The need for a precise knowledge of the beam in neutrino oscillation experiments

NA49-future for T2K

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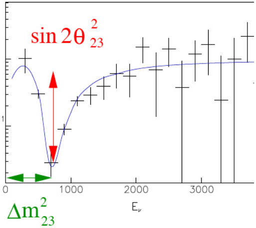
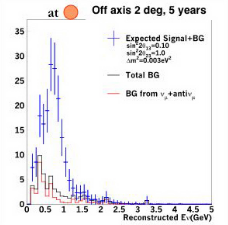
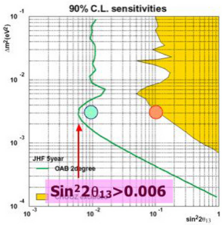
T2K

- Precision measurement on the atmospheric parameters ($\Delta m^2_{23} \sim 10\%$, $sin^2 2\theta_{23} \sim 1\%$): disappearence

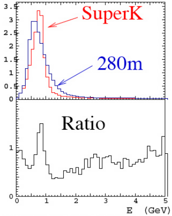


- θ_{13} measurement (by ν_e appearence)





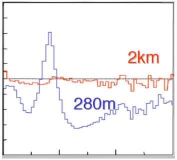
T2K is a precision experiment.
Both for ν_μ disappearence and for ν_e appearence, it relies on predicting a flux and spectrum (ν_μ or ν_e) at SK and comparing to the data.



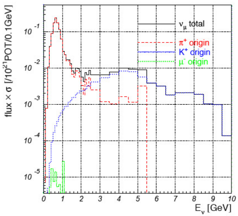
To predict:

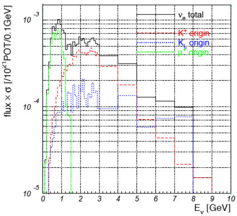
- measure near the production (flux and spectrum of each beam component ν_μ , ν_e , $\overline{\nu_\mu}$, $\overline{\nu_e}$)
- extrapolate (beam simulation)

To control a complicated Far/Near ratio, the solution is to understand the beam and the detector response in detail.



- The beam simulation should not only contain a full description of the focussing system but also a precise modeling of the pion production in the T2K conditions
- The uncertainty on the hadro production cross sections in the present Monte Carlo is large ($\approx$ 20% > K2K, but tuning more difficult)
- in the off-axis configuration, the F/N ratio is much more sensitive to the details of the pion and kaon production, in particular the angular distribution of the outgoing hadrons, compared to an on-axis beam.
- The ν_e contamination of the beam (main background for the ν_e appearence and θ_{13} measurement) comes from Ke3 and $\pi \to \mu \to e$ decay chains.



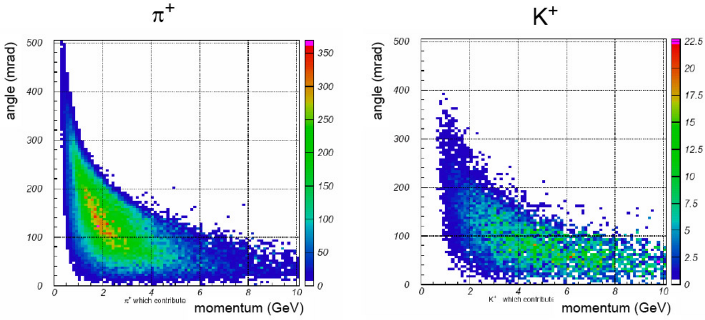


The T2K precision anticipated on the neutrino oscillation parameters requires to know the F/N flux ration to 2% or better.

this translates into a requirement of a precision of 2-3% on the differential cross-section (momentum and polar angle) for pion and kaon production in the phase space and conditions of T2K.

- there is almost no data available
- this means > 10% uncertainty on the flux ratio (7% in K2K, <4% with HARP)
- a dedicated hadroproduction experiment is essential
- statistics needed: $\approx$ 500K $\pi+$ and $\pi-$, 100K Kaons (to start with)

T2K ν parent hadron phase space



need to cover all this kinematical region and identify the outgoing hadrons
K component important for ν_e appearance signal (background)

requires: large acceptance
particle ID

The most promising option is the use of the NA49 detector
(acceptance and particle ID)

(DRAFT) Statement from T2K International Board of Representatives (IBR)

The T2K collaboration would like to stress the importance of the measurement of particle production from 30-50 GeV protons on carbon, as the available data are not of sufficient precision.

We support the NA49/T2K proposal very strongly.

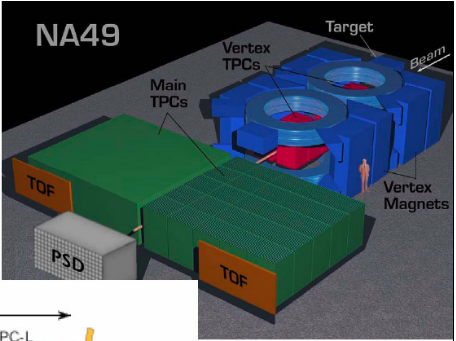
Work on NA49/T2K which leads to successful data-taking and analysis needed to produce hadron production data for the T2K flux calculation, would be considered a sufficient contribution to the T2K experiment to qualify as a T2K collaborator.

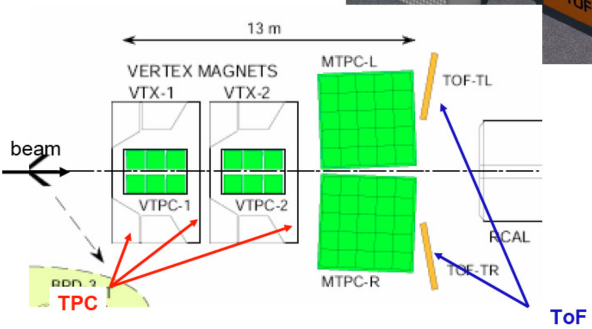
Members of NA49 who would thus contribute will be encouraged to apply to become members of T2K.

By following the same obligations, such as participation to data taking, common fund contribution, attending collaboration meetings, etc. they will have the same rights as all T2K members.

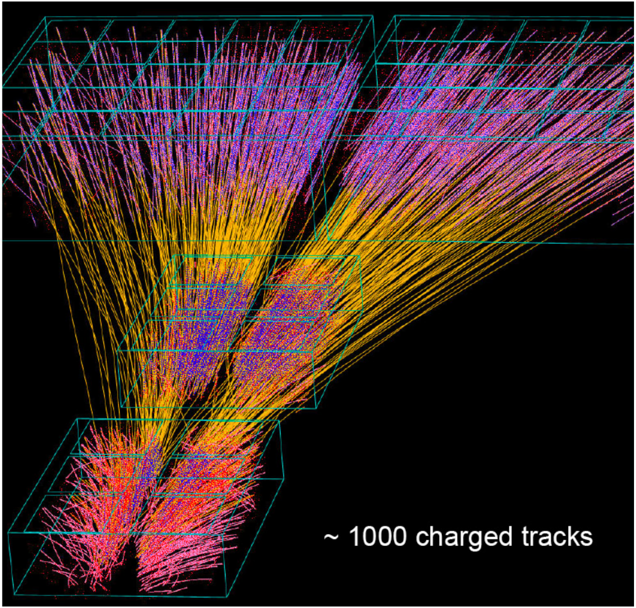
NA49 setup

NA49-future:
Study of hadron production in collisions of protons and nuclei at the CERN SPS

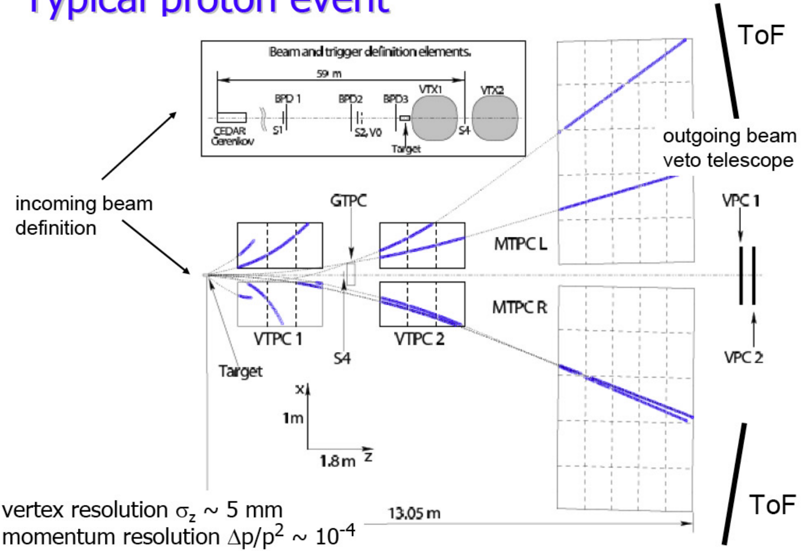




Heavy Ion Event



Typical proton event

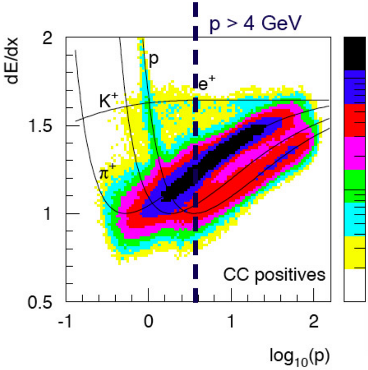


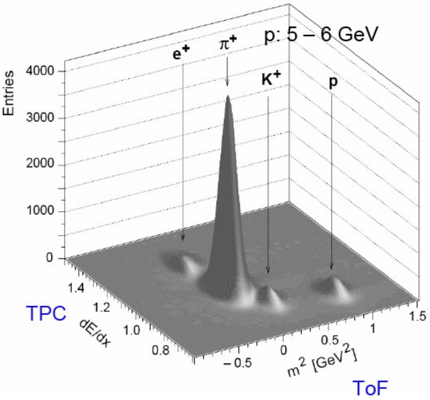
vertex resolution $\sigma_z \sim 5$ mm
momentum resolution $\Delta p/p^2 \sim 10^{-4}$

NA49 advantages

- advantages
  - the experiment exists (hardware and software)
  - well understood detector
  - large acceptance TPC
  - TPC works remarkably well (2006 test run)
  - particle ID (dE/dx and ToF)
  - almost no impact on SPS running (low intensity p beam)
  - modest investment for upgrades ~ 2 M CHF
- some –'s (work to be done)
  - 15 year old equipment and software
  - not used since 2002
  - very slow DAQ (old technology)
    new TPC readout under development (20 x faster)
  - limited ToF coverage
    possible extensions being considered

Particle ID (dE/dx in TPC & ToF)



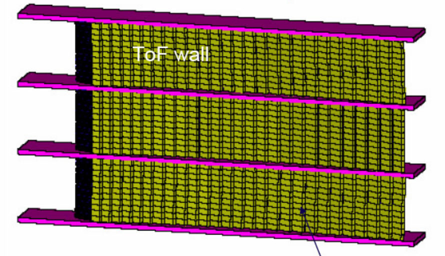


p < 4 GeV: ToF alone

p > 4 GeV dE/dx + ToF

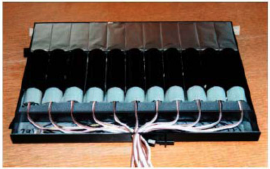
NA49 ToF

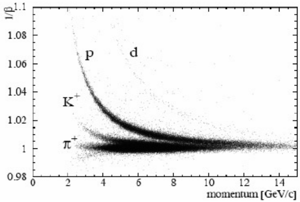
60 ps resolution

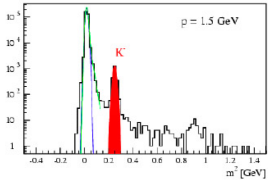


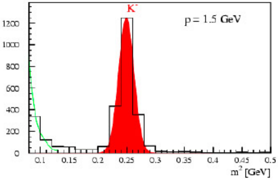
27 cassettes per shelf
3 shelfs
891 channels in total

891 scintillators
~ 3 x 6 cm2





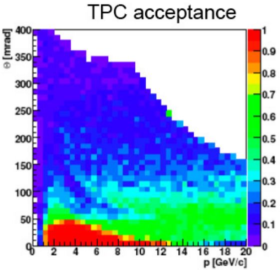


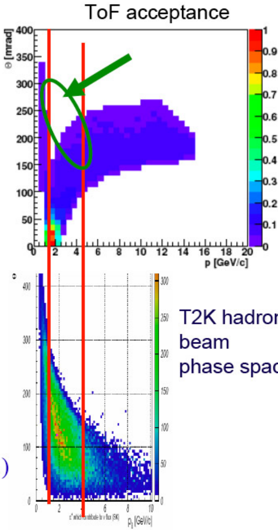


NA49 acceptance

« standard »

B fields rescaled to 30 GeV running





T2K hadron beam phase space

In order to cover lower momenta / larger angles with ToF consider different settings of NA49 apparatus:

- lower magnetic fields
- target position
- use only one magnet
- … several solutions possible

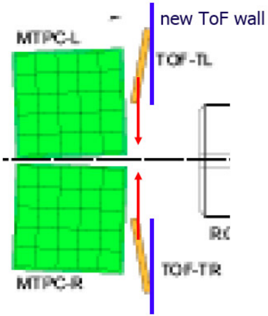
(Vadim did already some encouraging simulations …)

We are considering also to extend the ToF coverage

ToF Issues

- Restart ToF system and Calibration (Dubna ?)
- New readout - DAQ (Bari, Dubna ?)
- Limited acceptance
  - move the existing system closer to the beam
  - add a ToF wall ~2 x 1.5 m^2 on each side,
  - no need of high granularity, $\Delta t \sim 150$ ps
- Still looking for possible solutions
  in particular the ToF wall
- Acceptance studies
  - target location
  - magnetic field strengths

  Geneva (A.B.), Dubna (Kolesnikov), Frankfurt (Gazdicki)



TPC Issues

- Ideal for learning / refreshing TPC operations and analysis
  - ~ 40 m^3 volume
  - vertex TPCs in fringe magnetic field

- 2006 test beam
  - after 4 years still in very good conditions
  - test beam data being analyzed -> new gas mixture (Ar/CO_2)

- Readout:
  - ~ 20 x faster TPC readout
  - 400 k CHF, ½ will be covered by Swiss groups

- Calibration

Next steps & run plan

- NA49-future proposal submitted
  (don't expect immediate approval, summer 2007 ?)
- beam request for 2007 submitted
  (very likely, independent approval)
- continue beam studies initiated for the proposal
  impact of NA49 measurement
  dependence of ν beam properties on production mechanism
- 2007 run (in October)
  30 days with 30 GeV protons
  2 to 4 M triggers -> 500 k good events
  will already yield a significant measurement
- 2008 run
  45 days of beam time
  new, faster DAQ
  systematic measurements with 30, 40, 50 GeV proton beams and
  C targets with different thicknesses (π re-interactions, absolute x-sections)
- 2009 and later
  more beam if required

Beam studies issues

impact of NA49 measurement

- Effects of
  - K^+/pi^+, K^0/pi^++ ratio
  - angular distribution (p_T)
  - longitudinal distribution
  - target and horns misalignement

studies based on current beam MonteCarlo no ND included (yet)

ν + N n.c. π^0 prod.
near / far ratio for ν_μ, ν_e, π^0

- statistics required
  T2K not statistics limited (ν_μ disappearence)
  Q: 500k π events -> ~ 2 % error on the flux ratio ?

- work just started (Kobayashi-san et al.), in parallel with NA49 run preparations

Work for 2007

T2K specific

- simulations
  (definition of setup)
- trigger
- restart ToF system
- ToF readout
  (gain 2 x in DAQ rate)
- ToF acc. extension
- target(s)

still to assign various tasks

NA49

- repair TPC gas system
- new slow control
- refurbish beam pos. detect.
- refurbish cooling system

- prototype TPC electronics
  (will gain 12 x in DAQ rate)
- prototype PSD module
  (particle spectator detector)

- run preparation
- data taking (~100 shifts to be covered by T2K)
- analysis ...

T2K studies

- study of $\delta(\Phi_\nu^{SK})$ vs $\delta(N_{bkg})$

$$\Phi_\nu^{SK} = \Phi_\nu^{ND} \times R_{F/N}$$

  - $\nu\mu$ NC background
    - uncertainty of the high energy region also causes δNbkg
    - needs to measure $\delta\Phi^{SK}$ ~ <10%

$\delta(R_{F/N}$ for $\nu_\mu)$ < a few %

  - beam νe background
    - uncertainty of 0.0 - 1.0 GeV region directly causes δNbkg
    - needs to measure $\delta\Phi^{SK}$ ~ <10%

$\delta(R_{F/N}$ for $\nu_e)$ < a few %

Conclusions

- the need for a dedicated hadro-production experiment to achieve the precision goals of T2K is recognized
- NA49-future is the best frame for this measurement, and the timing, although short, is appropiate
- help is needed, not only from the hardware side but also from the analysis front (HARP analysis has been far from trivial and experienced people are encouraged to join!!!)