The Main Injector Particle Production Experiment at Fermilab

Rajendran Raja
Fermilab

- Beam
- MIPP experiment
  - » Physics
  - » Engineering measurements
- Particle ID
- Some results
- Upgrade plans

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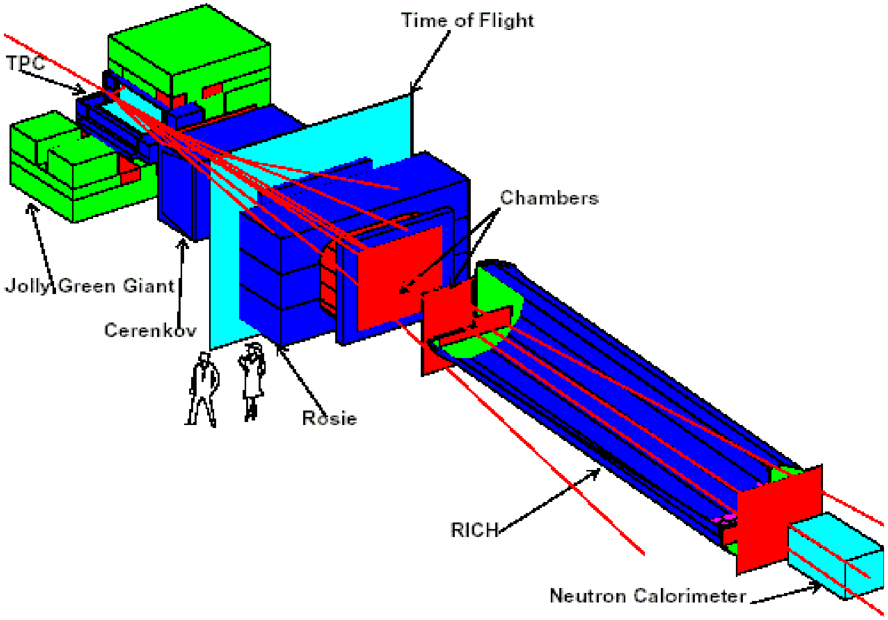
MIPP

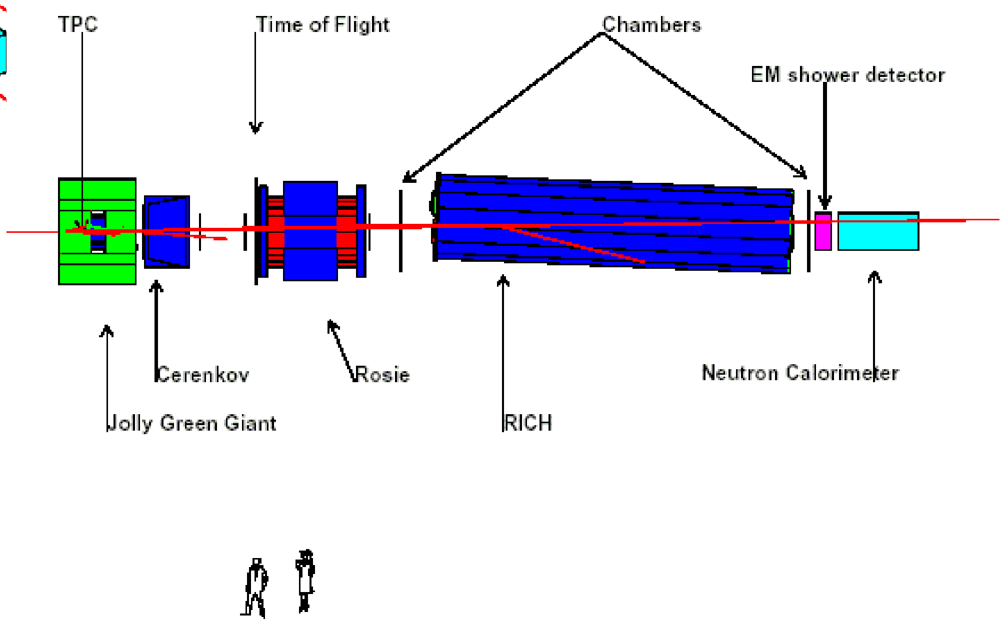
Main Injector Particle Production Experiment (FNAL-E907)



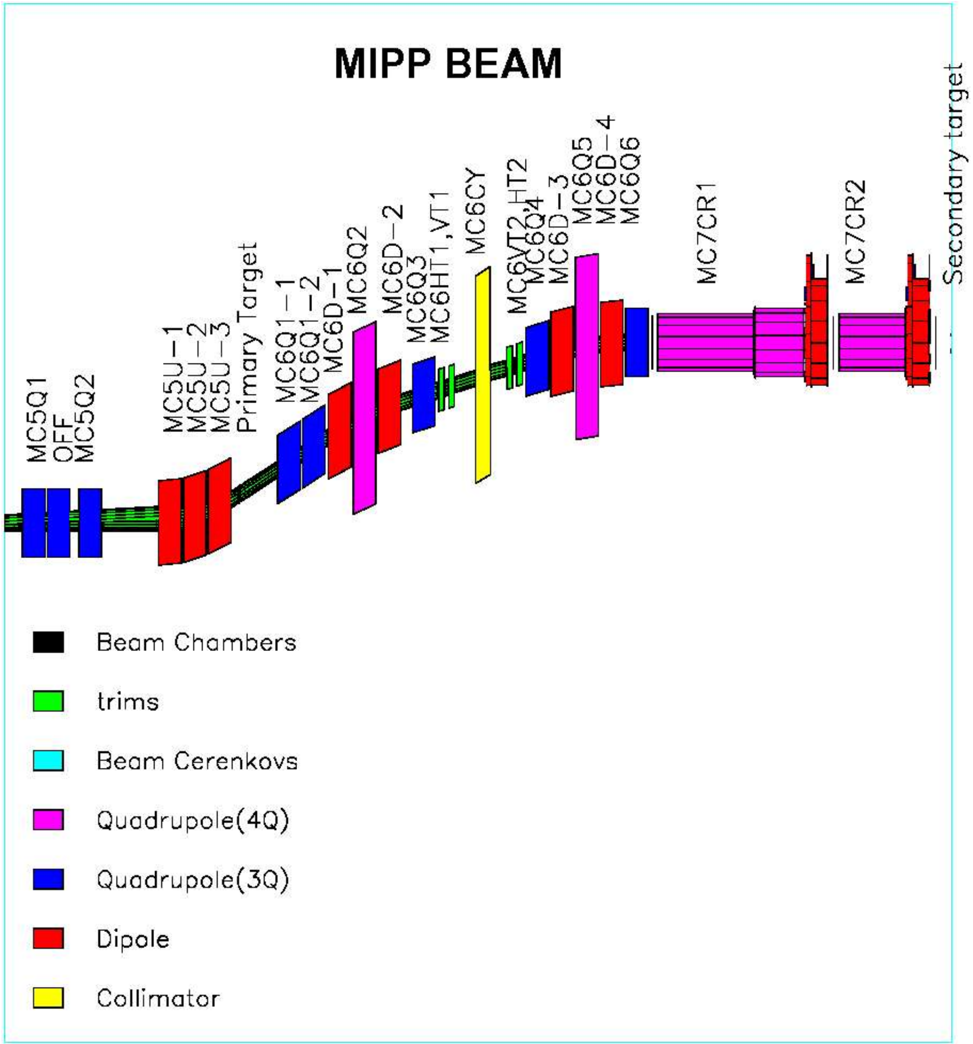
MIPP

Main Injector Particle Production Experiment (FNAL-E907)

Vertical cut plane



MIPP Secondary Beam



Installed in 2003. Currently taking physics data. Has produced beams of both polarity from 5 GeV/c to 90 GeV/c. Can produce lower energy beams of ~ 1GeV/c by changing power supplies (trim element supplies) and installing Hall Probes in each magnet to control the hysteresis effects.

Can be used to make measurements of particle production from ~30 nuclei of interest with the upgraded MIPP DAQ running at 3KHz. Can do 1 nucleus per day (5million events) and revolutionize our ability to predict the behavior of hadronic showers in detectors.

Status of MIPP Now-
Collision Hall

Brief Description of Experiment

- Approved November 2001
- Situated in Meson Center 7
- Uses 120GeV Main Injector Primary protons to produce secondary beams of $\pi^{\pm}$ $K^{\pm}$ $p^{\pm}$ from 5 GeV/c to 100 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. Existing data poor quality.

Physics Interest

- Particle Physics-To acquire unbiased high statistics data with complete particle id coverage for hadron interactions.
  - » Study non-perturbative QCD hadron dynamics, scaling laws of particle production
  - » Investigate light meson spectroscopy, pentaquarks?, glueballs
- Nuclear Physics
  - » Investigate strangeness production in nuclei- RHIC connection
  - » Nuclear scaling
  - » Propagation of flavor through nuclei
- Service Measurements
  - » Atmospheric neutrinos – Cross sections of protons and pions on Nitrogen from 5 GeV- 120 GeV
  - » Improve shower models in MARS, Geant4
  - » Make measurements of production of pions for neutrino factory/muon collider targets
  - » Proton Radiography– Stockpile Stewardship- National Security
  - » MINOS target measurements – pion production measurements to control the near/far systematics
- HARP at CERN went from 2-15GeV incoming pion and proton beams. MIPP will go from 5-100 GeV/c for 6 beam species $\pi^{\pm}$ $K^{\pm}$ $p^{\pm}$ -- 420M triggers. 3KHZ TPC.

MIPP Physics Program

MIPP-I has 4 distinct clientele for its data, which are interconnected. They are

Liquid H2, D2 –non-perturbative QCD

p-A, p-rad (aka SURVEY)

NUMI thin and full target measurements

LN2– Atmospheric neutrinos

MIPP-Upgrade (100 times faster DAQ)will address

missing hadron resonances problem using low energy beams (1-5 GeV/c)

Obtain higher statistics NUMI target data

Solve the hadron shower simulaton problem

Run Plan-Adopted after dir review Nov 2004

Run Plan v7		Summary by Target and Beam Energy Number of events, x 10^6										
Target		**Momentum (GeV/*c*)**										**Totals**
Z	**Element**	**5**	**13.3**	**15**	**20**	**30**	**40**	**50**	**60**	**75**	**120**	
1	**H**	4.40		4.20		4.40		4.20		4.20		**21.40**
1.2	**D**	0.60		0.60		0.60		0.60		0.60		**3.00**
4	**Be**	1.00	1.00			1.00		1.81		1.00	6.60	**12.41**
6	**C**	1.00	1.00		1.57		1.66		1.57		1.58	**8.38**
	NuMI										4.61	**4.61**
7	**N**	1.00	1.00			1.00						**3.00**
29	**Cu**					1.00		2.00		1.00	4.00	**8.00**
83	**Bi**	1.00	1.00			1.00		2.00		1.00	6.60	**12.60**
92	**U**							2.00				**2.00**
Totals		**9.00**	**4.00**	**4.80**	**1.57**	**9.00**	**1.66**	**12.61**	**1.57**	**7.80**	**23.39**	**75.40**

Run Plan v7			Priority 1 Summary by Target and Beam Energy Number of events, x 10^6							
Target			**E**							**Total**
Z	**Element**	**Trigger Mix**	**13.3**	**15**	**30**	**40**	**50**	**75**	**120**	
1	**H**	**Normal**		0.80			**0.80**	0.80		**2.40**
4	**Be**	***p* only**							1.00	**1.00**
		Normal					**0.50**			**0.50**
6	**C**	***p* only**	0.40			0.40			0.40	**1.10**
NuMI		***p* only**							0.40	**0.40**
83	**Bi**	***p* only**							1.00	**1.00**
		Normal			**0.50**		**1.00**			**1.50**
92	**U**	**Normal**					1.00			**1.00**
Total			**0.40**	**0.80**	**0.50**	**0.40**	**3.30**	**0.80**	**2.80**	**8.90**

MIPP-TPC

- This Time Projection Chamber, built by the BEVALAC group at LBL for heavy ion studies currently sits in the E-910 particle production experiment at BNL, that has completed data taking. It took approximately $3million to construct.
- Can handle high multiplicity events. Time to drift across TPC=16 μs.
- Electronic equivalent of bubble chamber, high acceptance, with dE/dx capabilities. Dead time 16 s. i.e unreacted beam swept out in 8 s. Can tolerate 10^5 particles per second going through it.
- Can handle data taking rate ~60Hz with current electronics. Can increase this to ~1000 Hz with an upgrade.
- TPC dimensions of 96 x 75 x 150 cm.

TPC

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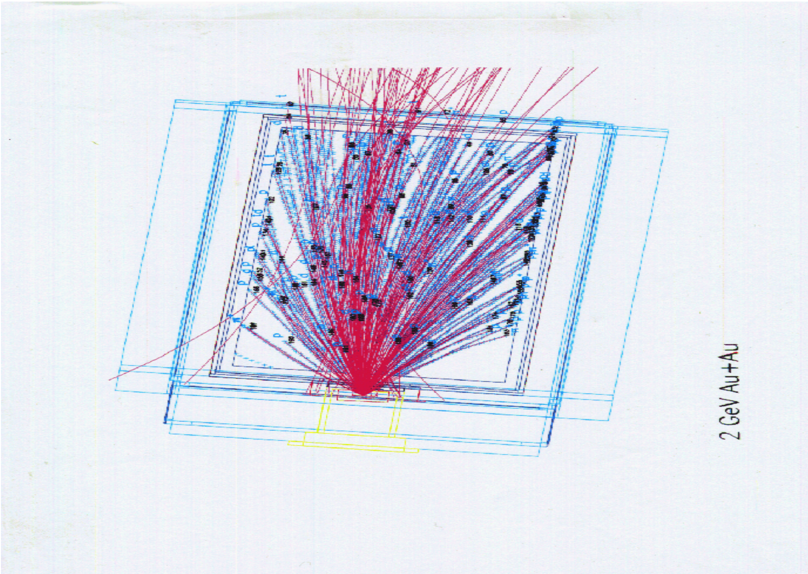
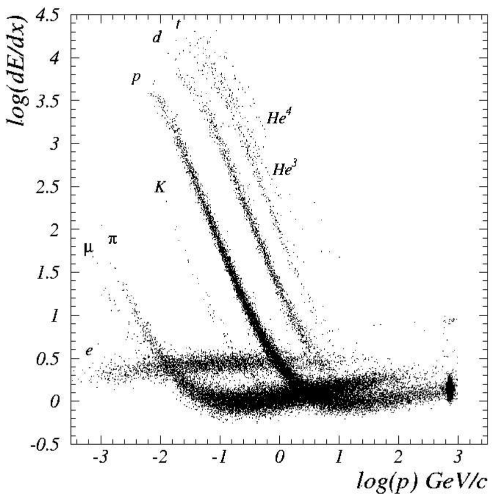
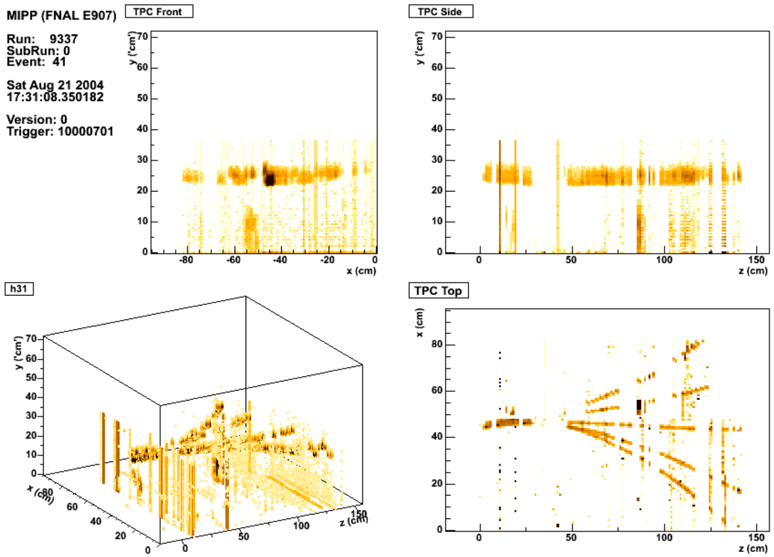
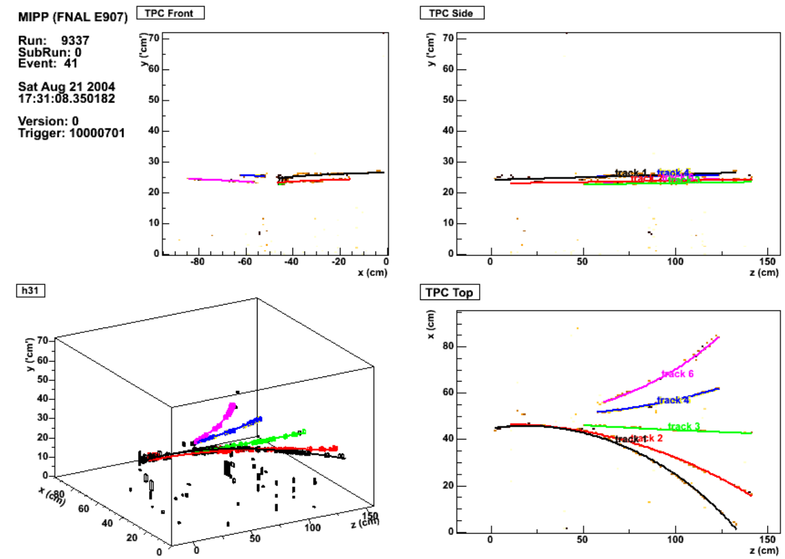


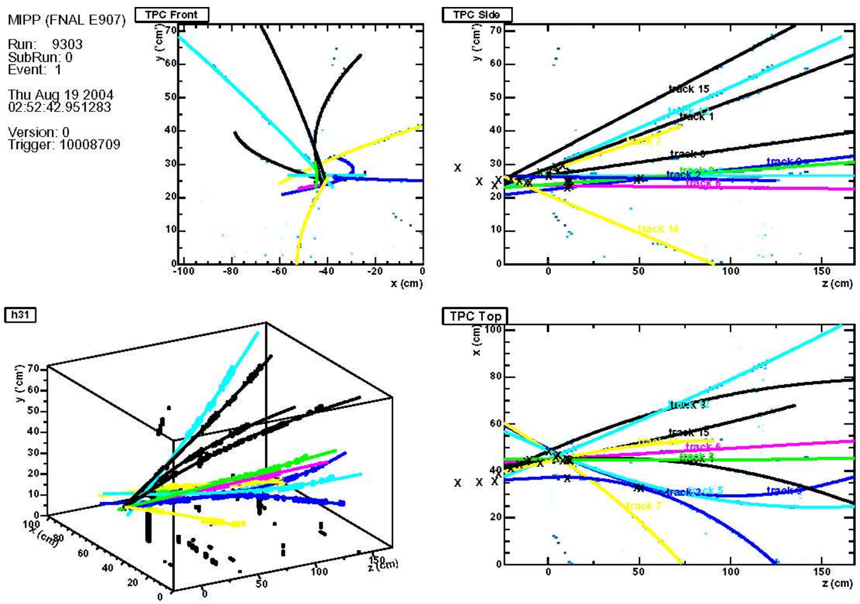
TPC dE/dx Particle ID- BNL E910

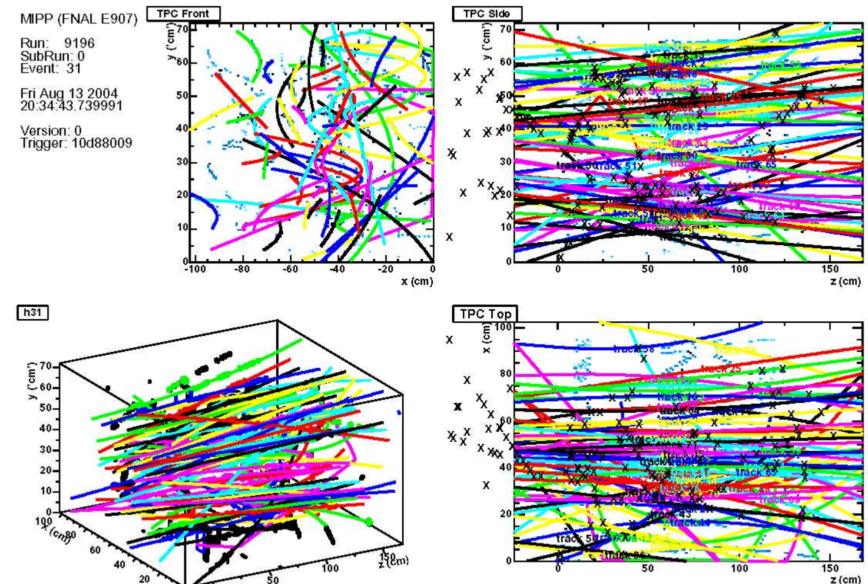


Preliminary results from Engineering run



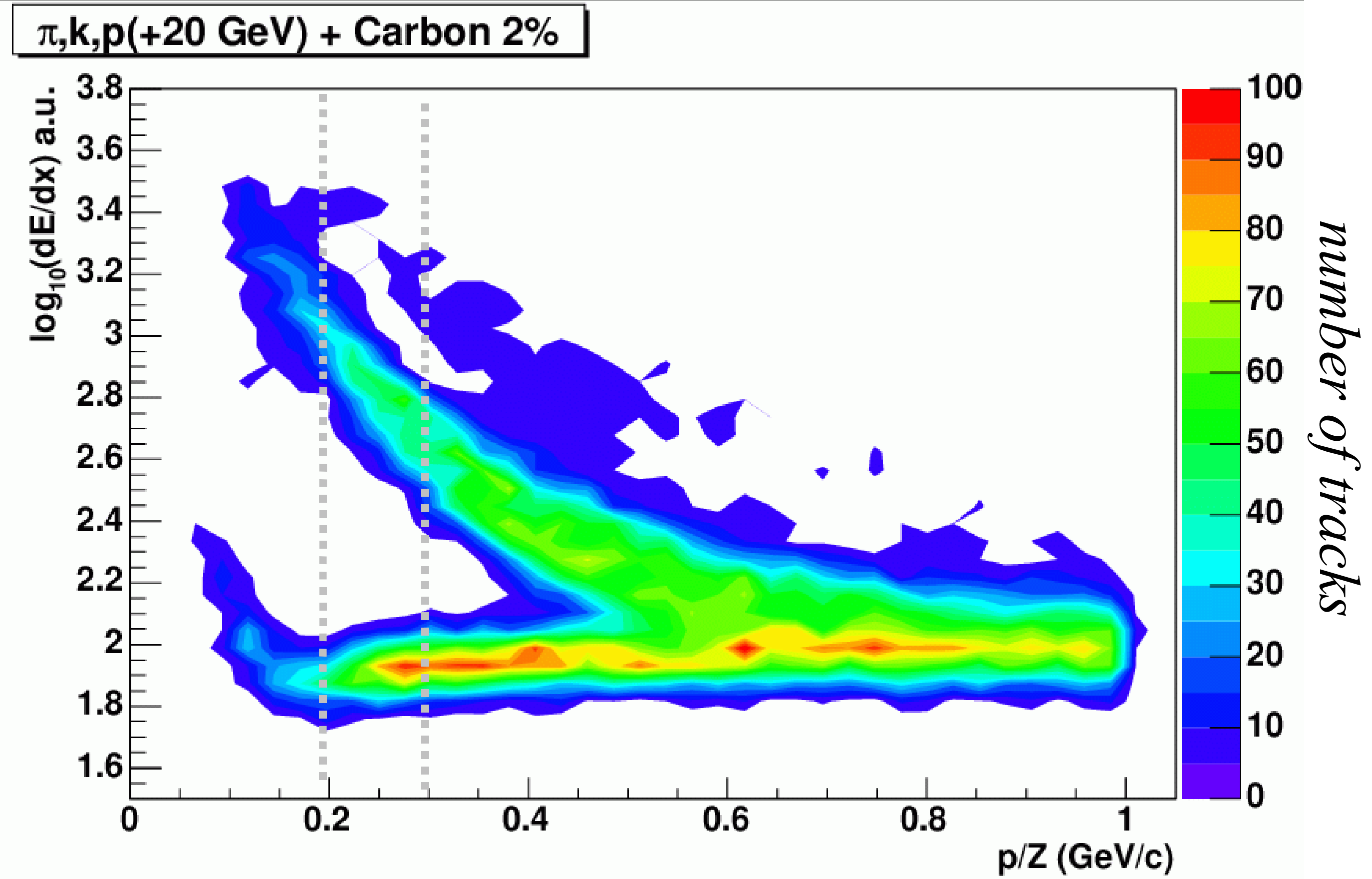


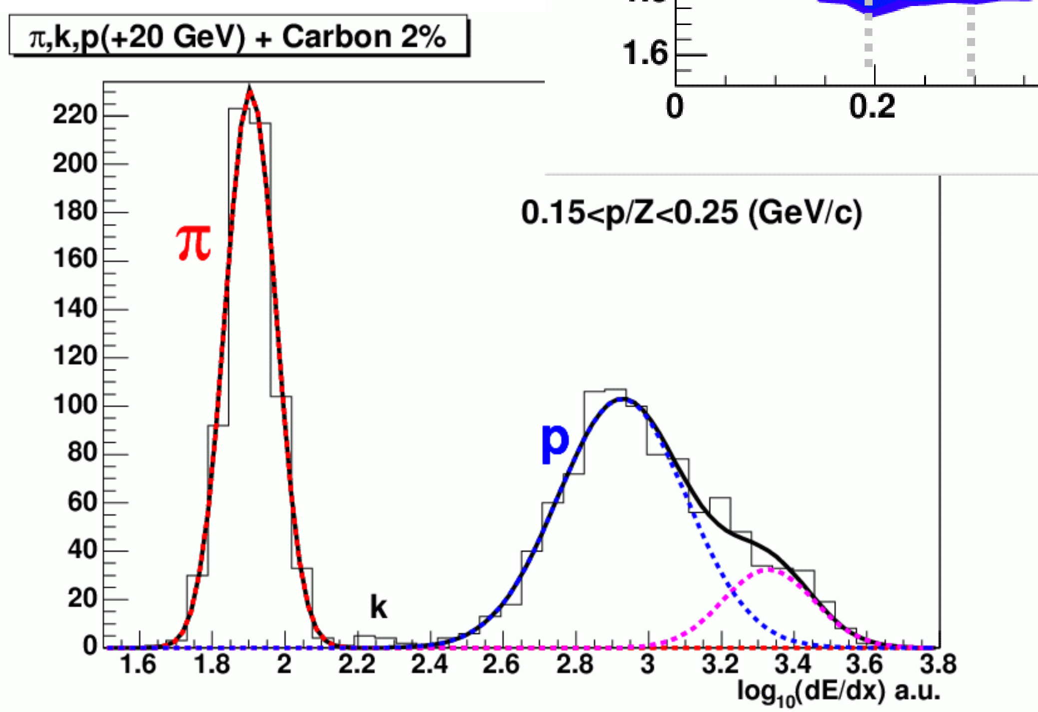




dE/dx in TPC

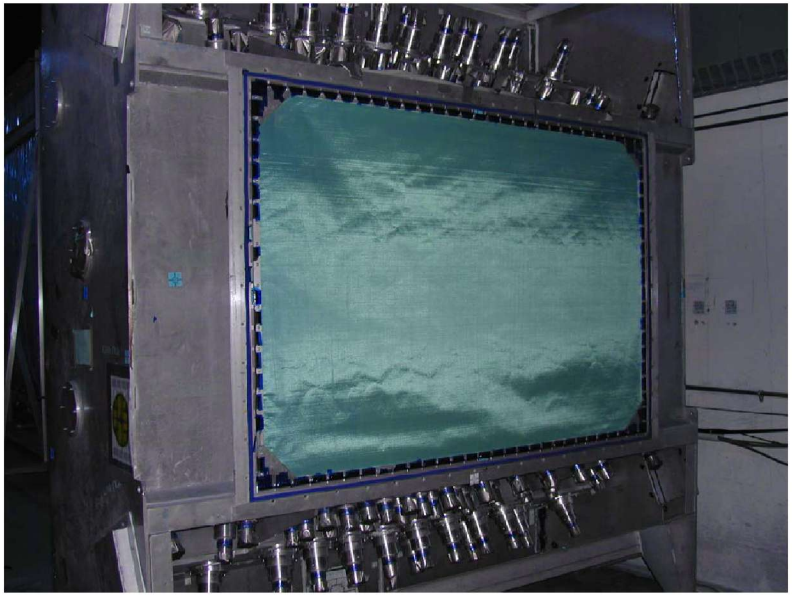
20 GeV π/K/p beam incident on carbon target





- Preliminary calibration of TPC gains
- Momentum from helix fits
- Slice shows momentum range from 150 to 250 MeV/c

MIPP Cherenkov



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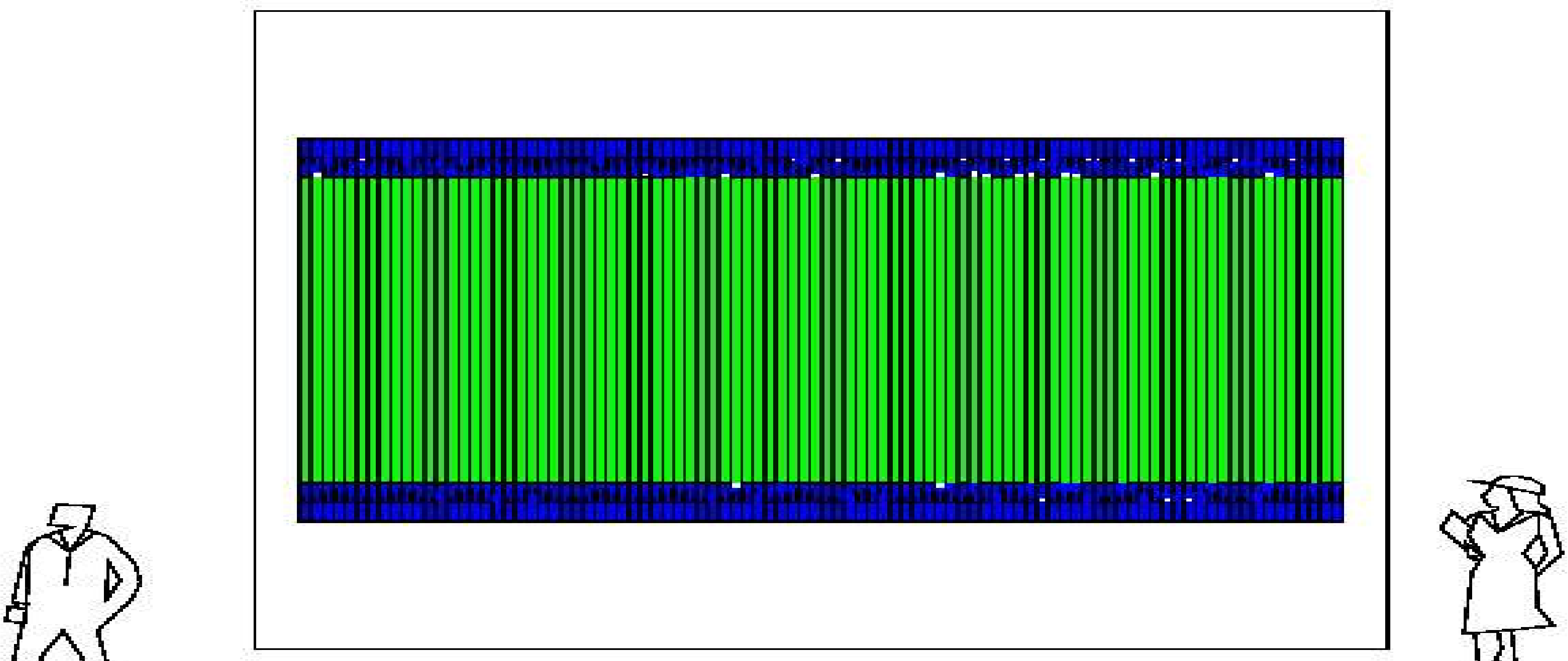
Time of Flight

- Time of flight ($220K) . Designed and built by MIPP

5cmx 5cm square scintillator bars in Rosie aperture, 10cmx10cm outside.
~ 150ps resolution.

MIPP- Time of flight system

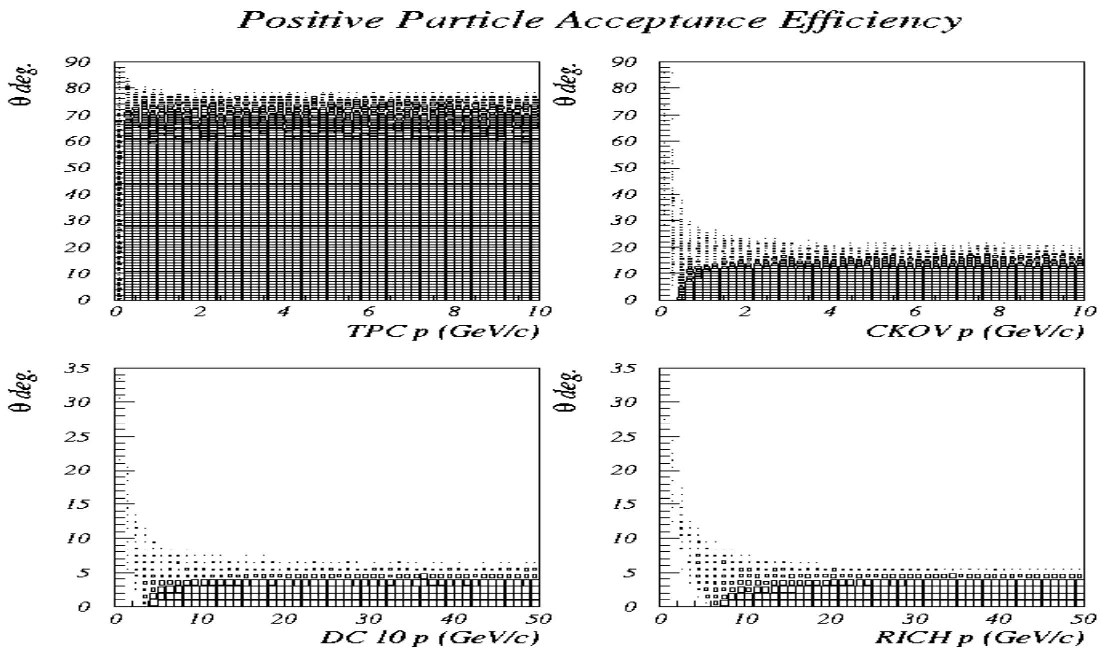


Calorimeters

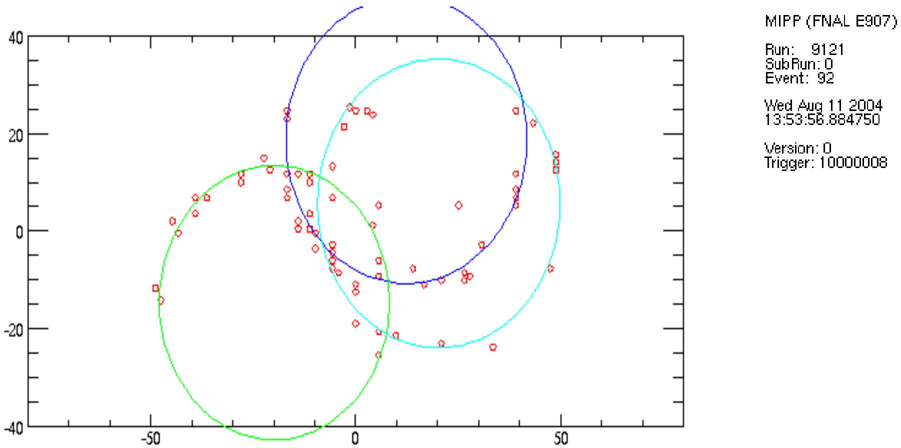
EM calorimeter followed by hadron calorimeter

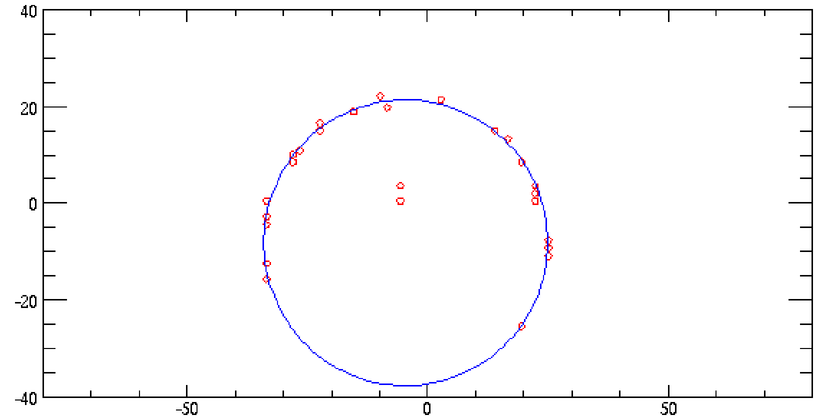
Particle acceptances and resolutions

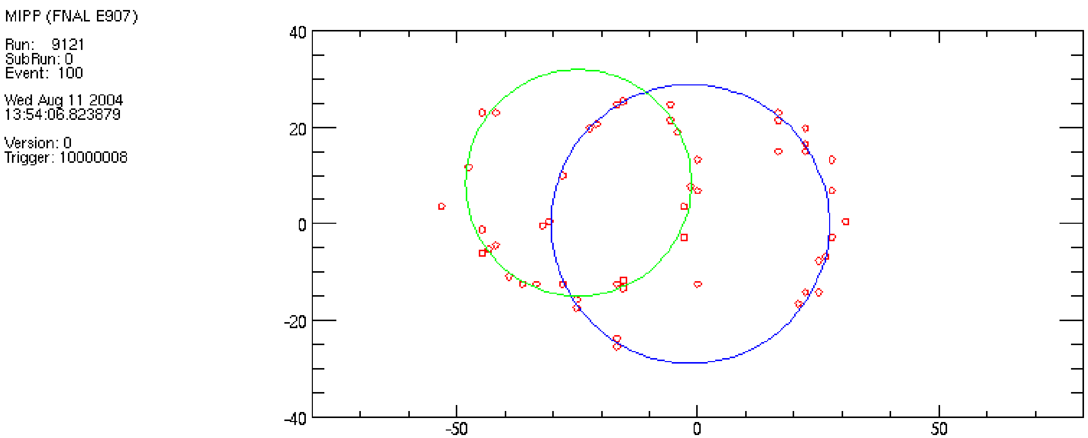
- a)10 Hits in TPC
- b)a hit in the Cerenkov
- c)a hit in Drift Chamber 10 (just before RICH)
- d)Passage through mid-Z plane of RICH.
- Regular Target and NUMI target
- Four cases of particles considered
- (Cumulative AND)



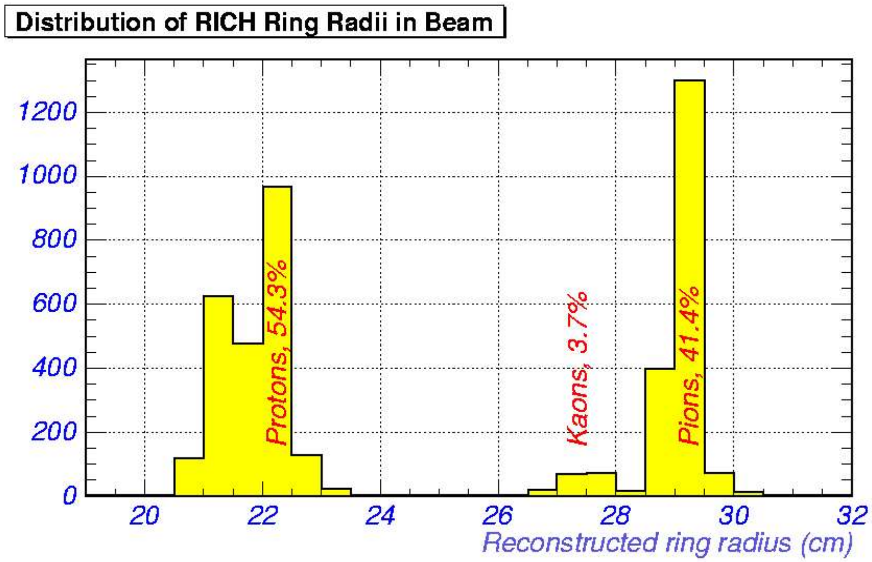
RICH rings pattern recognized





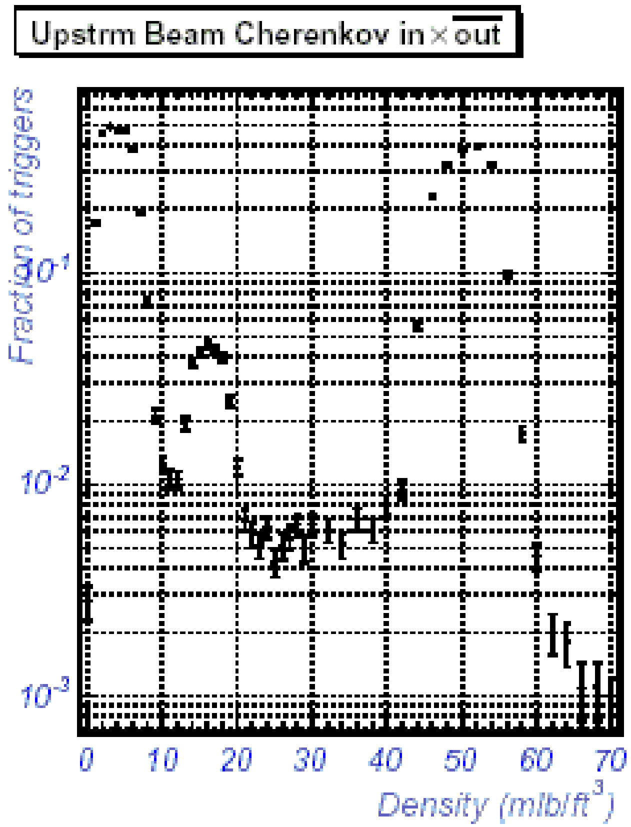


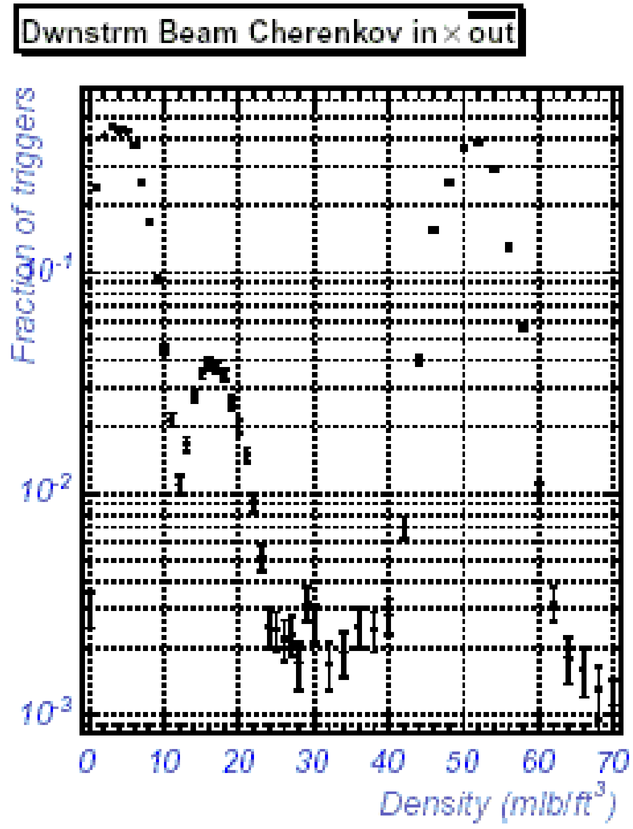
RICH radii for + 40 GeV beam triggers



Beam Cherenkovs

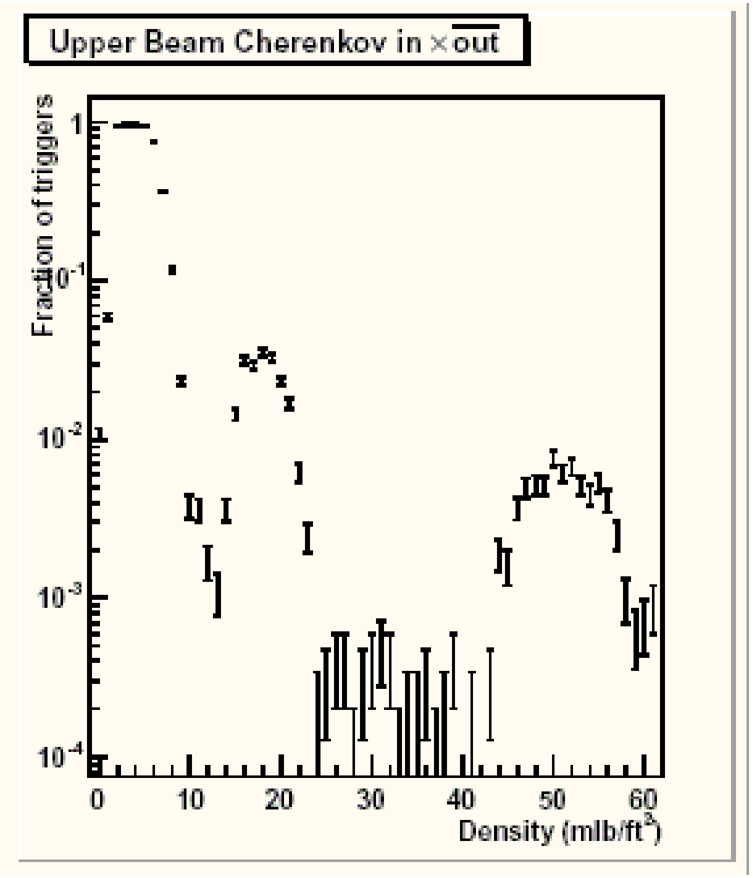
- Pressure curve Automated- Mini-Daq-APACS 30 minutes per pressure curve.+40GeV/c beam.

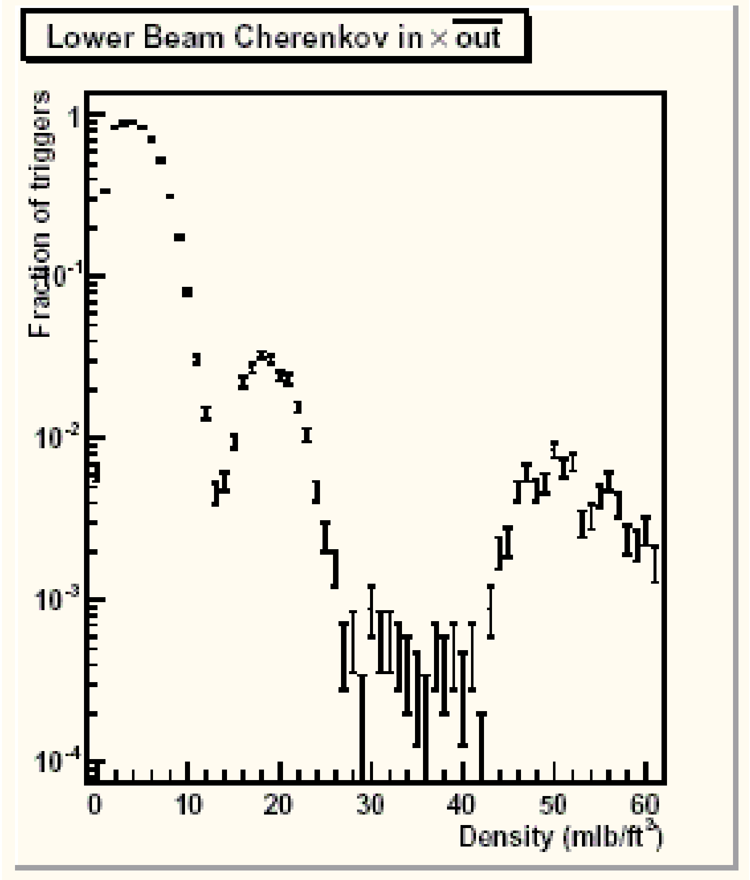




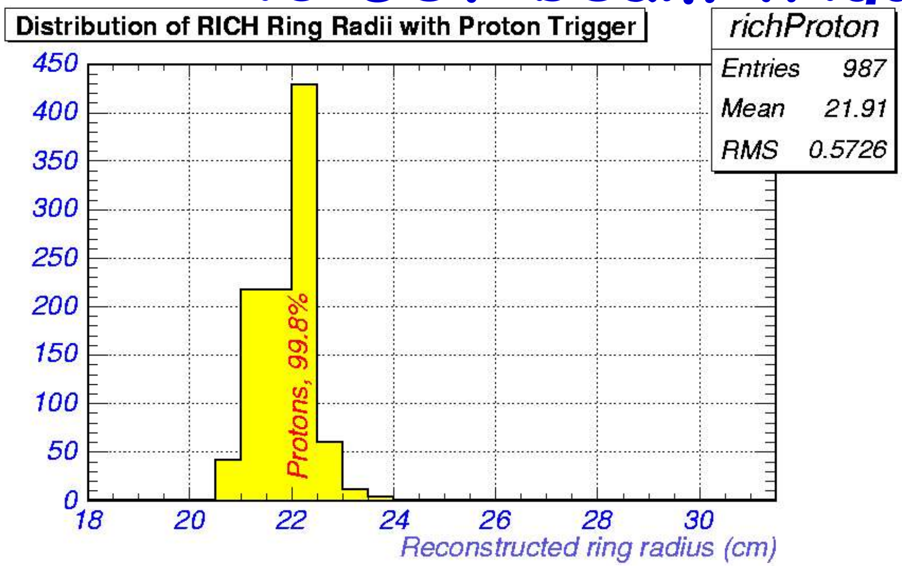
Beam Cherenkovs

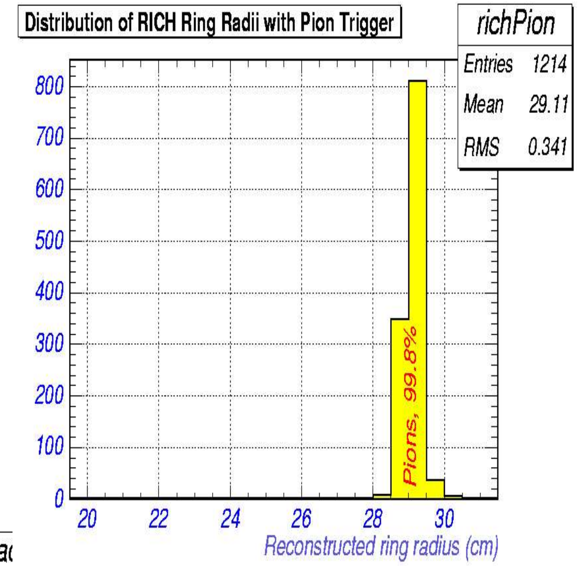
- 40 GeV/c negative beam

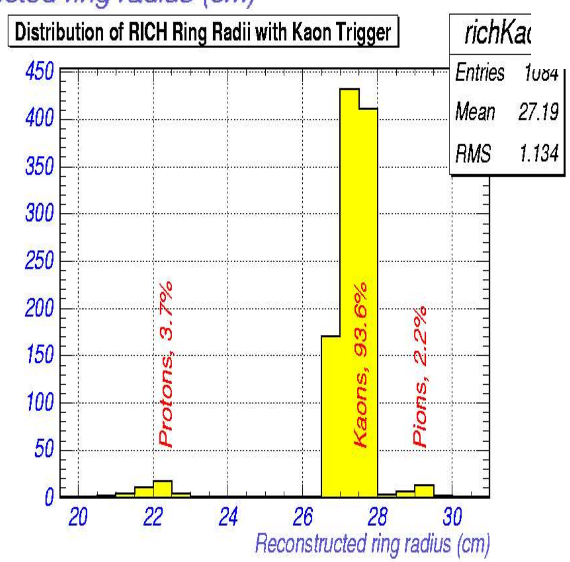




Comparing Beam Cherenkov to RICH for +40 GeV beam triggers-No additional cuts!

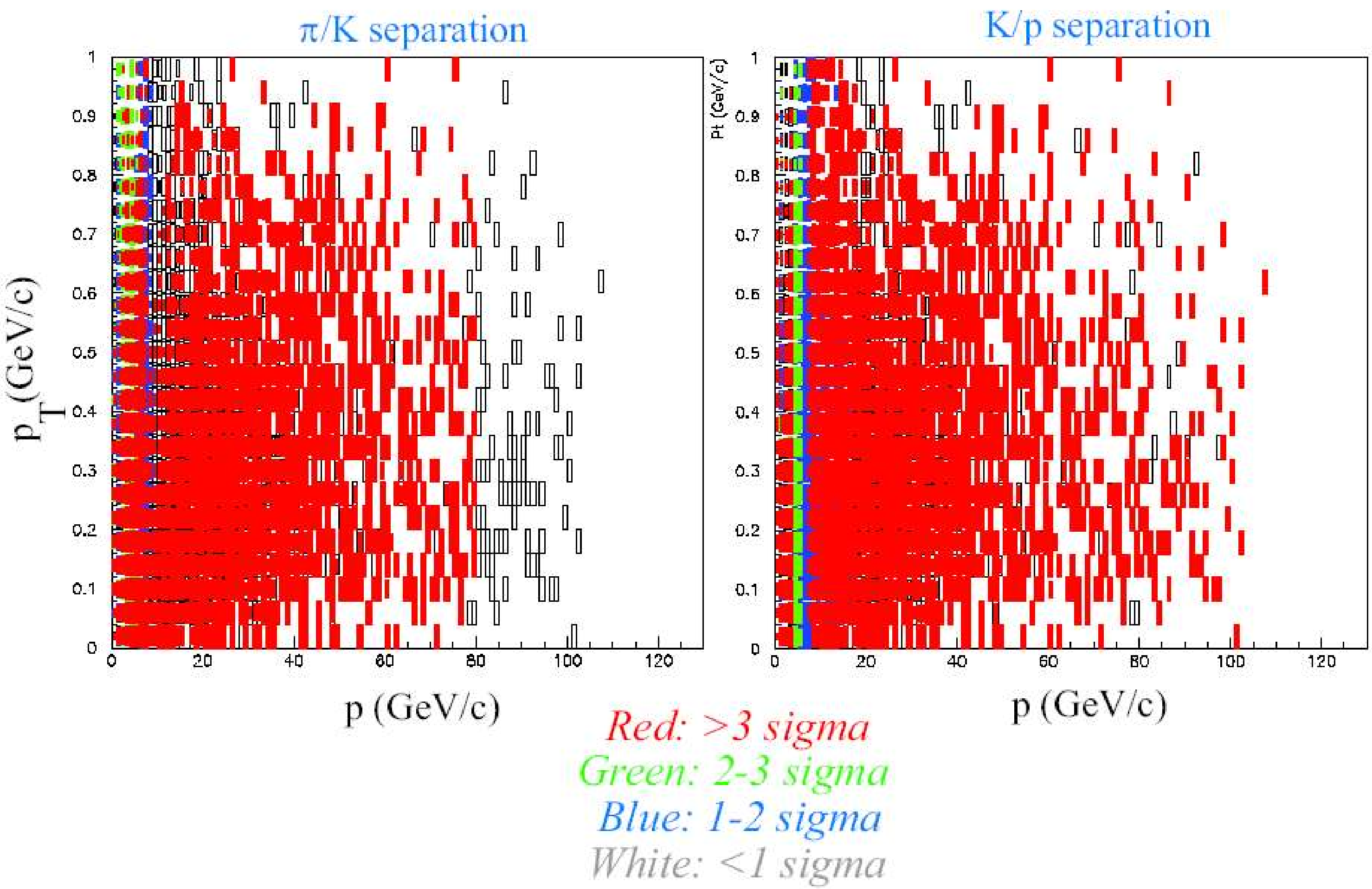




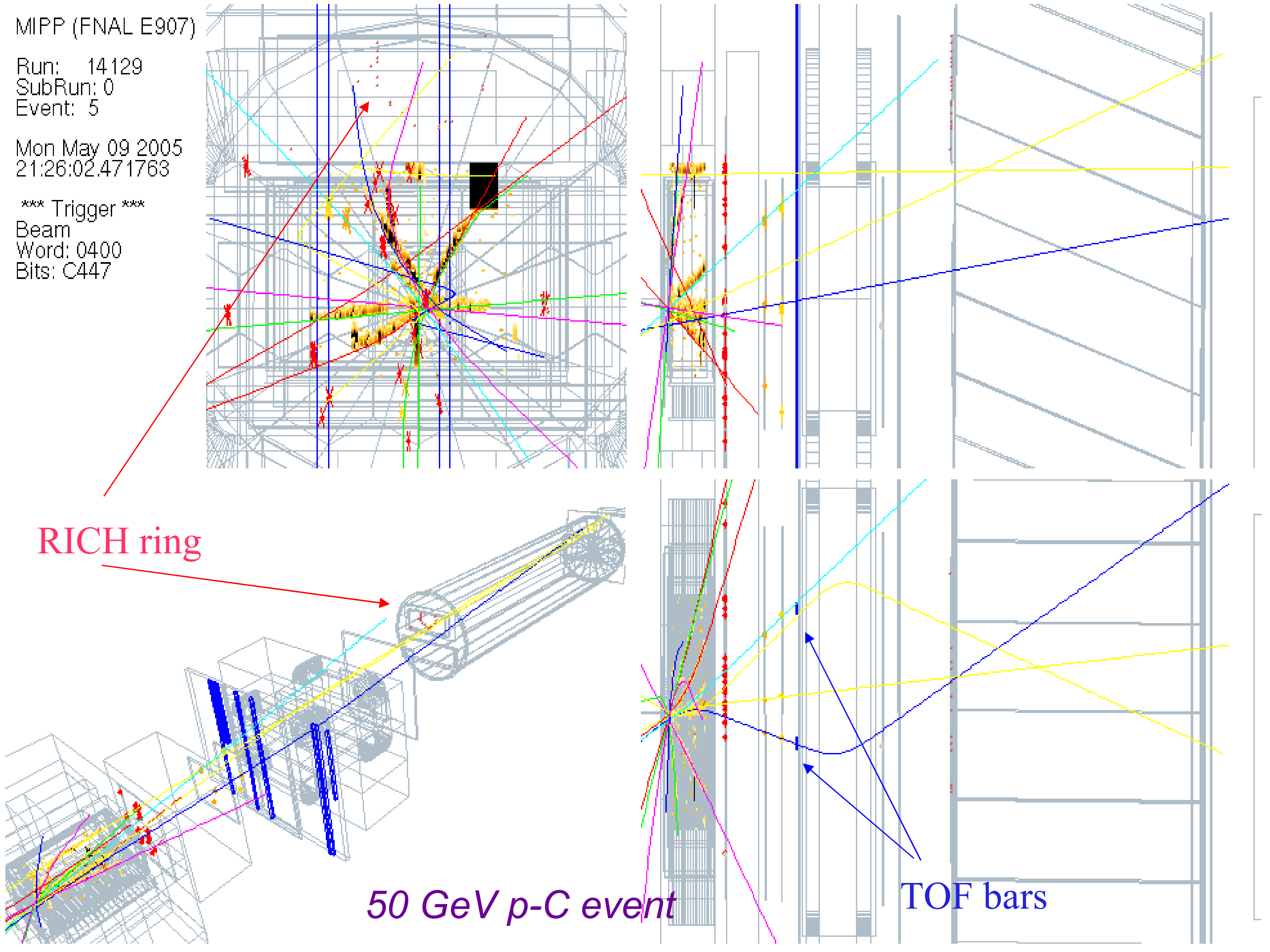


MIPP Particle ID

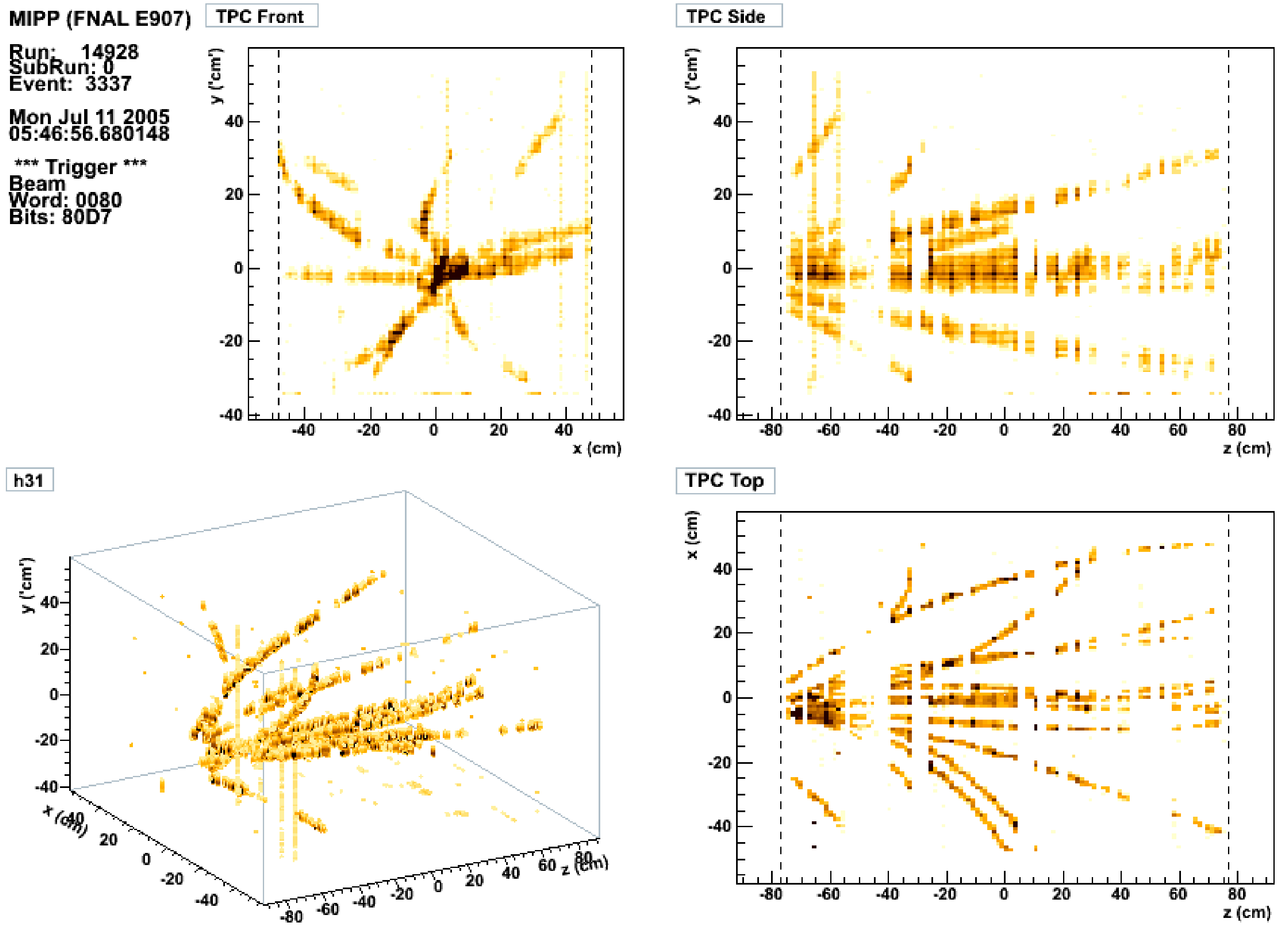
Particle ID Performance



J


MIPP (FNAL E907)
Run: 14129
SubRun: 0
Event: 5
Mon May 09 2005
21:26:02.471763
*** Trigger ***
Beam
Word: 0400
Bits: C447
RICH ring
TOF bars
50 GeV p-C event

Sample Event On NuMI Target



- NuMI target ran in July'05
- Collected 1.5M events
- Target returned to NuMI

First look at NuMI target data

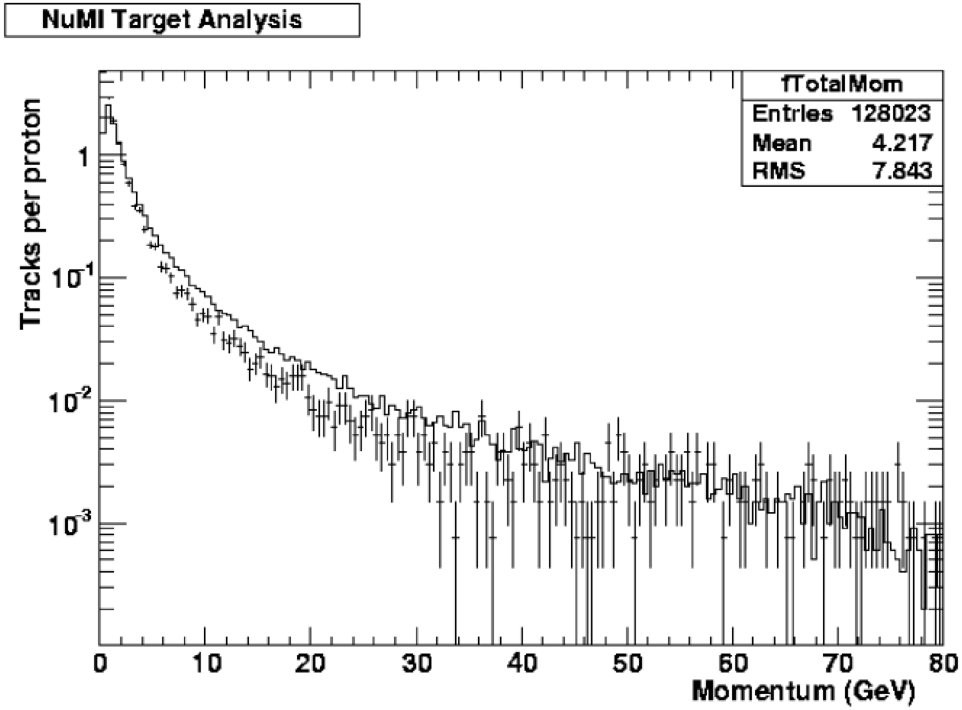
Very preliminary

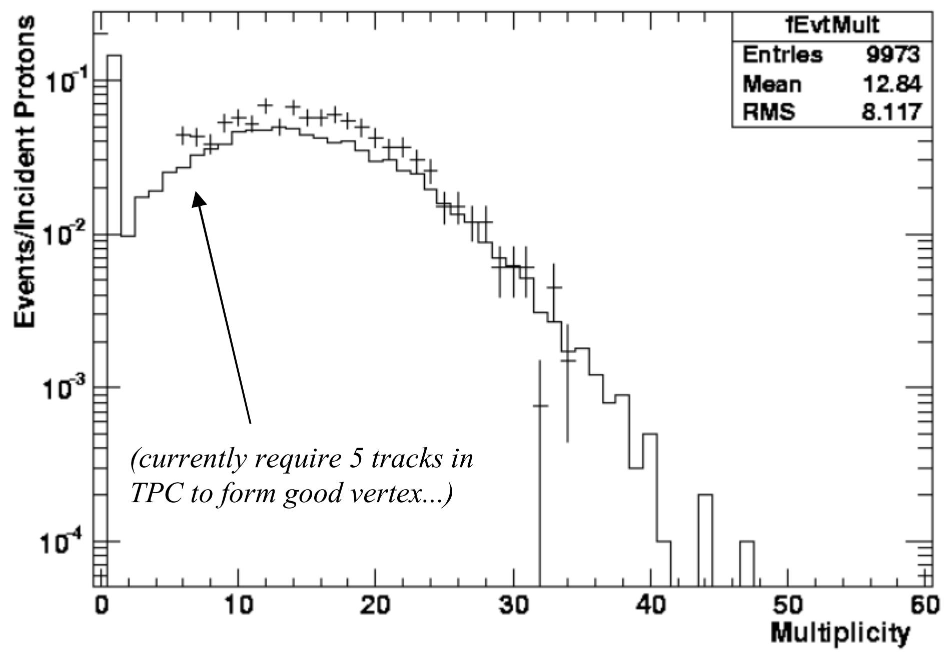
Based on fast TPC-only helix fits

Comparisons are to FLUKA Monte Carlo

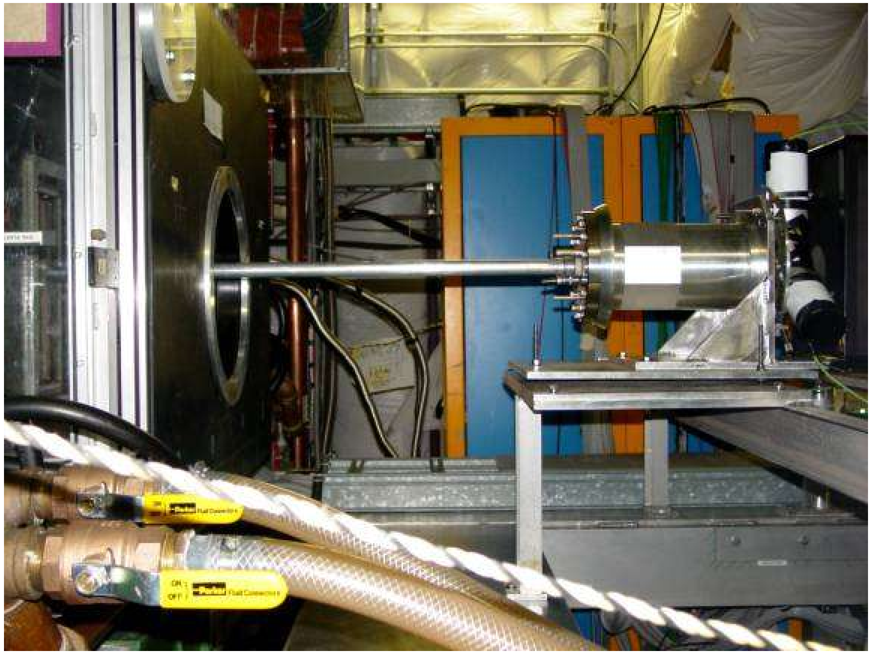
Top: Multiplicity distribution

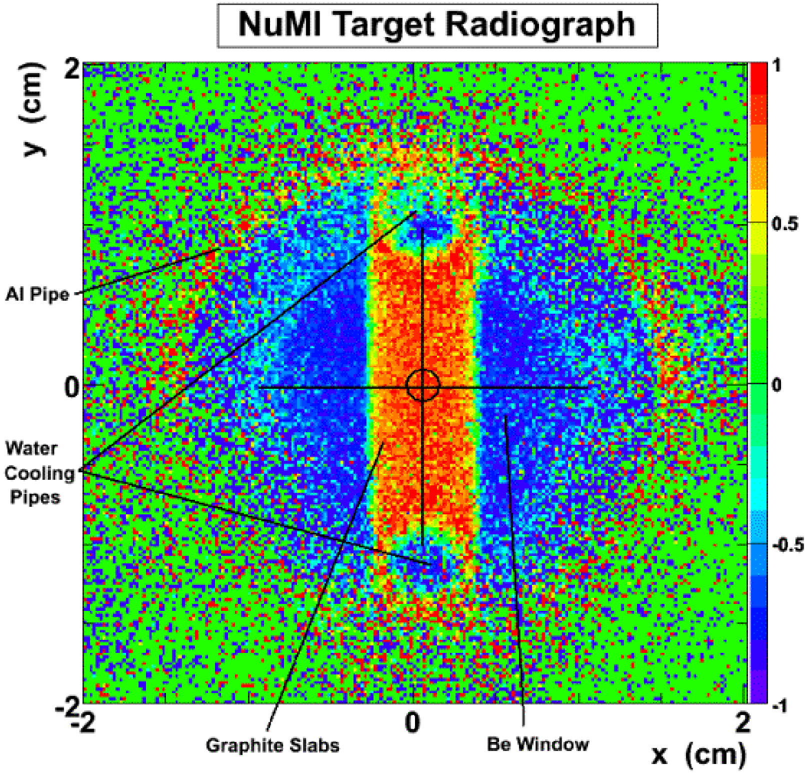
Bottom: Momentum distribution





NUMI target pix





Uses of MIPP QCD data

- Mostly will come from Liquid H2 target.
- We plan to take 18 million events on LH2 with 6 beam species ($\pi^{\pm}$, $K^{\pm}$, $p^{\pm}$)over a momentum range that spans 5 GeV/c to 90 GeV/c.
- We also plan to run Liquid deuterium, which will add np cross sections.
- We plan to re-open the study of non-perturbative QCD by publishing datasets with full particle ID in DST form in DVD's. Any person interested in testing his theory can obtain a dataset.
- We can study exclusive particle reactions with unprecedented accuracy and particle id using constrained fitting.

Uses of MIPP QCD data

- Examples of exclusive channels are

$\pi^+ p \to A_1(1270)p$ Resonance production and diffractio n

$\pi^+ p \to K^+\Sigma^+$ Strangenes s production

$K^+ p \to pp\overline{\Lambda}$ strangenes s and Baryon number production

$K^+ p \to \Delta^+ K^0 \pi^+$ charge exchange and resonance production

$p^+ p \to ppK^+K^-$ Difraction , strangenes s production

$p^+ p \to pp\pi^+\pi^-$ Diffractiv e Dissociati on, Pomerons

$\pi^- p \to \pi^0 n$ Classic ρ exchange reaction

$\pi^- p \to K_*^0(892)\Lambda$ Strangenes s resonance production

$K^- p \to K_3^{*-}(1780)p$ Exotic resonance production

$K^- p \to pK^-$ Strange Baryon exchange

$p^- p \to 3\pi^+ 3\pi^-$ Annihilati on

$p^- p \to p\overline{n}\pi^-$ $\overline{\text{p}}$ diffractio n (4C if we detect $\overline{\text{n}}$, else 1C)

A more complete list of exclusive channels in all the beam species is available at

http://ppd.fnal.gov/experiments/e907/notes/MIPPnotes/public/pdf/MIPP0010/MIPP0010.pdf

Uses of MIPP QCD data

- Missing neutral channels are available as 1C fit.
- Diffraction in 6 beam species with particle id.
- Annihilation as a function of beam momentum
- Flavor propagation in nuclei $K^{\pm}$ propagating through nuclei. How fast is strangeness exchanged?
- Exotic resonances such as glueballs and pentaquarks can be searched for. Unprecedented particle ID and acceptance capabilities as well as the presence of 6 beam species in one experiment will help unravel the nature of the found objects.
- Upgrading the TPC electronics will enable MIPP to take data at 1000HZ instead of the current 60HZ. This will enhance the physics potential of MIPP.

General scaling law of particle fragmentation

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

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

- 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.
- The proposed experiment will test the law as a function of s and t for various particle types a ,b and c for beam energies between ~5 GeV/c and 120 GeV/c to unprecedented statistical and systematic accuracy in 36 reactions.

Estimation of the Annihilation component in pbar-p interactions

- **R.Raja, Phys.Rev.D16:142,1977**
- Conventional method is to subtract pp cross section from pbar-p cross sections. Works well for total cross section, and multiplicity cross sections. Works for neutral pion inclusive cross sections but FAILS for charged pion inclusive cross sections.

Estimation of the annihilation component

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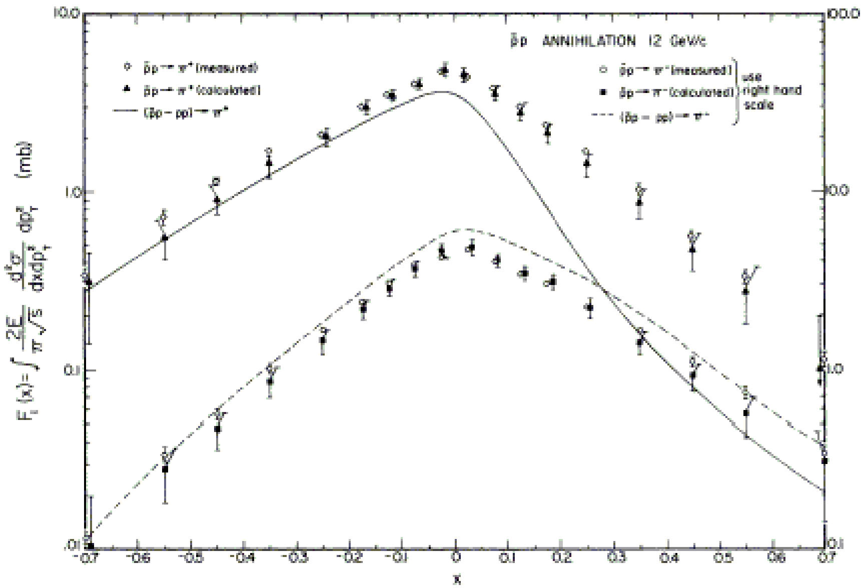


FIG. 1. Comparison of explicit annihilation data at 12 GeV/c with predictions of the derived formulas. Note the different scales for the two sets of data. The curves are the predictions of the charge-symmetry-violating subtraction formulas.

Estimation of the annihilation component

$$\bar{p}p \to \pi^+ + X \equiv \bar{p}^+ \ ; \ \bar{p}p \to \pi^- + X \equiv \bar{p}^-$$

$$\bar{p}p \to \pi^+ + X(ann.) \equiv \bar{p}_A{}^+ ; \ \bar{p}p \to \pi^- + X(ann.) \equiv \bar{p}_A{}^-$$

$$pp \to \pi^+ + X \equiv p^+ \ ; pp \to \pi^- + X \equiv p^-$$

Denote by Π the Parity inversion operator

Then

$$\Pi\bar{p}^+ = \bar{p}^- ; \Pi\bar{p}^- = \bar{p}^+ ; \Pi p^+ = p^+ ; \Pi p^- = p^-$$

$$\Pi\bar{p}_A{}^+ = \bar{p}_A{}^- ; \Pi\bar{p}_A{}^- = \bar{p}_A{}^+$$

whereas for $\pi^{0\text{'s}}$, both $\bar{\text{p}}$p and pp are even under inversion.

- So π^0 production in annihilation information is available by subtraction

$$\bar{p}_A^0 = \bar{p}^0 - p^0$$

- but not $\pi^\pm$.

$$\bar{p}_A^+ \neq \bar{p}^+ - p^+ \qquad \bar{p}_A^- \neq \bar{p}^- - p^-$$

Estimation of the annihilation component

- However, the sum of π^+ and π^- is even under inversion, so we can write

$$\overline{p}_A^+ + \overline{p}_A^- = (\overline{p}^+ + \overline{p}^-) - (p^+ + p^-)$$

- However, the term $\overline{p}_A^+ - \overline{p}_A^-$ is odd under parity inversion and cannot be obtained from pp data. An expression that can be written for the odd term that treats annihilation and non-annihilation symmetrically is

$$\frac{\overline{p}_A^+ - \overline{p}_A^-}{\overline{p}_A^+ + \overline{p}_A^-} = \frac{\overline{p}_N^+ - \overline{p}_N^-}{\overline{p}_N^+ + \overline{p}_N^-} = \frac{\overline{p}^+ - \overline{p}^-}{\overline{p}^+ + \overline{p}^-}$$

Estimation of the annihilation component

- This leads to

$$\overline{p}_A^{\,+} = \left(\frac{(\overline{p}^{\,+} + \overline{p}^{\,-}) - (p^{+} + p^{-})}{(\overline{p}^{\,+} + \overline{p}^{\,-})} \right) \overline{p}^{\,+}$$

- And
-

$$\overline{p}_A^{\,-} = \left(\frac{(\overline{p}^{\,+} + \overline{p}^{\,-}) - (p^{+} + p^{-})}{(\overline{p}^{\,+} + \overline{p}^{\,-})} \right) \overline{p}^{\,-}$$

Explanation for the charge asymmetry relation

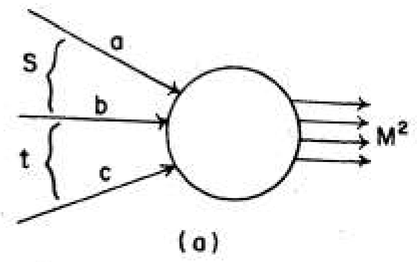
- See "Observation of New regularity in hadronic spectra", R.Raja Phys.Rev.D 18 (1978)204.
- The relation

$$\frac{\overline{p}_A^{+} - \overline{p}_A^{-}}{\overline{p}_A^{+} + \overline{p}_A^{-}} = \frac{\overline{p}_N^{+} - \overline{p}_N^{-}}{\overline{p}_N^{+} + \overline{p}_N^{-}} = \frac{\overline{p}^{+} - \overline{p}^{-}}{\overline{p}^{+} + \overline{p}^{-}}$$

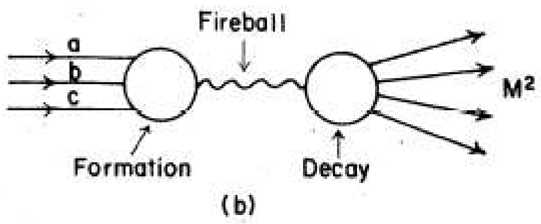
can be explained if one posits that the three body scattering happens in two steps. Formation of the fireball followed by its decay. Similar to the Bohr Compound nucleus hypothesis

Scaling Law

$$\sigma(abc \to X) = F(M^2, s, t) D_X(M^2)$$
$$\sigma(abc \to X_s) = F(M^2, s, t) D_{X_s}(M^2)$$



$$\frac{\sigma(abc \to X_{sub})}{\sigma(abc \to X)} = \frac{F(M^2, s, t) D_{X_{sub}}(M^2)}{F(M^2, s, t) D_X(M^2)} = \alpha_{sub}(M^2)$$



$$\frac{f(ab \to \bar{c} + X_{sub})}{f(ab \to \bar{c} + X)} = \alpha_{sub}(M^2)$$

- Continuing on to physical t values, one gets

Scaling law

- Applying to annihilations, one gets

$$\frac{\bar{p}_A^+(M^2,s,t)}{\bar{p}^+(M^2,s,t)} = \alpha_A^+(M^2)$$

$$\frac{\bar{p}_A^-(M^2,s,t)}{\bar{p}^-(M^2,s,t)} = \alpha_A^-(M^2)$$

$\alpha_A^+(M^2) = \alpha_A^-(M^2)$ due to C symmetry

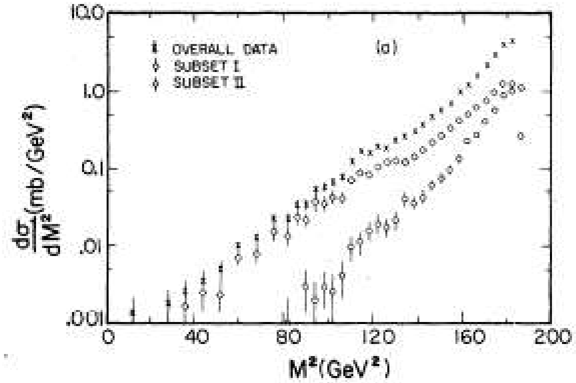
leading to

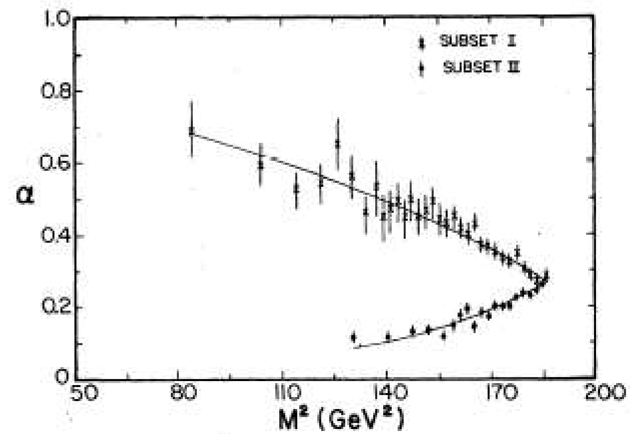
$$\frac{\bar{p}_A^+ - \bar{p}_A^-}{\bar{p}_A^+ + \bar{p}_A^-} = \frac{\bar{p}_N^+ - \bar{p}_N^-}{\bar{p}_N^+ + \bar{p}_N^-} = \frac{\bar{p}^+ - \bar{p}^-}{\bar{p}^+ + \bar{p}^-}$$

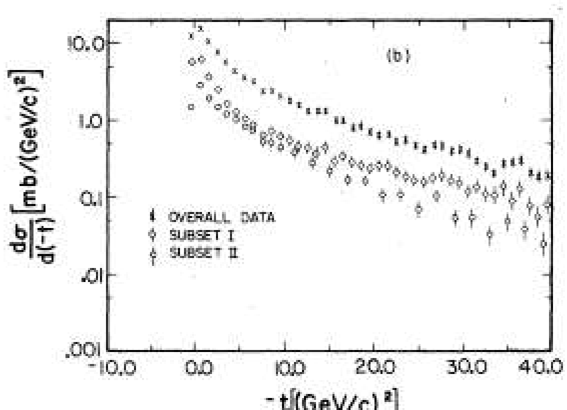
- This factorization and decay is general. So does it apply to other subsets? The answer is yes!

Scaling Law

- 100 GeV/c $\bar{p}p$ data is divided into 2 subsets of multiplicity.
- Subset I= multiplicities 2,4,6
- Subset II= multiplicities 12,14,16







Scaling law tests with MIPP

Negative beam reactions

19	π^-	+	p	------->	π^+	+	X
20	π^-	+	p	------->	K^+	+	X
21	π^-	+	p	------->	p	+	X
22	π^-	+	p	------->	π^-	+	X
23	π^-	+	p	------->	K^-	+	X
24	π^-	+	p	------->	p^-	+	X
25	K^-	+	p	------->	π^+	+	X
26	K^-	+	p	------->	K^+	+	X
27	K^-	+	p	------->	p	+	X
28	K^-	+	p	------->	π^-	+	X
29	K^-	+	p	------->	K^-	+	X
30	K^-	+	p	------->	p^-	+	X
31	p^-	+	p	------->	π^+	+	X
32	p^-	+	p	------->	K^+	+	X
33	p^-	+	p	------->	p	+	X
34	p^-	+	p	------->	π^-	+	X
35	p^-	+	p	------->	K^-	+	X
36	p^-	+	p	------->	p^-	+	X

Among the 36, there are 15 crossing symmetry relations and 3 C symmetry relations

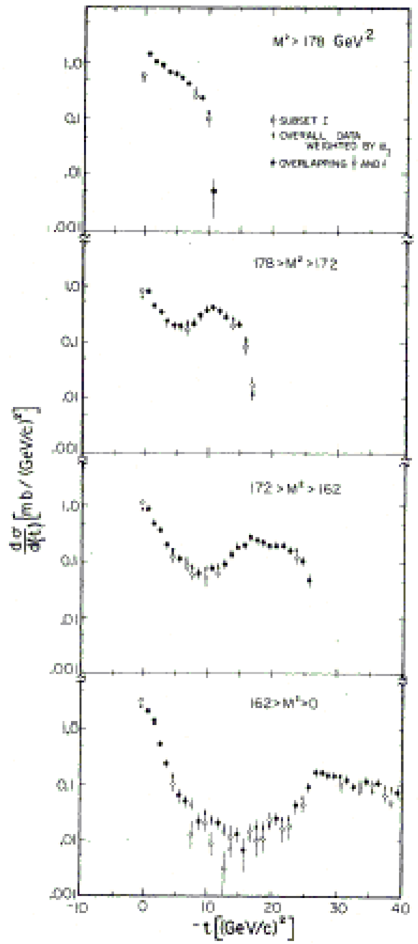


FIG. 4. Comparison of the t distribution for subset I with overall data weighted by $\alpha_I(M^2)$ for various M^2 ranges.

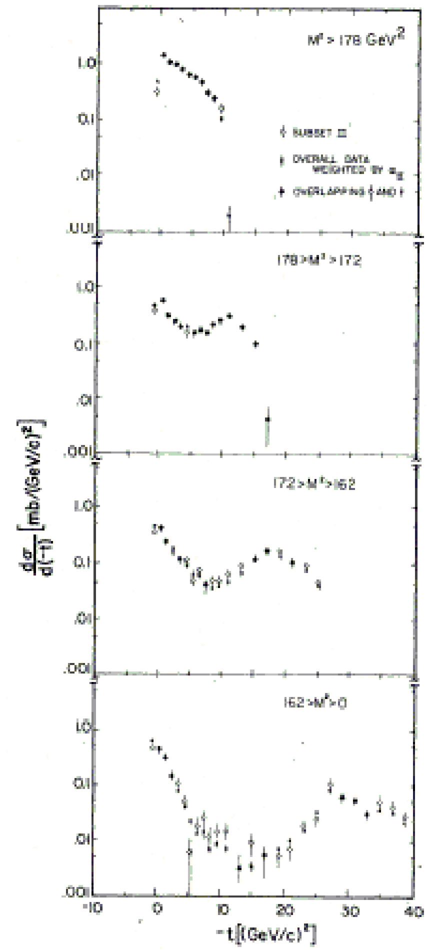


FIG. 5. Comparison of the t distribution for subset II with overall data weighted by $\alpha_{II}(M^2)$ for various M^2 ranges.

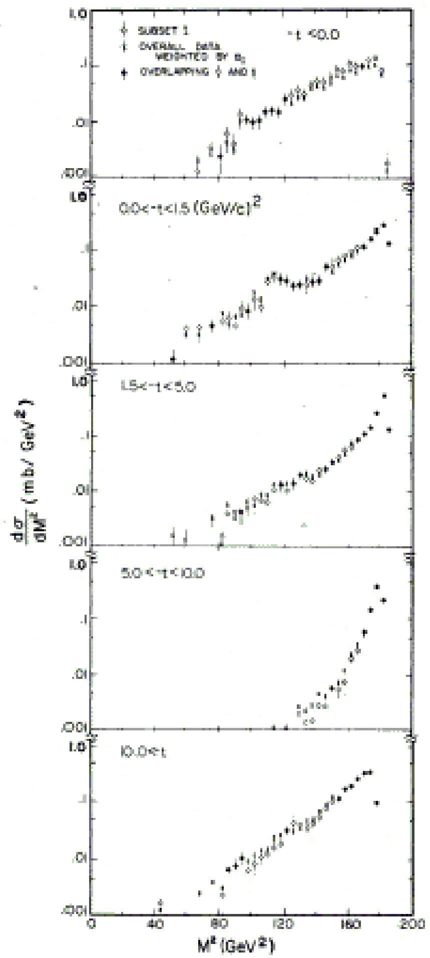


FIG. 6. Comparison of the M^2 distribution for subset I with overall data weighted by α_I (M^2) for various t ranges.

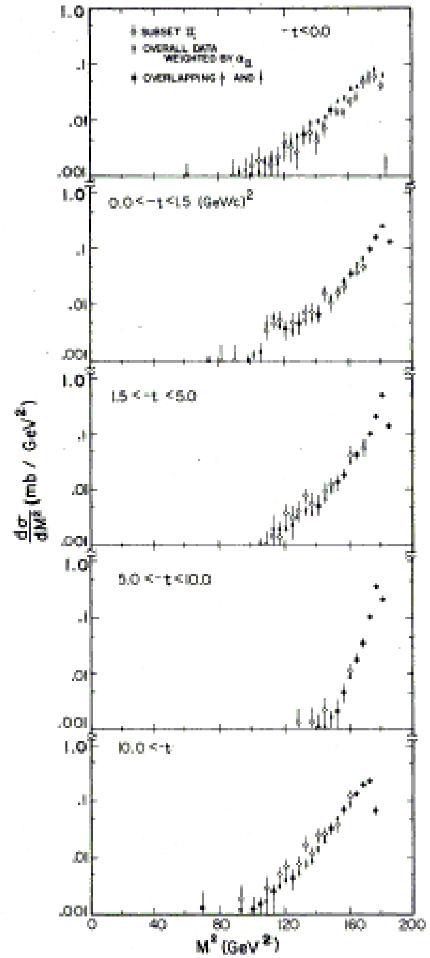


FIG. 7. Comparison of the M^2 distribution for subset II with overall data weighted by α_{II} (M^2) for various t ranges.

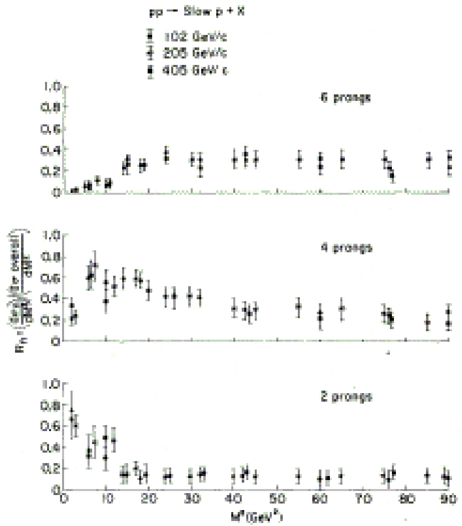


FIG. 8. The ratio of the semi-inclusive cross section to the overall cross section vs M^2 for 2, 4, and 6 prongs at beam momenta 102, 205, and 405 GeV/c.

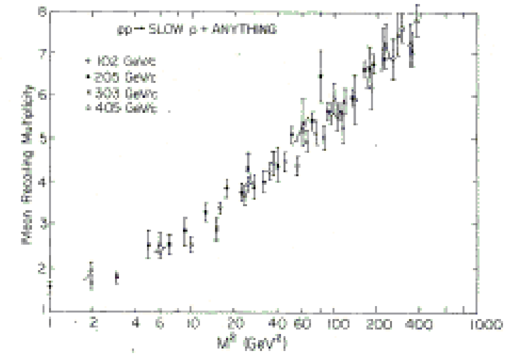


FIG. 9. The mean recoiling multiplicity as a function of M^2 at beam momenta 102, 205, 303, and 405 GeV/c.

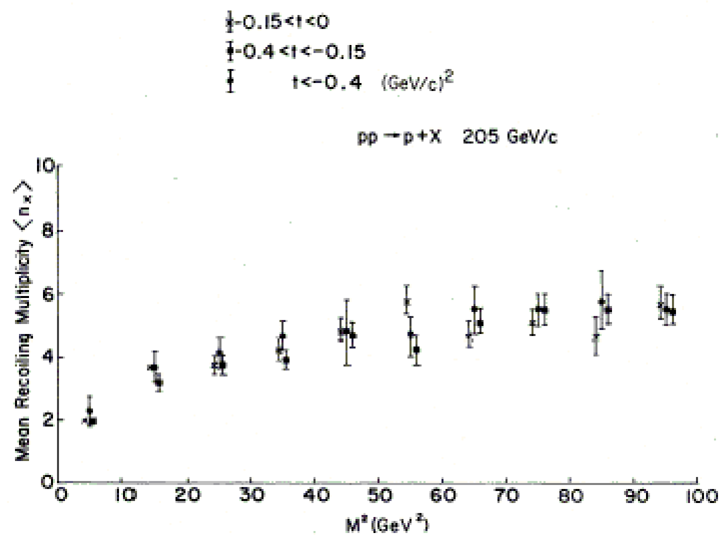
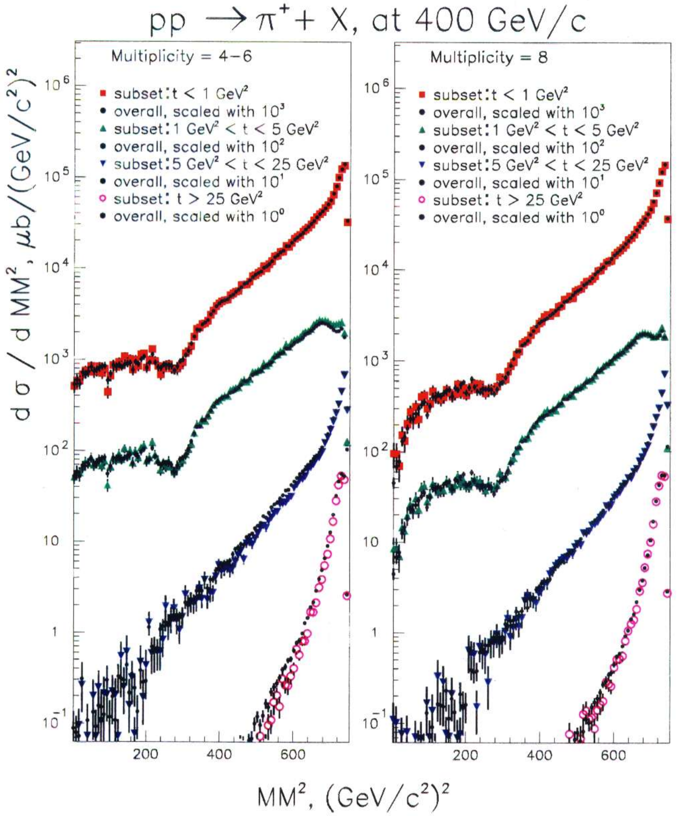


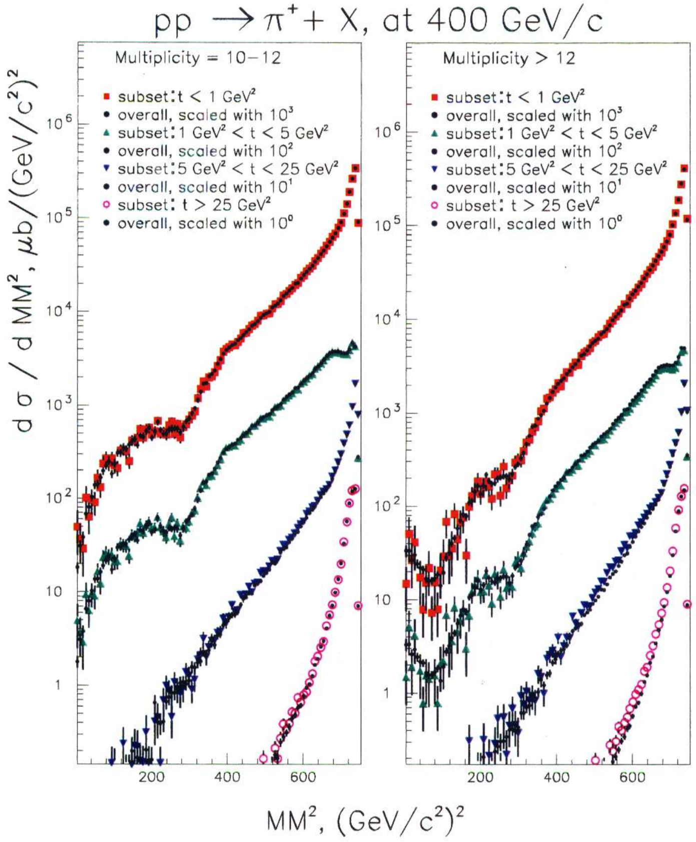
FIG. 10. The mean recoiling multiplicity as a function of M^2 for various t ranges at 205 GeV/c.

European Hybrid Spectrometer data

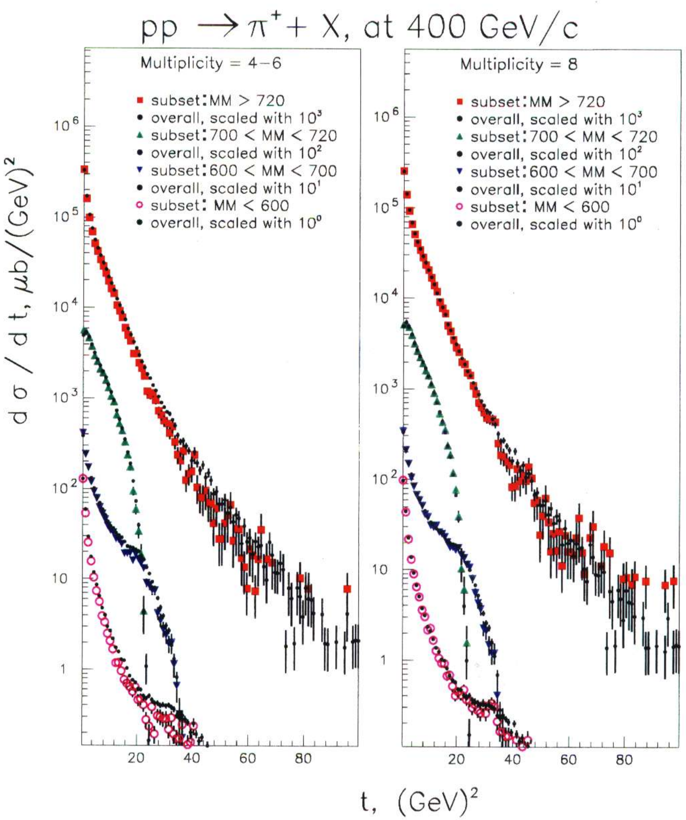
- 1 million events in EHS would have taken 3 years to analyze- Scan measure and track match. Incomplete particle id. Only data available at fixed s. Can test t independence. It takes MIPP ~ 8 hours to acquire 1 Million events, fully track matched and particle id'd.
- We have verified the scaling law in 12 reactions using EHS data at fixed s. (Y.Fisyak,R.Raja, Proceedings of the DPF1992 conference)

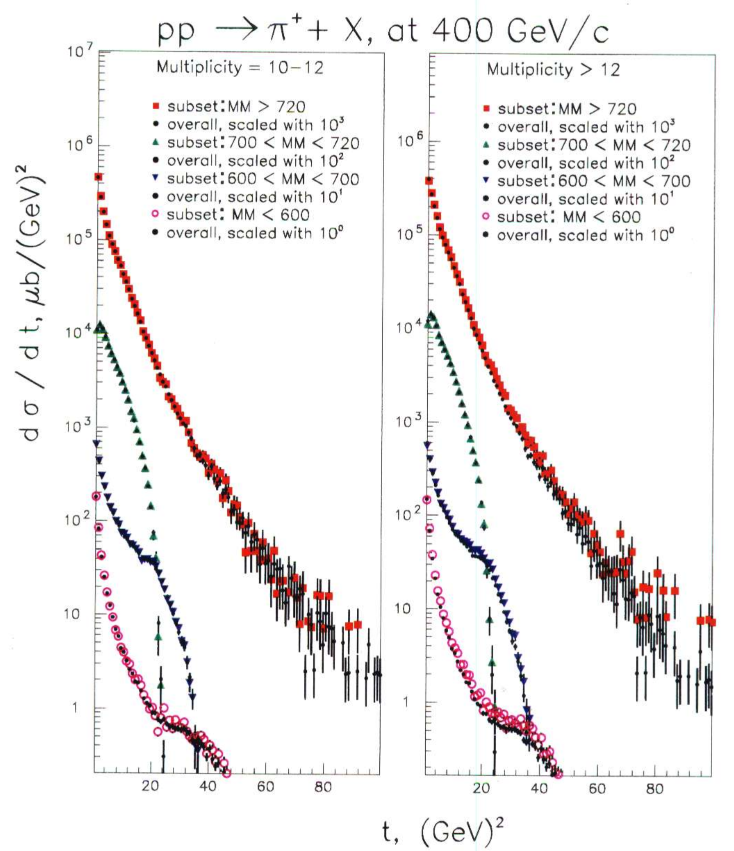
Scaling Law-EHS results





Scaling law -EHS results





Scaling Law tests with MIPP

- MIPP will test the scaling law with 36 reactions both in s and in t.
- Positive beam reactions

1	π^+	+	p	------->	π^+	+	X
2	π^+	+	p	------->	K^+	+	X
3	π^+	+	p	------->	p	+	X
4	π^+	+	p	------->	π^-	+	X
5	π^+	+	p	------->	K^-	+	X
6	π^+	+	p	------->	p^-	+	X
7	K^+	+	p	------->	π^+	+	X
8	K^+	+	p	------->	K^+	+	X
9	K^+	+	p	------->	p	+	X
10	K^+	+	p	------->	π^-	+	X
11	K^+	+	p	------->	K^-	+	X
12	K^+	+	p	------->	p^-	+	X
13	p	+	p	------->	π^+	+	X
14	p	+	p	------->	K^+	+	X
15	p	+	p	------->	p	+	X
16	p	+	p	------->	π^-	+	X
17	p	+	p	------->	K^-	+	X
18	p	+	p	------->	p^-	+	X

Scaling law tests with MIPP

- For instance the functions $\alpha_s(M^2)$ by crossing symmetry must be the same for $\pi^+ p \rightarrow \pi^+ + X$ and $\pi^- p \rightarrow \pi^- + X$.
- Similarly

$$\bar{p}p \rightarrow \pi^+ + X \text{ and } \pi^- p \rightarrow p + X$$

Have the same $\alpha_s(M^2)$. So a diffractive process is linked to a central production process!

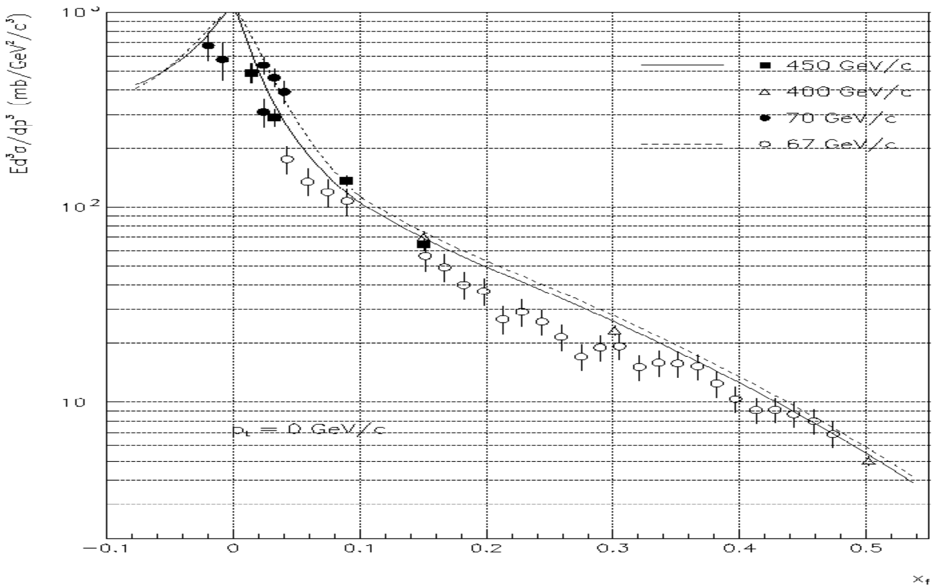
Implications of scaling law

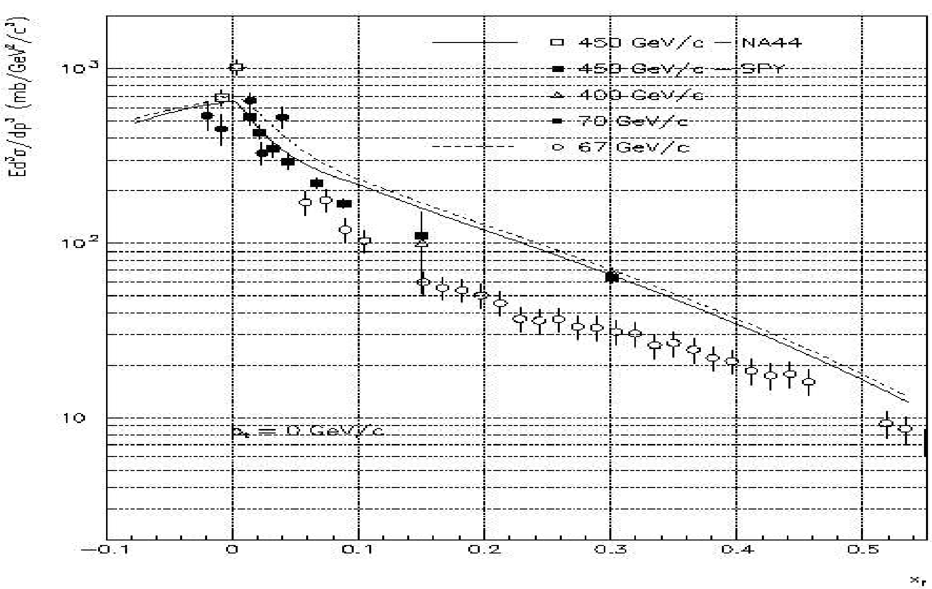
- Implies that the pseudo-resonance states x behave as particles, there is fast equilibrium upon scattering. Argues against independent quark fragmentation in DIS. Argues for promoting the state X to have a structure that varies with M^2. This leads naturally to scale breaking.
- I believe that if MIPP can establish this scaling to better than a percent or so in all 36 channels, we have to take these views seriously and alter our theories in accordance.

Hadron Shower Simulator problem

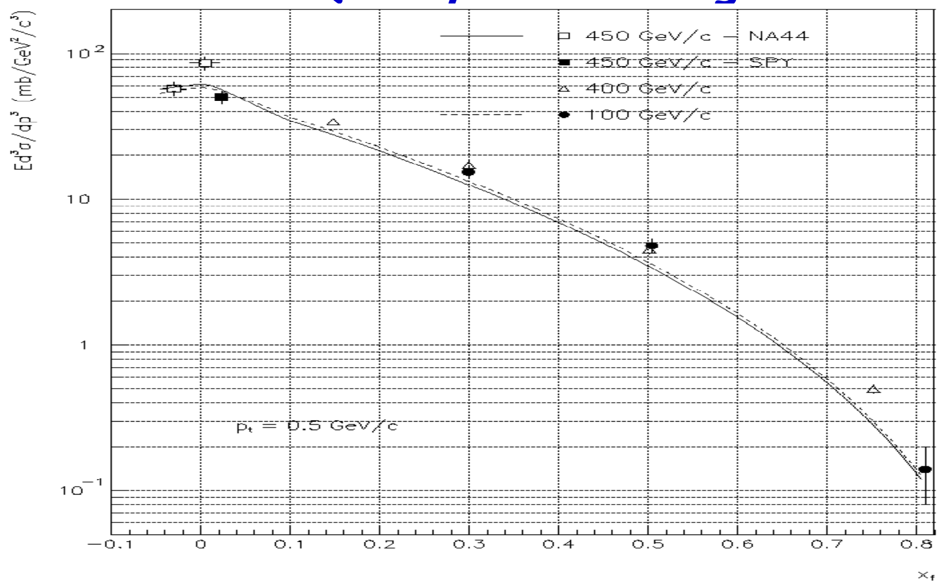
- All neutrino flux problems (NUMI, MiniBoone, K2K, T2K,Nova, Minerva) and all Calorimeter design problems and all Jet energy scale systematics (not including jet definition ambiguities here) can be reduced to one problem- the sorry state of hadronic shower simulators. MIPP upgrade can solve this problem for once and for all.
- Timely completion of MIPP upgrade progam can help CDF/D0 systematics, CMS/ATLAS, CALICE and all neutrino experiments.
- Myth-I Put designed calorimeter in test beam and use the data to tune the simulator_-D0 experience. You need test beam to test the hardware.
- Myth-II Take test beam data at various incident angles and use it to interpolate –H-matrix experience
- In order to have better simulator, we need to measure event by event data with excellent particle ID using 6 beam species (pi,K,P and antiparticles) off various nuclei (LH2 critical) at momenta ranging from 1 GeV/c to ~100 GeV/c. MIPP upgrade is well positioned to obtain this data.
- MIPP can help with the nuclear slow neutron problem.
- Current simulators use a lot of „Tuned theory". Propose using real library of events and interpolation.

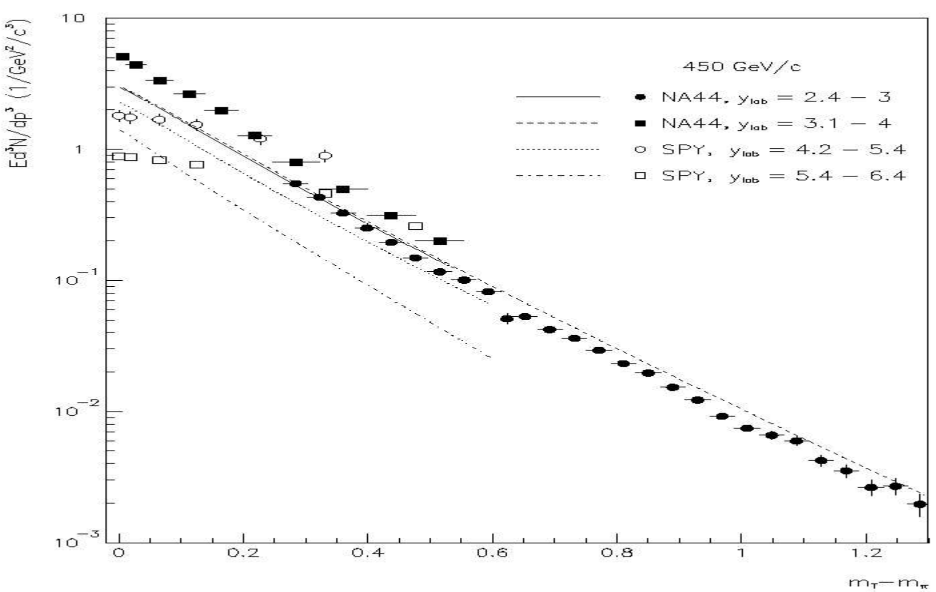
Quality of existing data





Quality of existing data



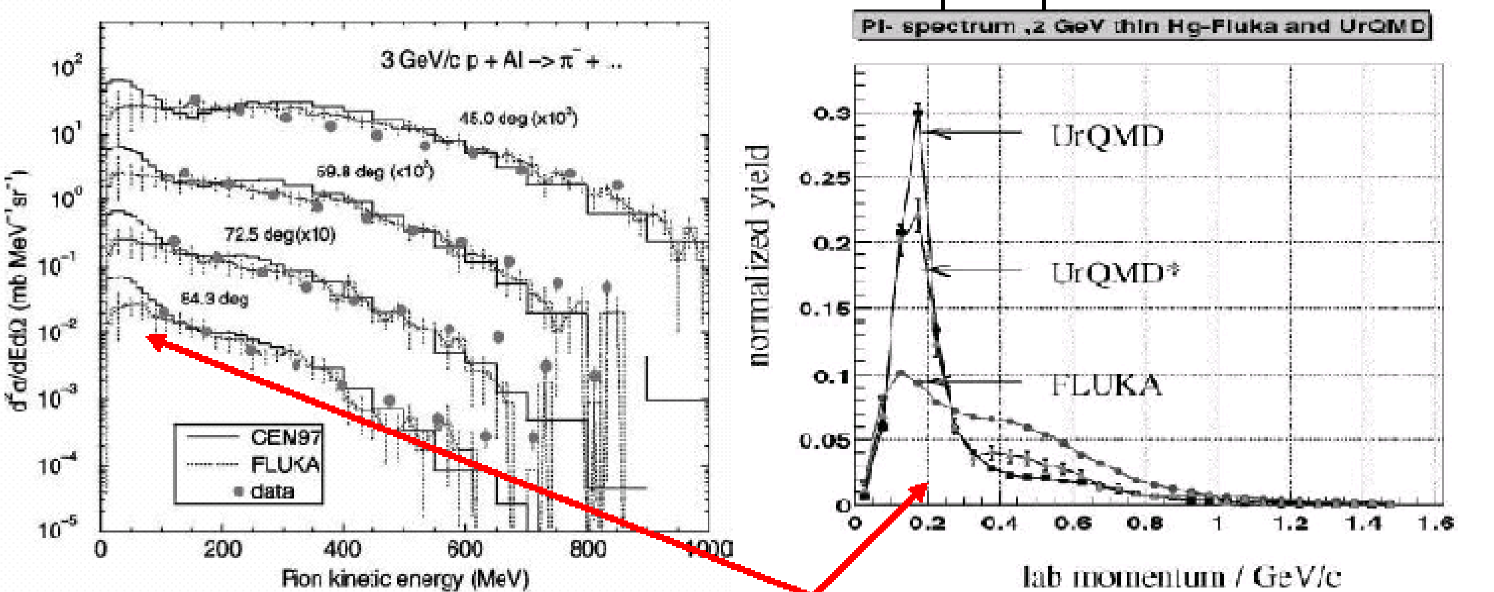


Discrepancies between hadronic generators

Lack of experimental data and large uncertainties in the calculations,

in particular for thick and high Z target materials

Differential distributions for pion production:



NIMA451(2000)327

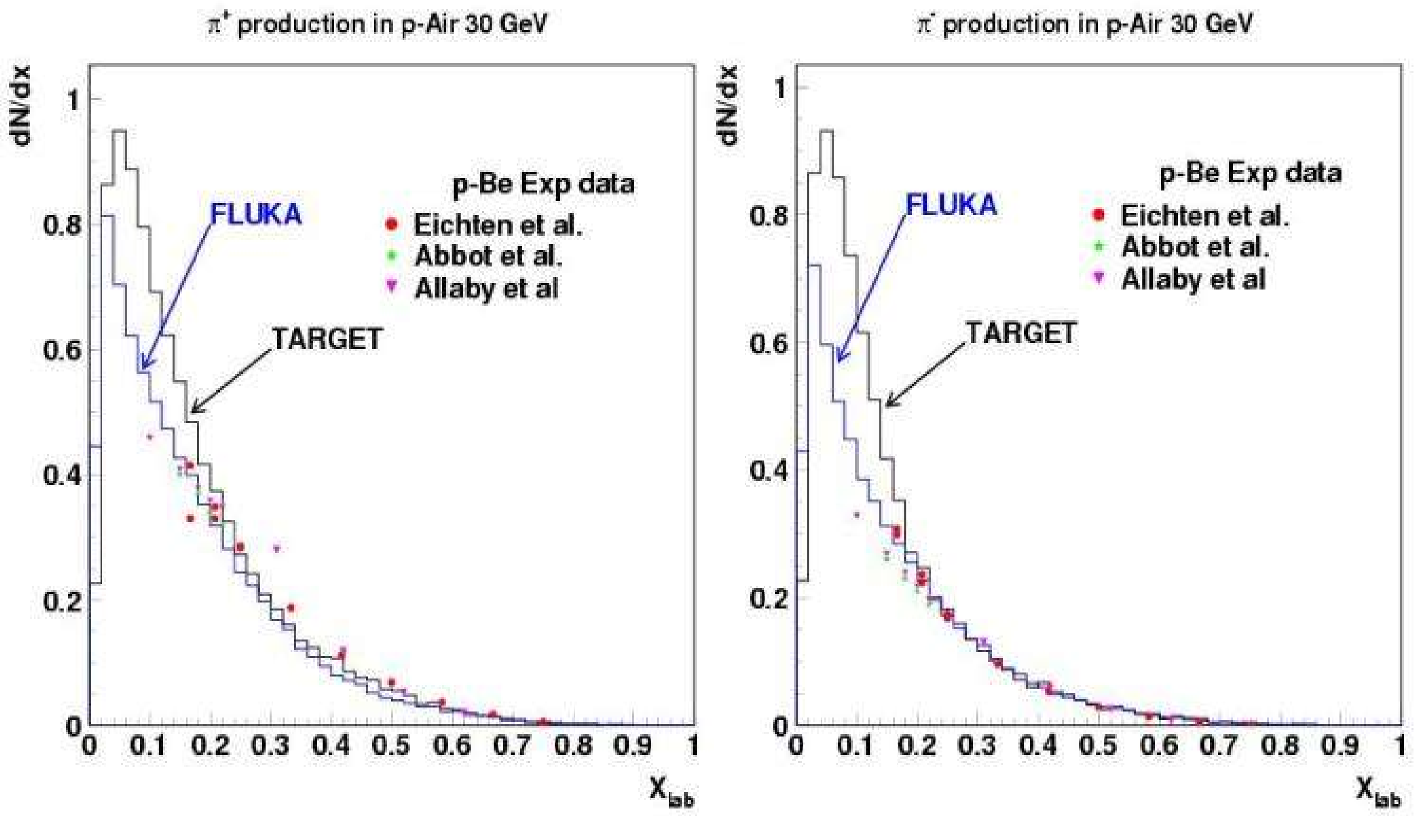
NIMA472(2001)5

NO DATA !

➔ Thin and thick targets, scan in Z

Discrepancies between hadronic generators

27



G.Battistoni

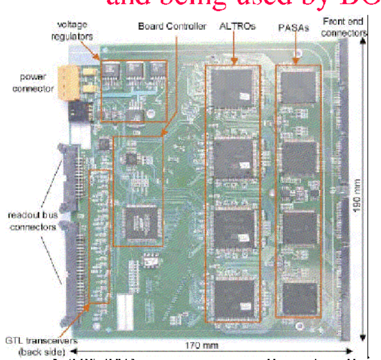
9/00

MIPP Upgrade program

- Speed up TPC DAQ by using ALICE ALTRO/PASA chips. We have ben given he green light to acquire these chips from CERN ($80K).
- Speed up rest of DAQ.

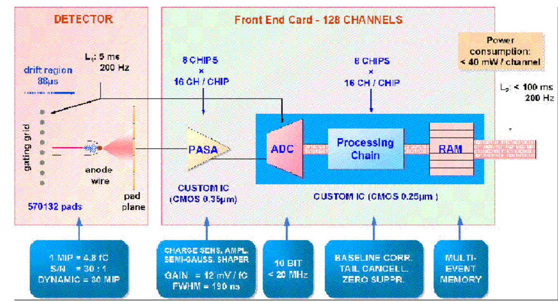
ALICE PASA/ALTRO Chip

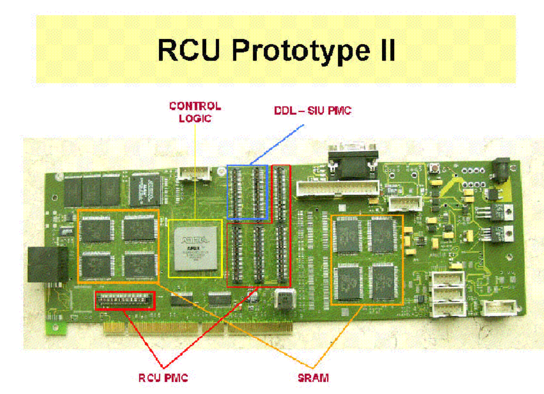
- PASA-Preamp/Pulse shaper One chip=16 pads.
- ALTRO-Digitizes,memory buffer. Controlled by ALTRO bus (40bits wide) with a Readout Control Unit.
- Thoroughly debugged and tested for ALICE. Needed by STAR, TOTEM, MIPP and being used by BONUS.



ALICE Front end card needs to be rearranged to look like a stick.

ALTRO/PASA chips





Nuclei of interest- 1st pass list

- The A-List
- H_2,D_2,Li,Be,B,C,N_2,O_2,Mg,Al,Si,P,S,Ar,K,Ca,,Fe,Ni,Cu,Zn,Nb,Ag,Sn,W,Pt,Au,Hg,Pb,Bi,U
- The B-List
- Na, Ti,V, Cr,Mn,Mo,I, Cd, Cs, Ba
- On each nucleus, we can acquire 5 million events/day with one 4sec beam spill every 2 mins and a 50% downtime.
- We plan to run several different momenta and both charges.
- The libraries of events thus produced will be fed into shower generator programs which currently have 30 year old single arm spectometer data with high systematics

Additional Physics with upgraded MIPP

- Non-Perturbative QCD
  - » Test scaling in two particle inclusives- More variables. Need more statistics.
- More nuclei can be measured-Solve the hadron shower simulation problem once and for all important for Linear collider calorimetry.
- Future Neutrino experimental targets-FINESSE, T2K, Minerva, Nova, Minos, Pierre Auger
- Low Momentum Pion and Kaon Physics. Pion beams of 1 GeV/c and Kaon beams of 5 GeV/c and greater are possible.

Missing baryon Resonances

- Low momentum pions (<5 GeV/c) need new power supplies that regulate at such low current. J.Lentz proposes using trim element supplies (plentiful at the lab) and switching between the two sets as running conditions demand. Will build similar beam in M-Test
- 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

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

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

- 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? Frank Wilczek has expressed great interest in this MIPP physics topic.
- Good thesis topics for grad students- Test beam work + MIPP work

-------- Original Message --------

Subject: Re: [Fwd: Information on the MIPP experiment]**Date:** Fri, 21 Oct 2005 15:51:02 -0400

From: Frank Wilczek wilczek@MIT.EDU

To: Rajendran Raja raja@fnal.gov

CC: SELEM, ALEXANDER <aselem@calmail.berkeley.edu>, gross@itp.ucsb.edu**References:** <43594054.9020201@fnal.gov>

Hi, I find it very interesting. Pursuing some ideas on diquarks (with Alex Selem) led us into a broad survey of hadron spectroscopy. That emphasized two things for me: 1. There are some strikingly simple patterns in the data that are poorly understood from the point of view of QCD. 2. There are many holes in the data, if these patterns are not misleading us. In other words, there are lots of predictions to be tested, and refined. We're in the process of writing this up, but in the meantime I've attached my presentation (in keynote and .pdf) which should give you some idea what's coming. I hope you find it useful.

All best wishes, Frank Wilczek

Timeline

- Run Till next shutdown in currrent mode
- Acquire Altro/PASA chips
- Design New TPC Sticks
- Get approval for proposal. We have appealed the PAC decision
- Get new collaborators
- Run in 2006 (end of 206) in upgraded mode with current beam.
- Design lower momentum beam. Beam cernkovs may need redesign (too much multiple scattering)
- Lots of graduate student theses
- Possible to affect shower simulators on 2007 time frame.