XENON1T Demonstrator

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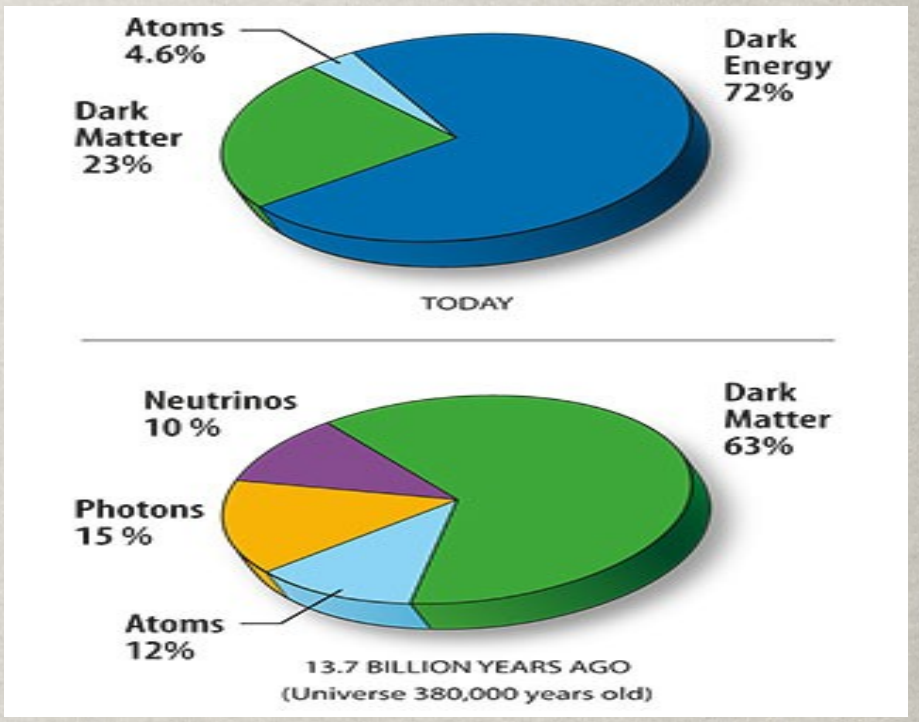
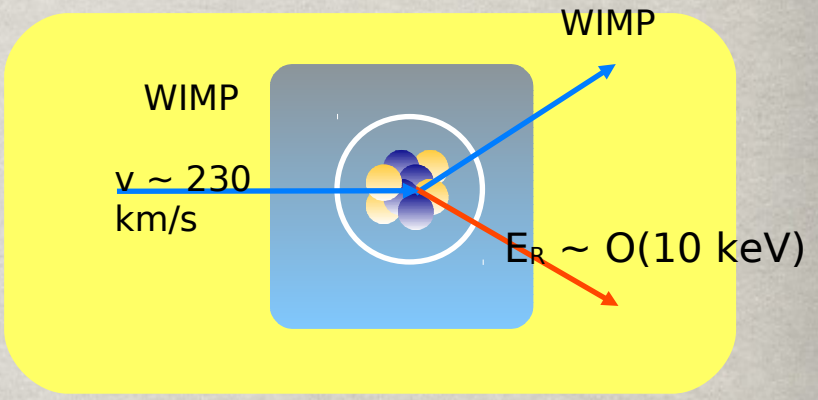
Our Universe

- Most of the matter in our universe is made of Dark Matter
- Dark Matter lies outside the scope of the Standard Model
- Weakly Interacting Massive Particles (WIMPS) are predicted in most Beyond-Standard-Model (BSM) theories (SUSY, KK, ...)
- Their interaction is so weak that out of 10^{15} that pass through your body per day, only <10 interact
- How can we detect them in a lab?

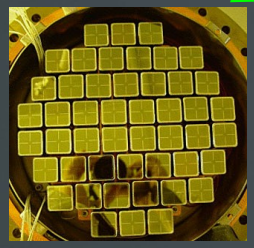


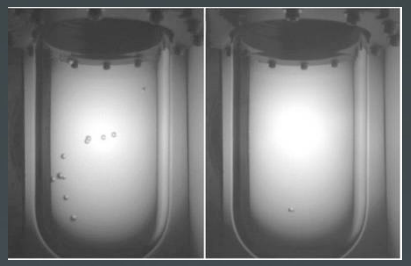
Direct Detection of WIMPs

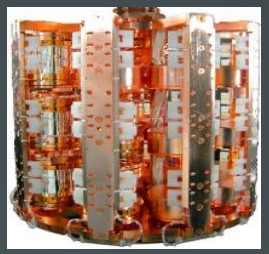
- The DM halo density is around
  $\rho \sim 0.3\ \mathrm{GeV cm^{-3}}$
- WIMP flux on earth is about $10^5\ \mathrm{cm^{-2} s^{-1}}$ (for 100 GeV WIMP). This flux is large enough to enable detection in the lab.
- Direct detection by their elastic collision with nuclei in ultra-low background detectors
- Spin Independent (SI) $\sigma \sim A^2$,
  SD~WIMP couples to nuclear spin J_N



Dark Matter Direct Detection







PICASSO
SIMPLE
COUPP

HEAT

CDMS I-II
superCDMS
EDELWEISS I-II

WIMP

Detector

CRESST -II
ROSEBUD

WIMP

IONIZATION

SCINTILLATION

+time measurement

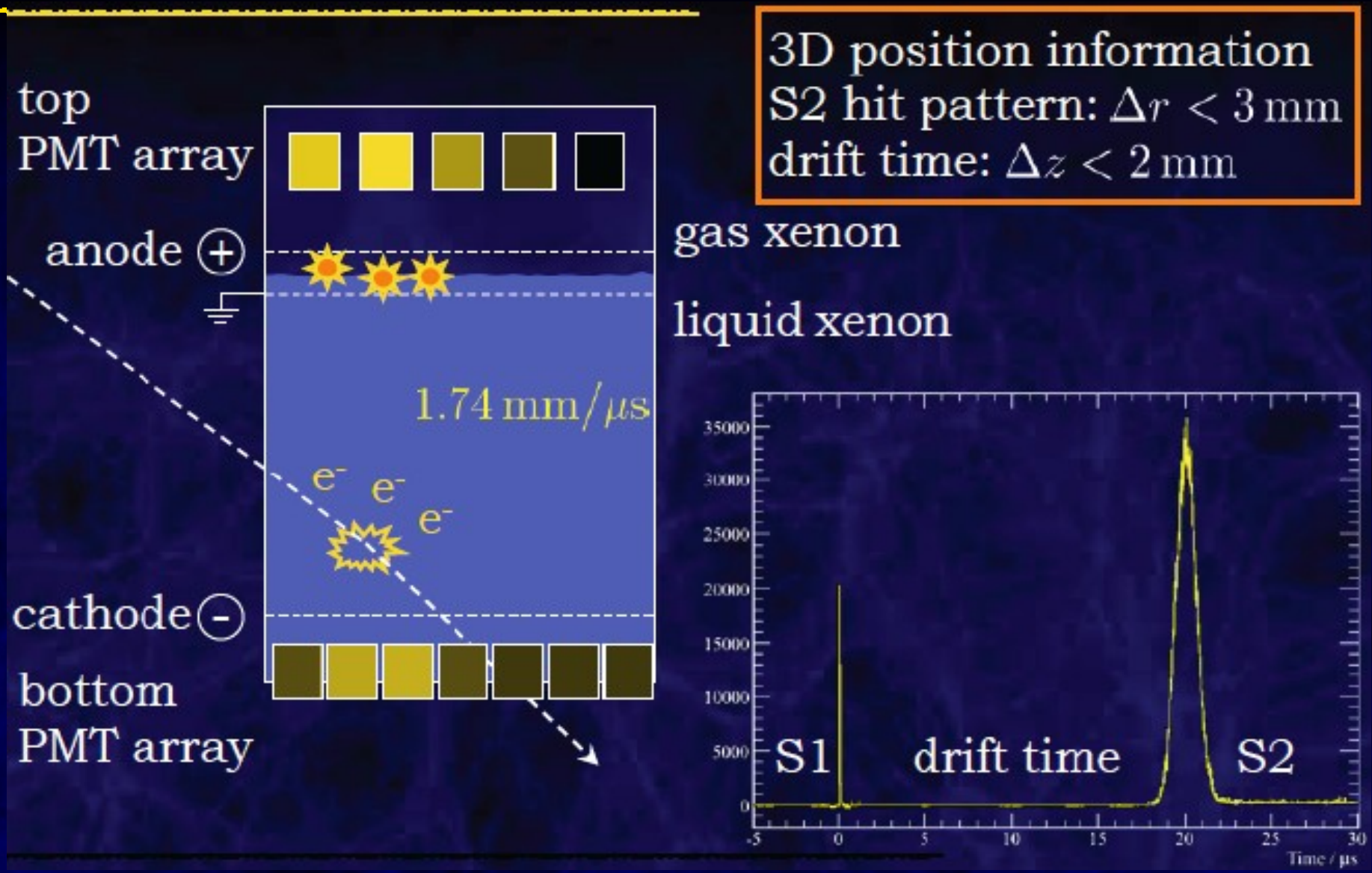
ZEPLIN I
CLEAN
DEAP
XMASS

HPGe exp.
IGEX → GEDEON
GERDA
CoGeNT

ZEPLIN II-III
XMASS II
LUX
XENON
WARP,
ArDM
DarkSide

DAMA / LIBRA
KIMS

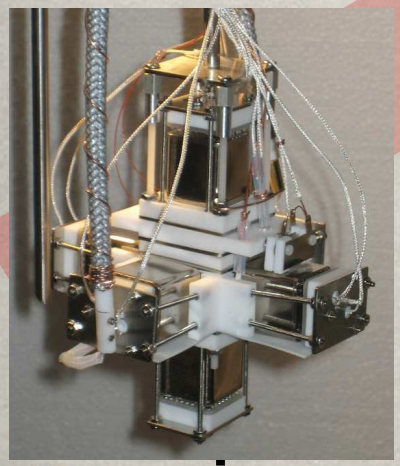
The XENON Detector Concept



→ lots of information for each event

The XENON Program

XENON R&D

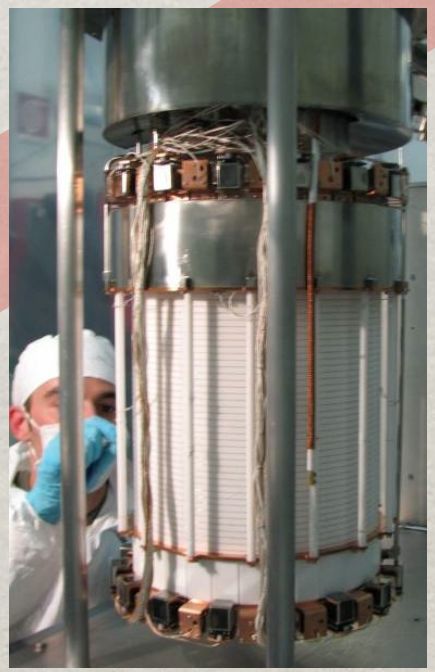


ongoing

XENON10

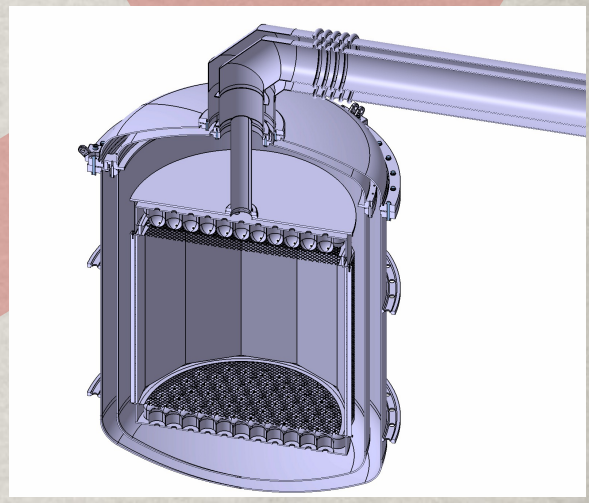
PRL100
PRL101
PRD 80
NIM A 601

XENON100



2008-2011
taking science data
first results: PRL105

XENON1T

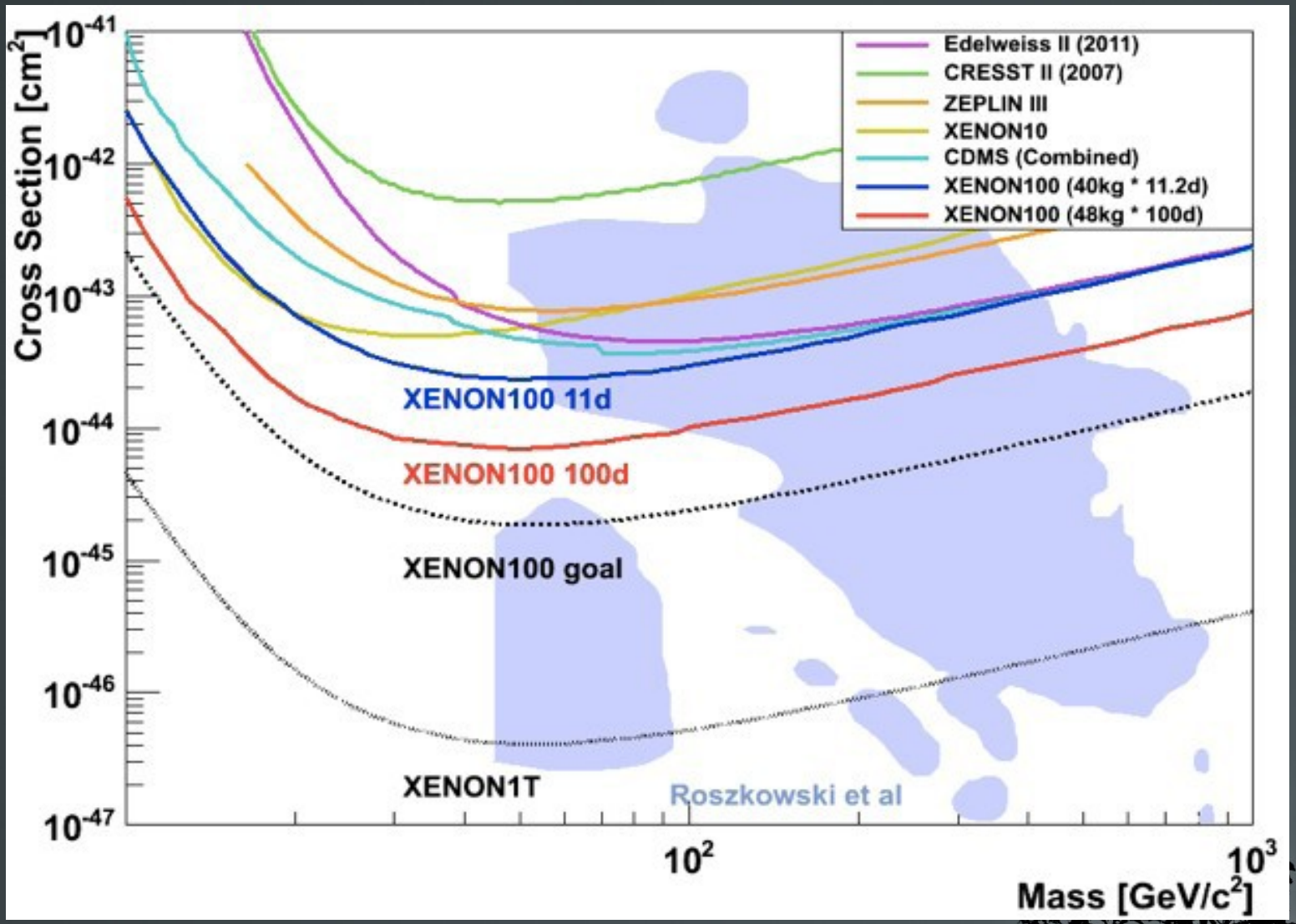


1 ton fiducial
2.4 t total
@180K

2011-2015

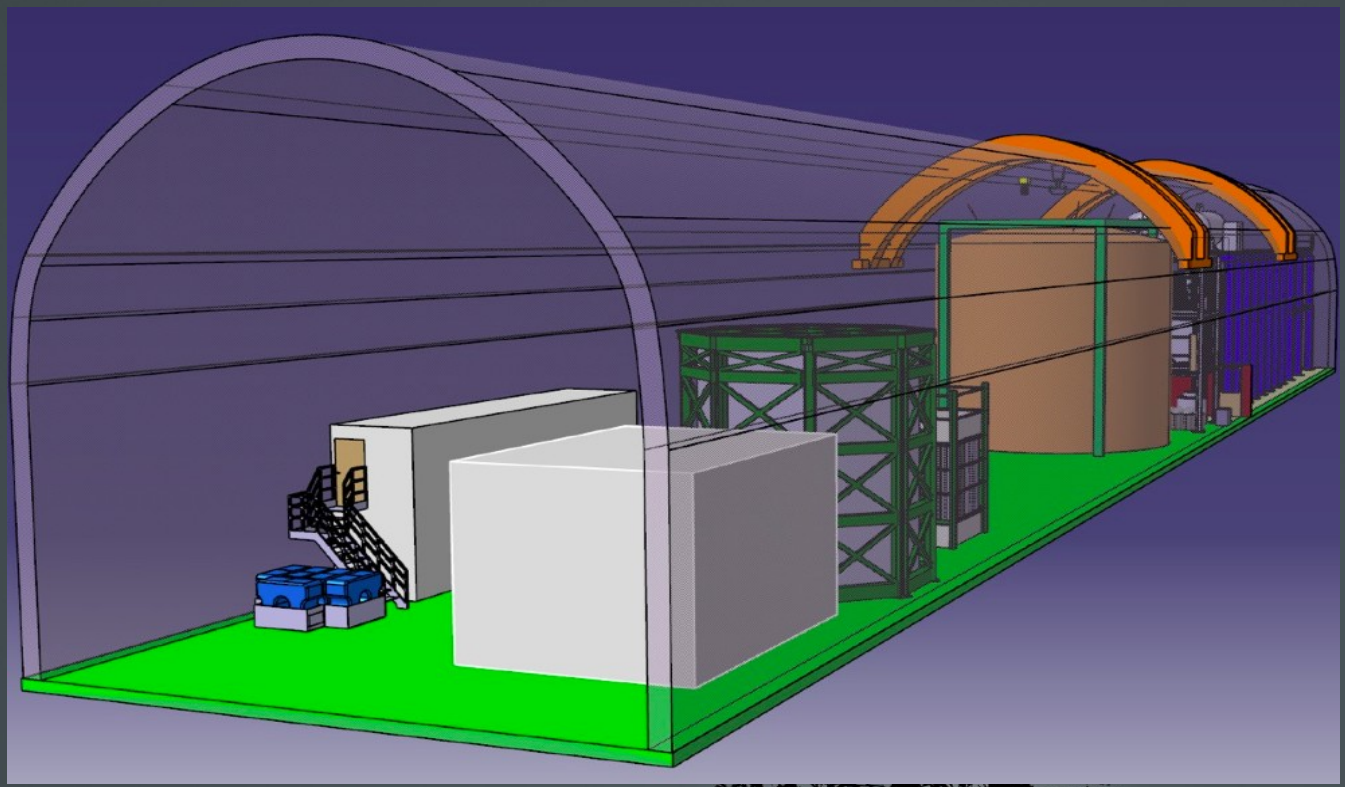
The XENON1T collaboration

XENON sensitivity goal

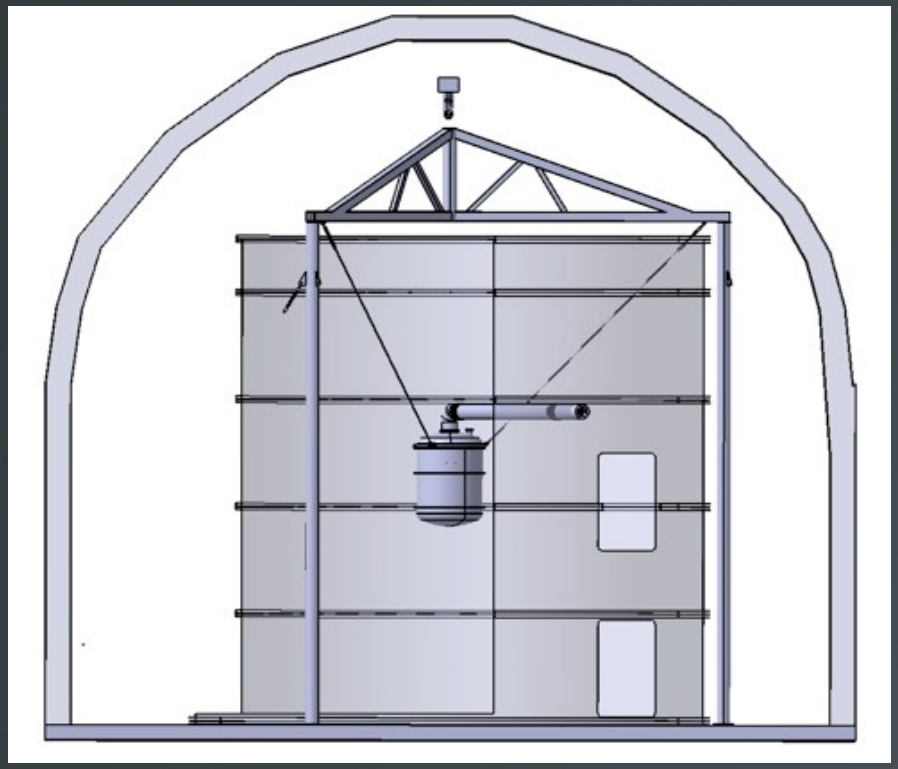


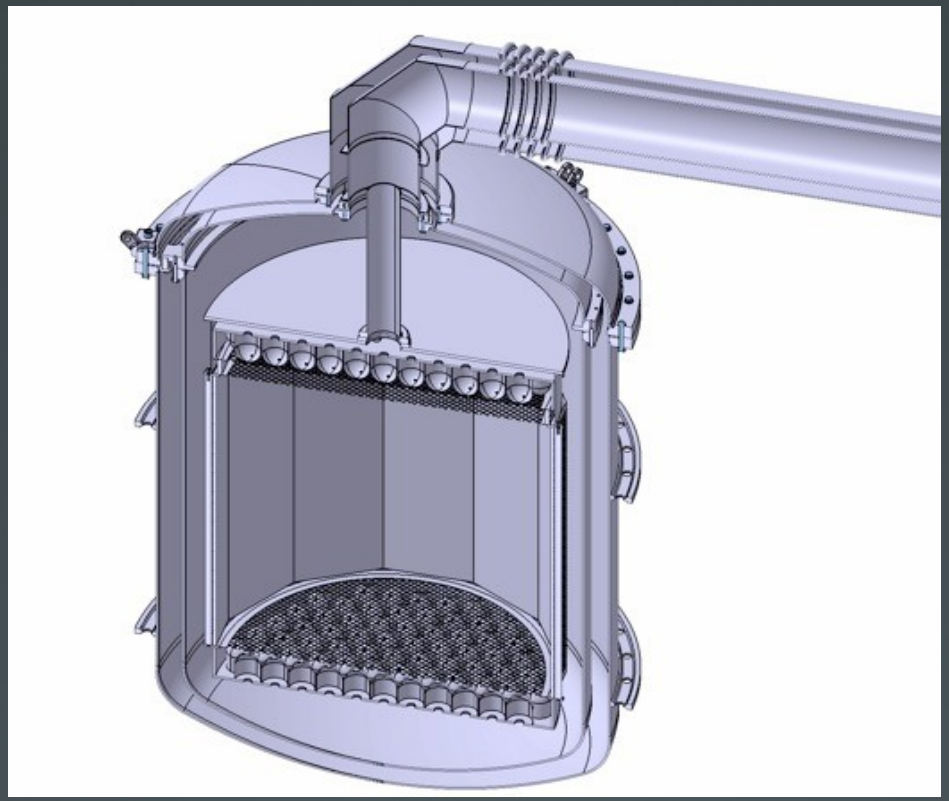
The future: XENON1T

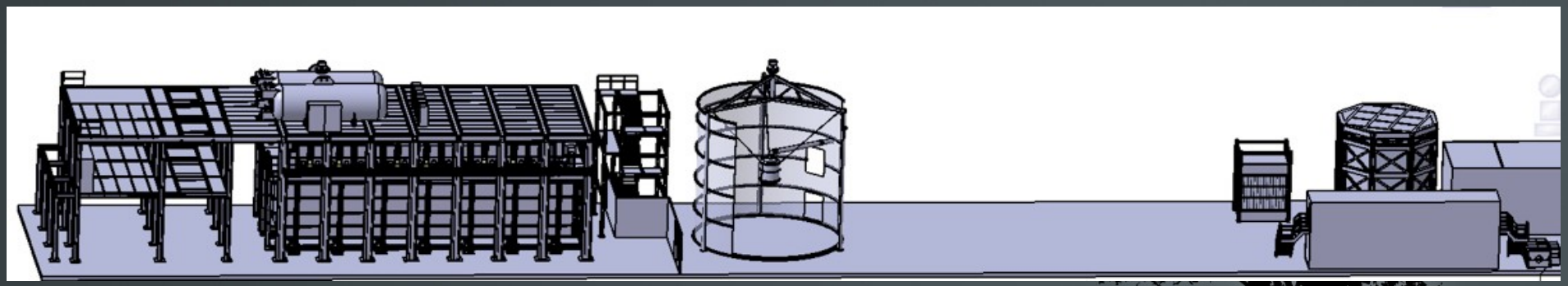
- 2.4 tons of liquid Xenon with a 1 ton fiducial volume
- 5 meter radius water shield instrumented with PMTs
- Approved to be built in Hall B in LNGS



The future: XENON1T

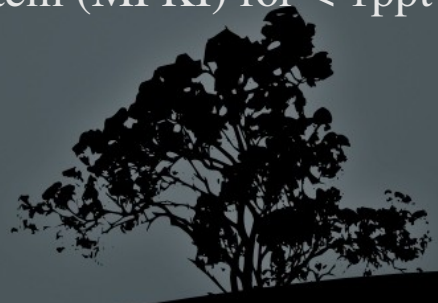






Highlights of technologies and concepts for XENON1T

- XENON1T Demonstrator for long drift and HV tests (Columbia and Rice)
- Cryogenics system with heat exchanger high flow rate purification (Columbia)
- Measured QE at low temperature of 3" Hamamatsu R1140 and R8520 with LT Bialkali PC (Columbia & Munster)
- Measured response of 3" QUPIDs in LXe (UCLA)
- Measured radioactivity of all above PMTs for XENON (Zurich)
- Measured low activity SS and Ti for XENON1T cryostat (Zurich)
- Designed a new system for storage of 3 ton Xe in gas and liquid phase (Subatech)
- Designing new Kr distillation column (Munster)
- Developed Atom Trap (Columbia) and Mass Spectrometry system (MPKI) for < 1ppt measurement of Kr/Xe



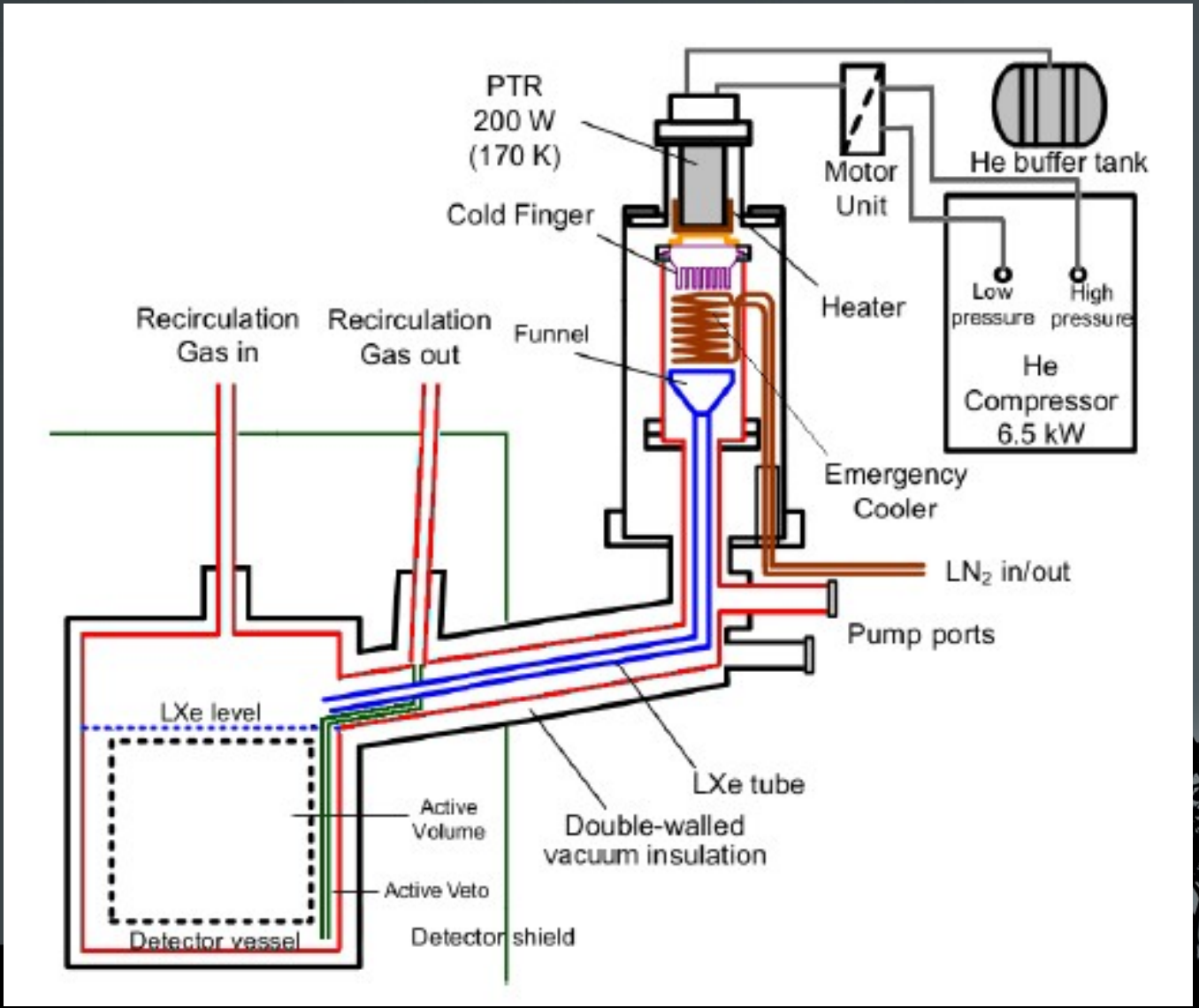
Challenges for 1 Meter Drift LXe TPC

- Purification:
  - High speed recirculation (2.4t purification must not take months...) **Cost: 11 Watt/slpm**, ~80% for latent heat
  - Long electron lifetime
- High Voltage:
  - Notoriously problematic
  - Feedthrough (Vacuum, size, radiopurity)
  - Meshes
  - PMTs/QUPIDs

XENON1T Demonstrator

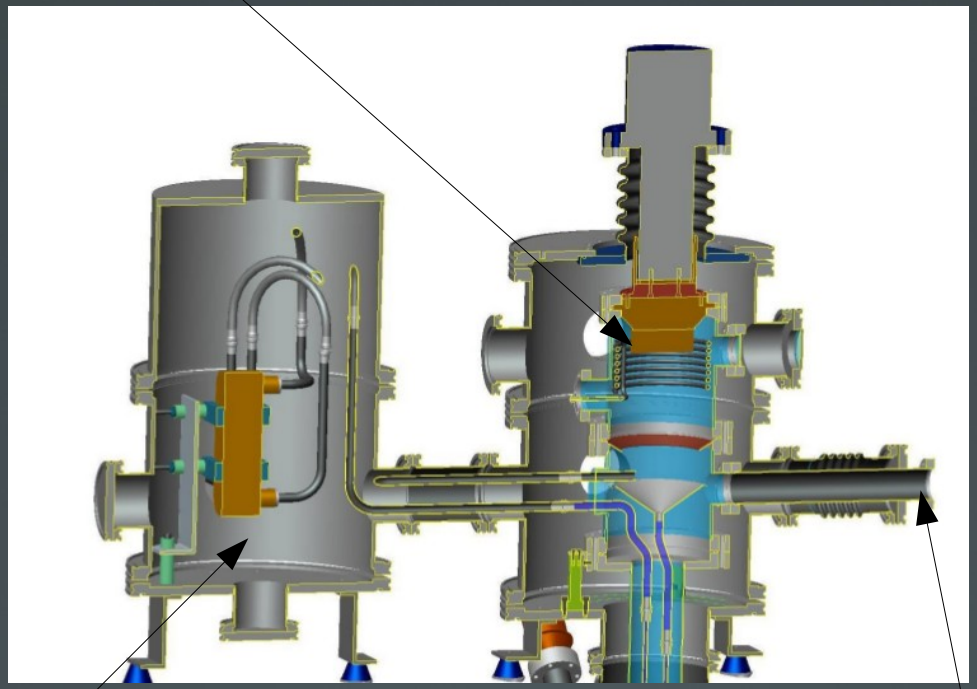
Cooling: XENON100 cooling system

- Separating the cooling / circulation from the TPC, for the sake of low background



Cooling and heat exchange

Xe volume separated from the cooler



TPC ↓

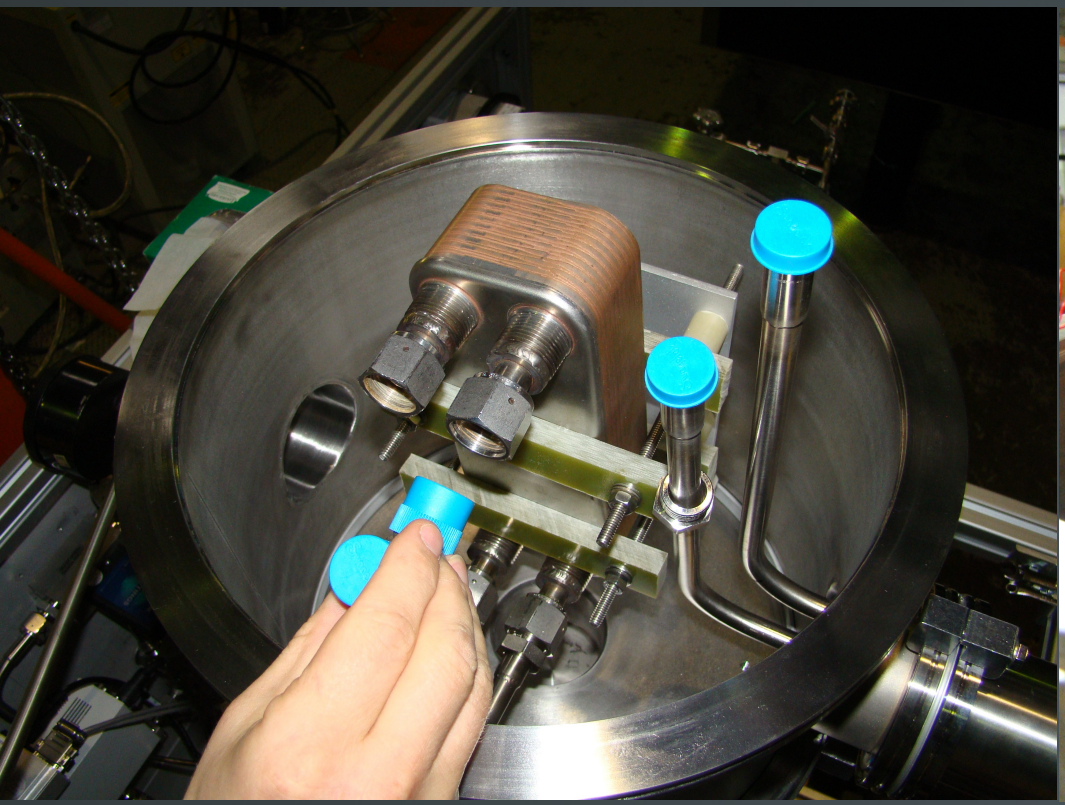
pump

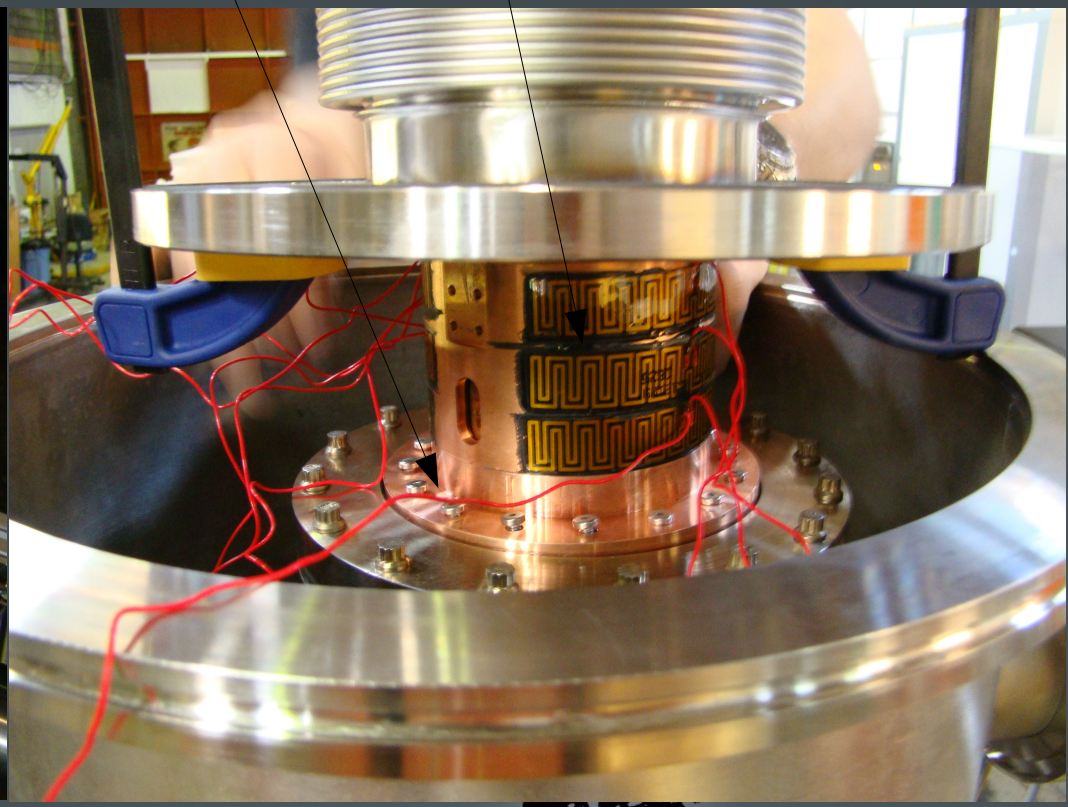
Heat exchanger

Heater

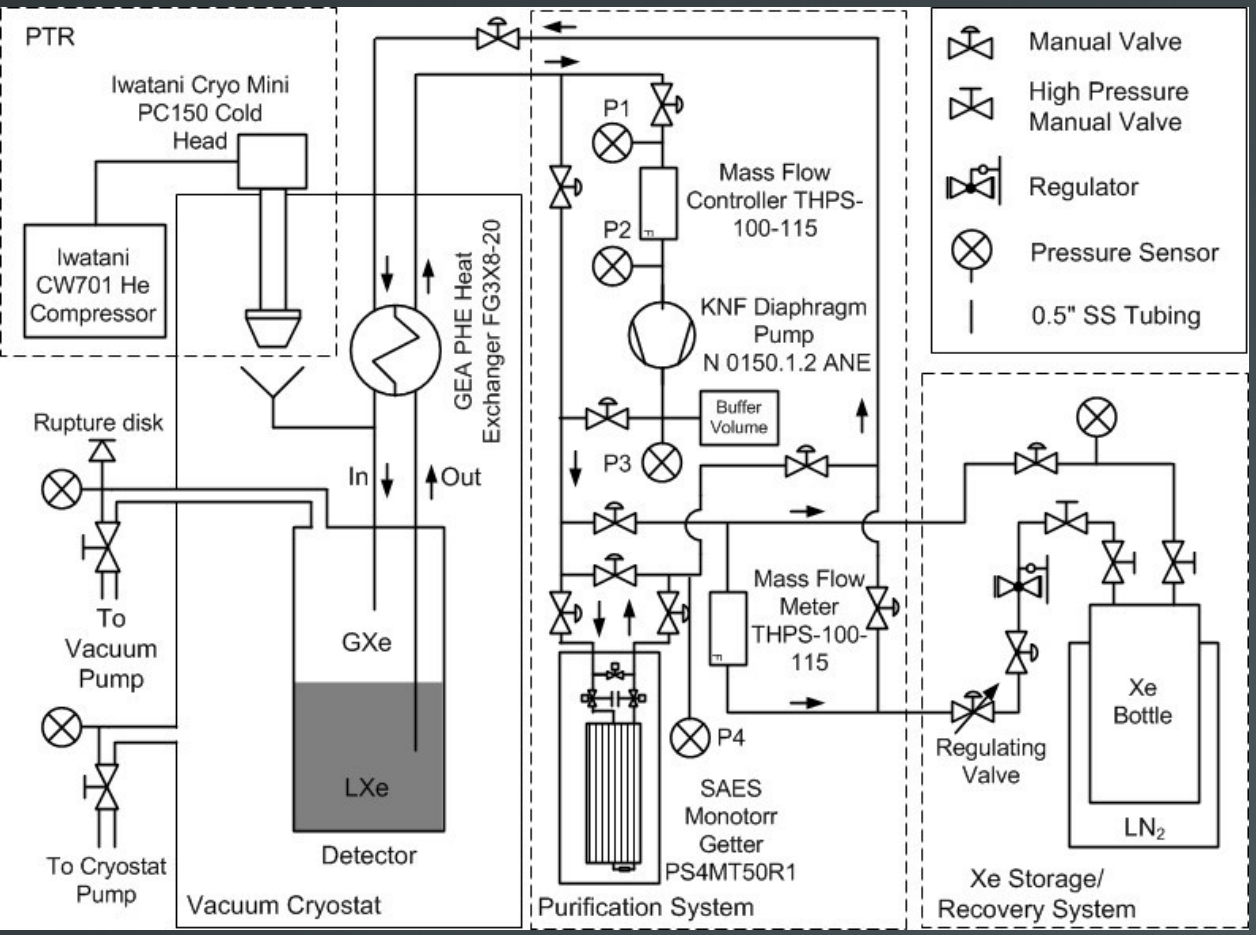
Connection between
cold finger and cooler

What is wrong here?





Gas system



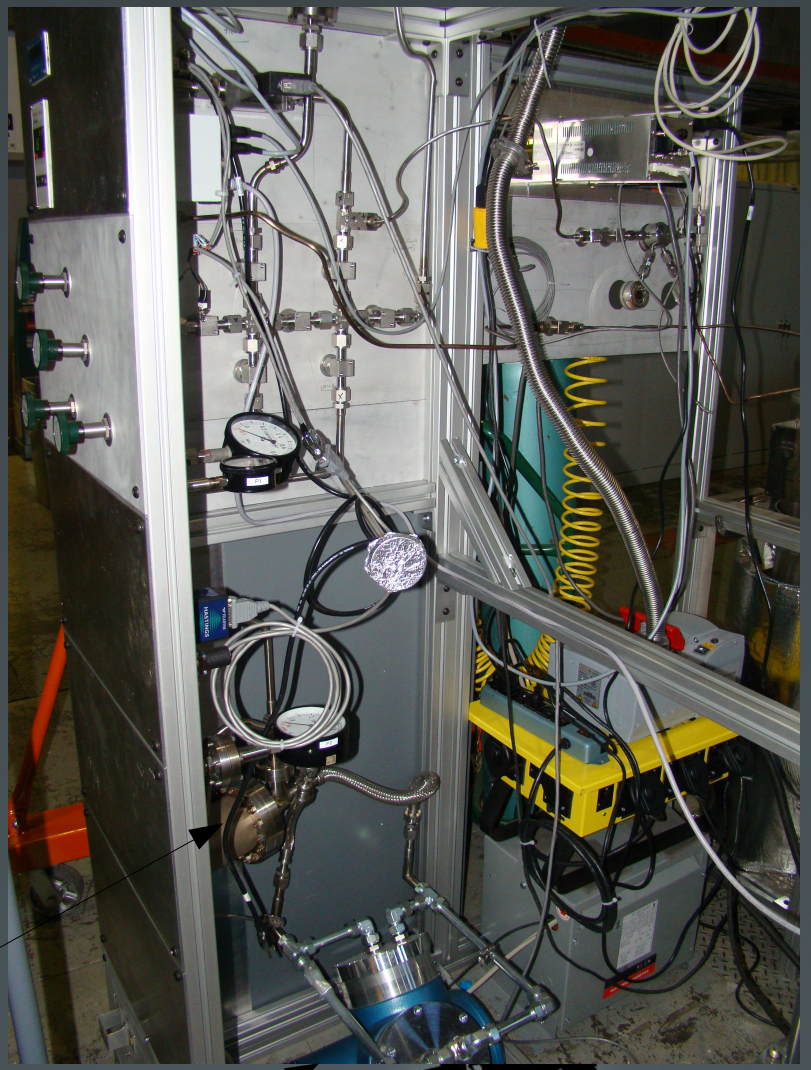
½" pipes for low resistance to flow

Large capacity pump by KNF – capable of flowing 200 slpm

Large capacity SAES getter – nominally capable of 75 slpm

Buffer volume

Heat exchanger



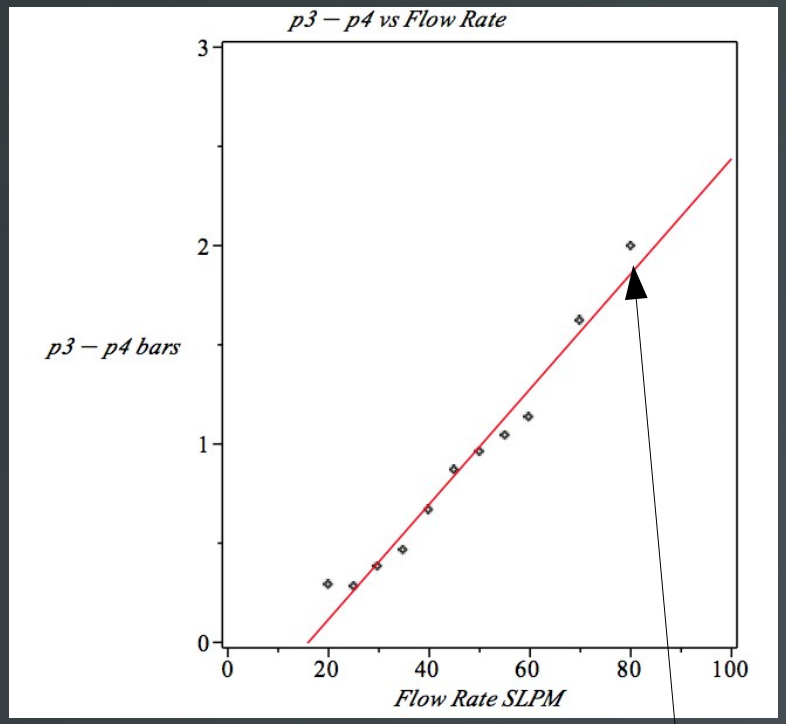
Getter

Buffer Volume

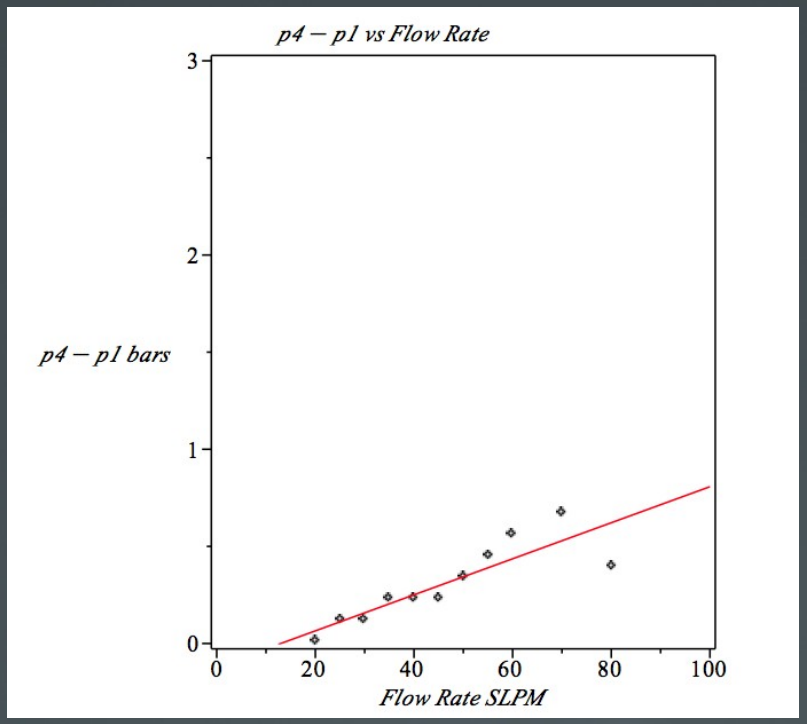
Pump

Fast recirculation

Pressure drop on the getter



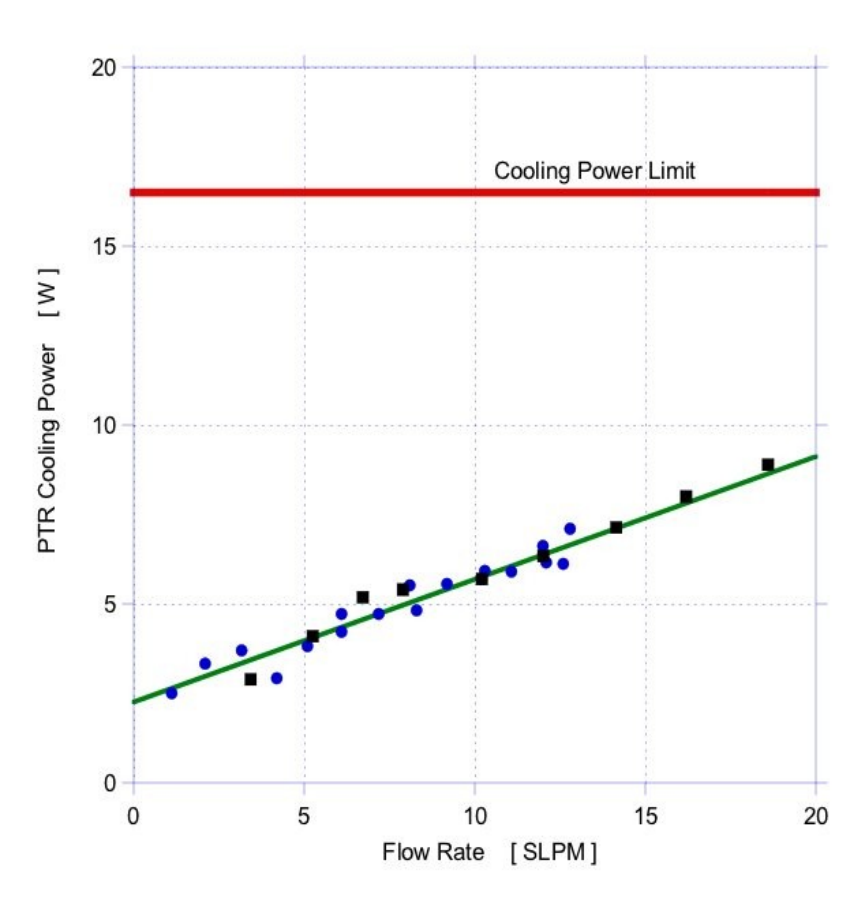
Pressure drop on the Heat Exchanger



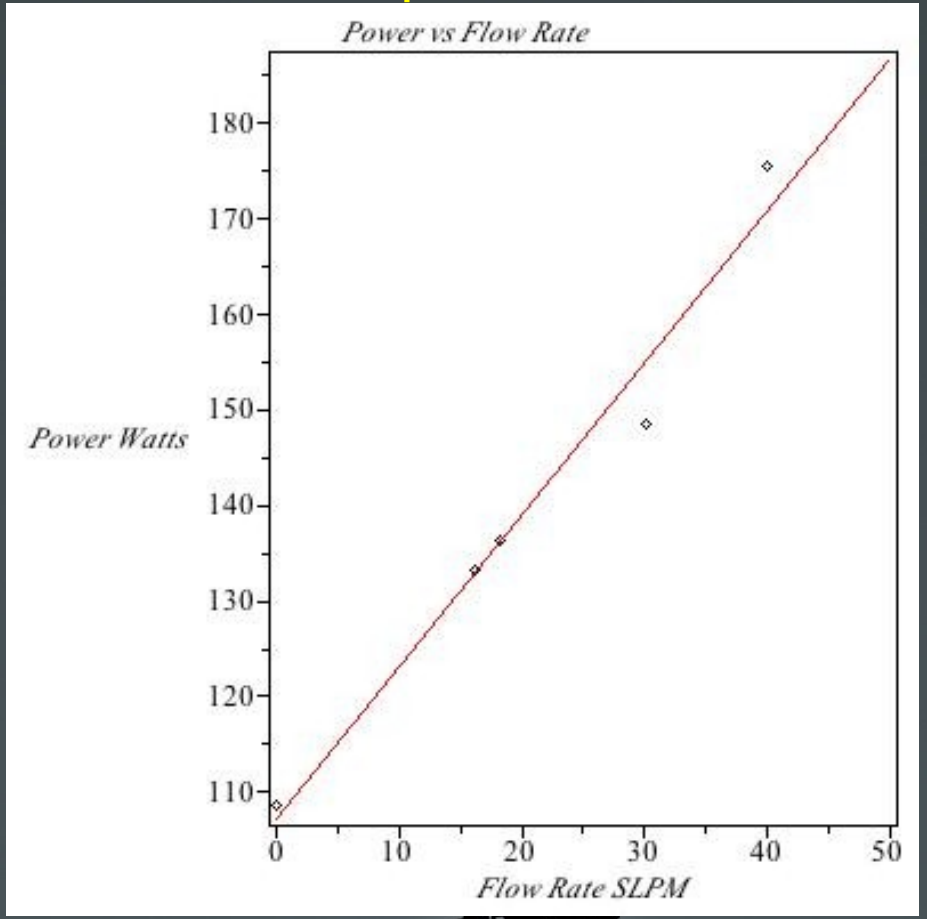
Violent pressure fluctuations, buffer volume required

Heat exchange efficiency

On a smaller system (28W cooler), up to 13 slpm Lxe – 96%!

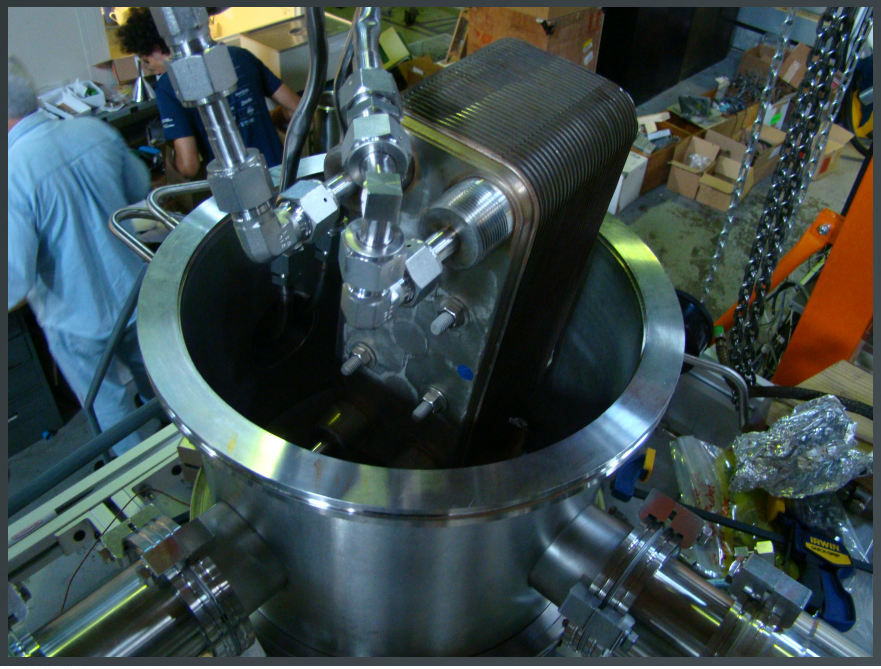


With the same Heat exchanger, limited to 40 slpm – down to 85%



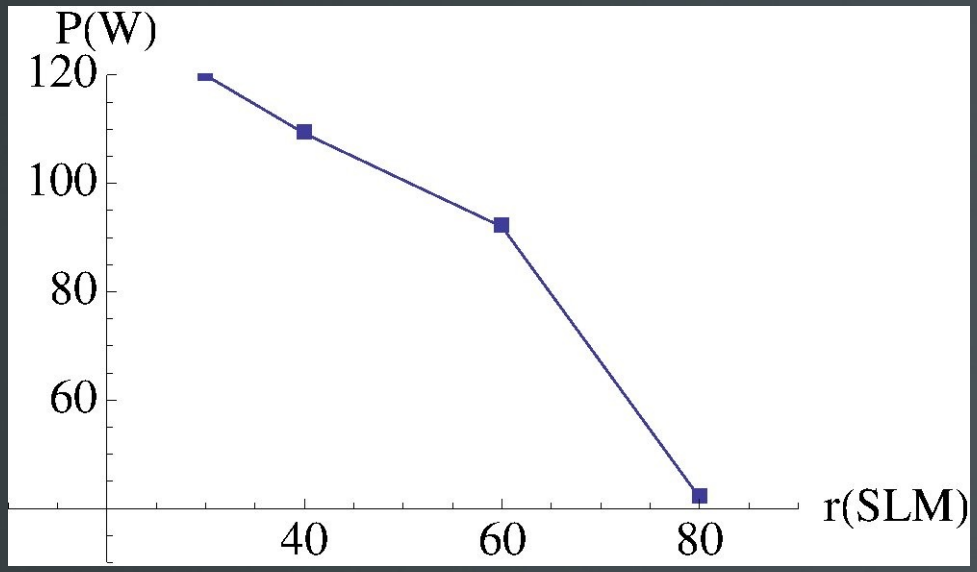
JINST 6 P03002 (2011)

Larger HE



High capacity (almost 4 litres) heat exchanger

Mounted correctly, ¼" pipes on the liquid side

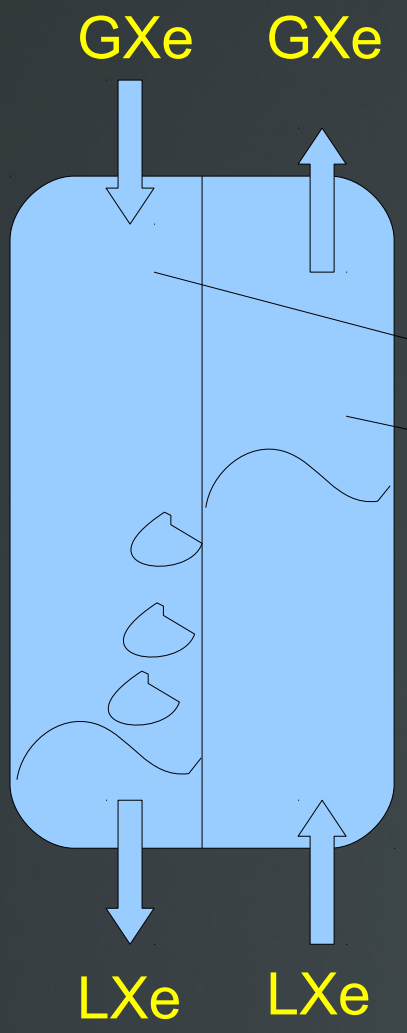


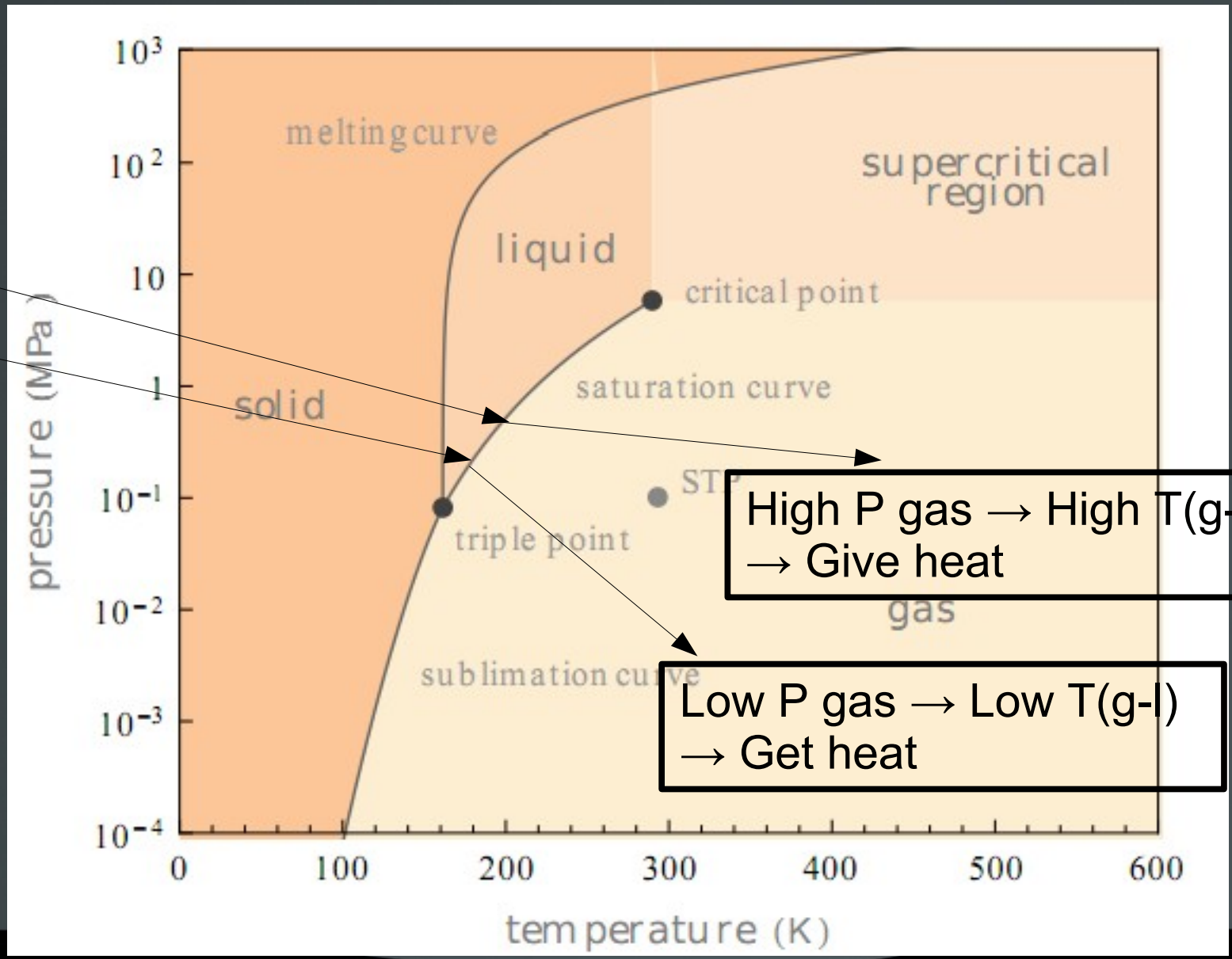
Efficiency > 90% up to 70 slpm

Able to circulate ~90 slpm

higher flow expected after more tuning

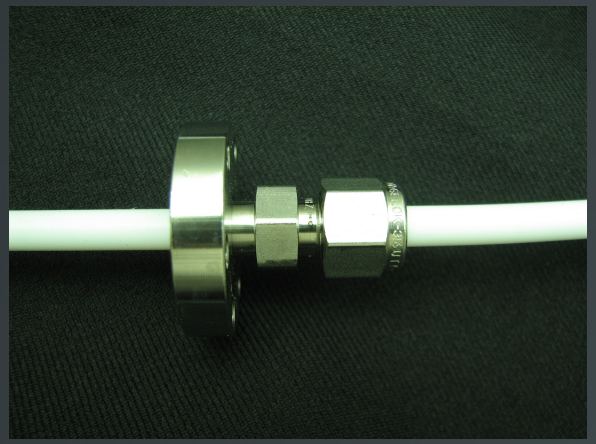
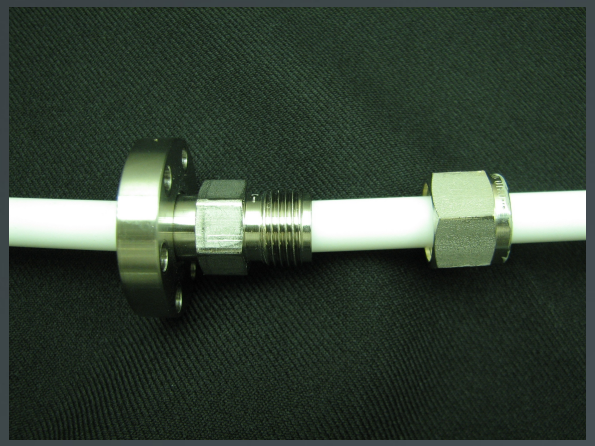
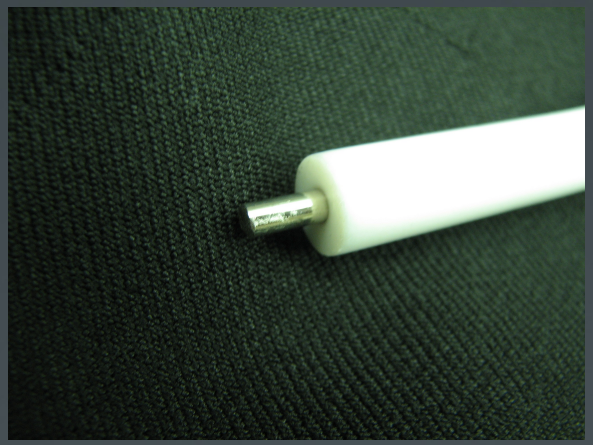
Physics principle – liquid heat exchange





Movie

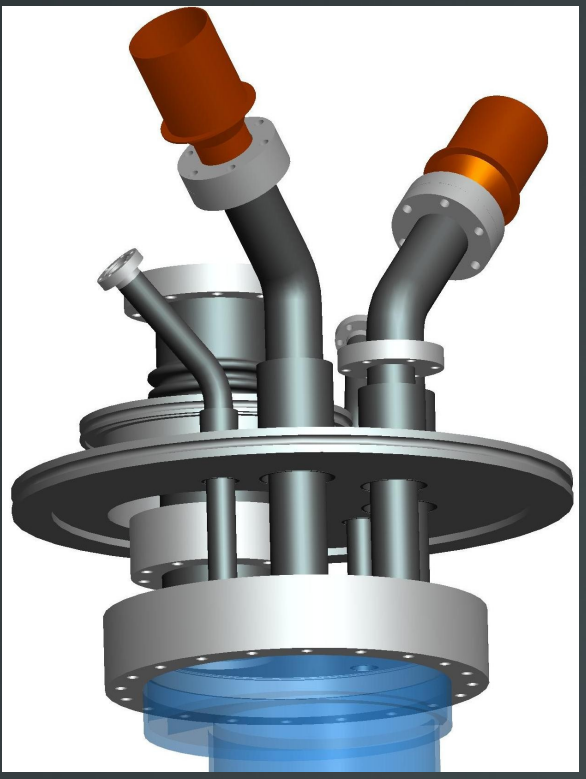
High voltage FT

Special Feed Through, based on design used for Xe100:
- 3/8" tube, fits on a mini CF or CF40
- Low radioactivity
- Leak tight at operation conditions
- Tested with a grid in Lxe up to 60kV

Dedicated test setup at Columbia/Rice

TPC



TPC and vacuum jacket designed to have a net of 1m drift

Testing both 3" Hamamatsu PMT and QUPID

Being manufactured, will be ready in a few weeks.

Summary

- The first phase of the XENON1T Demonstrator has been completed
- High circulation rate up to 90 SLPM has been achieved. Higher rate expected in the future
- Low radioactivity HV feed-through tested with cathode mesh in LXe up to 60 KV
- Two-phase TPC with drift gap up to 1 meter is being manufactured
- Both 3" PMTs and QUPIDs will be tested in this TPC