# The new optical device for turn to turn beam profile measurement

*Presented by: Dorokhov V.L.*

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# Outline

- *Problems*
- *The «old» turn-to-turn beam profile monitor*
- *The «new» turn-to-turn beam profile monitor*
- *Discussion*
- *Conclusion*

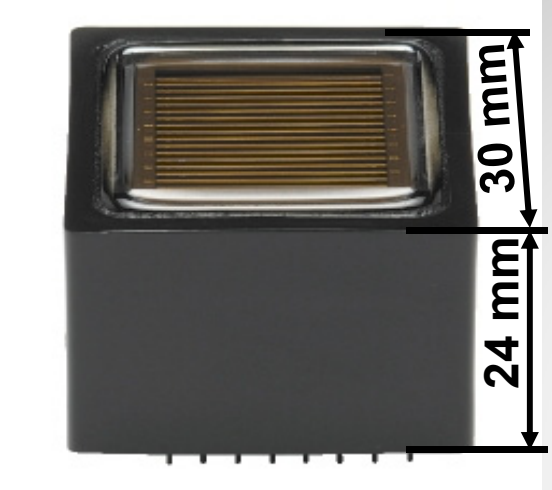
# Problems:

- *The study of transversal beam distribution within fast instabilities*
- *The routine measurement of betatron and synchrotron tunes*

# The requirements to device:

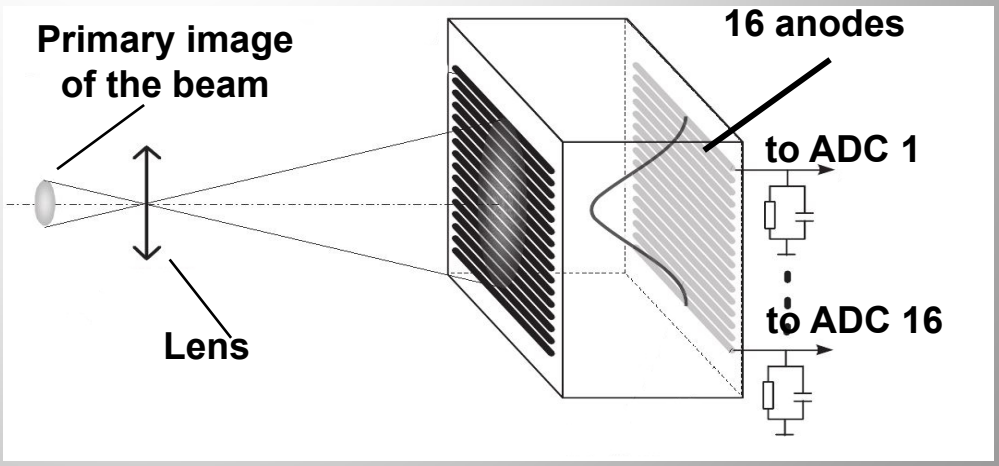
- *Measurement of the distribution during tens of thousands of beam turns*
- *The wide dynamic range*
- *The moderate spatial distribution*

# The “old” turn-to-turn beam profile monitor




*Multi-Anode Photomultiplier Tube Hamamatsu R5900U-00-L16*

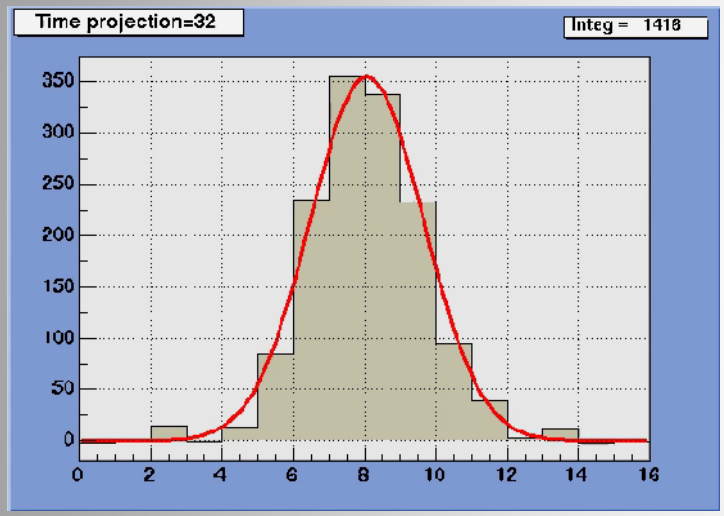
| The basic parameters of the device | |
|---|---|
| ***Size*** | 250 x 100 x 100 mm |
| ***Interface*** | 100Mb ethernet |
| ***Internal memory*** | ~4 M ($2^{17}$ beam profile at 16 points) |
| ***Analyzable frequency range*** | 10 Hz to 1 MHz |
| ***Single anode size*** | 0.8 x 16 mm |
| ***Range of the spectral sensitivity*** | 300-650 nm |



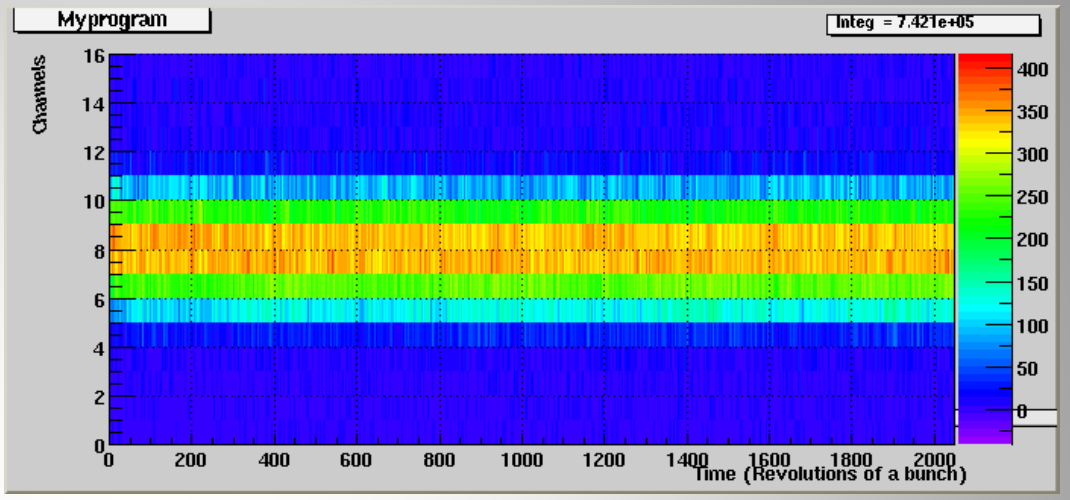

*Optical scheme of the beam profile monitor*

DIPAC2005

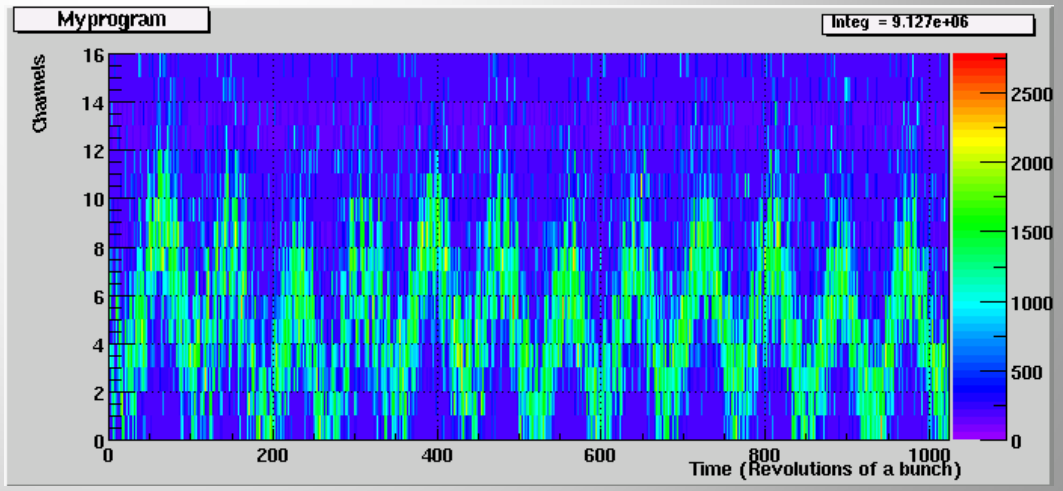
# MAPMT: Experimental results




*Acquired beam profiles and their Gaussian fit*

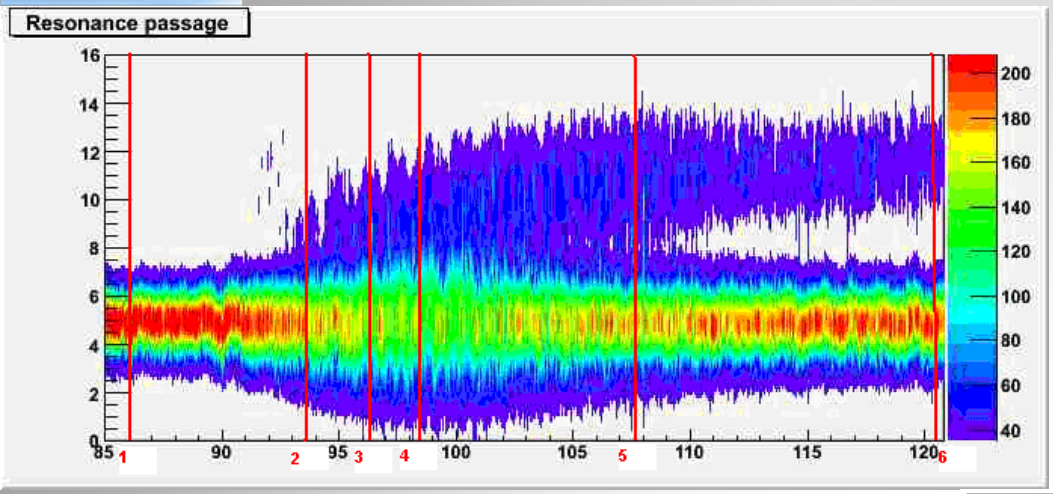



*The equilibrium position of the beam*



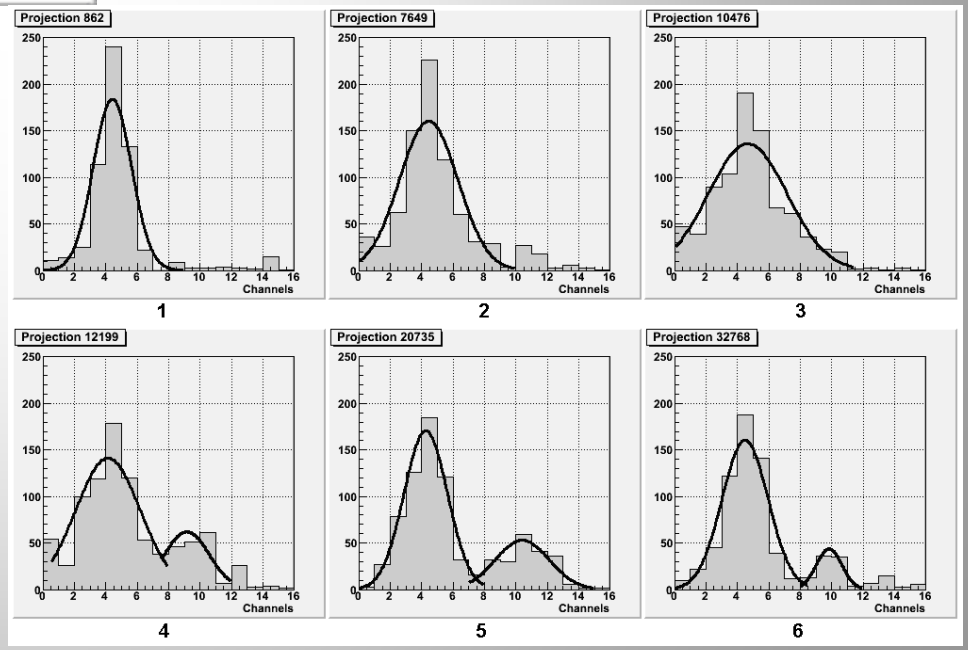

*The phase oscillations of the beam*

# MAPMT: Experimental results



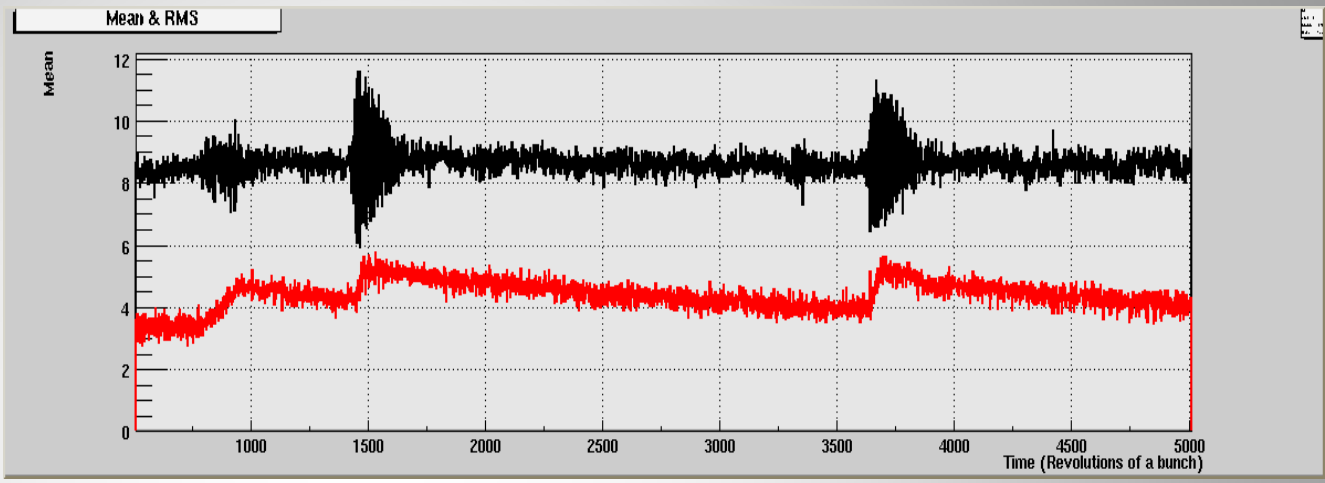

*The moment of crossing of the betatron resonance*

*The recorded vertical beam profiles at the different turns in the process of crossing of the betatron resonance*

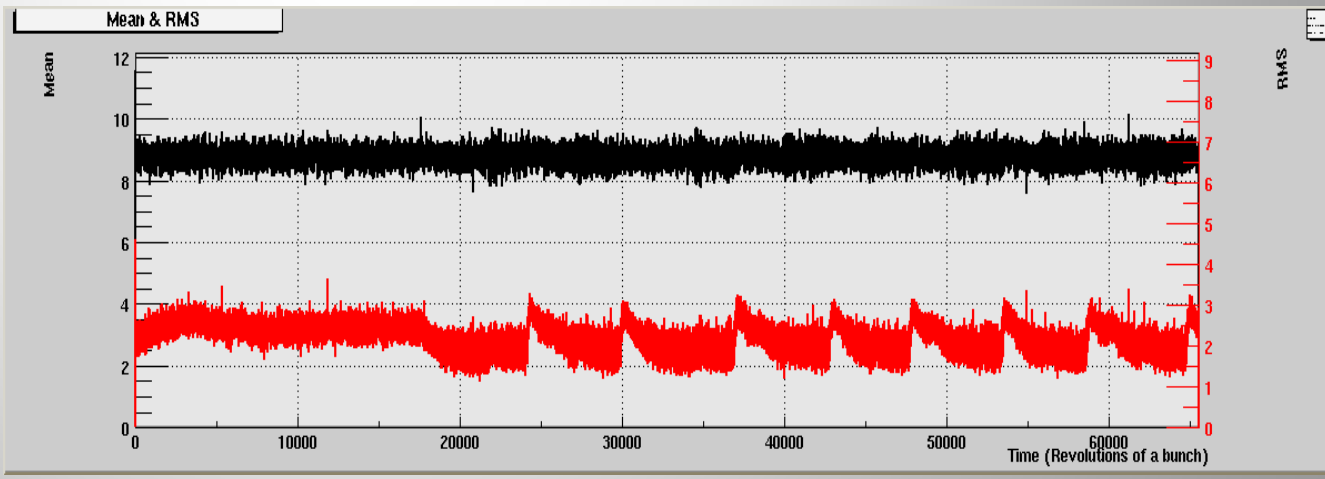


# MAPMT: Experimental results

*Beam dipole oscillations (black plot) and $\sigma_y$ behavior (red plot) during the electron and positron beams convergence at the interaction point.*

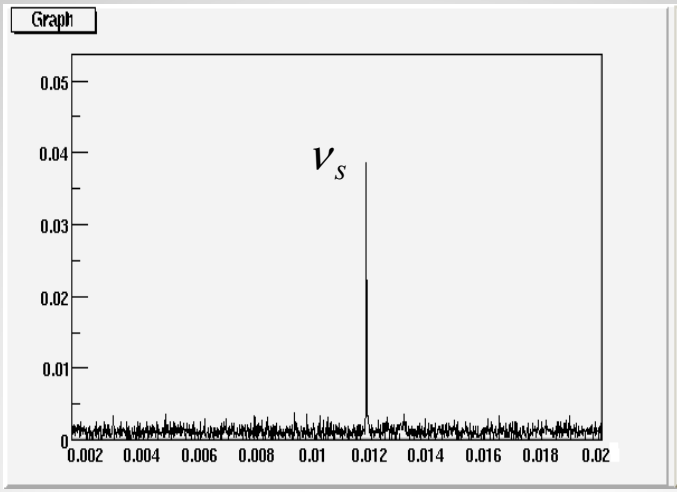


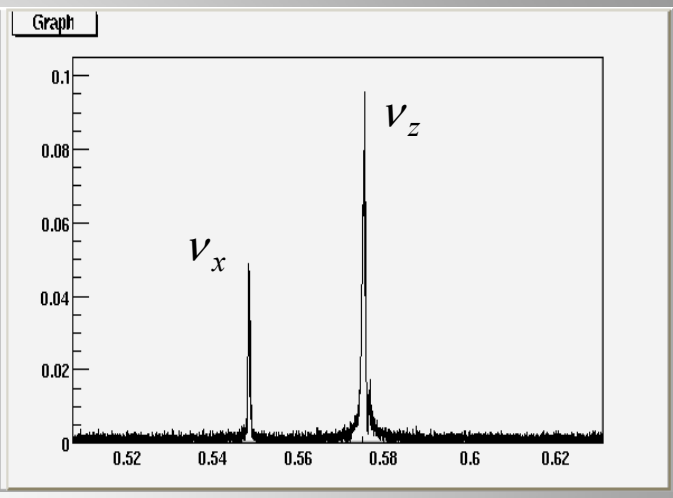

*Convergence of the electron and positron beams accompanied by quadrupole instability.*



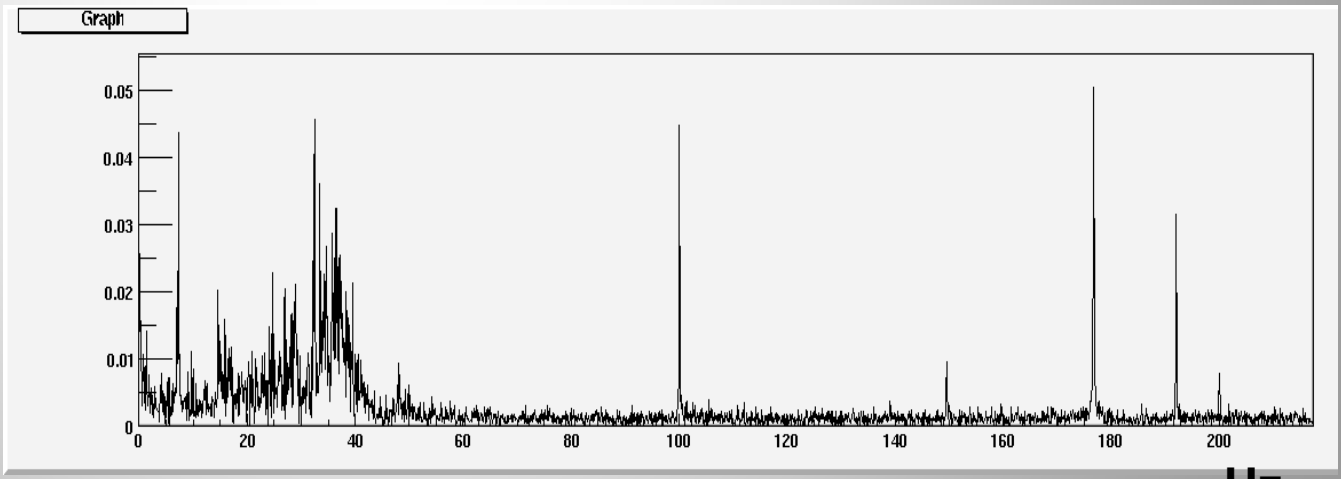
# MAPMT: Experimental results

*The synchrotron and the betatron oscillation frequency of the beam, defined by a Fourier analysis of the dipole oscillation*



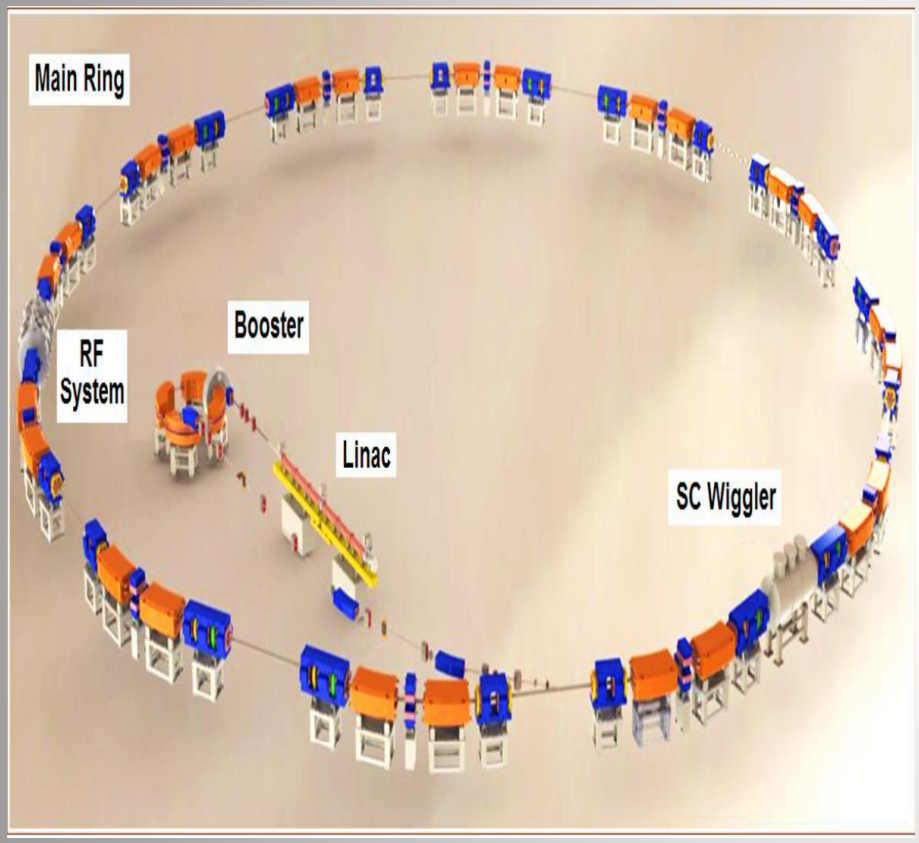

*The range of low-frequency vertical oscillation of the beam. MAPMT signal recording time of about 10 seconds*



# Some disadvantages

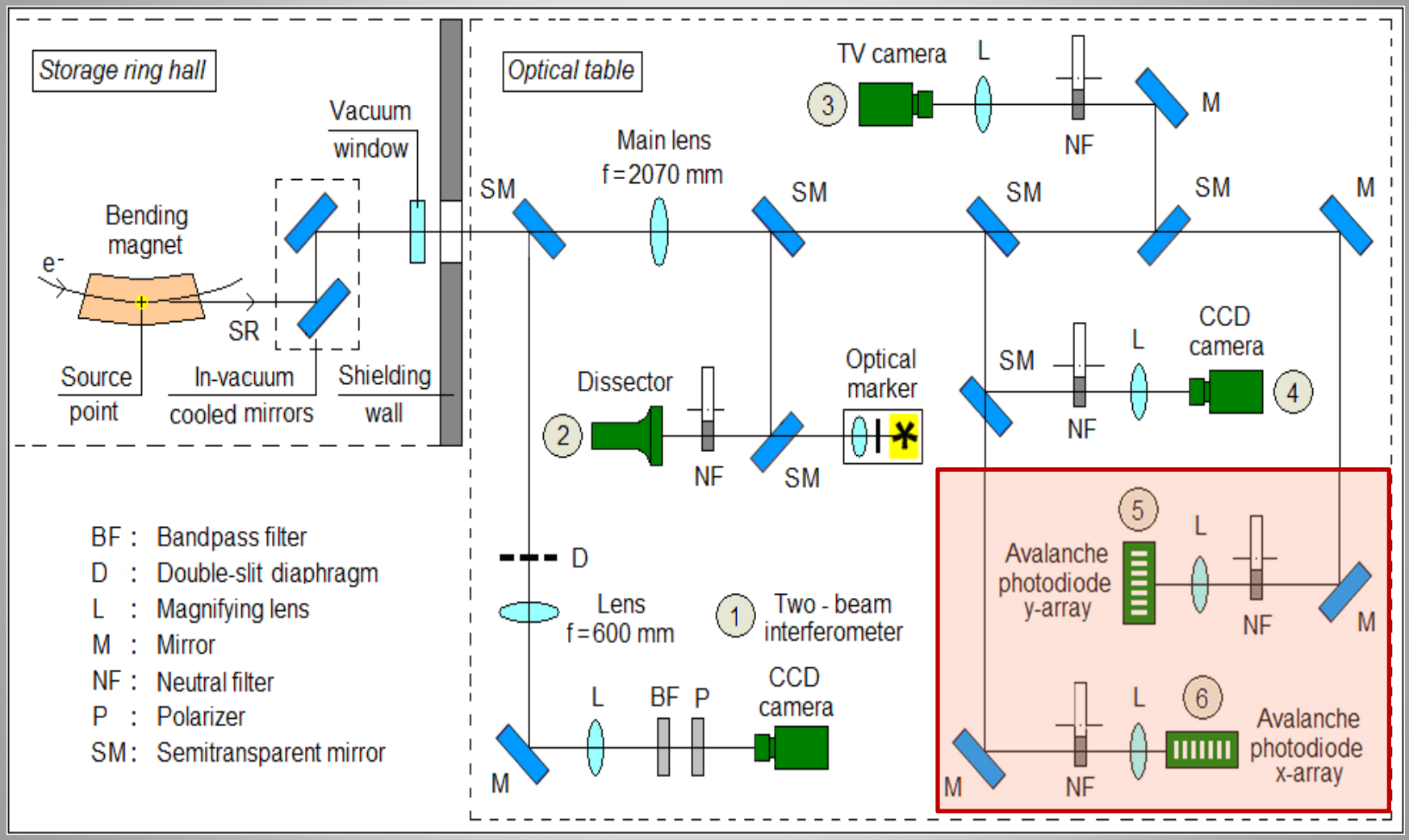
- The photomultiplier (MAPMT) is designed to operate in photon count mode and has a low value of an average anode current
- The approach applied for acquirement of anode signals can't be used for multi-bunched beam
- The beam instabilities with duration about period of synchrotron frequency can be accompanied by betatron oscillations and it is desirable to record both transversal beam profiles synchronously during hundreds thousands of a beam revolutions

# SIBERIA-2 Source of Synchrotron Radiation




| Parameters | |
|---|---|
| Energy, GeV | 0,45 – 2,5 GeV |
| Accelerating frequency, $\nu_{RF}$, MHz | 181.14 |
| Circumference, *C*, m | 124.13 |
| Beam lifetime (E = 2,5 GeV), hours | 10÷25 |
| Beam current, *I* (multibunch) | 0.1÷0.3 A |
| Revolution frequency, MHz | 2.4152 |
| Number of bunches | 75 |
| Bunch duration (FWHM), ns | 0.16 |
| Number of electrons in single bunch at $I_b$ = 1 mA | $2.6 \cdot 10^9$ |

# The “new” turn-to-turn beam profile monitor



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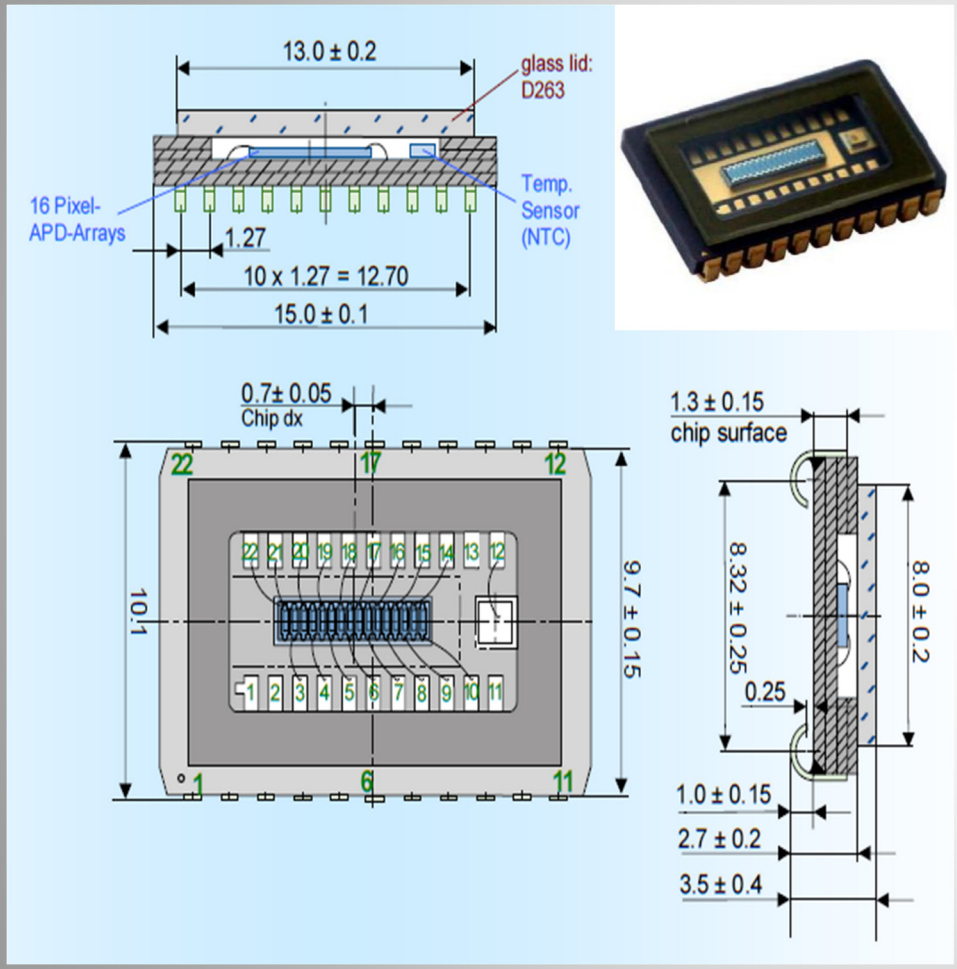
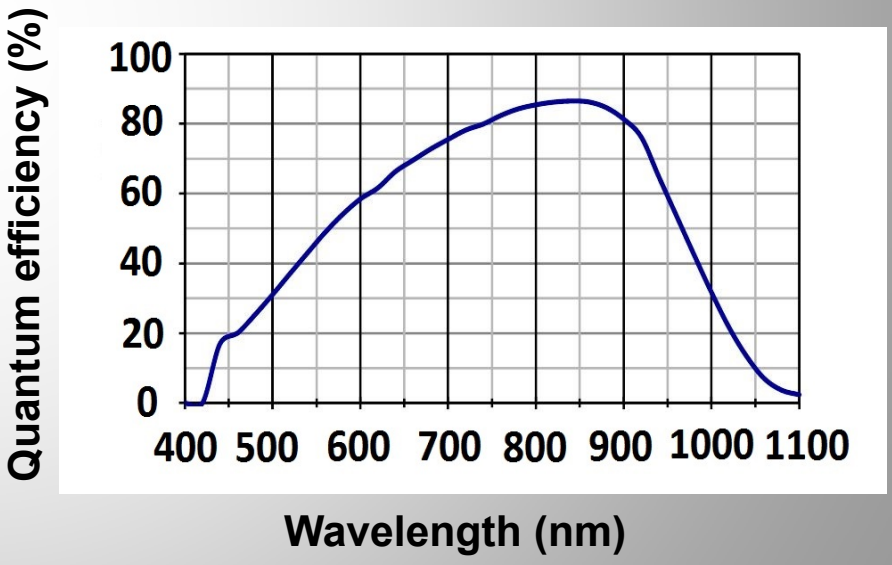



| Parameters of APD linear array | |
|---|---|
| *No of elements* | 16 |
| *Rise time* | 2 ns |
| *Cross talk* | 50 dB |
| *Peak DC current* | 0.25 mA |

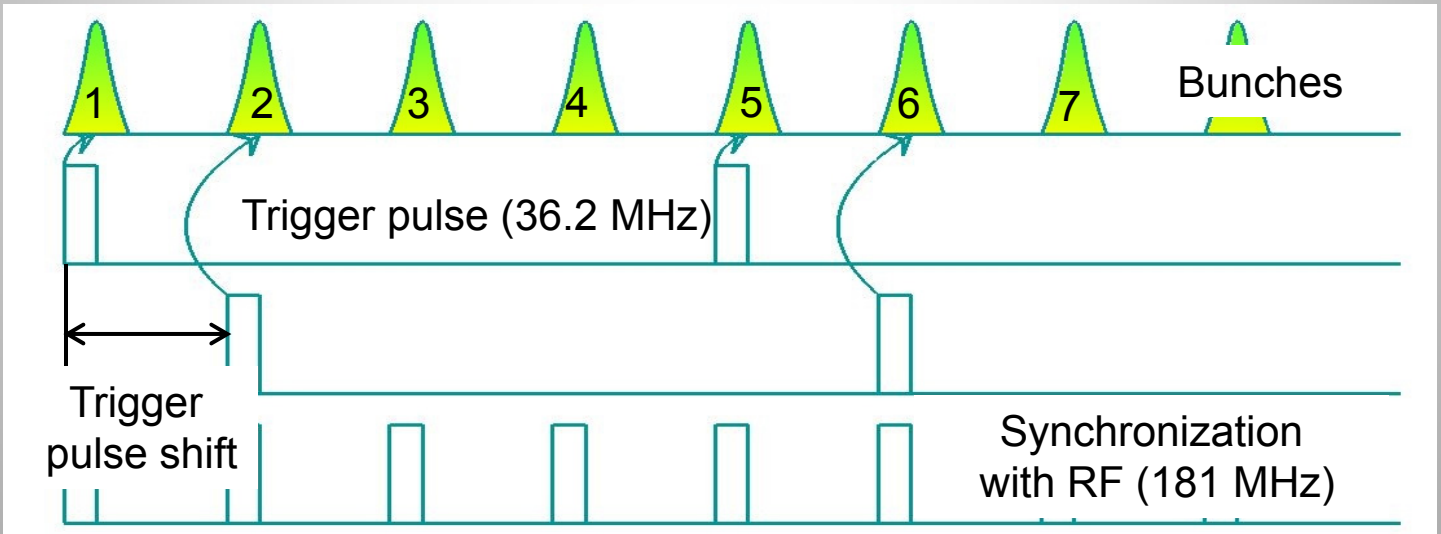


# The “new” turn-to-turn beam profile monitor

| The main parameters of the "new" profile monitor | |
|---|---|
| *Frame resolution, pixels* | 1x16 |
| *Frame rate, Mfps* | 50 |
| *Time resolution, ns* | 5 |
| *Dynamic range, bit* | 12 |
| *Memory, frames* | 15625000 |
| *Data transfer speed, Mbps* | 100 |
| *Spectral range, nm* | 450…1050 |
| *Pixel size, um* | 320 |
| *Max quantum efficient, %* | 85 |
| *Max avalan. multiplication* | 100 |
| *Max power consumption, W* | 25 |
| *Supply voltage, V* | 220 |
| *Module size, mm* | 100x100x400 |

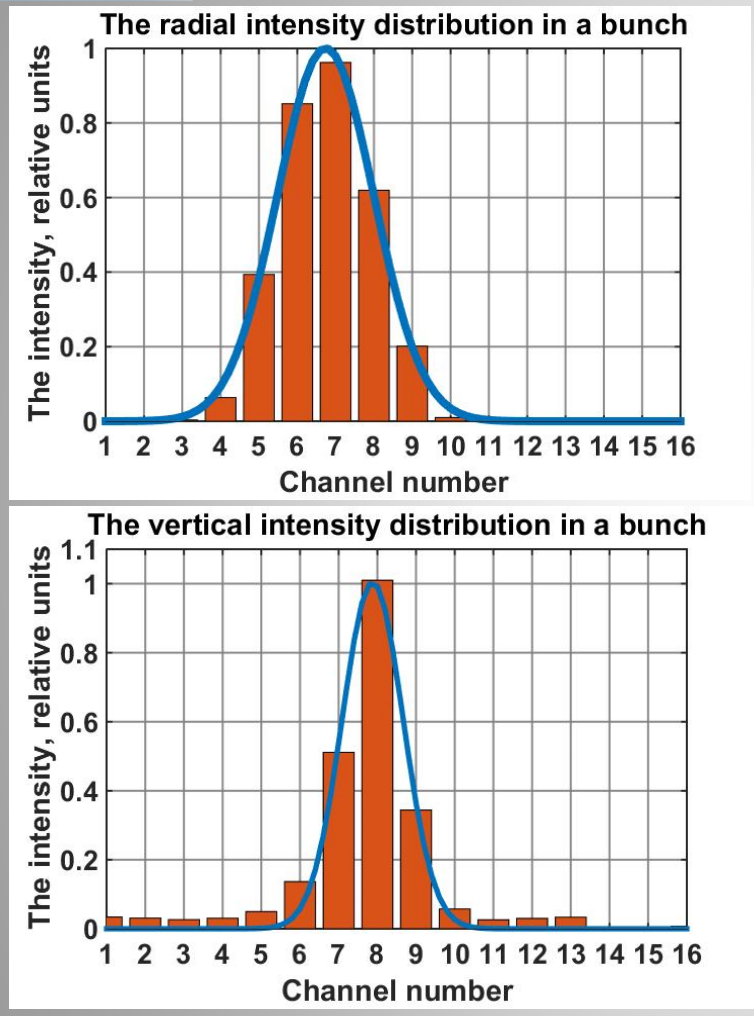
# The “new” turn-to-turn beam profile monitor

The Multi-channel registration of each bunch is possible but requires 16-channel ADC with 200 MHz sampling rate. The compromise solution is to record every 5th bunch with the ability to select a specific sequence of bunches (16-channel 50 MHz ADC with serial outputs is used). Any sequence can be chosen by configuring the synchronization unit via device graphical user interface.

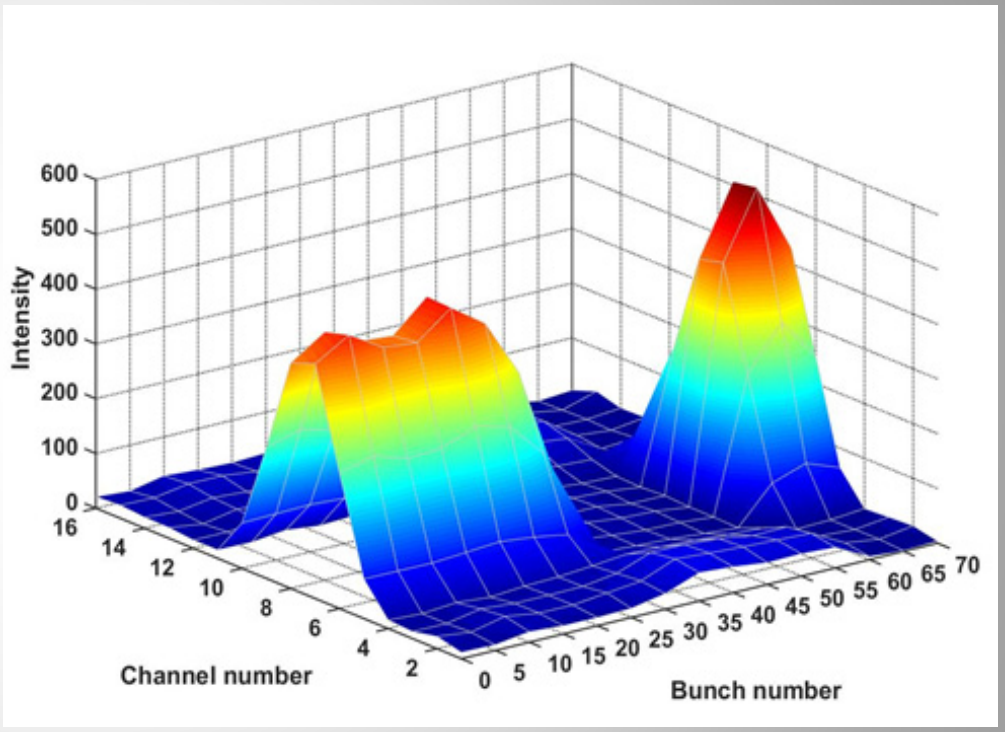



*The selection of the different sequence of bunches.*
*Any sequence can be selected by shifting of the trigger pulse*

# The “new” turn-to-turn beam profile monitor

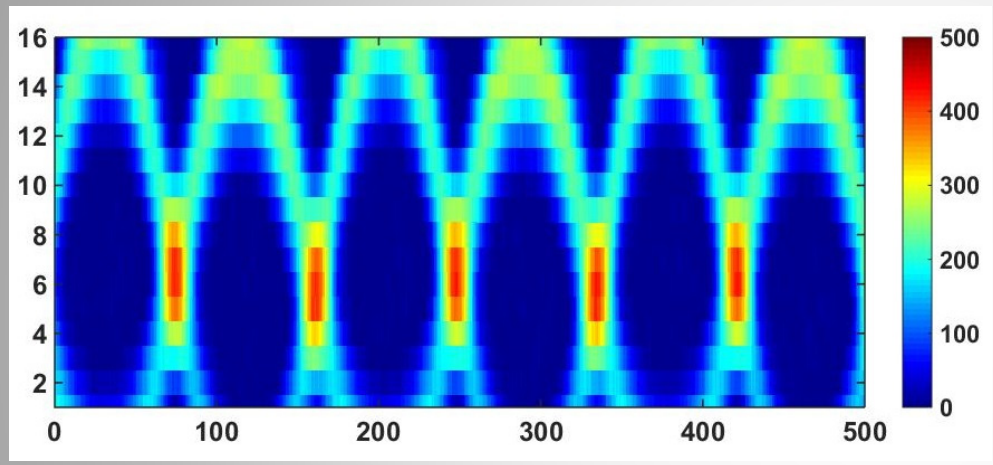



*Horizontal and vertical bunch profiles*

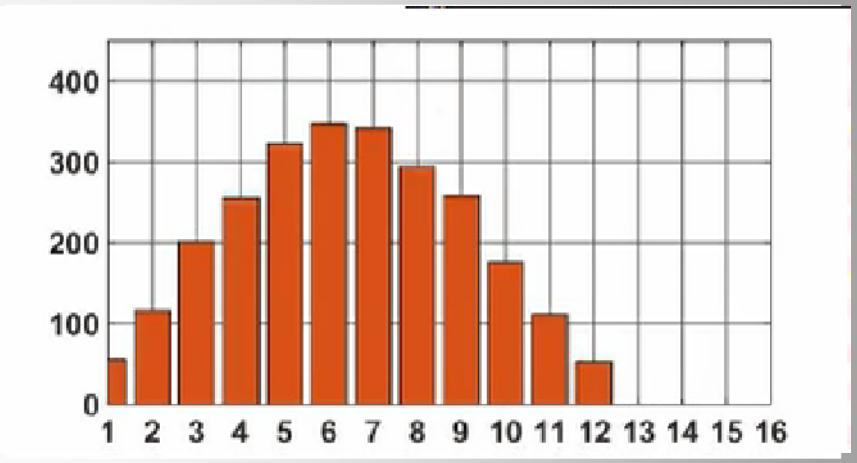



*The horizontal profiles of the bunches at different separatrix of SIBERIA-2 acquired at one turn of the beam*

# The “new” turn-to-turn beam profile monitor

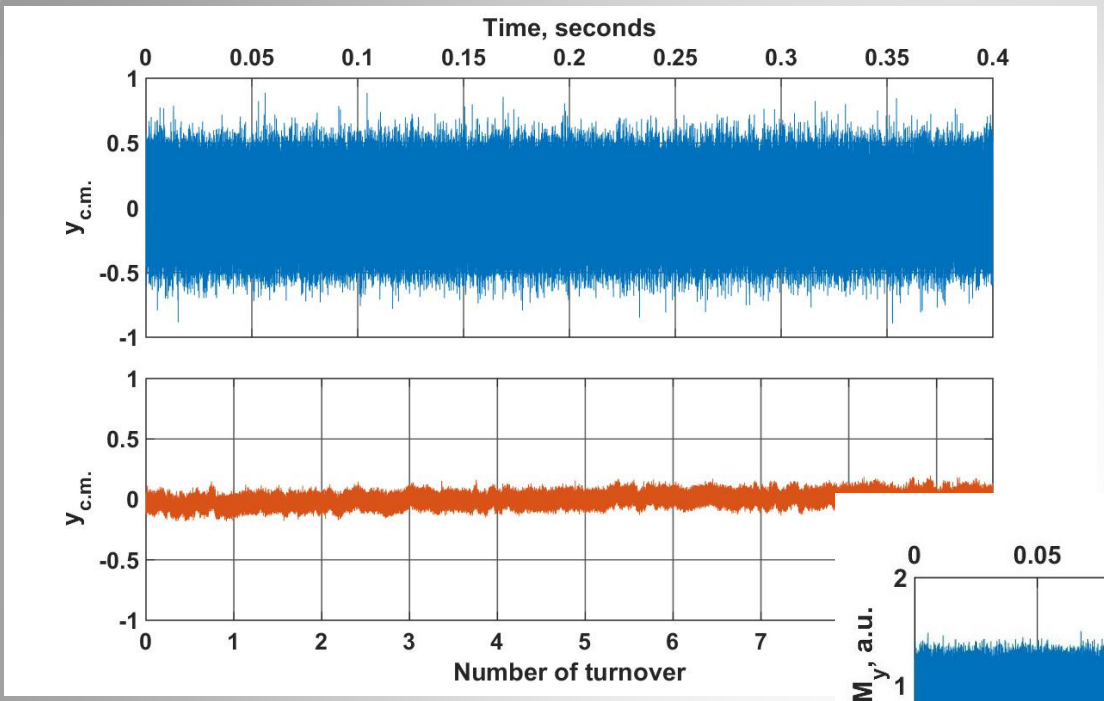



*Beam evolution during phase oscillations in a horizontal plane*

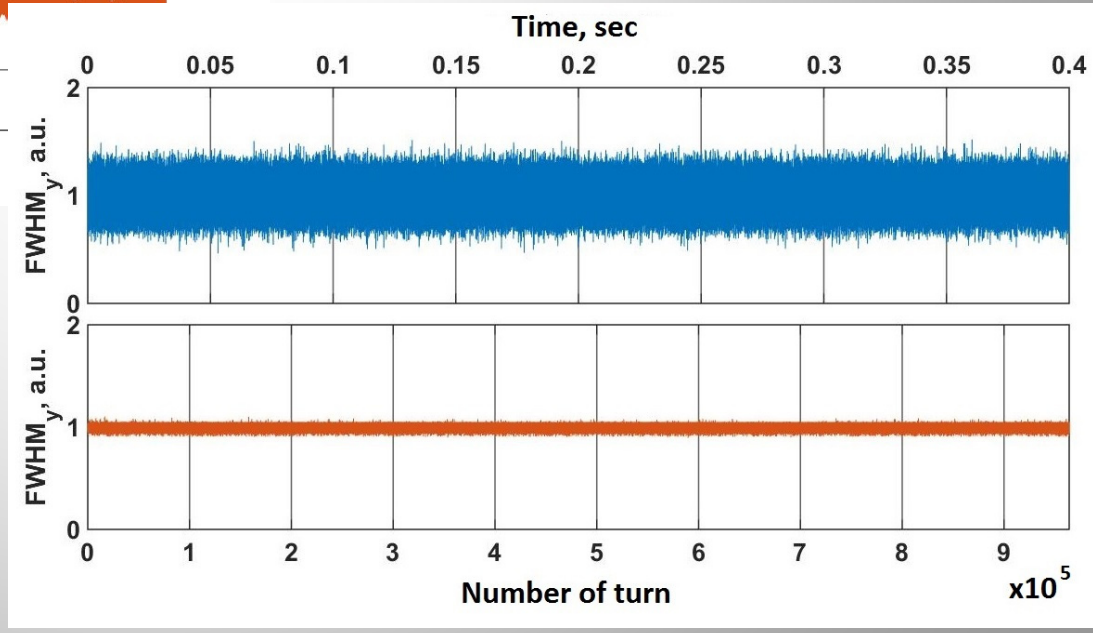



*Turn to turn horizontal distribution in a bunch during phase oscillations*

# The “new” turn-to-turn beam profile monitor



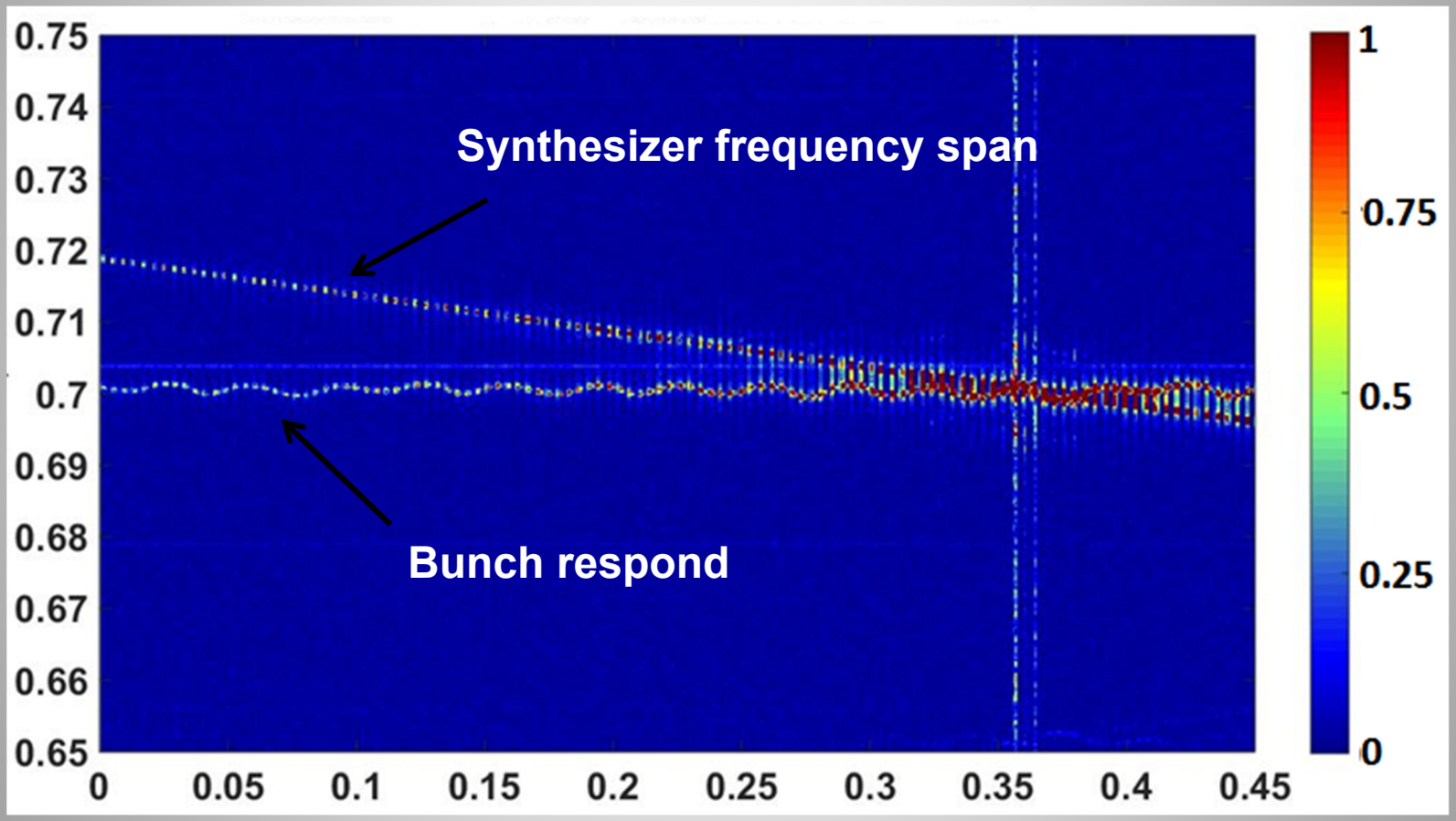

*The coordinate of the center of mass of the bunches acquired by old (blue) and new (red) FPM at the same conditions*




*The half width of the bunch acquired by old (blue) and new (red) FPM at stable beam conditions*

# The “new” turn-to-turn beam profile monitor

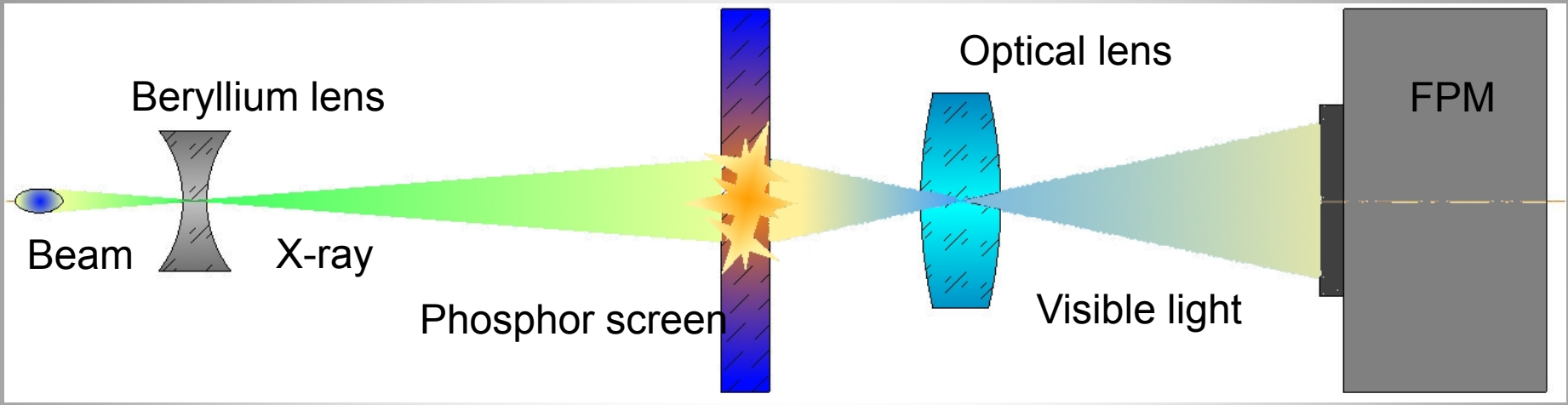
*The spectrogram of the coordinate of the center of mass of the vertical beam profile registered over the ~ 1.6-million revolutions*



# DISCUSSION

The FPM can be applied for routine runs of cyclic accelerators, but is more useful for experiments in the accelerator physics. The new profile monitor based on linear APD array has a better parameters and more experimental opportunities in comparing with the predecessor.

# DISCUSSION




The spatial resolution of the optical diagnostics is restricted by the diffraction limit, but this problem can be solved with X-ray optics, say, a beryllium lens. The phosphors with a response time about 3 ns can be manufactured now. It allows acquiring the beam image created by beryllium lens with a proper temporal resolution.

# Conclusion

- The Fast Profile Meter based on avalanche photodiode array is successfully tested at SIBERIA-2 storage ring.
- The new device can acquire above $1.5 \times 10^6$ measurements of the vertical or horizontal electron beam profile at 16 points with a temporal resolution of 5 ns at 50 MHz rate.
- It has become possible to measure the profiles of the selected bunches of the beam and study the multi-bunch beam instabilities.

# Thank you for attention!