How to Identify Inclusive Neutrons?

The forward neutron can detected by HCAL

$E_{HCAL} > E_{min}$, where E_{min} is about 1/3 of P_{beam}

E_{HCAL} - the HCAL energy assuming no any charged tracks pointing into HCAL.

If some charged tracks pointing to HCAL, then:

E_{HCAL}-$E_{trk} > E_{min}$, where E_{trk} is the sum track energies within HCAL

With above requirements I still have leakage of the beam straight through tracks.

They mainly comes from the single track vertices (N=1). To reduce it I applied following cut:

$P_{trk} < P_{beam}$-E_{min}, where P_{trk} is momentum of i-track in event, E_{min} is same as above. This cut is equivalent to the energy balance requirement.

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How to Select Inclusive Protons?

Proton track identified by RICH

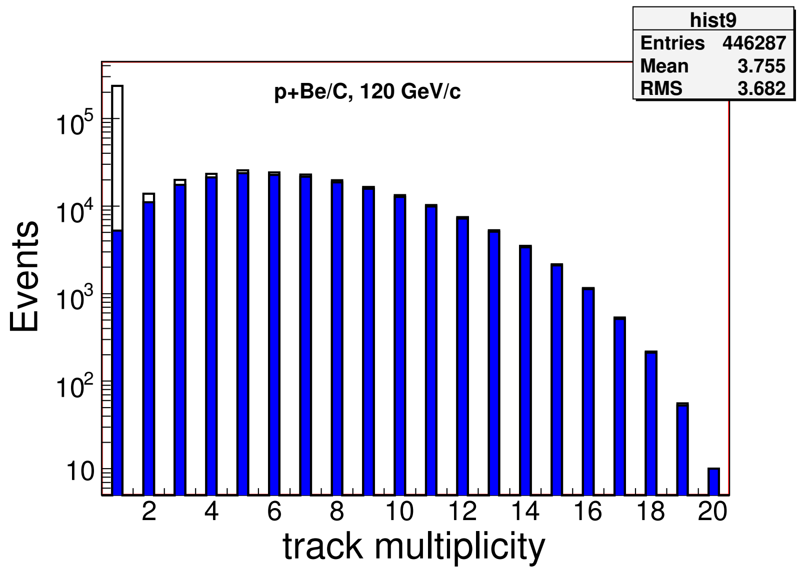
If more than one proton, then select with highest momentum.

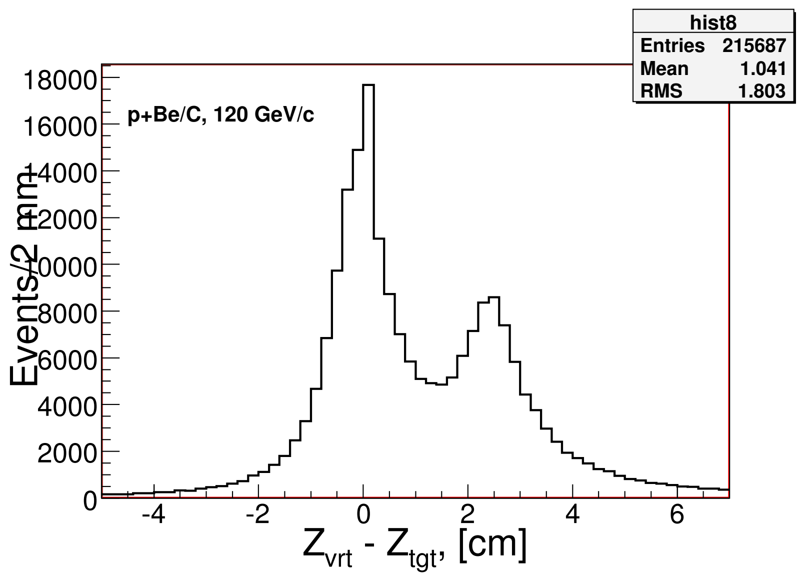
No any calorimeter info needed for protons, unless some consistency check.

- Runs: 15260 - 16090, thin targets
- Momentum - 120 GeV/c
- Targets - Be, Bi and C
- Trigger - proton interactions
- Event/track selection cuts:

  - select events with nTrks$<$20
  - use events with single beam track
  - the vertex should be within the target sizes
  - require the good quality tracks in the vertex:
  - reasonable nTPC hits, track timing, $p_{trk} >0.2$ GeV/c and $p_{trk} <1.2 \cdot P_{beam}$

track multiplicity and Z point of interactions





Top plot - black line plot illustrates the track multiplicity of 120 protons at Be target. N=1 bin represents mostly the events with the beam straight through tracks. Blue colored plot illustrates the events survived following cuts: 1)if N=1 then P_{trk} should be less than 55 GeV/c and/or no high momentum track pointing to HCAL and 2)interaction point should be within target position and size.

Bottom plot - the reconstructed vertices position in Z direction. The peak at z=0 represents the interactions with the Beryllium target, the peak at z=2.5 cm represents the interactions with the trigger counter.

How cuts works? Cut 1: 446287→215687 (48%), cut 2: 215687→200120 (93%). High survived rate by cut 2 because the target loose position requirement was applied on early steps.

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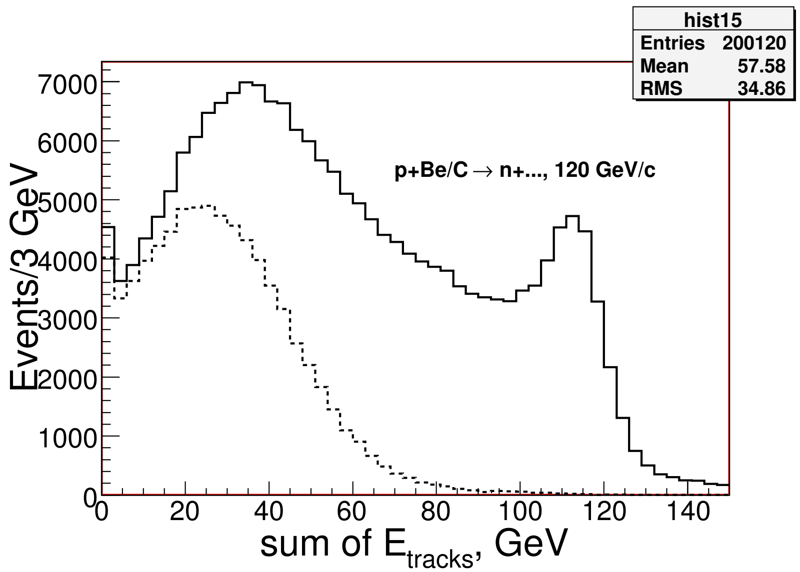
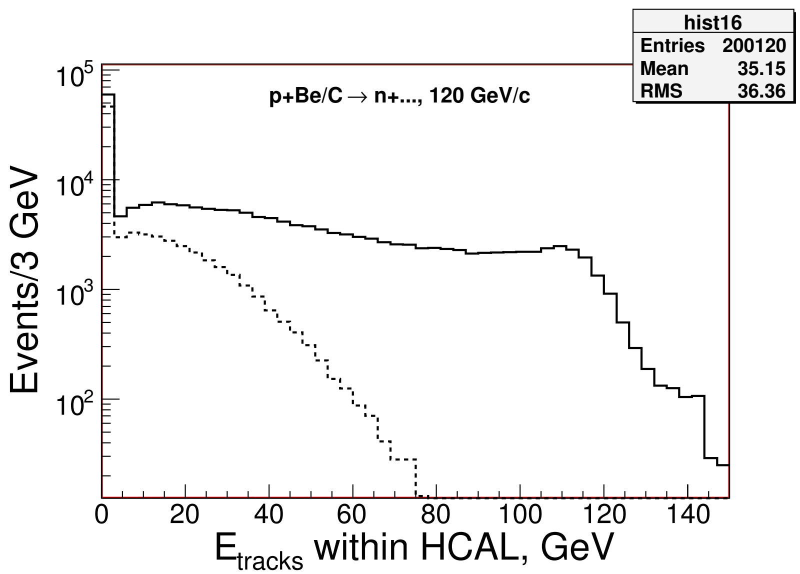
E_{trk}: all vs within HCAL



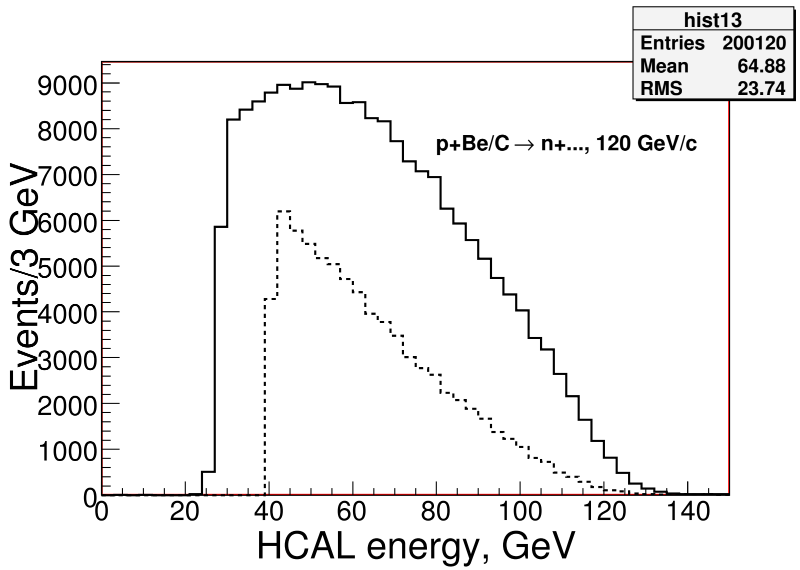


Both left plots illustrate the sum of energy of charged tracks emerged from the interaction point in target reqion. If secondary track was identified by RICH, then proper mass hypothesis was applied. Otherwise it assumed as a pion.

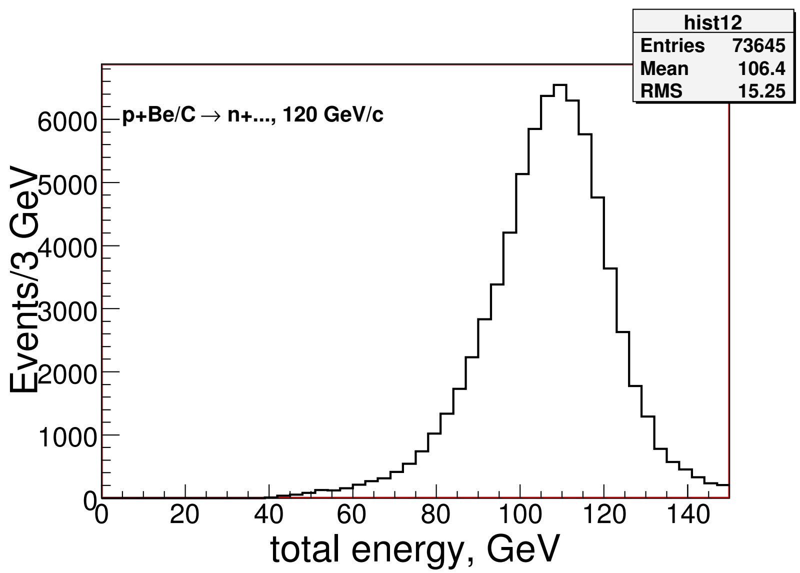
Top plot - black line plot illustrates the sum of E_{trk} in vertex. The bump around 110 GeV illustrates the leakage of the beam straight strough tracks. The dashed plot illustrates what will happen after applying the inclusive neutron requirements (they listed on page 1).

Bottom plot - black line plot illustrates the sum of E_{trk} those tracks which pointing into HCAL volume. The dashed plot illustrates what will happen after applying the inclusive neutron requirements. With dashed plots I am more confident that I properly selected the inclusive neutrons.

E_{HCAL} and E_{tot}

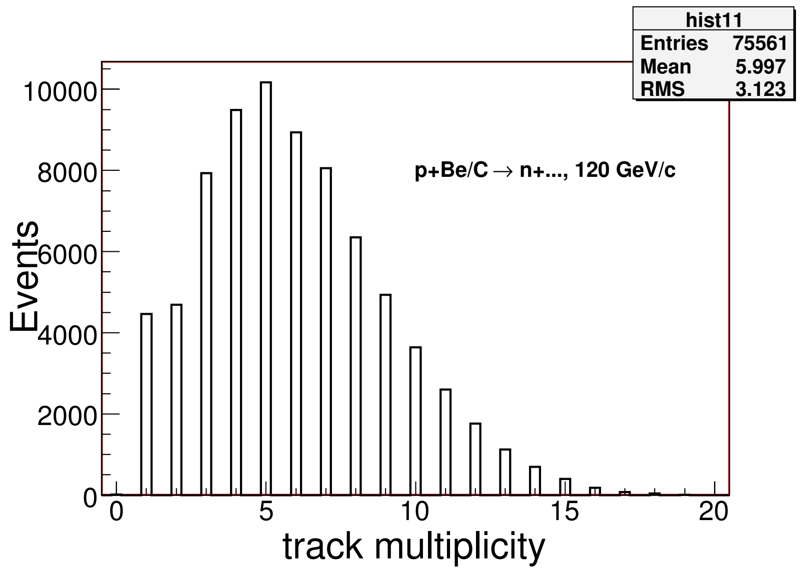


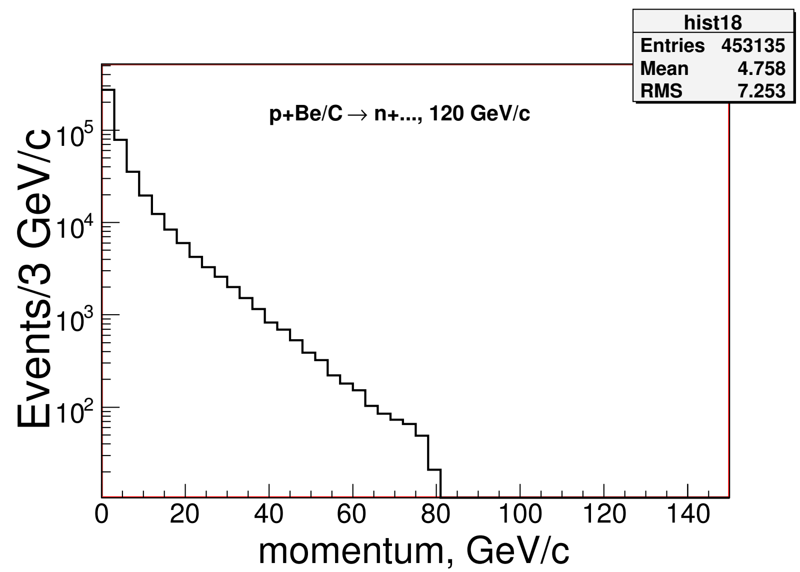
Top plot - black line plot illustrates the energy deposited into HCAL. The dashed plot illustrates what will happen after applying the inclusive neutron selection requirements (they listed on page 1). What is the inclusive neutron rate? In compare vs previuos selection: 200120⟶75561 (38%). Cumulative rate: 446287⟶75561 (17%).Rate per 1 incident proton: $2.8 \cdot 10^{-3}$



Bottom plot illustrates the total energy distribution, where E_{tot} = E_{trk} + E_{EMCAL} + E_{HCAL} - $E_{trk-in-hcal}$. E_{EMCAL} is energy deposited into whole volume of EMCAL, the last term takes care of the double counting. The peak position is about 5 GeV below that the mean of beam energy. It might be due to of the π^o in interaction, when the gamma's are off from calorimeters. Low energy tail also might be from same source, when π^o is sort of the leading particle.

N_{trk} and p_i

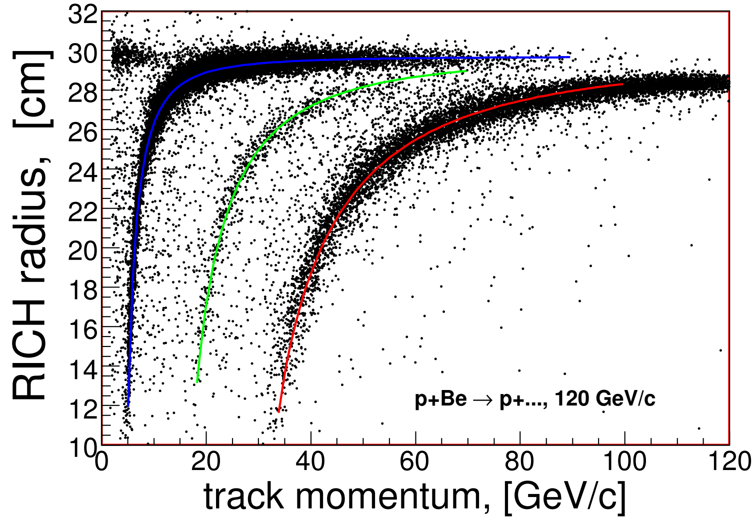


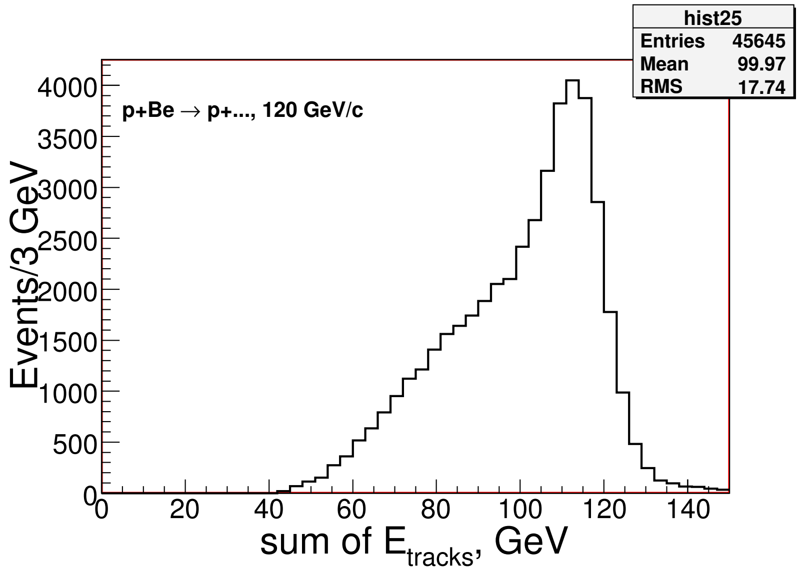


Top plot illustrates the charged track multiplicity, N_{trk}, when they all emerged from the same interaction point and they associated with the neutron.

Bottom plot illustrates the momentum distribution of the charged tracks, (p_i), associated with the neutron.

RICH radius and E_{tot}

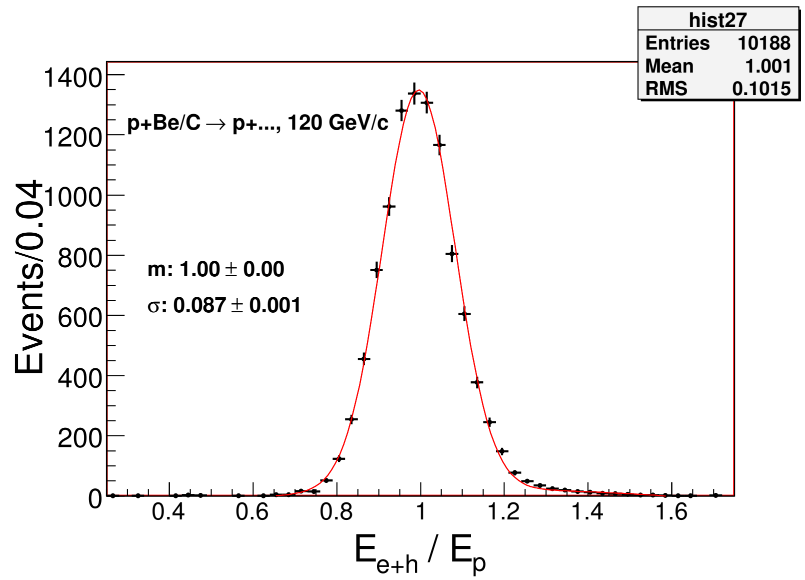


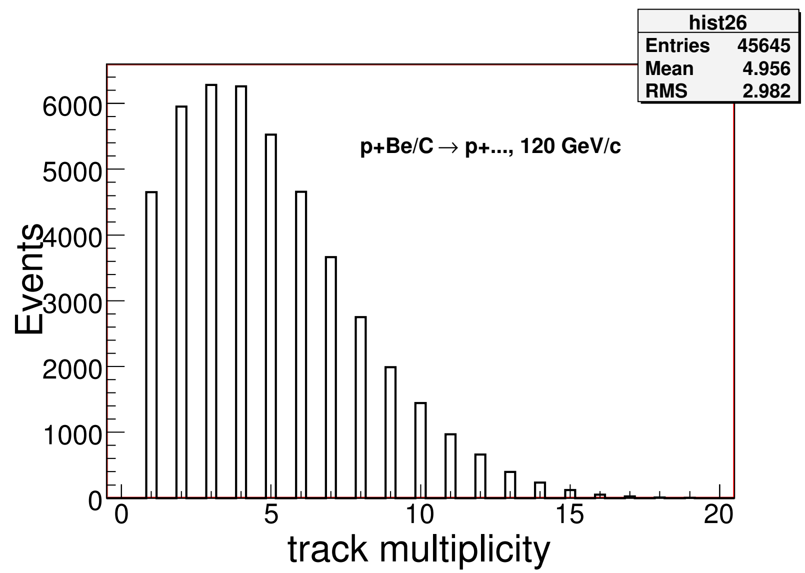


Top plot illustrates the particles identification by RICH. For pions I selected momentum range: 3-90 GeV/c, for kaons 15-70 GeV/c and for proton $p_{tot} > 30$ GeV/c. The track considered to be identified if the radius value is within ± 1.2 cm in respect to the colored curve.

Bottom plot illustrates the charged track total energy distribution. Low energy tail might be due to of π^{o}'s.

inclusive protons: E_{e+h}/E_p and N_{trk}



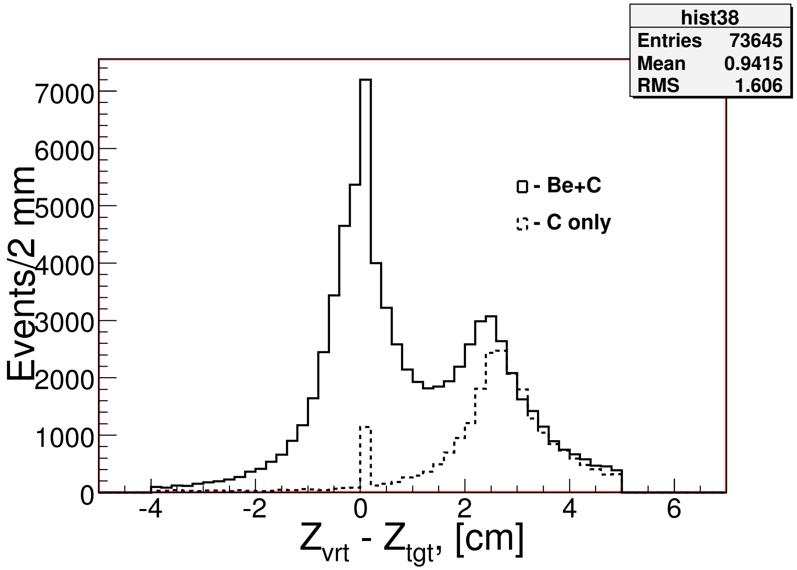


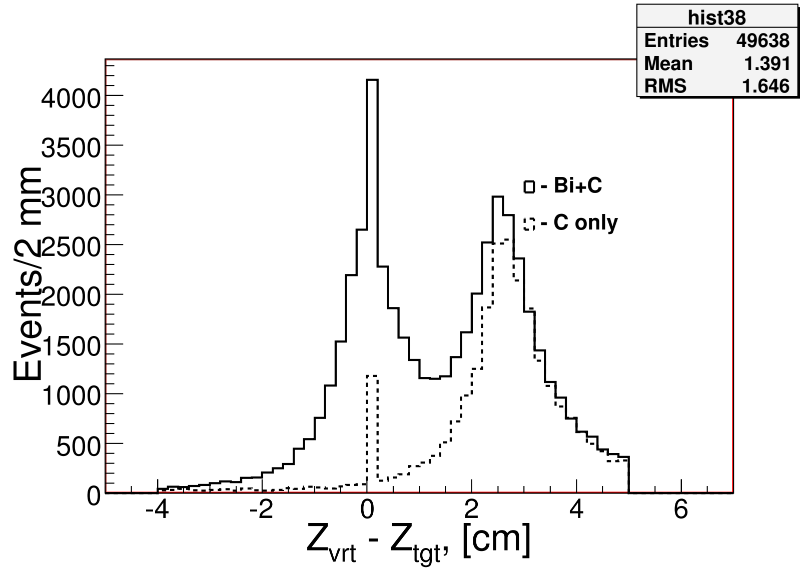
One more cross-check with the proton sample. If everything measured correctly, then the energy of proton from tracking should be consistent with what was measured by calorimeters. For this test I need to select the single proton pointing into calorimeters and EMCAL's shower should be in match with proton track. Of course only a part of events might satisfy to this requirement. Top plot illustrates the E_{e+h}/E_p ratio distribution, where E_p is measured by upstream spectrometer and E_{e+h} by calorimeters.

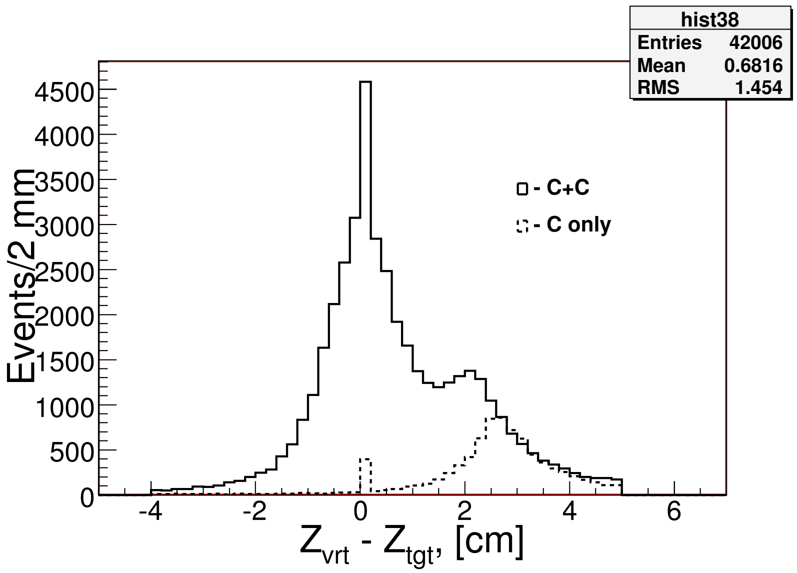
Bottom plot illustrates the charged track multiplicity, N_{trk}, when they all emerged from the same interaction point and they associated with the leading proton. The mean value difference: N_{trk}(n) - N_{trk}(p) = 1. Is it due to of charge conservation law?

results

vertex position in Z direction





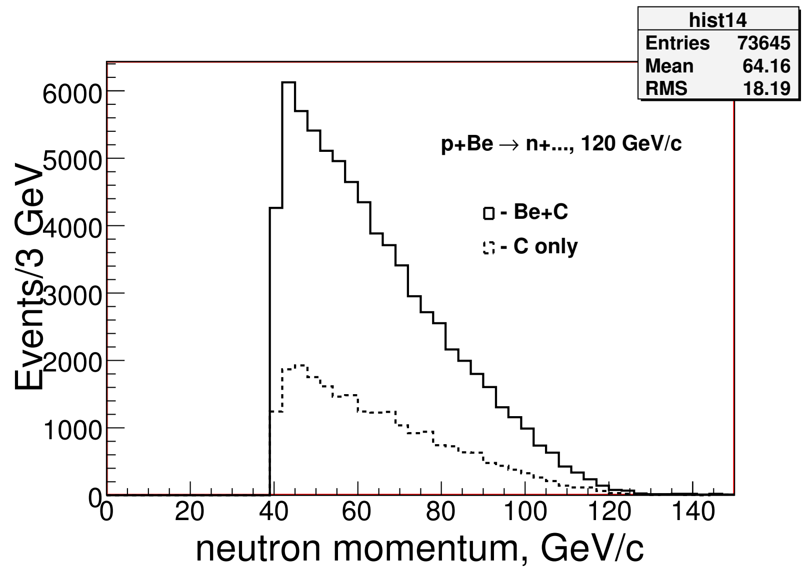


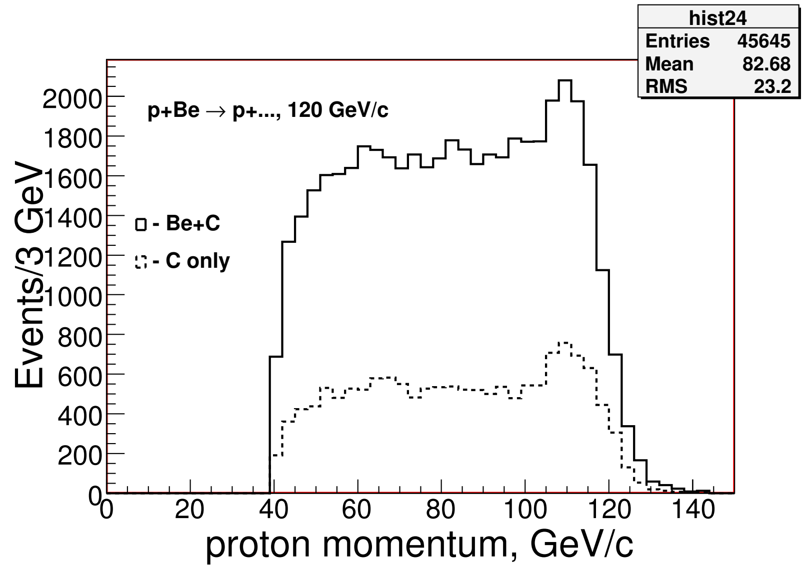
All three plots are the reconstructed vertices position in Z direction: top left - on Beryllium, bottom left - on Carbon(2%) and top right - on Bismuth targets. The dashed plots are the target-out data, they all scaled-up.

I am surprised to see that the number of interactions on higher atomic number target is less that on the light target. I expected to see opposite effect.

Another interesting observation: the number of interactions on actual Carbon target is dominated over the scintillator.

p_n and p_p, target-OUT subtracted

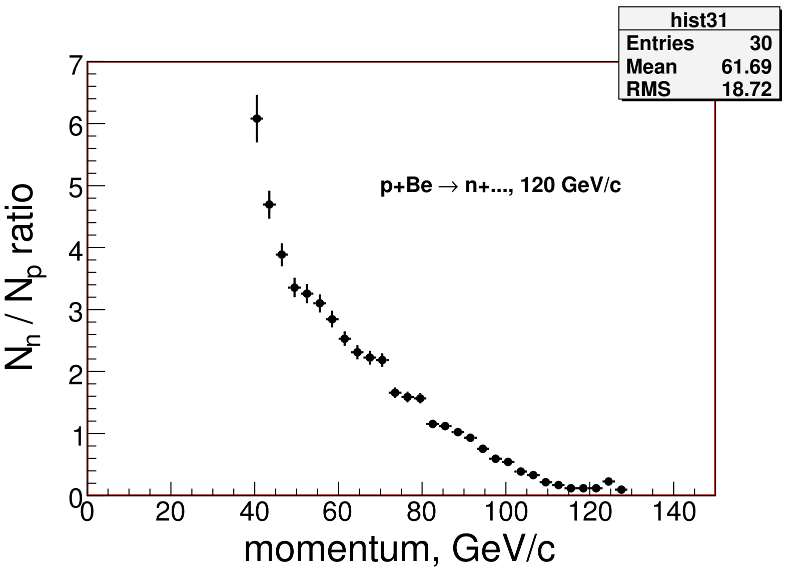




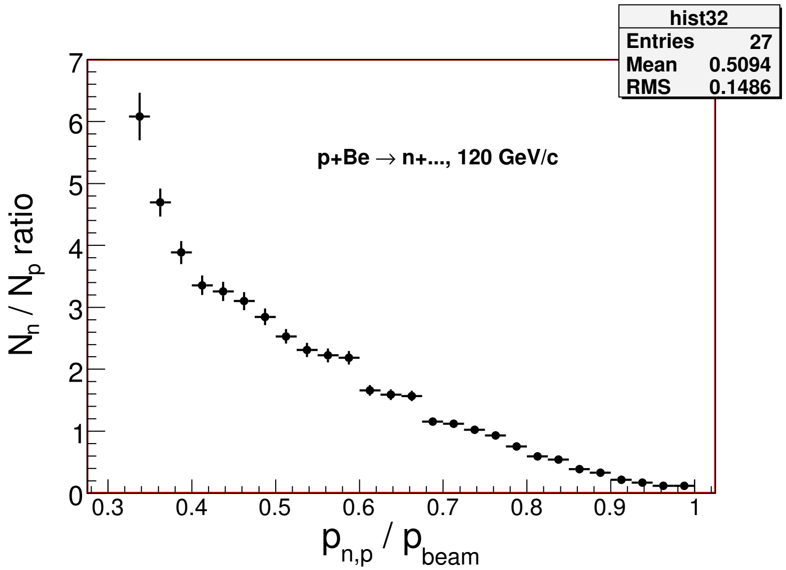
Top solid plot - the neutron momentum distribution, where neutron energy was calculated as $E_{neutron}$ = E_{HCAL} - $E_{trk-in-cals}$, where E_{HCAL} is energy deposited into HCAL and $E_{trk-in-cals}$ is sum of track energies pointing into HCAL. The dashed line plot - target-OUT data, which was scaled-up to the same number of the incident beam protons that Beryllium data.

Bottom solid plot - the leading proton momentum distribution. The dashed line plot - target-OUT data, which was scaled-up to the same number of the incident beam protons that Beryllium data.

N_n / N_p, target-OUT subtracted



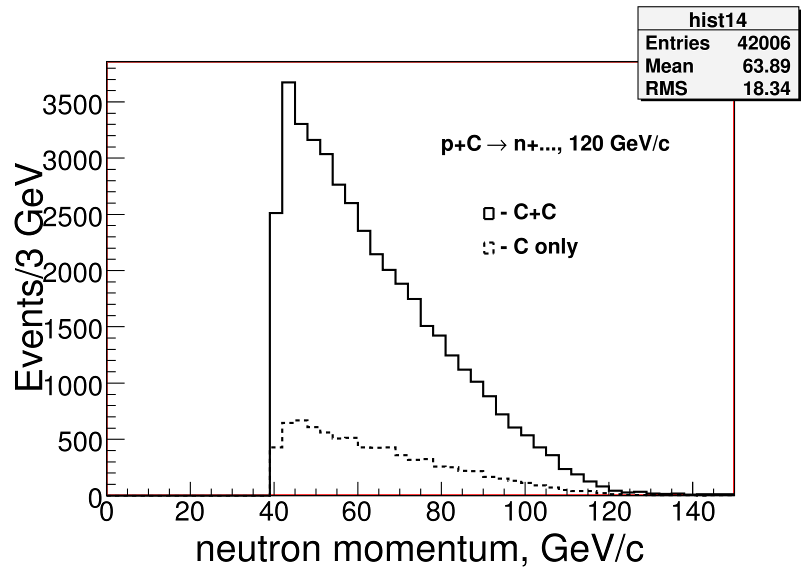
Top plot - ($N_{n,in}$-$N_{n,out}$) / ($N_{p,in}$-$N_{p,out}$) ratio distribution vs the momentum, where "in" and "out" abbreviations means target-IN and target-OUT, respectively. The target-OUT data has been scaled-up to the same number of the incident beam protons that Beryllium data.

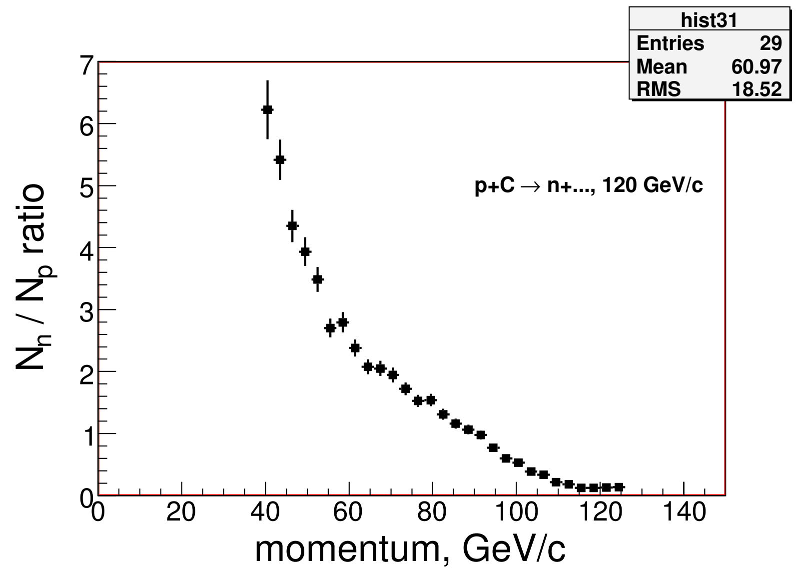


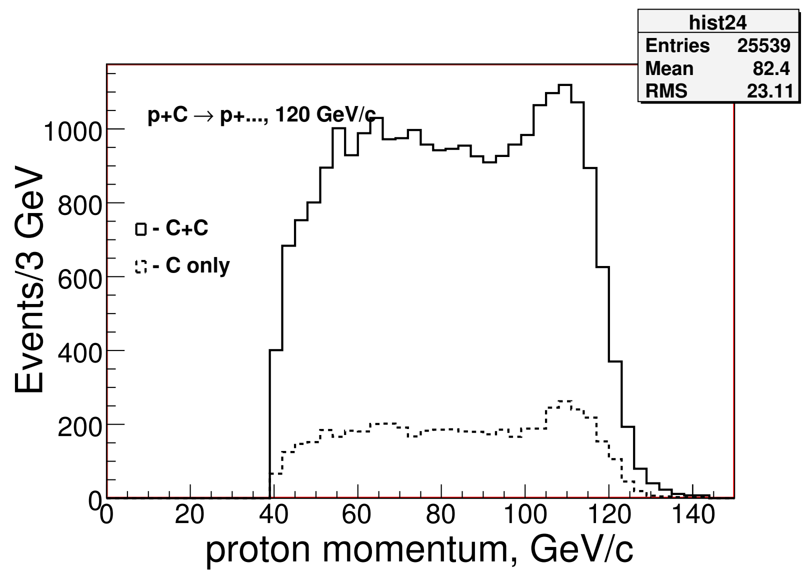
Bottom plot - ($N_{n,in}$-$N_{n,out}$) / ($N_{p,in}$-$N_{p,out}$) ratio distribution vs the momentum fraction in respect to P_{beam}.

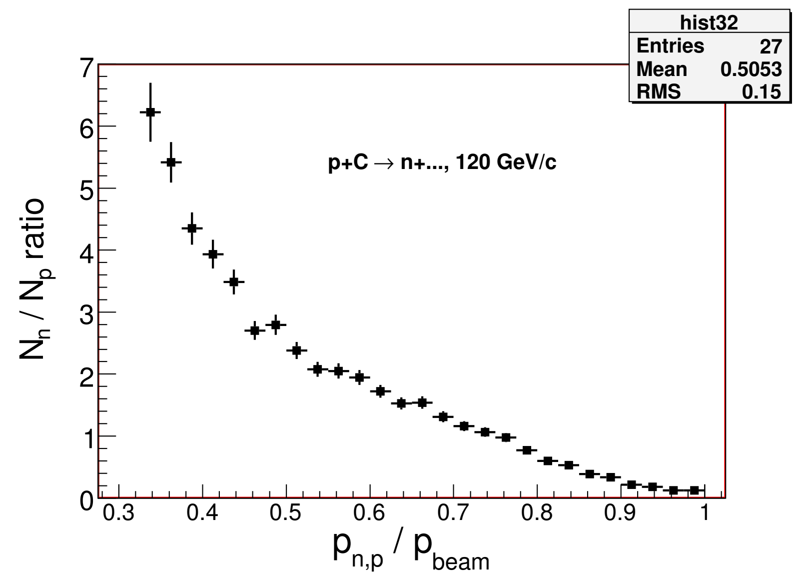
MJL comments: "...I think it would be very interesting and surprising if the ratio is $>$1 below 2/3rds of the beam energy".

Carbon target









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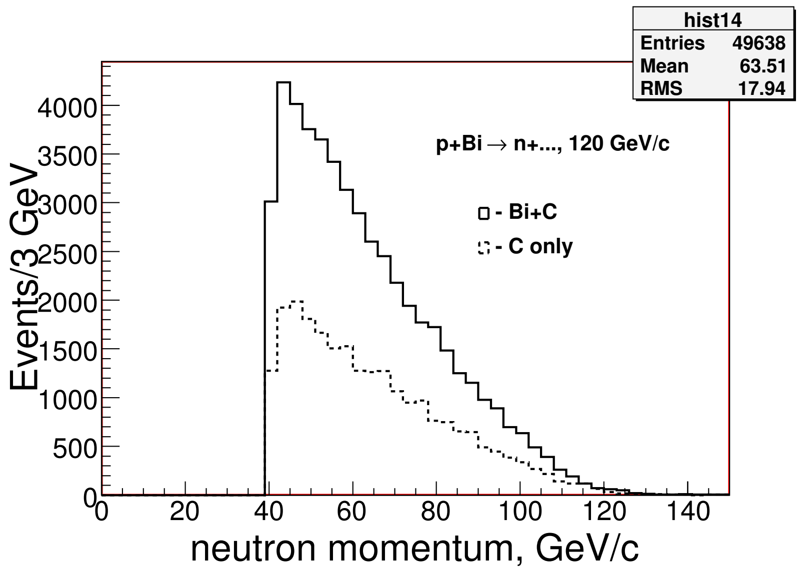
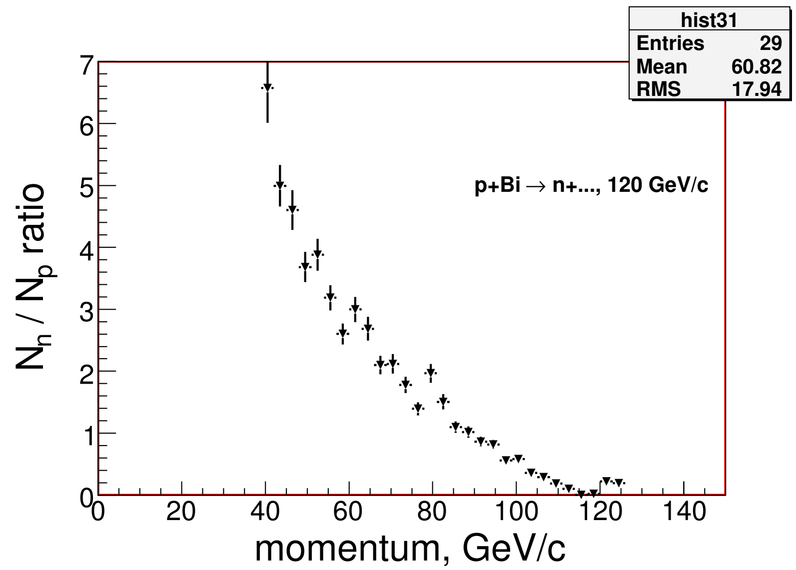
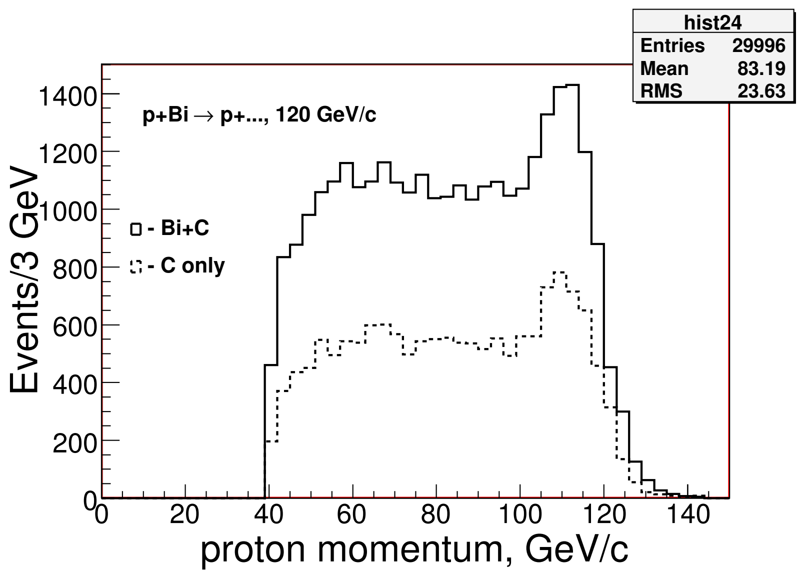
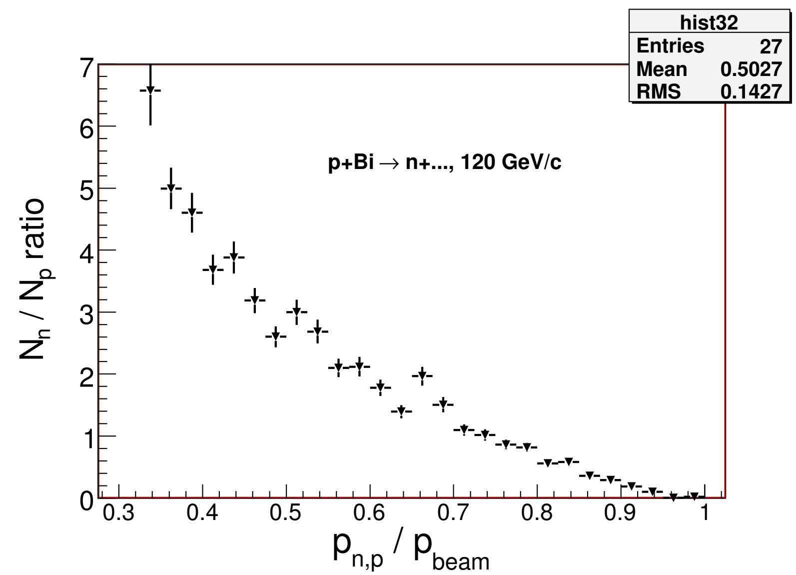
Bismuth target

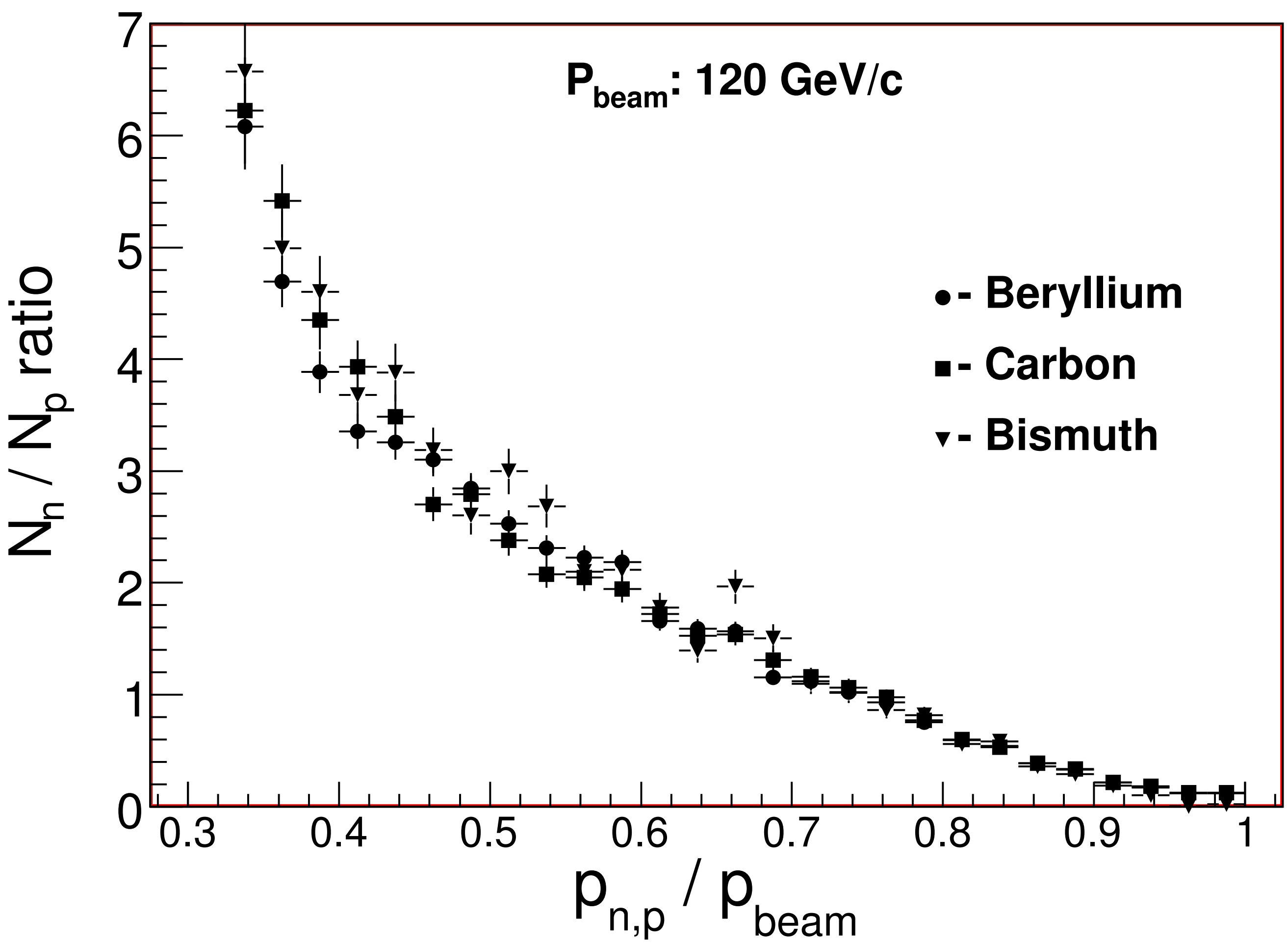








combined



P_{beam}: 120 GeV/c
●- Beryllium
■- Carbon
▼- Bismuth
N_n / N_p ratio
$p_{n,p} / p_{beam}$
0
1
2
3
4
5
6
7
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

possible next steps

trigger bias studies (MC)

neutron and proton acceptance (MC)

other momentum

comparison with model(s)