MIPP Experiment Upgrade

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Fermilab

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

MIPP collaboration list

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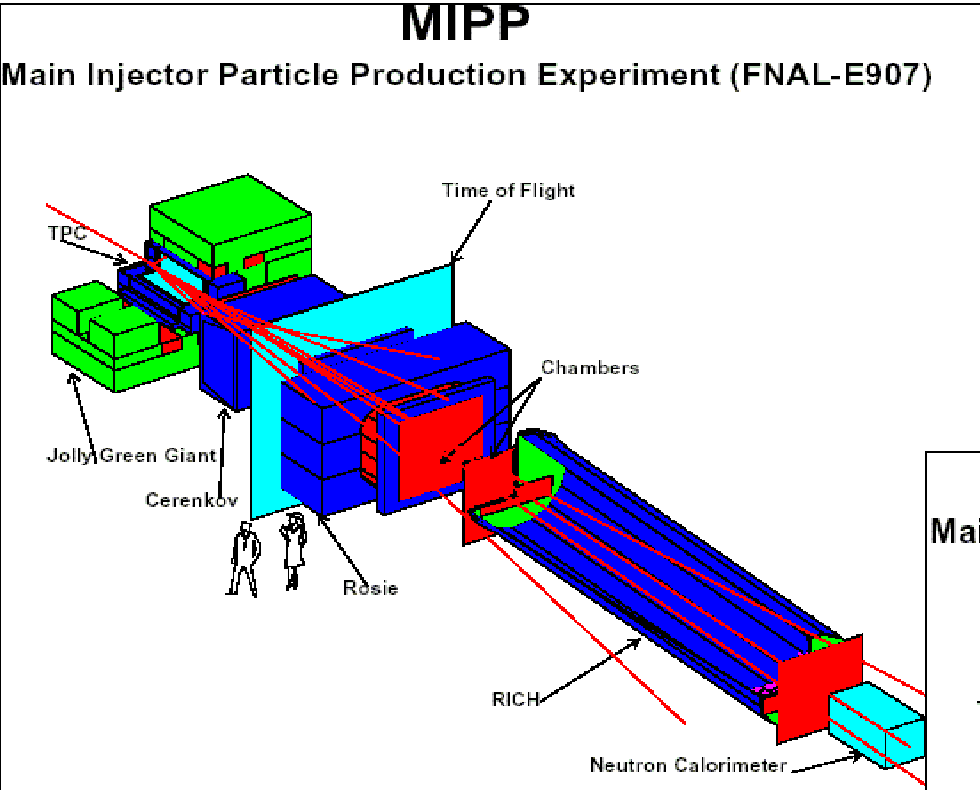
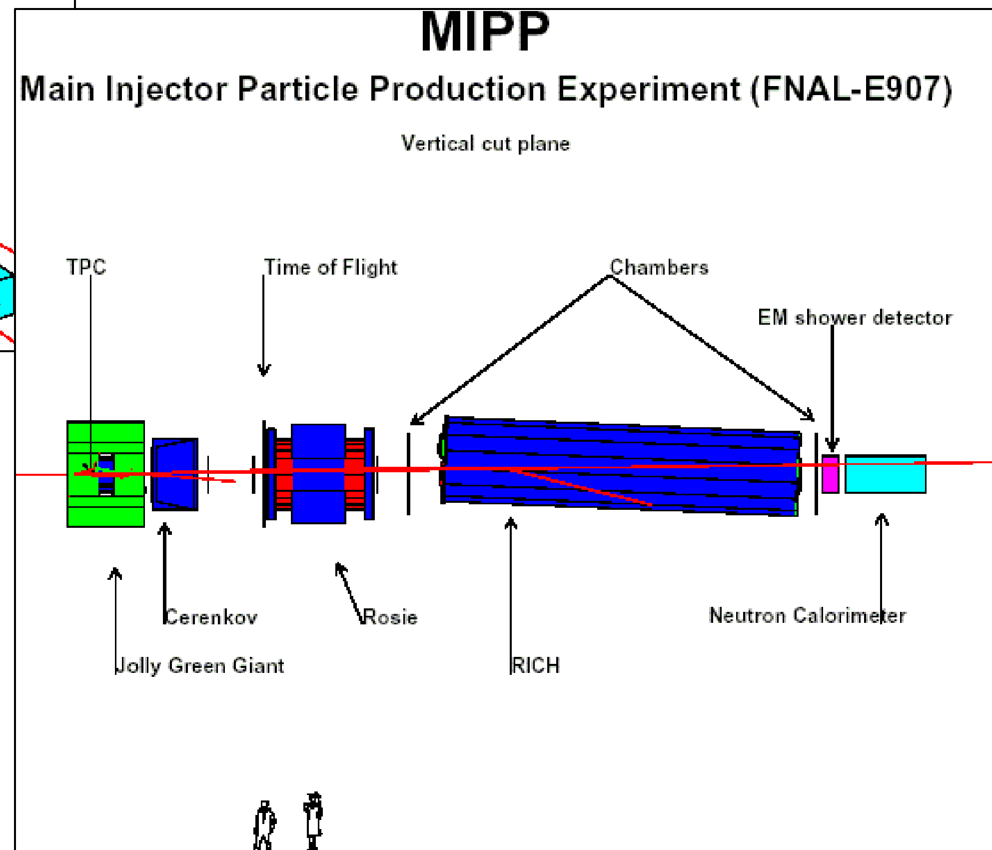

MIPP
Main Injector Particle Production Experiment (FNAL-E907)
Time of Flight
TPC
Chambers
Jolly Green Giant
Cerenkov
Rosie
RICH
Neutron Calorimeter


MIPP
Main Injector Particle Production Experiment (FNAL-E907)
Vertical cut plane
TPC
Time of Flight
Chambers
EM shower detector
Cerenkov
Rosie
Neutron Calorimeter
Jolly Green Giant
RICH

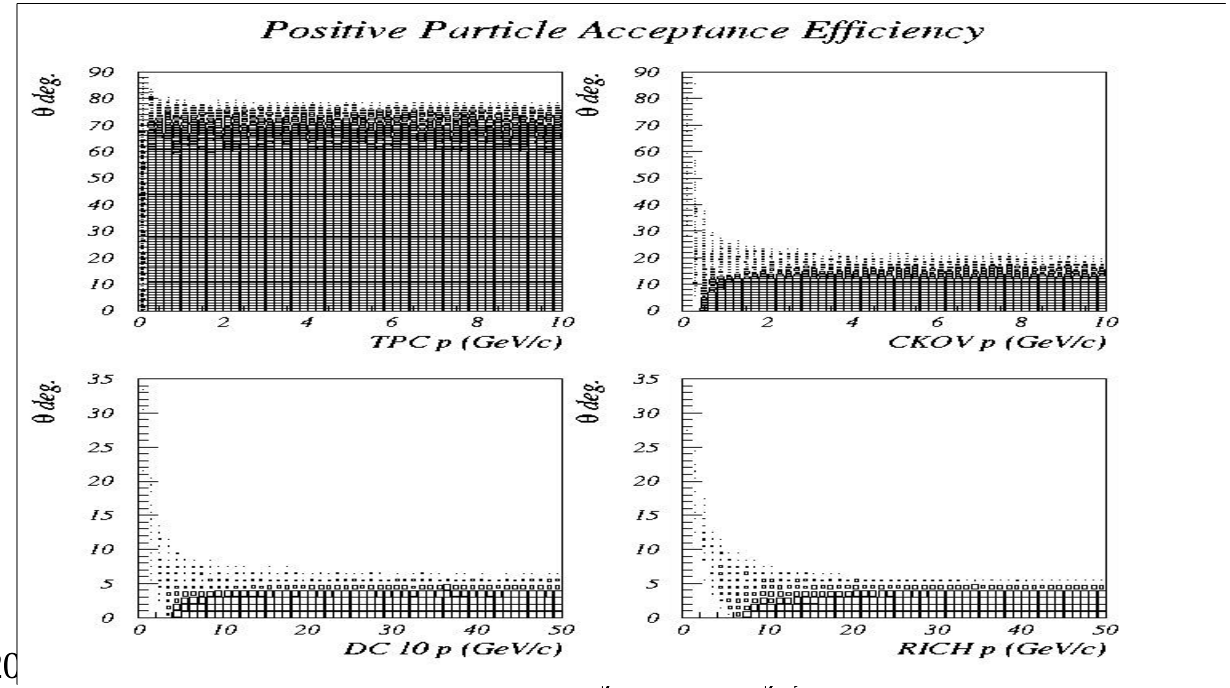
Status of MIPP Now- Collision Hall

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.

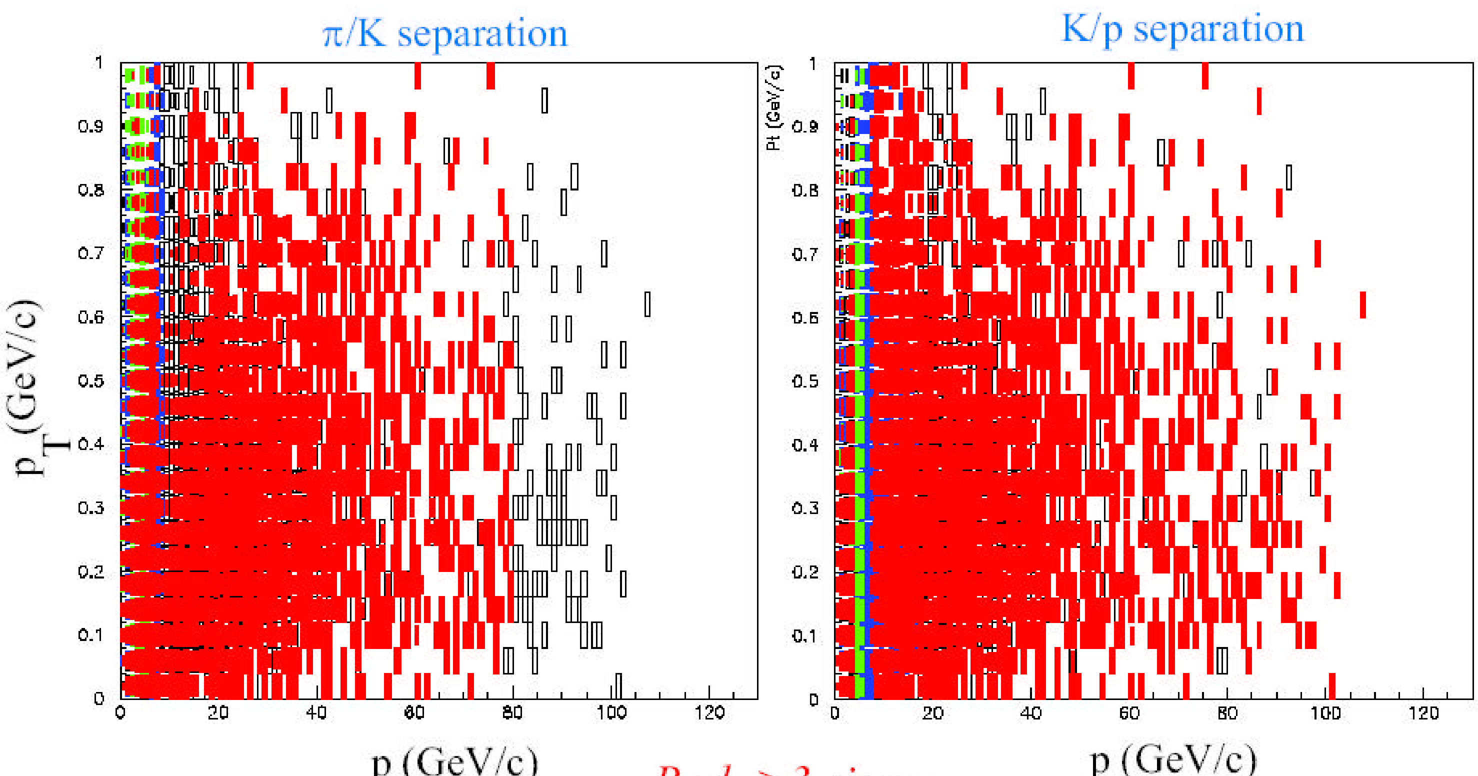
Particle acceptances and resolutions

- 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)



MIPP Particle ID

Particle ID Performance



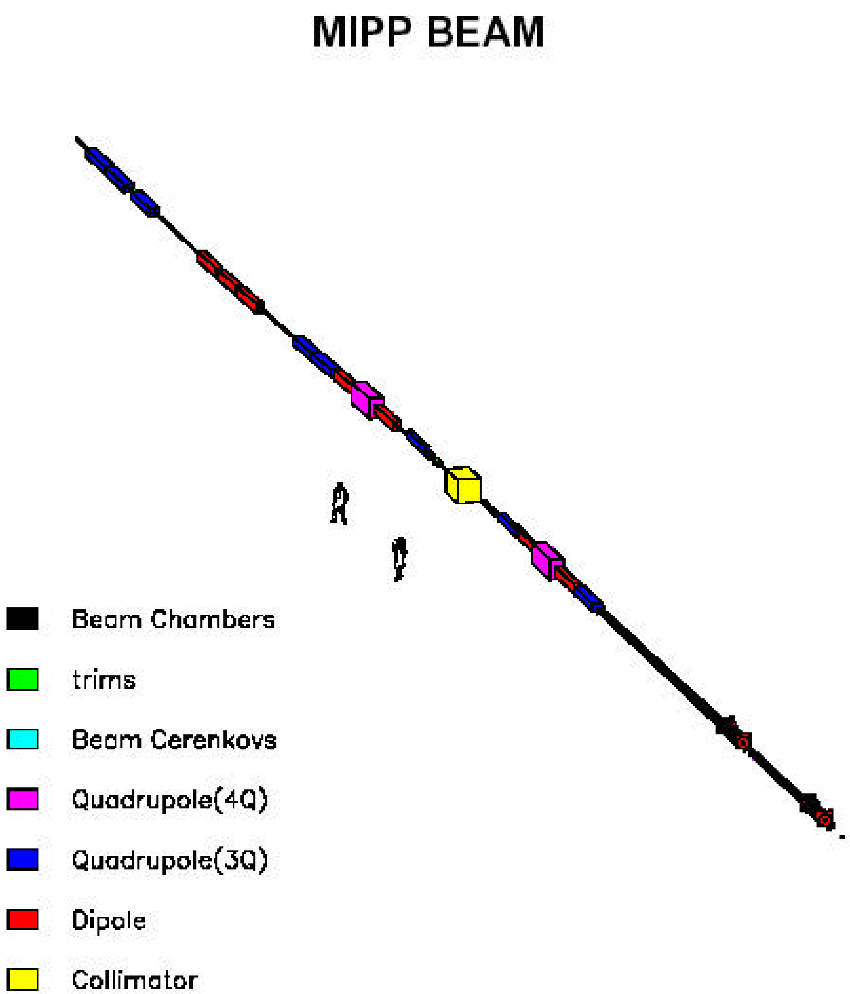
Red: >3 sigma
Green: 2-3 sigma
Blue: 1-2 sigma
White: <1 sigma

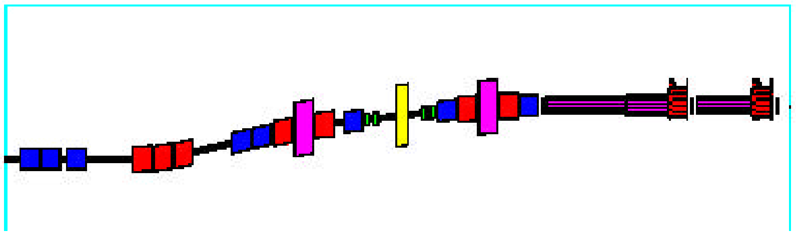
Physics Interest

- 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 Secondary Beam

Installed in 2003. Delivering slow spill commissioning beam (40GeV/c positives since February 2004). Finished Engineering run in Aug 2004.





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**

General scaling law of particle fragmentation

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

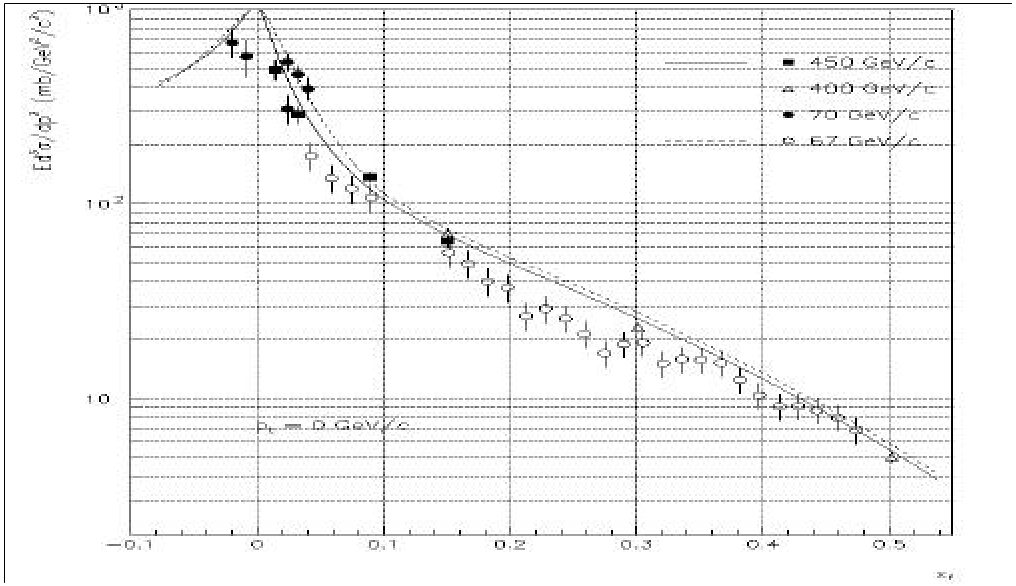
$$\frac{f(a+b\rightarrow c+X_{subset})}{f(a+b\rightarrow c+X)} \equiv \frac{f_{subset}(M^2,s,t)}{f(M^2,s,t)} = b_{subset}(M^2)$$

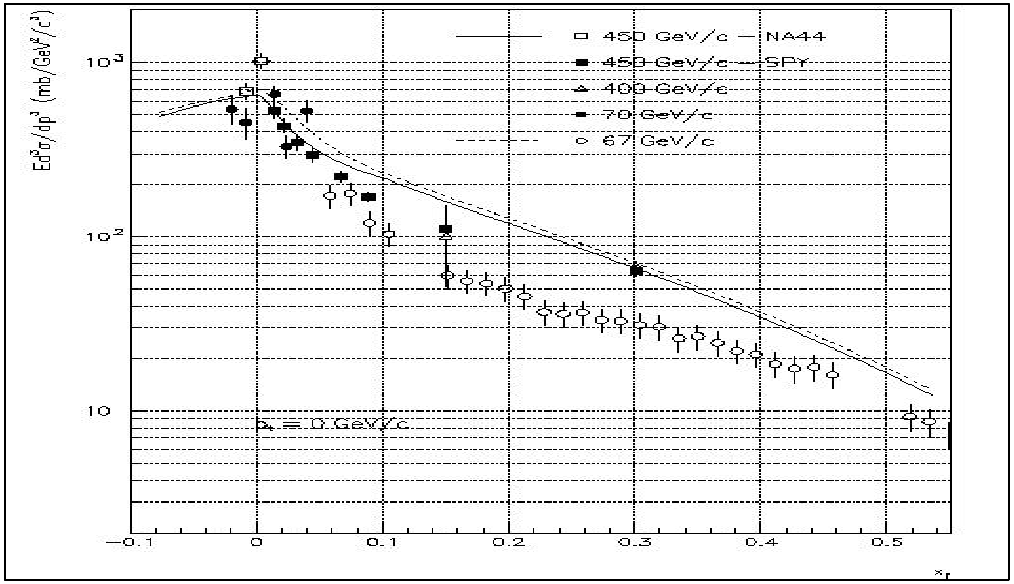
- where M^2,s and t are the Mandelstam variables for the missing mass squared, CMS energy squared and the momentum transfer squared between the particles a and c. PRD18(1978)204.
- Using EHS data, we have tested and verified the law in 12 reactions (DPF92) but only at fixed s.
- The proposed experiment 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.

Hadron Shower Simulator problem

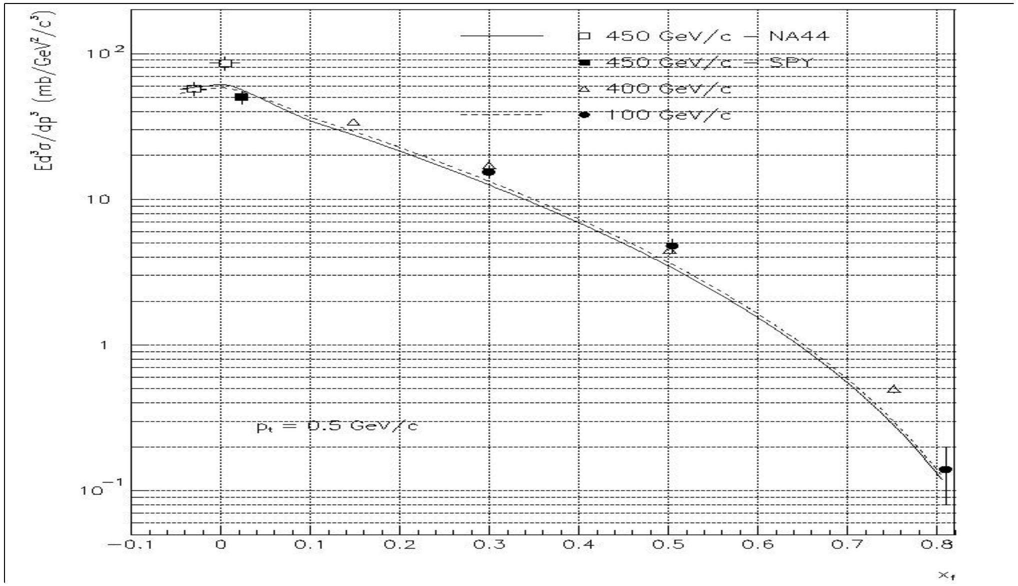
- All neutrino flux problems (NUMI, MiniBoone, K2K, T2K,Nova, Minerva) and all Calorimeter design problems and all Jet energy scale systematics (not including jet definition ambiguities here) can be reduced to one problem- the sorry state of hadronic shower simulators. MIPP upgrade can solve this problem 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.

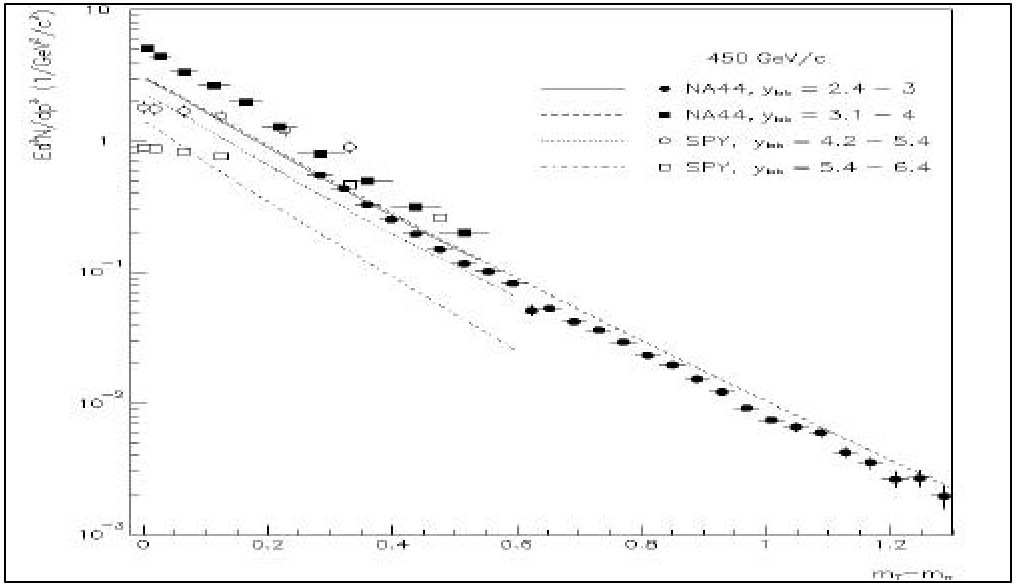
Quality of existing data





Quality of existing data



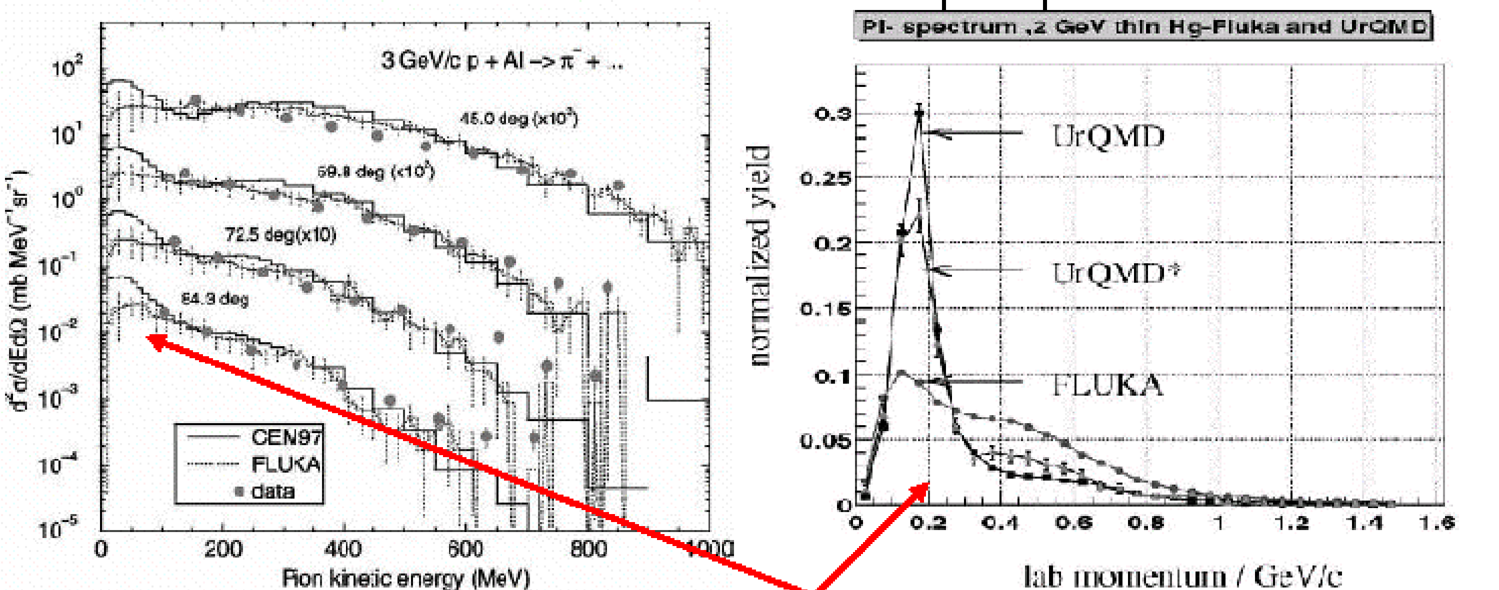


Discrepancies between hadronic generators

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

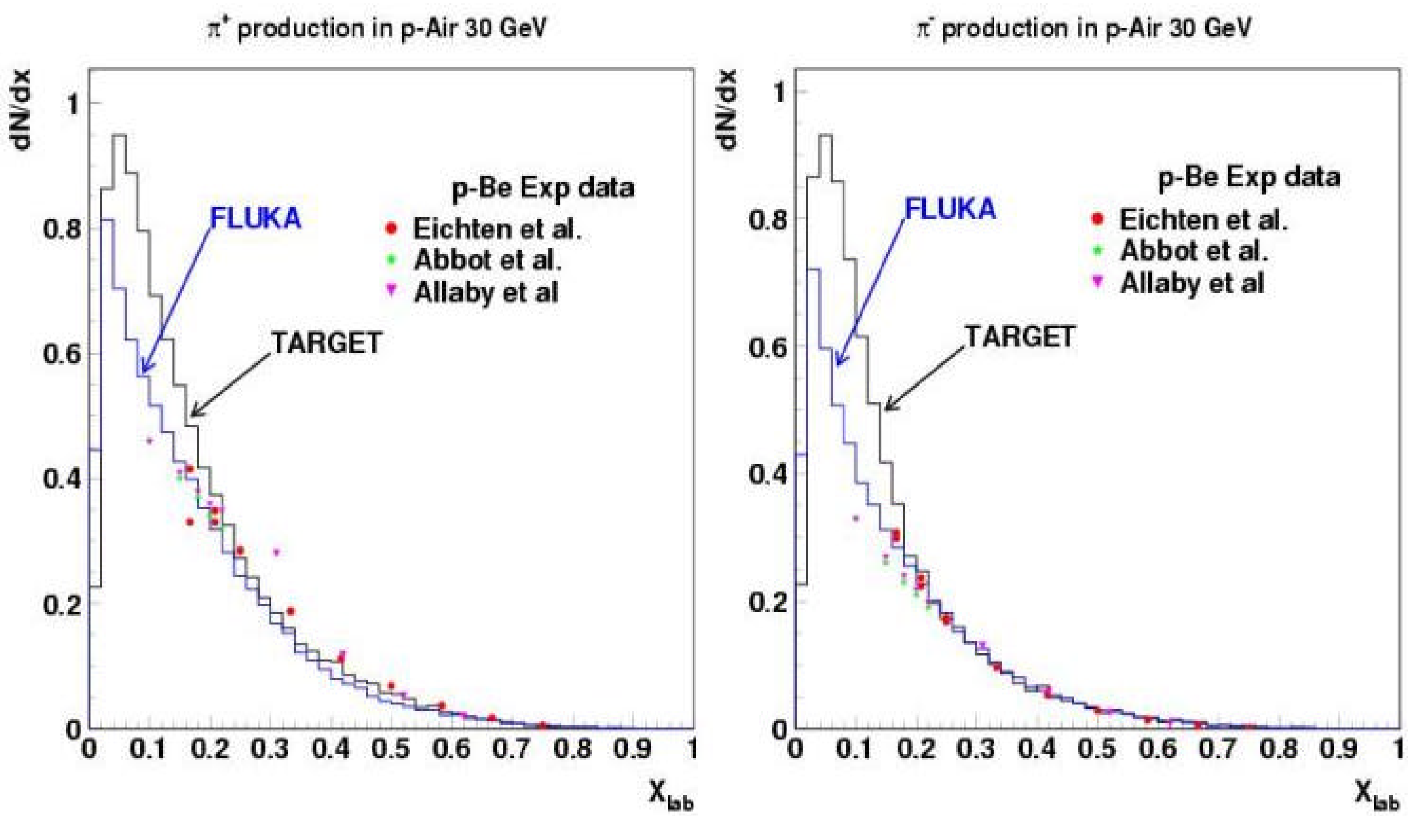
NIMA472(2001)5

NO DATA !

➔ Thin and thick targets, scan in Z

Discrepancies between hadronic generators

27



G.Battistoni

?/00

Historical overview(from M. Catenesi NUFACT04)

- Mostly based on measurement of particle yields along beam lines
- Experiments done making (smart) use of existing facilities
  - » No experiments built on-purpose
- Low (~20GeV/c) and high (~400GeV/c) primary proton momenta, forward angular region (<150mrad)
- Low statistics and/or limited number of data points
  - » J. Allaby et al., CERN-70-12
    - p-nuclei (B4C, Be, Al, Cu, Pb) and p-p collisions at 19.2 GeV/c
    - Single arm spectrometer
  - » G. Eichten et al., Nucl. Phys. B44(1972) 333
    - p, K production in p-nuclei collisions (Be, B4C,Al, Cu, Pb targets) at 24 GeV/c
    - Single arm magnetic CERN-Rome spectrometer

Eichten et Al. based on CERN-70-12

PARTICLE PRODUCTION IN PROTON INTERACTIONS IN NUCLEI AT 24 GeV/*c*

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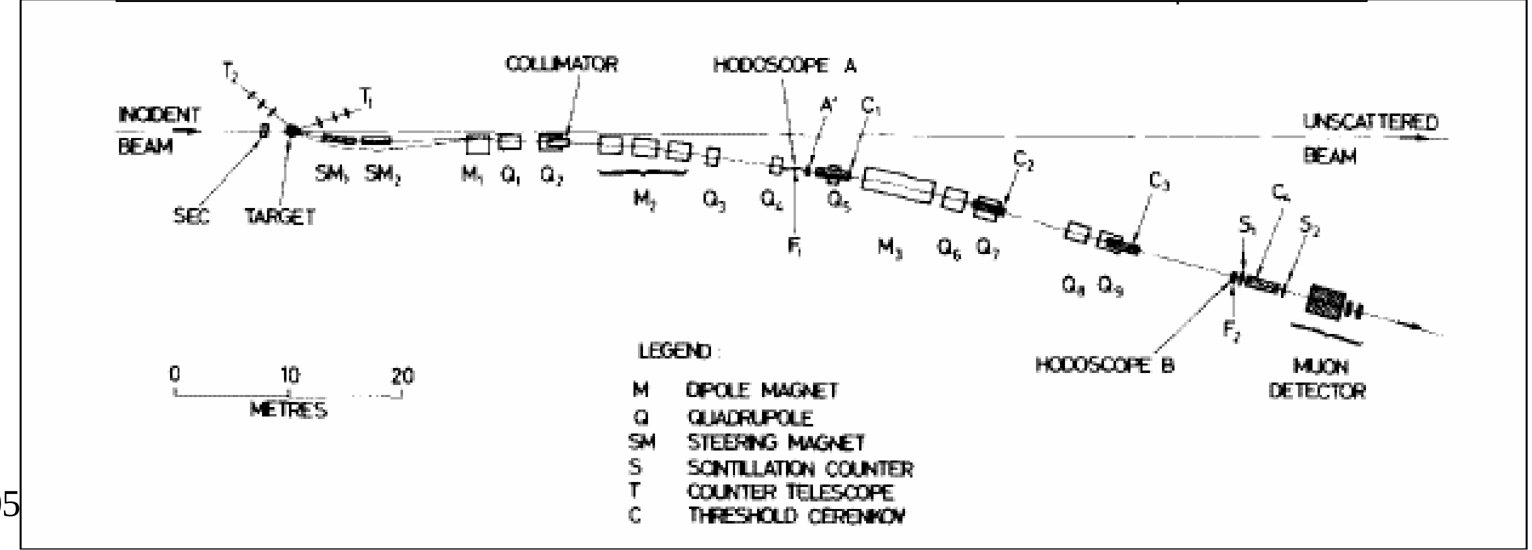
Received 15 March 1972

Abstract: Particle production by 24 GeV/*c* protons from Be, B_4C, Al, Cu and Pb has been measured. Pion, kaon, proton and antiproton production spectra measured over a range of angles from 17 to 127 mrad and momenta from 4 to 18 GeV/*c* are given in a table.



- Motivations and scope

The aim of the present experiment was to measure pion and kaon production in proton-nucleus collisions at 24 GeV/c primary proton momentum. The measurements cover the secondary momentum range 4–18 GeV/c and the angular range 17–127 mrad. These data are essential for the estimation of the neutrino spectrum for the present CERN neutrino experiment.

- Experiment's uncertainties

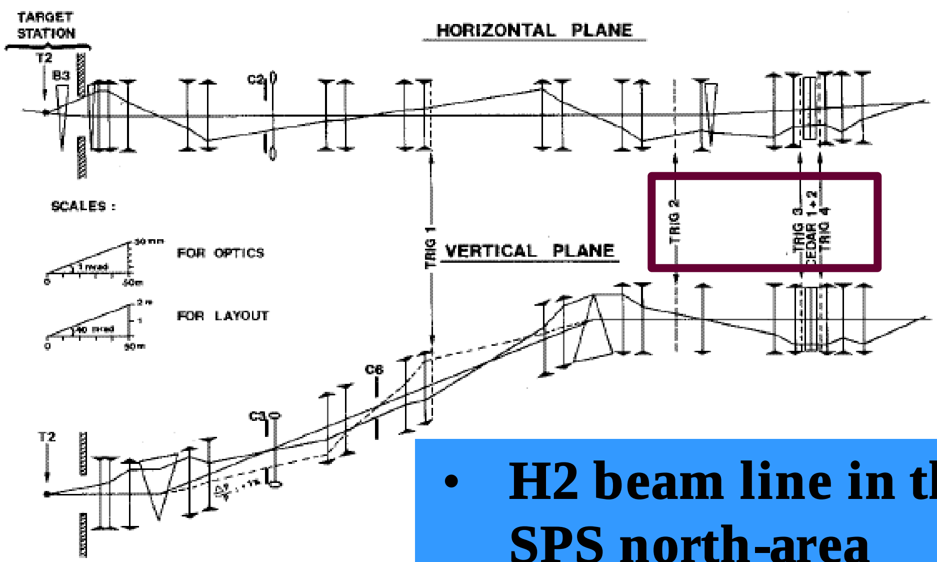
The statistical errors were nearly always negligible compared to the systematic errors. The overall scale error arising from the uncertainties in the spectrometer acceptance and in the absolute calibration of the primary proton beam intensity (by Al activation) is estimated to be 15% [4]. The systematic errors of individual data points are determined by the irreproducibility of a given spectrometer (setting (about 5%) and by the uncertainties in the corrections applied (2–5% depending on momentum). Ratios obtained from one and the same spectrometer setting (K/π ratios and ratios between different targets) are much more accurate (total error generally less than 4%), as most systematic errors drop out. Details of the data evaluation have been given in refs. [5, 6].

NA20 (Atherton et al.) @ CERN-SPS

- **Secondary energy scan: 60,120,200,300 GeV**

List of targets

Length (in beam direction) (mm)	Width (horizontal) (mm)	Height (vertical) (mm)
500	160	2.0
300	160	2.0
300	160	1.5
100	160	2.0
40	160	2.0



- **H2 beam line in the SPS north-area**

Fig. 1 Layout and optics of H2 beam

Overall quoted errors
Absolute rates: ~15%
Ratios: ~5%
These figures are typical of this kind of detector setup

The total measurement error is dominated by the following three systematic errors:

i) SEM calibration, see Section 3.2.1 ≃ 5%

ii) errors in beam optics, see Section 3.1.4 ≃ 4%

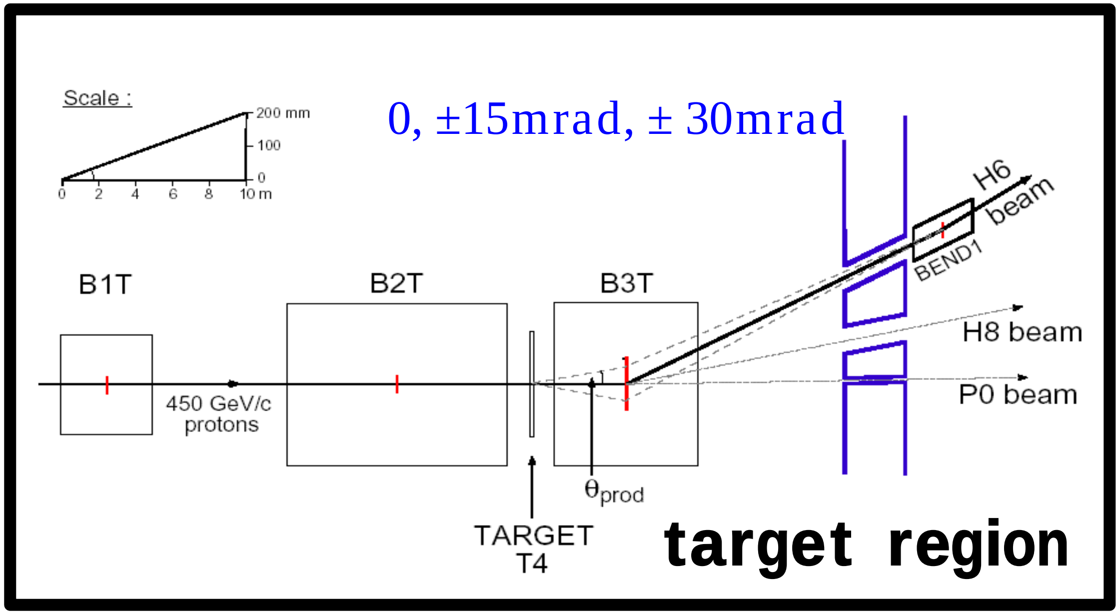
iii) collimator opening uncertainty ≃ 1-4%.

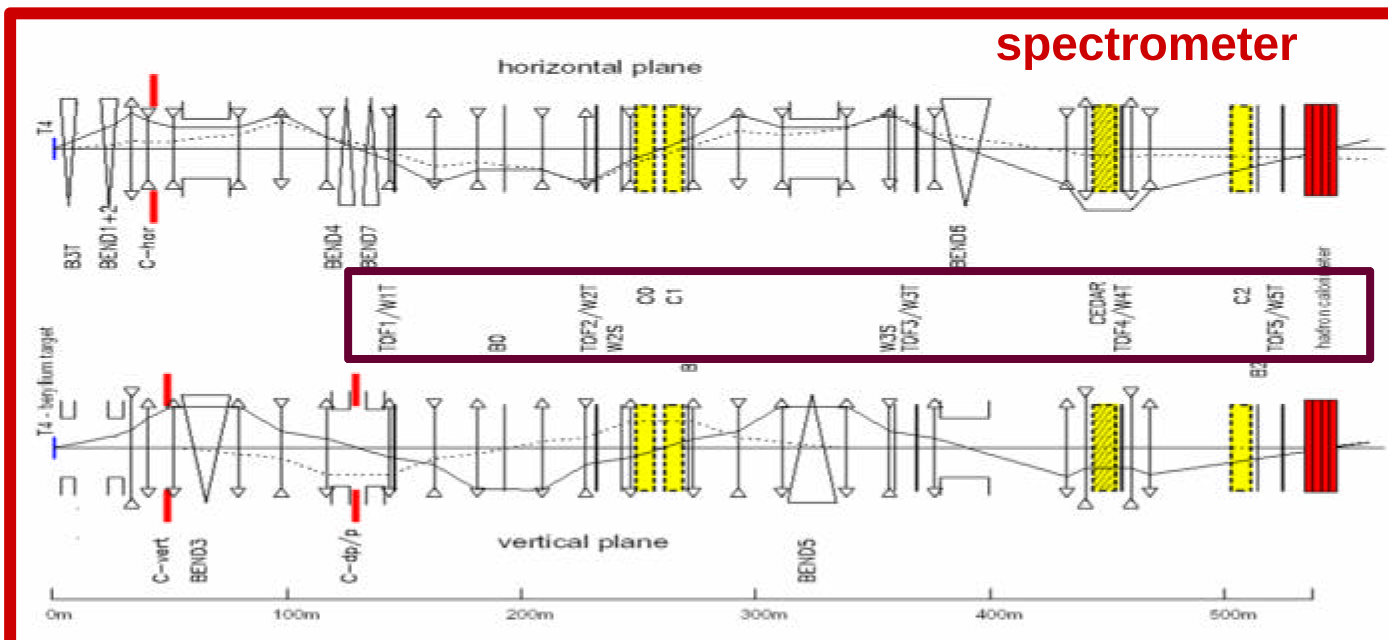
All other corrections are of the order of or less than 1%.

SPS: NA56/SPY

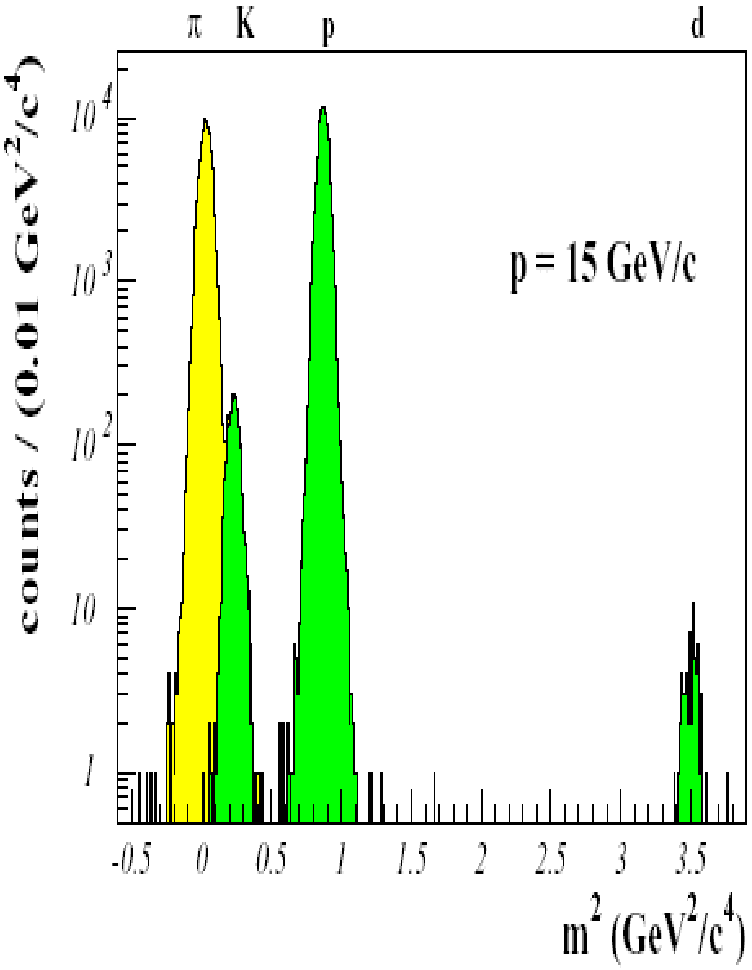
- Most likely the most advanced study done with instrumented beam line experiments
- Dedicated to WANF (CHORUS/NOMAD) (and CNGS) experiments
- To address discrepancies beam spectrum, shape and composition as measured in CHORUS/NOMAD compared to MC predictions.
- 450GeV/c incident protons, 7→135 GeV/c secondaries (overlap with Atherton)
- Exploits TOF / Cherenkov / Calorimetry

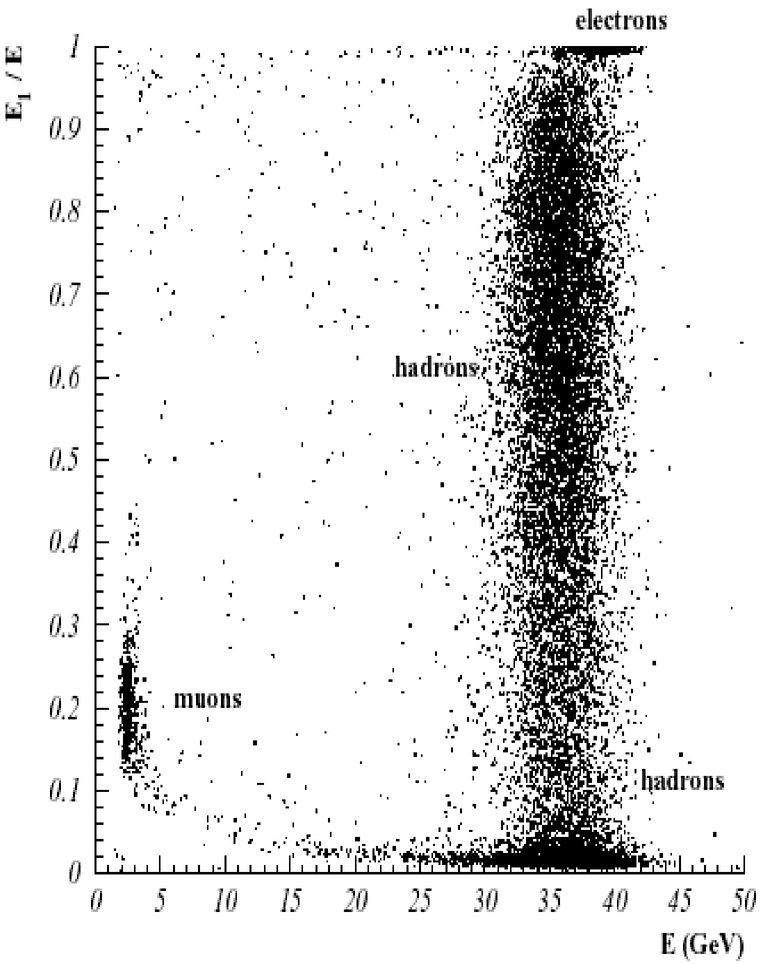
SPY:1996


Scale :
200 mm
100
0
0 2 4 6 8 10 m
0, ±15mrad, ± 30mrad
H6 beam
BEND1
B1T
B2T
B3T
H8 beam
450 GeV/c protons
P0 beam
θprod
TARGET T4
target region


spectrometer
horizontal plane
T4
B3T
BEND1+2
C-hor
BEND4
BEND7
BEND6
TOF1/W1T
B0
TOF2/W2T
W2S
C0
C1
W3S
TOF3/W3T
CEDAR
TOF4/W4T
C2
TOF5/W5T
hadron calorimeter
T4 - beryllium target
vertical plane
C-vert
BEND3
C-dp/p
BEND5
0m
100m
200m
300m
400m
500m

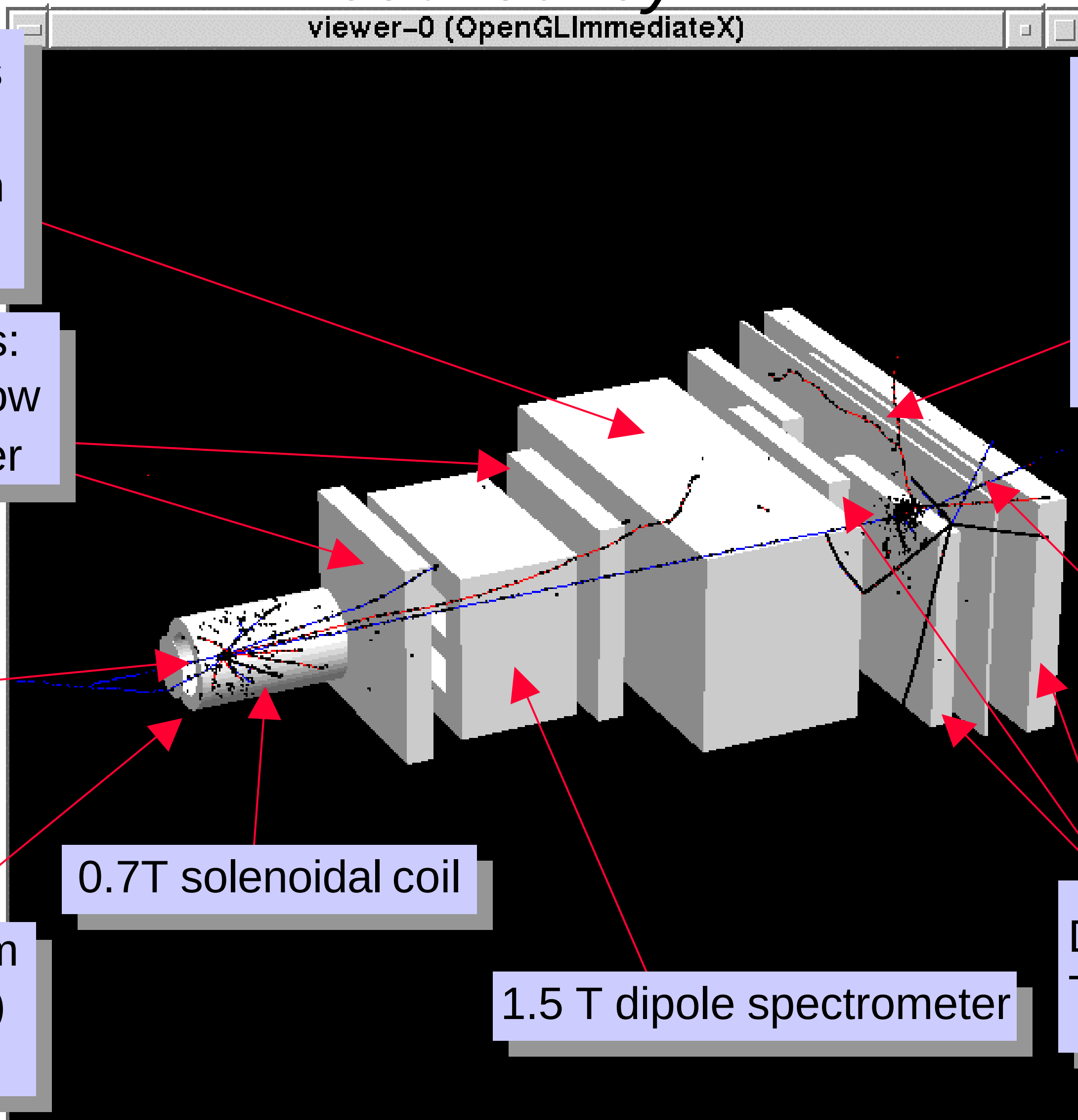
SPY measurement principle





- TOF + Cherenkov, cross-check with calorimetry.

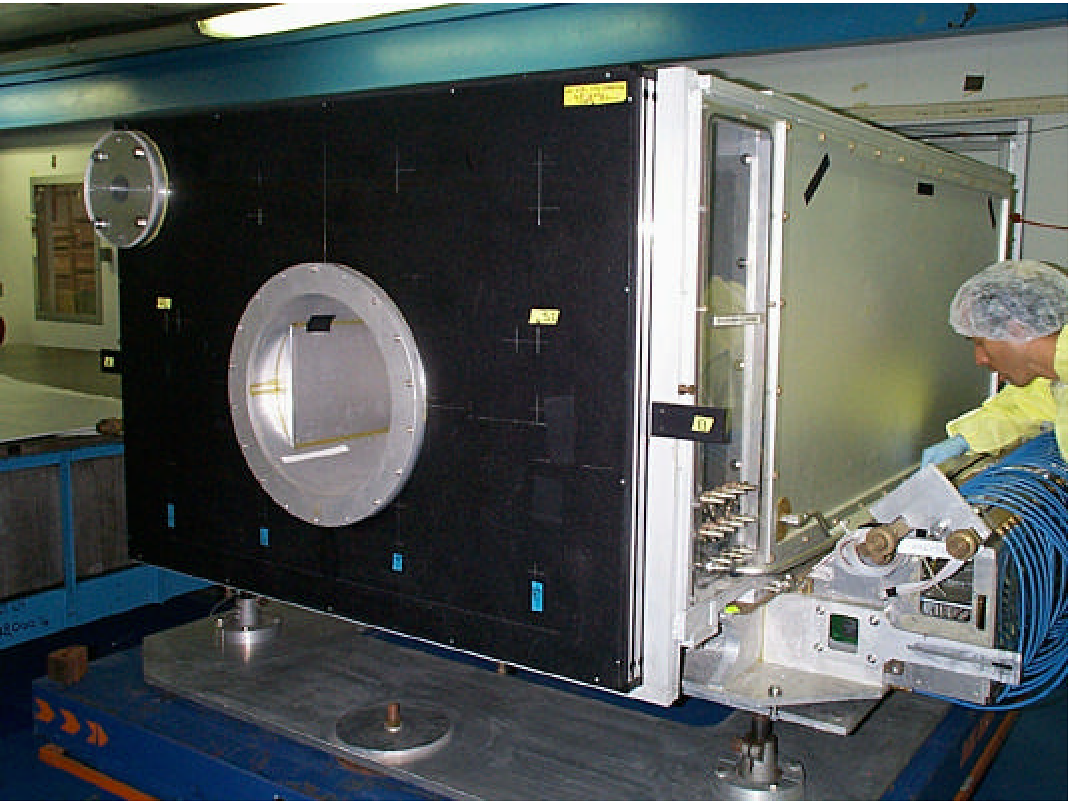
The Harp detector: Large *Acceptance, PID Capabilities , Redundancy*

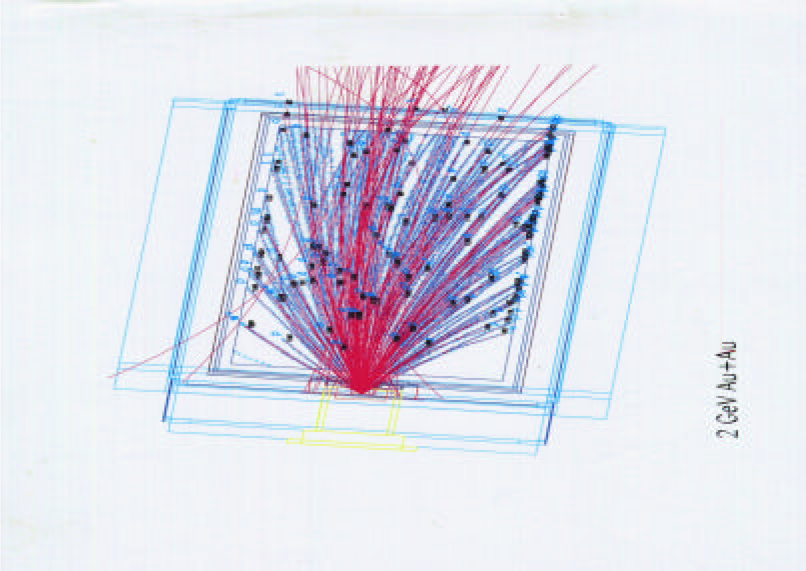


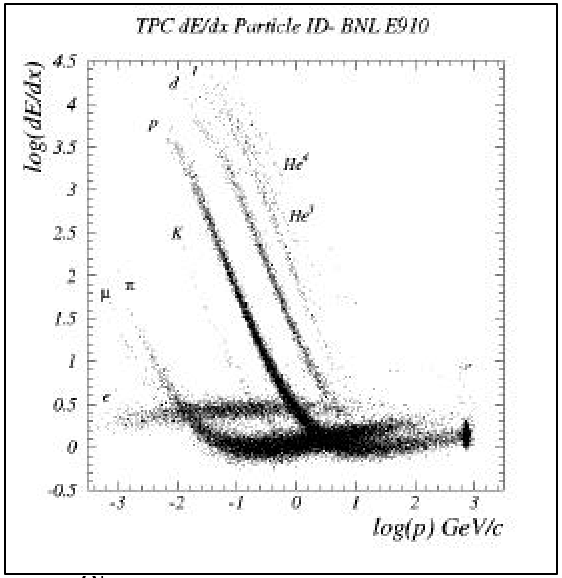
MIPP - TPC

- 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 16μs. i.e unreacted beam swept out in 8μs. 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.

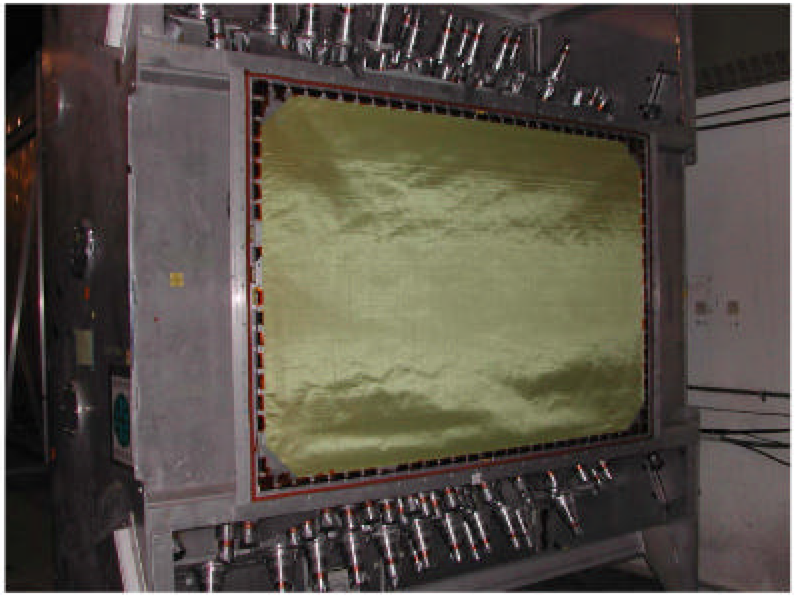
TPC




2 GeV Au+Au


TPC dE/dx Particle ID- BNL E910
log(dE/dx)
log(p) GeV/c
d
t
p
He^4
He^3
K
μ
π
e

MIPP Cherenkov



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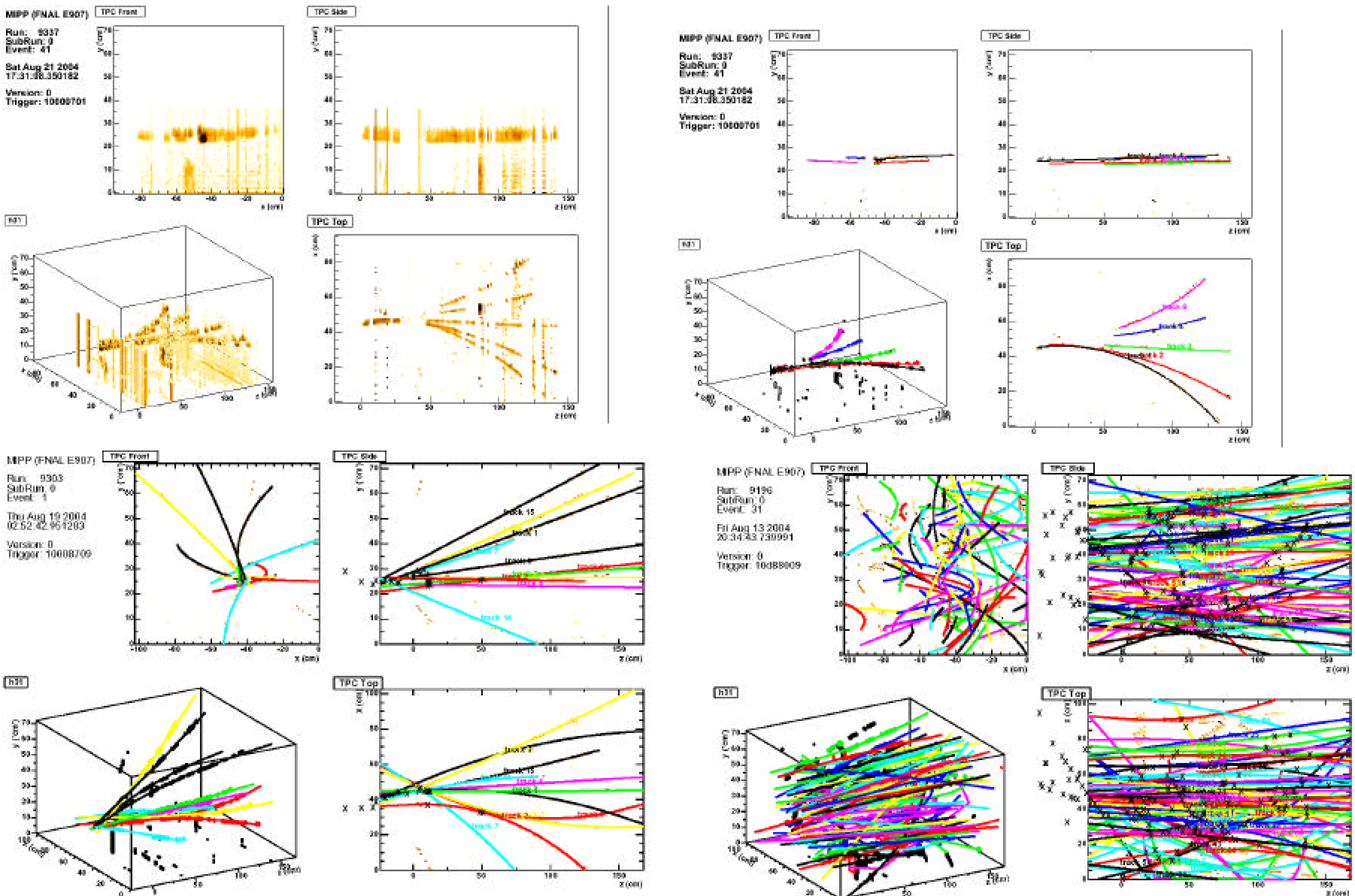
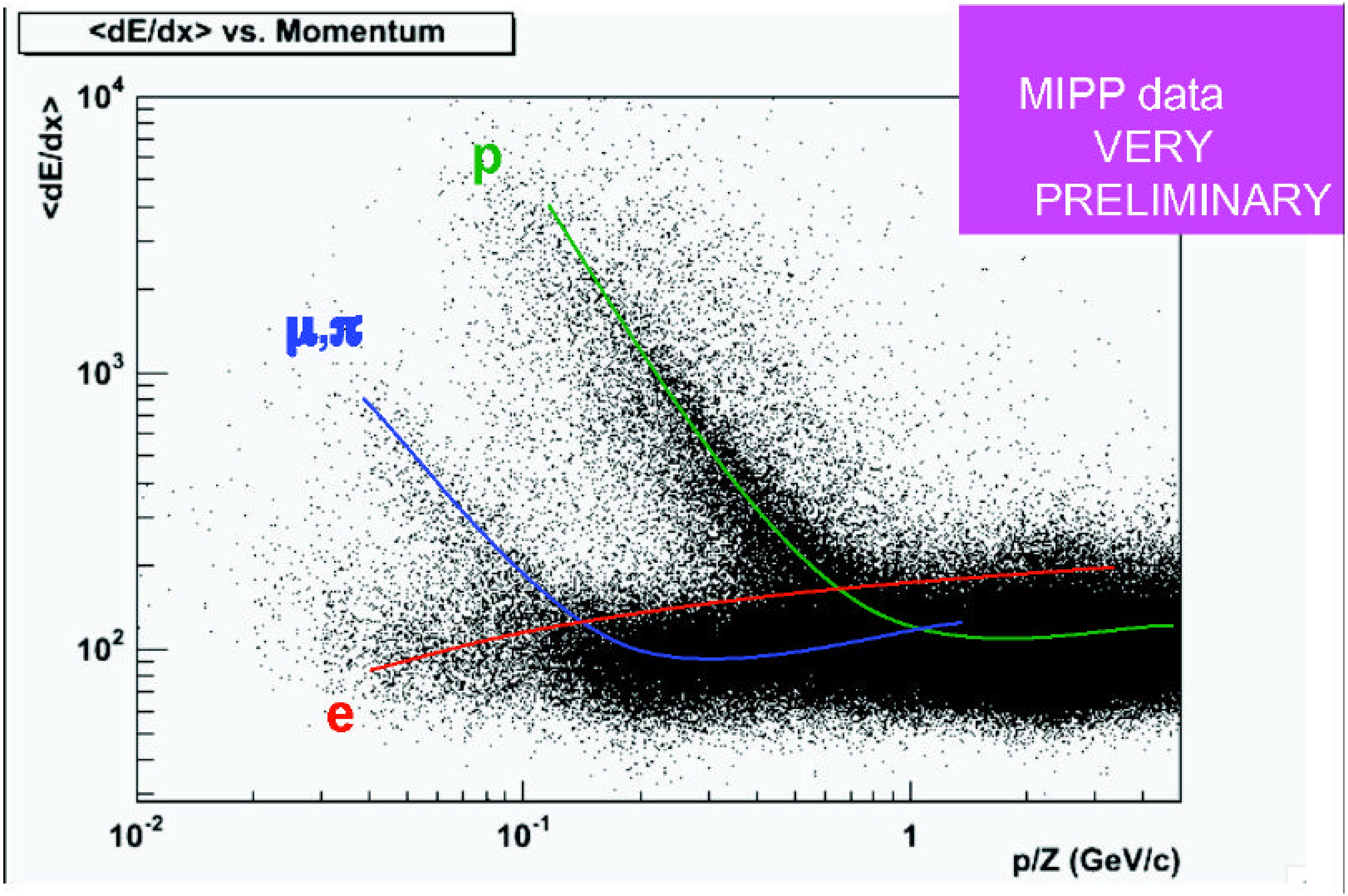
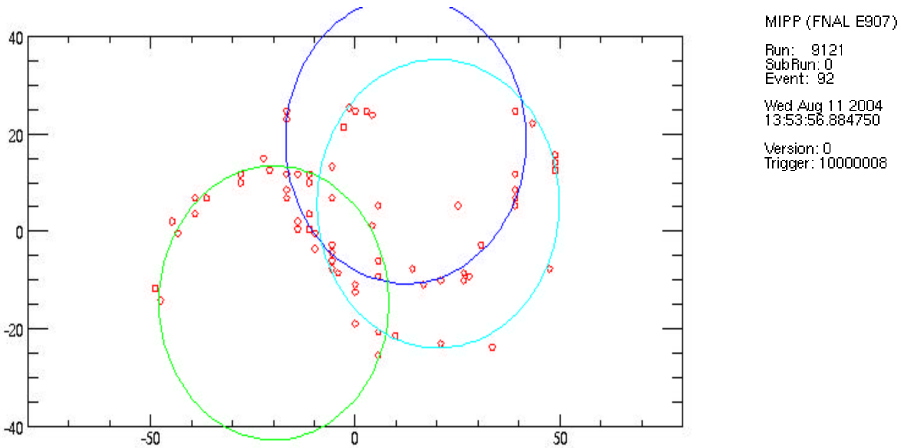
Preliminary results from Engineering run

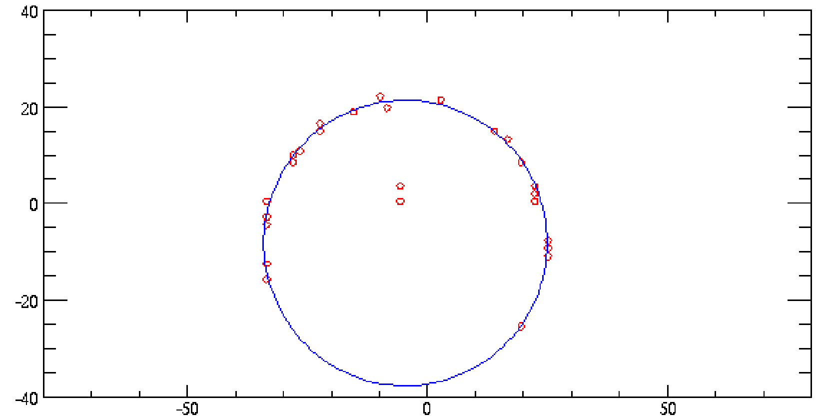


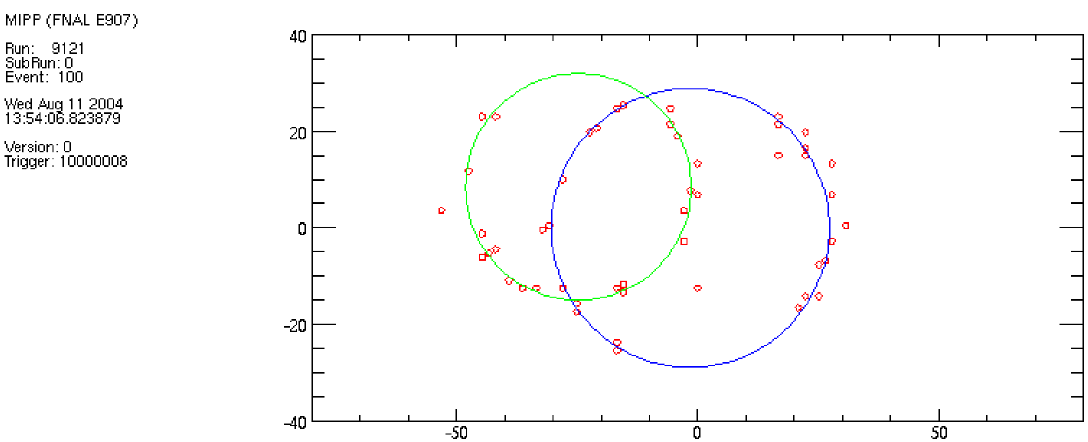
MIPP TPC DATA!



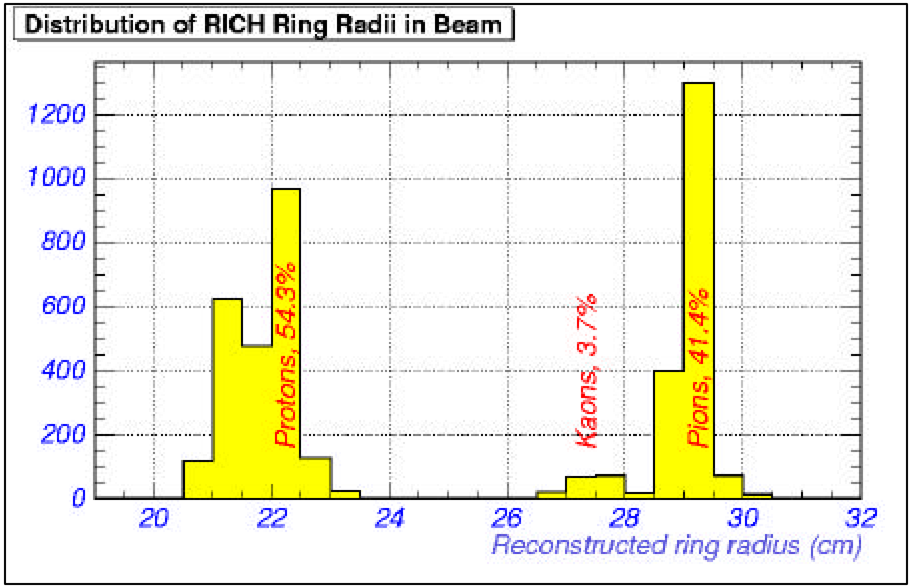
RICH rings pattern recognized





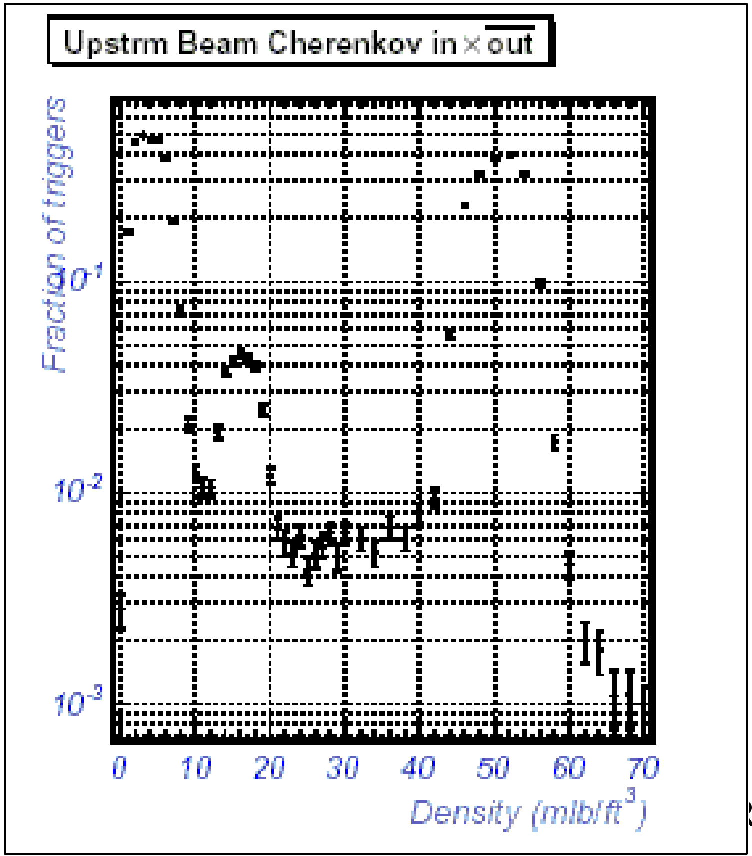


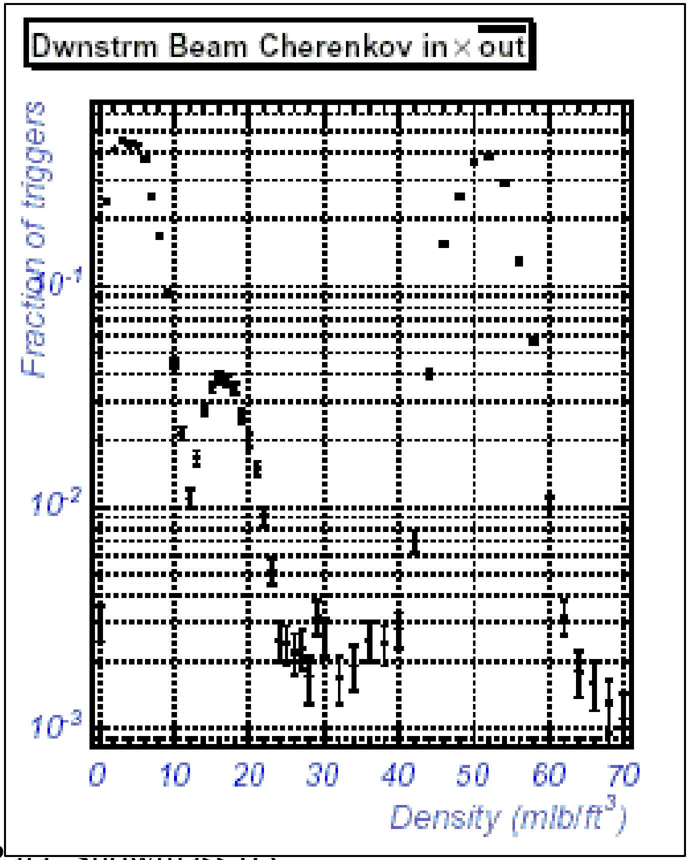
RICH radii for + 40 GeV beam triggers



Beam Cherenkovs

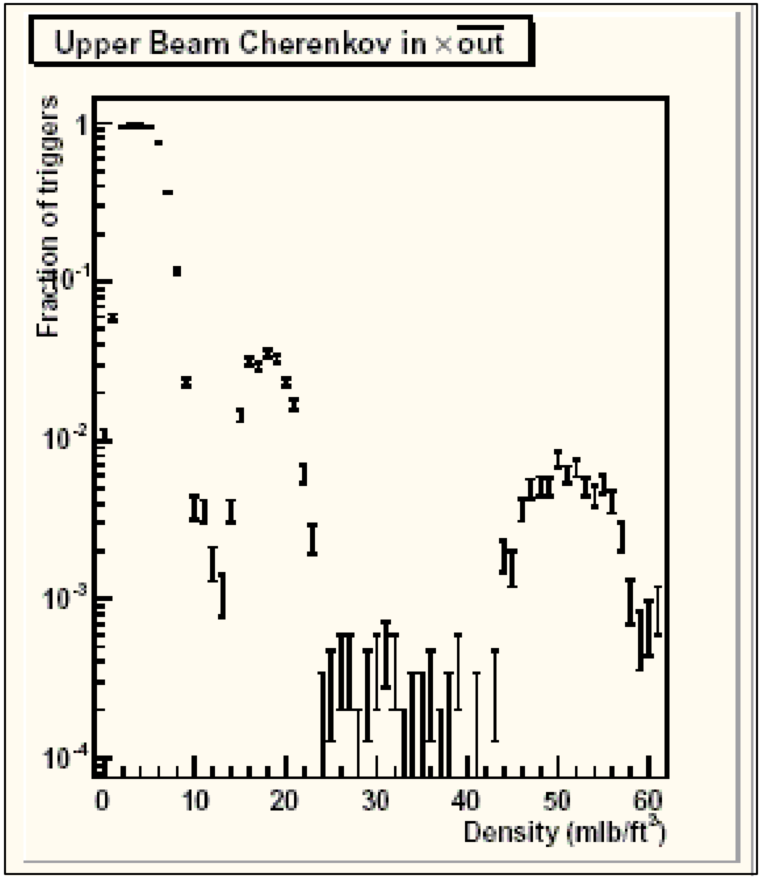
- Pressure curve Automated- Mini-Daq-APACS 30 minutes per pressure curve.+40GeV/c beam.

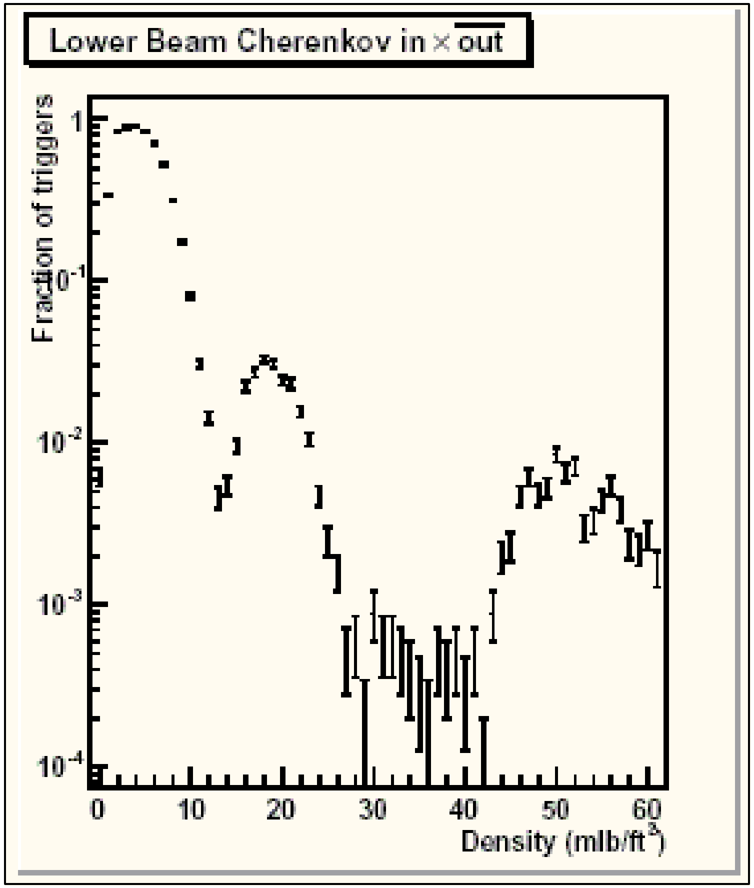




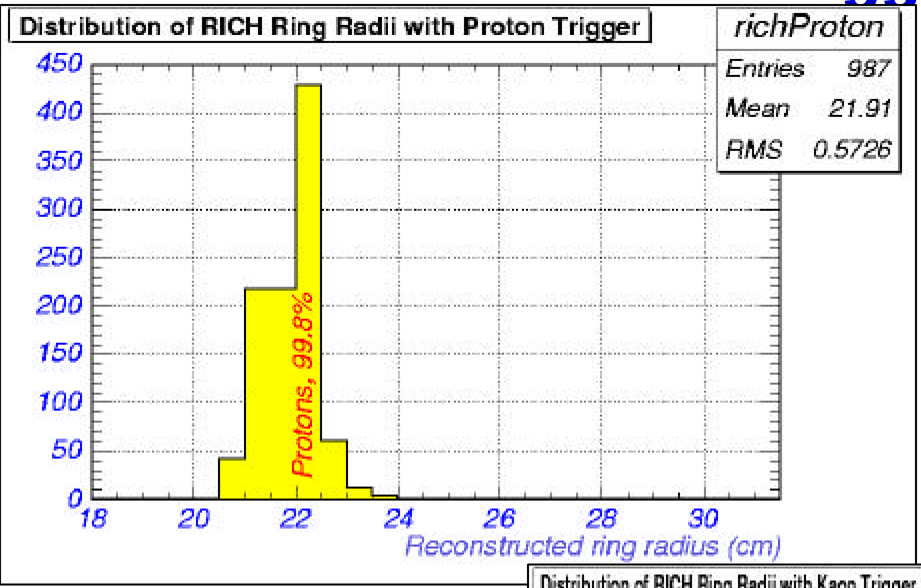
Beam Cherenkovs

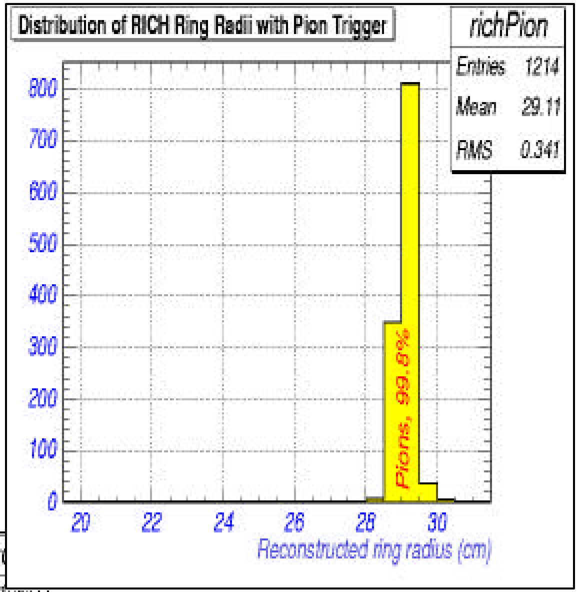
- 40 GeV/c negative beam

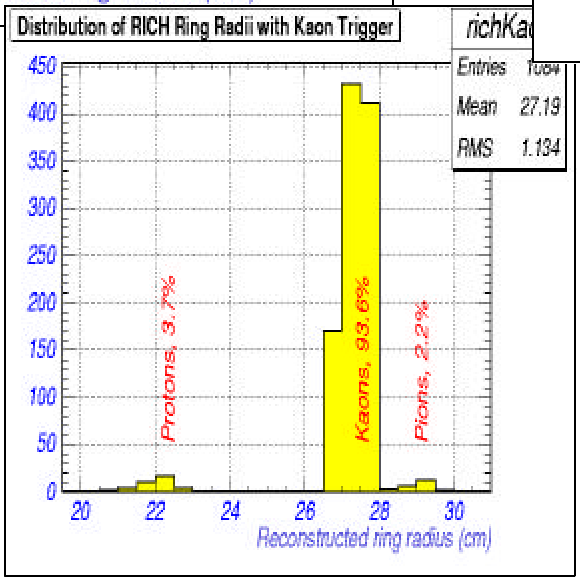




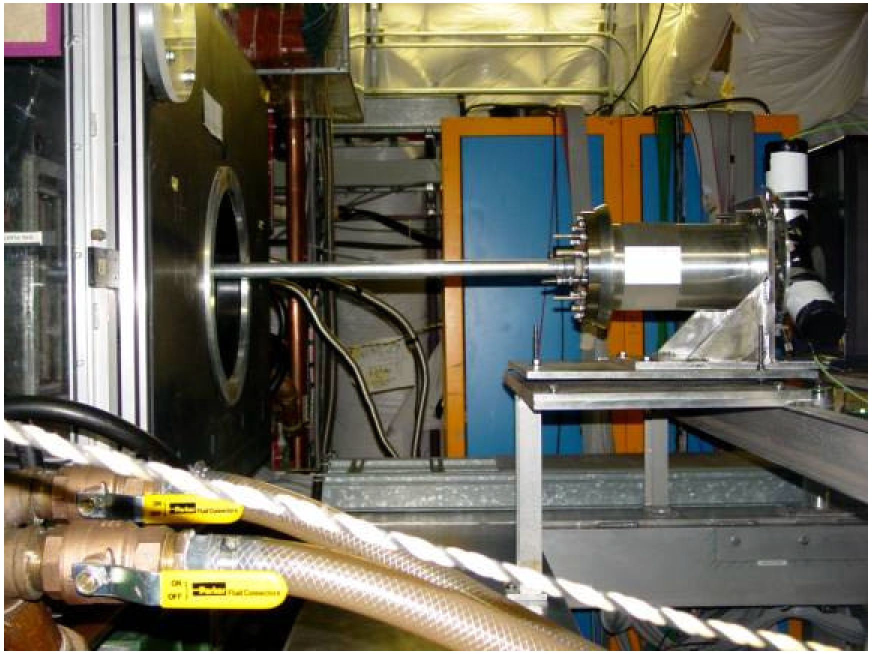
Comparing Beam Cherenkov to RICH for +40 GeV beam triggers-No additional cuts!

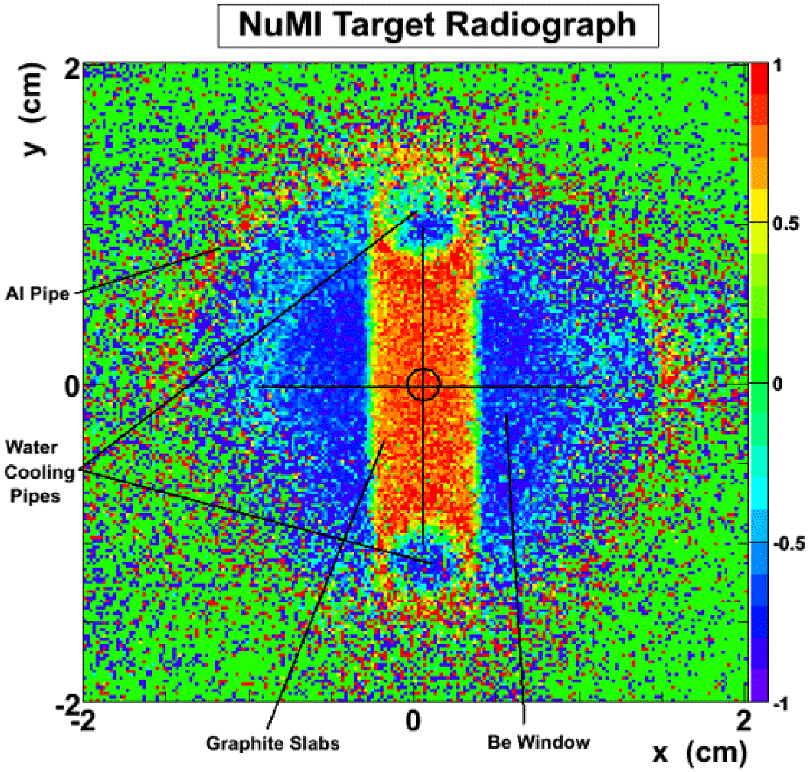






NUMI target pix



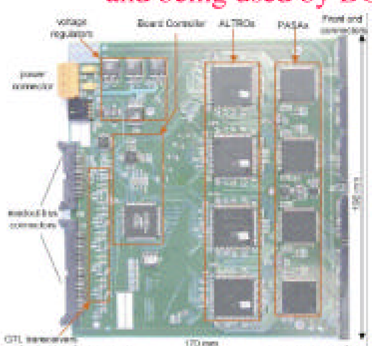


MIPP Upgrade program

- 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.

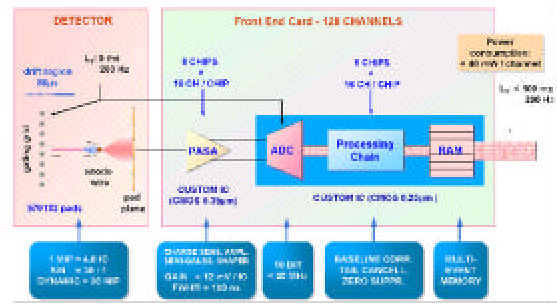
ALICE PASA/ALTRO Chip

- 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.

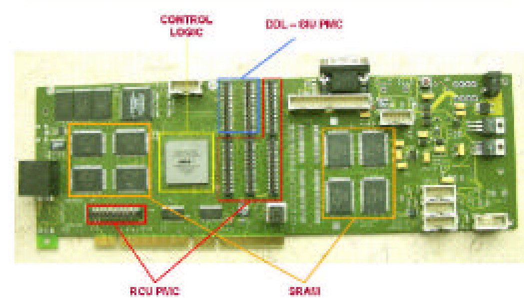


ALICE Front end card needs to be rearranged to look like a stick.

ALTRO/PASA chips



RCU Prototype II



Upgrading the DAQ of the rest of MIPP to run at 3kHz.

- RICH and Hadron Calorimeter-Will work as is
- EM Cal- Use Lacroy FERA ADC's from Prep.
- Proportional Chambers-Use Hyper CP electronics-5000 channels
- Multi Cell Cerenkov-Use FERA bus to readout the 96 channels faster.
- Time of Flight system-~100 channels. Zero suppress, FERA bus.
- Drift chambers-7808 channels for drift chambers and 1920 for beam chambers.- CDF or KTEV electronics
- DAQ software-Improve interrupt handling,Write better VME drivers, Make use of DMA on the VME bus.

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Jolly Green Giant Coil Fix

- One of the bottom coils has developed shorts. We are running with several turns shorted out. After the October shutdown, we propose to fix the coil.

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Labor and costs in repairing the JGG coil

Equipment	Action	Manpower	Manweeks	M&S
BCKOV				
	secure & disconnect vacuum	2 techs, 2 weeks	4	
	re-install vacuum & test	3 techs, 3 weeks	9	
	remove cable tray & hardline	2 techs, 1 week	2	
	re-install cable tray & hardline	3 techs, 2 weeks	6	
	M&S purchases	$2K		$2,000
Beam pipe				
& concrete supports	move to side	4 techs, 1 week	4	
	re-install	4 techs, 2 weeks	8	
LH2 Target	Move LH2 target equipment out	2 techs 1 week	2	
TPC				
	De-cable	By experimenters		
	Re-cable	By experimenters		
	remove electrical conduit	M&S $4K		$4,000
	re-install electricalconduit	M&S $8K		$8,000
	move out TPC & support st&	3 techs, 1 week	3	
	re-install TPC & support st&	3 techs, 1 week	3	
JGG				
	de-cable	2 techs, 2 days		
	re-cable	2 techs, 3 days	1	
	de-hose	1 tech, 1 day		
	re-hose	1 tech, 4 days	1	
	remove coil	M&S $15K	1	$15,000
	install coil	M&S $6K	1	$6,000
Repair JGG coil				
	M&S	$90K		$90,000
	OH	$20K		$20,000
	total man weeks		45	
	total M&S			**$145,000**

- Optional Upgrades

Cryogenic target -Extra cryo cooler	$32,000
TPC Rewind (M&S)	$10,000
RICH phototube upgrade (Hamamatsu tubes, bases)	$204,000

Total Running time requested

Physics Topic	Run Time (c
MIPP -I	18.1 days
New neutrino experiment target (10 million events)	2.3 days
Additional Nucleus (5 million events)	1.15 days
Two particle inclusive scaling (100 million events)	23.1 days
Pentaquark search (K+ beam)	12 days
Cascades search (K- beam)	15 days
Missing baryon search using low momentum pions	82 days

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 (tomuch multiple scattering)
- Lots of graduate student theses
- Possible to affect shower smulators on 2007 time frame.