Paper 025 / Application 002

ProjectionLab: A JMP0X1B Control Stack for UHV Electrostatic Null Experiments

Sequencing pressure, polarity, shielding, inversion, and force metrology as typed experimental effects

JMP0X1B Research Group

Working paper draft / June 13, 2026

Abstract

ProjectionLab is a proposed control stack for ultra-high-vacuum electrostatic null experiments. It operationalizes the experimental papers by controlling pressure ladders, high-voltage profiles, polarity reversals, shield states, device inversion, cable dummies, and force metrology windows. The software goal is conservative: make it difficult to run an uninterpretable experiment.

Status. Draft manuscript for review and revision. This paper is not an empirical claim of new physics or field-ready technology. It is a structured proposal, theory note, protocol, or application architecture intended to be auditable, falsifiable, and publishable with source.

Contents

1 Problem

Electrostatic null tests have many controls and safety constraints. Manual sequencing increases the chance of missing a pressure state, changing cable routing, unblinding too early, or losing telemetry. The problem is to provide a control stack that enforces declared experimental matrices and produces data compatible with null ledgers and stress-energy audits.

2 Model

ProjectionLab represents an experiment as a matrix of device states and control transformations. Each cell has required preconditions and telemetry channels. The scheduler refuses to execute a claim-producing run unless calibration, dummy, and safety states are complete.

$$\mathcal{E} = \mathcal{D} \times \mathcal{P} \times \mathcal{V} \times \mathcal{S} \times \mathcal{O},$$

where $\mathcal{D}$ is device class, $\mathcal{P}$ pressure state, $\mathcal{V}$ voltage and polarity, $\mathcal{S}$ shielding, and $\mathcal{O}$ orientation.

$$\text{Coverage} = \frac{|\mathcal{E}_{\text{completed}}|}{|\mathcal{E}_{\text{required}}|}.$$

3 Claims

1. **Claim 1.** Experimental coverage should be computed during execution, not reconstructed after the fact.
2. **Claim 2.** High-voltage and vacuum operations should be explicit effects with interlocks and audit logs.
3. **Claim 3.** A null run without dummy and inversion coverage should be blocked from mechanism-specific reporting.
4. **Claim 4.** ProjectionLab can produce standardized data frames for downstream Bayesian and FEM comparison.

4 Evidence Plan

The prototype evidence is a hardware-in-the-loop simulation and a dry-run with instrument emulators. Acceptance requires correct handling of aborted runs, pressure failures, high-voltage interlocks, blinded labels, and repeated calibration checks. A later hardware trial can run low-voltage vacuum controls before any high-risk operation.

5 JMP0X1B Implementation Surface

Implementation in JMP0X1B should use actors for pump, gauge, high-voltage supply, balance, environmental telemetry, shield controller, and run supervisor. Each actor emits typed events into an append-only log.

Illustrative JMP0X1B-style contract

```
actor UHVSupervisor {
    fn require_matrix(matrix: ExperimentMatrix) -> Gate effects{Audit}
    fn step(cell: MatrixCell) -> RunFrame effects{Vacuum, HighVoltage, Telemetry, Safety}
    fn coverage() -> CoverageReport effects{Deterministic}
}
```

6 Release And Review Plan

Release the control-matrix schema, emulator traces, interlock policy, example experiment bundle, and PDF/TeX paper explaining failure modes.

7 Open Questions

- Which balance interface should be supported first?
- How should manual device inversion be logged and verified?
- Can a low-cost vacuum system emulate enough controls for software validation?
- What safety policies must be external to the research code?

8 Conclusion

ProjectionLab turns electrostatic null methodology into operational software. Its most important feature is refusal: it refuses to make weak runs look stronger than they are.

References

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