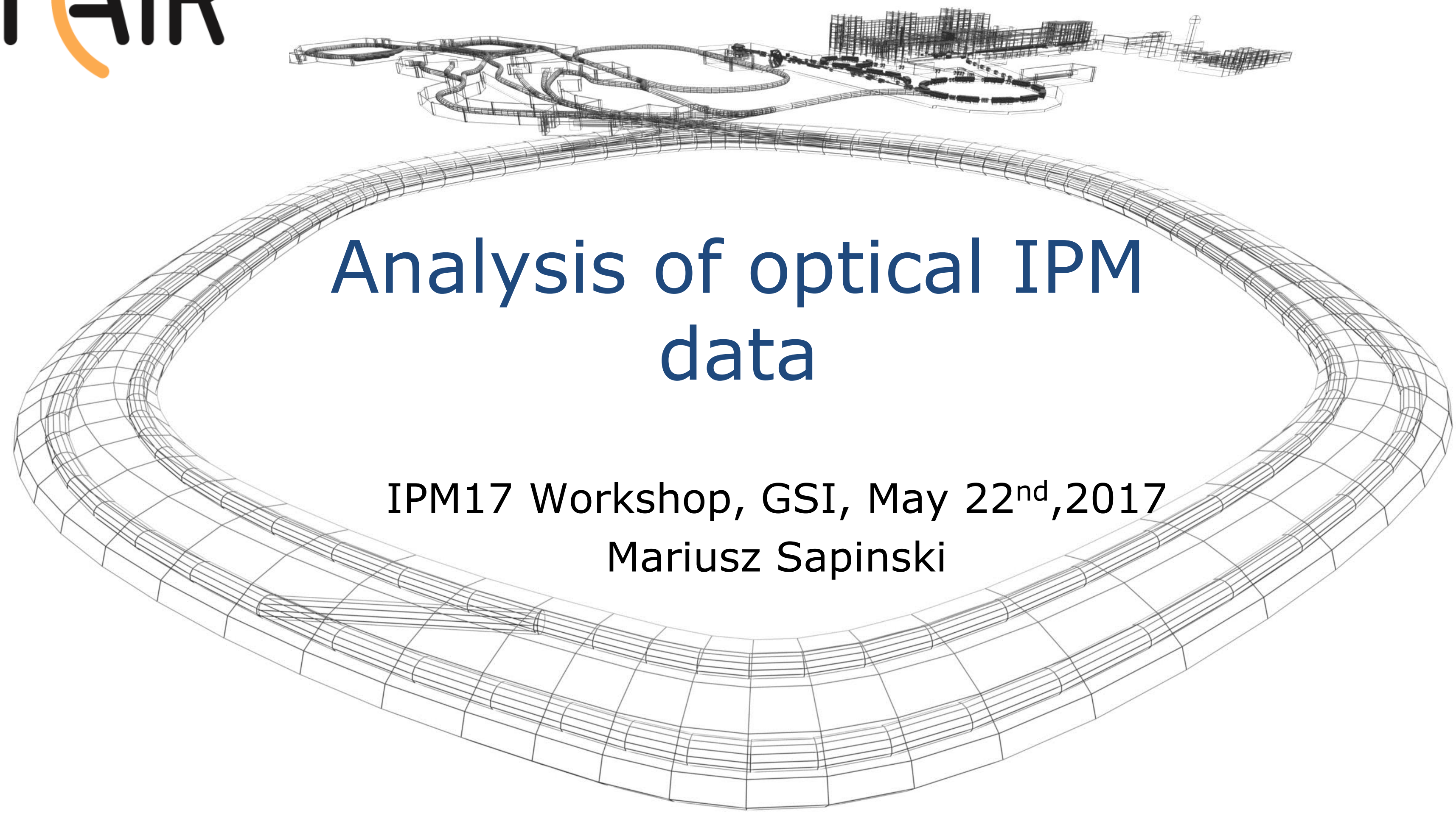
# Analysis of optical IPM data



IPM17 Workshop, GSI, May 22nd,2017

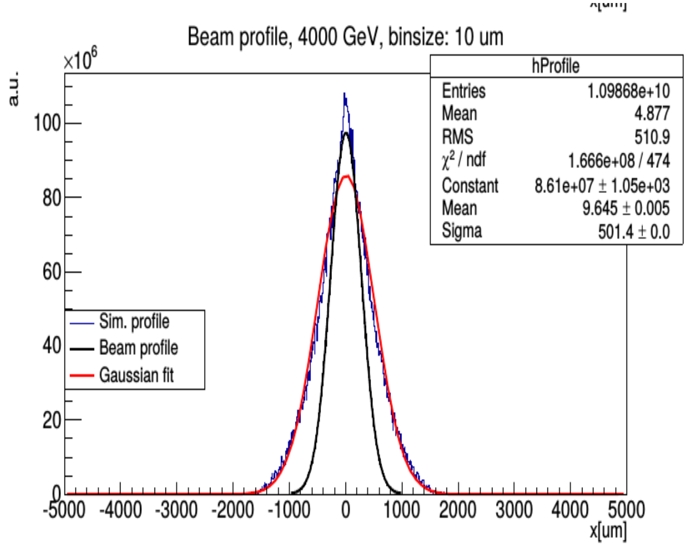
Mariusz Sapinski

# Outlook

- Motivation.
- LHC IPM.
- Features of 2D IPM image on example of LHC monitor.
- Filtering in frequency domain.
- Slicing 2D image – camera tilt correction.
- Deconvolution of optical Point Spread Function (PSF).
- Conclusions.

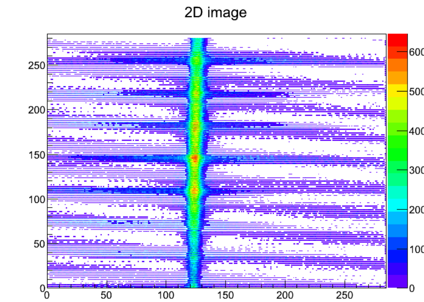
# Motivation

- Inability to calibrate LHC IPM (BGI) attributed to beam space-charge.
- This leads to non-gaussian deformation of observed profiles.
- Can we see this deformation in LHC data?
- In other words: can we clean the data from other effects?




The following examples are obtained using ROOT.
After recent experiences I would rather recommend Python and numpy.

# LHC IPM


2D image
250
200
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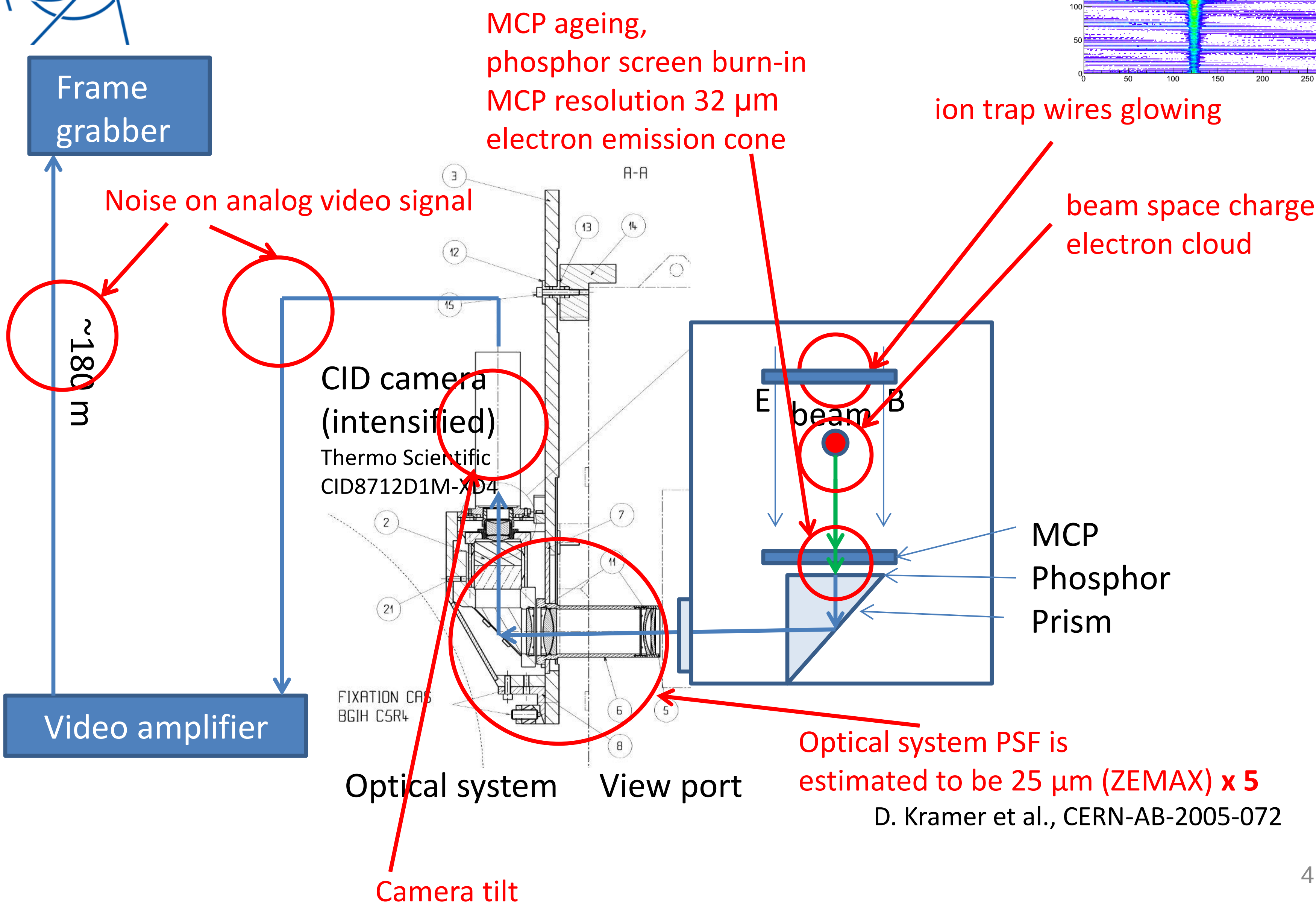
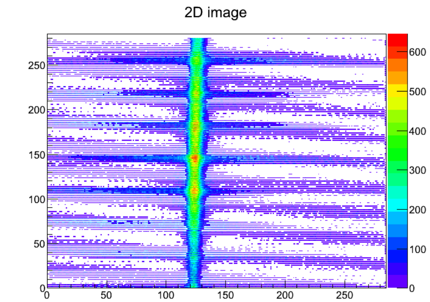

MCP ageing,
phosphor screen burn-in
MCP resolution 32 µm
electron emission cone
ion trap wires glowing
beam space charge,
electron cloud
Frame grabber
Noise on analog video signal
~180 m
CID camera
(intensified)
Thermo Scientific
CID8712D1M-XD4
E
beam
B
MCP
Phosphor
Prism
Video amplifier
A-A
FIXATION CAS
BGIH C5R4
Optical system
View port
Optical system PSF is
estimated to be 25 µm (ZEMAX) **x 5**
D. Kramer et al., CERN-AB-2005-072
Camera tilt

# LHC IPM


2D image
250
200
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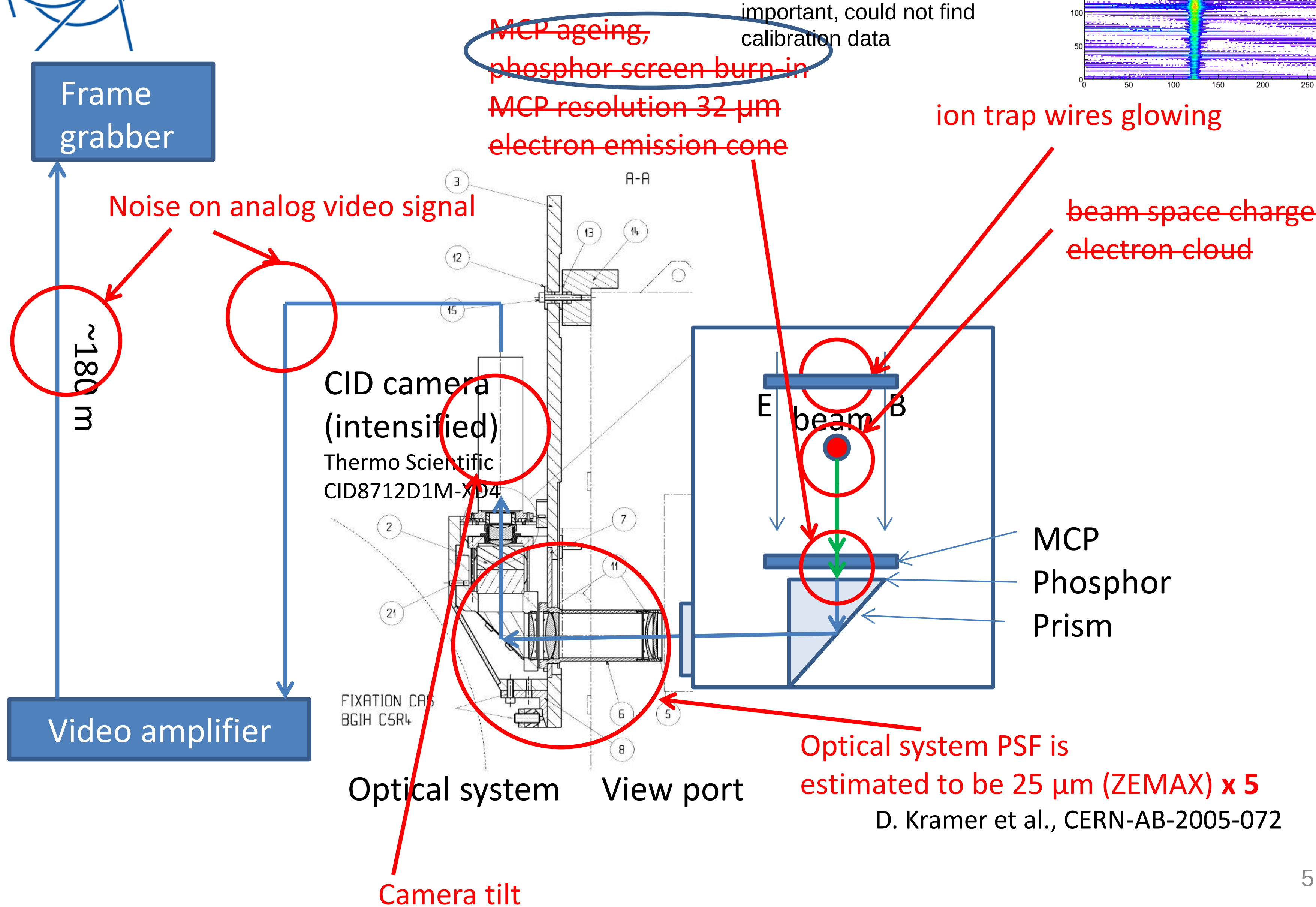
~~MCP ageing,~~
~~phosphor screen burn-in~~
important, could not find
calibration data
~~MCP resolution 32 µm~~
~~electron emission cone~~
ion trap wires glowing
~~beam space charge,~~
~~electron cloud~~
Frame
grabber
Noise on analog video signal
~180 m
CID camera
(intensified)
Thermo Scientific
CID8712D1M-XD4
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FIXATION CAS
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View port
Optical system PSF is
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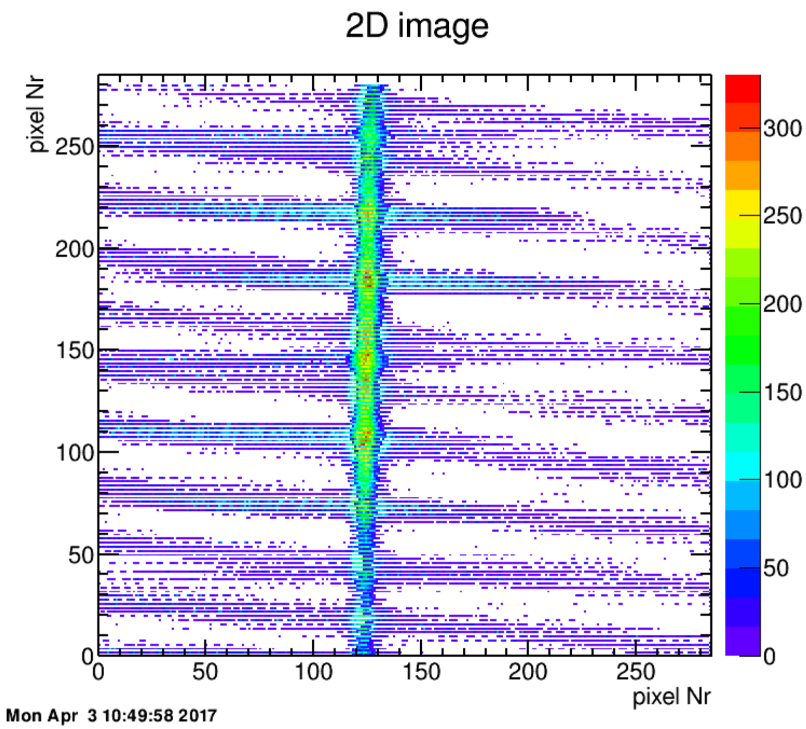
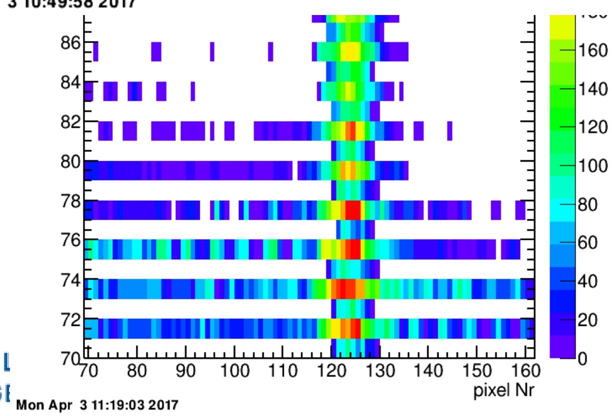
D. Kramer et al., CERN-AB-2005-072
Camera tilt

# Features of a raw 2D image



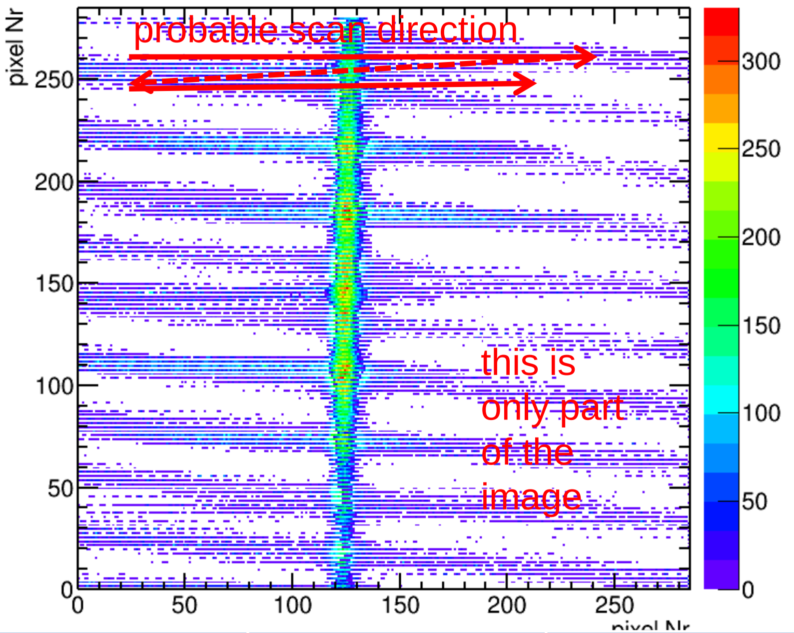

- LHC IPM B2V at 4 TeV as example.
- Data from August 26, 2012.
- Effects seen on the image:
  - ‘TV-noise’ (stripes)
  - interlace
  - additional periodicity related to ion-trap wires
  - camera tilt
  - nonuniformity of MCP/Phosphor response
  - Point Spread Function of optical system




← interlace

# convert to 1D signal

2D image




| | period | frequency |
|---|---|---|
| image | 40 ms | 25 Hz |
| half-image | 20 ms | 50 Hz |
| line | 64 µs | 15625 Hz |
| pixel | 81.42 ns | 12.3 MHz |

← sampling frequency

- Camera specification:

**Thermo Scientific CID8712D**

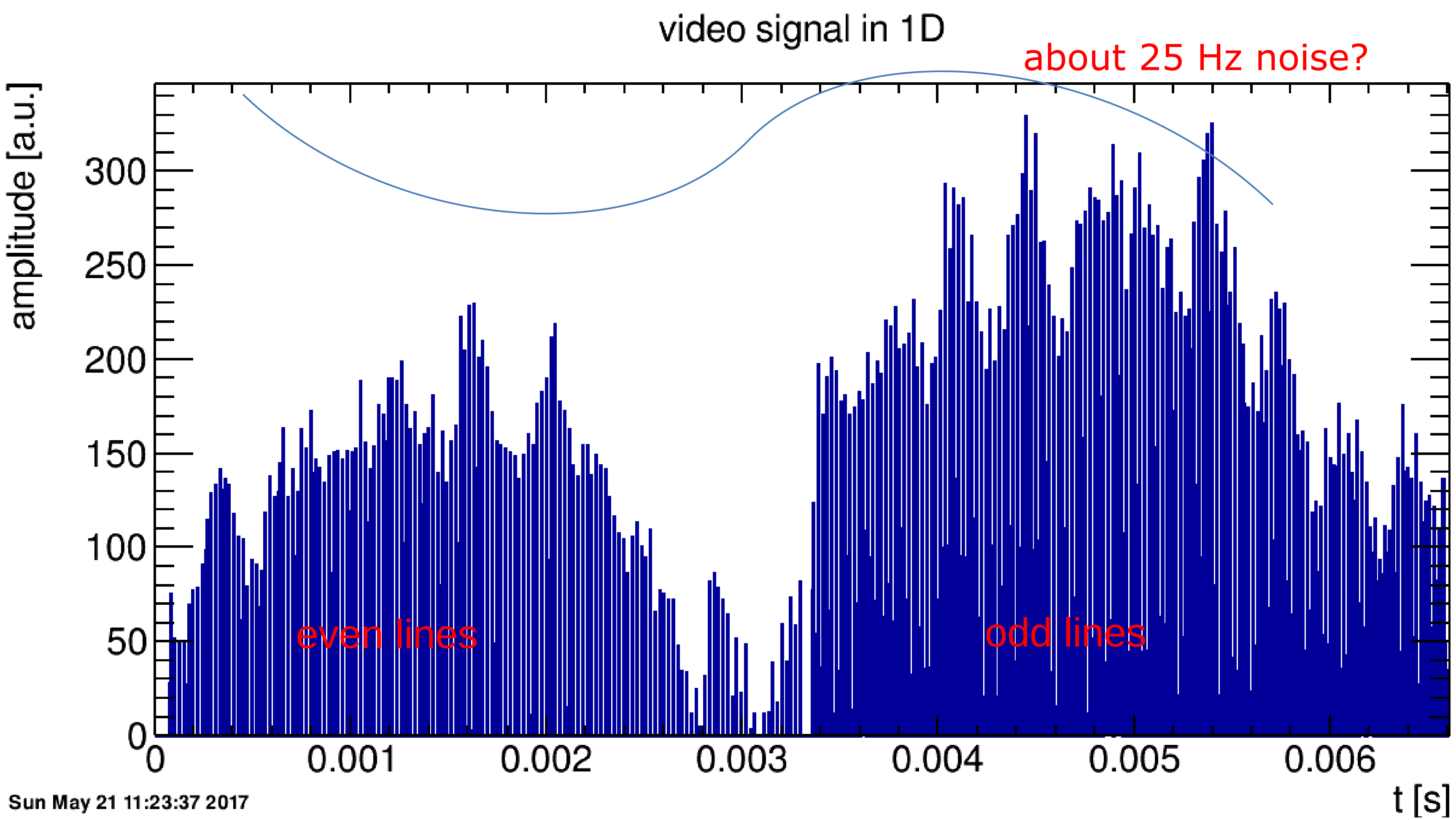
**Imager**

| | |
|---|---|
| Image Format | 786H x 612V |
| Total Pixels | 768H x 575V |
| Pixel Size | 11.5 x 11.5 micron |
| Full Well Capacity | ›250,000 electrons |
| Active Area | 11 mm diagonal |
| Optical Format | 2/3” |

| | |
|---|---|
| Scanning Format | CCIR, 25FPS, Interlace |
| Resolution | ›500 TVL (horizontal) |
| S/N Ratio | -47db typ. signal/RMS 10KHz - 4.2MHz |
| Sensitivity | Full output at .7fc 0db Gain, T=2850K |
| Composite Video | 1V p-p, terminated into 75 ohm |

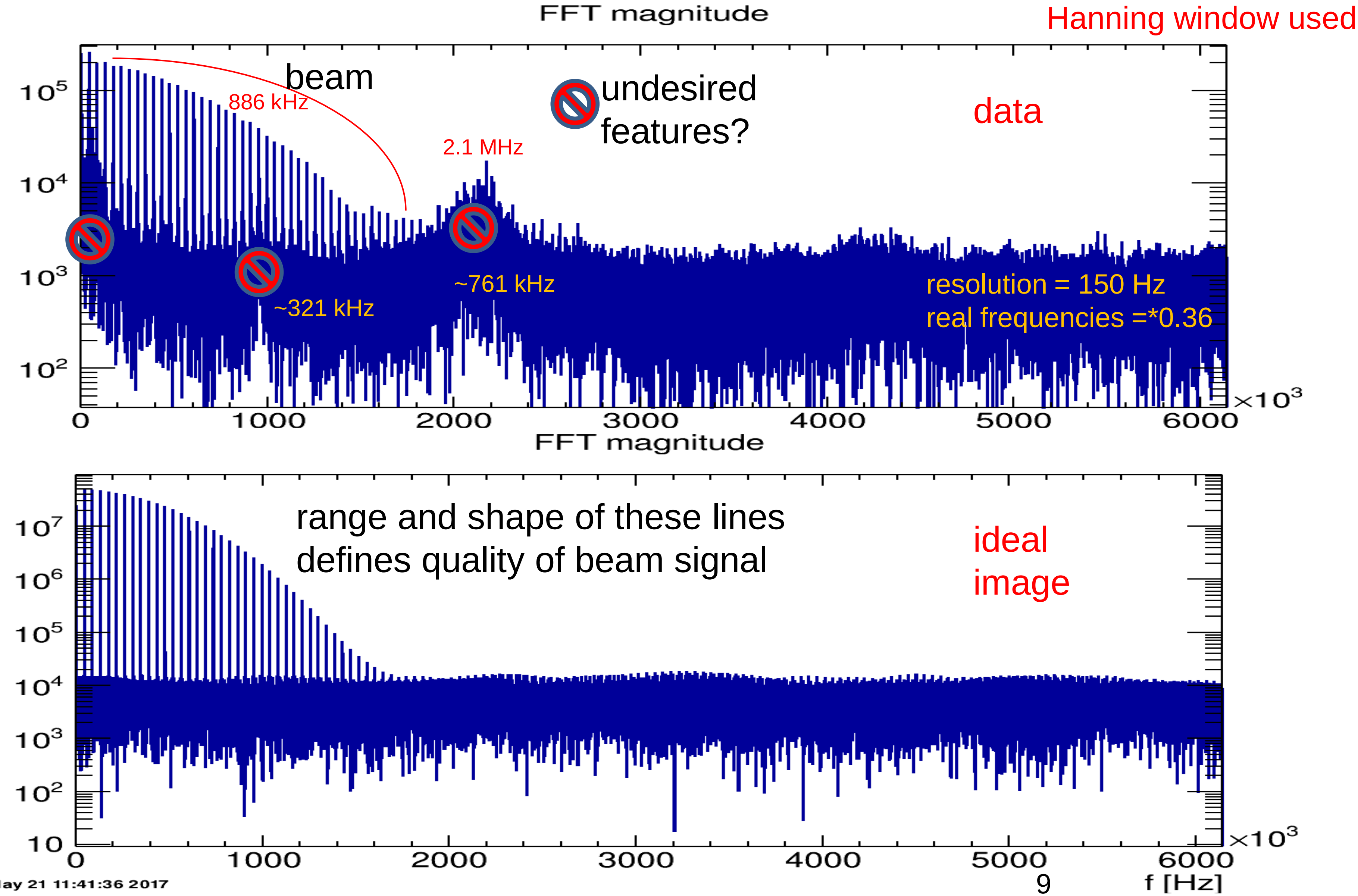
BTW, bandwidth of typical video cable 6 MHz → rotate camera?

# convert to 1D signal




part of image so: 6 ms instead of 40 ms

# 1D signal - FFT

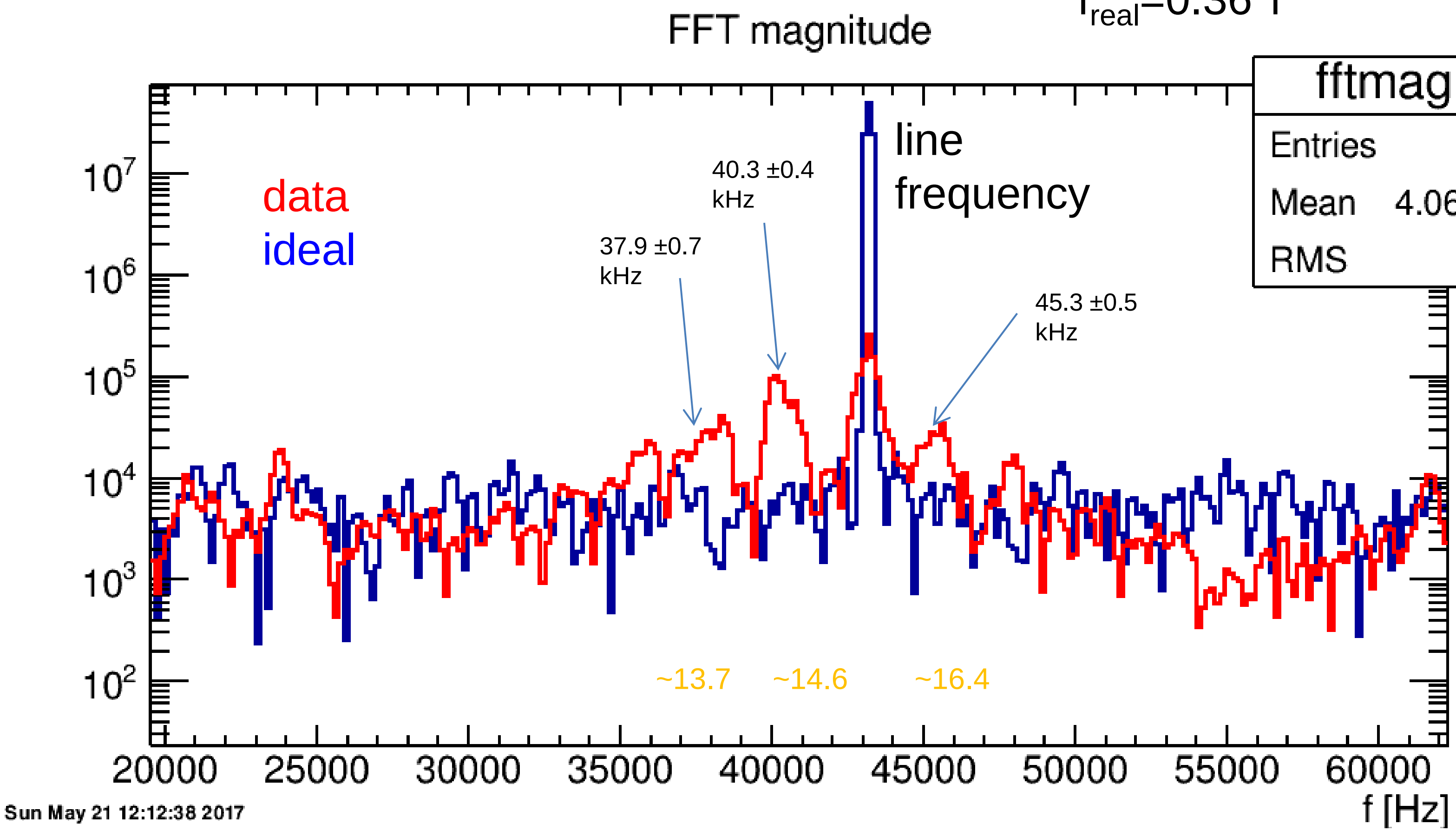


# FFT – zoom around line frequency

because of image cropping line frequency is now about (786/285)*15625 Hz=

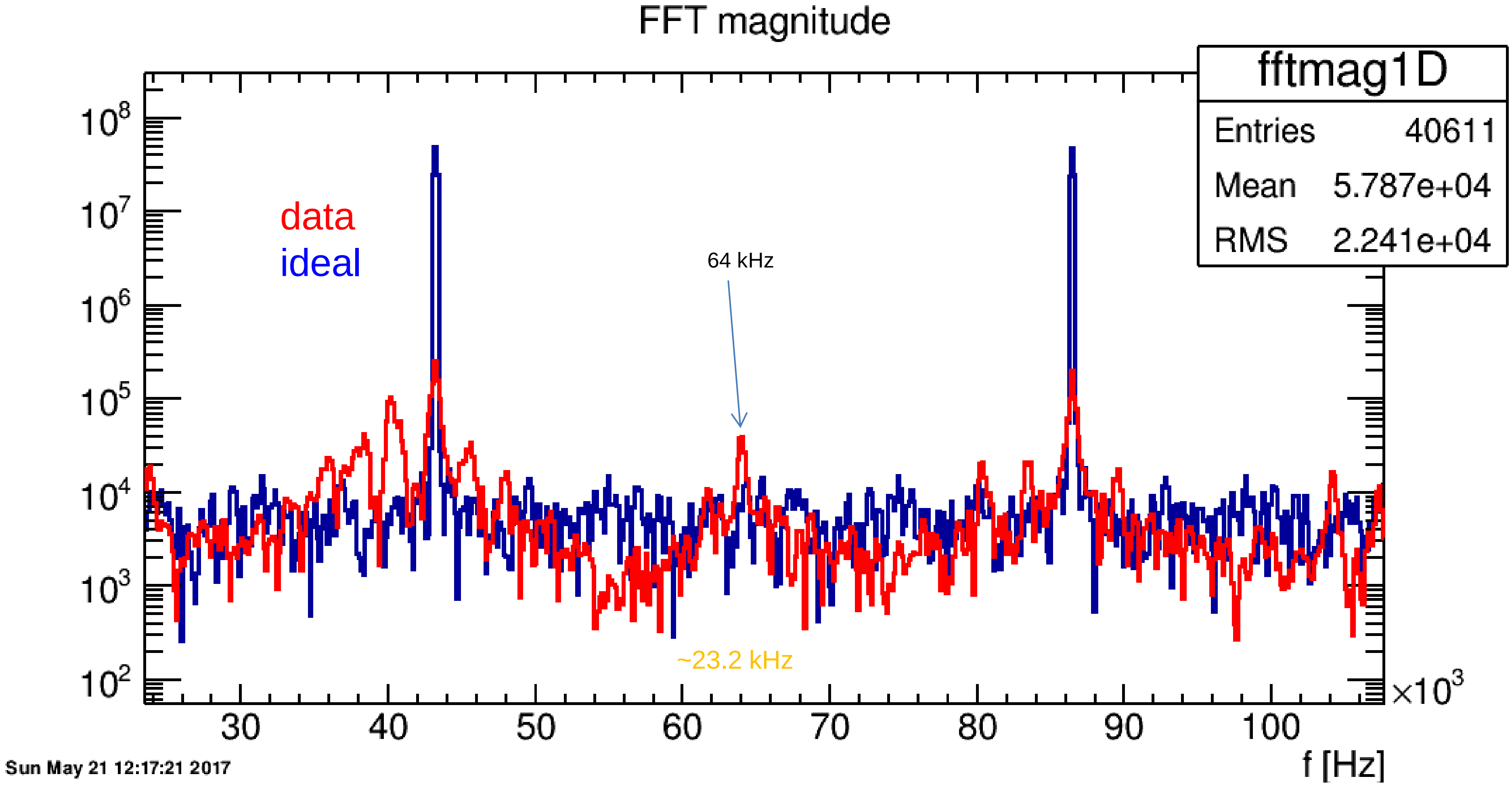
~43 kHz

$f_{real}$=0.36*f



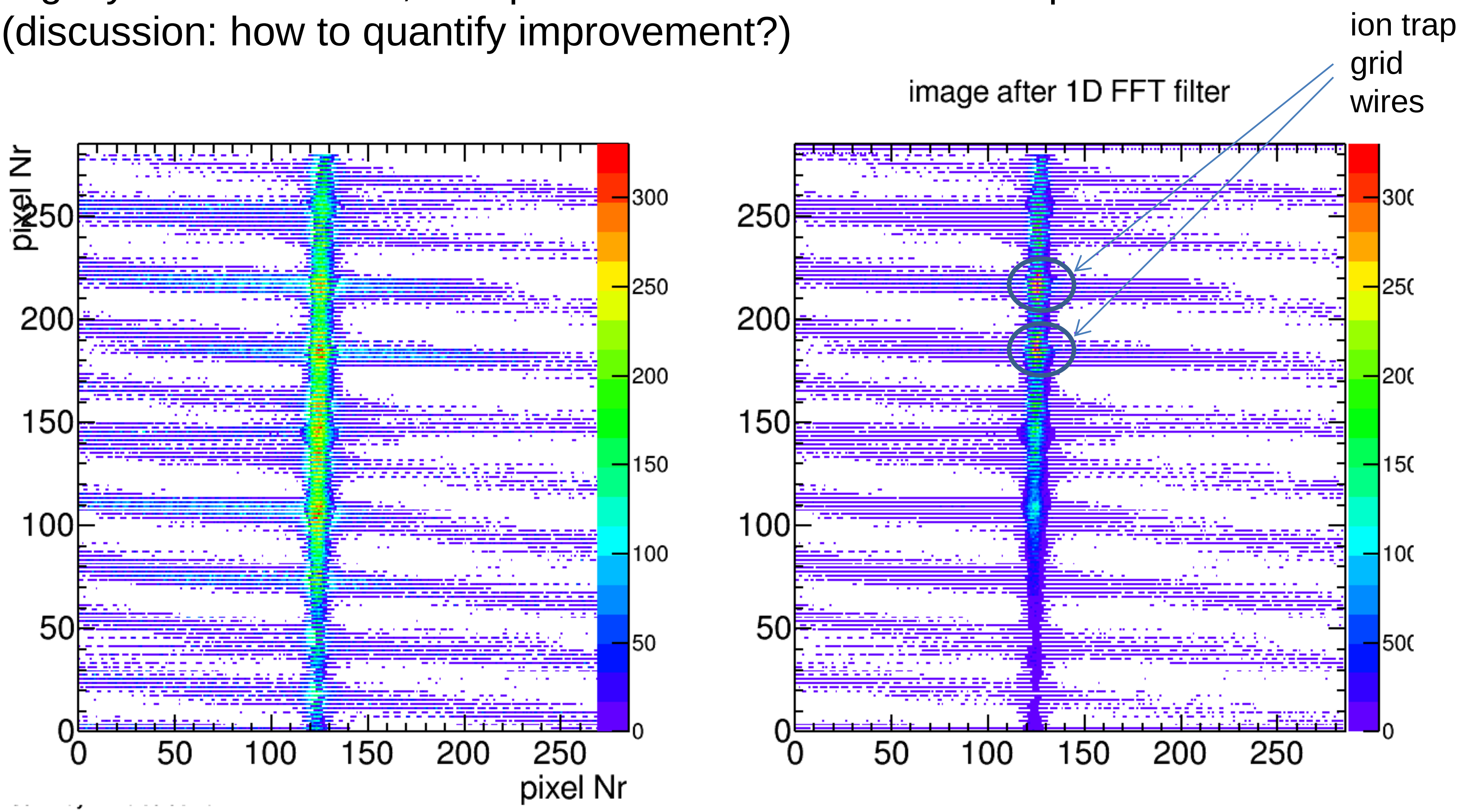
# FFT – zoom around line frequency

unzoom a bit



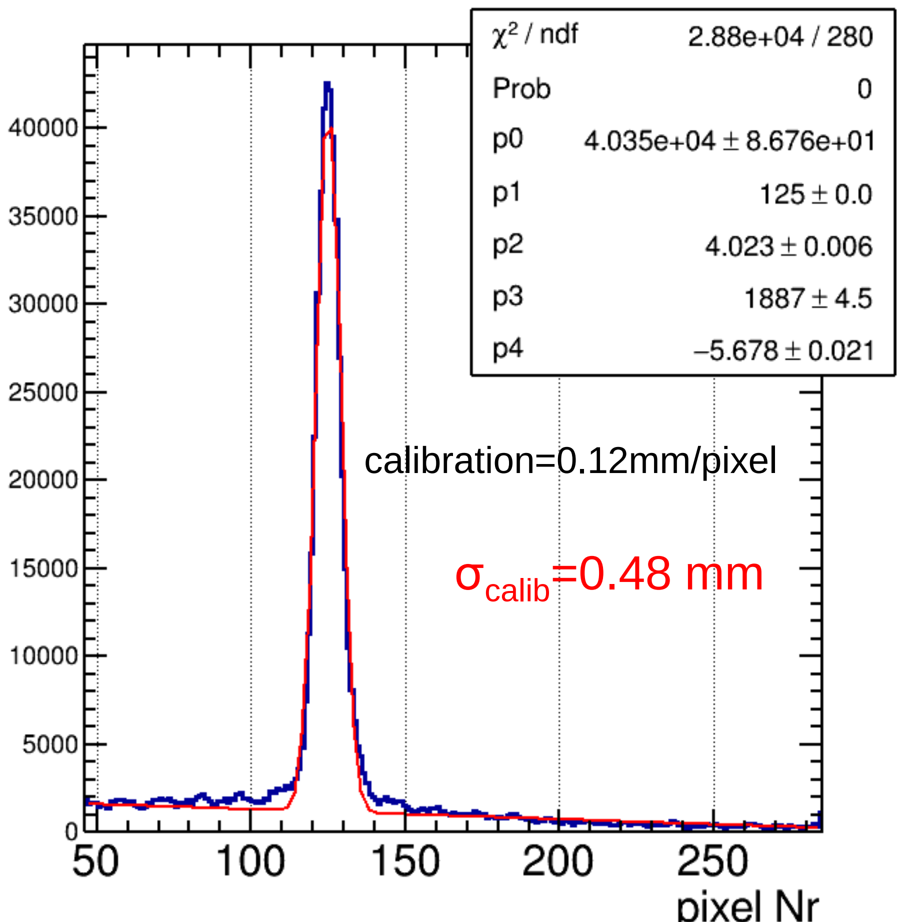
# after filtering

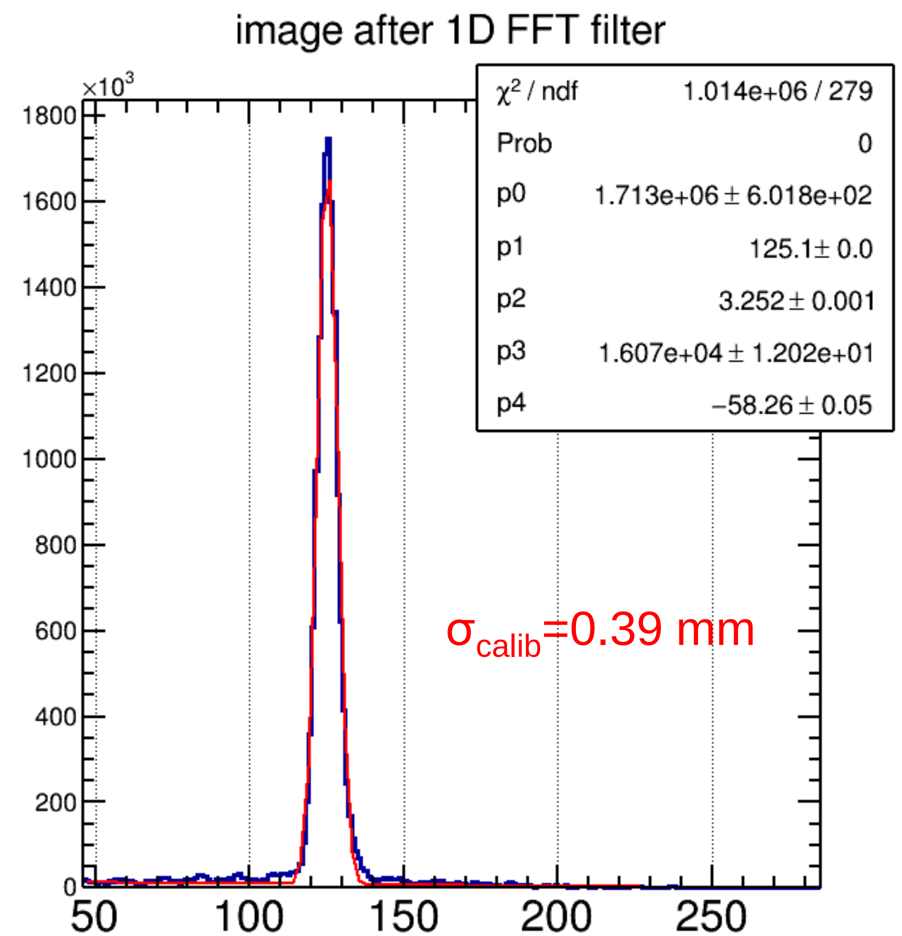
slightly better contrast, less power in bands but no real improvement
(discussion: how to quantify improvement?)



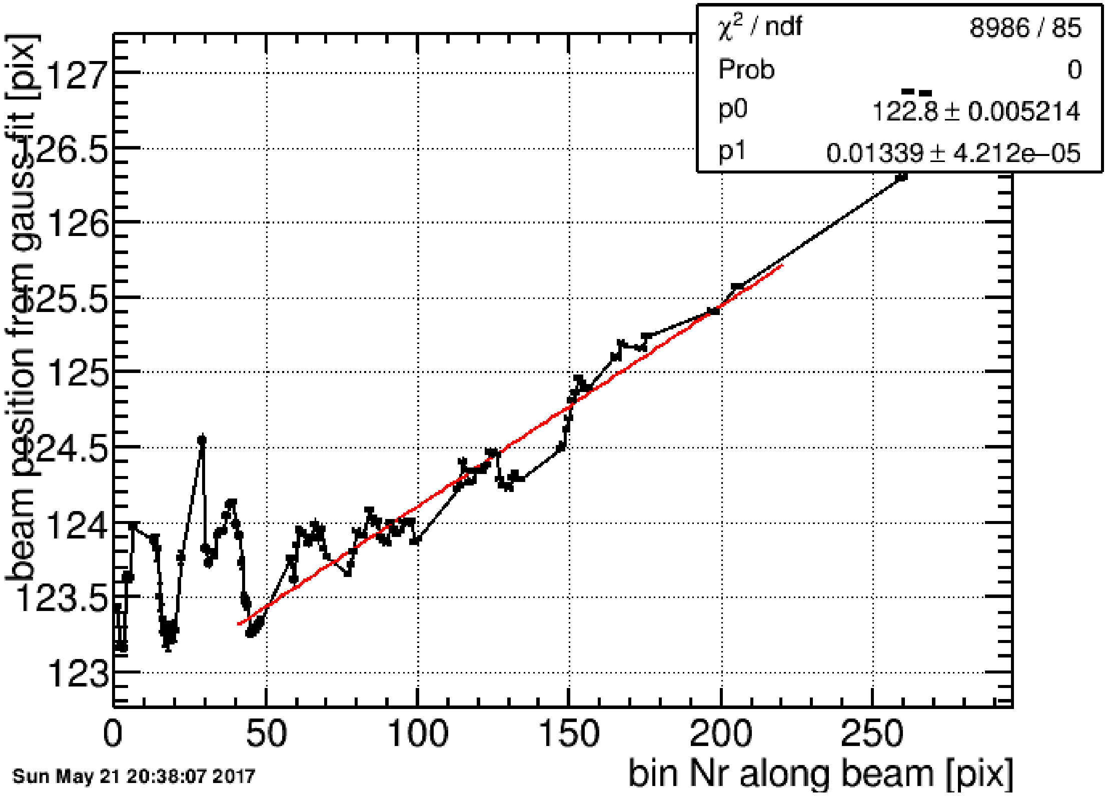
# after filtering

profile looks better



# Camera tilt



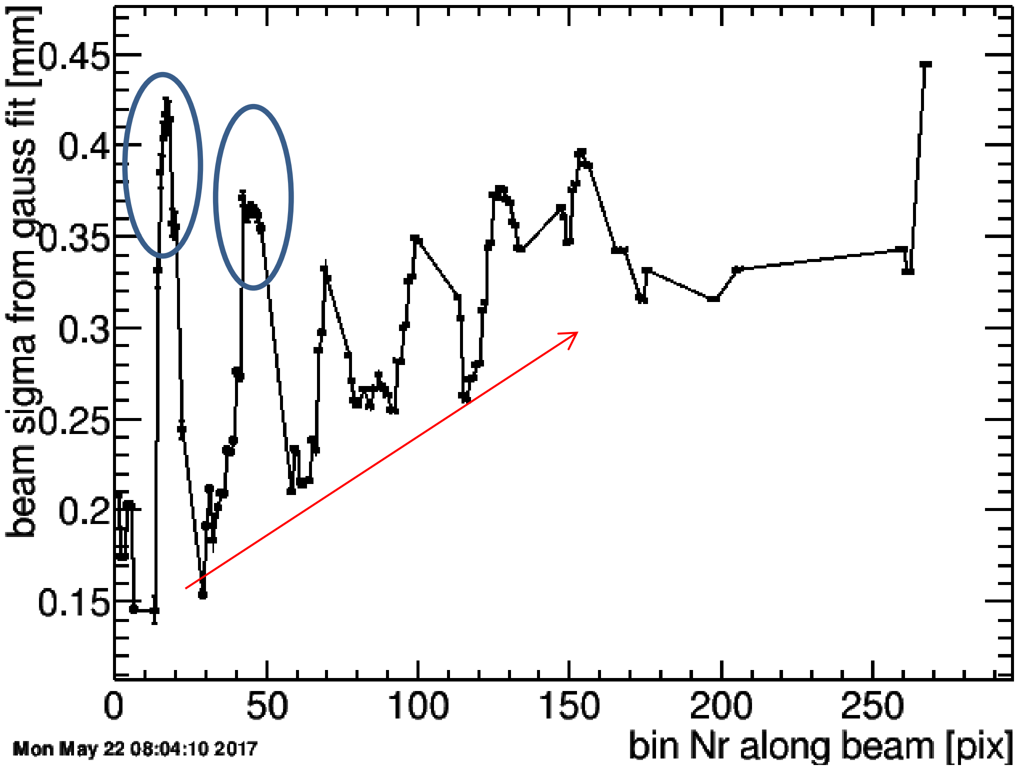

tilt is 7 degrees:

- 3.8 pixels along the image
- or 219 µm

beam size is comparable

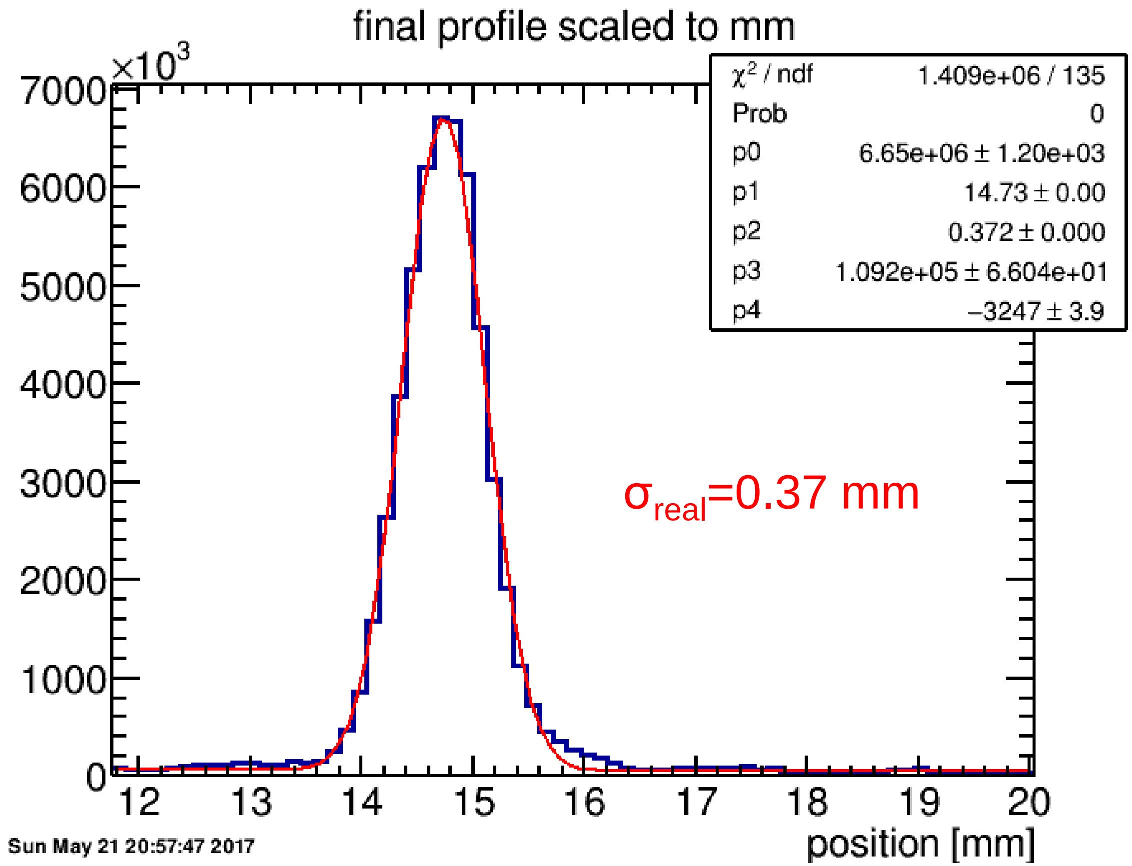
– tilt is important

# Beam width along the image



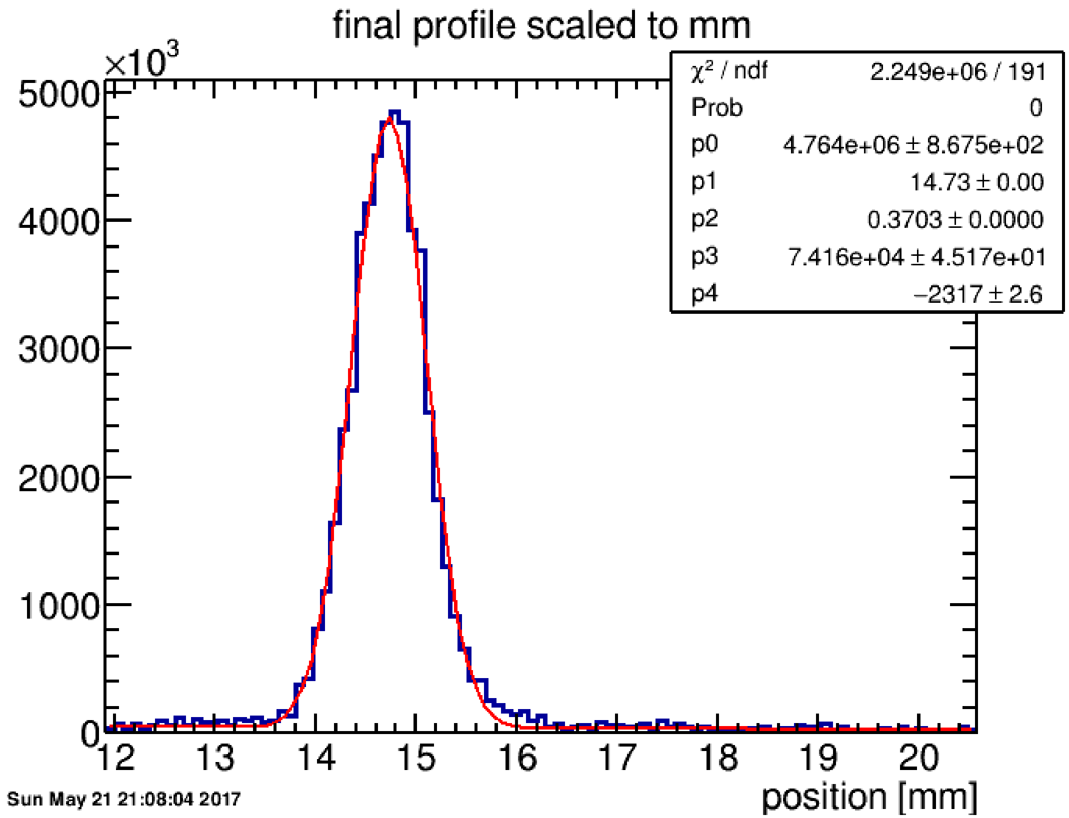

- grid wires give larger σ – should be filtered out
- fitted sigma increases along the beam – amplitude effect (?)

# Tilt correction




- effect on sigma: about 5%
- idea: use the tilt to increase the binning of the histogram

# Tilt correction




- 40% more bins, so bin size at beam position: 57.5→41 µm
- looks a little better
- but be careful not to introduce artefacts
- optical PSF is much bigger then bin size!

# PSF deconvolution

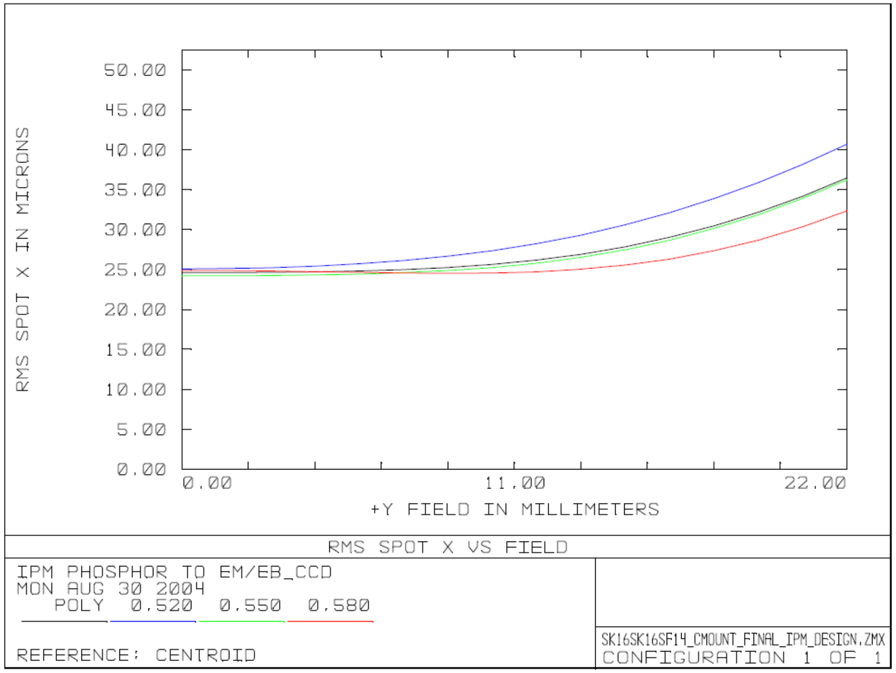



Figure 5: RMS spot size (x component) for different wavelengths.

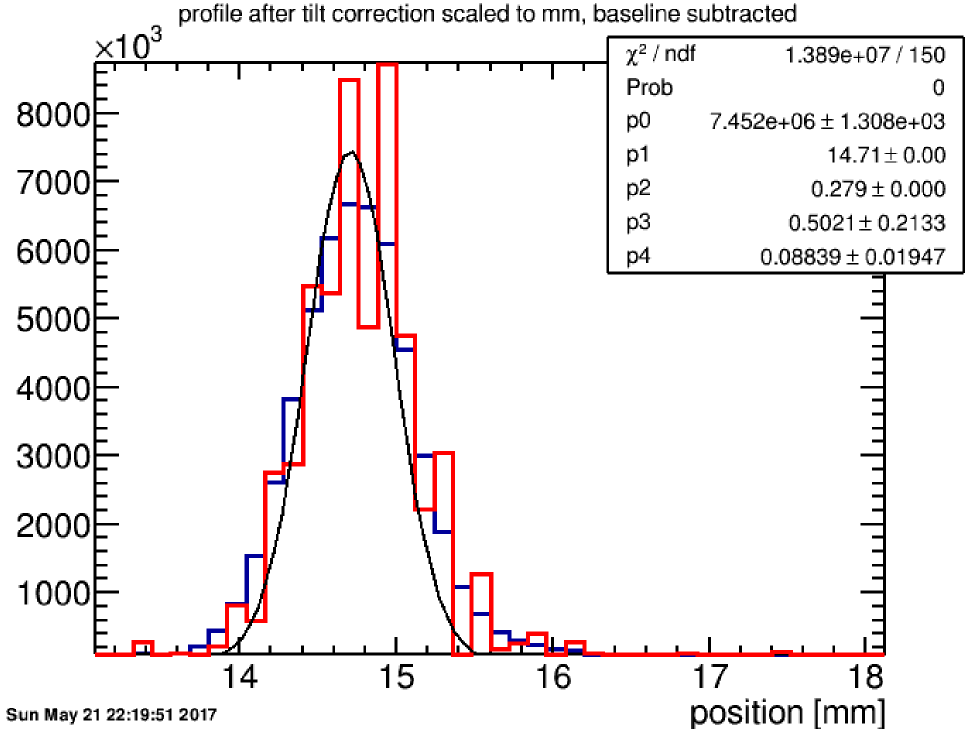
D. Kramer et al., CERN-AB-2005-072

- RMS spot size is 25 µm on sensor side
- Optical system magnification is 0.2
- So RMS spot size on beam side is 125 µm
- Lets assume PSF is gaussian: sigma = RMS
- if beam is gaussian, the correction is simple:

$\sigma=\sqrt{(\sigma_{meas}^2-\sigma_{psf}^2)}$ = 0.35 mm (another 5%)!

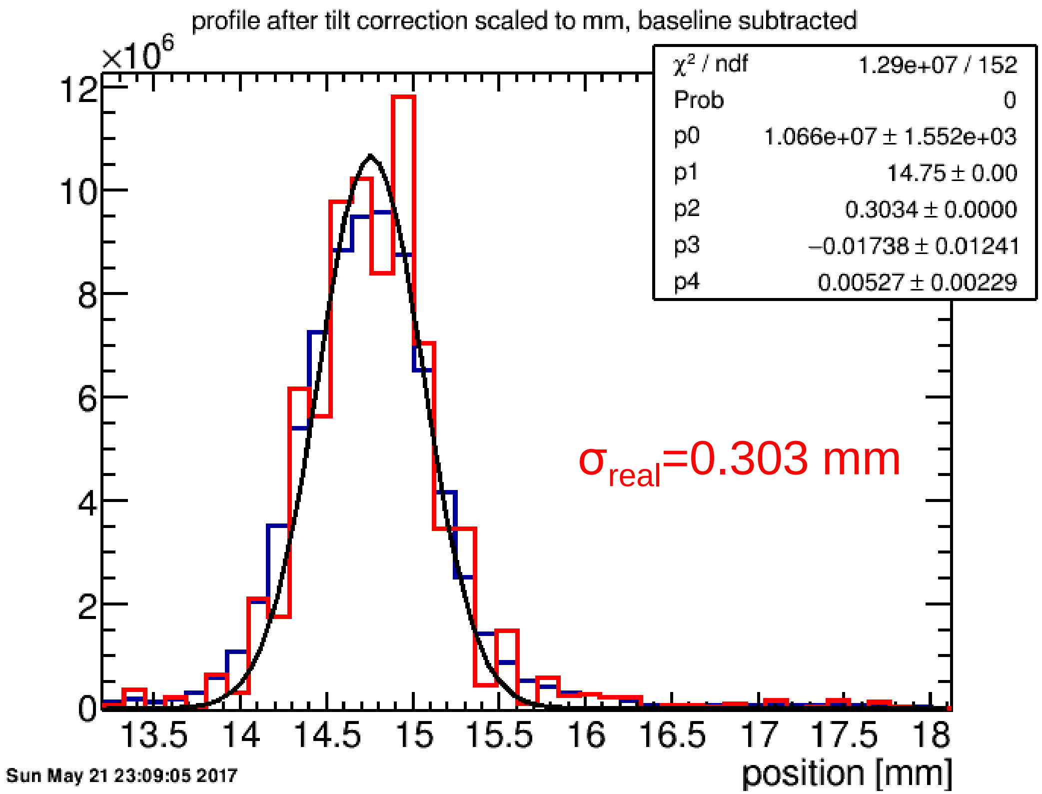
# PSF deconvolution

- We can also try to use deconvolution algorithm, eg. Gold deconvolution implemented in ROOT::TSpectrum




- Increased binning not applied here.
- Result not convincing.
- “Windowing before FFT decreases resolution”.
- Try without Hanning window.

# PSF deconvolution




- Result slightly better, but still not convincing.
- More study needed.
- Better resolution would be definitely helpful.

# Conclusions

- Signal cleaning with FFT not very successful.
- However it gives 19% smaller σ.
- Tilt correction crucial, further σ decrease (~5%).
- Tilt maybe potentially used to increase profile sampling.
- Optical Point-Spread Function effect is significant.
- However deconvolution is did not work yet.
- Overall data quality not good – lack of calibration files, sigma variation along the image, etc.
- If we want to study further profile deformation in electron IPM with magnetic field, need other data:
  - J-PARC? SIS18?

# Acknowledgements

special thanks for discussions and suggestions to
Sofia Kostoglou (CERN), Dominik, Rahul.

**Thank you for your attention!**

# Spare slides