ARA detector calibration with Telescope Array Electron Light Source

Romain Gaior for the Chiba group
ARA: Askaryan Radio Array

- Detection of UHE cosmogenic neutrino
- Expected sensitivity 10x IceCube

- Elemental detector: string of 4 antennas (2 vert/2 hori polarization)
- 1 station = 4 strings
- 3 stations installed (37 planned)

- Coherent emission from charge excess in neutrino induced shower (Askaryan effect)
- Radio attenuation length in ice ~ 1km (at optical wavelength ~ 100 m)
- Bipolar pulse of few ns
**ARA @ Utah**

**Concept:** Shoot electrons in ice to produce a shower and observe the Askaryan like signal

**Source:**
- Telescope Array LINAC
- Ice block as a target

**Detector:**
- ARA antenna + ampli
- Fast oscilloscope

**Will be conducted in January (2015)**
Concept: Shoot electrons in ice to produce a shower and observe the Askaryan like signal

**Source:**
- TA LINAC electron beam
- Ice block as a target

**Detector:**
- ARA antenna + ampli
- Fast oscilloscope

**Probe the parameterization of the radio signal** used in ARA simulation

**Check the absolute calibration** of ARA antenna
Source and Target

**Source: TA LINAC**
- source of 40 MeV electron
- maximum of $10^9$ particles/s
- bunch of few ns long divided in sub bunches (every 350 ps)
- bunch length can be changed

**Target: Ice block**
- 100cm x 30cm x 30 cm
- Installed in a plastic box 1m above the beam exit
- can be inclined to choose the exit angle of radio wave
E field simulations

- G4 simulation of target
- Shower length ~ 20 cm
- more plateau like than shower dev.

- each subbunch creates a separated E field

particle distribution in target

Complete E field simulation

-\[ E_{beam} = 40 \text{ MeV} \]
-\[ N(e-p) \]
Detector setup

Antenna tower
- Adjustable height: 7 -> 12 m
+ horizontal pole of 6m
+ antenna support for vertical and horizontal polarizations

Antennas
- two antennas at the same time
- 3-4 m from the tower
- Calibration and simulation in progress
Multiple bunches create interferences in the radio signal

Antenna response widens the signal in time

Expected signal ~ tens of mV
On site test on Nov. 2014

Purposes

1. Site check
2. Work on beam length and monitoring
3. Radio noise survey
4. «Rehearsal»
Electron Beam studies

- Bunch length reduced to 5ns *(thanks to Shibata san and KEK engineers)*
- Subbunch structure measured with FC
- Total charge measured also with WCM *(FC stops the beam)*
- Good correlation (~3% spread)
Radio noise on site

- Rather radio **quiet environment**
- No constant noise from the LINAC
- We did observe a larger noise from the **control room**
  
  *(will be shielded in January)*
Transient noise from beam

- Small signal from the beam itself (no target)
- Probably from «sudden birth»
→ small background

R. Gaior (Neutrino Frontier Dec. 2014)
Test of complete chain

- Polarized signal observed
- order of 100mV in vert.
- ... but similar without ice!

→ Transition radiation from plastic

R. Gaior (Neutrino Frontier Dec. 2014)
Test of complete chain

- Hole in plastic box
- Signal reduced by a factor 5
- Still higher than without target
- Horizontal polar. not expected
→ might have observe Askaryan like signal!

R. Gaior (Neutrino Frontier Dec. 2014)
- Vertical polarization dominant
- Radio signal dependence $\sim$ quadratic
- Contribution from TR from air-plastic
  
  (will be reduced in real condition with a hole in ice box)
- Possible contribution from air-ice transition

$\rightarrow$ Analysis ongoing to disentangle Askaryan from TR
• Experiment will be held in January
  - Everything was shipped and arrived on site
  - Mechanics work for ice box structure being done at Utah
  - Equipment tested in lab

  set up will be really better than the previous pictures !!

• 4 days of beam
  - nominal measurement ~ 1 day
  - additional tests for background characterization
• ARA @ Utah aims at a confirmation of radio coherent signal and detector calibration
• Full simulation from particle to electric field
• Design and implemented the experimental setup
• First tests on site conclusive, but TR might be an issue

Experiment conducted next January !!!
Thanks for your attention

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R. Gaior (Neutrino Frontier Dec. 2014)
Back up: Beam shape convolution

Charge ratio of the each bunch

![Graph of charge ratio vs. bunch number]

E field [V/m]

![Graph of electric field vs. time]

R. Gaior (Neutrino Frontier Dec. 2014)
Back up: Radio signal parameterization

\[ \tilde{A}(\theta, t) = \frac{\mu}{4\pi R} \sin \theta \hat{p} \int_{-\infty}^{\infty} dz' \cdot Q(z') \cdot F_p \left( t - \frac{nR}{c} - z' \left( \frac{1}{v} - \frac{n \cos \theta}{c} \right) \right) \]

(J. Alvarez Muniz et al, PRD 84, 103003)

\( Q(z) \): charge at depth \( z \)

\( F_p \): Form factor (determined with full simulation)
Back up: Target setup

Ice box

**Top view**

- Ice box
  - Plastic box (1 cm thick, leave top open, 110 cm L x 50 cm W x 32 cm H)
  - Ice (100 cm L x 25 cm W x 30 cm H, 75 kg)
  - Hole for the beam (Krypton shield, Thin plastic)
  - Put dry ice in spaces

**Side view**
Back up: Target setup
Back up: Target setup

Experiment setup

beam injection point

rail structure so that we can move
ice support and we can
close the cover box

slide

wood: 50 cm W x 10 cm H x 400 cm L: ~100 kg
Or similar
Bent will be 5 mm or so

K. Mase

ARA analysis call (2014/12/15)
Back up: ARA

![Image 1](http://example.com/image1.jpg)

![Image 2](http://example.com/image2.jpg)

![Graph 1](http://example.com/graph1.png)

![Graph 2](http://example.com/graph2.png)

R. Gaior (Neutrino Frontier Dec. 2014)