

“

Nature isn't classical, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look easy.

Richard Feynman



Bill Wisotsky, Principal Quantum Systems Architect



Who we are...

Our Vision *To be the most trustworthy analytics partner on the planet*

Our Mission *To provide knowledge in the moments that matter*

BANKING | CAPITAL MARKETS | COMMUNICATIONS | EDUCATION | ENERGY AND UTILITIES | GOVERNMENT |
HEALTH CARE | INSURANCE | LIFE SCIENCES | MANUFACTURING | RETAIL | SERVICES

12,000+
Global Employees

150+
Countries with
Customers

83,000+
Customer Sites

1976
Year
Established

96%
Annual Customer
Retention



We Are Here!



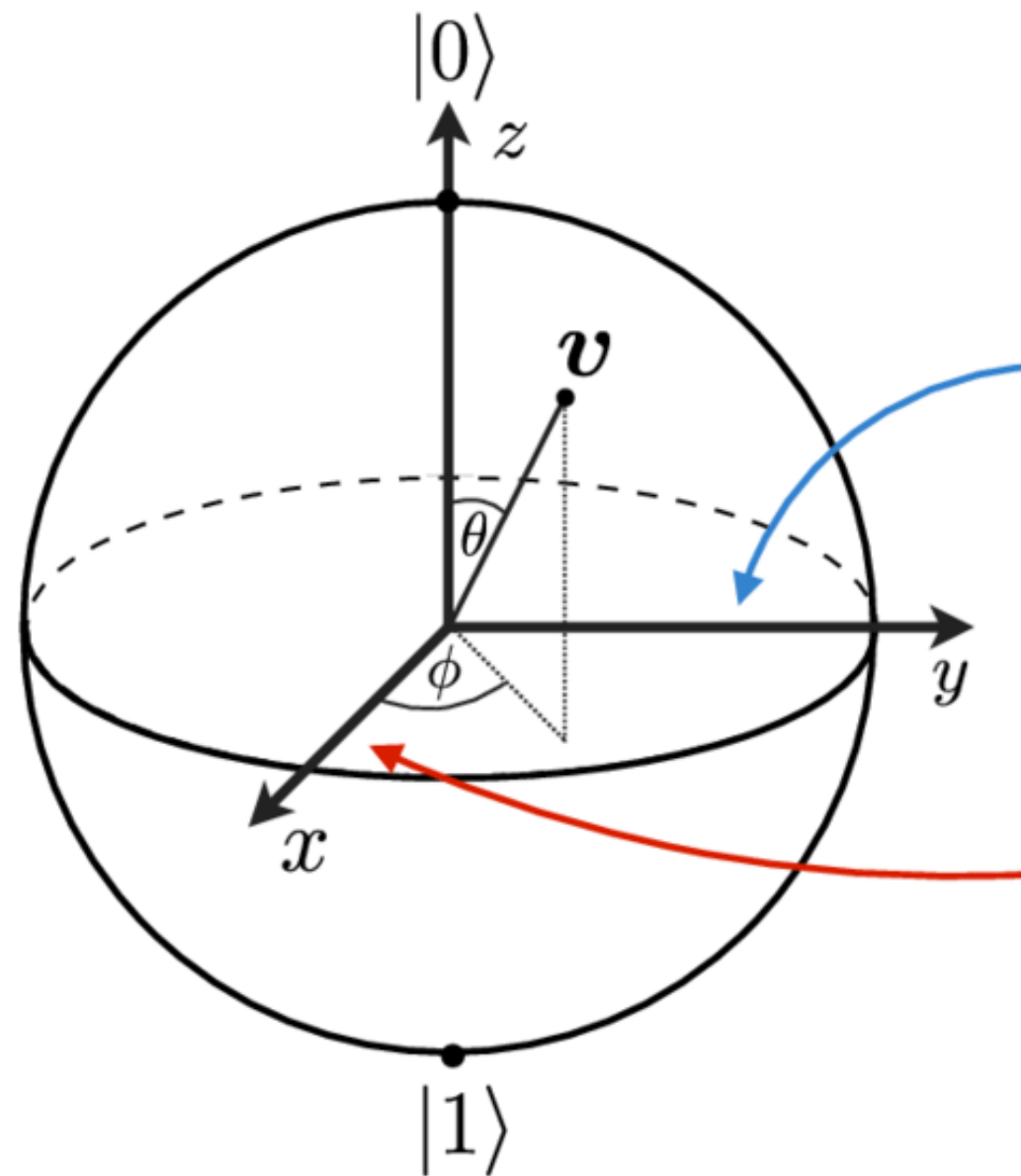
What is Quantum Computing ?

“

If you aren't confused by
quantum mechanics, you haven't
really understood it.

Neils Bohr

The Bloch Sphere



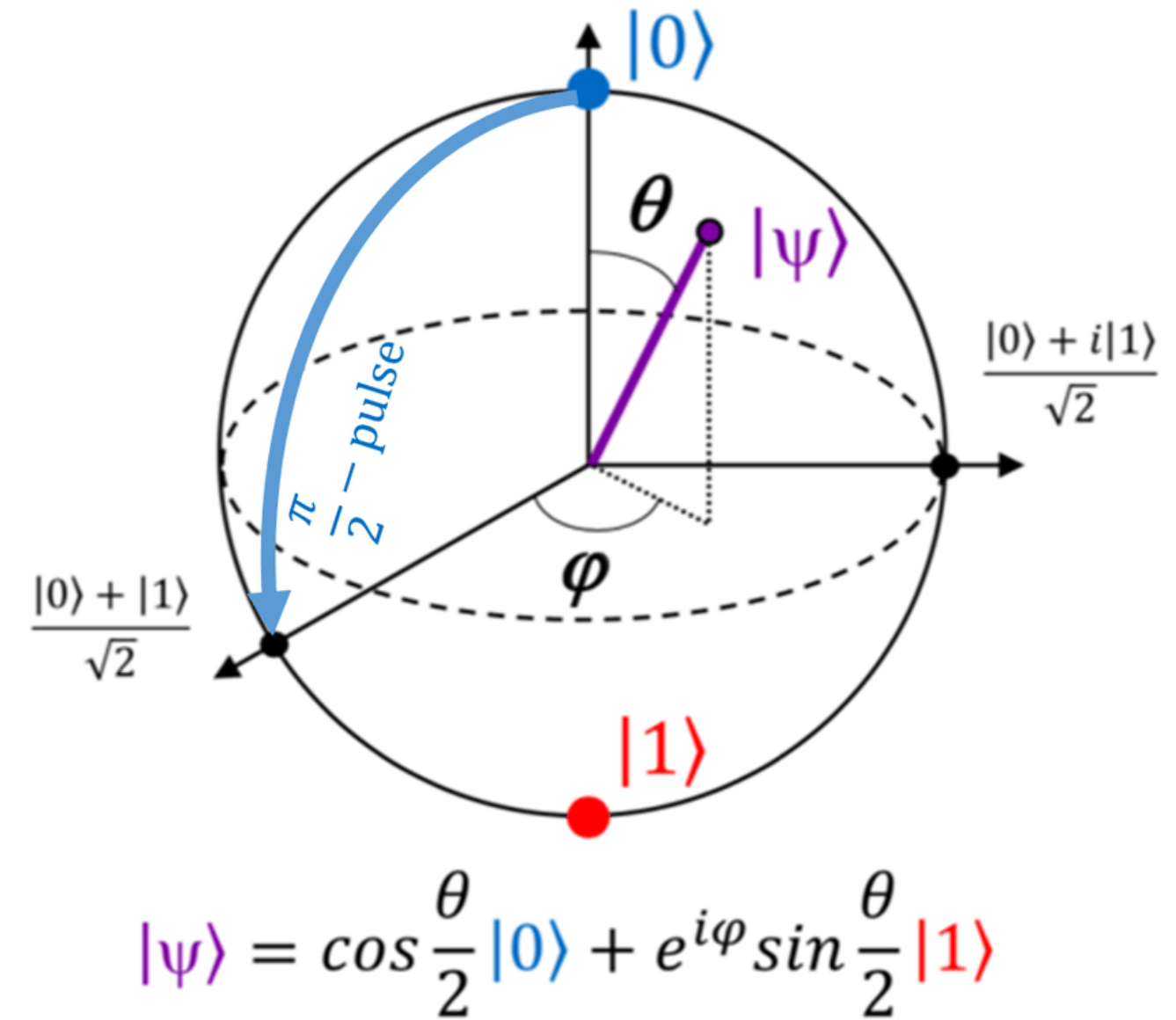
Pole states:

$$|i+\rangle = \frac{1}{\sqrt{2}}(|0\rangle + i|1\rangle)$$

$$|i-\rangle = \frac{1}{\sqrt{2}}(|0\rangle - i|1\rangle)$$

$$|+\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$$

$$|-\rangle = \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle)$$



A **Quantum State** is a **combination** of **three** different **axes**.

Classic bits versus qubits

The qubit state can be both 0 and 1 until measured

Classical bit

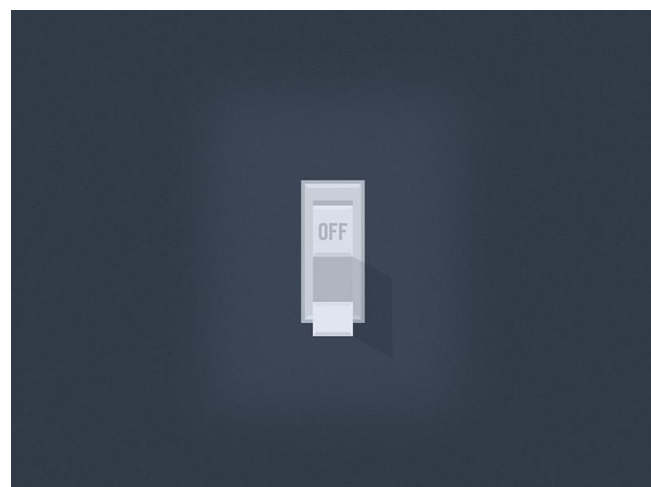
0



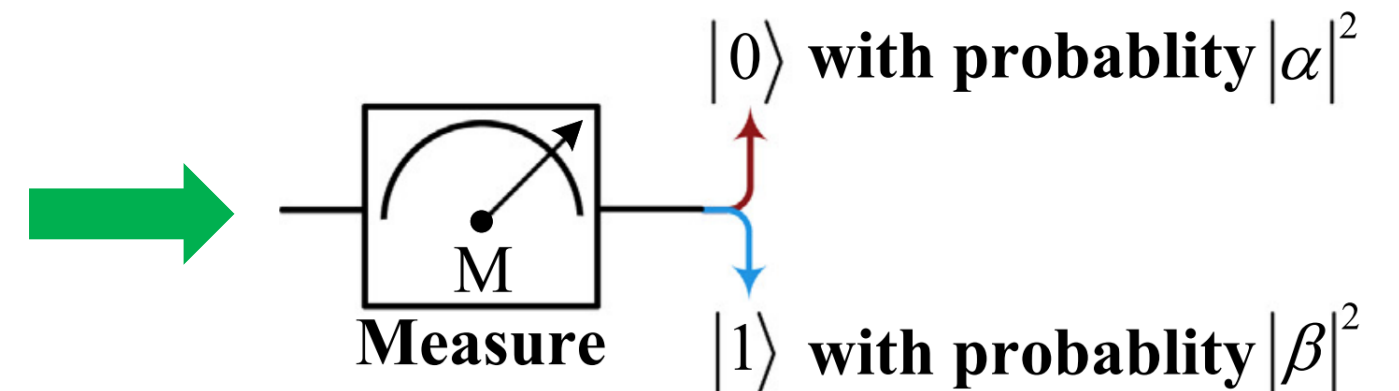
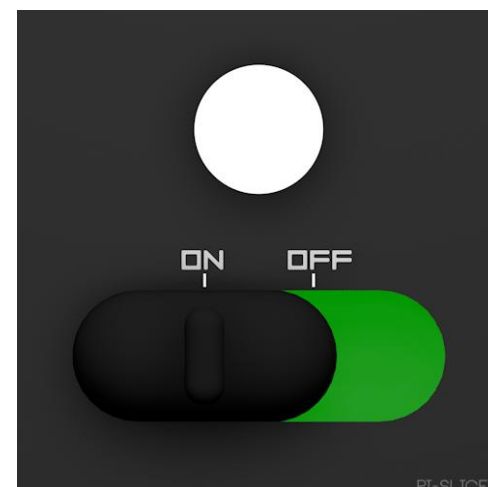
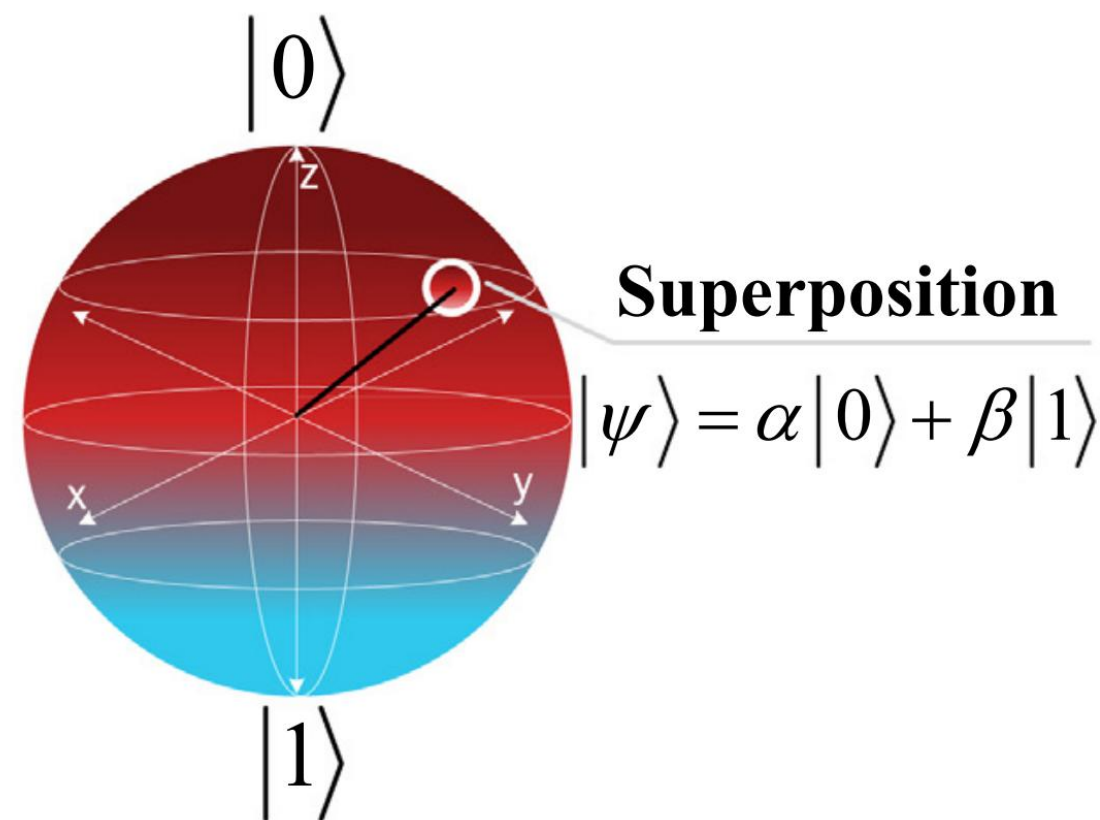
or



1



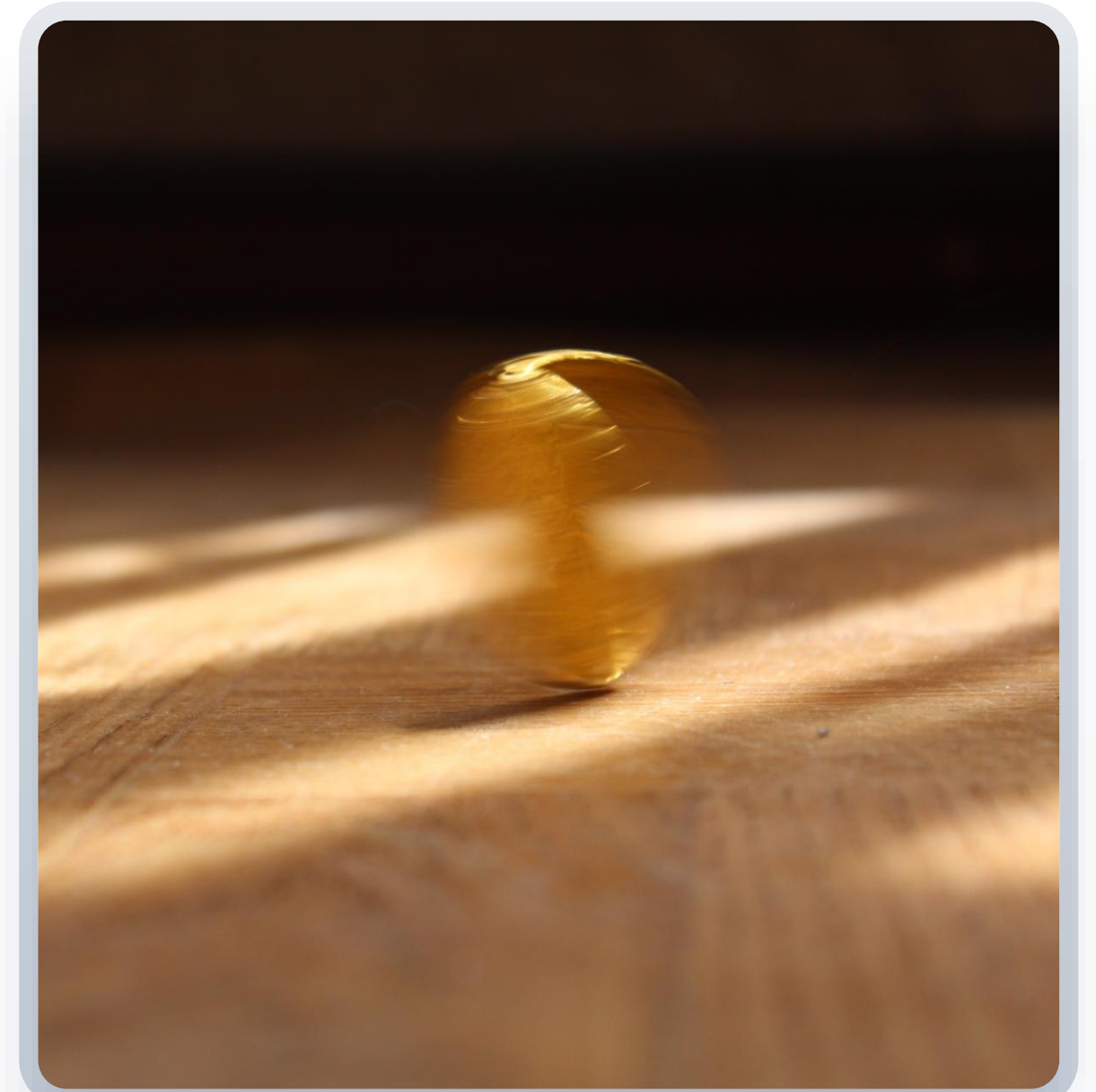
Quantum bit (Qubit)



© Lee Shephard, August 19, 2008.

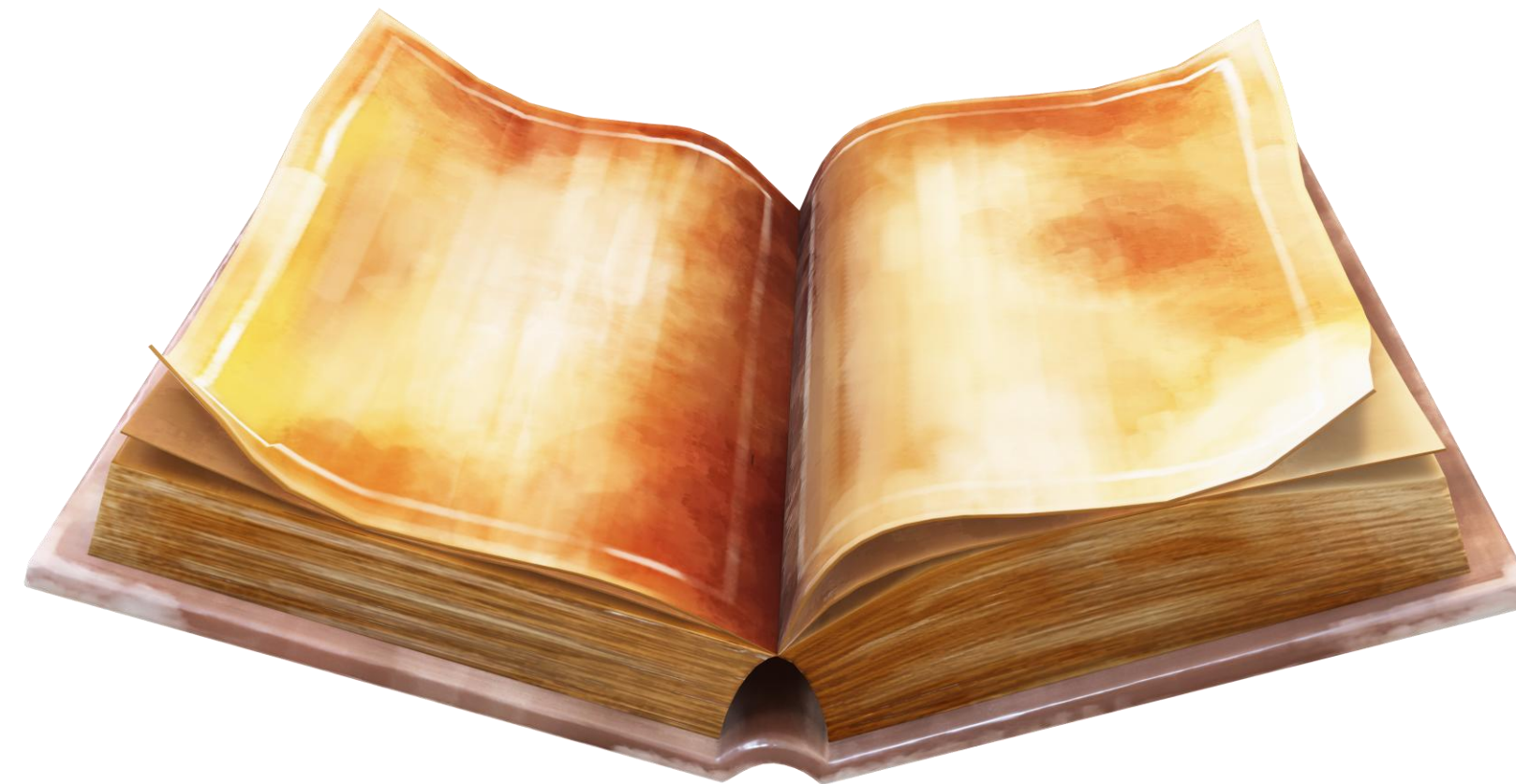
Superposition

Number of Qubits	Simultaneous Computation States (2^n -qubits)
1	2 (1 and 0)
2	4 (00 01 10 11)
3	8 (000 001 010 100 101 110 111 011)



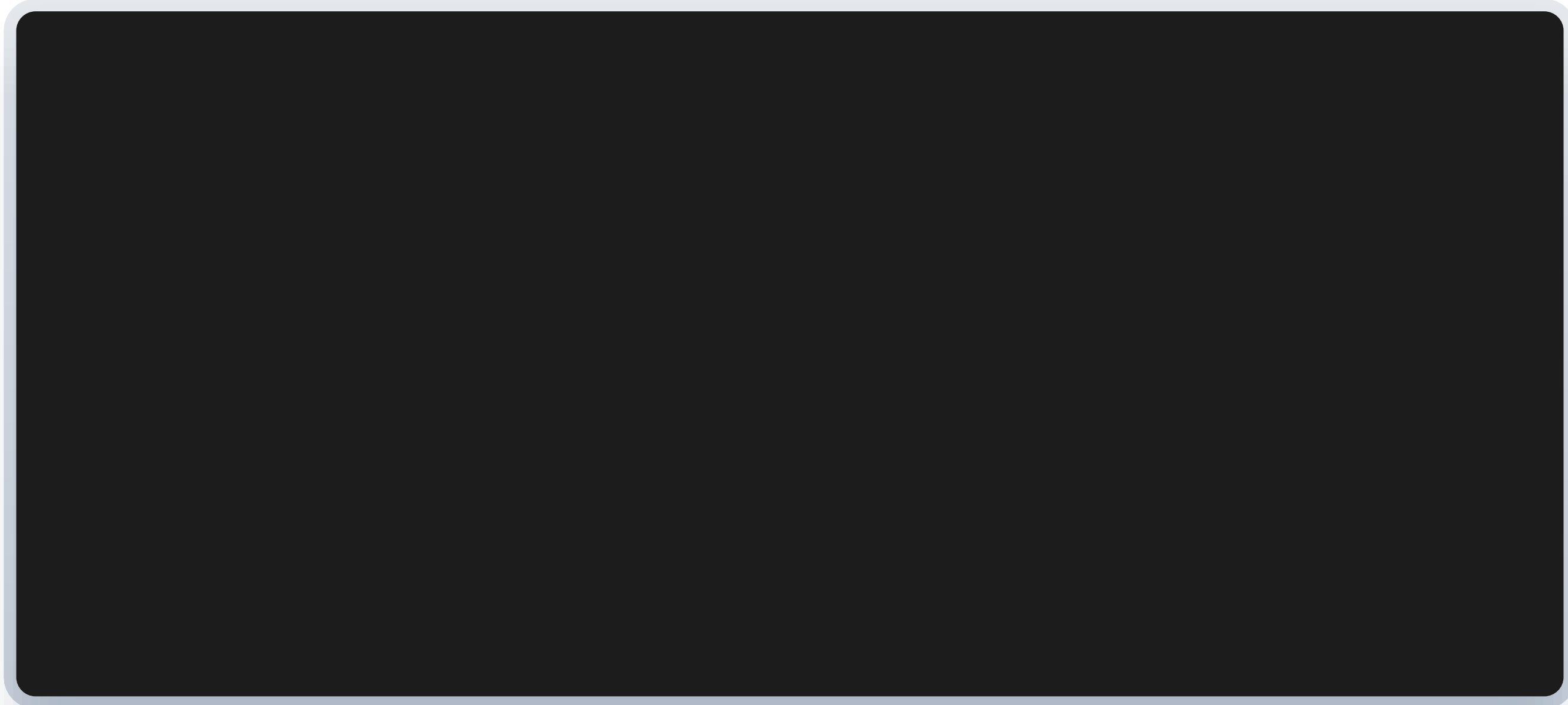
A qubit **isn't just 0 or 1—it's both.**
And, with **each qubit, the state space doubles.**

Quantum Entanglement

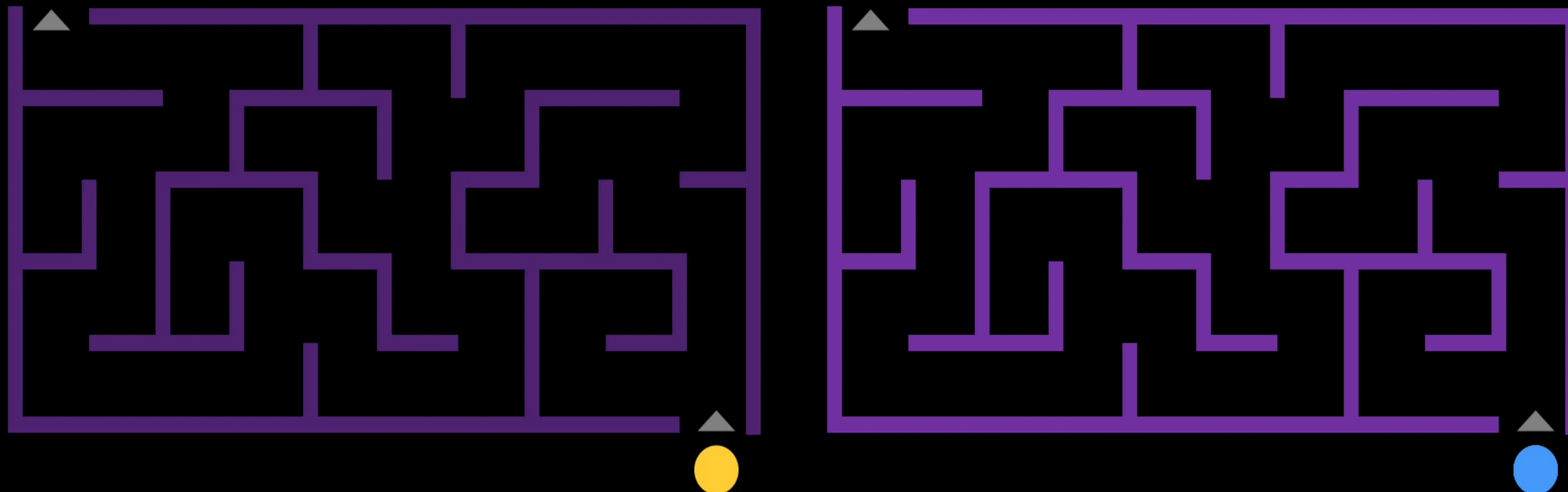


Quantum particles can become **entangled, remaining linked** no matter how far apart they are
“**Spooky action at a distance.**” –Albert Einstein

Quantum Tunneling



In the quantum world, **barriers aren't walls—they're probabilities**



Quantum Computing turns a maze from a **sequence of guesses**
into a **single, parallel exploration**

Approaches to Quantum Computing



Quantum computation is... a distinctly new way of harnessing nature... It will be the first technology that allows useful tasks to be performed in collaboration between parallel universes and then sharing the results.

David Deutsch



Quantum Annealing

- Combinatorial optimization problems
- Use of Adiabatic Method
- Can handle large problems
- Commercial uses today

Quantum Circuits (Gates)

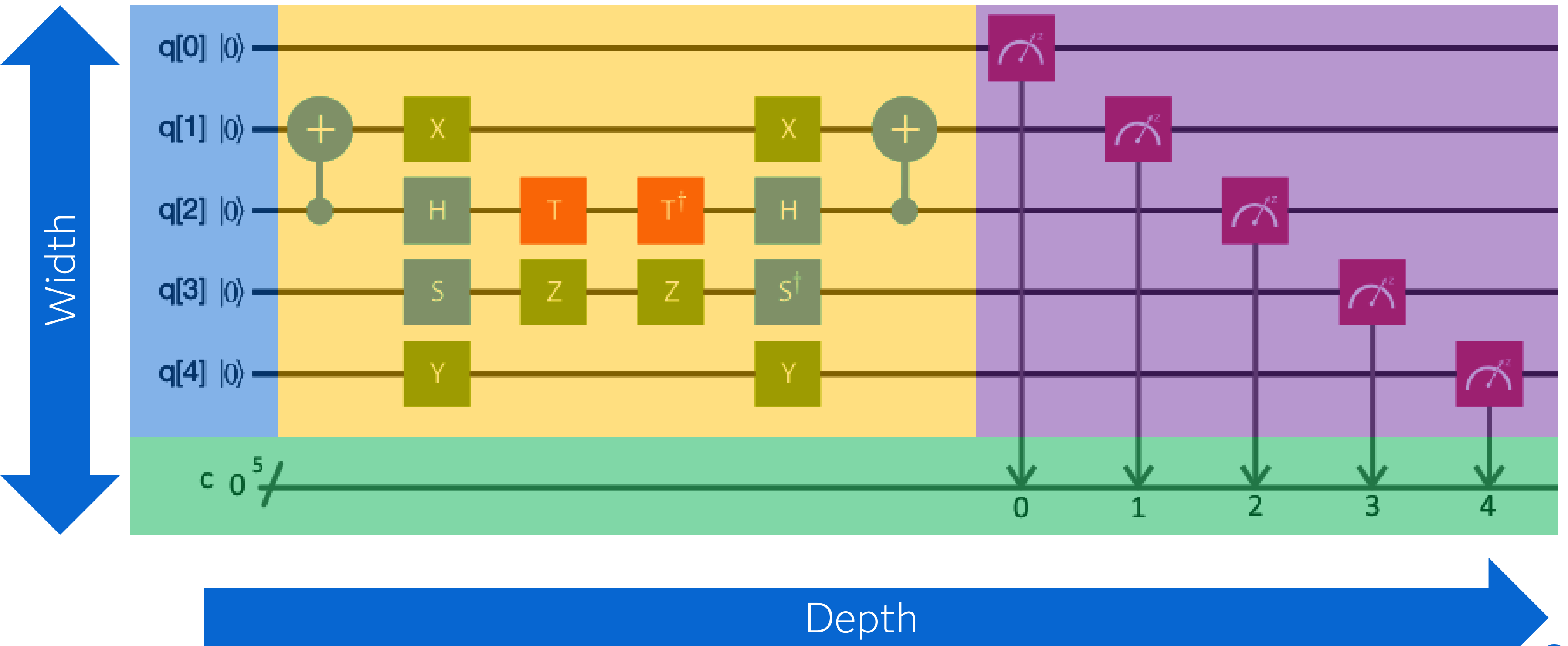
- Universal quantum computing
- Use of circuit and gates
- Need fault tolerance and error mitigation

Topological Quantum Computing

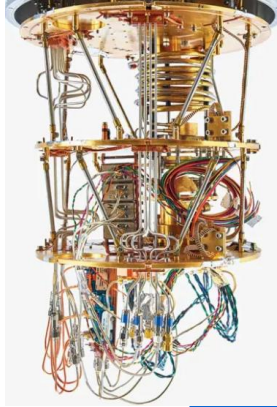
- Very early stages
- Resistant to Errors
- Fibonacci Anyons
- Majorana

Noisy Intermediate Scale Quantum (NISQ)

Anatomy of a Quantum Circuit

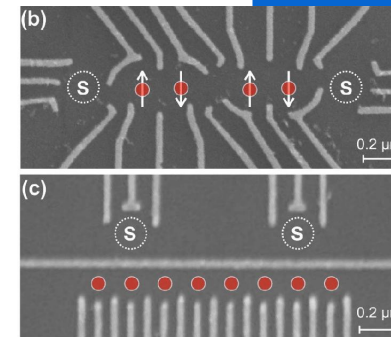


Quantum Computing Modalities



Super-Conducting

- IBM, Google, Rigetti
- Fast Gate Times
- QPU Mapping



Spin Qubits

- Intel, Diraq
- CMOS Fabrication
- High Connectivity



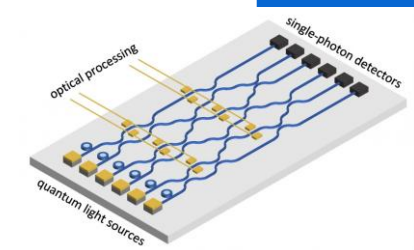
Trapped Ions

- IonQ, Quantinuum
- High Fidelity
- Long Coherence
- All-All Connectivity



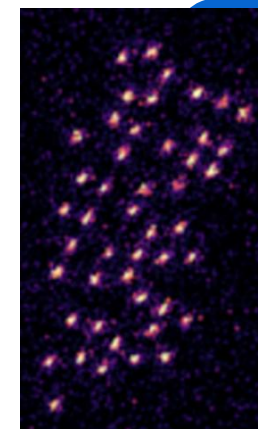
Topological

- Microsoft
- Intrinsic Error Resistant
- Majorana



Photonic

- Xanadu, PsiQuantum
- Room Temperature
- Qudits



Neutral Atoms

- QuEra, Infleqion, Atom
- Room Temperature
- All-All Connectivity
- Optical Tweezers

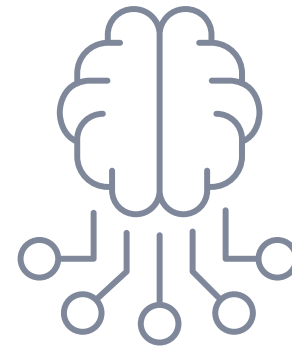
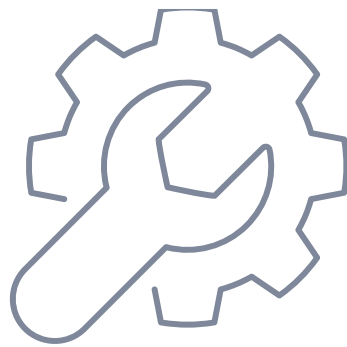
Quantum Use Cases



Many people hear ‘quantum computer’ and think instant world domination. It’s more like a very slow world domination played on a different chessboard.

Peter Shor

Optimization

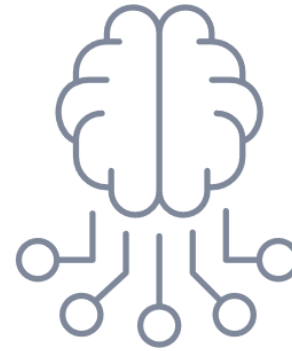


Optimization

- Complex Combinatorial Relationships
- Exponential Large Solution Spaces
 - Routing
 - Scheduling
 - Supply Chain
 - Resource Allocation
 - Others

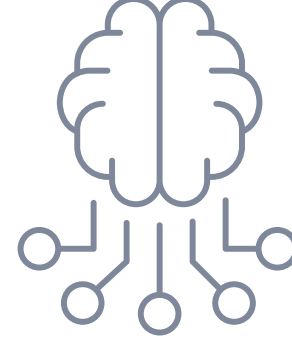


Machine Learning



Machine Learning

- Quantum Kernels
- Feature Spaces
- Generative Models
- Predictive Models
- Hybrid QML
- Expressivity & Sampling
- HHL Linear Equations



Simulation



Simulation

- Drug Discovery
- Material Design
- Protein Folding
- Quantum Science
- HHL Linear Equations
- Quantum Monte Carlo

Quantum Computing in Agriculture

“

Quantum mechanics makes us
rethink every assumption in every
field – from computing to
consciousness.

Seth Lloyd

Optimization Problems

Ration Optimization

- Multi-objective optimization (cost, nutrition, environment).
- Combinatorial explosion at scale.

Feed Supply Chain

- Routing, sourcing, and blending are tightly coupled.
- NP-hard optimization problems.

Resource Allocation

- Competing constraints (land, water, regulation).
- Multi-objective trade-offs limit optimal solutions.

Common challenge: multi-objective, combinatorial optimization at scale.

Learning from Biological Data (QML)

Genomics & Genetic Selection

- Millions of markers → extreme dimensionality.
- Gene interactions → combinatorial explosion.

Precision Livestock & Biosensing

- Continuous, multimodal sensor streams.
- Complex temporal patterns don't scale.

Animal Health & Epidemiology

- Disease spreads on large contact networks.
- Sparse data + large graph complexity.

Common challenge: high-dimensional learning and combinatorial scaling.

Complex Systems (Simulations)

Feed Additive & Molecular Discovery

- Molecular interactions require quantum-level simulation.
- Classical methods scale poorly with system size.

Systems Biology & Flux Analysis

- Thousands of coupled biochemical reactions.
- Parameter estimation is high-dimensional and non-convex.

Microbiome & Gut Ecosystem

- Thousands of interacting microbial species.
- Predicting system response becomes intractable.

Common challenge: large-scale, coupled simulations with poor classical scaling.

Applied Quantum at SAS

Selected Optimization POC Example

Application by Industry



Insurance

Disaster Response
Risk
Montecarlo



Financial Services

Fraud
Bankruptcy
Collateral Optimization
Portfolio Optimization



Healthcare

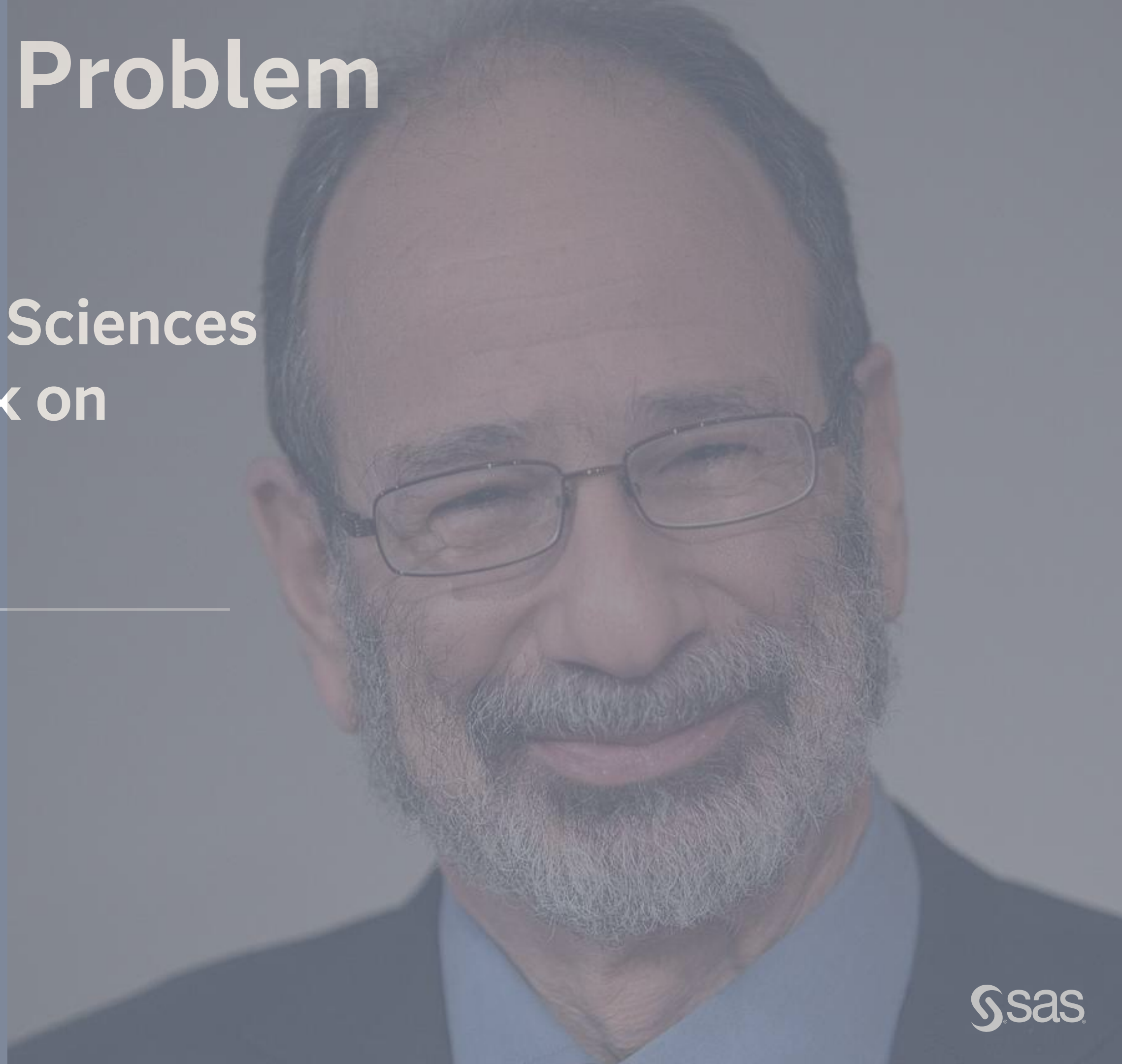
Kidney Exchange
Pharmaceuticals
Image Classification

Digital Twins

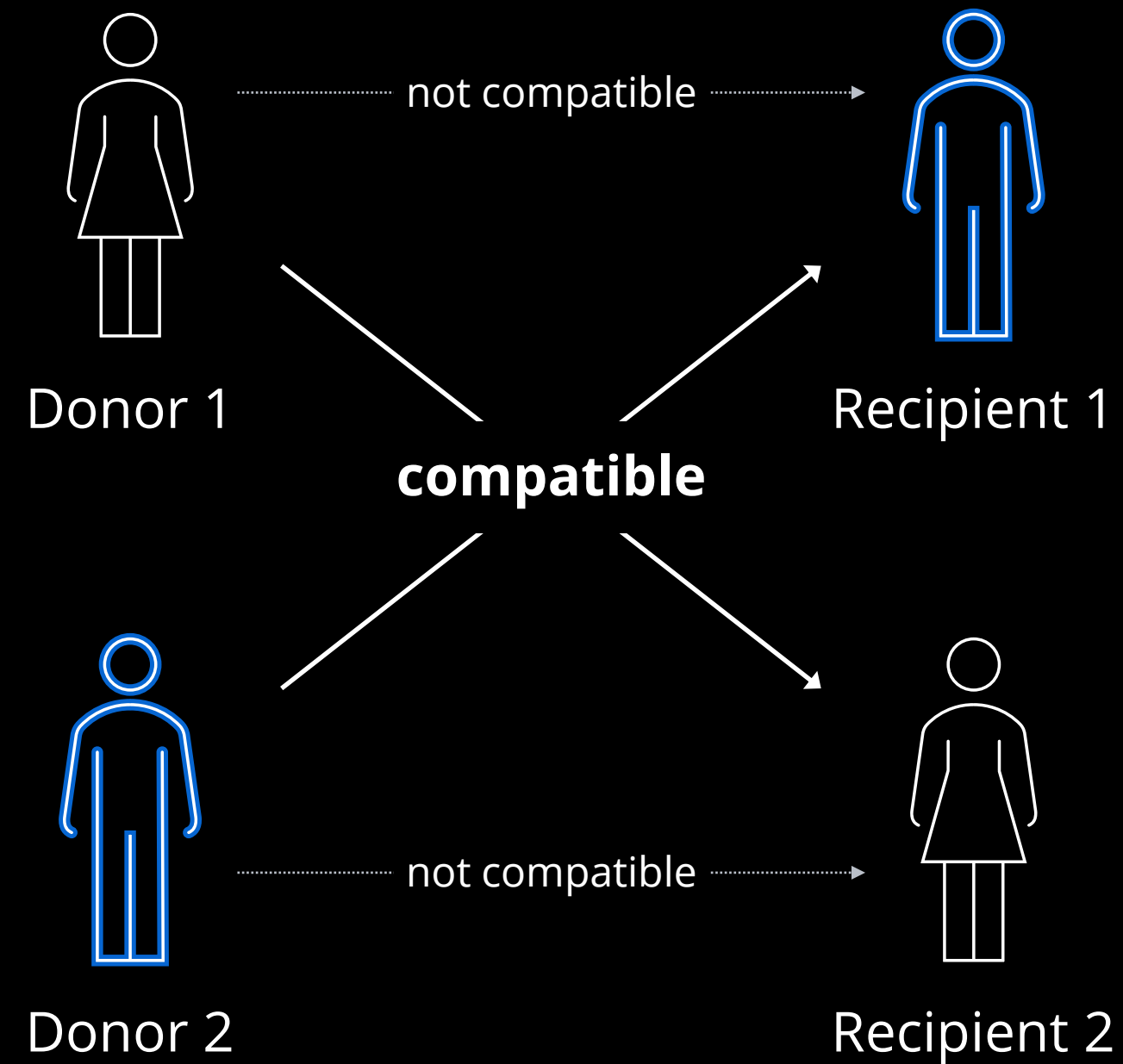
Kidney Exchange Problem

**Nobel Prize in Economic Sciences
in 2012 for applying work on
market design to kidney
exchange programs.**

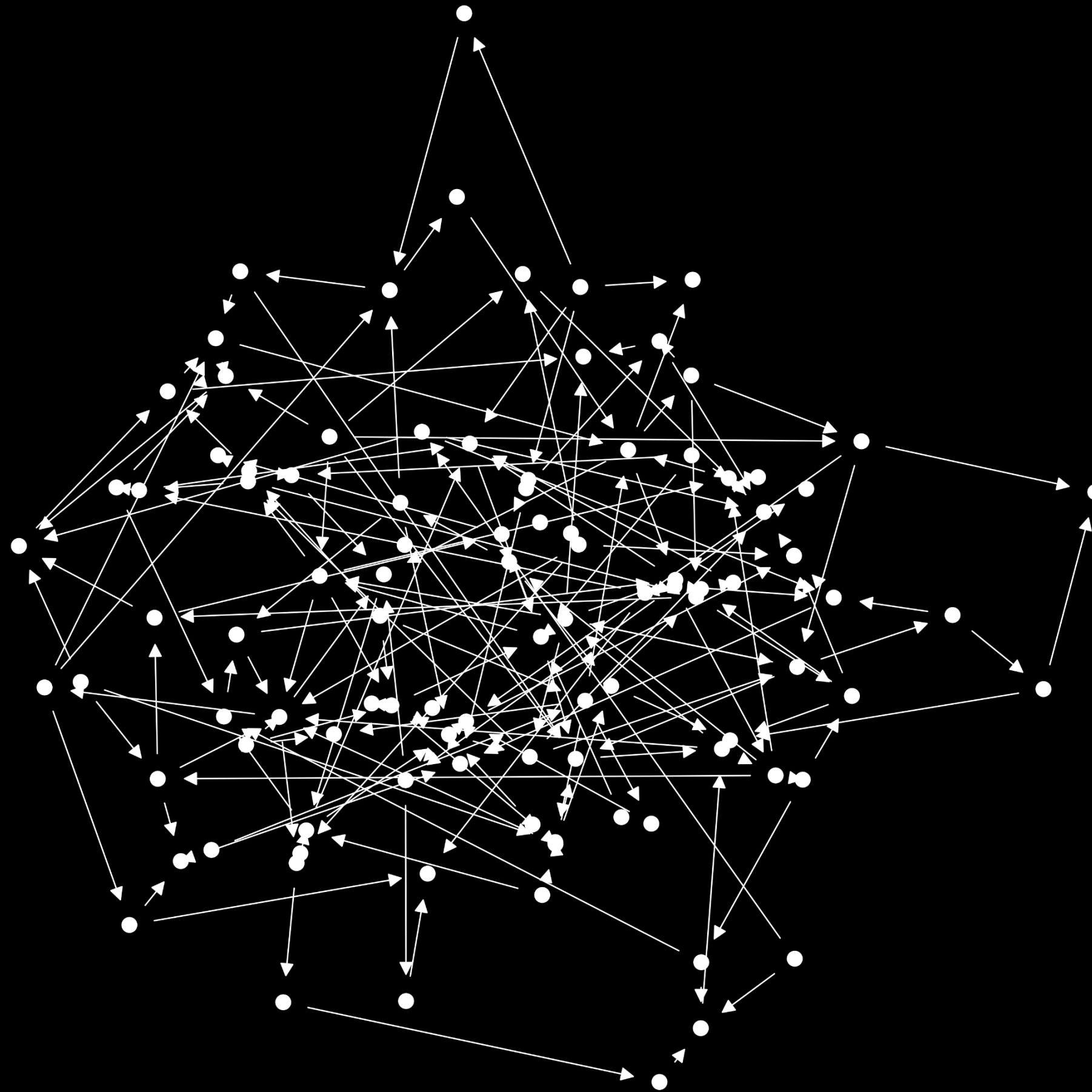
Alvin E. Roth



SOLVING KIDNEY EXCHANGE



SOLVING KIDNEY EXCHANGE



Kidney Exchange Problem – Classical Solve

EXECUTE CLASSICAL SOLVER

maximize

$$\sum_{(i,j) \in A} \sum_{m \in M} w_{ij} x_{ijm}$$

subject to

$$\sum_{m \in M} y_{im} + s_i = 1$$

$i \in N$

(Packing)

$$\sum_{(i,j) \in A} x_{ijm} = y_{im}$$

$i \in N, m \in M$

(Donate)

$$\sum_{(i,j) \in A} x_{ijm} = y_{jm}$$

$j \in N, m \in M$

(Receive)

$$\sum_{(i,j) \in A} x_{ijm} \leq L$$

$m \in M$

(Cardinality)

$$x_{ijm} \in \{0, 1\}$$

$(i, j) \in A, m \in M$

$$y_{im} \in \{0, 1\}$$

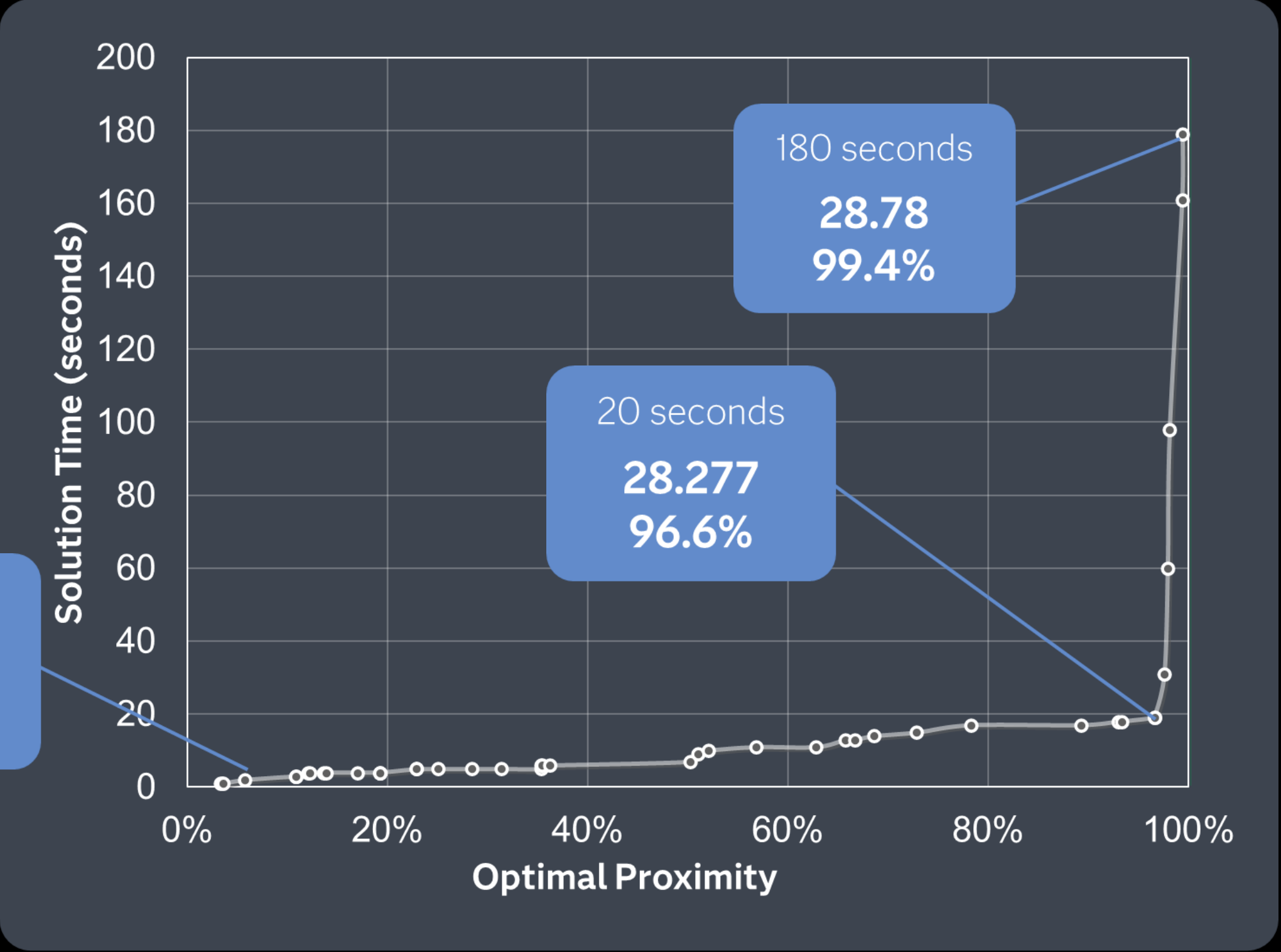
$i \in N, m \in M$

$$s_i \in \{0, 1\}$$

$i \in N$

Classical Solver

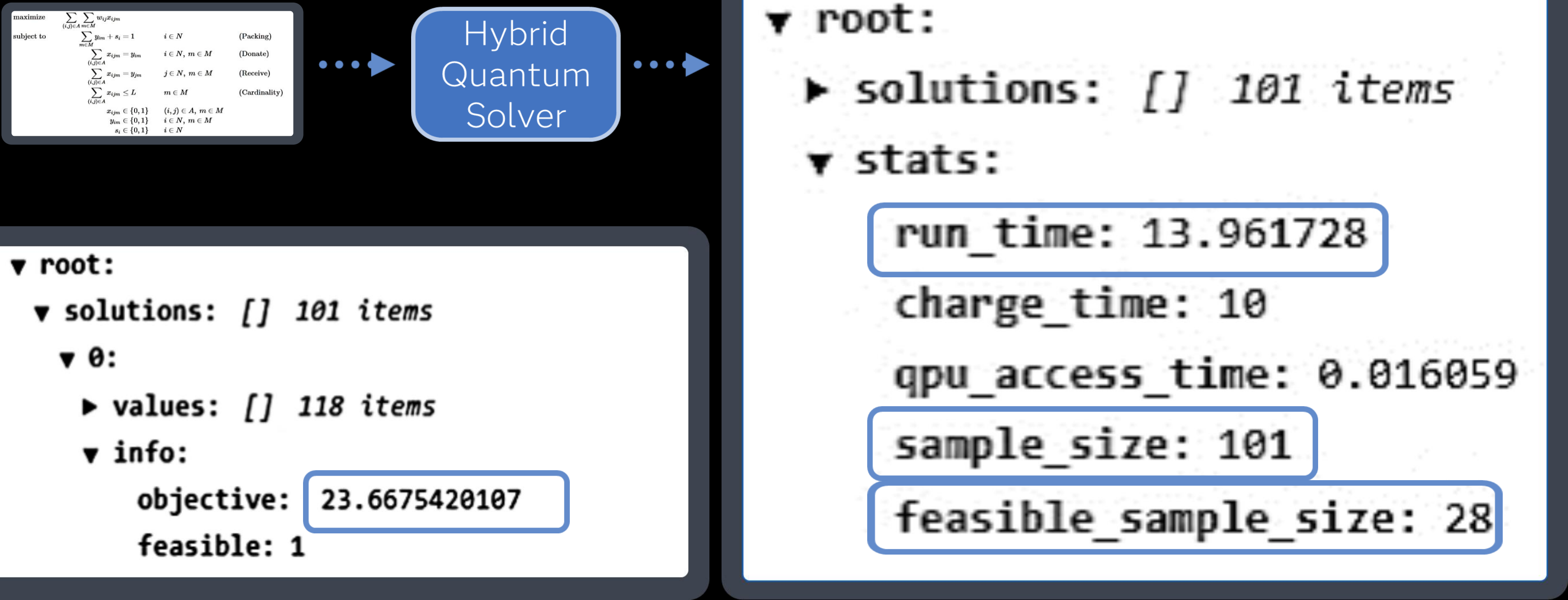
1 second
9.497
3.3%



Getting close to optimal is quick but proving optimality is hard.

Kidney Exchange Problem – Quantum Solve

EXECUTE QUANTUM-HYBRID SOLVER



Quantum gives high-quality solutions fast.

Kidney Exchange Problem – Hybrid Solve

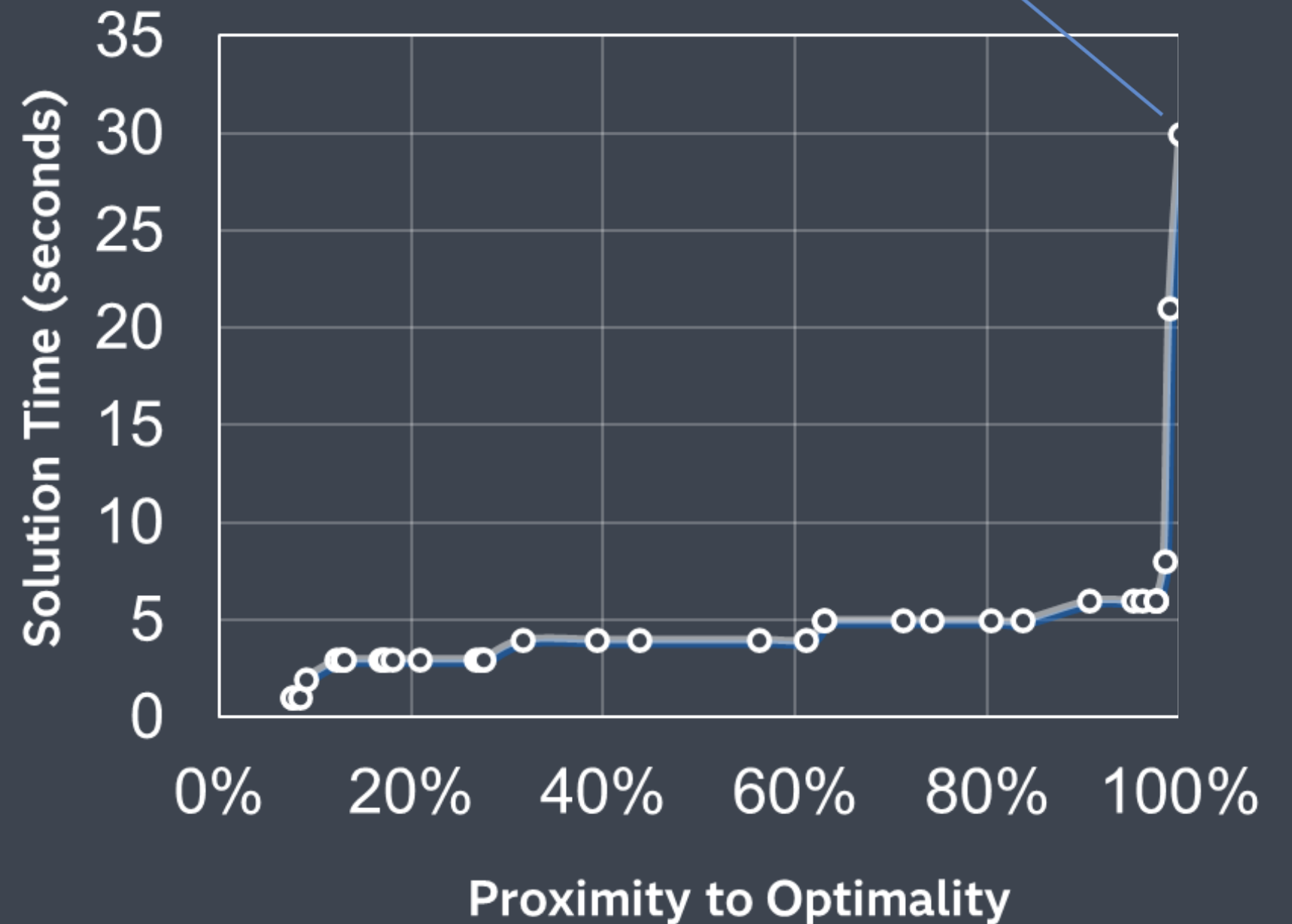
TWO STAGE APPROACH

maximize $\sum_{(i,j) \in A} \sum_{m \in M} w_{ij} x_{ijm}$
subject to $\sum_{m \in M} y_{im} + s_i = 1 \quad i \in N$ (Packing)
 $\sum_{(i,j) \in A} x_{ijm} = y_{im} \quad i \in N, m \in M$ (Donate)
 $\sum_{(i,j) \in A} x_{ijm} = y_{jm} \quad j \in N, m \in M$ (Receive)
 $\sum_{(i,j) \in A} x_{ijm} \leq L \quad m \in M$ (Cardinality)
 $x_{ijm} \in \{0,1\} \quad (i,j) \in A, m \in M$
 $y_{im} \in \{0,1\} \quad i \in N, m \in M$
 $s_i \in \{0,1\} \quad i \in N$

Hybrid
Quantum
Solver

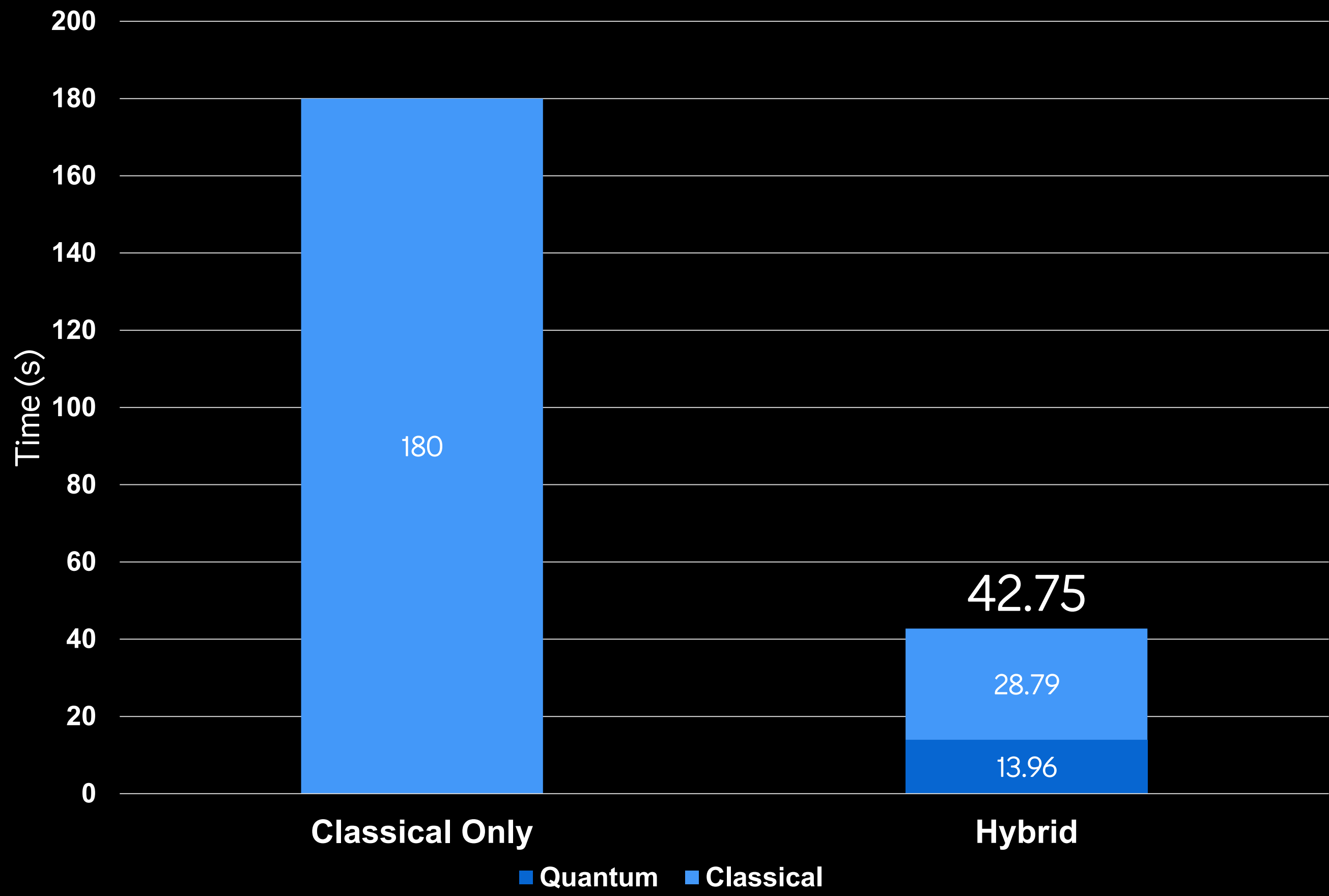
Classical
Solver

```
▼ root:  
  ► solutions: [] 101 items  
  ▼ stats:  
    run_time: 13.961728  
    charge_time: 10  
    qpu_access_time: 0.016059  
    sample_size: 101  
    feasible_sample_size: 28
```



Hybrid combines speed and proof.

Kidney Exchange Problem Comparison



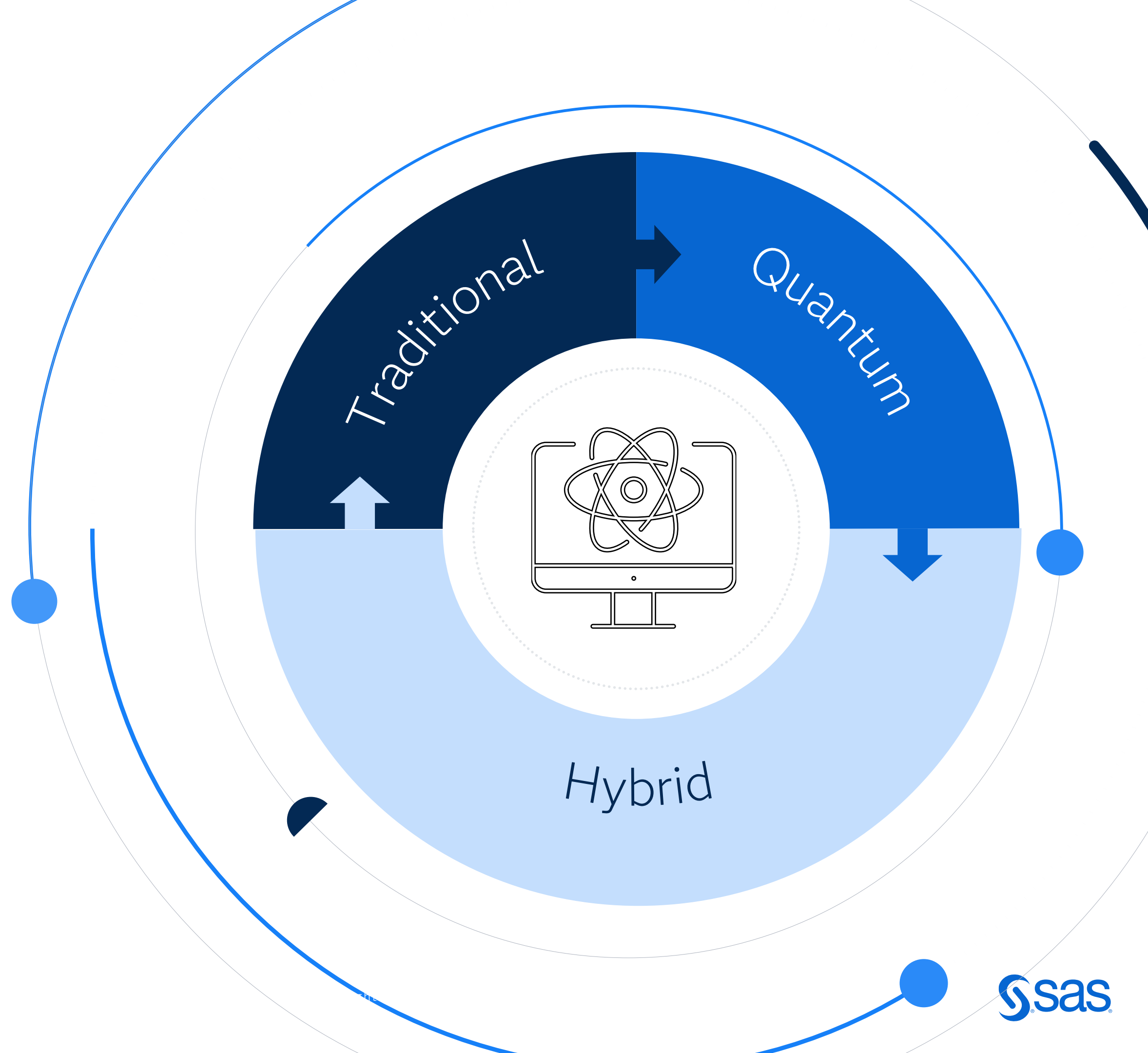
Quantum @ SAS

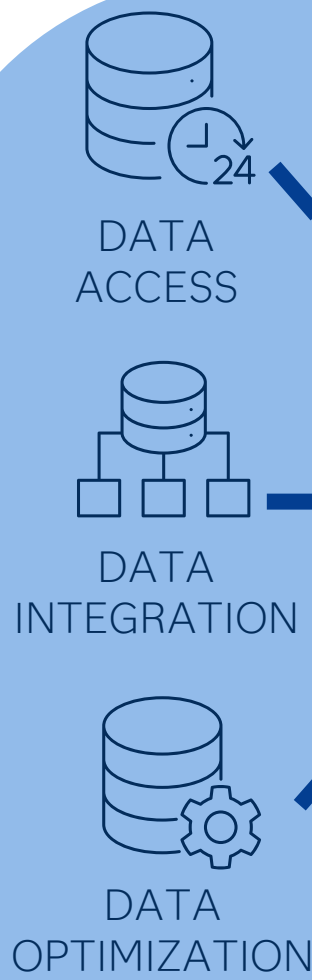
All Roads Lead to Hybrid

Pre-processing
Exploration
Baselines
Post-process

Projections
Data Generation
Feature Selection
Kernels

Hybrid





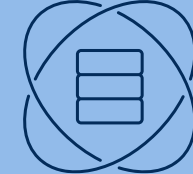
VIEWTABLE: WORK.TRAIN											
	id	member_id	loan_amnt	funded_amnt	funded_amnt_inv	term	int_rate	installment	grade	sub_grade	
1	68407277		3600	3600	3600	36 months	13.99	123.03	C	C4	lead
2	68355089		24700	24700	24700	36 months	11.99	820.28	C	C1	Engi
3	68341763		20000	20000	20000	60 months	10.78	432.66	B	B4	tech
4	66310712		35000	35000	35000	60 months	14.85	829.9	C	C5	Medi
5	68476807		10400	10400	10400	60 months	22.45	289.91	F	F1	Comm
6	68426831		11950	11950	11950	36 months	13.44	405.18	C	C3	Veter
7	68476668		20000	20000	20000	36 months	9.17	637.58	B	B2	Vice
8	67275481		20000	20000	20000	36 months	8.49	631.26	B	B1	road
9	68466926		10000	10000	10000	36 months	6.49	306.45	A	A2	SER
10	68616873		8000	8000	8000	36 months	11.48	263.74	B	B5	Venue
11	68356421		22400	22400	22400	60 months	12.88	508.3	C	C2	Exec
12	68426545		16000	16000	16000	60 months	12.88	363.07	C	C2	Senio
13	68338832		1400	1400	1400	36 months	12.88	471.1	C	C2	Softw
14	66624733		18000	18000	18000	60 months	19.48	471.7	E	E2	Softw
15	68466961		28000	28000	28000	36 months	6.49	858.05	A	A2	Senio
16	68354783		9600	9600	9600	36 months	7.49	298.58	A	A4	tech
17	68466916		25000	25000	25000	36 months	7.49	777.55	A	A4	Sales
18	68577849		18000	18000	18000	60 months	11.99	400.31	C	C1	GS-I
19	68506798		23000	23000	23000	60 months	8.49	471.77	B	B1	Teach
20	68495092		8650	8650	8650	36 months	19.89	320.99	E	E3	Progr
21	68566886		29900	29900	29900	60 months	12.88	678.49	C	C2	Corp
22	68009401		16000	16000	16000	60 months	14.85	379.39	C	C5	Book
23	68476702		28000	28000	28000	36 months	13.44	949.38	C	C3	Direct
24	68436666		5000	5000	5000	36 months	13.44	169.54	C	C3	Genie
25	68476715		6000	6000	6000	36 months	7.49	186.61	A	A4	Anal
26	67849662		4225	4225	4225	36 months	14.85	146.16	C	C5	medic
27	68596180		20000	20000	20000	36 months	5.32	602.3	A	A1	drive
28	68526907		16000	16000	16000	60 months	17.97	406.04	D	D4	Profes
29	68607141		17600	17600	17600	36 months	5.32	530.03	A	A1	Netwo
30	68526883		15000	15000	15000	36 months	5.32	451.73	A	A1	DEP
31	68341789		24250	24250	24250	60 months	24.24	701.01	F	F3	hware
32	68533595		12000	12000	12000	36 months	10.78	391.62	B	B4	Public
33	68415473		25000	25000	25000	60 months	13.99	581.58	C	C4	Exec
34	68537655		16800	16800	16800	60 months	12.88	381.23	C	C2	CEO
35	68446769		7000	7000	7000	36 months	7.49	217.72	A	A4	Comm
36	68467011		21000	21000	21000	60 months	13.99	488.53	C	C4	Rece

sas **viya**

VIEWTABLE: Work.Train											
	PCA_0	PCA_1	PCA_2	PCA_3	PCA_4	PCA_5	PCA_6	PCA_7	PCA_8	PCA_9	IIIIIIIZ
1	29964588.364	-217529.7297	-13349.12079	-7193.036189	-16736.65153	14142.488911	-13296.96302	3056.3448354	-3295.827093	-3696.009058	-0.260000002
2	-16210514.24	126336.88375	-16480.08233	51284.206831	-5474.943606	-19325.69173	5535.2903404	-2639.222961	-11072.63667	-11433.77301	0.0455555618
3	6836396.7397	345032.82963	-831186.54159	-22103.46885	-33011.75566	-17860.04367	19212.108051	26671.537015	-13623.1813	-3930.027299	-0.3033333312
4	-50935389.36	-180789.5163	32706.453959	-3255.49173	-8734.857934	16219.386645	-14063.4133	3043.1189488	5300.085309	4200.051643	0.1266666651
5	-75622542.42	-232090.2077	14228.864884	-30256.49526	7690.797655	6253.0741879	-5889.587426	-1180.058883	8409.872079	-1225.454775	0.1166666672
6	-9426143.427	149770.62899	32622.527825	-23752.2901	-25795.86283	-6034.114124	561.62649473	11106.123164	-5796.637702	-5704.662196	0.1022222266
7	28392633.373	-194156.7762	51166.957786	-11546.75891	-27263.74313	18275.836745	-17017.39522	-1557.00891	-4084.728819	-1807.416123	-0.2966666652
8	31086407.887	478799.43411	-54348.69665	92105.911498	-53862.56734	8784.3105499	8055.7195567	-2766.634783	9761.228595	-15394.29043	-0.3144444453
9	35840654.807	5078.4821575	-53057.25757	-9248.569305	-46784.37952	8289.7943897	-3966.298421	-8712.887323	1000.5396611	1939.0266591	-0.335555553
10	-84857594.72	-45823.48966	-67613.92568	10562.714602	-11802.14337	-9445.395268	-20703.78197	1124.0540683	11469.60885	3092.9709809	0.0922222212
11	-68125161.3	879412.81219	-242901.5227	-161596.8365	-21606.52779	-61462.05378	-27366.76628	39542.583018	6623.1815518	-8604.251354	0.0699999928
12	-42914881.67	-86810.7354	41990.094864	15340.197461	88702.658935	10683.531251	26587.429417	7549.9454415	-1738.68394	5386.1462998	0.1277777702
13	50369455.047	-207057.0454	40539.559431	-19869.75758	-22405.11318	17496.674534	7058.7065311	-1995.965057	9095.0384738	26.00500322	-0.2733333341
14	6563766.0093	-216826.3989	102382.43066	-46648.71615	-20849.07343	21990.117111	-12933.64865	5928.8893002	646.4608049	-5271.467085	-0.3177777763
15	39620537.276	-83677.20033	43500.028496	76907.420795	-29172.66861	14344.115899	-4045.012931	5697.0561758	-7026.816637	9095.509073	-0.3100000002
16	17077377.204	267169.59065	-26789.80415	-62873.51358	27586.773447	1470.8551359	-27856.90873	3388.4860124	-4933.540466	-444.2628273	-0.3233333353
17	-50443848.52	-137921.8055	-10815.73558	67057.394935	-17069.21333	-437.5553511	8169.6917308	6937.8446525	-332.8075574	-5776.552883	0.086666666
18	-58718622.09	223846.7944	-46373.12501	-25245.06067	115773.9858	-22194.14306	2090.3798879	17674.94652	-7602.918057	552.93219918	0.0922222212
19	45266381.549	331718.83676	-103370.3759	137976.97051	219454.68667	-2005.697065	-47328.74108	-70896.84087	-34146.97776	17326.950008	-0.308888882
20	-64589159.96	61744.625804	-18798.1562	-17077.50296	-38481.76317	12952.10728	2960.5691449	4651.611205	1250.408763	2718.5962229	0.0633333325
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22	-79209971.84	5736.1506683	-30214.67294	-15766.76509	-4668.747577	4345.7236333	-8518.753102	2852.2565388	8494.2448737	-819.2865243	-0.1000000015
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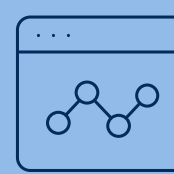
DATA MINING



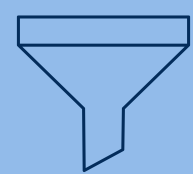
DATA SCIENCE



DATA TRANSFORMATION



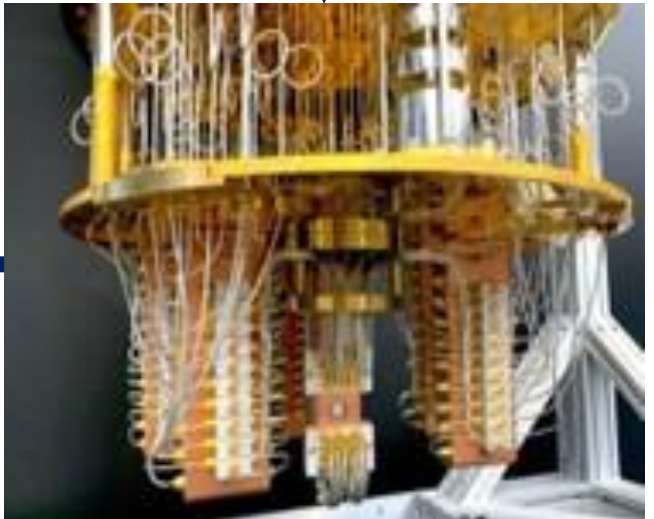
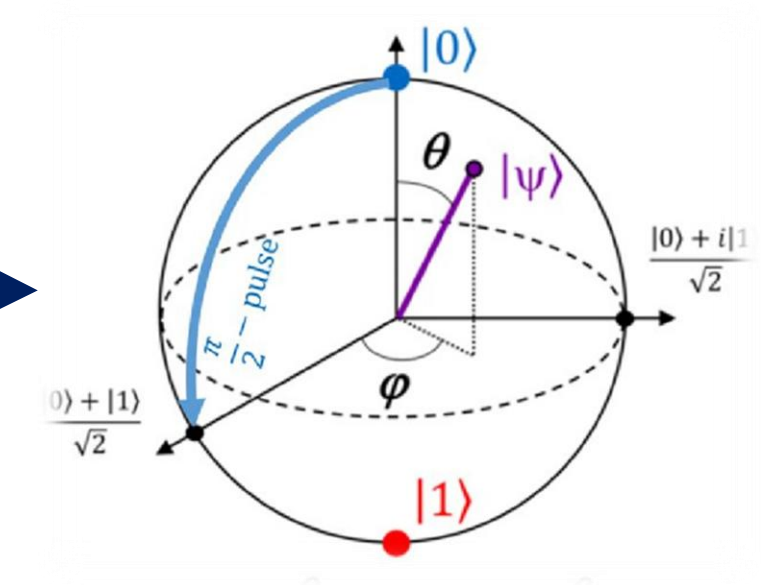
REPORTING



DATA FILTER



DATA VALIDATION



SAS Quantum Lab

SAS Language
Existing PROCS

Quantum Algorithms
Complex Quantum Circuits



Let's Chat?



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