HARP Note 04-001

ALIGNMENT OF THE HARP TOF-WALL

D. Gibin, A. Guglielmi, M. Laveder, M. Mezzetto
Dipartimento di Fisica "G.Galilei" and INFN, Padova, Italy

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Abstract

The position offsets of TOFW with respect to the NDC chambers have been determined together with a new estimation of the effective velocity of the light inside the scintillators.

1 Introduction

This notes describes the procedure used to obtain the geometrical alignment of the TOFW with respect to the NDC chambers. The TOFW offsets δ_x, δ_y along the X and Y directions are defined by the following relations:

$$\delta_x \equiv x_{NDC} - x_{TOFW} \qquad \delta_y \equiv y_{NDC} - y_{TOFW} \tag{1}$$

were (x_{NDC}, y_{NDC}) are the particle coordinates as measured by the NDC and then extrapolated to the TOFW and (x_{TOFW}, y_{TOFW}) are the corresponding track coordinates as determined by the TOFW itself. The adopted procedure to extract δ_y is given in section 2, while section 3 describes how to obtain δ_x. A new estimation of the effective velocity of the light inside the scintillators is then given in section 4. In the case of TOFW lateral palisades (Left and Right), one more offset δy_L has to be introduced (section5) to account for a systematic effect in the calibration procedure with cosmic rays:

$$\Delta y_L \equiv y_{NDC} - (y_{TOFW} + \delta_y) \tag{2}$$

where y_{TOFW} is the reconstructed event coordinate as measured by the TOFW corrected for the vertical displacement δ_y.
The event reconstruction is based on the V6r0 version of the HARP reconstruction code.

2 TOFW: vertical alignment

The TOFW central palisade consists of 13 counters 180 cm long, 21 cm wide and 2.5 cm thick that lie horizontally and are overlapped by 2.5 cm as shown in fig.2 . They are numbered from 0 (top) to 12 (bottom), therefore the zero of the vertical coordinate as measured by the TOFW is the center of counter n. 6. The distribution of the beam particle hits on the TOFW central palisade in no target conditions is shown in fig.1: the most hitted counter is n.7, clearly indicating a vertical displacement of the TOFW with respect to the beam position.

In order to center the TOFW on the beam in the vertical direction , beam particles passing through the overlap between counter n.6 and n.7 are measured. The data sample listed in table1 is analyzed with the following requirements :

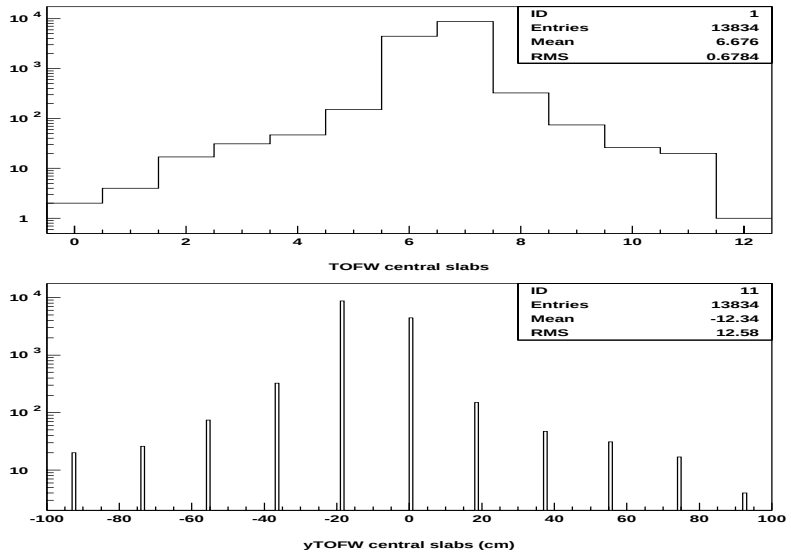

Figure 1: Distribution of beam particles (1 track events) on the TOFW central counters.

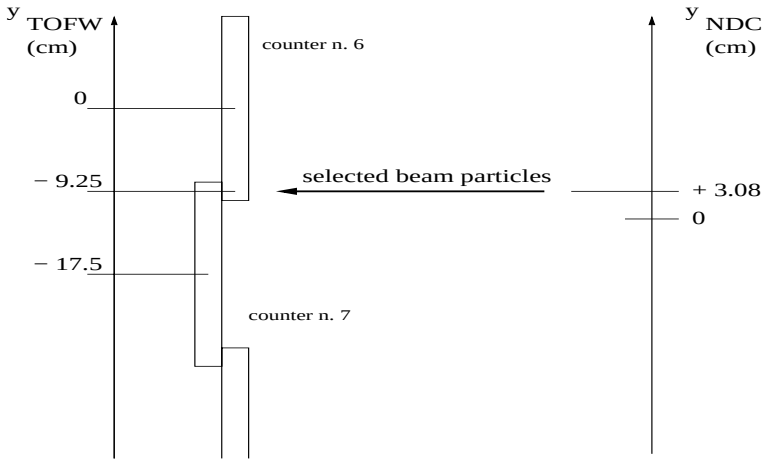

Figure 2: Geometry relative to the measurement used for the vertical alignment of the TOFW.

- beam particles: 1 reconstructed track in the NDC (> 21 points);
- only two hits in the central palisade of the TOFW;
- both the counter n. 6 and 7 are fired with a charge deposition $0.8 \div 2$ mip;
- a good match between NDC and TOFW is required in the horizontal plane, $|x_{NDC} - x_{TOFW}| \leq 5\,cm$, where no major effects have been observed.

The resulting event distribution of the vertical coordinate in the overlap between counter n. 6 and n. 7 as measured by NDC is centered at $y_{NDC}(\text{overlap}\,6-7) = 3.1\,cm$ (fig.

3). Therefore accounting for the position of the overlap 6-7 in the TOFW reference $y_{TOFW}(\mathrm{overlap}\,6-7) = -9.25\,cm$ the global vertical offset is:

$$\delta y \equiv y_{NDC} - y_{TOFW} = (3.1 + 9.25)\,cm = 12.3\,cm. \tag{3}$$

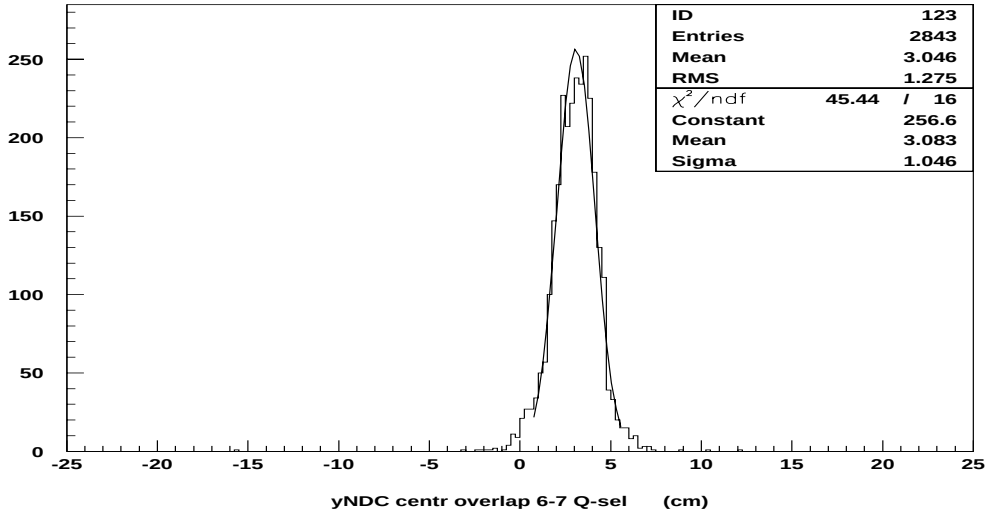

Figure 3: Vertical distribution of events in 2.5 cm overlap between TOFW central horizontal counters number 6 and 7 as measured by NDC.

run	events	setting	target id	momentum (GeV/c)	dipole current (A)	solenoid current (A)
13578	101085	416	0	-3.00	2910.00	889.40
13579	49255	415	0	-3.00	2910.00	889.40
12701	36928	369	0	-5.00	0	0
18363	96032	725	0	-5.00	2910.00	889.40
18364	72395	725	0	-5.00	2910.00	889.40
13423	46365	427	0	-8.00	2910.00	889.40
13463	70424	427	0	-8.00	2910.00	889.40
13517	77915	427	0	-8.00	2910.00	889.40
12843	42422	390	0	-12.00	2910.00	889.40
13614	74401	432	0	-12.00	2910.00	889.40

Table 1: List of runs used in the analysis for the TOFW vertical alignment. All runs considered have no target (target id = 0).

3 TOFW: horizontal alignment

To center the TOFW on the beam in the horizontal direction, the position x_{TOFW} of beam particles passing through the central region of NDC, $x_{NDC} \simeq 0$, are measured. The data of runs listed in table 2 are selected by requiring:

- up to 5 reconstructed tracks in NDC with more than 21 points per track;
- up to 5 particles hitting the TOFW-Central palisade with ($0.8 \div 2$ mip) of deposited charge;
- the NDC track must be well matched in the vertical plane to the hit position in TOFW corrected for the previous offset δ_y: $|y_{NDC} - (y_{TOFW} + \delta_y)| \leq 5\,cm$;
- only the reconstructed tracks at the center of the NDC are selected, $|x_{NDC}| \leq 2.5\,cm$.

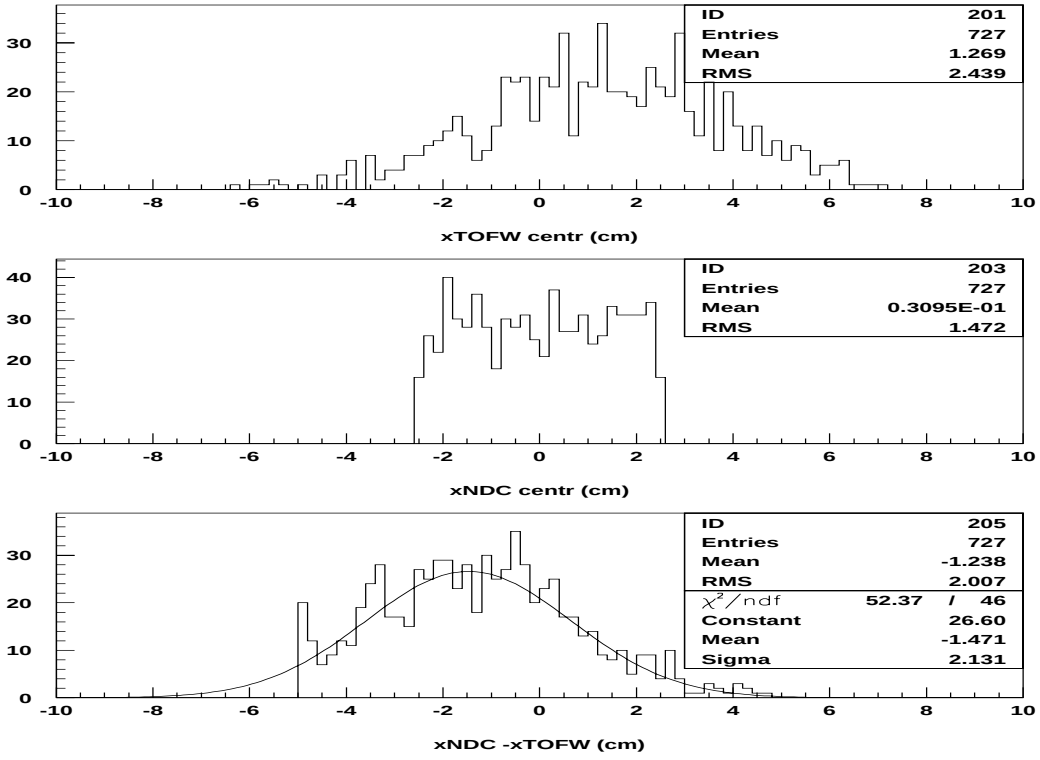

Figure 4: Distributions of the horizontal coordinates of the selected events as measured by TOFW-central palisade (top) and by NDC (center) and of their corresponding differences $x_{NDC} - x_{TOFW}$ (bottom).

The resulting event distributions of horizontal coordinates as measured by TOFW and NDC are displayed in fig.4. The distribution of the difference, on event by event basis, between NDC and TOFW horizontal event coordinates is centered at

$$\delta x \equiv x_{NDC} - x_{TOFW} = -1.5\, cm. \tag{4}$$

run	events	setting	target id	momentum (GeV/c)	dipole current (A)	solenoid current (A)
13578	101085	416	0	-3.00	2910.00	889.40
13579	49255	415	0	-3.00	2910.00	889.40
12701	36928	369	0	-5.00	0	0
18363	96032	725	0	-5.00	2910.00	889.40
18364	72395	725	0	-5.00	2910.00	889.40
13423	46365	427	0	-8.00	2910.00	889.40
13463	70424	427	0	-8.00	2910.00	889.40
13519	48262	422	0	-15.00	2910.00	889.40
13532	50731	422	0	-15.00	2910.00	889.40
13551	42409	422	0	-15.00	2910.00	889.40
13569	48414	422	0	-15.00	2910.00	889.40
19130	95855	804	0	+1.50	-1455.00	-889.40
19131	96285	804	0	+1.50	-1455.00	-889.40
14459	79078	494	0	+5.00	-2910.00	-889.40
13865	96691	461	0	+8.00	-2910.00	-889.40
13866	93941	461	0	+8.00	-2910.00	-889.40
15049	79502	506	0	+12.00	-2910.00	-889.40
15269	81182	519	0	+15.00	-2910.00	-889.40
15270	81076	519	0	+15.00	-2910.00	-889.40

Table 2: List of runs used in the analysis for the TOFW horizontal alignment. All runs considered have no target (target id = 0).

4 Determination of effective velocity of the light

The correct reconstruction of the hit position along a counter is based on a good measurement of the propagation velocity of the light inside the scintillators. The default approximated value present in the HARP TOFW reconstruction code at the time of this work was equal to $c/2$, where c is the light velocity in vacuum. To measure the

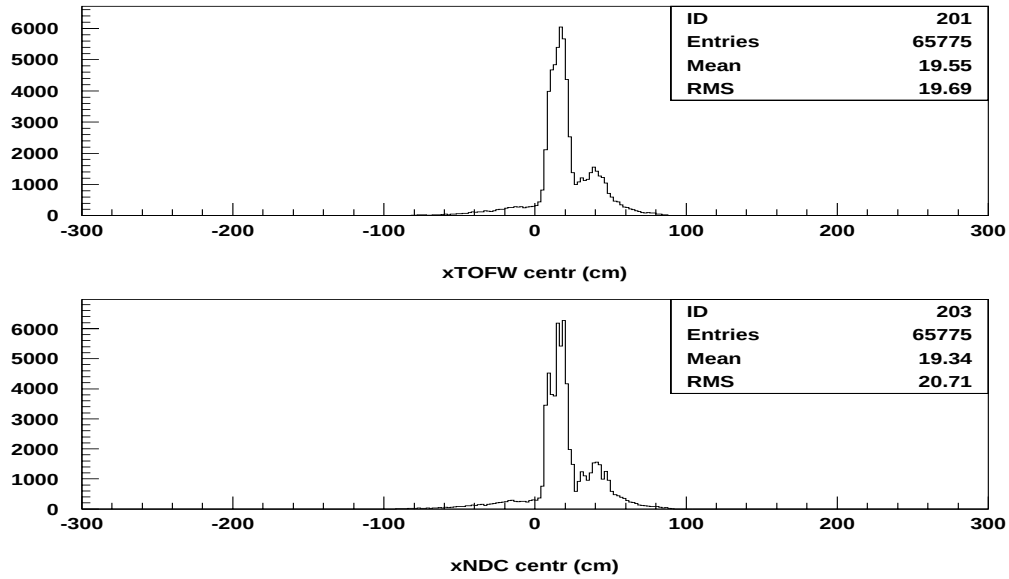

Figure 5: Distributions of the horizontal coordinates of the selected events as measured by TOFW-central palisade(top) and by NDC (bottom).

effective light velocity the reconstructed hit horizontal position on TOFW central palisade and on the faced NDC are measured selecting the events of runs listed in table 2 with the requirements:

- up to 5 reconstructed tracks in NDC with more than 21 points per track;
- up to 5 particles hitting the TOFW-central palisade with ($0.8 \div 2$ mip) of deposited charge;
- the NDC track must be well matched in the vertical plane to the hit position in TOFW corrected for the δ_y offset: $|y_{NDC} - (y_{TOFW} + \delta_y)| \leq 5\,cm$.

The resulting x_{TOFW} and x_{NDC} distributions are shown in (fig. 5). The effective velocity of the light in the scintillators is determined on the event by event basis, having included the δ_x, as:

$$v_{eff} = \frac{x_{NDC}}{x_{TOFW} + \delta_x} \cdot \frac{c}{2} \tag{5}$$

whose average value is $v_{eff} = 1.067 \cdot c/2$ (fig. 6). Therefore the parameter v_{eff}^{-1} is

$$v_{eff}^{-1} = 6.2\,\frac{ns}{m}\,. \tag{6}$$

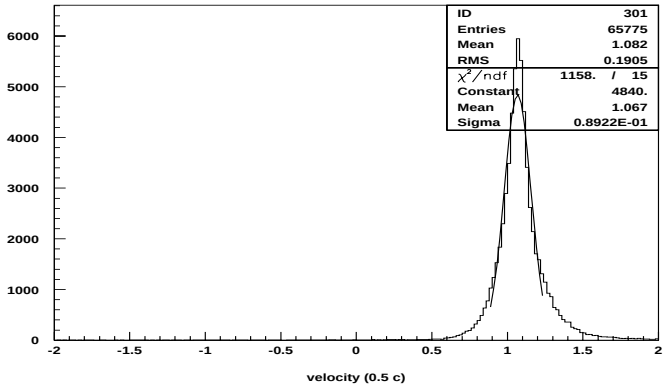

Figure 6: Distribution of the measured value of effective velocity of the light inside the scintillators in unit of 0.5 c.

5 Offset in lateral palisades

In lateral vertical counters (Left and Right palisades) the reconstruction of the TOFW vertical coordinate y_{TOFW} is affected by an additional systematic effect related to the cosmic ray calibration configuration used to measure the $y_{TOFW} = 0$ on the counters (fig.7). In fact, despite that the centers of TOFW lateral counters with the two calibration counters were aligned along a line with zenith angle $\theta = 45^o$, the preferred inclination of cosmic ray tracks during calibration resulted to be smaller, $\theta = 40^o$. As a consequence the cosmic rays cross the counters at an average position vertically displaced by a quantity Δy_L with respect to the geometrical center of the slabs.

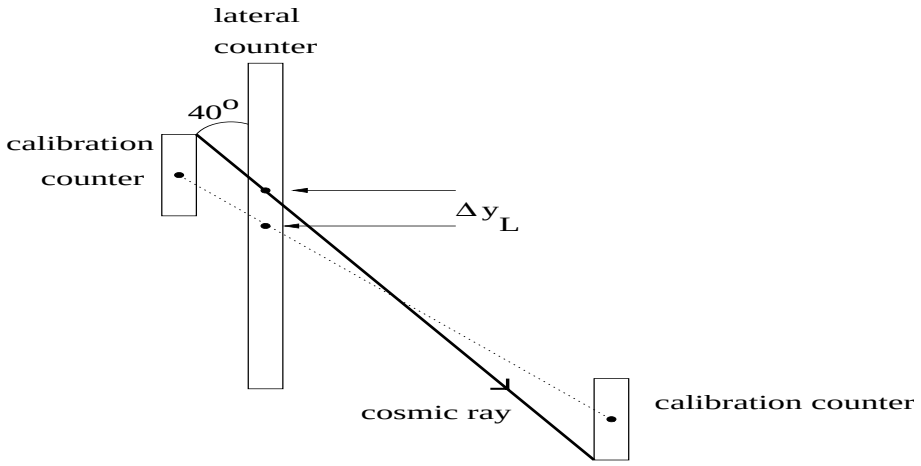

Figure 7: Lateral view of the setup used to determine the TOFW calibration constants for Left and Right lateral palisades (not in scale).

Therefore, to estimate this new offset Δy_L, the vertical coordinates y_{NDC} and y_{TOFW} of beam particles passing through the lateral palisades, the latest corrected for the previous offset δ_y, are measured. The events of runs in table 2 are analyzed with the

following requirements:

- up to 5 reconstructed tracks in NDC with more than 21 points per track;
- up to 5 particles hitting the TOFW lateral palisades with ($0.8 \div 2$ mip) of deposited charge;
- NDC tracks are well matched in the horizontal plane to the hit position in TOFW, corrected for the previous offset δ_x: $|x_{NDC} - (x_{TOFW} + \delta_x)| \leq 5\,cm$;
- the measured light velocity inside the scintillators is included.

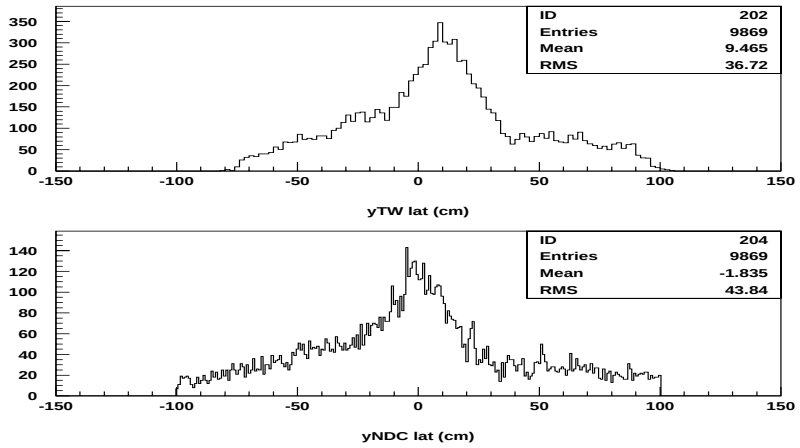

Figure 8: Distributions of the vertical coordinates of the selected events as measured by TOFW lateral palisades (δ_y correction included) (top) and by NDC (bottom).

The resulting distributions of the event y coordinates as measured by TOFW and NDC are displayed in fig.8. The average value of the reconstructed TOFW coordinate $(y_{TOFW} + \delta_y)$ is shifted to a positive value with respect to the NDC reconstruction (fig. 8). To better evaluate this effect the events reconstructed as $|y_{NDC}| \leq 2.5\,cm$ by NDC are selected. The final distribution of the difference between NDC and TOFW vertical event coordinates is shown in fig.9; the average value corresponding to the offset Δy_L is:

$$\Delta y_L \equiv y_{NDC} - (y_{TOFW} + \delta_y) = -10.8\,cm. \tag{7}$$

This effect happens to compensate the geometrical displacement δ_y in lateral palisades, resulting in a 1.5 cm only global effective correction on the vertical coordinate:

$$y_{NDC} = (y_{TOFW} + \delta_y) + \Delta y_L = y_{TOFW} + 1.5\, cm.$$

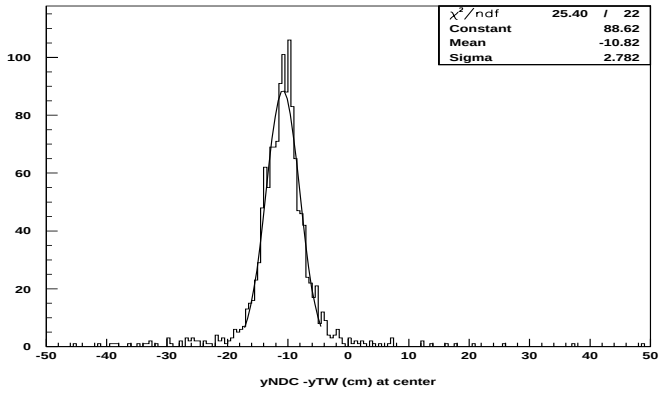

Figure 9: Difference between NDC and TOFW vertical event coordinates when beam particles are selected at the center in a 5 cm window around $y_{NDC} = 0$ position.

6 Conclusions

The geometrical offsets of TOFW with respect to the NDC chambers have been measured to be $\delta_x = -1.5\, cm$ and $\delta_y = 12.3\, cm$ respectively, so that

$$x_{NDC} = x_{TOFW} + \delta_x, \qquad y_{NDC} = y_{TOFW} + \delta_y.$$

In the case of the TOFW lateral palisades (Left and Right) one more offset $\Delta y_L = -10.8\, cm$ must be included for a systematic effect present in the calibration procedure with cosmic rays which compensates the δ_y offset:

$$y_{NDC} = (y_{TOFW} + \delta_y) + \Delta y_L = y_{TOFW} + 1.5\, cm.$$

From more precise measurements, the effective velocity of the light inside the scintillators is found to be:

$$v_{eff}^{-1} = 6.2\, \frac{ns}{m}.$$