Control and readout of qubits using FPGAs

from https://www.xilinx.com/products/boards-and-kits/zcu111.html

Integration of QICK-supported platforms in qibolab

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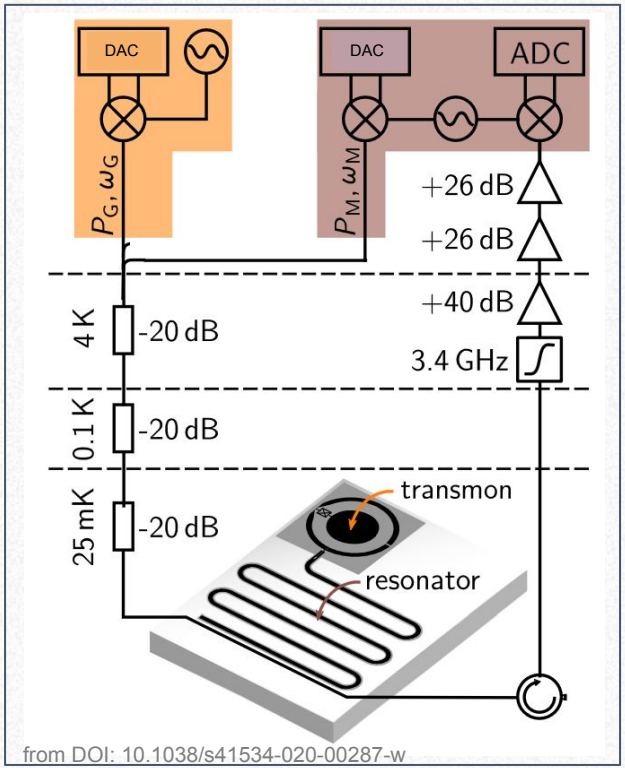
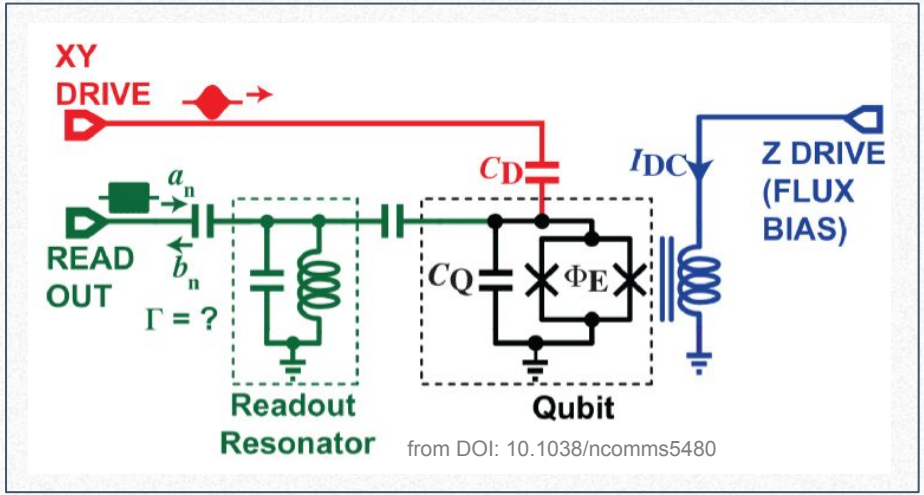
Control and readout of superconducting qubits



from DOI: 10.1038/s41534-020-00287-w



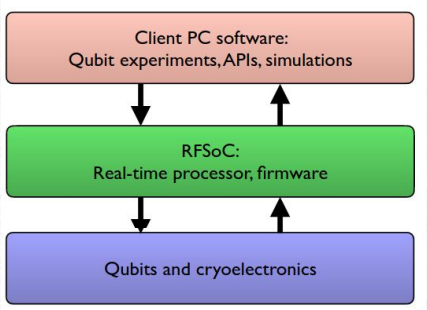
from DOI: 10.1038/ncomms5480

Available RFSoCs (QICK supported)

	# ADC	# DAC	Gen	DAC sampling rate	Currently used by
RFSoC4x2	4	2	3	9.85 GSPS	UNIMIB, TII
ZCU111	8	8	1	6.55 GSPS	UNIMIB, TII
ZCU208	8	8	3	10 GSPS	LNF
ZCU216	16	16	3	9.85 GSPS	Fermilab (QICK)

QICK integration in Qibolab

The QICK (Quantum Instrumentation Control Kit)
DOI: 10.1063/5.0076249



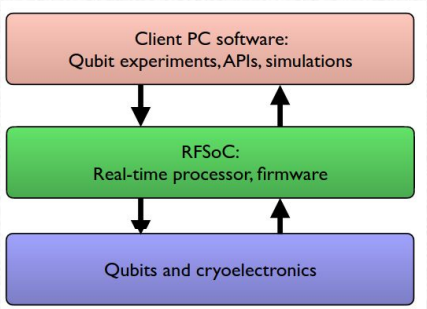
QICK

Processing system (PS)
Programmable Logic (PL)

QICK integration in Qibolab

The QICK (Quantum Instrumentation Control Kit)
DOI: 10.1063/5.0076249

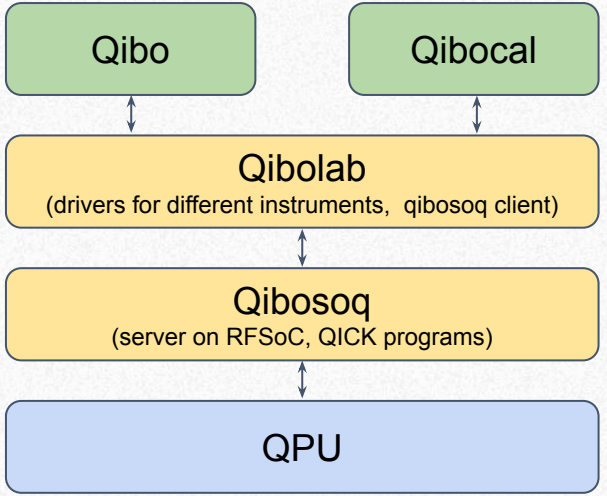
Qibolab - Qibosoq



QICK

Processing system (PS)
Programmable Logic (PL)

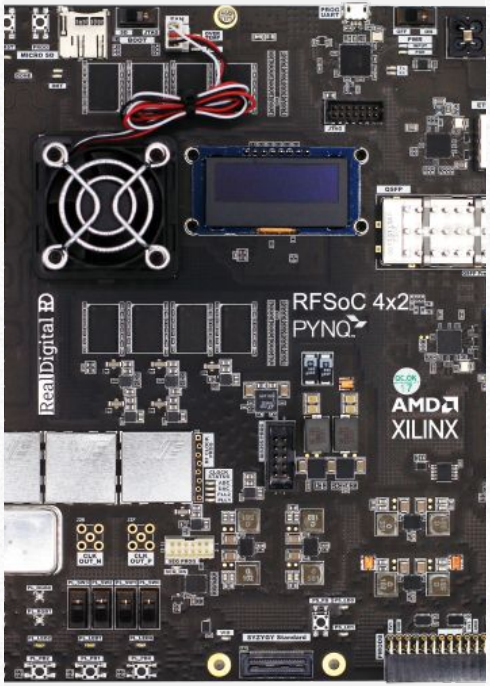
QIBO (a framework for quantum simulation)
DOI: 10.1088/2058-9565/ac39f5



Main characterization and calibration routines

	Main parameter obtained	Routine
Resonator spectroscopy	Resonator frequency	Single tone measurement at different frequencies
Resonator punch-out	Dispersive shift, optimal readout power	Single tone measurement at different frequencies and amplitudes
Qubit spectroscopy	Qubit frequency	Drive pulse at different frequencies followed by measurement at resonator frequency
Rabi (length, amplitude)	Optimal PI pulse parameters (gate X)	Drive pulse with different length/amplitude, measurement
Ramsey	T2	Double drive pulse (PI/2) with different delay between them, measurement
T1 experiment	T1	Pi pulse, different delay, measurement
Calibrate qubit state	Threshold and angle for discrimination	Preparation of N states 0 and N states 1
ALLXY	Analysis on characterization and detuning	Execution of all two gates combination with gates among {I, X, Y, X/2, Y/2}

1 non-flux-tunable qubit driver (RFSoC4x2)



from https://www.xilinx.com/support/university/xup-boards/RFSoC4x2.html

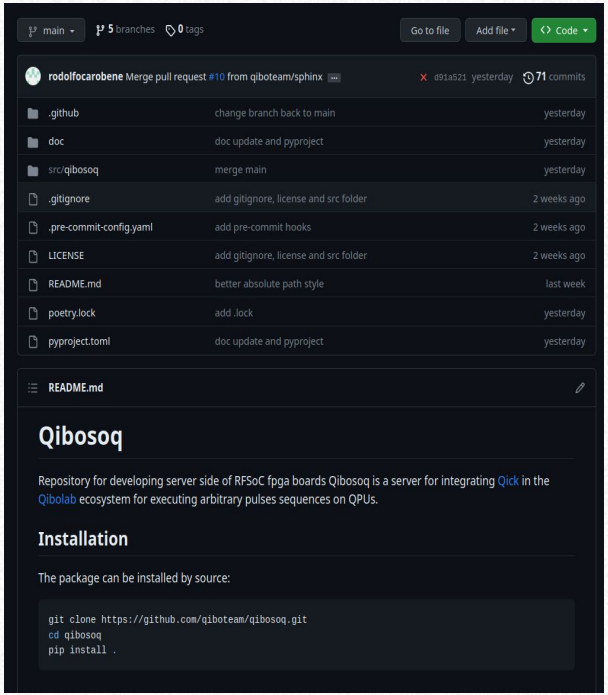
Board features

- Generation 3
- Zynq Ultrascale+ RFSoC XCZU48DR-1FFVG1517E

- 4 RF ADCs
- 2 RF DACs (9.85 GSPS)

- Available only for academics

1 non-flux-tunable qubit driver (RFSoC4x2)



from https://github.com/qiboteam/qibosoq

Driver features (qibosoq version 0.0.1) :

- Support for all qibocal calibration routines (with no flux dependance)
- Support for arbitrary circuits execution
- Support for arbitrary pulse sequences execution

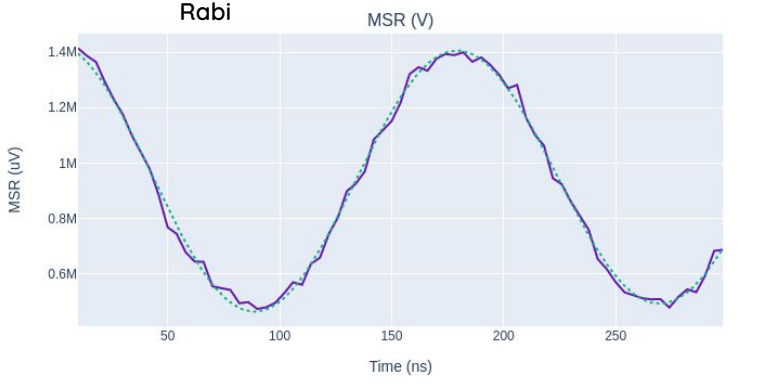
- Fast sweeps of pulses amplitude and frequency (useful for calibration purposes)

Features still to implement

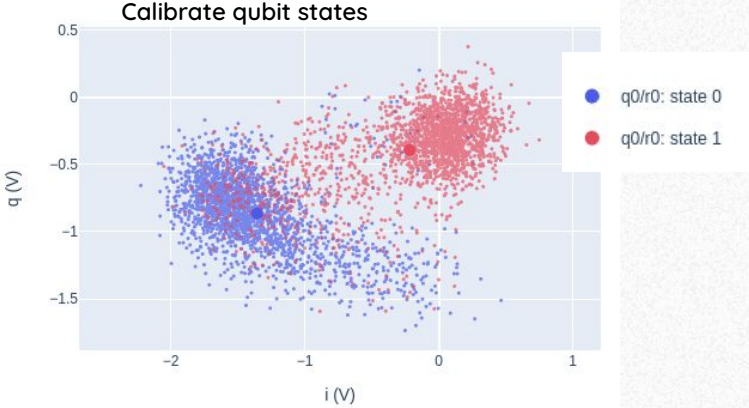
- Fast sweeps of pulses phase and duration
- Fast reset

1 non-flux-tunable qubit driver (RFSoC4x2)

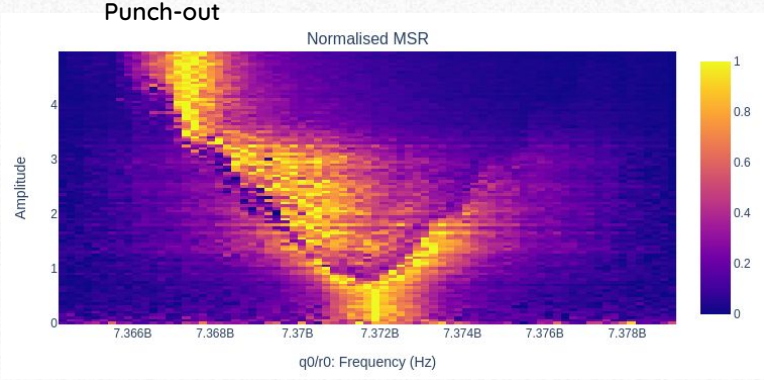
Rabi



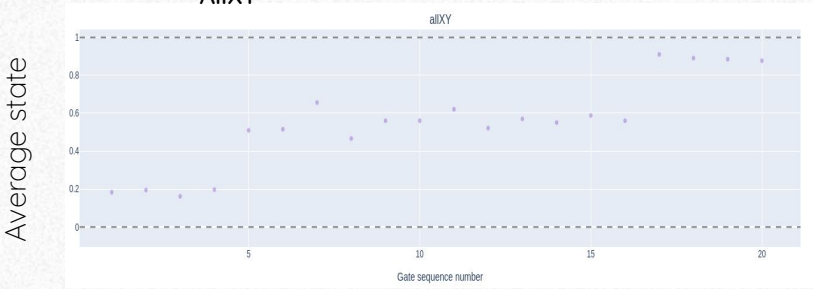
Calibrate qubit states



Punch-out

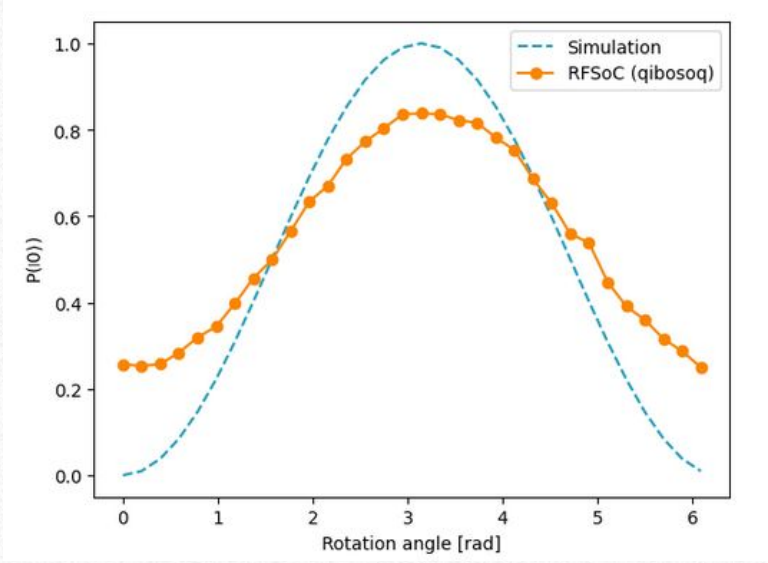


AllXY



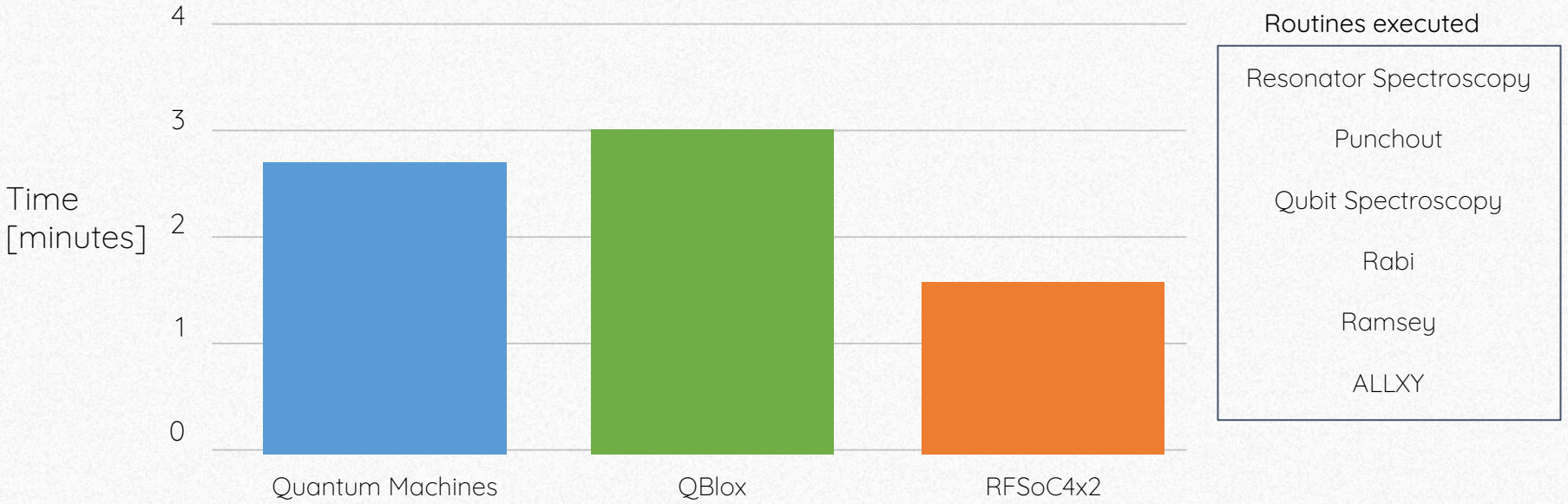
Execution of a circuit with RFSoC4x2 and Qibo

```python
import qibo
from qibo import models, gates
qibo.set_backend("qibolab", platform="tii1q_b1")
circuit = models.Circuit(1)
circuit.add(gates.RX(0, theta=0))
circuit.add(gates.M(0))

exp_angles = np.arange(0, 2*np.pi, np.pi/16)

res = []
for t in exp_angles:
    circuit.set_parameters([t])
    state = circuit.execute(nshots=4024)
    p0, p1 = state.probabilities(qubits=(0,))

    res.append(p0)
```

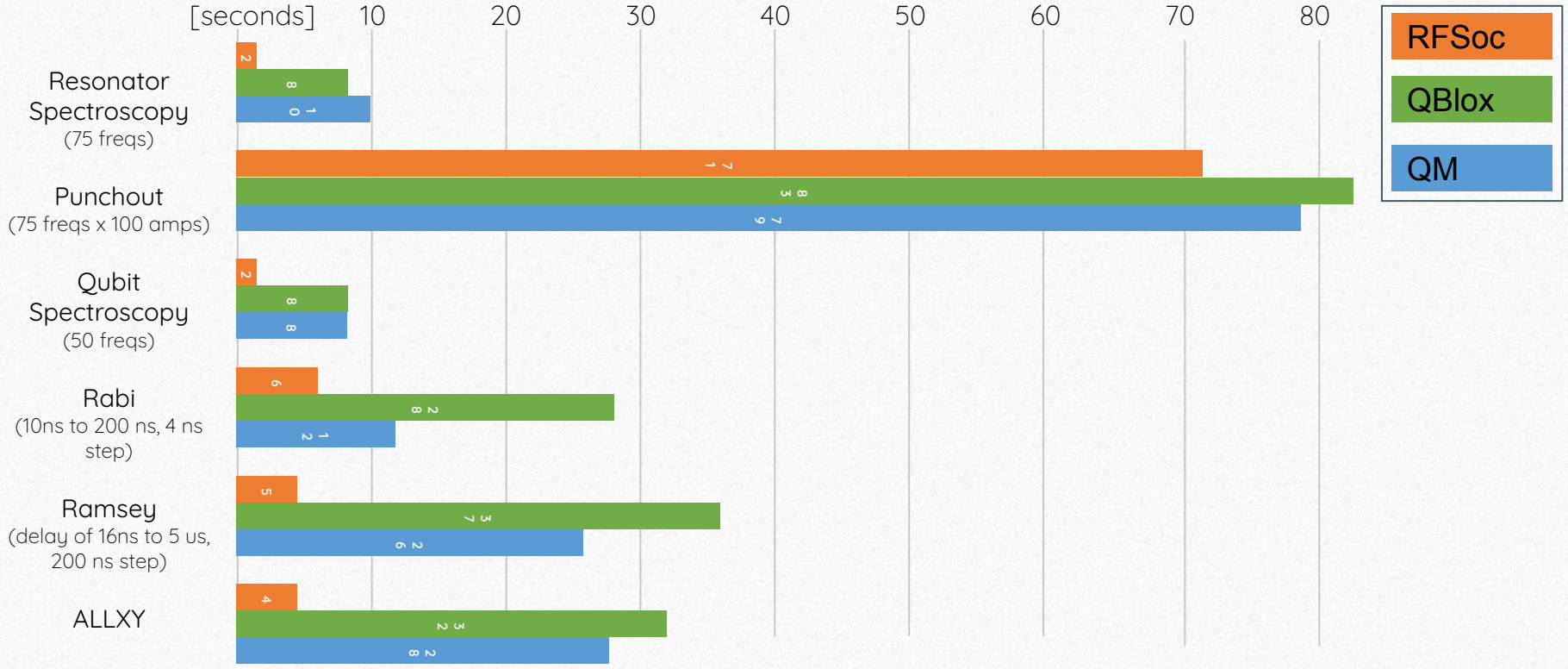


Control not fully calibrated!

RFSoC4x2 Vs Commercial Systems



RFSoC4x2 Vs Commercial Systems



3 flux-tunable qubits driver (ZCU111)

from https://www.xilinx.com/products/boards-and-kits/zcu111.html

Board features

- Generation 1
- Zynq Ultrascale+ RFSoC XCZU28DR-2FFVG1517E

- 8 RF ADCs
- 8 RF DACs (6.55 GSPS)

- Auxiliary board with DC outputs (XM500)
- Firmware for multiplexed readout

3 flux-tunable qubits driver (ZCU111)

from https://www.xilinx.com/products/boards-and-kits/zcu111.html

	State
Multiplexed readout (up to 4 tones)	✔
Automatic control of Local Oscillators	✔
Support for flux biases	work in progress
Support for fast flux pulses (2-qubits gate)	work in progress

Next targets

2-qubits gates

Qibocal
auto-calibration

ZCU208 -ZCU216
(3-7 qubit driver)

Multi-boards
synchronization

Thanks !