Hadronic Shower Modeling
APS April Meeting 2011

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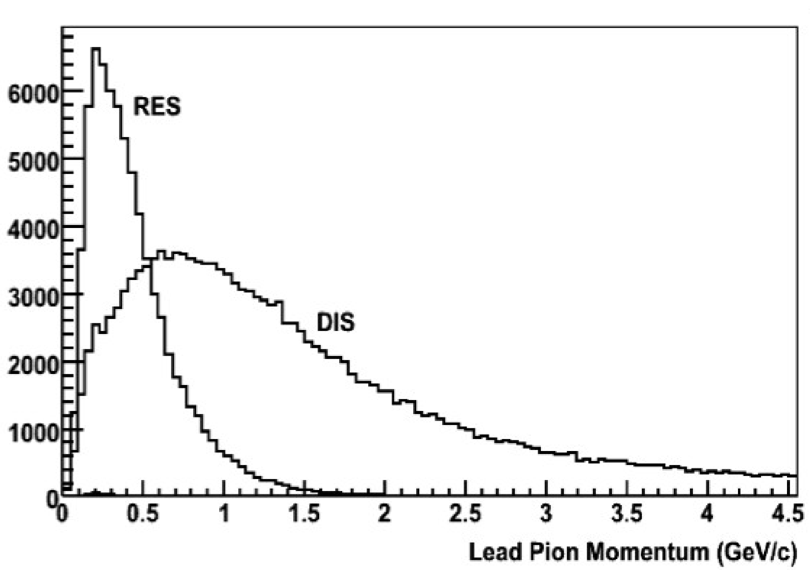
MINERνA

MINERνA Neutrino Experiment

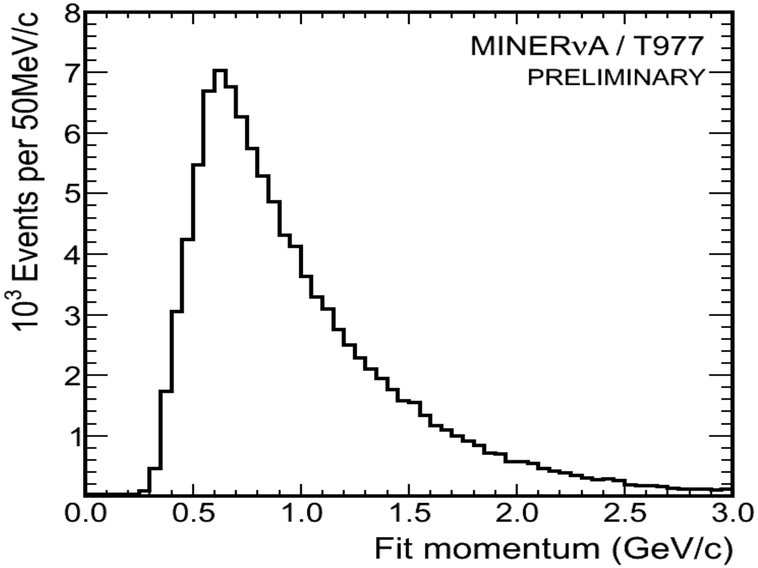
- MINERνA is a dedicated neutrino-nucleus cross-section experiment in the few GeV region. Future support of neutrino oscillation experiments.
- 121 finely segmented modules, fully active scintillator tracking region surrounded by electromagnetic and hadronic calorimeters.
- Wide range of nuclear targets (He, C, Fe, Pb, plastic, H_2O) in order to study nuclear effects in neutrino interactions.
- More details in the other three MINERνA lectures(Session R7: Neutrinos I, 05/02/2011, Room: Grand E): by Arturo Fiorentini in his talk “Measuring Nuclear Effects with MINERνA” ; by Jesse Chvojka in this talk “Anti-Neutrino Quasi-Elastic Scattering in MINERνA” and Julián Félix in his talk “The MINERνA TestBeam Study”.

MINERνA TestBeam Experiment

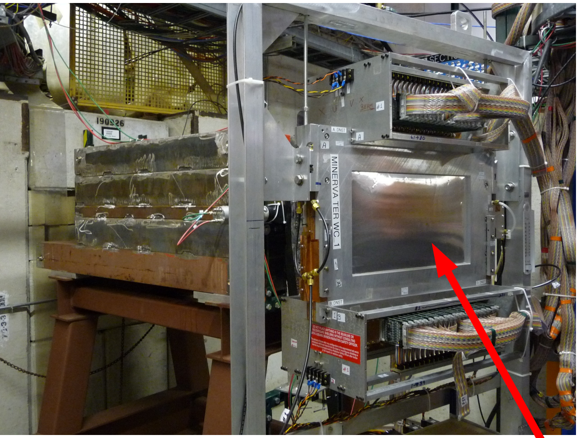
- Low momentum pions are very important in low energy neutrino-nucleus interactions (coherent and resonant pion production).
- The idea is to expose a smaller replica of the MINERνA detector to a beam of pions of known momentum and to measure a single particle response precisely.
- Test beam experiment provides hadronic response calibration for the MINERνA detector.



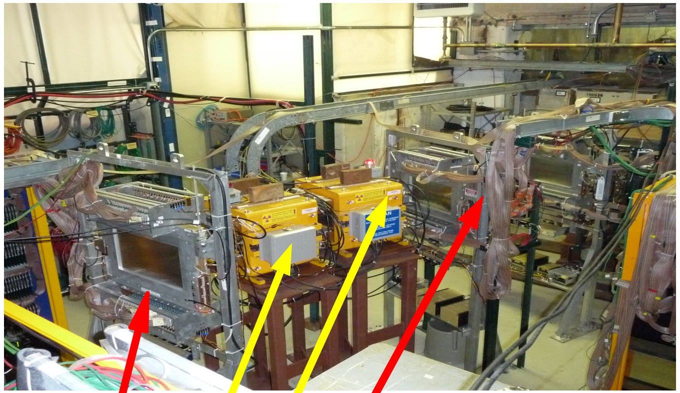
Tertiary Beam Momentum Distribution



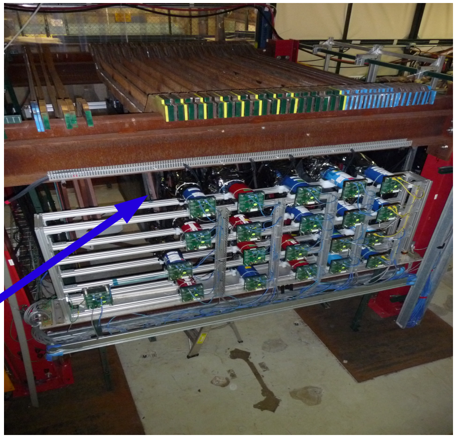
MINERνA TestBeam Experiment



Collimator

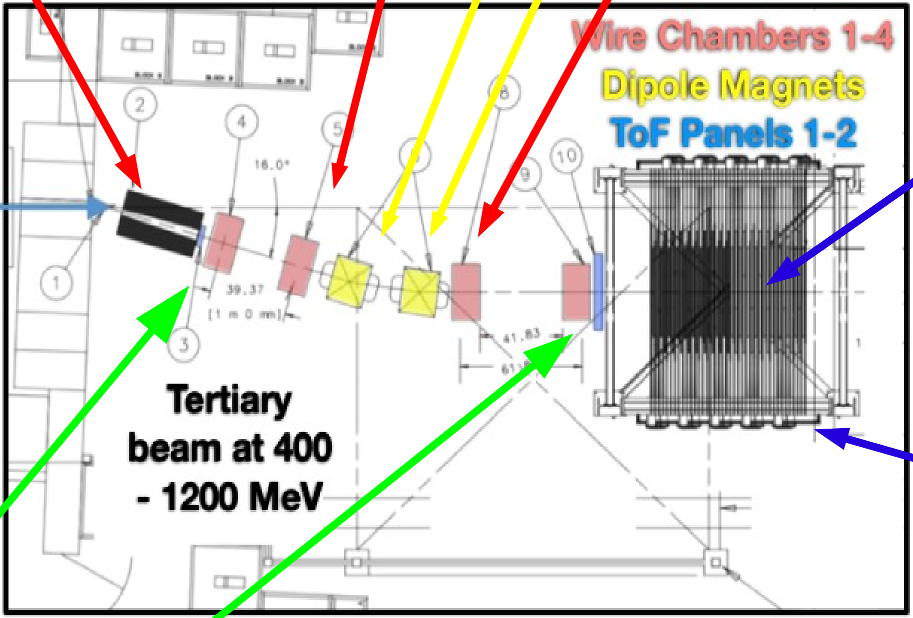


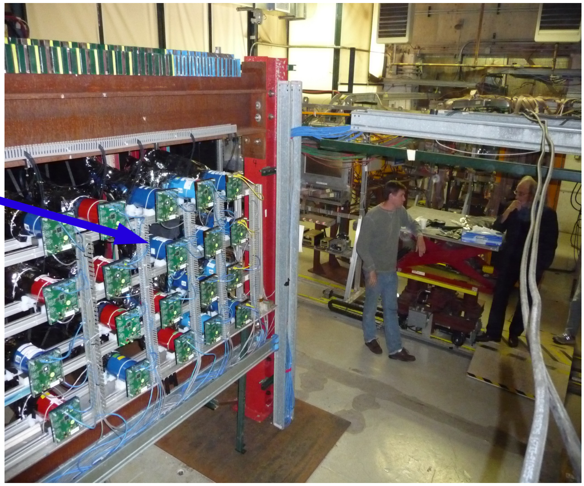
Two magnets and four wire chambers provide momentum reconstruction.



Copper Target

16 GeV Pion Beam



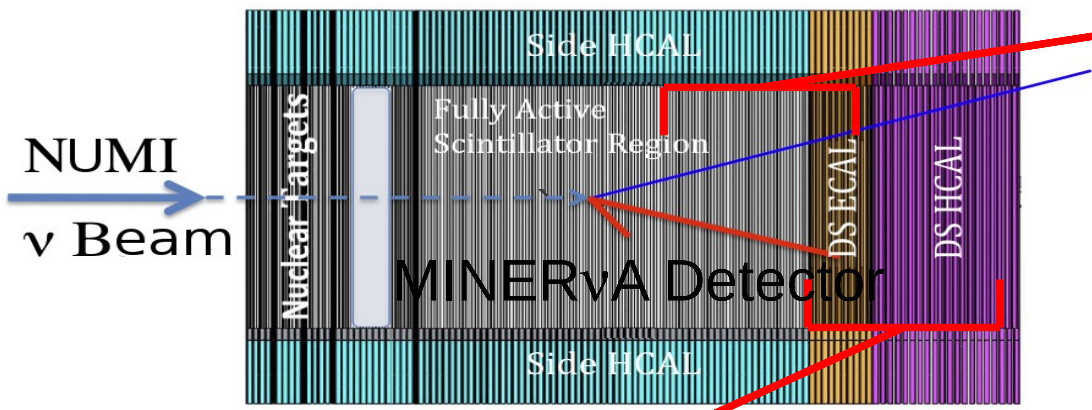


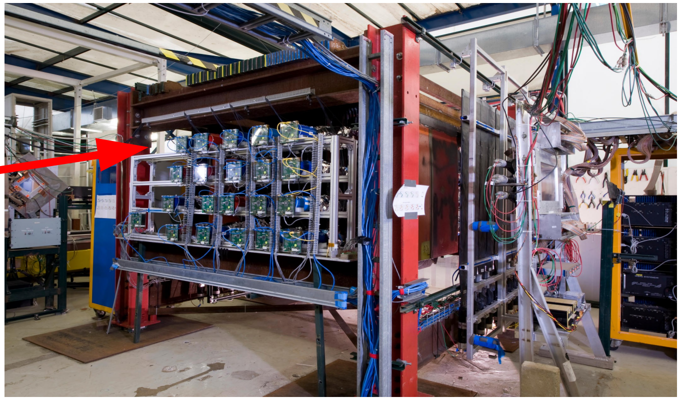
Time of flight system for particle identification :TOF1 downstream collimator and TOF2 upstream detector.

TOF2

TestBeam Detector

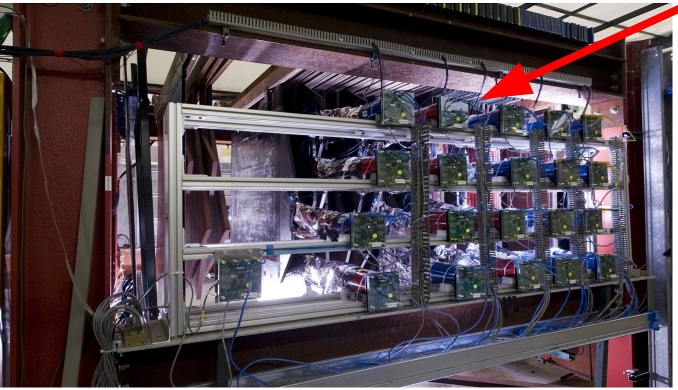
- 40 XUXV planes in stereoscopic orientation, reconfigurable, emulating different parts of the MINERνA full detector.
- Two configurations: 20 Tracker modules plus 20 Electromagnetic calorimeter modules and 20 Electromagnetic modules plus 20 Hadronic calorimeter modules. The latter configuration was employed in this analysis.





TB Detector: 20T-20ECAL

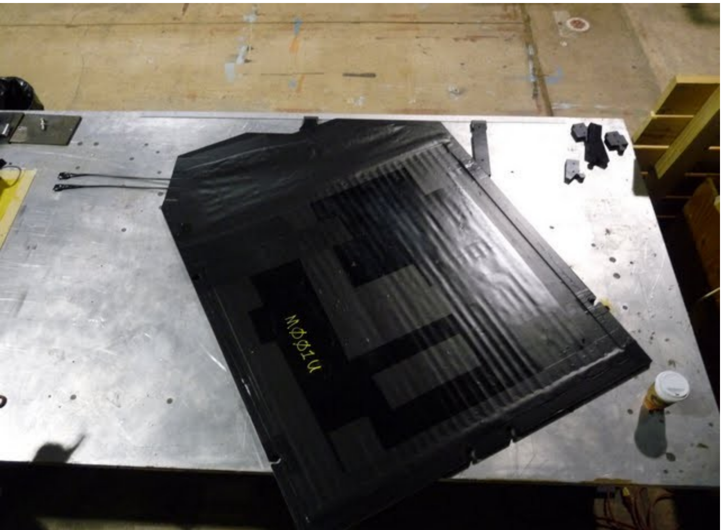
Two configurations:
TestBeam Detector

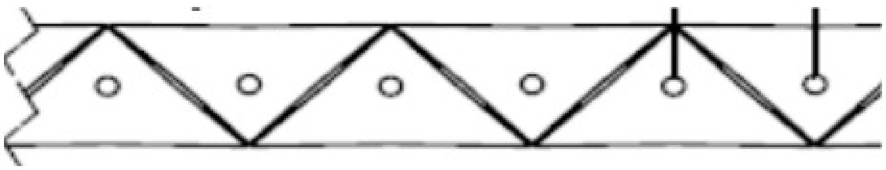


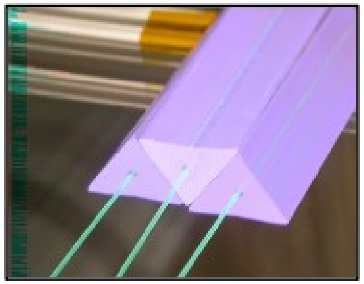
TB Detector:
20ECAL-20HCAL

TestBeam Detector

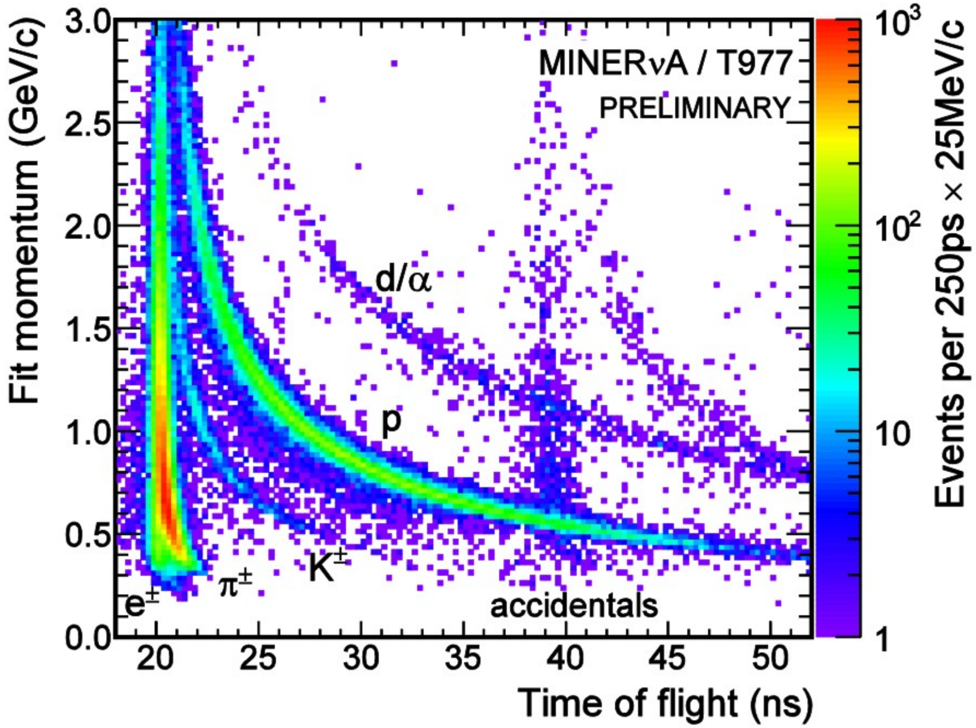
- Two kind of modules in the 20ECAL-20HCAL configuration: Electromagnetic calorimeter module and Hadronic calorimeter module.
- Calorimeter modules similar to the MINERνA full detector calorimeter modules (lower number of strips, smaller dimensions and rectangular shape instead of the MINERνA hexagonal shape, active area 1.07m^2).
- Electromagnetic calorimeter module: consists of a scintillator plane (63 triangular scintillator strips, containing a wave length shifting fiber for light collecting) and a Pb layer as an absorber (thickness: 1.98mm).
- Hadronic calorimeter module: consists of the same scintillator plane and a iron layer, also as an absorber (thickness: 25.94mm) .

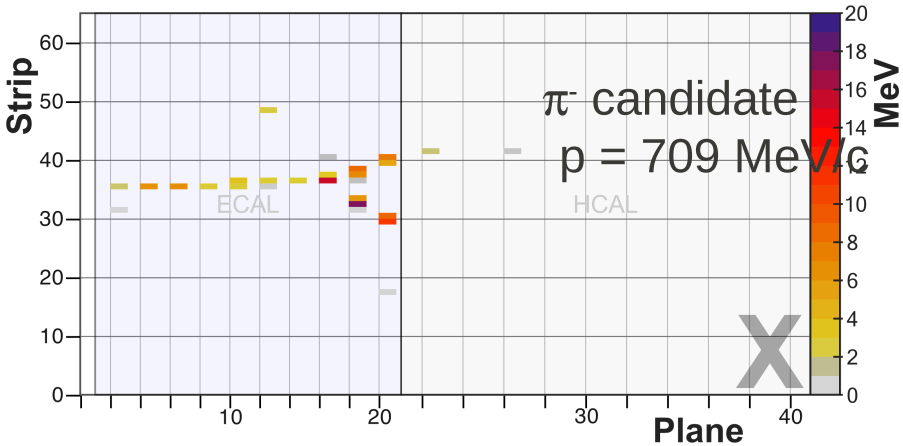






MINERνA TestBeam Experiment





This is what a pion event looks like!

- TestBeam took data during the summer of 2010 in both modes: $\pi^{\pm}$.

- Taken data currently in calibration process.

- More details of the MINERνA TestBeam experiment by Julián Félix in his talk “The MINERνA TestBeam Study”(Session R7: Neutrinos I, Monday, 05/02/2011, 2:18PM - 2:30PM).

G4 Cascade Models

- Two different Cascade models were taken in this analysis: Bertini Cascade and Binary Cascade.
- Intranuclear Cascade model: in particle-nuclear collisions the deBroglie wave length of the incoming particle is comparable to or shorter than the average intra-nucleon distance, allowing us to treat this as a classical scattering process.
- Full physics model composed by electromagnetic model + hadronic model.
- Same electromagnetic physics, just testing different hadronic physics.

Bertini and Binary Cascade

Features	Bertini Cascade	Binary Cascade
Starting point	Intranuclear cascade	Intranuclear cascade
Nucleon momentum	Fermi gas model	Fermi gas model
Target nucleus	Smooth nuclear medium	Detailed 3D collection of nucleons explicitly positioned in phase-space
Final state after each collision and secondaries production	According to free-particle cross section data	Modeled by cascading series of two-particle(binary) collisions. Secondaries created by decaying of resonances produced during collisions
Nuclear evolution between collisions	Boltzman equation	Hadrons transported in the field of nucleus by a Runge-Kutta method
Nuclear de-excitation	Pre-equilibrium, nucleus explosion, fission, evaporation methods, etc.	Precompound model
Energy range for pions	<10GeV	<1.5GeV

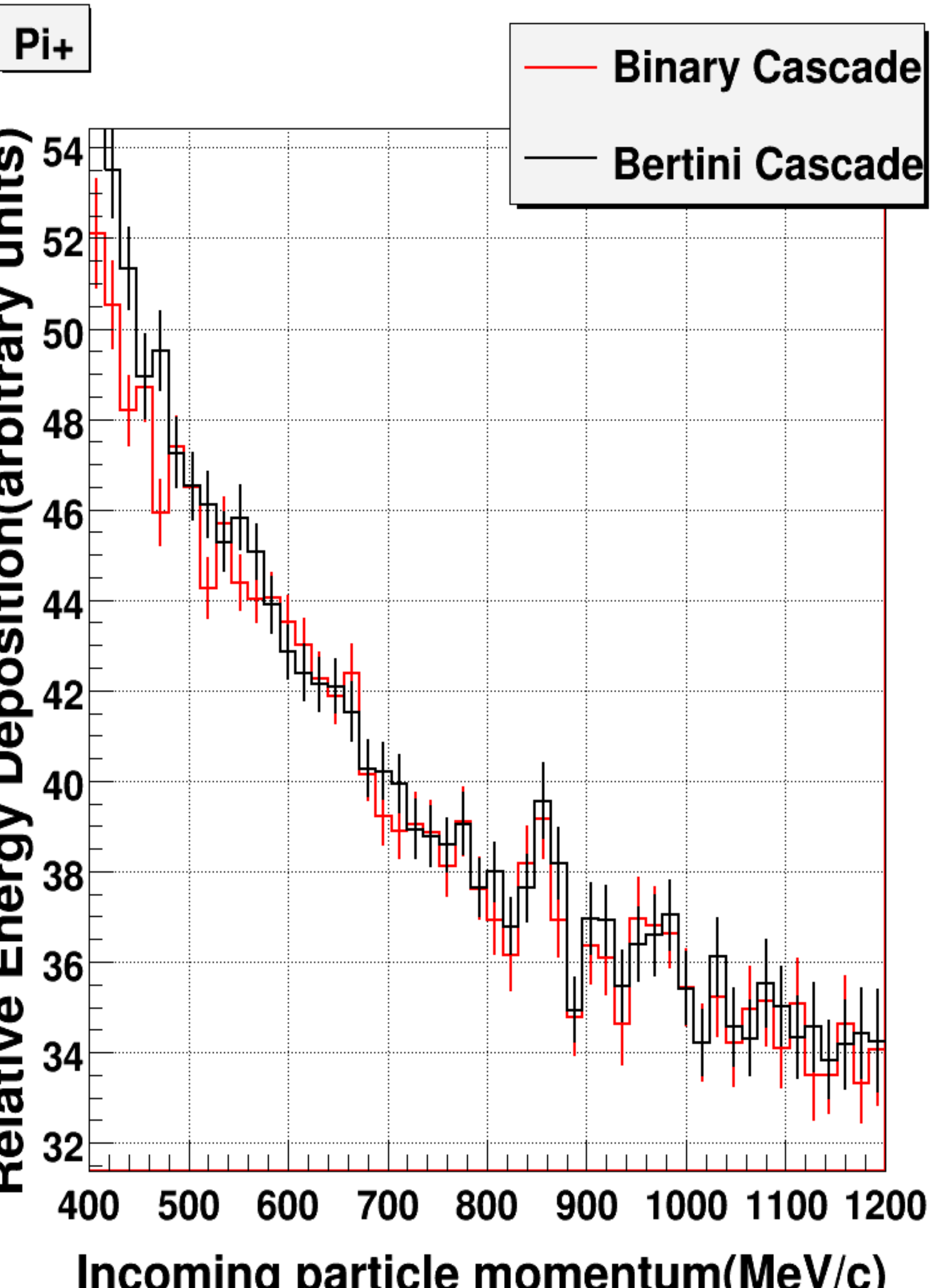
Goals of the Study and Variables

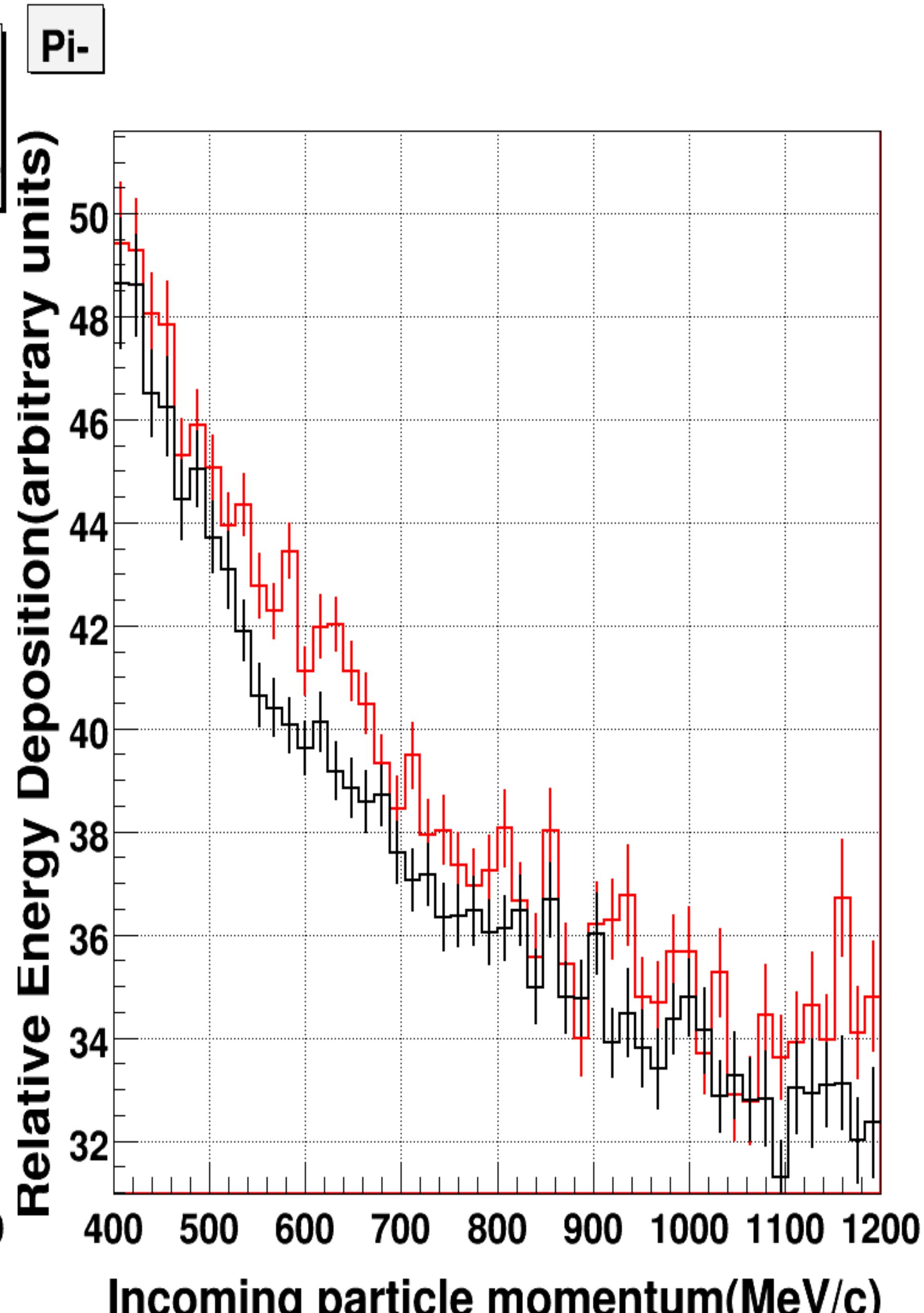
- Main goal is to find which model explains the data best. Hadronic shower characterization for Deep Inelastic Scattering studies in the MINERνA full detector.
- Variables:
  - Relative Fraction of the incoming energy absorbed by the scintillator for the two models.
  - Deposited Energy Fraction per longitudinal position for the two models.
- Study performed for the 20ECAL-20HCAL TestBeam configuration.

Relative Fraction of the incoming energy absorbed by the scintillator for the two models

- Fraction of the incoming energy deposited in the scintillator in arbitrary units: total deposited energy in the detector per event divided by the incoming particle energy(MC truth).
- Calculation made for both cases: $\pi^{\pm}$. Using a momentum distribution just like the testbeam.

Relative Energy fraction vs Momentum(MC)

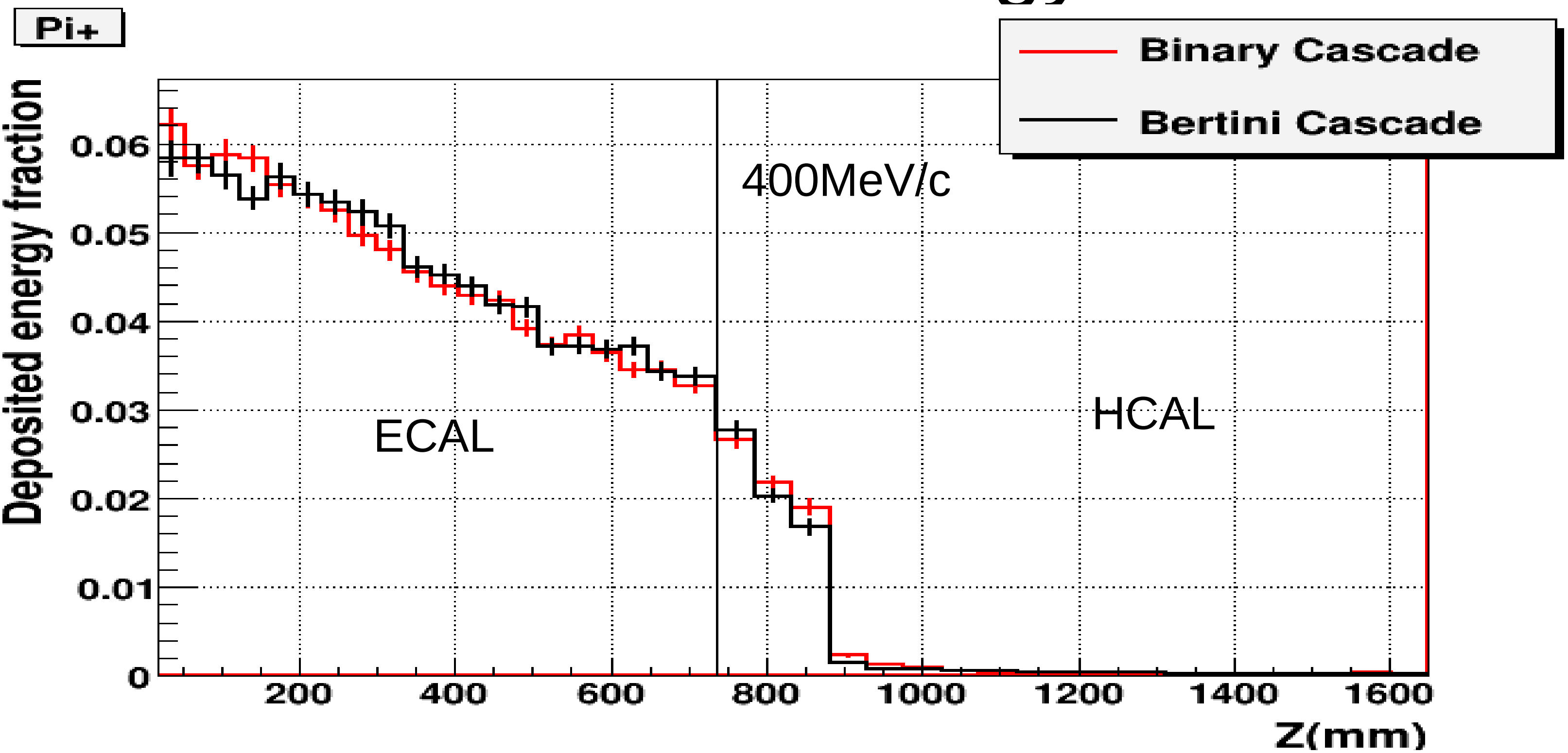


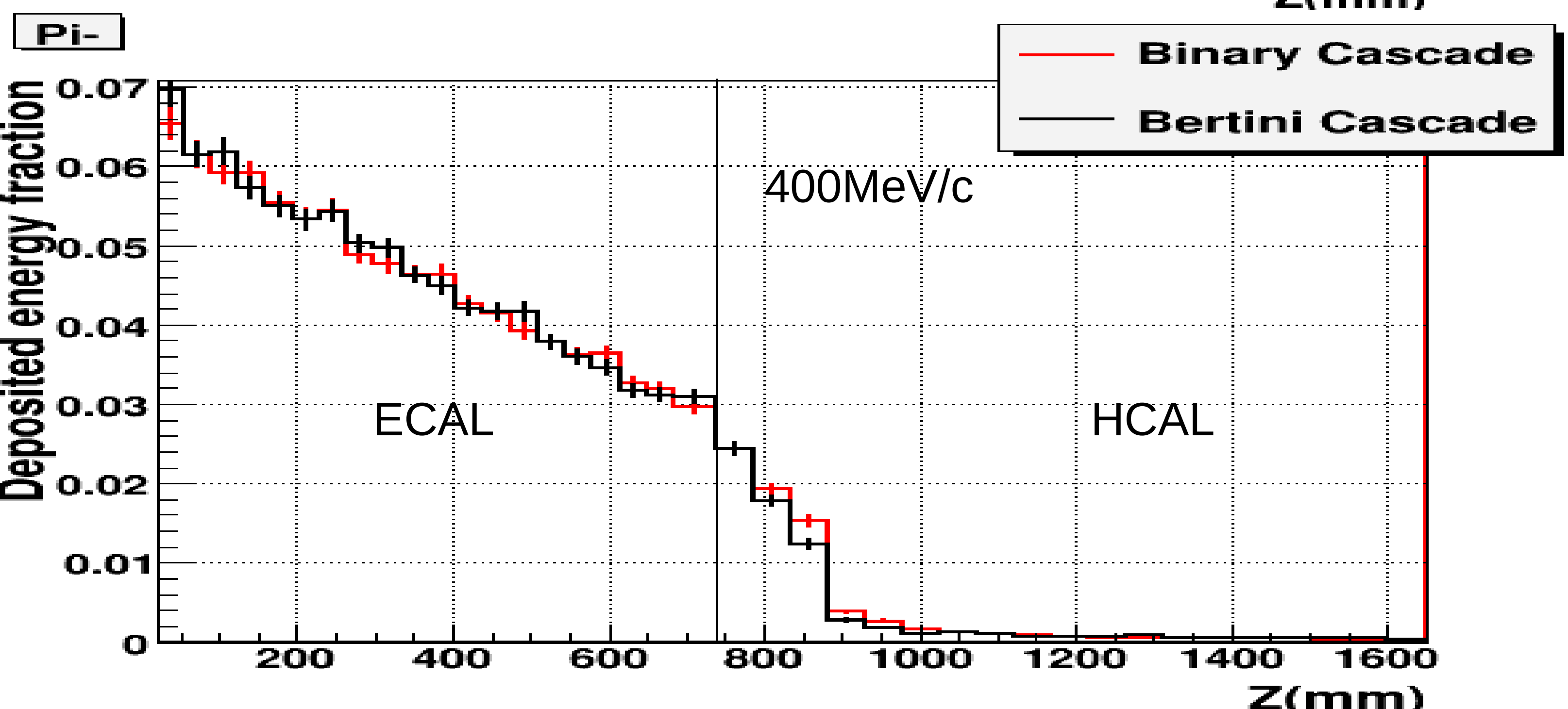


Deposited Energy Fraction per longitudinal position for the two models

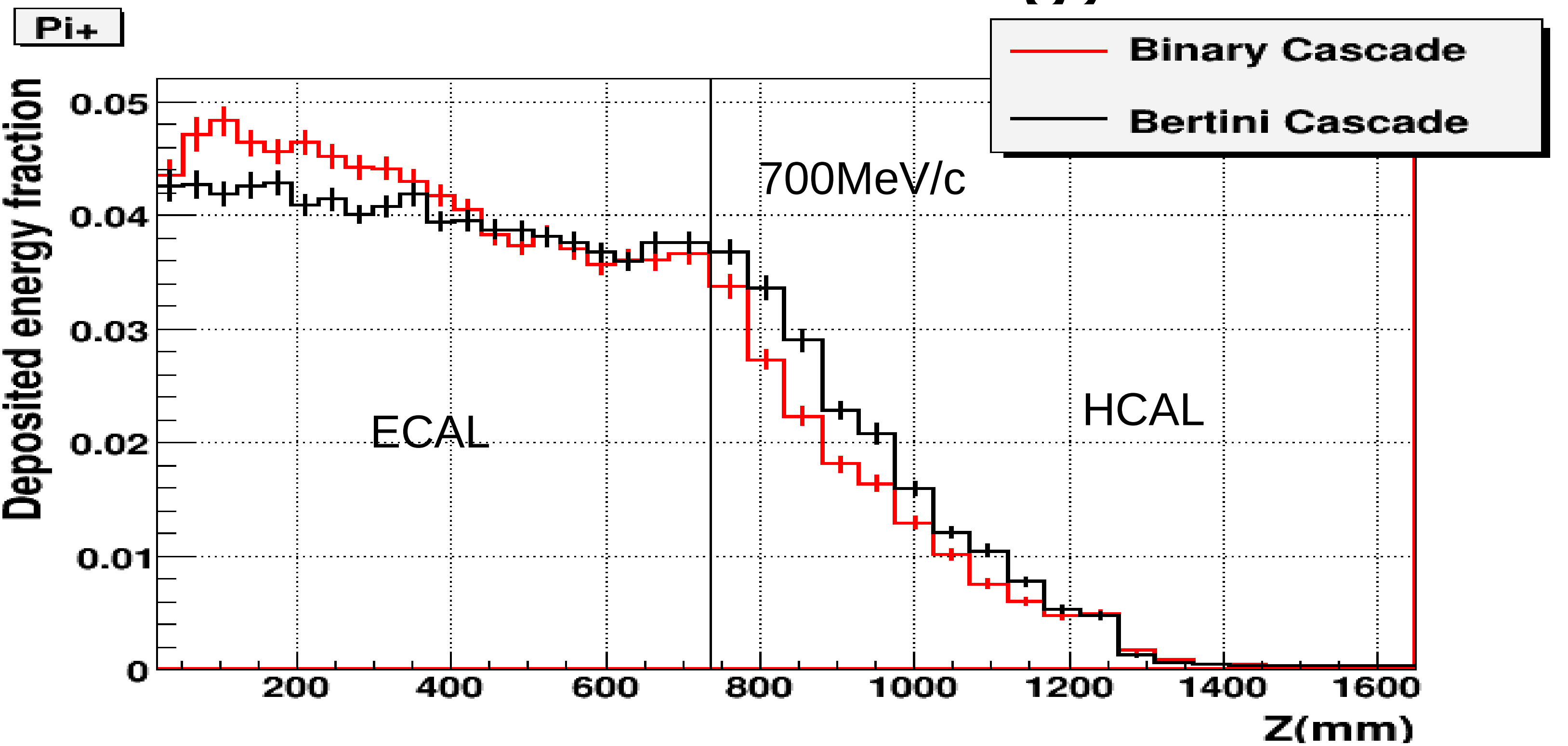
- Energy fraction deposited per module in each event: sum of deposited energy in each module per event divided by the total deposited energy in the detector per event.
- Analysis made for monoenergetic pion beams with energies covering the expected TestBeam spectrum: 400MeV, 700MeV, 1GeV, 1.2GeV.
- Calculation made for the two charged pions: $\pi^{\pm}$.
- Plots separated in two detector regions: ECAL and HCAL.

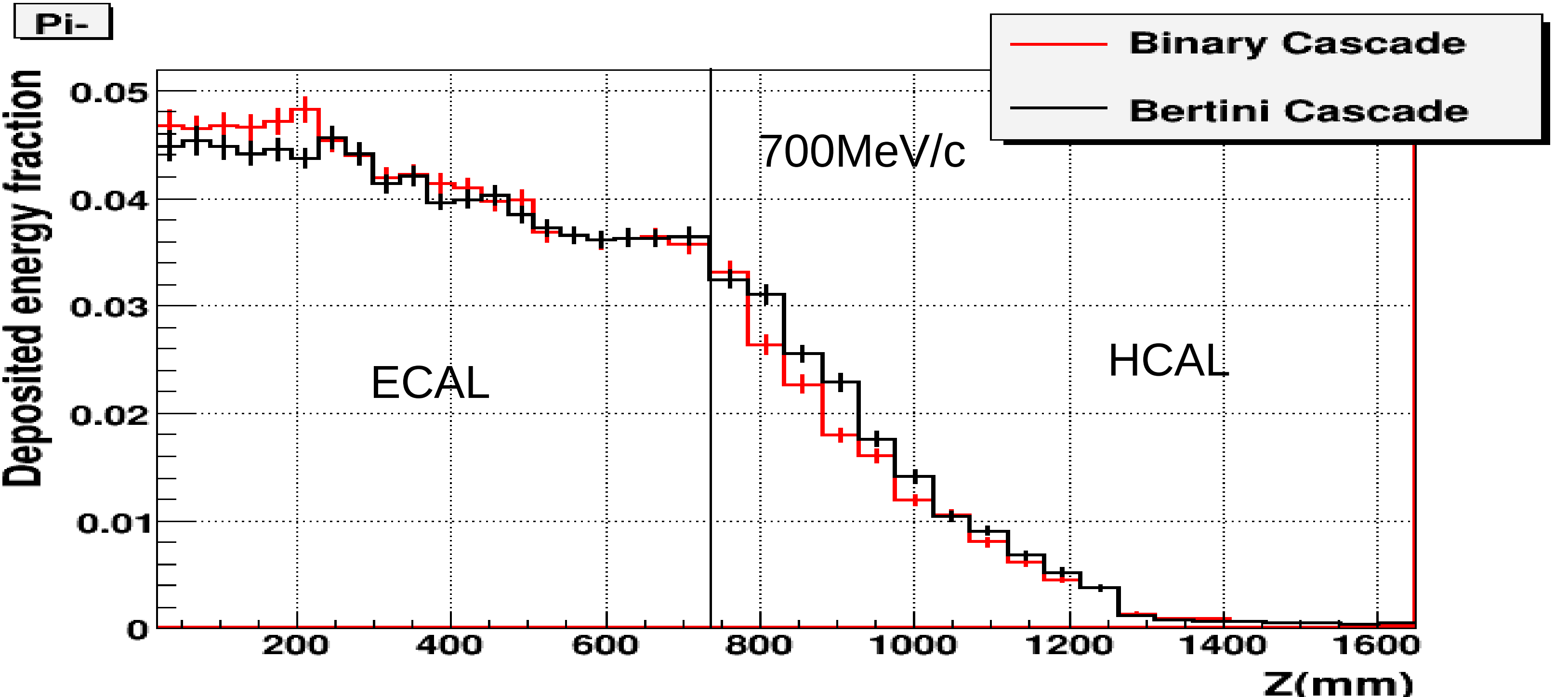
Reconstructed Energy fraction vs Z





Reconstructed Energy fraction vs Z





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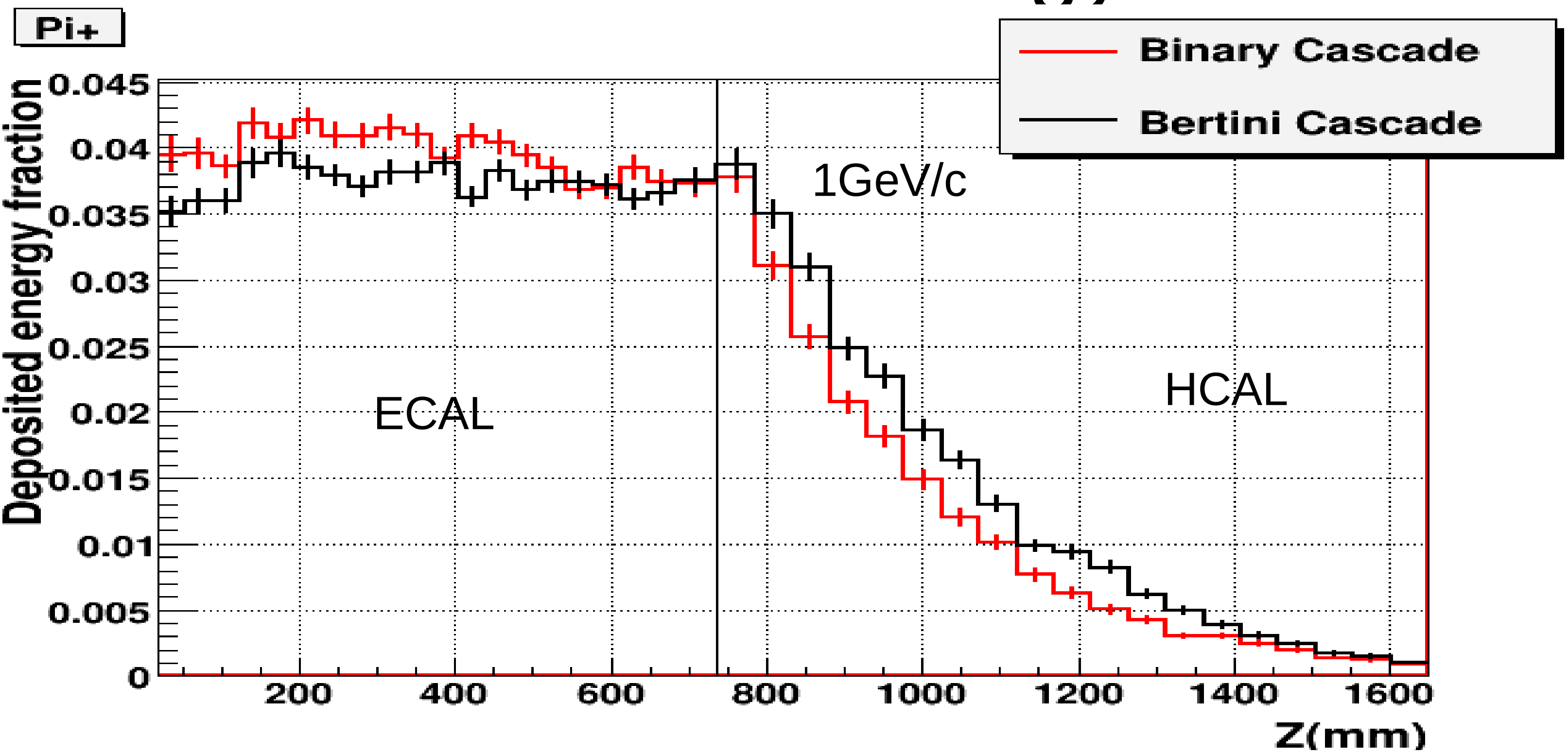
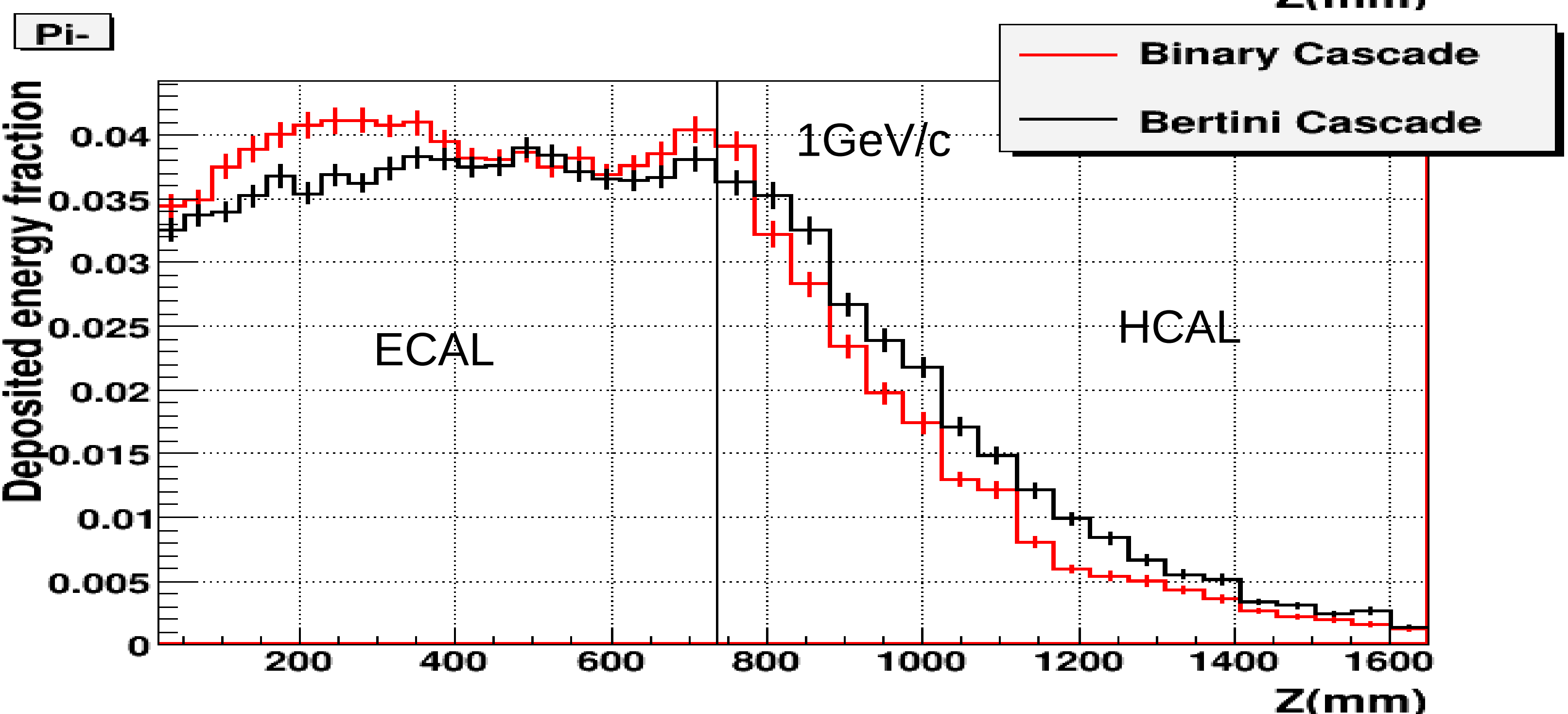
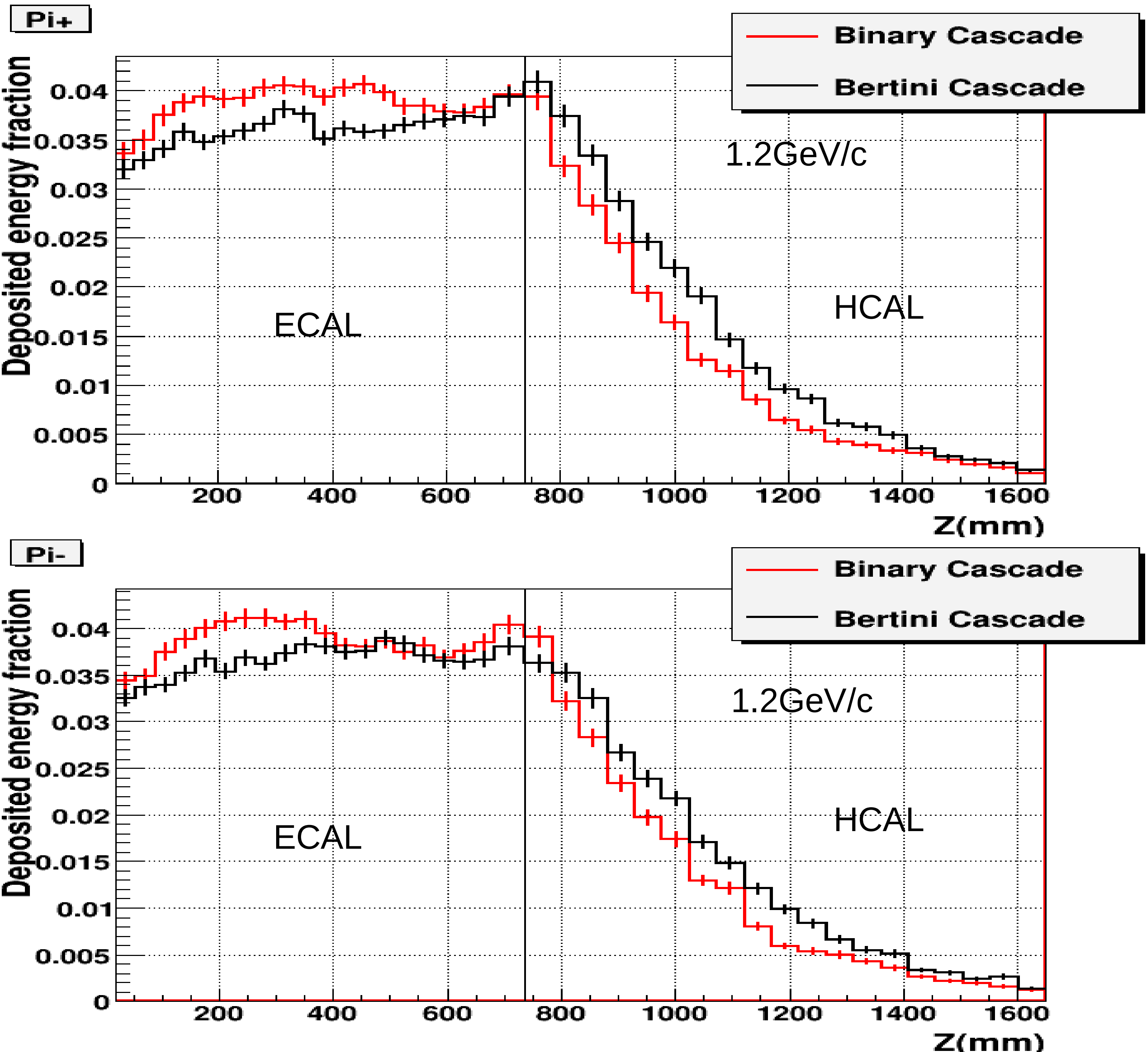


•As soon as the energy increases, hadronic physics shows up and differences between models are more obvious.



•Binary cascade model starts showering first and when it gets to the HCAL region has lost more energy than in the Bertini cascade model case.

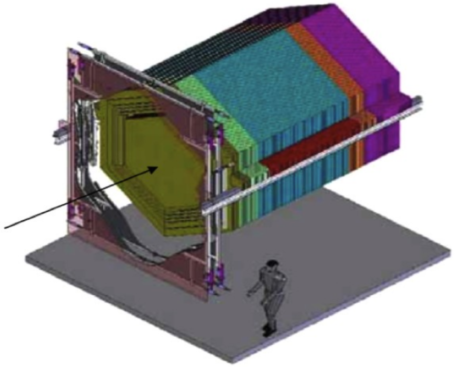
Reconstructed Energy fraction vs Z



Conclusions and Next Steps

- Above 700MeV differences between the two models in the longitudinal energy profile are visible.
- Still more variable to estimate(radial distribution and individual shower characterization) .
- Joining to the calibration efforts in the MINERνA TestBeam experiment in order to reach the main goal: validation.

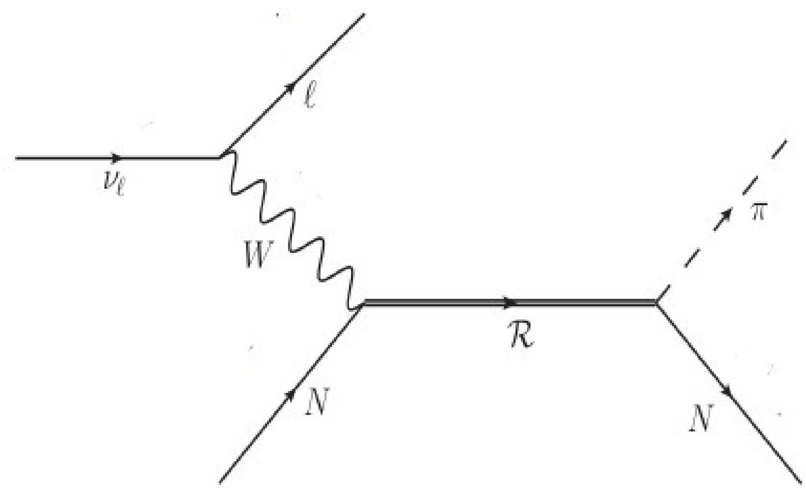
¡Gracias!



Backup Slides

Pions in Neutrino Interactions

- Resonant pion production:



- Coherent pion production: