3D Position Reconstruction in XeTPC

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XENON: Dual phase noble gas/liquid detector providing 3D position sensitivity

- **Background rejection**
- **Signal correction**

\[
\chi^2(x, y) = \sum_{i=1}^{N} \frac{(S_i - s_i(x, y))^2}{\sigma_i^2}
\]

- \(N\) = number of PMTs (top array only)
- \(S_i\) = nb. of photoelectrons (\(S_2\) experimental value)
- \(s_i(x,y)\) = Expected \(S_2\) for all possible \(x\) and \(y\) (from simulation)
- \(\sigma_i\) = Fluctuation of PMT signals (# of pe, gain, analysis error)
  + Uncertainties from simulation (geometry, statistical)
Goals of a new position reconstruction algorithm:

- good performances near the edge of the detector
- maintain good performances in presence of dead channels
- short computation time

Adaptive properties

Flexible training

“Fast” (1-2 order of magnitude than $\chi^2$ method)

Neural Network technique

Function approximation

Multilayer perceptron (tgh / linear neurons) backpropagation

Input / output: PMTs signals (top array) / xy position

- training $\rightarrow$ MC simulation (~40k events uniformly distributed - $3 \cdot 10^3$ phe/event)
- test $\rightarrow$
  - MC events (~40k events)
  - $^{137}$Cs calibration run
  - Data $\leftrightarrow$ Background data
  - Activated Xe run
Reconstructed position – MC position

**MC result**

Spatial resolution x-y axis

x-y resolution < 1mm (s)

Improvement of ~50% Respect to the Previous algorithm
Reconstruction error in the x-y plane
~ 1 mm  (~ 50% improvement)

Reconstruction error in the last 10 mm
~ 1.2 mm  (improvement > 56%)

MC results
Developing the technique: *polar reconstruction of the vertex position*

Output: combination of two different NNs  
radius + angle

Spatial resolution x-y axis: \( \sim 0.58 \) mm

Mean reconstructed error
MC results

\[ r \text{- resolution} \sim 0.59\text{mm} \]

Improved technique

Previous NN approach

Radial distribution of the events

Roberto Santorelli – APS meeting 4/14/2007
Dead channels correction

partial training pattern

MC results

comparison between full training pattern – partial training pattern

Vertices still uniformly distributed

R-resolution of $\sim 1.3$ mm in the blind region
Cs source – 662 keV (data)

Reconstructed position of the source

χ² method

NN method

Source position clearly reconstructed
NN → efficient correction of the dead channel effect
Radial distribution of the vertices

- Comparison data (NN/χ²) – MC (GEANT4)

- Cs source (data)

- NN -> Better performances near the edge of the detector
Activated Xenon (Data)

Gamma ray peaks 164 keV – 236 keV (from $^{129}\!\text{m}Xe$ and $^{131}\!\text{m}Xe$)

xy distribution of the events – 8x8 mm$^2$ map

\begin{align*}
\chi^2 & \quad \text{NN} \\
\text{Ni/N0} & \quad \text{NN}
\end{align*}
Activated Xenon (Data)

Radial distribution of the events

Graph showing radial distribution with three data sets: NN data, chi2 data, and ideal rate.
Conclusions

• The 2D position reconstruction through a NN technique has been investigated in XENON10

• The NN algorithm showed a better position resolution and a better edge event identification than the $\chi^2$ method on the MC simulated data. An x-y resolution of less than 1 mm has been evidenced.

• A good agreement between data and MC NN-distributions has been obtained (Cs - AcXe)

• The NN algorithm is weakly influenced by dead channels (MC - data)