

The main Injector Particle Production Experiment (MIPP) at Fermilab -Status and plans

Rajendran Raja
Fermilab

- Review Status of MIPP - E907- Took data till 2006 --18 million events- Analysis status
- Physics case for MIPP-Non perturbative QCD, scaling laws, missing baryon resonances
- Review the status of hadronic shower simulation models
 - » Status of particle production data
- Difficulties in using shower simulation models in experiments such as MINOS, MiniBoone, Atmospheric neutrino production, muon collider neutrino factory particle production, Project X kaon production, mu2e expt fluxes all have a common source.—our lack of knowledge of the strong interaction /non-perturbative QCD
- Review status of MIPP Upgrade Proposal FNAL-P960
 - » to obtain much higher statistics/quality data -- Deferred till we publish
- Ways to use new data directly in simulators—Hadronic Interaction libraries
- Conclusions

MIPP I-E907-collaboration list

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
- Uses 120GeV 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. Existing data poor quality.
- First Physics run- 18 million events 2005. Ended Feb 2006- Analyzing data
- Physics Case for E907 and P960

We have a theory of the strong interaction—in theory

- Why study non-perturbative QCD? Answer:- We do not know how to calculate a single cross section in non-perturbative QCD! This is >99% of the total QCD cross section. Perturbative QCD has made impressive progress. But it relies on structure functions for its calculations, which are non-perturbative and derived from data.
- Feynman scaling, KNO scaling, rapidity plateaus are all violated. We cannot predict elastic cross sections, diffractive cross sections, let alone inclusive or semi-inclusive processes. Regge “theory” is in fact a phenomenology whose predictions are flexible and can be easily altered by adding more trajectories.
- Most existing data are old, low statistics with poor particle id.
- QCD theorist states- We have a theory of the strong interaction and it is quantum chromodynamics. Experimentalist asks- what does QCD predict? One finds that we can only use the theory where the strong interaction becomes weak!
- We have declared this physics as “uninteresting” for ~ 30 years and hence our problems with systematics in every experiment where the strong interaction is either the signal or the background.

General scaling law of particle fragmentation

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

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

- 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 in principle test this in 36 reactions. MIPP upgrade can extend these scaling relation tests to two particle inclusive reactions which requires more statistics.

Scaling Law

$$\sigma(abc \rightarrow X) = F(M^2, s, t) D_X(M^2)$$

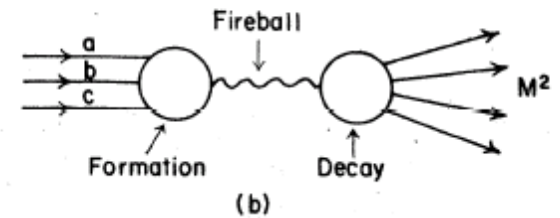
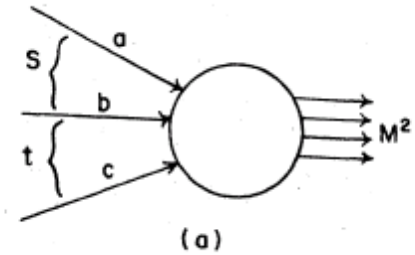
$$\sigma(abc \rightarrow X_s) = F(M^2, s, t) D_{X_s}(M^2)$$

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

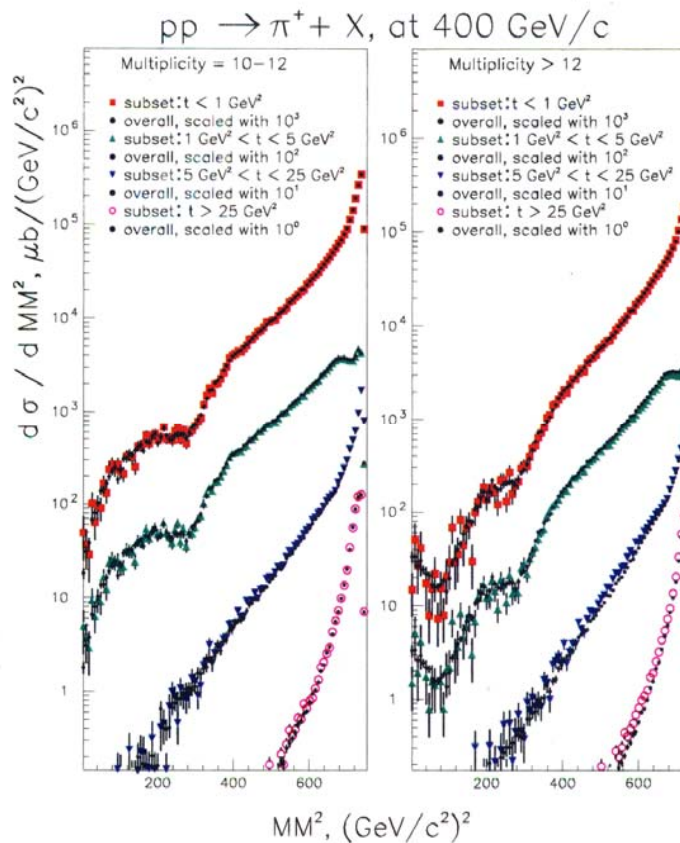
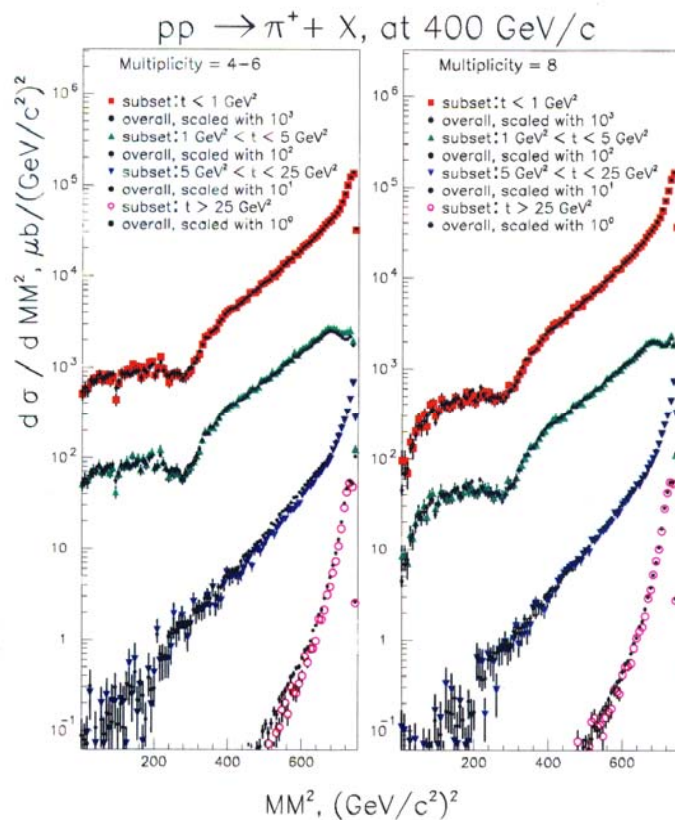
Continuing on to physical t values, one gets

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

Essentially, it states that semi-inclusive cross sections are not all independent but are connected by these relations.

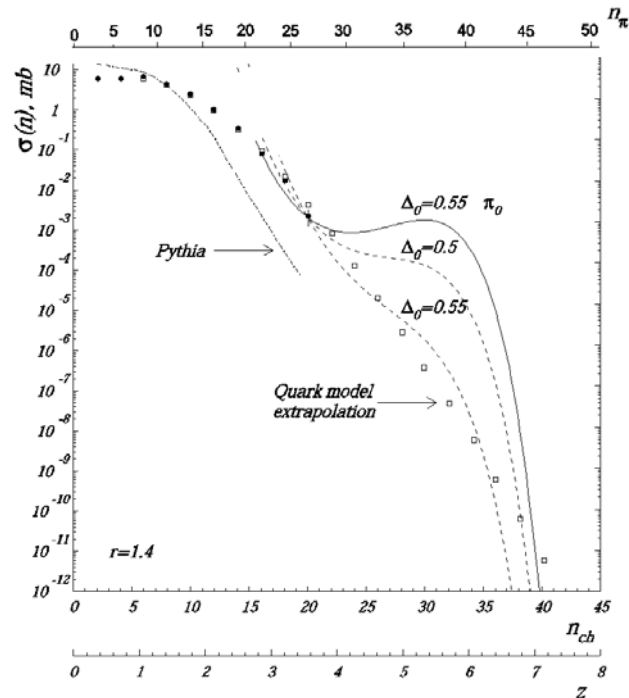


Scaling Law-EHS results



Other physics interests

High Multiplicity excess due to Bose-Einstein effects in pion emission?



GSI Darmstadt/ KVI are interested in measuring anti-proton cross sections for helping them design the PANDA detector better.

Nuclear physics- γ scaling, propagation of strangeness through nuclei. Measure spallation products.

Measure particle production off targets such as mercury, tantalum for neutrino factory/muon collider

Hadronic Shower Simulation 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 current state of hadronic shower simulators.

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

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

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

- 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

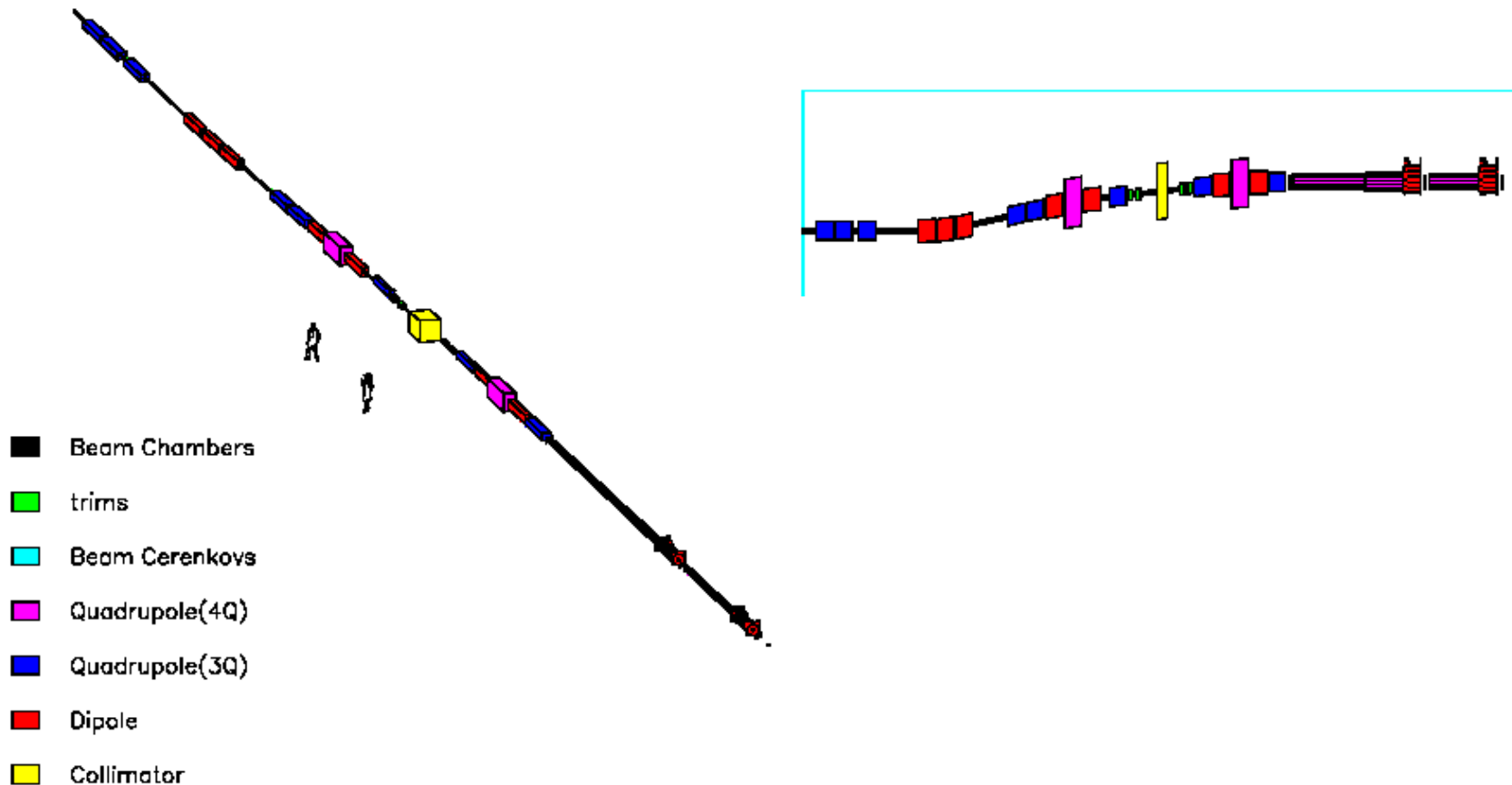
Data Taken In current run

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	0.21	1.94				1.98		1.73		
4	Be	p only									1.08	1.75
		Normal			0.10			0.56				
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									1.05	2.83
		Normal			0.52			1.26				
92	U	Normal						1.18				1.18
Total			0.21	2.73	0.86	5.48	0.50	13.97	0.96	2.04	4.63	31.38

MIPP Secondary Beam

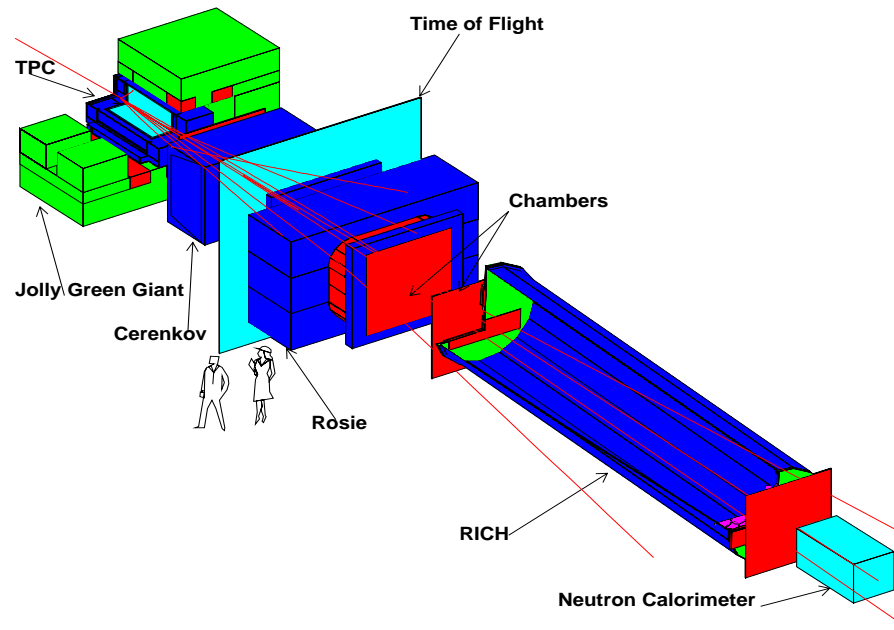
Installed in 2003. Excellent performance. Ran it successfully in MIPP from 5-85 GeV/c secondaries and 120 GeV/c primary protons. Excellent particle ID capabilities using 2 Beam Cerenkovs. For low momenta ($< \sim 10$ GeV/c) ToF is used for pid. Design principles and lessons learned used in M-test upgrade.

MIPP BEAM



MIPP

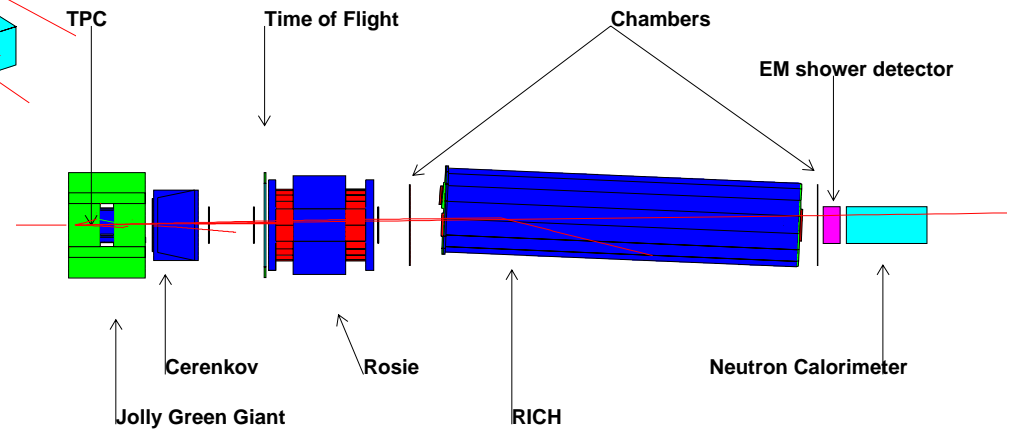
Main Injector Particle Production Experiment (FNAL-E907)



MIPP

Main Injector Particle Production Experiment (FNAL-E907)

Vertical cut plane



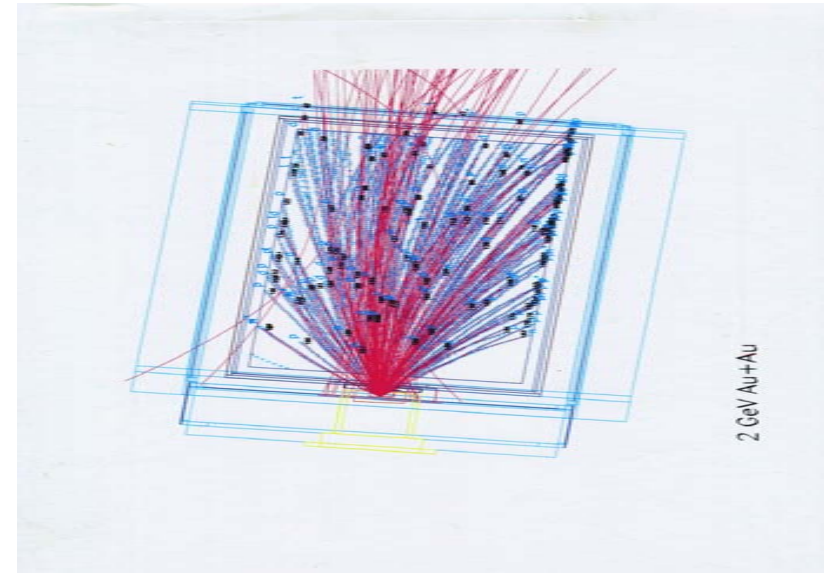
Installation in progress- Collision Hall



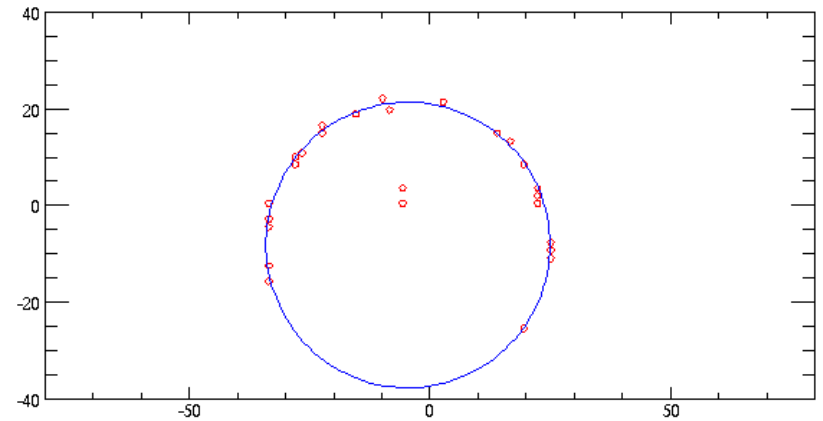
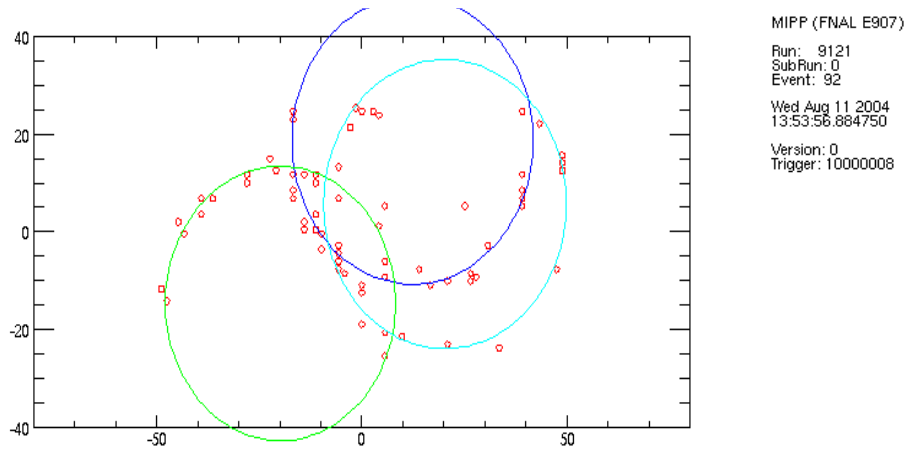
January 2008

Rajendran Raja, M

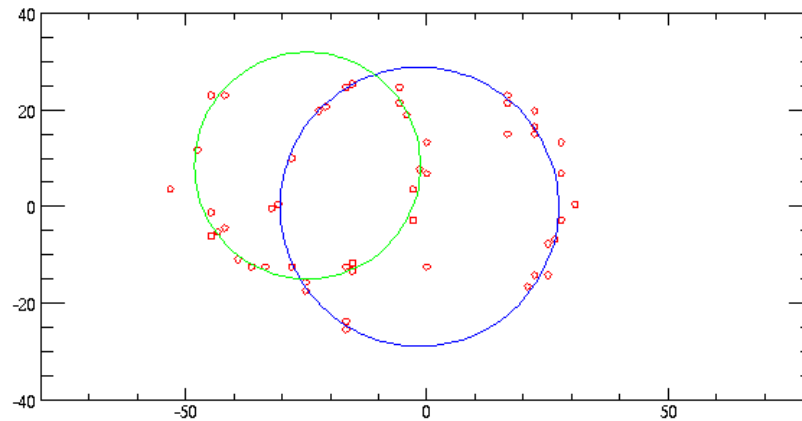
TPC



RICH rings pattern recognized

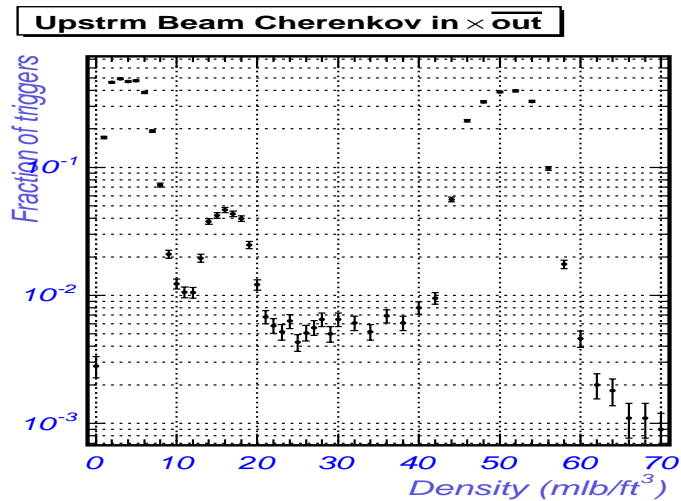


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Run: 9121
SubRun: 0
Event: 100
Wed Aug 11 2004
13:54:06.823879
Version: 0
Trigger: 10000008

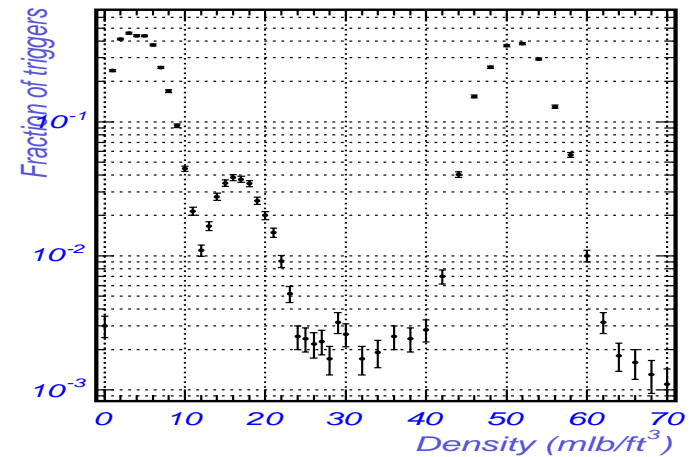


Beam Cherenkovs

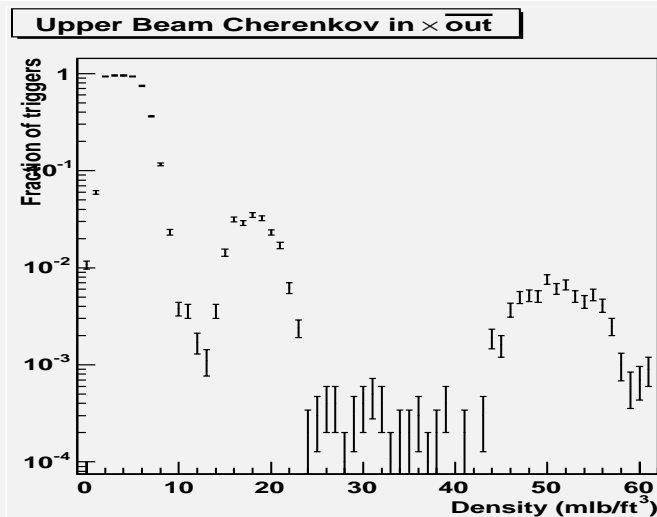
+40
GeV/c



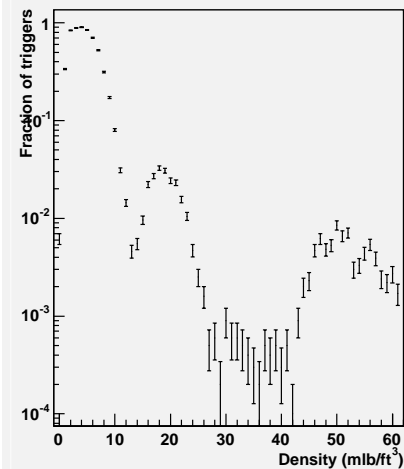
Dwnstrm Beam Cherenkov in \times out



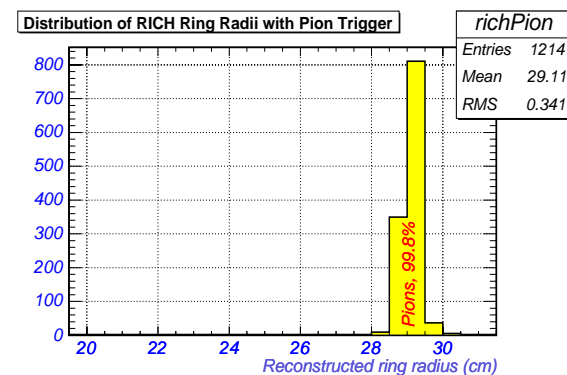
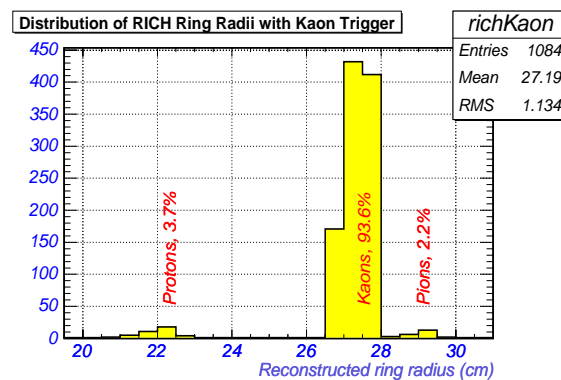
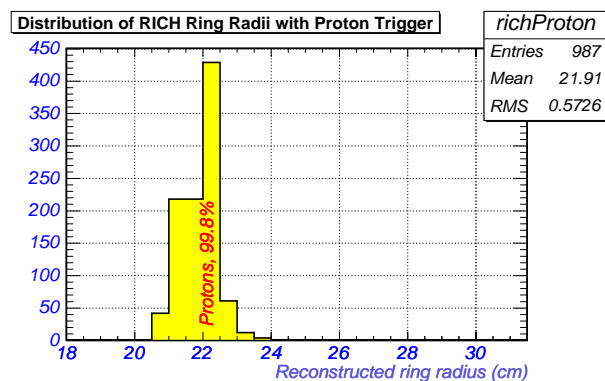
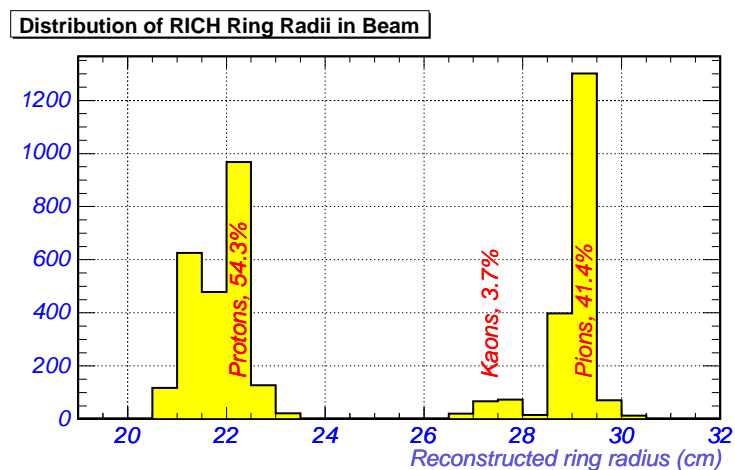
-40
GeV/c



Lower Beam Cherenkov in \times out



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

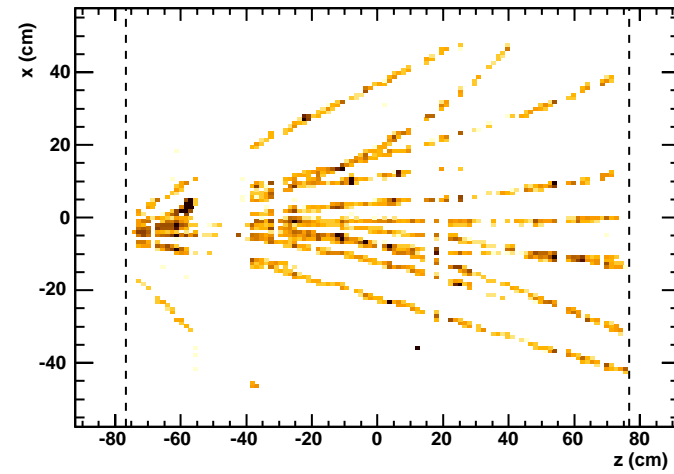
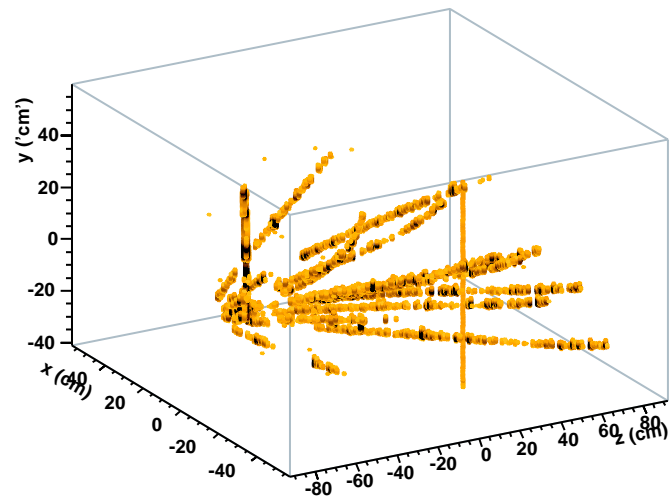
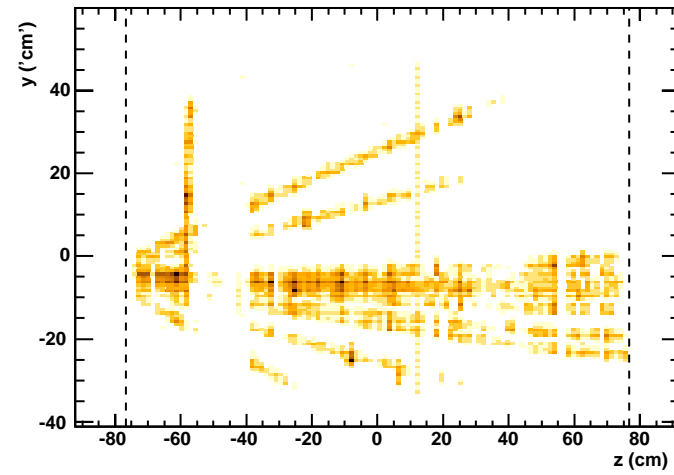
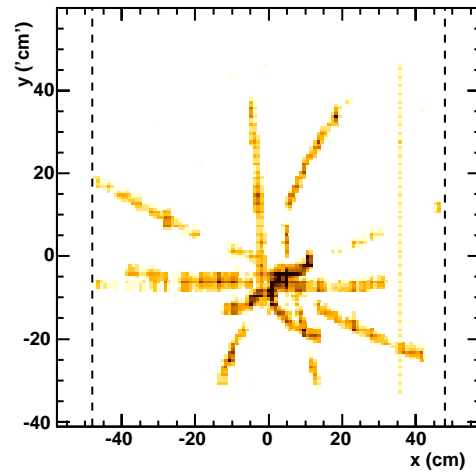


MIPP (FNAL E907)

Target: NuMI
Run: 15007
SubRun: 0
Event: 160

Sat Jul 16 2005
11:22:30.687398

*** Trigger ***
Beam
Word: 0080
Bits: 80D7



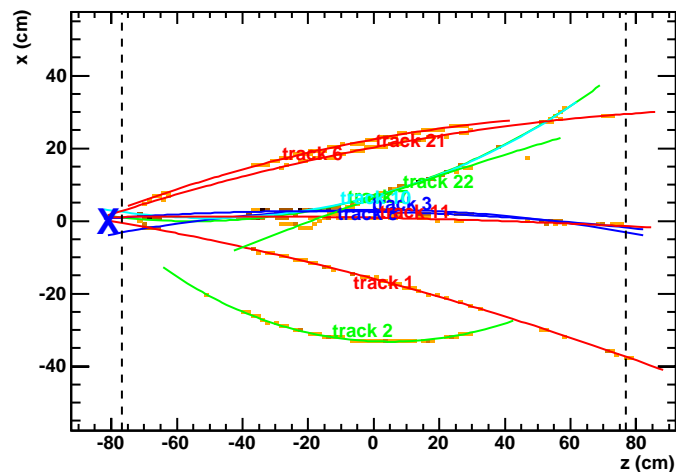
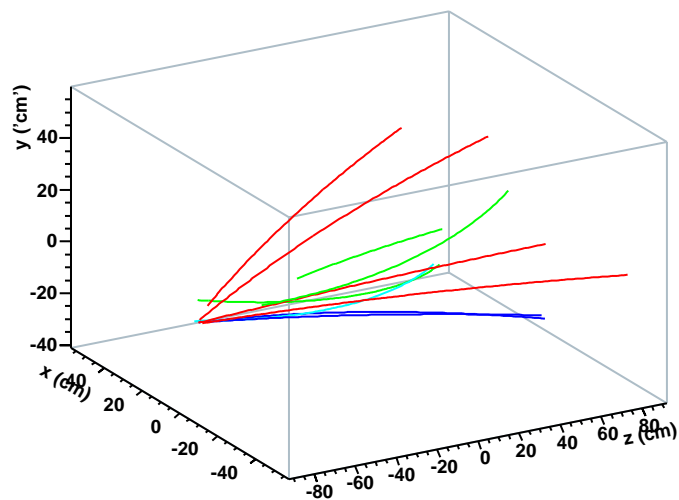
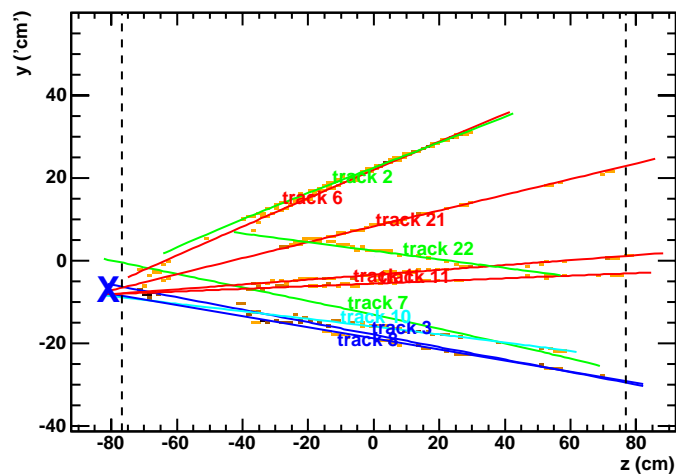
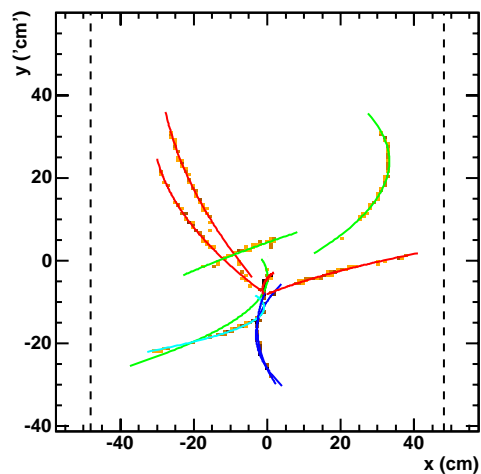
TPC Reconstructed tracks

MIPP (FNAL E907)

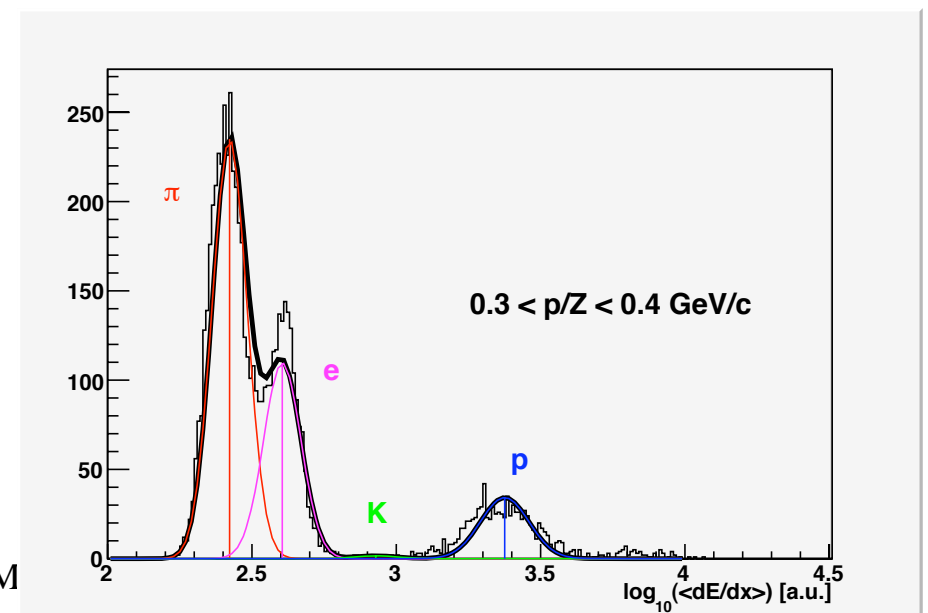
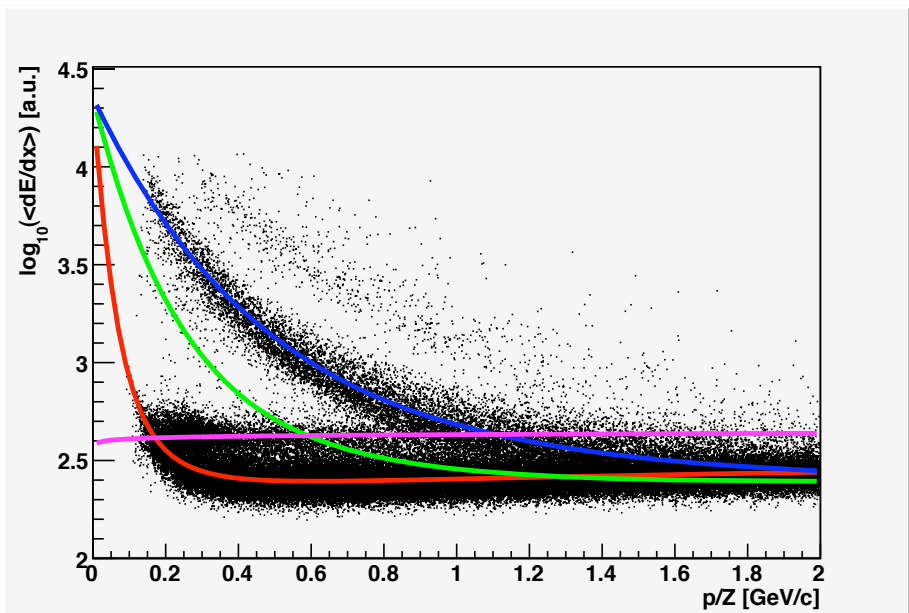
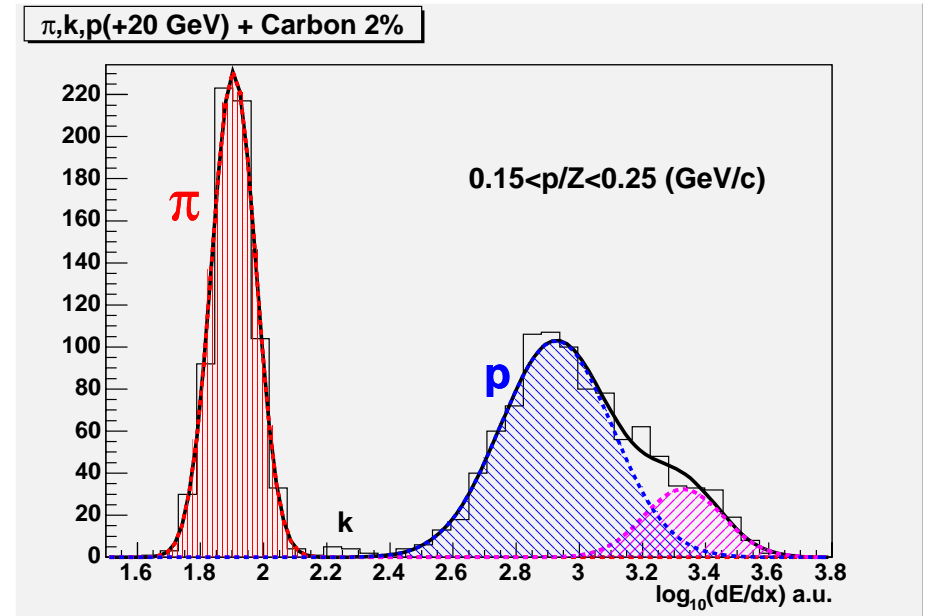
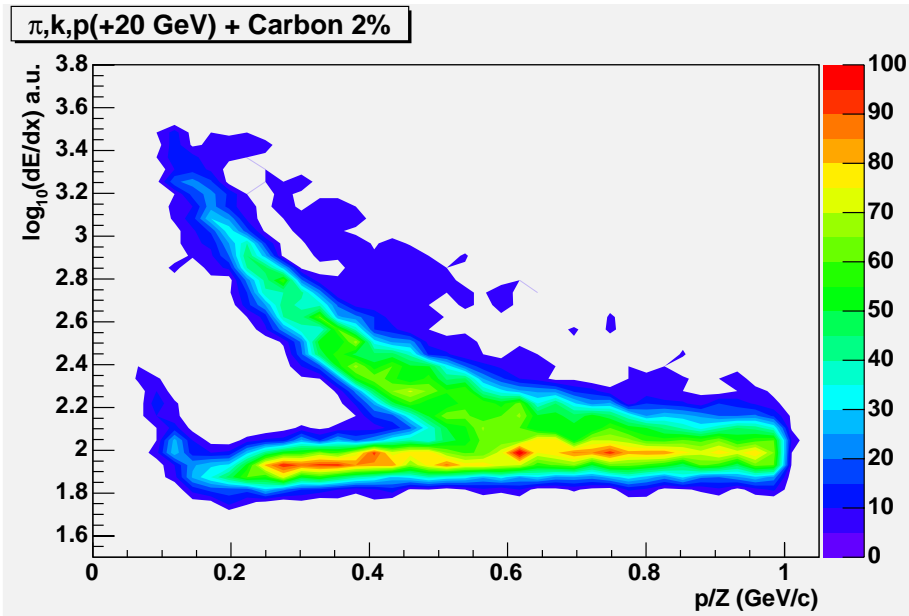
Target: Beryllium
Run: 12719
SubRun: 0
Event: 9

Mon Feb 28 2005
03:18:40.377278

*** Trigger ***
Beam
Word: 0400
Bits: C44F

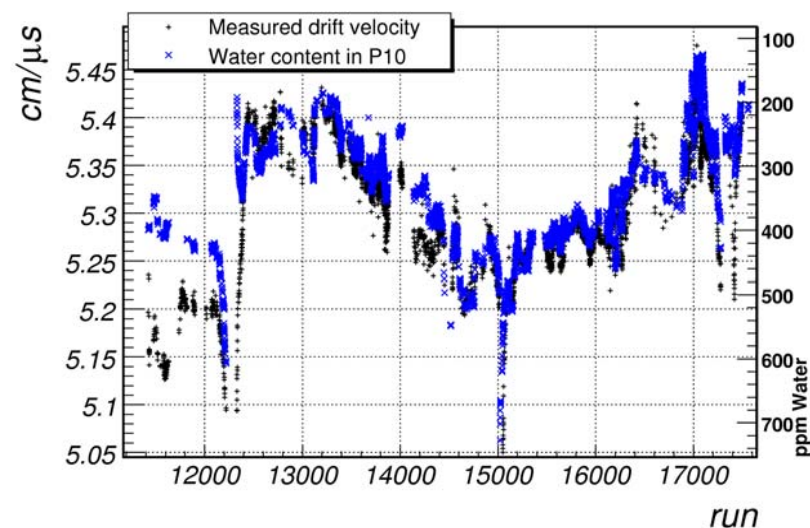
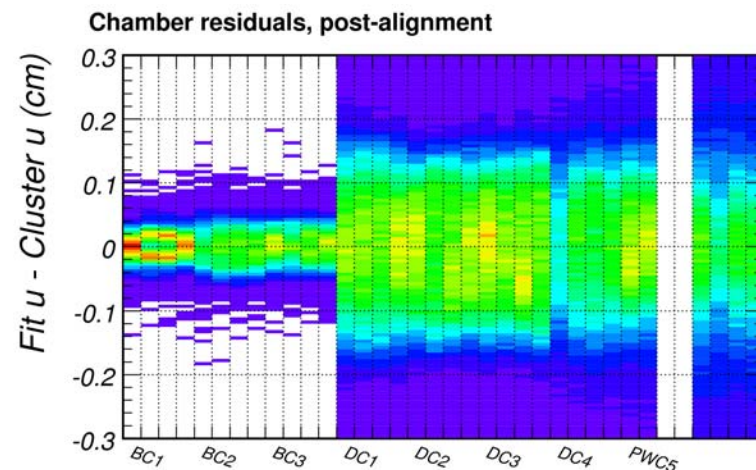


dE/dx in the TPC



Spectrometer Calibration

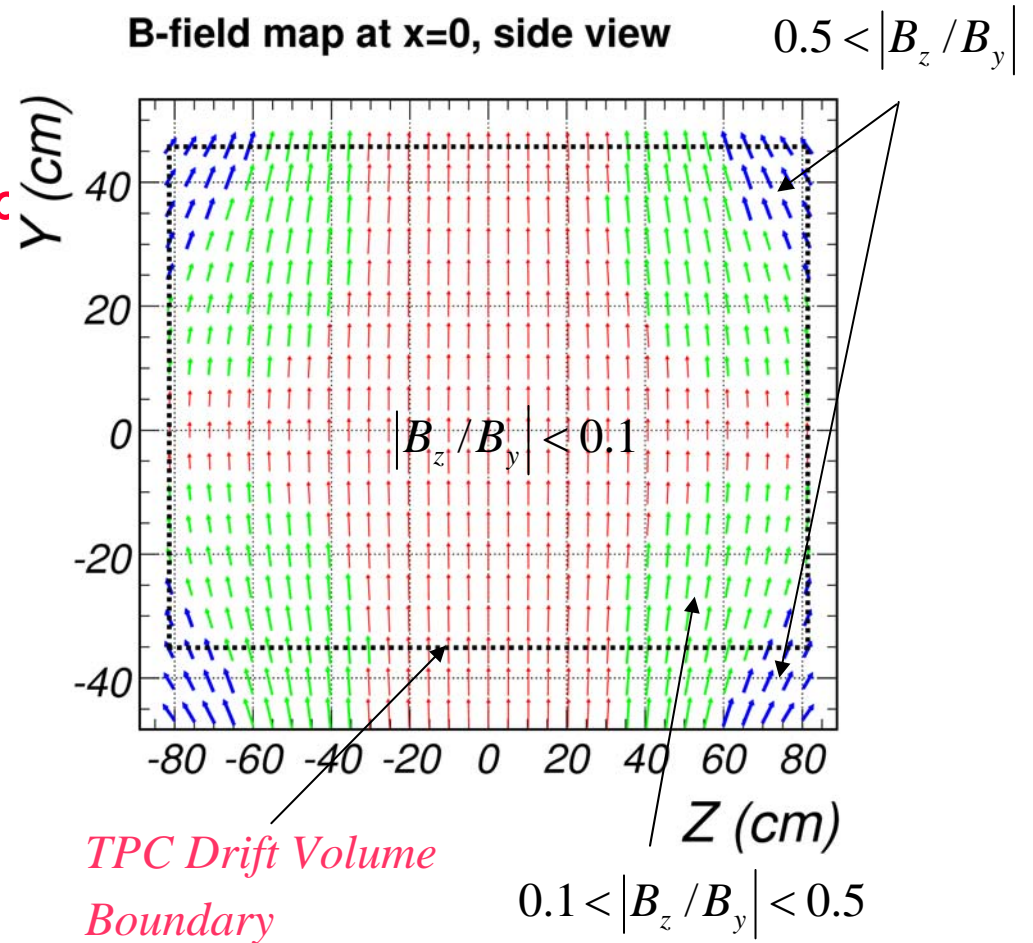
- Chamber alignment done for every run
 - » Helped to find bugs in geometry description and refine magnetic field maps
- TPC electron drift velocity measured for every run
 - » Strong correlation with water vapor contamination



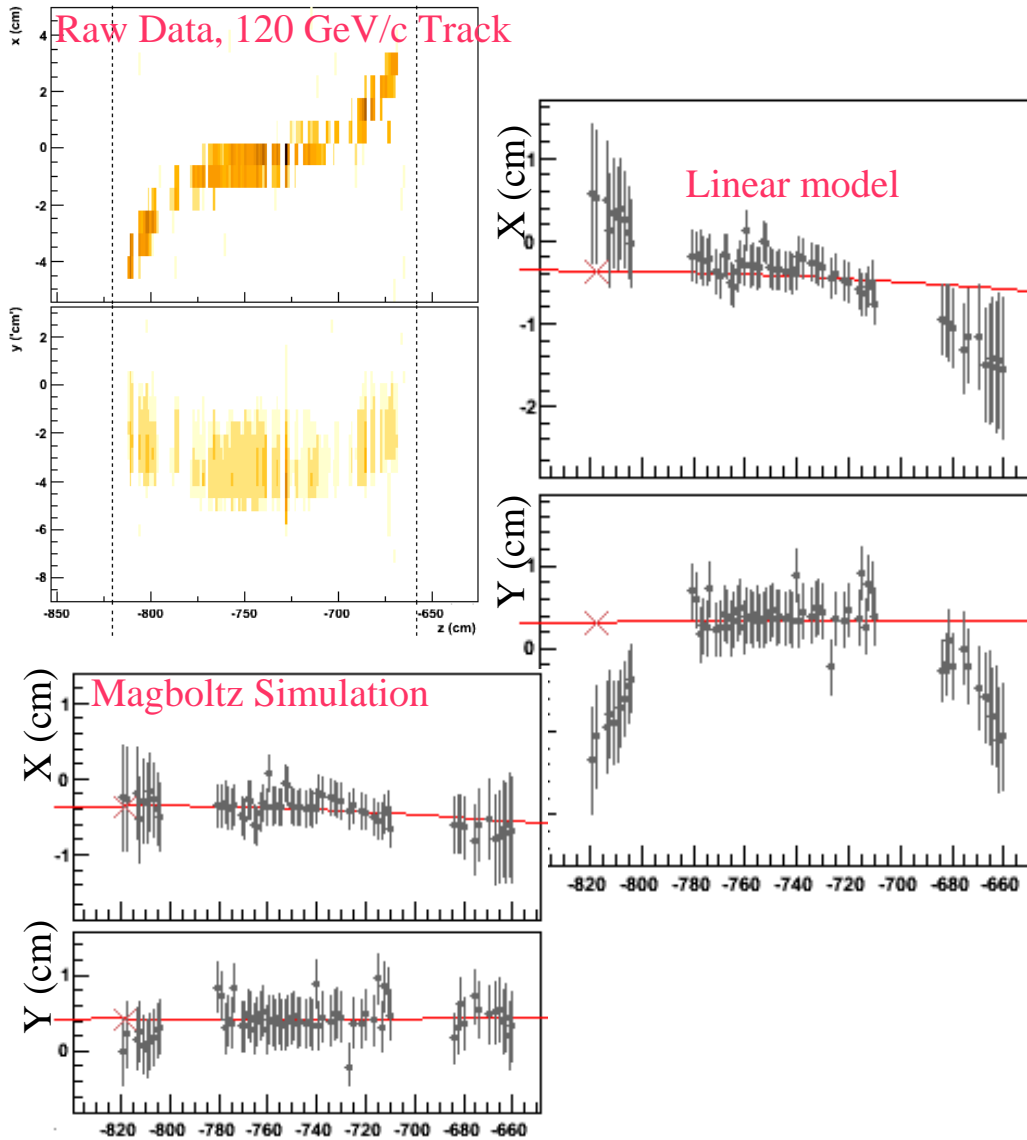
TPC Hit Reconstruction

- JGG field is non-uniform
 - » Enormous effect on electron drift in Ar/CH₄
- Previous experiments applied corrections based on steady state solution to linear model

$$m \frac{d\vec{v}}{dt} = e\vec{E} + e\vec{v} \times \vec{B} - \frac{1}{\tau} \vec{v}$$

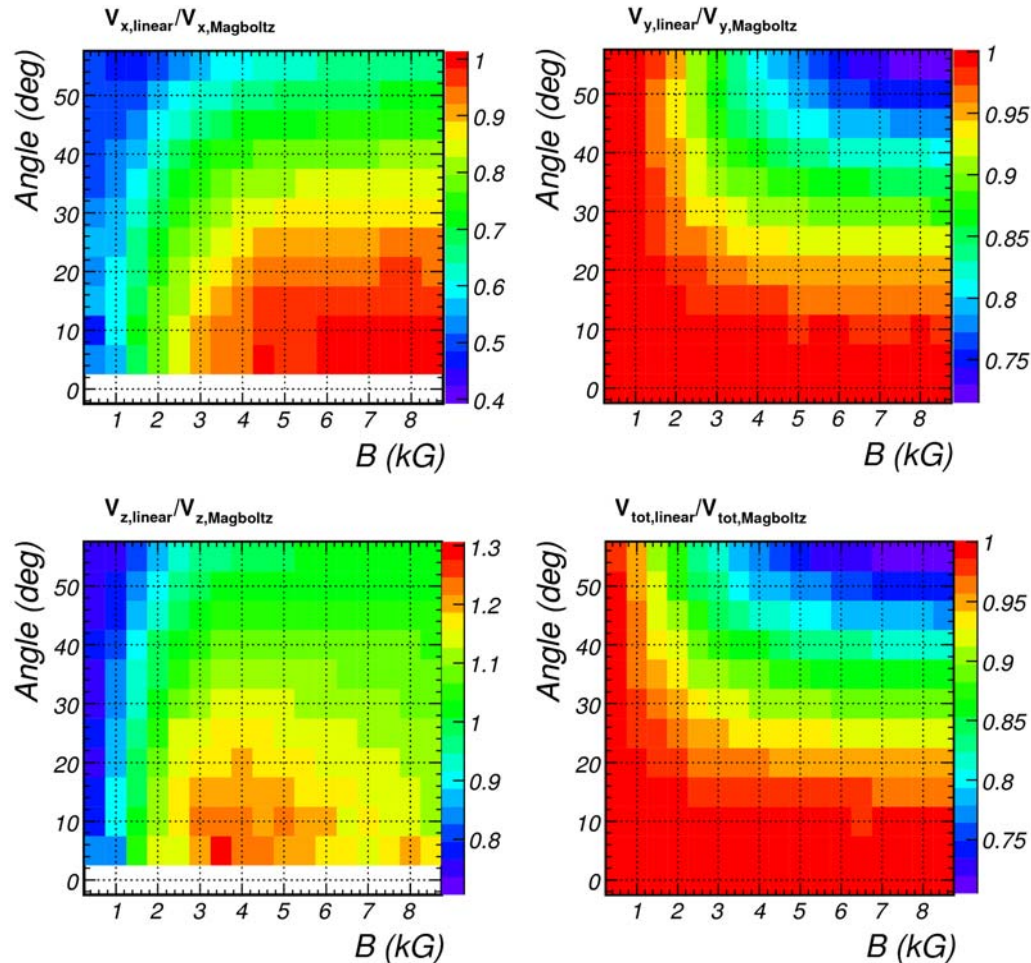


TPC Hit (cont.)



- Linear model fails to describe electron drift
- We use Magboltz simulation to map out drift velocity components as a function of v_0 , B-field strength, and angle between E and B-fields
- Good agreement with TPC data

Linear Drift Model vs Magboltz

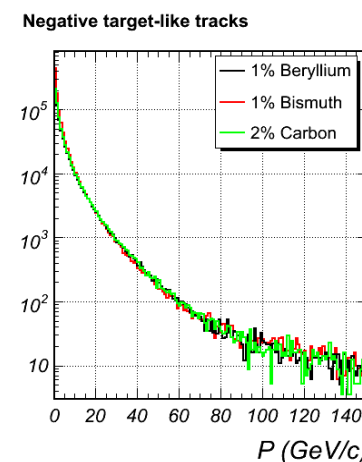
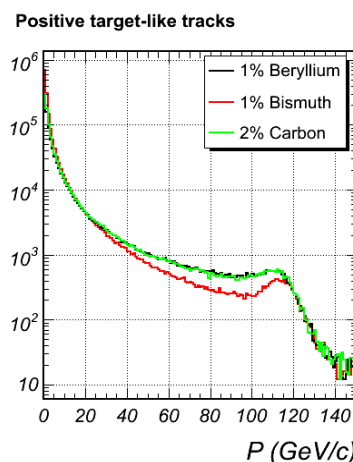
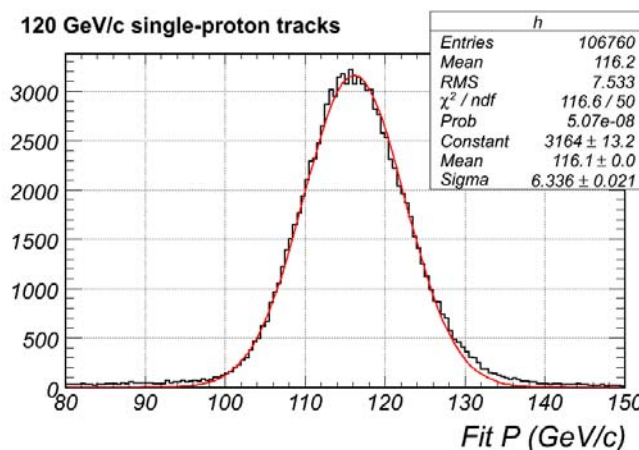


- Magnetic field inside the TPC varies from 3.5 to 8 kG
- The angle between E and B fields goes up to 50 degrees
- Difference in drift velocity components reaches 30%
 - » With 5 cm correction that's 1.5 cm!

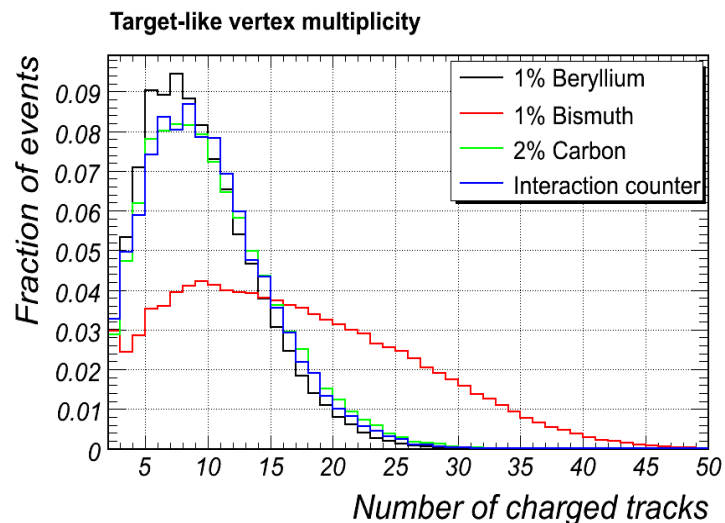
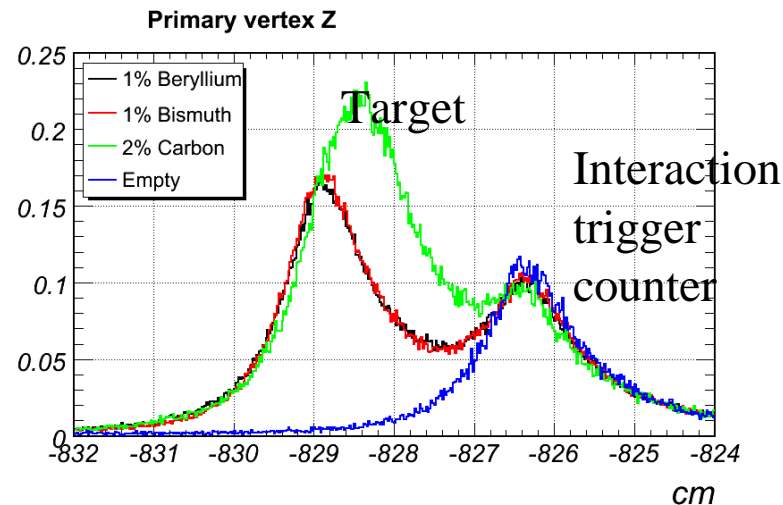
Track Reconstruction

Plots from 120 GeV/c proton data

- TPC tracks are fitted to helices
 - » Non-uniform B-field complicates the task
- Matched to chamber wires to form global tracks
 - » Fit using track templates
- Momentum resolution 5.5% at 120 GeV/c
 - » Drift times are not yet used



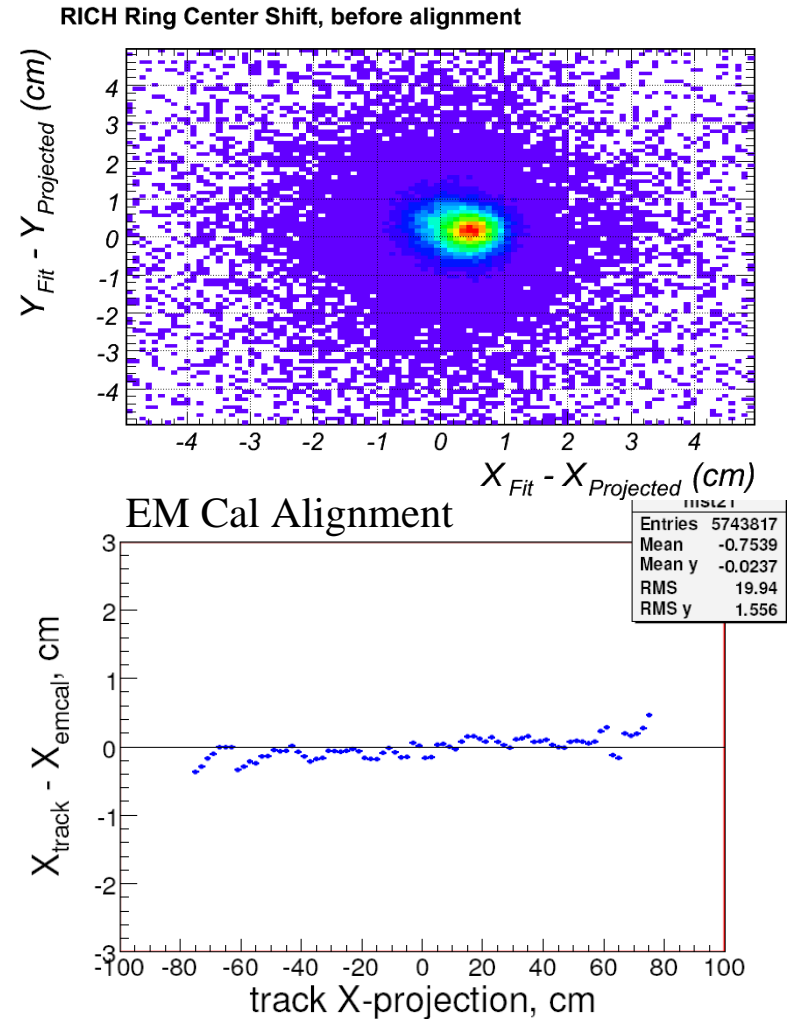
Vertex Reconstruction



- Vertex finding is done with deterministic annealing filter
- Vertex-constrained fit done with track templates
 - » 6mm vertex Z resolution
 - » X,Y resolution < 1mm

Calibration (cont.)

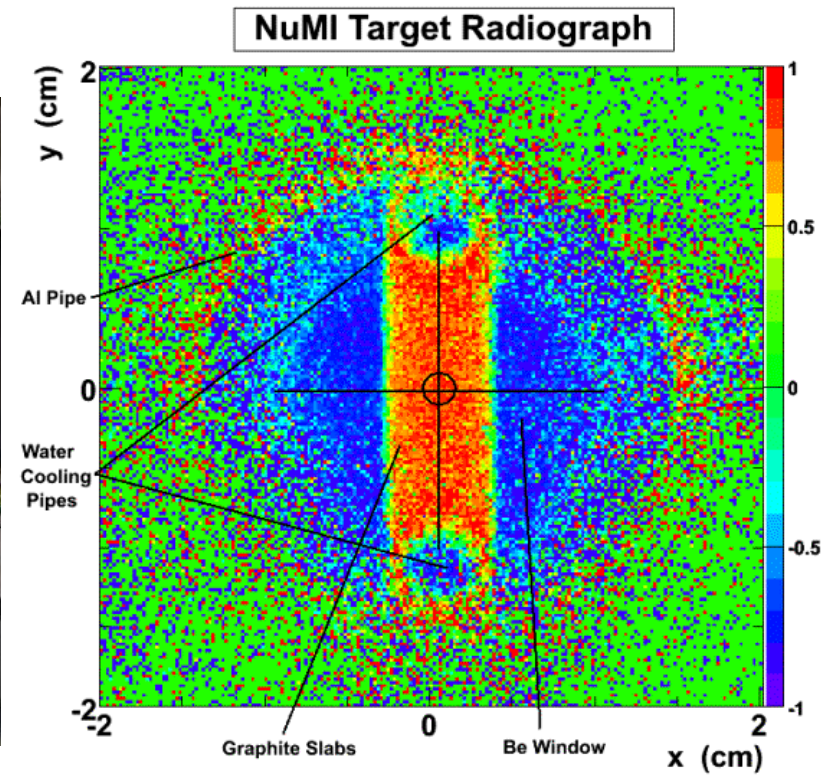
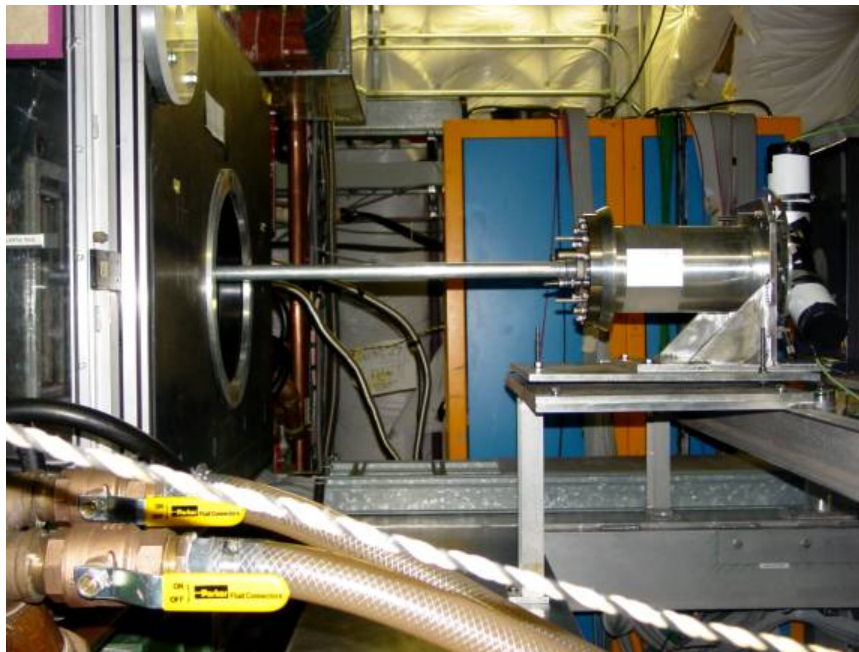
- Global tracking is used to
 - » Align the RICH
 - » Align EM calorimeter
 - » Compute drift attenuation in the TPC
 - » Compute ToF cable delays
 - » Calibrate Ckov light output
 - » Calibrate RICH index of refraction
- Calibration to be completed within 2 weeks



Event Reconstruction Summary

- Track reconstruction
 - » Form hits in TPC, find tracks and fit to helices
 - » Match TPC tracks to chamber hits, fit using track template method
- Vertex reconstruction
 - » Find vertices using Deterministic Annealing Filter (DAF)
 - » Make vertex constrained fits using track templates
- Particle identification
 - » Compute TPC dE/dX , track ToF, Cherenkov likelihood
 - » Match tracks to RICH rings and compute likelihoods
 - » Match tracks to calorimeter showers

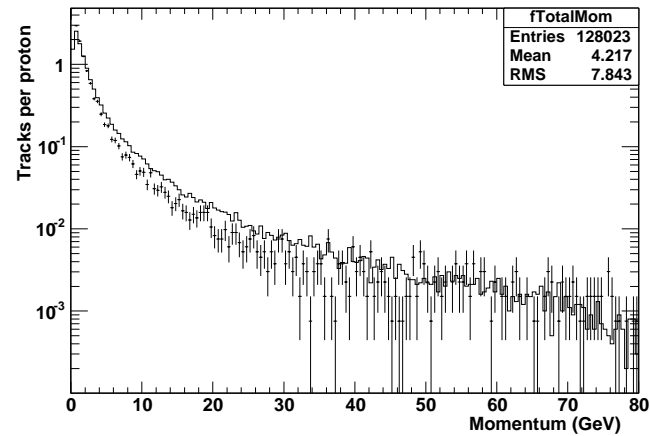
NuMI target pix



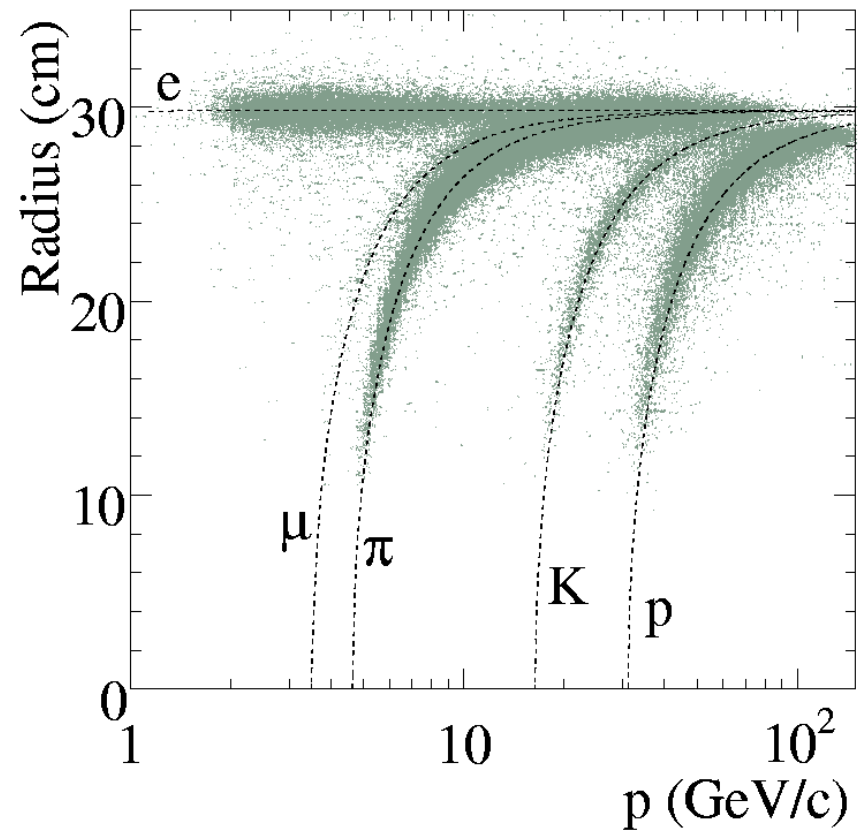
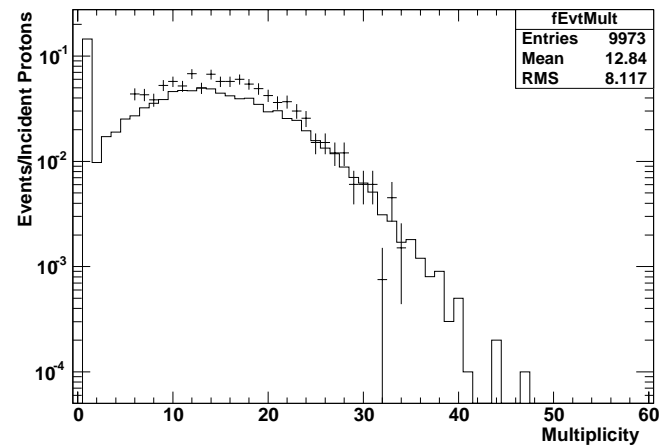
*Preliminary Comparison of
NUMI target to FLUKA
predictions*

RICH Rings
from NUMI
target

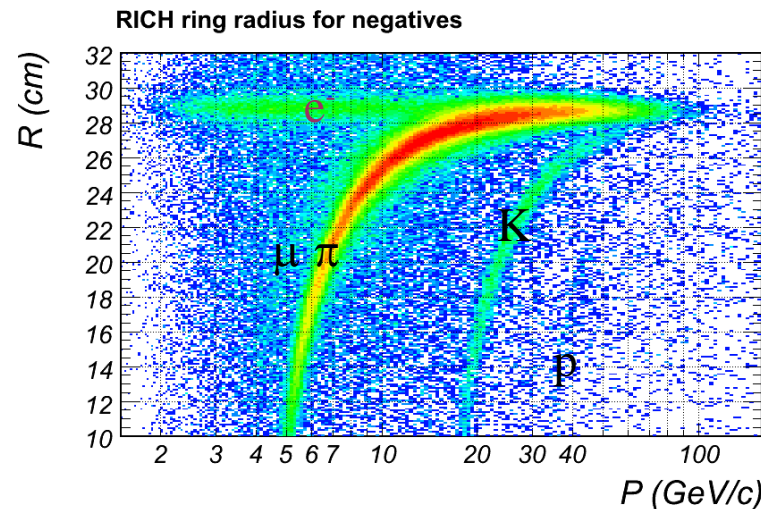
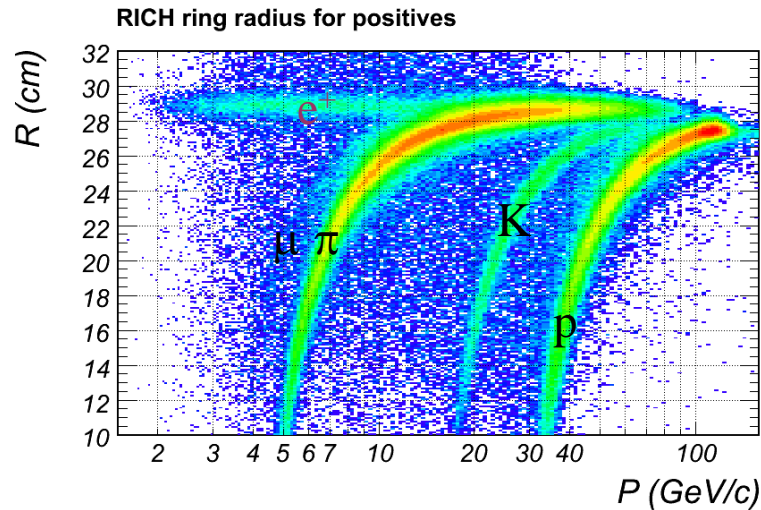
NuMI Target Analysis



NuMI Target Analysis

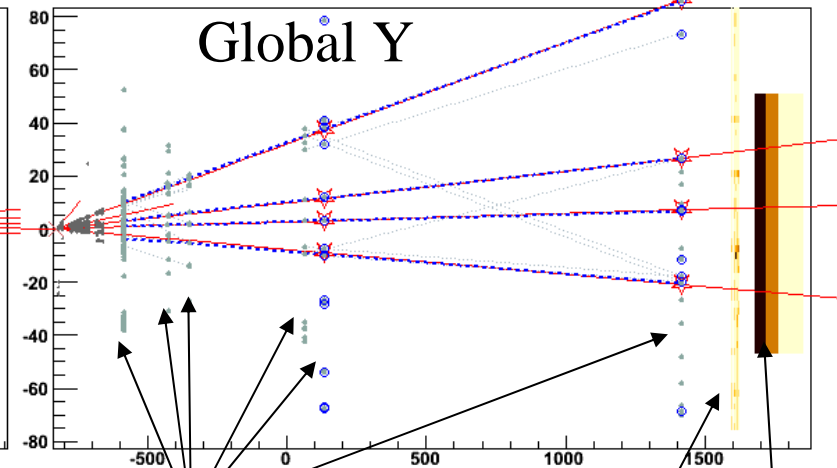
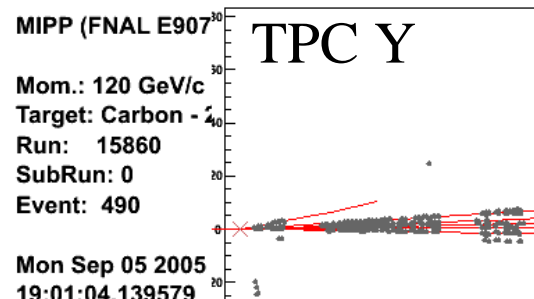
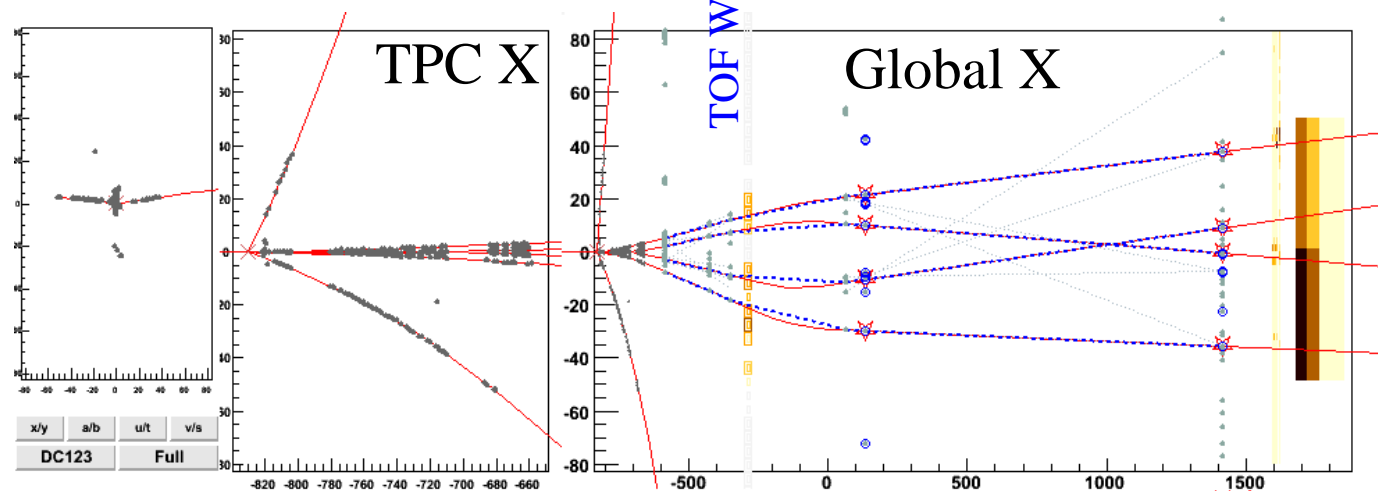


Particle ID (cont.)

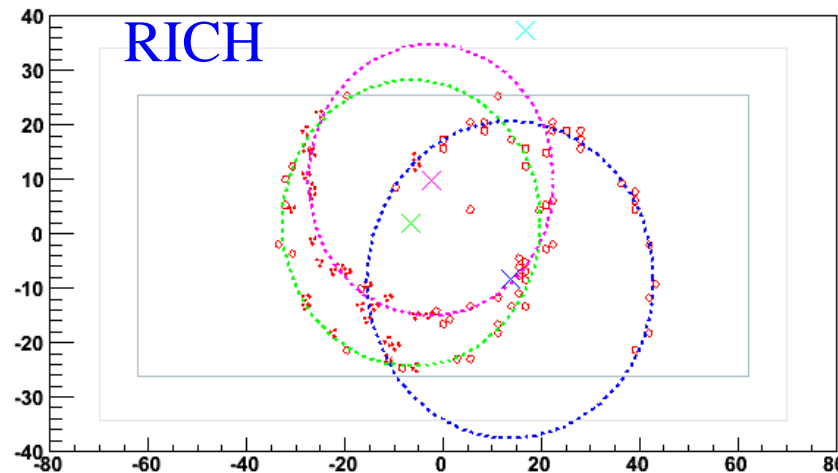


- RICH ring radius gives very good particle ID within acceptance
 - » $e/\mu/\pi$ to 12 GeV/c
 - $\approx \pi/K/p$ to 100 GeV/c
- Detector is calibrated and well understood

Reconstructed Proton-Carbon at 120 GeV/c Event



PMT Array



Wire Chambers

EM Cal

Hadron Cal

MIPP Cherenkov

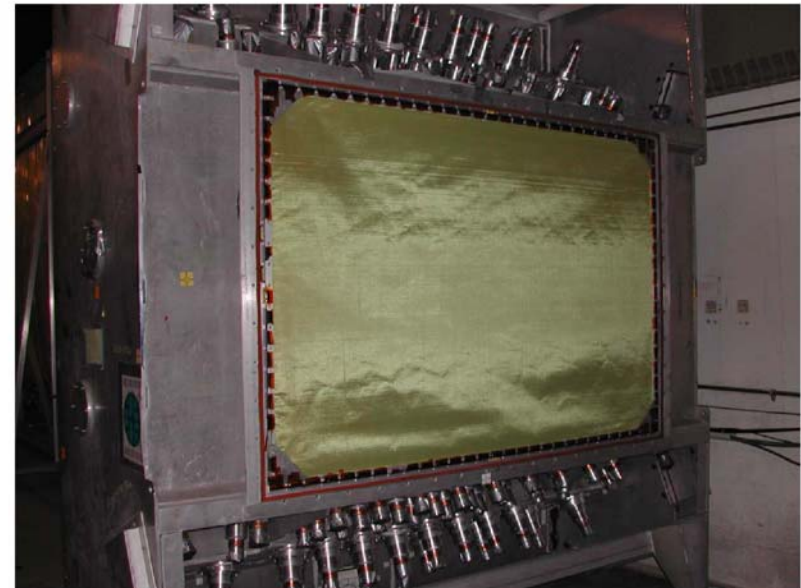
C4F10 gas

Thresholds

$\pi = 2.5 \text{ GeV}/c$

$K = 8.9 \text{ GeV}/c$

$P = 17.5 \text{ GeV}/c$

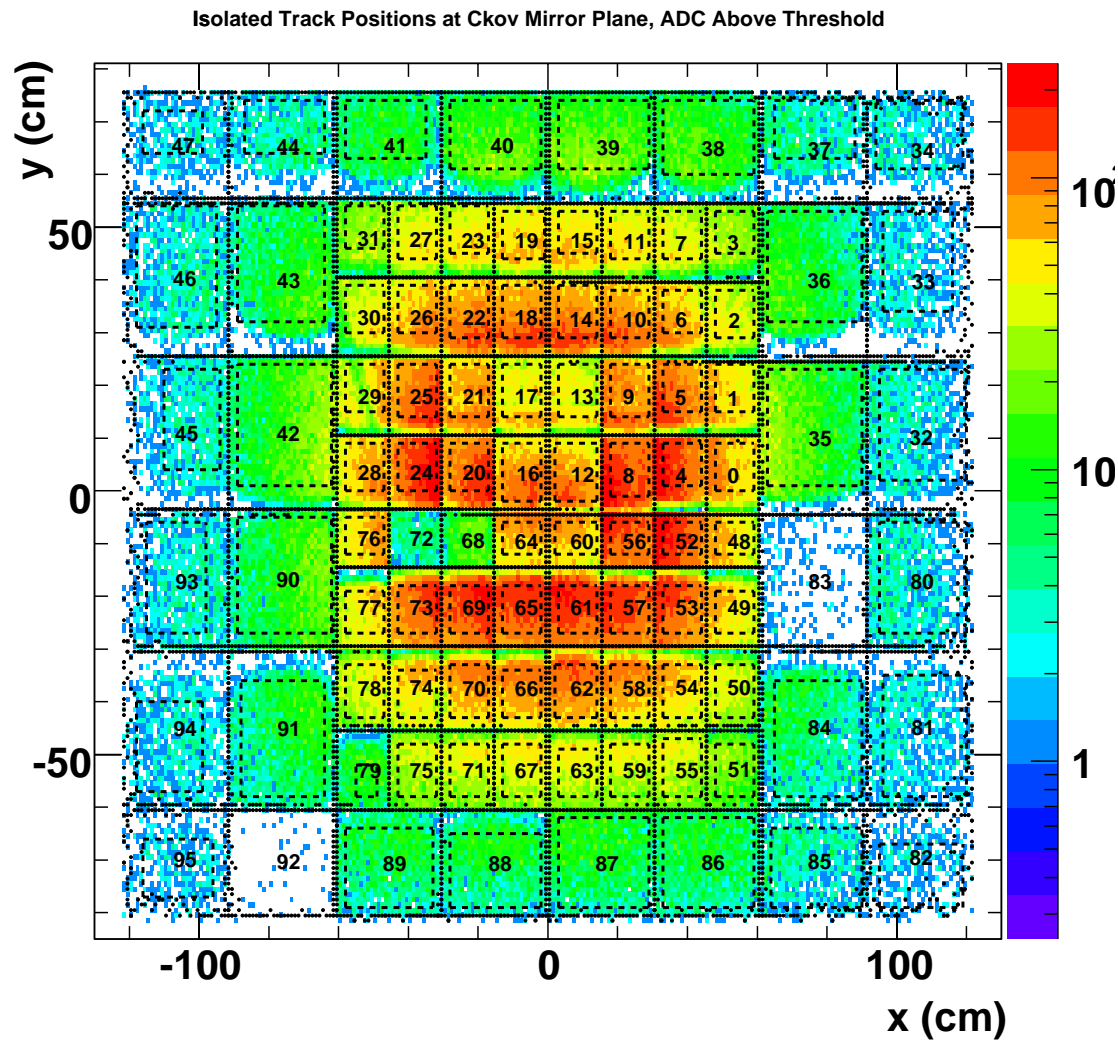


January 2008

Rajendran Raja, MIT European Seminar

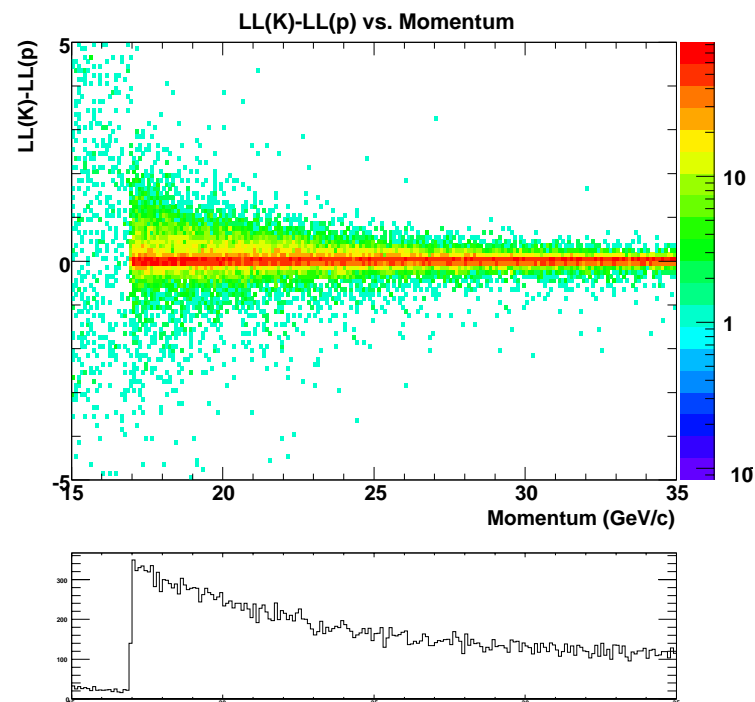
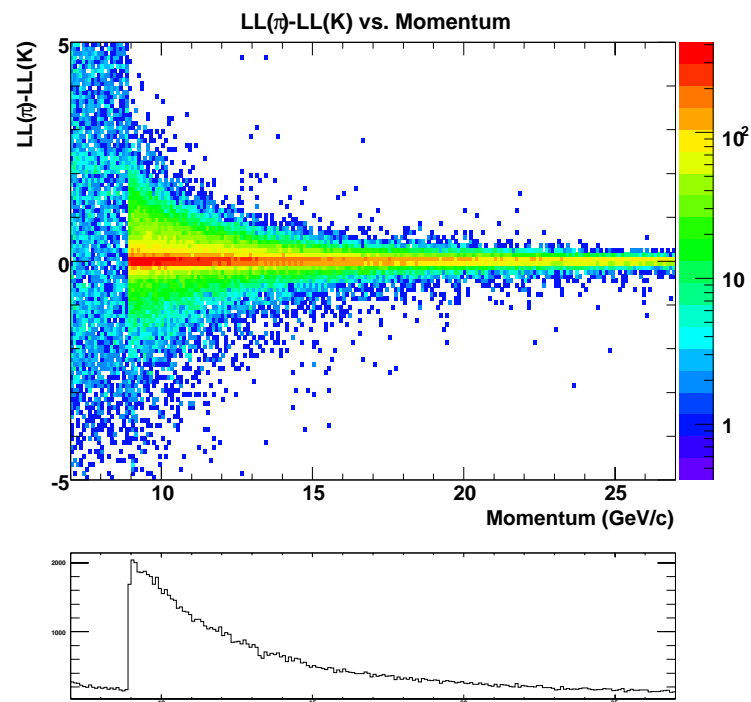
Ckov analysis-

Isolated track positions with ADC above threshold



Ckov analysis

- Every mirror calibrated with data assuming pions and Poisson statistics. Light yield lower than expected.

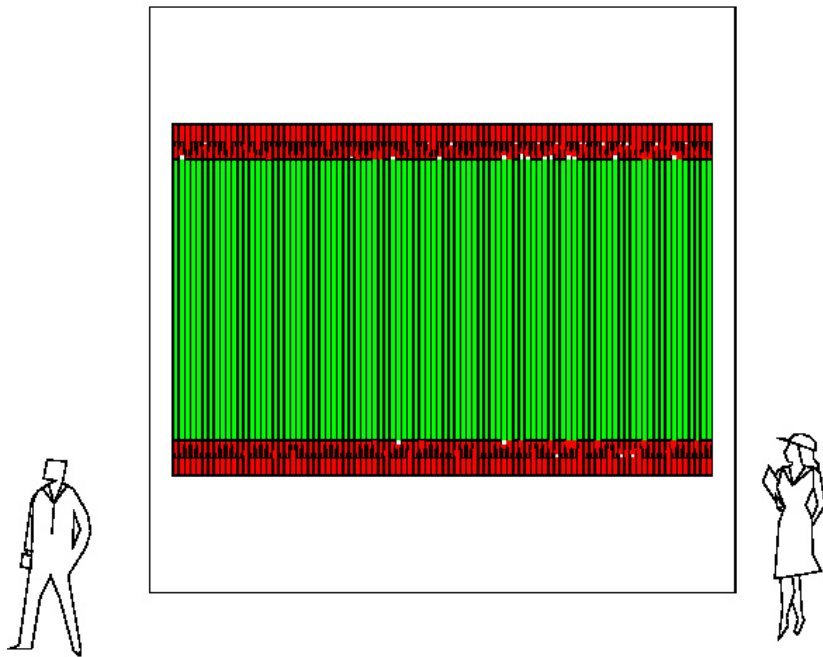


Time of Flight Wall

Designed and built by MIPP

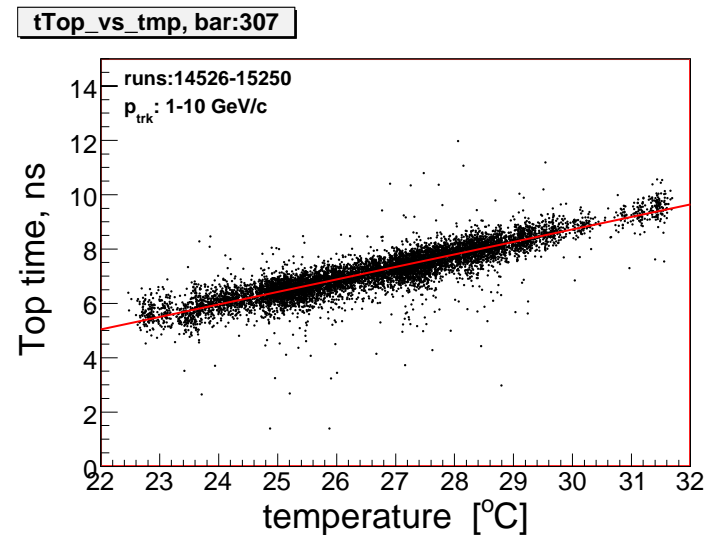
5cmx 5cm square scintillator bars in Rosie aperture, 10cmx10cm outside.
~ 200ps resolution.

MIPP- Time of flight system

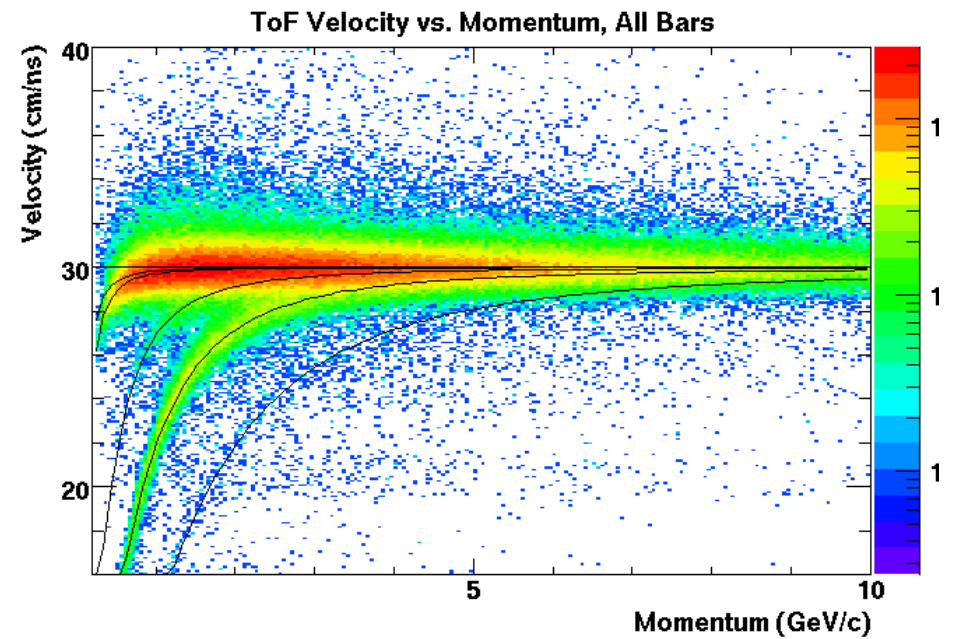
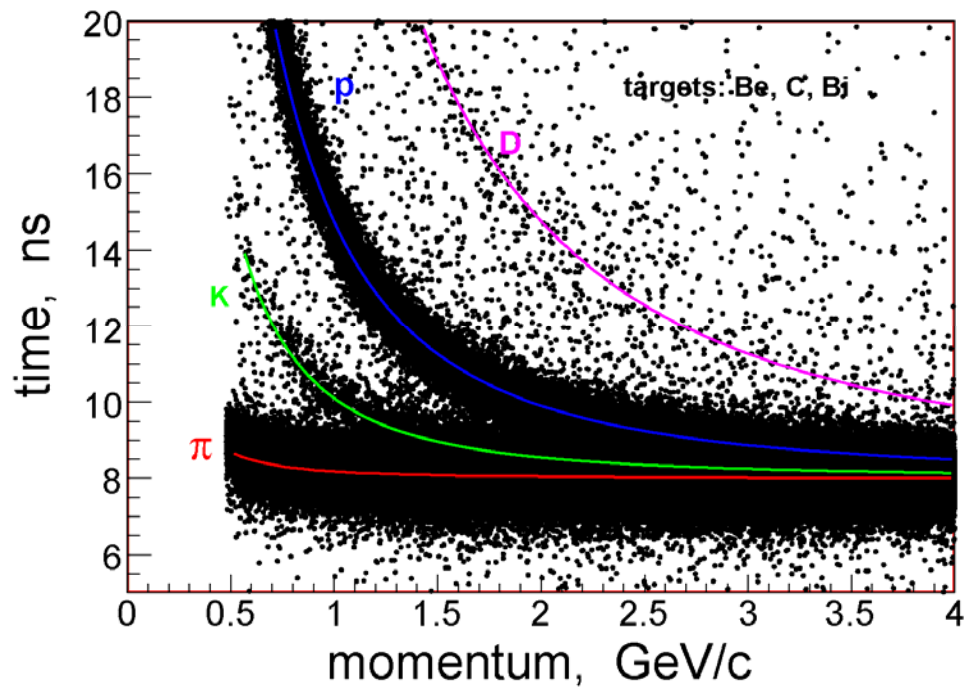


Temperature systematics

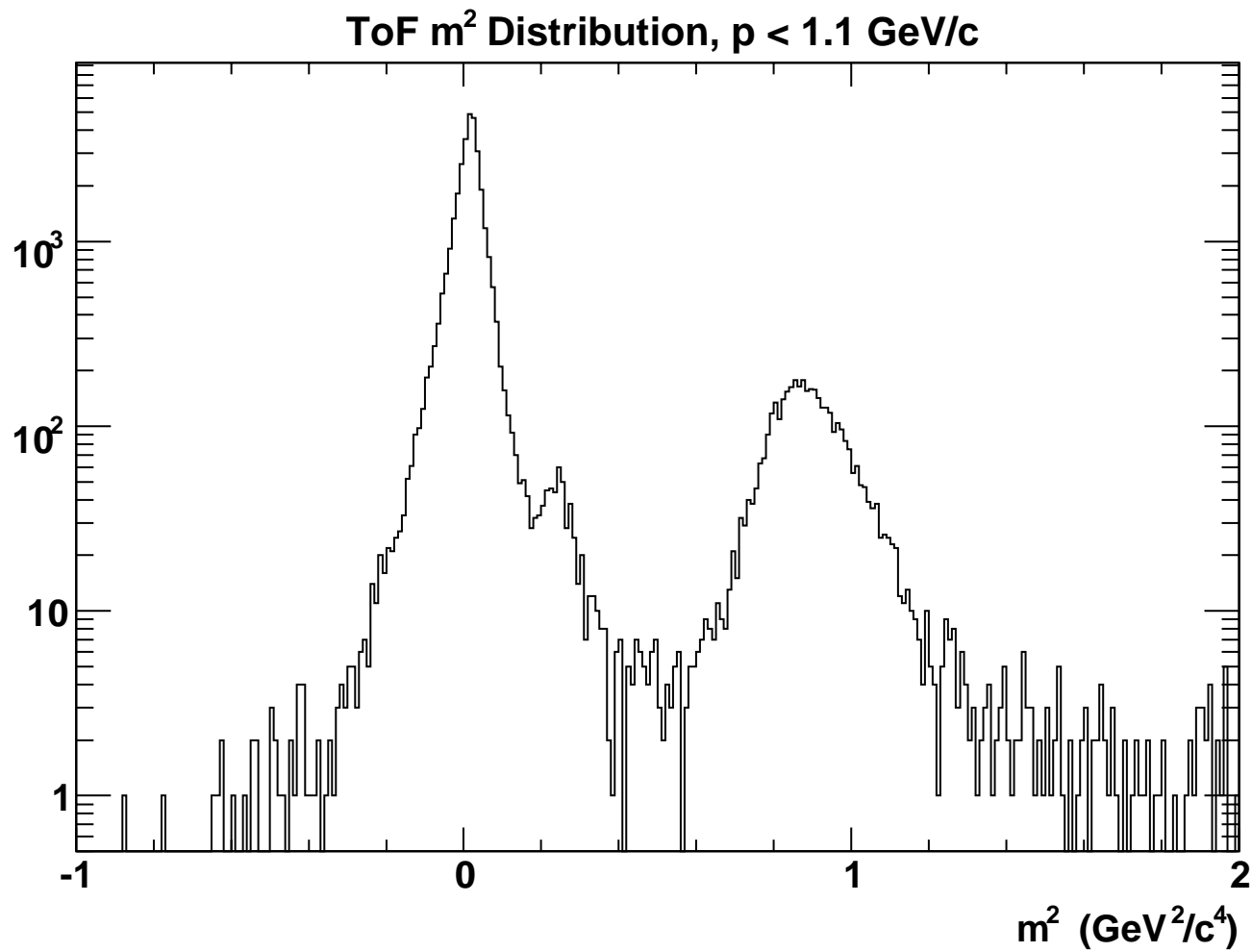
Crosstalk when neighboring bars hit



ToF analysis



ToF analysis

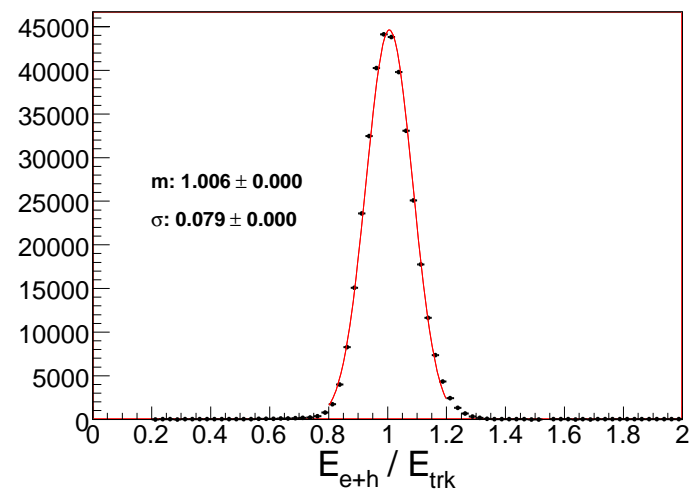
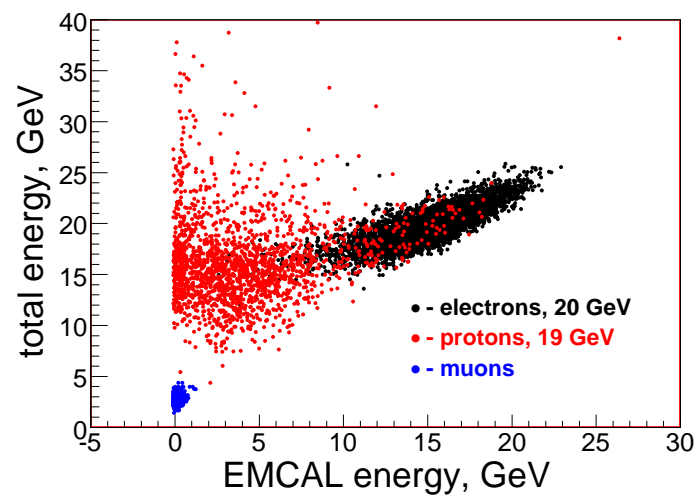


Calorimeters

EM calorimeter followed by hadron calorimeter

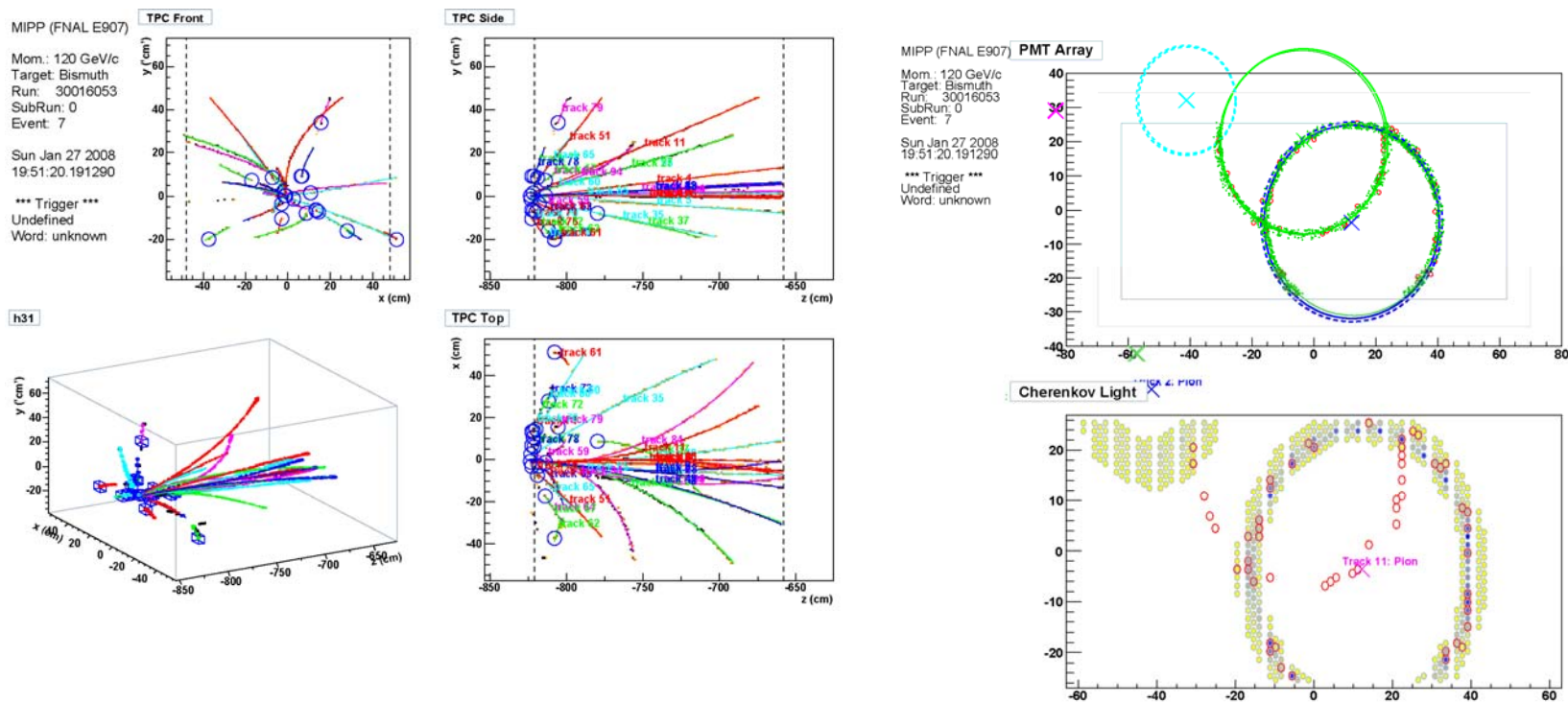


Calorimeter Analysis

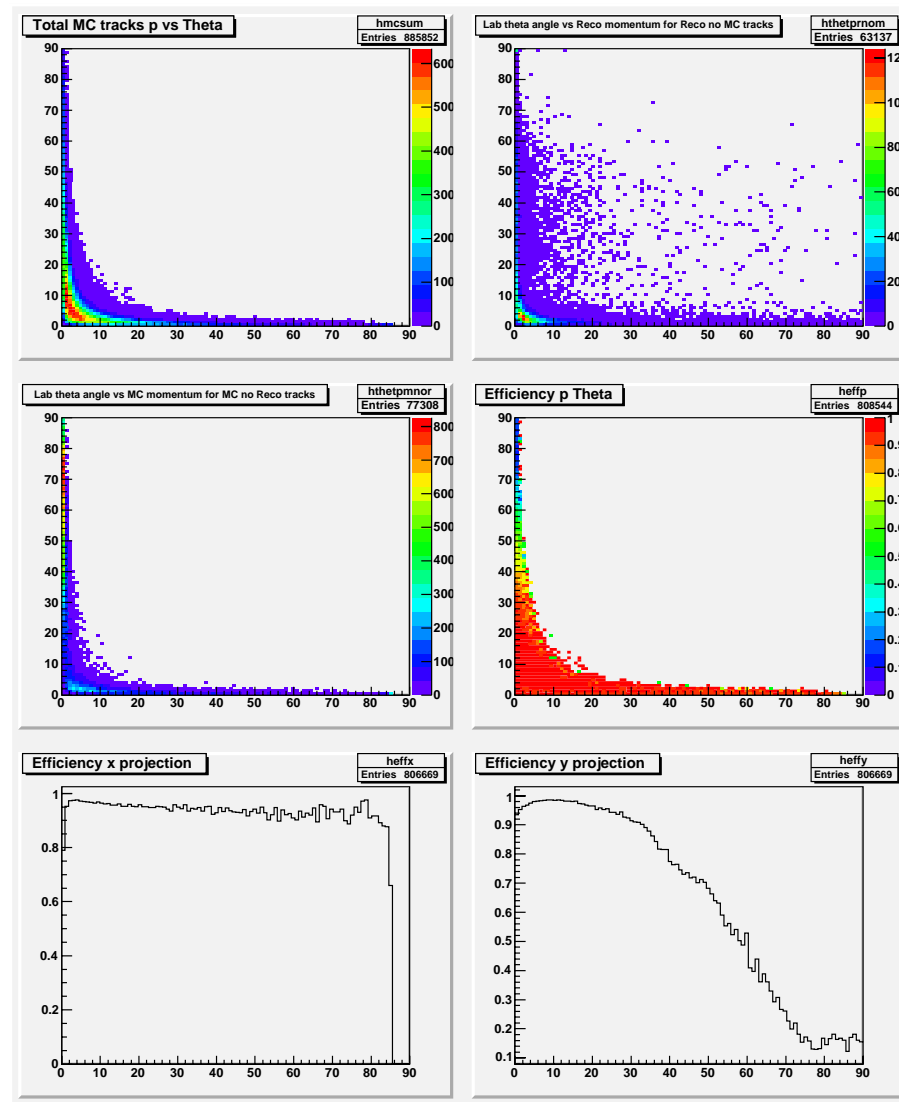


Acceptances and resolutions

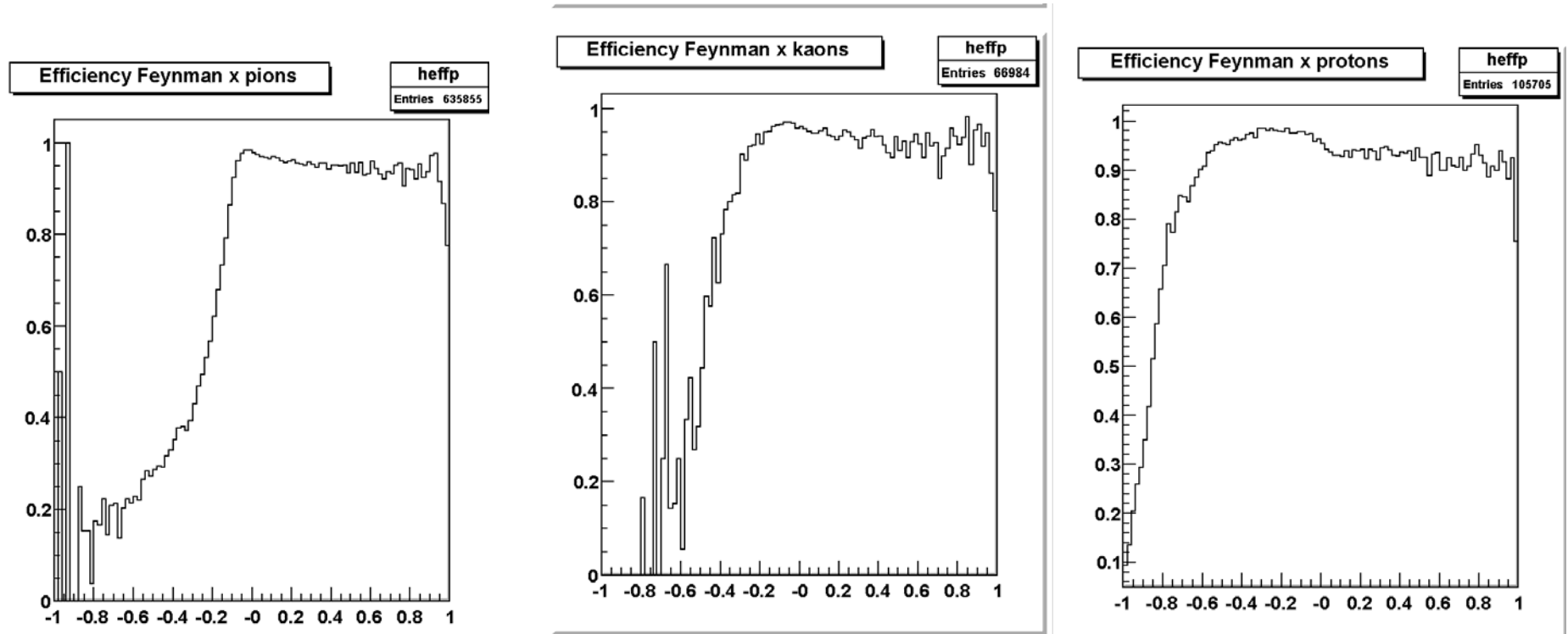
- Full MC Geant3 based. Use known tracks and match them to found tracks to determine acceptance*tracking efficiency + momentum resolution.
- MC event display



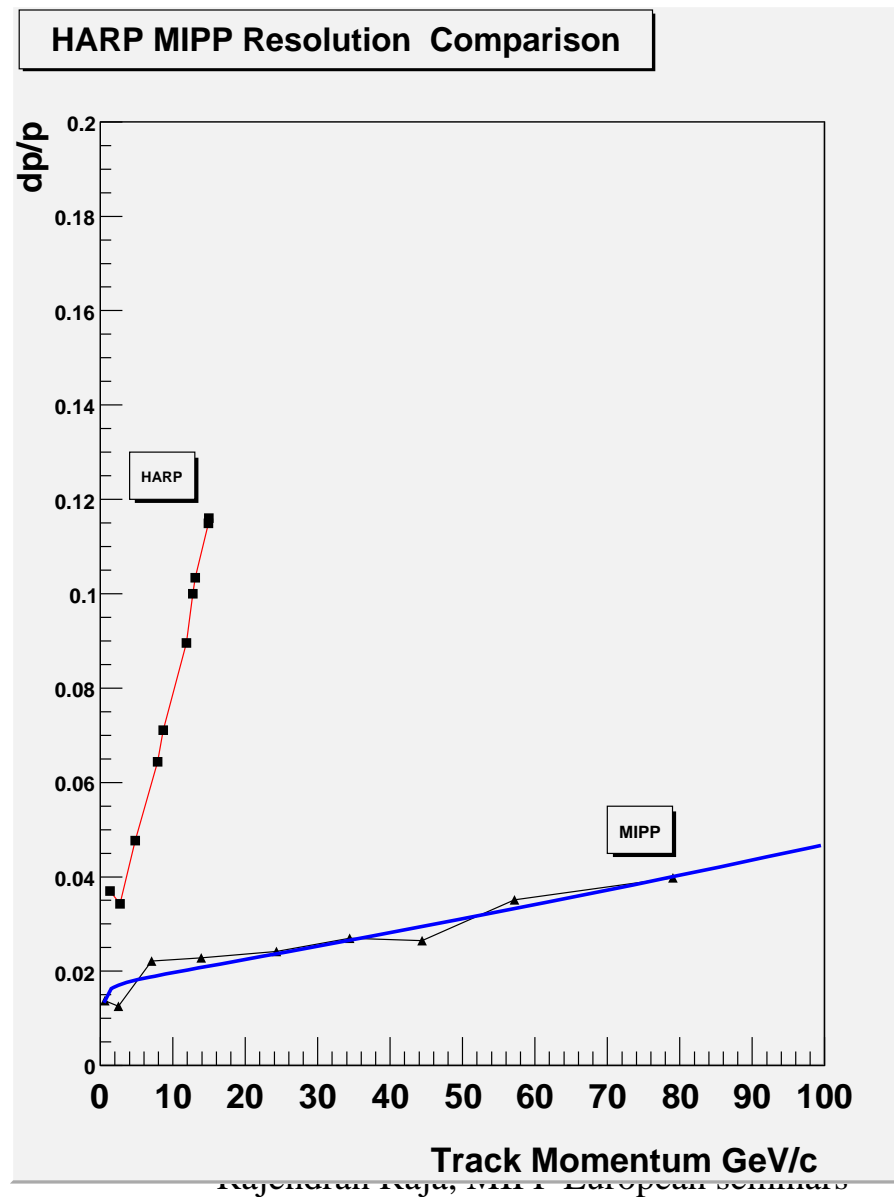
Acceptances



Feynman x acceptance



MIPP Momentum resolution



Hadron Shower Simulator problem

- Timely completion of MIPP upgrade program can help systematics in, CMS/ATLAS, CALICE and all neutrino experiments.
- Describe how showering is done in calorimeter simulations
- Why are correlations important?
- 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 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.— plastic ball detector
- Current simulators use a lot of „Tuned theory“. Propose using real library of events and interpolation.

Hadronic Shower Simulation Workshop

HSSW06

- Venue—Fermilab
September 6-8, 2006
- Experts from GEANT4, FLUKA, MARS, MCNPX, and PHITS attended as well users from Neutrino, ILC, Atlas, CMS communities. Goal was to reduce systematics between various models and arrive at a suite of programs that can be relied on.
- Major conclusion—too many models-new particle production data on thin targets needed to improve models.

**HADRONSIC SHOWER
SIMULATION WORKSHOP**

September 6 – 8, 2006

Fermi National Accelerator Laboratory
Batavia, Illinois

The workshop will bring together world experts in the field of hadronic shower development and establish a collaborative effort that will lead to a better understanding of hadronic cascades for hadron calorimetry for the ILC and LHC, neutrino fluxes and atmospheric showers. The workshop will evaluate existing event generator and transport codes. We will benchmark codes before the workshop. The workshop will identify the shortcomings of existing hadronic shower simulations and investigate the need to acquire new data to improve shower models.

<p>International Organizing Committee</p> <p>J. Apostolakis (CERN, Chair)</p> <p>S. Dytman (U. Pittsburgh)</p> <p>A. Ferrari (CERN)</p> <p>A. Heikkinen (Helsinki Institute of Physics)</p> <p>P. Loch (U. Arizona)</p> <p>S. Mashnik (LANL)</p> <p>G. McKinney (LANL)</p> <p>M. Messier (Indiana U.)</p> <p>N. Mokhov (Fermilab)</p> <p>K. Niita (RIKEN)</p> <p>A. Ribon (CERN)</p> <p>M. Thomson (Cambridge U.)</p> <p>R. Wigmans (Leuven Tech)</p> <p>D. Wright (SLAC)</p>	<p>Local Organizing Committee</p> <p>M. Albrow (Fermilab)</p> <p>D. Chakraborty (Northern Illinois U.)</p> <p>M. Demarteau (Fermilab)</p> <p>D. Elvira (Fermilab)</p> <p>J. Link (Virginia Tech)</p> <p>S. Magill (ANL)</p> <p>A. Para (Fermilab)</p> <p>R. Raja (Fermilab, Chair)</p> <p>C. Sazama (Fermilab)</p>
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<http://conferences.fnal.gov/hss06/>

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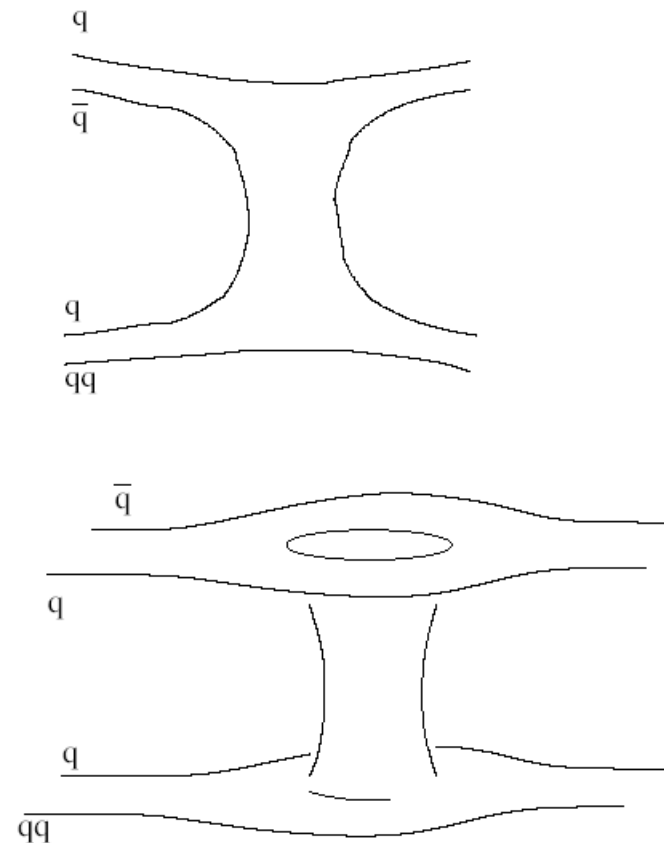
Deadline for registration: August 23th 2006 • email: sazama@fnal.gov • fax : (630) 840 8589

Describe a widely used model—

There exists no workable theory of the strong interaction in the non-perturbative regime. No cross section (elastic, diffractive, central) can be calculated from first principles. People resort to models with tunable parameters and arbitrary assumptions. To illustrate— let us review briefly DPMJET (Dual Parton Jet) concepts similar to QGSJET. Used in Fluka as well as by itself similar to QGSJET in Geant4.

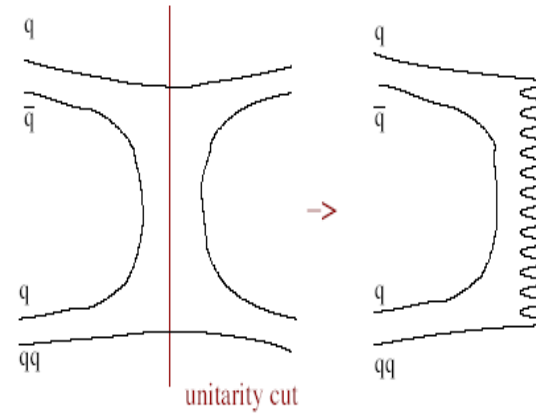
Reggeon exchange. Can either be thought of as a sum of t channel exchanges or as a sum of s channel resonances— Hence Dual.

Pomeron exchange Does not depend on flavor of scattering particles.

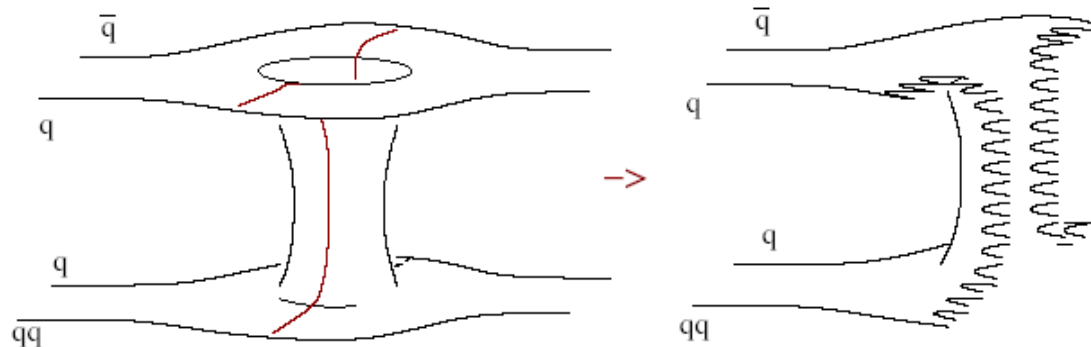


Dual Parton Model- Concepts-Optical theorem

Reggeon Exchange-
Single string of
hadrons

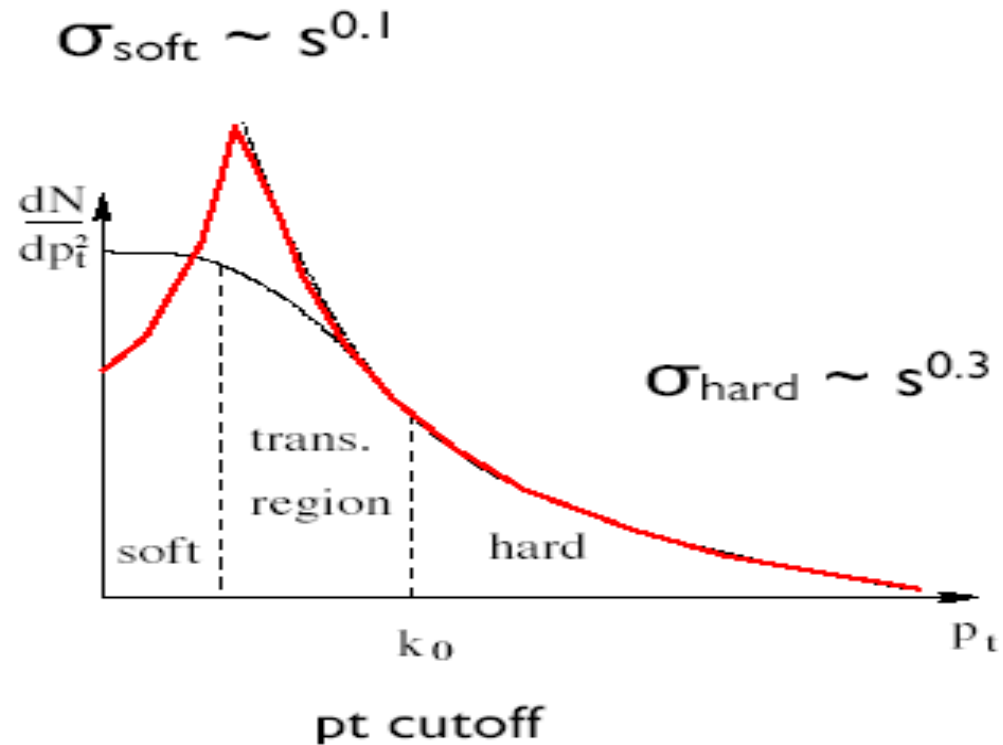


Pomeron
Exchange-Two
strings of
hadrons



Conceptual problem- Matching soft and hard processes.

This is done by tuning the transition region carefully! And arbitrarily

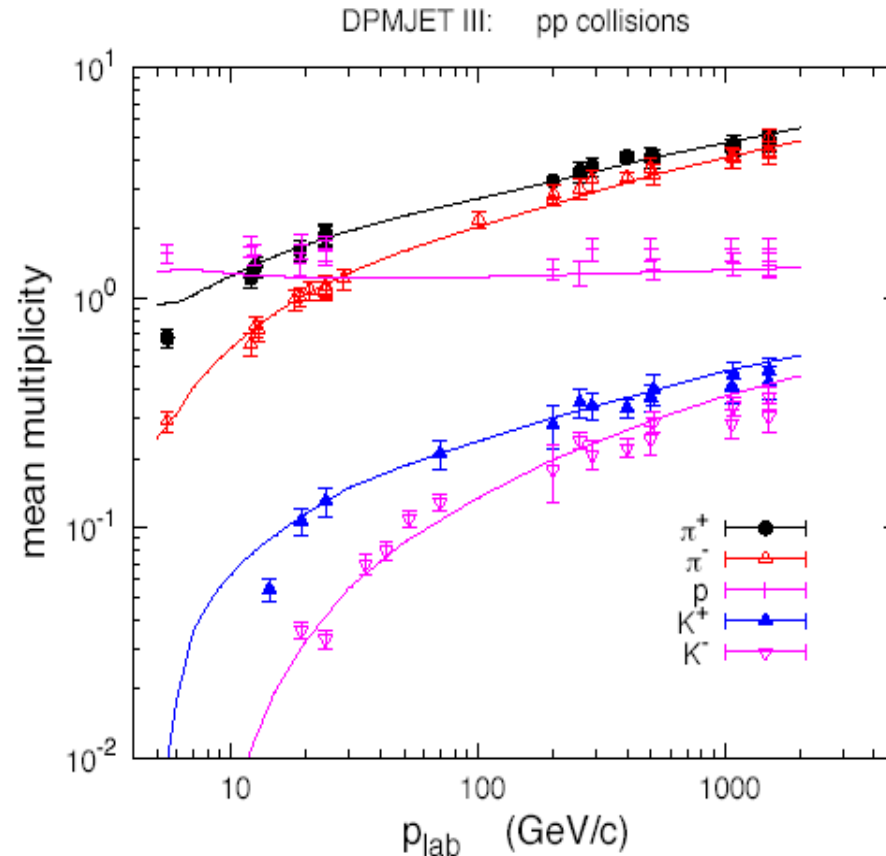


DPMJET-Multiplicities-Slides from R. Engel

DPMJET in p-p mode:
simulation of particle
production from
energy threshold on

proton - proton, $E_{\text{lab}} = 200\text{GeV}$

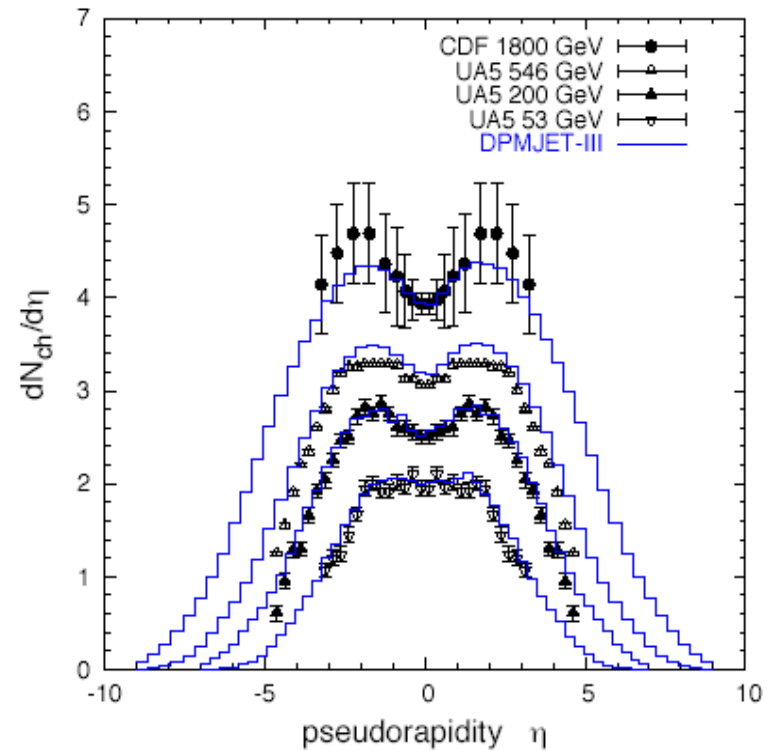
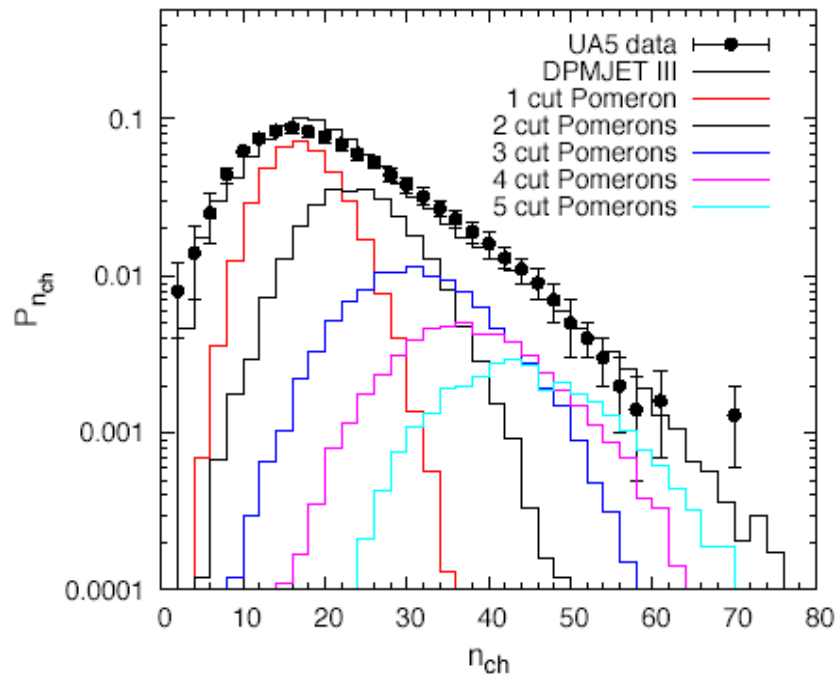
	Exp.	DPMJET-III
charged	7.69 ± 0.06	7.64
neg.	2.85 ± 0.03	2.82
p	1.34 ± 0.15	1.26
n	0.61 ± 0.30	0.66
π^+	3.22 ± 0.12	3.20
π^-	2.62 ± 0.06	2.55
K^+	0.28 ± 0.06	0.30
K^-	0.18 ± 0.05	0.20
Λ	0.096 ± 0.01	0.10
$\bar{\Lambda}$	0.0136 ± 0.004	0.0105



DPMJET- Collider distributions

(R. Engel)

Charged particle multiplicity distribution at 200 GeV cms.



Charged particle pseudorapidity distributions

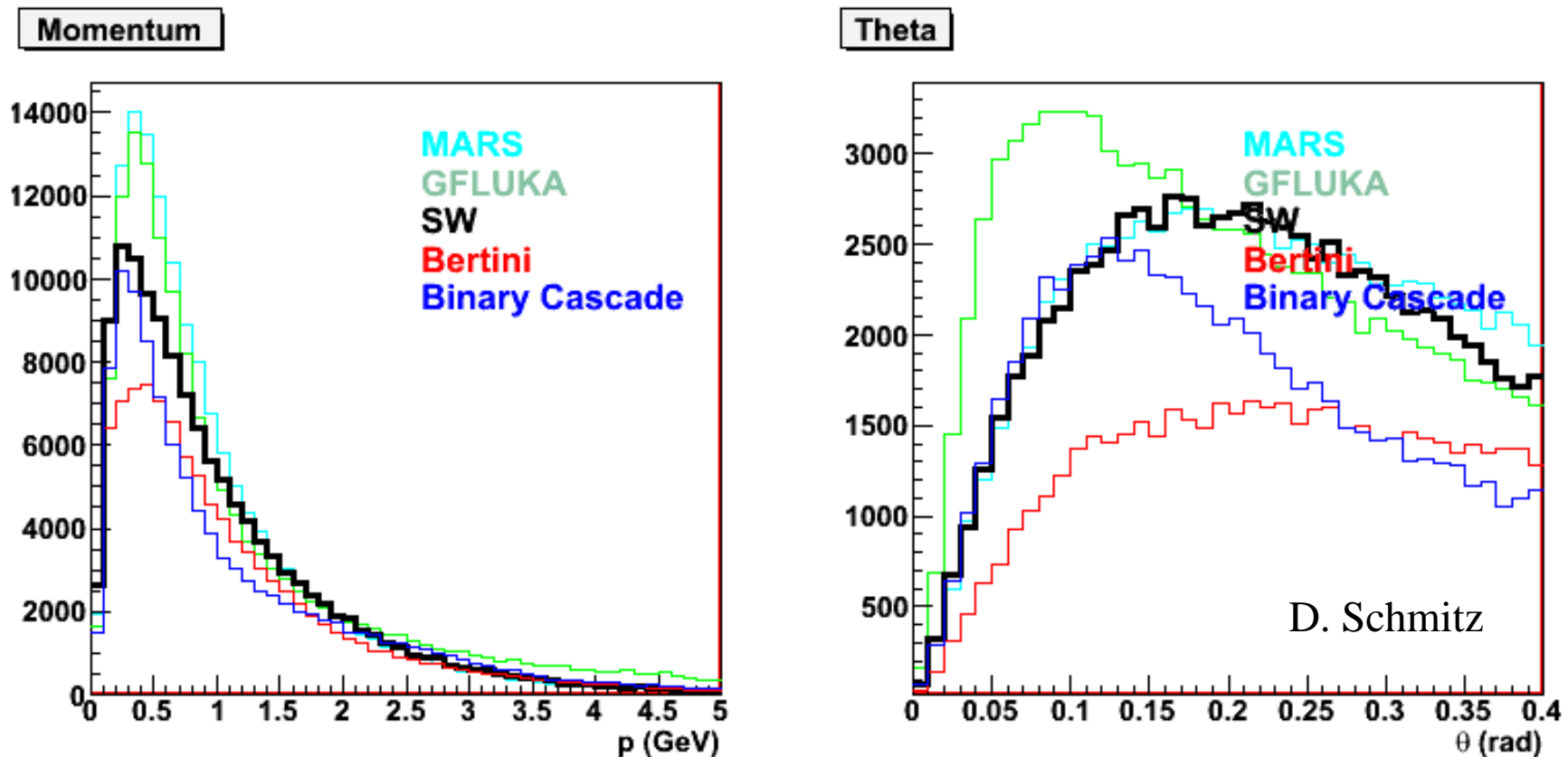
HSSW06 programs and models used by them

Program	Event Generator Models	Nuclear Break up models
Fluka05	Isobar model (below few GeV) own version of DPM + hadronization	PEANUT (Includes GINC) Generalized InterNuclear Cascade
Geant4	QGS + Fritiof String model $> 20\text{GeV}$ Bertini Cascade Model $< 10\text{GeV}$ Binary Cascade model Low Energy Parametrized Models & High Energy Parametrized Models (GHEISHA origin)	Geant4 Pre-compound model Bertini evaporation model Chiral Invariant Phase Space model (CHIPS) $< 20\text{MeV}$ Nuclear break-up libraries
MARS15	Inclusive event generator CEM03, LAQGSM03 Quark-Gluon String model	Generalized intra-nuclear cascade evaporation and fission models
PHITS	Jet AA Microscopic Transport Model (JAM) $> 20\text{MeV}$ Jaeri Quantum Molecular Dynamics model JQMD	Neutrons done as in MCNP JQMD
MCNPX	Fluka79 or LAQGSM	Intra Nuclear Cascade models Bertini, ISABEL, CEM, INCL4..

Models Fit to data where they have been tuned

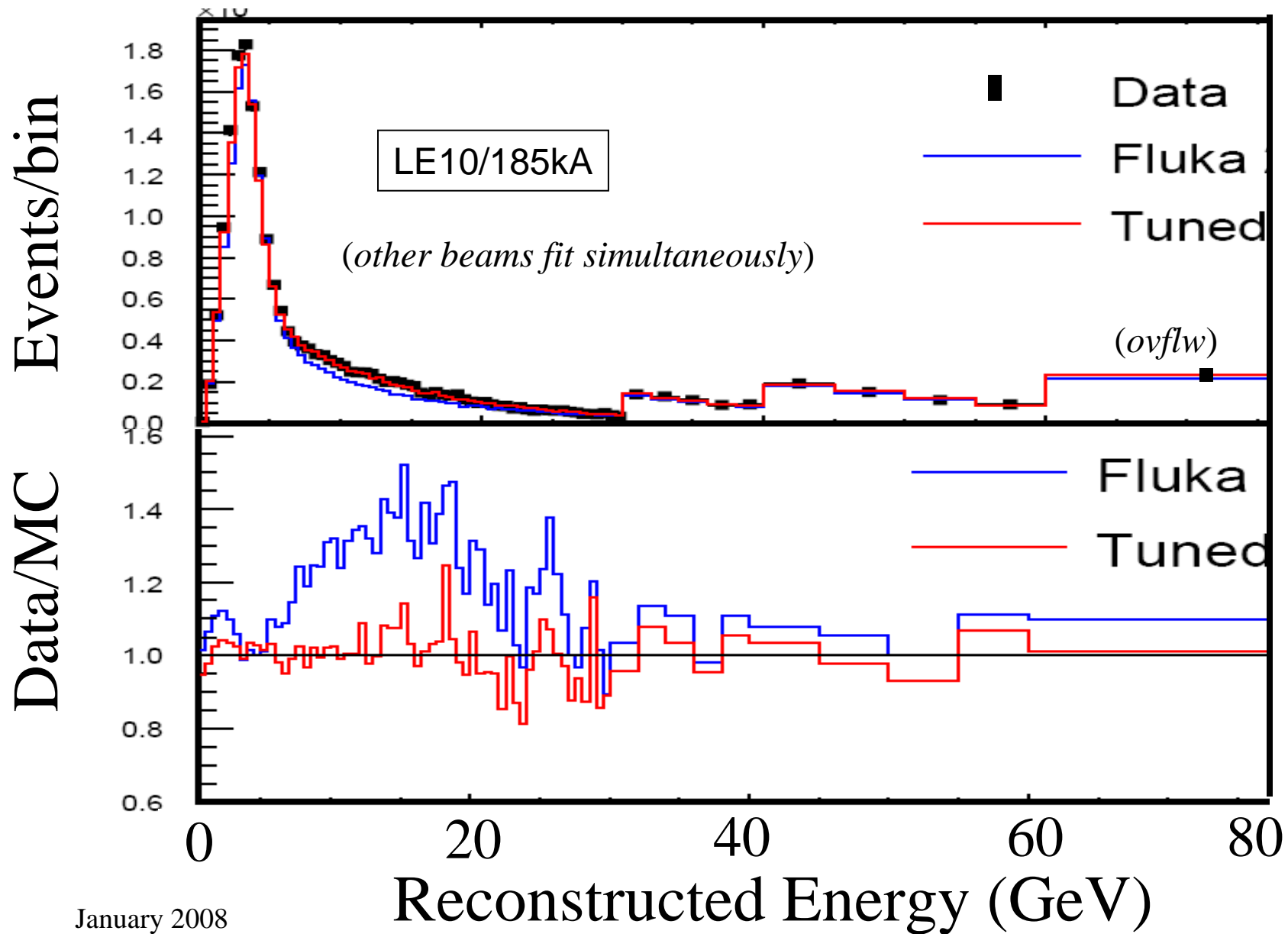
- Tuning done in single inclusive variable -eg Feynman x or multiplicity.
- Errors in models multiply when applied to the calorimeter problem. Repeated showering causes systematics to be enlarged.
- In order to get longitudinal and transverse shapes correctly, one needs to not only single particle inclusive cross sections but also multiparticle correlations.
- To do this we need new data.
- To illustrate—Neutrino targets (many interaction lengths) and transverse size of target restricted.

Miniboone-Sanford-Wang (SW) parametrizaion of E910 and HARP compared to other models

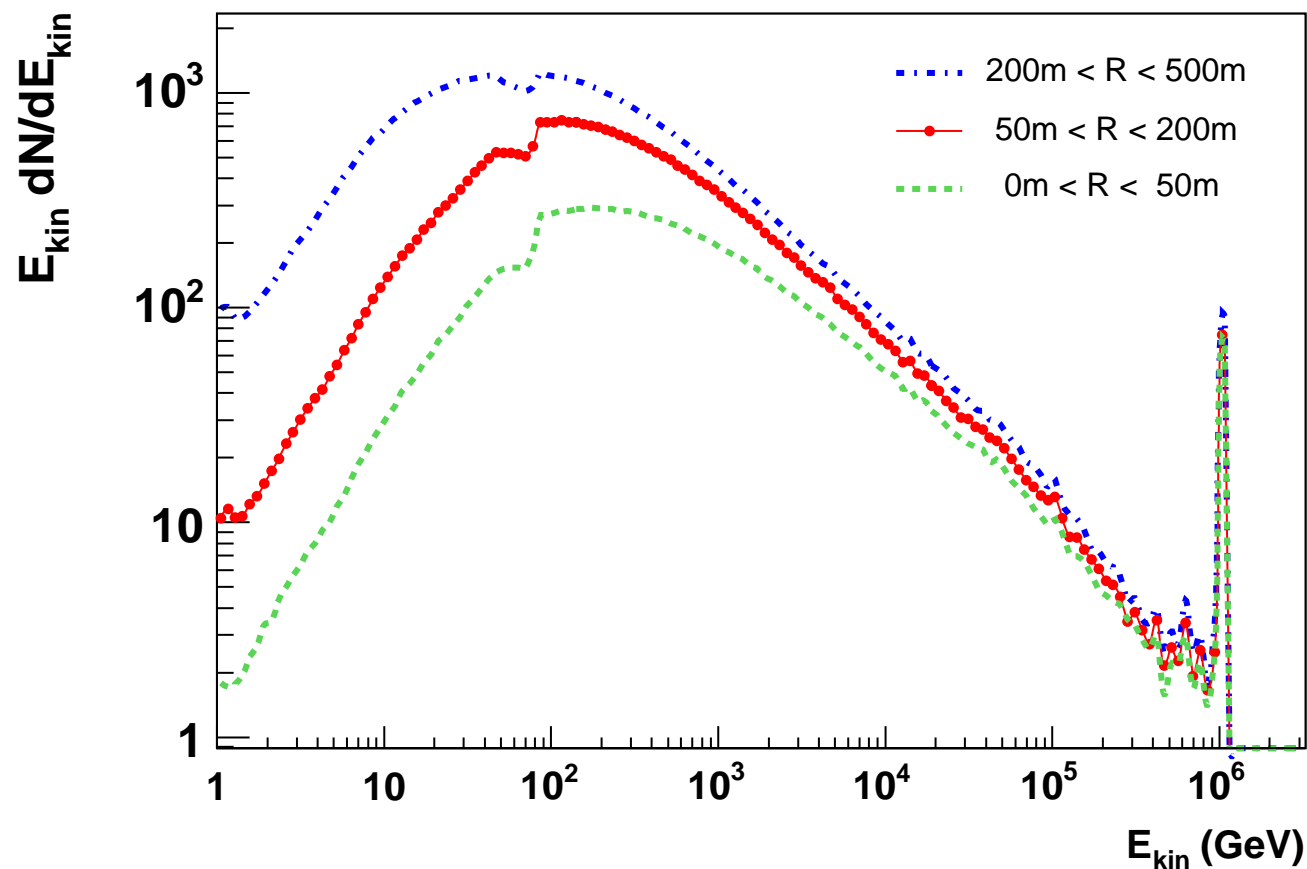


The differences are dramatic in the between models! But the E910 and HARP cross sections determine the correct model, which is very close to MARS.—Does this mean MARS is now the correct simulator to use?

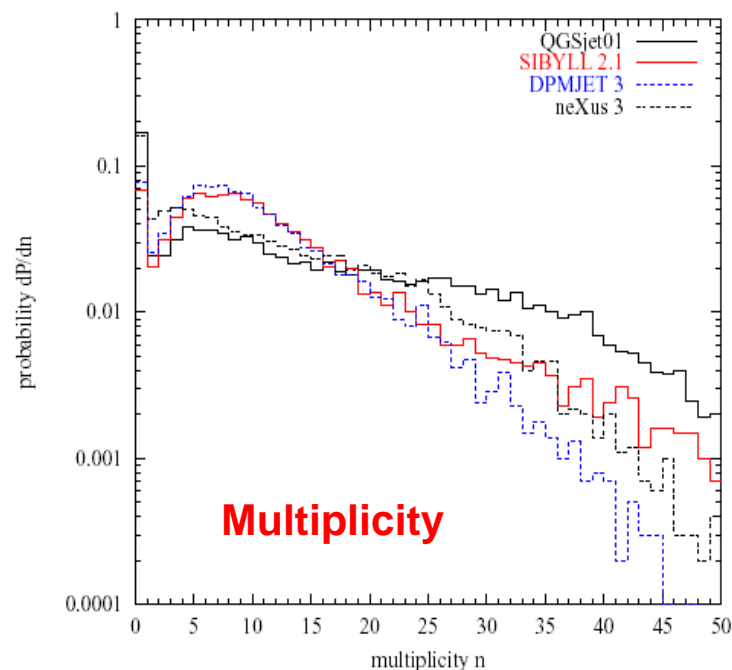
MINOS problem- (from S.Kopp)



*Meurer et al -Cosmic ray showers Discontinuity-
Gheisha at low energies and QGSJET at higher
energies-Simulation of air showers*

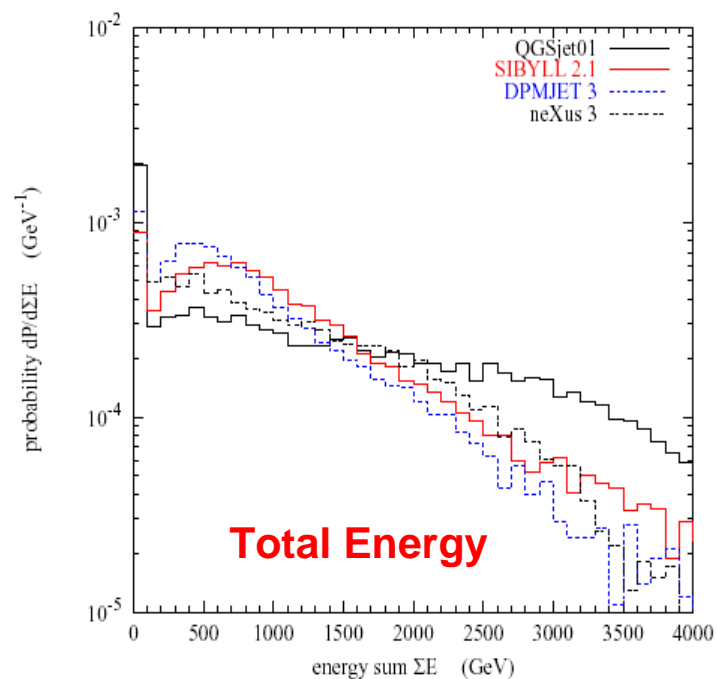


*Model Predictions: proton-proton at the LHC – Totem Expt-
S.Lami*



Multiplicity

total multiplicity in forward detector
($5 \leq \eta \leq 7$)



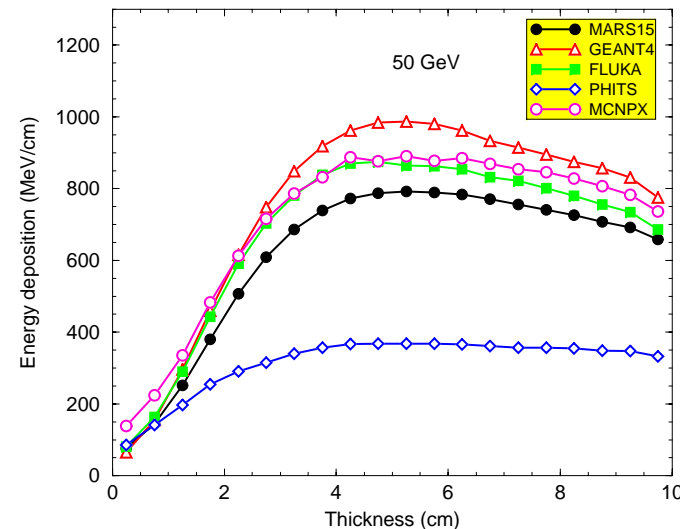
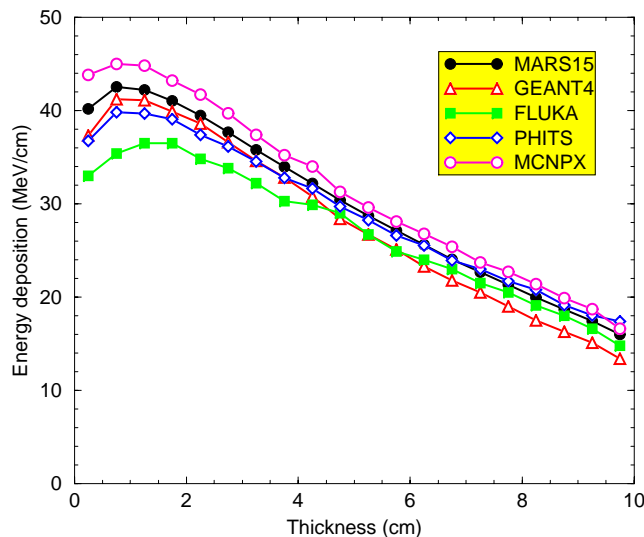
Total Energy

total energy in forward detector
($5 \leq \eta \leq 7$)

Predictions in the forward region within the CMS/TOTEM acceptance

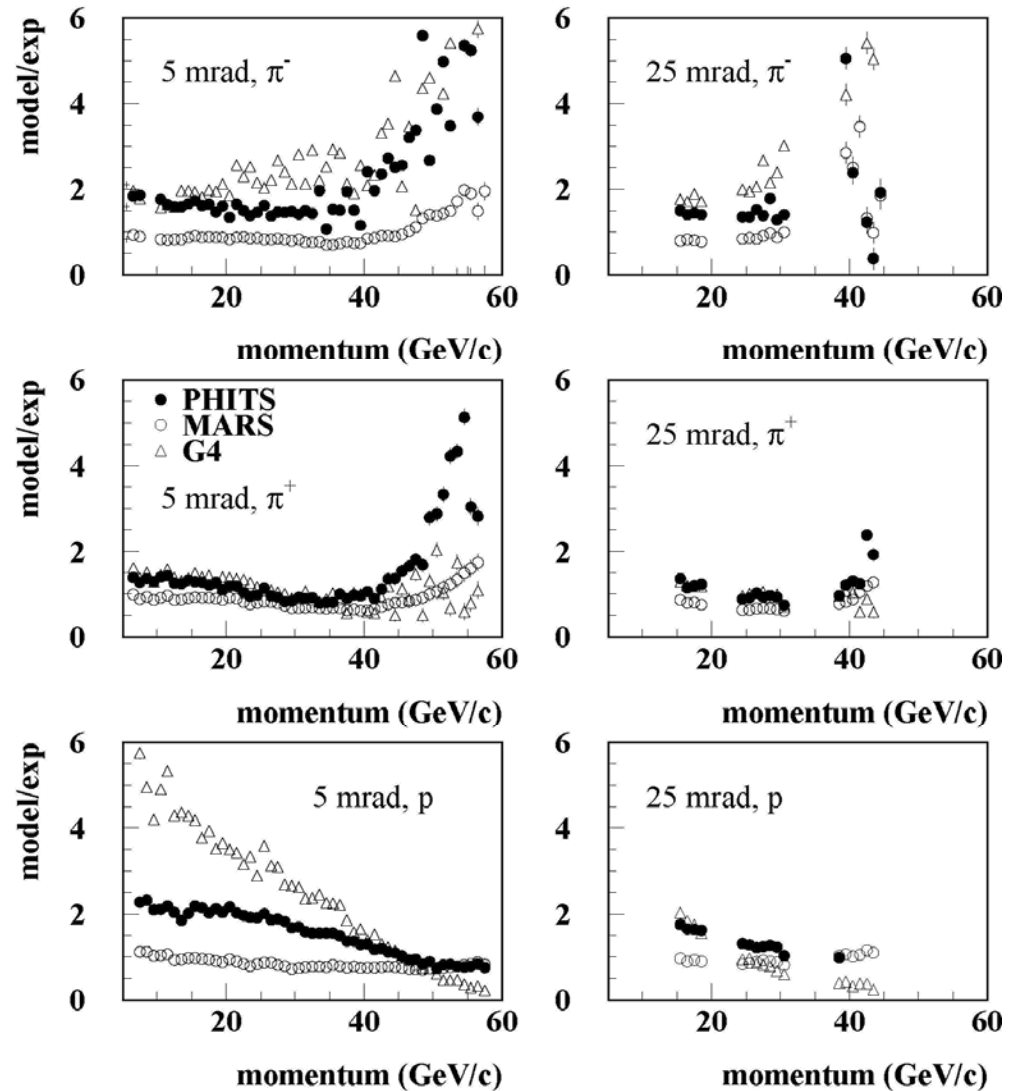
Benchmark example from HSSW06- (N. Mokhov, S. Striganov, D. Wright et al)

- Energy deposit profile as a function longitudinal depth in a tungsten rod of 1cm radius—Challenges to get longitudinal and transverse distributions correctly simultaneously.

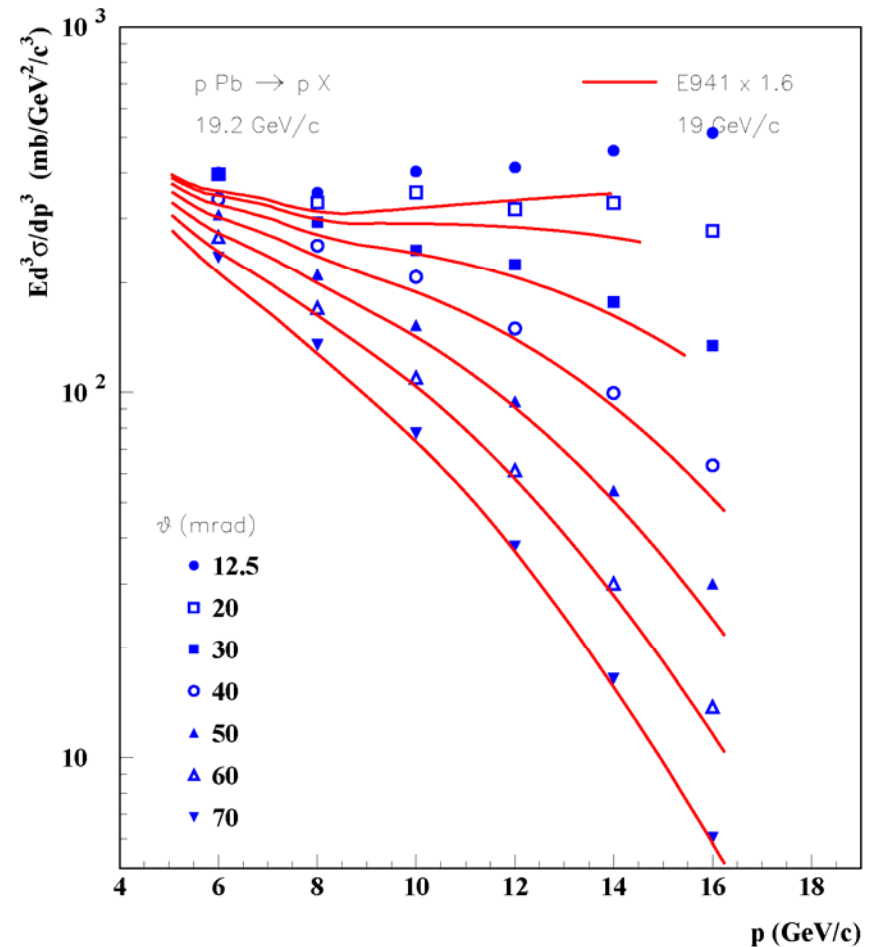
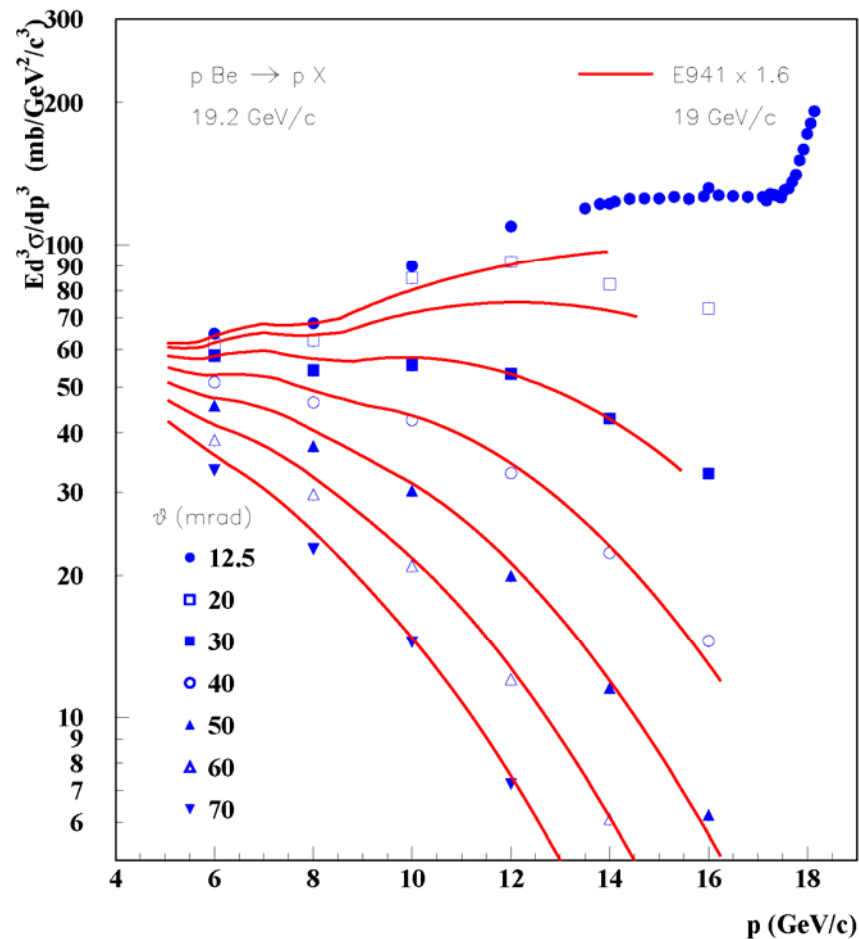


Models plotted as a function of ratio to data.

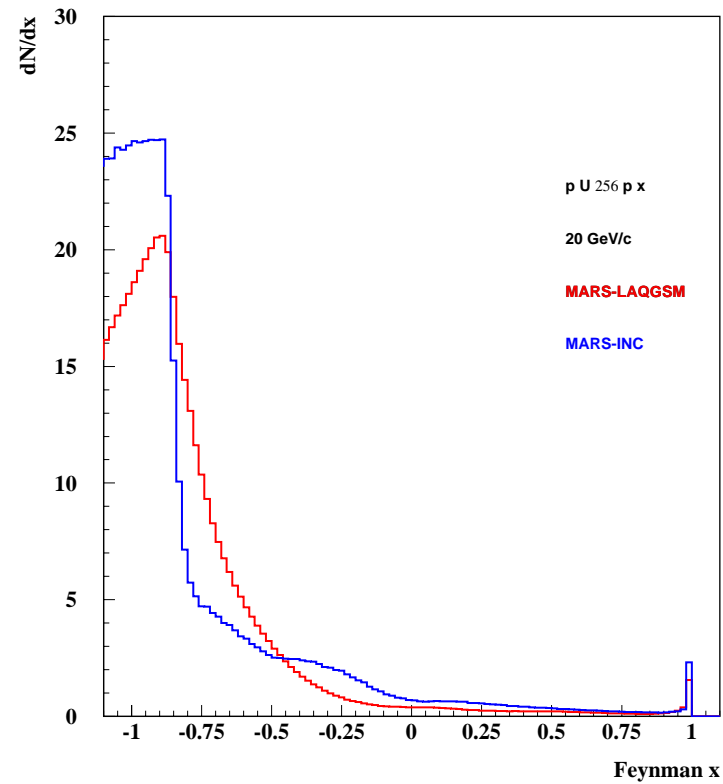
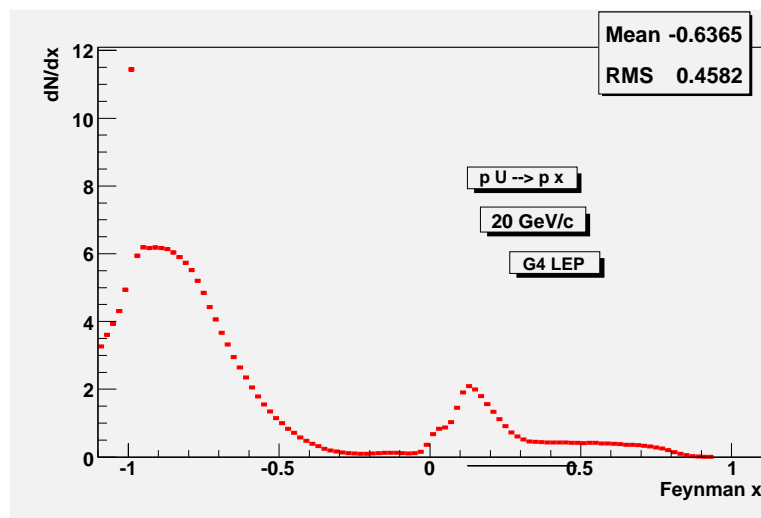
- Plotted on right are the ratios of model/data for various final state particles for 67 GeV/c protons on a thick aluminum target at protvino. Discrepancies of order 5-6 are evident between model and data. Models disagree amongst themselves.



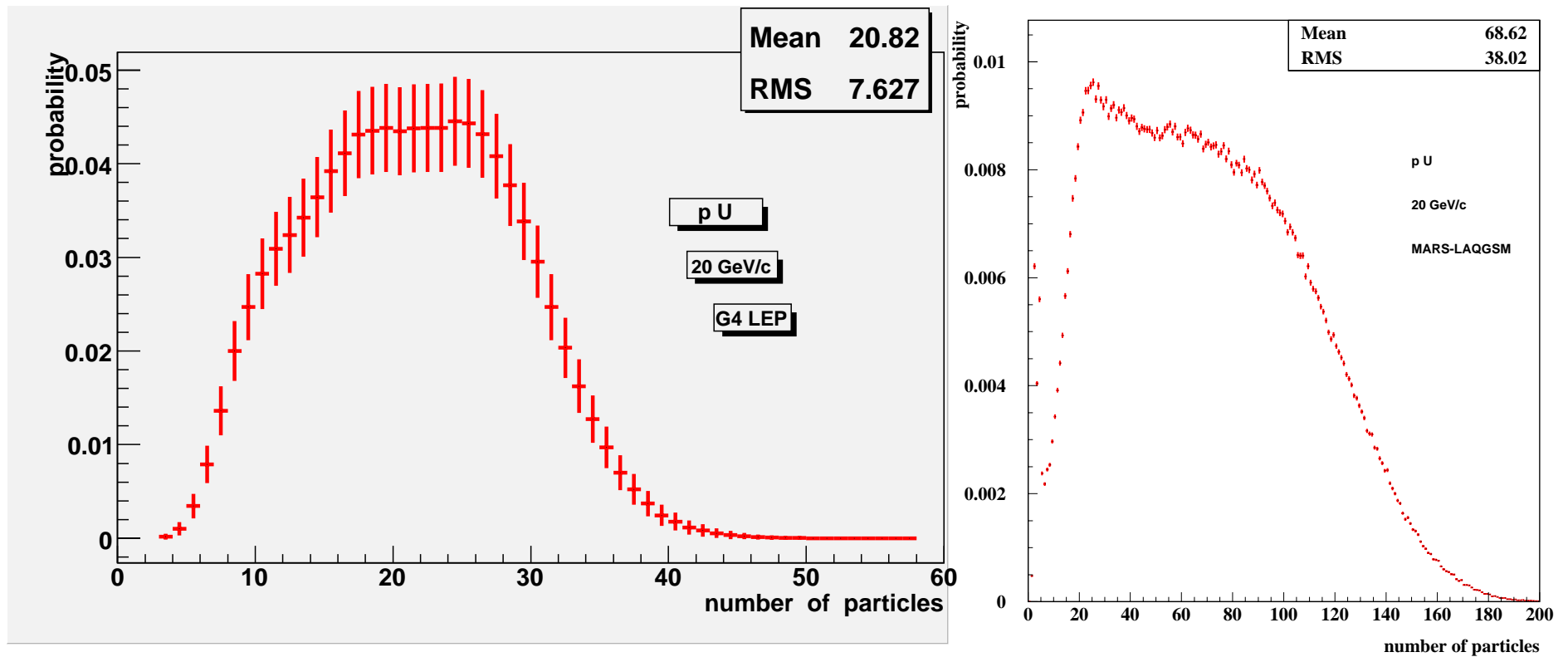
*Model Input data unreliable-some over 30 yrs old
a recent example 60% normalization error between 2
experiments.*



Thin target data model comparisons



Thin target data model comparisons



Interest in MIPP Upgrade data

January 10, 2008

Dr. R. Raja
Fermilab

Re: Interest in data provided by the upgraded MIPP experiment at Fermilab

Dear Raja:

We would like to express our keen interest in utilizing the data provided by the upgraded MIPP experiment at Fermilab in improving the predictive power of hadronic shower simulation codes. The upgraded MIPP experiment will provide high quality data with final state particle identification on 30 nuclei using six beam species with momentum ranging from 1 to 90 GeV/c. The present codes use models that are tuned on single-particle inclusive data taken over many years and not always mutually consistent with each other. The MIPP upgrade data will eliminate a significant portion of the systematic uncertainties involved in hadronic shower simulations. Improved codes will benefit diverse fields within the HEP community, such as the fixed target neutrino and kaon programs, the atmospheric neutrino program, cosmic rays, calorimetry simulations in hadron collider experiments, as well as outside HEP such as studies to design radiation safe spacecraft environments. Improved codes will also help planning and calorimeter design studies for the International Linear Collider and a Muon Collider.

Sincerely,

John Apostolakis (CERN), Dennis Wright (SLAC), on behalf of the GEANT4 team

Nikolai Mokhov (Fermilab) on behalf of the MARS team

Koji Niita (RIST/JAEA) on behalf of the PHITS team

Laurie Waters (LANL) on behalf of the MCNPX team

MIPP Upgrade P-960-collaboration list

D.Isenhowe,M.Sadler,R.Towell,S.Watson
Abilene Christian University
R.J.Peterson
University of Colorado, Boulder
W.Baker,B.Baldin,D.Carey, D.Christian,M.Demarteau,D.Jensen,C.Johnstone,H.Meyer, R.Raja,A.Ronzhin,N.Solomey,W.Wester,J-Y Wu
Fermi National Accelerator Laboratory
Bill Briscoe, Igor Strakovsky, Ron Workman
George Washington University, Washington D.C
H.Gutbrod,B.Kolb,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.Avdeichikov,R.Leitner,J.Manjavidze,V.Nikitin,I.Rufanov,A.Sissakian,T.Topuria
Joint Institute for Nuclear Research, 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.Kulbards,D.V.Nowinsky, A.K.Radkov,V.V.Sumachev
Petersburg Nuclear Physics Institute, Gatchina, Russia
A.Bujak, L.Gutay,
Purdue University
D.Bergman, G.Thomson
Rutgers 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
P.Sokolsky, W.Springer
University of Utah

10 new institutions have joined. More in negotiations. Previous collaboration built MIPP up from ground level. Less to do this time round.
More data.

January 2008

Rajendran Raja, MIPP European seminars

The Proposal in a nutshell

- MIPP one can take data at $\sim 30\text{Hz}$. The limitation is the TPC electronics which are 1990's vintage. We plan to speed this rate up to 3000Hz using ALTRO/PASA chips developed for the ALICE collaboration.
- Beam delivery rate- We assume the delivery of a single 4 second spill every two minutes from the Main Injector. We assume a 42% downtime of the Main Injector for beam manipulation etc. This is conservative. Using these figures, we can acquire 5 million events per day.
- Jolly Green Giant Coil Replacement- Towards the end of our run, the bottom two coils of the JGG burned out. We have decided to replace both the top and bottom coils with newly designed aluminum coils that have better field characteristics for the TPC drift. The coil order has been placed (\$200K).
- Beamline upgrade- The MIPP secondary beamline ran satisfactorily from 5 GeV/c - 85 GeV/c . We plan to run it from $\sim 1 \text{ GeV}/c$ to 85 GeV/c . The low momentum running will be performed using low current power supplies that regulate better. Hall probes in magnets will eliminate hysteresis effects.
- TPC Readout Upgrade- We have ordered 1100 ALTRO/PASA chips from CERN (\$80K). The order had to go in with a bigger STAR collaboration order to reduce overhead. We expect delivery in the new year of tested chipsets.

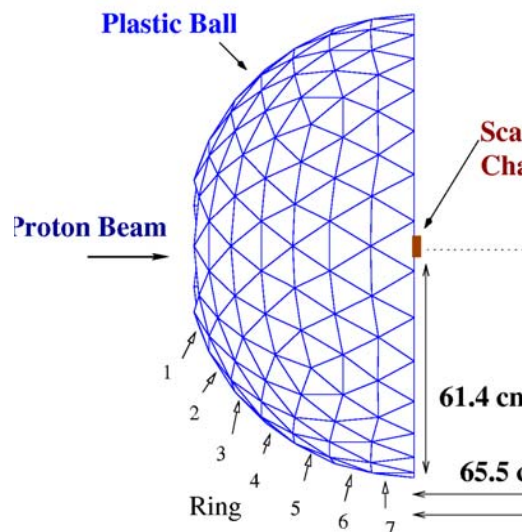
The Proposal in a nutshell

- MIPP- Recoil detector- GSI- Darmstadt / KVI Groningen have joined us. They will bring the plastic ball detector (a hemisphere of it) which will serve to identify recoil (wide angle) neutrons, protons and gammas from our targets. + Recoil cluster counting chamber ?
- Triggering system- We propose to replace the MIPP interaction trigger (scintillator/wire chamber) with 3 planes of silicon pixels based on the B-TeV design. Will enable us to trigger more efficiently on low multiplicity events.
- Drift Chamber/ PWC electronics- These electronics (E690/RMH) worked well for the first run. They are old (1990's). RMH will not do 3kHz. We will replace both systems with a new design that utilizes some of the infrastructure we developed for the RICH readout.
- ToF/CKOV readout-Plan to build new readout based on TripT chip (Used by Minerva) and a high resolution TDC chip. Will use the VME readout cards in common with RICH, TPC
- RICH detector and the Beam Cerenkovs will work as is.
- Calorimeter Readout- Switch to FERA ADC's (PREP).
- DAQ software upgrade- Front end DAQ software needs to be developed. The MIPP DAQ control software+ Data base can be kept as is.
- Plan is to store one spill's worth of data on each detector and read out the whole lot at end of spill.

Nuclei of interest- 1st pass list

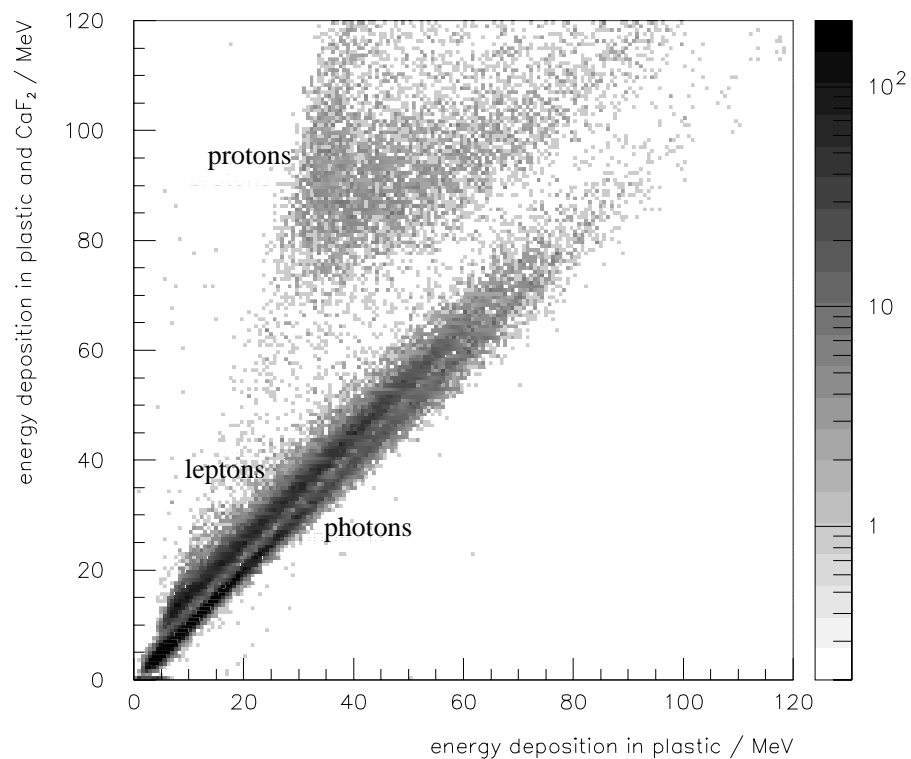
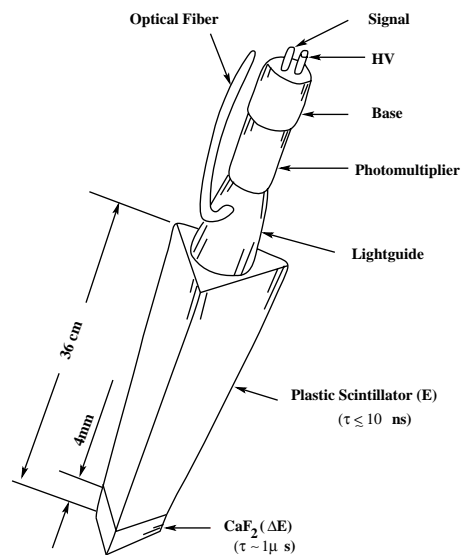
- The A-List
- $H_2, D_2, Li, Be, B, C, N_2, O_2, Mg, Al, Si, P, S, Ar, K, Ca, Fe, Ni, Cu, Zn, Nb, Ag, Sn, W, Pt, Au, Hg, Pb, Bi, U$
- The B-List
- $Na, Ti, V, Cr, Mn, Mo, I, Cd, Cs, Ba$
- On each nucleus, we can acquire 5 million events/day with one 4sec beam spill every 2 mins and a 42% downtime.
- 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 spectrometer data with high systematics

The recoil detector



3.3. Plastic Ball

31



Detect recoil
protons, neutrons,
pizeros and charged
pions,kaons

Spallation products

- Such a recoil detector coupled with the TPC can detect spallation products such as "grey" and "Black" protons, and neutrons as well as nuclear fragments.
- Table from Textbook on Calorimetry by Wigmans

	Binding Energy	Evaporation n (# neutrons)	Cascade n (# neutrons)	Ionization (#cascade p)	Target recoil
Before first reaction				(250)(π_{in})	
First reaction	126	27(9)	519 (4.2)	350(2.8)	28
Generation 2	187	63(21)	161(1.7)	105(1.1)	3
Generation 3	77	24(8)	36(1.1)	23 (0.7)	1
Generation 4	24	12(3)			
Total	414	126(41)		478(4.6)	32

TABLE I: Destination of 1.3 GeV total energy carried by an average pion produced in hadronic shower development in lead. Energies are in MeV.

Can we reduce our dependence on models?

- Answer- Yes- With the MIPP Upgrade experiment, one can acquire 5 million events per day on various nuclei with six beam species (π^\pm, K^\pm, p^\pm) with beam momenta ranging from 1 GeV/c-90 GeV/c. Full acceptance over phase space, including info on nuclear fragmentation
- This permits one to consider random access event libraries that can be used to generate the interactions in the shower.

Random Access Data Libraries

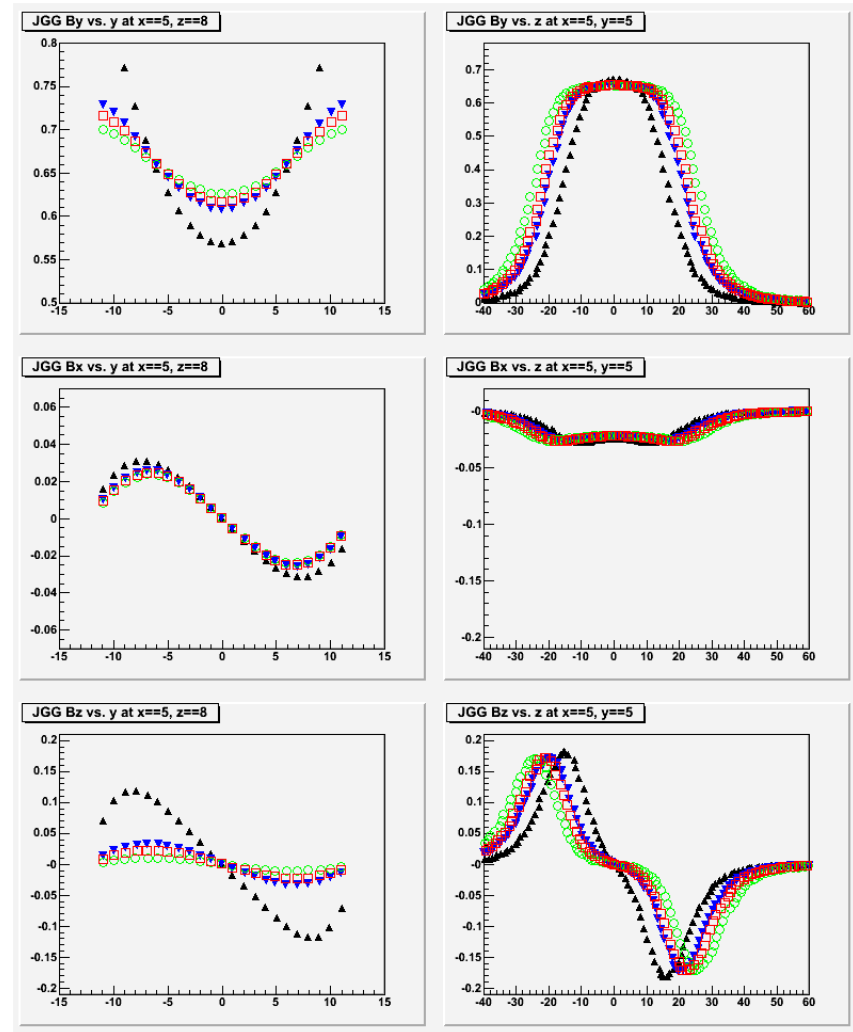
- Typical storage needed

Nuclei	beam species	momentum bins	events/bin	tracks/event	words/track
30	6	10	100000	10	5
Number of events			1.80E+08	Number of days	
Total number of words			9.00E+09	to take data	
Bytes			3.60E+10		

- Mean multiplicities and total and elastic cross section curves are parametrised as a function of s .
-

Upgrade in some detail- JGG repair

- Field calculations.
- Blue triangles current field.
- Inverted blue triangles 9" extension in z.
- Squares, circles show coils that are +12", +18" longer in z.
- 9" longer coils chosen.
- Much better ExB effects in the TPC. Distortions lower by a factor of 2.
- Coils made of Aluminum.
- Coils ordered. Money committed.
- We will ziptrack new magnet
- JGG Pole pieces have to be lengthened
- WBS task 2
 - » M&S 279K, Labor \$141K
- Coils fabricated.
- Magnet will be reassembled in Spring'08



TPC Electronics Upgrade

15,360 pads in TPC. $16\mu\text{s}$ to drift from top to bottom. IN principle, there are 3,800,000 individual data points possible. Each data point is a time bucket and a dE/dx ADC value. A MIPP event sparsely populates this space and is $\sim 110\text{kBytes}$ in size. The old readout is 1990's vintage and the readout system is heavily multiplexed and limited to 60Hz maximum. For our events, we were able to achieve $\sim 30\text{Hz}$.

Redesign with ALICE ALTRO/PASA chips with inbuilt zero suppression can produce a readout working at 3kHz. A factor of 100 in speed.

10 times more data using 10 times less beam time!



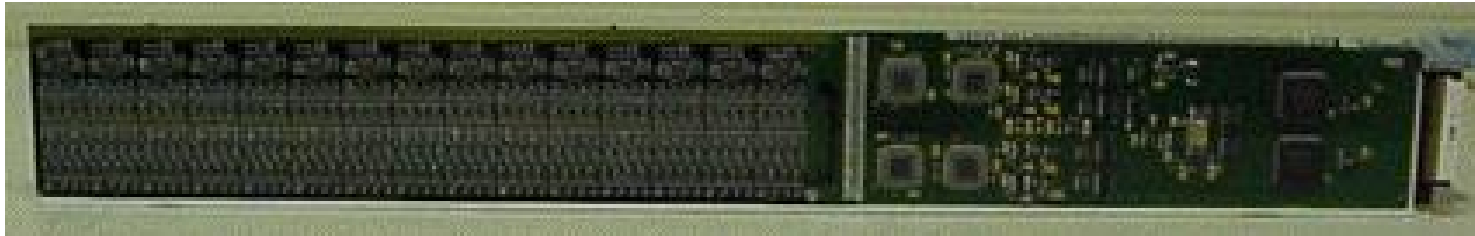
October 19 ,2006

Rajendran Raja, Presentation to the Fermilab PAC

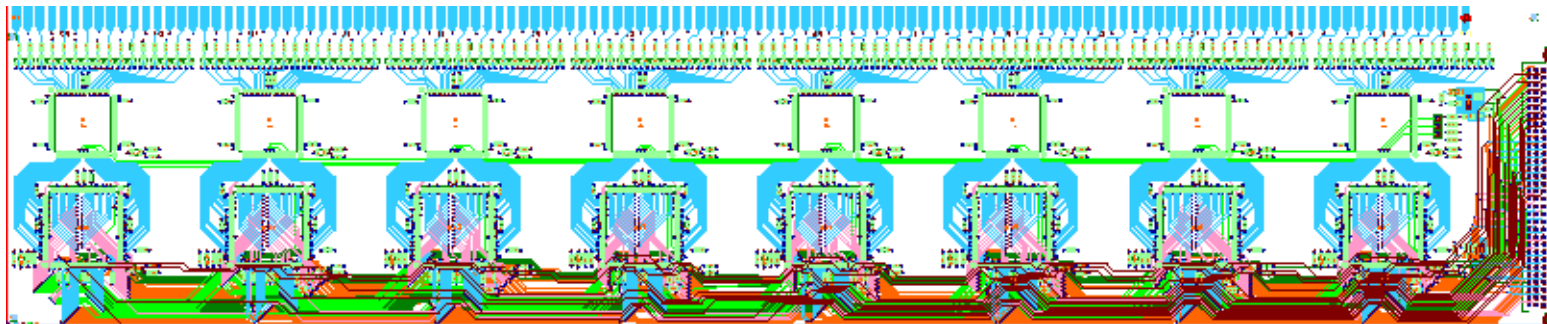
74

TPC electronics upgrade

- Old MIPP TPC "Stick" - 120 of these.

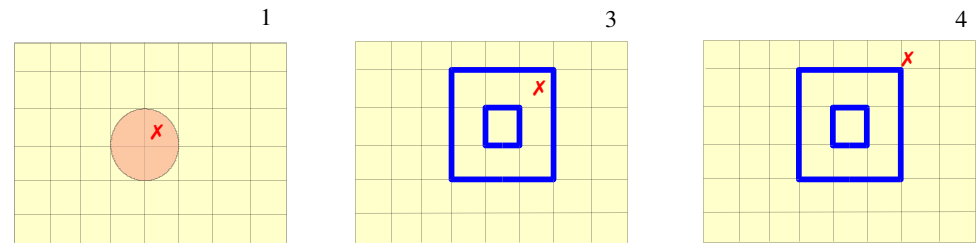
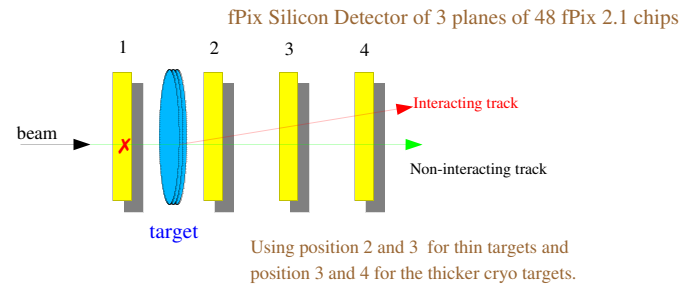


- New MIPP TPC "stick" layout using ALTRO/PASA chips. Chips in hand



MIPP Trigger Upgrade

- Beam sizes are large in MIPP due to the "low divergence" condition needed for beam CKOV's.
- Previous trigger of SCINT counter + 1st drift chamber wire signals performed satisfactorily for MIPP -I physics but needs improvement at low multiplicities—Landau tails.
- We propose to use silicon pixel counters (B-TEV, Phenix).
- Use a "Bull's Eye" system to detect absence of beam particle in final state to signal interactions. Also use the multiplicity in the final state as an additional piece of information.



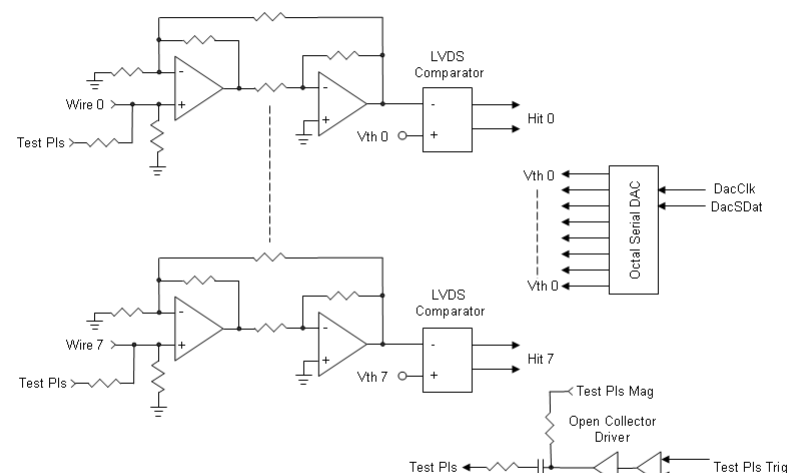
First layer before target tags where beam is and that there was only 1 hit cell. Brown circle represents where 86% of the beam hits the 4 cells in the center.

A bulls eye target, shown in blue, is made around the one cell hit location of plane1.

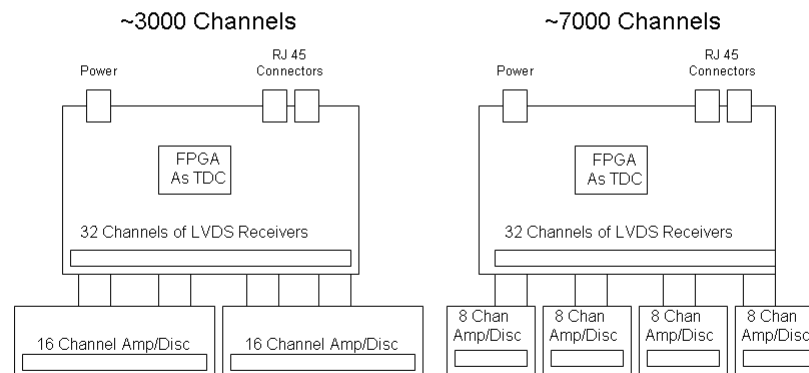
Drift Chamber/ PWC readout Upgrade

- Large PWC's use old CERN RMH electronics- Needs replacement.
- E690 electronics will work at these speed, if CAMAC DMA is implemented. The electronics are also aging and also put out a lot of heat.
- MIPP proposes a unified scheme for reading out both sets of chambers using a system that modifies the MIPP RICH readout cards by changing the latch to a TDC.
- Preamp cards being replaced Preamp/Discriminator front end cards.
- The RICH cards will store an entire spill's worth of events, which are readout in between spills.
- WBS task 4.2 M&S \$121.2K, Labor \$28.7K. Newest of the design efforts. Probably need to add 50% contingency.

8 Channel Amp/Disc – One per 8 channel Card, Two per 16 channel Card



High-Speed Differential Interfaces
 "Cyclone II devices can transmit and receive data through LVDS signals at a data rate of up to 640 Mbps and 805 Mbps, respectively. For the LVDS transmitter and receiver, the Cyclone II device's input and output pins support serialization and deserialization through internal logic."



ToF, CkOV, Calorimeter readouts

- **ToF/CkOV readout**
 - » Front end boards—TripT chip used by Minerva(ADC) and a high end TDC chip (TDC-GPX from ACAM, also used by LHC-b 30 ps timing resolution). Will buffer an entire spill. Delay cables will be eliminated.
 - » Backend will use RICH VME readout card for ToF/CkoV.
 - » WBS Task 4.3 M&S \$16K Labor \$18K
- **Calorimeter Readout**
 - » Propose 4 crates of FERA ADC's (K-TeV + PREP)
 - » Read out by 2 Hytec1365 CAMAC readout controllers.
 - » WBS Task 4.4 M&S \$15K

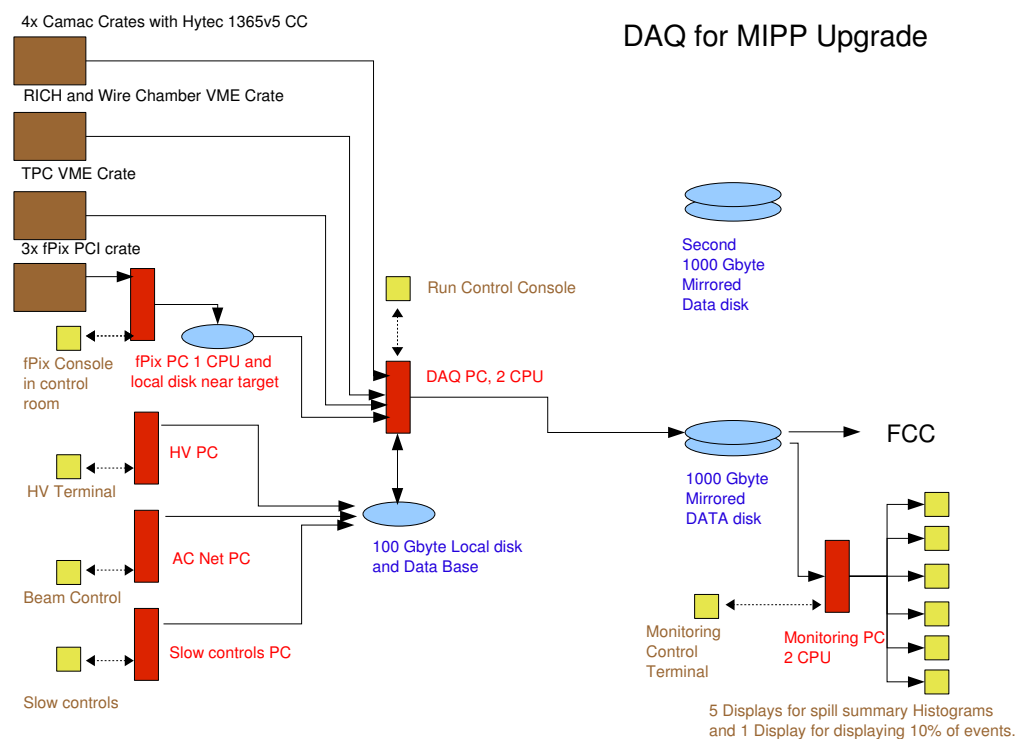
Beam Line Upgrade

Add low current power supplies and hall probes to facilitate low momentum running

WBS task 8 M&S \$56K

MIPP DAQ System upgrade

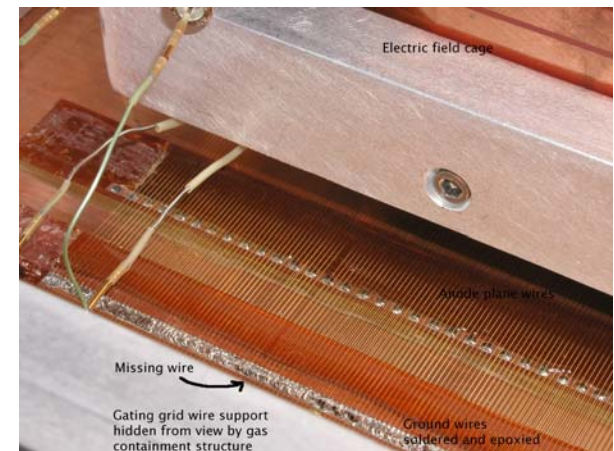
- Most of the DAQ upper layer software (Run control, Book keeping, plots) can be kept as is.
- New Power PC 5500's replace 6 existing ones.
- Linux kernel to migrate to it.(10 person weeks)
- Camac Hytec 1365V5 Module software(2 weeks)
- Update Event builder(6 weeks)
- FERA ADC readout (5 weeks)
- Modify event monitor(2 weeks)
- New fPix readout PC, DAQ PC with 1TB disk storage. All PC's will have GBit and 100MBit fast ethernet ports.
- 100 kbytes/event. 1.2 Gbyte of data per spill.
- 200Mbits/sec transfer from MC7 to Ptkmp.
- 6 Mbytes/second transfer rate into ENSTORE is needed to transfer 5 million events/day. CDF/D0 do 30-60 Mbytes/sec routinely.



WBS Task 6 M&S \$47K, Labor \$39K

Miscellaneous upgrades

- Beam Veto wall upgrade- Increase veto counter area
 - » WBS task 9 M&S \$20.1K Labor \$1.5K
- Cryogenic target upgrade
 - » Increase diameter of transfer pipe to cut interactions due to beam tails.
 - » Spare cryo-cooler
 - » Operate with Liquid N2 flask.
 - » WBS Task 3.2 M&S \$68K Labor \$76K
- Gas system and slow control upgrades
 - » Methylal refrigerator filling to be automated
 - » Automate RICH vessel topping up with CO₂
 - » Upgrade P10 gas system-to be supplied semi trailer rather than bottles.
 - » Upgrade Beam CKOV vacuum instrumentation (failure detection)
 - » More temperature probes in hall.
 - » CKOV pressure sensors to be replaced
 - » Additional slow control infra-structure - APACS system
 - » WBS task 3.1 M&S \$40.5K, Labor \$29.9K
- RICH and CKOV phototubes
 - » 7 CKOV PMT's need replacement (total 96)
 - » WBS task 3.5 M&S \$10K
 - » 912 PMT's in RICH were lost due to fire. RICH works without them. But upgrading it by more PMT's will help with efficiency near threshold.
 - » WBS task 3.6 FNAL M&S \$0K In kind \$150K



TPC rewind- Optional

WBS task 3.3 M&S \$9K

WBS	Task Name	Fermi M&S Cost	Fermi Labor Cost	Base Cost in FY06 \$	In Kind	Total Project Cost
0	MIPP Upgrade Totals	\$1,214,456	\$566,628	\$1,781,084	\$205,000	\$2,003,844
1	Project Management	\$55,000	\$0	\$55,000	\$0	\$55,000
2	Jolly Green Giant Repair	\$279,000	\$141,884	\$420,884	\$0	\$438,644
2.1	Jolly Green Giant disassembly/assembly	\$80,000	\$94,380	\$174,380	\$0	\$192,140
2.2	JGG coil design and fabrication	\$199,000	\$25,524	\$224,524	\$0	\$224,524
2.3	Ziptrack JGG magnet	\$0	\$21,980	\$21,980	\$0	\$21,980
3	Improvements on detector hardware	\$128,600	\$109,114	\$237,714	\$150,000	\$387,714
3.1	Gas System and Slow Controls Upgrade	\$40,500	\$29,868	\$70,368	\$0	\$70,368
3.1.1	RICH vessel fill automation	\$2,500	\$5,610	\$8,110	\$0	\$8,110
3.1.2	Methylal bath fill automation	\$5,000	\$7,228	\$12,228	\$0	\$12,228
3.1.3	P10 supply upgrade	\$5,000	\$6,664	\$11,664	\$0	\$11,664
3.1.4	TOF wall thermal instrumentation	\$2,000	\$4,232	\$6,232	\$0	\$6,232
3.1.5	Replacement of CKOV pressure sensors	\$2,000	\$412	\$2,412	\$0	\$2,412
3.1.6	Beam Ckov vacuum system	\$3,000	\$1,340	\$4,340	\$0	\$4,340
3.1.7	Calibration and maintenance	\$0	\$2,952	\$2,952	\$0	\$2,952
3.1.8	Slow Controls infrastructure upgrade	\$21,000	\$1,430	\$22,430	\$0	\$22,430
3.2	Cryogenic System Upgrade	\$68,000	\$75,598	\$143,598	\$0	\$143,598
3.2.1	Hydrogen Target transfer line	\$13,000	\$38,120	\$51,120	\$0	\$51,120
3.2.2	Nitrogen Target	\$10,000	\$23,260	\$33,260	\$0	\$33,260
3.2.3	Spare Cryocooler	\$45,000	\$14,218	\$59,218	\$0	\$59,218
3.3	TPC rewind	\$9,000	\$0	\$9,000	\$0	\$9,000
3.4	Chamber wire repairs	\$1,100	\$3,648	\$4,748	\$0	\$4,748
3.5	Ckov Photomultiplier tubes	\$10,000	\$0	\$10,000	\$0	\$10,000
3.6	RICH Photomultiplier tubes	\$0	\$0	\$0	\$150,000	\$150,000
4	Detector Readout Upgrades	\$362,920	\$197,918	\$560,838	\$0	\$568,513
4.1	TPC Electronics	\$225,920	\$150,847	\$376,767	\$0	\$384,442
4.2	Drift Chamber/Wire Chamber electronics	\$121,250	\$28,718	\$149,968	\$0	\$149,968
4.3	ToF + CKOV electronics board design	\$15,750	\$18,352	\$34,102	\$0	\$34,102
4.4	Calorimeter migration to Fera electronics	\$15,000	\$0	\$15,000	\$0	\$15,000
5	Trigger System Upgrade	\$145,900	\$51,400	\$197,300	\$0	\$208,300
5.1	Interaction Trigger Fpix	\$137,100	\$38,800	\$175,900	\$0	\$186,900
5.2	Interaction Trigger Board	\$8,800	\$12,600	\$21,400	\$0	\$21,400
5.3	Other Trigger Upgrades	\$0	\$0	\$0	\$0	\$0
6	DAQ Software and Hardware Upgrade	\$46,686	\$38,952	\$85,638	\$0	\$85,638
7	Offline farm Upgrade	\$0	\$0	\$0	\$0	\$0
8	Beam Line Upgrade	\$56,000	\$0	\$56,000	\$0	\$56,000
9	Enhanced Veto Wall	\$20,110	\$1,440	\$21,550	\$0	\$21,550
10	Recoil Detector	\$0	\$25,920	\$25,920	\$55,000	\$80,920
11	Visitor Support for Russian collaborators	\$105,240	\$0	\$105,240	\$0	\$105,240

Run Plan

Phase 1 Run Plan			
Target	Number of Events (Millions)	Running Time (Days)	Physics Need Group
NuMI Low Energy target	10	2	MINOS MINERVA
NuMI Medium Energy Target	10	2	MINERVA NOVA
Liquid Hydrogen	20	4	QCD PANDA DUBNA
Liquid Nitrogen	10	2	ICE CUBE
12 Nuclei			Nuclear Physics
D2 Be C Al Si Hg Fe Ni Cu Zn W Pb	60	12	Hadronic Showers
Total Events	110	22	
Raw Storage	11 TBytes		
Processed Storage	55 TBytes		

Phase 2 Run Plan			
Target	Number of Events (Millions)	Running Time (Days)	Physics Need Group
18 Nuclei			
Li B O2 Mg P S Ar K Ca			Nuclear Physics
Ni Nb Ag Sn Pt Au Pb Bi U	90	18	Hadronic Showers
10 Nuclei B-list			Nuclear Physics
Na Ti V Cr Mn Mo I Cd Cs Ba	50	10	Hadronic Showers
Total Events	140	28	
Raw Storage	14 TBytes		
Processed Storage	70 TBytes		

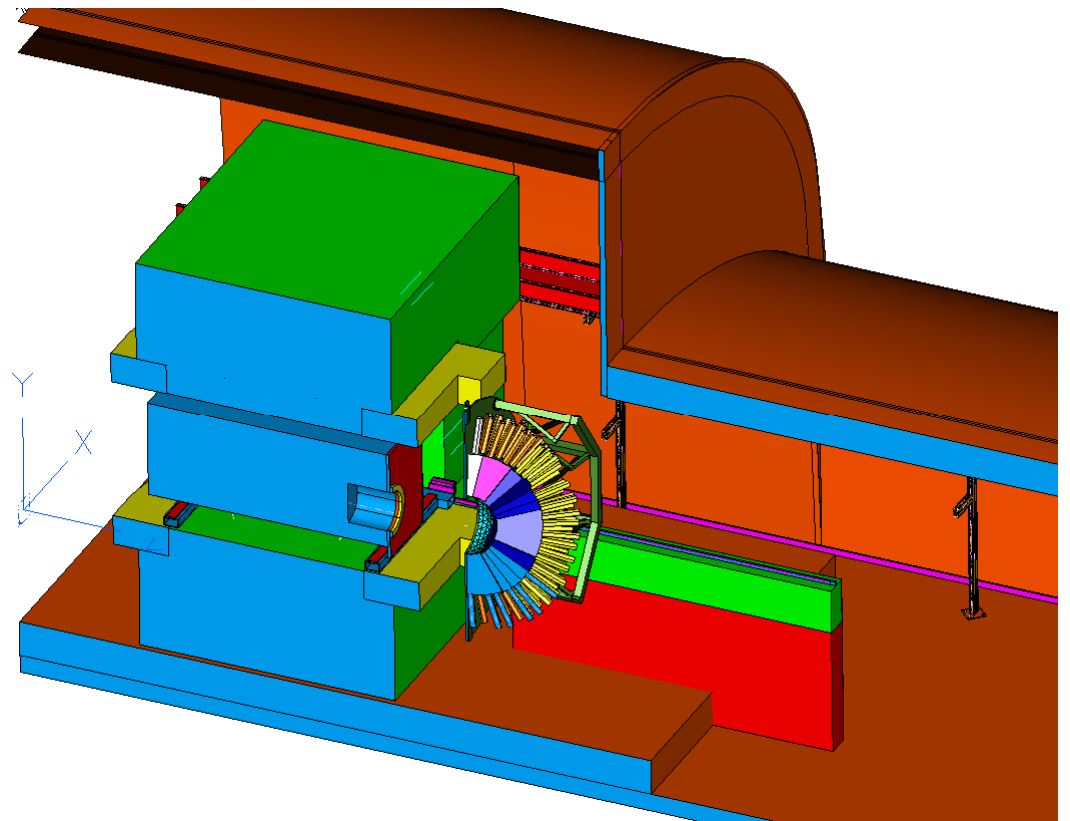
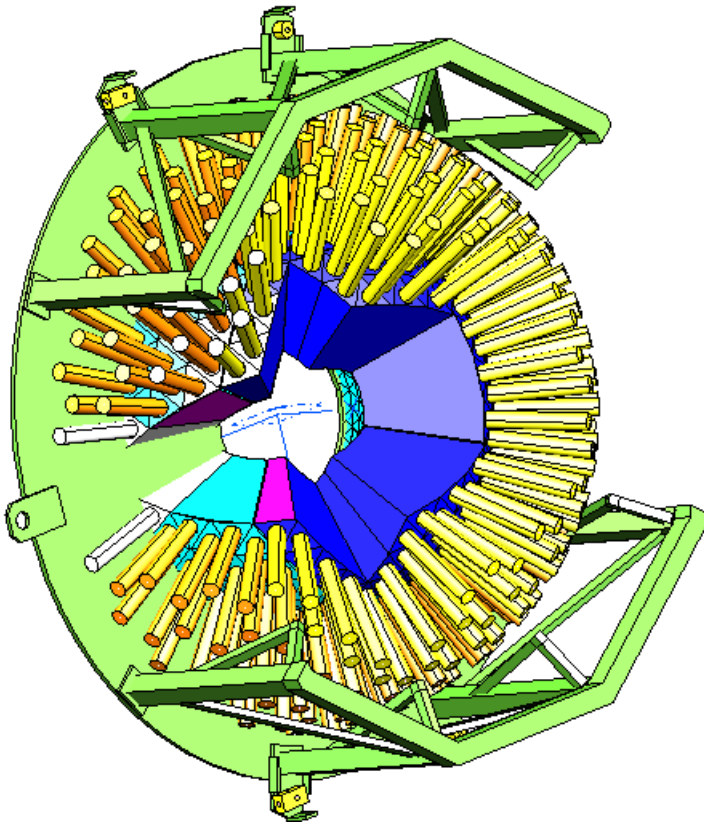
Phase 3 - Tagged Neutral beams for ILC 5 million events/day LH2 target

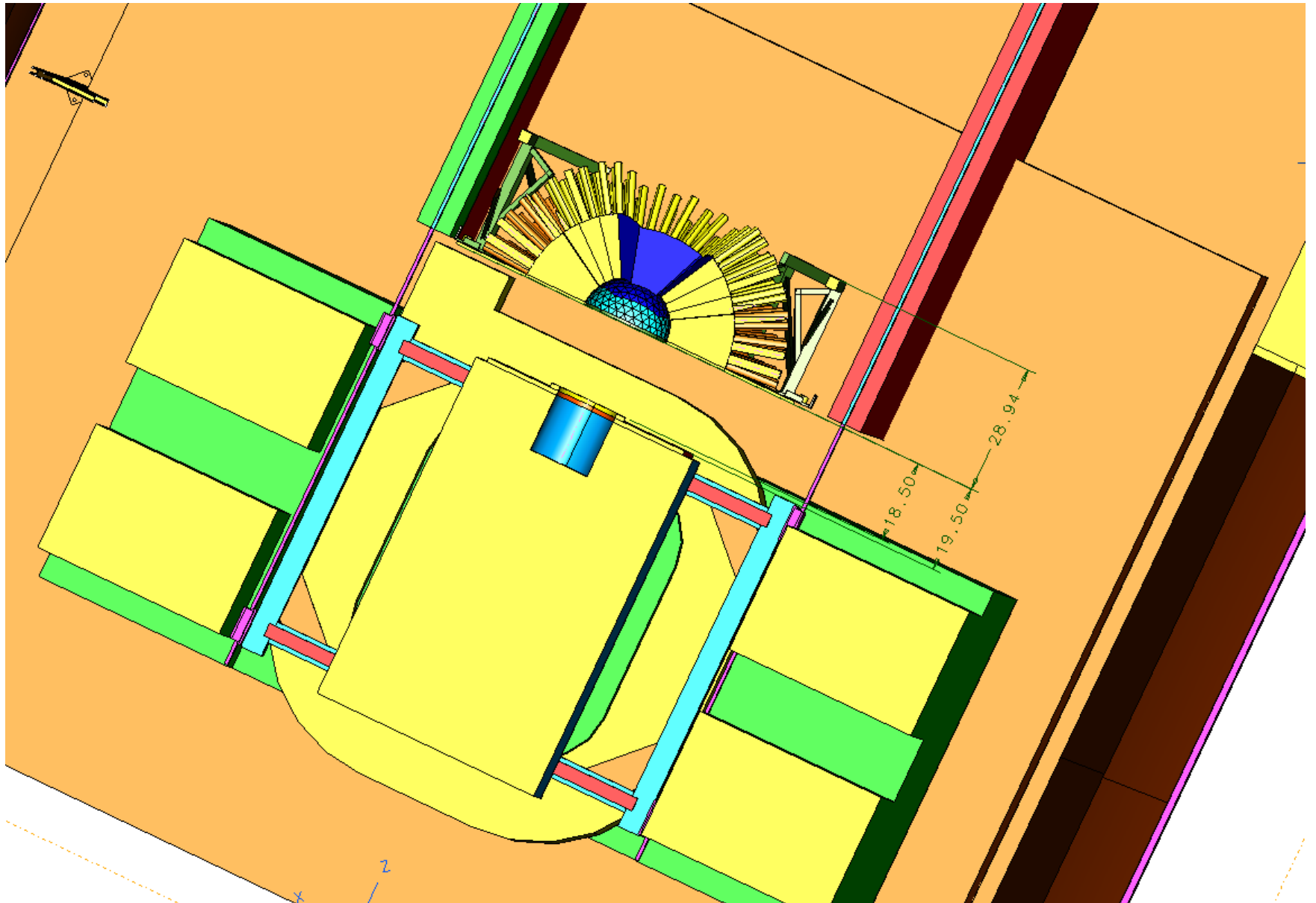
Missing baryon resonance search may request additional running depending on what is found.

Conclusions

- The MIPP Upgrade Collaboration has proposed a cost effective way to upgrade the experiment to speed up the DAQ by a factor of 100.
- We propose to add a recoil detector+chamber that will enhance the physics reach of the experiment.
- We propose to measure the NUMI LE/ ME targets.
- As well as 30 nuclei to benefit hadron shower simulators and the cosmic ray community.
- Tagged neutral beams possible for PFA studies(?)
- We propose to increase the momentum range of the beams (down to 1 GeV/c) that will benefit the hadron shower simulators and permit the search for missing baryon resonances.
- Collaborators Welcome

Plastic Ball Mount





MIPP LH₂ target

