WHO Workshop on Sensitivity of Children to EMF

Istanbul, Turkey

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Childhood Leukemia, EMF and Contact Current

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EPRI

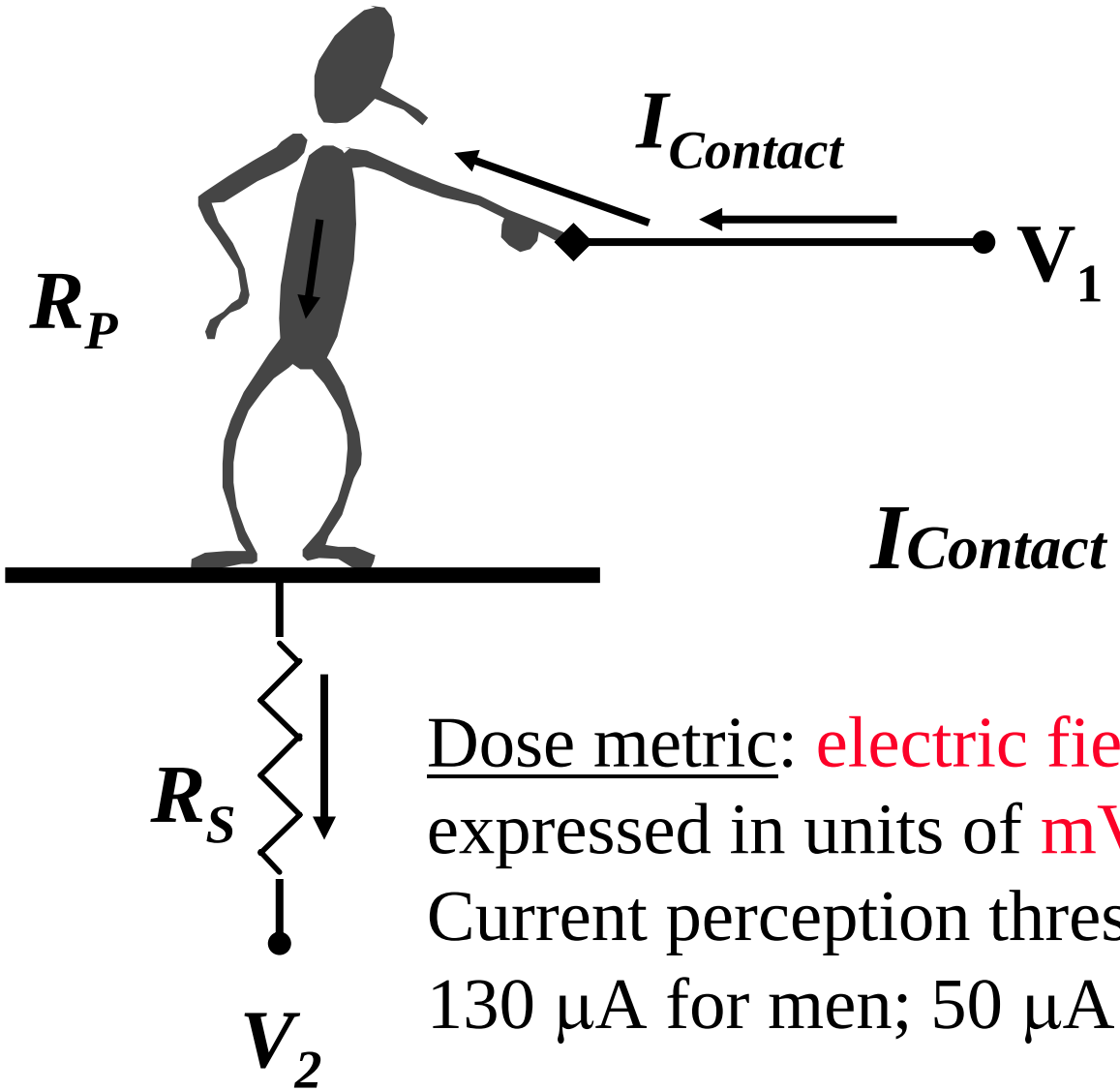
Background

- Epidemiologic association between childhood leukemia and residential magnetic fields despite
  - negative bioassays
  - biophysical plausibility issues
- Explanatory possibilities
  - control selection bias – under investigation
  - another exposure, requires
    - dose to target tissue (bone marrow)
    - association with residential field
    - frequent exposure

Limitations

- Engineering relationships based on multi-ground neutral distribution systems characteristic of the US
- Electrical systems in Europe and Asia uninvestigated thus far (research is now beginning)
- Apartments require investigation

Contact Current



$$I_{Contact} = \frac{V_1 - V_2}{R_P + R_S}$$

Dose metric: electric field in tissue expressed in units of mV/m

Current perception threshold ~ roughly 130 μA for men; 50 μA for children

Role of Bone Marrow in Leukemia

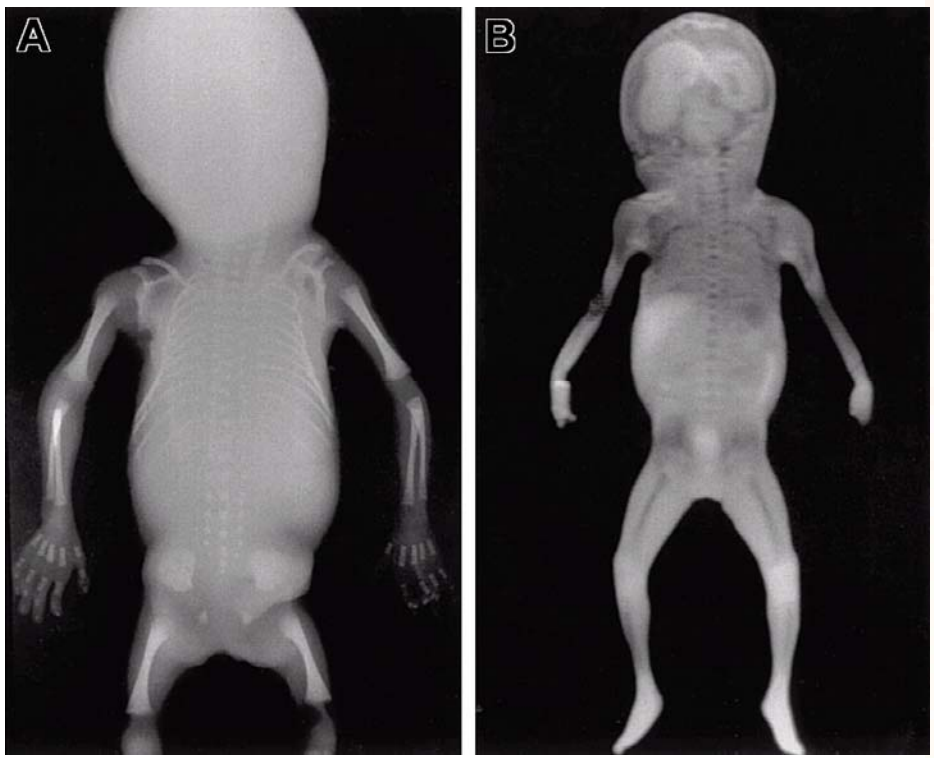
- "The universal common denominator of pediatric B-lineage ALL is a BM [bone marrow] origin of the disease." (LeBien, 2000)
- Most childhood leukemias initiated in utero (translocation, hyperdiploidy); secondary posnatal events (infection, other) trigger leukemic transformation
- "The earliest stages of clonal expansion in B-lineage ALL…may be characterized by a dependency on BM stromal cells for survival and growth…By the time a patient is diagnosed with B-lineage ALL a physical displacement of normal lymphohematopoiesis and BM architecture will have occurred." (LeBien, 2000)

Bone Marrow

Unlike children, adults lack red marrow in their long bones

21-week fetus

Radiograph MRI



Wilpshaar et al., 2000

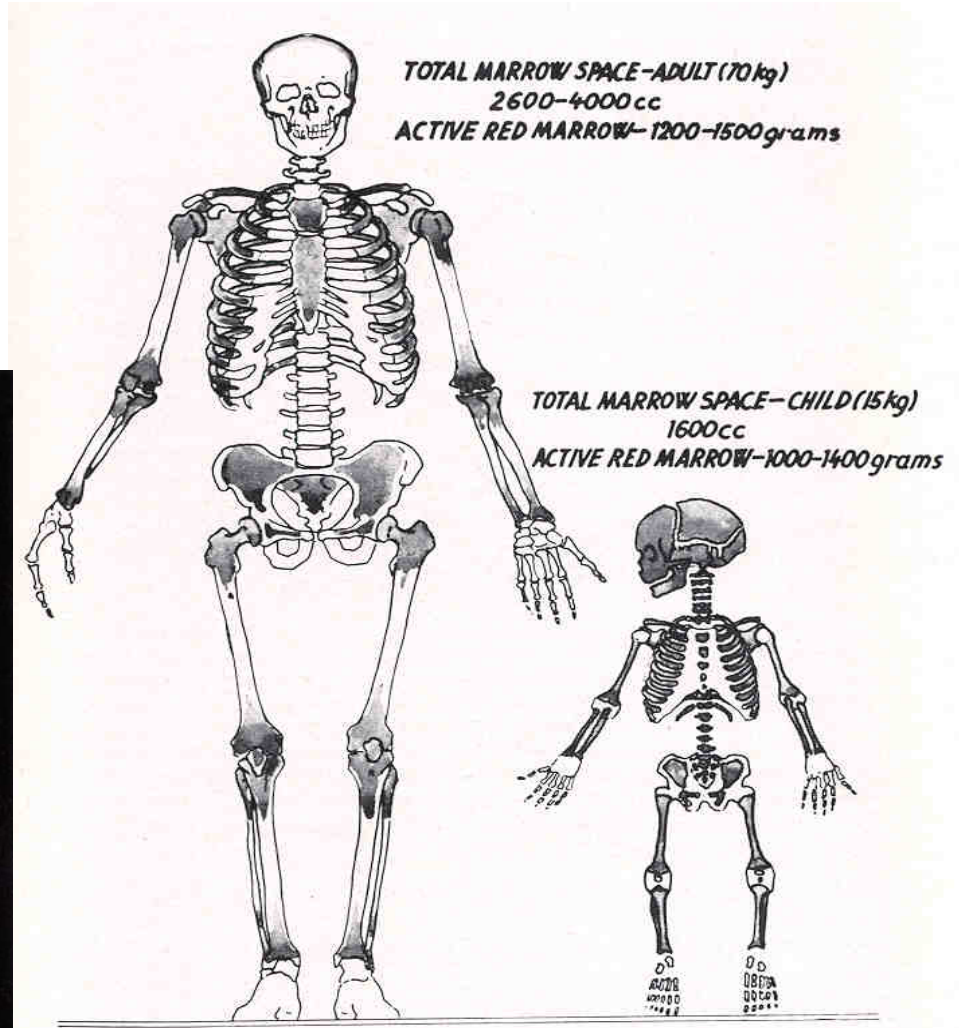


FIG. 4. Comparison of red active marrow bearing areas in the child and adult. Note the almost identical amount of active red marrow in child and adult despite fivefold discrepancy in bodyweight.

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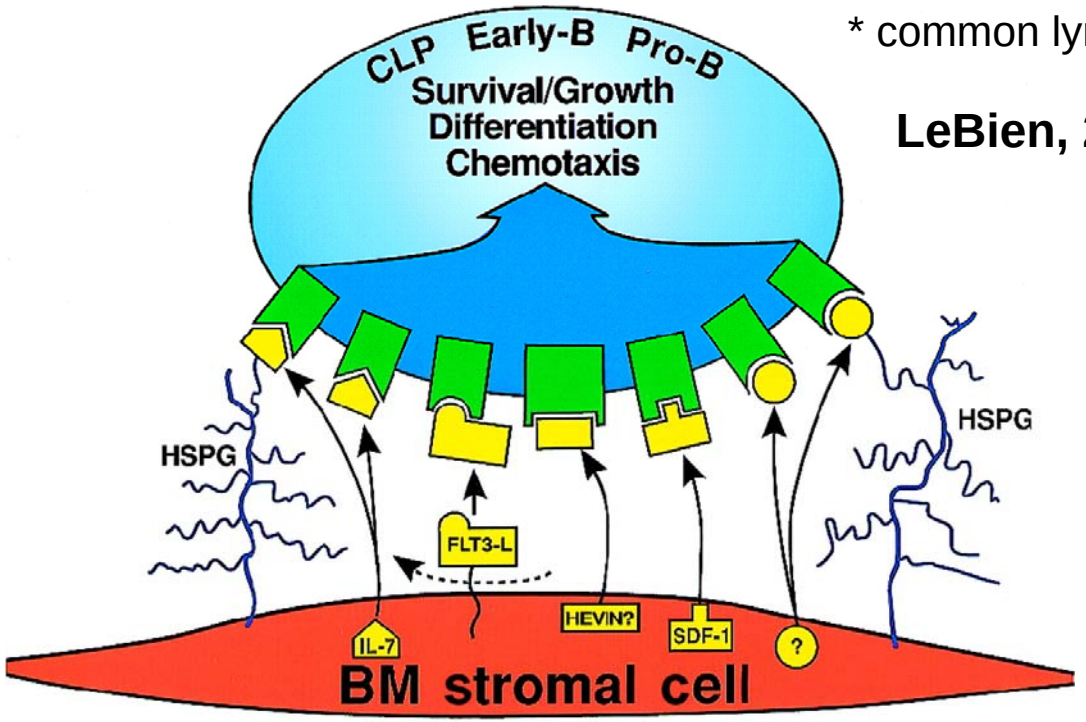
BM stromal cell–derived molecules that could transduce survival/growth, differentiation, or chemotactic signals to CLP*, early-B, or pro-B cells

* common lymphoid progenitor



LeBien, 2000

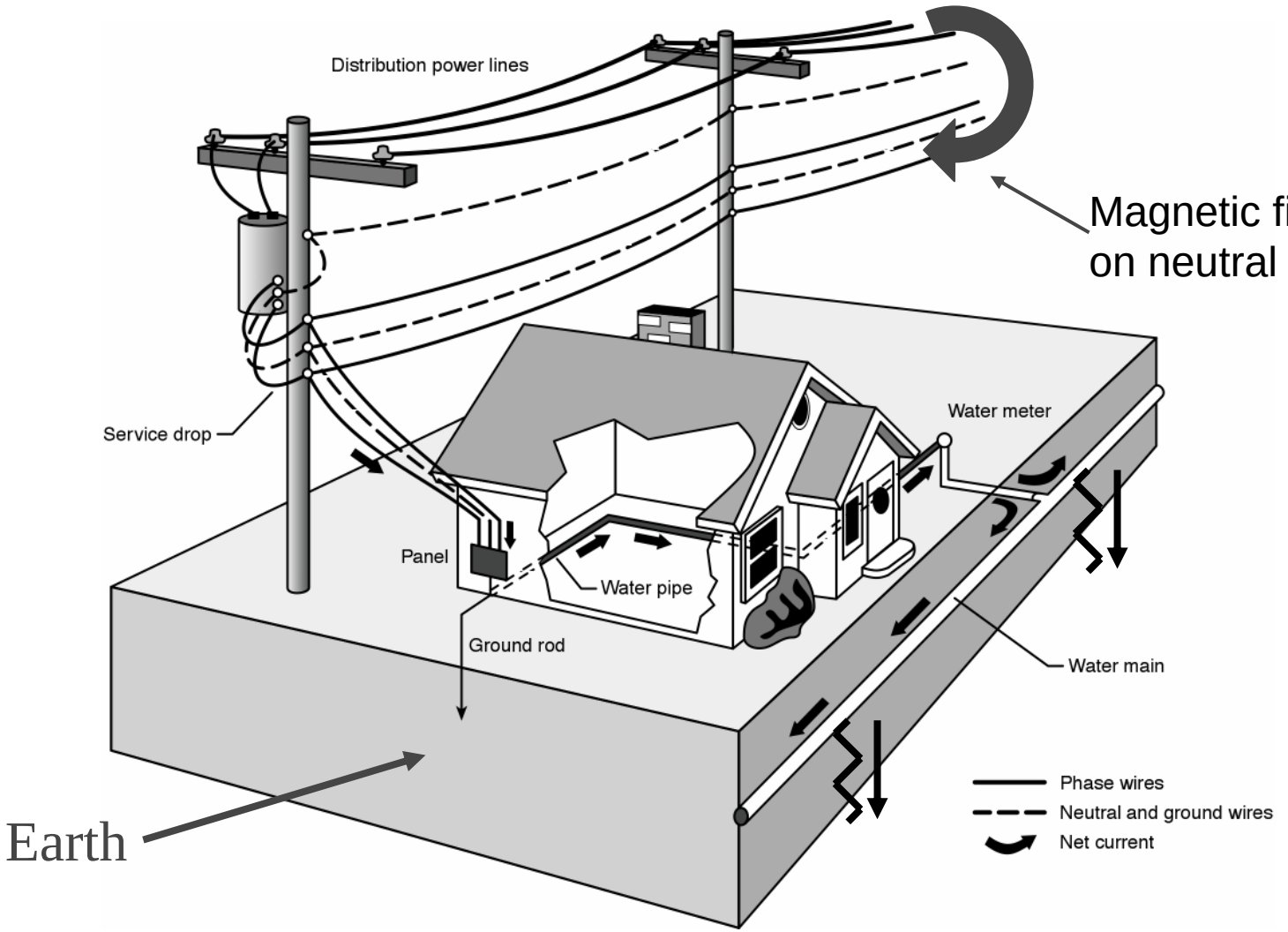
Stromal cells orchestrate hematopoiesis and may upregulate intercellular communication with other stromal cells during development and periods of immunological response (infection); interconnected stromal cell networks result in higher membrane potential when current flows through marrow.

Comparative Dosimetry for Bone Marrow: B-field vs contact current

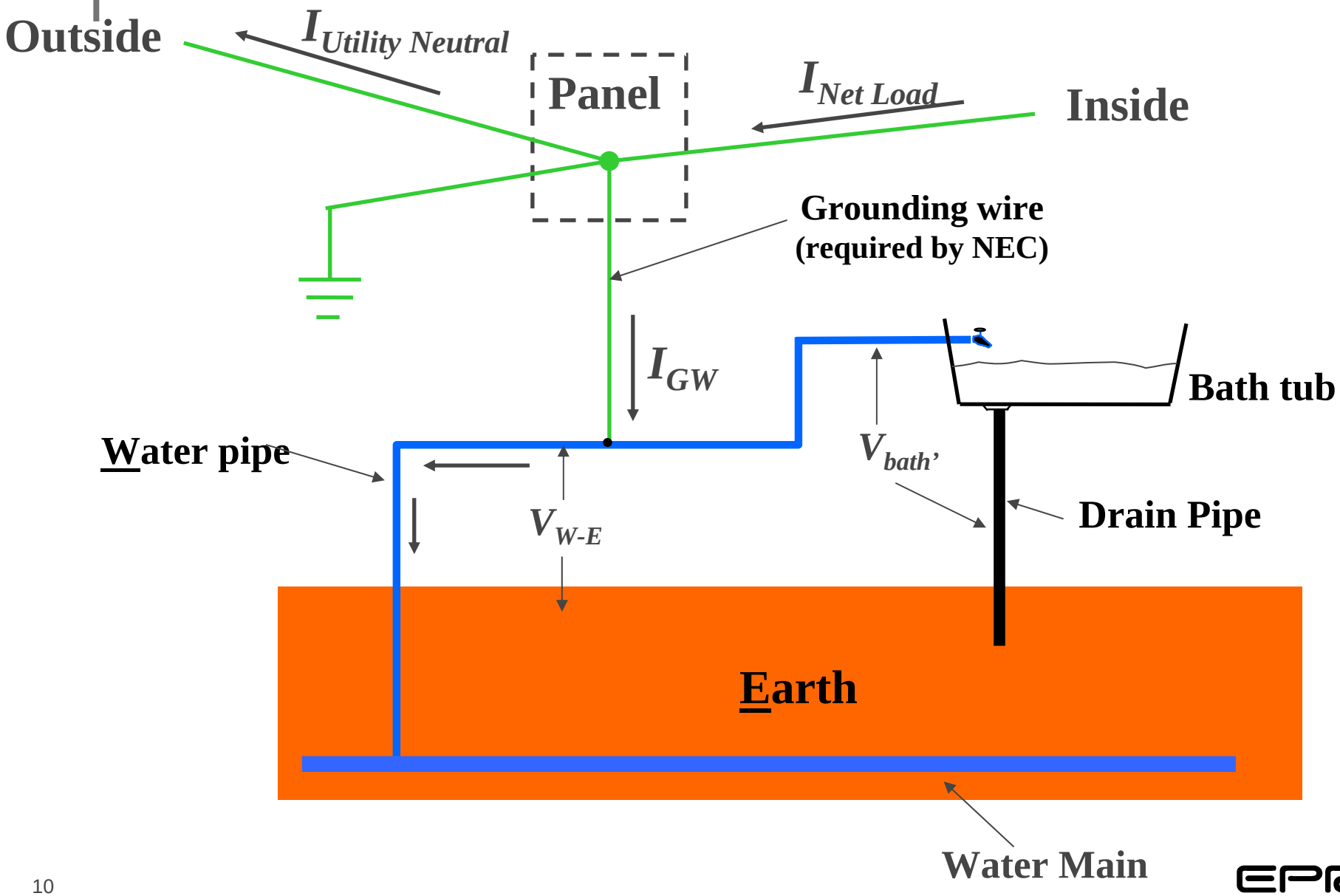
Model	Site	Exposure	Average (mV/m)	99th pctl (mV/m)
Child	Body	1 µT	0.0095	0.056
		10 µA	4.6	34.9
		CC:B Ratio	***484***	***623***
	Lower Arm	10 µA	50.7	149
Adult	Body	1 µT	0.013	0.077
		10 µA	1.75	12.6
		CC:B Ratio	***135***	***164***
	Lower Arm	10 µA	16.6	46.3

Dawson et al, 2001, 2002
Caputa et al, 2002

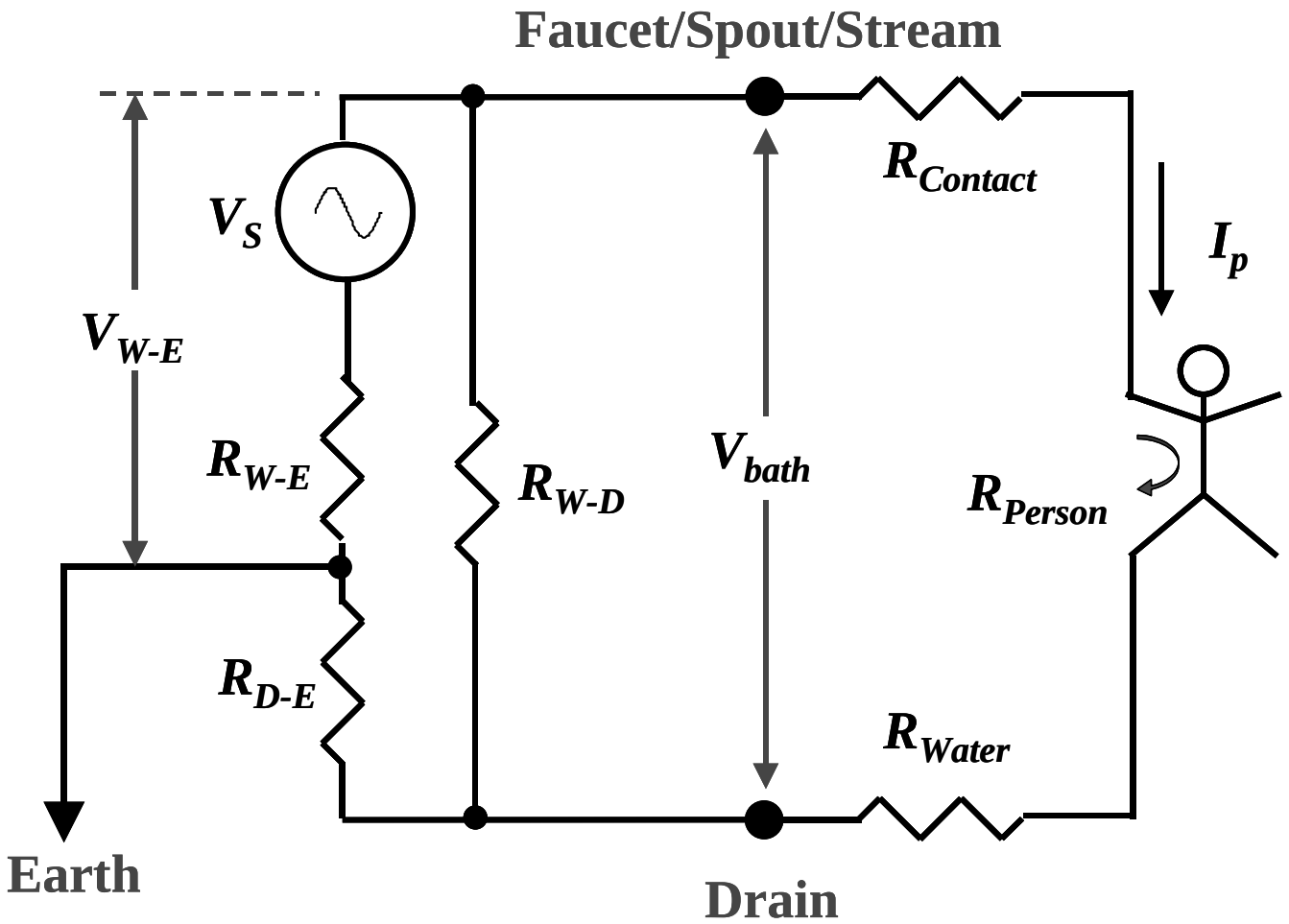
Residential Electrical Service



Basic Residential Grounding in US



Equivalent Circuit



V_{bath} is a variable fraction of $V_{W\text{-}E}$ depending on soil conditions and relative positioning of drain and water lines; V_{bath} negligible if either drain or residential water pipe is non conductive

Bathtub Exposure Scenario

Relationship Between Residential Magnetic Field and Contact Voltage

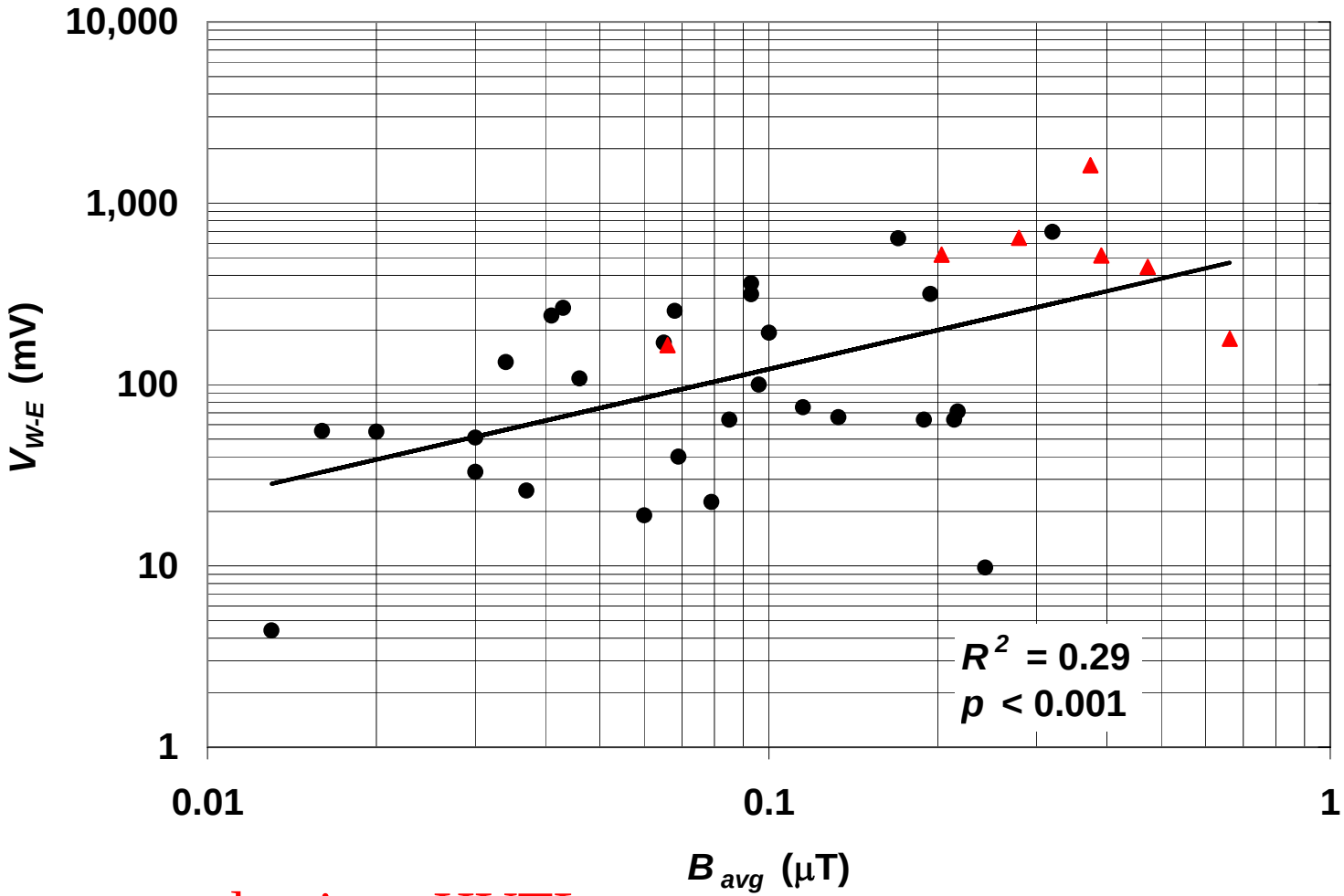
- Measurements
  - spot measurements in regional population samples
  - long-term (6 days) measurements within homes
- Computer Simulation
  - dissect contributions to B and V from primary, secondary, and transmission lines
  - examine possible effects of other variables (e.g., water main, neutral conductivity)
  - economy of resources
- Analysis
  - correlation of B with V: expression of relationship without respect to cutpoint; scatter plot may shed light on mechanism
  - association: examines whether high-tail observations co-exist; relevant to plausibility of confounding
  - small to moderate correlation does not eliminate possibility of strong association

Key Measurement/Modeling Parameters

- B_{avg}: the average magnetic field measured at the center of inhabited rooms
- $V_{W\text{-}E}$: the voltage from the water pipe to the earth under open circuit conditions: represents the interaction of the utility system with the residential grounding system; source of V_{bath}
- V_{bath}: the voltage between the water fixtures and the drain with a 1 kΩ resistor across the voltmeter (represents “live” current flow)

Pilot Study in Pittsfield, MA (N=36): $V_{W\text{-}E}$ vs B_{avg}

(Kavet and Zaffanella, 2002)

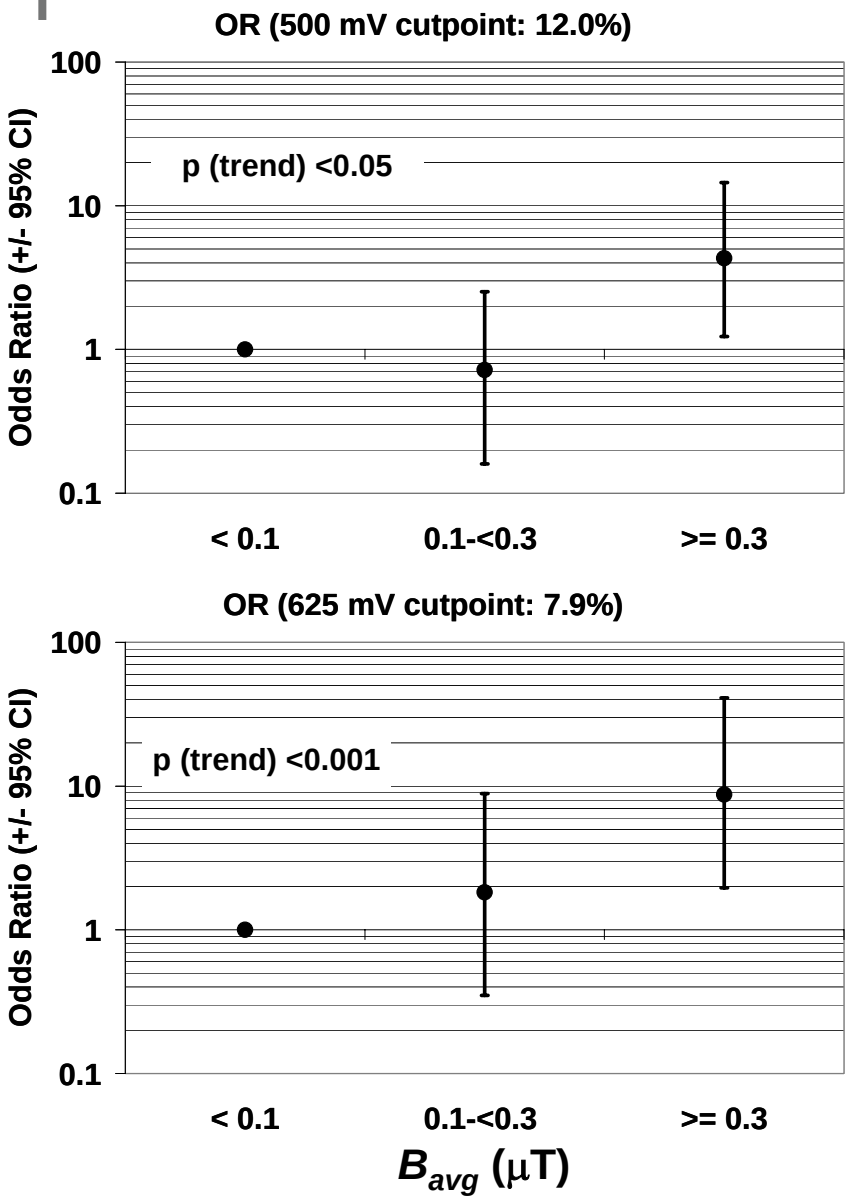


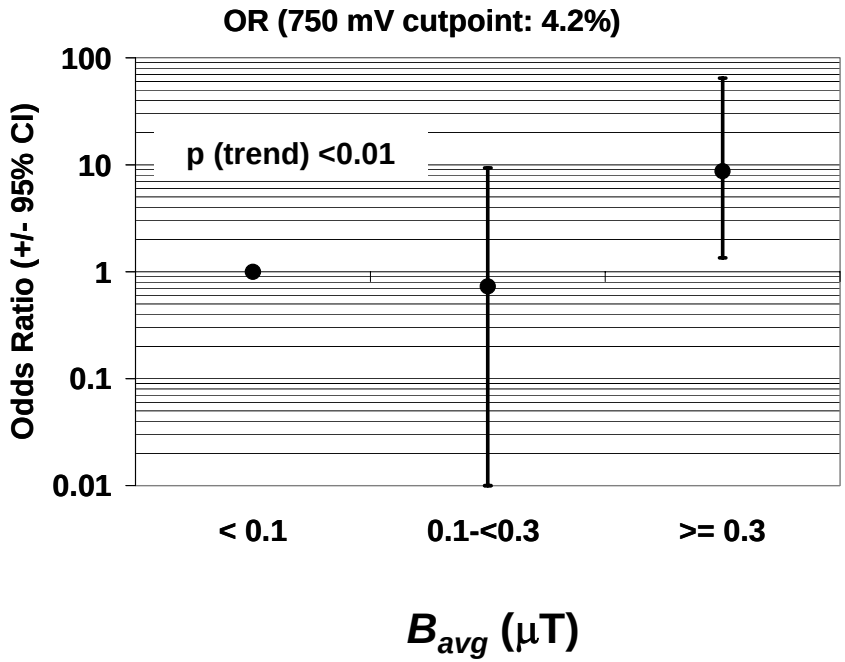
red points: HVTL

Denver Measurement Study
(Kavet et al, in press)

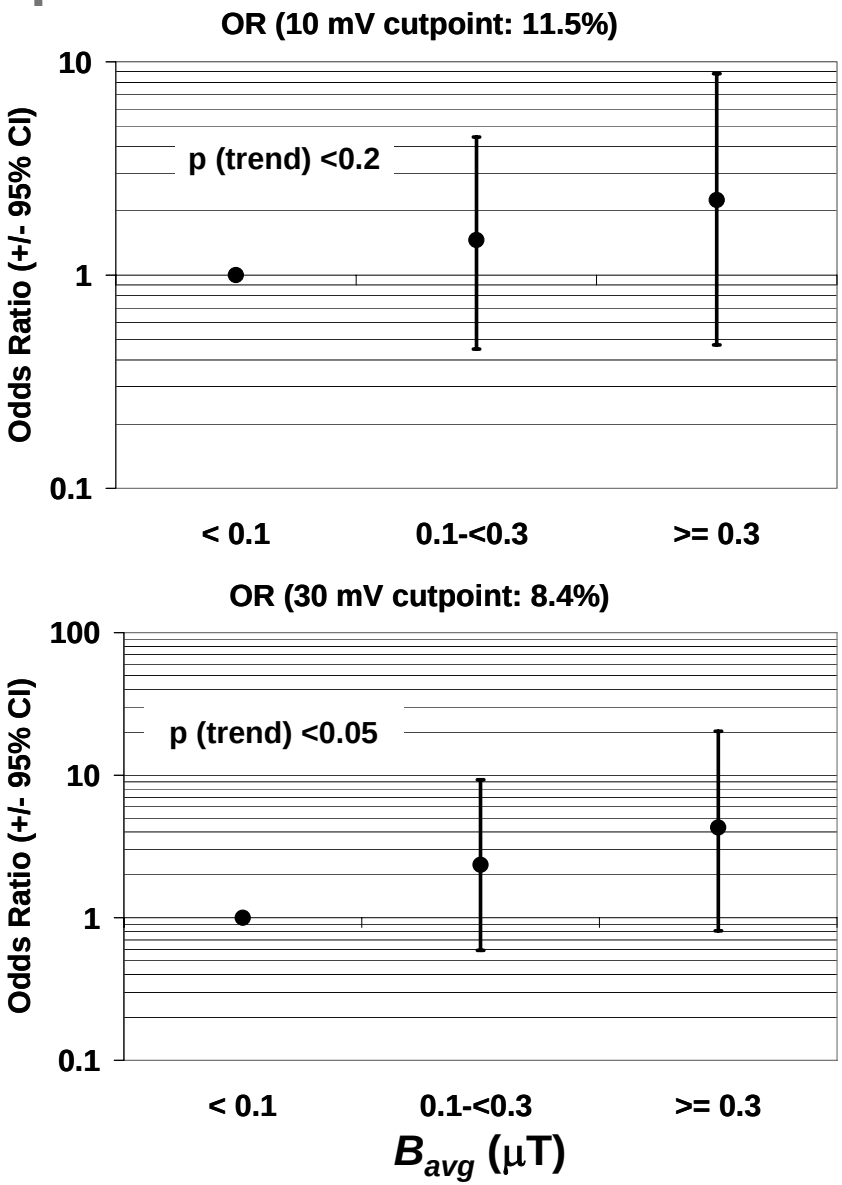
- Objective: Measure magnetic fields and contact voltages in homes that would have qualified for the Savitz study of childhood cancer in Denver, Colorado
- Denver was the site of the earliest and influential childhood cancer studies
- Quantify the association between the residential magnetic field and the voltage of the source for contact current
- 191 homes measured across the full spectrum of outdoor wiring configurations

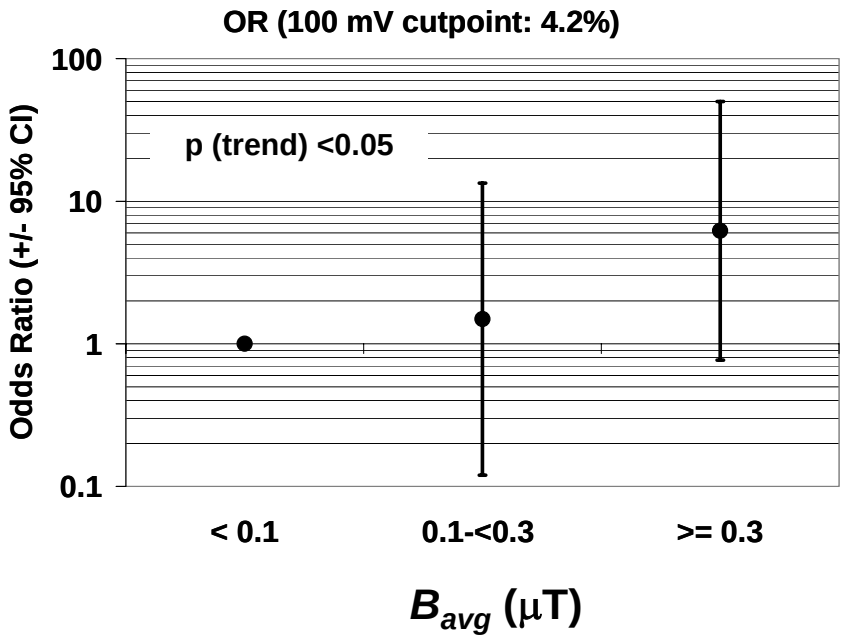
Denver Study: Association of V_{W-E} with B_{avg} Across V_{W-E} Cutpoints (from: Kavet et al, in press)





Denver Study: Association of V_{bath} with B_{avg} Across V_{bath} Cutpoints (from: Kavet et al, in press)

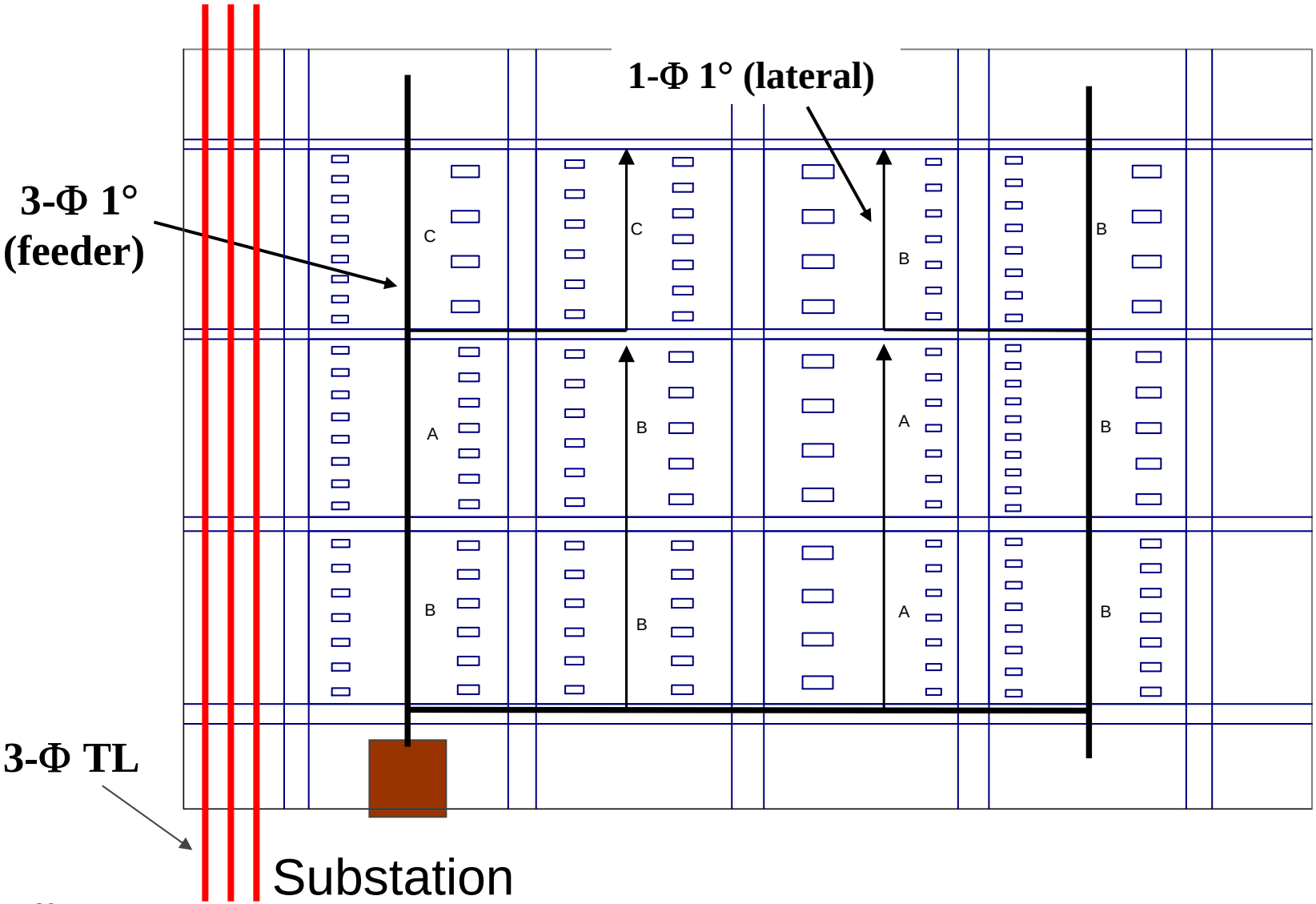




Computer Simulation: Categories of Features

- Study area geography (block size, street width, housing density)
- House lot/size/setback
- Outdoor line location (backyard, street-side)
- Outdoor line configuration (primaries, secondaries, neutrals, transformers)
- System neutral (location relative to phases, resistance)
- Electrical service (service drop, panel locations)
- Residential load (based on 1,000 home study)
- Ground path/resistance (routing and resistance of residential grounding elements)
- Water main type (conductive, nonconductive)

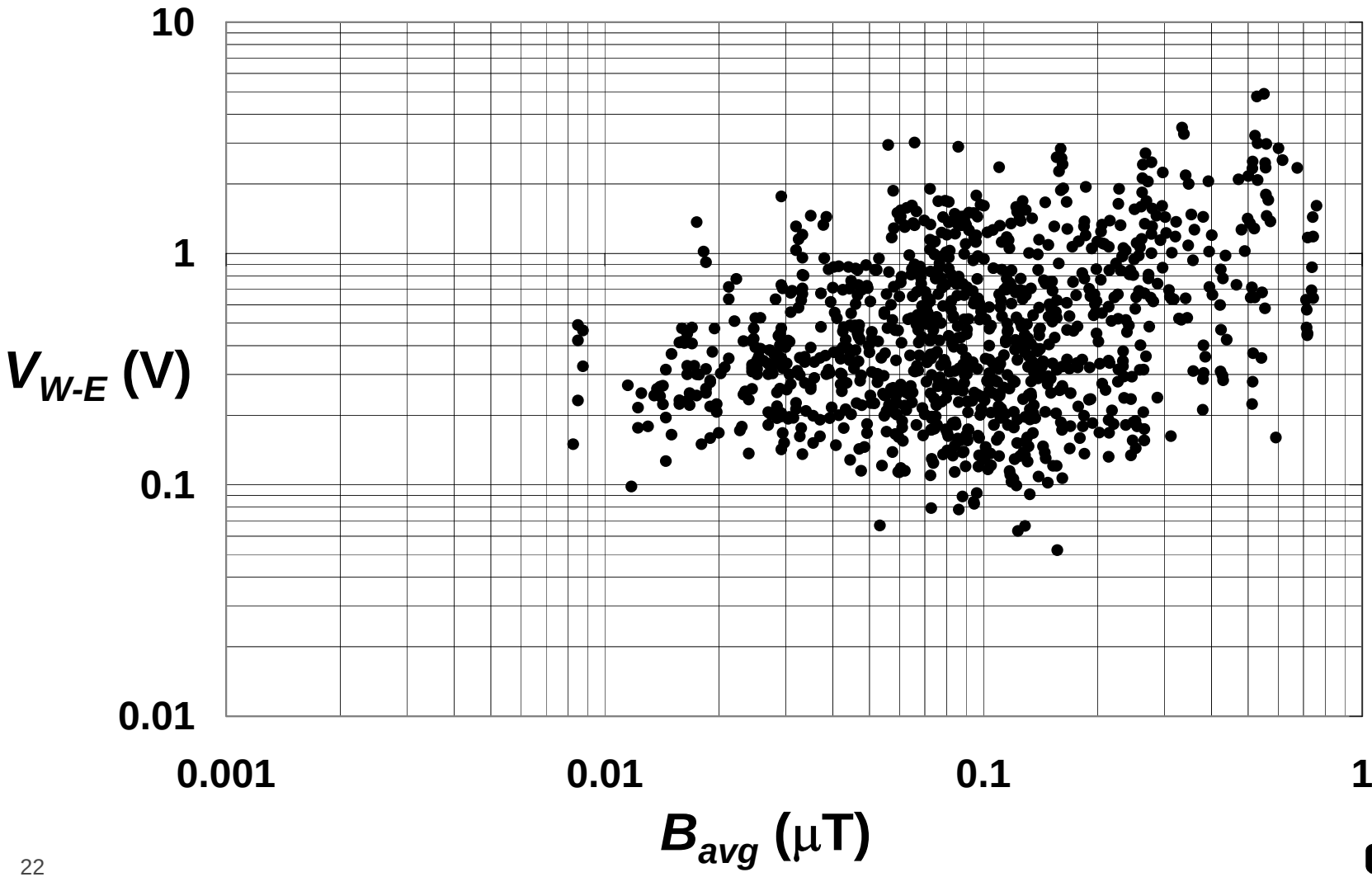
Overview of 3x4 Block Sample Study Area w/Backyard Lines (*N* = 152)



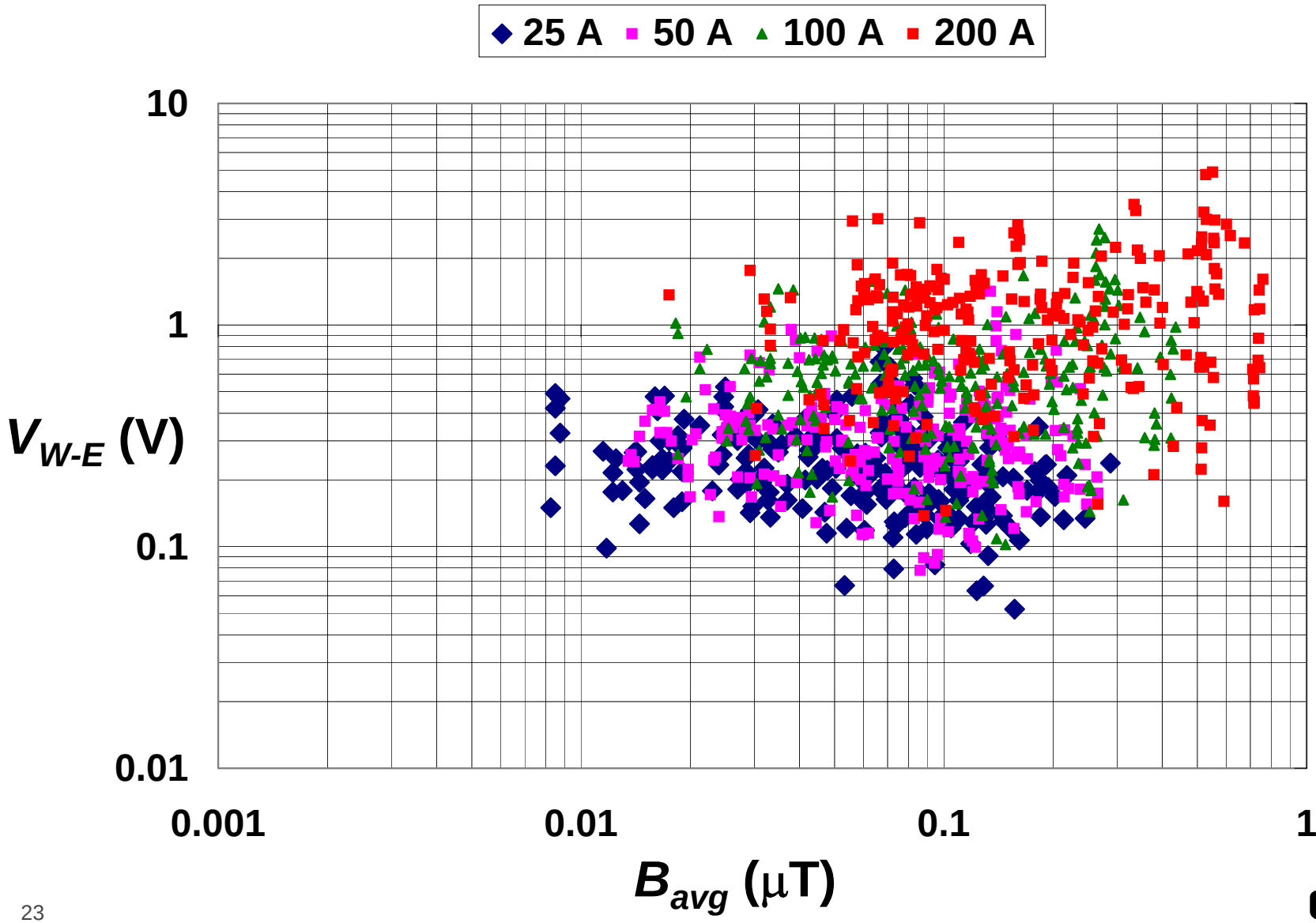
Computer Simulation

- 3x4 Blocks
- Backyard or front distribution, combined with either
- Conductive or non-conductive water mains
- 13 kV primaries
- Range of feeder currents, each with 25% unbalance
  - 25 A
  - 50 A
  - 100 A
  - 200A
- Each house “visited” 4 times for each feeder load
- Net Load = 4.34 A (GM); 1.87 GSD (from 1,000 home study); the same four random seeds used for each feeder load
- B_{avg} and $V_{W\text{-}E}$ averaged over the four visits; of 2,792 points, 1,000 selected randomly for visual purposes

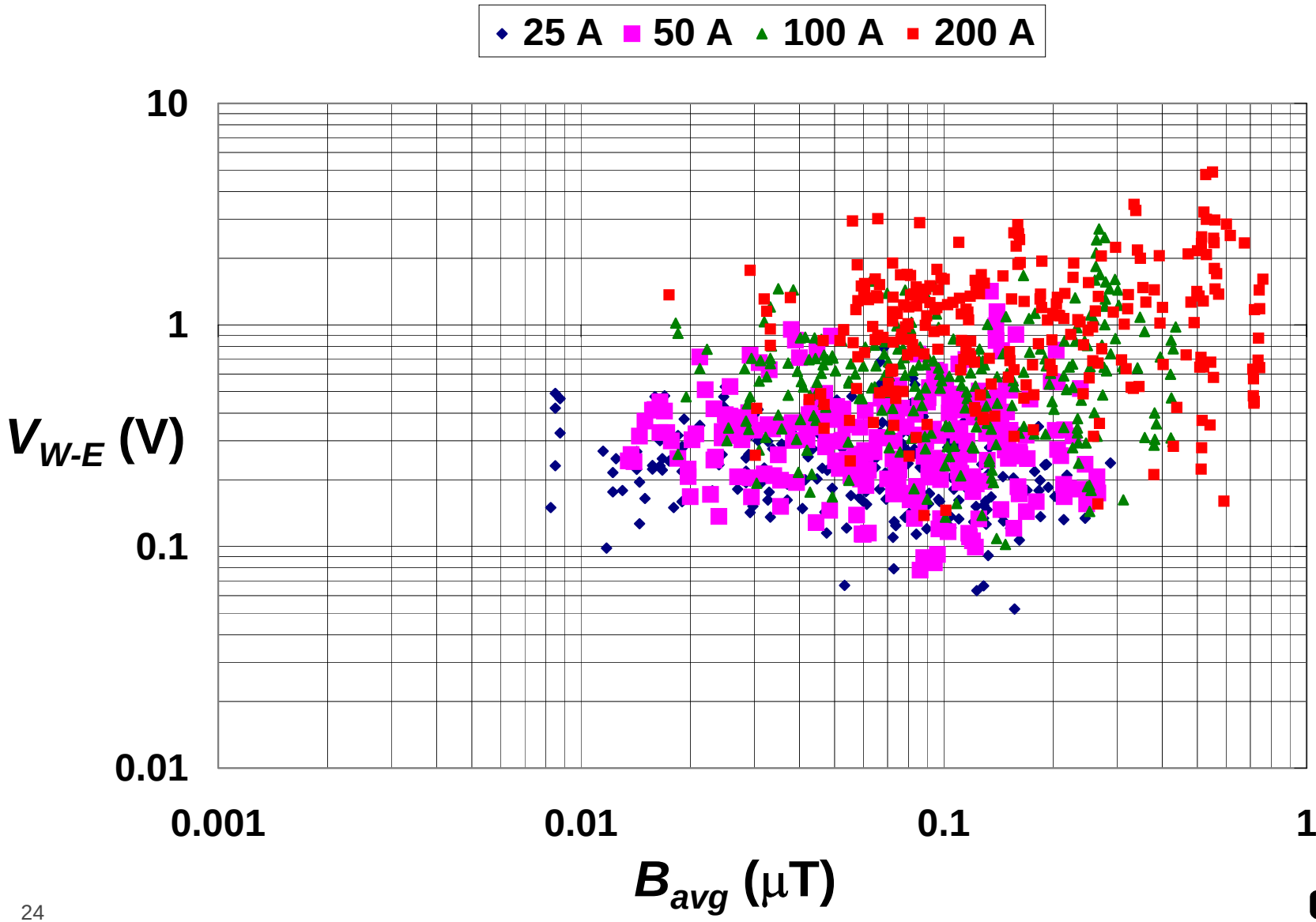
Composite Simulation Result



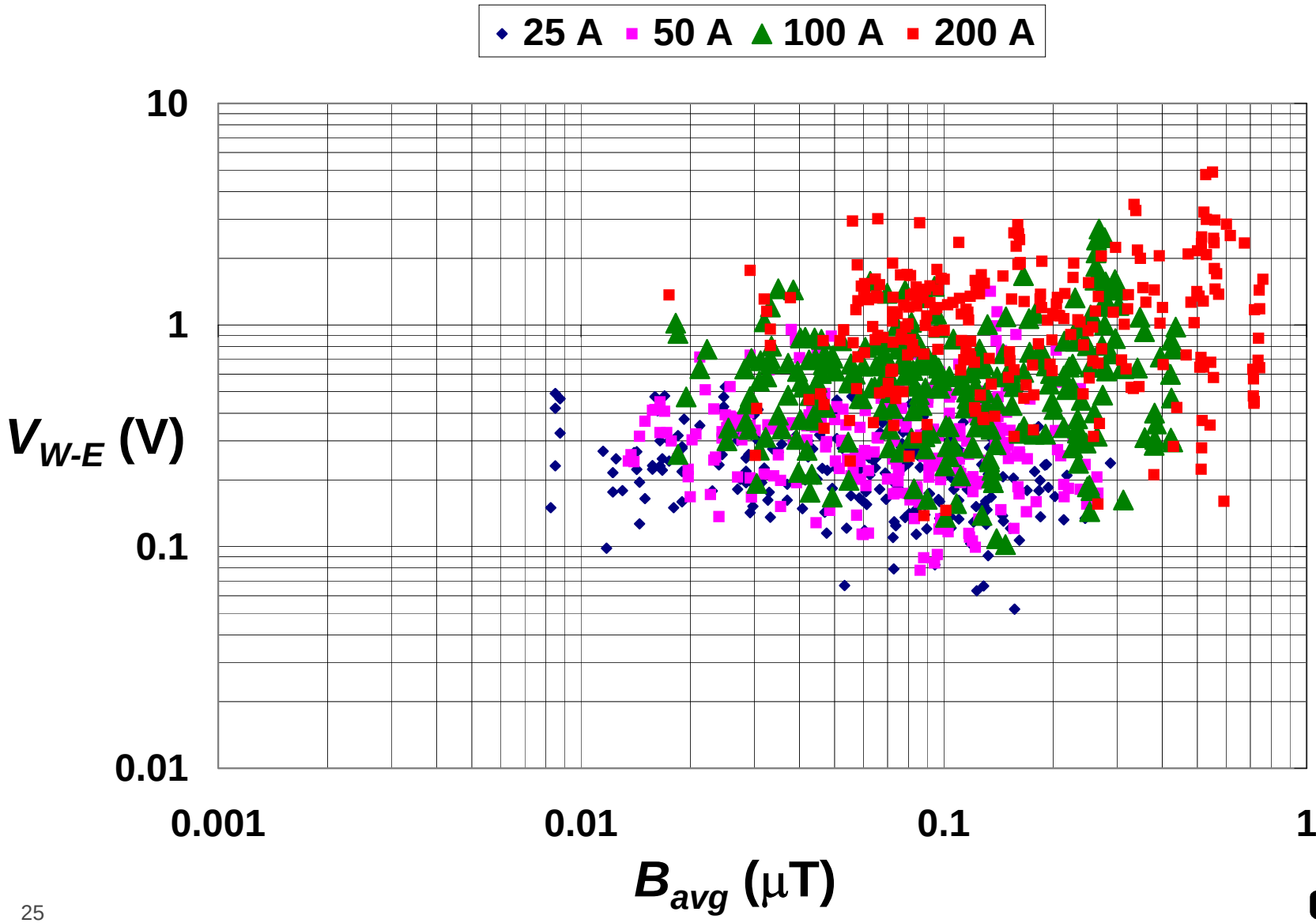
Simulation Result by Primary Load



Simulation Result by Primary Load



Simulation Result by Primary Load



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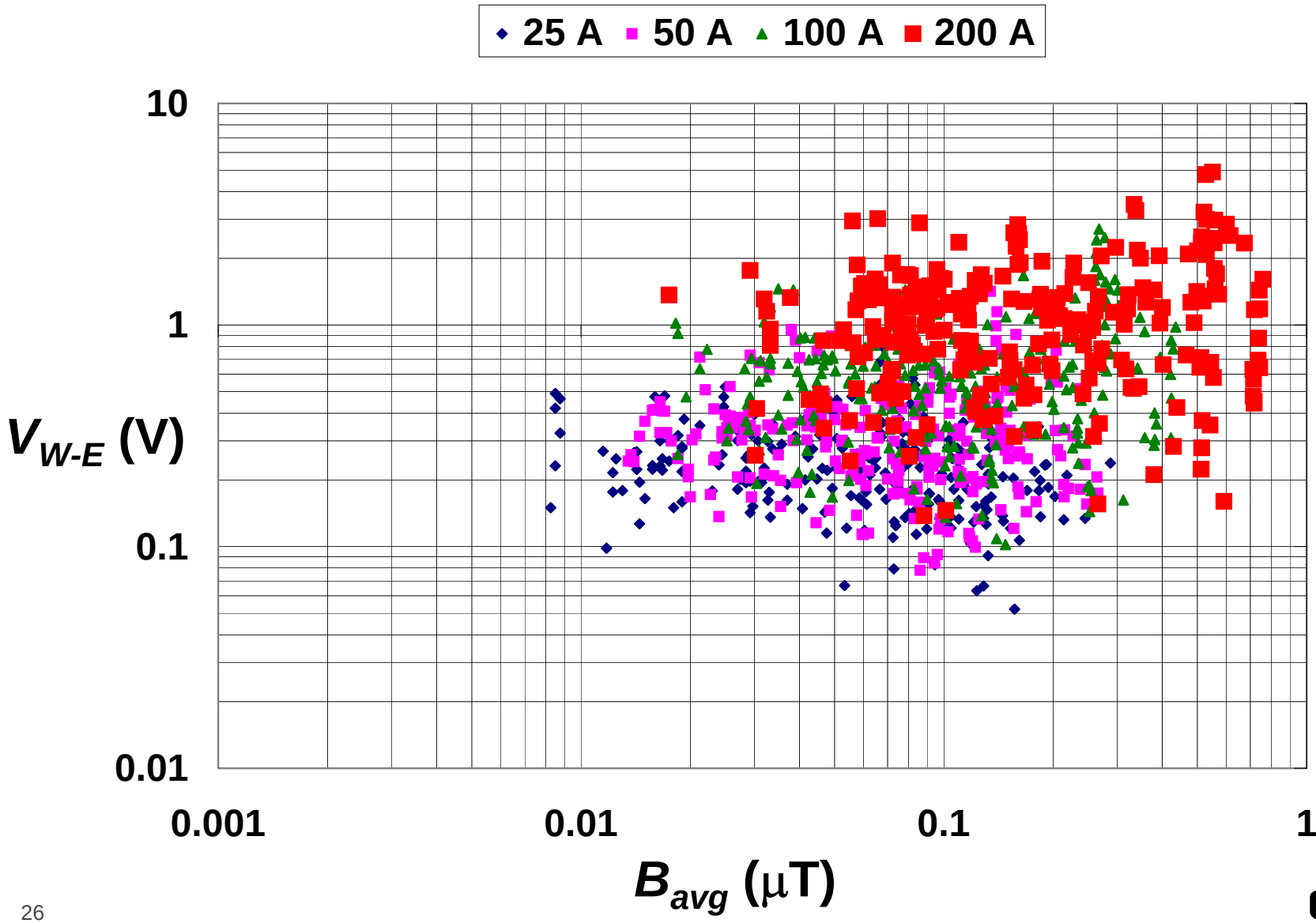
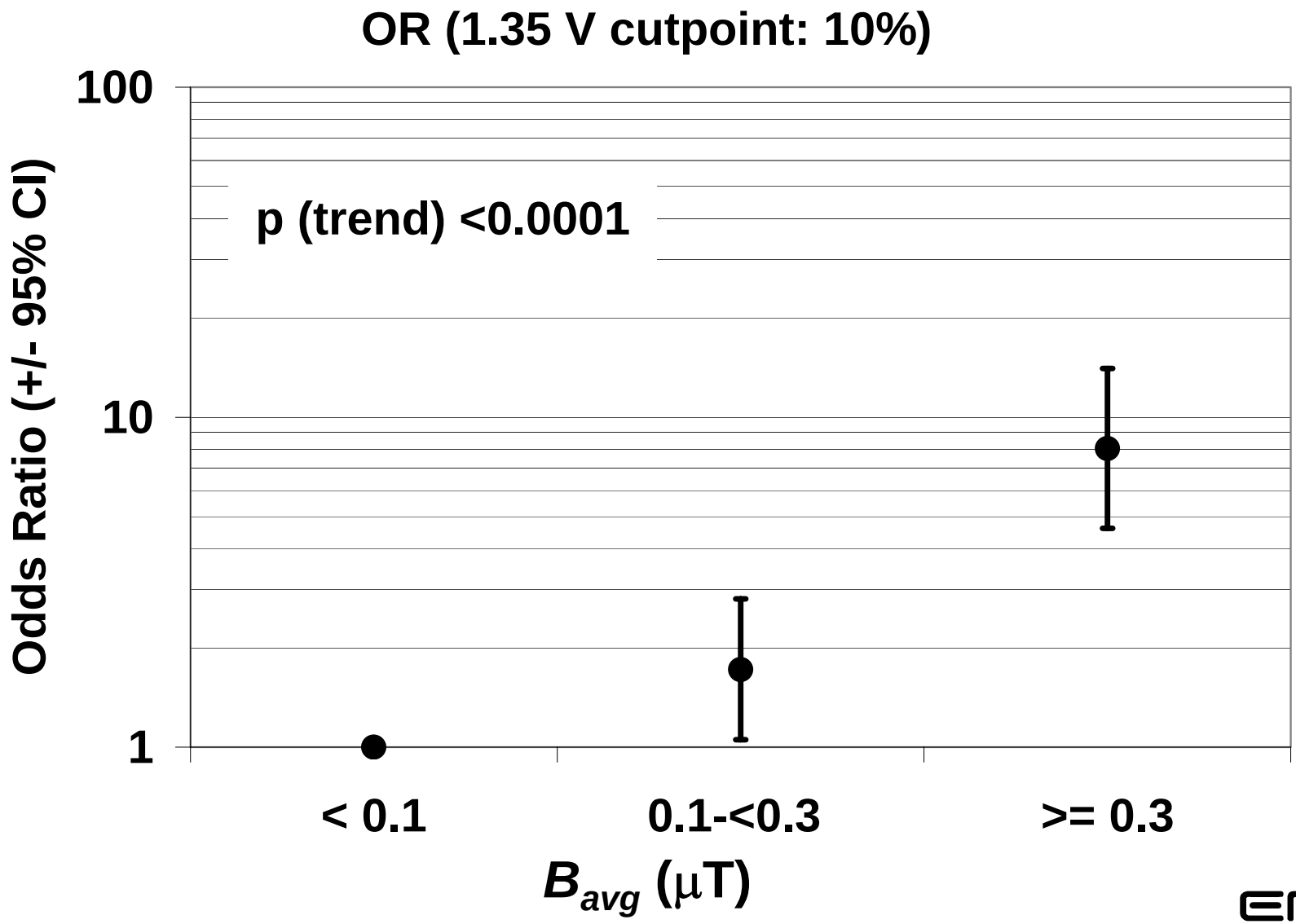


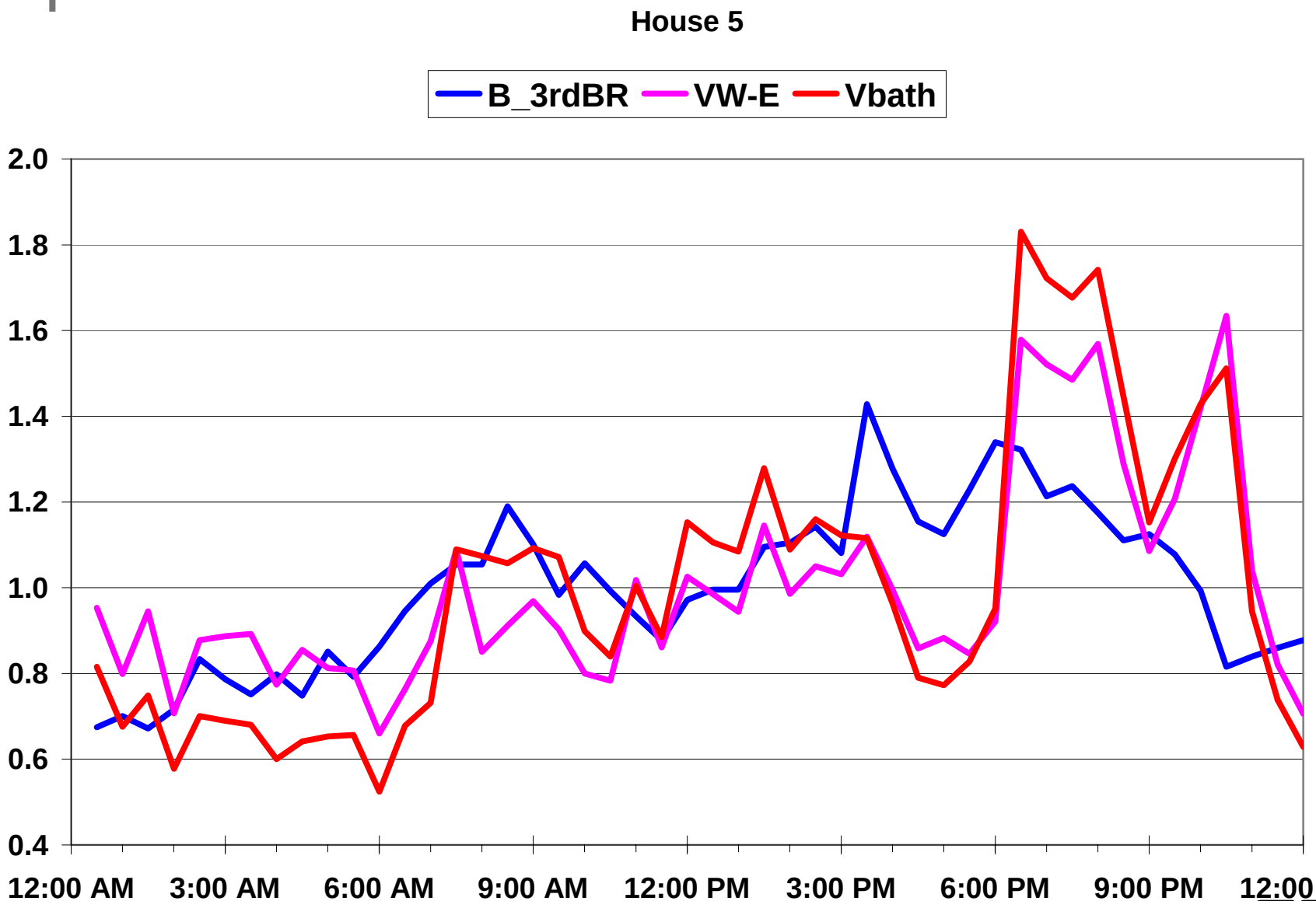
Simulation: Association of $V_{W\text{-}E}$ with B_{avg}



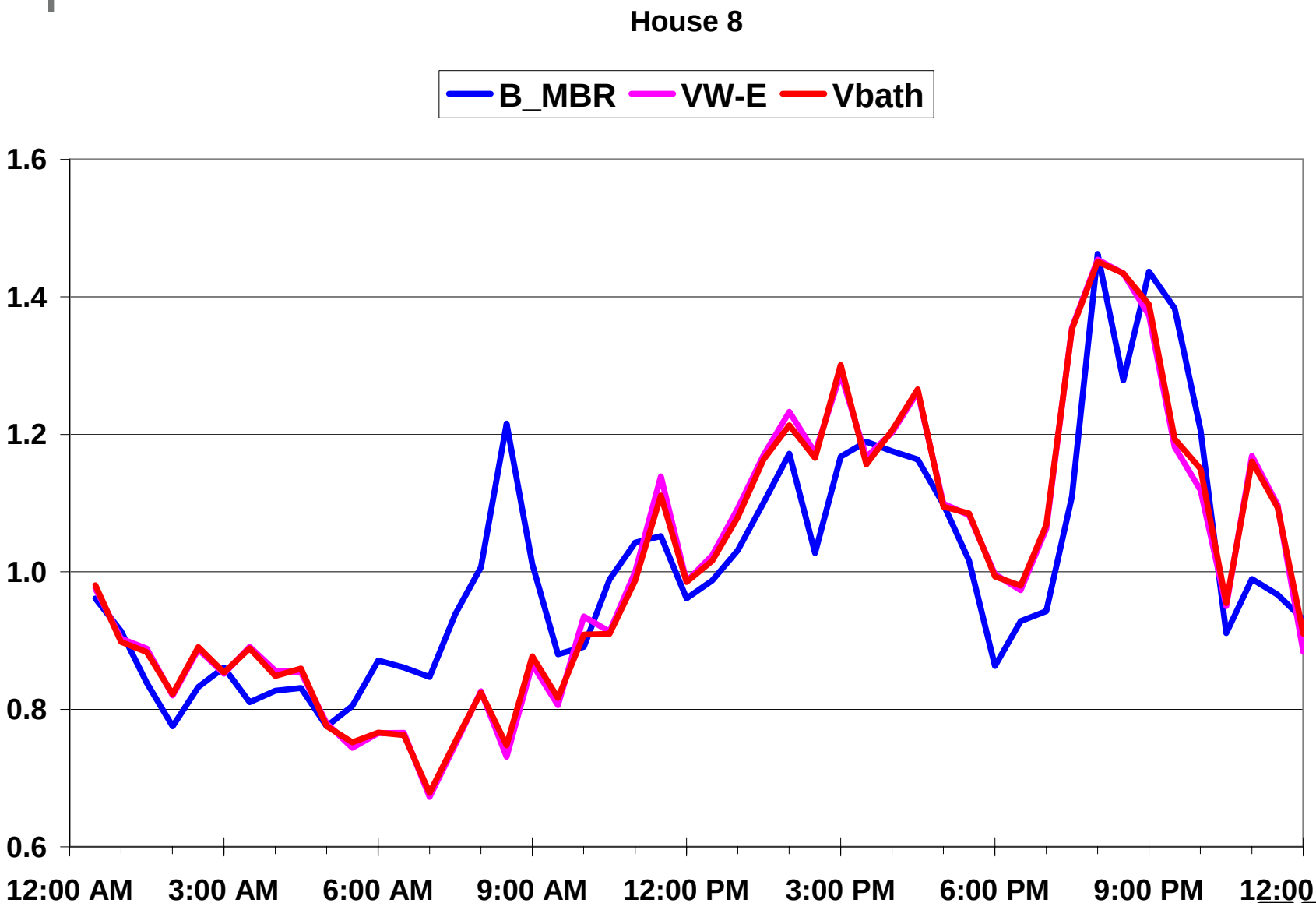
Long-Term Measurements Within Homes in San Jose, CA

- Continuous measurements for 6+ days
- Recording every minute
  - Magnetic field (B_{room})
    - EMDEX Lite (0.1 mG sensitivity)
    - In room with median field at screening
  - Faucet to drain voltage (V_{bath})
    - EMDEX II converted to voltmeter (1 mV sensitivity)
    - All readings with 1,000 ohms from faucet to drain
  - Water line to earth voltage ($V_{W\text{-}E}$)
    - EMDEX II converted to voltmeter (1 mV sensitivity)
    - No resistor
- Analysis
  - Data combined for each 30 minute segment of the 24-hr cycle (i.e., 48 segments per variable)
  - 24-hr graphs normalized to grand means; correlations computed (n = 48)
  - Unusual events censored (e.g., power outage)

Long-Term Measurements Within Homes in San Jose, CA: Results



Long-Term Measurements Within Homes in San Jose, CA: Results



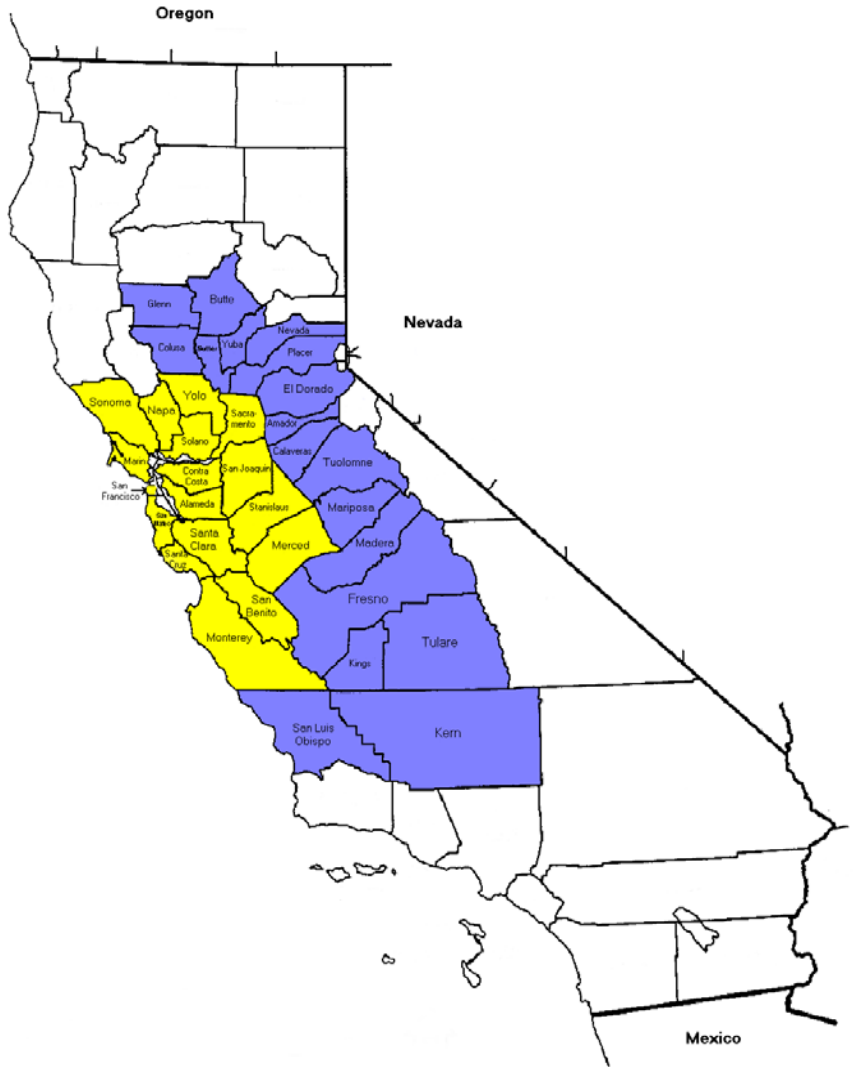
Summary of Correlations Among B, $V_{W\text{-}E}$ & V_{bath} over 6-day measurement period

	6-day Average			Pearson Correlation			Spearman Correlation		
House	B_{avg} (μT)	$V_{W\text{-}E}$ (mV)	V_{bath} (mV)	B_{avg}:$V_{W\text{-}E}$	B_{avg}:V_{bath}	$V_{W\text{-}E}$:V_{bath}	B_{avg}:$V_{W\text{-}E}$	B_{avg}:V_{bath}	$V_{W\text{-}E}$:V_{ba}
1	0.28	243	103	0.976	0.935	0.977	0.958	0.910	0.968
2	0.17	91	13	0.463	0.538	0.990	0.379	0.482	0.979
3	0.02	173	10	0.883	0.635	0.556	0.912	0.686	0.635
4	0.35	--	107	--	0.667	--	--	0.725	--
5	0.02	104	12	0.428	0.596	0.935	0.479	0.640	0.903
6	0.15	411	68	0.863	0.858	0.982	0.903	0.894	0.968
7	0.02	116	--	0.542	--	--	0.630	--	--
8	0.07	231	263	0.789	0.801	0.998	0.767	0.772	0.997
9	0.08	250	24	0.937	0.797	0.849	0.853	0.836	0.878

In every case to date, all three quantities are statistically significantly correlated with each other over 6-day long measurement periods

Northern California Childhood Leukemia Study at U Cal Berkeley

- 17 Bay Area counties
- 18 Central Valley counties
- Since 1995
- EMF/contact current component: 2003-06



Children's Bathing Behavior

Prior to launch of EMF/contact voltage study in the NCCLS,

- Recall survey of parents conducted by telephone (*N*=40)
- Bathing diary survey administered to separate set of parents (*N*=40), with recall survey preceding diary (*N*=39)
- Roughly 75-80% children >12 months old engage in contact behavior (~contact every two baths); lower for <12 months old (~contact every three baths)

Conclusion

- Thus far, exposure to contact current has demonstrated features that qualify it as a plausible factor that could be responsible for the association of childhood leukemia with residential magnetic fields:
  - dose to bone marrow
  - association with residential magnetic fields
  - children's bathing behavior consistent with frequent exposure
- Further investigation needed to characterize
  - electrical systems across nations
  - structures with multiple residences
- Investigation to identify candidate laboratory systems in progress
  - in vitro
  - in vivo