Simulation update

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CYGNO general meeting 04/06/20
Reconstruction of simulated images

Energy containment and resolution

- In the paper on nuclear recoils identification with neutrons we describe the basic- and super-cluster reconstruction
- It would be useful to show the energy containment on simulation: mean of \( E/E_{\text{true}} \) distribution
  - taken from Giulia / Fabrizio a sim of \( E=6 \) keV NRs either “pure MC” or with simulation of electronics noise + diffusion

**Considerations:**

1. w/o noise, containment better than 5%
2. With noise, it decreases to \(~80\%\). Not a problem, since 55Fe calibrates the absolute energy
   - it could be tuned on simulation
3. Resolution with noise+diffusion (4%) is still much better than in data (\(~15\%\) on Fe)
   - indicates that some more realistic model is needed in sim. 2.1 can be done once we have a better modeling

Measured energy resolution on 55Fe data
Reconstruction of simulated images

**Inputs to improve**

1. Noise modeling. Currently a simple Gaussian is used, with $\sigma = 2$ photons
   - the value is OK, but data has a distribution with non-Gaussian tails with much larger tail. This should be easy to address: just sample the measured distribution in data to assign the pixel noise

2. Diffusion modeling. The measured diffusion seems larger than the one predicted.
   - also here, one should try to use the measured one, instead of the simple $\sqrt{\langle z \rangle}$ model?

3. Other?
   - Fe data is a good dataset to validate this, since the clustering is trivial

→ At this stage we don’t include any error on the multiplication process: implement gain distribution

\[
\sigma_T = \sqrt{\left(\sigma_{T0}^2 + D_T^2 \cdot z\right)}
\]
\[
\sigma_{T0} = 300\,\mu m
\]

at the moment we are using **500 \,\mu m** for every track (corresponds to $\sim10$ cm drift in LEMON)

Slides by E. Di Marco
PMT simulation

The idea is to tune the PMT modelized response using $^{55}\text{Fe}$ data

- Short signals with peak amplitude greater than -120 mV selected;
- Their peaks were centralized;
- Mean signal obtained;

- Calibration factor for the number of created electrons: $1\text{e}^-/40\text{eV}$;
- Signal amplitude calibration factor: $0.66 \text{ mV/e}^-$;
- $^{55}\text{Fe}$ event energy: $5.9 \text{ keV}$;
- Number of electrons created in $^{55}\text{Fe}$ events: around $148 \text{ e}^-$. 

Slides by M. Migliorini
LIME background simulations

LIME Simulation Results - Gamma Background

Shielding - 50 cm water plus 5 cm, 10 cm, 15 cm and 20 cm Cu

<table>
<thead>
<tr>
<th>Shielding</th>
<th>Gamma Flux [n/cm²/s]</th>
<th>Evts/yr [0-20 keV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 cm Cu</td>
<td>6.9e-4</td>
<td>464000</td>
</tr>
<tr>
<td>10 cm Cu</td>
<td>-</td>
<td>54100</td>
</tr>
<tr>
<td>15 cm Cu</td>
<td>-</td>
<td>6771</td>
</tr>
<tr>
<td>20 cm Cu</td>
<td>-</td>
<td>970</td>
</tr>
</tbody>
</table>

50 cm water + 20 cm copper
or
100 cm water + 10 cm copper → O(10³) cpy

Goal <10⁴ cpy (ER) for E< 20 keV

For each additional 5 cm Cu the gamma background decreases about a factor of 8.

For each additional 25 cm water the gamma background decreases about a factor of 4.

Note: The gamma flux is not provided in this study because of the computer time that would be required. It will be important to further increase the statistics.
LIME background simulations

FrenchEigenvalueSpectrum

LIME Simulation Results - Neutron Background

Shielding - 50 cm water plus 5 cm Cu

- Number of events in [0-20] keV: 0.035963 ± 0.00784786 cpd/kg/keV
  Resulting in about 18.0445 ± 3.93764 events/year

- Number of NR in [0-20] keV: 0.0±0.0 cpd/kg/keV
  Resulting in about 0.0±0.0 NR/year

A.F.V. Cortez, CYGNO Simulation Meeting, 28th May, 2020

Goal <1 cpy (NR) for E< 20 keV

50 cm water + 5 cm copper
→ sufficient to have 0 NR evts/yr
(Equivalent time of simulation ~1 year)

Secondary gammas are negligible

Flux (n/cm²/s) | Neutron | Secondary Gamma
--- | --- | ---
@LNGS | 2.76e-6 | -
After 50 cm Water | 1.45e-9 | 1.66e-7
After 5 cm Cu | 9.64e-10 | 2.09e-7

Slides by A. Cortez
Summary and next steps

- **Reconstruction efficiency studies on MC (Fabrizio, Giulia, Emanuele)**
  - improve inputs to the digitization and re-digitize some MC samples
  - compare with data and see if with MC we reproduce resolution measured on data
  - once this is fixed → systematic efficiency and bkg rejection study on MC

- **PMT (Rafael, Mariana)**
  - tuning simulation on LEMON $^{55}$Fe data

- **LIME background simulations (Andrè, Giulia)**
  - external background: 1 m water + 10 cm copper gives 0 NR/year and $O(10^3)$ ER/year
    - compatible with space available in currently assigned site for LIME @LNGS
  - camera background: work in progress, we expect to be the dominant background

- **Sensitivity study (Giorgio, Elisabetta)**
  - Sensitivity curves with different background and energy threshold
  - Very important input to discussion on optimization of shielding, gas mixture, etc.

- **Solar neutrino with CYGNO (Elisabetta)**
  - look promising, some preliminary studies ongoing → could be a publication per se
Backup
Neutrinos with CYGNO

Goal: reproduce plot & verify expected number of events

HELLOZ: He @ 5 bar, 10 m drift, 1 mm x,y,z strips

Electron energy threshold: 100 keV

HELLAZ: A high rate solar neutrino detector with neutrino energy determination

59.6 keV electron in CYGNO 10 L prototype

2.0 cm

CYGNO PHASE-2 can detect order 50 events/year

with He:CF4 60:40 and 20 keV threshold

also confirmed with a complete calculation by Samuele Torelli (PhD student @GSSI)

<table>
<thead>
<tr>
<th></th>
<th>Diffusion</th>
<th>Target density</th>
<th>Electron energy threshold</th>
<th>Expected yield from pp</th>
</tr>
</thead>
<tbody>
<tr>
<td>HELLAZ</td>
<td>0.2 sqrt(cm)</td>
<td>3 kg/m³</td>
<td>100</td>
<td>0.5-1 m⁻³ y⁻¹</td>
</tr>
<tr>
<td>CYGNO</td>
<td>0.01 sqrt(cm)</td>
<td>1-1.5 kg/m³</td>
<td>10-20</td>
<td>1-2 m⁻³ y⁻¹</td>
</tr>
</tbody>
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back of the envelope evaluation

Slides by E. Baracchini
Neutrinos with CYGNO

Goal → reproduce this plot for our experiment

Goal → reproduce this plot for our experiment

Inputs → energy and angular resolution

Hellaz problem:
several version of this plot, even using the same parameters
→ need to understand which one is the right to compare with...

Preliminary study promising → could be a publication per se

Energy resolution of proportional ionisation counter

Angular resolution

Try to measure on MC

Giulia provided me MC sample (both MC truth & digitised hits)

Parameterise from pixel size, diffusion and multiple scattering

Slides by E. Baracchini