About simulation of silicon strip detectors: from single charge to heavy nuclei

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Nov 2, 2006

Outline

- **Silicon strip detector simulation by using a detailed full Monte Carlo code**
  - **Cluster size distribution**
  - **Charge distribution**
- **ToT simulation by using the Spice code**
  - **The electronic schematic file has been provided by Robert J.**
- **GSI beam test operation**

References:

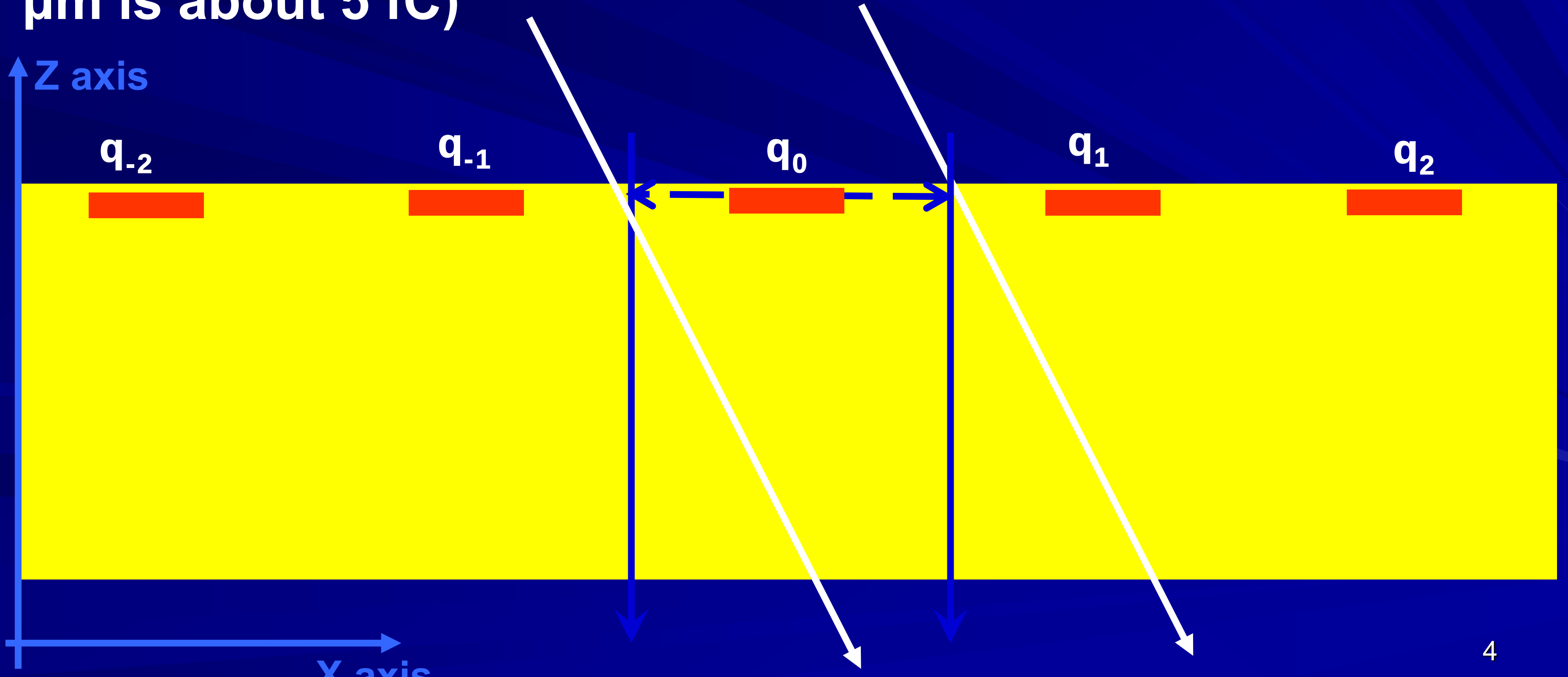
- ***M.N.Mazziotta et al., NIM A 533 (2004) 322***
- ***H. Bichsel, Rev. Mod. Phys. 60 (1988) 663***
- ***LAT-TD-00244***
- ***LAT-TD-01058***
- ***LAT-TD-01128***
- ***LAT-TD-03715***
- ***LAT-TD-04184***
- ***LAT-TD-08248***

Monte Carlo code for full simulation of silicon Strip detectors NIM A 533 (2004) 322

1. The ionization energy loss and the number of ionizing collisions per unit path length are evaluated from the differential cross section in Si (H. Bichsel, Rev. Mod. Phys. 60 (1988) 663)
2. The inelastic and elastic sattering angle is taken also into account
3. A complete calculation of the production of e–h pairs is done to generate the charge carriers produced by the absorption both of virtual (e.g. exchange photons of a charged) particle with the medium) and real photons (e.g. photons absorbed in the medium)
4. The δ-ray generation is also taken into account
5. Holes generated in a silicon detector will drift towards the p strips (grounded), electrons towards the n electrode (at positive voltage) under the action of the electric field. During their drift, electrons and holes are diffused by multiple collisions. Due to the motion of carriers, signals will be induced on the electrodes.
6. The current induced by a moving carrier on an electrode can be evaluated by applying the Shockley–Ramo theorem, and taking into account the drift velocity and the weighting field
7. The output voltage signals are finally evaluated by feeding the current signals into the electronic chain. The detector noise as well as the noise associated to the electronics, have been taken into account.

Cluster size analysis

To study the cluster sharing a sample has been simulated, crossing the detector across a strip with zero zenith angle (vertical tracks), 30° zenith and azimuth 0° and 30° zenith and azimuth 90° (i.e. tracks parallel to the strip direction). The threshold is set at 1.25 fC (the charge deposit in 400 μm is about 5 fC)



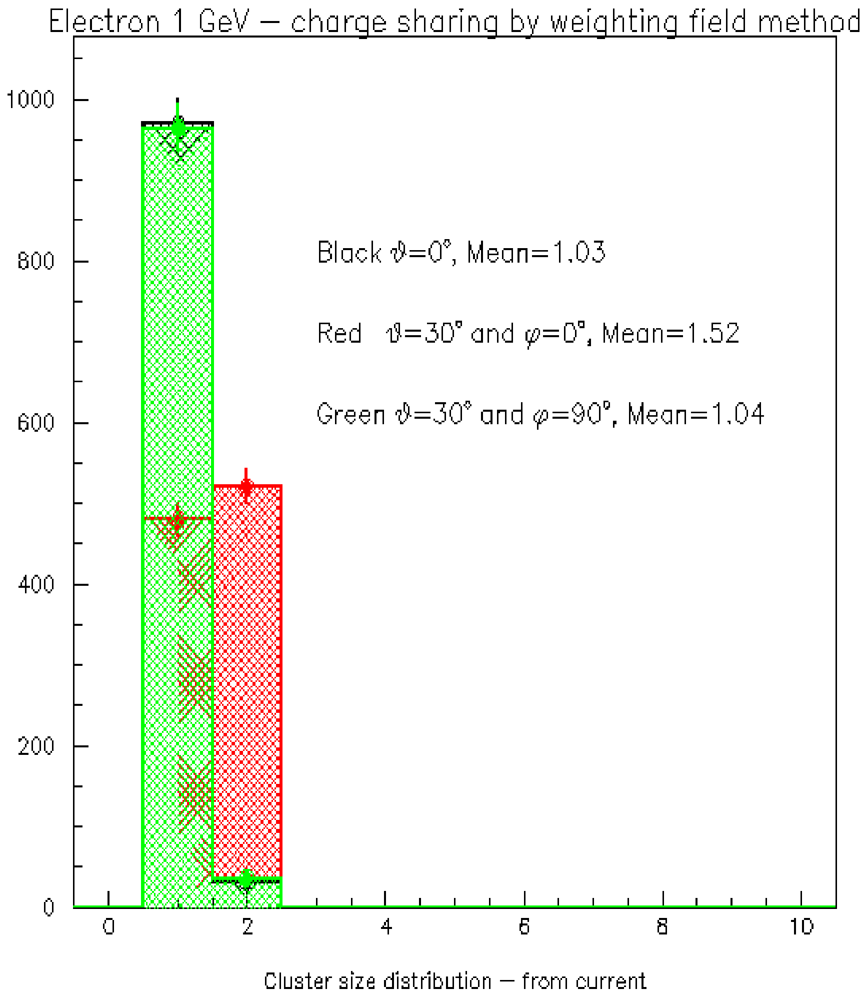
Charge collection method

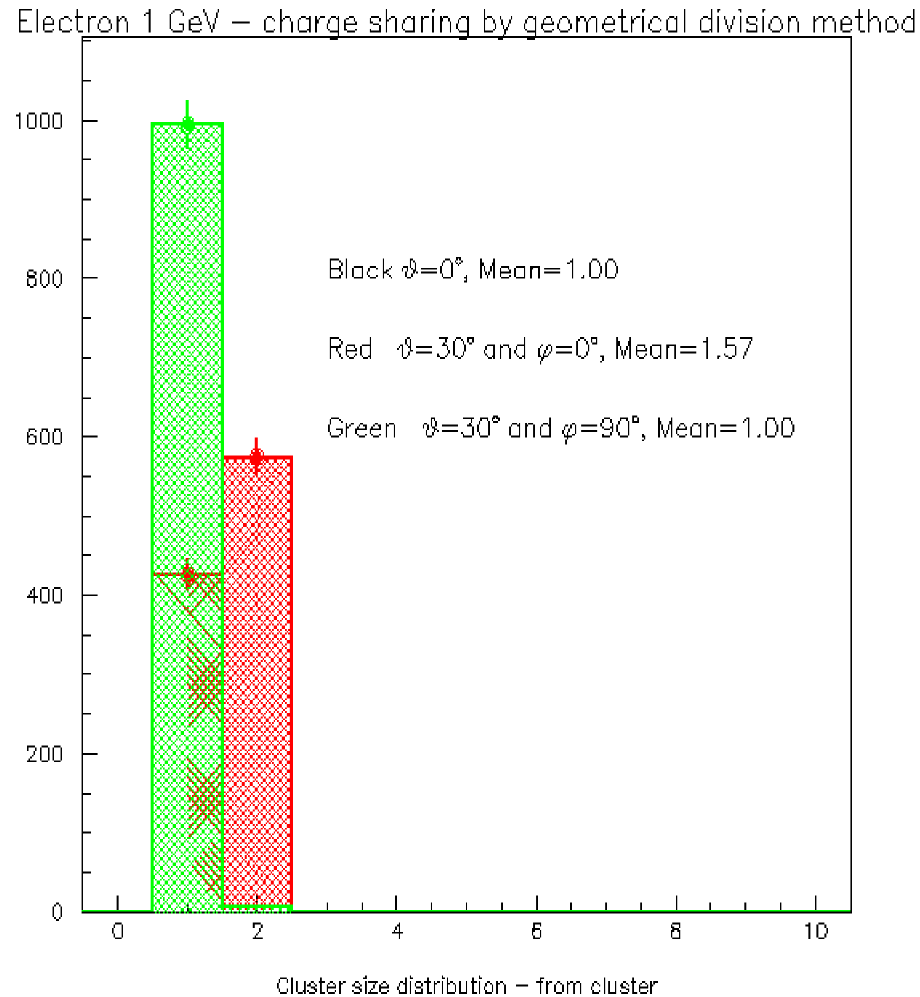
- Charge sharing by weighting field:
  - The charge q_k collected by the *k-th* strip is due to the integral of the current signal induced by the moving carriers on the readout electrodes.

$$i_k(t) = \sum_{carriers} -q\vec{v}(t)\cdot\vec{E}_k\left(\vec{r}(t)\right)$$

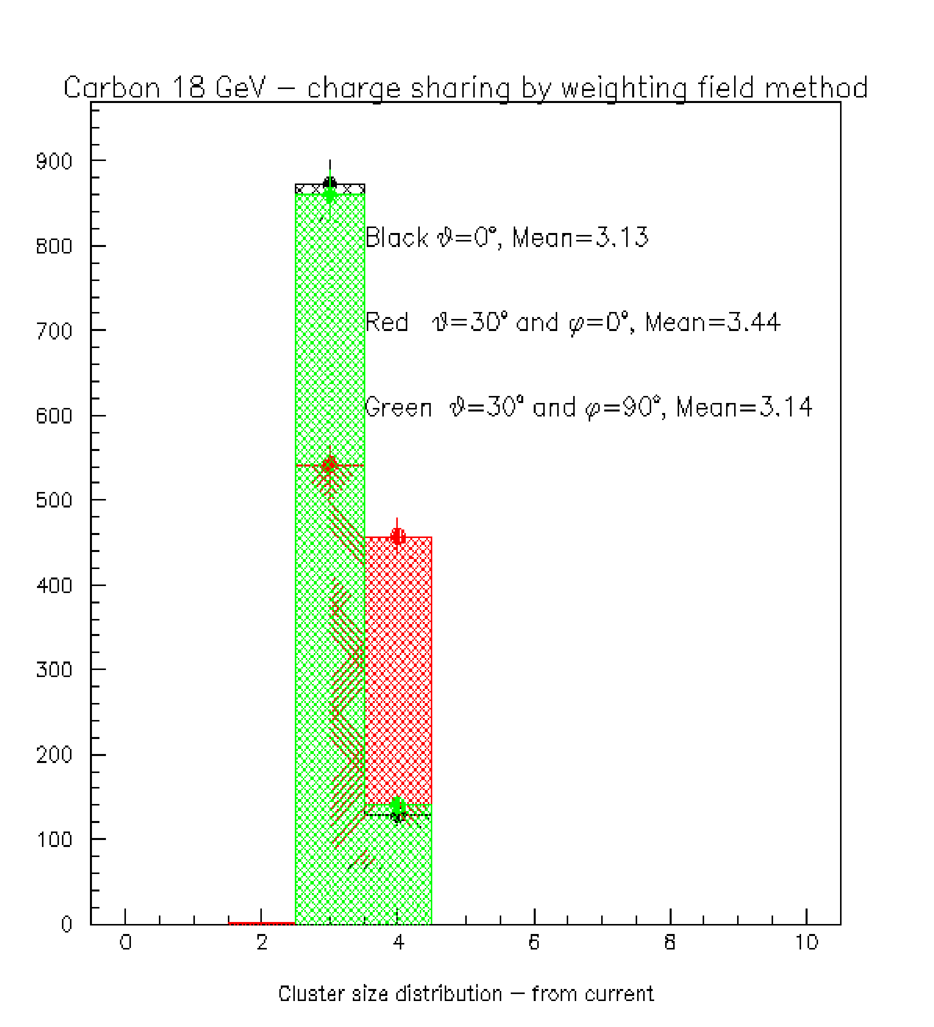
  - The weighting field E_k describes the geometrical coupling between the moving carrier and the *k-th* electrode (up to the step 6 in the slide 3).
- Geometrical division method
  - The charge q_k collected by the *k-th* strip is due to the sum of all carriers produced in the strip volume (up to the step 4 in the slide 3).

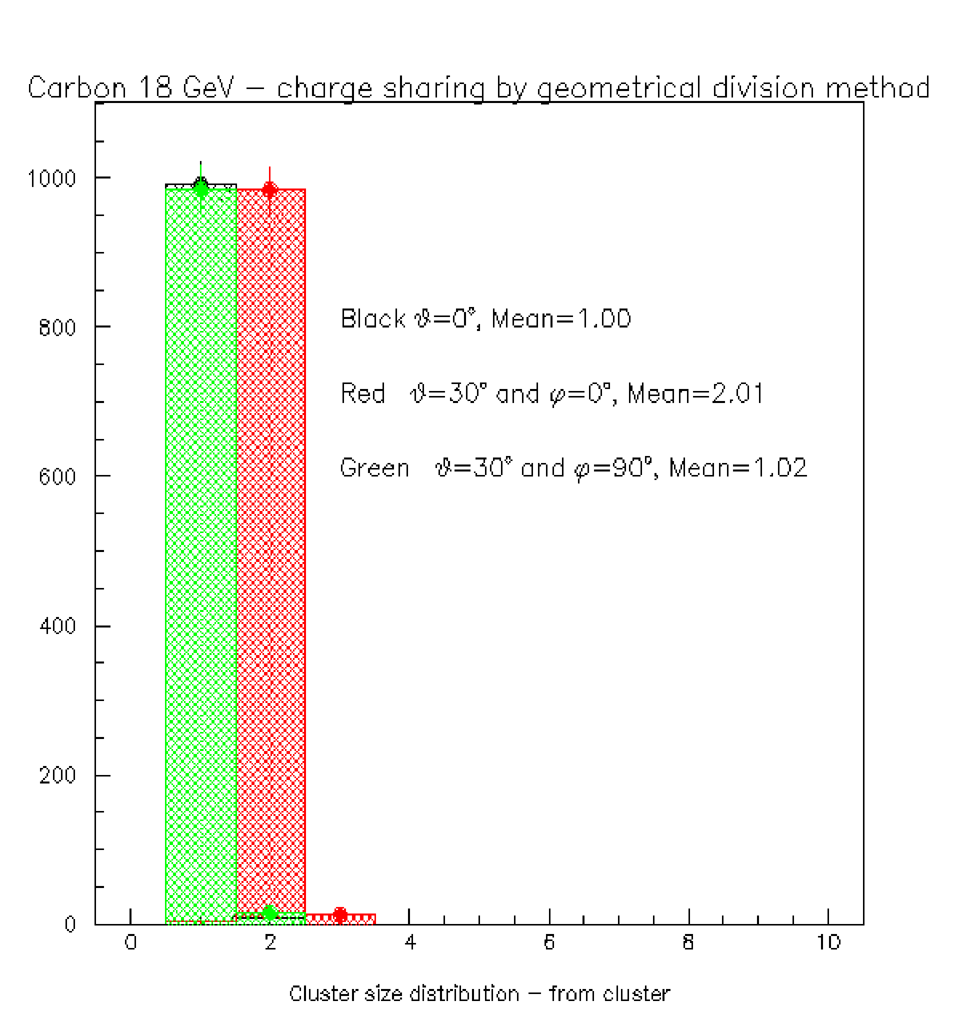
This MC: Electron 1 GeV



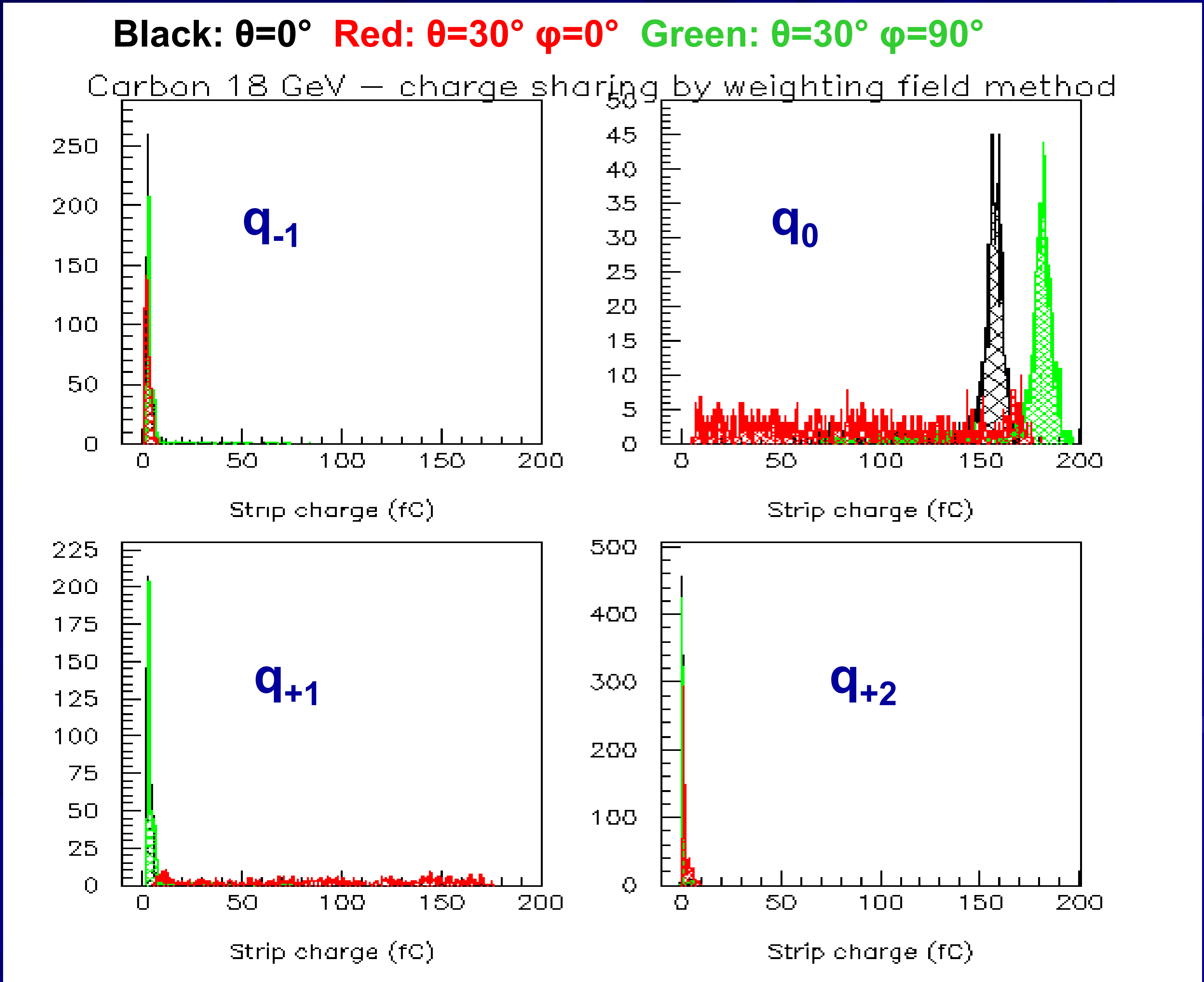


This MC: Carbon 18 GeV kinetic energy

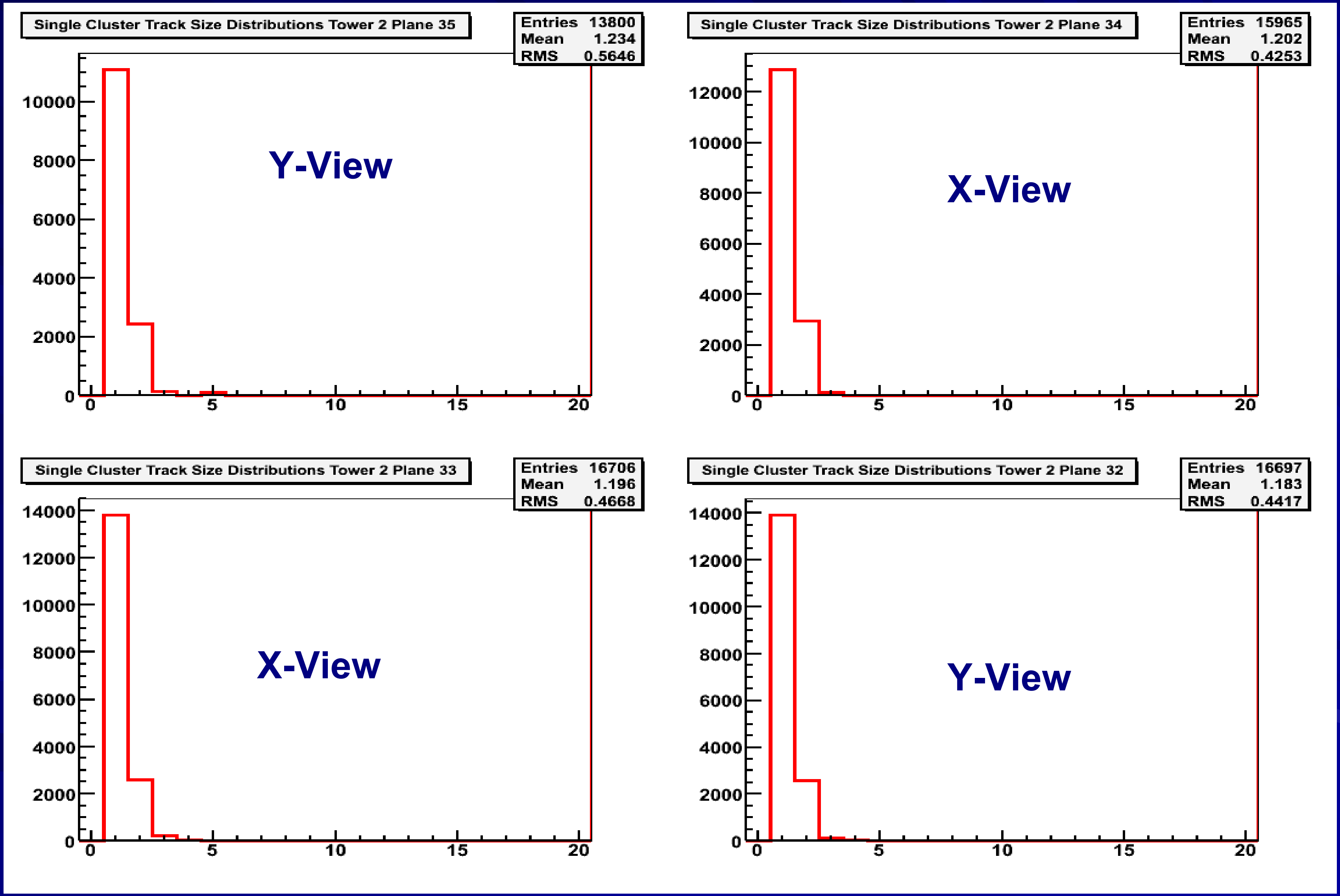




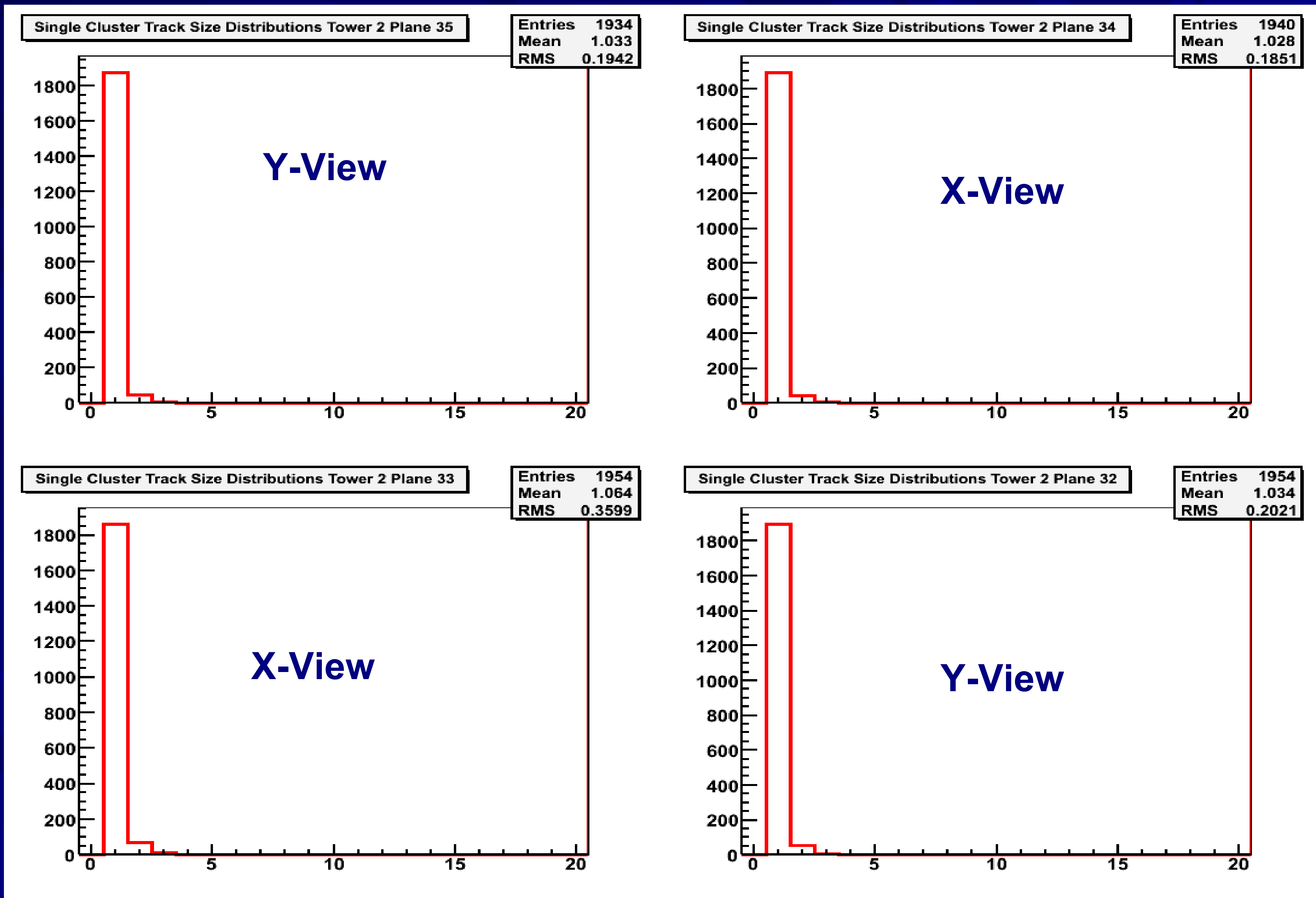
This MC: Carbon 18 GeV kinetic energy



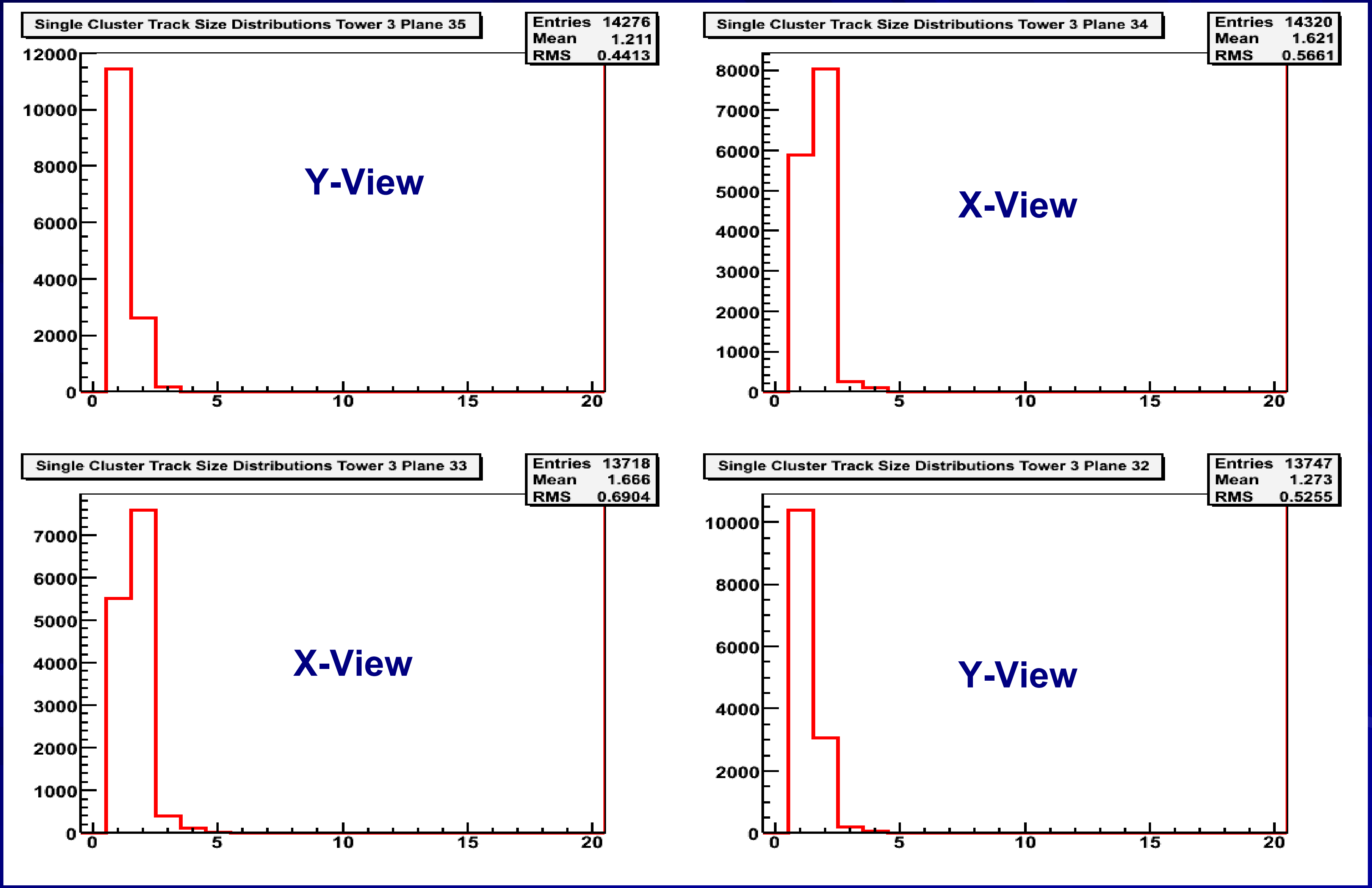
BT data: run 1460 Ele 5 GeV 0°



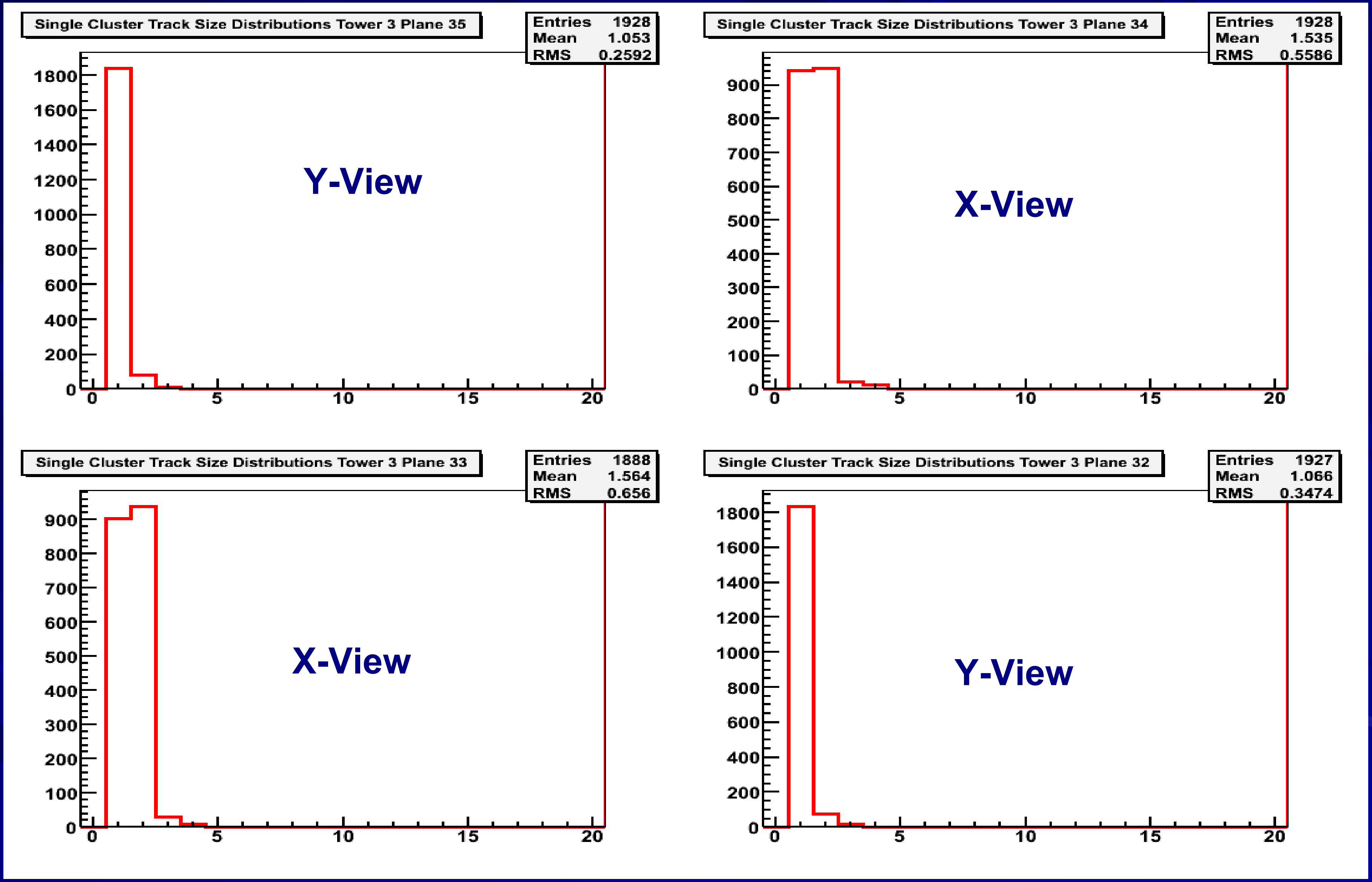
BT MC: run 122 Ele 5 GeV 0°



BT data: run 1493 Ele 5 GeV 30°

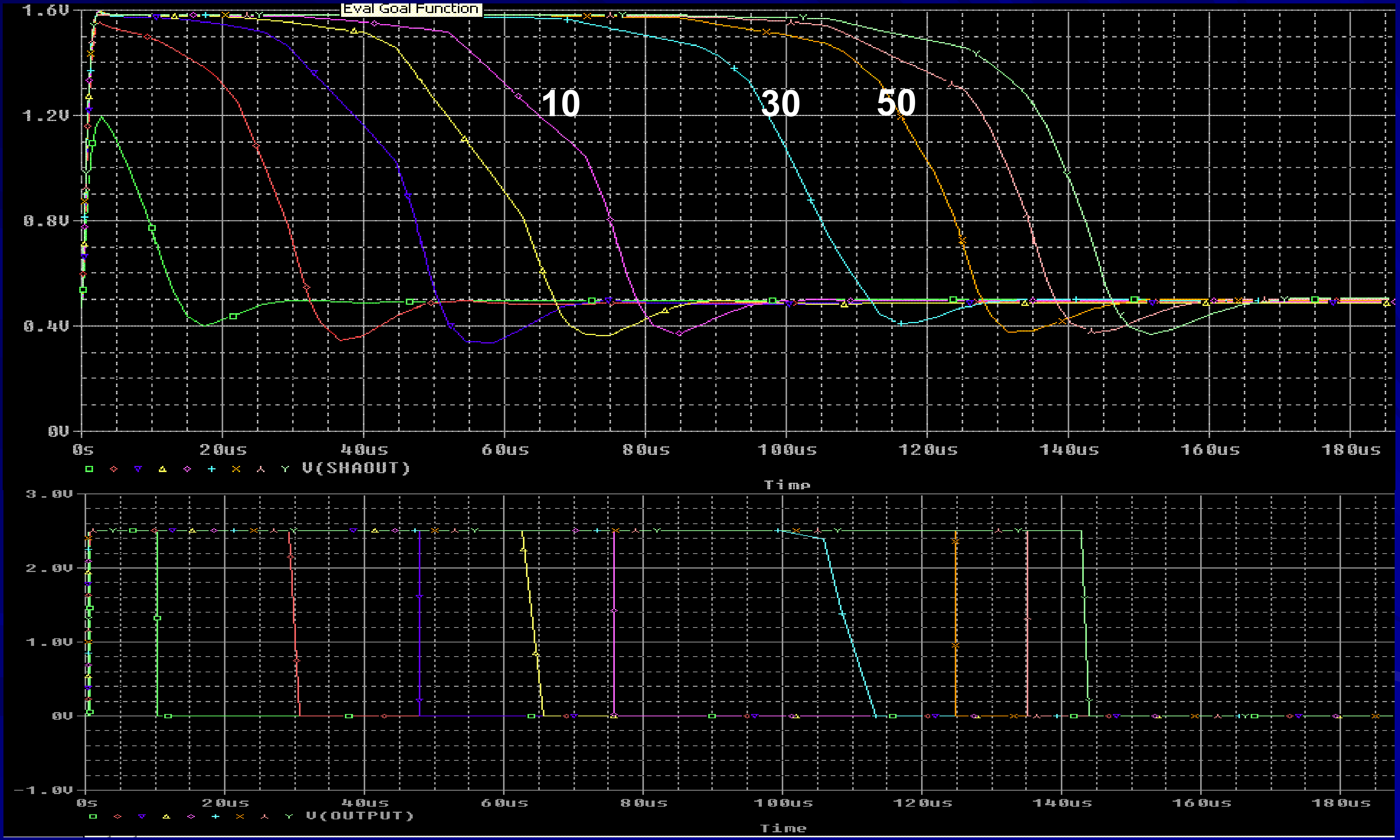


BT MC: run 179 Ele 10 GeV 30°

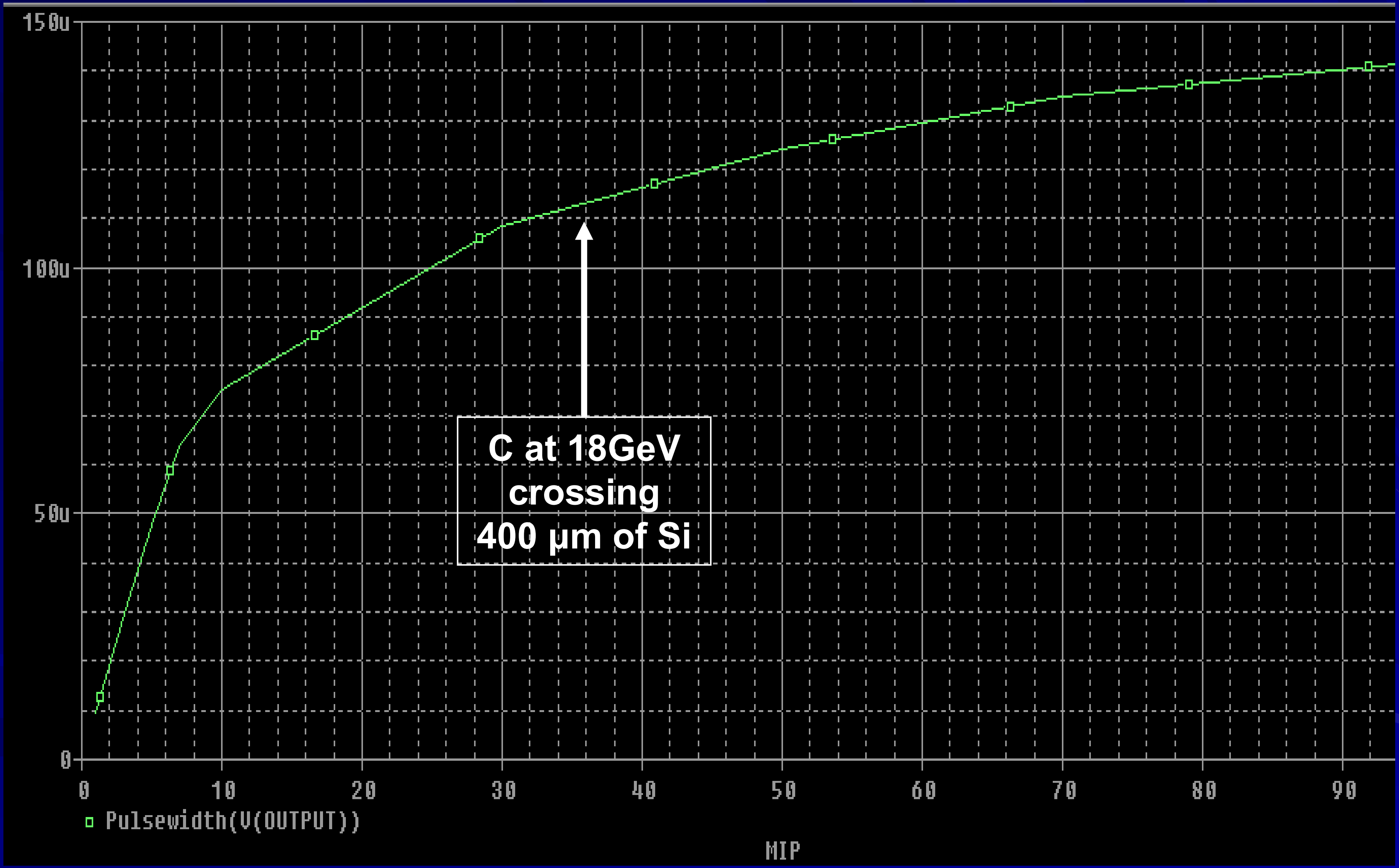


TKR Electronic: Spice simulation

Input charge: 1, 3, 5, 7, 10, 30, 50, 70 and 100 MIPs (1 MIP=5 fC)



ToT (Spice simulation)



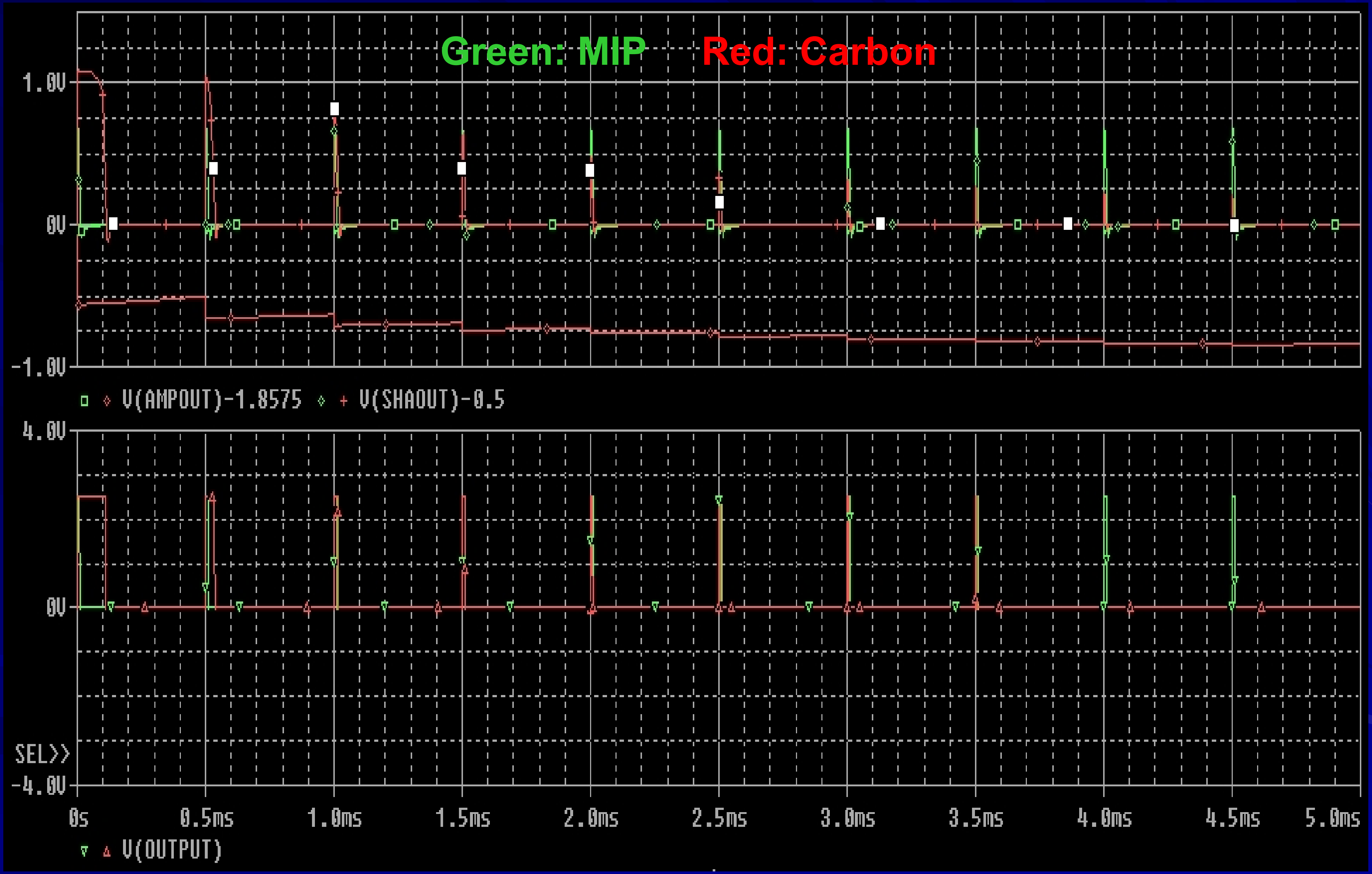
ToT by 18 GeV Carbon

- 0° angle run:
  - Cluster size is about 3
  - The charge deposit in the hit strip is about 170 fC
  - ToT is about 115 μs
- 30° angle run:
  - Cluster size is about 3.5
  - The charge deposit is about 200 fC
  - The charge is shared among the strips according to the azimuth angle:
  - Worst Case: the charge is collected by a single strip for Φ=90° (track length parallel to the strips)
  - The maximum ToT is about 125 μs
- Only 8 bits are reserved for the ToT value
  - According to the current setting the ToT full range is 50 μs, i.e. 4-5 MIPs
  - The ToT value could be saturated starting from He nuclei
  - Is it possible to change the ToT full range? Yes, it is (see last slide)
- Is there any other setting to do?

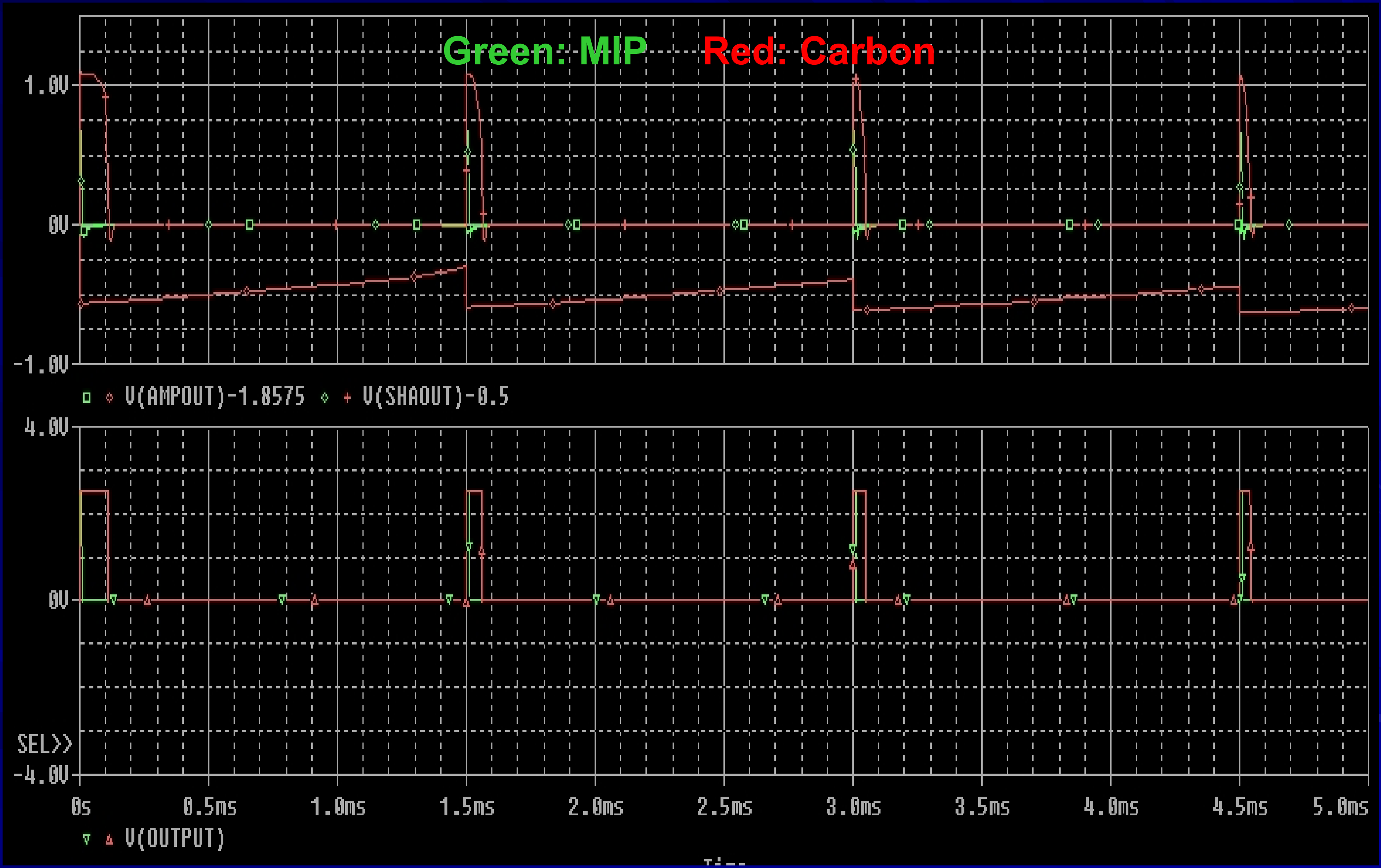
GSI operation rate

- To evaluate the maximum operation rate, a current pulse train has been simulated with Spice code
- The preamplifier recovery time for 18 GeV Carbon is about 2 ms (see next slides)

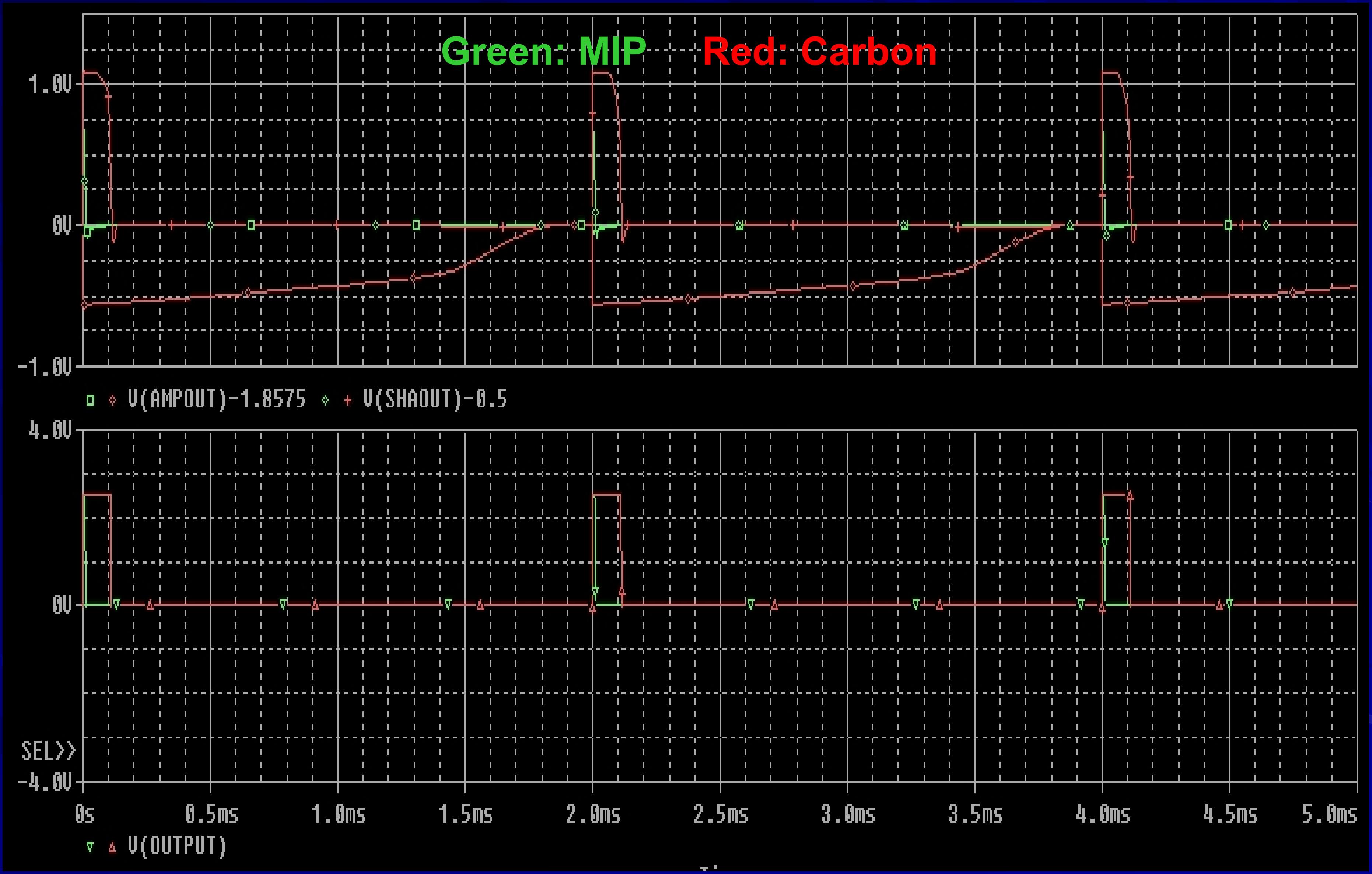
Pulse train with 0.5 ms delta time



Pulse train with 1.5 ms delta time



Pulse train with 2.0 ms delta time



GSI operation

- Up to 30°, with 2 ms of electronic recovery time and an average cluster size of 4 strips, the maximum allowed rate should be:
  - Pile-up/plane ~ 10% → rate ~ 50 Hz/mm^2
  - Pile-up/plane ~ 1% → rate ~ 5 Hz/mm^2
  - Pile-up/plane ~ 0.1% → rate ~ 0.5 Hz/mm^2
  - Keep in mind that we have 36 planes in the TKR
- Robert's suggestion:
  - *"The only way I can think of to extend the TOT counter range is to slow down the system clock. At 20 MHz it goes up to 50us, so if you run at 5 MHz instead, then it will go up to 200us (with less precision, obviously). You would also have to be careful to adjust the trigger timing to make sure that you capture data properly. Don't just slow down the clock and expect everything else to work exactly the same."*
- The current simulation code for the TKR needs to be reviewed for heavy nuclei, maybe not only!