Search for the neutrons from p + C $\longrightarrow$ n + X process

- Signature:

  a) recoil proton momentum is low ($\approx$2 GeV), it might be within or way off from TPC

  b) $P_n \approx P_{beam}$ (E_n measured in HCAL),

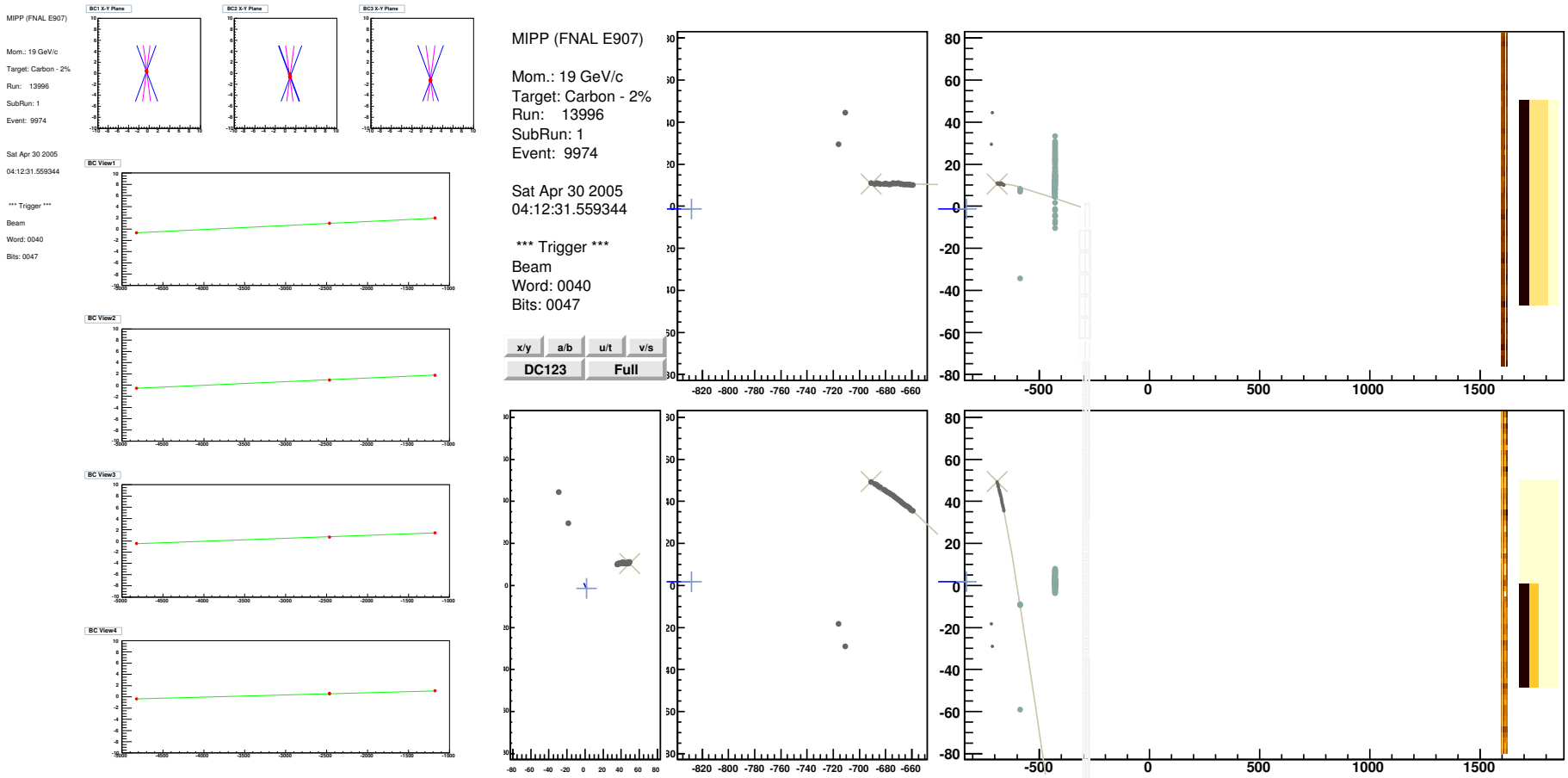
  c) no high-momentum tracks downstream of target (at least within reasonable time frame)

- Beam - protons, 20 GeV/c
- Target: thin carbon 1% and 2%
- Trigger: proton beam and/or proton interactions
- Event selection/rejection (detailed list on next slide)

Event selection/rejection requirements	Target-in	Target-out
run ranges	13996 - 14046	13998 - 14035
total number of entries	413498	109980
number of tracks per event $\leq$ 10	339643	94779
single beam track per event	139644	38400
beam track within target X size	135723	37121
beam track within target Y size	132298	36055
beam track timing: -10ns $<$ t $<$ 50ns	124991	33798
no charged tracks within EMCAL area	13878	1887
number of showers in EMCAL $\leq$1	11115	1441
number of proton beam and/or proton interaction triggers	4557	515
number of proton beam triggers (sample A)	133	34
number of neutron candidate events in sample A	12$\longrightarrow$8 (CAL$\geq$10 GeV)	7$\longrightarrow$5
number of proton interaction triggers (sample B)	4472	485
sample B: vertex within target sizes	402	69
sample B: beam track match with recoil track	321	65
sample B: proper number of TPC hits on recoil track	105	17
sample B: proper timing	65	7
sample B: proper charge q$>$0	64	6
sample B: number of neutron candidate events	25$\longrightarrow$9 (CAL$\geq$10 GeV)	3$\longrightarrow$1
total number of neutron candidate events in both samples	37$\longrightarrow$17 (CAL$\geq$10 GeV)	10$\longrightarrow$6

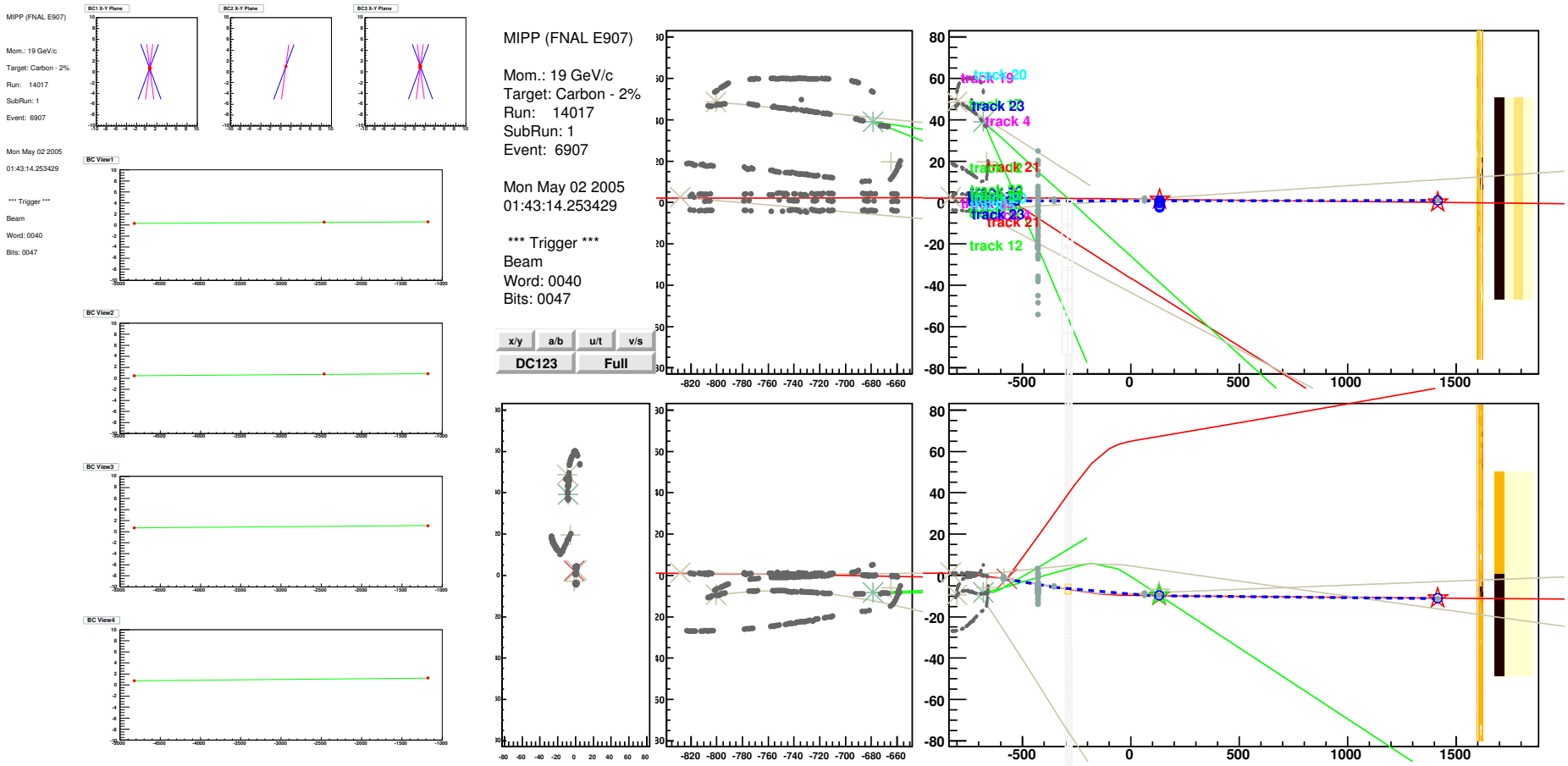
Table 1: List of event selection or rejection requirements with numbers of survived events for target-in and target-out cases.

sample A: run 13996 event 9974



An example of event from sample A. Single beam track - green line on left plot and blue short line on middle indicates where it enter into TPC. There are no any outgoing tracks. EMCAL=0, HCAL=12.1 GeV. RICH detector has no any hits.

sample A: run 14017 event 6907

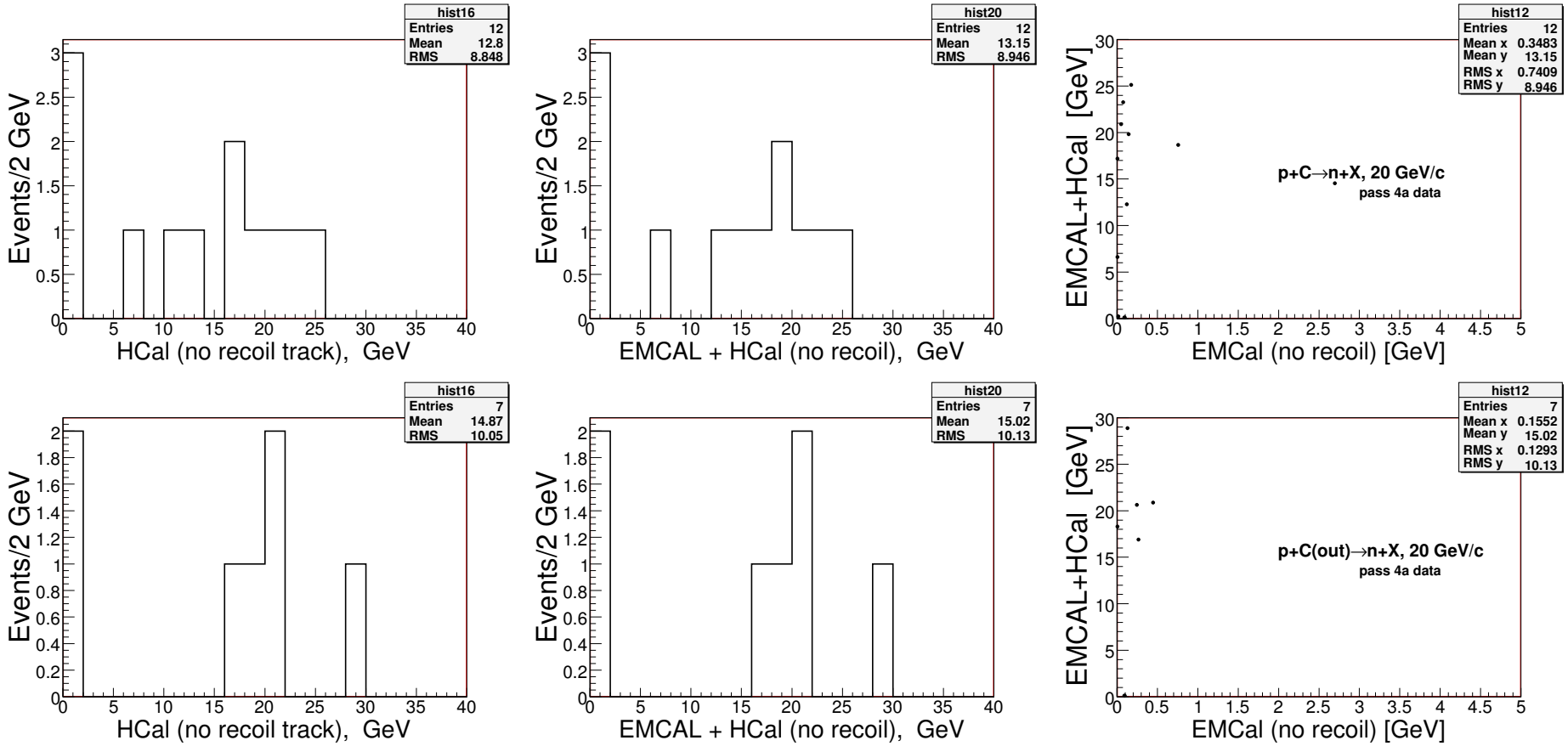


Another example of event from sample A. TPC track close to beam, red colored: Trk 3 Q=1 Time=6ns TPC hits=0. Fake candidate due to of track is failed to reco or reconstructed not properly. EMCAL=2.69 GeV, HCAL=11.7 GeV. RICH detector has 3 scattered hits. Overall, sample A has 3 such fake candidates.

University of Michigan

MIPP

sample A, Target-in vs Target-out: HCAL and EMCAL+HCAL



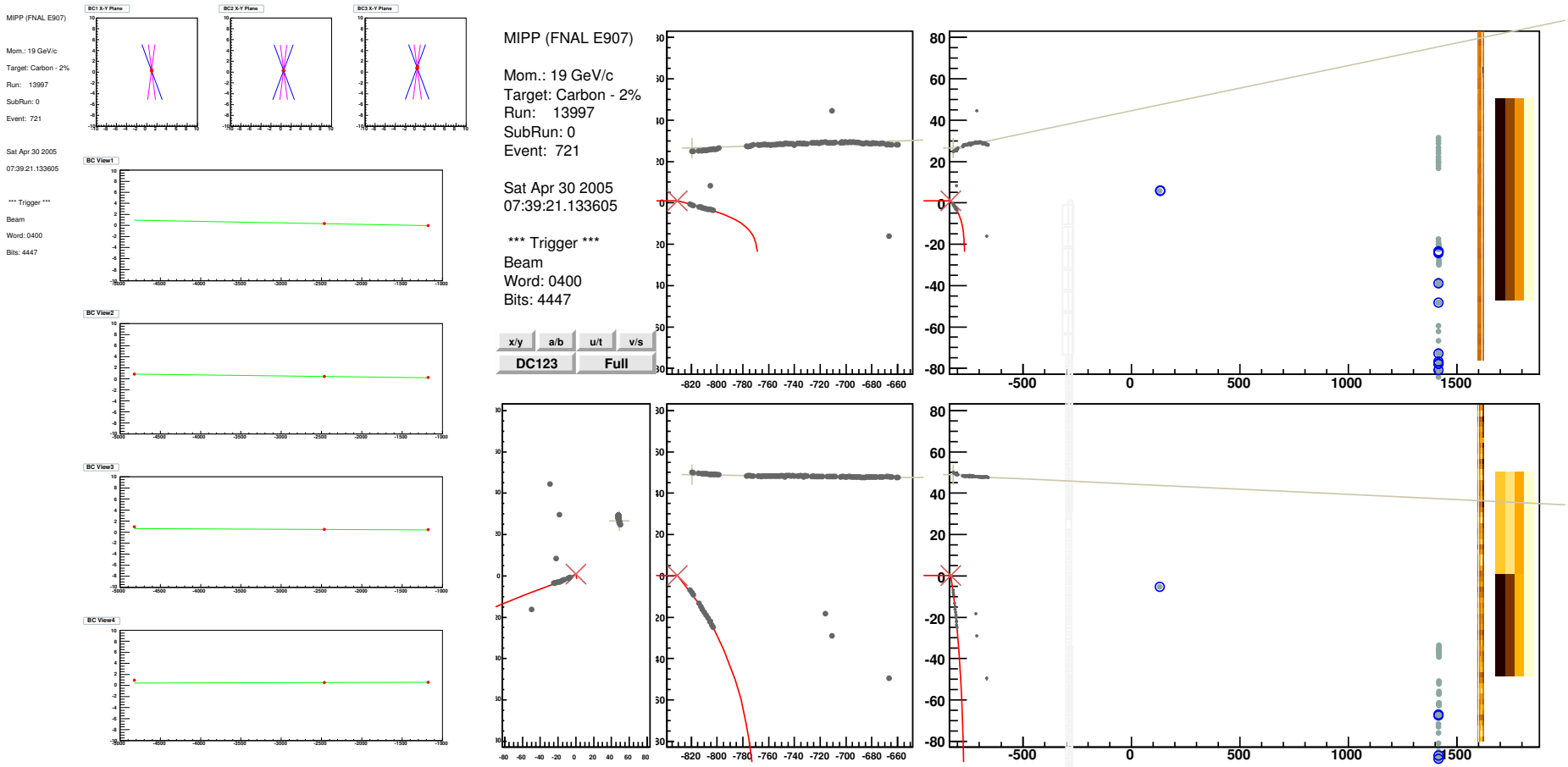
Sample A: top plots - target-in data, bottom - target-out data. On left - HCAL distribution, on middle - EMCAL+HCAL distribution, on right - EMCAL+HCAL vs EMCAL scatter plot.

sample A: summary

	Target-in	Target-out
number of events with proton beam triggers were used	7116	3051
number of incident beam protons = above x prescale	718716	308151
number of events with proton beam triggers were selected	133	34
number of neutron candidates	12	7
number of candidates with CAL$>$ 10 GeV	8	5
number of neutron candidates applying prescale factor	808	505
neutrons per single incident proton (x 10^{-3})	1.1$\pm$0.4	1.6$\pm$0.7

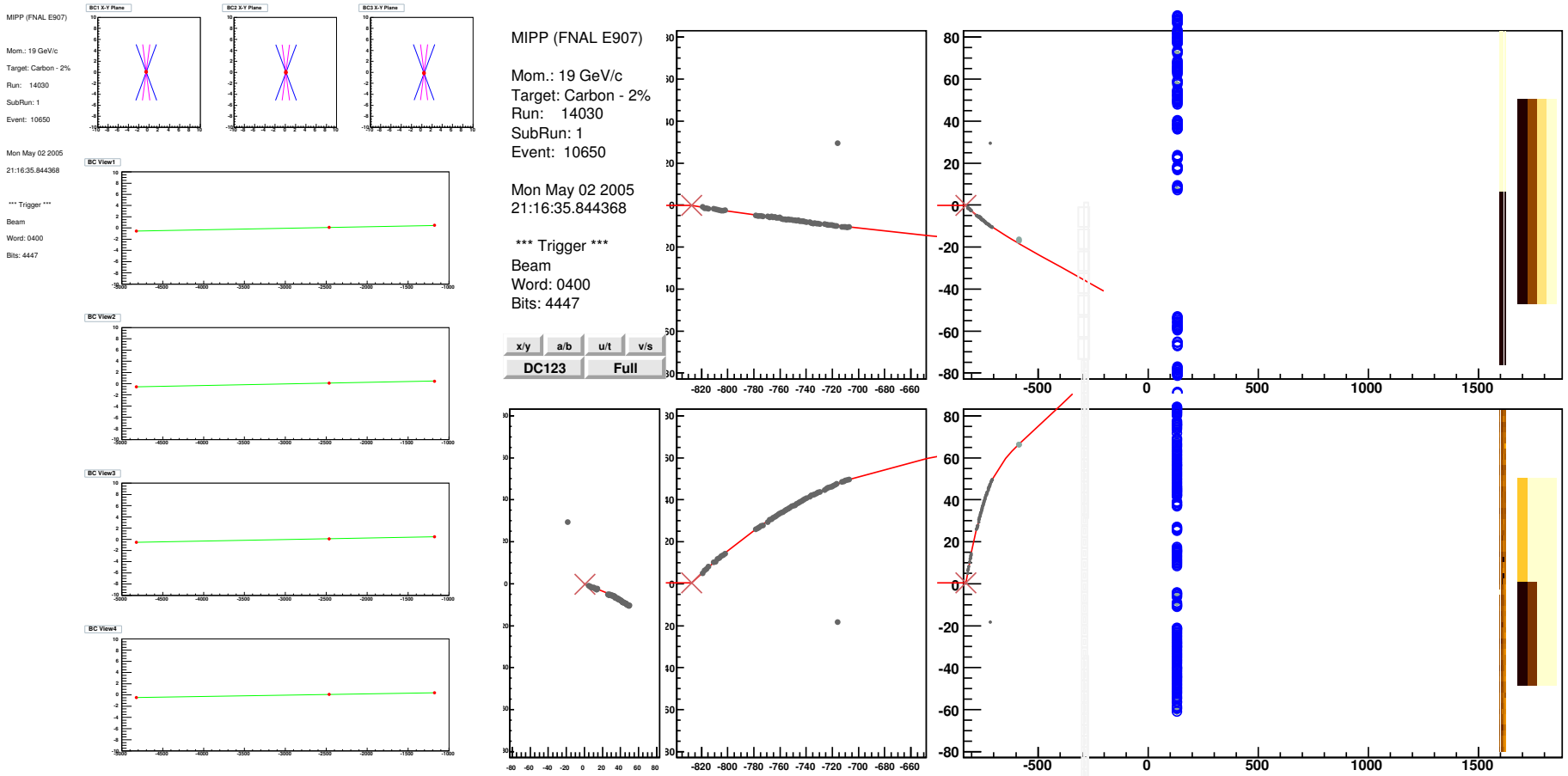
Table 2: Summary of the neutron candidate events in Sample A. The prescale estimate for the proton beam trigger is 1:101 (one proton beam trigger for 101 incident protons).

sample B: run 13997 event 721



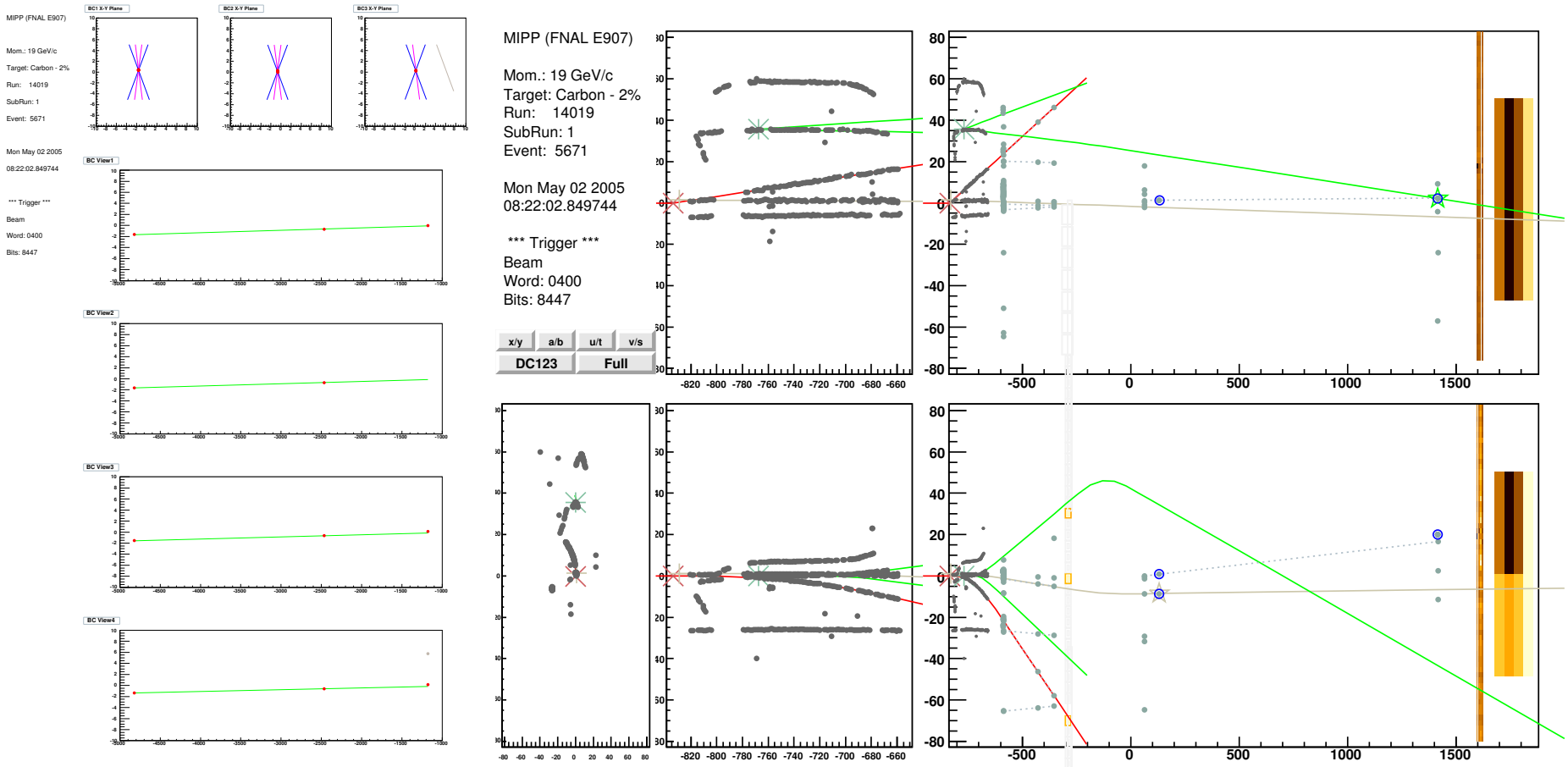
An example of event from sample B. Recoil track parameters: Ptot=0.29 GeV/c, nTPChits=21, Q=1. EMCAL=0, HCAL=11.4 GeV. RICH detector has no any hits.

sample B: run 14030 event 10650



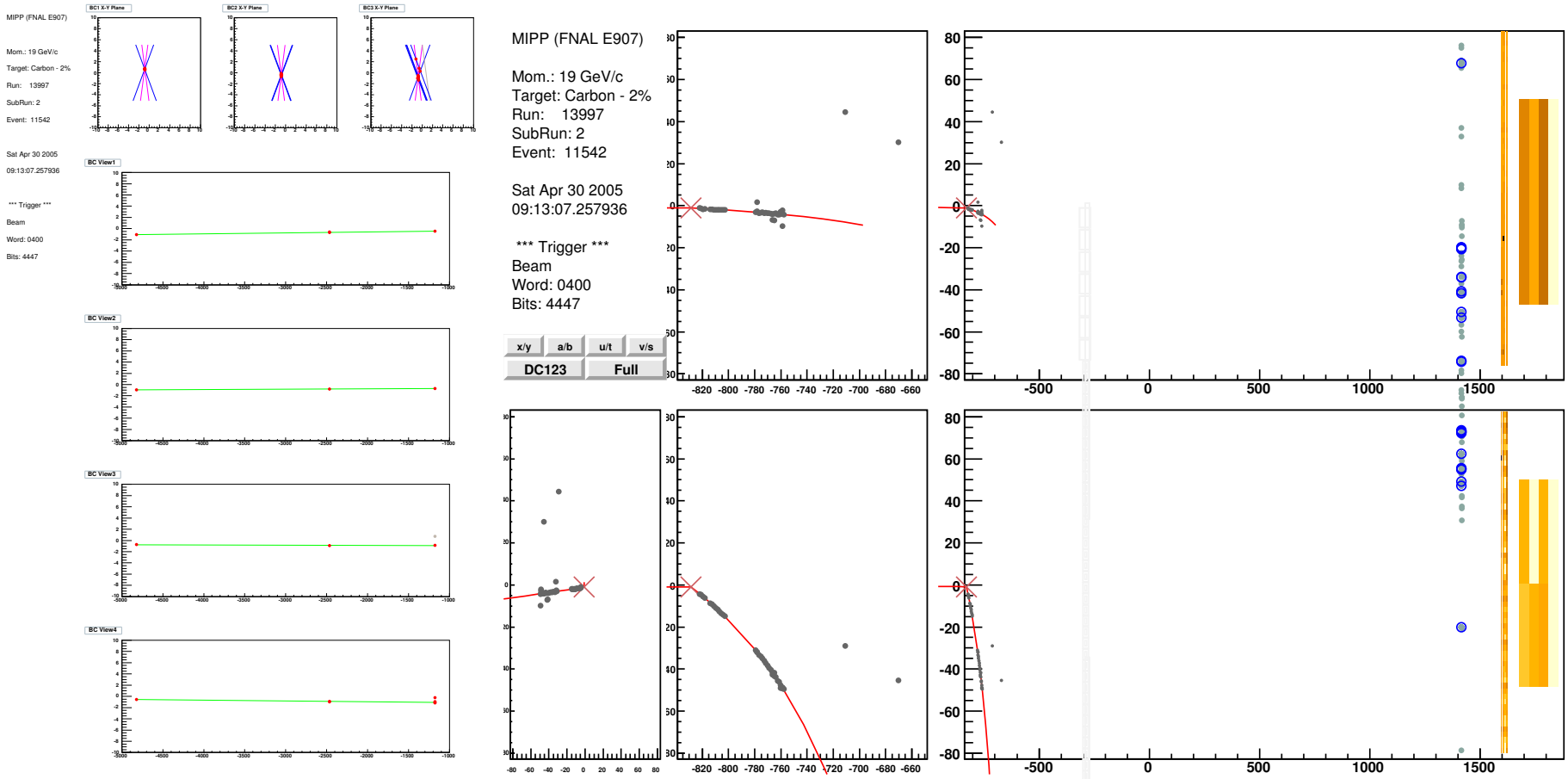
Another example of event from sample B. Recoil track parameters: Ptot=0.65 GeV/c, nTPChits=64, Q=1. EMCAL=1.39 GeV, HCAL=18.1 GeV. RICH detector has 4 randomly scattered hits.

sample B: run 14019 event 5671



Dirtiest example of event from sample B. Recoil track parameters: Ptot=1.9GeV/c, nTPChits=88, Q=1. EMCAL=0.25 GeV, HCAL=16.0 GeV. The gray track pointing to HCAL: Trk2 Q=1 Time=451ns. RICH detector has no hits.

sample B: run 13997 event 11542

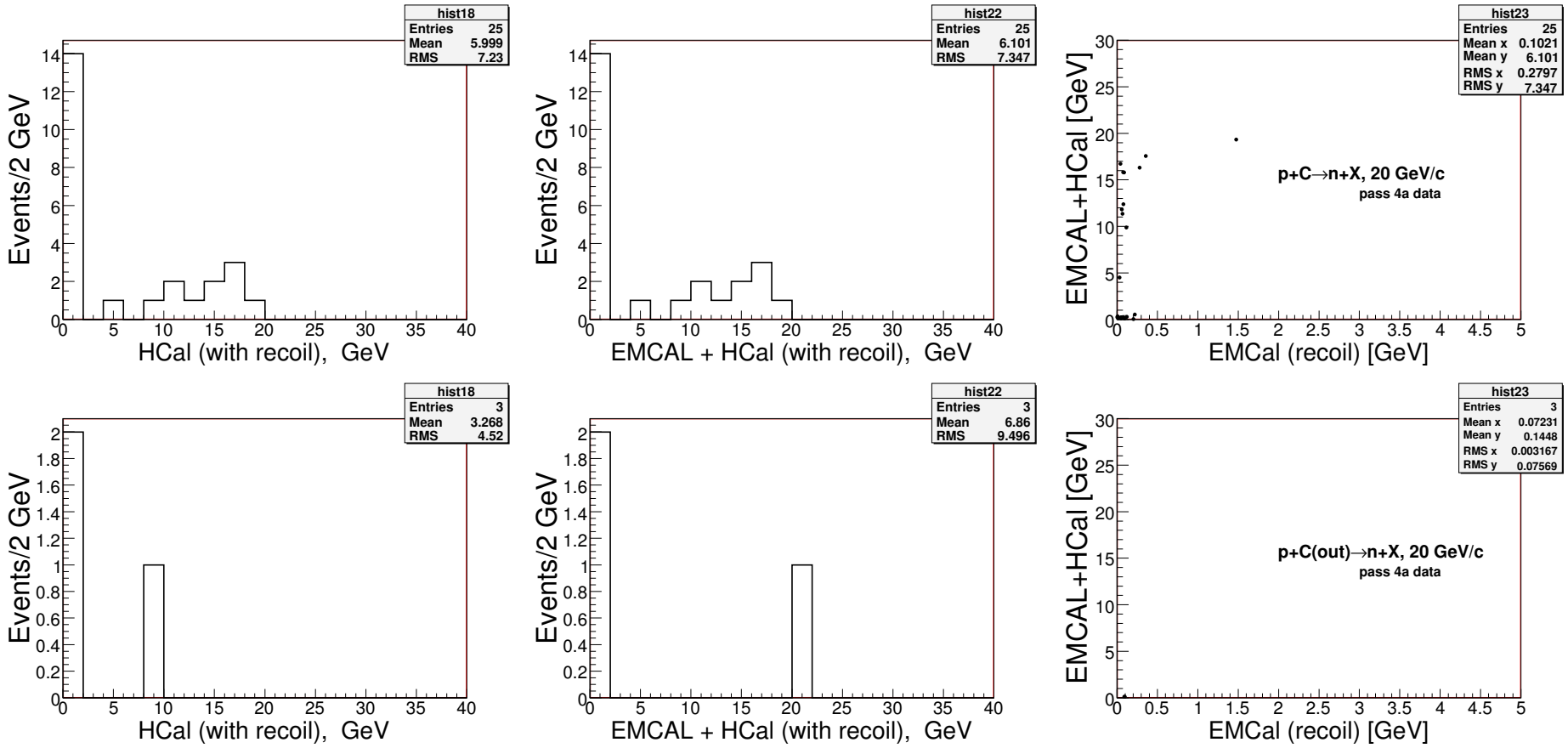


An example for HCAL ≈ 0. Recoil track parameters: Ptot=0.35 GeV/c, nTPChits=44, Q=1. EMCAL=0 GeV, HCAL=0 GeV, Shower position: X=57.2 cm (off from HCAL) Y=-42.9 cm. RICH detector has no hits.

University of Michigan

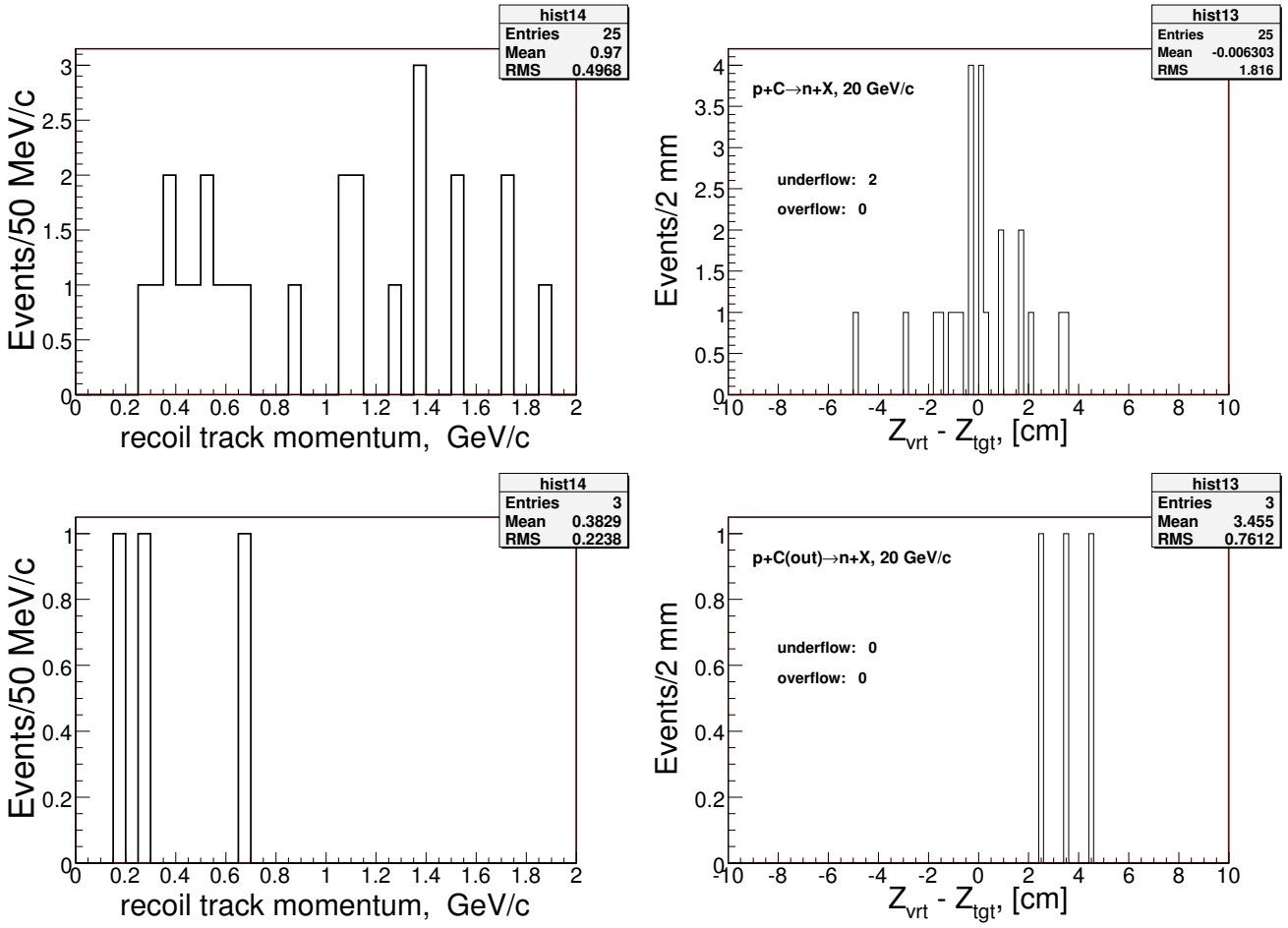
MIPP

sample B, Target-in vs Target-out: HCAL and EMCAL+HCAL



Sample B: top plots - target-in data, bottom - target-out data. On left - HCAL distribution, on middle - EMCAL+HCAL distribution, on right - EMCAL+HCAL vs EMCAL scatter plot. There are 3 entries on Target-out total vs EMCAL plot: 2 out of 3 are with HCAL≈0 and EMCAL=0.07 GeV contributions (small points on left bottom corner). Third event with EMCAL=10.6 GeV (out of histo).

sample B, Target-in vs Target-out: P_{tot} and Z_{vtx}



Sample B: top plots - target-in data, bottom - target-out data. On left - p_{tot} of the recoil track, on right - Z_{vtx} distribution, where the zero indicates the Carbon target position (0.5 cm thick). Both underflow events in Target-in sample are with HCAL $\approx$ 0 contributions. Data on Target-out Z_{vtx} distributions are consistent with interactions on the trigger scintillator.

sample B: summary

	Target-in	Target-out
number of incident beam protons (from sample A summary)	718716	308151
number of proton interaction events	4472	485
number of neutron candidates	25	3
number of neutron candidates with CAL$>$ 10 GeV	9	1
neutrons per single incident proton (x 10^{-5})	1.25$\pm$0.4	0.3$\pm$0.3

Table 3: Summary of the neutron candidates in Sample B. Since interactions on Target-out case take place on Carbon scintillator, then both Target-in and Target-out data can be combined. The continuous distribution beyond Carbons can give us an estimate on the background level.