Charged Pion Multiplicity Below 1.0 GeV/c from the MIPP Experiment

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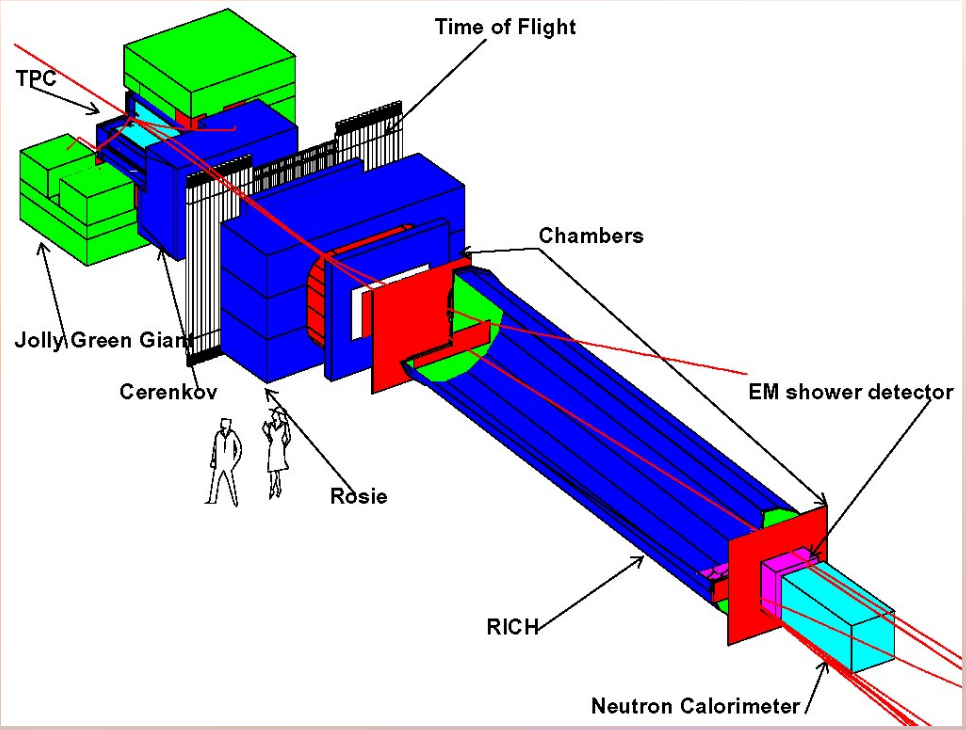
The Main Injector Particle Production (MIPP) Experiment

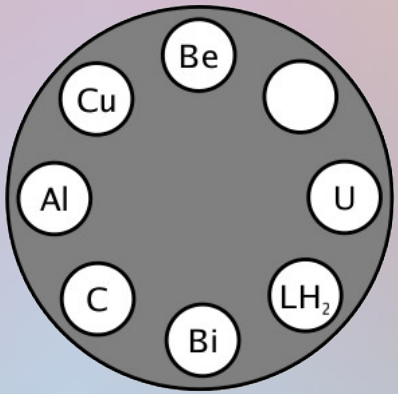
MIPP is a Fermilab experiment which had physics runs from January 2005 to February 2006.

Protons at 120 GeV/c were taken from the Main Injector and collided with a long copper target to produce secondary beams of 5 – 85 GeV/c $\pi^{\pm}$, $K^{\pm}$, and $p/\bar{p}$.

These were tagged by two beam Cherenkov counters, after which was positioned a wheel containing our experimental targets.



Downstream of the target there were a series of detectors which provided tracking and identification of produced particles.



Pion Multiplicity

The large range of targets and beam momenta allows us to use MIPP data to look at how certain quantities depend on these things.

For the current analysis, we use minimum-bias data to study interactions of 58 GeV/c $\pi^{\pm}$, $K^{\pm}$, and $p/\bar{p}$ beam particles with each of the targets to determine average pion multiplicities, which provides a measure of pion production and attenuation within these materials.

For one target, LH_2, we measure the same for two additional beam momenta, 20 and 85 GeV/c.

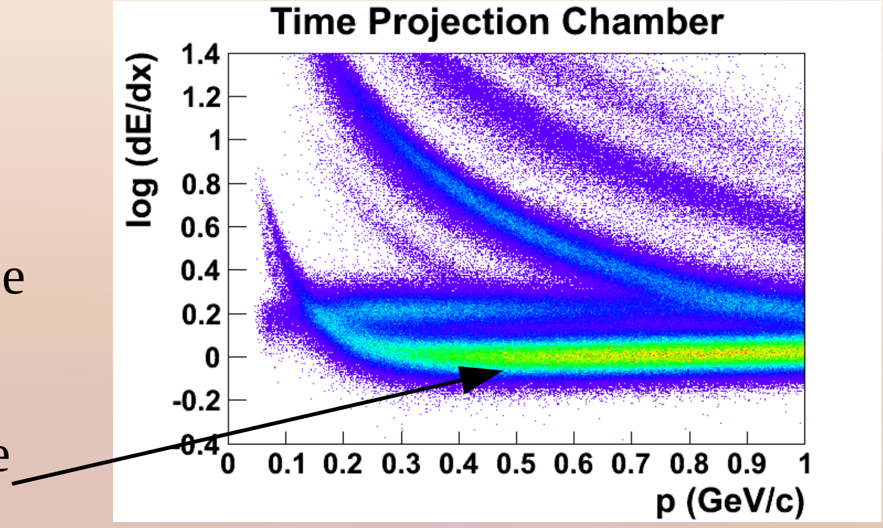
The low end of particle identification for MIPP is ~100 MeV/c, and from there, pions can be identified accurately up to 1.0 GeV/c with the TPC, so this is the range to which we restrict ourselves.

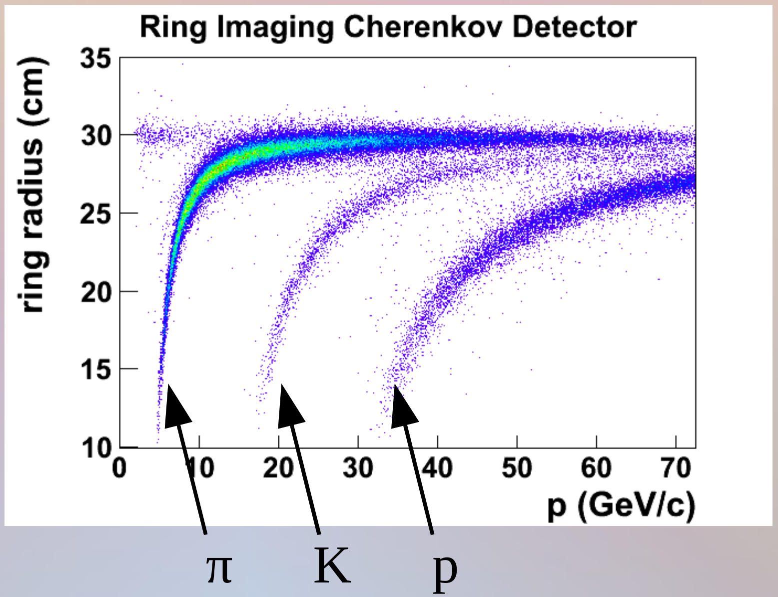
Particle Identification

Located directly downstream of the target, the TPC provides accurate tracking of produced particles in 3 dimensions.

Through the measurement of dE/dx, we also use the TPC for low momentum PID.

Pions can be identified up to ~1 GeV/c with the TPC.





Located farther downstream, the RICH provides PID of higher momentum particles by measuring the radius of the cone of Cherenkov light produced as they pass through.

We use this detector to identify uninteracted beam particles, in order to measure our beam purity.

Selection Cuts

A minimum-bias event is selected if:
 - there is no beam pileup (previous work has determined what the signals from our beam counters look like when there is pileup)

A vertex is selected if:
 - it has a reconstructed incoming track and at least two outgoing tracks
 - it is primary
 - the position is consistent with an interaction with the target

A track is selected if:
 - has enough hits in the TPC to be reasonably reconstructed
 - has a decent goodness-of-fit parameter

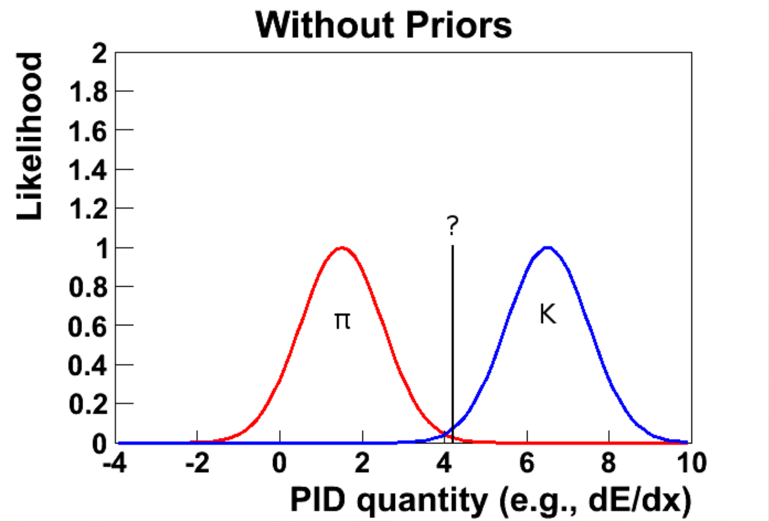
Global PID

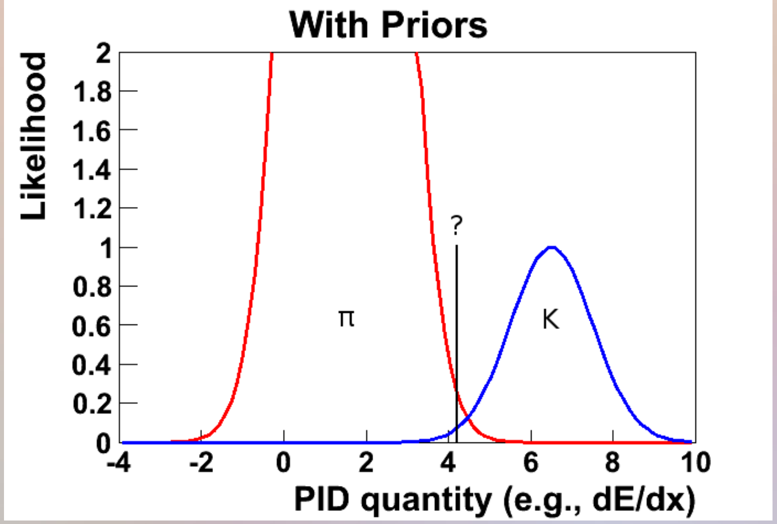
Global PID is an iterative method for PID based on Bayes' theorem.

How likely it is that a given particle is a pion depends not only on its dE/dx measurement, but also on the relative abundance of each species.

For each track, this algorithm determines weights for each particle hypothesis (for MIPP, e/π/K/p), not a definitive identification.

Thus, the pion weights for all tracks which pass cuts enter into this analysis.





Multiplicity Calculation

$$\langle M \rangle = \frac{1}{\varepsilon} \frac{\sum_i w_i - \frac{B}{B_b} \sum_i b_i}{N - \frac{B}{B_b} N_b}$$

w_i (b_i): pion weights for full (empty) target

N (N_b): events selected from full (empty) target data

B (B_b): minimum-bias triggers for full (empty) target

ε: acceptance

$$\varepsilon = \frac{\sum_i w_{reco,i}}{W_{truth}}$$

$w_{reco,i}$: pion weights from MC reconstruction

W_{truth}: number of true pions in MC

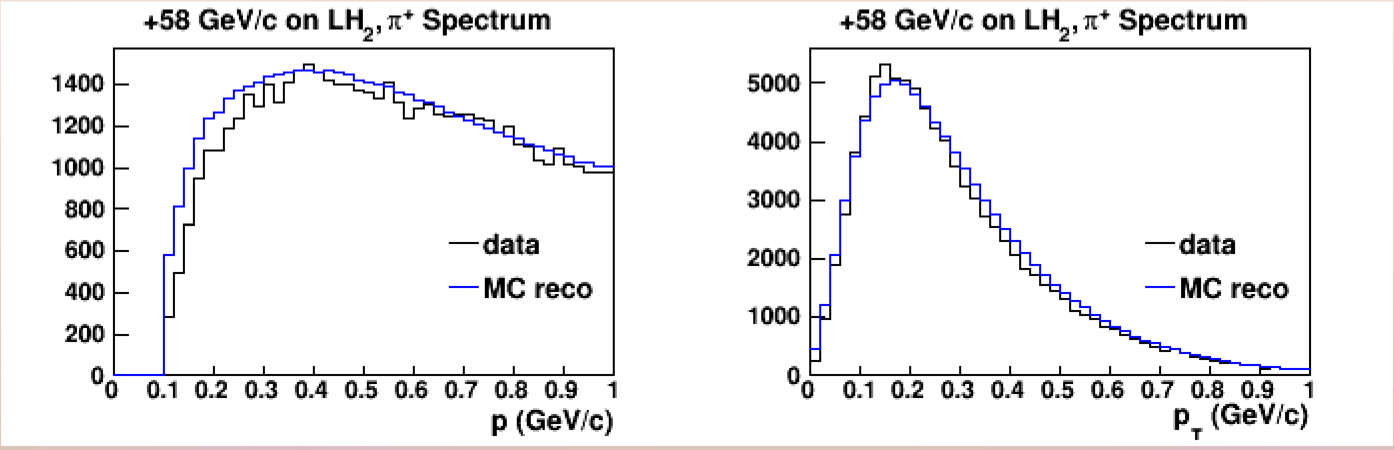
This number, ε, includes not only the geometric acceptance of the detector, but also other efficiencies (e.g., track-finding).

In all cases, it turns out to be ~70%.

How well do our MC and data agree?

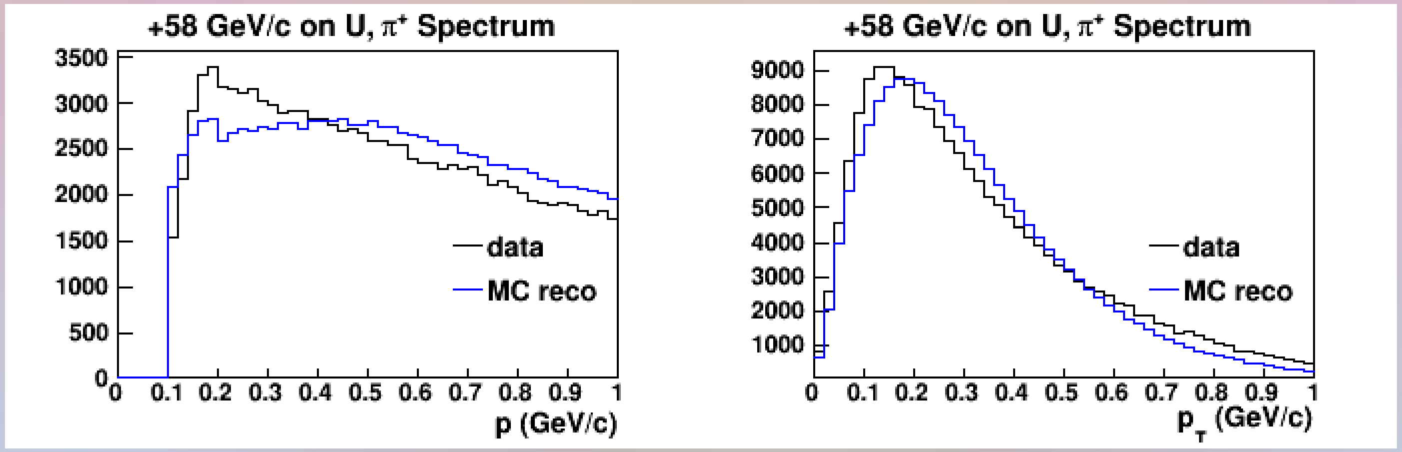
For light nuclei, the pion spectra agree quite well, ...

Example of Good Agreement

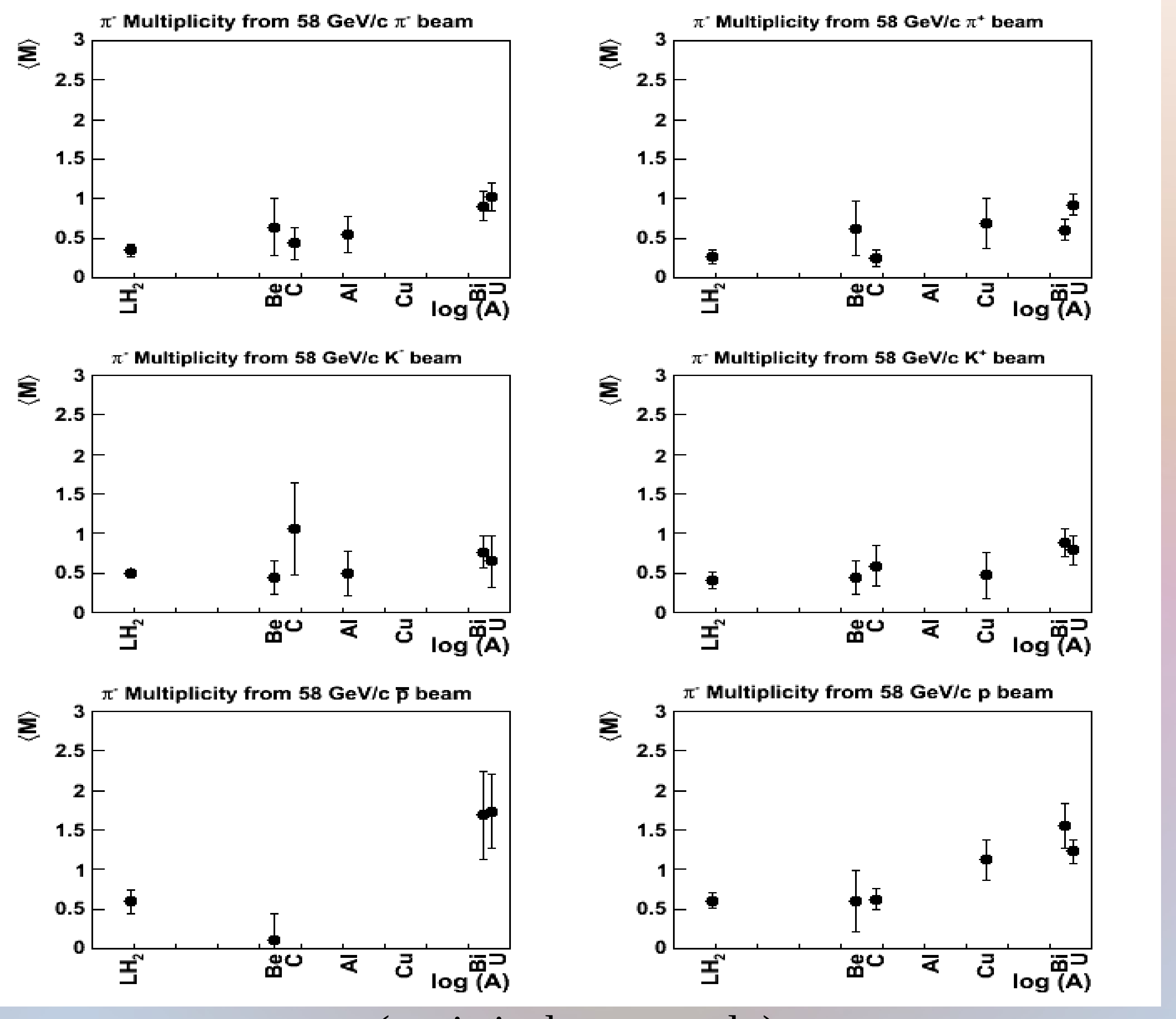


… but for heavier nuclei, there is somewhat more disagreement, so our systematic error may be larger.

Example of Not As Good Agreement

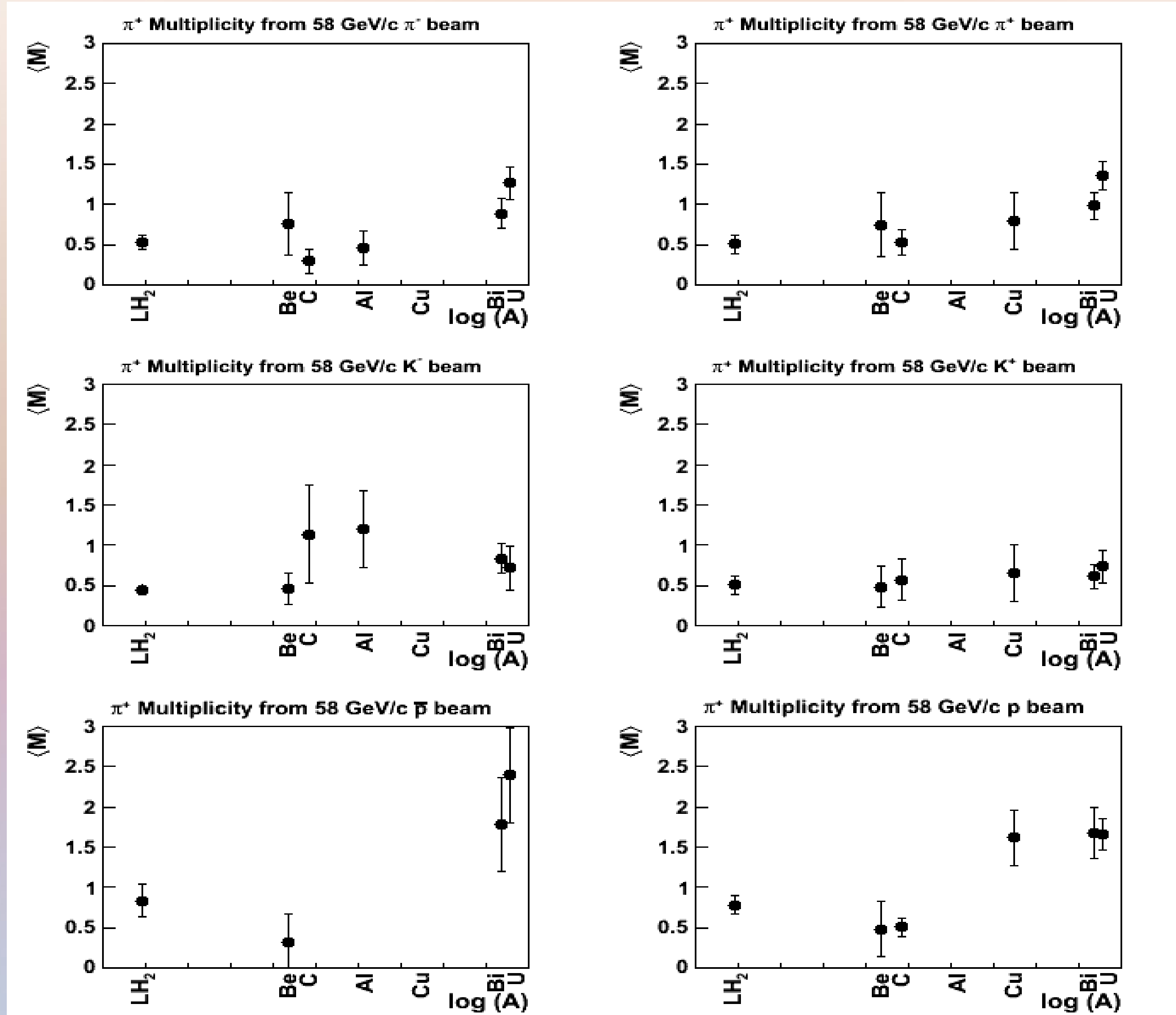


π^- Multiplicities versus log (A)



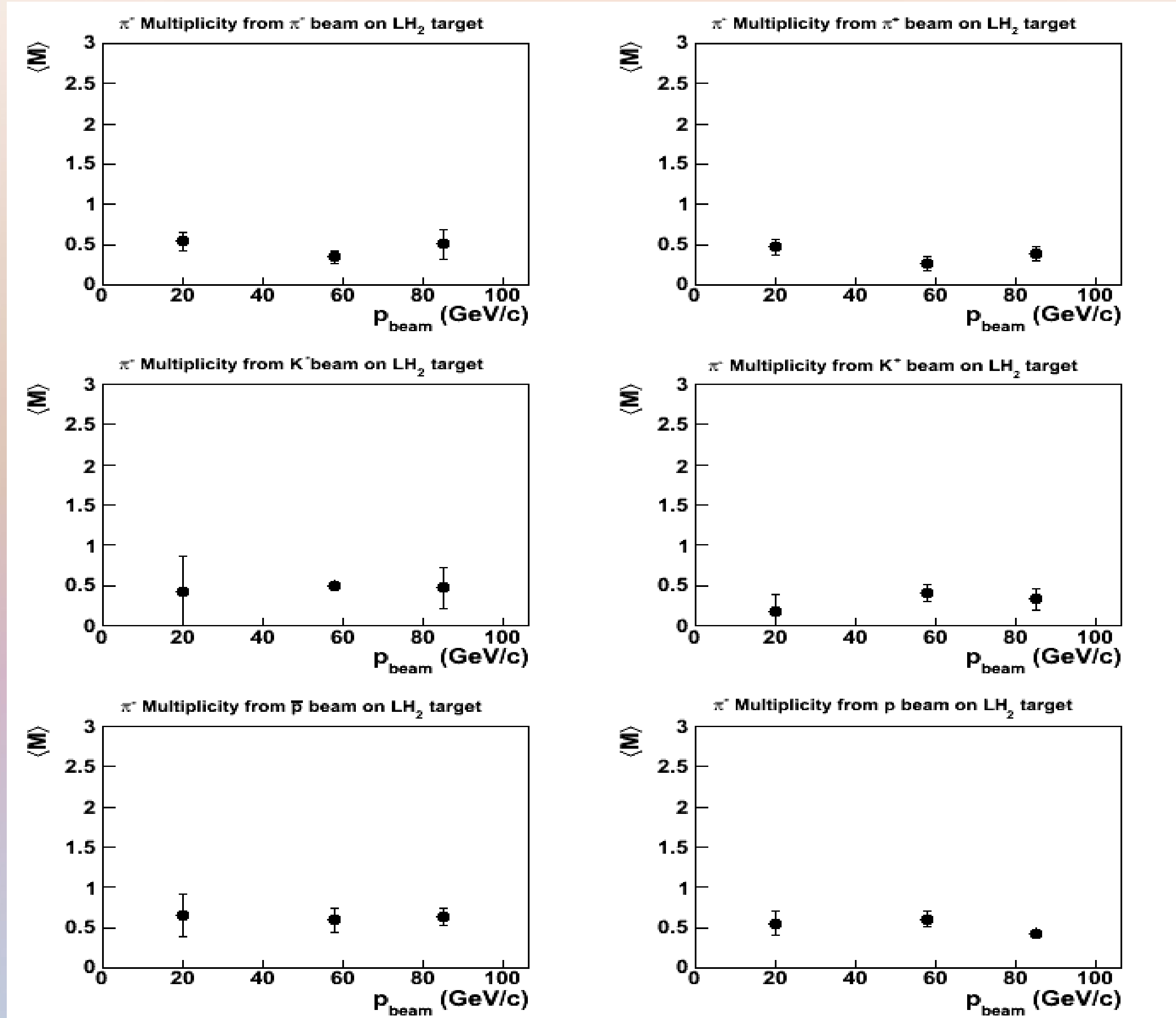
(statistical errors only)

π^+ Multiplicities versus log (A)



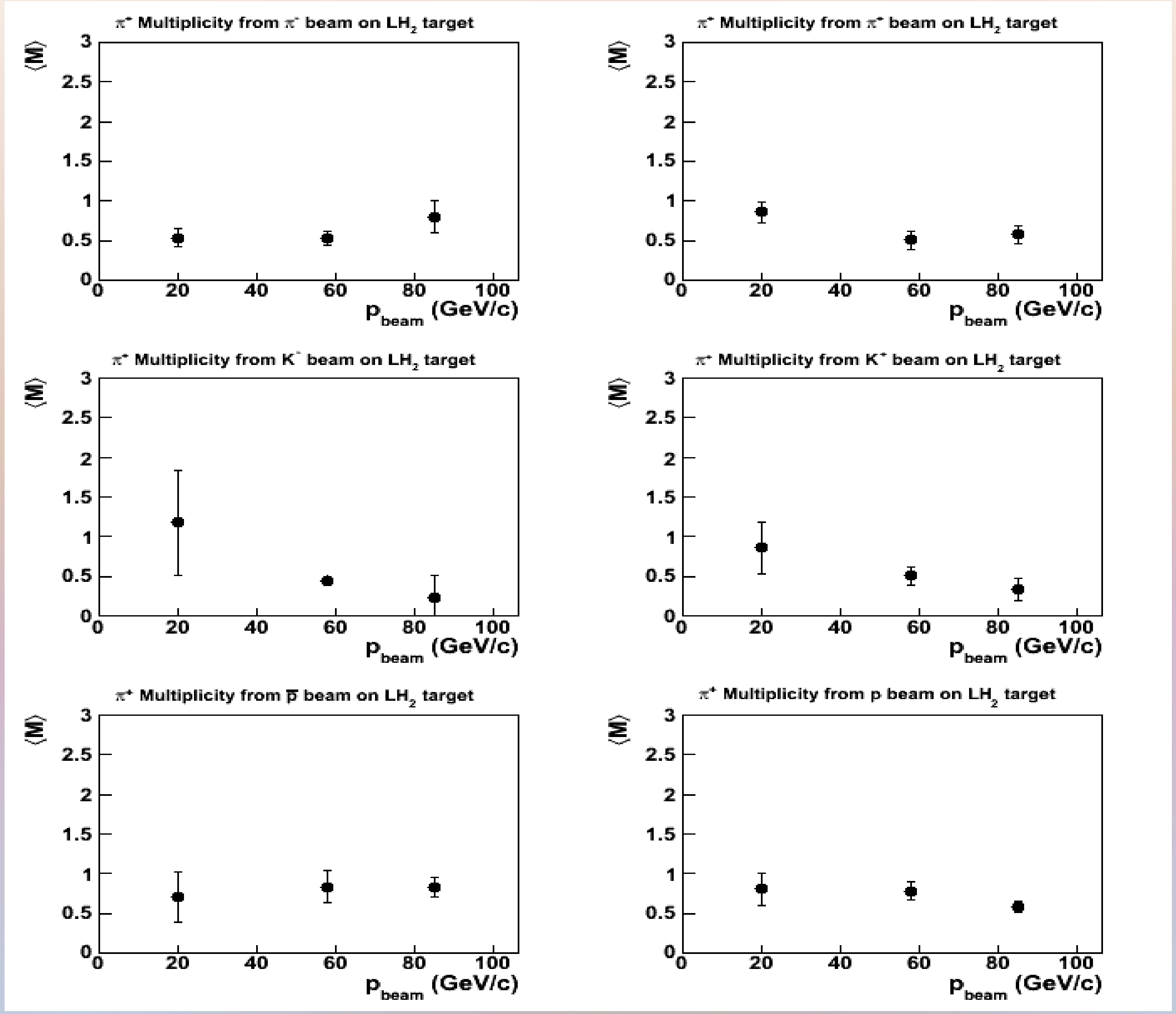
(statistical errors only)

π^- Multiplicities versus p_{beam}



(statistical errors only)

π^+ Multiplicities versus p_{beam}



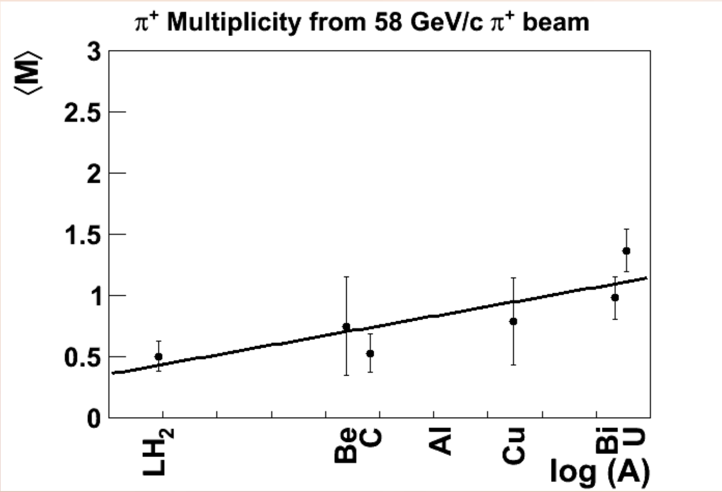
(statistical errors only)

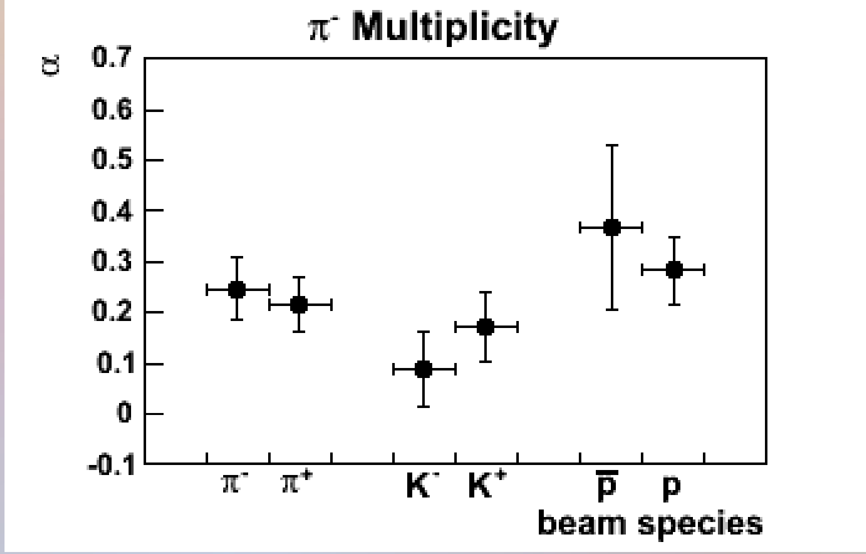
Power Law Fit

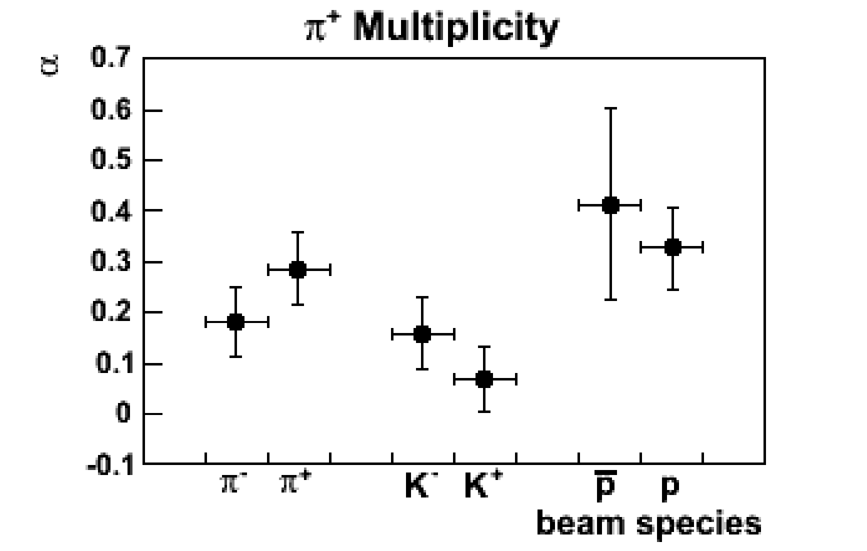
We can further quantify the dependence of our multiplicities on target atomic weight by fitting a power law to our numbers.

$$\langle M \rangle \propto A^{\alpha}$$

An example fit







Systematic Uncertainties

Work on systematic uncertainties is in progress...

Source of Uncertainty	Status
beam purity	affects multiplicities by ~0.03% on average
differences between MC and data	we will estimate by artificially reshaping MC spectra to match data
vertex cut (longitudinal direction)	we will estimate by redoing the analysis with different vertex selections

Summary

Using the wide range of beam momenta and targets in MIPP, we have calculated the dependence of low momentum pion multiplicity on target atomic weight and on beam momentum.

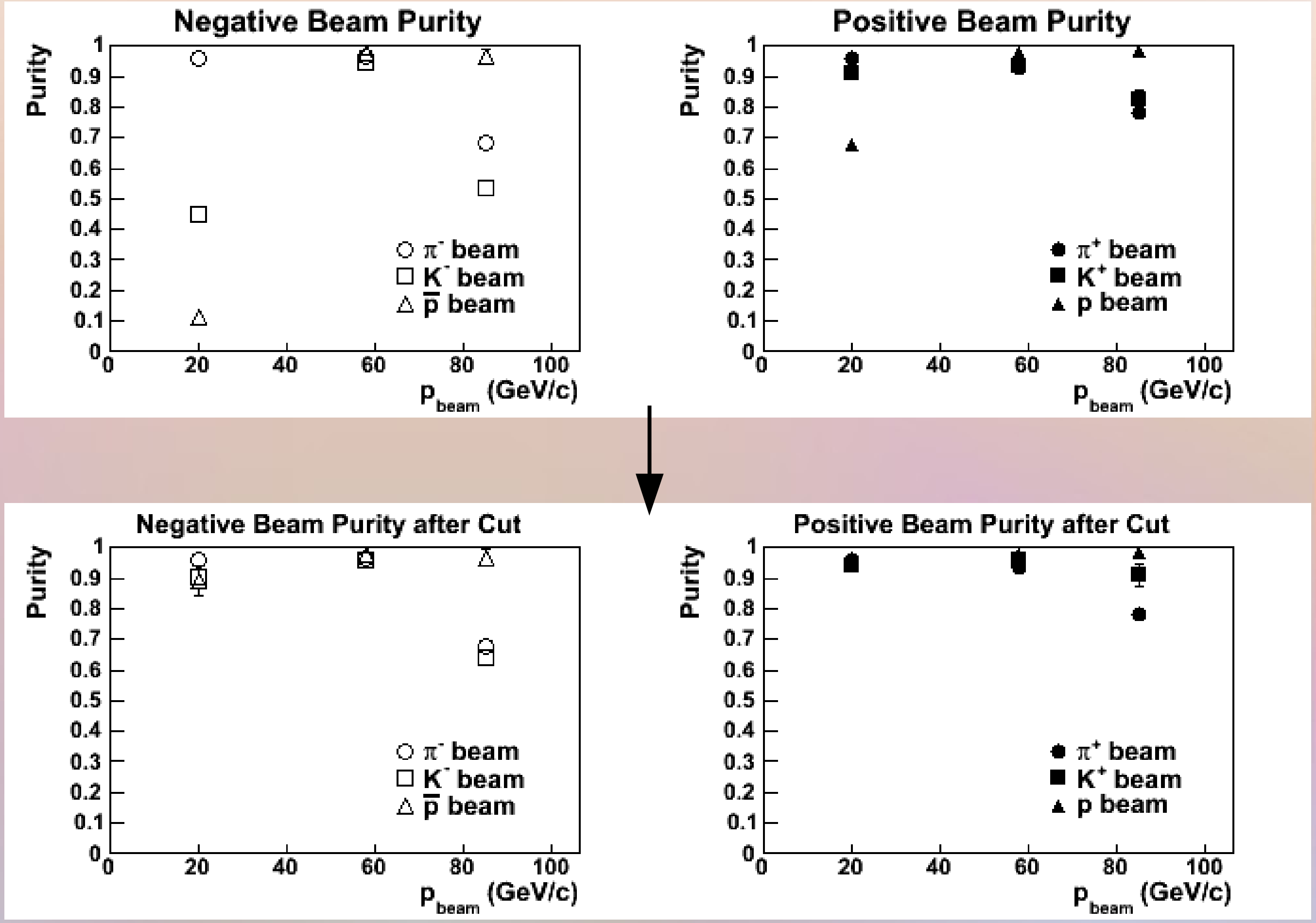
Additional work needs to be done on the systematics for this analysis; using minimum-bias data makes this a relatively easy task.

Backup Slides

Beam Purity

Beam purity is measured by using the RICH to identify uninteracted beam particles.

By cutting events offline for which the beam Cherenkov signals do not match with the PID that was recorded, we get significant improvements in purity.



Global PID – More Details

- Let H be a particle hypothesis (e, π, K, p) and let x be some PID quantity (e.g., dE/dx).

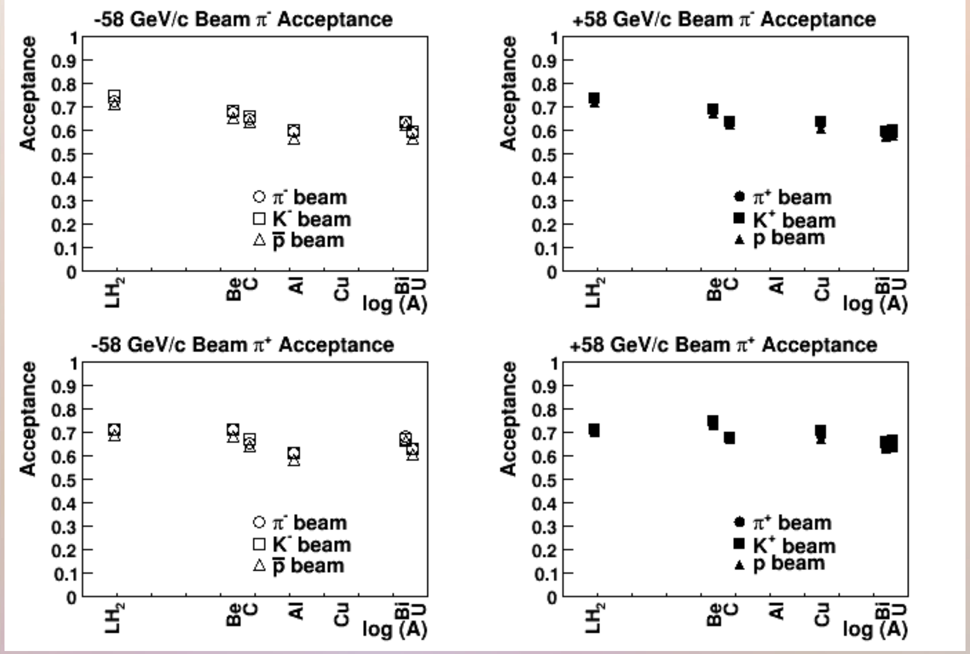
- From Bayes' theorem, the probability of a certain hypothesis H given some PID quantity x, i.e., the posterior probability, is

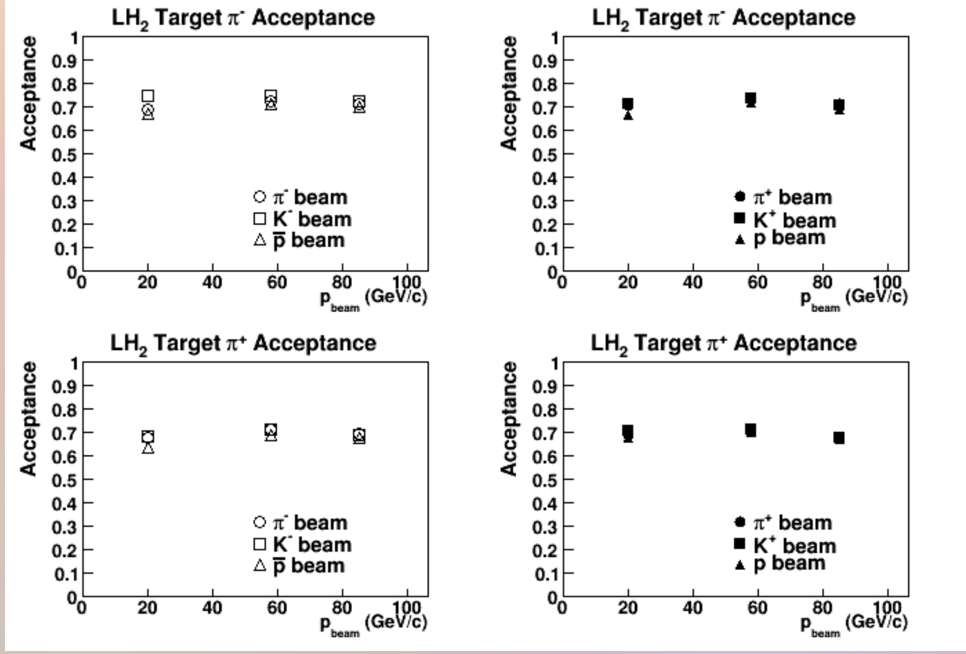
$$P(H|x)=\frac{P(x|H)P(H)}{P(x)}=\frac{P(x|H)P(H)}{\sum_i P(x|H_i)P(H_i)}$$

which is used to weight each track.

- But how do we determine the prior probability P(H)? We do so iteratively, starting with P(H) equal for each hypothesis. Then P(H|x) is calculated and fed into the next iteration as P(H). This continues until convergence.

Acceptance


-58 GeV/c Beam π⁻ Acceptance
+58 GeV/c Beam π⁻ Acceptance
-58 GeV/c Beam π⁺ Acceptance
+58 GeV/c Beam π⁺ Acceptance
Acceptance
log (A)
LH2
Be
C
Al
Cu
Bi
U
π⁻ beam
K⁻ beam
p̄ beam
π⁺ beam
K⁺ beam
p beam


LH2 Target π⁻ Acceptance
LH2 Target π⁺ Acceptance
Acceptance
p beam (GeV/c)
π⁻ beam
K⁻ beam
p̄ beam
π⁺ beam
K⁺ beam
p beam