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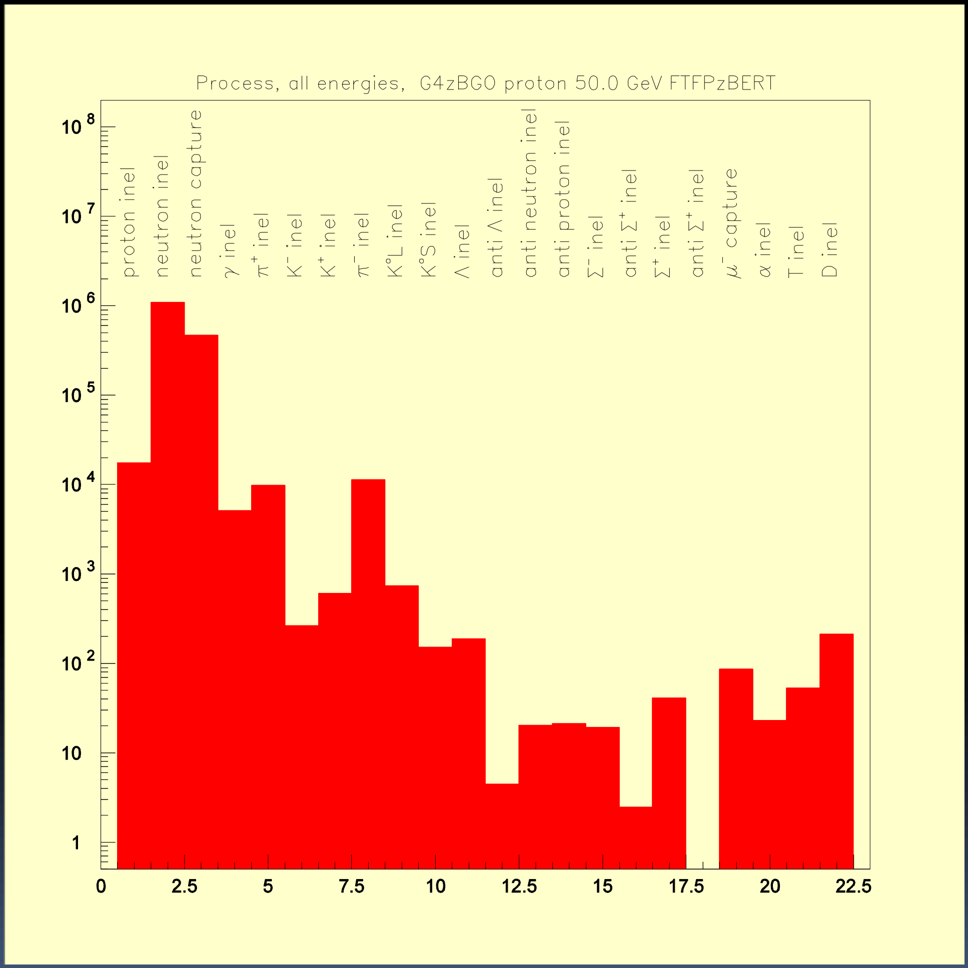
A GLIMPS AT FTFP_BERT: HADRON INTERACTIONS IN GEANT4

Using GEANT4 to Evaluate High Resolution Hadron Calorimeter?

- We want to explore the limits of performance of dual readout calorimetry. Monte Carlo simulation is the only practically available tool.
- To explore high resolution calorimetry it is necessary that the Monte Carlo simulation conserves energy on the event-by-event basis with the accuracy better than the resolution of the calorimeter
- So far: QGSP_BERT is the only model which conserves energy event-by-event
- But the model is valid only at low energies. Other models are phased in somewhere around 10 GeV.
- Recent suggestion: FTFP_BERT. Use Bertini at low energies, switch to Fritjof above 5 GeV. Expectation is that Fritjof is a better model for interactions on nuclei
- Will illustrate FTFP_BERT performance for 50 GeV protons (1000 events)

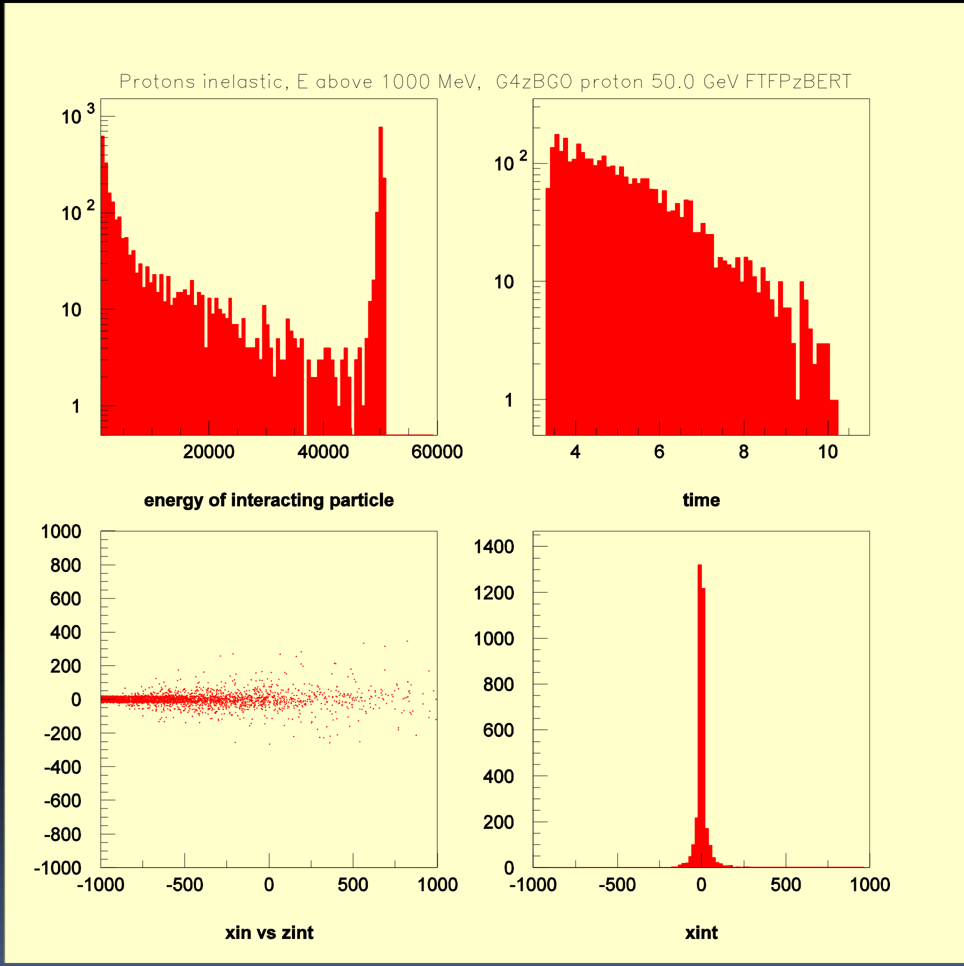
Inelastic Processes Simulated



- Collection of processes similar to QGSP_BERT. Need to find a good metric for comparison.
- per event ~ 20 proton inelastic interactions, ~ 20 interactions of charged pions
- ~ 500 neutron captures per event ➔ 4 GeV (8%) of energy recovered

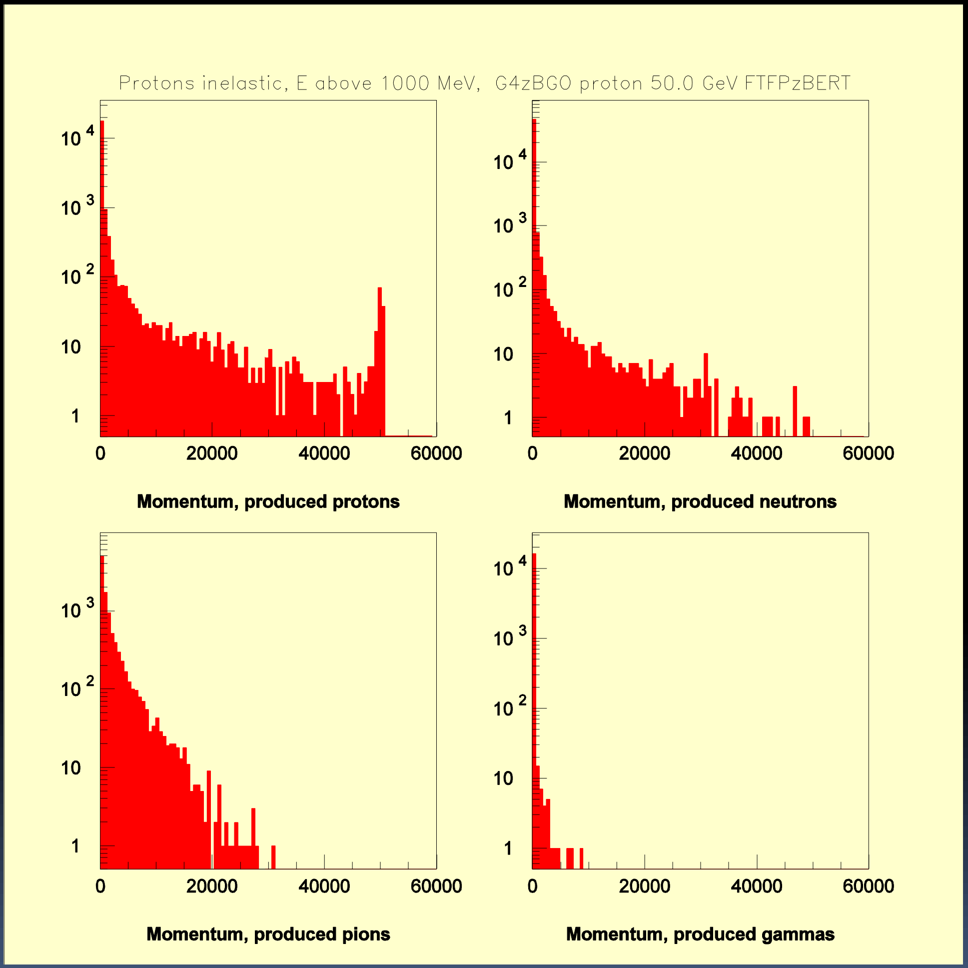
High Energy Proton Interactions (Above 1 GeV)

Space-time Characteristics



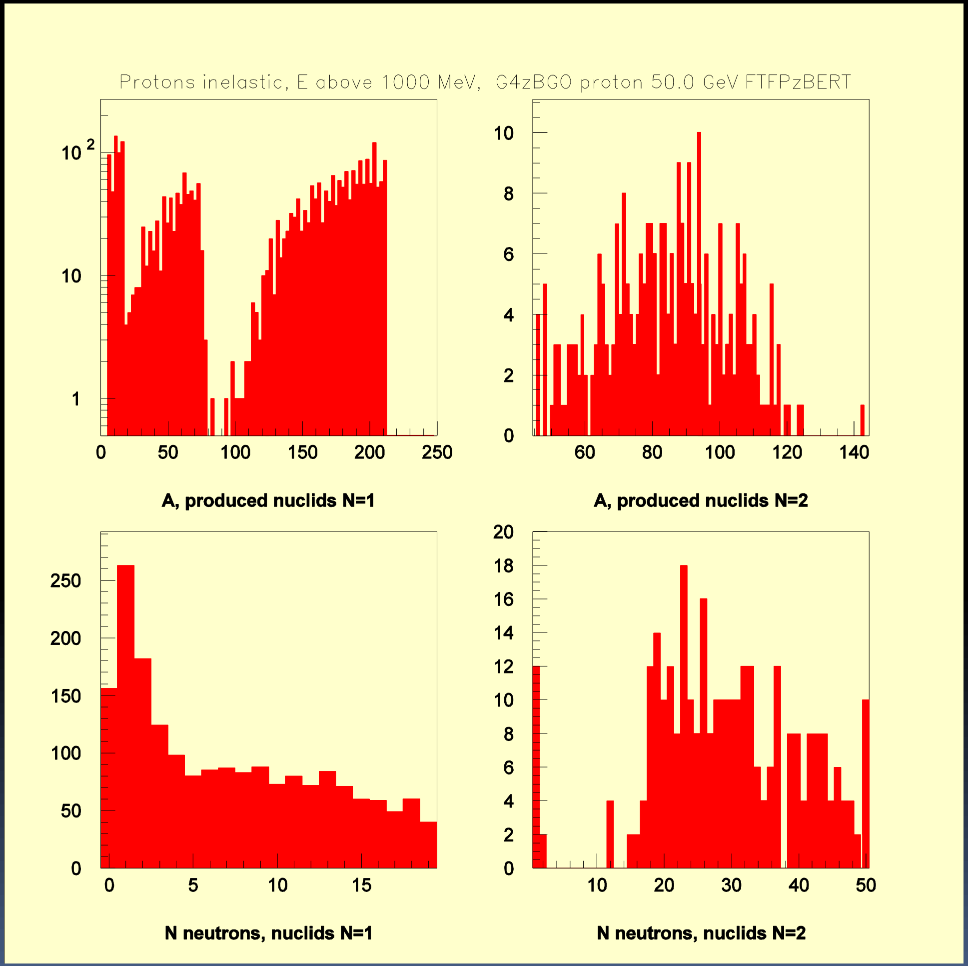
- primary protons and protons produced in p-nucleus interactions. Notice the leading particle effect (good!)
- All interactions very prompt, within 10 nsec
- Interactions confined to a very narrow tube along the beam direction, few cm radius.

Spectra of Produced Particles



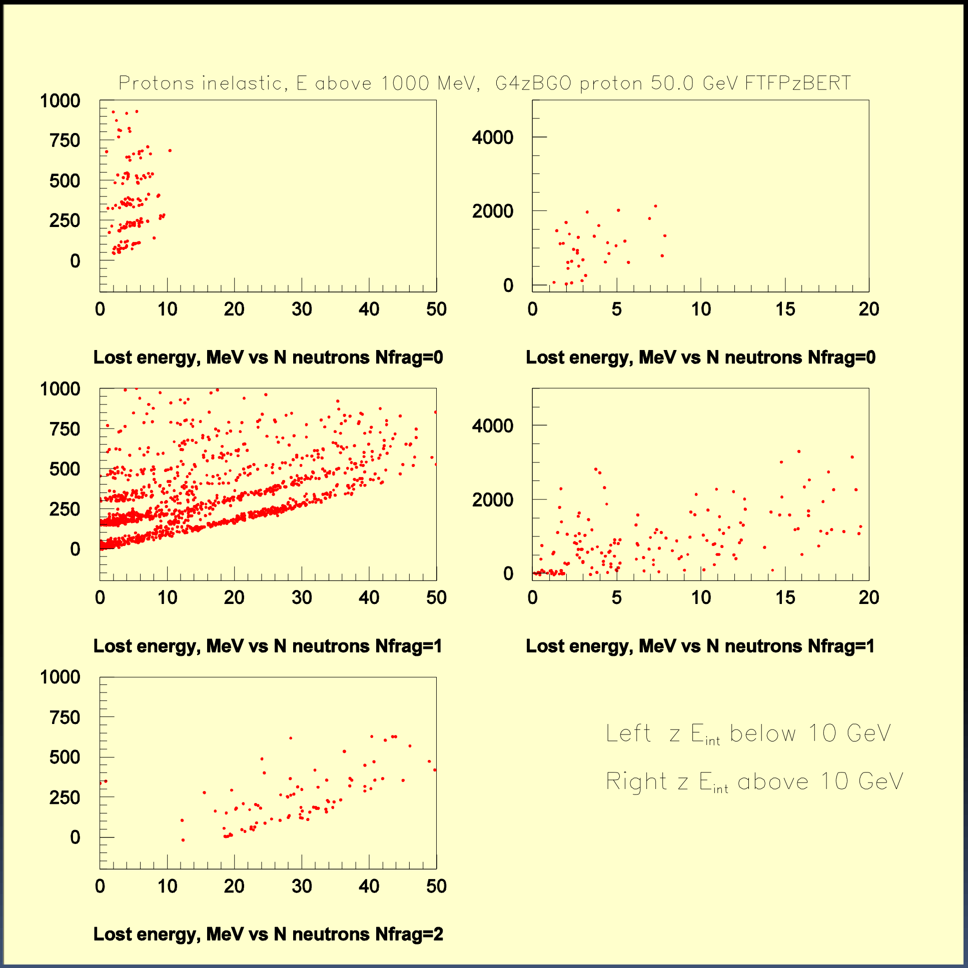
- Typical spectra of hadron-nucleus interactions
- protons (and even neutrons) have harder spectra than pions (leading quark effect)
- huge number of very soft protons and neutrons (nuclear evaporation and spallation)

Nuclear Reactions



- Large energy transfers to a nucleus ➔ large number of neutrons kicked out ➔ broad spectrum of produced nuclids
- relatively infrequent fission with large surplus of neutrons released

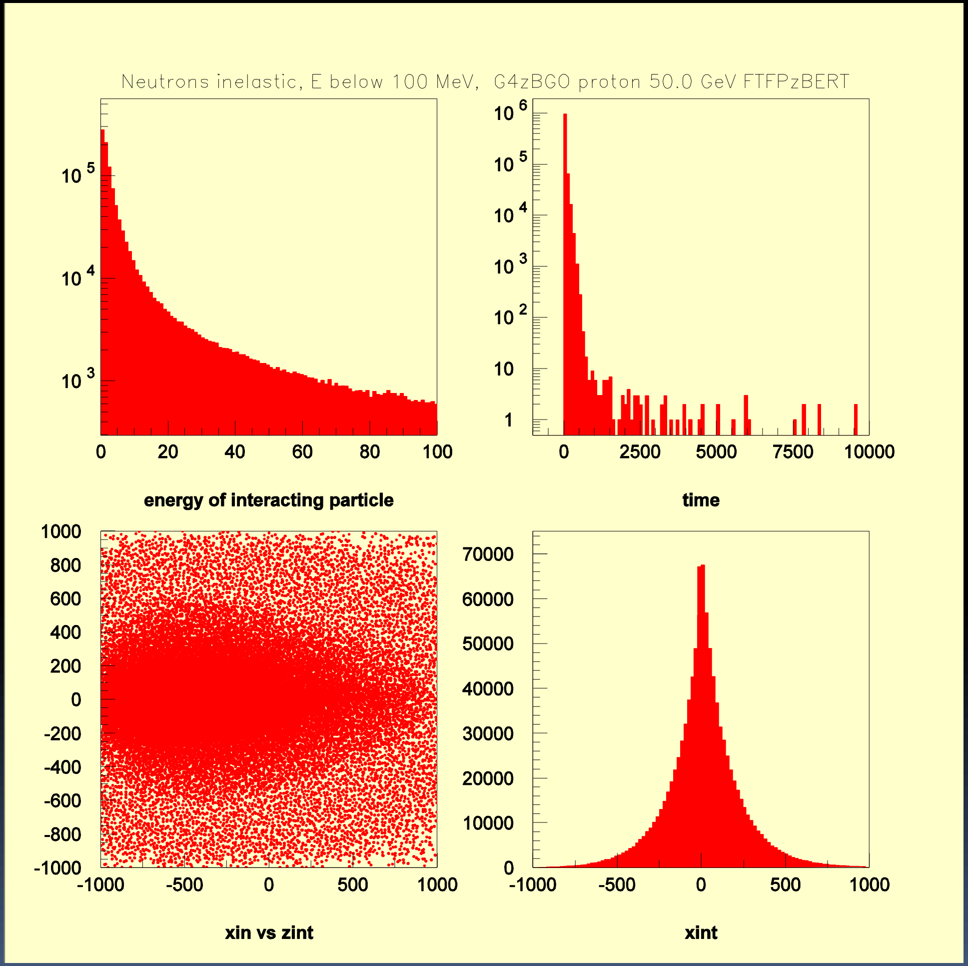
Binding Energy Losses?



- At 'low' energies (below 10 GeV)
  - missing energy increases with the number of released neutrons (binding energy)
  - missing energy somewhat smaller (at the same number of neutrons) for fission events (fission energy release!)
- At 'high' energies (above 10 GeV)
  - not much correlation between the numbver of neutrons and the missing energy → non-conservation of energy
  - Missing energy appears

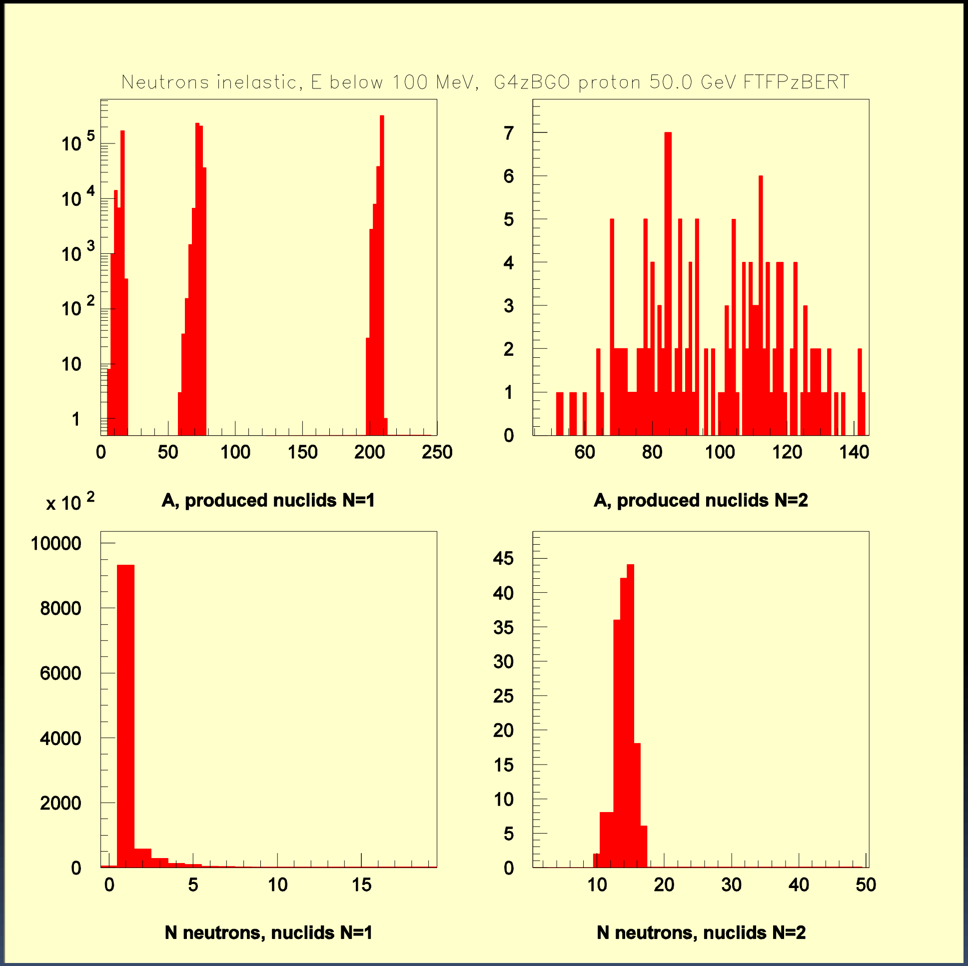
Low Energy Neutron Interactions (below 100 MeV)

Space-Time Characteristics



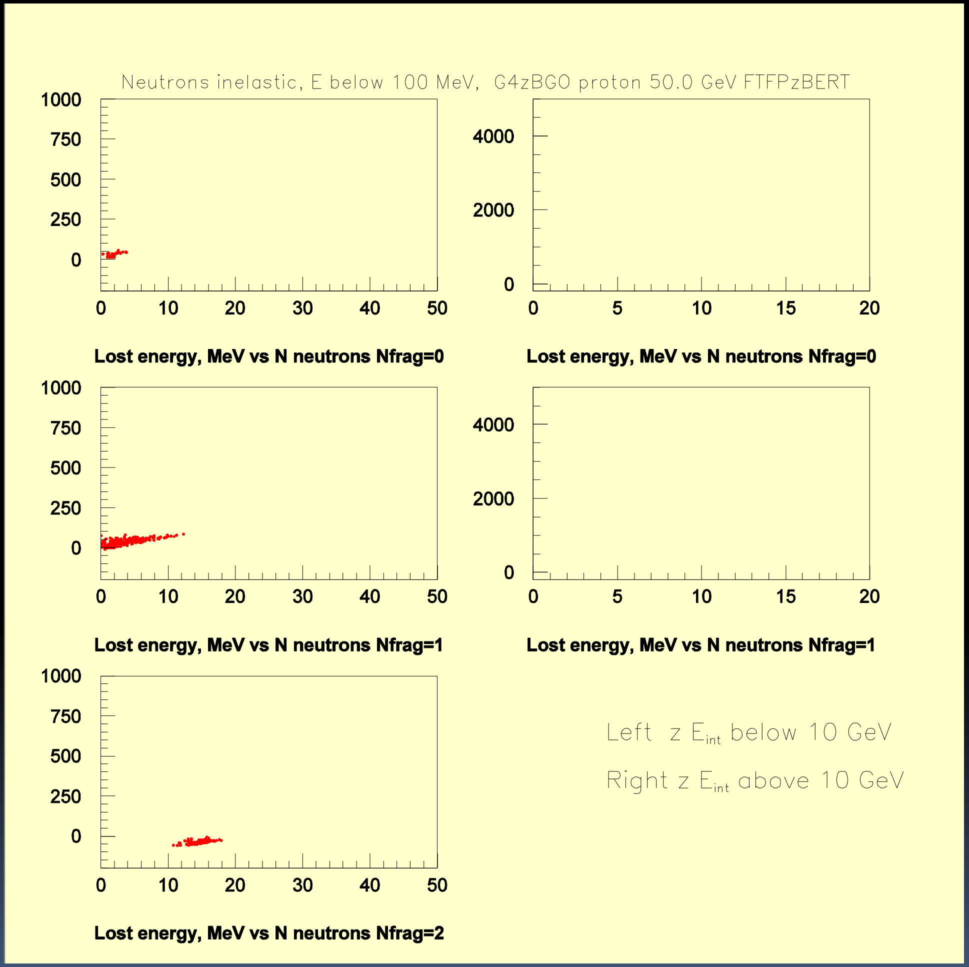
- most of neutron interactions at very low energies < 20 MeV
- most interactions relatively prompt, within 100-200 nsec
- interactions over large volume, both radially and along the shower axis

Nuclear Processes



- interactions of low energy neutrons with nuclei typically produce very few neutrons, most probably one and produce nuclids very close to the original nucleus
- Fission is very infrequent ~0.2 fission per event

Binding Energy Losses



Preliminary Impressions

- Most of the features/distributions look quite sensible
- Low energy behavior similar to QGSP_BERT (probably good)
- High energy model seems 'better' that those in the case of QGSP_BERT (smaller missing energy), albeit there is no correlation between the missing energy and number of neutrons
- It may be a better 'test case' for the dual readout calorimetry than QGSP_BERT
- Further studies necessary. In particular a comparison with CHIPS of interest
- Need to find a good metric for comparison of different models.