Defining the energy of the proton driver

the role of HARP as hadro-production experiment

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Overview

- The experiment and its goals
- Status of Analysis
  - Large Angle Region
  - Small Angle (or Forward) Region
- Conclusions & Plans

HARP (PS214)

- ***HA***d***R***on ***P***roduction Experiment at PS; (from proposal[(1)]):
- optimize the $\pi^+(\pi^-)$ yield for the ν-factory
- calculations of beam fluxes for K2K and MiniBoone
- input for calculations of atmospheric neutrino flux
- input for Monte Carlo hadronic generators

[(1) CERN-SPSC/99-35, SPSC/P315, Nov. 15th 1999]

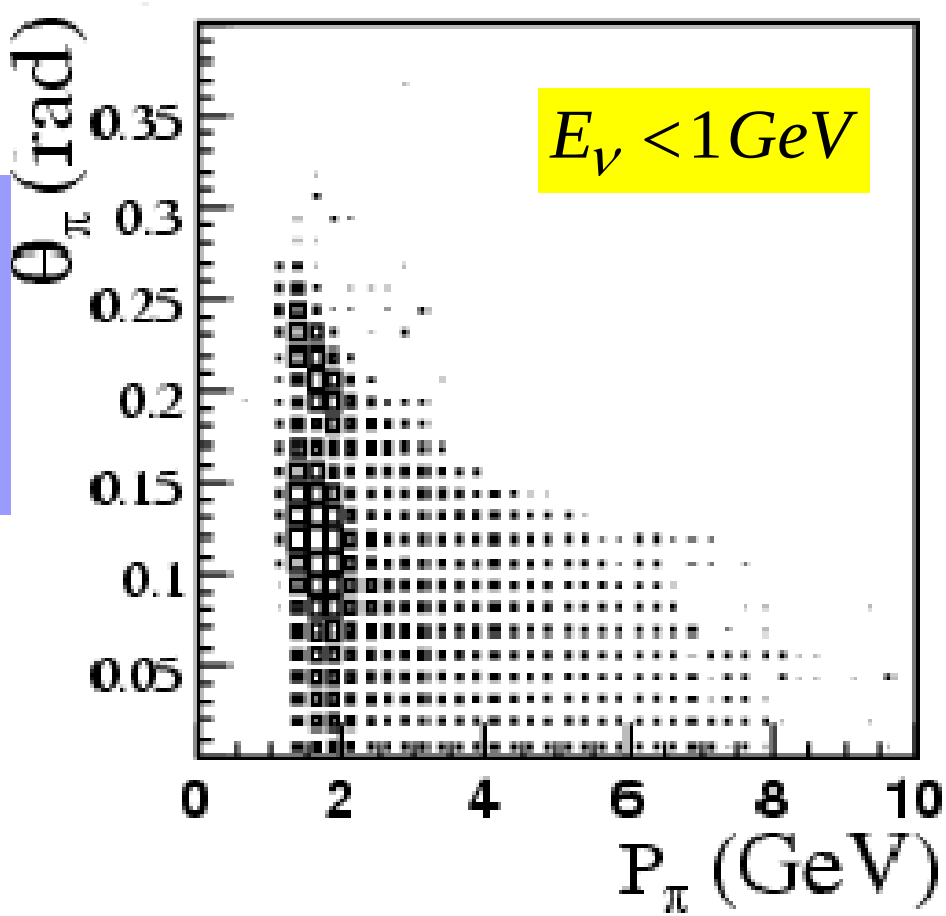
ν-factory (but also super-beams)

- maximize $\pi^+(\pi^-)$ production yield (/proton/GeV)
- optimize:
  - target material
  - proton energy
  - collection (p_L,p_T)
- simulations show large discrepancies on π yield and distributions
- Experimental knowledge rather poor:
  - Small acceptance, few materials tested
  - Old (Allaby et al., 1970, Eichten et al. 1972)
- Aim: π yield (π^+/π^-) known better than 5%

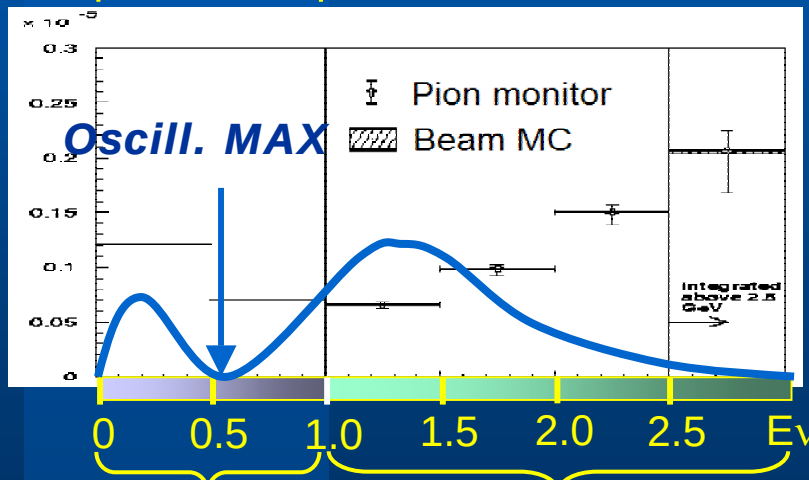
➔ ***thick target program: high Z at several p***

the K2K case

one of the largest systematic errors in K2K in the ν oscillation parameters comes from the uncertainty on the far/near ratio: depends on π-prod. model used



To be measured by HARP



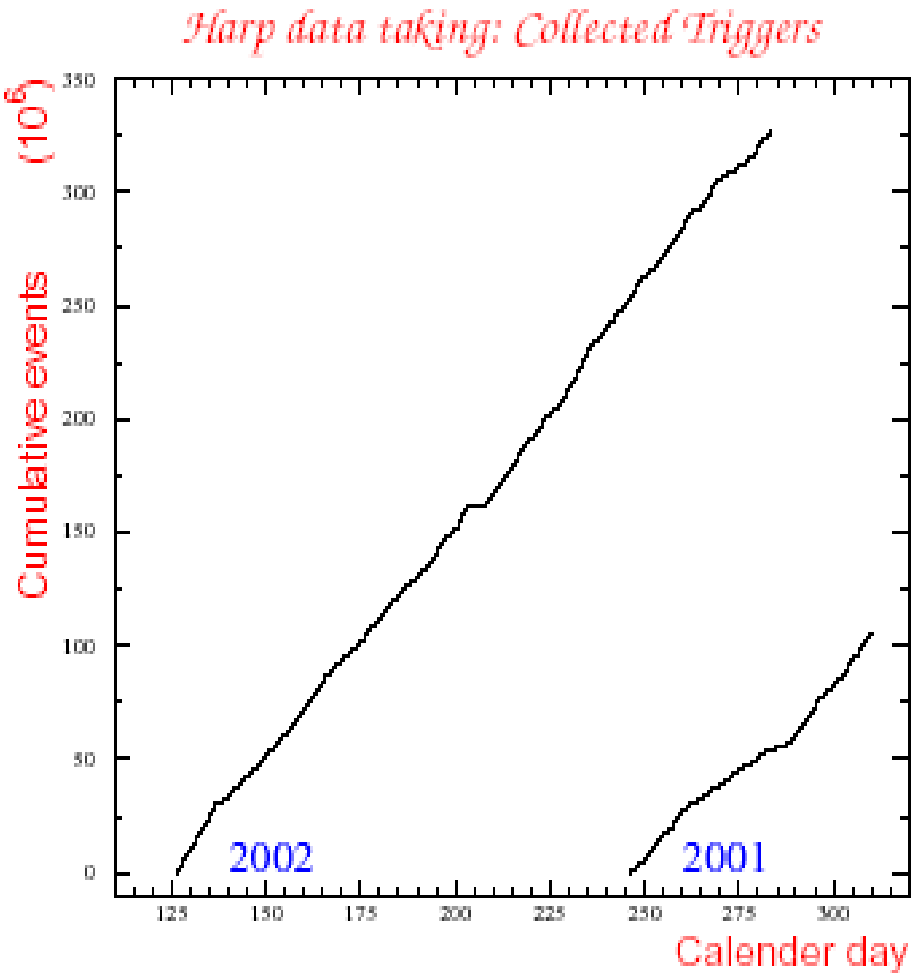
➔ ***special program with K2K-replica Al target***

- ***K2K request: $\Delta(F/N)/(F/N) < 3\%$***

DATA taking campaign: 2001-2002

- P [1.5 GeV/c – 15 GeV/c]
- (quasi) full solid angle (1) coverage
- wide list of targets: materials and sizes
  - from H to Pb
  - 2%, 5%,50%,100% λ
- High event rate: 2.5 kHz (~10^6 evts/day)

[(1) target inside the TPC!]



O(10⁶) events per setting

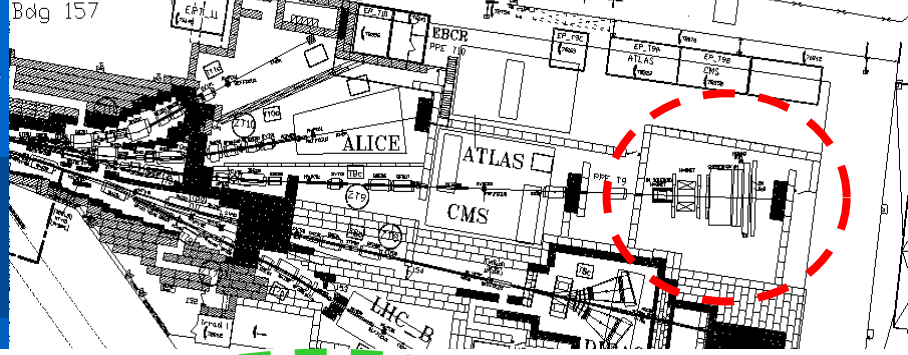
30 Tbytes of data

420 million events

Target material		Target length (λ%)	Beam Momentum (GeV)	#events (millions)
Solid targets	Be	2 (2001)	±3	233.16
	C		± 5	
	Al		± 8	
	Cu	5	± 12	
	Sn		± 15	
	Ta	100		
	Pb		Negative only 2% and 5%	
K2K	Al	5, 50, 100, replica	+12.9	15.27
MiniBooNE	Be		+8.9	22.56
Cu "button"	Cu		+12.9, +15	1.71
Cu "skew"	Cu	2	+12	1.69
Cryogenic targets	N_2	6 cm	±3	58.43
	O_2		± 5	
	D_2		± 8	
	H_2		± 12	
			± 15	
	H_2	18 cm	±3, ±8, ±14.5	13.83
Water	H_20	10, 100	+1.5, +8(10%)	9.6

T9-secondary line @ CERN-PS

HARP: detector overview



HARP
PS 214

drift chambers

time-of-flight scintillators

beam-muon identifier

electron identifier

Large Angle

TPC + RPCs in solenoid magnet

cosmics trigger wall

target

threshold Cherenkov

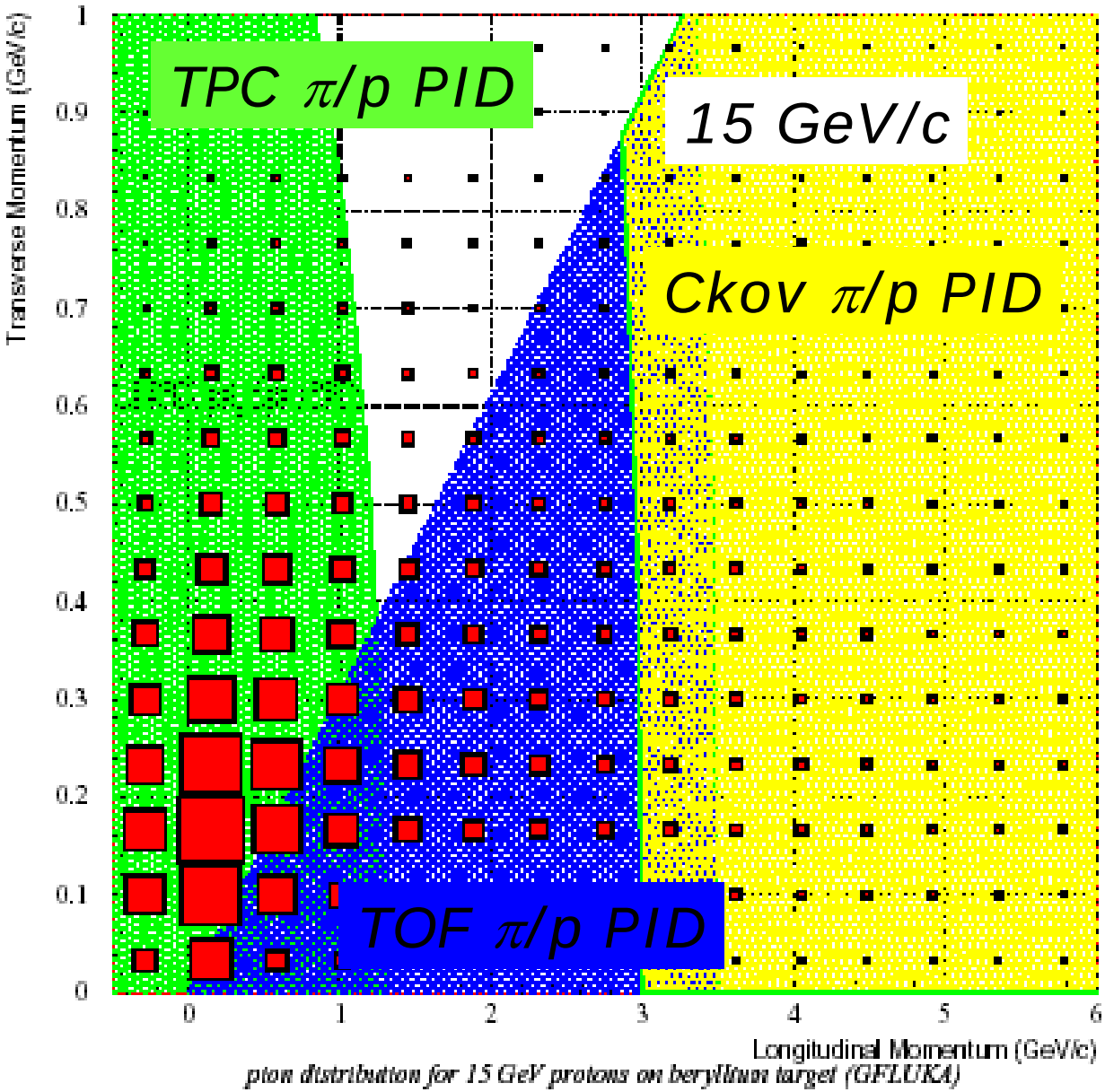
dipole magnet

Small Angle

T9 beam

FTP + RPCs

Simulated π from p on Be target (2-15 GeV/c)



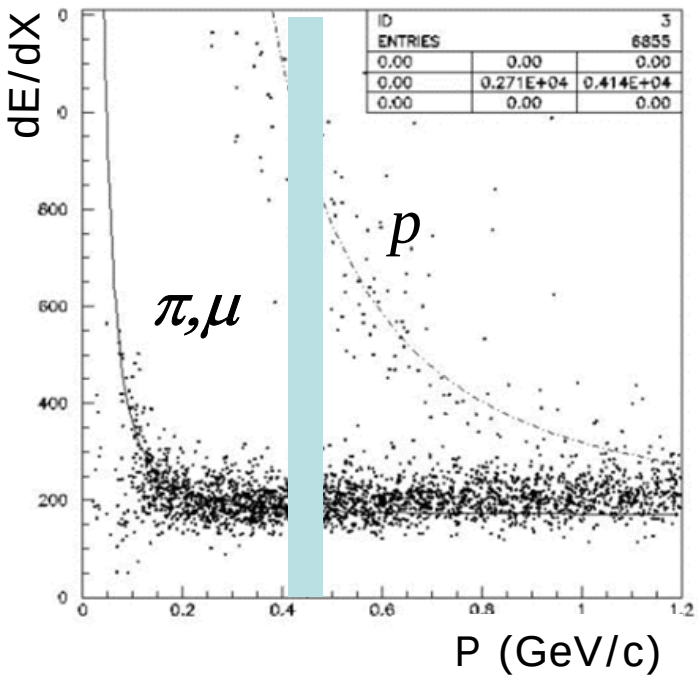
pion distribution for 15 GeV protons on beryllium target (GFLUKA)

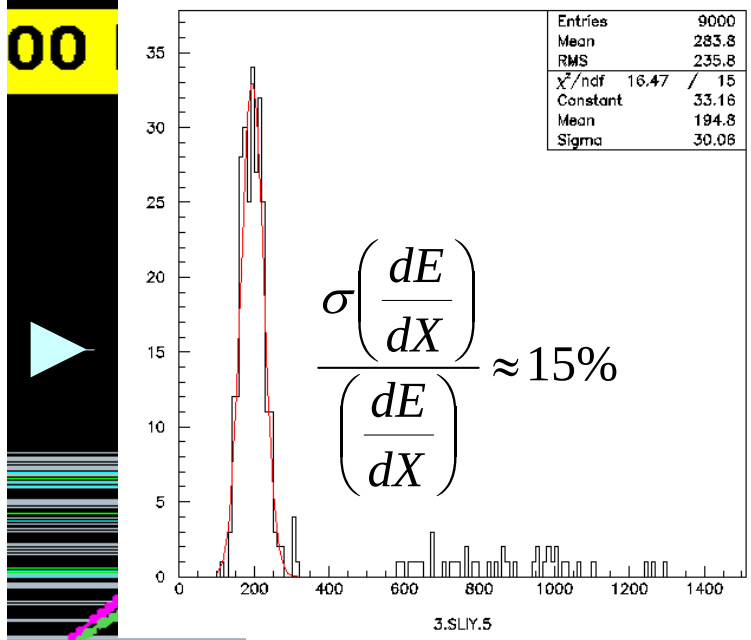
Large Angle: TPC (0.7 T)

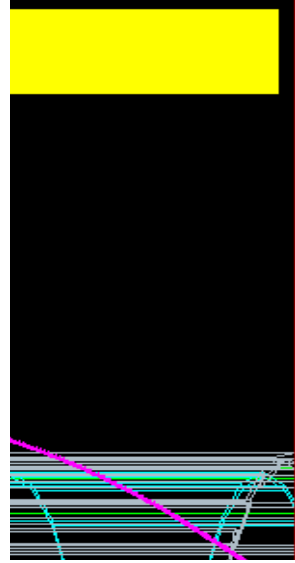
- TPC covers basically all the (p_L,p_T) space at low momenta, (~2 GeV/c), and most of it even at higher momenta (~15 GeV/c)

- calibration/equalisation, based on:
  - high statistics cosmics
  - ^{83}Kr -41.6 keV-
  - ^{55}Fe -5.9,3.0 keV- (2003 campaign)
  - data
- these data have allowed
  - computation of gains and mapping of dead pads: likely to be done on a run by run basis
  - first evaluation of dE/dX
  - first evaluation of the performance of a correction for a cross talk effect
  - improvement in momentum resolution of 30%
  - check of the improvements: data with a cryogenic H_2 target, 3 GeV/c π's and protons are being analyzed, looking for elastic scattering: $p(\pi),p \rightarrow p(\pi),p$

cosmics data







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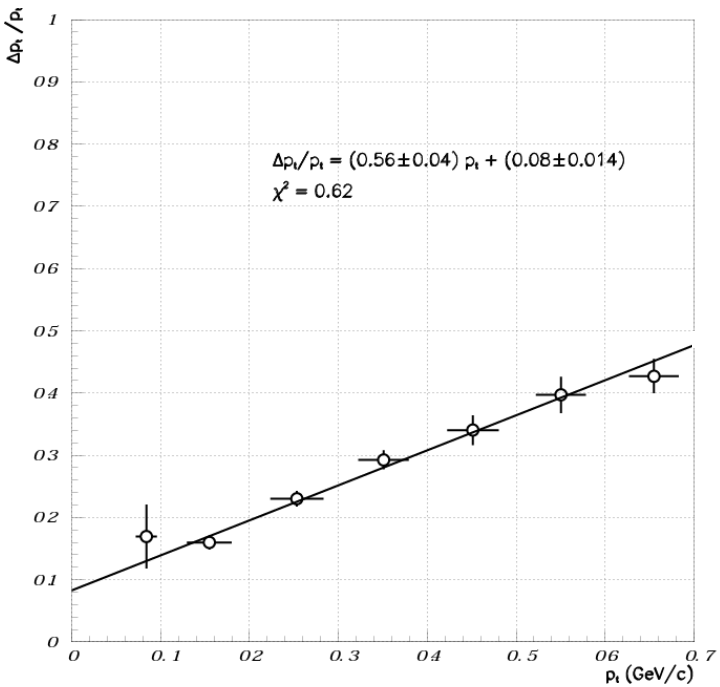
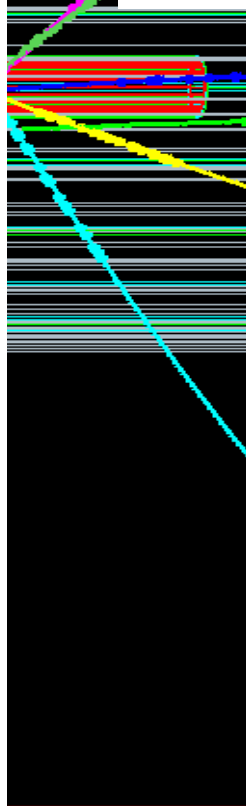
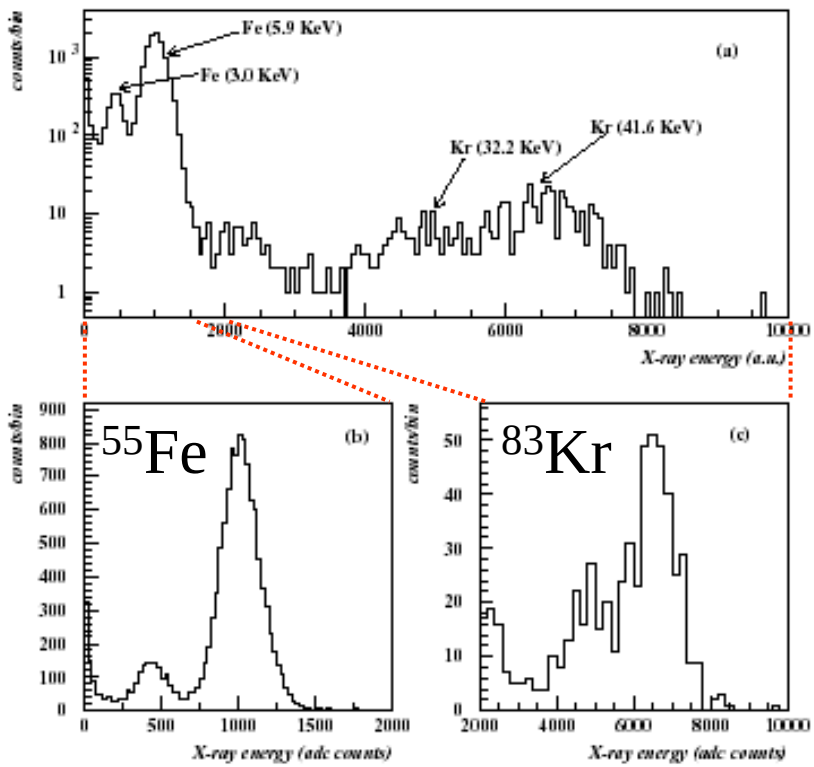
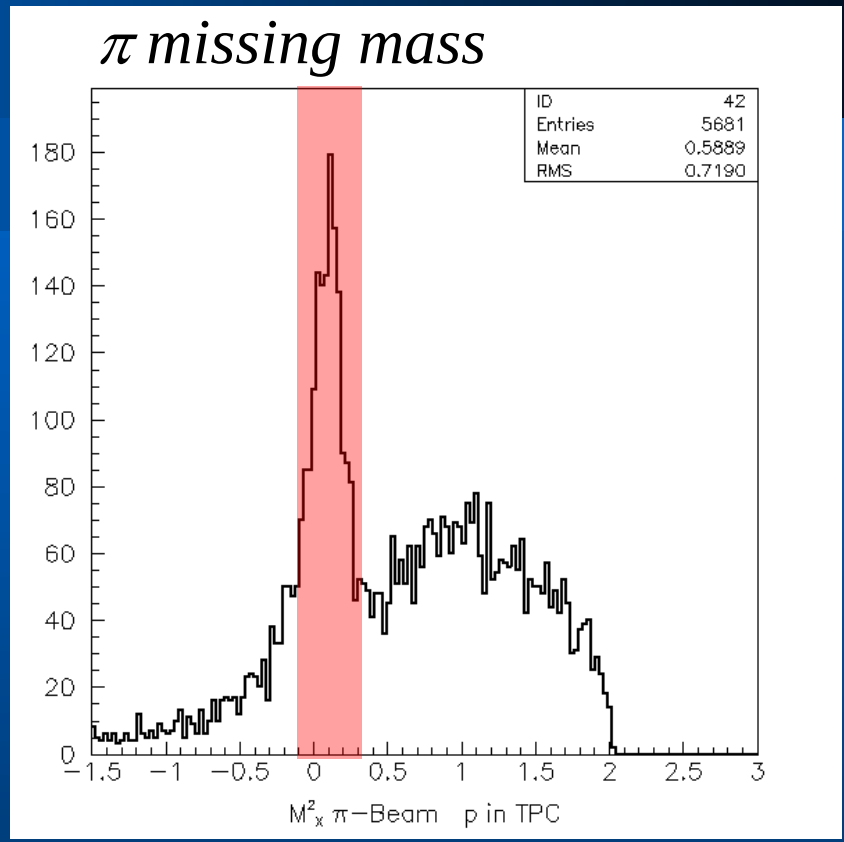


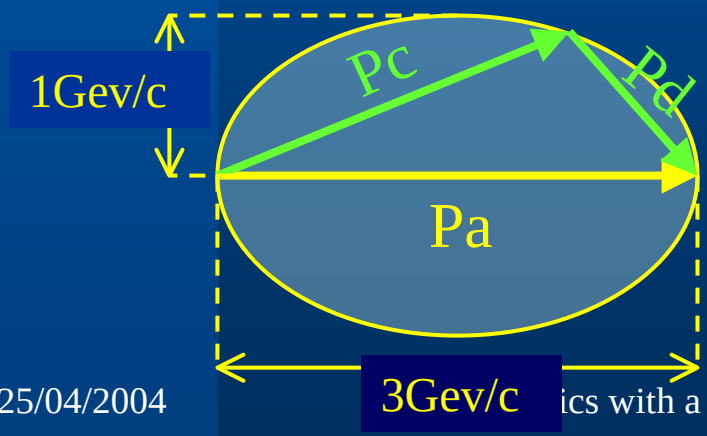




Elastic Scattering: $p(\pi)p \rightarrow p(\pi)p$

- Normalization+calibration tool:
  - measure elastic cross-section
  - compare with the average cross section from literature (accuracy ~ several percents)
  - adjust momentum and covariance matrix of all tracks to get right χ^2 distribution for elastic events
  - tune MC to get the right elastic cross section



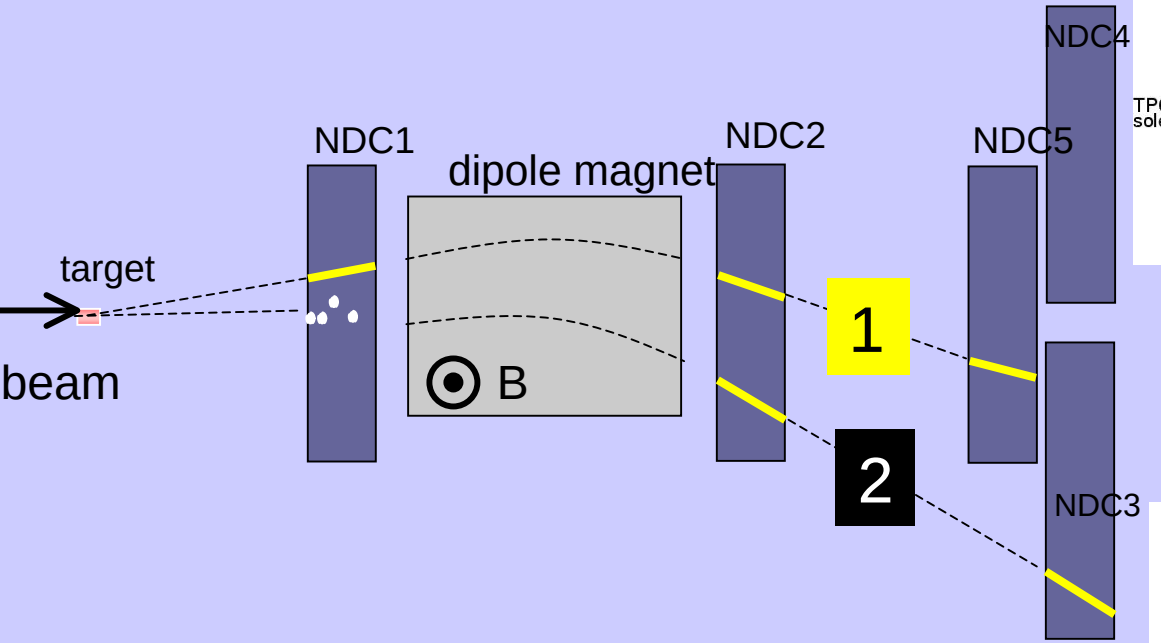


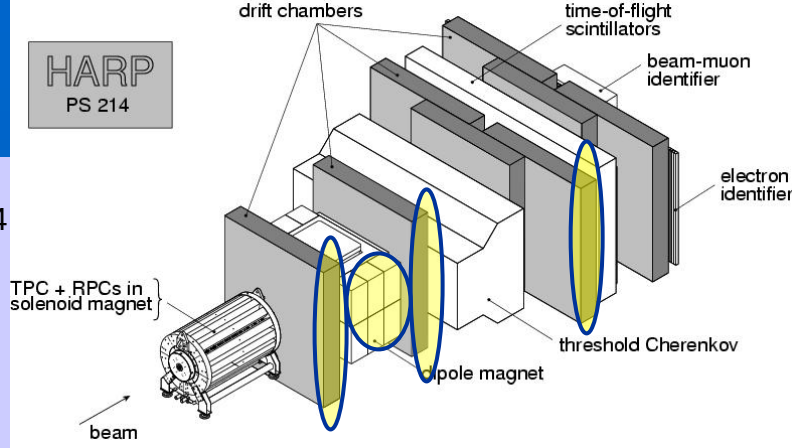
$M_x^2=(p_a+p_b-p_d)^2$

Small Angle: basically covered by the forward detectors

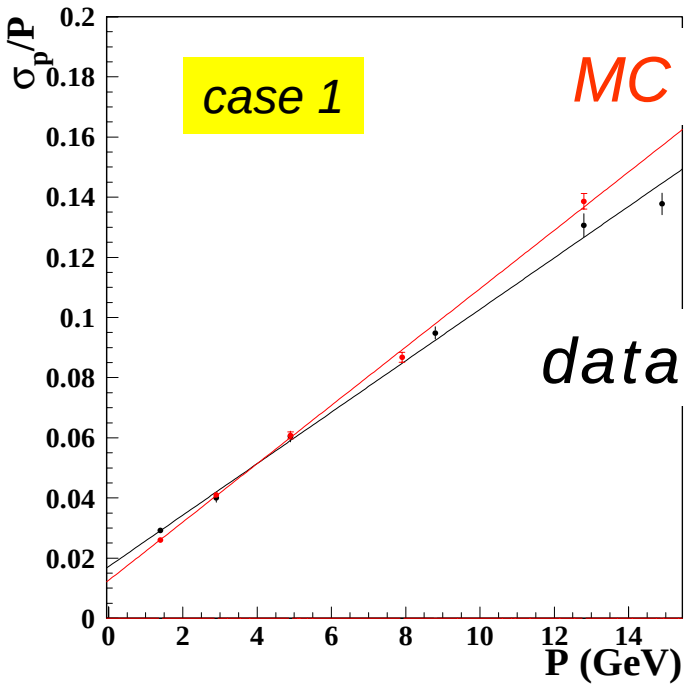
- tracking & momentum measurement:
  - provided by *drift chambers* (from NOMAD) + *dipole magnet* (1.0 Tm)
- PId given by an overlapped combination of:
  - a threshold *Cherenkov* counter
  - a *time of flight*
  - an *electron calorimeter*

Forward Tracking



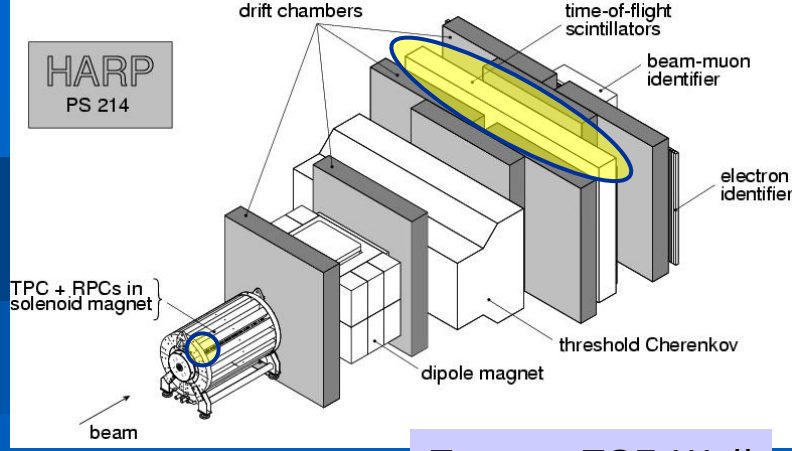


momentum resolution

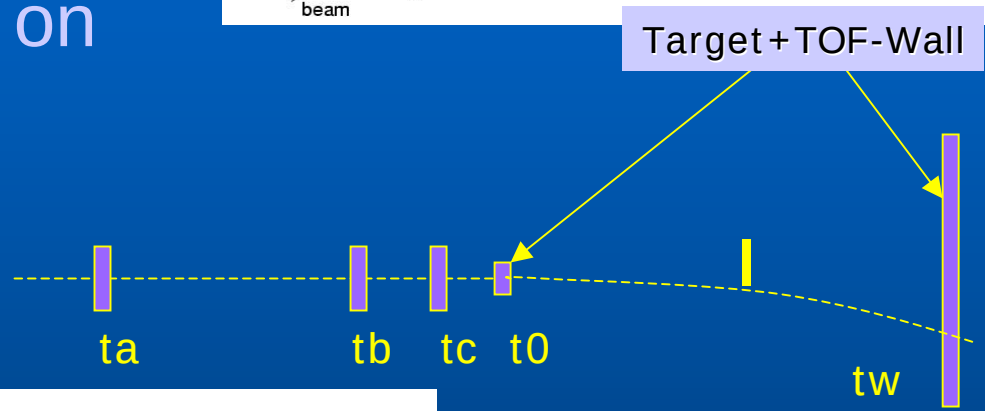


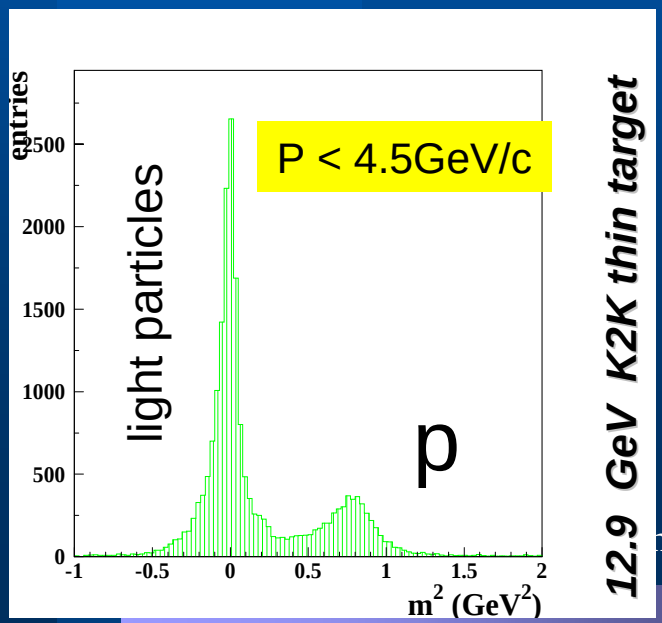
PId

- π/p separation (as a function of P)
- P < 4.5 GeV/c: relies on the TOF system

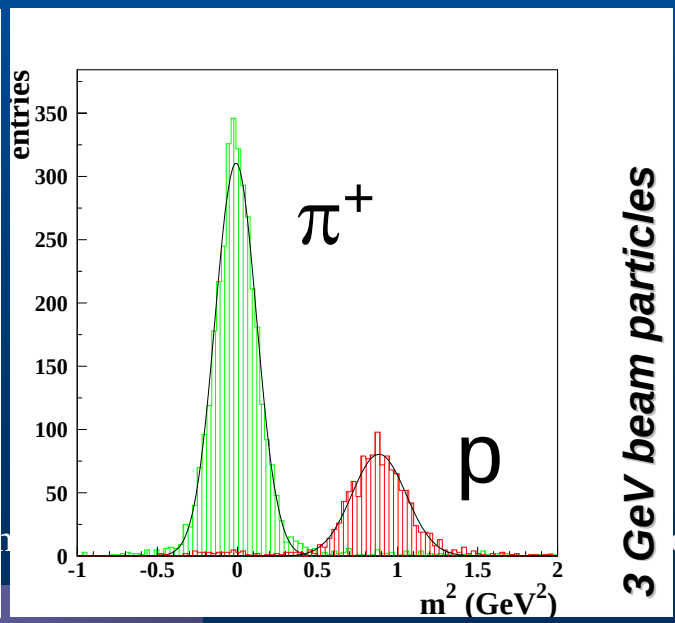


$$m^2 = p^2\left(\left(\frac{t_w - t_0}{\ell}\right)^2 - 1\right)$$





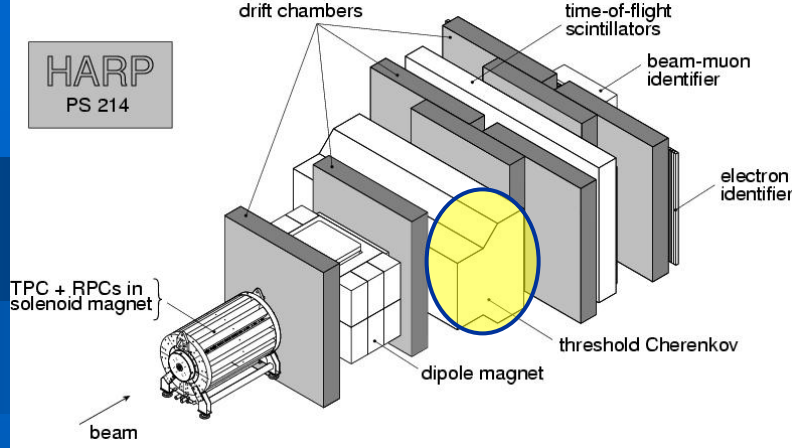
12.9 GeV K2K thin target



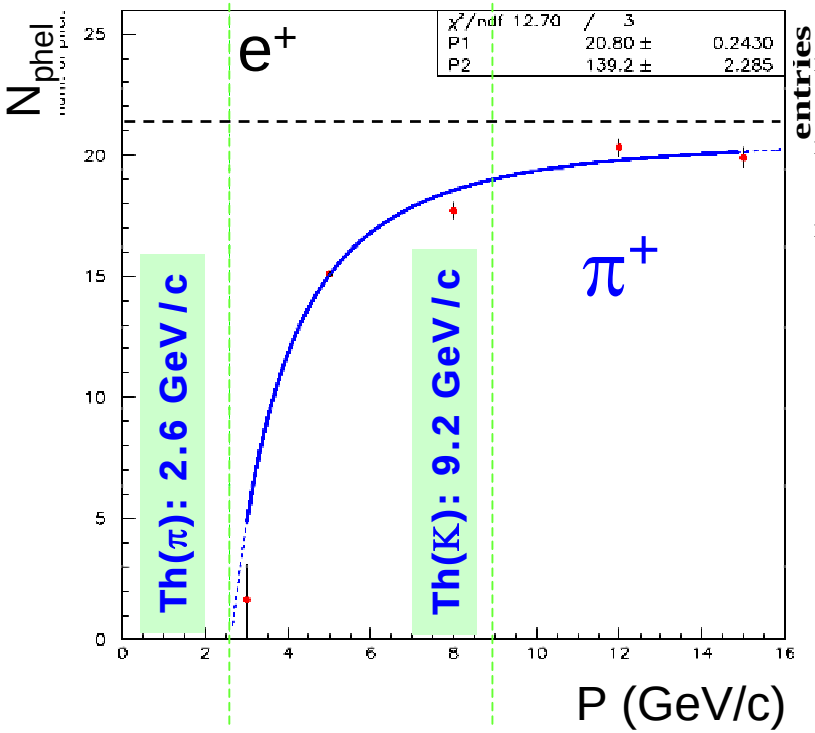
3 GeV beam particles

- Tof-W resolution: ~ 160 ps → >7σ π/p at 3 GeV
- Beam resolution: ~180ps (expected to improve)

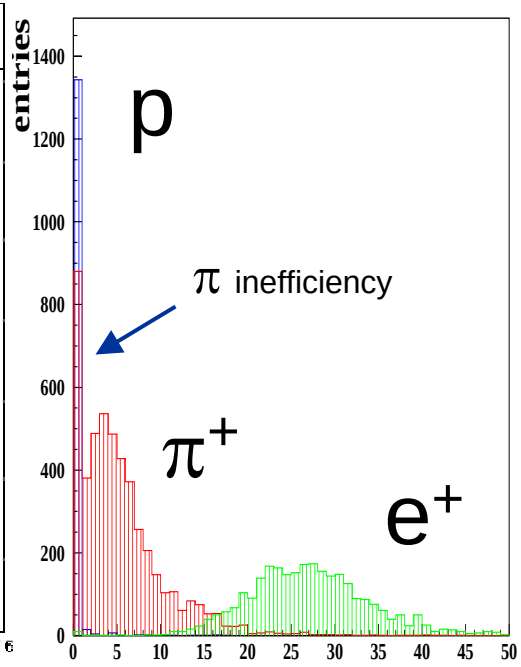
- π/p separation
  - P > 3 GeV/c: relies on a threshold Cherenkov
- π/K separation
  - 3<P<9 GeV/c

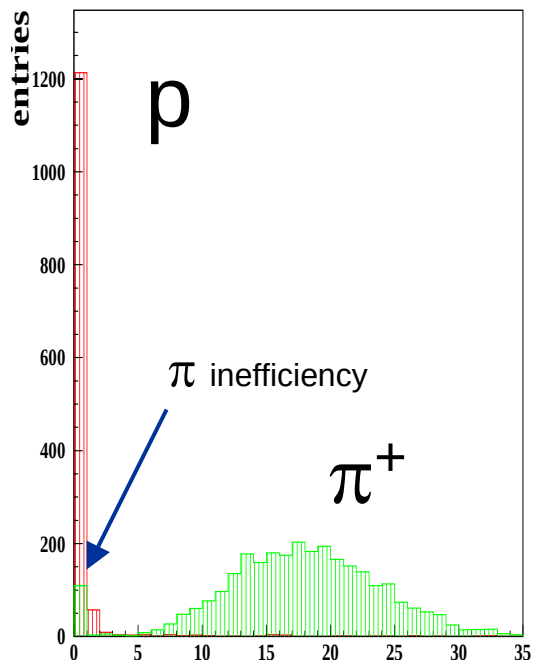


$$N_{phel} \propto N_0\left(1-\frac{1}{n^2}\left(1+(m/p)^2\right)\right)$$



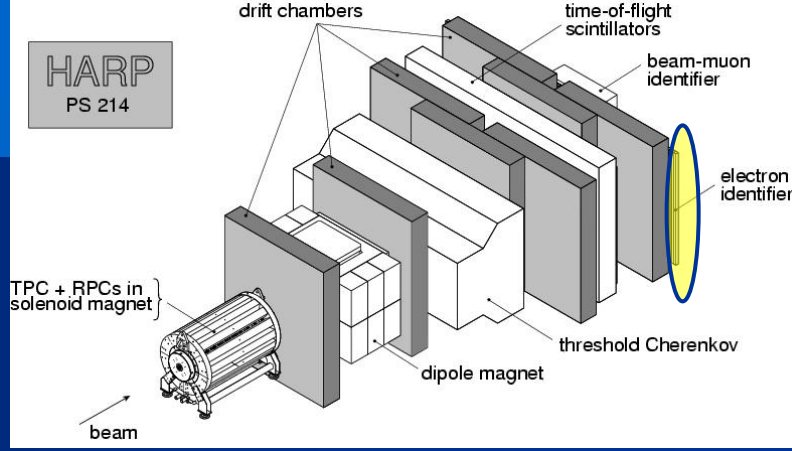
3 GeV/c ***5 GeV/c*** ***beam particles***



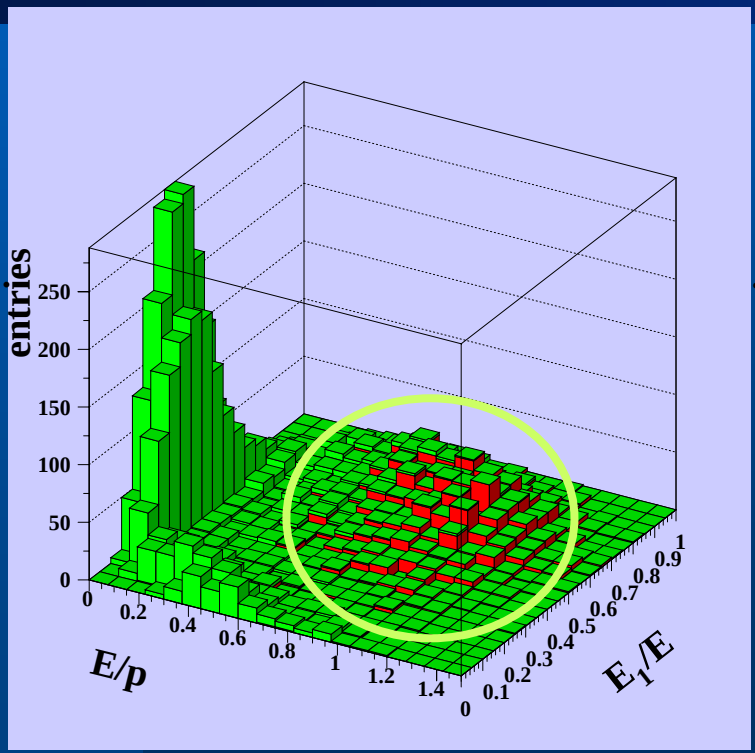


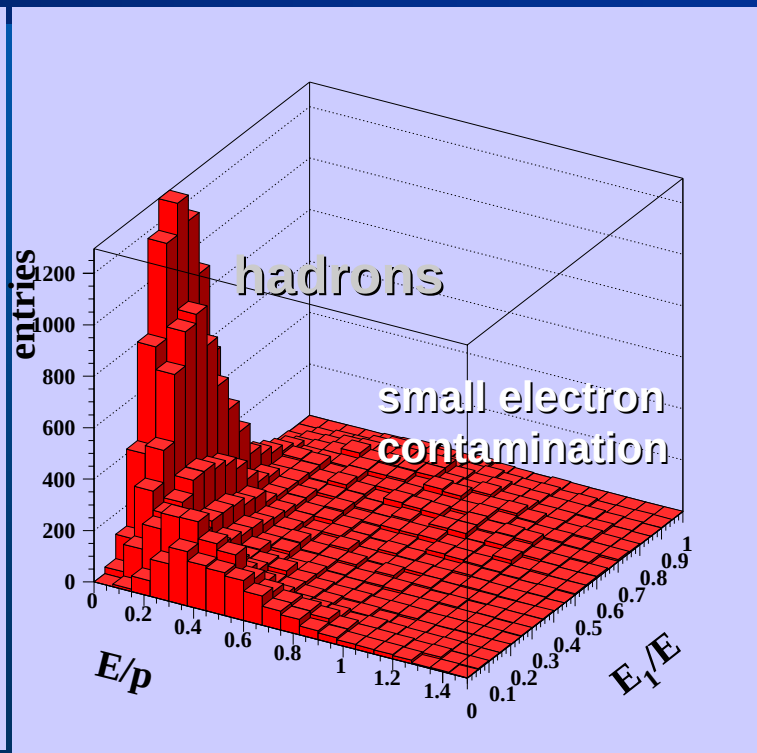
number of photoelectrons

- Discrimination between electrons and pions is provided by a combination of Cherenkov and Electron Identifier



3 GeV/c beam particles





12.9 GeV /c K2K thin target

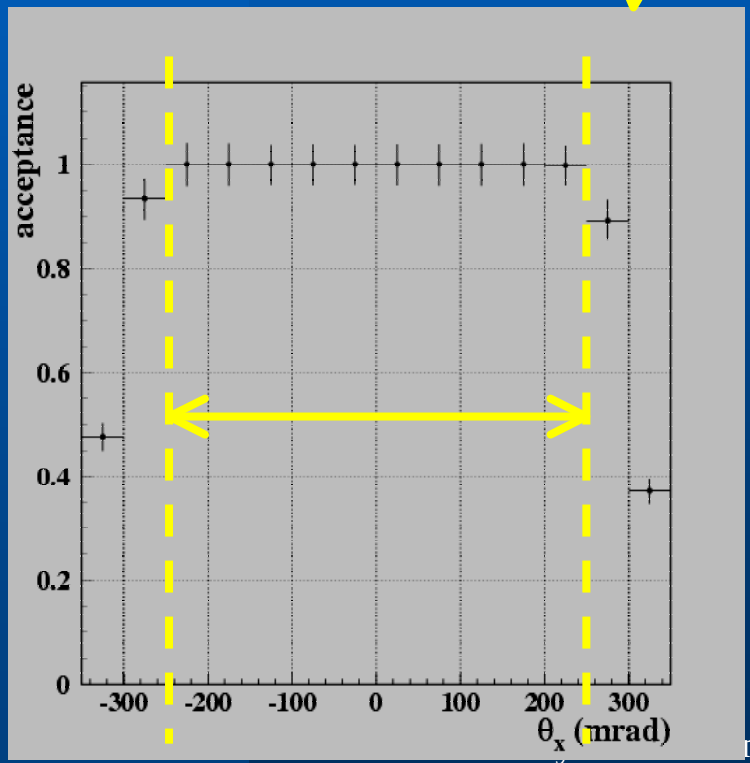
HARP first analysis

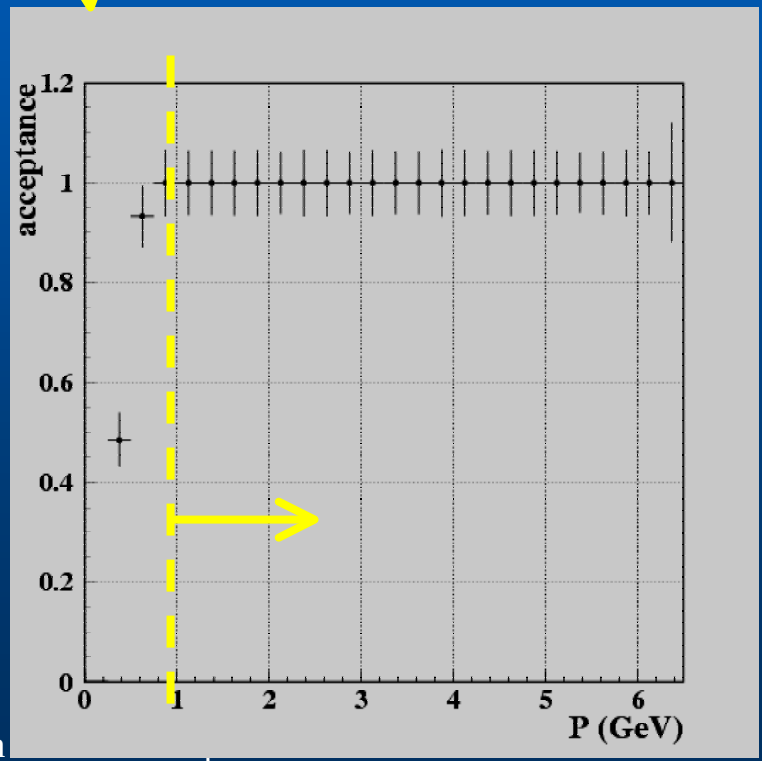
- Focused on the K2K case
- The small angle region covers the *(θ,p) region* relevant for K2K
- *well known region of the apparatus* in terms of
  - *acceptance*
  - *PId*
  - *efficiency (tracking, matching, PId …)*

K2K case (reprise)

- Thin Al (5% λ), P_{beam}=12.9 GeV/c
- Pπ>1 GeV/c
- $|\theta|$<250 mrad

K2K region of interest





multiMW proton

Cross Section:

$$\sigma_{ij}^{\pi} = F_{norm} M_{ij}^{kl} \frac{1}{\varepsilon_{kl}^{\pi}} \left(N_{kl}^{\pi} - N_{kl}^{bkg} \right)$$

$(i,j) = (p, \theta)$

normalization: not computed yet

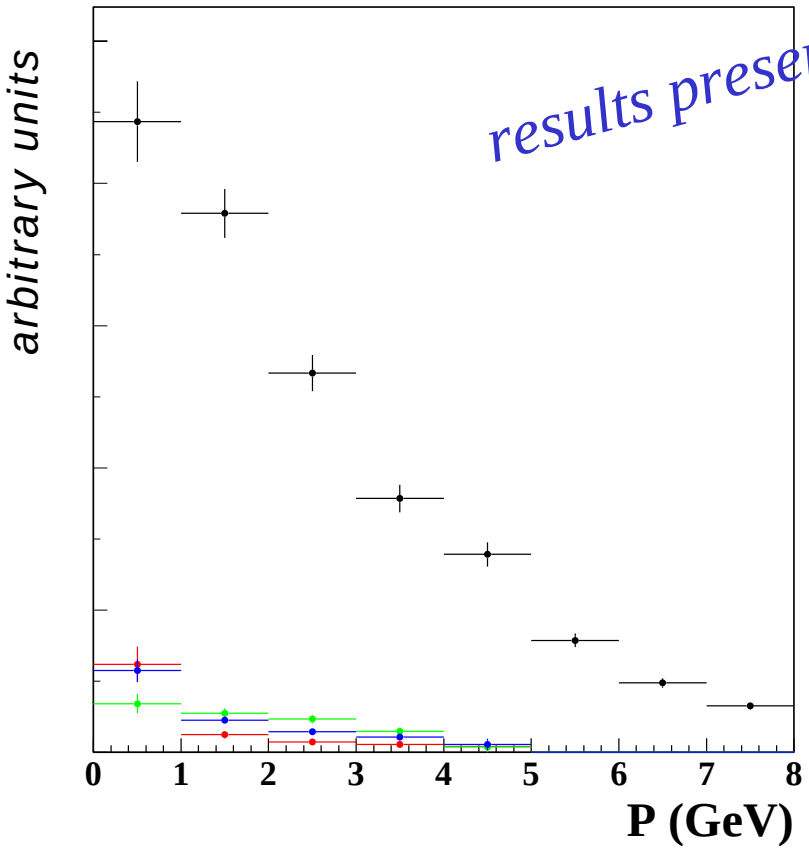
migration matrix: not computed yet

Total efficiency

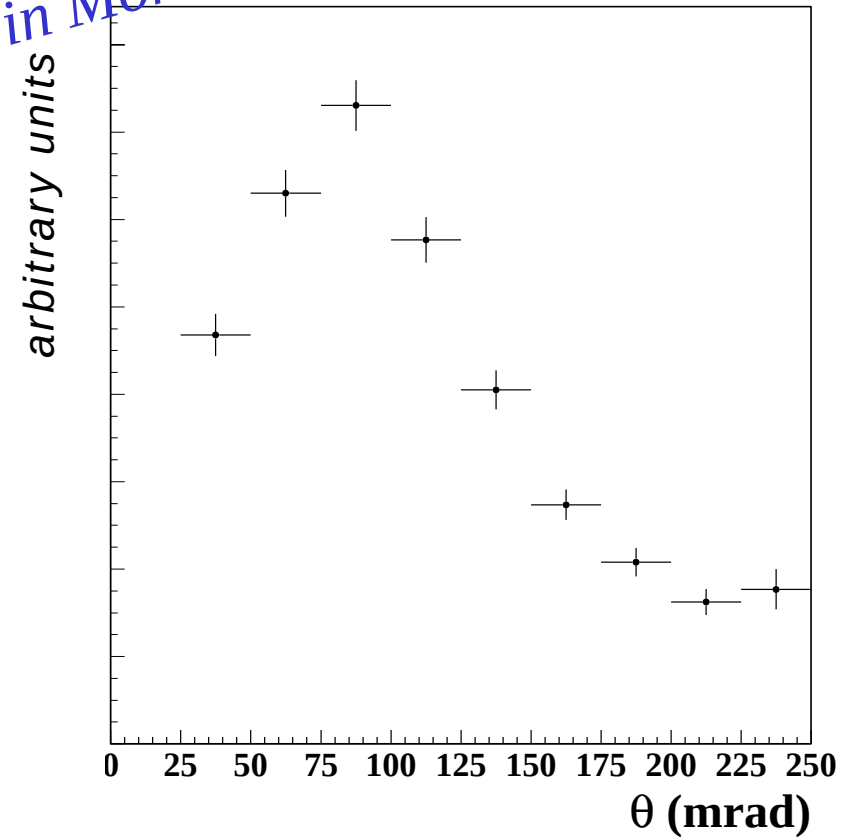
π-yield

bkg: misidentified π

π yield corrected for efficiency



results presented in Moriond



proton background for Tof
3 MC hadron generators

IMPORTANT
This background can be computed with the data

- ***The errors reflect the lack of MC statistics***
- ***Plots integrated over θ and p***
- ***No systematic errors included***

Conclusions-I

- ***HARP: recorded 420M events in 2 years (2001-2002)***
- ***The results shown today (first presented in Moriond) used 1/6 of our K2K thin target data***
- ***Forward spectrometer & PId detectors are well understood***
- ***MC/Data production "machinery" well under control***
- ***Data statistics is not a problem (5.6 M events after data quality)***
- ***Small systematic error expected***

Conclusions-II

- ***The forward angle analysis shows the potential of the experiment:***
  - ***1st cycle to be concluded very soon (full K2K replica, full statistics, systematics, normalization …)***
- ***The Large Angle analysis will fully exploit the physics reach of the experiment:***
  - ***TPC calibration being refined + readiness for analysis***
- ***Plans: produce a preliminary result for proton driver energy at Villars workshop***