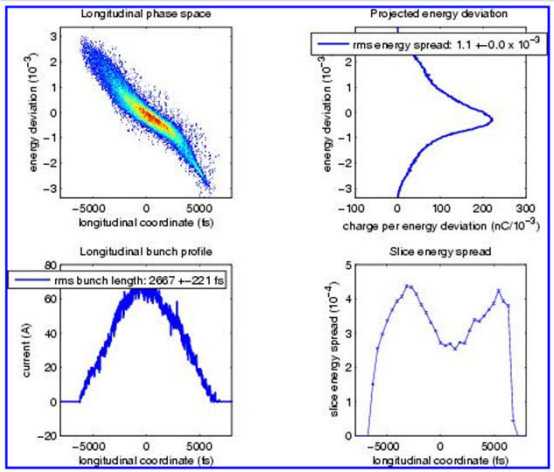
3 LOLA Measurements: close look

index = 10



log-book:

16.06.2011 19:55	ttflinac	tp2c99b905_d98f_4011_926a_1308318b535d.ps

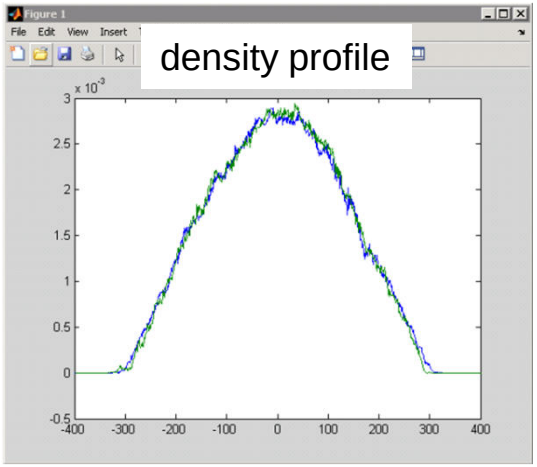


eliminate crosstalk
"time" to "energy"

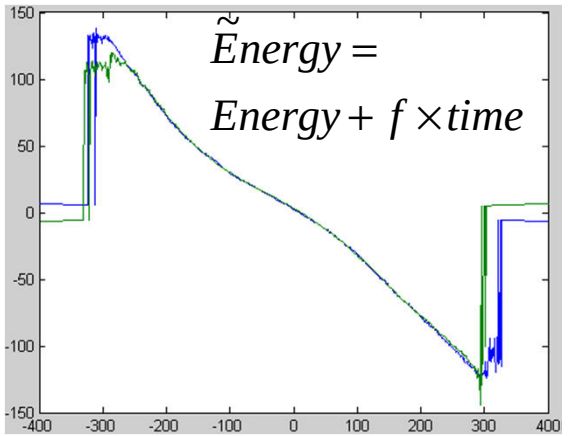
$$f = \frac{\boxed{const}}{time\_step}$$

slope 1 slope 2 (z-flipped)

20 measurements averaged



slice energy (elim.)

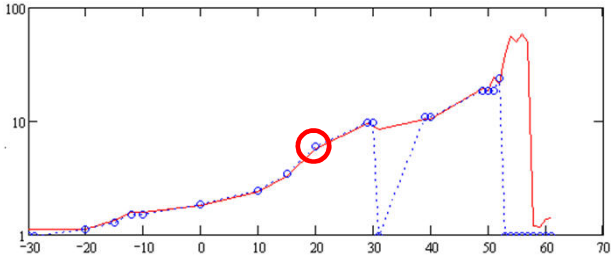


z

E

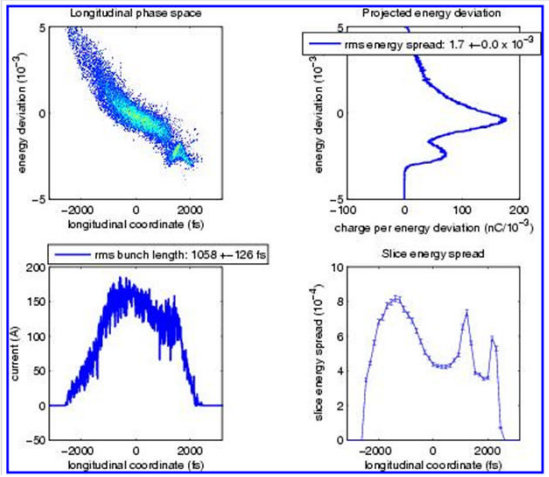
3 LOLA Measurements: close look

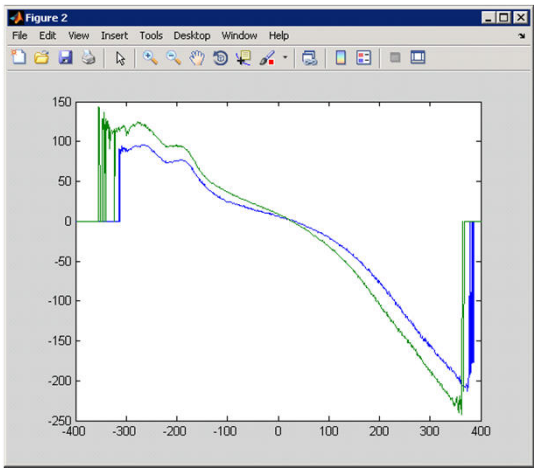
index = 20



log-book:

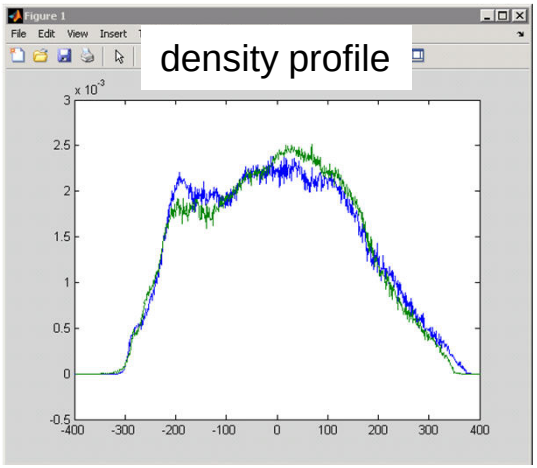
16.06.2011 20:31 | ttflinac | tp2c5807fa_289b_4992_be06_cd93641720c3.ps



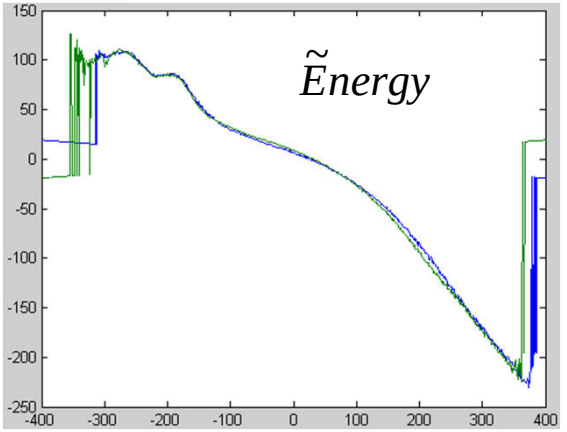


slope 1 slope 2 (z-flipped)

20 measurements averaged



slice energy (elim.)

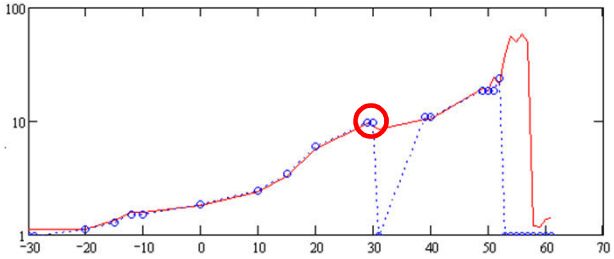


z

E

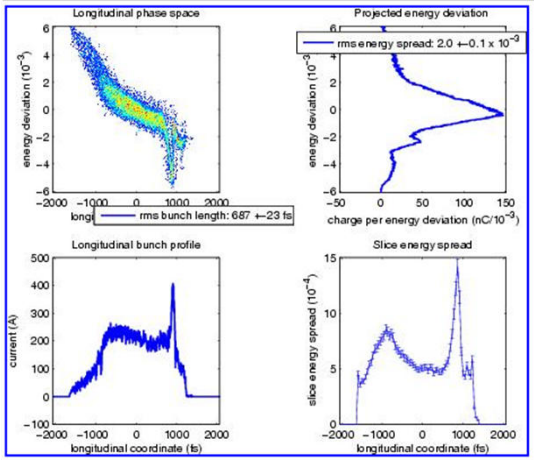
3 LOLA Measurements: close look

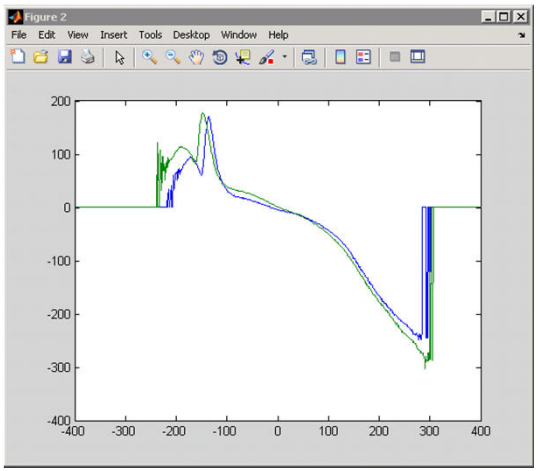
index = 30



log-book:

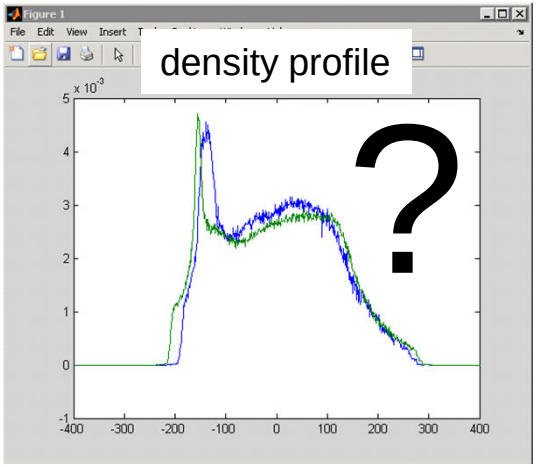
16.06.2011 20:46 | ttflinac | tpdfa6a1e5_6080_4646_9d59_4d28602e3813.ps



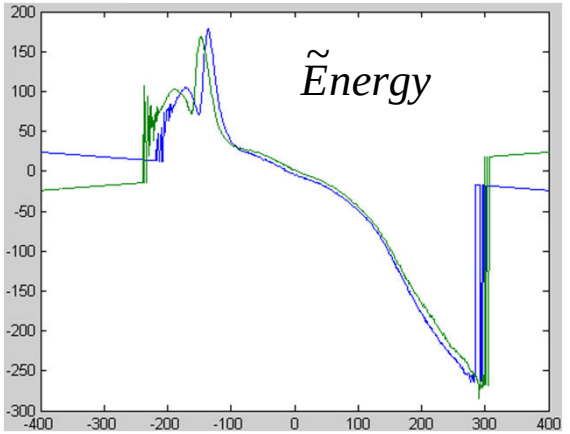


slope 1 slope 2 (z-flipped)

19 measurements averaged



slice energy (elim.)

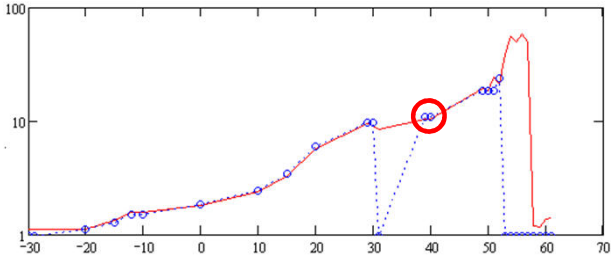


z

E

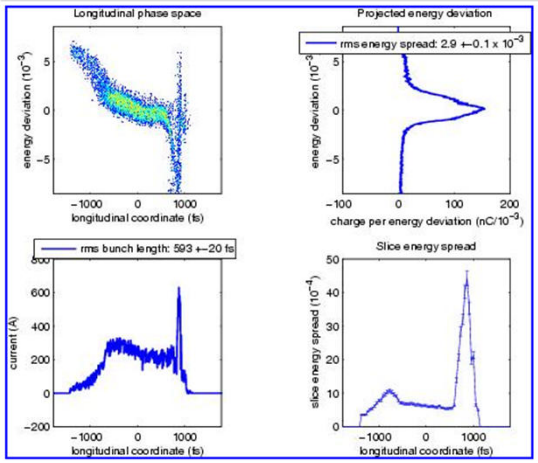
3 LOLA Measurements: close look

index = 40



log-book:

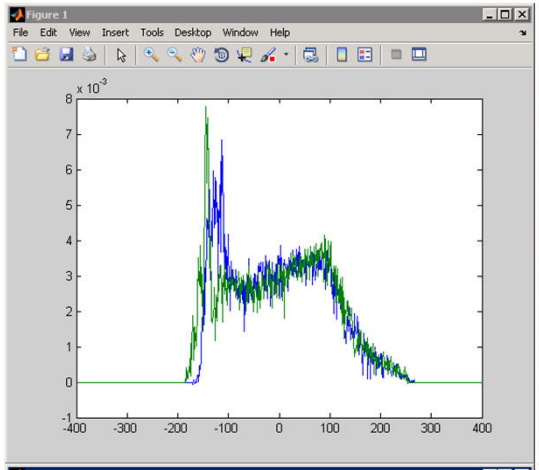
16.06.2011 21:05	ttflinac	tpa0891a5e_2448_4f53_af38_2454b7f7d462.ps

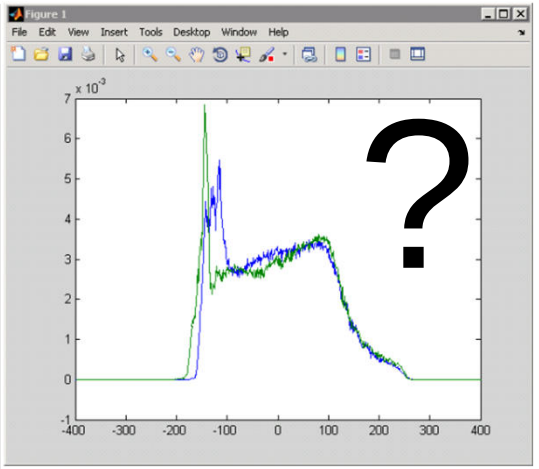


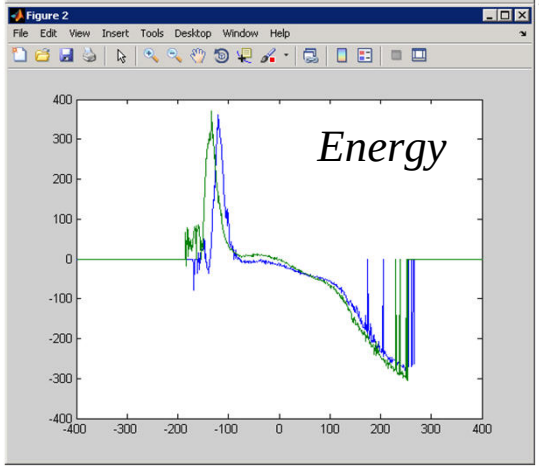
slope 1 slope 2 (z-flipped)

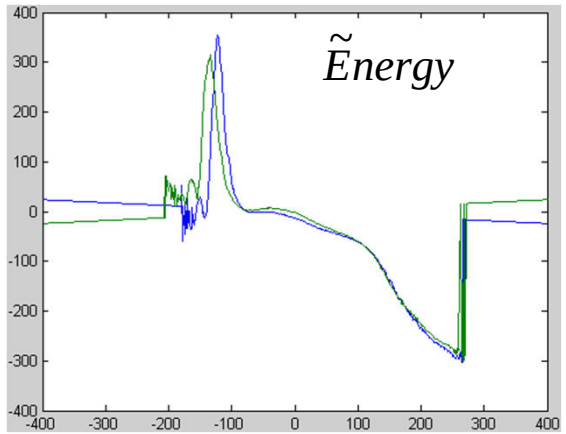
single measurement

18 measurements averaged









z

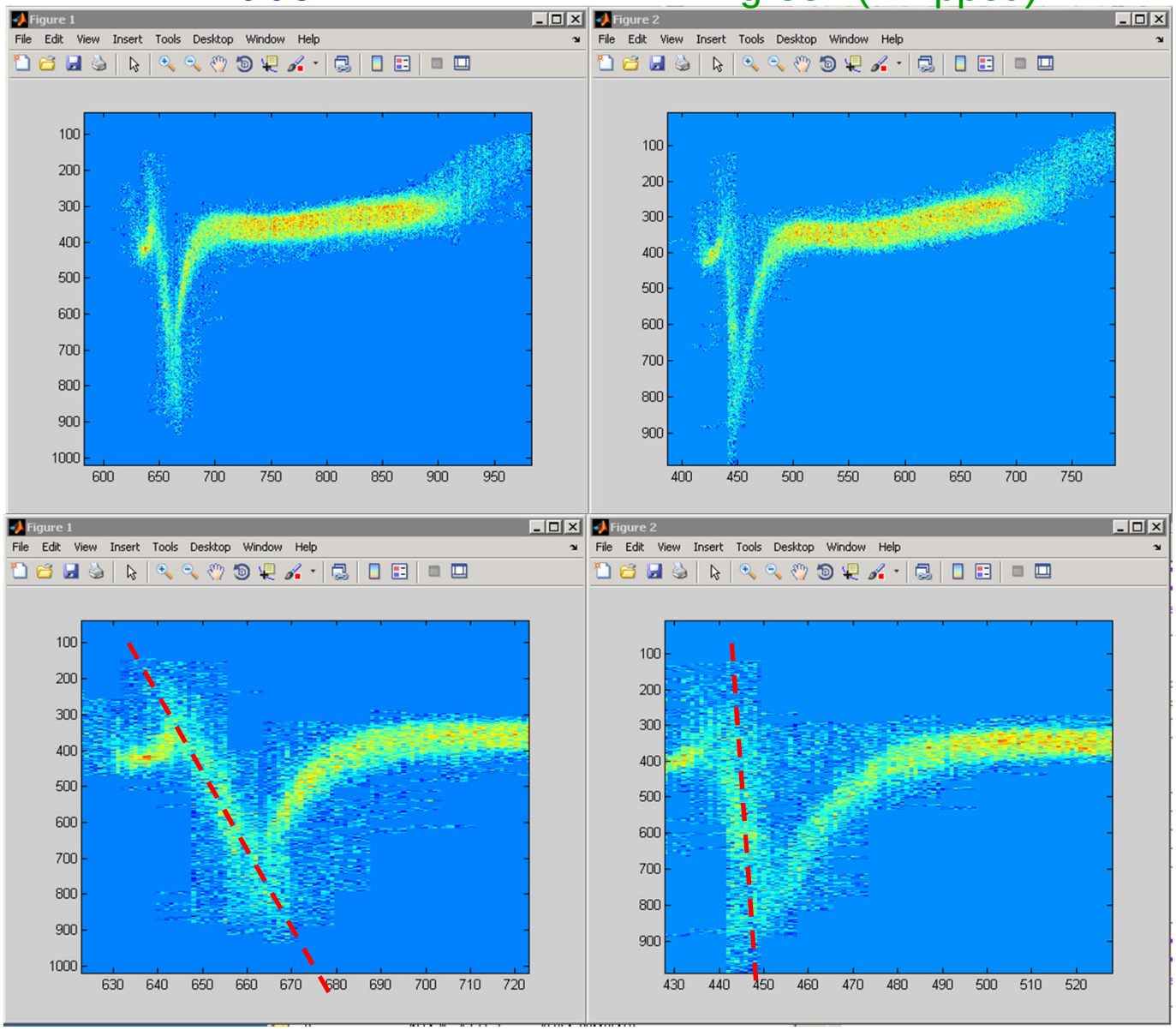
E

3 LOLA Measurements: close look

single measurement

blue

green (z-flipped)

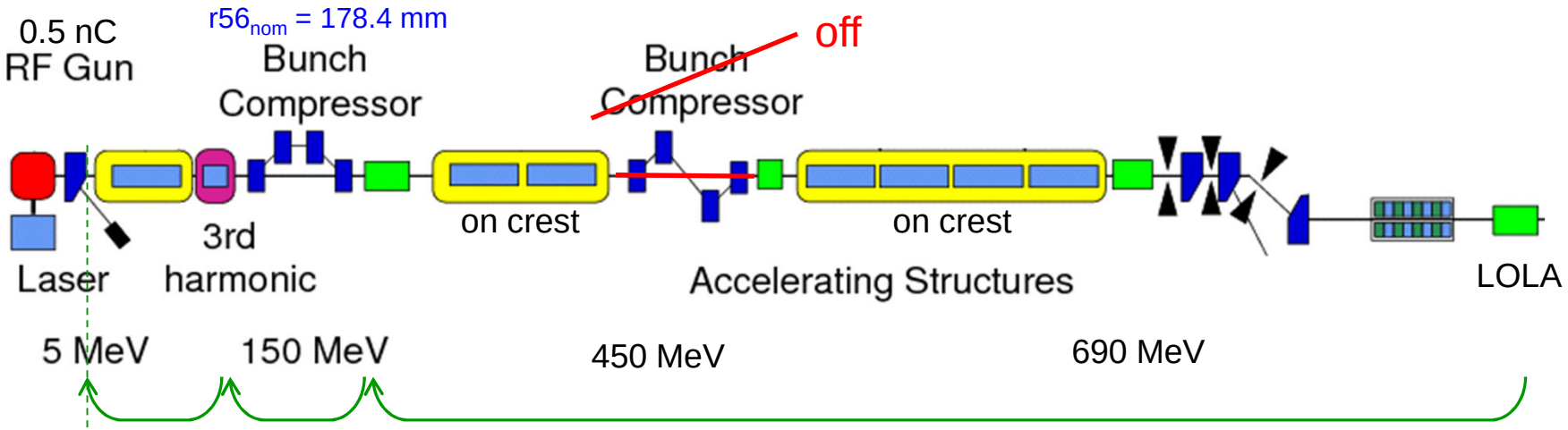


z

E

4 Analysis – Reconstruction of Initial Distribution – TE Method

time-energy-method



slice energy (LOLA measurement): $E_3(s_2)$ middle of bunch (50% of charge) is set to reference energy

after BC2: $E_2(s_2) = E_3(s_2) - E_{rf\,2}(s_2)$

before BC2: $E_2(s_2) = E_3(s_2) - E_{rf\,2}(s_2)$

$$s_1(s_2) = s_2 - D\left(\frac{E_2(s_2)}{E_{2,\mathrm{nom}}} - 1, r_{56,\mathrm{nom}}, t_{566,\mathrm{nom}}\right)$$

virtual initial distribution: $E_1(s_1) = E_2 - E_{rf\,1}(s_1)$

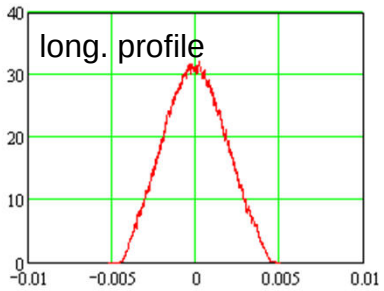
with: $E_{rf\,2}(s) = 540\,\mathrm{MeV}\cos ks$

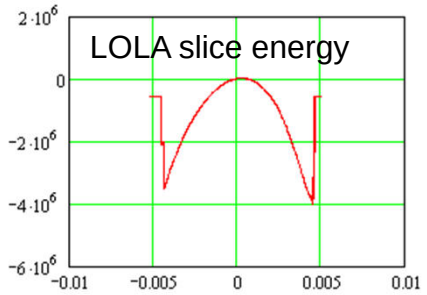
$$E_{rf\,1}(s) = A_1\cos(ks+\varphi_1) + A_3\cos(3ks+\varphi_3)$$

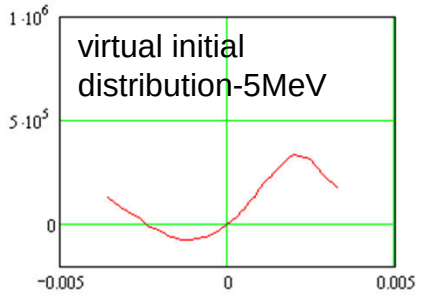
4 Analysis – Reconstruction of Initial Distribution – TE Method

pure time-energy-method

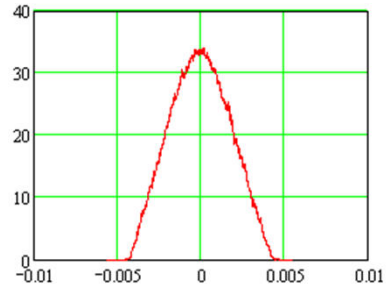
index = -30

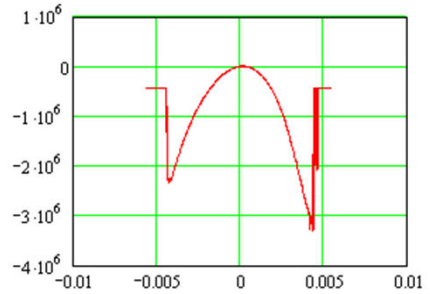


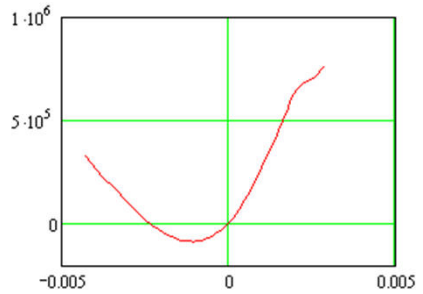




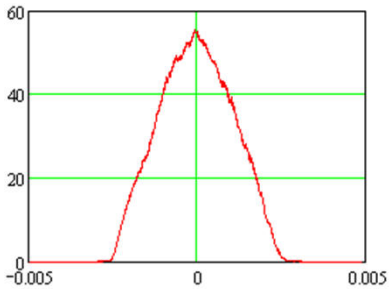
index = -20

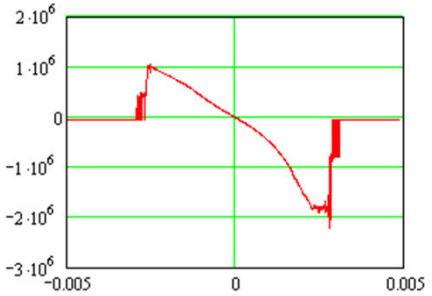


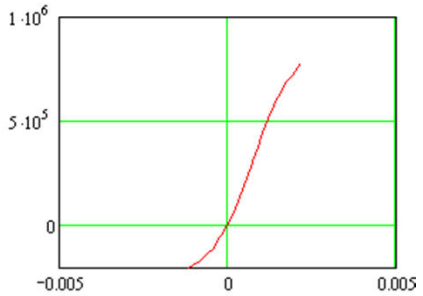




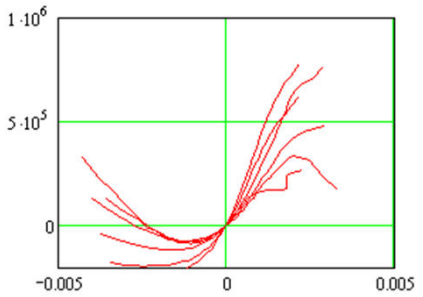
index = 0







index = -30, -20, -10, 0, 10, 20



possible source of error:
calibration factors, phase of rf after BC2

4 Analysis – Reconstruction of Initial Distribution – TE Method

modified time-energy-method

modified energy, time and phase calibration:

slice energy (LOLA measurement)

$$\tilde{E}_3(\tilde{s}_2) \rightarrow \quad E_3 = A \times \tilde{E}_3$$

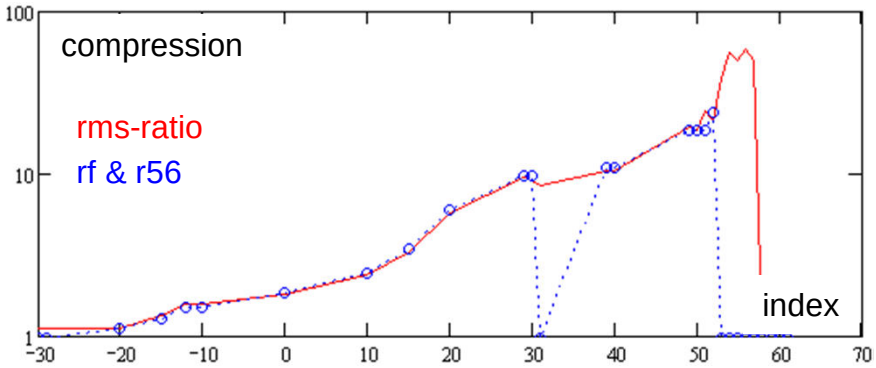
$$s_2 = T \times \tilde{s}_2$$

$$E_{rf\,2}(s) = 540\,\text{MeV}\,\cos(ks + P)$$

index = {-30, -20, -10, 0, 10, 20}

?! $A = 1.25$

T = "rms-ratio"/"rf & r56"

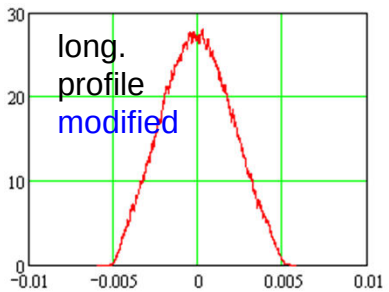


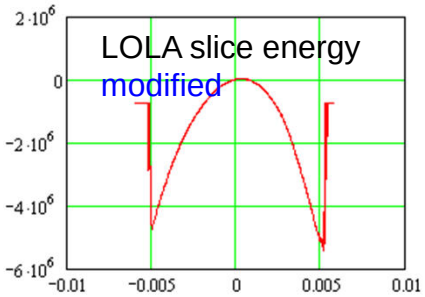
P/deg = {-0.15, -0.2, -0.1, -0.1, -0.1, -0.1}

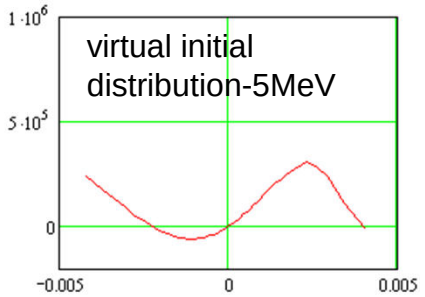
4 Analysis – Reconstruction of Initial Distribution – TE Method

modified time-energy-method

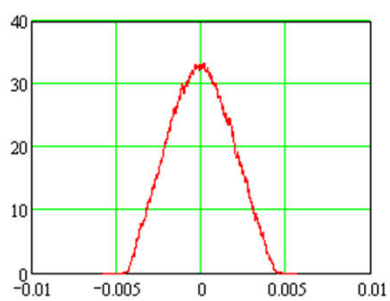
index = -30

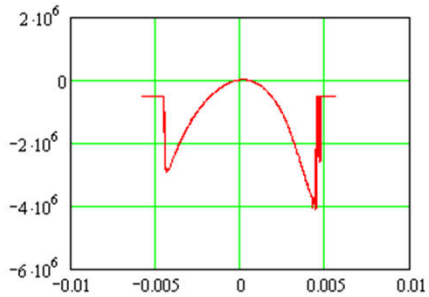


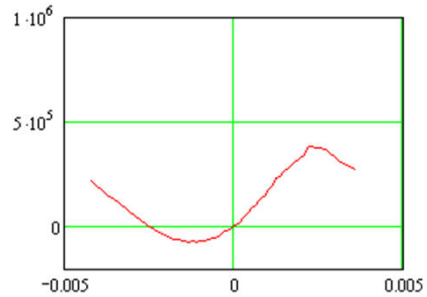




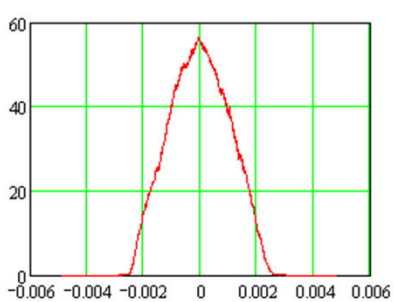
index = -20

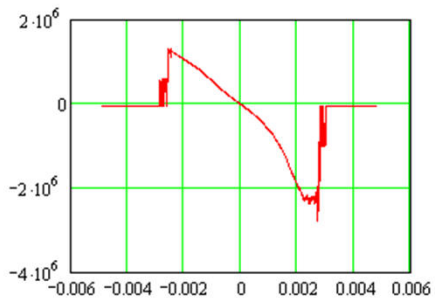


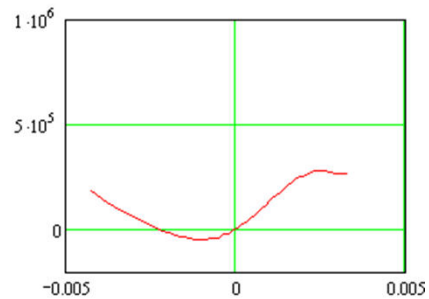




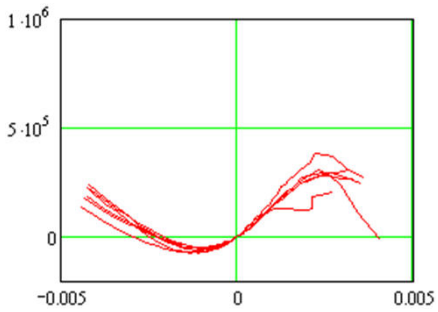
index = 0





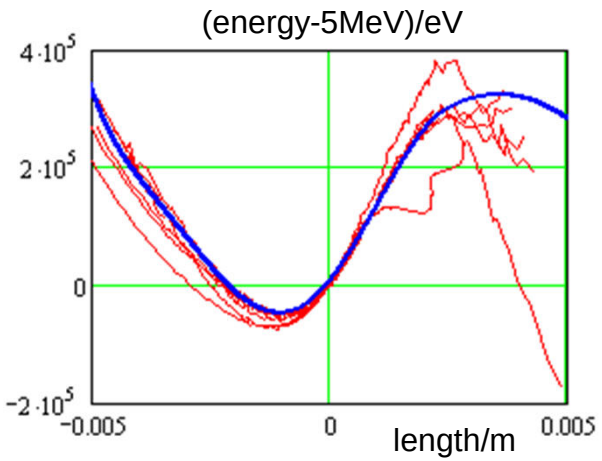


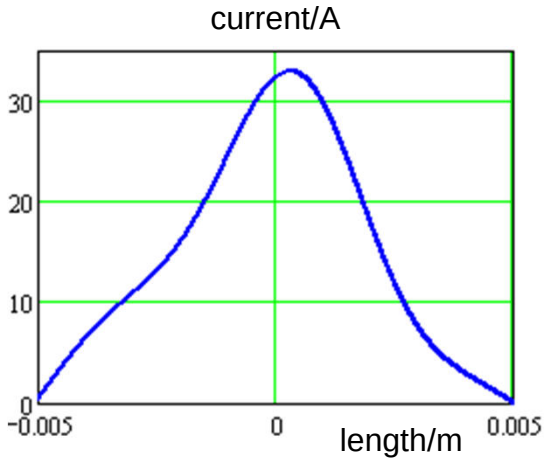
index = -30, -20, -10, 0, 10, 20



4 Analysis – Reconstruction of Initial Distribution – TE Method

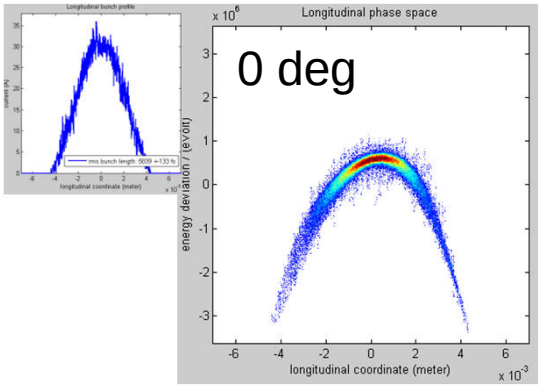
"reconstructed" initial distribution

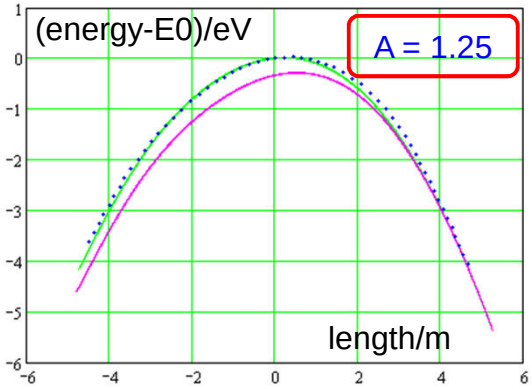




4 Analysis – Reconstruction of Initial Distribution – TE Method

forward calculation to LOLA



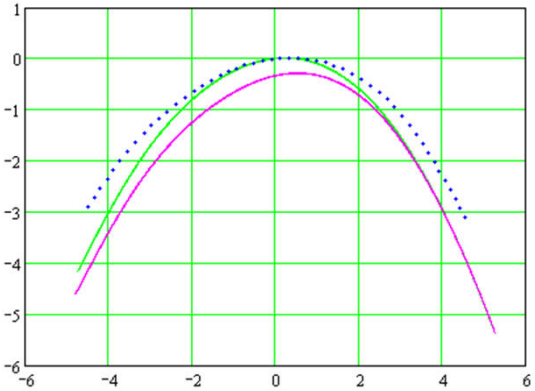


?!

measured (slice), scaled in time and energy

calculated without self effects

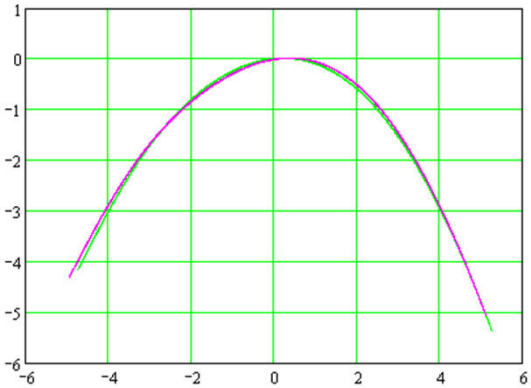
calculated with self effects



…, original energy scale

…

…

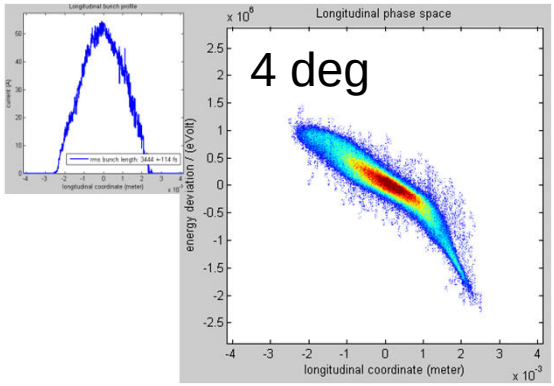


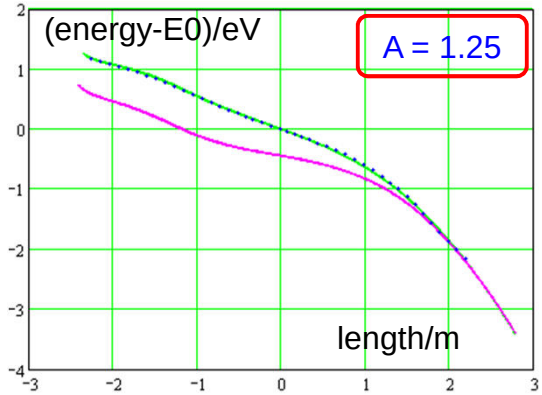
…

…, shifted

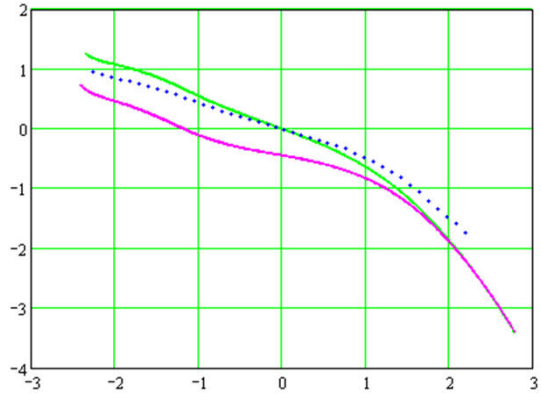
4 Analysis – Reconstruction of Initial Distribution – TE Method

forward calculation to LOLA

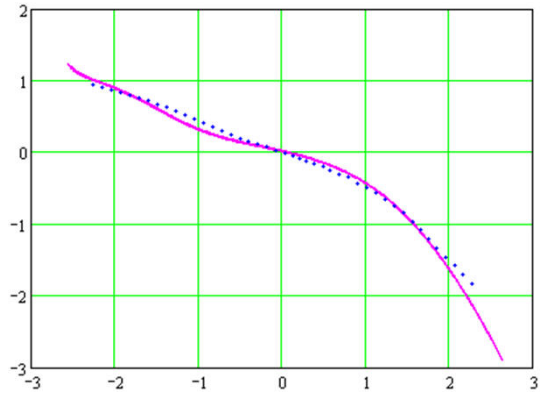




measured (slice), scaled in time and energy
calculated without self effects
calculated with self effects



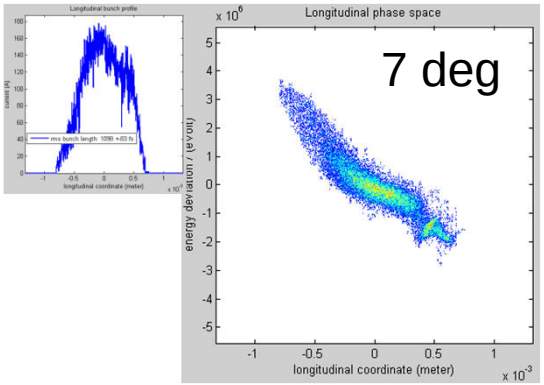
…, original energy scale
…
…

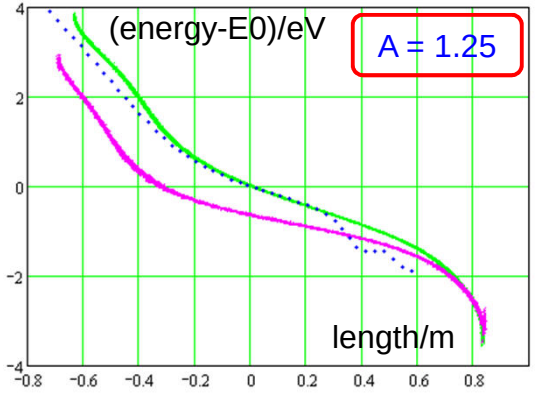


…, original energy scale
…, shifted

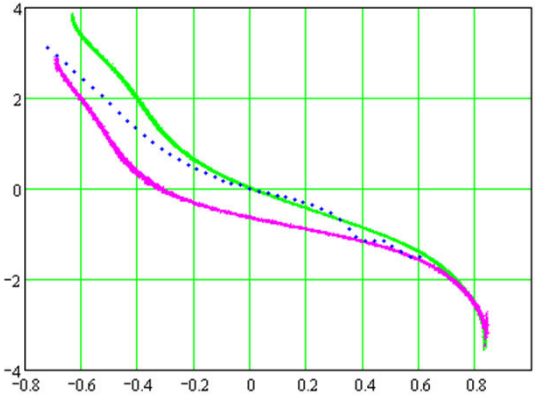
4 Analysis – Reconstruction of Initial Distribution – TE Method

forward calculation to LOLA

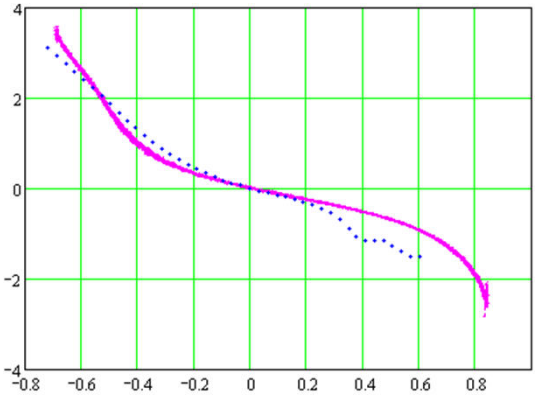




measured (slice), scaled in time and energy
calculated without self effects
calculated with self effects



…, original energy scale
…
…



…, original energy scale
…, shifted

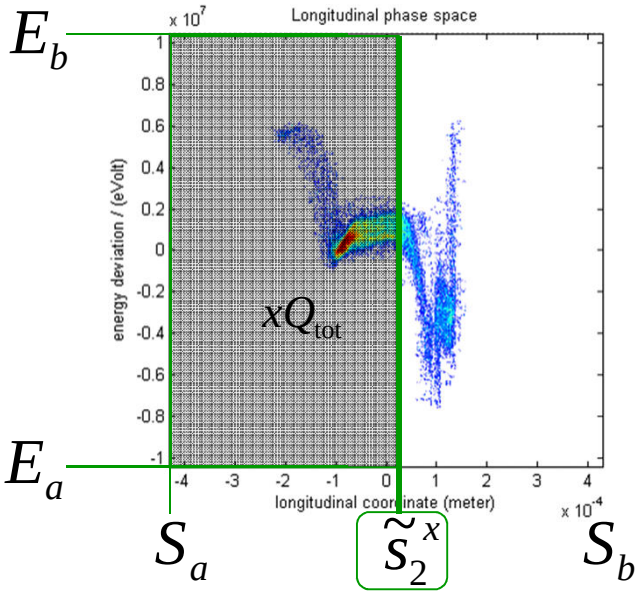
5 Analysis – Reconstruction of Initial Distribution – TT Method

time-time-method

vector with rf setting $\mathbf{r} = (A_1, \varphi_1, A_3, \varphi_3)$

definition of $s_2^x(\mathbf{r})$:

$$Q_{\text{tot}} = \int_{S_a}^{S_b} \int_{E_a}^{E_b} \psi(s, E, \mathbf{r}) ds dE$$



$$xQ_{\text{tot}} = \int_{S_a}^{\tilde{s}_2^x(\mathbf{r})} \int_{E_a}^{E_b} \psi(s, E, \mathbf{r}) ds dE$$

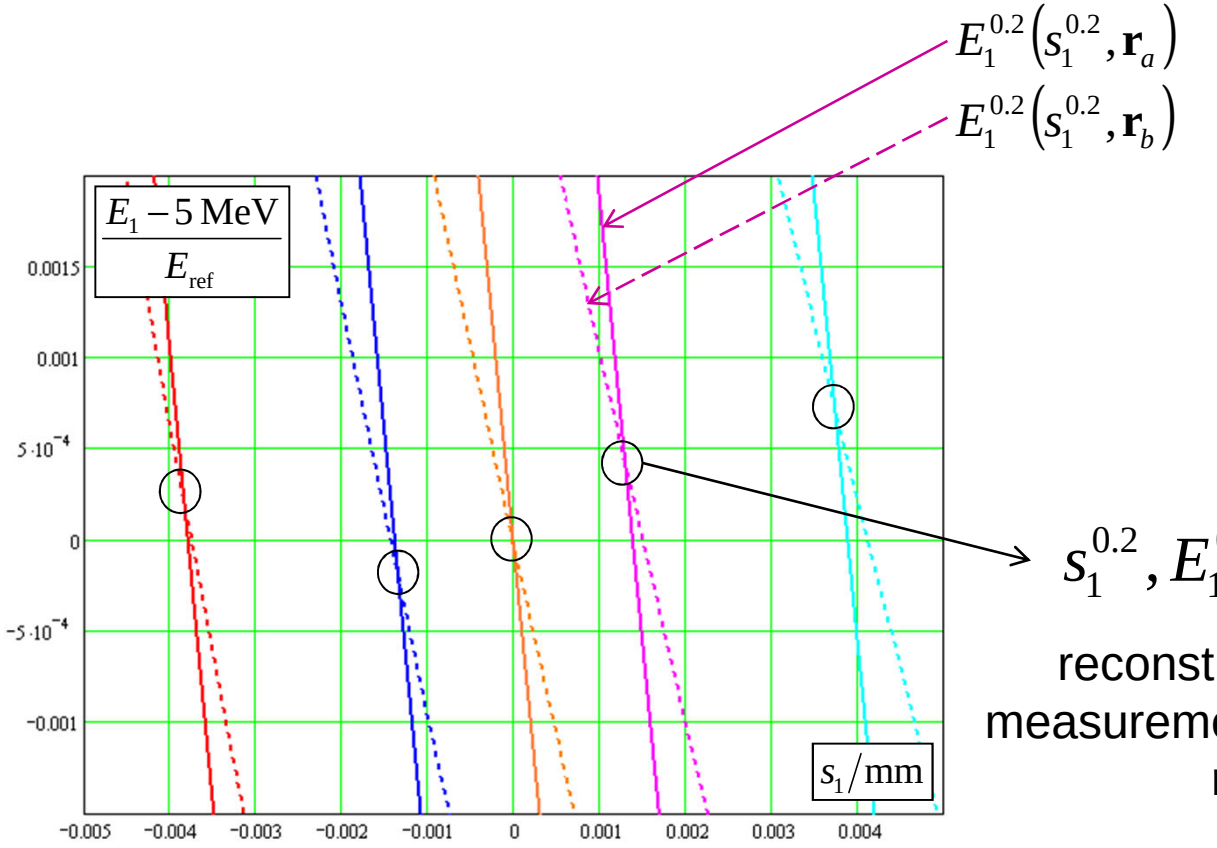
$$s_2^x(\mathbf{r}) = \tilde{s}_2^x(\mathbf{r}) - \tilde{s}_2^{0.5}(\mathbf{r})$$

5 Analysis – Reconstruction of Initial Distribution – TT Method

time-time-method

$$s_2^x(\mathbf{r}) = s_1^x + D\left(E_1^x + E_{rf}\left(s_1^x, \mathbf{r}\right)\right) \quad \text{with} \quad D(E) = r_{56}\frac{E - E_{\text{ref}}}{E_{\text{ref}}} + t_{566}\left(\frac{E - E_{\text{ref}}}{E_{\text{ref}}}\right)^2$$

known: $E_1^x\left(s_1^x, \mathbf{r}\right)$



reconstruction from time measurements for two different rf settings

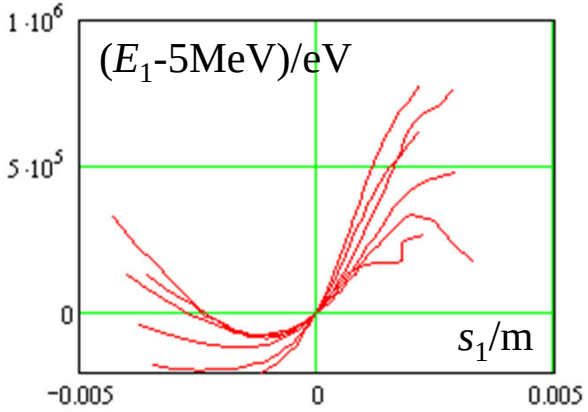
5 Analysis – Reconstruction of Initial Distribution – TT Method

virtual initial distribution

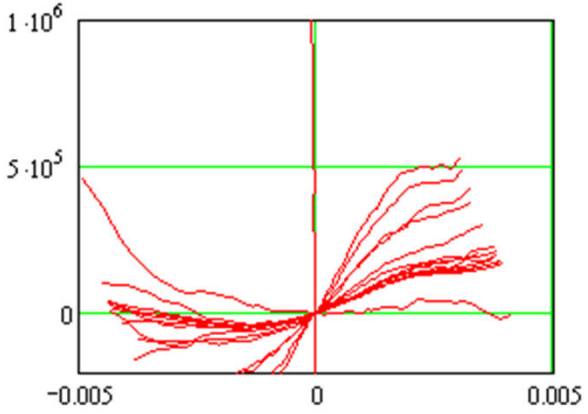
index = -30, -20, -10, 0, 10, 20

combinations for index = -30, -20, -10, 0, 10, 20

pure time-energy-method

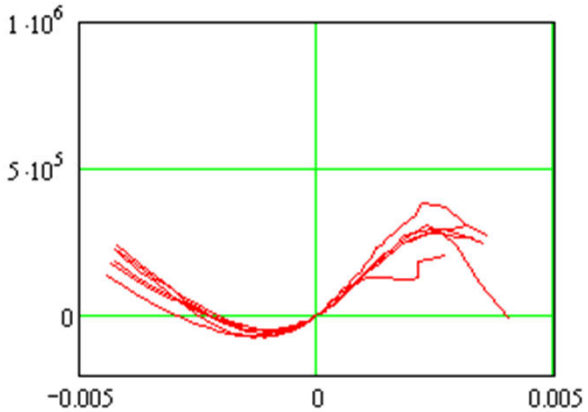


pure time-time-method



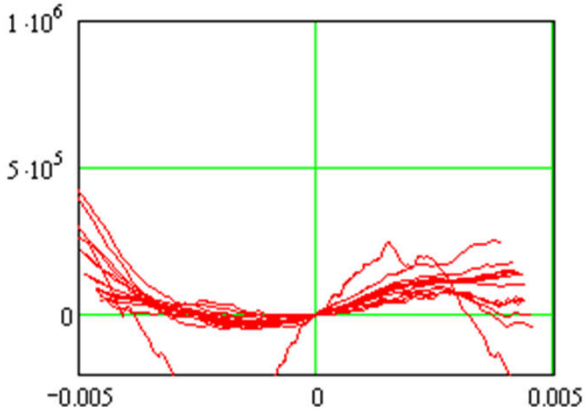
modified time-energy-method

modified energy, time and phase calibration



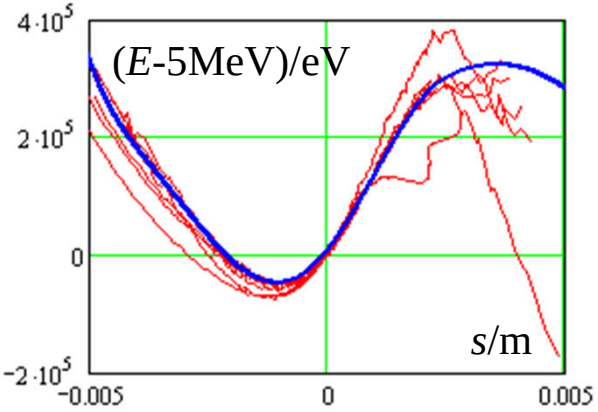
modified time-time-method

modified time calibration as for t-e-method

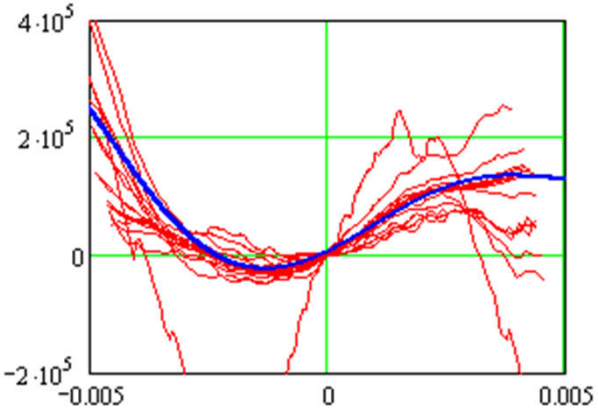


virtual initial distributions

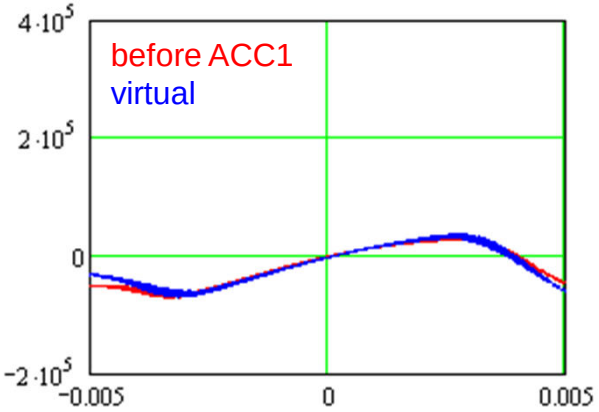
modified time-energy-method

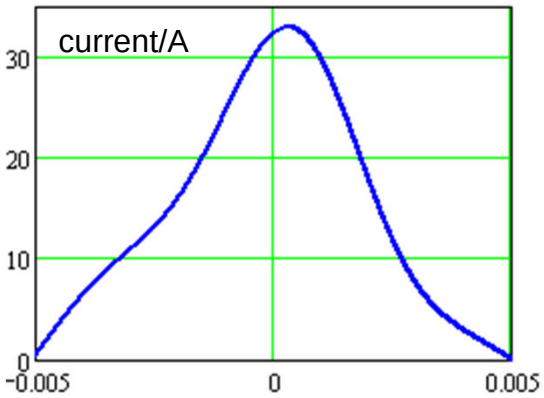


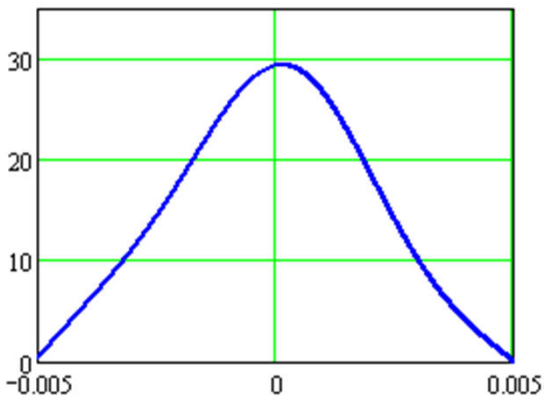
modified time-time-method

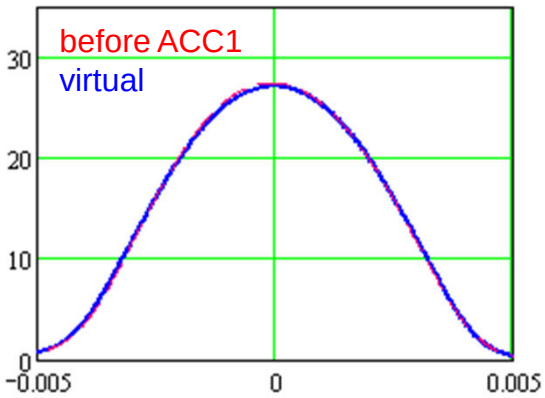


Astra (7 psec)



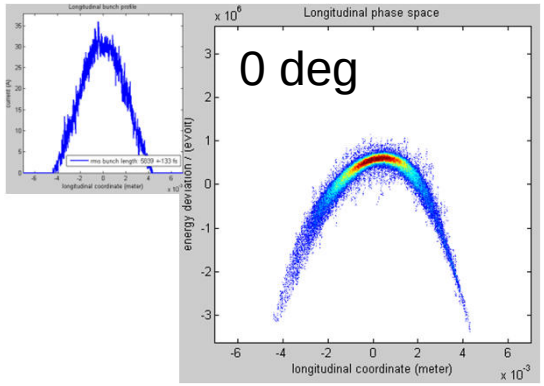


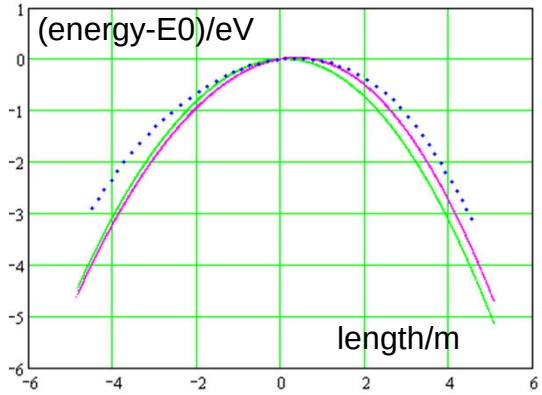




5 Analysis – Reconstruction of Initial Distribution – TT Method

forward calculation to LOLA

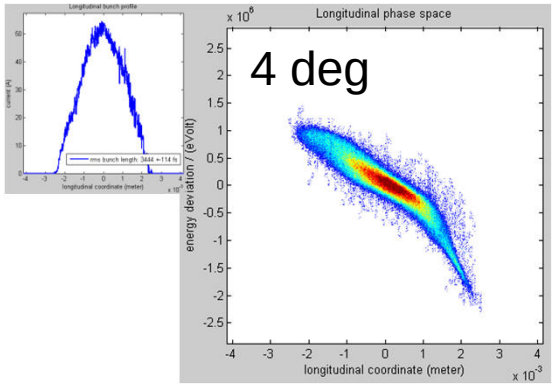


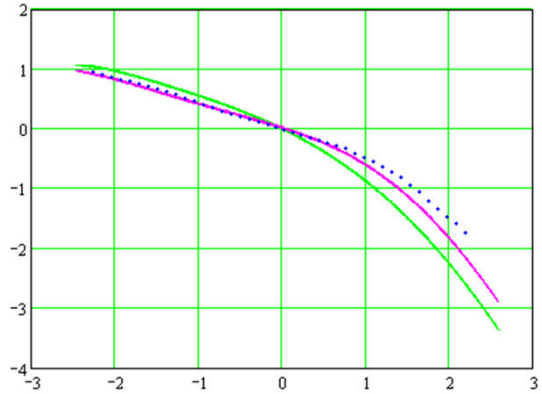


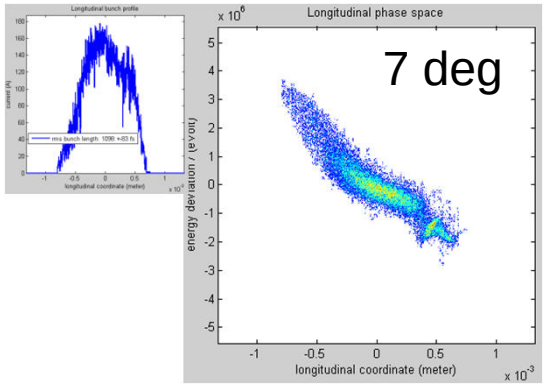
measured (slice), scaled in time

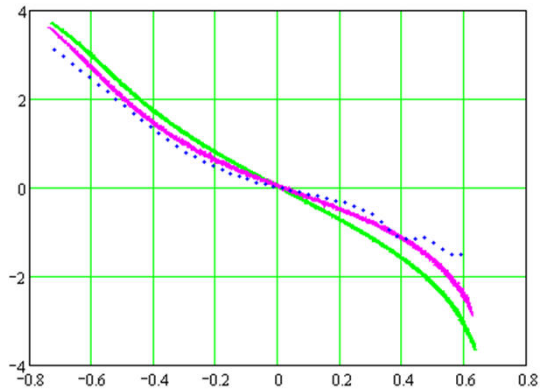
calculated without self effects

calculated with self effects, shifted from E_TT – wake(ACC1,AC39)









6 ASTRA

"bunch" length" and charge:

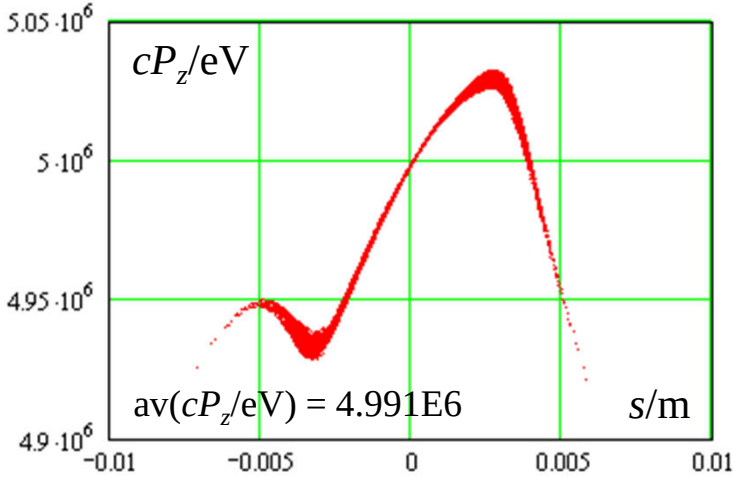
```
!--------------------------
Trms=0.0070
Qbunch=0.5
!--------------------------
```

ACC1 amplitude and phase:

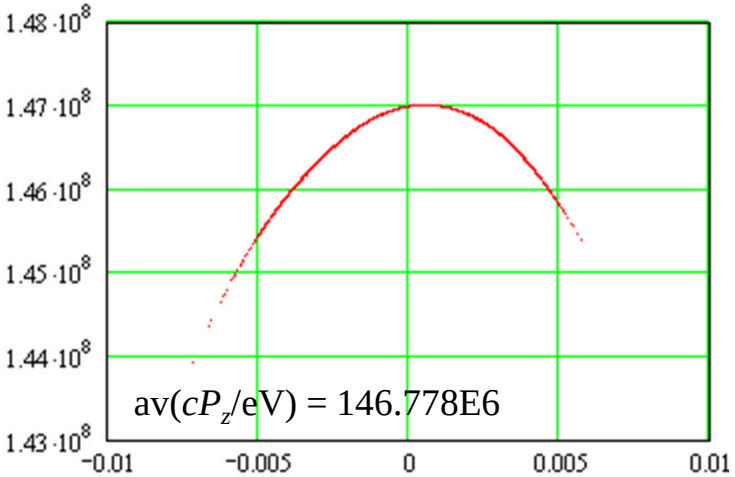
```
Mod_Efield(2)=26.12231,  Mod_Phase(2)=   0.0
Mod_Efield(3)=40.068675, Mod_Phase(3)=   0.0
```

(auto phasing)

Z=2.6m (before ACC1)



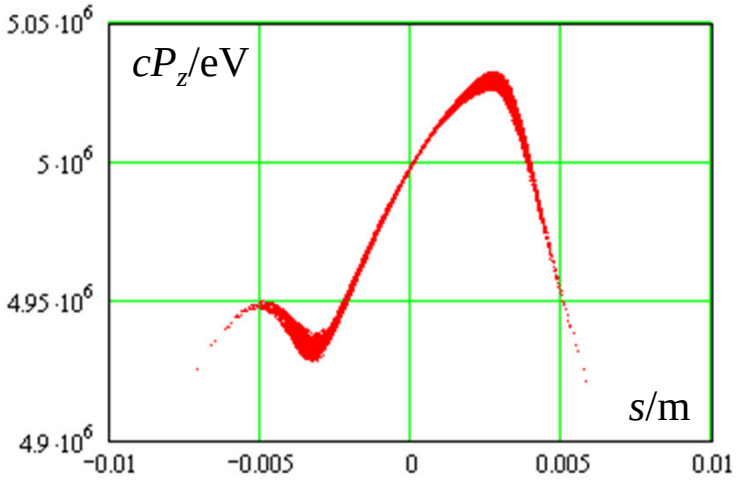
Z=13.8m (after ACC1)



6 ASTRA

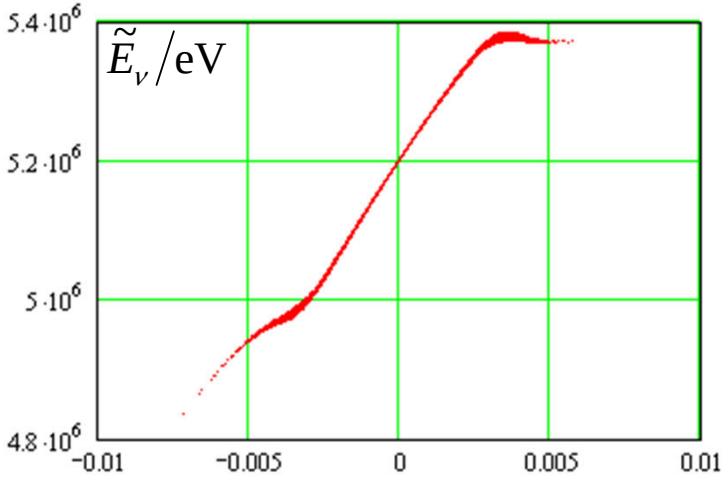
virtual initial distribution

Z=2.6m (before ACC1)



$\tilde{E}_v = E_v - E_{rf}(s_v)$ with $E_{rf}(s) = c\Delta P_{\mathrm{av}} \cos ks$

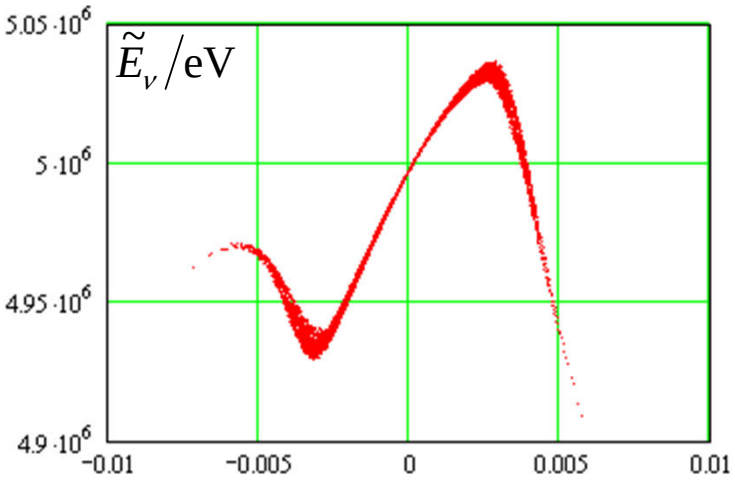
ΔcP_{av}/eV = 141.778E6



with fit parameters: $E_{rf}(s) = A\cos(ks + \varphi)$

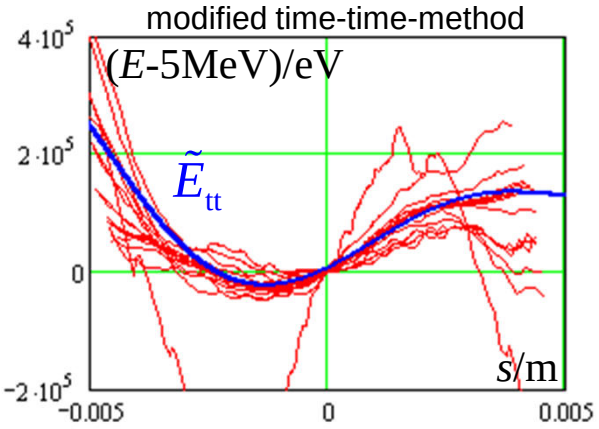
A/eV = 142.000E6

φ/deg = -0.677



6 ASTRA

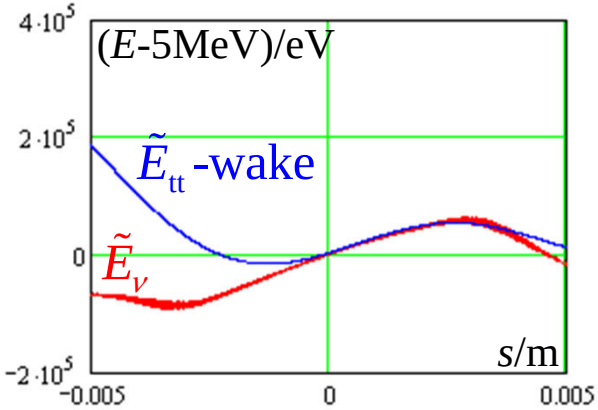
reconstructed virtual initial distribution includes errors by deviation of nominal rf (ACC1, ACC39) from real field



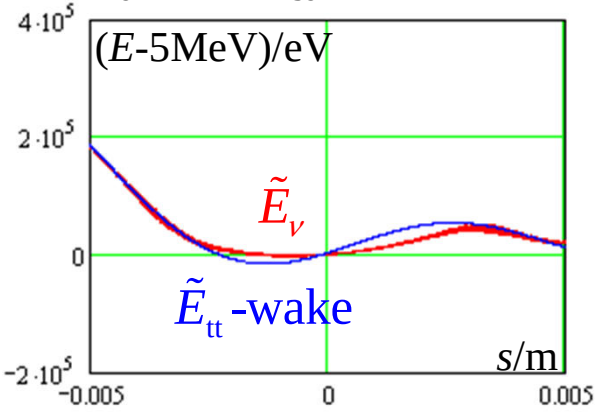
$$\tilde{E}_\nu = E_\nu - E_{rf}(s_\nu) \quad \text{with}$$

$$E_{rf}(s) = A\cos(ks+\varphi) + \begin{bmatrix} \delta E_{1c} \\ \delta E_{1s} \\ \delta E_{3c} \\ \delta E_{3s} \end{bmatrix}^t \begin{bmatrix} \cos(ks) \\ \sin(ks) \\ \cos(3ks) \\ \sin(3ks) \end{bmatrix}$$

$$\delta E_{1c} = \delta E_{1s} = \delta E_{3c} = 0\ \text{MeV}$$
$$\delta E_{3s} = 0.1\ \text{MeV}$$



$$\delta E_{1c} = -\delta E_{3c} = 1.95\ \text{MeV}$$
$$\delta E_{1s} = 0 \quad \delta E_{3s} = -0.17\ \text{MeV}$$

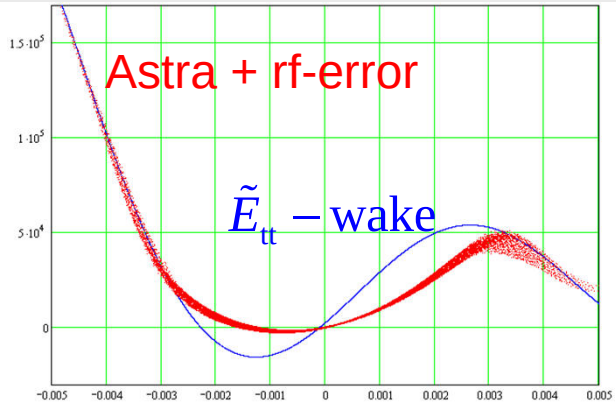


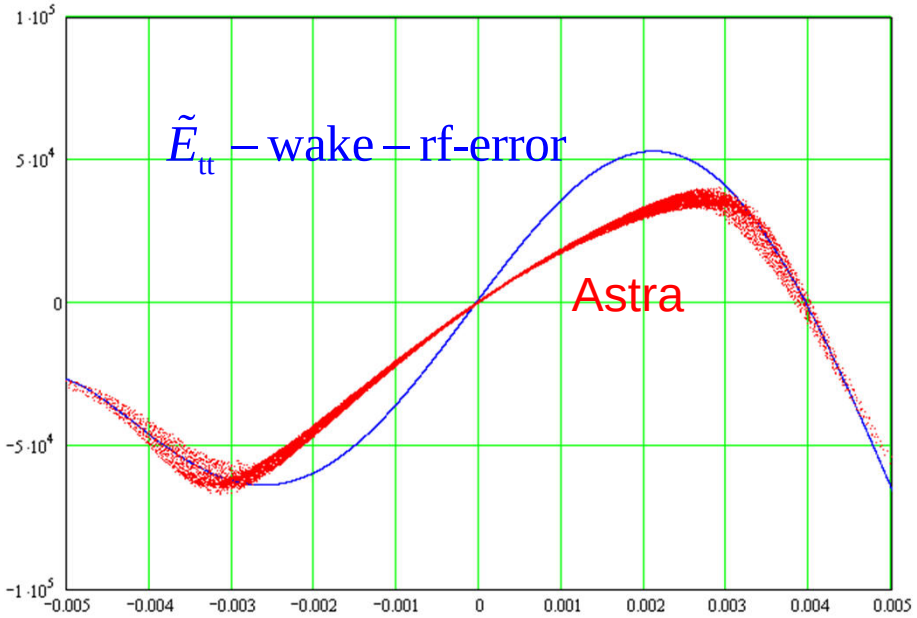
used for the following

6 ASTRA

$$\delta E_{1c} = -\delta E_{3c} = 1.95\ \text{MeV}$$

$$\delta E_{1s} = 0 \quad \delta E_{3s} = -0.17\ \text{MeV}$$





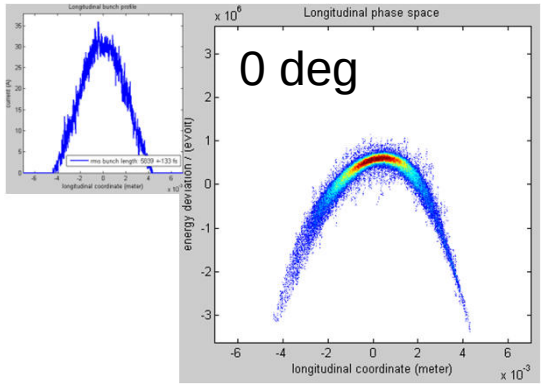
6 ASTRA

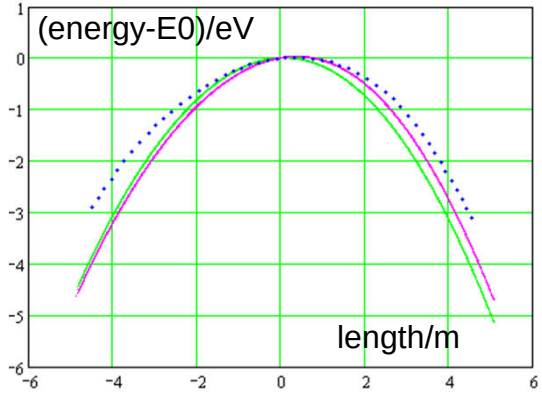
forward calculation to LOLA

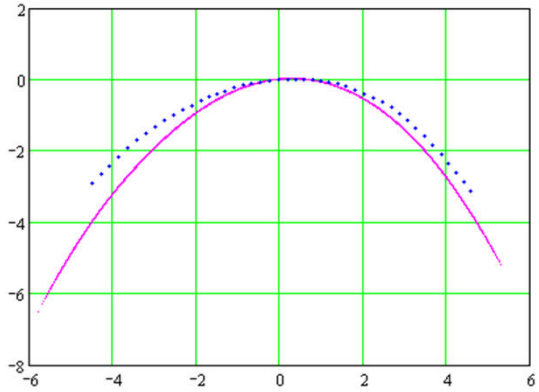
measured (slice), scaled in time
calculated without self effects
calculated with self effects, shifted

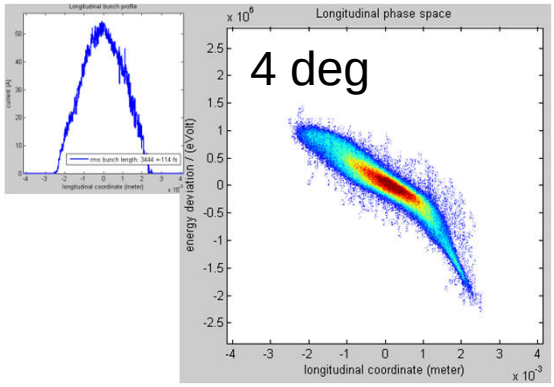
TT-method

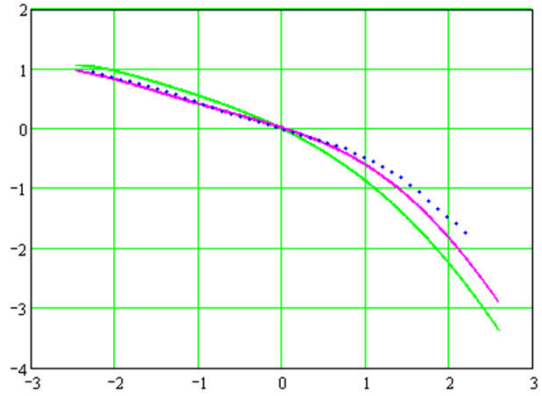
Astra

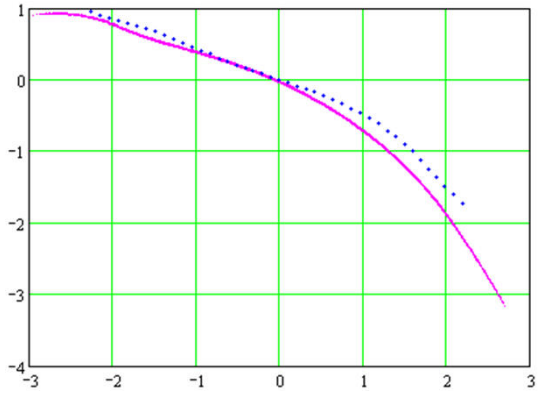


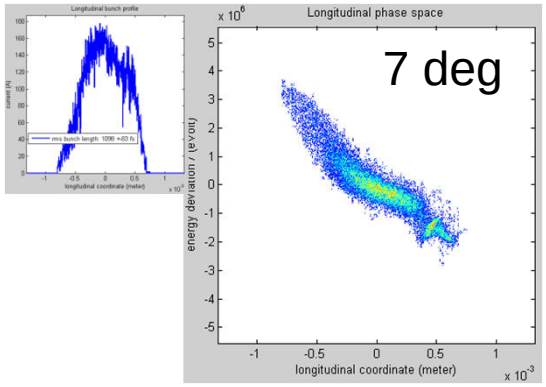


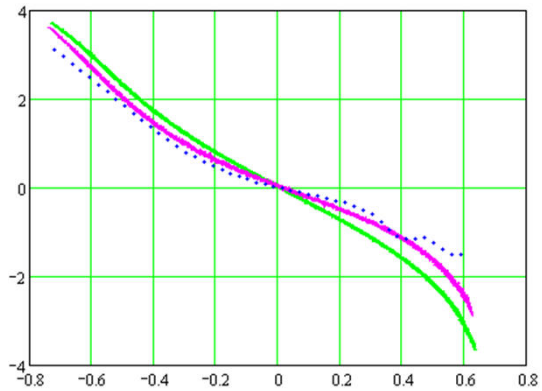


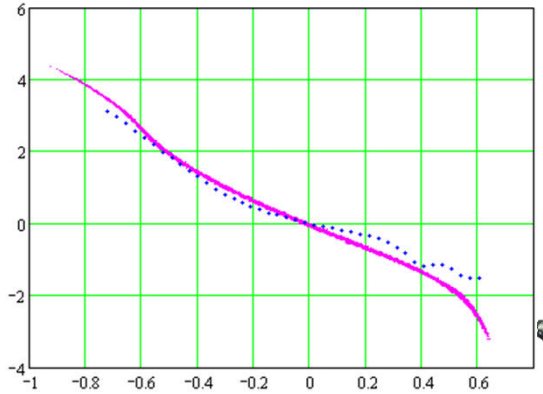






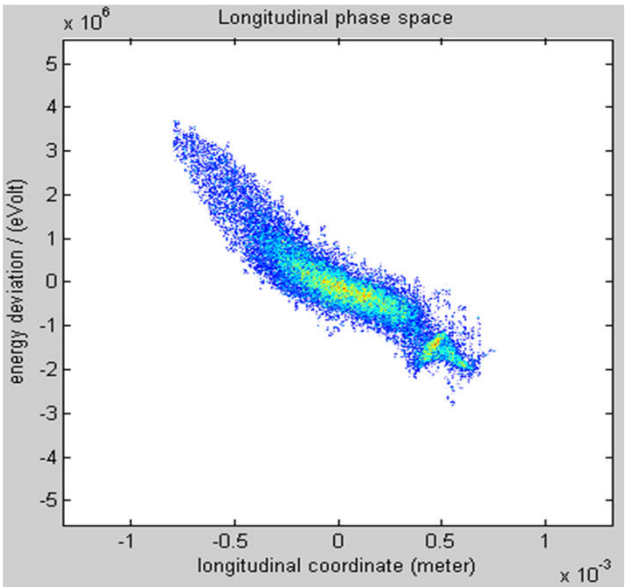


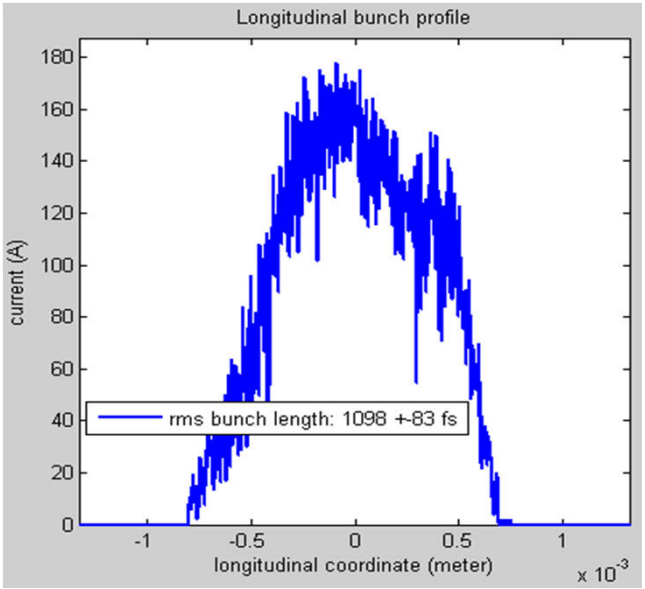


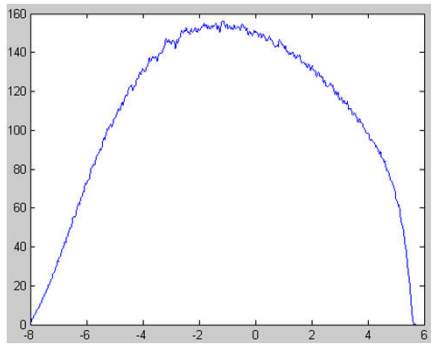


7 Phase Space: LOLA ↔ TT Method ↔ ASTRA

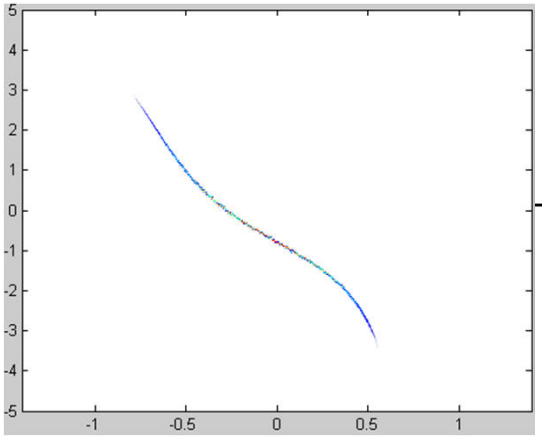
LOLA measurement:

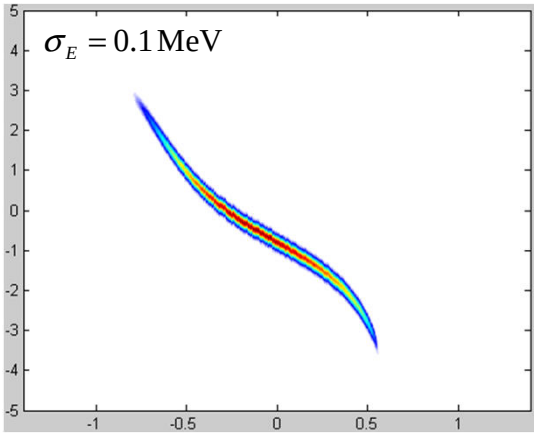


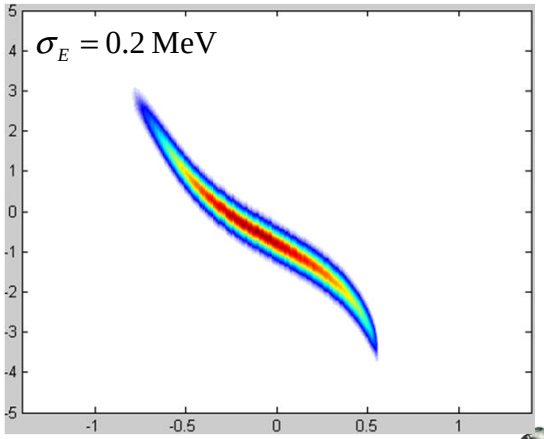




calculation with self effects:



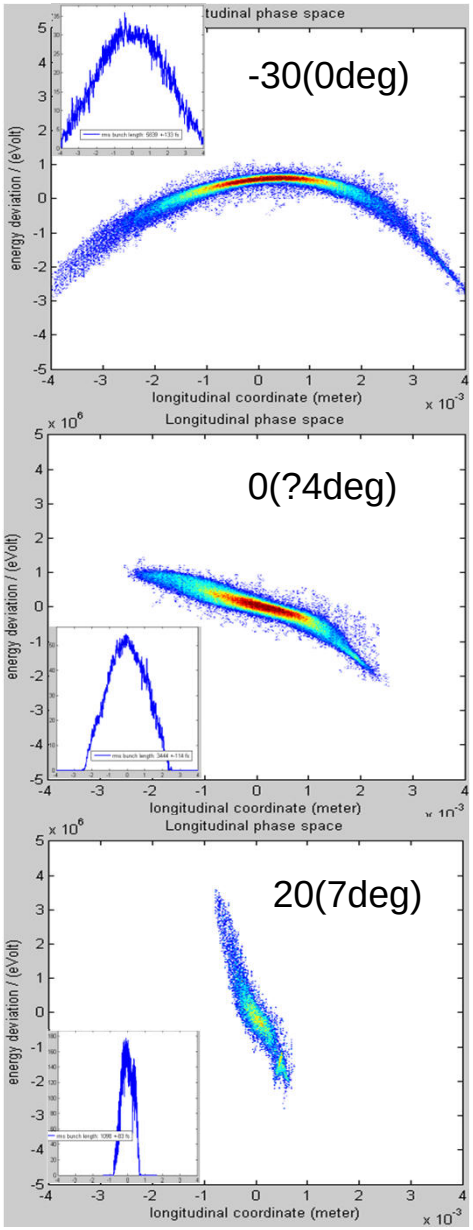




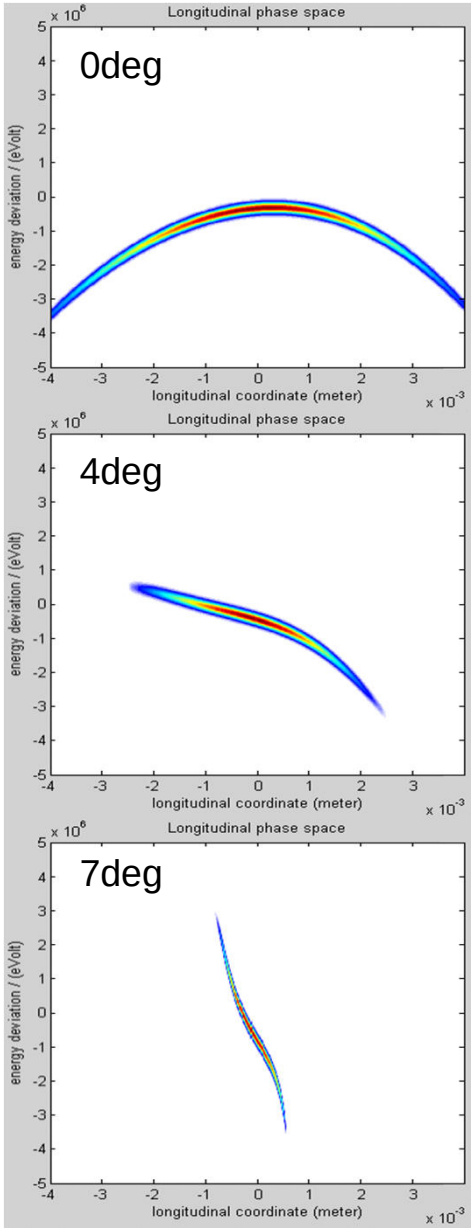
in the following: calculated results with additional energy spread of 0.1 MeV !

7 Phase Space: LOLA ↔ TT Method ↔ ASTRA

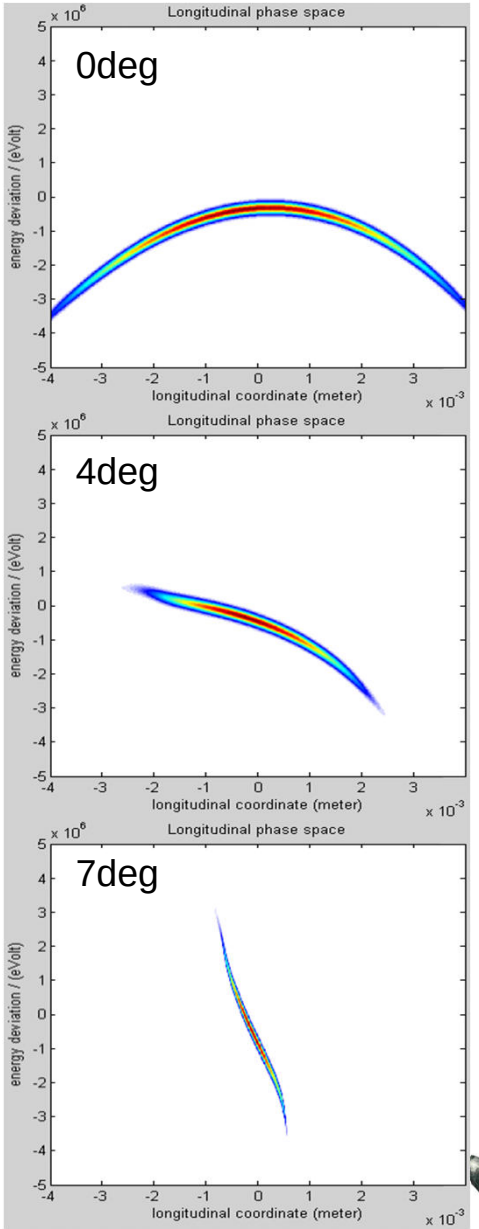
LOLA



TT-method

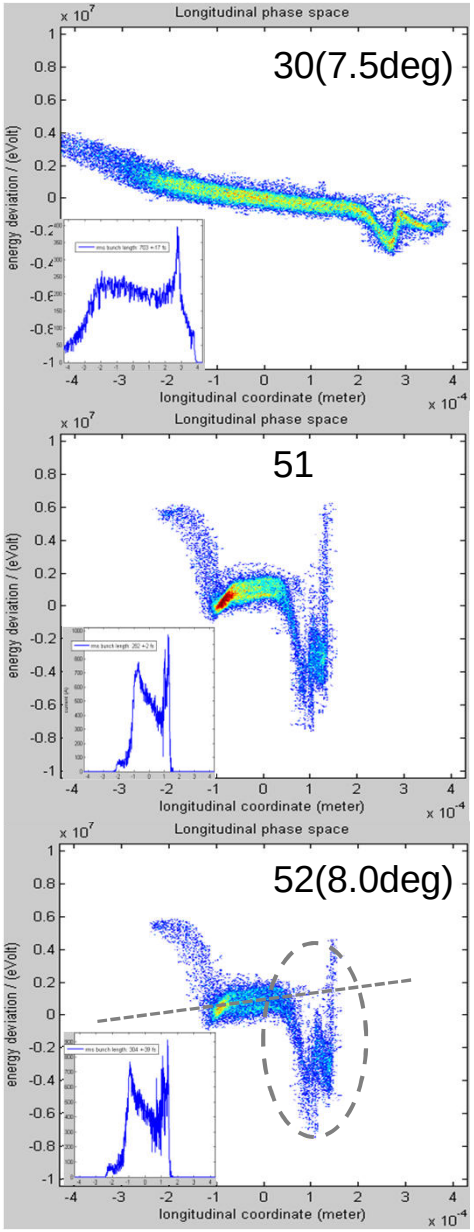


ASTRA



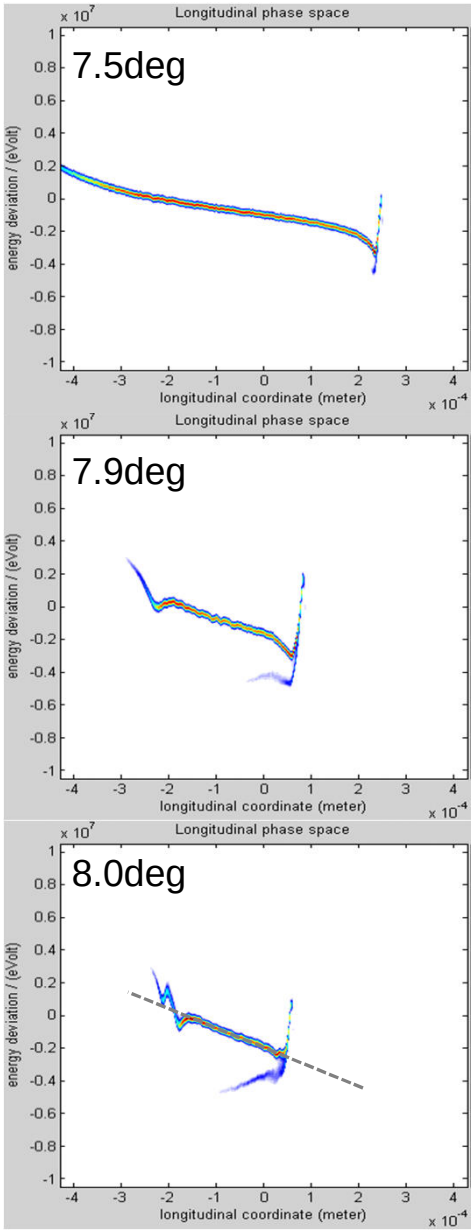
7 Phase Space: LOLA ↔ TT Method ↔ ASTRA

LOLA

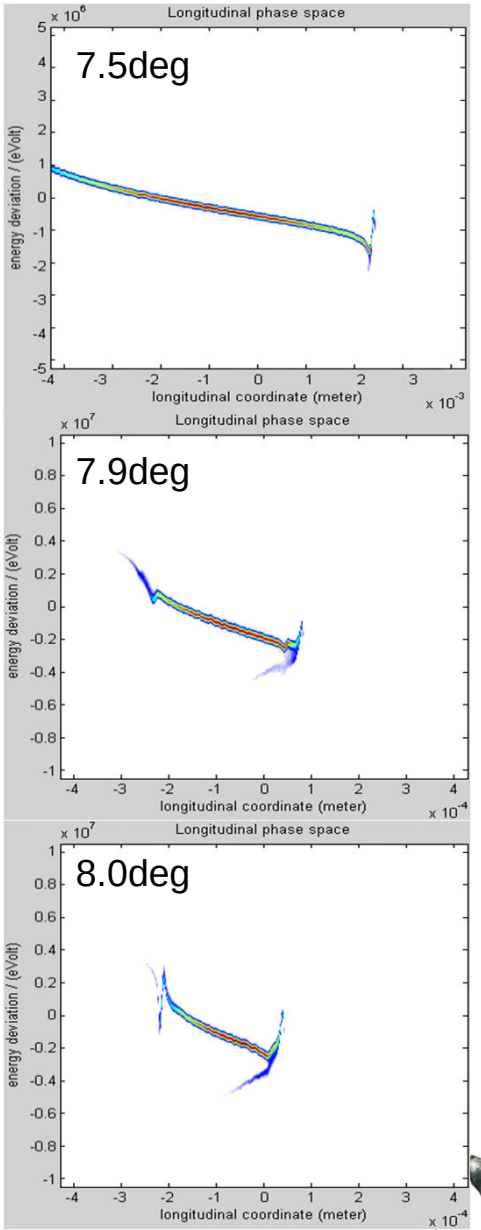


?

TT-method

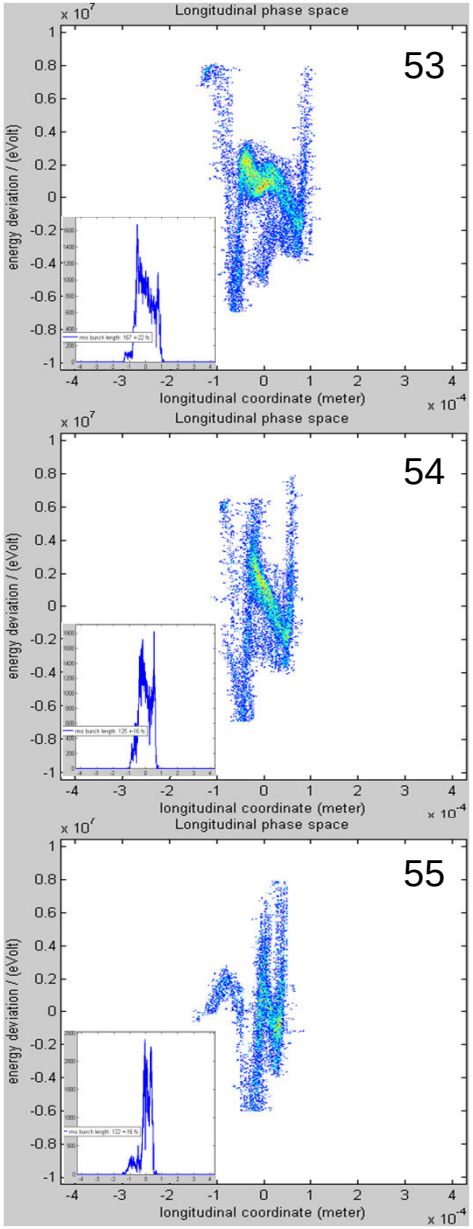


ASTRA

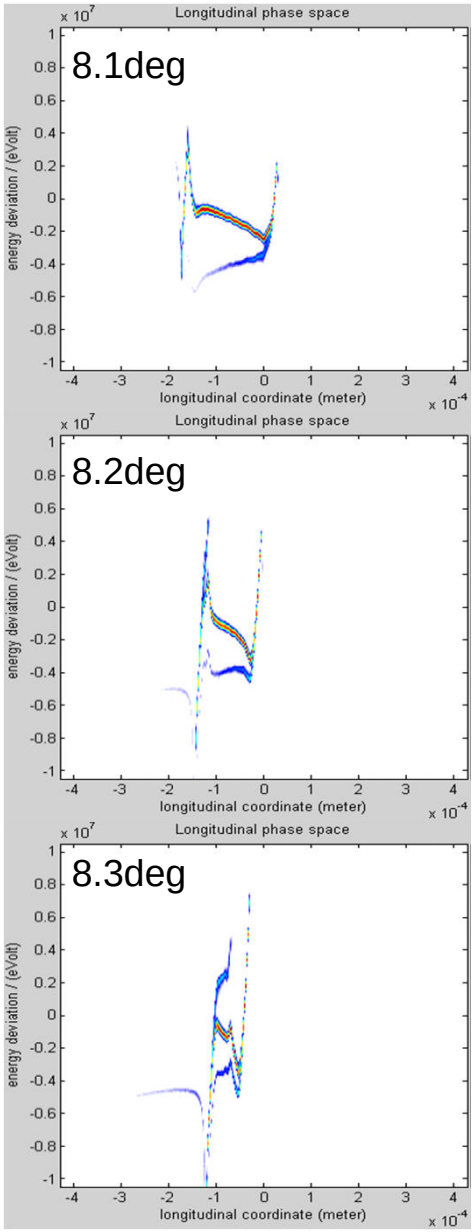


7 Phase Space: LOLA ↔ TT Method ↔ ASTRA

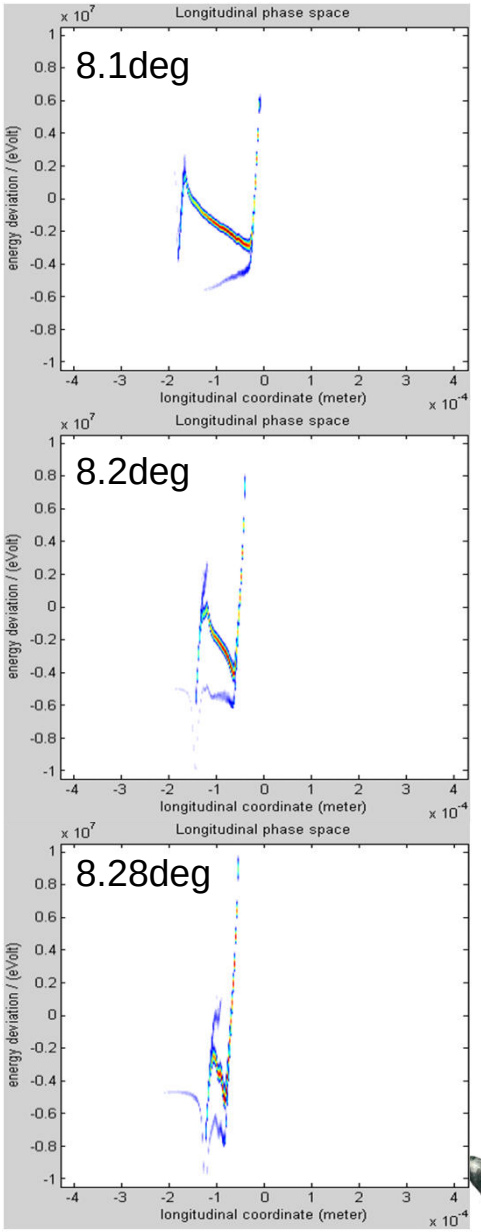
LOLA



TT-method

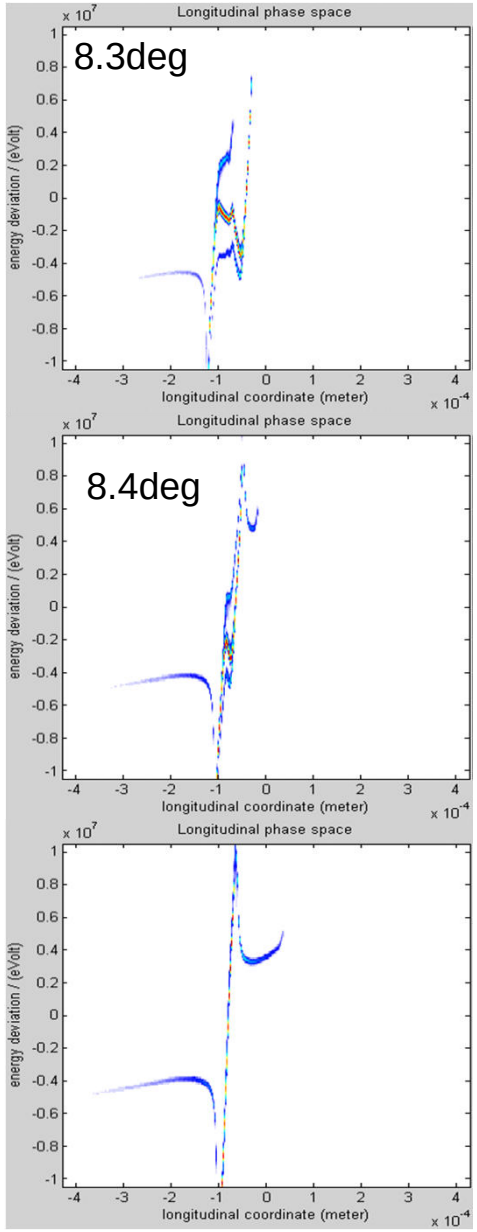


ASTRA

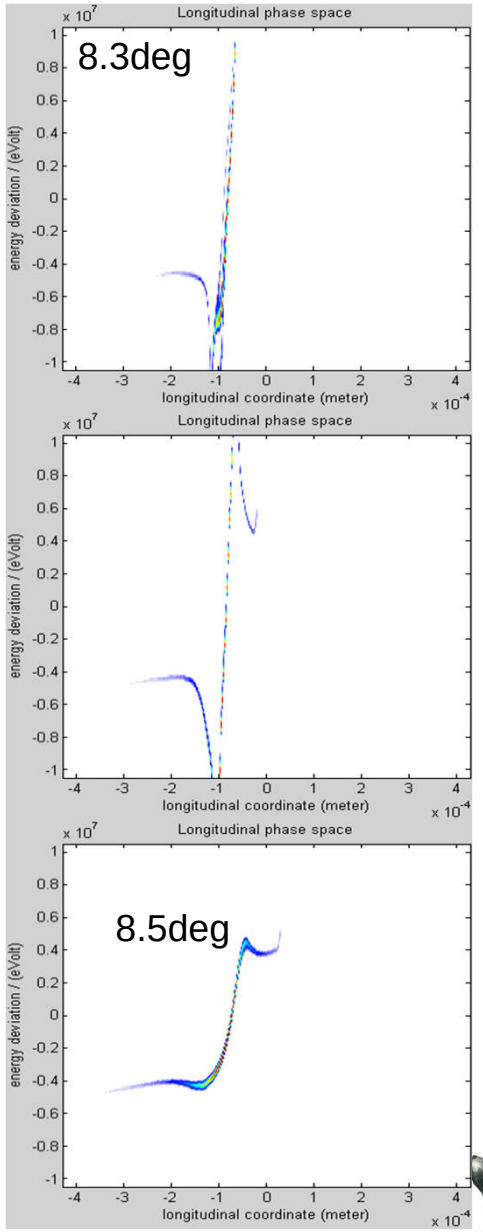


7 Phase Space: LOLA ↔ TT Method ↔ ASTRA

TT-method

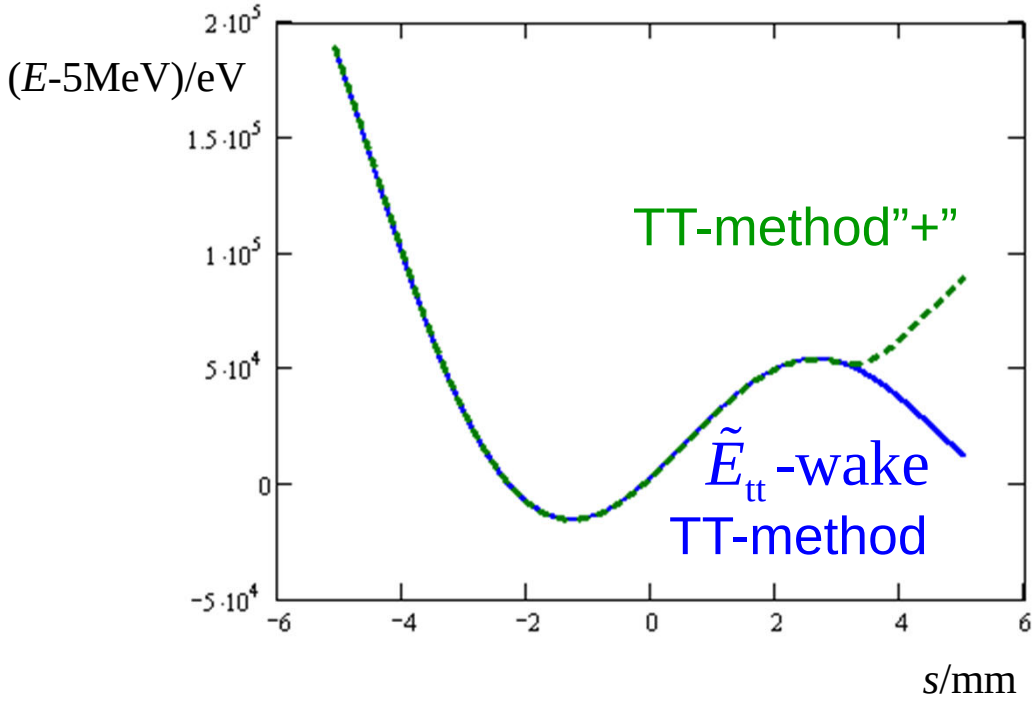


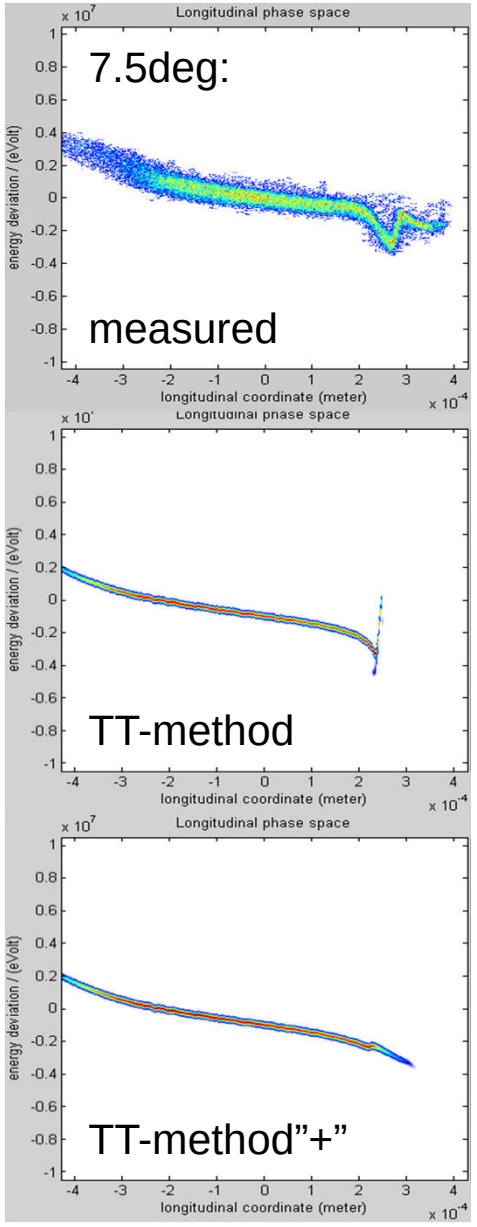
ASTRA



8 The Spike

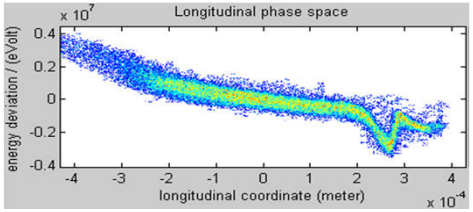
virtual initial distribution



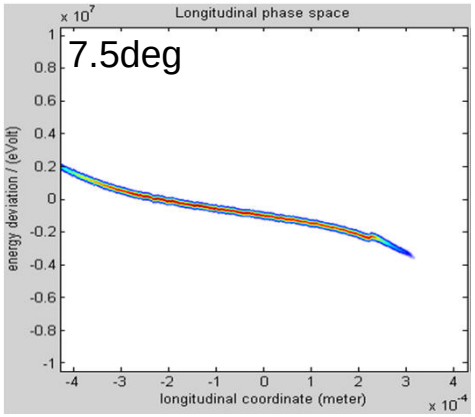


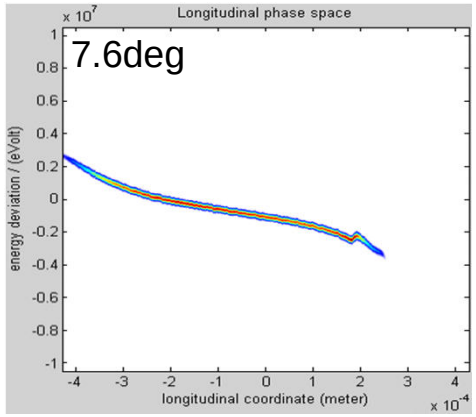
8 The Spike

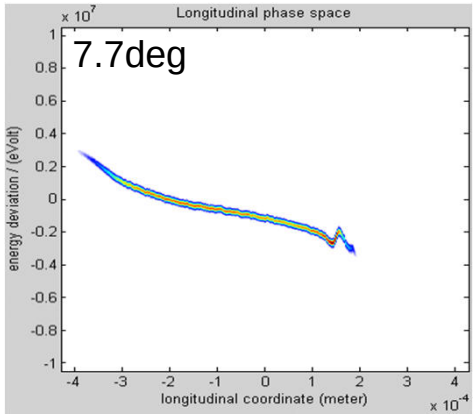
measured, 7.5deg:

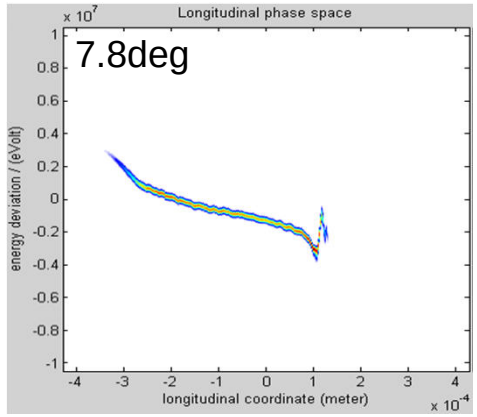


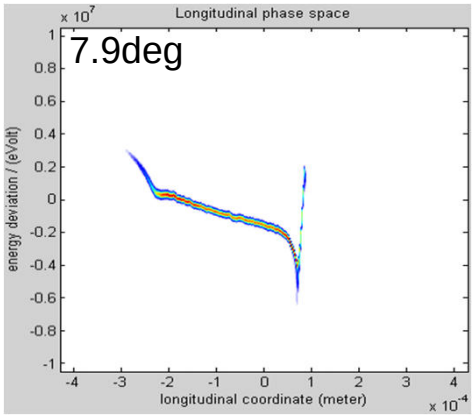
TT-method"+"

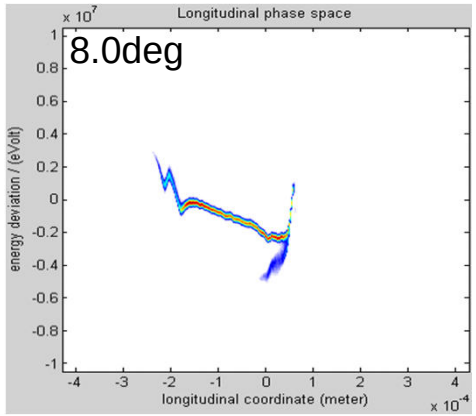


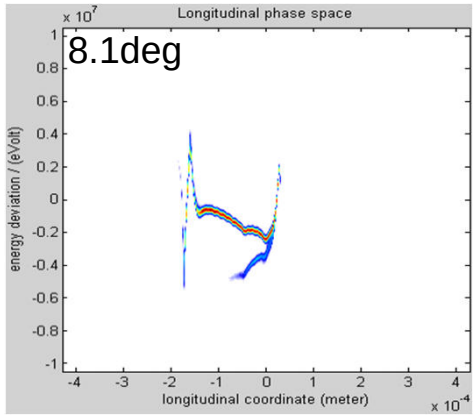


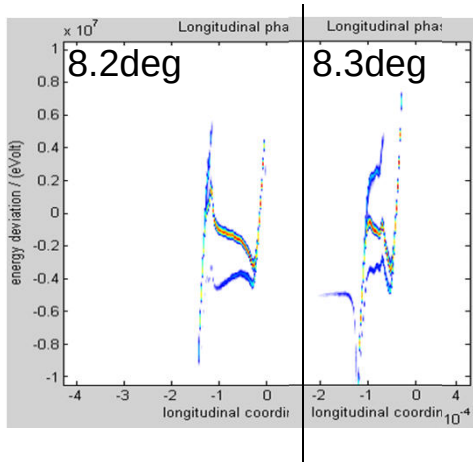




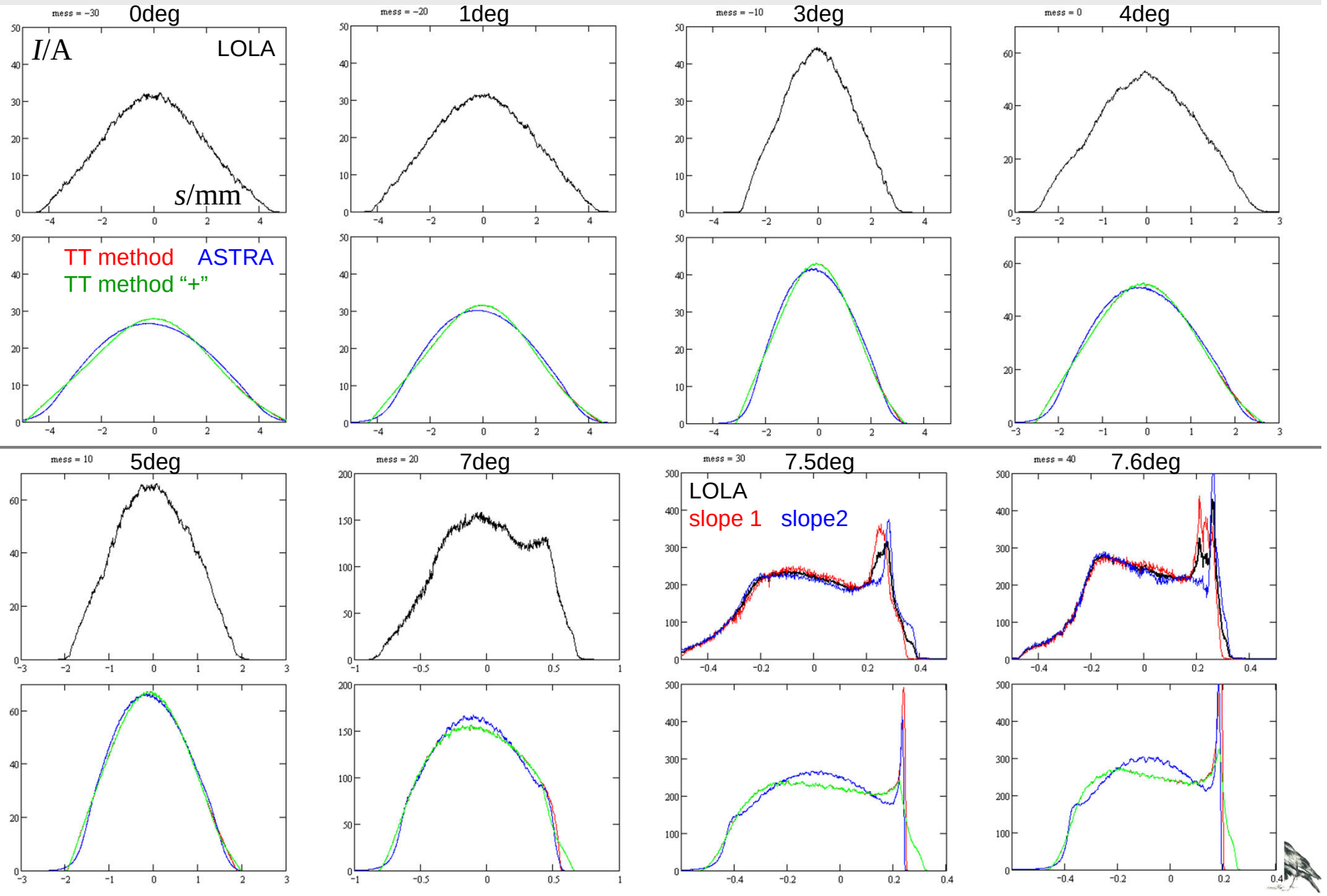




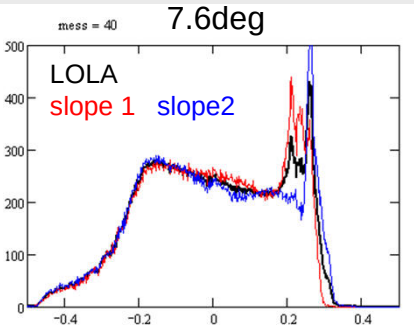


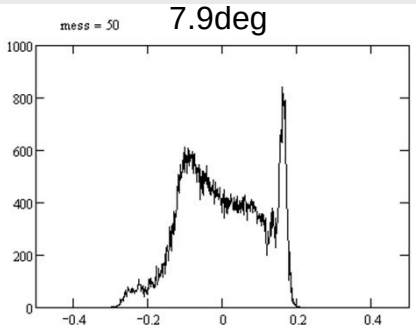


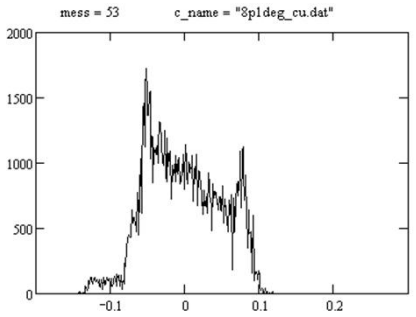
9 Current Distribution: LOLA ↔ TT Method ↔ ASTRA

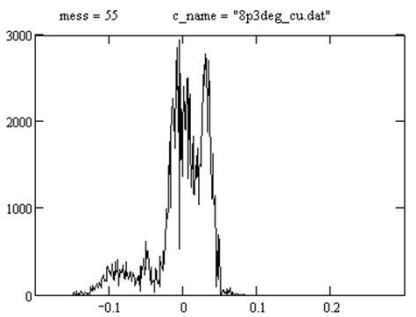


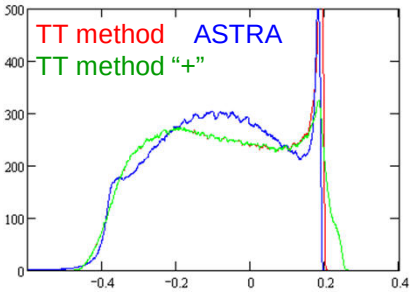
9 Current Distribution: LOLA ↔ TT Method ↔ ASTRA

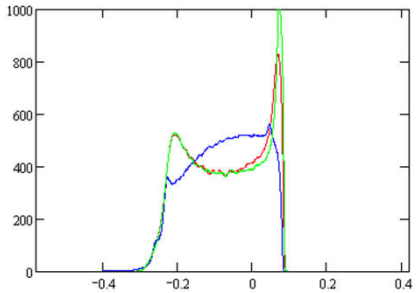


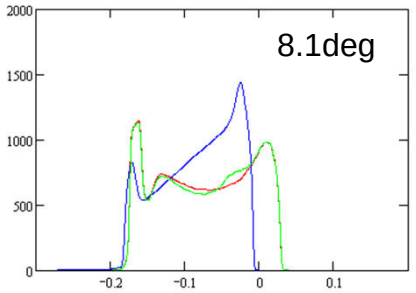


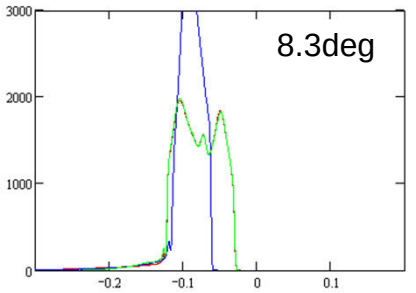


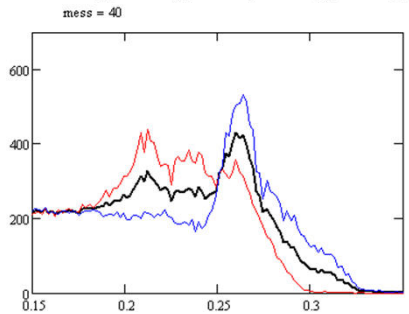


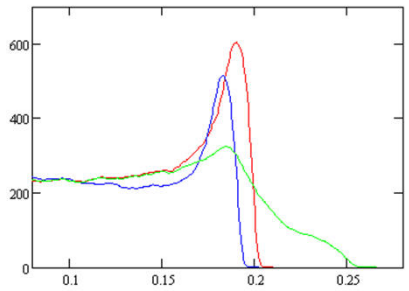




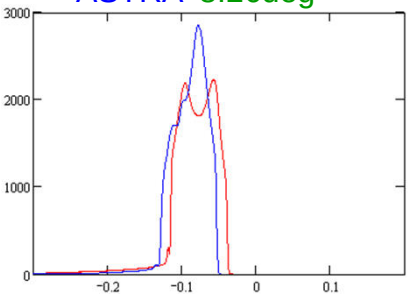








TT method 8.34deg
ASTRA 8.26deg



10 Summary

precise information of initial distribution is required

reconstruction with ET-method questionable; problems with energy scale!

reconstruction with TT-method ok for weak effects

1d model of longitudinal effects (SC, CSR and some wakes)

reconstruction with TT-method is not so bad for strong effects

middle compression is not understood

LOLA pictures not completely understood

virtual initial distribution different from ASTRA

qualitative differences for ASTRA distribution