Status of MIPP Upgrade

Rajendran Raja

Mipp Upgrade is making good progress

Hear from Electronics TPC, Chambers, Calorimeter, Plastic Ball

Fabricated chips on the way here.

JGG , Ziptrack

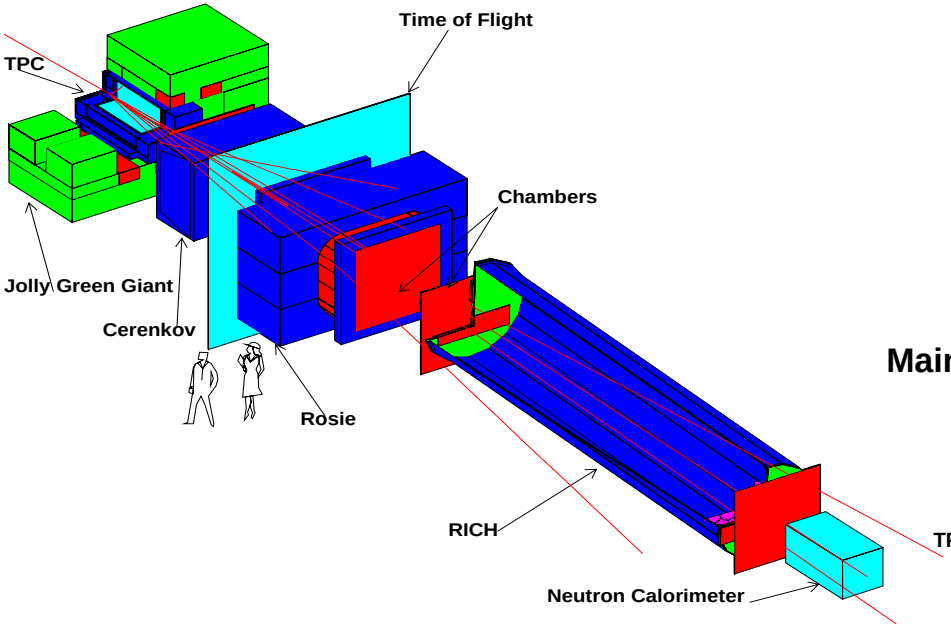
Analysis making good progress

More collaborators needed– Aspen Cosmic Ray Workshop-lots of interest

- Quantitative evaluation of MIPP data impact—
  - Shower Simulation
  - MINERVA, MINOS, NOVA
  - Missing Baryon Resonances
  - Cosmic Rays– Ralph Engel

MIPP

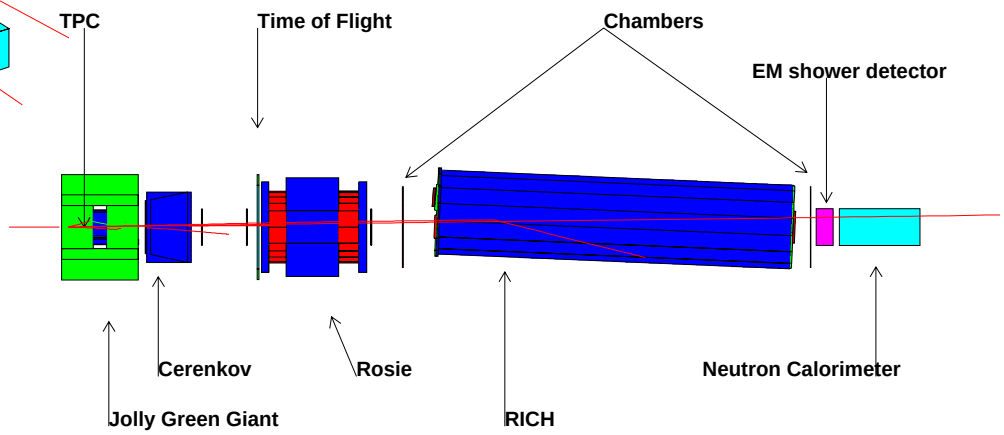
Main Injector Particle Production Experiment (FNAL-E907)



MIPP

Main Injector Particle Production Experiment (FNAL-E907)

Vertical cut plane



MIPP Upgrade collaboration list

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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,
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M. Messier,J.Paley
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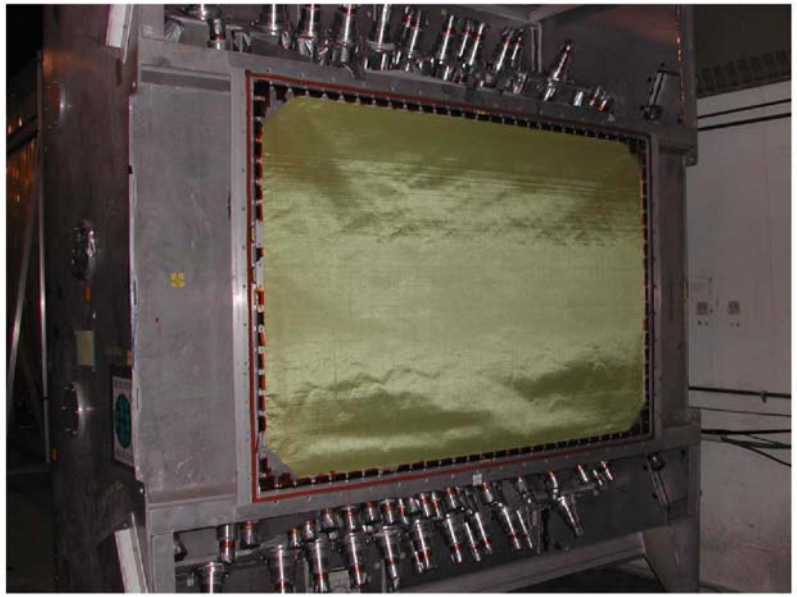
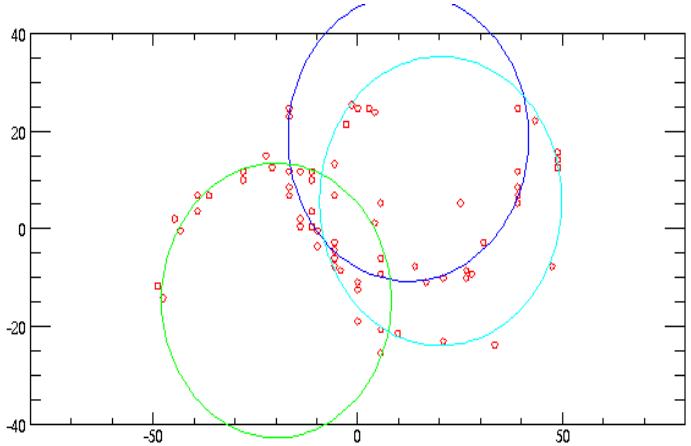
C.Dukes,C.Materniak,K.Nelson,A.Norman
University of Virginia
P.Desiati, F.Halzen, T.Montaruli,
University of Wisconsin, Madison
P.Sokolsky, W.Springer
University of Utah

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.

MIPP Cherenkov



RICH rings pattern recognized

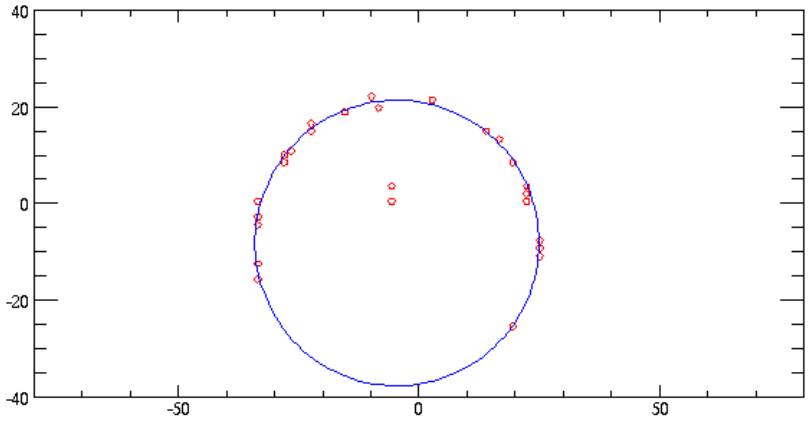


MIPP (FNAL E907)

Run: 9121
SubRun: 0
Event: 92

Wed Aug 11 2004
13:53:56.884750

Version: 0
Trigger: 10000008

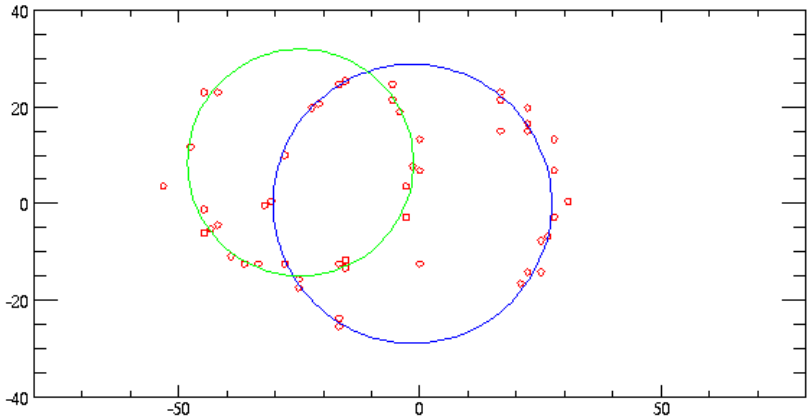


MIPP (FNAL E907)

Run: 9121
SubRun: 0
Event: 100

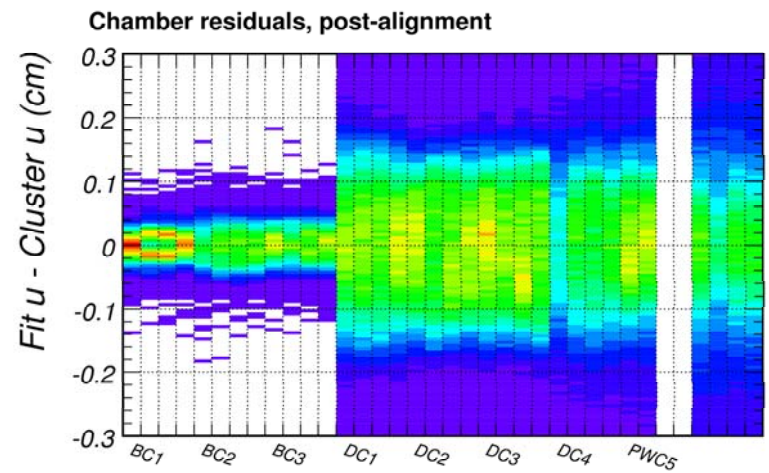
Wed Aug 11 2004
13:54:06.823879

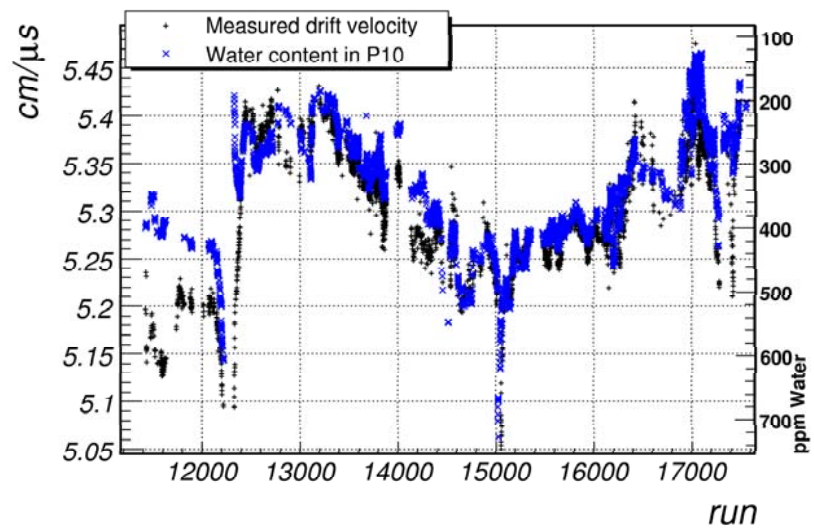
Version: 0
Trigger: 10000008



Ongoing analysis-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

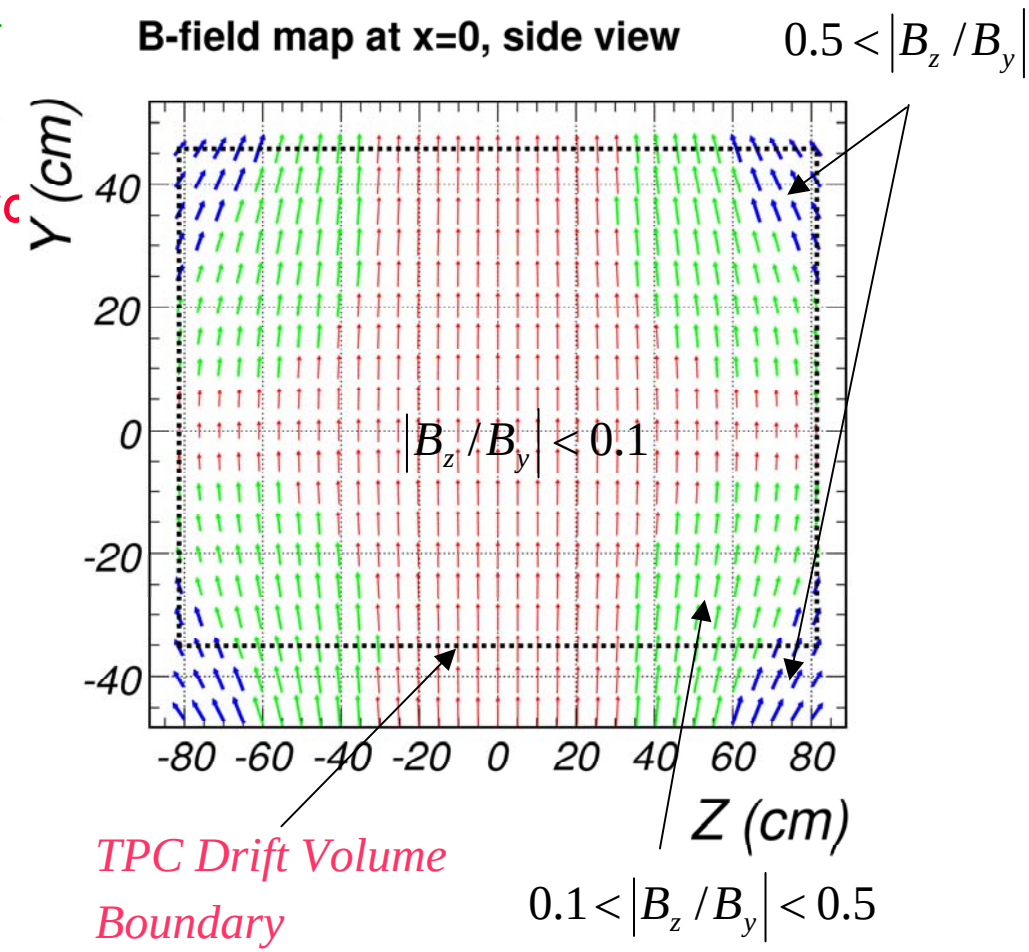




TPC Hit Reconstruction

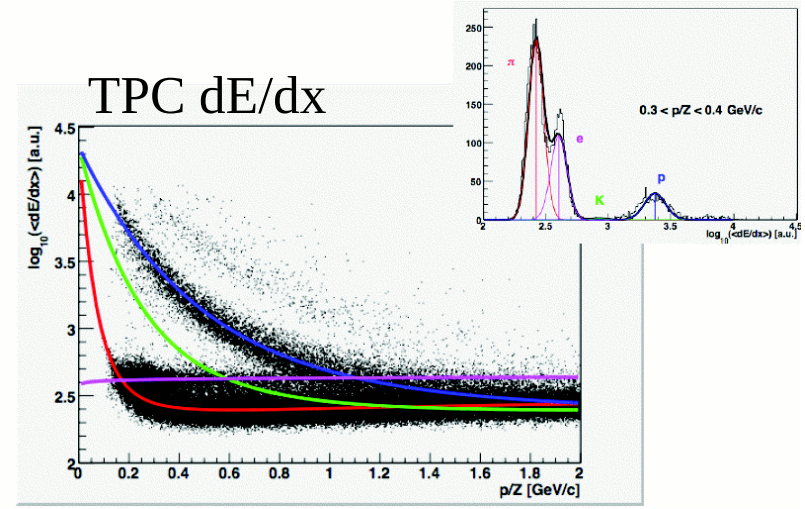
- JGG field is non-uniform
  - » Enormous effect on electron drift in Ar/CH_4
- Previous experiments applied corrections based on steady state solution to linear model

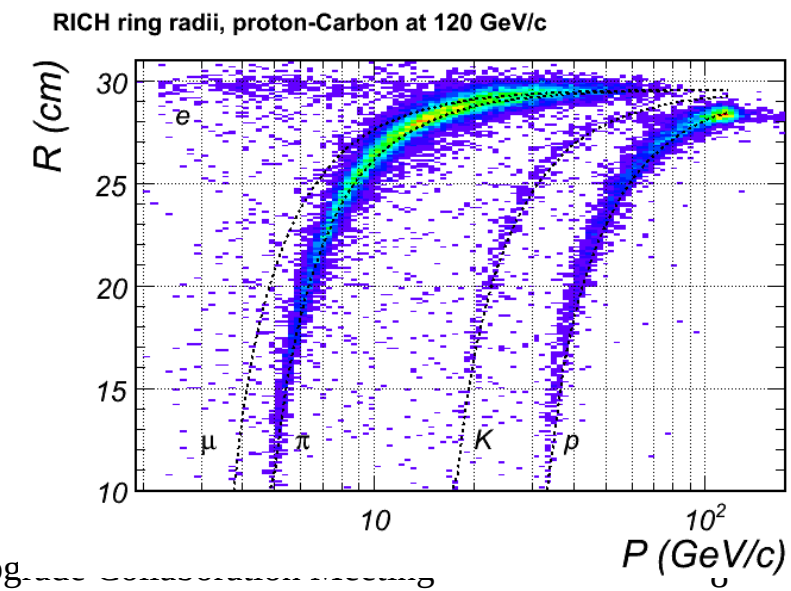
$$m\frac{d\vec{v}}{dt} = e\vec{E} + e\vec{v}\times\vec{B} - \frac{1}{\tau}\vec{v}$$



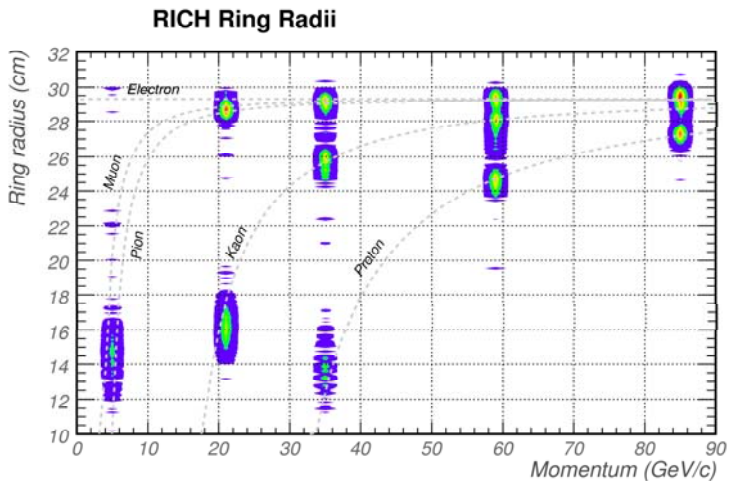
Particle ID status

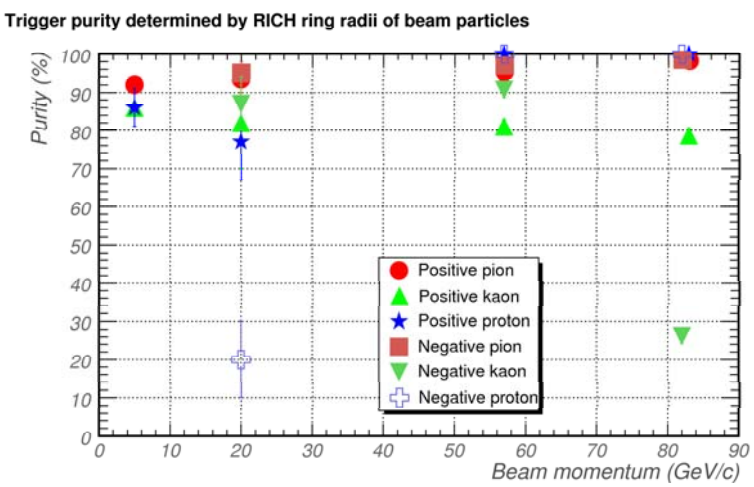
- TPC dE/dx calibration is in progress,
  - » Results to-date are promising
- TOF cable delays to be determined soon
- Cherenkov light calibration is largely done
- RICH calibration and likelihood calculation are nearly complete





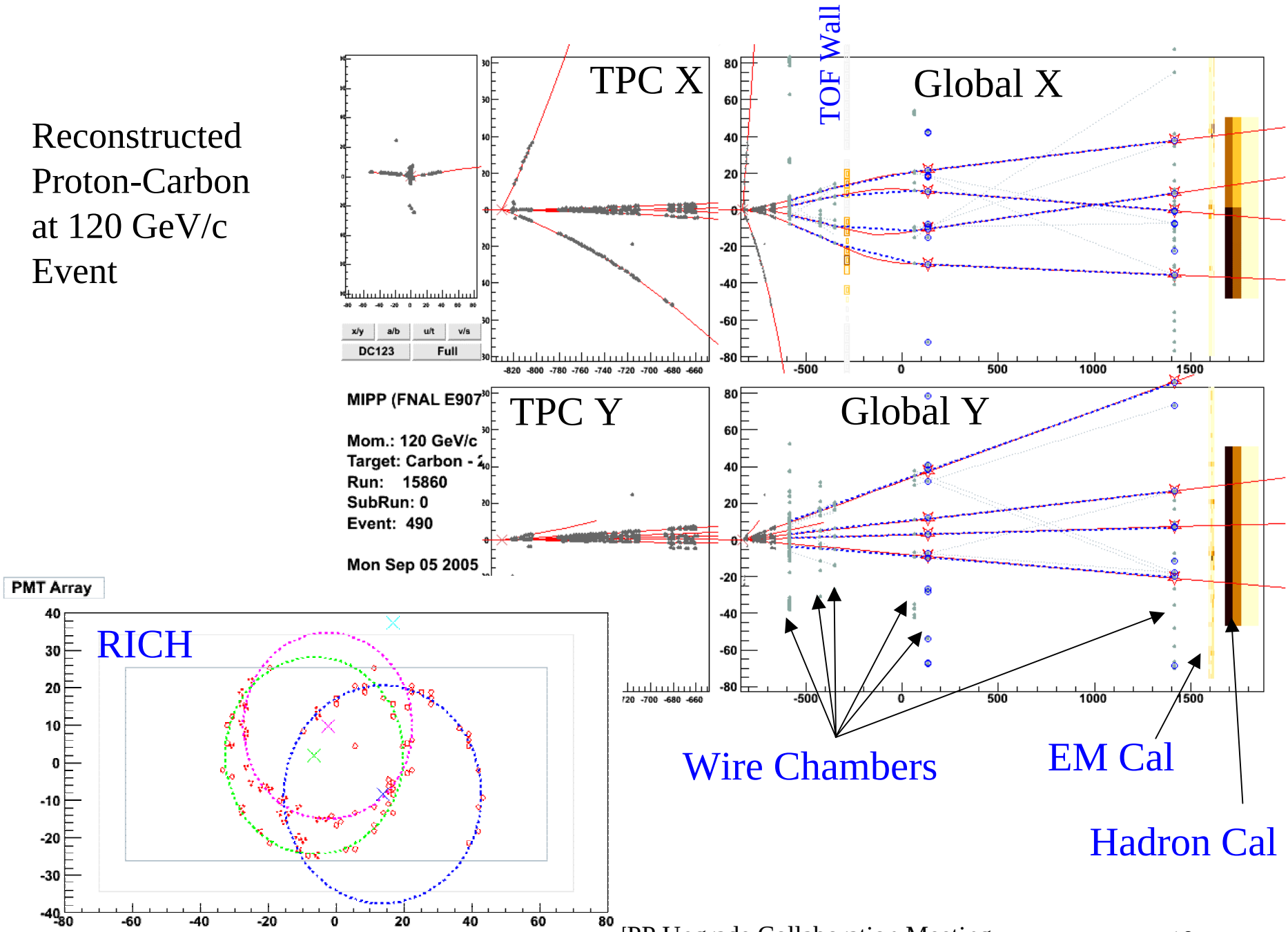
Secondary Beam Particle ID





- 2 beam Cherenkov threshold counters separate π/K/p from 20 to 90 GeV/c
  - » N_2 for momenta above 30 GeV/c
  - » C_4F_8O for proton at 20 GeV/c
- Trigger purity measured with the RICH is typically above 80% for minority particle

Reconstructed Proton-Carbon at 120 GeV/c Event

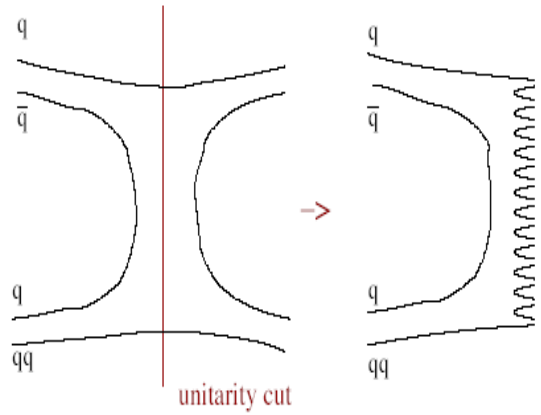


Hadronic Shower Simulation Problem-We have a theory of the strong interaction—in theory

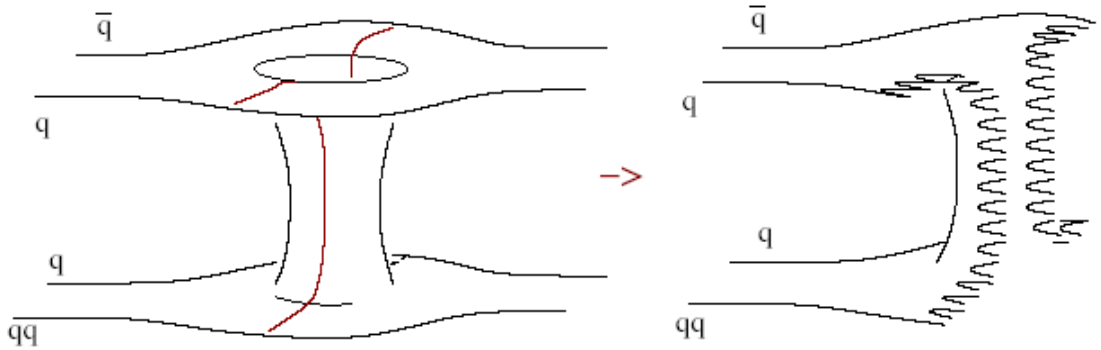
- Why study non-perturbative QCD? Answer:- We do not know how to calculate a single cross section in non-perturbative QCD! This is >99% of the total QCD cross section. Perturbative QCD has made impressive progress. But it relies on structure functions for its calculations, which are non-perturbative 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?

Dual Parton Model- Concepts-Optical theorem

Reggeon Exchange-Single string of hadrons

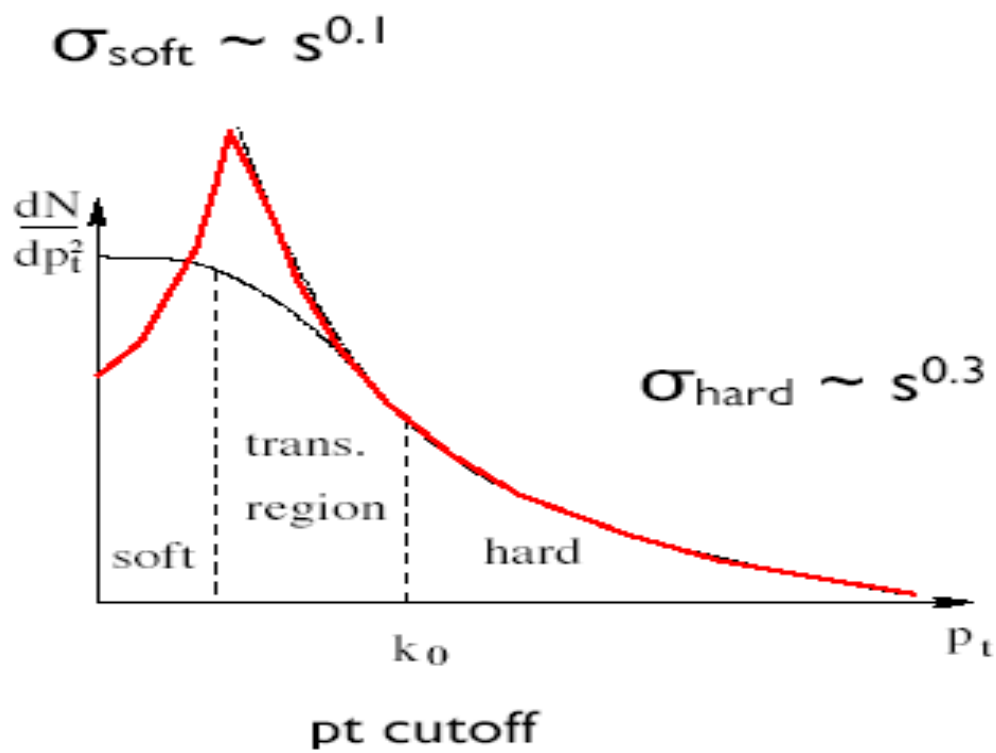


Pomeron Exchange-Two strings of hadrons

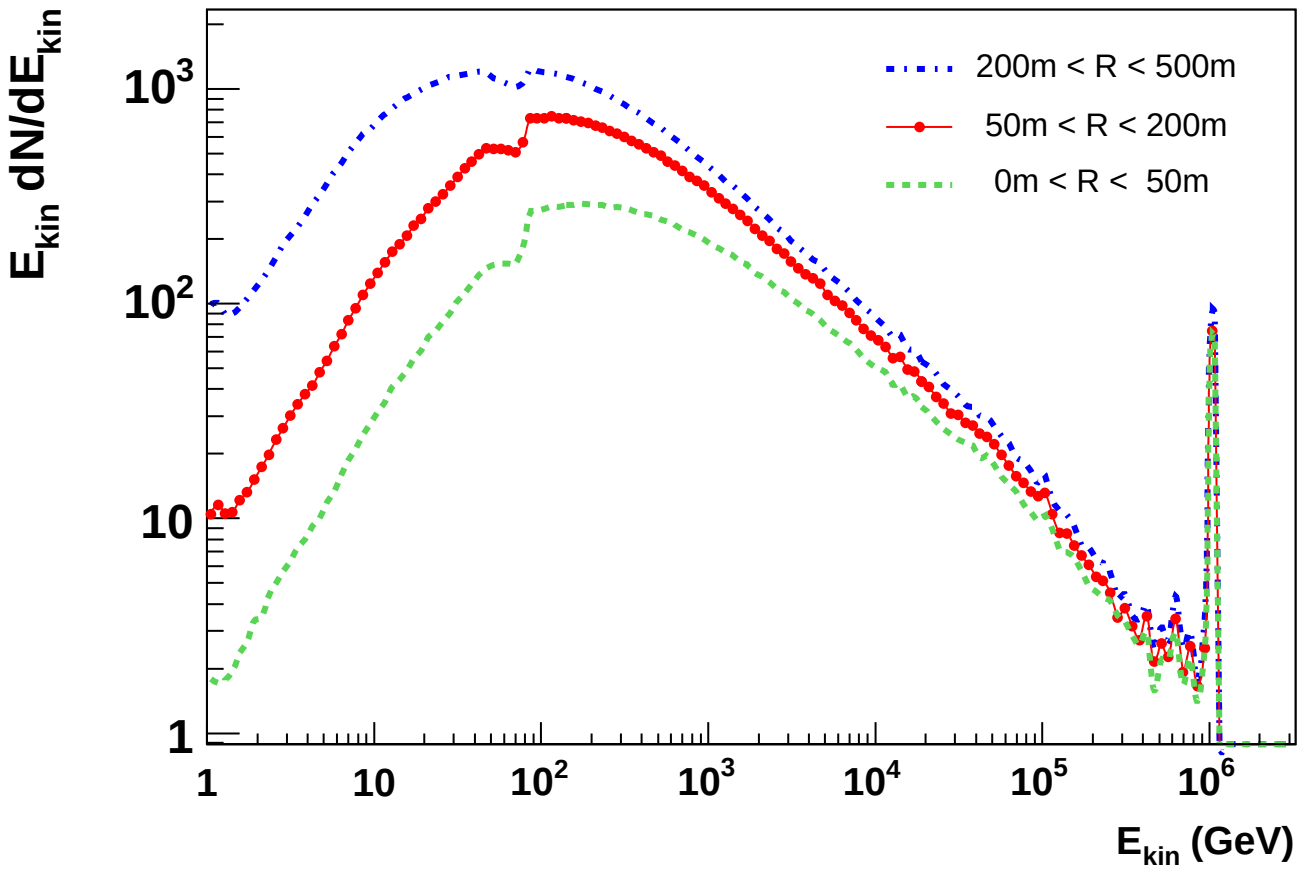


Conceptual problem- Matching soft and hard processes.

This is done by tuning the transition region carefully!



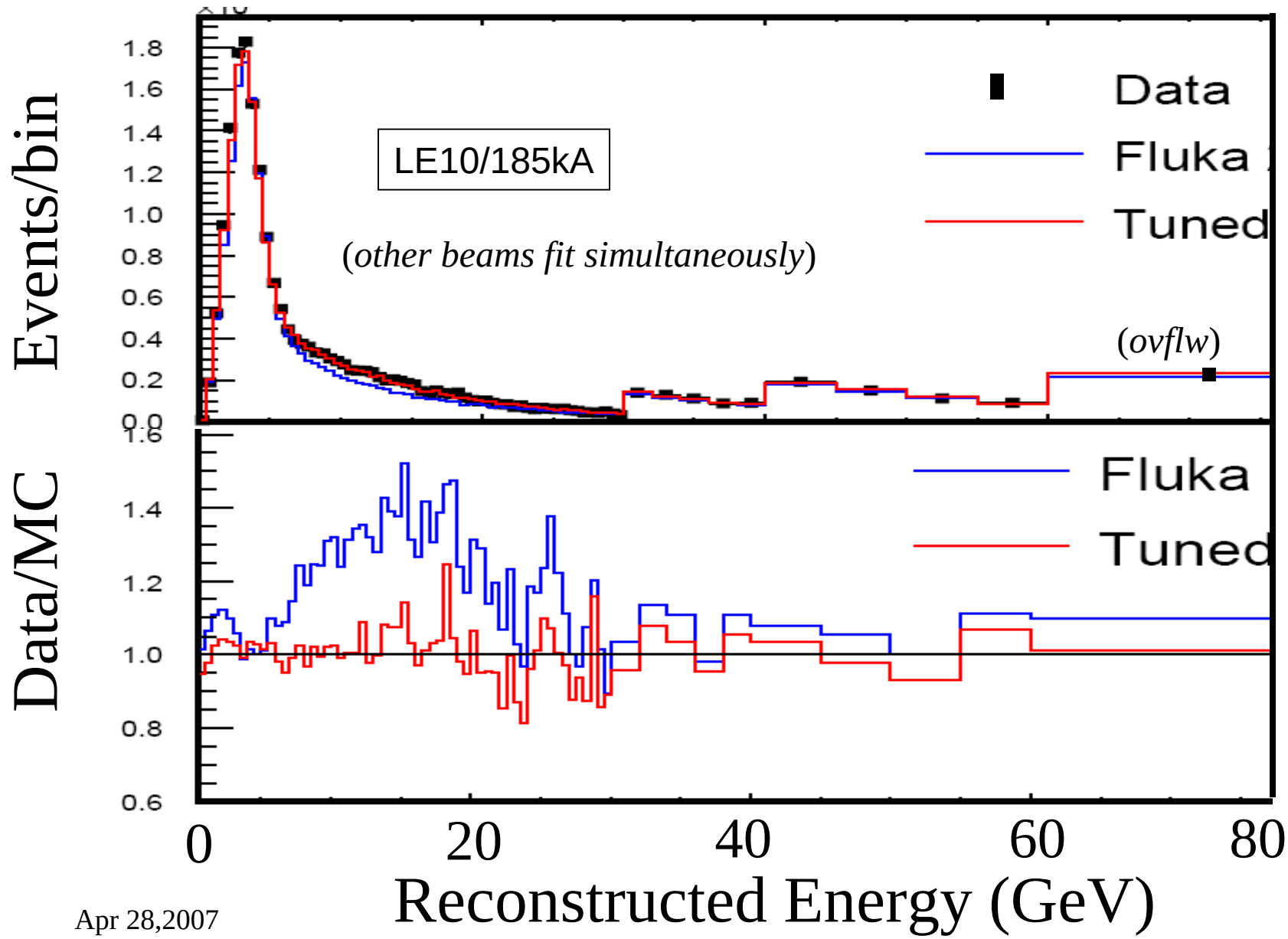
Meurer et al –Cosmic ray showers Discontinuity-Gheisha at low energies and QGSJET at higher energies-Simulation of air showers



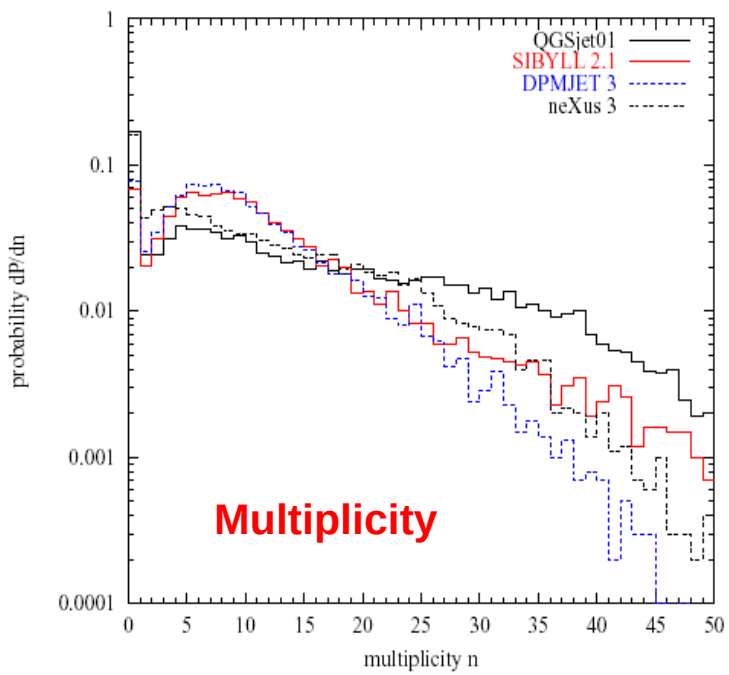
Plethora of models

- 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.

Results (Including >30 GeV)-S.Kopp

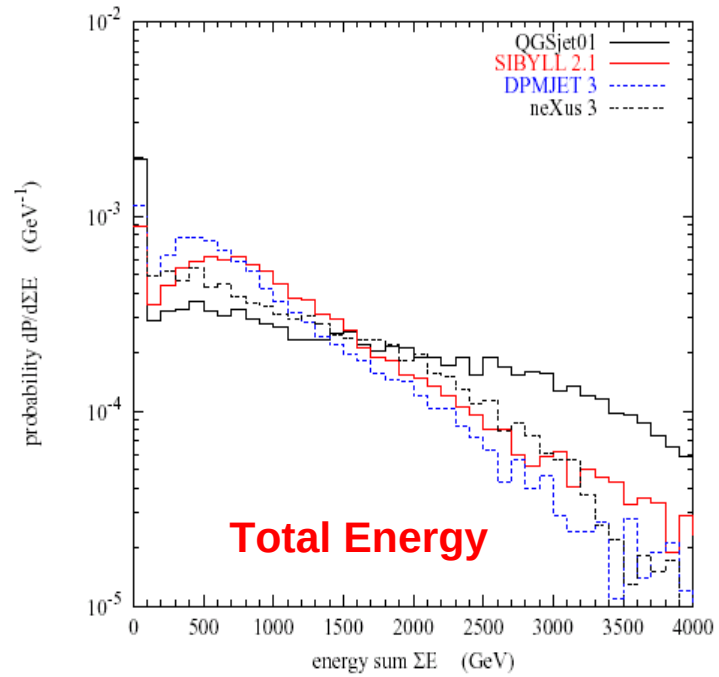


Model Predictions: proton-proton at the LHC –Totem Expt- S.Lami



total multiplicity in forward detector

$(5 \leq \eta \leq 7)$



total energy in forward detector

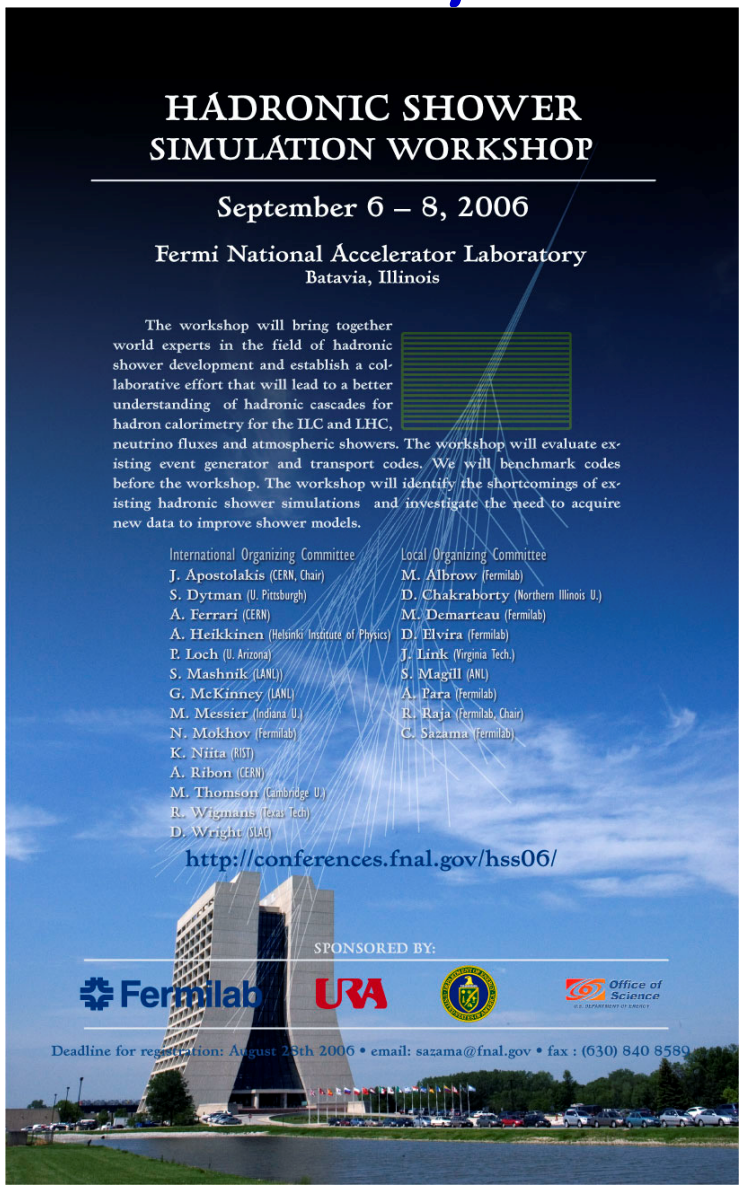
$(5 \leq \eta \leq 7)$

Predictions in the forward region within the CMS/TOTEM acceptance

(T1 + T2 + CASTOR)

Hadronic Shower Simulation Workshop HSSW06

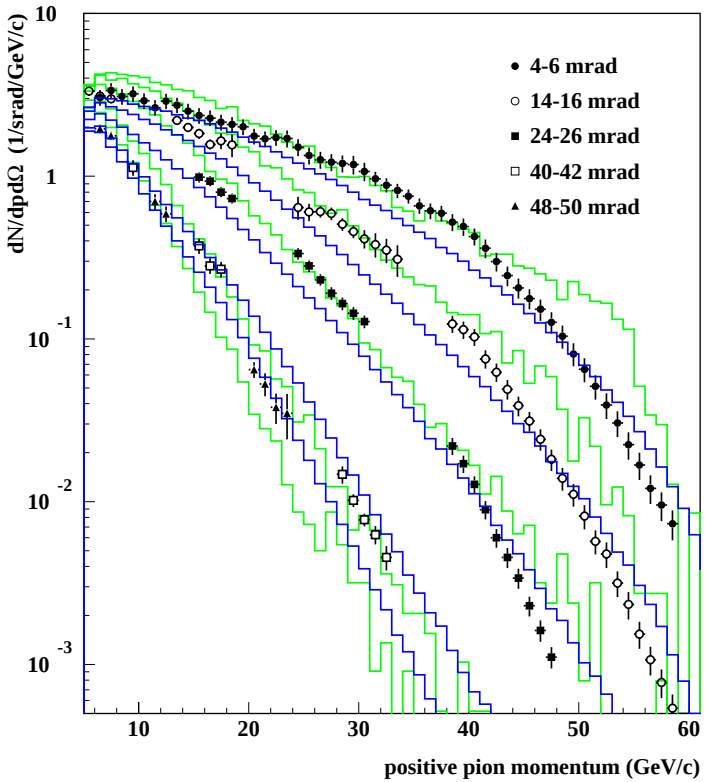
- Venue—Fermilab September 6-8, 2006
- Experts from GEANT4, FLUKA, MARS, MCNPX, and PHITS attended as well users from Neutrino, ILC, Atlas, CMS communities. Goal is to reduce systematics between various models and arrive at a suite of programs that can be relied on.

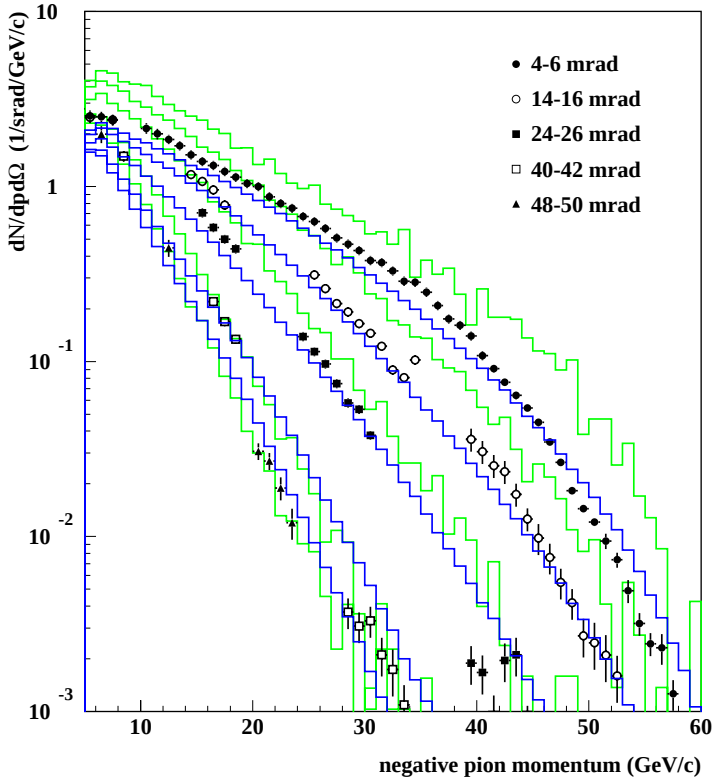


HSSW06 benchmark test 60cm Al target- Data from Protvino

Pion data. Blue curve MARS. Green curve PHITS.

Monte Carlos disagree with each other and the data!





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

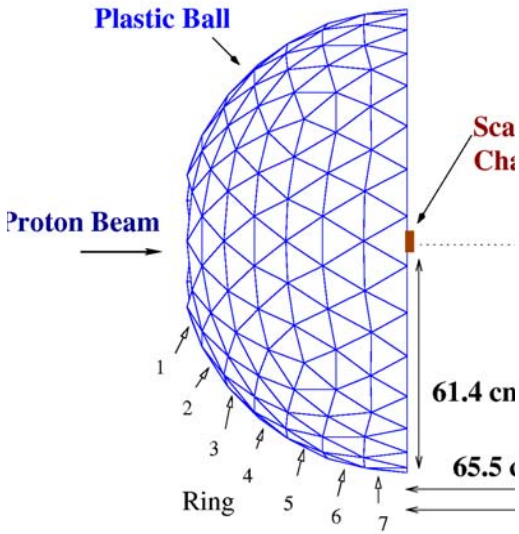
Spallation products

- 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

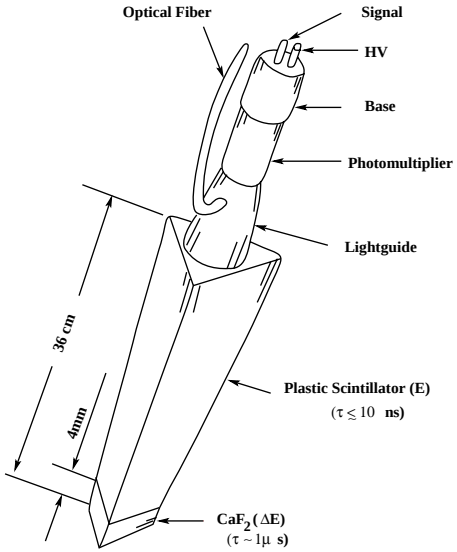
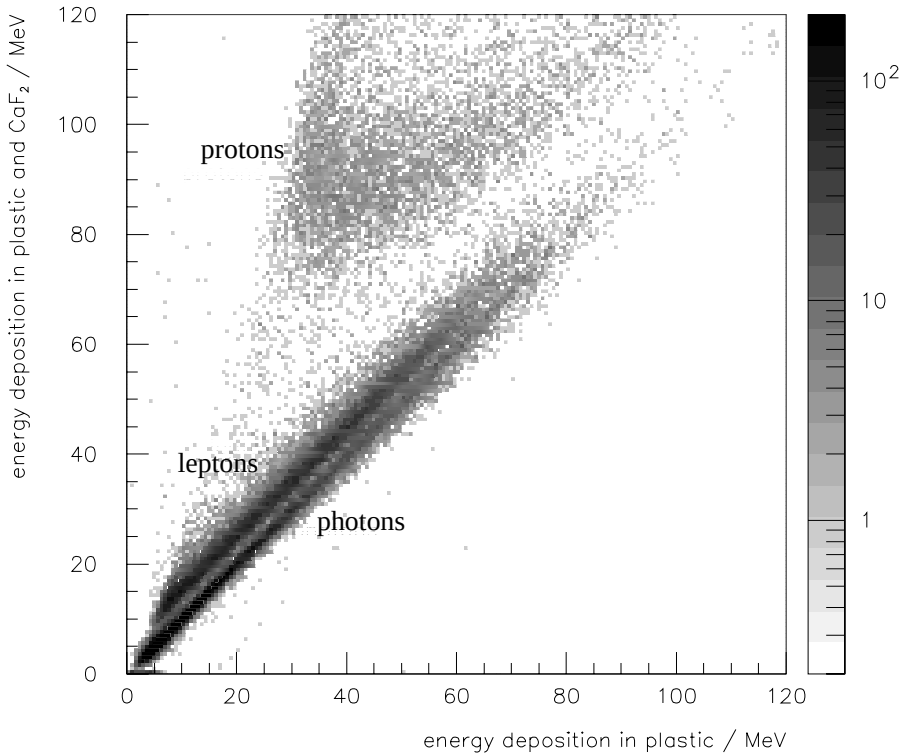


Figure 3.5: Schematic drawing of an individual Plastic Ball detector.



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

Random Access Data Libraries

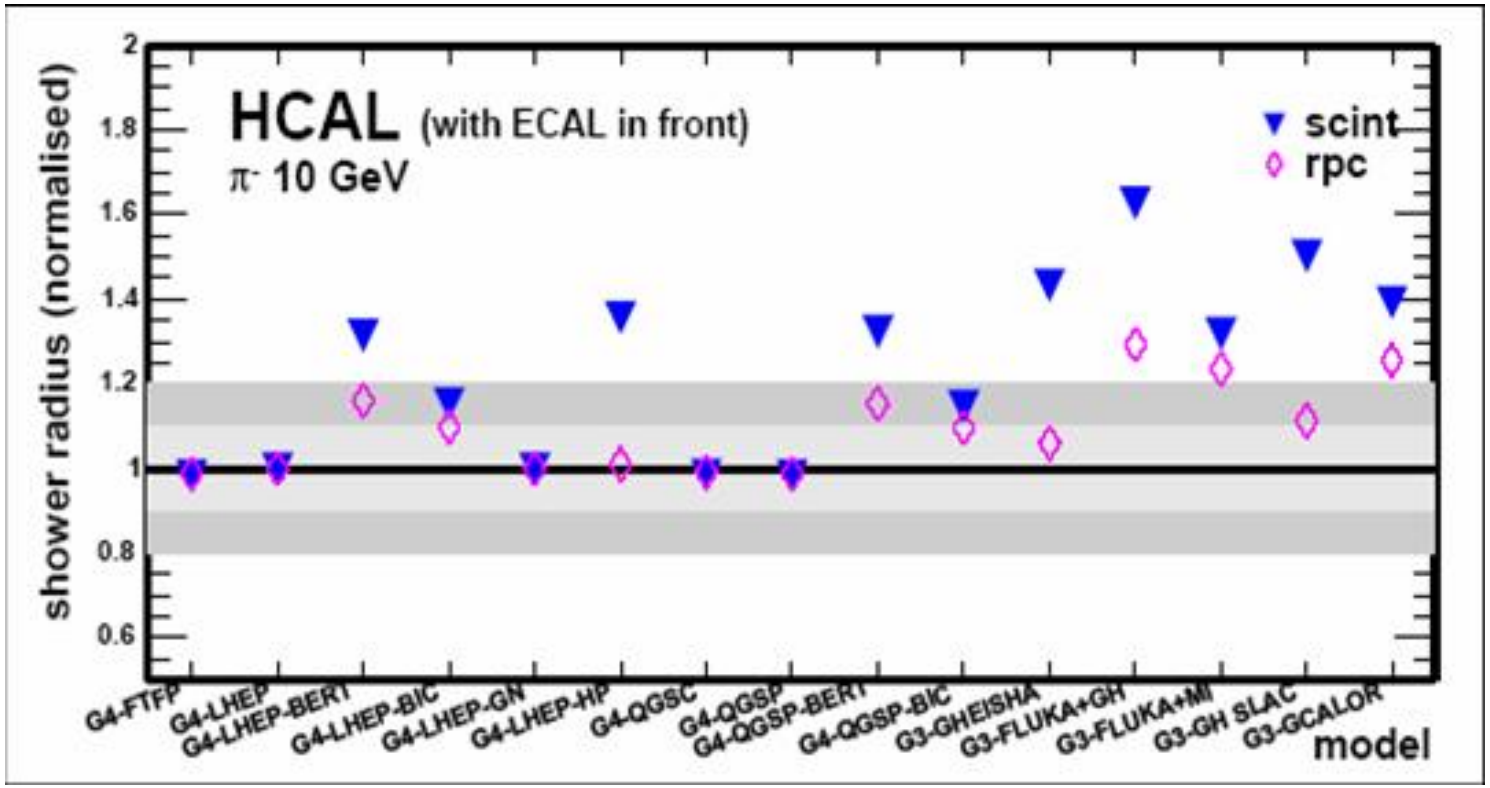
- Typical storage needed

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

$$pp \rightarrow pn\pi^+$$

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

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

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

See R.Raja-MIPP Note 130

~50K tagged neutrons per day

MIPP LH_2 target

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

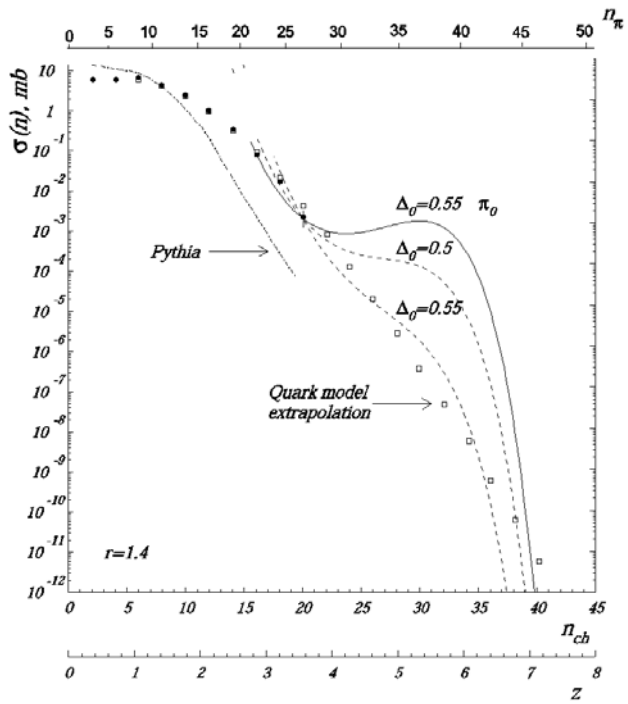
- States that the ratio of a semi-inclusive cross section to an inclusive cross section

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

- where M^2,s and t are the Mandelstam variables for the missing mass squared, CMS energy squared and the momentum transfer squared between the particles a and c. PRD18(1978)204.
- Using EHS data, we have tested and verified the law in 12 reactions (DPF92) but only at fixed s.
- MIPP will test this in 36 reactions. MIPP upgrade can extend these scaling relation tests to two particle inclusive reactions which requires more statistics.

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

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

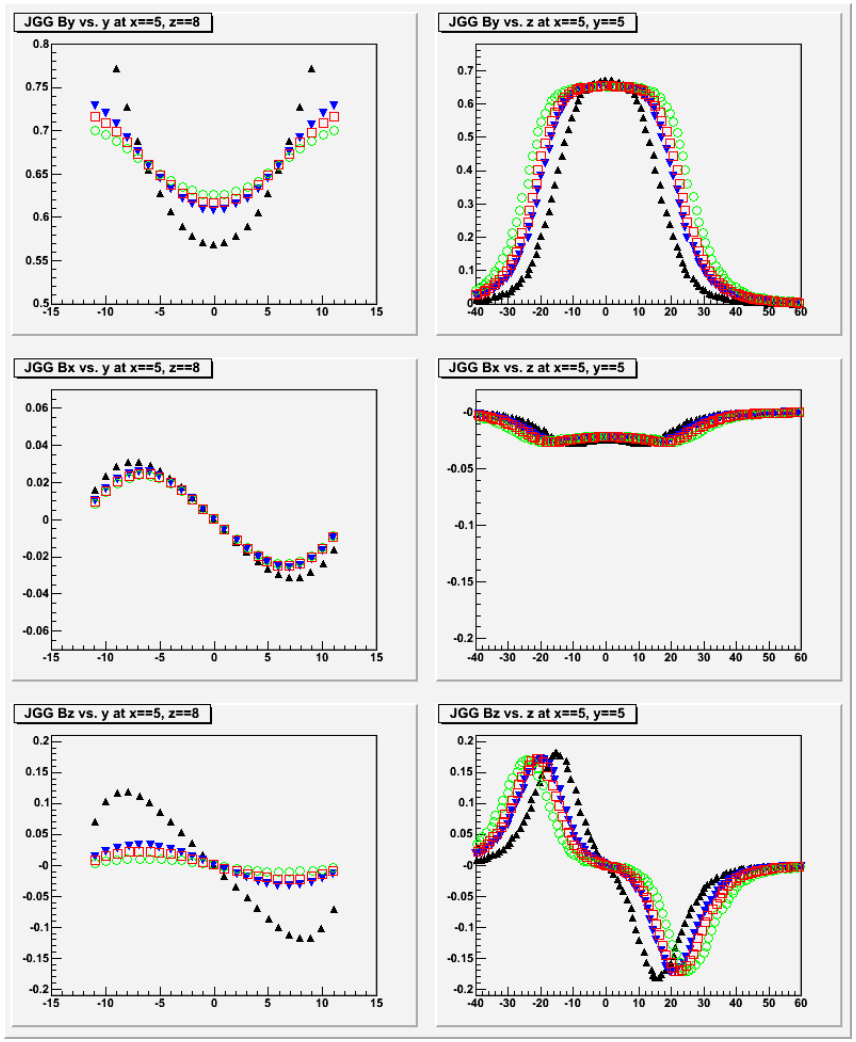
$$\gamma p \to \pi^0 p; \gamma p \to K^+ \Lambda; \gamma p \to \pi^+ \pi^- p$$

- 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.



New JGG coils being wound April 07

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.

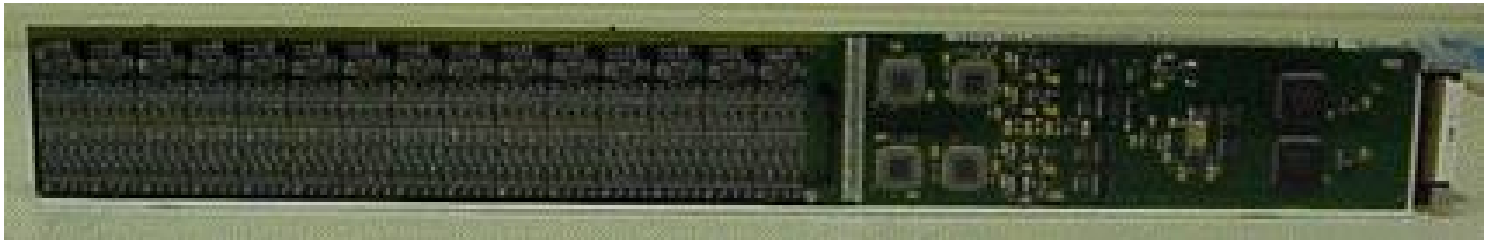
October 19 ,2006 Rajendran Raja, Presentation to the Fermilab PAC 74

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

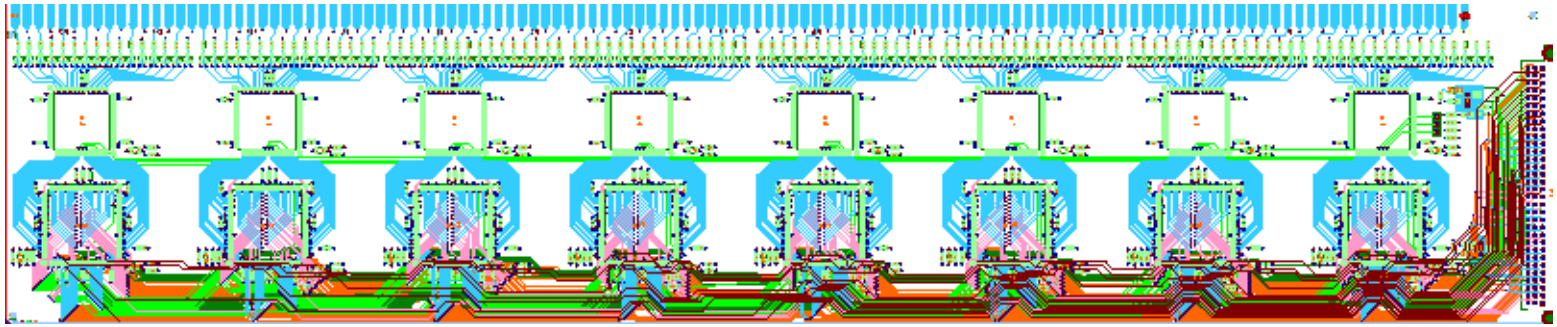
10 times more data using 10 times less beam time!

TPC electronics upgrade

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



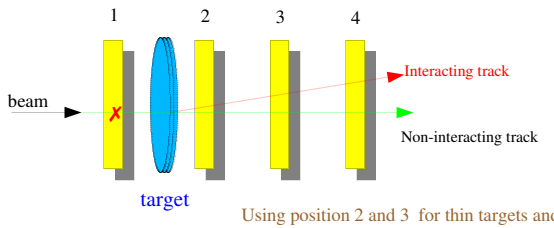
- New MIPP TPC "stick" layout using ALTRO/PASA chips.



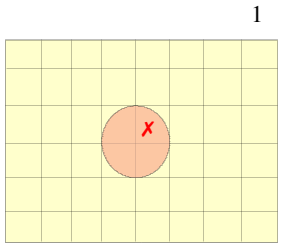
MIPP Trigger Upgrade

- 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.

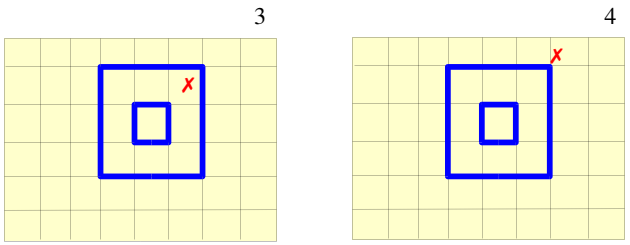
fPix Silicon Detector of 3 planes of 48 fPix 2.1 chips



Using position 2 and 3 for thin targets and position 3 and 4 for the thicker cryo targets.



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.

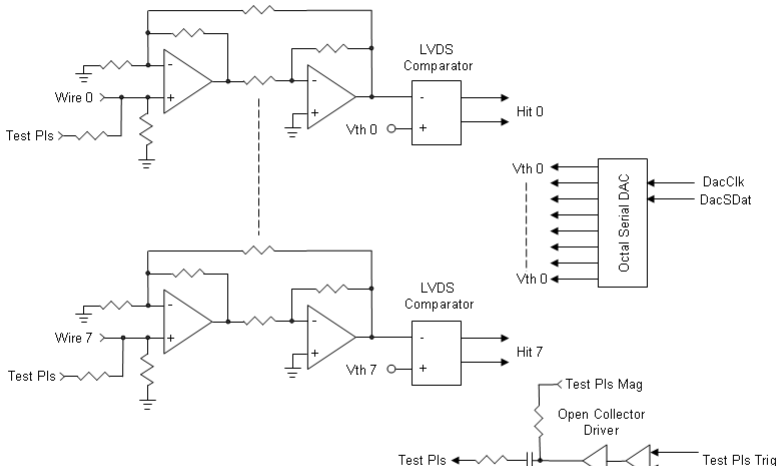


A bulls eye target, shown in blue, is made around the one cell hit location of plane1.

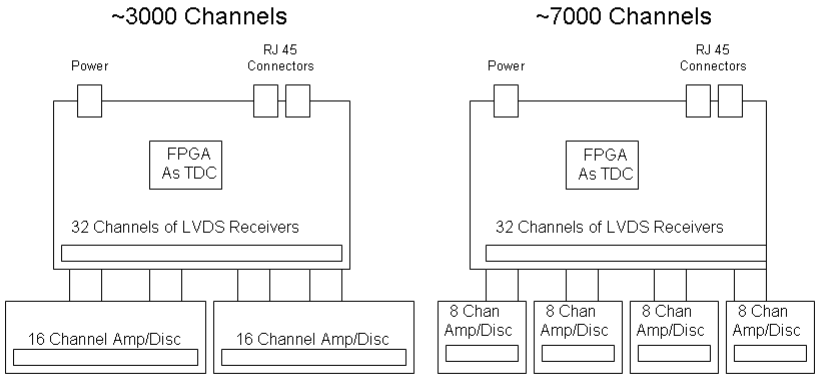
Drift Chamber/ PWC readout Upgrade

- 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

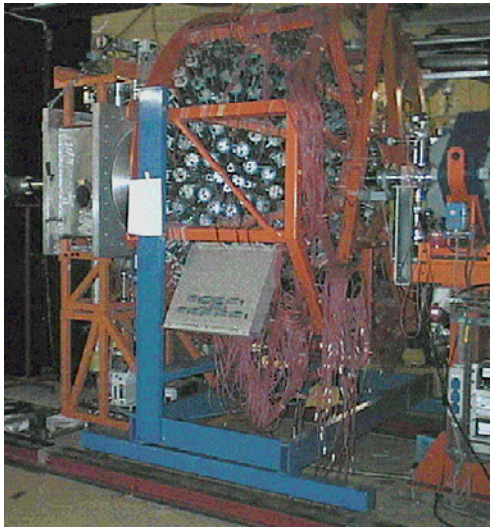


High-Speed Differential Interfaces
"Cyclone II devices can transmit and receive data through LVDS signals at a data rate of up to 640 Mbps and 805 Mbps, respectively. For the LVDS transmitter and receiver, the Cyclone II device's input and output pins support serialization and deserialization through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

- Calorimeter Readout
  - » Propose 4 crates of FERA ADC's (K-TeV + PREP)
  - » Read out by 2 Hytec1365 CAMAC readout controllers.

Beam Line Upgrade

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