Report on LAGUNA WP5
Evo Meeting (9th February 2012)

Dominikus Hellgartner

Technische Universität München

LENA-Meeting
20th February 2012

Contents

Agenda of LAGUNA conference in Paris (WP 5)

Detector presentations (3 h)

⇒ 1 h per detector:

- 45 min for two talks (preferably shorter)
- 15 min for discussion

General part (1 h)

- Presentation of GLoBES results based on the performance tables for each detector (20 min)
  Deadline for handing in revised versions:
  20th February → today
- Presentation about atmospheric neutrinos (20 min)
- Presentation about SN-neutrinos (20 min)
- Silvia expects to be asked to give a summary talk.
  ⇒ We need to prepare two slides showing our status/progress

Water Cherenkov – MEMPHYS

No changes since last LENA meeting

ITEM	EVALUATION	MEMPHYS	REMARKS
v_μ appearance β-b	MC simulation ref: arXiv:hep-ph/0603172	Generated events:115367 Particle ID: 95717 Michel Electron ID: 61347	Exposure: 4400 kt yr Full oscillation (P=1)
Background π+	MC simulation ref: arXiv:hep-ph/0603172	Generated events: 507 Particle ID: 204 Michel Electron ID: 107	CC/NC events
Background π-	MC simulation ref: arXiv:hep-ph/0603172	Generated events: 341 Particle ID: 100 Michel Electron ID: 8	CC/NC events
antiv_μ appearance β-b	MC simulation ref: arXiv:hep-ph/0603172	Generated events: 101899 Particle ID: 85285 Michel Electron ID: 69242	Exposure: 4400 kt yr Full oscillation (P=1)
Background π+	MC simulation ref: arXiv:hep-ph/0603172	Generated events: 674 Particle ID: 240 Michel Electron ID: 120	CC/NC events
Background π–	MC simulation ref: arXiv:hep-ph/0603172	Generated events: 400 Particle ID: 118 Michel Electron ID: 8	CC/NC events
Eres	MC simulation ref: arXiv:hep-ph/0603172	Gaussian distribution with σ=43 MeV	
v_μ desappearance SB	ref: arXiv:hep-ph/0603172		
Background Composition	ref: arXiv:hep-ph/0603172	Composition: 90% v_e CC, 6% π0 NC, 3% misID muons from CC, 1% antiv_e CC	

PHYSICAL POTENTIAL	PERSPECTIVES
Discovery reach of sin^{2}2θ_13=5 10^-3 mean, for certain values of δCP values of 10^-4 are possible. β-b performances depend on the neutrino flux intensity! Systematical Error = 2%	MC Simulation with more events and more background sources: π0 ! β-b background strongly peaked at low energies--->does not affect the measure?

LAr - GLACIER

- Details to be found in presentation: `http://pprc.qmul.ac.uk/~lodovico/Laguna_FDL20120209.pdf`
- Based on arXiv:1109.6526v1
- Detector performance:

Detector characteristics	LArTPC (Both $\mu^\pm$ and $e^\pm$)
Fiducial mass	$10 - 100$ kt
Neutrino energy threshold	0.5 GeV
Detection efficiency (ϵ)	100% for $\mu^\pm$ 80% for $e^\pm$
Energy resolution (δE) (GeV)	$0.15\sqrt{\mathrm{E/GeV}}$ for CC $\mu^\pm$ and $e^\pm$ sample
NC background smearing	Migration matrices (different for ν and $\bar{\nu}$)
Bin size	0.125 GeV
NC background rejection efficiency	99.5%
Background from misidentified muons	0.5%
Efficiency for intrinsic $\nu_e/\bar{\nu}_e$ contamination	80%
Signal error (systematic)	5%
Background error (systematic)	5%

- Planned partial update at LAr meeting (22th February)
- Planned total revision for the Paris meeting

LENA: β-beam I

- Interactions simulated with GENIE event generator
- All interactions in the center of LENA
- Used channels: $\overset{(-)}{\nu}_\mu$-appearance

  $\Rightarrow$ Signal identification via tagging of $\mu^\pm$-decay

  $\Rightarrow$ Background: res/dis/coh events with $\pi^\pm$
- Performance:

- **ν_μ appearance:**

item	evaluation	LENA	Remarks
signal	MC simulation, [1]	Generated events: 3901 (CC) μ^- tagged: 3448 (88%)	Full oscillation (ν_μ sample)
Background $\pi^\pm$	MC simulation, [1]	Generated events: 4800 (CC)/ 300 (NC) $\mu^\pm$ tagged: 3800 (79%) /223 (74%)	No oscillation (ν_e generated $\pi^\pm$ only)

- **$\bar{\nu}_\mu$ appearance:**

item	evaluation	LENA	Remarks
signal	MC simulation, [1]	Generated events: 1457 (CC) μ^- tagged: 1312 (90%)	Full oscillation (ν_μ sample)
Background $\pi^\pm$	MC simulation, [1]	Generated events: 2000 (CC)/ 1600 (NC) $\mu^\pm$ tagged: 118 (6%) / 673 (42%)	No oscillation (ν_e generated $\pi^\pm$ only)

LENA: β-beam II

- Energy reconstruction by photon counting + position dependent correction
- Treatment of NC and CC backgrounds in one migration matrix:

channel	item	used events
$\nu_e \to \nu_\mu$	signal	3448
$\nu_e \to \nu_\mu$	background	4023
$\bar{\nu}_e \to \bar{\nu}_\mu$	signal	1312
$\bar{\nu}_e \to \bar{\nu}_\mu$	background	755

  $\Rightarrow$ Resolution between 5% and 10%
- Discovery reach: $\sin^2(2\theta_{13}) = 0.05$ mean
- Algorithms to discriminate against $\pi^\pm$ required
- Impact of the $\overset{(-)}{\nu}_e$-disappearance channel not yet evaluated
- Impact of further backgrounds (without $\pi^\pm$) not yet evaluated

LENA: Superbeam to Phyäsalmi: Energy reconstruction

- Energy reconstruction can be done by:
  - Photon counting + position dependent correction
  - Full event reconstruction (Juha Peltoniemi)

⇒ Performance dependent on event reconstruction capabilities.

approach	evaluation	LENA	Remarks
simple photon counting (calorimetric approach)	MC simulation Generated events: 2000 (ν_μ-CC) 1000 (ν_e-CC)	$\lesssim 10\%$	flat spectrum, no track reconstruction used
full event reconstruction	Scinderella MC Code, [2] Generated events: $\lesssim 100$ (all types)	$\lesssim 3\%$	For full potential FADC readout required

LENA: Superbeam to Phyäsalmi : Background discrimination

- Have to discriminate between ν_e-CC and ν_μ-CC events.
  - Results from Juha Peltoniemi (full event reconstruction) look promising
  - Has to be verified with LENA-MC and higher statistics
- Additionally, separation of NC and CC channels is required
- Especially for $\overset{(-)}{\nu_e}$-appearance, NC-π^0 are dangerous
  - Sebastian Lorenz's results using boosted decision trees look promising

$\Rightarrow$ Current table:

item	evaluation	LENA	Remarks
e$\leftrightarrow$ μ	Scinderella MC Code, [2] Generated events: $\lesssim$ 100 (all types)	no misidentification observed	For full potential FADC readout required
$\pi^0 \leftrightarrow e^\pm$	MC Simulation, [3] Generated events: $\sim$ 200 000 e$^-$ and π^0 each (sub GeV, no Vertex)	30% background at 92% efficiency 10% background at 63% efficiency 1% background at 17% efficiency	constant event position and direction

LENA: Estimation of the NC-background

Based on results of GENIE-Simulations

- 44% of all NC events have at least one π^+
  - $\Rightarrow$ Tagging by looking for μ^+ decays (86% tagging efficiency)
    - π^- typically captured before they decay
- 47% of the remainder have at least one π^0
  - $\Rightarrow$ Use Sebastian's values for $\pi^0 \leftrightarrow e^\pm$ discrimination
- 7.2% of the remainder produce $e^\pm$, γ, $K^{0,\pm}$ or heavier particles
  - $\Rightarrow$ Conservative assumption: No discrimination possible
- 31% of the remainder are basically pure π^-
  - $\Rightarrow$ Should be easy to tag via pulse shape
- The remaining events contain only (anti) protons and neutrons.
  - $\Rightarrow$ Should be easy to tag via pulse shape

$\Rightarrow$ NC-contamination $\in [11\%, 34\%]$, dependent on the performance for the last two event types

$\Rightarrow$ Signal efficiency at 27.7% (best case!)

LENA: Suggestion of changes to the high energy performance table

- Add some additional information on the used β-beams.
- Update the values for the e$\leftrightarrow$ π^0 discrimination to the values of Sebsatian's diploma thesis
- Add the proposed values for the NC-background (see last slide) to the table

Event type	Fraction of NC-events	LENA	Remarks
At least one π^+	44%	Discrimination by tagging of decay muon, efficiency 86% [2]	Efficiency determined at sub GeV energies, π^- captured at ^{12}C
At least one π^0 but no π^+	32%	MVA[4] 10% contamination	Discrimination should be better for events with multiple π^0
At least one e$^\pm$, γ, K$^{0,\pm}$ or heavier, neither π^0 nor π^+	1.7%	No discrimination available	To be studied
"pure" π^-	7%	Kinematic of pion corresponds to $\mu^\pm$, pulse shape discrimination should be applicable.	For pure e-μ discrimination via pulse shape, see [2]
Events with only p$^\pm$ or $\overset{(-)}{n}$	15%	Quenched to lower energies different pulse shape	

Conclusion

- High energy physics table is the base for the detector-performance for ν-beams as presented at the Paris meeting.
- LENA performance for β-beam
  - Appearance channel nearly complete
  - Disappearance channel not yet dealt with, of minor importance

  $\Rightarrow$ No urgent action required
- LENA performance for Superbeam to Phyäsalmi.
  - Juha's work predicts good performance
  - Sebastian's analysis with boosted decision trees looks promising
  - First estimation of NC-background contamination

  $\Rightarrow$ More work has to be done to get reliable values!

Thank you for your attention

Possible problems

- Efficiency of muon-tagging at very high energies, degradation due to long duration of primary event?
- Impact of produced protons and especially neutrons on the pulse shape?