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"LAr in NOVA experiment"

a point of view of two enthusiastic neutrino people...

- **main issues for NOVA experiment**
- **LAr how, were and why:**
  at near detector site
  at $\sim$ surface ?

Yale, July 11, 2006

Topics of NOVA experiment

- *2 GeV ν_μ Superbeam, 1 MW 120 GeV/c proton on target*
- *near and far Lsc detectors, L = 820 Km, 14 mrad Off-axis*
- *$\nu_\mu \rightarrow \nu_e$ appearance at atmosph. ν oscillation parameters*

  $\nu_\mu \rightarrow \nu_\tau$ disappearance (atmosph. ν oscillations)

  $\sin^2 2\theta_{13}$, δ_{CP} investigation, neutrino mass hierarchy,

  precise measurement of Δm^2_{23} and $\sin^2 2\theta_{23}$,...

Main ingredients:

- *neutrino beam knowledge, in particular the ν_e contamination and its related systematics*
- *neutrino cross-sections*
- *efficiency/backg of the near/far detectors*

LAr T200 in NOVA

Considers a ICARUS like, T200 Liquid Argon module, built with new techology

dimensions: $4 \times 4 \times 9$ *m*^{3}*, 144 m*^{3} *of LAr, 200 tons of LAr* $\rightarrow \sim 100$ *tons of fid. vol. (tbe !)*

perfectly suitable for NOVA ν *detection requirements, which can be housed at the near detector site:*

- *A) in the decay tunnel,* $\sim 10^6 \nu_\mu$ *CC event rate per* $6.5 \cdot 10^{20}$ *pot in T200 (NOVA proposal): site 1: 7.5 evt/p-pulse, site 2: 2.5 evt/p-pulse,site 3: 0.8 evt/p-pulse, p-pulse:* $6 \cdot 10^{13}$ *pot backgr:* μ *beam-halo from* ν *interactions upstream the site: tbe!*
- *B) at the surface ! 915 m downstream the target,* ~ 105 *mrad Off-Axis*

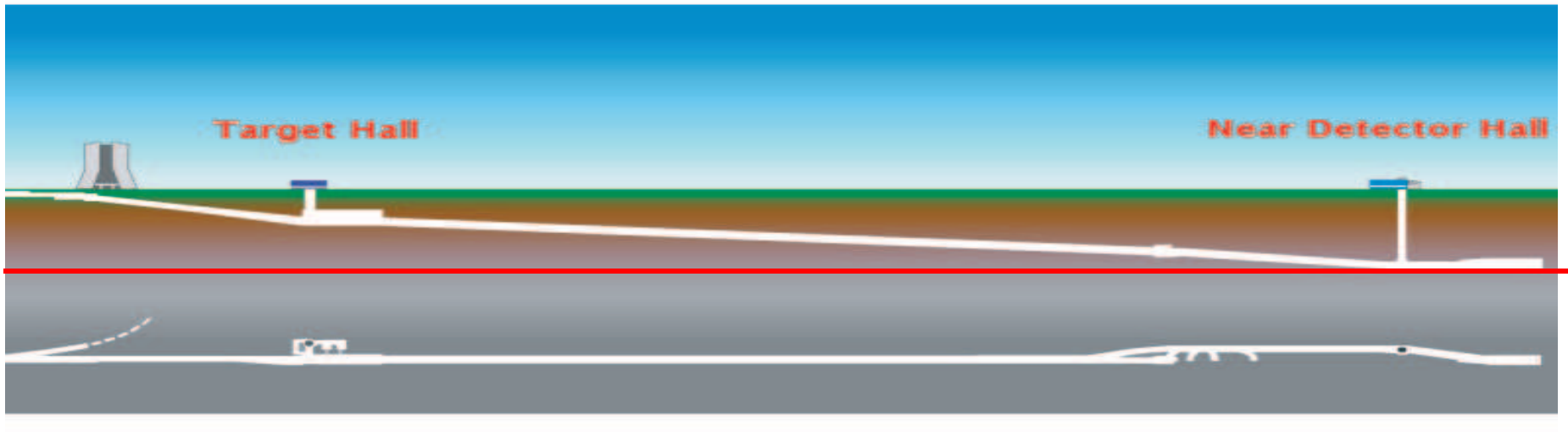


Fig. 4.1: Plan (bottom) and elevation (top) views of the NuMI beam line.

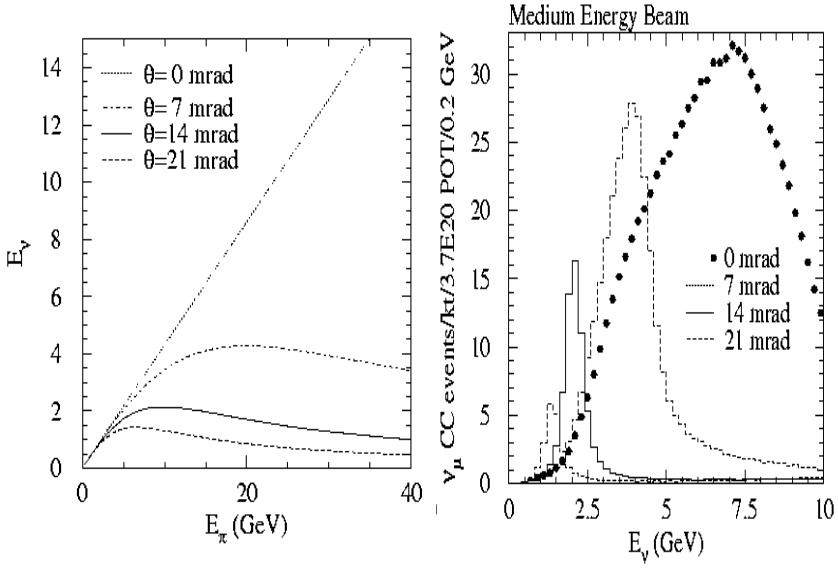
at the surface: an interesting option!

the kinematics of the Off-Axis technique offers, in this site, a unique possibility to measure the neutrino beam from K's well separated from π's component whose flux F is determined as:

$$F = (\frac{2\gamma}{1+\gamma^2\theta^2})^2 \cdot \frac{A}{4\pi z^2}$$

$$E_\nu = \frac{0.43 E_\pi}{1+\gamma^2\theta^2}$$

with $\gamma = E_\pi/m_\pi$, A detector area at distance z from the target



... the horns will focalize On-Axis with the same efficiency both π^+ and K^+ with the same momentum
...HOWEVER the decay kinematics is different for K ($m_K > m_\pi$), different γ and $0.43 \rightarrow 0.96$:
the resulting ν_μ component will be more energetic/broader for the same meson energy and θ angle!

from NOVA proposal:

for larger Off-Axis angle, $\theta \sim 75$ mrad,

but at a short distance,

to preserve the ν flux intensity,

- *ν_μ flux from π^+ is suppressed*
- *ν_μ flux from K^+ is enhanced*

... the neutrinos from K^+ stand-out !

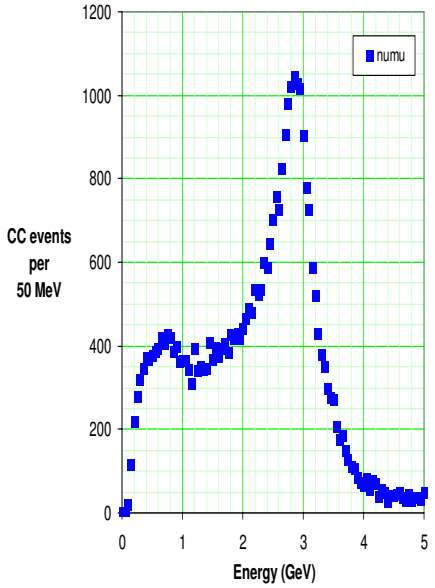


Fig. 9.7: Charged Current event spectra vs. energy for neutrino events in the 20.4 ton fiducial mass of the NO A Near Detector placed the MINOS Surface Building for 6.5 x 10^{20} p.o.t.

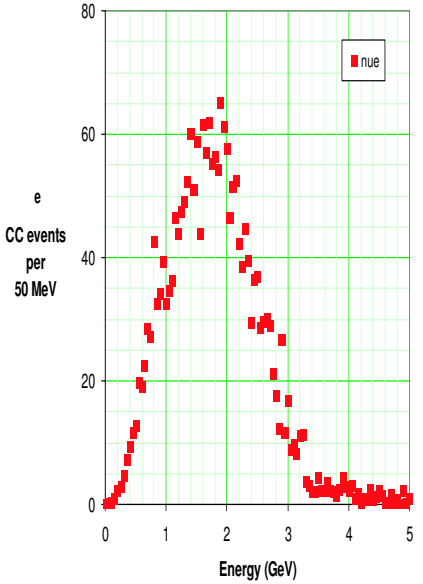


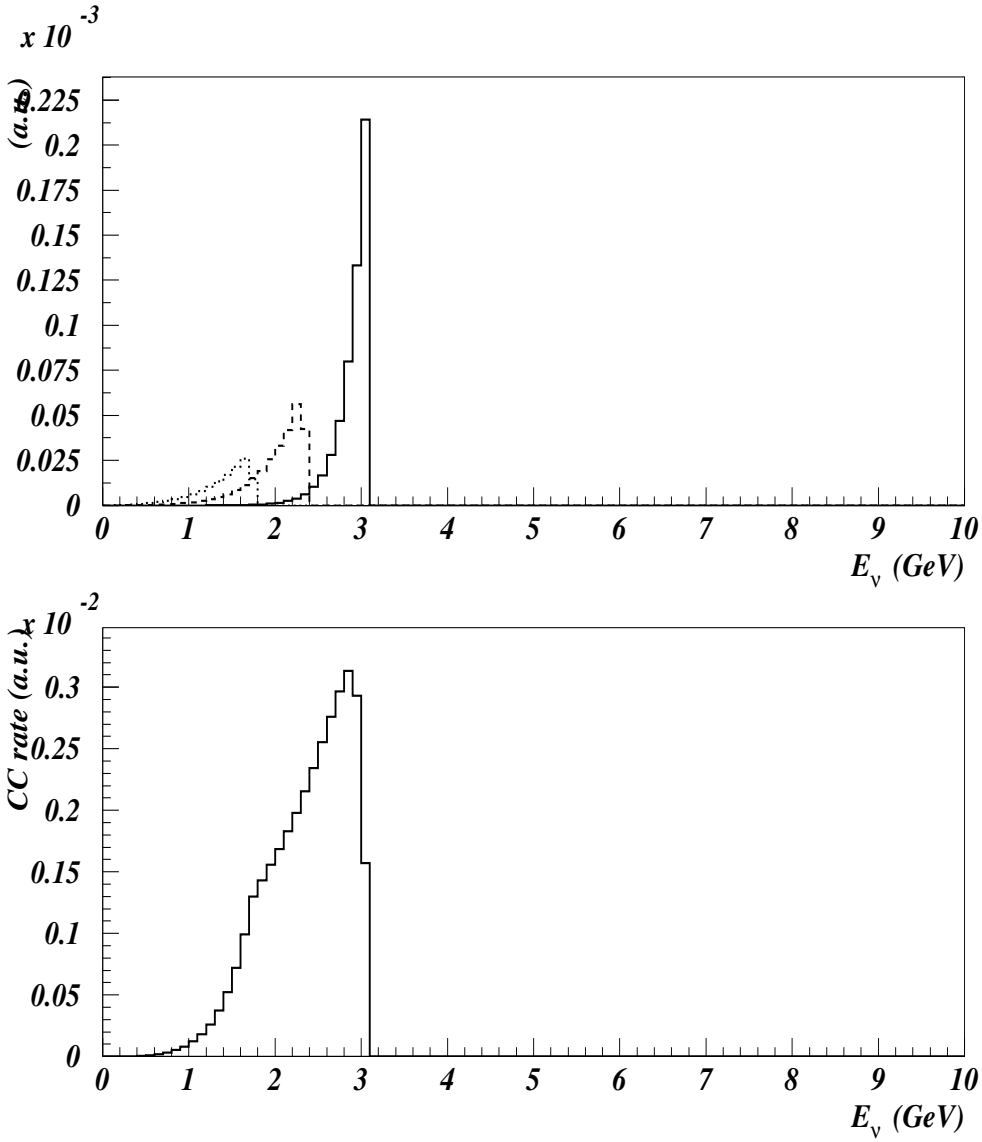
Fig. 9.8: Charged Current $_e$ event spectra vs. energy for neutrino events in the 20.4 ton fiducial mass of the NO A Near Detector placed the MINOS Surface Building for 6.5 x 10^{20} p.o.t.

ν_μ and ν_e CC at 75 mrad Off-Axis as calculated by NOVA ($6.5 \cdot 10^2 0$ pot, 20.4 t Liquid Scintillator Prototype at 915 m, ~ -25 m deep, erroneously quoted at the surface, A. Marchionni private comm.): ~ 45000 ν CC

ν_μ from 2 body K-decay

decay of K^+ flying in forward direction in 675 m decay tunnel with a detector 75 mrad Off-Axis 915 m from the target with M.E. beam, horn focusing in $7 \leq p \leq 21$ GeV/c

- *ν_μ flux energy distribution for K^+ with 7 GeV (full), 14 GeV (dashed), 21 GeV (dotted)*
- *ν_μ CC energy distribution for kaons with energies uniformely distributed inside $7 \div 21$ GeV range (bottom)*



necessary a new full simulation to understand

confirm this K-peak on the background

- 3 body decay of K (B.R. $\sim 3\%$)

- defocused components (negative mesons)

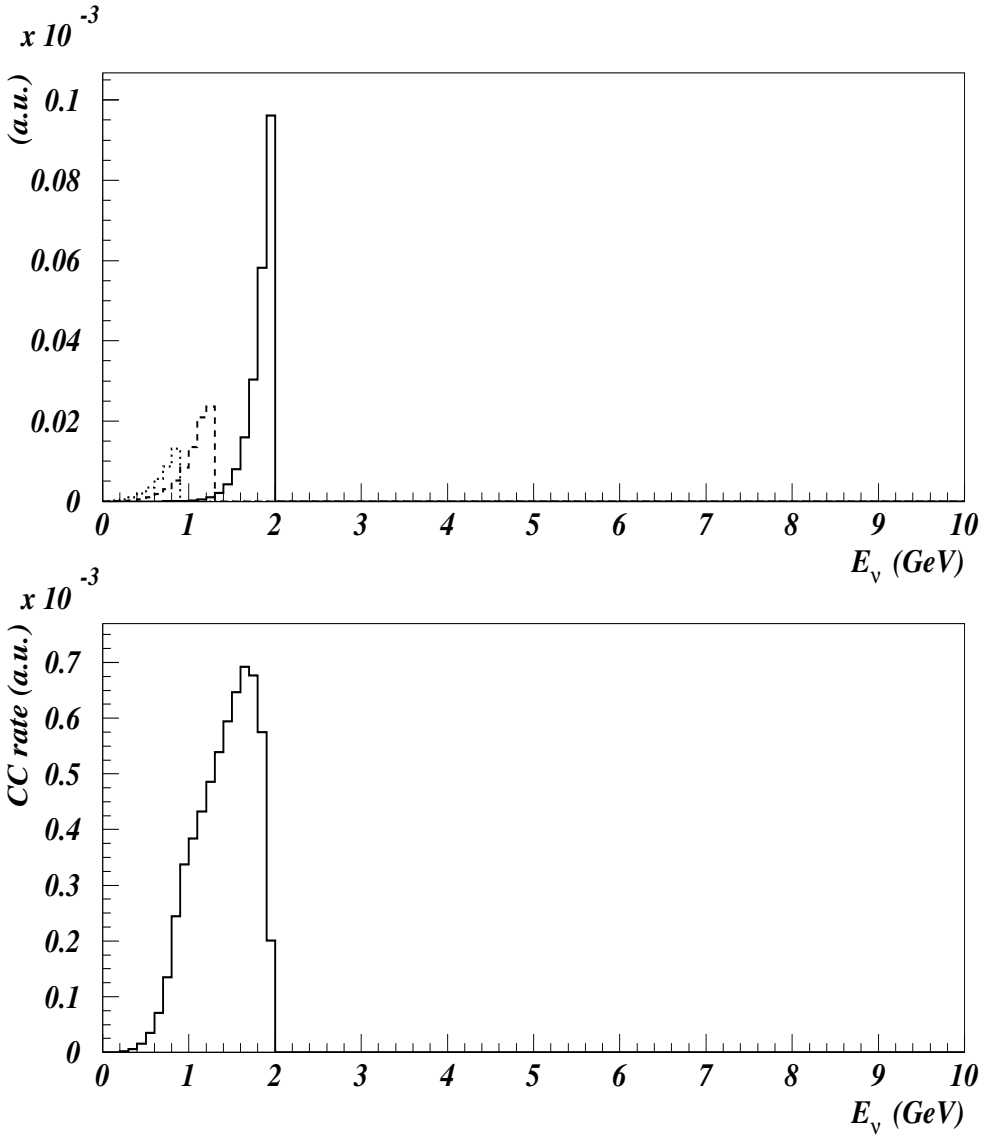
- reinteractions...

ν_μCC energy distribution $\simeq$ quoted by NOVA: $E_{peak} \sim 2.8$ GeV, FWHM ~ 1 GeV

at the surface ~ 105 mrad Off-Axis:

as an effect of 75 mrad to 105 mrad detector displacement:

- *the ν_μ peak from 2-body K-decay moved from 2.9 to 1.8 GeV*
- *the CC-event rate is roughly reduced by more than a factor 4*



these reductions seem to be in agreement with new calculations redone with the detector at surface (B. Fleming):

NoVA-prop. (75 mrad): 45000 ν_μ CC E_ν-peak $\sim$ 2.8 GeV

new-calc. (105 mrad): 10500 ν_μ CC, E_ν-peak $\sim$ 1.9 GeV

for 20.4 t detector mass, 6.5 ^{20} pot

T200 LAr detector at surface in the near NOVA detector hall exposed at ME neutrino beam will measure for 6.5 10^{20} pot/year (from NOVA prop.: 20.4 t LSc $\rightarrow$ 100 t LAr, rescaled by 0.25):

- *16000 ν_μ-CC/year from K^+ decay ($1 \div 1.9$ GeV range), 0.05 evt/p-pulse*
- *2500 ν_e-CC/year from K^+ decay*
    - *measurements of well peaked ν_μ from K^+ : $\rightarrow$ integral measurement of ν_μ from K^+ in NOVA at 14 mrad Off-Axis, isolating this important component in the beam, from $105 \rightarrow 14$ mrad: kinematics only!*
    - *measurement of well peaked ν_e from K^+: $\rightarrow$ integral mesurement of the intrinsic ν_e from K^+, the more important ingredient in NOVA!*
    - *measurement of ν cross-sections*
    - *comparison of ν detection in LAr/LSc prototype:*

      $\rightarrow$ measurement of detection efficiency/background in NOVA !

These items are expected to have a fundamental impact in the NOVA for both $\nu_\mu \rightarrow \nu_\tau$ (ν_μ disappearance) and $\nu_\mu \rightarrow \nu_e$ oscillation searches as beam knowledge, systematics and event rate...

Conclusions

The use of T200 LAr detector "as fine grained and high performance detector at near site" in NOVA experiment looking for $\nu_\mu \rightarrow \nu_\tau$ and $\nu_\mu \rightarrow \nu_e$ oscillations can be an extremely interesting option especially if installed at surface in the near NOVA detector hall.

In this location ~ 105 mrad Off-Axis it will be possible to isolate the K^+ component of the secondary beam by measuring a well peaked ν_μ and ν_e just coming from K^+. These measurements will have a large impact in NOVA as intrinsic ν_e beam contamination and ν_μ flux for both event rate and systematics. Moreover measurements of neutrino cross-section and detection efficiency of LSc in NOVA (if LAr will be coupled to LSc prototype) can be also performed .

... full MC studies of neutrino flux at surface, as rate, shape and contaminations are required in order to well establish this neutrino K-peak signal w.r.t. background!