The Main Injector Particle Production Experiment (MIPP) at Fermilab

Holger Meyer
Fermilab

Joint Meeting of Pacific Region Particle Physics Communities
(DPF2006+JPS2006...)
October 29 – November 3, 2006
Sheraton Waikiki Hotel, Honolulu, Hawaii

MIPP Collaboration

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Outline

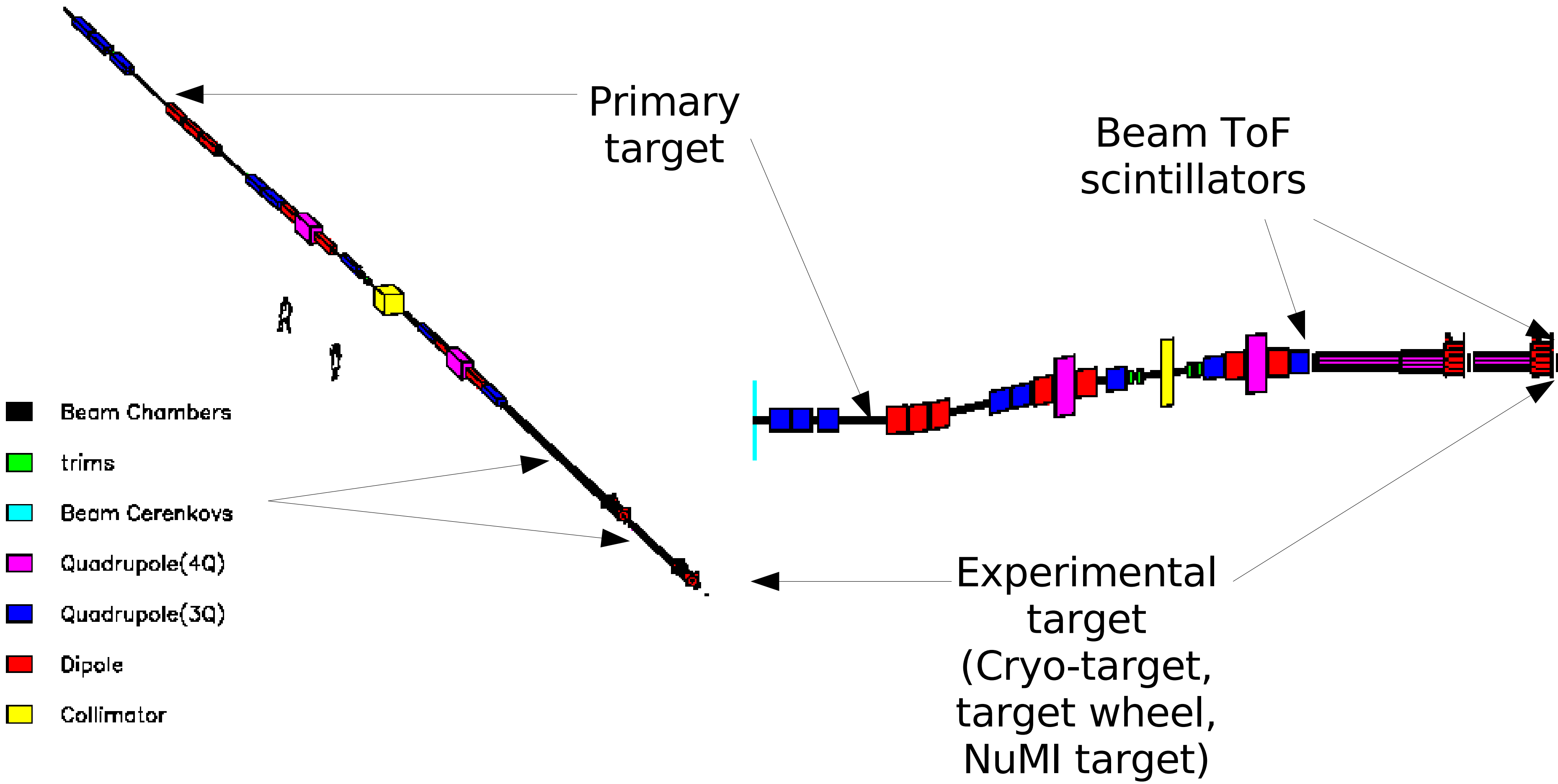
- Overview of the Experiment
  - Beam & detector
  - Data reconstruction & analysis
- Physics Motivation
  - QCD
  - Spectroscopy
  - Nuclear physics
  - Service measurements
    - neutrino experiments
    - hadron shower simulation
- MIPP Upgrade

Brief Description of Experiment

- Approved November 2001
- Situated in Meson Center 7, Fermilab Fixed Target
- Uses 120 GeV Main Injector Primary protons to produce secondary beams of $\pi^{\pm}$, $K^{\pm}$, $p^{\pm}$ from 5 GeV/c to 85 GeV/c to measure particle production cross sections of various nuclei including hydrogen.
- Using a TPC we measure momenta of ~all charged particles produced in the interaction and identify the charged particles in the final state using a combination of dE/dx, ToF, differential Cherenkov and RICH technologies.
- Open Geometry - Lower systematics. TPC gives high statistics.
- First Physics run - 18 million events in Jan 2005 to Feb 2006.
- Detector upgrade for next run
  - faster readout, much more data

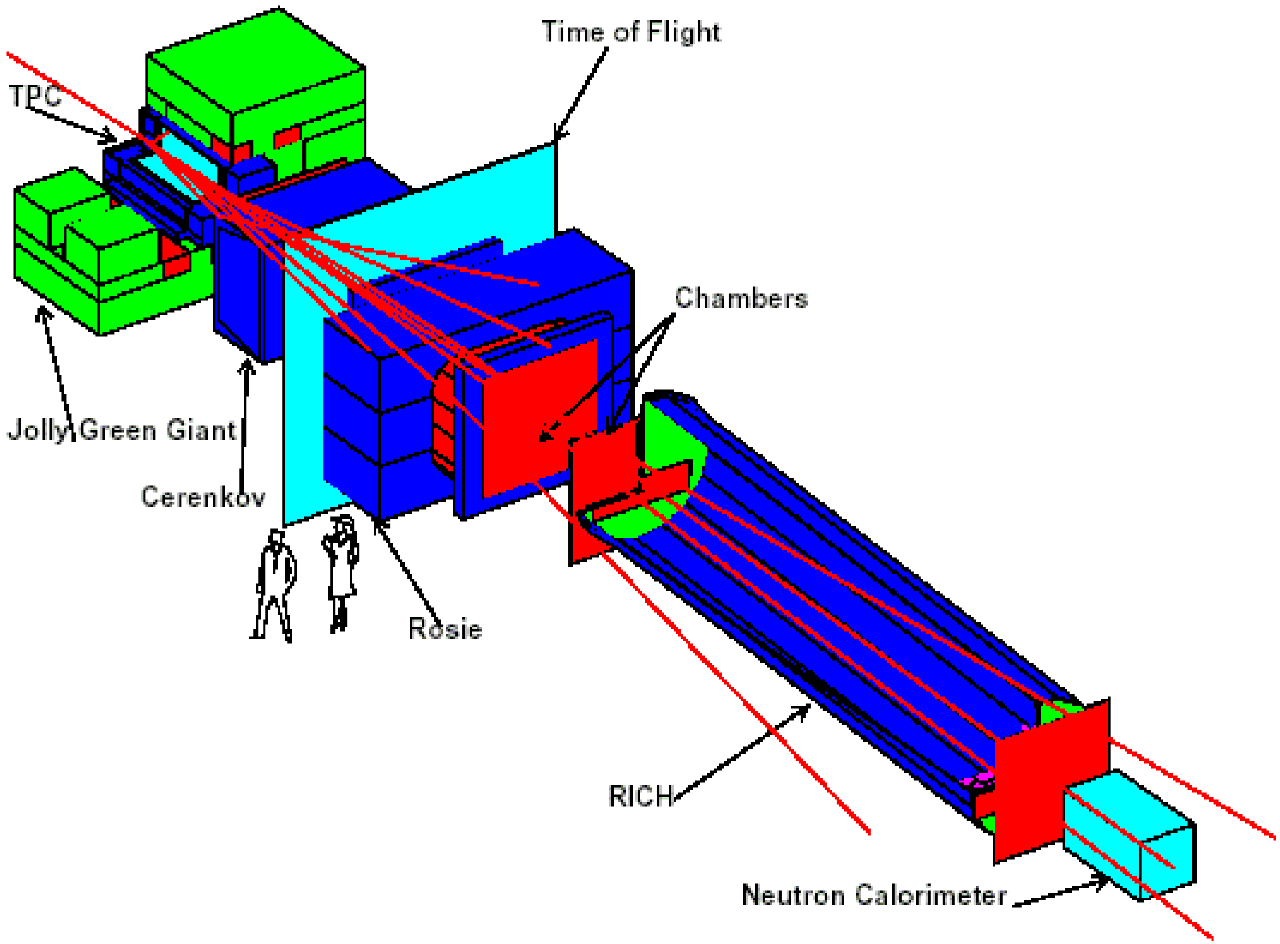
MIPP Secondary Beam

Excellent performance. Successfully ran 5-85 GeV/c secondaries and 120 GeV/c primary protons. Excellent particle ID capabilities using 2 Beam Cherenkovs. Also use ToF for low momenta. 95 meters long.



MIPP

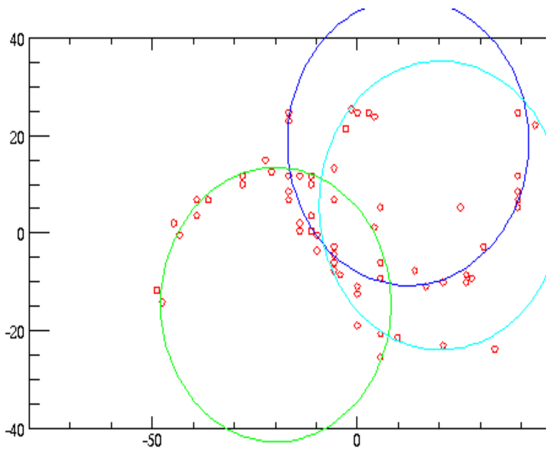
Main Injector Particle Production Experiment (FNAL-E907)



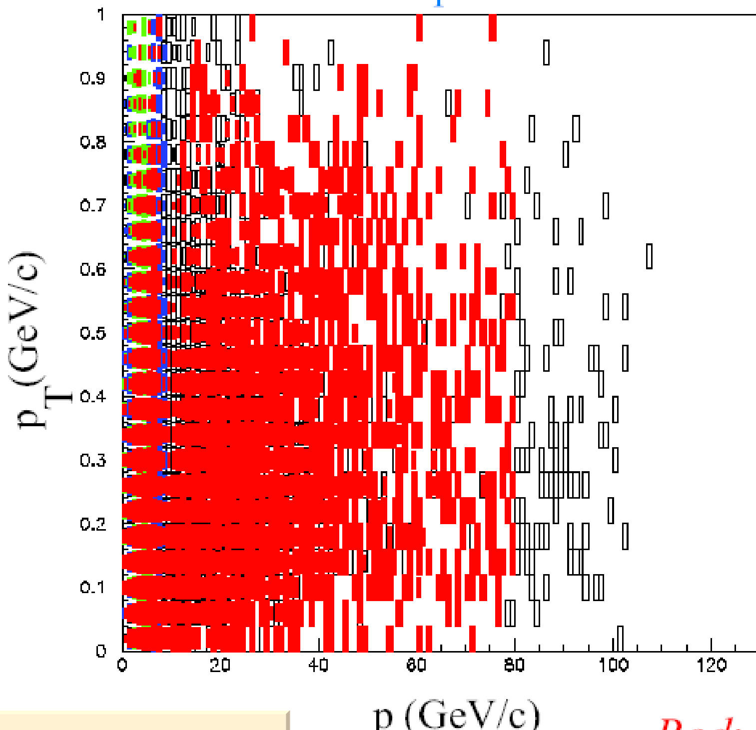
MIPP Data Set

Data Summary 27 February 2006			Acquired Data by Target and Beam Energy Number of events, x 10^6									
Target			**E**									**Total**
Z	**Element**	**Trigger Mix**	**5**	**20**	**35**	**40**	**55**	**60**	**65**	**85**	**120**	
0	**Empty**[1]	**Normal**		*0.10*	*0.14*			*0.52*			*0.25*	***1.01***
	***K* Mass**[2]	**No Int.**				*5.48*	*0.50*	*7.39*	*0.96*			***14.33***
	Empty LH[1]	**Normal**		*0.30*				*0.61*		*0.31*		**7.08**
1	**LH**	**Normal**	[illegible]	**1.94**				**1.98**		**1.73**		
4	**Be**	***p* only**									[illegible]	**1.75**
		Normal			[illegible]			[illegible]				
6	**C**	**Mixed**						**0.21**				**1.33**
	C 2%	**Mixed**		**0.39**				**0.26**			**0.47**	
	NuMI	***p* only**									**1.78**	**1.78**
13	**Al**	**Normal**			*0.10*							***0.10***
83	**Bi**	***p* only**									[illegible]	**2.83**
		Normal			[illegible]			[illegible]				
92	**U**	**Normal**						[illegible]				**1.18**
Total			**0.21**	**2.73**	**0.86**	**5.48**	**0.50**	**13.97**	**0.96**	**2.04**	**4.63**	**31.38**

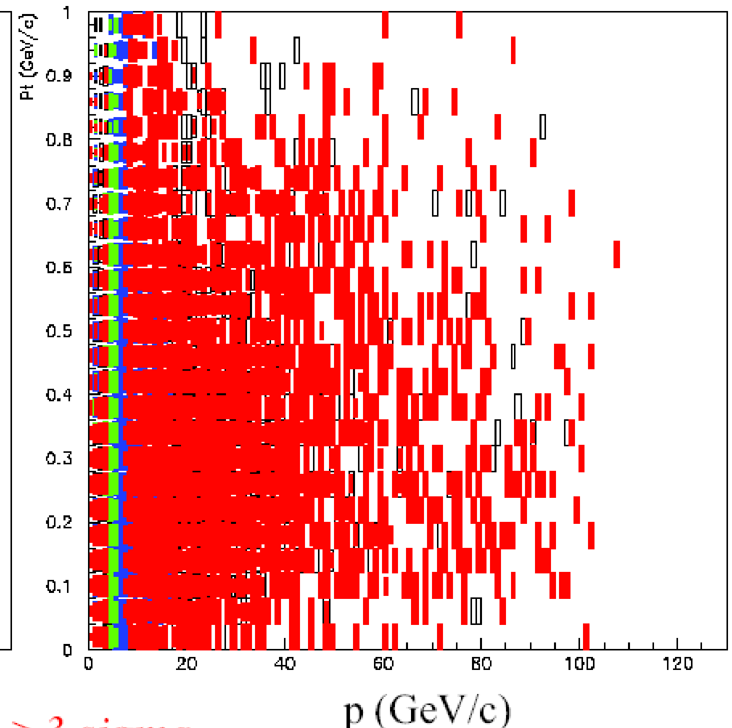
Particle ID Performance



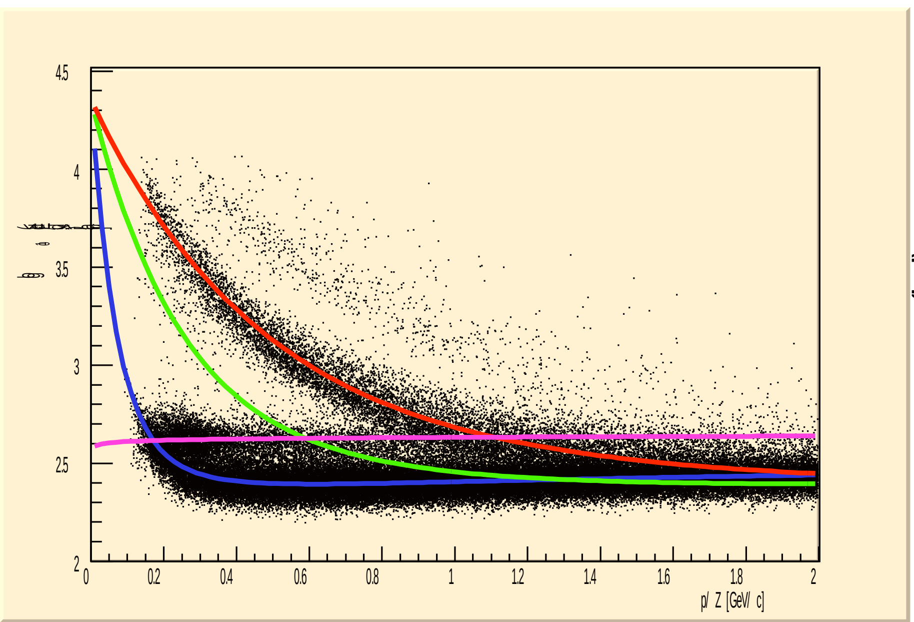
π/K separation

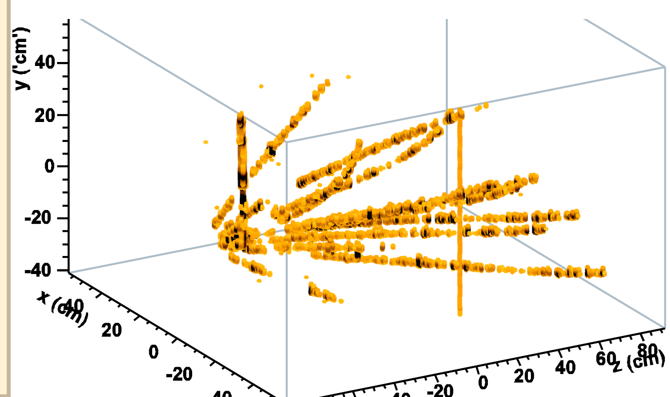


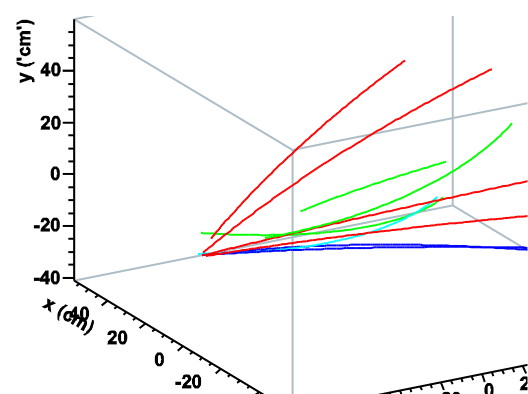
K/p separation



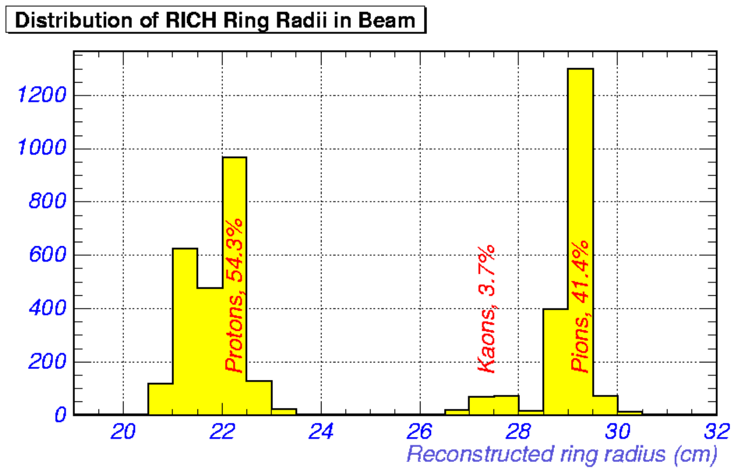
Red: >3 sigma
Green: 2-3 sigma
Blue: 1-2 sigma
White: <1 sigma

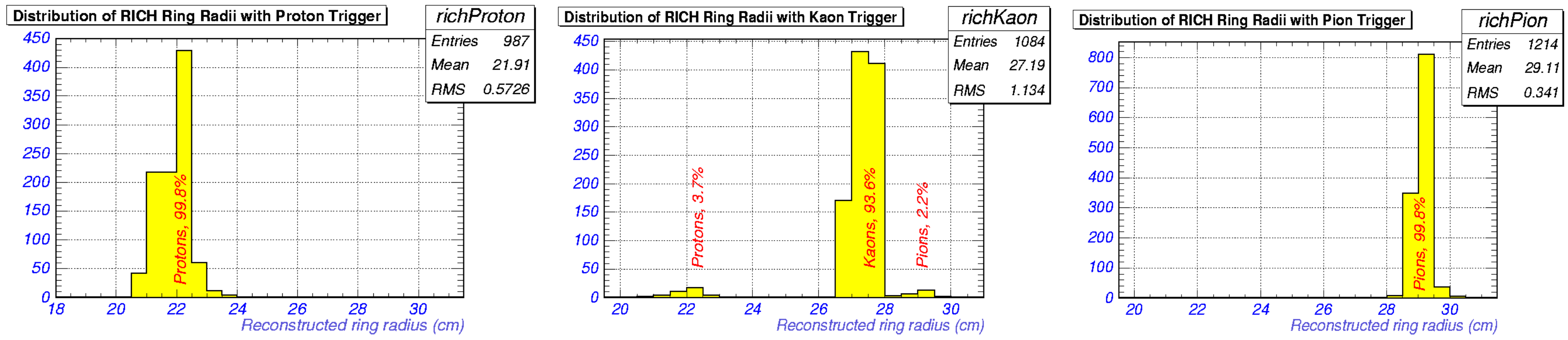




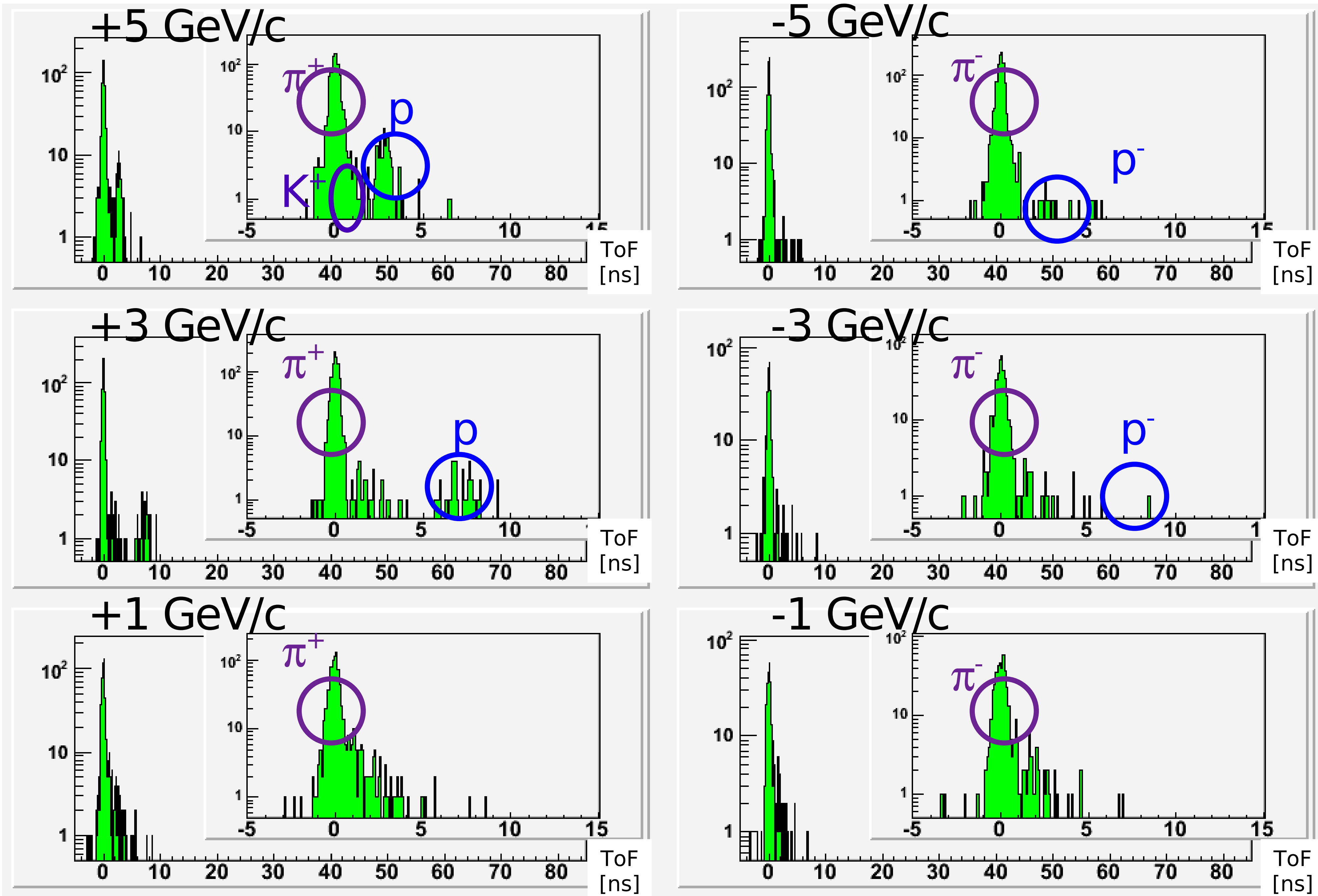


Comparing Beam Cherenkov to RICH for +40 GeV/c beam triggers - No additional cuts!





MIPP beam at low momentum



MIPP Reconstruction Status

- Done: (8 months since end of run)
  - Low level calibrations
  - B-field mapping, ExB corrections in TPC
  - Track reconstruction, Hit association
  - Track based detector alignment
  - RICH ring fits
  - Vertexing
  - Full detector Monte Carlo
- Further improvements: (soon)
  - Kalman, refined PID

MIPP Physics Overview

- Particle Physics
  - Non-perturbative QCD hadron dynamics, Particle fragmentation scaling laws
  - Spectroscopy - Missing baryon resonances, ...
- Nuclear physics
  - Y-scaling (Measure cross sections of hadrons on nucleons *in the nuclear medium.*)
  - Propagation of strangeness through nuclei
- Service measurements
  - Hadron Shower Models in Geant4, MARS,...
  - Neutrino production (NuMI, atmospheric, ν-factory)
  - Proton radiography, stockpile stewardship, national security applications

Missing Baryon Resonances

- Partial wave analyses of πN scattering have yielded some of the most reliable information of masses, total widths and πN branching fractions. In order to determine couplings to other channels, it is necessary to study inelastics such as

$$\pi^- p \to \eta n \qquad \pi^- p \to \pi^+ \pi^- n \qquad \pi^- p \to K \Lambda$$

$$\gamma p \to \pi^0 p \qquad \gamma p \to \pi^+ \pi^- p \qquad \gamma p \to K^+ \Lambda$$

- All of the known baryon resonances can be described by quark-diquark states. Quark models predict a much richer spectrum. Where are the missing resonances? F.Wilczek, A. Selem
- "..this could form the quantitative foundation for an effective theory of hadrons based on flux tubes"– F.Wilczek

Why non-perturbative QCD?

- It is not understood.
  - >99% of the total QCD cross section is non-perturbative. We cannot calculate these cross sections. Perturbative QCD has made impressive progress. But it relies on structure functions, which are non-perturbative and derived from data.
  - Feynman scaling, KNO scaling, rapidity plateaus are all violated. Regge theory is in fact phenomenology with flexible predictions that can be altered by adding more trajectories.
- Existing data are sparse, low statistics, poor particle id
- MIPP will publish its data set
  - Test your own theory

General Scaling Law of Particle Fragmentation

- States that the ratio of a semi-inclusive cross section to an inclusive cross section

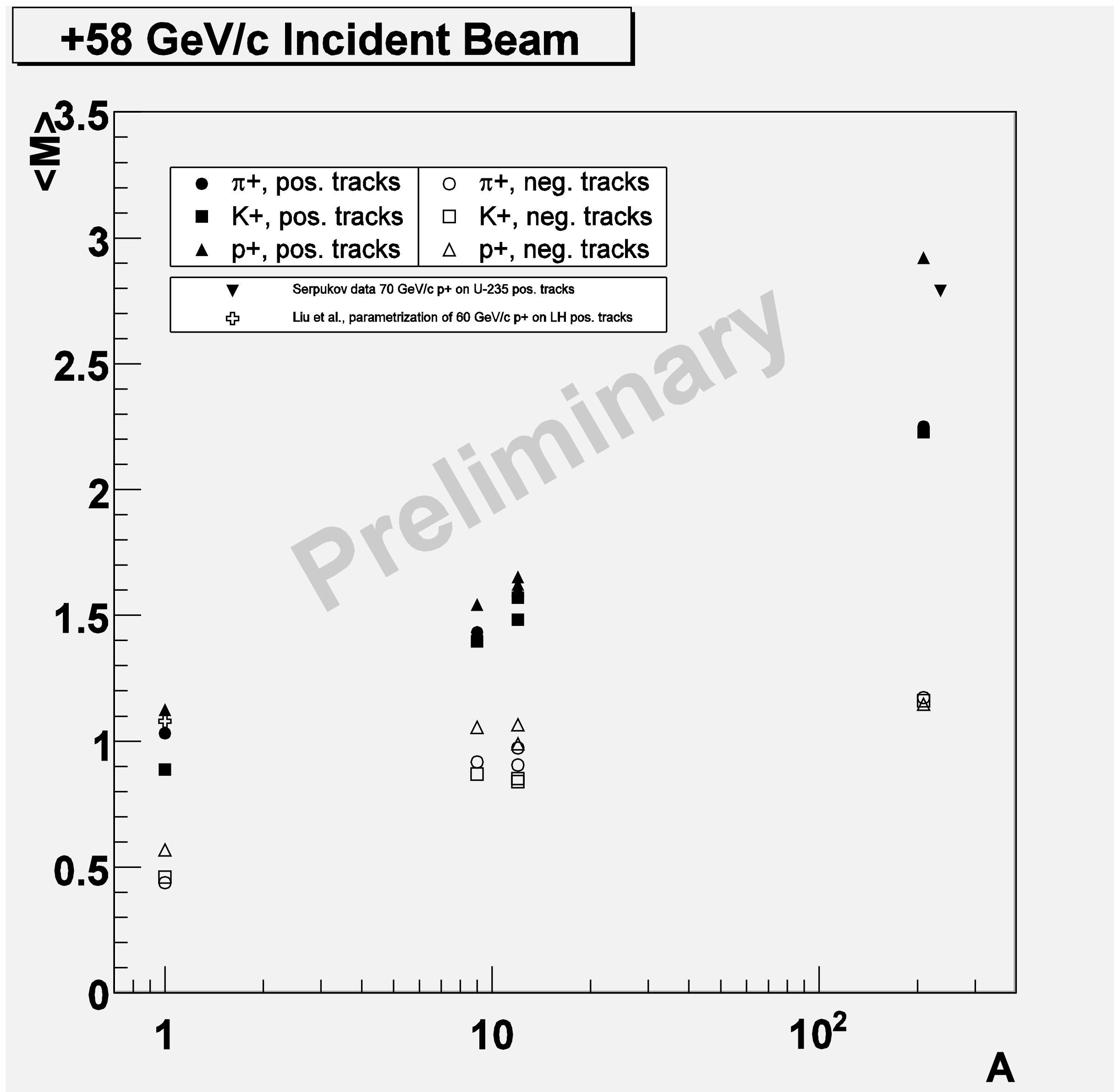
$$\frac{f\left(a+b\rightarrow c+X_{subset}\right)}{f\left(a+b\rightarrow c+X\right)} \equiv \frac{f_{subset}\left(M^2,s,t\right)}{f\left(M^2,s,t\right)} = \beta_{subset}\left(M^2\right)$$

- where M^2,s and t are the Mandelstam variables for the missing mass squared, CMS energy squared and the momentum transfer squared between the particles a and c. PRD18(1978)204.
- Using EHS data, we have tested and verified the law in 12 reactions (DPF92) but only at fixed s.
- MIPP will test this in 36 reactions. MIPP upgrade can extend these scaling relation tests to two particle inclusive reactions which requires more statistics.

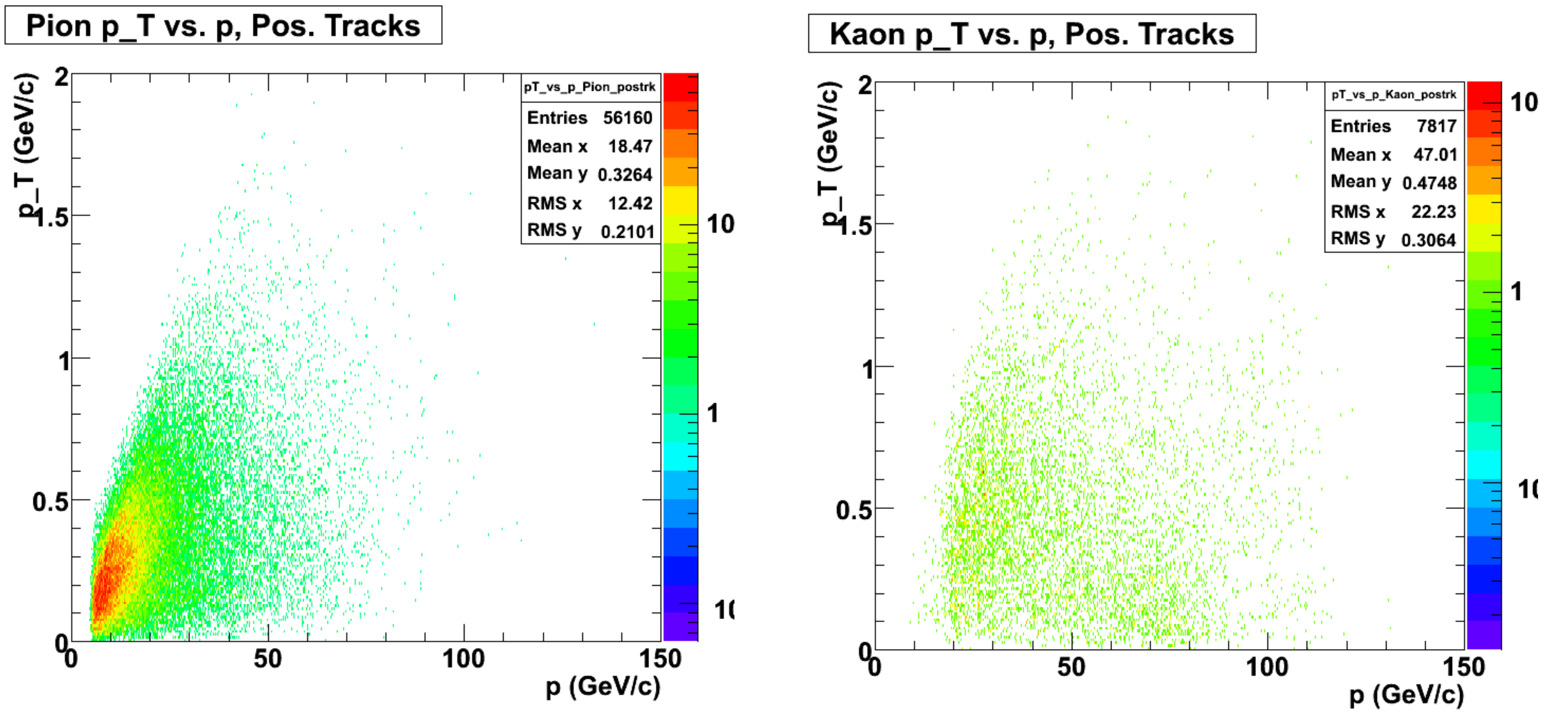
Scaling Law tests in MIPP

- 36 reactions (6 beam species on LH_2, 6 different particles in final state)
- 15 Crossing symmetry and 3 Charge symmetry relations among these 36 reactions
  - These should have same scaling behavior
- For example:
  - $\pi^+ p \to \pi^+ + X$ and $\pi^- p \to \pi^- + X$
  - $\bar{p}\, p \to \pi^+ + X$ and $\pi^- p \to p + X$
    - Links diffractive process to central production process!

Target Fragmentation Multiplicities

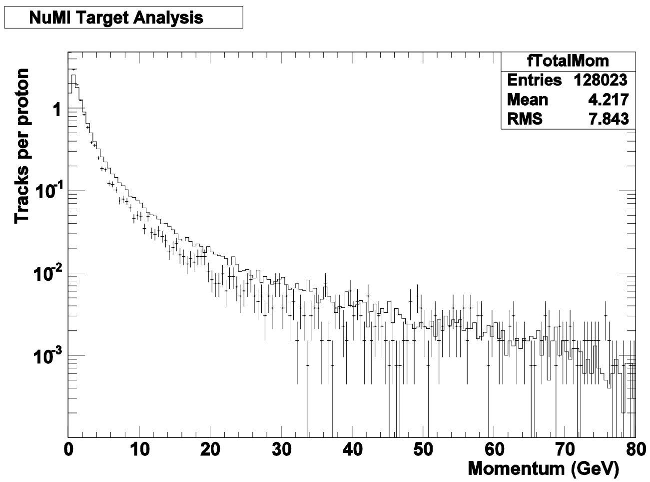


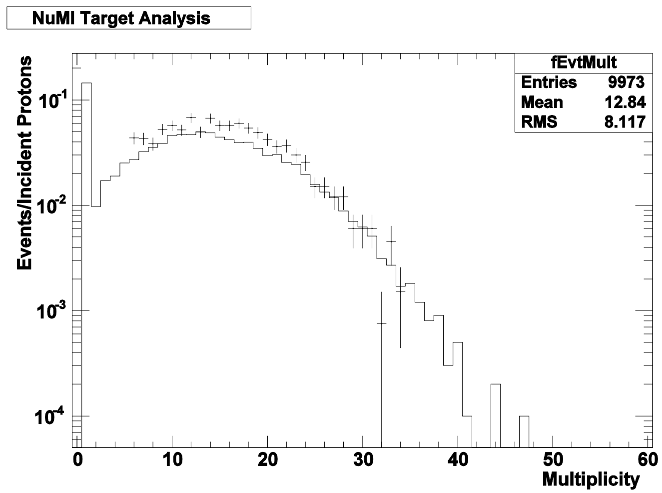
Particle ID on NUMI Target

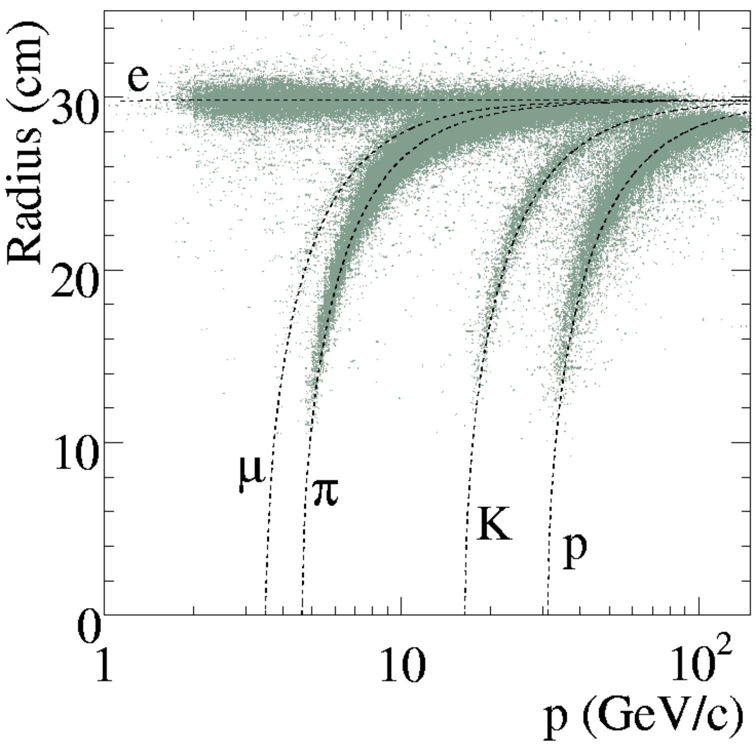


Preliminary Comparison of NUMI target to FLUKA predictions

RICH Rings from NUMI target







Summary

- MIPP acquires unbiased high statistics data with complete particle id coverage
  - test a particle fragmentation scaling law and provide data for the study of non-perturbative QCD
  - address a broad range of physics topics
- Results from the first run are expected in next few months
- The upgrade with faster DAQ and other improvements will open up even more interesting opportunities
  - Collaborators welcome!

Backup Slides

MIPP Upgrade Collaboration

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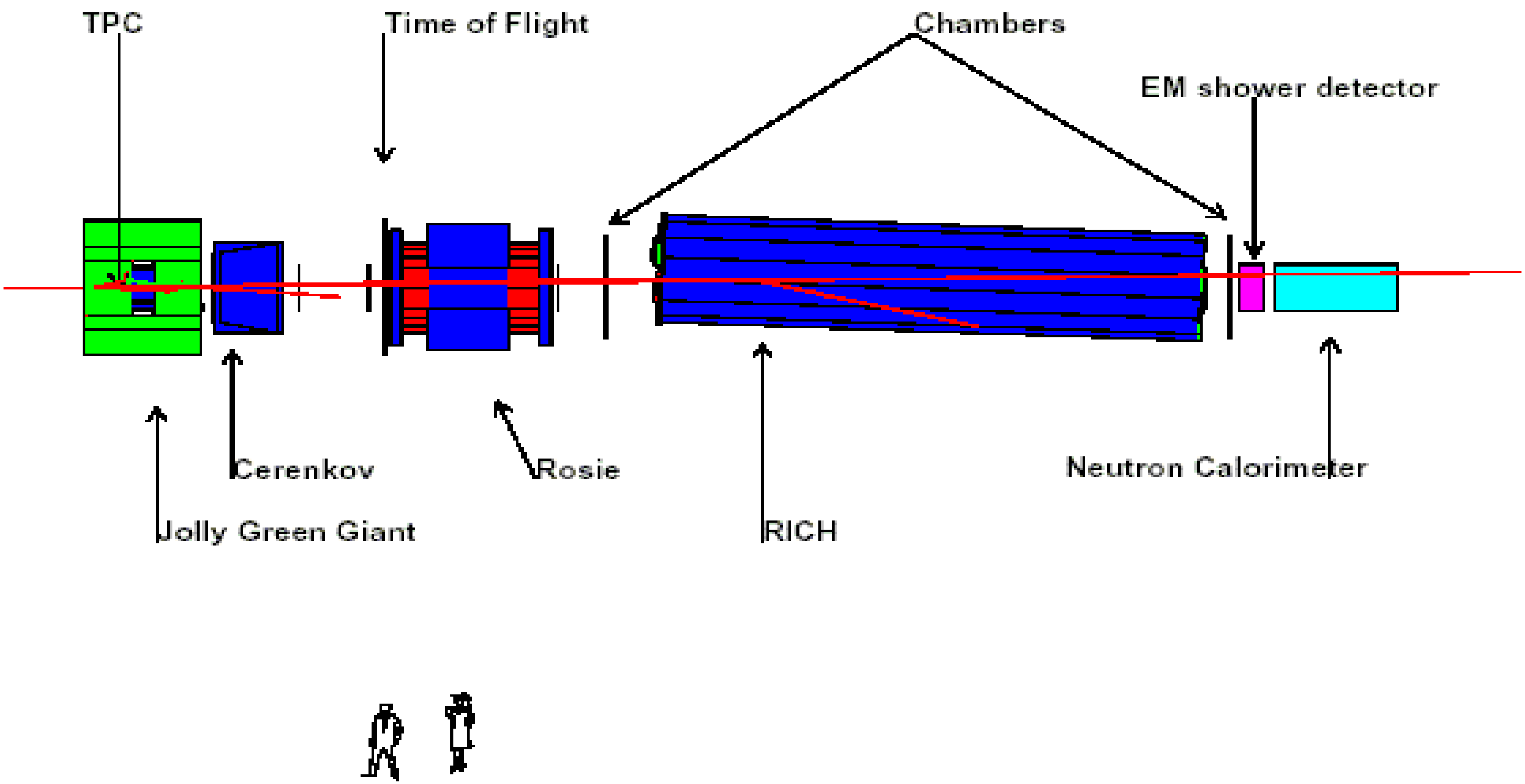
Livermore dropped out. Rest still on proposal. 7 new institutions have joined. More in negotiaitions.

MIPP

Main Injector Particle Production Experiment (FNAL-E907)

Vertical cut plane



Beam Survival Probability and ToF

Beam particle decay and ToF in the MIPP beam line								
Particle	Mass	Livetime	Beam Momentum [GeV/c]					
	[GeV/c^2]	[ns]	1	3	5	10	15	20
Beam-length	95.85 [m]		Survival Probability [%] in MIPP beam:					
Pion	0.14	26.03	18.01	56.48	70.98	84.25	89.20	91.79
Kaon	0.49	12.38	0.00	1.43	7.82	27.96	42.75	52.87
Proton	0.94	1E+39	100.00	100.00	100.00	100.00	100.00	100.00
			Particle Beta:					
Pion	0.14	26.03	0.99	1.00	1.00	1.00	1.00	1.00
Kaon	0.49	12.38	0.90	0.99	1.00	1.00	1.00	1.00
Proton	0.94	1E+39	0.73	0.95	0.98	1.00	1.00	1.00
X(T01-TBD)	37.69 [m]		Time of Flight [ns] between TBD and T01:					
Pion	0.14	26.03	126.94	125.86	125.77	125.73	125.73	125.72
Kaon	0.49	12.38	140.21	127.41	126.33	125.87	125.79	125.76
Proton	0.94	1E+39	172.40	131.73	127.91	126.27	125.97	125.86
			Time of Flight [ns] between TBD and T01 wrt beta=1:					
Pion	0.14	26.03	1.22	0.13	0.05	0.01	0.00	0.00
Kaon	0.49	12.38	14.48	1.69	0.61	0.15	0.07	0.04
Proton	0.94	1E+39	46.67	6.00	2.19	0.55	0.24	0.14