dE - measurements program

Measurements with long Gaussian laser pulse

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δE-meeting
Zeuthen, 01.12.2016

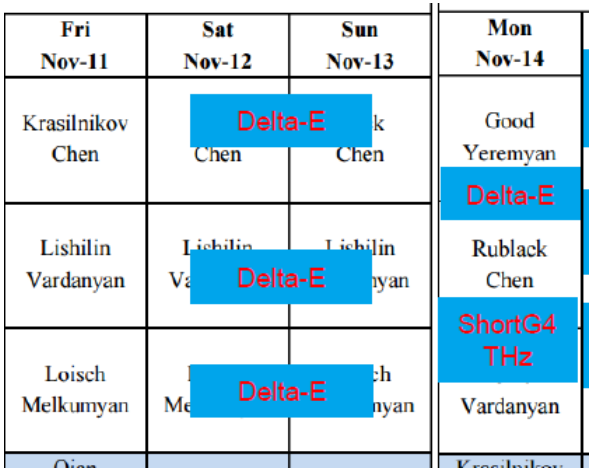
δE -Measurement program

1. Ecath=60MV/m (?additionally 45MV/m as an option)
2. Gun phase: MMMG
3. Laser temporal profile: long Gaussian of ~11ps FWHM
4. Bunch charge: 0.4 nC
5. BSA=BSA0 (interpolated optimum for each bunch charge – based on the 2015 results) and 2*BSA0 (? relaxed transverse space charge by a factor of 4). Please check the rms spot size at VC2: XYrms~BSA/4:

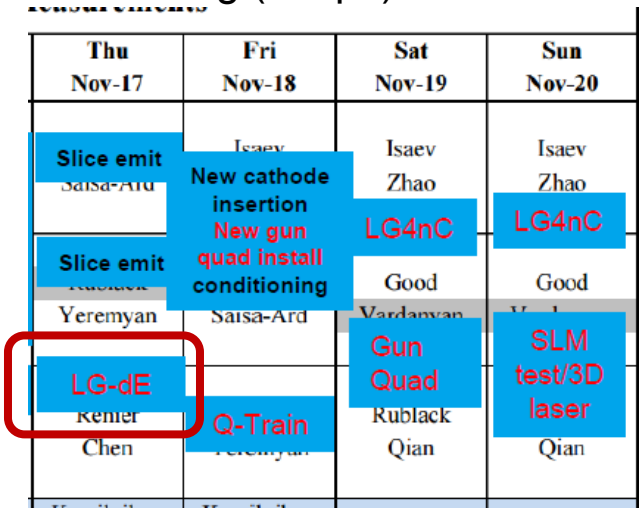
Meas \ charge→	**0.4 nC**
Laser temporal	**Long Gauss**
A	**1.1 mm**
B	**2.2 mm**

   e.g., for measurement "0.4-A" → BSA=1.1mm
6. CDS booster: 3MW, phase scan for LPS tomography. The CDS phase for TDS measurements: min projected energy spread at HEDA2(?)
7. Expected measurements (for each of 6 setups: 0.4-A and 0.4-B – to be saved in e.g. …\measure\LongPhSp\2016\deltaE\longG\0.4-A\...):
   a. Laser transverse distribution at VC2 (20+20frames)
   b. Beam momentum scan in LEDA as a function of gun SP Phase → MMMG gun phase, <Pz>, PZrms
   c. Laser attenuator scan (LT-scan) for the MMMG phase with LOW.FC1 (if it is too noisy – use LOW.FC2, also LOW.ICT1/HIGH1.ICT1), adjust the LT for the goal charge, measure the bunch charge
   d. Beam momentum in HEDA1 as a function of the booster SP phase (very detailed – to be used for LPS reconstruction). Don't forget to adjust the e-beam at the reference screen HIGH1.Scr5 (centered and vertically focused). Booster phase MMMG (or min energy spread at HEDA1?).
   e. Setup the e-beam trajectory; e.g. from 31.10.2016 05:18 (PITZ logbook)
   f. E-beam projected emittance at EMSY1 vs. main solenoid current (use fastscan3), Imain* for minimum XY-emittance.
   g. Beam transport to the PST.Scr1, TDS measurements of the bunch temporal profile (Imain to be tuned as well? Or use one delivering the best emittance).
   h. Beam transport to HEDA2 (Imain to be tuned as well?), quad settings for the best HEDA resolution – save magnet settings and beam images at screens in the HIGH section. Check the TDS phase range at HIGH2.Scr1 – not to be cut by the beam line aperture.
   i. Beam momentum in HEDA2 as a function of the booster SP phase→ booster phase for the minimum projected momentum spread.
   j. LPS measurements at HEDA2 with applied TDS:
      i. TDS phase scan (calibration)
      ii. TDS at zero phase – momentum measurements with OMA
      iii. TDS off – momentum measurements with OMA

Short (~2ps) Gaussian



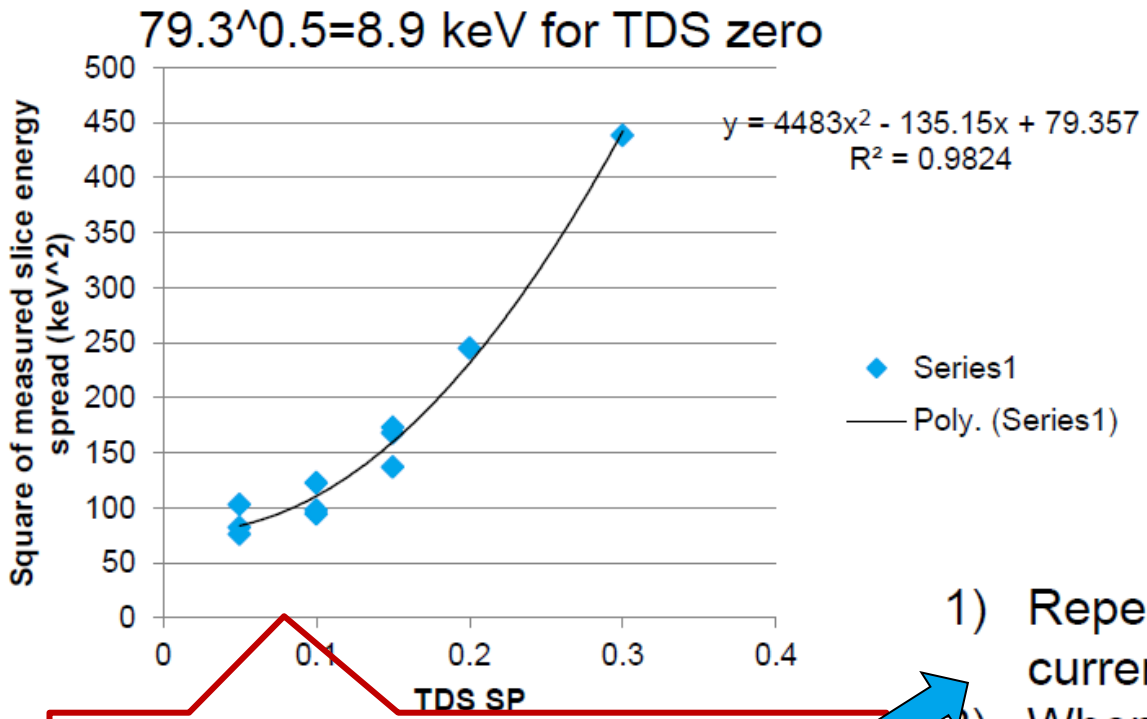
Long (~11ps) Gaussian



Slice energy spread measurement

- Real slice energy spread
- TDS contribution
- Beta function contribution

$$\delta_E^{measured} \approx \sqrt{\left(\delta_E^{real}\right)^2 + \left(\delta_E^{\beta}\right)^2 + \left(\delta_E^{TDS}\right)^2}$$



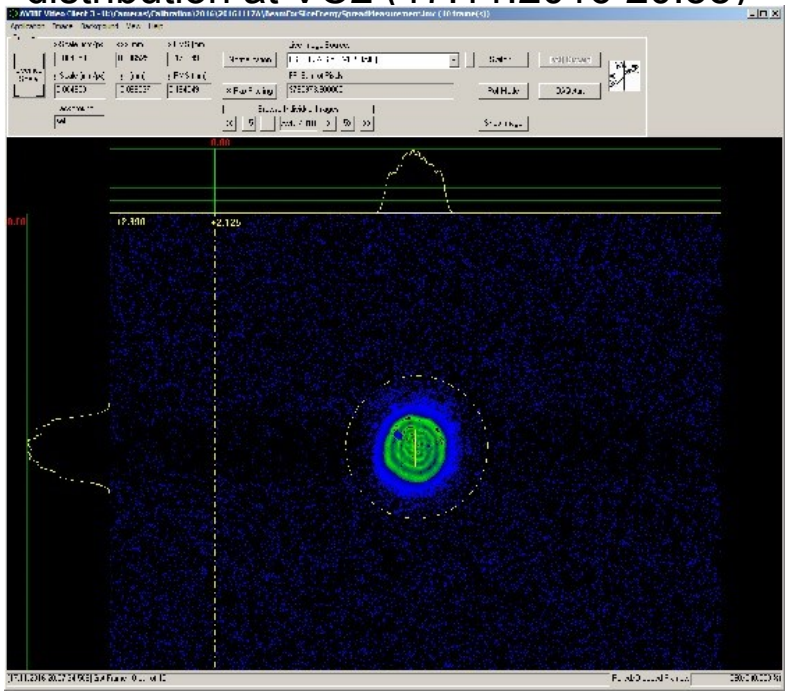
Temporal profile	FWHM
Short Gaussian	~1.8-2ps
Long Gaussian	~11-11.5ps

Measurements with short Gaussian
taken on 20161113N
with 100 pC, 0.75 mm

1) Repeat this measurement with current long gaussian laser
2) When optimize xrms on dipole2, turn off & degauss HEAD2, Use screen (H2.scr2) after HEDA2 as a 'ref' to min Xrms

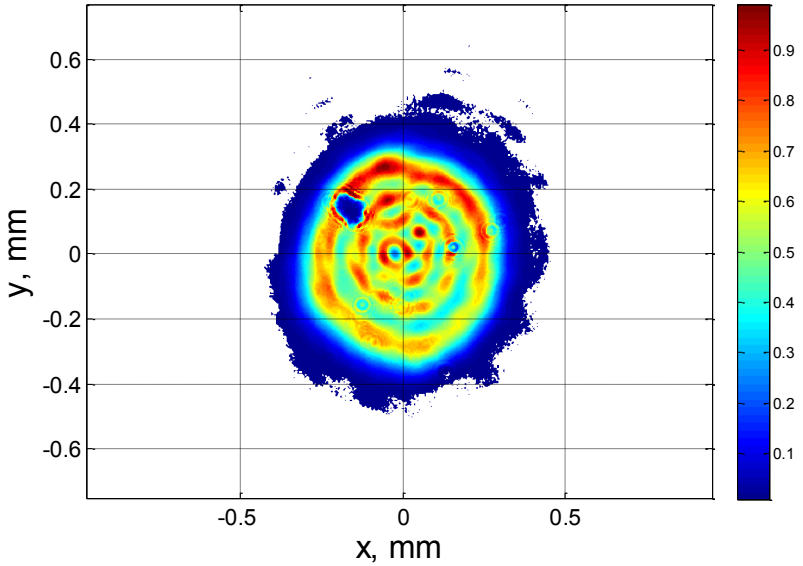
Measurements with long Gaussian on 17.11.2016A-N: VC2

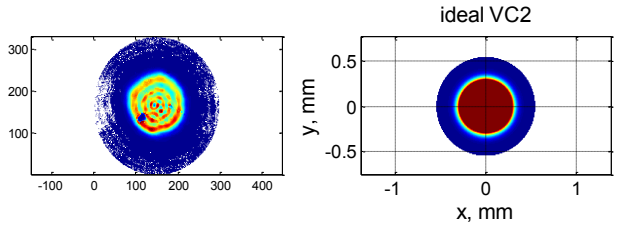
- Photocathode laser: transverse distribution at VC2 (17.11.2016 20:58)



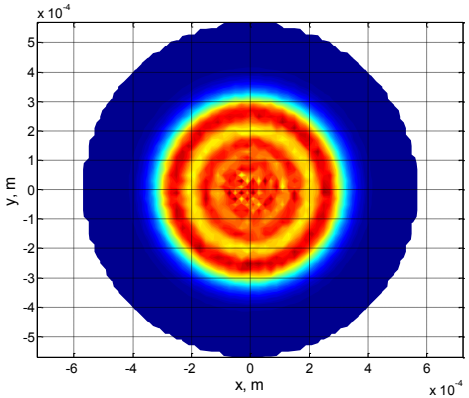
Xrms=0.179mm
Yrms=0.194mm

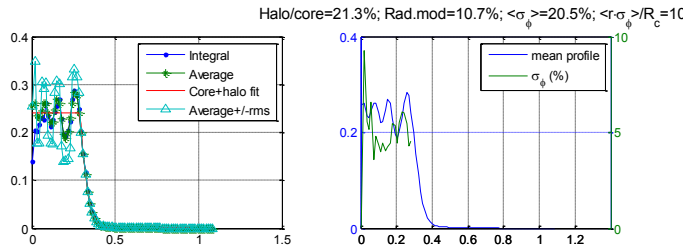
XYrms=0.186mm





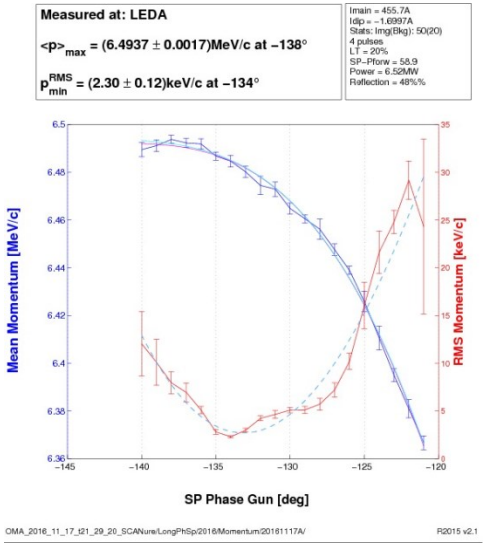
Used in ASTRA simulations
XYrms=0.186mm
Trms=4.88ps
(11.5ps FWHM)



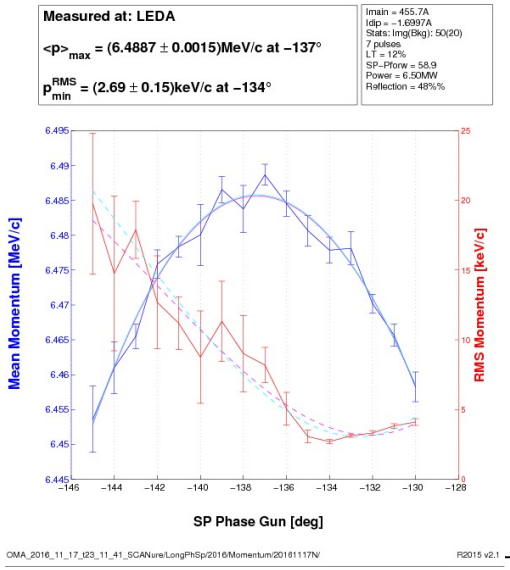


Measurements with long Gaussian on 17.11.2016A-N: Pz-gun

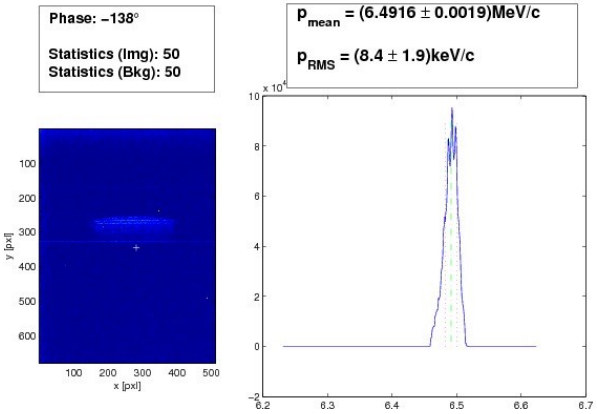
- LEDA scan (17.11.2016 21:29)



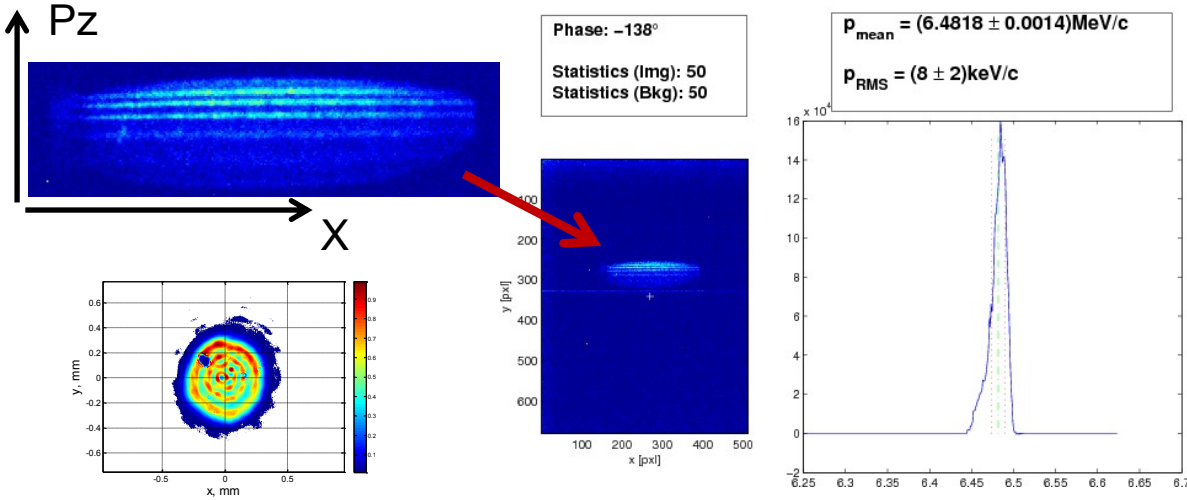
- LEDA scan (17.11.2016 23:11)



- LEDA projection at MMMG phase, -138 deg (17.11.2016 21:30)

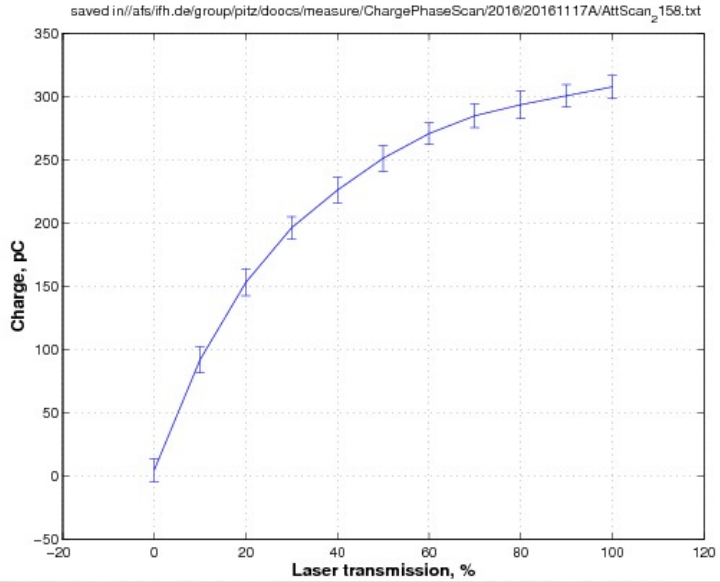


- LEDA projection at MMMG phase, -138 deg (17.11.2016 23:30)

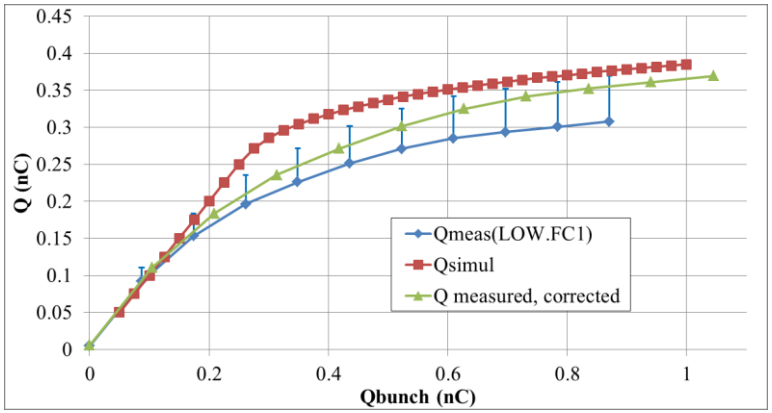


Measurements with long Gaussian on 17.11.2016A-N: Q

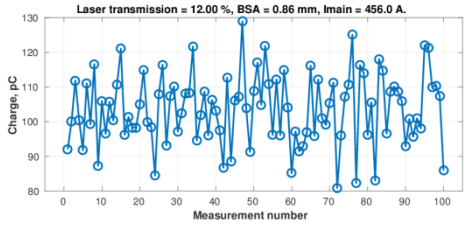
- Attenuator scan @Low.FC1, 6.5 MW gun power, BSA 0.75 mm (17.11.2016 22:00)

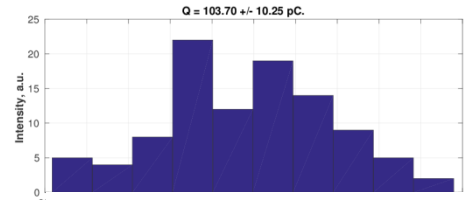


Charge measurement using Low.FC1; calibration corrected by 1/1.

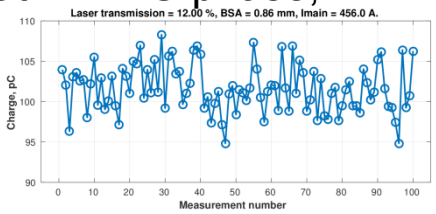


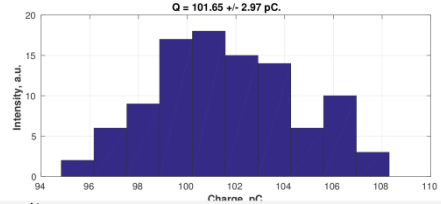
- Charge (LOW.FC1) at MMMG phase, (17.11.2016 22:04)





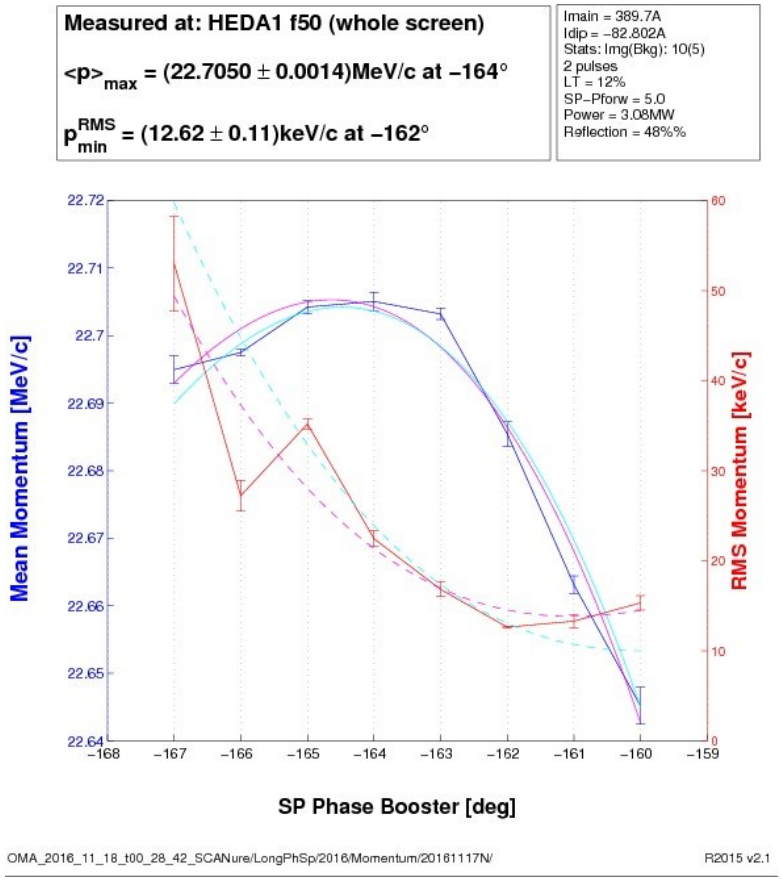
- Charge (LOW.FC1) at MMMG phase, (17.11.2016 23:42)



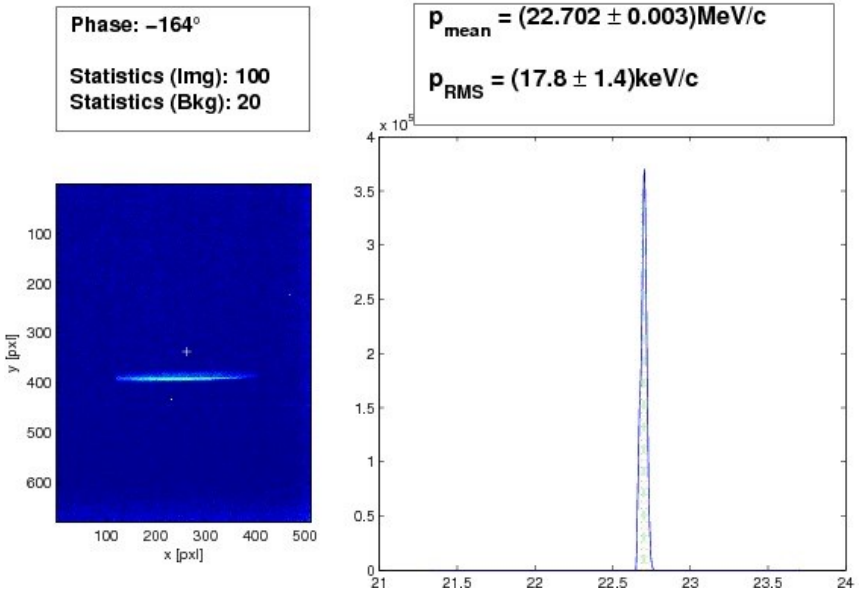


Measurements with long Gaussian on 17.11.2016A-N: Pz-final

- HEDA1 scan (18.11.2016 00:28)



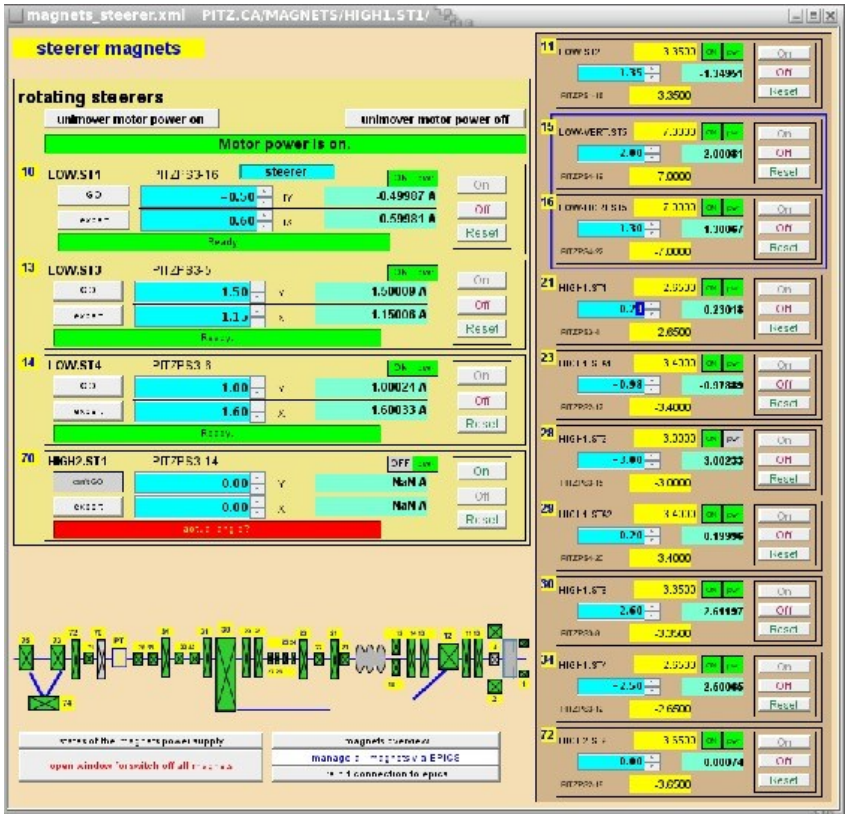
- LEDA projection at MMMG phase, -138 deg (18.11.2016 00:31)



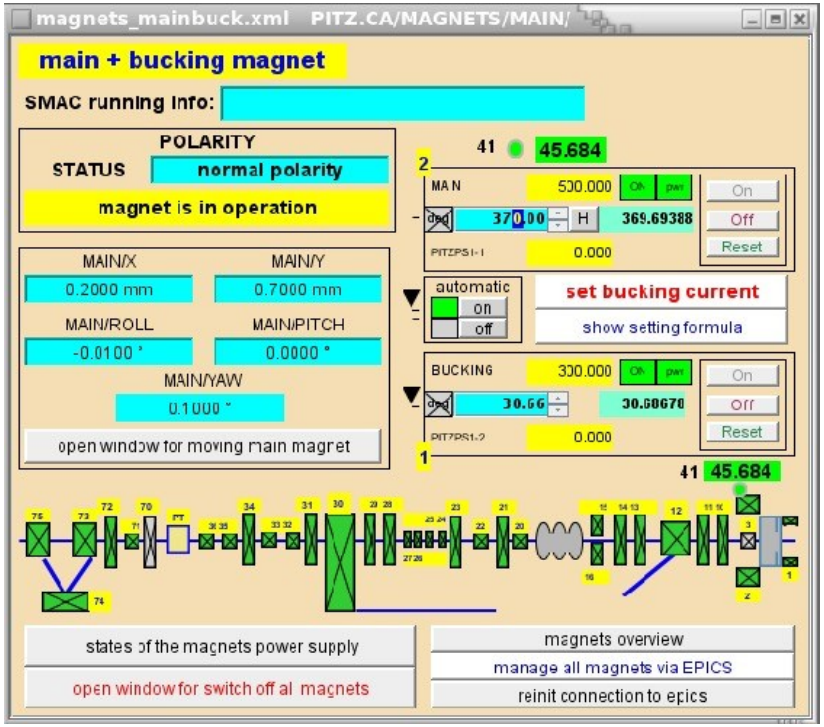
NB: HEDA1 problems are due to a temperature problem

Measurements with long Gaussian on 17.11.2016N: Transport to PST.Scr1

- restored steering from 31.10.2016 (18.11.2016 00:37)

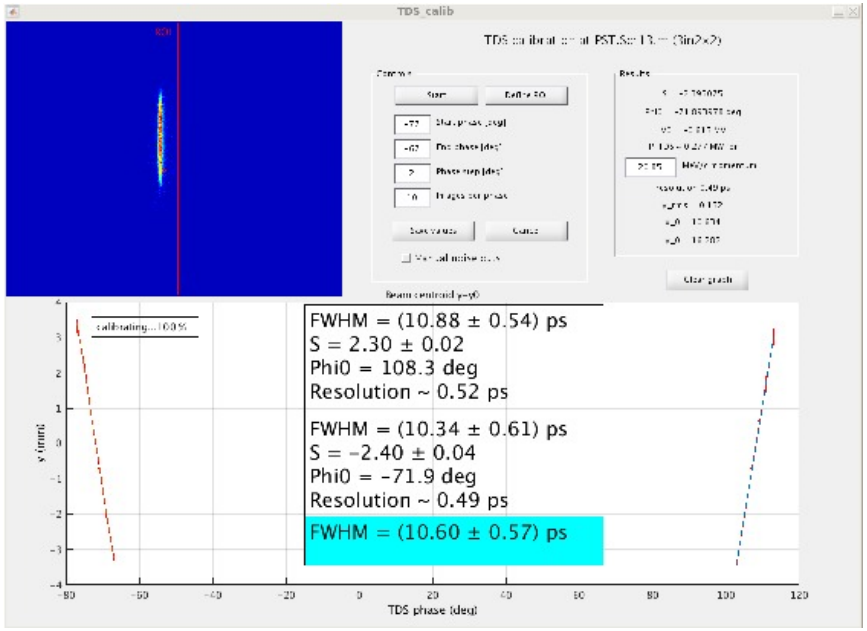


- Imain=370A, Ibuck=30.66A, compensated ➔ same as on 13.11.2016 (18.11.2016 00:44)

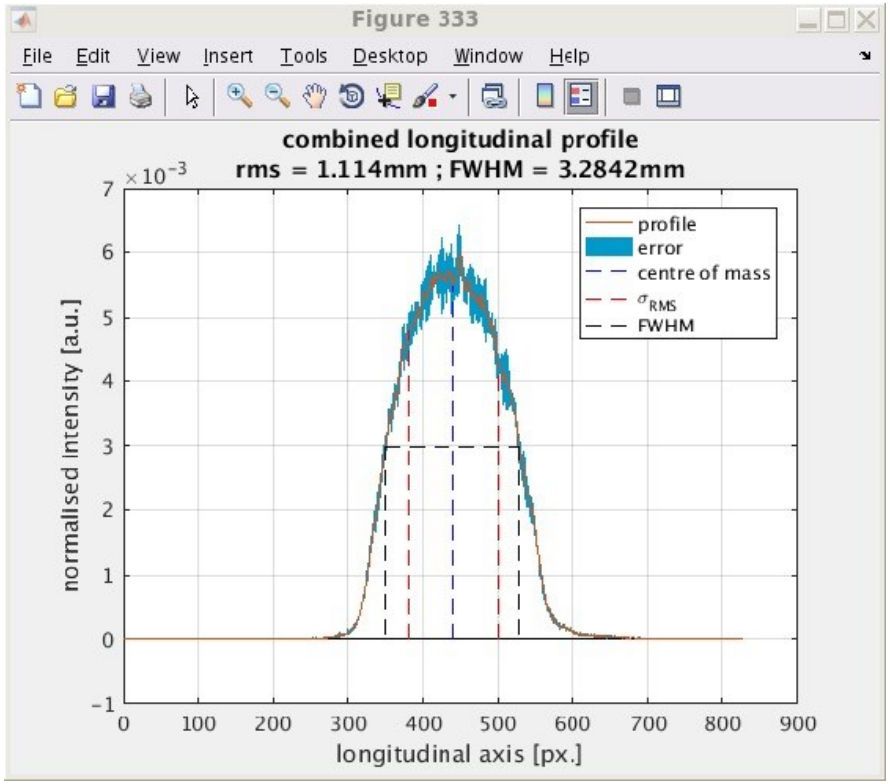


Measurements with long Gaussian on 17.11.2016N: TDS

- TDS calib,
  TDS SP=0.6MV, PST.Scr1 f200
  (18.11.2016 01:02)

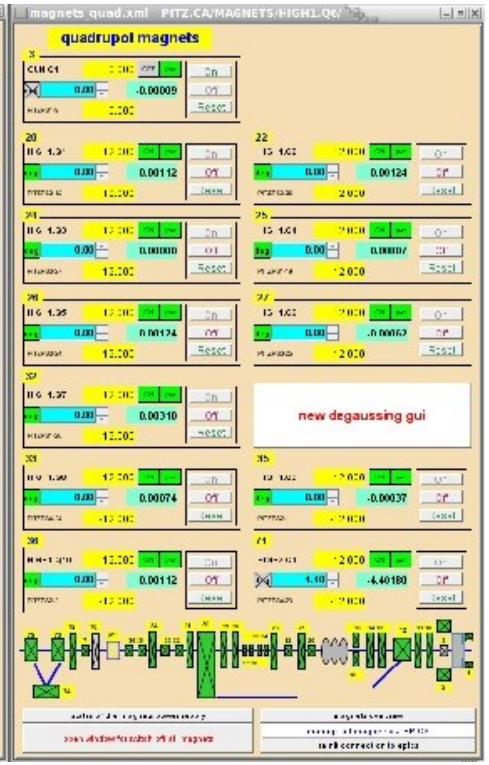


- longitudinal profile
  (18.11.2016 01:02)

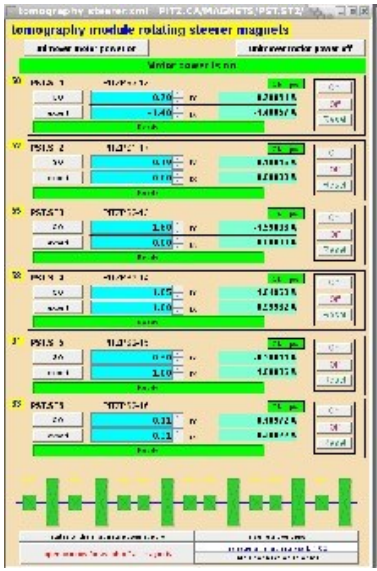


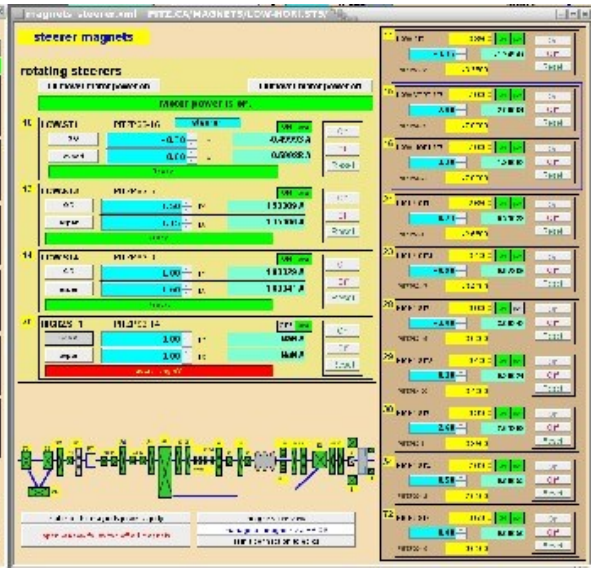
Measurements with long Gaussian on 17.11.2016N: transport to HEDA2

- Quad settings (18.11.2016 01:40)



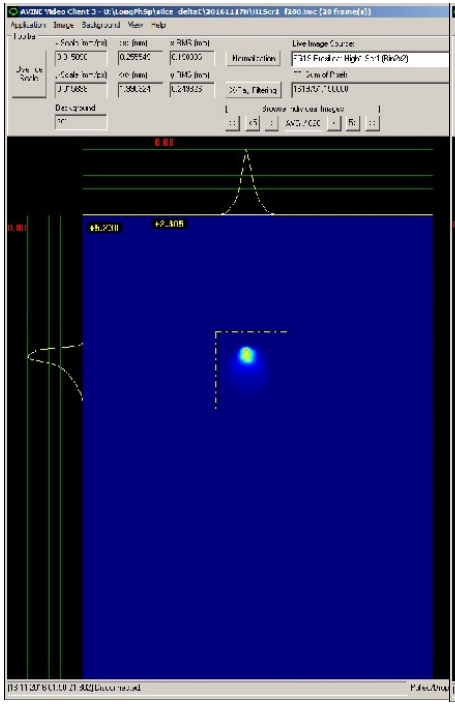
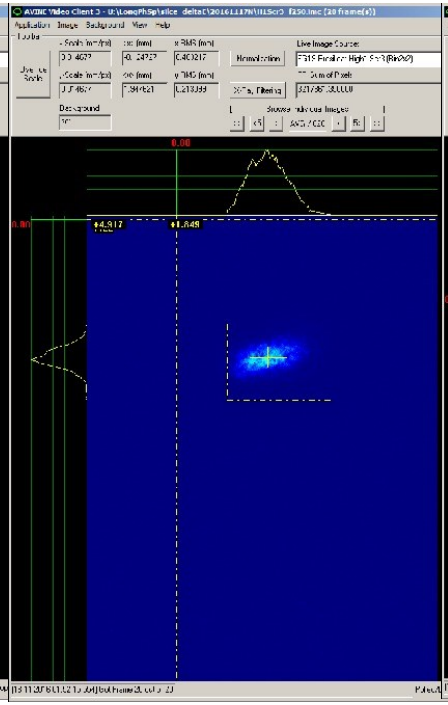
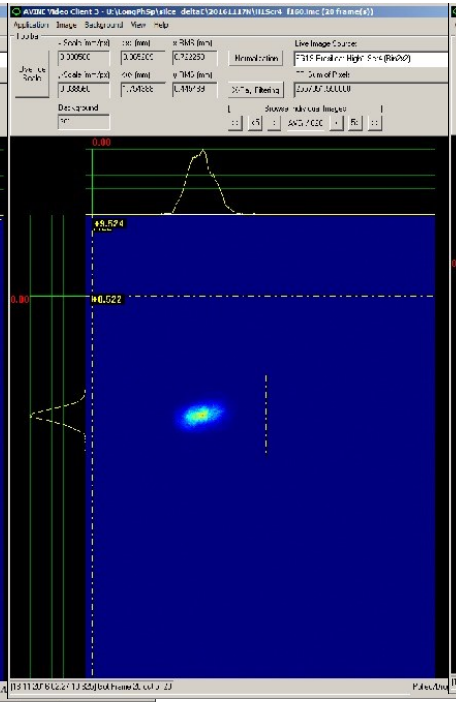
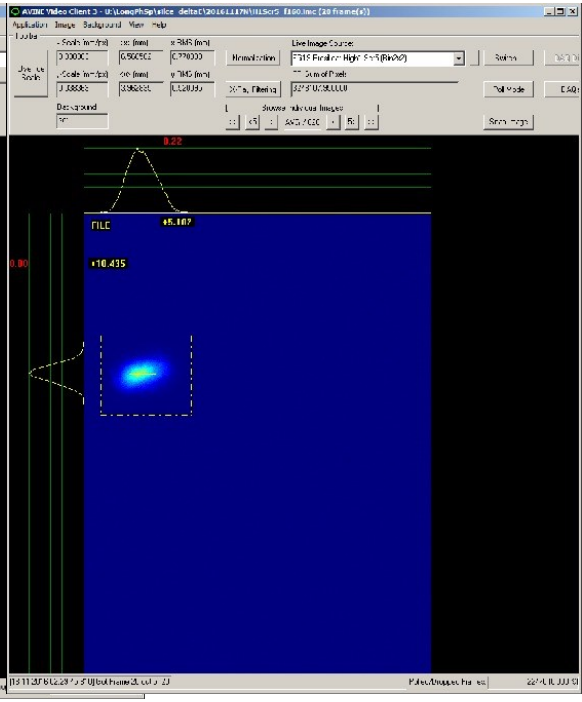
- Steerers (18.11.2016 01:45)





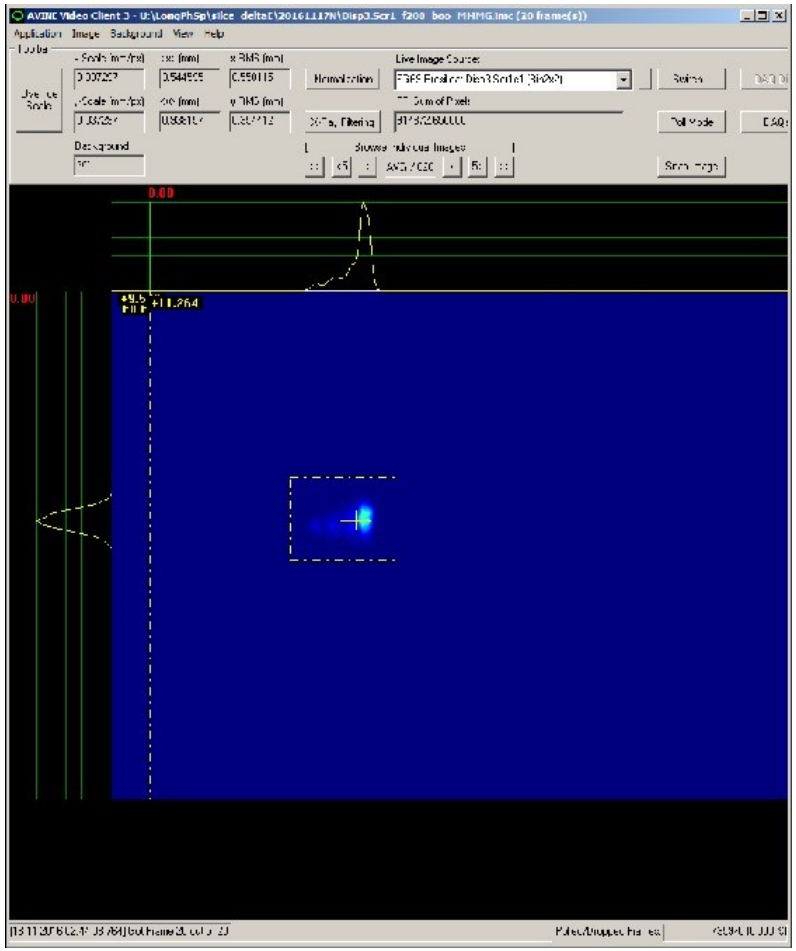
Measurements with long Gaussian on 17.11.2016N: Transport

- beam at H1.Scr1 f200
  z=5.277m
  1p12g
  (18.11.2016 01:40)
- beam at H1.Scr3 f250
  z=7.125m
  1p22g
  (18.11.2016 01:52
- beam at H1.Scr4 f160
  z=8.410m
  1p22g
  (18.11.2016 02:27
- beam at H1.Scr5 f160
  z=8.920m
  1p24g
  (18.11.2016 02:30

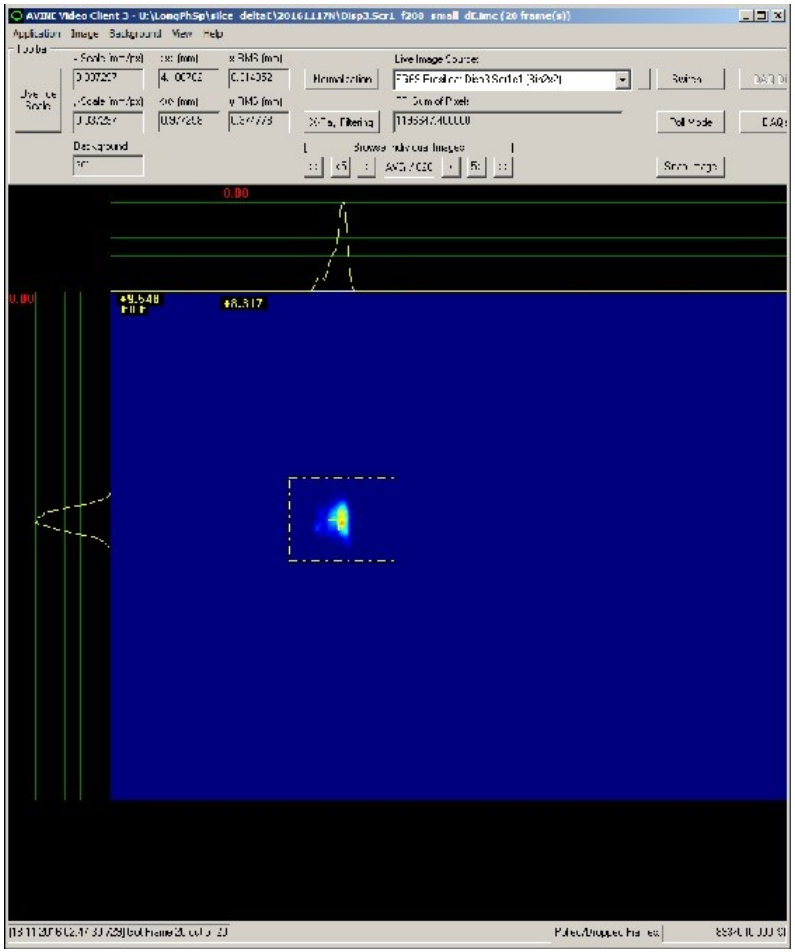





Measurements with long Gaussian on 17.11.2016N: HEDA2

- beam at Disp3.Scr1 f200, booster at MMMG phase 1p4g
  (18.11.2016 02:44)

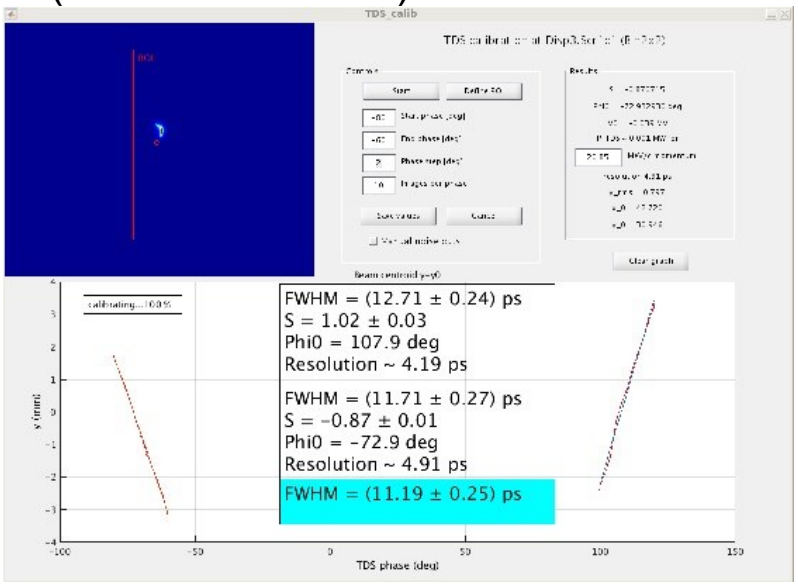


- beam at Disp3.Scr1 f200, booster at smalest dE phase = -162.4 deg
  (18.11.2016 02:48)

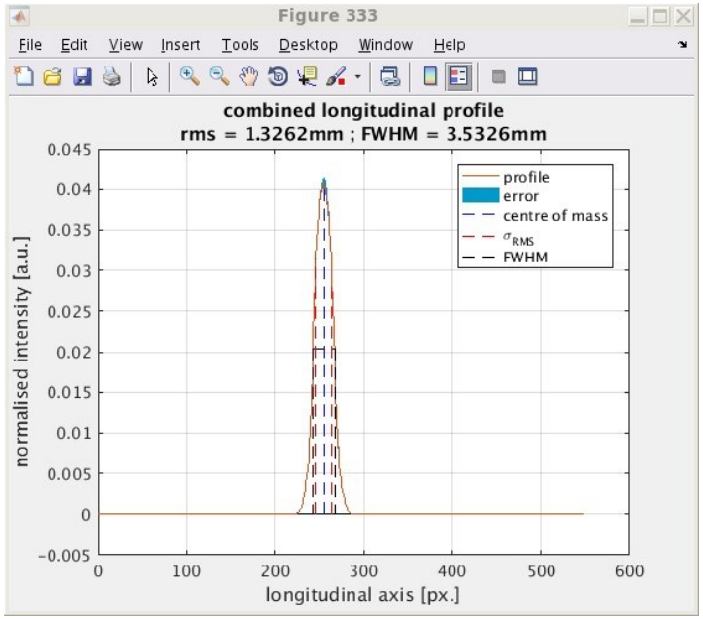


Measurements with long Gaussian on 17.11.2016N: TDS+HEDA2

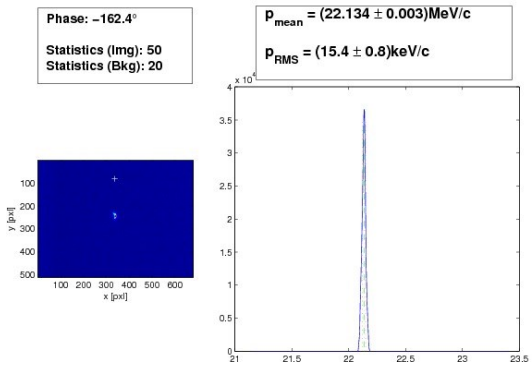
- TDS calib,
  TDS SP=**0.05MV**,
  (18.11.2016 03:58)

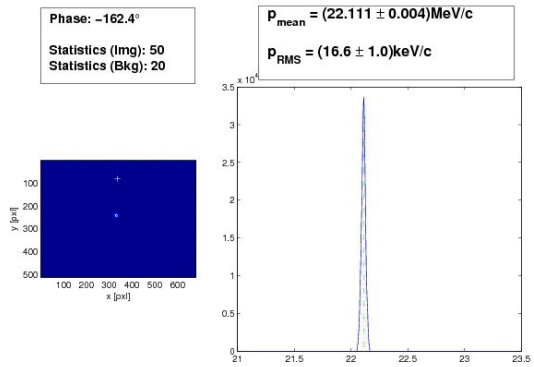


- longitudinal profile
  (18.11.2016 03:58)



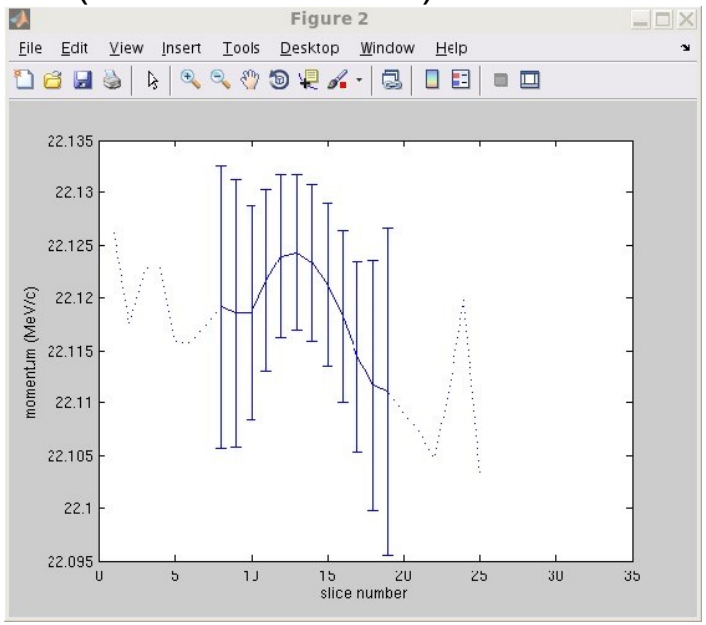
- Pz-distributions
  w/ TDS (18.11.2016 04:00) w/o TDS (18.11.2016 04:00)

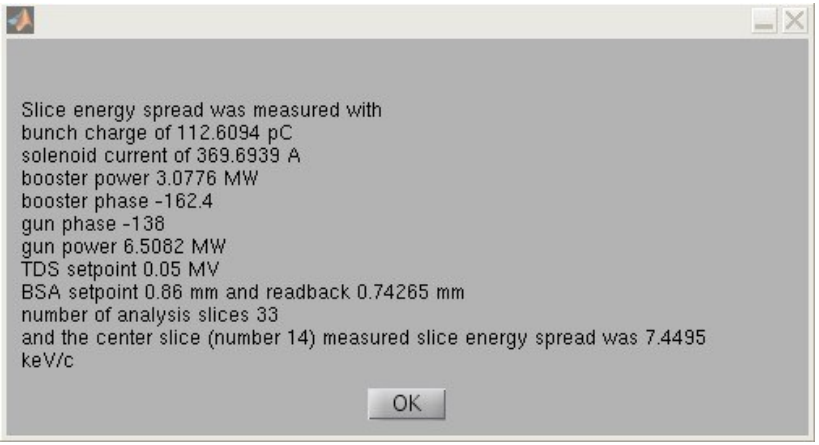




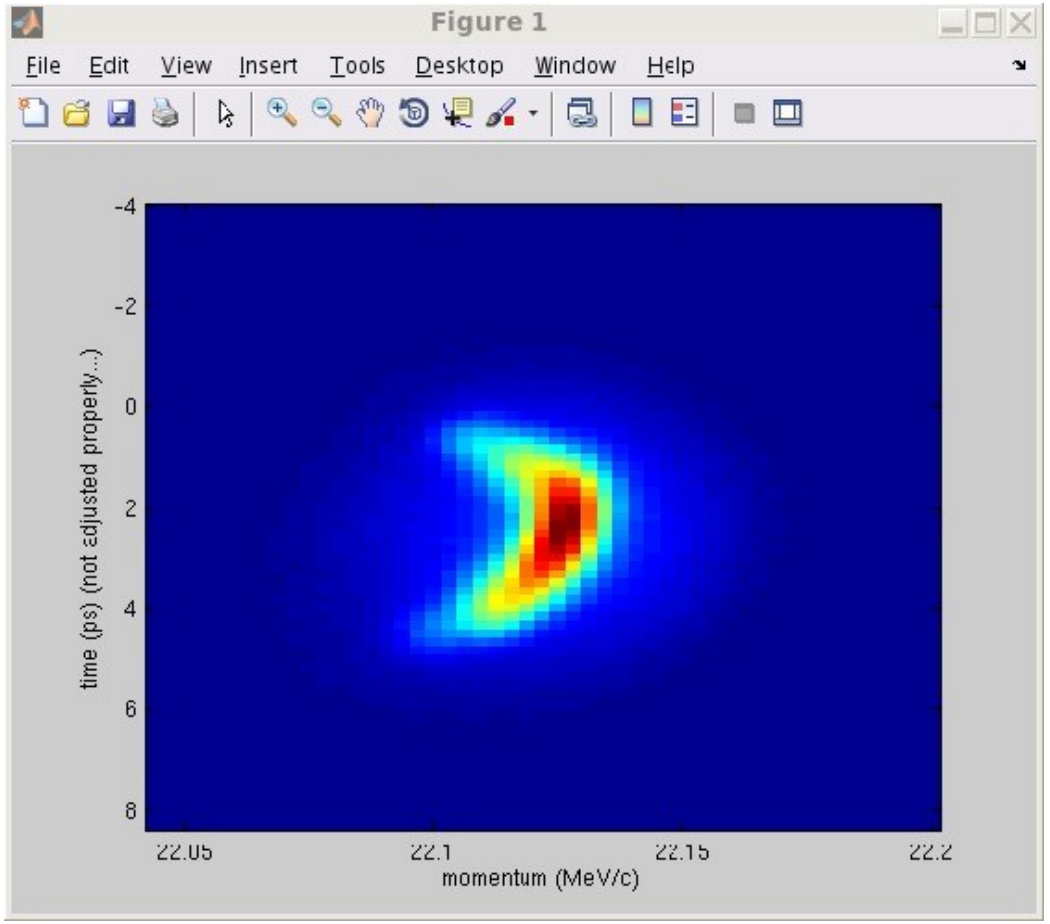
Measurements with long Gaussian on 17.11.2016N: TDS+HEDA2

- LPS, TDS SP=**0.05MV**, (18.11.2016 04:04)





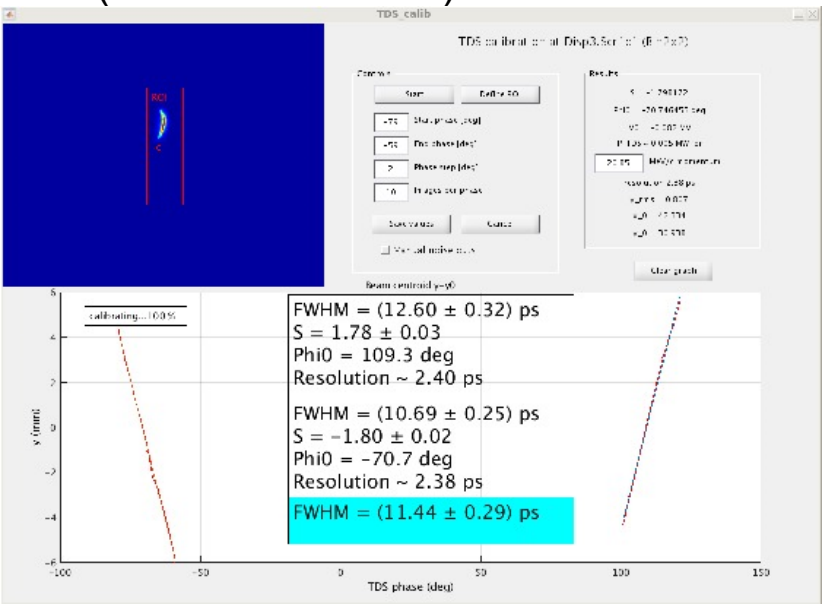
- LPS (18.11.2016 04:04)



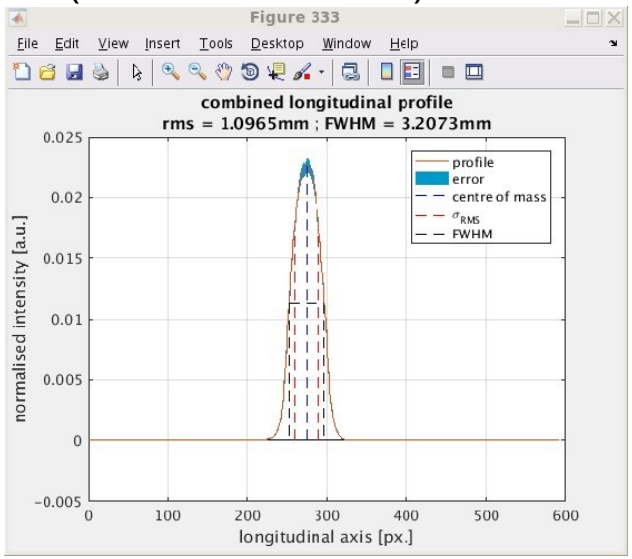
file /doocs/measure/LongPhSp/2016/deltaE/shortG/2016/20161117N/sliceEspread_0403.mat

Measurements with long Gaussian on 17.11.2016N: TDS+HEDA2

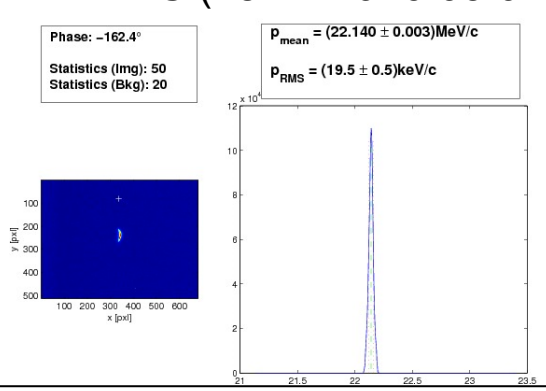
- TDS calib,
  TDS SP=**0.1MV**,
  (18.11.2016 03:01)

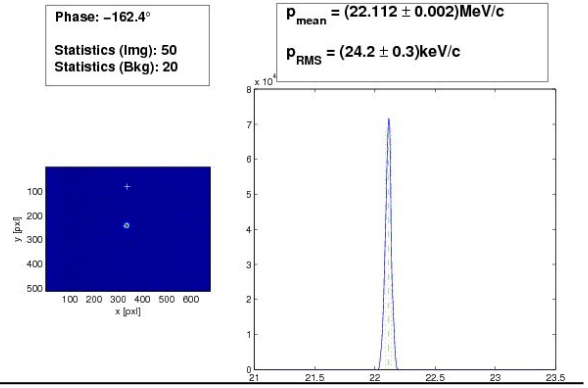


- longitudinal profile
  (18.11.2016 03:01)



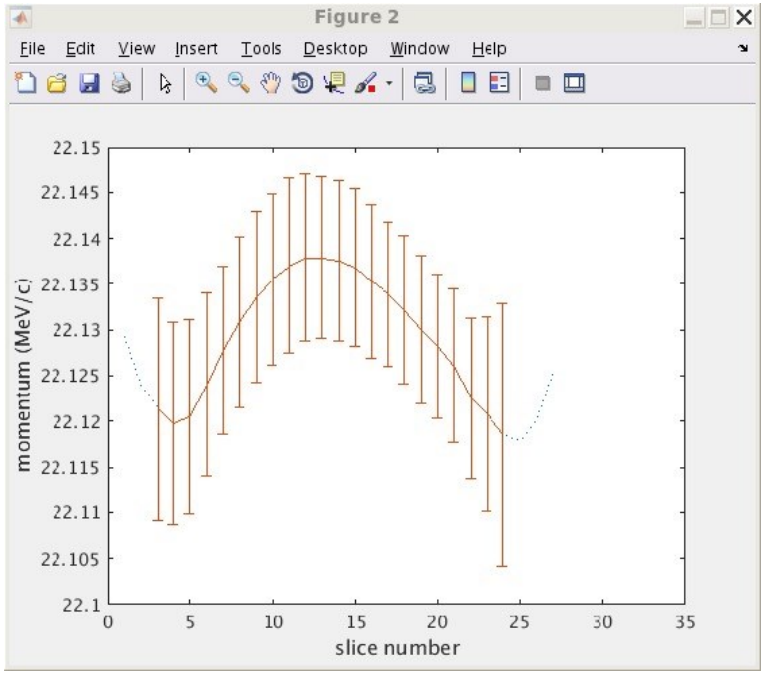
- Pz-distributions
  w/ TDS (18.11.2016 03:07) w/o TDS (18.11.2016 03:08)

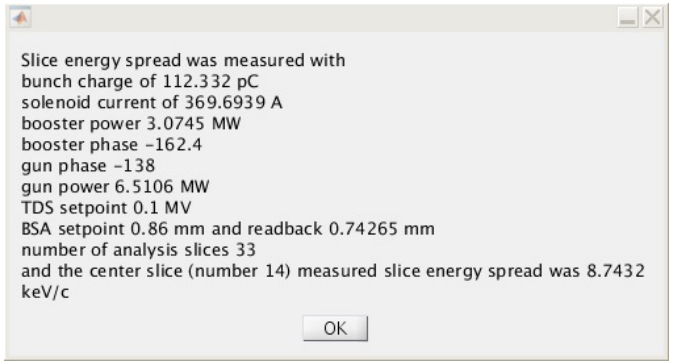




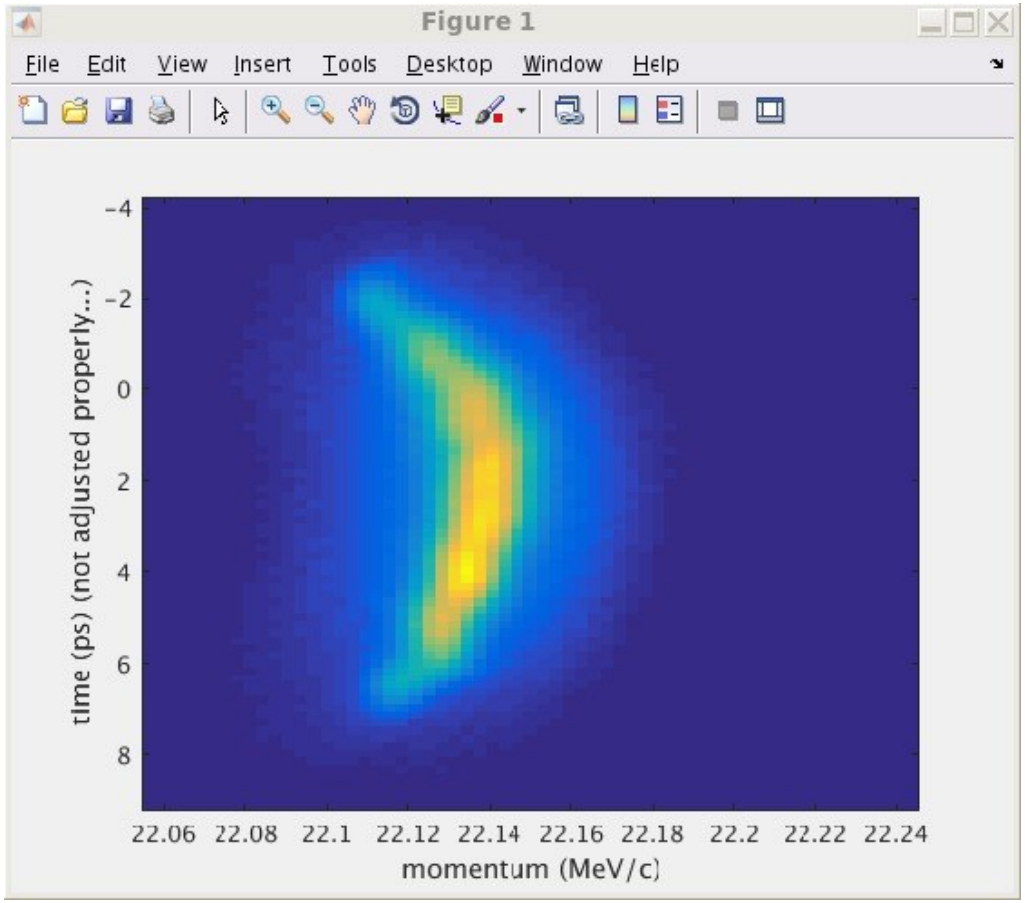
Measurements with long Gaussian on 17.11.2016N: TDS+HEDA2

- LPS, TDS SP=**0.1MV**, (18.11.2016 03:13)





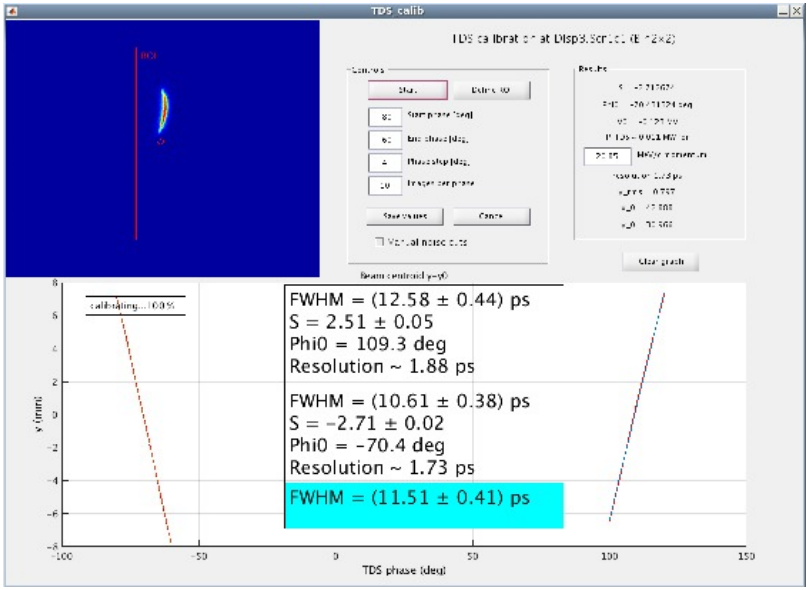
- LPS (18.11.2016 03:13)



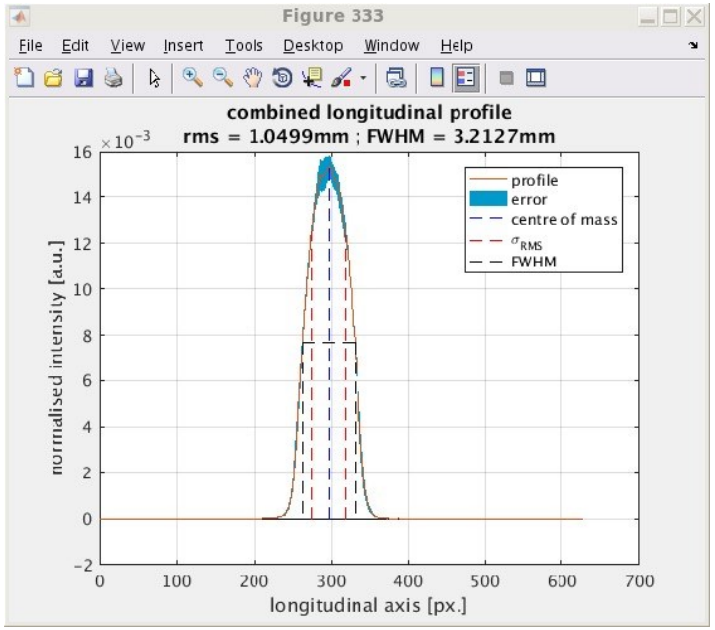
file
/doocs/measure/LongPhSp/2016/deltaE/shortG/2016/20161117N/sliceEspread_0310_MMS.mat

Measurements with long Gaussian on 17.11.2016N: TDS+HEDA2

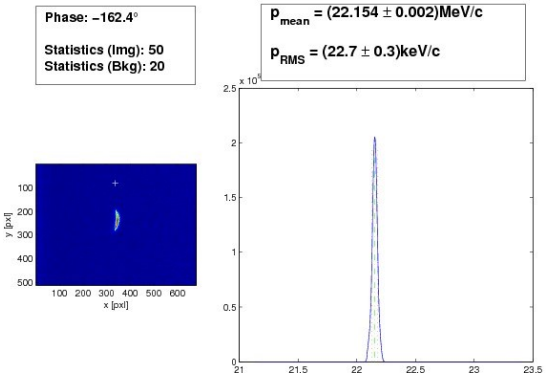
- TDS calib,
  TDS SP=**0.15MV**,
  (18.11.2016 03:25)



- longitudinal profile
  (18.11.2016 03:25)

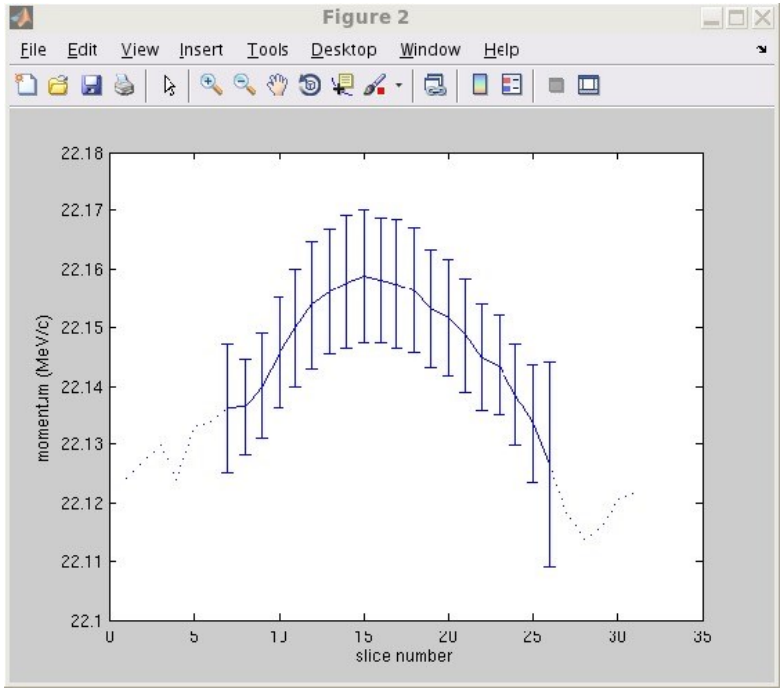


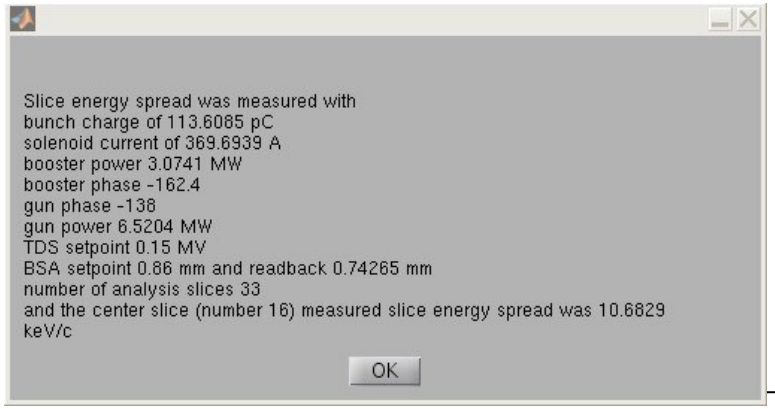
- Pz-distributions
  w/ TDS (18.11.2016 03:27) w/o TDS (18.11.2016 03:28)



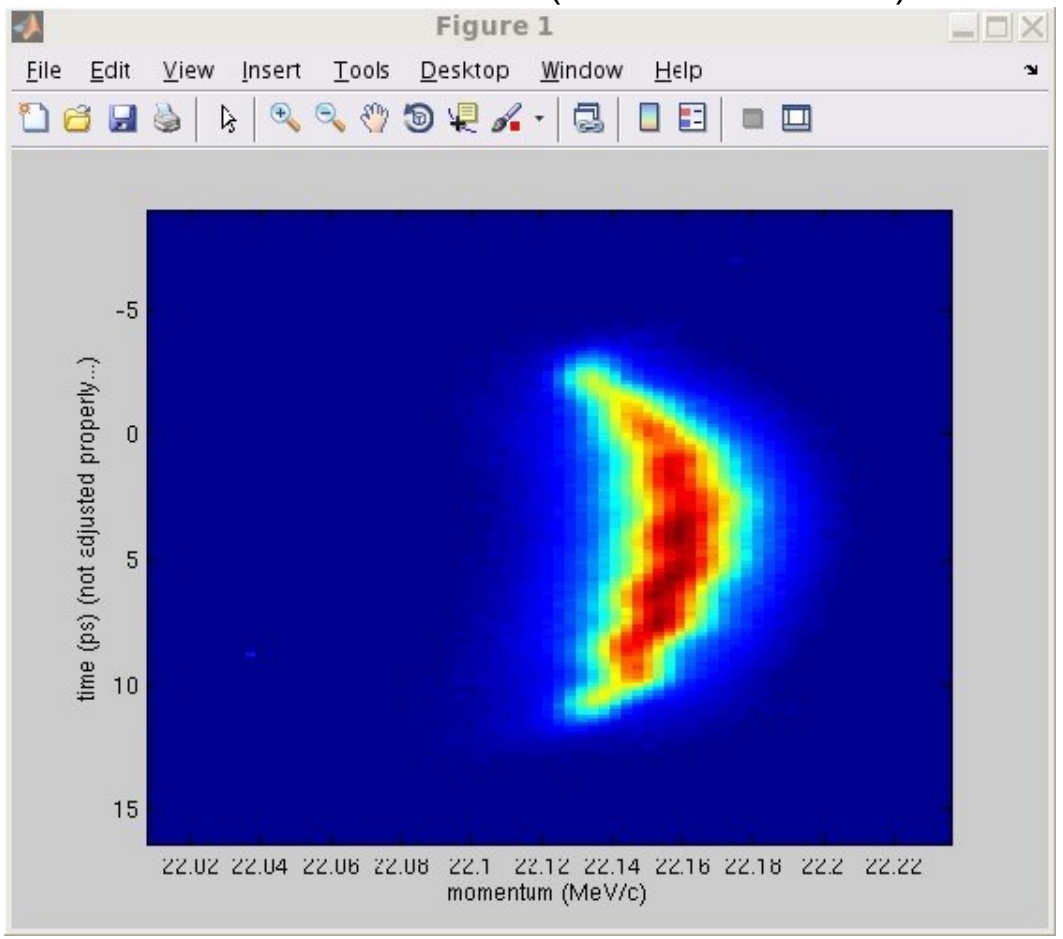
Measurements with long Gaussian on 17.11.2016N: TDS+HEDA2

- LPS, TDS SP=**0.15MV**, (18.11.2016 03:32)





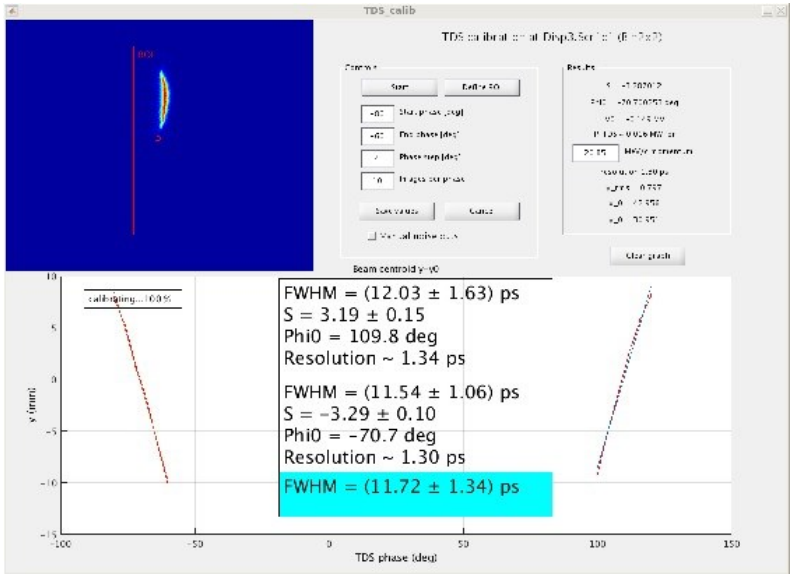
- LPS (18.11.2016 03:32)



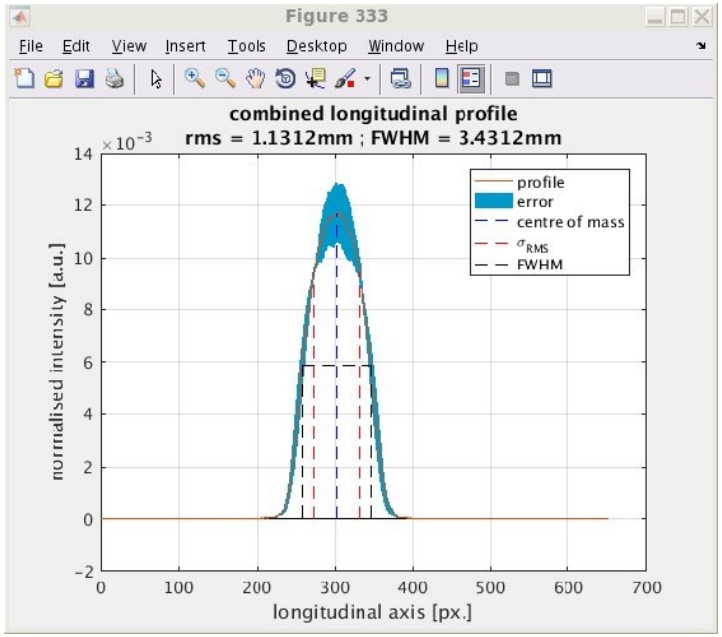
file /doocs/measure/LongPhSp/2016/deltaE/shortG/2016/20161117N/sliceEspread_0328.mat

Measurements with long Gaussian on 17.11.2016N: TDS+HEDA2

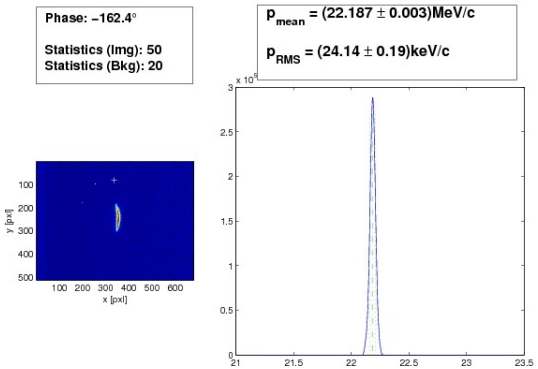
- TDS calib,
  TDS SP=**0.20MV**,
  (18.11.2016 03:35)

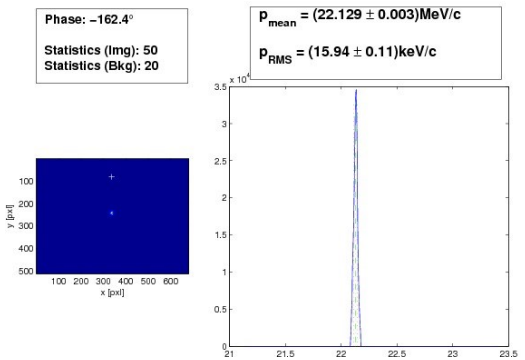


- longitudinal profile
  (18.11.2016 03:35)



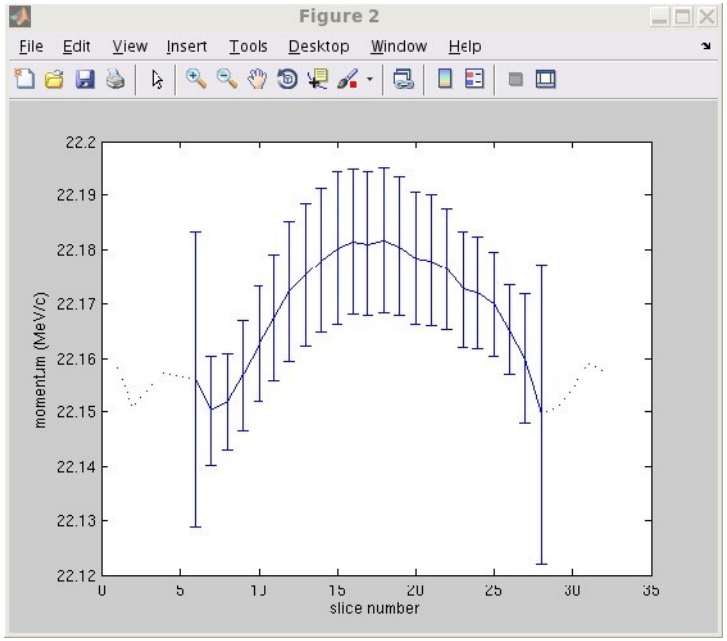
- Pz-distributions
  w/ TDS (18.11.2016 03:37) w/o TDS (18.11.2016 03:38)

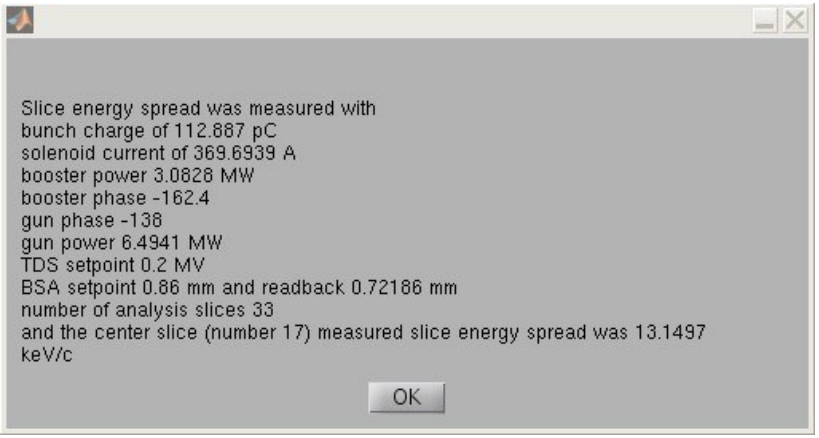




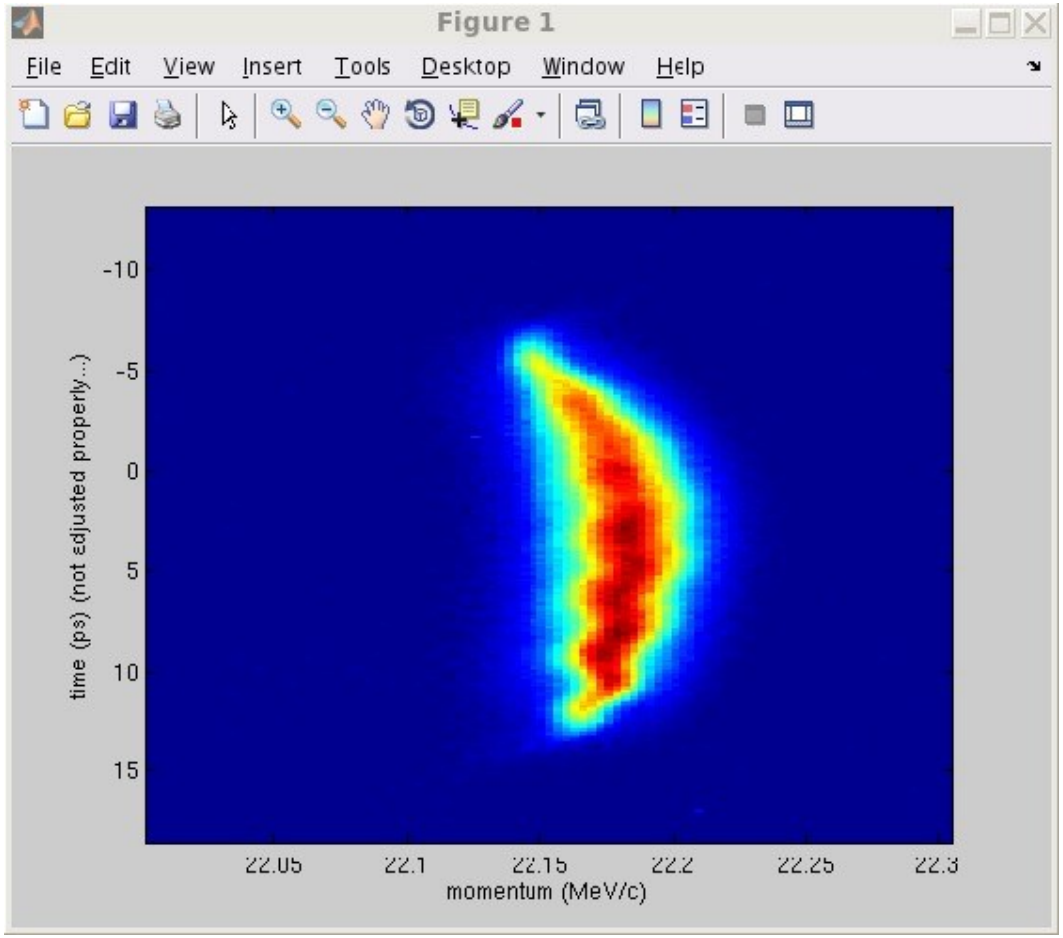
Measurements with long Gaussian on 17.11.2016N: TDS+HEDA2

- LPS, TDS SP=**0.20MV**, (18.11.2016 03:39)



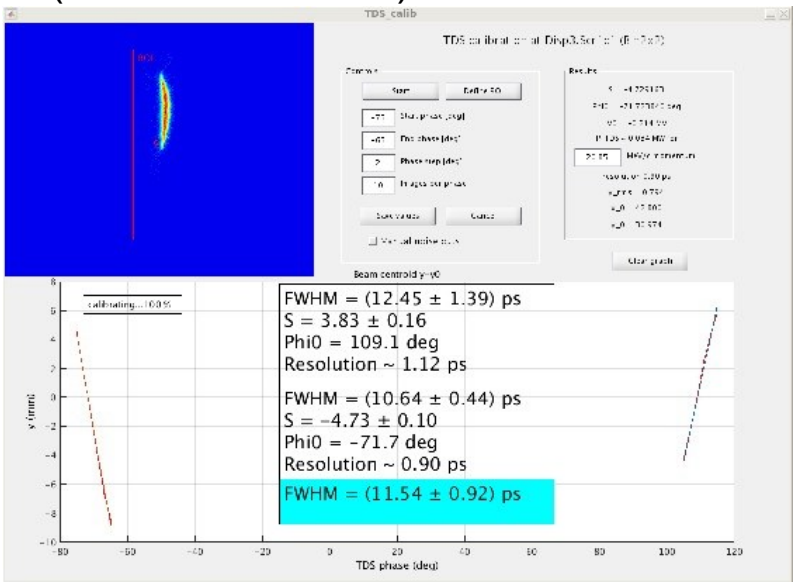


- LPS (18.11.2016 03:32)

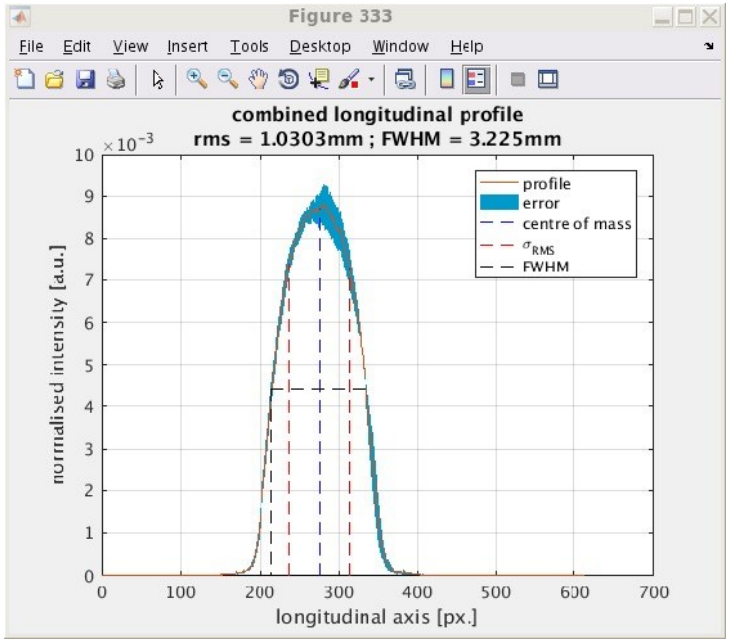


Measurements with long Gaussian on 17.11.2016N: TDS+HEDA2

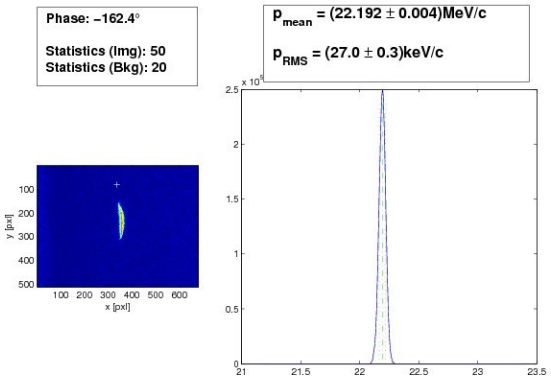
- TDS calib,
  TDS SP=**0.25MV**,
  (18.11.2016 03:48)



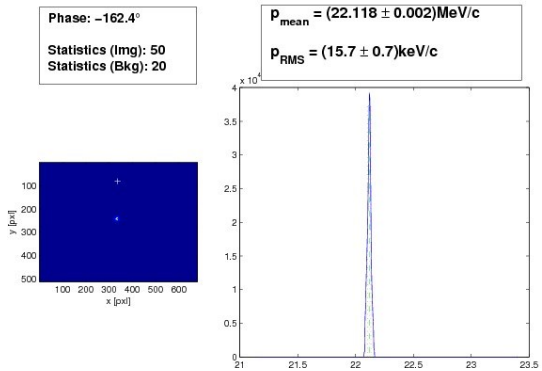
- longitudinal profile
  (18.11.2016 03:48)



- Pz-distributions
  w/ TDS (18.11.2016 03:49)

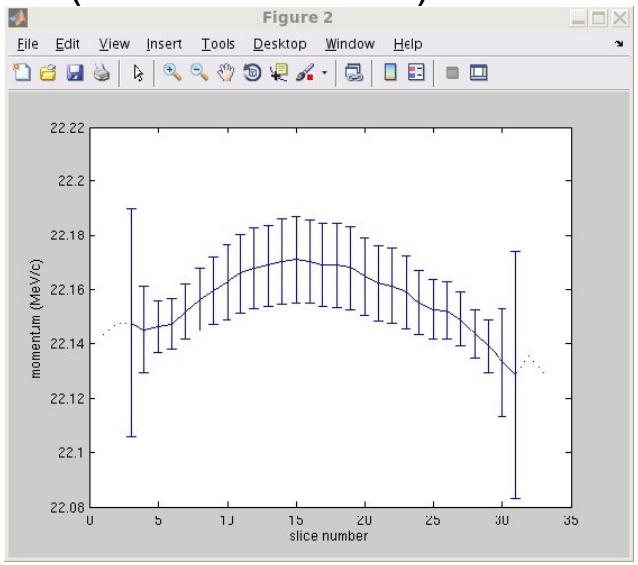


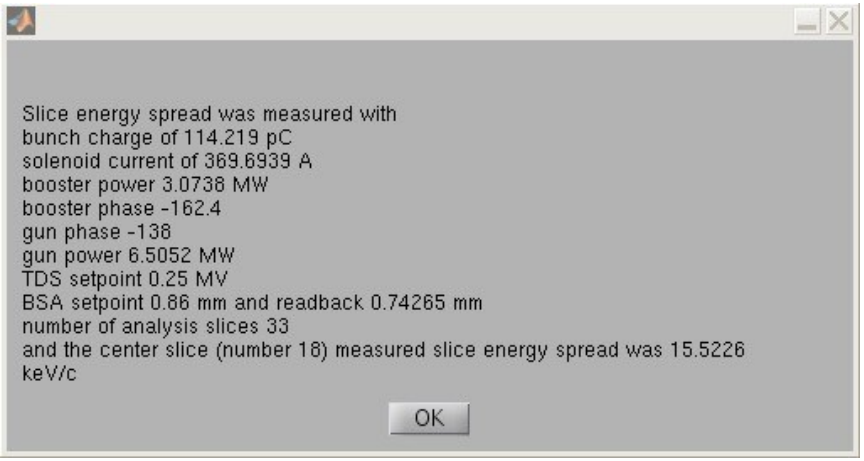
w/o TDS (18.11.2016 03:50)



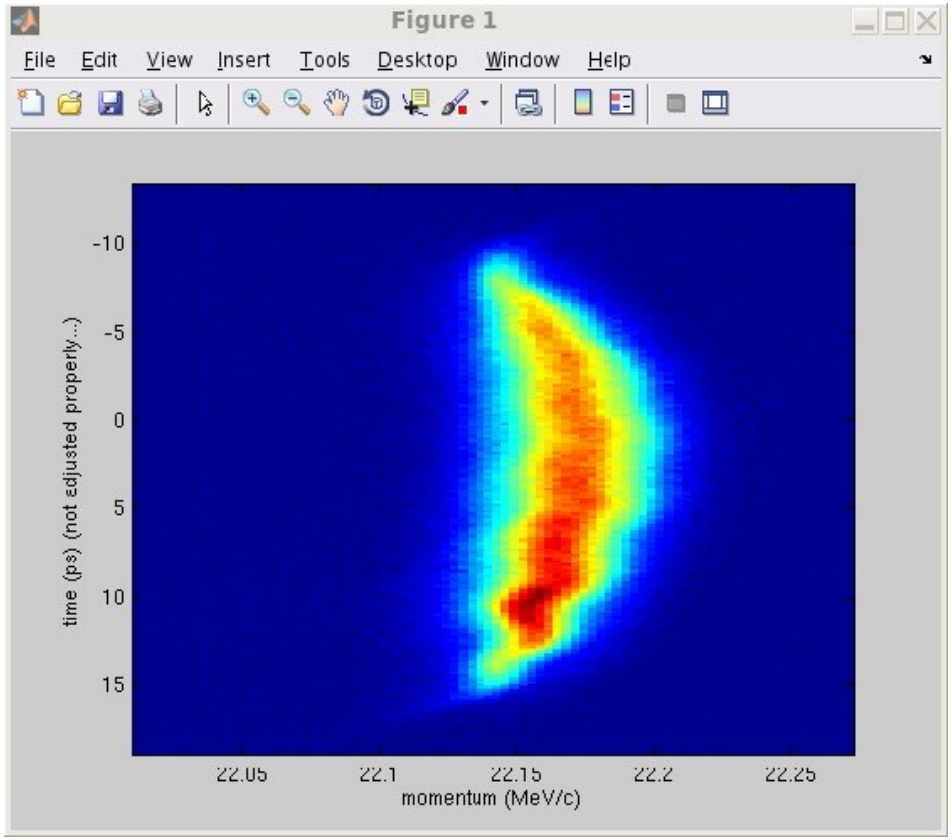
Measurements with long Gaussian on 17.11.2016N: TDS+HEDA2

- LPS, TDS SP=**0.25MV**, (18.11.2016 03:52)





- LPS (18.11.2016 03:52)



file /doocs/measure/LongPhSp/2016/deltaE/shortG/2016/20161117N/sliceEspread_0351.mat

TDS SP scan

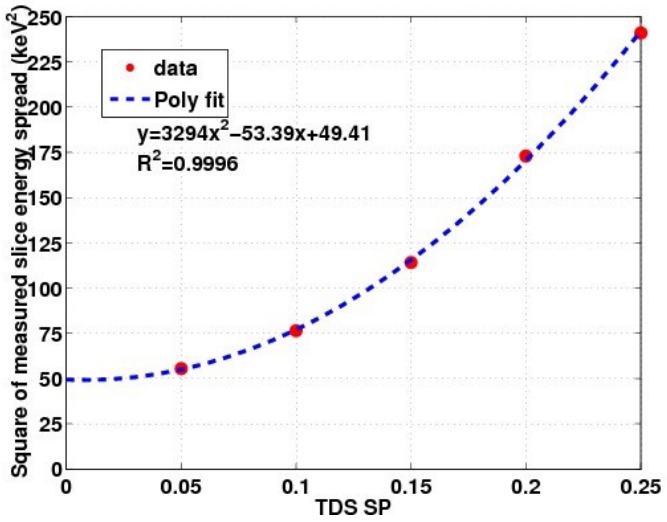

data
Poly fit
y=3294x^2−53.39x+49.41
R^2=0.9996
Square of measured slice energy spread (keV^2)
TDS SP

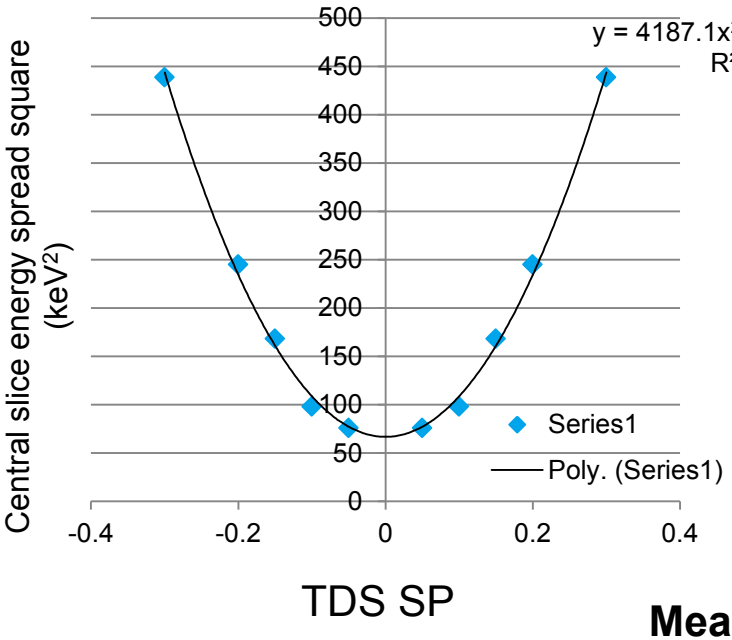
Figure 1
File Edit View Insert Tools Desktop Window Help
time (ps) (not adjusted properly...)
momentum (MeV/c)

Slice energy spread with long Gaussian laser

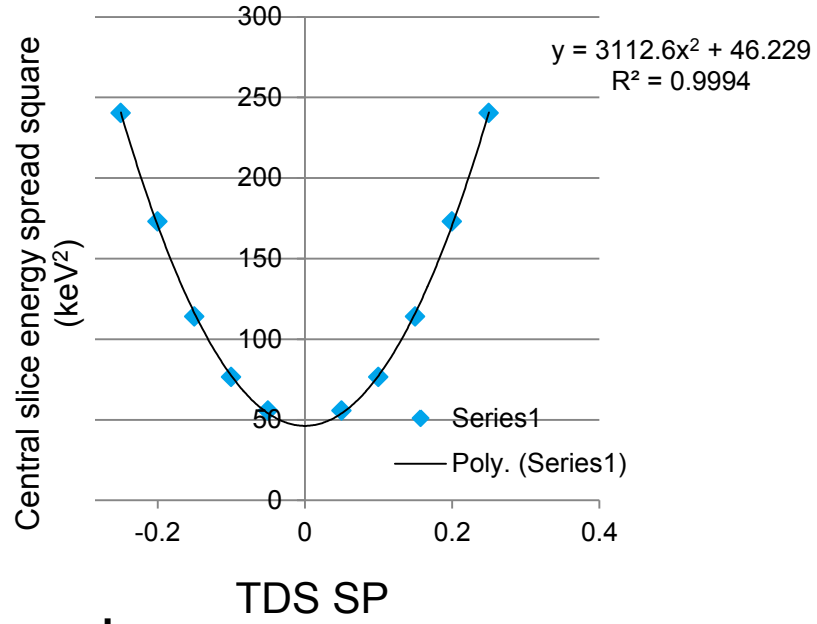
- Slice energy spread measurement
  - Real slice energy spread
  - TDS contribution
  - Beta function contribution

$$\delta_E^{measured} \approx \sqrt{\left(\delta_E^{real}\right)^2 + \left(\delta_E^{\beta}\right)^2 + \left(\delta_E^{TDS}\right)^2}$$

8.2 keV for TDS zero (Short Gaussian)



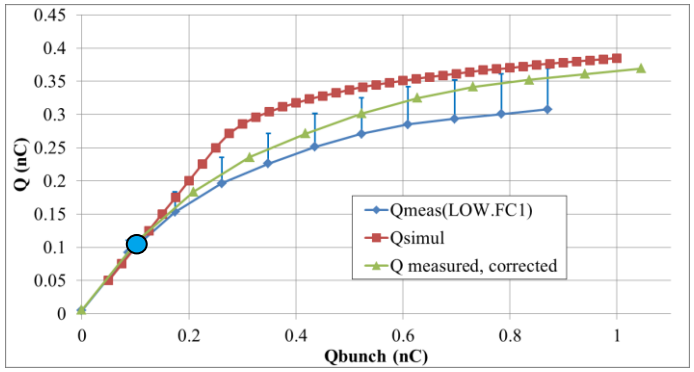
6.8 keV for TDS zero (Long Gaussian)

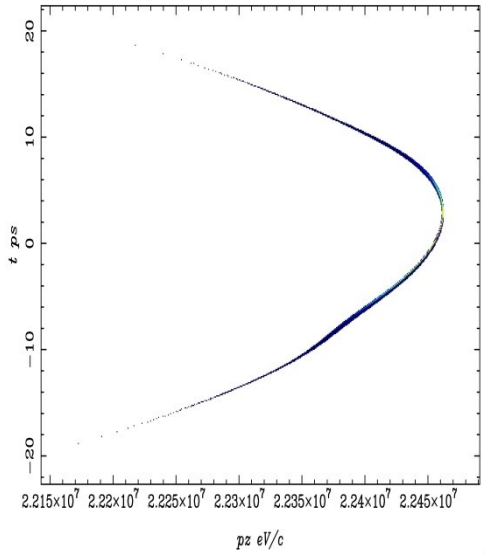


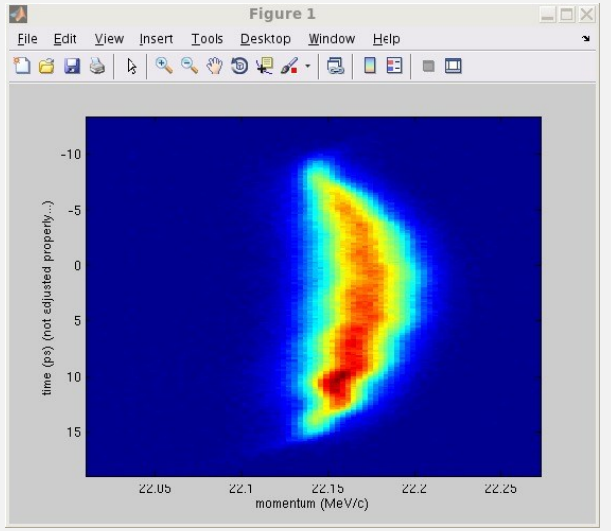
Measurement example
20161113N ←→ 20161117N
100 pC, 0.75 mm

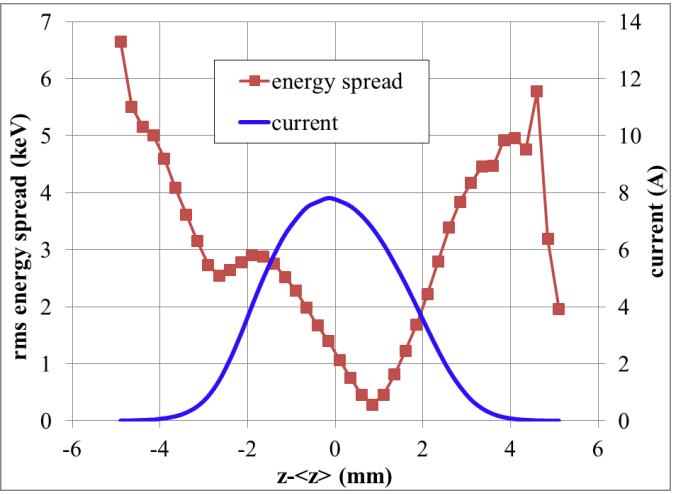
+ASTRA simulations

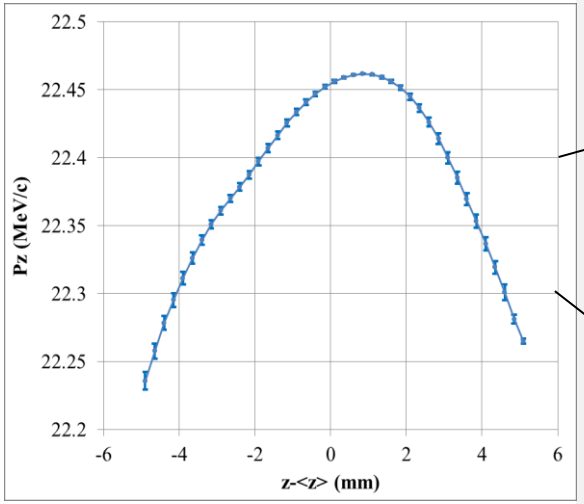
Measurements SP(TDS)=0.25

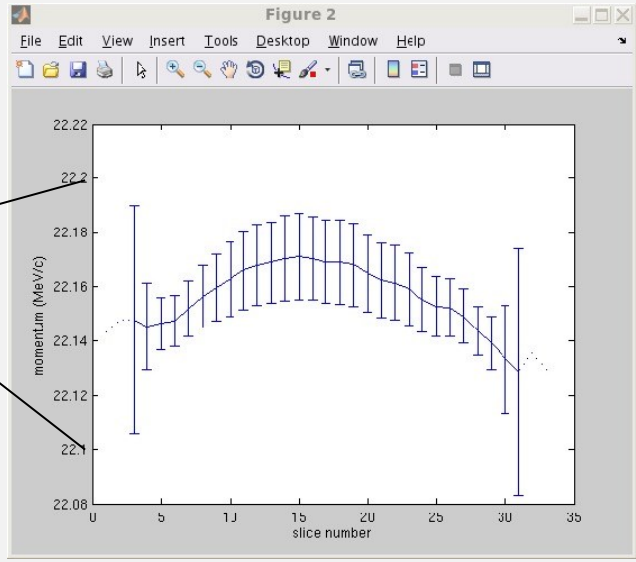












Conclusions (preliminary)

- Original measurements program with long Gaussian cathode laser pulses (0.4nC x BSA=1.1-2.2mm) was not realized due to the short time
- But measurements with 100pC and BSA=0.75mm (eff) was done (for more consistency to measurements with short Gaussian pulses)
- Still resolution on the slice energy spread seems to be the main limiting factor:
  - Beam transverse size in the HEDA2 dipole (beat function)
  - TDS induced energy spread (estimated $\frac{d(\delta E)}{dSP(TDS)} \sim 3\frac{eV}{MV}$)
- Measured longitudinal phase space (LPS) shows modulation even with long Gaussian cathode laser pulses:
  - MBI (also in LEDA)?
  - Space charge effect while transport, e.g. quad (over)focusing?
  - Measurement artifact??
- …

Short Gaussian pulses measurement program

δE - measurements program

1. Ecath=60MV/m (?additionally 45MV/m as an option)
2. Gun phase: MMMG
3. Laser temporal profile: short Gaussian of ~2 ps FWHM
4. Bunch charge: 0.2 nC and 0.1 nC
5. BSA=BSA0 (interpolated optimum for each bunch charge – based on the 2015 results) and 2*BSA0 (? relaxed transverse space charge by a factor of 4). Please check the rms spot size at VC2: XYrms~BSA/4:

Meas \ charge→	**0.2 nC**	**0.1 nC**
Laser temporal	**Short Gauss**	
A	**0.85 mm**	**0.75 mm**
B	**1.7 mm**	**1.5 mm**

   e.g., for measurement "0.1-A" → BSA=0.75mm, for "0.2-B" – BSA=1.7 mm
6. CDS booster: 3MW, phase scan for LPS tomography. The CDS phase for TDS measurements: min projected energy spread at HEDA2(?)
7. Expected measurements (for each of 6 setups: 0.2-A … 0.1-B – to be saved in e.g. …\measure\LongPhSp\2016\deltaE\shortG\0.2-A\...):
   a. Laser transverse distribution at VC2 (20+20frames)
   b. Beam momentum scan in LEDA as a function of gun SP Phase → MMMG gun phase, <Pz>, PZrms
   c. Laser attenuator scan (LT-scan) for the MMMG phase with LOW.FC1 (if it is too noisy – use LOW.FC2, also LOW.ICT1/HIGH1.ICT1), adjust the LT for the goal charge, measure the bunch charge
   d. Beam momentum in HEDA1 as a function of the booster SP phase (very detailed – to be used for LPS reconstruction). Don't forget to adjust the e-beam at the reference screen HIGH1.Scr5 (centered and vertically focused). Booster phase MMMG (or min energy spread at HEDA1?).
   e. Setup the e-beam trajectory; e.g. from 31.10.2016 05:18 (PITZ logbook)
   f. E-beam size at HIGH1.Scr1 vs. main solenoid current (use fastscan3)
   g. Beam projected emittance measurements at EMSY1: main solenoid current: focus at HIGH1.Scr1 and +1% of this value (?, rounding the Imain) over the focus.
   h. Beam transport to the PST.Scr1, TDS measurements of the bunch temporal profile (Imain to be tuned as well? Or use one delivering the best emittance).
   i. Beam transport to HEDA2 (Imain to be tuned as well?), quad settings for the best HEDA resolution – save magnet settings and beam images at screens in the HIGH section. Check the TDS phase range at HIGH2.Scr1 – not to be cut by the beam line aperture.
   j. Beam momentum in HEDA2 as a function of the booster SP phase→ booster phase for the minimum projected momentum spread.
   k. LPS measurements at HEDA2 with applied TDS:
      i. TDS phase scan (calibration)
      ii. TDS at zero phase – momentum measurements with OMA
      iii. TDS off – momentum measurements with OMA