COUPP-60 Installation Review

Fermilab, 5/8/12

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Topics From Committee Charge in this Talk

Technical preparedness

3. Has the experiment addressed known internal background sources? Is there a sufficient inventory of materials and associated testing to give confidence that these backgrounds are unlikely to significantly limit the experimental sensitivity?

Items # 1, 2 ,4 from "Charge to Committee" addressed in talks by Lippincott, Dahl, Ramberg

Resource requirements:

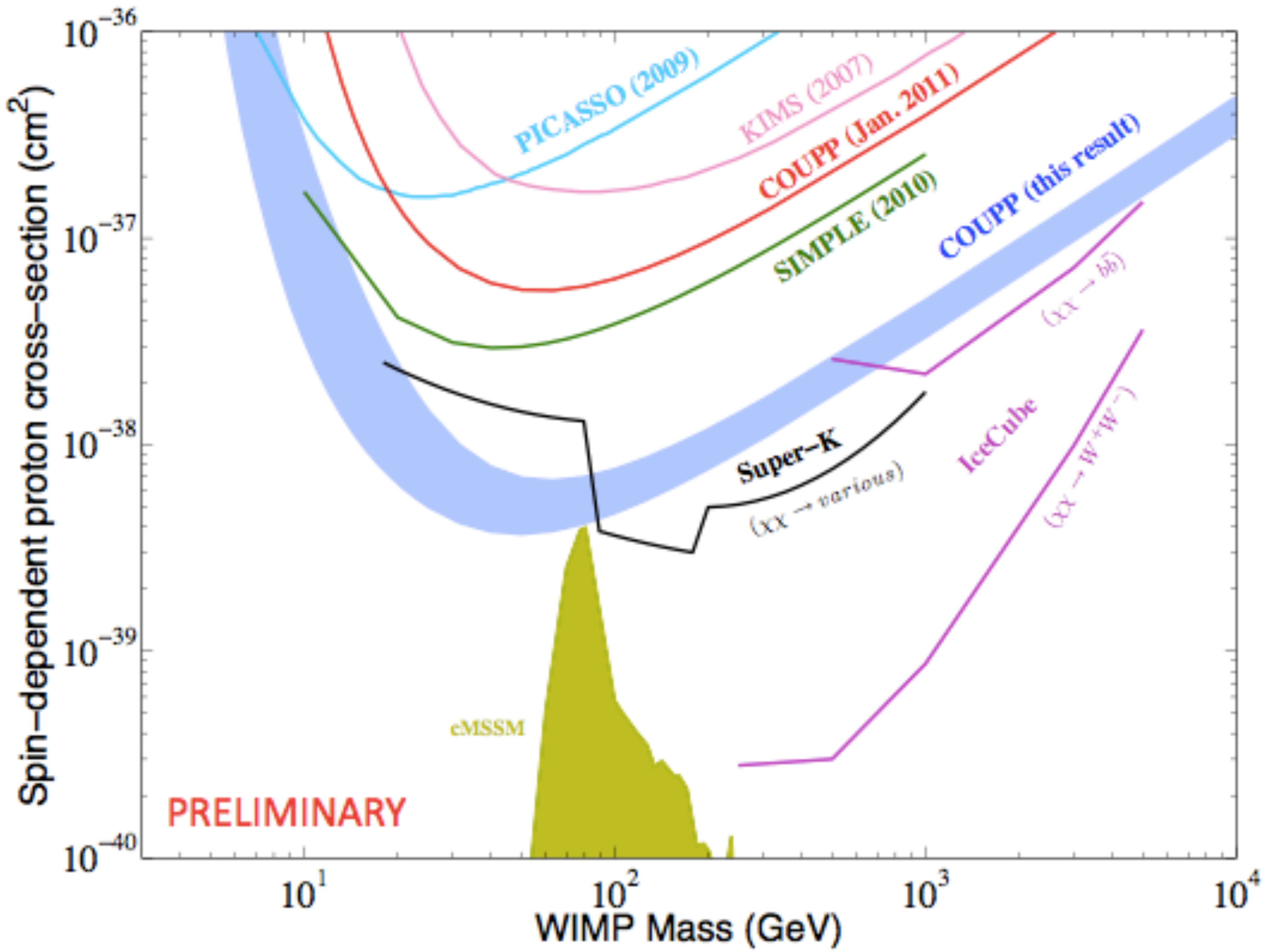
1. Does the proposed plan cover all of the steps likely to be required for this deployment?
2. How does the COUPP 60 kg deployment plan mesh with plans for operating COUPP 4-kg? Is there sufficient scientist manpower available to do both?
3. Have the needed technical resources been identified, and are they likely to be available on the timescale needed for deployment?
4. Are the resource estimates consistent with past experience deployment at MINOS and 4kg chamber at SNOLab?

Item #5 (safety) Primarily addressed in Erik Ramberg's talk

COUPP-60 History

- COUPP-60 Proposal, Sept 2006 for “Phase I”: Minos site.
- 2009 Testing at D0. Proposal for eventual move to SNOLAB.
- 2010 First Test at NuMI– Problems with CF3I stability.
- 2011 Second test at NuMI after chemistry R&D show improved stability (Hugh Lippincott’s talk)
- 2012 Detector improvements in preparation for SNOLAB move (Eric Dahl’s talk). Designs for SNOLAB site installation, safety (Erik Ramberg’s talk)
- Now: Ready to begin moving equipment…

COUPP2L SNOLAB Results



https://hepconf.physics.ucla.edu/dm12/talks/hall.pdf

COUPP-4 Result

- World's best sensitivity to spin dependendent (WIMP-proton) interactions above 30 GeV.
- Background: 20 single bubble events observed in 553 kg-days after acoustic alpha rejection cut.
- Observed three multiple bubble events, indicating that neutrons are contributing to the background. Based on measurements of material radiopurity and simulations, we identified likely sources for these events (next slide).
- A fraction of single bubble events can not be accounted for by known neutron sources. About half of the singles events have strange characteristics suggesting that they are not from nuclear recoils (time clustering, abnormal acoustic parameter distribution). Hugh has slides on this.

Background Estimates:

Radiopurity measurements + Monte Carlo

Material	Source	Concentration	Rate in DM-34°C	Rate in DM-37°C	Rate in DM-40°C
			(10^{-3} cts/kg_{CF_3I}/day)		
Glass (viewports)	^{238}U (α,n)	0.513±0.055 ppm	$3.87^{+0.42}_{-0.42}$	$4.20^{+0.45}_{-0.45}$	$4.46^{+0.47}_{-0.47}$
PZT (piezos)	^{238}U s.f.	3.95±0.43 ppm	$1.64^{+0.18}_{-0.18}$	$1.79^{+0.19}_{-0.19}$	$1.90^{+0.20}_{-0.20}$
Glass (viewports)	^{232}Th (α,n)	0.528±0.058 ppm	$1.30^{+0.14}_{-0.14}$	$1.41^{+0.15}_{-0.15}$	$1.50^{+0.16}_{-0.16}$
			(10^{-4} cts/kg_{CF_3I}/day)		
PZT (piezos)	^{238}U (α,n)	3.95±0.43 ppm	$6.04^{+0.66}_{-0.66}$	$6.66^{+0.71}_{-0.71}$	$7.14^{+0.75}_{-0.75}$
Glass (viewports)	^{238}U s.f.	0.513±0.055 ppm	$4.87^{+0.52}_{-0.53}$	$5.29^{+0.56}_{-0.56}$	$5.63^{+0.59}_{-0.60}$
Norite (rock walls)	^{238}U/^{232}Th	1.2/3.3 ppt	$1.26^{+0.71}_{-0.57}$	$1.26^{+0.71}_{-0.57}$	$1.26^{+0.71}_{-0.57}$
Steel (pressure vessel)	^{238}U s.f.	~1 ppb	$0.92^{+0.10}_{-0.10}$	$1.00^{+0.11}_{-0.11}$	$1.07^{+0.11}_{-0.11}$
			(10^{-5} cts/kg_{CF_3I}/day)		
PZT (piezos)	^{232}Th (α,n)	1.18±0.15 ppm	$6.33^{+0.69}_{-0.69}$	$6.98^{+0.75}_{-0.74}$	$7.51^{+0.80}_{-0.80}$
J-B Weld (epoxy)	^{238}U s.f.	0.173±0.019 ppm	$5.83^{+0.63}_{-0.63}$	$6.34^{+0.67}_{-0.68}$	$6.74^{+0.72}_{-0.71}$
PCB (preamps)	^{232}Th (α,n)	2.01±0.22 ppm	$4.89^{+0.53}_{-0.53}$	$5.32^{+0.56}_{-0.57}$	$5.63^{+0.60}_{-0.60}$
PCB (preamps)	^{238}U s.f.	0.491±0.056 ppm	$4.41^{+0.48}_{-0.48}$	$4.80^{+0.51}_{-0.51}$	$5.11^{+0.54}_{-0.54}$
PCB (preamps)	^{238}U (α,n)	0.491±0.056 ppm	$3.36^{+0.36}_{-0.36}$	$3.63^{+0.39}_{-0.39}$	$3.87^{+0.41}_{-0.41}$
J-B Weld (epoxy)	^{238}U (α,n)	0.173±0.019 ppm	$2.11^{+0.23}_{-0.23}$	$2.26^{+0.24}_{-0.24}$	$2.38^{+0.25}_{-0.25}$
Quartz (flange)	^{238}U s.f.	42±4 ppb	$1.92^{+0.21}_{-0.21}$	$2.09^{+0.22}_{-0.22}$	$2.21^{+0.23}_{-0.23}$
Quartz (flange)	^{238}U (α,n)	42±4 ppb	$1.40^{+0.15}_{-0.15}$	$1.52^{+0.16}_{-0.16}$	$1.64^{+0.17}_{-0.18}$
			(10^{-6} cts/kg_{CF_3I}/day)		
Steel (pressure vessel)	(μ,n)		$4.55^{+0.49}_{-0.49}$	$4.87^{+0.52}_{-0.52}$	$5.12^{+0.54}_{-0.54}$
Glycol (hydraulic fluid)	^{238}U total	31±0.42 ppt	$4.40^{+0.48}_{-0.47}$	$4.76^{+0.51}_{-0.51}$	$5.06^{+0.53}_{-0.53}$
J-B Weld (epoxy)	^{232}Th (α,n)	0.097±0.012 ppm	$4.05^{+0.43}_{-0.43}$	$4.31^{+0.46}_{-0.46}$	$4.54^{+0.48}_{-0.48}$
Quartz (flange)	^{232}Th (α,n)	~30 ppb[a]	$3.88^{+0.42}_{-0.42}$	$4.22^{+0.45}_{-0.45}$	$4.54^{+0.48}_{-0.48}$
CF_3I (target)	(μ,n)		$3.74^{+0.40}_{-0.40}$	$3.99^{+0.42}_{-0.42}$	$4.21^{+0.44}_{-0.44}$
Steel (pressure vessel)	^{238}U (α,n)	~1 ppb	$0.95^{+0.10}_{-0.10}$	$1.04^{+0.11}_{-0.11}$	$1.11^{+0.12}_{-0.12}$
			(10^{-7} cts/kg_{CF_3I}/day)		
Steel (pressure vessel)	^{232}Th (α,n)	~1 ppb	$3.88^{+0.42}_{-0.42}$	$4.26^{+0.45}_{-0.46}$	$4.54^{+0.48}_{-0.48}$
Glycol (hydraulic fluid)	(μ,n)		$3.16^{+0.34}_{-0.34}$	$3.44^{+0.37}_{-0.37}$	$3.69^{+0.39}_{-0.39}$
Water (buffer fluid)	(μ,n)		$2.84^{+0.30}_{-0.30}$	$2.99^{+0.32}_{-0.32}$	$3.12^{+0.33}_{-0.33}$
Water (shielding)	^{222}Rn (α,n)	15.9 atoms/cm^3	$1.35^{+0.25}_{-0.30}$	$1.66^{+0.30}_{-0.29}$	$1.83^{+0.31}_{-0.34}$
			(10^{-8} cts/kg_{CF_3I}/day)		
Water (shielding)	(μ,n)		$5.23^{+0.57}_{-0.56}$	$5.54^{+0.61}_{-0.59}$	$5.92^{+0.63}_{-0.65}$
			(10^{-3} cts/kg_{CF_3I}/day)		
Total			$8.33^{+0.48}_{-0.48}$	$9.05^{+0.52}_{-0.52}$	$9.63^{+0.55}_{-0.55}$

Figure from
D. Fustin, PhD Thesis, 2011.

Radiopurity Upgrades

Higher purity materials will suppress expected neutron background below 1 event per live year:

- New Piezoelectric Acoustic Sensors (COUPP60 & COUPP4)
  - Piezoceramic produced at Virginia Tech, using reagents pre-screened at U. Chicago. Being assembled into transducers at IUSB.
  - Measurements of Uranium and Thorium indicate two order of magnitude reduction in neutron emissions.

- Fused silica pressure vessel windows (COUPP-60 and COUPP-4)
  - Fused silica is at least three orders of magnitude lower in U and Th than the glass ports we have used up until now.
  - We have received pressure vessel windows for both detectors from vendors.

- Low Background Steel (COUPP60)
  - A supplier of reliably low activity stainless steel was identified by DEAP3600 collaboration (typically ~0.1 ppb Uranium).
  - We specified this material for new COUPP-60 vessel.
  - Samples of material procured for our vessel have been counted at U. Chicago.

Deployment Plan

- We began to develop a detailed plan and budget for SNOLAB deployment in spring of last year.
- The initial statement of the plan is in our DOE FY11 and FY12 field work proposals, which represented the collaboration consensus on what steps needed to be taken to get the detector to SNOLAB.
- *The original plan described in the FWPs will be reviewed on following slides, with notes on the changes that have occurred (in red).*

Deployment Plan: FY11 FWP

1. Produce a comprehensive safety plan for the SNOLAB installation of COUPP-60. The critical issue for this study is the strategy for avoiding high levels of human exposure to CF3I in case of equipment failures... ✔

2. We will work with SNOLAB to complete work on utility lines and the COUPP water shielding tank to anticipate the arrival of the COUPP-60 detector. These items are primarily the responsibility of SNOLAB. Work still in progress– all necessary Fermilab design input was provided. ✔

3. Materials screening program for radiopurity. Retrofitting and removal of internal neutron sources from both COUPP-4 and COUPP-60. ✔

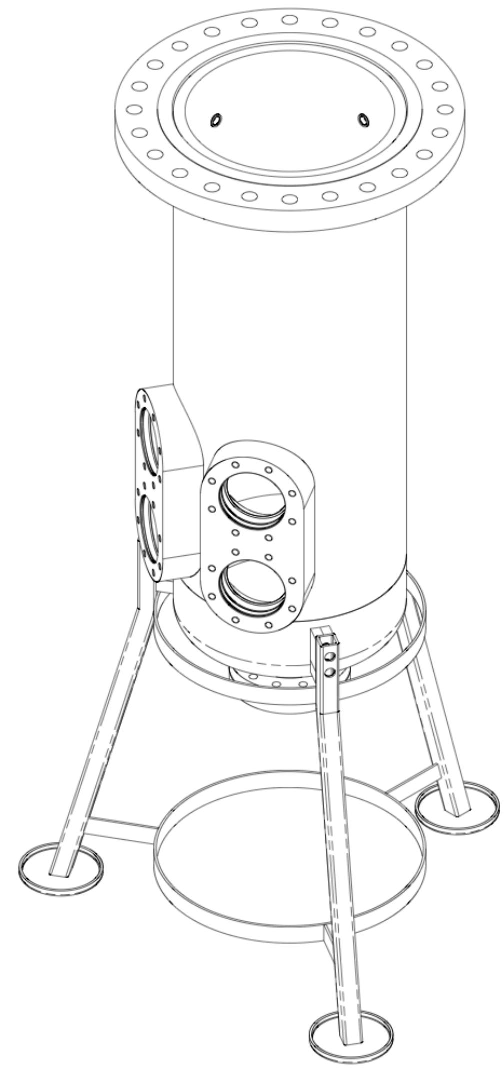
4. Redesign of the COUPP illumination system to improve the quality of photography, while reducing the required amount of illumination power to a level which will avoid chemical changes in the CF3I. Includes new LED illumination array and reflector panel. Hardware finished, testing still required ✔

Deployment Plan: FY11 FWP Ctd.

5. The video cameras, which are marginal in terms of video frame rate, resolution and sensitivity, will be replaced ✔
6. We will continue R&D on chemical purity and chemical compatibility issues, with goal of demonstrating stability ✔
7. Preparation of detector installation site, including a new clean room. Need for clean room at SNOLAB was eliminated by changing assembly sequence.
8. We will study a possible upgrade to the COUPP-60 pressure vessel which would simplify the optical scheme and allow viewing of approximately twice as much target volume by adding additional windows and doubling the number of video cameras. We decided to go ahead and build this. ✔

New Outer Pressure Vessel

- Meets Canadian codes. Will be TSSA approved and registered in Ontario.
- Low radioactivity stainless steel to reduce neutron background to < 1 event per year.
  - 1 ppb Uranium would produce 0.5 events per live year in 75-kg of CF3I.
  - Steel comes from supplier identified by Miniclean (Outokumpu). Typical samples in SNOLAB radiopurity database are an order of magnitude better than we need (0.1 ppb)
- Fused silica windows for photography. Four ports allow imaging of 75 kg of CF3I.
- Contract awarded to All- Weld (Toronto) in January. Expect delivery in May.



Counting Results from COUPP-60 Construction Material Samples

COUPP Counting Results

Limits are 90% C.L.

Date	Sample	livetime (days)	mass (kg)	238 U ppb	mBq/kg	232 Th ppb
14 Mar 2012	12.5 in Flange	1.53	23	< 2.9	< 36	< 6.0
20 Mar 2012	Silicon window	3.33	2.764	< 1.7	< 21.	< 3.2
24 Mar 2012	Heat 853095-1A	3.59	18.9	< 1.0	< 13	1.2 +/- 1.2
3 Apr 2012	Heat 852286-1A	4.37	10.4	< 1.0	< 12	1.9 +/- 1.1
3 Apr 2012	92ML Arlon Material	0.036	0.55	460 +/- 60	5700 +/- 700	1640 +/- 180
15 Apr 2012	Pressure vessel shell	4.91	1.166	0.13 +/- 0.85	1.6 +/- 10.6	0.2 +/- 1.5
18 Apr 2012	TIG filler wire	2.56	1.21	5.6 +/- 1.2	69 +/- 15	1.2 +/- 2.0
21 Apr 2012	Heat 610940	2.78	1.332	2.8 +/- 0.9	34 +/- 12	2.0 +/- 1.7
23 Apr 2012	Heat 65Y2	1.95	0.838	10.1 +/- 2.2	125 +/- 28	0.2 +/- 3.6
25 Apr 2012	Nuts + washers	1.4	4.584	10.1 +/- 1.4	125 +/- 17	2.7 +/- 2.1
27 Apr 2012	SA182-316/316L coupli	0.99	1.446	16.7 +/- 3.6	206 +/- 44	26 +/- 16 (Ac-:
1 May 2012	Heat 120466	3.46	1.022	10.3 +/- 2.1	127 +/- 26	4.6 +/- 3.5

Deployment Plan: FY12 FWP

1. Relocation of all equipment from Fermilab to SNOLAB. Planned.
2. Acquisition of personal protective equipment. Plan to purchase respirators.
3. Installation of water handling equipment. Planned.
4. Assembly of detector inside water shielding tank. Planned.
5. New low-radioactivity acoustic sensors. Planned.
6. Construction of fluid and electrical connections between bubble chamber and hydraulic control and fluid cart modules. Planned.
7. Fill the detector with fluids and commission it. Planned.
8. New compute and disk server for data analysis. Use existing cluster.
9. Operate COUPP-4 with improved low-activity acoustic sensors and better pressure controls. Planned for June. Controls upgrades deferred.
10. Calibration measurements (CIRTE, neutrons) In progress. First CIRTE run appears to be a success. Mostly paid for with KA-15 (R&D) funds.

Scope Increases

- Few changes in scope compared to what we proposed to DOE a year ago:
  - Most important change was to accelerate construction of new Outer Vessel which was originally proposed as an upgrade after an initial run with the old vessel. We eliminated the planned run with the old vessel in favor of going straight to the new one. The procurement of the vessel has driven the schedule for the project over the last year– delivery is expected on June 1^{st}, about 11 months after 1^{st} concept drawings in summer 2011.
  - A second area of scope increase was the COUPP-60 control system expansion and upgrade. New instruments were added for remote monitoring, failure detection (e.g. glycol leak, CF3I leak, blocked pump), and better software for remote monitoring and alarms was added (iFix). These changes should improve our ability to operate the detector remotely.

Schedule

- Schedule was developed from the bottom up using a detailed, resource loaded WBS.
- Project Manager and Subsystem Managers can independently see and update the schedule at any time using Web-based Project Management software (Clarizen)
- Software sends automatic reminders on what tasks are open to the responsible manager.
- Progress is discussed in weekly collaboration meetings/ phone conferences.
- Milestone reports are generated each month, allowing schedule drift to be tracked over time.

WBS Example

- Tasks have assigned resources (people + money), schedule information and brief descriptions of the scope of the work. Level of detail and quality of information vary, with more attention paid to critical path items.

Name	Manager		Start Date	Duration	% Complete	M&S	Travel	Total Estimate Cost
COUPP	Sonnenschein		12/07/10	501 d	10	359,764	68,500	813,083
Area 1: Chamber Components	Dahl		12/07/10	402 d	23	159,014	1,000	260,674
Area 2: COUPP-60 Installation	Lippincott		12/07/10	501 d	18	105,600	52,000	315,526
Chemical Tests	Lippincott		07/01/11	207 d	21	10,000		58,122
NuMI run fall 2011	Lippincott		07/01/11	131 d	100	10,000		58,122
Make decision regarding purification	Lippincott		11/01/11	120 d	0			
CF3I	Lippincott		03/01/12	120 d	0	51,000		59,160
Purchase storage vessel	Lippincott		03/01/12	60 d	0	1,000		1,160
Purchase CF3I	Lippincott		05/24/12	60 d	0	50,000		58,000
Disassembly of bubble chamber at NuMI	Lippincott		10/14/11	63 d	100			5,851
High Purity Fluid Skid	Lippincott		12/07/10	407 d	28	6,500		20,179
Move from NuMI to Lab 3	Lippincott		12/27/11	1 d	100			
Disassembly and inspection	Lippincott		01/19/12	20 d	100			1,938
Cleaning	Lippincott		02/16/12	10 d	50			4,886
Reassambly	Lippincott		03/01/12	10 d	0	2,000		5,228
Crate	Lippincott		05/17/12	5 d	0	1,100		4,184
Ship to SNOLAB	Lippincott		05/24/12	5 d	0	1,400		1,624
Ship underground	Lippincott		05/31/12	5 d	0			
Consumables	Lippincott		12/07/10	1 d	0	2,000		2,320
Assemble underground	Lippincott		06/07/12	5 d	0			

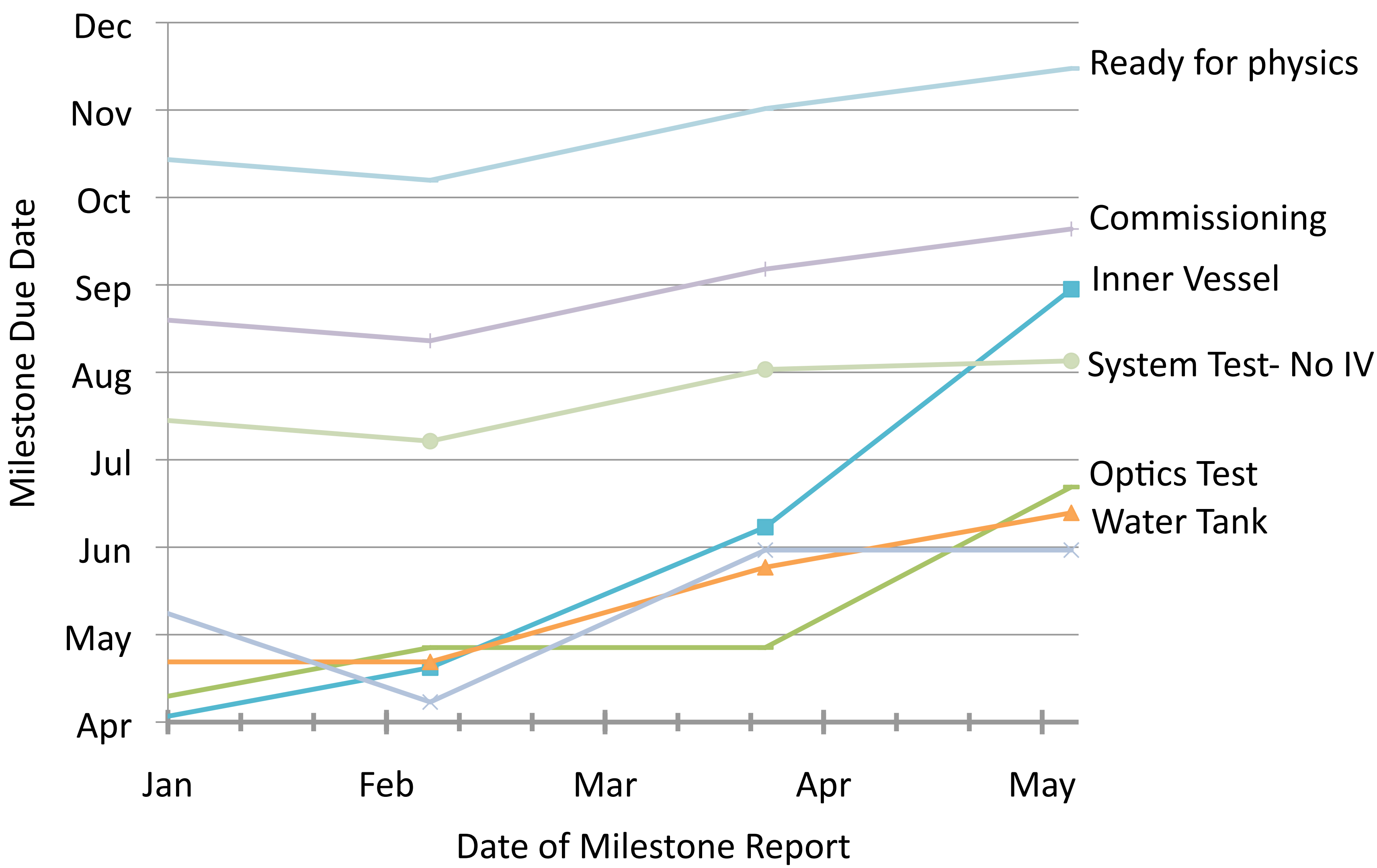
Gantt Chart

- See PDF chart file posted with this talk.

Milestone Report- May 7, 2012

Name	**Due Date**
Pass NuMI Chemical Test	11/15/11
New Outer Vessel Vendor Selection	12/06/11
CIRTE Chamber Ready	02/01/12
New Camera Decision	04/11/12
2nd Generation Acoustic sensors ready	05/15/12
Pass SNOLAB Safety Review	05/23/12
Start COUPP-4 Run 2	05/25/12
Outer Vessel Ready	06/12/12
Water Tank Ready	06/25/12
Pass Optics and Illumination Test	07/04/12
Pass Video Acquisition Test	08/15/12
System Test-- No IV	08/17/12
Inner Vessel Ready	09/11/12
Start Commissioning	10/02/12
Ready for Physics Runs	11/27/12

Milestone Tracking- Last 4 Months



Schedule– The Big Picture

Schedule table from FY11 Field Work Proposal

FY09	Complete fabrication and testing at D0
FY10	Commissioning of 60-kg detector at NuMI, 4-kg detector at SNOLAB
FY11	Installation of underground infrastructure for COUPP-60 COUPP-4 running and refurbishment at SNOLAB Acoustic sensor R&D Chemistry R&D, Optics improvements for COUPP-60
FY12	Recommission COUPP-60 underground at SNOLAB COUPP-4 calibration runs at SNOLAB
FY13	COUPP-60 Running at SNOLAB

Installation Work at SNOLAB

• By the end of this May, most of COUPP-60 equipment will be ready to ship to SNOLAB (inner vessel is main exception, which comes in August)

• At SNOLAB, work will be done mainly by physicists and the SNOLAB installation technician team, lead by Brian Morissette. We expect to have 4-5 people working together underground. The director of SNOLAB has said that we have a high priority for tech support over the summer.

•. We expect to need on-site assistance from Fermilab technicians and engineers only for a few of the more challenging assembly steps, such as inner vessel insertion. We are planning 2-3 week-long trips by teams of 2 people for these steps.

• We expect little interference between COUPP-4 and COUPP-60 at SNOLAB. Refurbished COUPP-4 inner vessel will be installed in late May/ early June, before COUPP-60 components arrive at SNOLAB.

SNOLAB Installation Work Plan

May-
Brian Morissette + 2 SNOLAB techs + Eric Vazquez Jauregui + Eric Dahl + Hugh Lippincott
Install bottom rings of water tank walls-- inner and outer
Install styrofoam tank bottom
Build tank walls from prefabbed sections
Install COUPP-4 refurbished inner vessel. Refill COUPP-4.

June-
Andrew + Eric VJ + Brian + 2 SNOLAB techs
Place access stairs
Install fall restraints
Install tank ventilation fan
Install inner and outer water tank liner
Place polyethylene bottom plates
Place outer vessel steel base plate on polyethylene
Place outer vessel stand on base plate
Place outer vessel on its stand
Assemble water tank perimeter plates
Insert water tank insulation blankets between inner and outer walls
Place hydraulic cart
Place water pump & heater skid

July
Hugh + Eric VJ + Brian + Snolab Techs + Optional (Pete Simon + 1 Tech x 1 wk)
Connect hydraulic cart to perimeter plates using prefab pipe segments
Connect outer vessel bottom to perimeter plates using prefabs
Connect water skid to perimeter plates using prefabs.
Install OV temperature sensors
Install OV top flange
Connect piping from outer lid to OV top flange.
Install water tank temperature sensors
Install viewport connection tubes to outer lid.
Install acoustic sensor conduit to outer lid
Utility (water, electricity, air) hookups to water system and hydraulic cart
Place glycol handling cart
Control system cabling and instrument check

August
Hugh, Erik Ramberg, Andrew + Eric Dahl + others
Fill outer vessel with glycol
Fill water tank with water and heat to 40 degrees
Test outer vessel pressure cycling
Empty water tank
Remove water tank wall segments
Remove outer vessel lid and place on stand.

September
Hugh, Andrew, Eric VJ + Optional (Pete Simon + 1 Fermi tech x 1 wk)
Insert reflector
Install CFI alarm system
Install forced air vent safety system
Test alarm and air vent system
Attach camera packages
Attach inner vessel to outer vessel lid.
Attach and wire acoustic sensors through OV lid
Nest OV lid/ IV assembly in OV
Install distillation cart
Install vapor transfer line from distillation cart to inner vessel
Install water connection to distillation cart inlet
Connect IV instrumentation
Receive CF3I transport cylinders underground.

October
Start Commissioning

Funding

- DOE
  - Base KA-13 funding covers 4 scientist FTEs at Fermilab.
  - 1095 k$ received in FY11-FY12 for COUPP-60 installation. This fully funds the installation of the detector at SNOLAB according to current budget, with modest contingency for dealing with unexpected problems.
  - Additional KA-15 R&D funds (~ 100 k$ in FY12) help with COUPP-4 and CIRTE.
- NSF
  - Continuing base funding for students at U. Chicago and IUSB, postdocs at Chicago and Engineering at IUSB.
  - 600 k$/year from DUSEL S4, last three years
  - NSF renewal of KICP– more student, postdoc support, some equipment.
  - NSF contribution pays for much of COUPP-4 operations, all of acoustic sensor development work.

COUPP60 Budget Status As of May 1st

- Funding received (FY11 + FY12): 1095 k$
- Obligated $ as of 5/1/12: 563 k$
- Remaining funds: 532 k$
- Estimated future costs: 442 k$
- Contingency: 90 k$ (20.3% of estimated costs)

** However– estimated cost has risen over time. Contingency on remaining work has eroded from 30% at start of project to 20% now ***

Expected Future M&S Costs

- Includes all individual items costing more than 5 k$

	K$
Travel	82
CF3I	50
Safety vent	18
Crating and shipping	13
Engineering for TSSA certification	10
Labview licenses	9
Access platforms, stairs	8
Protective equipment	5
Tubes & fittings	5
Total	200

=> About ½ of remaining 442 k$ budget is M&S

Conclusions:

- Largely done with Fermilab phase of COUPP-60, with equipment expected to ship soon.
- Starting SNOLAB phase in June with arrival of new Outer Vessel from vendor.
- We have more detailed work plans and budgets than we had in the past and are checking the numbers more frequently. Trying to implement standard project management practices.
- Funding appears to be sufficient in absence of major surprises. Contingency on future work is at 20% level.
- Keeping "boots underground" at SNOLAB will be a challenge. Collaboration will find a way to do it.