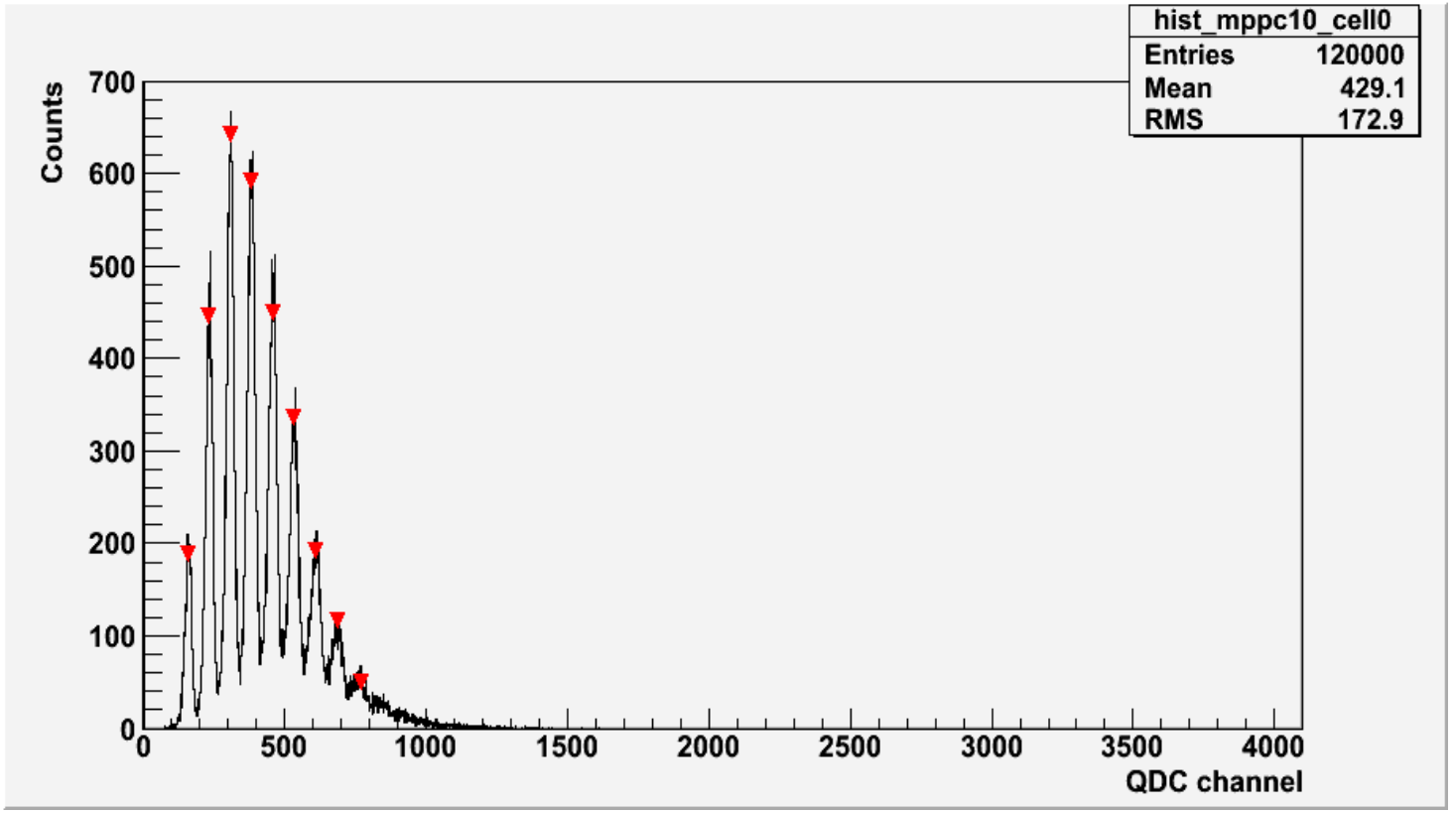
Operational Voltage Selection.

Orlando Soto.

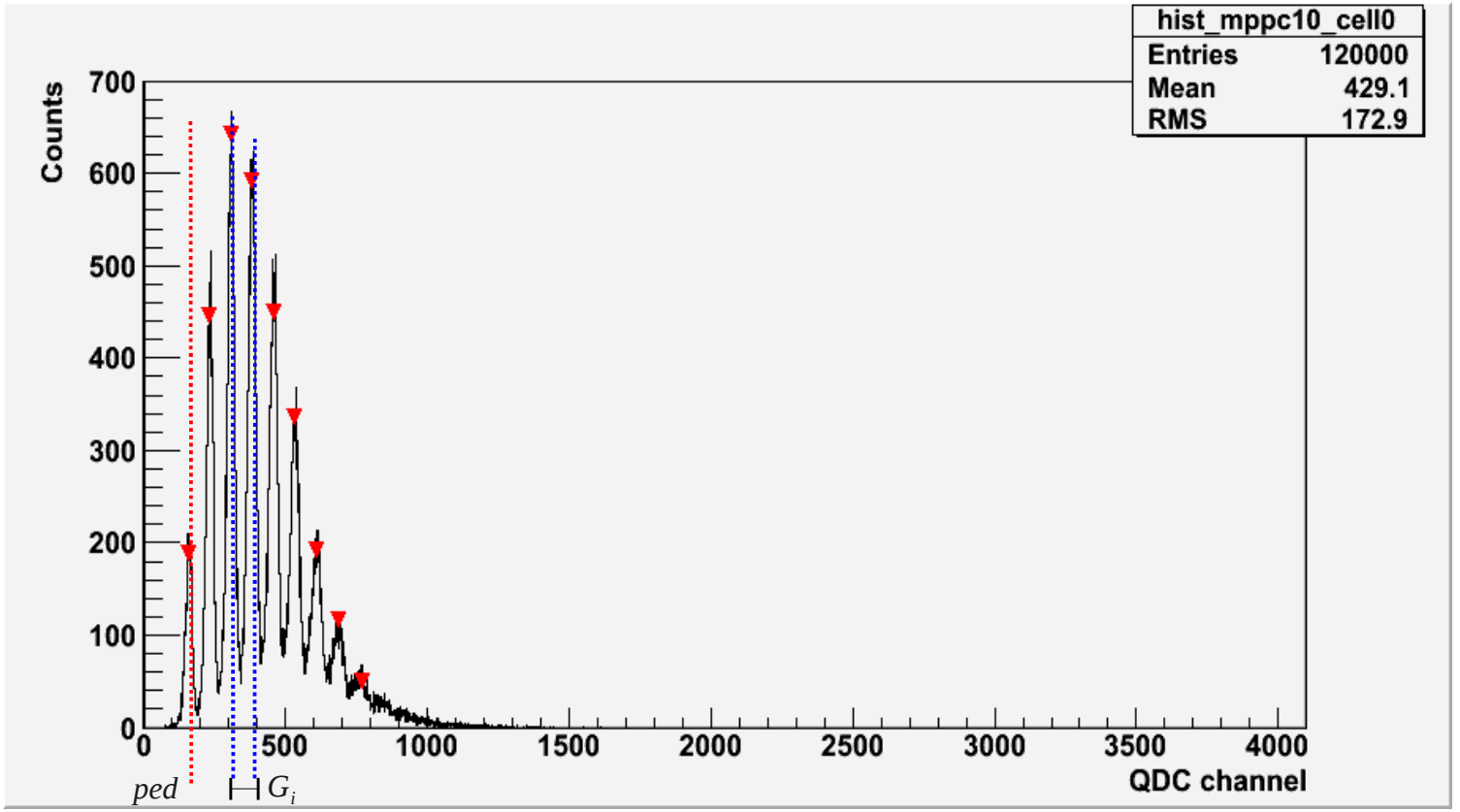
Given a temperature T_{USM}, for each cell in one MPPC we have histograms at 13 differents bias voltages[1] V_i, starting with corrected Hammamatsu operational voltage[2], decreasing -0,1 [V] steps.



[1] $V_i = V_0 - 0{,}1 \cdot i$

[2] *temperature correction*:
$\Delta t \cdot 0.056[V] \Rightarrow V_0 = \bar{V}_{hammamatsu} + (25 - T_{usm}) \cdot 0.056$

From these histograms we get gain (G_i), average number of photoelectrons (μ_i), cross-talk probability ($\Delta\mu_i$) according to:



$Mean$

RMS

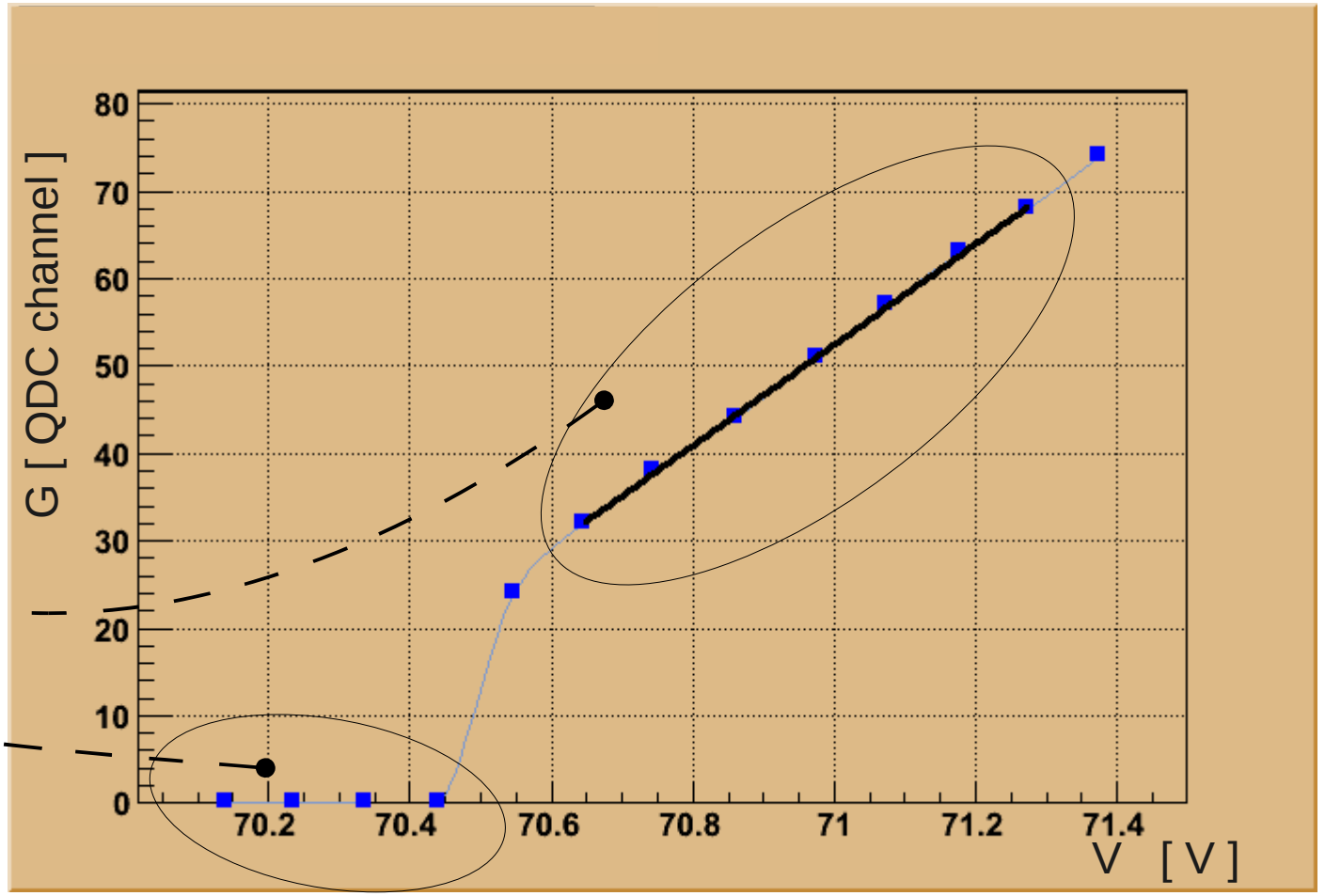
ped

G_i

$$\mu_i = \frac{-\left(RMS^2/G_i - (Mean - ped)/G_i\right) + \sqrt{\left(\left(RMS^2/G_i - (Mean - ped)/G_i\right)^2 + 4*\left((Mean - ped)/G_i\right)^2\right)}}{2}$$

$$\Delta\mu_i = \frac{(Mean - ped)}{\mu_i} - 1$$

For each cell we estimate Break Down Voltage from first order polynomial fit over the meaningful voltages.



Meaningful points

Discarded points set to 0

$$G(V) = p_0 + p_1 \cdot V$$

$$G(V_{BDV}) = 0 \quad \Rightarrow \quad V_{BDV} = -p_0 / p_1$$

The next slides shows the evolution of the dispersion between cells of the same mppc for the quantities: number of photoelectrons, gain, and the product of both quantities, at a given temperature (5 ºC, 7 ºC, 20 ºC).

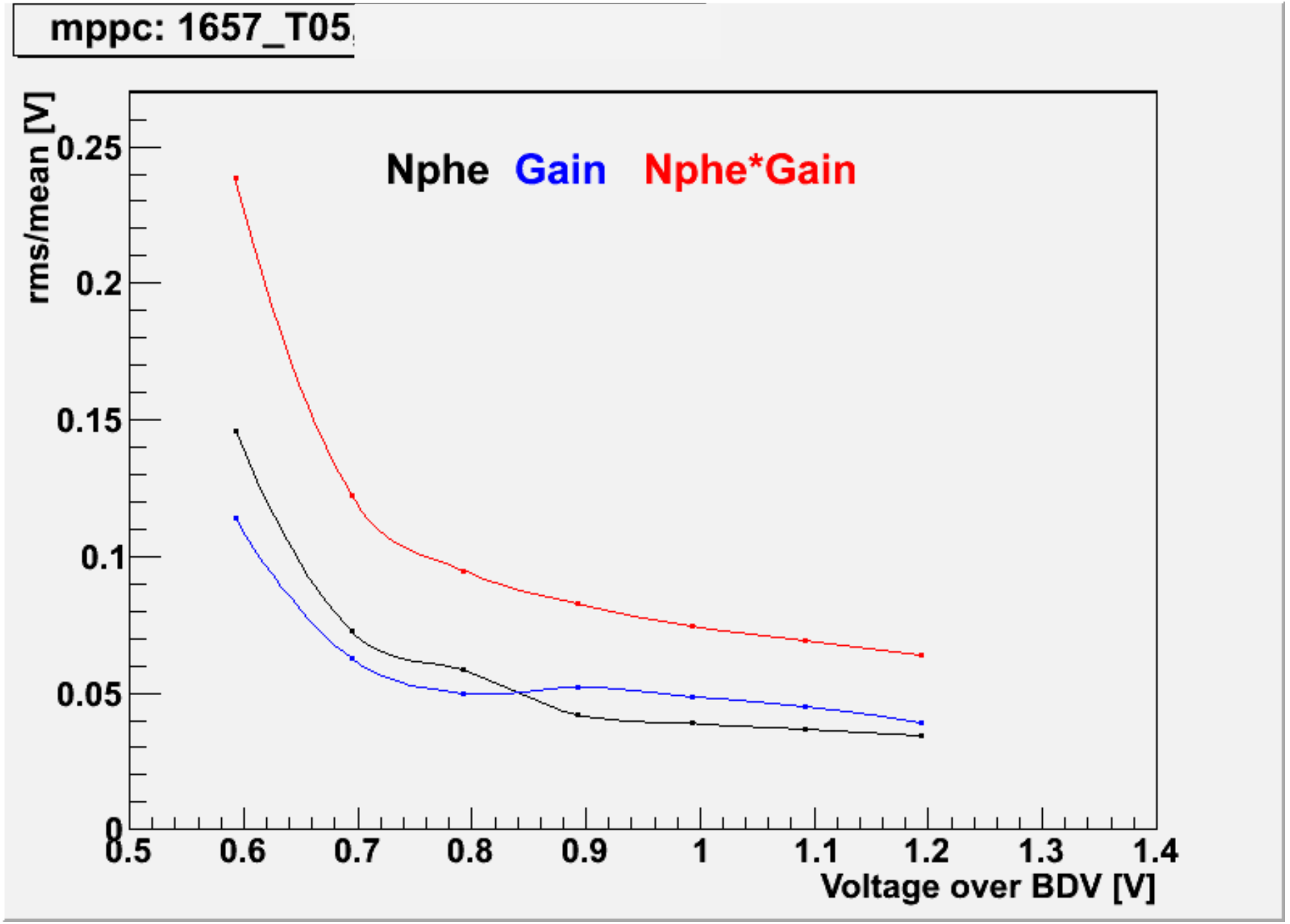
$$Mean_{\mu_i} = \frac{1}{16} \cdot \sum_{k=1}^{16} \mu_{ik}\,; \quad RMS_{\mu_i} = \sqrt{\frac{1}{16} \cdot \sum_{k=1}^{16} (\mu_{ik})^2 - Mean_{\mu_i}^2}$$

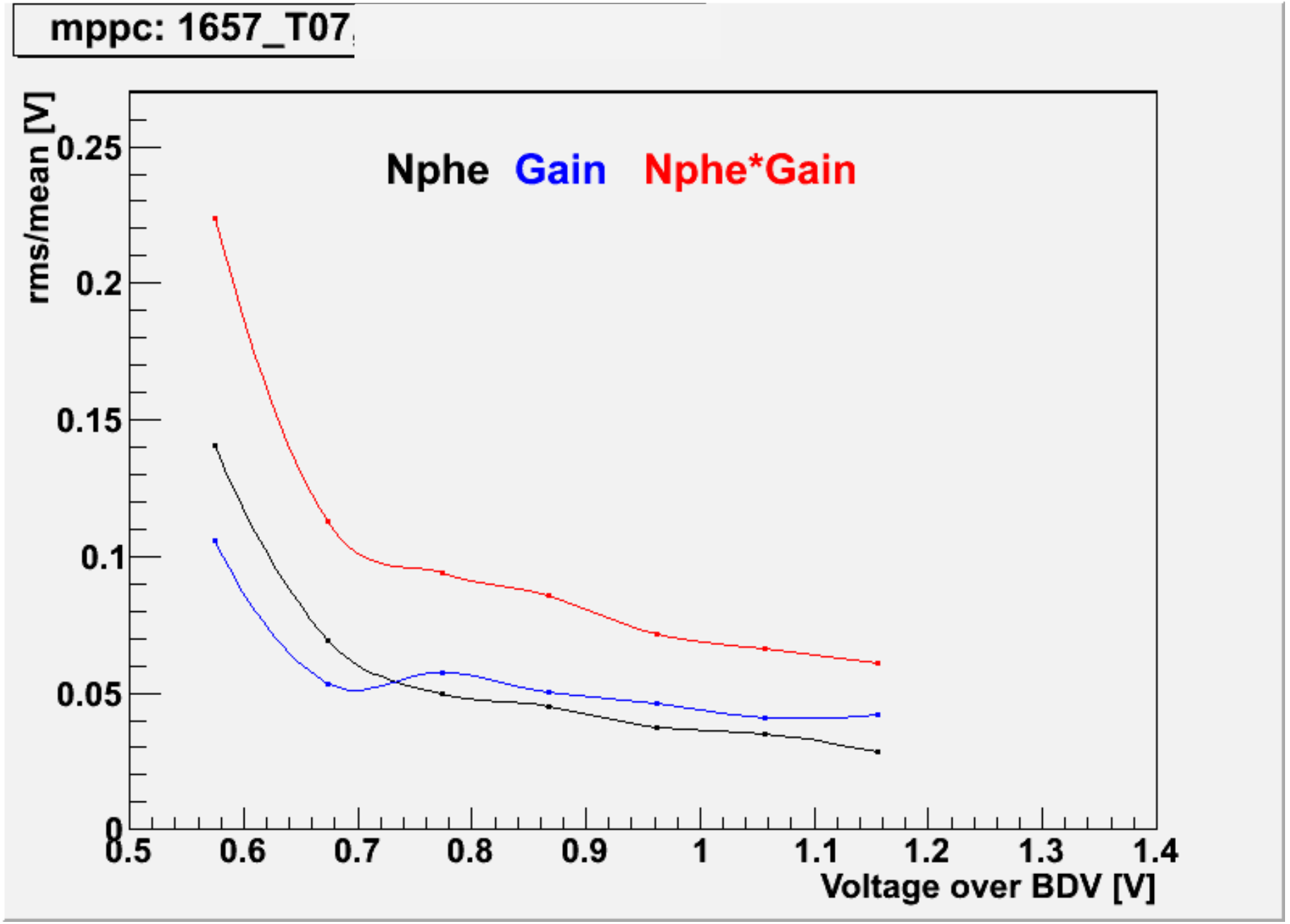
$$Mean_{G_i} = \frac{1}{16} \cdot \sum_{k=1}^{16} G_{ik}\,; \quad RMS_{G_i} = \sqrt{\frac{1}{16} \cdot \sum_{k=1}^{16} (G_{ik})^2 - Mean_{G_i}^2}$$

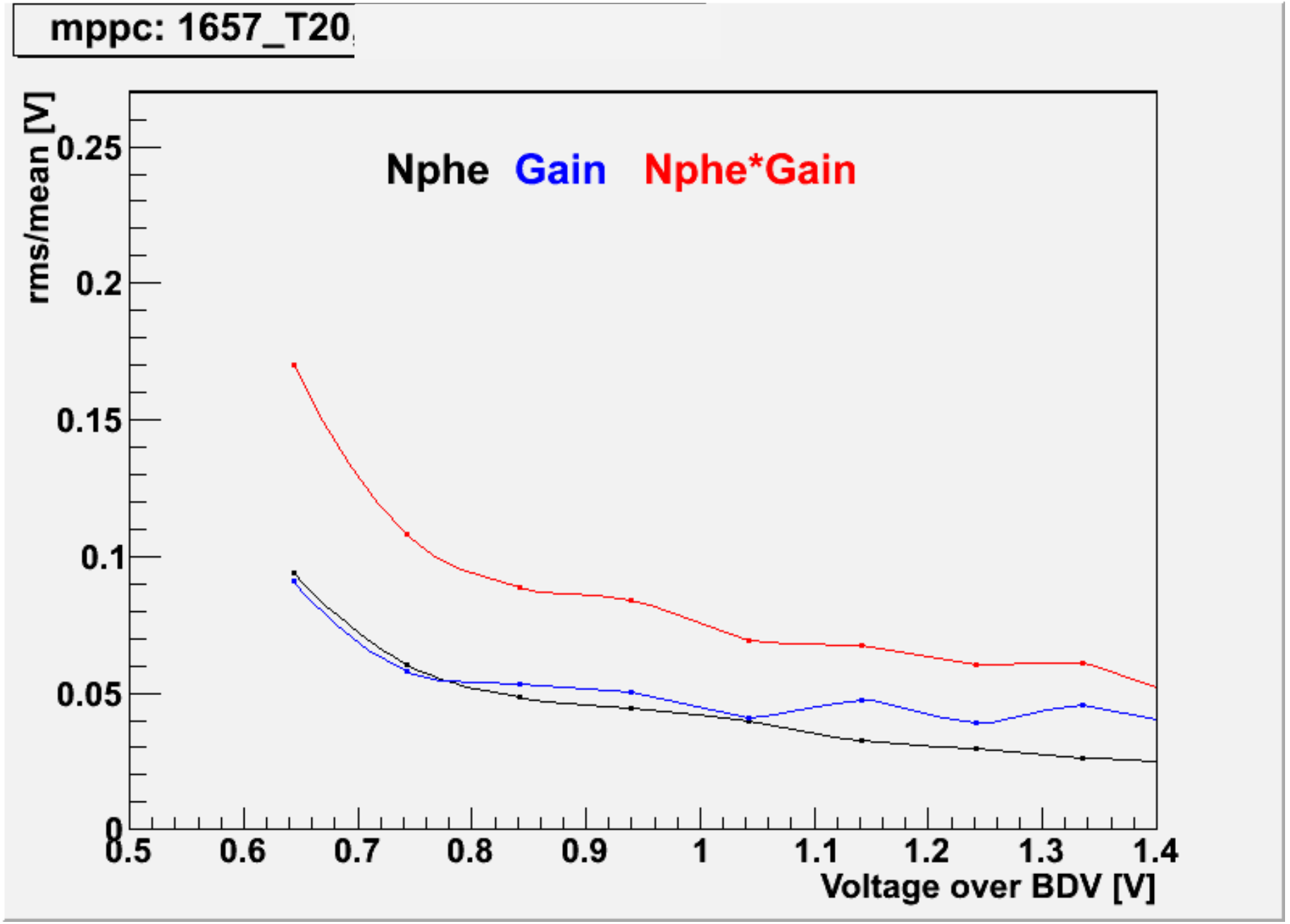
$$Mean_{\mu_i \cdot G_i} = \frac{1}{16} \cdot \sum_{k=1}^{16} \mu_i \cdot G_{ik}\,; \quad RMS_{\mu_i \cdot G_i} = \sqrt{\frac{1}{16} \cdot \sum_{k=1}^{16} (\mu_i \cdot G_{ik})^2 - Mean_{Nphe_i \cdot G_i}^2}$$

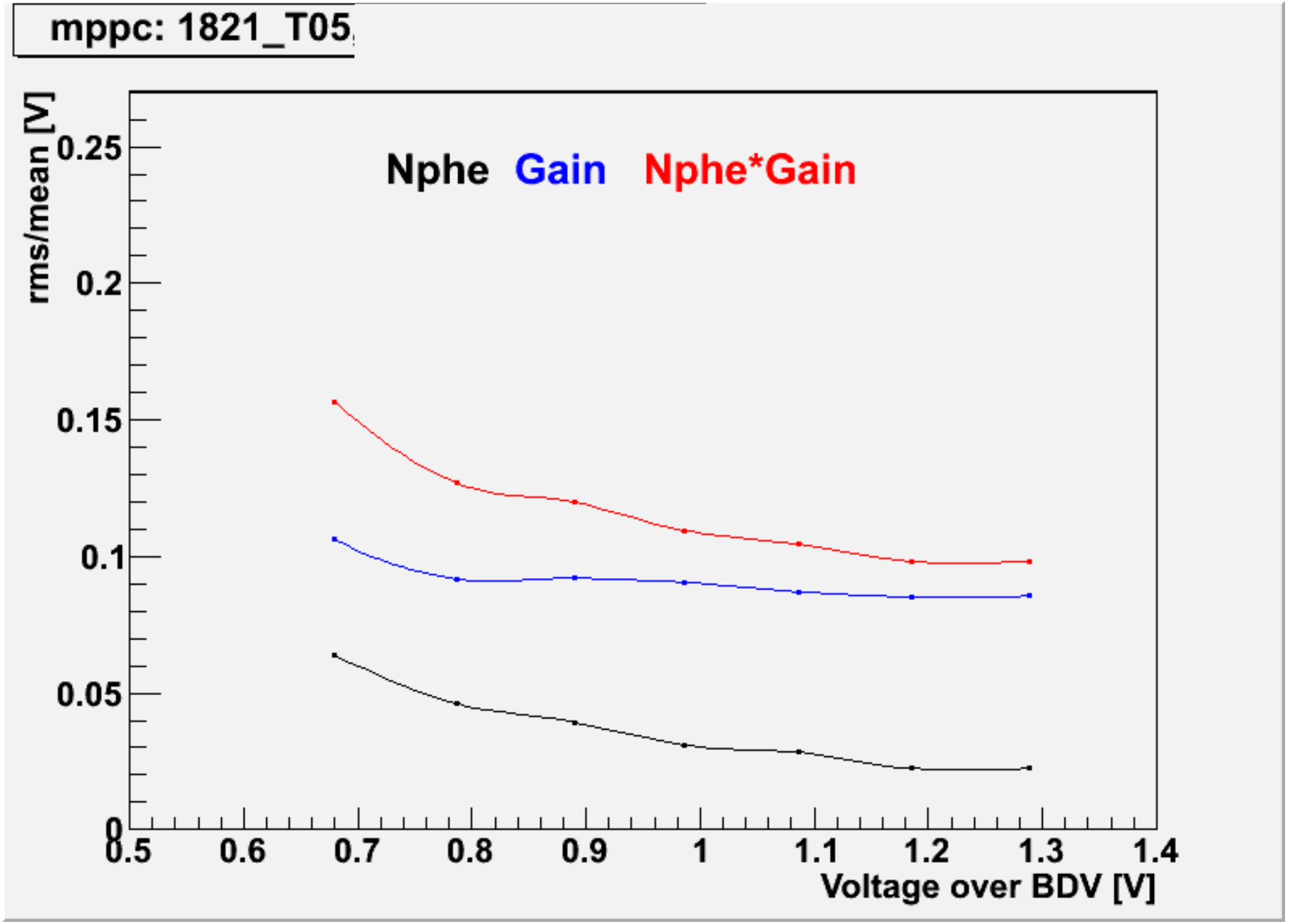
The y-axis of plots shows $RMS_{xxx} / Mean_{xxx}$.
The x-axis of the plots shows the over voltage from the average BDV for the MPPC.

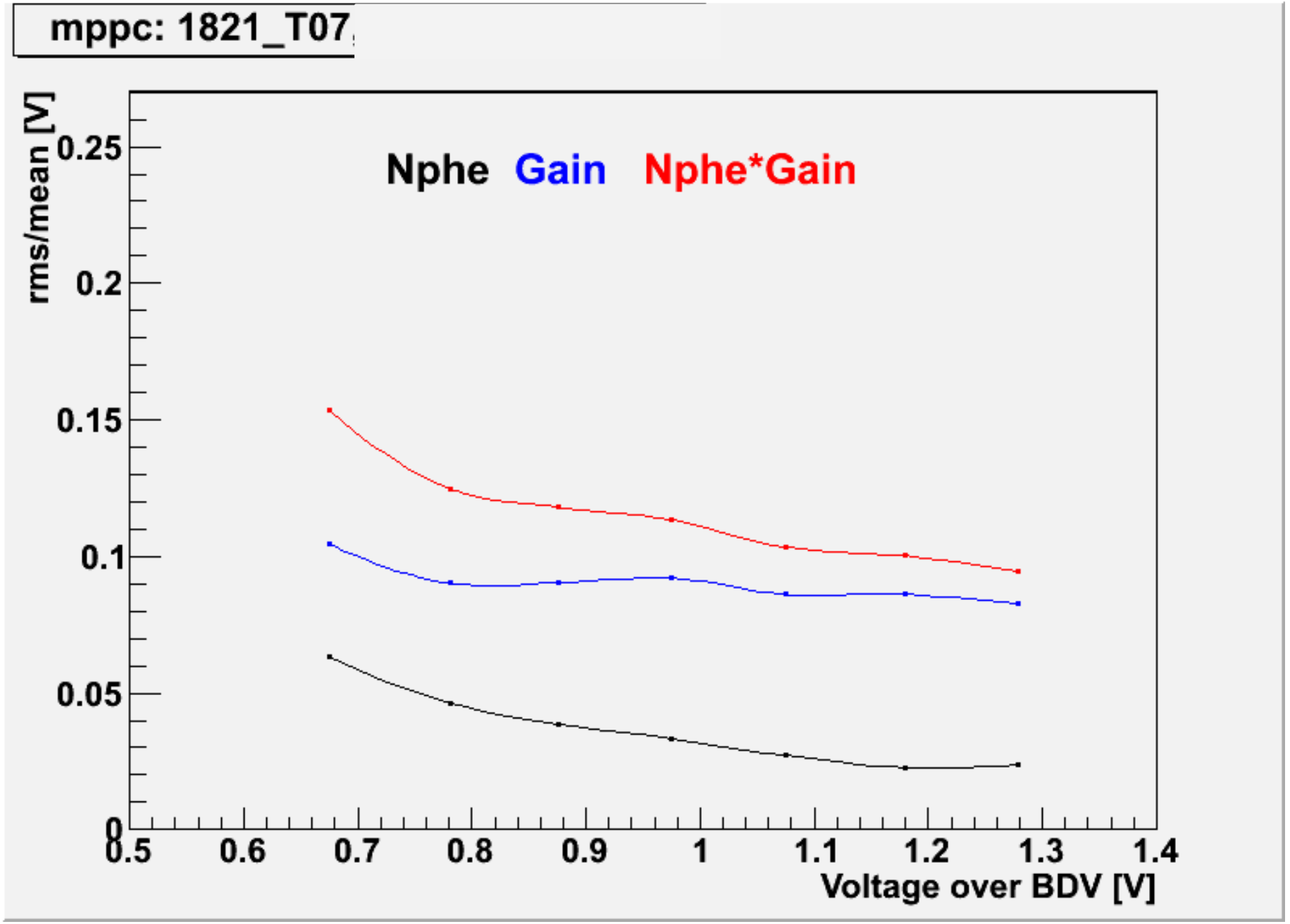
$$avg_{V_{BDV}} = \frac{1}{16} \cdot \sum_{k=1}^{16} V_{BDVk}$$

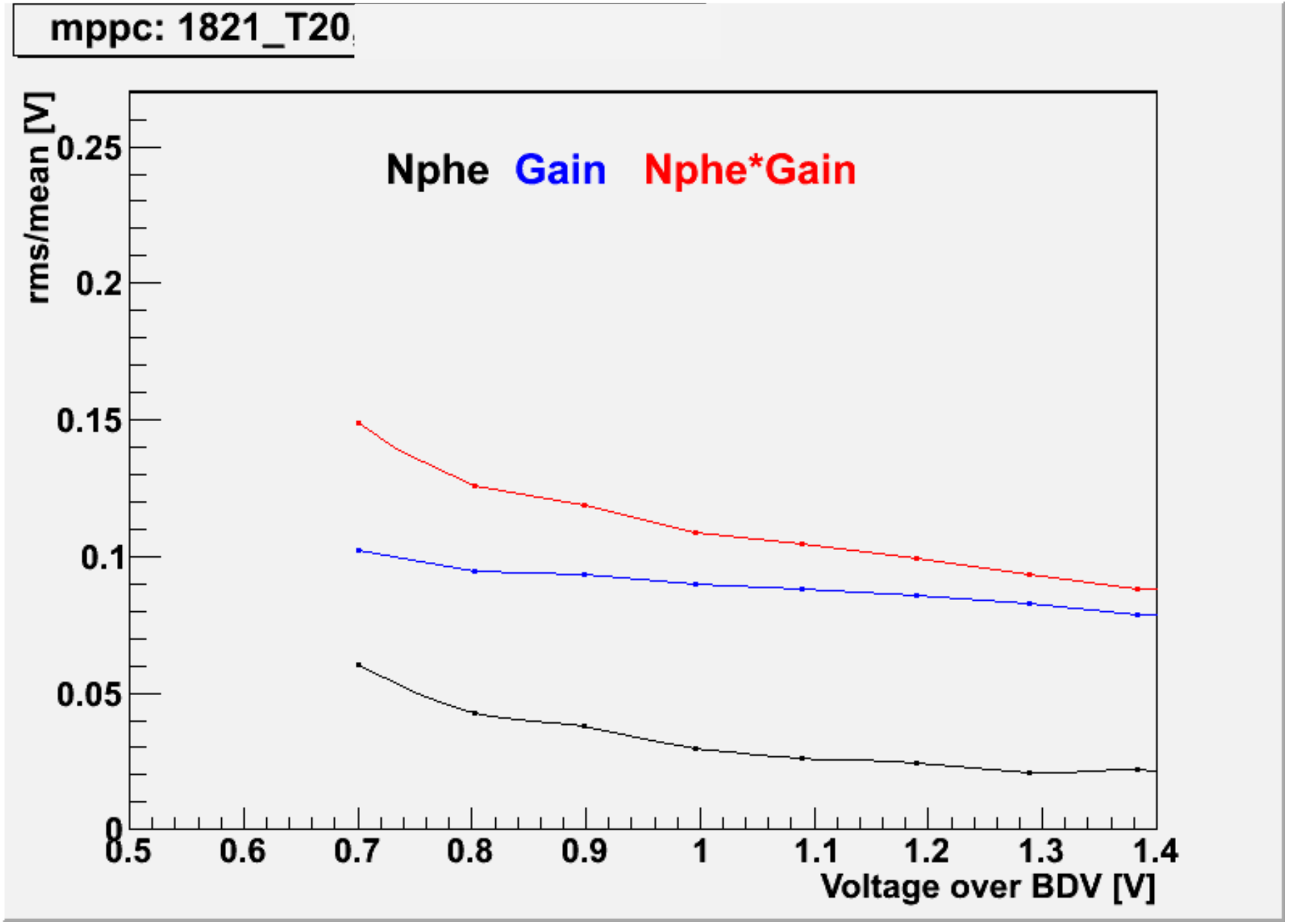

mppc: 1657_T05
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

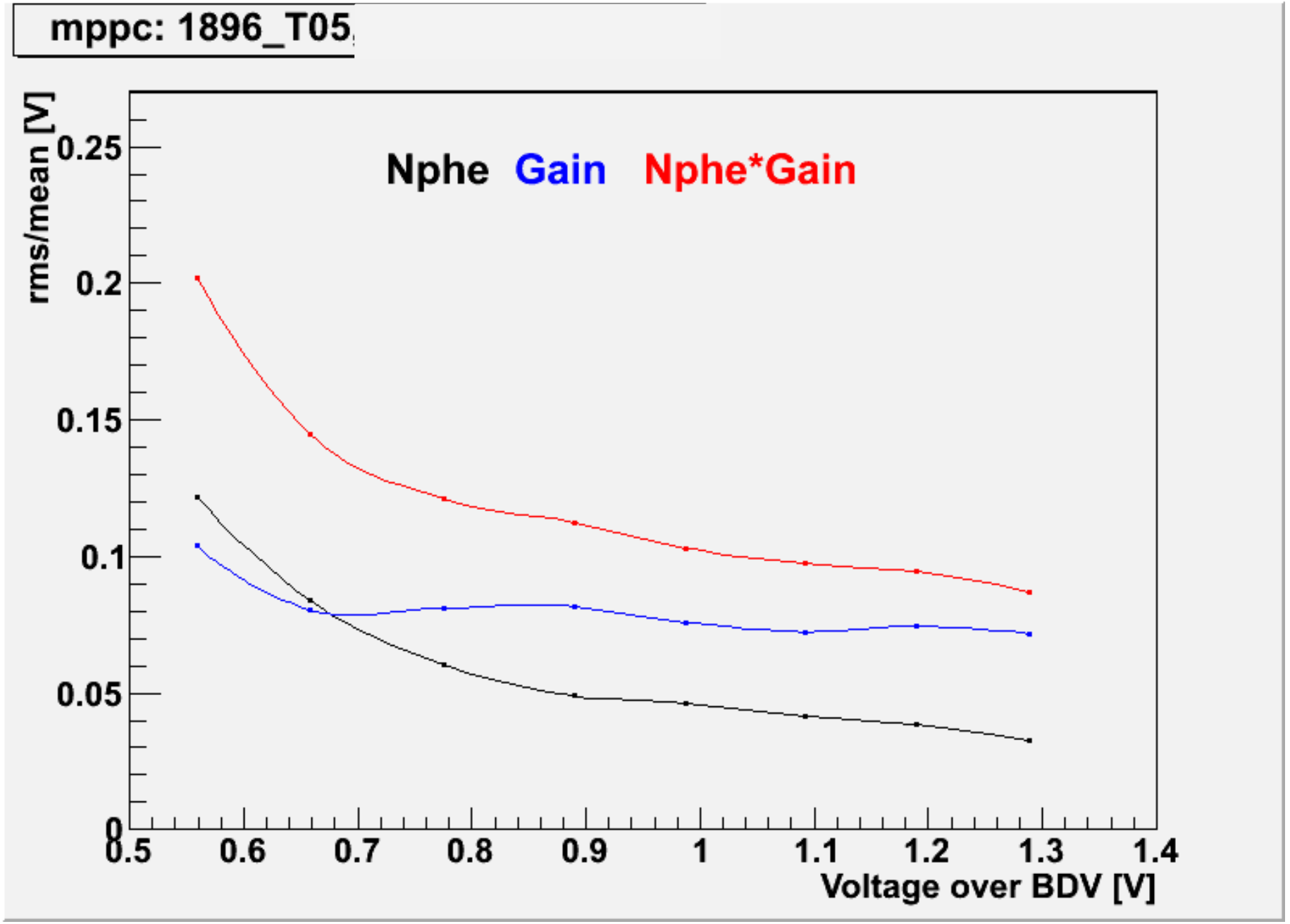

mppc: 1657_T07
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

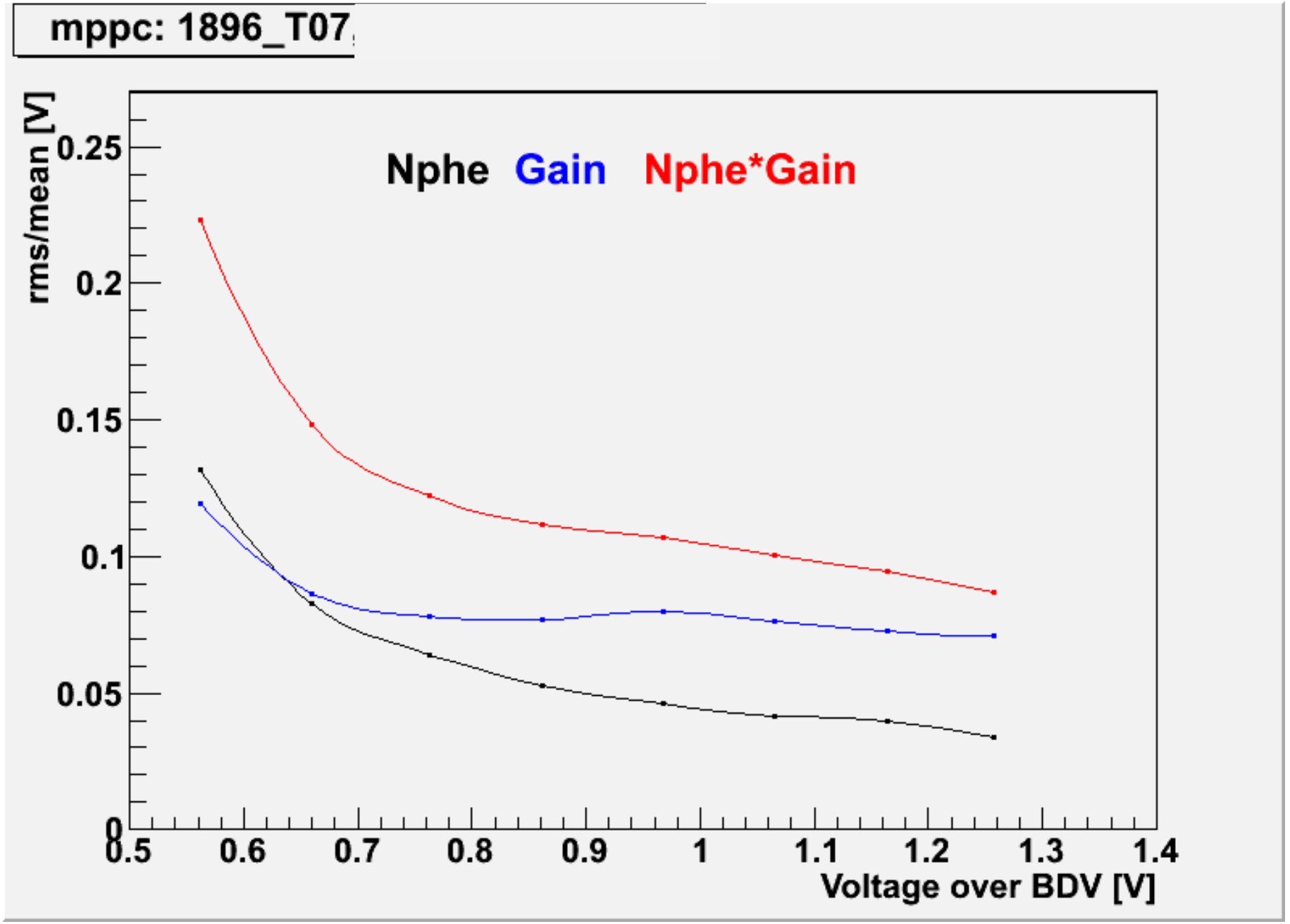

mppc: 1657_T20
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

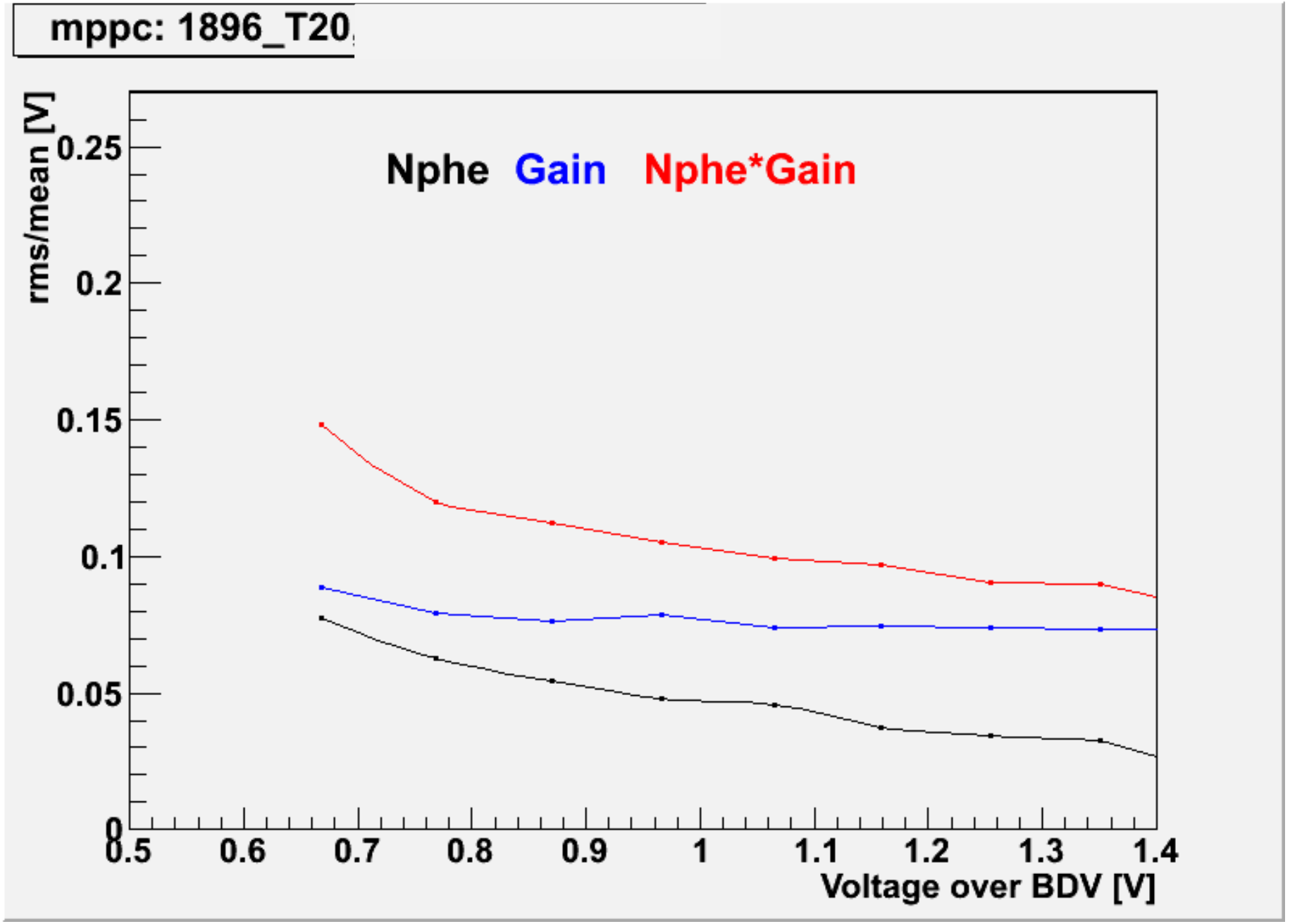

mppc: 1821_T05
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

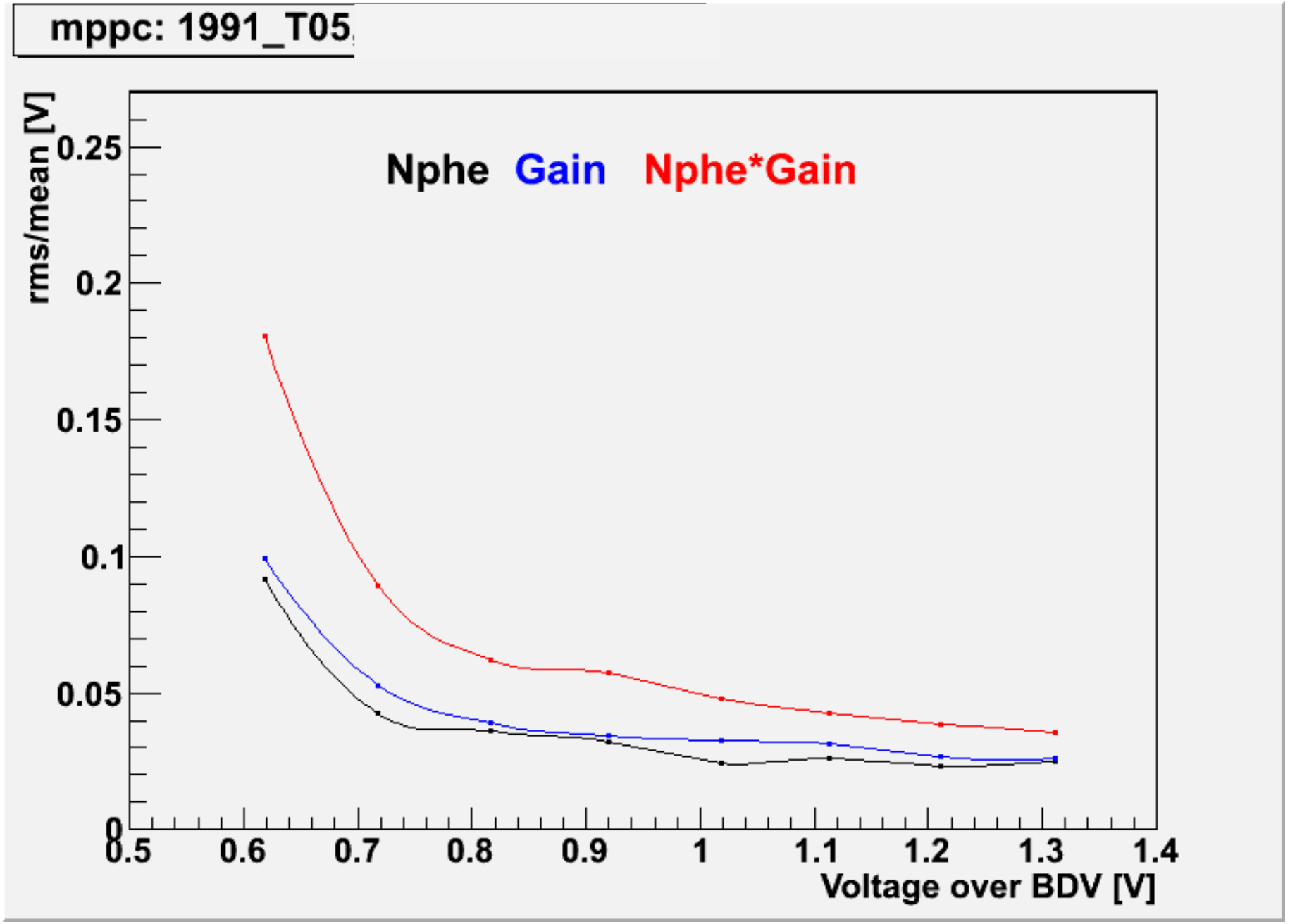

mppc: 1821_T07
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

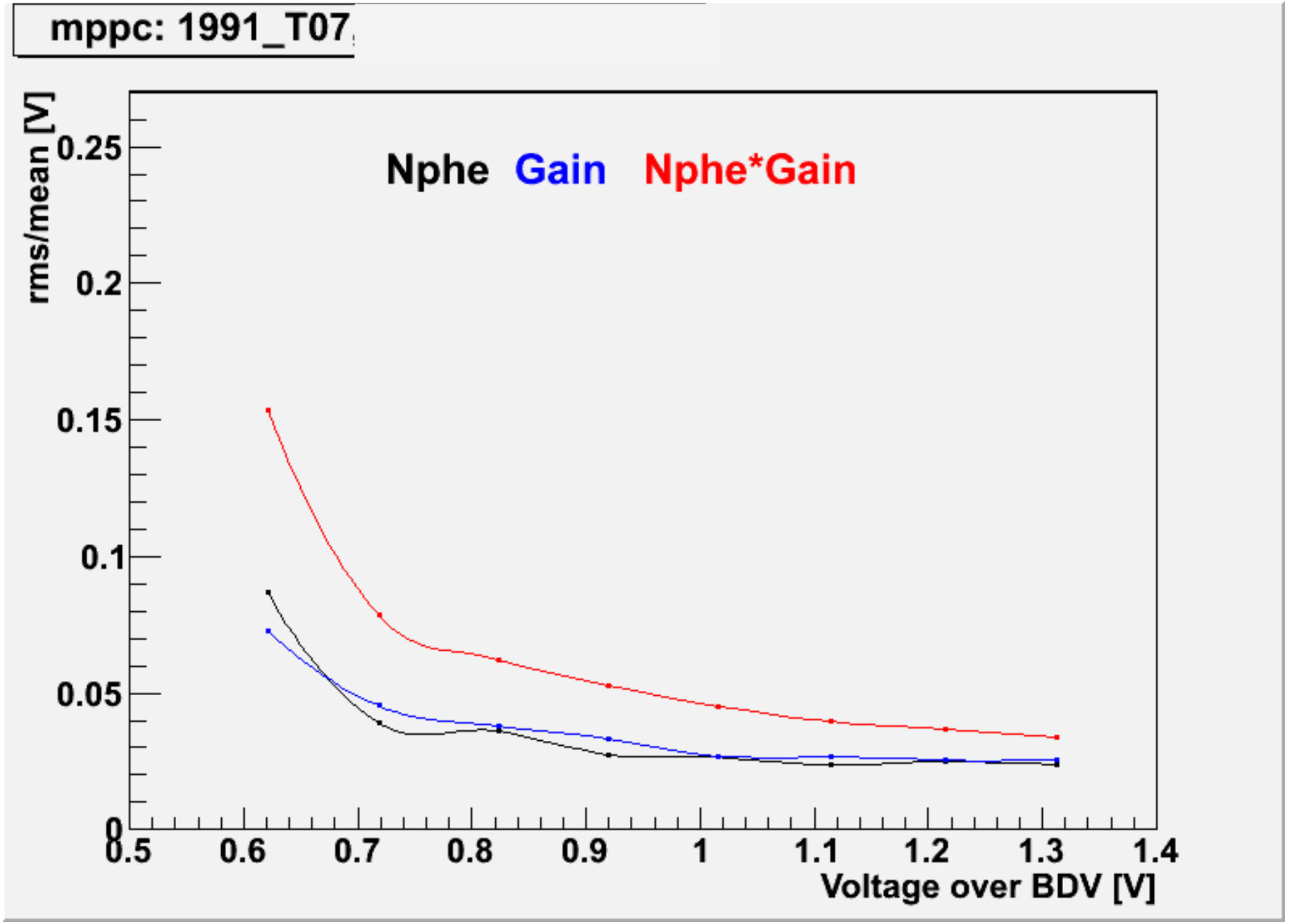

mppc: 1821_T20
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

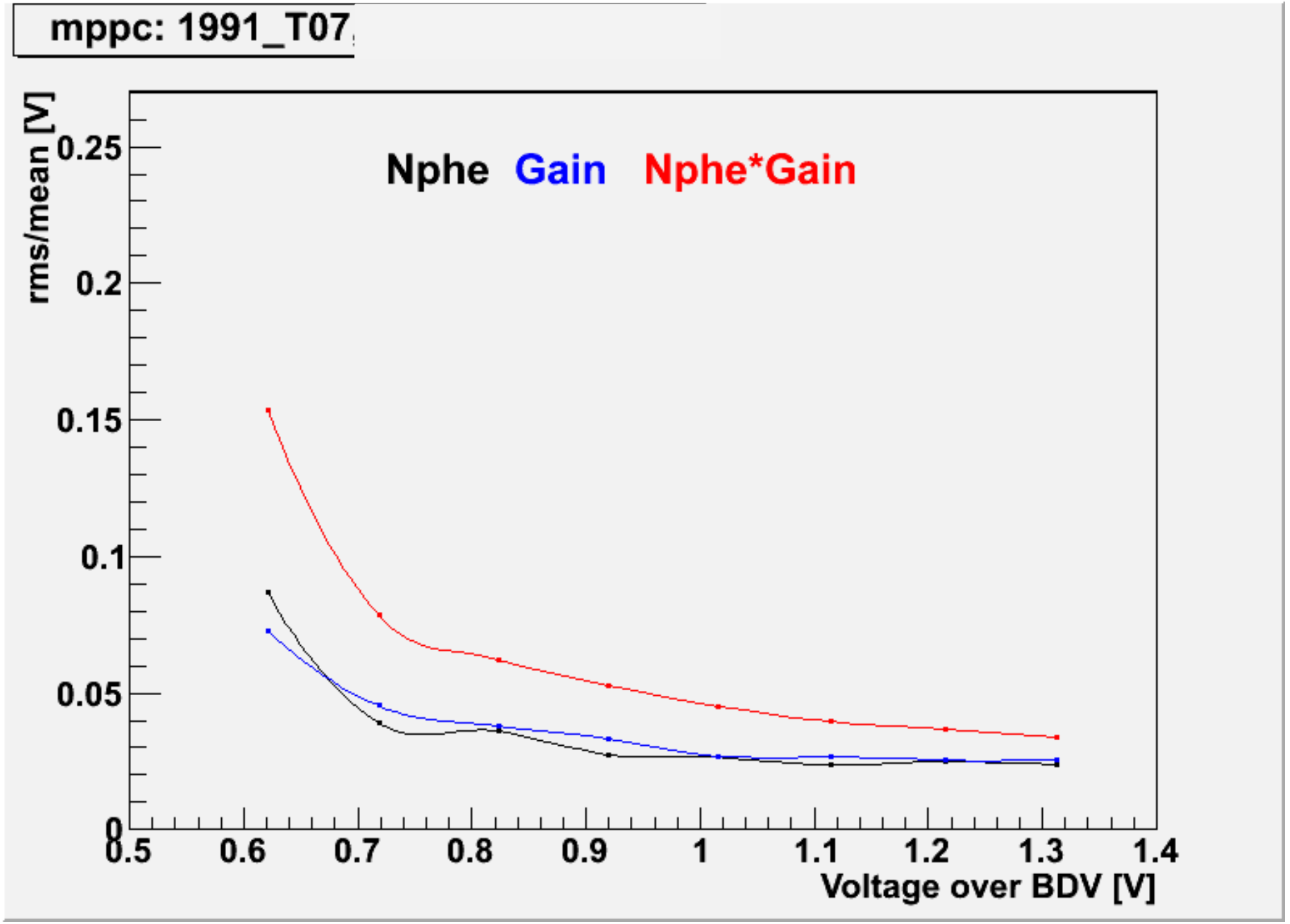

mppc: 1896_T05
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

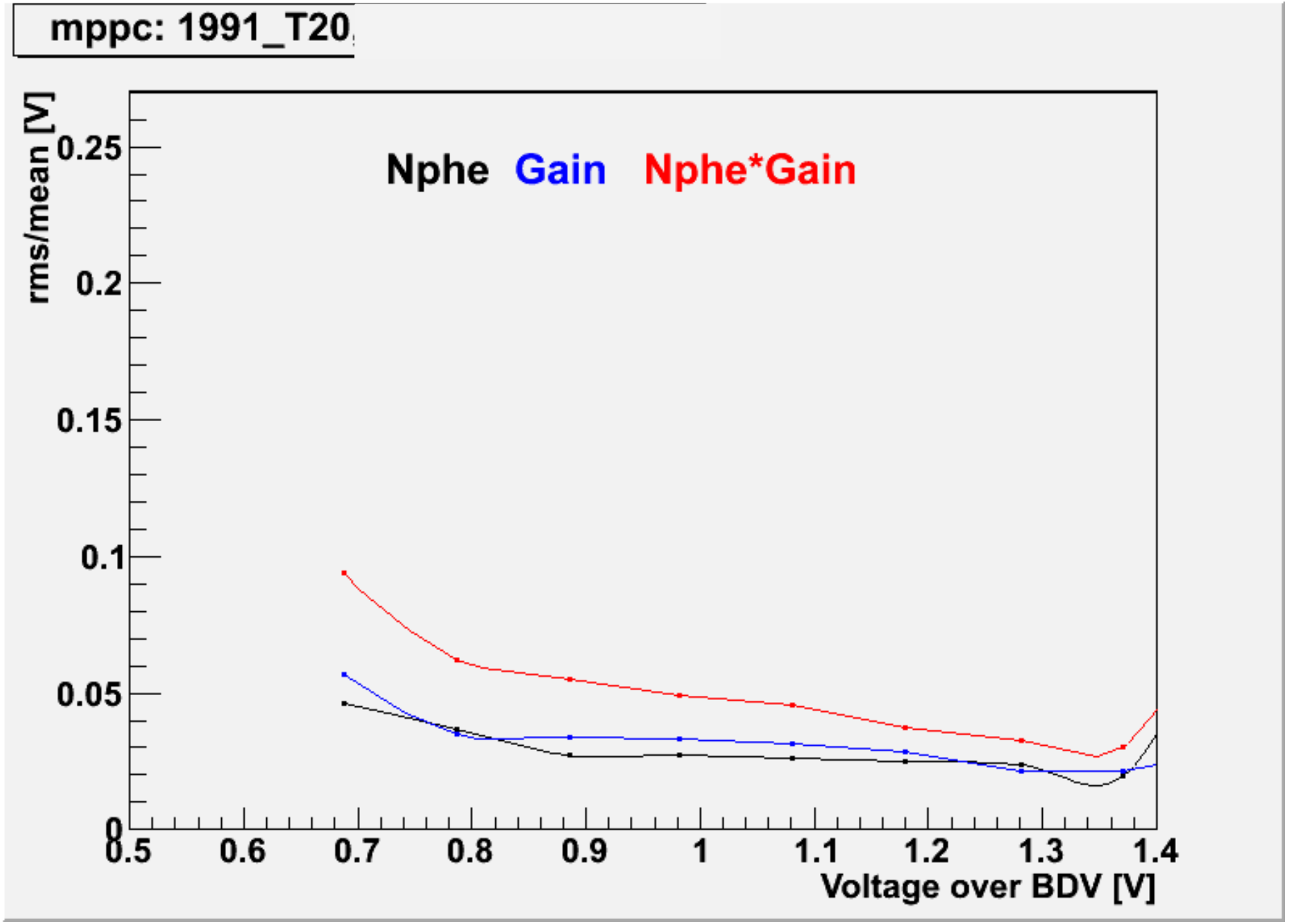

mppc: 1896_T07
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

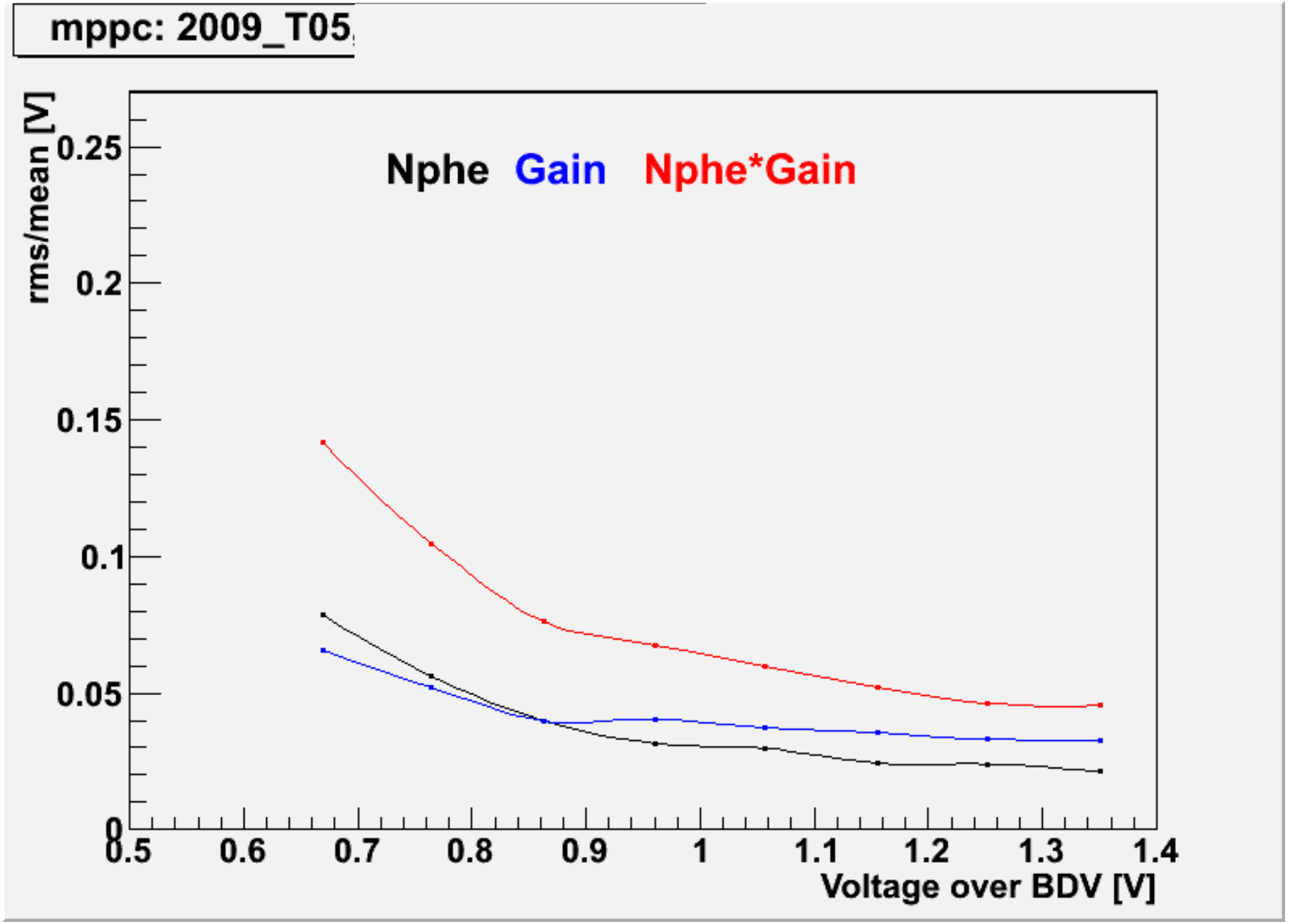

mppc: 1896_T20
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

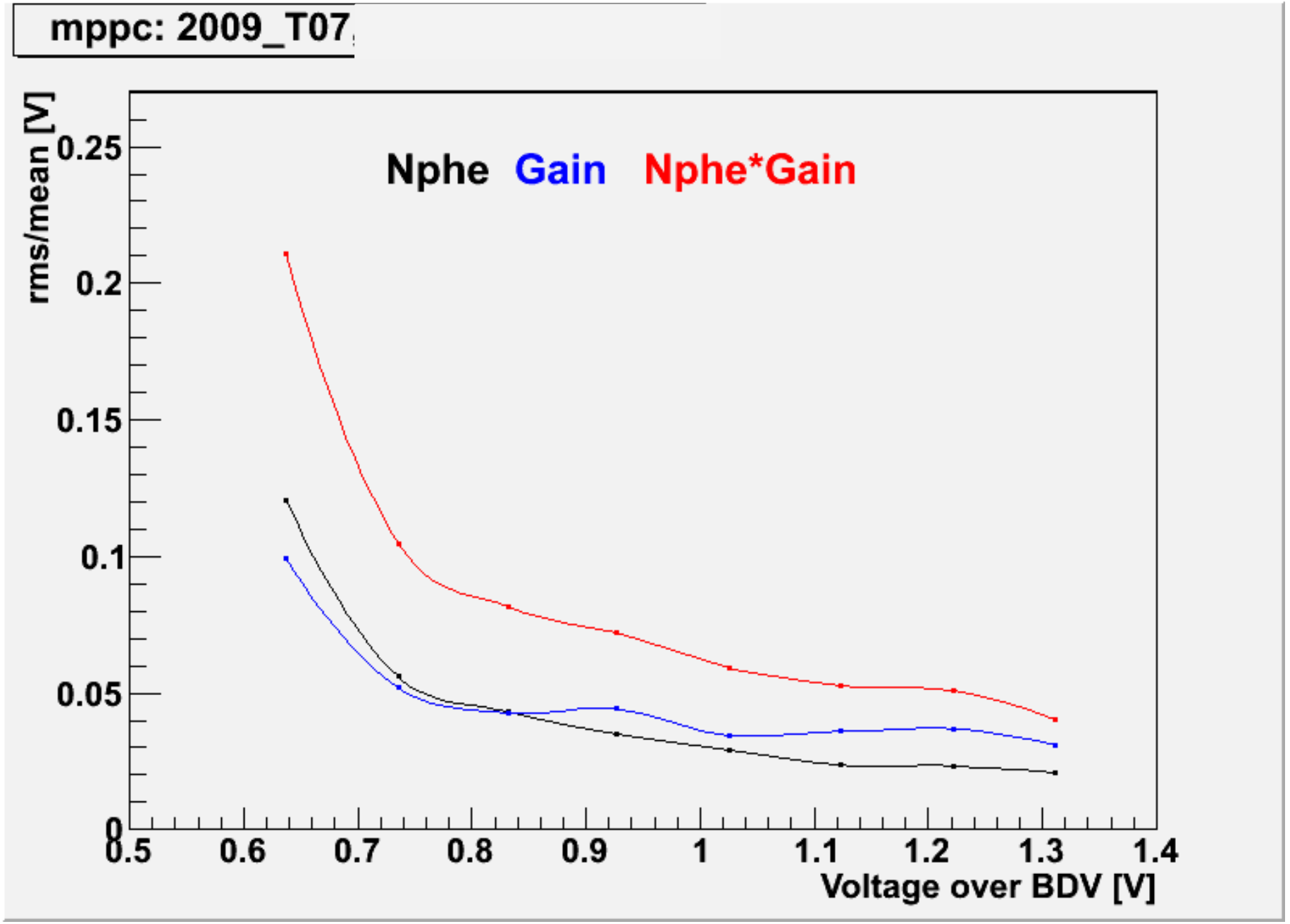

mppc: 1991_T05
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

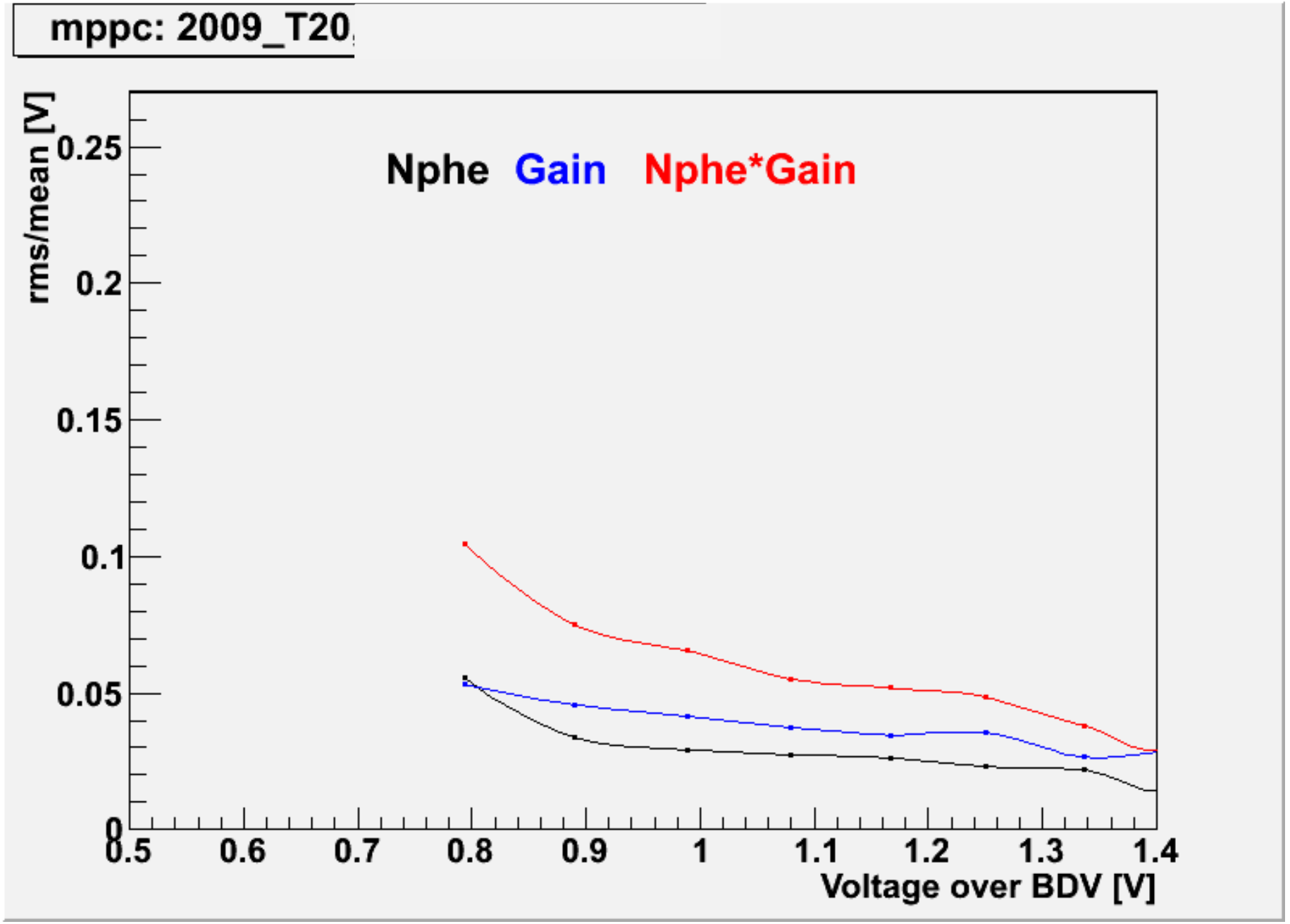

mppc: 1991_T07
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

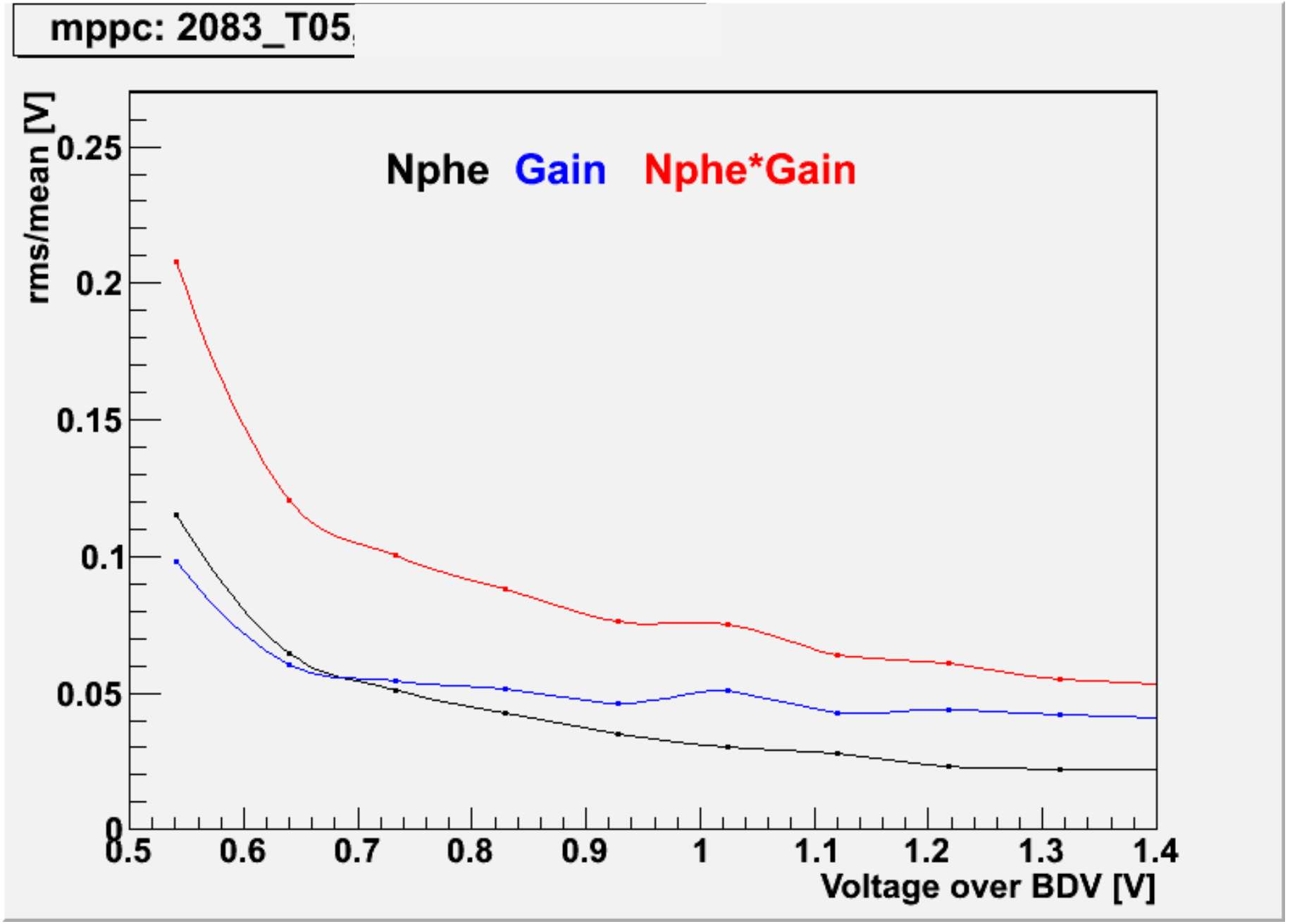

mppc: 1991_T07
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

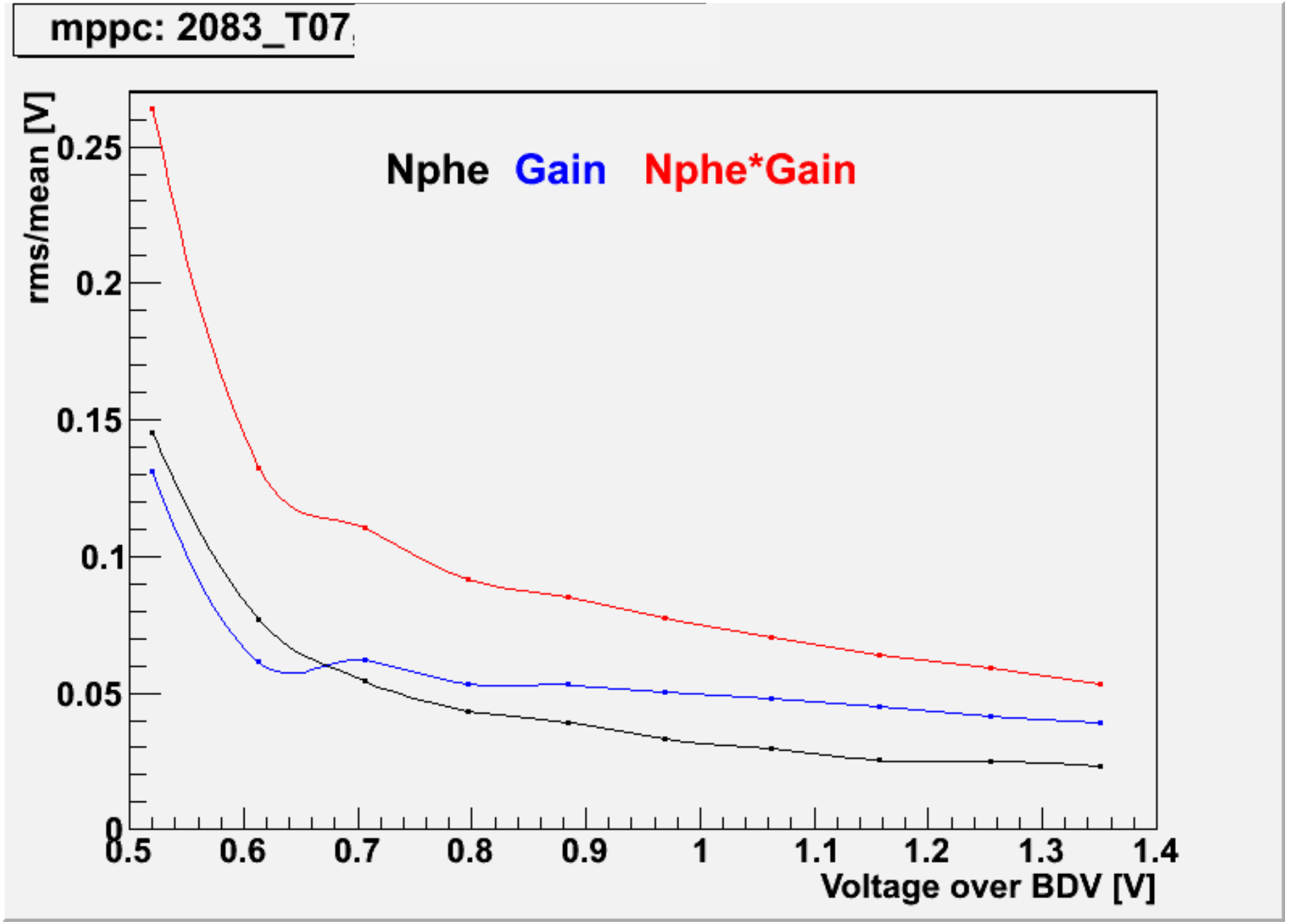

mppc: 1991_T20
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

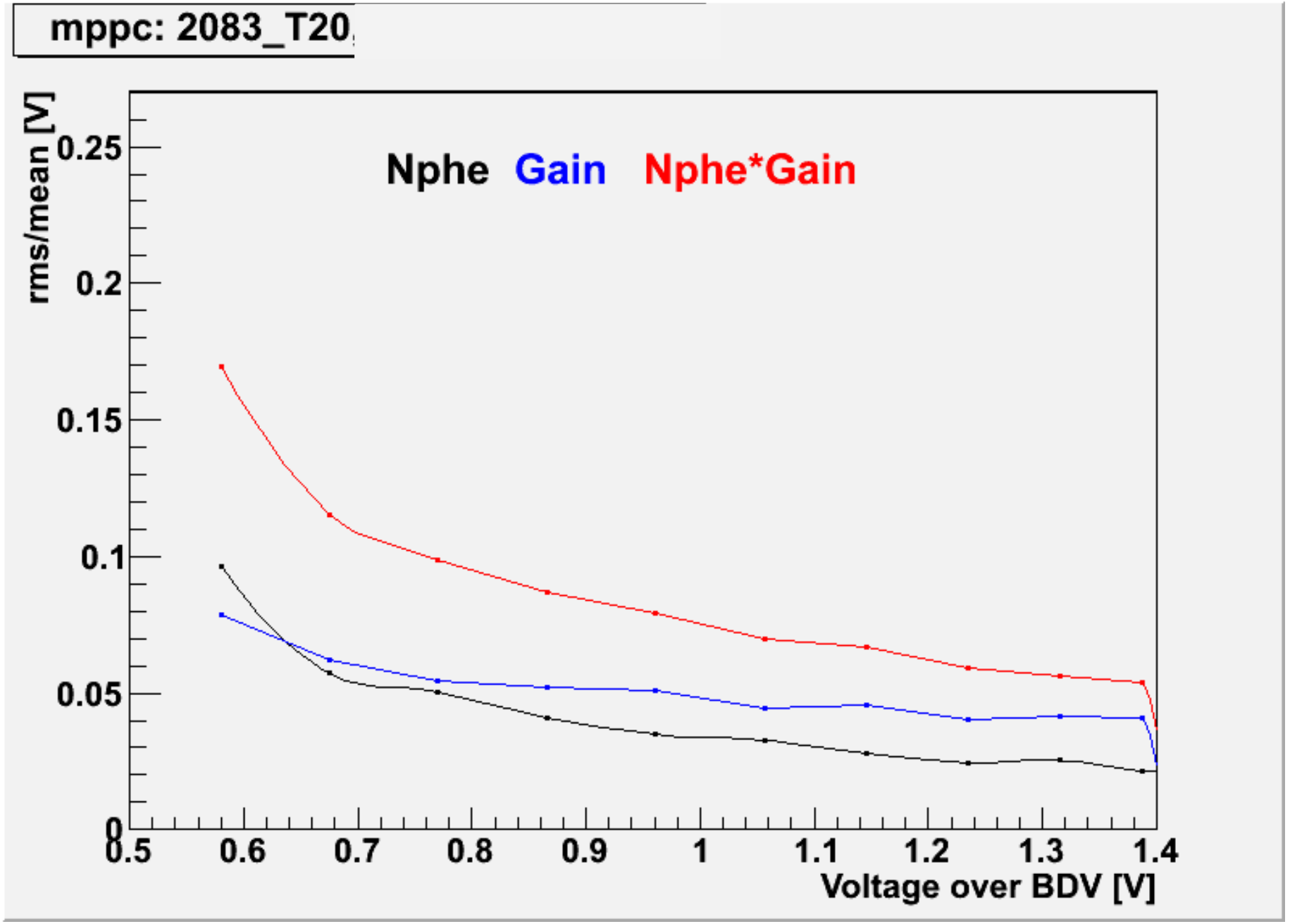

mppc: 2009_T05
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

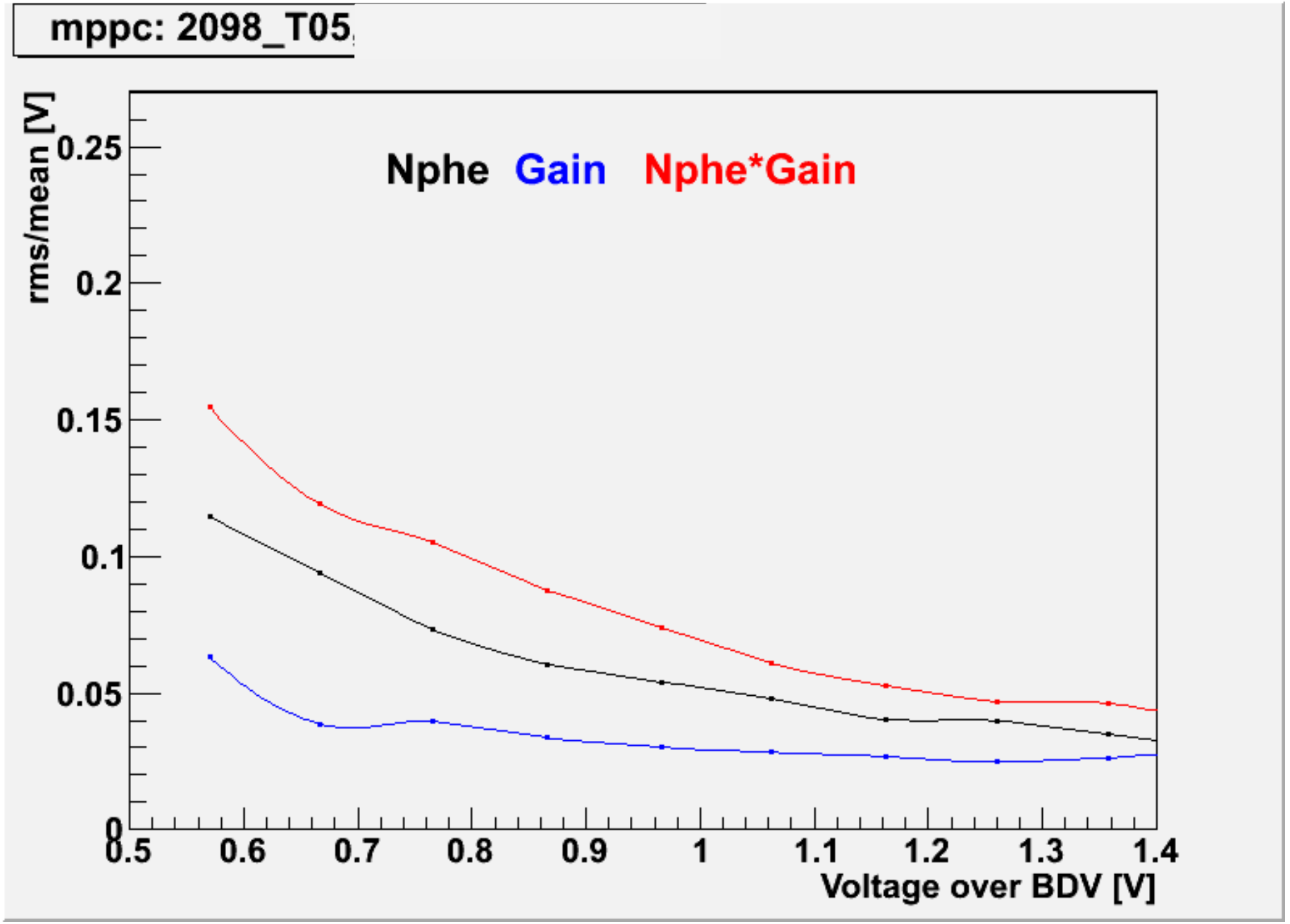

mppc: 2009_T07
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

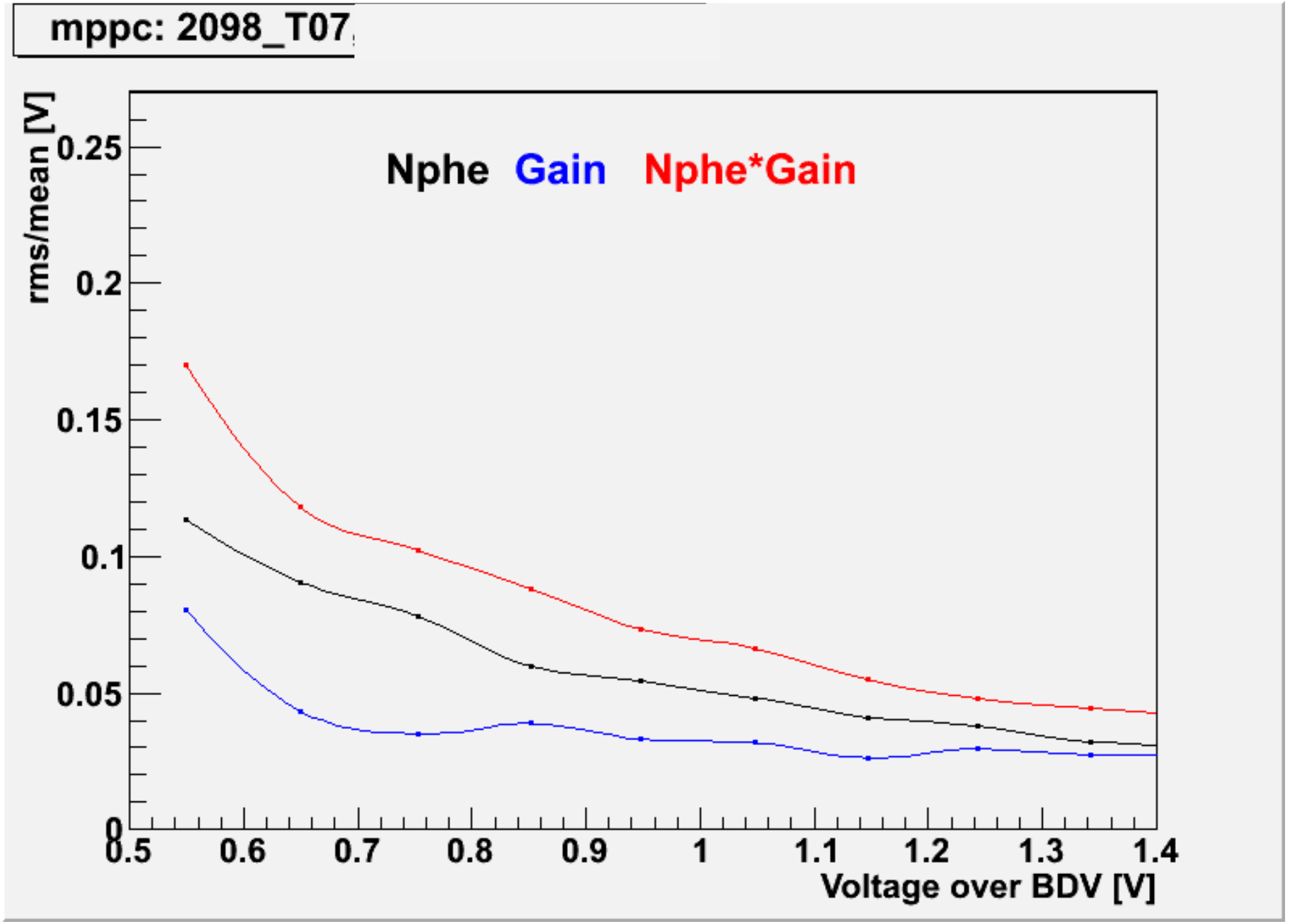

mppc: 2009_T20
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

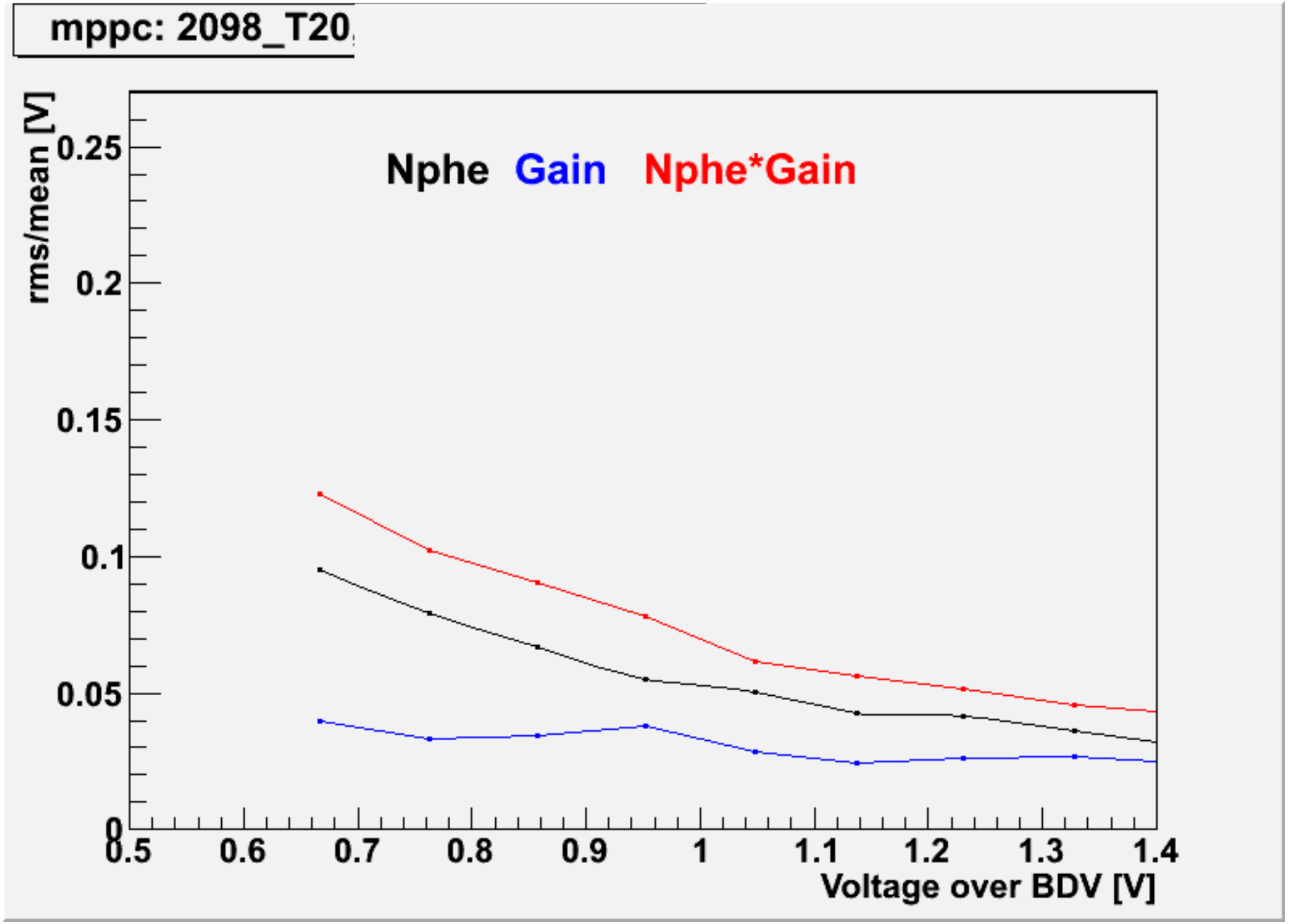

mppc: 2083_T05
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

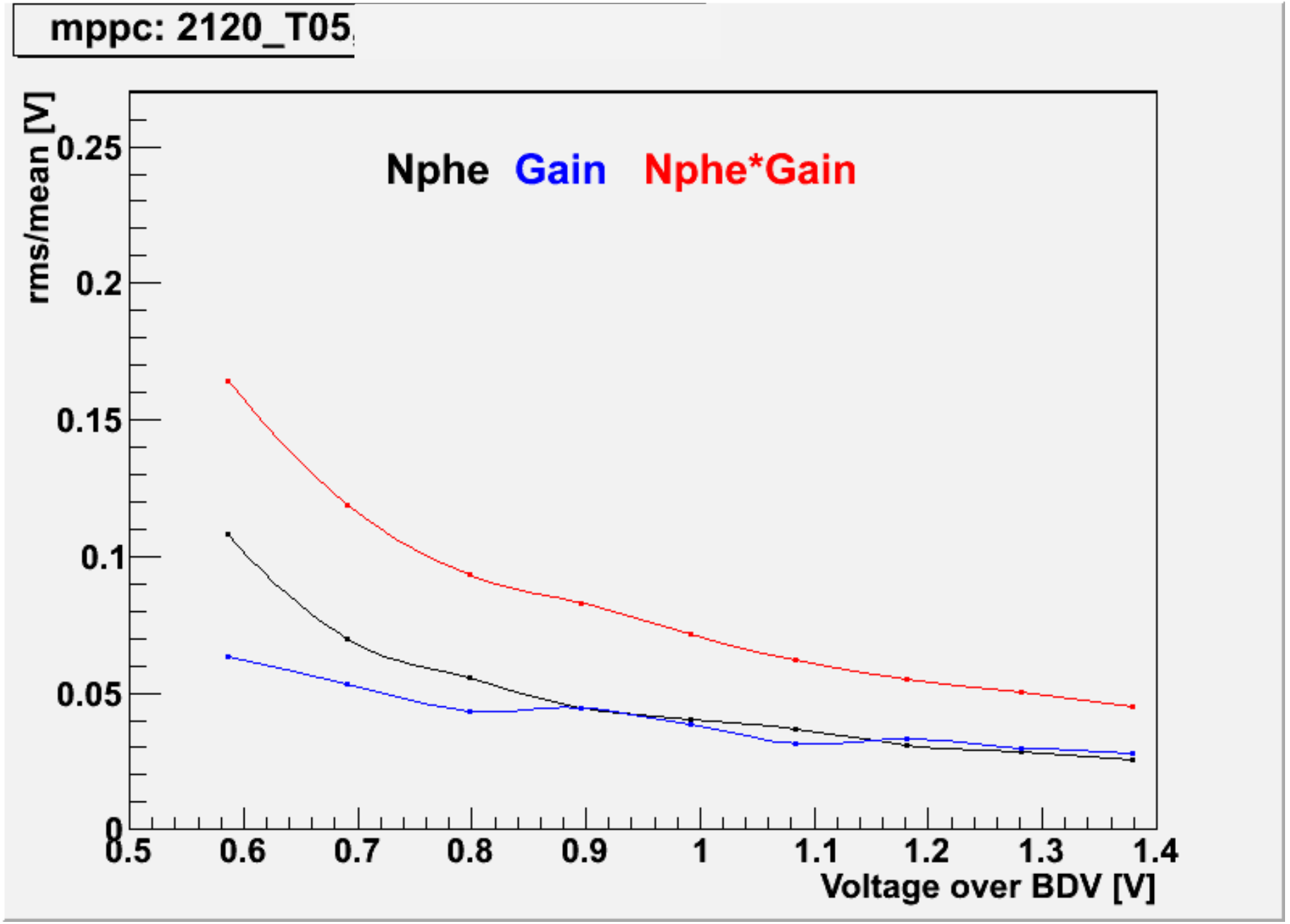

mppc: 2083_T07
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

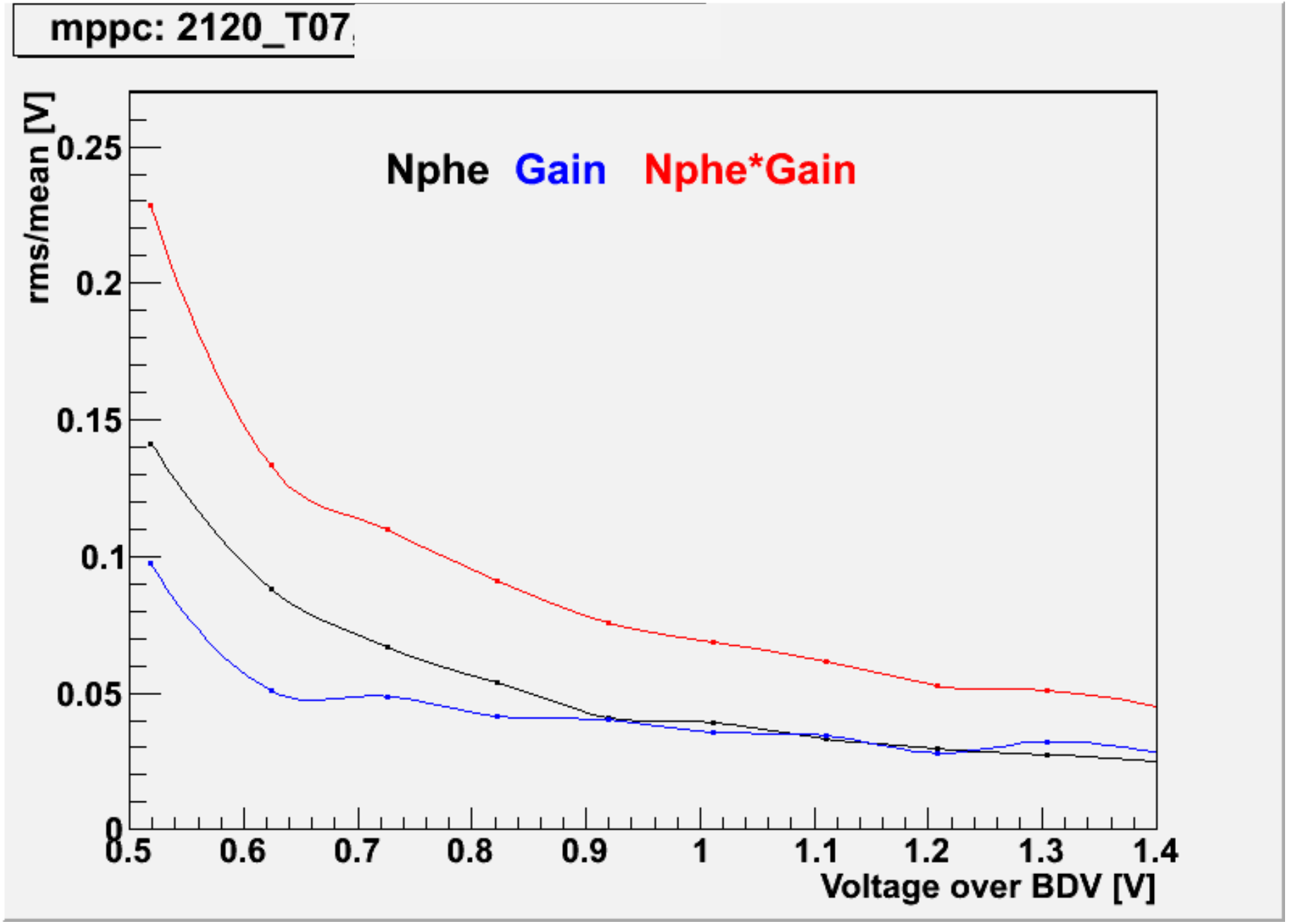

mppc: 2083_T20
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

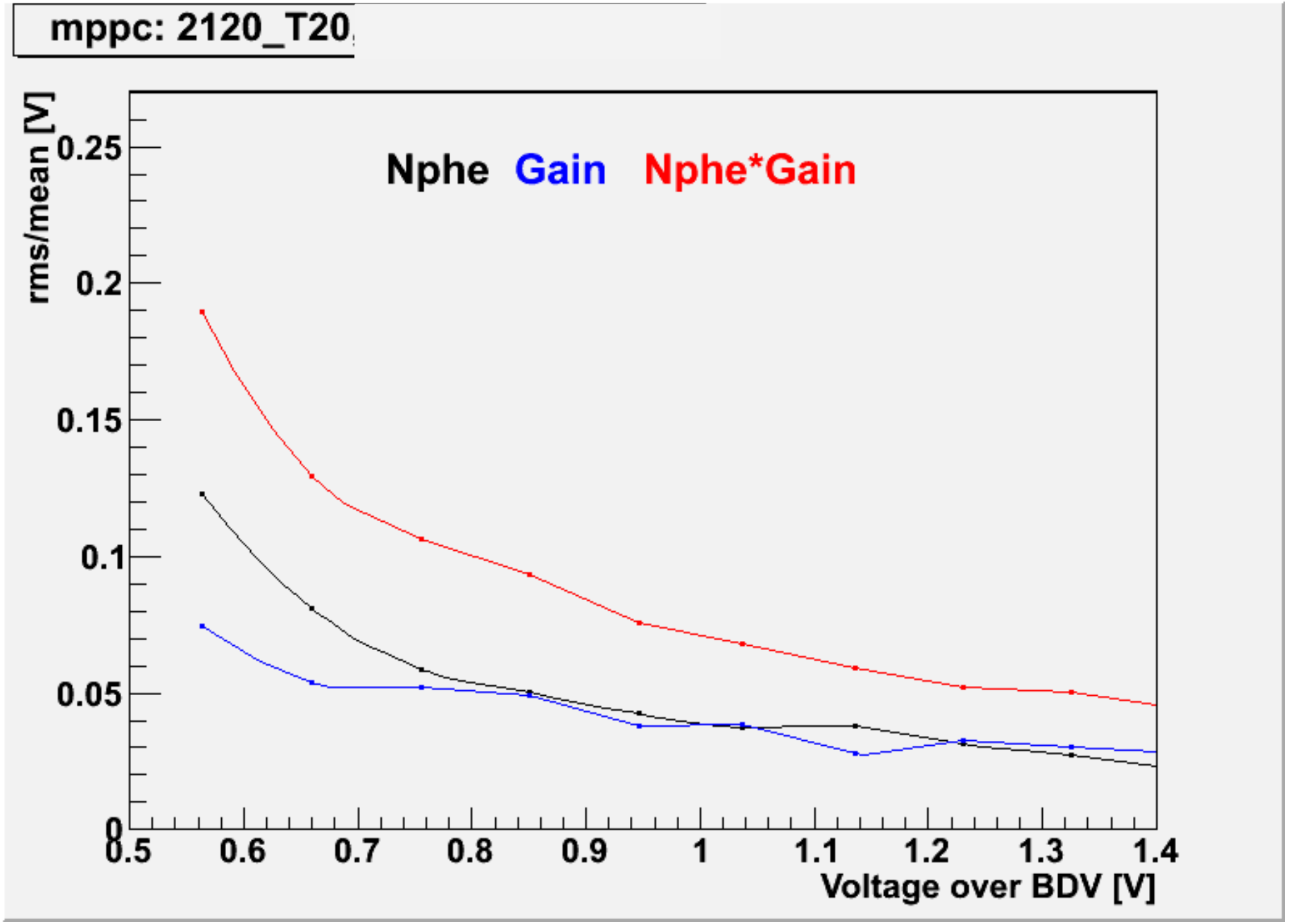

mppc: 2098_T05
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

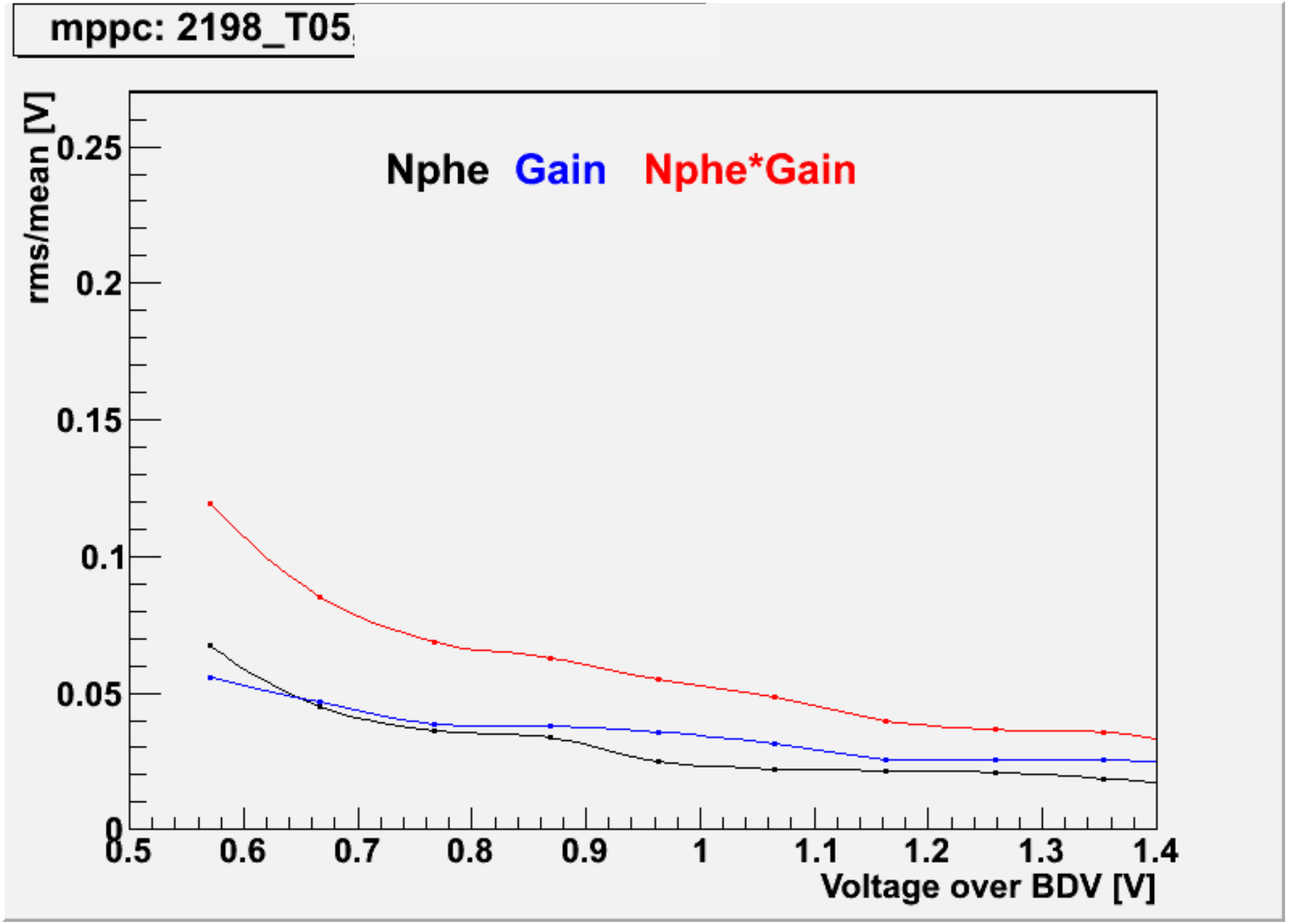

mppc: 2098_T07
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

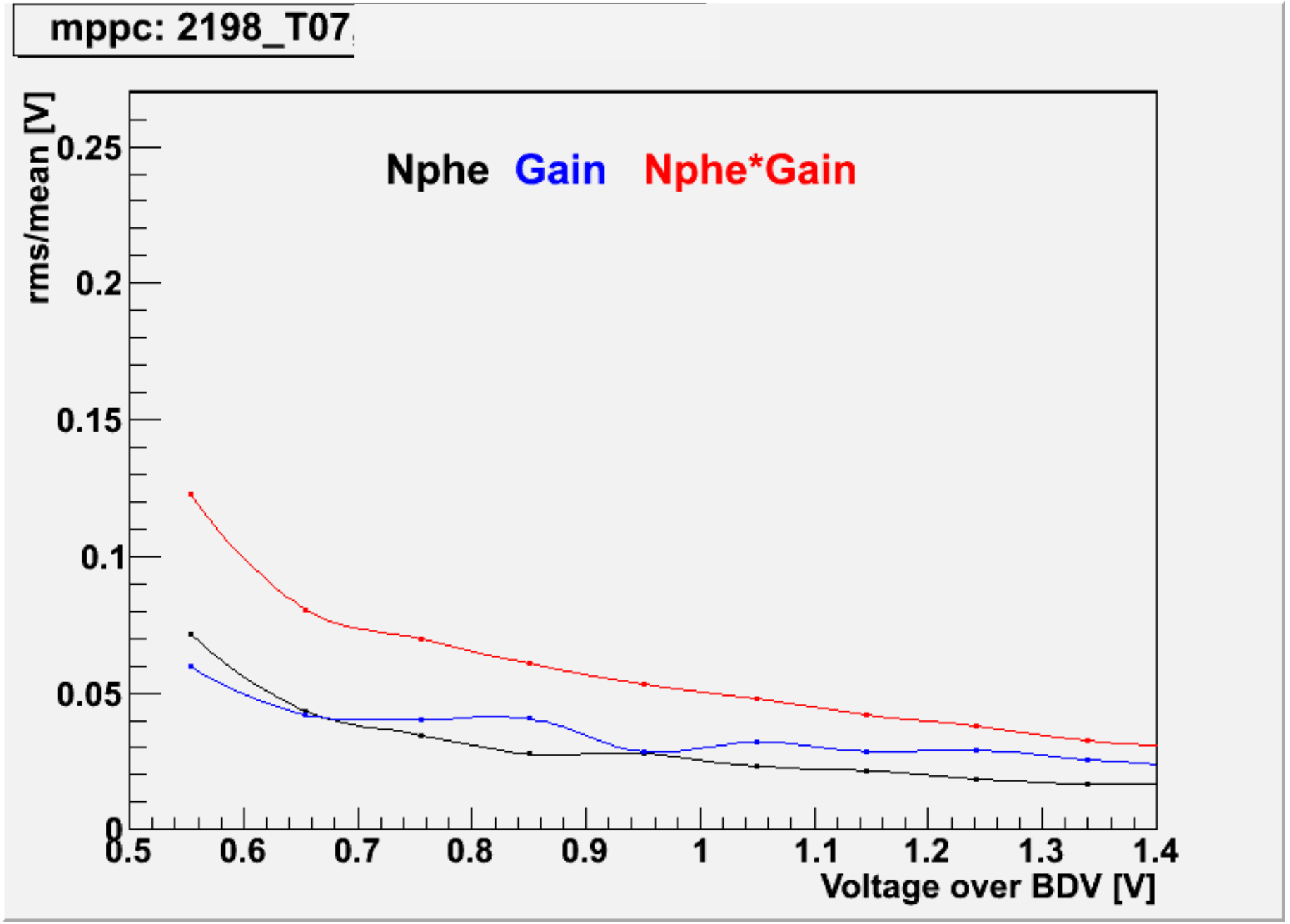

mppc: 2098_T20
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

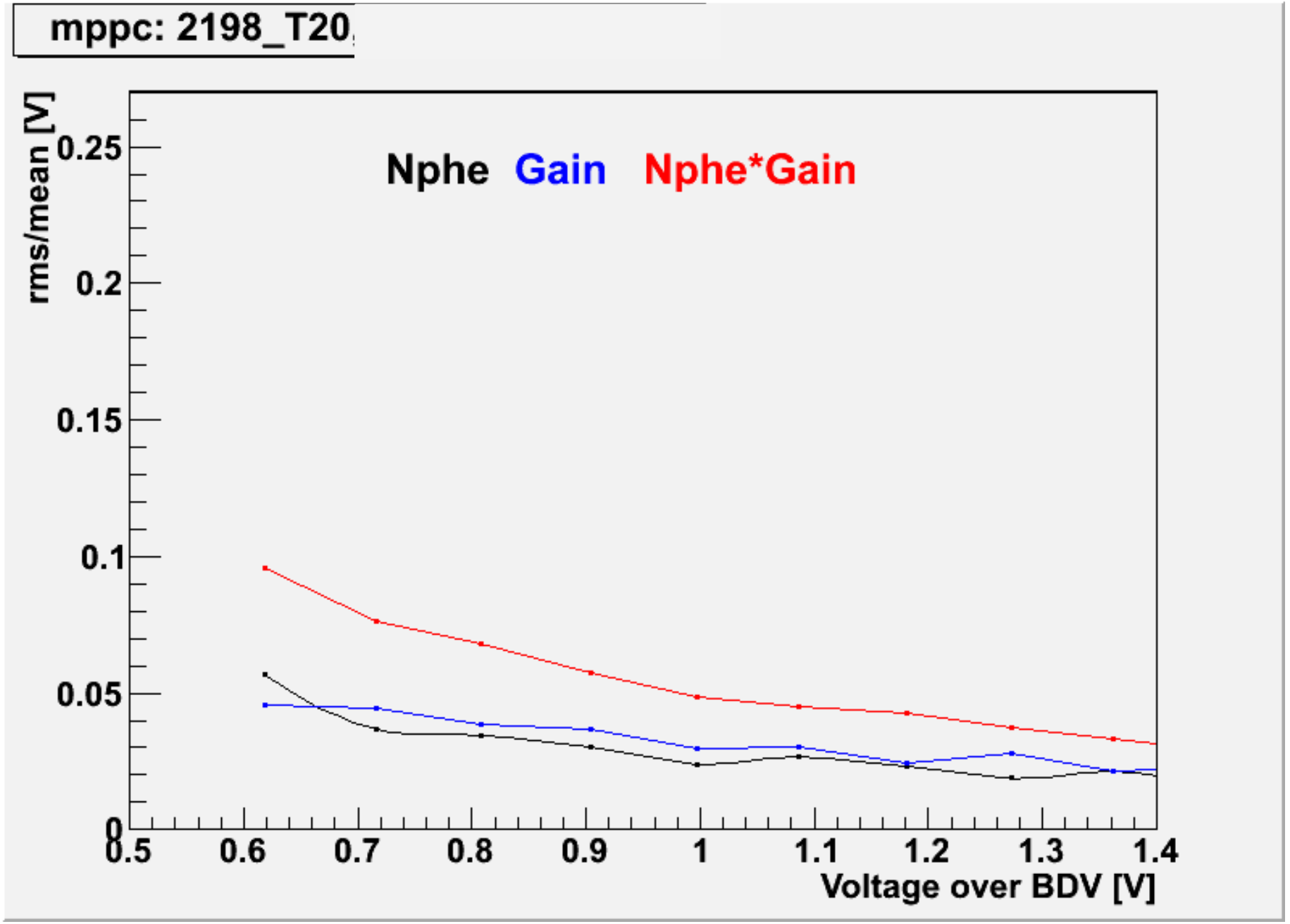

mppc: 2120_T05
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

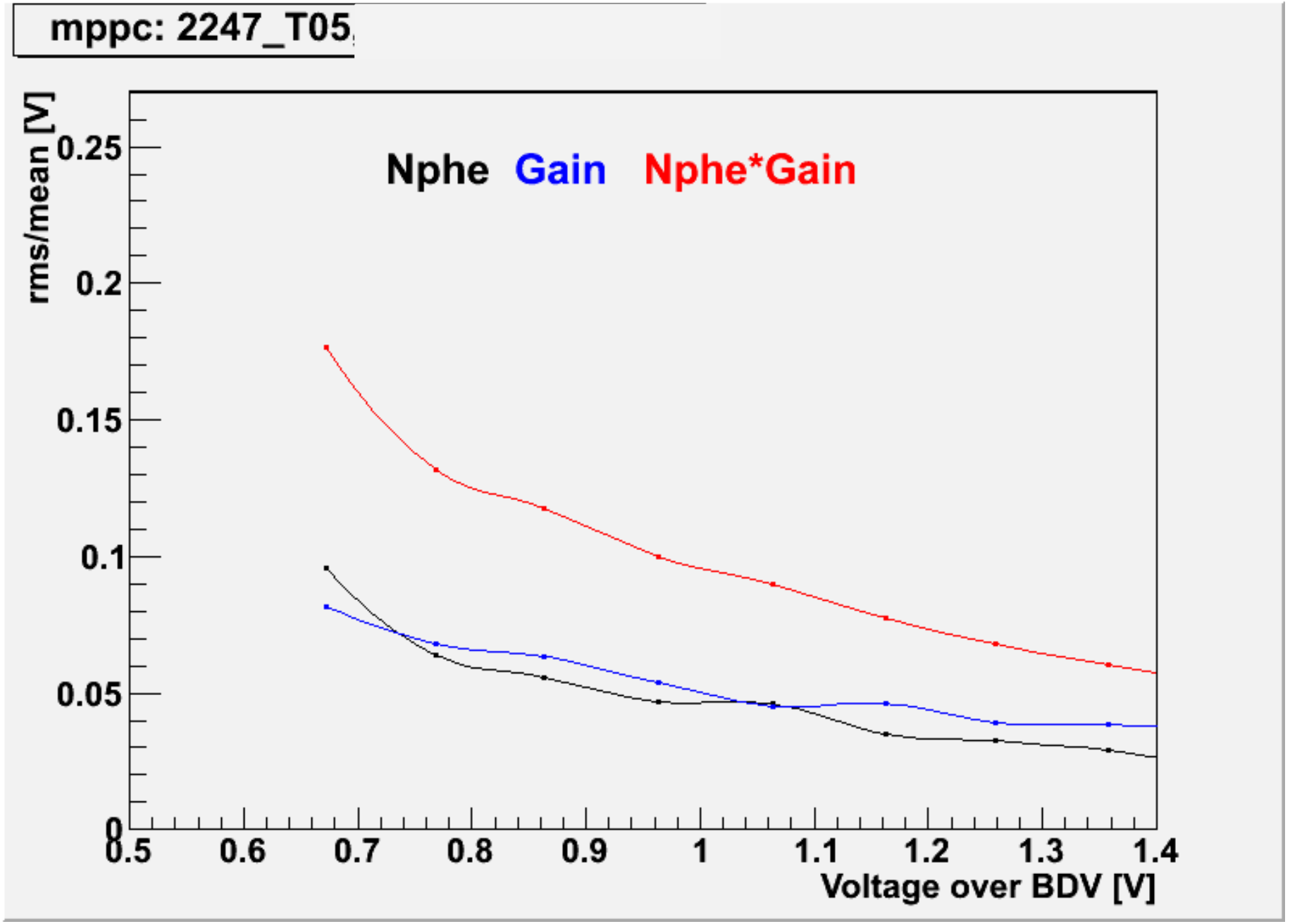

mppc: 2120_T07
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

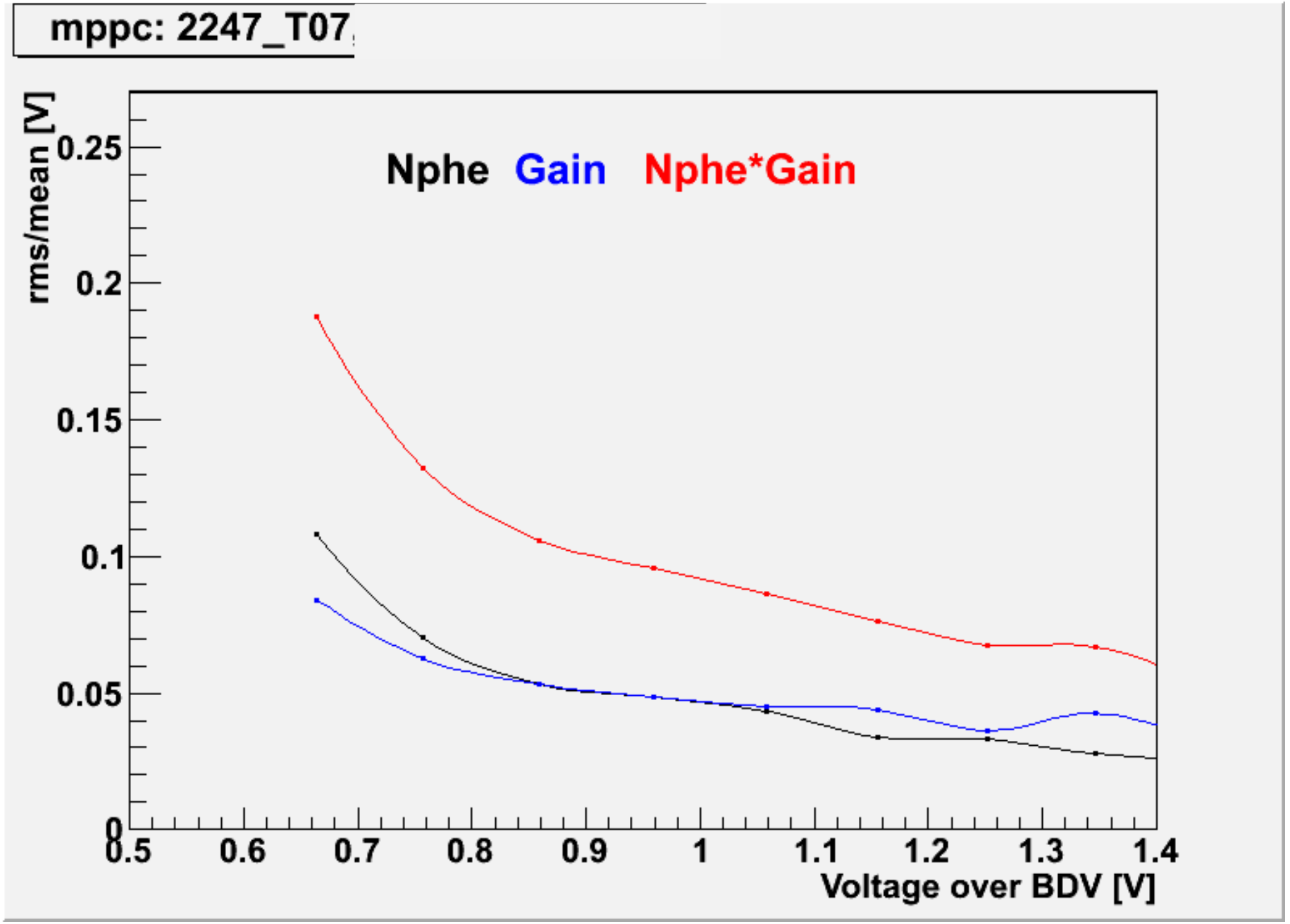

mppc: 2120_T20
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

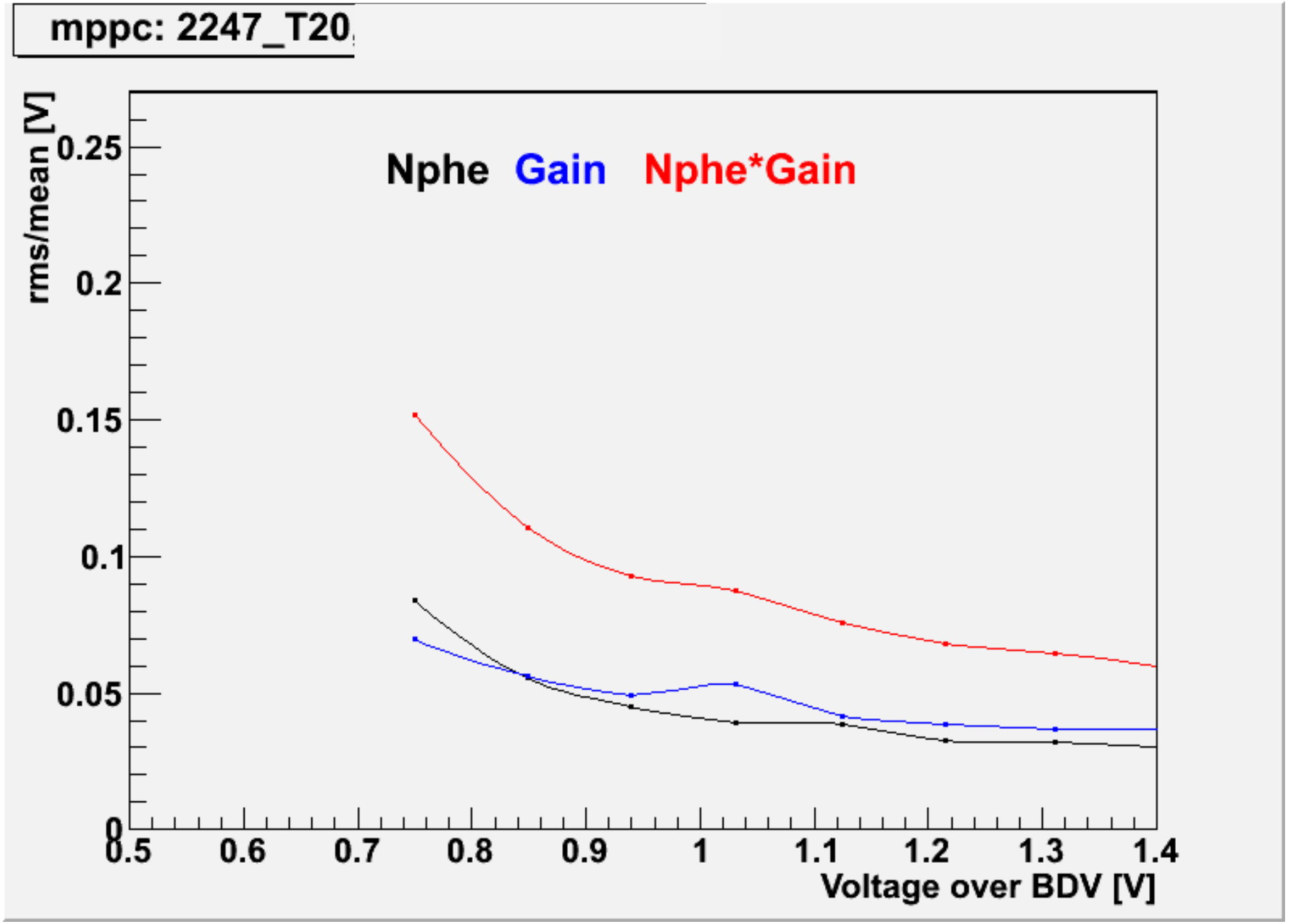

mppc: 2198_T05
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

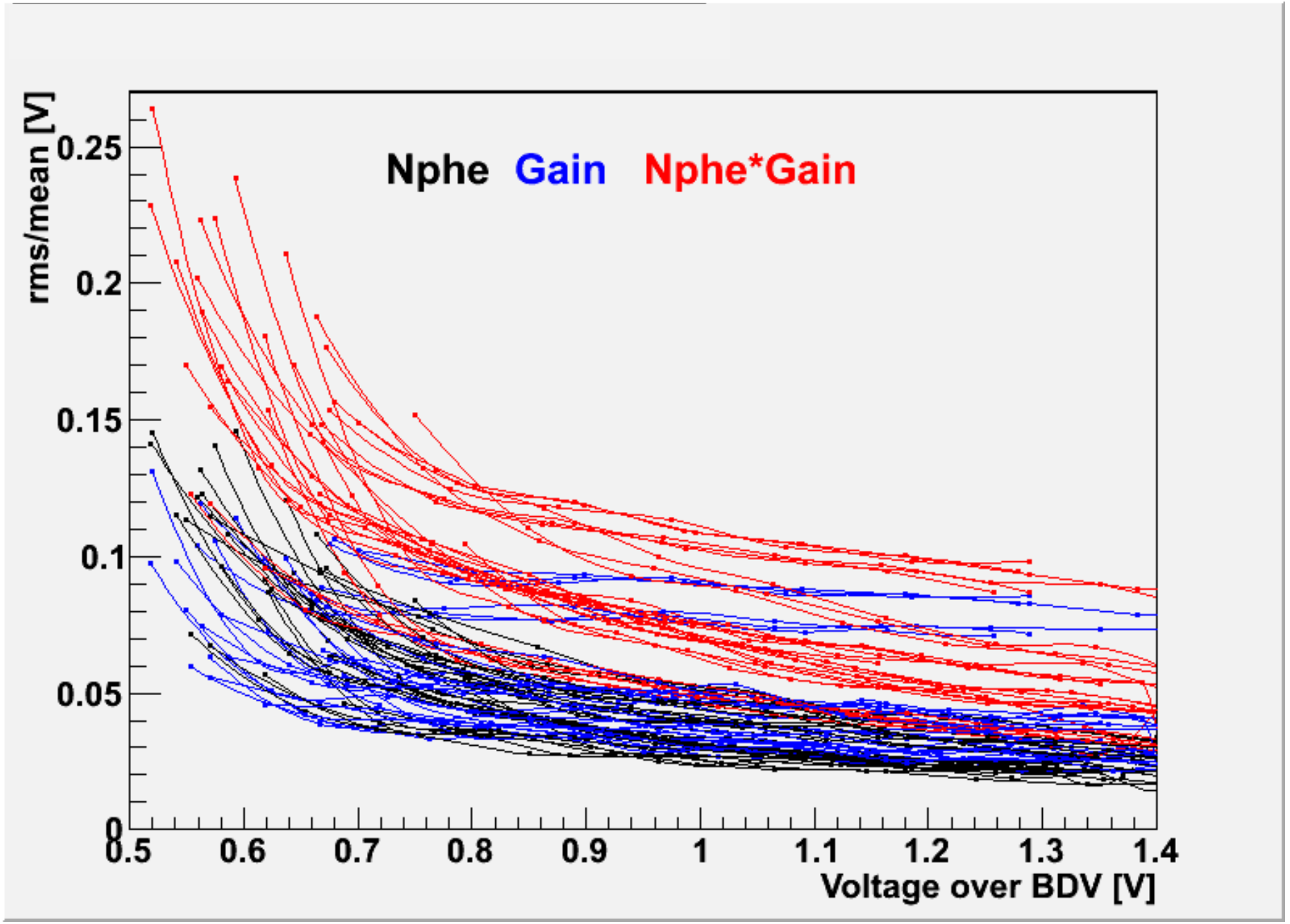

mppc: 2198_T07
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]


mppc: 2198_T20
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]


mppc: 2247_T05
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]


mppc: 2247_T07
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]


mppc: 2247_T20
Nphe
Gain
Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]


Nphe Gain Nphe*Gain
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]

In order to get plots for each mppc amplitude we made the following.

For each temperature, voltage.
1. We take the light histogram with pedestal substracted from each cell (hcell_ps_i).

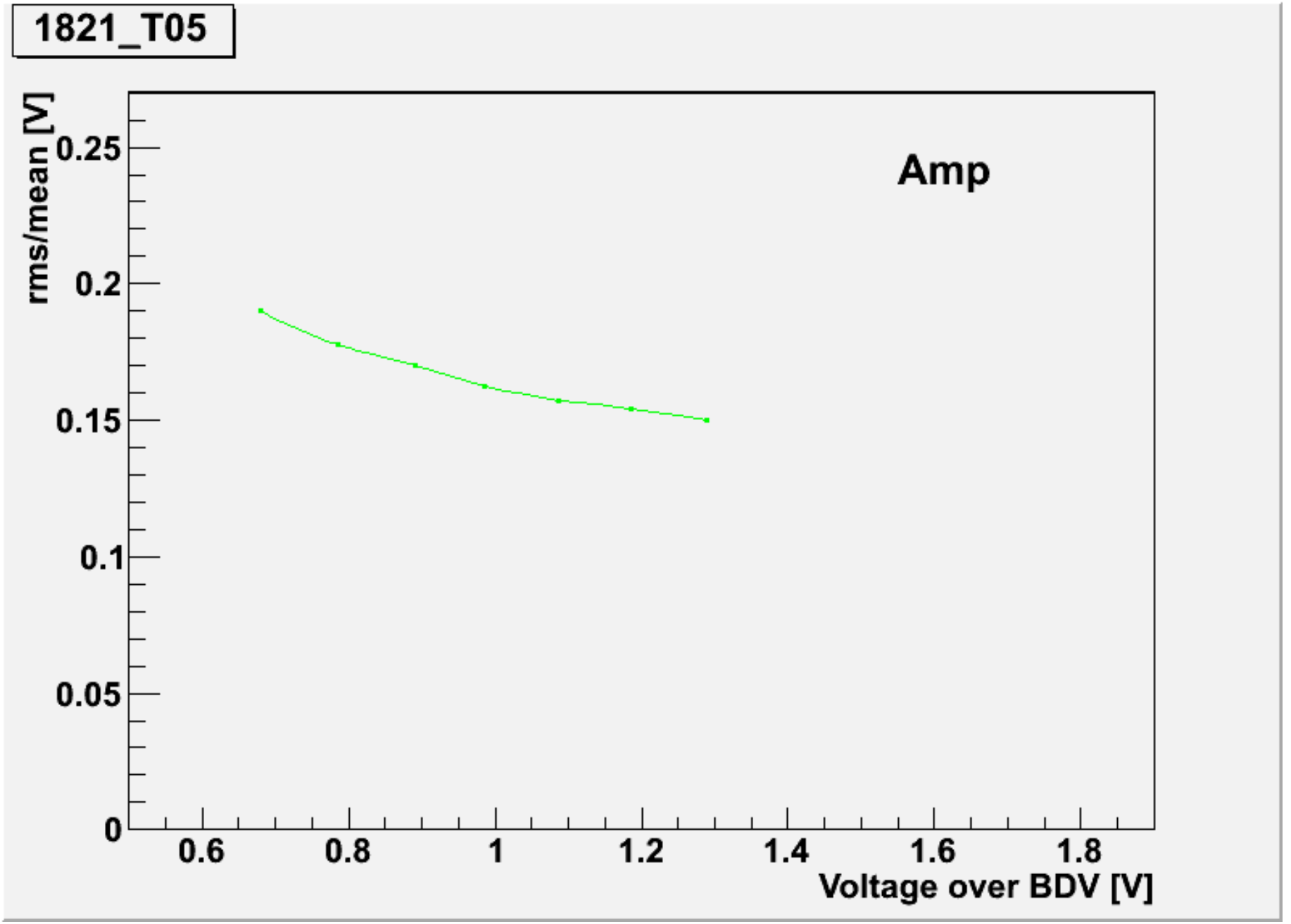
2. we made a new histogram with range [-5000 , 4096*16 -5000] (h_sum_amp_v).

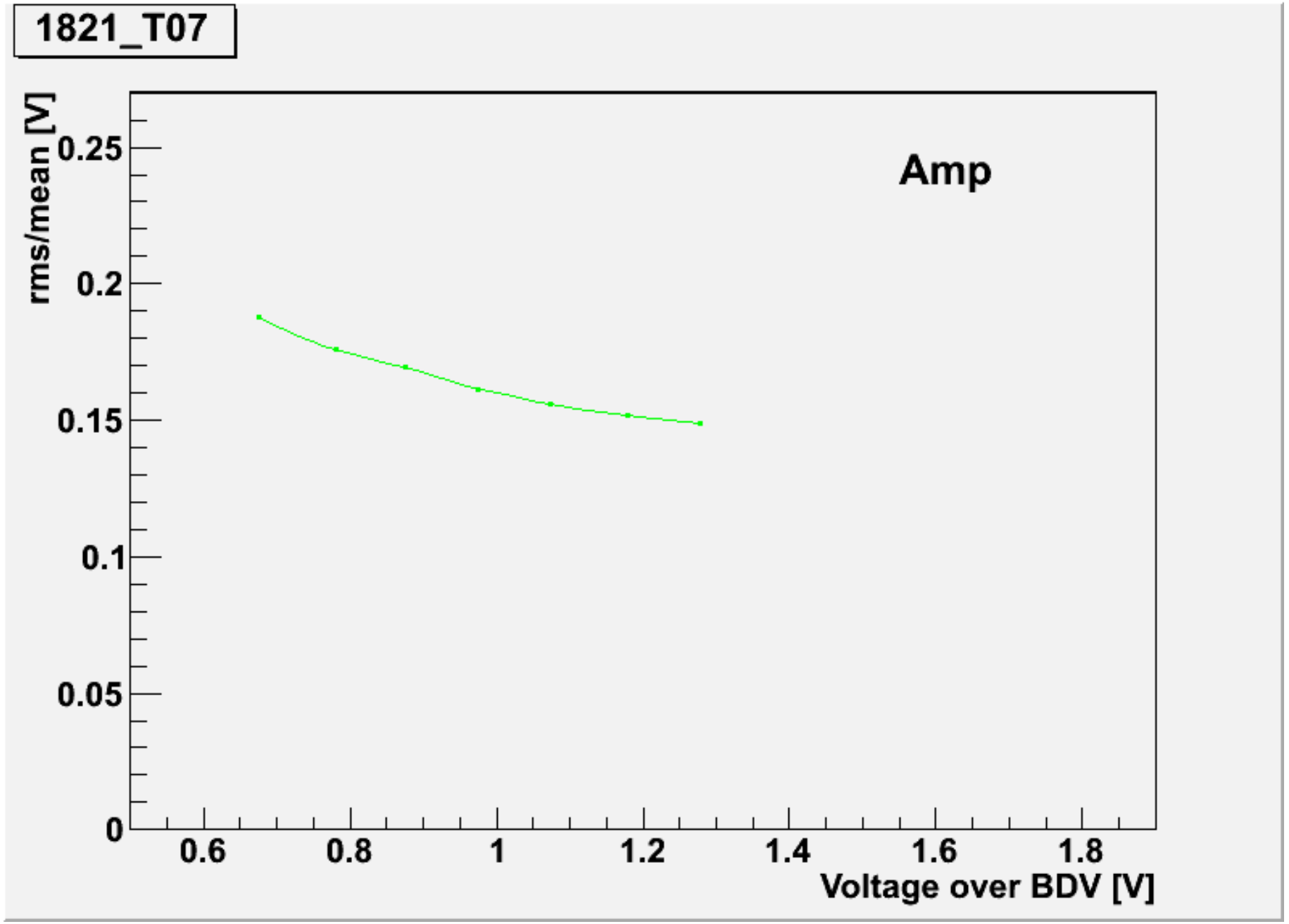
3. we filled h_sum_amp_v taking values from random numbers distributed according the histograms hcell_ps_i:

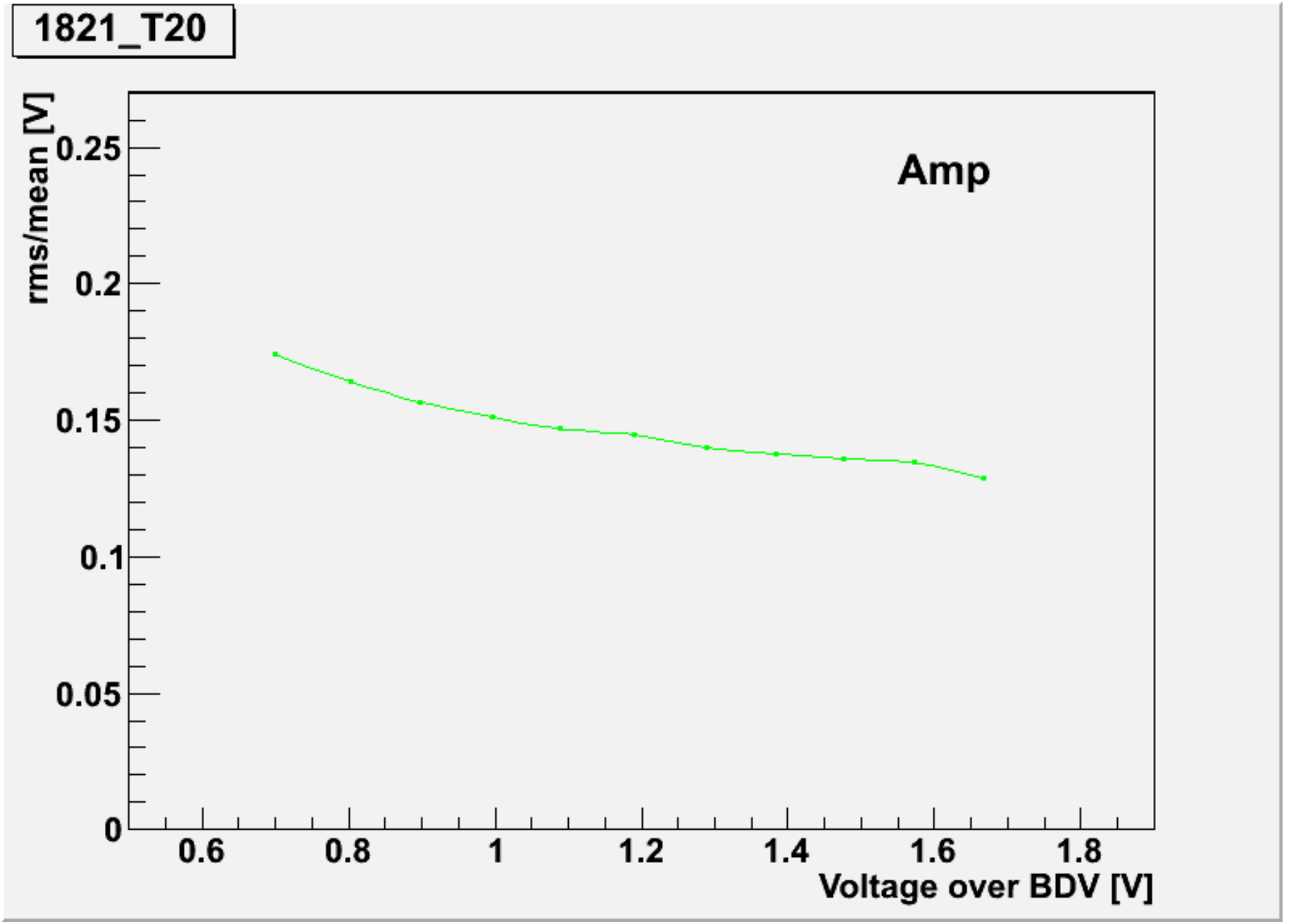
```
sum_amp = hcell_ps_0->GetRandom() + hcell_ps_1->GetRandom()
                + ... + hcell_ps_15->GetRandom()
h_sum_amp_volt->Fill( sum_amp )
```

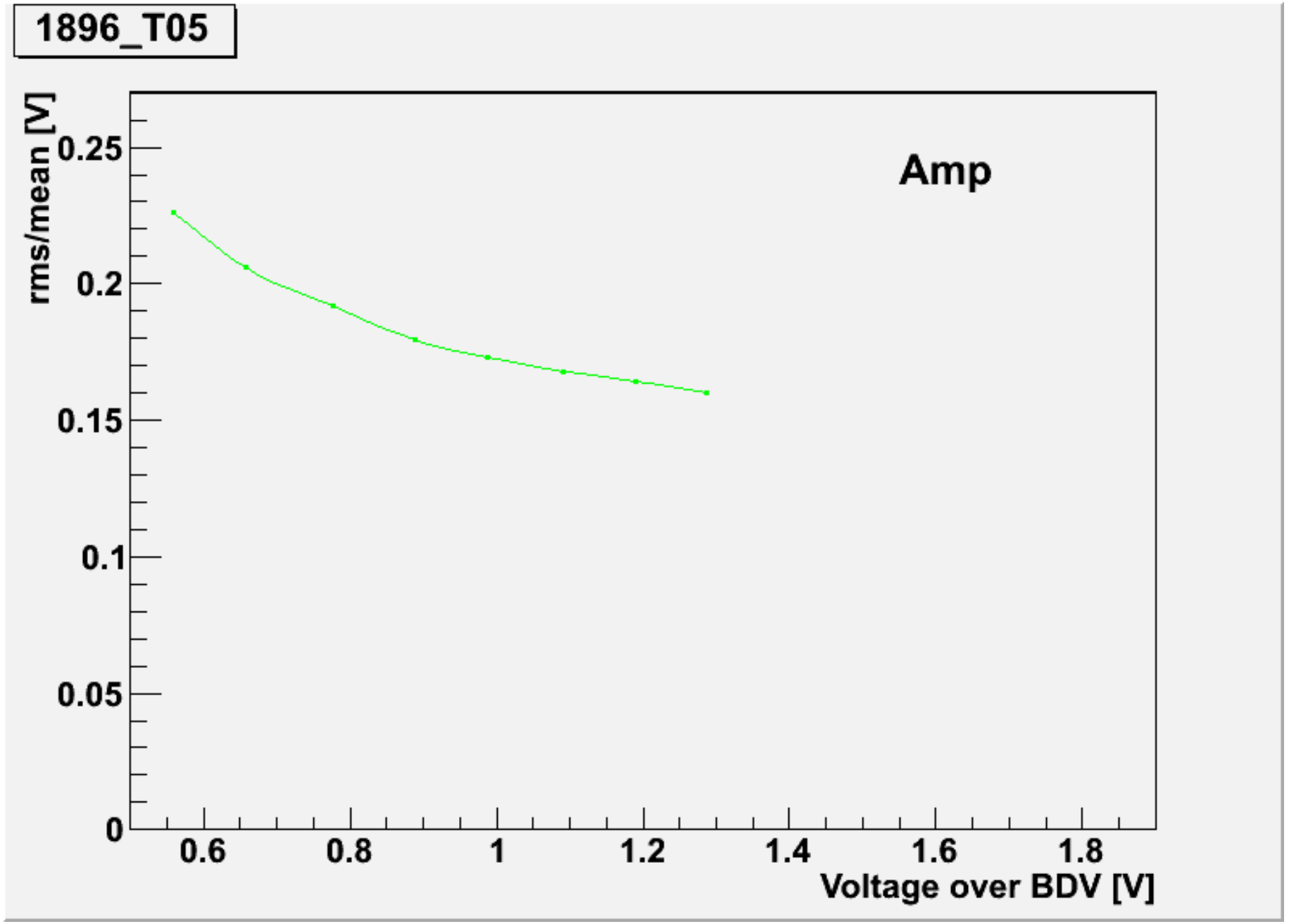
we take 120000 events.

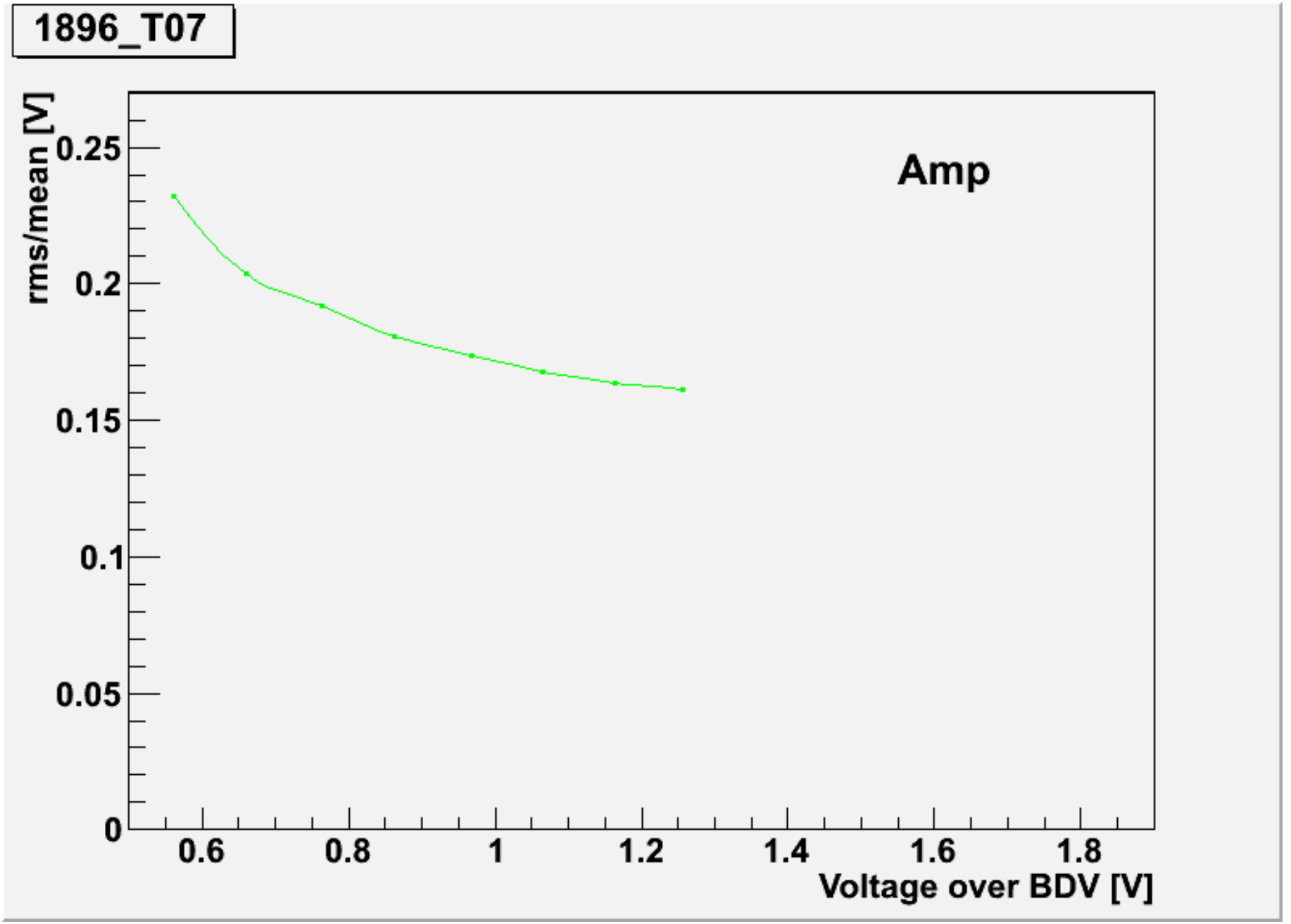
4. Finally we made the plots rms/mean vs volt for h_sum_amp_v in each temperature.

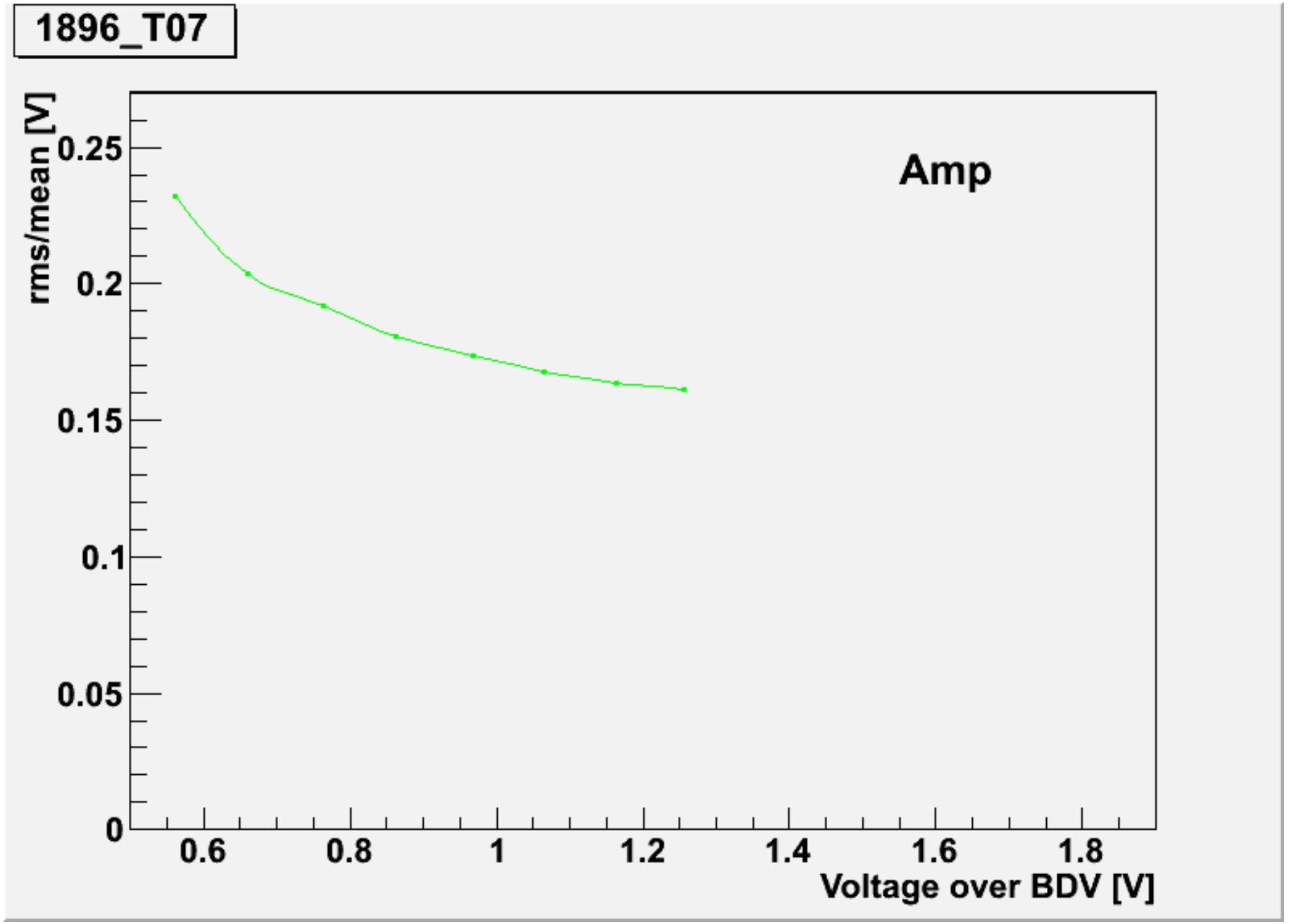

1821_T05
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

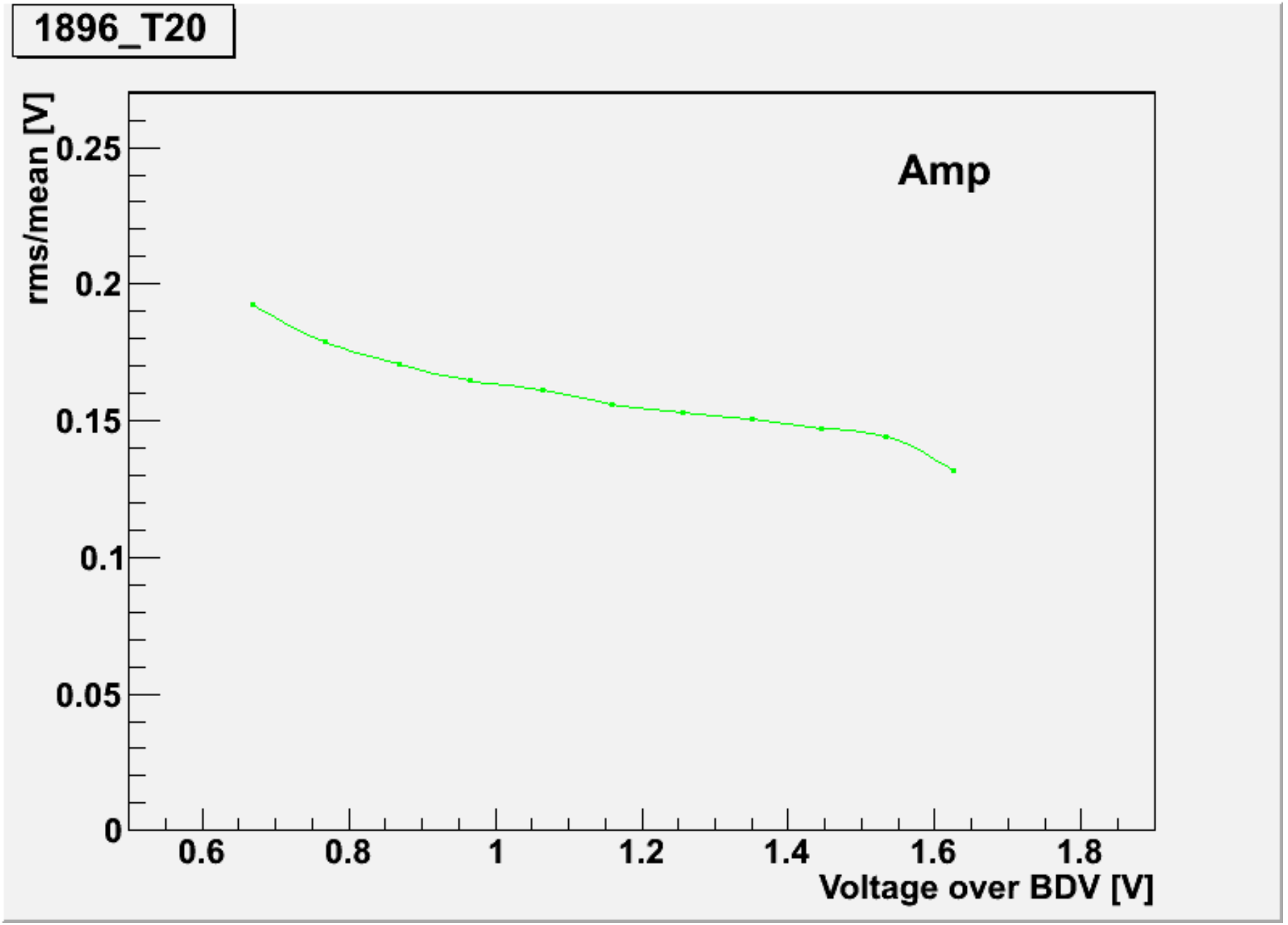

1821_T07
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

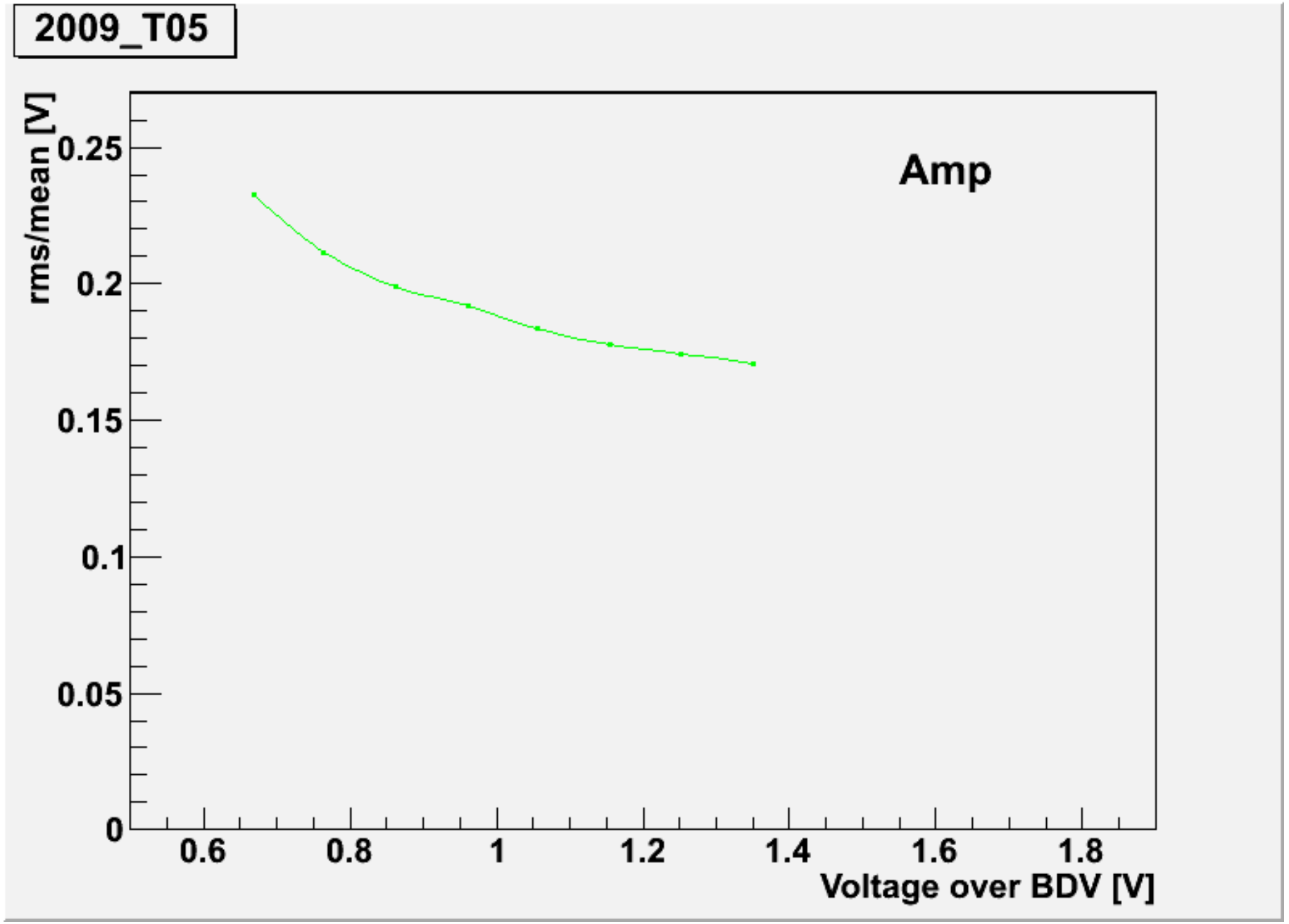

1821_T20
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

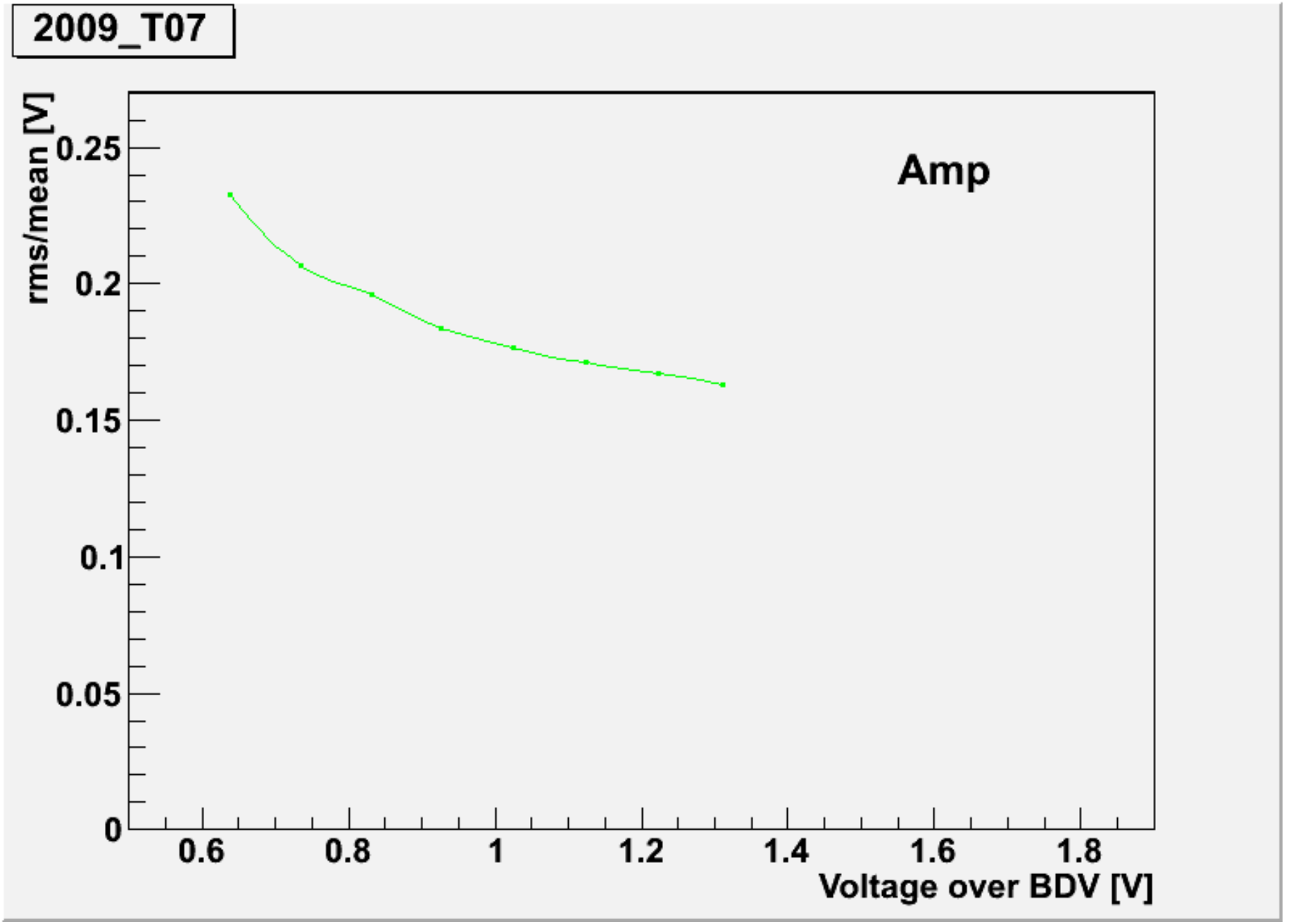

1896_T05
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

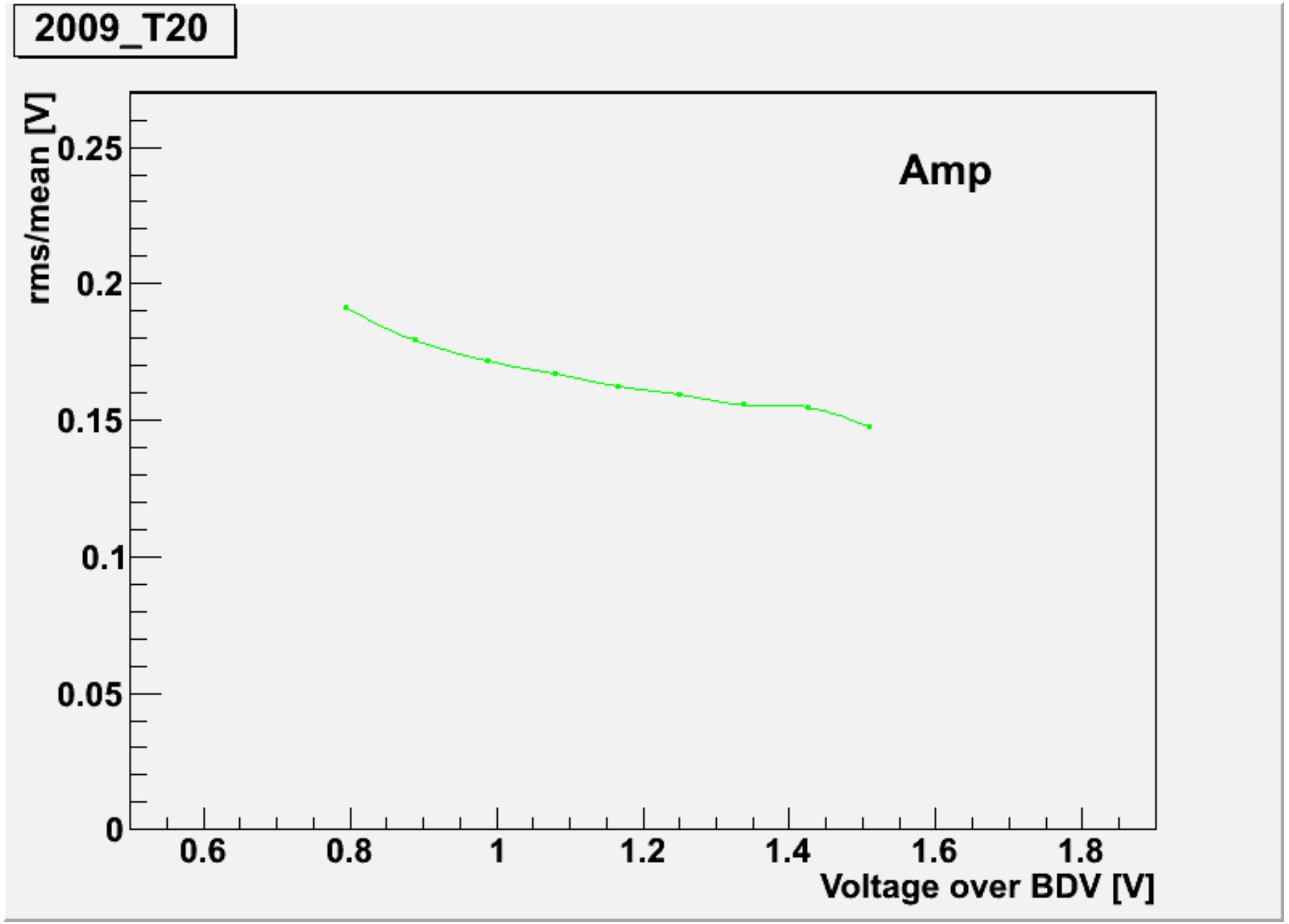

1896_T07
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

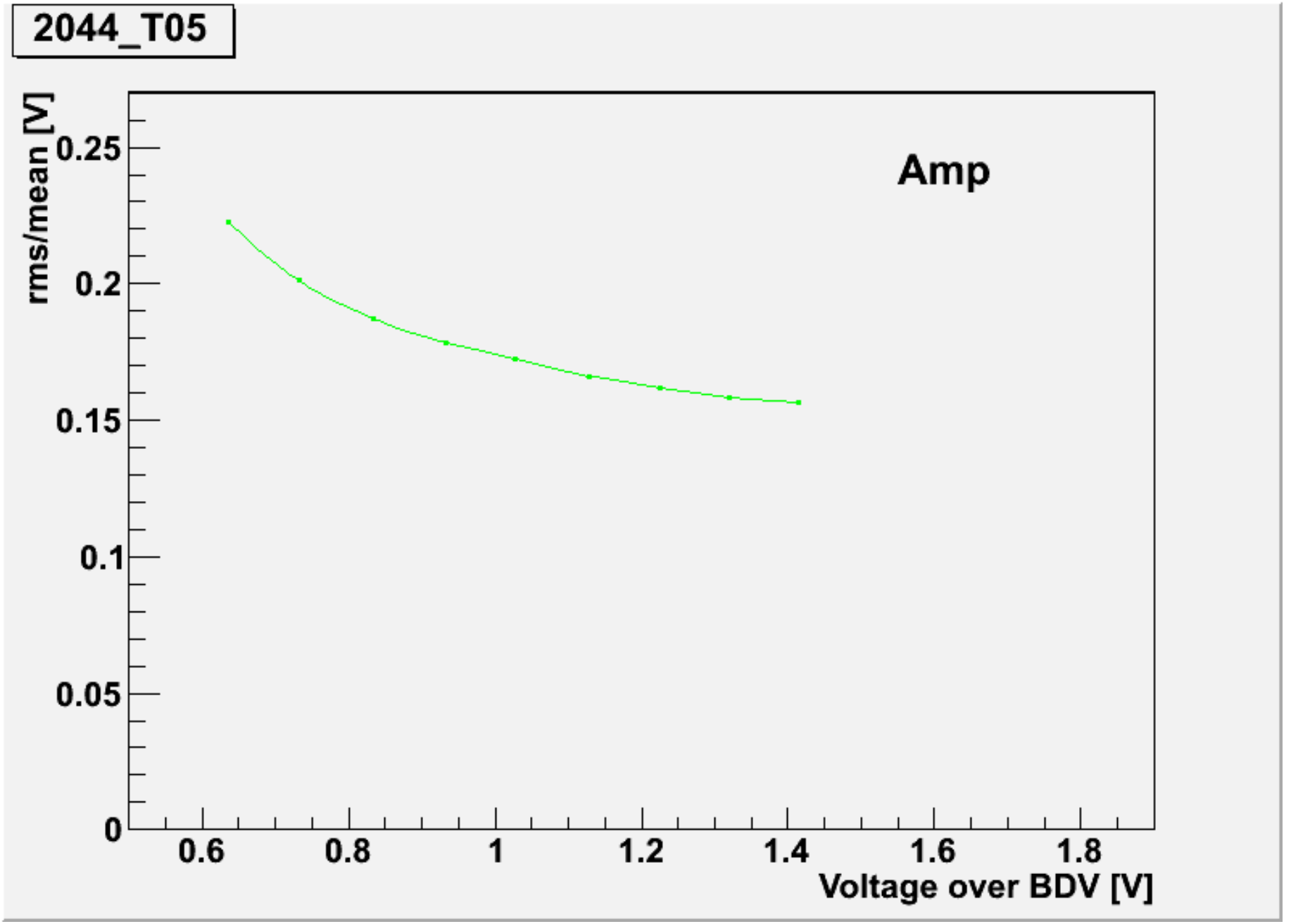

1896_T07
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

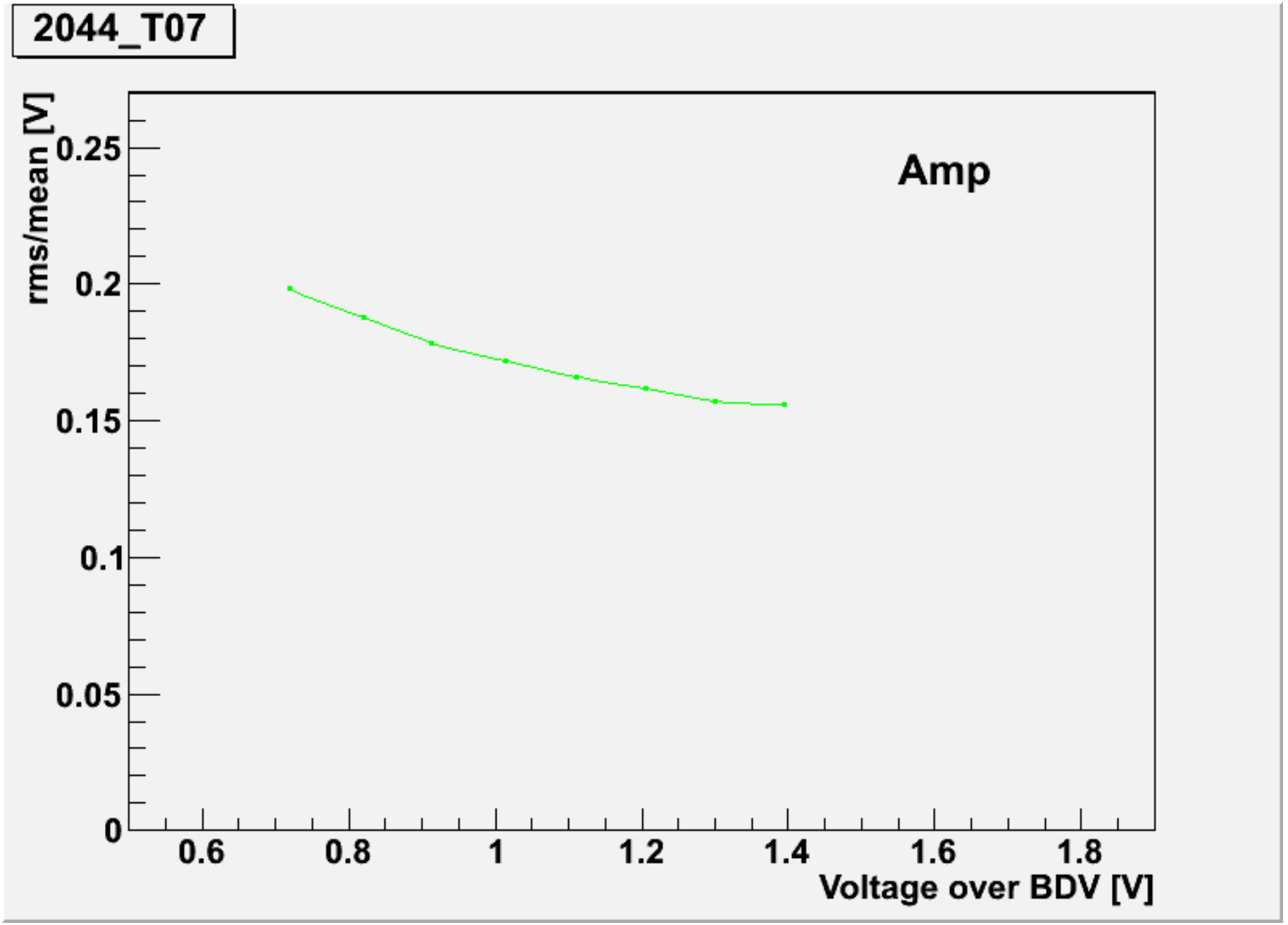

1896_T20
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

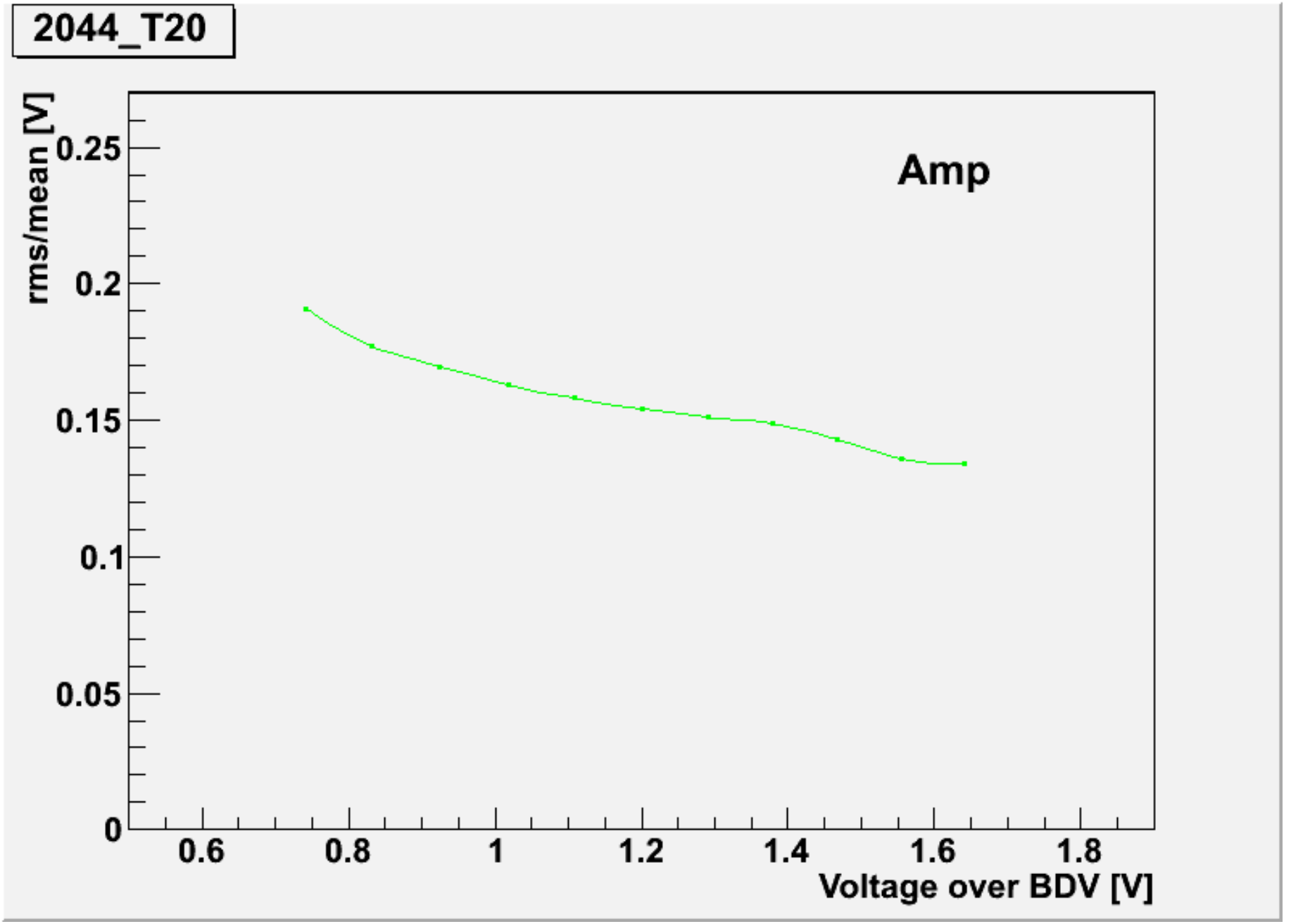

2009_T05
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

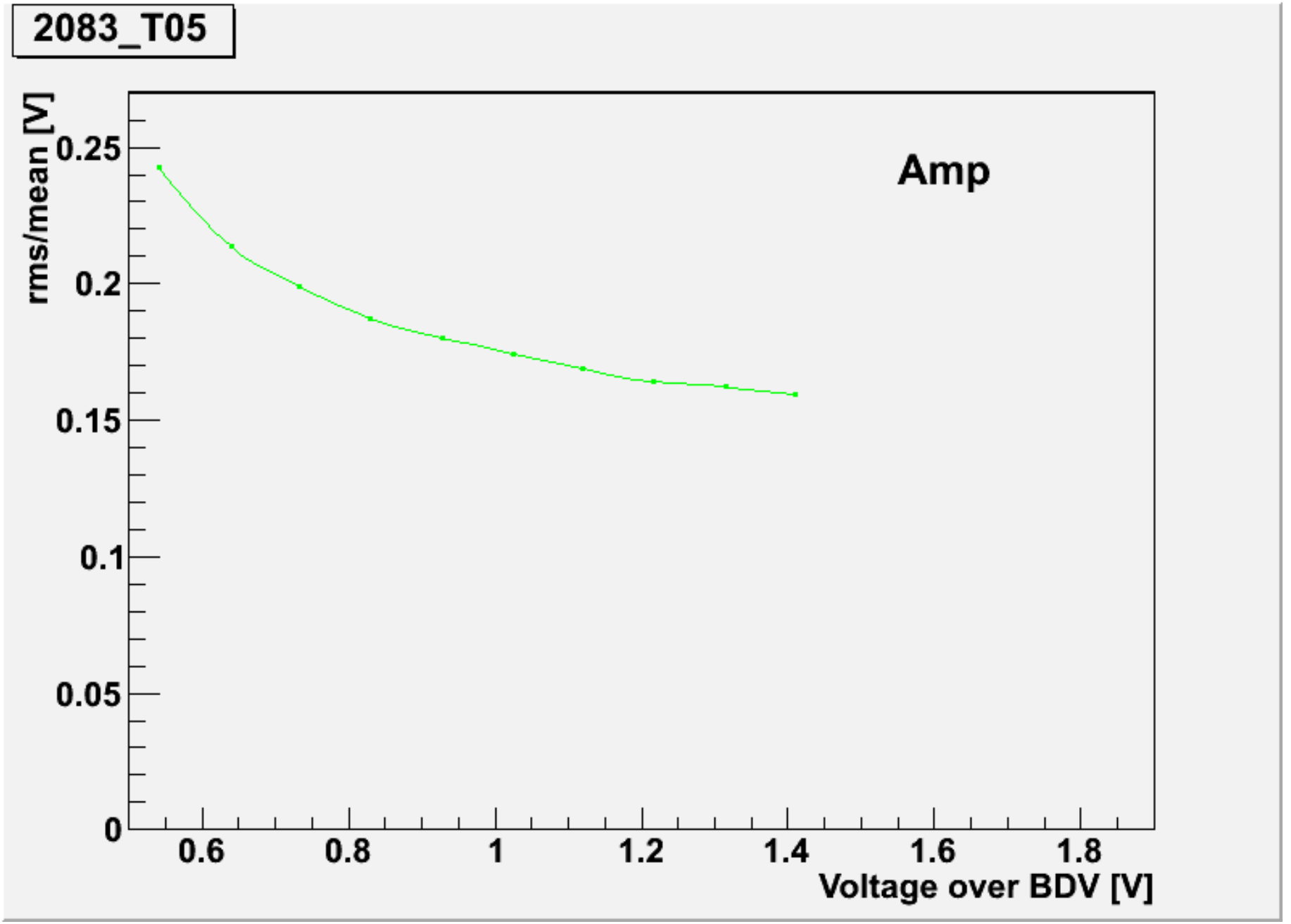

2009_T07
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

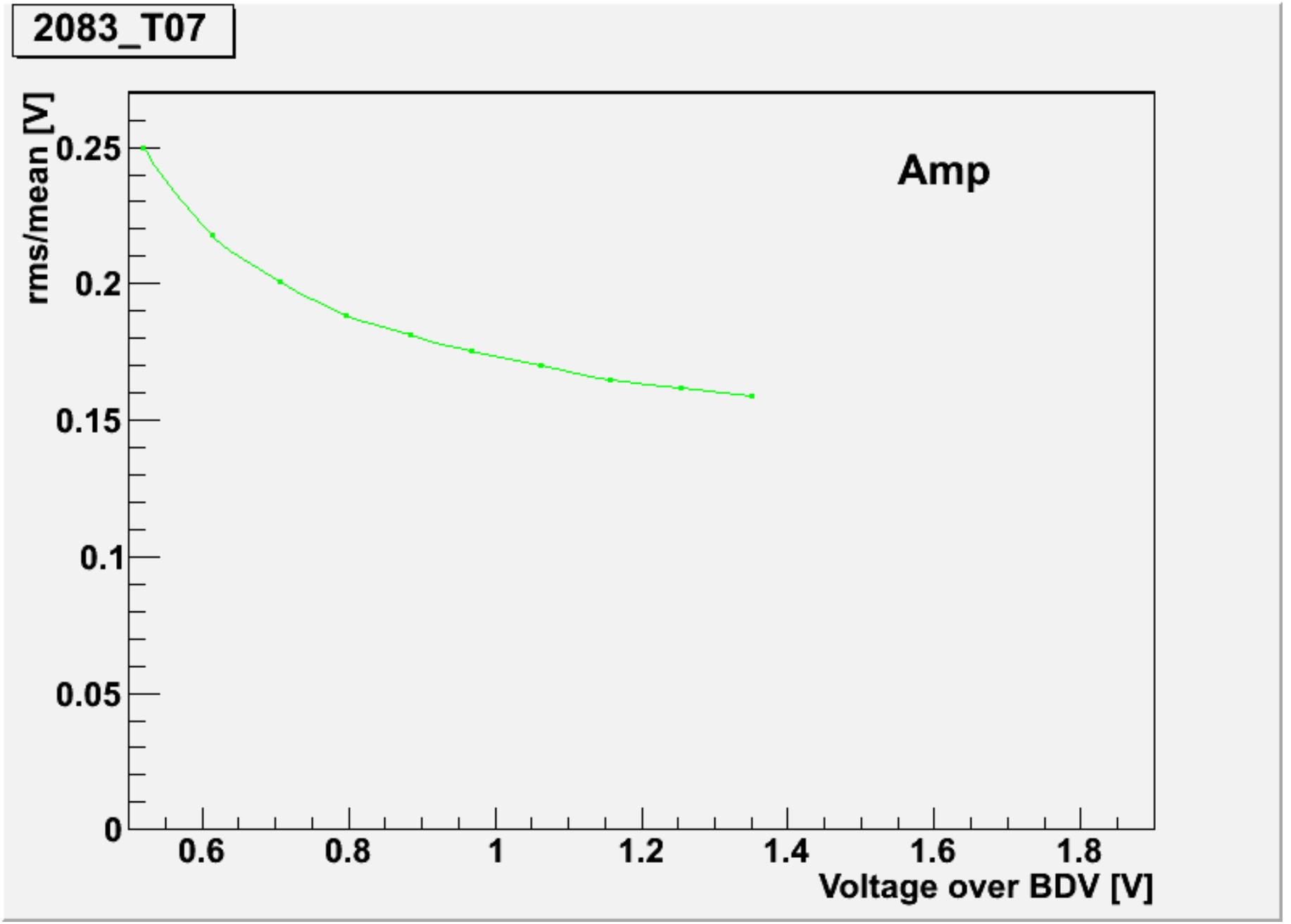

2009_T20
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

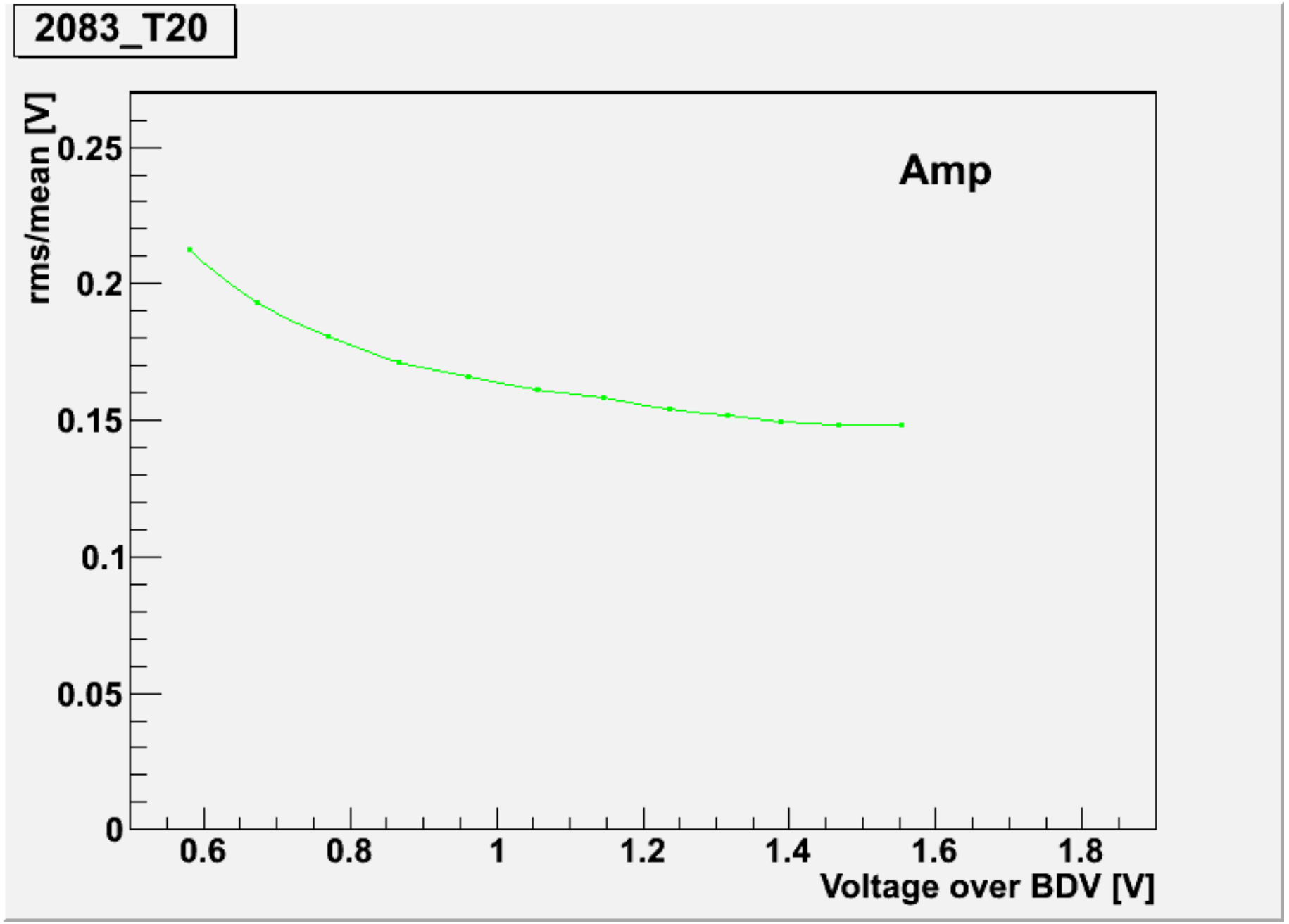

2044_T05
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

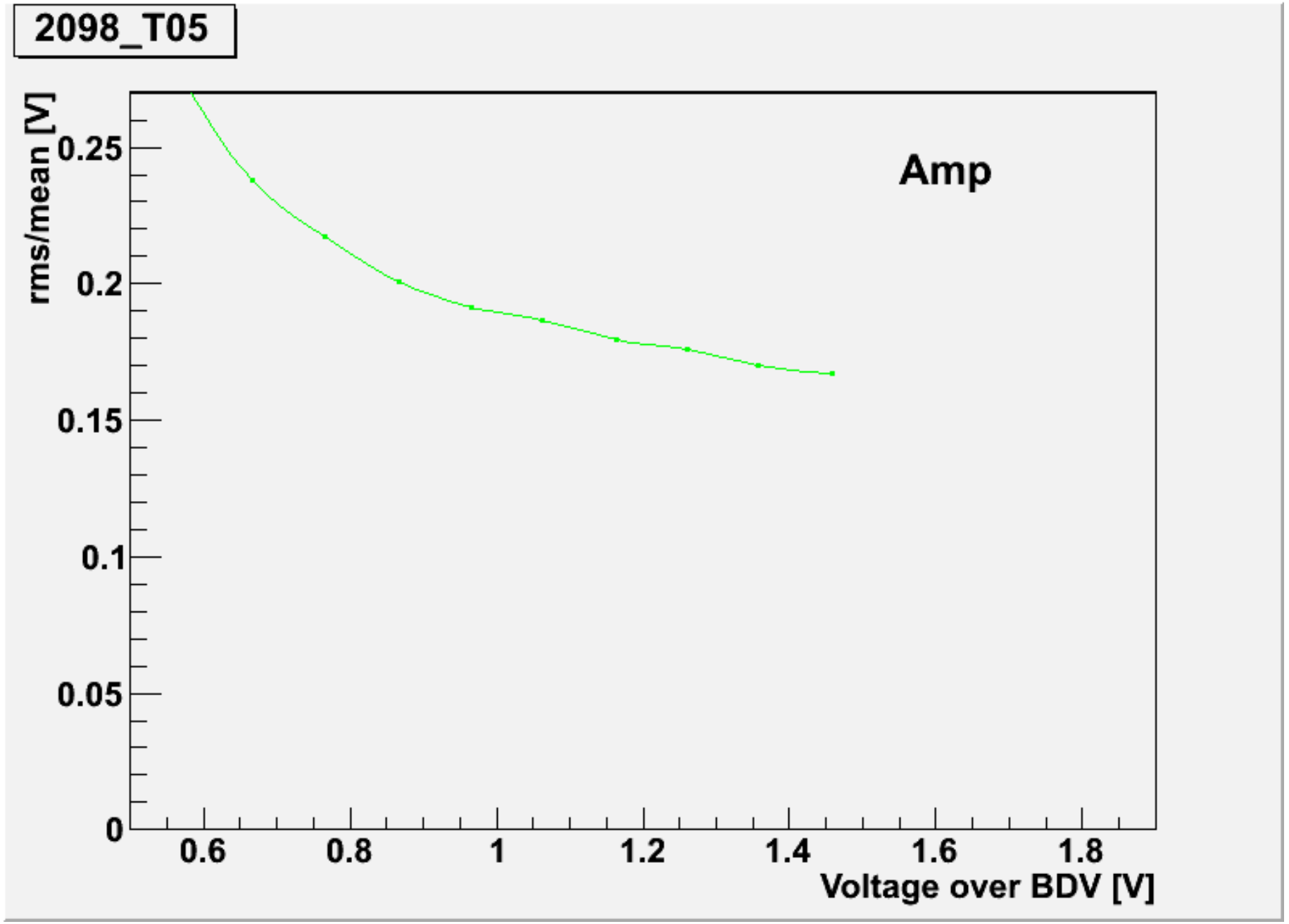

2044_T07
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
Amp
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

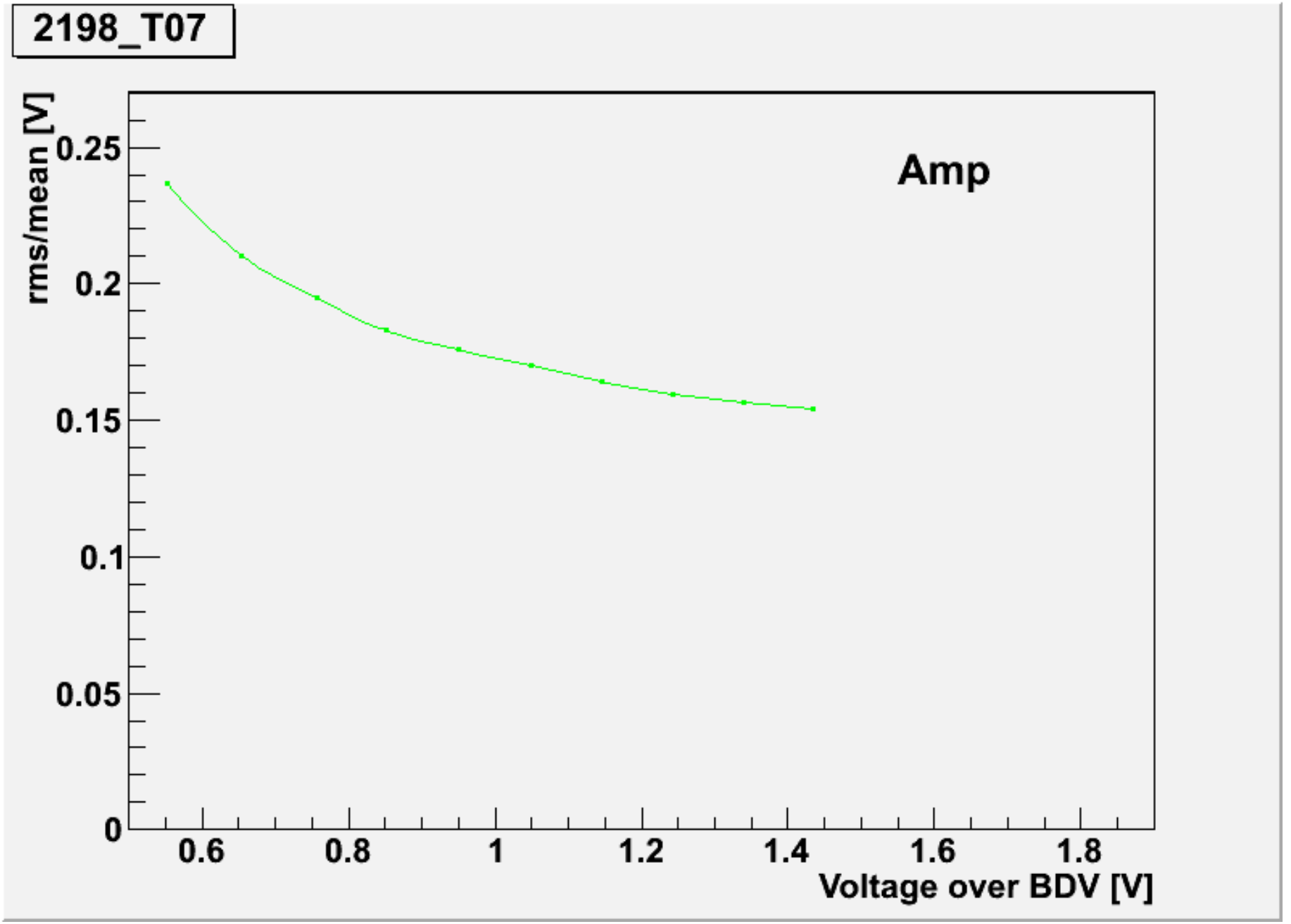

2044_T20
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
Amp
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

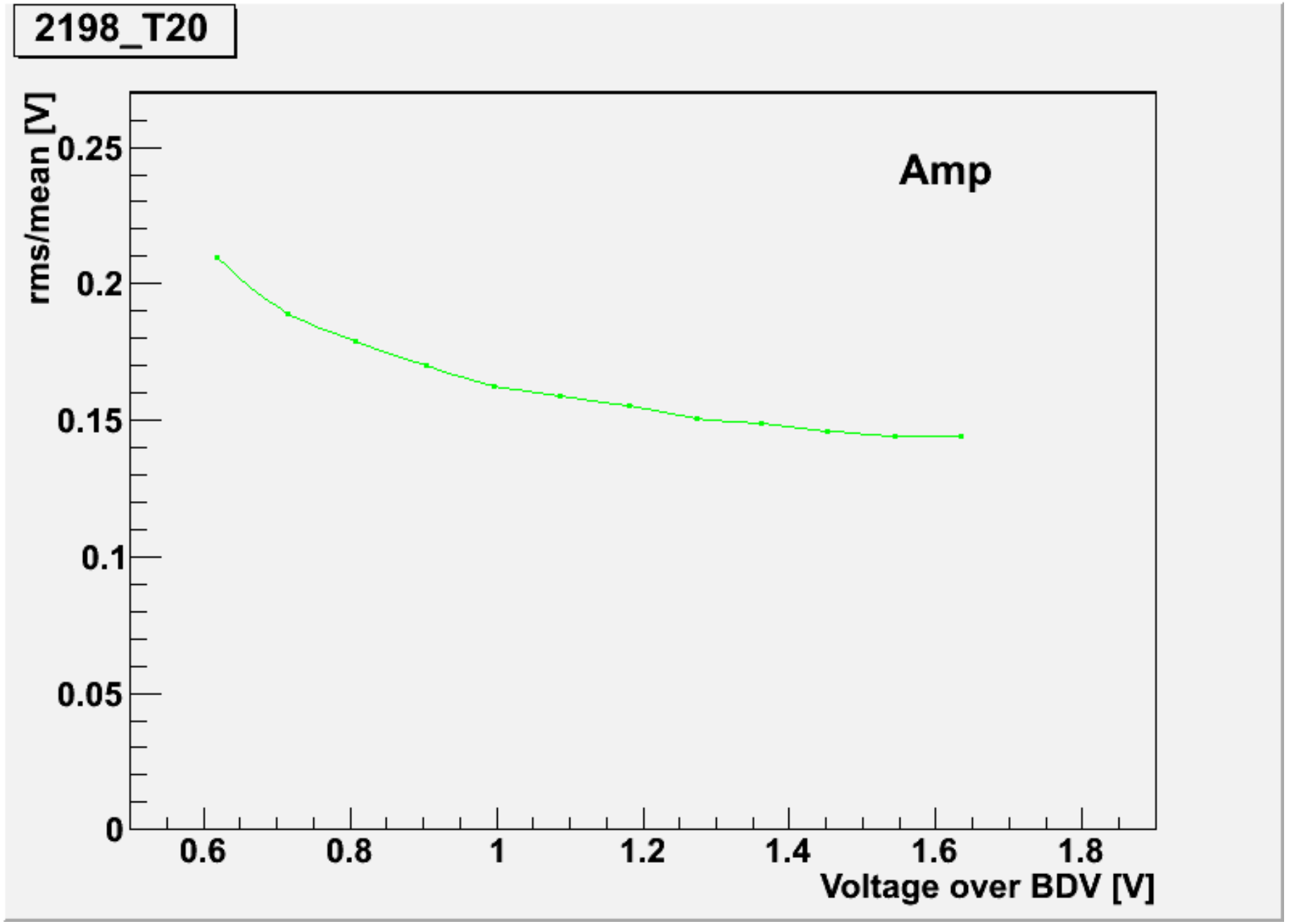

2083_T05
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
Amp
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

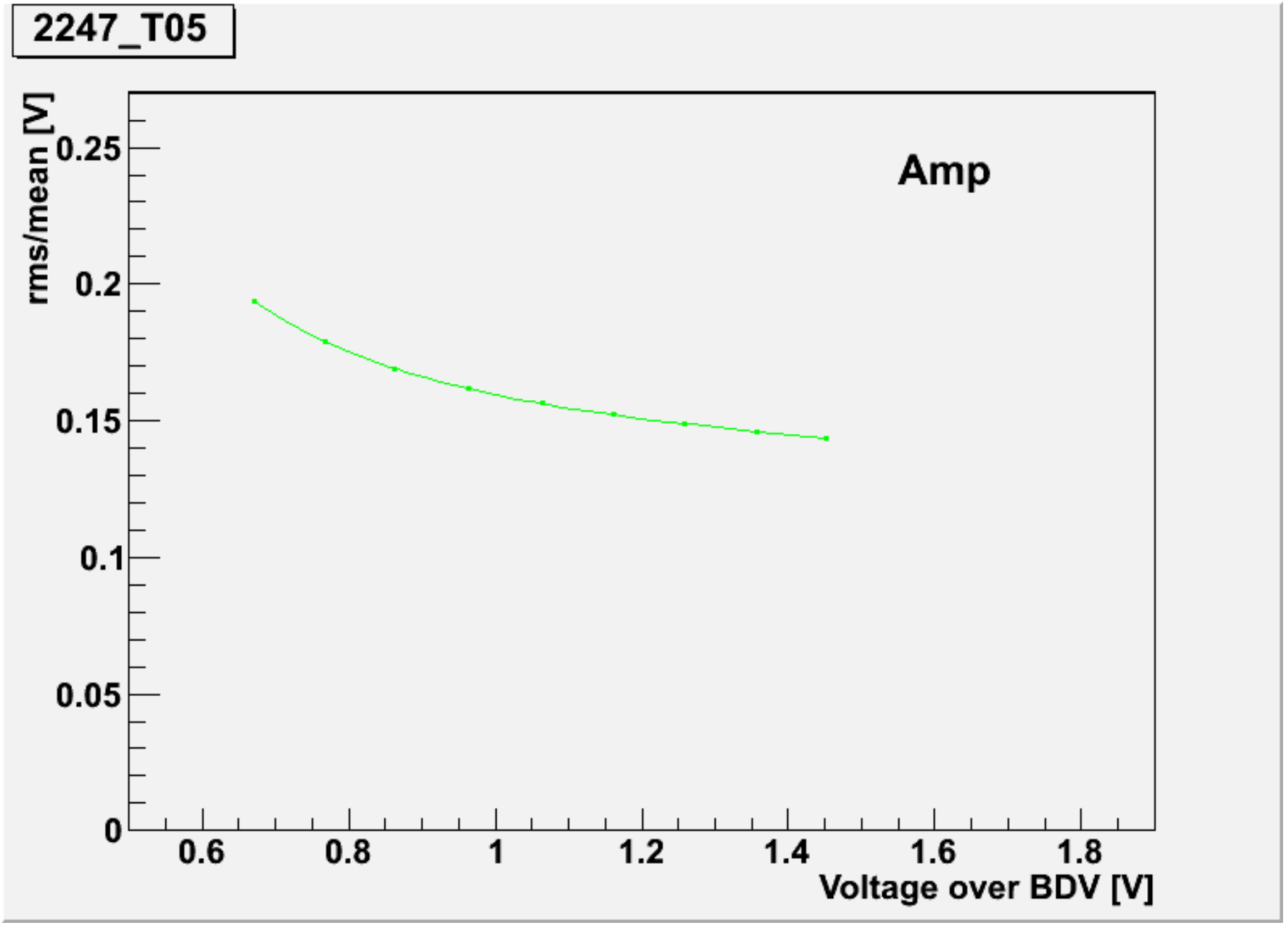

2083_T07
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
Amp
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

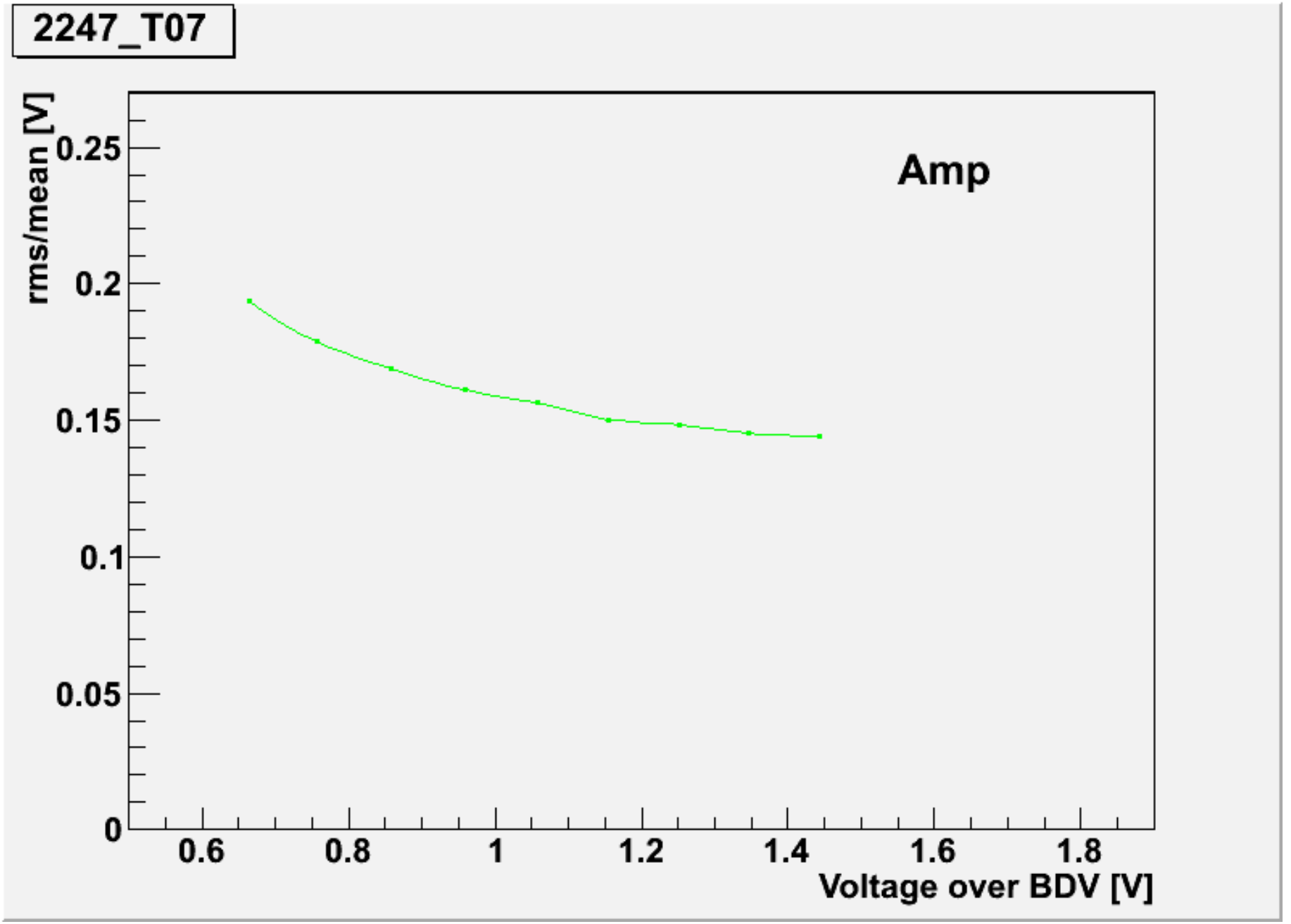

2083_T20
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
Amp
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

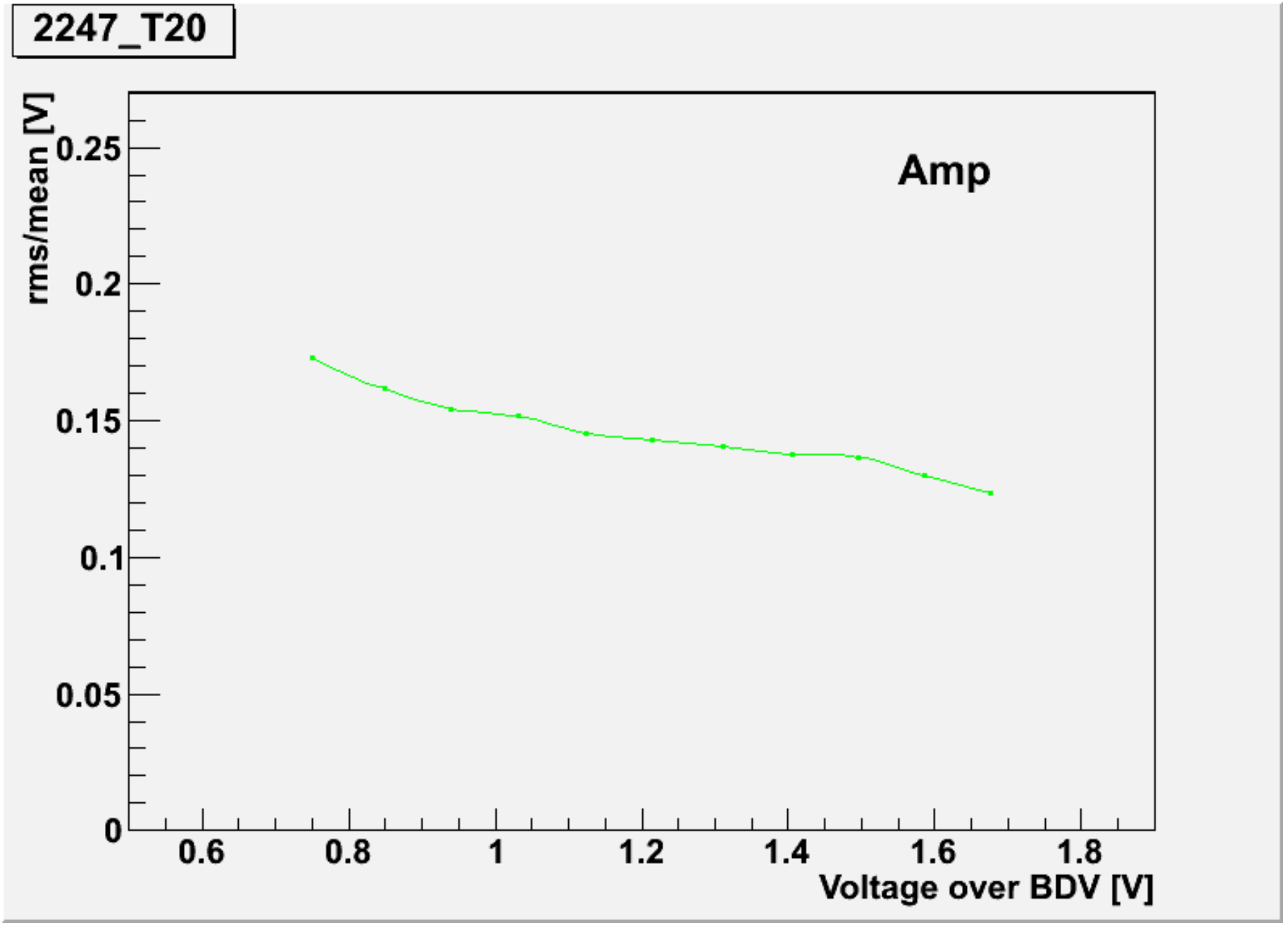

2098_T05
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]

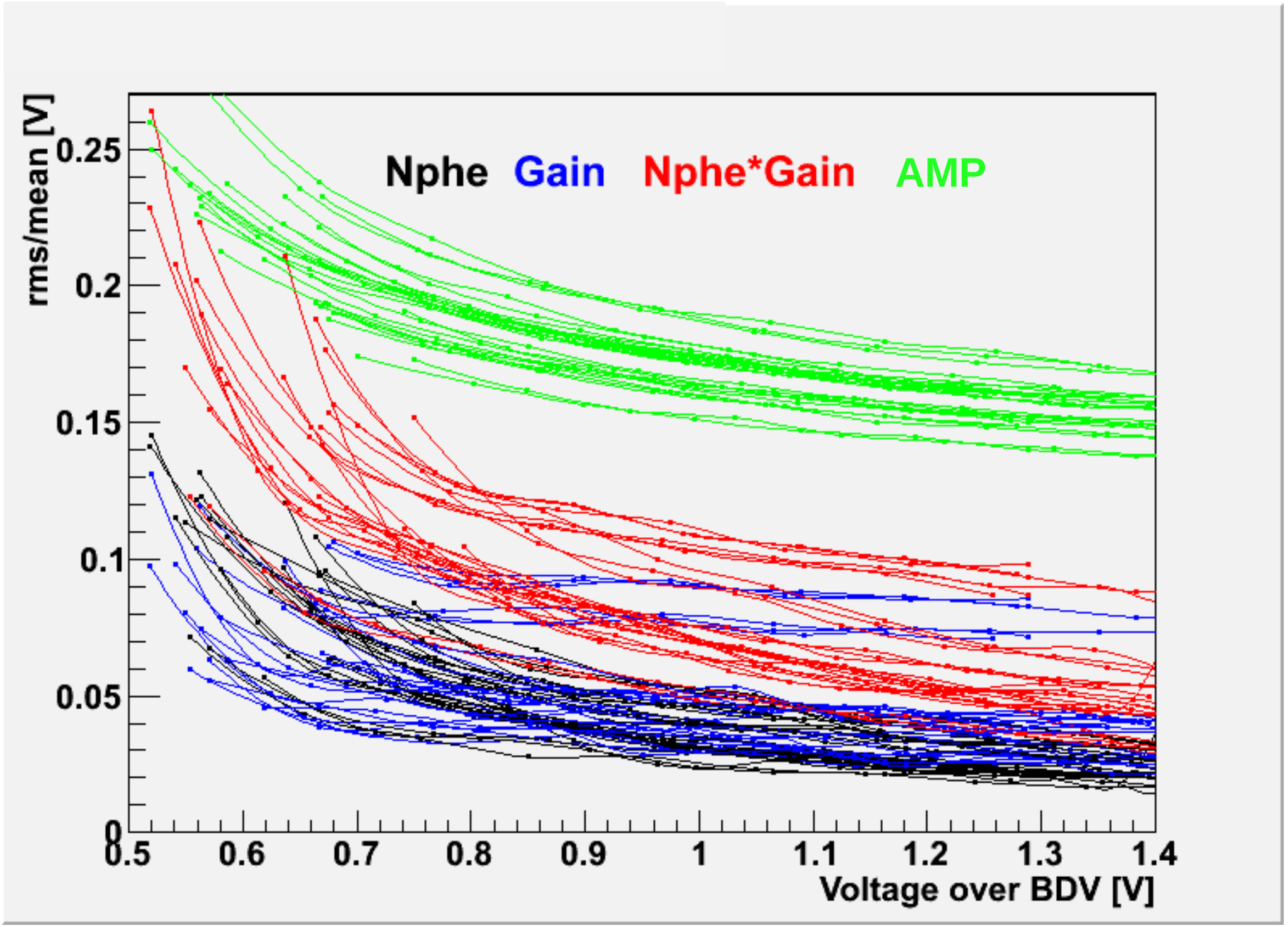

2198_T07
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]


2198_T20
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]


2247_T05
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
Amp
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]


2247_T07
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
Amp
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]


2247_T20
Amp
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
Voltage over BDV [V]


Nphe
Gain
Nphe*Gain
AMP
rms/mean [V]
0.25
0.2
0.15
0.1
0.05
0
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
Voltage over BDV [V]