A TLD Dose Algorithm for Mixed Fields at a Nuclear Weapons Facility

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Problem

- Design a TLD based personnel dosimeter to monitor whole body exposures to mixed beta, photon, and neutron fields

Specific Challenges

- Changing fields
  - Requires variable correction factors
- Mobile work force
  - One algorithm for all workers, must handle all fields
- Accommodate mixtures of all three fields
- Report doses at 7, 300 and 1000 $mgcm^{-2}$

Solution

- Eight element TLD badge
  - Panasonic UD-812/809
- Dose algorithm using function based correction factors
  - Energy dependent correction factors calculated for each set of TLD readings
- Calculate photon, beta and neutron doses for each badge reading

Today's Presentation

- Badge description
- Algorithm design
  - Emphasis on neutron portion
- Test results
  - Synthetic testing
  - DOELAP results

TLD Design

	E1 (812)	E2 (812)	E3 (812)	E4 (812)	E5 (809)	E6 (809)	E7 (809)	E8 (809)
Phosphor	$^{7}Li_2{}^{11}B_4O_7$	$^{7}Li_2{}^{11}B_4O_7$	$CaSO_4$	$CaSO_4$	$^{7}Li_2{}^{11}B_4O_7$	$^{6}Li_2{}^{10}B_4O_7$	$^{6}Li_2{}^{10}B_4O_7$	$^{6}Li_2{}^{10}B_4O_7$
Filtration (front/back)	plastic	plastic	plastic	plastic+Pb	Cd/Cd	Sn/Cd	Cd/Cd	Cd/Sn
mg/cm^2	17	300	300	1000	900	800	900	900
Sensitivity	β, γ	β, γ	β, γ	γ	γ	γ, n_{th}	γ, n	γ, n_{albedo}
Primary use	beta	beta	gamma	gamma	gamma	neutron	neutron	neutron

Algorithm Design

Isolate and characterize each component (γ, β, η)

- Calculate component specific response
- Use the 8 readings to characterize each component

Calculate correction factors

Calculate doses for each component

Sum significant component doses

Algorithm Design - Photons

- Photon responses: **E2, E4, E5**
- Photon characterization: **E3/E4, E5/E4**
- Result is three sets of calculated photon doses

Algorithm Design - Betas

- Subtract photon interference
  - calculated from E4, E5 and characterization ratios

    NetE1 = (E1 - E1 $_{\gamma}$)

    NetE2 = (E2 - E2 $_{\gamma}$)
- Beta response = **NetE1**
- Beta field characterized by: **NetE1/NetE2**

Algorithm Design - Neutrons

- Subtract photon interference
  - calculated from E5

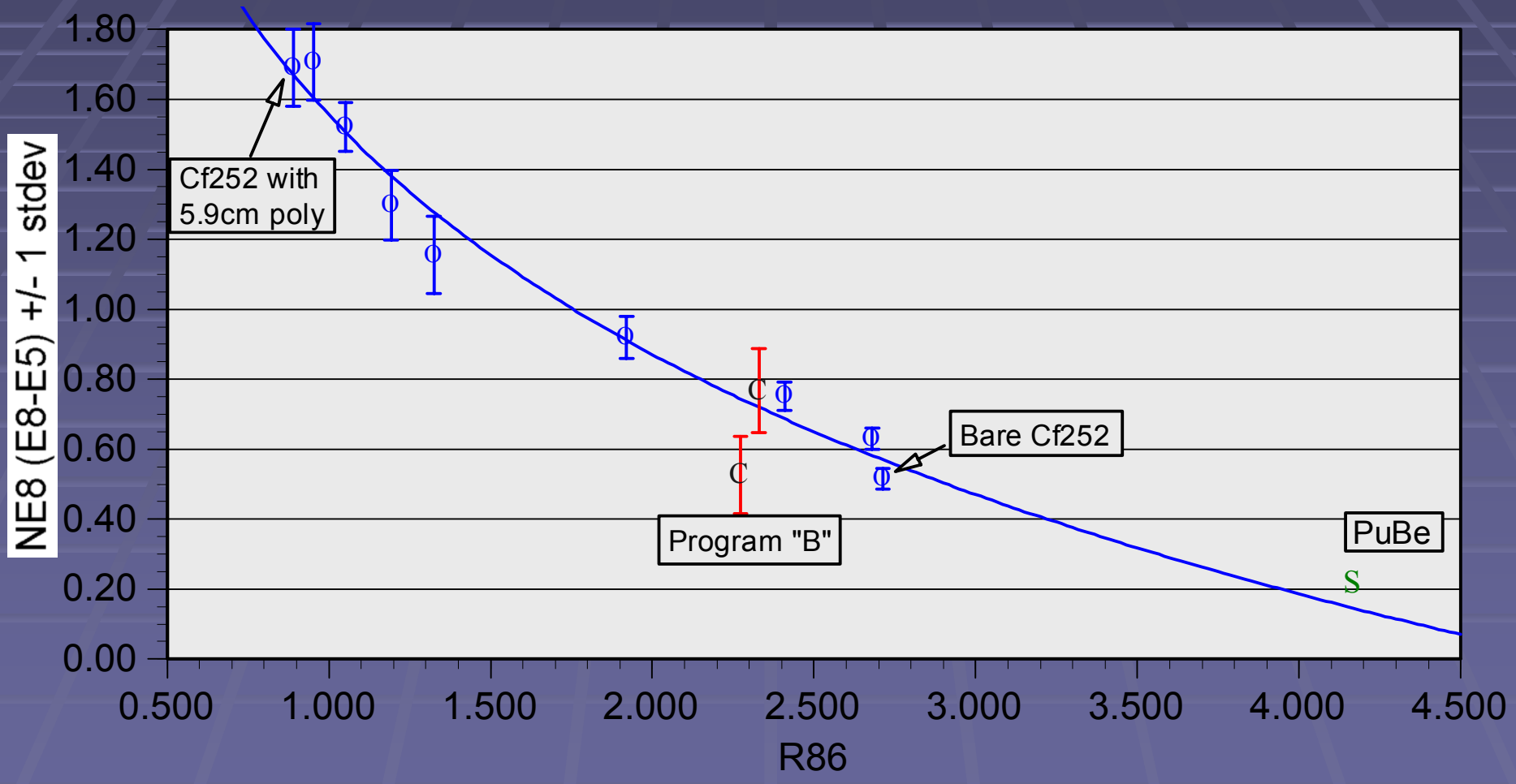
    NE8 = (E8 - E8 $_{\gamma}$)

    NE6 = (E6 - E6 $_{\gamma}$)
- Neutron response: **NE8**
- Neutron characterization: **NE8/NE6**
  - Albedo signal:incident thermal signal

Neutron Correction Factor

- Neutron correction factor is a function of the ratio of albedo:incident thermal
- Model was generated from test data using ^{252}Cf with 9 configurations of moderation from 0.6 cm to 5.9 cm of PMMA
- Experimental data fit within 10%
- Field data (worst case) within 30%

Neutron Correction Factor



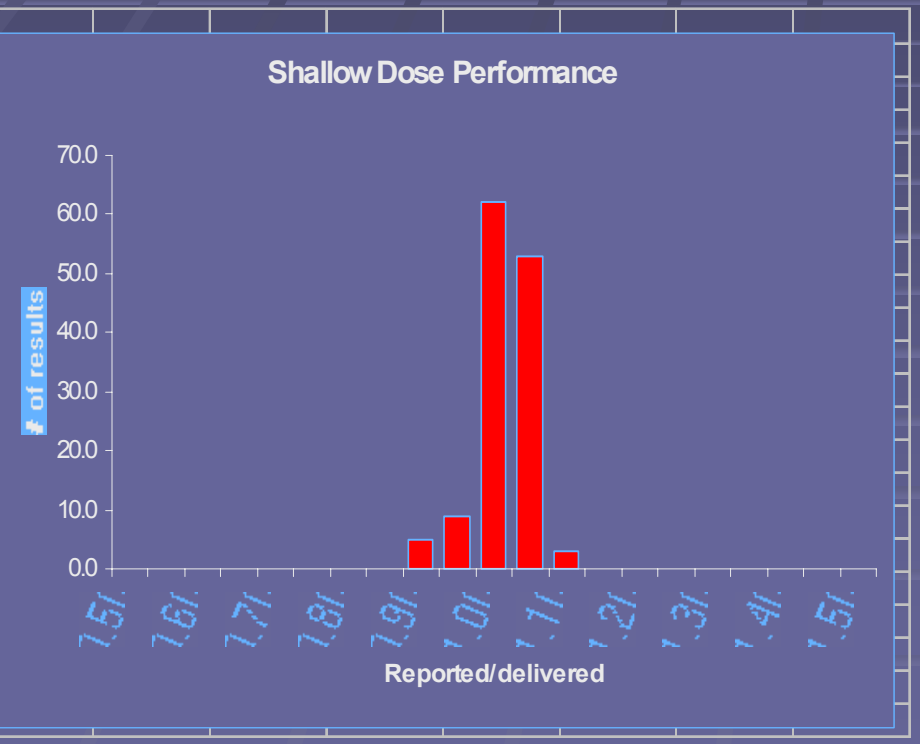
Performance

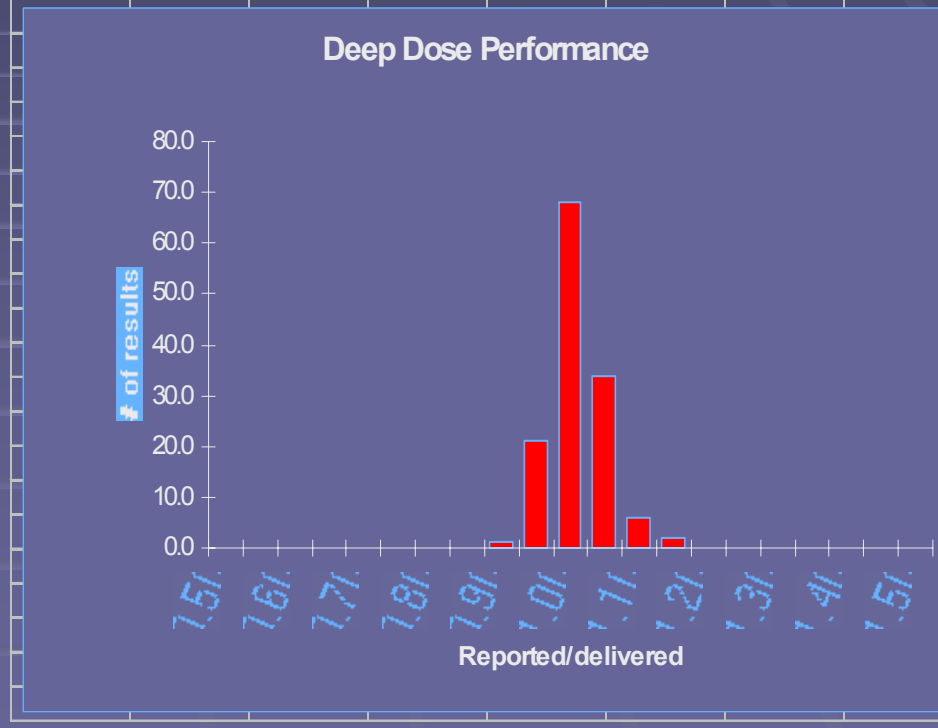
- Synthetic testing
- DOELAP testing

Synthetic Testing

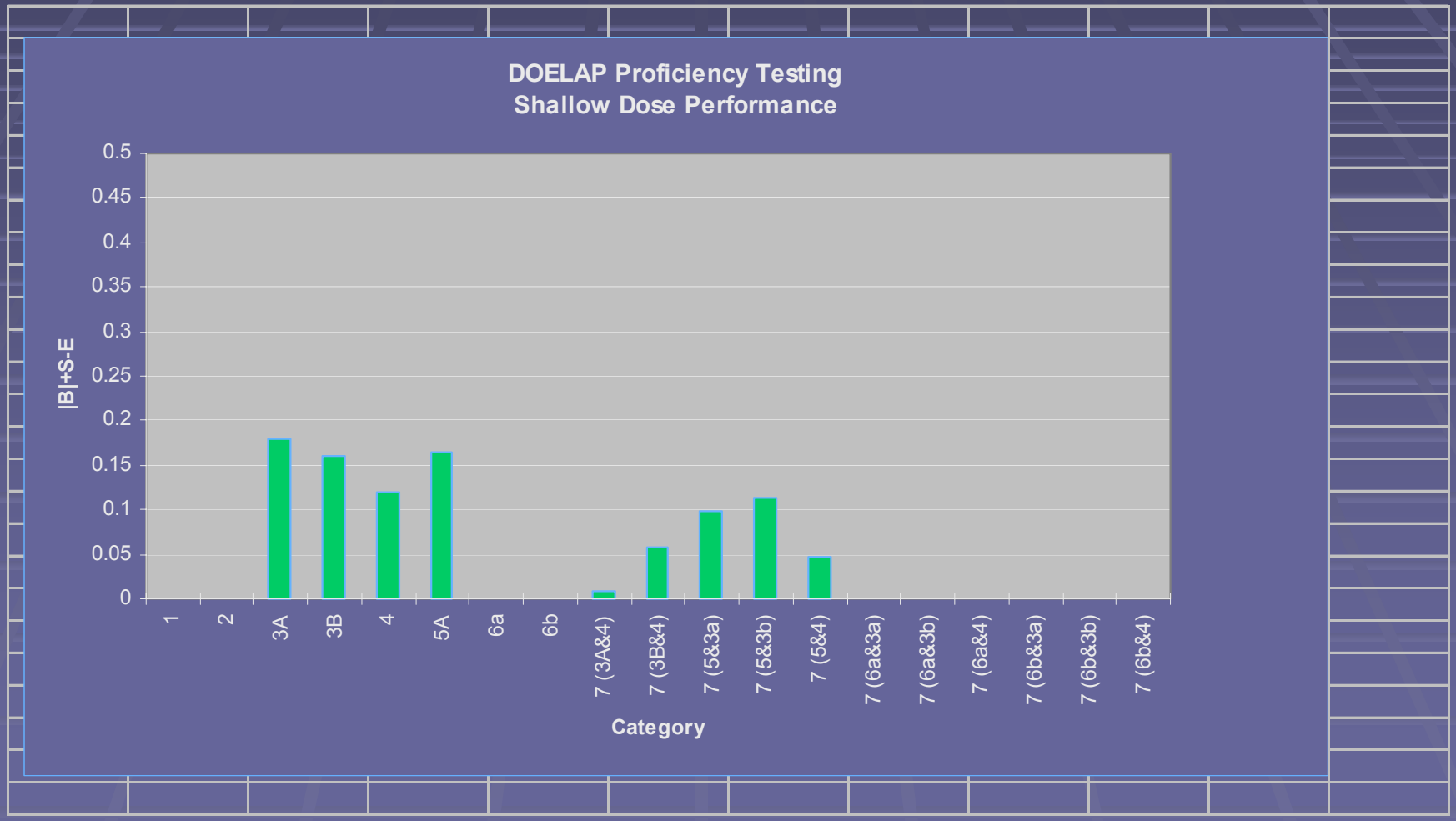
- Calculate expected responses for pure and mixed DOELAP style fields - using response data
- Process expected responses through algorithm and calculate bias
- Results reflect algorithm performance, isolated from other system variables

Synthetic Testing Results

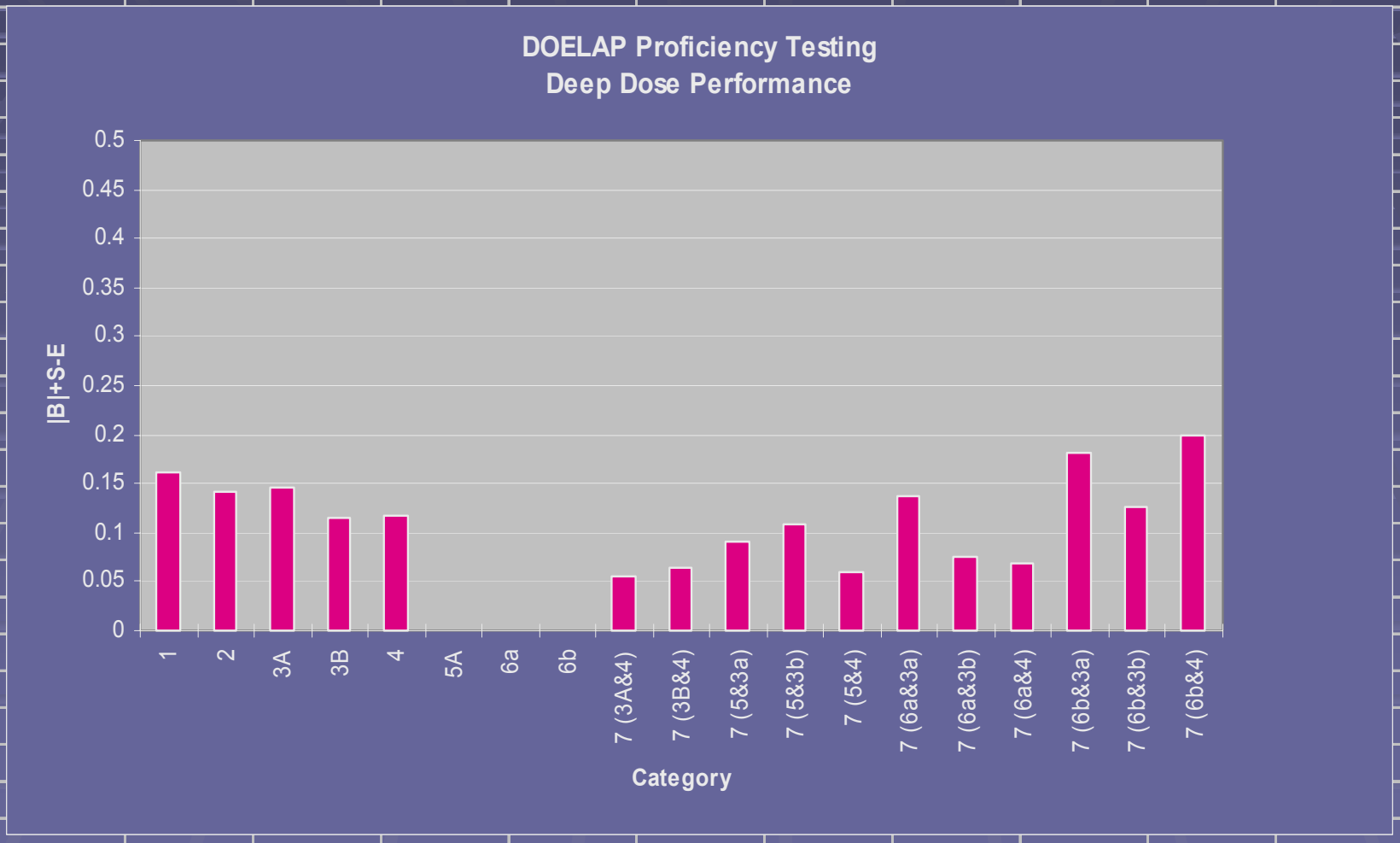




DOELAP Results - Shallow Dose



DOELAP Results - Deep Dose



Future Developments

- Incorporation of uncertainty analysis
  - calculate expanded uncertainty for all dose results
  - use uncertainty for algorithm decision points
- Additional field measurements

Summary

- Single dosimeter badge and dose algorithm for all radiation workers
- All TLD - no ancillary system required
- Excellent performance in mixed fields of photons from 16 keV; betas from 800 keV; and neutrons from ^{252}Cf unmoderated to 6 cm of PMMA