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Addendum to the HARP WhiteBook

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Abstract

In this Addendum to the HARP WhiteBook, gross contradictions are discussed between (i) the 2006 HARP Status Report to the SPSC, (ii) the HARP Technical Paper, (iii) the 'Rebuttal' of our 'Comments' on the HARP Technical Paper, and (iv) the IEEE Paper on the RPC performance, all of which were published within three months only. It is shown that the published TPC p_{T} resolution of $\sim 30\%$ at $p_{\mathrm{T}} = 1$ GeV/c, the published intrinsic RPC time resolution of ~ 140 ps, and the published overall time resolution of 305 ps for pion tracks cannot co-exist, and thus cannot be part of a coherent physics analysis.

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1 Preamble

On 20 October 2006, our group became aware by way of an email sent by J.J. Blaising, CERN-PH Department Leader, that 'official' HARP had submitted in August 2006 a paper for publication in IEEE [1], entitled 'Physics Performance of the Barrel RPC System of the HARP Experiment'. The authors of this paper are M. Bogomilov, A. Artamonov, S. Giani, D. Kolev, J. Panman, R. Tsenov, and I. Tsukerman.

This paper — which has the spokesperson at that time as co-author — has never been circulated within the HARP Collaboration, in contradiction to claims put forward by the acting spokesperson in an email sent on 17 October 2006 to S. Bertolucci, J.J. Blaising, T. Carli and L. Rolandi. The paper was never listed among 'Drafts' [2] or among 'Conference Contributions' [3] on the pertinent 'official' HARP web pages.

Our group — which by the way has 100% ownership of the RPCs in terms of design, construction, and operation, and unquestionable priority in high-precision calibration of the RPCs — had before J.J. Blaising's email no knowledge whatsoever of this IEEE Paper (otherwise we would have strongly protested as we did with the HARP Technical Paper [4]).

The preparation and submission of this IEEE Paper under such circumstances raises a number of serious questions.

Most of them are for others to answer.

Yet after examination of the IEEE paper, we consider it our professional duty to make the scientific community aware of the contradictions between the following four papers which were all published within three months only (July to September 2006):

1. the 2006 HARP Status Report to the SPSC [5];
2. the IEEE Paper [1];
3. the HARP Technical Paper [4]; and
4. the 'Rebuttal' [6] of our 'Comments' [7] on the HARP Technical Paper.

Out of our many critical comments on the 'official' large-angle analysis in our WhiteBook [8] — which we all keep up — we recall here one that is of particular relevance for a correct physics analysis of large-angle production of pions and protons: we stated (WhiteBook, Section 3.1, p.25)

'that the real momentum resolution of 'official' data is somewhere between 50 and 100%, i.e. significantly worse than the 'official' resolution of

$$\Delta p_{\rm T}/p_{\rm T} = (0.25 \pm 0.01)p_{\rm T} + (0.04 \pm 0.005)\ ({\rm GeV}/c)^{-1}$$

claimed in the Final Draft of the HARP Technical Paper'.

The (for us) unexpected appearance of the IEEE Paper was instrumental as it contains new information that makes the inconsistencies between the above cited four 'official' papers publicly visible. Without the need of insiders' knowledge, anybody is now able to reproduce the arguments that are developed below.

In the following, we prove that

- **either the reported ~ 140 ps intrinsic RPC resolution is grossly wrong,**
- **or the reported $\sim 30\%$ TPC p_T resolution at $p_\mathrm{T} = 1$ GeV/c is grossly wrong,**
- **or both.**

2 TPC resolution versus RPC resolution

In this Section, we derive a formula that translates a given RPC system time resolution[1] into the equivalent TPC p_T resolution.

We consider particles the transverse momentum p_T of which is measured in the TPC, and the velocity $\beta = v/c$ of which is measured in the barrel RPCs. From the *measured* velocity β and the reconstructed track length one can calculate the *predicted* p_T, and *vice versa.*

We discuss in terms of $1/p_\mathrm{T}$ rather than in terms of p_T because of the Gaussian resolution of the former.

The relation between $p_\mathrm{T}^\mathrm{RPC}$ and β is

$$\frac{1}{p_\mathrm{T}^\mathrm{RPC}} = \frac{\sqrt{1/\beta^2 - 1}}{m \ \sin\theta} \ , \tag{1}$$

where m is the particle rest mass and θ the track's polar angle.

Differentiation gives the resolution of this quantity:

$$\sigma_{1/p_\mathrm{T}^\mathrm{RPC}} = \Delta(1/p_\mathrm{T}) = -\frac{\Delta p_\mathrm{T}}{p_\mathrm{T}^2} = \frac{d(1/p_\mathrm{T})}{d\beta}\Delta\beta \ , \tag{2}$$

where $\Delta\beta$ is the resolution of the velocity measurement. The latter is determined by the RPC system time resolution and the resolution of the measurement of the track length L in the TPC:

$$\Delta\beta = \frac{1}{c}\sqrt{\left(\frac{\Delta L}{t_\mathrm{TOF}}\right)^2 + \left(\frac{L\Delta t}{t_\mathrm{TOF}^2}\right)^2} \ . \tag{3}$$

[1] The RPC 'system time' resolution results essentially from the convolution of the 'intrinsic' RPC time resolution with the time jitter of the time of arrival of the beam particle at the target.

Numerically, the first term is small in comparison with the second term and can be neglected[2]. Therefore we get

$$\Delta\beta \simeq \frac{\beta}{t_{\rm TOF}}\Delta t = \frac{c\beta^2}{L}\Delta t = \frac{c\beta^2 \sin\theta}{R}\Delta t \; , \tag{4}$$

where $R \simeq 43$ cm is the radius of the RPC cylinder. By equating L with $R/\sin\theta$, we neglected the track curvature which is a valid approximation.

For the second component of $\sigma_{1/p_{\rm T}^{\rm RPC}}$ in Eq. (2) we get:

$$\frac{d(1/p_{\rm T})}{d\beta} = \frac{-1}{m\beta^2 \sin\theta} \frac{1}{\sqrt{1-\beta^2}} \; . \tag{5}$$

Inserting the expressions (4) and (5) into Eq. (2) we get eventually the formula that we need for the further discussion:

$$\sigma_{1/p_{\rm T}^{\rm RPC}} = \frac{c}{m\; R\; \sqrt{1-\beta^2}} \, \Delta t \; . \tag{6}$$

Numerically, the resulting $\sigma_{1/p_{\rm T}} = \left|\frac{\Delta p_{\rm T}}{p_{\rm T}^2}\right|$ denotes the relative $p_{\rm T}$ resolution at $p_{\rm T} = 1$ GeV/c.

The resolution $\sigma_{1/p_{\rm T}^{\rm RPC}}$ does not depend on the polar angle θ (apart from a small residual dependence on θ because the measured RPC time resolution depends slightly on the pad ring number and thus on θ).

3 Published 'official' claims on the TPC $p_{\rm T}$ resolution

In Section 5.1.9 (p.30f) of the HARP Technical Paper the $p_{\rm T}$ resolution for cosmic-ray muons is quoted as

$$\Delta p_{\rm T}/p_{\rm T} = (0.25 \pm 0.01) p_{\rm T} + (0.04 \pm 0.005)\; ({\rm GeV}/c)^{-1} \; . \tag{7}$$

Although not said explicitly, the reader is clearly led to believe that this resolution also applies for physics tracks[3].

Explicit confirmation of this is found in the 'Rebuttal' in Section 3.5 (p.15), where a $p_{\rm T}$ resolution of $(30 \pm 3)\%$ at $p_{\rm T} = 1$ GeV/c is strongly confirmed.

Further explicit confirmation is found in the IEEE Paper in Section IV B (p.7) where it is stated that the relative momentum resolution — of ~ 200 MeV/c pions, as can be derived

[2]For example, for a relativistic particle at $\theta = 90°$, the distance is 43 cm and the time-of-flight is 1400 ps; with $\Delta L \sim 0.5$ cm and $\Delta t \sim 180$ ps we get for the first term 1.3×10^{-7} and for the second term 1.6×10^{-5}.

[3]There is nowhere a statement to the contrary.

from *'the derivative $\delta(\beta)/\delta(p)$ between two and one'* — is $\approx 10\%$. This checks well with $25 \cdot 0.2 + 4 = 9\%$ from Eq. (7).

Therefore, Eq. (7) represents the 'official' HARP p_{T} resolution for physics tracks. In the following, we use a p_{T} resolution of 30% at $p_{\mathrm{T}} = 1$ GeV/c.

4 Published 'official' claims on the intrinsic RPC time resolution

The published 'official' intrinsic RPC time resolution was strongly varying with time. It is instructive to study Table 1 which recalls succinctly the 'official' claims and — for comparison — the claims made by our group, in time-ordered mode. It is not clear why the HARP Technical Paper reports — at nearly the same time — a resolution of 203 ps while the IEEE Paper and the 'Rebuttal' report a resolution of 141 ps.

Table 1: Time-ordered claims on intrinsic RPC time resolution (ps).

Date	'Official'	Our group
August 2003 [9]		150
September 2004 [10]	≈ 400	
November 2004 [11]		146
March 2005 [12]		140
December 2005 [13]	199	
August 2006 [1]	141	
September 2006 [4]	203	
September 2006 [6]	141	
October 2006 [14]		127

In the following, we use an intrinsic RPC time resolution of 140 ps.

5 What is wrong with pion tracks?

In this Section, we discuss the inconsistencies of published 'official' statements on the physics performance of pion track reconstruction.

Figure 12 in the IEEE Paper (p.7) asserts that the experimentally determined overall time resolution, that is the convolution of the RPC system time resolution and the equivalent TPC p_{T} resolution, is

$$305 \text{ ps} .$$

Subtracting quadratically an intrinsic RPC time resolution of 140 ps, and a beam timing resolution of 70 ps, one gets 260 ps (as correctly stated in the paper on p.6).

From Eq. (6) with $\Delta t = 260$ ps, $m = m_\pi$, and an average pion velocity of $\beta = 0.82$ (for an average pion momentum of 200 MeV/c, read from Fig. 15 on p.8 of the IEEE Paper, and stipulated *ibidem* on p.7) one gets

$$\sigma_{1/p_{\rm T}^{\rm RPC}} \simeq 2.3\ ({\rm GeV}/c)^{-1}\ . \qquad (8)$$

This result[4] gives for 200 MeV/c pions a resolution of 46%, which is to be compared with 9% from Eq. (7), and with the claim of $\approx$ 10% (IEEE Paper p.7).

We claim a bad TPC performance in the 'official' analysis but not even we can imagine that it is that bad. Therefore, while we consider this result as confirmation that the 'official' TPC $p_{\rm T}$ resolution is not correct, we conclude that also the 'official' intrinsic RPC resolution cannot be correct.

The published 30% TPC $p_{\rm T}$ resolution, the published 140 ps intrinsic RPC time resolution, and the published 305 ps overall time resolution for pion tracks exclude each other, and cannot possibly be part of a coherent physics analysis.

6 What is wrong with proton tracks?

6.1 $p_{\rm T}$ resolution from proton elastic scattering

We point to contradictory evidence presented in the 2006 HARP Status Report to the SPSC (Sections 4.1 and 4.2, p.23ff) on the physics performance of proton track reconstruction.

1. From the sentence on p.28 *'The θ resolution is shown as a function of the momentum of the proton when it enters the gas'* we infer that the same is the case for the proton momentum shown in Fig. 29 on p.30;

2. From Fig. 25 on p.26 one reads for a momentum of 400 MeV/c a relative resolution $\Delta p_{\rm T}/p_{\rm T} \sim 0.15$, consistent with 0.14 calculated from Eq. (7);

3. From Fig. 29 on p.30 one reads for 400 MeV/c protons from elastic proton scattering a relative resolution $\Delta p/p \sim 0.38$ (never mind the mistake in the ordinate label);

4. On p.27 it is stated that the polar angle of these protons is 70 degrees, hence p is very close to $p_{\rm T}$;

5. So what is the origin of this discrepancy between 0.14 and 0.38?

[4] We caution, though, that the linear approximation breaks down when the variation becomes comparable to the average.

6. On p.28 one reads the explanation: *'The momentum resolution at low momentum is dominated by the straggling of the energy-loss, therefore a comparison with the simulation is needed. The comparison of the measured and simulated momentum resolution is shown as a function of momentum in Fig. 29'.*

First, we note that the momentum loss (caused by energy loss from ionization) of a 400 MeV/c proton in the material before entering the TPC is about 25 MeV/c. This momentum loss has a statistical 'straggling' error of less than 15 percent, i.e. at most 4 MeV/c.

Therefore, we ask:

1. How can 'energy straggling' increase a claimed momentum resolution of $0.16 \cdot 400 =$ 64 MeV/c to the actually observed resolution of $0.38 \cdot 400 = 152$ MeV/c?

2. How can a Monte Carlo simulation reproduce such a result?

We conclude that the real p_{T} resolution for physics data (i.e. not for cosmic muons) in the 'official' HARP analysis is 0.38/0.14 = 2.7 times worse than the claimed p_{T} resolution, at 400 MeV/c momentum.

This conclusion invalidates the claim of a 'successful physics benchmark' from elastic proton–proton scattering for the very same reason that is the cause of the wrong '500 ps effect' discussed below.

6.2 The '500 ps effect'

The '500 ps effect' refers to the 'official' claim that the pion and proton time-slewing corrections differ by $\sim$ 500 ps. This claim is demonstrated in Figs. 7 (p.4), 15 and 16 (p.8) of the IEEE Paper, and at some length discussed on p.4.

It is repeated in the HARP Technical Paper with the phrase (Section 5.2.3, p.36f) *'The measured time-charge dependence for protons is shifted typically by about 500 ps towards shorter times due to their higher ionization rate, hence steeper rise of the pulse leading edge.'*

It seems that the authors consider this a real effect, if not a discovery. In fact, it is plain nonsense, not worth a further discussion[5].

The origin of this nonsense is that the authors did not appreciate the consequences of their bad TPC p_{T} resolution for the calculation of proton velocities.

7 Synopsis and Epilogue

We have conclusively shown that the published 'official' TPC p_{T} resolution of $\sim$ 30% at $p_{\mathrm{T}} = 1$ GeV/c, the published 'official' intrinsic RPC time resolution of $\sim$ 140 ps, and the

[5]For a correct analysis of the situation see Ref. [14].

published ‘official’ overall time resolution of 305 ps for pion tracks cannot co-exist. Thus they cannot be part of a coherent physics analysis as ‘officially’ purported.

We tried a synopsis of the inconsistencies published in the aforementioned four ‘official’ papers.

A possible scenario could be the following: a (bad) TPC p_{T} resolution of 100% at 1 GeV/c which is for pions equivalent to a time resolution of 114 ps according to Eq. (6); a (realistic) beam timing resolution of 110 ps; and a (bad) intrinsic RPC time resolution of 260 ps. Quadratically added, this would check with the reported total of 305 ps for pion tracks.

We wonder how such inconsistencies and obviously questionable results could successfully bypass all mechanisms that usually prevent wrong results from being published.

We wonder of the professional standard of authors who pretend in papers to the SPSC and to the public a consistent set of detector performances for physics analysis while the opposite is the case.

Then, in the name of the technical staff that built the RPCs: we wonder how the authors could dare publishing so blatantly wrong electronics characteristics as done in the IEEE paper, without having made any attempt to cross-check with the experts.

Finally, we wonder of the ethics level of authors who publish a CERN Scientific Document on the performance of the HARP RPCs without proper reference to those who designed, constructed and operated the RPCs.

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