The MIPP Experiment Upgrade and Hadronic Shower Simulations

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- Review the status of hadronic shower simulation models
  - » DPMJET, Mars, Geant4 models
  - » Will leave out MCNPX, PHITS and other models.
  - » Status of particle production data
- Difficulties in using shower simulation models in experiments such as MINOS, MiniBoone, Atmospheric neutrino production, Hadron Calorimetry (ILC in particular)
- Review plans to obtain higher quality data- MIPP Upgrade FNAL-P-960
- Ways to use new data directly in simulators—Hadronic Interaction libraries
- Tagged Neutral beams

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? Almost as bad as the folks who claim string theory is the theory of everything! Experimentalist asks-what does it predict?

Elastic scattering

- The entire strong interaction problem can be reduced to our ignorance in describing the very simple process of elastic scattering.– By the optical theorem

$$\sigma_{tot} \propto \mathrm{Im}(\text{forward elastic scattering amplitude})$$

$$\sigma_{tot} \propto s^{\alpha(0)-1}$$

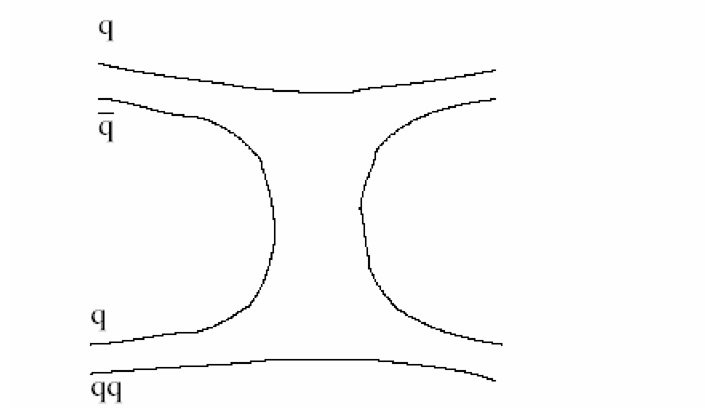
- Where $\alpha(0)$ is the intercept of the leading Regge trajectory, commonly known as the Pomeron. In the era when total cross sections were thought to asymptote to a constant value, this intercept was taken to be unity. Since it has been shown conclusively that the cross sections rise with energy, this intercept is now thought to be ~1.095
- This leads to a power law rise in total cross sections, which will eventually violate unitarity-Froissart bound states cross sections should not grow faster than $\log^2 s$!

DPMJET-Dual Parton Model Jet

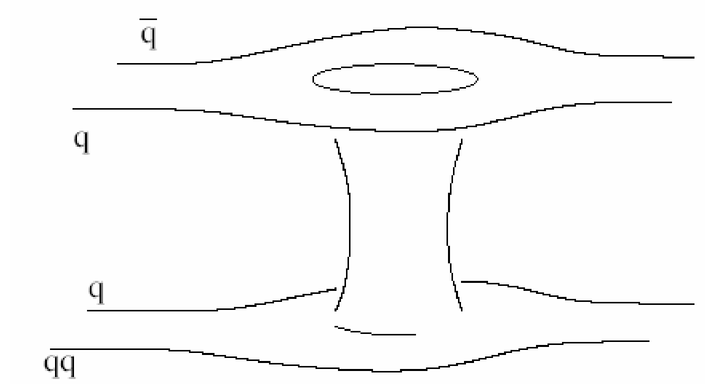
- Two component (soft and hard scattering). Super critical soft and pomerons coupled with triple pomeron scattering for diffraction and hard scattering by QCD improved partonmodel. Chew, Rosenzweig(76), Hang-Mo et al(75), Capella et al(94),J.Ranft(92)
- Code implementation- Ranft,Engel,Roesler
- Used by itself and also in Fluka.
- Good for Diffractive production as well as multiplicities
- Incorporates Cronin Effect, Glauber model for particle propagation in nuclei. Hadronization of hard partons handled by BAMJET, DECAY or the LUND JETSET.
- Excellent review by J.Ranft PRD51 (95)64.

Dual Parton Model concepts

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

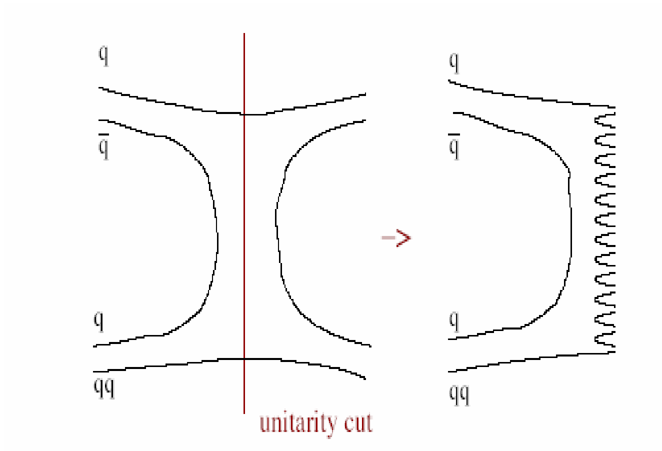


Pomeron exchange Does not depend on flavor of scattering particles.

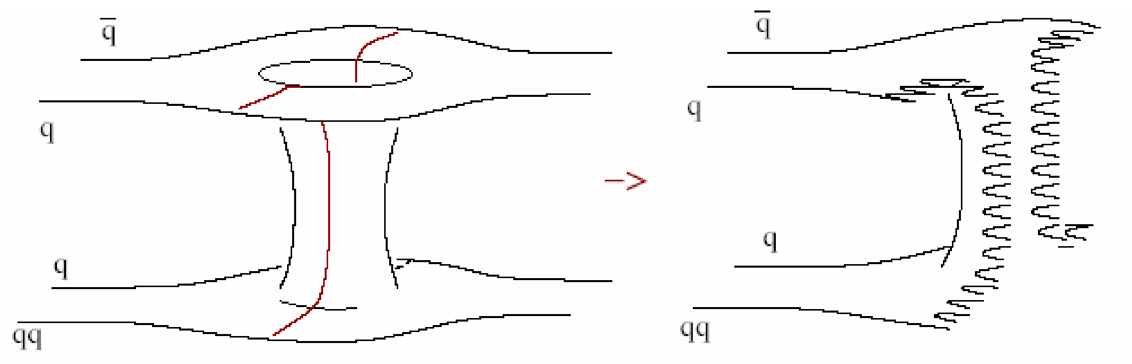


Dual Parton Model- Concepts-Optical theorem

Reggeon Exchange-Single string of hadrons

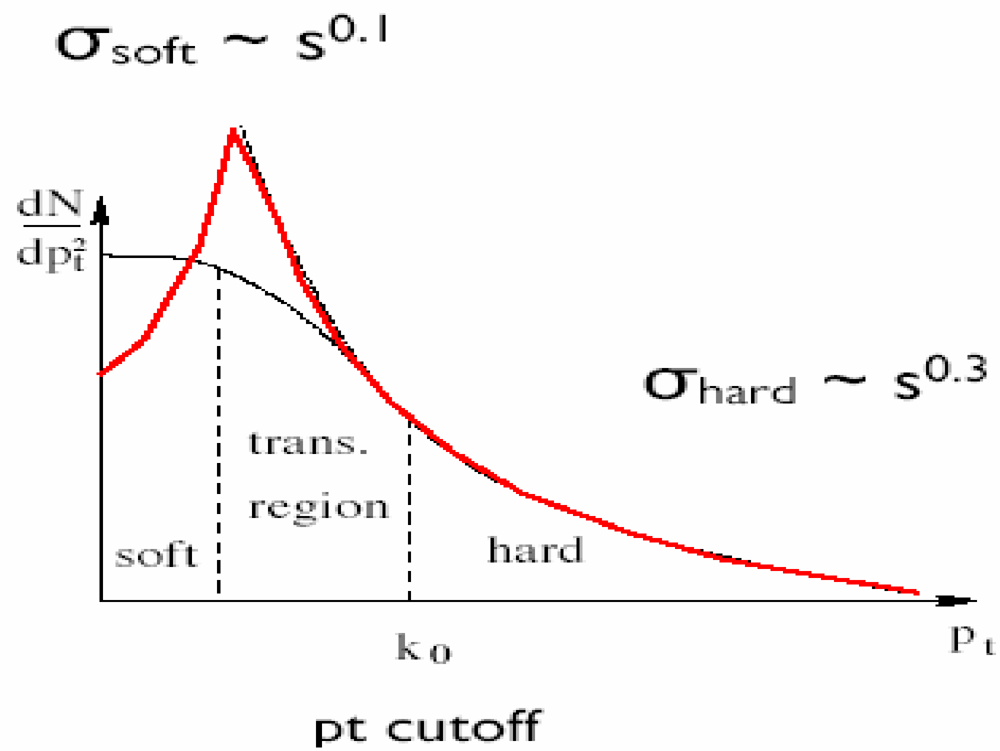


Pomeron Exchange-Two strings of hadrons



Conceptual problem- Matching soft and hard processes.

This is done by tuning the transition region carefully!



Validation of DPMJET(Ranft)

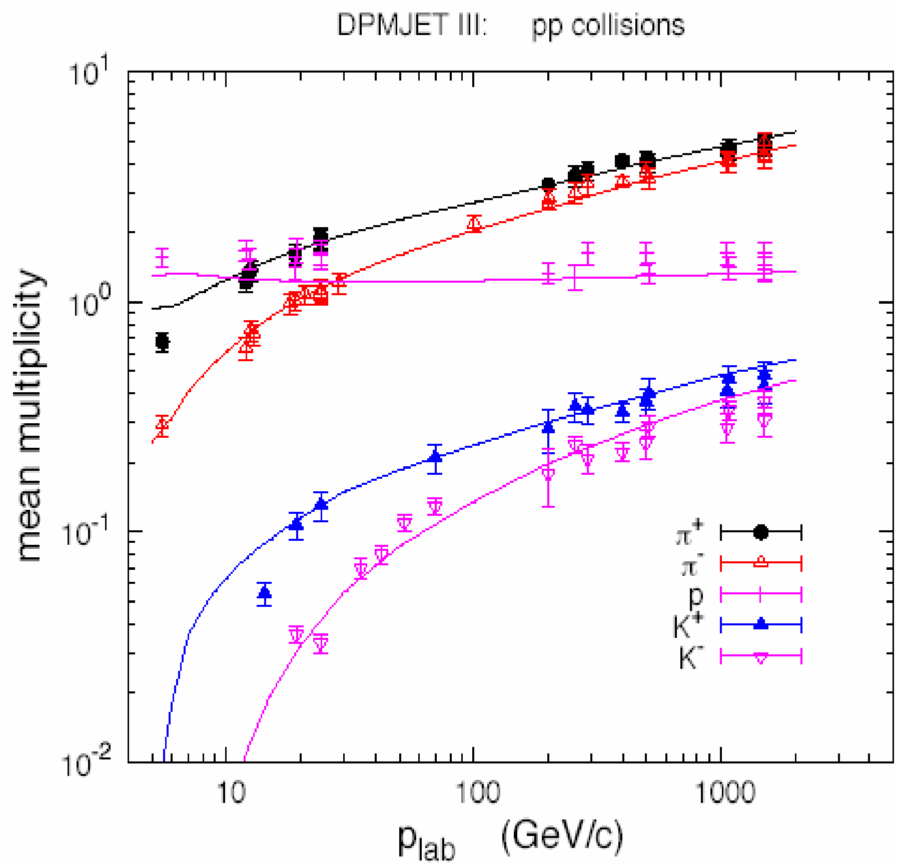
- Predictions compared to multiplicities and single particle inclusive cross sections.
- Experiments used- Brenner et al(82), EHS-NA22 (88), LEBS-HES(91),EHS-RCBC(87),Kafka et al(77), Kichimi et al(79)…
- Single particle inclusives fit well. Since inelastic cross sections are tuned to agree to data, multiplicities come out OK as well.
- Correlations between particles not addressed completely. None of these models can, since no complete theory exists.

DPMJET-Multiplicities-Slides from R.Engel

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

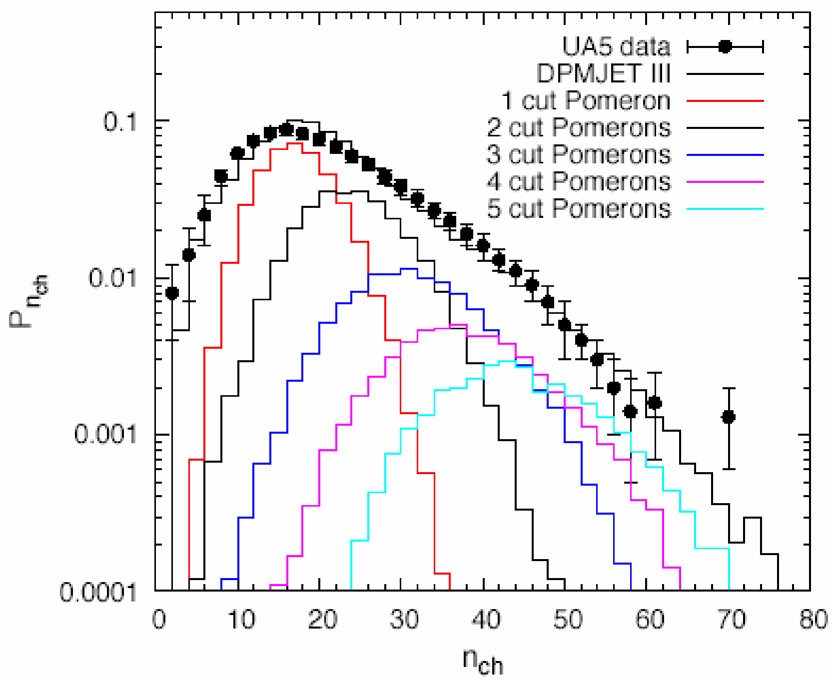
proton - proton, $E_{lab} = 200GeV$

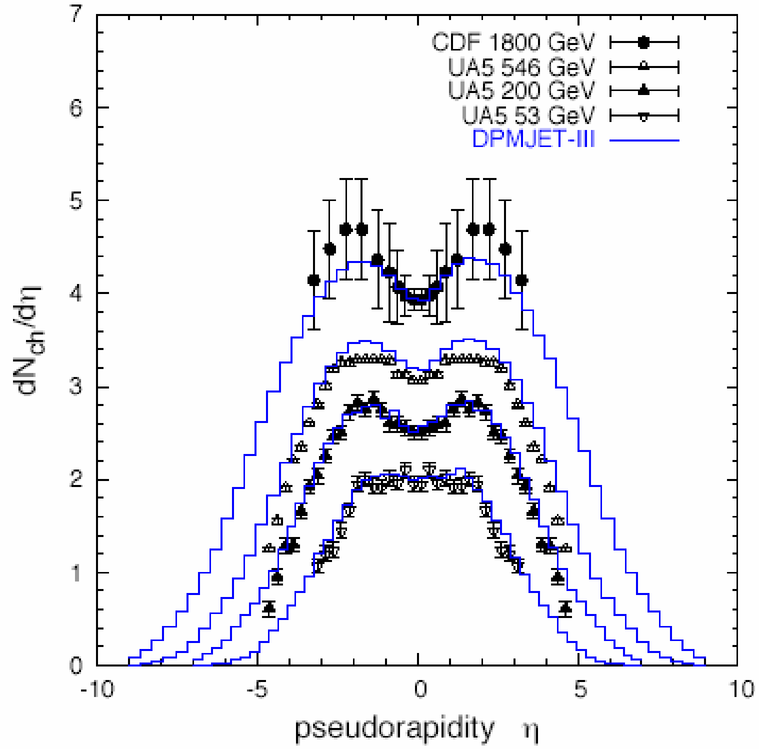
	Exp.	DPMJET-III
charged	7.69 ± 0.06	7.64
neg.	2.85 ± 0.03	2.82
p	1.34 ± 0.15	1.26
n	0.61 ± 0.30	0.66
π^+	3.22 ± 0.12	3.20
π^-	2.62 ± 0.06	2.55
K^+	0.28 ± 0.06	0.30
K^-	0.18 ± 0.05	0.20
Λ	0.096 ± 0.01	0.10
$\bar{\Lambda}$	0.0136 ± 0.004	0.0105



DPMJET- Collider distributions (R.Engel)

Charged particle multiplicity distribution at 200 GeV cms.





Charged particle pseudorapidity distributions

GEANT4 Parton String Models-Slides from G4 group-D.Wright

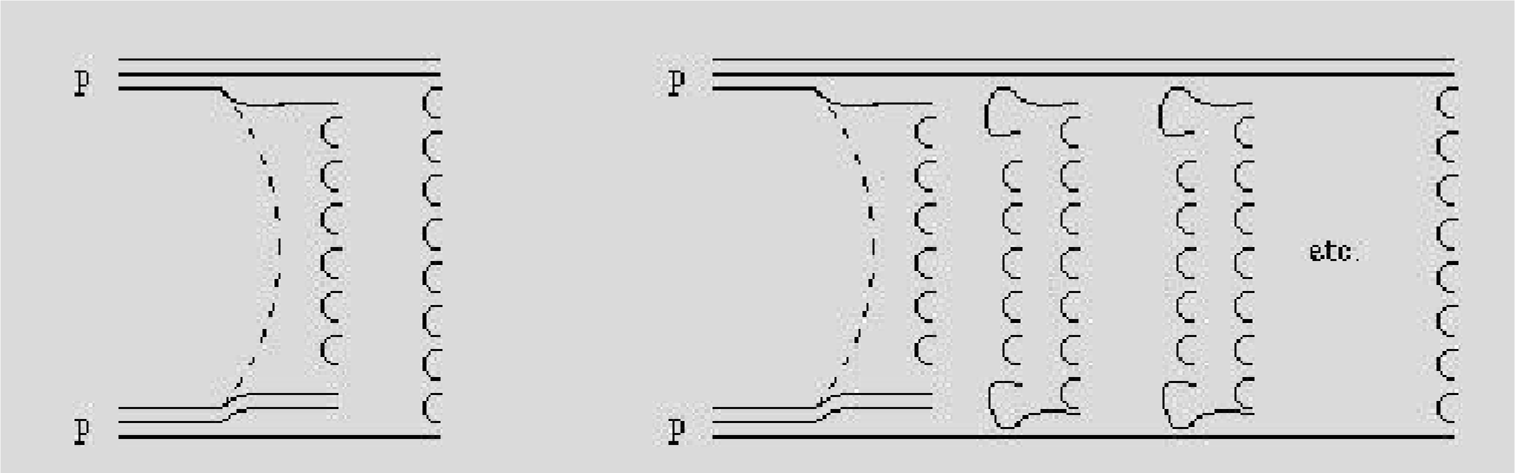
- Quark Gluon String model
- Diffractive String Model
- Bertini Cascade Model(Classsical solution to Boltzmann equation on average. No scattering matrix calculated. Vcalid for incident energies 0-10 GeV, for p,n,π
- Parametrized models
- Allows data-driven models as well
- Excellent Geometry package—Provides widely used framework

- Models split into
  - » Strings excitation part
  - » String hadronization

- Damaged nucleus passed to either
  - » pre-compound model
  - » CHIPS for nuclear fragmentation

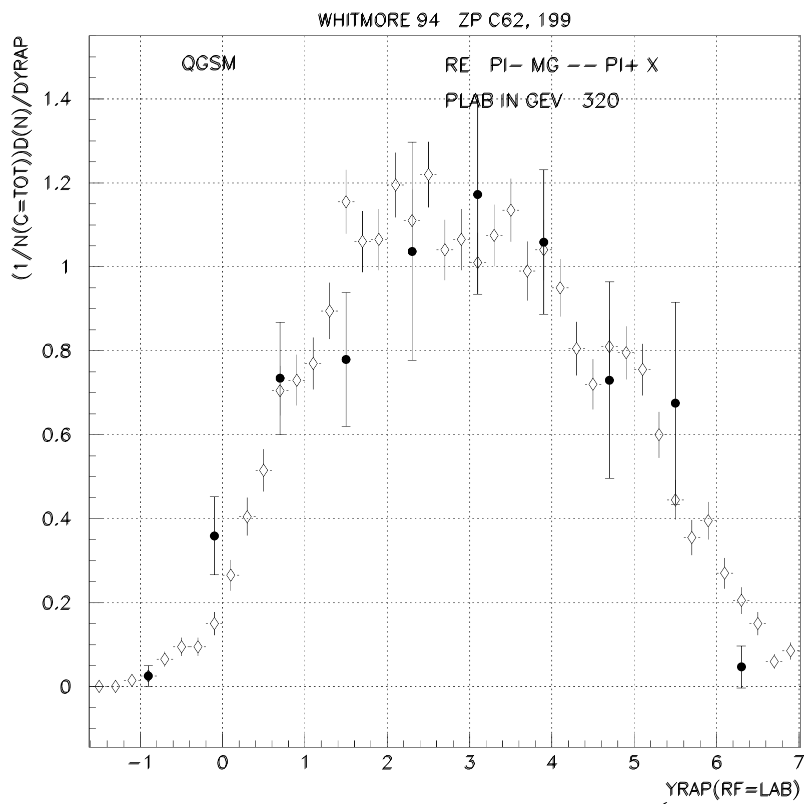
Quark Gluon String Model- QGSJET(Geant4)

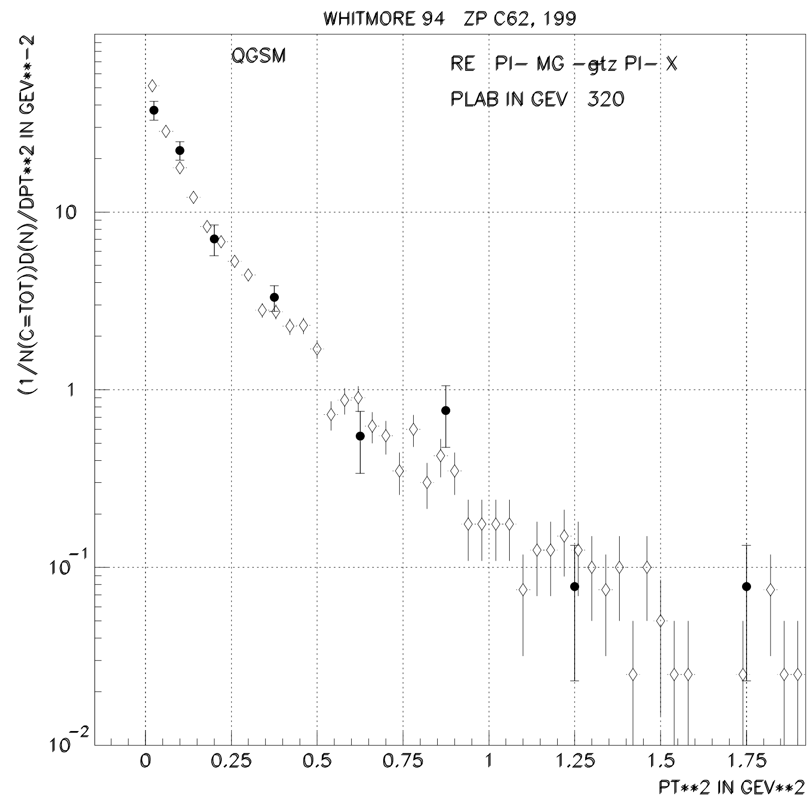
- Pomeron exchange model
  - » Hadrons exchange one or several Pomerons
- Equivalent to color coupling of valence quarks
- Partons connected by quark gluon strings



QGSM - Results-GEANT4

pi- Mg → pi+ X , Plab 320 GeV/c





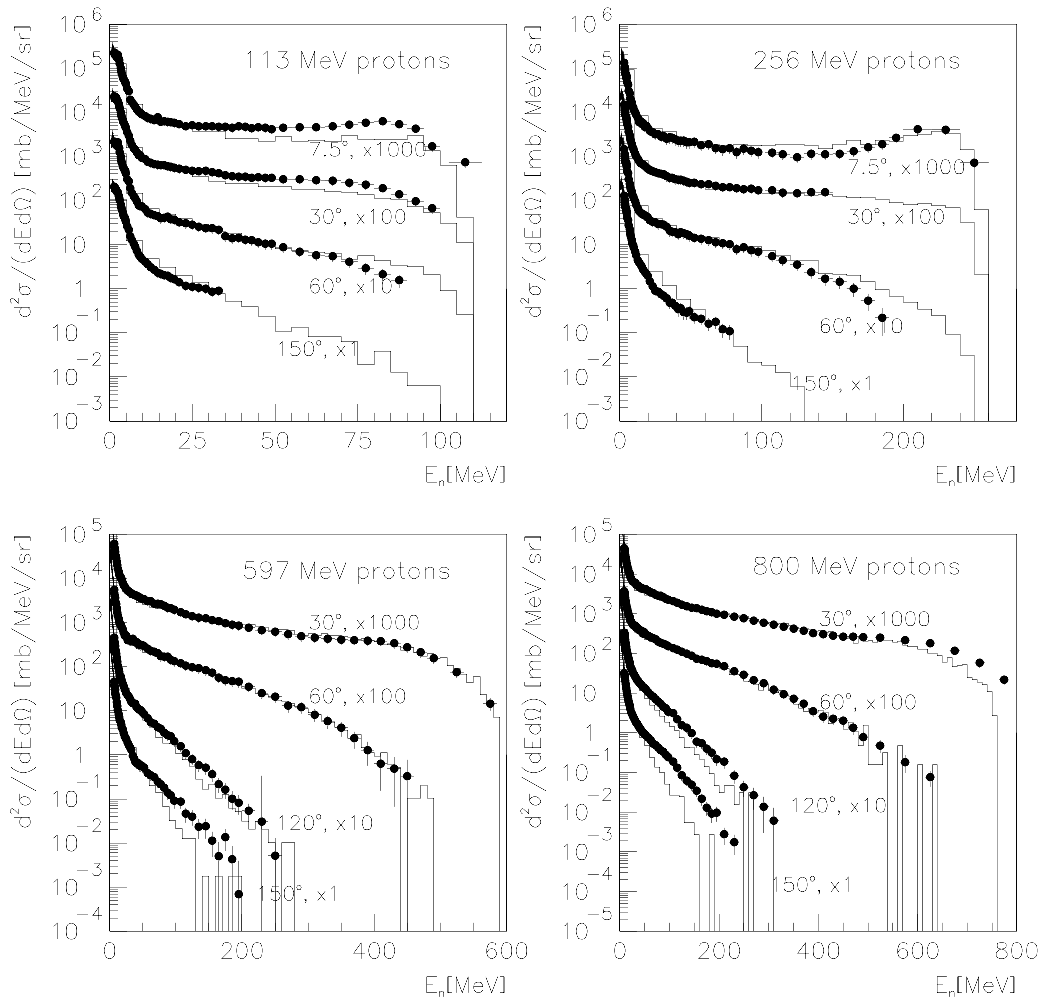
Rapidity $\eta = \frac{1}{2}\ln\left(\frac{E+p_z}{E-p_z}\right)$

P_t^2 [GeV^2]

Binary Cascade-Geant4

- Modeling interactions of protons, neutrons, pions with nuclei
- Incident particle kinetic energy 50 MeV - 2GeV
- Extension for light ion reactions
- Wounded nucleus passed to pre-compound model and nuclear de-excitation models.

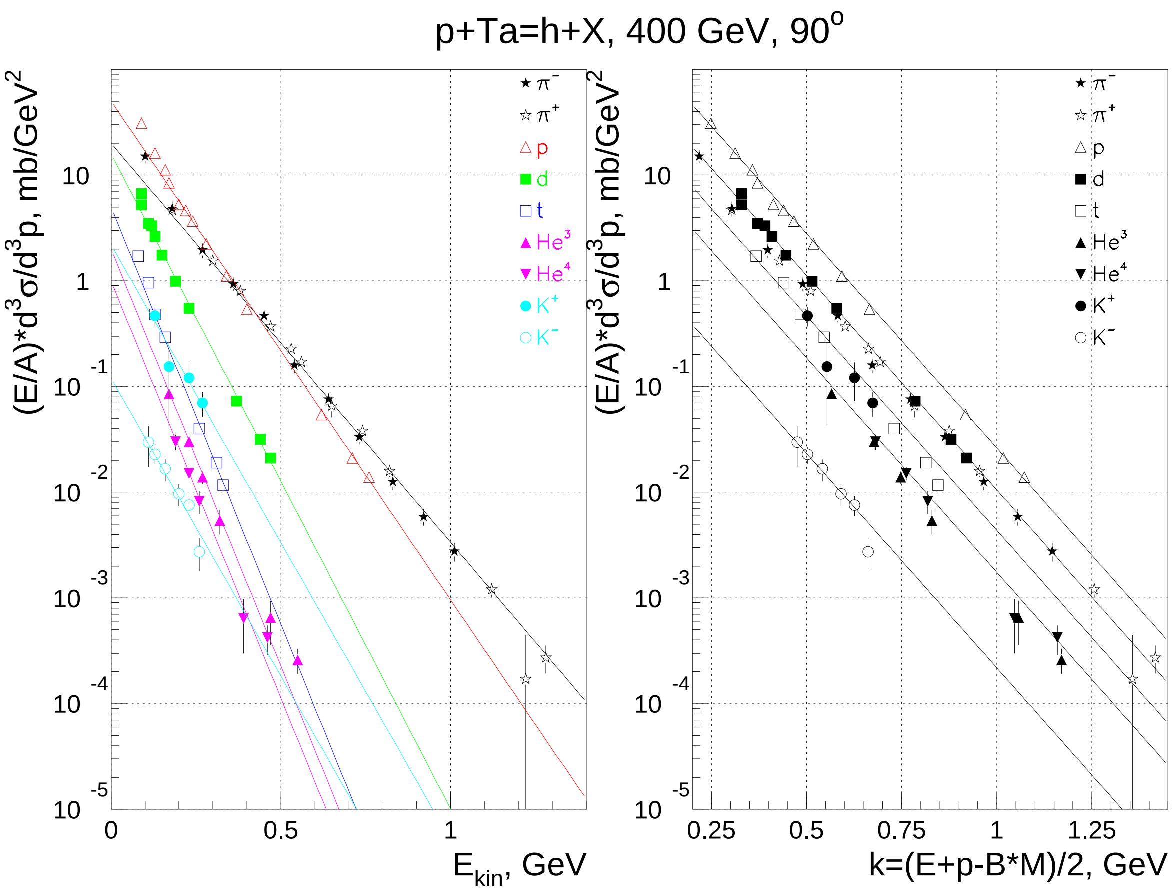
Binary Cascade - results



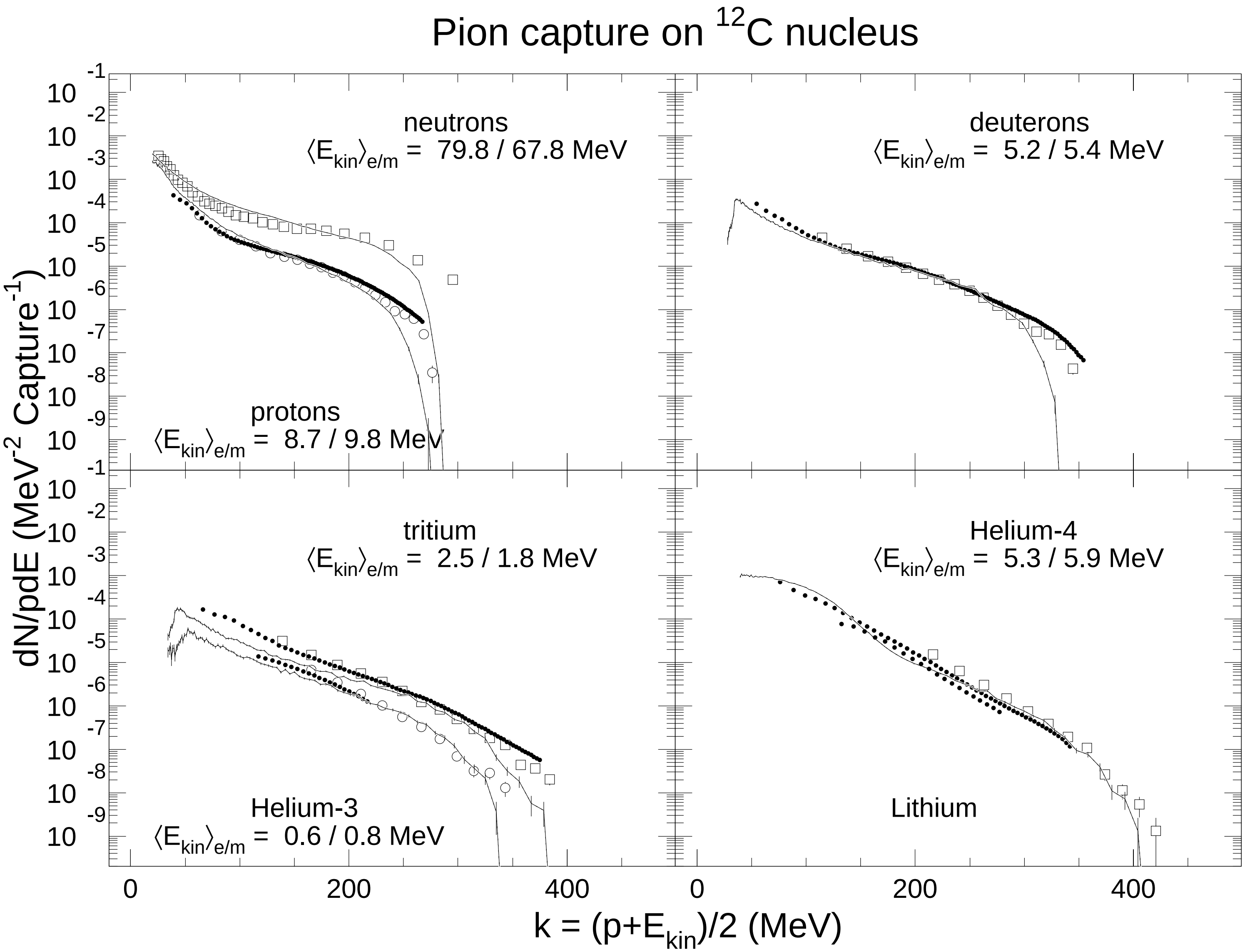
p Pb -> n X

Chiral Invariant Phase Space (CHIPS)-Geant4

- CHIPS is based on homogeneous invariant phase distribution of massless partons
-



Validation of CHIPS model for pion Capture at Rest on Carbon

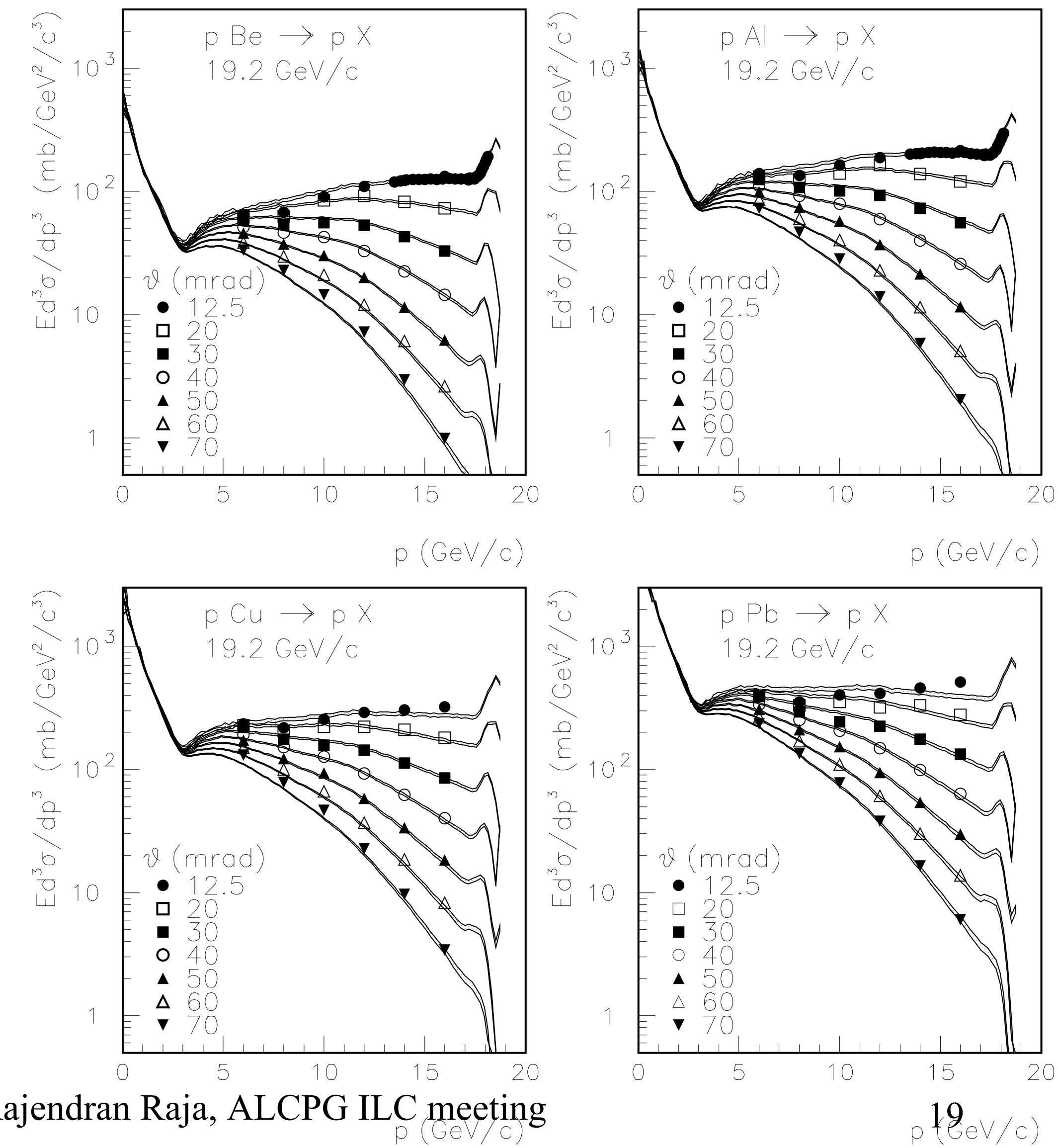


MARS15 code- Mokhov et al. FNAL-conf-04/269-AD

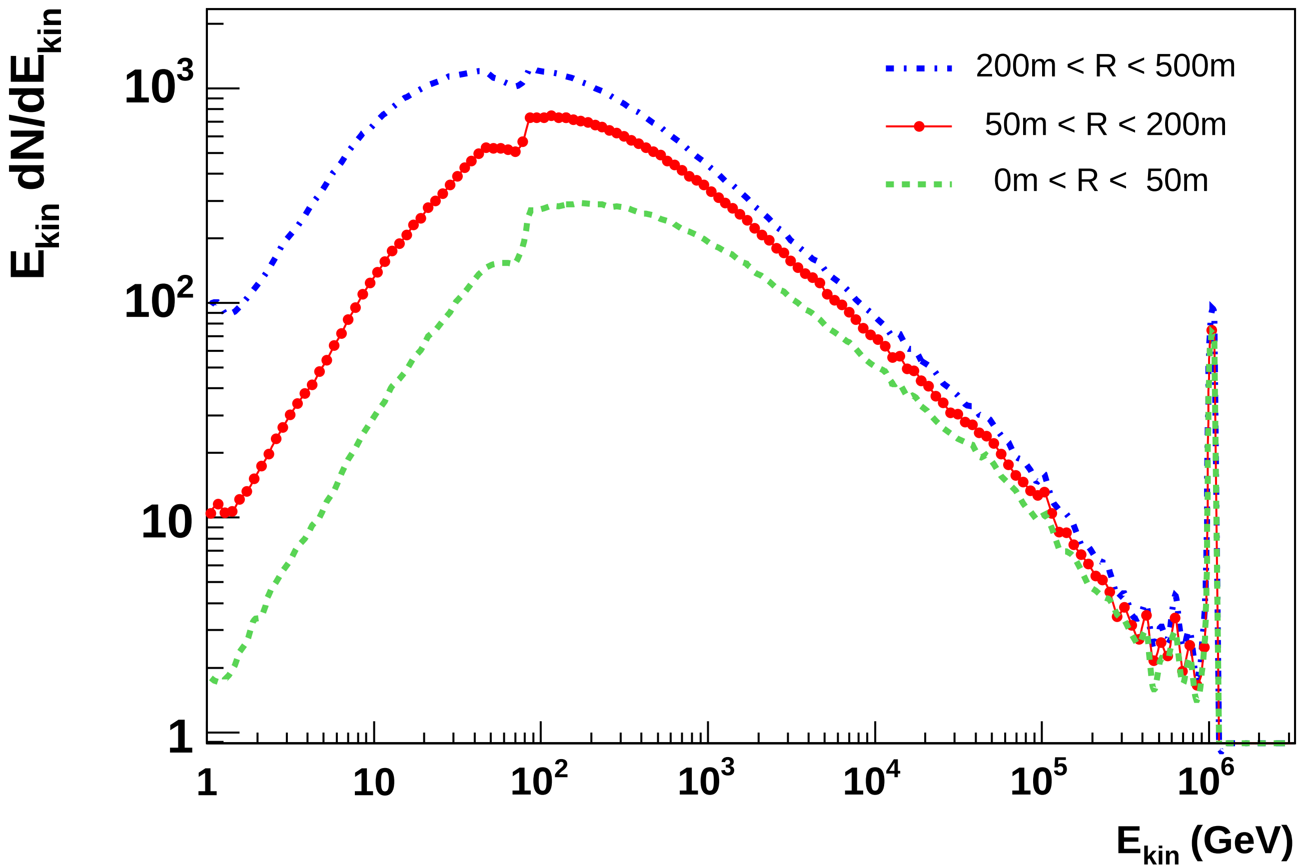
- Total and elastic hadron nucleon cross sections described by fits to experimental data. Cross sections for hyperon-nucleon cross sections using Additive Quark model rules. At energies above 5 GeV, agrees well with data.
- Inclusive event generator- Particles described inclusively with each particle carrying a statistical weight depending on the partial multiplicity for that event. Energy and momentum are conserved on average. Inclusive particle production for nuclear interactions above 3 GeV is modeled by weighting the pp cros section by a nuclear modification factor.
- Exclusive Event Generator-Two versions- Cascade-Exciton model CEM03 of Mashnik et al combined with Fermi breakup model, coalescence model and an improved version of the Generalized Evaporation-fission model (GEM2) is used as default for hadron nucleus interactions below 5 GeV. The 2003 version of the Los Alamos Quark Gluon String model LAQGSM03 was implemented for particle and heavy ion projectiles at 10 MeV/A-800 GeV/A.
- Also uses DPMJET3 for the first vertex in the cascade tree.– For very high energies LHC and cosmic rays up to 100 TeV.

MARS15- Validation plots

Invariant cross sections pA→pX in MARS at 19.2 GeV/c vs data.Allaby et al (1970).



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



Plethora of models

- No complete theory exists-unlike in QED/EGS case
- A plethora of models exists. Not all can be correct. In fact none can describe all data. All models tuned to single particle inclusive cross sections. We are now asking questions where particle correlations are important—Eg How wide is the shower from a particle.
- So the approach of “Validating models and tuning them with data” will only have limited success. Anytime we open up new territory, we will need to re-validate. Unless we take a new tack, and maximize the use of data and minimize the use of theory in the shower simulation. I will describe this approach towards the end.

Miniboone Pre-existing Production Data—J.Link FNAL Wine and Cheese

π Production

Experiment	P_{beam} (GeV/c)	Year
Allaby	19.1	1970
Cho	12.4	1971
Marmer	12.3	1969
Vorontsov	10.1	1983

E910 and HARP

K^0 Production

Experiment	P_{beam} (GeV/c)	Year
Abe	12	1987

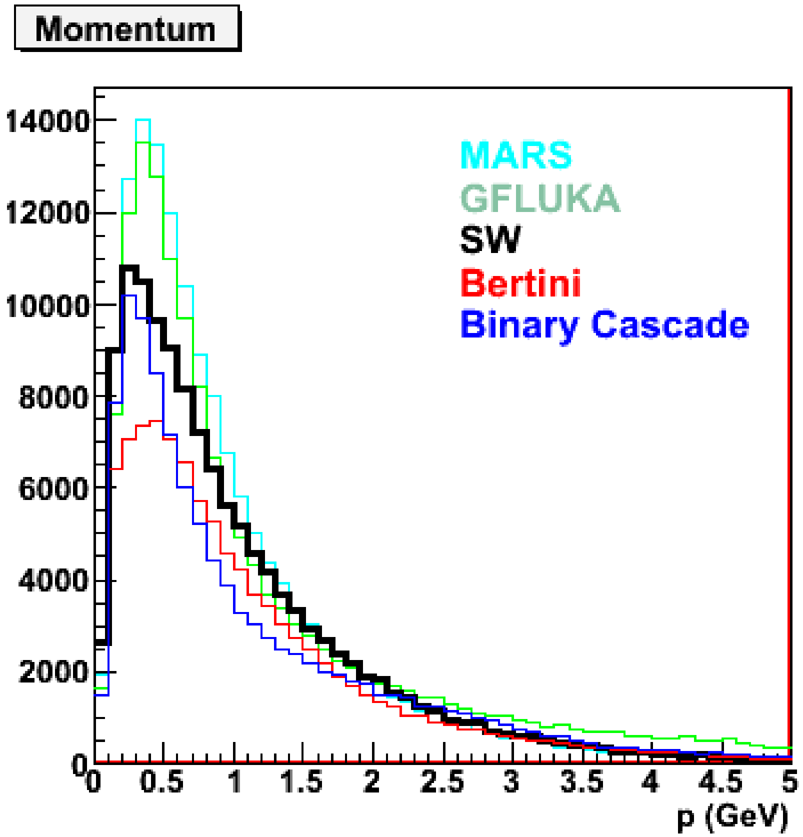
Initially E910 only

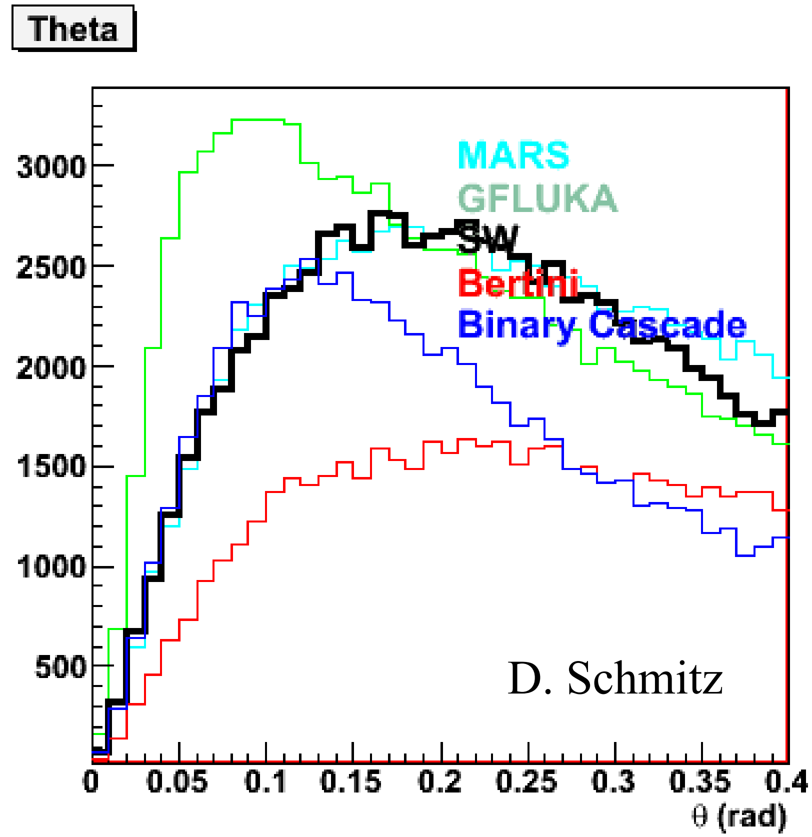
K^+ Production

Experiment	P_{beam} (GeV/c)	Year
Abbott	14.6	1992
Aleshin	9.5	1977
Allaby	19.1	1970
Dekkers	18.8, 23.1	1964
Eichten	24.0	1972
Lundy	13.4	1965
Marmer	12.3	1968
Piroue	2.74	1966
Vorontsov	10.1	1983

HARP only

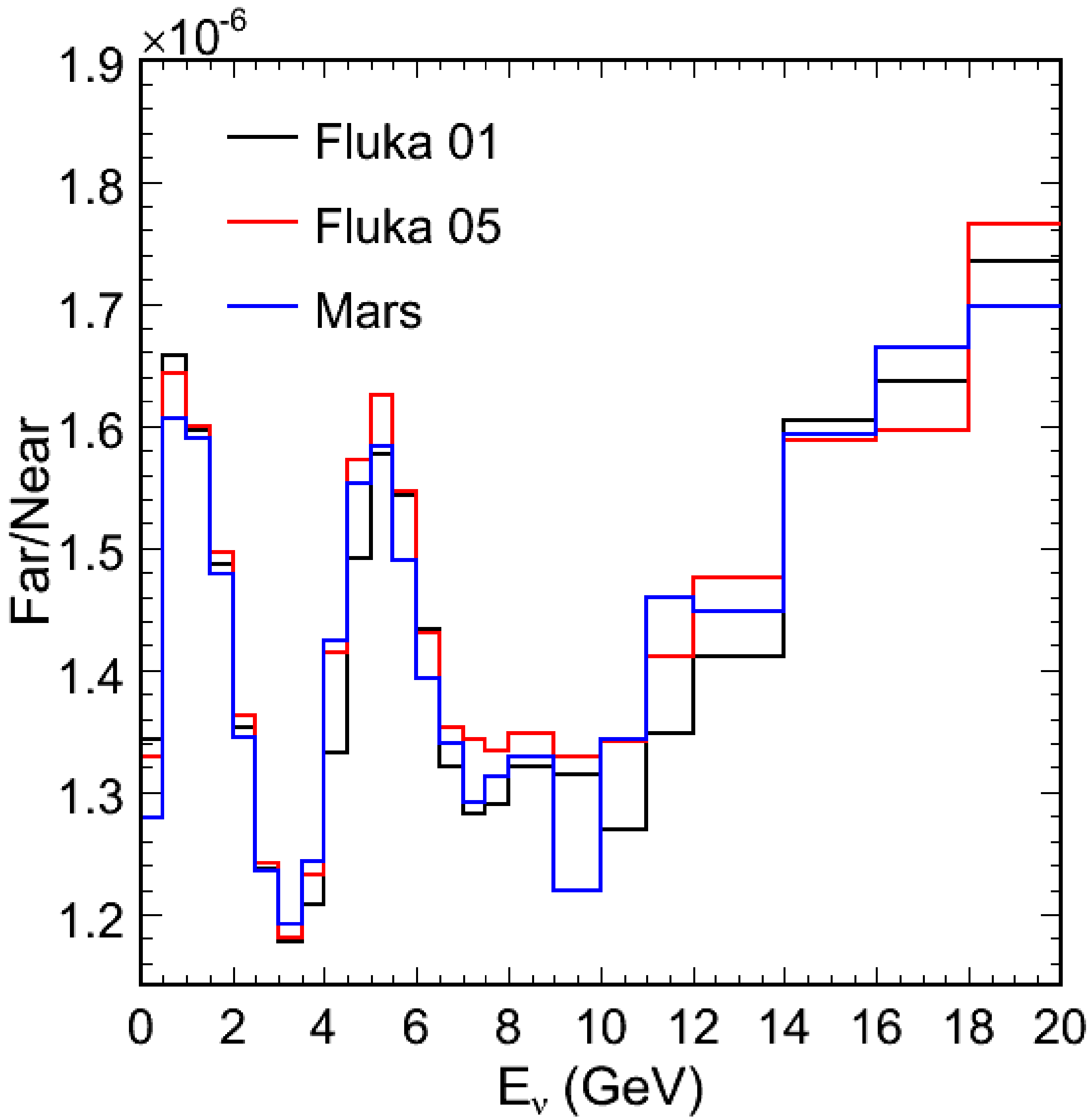
Miniboone-Sanford-Wang (SW) parametrizaion of E910 and HARP compared to other models





The differences are dramatic in the π spectra as well! But the E910 and HARP cross sections determine the correct model, which is very close to MARS.

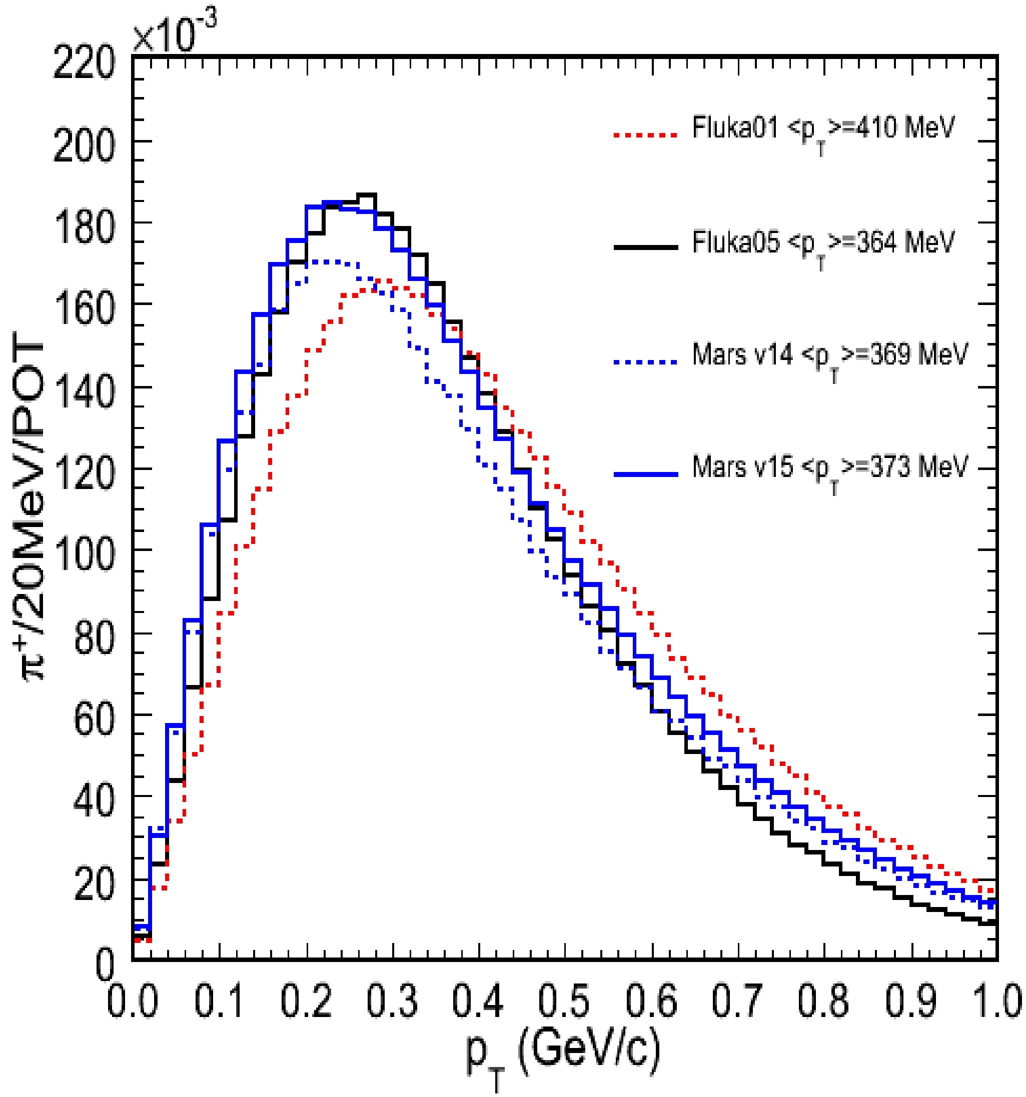
Why Hadron Production Is Important to NuMI-slides from S.Kopp



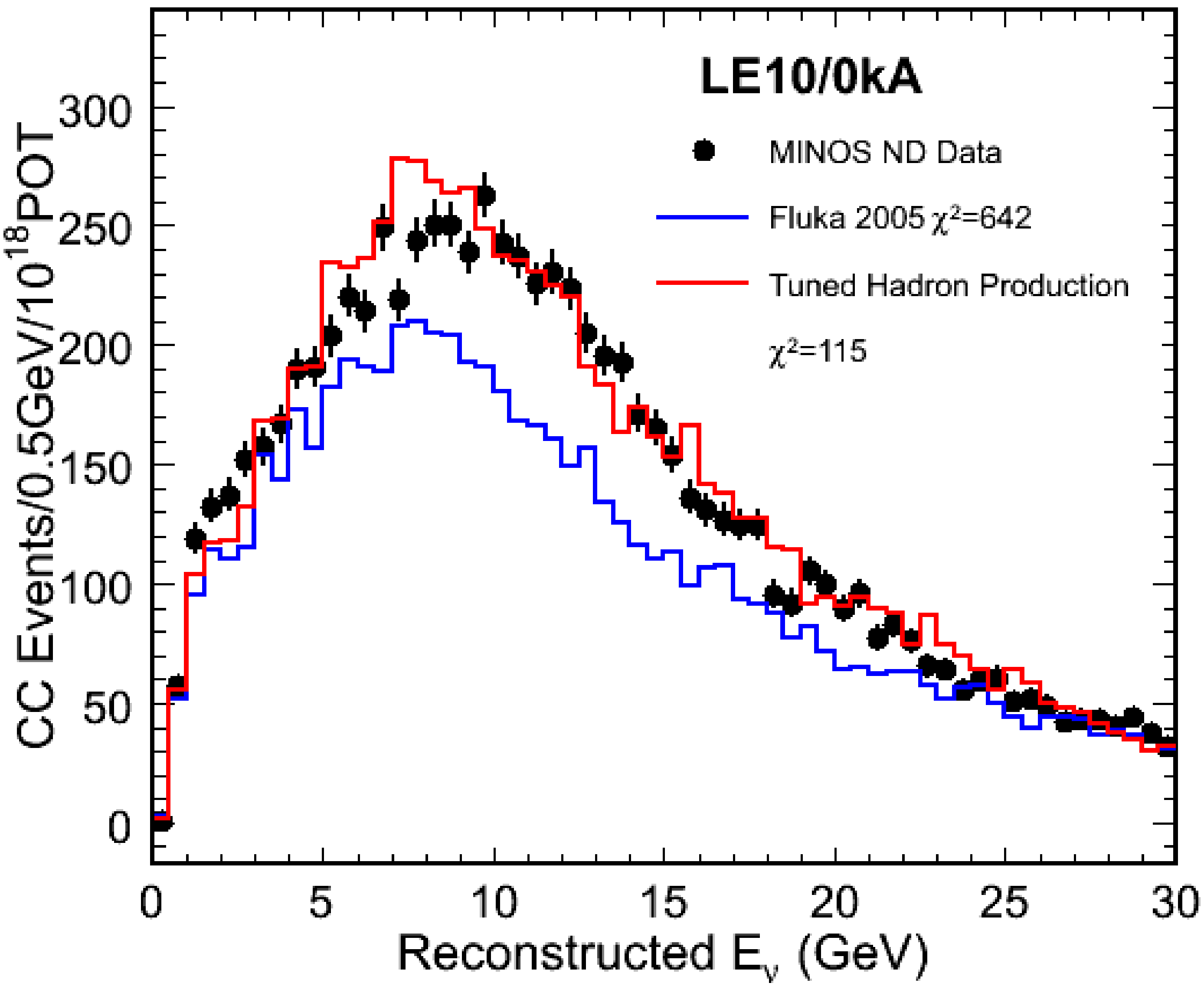
- Two-detector experiment for ν_μ disappearance measurement.
- Agreement 'OK' in ND, within model spread.
- But what should we use as error in predicted beam spectrum? (model correlation?)

Compare Hadron Production Models-S.Kopp

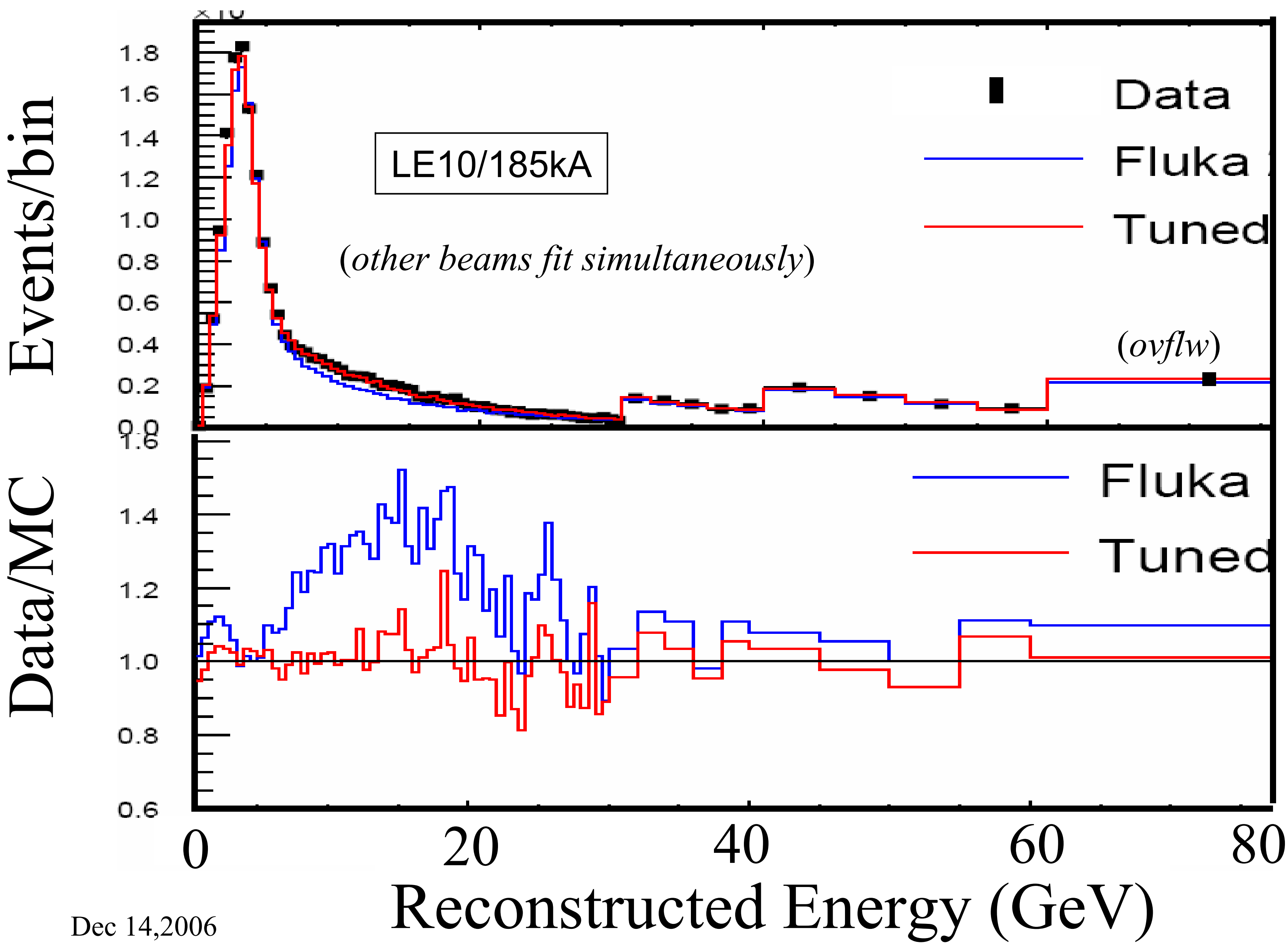
Model	$\langle p_T \rangle$ (GeV/c)
GFLUKA	0.37
Sanf.-Wang	0.42
CKP	0.44
Malensek	0.50
MARS - v.14	0.38
MARS - v.15	0.39
Fluka 2001	0.43
Fluka 2005	0.36



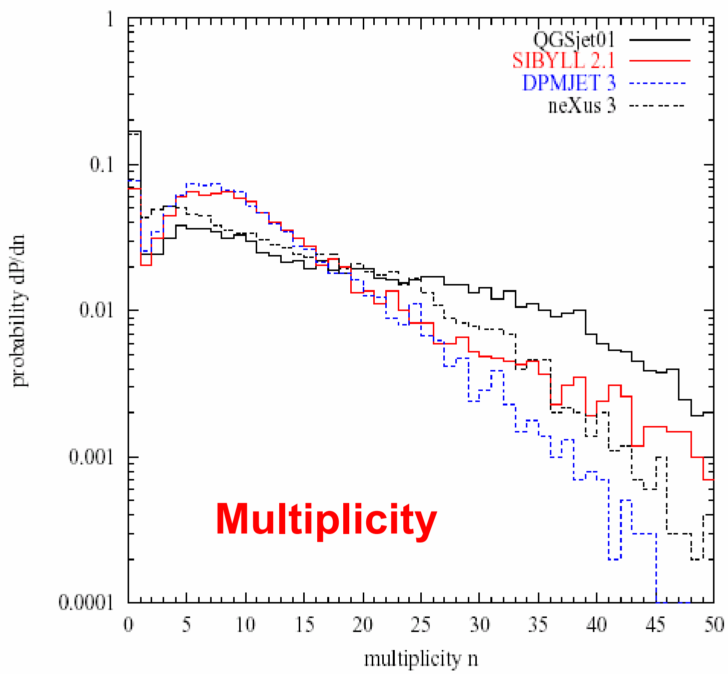
ND Spectra After Reweighting (VI)-S.Kopp



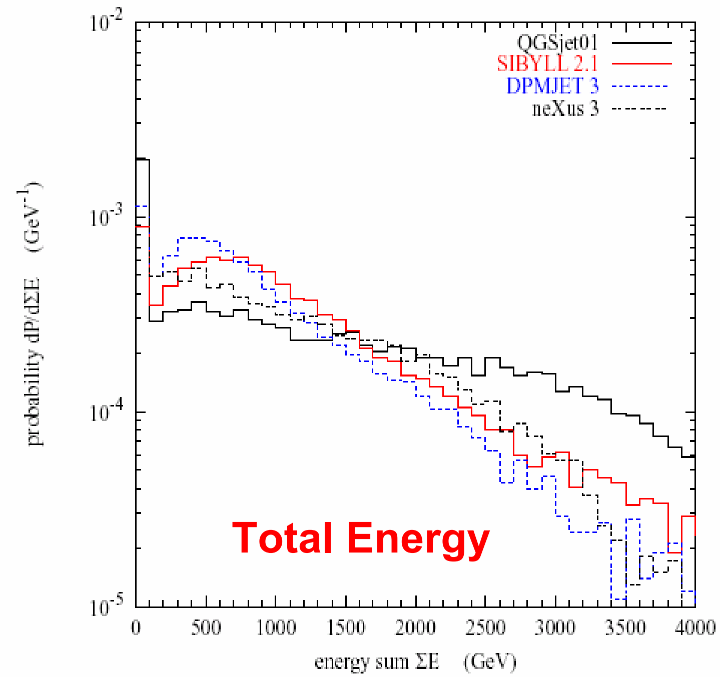
Results (Including >30 GeV)-S.Kopp



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



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



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

Predictions in the forward region within the CMS/TOTEM acceptance

(T1 + T2 + CASTOR)

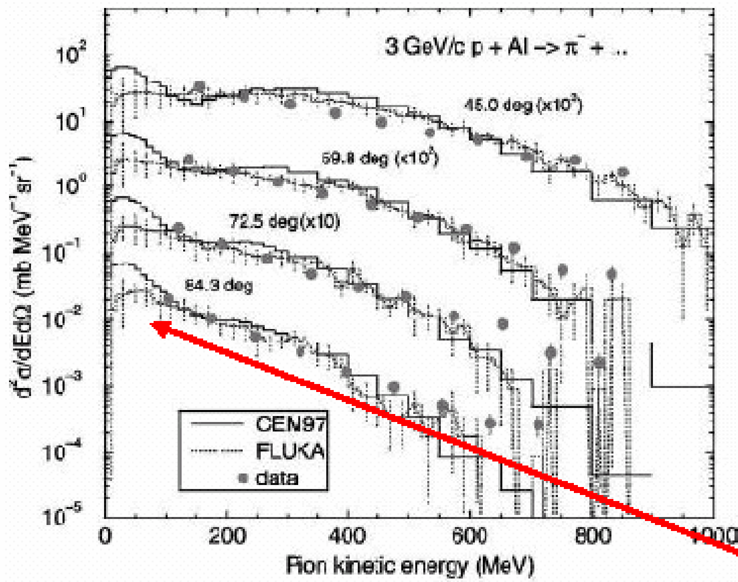
Hadron Shower Simulator problem

- 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 current state of hadronic shower simulators.
- Timely completion of MIPP upgrade progam can help systematics in, 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 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.

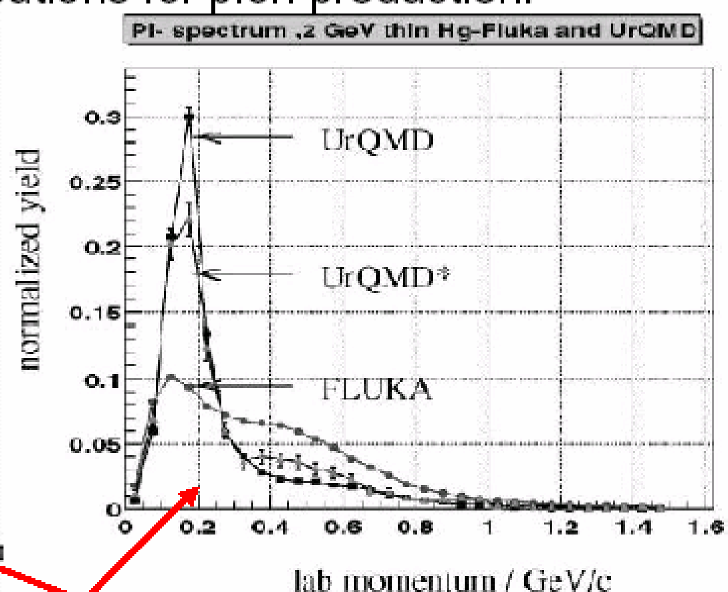
Discrepancies between hadronic generators

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



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NO DATA !

➔ Thin and thick targets, scan in Z

Discrepancies between hadronic generators- Testing particle production off nitrogen(Be extrapolated)

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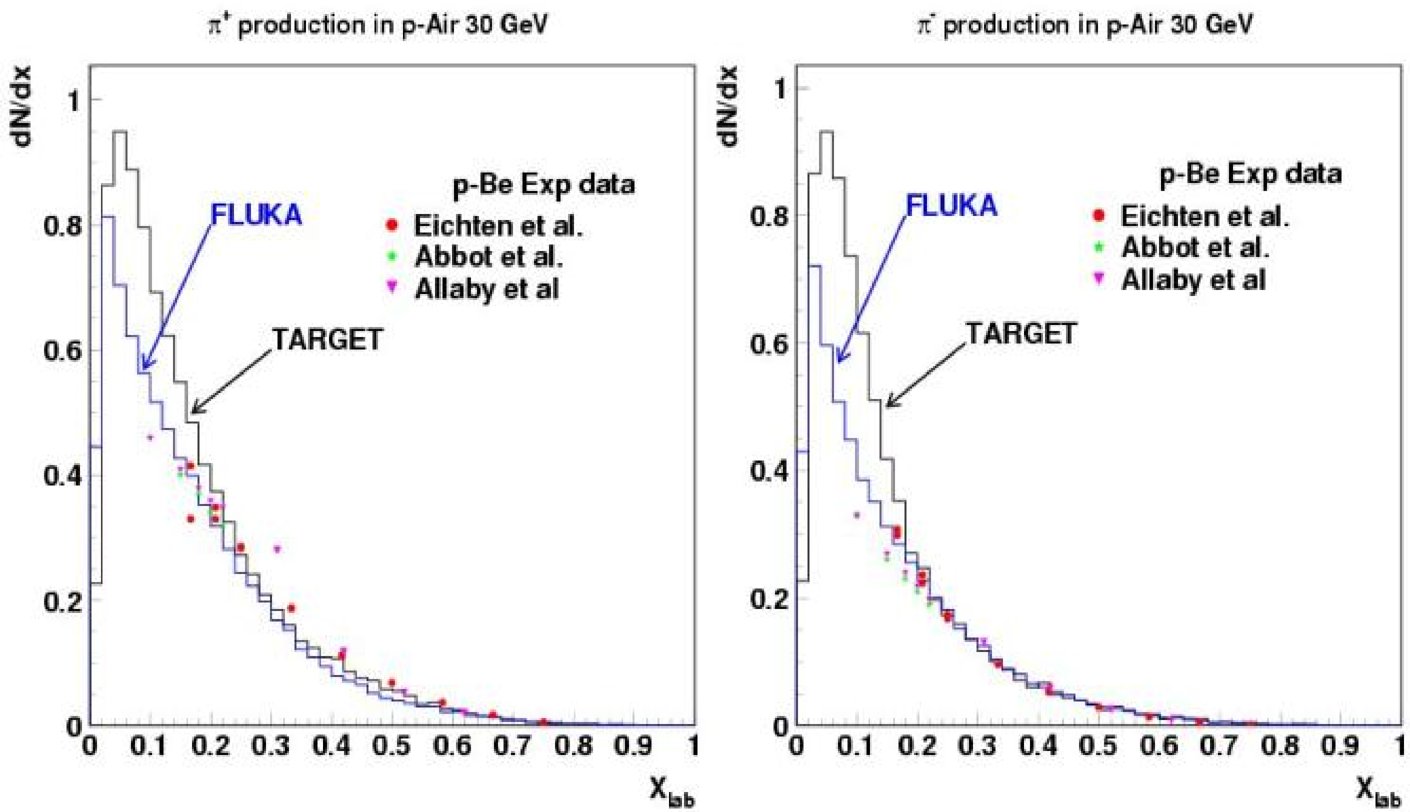
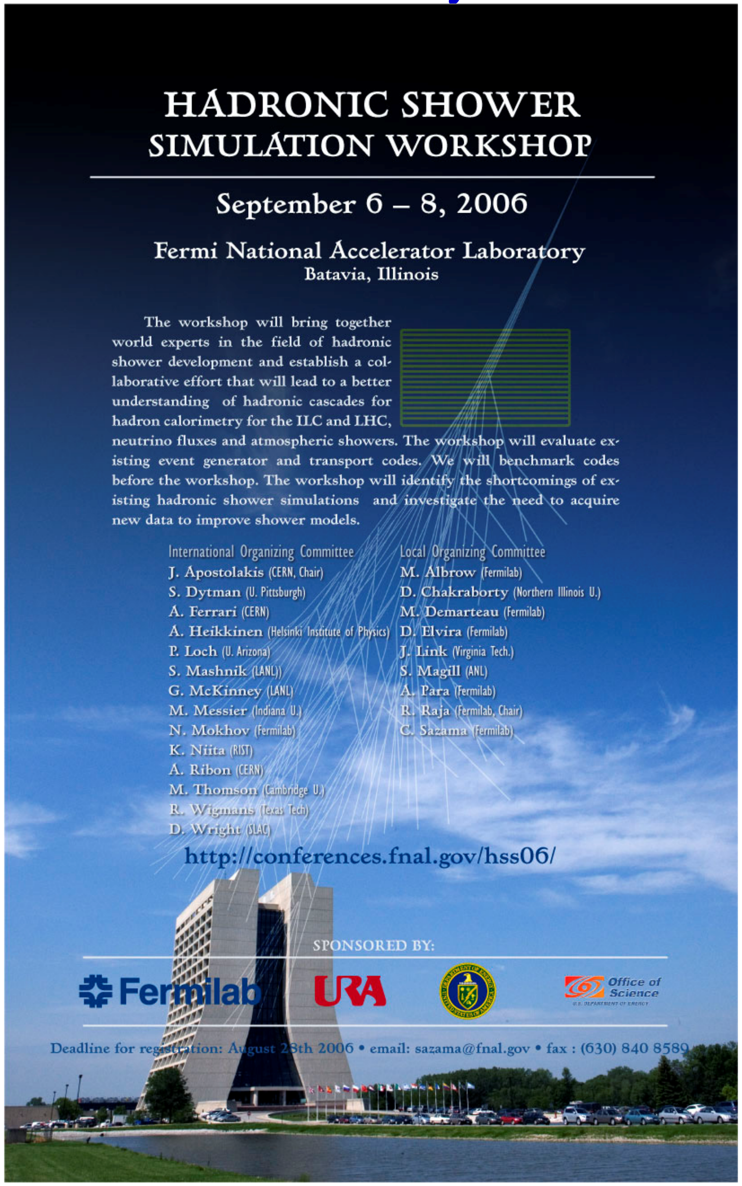


G.Battistoni

Hadronic Shower Simulation Workshop HSSW06

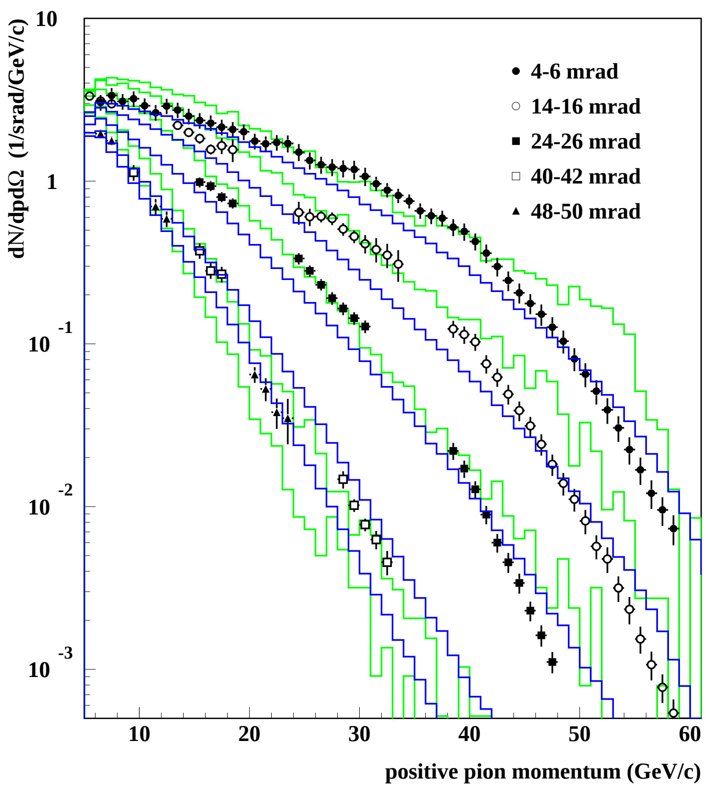
- Venue—Fermilab September 6-8, 2006
- Experts from GEANT4, FLUKA, MARS, MCNPX, and PHITS attended as well users from Neutrino, ILC, Atlas, CMS communities. Goal is to reduce systematics between various models and arrive at a suite of programs that can be relied on.

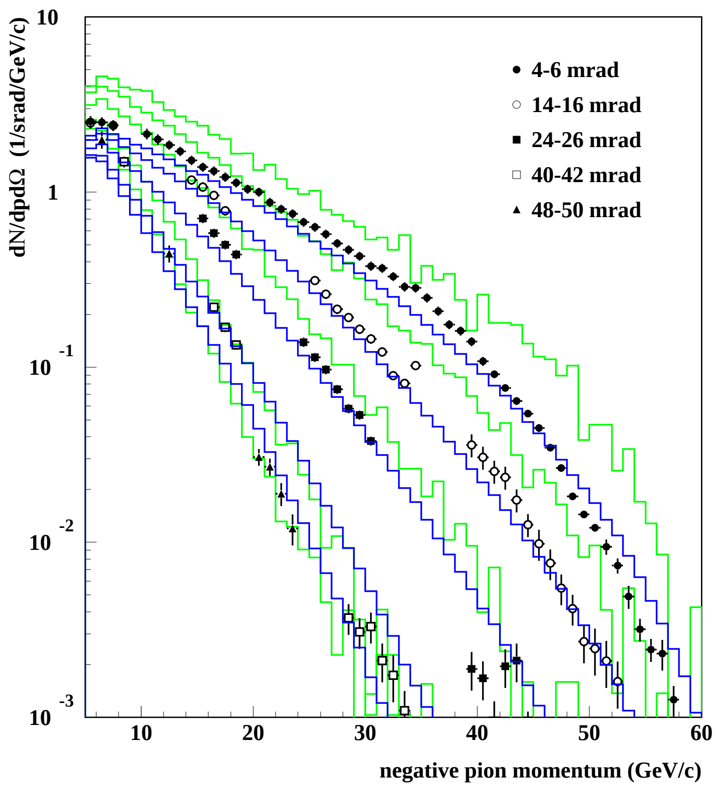


HSSW06 benchmark test 60cm Al target- Data from Protvino

Pion data. Blue curve MARS. Green curve PHITS.

Monte Carlos disagree with each other and the data!

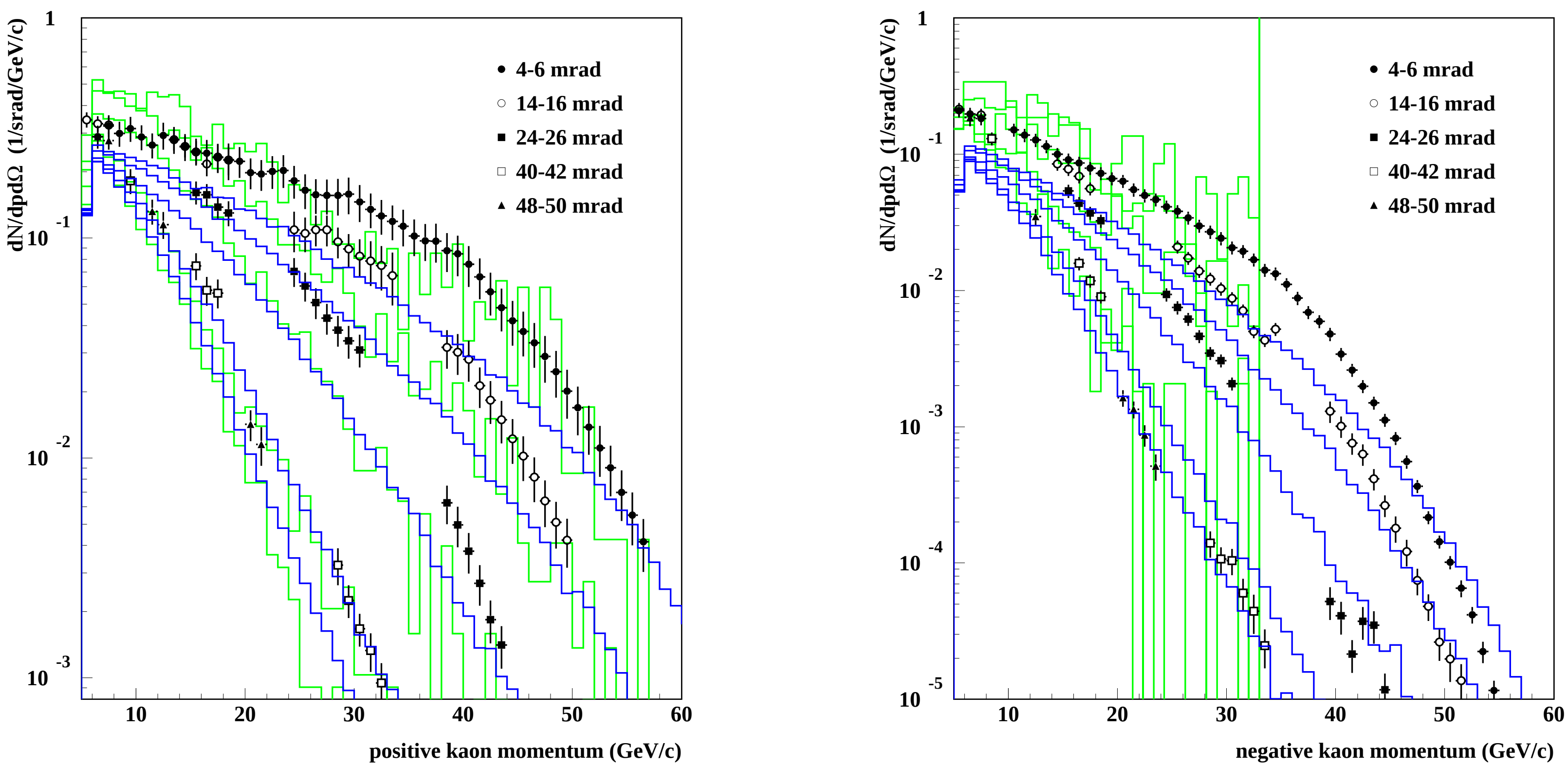




HSSW06 benchmark test 60cm Al target- Data from Protvino

Kaon data. Blue curve MARS. Green curve PHITS.

Monte Carlos disagree with each other and the data!



MIPP Upgrade collaboration list

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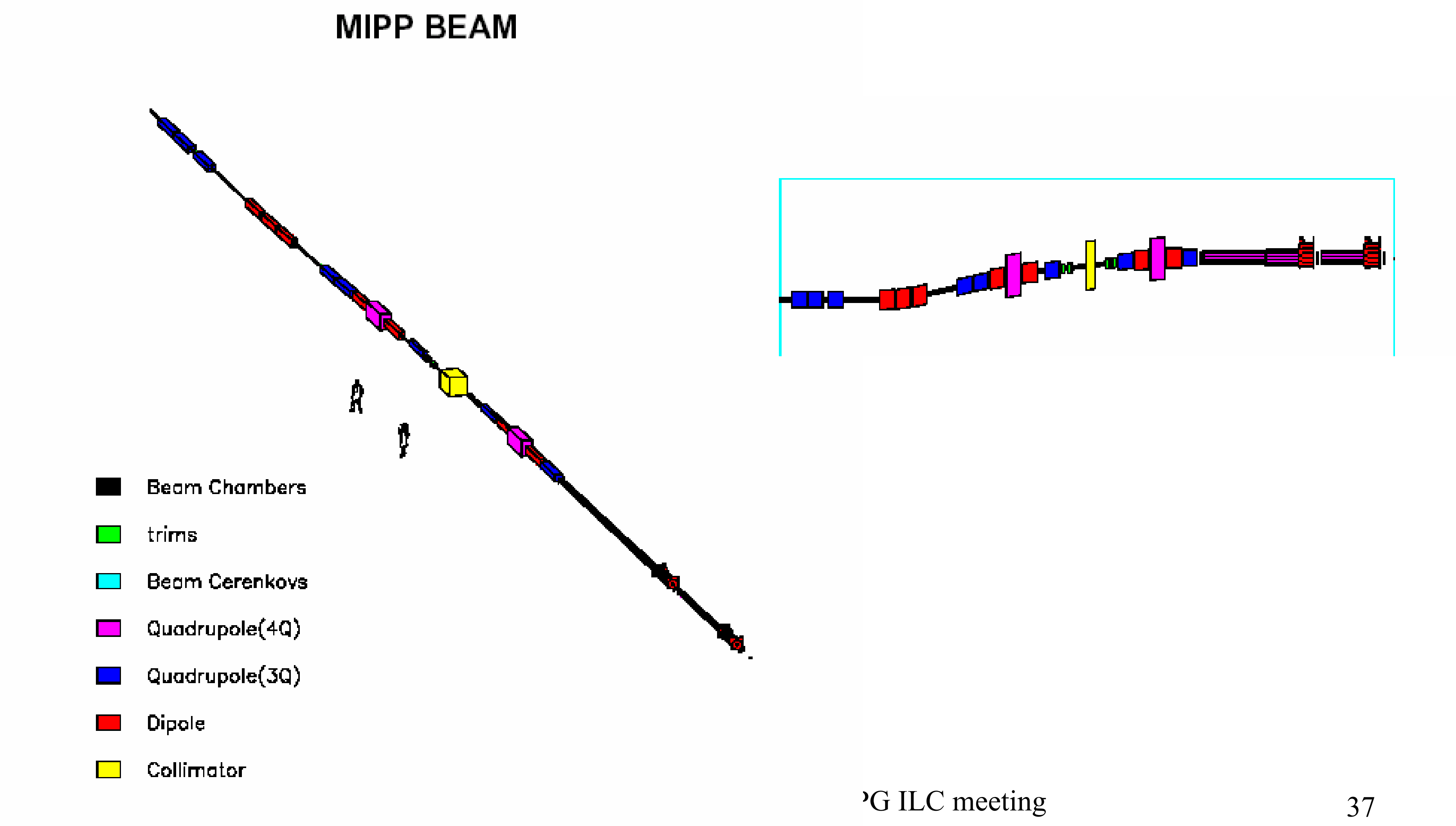
Livermore dropped out. Rest still on proposal. 10 new institutions have joined. More in negotiations. Previous collaboration built MIPP up from ground level. Less to do this time round. More data.

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

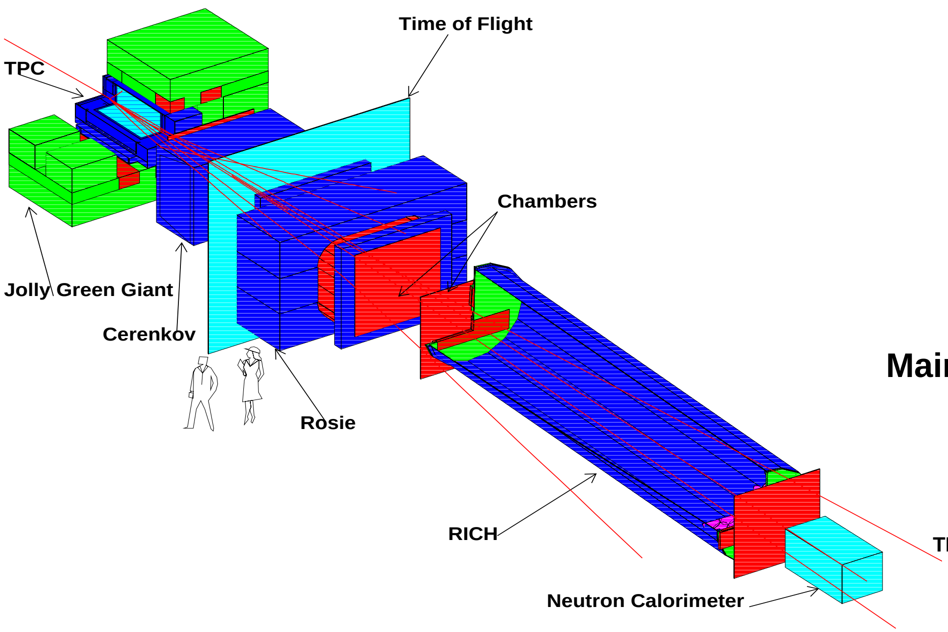
MIPP Secondary Beam

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 (<~10 GeV/c) ToF is used for pid. Design principles and lessons learned used in M-test upgrade.



MIPP

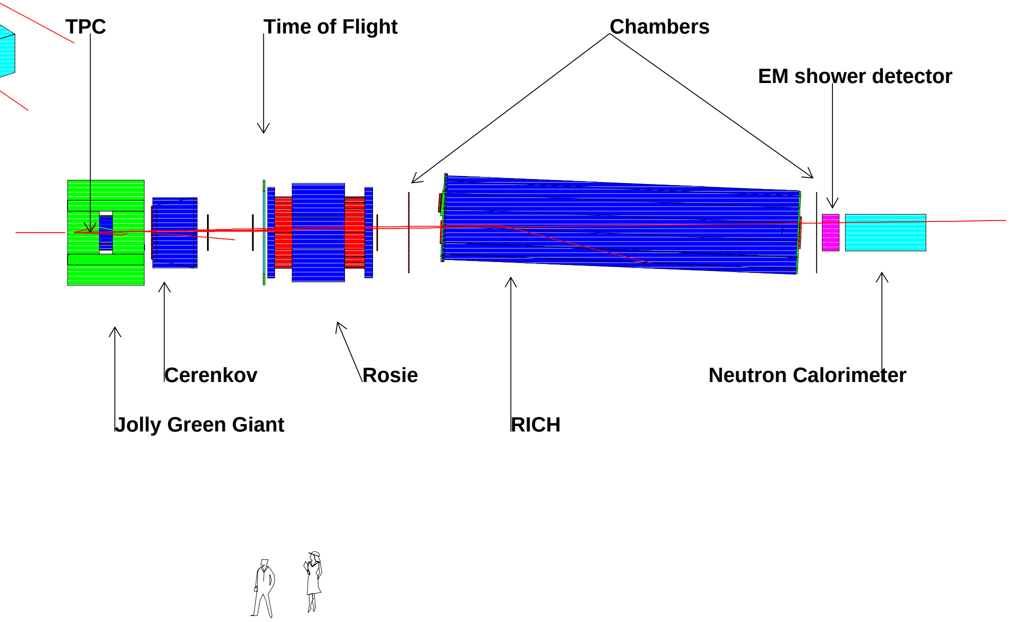
Main Injector Particle Production Experiment (FNAL-E907)



MIPP

Main Injector Particle Production Experiment (FNAL-E907)

Vertical cut plane



Installation in progress- Collision Hall

TPC

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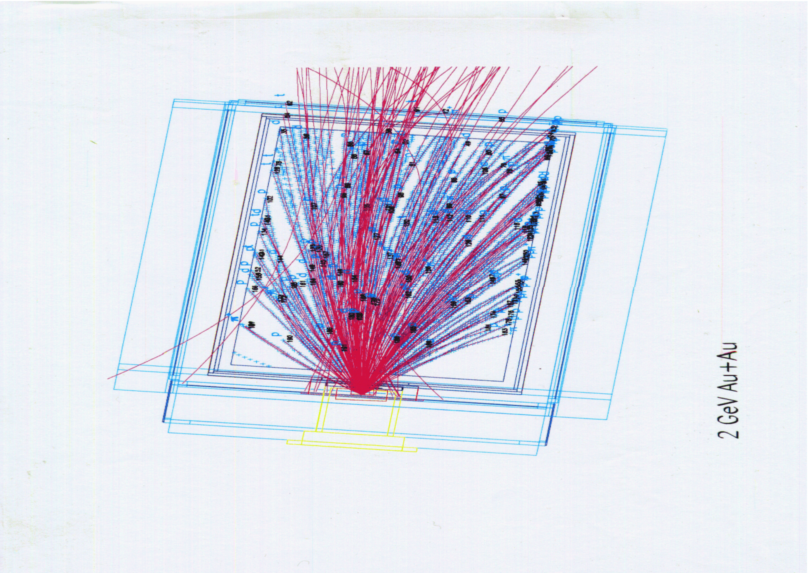
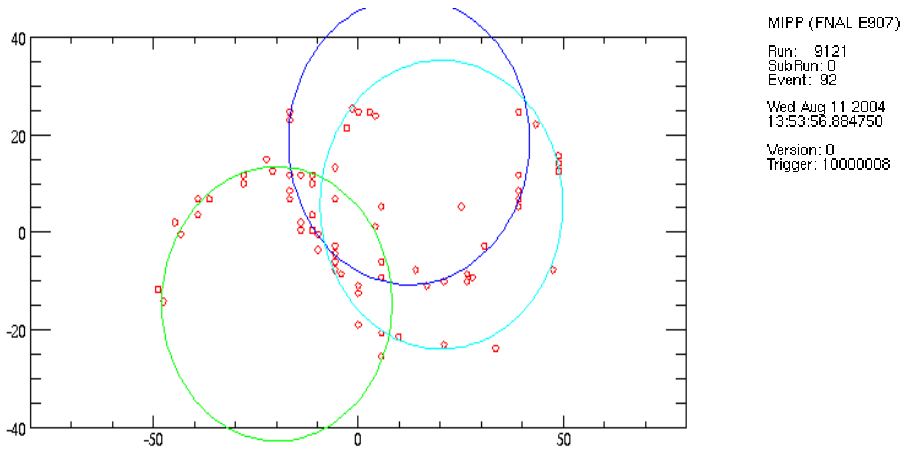
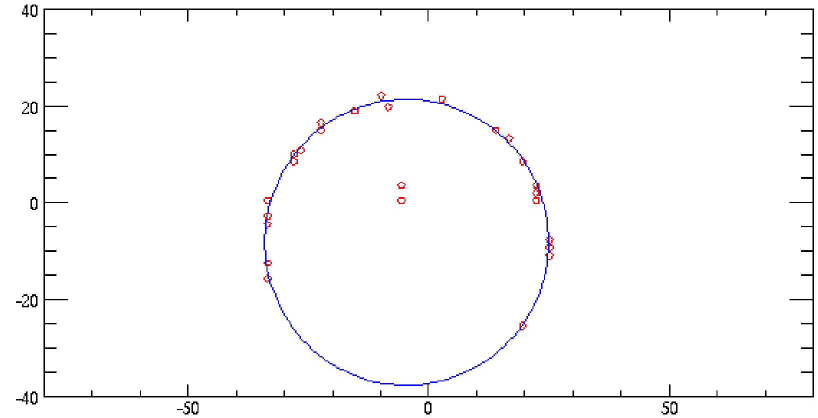
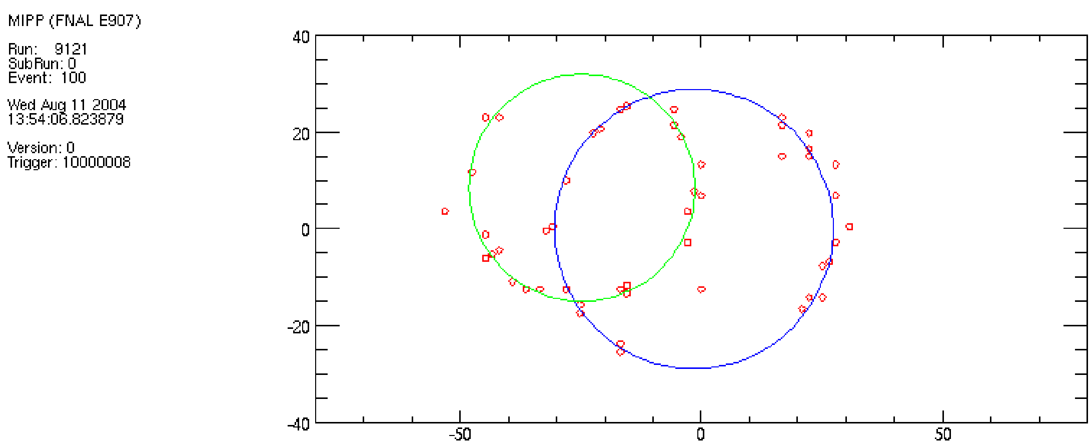


RICH rings pattern recognized

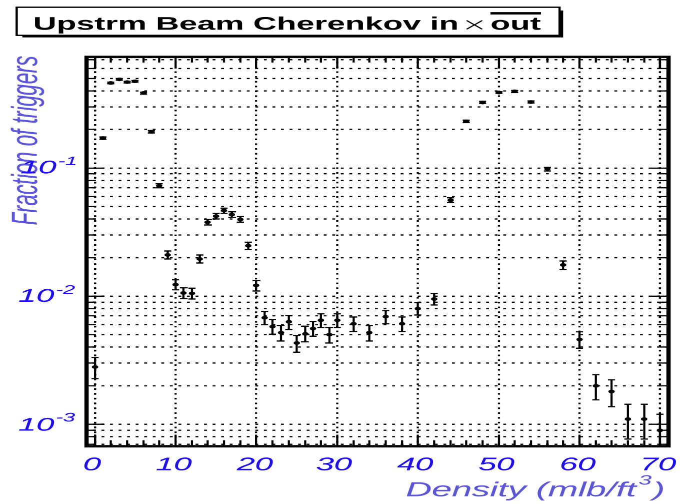


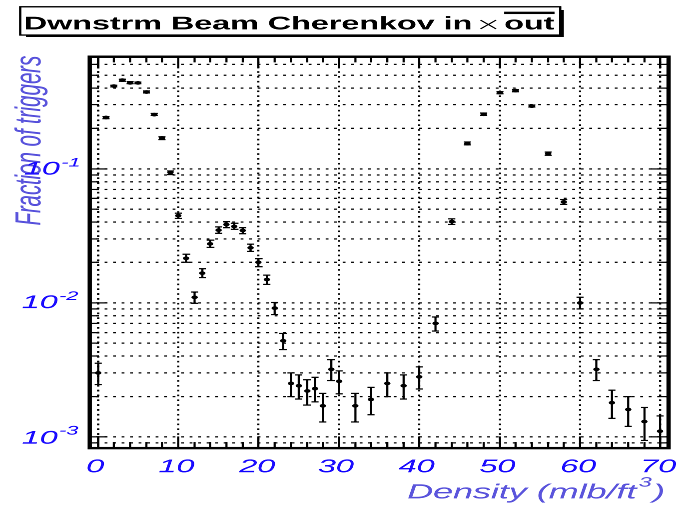




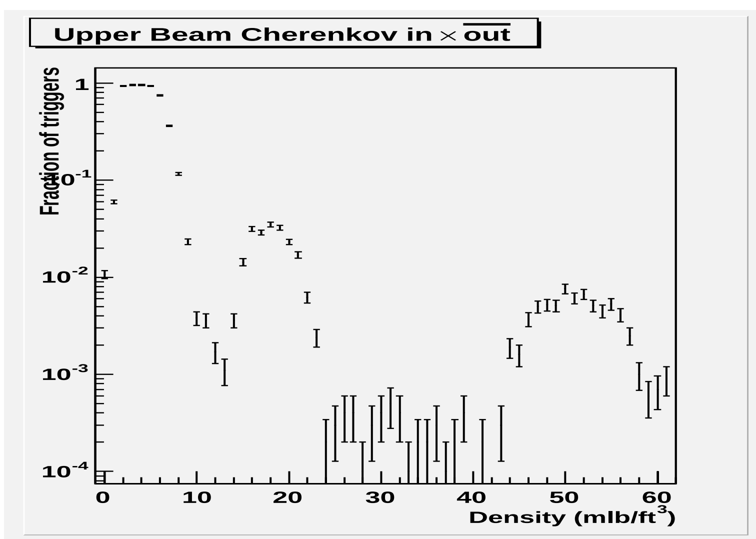
Beam Cherenkovs

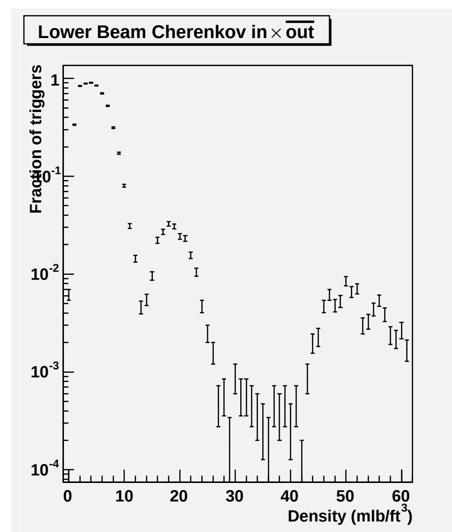
+40 GeV/c



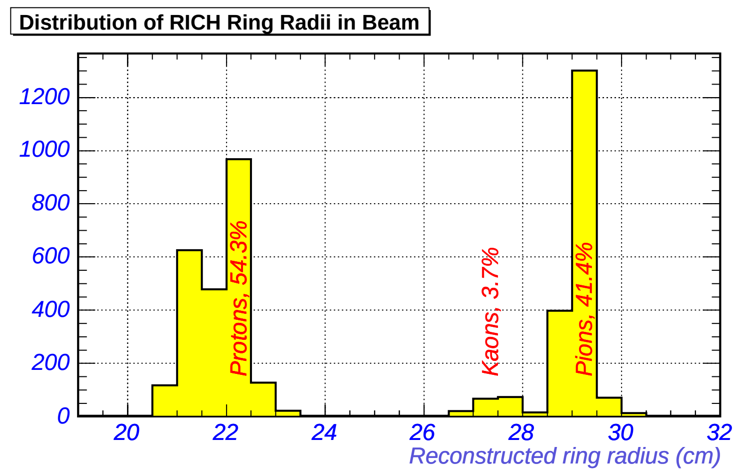


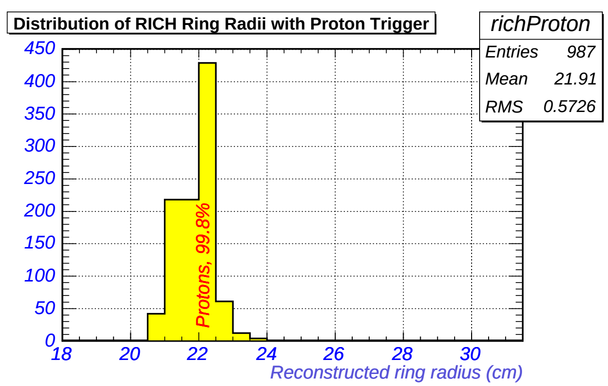
-40 GeV/c

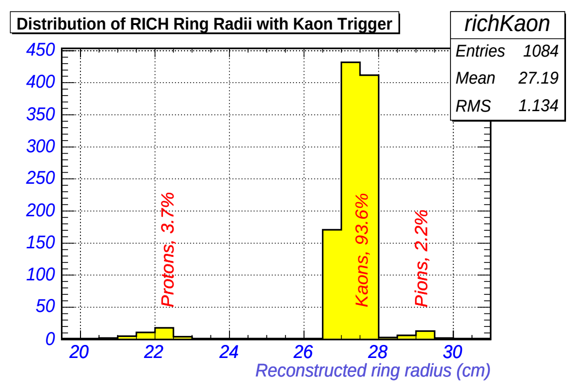


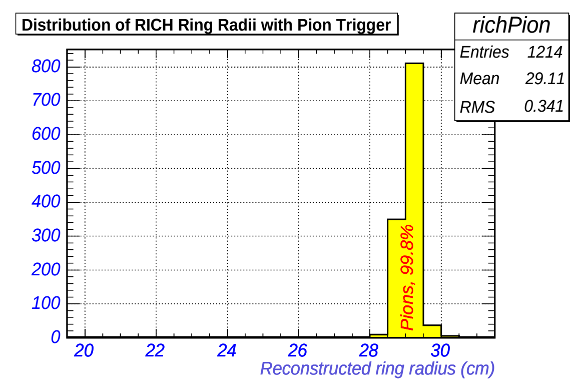


Comparing Beam Cherenkov to RICH for +40 GeV beam triggers-No additional cuts!



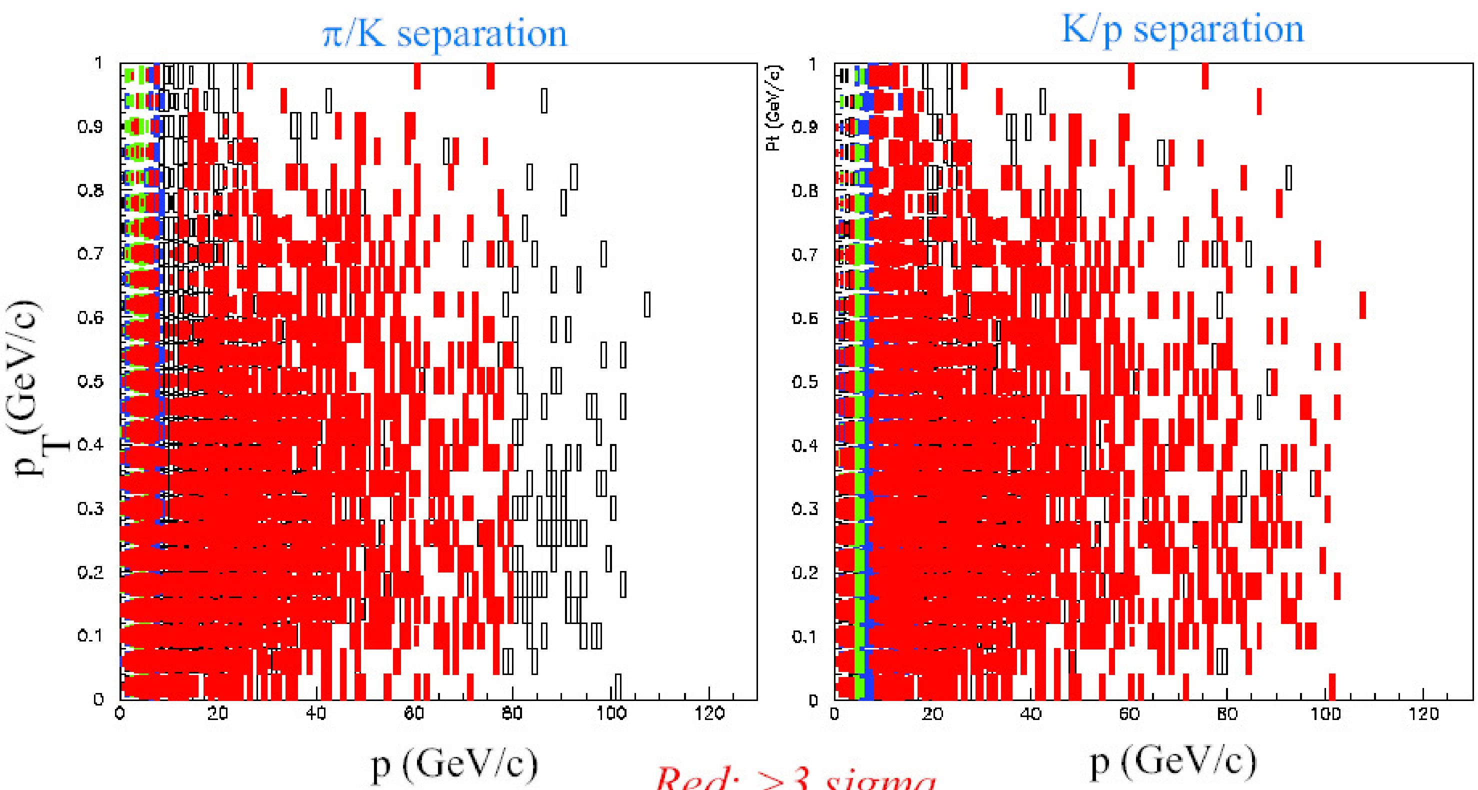






Expected MIPP Particle ID

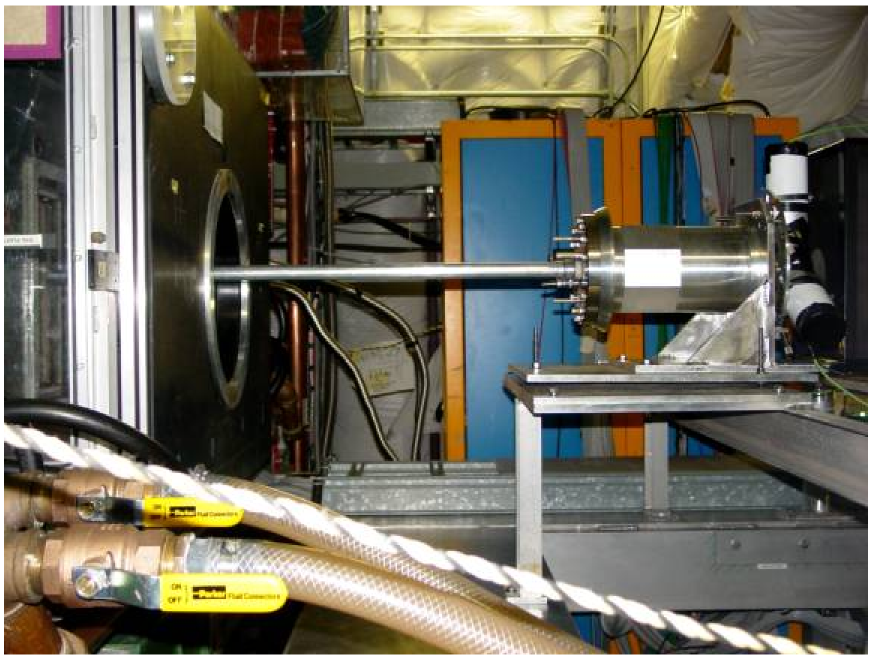
Particle ID Performance

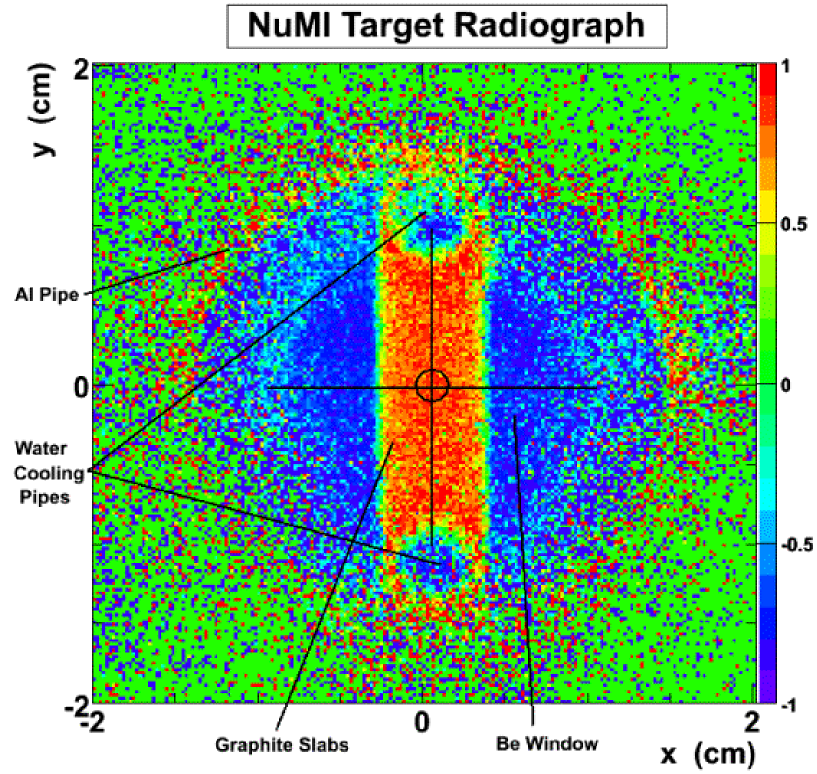


Red: >3 sigma
Green: 2-3 sigma
Blue: 1-2 sigma
White: <1 sigma

I

NUMI target pix



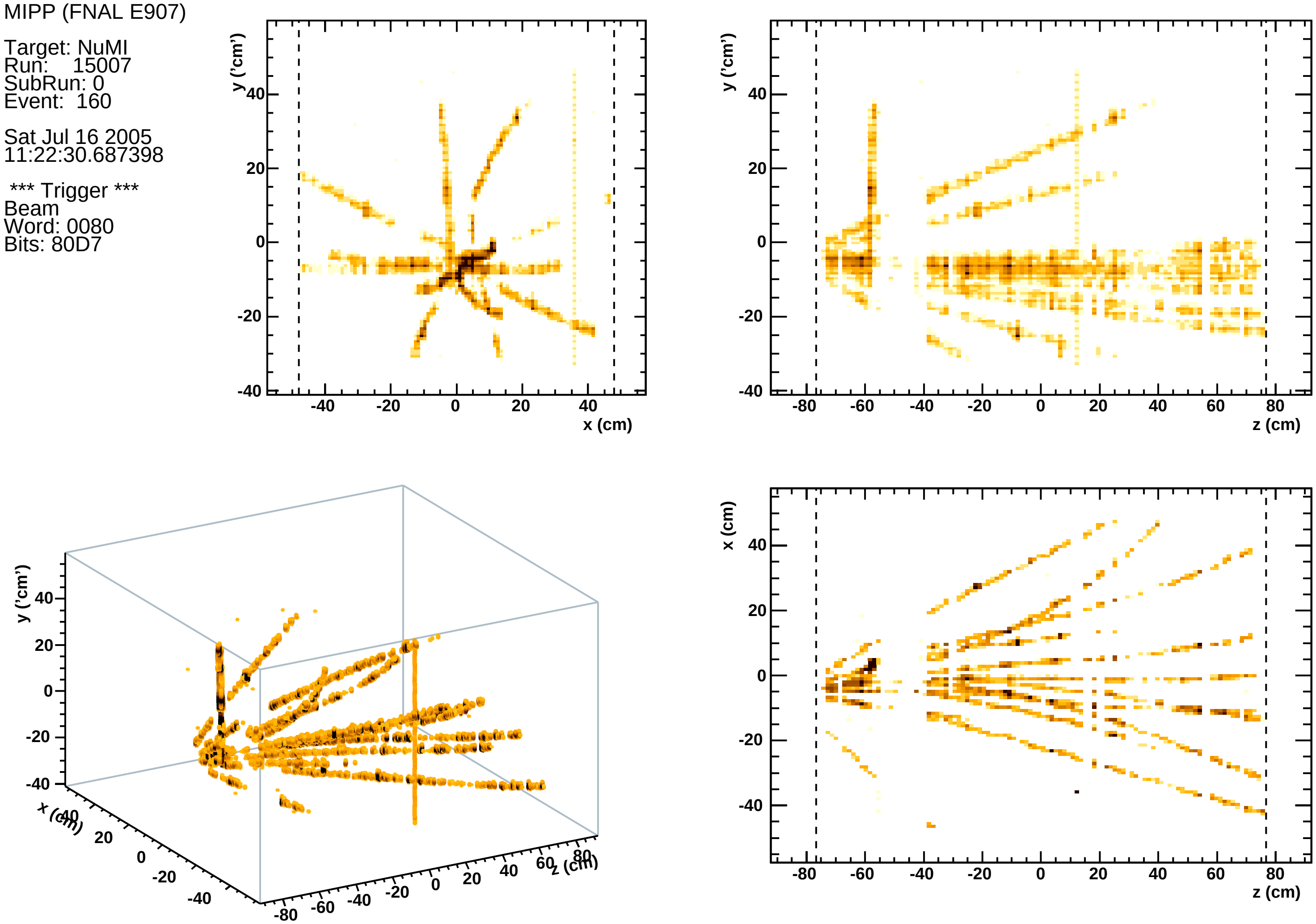


MIPP (FNAL E907)

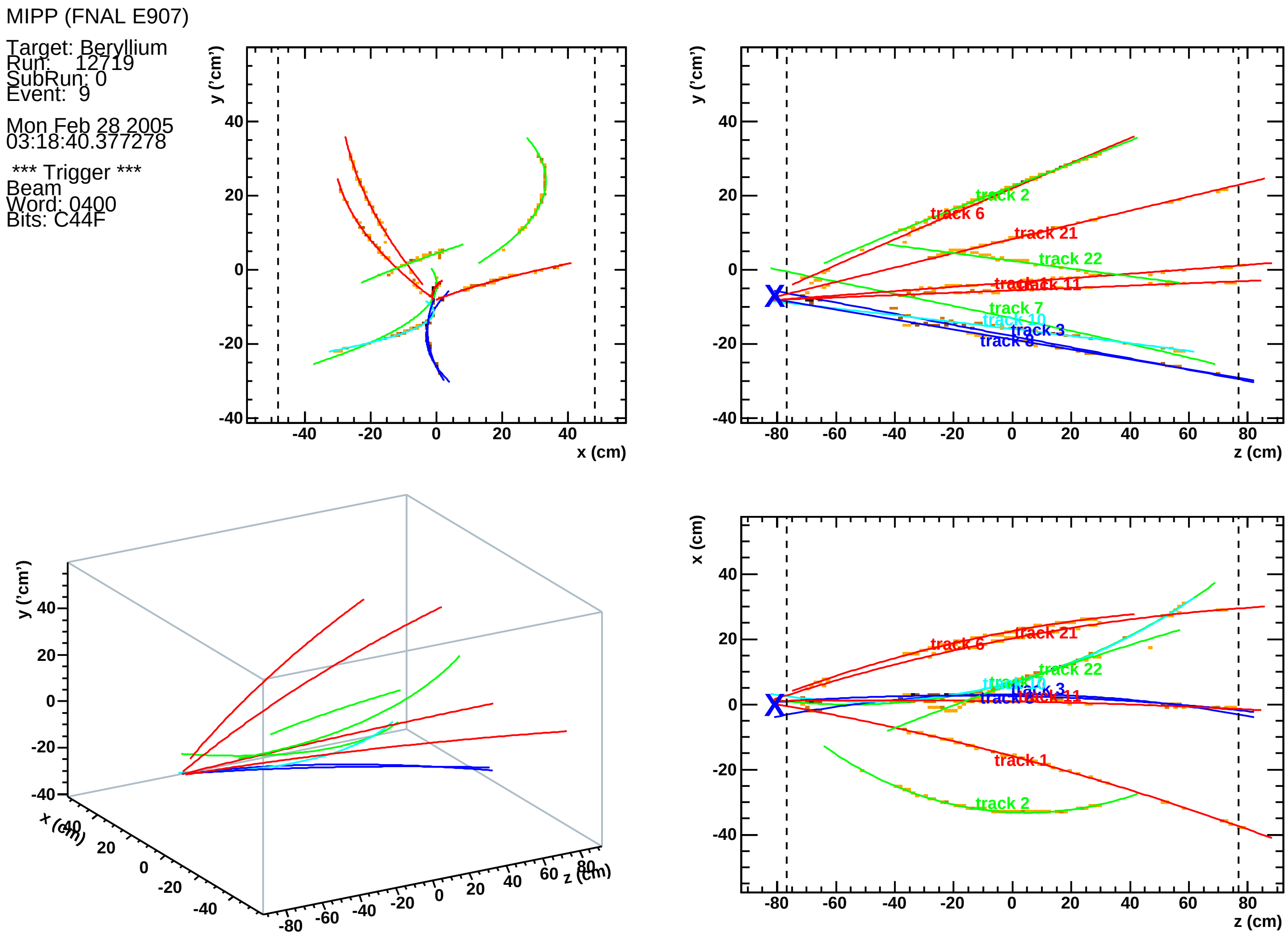
Target: NuMI
Run: 15007
SubRun: 0
Event: 160

Sat Jul 16 2005
11:22:30.687398

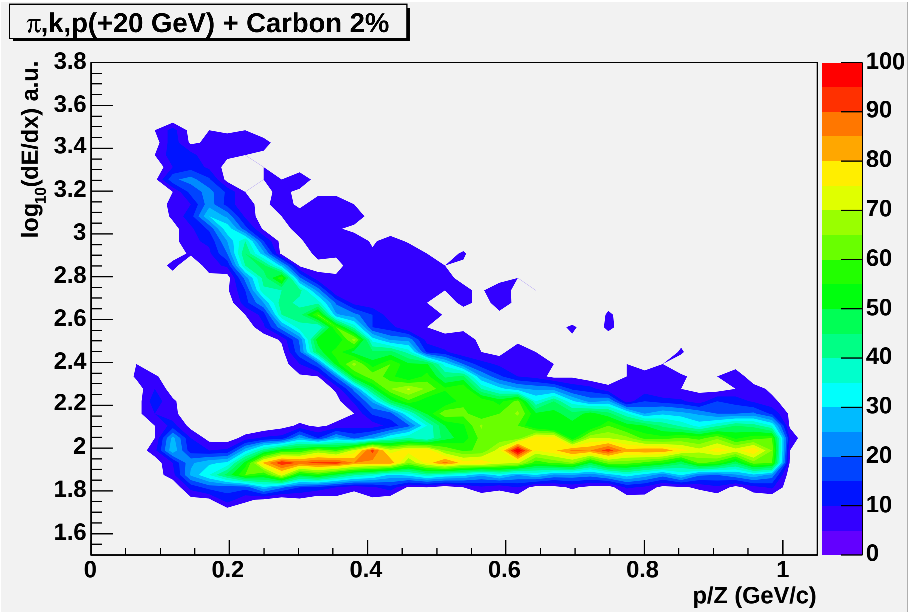
*** Trigger ***
Beam
Word: 0080
Bits: 80D7

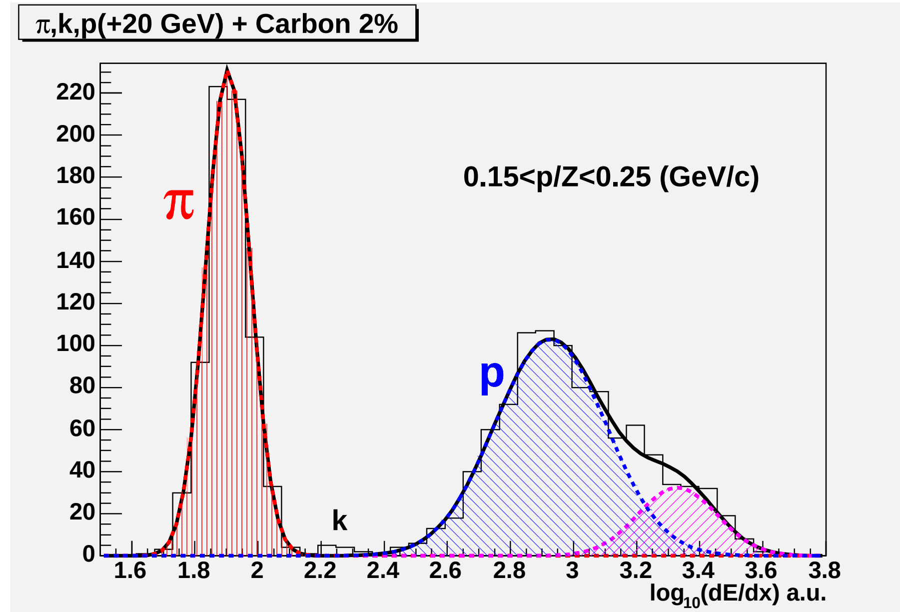


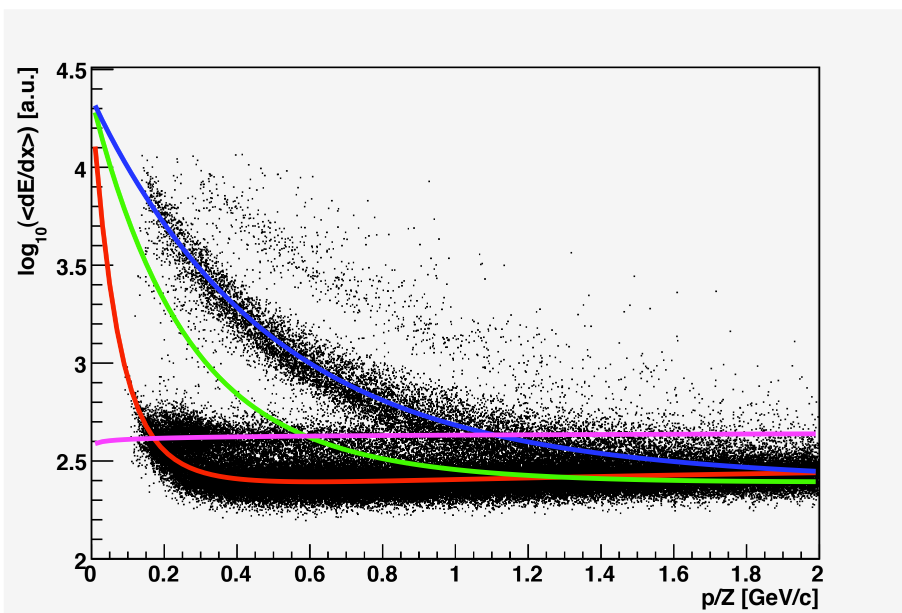
TPC Reconstructed tracks



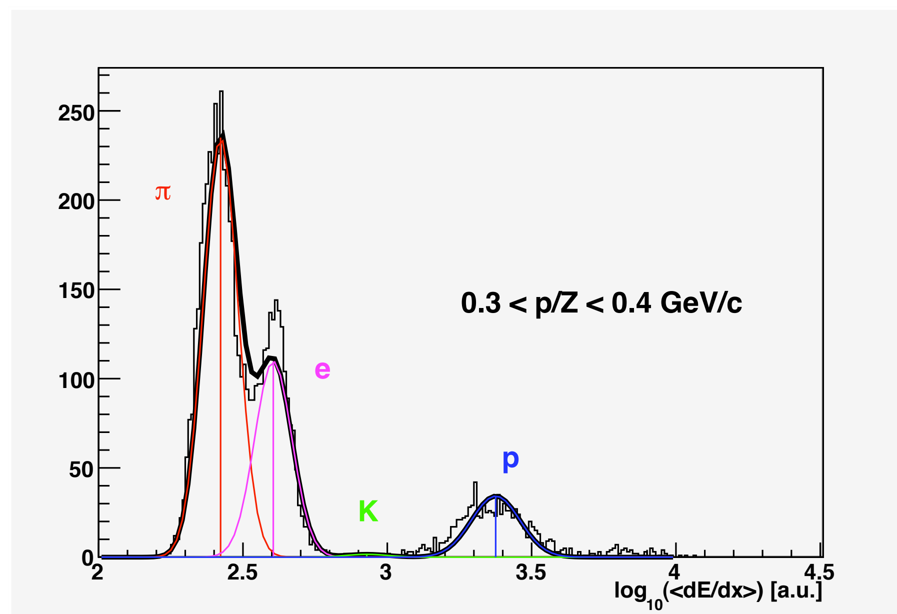
dE/dx in the TPC



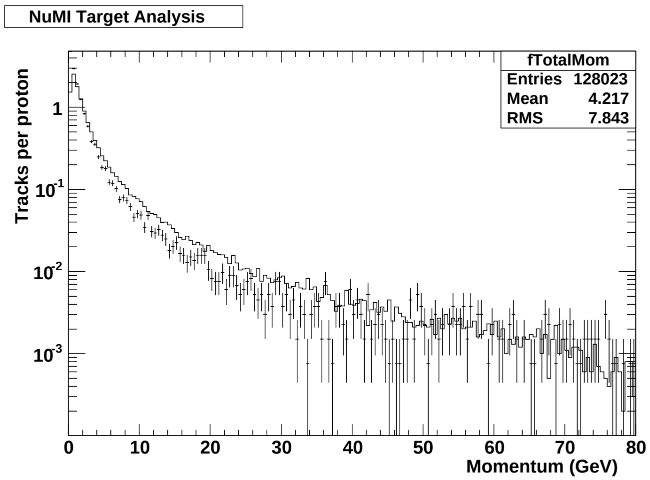


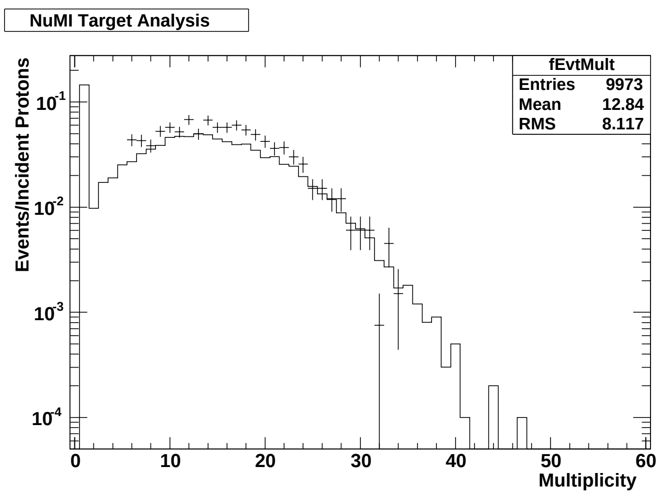


n Raja,

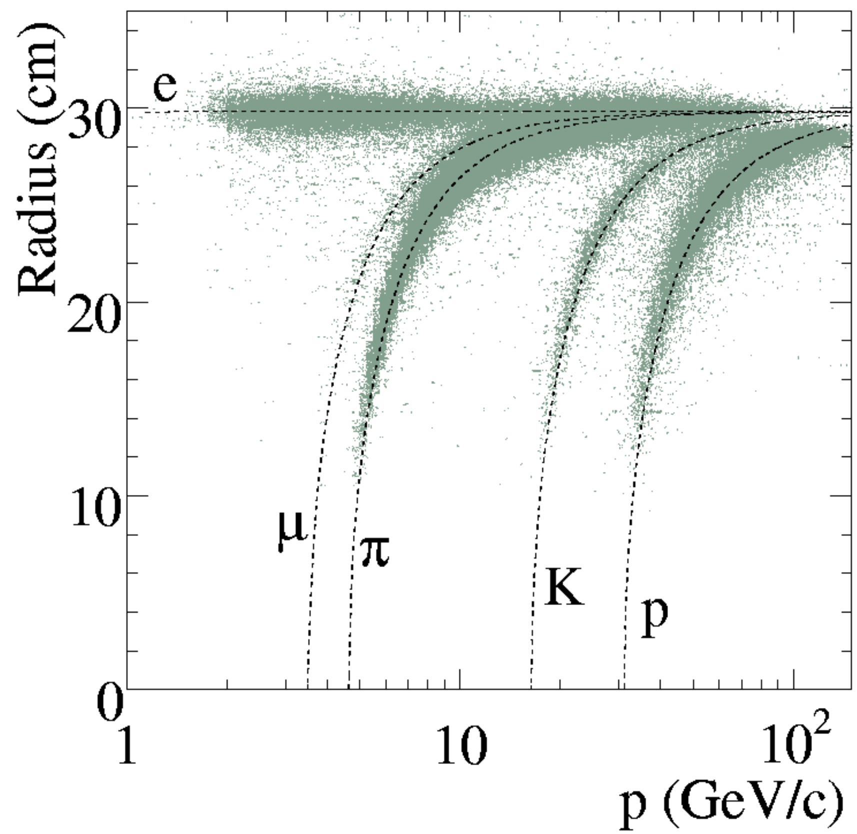


Preliminary Comparison of NUMI target to FLUKA predictions

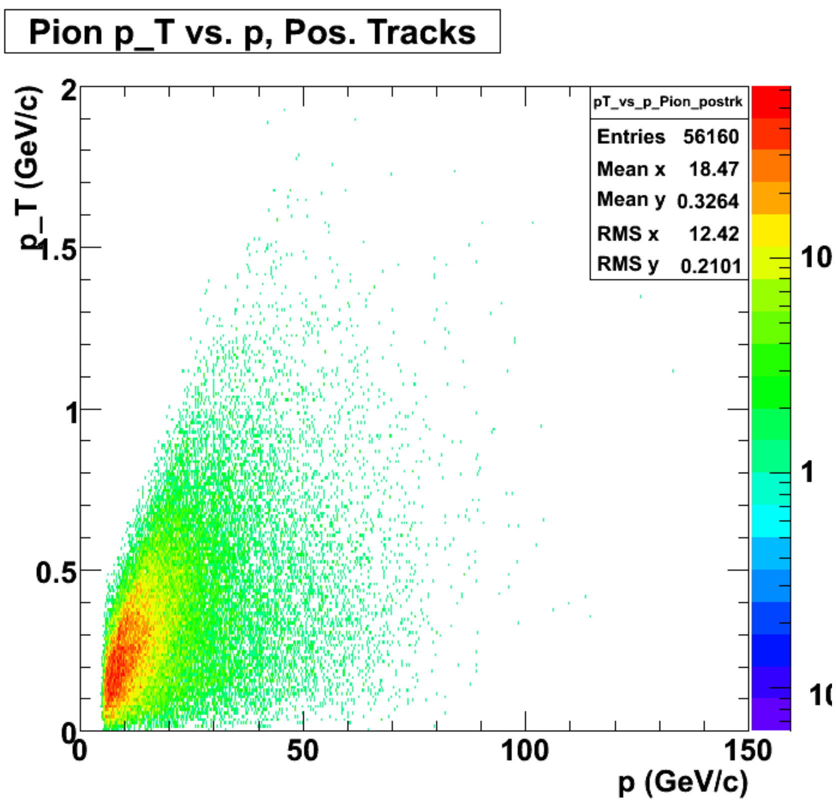


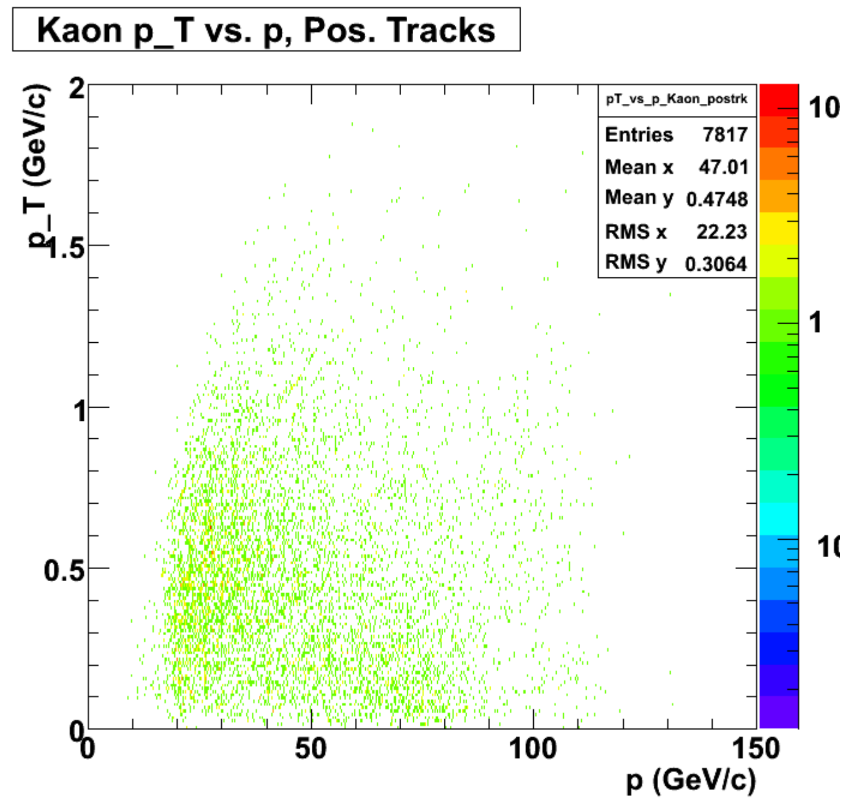


RICH Rings from NUMI target



Particle ID on NUMI target





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**

The Proposal in a nutshell

- MIPP one can take data at ~30Hz. 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 5GeV/c-85GeV/c. We plan to run it from ~1 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.
- 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

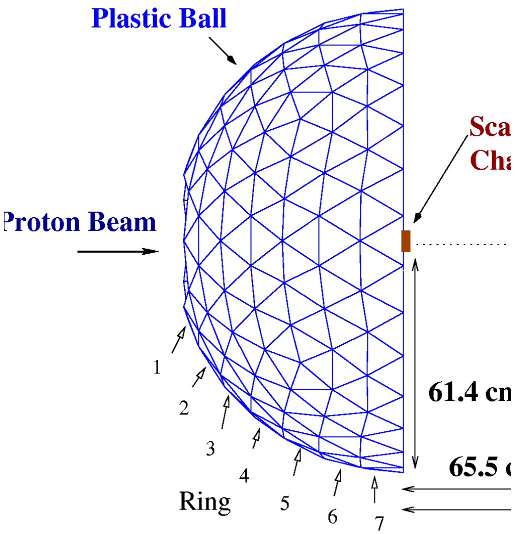
Spallation products

- 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	Evaportion 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.

The recoil detector



3.3. Plastic Ball 31

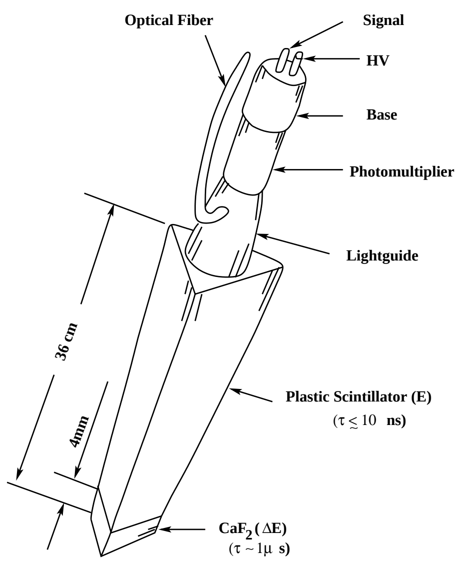
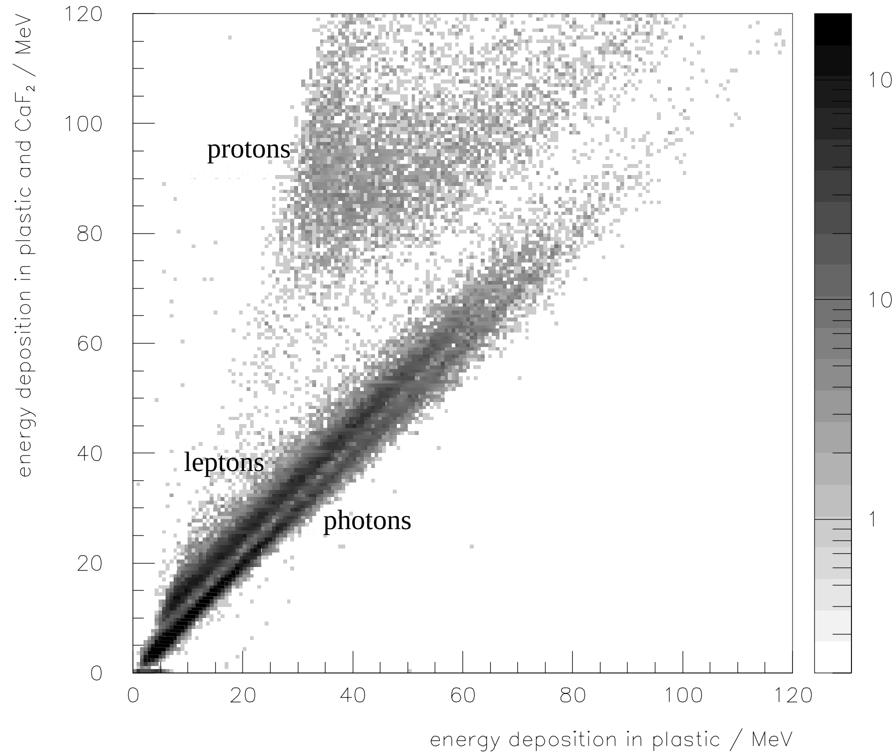


Figure 3.5: Schematic drawing of an individual Plastic Ball detector.



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

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 ($\pi^{\pm}$,$K^{\pm}$,$p^{\pm}$) 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

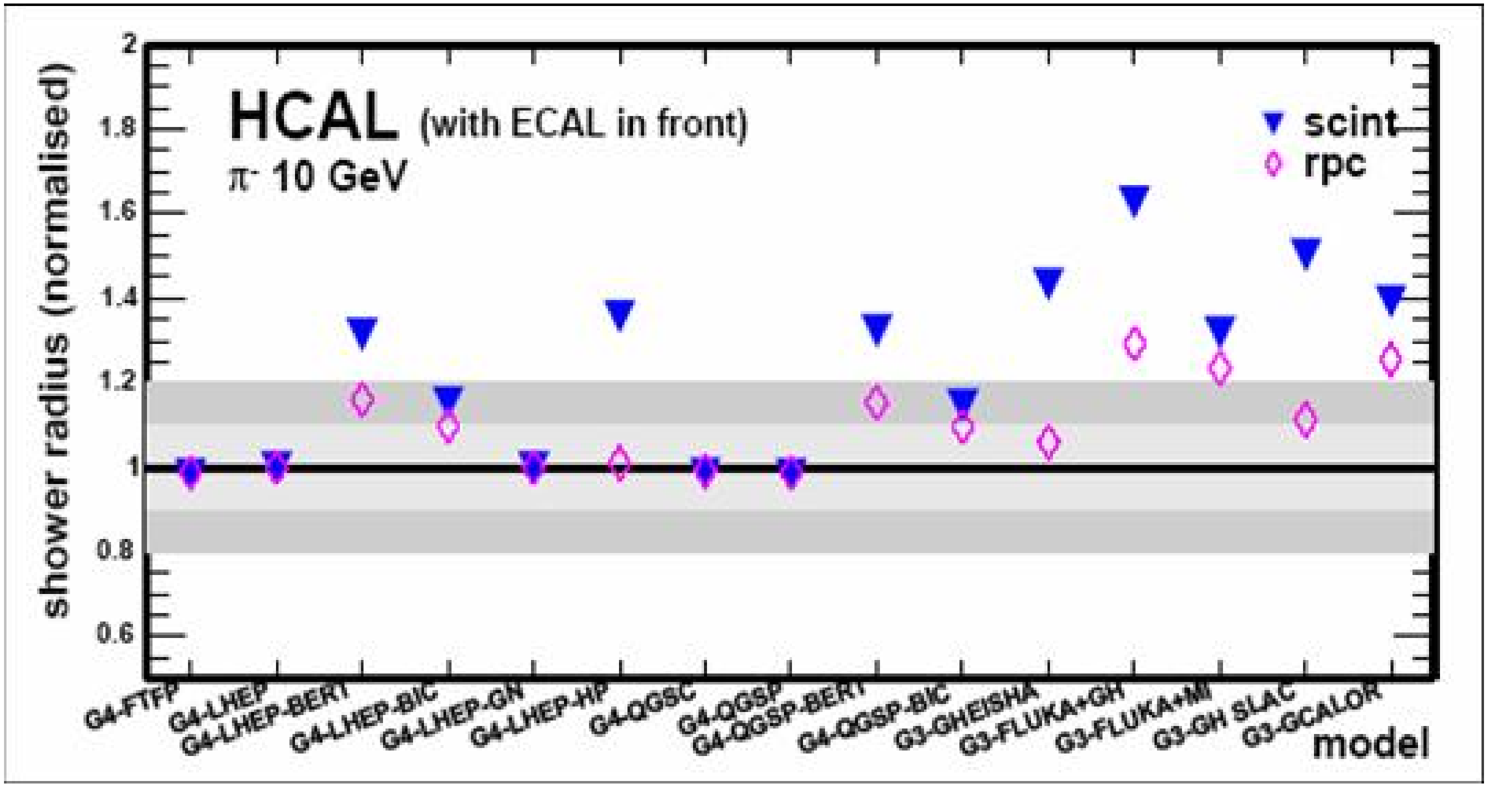
Nuclei	beam species	momentum bins	events/bin	tracks/event	words/track
30	6	10	100000	10	5

Number of events	1.80E+08	Number of days	36
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.
-

ILC needs

- Particle flow algorithm needs to distinguish neutral and charged energy deposits in the calorimeter. Depending on simulator used, the shower radius of a charged pion shower varies by as much as 60% in a calorimeter.



Tagged neutron and K-long beams in MIPP-For ILC Particle flow algorithm studies

- MIPP Spectrometer permits a high statistics neutron and K-long beams generated on the LH2 target that can be tagged by constrained fitting. The neutron and K-long momenta can be known to better than 2%. The energy of the neutron (K-long) can be varied by changing the incoming proton(K^+) momentum. The reactions involved are

$$pp \to pn\pi^+$$

$$K^+p \to pK_L^0\pi^+$$

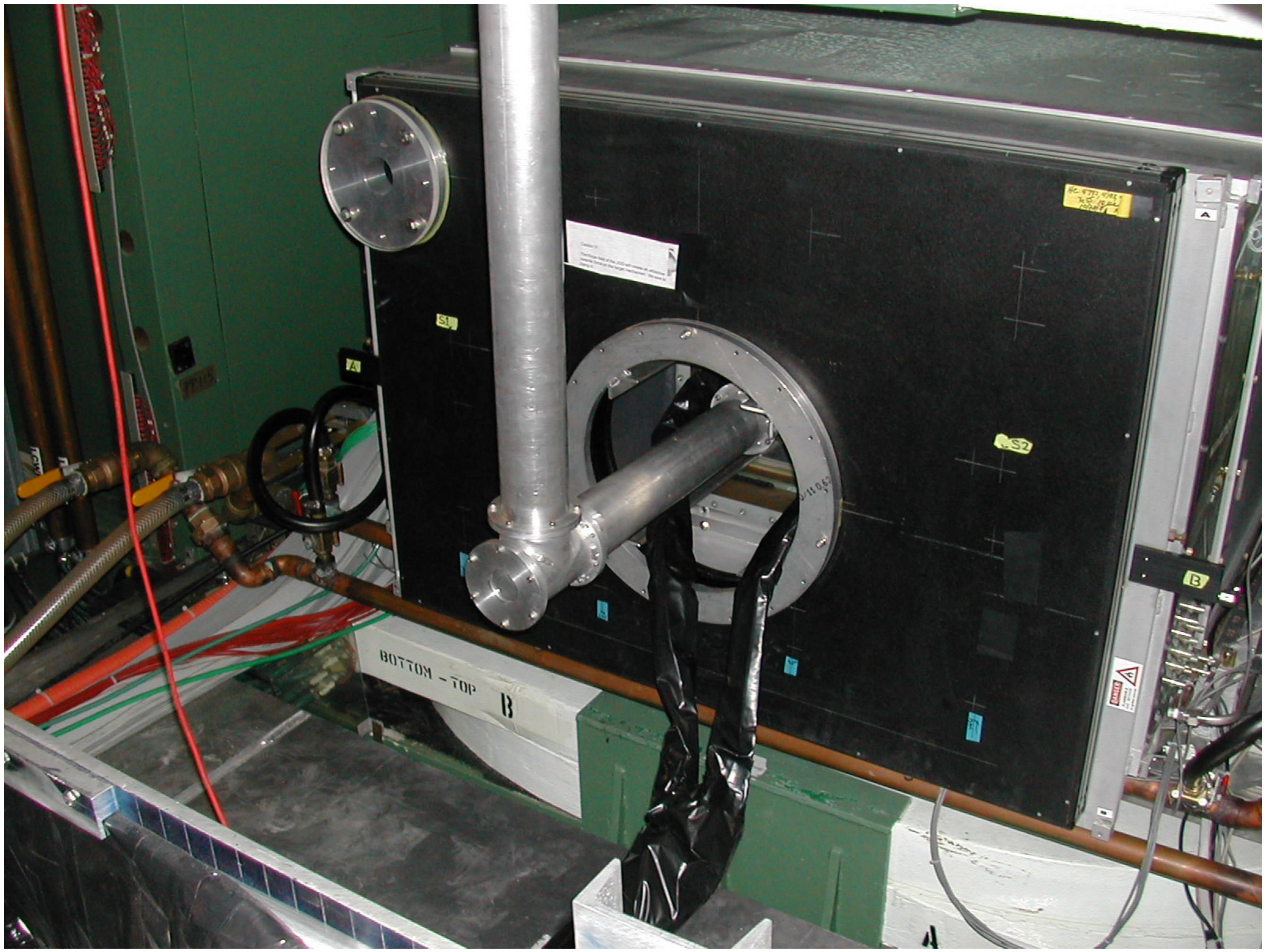
$$K^-p \to pK_L^0\pi^-$$

$$\bar{p}p \to \bar{n}\pi^-p$$

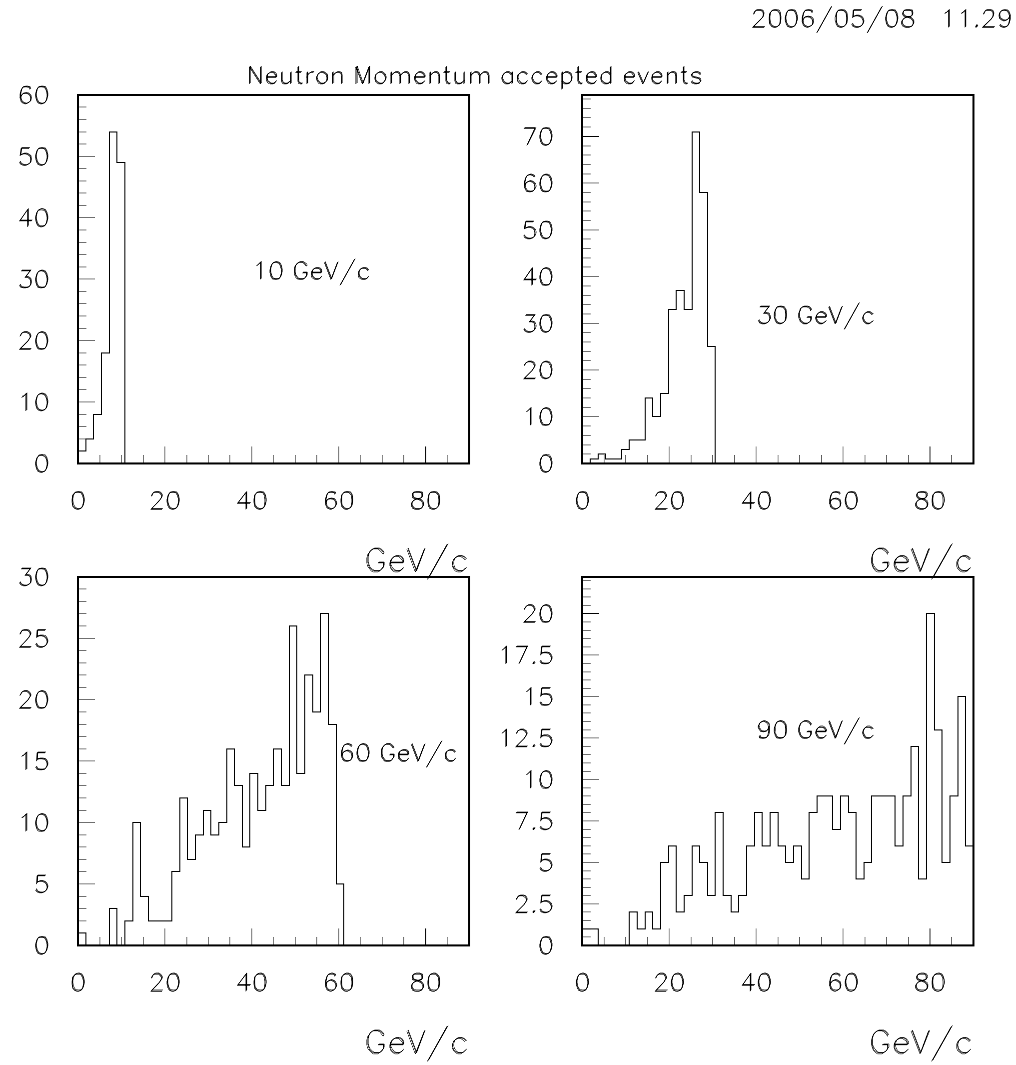
See R.Raja-MIPP Note 130

~50K tagged neutrons per day

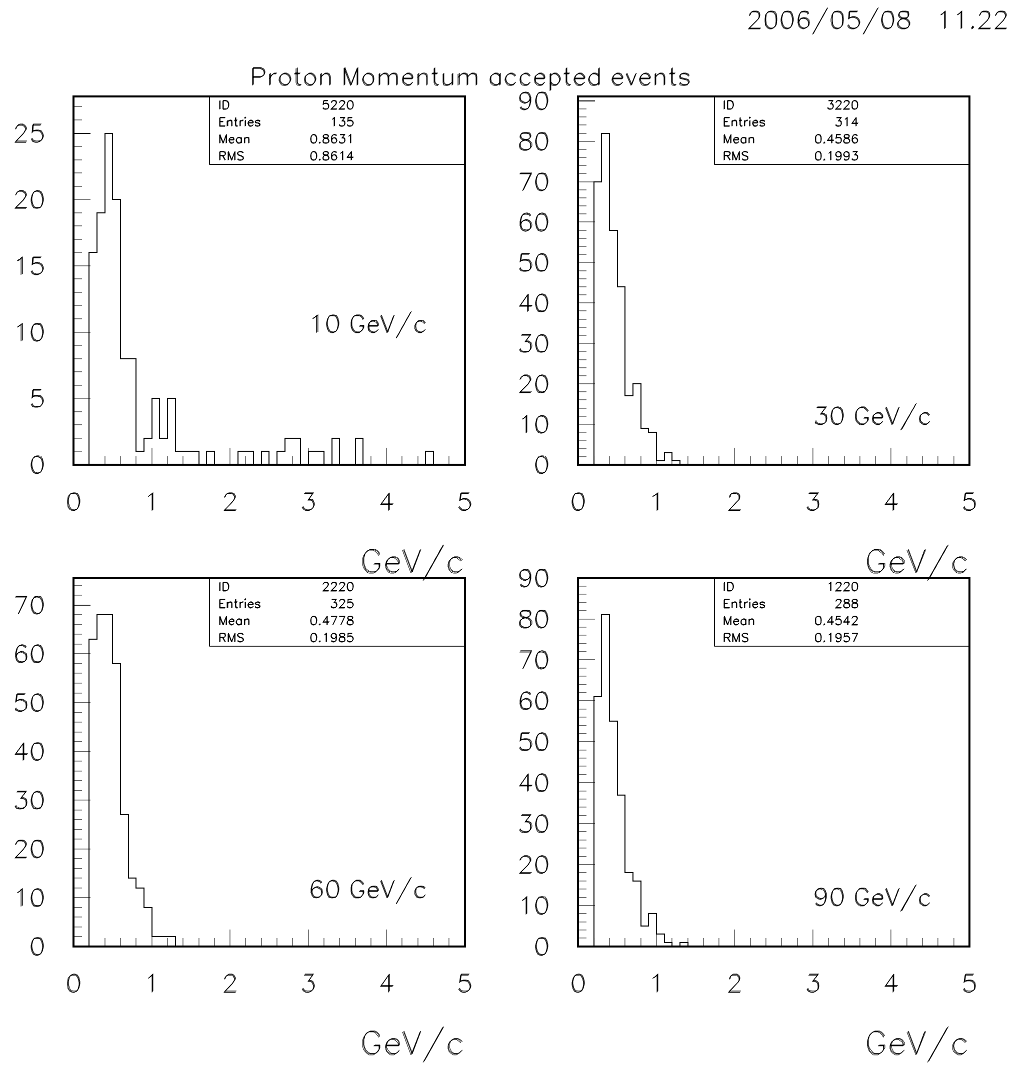
MIPP LH_2 target



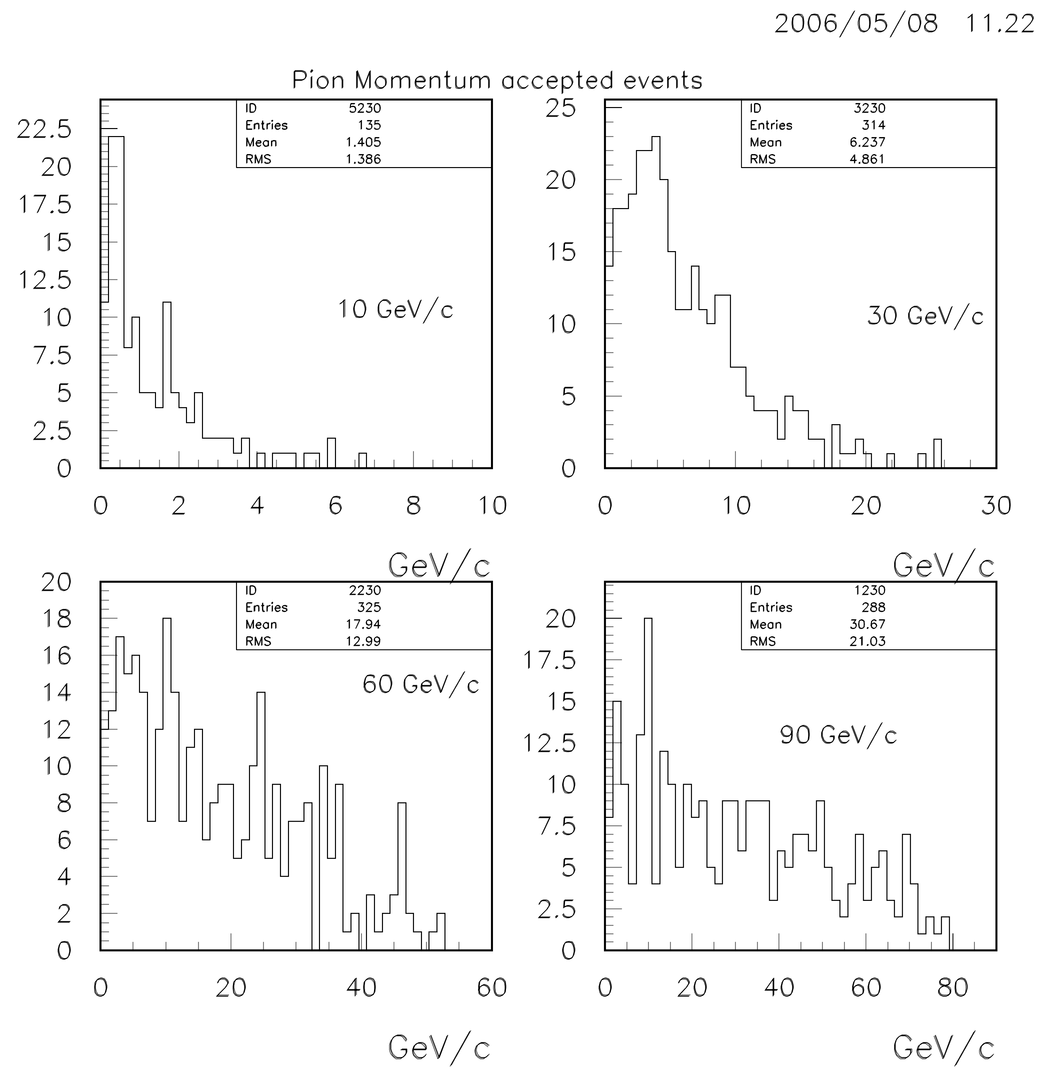
Neutron spectra for various beam momenta



Proton spectra for various beam momenta



Pion spectra for various beam momenta



Expected tagged neutral beam rates

Beam Momentum GeV/c	Proton Beam n/day	K+ beam K-Long/day	K- beam K-Long/day	Antiproton beam anti-n/day
10	20532	4400	4425	6650
20	52581	9000	9400	11450
30	66511	12375	14175	13500
60	47069	15750	14125	13550
90	37600			

General scaling law of particle fragmentation

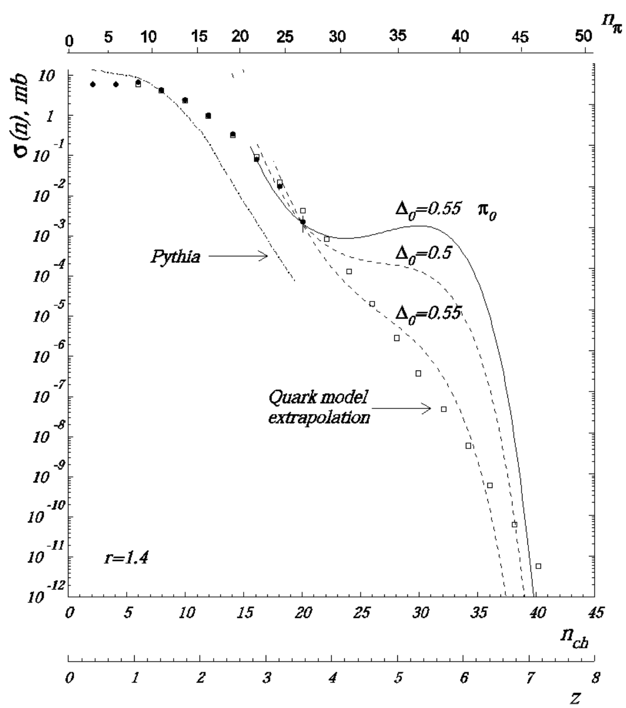
- States that the ratio of a semi-inclusive cross section to an inclusive cross section

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

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

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- y scaling, propagation of strangeness through nuclei. Measure spallation products.

Missing baryon Resonances

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

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

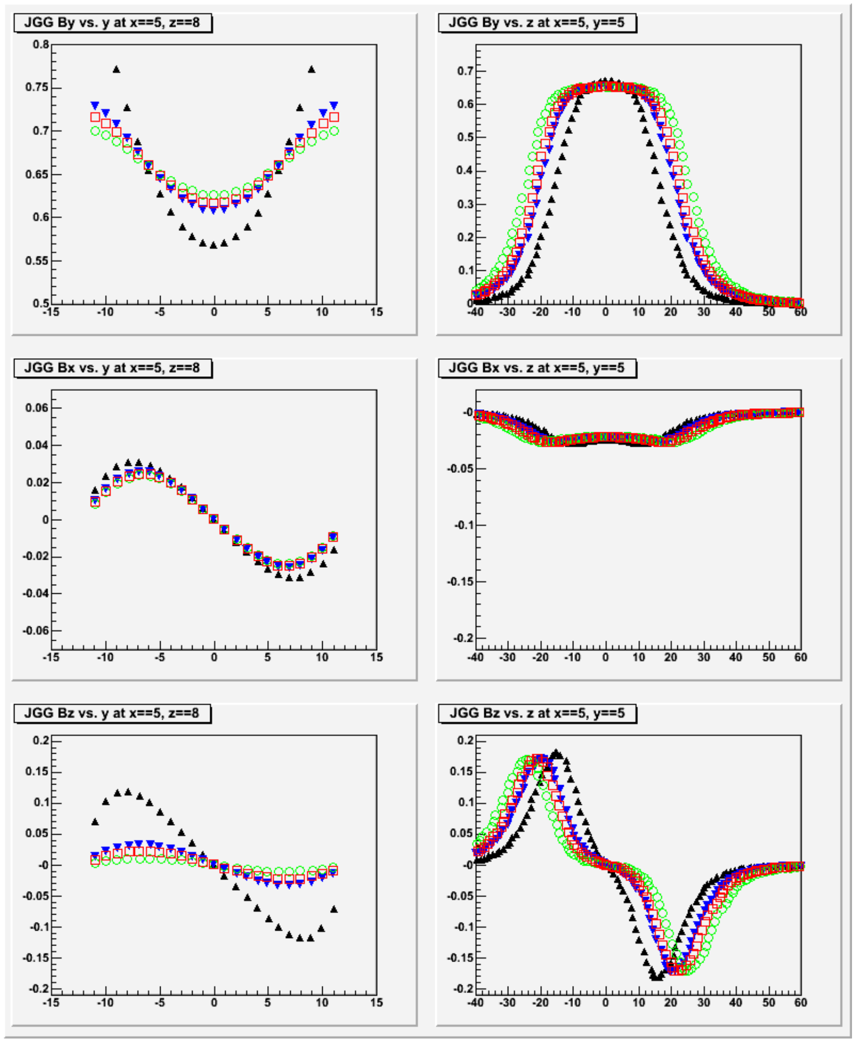
$$\gamma p \to \pi^0 p; \gamma p \to K^+ \Lambda; \gamma p \to \pi^+ \pi^- p$$

- 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? F.Wilczek, A. Selem
- "..this could form the quantitative foundation for an effective theory of hadrons based on flux tubes"- F.Wilczek

Upgrade in some detail- JGG repair

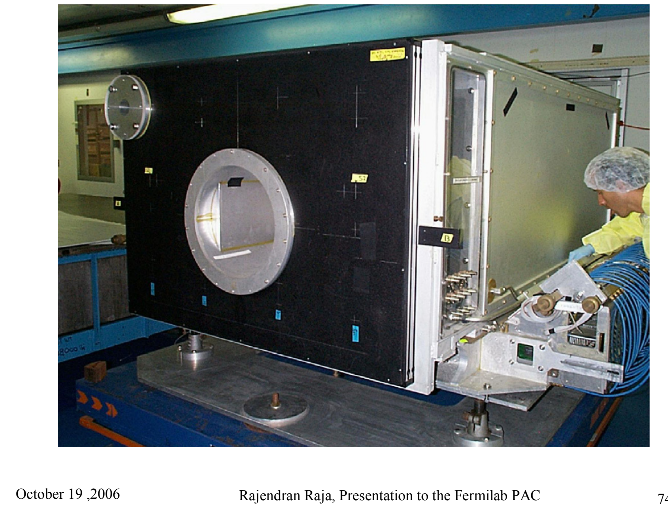
- Field calculations.
- Blue triangles current field.
- Inverted blue triangles 9" extension in z.
- Squares, circles show coils that are +12", +18" longer in z.
- 9" longer coils chosen.
- Much better ExB effects in the TPC. Distortions lower by a factor of 2.
- Coils made of Aluminum.
- Coils ordered.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

- Costs include no contingency at this stage. Probably need to add 20% contingency.



TPC Electronics Upgrade

15,360 pads in TPC. 16μs 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 ~ 110kBytes 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 ~30Hz.

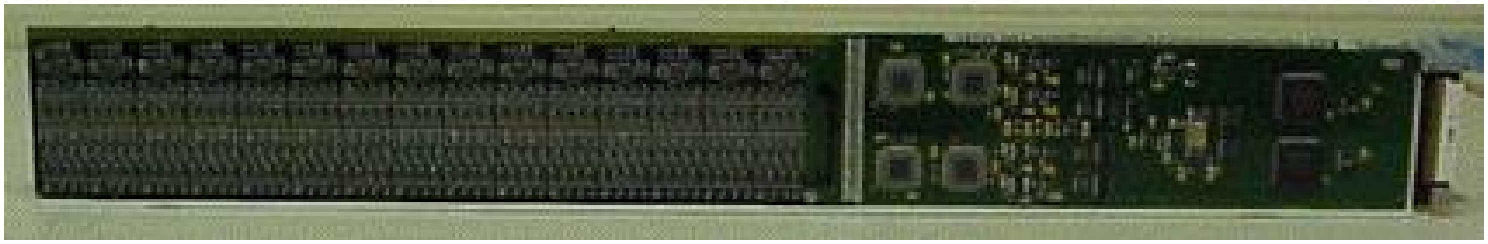


Redesign with ALICE ALTRO/PASA chips with inbuilt zero suppression can produce a readout working at 3kHz. A factor of 100 in speed.

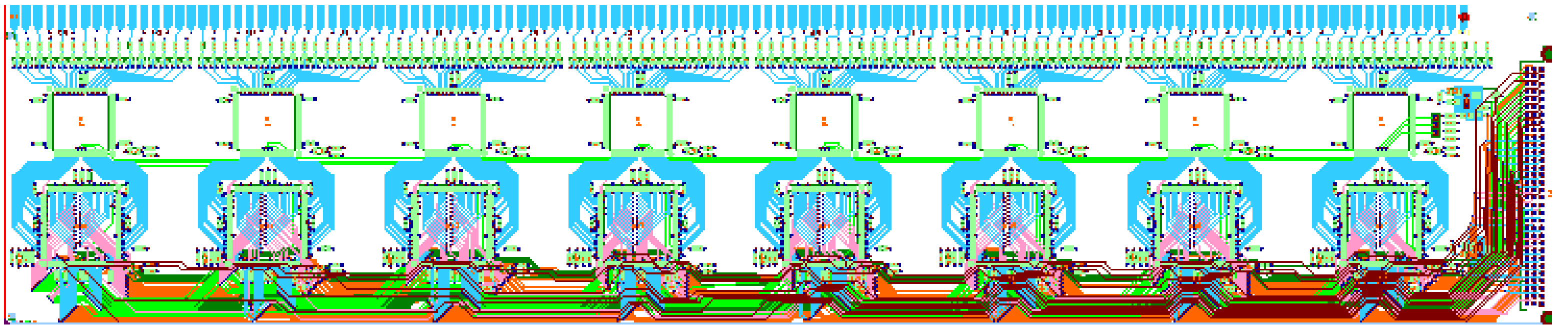
10 times more data using 10 times less beam time!

TPC electronics upgrade

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

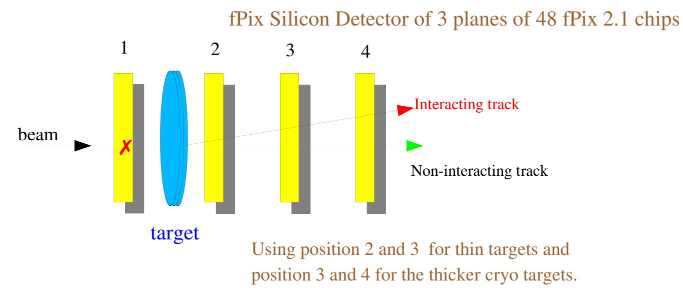


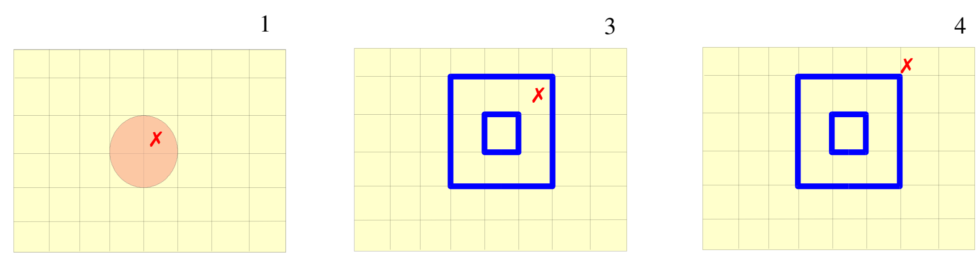
- New MIPP TPC "stick" layout using ALTRO/PASA chips.



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.





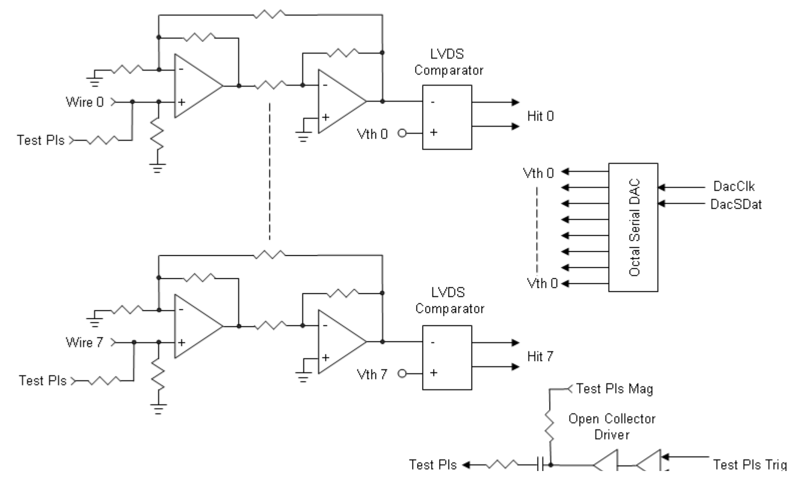
First layer before target tags where beam is and that there was only 1 hit cell. Brown circle represents where 86% of the beam hits the 4 cells in the center.

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

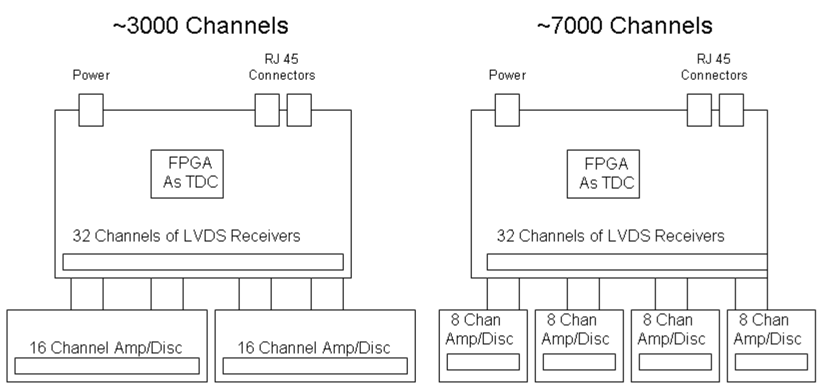
Drift Chamber/ PWC readout Upgrade

- 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

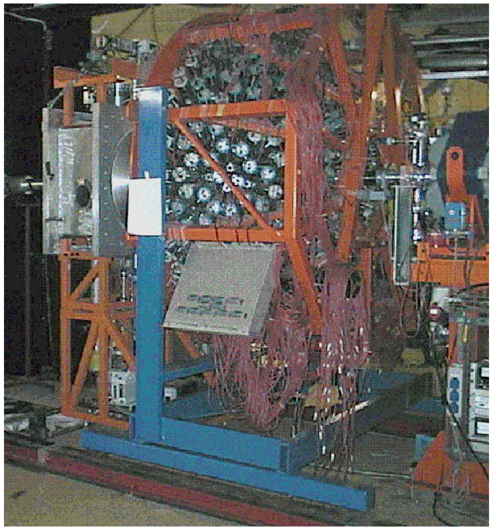


High-Speed Differential Interfaces
"Cyclone II devices can transmit and receive data through LVDS signals at a data rate of up to 640 Mbps and 805 Mbps, respectively. For the LVDS transmitter and receiver, the Cyclone II device's input and output pins support serialization and deserialization through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



Plastic Ball Recoil detector

- Plastic ball detector is avaliable. GSI/KVI have joined MIPP. We will install a hemisphere in MIPP. Mounting details to be worked out. Need the ability to remove the detector to repair it and the TPC.
- Transportation to Fermilab.
- GSI/KVI will play a lead role in making this happen
- Detector will help in all aspects of MIPP data including tagged neutral beams, missing baryon resonances and hadronic shower simulation data.



Picture of the full plastic ball at KVI

WBS task 10 Fermi M&s $0

Labor $25.9K, In Kind $55K

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

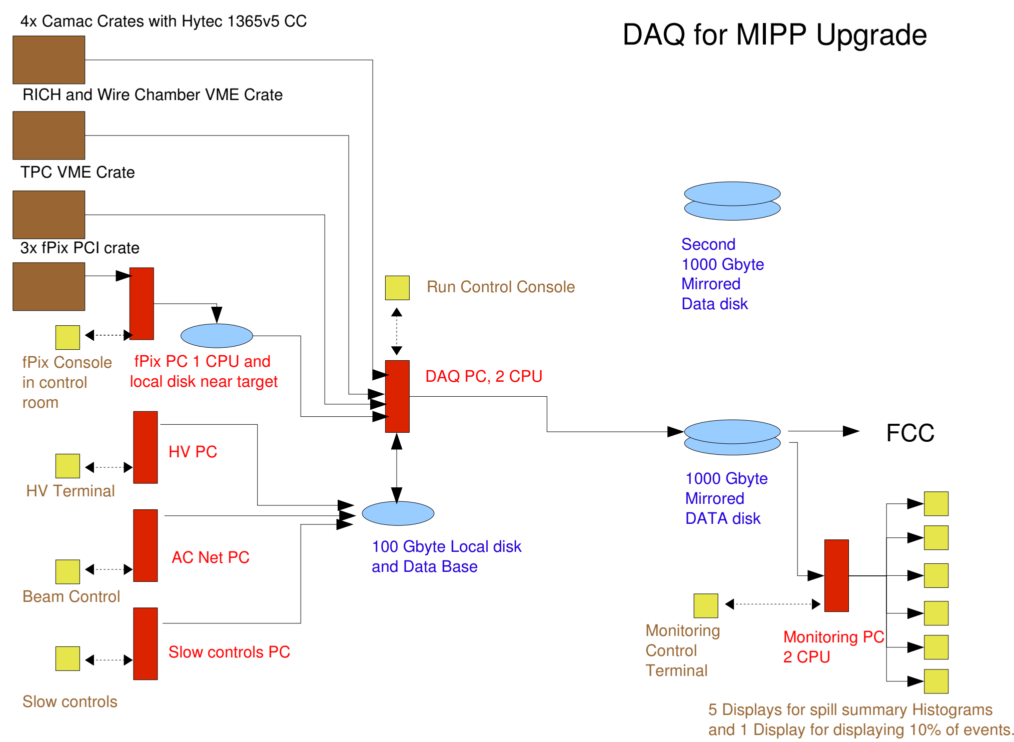
Beam Line Upgrade

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

WBS task 8 M&S $56K

MIPP DAQ System upgrade

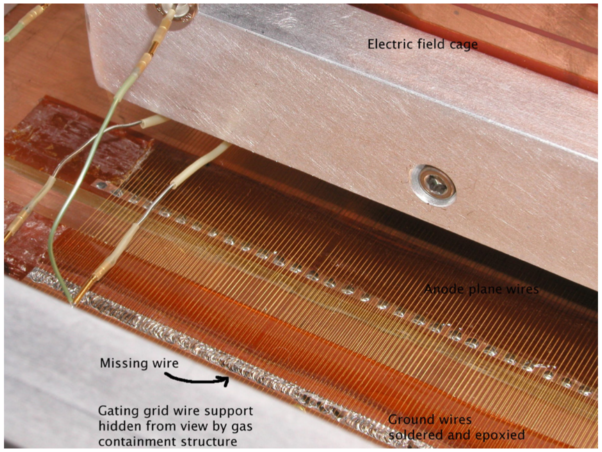
- Most of the DAQ upper layer software (Run control, Book keeping, plots) can be kept as is.
- New Power PC 5500's replace 6 existing ones.
- Linux kernel to migrate to it.(10 person weeks)
- Camac Hytec 1365V5 Module software(2 weeks)
- Update Event builder(6 weeks)
- FERA ADC readout (5 weeks)
- Modify 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 CO_2
  - 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

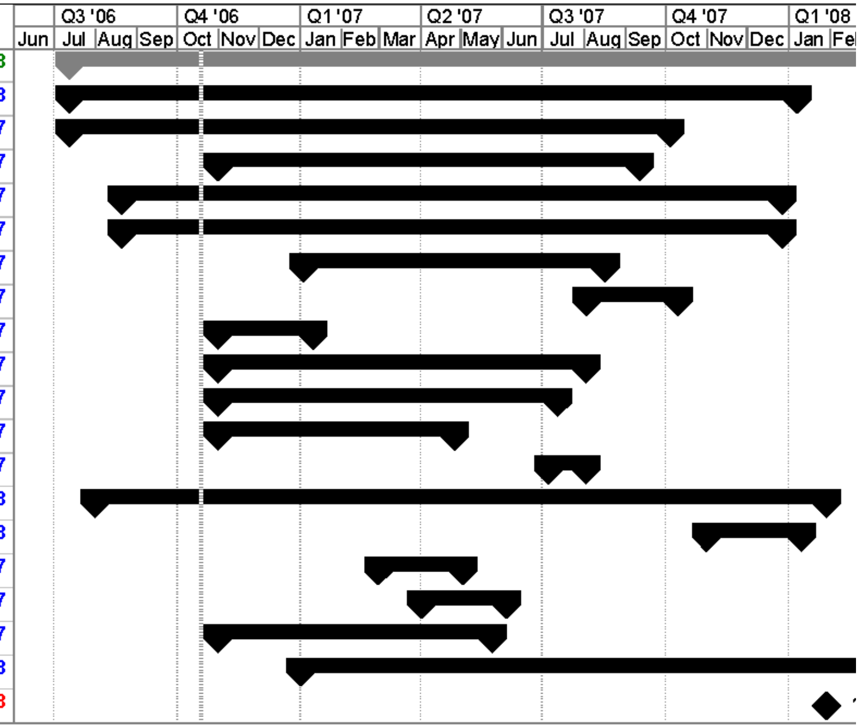


TPC rewind- Optional

WBS task 3.3 M&S $9K

MIPP Upgrade Timeline

WBS	Name	Duration	Start	Finish
0	MIPP	127.8 wks	Thu 7/13/06	Tue 12/23/08
1	Project Management	74.2 wks	Thu 7/13/06	Mon 1/7/08
2	Jolly Green Giant Repair	62 wks	Thu 7/13/06	Thu 10/4/07
3	Improvements on detector hardware	43 wks	Wed 11/1/06	Tue 9/11/07
4	Detector Readout Upgrades	67.8 wks	Mon 8/21/06	Thu 12/27/07
4.1	TPC Electronics	67.8 wks	Mon 8/21/06	Thu 12/27/07
4.2	Drift Chamber/Wire Chamber electronics	31.7 wks	Thu 1/4/07	Fri 8/17/07
4.3	ToF + CKOV electronics board design	9.5 wks	Fri 8/3/07	Wed 10/10/07
4.4	Calorimeter migration to Fera electronics	9 wks	Wed 11/1/06	Wed 1/10/07
5	Trigger System Upgrade	37.6 wks	Wed 11/1/06	Thu 8/2/07
5.1	Interaction Trigger Fpix	34.6 wks	Wed 11/1/06	Thu 7/12/07
5.2	Interaction Trigger Board	25.4 wks	Wed 11/1/06	Thu 4/26/07
5.3	Other Trigger Upgrades	4 wks	Fri 7/6/07	Thu 8/2/07
6	DAQ Software and Hardware Upgrade	74.6 wks	Tue 8/1/06	Tue 1/29/08
7	Offline farm Upgrade	9 wks	Thu 11/1/07	Thu 1/10/08
8	Beam Line Upgrade	9 wks	Thu 3/1/07	Wed 5/2/07
9	Enhanced Veto Wall	9 wks	Mon 4/2/07	Mon 6/4/07
10	Recoil Detector	28 wks	Wed 11/1/06	Thu 5/24/07
11	Visitor Support for Russian collaborators	103.2 wks	Tue 1/2/07	Tue 12/23/08
12	Commissioning Run Start	0 wks	Tue 1/29/08	Tue 1/29/08



- Detailed schedule to be found in
  - » http://ppd.fnal.gov/experiments/e907/notes/MIPPnotes/public/pdf/MIPP0139/MIPP0139.pdf

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 (MIlions)	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 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.
- This and the tagged neutral beams will benefit the ILC PFA algorithm 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.
- Timely approval will benefit us on all fronts including speeding up the analysis of the data in hand.