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Modeling Approaches and Testing Strategies for Independent Features in Configurable Software

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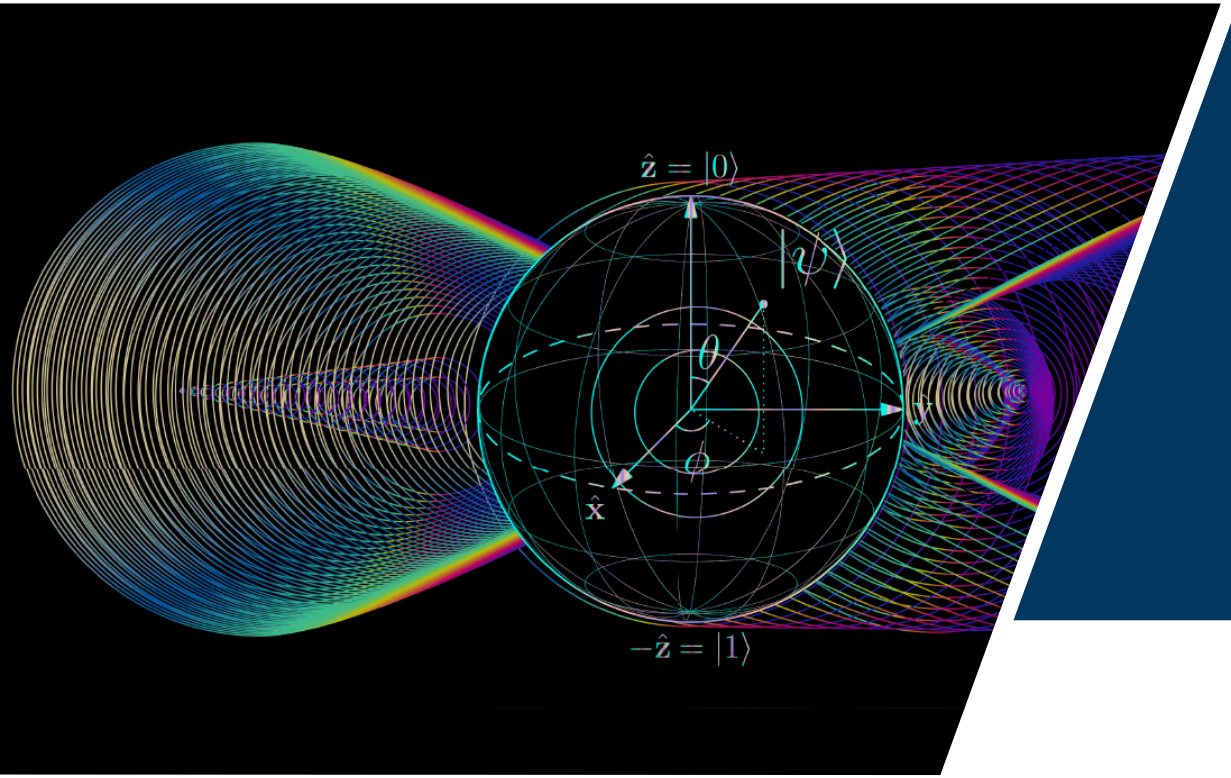
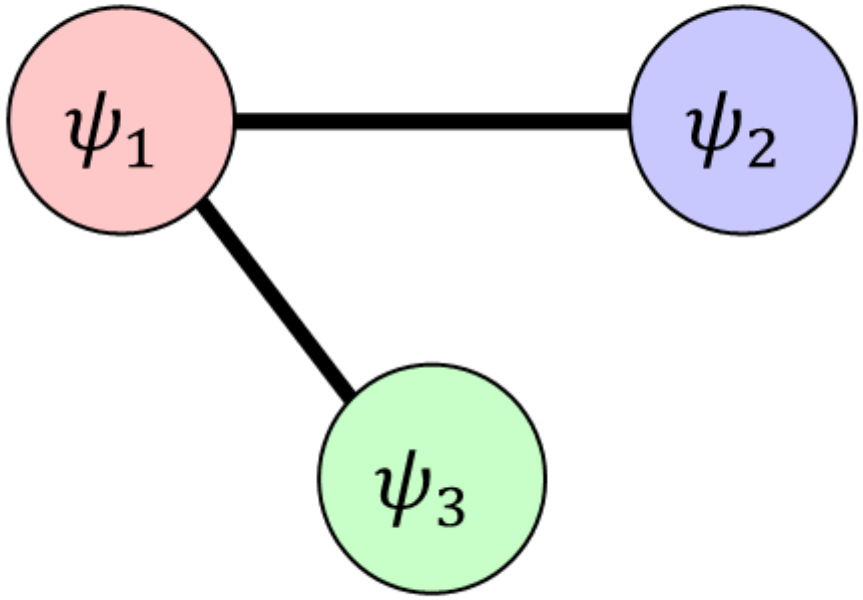
Quantum State Tomography



- A Qbit may be measured in X, Y and Z direction
- Am n Qbit system requires (3^n) Measurements
- Tackle exponential explosion by only partially measuring

Partial Quantum State Tomography [1] Example

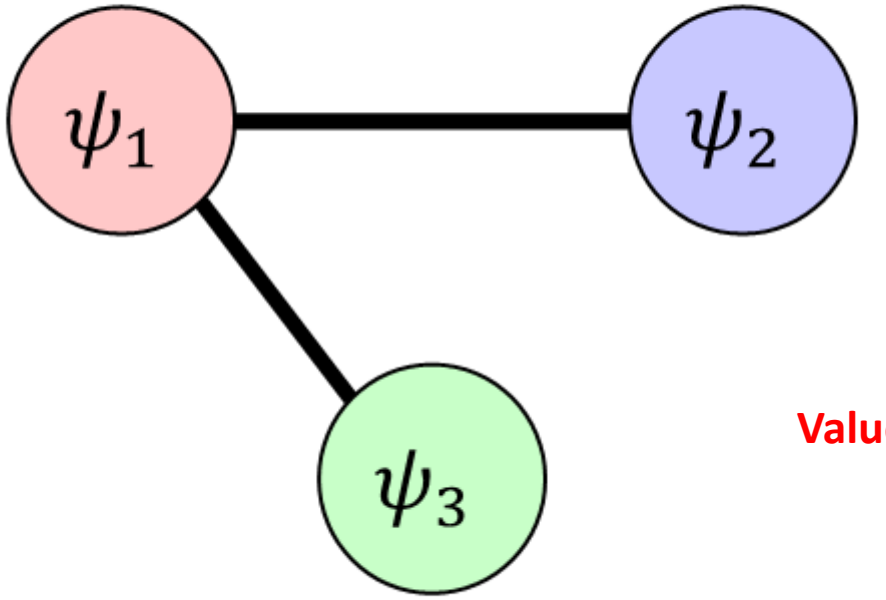


- Only measure marginal-states $\{\psi_1, \psi_2\}$ and $\{\psi_1, \psi_3\}$
- Required measurement settings:

$\{\psi_1, \psi_2\}$	$\{\psi_1, \psi_3\}$
X_1X_2	X_1X_3
X_1Y_2	X_1Y_3
X_1Z_2	X_1Z_3
Y_1X_2	Y_1X_3
Y_1Y_2	Y_1Y_3
Y_1Z_2	Y_1Z_3
Z_1X_2	Z_1X_3
Z_1Y_2	Z_1Y_3
Z_1Z_2	Z_1Z_3

[1] Ahana Ghoshal, Carlos de Gois, Kiara Hansenne, Otfried Gühne, & Hai-Chau Nguyen. (2025). Qubits in second quantisation in fermionic

Partial Quantum State Tomography Example

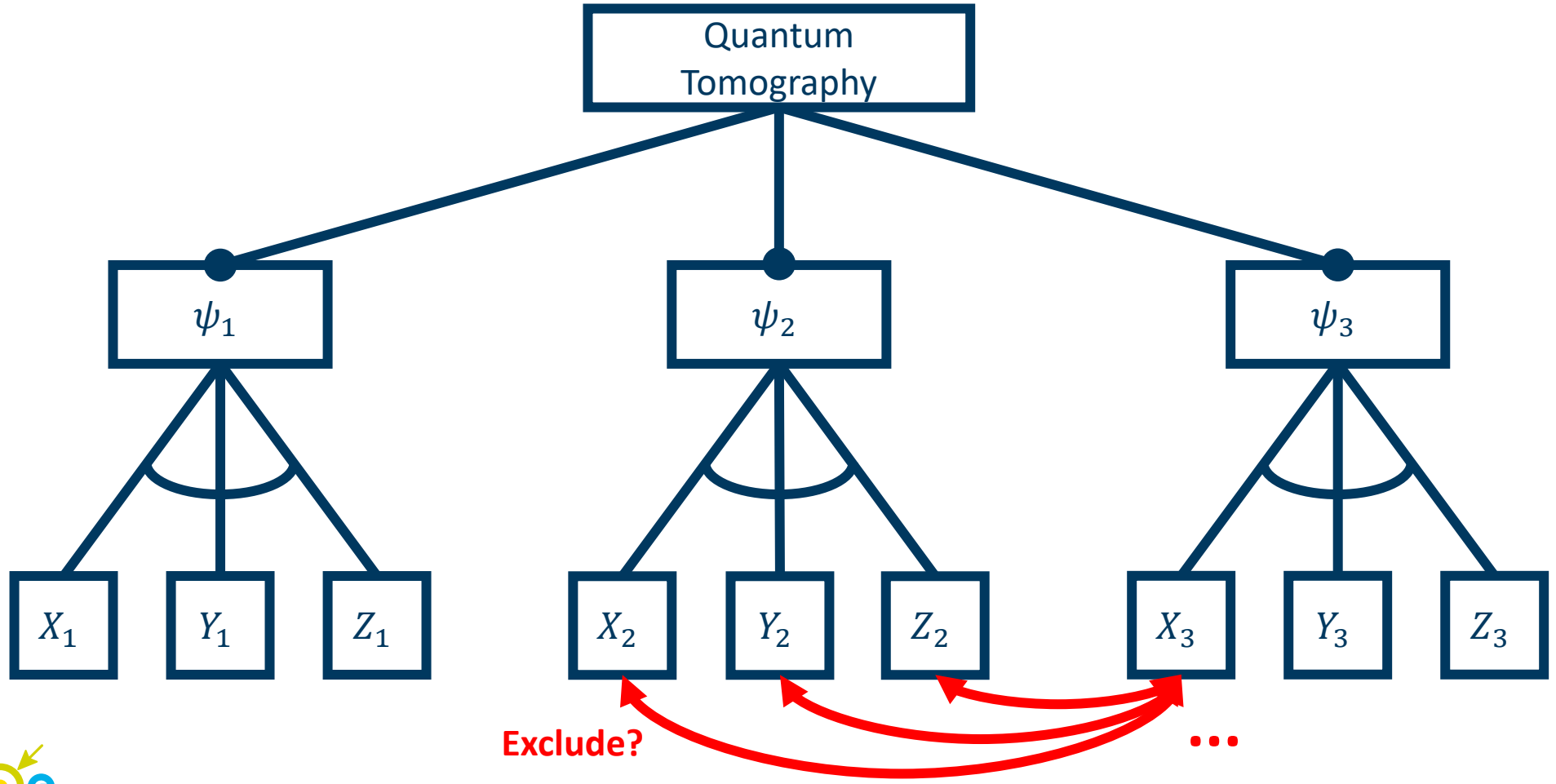


- Combine partial measurements to cover all required ones:

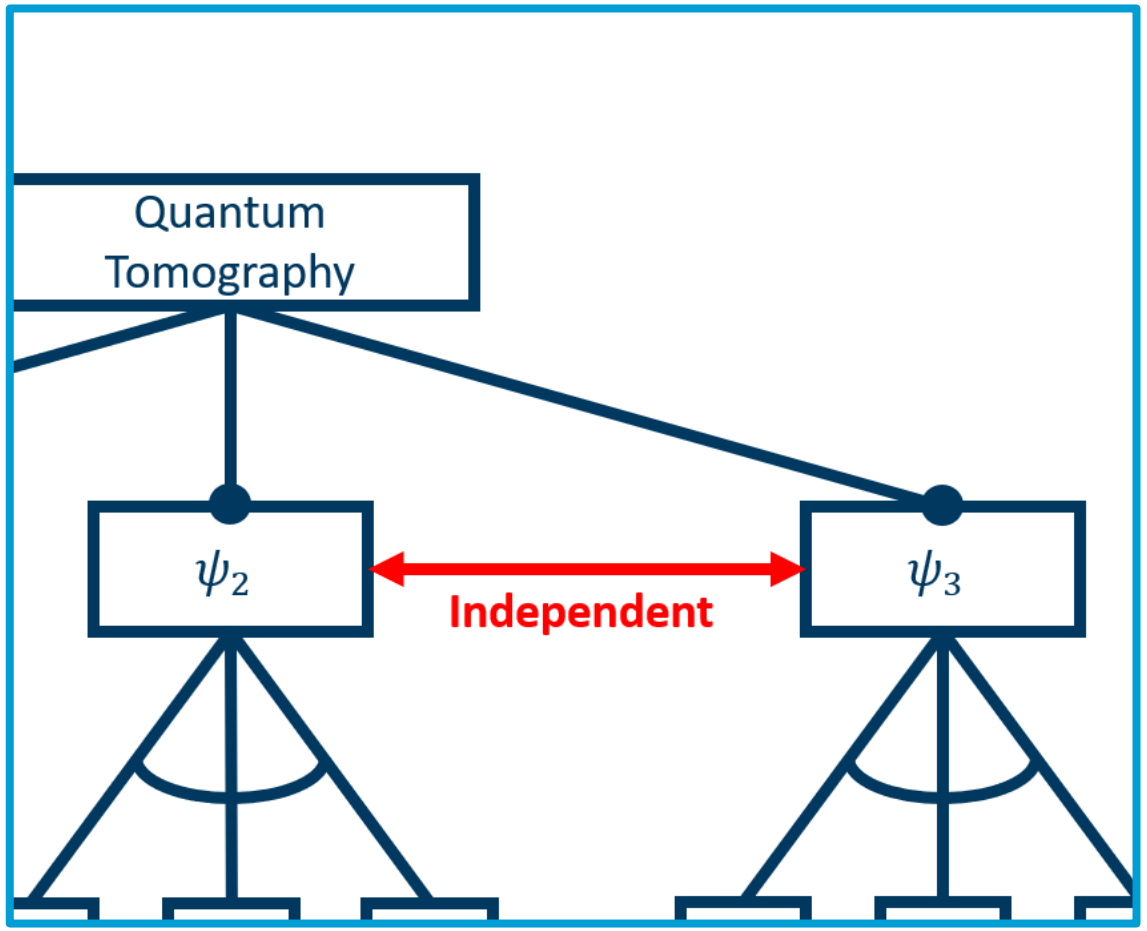
$\{\psi_1, \psi_2\}$	$\{\psi_1, \psi_3\}$	Measurement
X_1X_2	X_1X_3	$X_1X_2X_3$
X_1Y_2	X_1Y_3	$X_1Y_2Y_3$
X_1Z_2	X_1Z_3	$X_1Z_2Z_3$
Y_1X_2	Y_1X_3	$Y_1X_2X_3$
Y_1Y_2	Y_1Y_3	$Y_1Y_2Y_3$
Y_1Z_2	Y_1Z_3	$Y_1Z_2Z_3$
Z_1X_2	Z_1X_3	$Z_1X_2X_3$
Z_1Y_2	Z_1Y_3	$Z_1Y_2Y_3$
Z_1Z_2	Z_1Z_3	$Z_1Z_2Z_3$

Value Schemas **Configurations**

Modeling the Quantum State Tomography Problem as a Feature Model

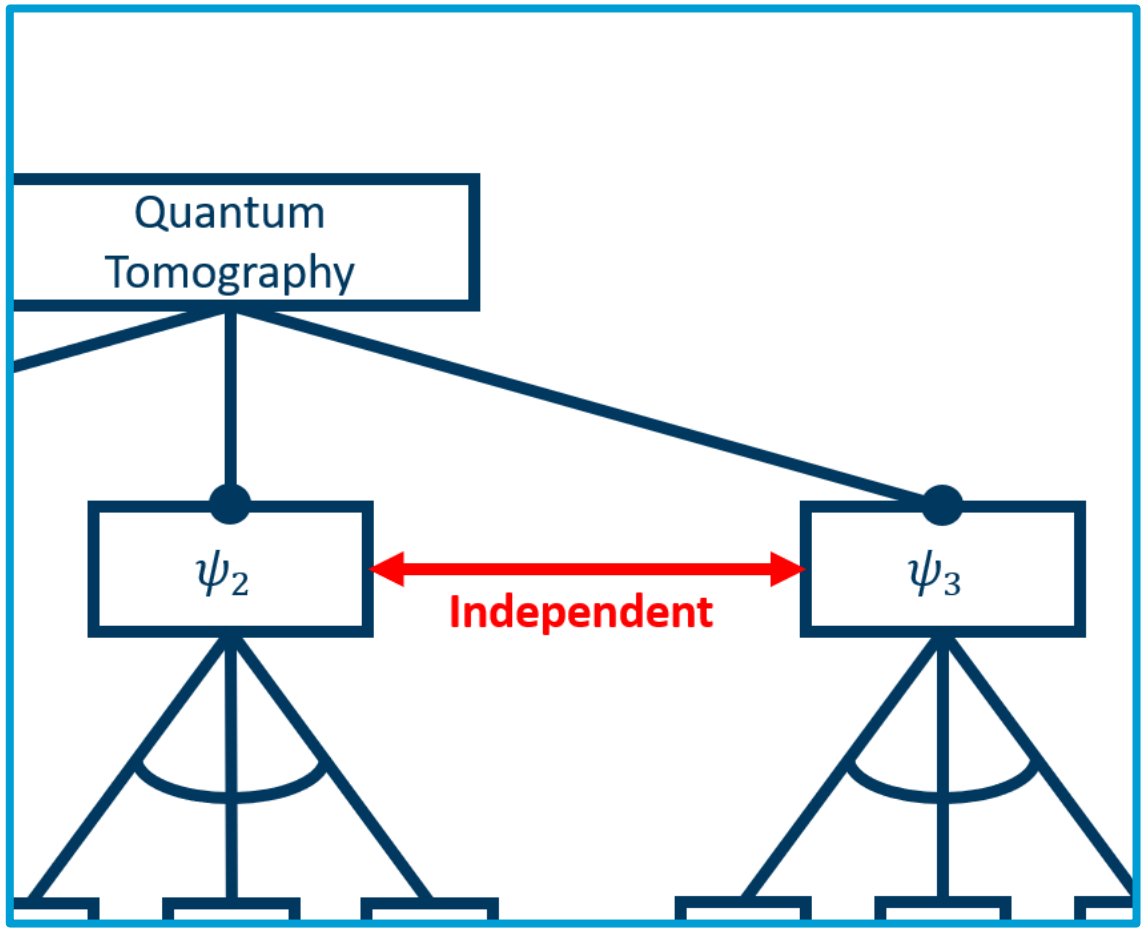


Syntax and Semantics of an Independent Feature Edge



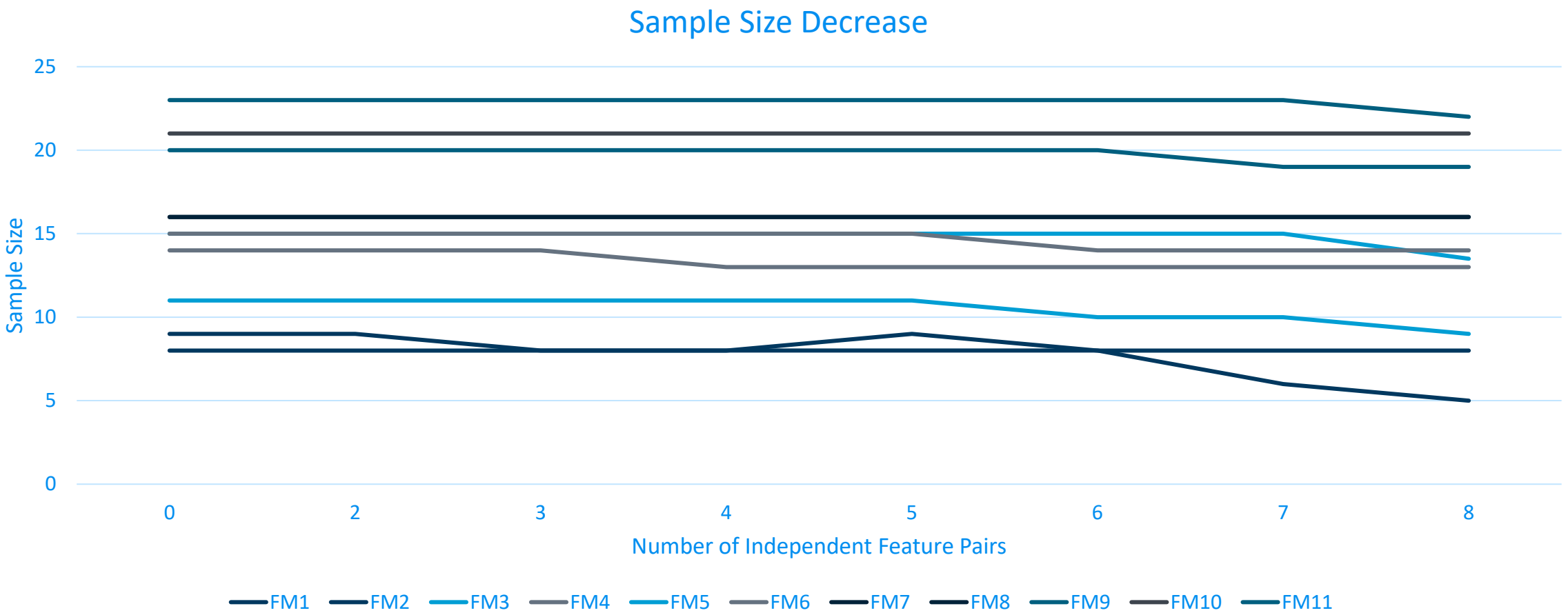
- Connects at least 2 up to arbitrary many features
- Might also denote that child features are independent
- Does not affect on the configuration space
- **Effect: Independent features don’t have to be sampled in combination.**

Syntax and Semantics of an Independent Feature Edge

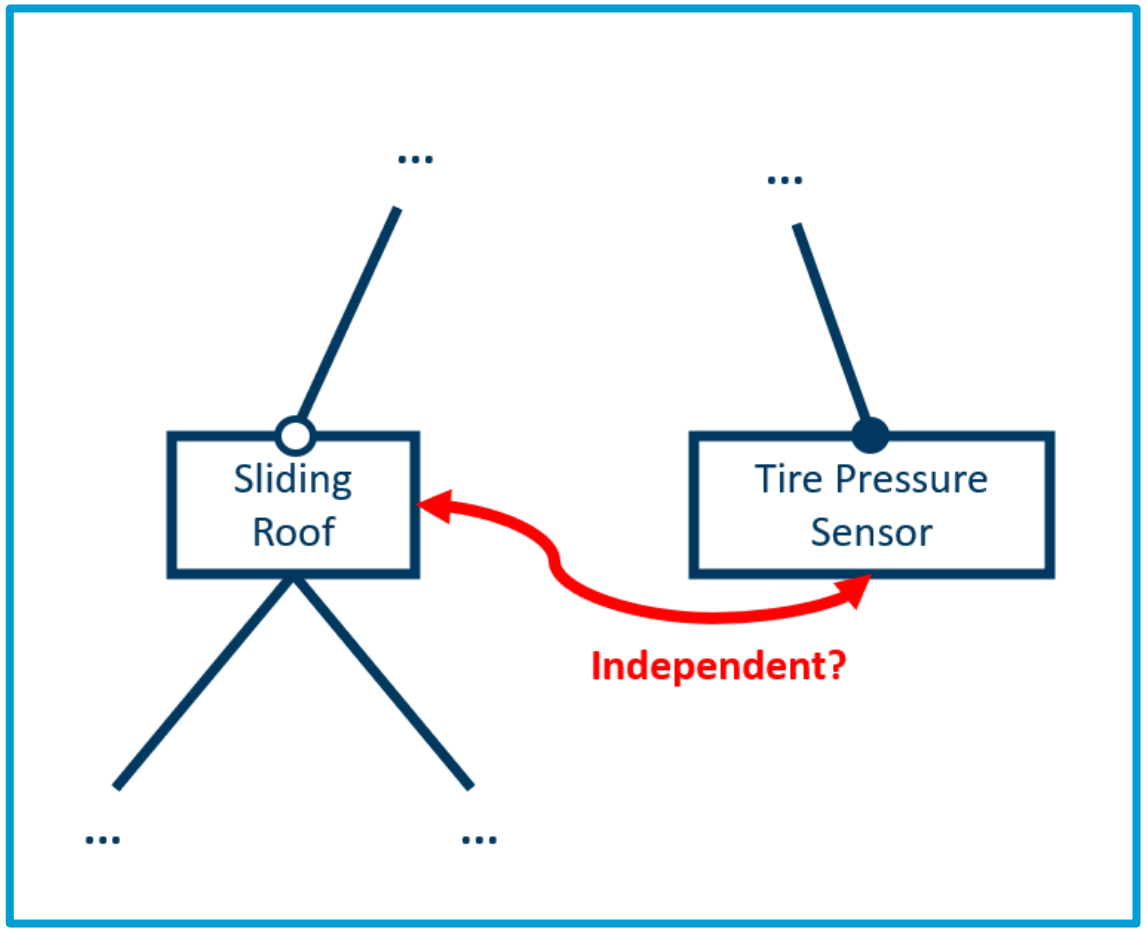


- Already (kind of) supported by YASA
- **Not yet expressible in feature models**
- Enable modelling the partial quantum tomography problem as a feature model
- Enable fine tuned testing with smaller samples

Preliminary Evaluation Results

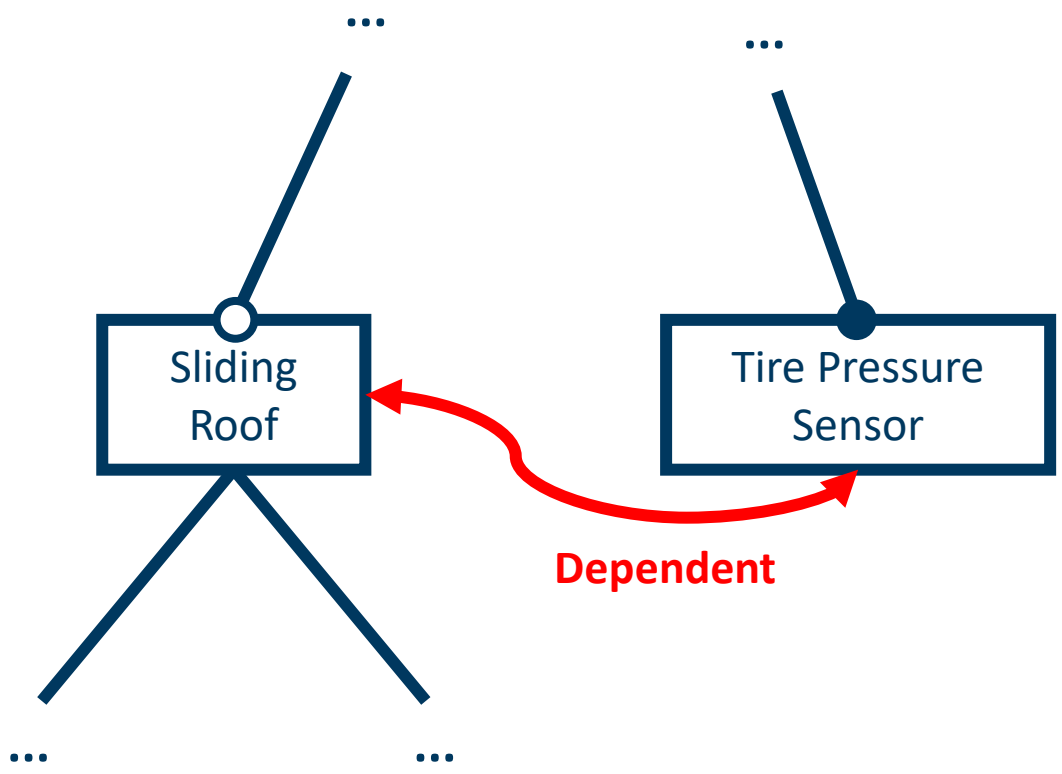


How to determine Independent Feature Edges?



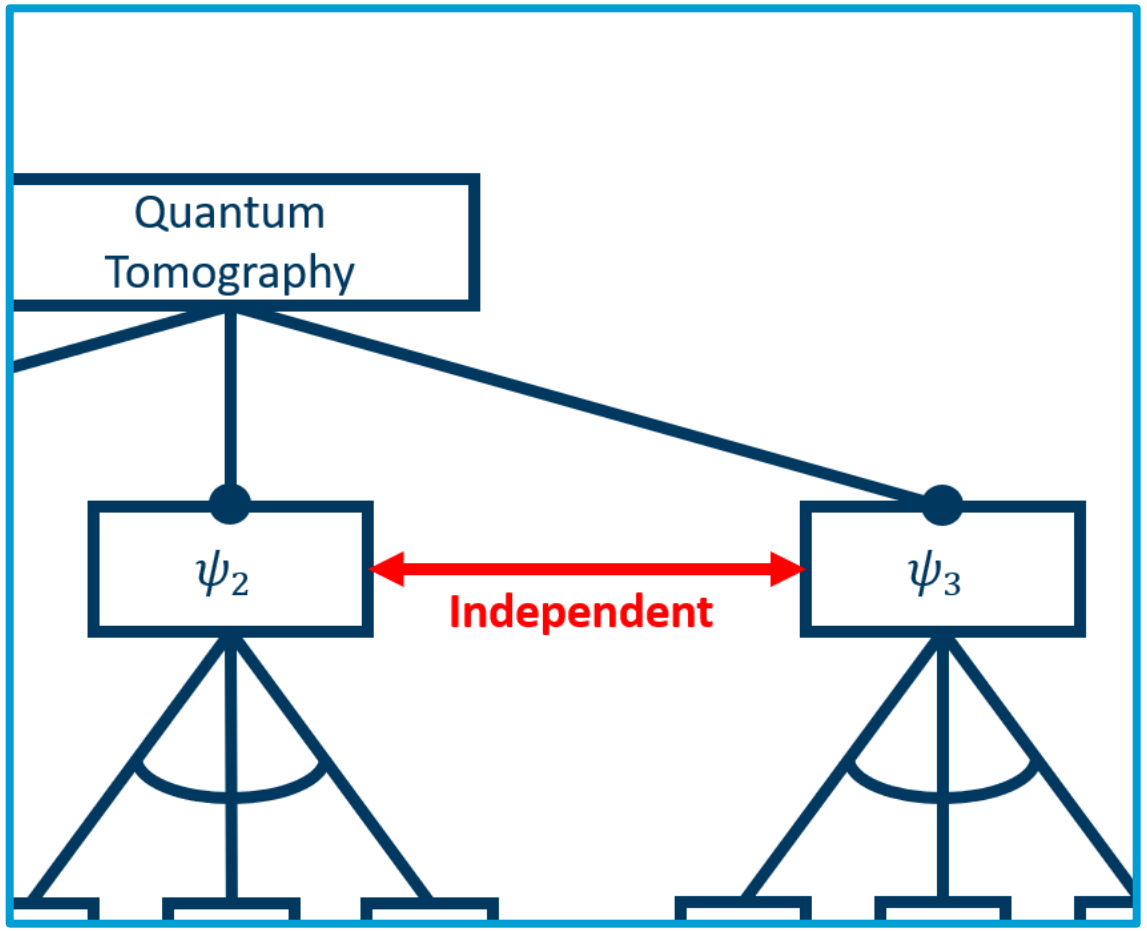
- For SPL: Requires knowledge about the implementation
  - ➢ Utilize domain experts
- Recommend feature pair based on:
  - Distance in feature model
  - Commit History
  - ...
- Annotate dependencies explicitly

Additional Edge Type “Dependent Feature Edge”



- Explicitly denote that two features interact in the implementation
- Fully capture knowledge of which feature combinations might be dispensable and which ones are not
- What additional feature edges might be helpful...?

Summary and Conclusion



- Extensions to feature models are required to model problems like **partial quantum state tomography** as feature models
- We propose introducing **feature edges** specifying which feature combinations are dispensable
- **Capture domain knowledge** within the feature model which can be utilized to obtain smaller samples

Backup Slide

Sample Time

	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11
0	1	3	7	29	33	89	88	359	678	708	828.5
2	1	3	7	28	33	88	87	359	675	715	827.5
3	1	3	7	28	33	89	87	357	677	711	827
4	1	3	6	28	33	88	87	357	677	713.5	825
5	1	3	6	28	32	89	88	355	669	717	826
6	1	3	6	27	32	84	86.5	353	667.5	706	820
7	1	3	6	27	32	85	88	352	665	700	811
8	1	3	6	26	29	83	86.5	350	665	701	811