Optimizing the Bulk Analysis and C/O Log Patent Ideas

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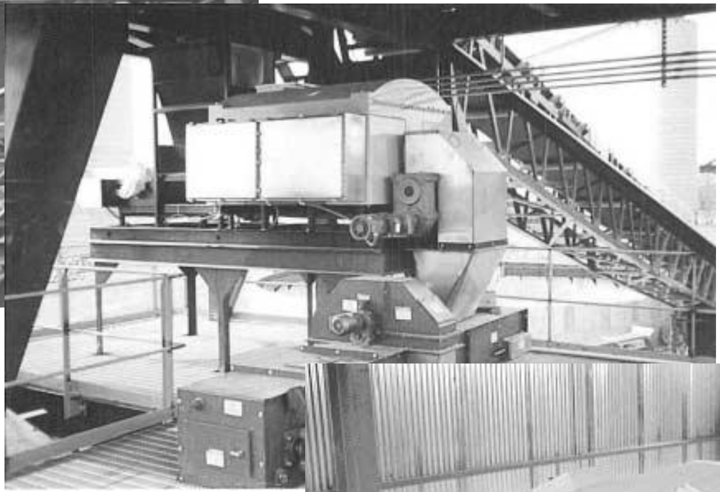
On-line Bulk Analyzers

On-line bulk analyzers began to be developed in the late 1970's and early 1980's in the United States, Australia, and Europe. Most analyzers were one of three types:

- On-line moisture meters employing microwave technology (Free H2O)
- On-line ash gauges using gamma ray attenuation technology
- Elemental analyzers used for ash, and sulfur, and sometimes ash constituent information as well. These analyzers relied on prompt gamma neutron activation analysis (PGNAA) for elemental analysis.
- When PGNAA is combined with a moisture meter, as is generally the case, moisture, calorific value and lbs. SO2 per million BTU can also be determined.

Berthold Ash and Moisture Gauge

1812C Analyzer from Thermo Gamma-Metrics



Coal Quality Manager (CQM) Analyzer from Thermo Gamma-Metrics (sample stream analyzer)

Thermo Gamma-Metrics CrossBelt Analyzer

“A MAJOR STEP FORWARD FOR ON-LINE COAL ANALYSIS”, R.C. Woodward, M.P. Evans, E.R. Empey, Thermo Electron Corporation

Why coincidence?

- Improvement: introduce gamma – gamma coincidence technique (CEAR and BNC (Budapest Neutron Center))
- Advantages of gamma – gamma coincidence technique
  - Increase the signal – to – noise ratio
  - Reduce the interference of background
  - Substantially reduce the complexity of a spectrum (Eliminate the hydrogen prompt gamma-ray peak. etc)

Previous Works in CEAR

- 1. Experiment Setup
- 2. LLS approach on Coincidence spectra
- 3. Diagonal/Q-value Summing
- 4. Monte Carlo simulation code – CEARCPG
- 5. Special Coincidence:
  - Carbon/Oxygen tool patent (CEARCO)
  - X-ray Fluorescence K and L coincidence (CEARXRF)

CEARCPG

- The first specific Monte Carlo Code that can be used for prompt gamma sampling and for prompt gamma coincidence spectra simulation.
- Coded in Fortran 95 on windows (Linux) platform.
- Can be used to analyze 42 elements, 97 isotopes and easy to update (ENDF).
- Neutron energy is from 10^{-11}MeV to 20 MeV. Gamma energy is from 1 keV to 20 MeV
- Modularized code. Easy to implement to other MC code
- General geometry package
- Detailed physics model
- Variance reduction techniques

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   45     6  -1.06      -42  33  -27  29

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   42       c/z        -14          0        8.3

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HAN X. G., (2005), Development of Monte Carlo Code for Coincidence Prompt Gamma-ray Neutron Activation analysis, *PhD thesis*, North Carolina State University

CEARCPG (cont.)

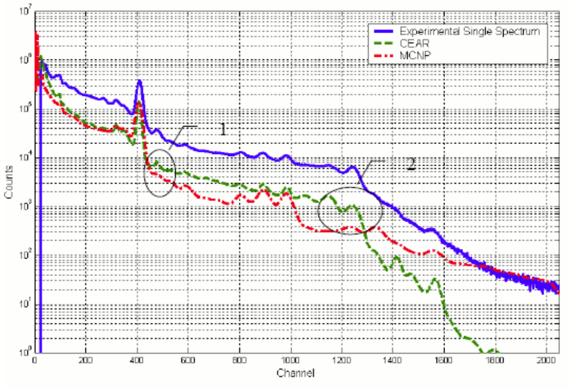
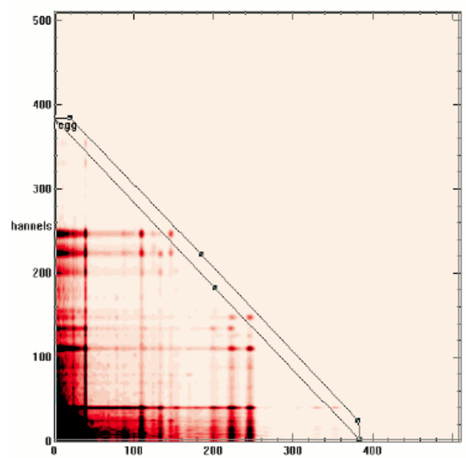
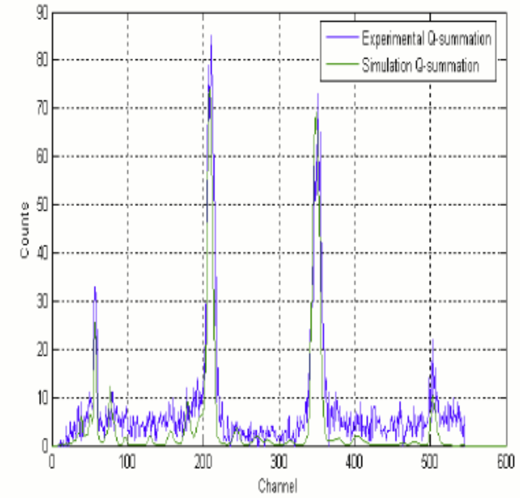
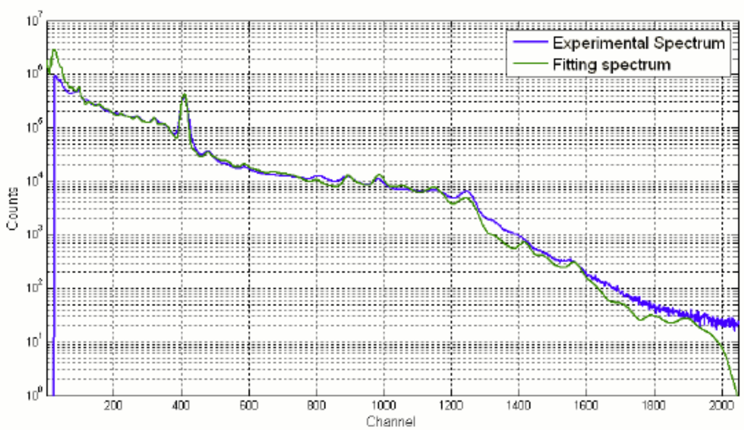
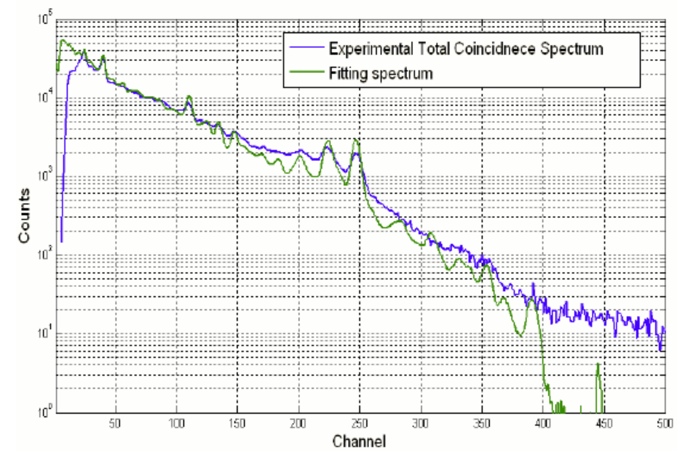


Figure 4- 22 The single spectra of pure sulfur sample. Where region 1 is the gamma rays from natural background and region 2 is the gamma rays from NaI detector activation









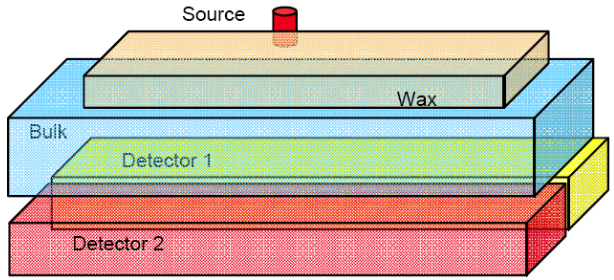
Why/What to optimize?

- Compared to the single spectrum, the magnitude of the total coincidence spectrum is 2 to 3 times lower.
- The placement of source and detectors are needed to be optimized to reach the maximum detection.

Detector choices

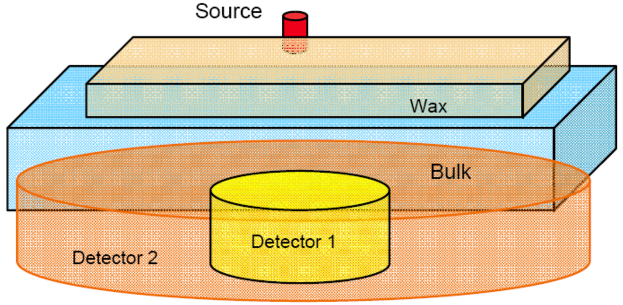
- NaI detector/BGO detector
  - 1. good energy and time resolution
  - 2. expensive for large crystals
- Liquid Scintillation detector
  - 1. cheap
  - 2. better total efficiency
  - 3. adjustable composition
  - 4. bad energy, but good time resolution

Possible Approaches



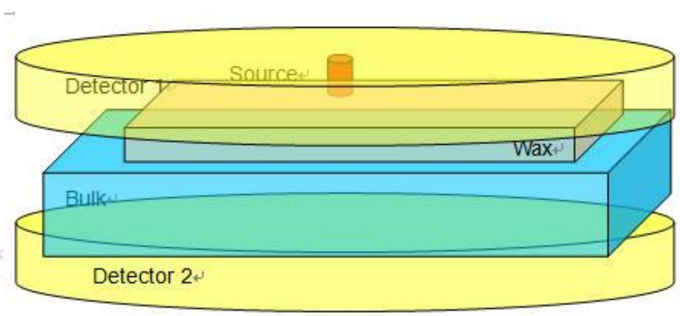
Rectangular design

1.Both NaI detectors -> Symmetric and same size (length-width-height)
2.One NaI and one liquid scintillation detector -> optimize size for both due to different detection efficiency.



Circular design (same side)

The radii of inside and outside detectors and thickness are needed to be optimized, no matter which kind of detectors combinations

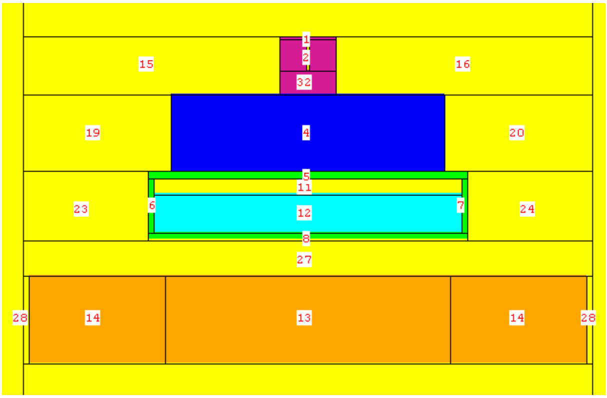


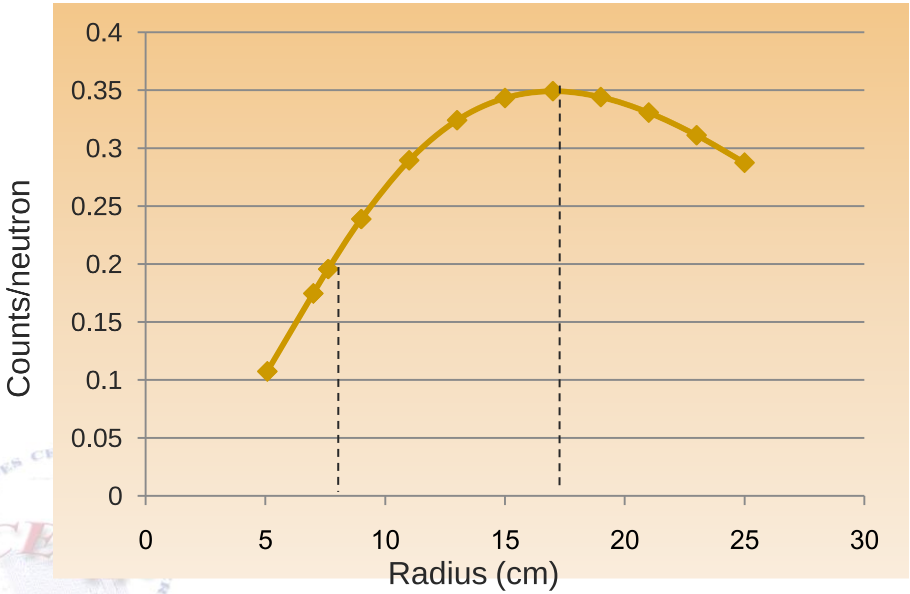
Circular design (both sides)

The radii and thickness of both detectors are needed to be optimized.
1.Both NaI detectors -> same size
2.One NaI and one liquid scintillation detector -> optimize size for both due to different detection efficiency

The best for same side approach

- Circular design (same side)
- Bare detectors
- Outside detector radius fixed at 49cm
- Changing the inside detector radius

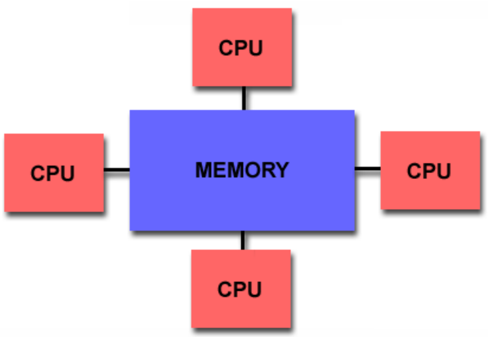


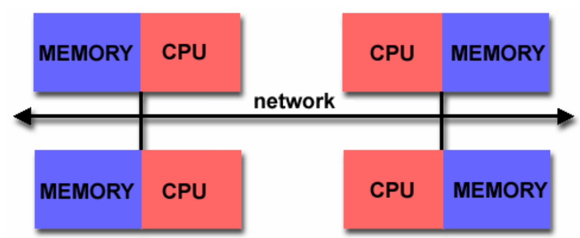


- Original two 6"by 6" detectors arrangement: 0.022478 counts/neutron
- The new design could be ~17 times better at most (inside ~12" outside ~19")
- For 6" detector inside, could be ~10 times better.

Parallel Computing

- Two Architectures: Shared Memory and Distributed Memory





- Message Passing Interface (MPI)
- Parallel Virtual Machine (PVM)

Future work

- 1. Simulate each geometry design
- 2. Coincidence Volume research
- 3. Investigate and simulate the performance of the Liquid Scintillation detector
- 4. Realistic design simulation
- 5. Parallel Computing feature (MPI) for CEARCPG
- 6. GUI for CEARCPG

C/O Log Patent Idea

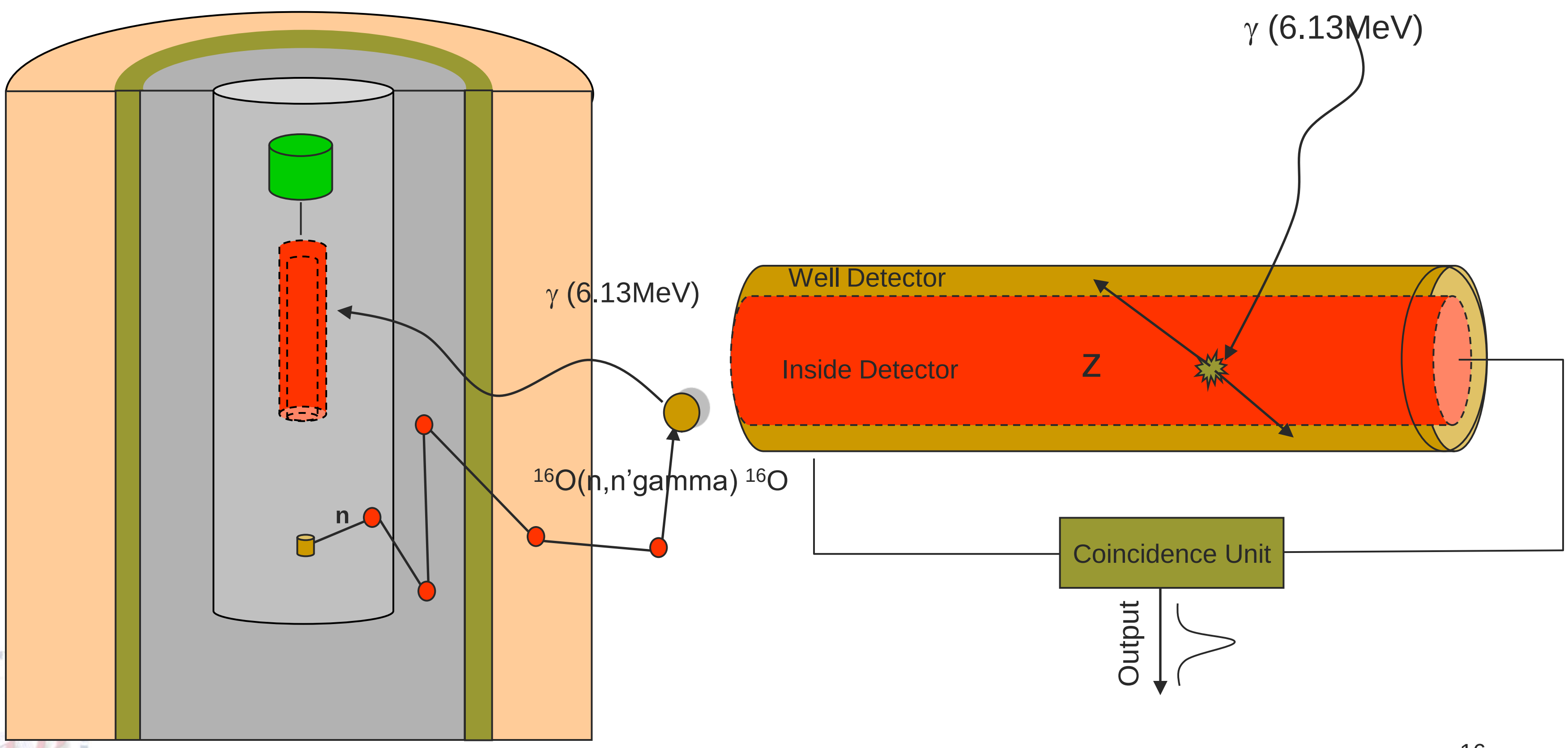
- 1. Overview
- 2. MC Simulation geometry and results
- 3. Proposed improvements

Overview

- Traditional C/O tools suffer from low efficiency, poor signal-to-noise ratio, and poor spectral resolution.

Overview

- Principle of Coincidence C/O tool



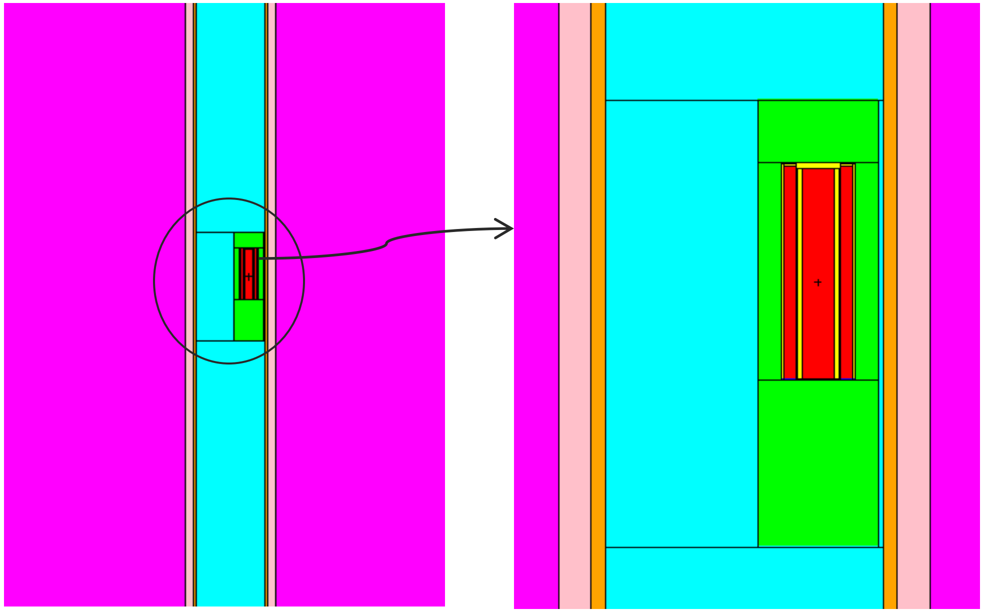
Monte Carlo Simulation Geometry

Detector arrangement

NaI

Well type detector: 4.4 X 14.4 cm, Thickness = 0.6393 cm;

Inside detector: 2.54 X 13.97 cm



Xiaogang Han, Robin P. Gardner, W.A. Metwally, and Pingjun Guo, A Conceptual C/O Tool Design with Coincidence Counting, SPWLA 47th Annual Logging Symposium, June 4-7, 2006

LLS on simulated single spectra

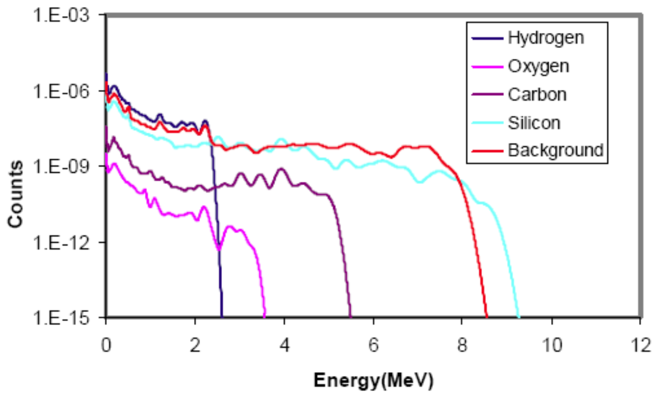


Fig. 3. *The calculated elemental library spectra from the neutron capture interaction.*

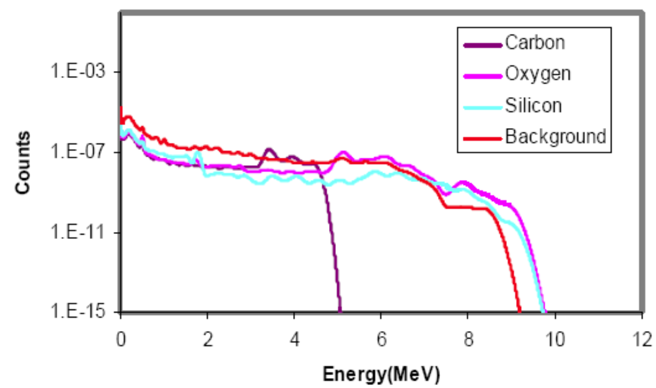
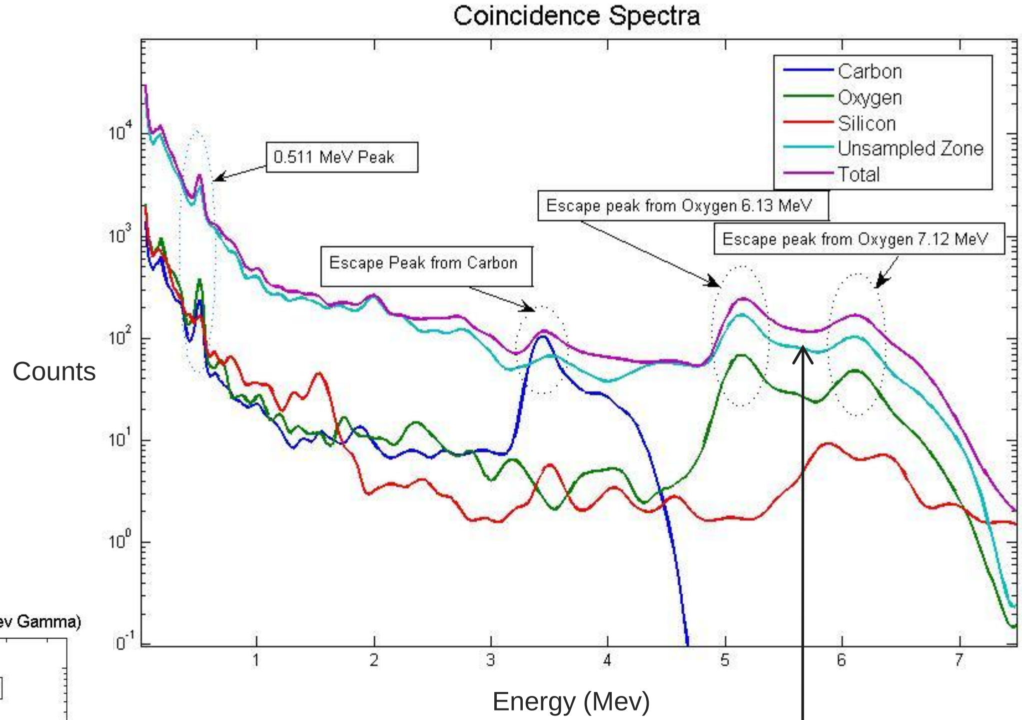


Fig. 4. The calculated elemental library spectra from the neutron inelastic scattering interaction.

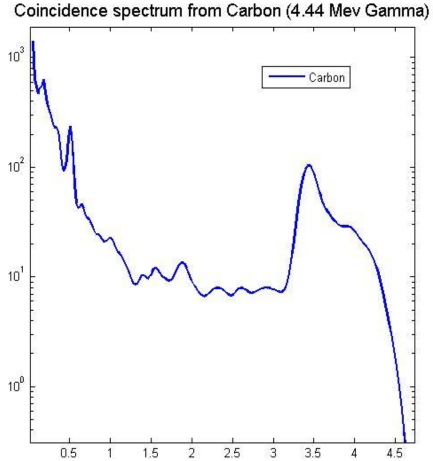
Library	Neutron capture		Error(%)	Neutron inelastic scattering		Error(%)
	True weight fraction (%)	Calculated weight fraction		True weight fraction	Calculated weight fraction	
Hydrogen	4.8	4.9	0.713	4.8		
Oxygen	38.0	-137.5	0.474	38.0	40.5	0.645
Carbon	26.4	24.6	0.726	26.4	28.2	0.321
Silicon	30.8	37.3	0.257	30.8	32.4	0.925

Robin P. Gardner, Xiaogang Han and Pingjun Guo, On Using Monte Carlo Generated Libraries for Applying the Library Least-Squares Analysis Approach to the C/O Tool, SPWLA 47th Annual Logging Symposium, June 4-7, 2006

Coincidence Spectra (projected to inside detector)

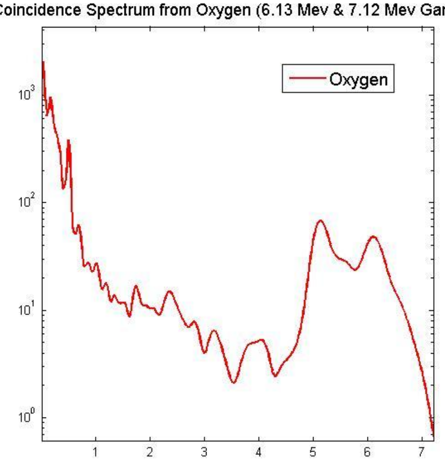


Coincidence spectrum from Carbon (4.44 Mev Gamma)



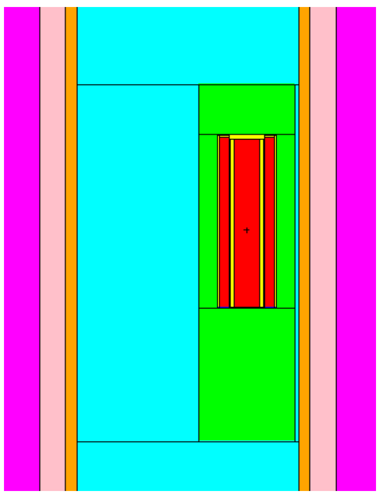
Too much coincidence responses from unsampled zones !

Coincidence Spectrum from Oxygen (6.13 Mev & 7.12 Mev Gamma)

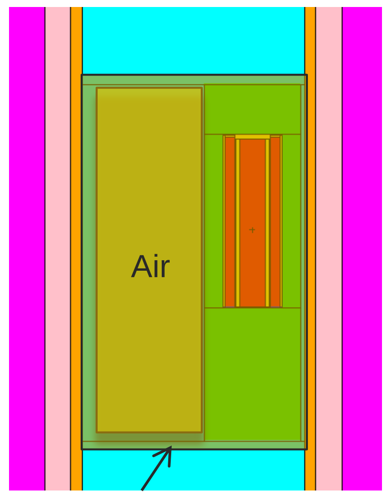


Optimize the tool design

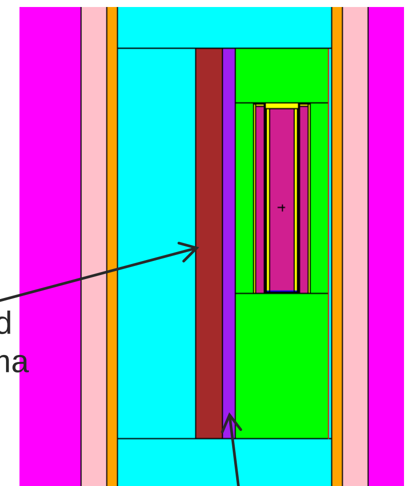
Original Design

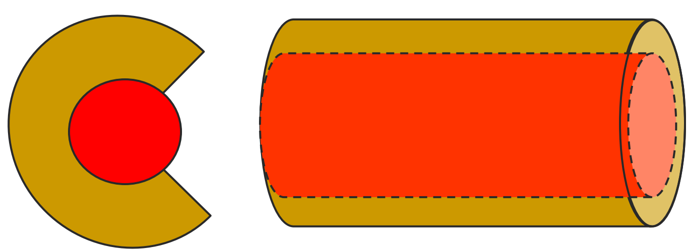


New Design 1



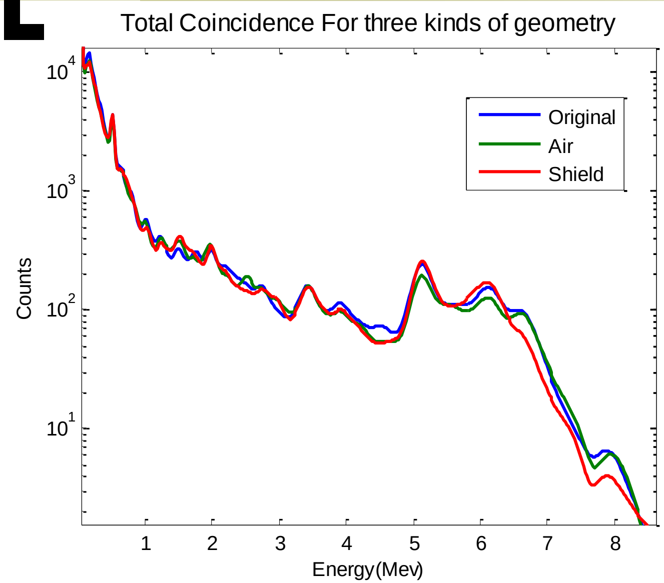
New Design 2

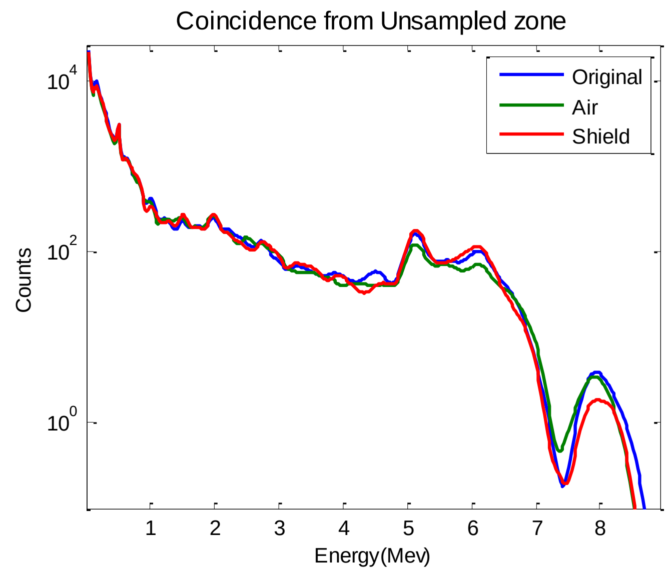


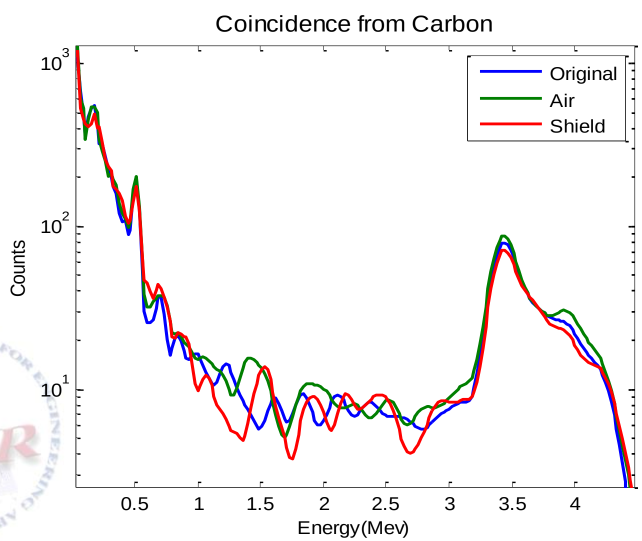


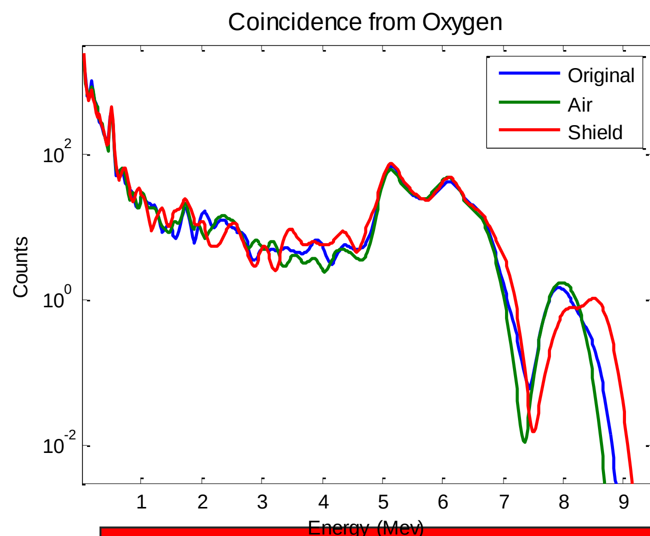
New Design 3

Results


Total Coincidence For three kinds of geometry
Original
Air
Shield
Counts
10^4
10^3
10^2
10^1
1
2
3
4
5
6
7
8
Energy(Mev)


Coincidence from Unsampled zone
Original
Air
Shield
Counts
10^4
10^2
10^0
1
2
3
4
5
6
7
8
Energy(Mev)


Coincidence from Carbon
Original
Air
Shield
Counts
10^3
10^2
10^1
0.5
1
1.5
2
2.5
3
3.5
4
Energy(Mev)


Coincidence from Oxygen
Original
Air
Shield
Counts
10^2
10^0
10^-2
1
2
3
4
5
6
7
8
9
Energy (Mev)

Possible ways to overcome that

1. Improve statistics
   → Simulation histories will be increased
   → Code will be modified for parallel computation

2. Many cases are in unsampled zone
   → The diagonal projection method

3. Phase libraries

Diagonal projection/Q-summing

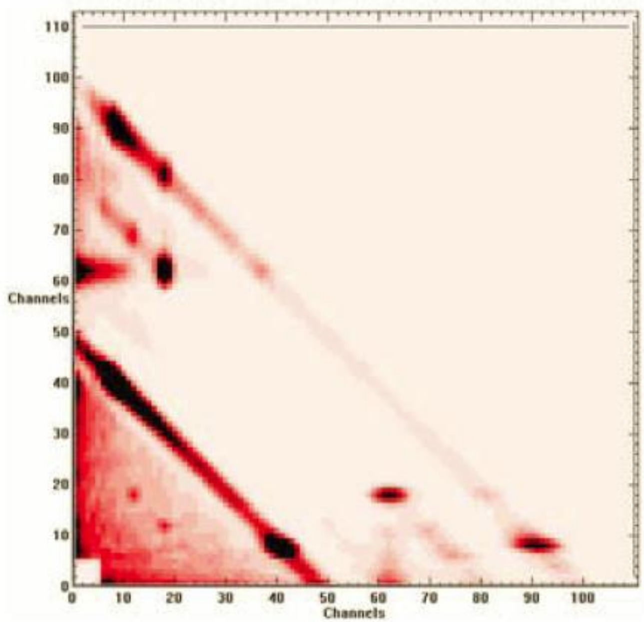
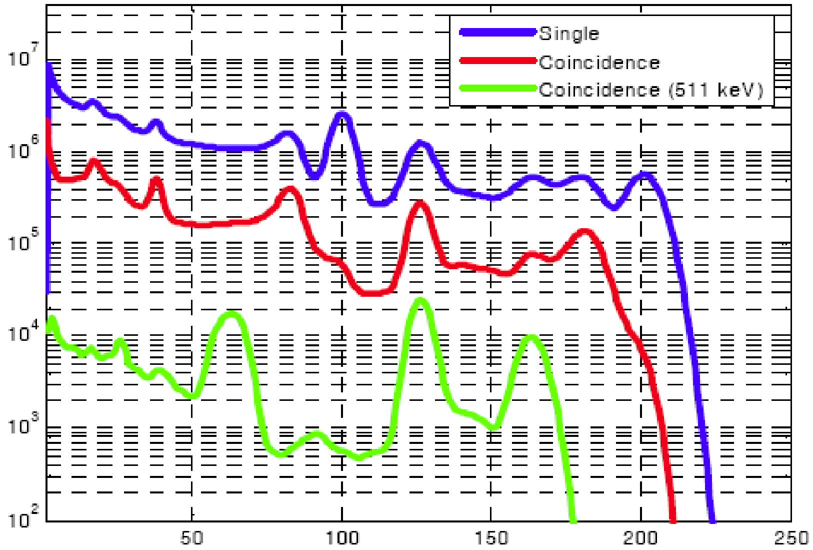


Fig. 6-a



Conclusions

- Coincidence PGNAA could be highly improved by optimizing design with CEARCPG, which gives it higher business potential.
- C/O patent is kind of new technology which could apply coincidence tech and promise various technique to get more information about the reservoir.