Calculation of beam optics on proton beamline by G4Beamline for COMET: Gaussian-shape bucket

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Monte Carlo simulation has been performed for an external extinction device on COMET experiment. In this simulatifon, 8 GeV proton beam has been injected into the external-extinction device with a Gaussian bunch shape in logitudinal direction. Two types of bunch are simulated. One is bunch on main bucket phase and the other one is on empty bucket phase.

I. SIMULATION OVERVIEW

The proton beam line for the external extinction device consists of an AC-dipole section and a final-focus section. On the final-focus section, a 5° bending magnet and 6° bending magnets are located and the proton beam is focused on a proton target. A quadrupole magnet is located at the center of six bending magnets and an achromatic optics is achieved for the proton beam .

The entire layout of the beamline is shown in Fig. 1.

In this simulation, two type of proton bunch are simulated and they are defferent in injection phase. Where one is main bucket beam which is injected into the AC-dipole section on a B-field phase of 0 degree and the other one is empty bucket beam which is injected into the AC-dipole section on a B-field phaser of 45 degrees.

The simulation has been performed with G4beamline. For each bunch, 100,000 protons are injected into the proton beamline and tracked.

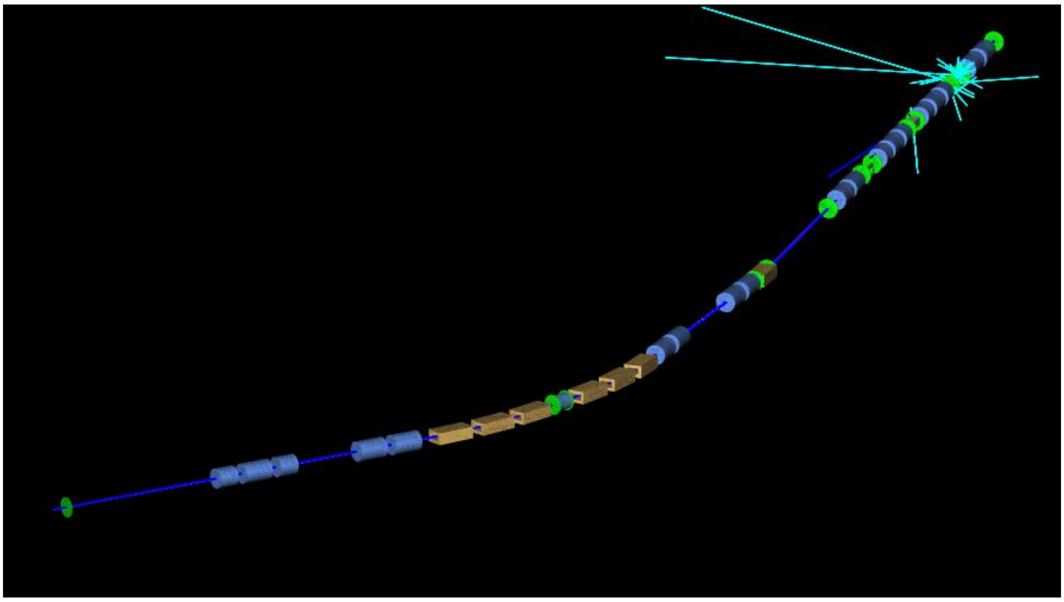

FIG. 1: Entire layout

The simulation conditions are shown as follows.

- Injection position: entrance of AC dipole section
- nEvents: 100,000
- Initial beam conditions
  - Momentum=8888.9 MeV/c
  - σ_X=10.0 mm (Gaussian distribution)
  - σ_{Xp}=0.125x10^{-3} rad (Gaussian distribution)
  - σ_Y=1.5 mm (Gaussian distribution)
  - σ_{Yp}=1.665x10^{-3} rad (Gaussian distribution)

  - σ_P=-26.7 MeV/c (uniform distribution)
  - σ_T=50 nsec (Gaussian distribution)

- B-field of AC-dipole
  - Frequncy: 2600 nsec
  - Amplitude: 0.0600 T
  - Wave function: sunisoidal
- Collimator
  - Material: Tungsten
  - Length along beam axis: 1.5 m
- Physics Process
  - physics=LHEP_BERT_HP
  - doDecay=0
  - Enegycut=0.1 MeV
- Input file for G4beamline
  - acd_ff-01-gaussian-main_buckt.in (main bucket bunch)
  - acd_ff-01-gaussian-empty_buckt.in (empty bucket bunch)

A. Detector positions

In this simulation, virtual detectors are located at following positions.

- The entrance of the AC-dipole section
- inlet of the collimator
- outlet of the collimator
- inlet of the final-focus section
- outlet of the final-focus section

II. MAIN BUCKET BEAM

A. Trace of proton beam

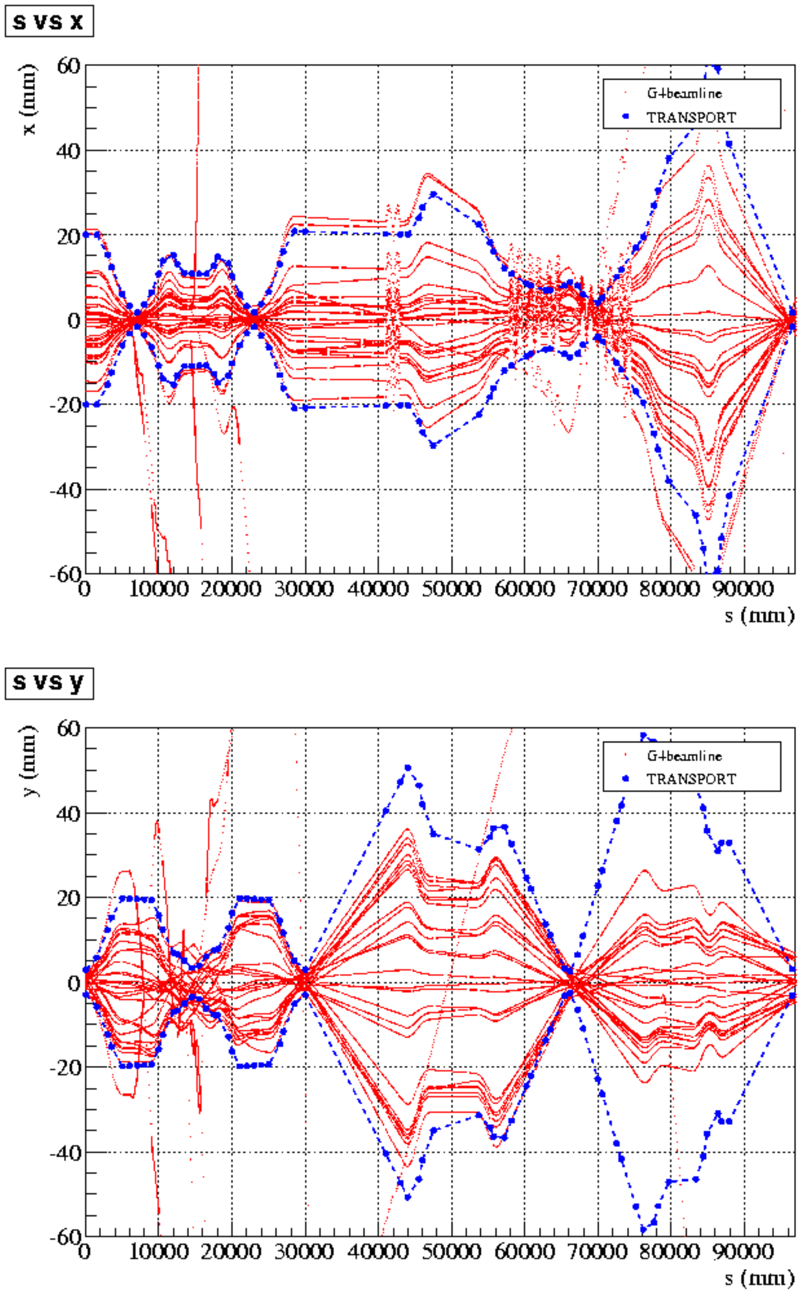

FIG. 2: Trace of proton beam. Upper: x vs z. Lower: y vs. z。

B. Initial beam (Entrance of the AC-dipole section)

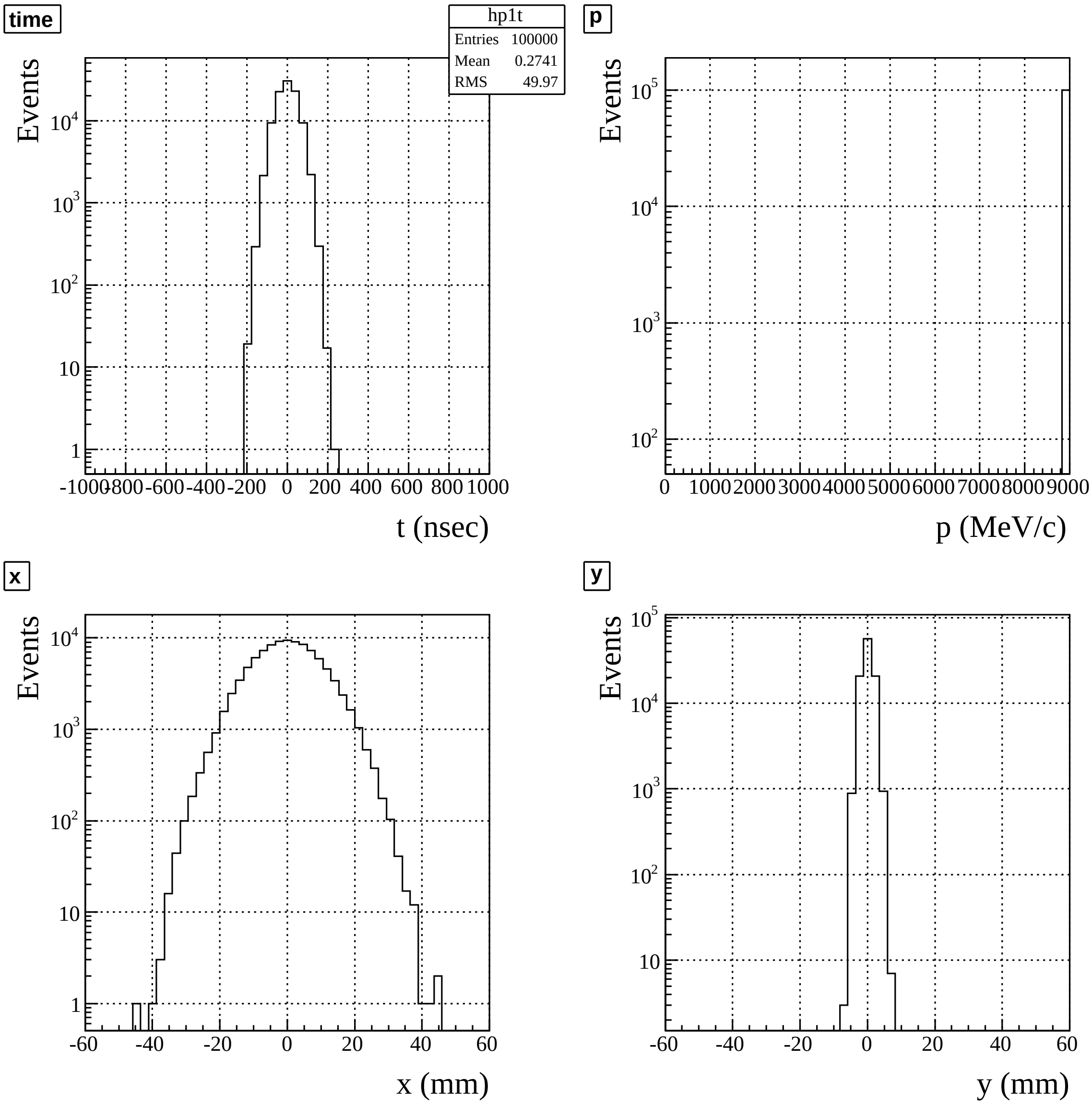

FIG. 3: Inlet of the AC-dipole section. Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

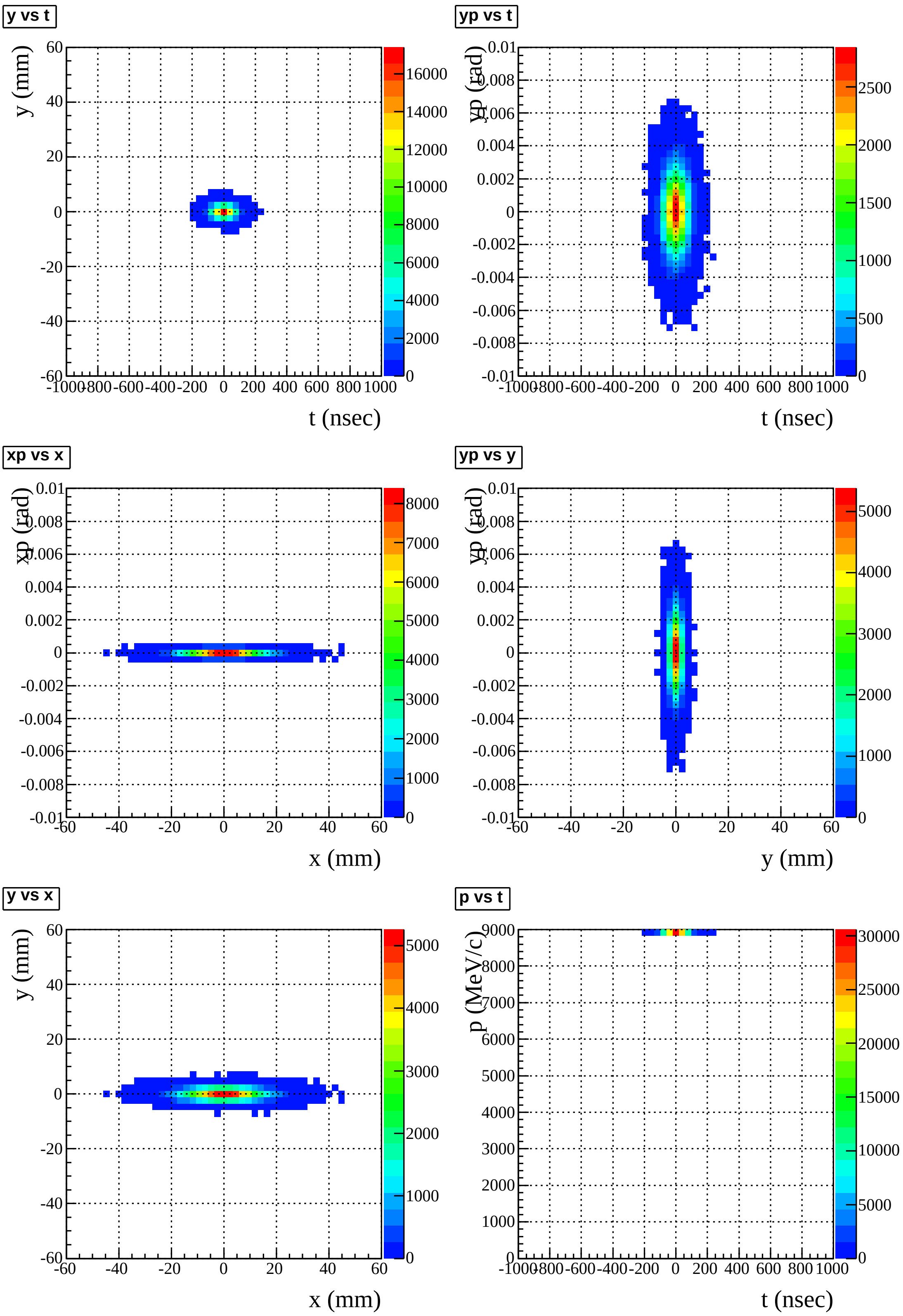

FIG. 4: Inlet of the AC-dipole section. Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution $(x - x')$. Middle right: Phase distribution $(y - y')$. Lower left: Beam profile $(x - y)$. Lower right: time vs momentum.

C. Entrance of the first AC-dipole

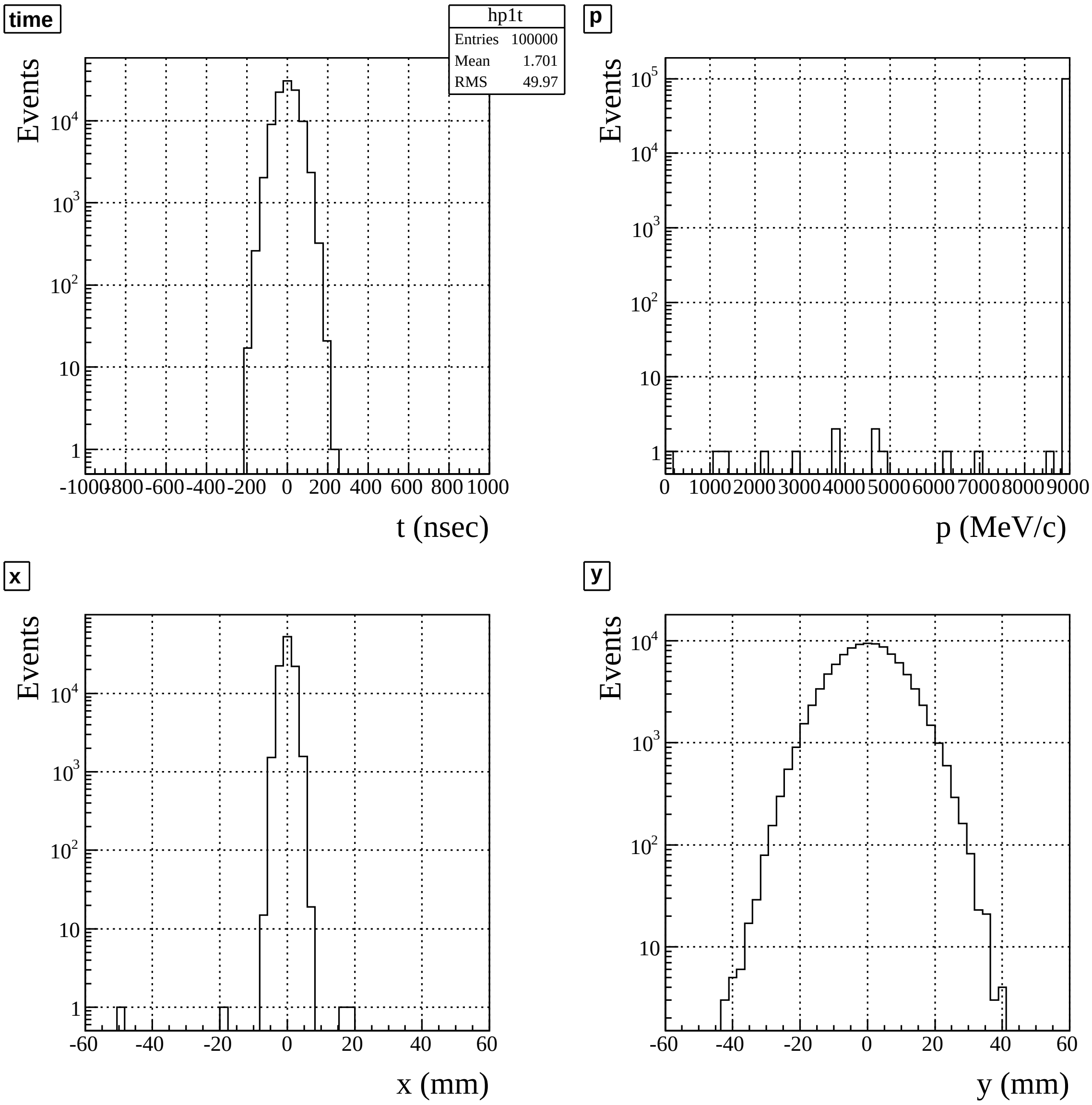

FIG. 5: Inlet of the 1st AC-dipole. Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

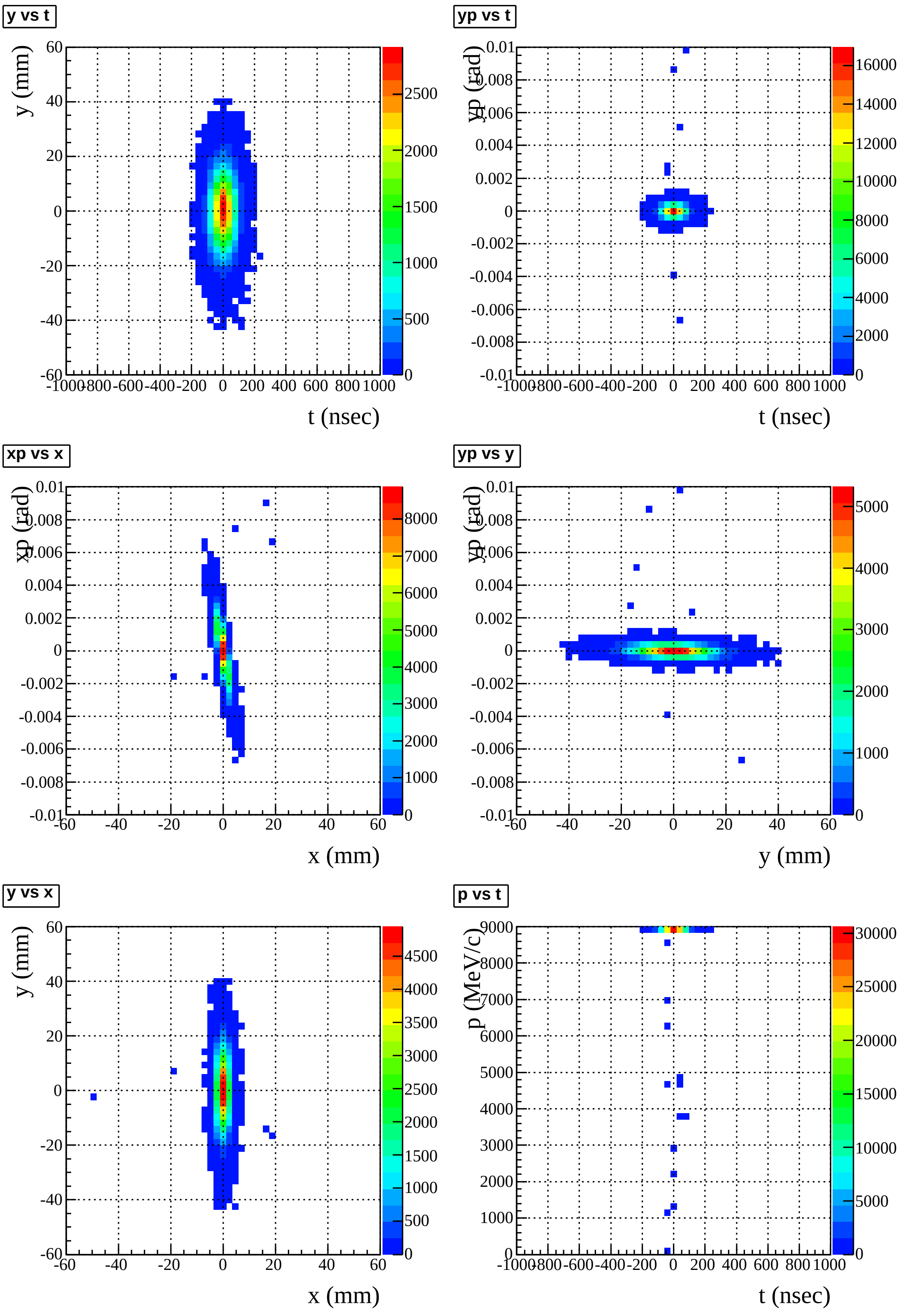

FIG. 6: Inlet of the 1st AC-dipole. Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution ($x - x'$). Middle right: Phase distribution ($y - y'$). Lower left: Beam profile ($x - y$). Lower right: time vs momentum.

D. Entrance of the collimator

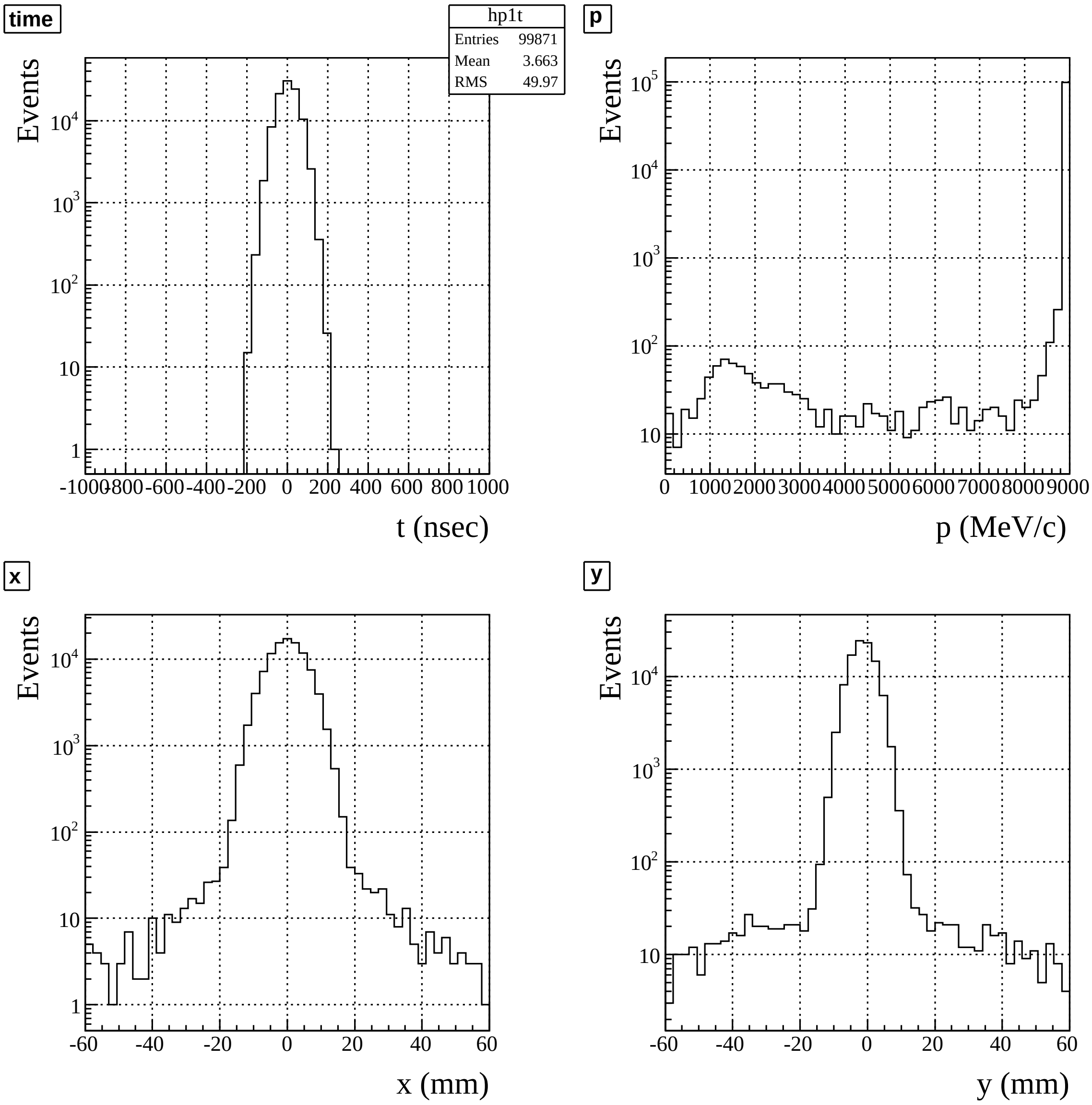

FIG. 7: Inlet of the collimator. Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

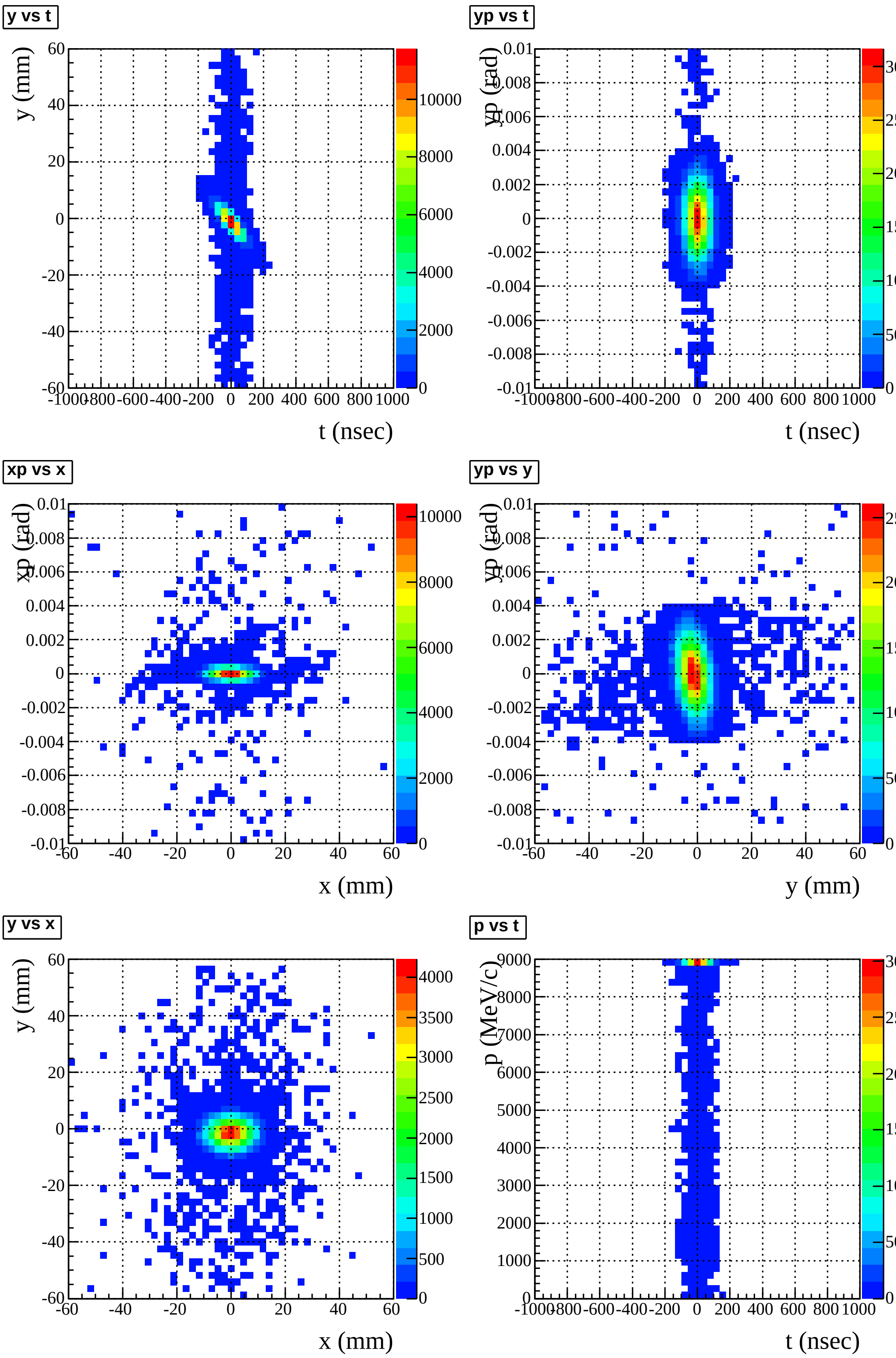

FIG. 8: Inlet of the collimator. Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution $(x - x')$. Middle right: Phase distribution $(y - y')$. Lower left: Beam profile $(x - y)$. Lower right: time vs momentum.

E. Outlet of the collimator

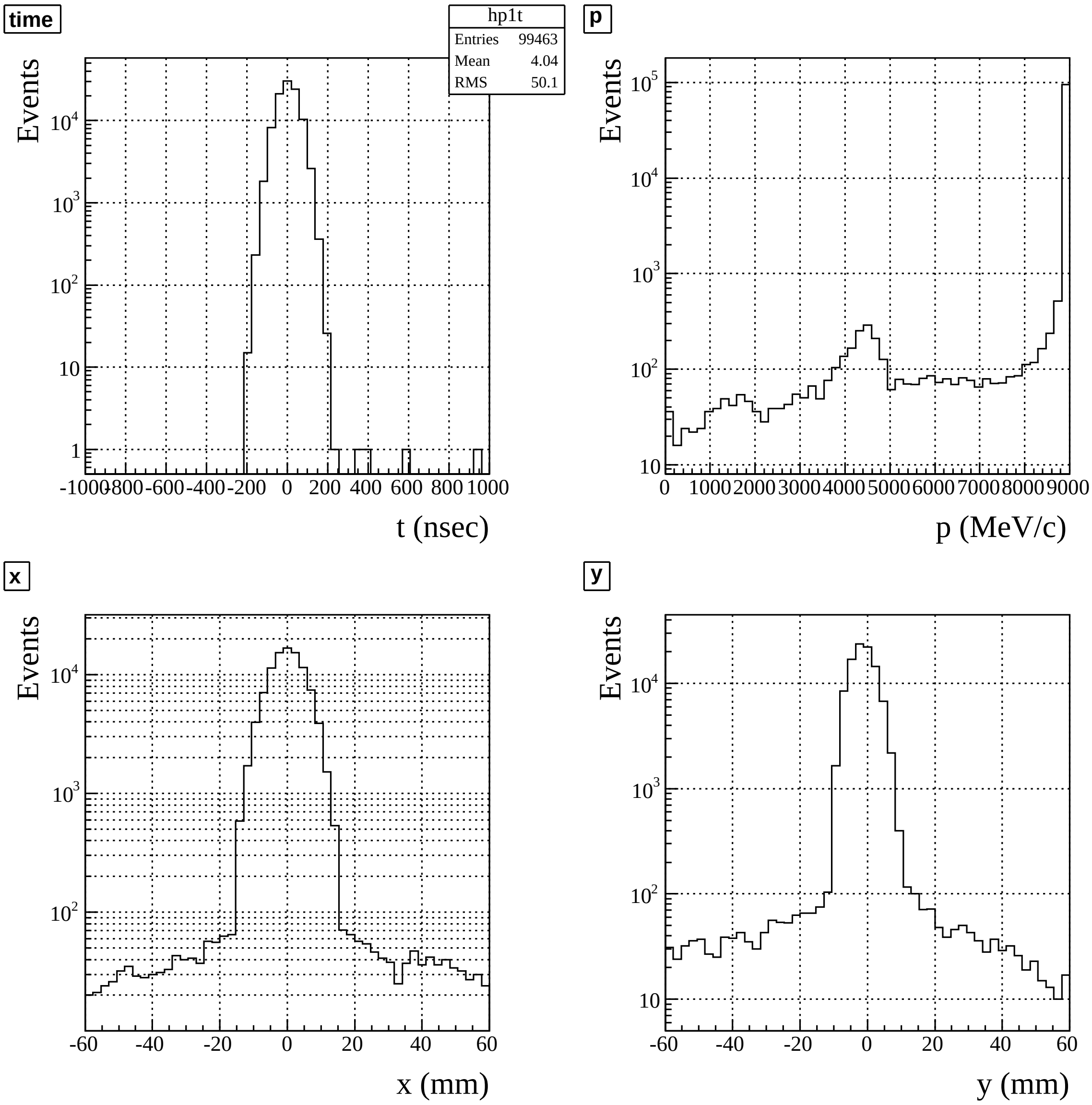

FIG. 9: Collimator outlet. Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

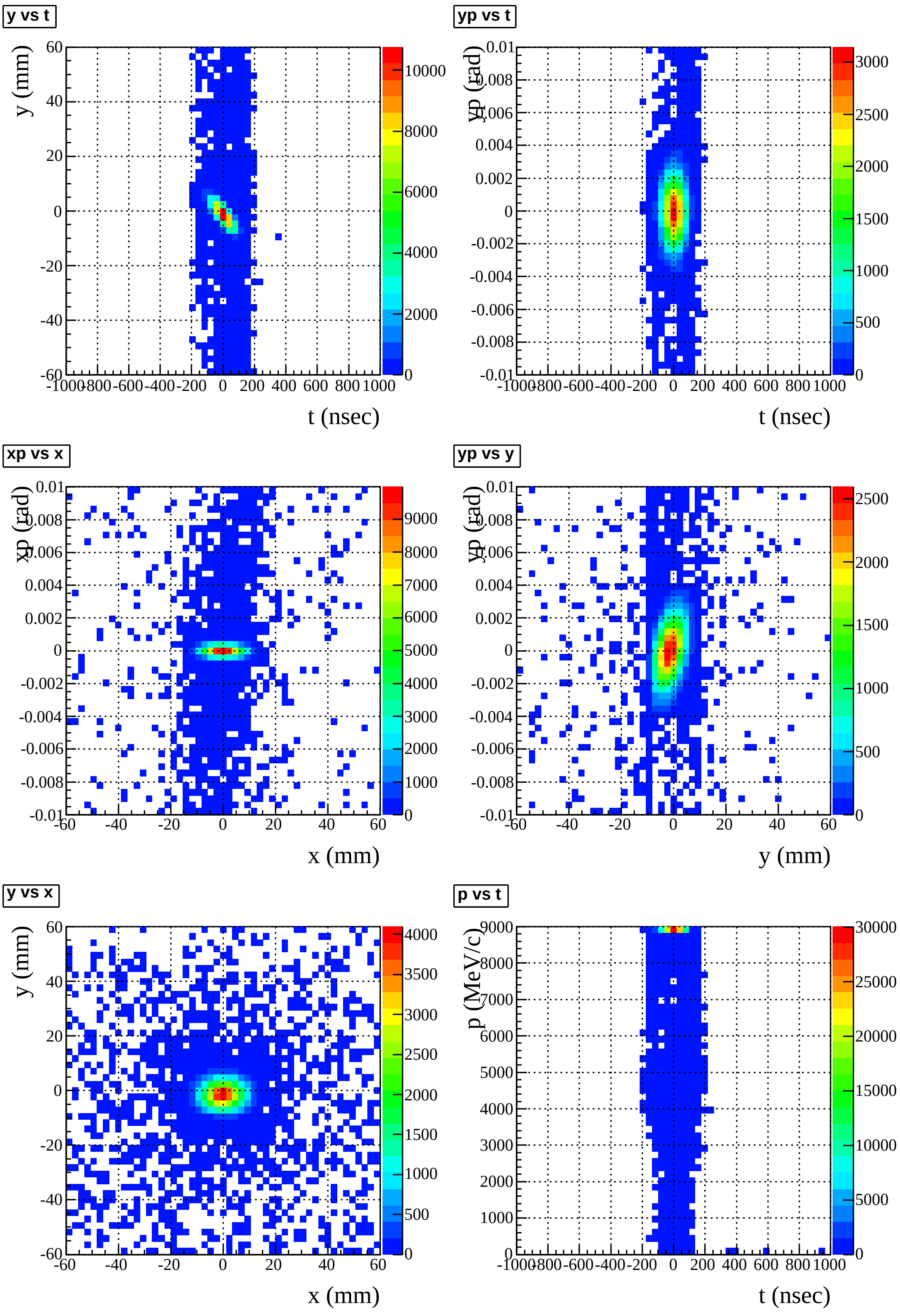

FIG. 10: Outlet of the collimator. Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution $(x - x')$. Middle right: Phase distribution $(y - y')$. Lower left: Beam profile $(x - y)$. Lower right: time vs momentum.

F. Outlet of the AC-dipole section (inlet of the final-focus section)

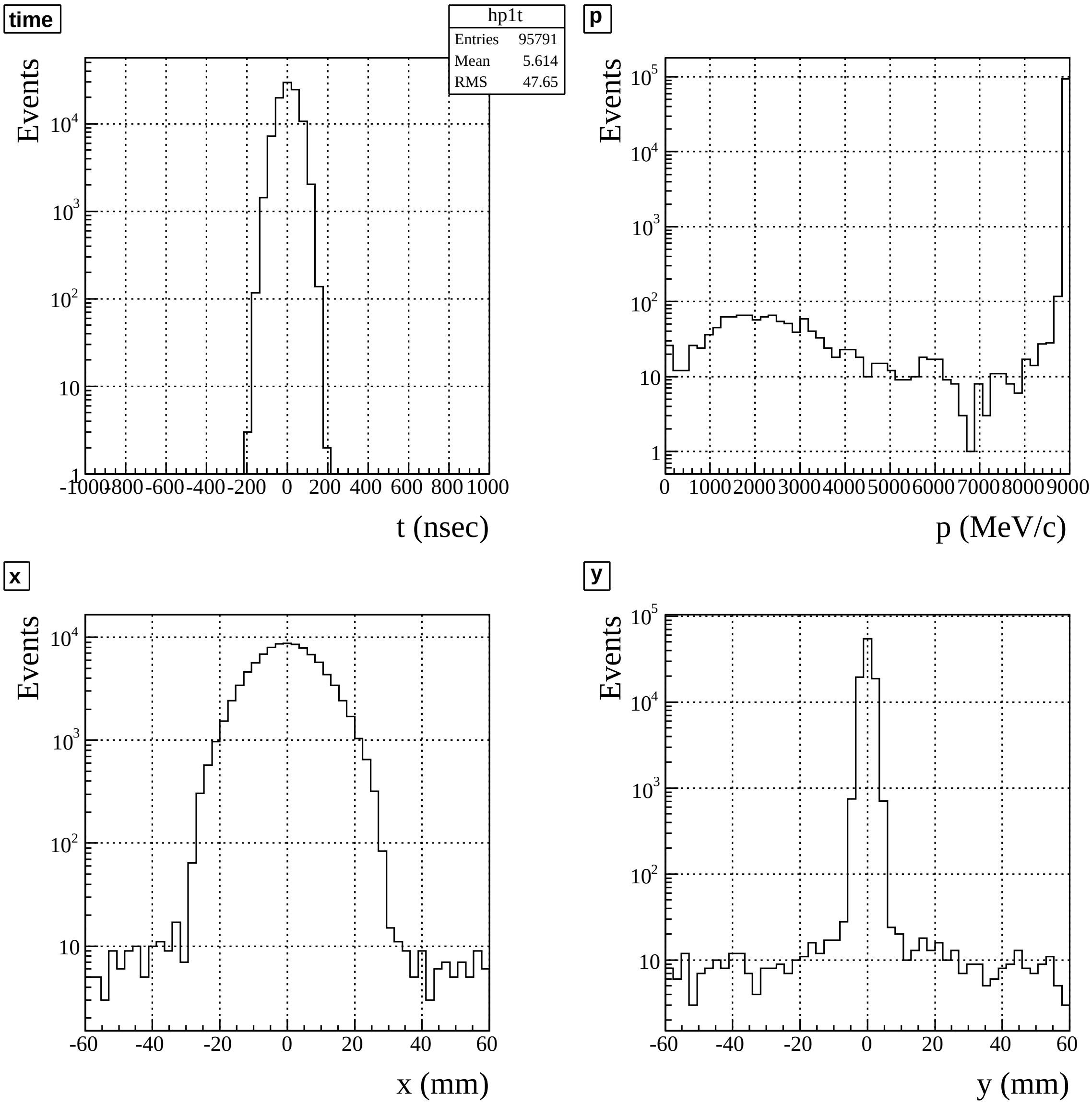

FIG. 11: Outlet of the AC-dipole section (inlet of the final-focus section). Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

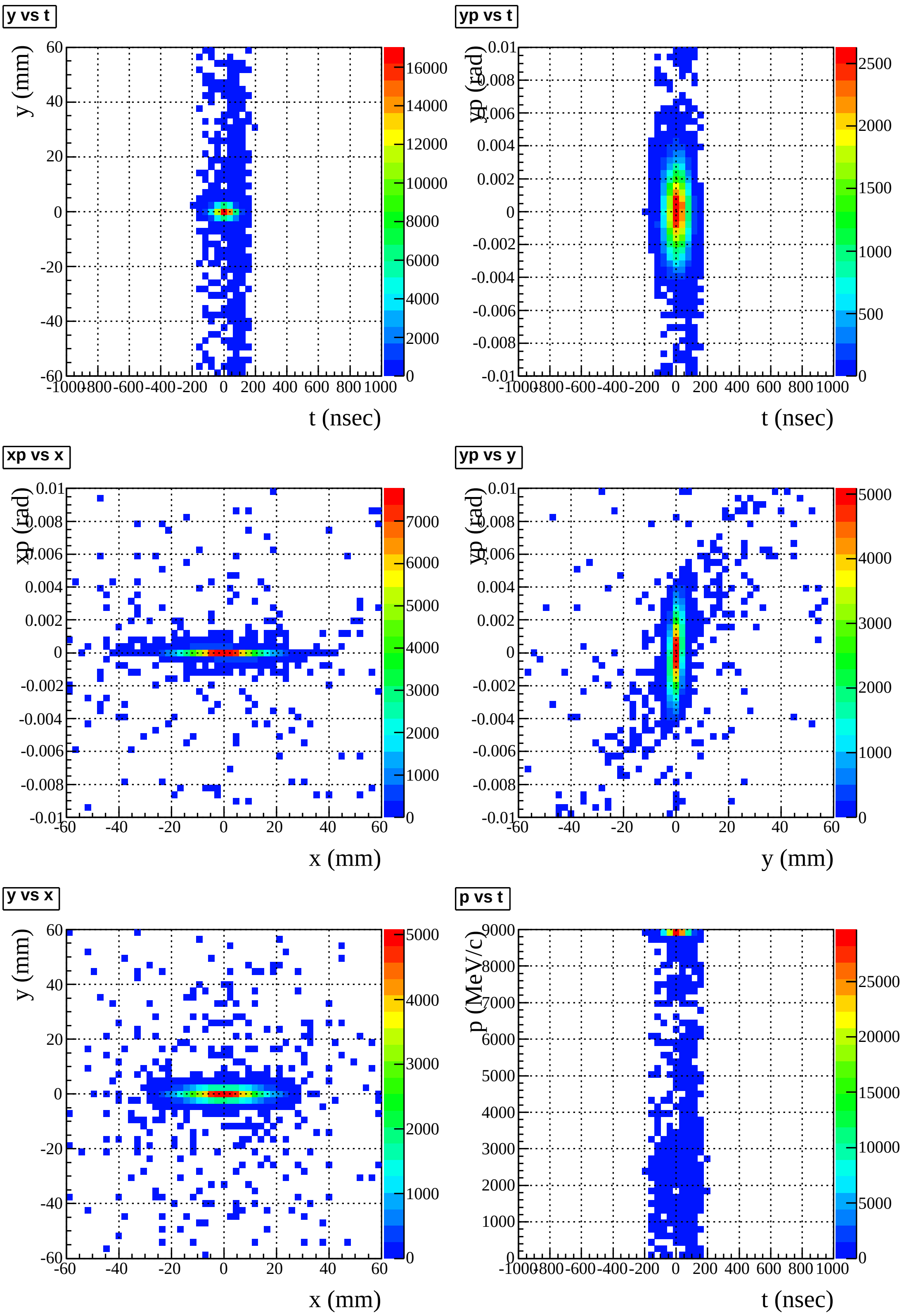

FIG. 12: Outlet of the AC-dipole section (inlet of the final-focus section). Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution $(x - x')$. Middle right: Phase distribution $(y - y')$. Lower left: Beam profile $(x - y)$. Lower right: time vs momentum.

G. Outlet of the final-focus section (on the proton target)

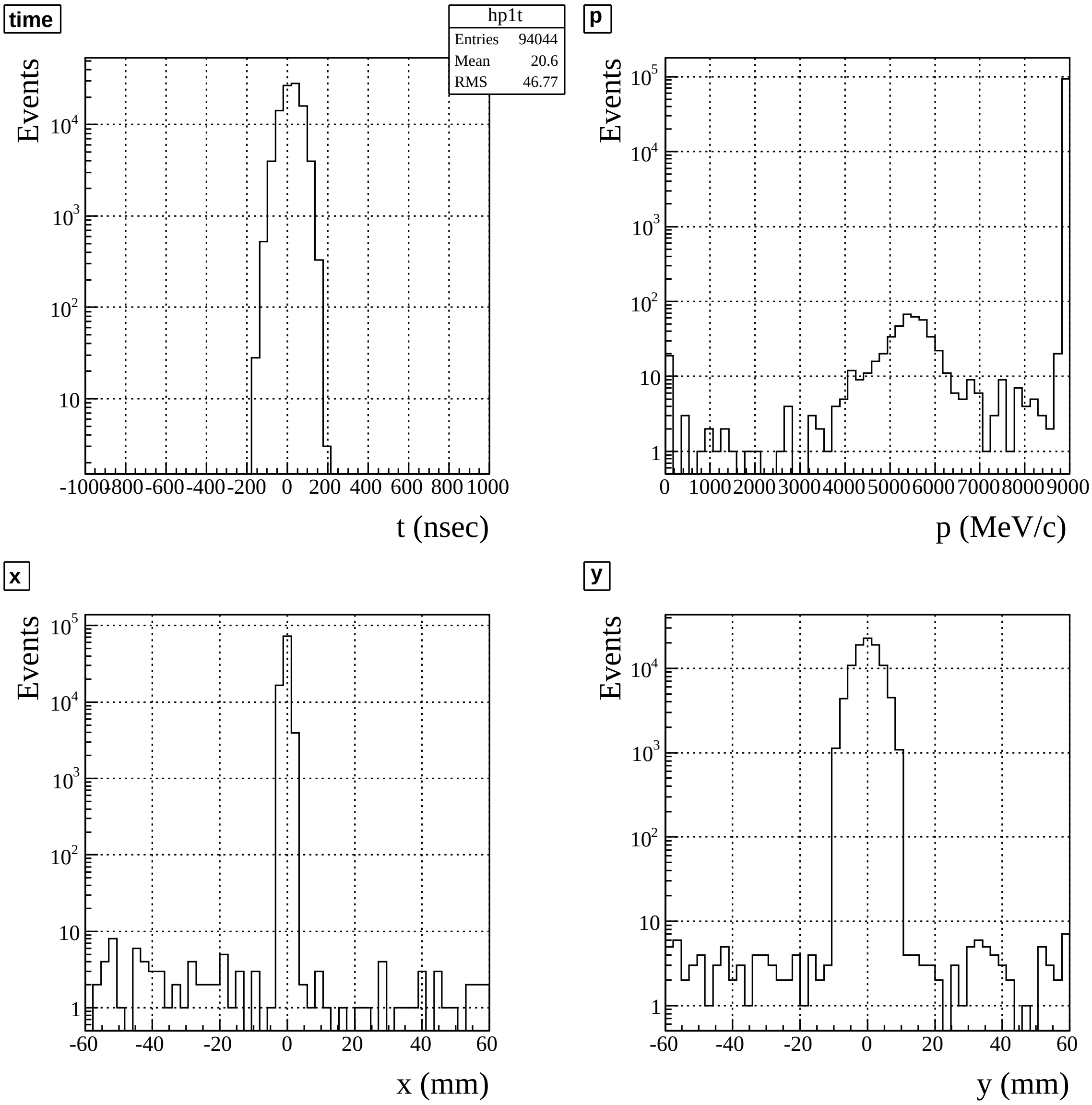

FIG. 13: Outlet of the final focus section. Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

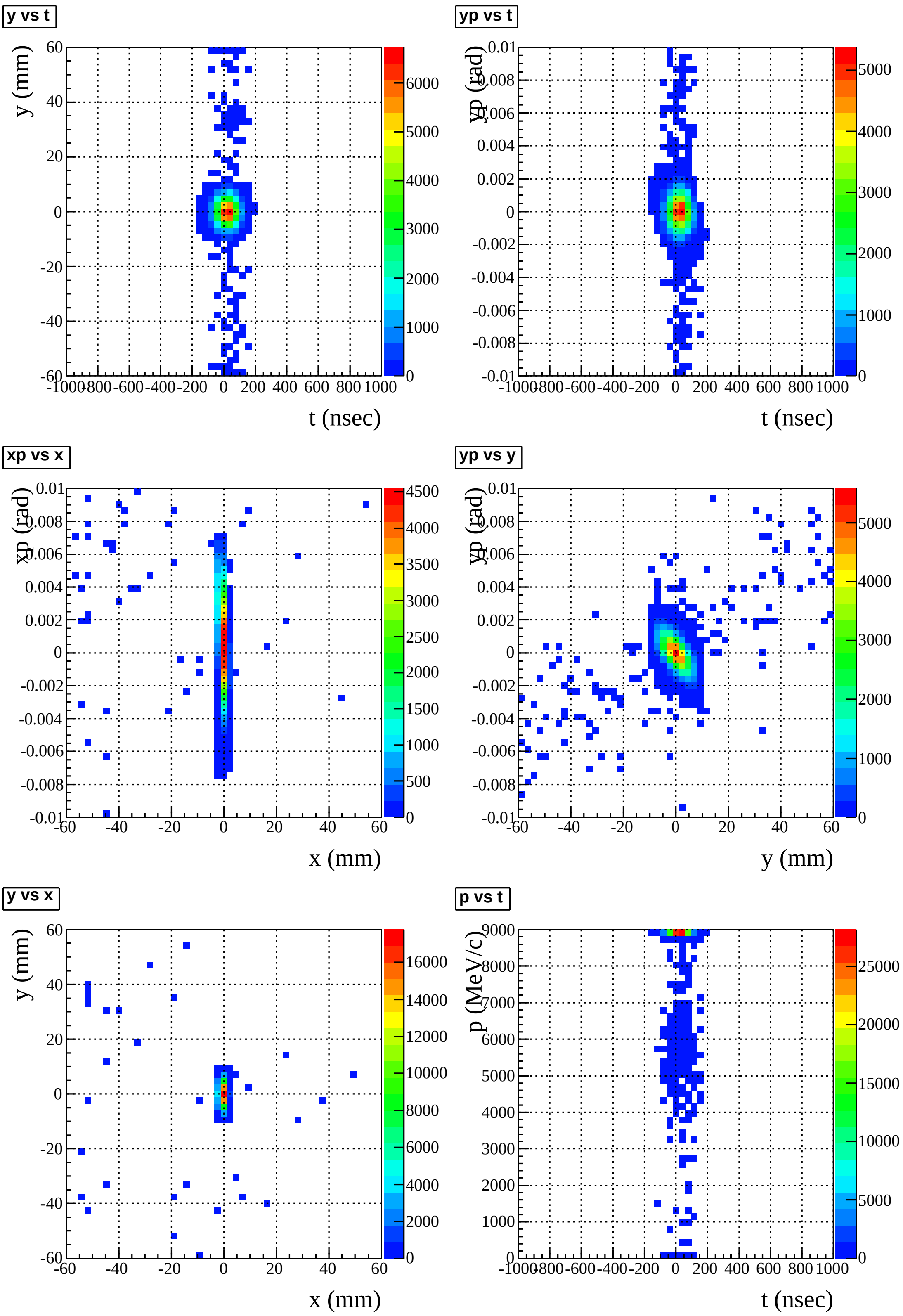

FIG. 14: Outlet of the final-focus section. Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution $(x - x')$. Middle right: Phase distribution $(y - y')$. Lower left: Beam profile $(x - y)$. Lower right: time vs momentum.

III. EMPTY BUCKET BEAM

A. Trace of proton beam

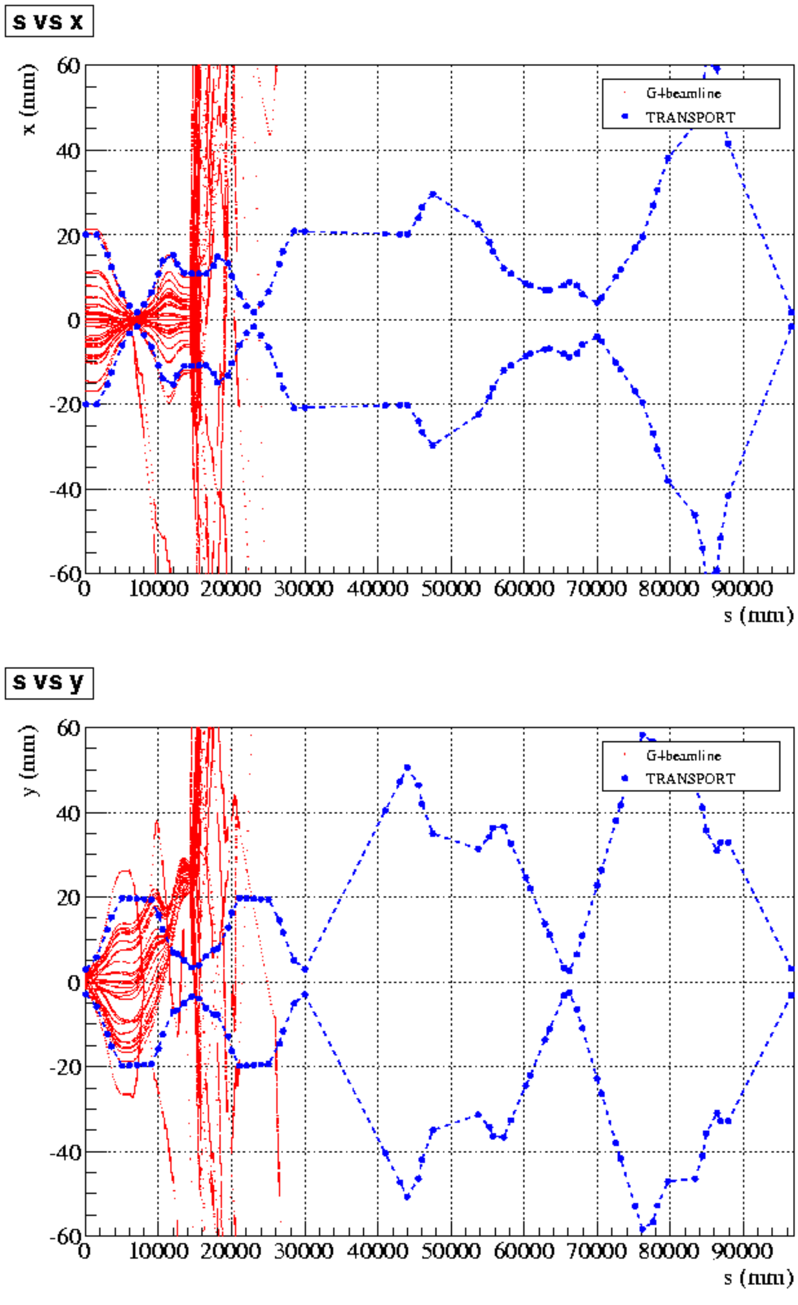

FIG. 15: Trace of proton beam. Upper: x vs z. Lower: y vs. z.

B. Entrance of the AC-dipole section

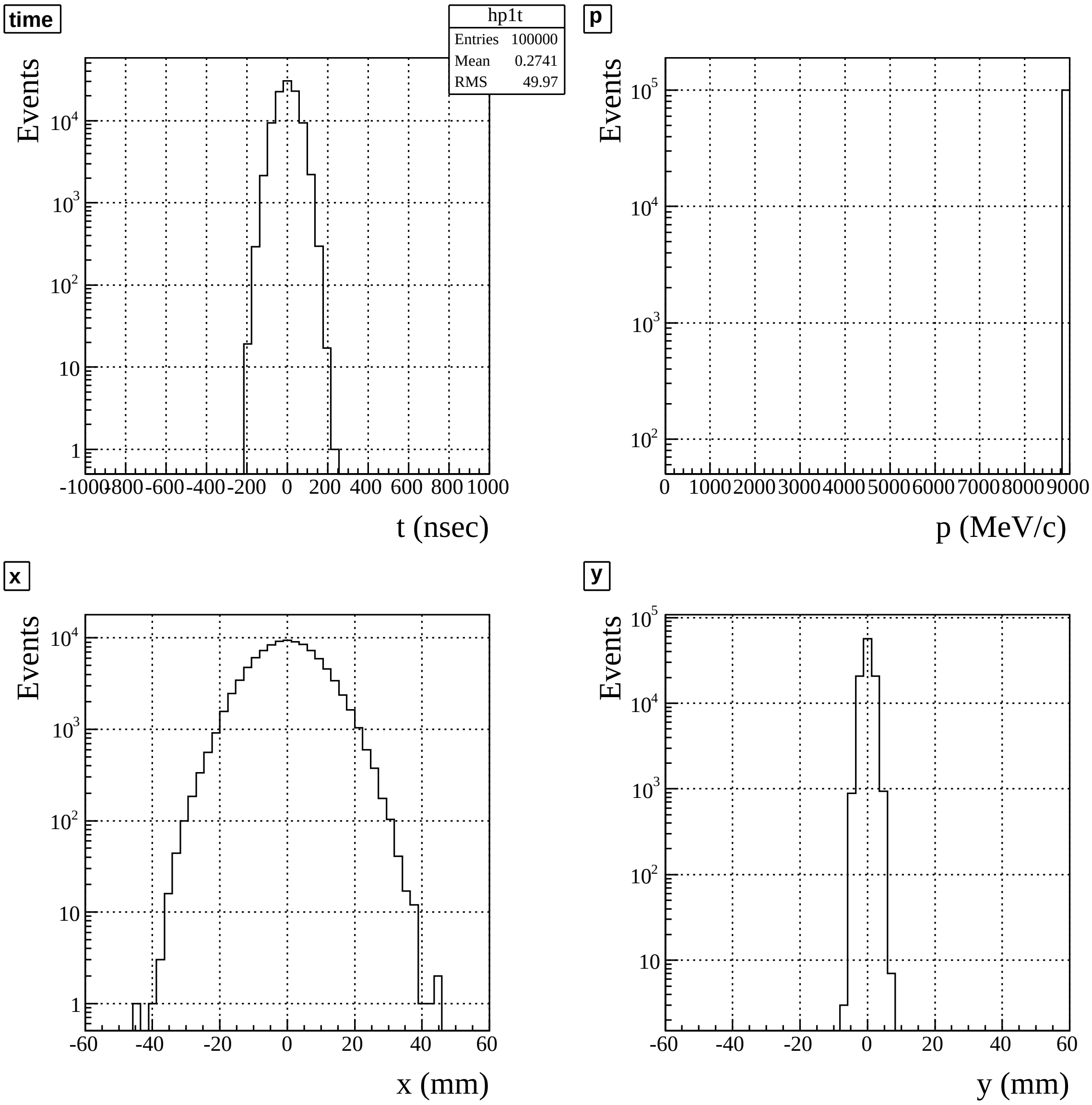

FIG. 16: Inlet of the AC-dipole section. Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

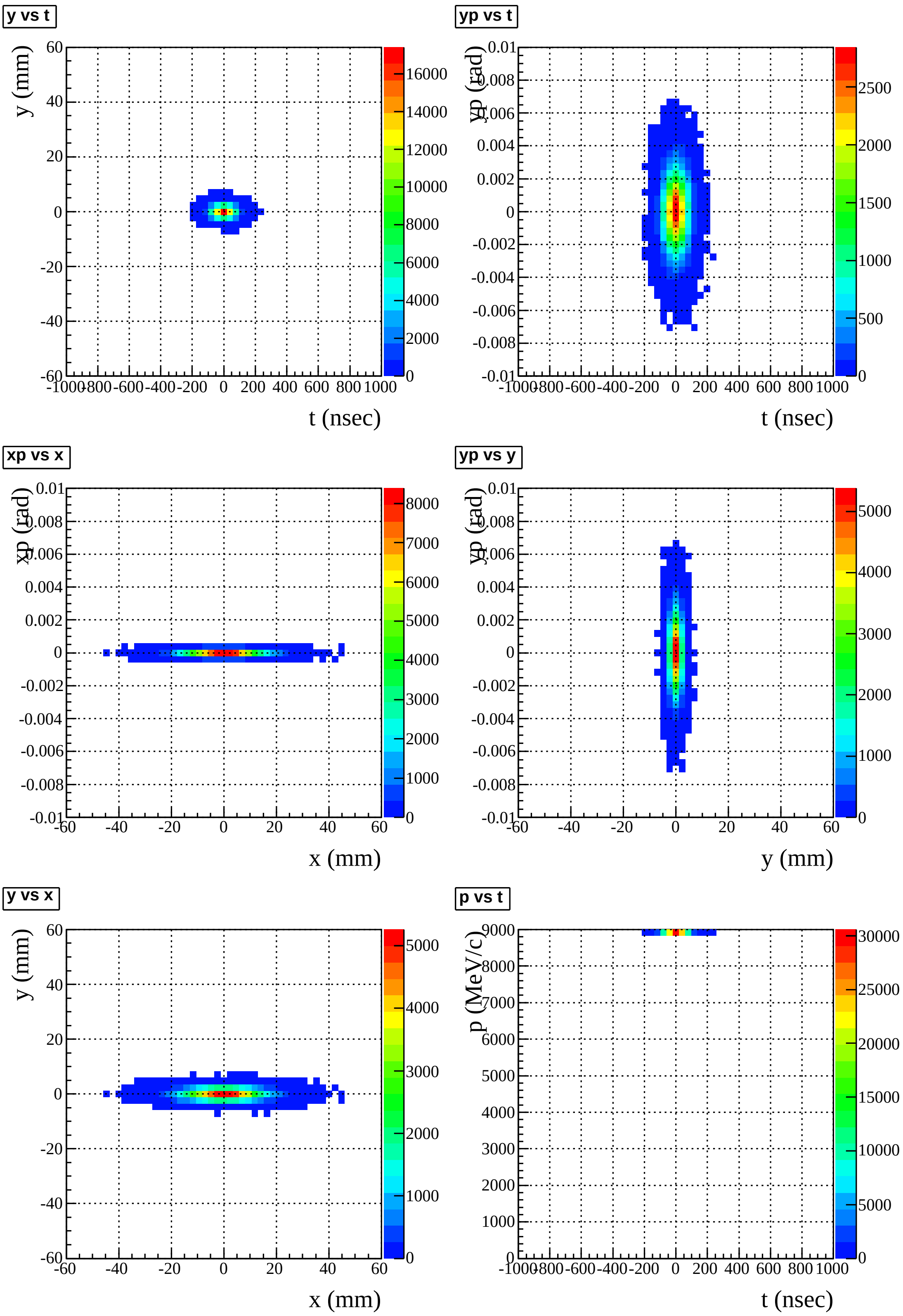

FIG. 17: Inlet of the AC-dipole section. Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution $(x - x')$. Middle right: Phase distribution $(y - y')$. Lower left: Beam profile $(x - y)$. Lower right: time vs momentum.

C. Entrance of the first AC-dipole

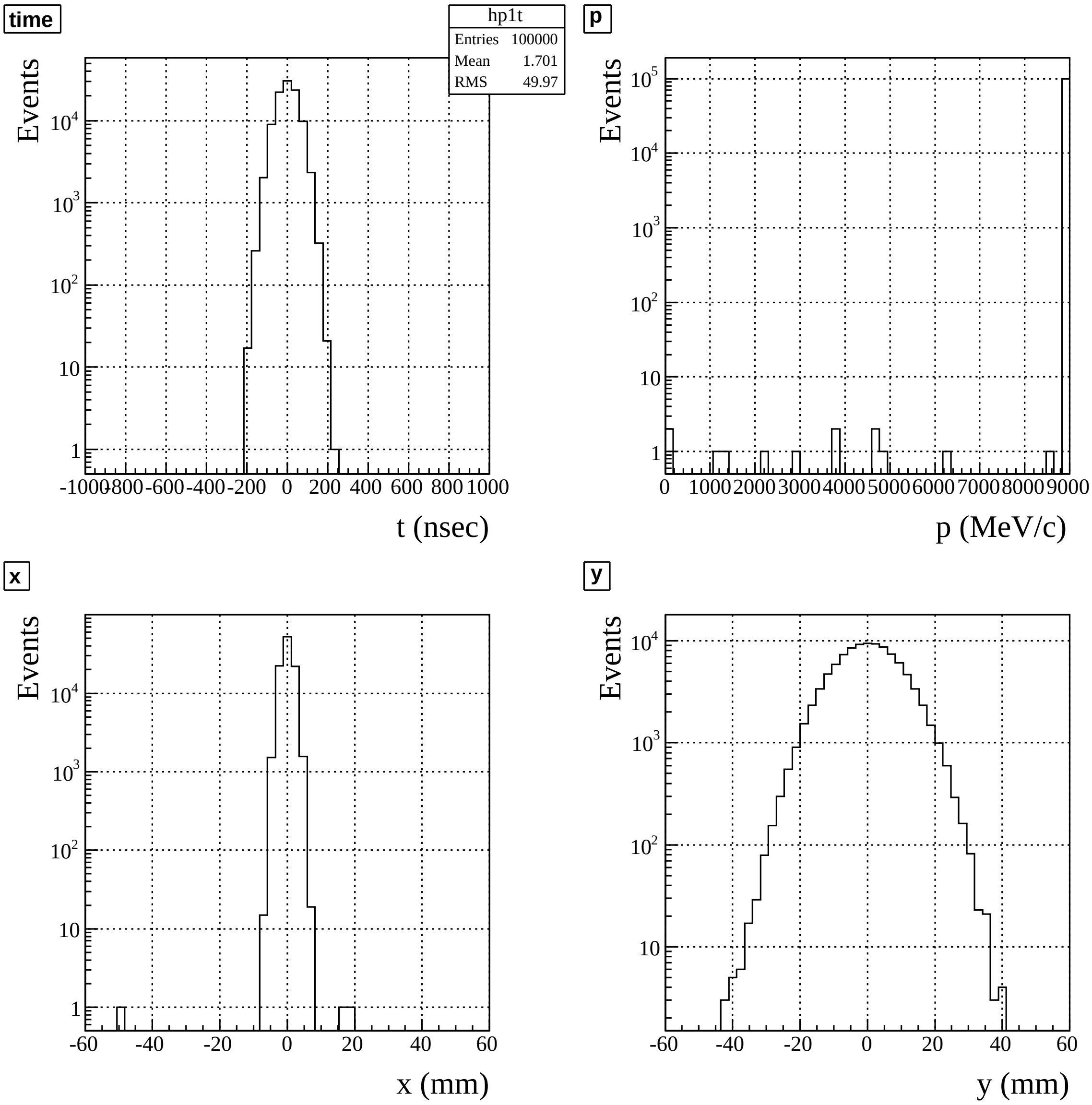

FIG. 18: Inlet of the 1st AC-dipole. Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

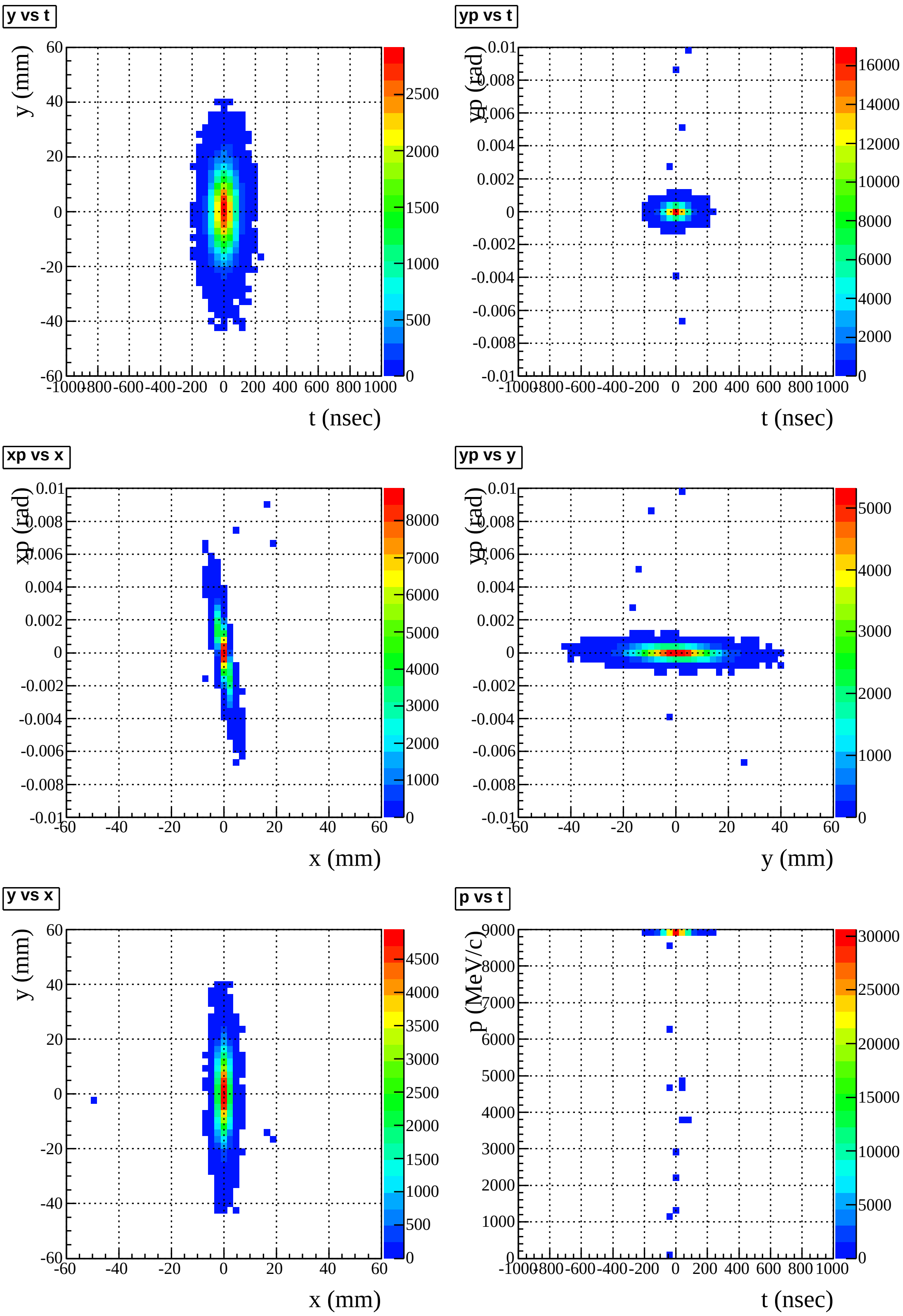

FIG. 19: Inlet of the 1st AC-dipole. Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution ($x - x'$). Middle right: Phase distribution ($y - y'$). Lower left: Beam profile ($x - y$). Lower right: time vs momentum.

D. Inlet of the collimator

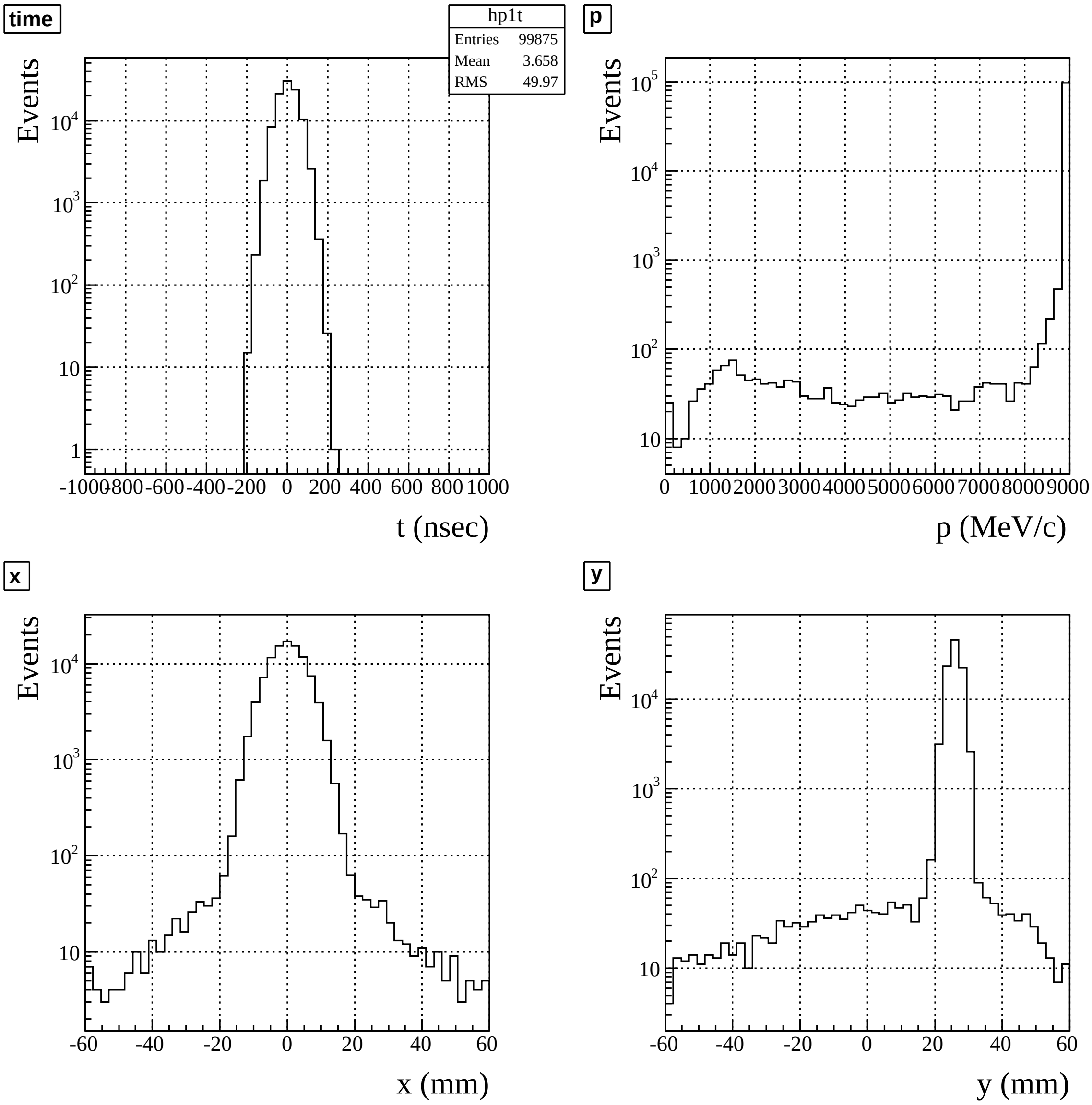

FIG. 20: Inlet of the collimator. Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

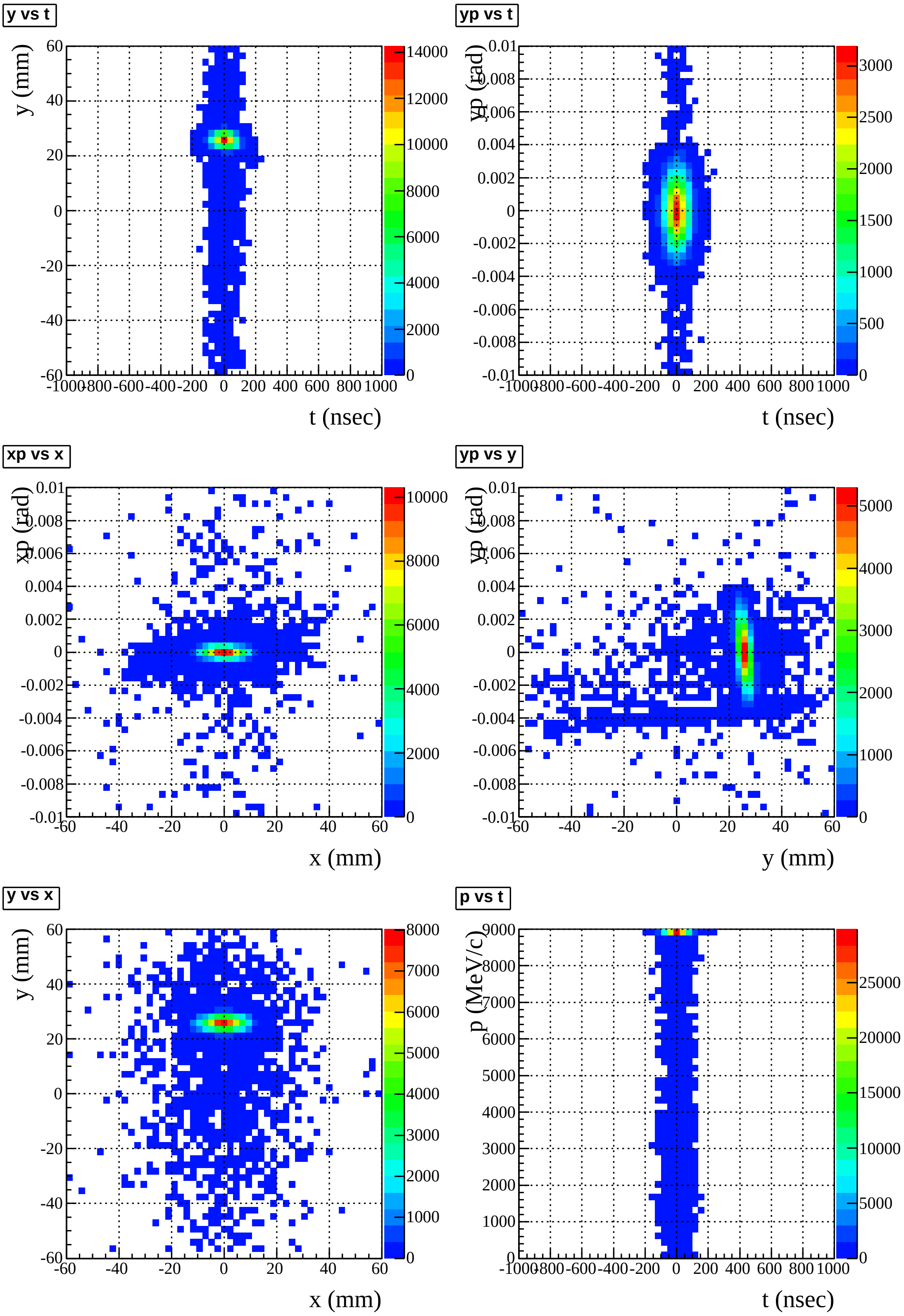

FIG. 21: Inlet of the collimator. Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution $(x - x')$. Middle right: Phase distribution $(y - y')$. Lower left: Beam profile $(x - y)$. Lower right: time vs momentum.

E. Outlet of the collimator

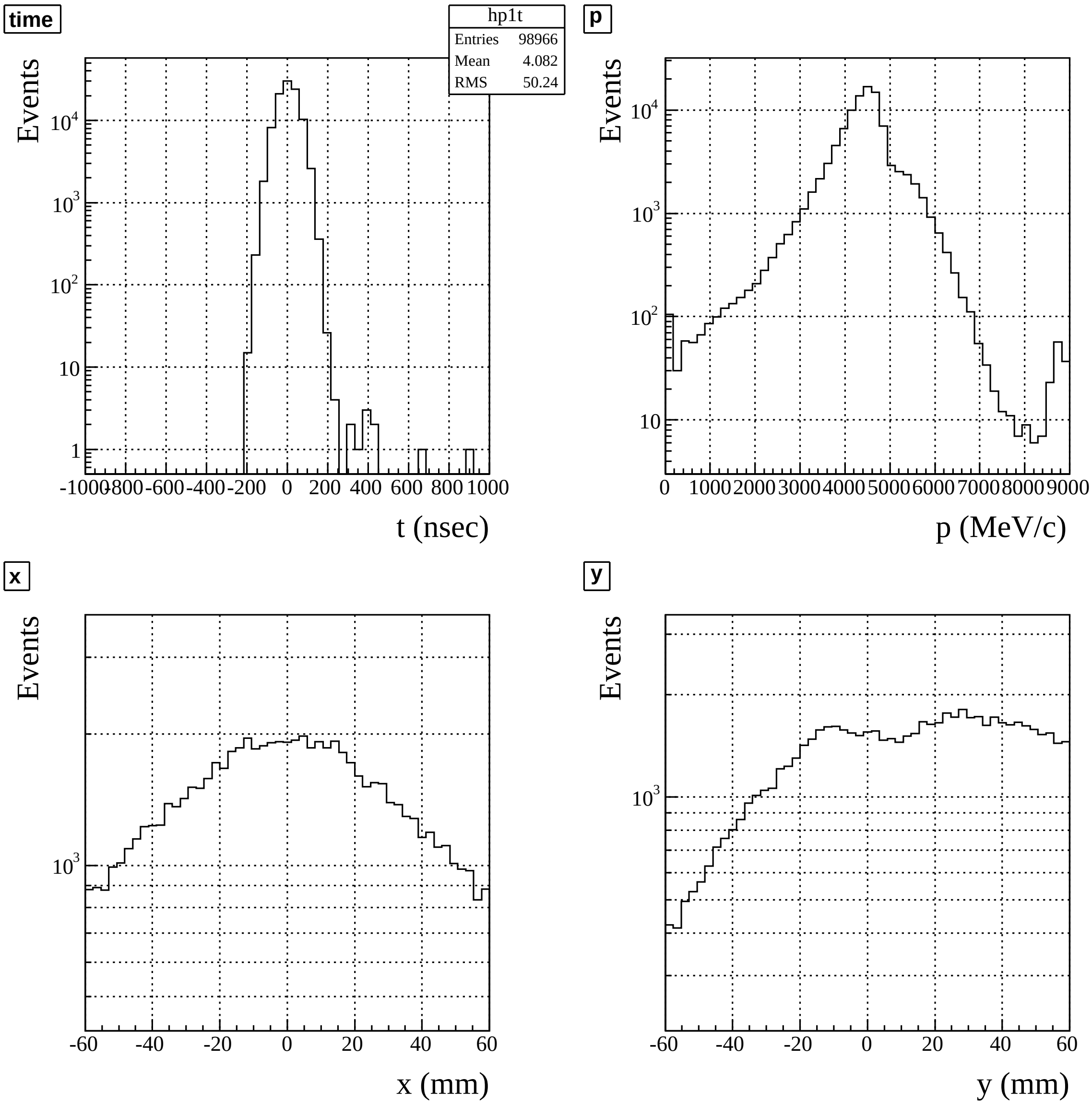

FIG. 22: Collimator outlet. Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

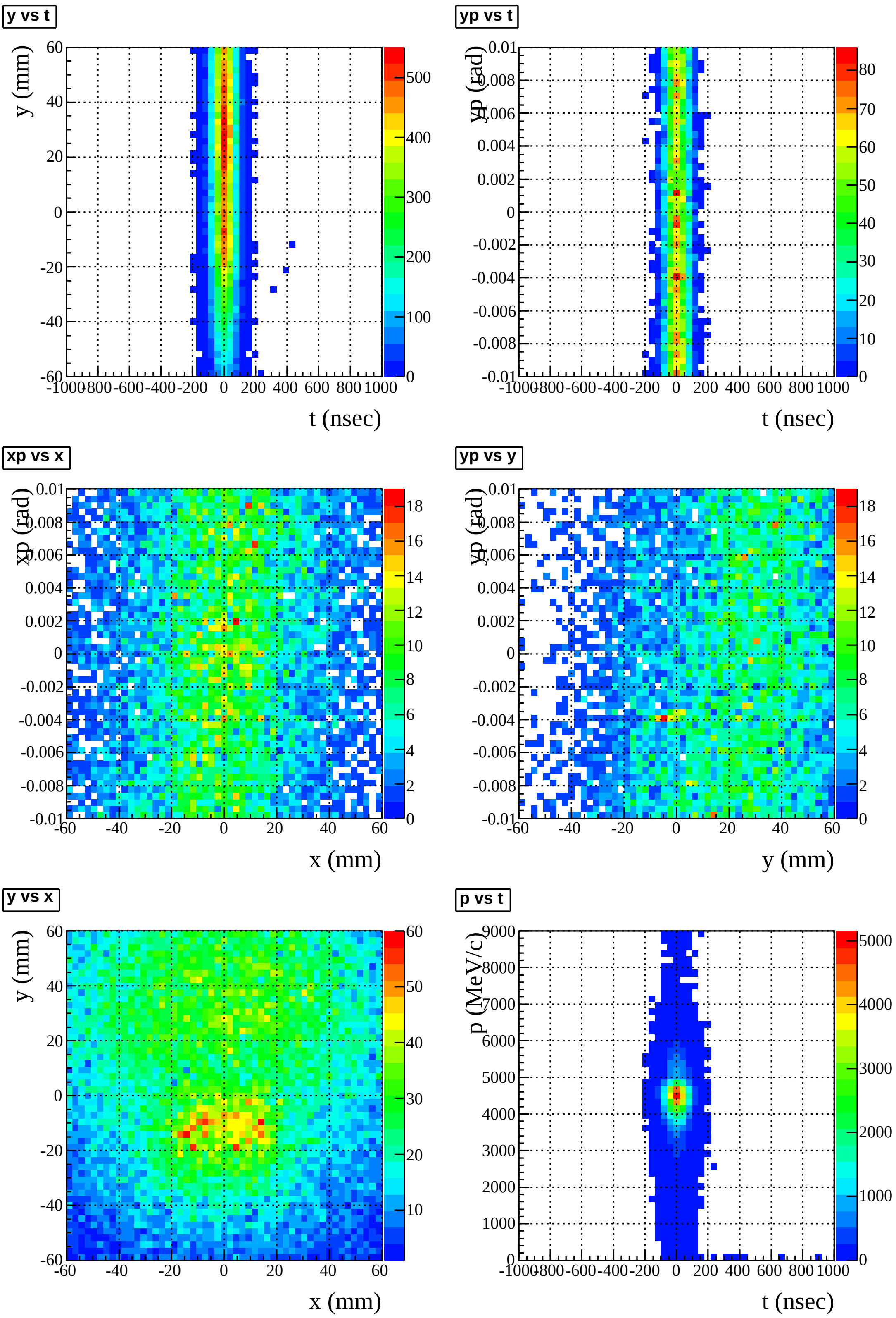

FIG. 23: Outlet of the collimator. Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution $(x - x')$. Middle right: Phase distribution $(y - y')$. Lower left: Beam profile $(x - y)$. Lower right: time vs momentum.

F. Outlet of the AC-dipole section (inlet of the final-focus section)

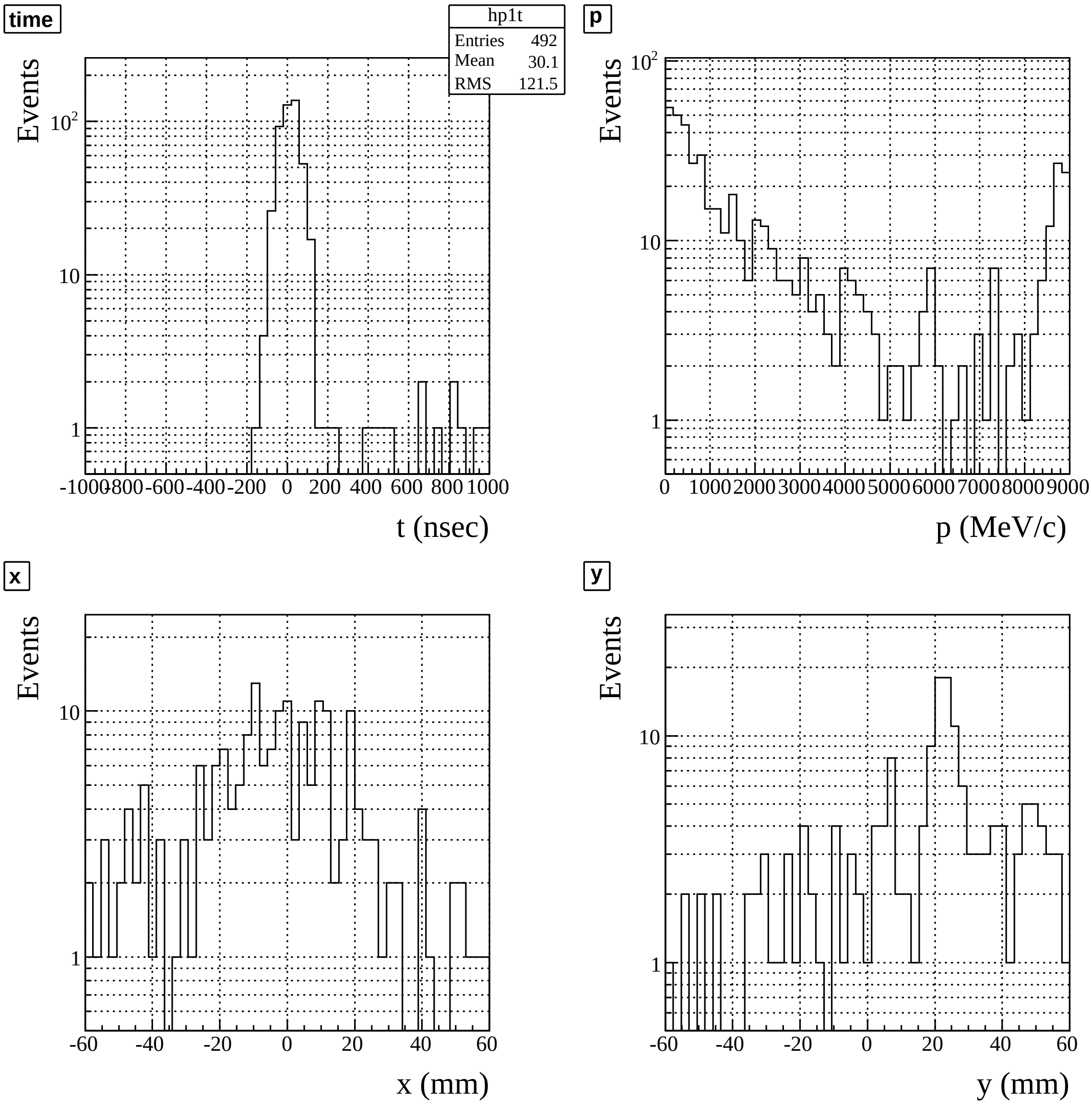

FIG. 24: Outlet of the AC-dipole section (inlet of the final-focus section). Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

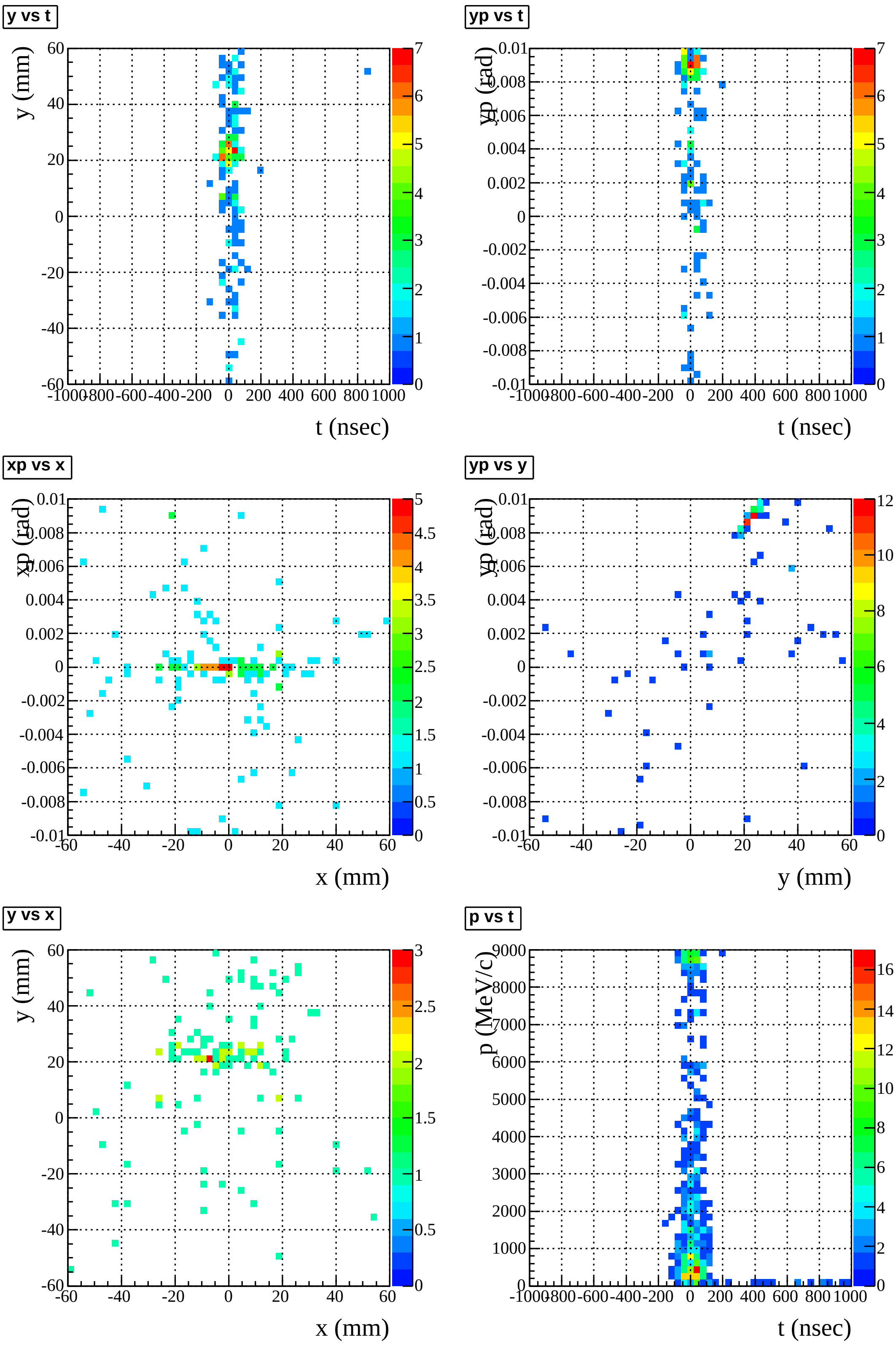

FIG. 25: Outlet of the AC-dipole section (inlet of the final-focus section). Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution $(x - x')$. Middle right: Phase distribution $(y - y')$. Lower left: Beam profile $(x - y)$. Lower right: time vs momentum.

G. Outlet of the final-focus section (on the proton target)

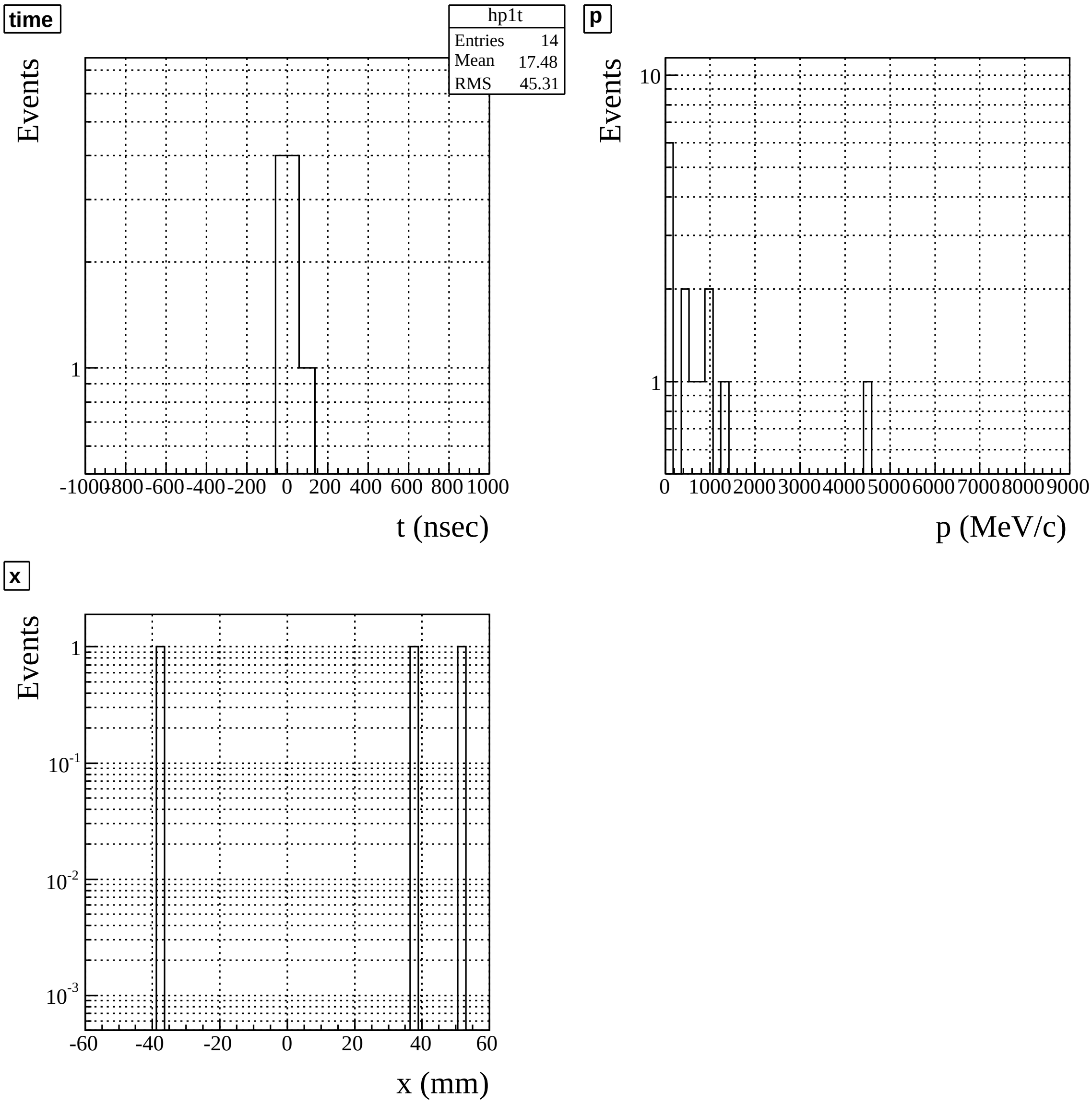

FIG. 26: Outlet of the final focus section. Upper left: time sepctrum. Upper right: Momentum spectrum. Lower left: Beam profile in x axis. Lower right: Beam profile in y axis.

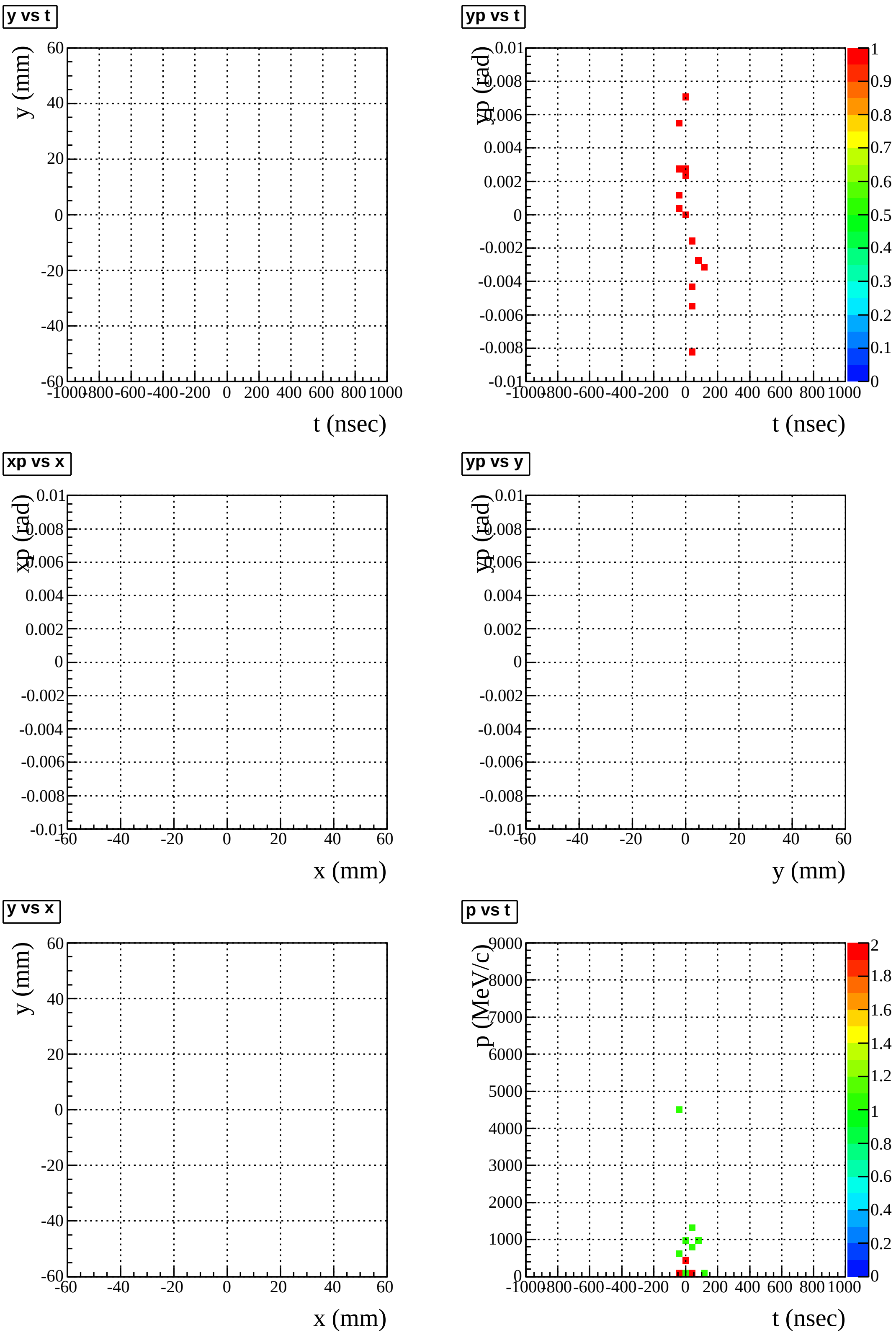

FIG. 27: Outlet of the final-focus section. Upper left: time vs y. Upper right:time vs y'. Middle left: Phase distribution $(x - x')$. Middle right: Phase distribution $(y - y')$. Lower left: Beam profile $(x - y)$. Lower right: time vs momentum.

IV. INPUTFILE FOR B4BEAMLINE

A. Simulation of main bucket

```
# 2009/01/18 AC Dipole is varied with sinusoildal wave.
#       "fieldexpr" is used instead of "genericbend" as AC dipole.
#
# 2009/01/09 New AC Dipole Section
#
# Two DFD triplets are used.
#
# After SM
#
# ----------------------------------------------
# trace the first 10 events
# ----------------------------------------------
trace nTrace=10 primaryOnly=1
# ----------------------------------------------
# Parameters
# ----------------------------------------------
param maxStep=100.0
param PI=3.14159265358979
#-----------------------------------------------
# LightVel : Light volocity [m/sec]
#-----------------------------------------------
param LightVel=2.99792458E8
#-----------------------------------------------
# protonMom : Proton beam momentum [MeV/c]
#-----------------------------------------------
param protonMom=8888.9
param beta=0.994475134
#-----------------------------------------------
# t_acd : period of AC dipole field [nsec]
#-----------------------------------------------
param t_acd=2600.0
#-----------------------------------------------
# f_adc : frequency of AC dipole [Hz] (=384,615 Hz @ $t_acd=2600 nsec)
#-----------------------------------------------
param f_acd=1.0/$t_acd*1.0E9
#-----------------------------------------------
# Laa : Distance between 1st and 2nd AC dipole [m].
#-----------------------------------------------
param Laa=16.0
param delPhase=$Laa/$beta/$LightVel*1E9/$t_acd*$PI*2.0
#-----------------------------------------------
# len_bunch : half length of proton beam bunch [nsec].
param len_bunch=50.
#param ad_delT=$t_acd*0.25
param ad_delT=0.0
#-----------------------------------------------
#-----------------------------------------------
# Comment out by YA
physics LHEP_BERT_HP doDecay=0 doStochastics=1 minRangeCut=0.020
trackcuts kill=nu_e,nu_mu,nu_tau kineticEnergyCut=.1 maxTime=260000.0
particlecolor proton=1,1,1 pi-=1,0,1 mu-=0,1,0 e-=1,0,0 \
              plus=0,0,1 minus=1,1,0 neutral=0,1,1

#-----------------------------------------------
```

```
# b_acd : Amplitude of AC dipole field [T]
#-----------------------------------------------
param histoFile=acd_ff-01-main_buckt
#param histoFile=acd_ff-01-empty_buckt
#param histoFile=test
param b_acd=0.0600
#param b_acd=0.0
#param histoFile=acdipole-08-b000
#param b_acd=0.0
#param histoFile=acdipole-08-b073
#param b_acd=0.00725
beamlossntuple beamloss format=root filename=primary-b-loss.root

param zlength=0.0

# ----------------------------------------------
# Beam Setting
# ----------------------------------------------
# Gaussian beam
beam gaussian nEvents=100000 firstEvent=1 \
     beamX=0 beamY=0 beamZ=0 meanMomentum=$protonMom \
     sigmaX=10.0 sigmaXp=0.125e-3 sigmaY=1.5 sigmaYp=3.33e-3/2. \
     sigmaP=-26.7 sigmaT=$len_bunch
#     sigmaP=-26.7 sigmaT=-$t_acd*0.25
# end of Gaussian beam
#beam ellipse nEvents=10 firstEvent=1 \
#     beamX=0 beamY=0 beamZ=0 meanMomentum=$protonMom \
#     sigmaX=20.0 sigmaXp=0.25e-3 sigmaY=3.0 sigmaYp=3.33e-3 \
#     sigmaP=-26.7 sigmaT=$len_bunch
# test beam (zero emittance beam)
#beam ellipse nEvents=100 firstEvent=1 \
#     beamX=0 beamY=0 beamZ=0 meanMomentum=$protonMom \
#     sigmaX=0.0 sigmaXp=0. sigmaY=0.0 sigmaYp=0.0 \
#     sigmaP=0 sigmaT=$len_bunch
###############################################################

reference particle=proton referenceMomentum=$protonMom beamZ=0 beamX=0 beamY=0

# ----------------------------------------------
# Definition of magnets
# ----------------------------------------------

param QIRONCOL=0.4,0.6,1.0
param DIRONCOL=1.0,0.8,0.4
param COLLCOL=0.2,0.8,0.8

param AKF1=6.364748
param AKF2=13.001271
param AKD1=-6.609374
param AKD2=-11.17290
param AKD3=-10.71605

param LQUAD1=1500.
param LQUAD2=1000.


param mq1_length=$LQUAD1
genericquad MQ1 fieldLength=$mq1_length ironLength=$mq1_length \
```

```
    gradient=-1.756740763 apertureRadius=55. ironRadius=500.\
    ironColor=$QIRONCOL

param mq2_length=$LQUAD1
genericquad MQ2 fieldLength=$mq2_length ironLength=$mq2_length \
    gradient=2.136592619 apertureRadius=55. ironRadius=500.\
    ironColor=$QIRONCOL

param mq3_length=$LQUAD1
genericquad MQ3 fieldLength=$mq3_length ironLength=$mq3_length \
    gradient=3.21362967 apertureRadius=55. ironRadius=500.\
    ironColor=$QIRONCOL


param mq4_length=$LQUAD1
genericquad MQ4 fieldLength=$mq4_length ironLength=$mq4_length \
    gradient=-4.759703763 apertureRadius=55. ironRadius=500.\
    ironColor=$QIRONCOL
#######################
#  AC Dipole Section
#######################
param aq1_length=$LQUAD1
genericquad AQ1 fieldLength=$aq1_length ironLength=$aq1_length \
    gradient=$AKF1 apertureRadius=55. ironRadius=500.\
    fringe=0, ironColor=$QIRONCOL

param aq2_length=$LQUAD1
genericquad AQ2 fieldLength=$aq2_length ironLength=$aq2_length \
    gradient=$AKD1 apertureRadius=55. ironRadius=500.\
    fringe=0, ironColor=$QIRONCOL

param ad_length=2000.0
param ad_fldWidth=50.
param ad_fldHeight=10.
param ad_gapWidth=50.
param ad_gapHeight=10.
####################################################################
fieldexpr   ADt1 factorB=$b_acd \
    time=sin(2.*$PI*$f_acd*(t-$ad_delT)*1.0E-9) \
    Bx=0.0 By=1.0 Bz=0.0 nX=20 nY=20 nZ=100 nT=100 \
    length=$ad_length width=$ad_fldWidth height=$ad_fldHeight \
    tmin=-$t_acd*0.5 tmax=$t_acd*0.5
#     tmin=-$len_bunch*2.0 tmax=$len_bunch*2.0
fieldexpr   ADt2 factorB=$b_acd \
    time=sin(2.*$PI*$f_acd*(t-$ad_delT)*1.0E-9-$delPhase) \
    Bx=0.0 By=1.0 Bz=0.0 nX=20 nY=20 nZ=100 nT=100 \
    length=$ad_length width=$ad_fldWidth height=$ad_fldHeight \
    tmin=-$t_acd*0.5 tmax=$t_acd*0.5
#     tmin=-$len_bunch*2.0 tmax=$len_bunch*2.0
####################################################################
#genericbend AD fieldLength=$ad_length By=$b_acd fieldHeight=$ad_fldHeight \
#     ironHeight=100. fieldWidth=$ad_fldWidth ironWidth=100. \
#     ironLength=$ad_length fringe=0 ironColor=$DIRONCOL
genericbend AD fieldLength=$ad_length By=0.0 fieldHeight=$ad_fldHeight \
    ironHeight=100. fieldWidth=$ad_fldWidth ironWidth=100. \
    ironLength=$ad_length fringe=0 ironColor=$DIRONCOL

param aq3_length=$LQUAD2
```

```
genericquad AQ3 fieldLength=$aq3_length ironLength=$aq3_length \
    gradient=$AKD2 apertureRadius=55. ironRadius=500.\
    fringe=0, ironColor=$QIRONCOL

param aq4_length=$LQUAD1
genericquad AQ4 fieldLength=$aq4_length ironLength=$aq4_length \
    gradient=$AKF2 apertureRadius=55. ironRadius=500.\
    fringe=0, ironColor=$QIRONCOL

param aq5_length=$LQUAD2
genericquad AQ5 fieldLength=$aq5_length ironLength=$aq5_length \
    gradient=$AKD3 apertureRadius=55. ironRadius=500.\
    fringe=0, ironColor=$QIRONCOL

param collimator_length=1500.
param collimator_gap=18.
param collimator_gapx=30.
param collimator_height=200.
param collimator_width=200.
box COLLIMATOR height=$collimator_height \
       width=$collimator_width*2.+$collimator_gapx \
       length=$collimator_length \
       material=W
box COLLIMATORX height=$collimator_gap width=$collimator_width \
length=$collimator_length \
        material=W

param aq6_length=$LQUAD2
genericquad AQ6 fieldLength=$aq6_length ironLength=$aq6_length \
    gradient=$AKD3 apertureRadius=55. ironRadius=500.\
    fringe=0, ironColor=$QIRONCOL

param aq7_length=$LQUAD1
genericquad AQ7 fieldLength=$aq7_length ironLength=$aq7_length \
    gradient=$AKF2 apertureRadius=55. ironRadius=500.\
    fringe=0, ironColor=$QIRONCOL

param aq8_length=$LQUAD2
genericquad AQ8 fieldLength=$aq8_length ironLength=$aq8_length \
    gradient=$AKD2 apertureRadius=55. ironRadius=500.\
    fringe=0, ironColor=$QIRONCOL

param aq9_length=$LQUAD1
genericquad AQ9 fieldLength=$aq9_length ironLength=$aq9_length \
    gradient=$AKD1 apertureRadius=55. ironRadius=500.\
    fringe=0, ironColor=$QIRONCOL

param aq10_length=$LQUAD1
genericquad AQ10 fieldLength=$aq10_length ironLength=$aq10_length \
    gradient=$AKF1 apertureRadius=55. ironRadius=500.\
    fringe=0, ironColor=$QIRONCOL

#######################
#  Final Focus Section
#######################
param fq1_length=1500.
genericquad FQ1 fieldLength=$fq1_length ironLength=$fq1_length \
    gradient=-4.851 apertureRadius=100. ironRadius=500.\
```

```
    ironColor=$QIRONCOL

param fq2_length=1500.
genericquad FQ2 fieldLength=$fq2_length ironLength=$fq2_length \
    gradient=4.394 apertureRadius=100. ironRadius=500.\
    ironColor=$QIRONCOL

param fd1_length=2000.0
param fd1_By=1.293321
genericbend FD1 fieldLength=$fd1_length By=$fd1_By fieldHeight=300. \
    ironHeight=600. fieldWidth=600. ironWidth=900. \
    ironLength=$fd1_length fringe=0\
    ironColor=$DIRONCOL

param fq3_length=1500.
genericquad FQ3 fieldLength=$fq3_length ironLength=$fq3_length \
    gradient=3.031 apertureRadius=100. ironRadius=500.\
    ironColor=$QIRONCOL

param fq4_length=1500.
genericquad FQ4 fieldLength=$fq4_length ironLength=$fq4_length \
    gradient=-4.394 apertureRadius=100. ironRadius=500.\
    ironColor=$QIRONCOL

param fd2_length=2000.0
param fd2_By=1.551769
genericbend FD2 fieldLength=$fd2_length By=$fd2_By fieldHeight=300. \
    ironHeight=600. fieldWidth=600. ironWidth=900. \
    ironLength=$fd2_length fringe=0\
    ironColor=$DIRONCOL

param fd3_length=2000.0
param fd3_By=1.551769
genericbend FD3 fieldLength=$fd3_length By=$fd2_By fieldHeight=300. \
    ironHeight=600. fieldWidth=600. ironWidth=900. \
    ironLength=$fd3_length fringe=0\
    ironColor=$DIRONCOL

param fd4_length=2000.0
param fd4_By=1.551769
genericbend FD4 fieldLength=$fd4_length By=$fd4_By fieldHeight=300. \
    ironHeight=600. fieldWidth=600. ironWidth=900. \
    ironLength=$fd4_length fringe=0\
    ironColor=$DIRONCOL

param fq5_length=1000.
genericquad FQ5 fieldLength=$fq5_length ironLength=$fq5_length \
    gradient=14.661 apertureRadius=50. ironRadius=400.\
    ironColor=$QIRONCOL

param fd5_length=2000.0
param fd5_By=1.551769
genericbend FD5 fieldLength=$fd5_length By=$fd5_By fieldHeight=300. \
    ironHeight=600. fieldWidth=600. ironWidth=900. \
    ironLength=$fd5_length fringe=0\
    ironColor=$DIRONCOL

param fd6_length=2000.0
```

```
param fd6_By=1.551769
genericbend FD6 fieldLength=$fd6_length By=$fd6_By fieldHeight=300. \
    ironHeight=600. fieldWidth=600. ironWidth=900. \
    ironLength=$fd6_length fringe=0\
    ironColor=$DIRONCOL

param fd7_length=2000.0
param fd7_By=1.551769
genericbend FD7 fieldLength=$fd7_length By=$fd7_By fieldHeight=300. \
    ironHeight=600. fieldWidth=600. ironWidth=900. \
    ironLength=$fd7_length fringe=0\
    ironColor=$DIRONCOL

param fq6_length=1500.
genericquad FQ6 fieldLength=$fq6_length ironLength=$fq6_length \
    gradient=-4.394 apertureRadius=100. ironRadius=500.\
    ironColor=$QIRONCOL

param fq7_length=1500.
genericquad FQ7 fieldLength=$fq7_length ironLength=$fq7_length \
    gradient=3.031 apertureRadius=100. ironRadius=500. \
    ironColor=$QIRONCOL

param fq8_length=1000.
genericquad FQ8 fieldLength=$fq8_length ironLength=$fq8_length \
    gradient=-6.929 apertureRadius=100. ironRadius=500.\
    ironColor=$QIRONCOL

param fq9_length=1500.
genericquad FQ9 fieldLength=$fq9_length ironLength=$fq9_length \
    gradient=9.048 apertureRadius=100. ironRadius=500.\
    ironColor=$QIRONCOL

param fq10_length=1000.
genericquad FQ10 fieldLength=$fq10_length ironLength=$fq10_length \
    gradient=-6.929 apertureRadius=100. ironRadius=500.\
    ironColor=$QIRONCOL

# ---------------------------------------------
# beam monitor
# ---------------------------------------------
virtualdetector det radius=500.0 length=0.1 material=Vacuum \
noSingles=1 color=0.0000,1.0000,0.0000

# ---------------------------------------------
# placements
# ---------------------------------------------
############################
#AC dipole section
############################
param zlength=0.0
place det z=1.0 rename=bm_acdin
param zlength=$zlength+1500.

place AQ1 z=$zlength+$aq1_length/2.
param zlength=$zlength+$aq1_length

param zlength=$zlength+500.
```

```
place AQ2 z=$zlength+$aq2_length/2.
param zlength=$zlength+$aq2_length

param zlength=$zlength+999.
place det z=$zlength rename=bm_ad1in
param zlength=$zlength+1.
#--------------------AC Dipole----------------------------#
place AD z=$zlength+$ad_length/2. rotation=Z90.
place ADt1 z=$zlength+$ad_length/2. rotation=Z90. rename=AD1
#-----------------end of AC Dipole------------------------#

#place det z=$zlength+$ad_length/2.+1. rename=bm_ad1cen

param zlength=$zlength+$ad_length

param zlength=$zlength+1.
place det z=$zlength rename=bm_ad1out
param zlength=$zlength+999.

place AQ3 z=$zlength+$aq3_length/2.
param zlength=$zlength+$aq3_length

param zlength=$zlength+500.

place AQ4 z=$zlength+$aq4_length/2.
param zlength=$zlength+$aq4_length

param zlength=$zlength+500.

place AQ5 z=$zlength+$aq5_length/2.
param zlength=$zlength+$aq5_length

param zlength=$zlength+1500-$collimator_length/2.-1.0
place det z=$zlength rename=bm_collin
param zlength=$zlength+1.

place COLLIMATOR y=($collimator_gap+$collimator_height)/2. \
      z=$zlength+$collimator_length/2. rename=COLLU
place COLLIMATOR y=-($collimator_gap+$collimator_height)/2. \
      z=$zlength+$collimator_length/2. rename=COLLD
place COLLIMATORX y=0. x=($collimator_gapx+$collimator_width)/2 \
      z=$zlength+$collimator_length/2. rename=COLLR
place COLLIMATORX y=0.  x=-($collimator_gapx+$collimator_width)/2 \
      z=$zlength+$collimator_length/2. rename=COLLL

param zlength=$zlength+$collimator_length

param zlength=$zlength+1.
place det z=$zlength rename=bm_collout
param zlength=$zlength+1500-$collimator_length/2.-1.0

place AQ6 z=$zlength+$aq6_length/2.
param zlength=$zlength+$aq6_length

param zlength=$zlength+500.

place AQ7 z=$zlength+$aq7_length/2.
```

```
param zlength=$zlength+$aq7_length

param zlength=$zlength+500.

place AQ8 z=$zlength+$aq8_length/2.
param zlength=$zlength+$aq8_length

param zlength=$zlength+999.
place det z=$zlength rename=bm_ad2in
param zlength=$zlength+1.

#--------------------AC Dipole----------------------------#
place AD z=$zlength+$ad_length/2. rotation=Z90.
place ADt2 z=$zlength+$ad_length/2. rotation=Z90. rename=AD2
#-----------------end of AC Dipole------------------------#

#place det z=$zlength+$ad_length/2.+1. rename=bm_ad2cen

param zlength=$zlength+$ad_length

param zlength=$zlength+1.
place det z=$zlength rename=bm_ad2out
param zlength=$zlength+999.

place AQ9 z=$zlength+$aq9_length/2.
param zlength=$zlength+$aq9_length

param zlength=$zlength+500.

place AQ10 z=$zlength+$aq10_length/2.
param zlength=$zlength+$aq10_length

param zlength=$zlength+1500.

place det z=$zlength rename=bm_ffin

############################
# Final Focus Section
############################

param zlength=$zlength+11000.

place det z=$zlength-1. rename=bm_fd1in rotation=Y-2.5

place FD1 z=$zlength+$fd1_length/2. rotation=Y-2.5
cornerarc z=$zlength angle=-5.0 centerRadius=$protonMom/$fd1_By/300.*1000

param zlength=$zlength+$fd1_length


place det z=$zlength+1. rename=bm_fd1out rotation=Y2.5

param zlength=$zlength+500.

place FQ1 z=$zlength+$fq1_length/2.
param zlength=$zlength+$fq1_length

param zlength=$zlength+500.
```

```
place FQ2 z=$zlength+$fq2_length/2.
param zlength=$zlength+$fq2_length

param zlength=$zlength+6200.

place FQ3 z=$zlength+$fq3_length/2.
param zlength=$zlength+$fq3_length

param zlength=$zlength+500.

place FQ4 z=$zlength+$fq4_length/2.
param zlength=$zlength+$fq4_length

param zlength=$zlength+1000.

place FD2 z=$zlength+$fd2_length/2. rotation=Y-3.0
cornerarc z=$zlength angle=-6.0 centerRadius=$protonMom/$fd2_By/300.*1000
param zlength=$zlength+$fd2_length

param zlength=$zlength+614.

place FD3 z=$zlength+$fd3_length/2.  rotation=Y-3.0
cornerarc z=$zlength angle=-6.0 centerRadius=$protonMom/$fd3_By/300.*1000

param zlength=$zlength+$fd3_length

param zlength=$zlength+614.

place FD4 z=$zlength+$fd4_length/2.  rotation=Y-3.0
cornerarc z=$zlength angle=-6.0 centerRadius=$protonMom/$fd4_By/300.*1000
param zlength=$zlength+$fd4_length

param zlength=$zlength+750.

place det z=$zlength-1. rename=bm_fq5in

place FQ5 z=$zlength+$fq5_length/2.
param zlength=$zlength+$fq5_length

place det z=$zlength+1. rename=bm_fq5out

param zlength=$zlength+750.

place FD5 z=$zlength+$fd5_length/2.  rotation=Y-3.0
cornerarc z=$zlength angle=-6.0 centerRadius=$protonMom/$fd5_By/300.*1000
param zlength=$zlength+$fd5_length

param zlength=$zlength+614.

place FD6 z=$zlength+$fd6_length/2.  rotation=Y-3.0
cornerarc z=$zlength angle=-6.0 centerRadius=$protonMom/$fd6_By/300.*1000
param zlength=$zlength+$fd6_length

param zlength=$zlength+614.

place FD7 z=$zlength+$fd7_length/2.  rotation=Y-3.0
cornerarc z=$zlength angle=-6.0 centerRadius=$protonMom/$fd7_By/300.*1000
```

```
param zlength=$zlength+$fd7_length

param zlength=$zlength+1000.

place FQ6 z=$zlength+$fq6_length/2.
param zlength=$zlength+$fq6_length

param zlength=$zlength+500.

place FQ7 z=$zlength+$fq7_length/2.
param zlength=$zlength+$fq7_length

param zlength=$zlength+3700.

place FQ8 z=$zlength+$fq8_length/2.
param zlength=$zlength+$fq8_length

param zlength=$zlength+500.

place FQ9 z=$zlength+$fq9_length/2.
param zlength=$zlength+$fq9_length

param zlength=$zlength+500.

place FQ10 z=$zlength+$fq10_length/2.
param zlength=$zlength+$fq10_length

param zlength=$zlength+8700.

place det z=$zlength rename=bm_ffout

# End of final focus section

#
# ntuple
#
ntuple acdin format=root detectors=bm_acdin
ntuple ad1in format=root detectors=bm_ad1in
#ntuple ad1cen format=root detectors=bm_ad1cen
ntuple ad1out format=root detectors=bm_ad1out
ntuple collin format=root detectors=bm_collin
ntuple collout format=root detectors=bm_collout
ntuple ad2in format=root detectors=bm_ad2in
#ntuple ad2cen format=root detectors=bm_ad2cen
ntuple ad2out format=root detectors=bm_ad2out
ntuple ffin format=root detectors=bm_ffin
ntuple fd1in format=root detectors=bm_fd1in
ntuple fd1out format=root detectors=bm_fd1out
ntuple fq5in format=root detectors=bm_fq5in
ntuple fq5out format=root detectors=bm_fq5out
ntuple ffout format=root detectors=bm_ffout
```

B. Simulation of empty bucket

Here, difference between the input file of main bucket simulation and empty bucket one is only shown.

```
comet% diff acd_ff-01-gaussian-main_buckt.in acd_ff-01-gaussian-empty_buckt.in
44,45c44,45
< #param ad_delT=$t_acd*0.25
< param ad_delT=0.0
---
> param ad_delT=$t_acd*0.25
> #param ad_delT=0.0
57,58c57,58
< param histoFile=acd_ff-01-main_buckt
< #param histoFile=acd_ff-01-empty_buckt
---
> #param histoFile=acd_ff-01-main_backt
> param histoFile=acd_ff-01-empty_backt
```