Solid Xenon R&D Project
Phase-2 Proposal

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Fermilab

PPD/FCPA Review
11 March 2010

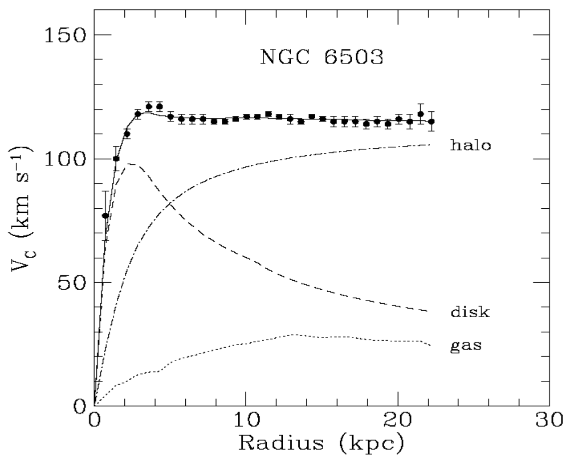
Outline

- Dark Matter Search
- Axion Search
- Solid Xenon R&D Phase-1 results
- Solid Xenon R&D Phase-2 proposal
- Summary

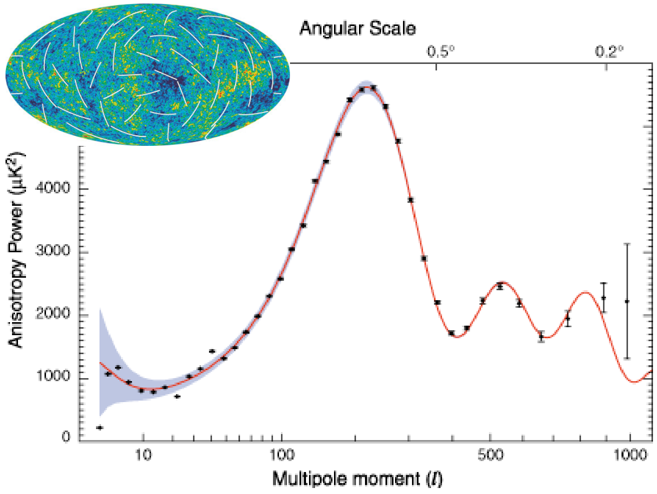
Dark Matter

Astrophysical Observations of Dark Matter

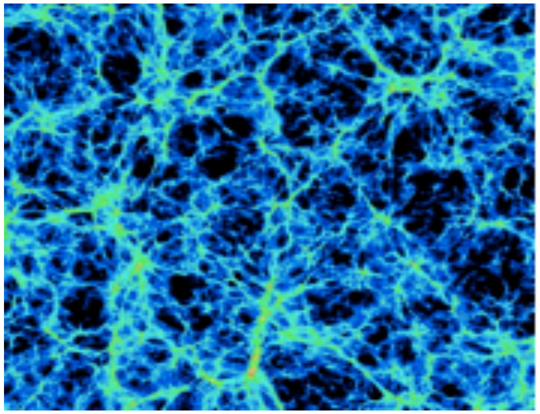
Rotation Curves of Galaxies



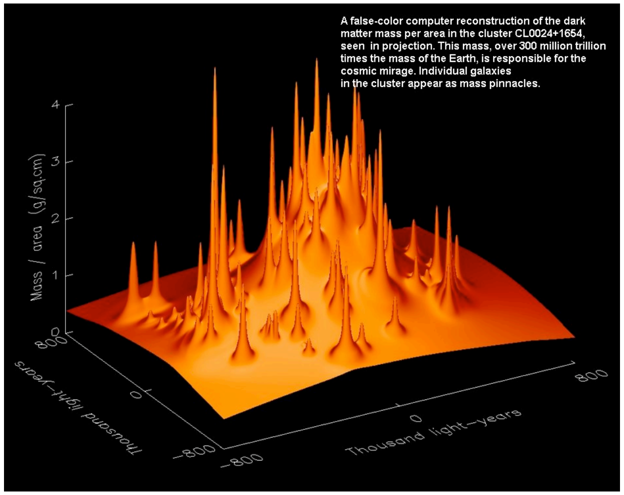
CMB



Large Scale Structure



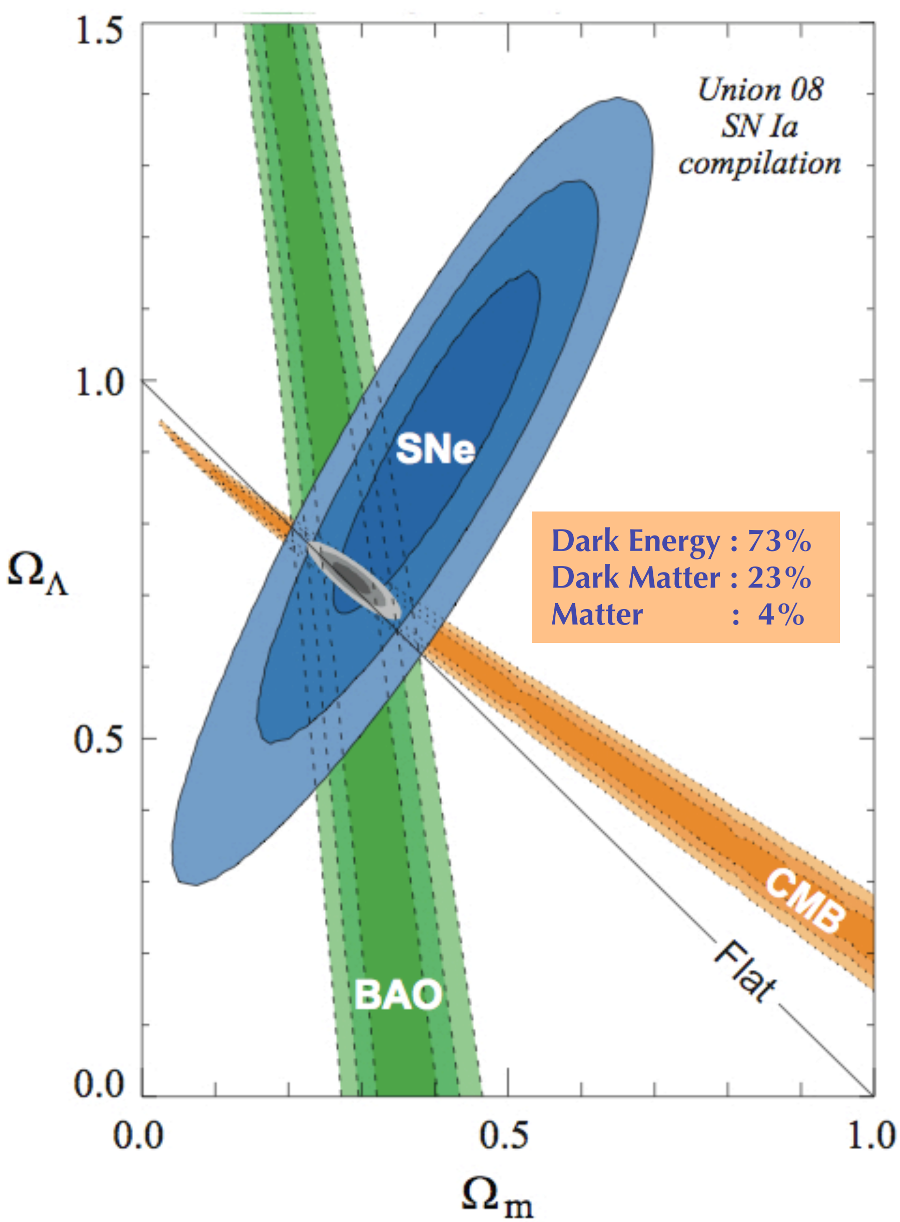
Galaxy Cluster



Dark Matter Ring

Bullet Cluster

The Universe is Dark



- We know the Dark Matter is
  stable / non-baryonic / non-relativistic / interacts gravitationally

- We don't know what it actually is
  mass / coupling / spin / composition / distribution in the Universe ...

- Cosmology suggests to probe EW scale

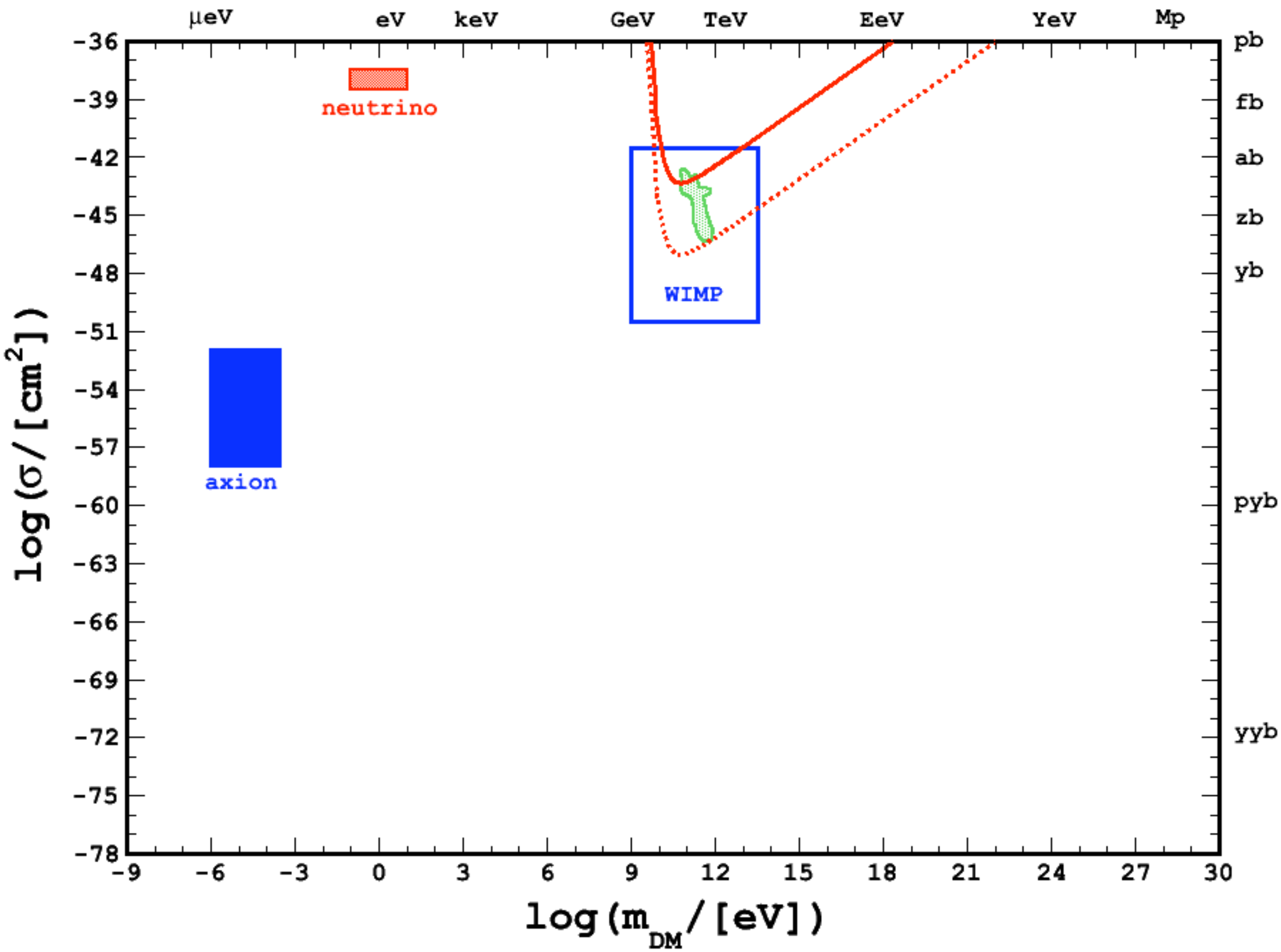
$$\Omega_{DM} \sim \langle \sigma_A v \rangle^{-1}$$

$$\sigma_A = \alpha^2 / M^2_{EW}$$

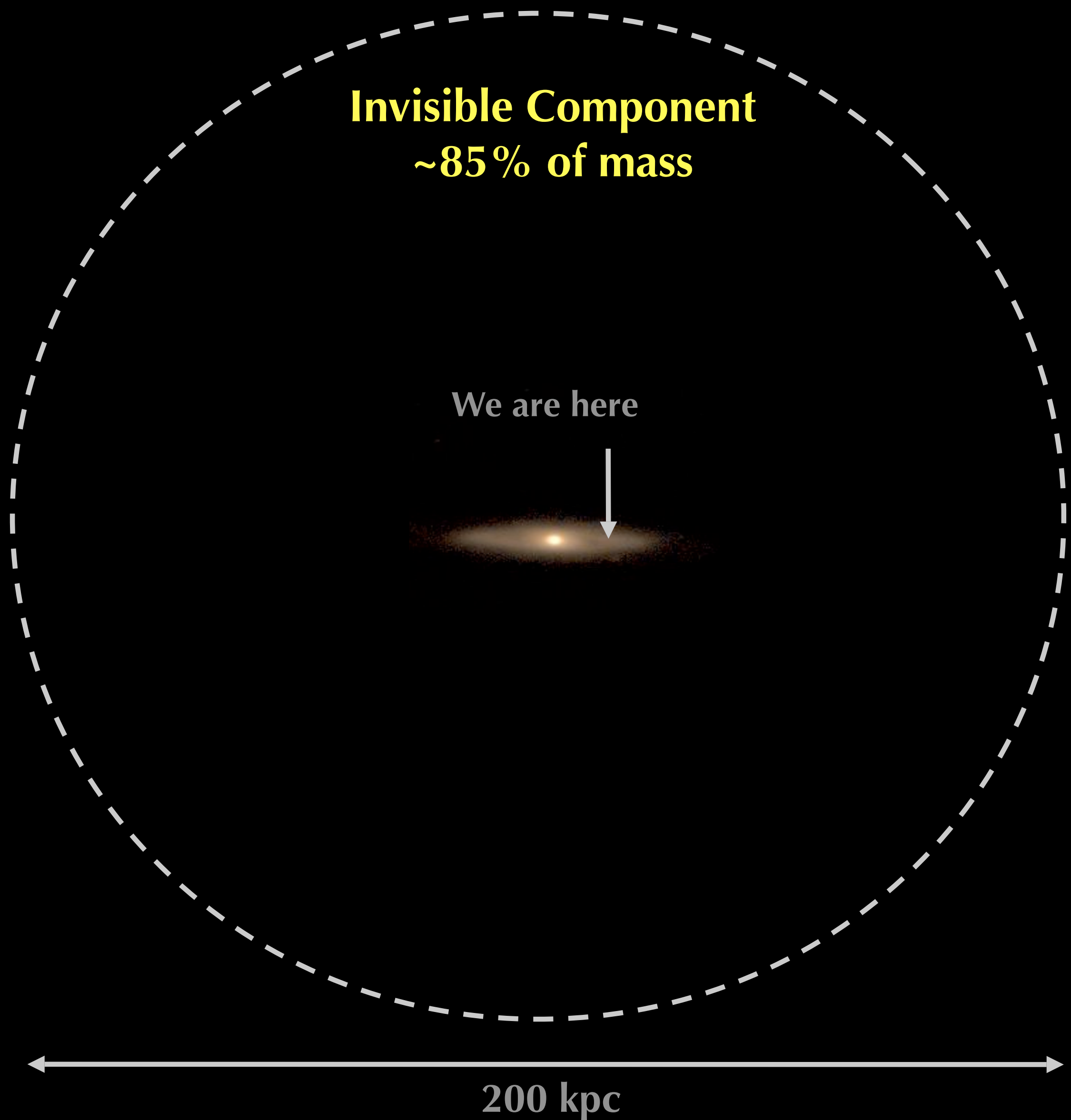
- SUSY model provides electroweak scale stable neutral particle

- However the Dark Matter is not necessarily a SUSY particle.

Big Picture : World Map of Dark Matter

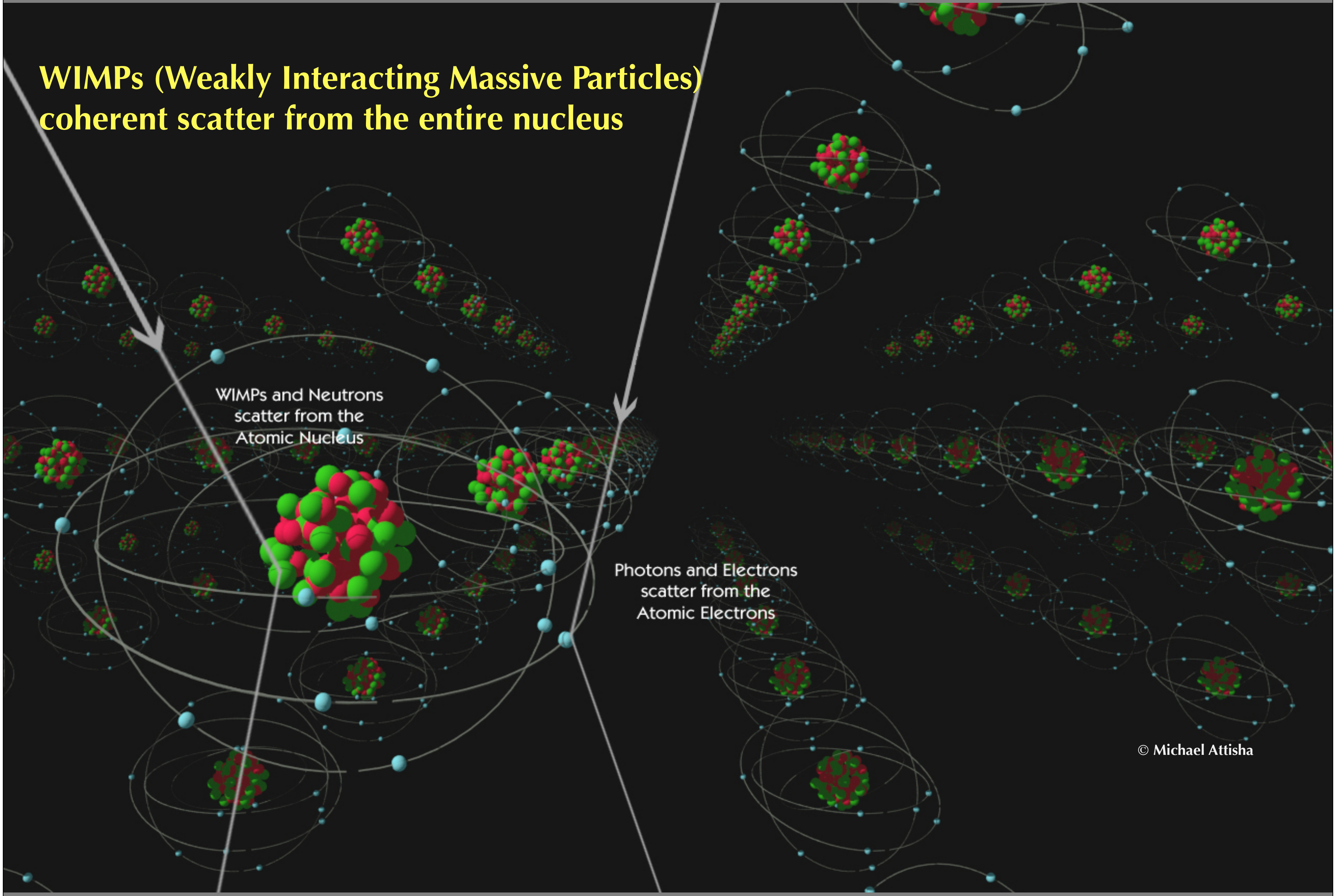


Dark Matter Halo in Our Galaxy

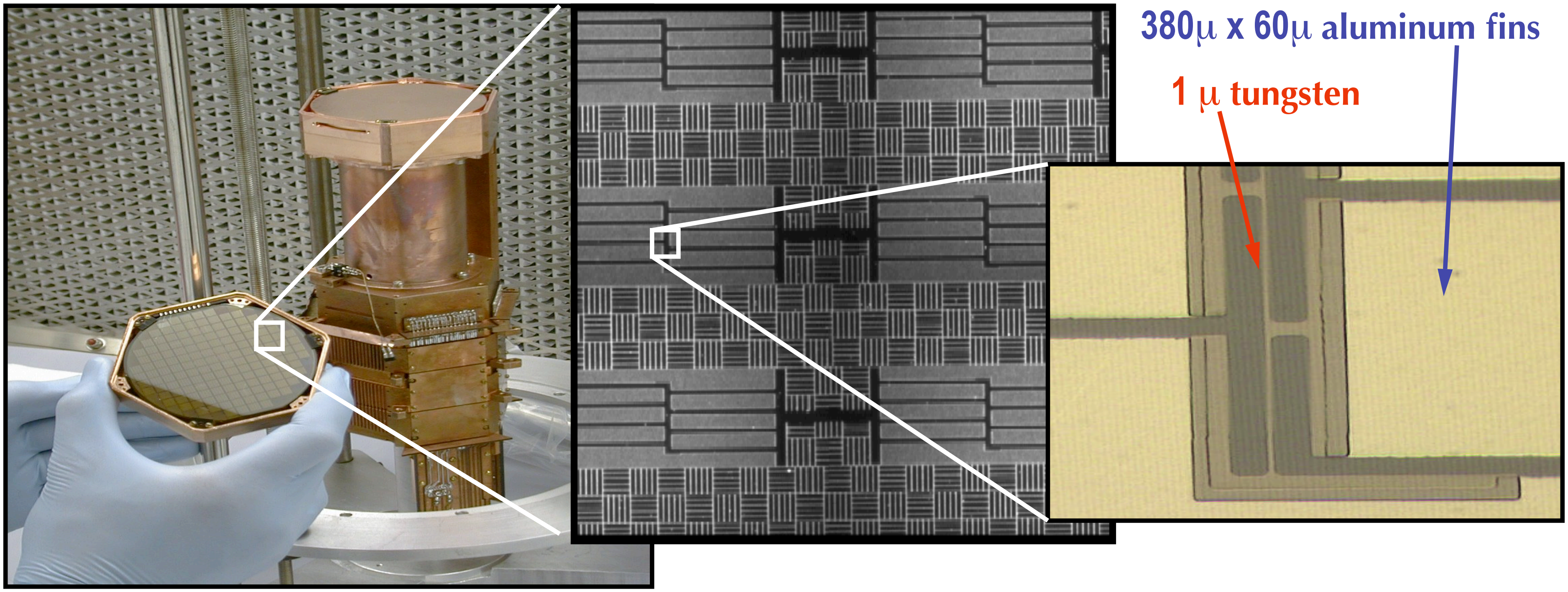


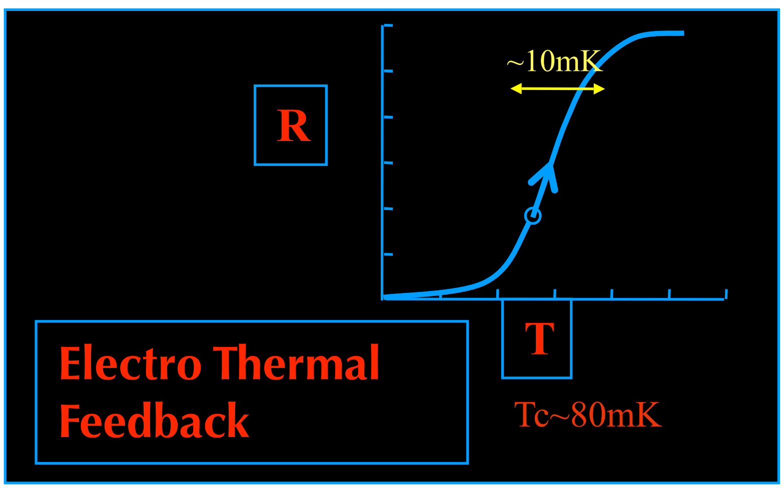
Direct Detection of Dark Matter

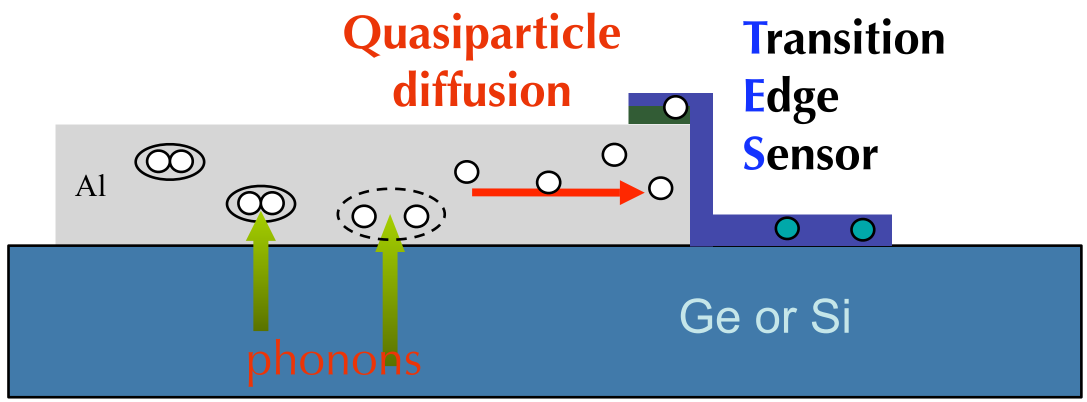
WIMPs (Weakly Interacting Massive Particles) coherent scatter from the entire nucleus



CDMS Detector



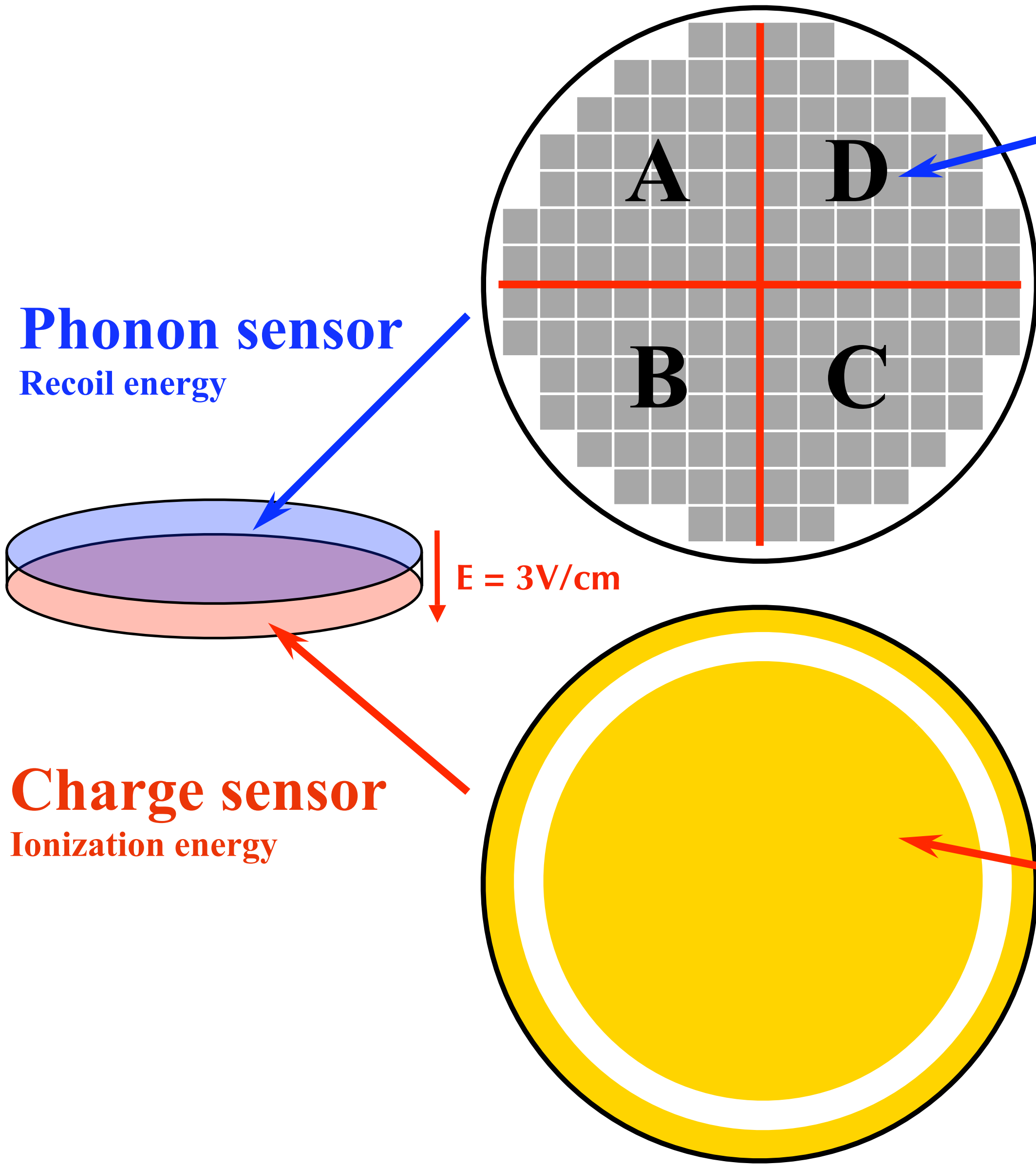


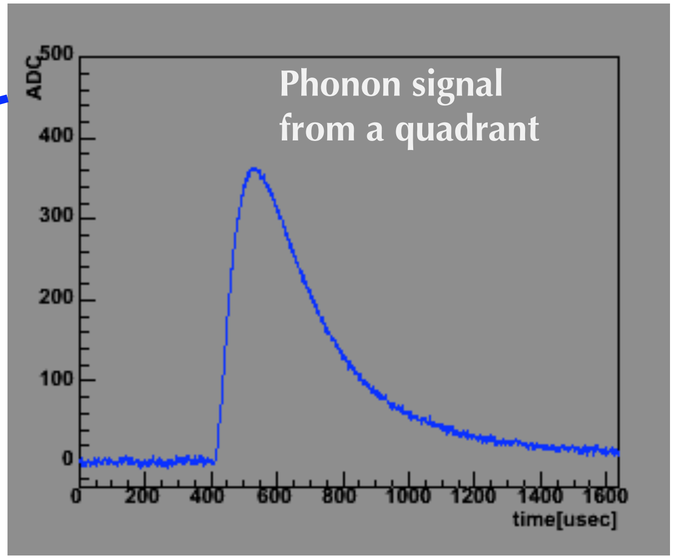


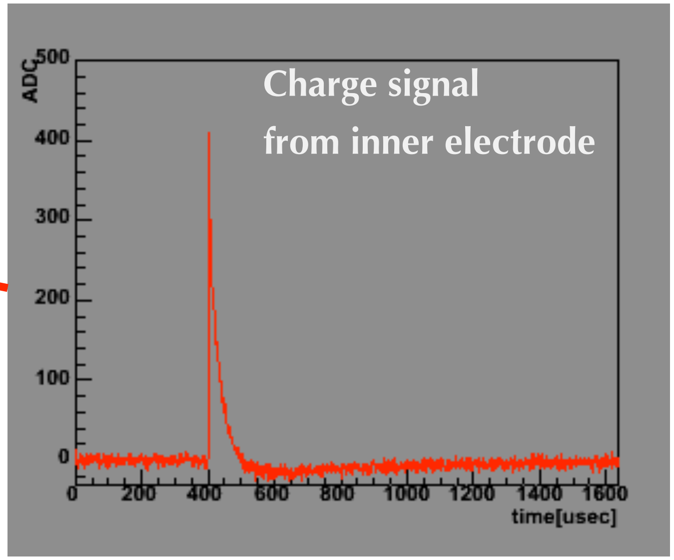
CDMS Detector Readout

Phonon sensor
Recoil energy

Charge sensor
Ionization energy

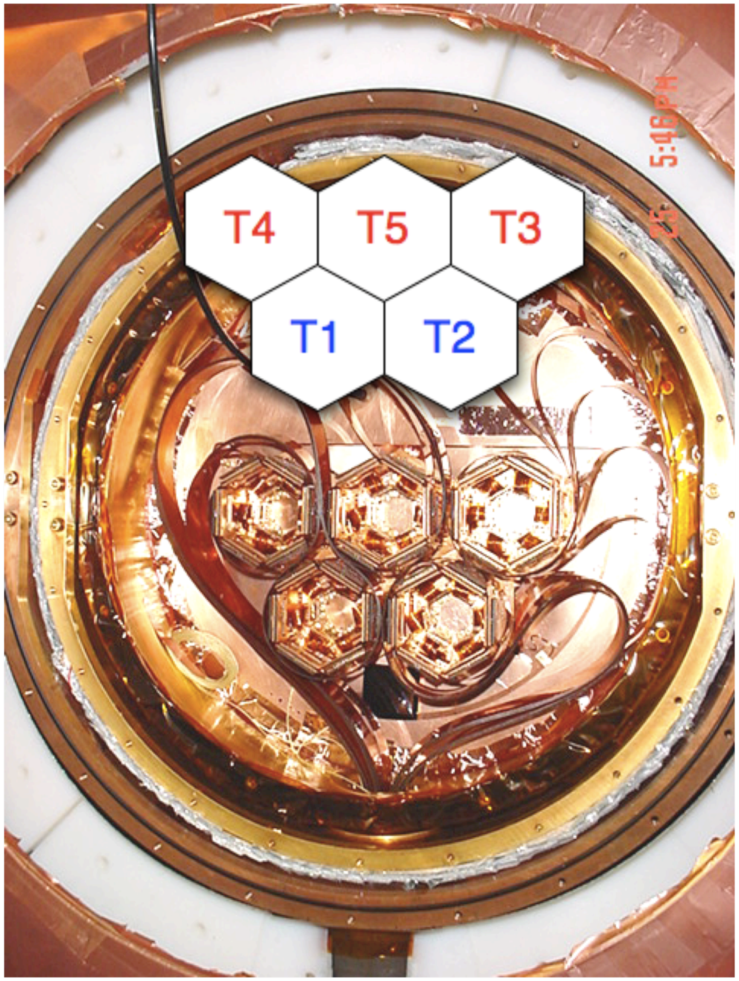




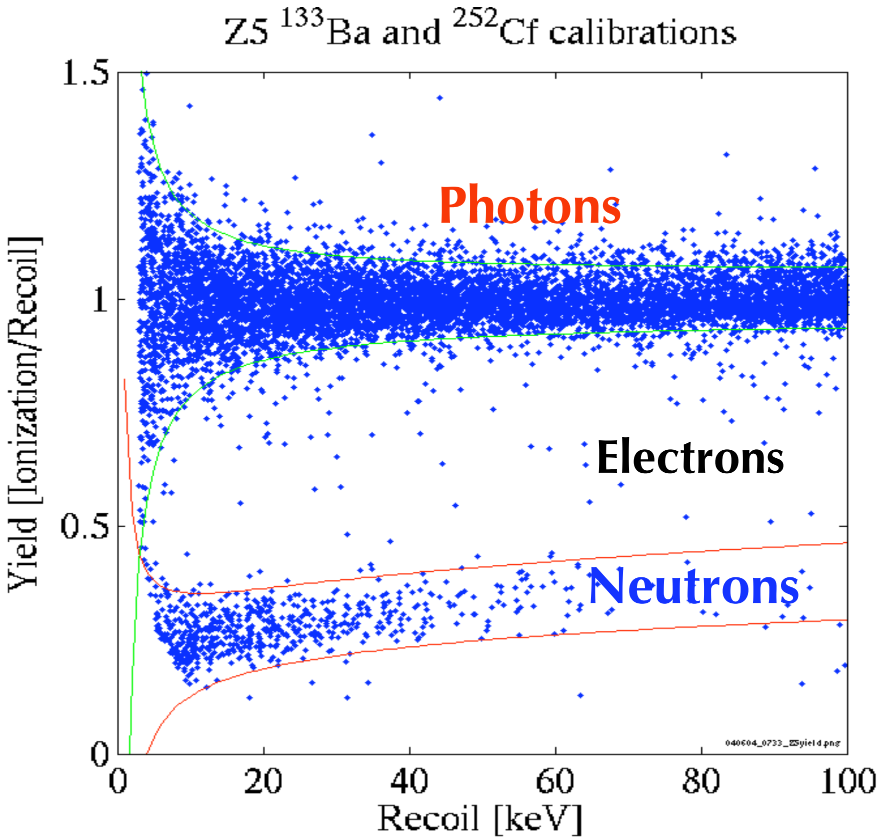


CDMS Five Tower Operation

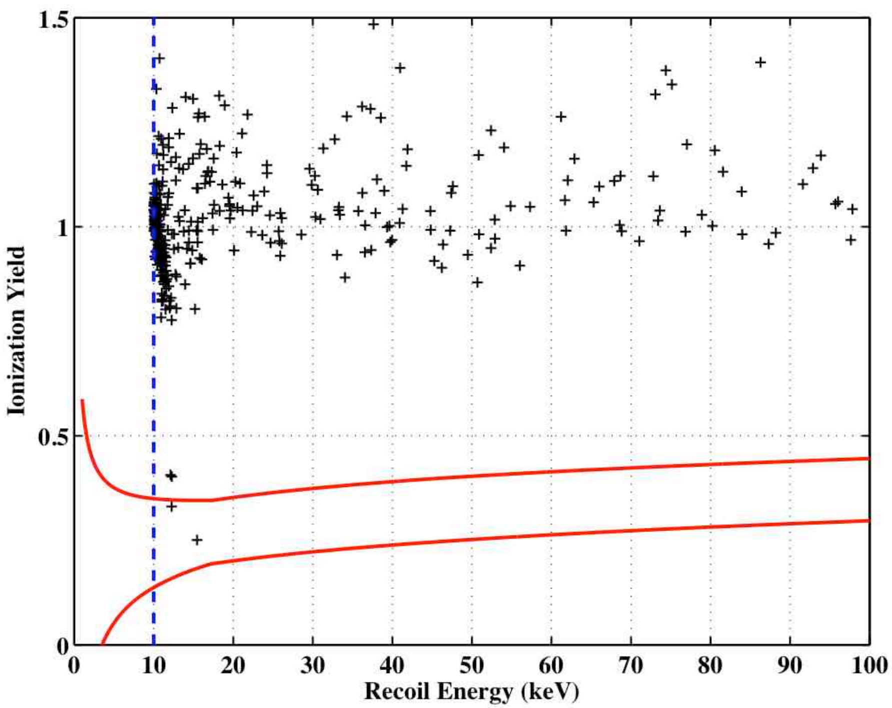
30 detectors (6 detectors / tower)
4.75 kg Ge, 1.1 kg Si
~612 kg-day raw exposure

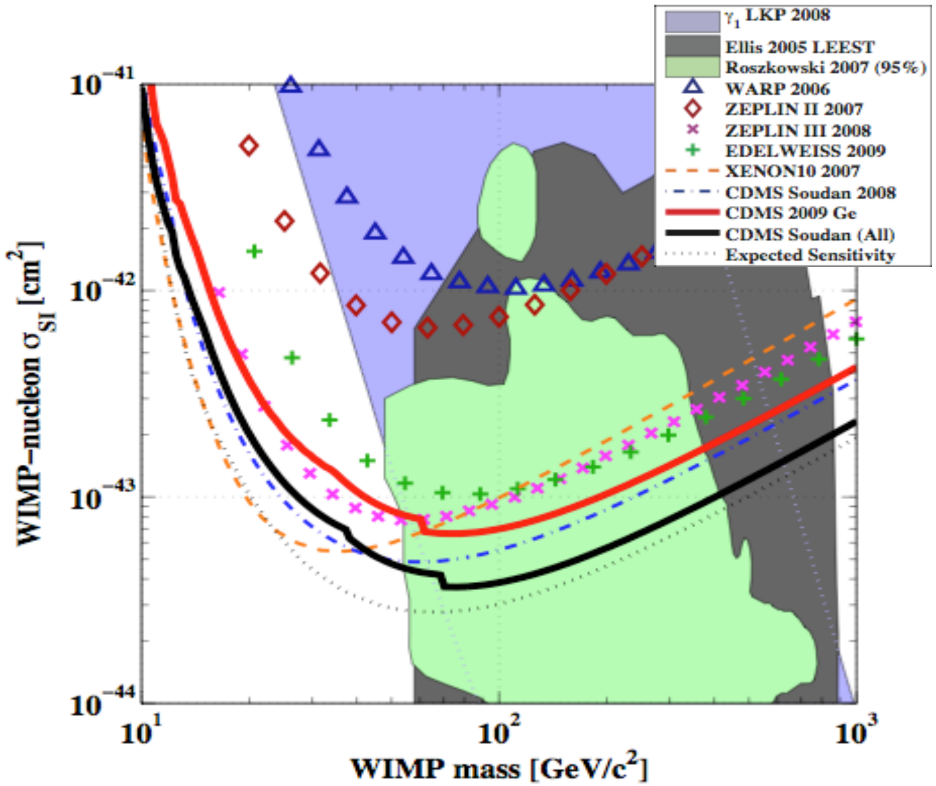


Yield = E(ionization) / E(recoil)



CDMS Dark Matter Search Result (Dec 2009)





Background Estimations

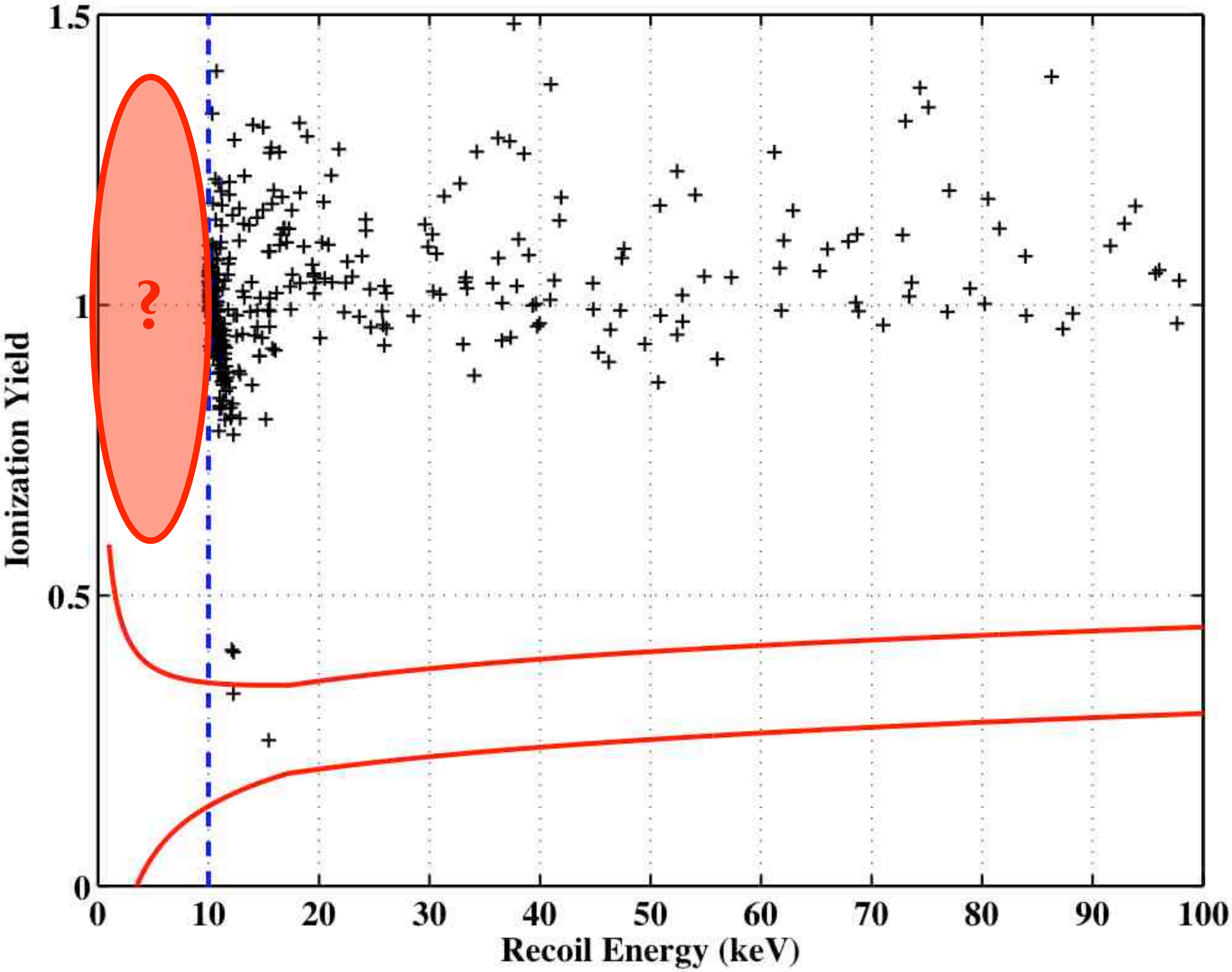
0.8±0.1(stat.)±0.2(sys.) surface events

$0.04^{+0.04}_{-0.03}$ cosmogenic neutrons

0.04 - 0.06 radiogenic neutrons

194.1 kg-days net exposure after cuts
In the presence of 2 events
(no background subtraction)

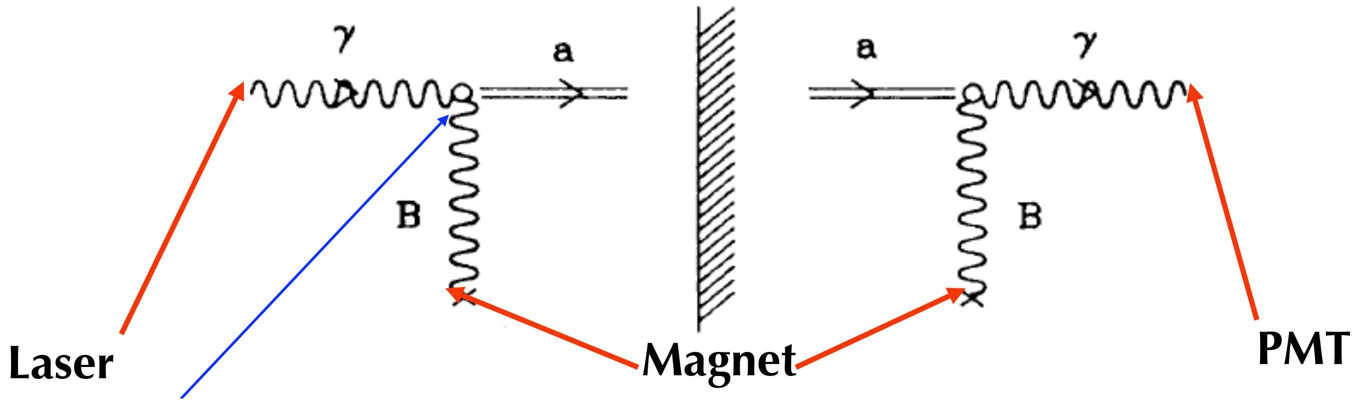
New CDMS Limit (@70GeV)
$\sigma = 3.8 \times 10^{-44}$cm^2 (90%CL)



1.5
1
0.5
0
Ionization Yield
?
0
10
20
30
40
50
60
70
80
90
100
Recoil Energy (keV)

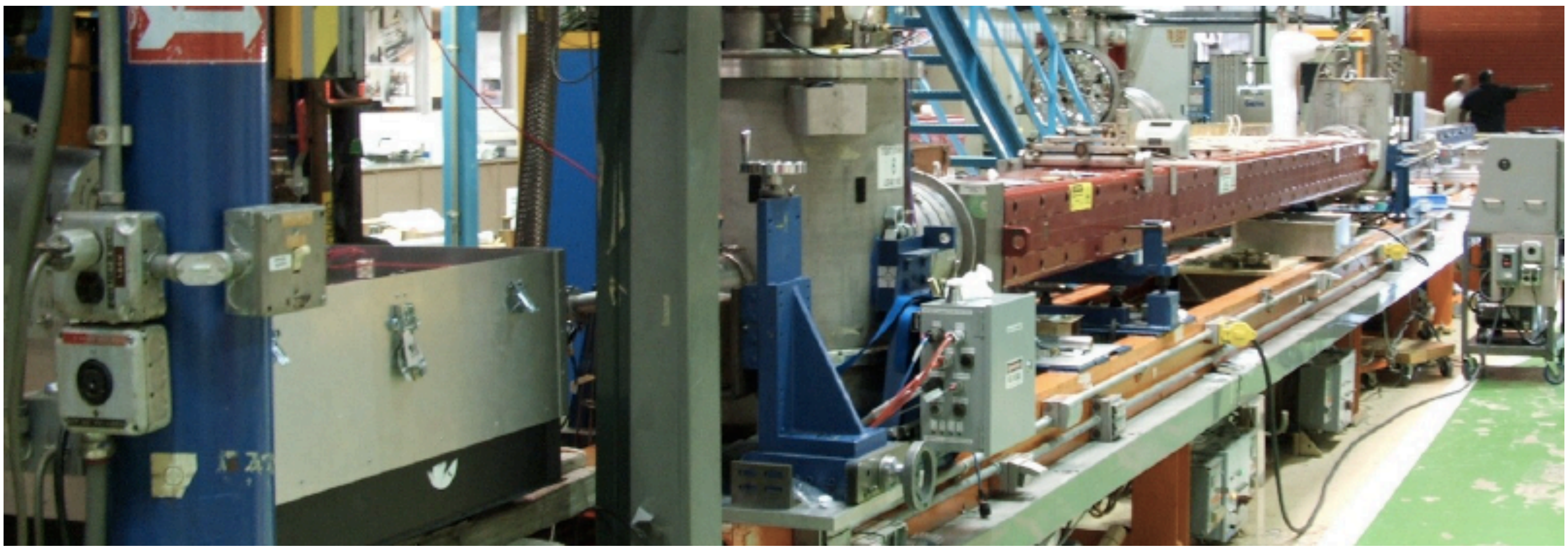
Axions

Axion Detection Principle

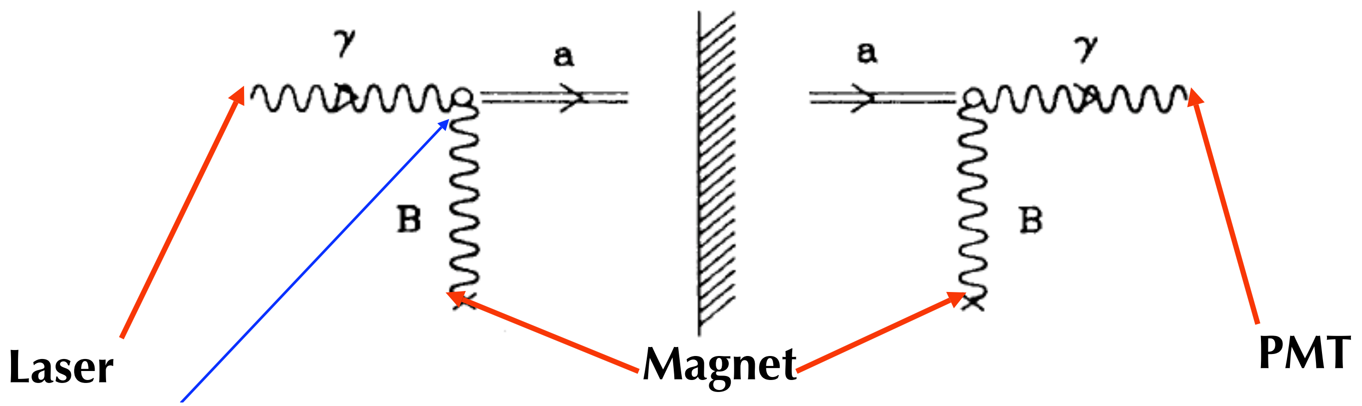


$$\mathcal{L}_{\rm int} = -\frac{1}{4}\frac{\phi}{M}F_{\mu\nu}\widetilde{F}^{\mu\nu} = \frac{\phi}{M}(\vec{E}\cdot\vec{B})$$

GammeV@FNAL(2007)



Axion Detection Principle



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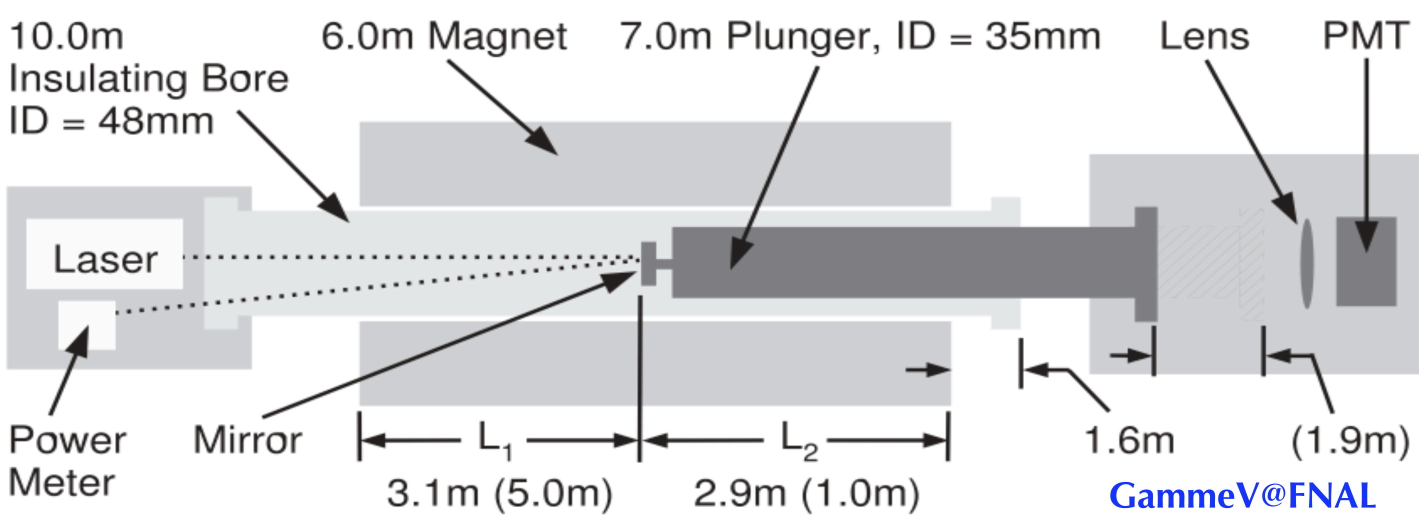
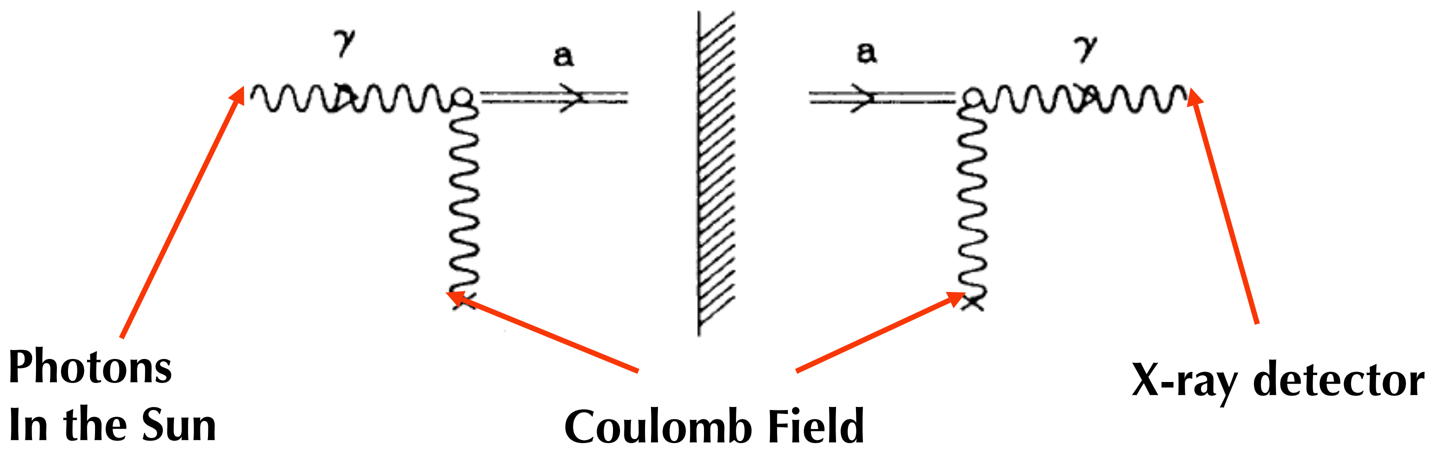
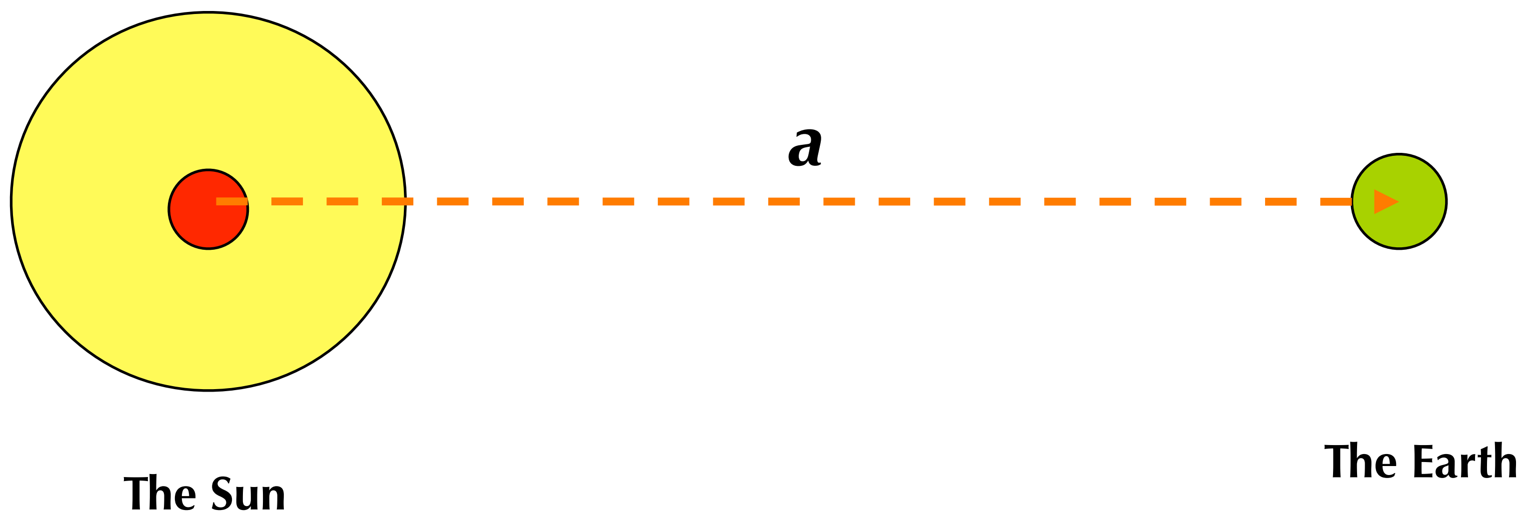


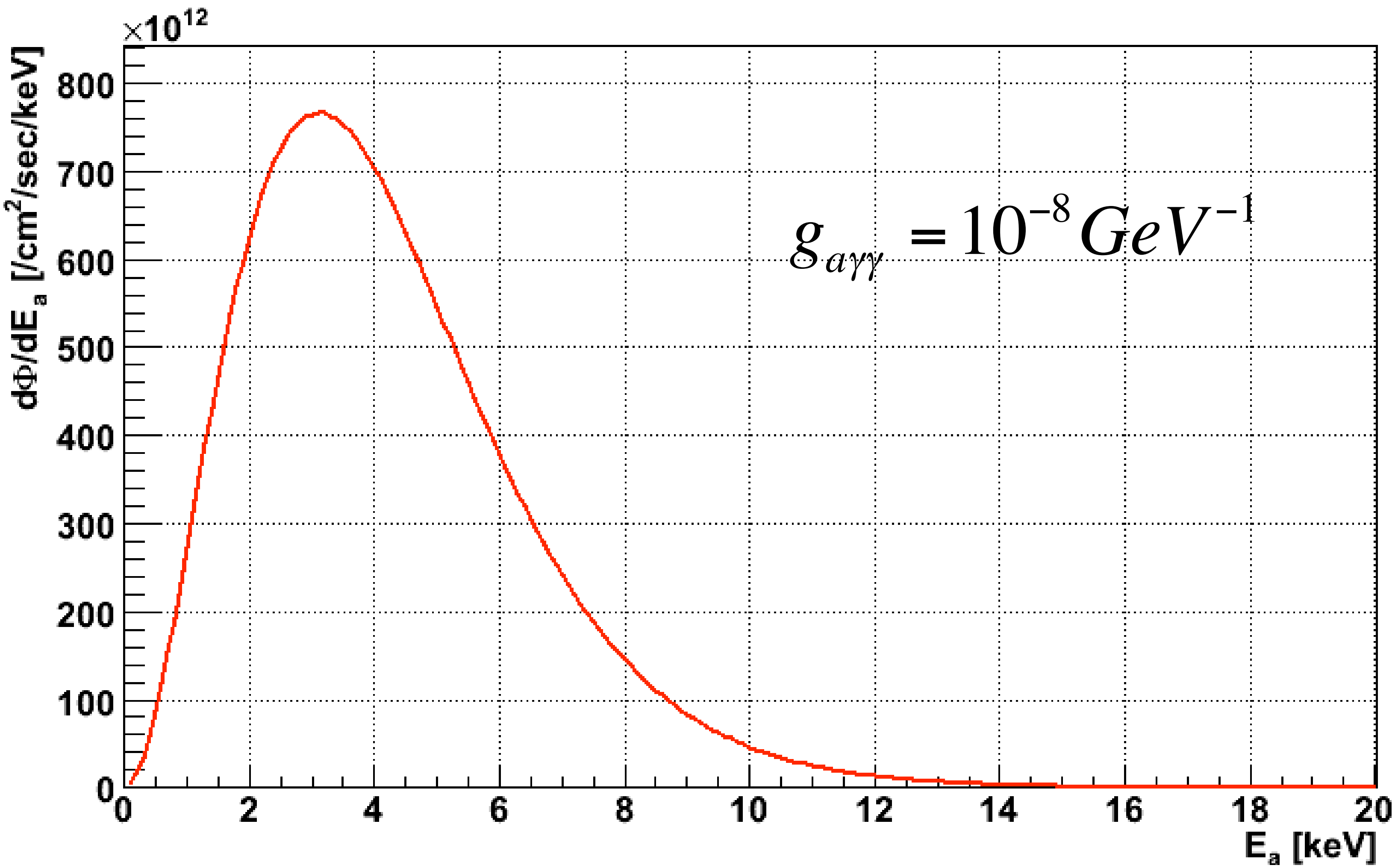
GammeV@FNAL
PRL100,080402(2008)

Solar Axion Detection Principle

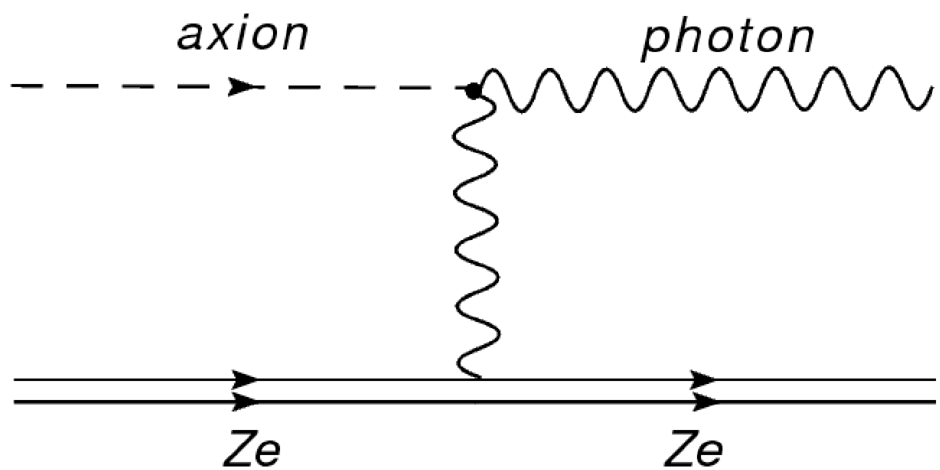




Solar Axion : $g_{a\gamma\gamma}$ coupling



Axion-photon conversion : Primakoff effect



$$\sigma = \frac{g_{a\gamma\gamma}^2 (Ze)^2}{64\pi^2} \frac{k^4}{(r_0^{-2} + q^2)^2}$$

$$g_{a\gamma\gamma} = 10^{-8}\,\mathrm{GeV}^{-1},\ k \approx \mathrm{keV},\ q \approx \mathrm{keV},\ Z \approx 100$$

$$\sigma \approx 10^{-43}\,\mathrm{cm}^2\ !!$$

Crystal and Bragg Scattering

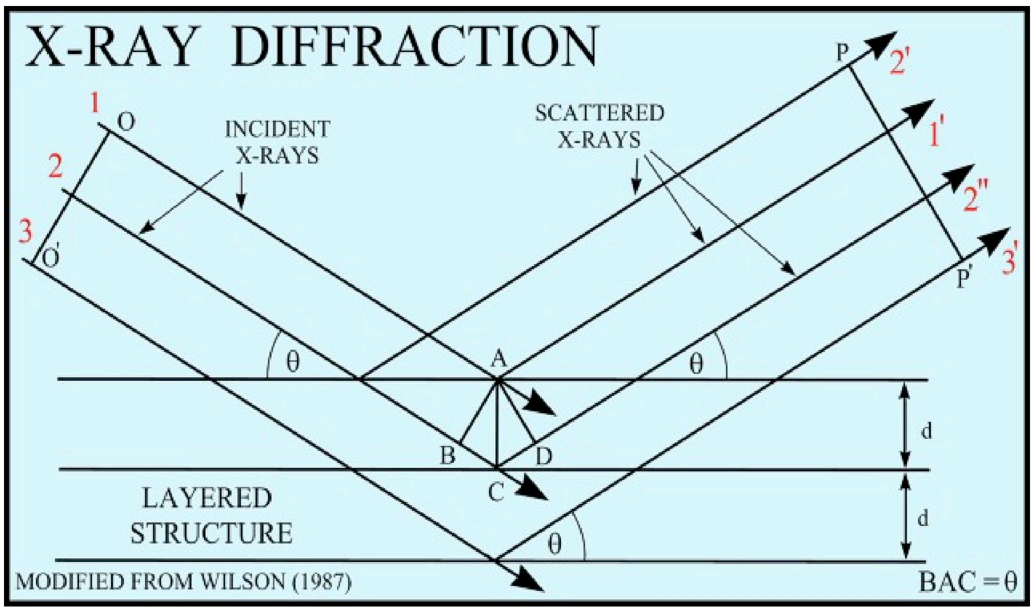
Coherent scattering of an axion in crystal planes

$$R(E) = \int 2c\frac{d^3q}{q^2} \cdot \frac{d\Phi}{dE} \cdot [\frac{g^2_{a\gamma\gamma}}{16\pi^2}|F(\vec{q})|^2 \sin^2(2\theta)]$$

$$F(\vec{q}) = k^2 \int d^3x \; \phi(\vec{x}) e^{i\vec{q}\cdot\vec{x}}$$

$$\phi(\vec{x}) = \sum_i \phi_i(\vec{x}) = \sum_i \frac{Ze}{4\pi|\vec{x}-\vec{x}_i|} e^{-\frac{|\vec{x}-\vec{x}_i|}{r}} = \sum_G n_G e^{i\vec{G}\cdot\vec{x}}$$

Bragg condition



BRAGG LAW

$$2d(\sin\theta) = \lambda_o$$

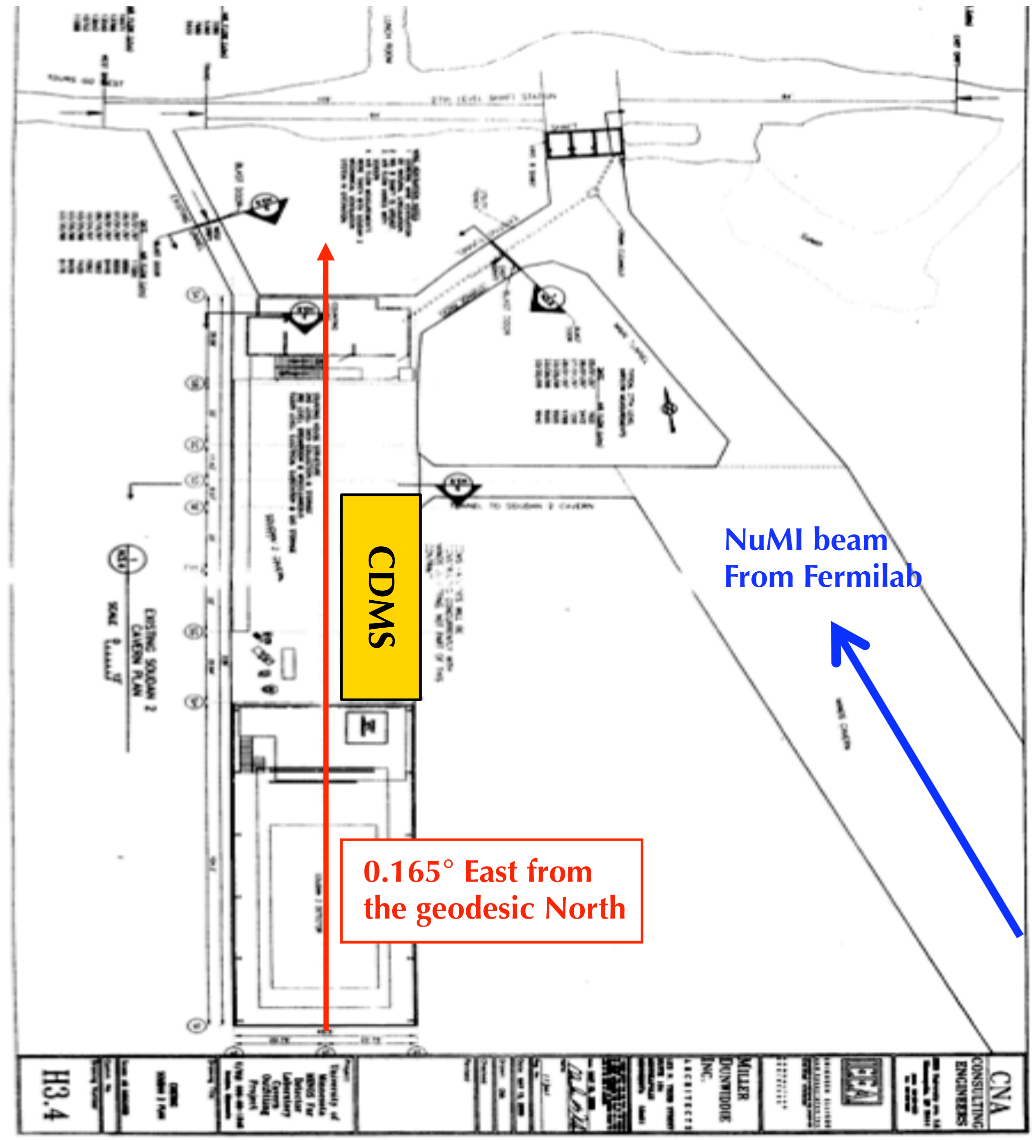
where:

- d = lattice interplanar spacing of the crystal
- θ = x-ray incidence angle (Bragg angle)
- λ = wavelength of the characteristic x-rays

$$E_a = \hbar c \frac{|\vec{G}|^2}{2\hat{u}\cdot\vec{G}}$$

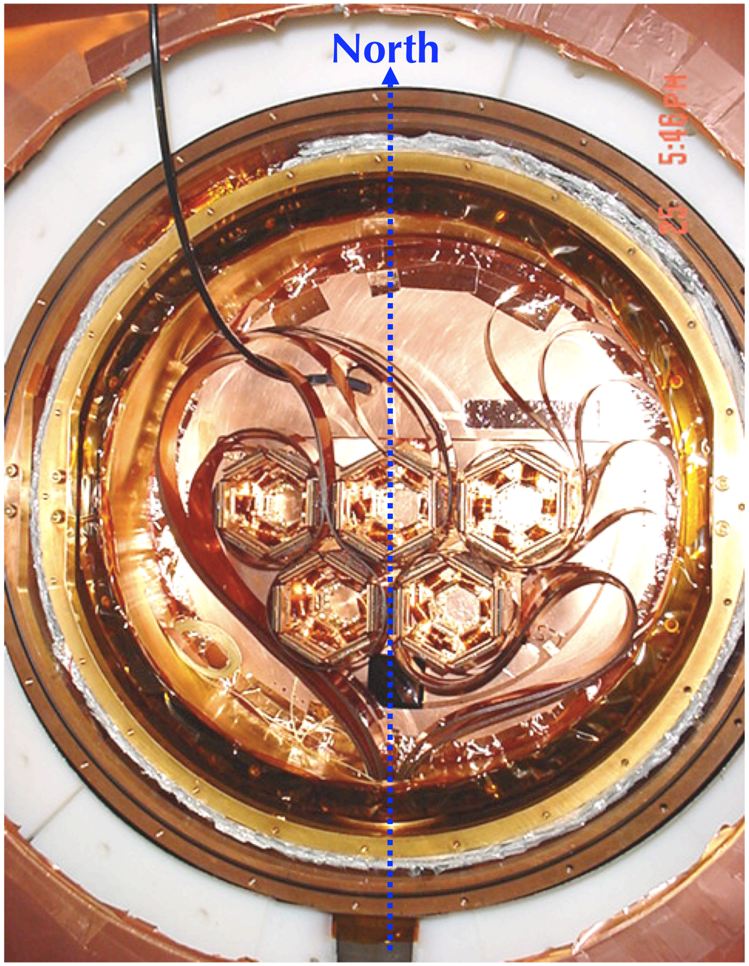
Directions in the mine

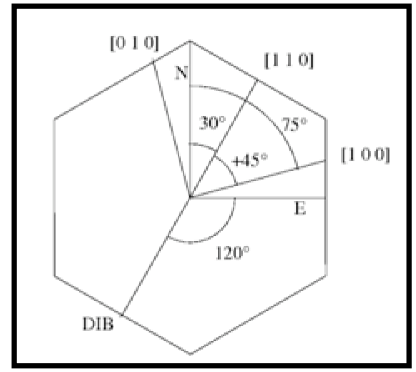
- Amazing collaboration among the CDMS, NuMI/MINOS and old mine crews
- FNAL Alignment Group measured the geodesic north in the Soudan mine (1999)

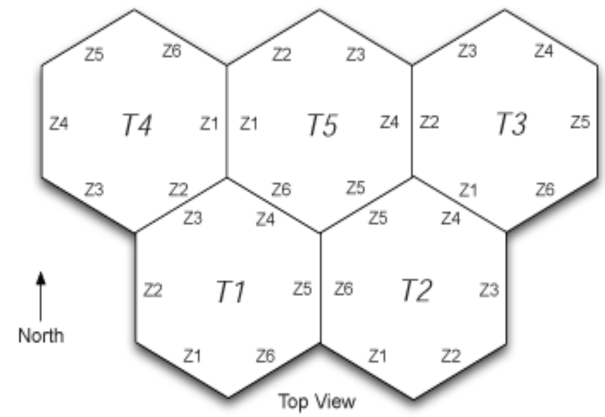


Direction of the crystal plane

- Overall error in the direction measurement : 3 degree
- Germanium crystal structure : Face-Centered-Cubic (*fcc*)







The following shows detector stack placement:

	T1	T2	T3	T4	T5
Z1	G6	S14	S17	S12	G7
Z2	G11	S28	G25	G37	G36
Z3	G8	G13	S30	S10	S29
Z4	S3	S25	G33	G35	G26
Z5	G9	G31	G32	G34	G39
Z6	S1	S26	G29	G38	G24

Side View

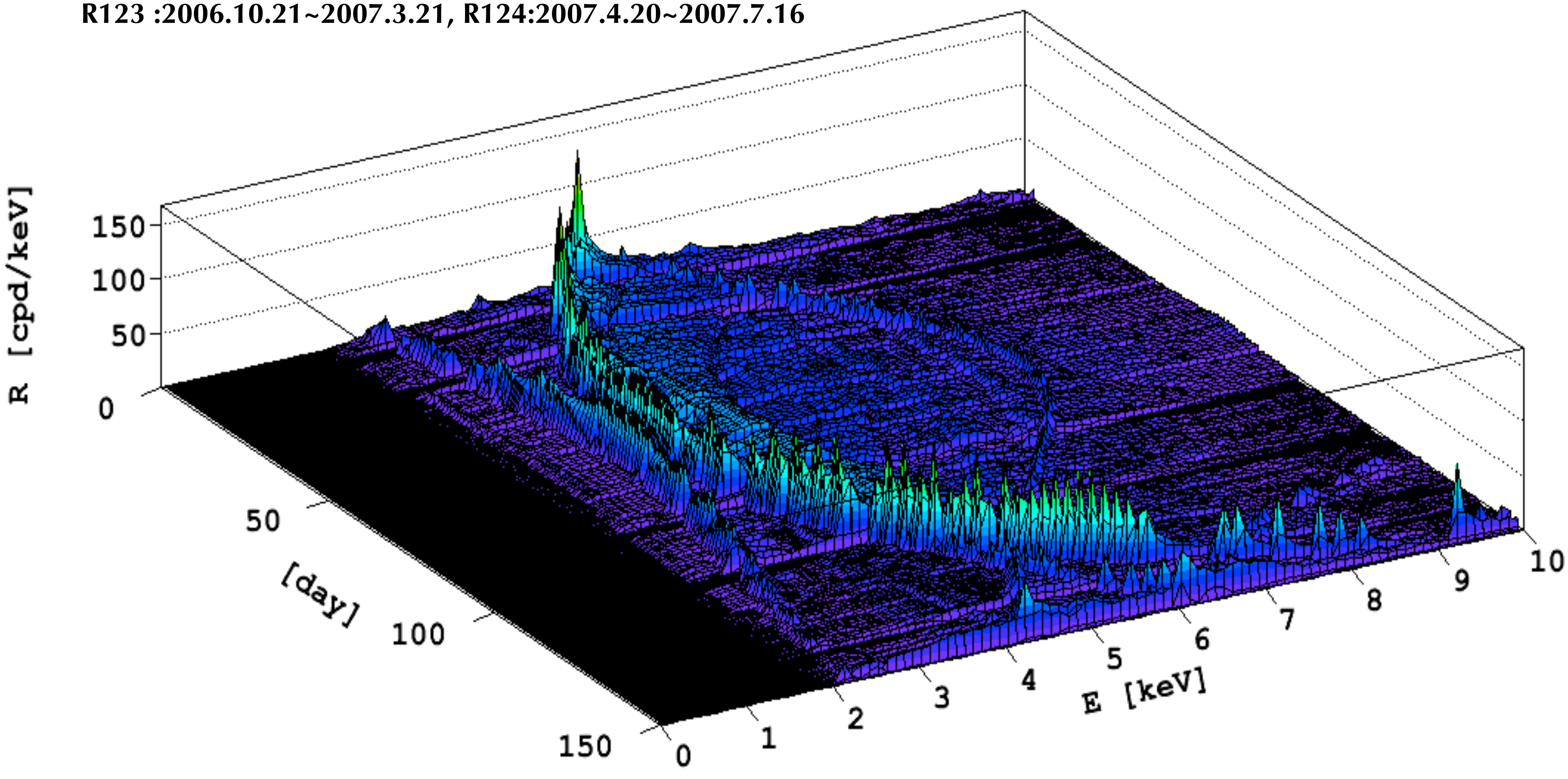
Expected Solar Axion Event Rate

<u>Very detailed calculations are involved</u>

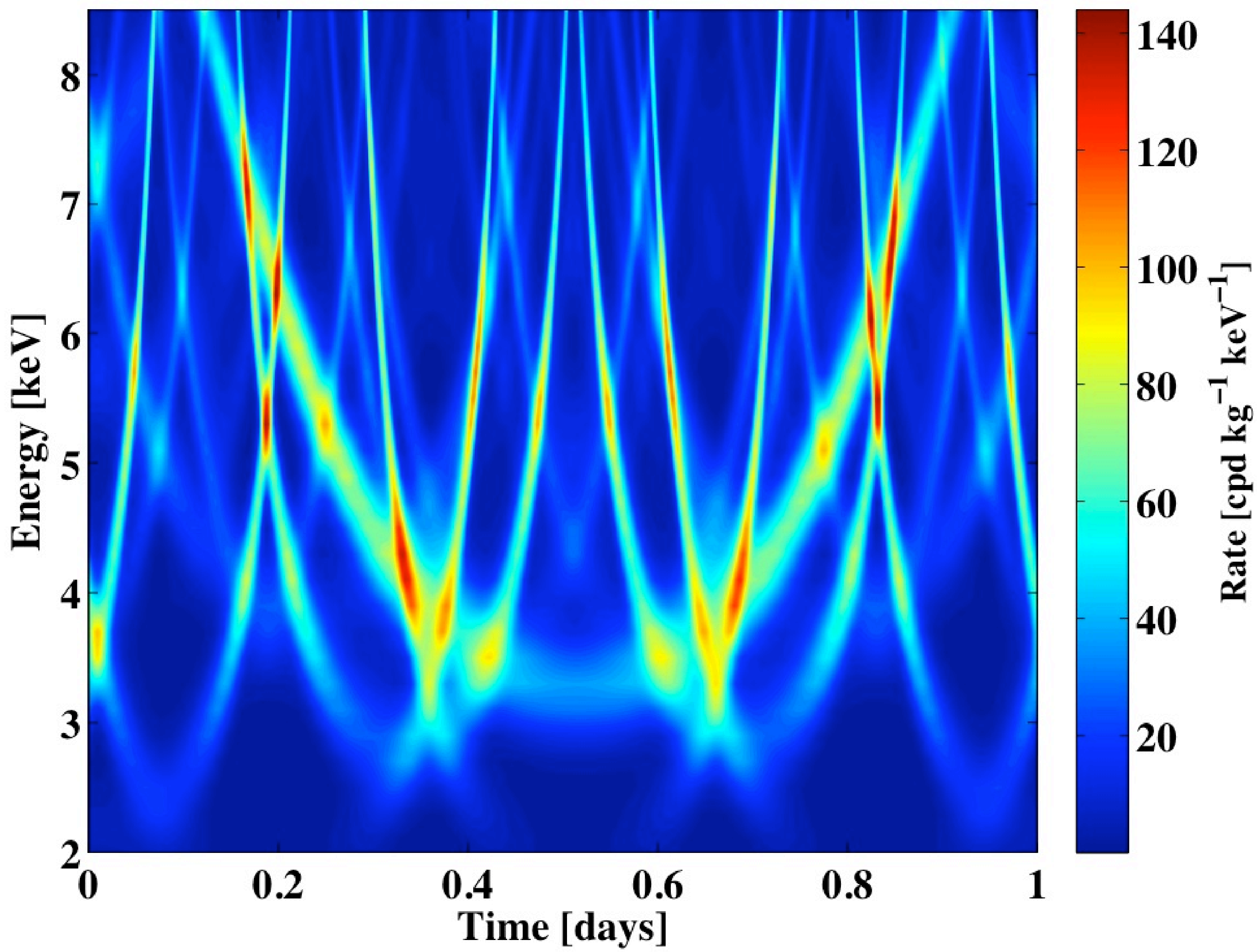
- Seasonal variation of the solar flux
- The height of the Sun changes in seasons
- Detector energy resolutions
- Systematic uncertainty of the detector direction
- Detector livetime information

R123 :2006.10.21~2007.3.21, R124:2007.4.20~2007.7.16

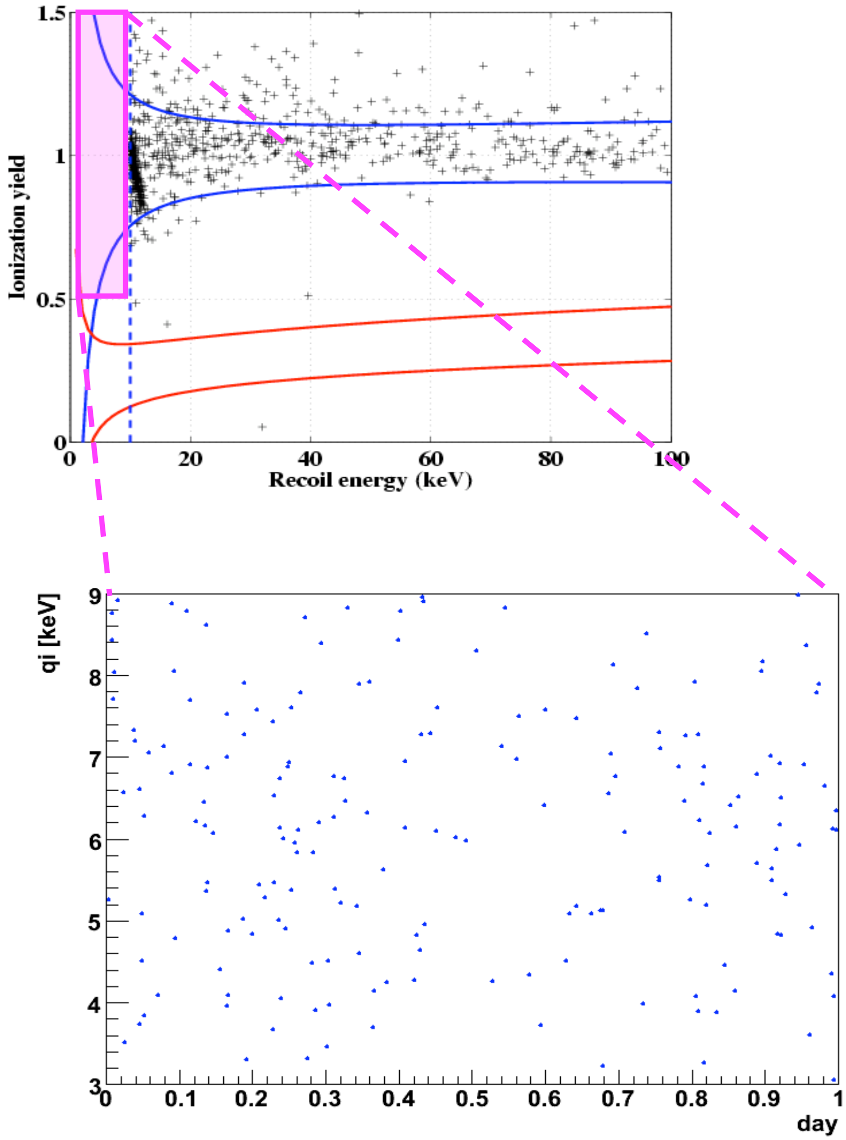
**200 CPUs x 2 weeks
@FermiGrid**

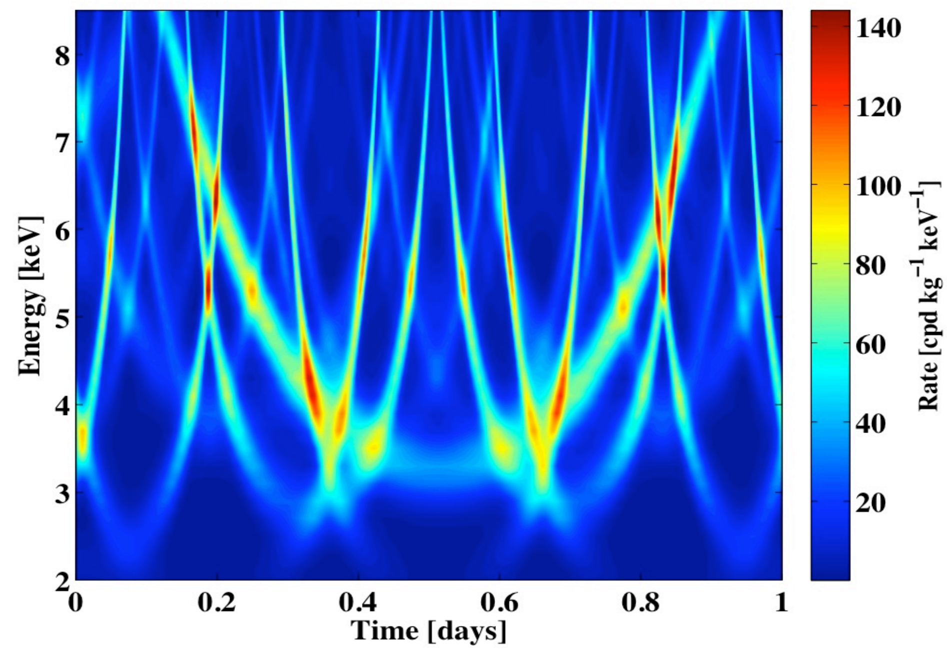


Expected Solar Axion Event Rate



CDMS Low Energy Gammas





Unbinned Likelihood Fit

$$R(E,t,d) = \lambda A(E,t,d) + B(E,d),$$

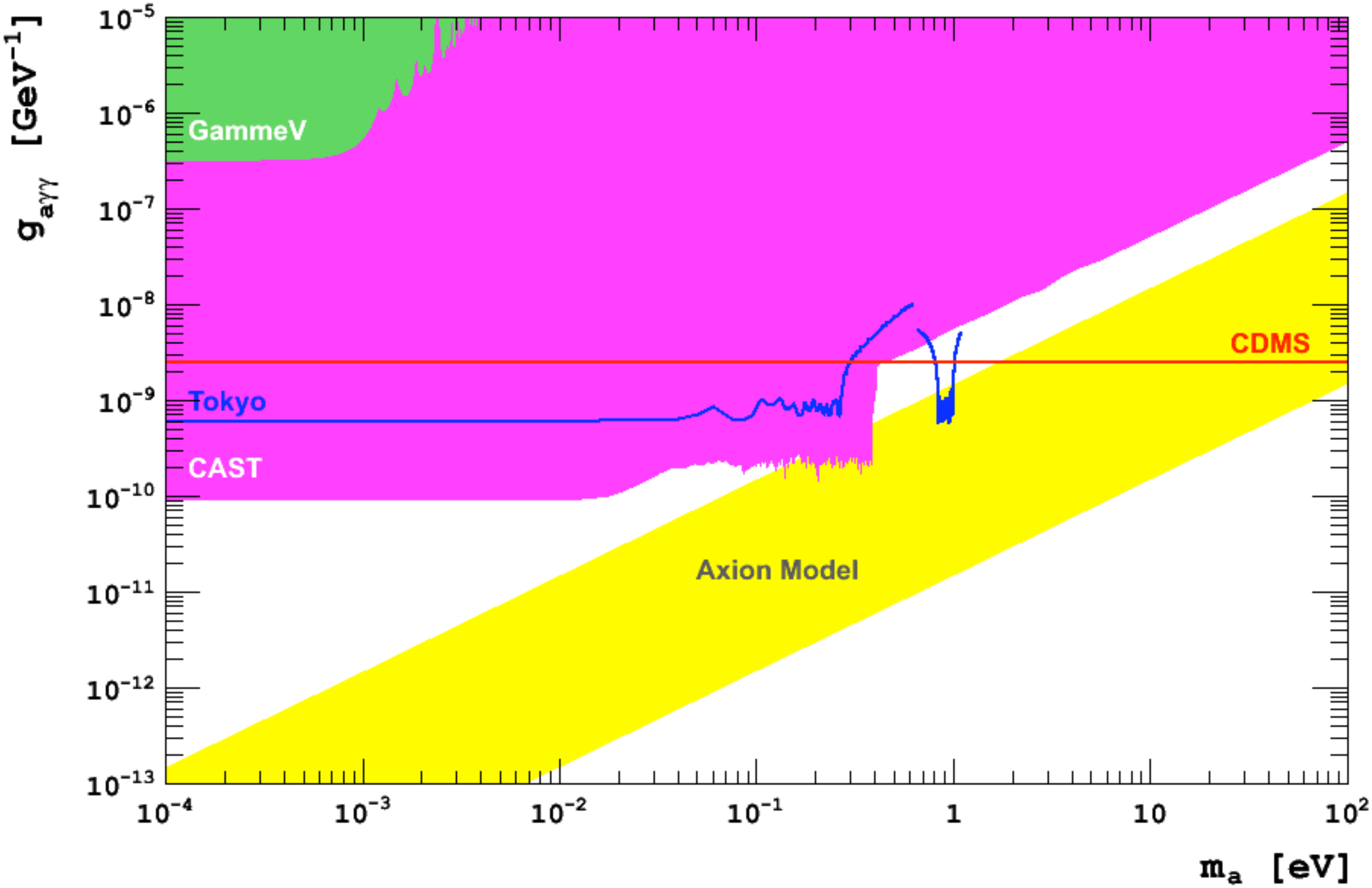
$$\lambda = [g_{a\gamma\gamma}/(10^{-8}\,\mathrm{GeV}^{-1})]^2$$

$$B(E,d) = \varepsilon(E,d)[\alpha(d) + \beta(d)E + \gamma(d)/E]$$

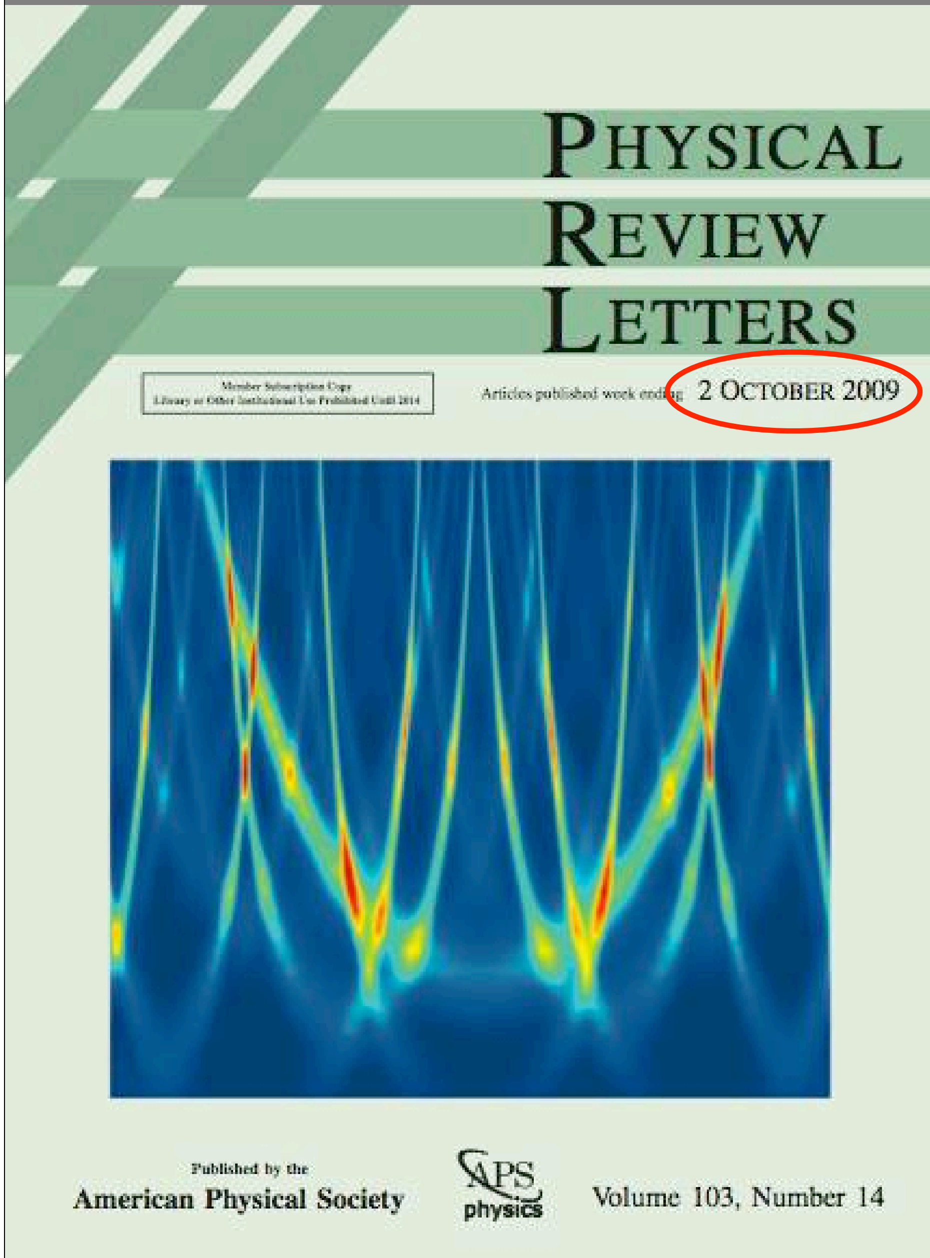
$$R_T = \sum_d \int dEdtR(E,t,d;\lambda,\alpha(d),\beta(d),\gamma(d))$$

$$\log(L) = -R_T + \sum_i \log(R(E_i,t_i,d_i))$$

The First Solar Axion Limit from CDMS



PRL Cover and FermiToday



Fermilab Today — Friday, Oct. 30, 2009

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Calendar

Have a safe day!

Friday, Oct. 30
3:30 p.m.
DIRECTOR'S COFFEE BREAK - 2nd Flr X-Over
THERE WILL BE NO JOINT EXPERIMENTAL-THEORETICAL PHYSICS SEMINAR THIS WEEK

Monday, Nov. 2
1:30 p.m.
Research Techniques Seminar - Curia II
Speaker: Juha Kalliopuska, VTT Micro and Nanoelectronics, Finland
Title: Edgeless Detectors for High Energy Physics Applications
2:30 p.m.
Particle Astrophysics Seminar - One West
Speaker: Tyce DeYoung, Pennsylvania State University
Title: Particle Physics and Astrophysics with IceCube
3:30 p.m.
DIRECTOR'S COFFEE BREAK - 2nd Flr X-Over
4 p.m.
All Experimenters' Meeting Special Topics: ILC Cavity Gradients and Manufacturing; CMS/LHC Report - Curia II

Click here **for NALCAL, a weekly calendar with links to additional information.**

Campaigns

Take Five

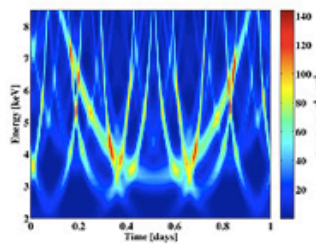
Tune IT Up

H1N1 Flu

For information about H1N1, visit Fermilab's flu information site.

Fermilab Special Result of the Week

CDMS looks for finger prints of axions



The finger print that CDMS is looking for: the expected solar axion event rate in a germanium detector depends on the energy of the axions and the position of the sun in the sky. The position of the sun is plotted as time of day.

The theory of strong interactions, known as quantum chromodynamics, predicts that matter and antimatter behave slightly differently, a phenomenon known as CP violation. However, CP violation has never been observed in strong interactions.

In order to save QCD from this dilemma, theorists predict the existence of a particle known as the axion, which barely interacts with matter. While the particle fixes the CP violation problem, experiments have not yet detected any axions.

According to theory, an axion could emerge when a photon traverses a very strong electric or magnetic field. The core of the sun would be a perfect region for the creation of axions. The particles would immediately escape the sun and some of them would travel through Earth.

The Cryogenic Dark Matter Search, which takes place deep underground in the Soudan Underground Laboratory in Minnesota, has searched for axions and set new limits on the properties of these particles. The result made the cover of the Oct. 1 issue of Physical Review Letters.

The primary goal of the CDMS collaboration is the search for weakly interacting massive particles, which are candidates for dark matter particles. But its germanium and silicon detectors, which

Recovery Act Feature

Roll out the wavelength shifter barrel

The first barrels of the chemical powders PPO and bis-MSB began arriving at Fermilab in September. During the next year, Fermilab will receive 8,700 kilograms of the powders.

The first batches of two powdered chemicals, dubbed wavelength shifters, for the future NOvA neutrino project arrived by the barrel at Fermilab recently.

The American Recovery and Reinvestment Act funded the $2.1 million contract for the wavelength shifters, a crucial element for the neutrino project.

Scientists will use the two chemical powders, called PPO and bis-MSB, to change the wavelength of particles of light, called photons, into the required range for the experiment.

During the next year, Fermilab will receive 8,700 kilograms of the wavelength shifters. So far Fermilab has received 3,060 kilograms of the PPO and 120 kilograms of the bis-MSB powders.

"It takes a long time to manufacture this large an amount of the powders," said John Cooper, Fermilab NOvA project manager. Fermilab will receive the wavelength shifters in multiple shipments as they become available, he said.

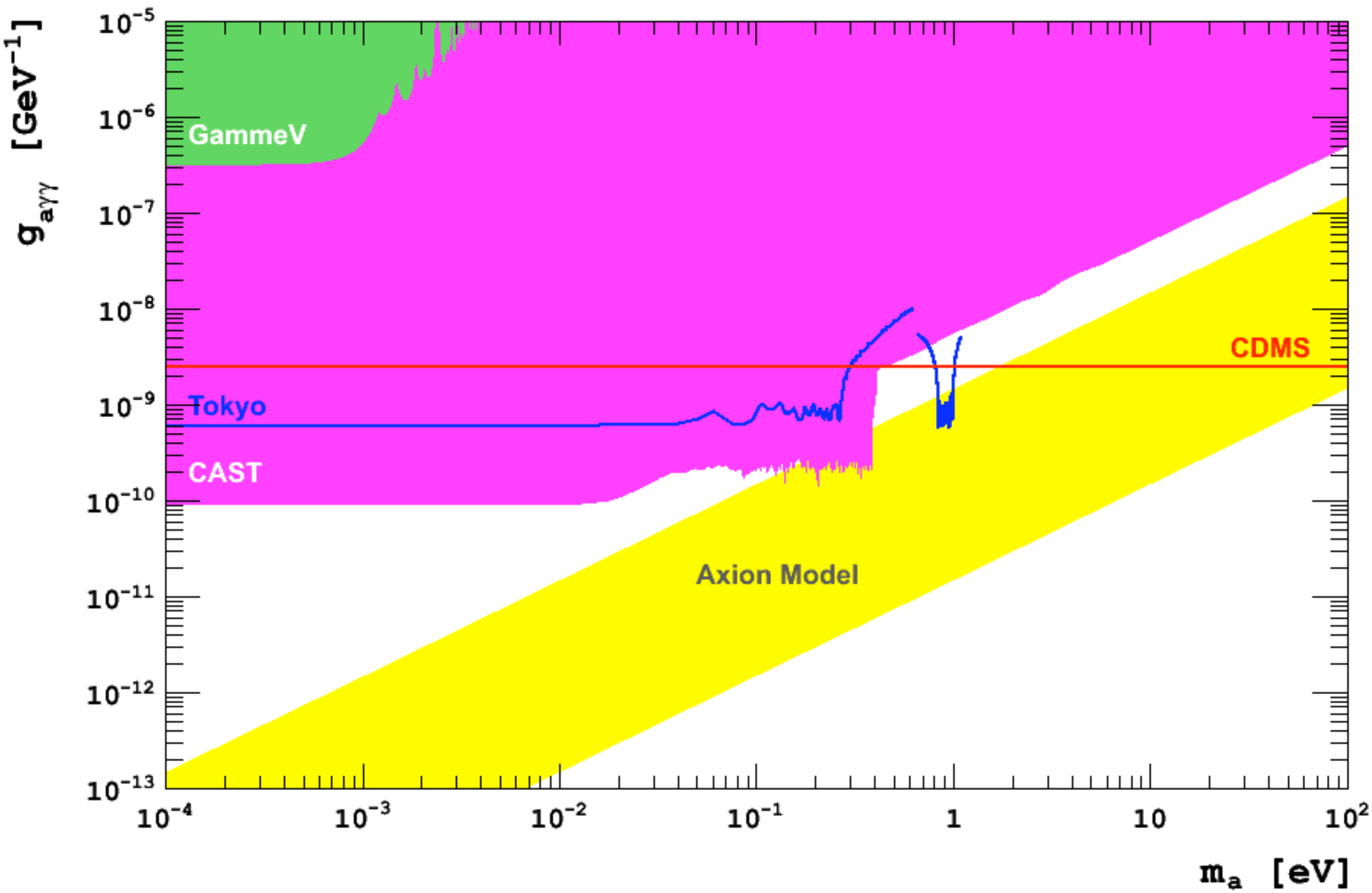
As each shipment arrives, scientists from Fermilab and Northern Illinois University will test the chemical powders for quality control. Using an ultraviolet and visible spectrophotometer, for example, scientists can study the powder's transmittance, which is the area of the light spectrum the material absorbs and transmits.

"These tests tell us about the purity of the powder," said Fermilab chemist Anna Pla-Dalmau. "We requested 99.5 percent purity for NOvA, and we want to make

2010 APS Calendar

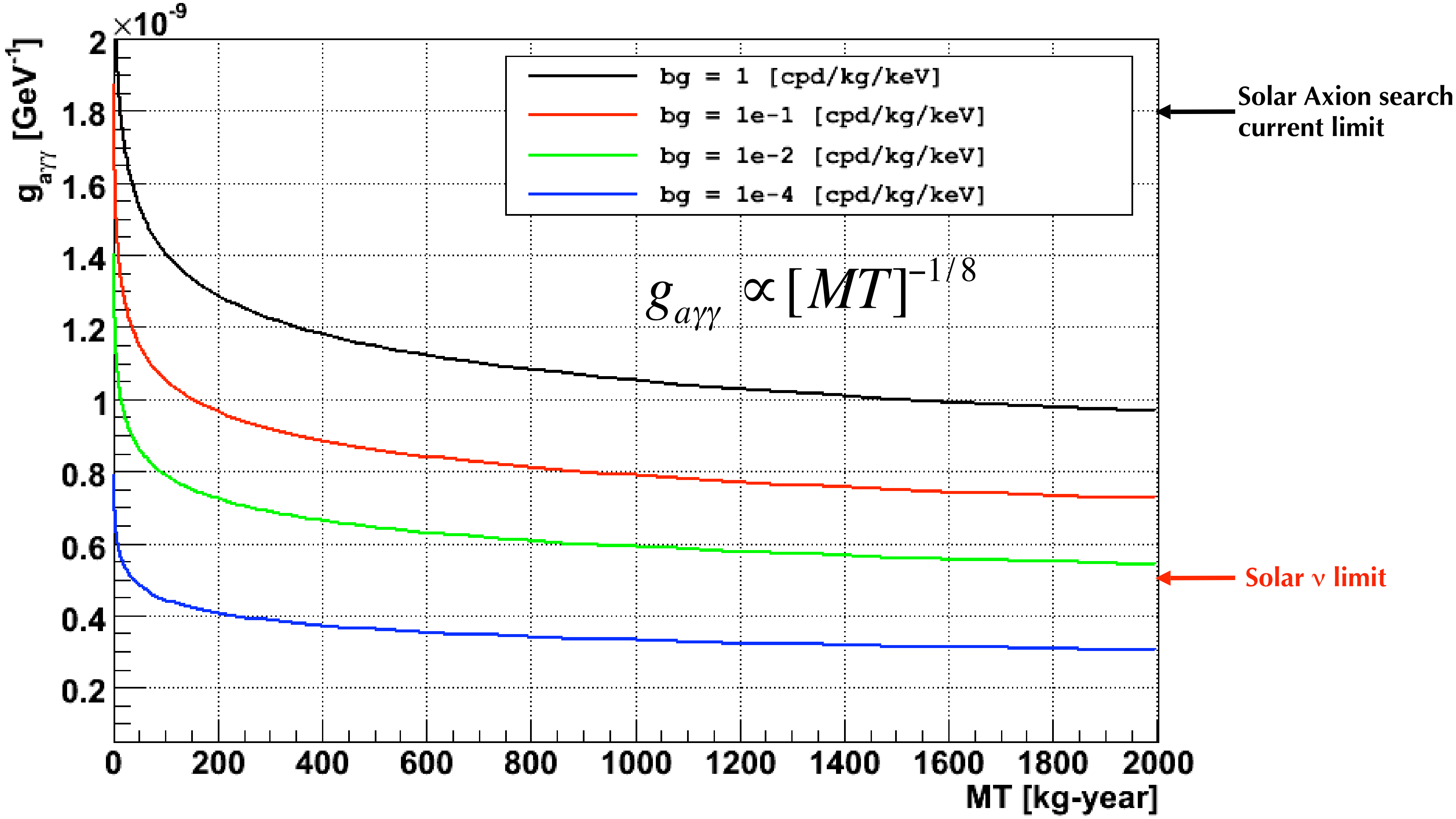
Future

Axions : "Invented to save QCD"

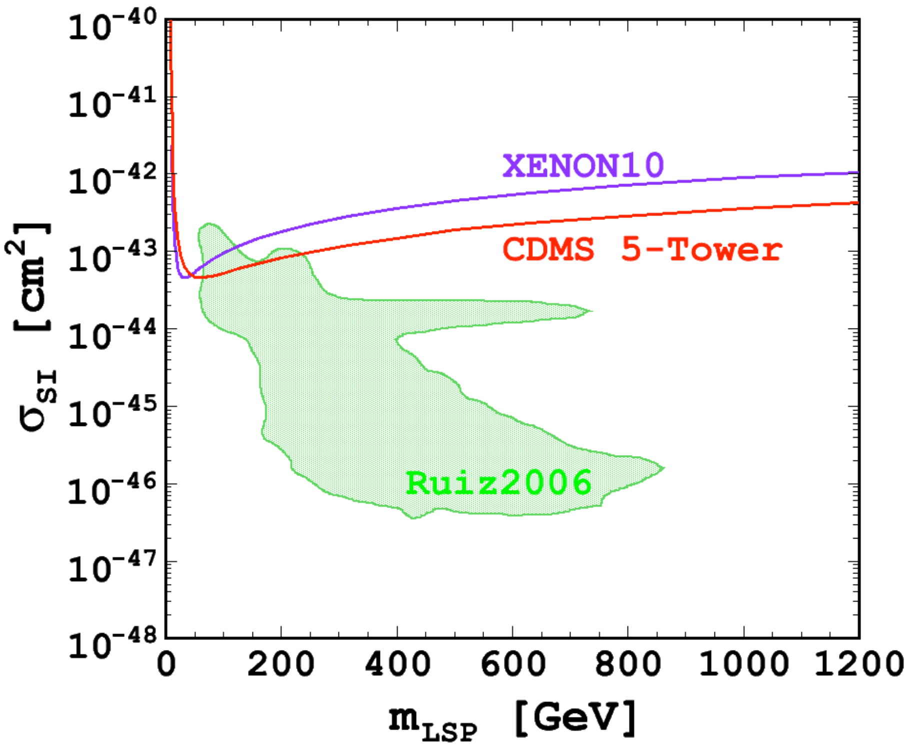


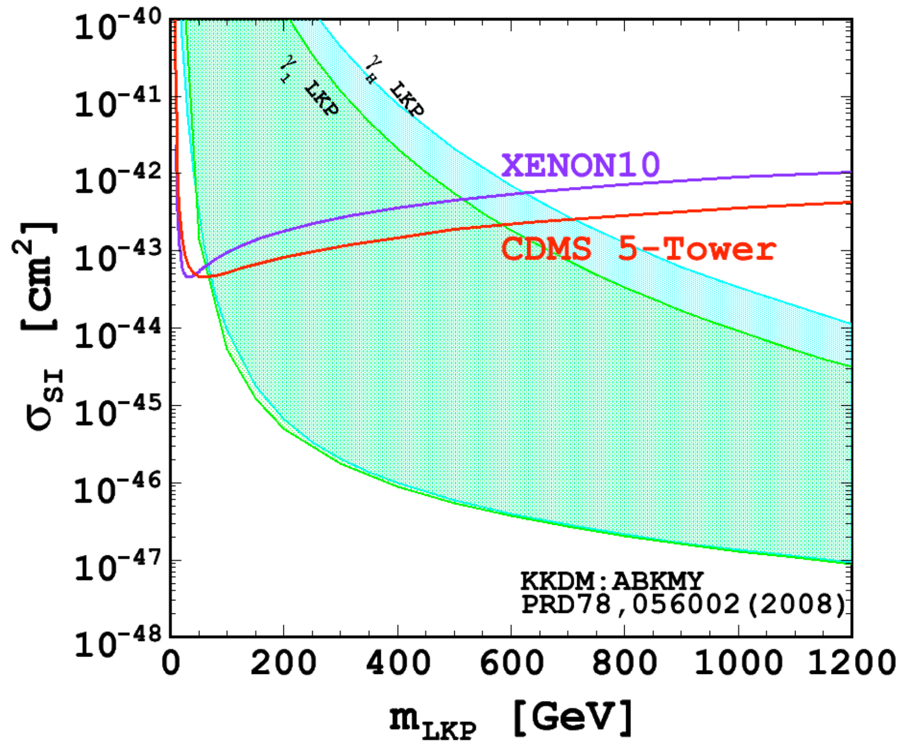
Key to Future Solar Axion Searches

- It's not quite about the detector volume
- It's more seriously about the backgrounds!



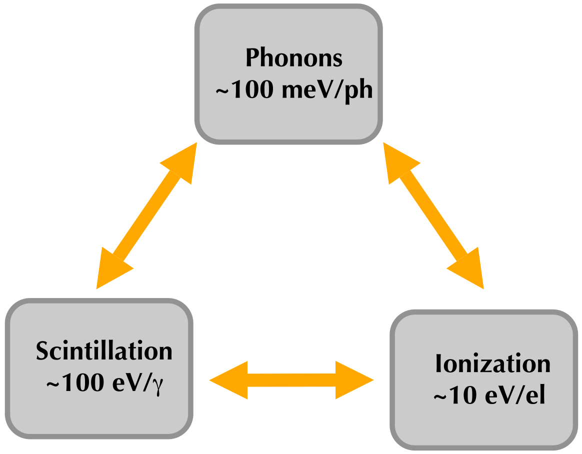
Dark Matter Search





- Most models are at $\sigma > 10^{-47}$cm^2
- The goal for the major Dark Matter experiments:
  - ➔ nuclear recoil background level should be controlled less than ~10^{-7} dru (= counts/day/kg/keV)
  - ➔ Current CDMS nuclear recoil background level (world best) : ~10^{-4} dru
- 10^3 times better background control required !

Solid Xenon



Why Xenon ?

- No long-lived Xe radio isotope (no intrinsic background)
- High yield of scintillation light
- Scintillation wavelength : 175nm (optically transparent)
- Relatively high melting point : T_m = 161K
- Simple crystal structure : *fcc* (same as Ge)
- Easy purification (distillation, etc)
- Self shielding : Z=54

Why Solid ?

- For solar axion search, being a crystal is crucial (Bragg scattering)
- Even more scintillation light (61 γ/ keV) than LXe (42 γ/ keV)
- Drifting electrons faster in the crystal
- Superb low noise superconducting sensors are running at low temperature (mK ~ K)
- Phonon read out : largest number of quanta (~10,000 phonons / keV)
  - In principle best energy resolution can be achieved in phonon channel
  - Luke-phonon readout will provide ionization energy and position information
- No further background contamination through circulation loop (no convection mix)
- Optimal detector design for low background experiment
  - Possible container free design
  - No outgassing issue

Xenon Properties

Atomic number :Z	54	
Boiling point (1 $[atm]$)	165	$[K]$
Melting point (1 $[atm]$)	161	$[K]$
Triple point properties		
Density		
Gas	8.18×10^{-3}	$[g/cm^3]$
Liquid	2.96	
Solid	3.40	
Temperature	161.391	$[K]$
Pressure	612.2	$[Torr]$

ΔT = 4K

Compact

	Gas	Liquid	Solid
W-value $[eV]$	21.5	15.6[1]	12.4[2] 19.5 [3]
Fano factor	< 0.17	0.0041 [1]	?
Electron drift velocity $[cm/sec]$	$\sim 10^5$ at $1[kV/cm]$	3.0×10^5[4] $> 5[kV/cm]$	5.0×10^5[4] $> 5[kV/cm]$
Ion or Hole drift velocity $[cm/sec]$	Positive ion 0.76 at $1[kV/cm]$	Positive ion 0.3 at $1[kV/cm]$	Hole 18[4] at $1[kV/cm]$

More electrons / keV ?
or less ?

Faster electron drift ?

Slow hole drift
Single directional Luke-phonon?

Index of refraction?, diffusion coefficient?, specific heat?, dielectric constant in solid? ,…

Science

(1) Solar axion search
- scintillation / (ionization)

(2) Dark matter search
- scintillation / ionization / (phonon)

(3) Neutrinoless double beta decay (0v2b) : ^{136}Xe enriched
- scintillation / ionization / phonon

(4) pp-Solar neutrino measurement : ^{136}Xe depleted
- Neutrino Oscillation / pp-Solar ν flux measure

(5) Supernova detection

(6) Neutrino coherent scattering

(7) Medical usage (MRI/NMR) : Hyperpolarized ^{131}Xe

Full of science topics

- Strong motivation to initiate R&D project
- But it does not necessarily mean we can initiate real science experiment
- We need proven technology in order to achieve immediate science goal

Short History of Solid Xenon (Argon)

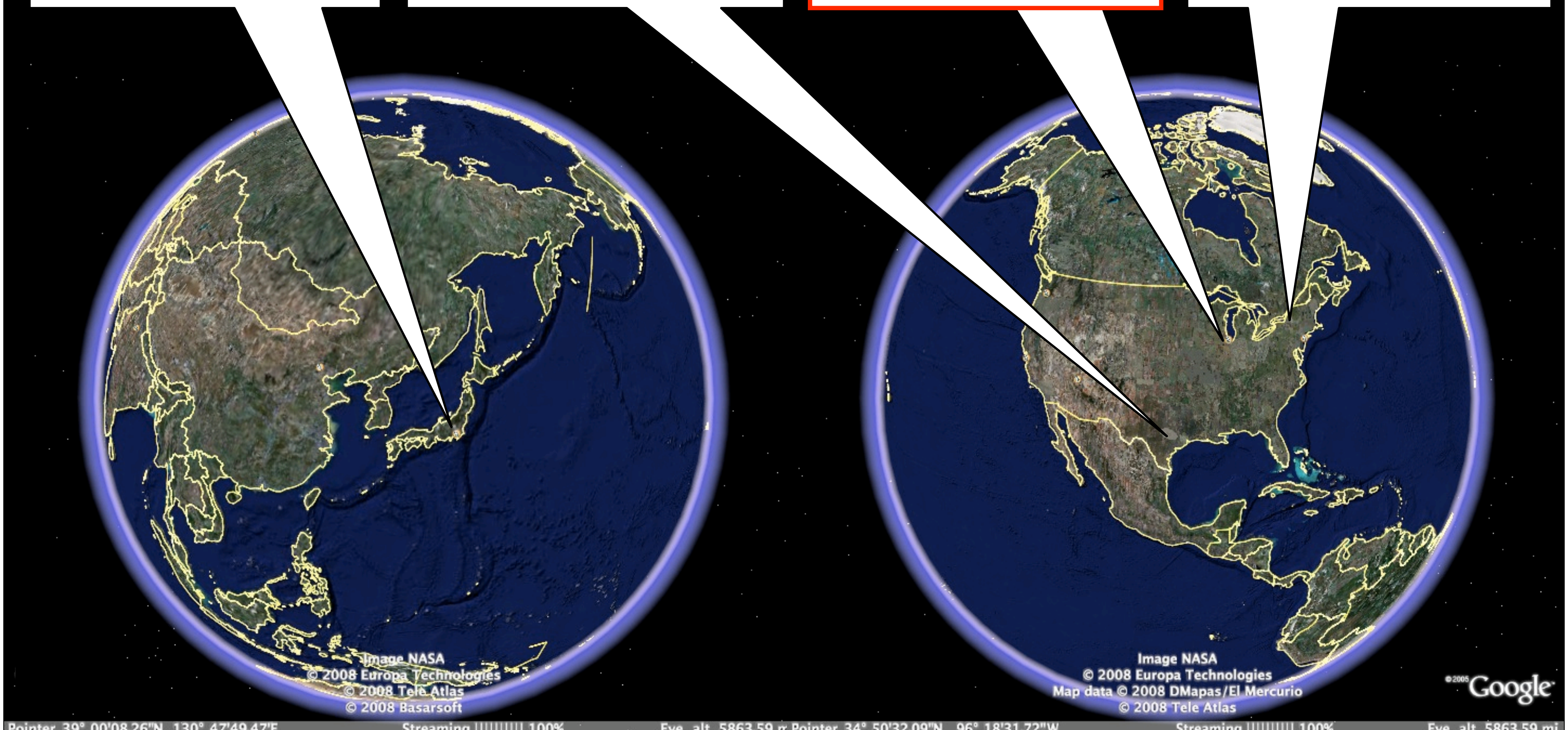
1999@Japan
Successful contact of thin Solid Xenon to an ionization sensor using carbon graphite film

2004@TAMU
Ionization readout from Solid Ar (not Xe). Failed to grow large crystals

1994@FNAL
Solid Argon detector wasn't successful

2008@FNAL
Solid Xenon Project initiated

2004@Syracuse
A student grew large Xenon crystals everyday without any problem for medical research



Solid Xenon in Japan 1999

Development of a Solid Xe Ionization Chamber

H.Nawa Y.Tamagawa M.Miyajima
Department of Applied Physics, Fukui University
9-1, Fukui 3-chome, Fukui, 910-8507, Japan

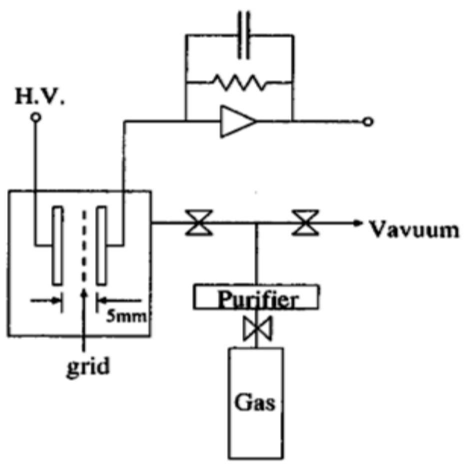


Figure 1: Schematic drawing for a solid xenon ionization chamber and a gas handling system

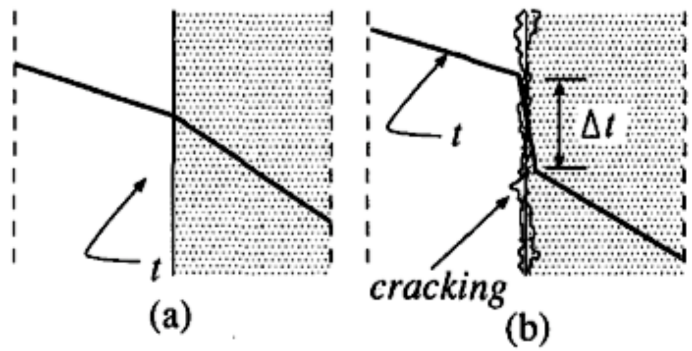


Figure 2: The temperature distribution near the contact surface of solid xenon and metal
(a).Perfect contact, (b).Imperfect contact

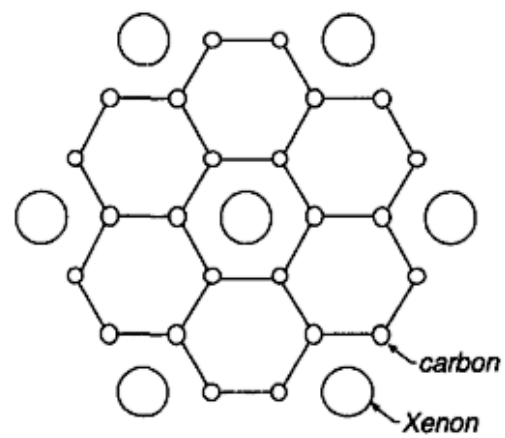


Figure 3: the first xenon layer grown on carbon graphite

Epitaxial growth of Xenon Crystal

Kramer 1976 : Epitaxial growth of xenon crystal on Carbon-graphite film

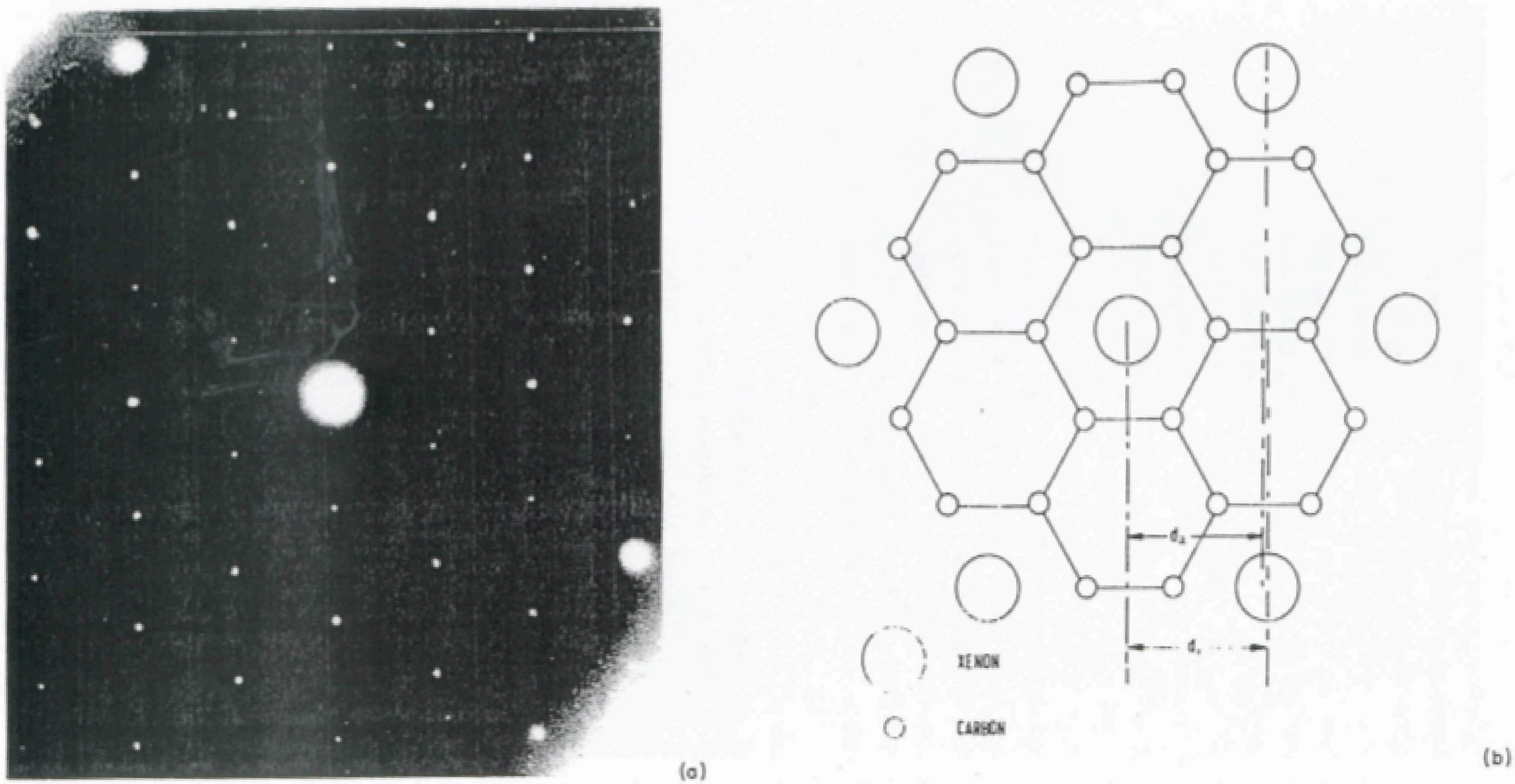
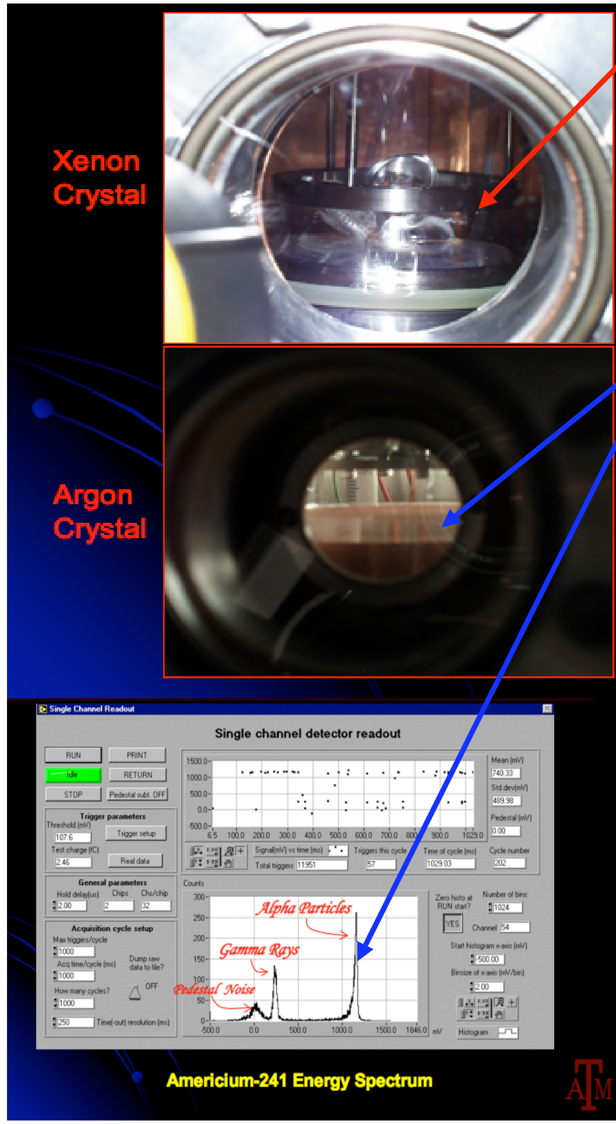


FIG. 17 (a) Electron diffraction pattern of epitaxial Xe on graphite, (b) orientation relationship between Xe and (0001) graphite, giving $(2\bar{2}0)$ spacing of xenon, d_1, and (1010) spacing of graphite d_2 (Kramer, 1976).

TAMU Solid Argon/Xenon chamber

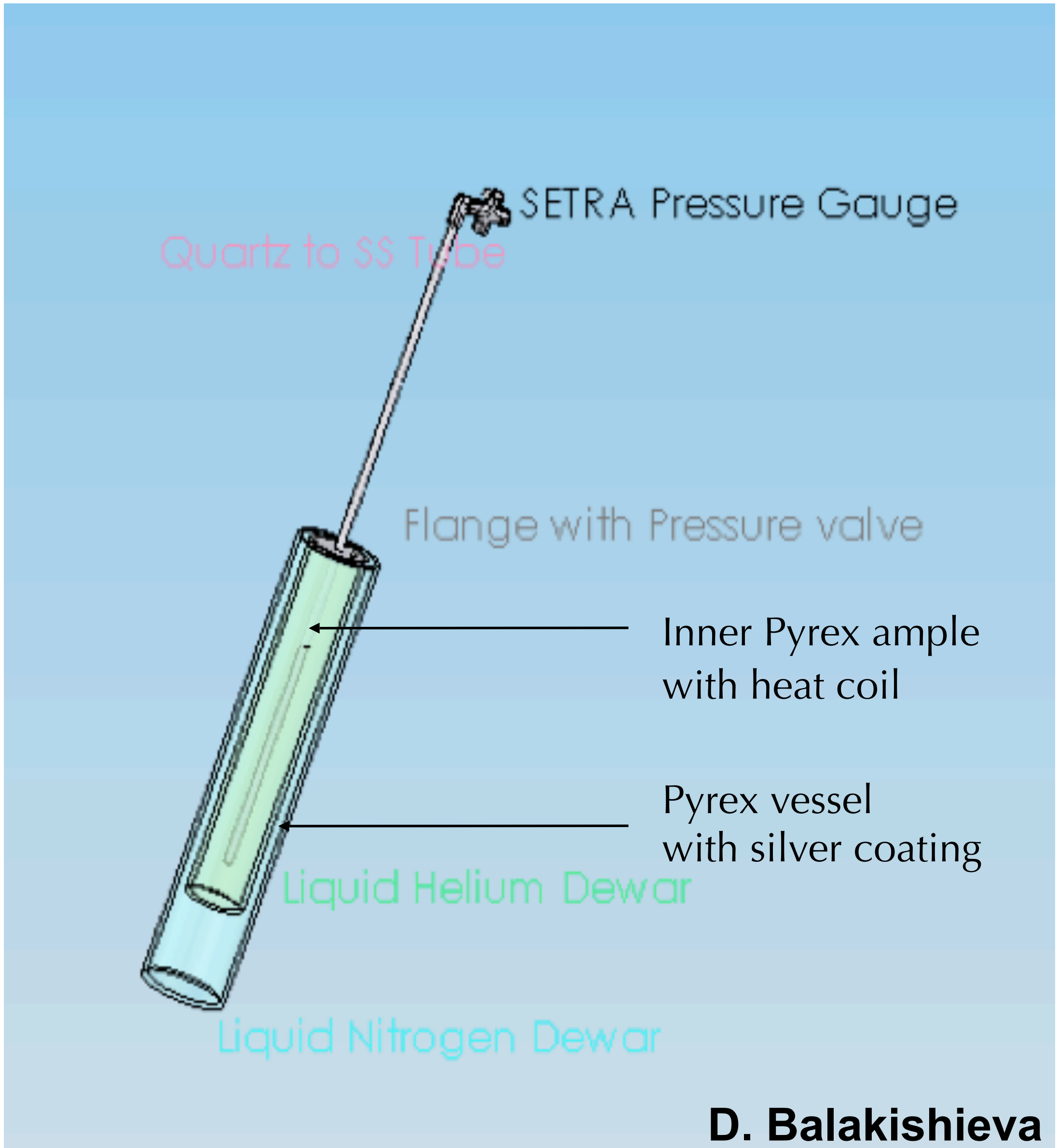
Failed to Grow Xenon Crystal



Small scale Ar crystal grow & readout ionization signal

May 2008 @TAMU

Syracuse Cryobath Design



The purpose of the bath was to grow hyperpolarized Xe crystal for medical usage (MRI/NMR)

Pros

The cryobath has been used for years to grow Xe crystal

Most parts are commercially available

Cons

U.Syracuse decided to use the cryobath for cold fusion study

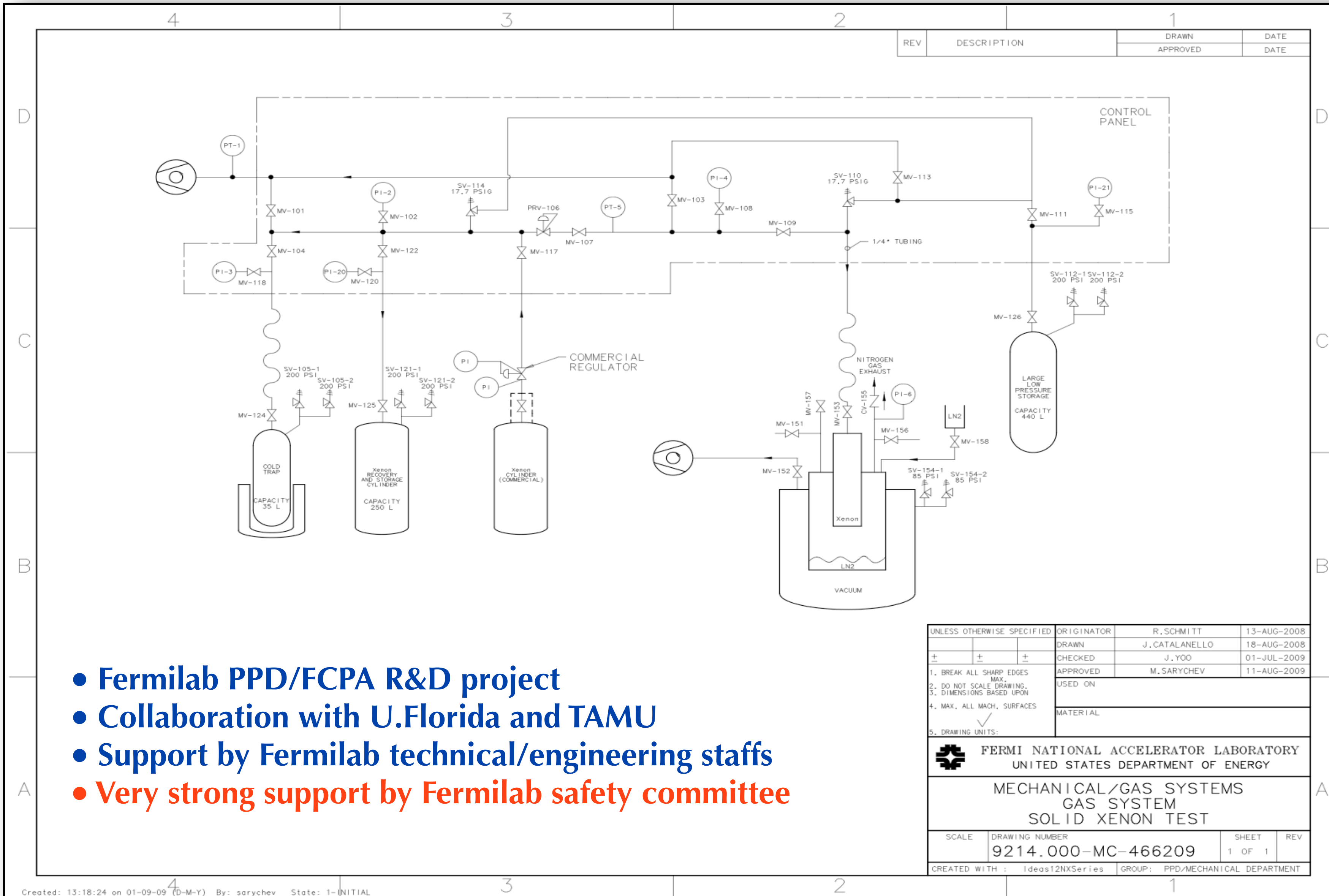
Stepwise approach was suggested by FCPA review committee (May 2008)

Does this setup satisfy Fermilab Safety Regulations?

Solid Xenon R&D Phase-1

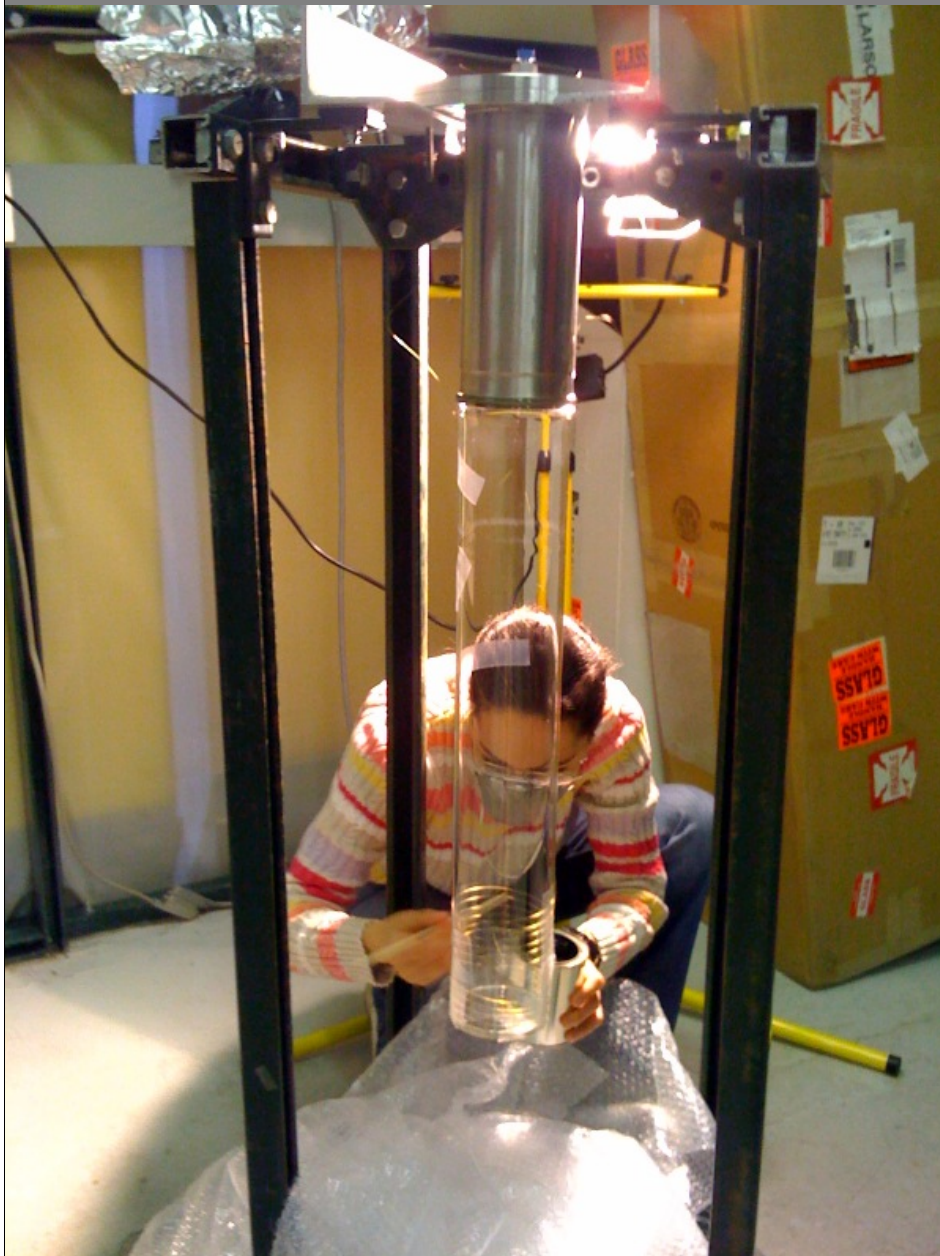
- Grow Xenon Crystal -

Fermilab Solid Xenon Phase-1 : grow crystal

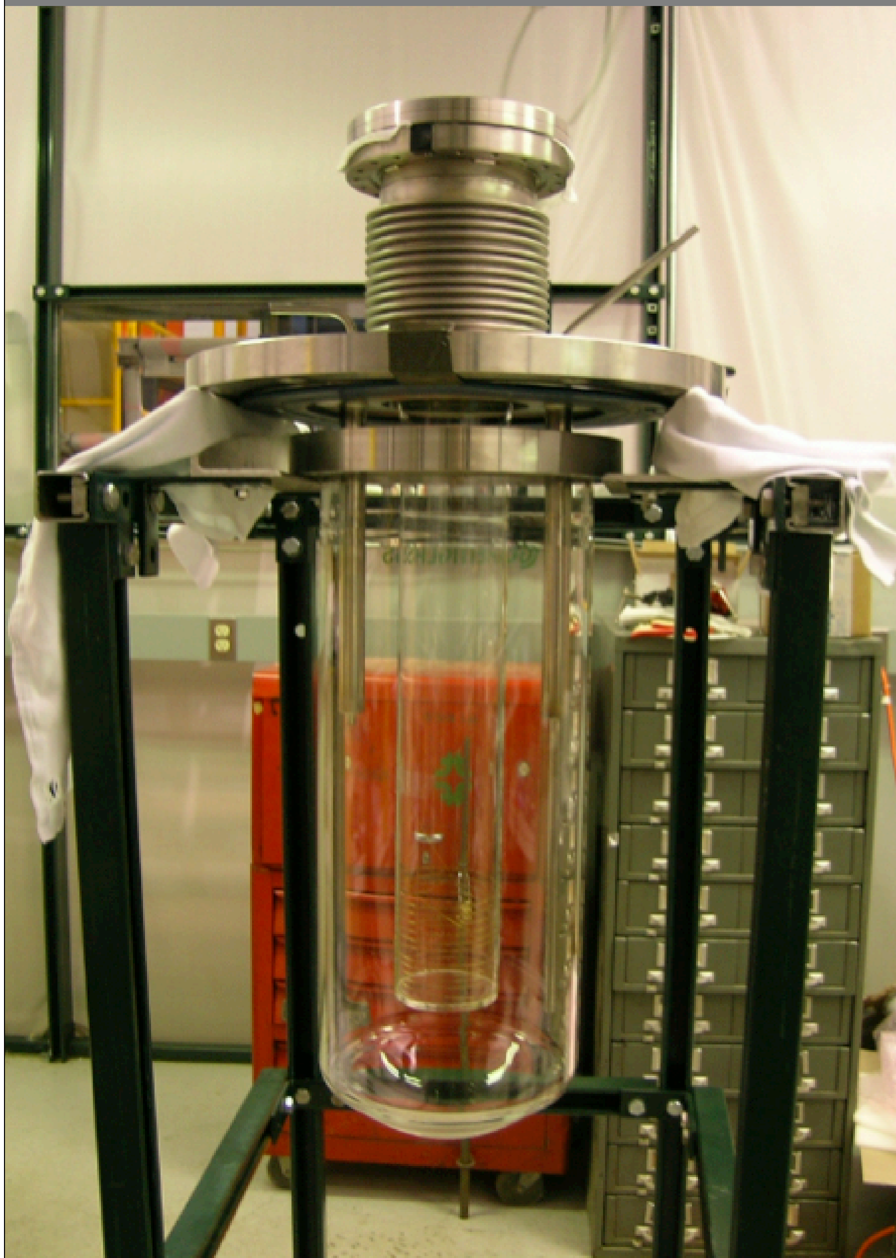


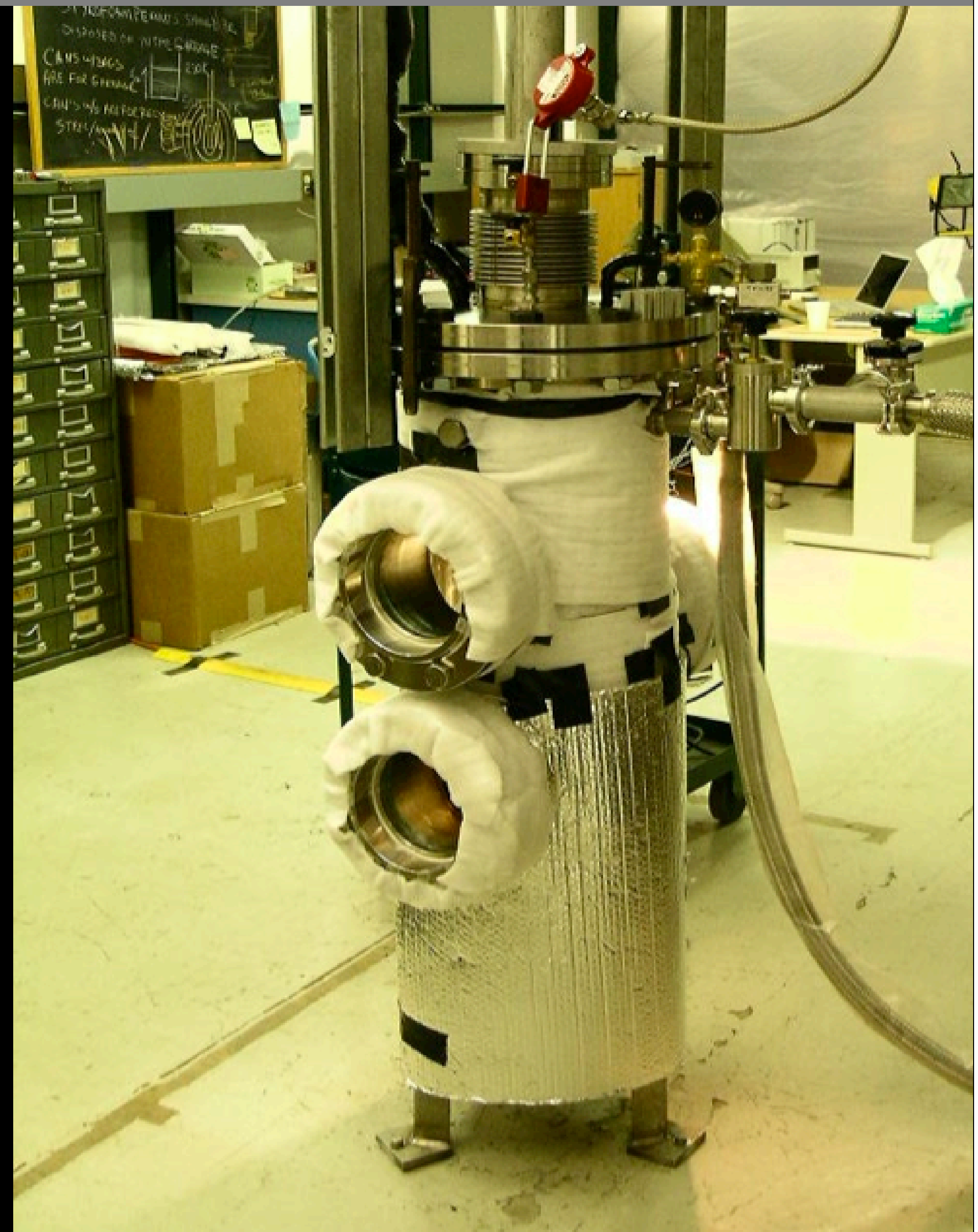
- Fermilab PPD/FCPA R&D project
- Collaboration with U.Florida and TAMU
- Support by Fermilab technical/engineering staffs
- Very strong support by Fermilab safety committee

Glass Chambers and Vacuum Jacket

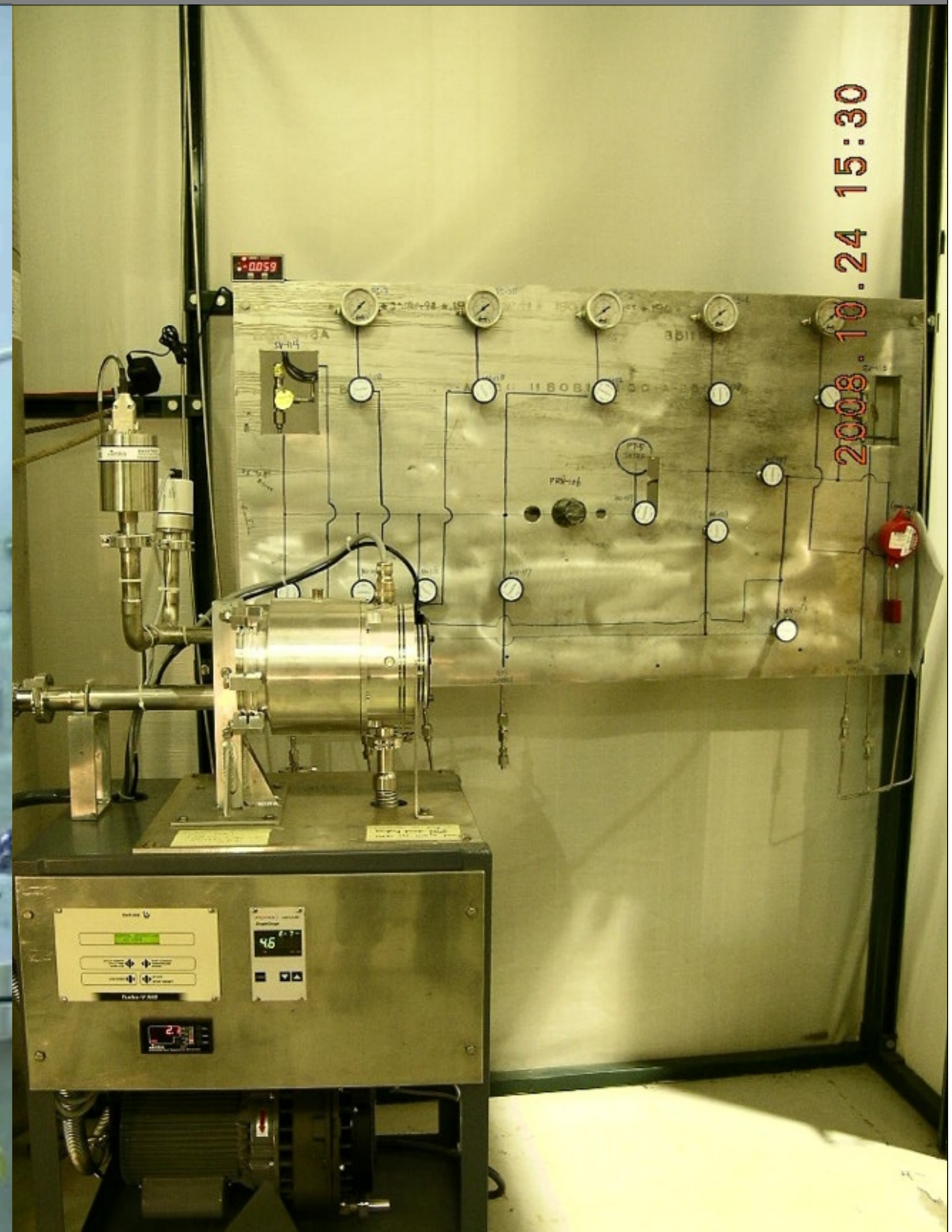


Glass Chambers and Vacuum Jacket

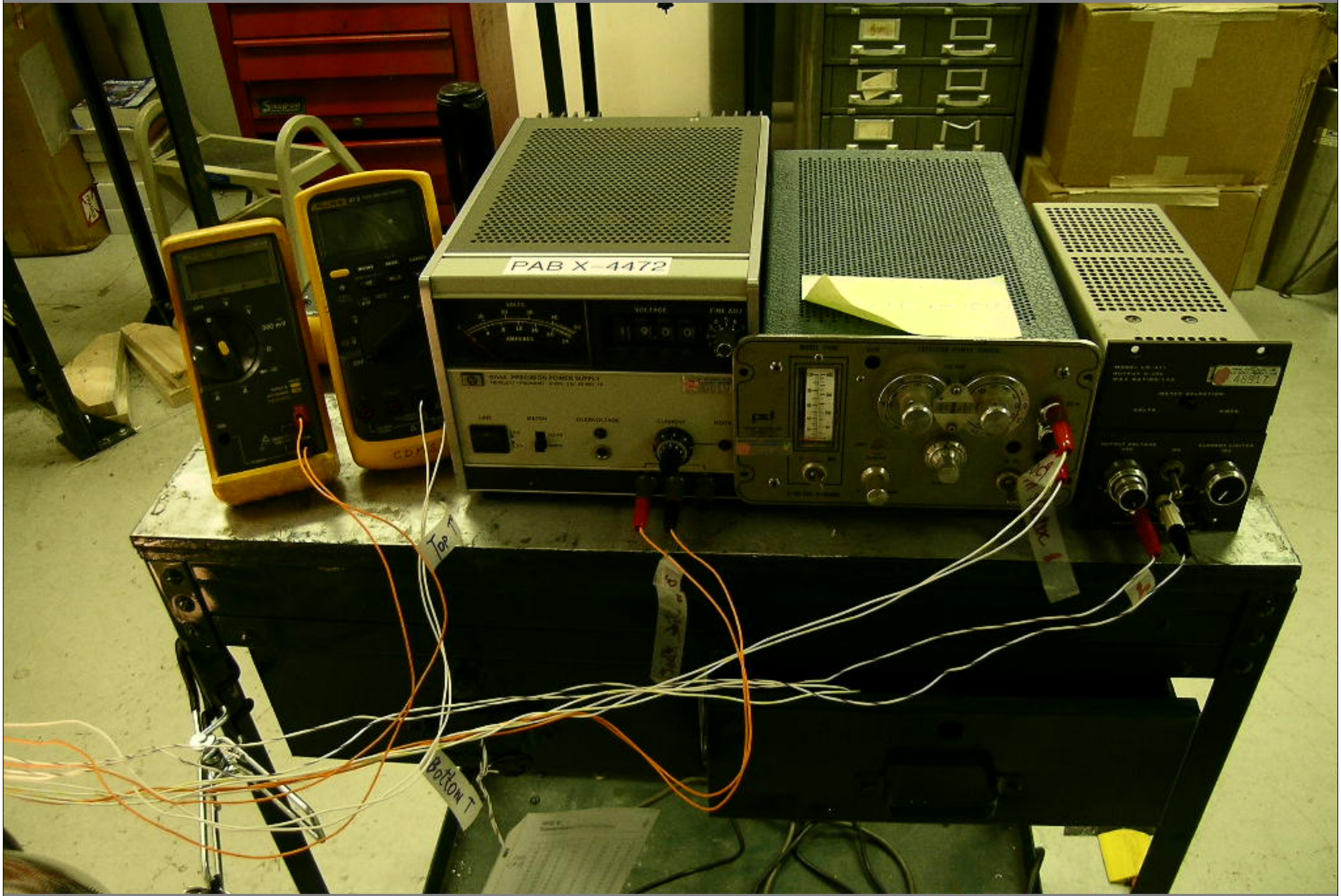




Backup Chambers and Manifolds

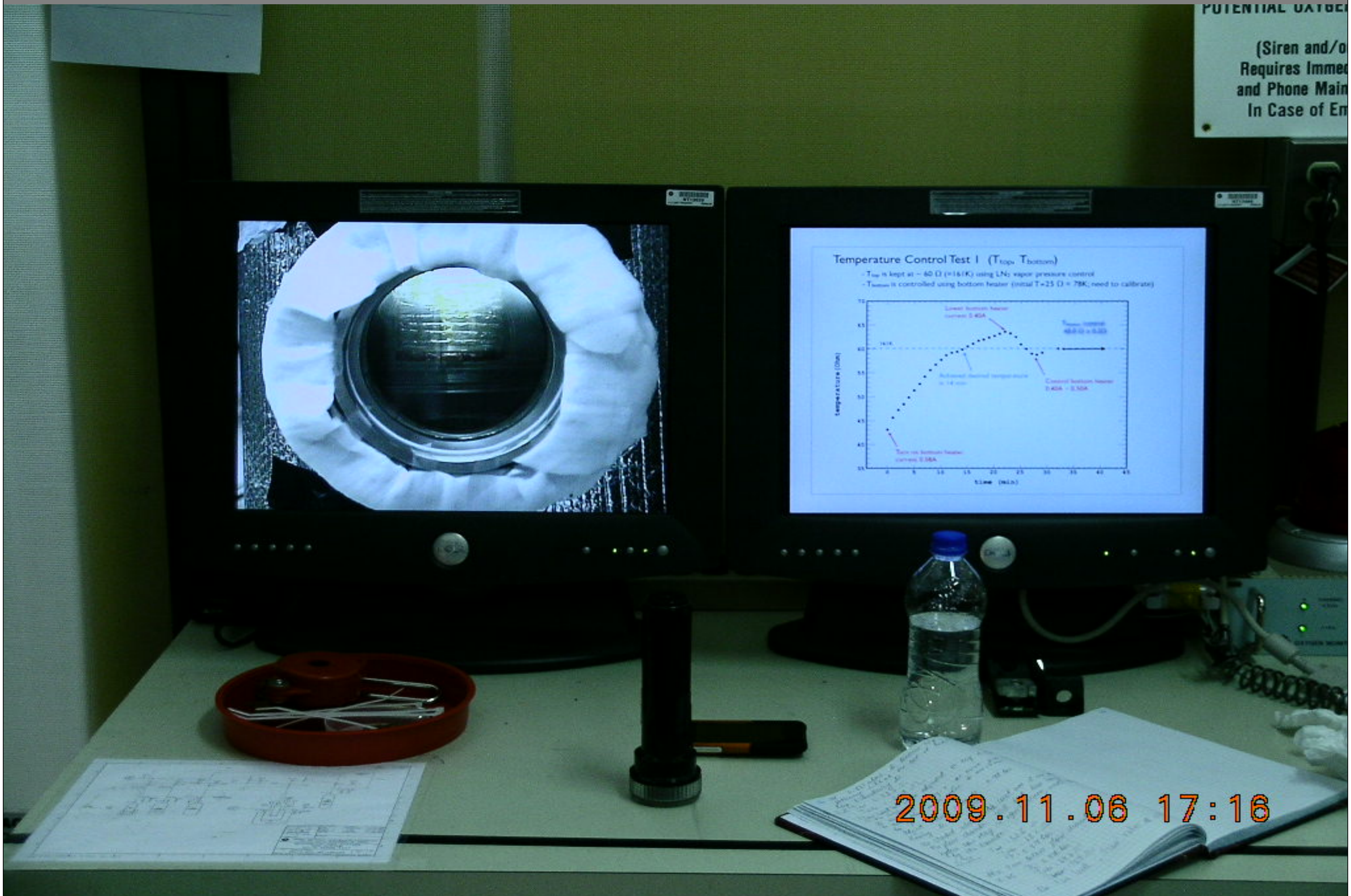


Solid Xenon DAQ



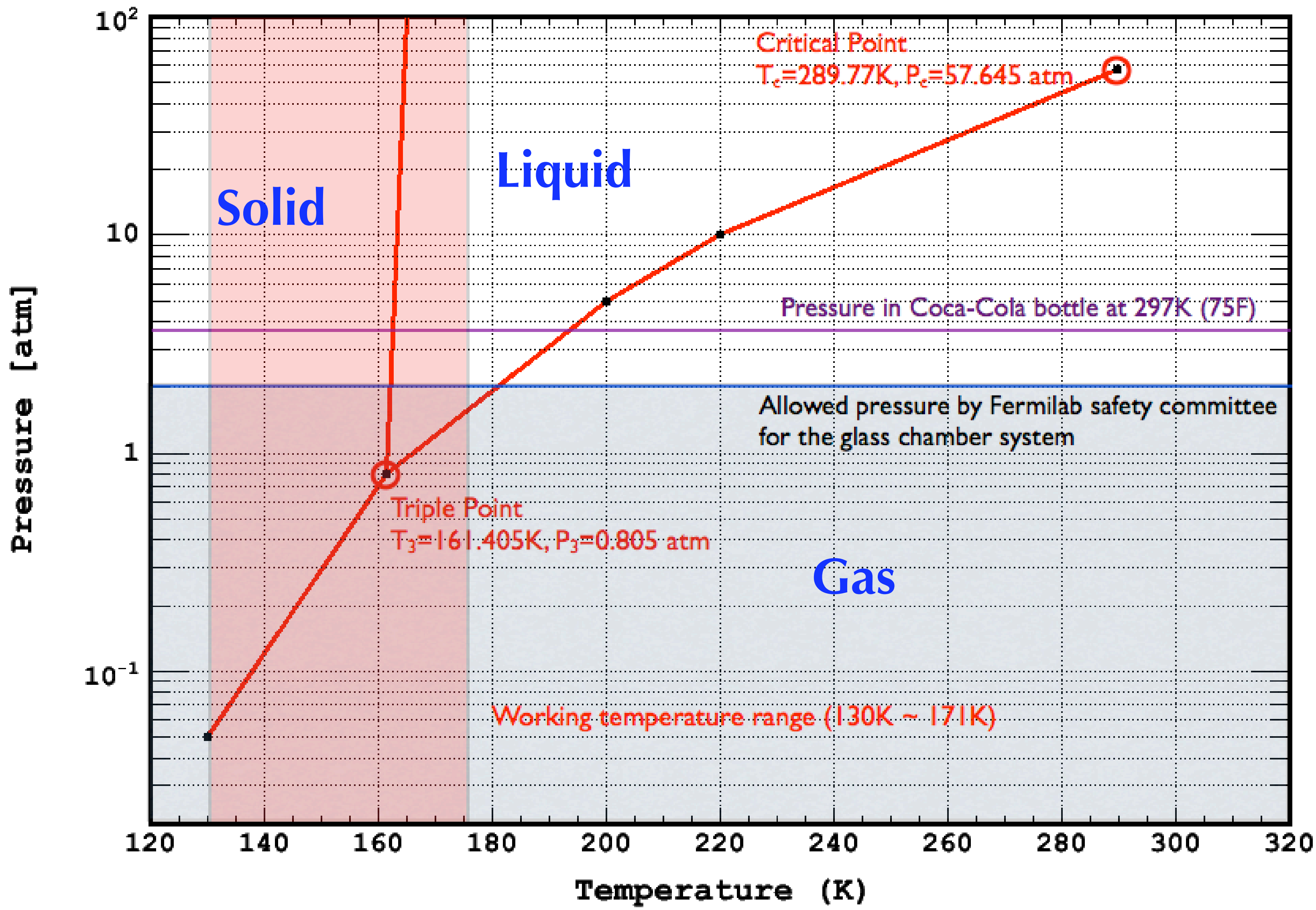
Solid Xenon DAQ

Solid Xenon DAQ

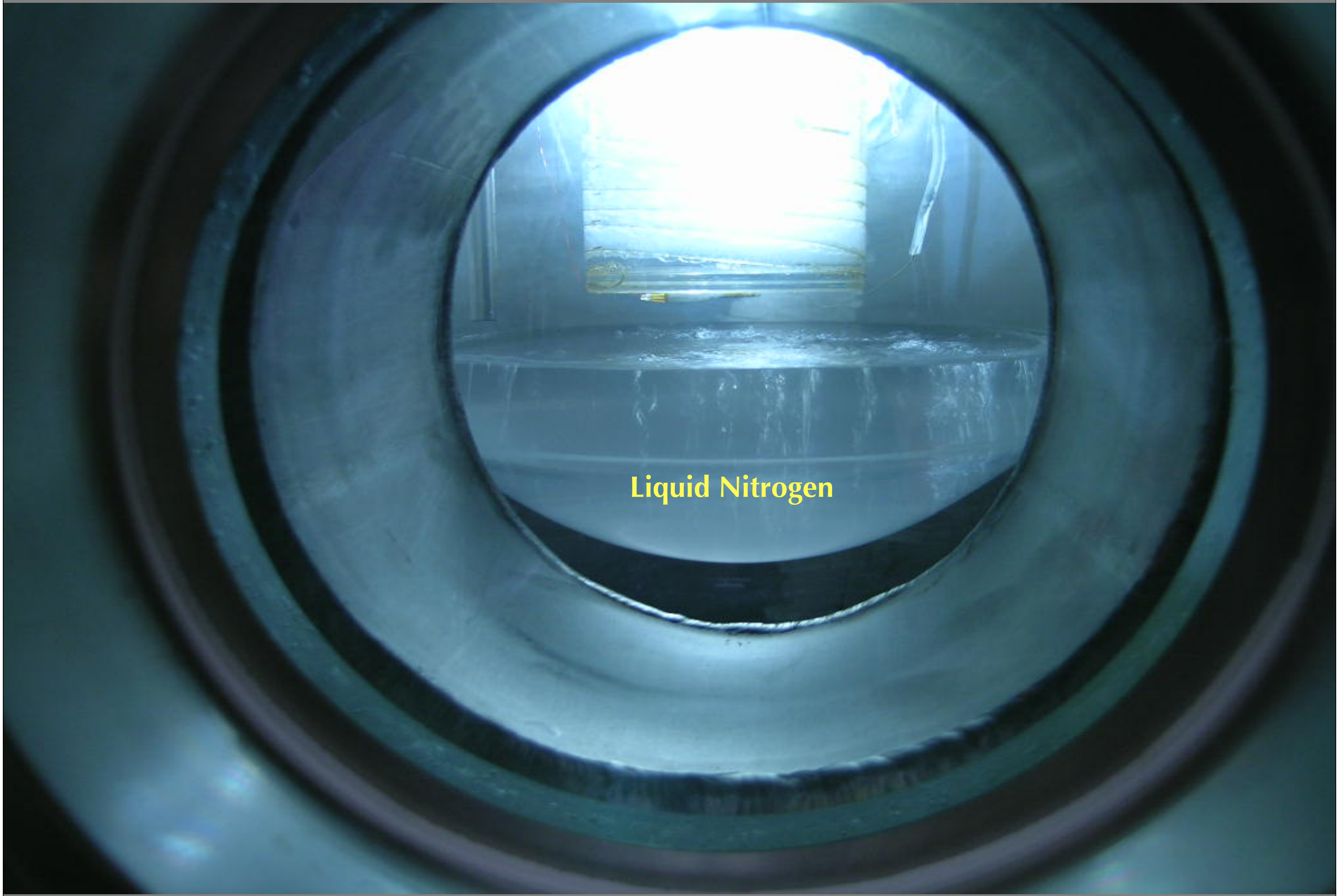


Solid Xenon Setup : Lab-F

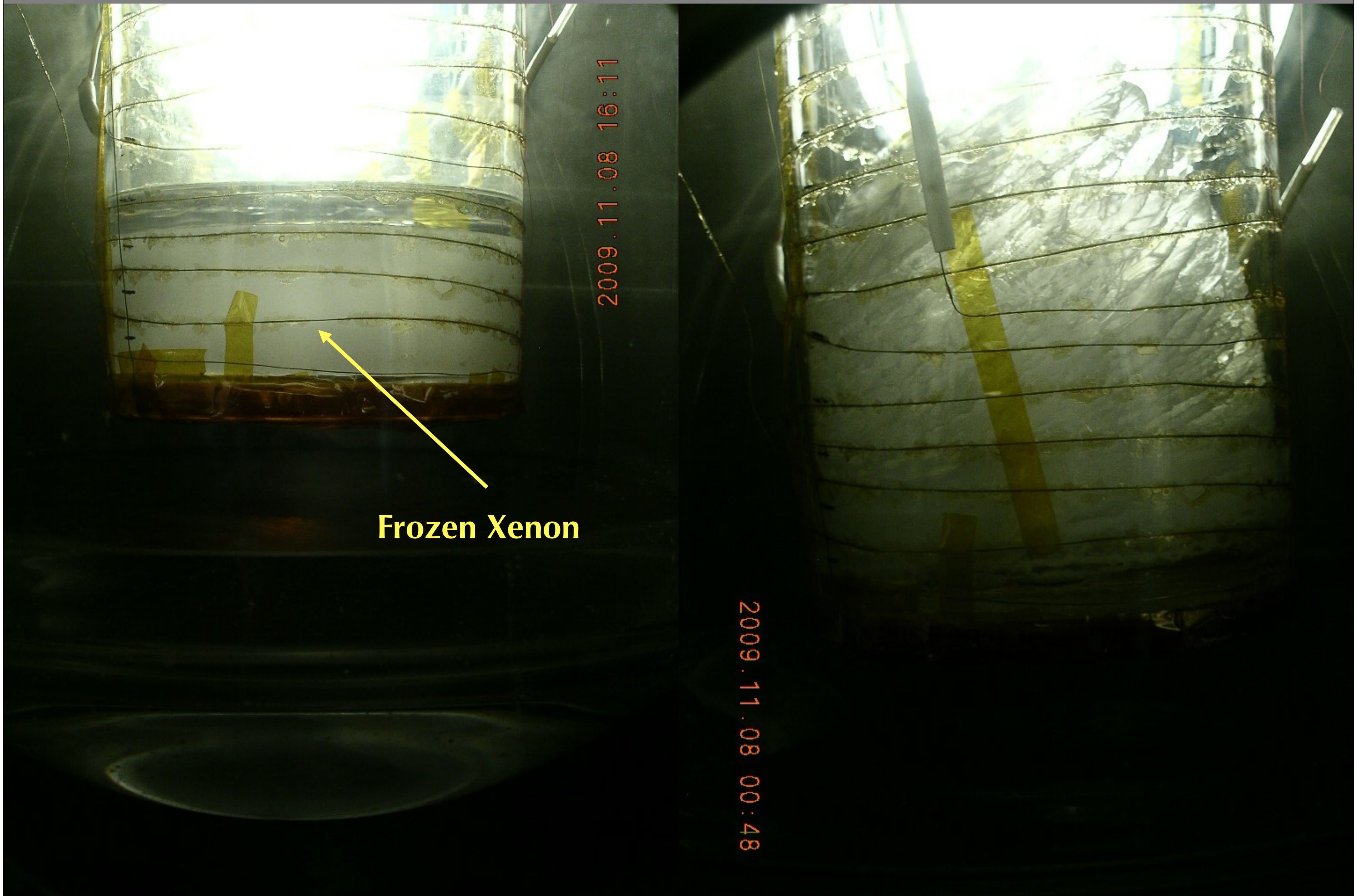
Xenon Phase Diagram



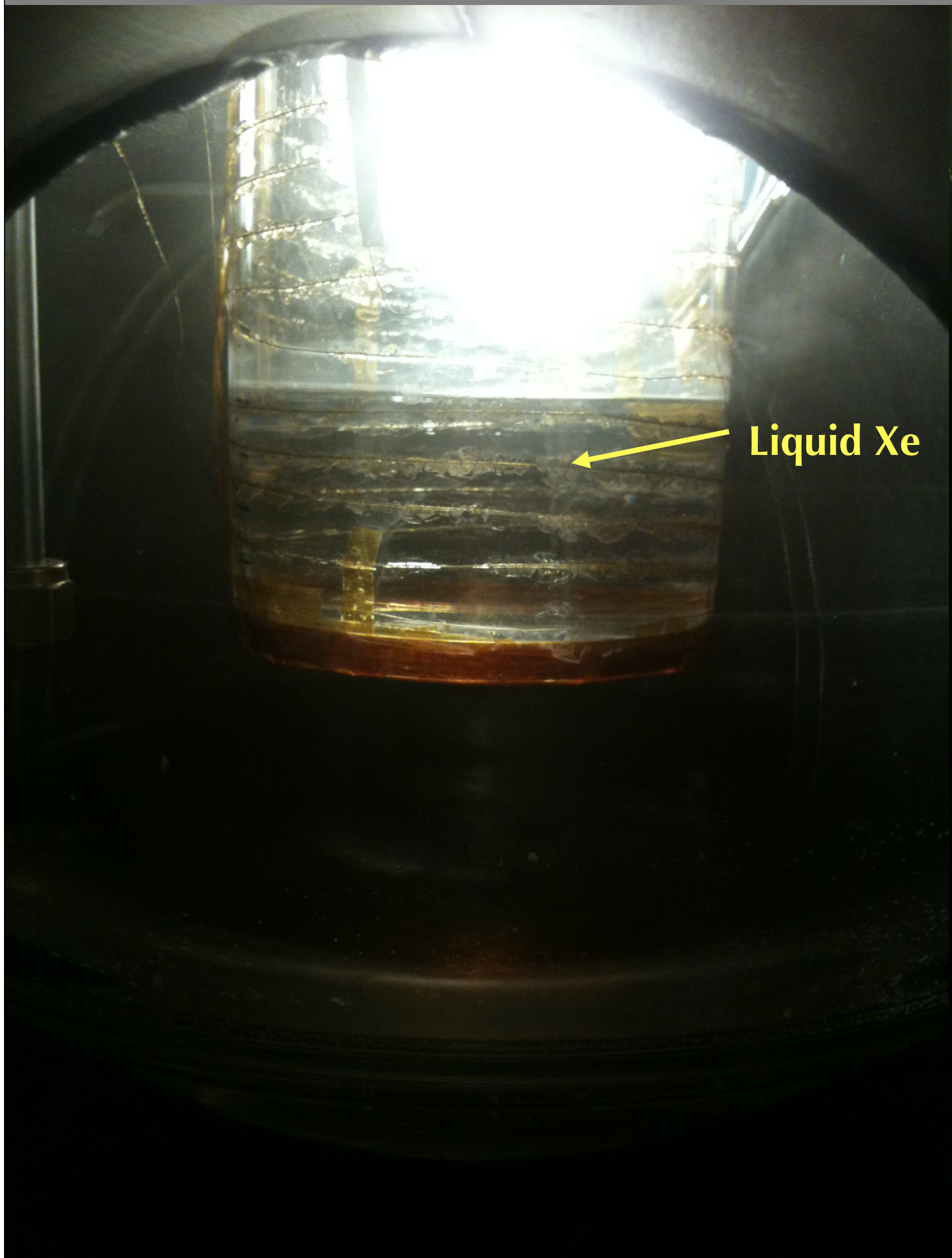
Cryobath : Liquid Nitrogen

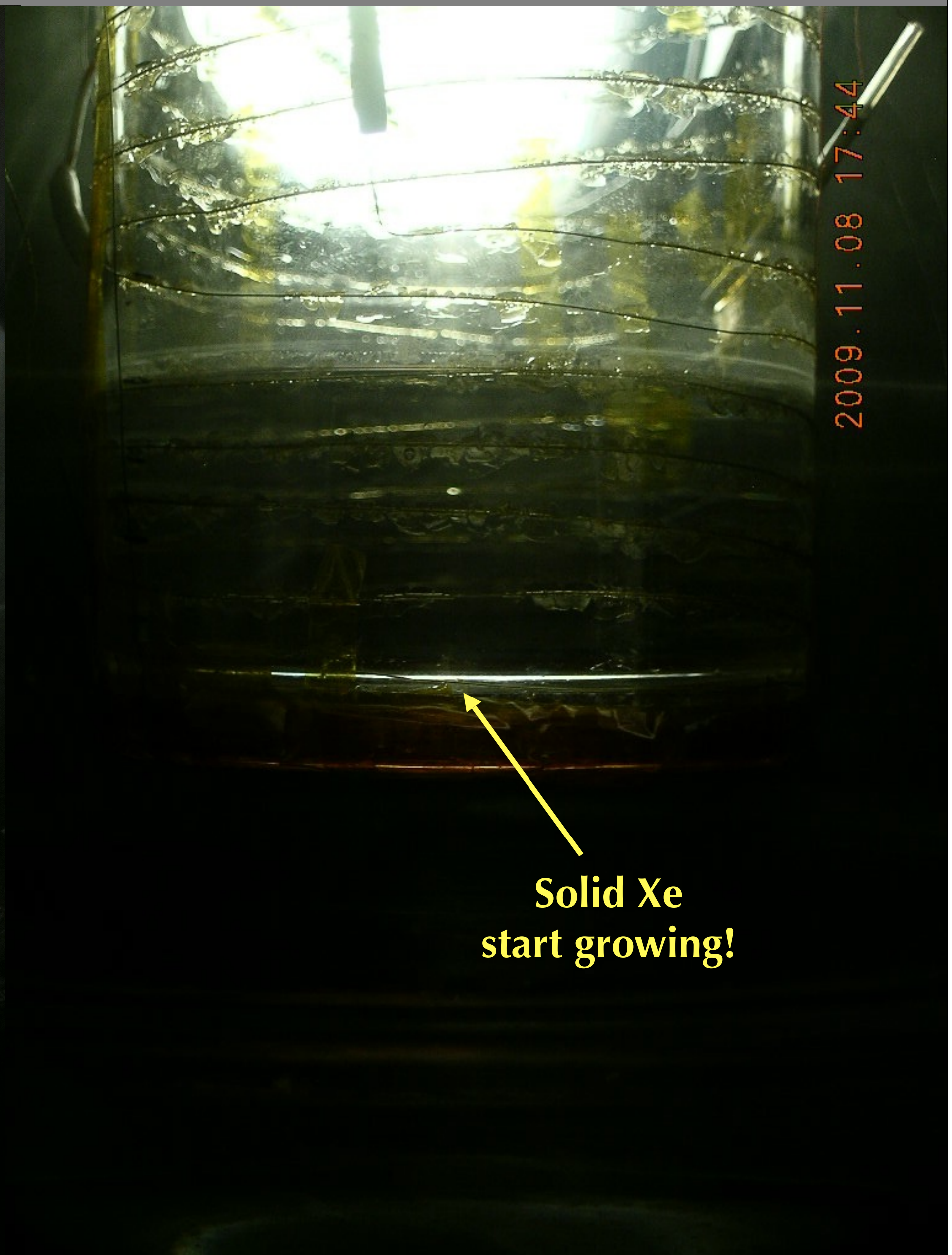


Frozen Xenon

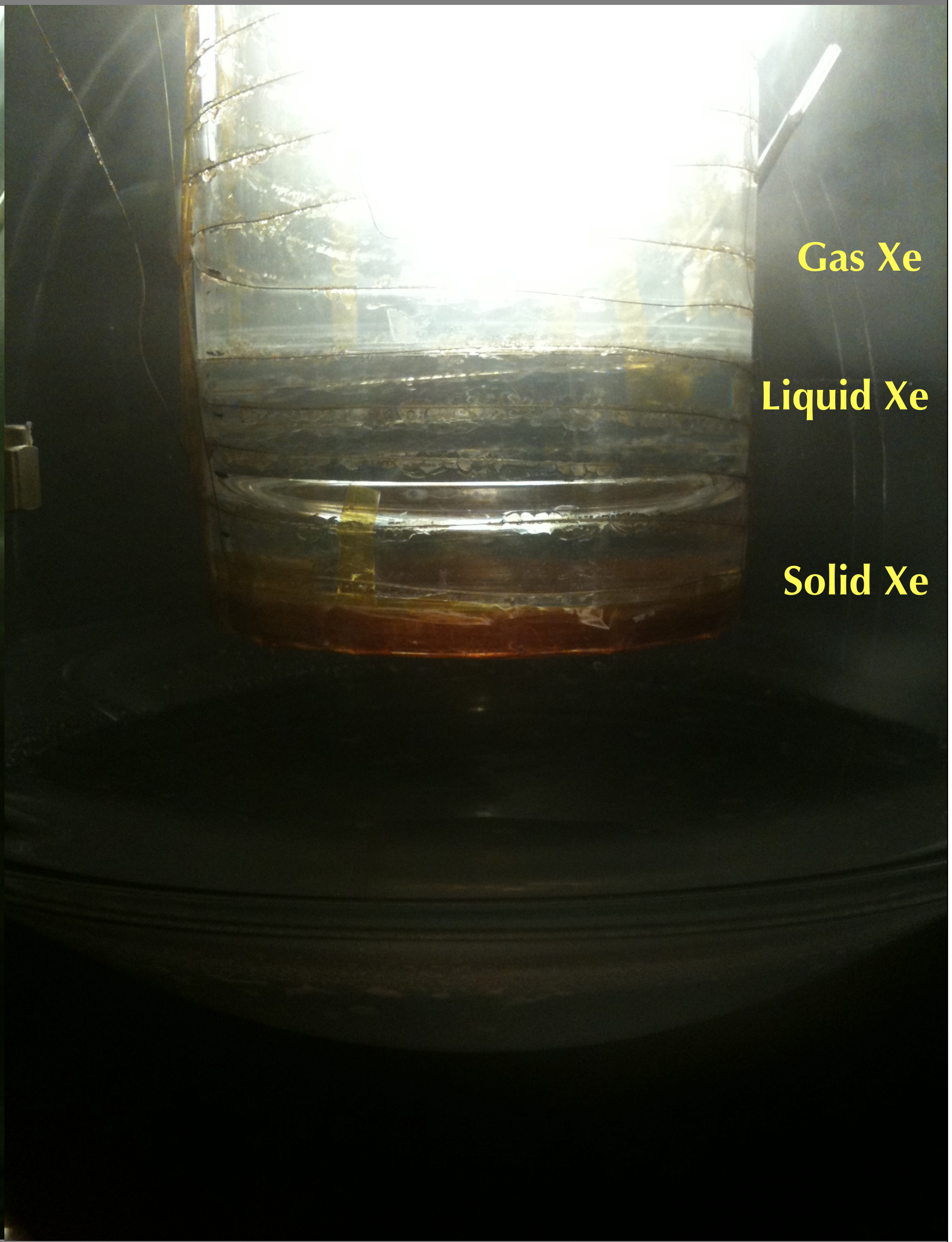


The First Xenon Crystal at Fermilab

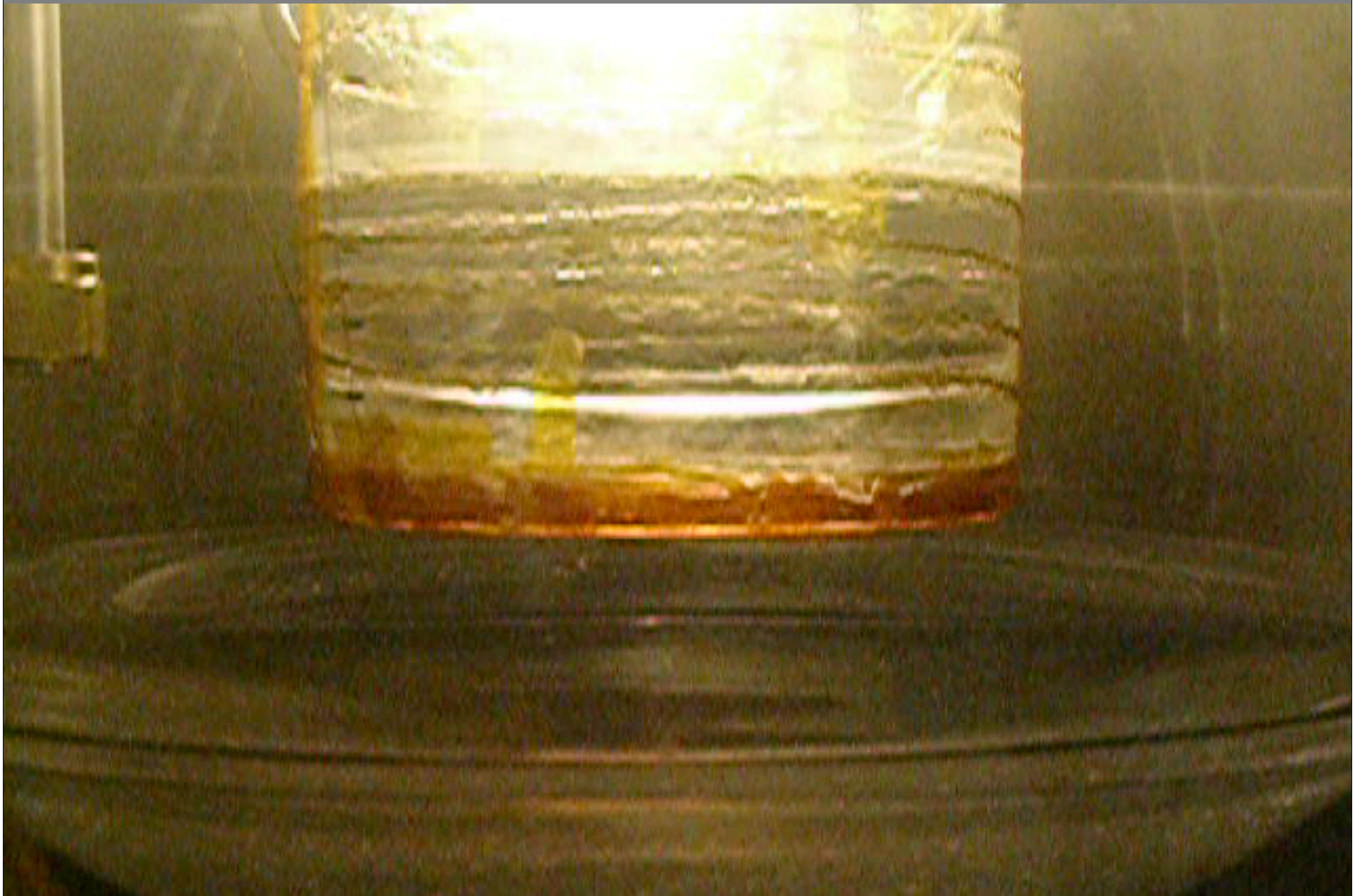




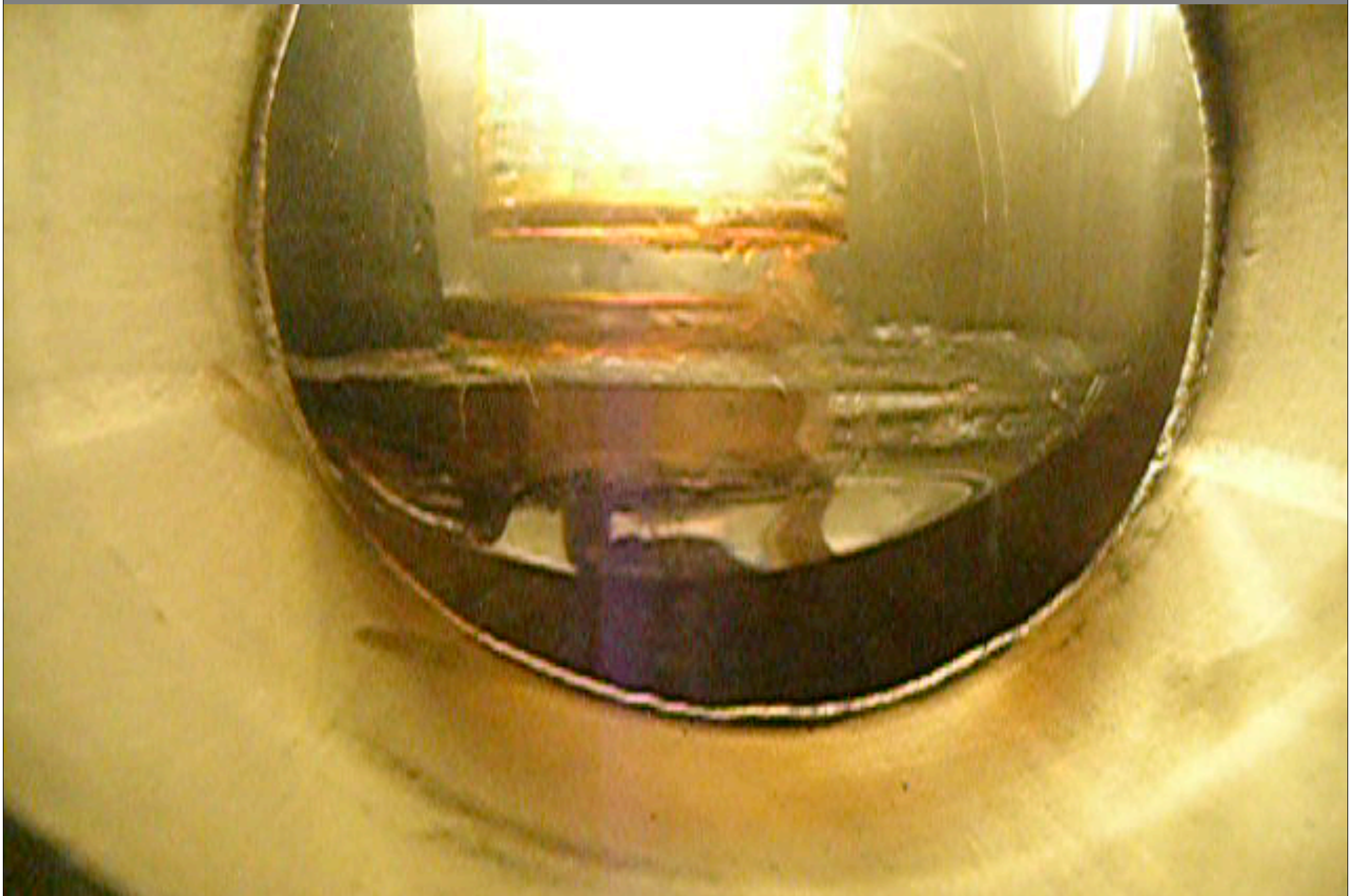
The First Xenon Crystal at Fermilab



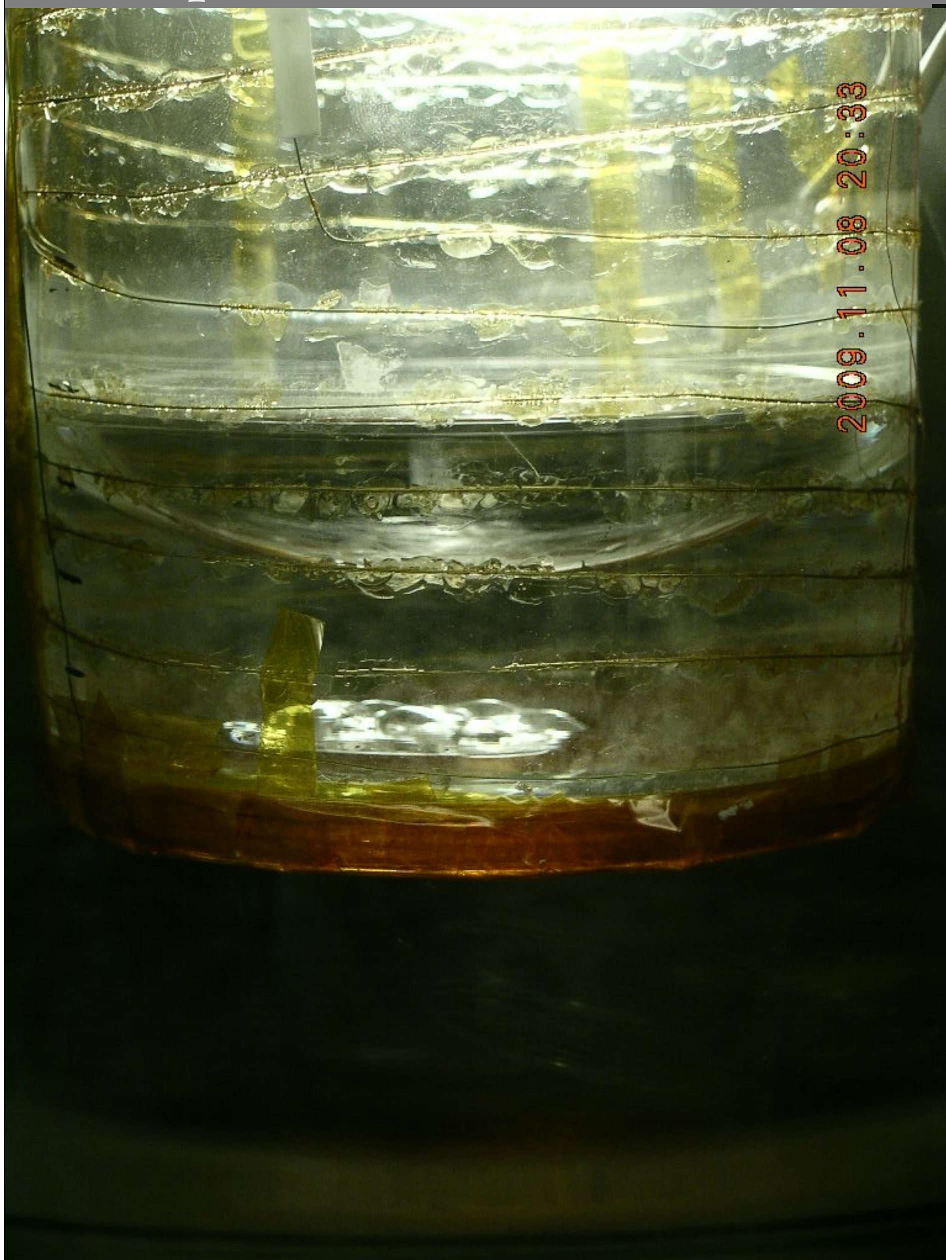
Triple Phase : How do we know ?



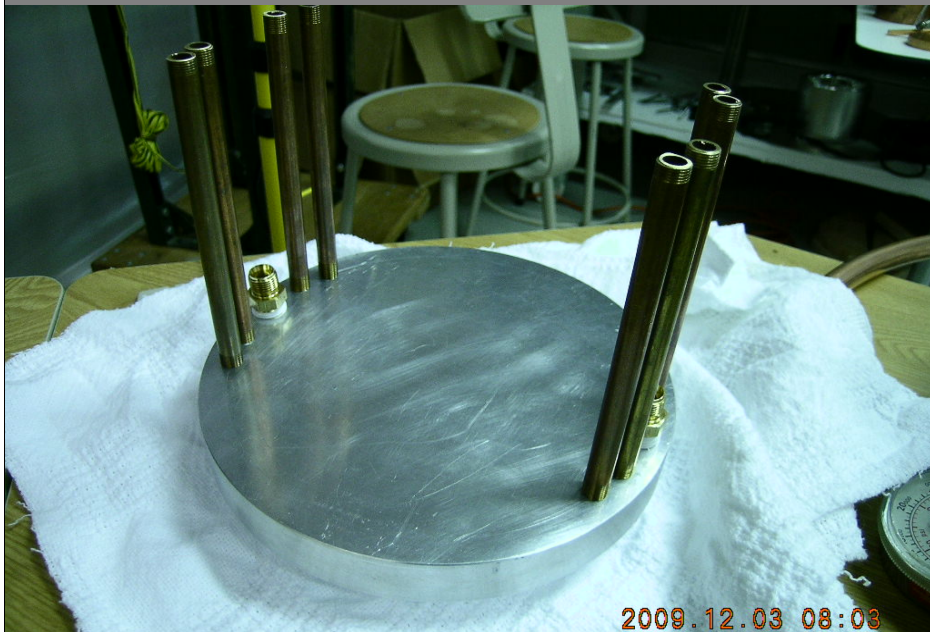
Need a quiet cooling system

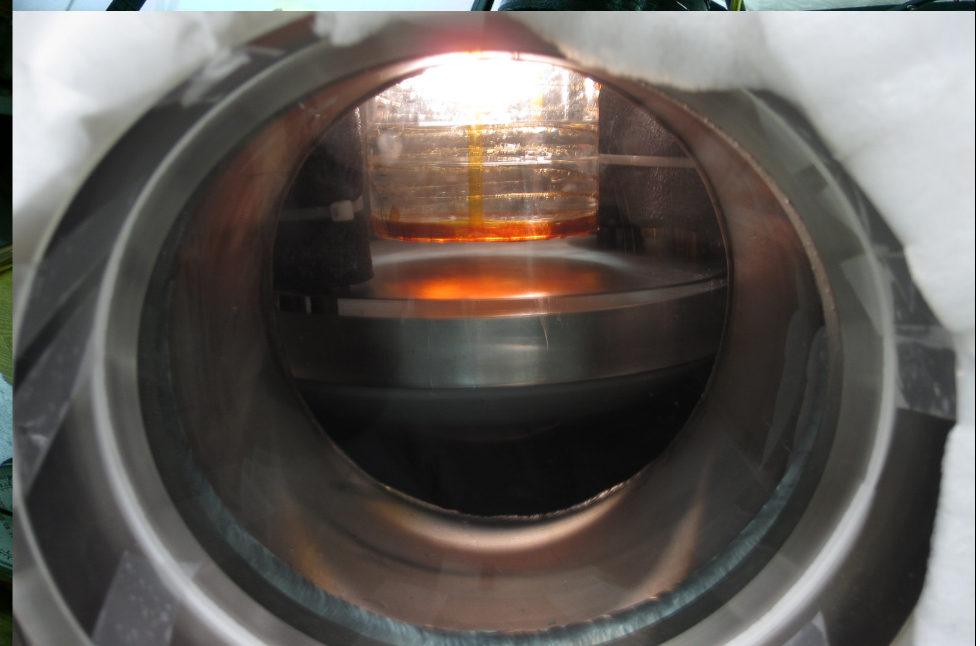


Temperature & Pressure Control are the keys

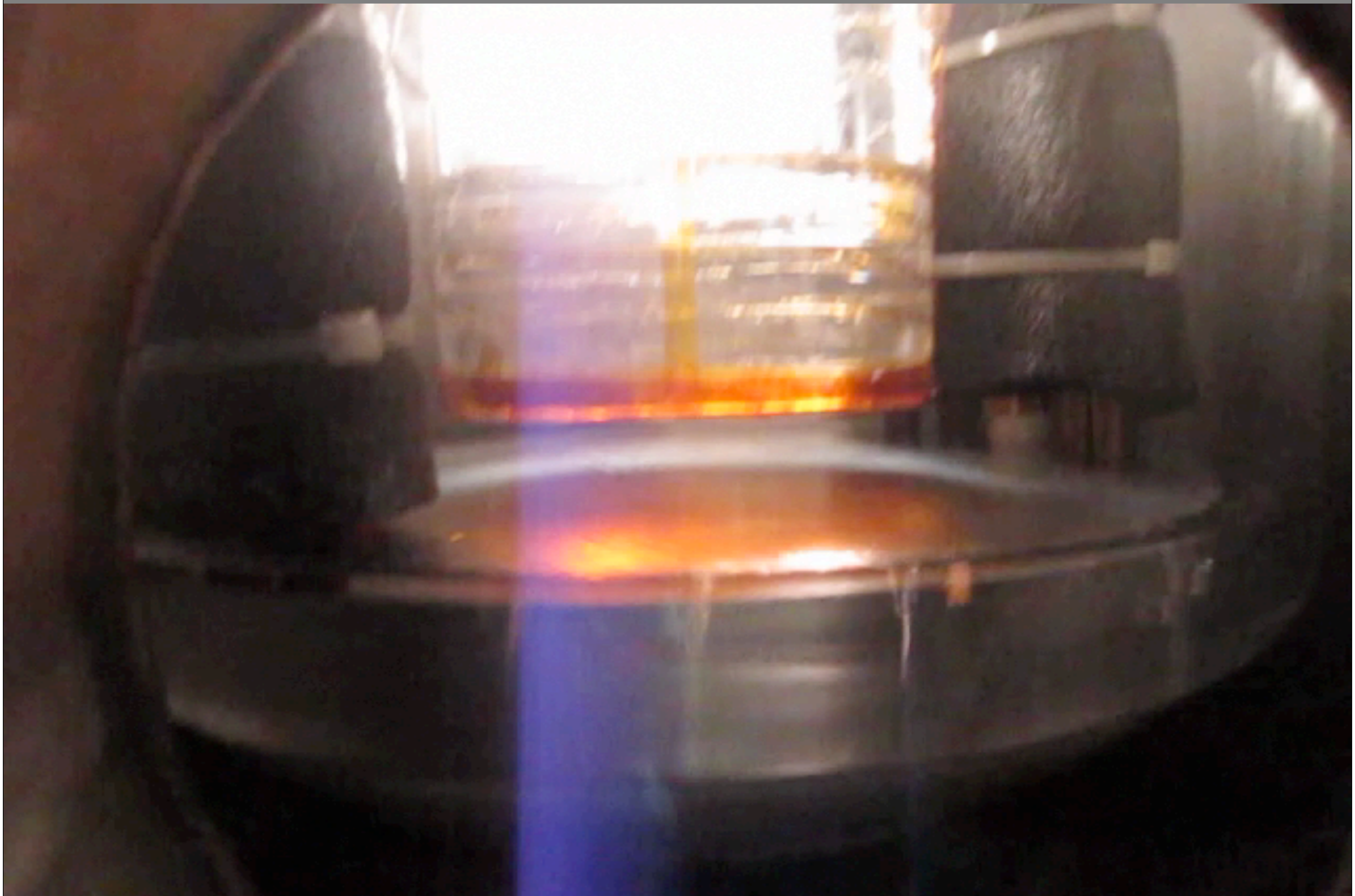


Effective Phase Separator

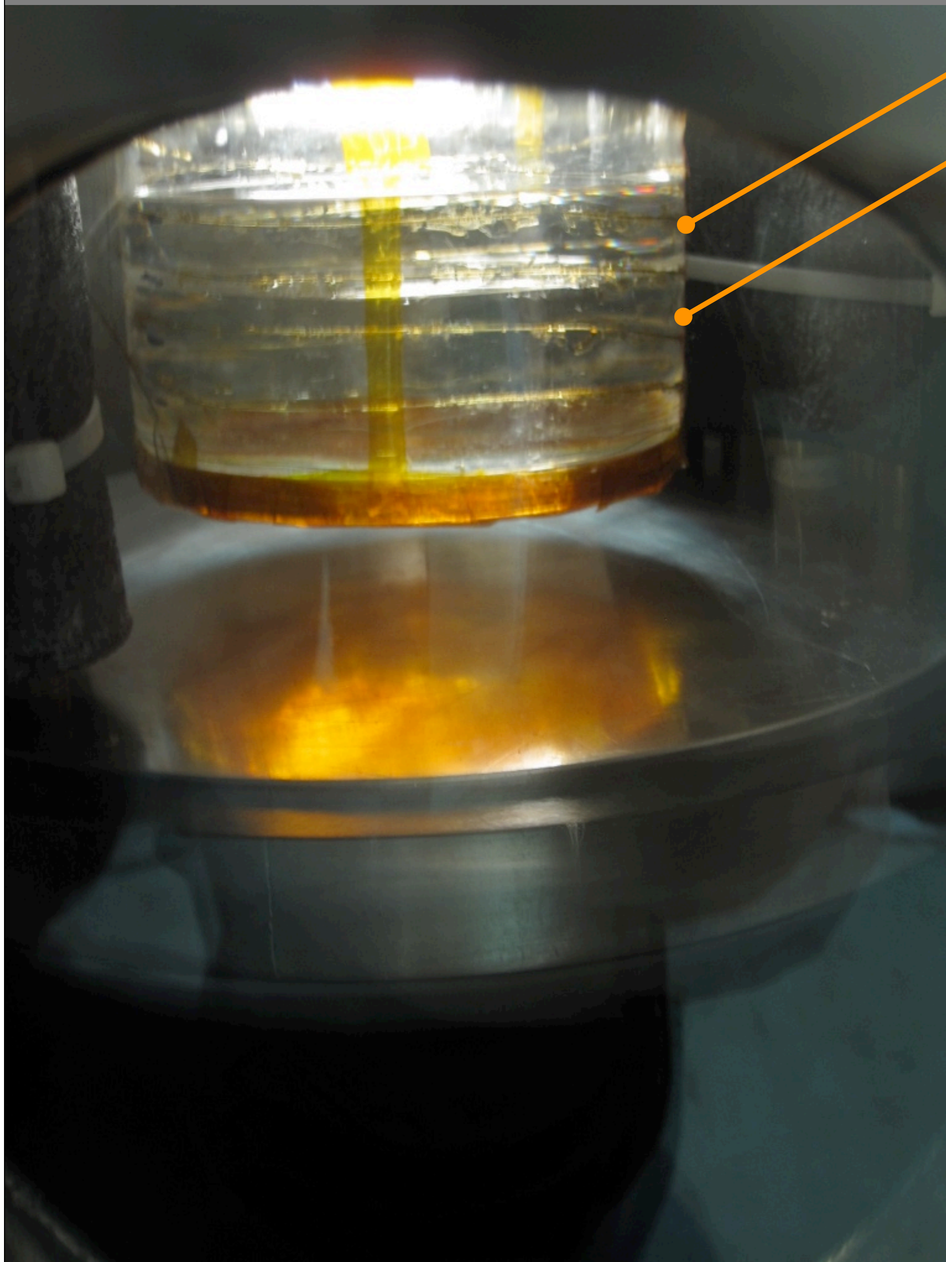




Effective Phase Separator



Prescription



Liquid Xenon

Solid Xenon (~850g)

Prescription within Fermilab Safety regulation

- Top T : 160 ± 0.5K
- Bottom T : 145 ± 0.5K
- Xenon gas pressure : 1.0 ± 0.1 atm
- Patience : 3cm growth / 10 hours

We tried only one method yet, but there are many other ways to produce crystals; vapor deposition, flash freezing, cryobath method etc

- Faster growth induces optical defects in the bulk
- Vibration free configuration is necessary
  - Cryocooler may not be a good choice
  - Pulse tube refrigerator is worth to try
- Full automatic control system of temperature and pressure is necessary to grow a larger crystal
- Transparency has to be quantitatively measured using calibrated light source system in the future

What's Next ?

Phase 1: Growing Solid Xenon ~kg size
- Completed (@Lab-F)!
- PPD/FCPA management approved to move the Phase-1 setup to PAB (for phase-2)

Phase 2: Scintillation light readout (6 months schedule)
- Full automatic controller setup for crystal growth (pressure & temperature control)
- Xenon purification system and mass spectroscopy
- Scintillation light measurement from the solid xenon (compare with liquid phase one)
- Temperature dependence of scintillation light emission

Phase 3: Ionization readout and study crystal characteristics (plan)

Solid Xenon properties (Spectromag - already obtained)
- Transparencies, absorption, index of refraction …
- Lower temperature characteristics (~4K)

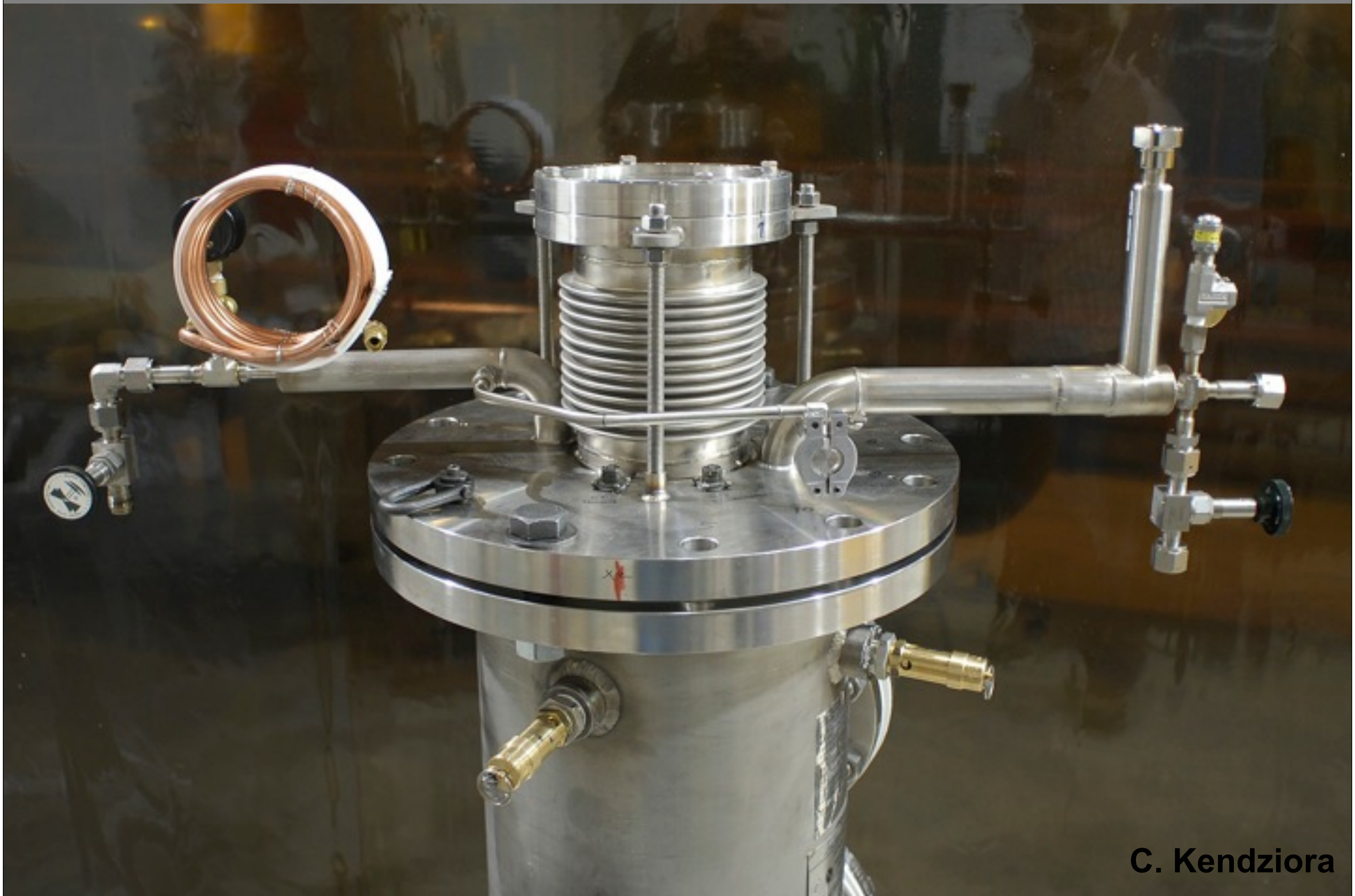
Ionization readout
- Ionization readout by drifting electrons (grid mash)

Demonstrate large solid xenon crystal growth (>10 kg)
- Make a full prescription for growing large solid xenon

Design 10 kg phase prototype detector

Pre-Phase-2: Moving to PAB (Completed)

Pre-Phase-2: Improving system

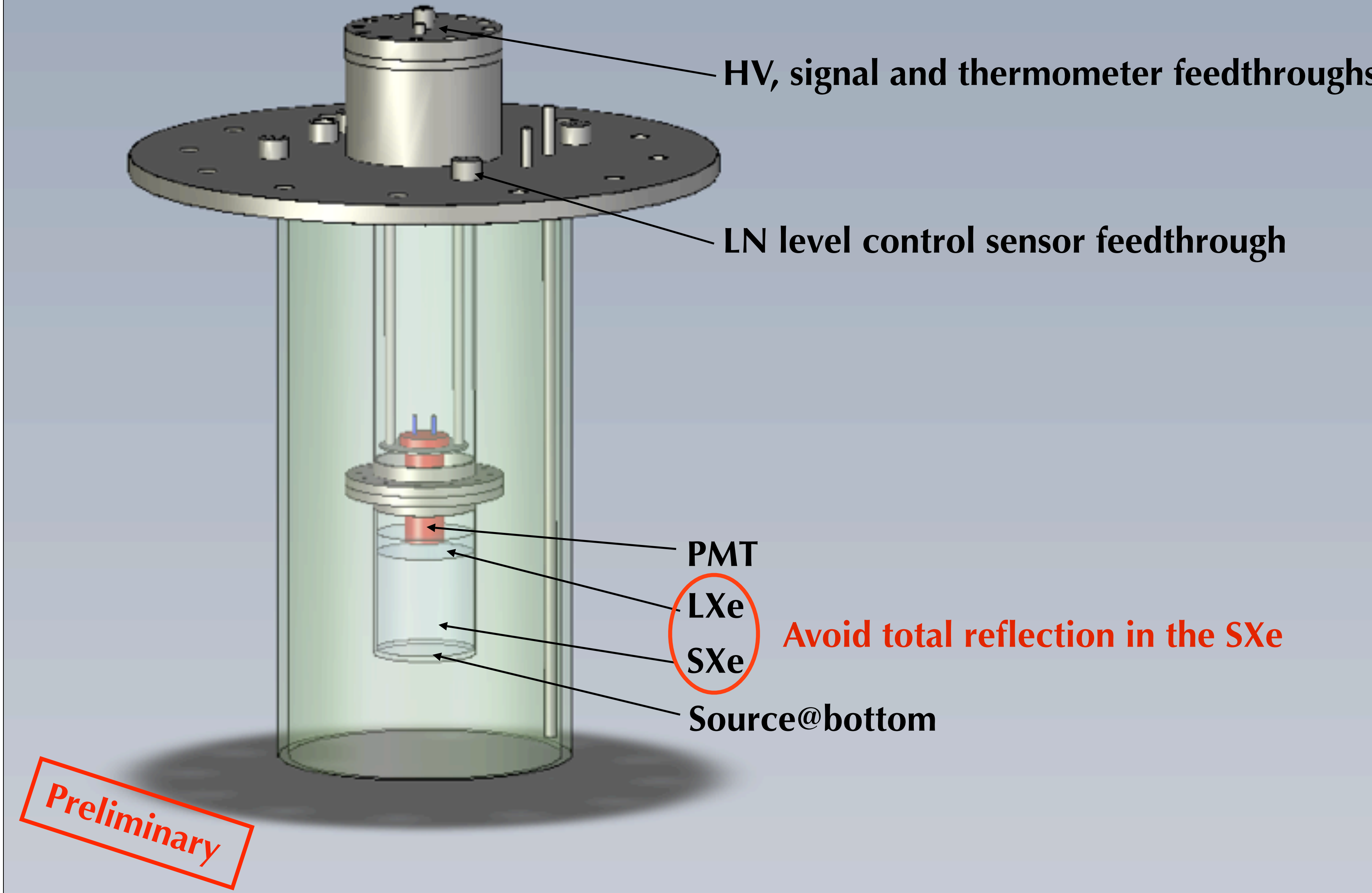


Solid Xenon R&D Phase-2

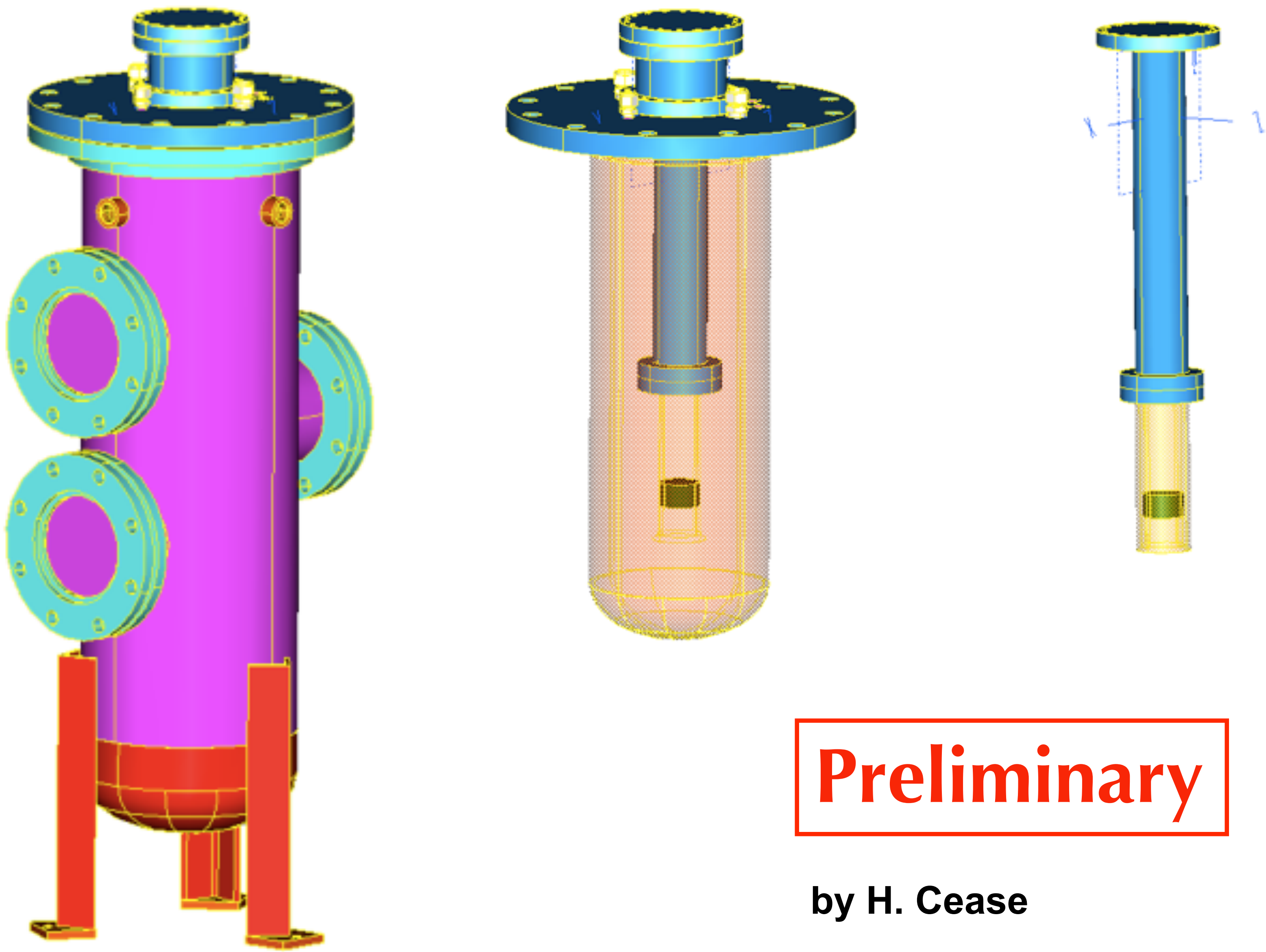
- Readout Scintillation Light -

Phase-2: Scintillation light readout

Conceptual chamber design for Phase-2 R&D



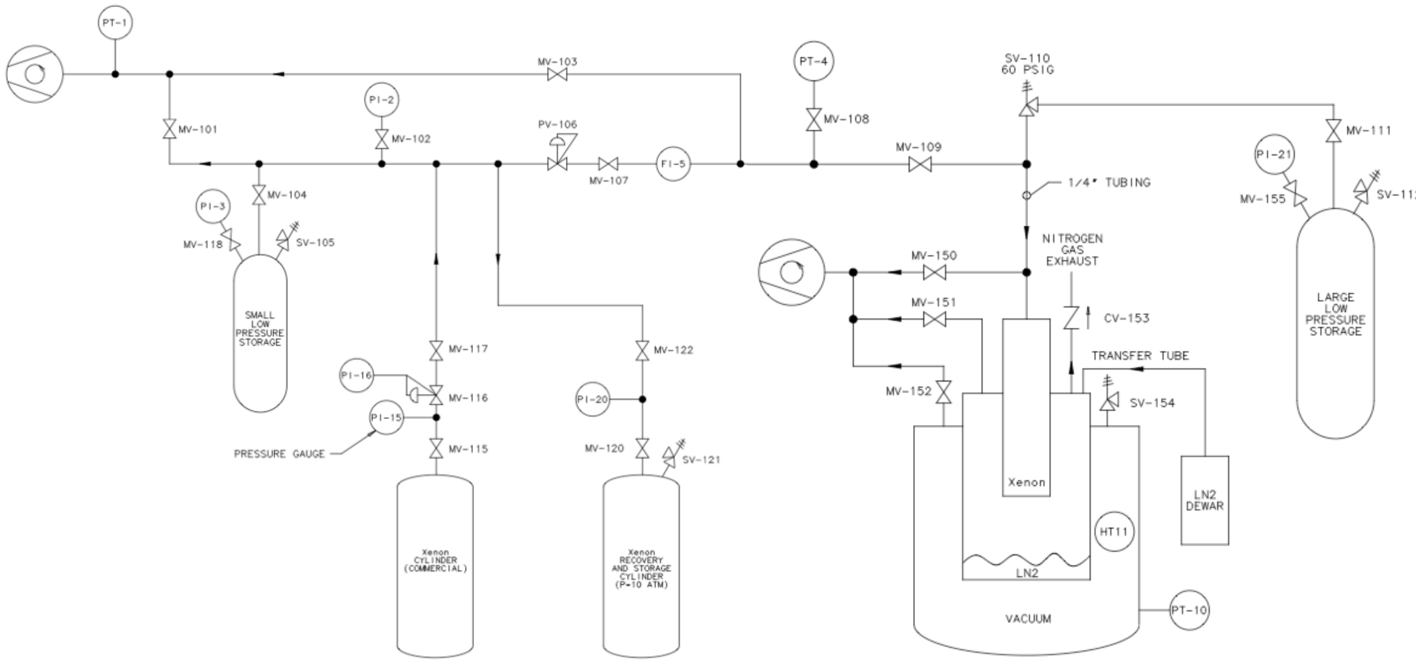
Phase-2: Engineering drawing started



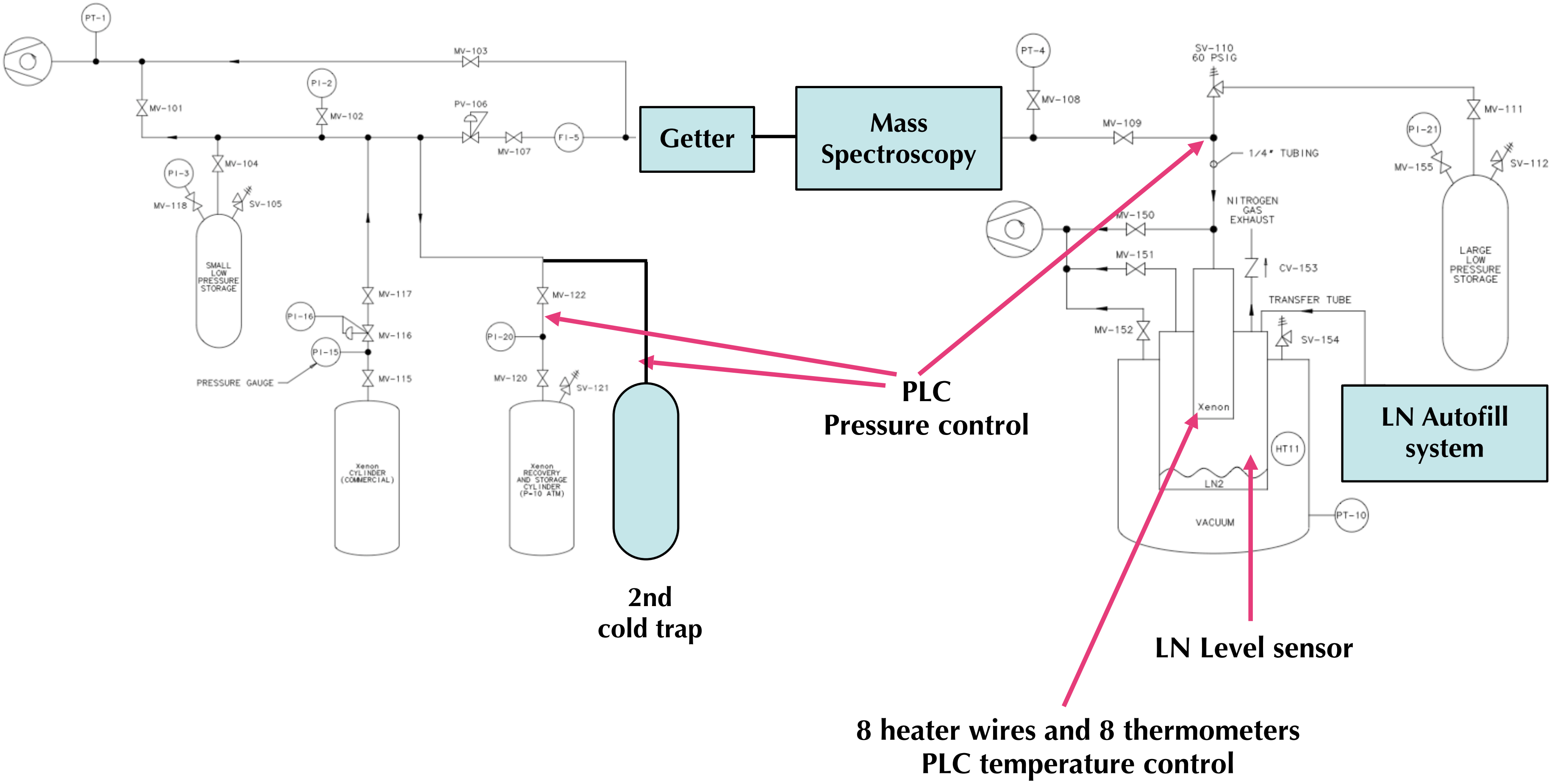
Preliminary

by H. Cease

Solid Xenon - Additional Tubing

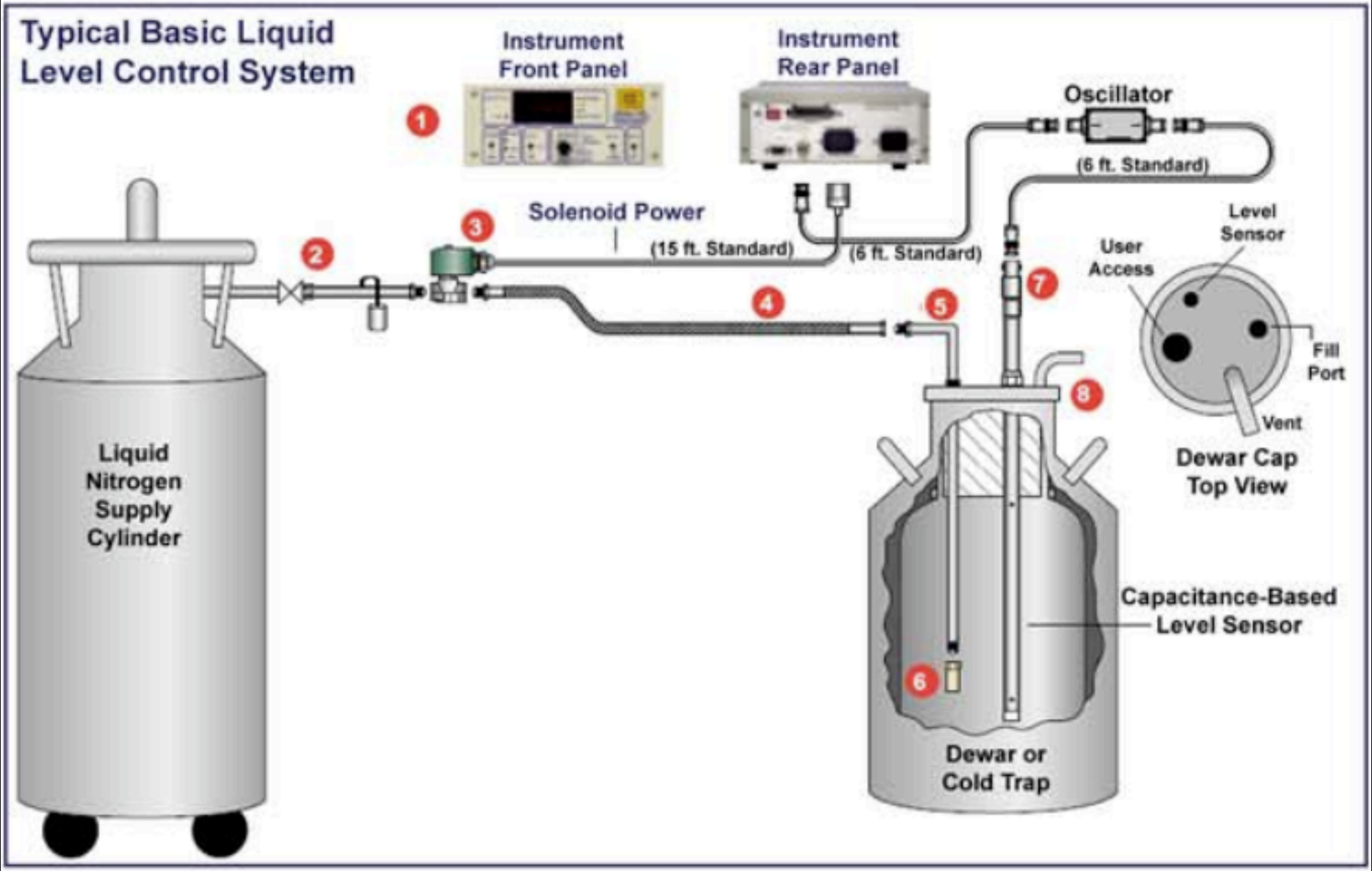


Solid Xenon - Additional Tubing



Centralized Programmable Logic Controller will operate the system

Phase-2: Autofill LN_2 System



Phase-2: Xenon purification system

MonoTorr PS4-MT3-R-1 (SAES)

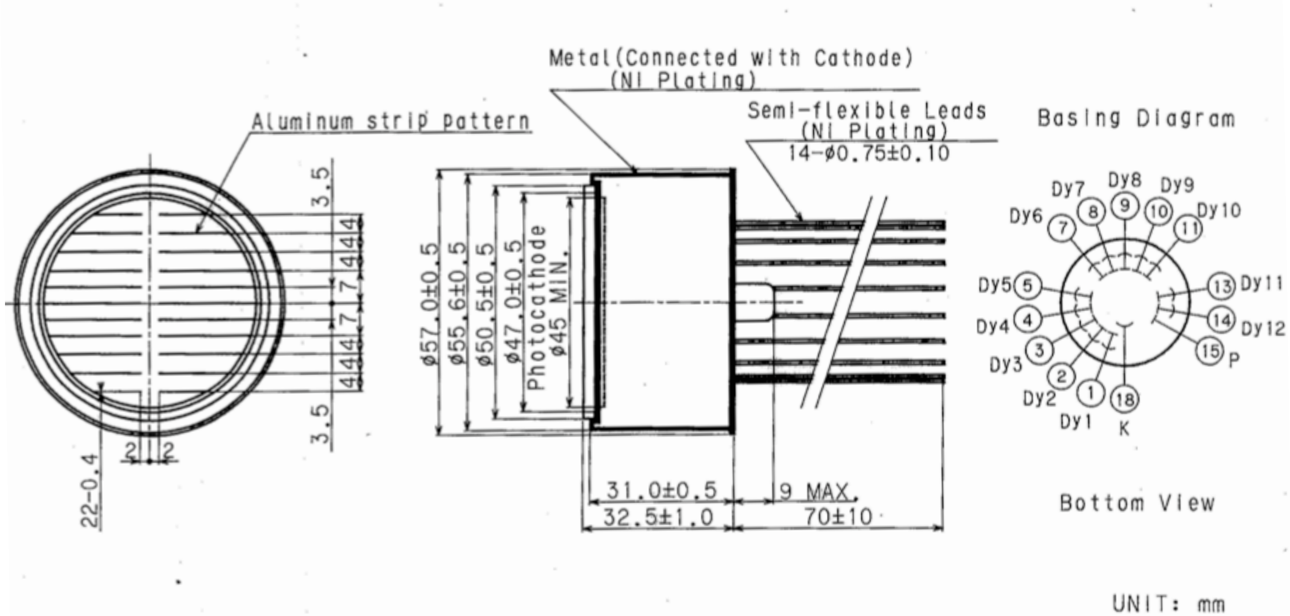
- **Heated Getter purifier for Xenon Gas**
- **Continuous operation, non-consumable**
- **Removes H_2O, O_2, CO, CO_2, H_2 and CH_4 to < 1ppb per impurity**
- **Replacement cartridge**
- **Max flow rate 50 slpm**

Analytical Specifications (based on 99.999% pure inlet gas)					
SPG Standard Outlets - Phase II 3000			SPG Standard Outlets - Phase II 15000		
Outlet Impurity	0-20 slpm	20-50 slpm	Outlet Impurity	0-30 slpm	30-75 slpm
O_2	< 1 ppb	< 1 ppb	O_2	< 1 ppb	< 1 ppb
H_2O	< 1 ppb	< 1 ppb	H_2O	< 1 ppb	< 1 ppb
CO	< 1 ppb	< 1 ppb	CO	< 1 ppb	< 1 ppb
CO_2	< 1 ppb	< 1 ppb	CO_2	< 1 ppb	< 1 ppb
H_2	< 1 ppb	< 10 ppb	H_2	< 1 ppb	< 10 ppb
N_2 (Rare gas only)	< 1 ppb	< 10 ppb	N_2 (Rare gas only)	< 1 ppb	< 10 ppb
CH_4	< 1 ppb	< 10 ppb	CH_4	< 1 ppb	< 10 ppb

Phase-2: Scintillation light readout (plan)

Hamamatsu R9869

- Spectral Response 169 ~ 650 nm
- Operating ambient temperature : 163K ~ 323K
- Bialkali photocathode
- Quantum Efficiency at 175nm : 20%
- Gain : 10^6
- Anode pulse rise time : 2.3 nsec
- Synthetic silica glass window
- Metal channel Dynode (12 stage)
- Weight : 95g
- 1 KV supply voltage, 0.1mA anode current
- Pressure resistance : 5 atm

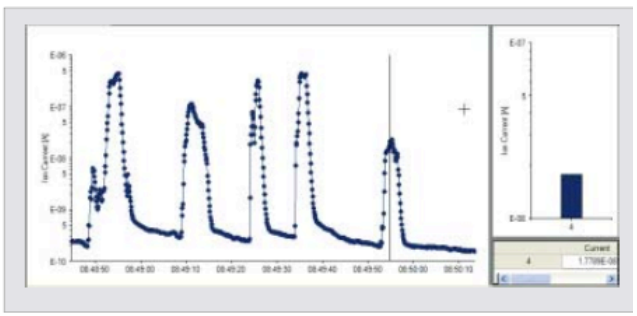


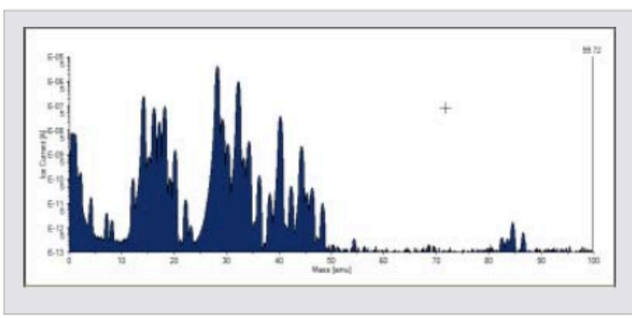
Phase-2: Scintillation light readout (plan)

PrismaPlus™

PrismaPlus (PFEIFFER)

- Compact Mass Spectrometer
- Mass range : 1~200 amu
- Residual gas analysis -- leak detection
- Quadrupole controller





PrismaPlus™	QMG 220 F1	QMG 220 F2	QMG 220 F3	QMG 220 M	QMG 220 M2	QMG 220 M3
Detector		Faraday (F)			C-SEM/Faraday (M)	
Mass range	1–100 amu	1–200 amu	1–300 amu	1–100 amu	1–200 amu	–300 amu
Rod system, diameter/length			6 mm / 100 mm			
Min. detection limit, Faraday[1]	1×10^{-12} mbar	2×10^{-12} mbar	4×10^{-12} mbar	5×10^{-12} mbar	1×10^{-11} mbar	$x10^{-11}$ mbar
Min. detection limit, C-SEM[1]	–	–	–	1×10^{-14} mbar	$< 2 \times 10^{-14}$ mbar	4×10^{-14} mbar
Ar sensitivity, Faraday[1]	1×10^{-3} A/mbar	6×10^{-4} A/mbar	3×10^{-4} A/mbar	5×10^{-4} A/mbar	3×10^{-4} A/mbar	$,5 \times 10^{-4}$ A/mbar
Ar sensitivity, C-SEM[1]	–	–	–	200 A/mbar	200 A/mbar	00 A/mbar
Max. operating pressure[2], Faraday operation			1×10^{-4} mbar			
Max. operating pressure, C-SEM operation	–	–	–	1×10^{-5} mbar	1×10^{-5} mbar	$x10^{-5}$ mbar
Contribution to adjacent mass (40/41)[1]	< 10 ppm	< 20 ppm	< 50 ppm	< 10 ppm	< 20 ppm	50 ppm
Operating temperature, analyzer			150 °C			
Operating temperature, electronics			0–40 °C			
Bakeout temperature, analyzer[3]			200 °C / 300 °C			
Connection flange			DN 40 CF-F			
Resolution at 10 % peak height			0.5–2.5 amu			
Measurement speed, analog/bargraph scan			20 ms – 60 s/amu			
Measurement speed, Stair			2 ms – 60 s/amu			
Measurement speed, MID			2 ms – 60 s/amu			
Number of measurement channels in MID			128			
Reproducibility of peak ratio[3]			± 0.5 %			
Interface			Ethernet			
Input, digital			External protection			
Supply voltage			90–260 VAC, 50/60 Hz			
Weight	2.4 kg	2.4 kg	2.4 kg	3.8 kg	3.8 kg	3.8 kg

Equipments that we already have

Almost all parts from Phase-1 will be used

- Pressure chambers and xenon backup chambers : $40,000
- Turbo pump system : ($30,000 from CDMS)
- Oil-free leak detector : ($40,000 from PAB)
- Manifolds for gas handling (need modification): $20,000
- Glass chambers : $5,000
- Xenon gas (1200L) : 200L ($4,000) Fermi Xenon, 1000L($3,000) U.Florida Xenon

Additional parts obtained or borrowed for Phase-2

- Diaphragm micro pumps : ($10,000 from KTeV TRD system)
- Oscilloscopes : ($20,000 from MINOS and Meason Beam)
- Turbo and roughing pumps : ($50,000 from CDMS/PAB)
- Edge welded bellows : ($10,000 from Accelerator Division)
- DAQ system + computer : (from Fermi Preb)

Cost Estimation for Phase-2

Parts for Phase-2 (scintillation readout)

- Automatic controller (pressures and temperatures; PLC and modules): $12,000
- Mass spectroscopy(PrismaPlus PFEIFFER 0~200AMU): $14,000
- Xenon purification system(SAES MonoTorr PS4-MT3-R-1 and cartridge): $13,000
- PMTs (Hamamatsu R9869 or R11410): $10,000 ($5,000 x 2)
- Inner glass chambers and supporting structure (Custom made): $6,000
- New top flange and piping/tubing: $6,000
- Operational cost : $5,000

Total cost for parts : $66,000 (+30% contingency)

Additional Parts for electron drift (not in the current proposal)

- Additional PMT : $5,000
- Grid mash structure + supporting structure + HV electronics : $15,000
- Electron purity monitor : $6,000 (ArTPC group is currently making this)
- Additional tubing and piping : $5,000
- Operational cost : $5,000

Additional total for electron drift : $36,000

Phase-2: Manpower

Collaboration

Jonghee Yoo, Tarek Saab, Durdana Balakishieva, Rupak Mahapatra, Jimmy Erikson

Technical & Engineering support (request)

PLC hardware and Soft ware: Rich Schimitt and PPD control team (3 man weeks)

Cryogenics system engineering: Herman Cease (3 hours/week)

PMT and DAQ: Sten Hansen and his team (2 man weeks)

ODH analysis at PAB: Terry Tope (half day)

Overall Technical support: Carry Kenziora, Bill Miner, Kelly Hardin(PAB)

Additional support: Kourosh Taheri, John Voirin(Lab-F), Lenny Harbacek(Welding)

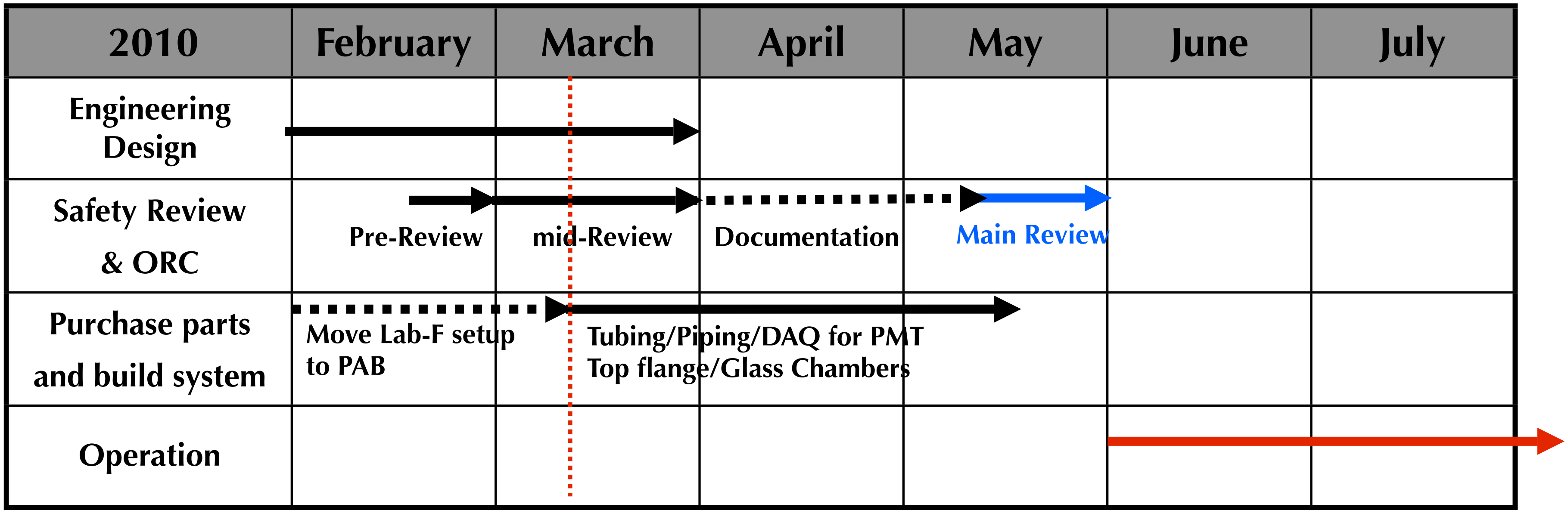
Safety support

Operational Review Chair: Leo Bellantoni

Safety Review: Philip Pfund, Brian Degraff, Dave Pushka, Tom Page

Radiation Safety: Kathy J Graden

Schedule



Mile Stones (given that the safety review is done on time)

2010 July ~ August: Physics goal of the 2nd phase

(1) Automate xenon crystal growth

(2) Demonstration of scintillation light readout from solid xenon

(3) Compare light yield between liquid xenon and solid xenon

(4) Purity vs. light yield (& transparency of solid xenon if possible)

2010 August ~ September: Test for phase-3 propoal

(1) Diffusion test for various gases -- especially H_2O

(2) Test various inner glass configurations for electron drift system (3rd phase)

(3) Prepare solid xenon phase-3 proposal: for electron drift & solid xenon characteristics test

Summary

1. Solid Xenon Project: Phase-1 Results

- Multi-purpose detector R&D project using solid phase of xenon is just started
- Crystal clear large scale solid xenon growth is demonstrated (~850g)
- A robust prescription of growing crystal within Fermilab safety regulation is reported
- Phase-1 system has been moved from Lab-F to PAB (instrumentation is completed)

2. Solid Xenon Project : Phase-2 Proposal

- Automate the crystal growing procedure (pressure and temperature control)
- Scintillation light readout using UV sensitive PMT (simple DAQ)
- Test phase-3 (electron drift chamber) design issue

Total Budget Request

Purchase new parts: $66,000 + (30% contingency)

Engineering & Technical support request

- Cryogenics system design: 3 hours/week
- DAQ eng&tech: 2 man weeks
- PLC controller eng&tech: 3 man weeks
- Overall general technical support: 20 man weeks