Fermilab MIPP cross-section results and future ideas for a Nitrogen run

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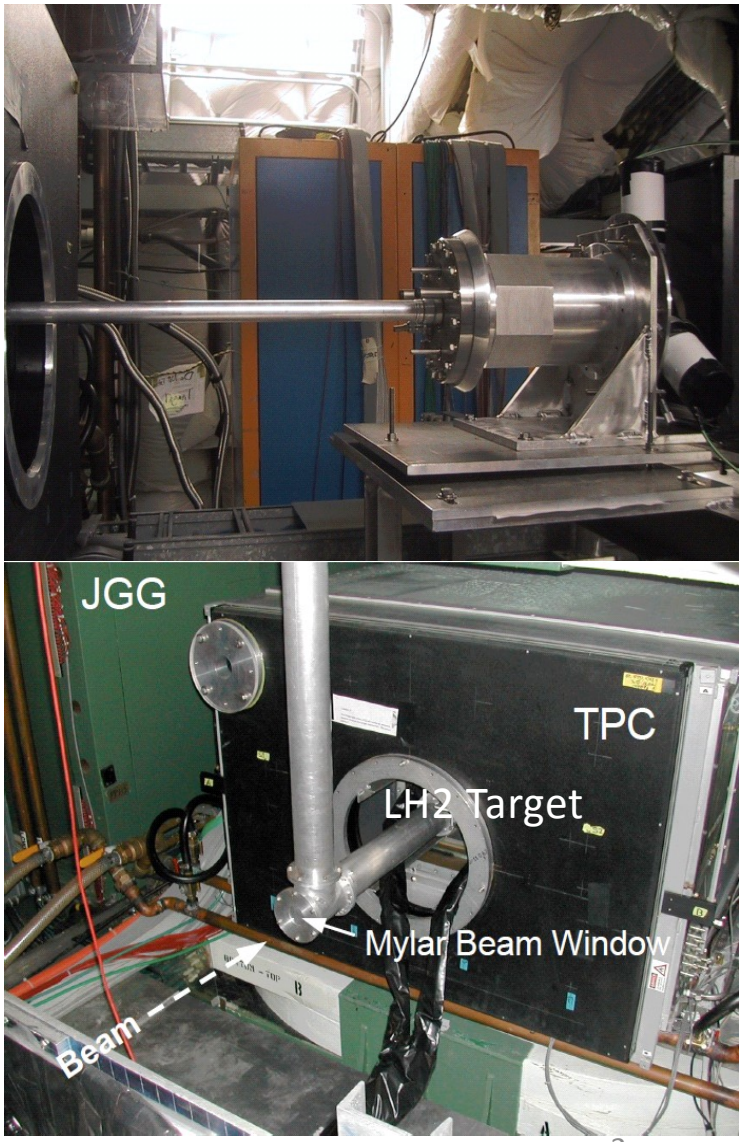
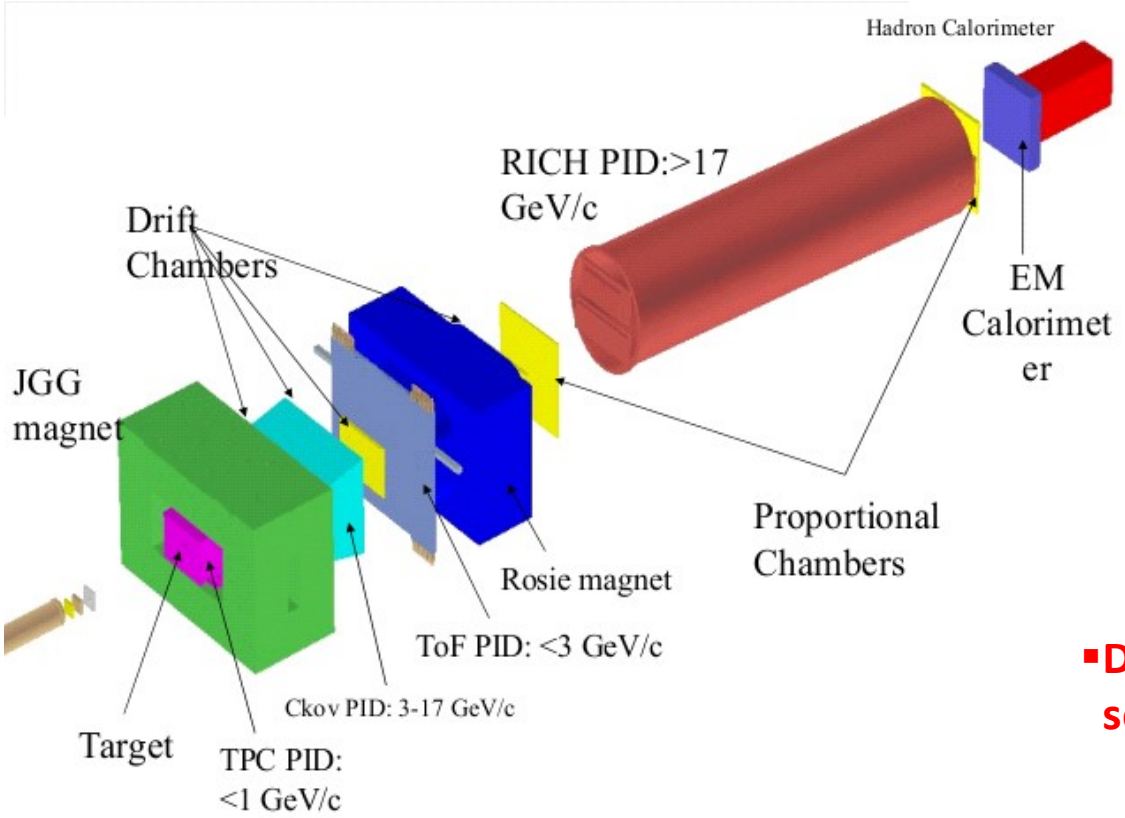
Introduction

- Main Injector particle production (MIPP) experiment is a Fermilab experiment.
- It took physics runs from December 2004 to February 2006.
- Primary beam of protons at 120GeV/c from main injector.
- Secondary beams of π's, K's and p's from 5-90GeV/c were produced after colliding 120GeV/c protons on copper target.
- ~18 million events collected from LH_2, Be, C, Bi, U and NuMI targets



MIPP Spectrometer



- Goal: To Measure Production Cross-section with particle id using various beam and targets

- **Designed for excellent particle id separation (2-3σ)**
  - ✓ ***TPC : < 1 GeV/c***
  - ✓ ***TOF : 1-3 GeV/c***
  - ✓ ***DCKov: 3-17GeV/c***
  - ✓ ***RICH:17-90GeV/c***

- **Full Acceptance spectrometer**
- **Two Analysis magnet deflect in opposite direction**
- **TPC + 4 Drift Chambers + 2 PWCS for tracking**

•Standard Cross-section analysis on liquid Hydrogen or solid Nuclear targets like Carbon are possible.

Inelastic cross section measurements (PRELIMINARY)

$$\text{Cross section} = \frac{N_{int} \times 10000}{N_{beam} \times n_t \times \varepsilon} \text{ mb}$$

$$n_t = \frac{N_A \times \text{density} \times \text{thickness}}{\text{Atomic weight}} \text{ cm}^{-2}$$

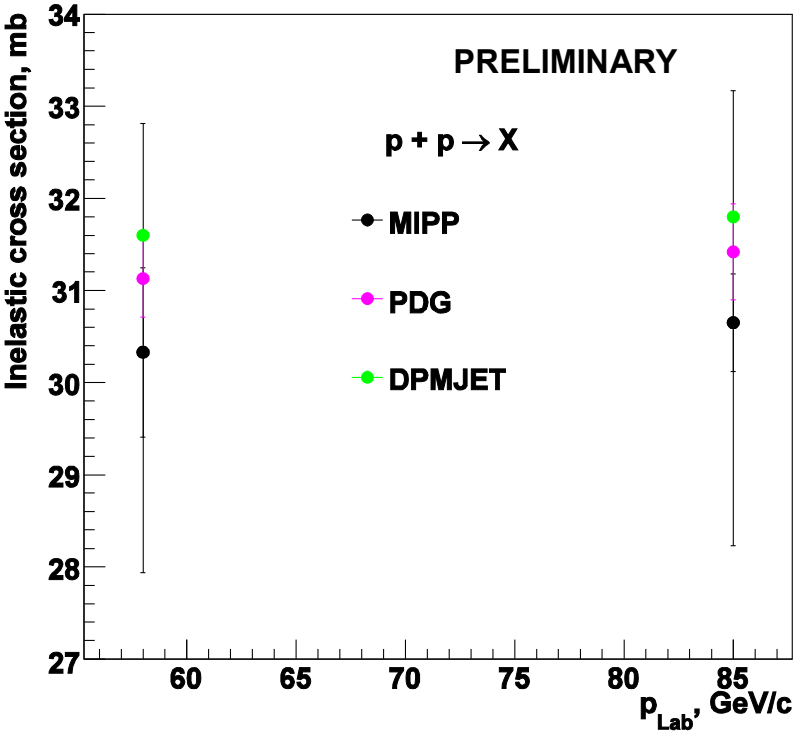
Energy (GeV)	PDG (mb)	DPMJET (mb)	MIPP (mb)
58	31.13 ± 0.13 (stat)	31.6	30.33 ± 0.92 (stat) $^{+2.39}_{-2.48}$ (syst)
85	31.42 ± 0.13 (stat)	31.8	30.65 ± 0.53 (stat) $^{+2.42}_{-2.52}$ (syst)

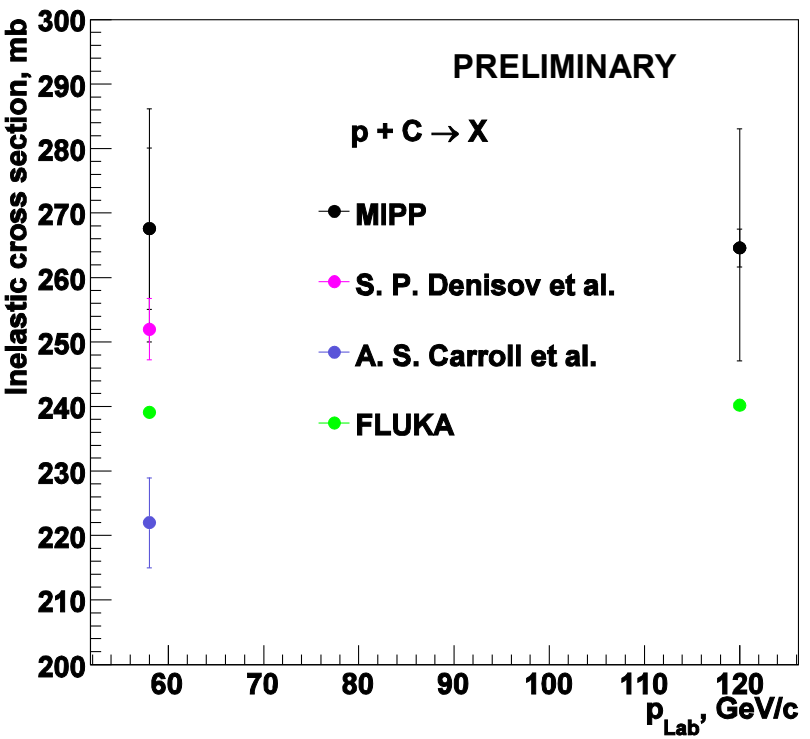
58 and 85 GeV/c p-H interactions

Energy (GeV)	Previous measurements (mb)	FLUKA (mb)	MIPP (mb)
58	252 ± 4 (stat) (Nucl. Phys. B61, (1973), 62) (IHEP, Serpukhov) 222 ± 7 (stat+syst) (Phys. Lett. B80, (1979), 319) (FNAL)	239.1	267.6 ± 12.5 (stat) $^{+17.6}_{-18.6}$ (syst)
120		240.2	264.6 ± 2.94 (stat) $^{+17.5}_{-18.5}$ (syst)

58 and 120 GeV/c p-C interactions

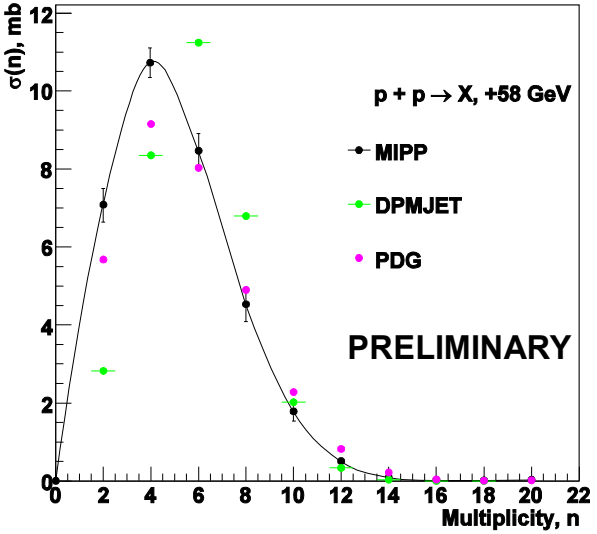
Comparison of MIPP data with MC and previous measurements

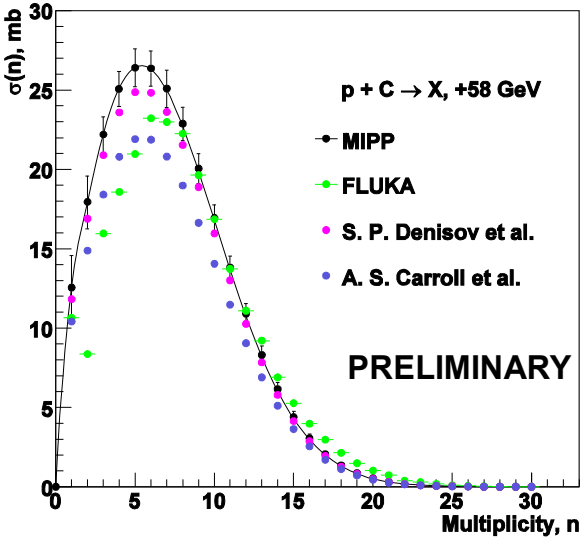




- p+p at 58 and 85 GeV: data consistent, within error bars, with the PDG and DPMJET
- p+C at 58 GeV: data consistent, within error bars, with measurement of S. P. Denisov et al. (IHEP, Serpukhov) and ~20% higher than the measurement of A. S. Carroll et al. (FNAL). FLUKA is ~11% lower than the data
- p+C at 120 GeV: FLUKA is ~9% lower than the data

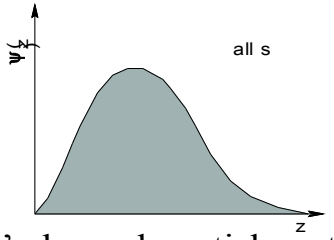
LH_2 and Carbon multiplicities





- For LH_2 target, charged multiplicities should be even. Both even and odd multiplicities in data because of acceptances and reconstruction inefficiencies
- KNO Scaling function is used to get the data true probabilities.
- KNO Scaling relation:

$$P_n(s) = \frac{\Psi(n/\langle n(s)\rangle)}{\langle n(s)\rangle}, \quad \frac{n}{\langle n(s)\rangle} = Z$$



where $P_n(s)$ is the probability of producing 'n' charged particles at a particular energy 's', $\langle n(s)\rangle$ is the average multiplicity and $\Psi(n/\langle n(s)\rangle)$ is the KNO function

$\Psi(Z) = (3.97Z + 33.7Z^3 - 6.64Z^5 + 0.332Z^7)e^{-3.04Z}$

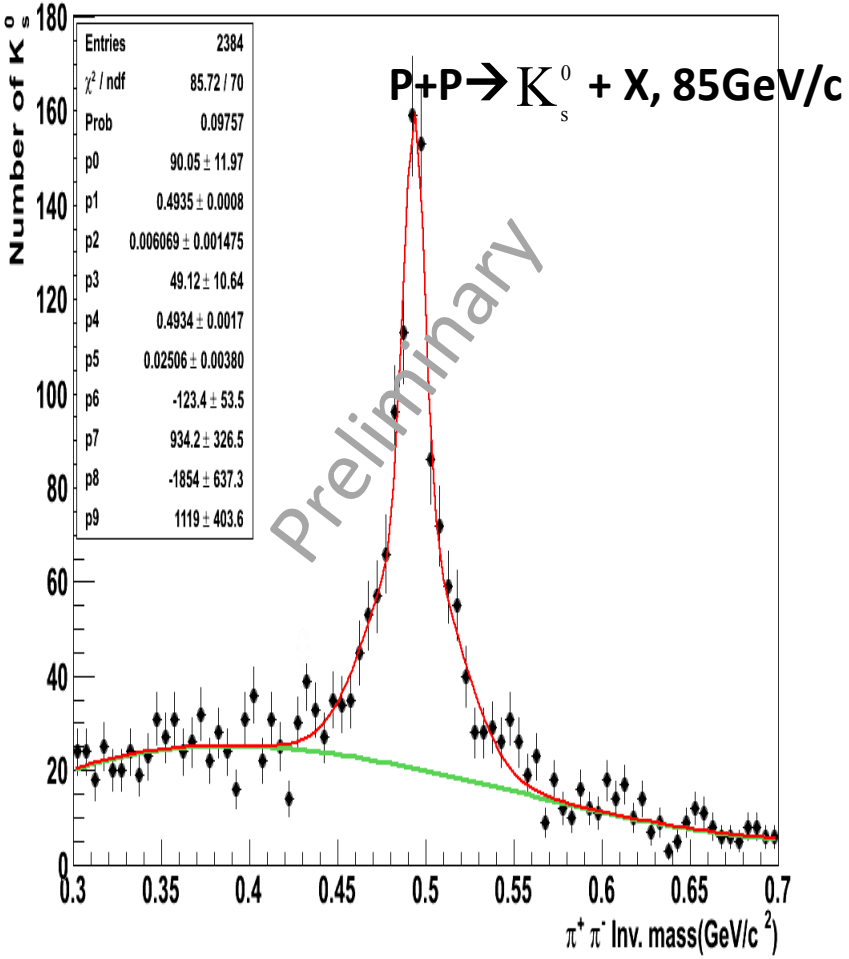
P. Slattery, Phys. Rev. Lett. 29, (1972), 1624

- The $\langle n\rangle$ from our data is used. Probabilities are multiplied by the average inelastic cross section to get the cross sections as a function of multiplicity
- Similarly cross sections are calculated for Carbon target where multiplicities are both odd and even
- For LH_2 target, discrepancies found between the data and PDG at the lower end and tails. For Carbon target, the data is consistent, within error bars, with measurement of S. P. Denisov et al.. The DPMJET and FLUKA shapes not consistent with the data

- Special cross-sections such as K^0_s production can also be studied with the existing MIPP data.

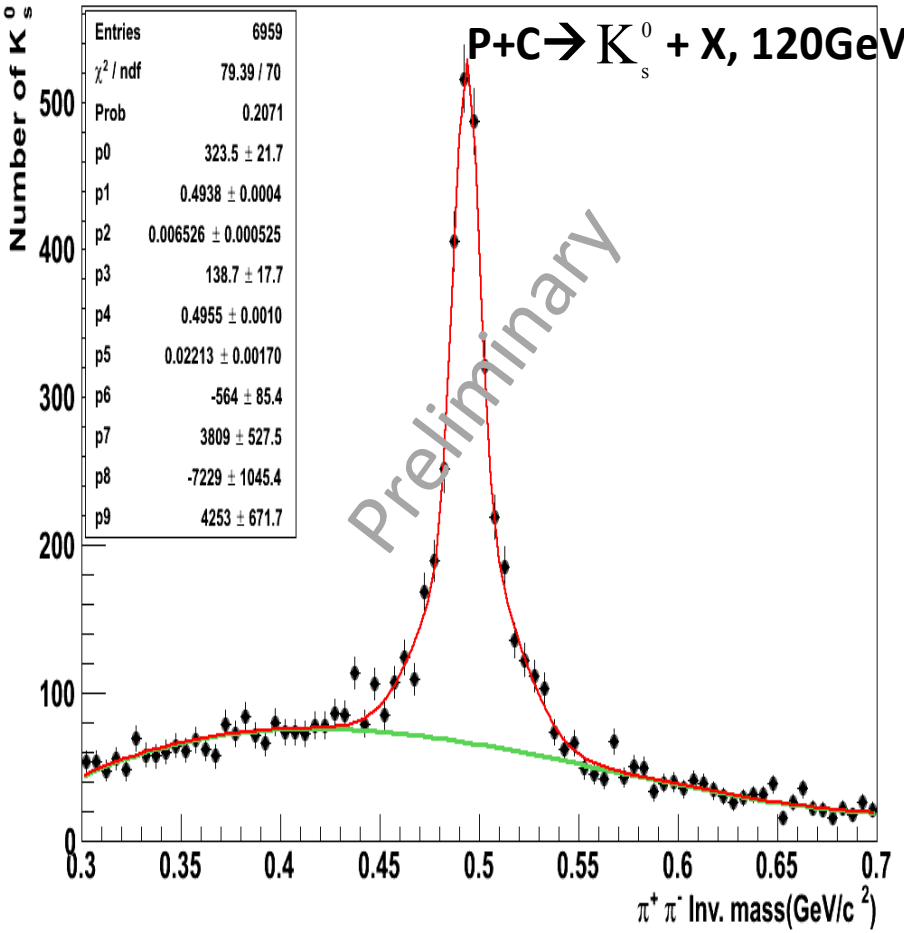
Background Subtracted $\pi^+\pi^-$ Invariant Mass

DATA



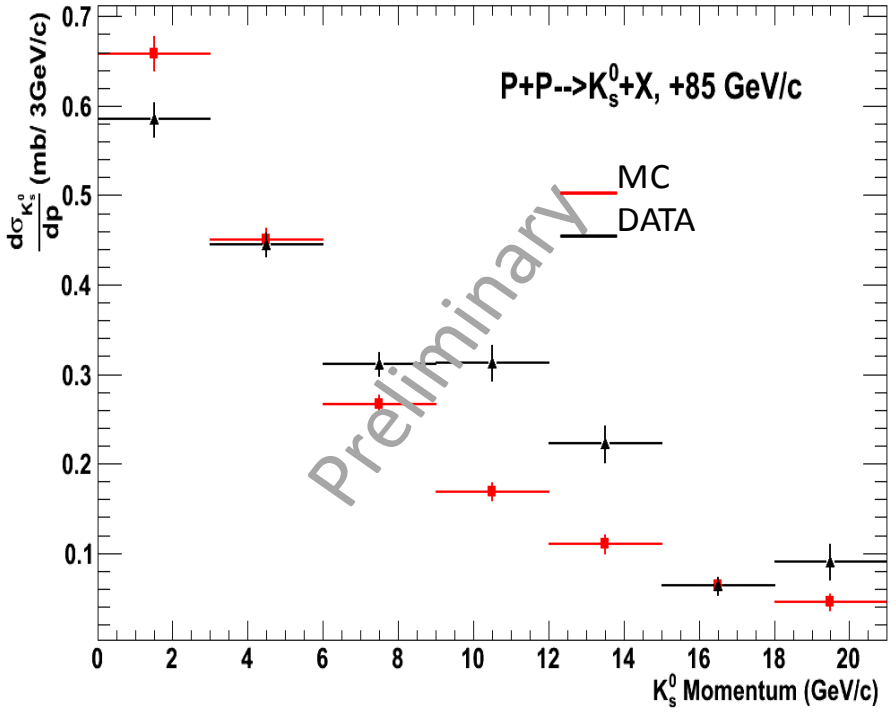
P+P→ K^0_s + X, 85GeV/c

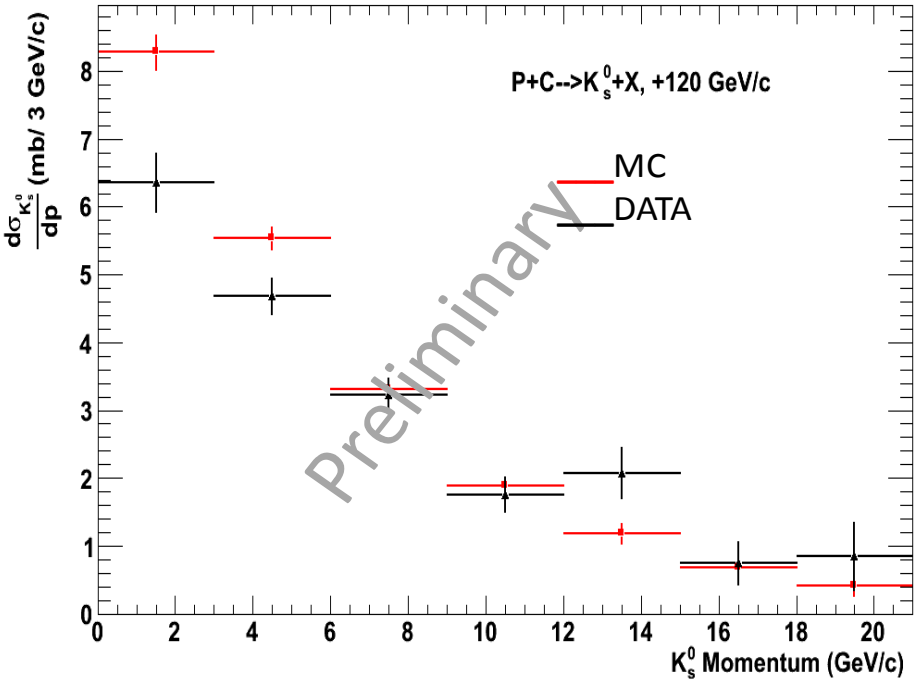
DATA



P+C→ K^0_s + X, 120GeV/c

K_s^0 Cross-section





Target/beam Energy	MC Cross-section (mb)	Data Cross-section (mb)
LH_2 / 85	5.5 ± 0.08 (stat)	6.2 ± 0.11(stat)
Carbon / 120	63.9 ± 1.15 (stat)	59.2 ± 2.41(stat)

Preliminary

•Conclusion from what has just been presented from the MIPP ongoing analysis are:

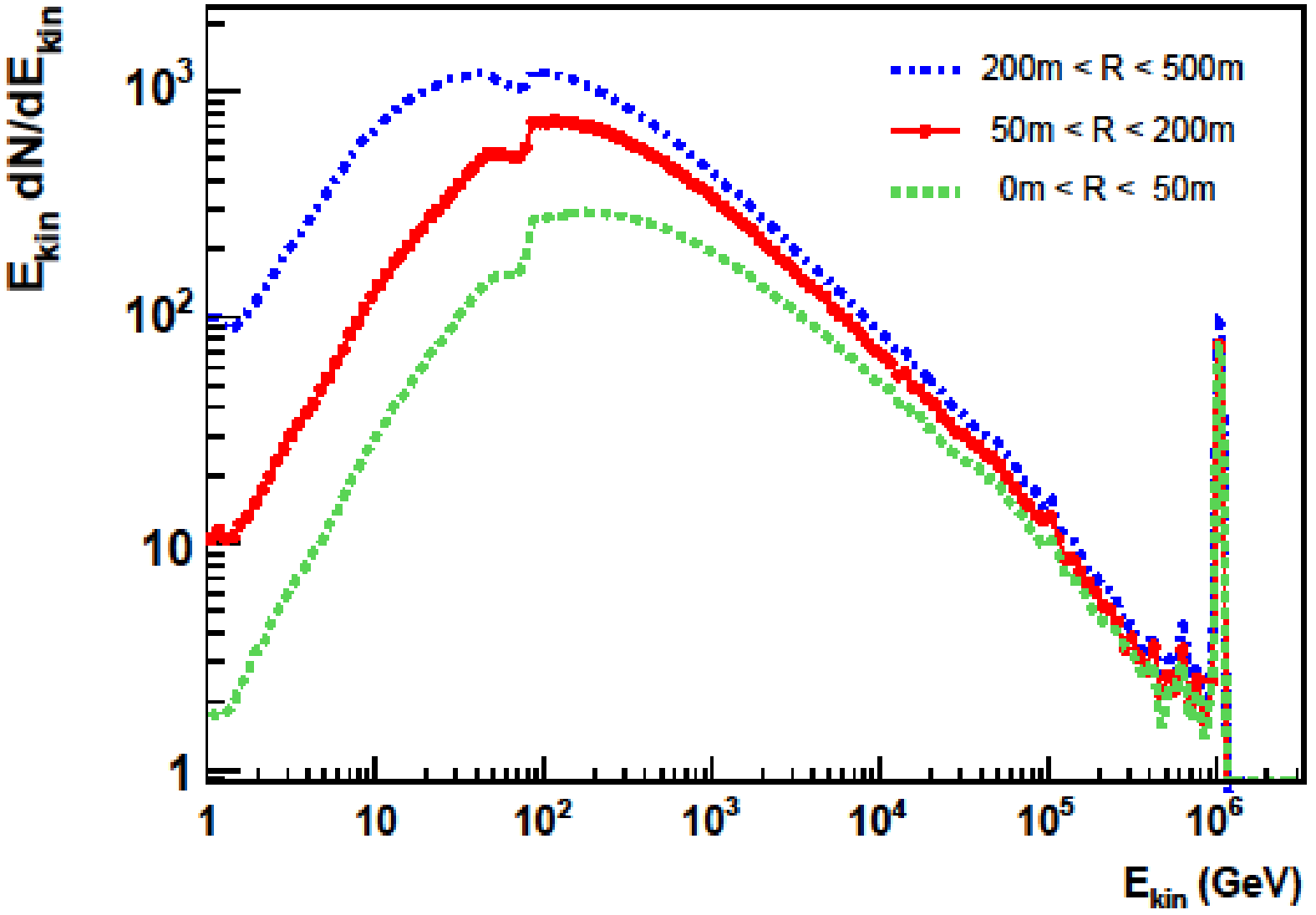
MIPP cross-section experiment and data are wonderful and we have improved results.

Our data is limited and can use an improved run with higher data acquisition rate.

Special runs for Cosmic Rays such as with Liquid Nitrogen targets and high statistics are soon possible.

A small effort from people interested in this would help get it funded and approved for data taking.

Hadronic shower development known problems



Future MIPP Liquid Nitrogen plan

- Put together an extended team of scintiests interested in the Nitrogen cross-section running.
- Request for a extension of the MIPP (E907) experiment for Cosmic-Ray needs (not a new experiment).
- Improve the readout of a few detectors:
  1) TPC, Drift Chambers, TOF and Ckov (all of this is designed and ready)
  2) Keep Trigger, Beam ID, and other elements but fine tune for special needs.

During the preparation of the *Proposal to upgrade the MIPP Experiment* the resources needed for each upgrade task have been determined. This document lists the cost and labor resources needed throughout the project. The full Gantt chart is attached.

The MIPP upgrade project is divided into tasks as shown in the table. The total project cost is ~$2 million. Fermilab M&S accounts for $1.2 million and >20,000 hours of Fermilab Labor add $567,000 for a total Fermilab Base Cost of $1.78 million. We expect In Kind Contributions from collaborating universities and laboratories of $205,000.

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

- Costs are low for a small improved MIPP Nitrogen Cross-section experiment.
- The MIPP experiment is fully debuged and understood to produce cross-section physics
- The time is perfect for the MIPP Nitrogen Cross-section running at Fermilab.
- This will improve Physics results from Cosmic Ray experiments that could use improved MC simulations.