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Parametrisation functions of the RPC based muon trigger

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Abstract

This note presents new parametrisation functions for the RPC based muon trigger, namely: ACCMRPC for the acceptance and EFFMRPC for the efficiency. The charge of the muon is taken into account. The detector region where $\mu^+\mu^-$ acceptance is equal is given by funcion ISYMRPC.

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1 Principles of operation

The RPC based muon trigger operates on four (logical) trigger planes MS1÷MS4. Each plane is equipped with strips (of about $5/16^o$ width each). A muon, passing solenoidal magnetic field of the detector crosses RPC planes, lighting strips on its way (Fig. 1). Due to bending in the magnetic field, the combination of lighted strips is correlated with the muon transverse momentum. Thus, comparison of lighted strips configuration (called pattern) with the set of predefined combinations (called set of valid patterns) gives information about muon momentum, enabling triggering.

The dead areas and chamber inefficiencies force us to introduce algorithm in which the event may be triggered even if only three hits in four chambers match a predefined pattern (called strong 3 out of 4 algorithm).

The detailed description of the RPC trigger algorithms and performance may be found elsewhere [1].

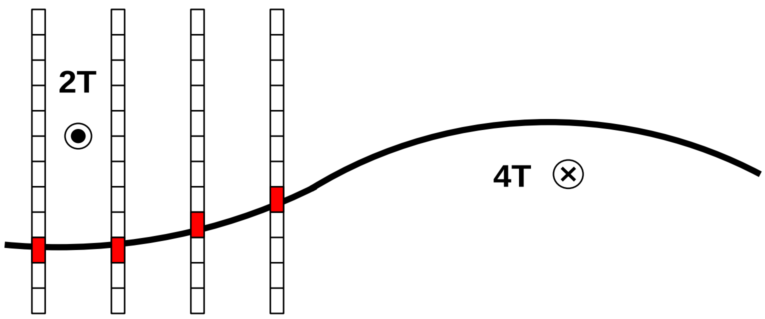


Figure 1: RPC trigger principle

2 The underlying simulation

The simulation study was performed using CMSIM 101[2] program based on GEANT package. The CMS layout corresponding to geometry version 14 (preliminary release) has been used (it is presented on Fig 2 where the RPC position is especially marked).

The RPC trigger system consists of six RPC planes in the barrel region, labelled MB1÷MB4,MB1',MB2' (MB stands for Muon Barrel) and of six RPC planes in the endcaps: MF0,MF1a,MF1b,MF2÷MF4 (here MF stands for Muon Forward). In each η direction only four planes are chosen (logical trigger planes MS1÷MS4), in such a way, that every high p_t muon should cross active areas of at least 3 of them. In the barrel four logical planes are chosen to be MB1+MB2+MB3+MB4 whereas in forward (MF0/MF1a/MF1b)+MF2+MF3+MF4. In the intermediate η regions the choice of four logical planes is more tricky, forward and barrel stations are combined together. Since in the barrel only relatively hard muons ($p_t > 6 \div 7 GeV/c$) may freely penetrate stations MS1÷MS4 (hence algorithm based on MB1÷MB4 is called high p_t trigger) two additional stations MB1',MB2' accomplishing MB1 and MB2 to form low p_t trigger to decrease minimal possible trigger thresholds (down to about 4 GeV/c).

The RPC trigger is segmented into 39 towers ($-19 \ldots 0 \ldots 19$) in pseudorapidity (see Tab. 1), covering pseudorapidity interval $|\eta| < 2.4$. For each tower independent set of

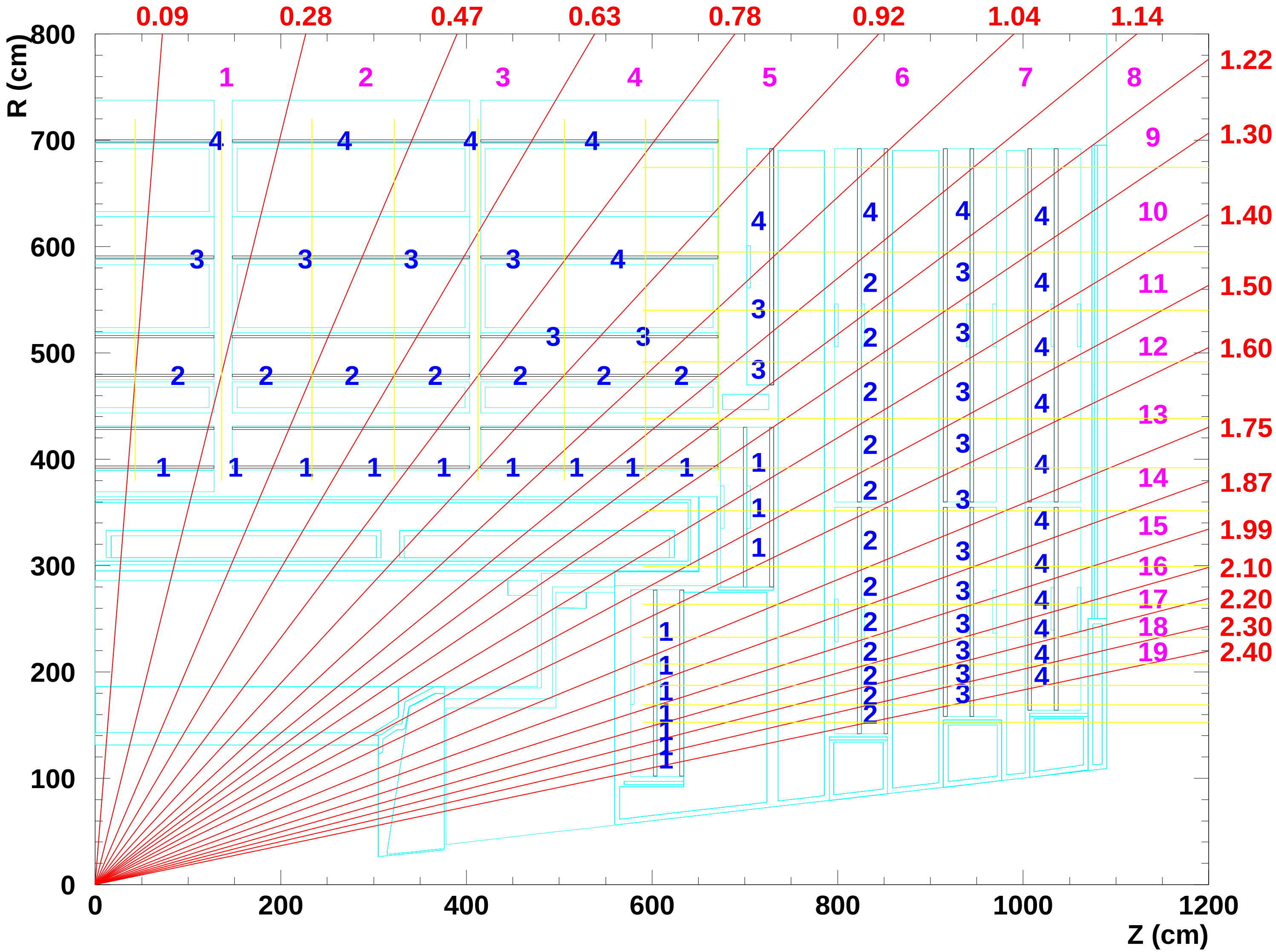


Figure 2: GEANT implementation of the RPC geometry. For each η tower its number, range and four logical trigger planes are marked.

bin	η *interval*
0	0. - 0.09
1	0.09 - 0.28
2	0.28 - 0.47
3	0.47 - 0.63
4	0.63 - 0.78
5	0.78 - 0.92
6	0.92 - 1.04
7	1.04 - 1.14
8	1.14 - 1.22
9	1.22 - 1.30
10	1.30 - 1.40
11	1.40 - 1.50
12	1.50 - 1.60
13	1.60 - 1.75
14	1.75 - 1.87
15	1.87 - 1.99
16	1.99 - 2.10
17	2.10 - 2.20
18	2.20 - 2.30
19	2.30 - 2.40

Table 1: Pseudorapidity division of RPC system

bin	p_t *interval* (GeV)
1	1.0 - 1.2
2	1.2 - 1.5
3	1.5 - 2.0
4	2.0 - 2.5
5	2.5 - 3.0
6	3.0 - 3.5
7	3.5 - 4.0
8	4. - 5.
9	5. - 6.
10	6. - 7.
11	7. - 8.
12	8. - 10.
13	10. - 12.
14	12. - 14.
15	14. - 17.
16	17. - 20.
17	20. - 25.
18	25. - 30.
19	30. - 35.
20	35. - 40.
21	40. - 50.
22	50. - 70.
23	70. - 100.
24	100. - ∞

Table 2: Transverse momentum binning

predefined valid patterns is provided. It should be stressed that a set of valid patterns was prepared analysing μ^+ tracks only, and than (during the simulation) it is symmetrised to take into account muons of opposite sign. Although each of 39 towers is divided into 144 segments the cylindrical symmetry is assumed. Thus the parametrisation routines needs as an input parameter η but not ϕ. Nonuniformites in ϕ cannot be easily parametrised and can be reproduced only by detailed (GEANT) simulation.

To probe trigger efficiency and acceptance a package of jobs was dedicated for muon of various p_t values. Each job was dedicated for a narrow p_t interval (p_t bin) in the full η coverage of a muon system (flat distribution in η). In the average $\sim 10^5$ μ^+ and μ^- events was generated for a p_t bin. The correspondence between p_t and bin number may be found in Tab. 2.

3 Parametrisations

The obtained trigger acceptance and efficiencies for various p_t cuts, are tabulated in η and p_t bins defined in Tab. 1 and 2. The results are available as a FORTRAN functions ACCMRPC (acceptance) and EFFMRPC (efficiency). The outcoming μ^+ μ^- symmetric region of RPC operation is provided by the routine ISYMRPC.

Both **accmrpc.f** and **effmrpc.f** reads some input data from a binary file **mrt2.dat** that is opened on unit number given by the parameter LUN for which the default value 99 is used. One can change it freely if necessary. The file **mrt2.dat** should be copied (or linked) to the working directory.

The parametrisation functions **accmrpc.f, effmrpc.f, isymrpc.f** as well as the necessary file **mrt2.dat** are available on AFS under the directory[4]:

/afs/cern.ch/user/k/konec/public/html/rpcpar/

Furthermore one may find **mrt2.dat** under the directory:

$CMS_PATH/cmsim/cmdb/muon/

Functions **accmrpc.f, effmrpc.f, isymrpc.f** will be available in standard CMSIM package in the patch //MRPC/RPCPAR. In case of any troubles do not hesitate to send an e-mail to the author (MK).

3.1 Acceptance

```
FUNCTION ACCMRPC( ETA, PT, ICHARGE)
REAL     ACCMRPC

REAL ETA         ! pseudorapidity of a muon
REAL PT          ! transverse momentum (GeV) of a muon
INTEGER ICHARGE  ! muon charge (+/-1)

INTEGER    nREQUIRED           !definition of acceptance,
PARAMETER ( nREQUIRED = 2 )    !required number of penetrated
                               !logical planes

INTEGER    LUN          !unit number used internally
PARAMETER (LUN = 99)    !by the routine
```

In the current version muon is called accepted if it has penetrated at least nREQUIRED logical high p_t planes. The default is two, but it may be varied between one and four by changing the integer parameter nREQUIRED. The ACCMRPC function returns the acceptance probability. The outcome from the routine is presented on Fig. 3.
Note: Muons were generated with p_t down to 1GeV only and the function returns always zero below this value.In the reality however even softer muons may reach first muon station in forward direction at pseudorapidity $2.2 - 2.4$.

[4]It is visible on web at address: *http://cmsdoc.cern.ch/~konec/rpcpar/*

3.2 Efficiency

```
FUNCTION EFFMRPC(PT_CUT, ETA, PT, ICHARGE)
REAL EFFMRPC
REAL PT_CUT      ! trigger threshold (GeV)
REAL ETA         ! pseudorapidity of a muon
REAL PT          ! transverse momentum (GeV) of a muon
INTEGER ICHARGE  ! muon charge (+/-1)
INTEGER    LUN              !unit number used internally
PARAMETER (LUN = 99)        !by the routine
```

The EFFMRPC returns the probability that muon will give a trigger for given transverse momentum cut PT_CUT. Only discrete set of cuts is defined (as in Tab. 2). The input parameter PT_CUT is truncated to nearest lower value listed in Tab. 2. The lowest possible threshold may be set by putting PT_CUT=0. Function EFFMRPC is to replace old function EFFMUTR which is now obsolete. The outcome from the EFFMRPC routine is presented in Fig. 4.

3.3 Symmetric region of RPC trigger response

Equal μ^+/μ^- acceptance and trigger efficiency is crucial for some kind of study, ex. CP violation where $\mu^+ - \mu^-$ asymmetries are to be measured. However, in some detector regions the assymetry in response to opposite charge muons is significant. This motivated us to define a μ^+ μ^- symmetric region for the RPC trigger operation for which appropriate function ISYMRPC is provided.

The symmetric region is defined in η, p_t plane. In the Fig 5 a way to define it is shown, for a full set of considered pseudorapidity intervals. On the left plots the acceptance[5] (solid points) and efficiency (open points) are presented. On the right side the μ^+/μ^- acceptance ratio is shown (solid circles). The symmetric region is defined as follows:

- acceptance of μ^+ and μ^- is greater than 0.75
- μ^+/μ^- acceptance ratio lies in the interval $0.98 \div 1.02$

Minimum p_t passing both conditions is considered. For safety reason an one p_t bin (Tab. 2) margin is kept and symmetric region is defined to start from that point. It is shown as a hashed area on the right plots. On the top of that the μ^+/μ^- efficiency (lower available p_t cut) ratio is superimposed (open points). One may observe that in defined symmetry region μ^+/μ^- efficiency ratio is flat but in some η towers is still significantly different than one. Since the used set of valid patterns is $\mu^+ - \mu^-$ symmetric a further improvement might be achieved by developing algorithms that generates set of valid patterns.

```
FUNCTION ISYMRPC ( ETA, PT)
INTEGER ISYMRPC
REAL ETA         ! pseudorapidity of a muon
REAL PT          ! transverse momentum (GeV) of a muon
```

Integer function ISYMRPC returns 1 for η, p_t symmetric region, 0 elsewhere. Its outcome is presented in the Fig. 6

[5]defined with nREQUIRED = 2

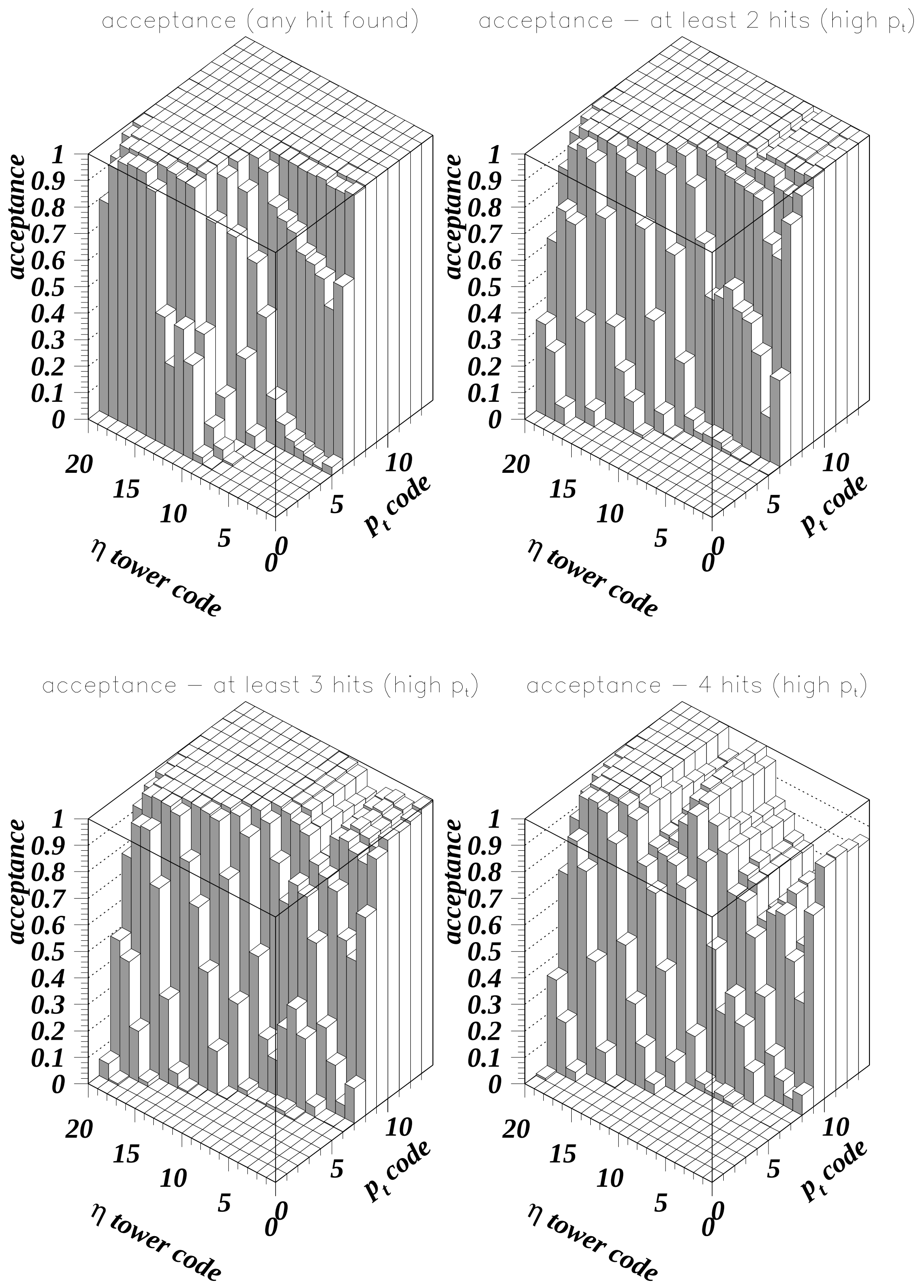


Figure 3: Acceptance by ACCMRPC for different values of parameter nREQUIRED. The default is nREQUIRED=2. Histograms are plotted in terms of η and p_t bins (see Tab. 1 and 2) for muons of positive charge.

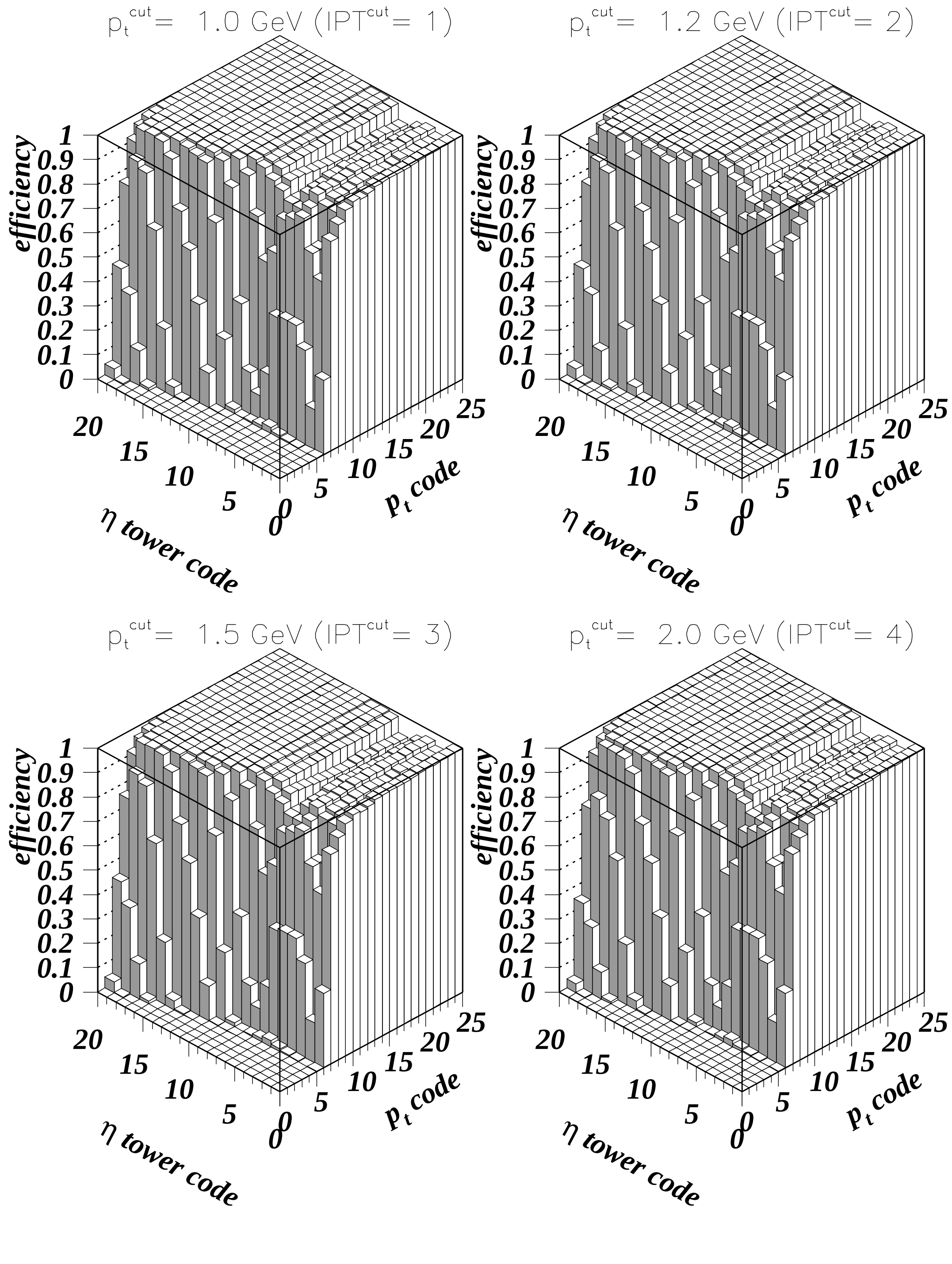


Figure 4: (A) - Efficiency by EFFMRPC for p_t cut 1.0 – 2.0 GeV. Histograms are plotted in terms of η and p_t bins (see Tab. 1 and 2) for muons of positive charge.

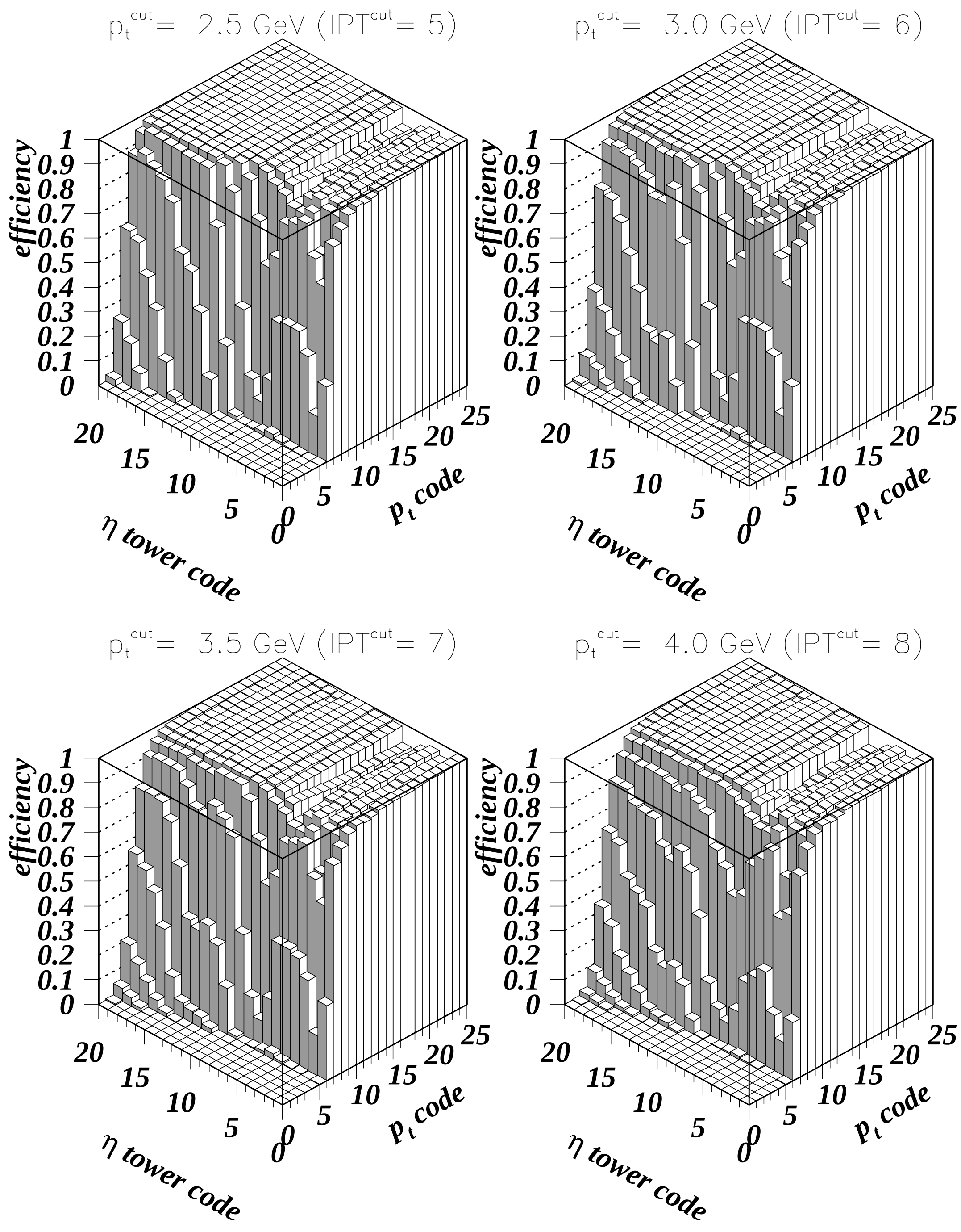


Figure 4: (B) - Efficiency by EFFMRPC for p_t cut 2.5 – 4. GeV. Histograms are plotted in terms of η and p_t bins (see Tab. 1 and 2) for muons of positive charge.

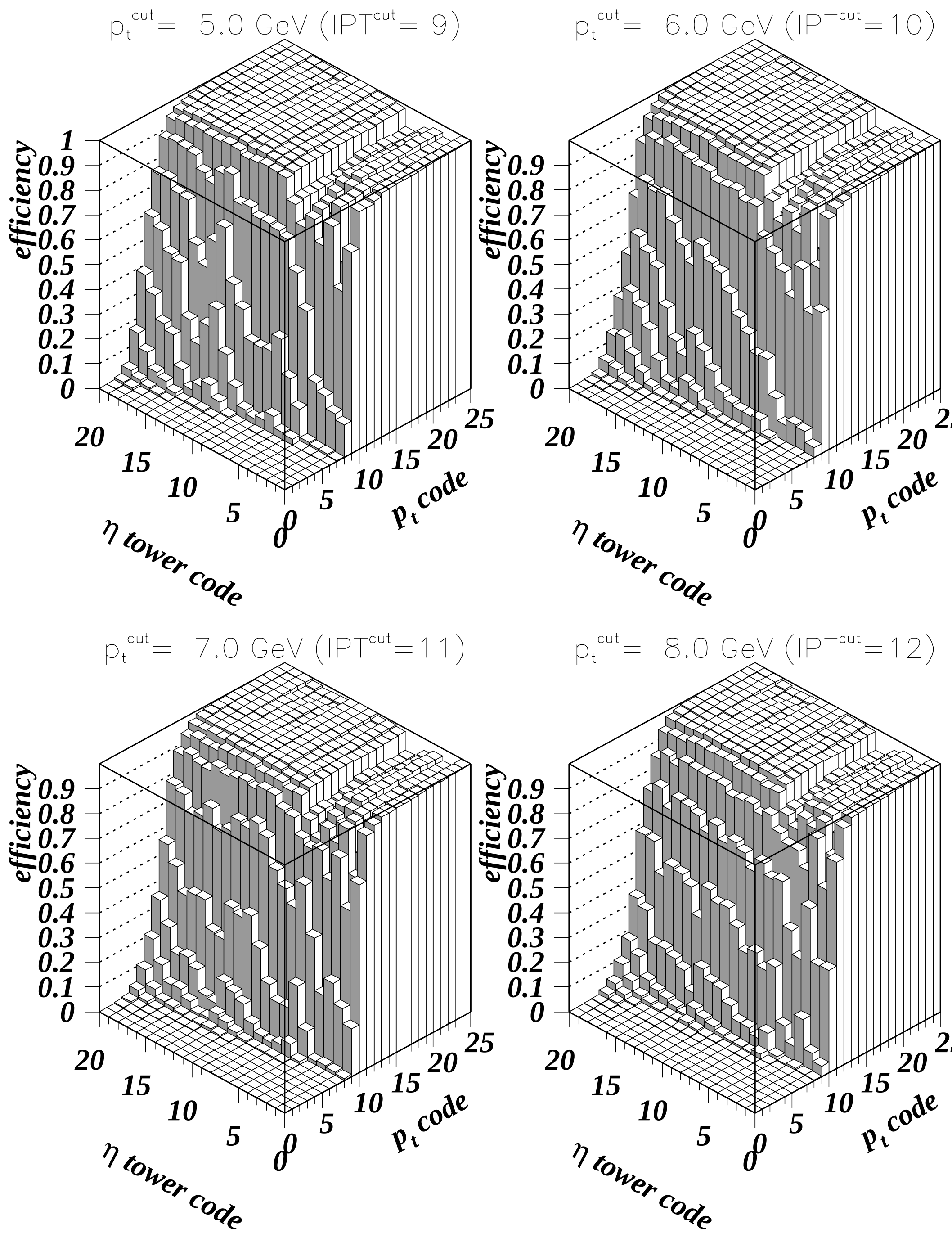


Figure 4: (C) - Efficiency by EFFMRPC for p_t cut 5.0 – 8.0 GeV. Histograms are plotted in terms of η and p_t bins (see Tab. 1 and 2) for muons of positive charge.

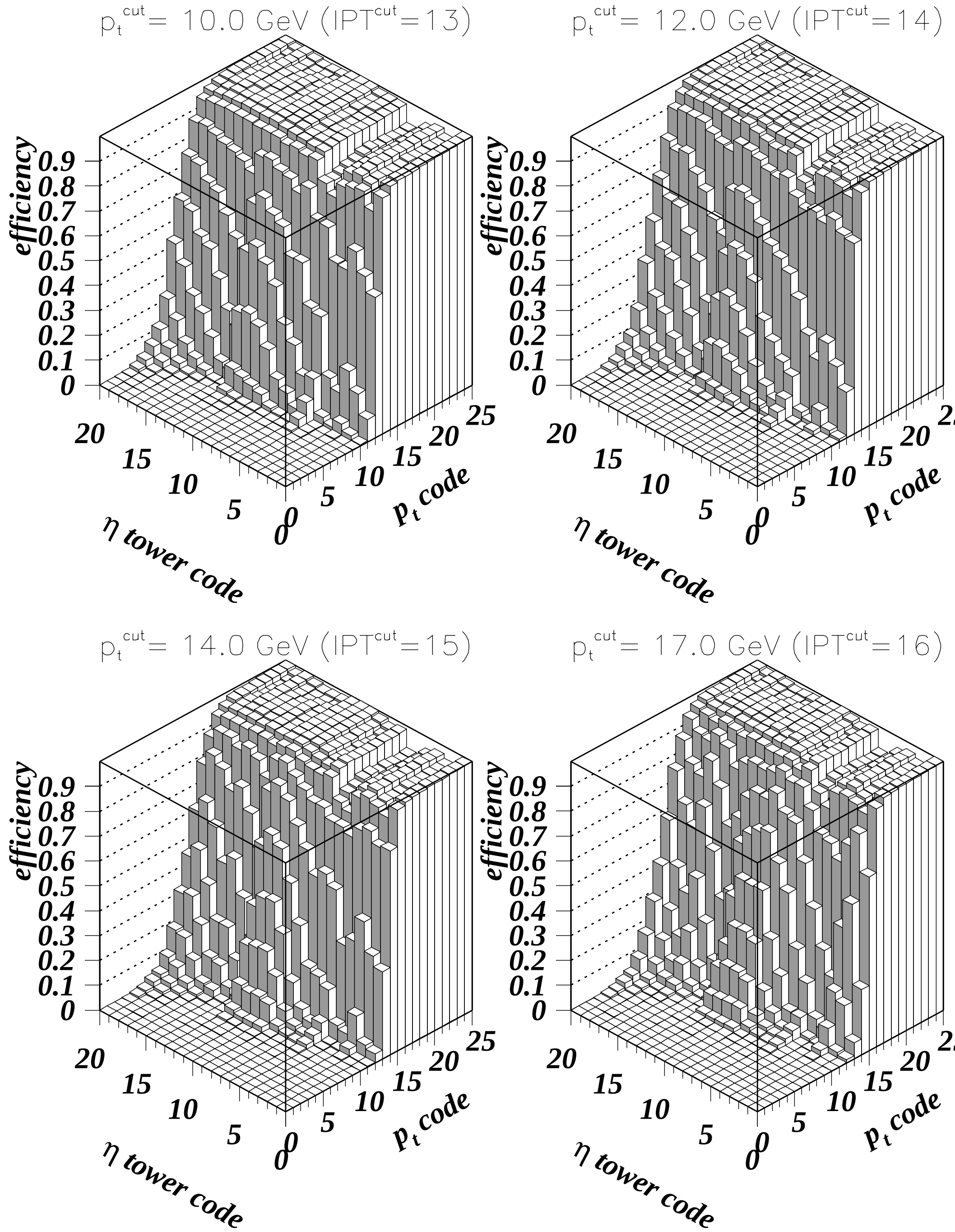


Figure 4: (D) - Efficiency by EFFMRPC for p_t cut 10.0 – 20. GeV. Histograms are plotted in terms of η and p_t bins (see Tab. 1 and 2) for muons of positive charge.

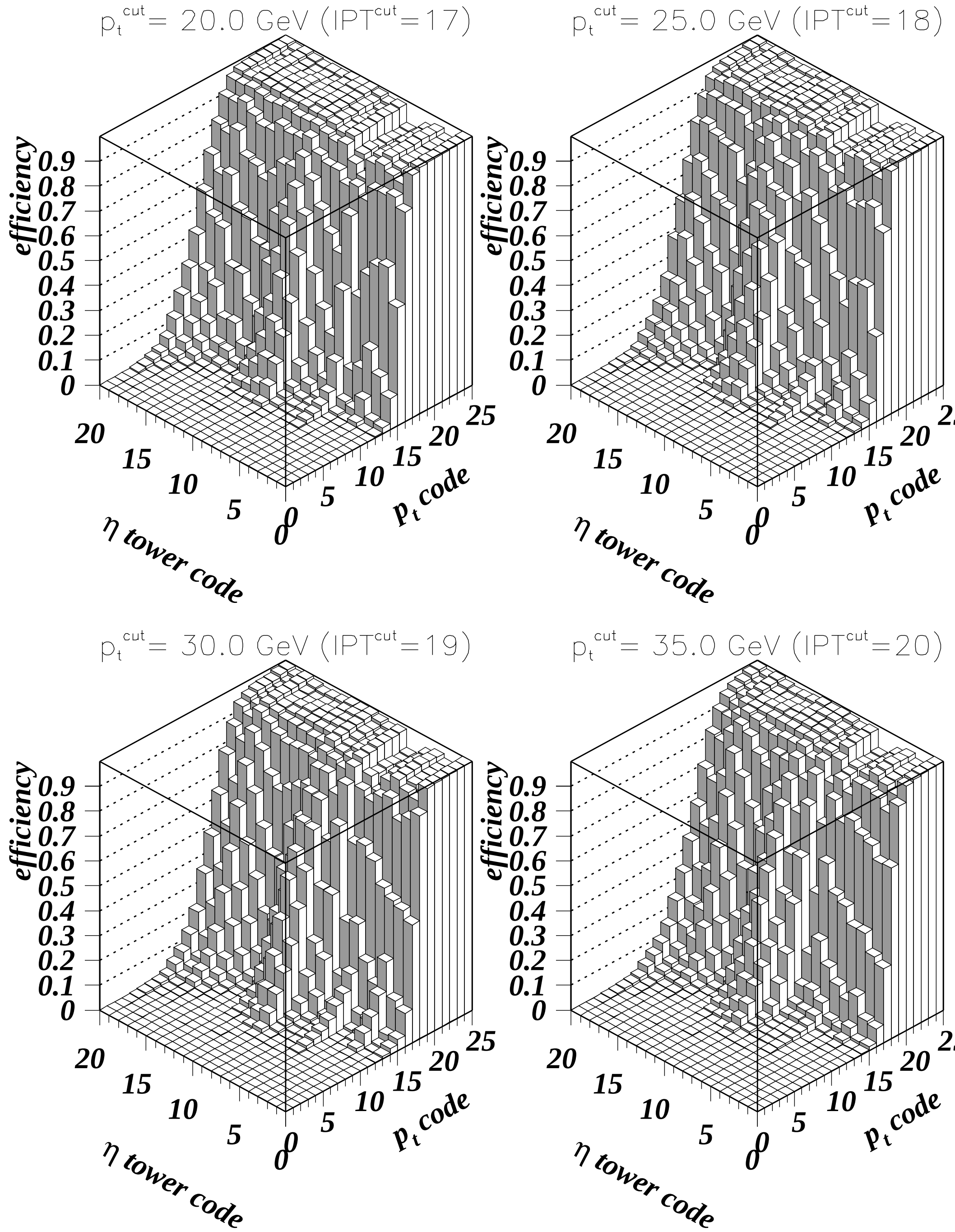


Figure 4: (E) - Efficiency by EFFMRPC for p_t cut 20. – 40. GeV. Histograms are plotted in terms of η and p_t bins (see Tab. 1 and 2) for muons of positive charge.

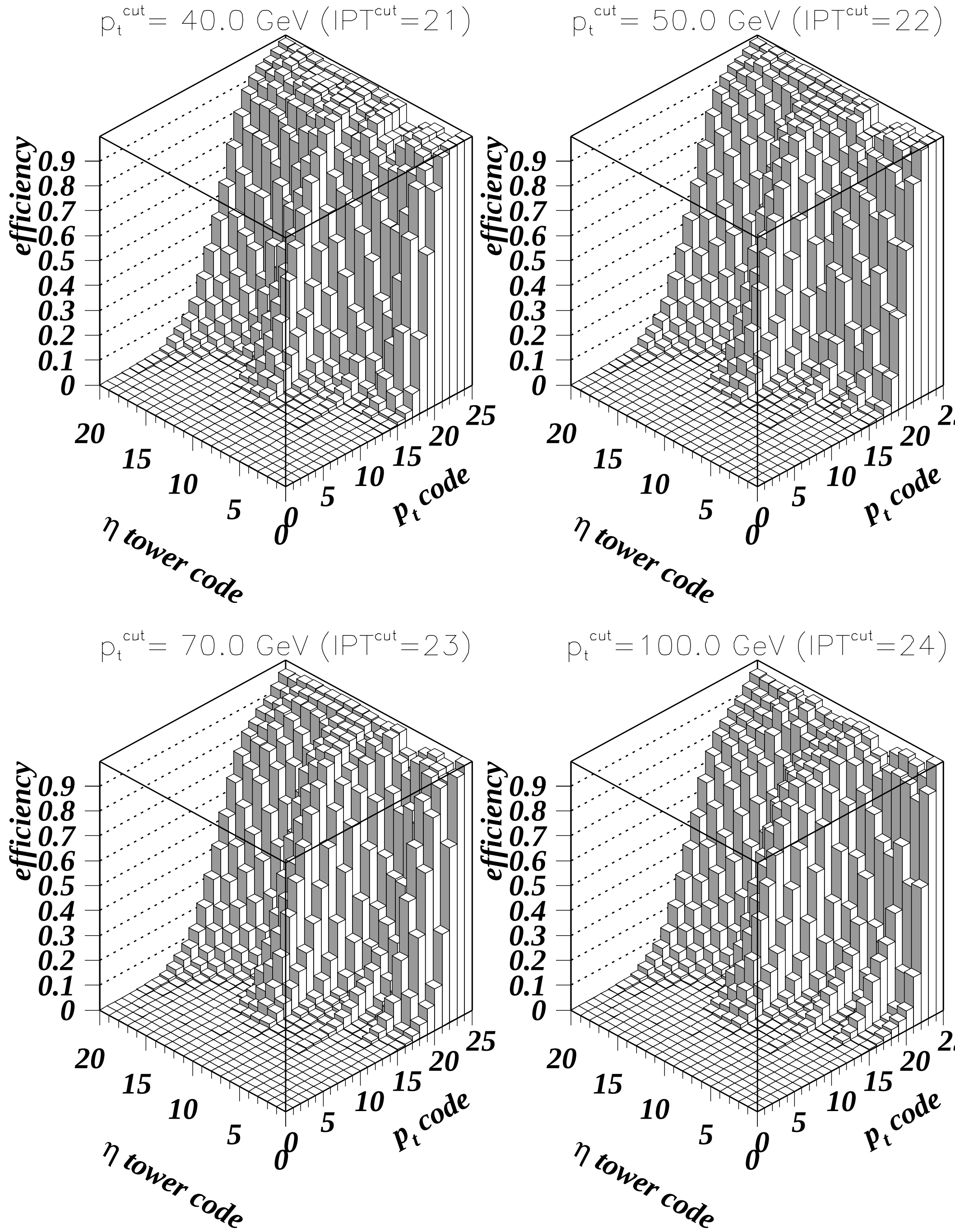


Figure 4: (F) - Efficiency by EFFMRPC for p_t cut 40. – 100. GeV. Histograms are plotted in terms of η and p_t bins (see Tab. 1 and 2) for muons of positive charge.

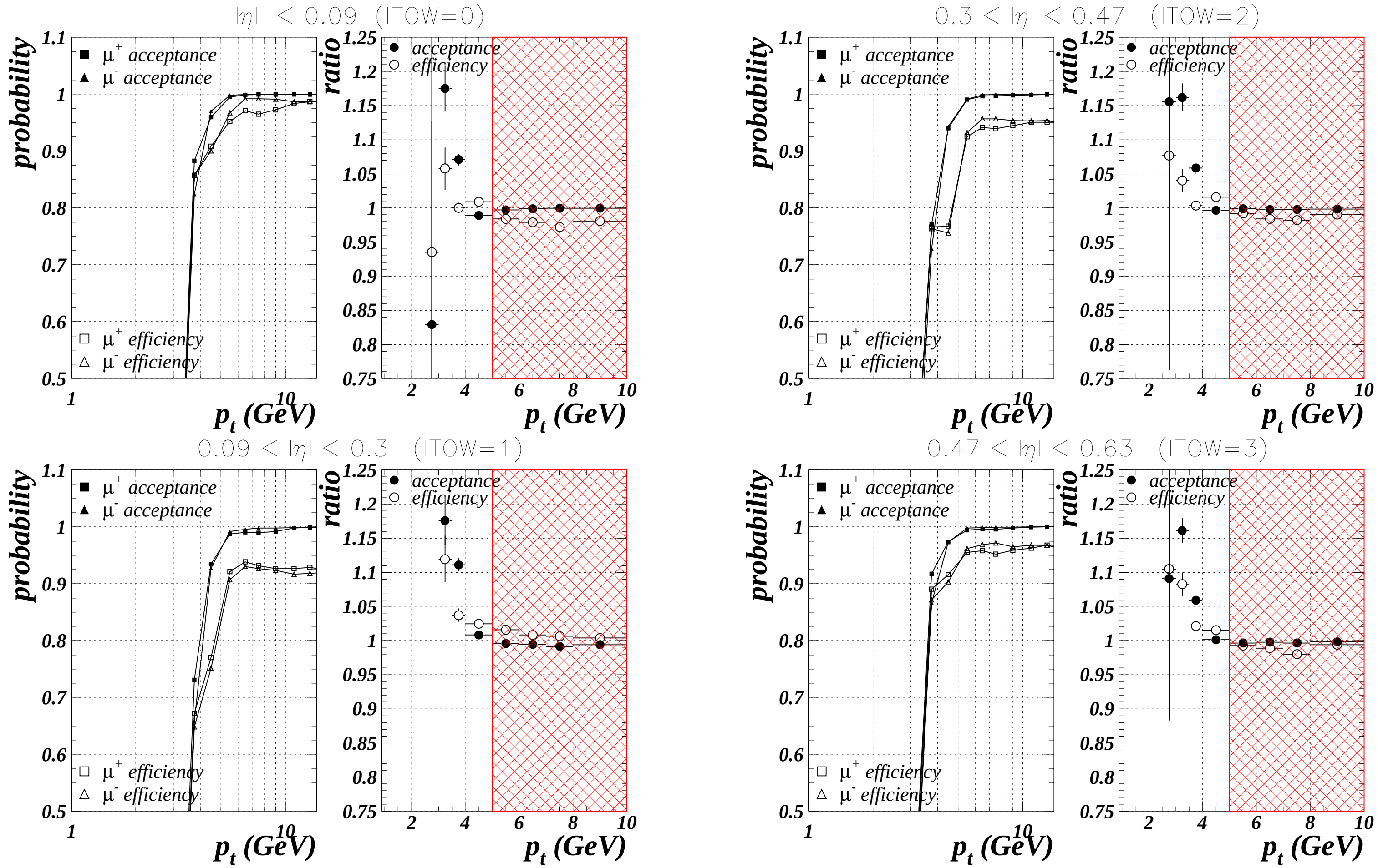
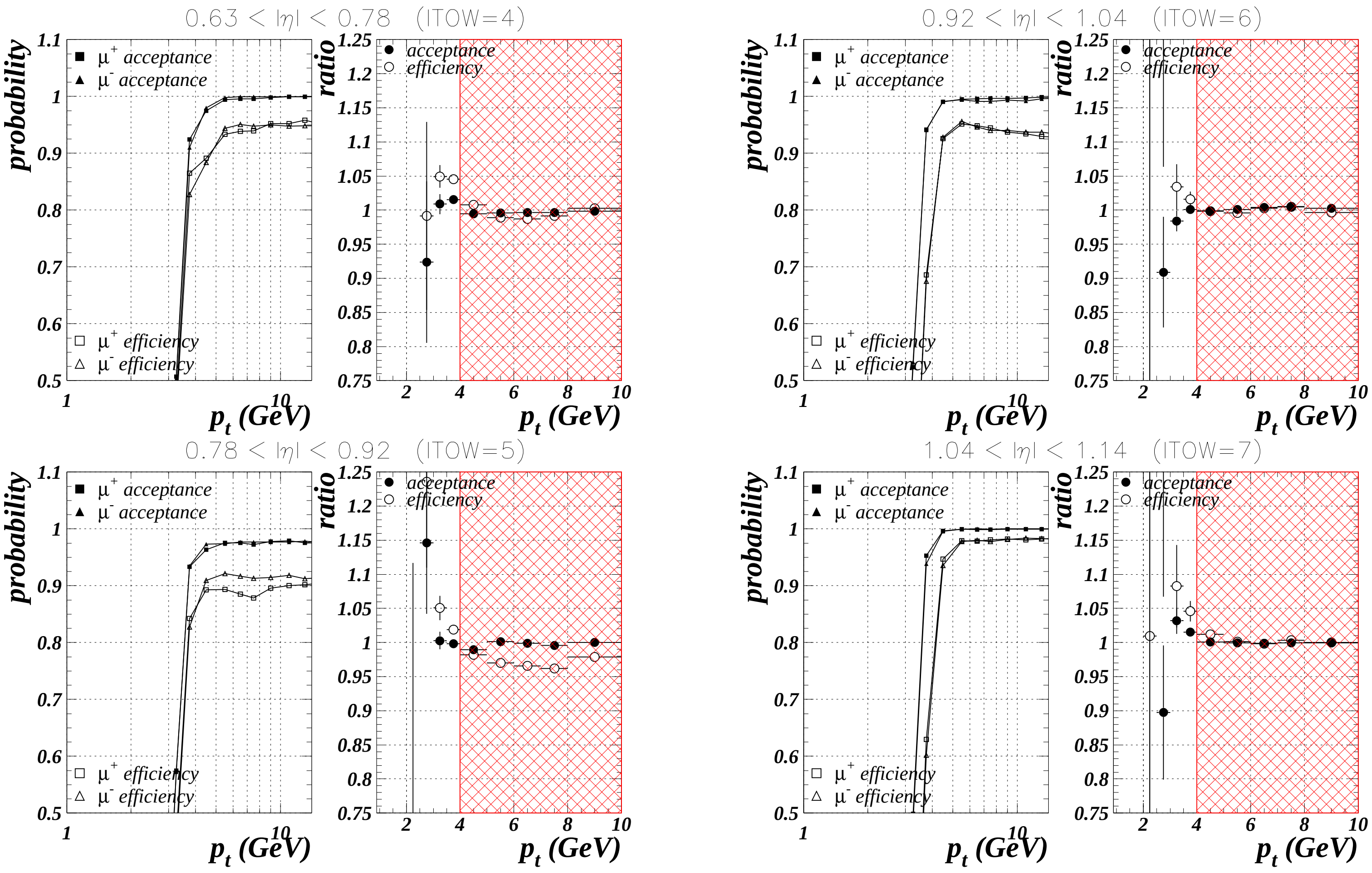
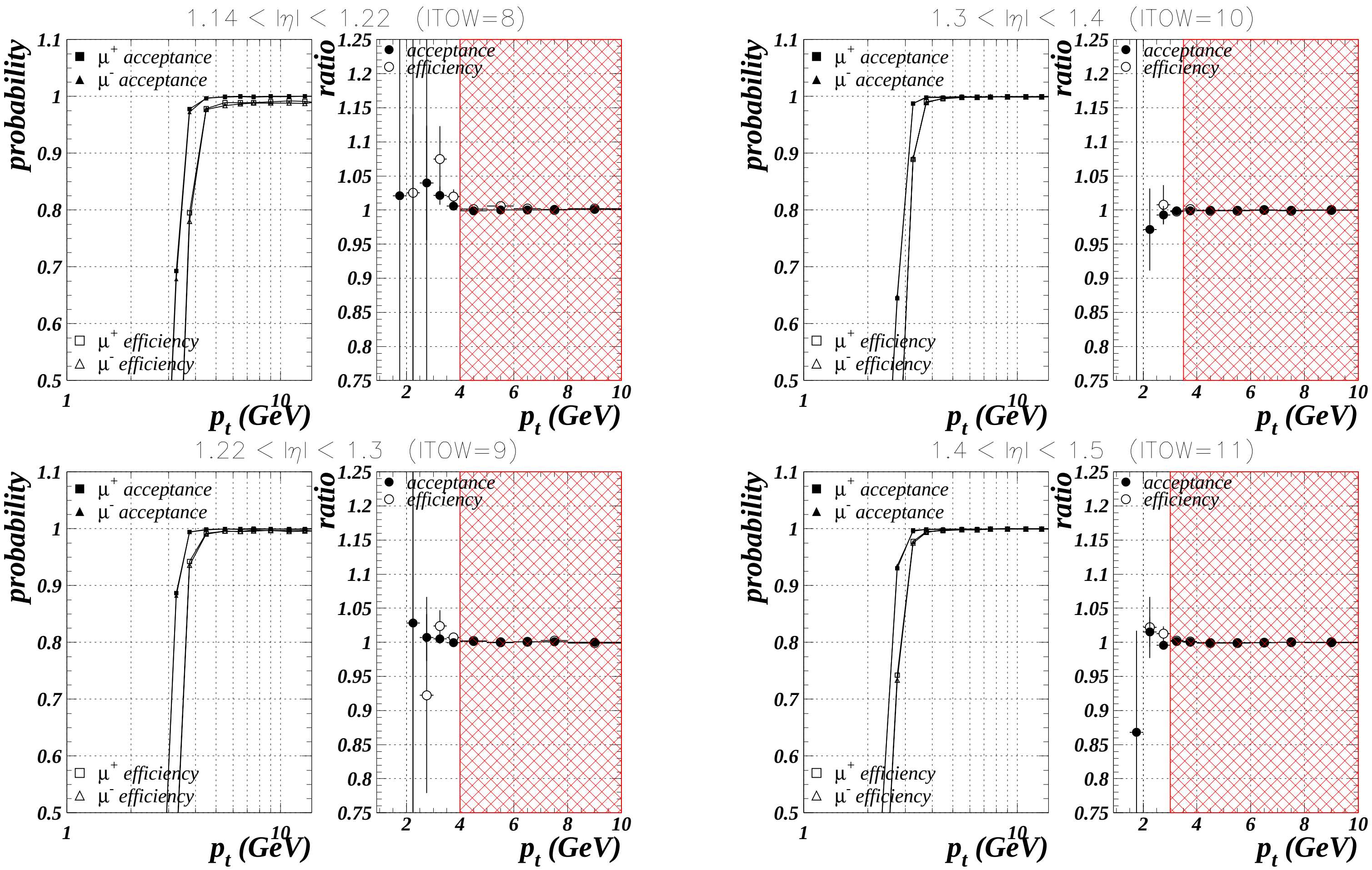
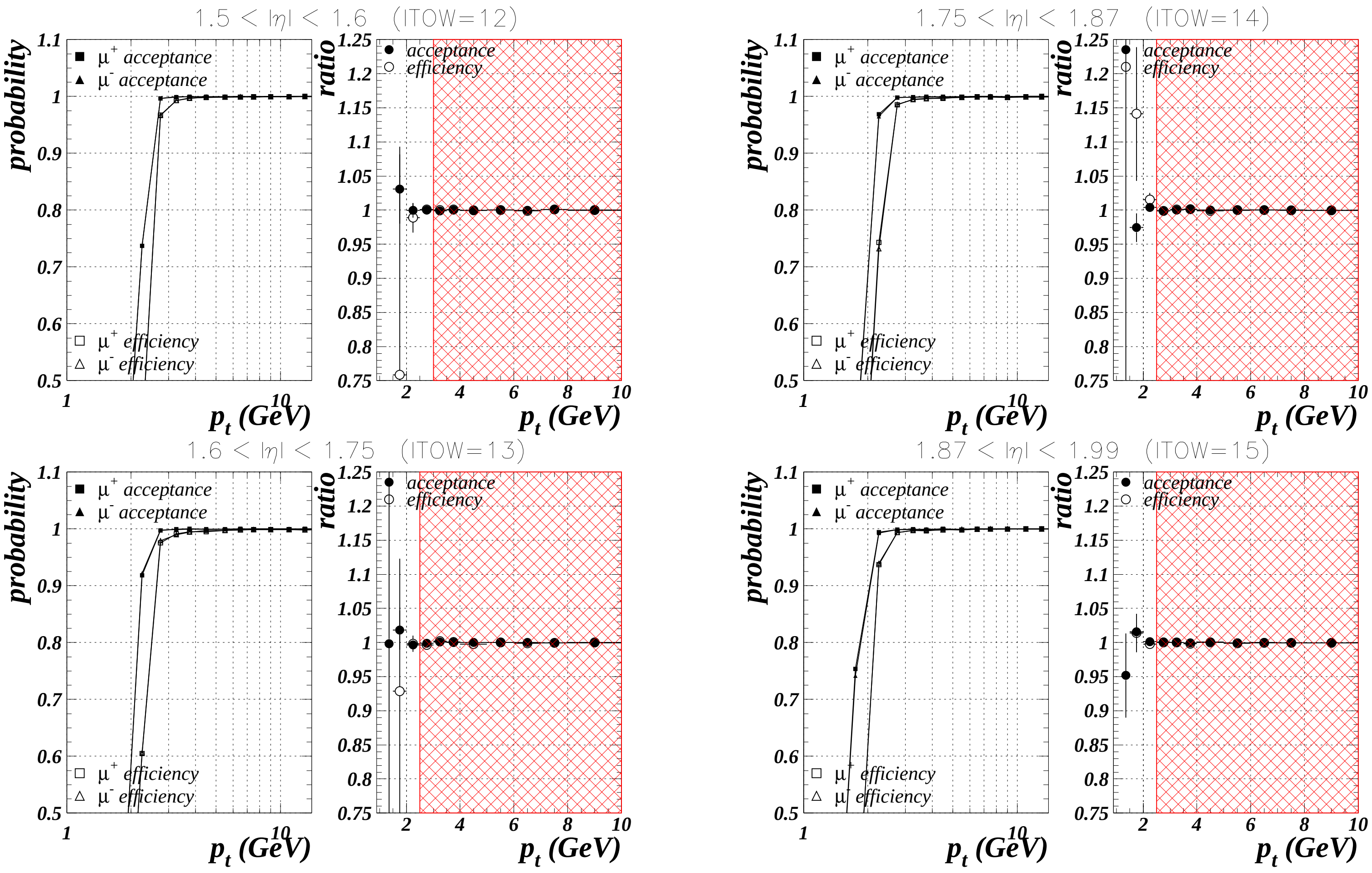


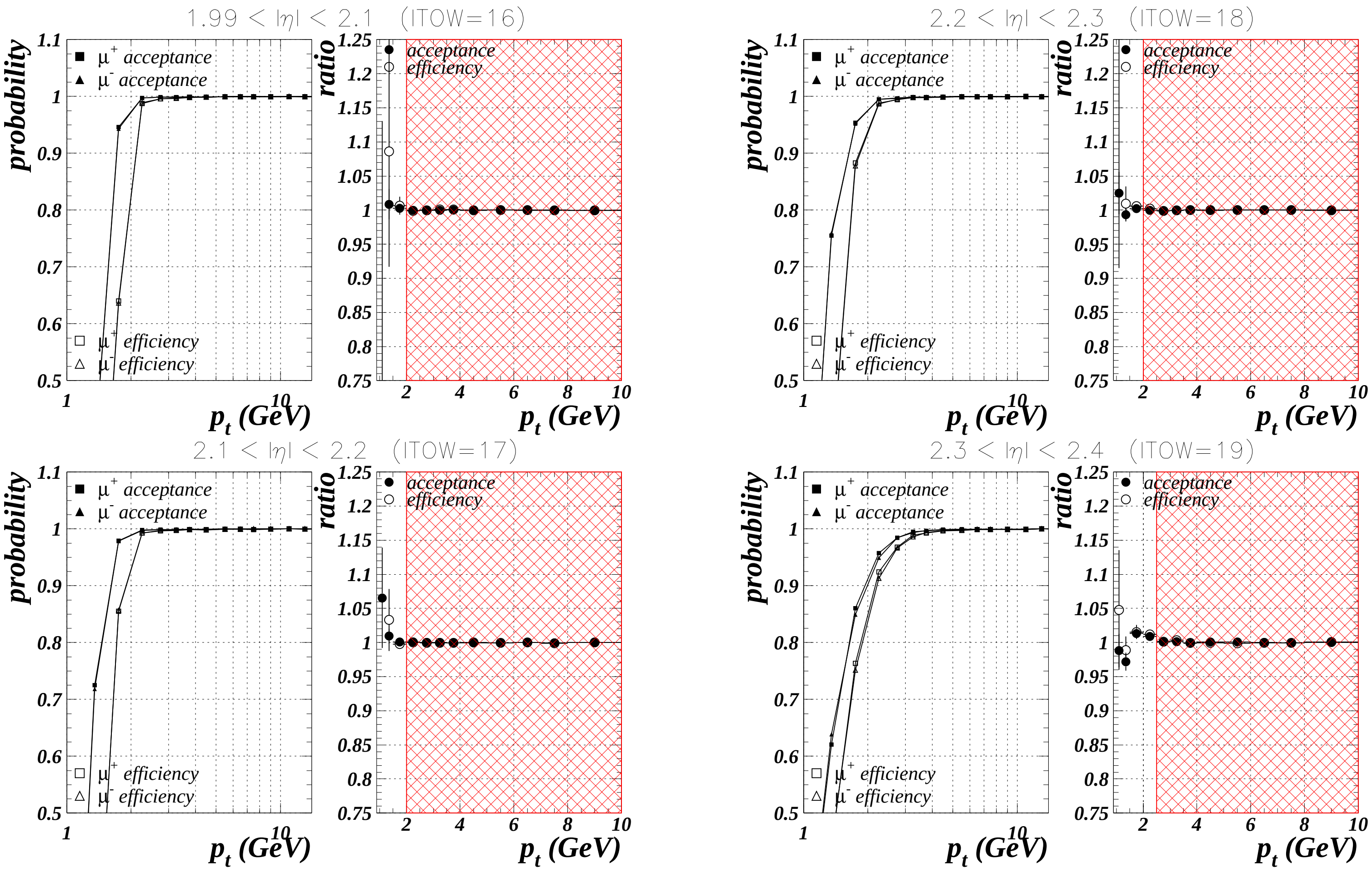
Figure 5: Definition of symmetric region for for RPC trigger operation. On the left plot of each pair acceptance and efficiency is shown. On the right plots μ^+/μ^- ratio of acceptance and efficiency is drawn. The dashed area corresponds to symmetric region of operation.


0.63 < |η| < 0.78 (ITOW=4)
0.92 < |η| < 1.04 (ITOW=6)
0.78 < |η| < 0.92 (ITOW=5)
1.04 < |η| < 1.14 (ITOW=7)
probability
ratio
μ+ acceptance
μ- acceptance
μ+ efficiency
μ- efficiency
acceptance
efficiency
pt (GeV)


1.14 < |η| < 1.22 (ITOW=8)
1.3 < |η| < 1.4 (ITOW=10)
1.22 < |η| < 1.3 (ITOW=9)
1.4 < |η| < 1.5 (ITOW=11)
probability
ratio
μ+ acceptance
μ- acceptance
μ+ efficiency
μ- efficiency
acceptance
efficiency
pt (GeV)



1.5 < |η| < 1.6 (ITOW=12)
1.75 < |η| < 1.87 (ITOW=14)
1.6 < |η| < 1.75 (ITOW=13)
1.87 < |η| < 1.99 (ITOW=15)
probability
ratio
μ+ acceptance
μ- acceptance
μ+ efficiency
μ- efficiency
acceptance
efficiency
pt (GeV)



1.99 < |η| < 2.1 (ITOW=16)
2.2 < |η| < 2.3 (ITOW=18)
2.1 < |η| < 2.2 (ITOW=17)
2.3 < |η| < 2.4 (ITOW=19)
probability
ratio
μ+ acceptance
μ- acceptance
μ+ efficiency
μ- efficiency
acceptance
efficiency
pt (GeV)

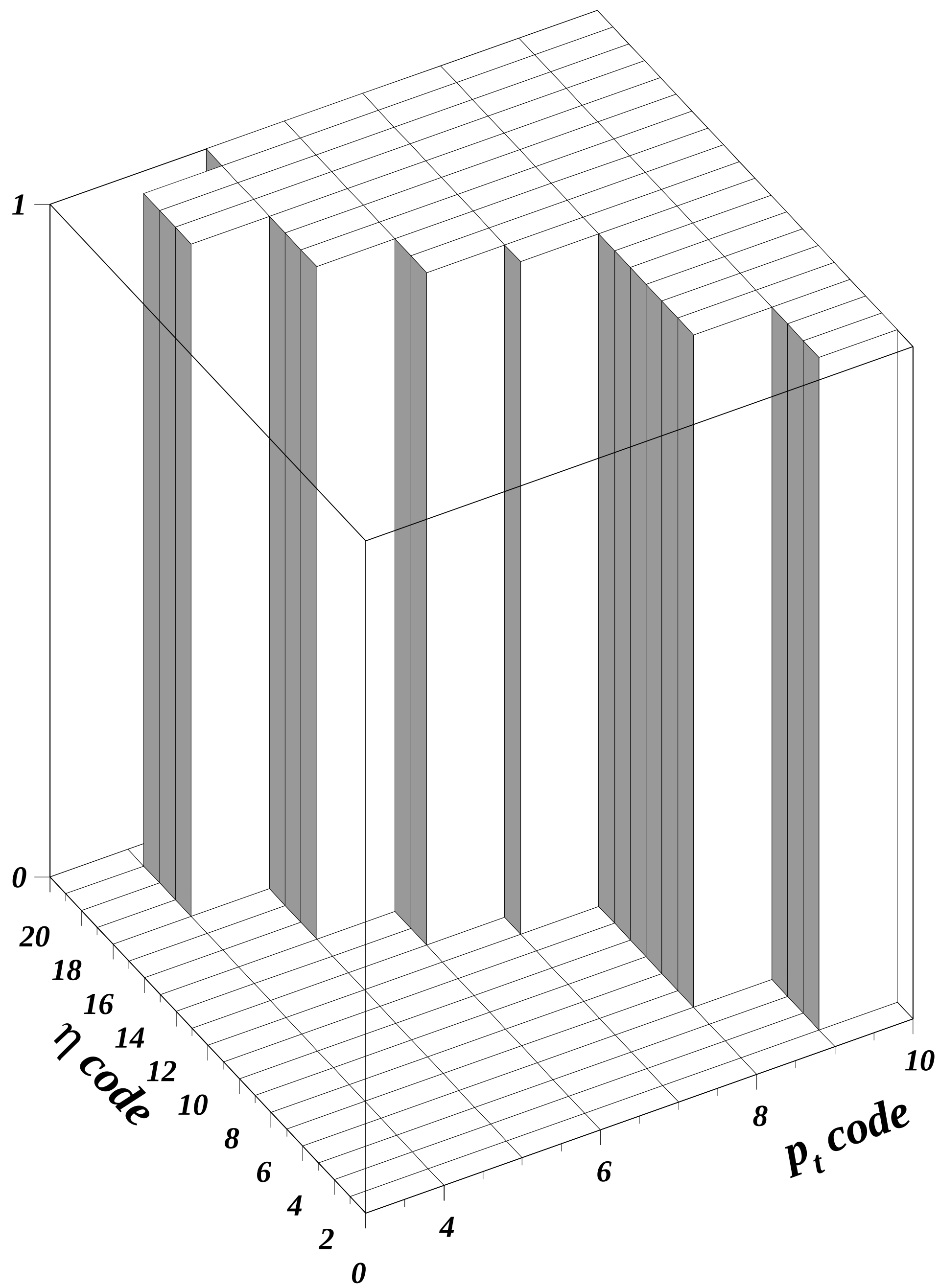


Figure 6: Symmetric region of RPC trigger operation. Note that histogram is plotted in η and p_t bin as defined in Tab. 1 and 2.

References

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[2] *CMS Simulation Package - Users Guide and Reference Manual*, in preparation. See *http://cmsdoc.cern.ch/~sunanda/swsi_guide.html*