KLG4Sim: A Detailed Geant4 Simulation for Kamland

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On Behalf of the KLG4Sim-Working Group:
Alabama, Berkeley, CalTech, Kansas, Stanford
(Additional authors added depending on who shows up for our meeting)

Klg4sim pictures courtesy of Glenn-Horton Smith
Monte Carlo is Beneficial

A priority for the next reactor analysis is to reduce systematic uncertainty.

A detailed, well-tuned and reliable Monte Carlo can be very useful for:

- Reducing systematic uncertainty in vertex and energy reconstruction, especially in conjunction with the 4pi calibration system.
- Mapping out a calibration plan for the 4pi deployment.
- Understanding backgrounds (potentially very useful for solar phase).
- Demonstrating excellent understanding of the detector and dataset (nice for a PRD?).
- Increasing general body of knowledge on simulation of large-scale scintillating volumes (potentially very useful for future experiments like Theta13).
KLG4Sim Overview

User Supplied Algorithms
- Particle Generators
- Customized physics processes
- Electronics readout
- Output file formats

Detector Descriptions
- Material Properties
- Geometry

KLG4Sim
Simulated Response of KamLAND Detector

User Supplied Commands Via Macros or Interactive Sessions

Geant4
- Object oriented framework and kernel
- Particle interactions with material
- Particle transport
- User interface

Written by Glenn Horton-Smith, with contributions from numerous other groups (Tohoku, CalTech, Stanford, LBNL, UTK, UH, TUNL, LSU, UA, Drexel... to name a few).

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KLG4sim user interface is very simple and highly adaptable for scripting

A very simple macro

```
/run/initialize} Setup geometry and materials
/process/activate Cerenkov } Choose physics processes
/klsclnt/on
/generator/rates 3 1
/generator/gun gamma x y z px py pz K.E. kx ky kz
/event/output_file my_gammas.root } Output
/run/beamOn 100 } simulate 100 events
```

A very extensive graphical package is also controlled through this interface
Existing Features: Geometry

View from lower chimney

KLG4sim (raytrace)

Pictures by Glenn Horton-Smith
http://general.krl.caltech.edu/KamLAND/montecarlo/KLG4sim/picture/gallery

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**Existing Features: Generators**

**Customized Particle Generators:**
- Specify initial momentum, polarizations, energy, and types of particle to run through detector simulation.

- Standalone fortran generators for Co60, Ge68, Rn, Th, U, Zn (by Andreas Piepke)

- Fishline and weight geometries for z axis deployment also implemented

Generators still need testing?
4pi geometries not in place yet.
Customized Physics Processes

To name just a few KamLAND specific algorithms that are part of KLG4sim:

KLScint – An extensively modified version of G4Scintillation, to better handle optical photon production and transport through LS.

KLOpAttenuation – Modification of G4OpAbsorption to include elastic scattering.

PMTOpticalModel – “fast parameterization” of PMT interactions (partial reflection, transmission, absorption, and hit generation).

Parameterization of Entire Detector Response: “Fast KLG4sim”, outputs PMT hits vs energy (no hit timing info?). Useful if one’s study does not rely on the details of optical photon transport.
More Existing Features…

*KLG4Sim source code available in CVS repository*

KLG4Sim w/ updated version of Geant4 (v6.1) on pdsf – no need to install on your own computer! Ask me or see lbl webpage for instructions to run.

Documentation (not absolutely complete, but we’re working on it!)

- [http://general.krl.caltech.edu/KamLAND/montecarlo/KLG4sim/](http://general.krl.caltech.edu/KamLAND/montecarlo/KLG4sim/)

Example Macros in /mySourceCode/KLG4sim/mac/

**Flexible File Output Formats:**
Various options: AKat, AKat (w/ basic electronics sim), root, hbook, sf, and ascii.
Unfinished Task: Tuning

LS materials descriptions mostly based on bench measurements (Iwamota, Tajima, Kawashima, Inoue).

However…
- Bench measurements are not necessarily reliable enough for a detailed detector simulation.
- Crude tuning attempts performed in the past, but poor records exist

Tuning is required, but no simple roadmap exists yet. It may prove to be very challenging, depending on the required level of data/MC agreement.

Starting over from scratch, (with new people too): Chris, Dipanjan, and Lauren

Currently working on data/KLG4sim comparisons, parameter varying studies, thinking about techniques for systematic tuning strategy.
Data/MC Timing Studies

Run 2248: J. Laser at z = -5.0 m

- Bottom PMT First Hit Times
  - FWHM = 35 ns

- Top PMT First Hit Times

Photon bomb at z = -5.0 m

- Bottom PMT First Hit Times
  - FWHM << 1 ns

- KLG4sim

<table>
<thead>
<tr>
<th>$V_{\text{group}}$ (mm/ns)</th>
<th>Data</th>
<th>KLG4sim</th>
<th>Theor.</th>
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http://general.krl.caltech.edu/~jillings/kamland/

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Data/MC Detected Light Yields

http://kamland.lbl.gov/internal/lhhsu/MonteCarlo/archive/Sept_04/Sept_04_24/

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More Issues to be Addressed

To name just a few…

- Simulation of $4\pi$ must be added (more about this on next slide).
- Electronics readout simulation underdeveloped.
- Mass produced MC output (once KLG4sim is well tuned).
- Documentation
- Buggy and idiosyncratic user interface. Still a number of wrinkles, the more users, the better!


It's not hopeless! In the past, KLG4sim has been useful for vertex fitter and DTF(2) development

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A Roadmap: $4\pi$ and Beyond

The $4\pi$ calibration group has expressed interest in MC studies!

- Shadowing effect of z axis and 4pi deployment systems
- Number of source positions in $R$, $\theta$, and needed

In response, KLG4sim issues for the next few months:

- Coding: $4\pi$ geometry and verification of existing source geometries.
- Tuning studies: Verify that KLG4sim reproduces basic detector responses, comparisons between data and MC both before and after running through vertex reconstruction.
- Shadowing studies: Comparison with real data, design of a shadowing test object.

Additionally

*It would also be nice to aim for mass production of quality, reliable mc for use by the general collaboration on a ~6 month timescale.*

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To make MC that will be useful for the next reactor analysis requires realization on a short timescale.

Enough projects to keep the few people working on this very, very busy!

Serious, focused effort by a number of people is needed – wide participation encouraged!

Mention group composition, plan for regular meetings, developer's rules, ?? The point, is that a focus group of dedicated Monte Carlo afficionados is the the process of coming into existence.

this second half of this slide will largely depend on outcome of meeting, I think
Summary

• Detailed KamLAND geometries, material descriptions and customized features in place.

• Tuning and Data/MC comparison studies are a priority! They are underway, but a great deal of work remains to be done.

• Immediate Goal: Focus on prep. KLG4sim for $4\pi$ studies, help to determine deployment schedule (shadowing, and source placement).

• A KLG4sim-working group, with focused goals and a cohesive effort is being assembled.
Concluding Remarks

The bottom line: A dedicated MC group is forming and KamLAND MC will hopefully become a reality. MC is a fancy tool who’s usefulness is determined by how much work is put into it and how it is used.

Please attend the next MC meeting if you are interested in this work.

Special thanks to:
Glenn Horton-Smith, Chris Jillings, Karsten Heeger, and Patrick Decowski.

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Existing Features: Geometry

KamLAND self-illuminated by $\alpha$ particles

*Pictures by Glenn Horton-Smith*

http://general.krl.caltech.edu/KamLAND/montecarlo/KLG4sim/

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