The Main Injector Particle Production Experiment (MIPP) at Fermilab

Holger Meyer
Fermilab

- Overview of the Experiment
  - Beam & Detectors
  - Physics
- Low momentum beam at MIPP

MIPP Collaboration

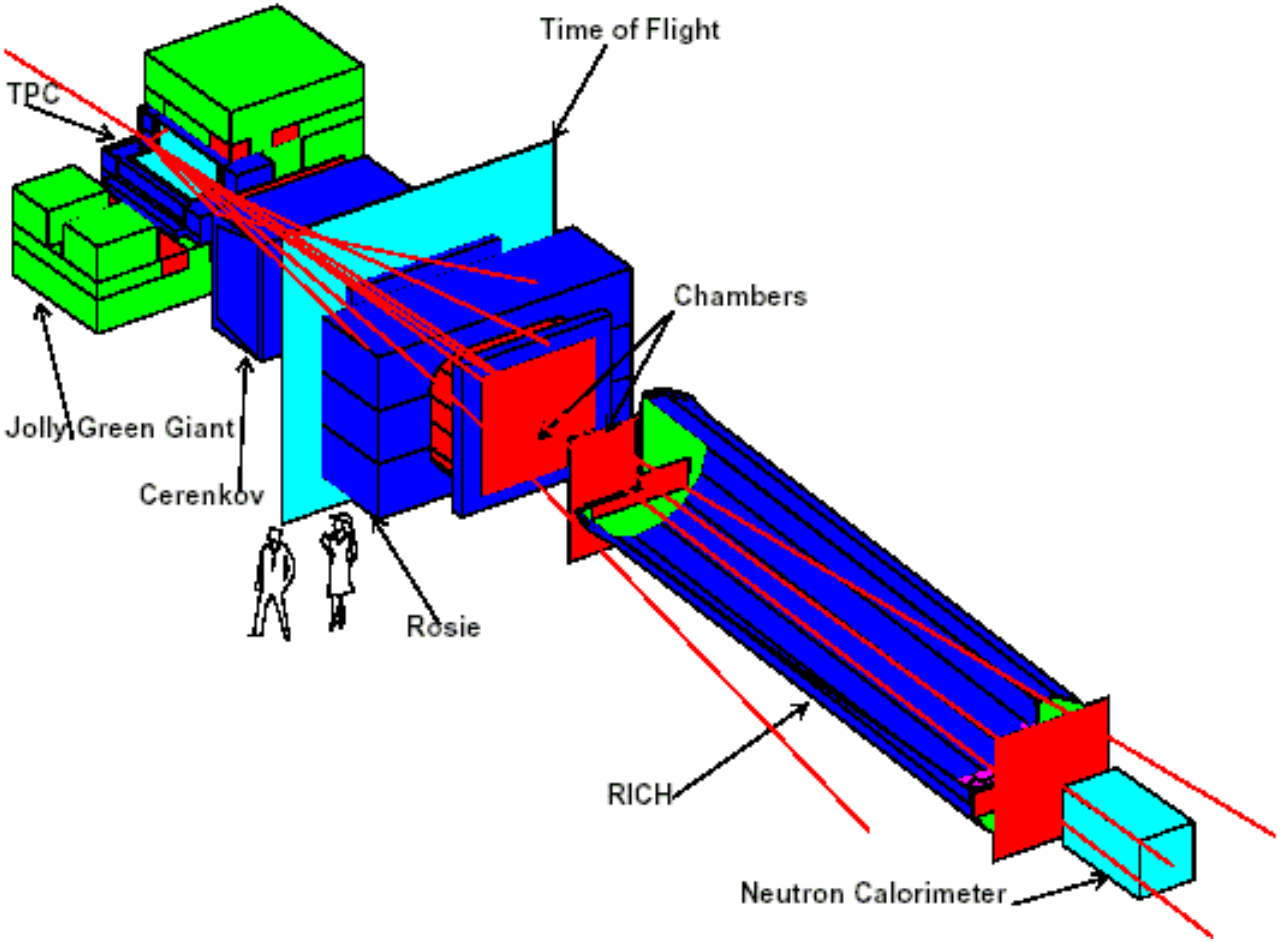
Y.Fisyak Brookhaven National Laboratory
R.Winston EFI, University of Chicago
R.J.Peterson University of Colorado, Boulder,
E.Swallow Elmhurst College and EFI
W.Baker, D.Carey, J.Hylen, C.Johnstone, M.Kostin, H.Meyer, N.Mokhov, A.Para, R.Raja, S. Striganov
Fermi National Accelerator Laboratory
G.Feldman, A.Lebedev, S.Seun
Harvard University
P.Hanlet, O.Kamaev, D.Kaplan, H.Rubin, N.Solomey, Y.Torun
Illinois Institute of Technology
U.Akgun, G.Aydin, F.Duru, E.Gülmez, Y.Gunaydin, Y.Onel, A.Penzo
University of Iowa
N.Graf, M.Messier, J.Paley
Indiana University
P.D.BarnesJr., E.Hartouni, M.Heffner, J.Klay, D.Lange, R.Soltz, D.Wright
Lawrence Livermore Laboratory
R.L.Abrams, H.R.Gustafson, M.Longo, T.Nigmanov, H-K.Park, D.Rajaram
University of Michigan
A.Bujak, L.Gutay, D.E.Miller
Purdue University
T.Bergfeld, A.Godley, S.R.Mishra, C.Rosenfeld, K.Wu
University of South Carolina
C.Dukes, L.C.Lu, C.Maternick, K.Nelson, A.Norman
University of Virginia

Brief Description of Experiment

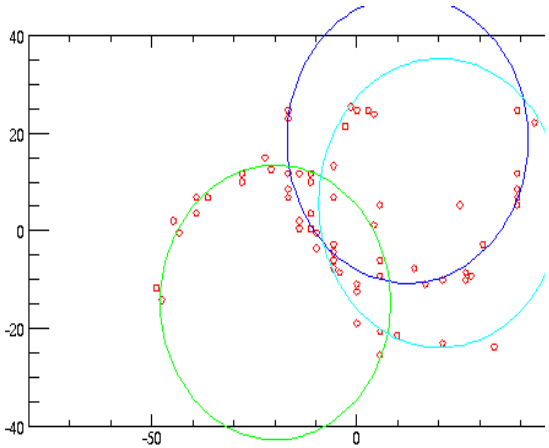
- Approved November 2001
- Situated in Meson Center 7, Fermilab Fixed Target
- Uses 120 GeV Main Injector Primary protons to produce secondary beams of $\pi^{\pm}$, $K^{\pm}$, $p^{\pm}$ from 5 GeV/c to 85 GeV/c to measure particle production cross sections of various nuclei including hydrogen.
- Using 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.
- Upgrade proposed to PAC on 19 Oct 2006
  - faster readout, much more data

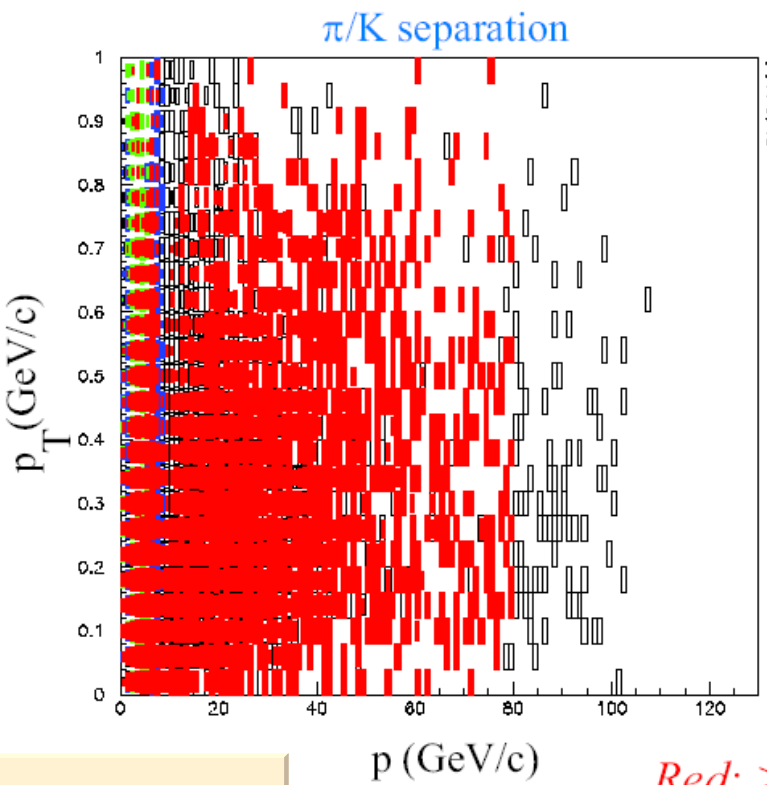
MIPP

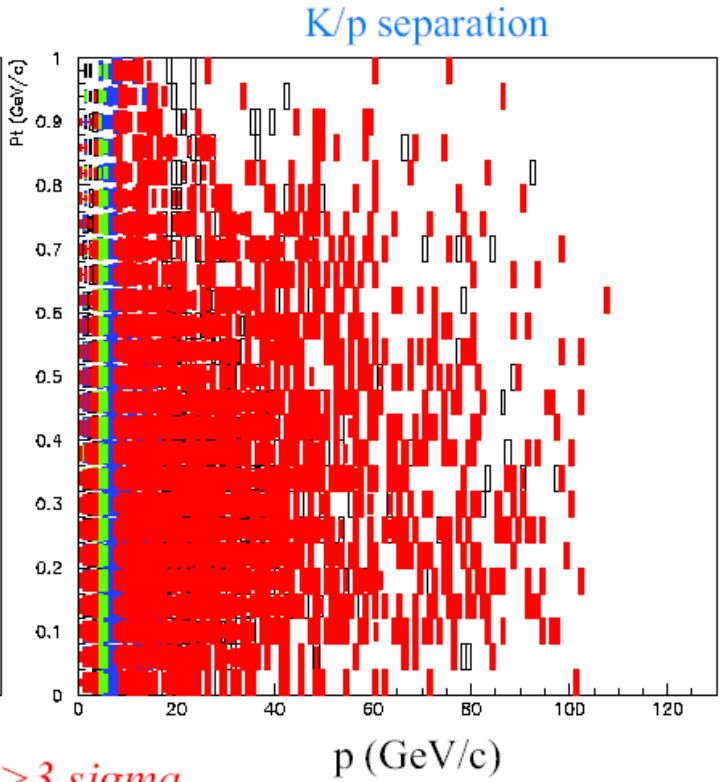
Main Injector Particle Production Experiment (FNAL-E907)



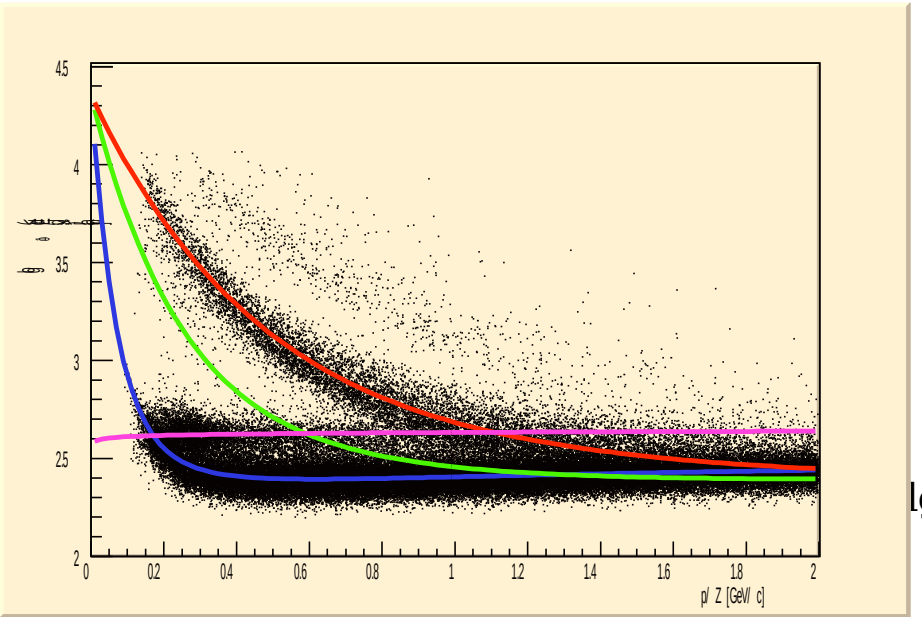
Particle ID Performance





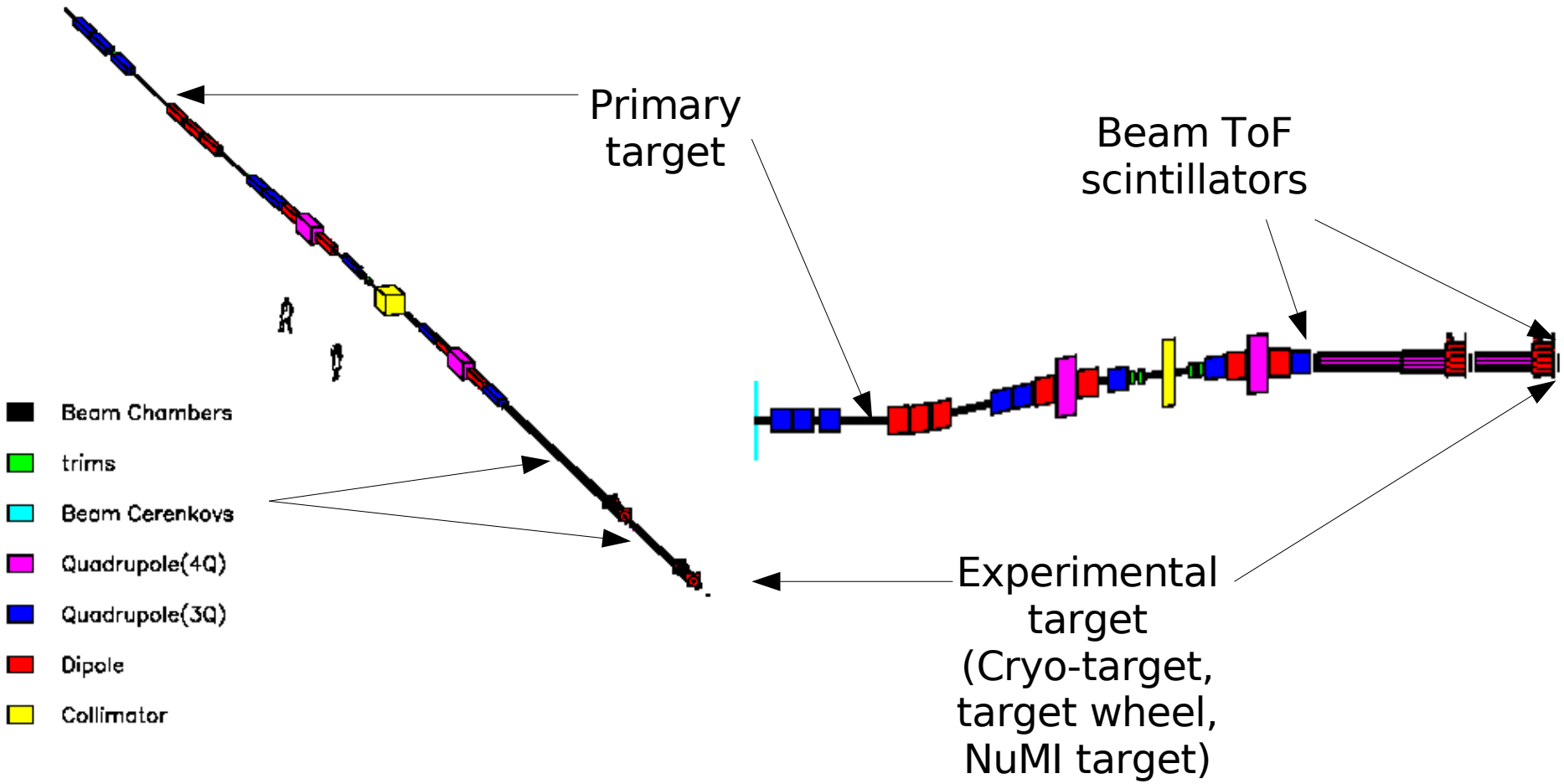


Red: >3 sigma
Green: 2-3 sigma
Blue: 1-2 sigma
White: <1 sigma

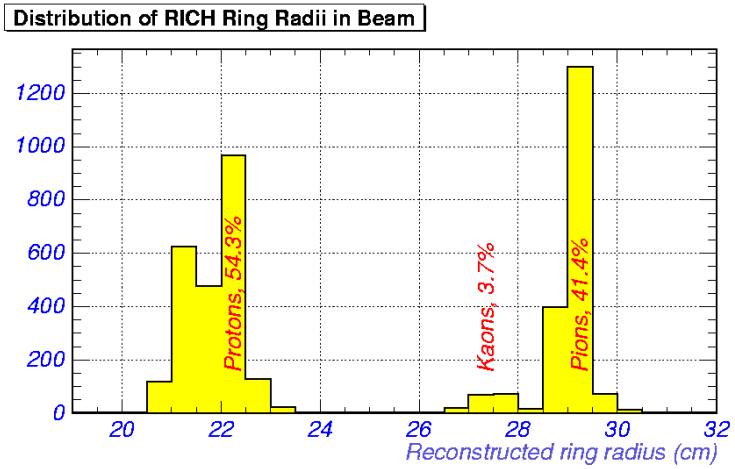


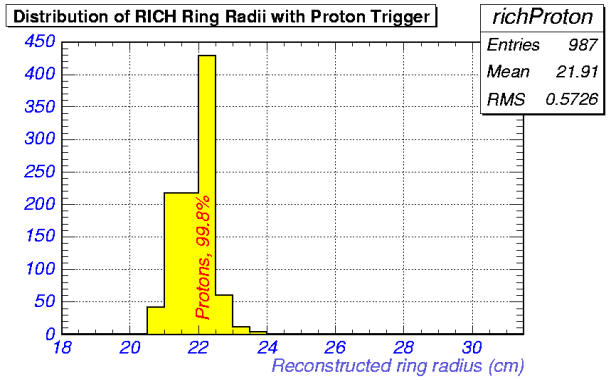
MIPP Secondary Beam

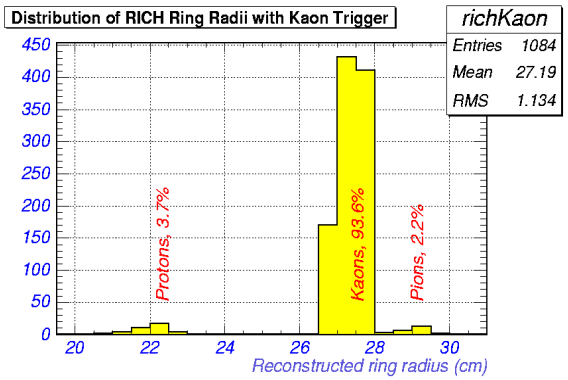
Excellent performance. Successfully ran 5-85 GeV/c secondaries and 120 GeV/c primary protons. Excellent particle ID capabilities using 2 Beam Cherenkovs. Also use ToF for low momenta. 95 meters long.

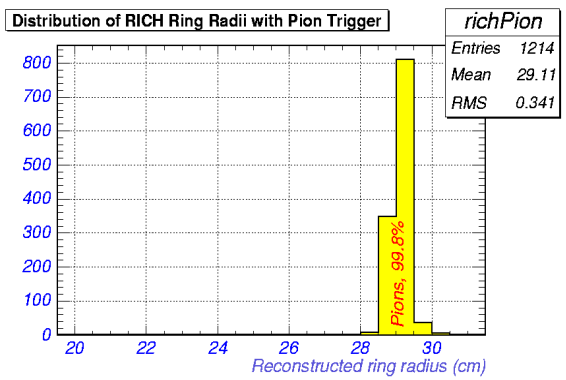


Comparing Beam Cherenkov to RICH for +40 GeV beam triggers-No additional cuts!









MIPP Physics

- Non-perturbative QCD hadron dynamics
  - Particle fragmentation scaling laws
- Missing baryon resonances
- Nuclear physics
  - y-scaling
  - Propagation of strangeness through nuclei
- Service measurements
  - Hadron Shower Models in Geant4, MARS,...
  - Calorimetry
  - Neutrino production (NuMI, atmospheric, ...)

General Scaling Law of Particle Fragmentation

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

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

- 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.

Missing Baryon Resonances

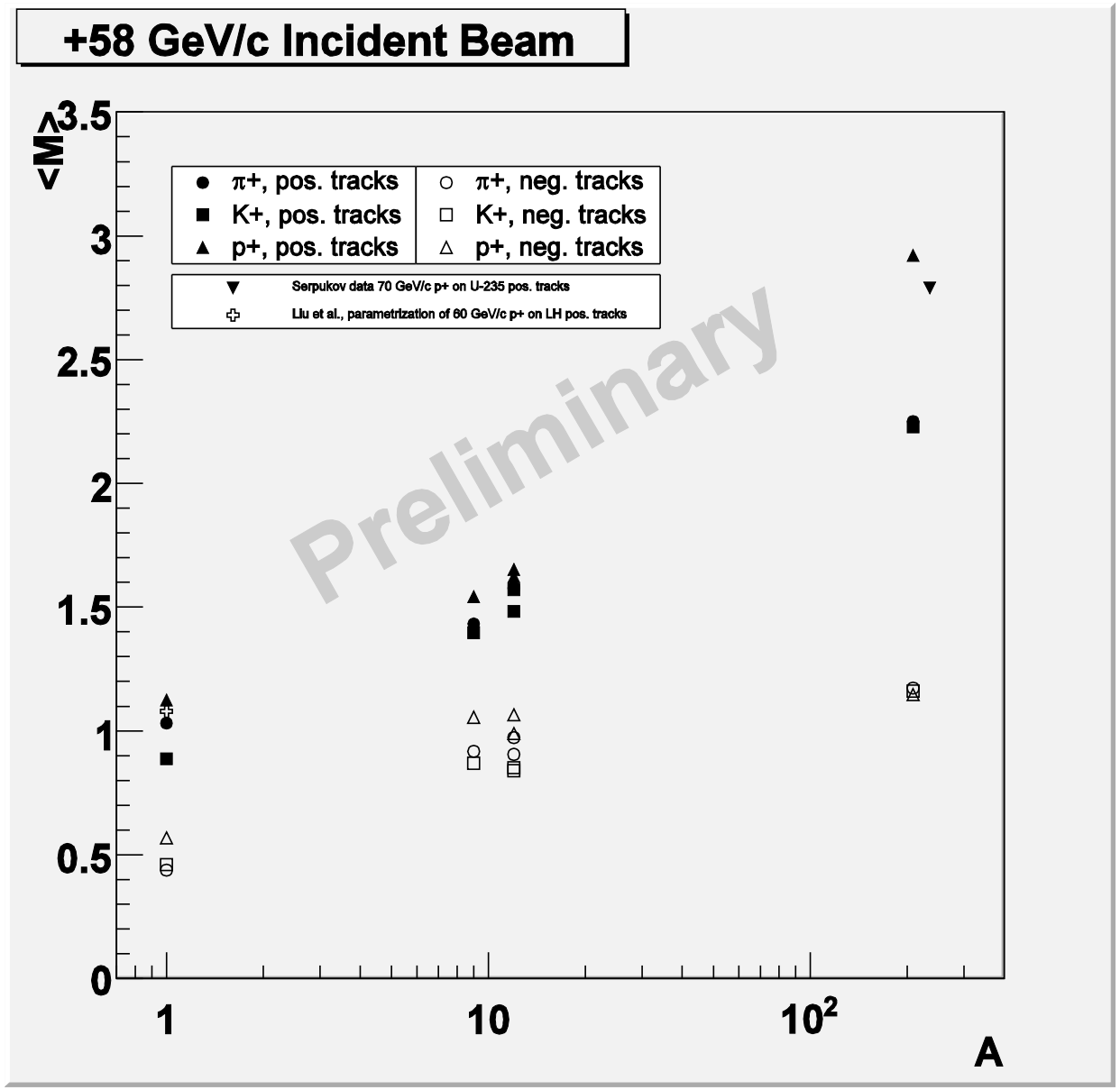
- Partial wave analyses of πN scattering have yielded some of the most reliable information of masses, total widths and πN branching fractions. In order to determine couplings to other channels, it is necessary to study in elastics such as

$$\pi^- p \to \eta n \quad \pi^- p \to \pi^+ \pi^- n \quad \pi^- p \to K^0 \Lambda$$

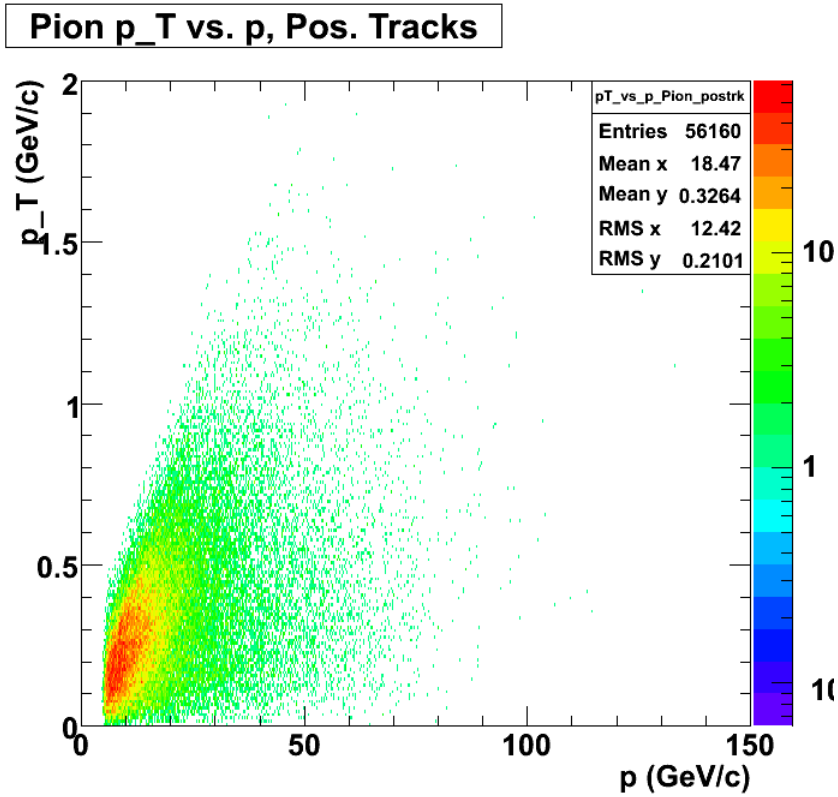
$$\gamma p \to \pi^0 p \quad \gamma p \to K^+ \Lambda \quad \gamma p \to \pi^+ \pi^- p$$

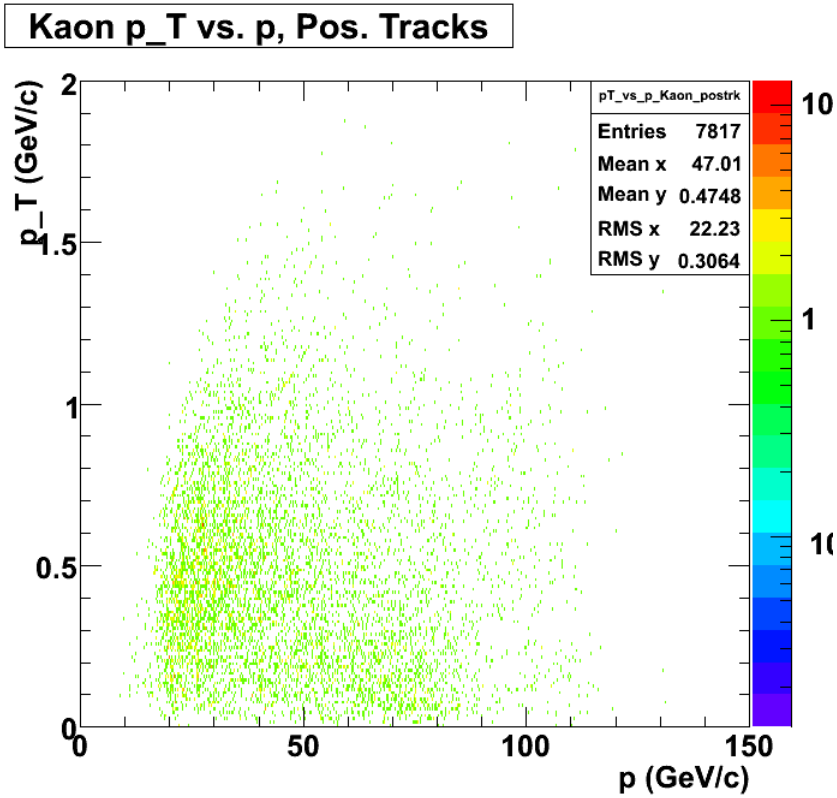
- All of the known baryon resonances can be described by quark-diquark states. Quark models predict a much richer spectrum. Where are the missing resonances? F.Wilczek, A. Selem
- "..this could form the quantitative foundation for an effective theory of hadrons based on flux tubes"– F.Wilczek

Target Fragmentation Multiplicities



Particle ID on NUMI Target





Low Momentum Beam at MIPP

- Previously data down to 5 GeV/c
- Upgrade beam line magnets
  - Hall probes (eliminate Hysteresis)
  - Low current power supplies (better stability)
- Beam PID at low momentum with ToF
- Minimize material in the beam
  - Multiple scattering

Beam Survival Probability and ToF

Beam particle decay and ToF in the MIPP beam line								
Particle	Mass [GeV/c^2]	Livetime [ns]	Beam Momentum [GeV/c] 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

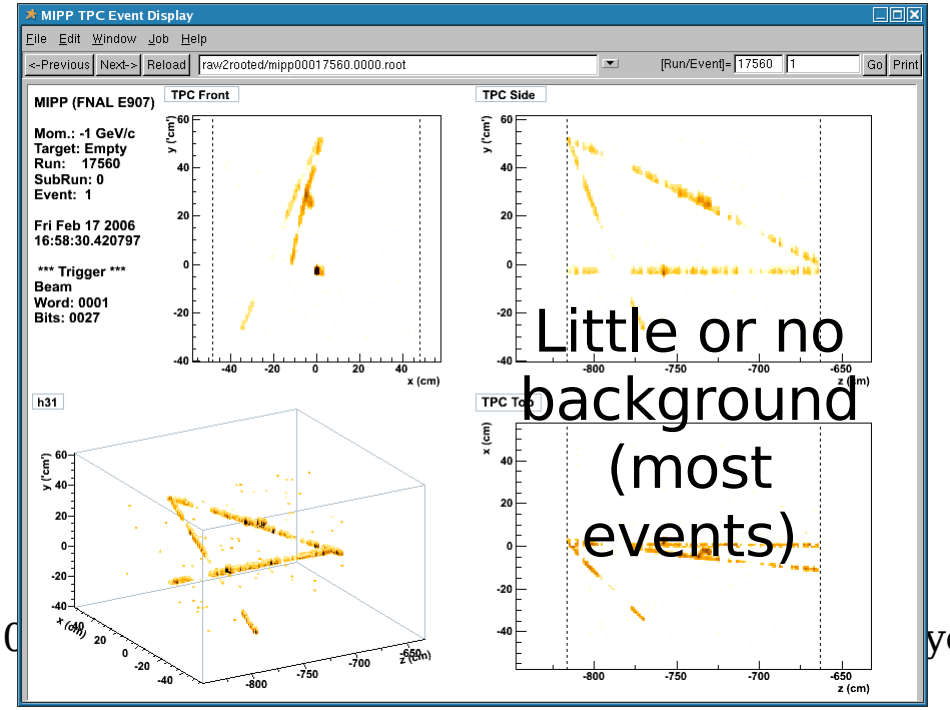
6 Test Runs

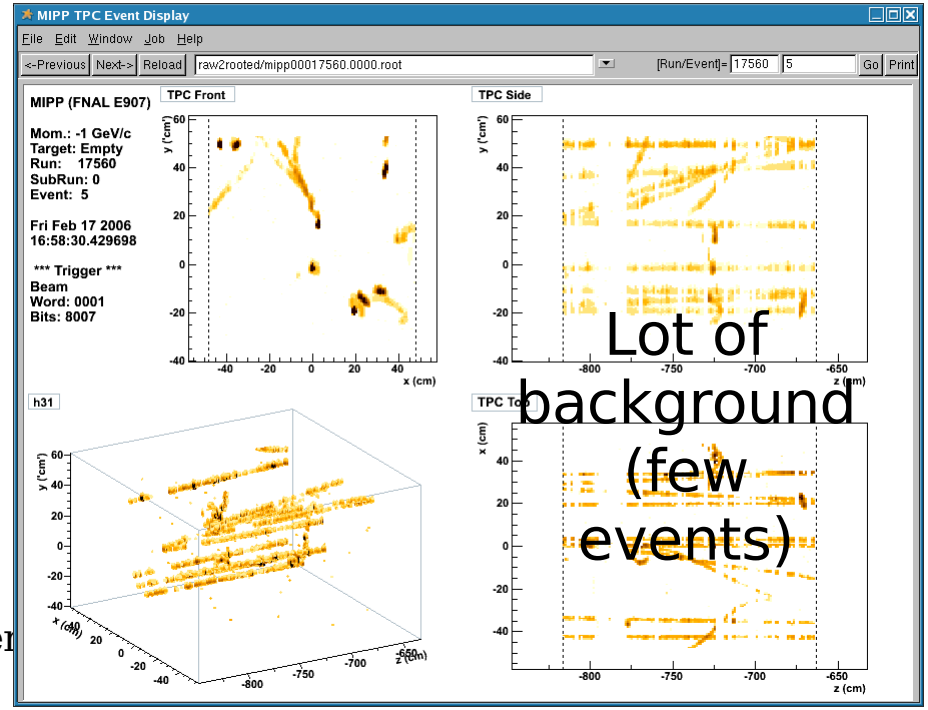
- This analysis is based on 6 short test runs taken on 2/17/2006
  - Nothing tuned, nothing optimized
  - Trigger on any beam particles, no selection

Momentum	Run Number	Events	Spills w/ beam	Events per Spill	Start time	End time	Secondary beam/spill	Intensity [ppp]
-3	17559	415	4	103.75	04:42:50 PM	04:53:23 PM	17000	1.18E+011
-1	17560	474	7	67.71	04:57:52 PM	05:14:51 PM	1800	1.18E+011
-5	17561	1149	10	114.9	05:18:53 PM	05:34:01 PM	85000	1.17E+011
5	17562	1002	11	91.09	10:44:42 PM	10:57:16 PM	9000	3.82E+010
3	17563	1058	14	75.57	10:58:13 PM	11:13:39 PM	3500	3.47E+010

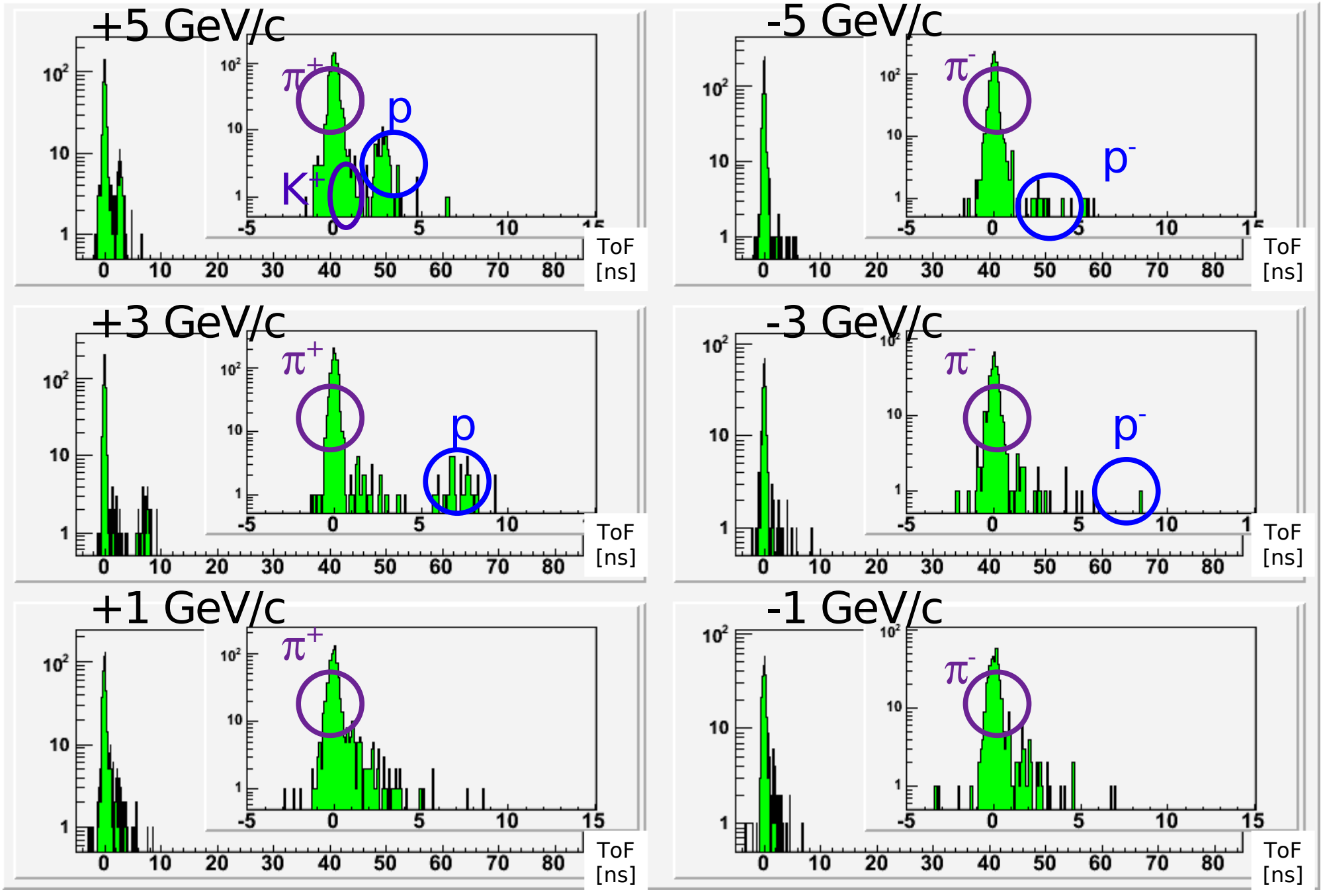
Beam backgrounds

- Beam halo and background from spray off collimators – Not a problem
  - Number of Beam tracks per event
  - TPC gives ±8 μs view around the trigger time





MIPP beam at low momentum



Conclusions

- MIPP does interesting physics in many areas
  - More results from the first run soon
- The upgrade with faster DAQ and lower momentum beams will open up even more interesting opportunities
  - Collaborators welcome!

Backup Slides

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		**1.94**				**1.98**		**1.73**		
4	Be	*p* only										**1.75**
		Normal										
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										**2.83**
		Normal										
92	U	Normal										**1.18**
Total			**0.21**	**2.73**	**0.86**	**5.48**	**0.50**	**13.97**	**0.96**	**2.04**	**4.63**	**31.38**

MIPP beam line elements

Z-cent [ft]	X-cent [ft]	Y-cent [ft]	Position Code	Element Code
1323.39	0	4.38	MC6IC1	Ion Chamber
1323.88	0	4.39	MC6WC1	SWIC
1324.82	0	4.41	MC6T1	Primary Target
1327.83	0	4.48	MC6TC	Target Cage
1334.82	0	4.64	MC6ABS	Absorber
1345.92	0	4.9	MC6Q1-1	FRD-11909
1356.92	0	5.15	MC6Q1-2	FRD-11910
1368.32	0	5.39	MC6D-1	FRD-10801
1379.32	0	5.6	MC6Q2	FRD-11528
1390.32	0	5.77	MC6D-2	FRD-20147
1397.96	0	5.87	MC6SC1	Scraper 1
1405.6	0	5.96	MC6Q3	FRD 11596
1412.85	0	6.05	MC6VT1	TDTA003
1416.35	0	6.1	MC6HT1	TDTA006
1432.92	0	6.28	MC6CY	FRD50095 Momentum Collimator
1437.36	0	6.33	MC6SC2	Scraper 2
1445	0	6.41	MC6VT2	TDTA007
1448.5	0	6.45	MC6HT2	TDTA005
1450	0	6.47	MC6T0	T0 Counter
1455.75	0	6.54	MC6Q4-1	FRD 11417
1466.75	0	6.65	MC6D-3	FRD-11244
1477.75	0	6.73	MC6Q5	FRD-11742
1488.75	0	6.78	MC6D-4	FRD-20018
1499.75	0	6.79	MC6Q6	FRD 11415
1505.5	0	6.79	MC7WC1	SWIC
1506	0	6.79	MC7HD1	Beam Hodoscope
1506.92	0	6.79	MC7BC1	Beam Chamber
1546.92	0	6.79	MC7CR1	Beam Cerenkov
1586.92	0	6.79	MC7BC2	Beam Chamber
1607.74	0	6.79	MC7CR2	Beam Cerenkov
1628.56	0	6.79	MC7BC3	Beam Chamber
1629.64	0	6.79	MC7HD2	Beam Hodoscope
1630.48	0	6.79	MC7WC2	SWIC

Primary target to JGG:	95.85 Meters
To TBD:	55.23 Meters
To T01:	92.92 Meters

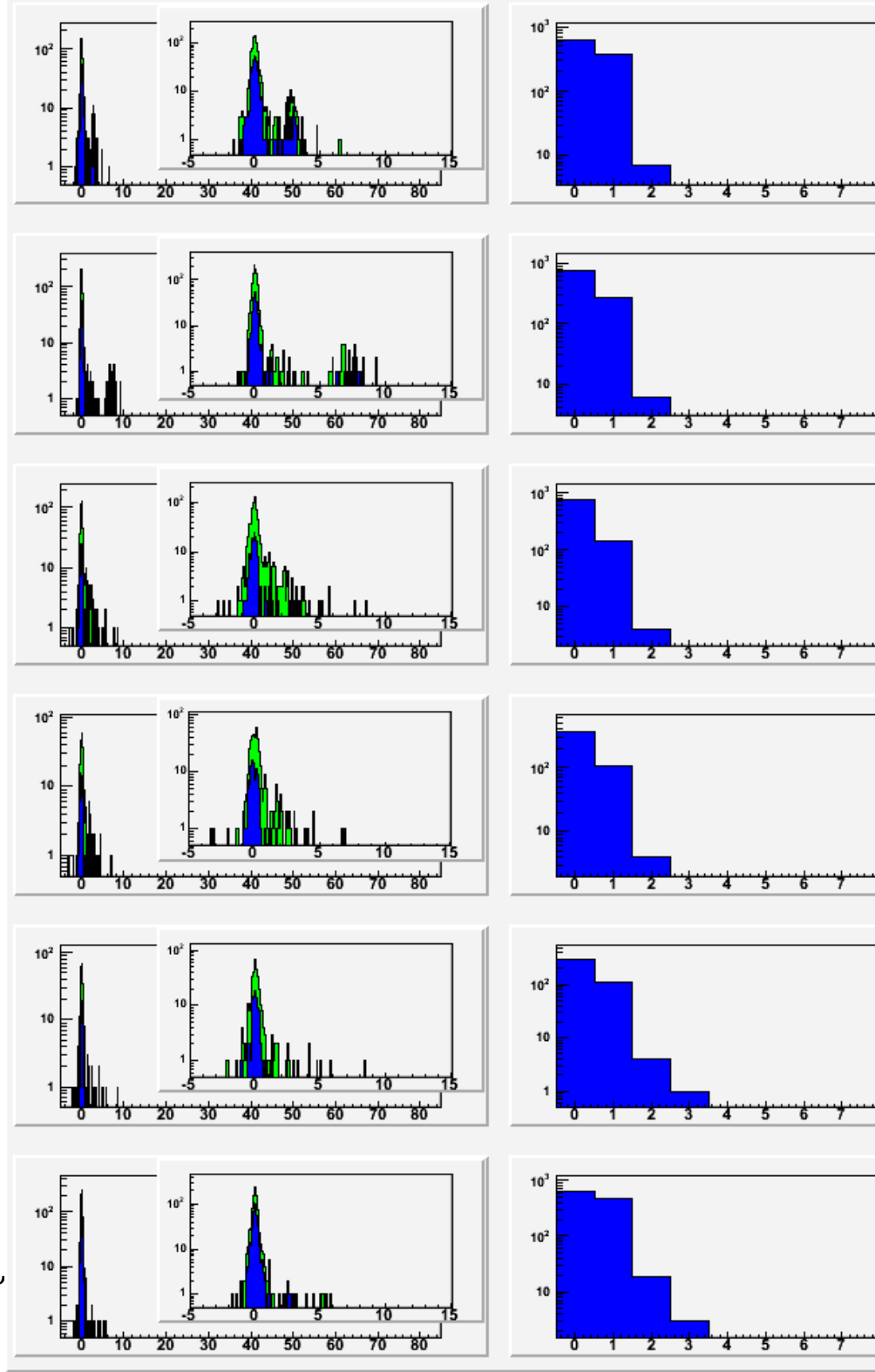
From
http://ppd.fnal.gov/experiments/e907/Beam/mipp_beam_sheet_8.htm

MIPP beam at low momentum

Momentum	Events per Spill	Secondary beam/spill	Intensity [ppp]
5	91.09	9000	3.82E+010
3	75.57	3500	3.47E+010
1	38.75	300	3.41E+010
-1	67.71	1800	1.18E+011
-3	103.75	17000	1.18E+011

Beam ToF

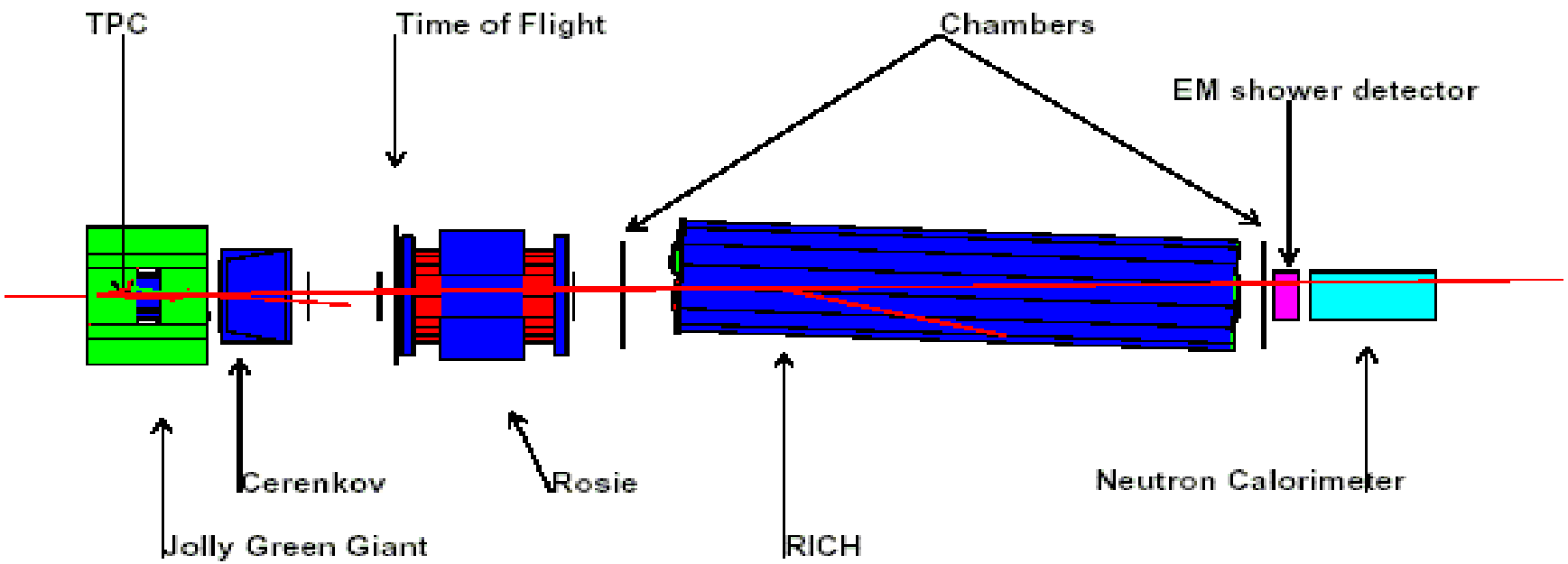
- Left pads: BToF
  - Time of flight in MIPP beam (β=1 particles at 0 ns)
    - Pions at 0 ns and Protons at >2 ns
- Right pads: NBTrk
  - Number of reconstructed beam tracks



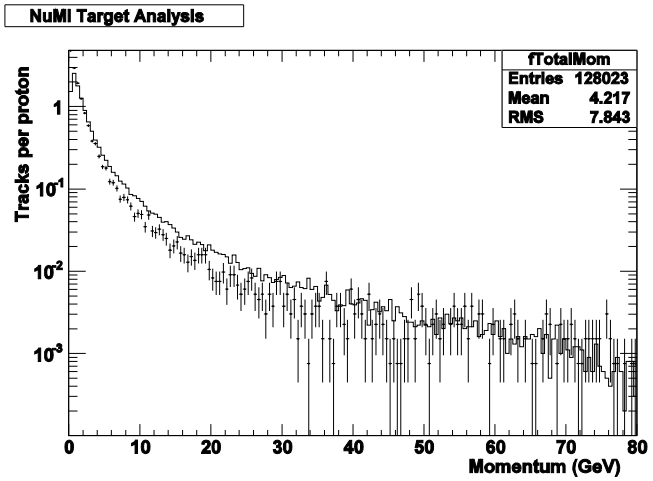
MIPP

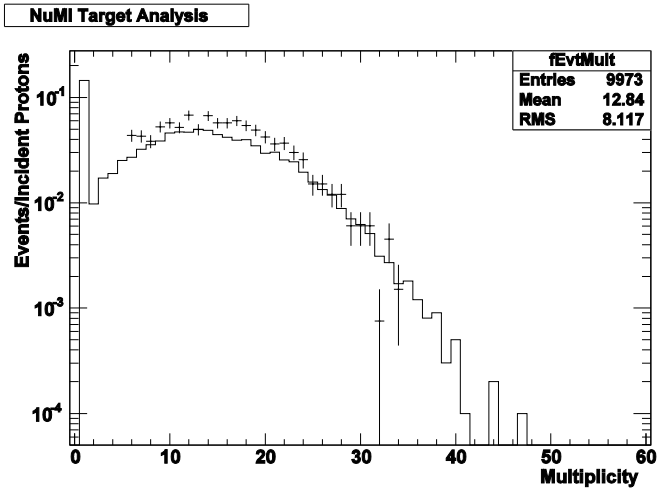
Main Injector Particle Production Experiment (FNAL-E907)

Vertical cut plane

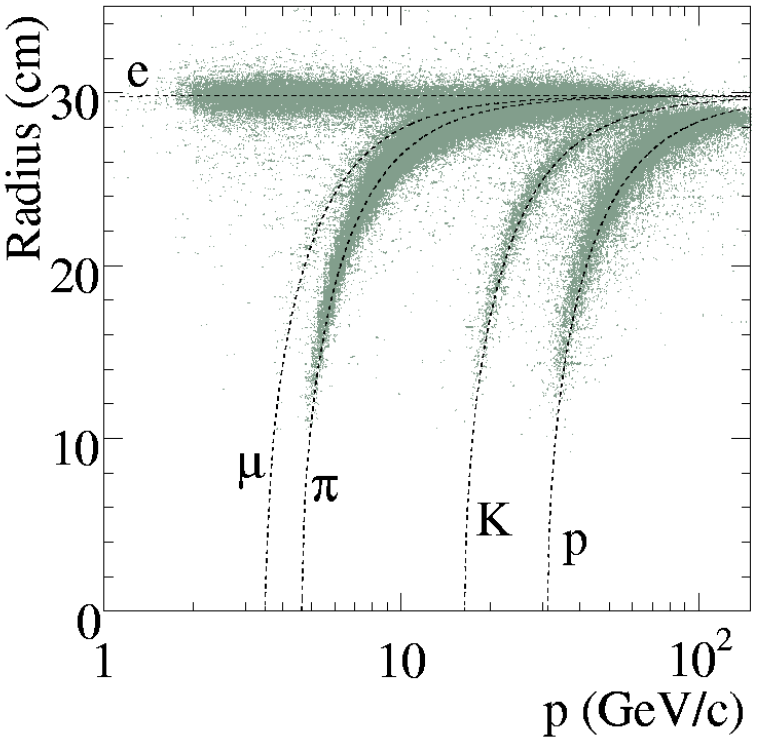


Preliminary Comparison of NUMI target to FLUKA predictions





RICH Rings from NUMI target



MIPP Upgrade Collaboration

D.Isenhower,M.Sadler,R.Towell,S.Watson
Abilene Christian University
R.J.Peterson
University of Colorado, Boulder
W.Baker,D.Carey, D.Christian,M.Demarteau,D.Jensen,C.Johnstone,H.Meyer, R.Raja,A.Ronzhin,N.Solomey,W.Wester
Fermi National Accelerator Laboratory
H.Gutbrod,K.Peters,
GSI, Darmstadt, Germany
G. Feldman,
Harvard University
Y.Torun,
Illinois Institute of Technology
M. Messier,J.Paley
Indiana University
U.Akgun,G.Aydin,F.Duru,E.Gülmez,Y.Gunaydin,Y.Onel, A.Penzo
University of Iowa
V.Avdeichicov,R.Leitner,J.Manjavidze,V.Nikitin,I.Rufanov,A.Sissakian,T.Topuria
Joint Institute for Nuclear Researah, Dubna, Russia
D.M.Manley,
Kent State University
H.Löhner, J.Messchendorp,
KVI, Groningen, Netherlands
H.R.Gustafson,M.Longo,T.Nigmanov, D.Rajaram
University of Michigan
S.P.Kruglov,I.V.Lopatin,N.G.Kozlenko,A.A.Kulbardis,D.V.Nowinsky, A.K.Radkov,V.V.Sumachev
Petersburg Nuclear Physics Institute, Gatchina, Russia
A.Bujak, L.Gutay,
Purdue University
A.Godley,S.R.Mishra,C.Rosenfeld
University of South Carolina
C.Dukes,C.Materniak,K.Nelson,A.Norman
University of Virginia
P.Desiati, F.Halzen, T.Montaruli,
University of Wisconsin, Madison

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