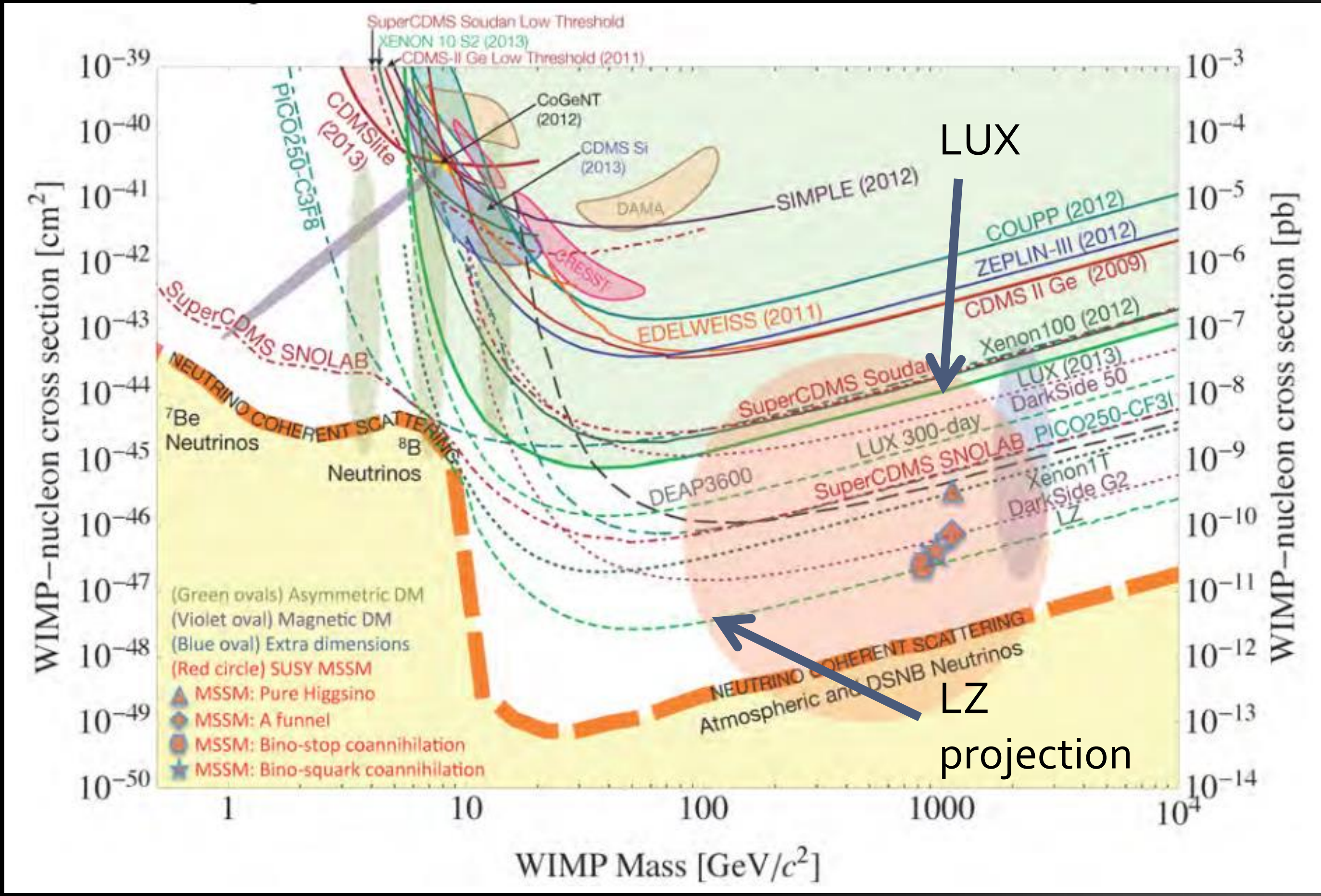
The LZ System Test

Shaun Alsum

LZ - LUX-Zeplin

- Bigger version of LUX (in most respects)
- 7 tonnes active LXe vs 300 kg in LUX

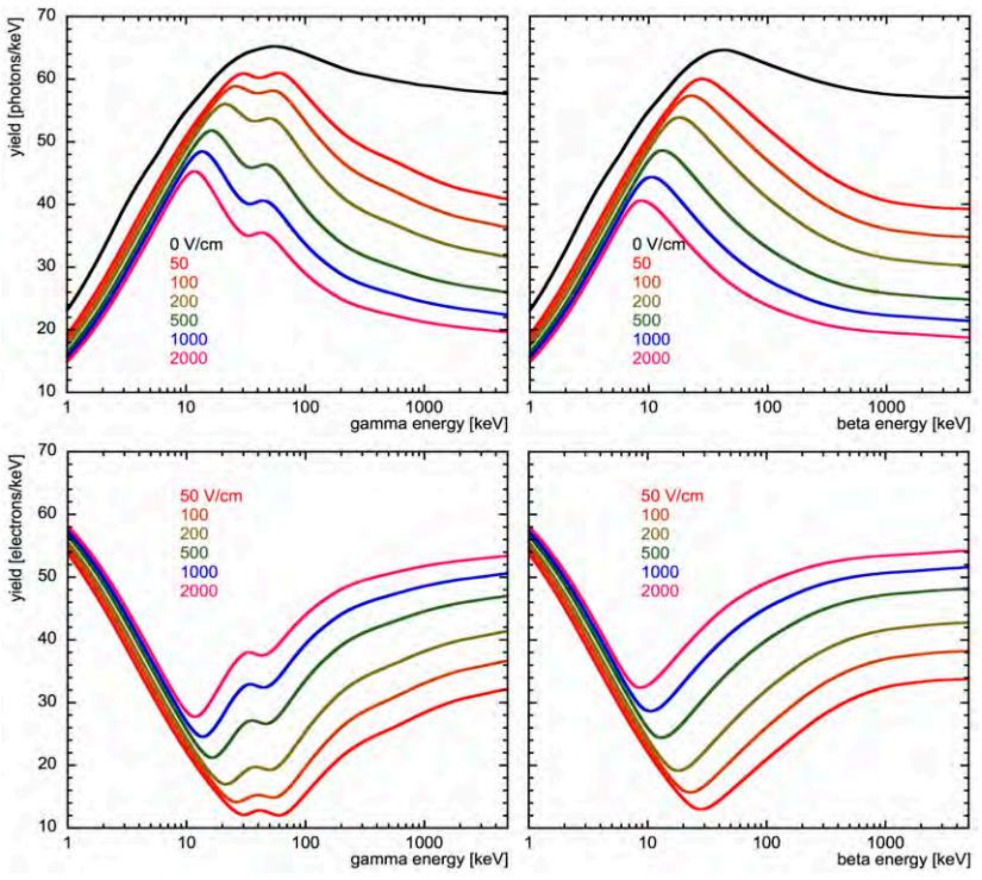


System Test – Brief Overview

- Prototype detector for LZ
  - 65 cm high, 15 cm diameter (LZ 1.5m ea.)
  - ~100 kg Lxe (LZ 10 tonnes)
  - 2 PMTs (LZ 488 in arrays)
- Located at SLAC in Menlo Park, CA

Goal 1 – High Voltage Testing

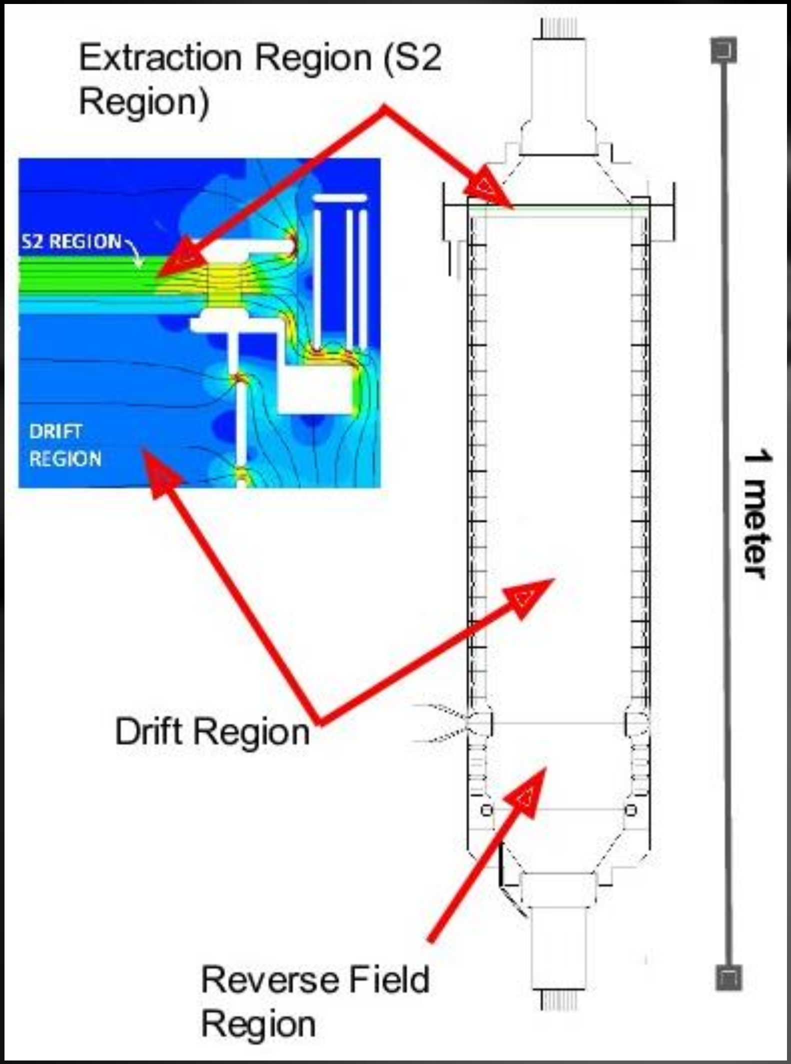
- Need high voltage for additional S2 (electron drift charge signal).
- In general, the higher the better (though this has been disputed recently).



- This has traditionally been a problem for similar TPCs (LUX, Zeplin, etc)
- In the past, detectors were just built without tested designs for HV and so had no assurances of meeting their goals.
  - LZ wants 700 V/cm
  - LUX run03 ran with 180 V/cm
- Excessive electric fields at cathodic surfaces can cause light.

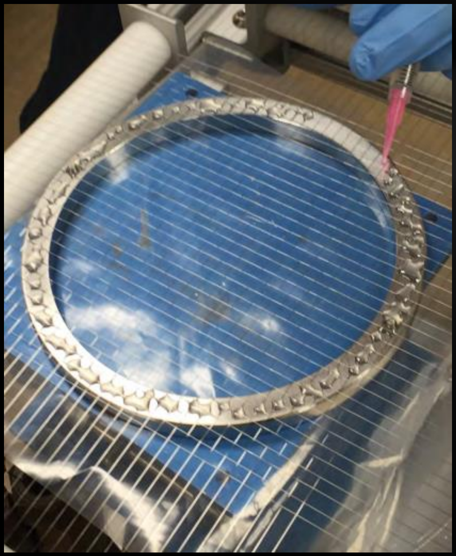
High voltage – trouble areas

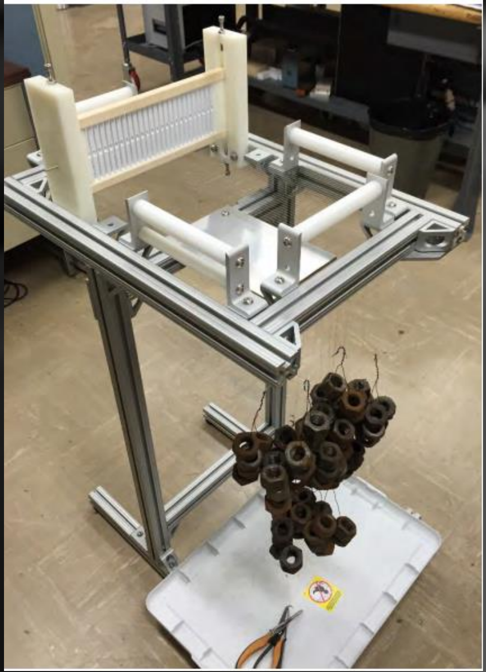
- The System test TPC is designed to have the same electric field strengths in both
  - Bulk Xenon
  - TPC structures
- The System test will attempt to ensure that the LZ TPC design will not create any excess light via ???



High Voltage - Grids

- Grids can also produce light via ???
  - It is thought that minor nonuniformities in the wire surfaces create local regions of high field.
- The fast turnaround of system test makes it ideal(er than everything else) for testing various grid-making techniques.
  - Different wire materials,
  - Sizes
  - Coatings
  - Electroplishing



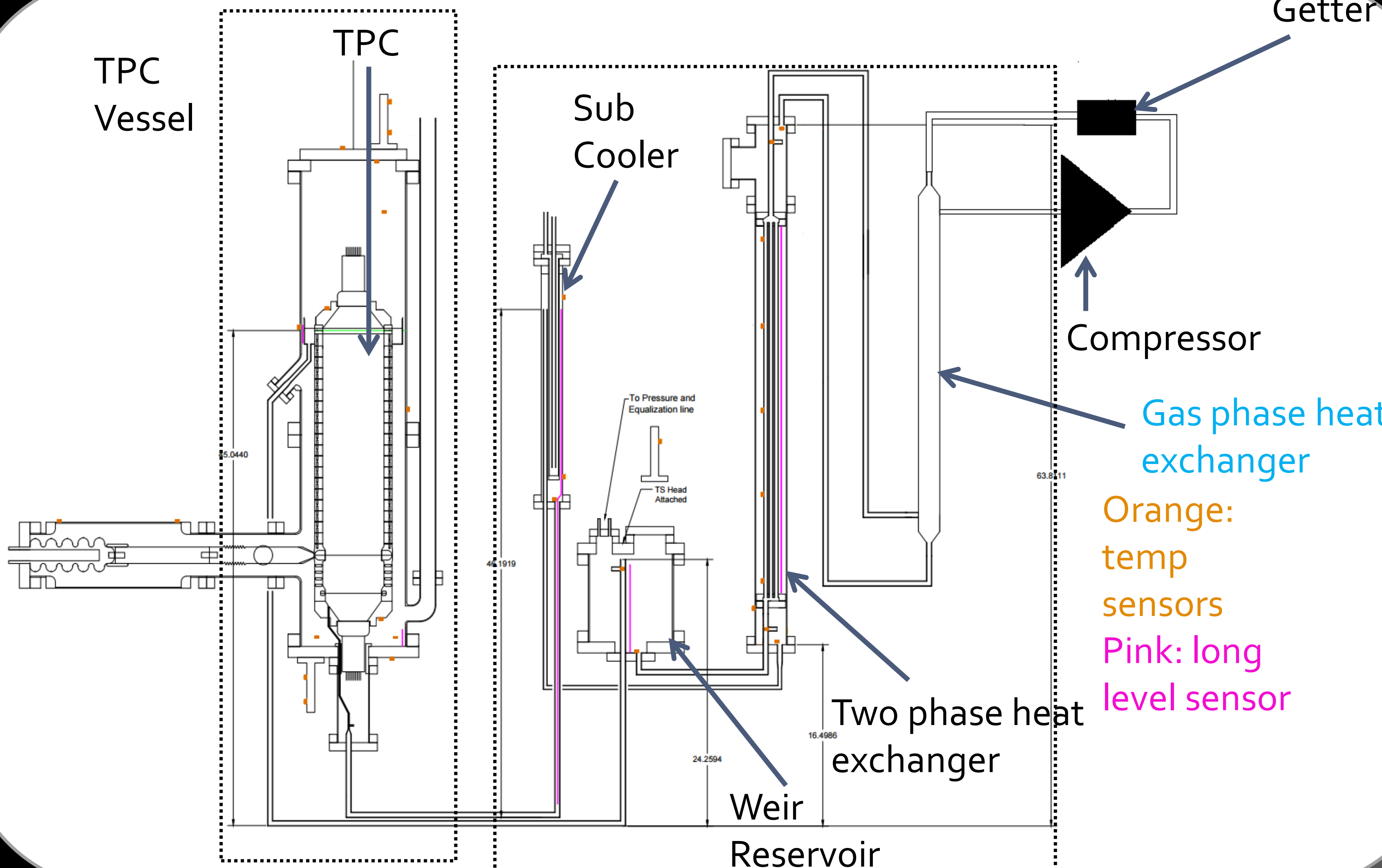


Our high tech grid making techniques

Goal 2 – Circulation Studies

- LZ is circulating at a much greater rate (200 slpm vs 20 in LUX)
  - Requires more powerful pump
  - More powerful heat exchanger
  - etc
- Some design elements have changed (weir reservoir far from TPC, etc.)
  - Make sure there are no unforeseen problems with new design

Circulation Path



Description of Path Elements

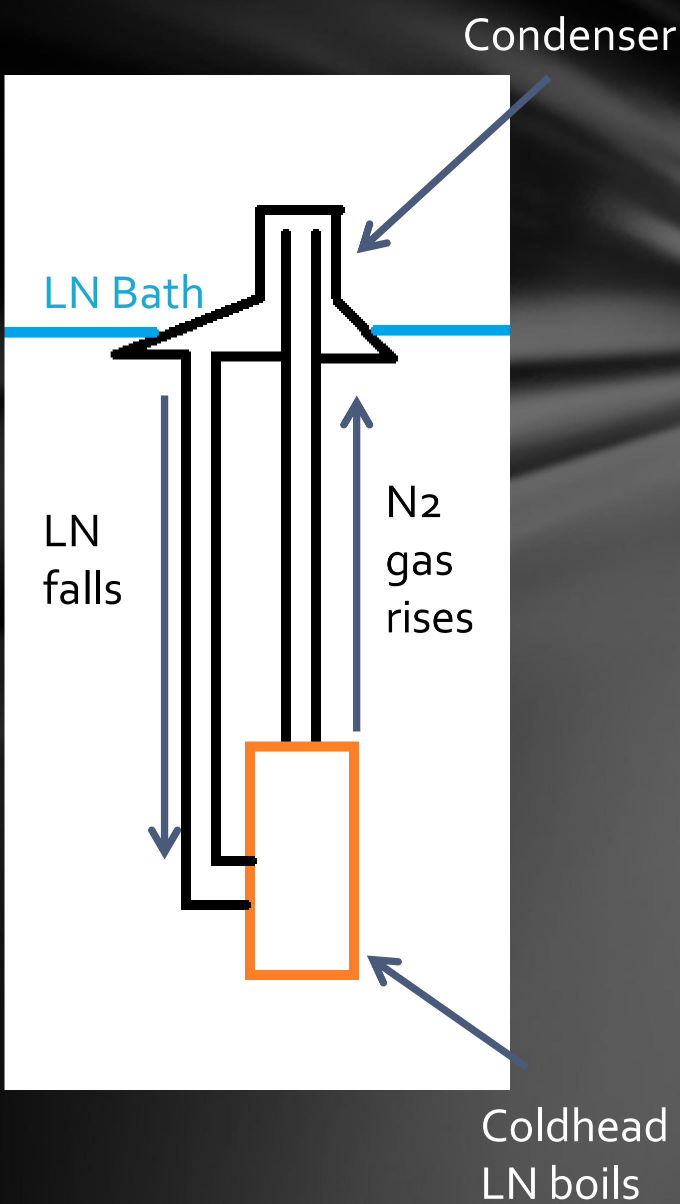
- Weir – Disc with holes at set height, allowing LXe to flow out of the TPC at a set height.
- Weir reservoir – Small buffer volume that decouples the LXe level in the detector from that in the heat exchangers
- Heat exchangers – Tubes running through an outer volume that allow heat transfer from entering xenon to exiting xenon
- Compressor – Large pump that pushes Xe through the whole system
- Getter – Heated column of zirconium that reacts with -drawing out- non-noble impurities in the Xe
- (Back through heat exchangers)
- Sub Cooler – Vessel that cools LXe below the condensation point, eliminating remaining bubbles

But How You Gonna Cool It?!

- Magic.
- And Thermosyphons.

Thermosyphons

- Two tubes, a condenser space, and a coldhead comprise a thermosyphon (most of ours, can be done with one tube)
  - One tube carries LN down using gravity.
  - The LN boils on the coldhead surface, transferring heat from the coldhead to the N_2.
  - The second tube carries the gas back up.
  - The condensing space is submerged in a LN bath which condenses the N_2 gas back into liquid. (note: LN is condensing N_2, so the TS line must be slightly pressurized)
- A heater is typically added on the coldhead for fine adjustment.



The Thermosyphon Salesman Section

- Cools more efficiently than simple convection because the latent heat of vaporization is so much higher than heat required to change the temperature by any reasonable amount.
  - N_2 Heat of Vaporization: ~199 kJ/kg
  - N_2 Specific Heat < 1.039 kJ/(kg K)
- No moving parts.
- Little maintenance.
- Keeps working in the event of a power failure.
- Works regardless of size provided it is oriented such that gravity draws liquid to the bottom.
- Huge range in possible cooling power.
- Can work on lines without stopping other Thermosyphons.

To be continued…

Backup

How it works (continued)

The tubes are insulated from the outer surface of the lines by a vacuum separate from that of the dewar.

The surface off of which the nitrogen boils is a (typically copper) head.

Heaters are also attached to the head in order to fine tune the amount of cooling to precisely the amount of heat loss in the system.

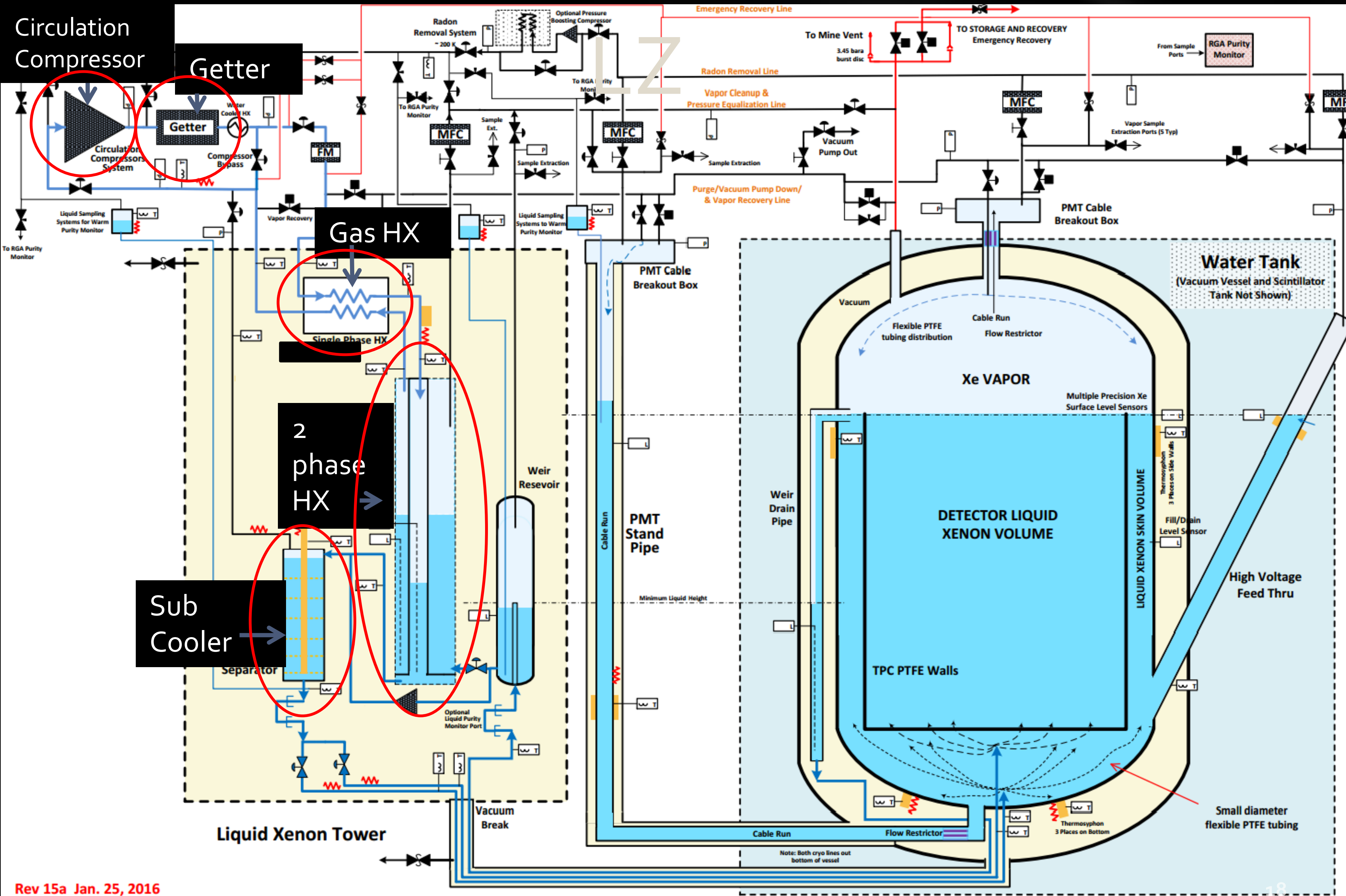
High Power, Low Power

The Low power configuration is a single tube down which LN flows while simultaneously the gaseous nitrogen flows upward.

The high power configuration consists of two tubes forming a loop. One in which the LN falls, and one in which the gaseous nitrogen rises.

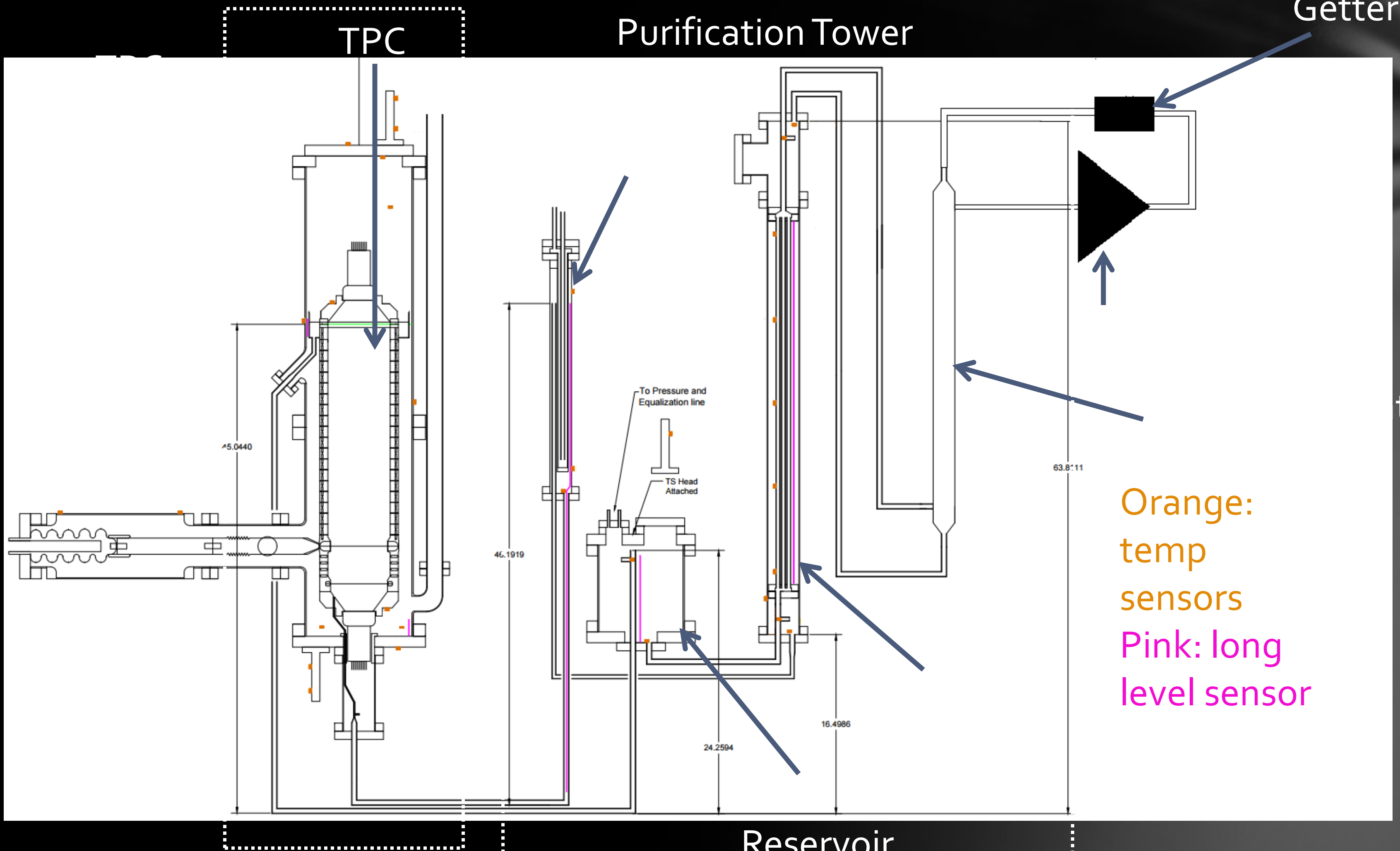
The high power configuration is advantageous because flow is always one direction instead of obstructing the flow from the opposite direction.

This terminology is also used to describe two different flow regimes of nitrogen in the tubes.

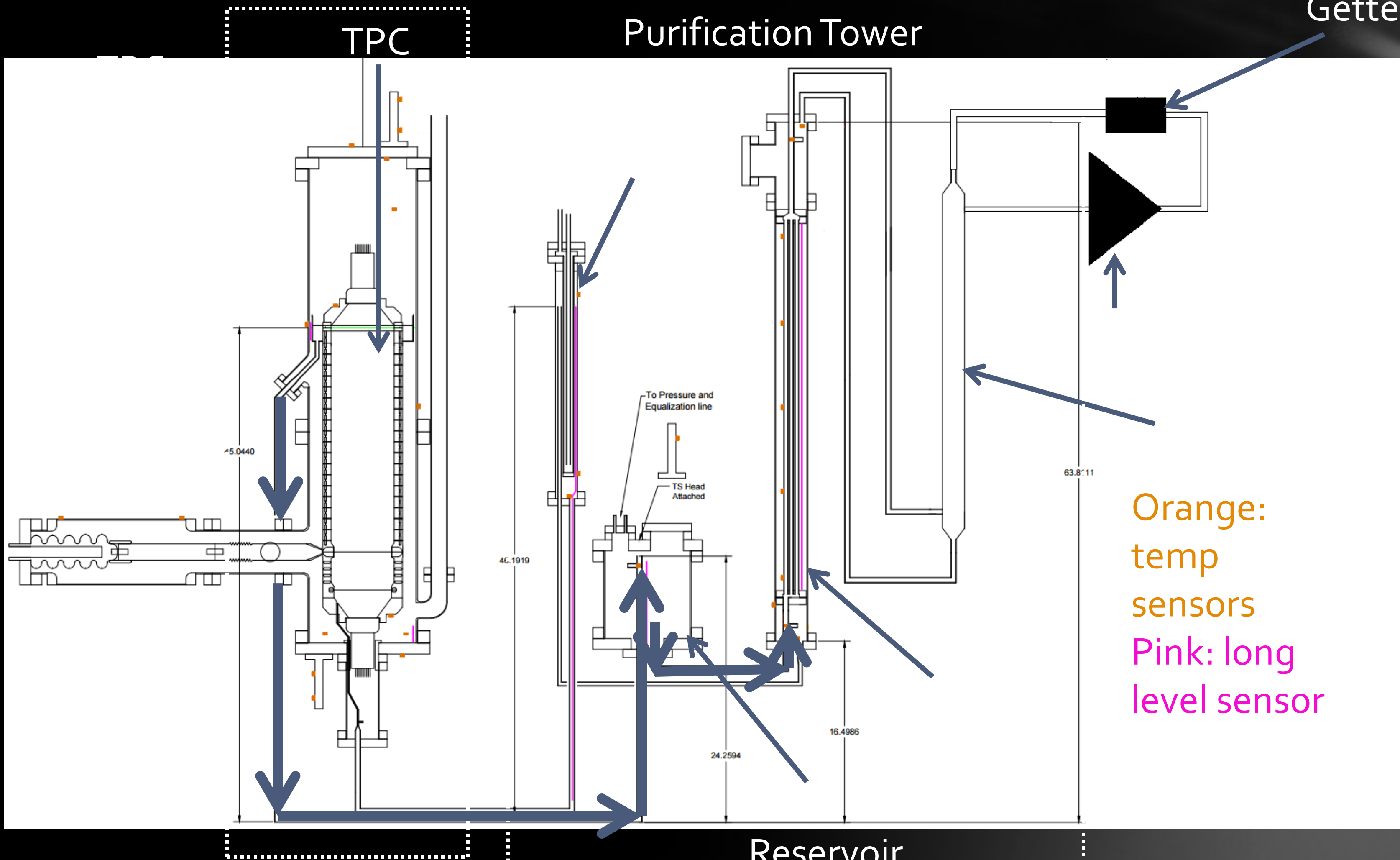


Circulation Compressor
Getter
Gas HX
2 phase HX
Sub Cooler
Circulation Compressors System
Getter
Water Cooled HX
Compressor Bypass
FM
Radon Removal System
~200 K
Optional Pressure Boosting Compressor
To RGA Purity Monitor
MFC
Sample Ext.
Sample Extraction
Vapor Recovery
Liquid Sampling Systems for Warm Purity Monitor
Liquid Sampling Systems to Warm Purity Monitor
To RGA Purity Monitor
Single Phase HX
Weir Resevoir
Separator
Optional Liquid Purity Monitor Port
Vacuum Break
Liquid Xenon Tower
Emergency Recovery Line
To Mine Vent
3.45 bara burst disc
TO STORAGE AND RECOVERY
Emergency Recovery
From Sample Ports
RGA Purity Monitor
Radon Removal Line
Vapor Cleanup & Pressure Equalization Line
Vacuum Pump Out
Vapor Sample Extraction Ports (5 Typ)
Purge/Vacuum Pump Down/ & Vapor Recovery Line
PMT Cable Breakout Box
PMT Cable Breakout Box
Water Tank
(Vacuum Vessel and Scintillator Tank Not Shown)
Vacuum
Flexible PTFE tubing distribution
Cable Run
Flow Restrictor
Xe VAPOR
Multiple Precision Xe Surface Level Sensors
Cable Run
PMT Stand Pipe
Weir Drain Pipe
DETECTOR LIQUID XENON VOLUME
LIQUID XENON SKIN VOLUME
Fill/Drain Level Sensor
High Voltage Feed Thru
Minimum Liquid Height
TPC PTFE Walls
Thermosyphon 3 Places on Bottom
Small diameter flexible PTFE tubing
Cable Run
Flow Restrictor
Note: Both cryo lines out bottom of vessel
LZ
Rev 15a Jan. 25, 2016

System Test


TPC
Purification Tower
Getter
Reservoir
To Pressure and Equalization line
TS Head Attached
24.2594
16.4986
Orange: temp sensors
Pink: long level sensor

System Test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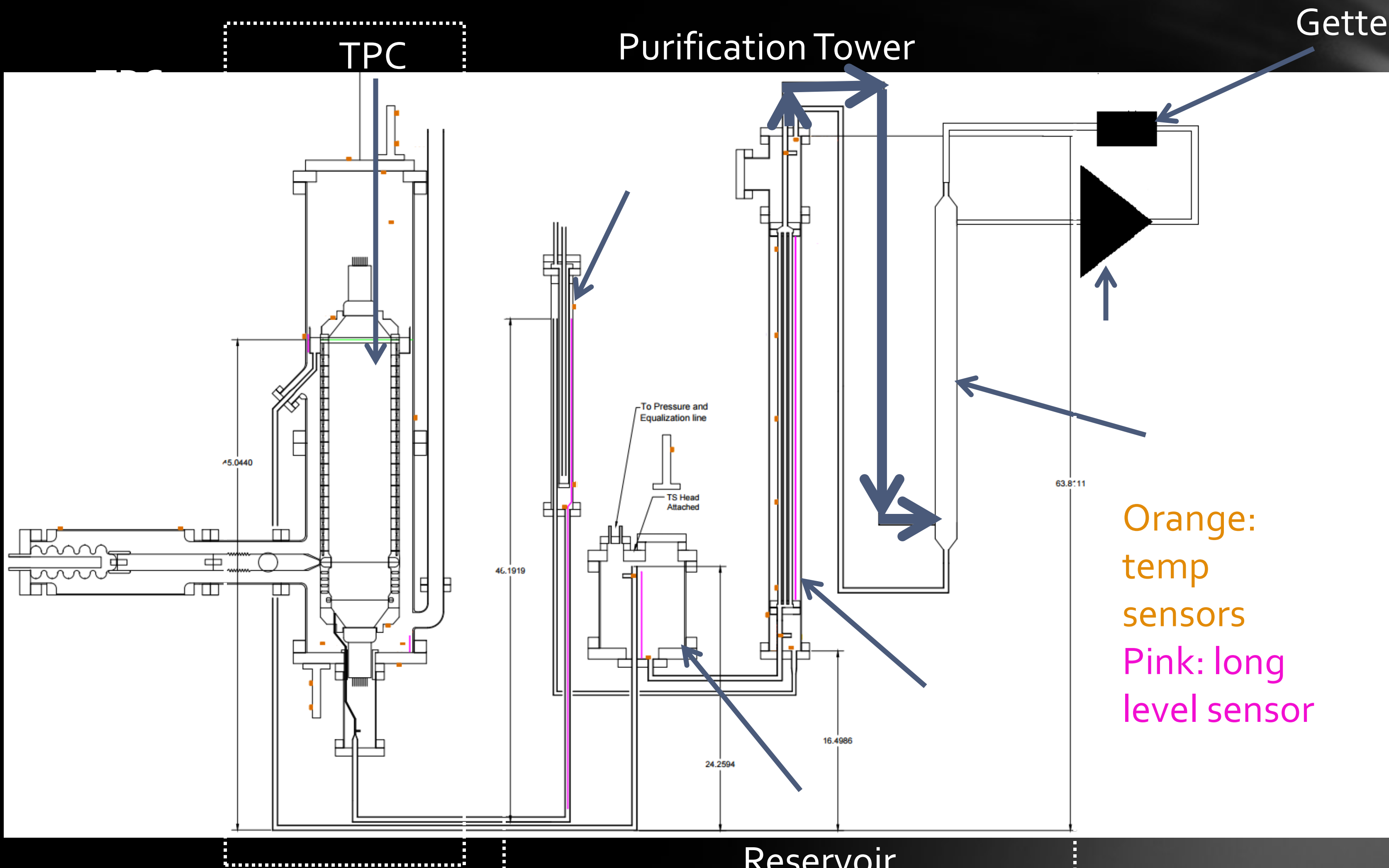
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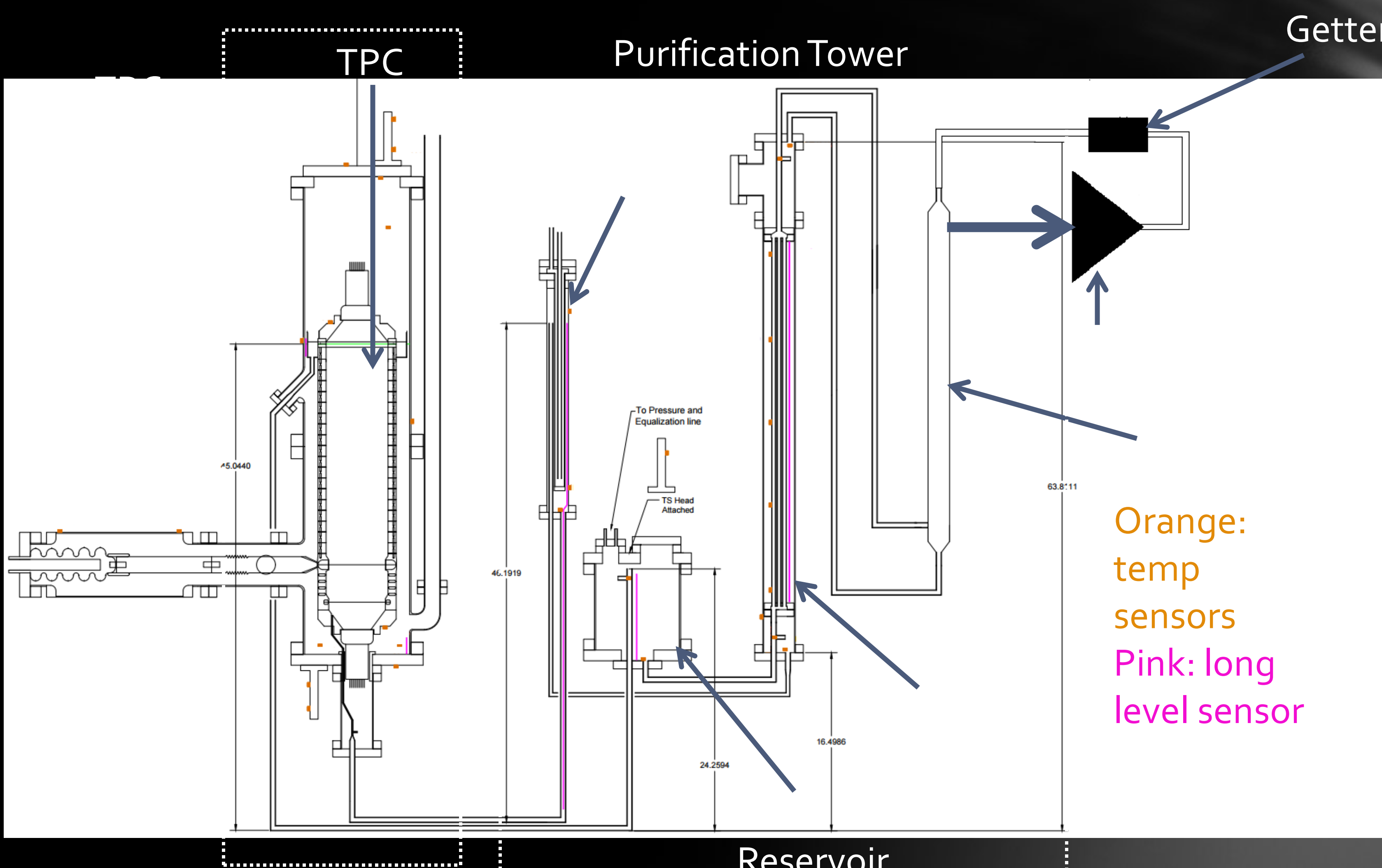

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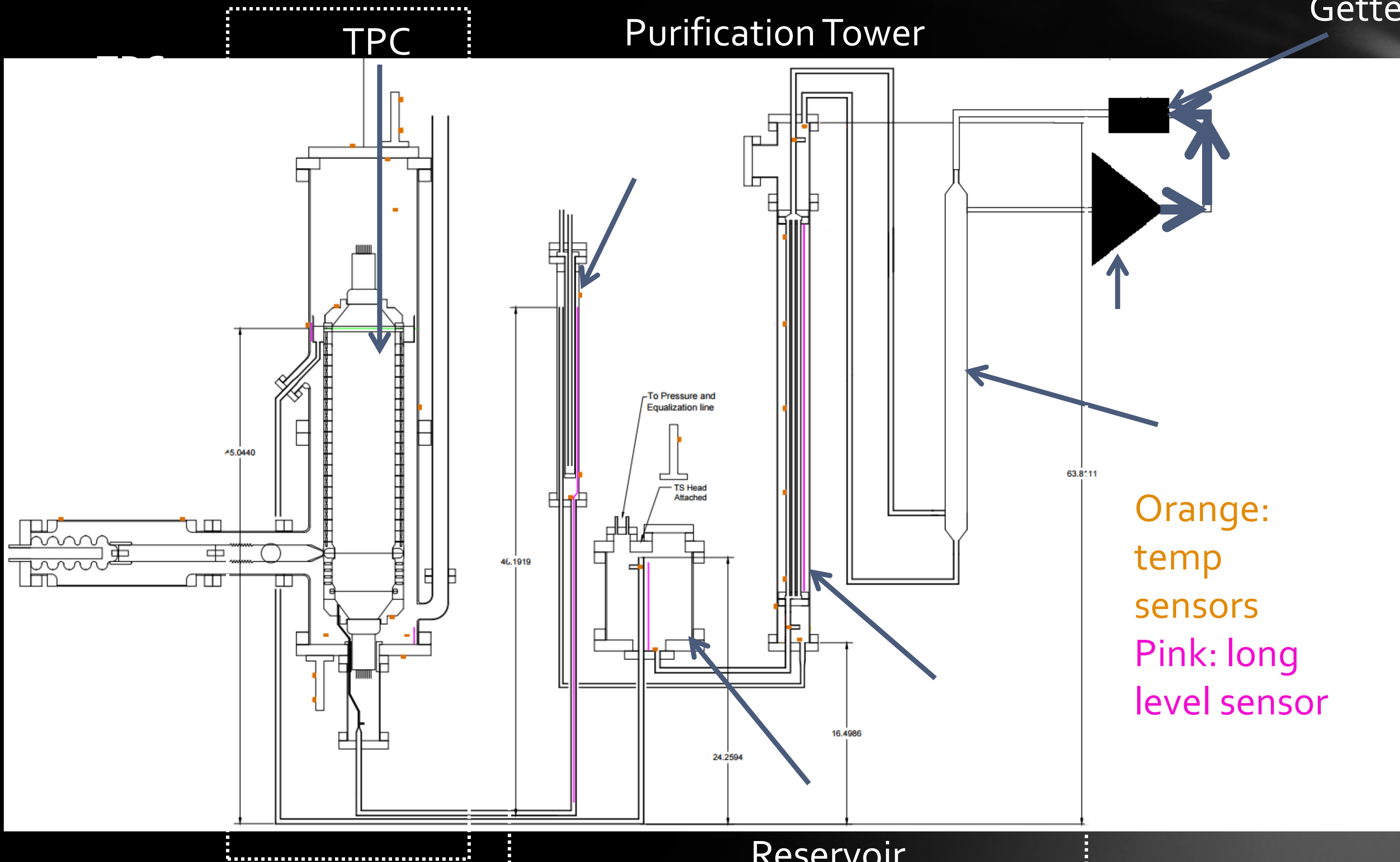

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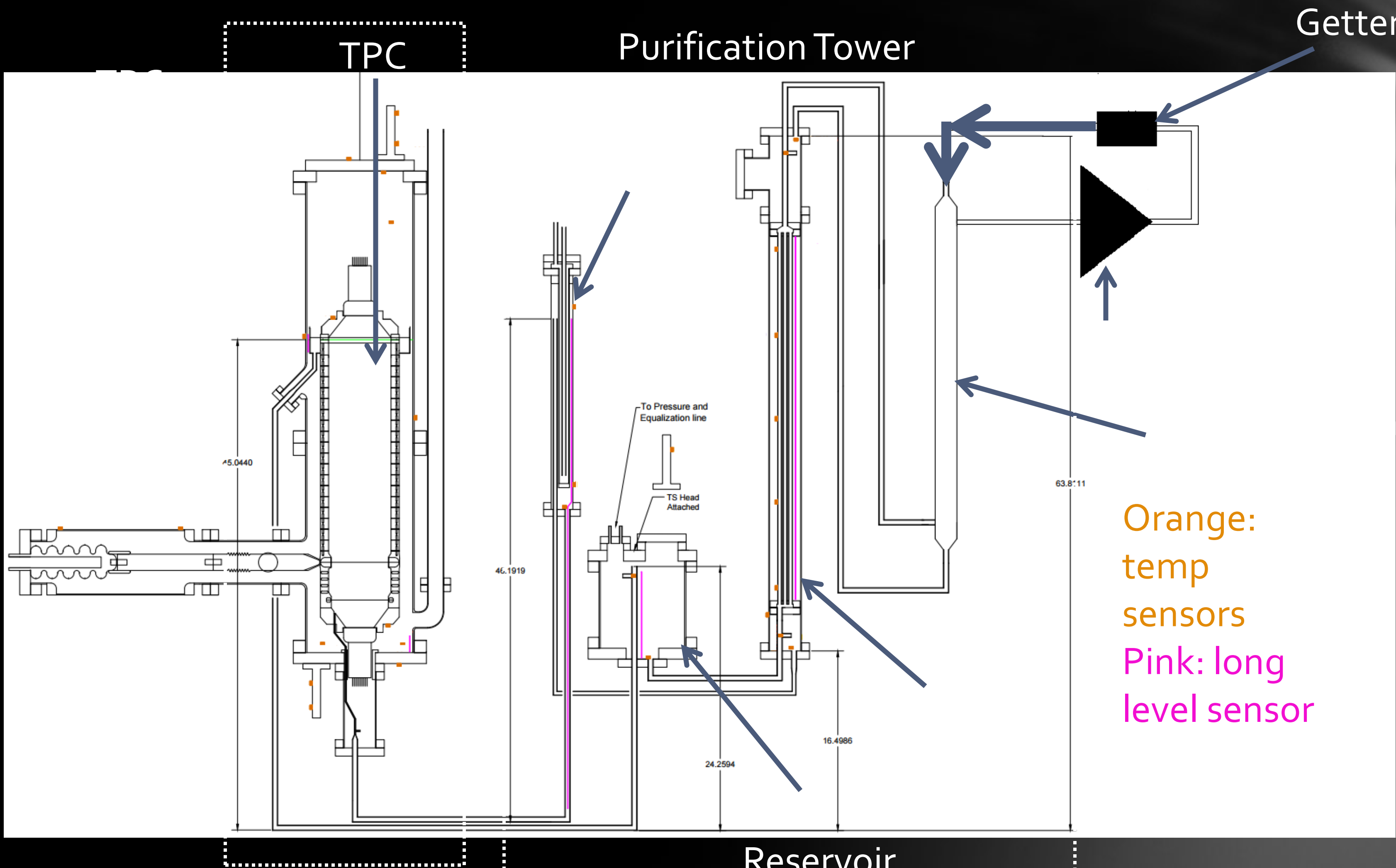
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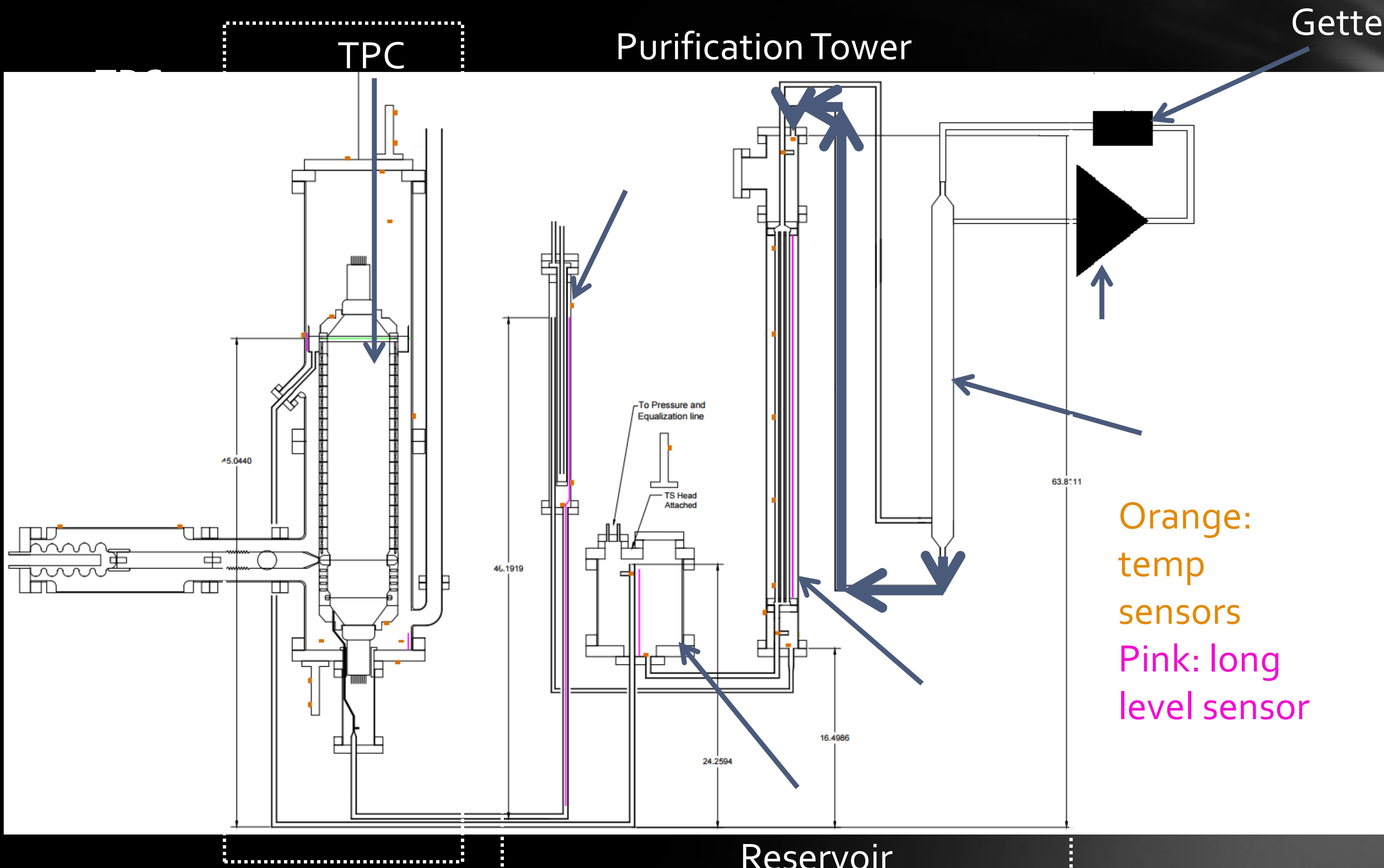

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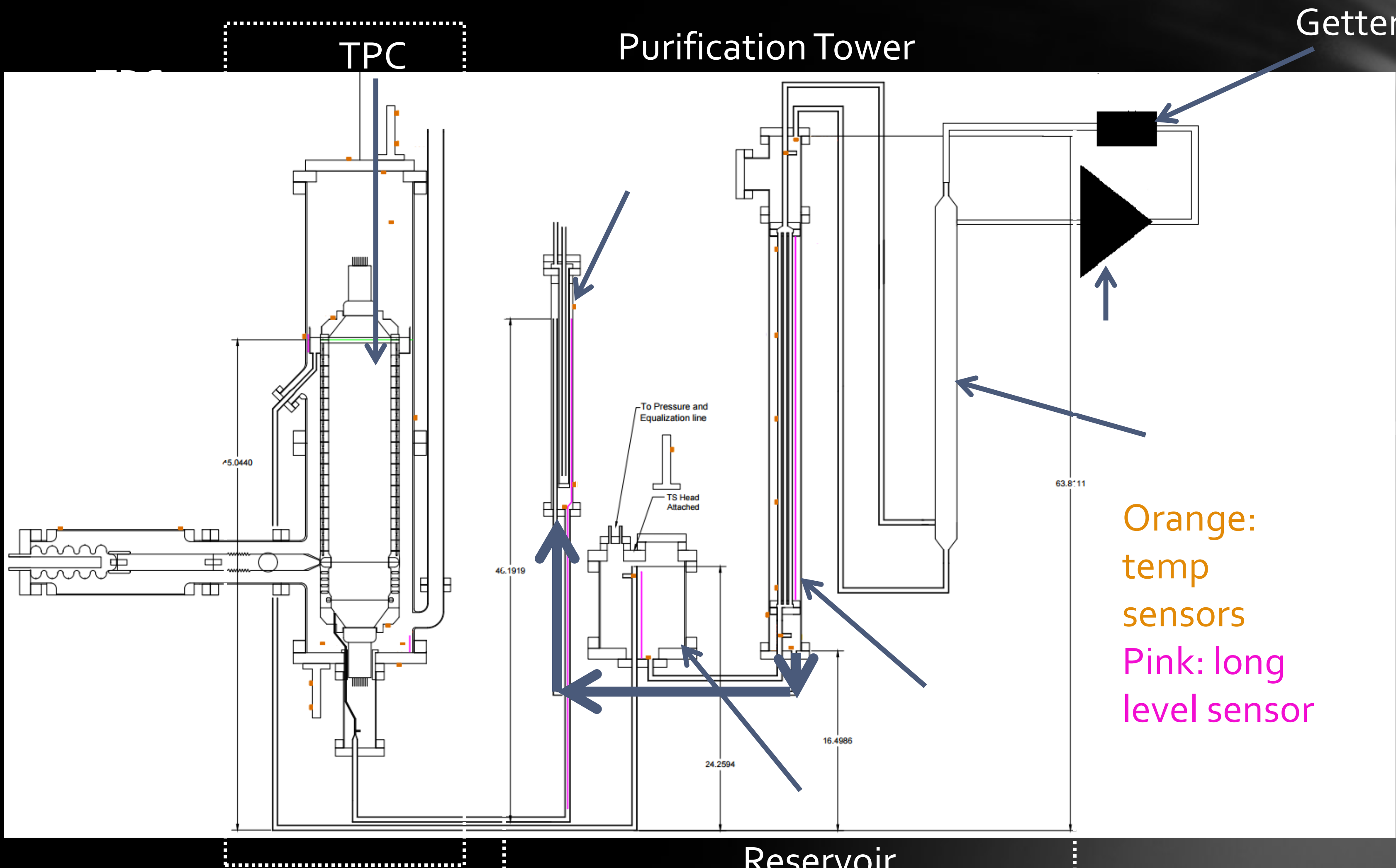
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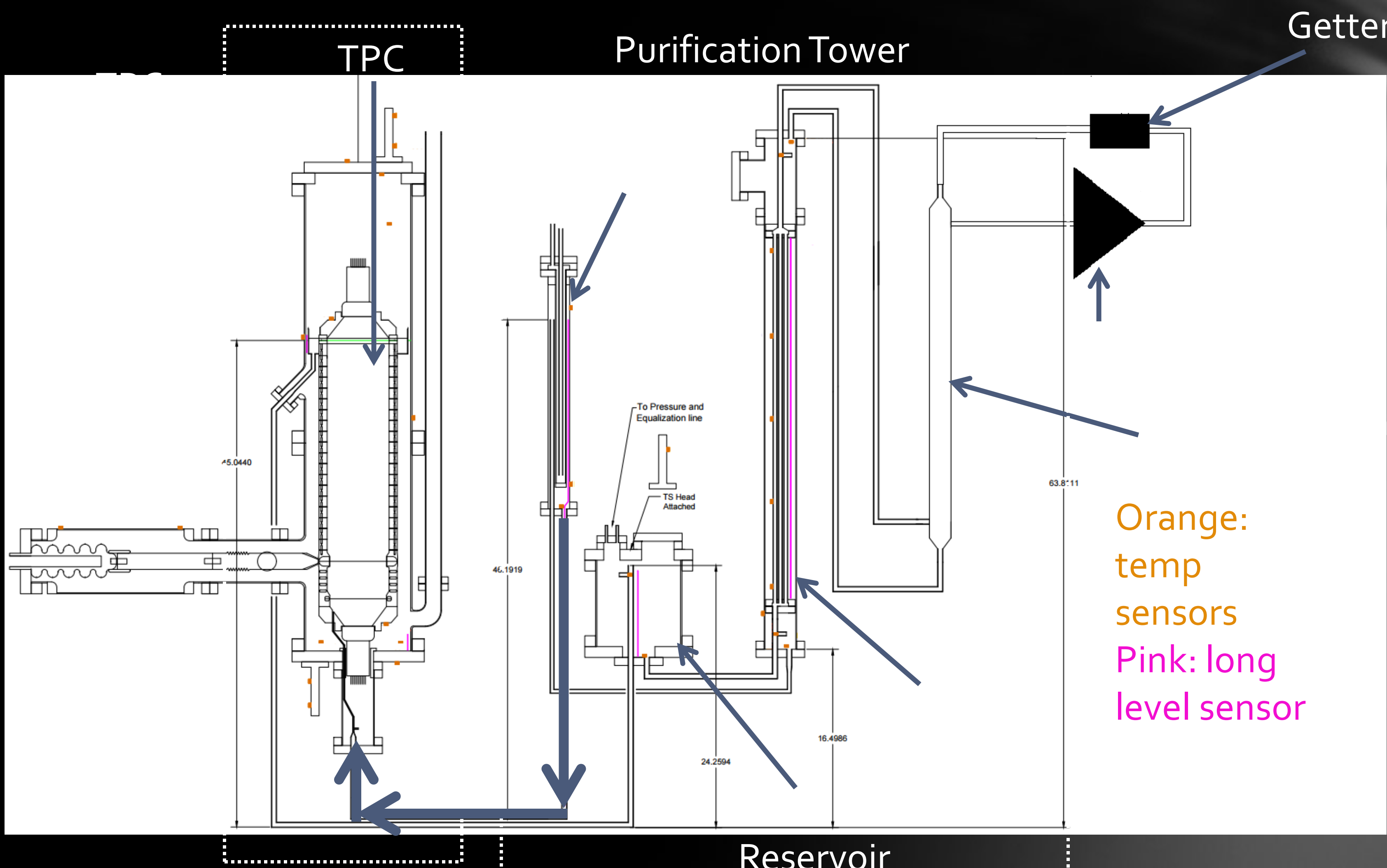
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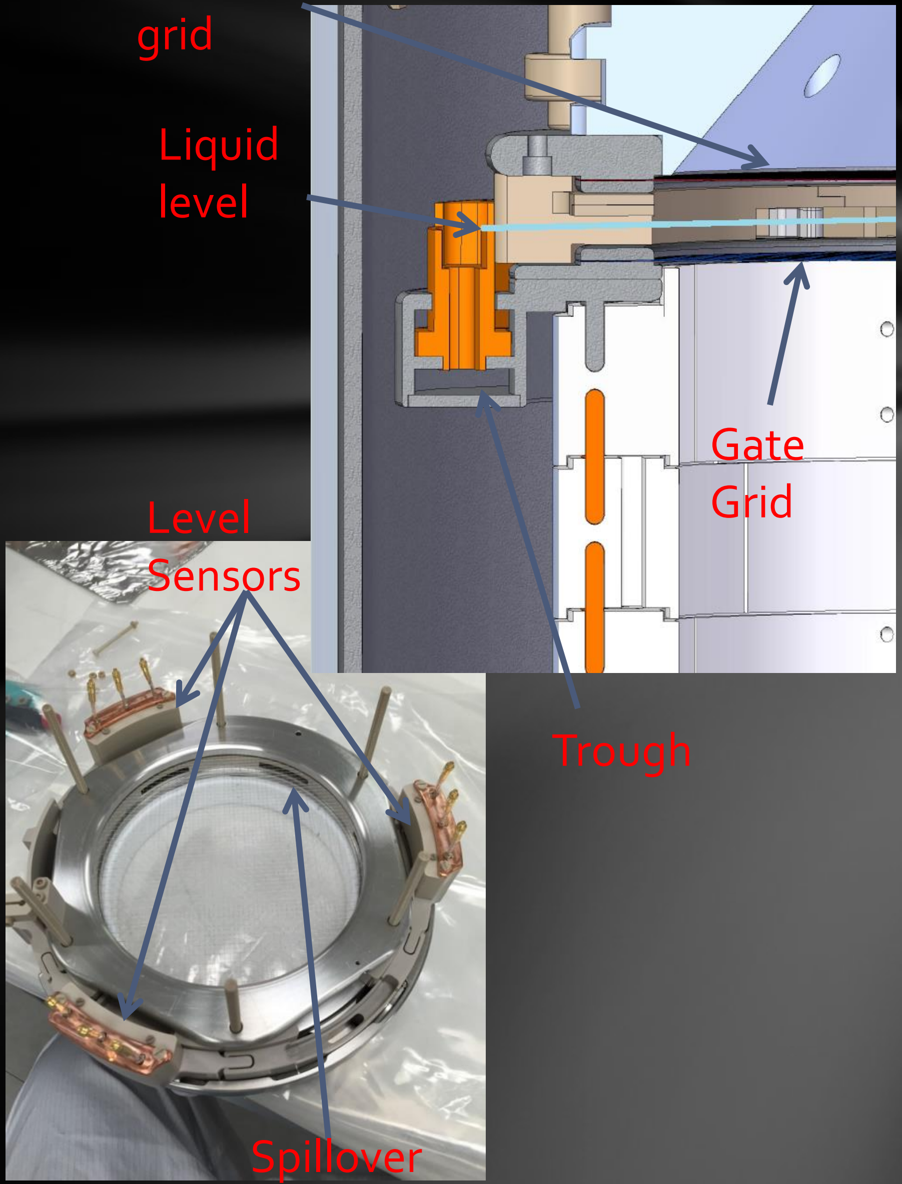
Circulation - Weir

Xe level maintained between two grids

3 precision level sensors monitor stability and uniformity of surface.

Flow from bottom to top minimizes dead zones.



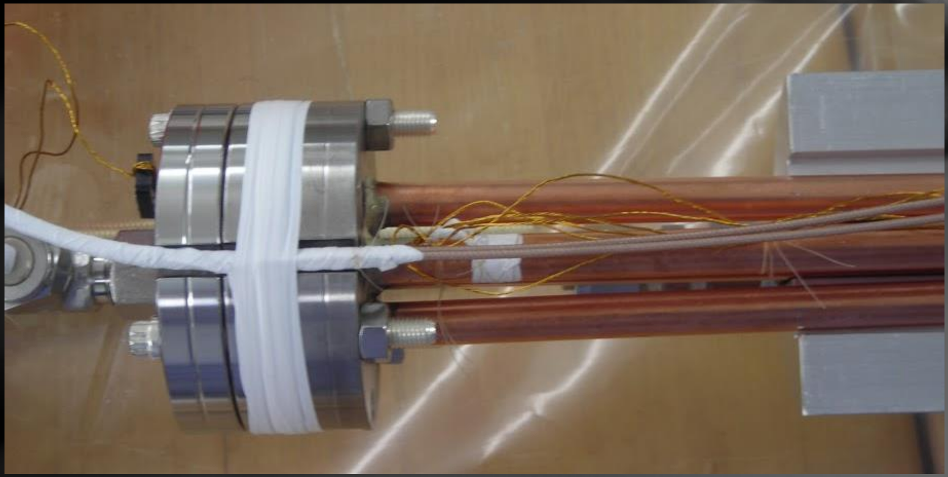
Circulation – Heat Exchangers

Weir flows to two heat exchangers.

- Custom two phase heat exchanger with instrumentation
- Commercial gas heat exchanger
- Both tube and shell design

95% thermodynamic efficiency

- Greatly reduces needed cooling power



Two phase heat exchanger at various stages of construction.

Circulation - Compressor

Fluitron A2-10-CS Diaphragm compressor

- All-metal diaphragms and seals.
- Far larger than the LUX pumps (200 slpm vs 20 slpm)
- Noise and vibration isolation needed
  - Located in separate structure

System test trying smallest model for practice with technology

Purification via Getter

SAES Monotorr commercial getter.

- Previous experiment experience
- Requires Gas flow not liquid

How it works:

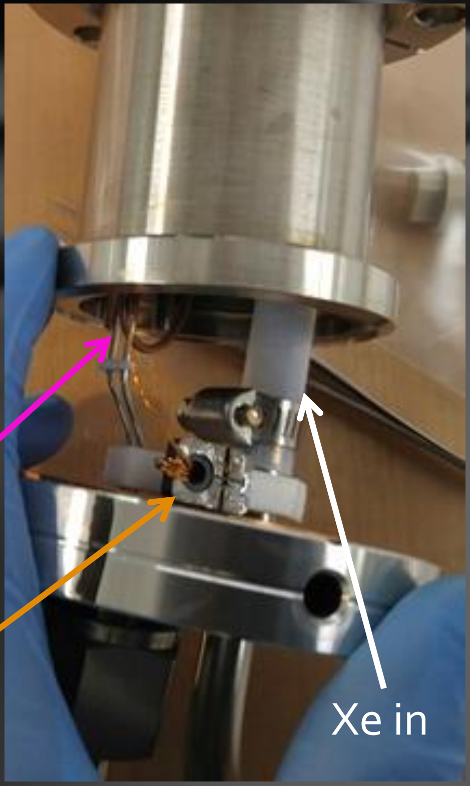
- non-noble impurities bind to surface of highly reactive zirconium pellets
- pellets are heated (~450° C) to allow diffusion into bulk

Circulation – Sub Cooler

Heat exchangers only cool to condensation temp

- Fast circulation could allow bubbles through.

Cools below condensation point, eliminating bubbles



Bottom Flange