The HARP Experiment

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on behalf of the HARP Collaboration

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Outline

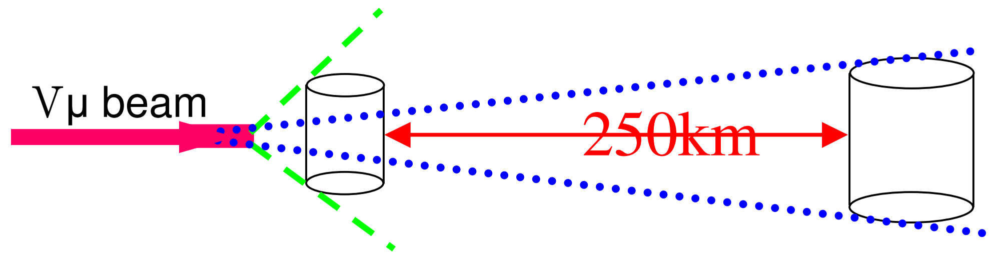
- Goals for a HAdRon Production experiment
- Example: KEK PS Neutrino beam-line
- Detector layout and performance
- Physics analysis: pion yield for the K2K target
- Summary & Conclusions

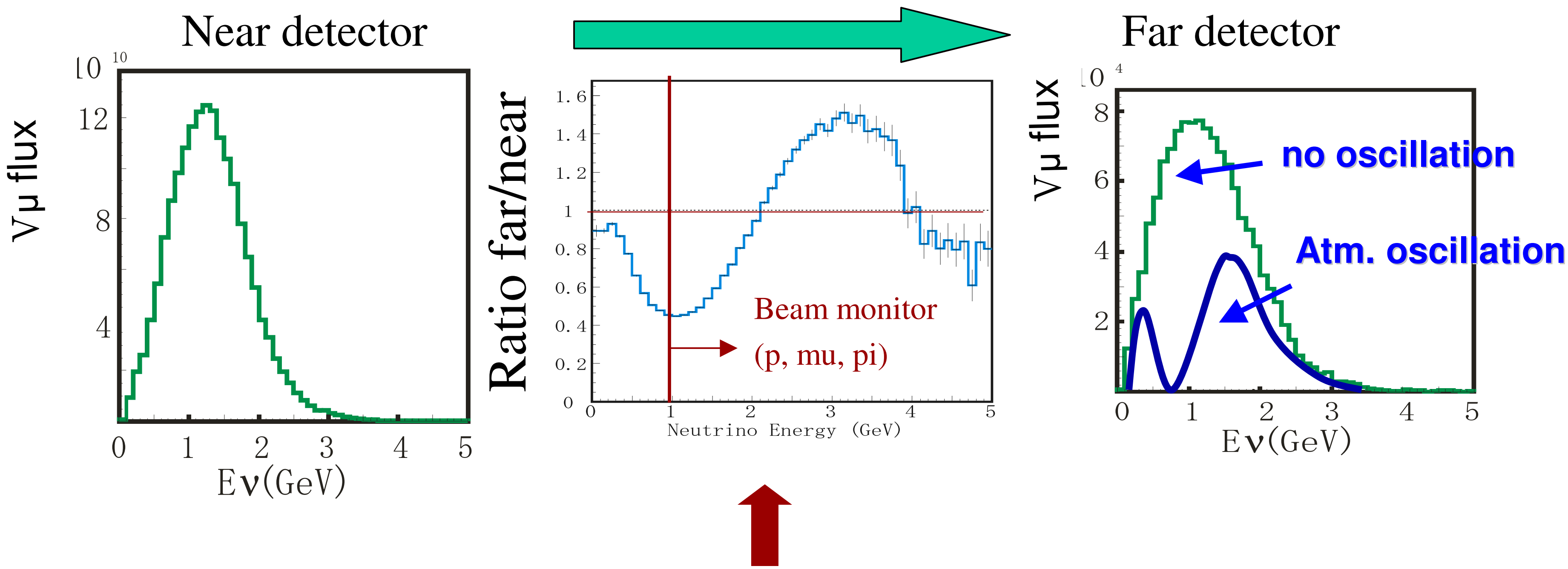
Goals for a HAdRon Production experiment

- Atmospheric Neutrino flux
- Neutrino beams:
  - Fermilab booster neutrino beam-line (8.9 GeV/c)
  - KEK PS neutrino beam-line (12.9 GeV/c)
  - Neutrino Factory
  - Super-beams (SPL, JPARC…)
- Input for MC generators
- Existing data (single arm or low statistics)

Example: K2K experiement

- KEK PS neutrino beam sent
to SK detector (250 Km)
- ν_μ disappearance
- Verify atmospheric neutrino deficit

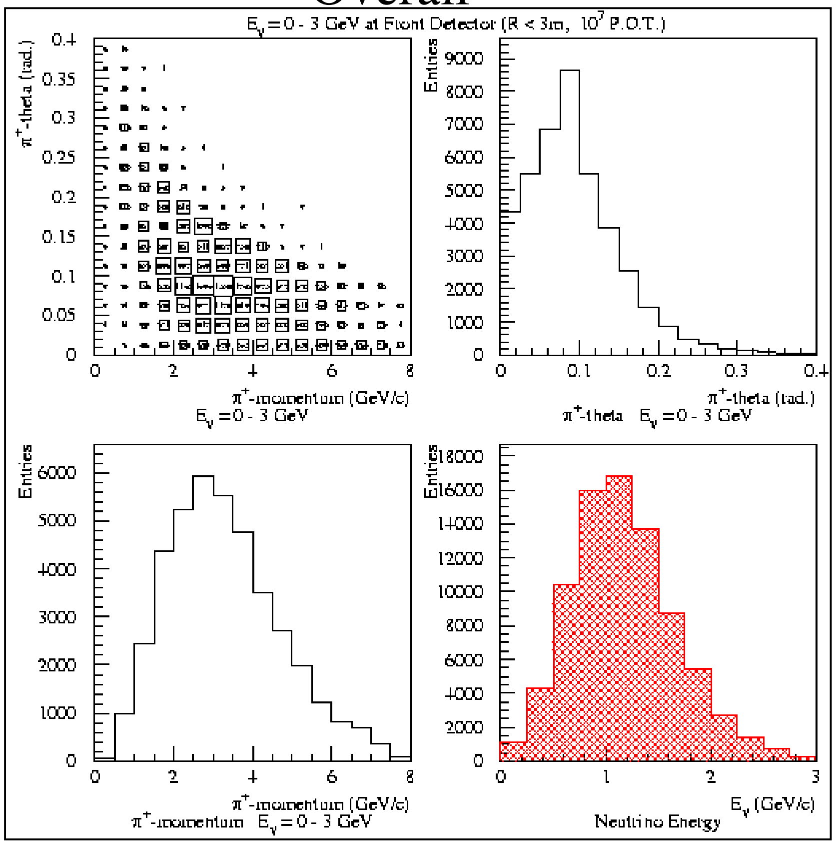




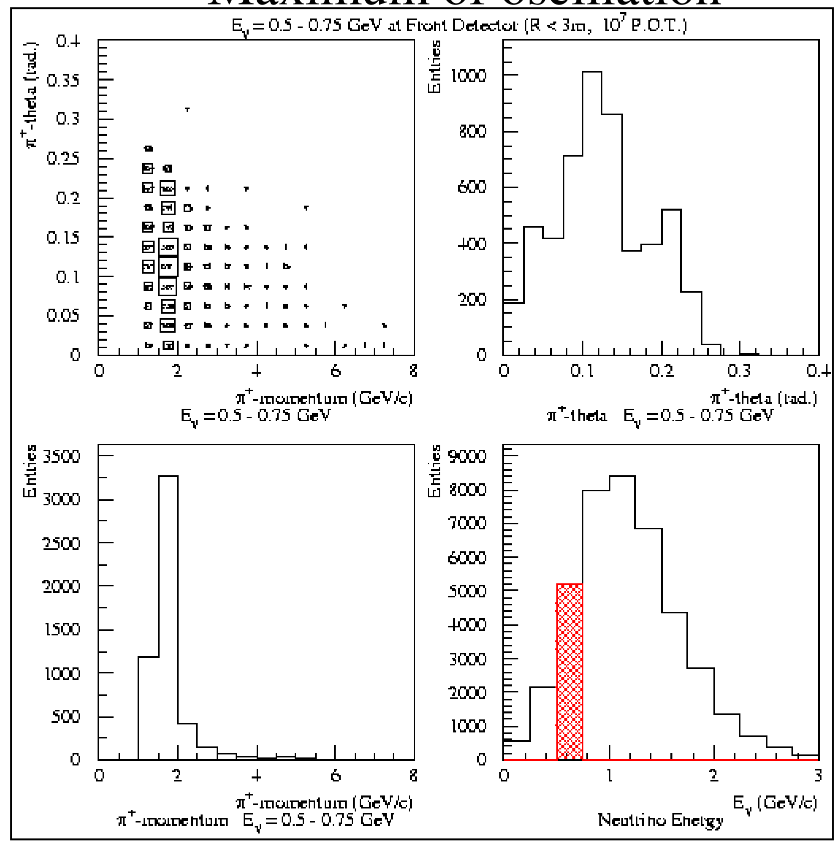
Different solid angle coverage

Example: K2K requirements for HARP

Overall



Maximum of oscillation



E_{ν_μ} 0~5 GeV:

$P_\pi < 10$ GeV/c

$\theta_\pi < 300$ mrad

E_{ν_μ} ~0.6 GeV:

1 eV/c< $P_\pi < 2$ GeV/c

$\theta_\pi < 250$ mrad

The HARP Experiment

- Measurement of absolute and differential cross-section for hadron prod.
- Over full solid angle
- 1.5<P$_{beam}$<15 GeV/c, fixed targets

$$\frac{d\sigma}{dp d\Omega} = \frac{N(p,\Omega)}{\phi}$$

We need:

•Momentum measurement

•Particle identification

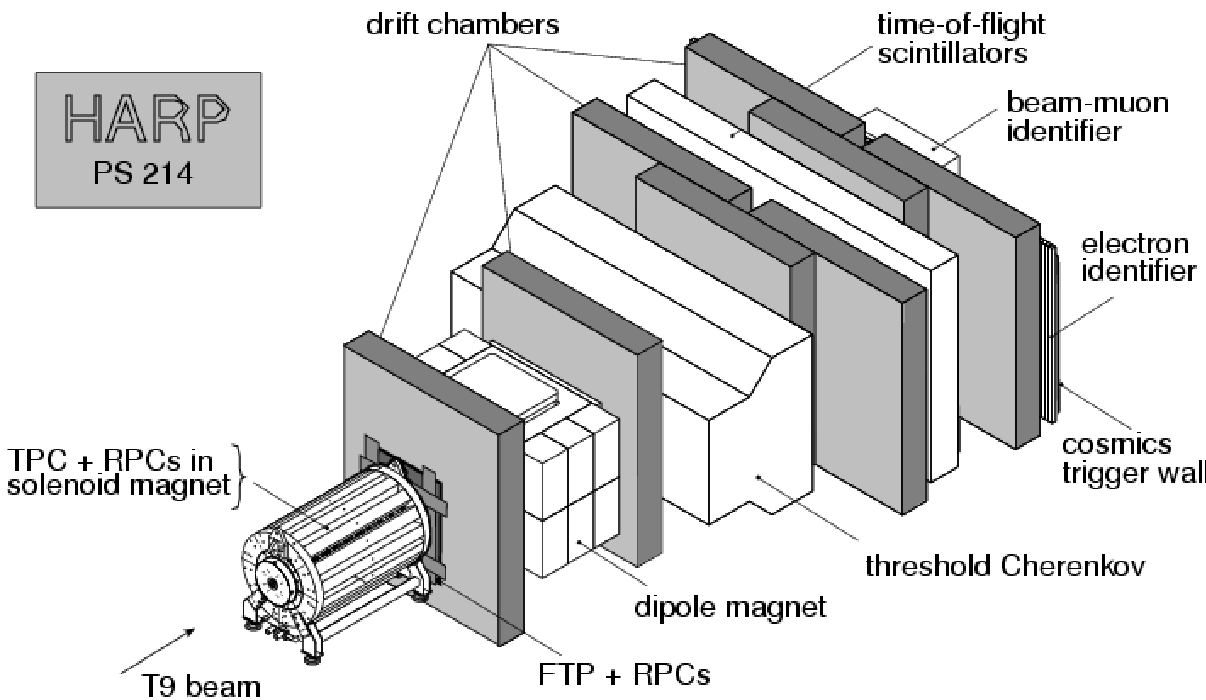
•Tracking

Over full solid angle

•Good geometrical &

PiD efficiency

HARP
PS 214



Targets & data

Data taking at the CERN PS T9 beam line during 2001 & 2002

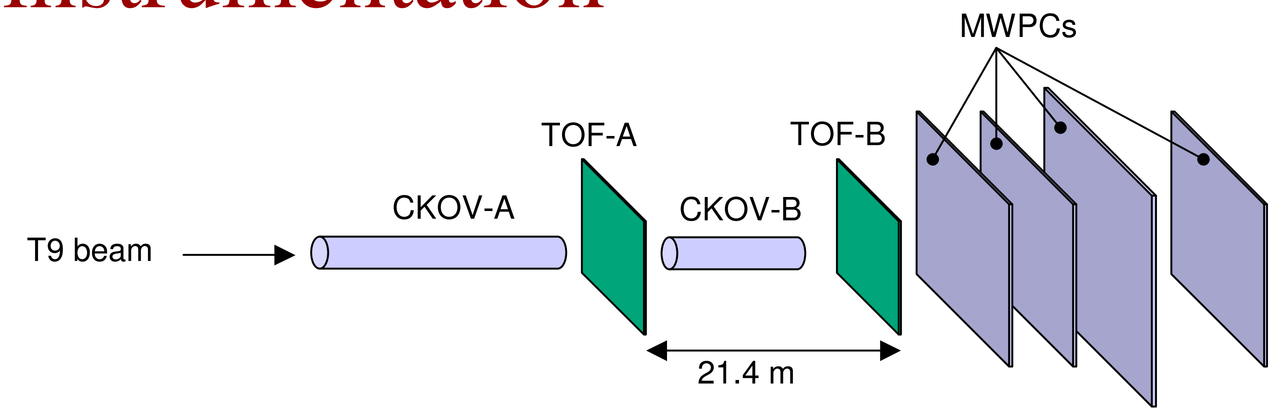
Beam momenta: 1.5-15 GeV/c

A total of 420 M events were recorded

Targets used:

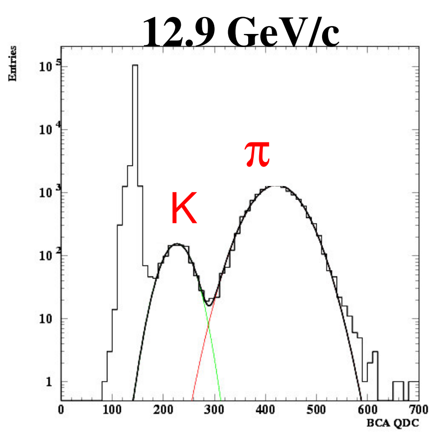
- Solids: Be, C, Al, Cu, Sn, Ta, Pb
- Liquid: H_20
- Cryogenic: H, D, N, O
- Neutrino experiments replicas: K2K (Al), MiniBooNE (Be)

Beam instrumentation

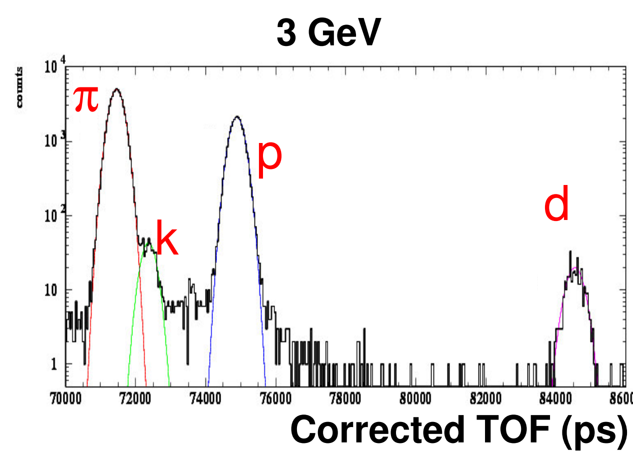


beam PiD

Cherenkov



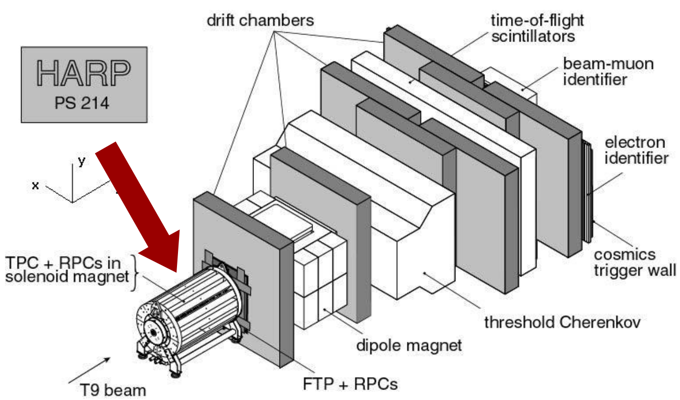
Time-Of-Flight

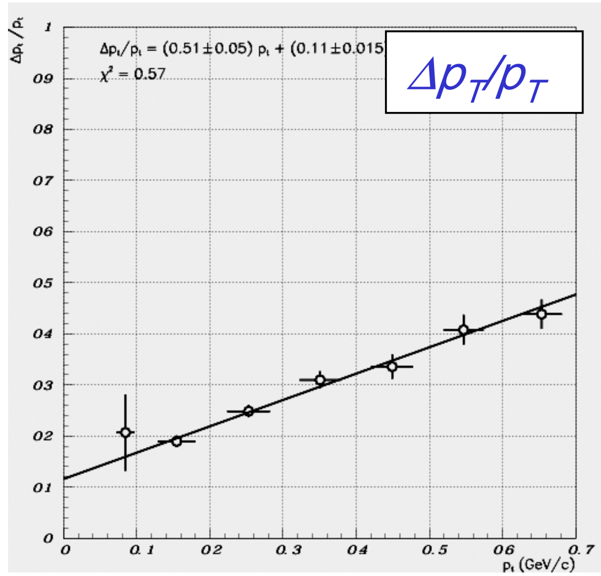


MWPC: incident beam direction (σ<100μm, 96% eff)

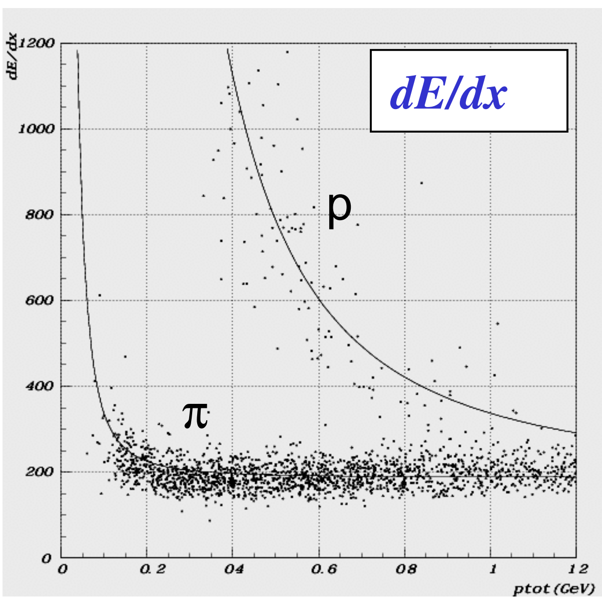
TOF also provides T0 with σ~70ps

Large Angle spectrometer: TPC

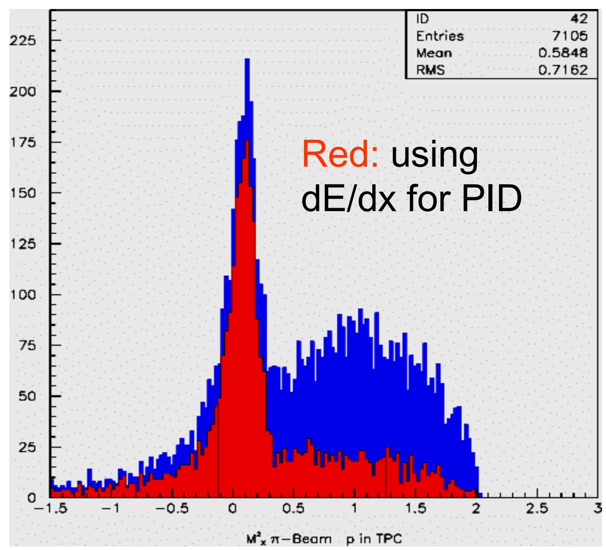




Momentum resolution vs. momentum for cosmic ray tracks. Res. Is evaluated by measuring P_T in two arms of the same track.

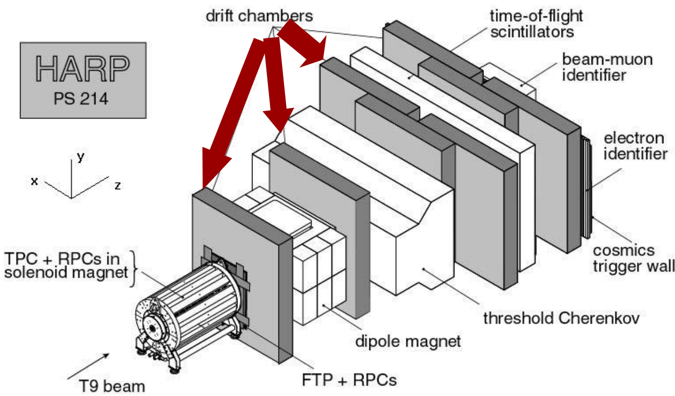


dE/dx measurement

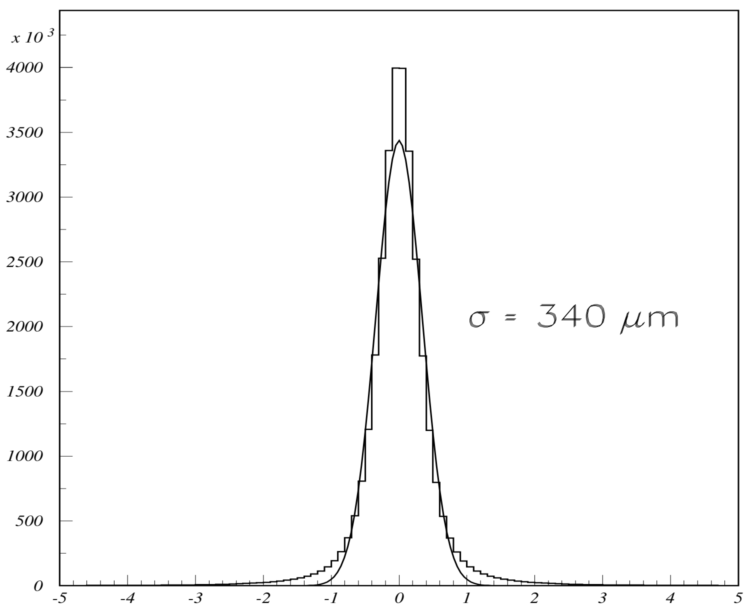


Missing mass in a pion proton elastic scattering interaction where only the final proton is measured.

Forward tracking: Drift Chambers



Aligned with cosmic rays and beam muons. σ = 340µm



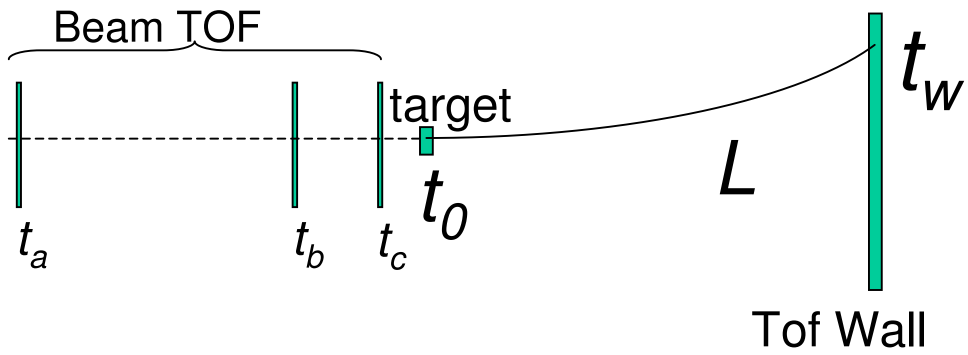
- **5 modules**
- **4 DC per module**
- **3 wire planes per DC**
- **+5˚, 0˚,-5˚ rotation between planes**
- **reused from NOMAD (massive)**
- **gas mixture: Ar/CO_2/CH_4 90/9/1**

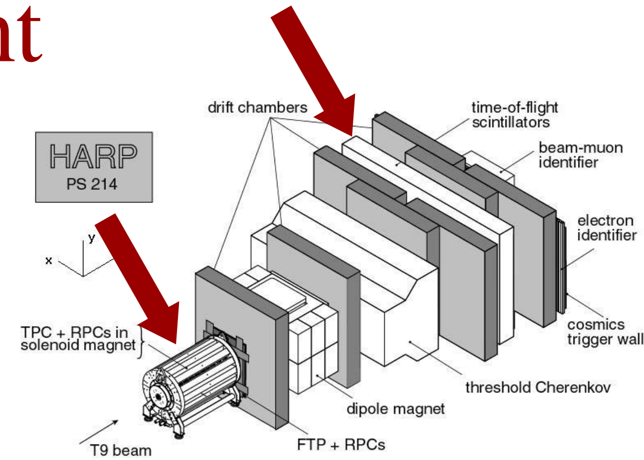
  different from NOMAD (Ar/CH_4 50/50)

  => lower hit finding efficiency of 80%

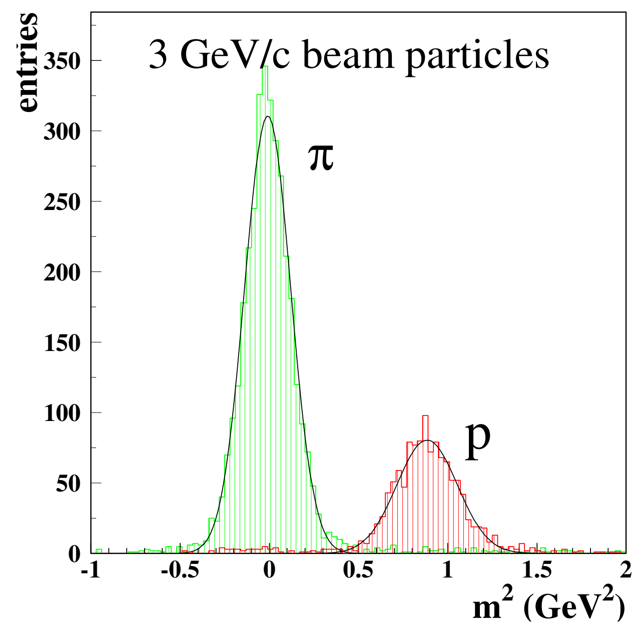
  (however, tracking eff. ~ 100%)
- **Efficiency is stable but depends on:**
  - **track multiplicity**
  - **opening angle between tracks**
  - **hit density**
- **Well understood and reproduced by MC**

Forward PiD by Time-Of-flight





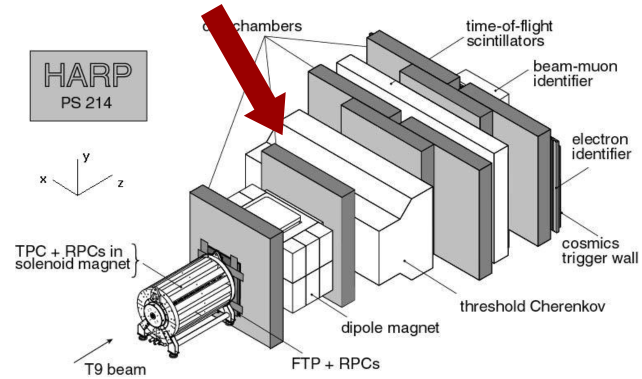
- TOF Wall: 42 slabs of fast scintillators read at both ends by PMTs. res ~160 ps
- t_0 provided by the beam TOF. res ~70 ps
- 3σ separation of:
  - ✓ π/p up to 4.5 GeV/c
  - ✓ κ/π up to 2.4 GeV/c
- π/p separation of 5σ at 3GeV/c



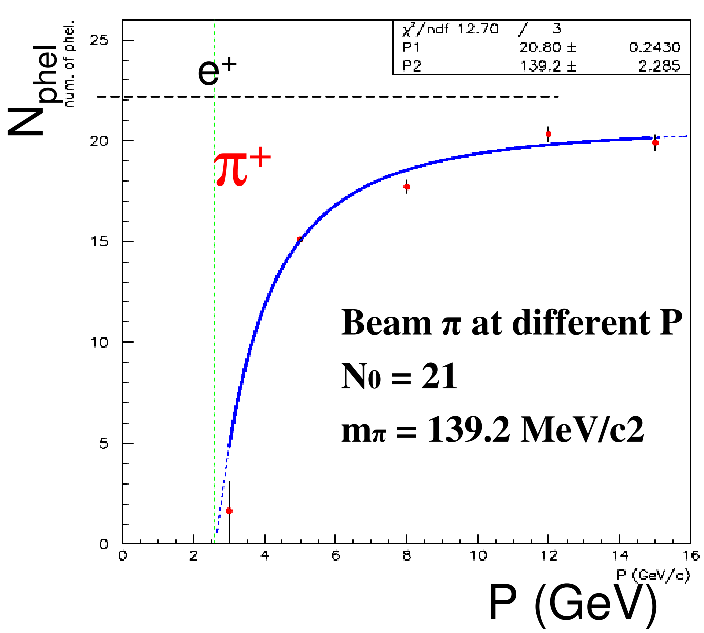
$$m^2 = p^2 \cdot \left(\left(\frac{t_w - t_0}{L} \right)^2 - 1 \right)$$

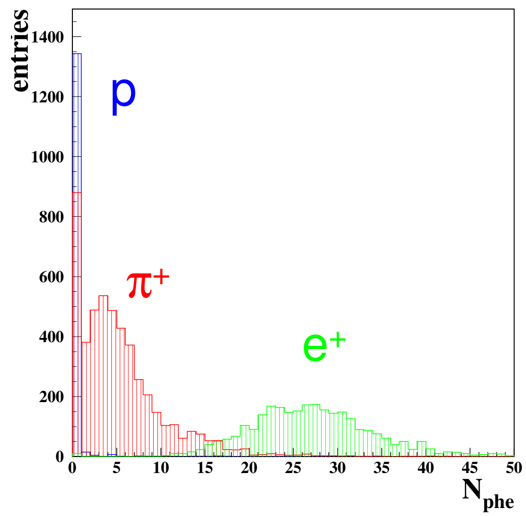
Forward PiD by Cherenkov

- C_4F_{10} => n=1.0014
- mirrors, Winston cones + 32 PMTs (16+16)
- threshold mode, Np.e also used
- π/e P<3 GeV/c
- π/p P>3 GeV/c
- π/κ 3<P<9 GeV/c

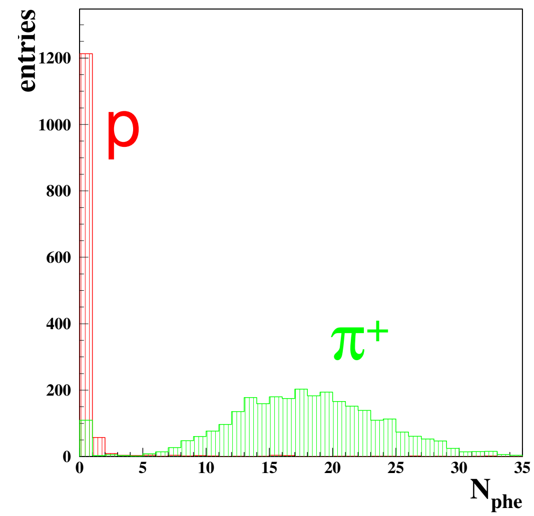


$$N_{p.e.} \propto N_0 \cdot \left[1 - \frac{1}{n^2} \cdot \left\{ 1 + (m/p)^2 \right\} \right]$$





3 GeV/c beam particles

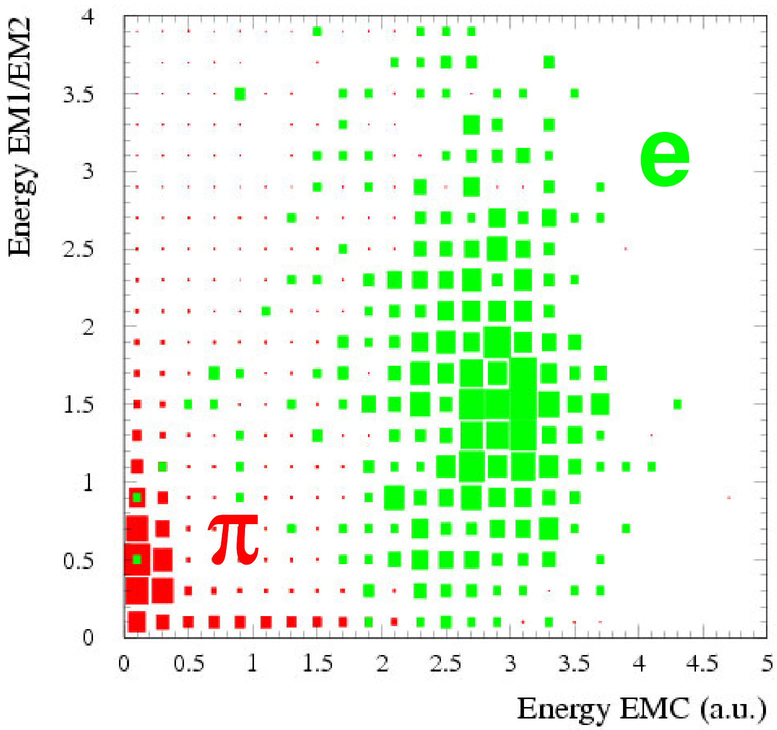


5 GeV/c beam particles

Forward PiD using the calorimeter

- h/e separation
- 2 planes Pb/fibre (4/1):
  i. EM1: 4 cm thick
  ii. EM2: 8 cm thick
- 16 X_0
- spaghetti type
- reused from CHORUS

$$\frac{\sigma_E}{E} = \frac{23\%}{\sqrt{E(GeV)}}$$



3 GeV/c beam particles

Pion yield for the K2K thin target (5% λ)

- Nπ(p, Ω)/Φ
- Correct for:
  - Acceptance eff. (MC)
  - Tracking eff. (MC+Data)
  - π id. eff. (Data)
  - π purity (bkg.) (Data)
  - migration between bins (Not yet)

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

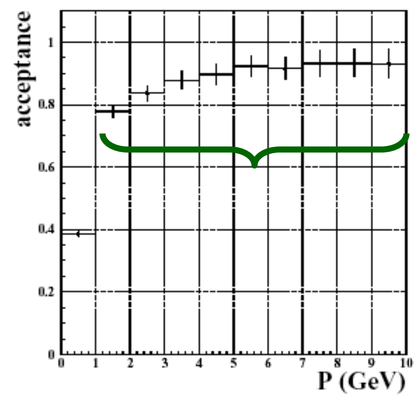
absolute norm. not included yet (F_{norm})

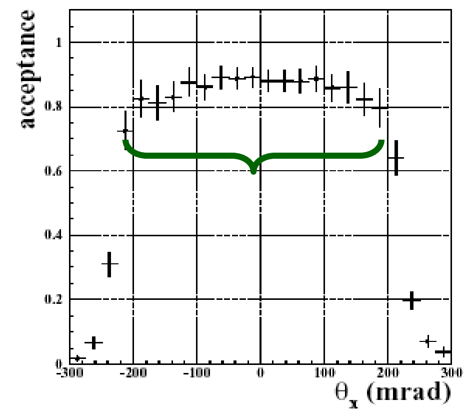
Migration matrix not included yet (M_{ij}^{kl})

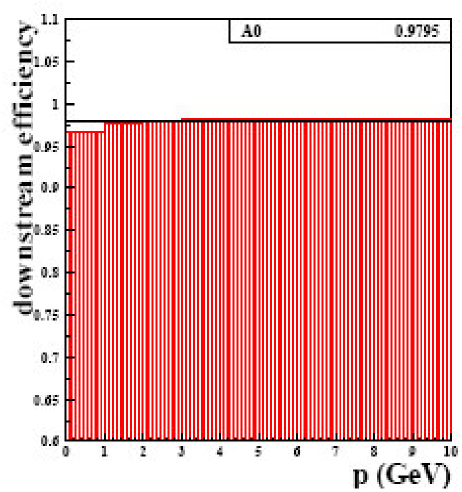
total eff. (ε_{kl}^{π})

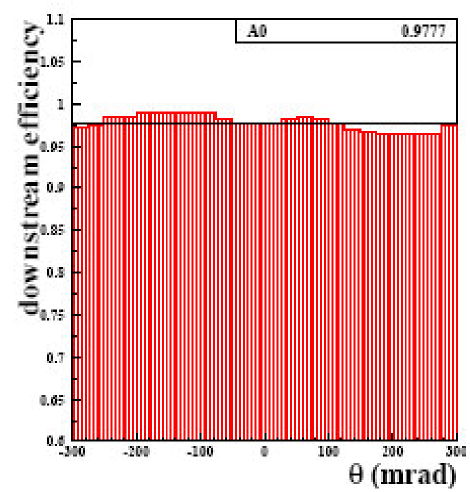
pion yield (N_{kl}^{π})

background (N_{kl}^{bkg})







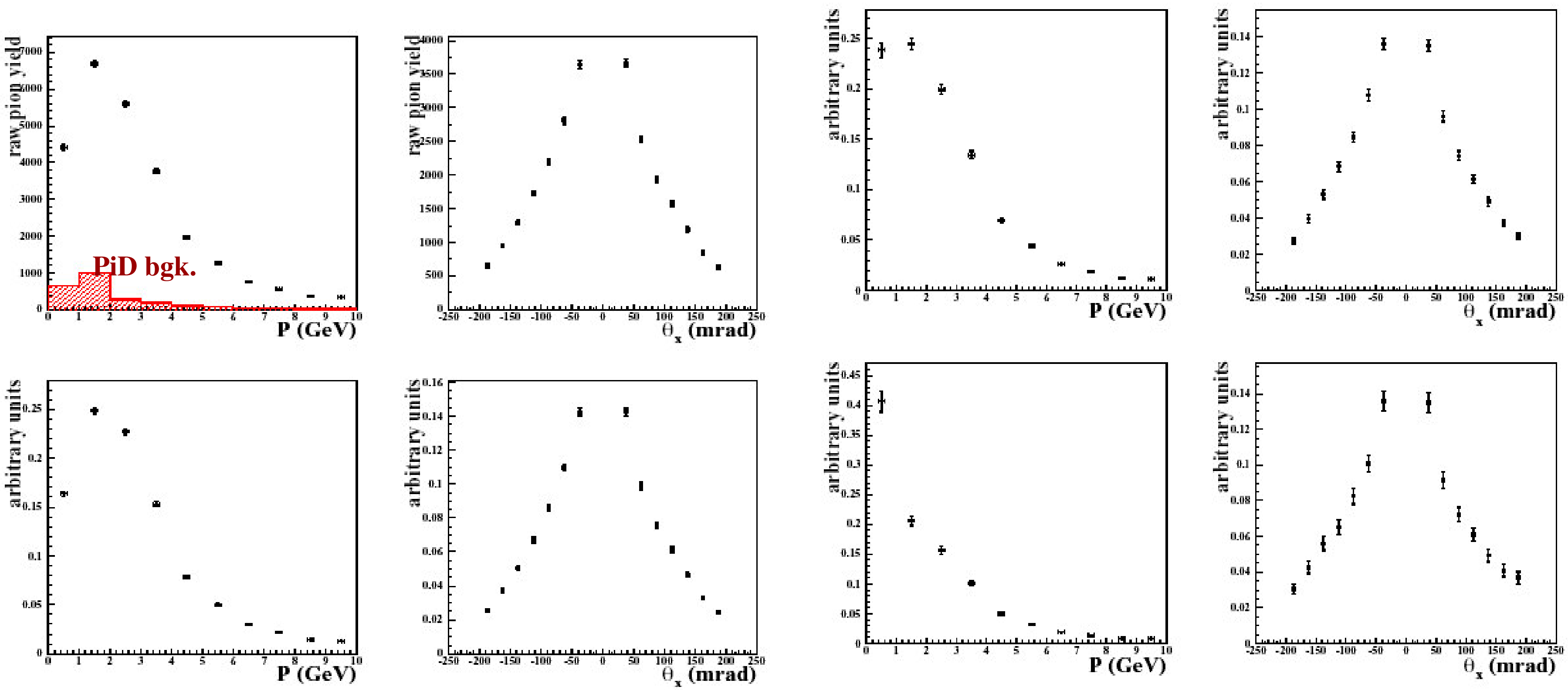


downstream eff ~ const. ~ 98%

Pion yield for the K2K thin target:

Raw

eff. corrected



PiD bgk. subtracted

acceptance corrected

Conclusions & ToDo

- Harp took data successfully during 2001&2002 over a wide range of targets
- Detector, PID, tracking efficiency well understood and robust
- HARP first results available
- Measurement needed for K2K far/near ratio will come shortly
- ToDo:
  - compute migration matrix
  - empty target subtraction
  - normalisation to beam
- MiniBooNE target analysis will be presented later today
- Same machinery will be used for the rest of analysis