P322

Proposal for hadron production measurements using the NA49 detector for use in long-baseline and atmospheric neutrino flux calculations

Bari, Bartol, Bratislava, Budapest, Caltech, CERN, Crakow, Dubna, Frankfurt, Harvard, UCL, Marburg, Milan, Naples, Oxford, Padova, College de France, Protvino, Rome I, RAL, Sheffield, Sofia, Stanford, Sussex, U. Texas, Warsaw, Zagreb

V. Palladino - 31/5/2001

http://www.hepl.harverd.edu/~messier/na491/

disinfection campaign

... the virus of hedronic uncertainties

PS Alleby et al. 1970 24 GeV CPS ν

SPS Atherton et al. 1980 400 GeV SPS ν

SPY 1996 450 GeV

atmo ν

need wide integral over fwd ph. space

.... many sperse small subsets ... large uncertai

.... forced to major model depende

inter + extrapolations

30% abs, 7% re

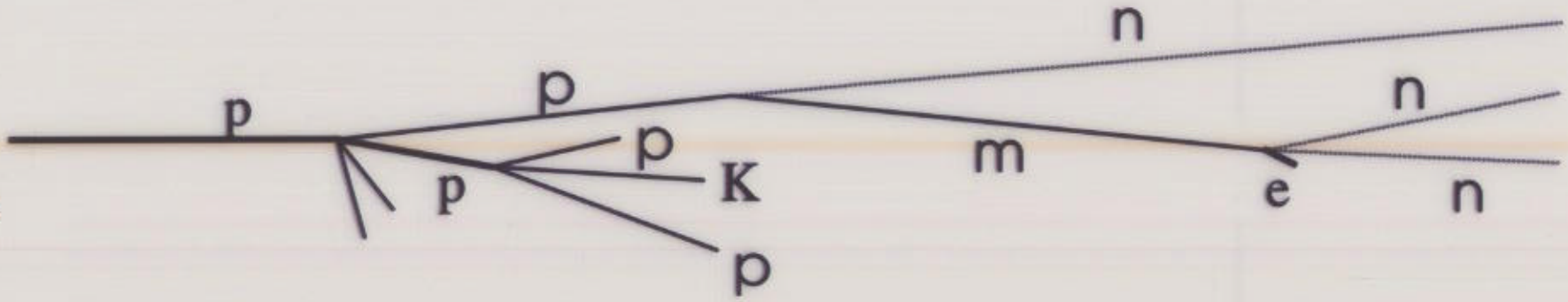
HARP ν Fact

atmo

HARP III

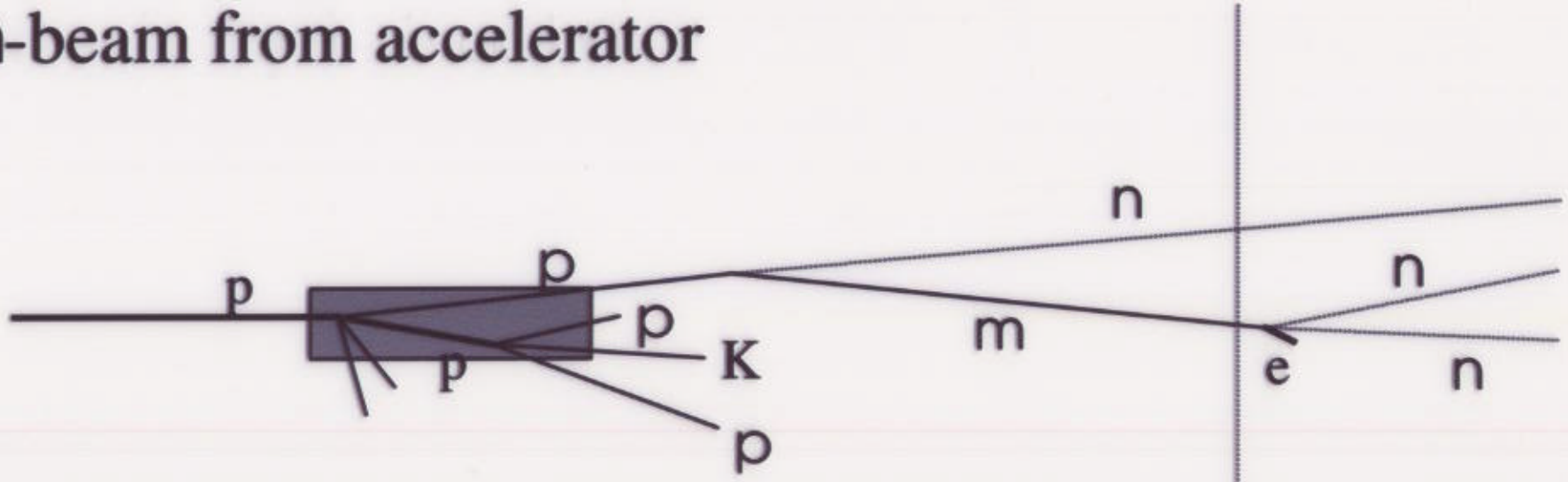
atmo + NuMI 120 GeV + CNGS 400 GeV

Anatomy of a Neutrino Producing Hadron Shower I.



Anatomy of a Neutrino Producing Hadron Shower II.

n-beam from accelerator



Mono-energetic beam

Hits a target

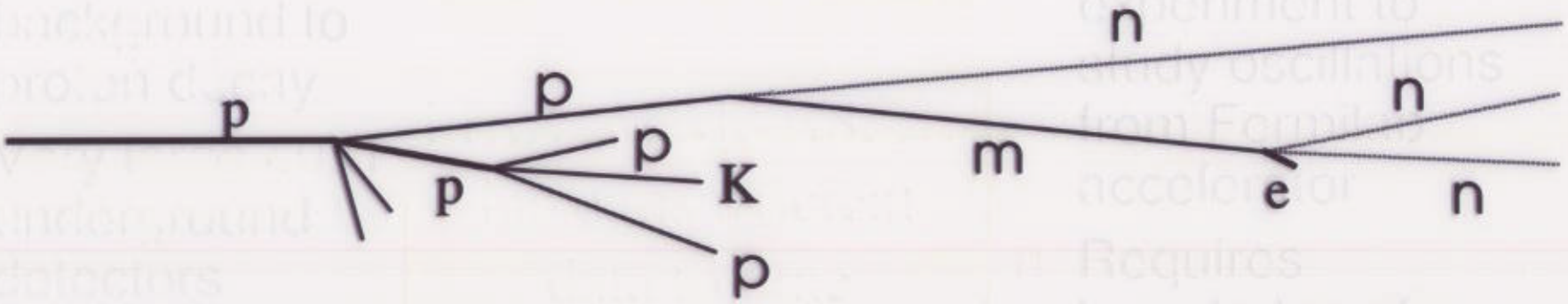
Many secondary and tertiary interactions

Conventional Super-Conventional

Cooled and accelerated muons

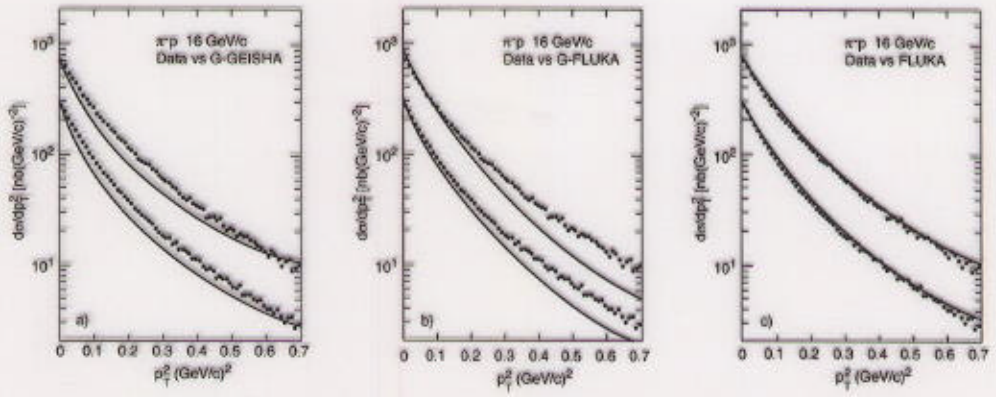
Anatomy of a Neutrino Producing Hadron Shower III.

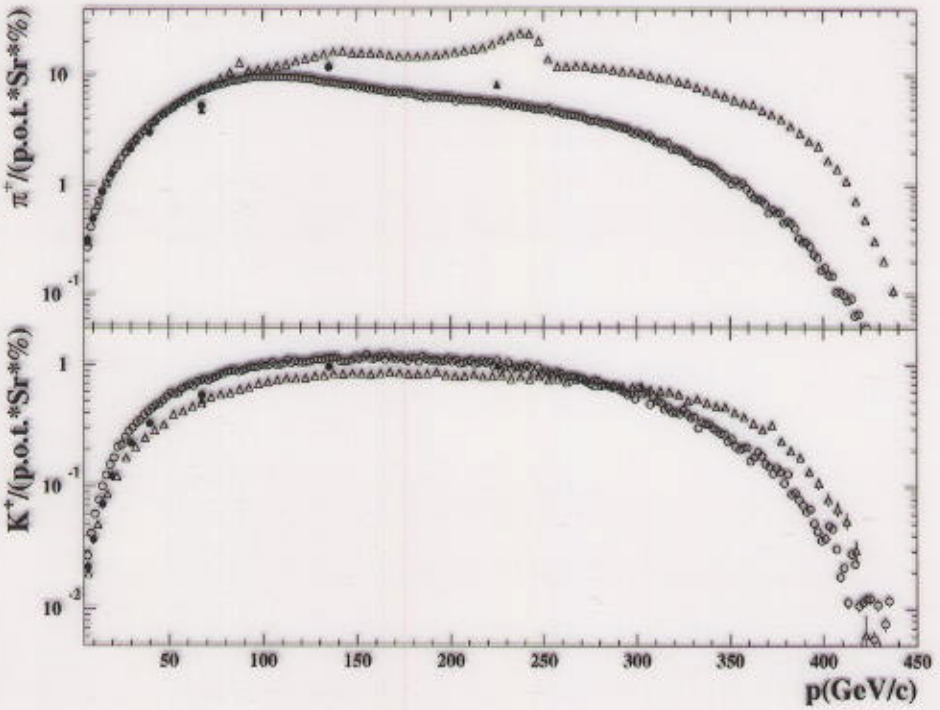
Cosmic ray induced n



Protons from cosmos	Target = upper atmosphere		Muon decay is important
•Solar modulation •Geomagnetic field	X_0 ~ 90 g/cm2 = 20 km up	•3-D effects important (but not as important as effects being addressed in this proposal)	Some hit earth (more likely for the vertical ones)

MC generator comparison





HARP experiment PS214

Status Report to the SPSC, 31/10/2000

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22 institutes
107 authors

HARP will measure.....

Hadronic production cross sections ($d\sigma/dP_t.dP_l$) at various energies and with various targets

***Goal*: 2% accuracy over all phase space**

$O(10^6)$ events/setting, low systematic error

CERN PS, T9 beam, 2 GeV/c - 15 GeV/c

"Stage 0"

Technical run with partial set-up, 25 September - 25 October 2000

Stage 1

Measurements with solid and crygenic targets, 2001

Future plans:

- **Measurements with incoming Deuterium and Helium, 2002**
- **~100 GeV incoming beam, using NA49 set-up**

Deliverables

Input data

for the design of the Neutrino factory/Muon collider

Input data

for the Atmospheric neutrino flux calculations

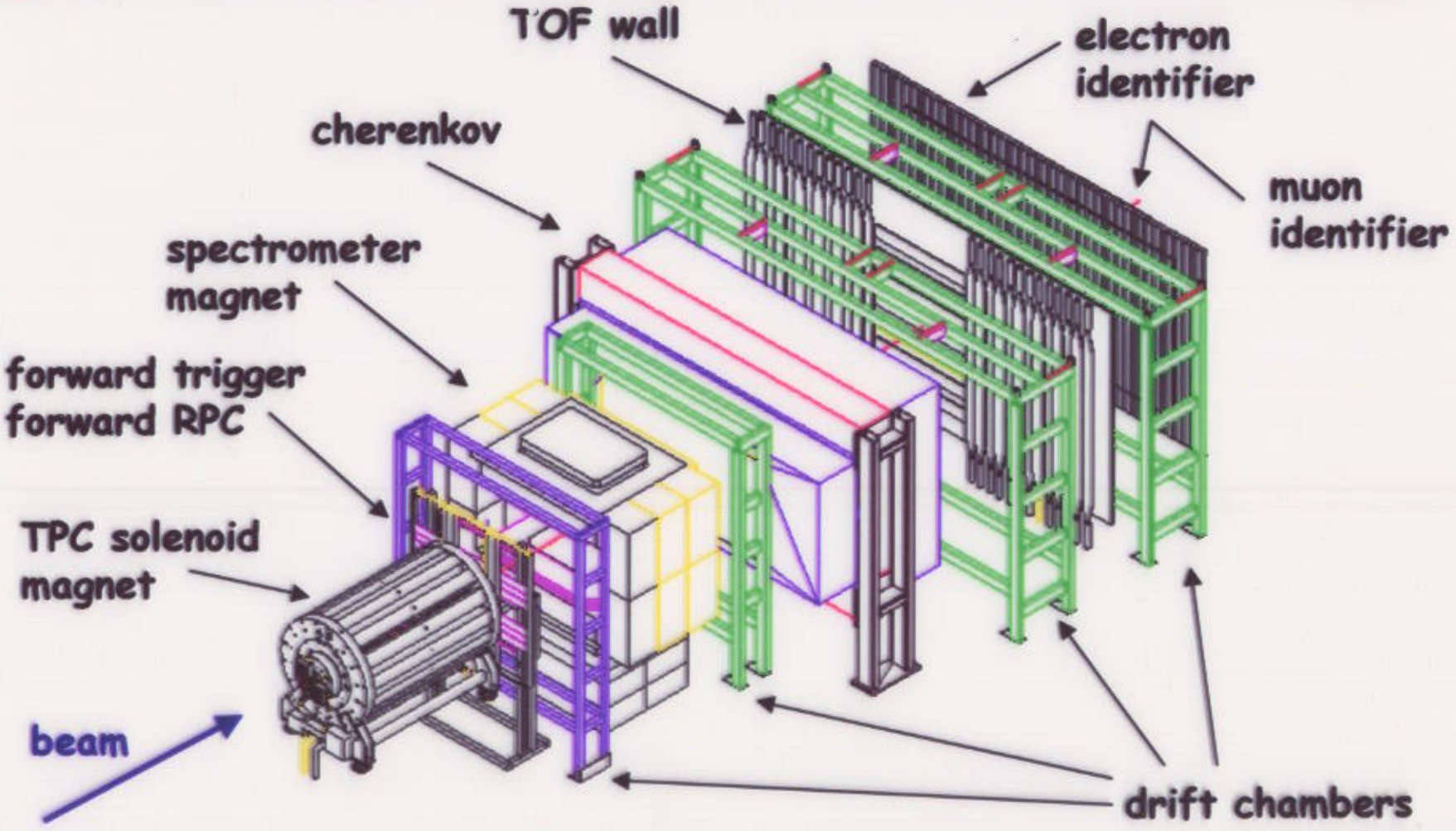
Precise predictions

of the neutrino fluxes for the K2K and MiniBooNE experiments

Input data

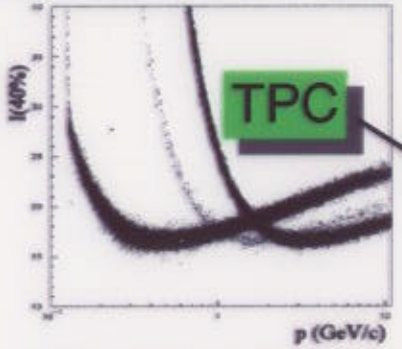
for the hadron generators in Monte Carlo simulation packages

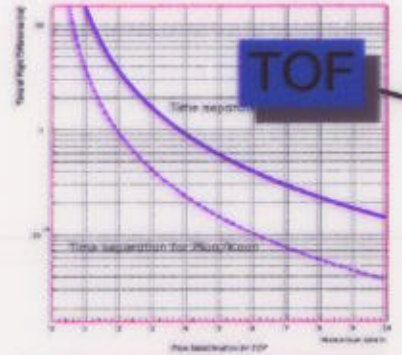
Experimental setup

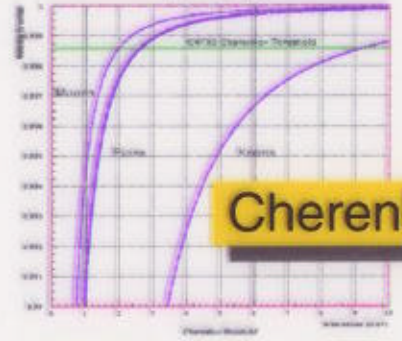


HARP technical run

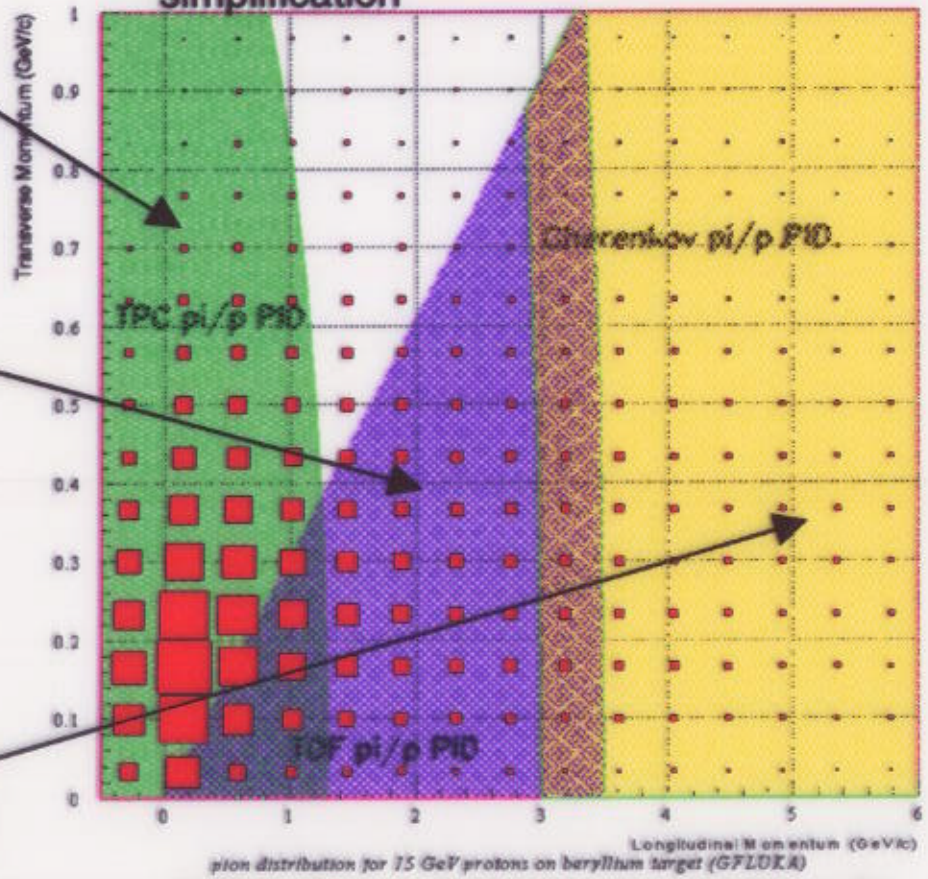
p/π separation







p/π separation at 4σ level, "conservative" simplification



pion distribution for 15 GeV protons on beryllium target (GFLUKA)

Pt-Pl box plot of π distribution from 15 GeV p on Be thin target

Goals of the Addendum:

1. Extend the hadron production study for a precise atmospheric-neutrino flux to helium projectiles

2. Obtain data for helium-proton interactions (relevant for the understanding of D, ^{3}He, and $\bar{p}$ in the cosmic-ray flux)

3. Obtain data with an isoscalar projectile (possibly interesting for a Neutrino Factory driver operated with deuterons)

Proposal for new hadron production measurements

Atmospheric ■

- Originally just a background to proton decay
- Very large 40kT underground detectors operational, more proposed
- Need to increase understanding of measurement details

Hadron production Monte-Carlo

FLUKA, MARS, … have insufficient data to tune

New measurements

NA49

MINOS

- Disappearance experiment to study oscillations from Fermilab accelerator
- Requires knowledge of neutrino fluxes to accurately determine ■ oscillation parameters

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continuity with HARP

Large Acceptance

$\lesssim 4\pi$

⇒ small uncertainty

... while small acceptance

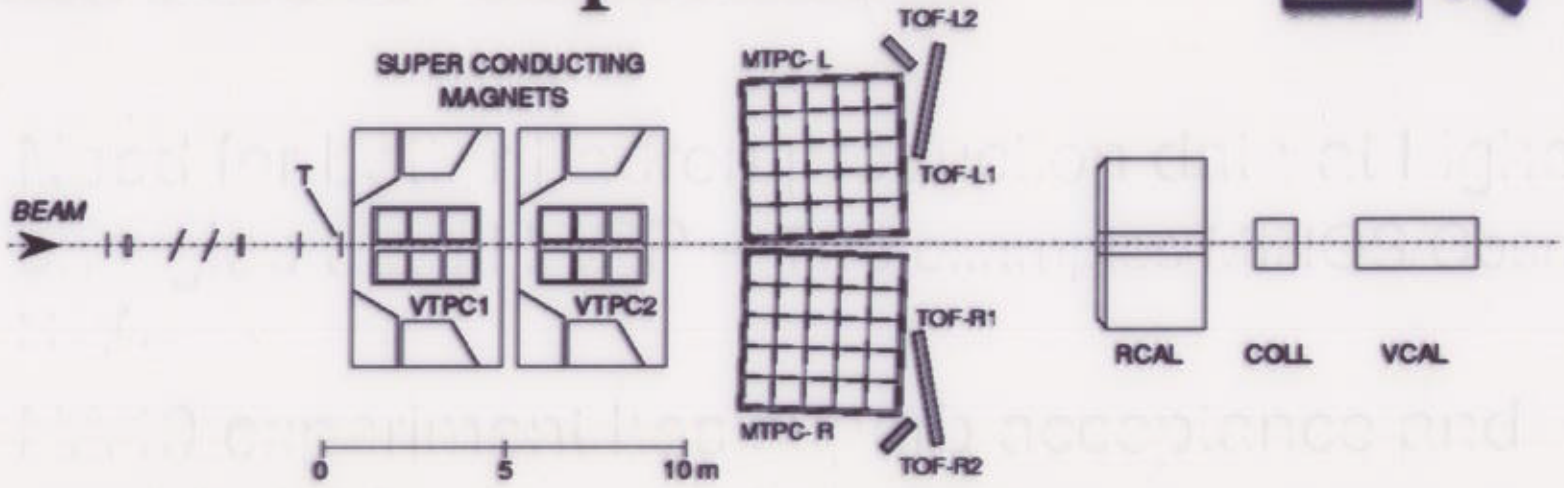
< milli st-rad

single-arm spect (SPY)

⇒ ~10% systematic uncertainty

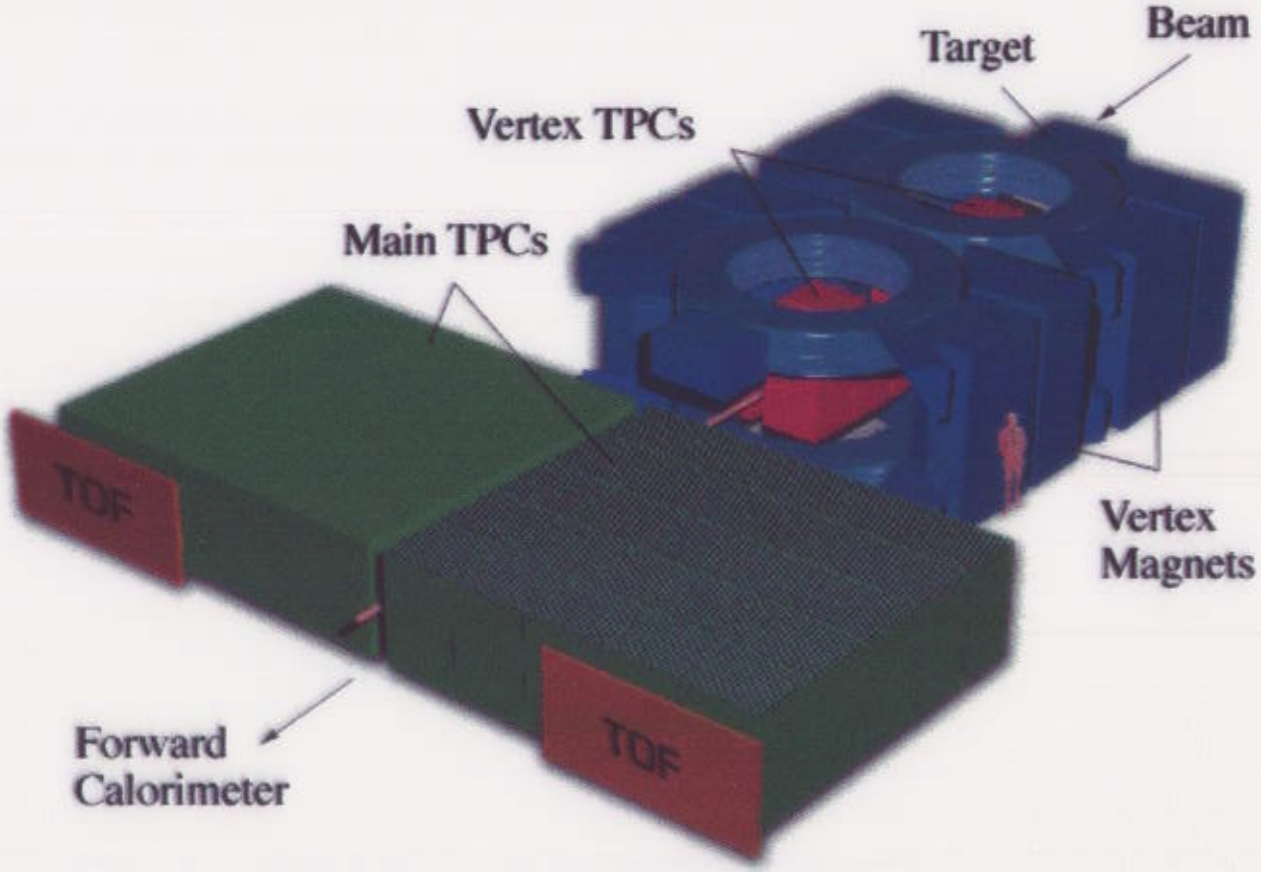
... at best ...

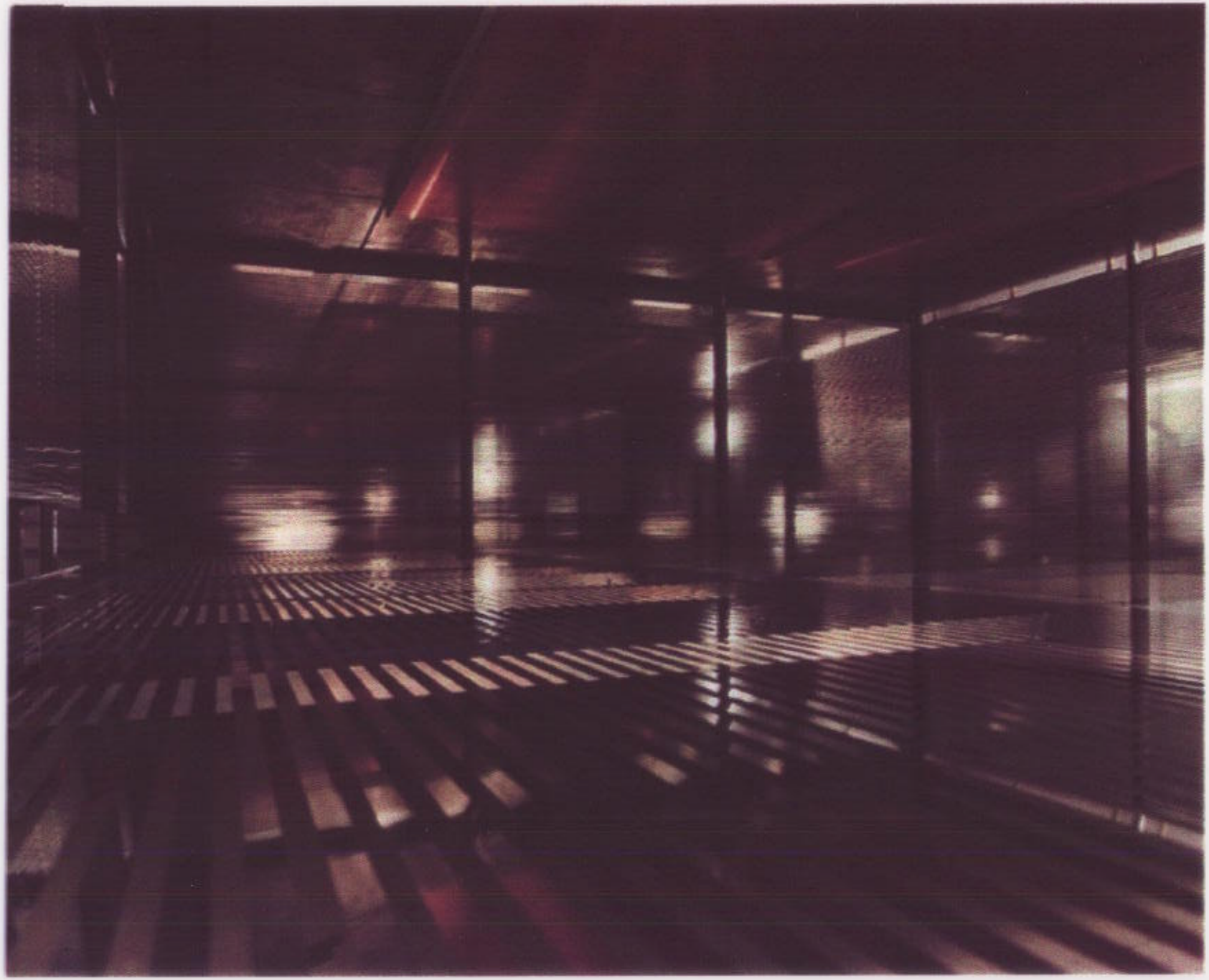
The NA49 experiment

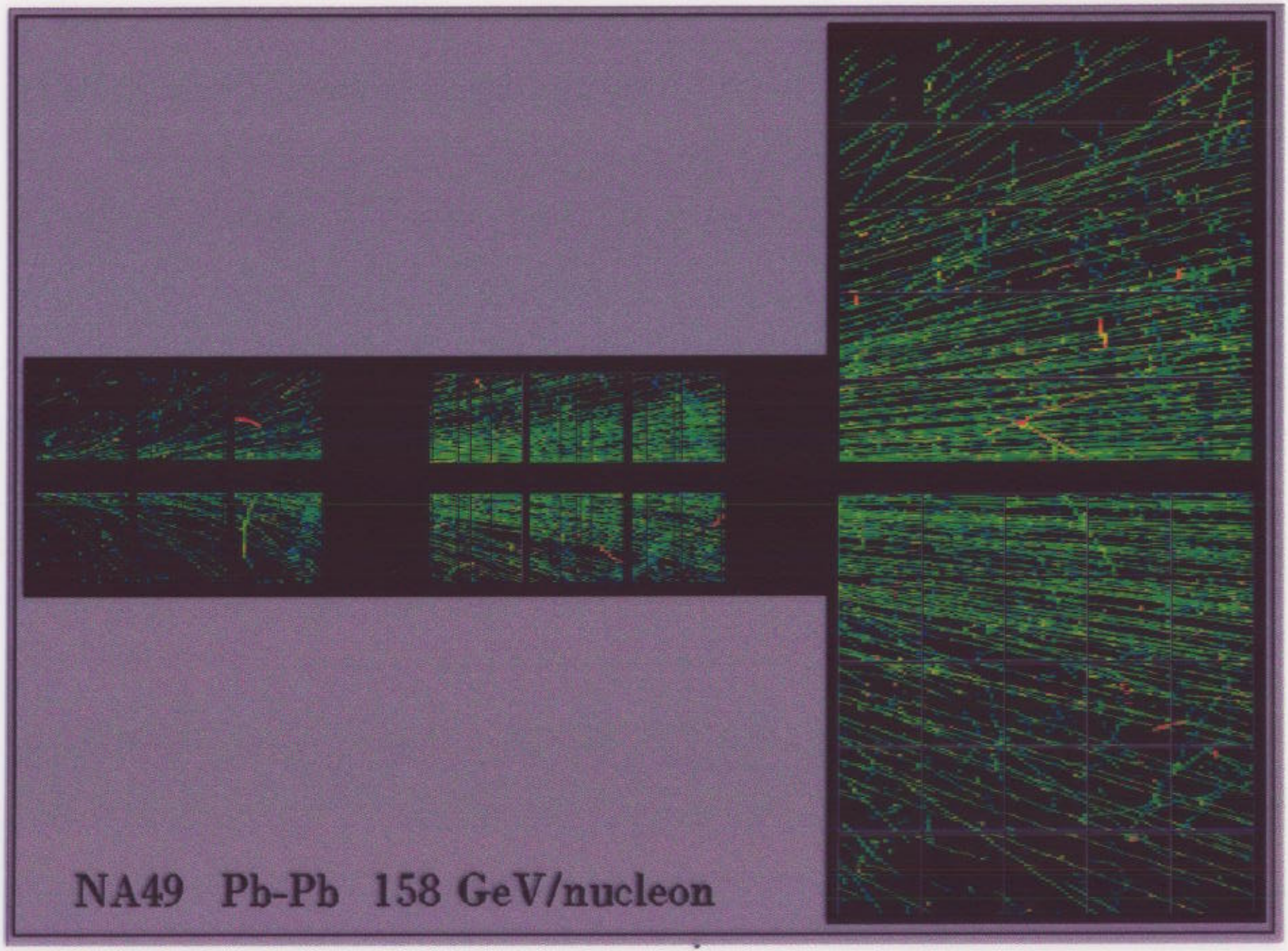


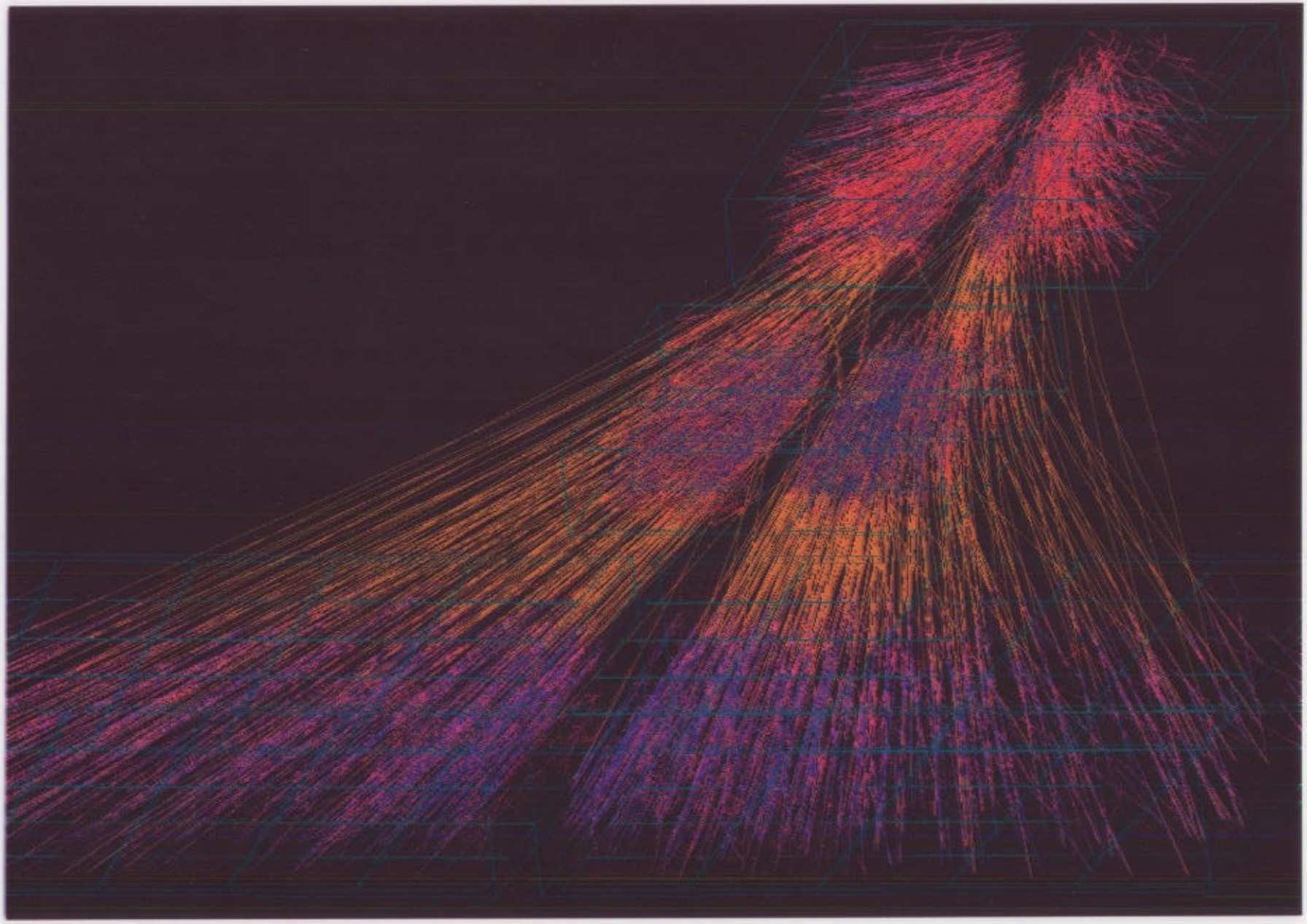
- Four large TPCs.
  - Drift vertically up.
  - Pad readout follows trajectories.
  - Very large acceptance.
  - Superconducting magnets 1.5T field.
- TOF (4-12 GeV).
- Beam.
  - H2 beam line (secondaries).
  - CEDAR particle ID - in trigger.
- DAQ – 1 million triggers/week.
- Trigger – We will use min bias 'bulls-eye' trigger.

The NA49 experiment



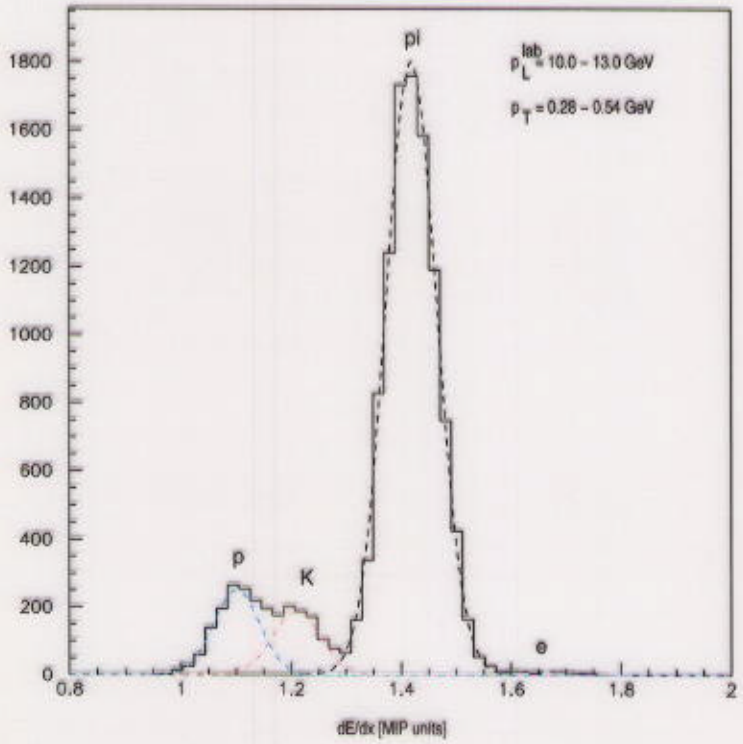



NA49 Pb-Pb 158 GeV/nucleon

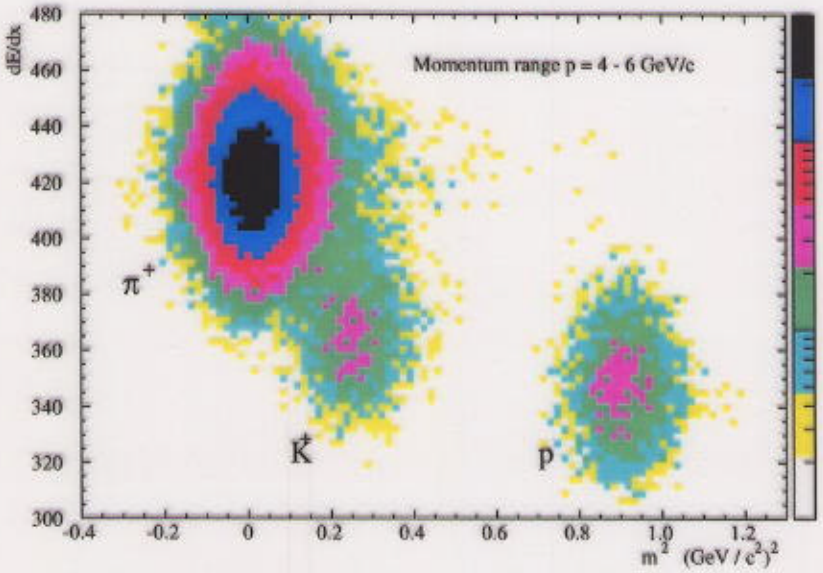


NA49 particle ID

dE/dx ONLY

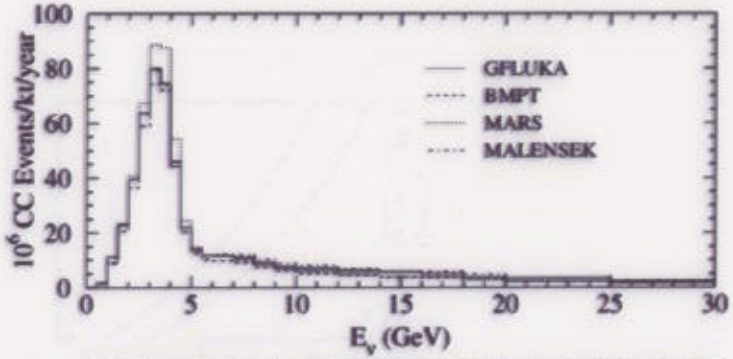


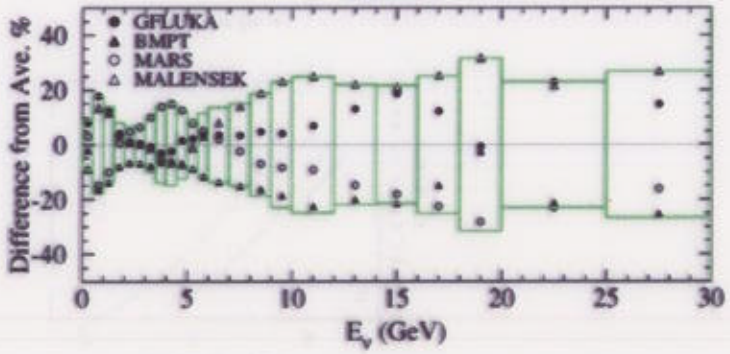
dE/dx + TOF



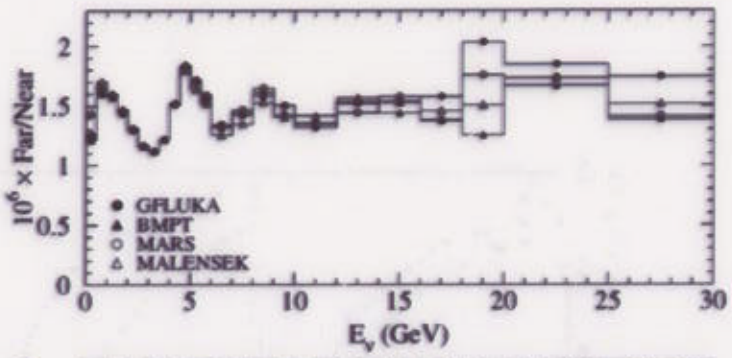
NOTE: LOGARITHMIC Z AXIS

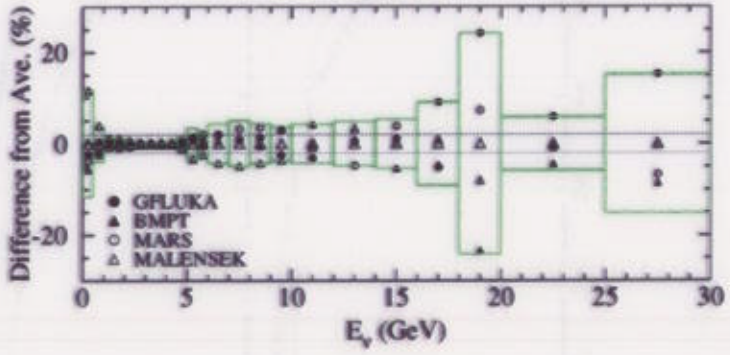
MINOS - Near/Far flux ratio





absolute 10-25%
near

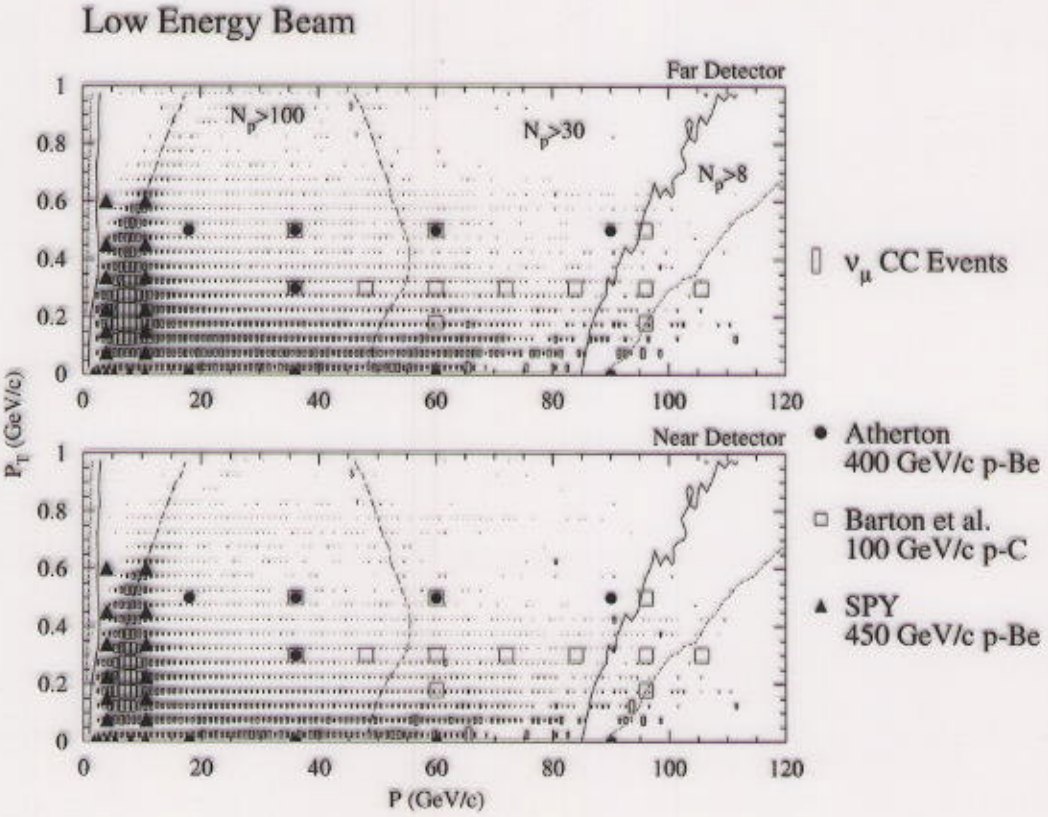




far/near 0-10%

⇒ 2%

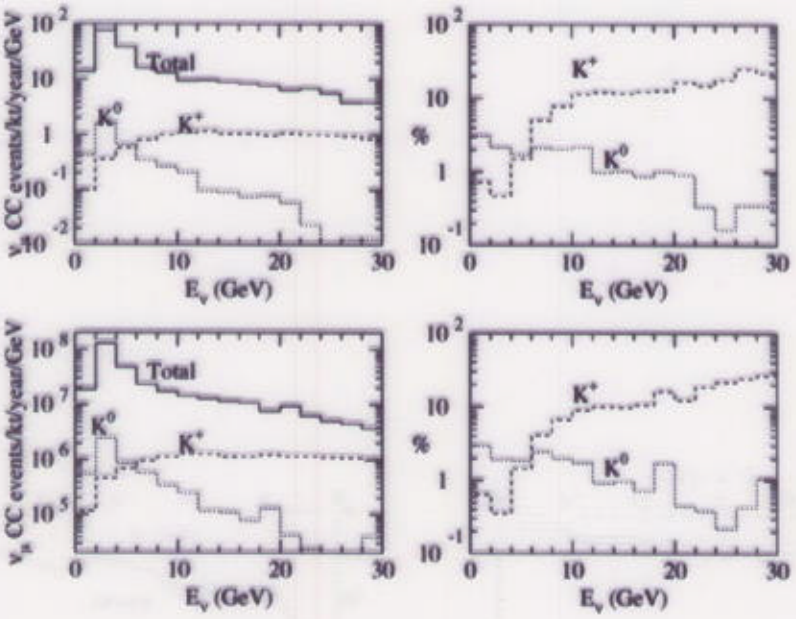
MINOS Acceptance in NA49

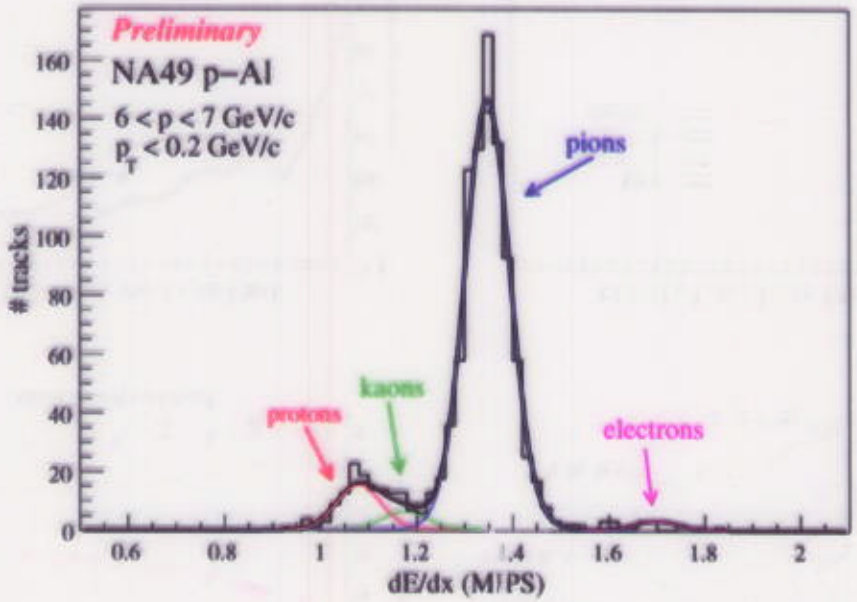


- p,p_T of secondaries producing neutrinos
- Prior measurements 100 GeV, 400/450 GeV
- $n_p = 8$ Gives good tracking
- $n_p = 30$ Gives good dE/dx

Almost complete acceptance for NuMI particles.

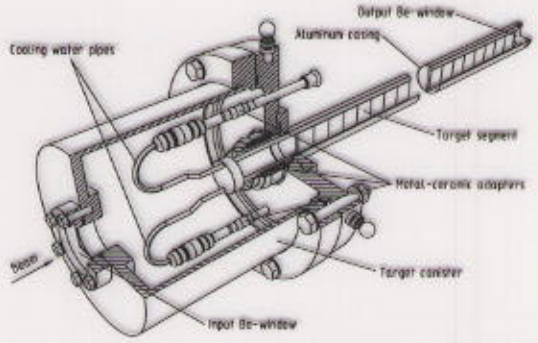
MINOS - Particle identification

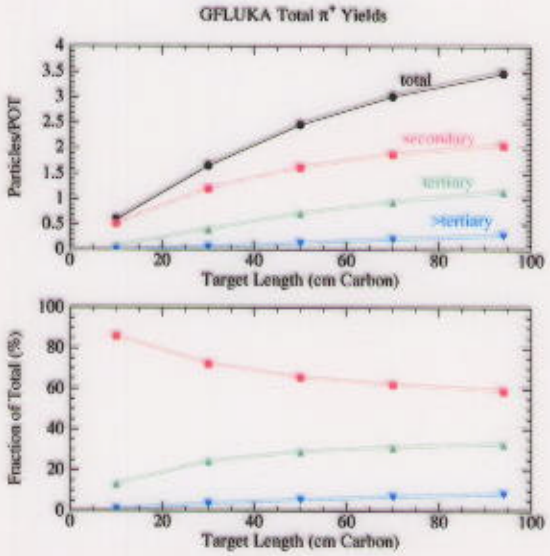


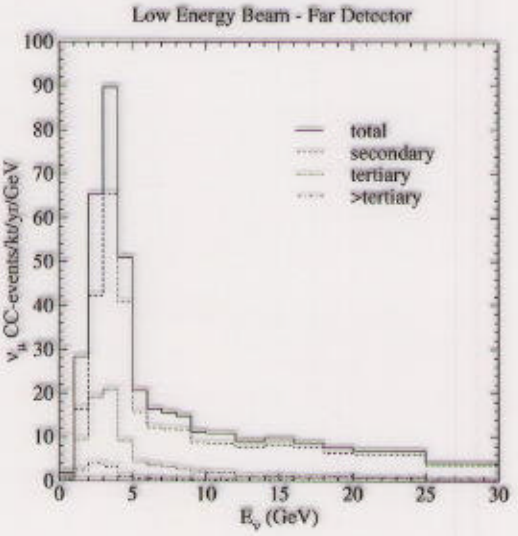


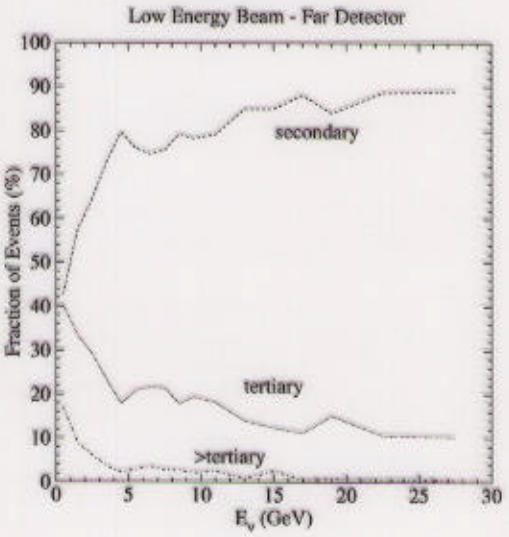
- Kaons are important - particularly at high E_ν
- dE/dx gives particle separation.
- Proposed data sample: error $\sim 15\% \propto$ stat error
- Leads to high-E_ν flux error of 30% $\times 15\% = 5\%$

MINOS measurements







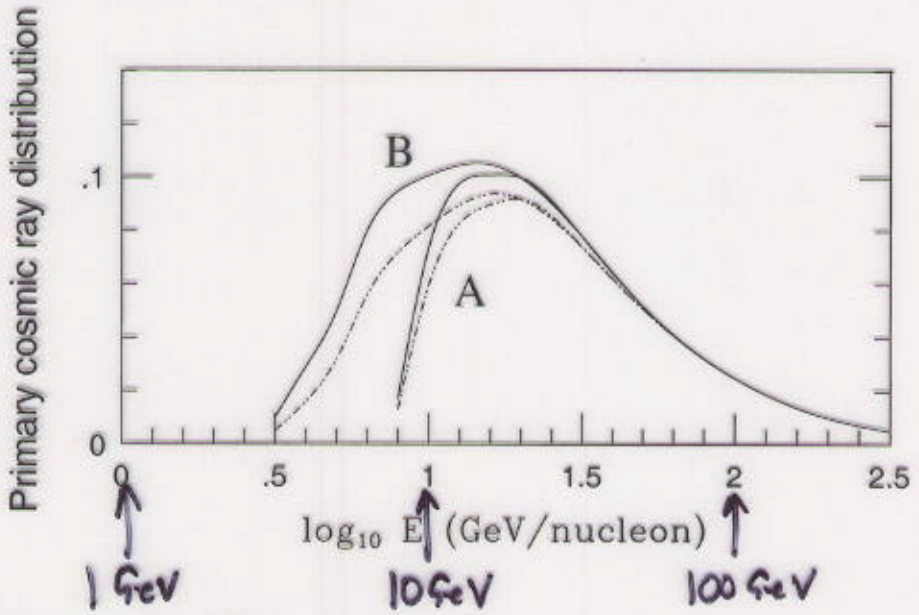


- Fundamental measurements with thin targets
- Tertiaries: Lower energy cross sections from HAR
- Most data at 120 GeV, some p and π data at low
- Carbon target

WHAT TYPES OF INTERACTIONS MAKE ATMOSPHERIC - νs.

(a) SUPER KAMIOKANDE SUB-GeV SAMPLE

PROTON ENERGY



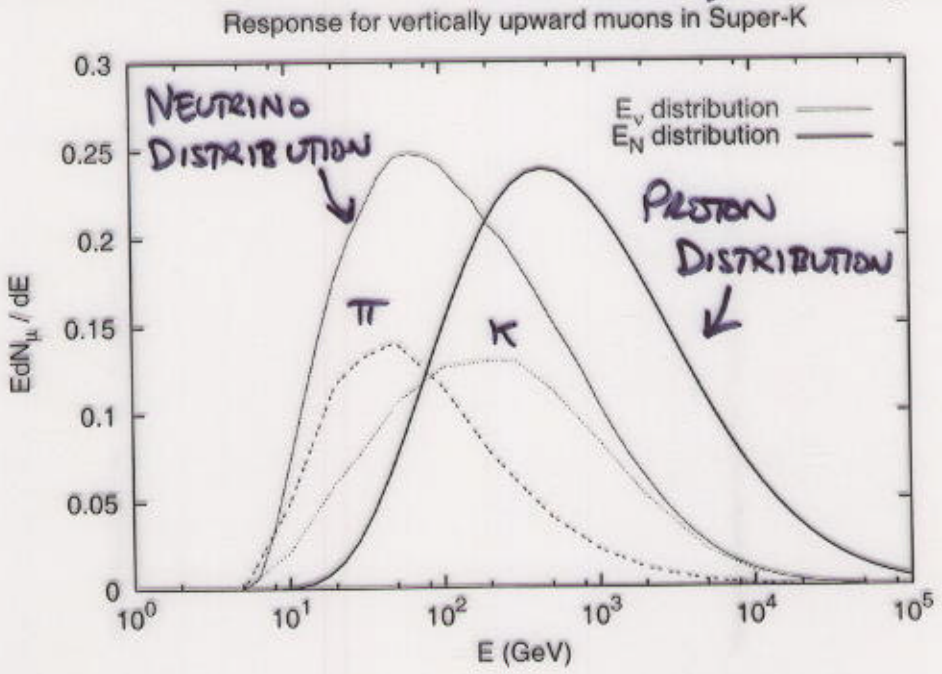
B. SUPER KAMIOKANDE DOWN SAMPLE

A. SUPER KAMIOKANDE UP SAMPLE

- OTHER DETECTORS (E.G. GRAN SASSO) ARE MORE LIKE CURVE B - GEOMAGNETIC EFFECTS ARE VERY STRONG AT KAMIOKA.
- SOLAR MODULATION SHOWN BY DASHED CURVES.

SECONDARY MOMENTUM IMPORTANT
SECONDARY Pt LESS IMPORTANT
} NEED TO SEE MAXIMUM PHASE

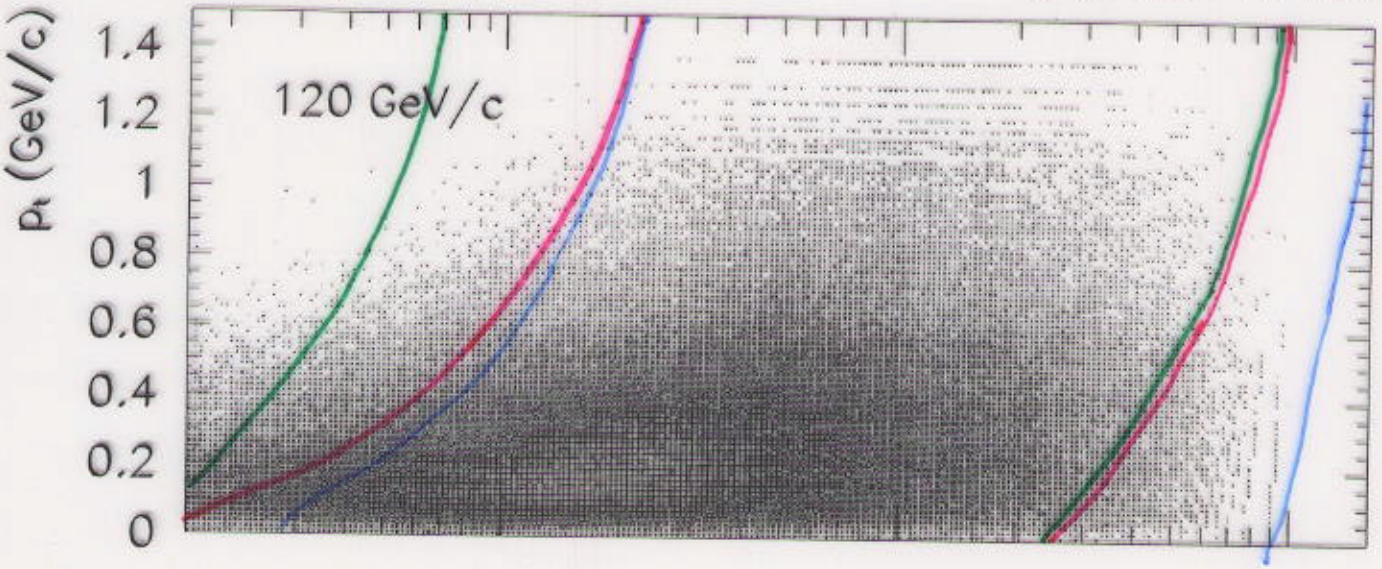
(b) THROUGH GOING UPWARD MUONS ... (MACRO, ANTARES, AMANDA...



ATMOSPHERIC ν ACCEPTANCES

AT 120 GEV
1·3% π^- BACK IN LA
3·7% $< P_L = 0.16$ GeV
5% NOT IN PLOTS

CONDITION TO SEE TRACK: $N_p > 8$

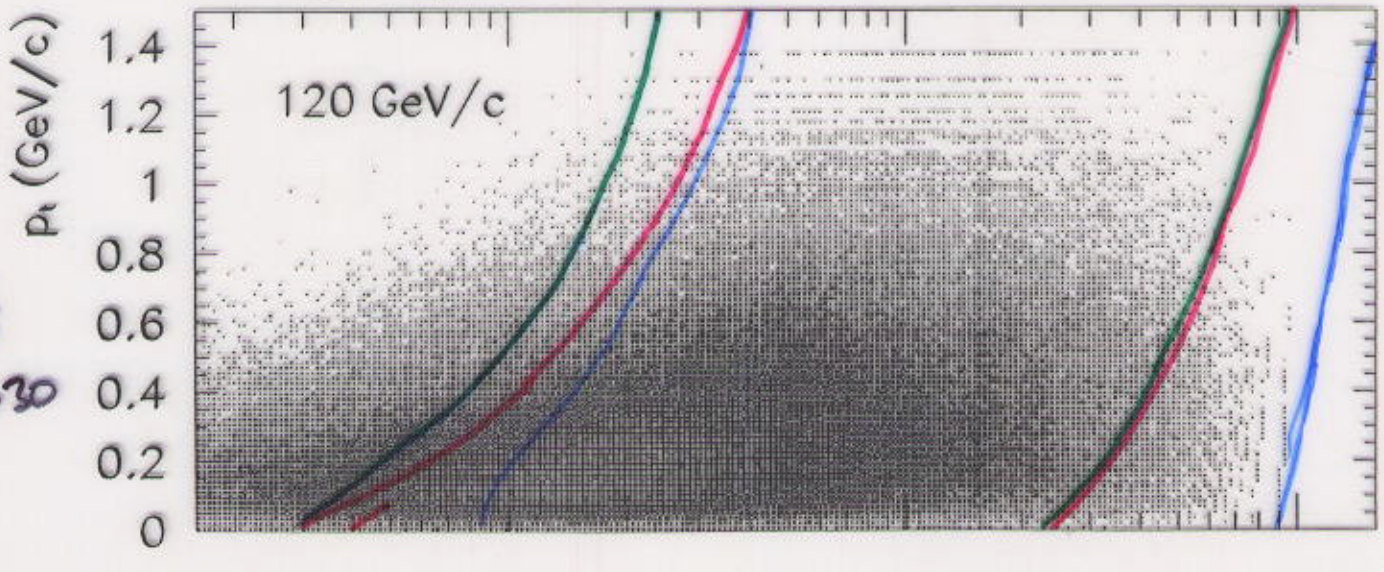


CONTOURS FOR 100% ACCEPTANCE IN ϕ-WEDGE

- FULL FIELD, NORMAL TARGET POSITION
- QUARTER FIELD, NORMAL TARGET POSITION
- QUARTER FIELD, NEAR TARGET

- RUN IN TWO CONFIGURATIONS.
  (1) NORMAL (= MAX) FIELD, NORMAL TARGET POSITION ← AS MINOS
  (2) 1/4 FIELD, CLOSE TARGET
- GIVES EXCELLENT ACCEPTANCE
- SYST. CHECK, MEASURING SAME QUANTITY IN DIFFERENT PARTS OF DETECTOR
- CARBON + SOME AL POINTS, SEE WHAT N_2, O_2 TURN OUT LIKE IN HARP.

CONDITION TO DO dE/dx $N_{POINTS} > 30$



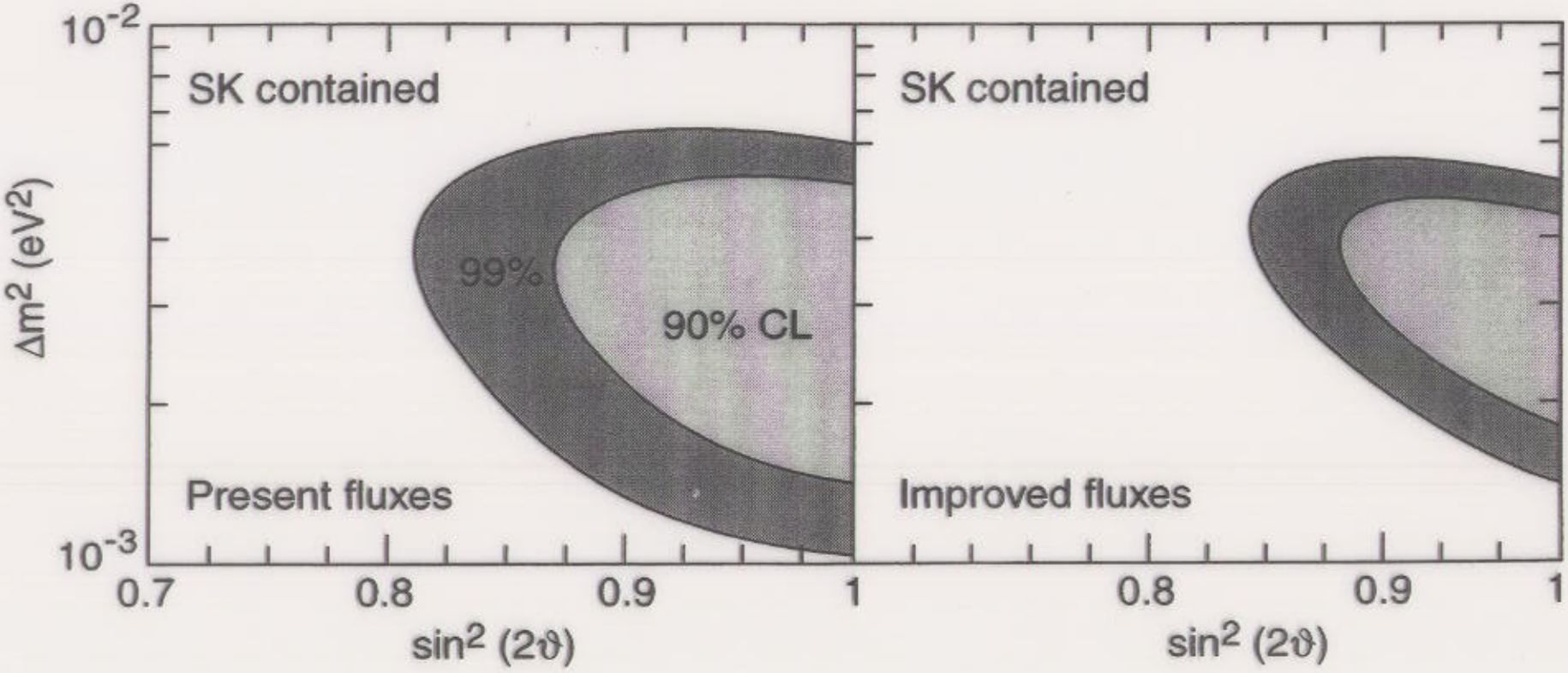


Figure 1: SuperKamiokande neutrino-oscillation results with current and improved atmospheric-neutrino-flux error

Proposed measurements

Beam type	Momentum (GeV/c)	Target material	Thickness (int. len.)	Magnetic field	# triggers $\times 10^5$
p	40	C	2%	Nominal	10
π	40	C	2%	Nominal	10
p	40	C	2%	Low	5
p	40	Al	2%	Nominal	5
p	70	C	2%	Nominal	5
p	70	C	2%	Low	5
p	120	C	2%	Nominal	25
p	120	C	50%	Nominal	10
p	120	C	100%	Nominal	10
p	120	C	2%	Low	5
p	120	Al	2%	Nominal	5
p	200	C	2%	Nominal	5
p	350	C	2%	Nominal	5

Financial expenditure

Assuming 6 weeks in 2002 and 6 weeks in 2003

Running expenses	Cost (kCHF) (A)	(B)
Gases	70	70
Electronics rental fee (EP Pool)	60	90
Data recording media	80	80
Maintenance, repairs	50	75
Subsistence of experts (20 months)	80	80
Total	340	395

(A) Assuming NA49 lead running in 2003
(B) Shared with NA49 current approved only

Material	Cost (kCHF)
Target and target holder materiel	10
Miscellaneous	20
HARP cryogenic target mods (opt)	20
Total	50

first SPSC unofficial reactions

well received ....

... will ask questions

1) impact ... ν_{beam}, ν_{etmo}

2) systematic

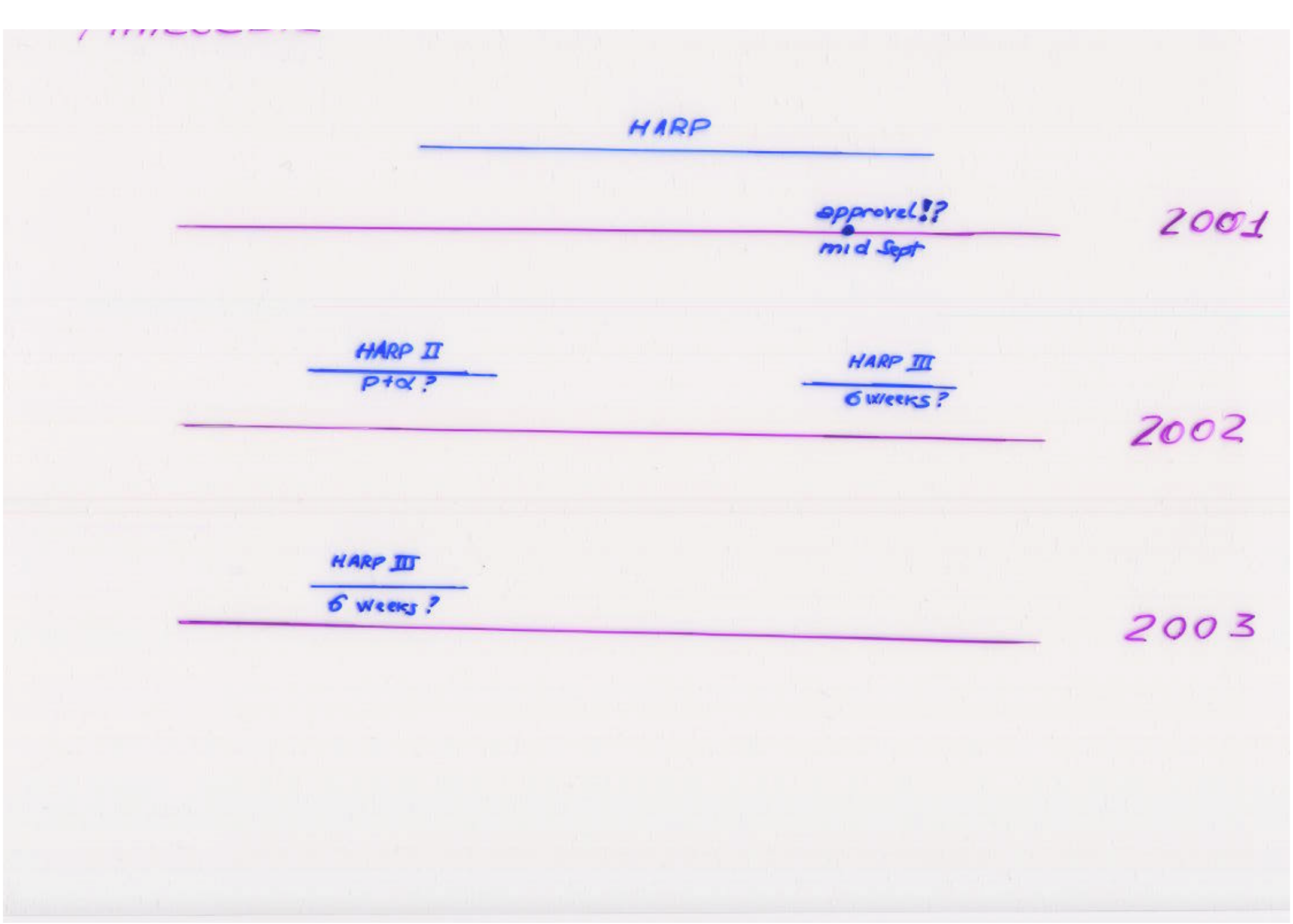
3) sample sizes ... run time ..

.....

... addendum of answers by Aug 2

SPSC early Sept

Res. Board mid Sep


HARP
approval!?
mid Sept
2001
HARP II
P+Q?
HARP III
6 weeks?
2002
HARP III
6 weeks?
2003

Conclusions.

- Need for better hadron production data at higher energies than HARP – Two examples MINOS/Cosmic-
- NA49 experiment has superb acceptance and particle ID for our requirements.
- The experiment is debugged, field mapped, calibration procedures known etc.

We propose to use it…