

The MIPP experiment

The **M**ain **I**njector **P**article **P**roduction

Albert De Roeck (CERN)

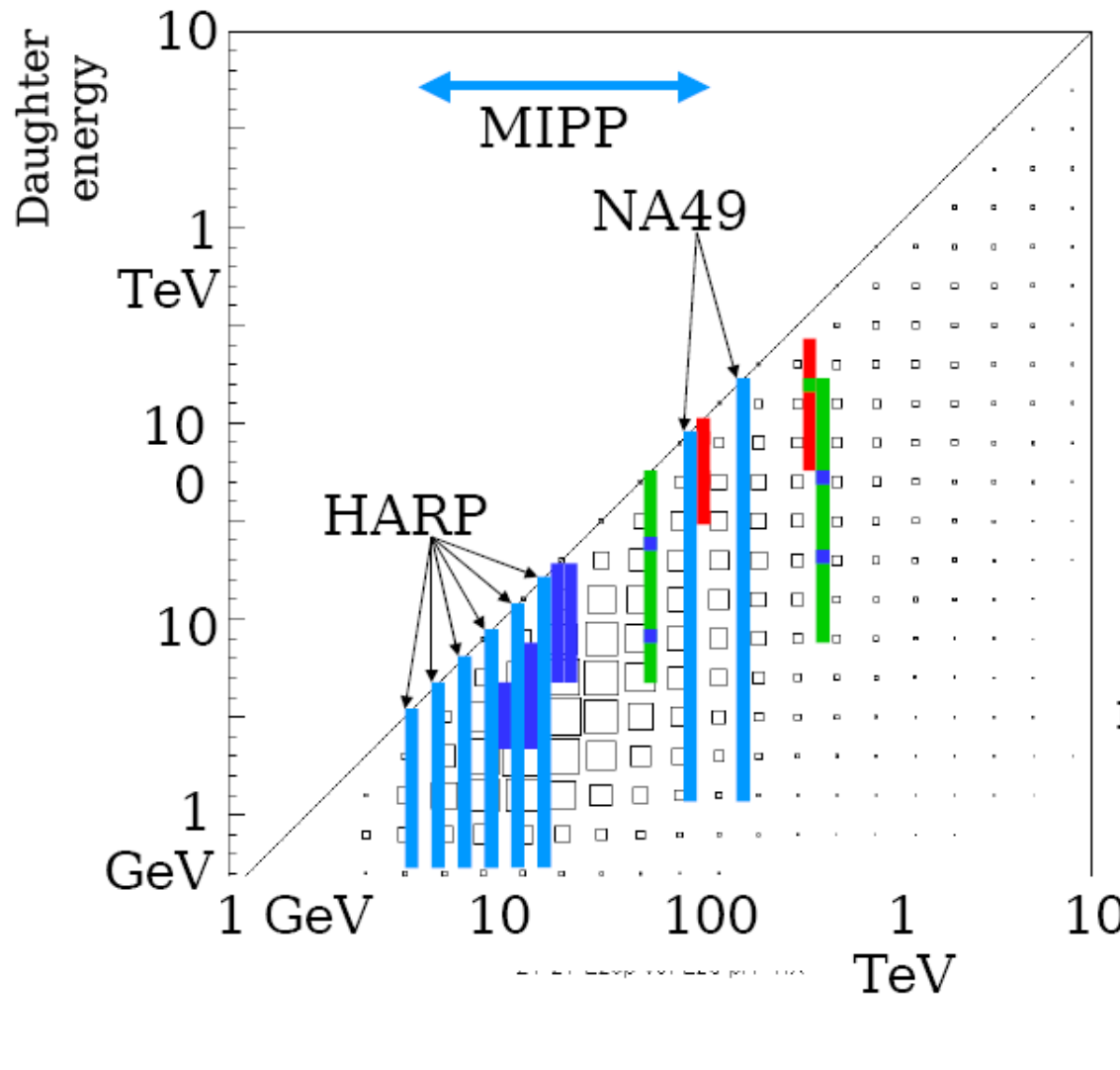
G4TF 21 Nov 06

Most slides from Rajendran Raja (FNAL)

Fixed Target Data

New measurements

[from Giles Barr]



Boxes show importance of phase space region for contained atmospheric neutrino events.

Cosmic Ray Conference

MIPP

- Beams of π, K, p both charges from 5 GeV \rightarrow 100 GeV, to measure particle production on nuclei
- \sim Full acceptance

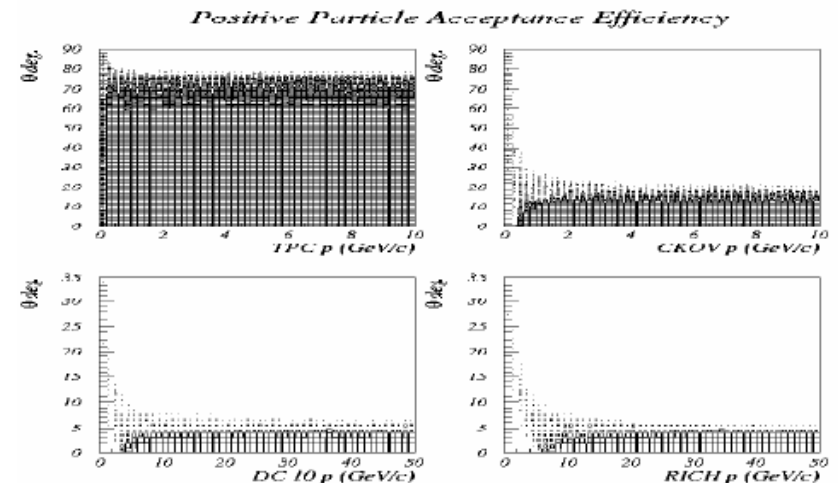
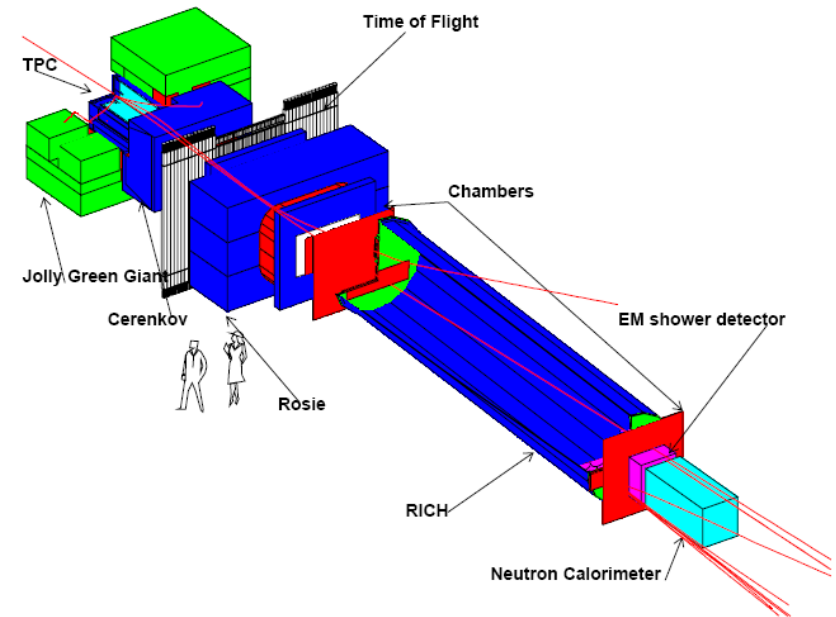
MIP upgrade

- Increase data taking rate by a factor 100
- Increase acceptance in the backward region
- Lower beam momenta/ K^0 and neutron beams
- 30 Nuclei from $H_2 \rightarrow U$

\Rightarrow Looking for interested collaborators to join for the analysis/data taking

Timeline: (pre-October 06)
run end of 2007 in upgrade mode with the current beam

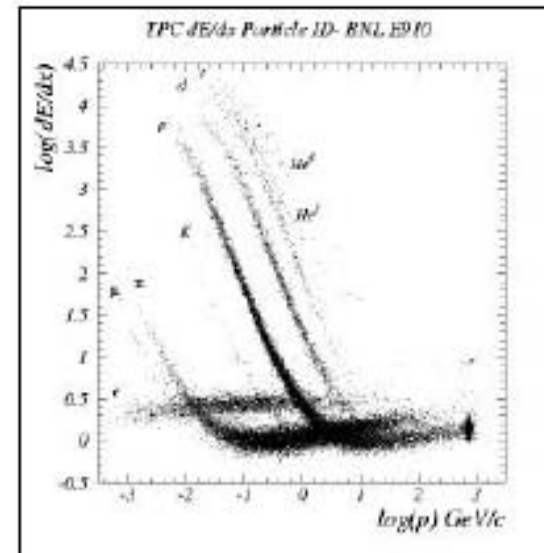
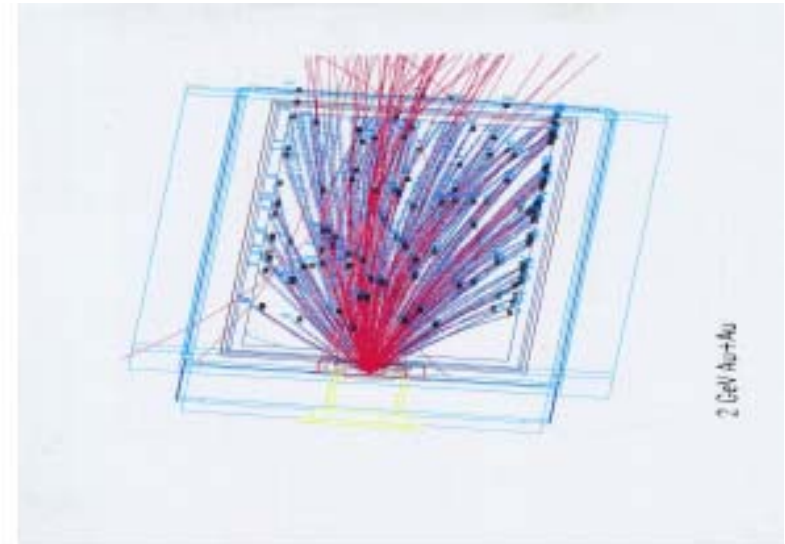
MIPP-like experiment at 1 TeV beam?



Brief Description of Experiment

- Approved November 2001
- Situated in Meson Center 7
- Uses 120GeV Main Injector Primary protons to produce secondary beams of π^\pm K^\pm p^\pm from 5 GeV/c to 100 GeV/c to measure particle production cross sections of various nuclei including hydrogen.
- Using a TPC we measure momenta of ~all charged particles produced in the interaction and identify the charged particles in the final state using a combination of dE/dx, ToF, differential Cherenkov and RICH technologies.
- Open Geometry- Lower systematics. TPC gives high statistics. Existing data poor quality.
- First Physics run- 18 million events 2005. Ended Feb 2006

MIPP TPC



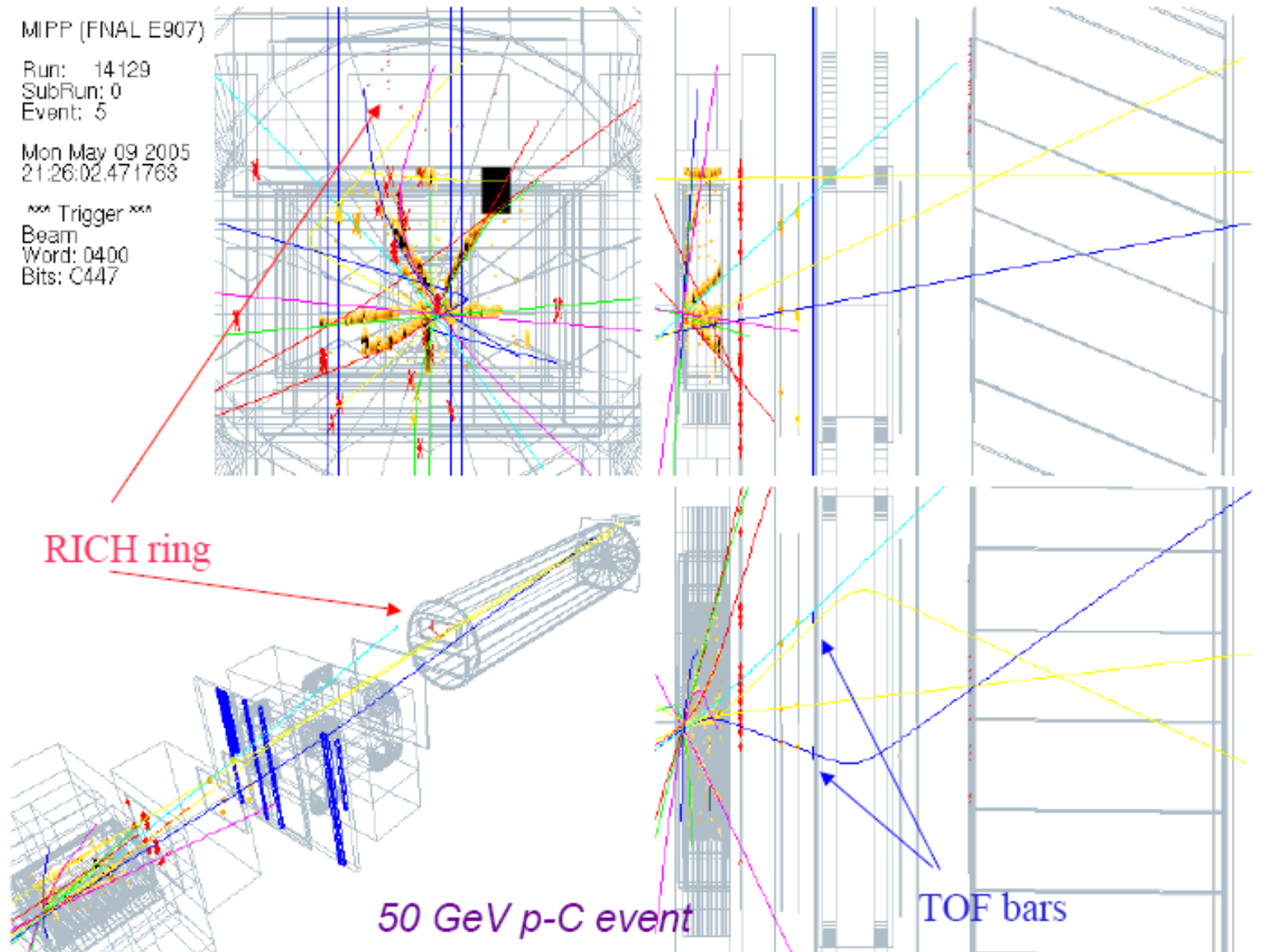
MIPP Event

MIPP (FNAL E907)

Run: 14129
SubRun: 0
Event: 5

Mon May 09 2005
21:26:02.471763

*** Trigger ***
Beam
Word: 0400
Bits: C447



Data Taken In current run

Data Summary 27 February 2006			Acquired Data by Target and Beam Energy Number of events, x 10 ⁶									Total
Target			E									
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	
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

Physics of current Run

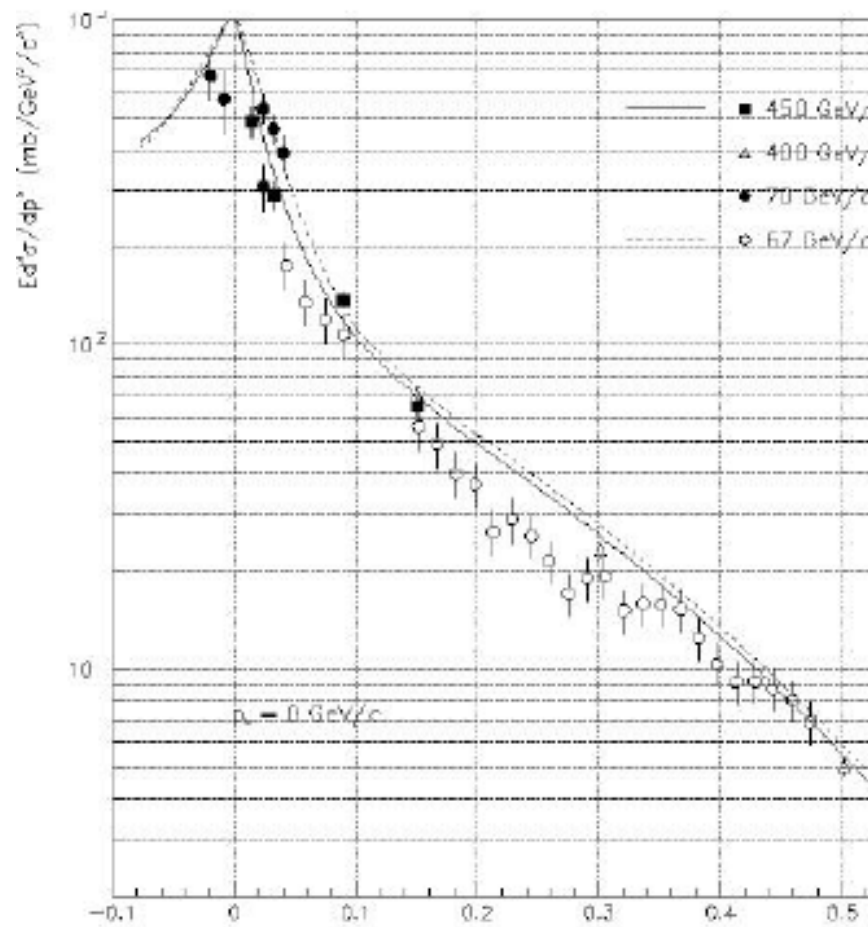
- Particle Physics-To acquire unbiased high statistics data with complete particle id coverage for hadron interactions.
 - » Study non-perturbative QCD hadron dynamics, scaling laws of particle production
 - » Investigate light meson spectroscopy, pentaquarks?, glueballs
- Nuclear Physics
 - » Investigate strangeness production in nuclei- RHIC connection
 - » Nuclear scaling

⇒ Better data to improve simulation packages

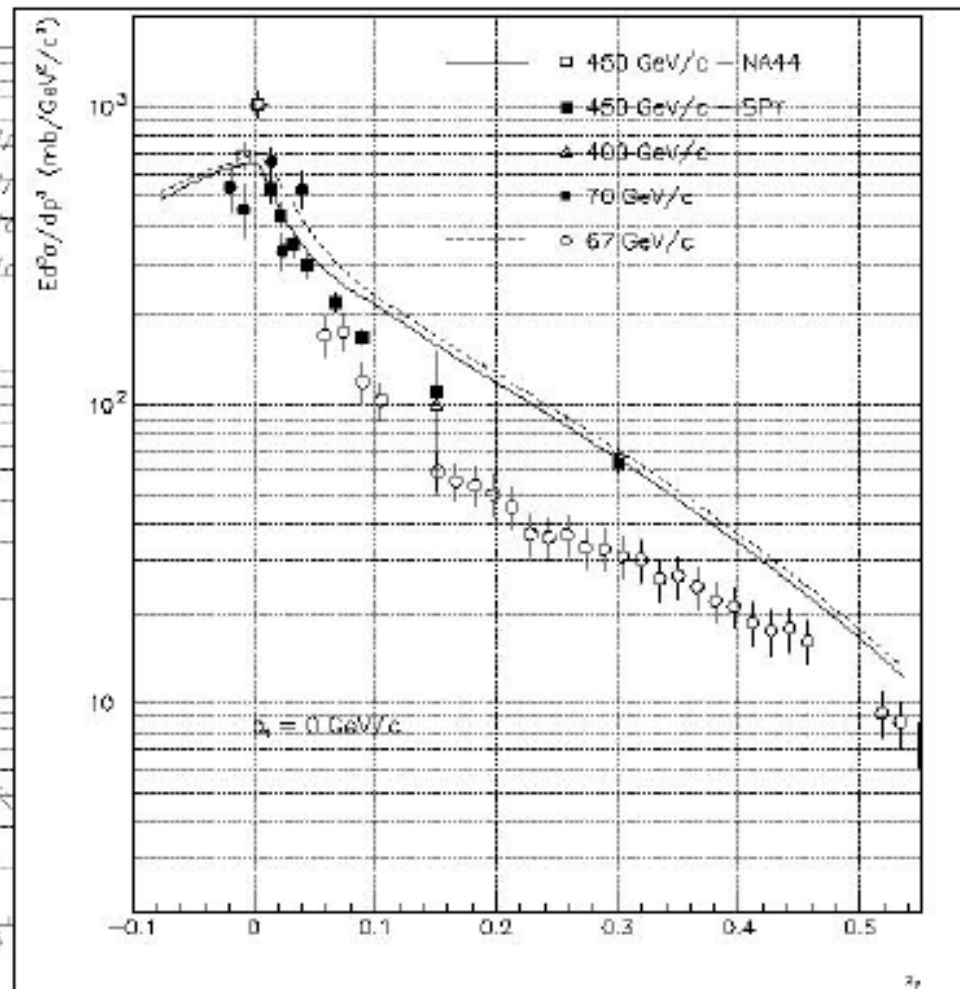
- Service Measurements
 - » Atmospheric neutrinos - Cross sections of protons and pions on Nitrogen from 5 GeV- 120 GeV
 - » Improve shower models in MARS, Geant4
 - » Proton Radiography- Stockpile Stewardship- National Security
 - » MINOS target measurements - pion production measurements to control the near/far systematics
- Will make DST's available for the public on DVD's after we are done.
- HARP at CERN went from 2-15GeV incoming pion and proton beams. MIPP will go from 5-85 GeV/c for 6 beam species $\pi^\pm K^\pm p^\pm$ -- 420M triggers. 3KHZ TPC.

Quality of existing data

Invariant π^- cross section
pBe interactions vs
models



Invariant π^+ cross section
pBe interactions vs
models



MIPP Upgrade program

- MIPP has been asked to submit a proposal in Oct 2006 to the PAC by Fermilab management.
- Speed up TPC DAQ by using ALICE ALTRO/PASA chips. We have been given the green light to acquire these chips from CERN (\$80K).
- Speed up rest of DAQ.
- Is important for
CDF/D0, CMS/Atlas (hadronic Energy scale)
PIERRE AUGER/ICE CUBE(hadronic Energy scale)
Super K/Hyper K (Neutrino Spectra)
MINOS/MINERvA/NOvA. (Neutrino spectra)
CALICE (hadronic energy scale/resolutions)

Upgrade the beam to run at lower energies

- Currently, we can run reliably in the beam momentum range $10 \text{ GeV}/c$ - $90 \text{ GeV}/c$. With the installation of trim element power supplies that regulate at lower currents and by installing Hall probes in the magnets to measure the actual field (hysteresis), we feel we can get secondary beams as low as $1 \text{ GeV}/c$. Kaon beams as low as $3 \text{ GeV}/c$ are possible.
- This allows measurements crucial for the hadronic shower simulation problem.
- Missing Baryon Resonances (F.Wilczek interest).
Coupled channel partial wave analyses
- $P\bar{p}$ - P annihilation studies

Nuclei of interest- 1st pass list

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

Upgrade Run Plan

- Engineering run - 2months.
- Run MINOS Target for Full 10million events—
2days running
- Run Minerva Medium energy target-2days
- Run LH2 for further scaling law studies 10 days
- Run LD2 for further scaling law studies 10 days
- Run LN2 for atmospheric studies 5 days
- Run 27 nuclei for shower simulations 27 days
- Total calendar running- 56 days

Collect ~ 250 Million events

Timeline

August 2006

- Run Till next shutdown in current mode
- Acquire Altro/PASA chips
- Design New TPC Sticks
- Get approval for proposal. We have appealed the PAC decision
- Get new collaborators
- Run in 2007 (end of 2007) in upgraded mode with current beam.
- Design lower momentum beam. Beam Cerenkovs may need redesign (too much multiple scattering)
- Lots of graduate student theses
- Possible to affect shower simulators on 2008 time frame.

Conclusions

- MIPP has acquired data of unprecedented quality on particle production using 6 beam species on several nuclei and the MINOS target.
 - More data is needed for the neutrino program on their targets-MINOS, MINERVA, NOVA.
 - MIPP Upgrade will obtain 10 times more data than MIPP with 10 times less beam time.
 - Data that can revolutionize our understanding of hadronic shower generation, non-perturbative QCD will be obtained.
 - Missing Baryon resonance problem, Missing cascade resonances (~20 each are missing if tri-quark models are correct) can be addressed.
 - Cosmic ray systematics can be significantly improved with MIPP upgrade data.
- Collaborators from the cosmic ray community are essential to see this part of the program to success.

Collaborators from any interested community are welcome/needed

Status today

- MIPP upgrade was presented to the PAC in October.
 - They wanted to see results the analysis of the existing data and the collaboration to become stronger.
 - They need more quantitative information on the impact of the proposed measurements. Eg. How would the cross section measurements impact the performance of the simulation programs?
 - Can G4 help here?
 - Decision on MIPP is deferred in time until these points are addressed.
- More people have joined MIPP (GSI/KVI and Utah/Rutgers joined)
 - But needs still to grow. New groups are invited to participate!!
- The G4 already people wrote strong letters of support to the PAC
- Proposal can be found on:
<http://ppd.fnal.gov/experiments/e907/notes/MIPPnotes/public/pdf/MIPP0138/MIPPO138.pdf>

Backup

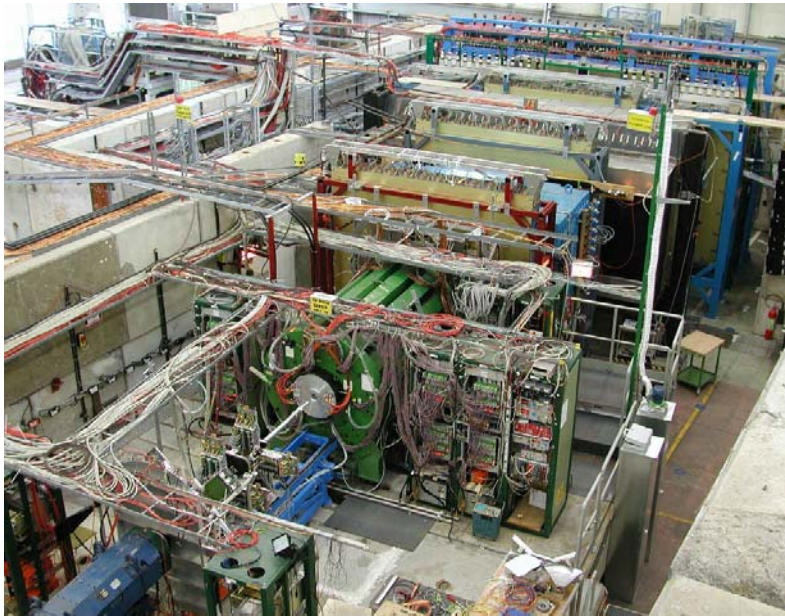
Hadron Shower Simulator problem

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

MIPP upgraded data taking times

- The entire MIPP I (current run, approved physics) dataset (75 million events) can be acquired in 18.1 calendar days!
- We can also do additional physics which I will describe.
- This has brought in new collaborators, several (4) signing the proposal and several more institutions expressing strong interest.

HARP

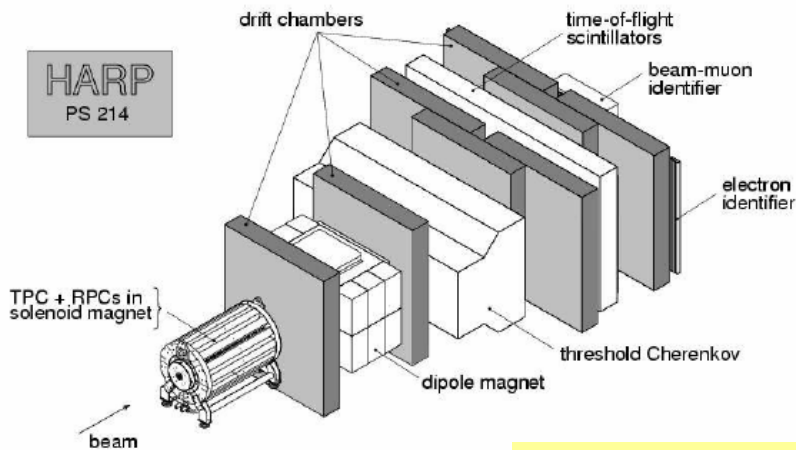


C. Meurer

Systematic study of hadron production

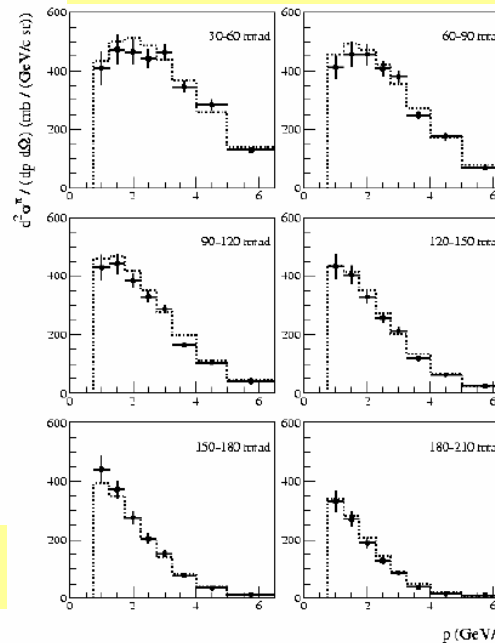
- Beam momenta from 1.5-15 GeV/c
- Targets from H to Pb

Data taking finished
 Experiment now in the analysis phase
 Data important for Neutrino experiments

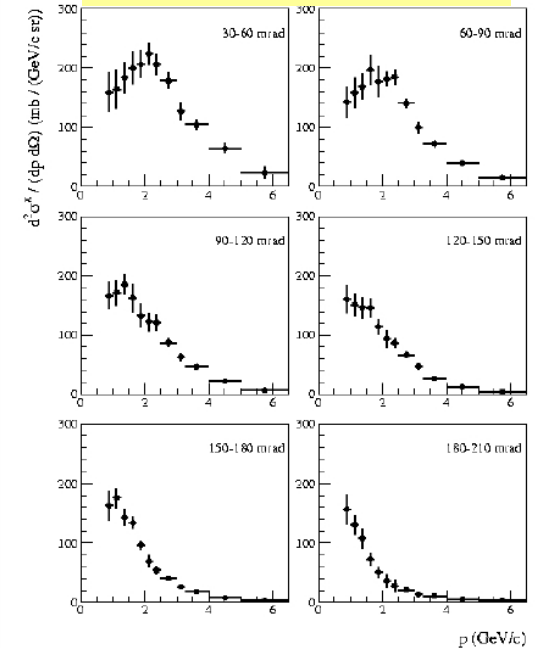


New: pC data!

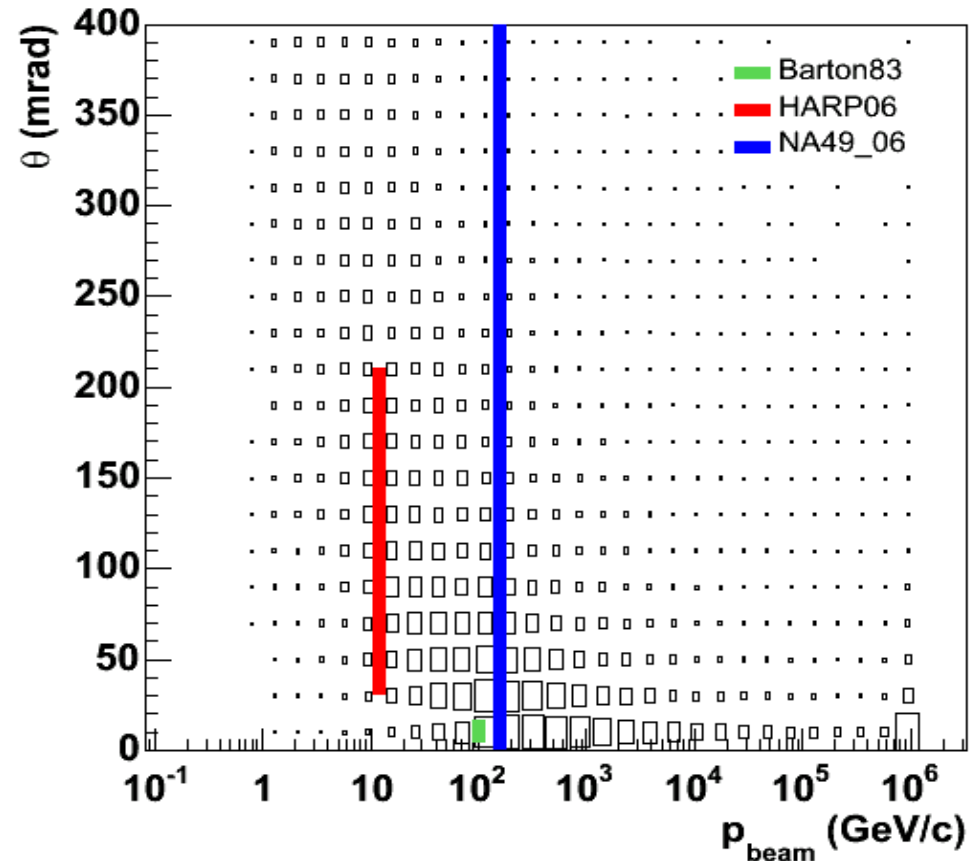
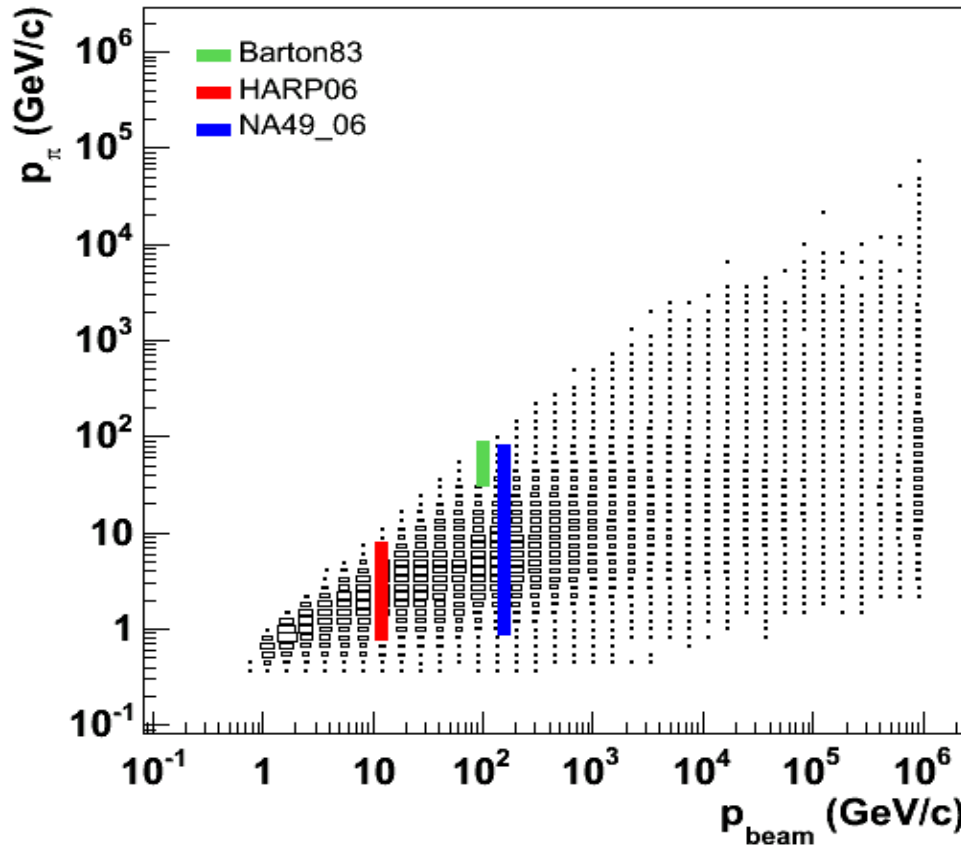
$p(12.9 \text{ GeV})\text{Al} \rightarrow \pi + X$



$p(8.9 \text{ GeV})\text{Be} \rightarrow \pi + X$



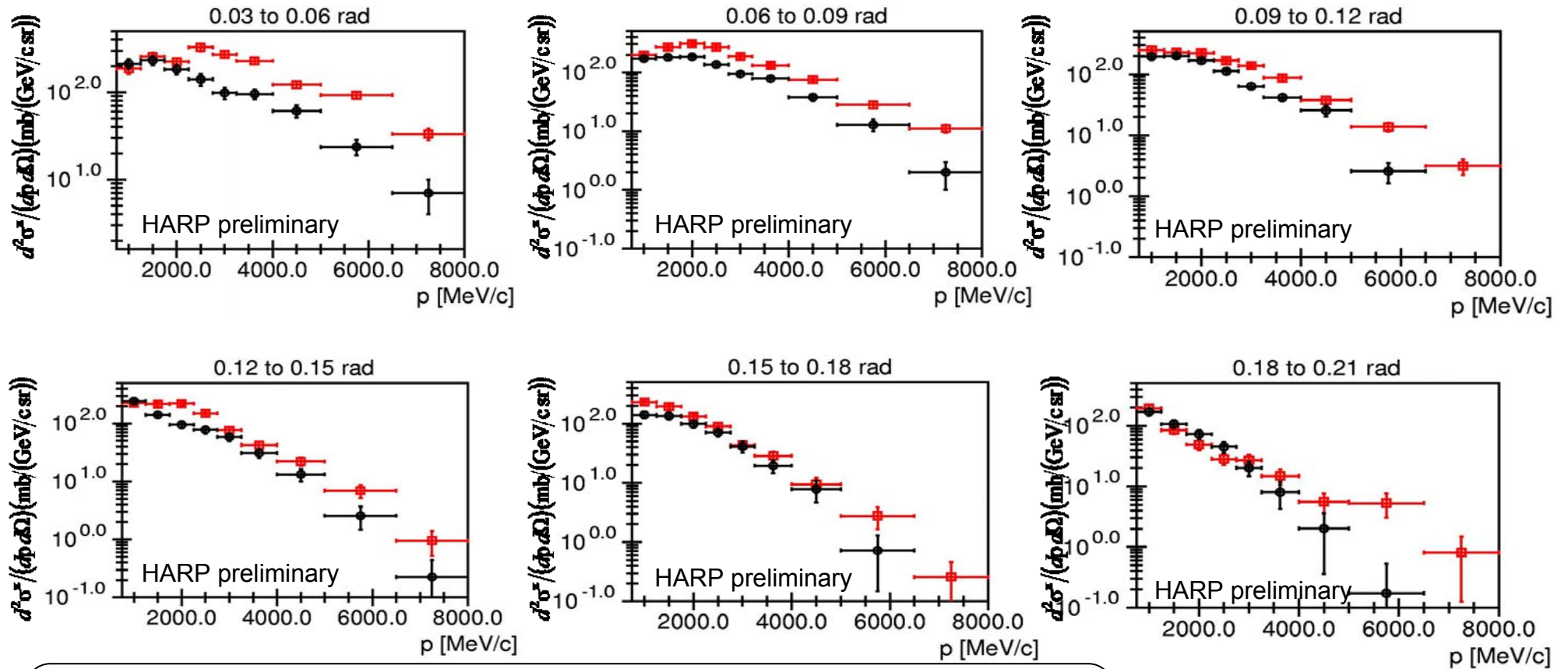
New p+C data: NA49, HARP



Data: $p+C \rightarrow \pi+X$
 EAS: $p+air \rightarrow \pi+X$

Existing: proton beam \rightarrow 21% of grandmother particle
 Still needed: pion beam \rightarrow 72% of grandmother particle

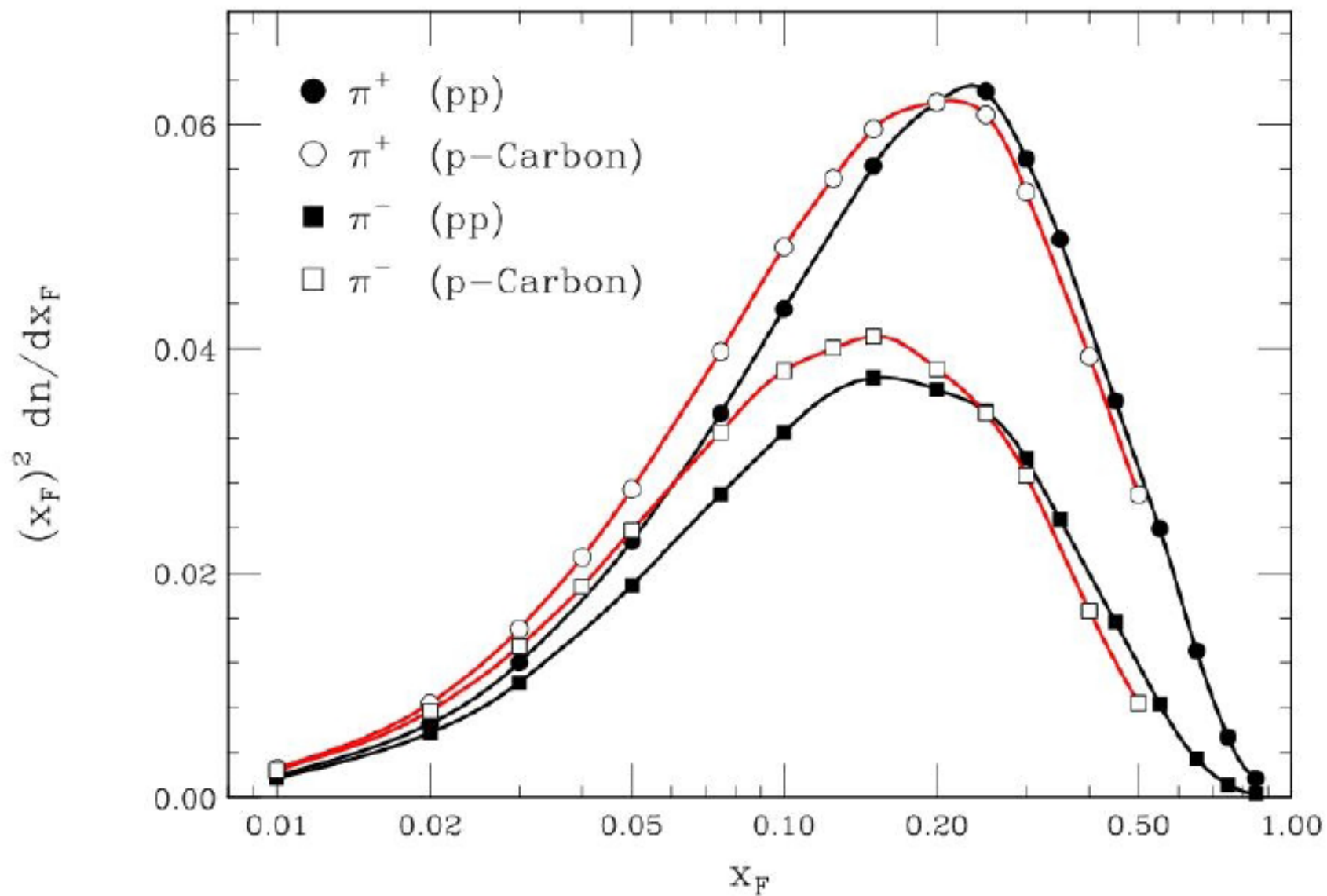
$p+C \rightarrow \pi^\pm + X, p_{\text{beam}} = 12 \text{ GeV}/c$



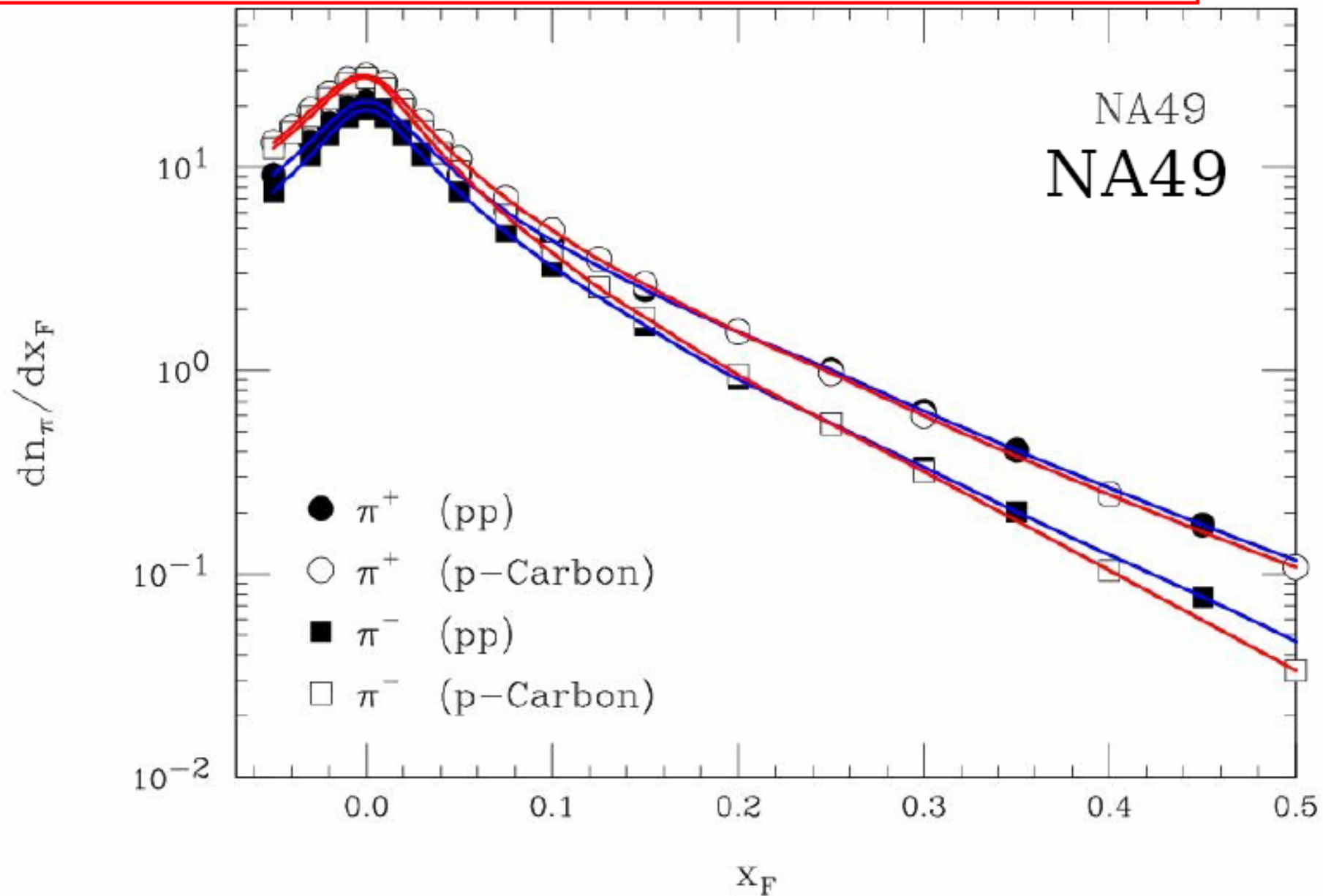
- π^+ : leading particle effect
- Comparison with models in preparation
- Error: stat. and syst. error
 → syst. error: kaon subtraction in progress

π^-, π^+

NUCLEAR effects: pp vs $p-^{12}\text{C}$

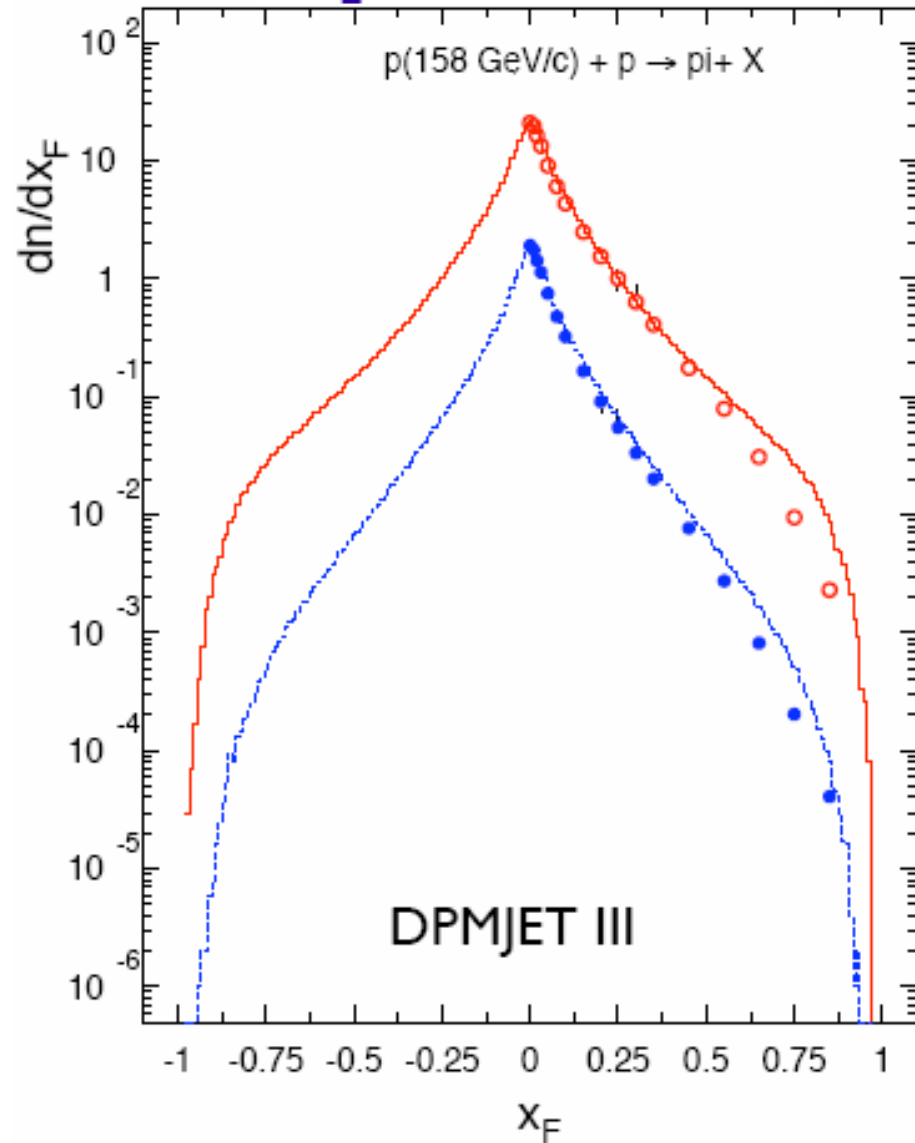


NUCLEAR effects: pp vs $p-^{12}\text{C}$

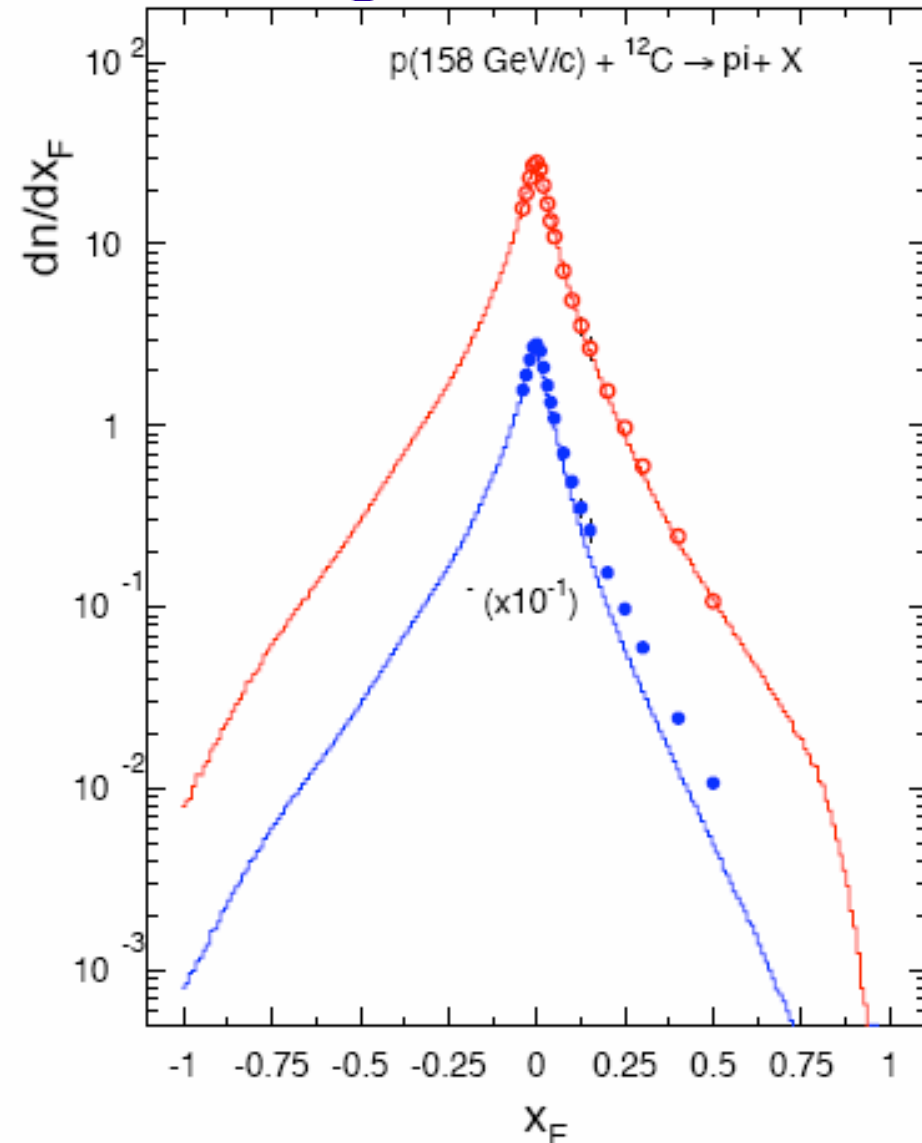


New NA49 data (p-p and p-C, 158 GeV)

hep-ex/0510009

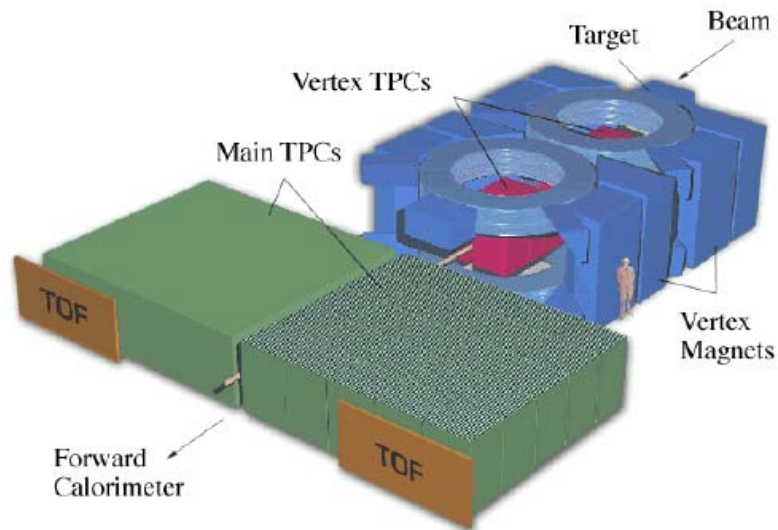


hep-ex/0606028.



NA49 Upgrade

New measurements of pp and pA and AA collisions 30-200 (10A-158A) GeV



- measurements of hadron production in nucleus-nucleus collisions, in particular fluctuations and long range correlations, with the aim to identify the properties of the onset of deconfinement and search for the critical point of strongly interacting matter,

- measurements of hadron production in proton-proton and proton-nucleus interactions needed as reference data for better understanding of nucleus-nucleus reactions; in particular correlations, fluctuations and high transverse momenta will be the focus of this study,

- measurements of hadron production in hadron-nucleus interactions needed for neutrino and cosmic-ray experiments.

With an upgraded experiment:

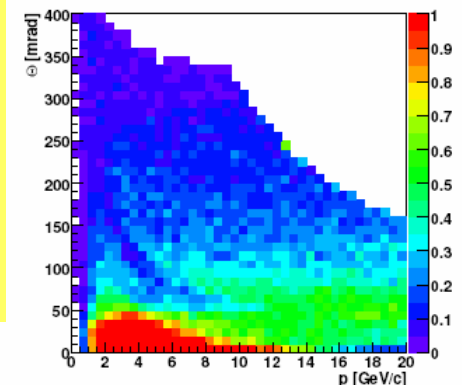
Stage I: modest improvements (computing, some readout)

Stage II: DAQ upgrade (x20) and TPC acceptance improvement

Stage III: add projectile spectator detector

Propose a program for 2007-2011

TPC acceptance for 40A GeV



At the stage of a letter of interest