Laguna-LBNO: Large Apparatus for Grand Unification and Neutrino Astrophysics & Long Baseline Neutrino Oscillations

Thomas Patzak
APC, University Paris Diderot Paris 7
On behalf of the LAGUNA-LBNO Collaboration

T. Patzak, APC, University Paris Diderot, TAUP2011, 5 – 9 September 2011, Munich, Germany
Laguna: Large Apparatus for Grand Unification and Neutrino Astrophysics

New megaton class, multipurpose detectors will allow to study these fundamental questions

**Particle physics**

Proton decay

$\theta_{13}$

CP-violation

**Neutrino astronomy**

Supernova neutrinos

Diffuse SN neutrinos

Atmospheric Neutrinos

Solar neutrinos

Dark matter annihilation

Geo-neutrinos...

T. Patzak, APC, University Paris Diderot, TAUP2011, 5 – 9 September 2011, Munich, Germany
Large Apparatus for Grand Unification and Neutrino Astrophysics

2008 - 2011
1.7 M€ from EU

7 candidate sites:
- Boulby
- Fréjus
- Caso
- LSC
- Pyhäsmi
- Sunlab
- IFIN-HH

... In a

See talk by W. Trzaska
✓ Laguna => very comprehensive evaluation of all sites, construction and costs
✓ Laguna => baselines from 130 km to 2300 km available in Europe = advantage
✓ Laguna => allowed to form a strong community in Europe (> 100 physicists and Ing.)
✓ Laguna => showed the need to evaluate constraints and costs for the detector options

New program: Laguna-LBNO (one of the two fully financed by EC, 5M€)
Start September 2011 – End September 2014

- Laguna-LBNO: evaluate costs for detector construction and long term running (> 30y)
- Laguna-LBNO: investigates complementary beam options from CERN
- Laguna-LBNO: deep study of physics potential for the combination detector/site
- Laguna-LBNO: strengthens the community even more:
  > 250 physicists, 13 countries, 39 beneficiaries

Focus on 3 options:

1. Shortest baseline (130 km), CERN -> Fréjus: no matter effects; clean measurement of LCPV
2. Longest baseline (2300 km), CERN -> Pyhäsalmi: matter effect; mass hierarchy, LCPV
3. (Existing CNGS beam (650 km), CERN -> Umbria)
Fréjus Tunnel

Deepest: 4800 m.w.e

Pyhäsalmi Mine

T. Patzak, APC, University Paris Diderot, TAUP2011, 5 – 9 September 2011, Munich, Germany
Laguna-LBNO: Pan European Infrastructure for Large Apparatus Studying Grand Unification, Neutrino Astrophysics and Long Baseline Neutrino Oscillations

New FP7 2010 DS starting September 1st 2011

250 participants:
- Universities & nat. labs
- CERN
- Industrial partners

Focus on 3 options:
1. Shortest baseline (130 km), CERN -> Fréjus: no matter effects; clean measurement of LCPV
2. Longest baseline (2300 km), CERN -> Pyhäsalmi: matter effect; mass hierarchy, LPCV
3. (Existing CNGS beam (650 km), CERN -> Umbria)
LAGUNA-LBNO consortium

13 countries, 45 institutions, ~300 members

France
- CEA
- CNRS-IN2P3
- Sofregaz*

Germany
- TU Munich
- University Hamburg
- Max-Planck-Gesellschaft
- Aachen(**)
- University Tübingen(**)

Poland
- IFJ PAN
- IPJ
- University Silesia
- Wroklaw UT
- EGHM CUPRUM*

Spain
- LSC
- UA Madrid
- CSIC/IFIC
- ACCIONA*

Romania
- IFIN-HH
- University Bucharest

Denmark
- Aahrus(**)

Italy
- AGT*

Russia
- INR
- PNPI

Japan
- KEK

Courtesy: A. Rubbia
LAGUNA-LBNO sites

New conventional beams to be considered based on CNGS experience

- CERN-Fréjus is a short baseline. It offers good synergy for enhanced physics reach with $\beta$-beam at $\gamma=100$

- CERN-Pyhäsalmi is the longest baseline. It offers good synergy for enhanced physics reach with a NF

- [CERN-Umbria has an existing beam but is considered at lower priority (missing near detector, limited power upgrade scenarios)]

Courtesy: A. Rubbia
Memphys
2 x 330 kt
220’000 8” or 10” PMT’s
QE > 25%
DR 1 to 300 p.e.
Time resolution 1 ns
Low after pulsing
Pressure 10 bars
Lifetime > 30 y

LENA
50 kt
55’000 8” PMT’s
QE > 25%
DR 0.2 MeV to 10 GeV
Time resolution < ns
Low after pulsing
Pressure 15 bars
Lifetime > 30 y

Glacier
100 kt
1’000 8” WLS-coated cryo PMT’s
27’000 cryogenic PMT’s
QE > 25%
Time resolution 0 ns
Lifetime > 30 y cryogenic!

See talk by A. Rubbia

T. Patzak, APC, University Paris Diderot, TAUP2011, 5 – 9 September 2011, Munich, Germany
SUPER-BEAMS   BETA-BEAMS

The main goals: search of a non-zero $\theta_{13}$ angle or its measurement; searching for possible leptonic CP violation; determining the mass hierarchy and the $\theta_{23}$ octant.

LAGUNA-LBNO Pyhäsalmi physics prospects and Galcier:

Muon disappearance

νμCC w/o oscill

νμCC w/ oscill

Event rates: CERN SPS 400 GeV
5 years @ 9.4x10^{19} pots/year

Muon disappearance

Electron appearance

ντCC appearance

τ appearance

sin^2θ_{23}=1.0, sin^2θ_{13}=0.1

Courtesy: A. Rubbia
LENA and beams:

In LENA: High-energy particle tracking based on Cherenkov-like scintillation light fronts.

Expected detector performance:

- $\nu_\mu$ selection based on delayed $\mu$-decay electrons:
  - $\nu_e$ rejection > 99.96% (95%CL)
  - for 85% $\nu_\mu$ acceptance

- calorimetric energy measurement:
  - e.g. $\Delta E_\nu = 22$ MeV at 400 MeV

- rejection of $\pi^\pm$ backgrounds:
  - work still in progress ...

- no sensitivity estimate yet, but first results look promising!

Courtesy: M. Wurm
<table>
<thead>
<tr>
<th></th>
<th>GLACIER</th>
<th>LENA</th>
<th>MEMPHYS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total mass</strong></td>
<td>100 Kton</td>
<td>50 kton</td>
<td>500 Kton</td>
</tr>
<tr>
<td><strong>p -&gt; eπ^0 in 10 y</strong></td>
<td>0.5 x 10^{35} y</td>
<td></td>
<td>1.2 x 10^{35} y</td>
</tr>
<tr>
<td>ε = 45%, ∼1 BG event</td>
<td></td>
<td></td>
<td>ε = 17%, ∼1 BG event</td>
</tr>
<tr>
<td><strong>p -&gt; v K in 10 y</strong></td>
<td>1.1 x 10^{35} y</td>
<td>0.4 x 10^{35} y</td>
<td>0.15 x 10^{35} y</td>
</tr>
<tr>
<td>ε = 97%, ∼1 BG event</td>
<td></td>
<td>ε = 65%, &lt;1 BG event</td>
<td>ε = 8.6%, ∼30 BG events</td>
</tr>
<tr>
<td><strong>SN cool off at 10 Kpc</strong></td>
<td>38,500 (all flavors)</td>
<td>20,000 (all flavors)</td>
<td>194,000 (mostly ν&lt;sub&gt;e&lt;/sub&gt;p→ν&lt;sub&gt;e&lt;/sub&gt;+n)</td>
</tr>
<tr>
<td>(64,000 if NH-L mixing)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sn in Andromeda</strong></td>
<td>7 - (12 if NH-L mixing)</td>
<td>4 events</td>
<td>40 events</td>
</tr>
<tr>
<td><strong>SN burst at 10 Kpc</strong></td>
<td>380 ν&lt;sub&gt;e&lt;/sub&gt; CC (flavor sensitive)</td>
<td>~ 30 events</td>
<td>~ 250 ν-e elastic scattering</td>
</tr>
<tr>
<td><strong>DSN</strong></td>
<td>50</td>
<td>20-40</td>
<td>250 (2500 with Gd)</td>
</tr>
<tr>
<td><strong>Atm. neutinos</strong></td>
<td>~1,100 events/y</td>
<td>5600/y</td>
<td>56,000 events/y</td>
</tr>
<tr>
<td><strong>Solar neutrinos</strong></td>
<td>324,000 events/y</td>
<td></td>
<td>91,250,000/y</td>
</tr>
<tr>
<td><strong>Geo-neutinos</strong></td>
<td>0</td>
<td>~ 3,000 events/y</td>
<td>0</td>
</tr>
</tbody>
</table>

*T. Patzak, APC, University Paris Diderot, TAUP2011, 5 – 9 September 2011, Munich, Germany*
The EU design study “menu”

**LAGUNA**
- far detector “RI” for astroparticle and beam physics
- three detector options
- seven potential sites
- excavation costs
- industrial links

**LAGUNA-LBNO**
- international consortium including EU, Japan and Russia
- two main far sites
- new conventional beam from SPS
- high energy MW-superbeam (HP-PS)
- near detector infrastructure
- detector magnetization
- detector construction and costs

**EuroNu**
- international consortium
- low energy MW-superbeam (HP-SPL)
- beta beam
- neutrino factory
- costs
- comparison of facilities

- Update European Strategy for Particle Physics

**next step(s) ?**

**Courtesy: A. Rubbia**
Summary

- World-wide interest for next generation long-baseline based on the conventional neutrino beam technology, with longer baselines to address CP-violation and mass hierarchy, as the next step beyond T2K/NOvA.
- Next generation Neutrino Physics will come from new, megaton scale underground detectors
- Europe has a unique advantage of big choice of sites, detector technologies and beam options
- $\beta$-beam is an European invention and provides unreached sensitivity to LCPV and $\theta_{13}$, intensively studied in Euronu
- Laguna-Pyhäsalmi beam will be studied in Laguna-LBNO by CERN
- A LAGUNA-LBNO staged approach (“pilot project”) will likely be proposed. Open to all interested!

http://www.laguna-science.eu/
Thank YOU!
Acknowledgements

• FP7 Research Infrastructure “Design Studies” LAGUNA (Grant Agreement No. 212343 FP7-INFRA-2007-1)