R&D for Solid Xenon Particle Detector

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TIPP 2014, Dark Matter Session II

Amsterdam

Friedrich-Alexander-Universität Erlangen-Nürnberg

IMPRS physics of light

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Fermilab

Outline

I. Crystallography

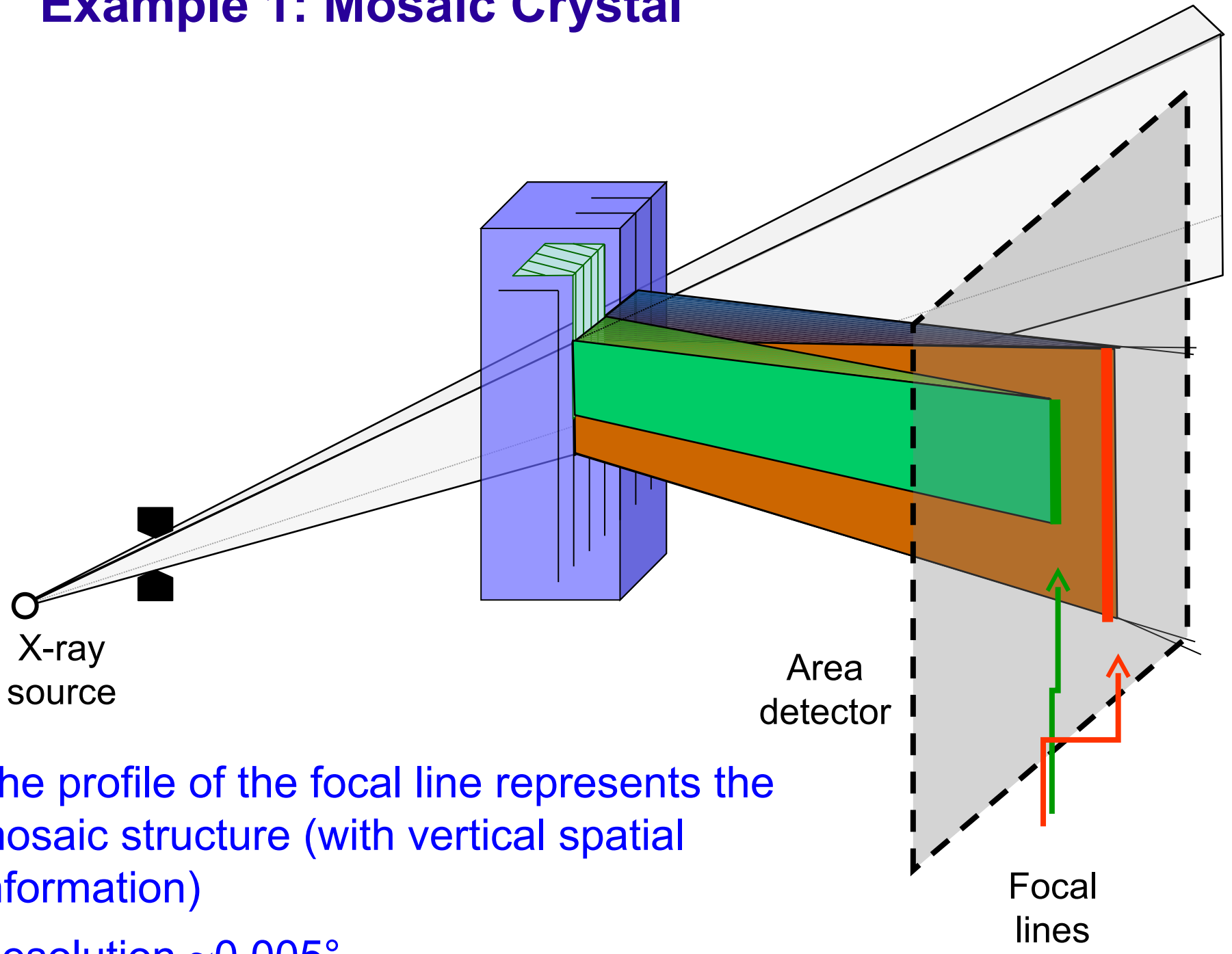
II. Detection of Scintillation Signal

III. Detection of Ionization Signal

IV. Next Steps

I. Crystallography

Example 1: Mosaic Crystal

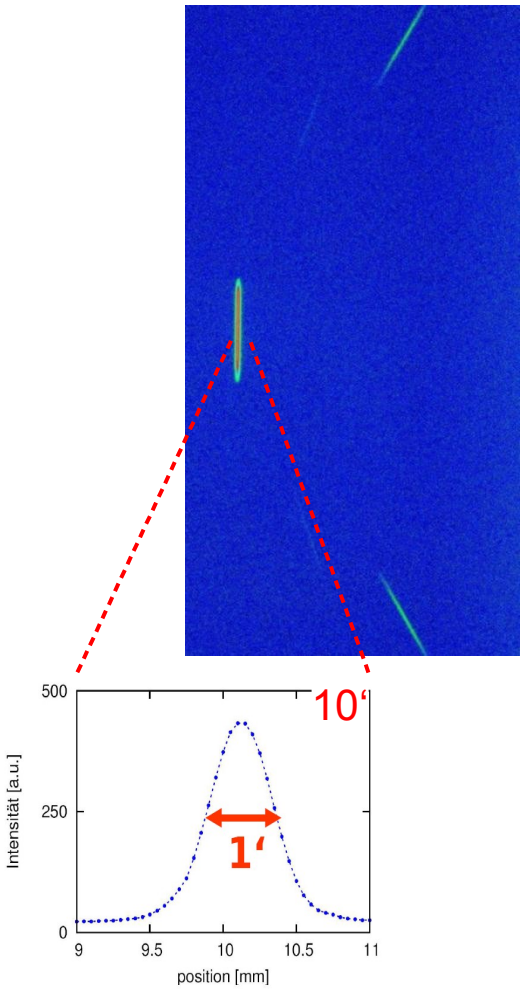


The profile of the focal line represents the mosaic structure (with vertical spatial information)

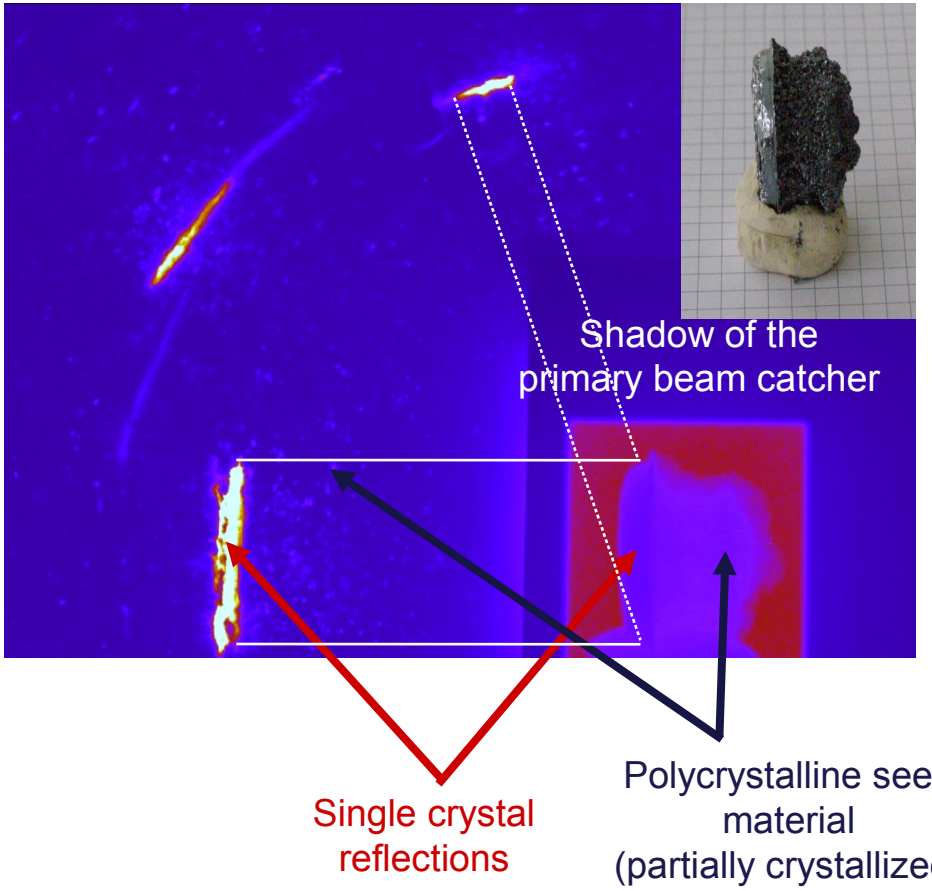
Resolution ~0.005°

Example 2: Silicon and SiGe Crystals

Ideal Si
CCD-detail: 20 x 10 cm²



SiGe by gas phase transport reaction
CCD-detail: 20 x 30 cm²

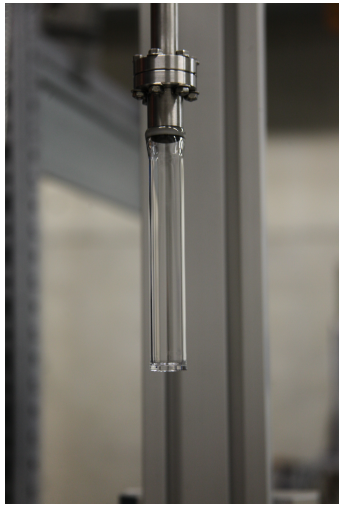


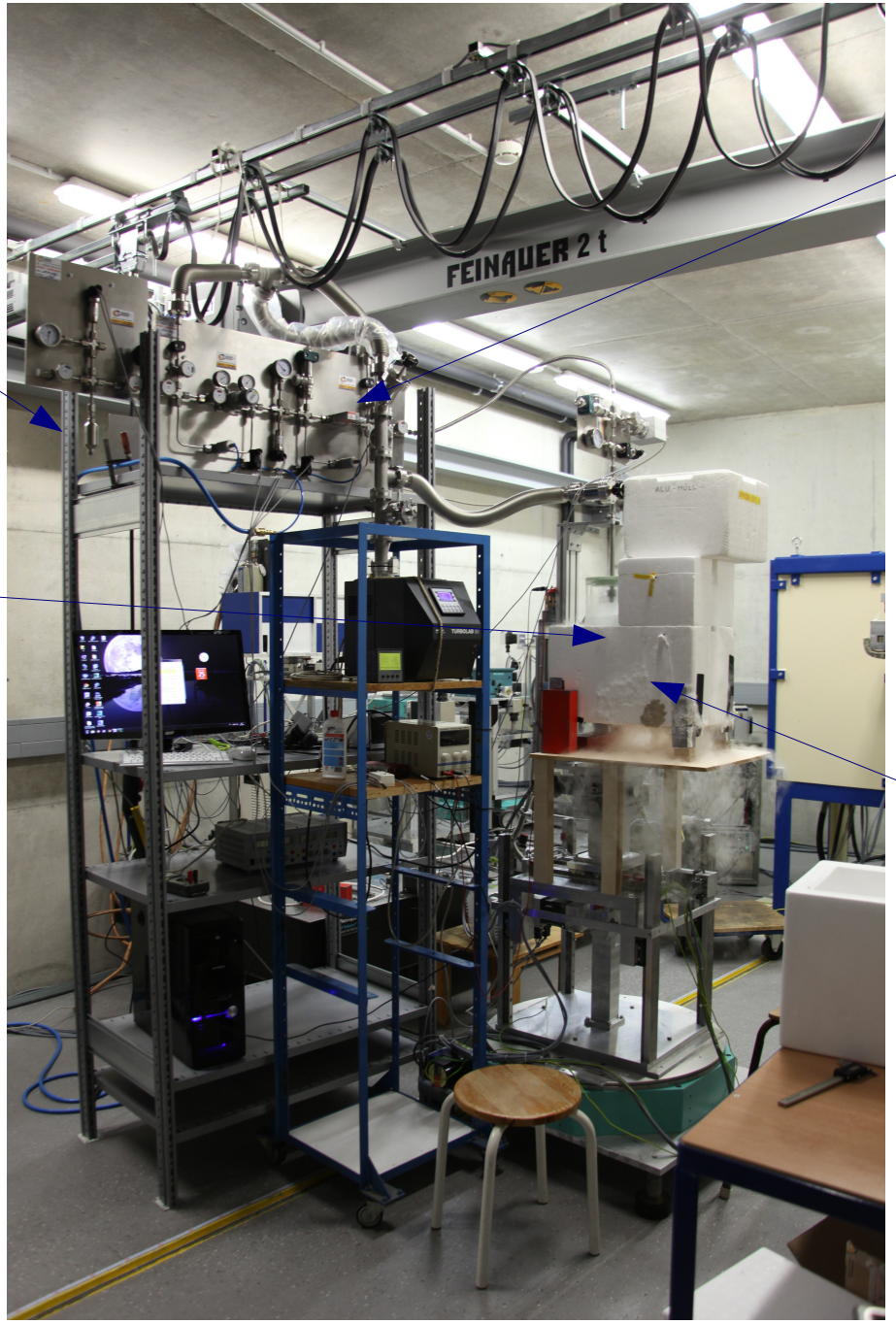
The Setup

The Setup

sample bottle (1l gas @ 15 bar)

xenon growth glas (d =16 mm)



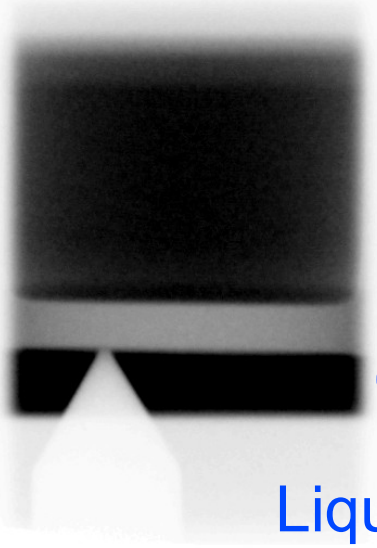


mass flow controller (< 10 ml/min)

temperature control (0.3° / 20 min)

Real Time Structure Observations with Solid Argon

Starting Point

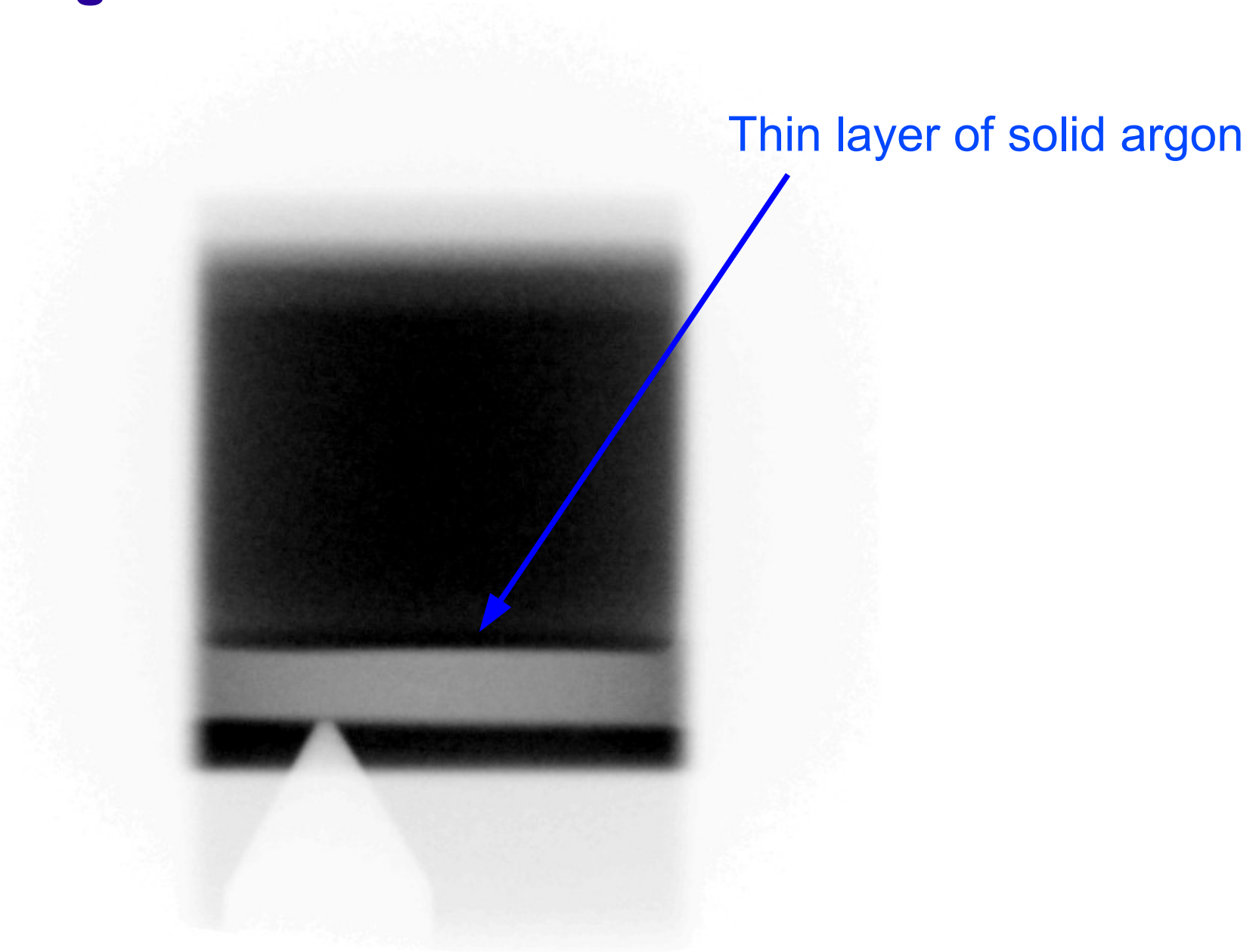


Bottom of the Glas
(~ 2 mm)

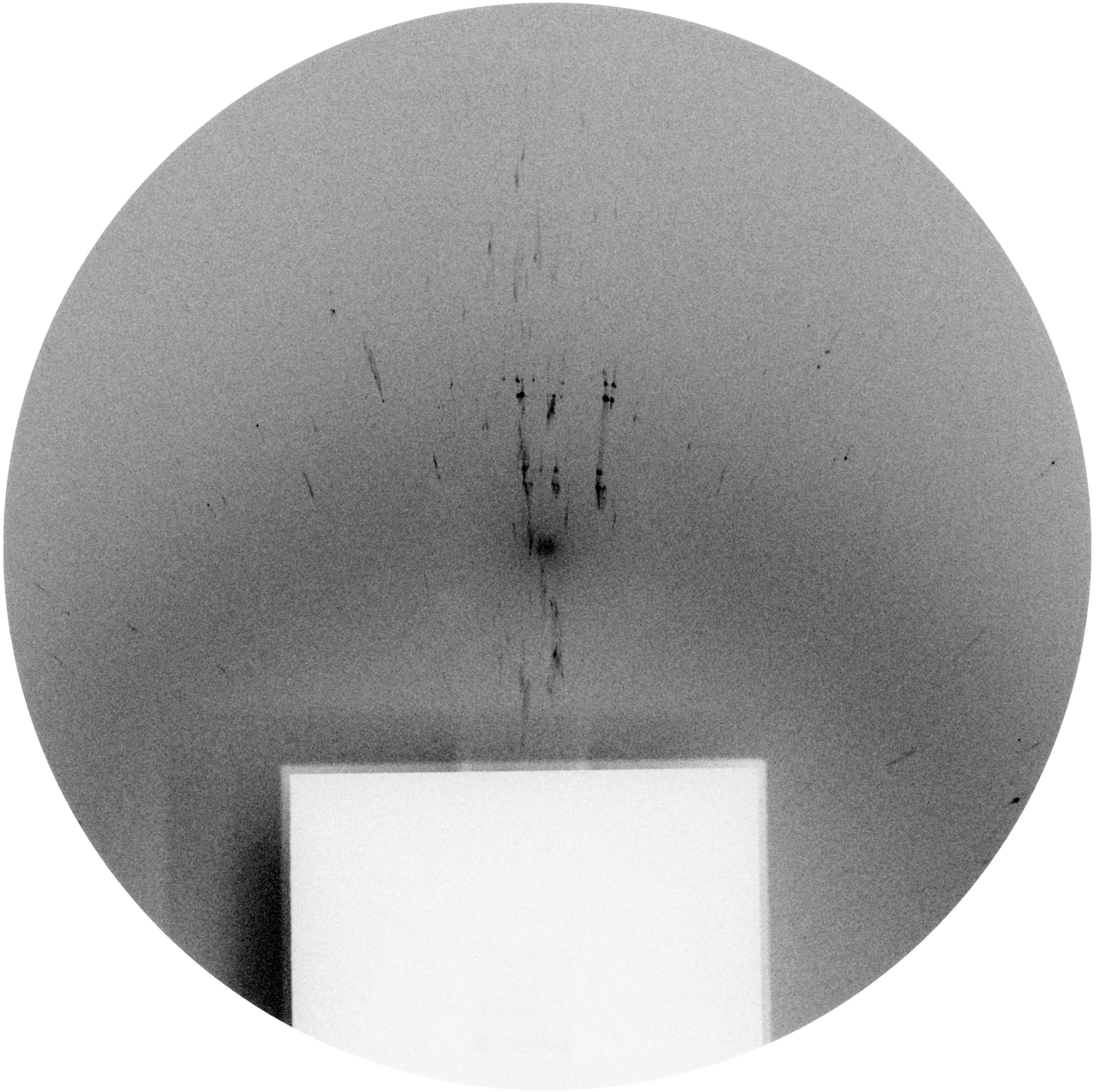
Cold Finger

Liquid Nitrogen

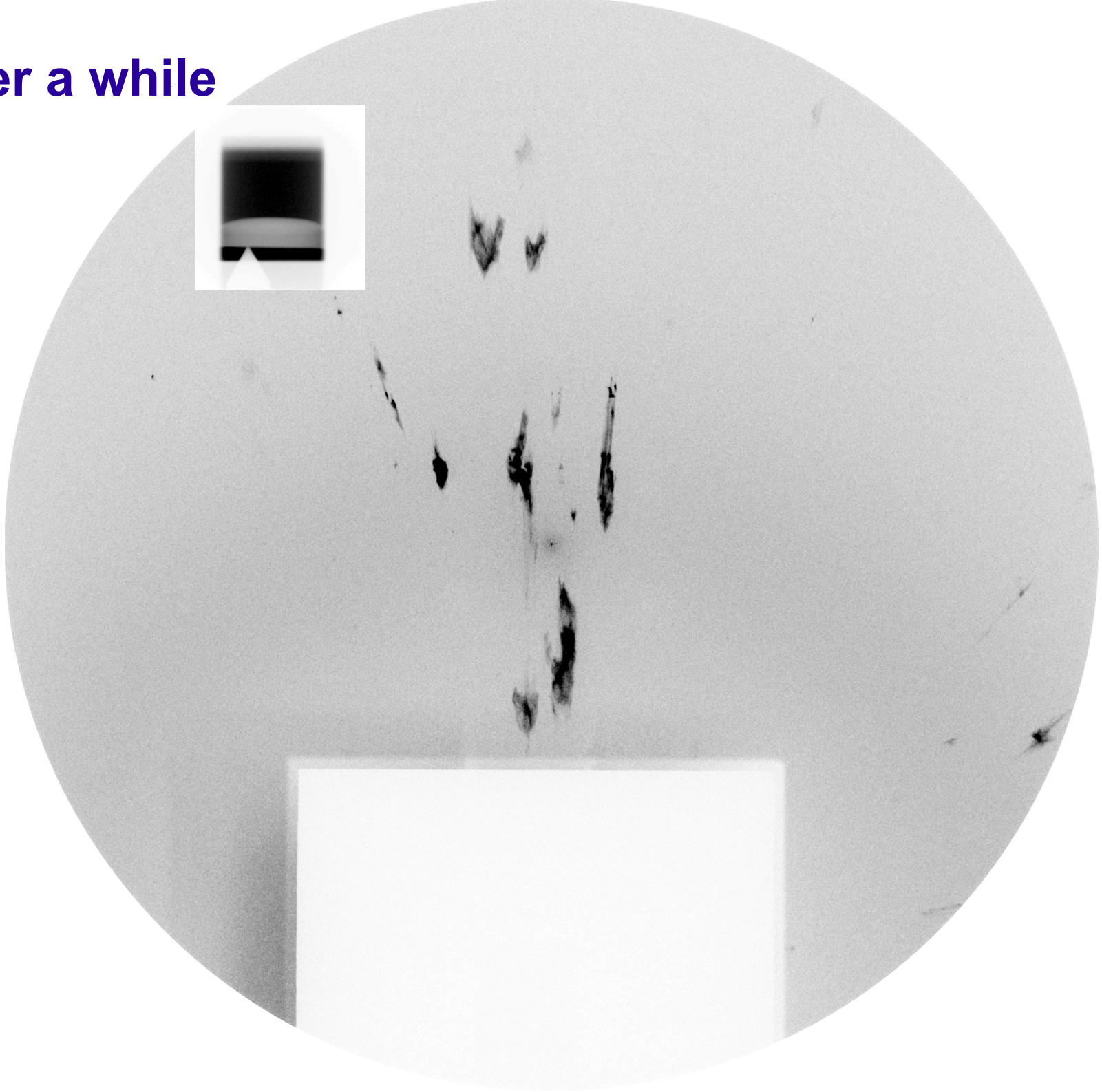
The Growing Starts



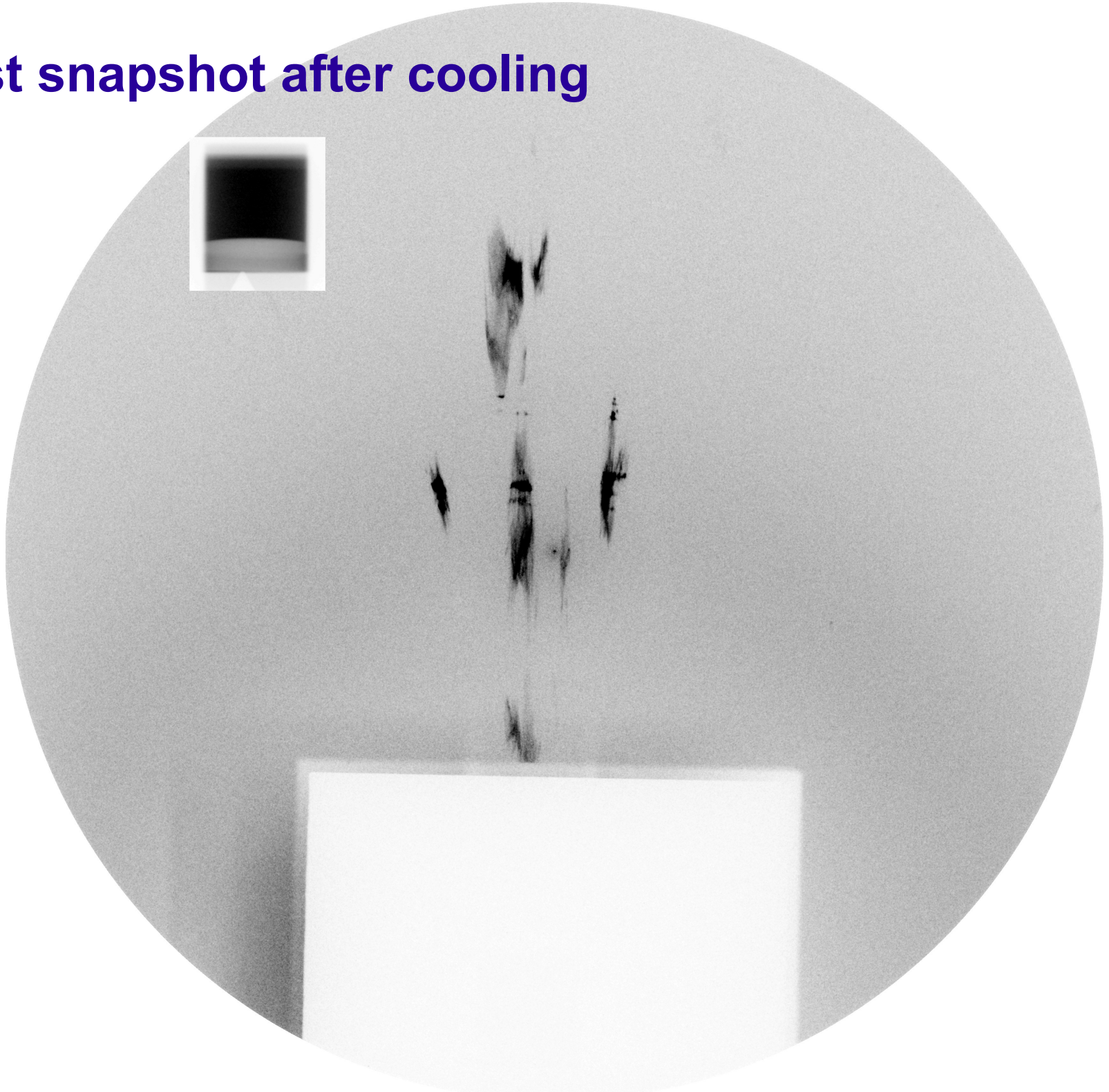
The Growing Starts – Laue Image



After a while



Last snapshot after cooling



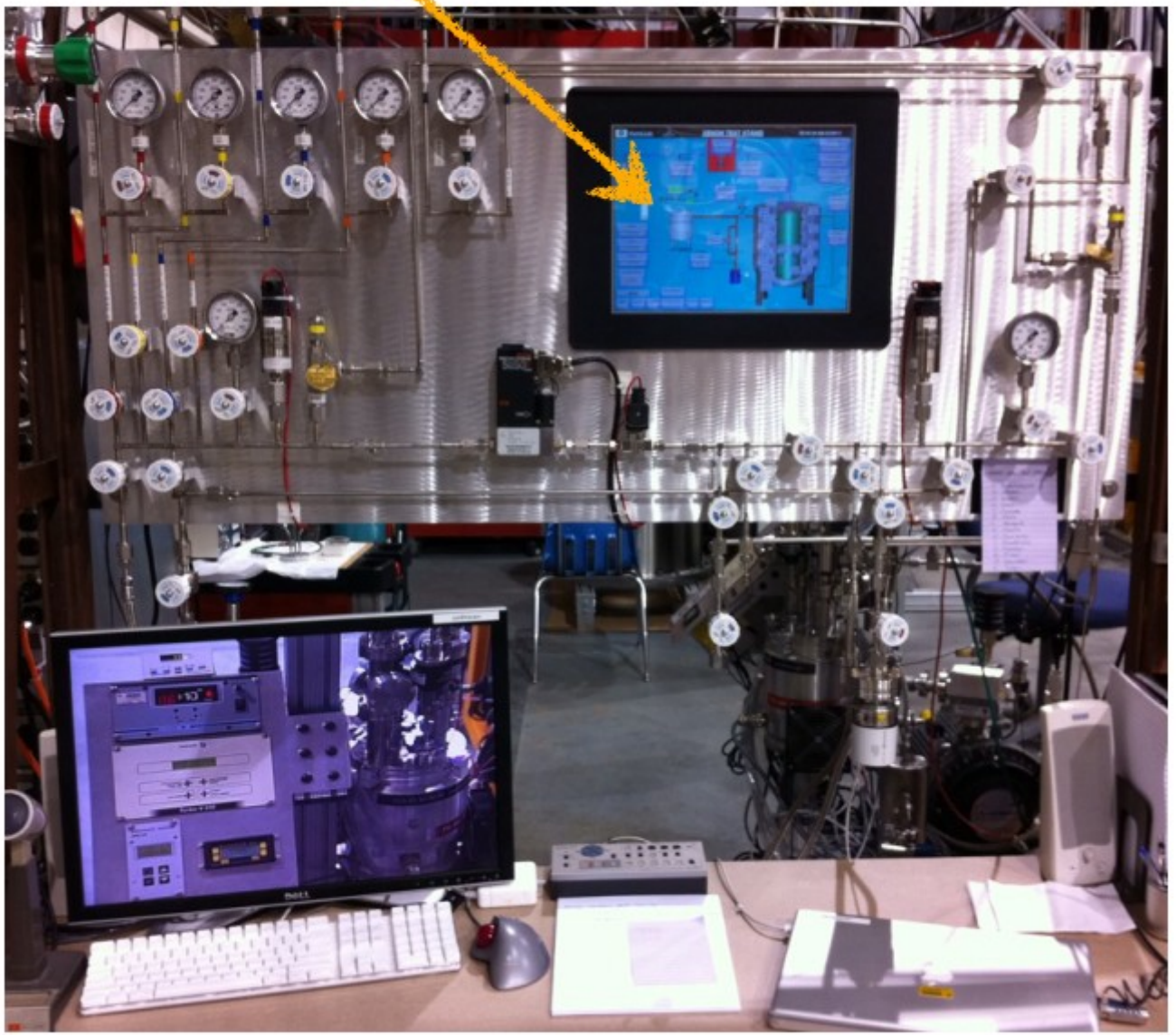
II. Results from Fermilab (Scintillation Reaodut)

as presented
by J. Yoo
at UCLA DM '14

Setup at Fermilab - Overview

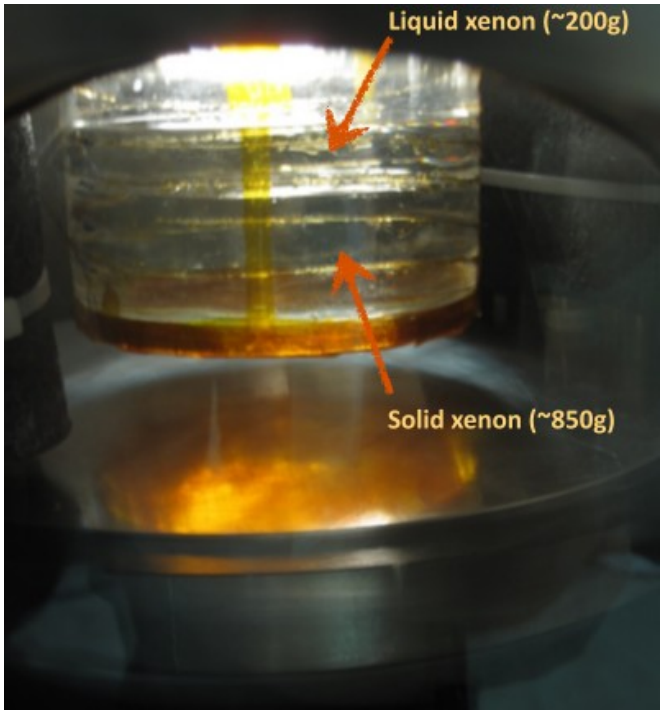
Setup at Fermilab – Gas Control

Cryobath level, temperature, pressure and flow rates control
Monitoring (graph) tools, remote control (D.Markley)



Setup at Fermilab – Crystal Growth

Setup at Fermilab – Crystal Growth



Solid xenon grown in Pyrex-glas (d = 84 mm)

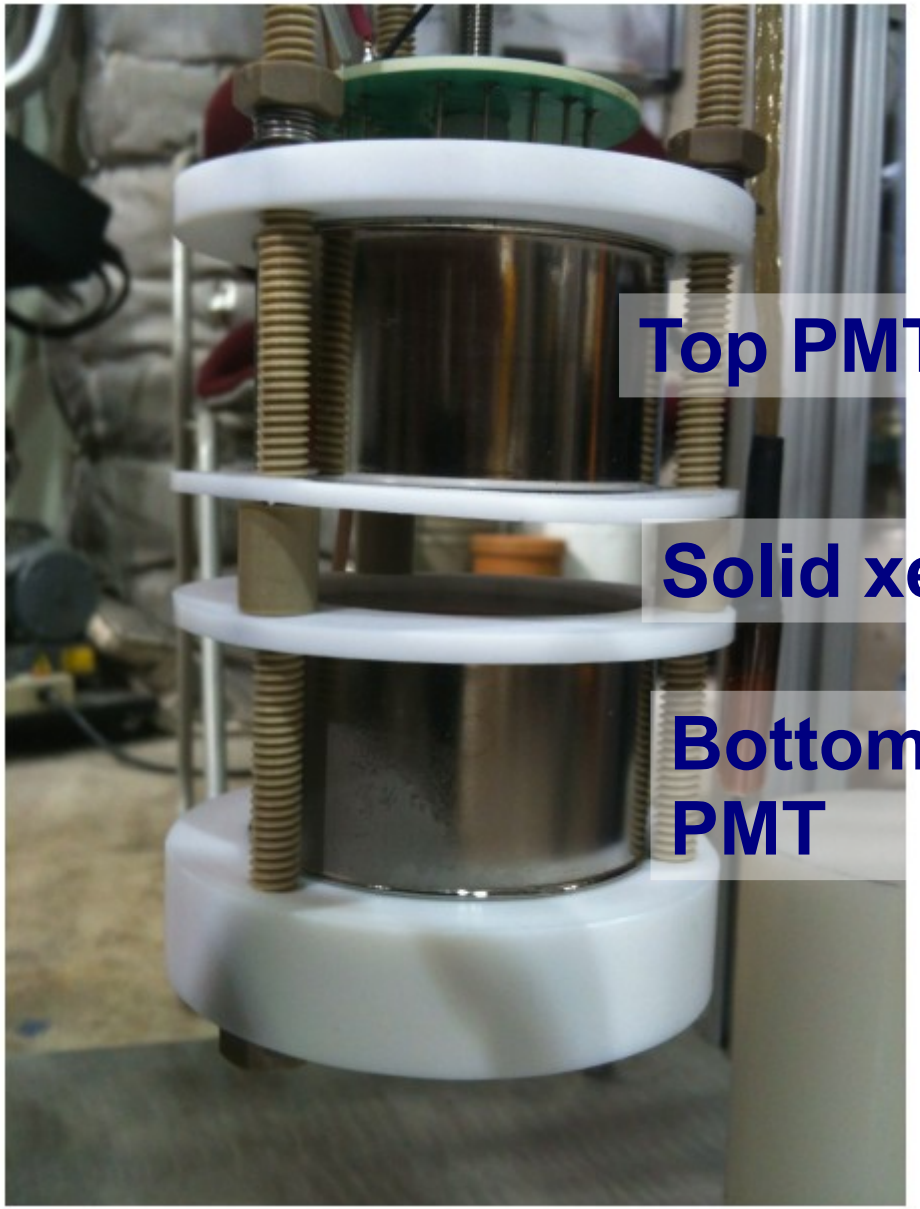
Reproducable growth of solid xenon from liquid phase up to ~1 kg

Recipe:
Bottom T: 145 K, Top T: 160 K,
Pressure: 1 atm, speed: 3 cm / 10 h

Scintillation Signal – PMT Setup

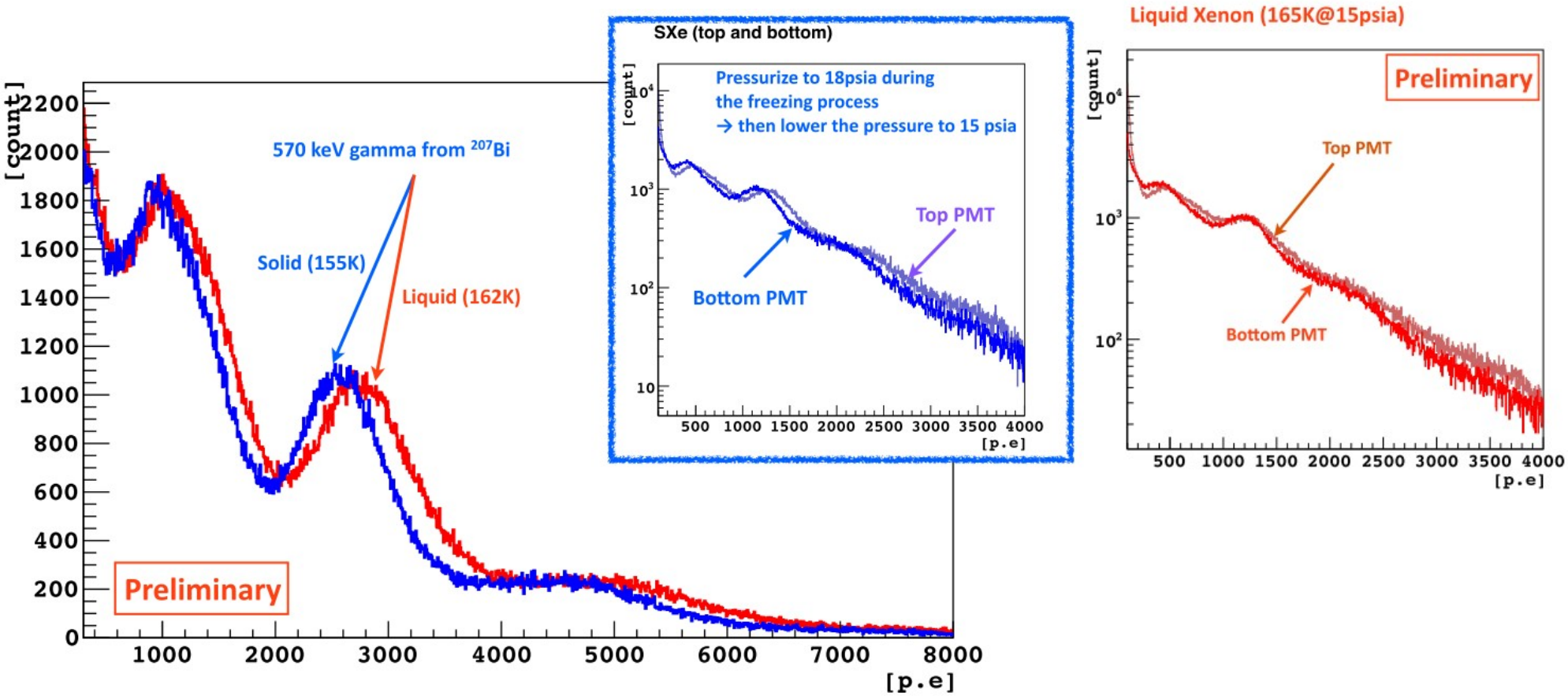
Hamamatsu **R6041-06MOD** PMTs

QE at 175 nm: ~ 20 %
Pressure resistance: 5 atm



From B. Pahlka '12

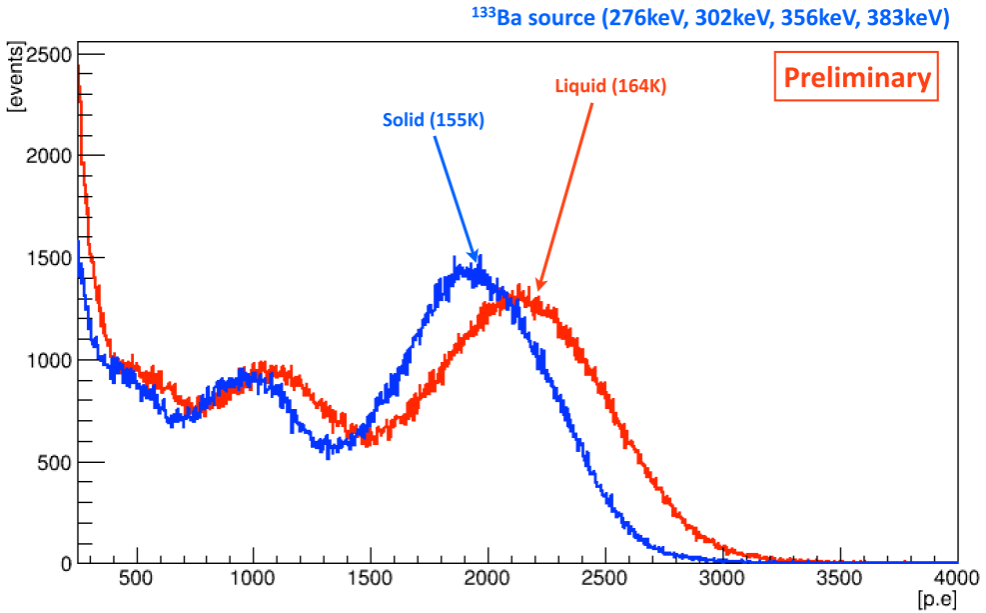
Scintillation Signal - Results



10 % less photon read-out

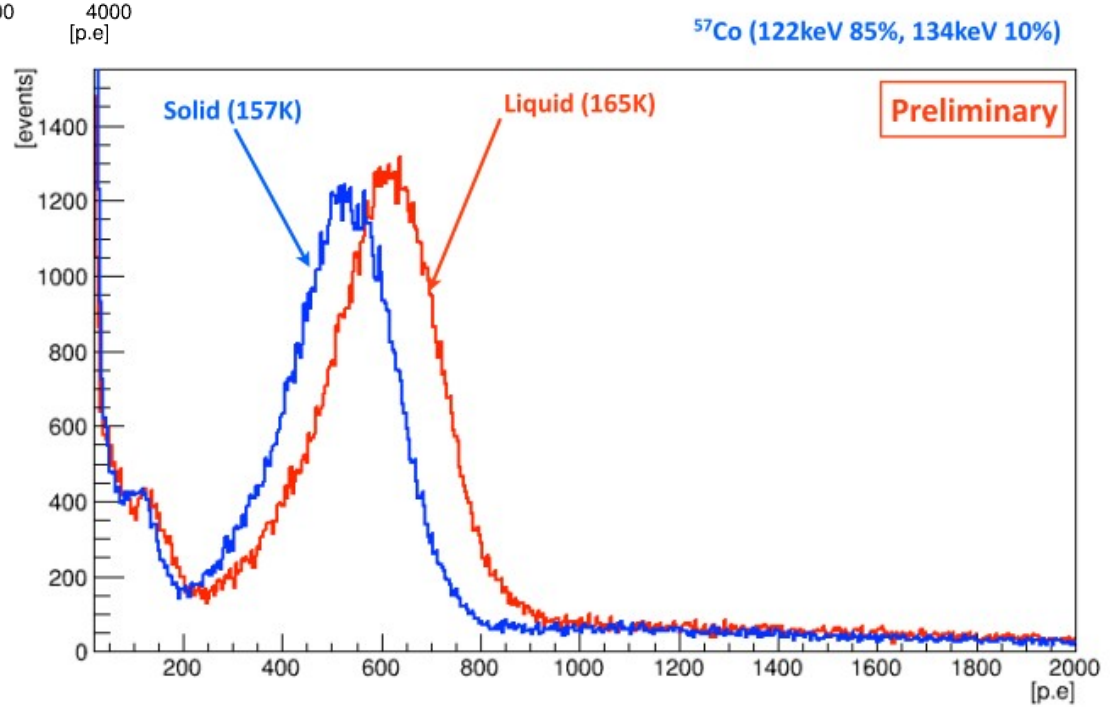
Can be understood by a shift of the wave-length of the emitted scintillation light to lower wave-length

Scintillation Signal



12 % less photon read-out

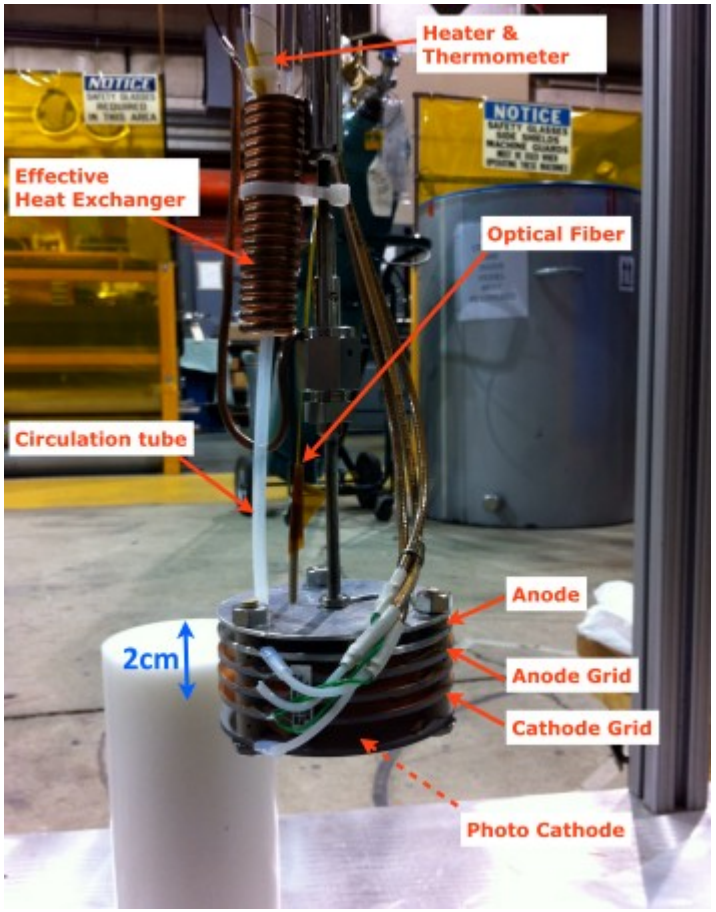
16 % less photon read-out



III. Results from Fermilab (Electron Drift)

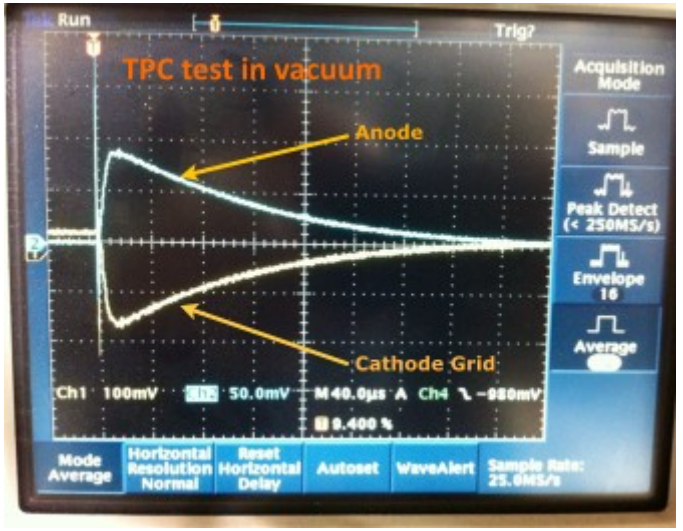
as presented
by J. Yoo
at UCLA DM '14

Ionization Signal – Setup Test

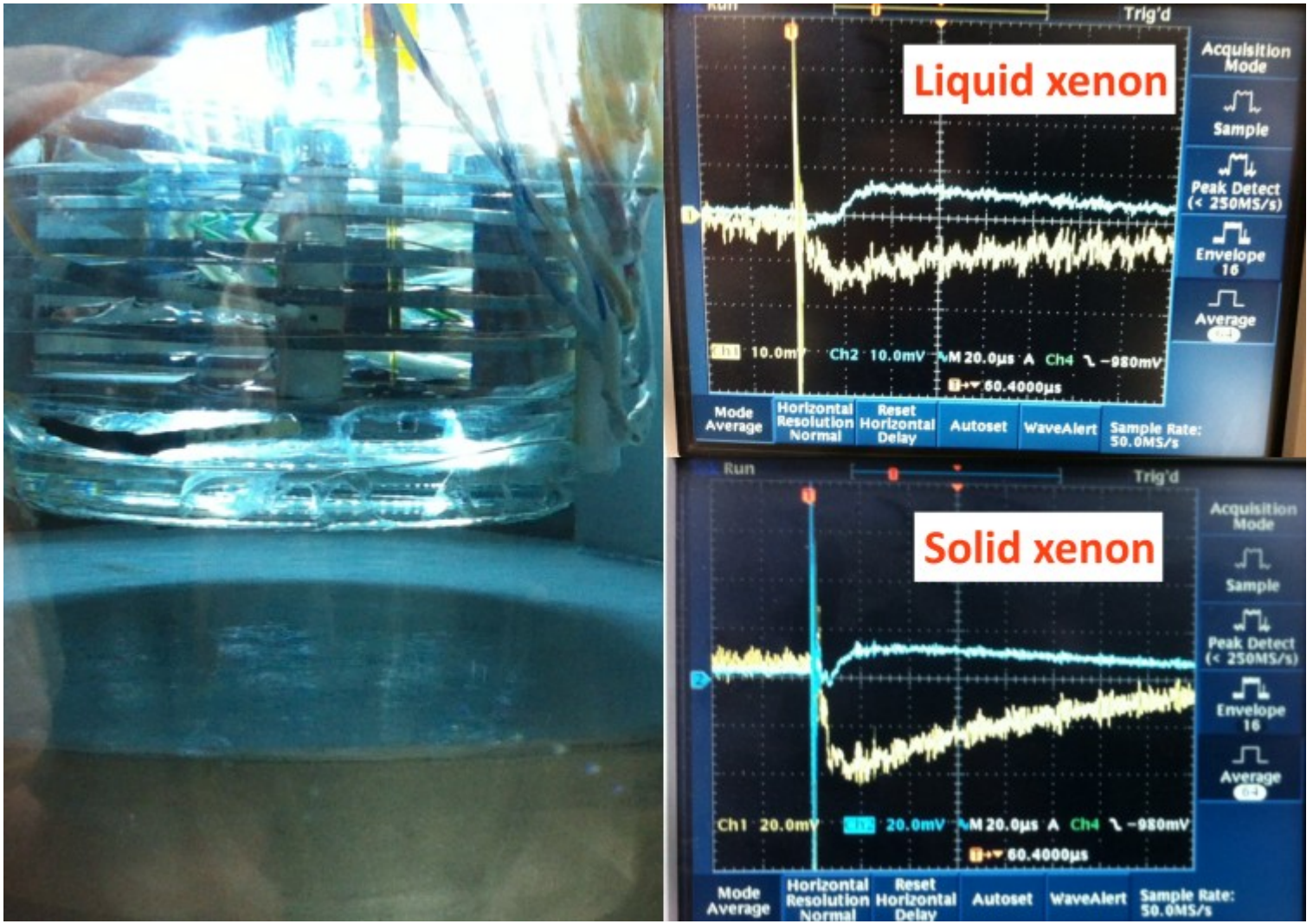


2 cm TPC with photocathode
at the bottom

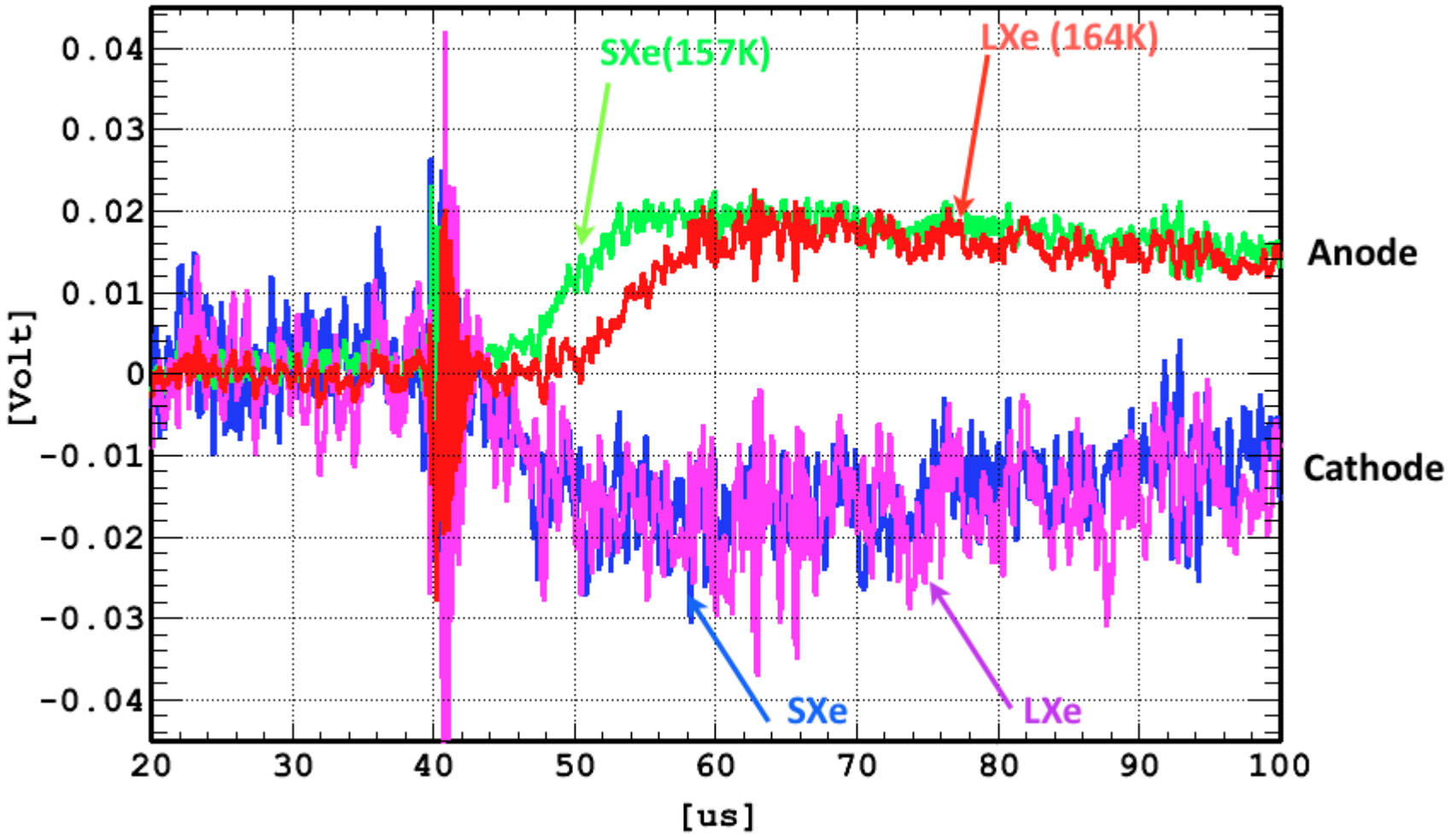
Test in vacuum before
Crystal growth



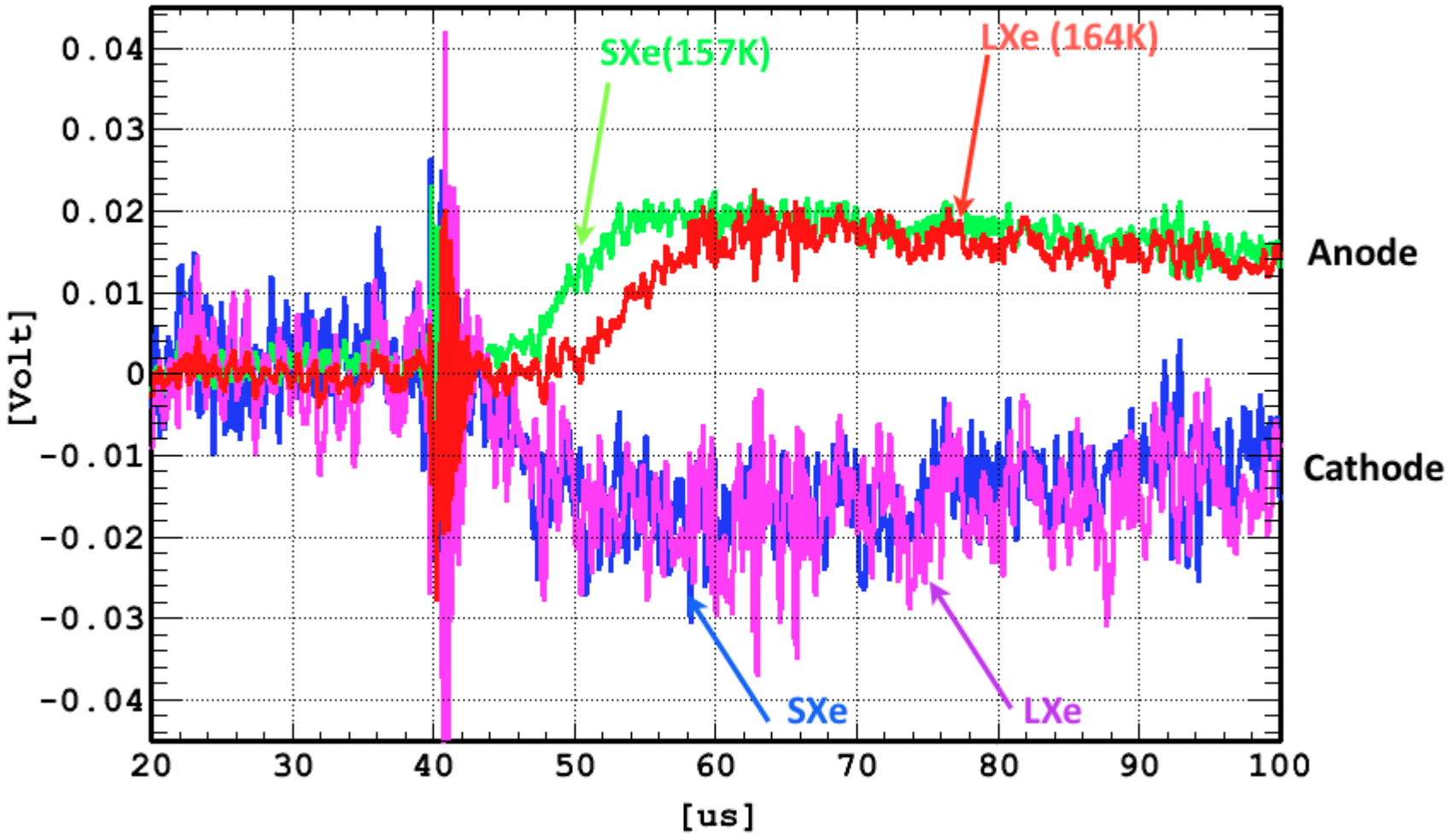
Ionization Signal – First Sucessful Tries



Ionization Signal - Results



Ionization Signal - Results



Electric Field: 1 kV/cm
Drift velocity:

~ 2 x 10^5cm/s in liquid and ~ 4 x 10^5cm/s in solid !

Summary: Results so far

1. Noble Gas Crystals can be grown and analyzed in-situ
→ Investigation of crystal structure and dependence on growth parameters

2. Scintillation photons measured in large solid xenon crystals
→ Compare results to Monte-Carlo to get deeper understanding

3. Electron drift was possible throurgh about 3 cm of solid xenon after purification.
→ Drift velocity twice as high as in liquid
→ Next: Measurements with radioactive sources

IV. Next Step: Electron Extraction

Outlook: Electron Extraction

Overall Goal: Extract electrons from a solid xenon crystal, accelerate them to at least 5 keV and measure them with a Timepix detector.

Step 1: Grow a solid xenon crystal and cool it down to 55 K (temperature vapor pressure of SXe at 10e-6mbar, ~10 cm mean free path at this pressure)
→ Design and Test a Setup with this capability.
→ Cryo Cooler required.

Step 2: Establish a ~10e-6mbar vacuum above the crystal without losing the crystal.

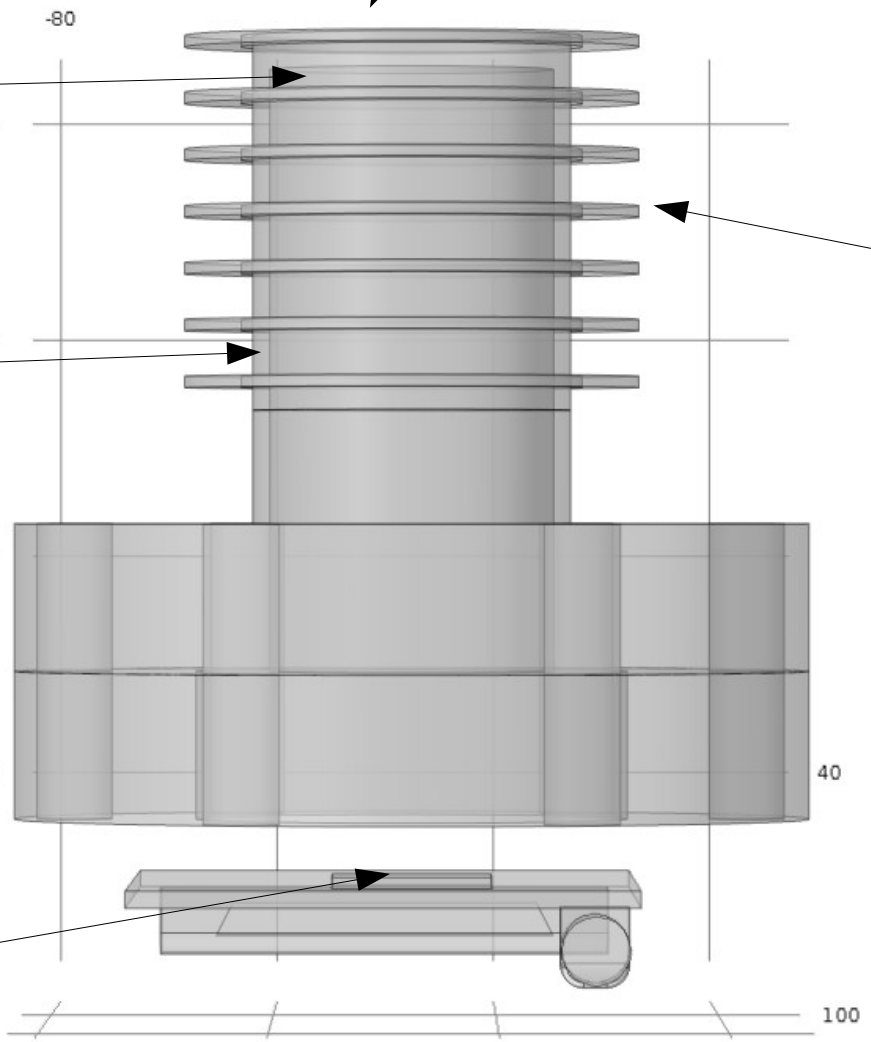
Step 3: Excite secondary electrons with a radioactive source and detect them on the chip.

Setup Idea

Attach Cryo Cooler here

Grow
Xenon-Crystal
here

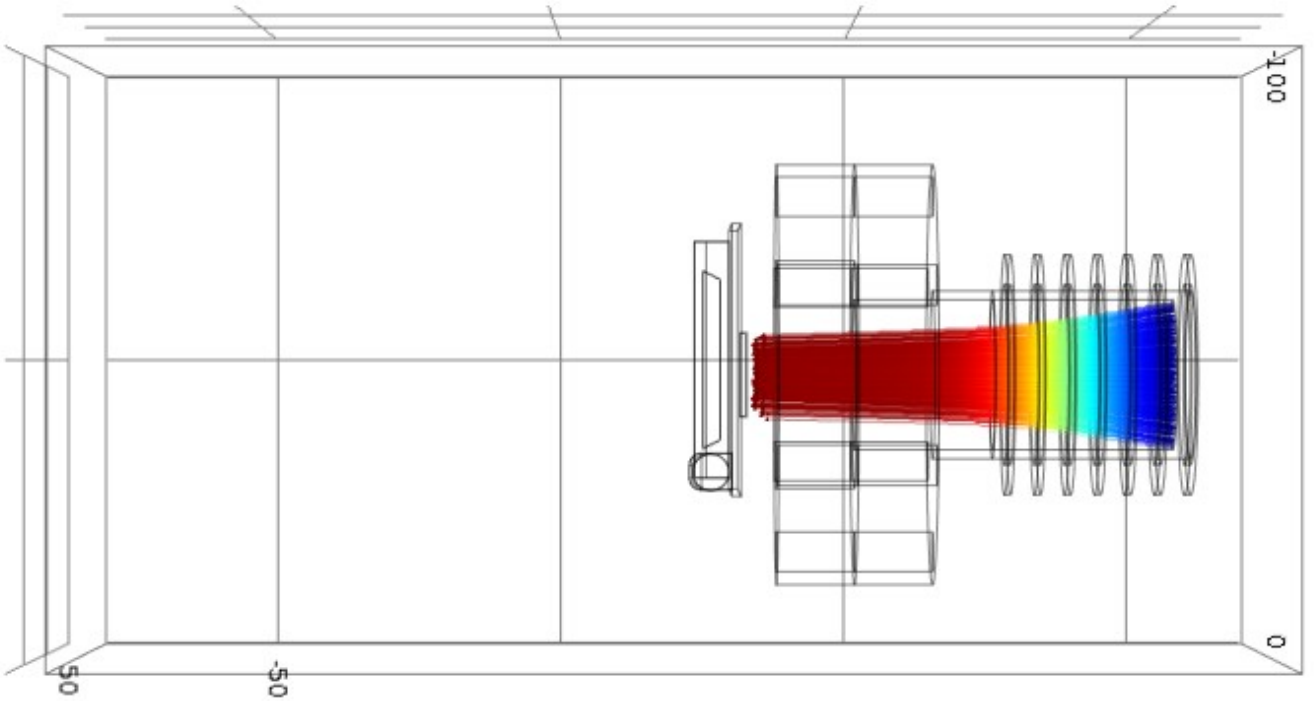
Xenon-Glas
Dielectric
→ does not shield
Electric field



Apply HV
(~ 10 keV)
to the rings
In order to extract
and accelerate
the electrons

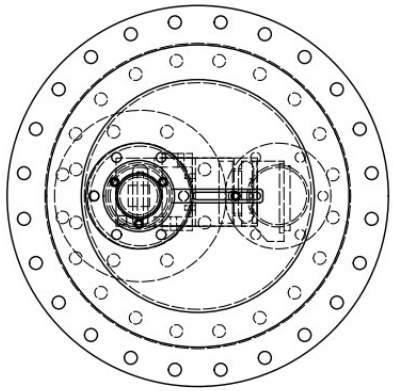
Detect electrons with
The Timepix here

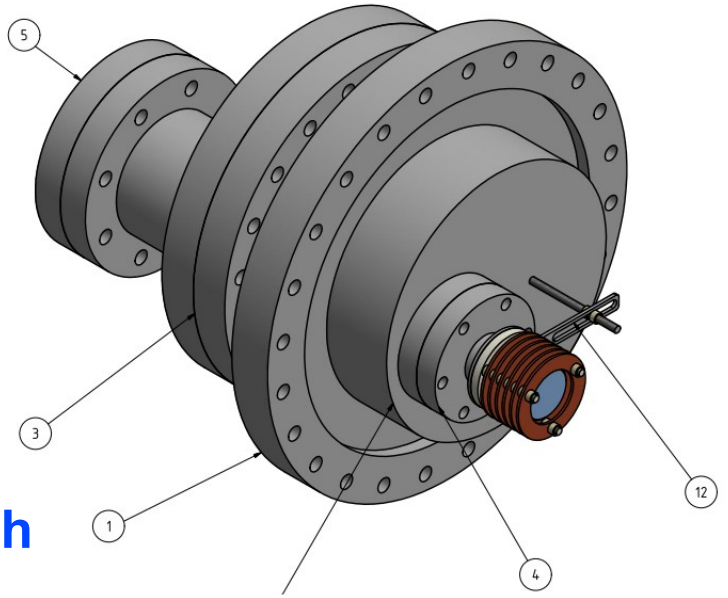
COMSOL Simulation



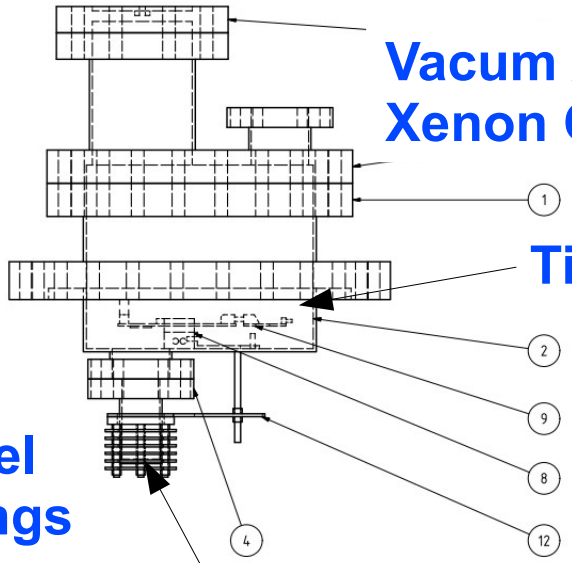
Very promising result: By applying 10 keV at the rings, The electrons are accelerated to about 8 keV at the Timepix Sensor layer

CAD of the Timepix-Test-Setup





Timepix Signal Feedthrough



Vacum /
Xenon Connection

Timepix

Glas Vessel
+ Field Rings

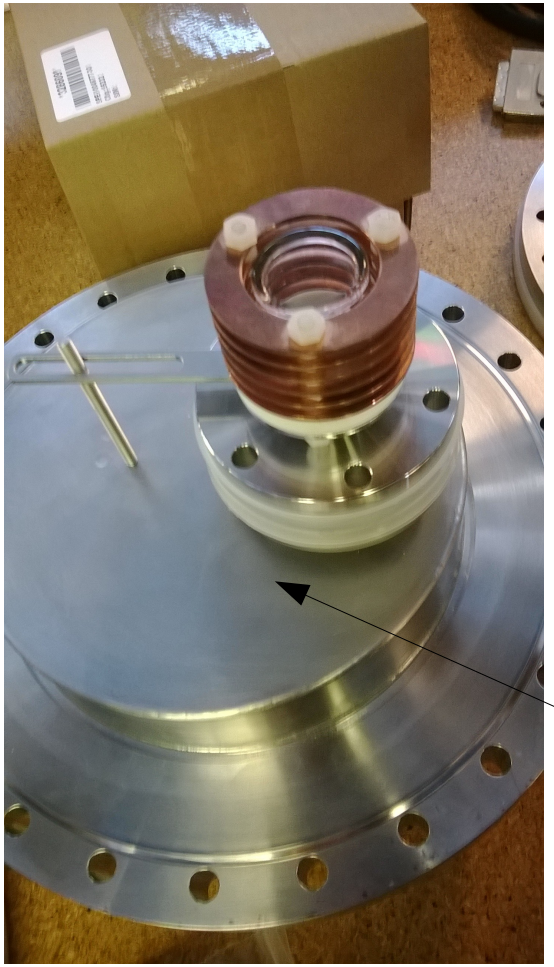
TEILELISTE			
OBJEKT	ANZAHL	BAUTEILNUMMER	BESCHREIBUNG
1	1	SXe_eDriftTest_D4_10inchTOPTPside	s. Zeichnung
2	1	SXe_eDriftTest_D4_10inchBOTTOMTPside	s. Zeichnung
3	1	SXe_eDriftTest_D4_8inchFlangeTOP	s. Zeichnung
4	1	CF-40-Glass2_MIR_MIR	Fa Vacom
5	1	SXe_eDriftTest_D2_TPfeedtr	Vorhanden
8	1	SXe_eDriftTest_D2_CernBoardHolder	s. Zeichnung
9	1	Timepix_CERN_board2_wRoutCable11	Vorhanden
12	1	SXe_eDriftTest_D4_EFieldShaper	s. Zeichnung
13	-	SXe_eDriftTest_D4_ptfe_betweenrings	s. Zeichnung

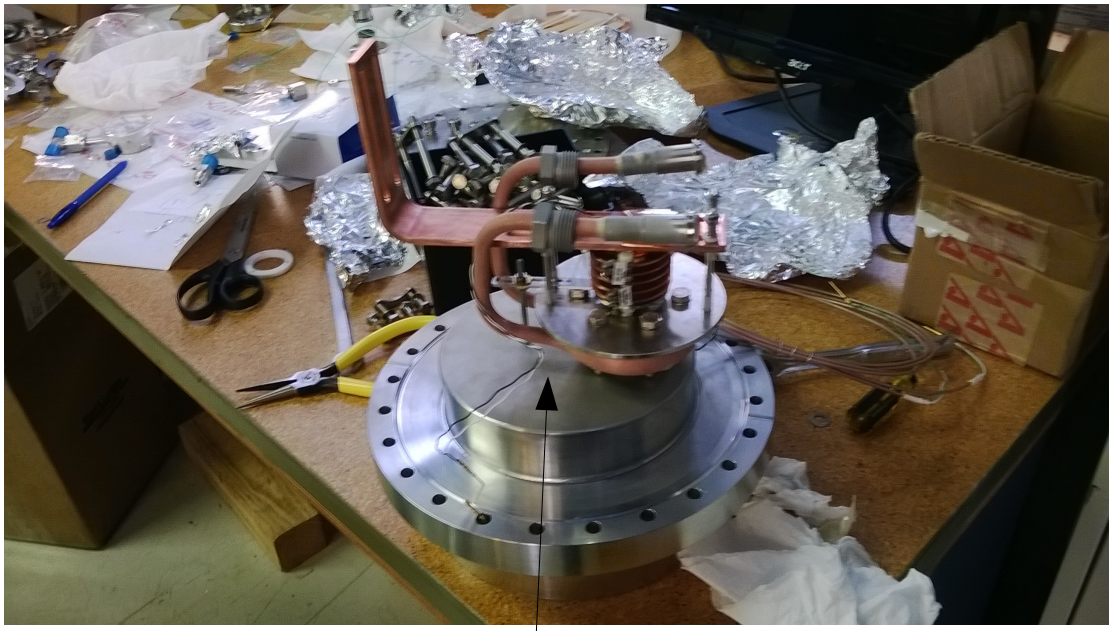
SXe_CernBoardFlange

SXe_eDriftTest_D4_PutTogethe

Xenon Crystal is grown here at the glass bottom.

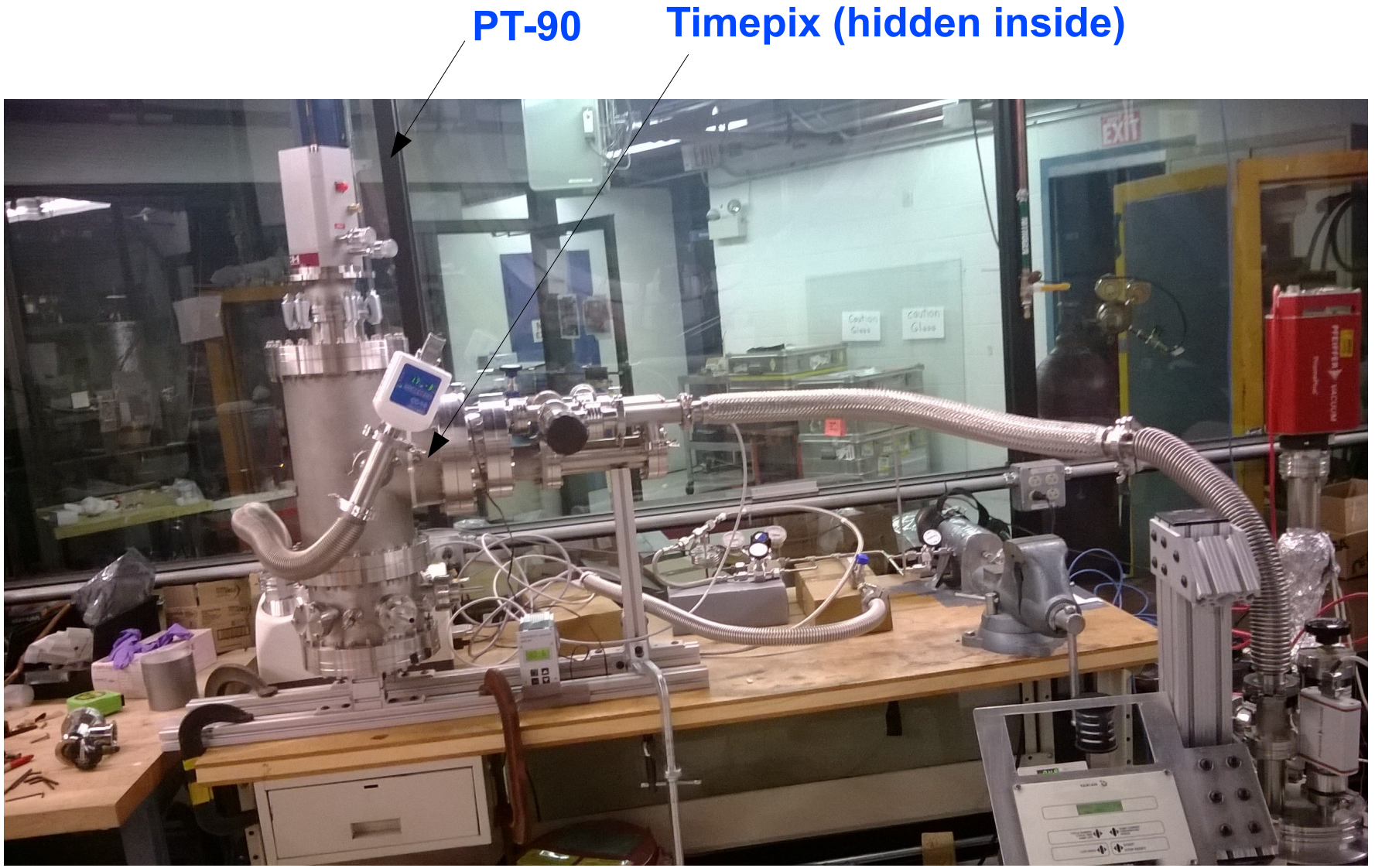
Photos of the Timepix-Test-Setup





Here is the Timepix inside (not visible)

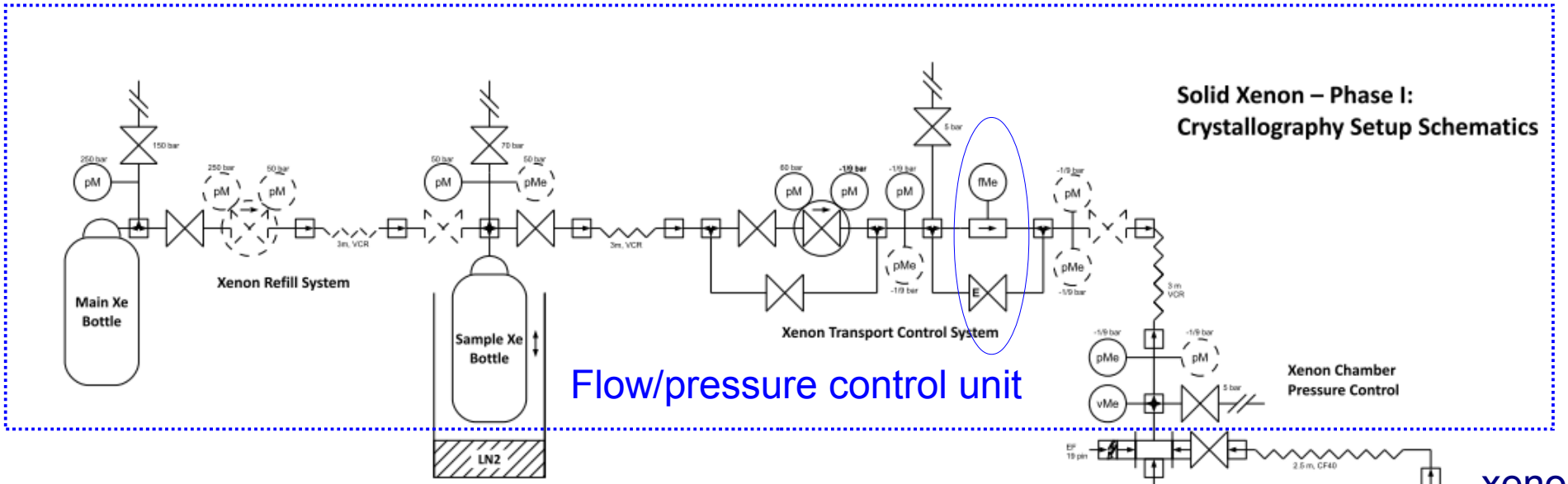
Full Setup with PT-90 mounted



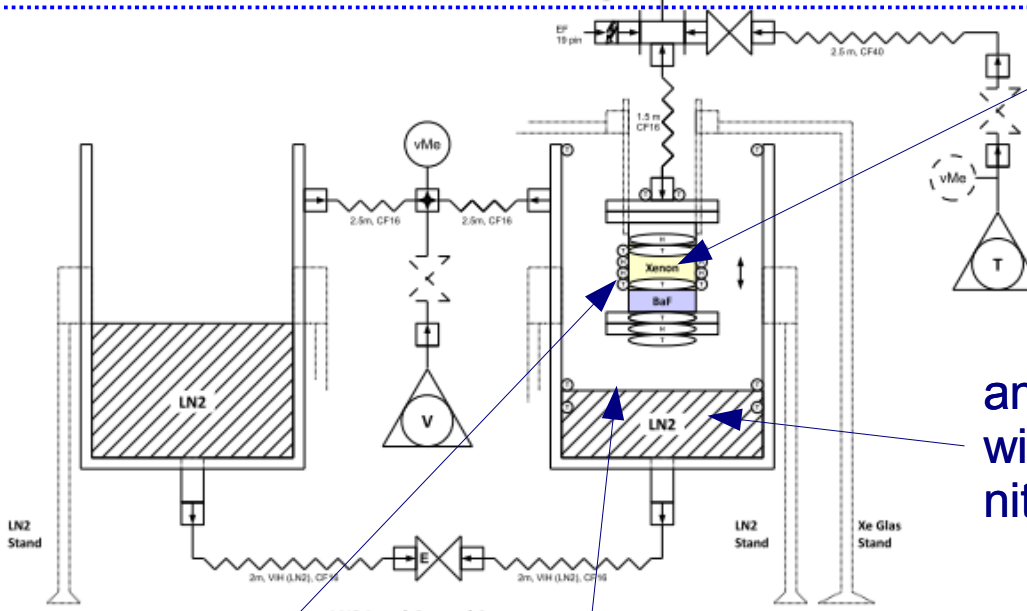
Cooldown-Test failed so far due to PT-90 malfunction

Thank you for your Interest! Questions?

The Setup



Parts List	
Part's Name	**Number (req. / rec.)**
High Pressure Valve	4/5
Low Pressure Valve	3/5
Electric Valve	1
Flow Meter	1
High Pressure Meter	3/4
Low Pressure Meter	2/4
High Pressure Meter El.	-/1
Low Pressure Meter El.	1/3
Vacuum Meter El.	2/3
Pressure Regulator	1/2
High Pressure Gas Bottle	1
Xenon Double-Sided Glas	1
LN2 Glas/Vacuum/Dewar	2
Cryovalve El., DN16	1
Cryotubes DN16, 2m	2
LN2 Stand	2
Xenon-Glas Stand	1
Thermometer	10/16
Vacuum Pump	1
Turbo Pump (+ Vac. Pump)	1
High Pressure Relief Valve	2
Low Pressure Relief Valve	2



VCR ¼" Flextube	3
CF16 Flextube	4
LN2 Dewar	1
VCR ¼" T	
VCR ¼" X	

VCR ¼" Female Fitting	1
VCR ¼" Female Fitting	1
CF-KF Adapter	2

Temperature control by control of the liquid nitrogen level (to about 1mm) and heaters surrounding the glas