High-resolution Gamma Tomography at the University of Michigan

Experimental and Computational Multiphase Flow Group

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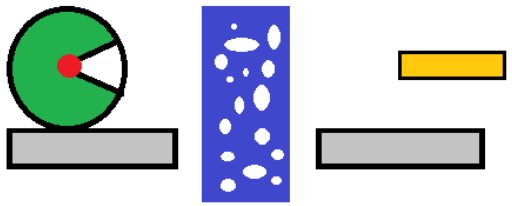
Introduction/background

Goal: development of in-house flexible, low cost, modular, high-resolution (≤1mm) gamma tomography system for flow imaging in complex geometries and/or high pressure system [better penetration/contrast than X-rays]

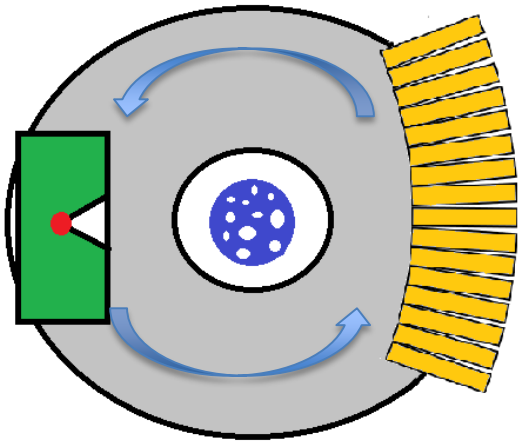
(Current setup accommodates **450 mm diameter objects** but could be increased)

Sketch

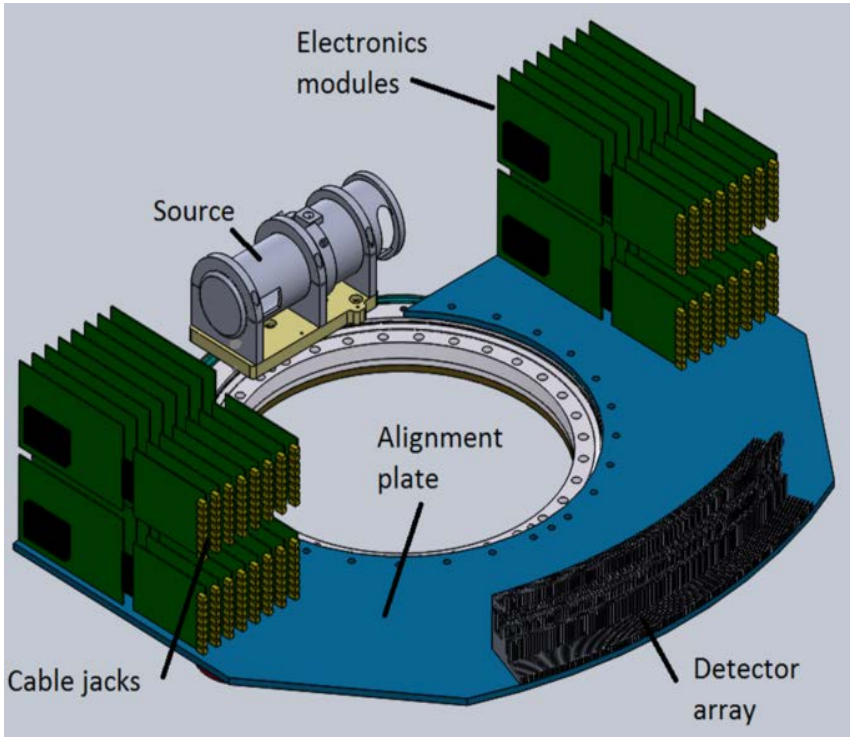
Side view



Top view

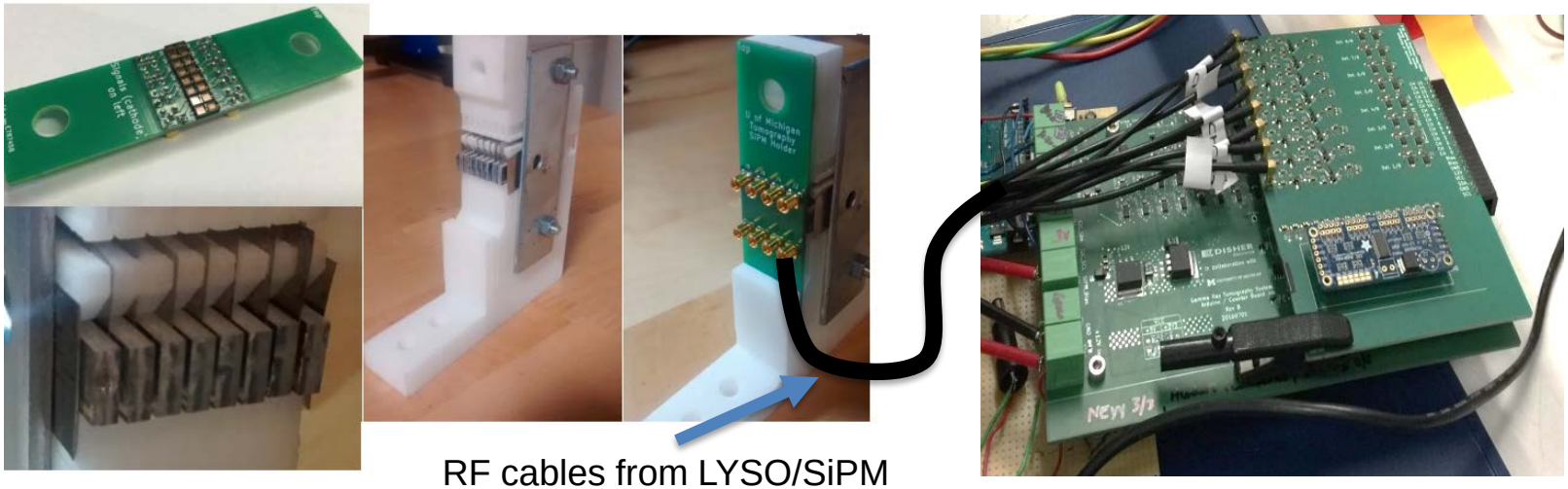


CAD image



Some technical details

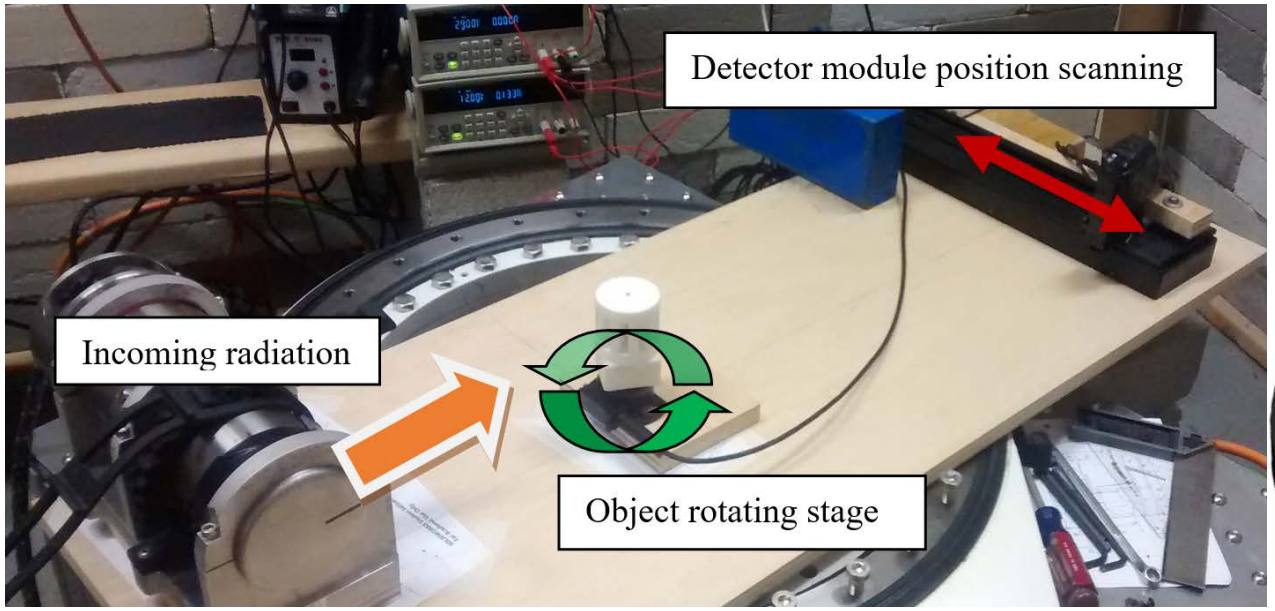
- Ir-192 chosen mainly for small emitting spot size vs (less imaging blur)
  - Three main energy lines (approx. 310, 475, 604 keV)
- Detector pitch of 2.5 mm, LYSO scintillators read out by Silicon photomultipliers
- Completely in-house scalable 8-detector electronics modules
  - Signal amplification
  - Two software-controlled energy discrimination thresholds per detector
  - 16-bit counters with no readout dead time (readout up to 100 Hz)
  - Simple TTL synchronization of counter readout
  - Data stored on board memory and read out later by WiFi

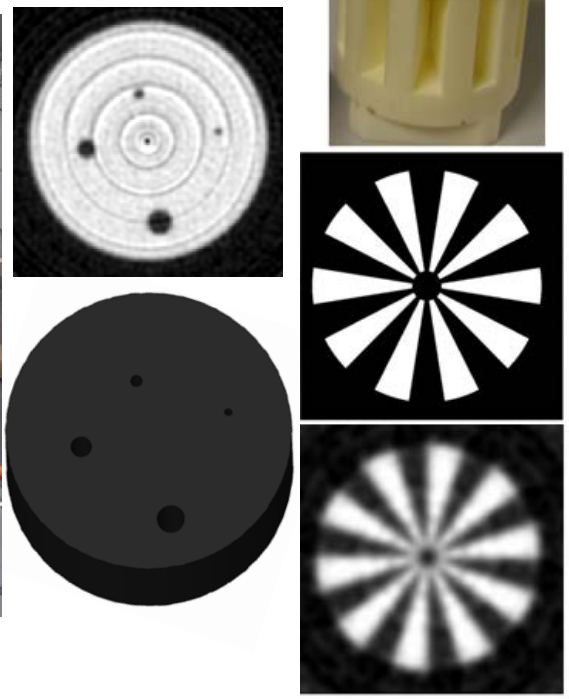


RF cables from LYSO/SiPM to readout boards

Imaging test setup

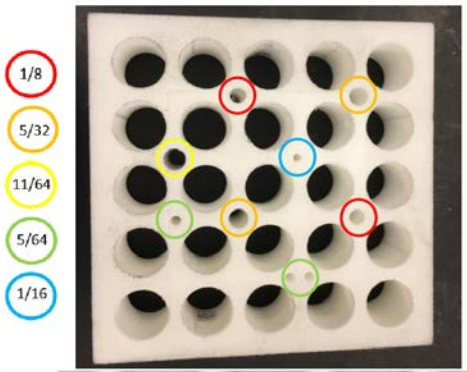
- Optimized arc geometry (300 mm source-object and 800 mm source-detector)
- Single module scanned linearly at each projection angle to simulate full array
- Test objects (e.g. Siemens star) verify 1 mm spatial resolution

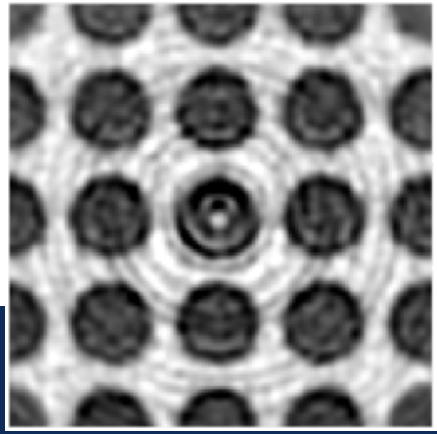


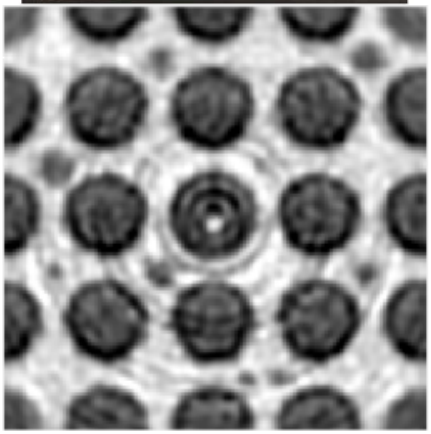


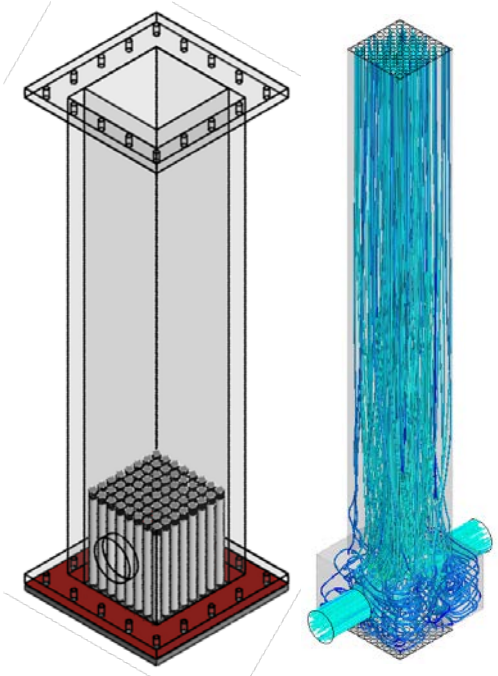
Current status and outlook

- Further validation with Incoloy/plastic stationary bundle mock-ups ongoing
- Complete detector array imaging system to be commissioned this year (60s/tomogram), along with vertical gantry for slice-by-slice 3D scanning of flow loops
- Tests with adiabatic then high-temp test loops are planned
- **Detector modules are scalable and adaptable to different detector sizes, array geometries (also 2D), and sources (LYSO→Plastic = fast neutron imaging) for a range of imaging applications**





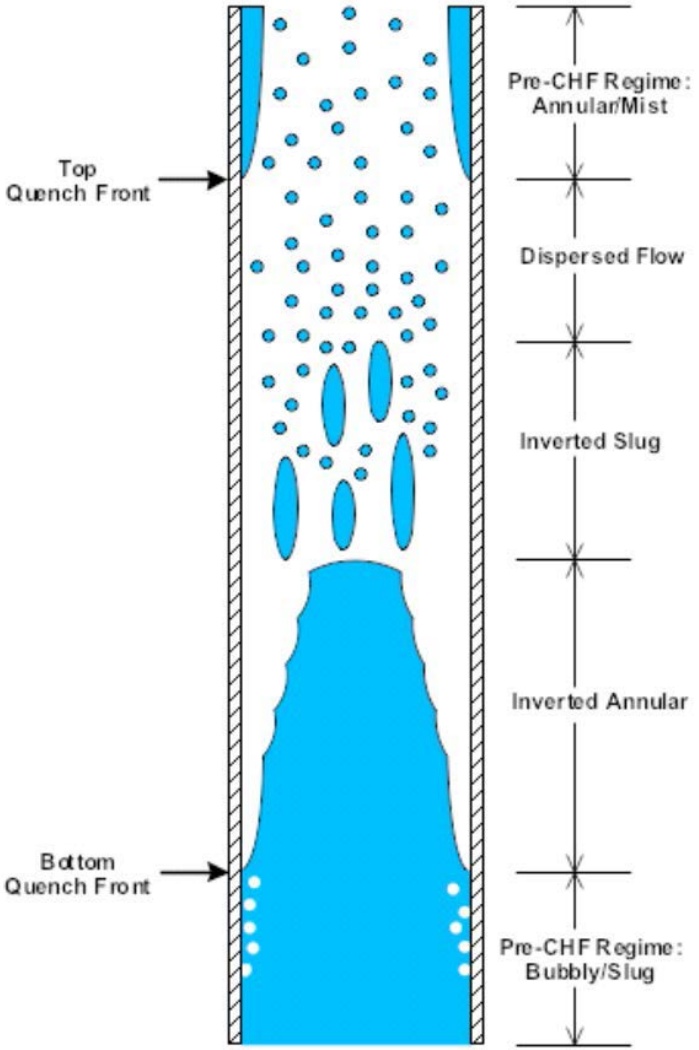


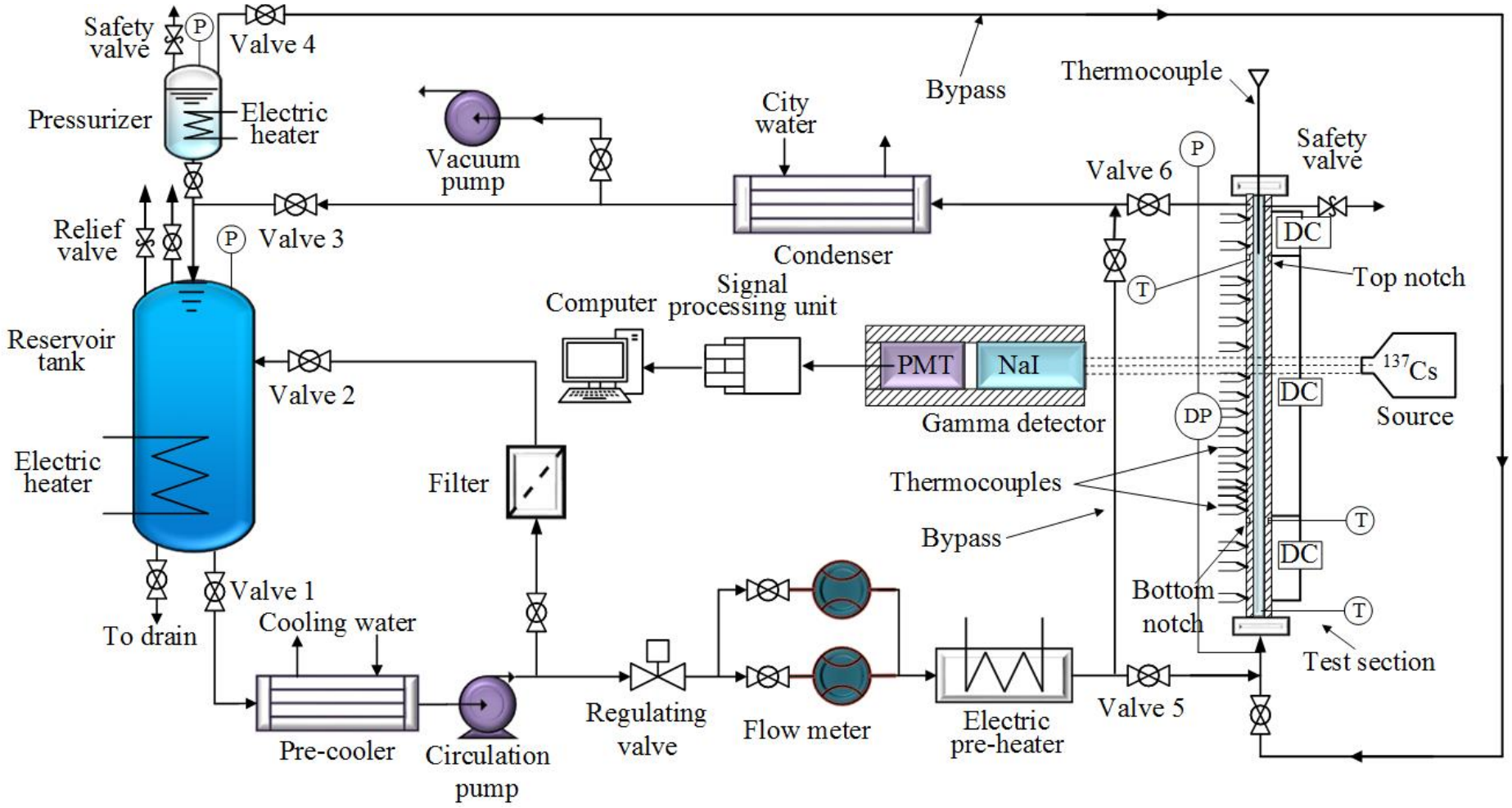


Further details:

See NURETH-17

- Research Objectives
  - To provide experimental data necessary for improvement of the models for IAFB and ISFB regimes in TRACE
  - Investigate flow regime transition criteria from IAFB to ISFB and ISFB to DFFB
- Experimental Conditions
  - Pressure: 0.14 to 3.4 MPa (20 to 500 psi)
  - Mass flux: 150 to 2,000 kg/m^2-s
  - Inlet subcooling: up to 50ºC




Safety valve
P
Valve 4
Bypass
Thermocouple
Pressurizer
Electric heater
Vacuum pump
City water
Valve 6
P
Safety valve
Relief valve
P
Valve 3
Condenser
DC
Top notch
T
Signal processing unit
Computer
Reservoir tank
Valve 2
PMT
NaI
137Cs
Source
DC
DP
Gamma detector
Electric heater
Filter
Thermocouples
Bypass
T
DC
Valve 1
Bottom notch
T
To drain
Cooling water
Test section
Pre-cooler
Circulation pump
Regulating valve
Flow meter
Electric pre-heater
Valve 5

- Tubular Test Section: Joule Heating
  - Material: Incoloy 800H/HT
  - Three DC power supplies
- Hot Patch Technique
  - Bottom and top notches
  - Thin-wall notch → Large local heat flux
- Instrumentation
  - X-ray radiography system
  - Gamma densitometer
  - Pyrofiber® automatic emissivity correcting IR thermometer
  - Flowmeters, pressure and differential pressure transducers, RTDs, thermocouples