Coherent Elastic Neutrino Nucleus Scattering (CENNS: P1040)

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for the CENNS Collaboration

Fermilab

5 June 2013

Fermilab Physics Advisory Committee

Outline

- Introduction to CENNS
- Low Energy Neutrino Source at Fermilab
- Backgrounds and Shielding
- Detector R&D
- Summary

Request to PAC

- Endorse the physics case for using the far-off-axis Booster Neutrino Beam to discover Coherent Elastic Neutrino Nucleus Scattering.

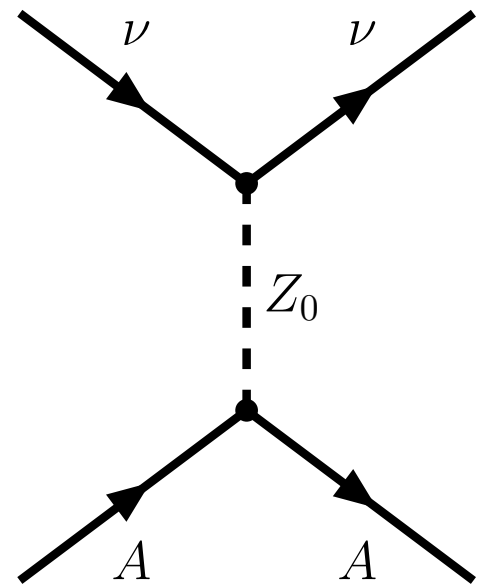
- Endorse the expenditure of modest Fermilab resources to pursue shielding and site placement study so that a full proposal can be developed.

Coherent Elastic Neutrino Nucleus Scattering

Coherent Elastic (Neutral Current) Neutrino Nucleus Scattering: CENNS

First prediction by D.Z. Freedman (Fermilab, 1973)

$$\mathcal{L}_{eff} = \frac{G_F}{\sqrt{2}} l^\mu j_\mu$$



Cross section for zero-momentum transfer limit

$$\sigma_{\nu N} \simeq \frac{4}{\pi} E_\nu^2 \left[Z\omega_p + (A - Z)\omega_n \right]^2$$

$$g(Z_0 u) = \frac{1}{4} - \frac{2}{3}\sin^2\theta_W, \qquad g(Z_0 d) = -\frac{1}{4} + \frac{1}{3}\sin^2\theta_W$$

$$\omega_p = \frac{G_F}{4}(4\sin^2\theta_W - 1), \qquad \omega_n = \frac{G_F}{4}$$

Differential cross section for finite momentum transfer

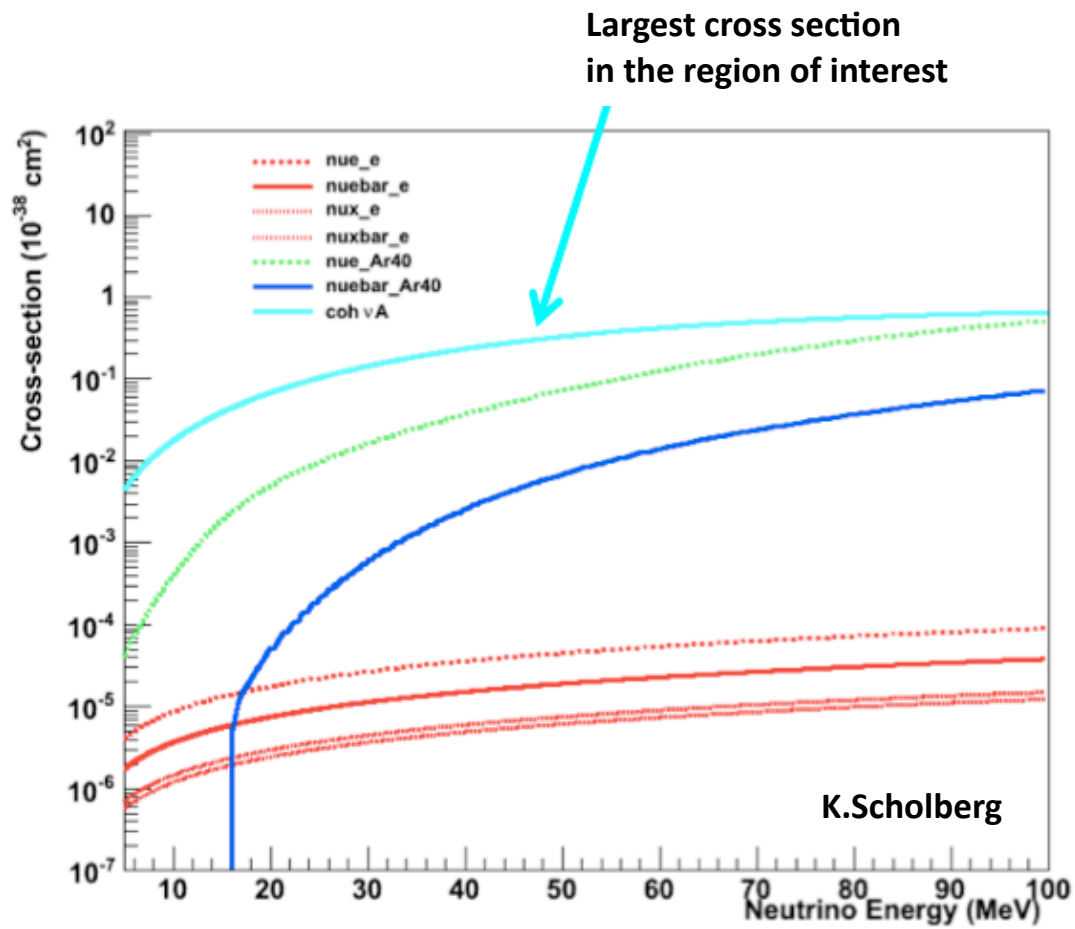
$$\frac{d\sigma}{dE} = \frac{G_F^2}{4\pi}[(1 - 4\sin^2\theta_w)Z - (A - Z)]^2 M \left(1 - \frac{ME}{2E_\nu^2}\right) F(Q^2)^2$$

Requirements of the CENNS

For most of the detector target nucleus, the coherence condition is fulfilled by neutrino energy of

$$E_\nu < \frac{1}{R_N} \simeq 50 \text{ MeV}$$

$$E_{max} \simeq \frac{2E_\nu^2}{M} \simeq \mathcal{O}(100) \text{ keV}$$



Requirements:

- **Intensive low energy neutrino source**
- **Large scale detector with 10s of keV energy threshold**

$$R \simeq \mathcal{O}(10^3)\left(\frac{\sigma}{10^{-39}cm^2}\right) \times \left(\frac{\Phi}{10^{13}\nu/year/cm^2}\right) \times \left(\frac{M}{ton}\right) events/year$$

Physics Impact of CENNS

CENNS Experiment

Measured as SM predicted

Discovery of CENNS!
(40 years of endeavor)

Low Energy Neutrino Physics
- Sterile neutrino oscillation study
- Supernova physics
- Background of Dark Matter search
- Neutron form factor study

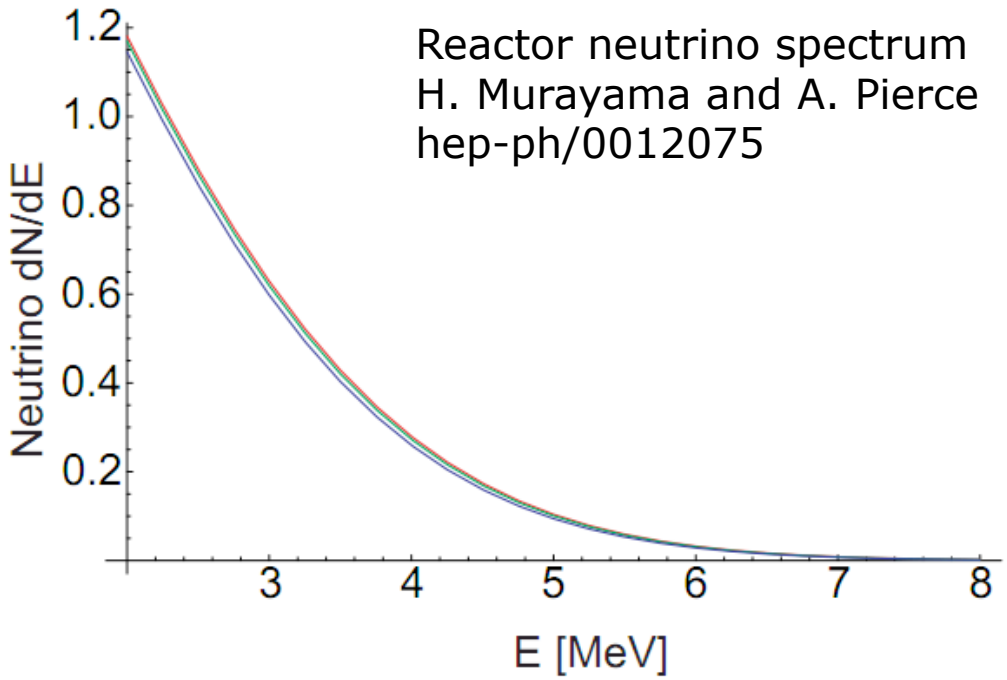
Off from SM prediction

New Physics!

New Paradigm
- Beyond SM interactions of neutrinos
- New physics for Dark Matter search
- Neutrino magnetic moment
- Test weak mixing angle ($sin\vartheta_W$)
- New theory

→ Neutrinos always provided us with the physics beyond the *then-Standard Model* !

Reactor Neutrinos



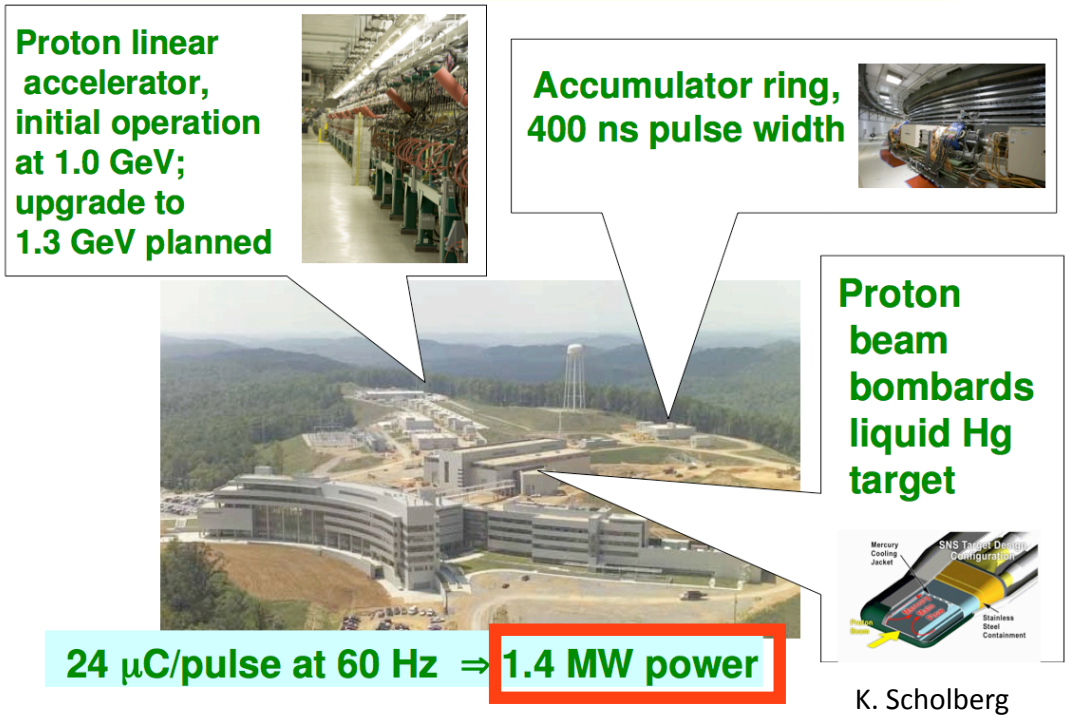
$$E_{max} \simeq \frac{2E_\nu^2}{M} < \mathrm{keV}$$

$$\Phi = 10^{20}\bar{\nu}_e/sec/4\pi R^2 \qquad (\Phi = 10^{12}\bar{\nu}_e/sec/cm^2 @\ 20\ \mathrm{m})$$

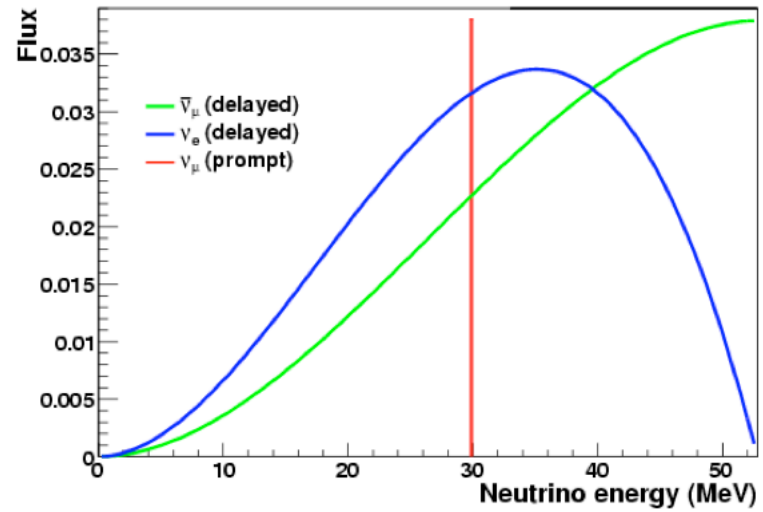
- Ultra-clean, kg-size, ~10 eV threshold detector
- Need to overcome steady state backgrounds and detector noise
- Reactor off-time can be used for background subtraction
- Detector development is challenging for a realistic experiment

CLEAR Proposal: SNS at ORNL

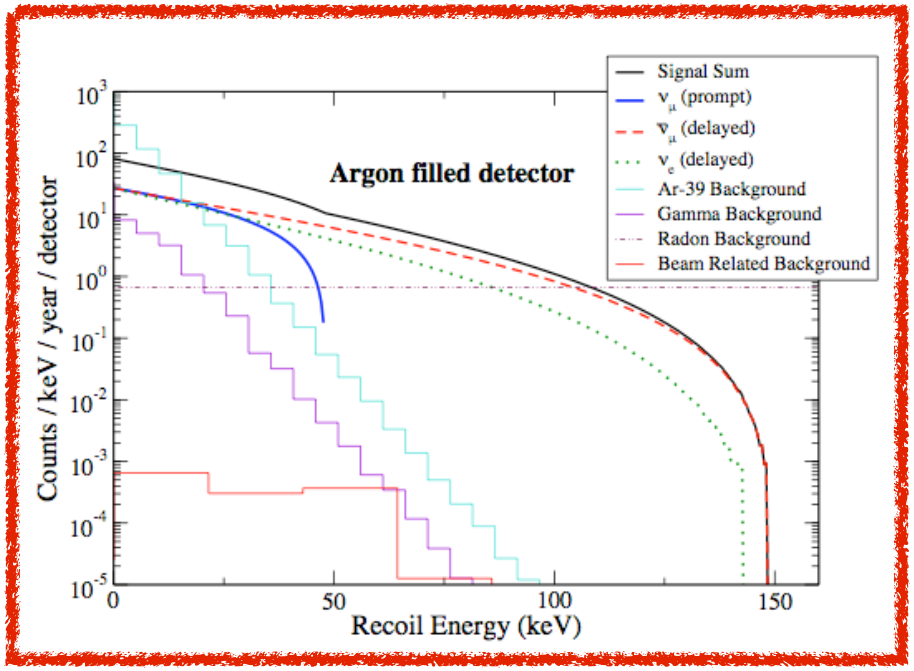
- vSNS at Oak Ridge National Lab
  F. Avignone and Y. Efremenko, J. Phys. G, 29 (2003) 2615-2628
- See **CLEAR** proposal : K. Scholberg *et al.*, hep-ex/0511042



K. Scholberg

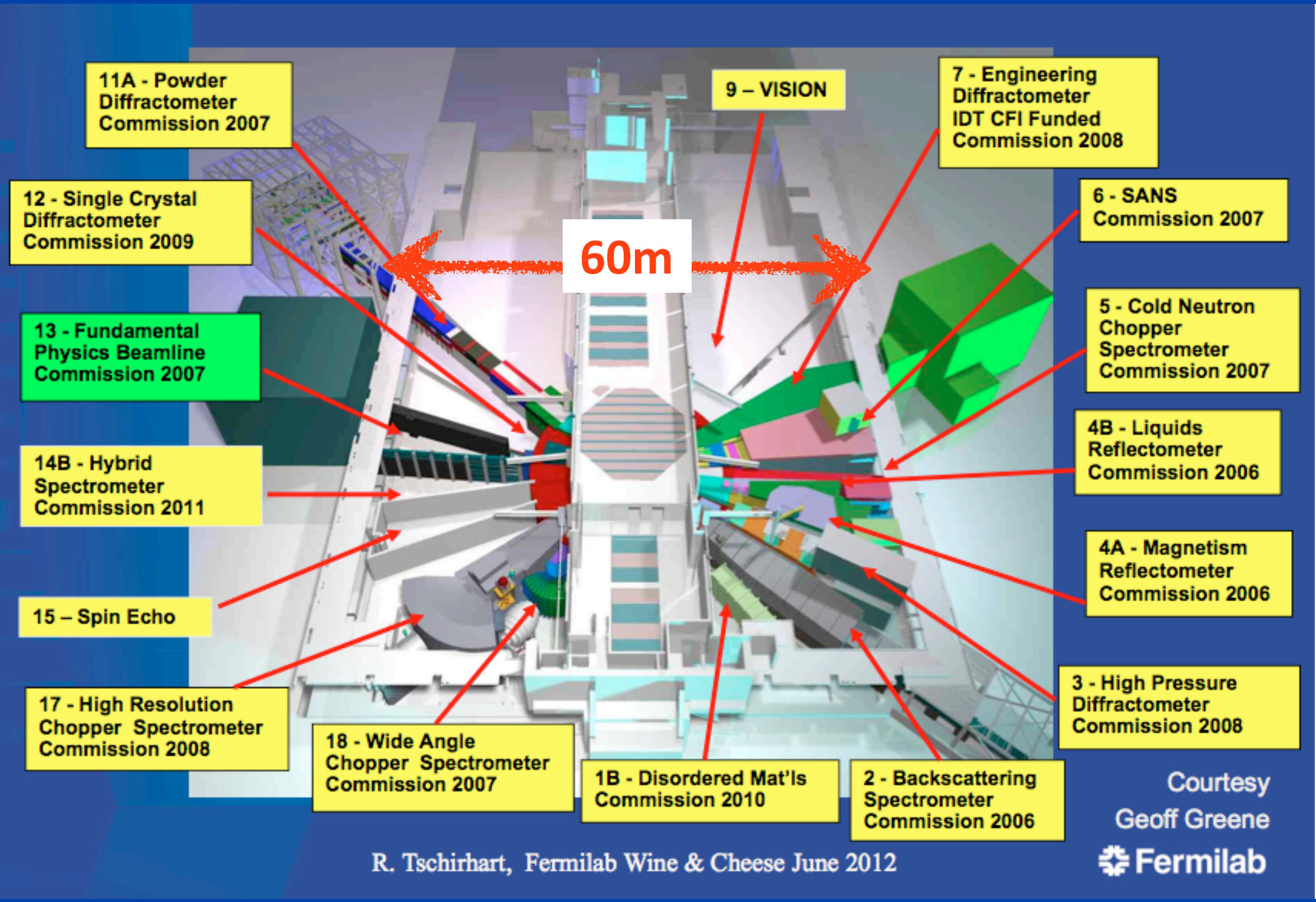


$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e$$



- Neutrinos from the pion decay at rest
- Flux ~ **$2\times 10^6/cm^2/s$** at **46m** from the target
- Steady state background rejection factor ~10^{-4}
- Expected event rate in a single-phase 500kg LAr detector: ~400 events/year of detection (E_{th}>30 keVnr)

ORNL SNS

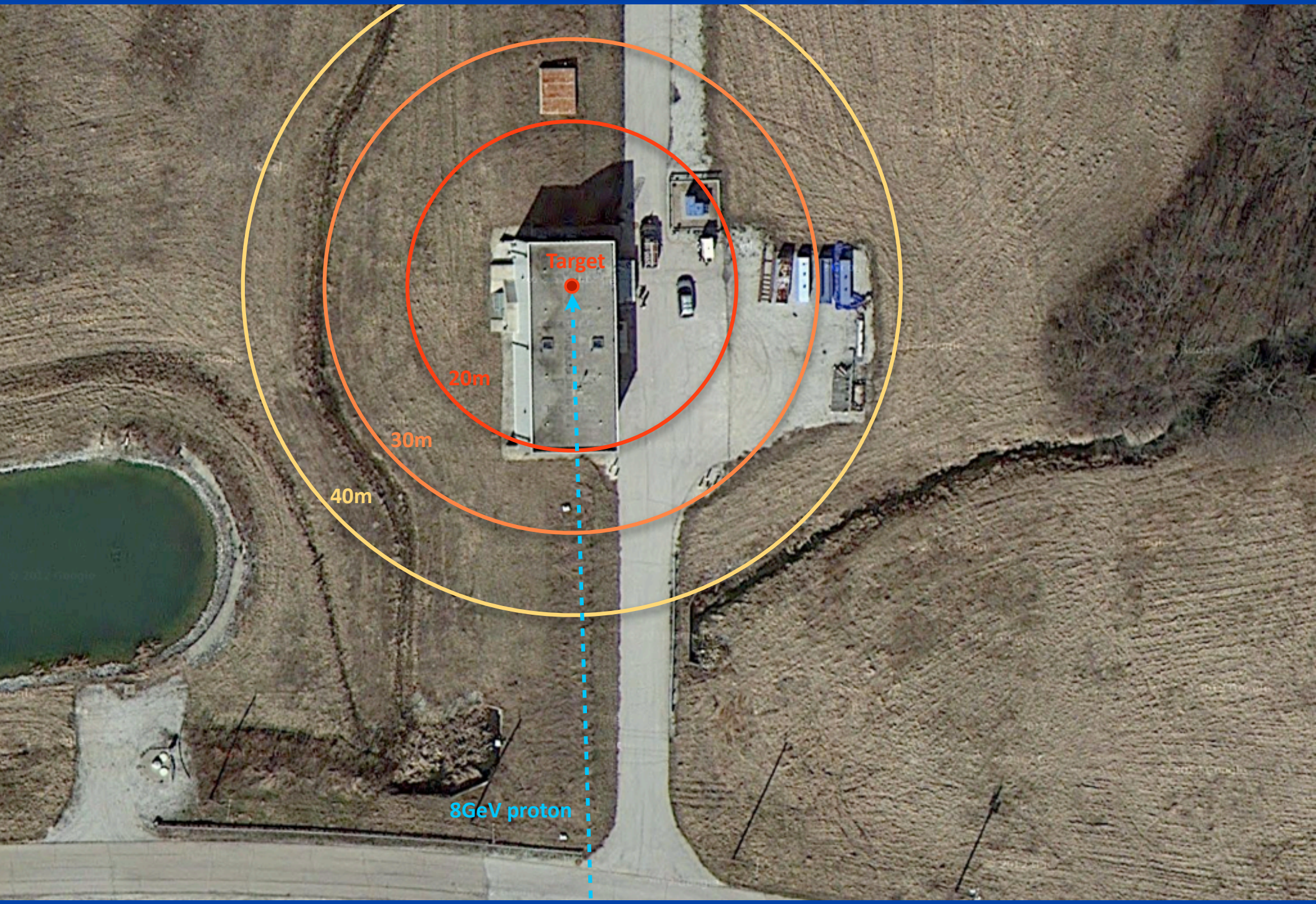

11A - Powder Diffractometer Commission 2007
12 - Single Crystal Diffractometer Commission 2009
13 - Fundamental Physics Beamline Commission 2007
14B - Hybrid Spectrometer Commission 2011
15 – Spin Echo
17 - High Resolution Chopper Spectrometer Commission 2008
18 - Wide Angle Chopper Spectrometer Commission 2007
1B - Disordered Mat'ls Commission 2010
2 - Backscattering Spectrometer Commission 2006
3 - High Pressure Diffractometer Commission 2008
4A - Magnetism Reflectometer Commission 2006
4B - Liquids Reflectometer Commission 2006
5 - Cold Neutron Chopper Spectrometer Commission 2007
6 - SANS Commission 2007
7 - Engineering Diffractometer IDT CFI Funded Commission 2008
9 – VISION
60m
R. Tschirhart, Fermilab Wine & Cheese June 2012
Courtesy
Geoff Greene
Fermilab

Neutrinos at Fermilab

Fermilab:

- The only national laboratory in US dedicated to the particle physics
- Strong support on neutrino physics programs

Fermilab Booster Neutrino Beam (BNB) Target Building

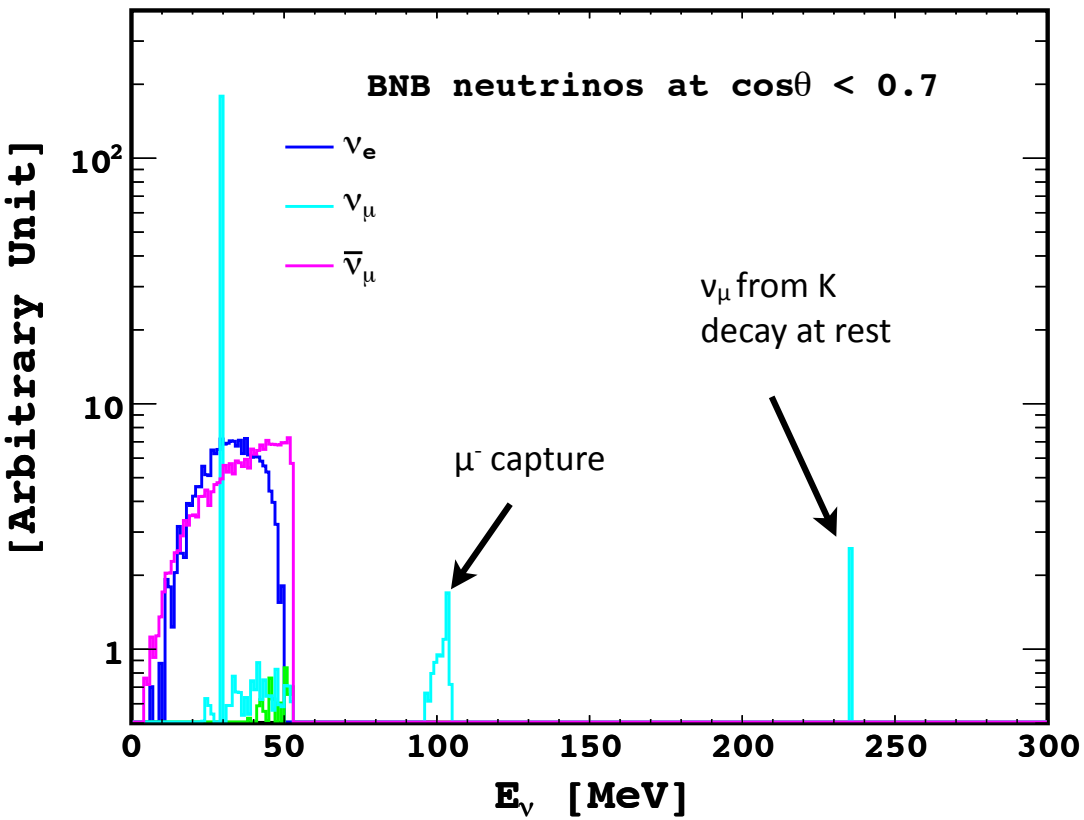


Far-Off-aXis Neutrinos at BNB

Beam MC Configuration

- Use standard Booster Beam MC
  - release stopping pion cuts in the original MC
- 8 GeV, 5Hz 5×10^{12} Protons on Beryllium target
  - 32 kW max power
- 173 kA horn current neutrino mode

From Booster Beam MC (S.Brice)

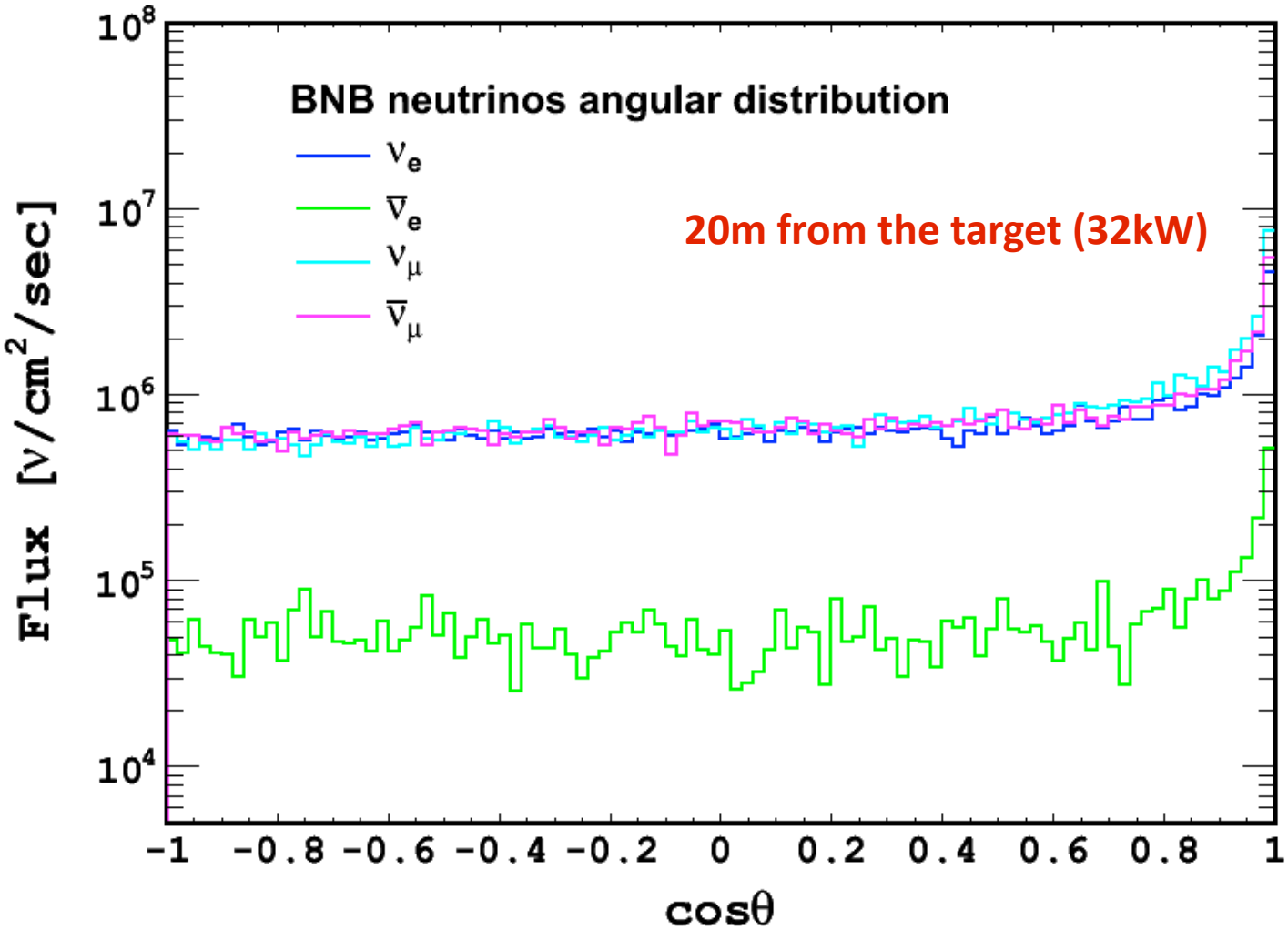


arXiv:0806.1449

Particle	Lifetime (ns)	Decay mode	Branching ratio (%)
π^+	26.03	$\mu^+ + \nu_\mu$	99.9877
		$e^+ + \nu_e$	0.0123
K^+	12.385	$\mu^+ + \nu_\mu$	63.44
		$\pi^0 + e^+ + \nu_e$	4.98
		$\pi^0 + \mu^+ + \nu_\mu$	3.32
K_L^0	51.6	$\pi^- + e^+ + \nu_e$	20.333
		$\pi^+ + e^- + \bar{\nu}_e$	20.197
		$\pi^- + \mu^+ + \nu_\mu$	13.551
		$\pi^+ + \mu^- + \bar{\nu}_\mu$	13.469
μ^+	2197.03	$e^+ + \nu_e + \bar{\nu}_\mu$	100.0

Dominant neutrino production process at the Far-Off-aXis is **pion decay at rest**

Far-Off-aXis Neutrinos at BNB



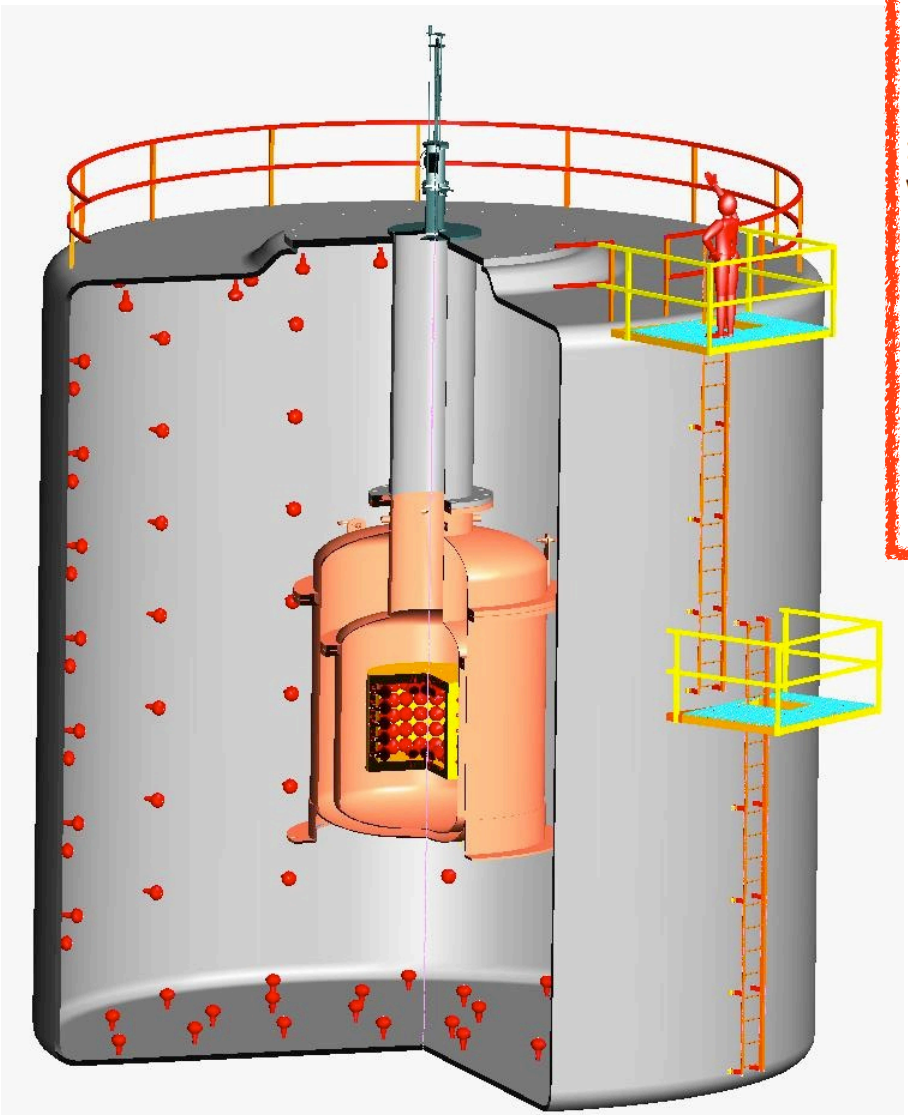
- **ϕ(BNB)≅ 5x10^5 ν/cm^2/s @20m, or 2x10^6 ν/cm^2/s @10m (cosθ<0.5)**

  (cf. ϕ(SNS)= 2x10^{6}ν/cm^2/s @46m, or 4.7×10^{6}ν/cm^2/s @30m)

- **Systematic uncertainties of the neutrino flux estimation should be checked in detail**

Low Energy Threshold LAr Neutrino Detector

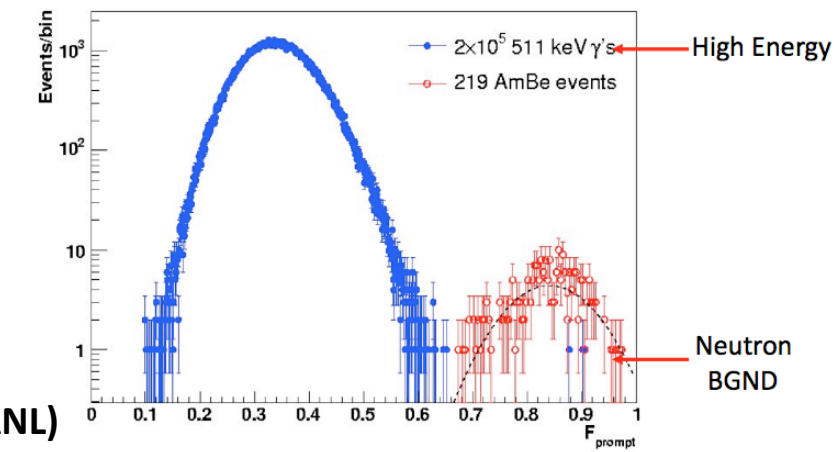
A ton-scale single phase LAr detector may perform the first ever observation of the CENNS at Fermilab



DEAP-0 Results & Projections for PSD in LAr

Avg. No. p.e.	Measured Leakage	Background Leakage	Projected PSD
50	$(2.4 \pm 0.6) \times 10^{-5}$	$(2.1 \pm 1.0) \times 10^{-5}$	1×10^{-10}
60	$(1.4 \pm 0.4) \times 10^{-5}$	$(1.5 \pm 0.9) \times 10^{-5}$	2×10^{-13}
70	$(1.0 \pm 0.4) \times 10^{-5}$	$(2.5 \pm 1.1) \times 10^{-5}$	1×10^{-17}

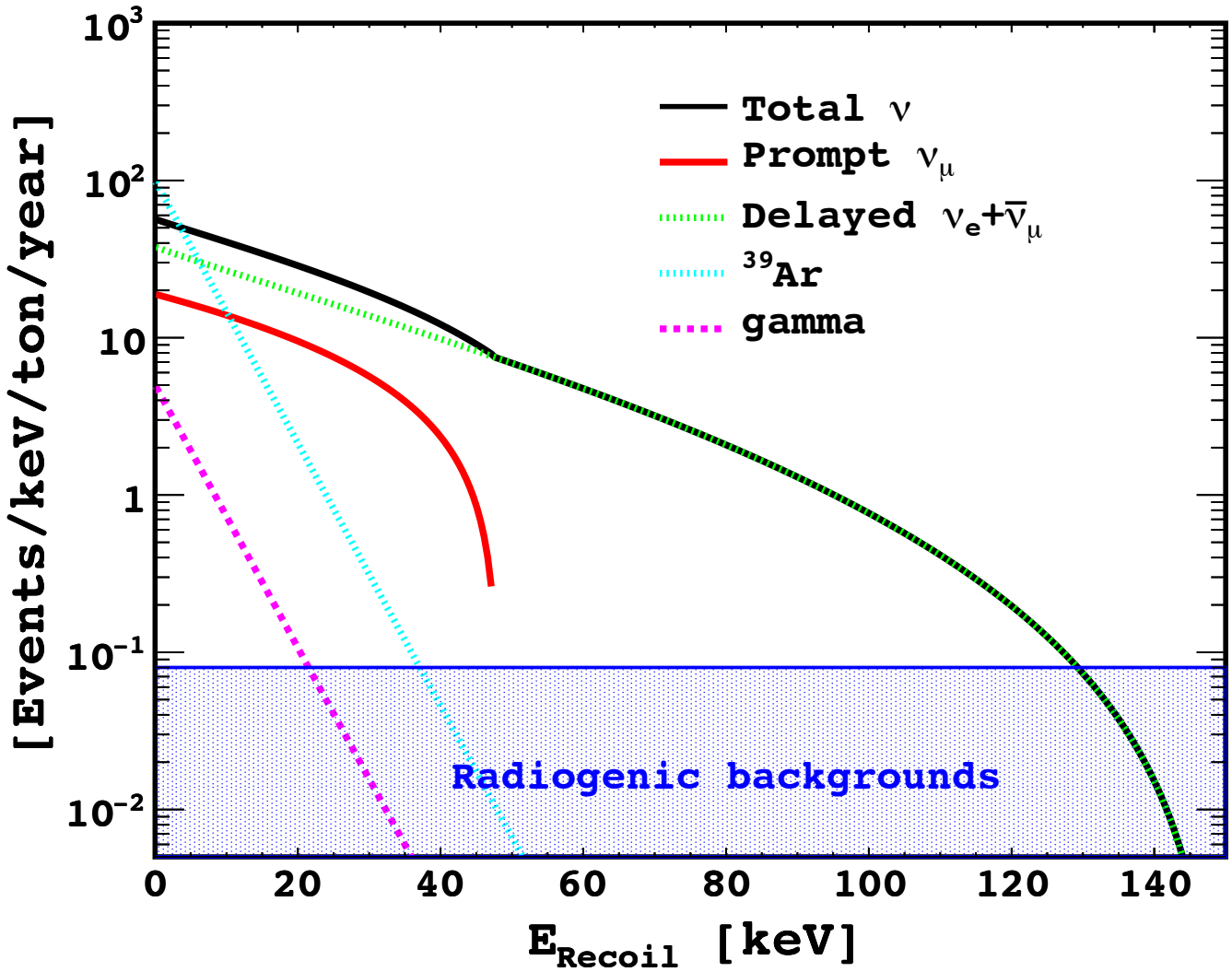
10 keV_{ee} with 5 p.e./keV



A. Hime (LANL)

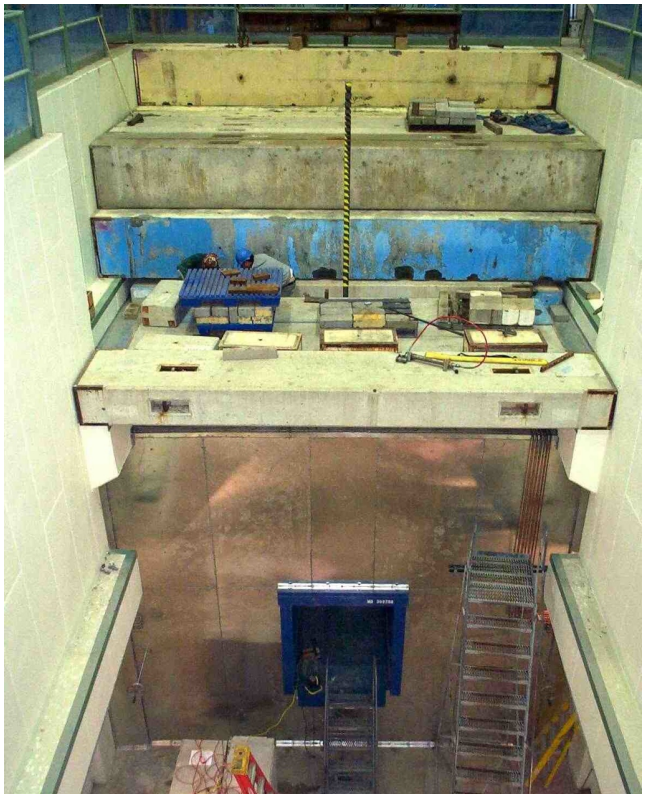
- Well known detector technology (DEAP/CLEAN)
- Use pulse shape discrimination of nuclear recoil (fast) and electron recoil (slow) signal in LAr (see Boulay and Hime: astro-ph/0411358)
- Long live (τ = 269yr) ^{39}Ar beta decay (1kBq/ton) wouldn't be a serious issue due to duty factor of pulsed beam & Pulse Shape Discrimination (PSD)

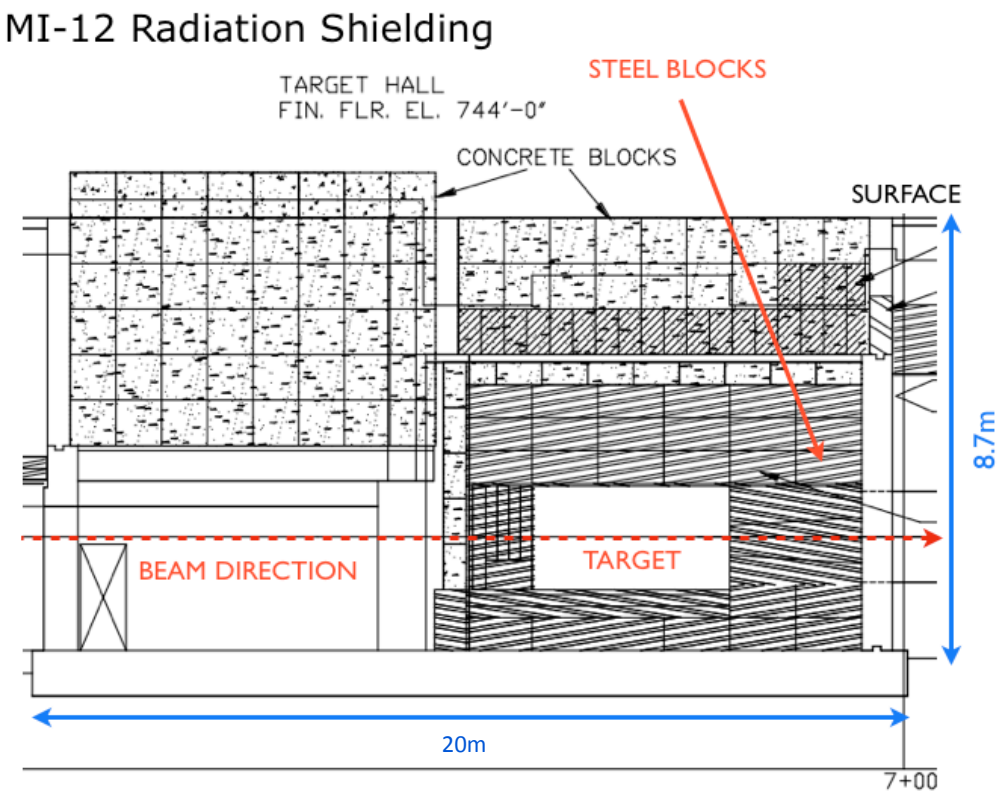
Expected CENNS Event Rates at Far-Off-Axis



- 20m from the target ($\phi \cong 5\times10^5$ v/cm^2/s)
- Steady state background rejection factor ~10^{-5} (Total exposure: ~300 sec/year)
- Event rate in a single-phase 1-ton LAr detector: ~200evt/ton/year (E_{th}> 30 keV @32kW)
- **Beam-induced neutron backgrounds ?**

BNB Target Radiation Shielding

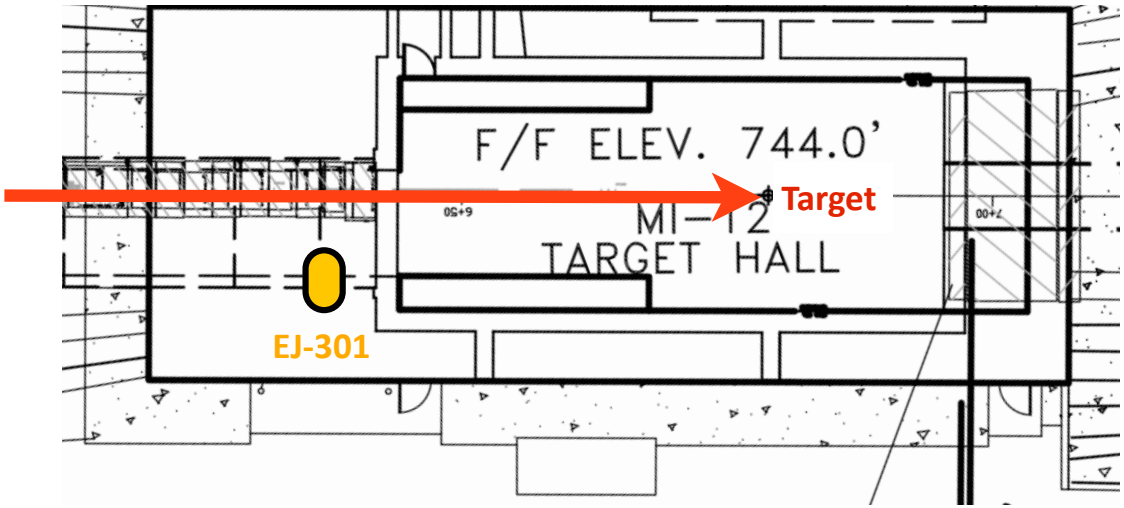


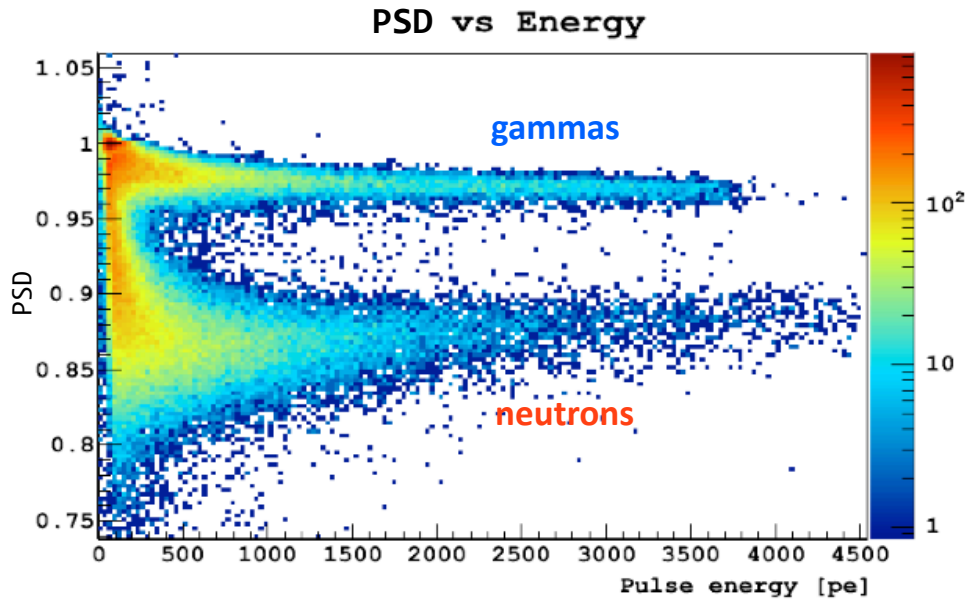


- Target is located 6.4m underground from the building surface
  - 2.6m-thick iron shielding blocks
  - 2.5m-thick concrete shielding blocks
- Neutron yield/pulse: N_n=(5×10^{12} pot/pulse) × (30 neutrons/proton)=1.5×10^{14} neutrons/pulse
  - ϕ_n(@surface;R=640cm w/ iron & concrete shielding) = ~102 neutrons/pulse/m^2
  - For 5"D×5"H neutron detector : Rate = 1.3 neutron pass/pulse
  - → **This is far from the accurate estimation**
- **Best way to figure out the backgrounds at the target building is to measure them**

Beam-induced Background Survey (2012)

MI-12 (TOP VIEW)





5"D EJ-301 (~kg) Commercial Liquid Scintillator (@target building surface)

- No (or rare, if any) beam-induced muons
- Gammas are easy to shield (lead blocks)
- Neutron shielding wasn't that easy
- High flux of neutrons are detected in the target building

SciBath : Neutral Particle Detector

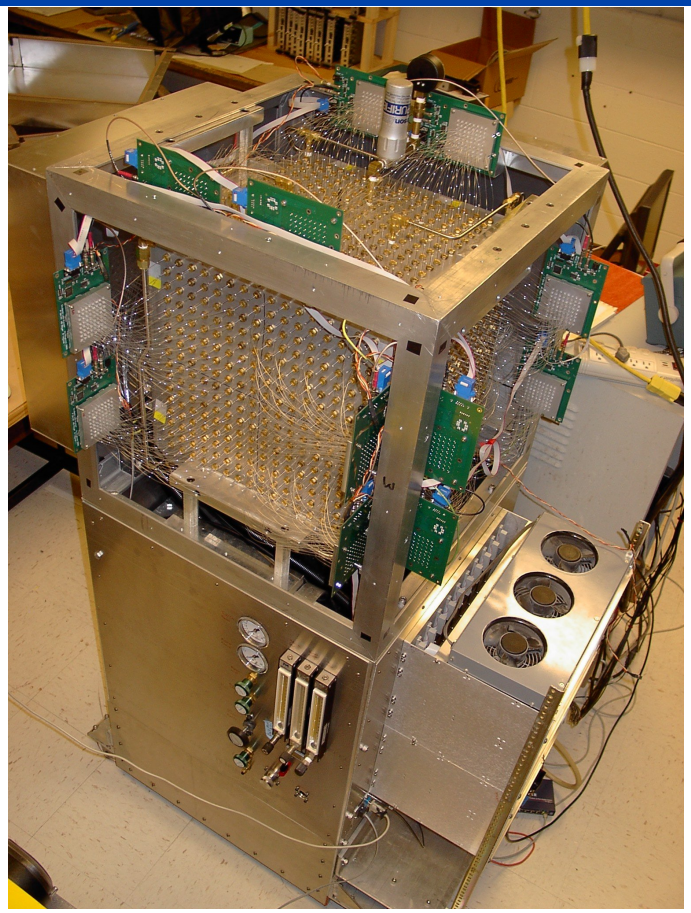
SciBath (Indiana University)

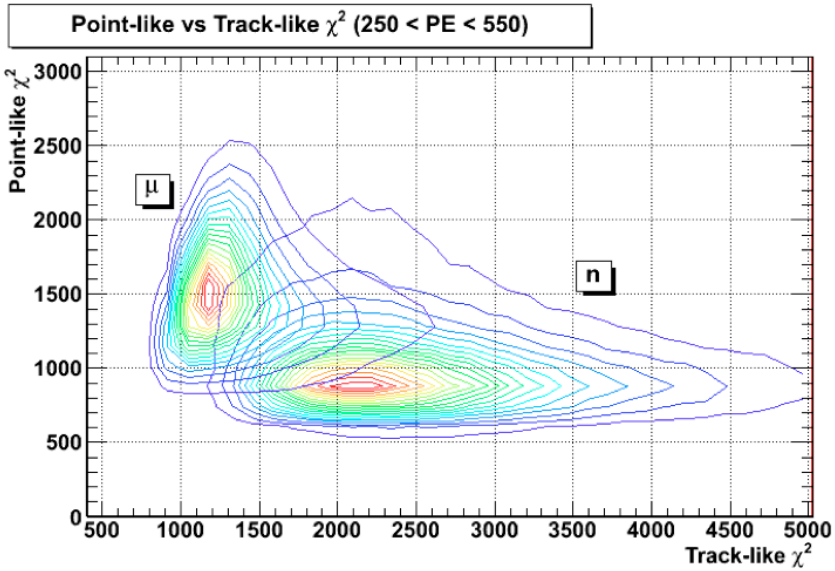
- Prof. R.Tayloe group's invention

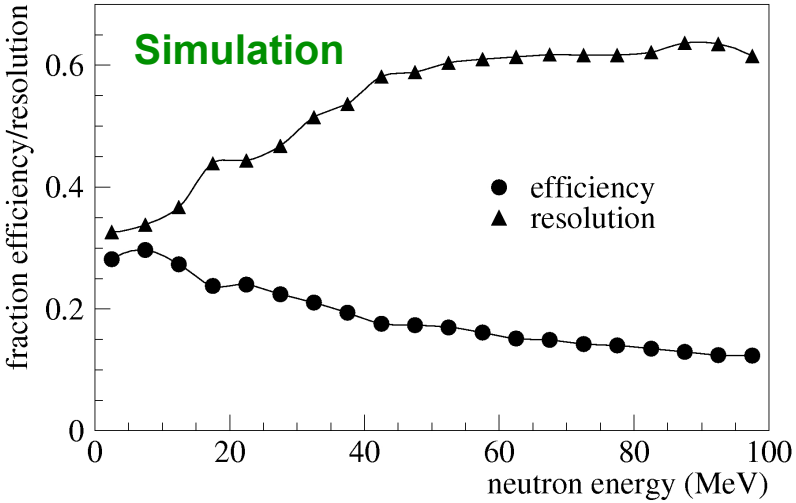
- (45cm)^3 volume containing
- 82 liters (70kg) of liquid scintillator:
  mineral oil, 11% pseudocumene, + PPO
- 3 16x16 grids, in x,y,z (768 total), 2.5cm spacing,
  1.5mm wavelength-shifting (WLS) fibers
  (UV->blue)
- coupled to clear plastic fibers, routed to readout:
- 12 Hamamatsu 64-anode PMTs
- custom-built readout system

Goal

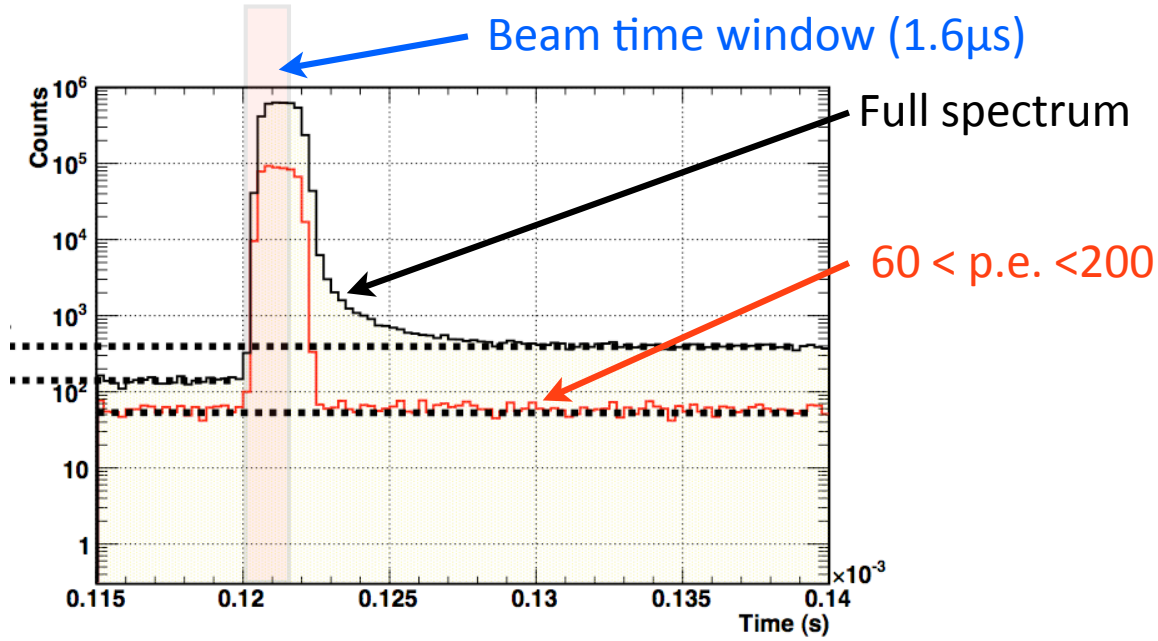
- Beam induced neutron background measurement
- cosmic-induced fast neutron flux measurement

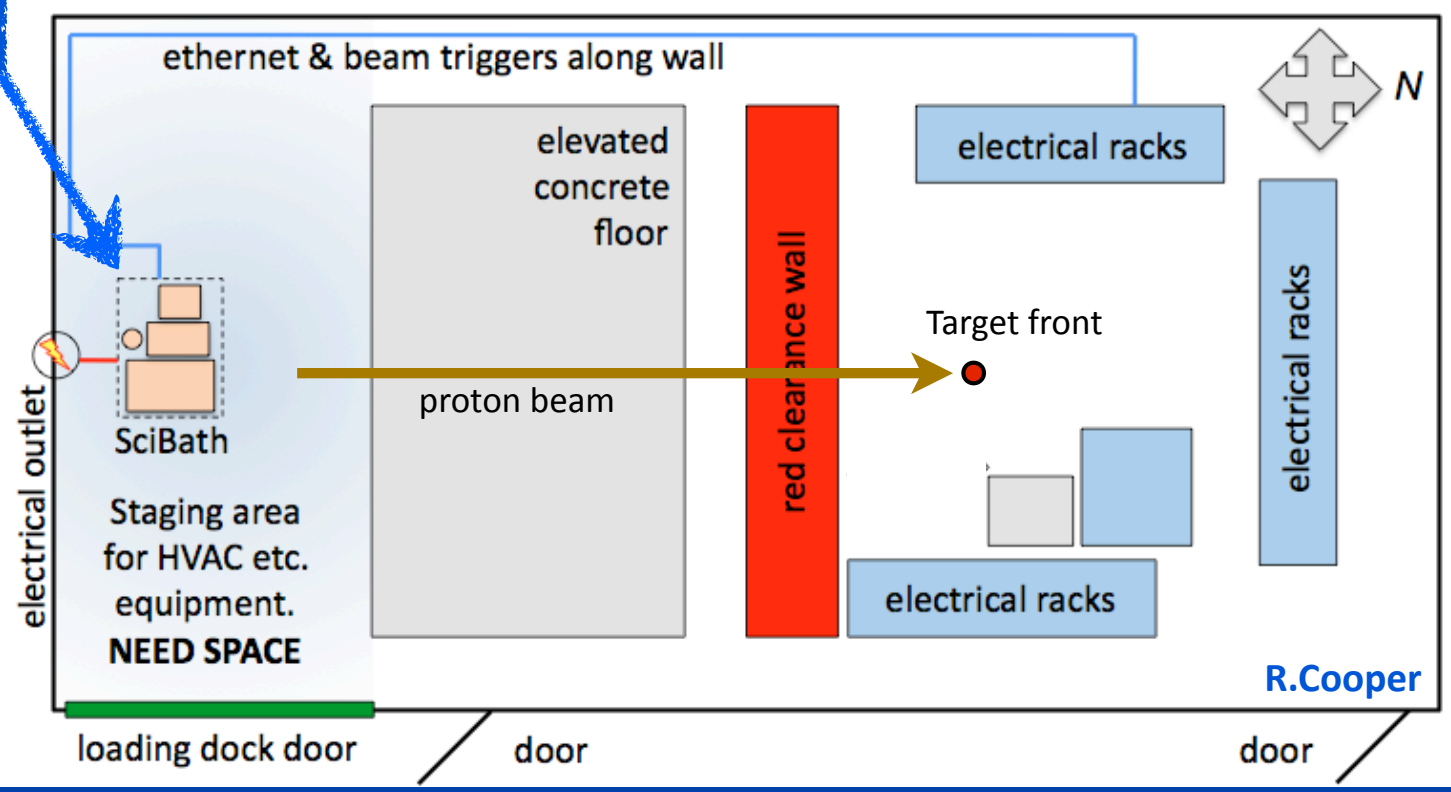






SciBath at BNB Target Building (2012)

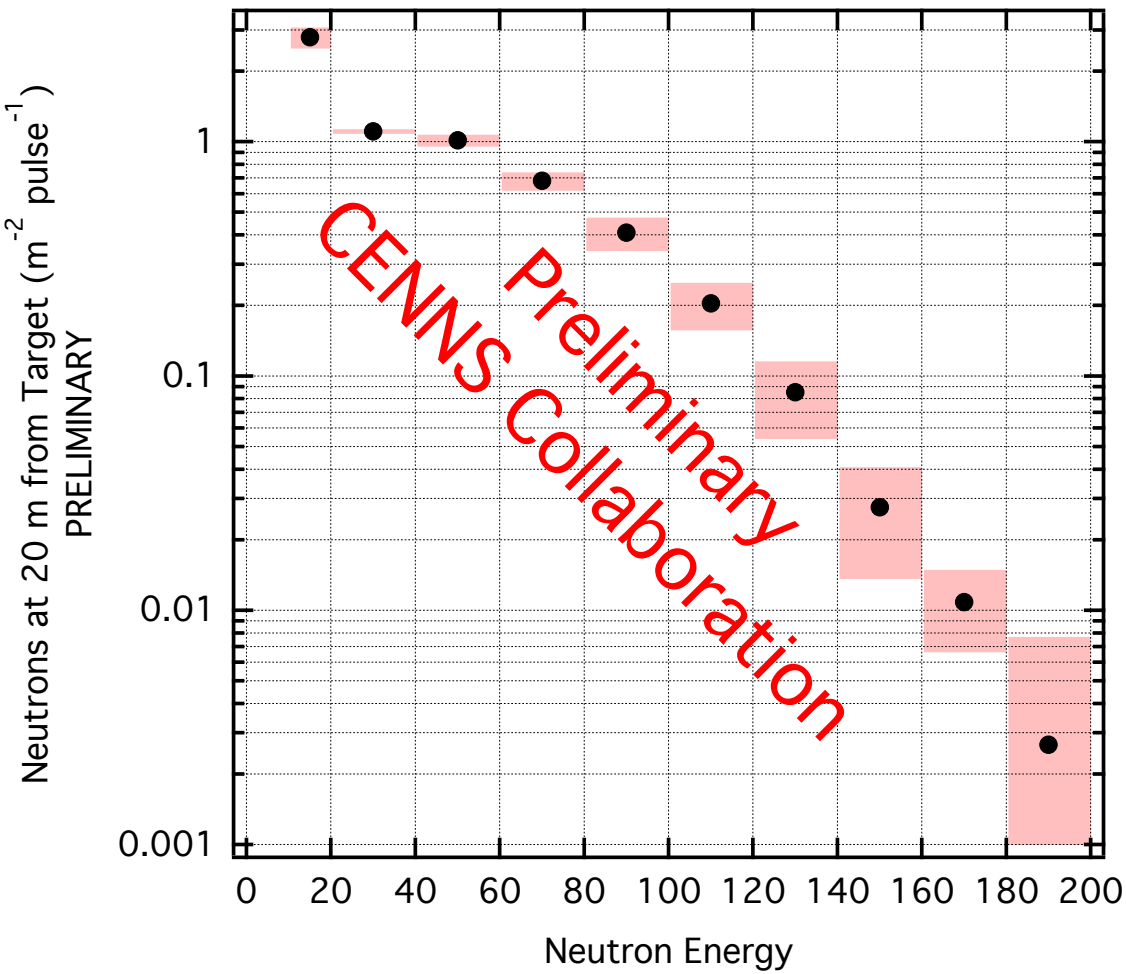




- Detector located in the target building (MI-12 @20m away from the target)
- Pre-beam, in-beam, off-beam backgrounds measurements
- Data taking: Feb~Apr 2012

Neutron Flux and Energy Spectrum

Measured neutron spectrum at MI-12



The experiment doesn't have to be zero background: trade offs between neutrino flux, background rate and live time

Fast Neutrons

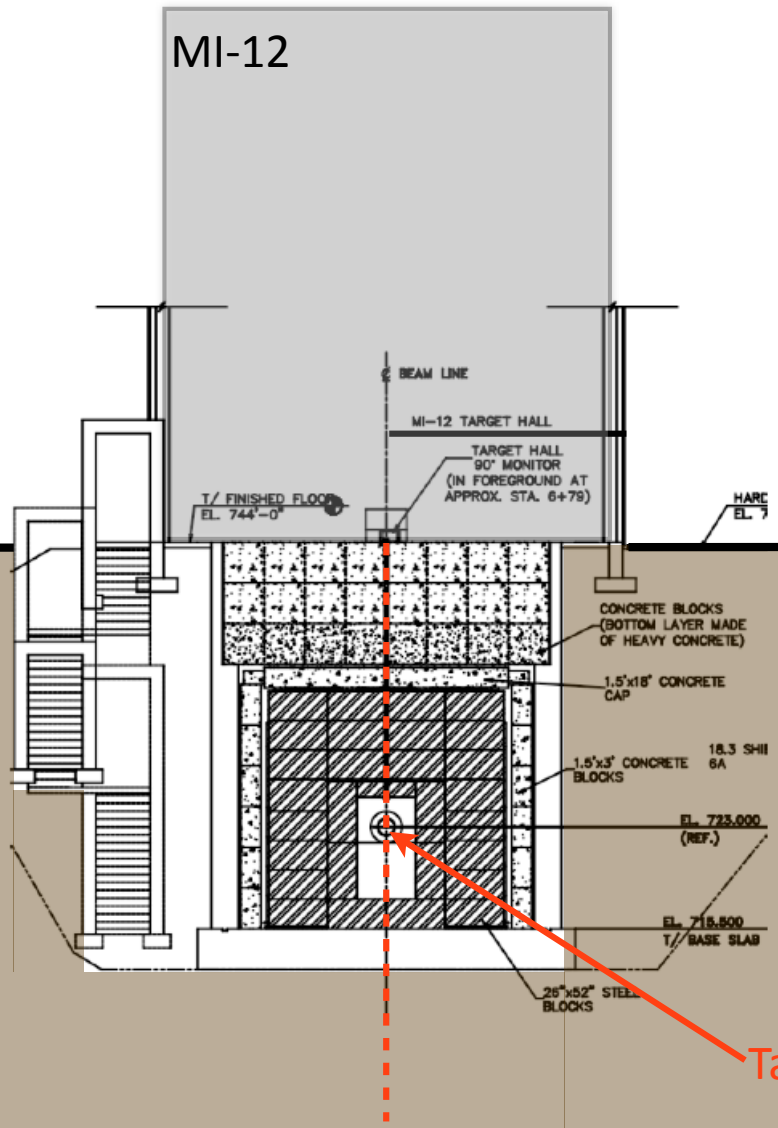
- **meters of shielding needed**
- **often counterintuitive**
- **need for different layers (steel, concrete, water, poly …)**

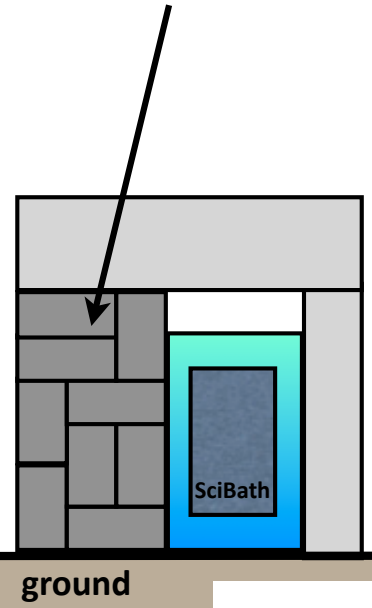
Neutron Shielding

Best way is to measure the neutron shielding effects at the experimental site.

Neutron Shielding Test Option

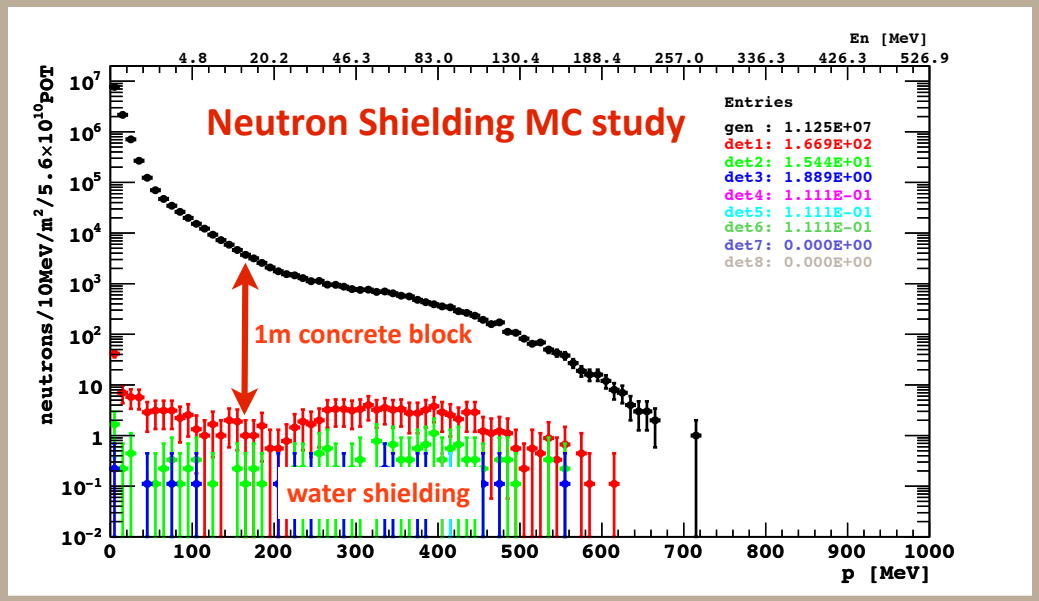
Concrete blocks
or other shielding material





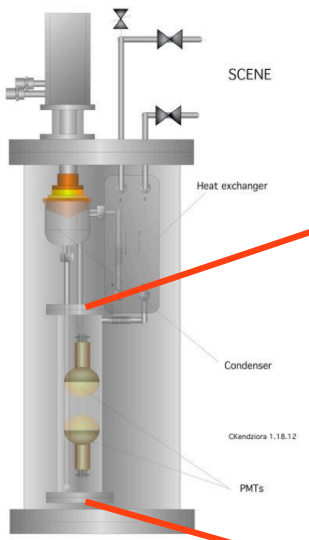
- Conceptually easy to build
- Fermilab has a lot of concrete blocks
- Easy to test shielding effects
- Need advice from AD safety team
- FESS consider this is a possible option

- **This test do not affect any activities at MI-12 and MicroBOONE experiment**



*** We are forming a team with NCSU and LANL neutronics group to carry out MC study of neutron shielding**

Low Energy Threshold LAr Detector Development

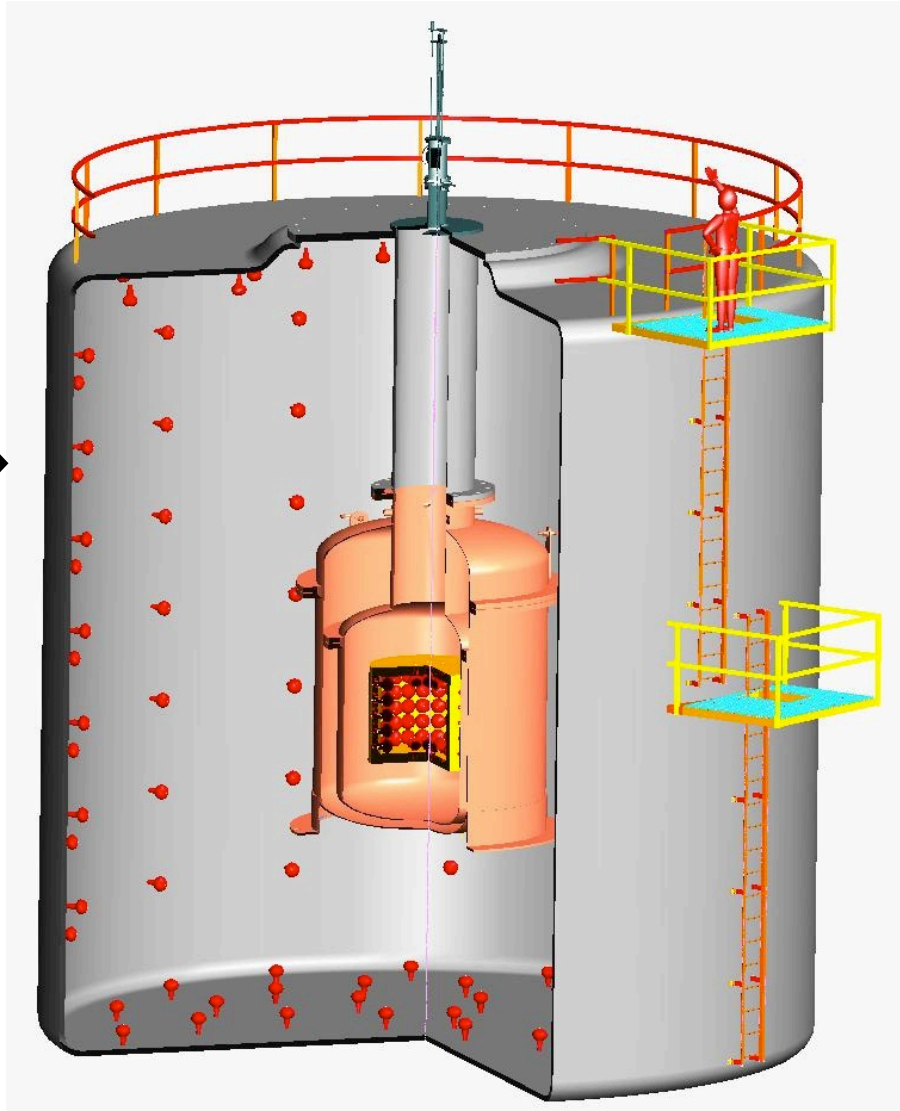


1-kg detector 2012

- Operational experience
- Measure scintillation light efficiency of nuclear recoils in LAr

10-kg detector 2013

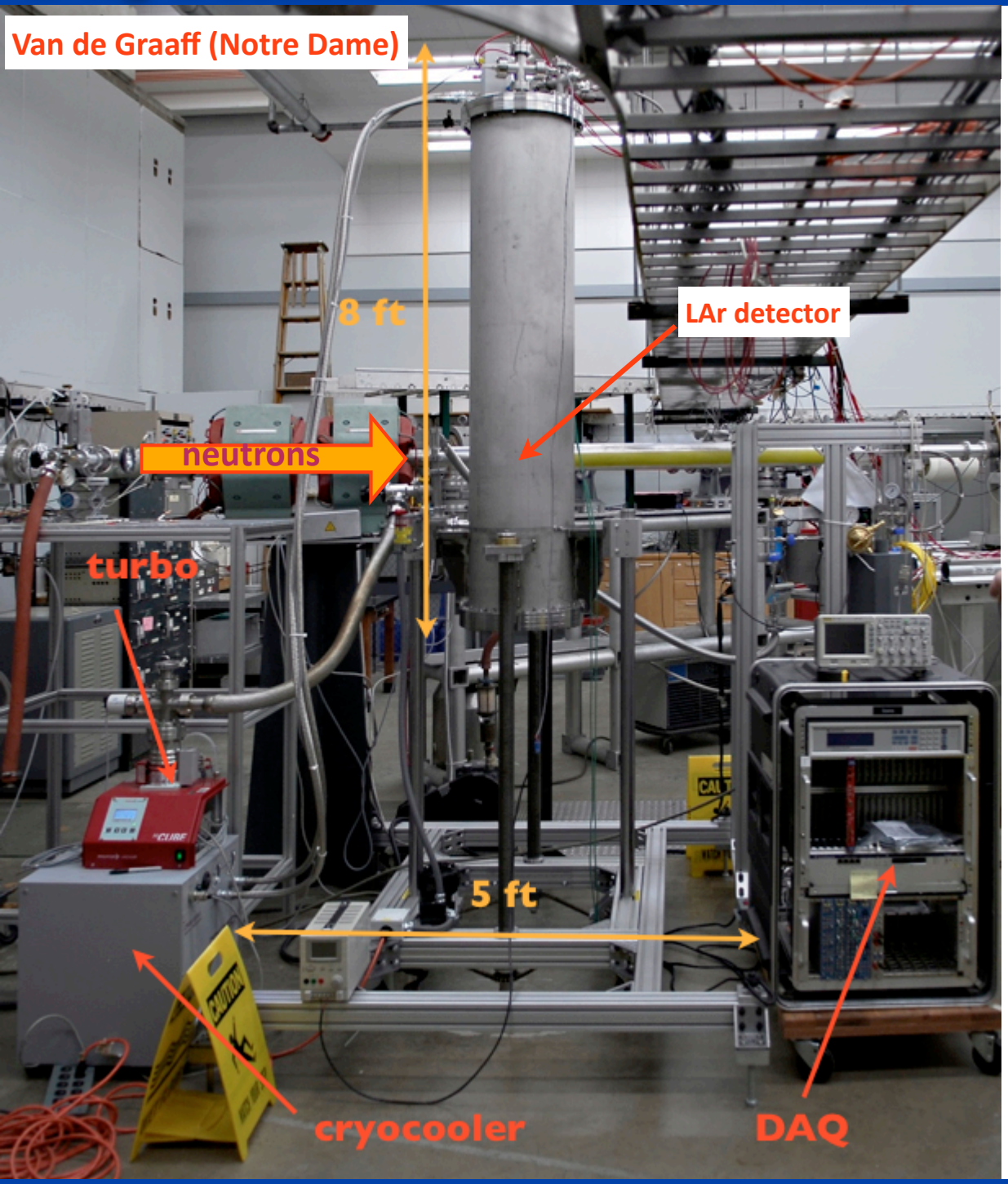
- Study beam induced neutron shielding near the beam target
- Characterize the BNB neutron backgrounds in LAr target
- Understand design issues of the ton-scale detector



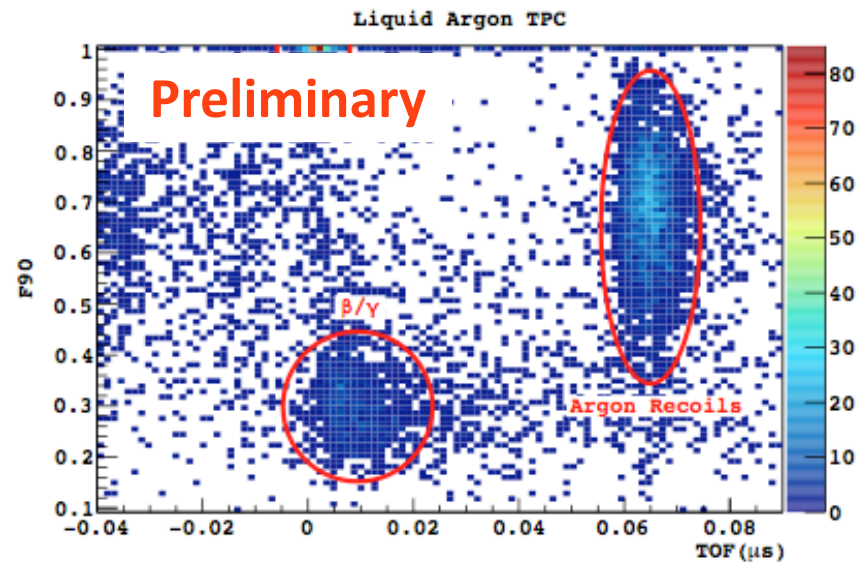
Ton-scale detector for the CENNS experiment

Detector R&D with LANL (Hime's group)

1-kg Detector in Neutron Beam



Neutron Beam Data



1-kg LAr prototype detector

- **SCENE Collaboration**: (CENNS+DarkSide)
  SCintillation Efficiency of Noble Elements
- Goals:
  Measure scintillation light yield
  in low-energy (<50 keV) nuclear recoils
- Can run in single-phase mode
  or dual phase TPC mode
- Use pulsed neutron beam
  at University of Notre Dame
- **Strong support by**
  Fermilab Detector R&D Group

10-kg Detector

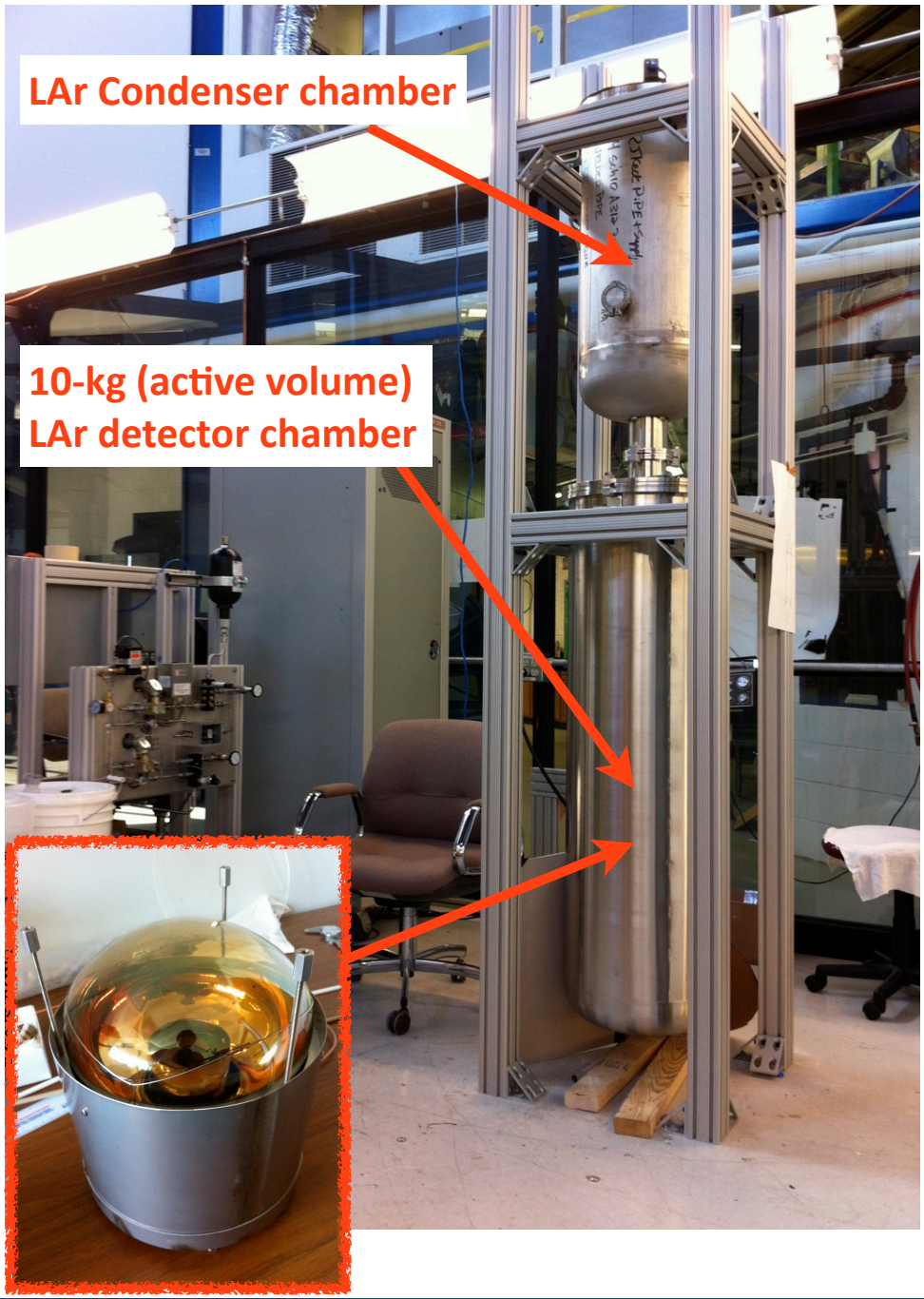
10-kg prototype detector

- Goals:
  - Neutron background study at BNB site
  - Demonstrate detector performance
  - Light collection efficiency R&D
    (energy threshold study)

- All major parts are ordered and purchased

- Initial phase will use two R5912-02MOD
  8” PMTs (Hamamatsu)
  - PMT test in progress

- Full detector to be ready in summer 2013



Prospect of LowE-ν Intensity Frontier

Far-off-axis BNB neutrino source is an extremely valuable resource to study beam background and neutrino flux

BNB Era

- Understand beam-induced neutron background at the BNB target area and establish shielding methods (~early 2014: depends on beam schedule)
- Propose CENNS experiment to Fermilab Physics Advisory Committee (2014)
- CENNS experiment (2017~2018)
- OscBNB experiment at Fermilab? (2018~)
  - One can imagine putting a full absorption targe
  - Target is cheaper if it is not a spallation source
- Supernova Neutrino Cross-section measurements
  - long-term needs of many nuclei for different N's and Z's

Project-X Era

- Neutrino flux and beam background study at BNB will be an important input to design the Project-X target
- BNB target station (MI-12) and detector infrastructure would still be very useful to test different target material
- The Project X stage-1 siting plan includes the option for a compressor ring which could drive a high power target for low energy neutrino experiments.
- A chance to design a detector close to source (4π coverage detector facilities?)

Summary

- **A lot of interesting physics cases in low energy neutrino interactions.**
  - More details: https://indico.fnal.gov/conferenceDisplay.py?confId=5926

- **Fermilab has a '*well-defined*' low-energy neutrino source: BNB.**
  - It is a very valuable asset by two practical reasons
    1. New physics in low energy neutrino study
    2. Beam and target parameter input study for Project-X program

- **CENNS was predicted at Fermilab. It can be discovered at Fermilab as well.**

- **Necessary next step for the full CENNS proposal development are**
  (1) demonstrate the neutron shielding and develop a design for the experiment
  (2) understand LAr detector response at the BNB
  (3) evaluate full systematic uncertainties of the CENNS experiment

Request to PAC

- Endorse the physics case for using the far-off-axis Booster Neutrino Beam to discover Coherent Elastic Neutrino Nucleus Scattering.

- Endorse the expenditure of modest ($200k M&S and 2 FTE in FY14) Fermilab resources to pursue shielding and site placement study so that a full proposal can be developed.

"Study of coherent, NC scattering of neutrinos would be a wonderful way to probe whether neutrinos oscillate into sterile states. ….. (Confession: I've long liked the idea of coherent neutrino scattering -- thinking about that is what got me to switch from strong-interaction particle physics to weak-interaction particle physics in 1973.)"

- Boris Kayser 2012-10-10 e-mail to Jonghee Yoo -

Backup Slides

CENNS Collaboration

Fermi National Accelerator Laboratory : S.J. Brice, E. Ramberg, B.Loer, R. Tesarek and J. Yoo

Duke University: K. Scholberg

Indiana University: R. Tayloe, R. Cooper and L. Garrison

Los Alamos National Laboratory: A. Hime, C. Mauger, M. Mocko, G. Muhrer, and K. Rielage

National Research Nuclear University (Russia): A. Bolozdynya

North Carolina State University: A. Young and R. Pattie

Universita Federico II and INFN (Italy): A. Cocco

University of California, Los Angeles: H. Wang

University of Florida: H. Ray

University of Houston: E. Hungerford

University of Tennessee: Y. Efremenko

Virginia Tech: C. Mariani

Yale University: F. Cavanna

Physics Cases of CENNS

Possible physics program with the existing neutrino source

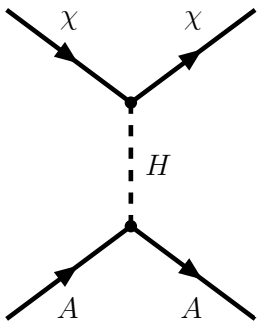
- **Discovery of CENNS (40 years of endeavor)**
- **Study of irreducible backgrounds of Dark Matter experiments**
- **Oscillations to sterile neutrinos (Neutral Current)**
- **Important input to understand supernova explosion**

Future Experiments with intensive neutrino source (Project-X era)

- **Test Standard Model weak mixing angle ($sin\vartheta_W$):** K.Scholberg, PRD73 (2006)
- **Non-standard interaction of neutrinos:** J.Barranco et al, hep-ph/0702175
- **Neutrino magnetic moment:** P. Vogel and J. Engel, Phys. Rev. D39, 3378 (1989)
- **Neutron form factor from coherent scattering of neutrinos:** K. Patton et al, Phys.Rev. C86 (2012) 024612

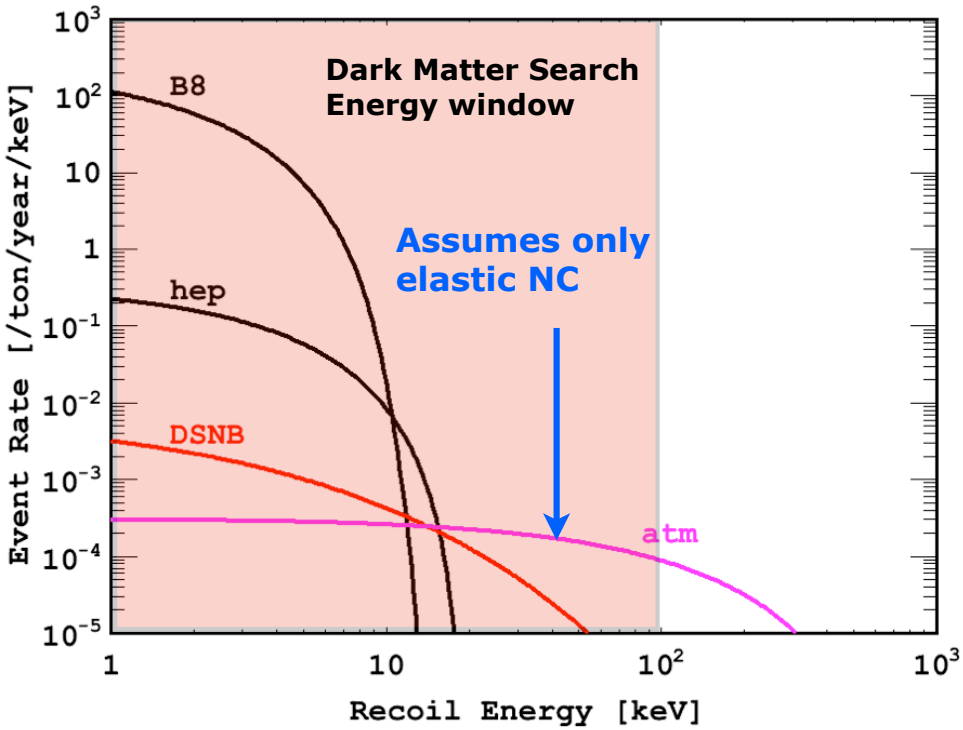
→ Neutrinos always provided us with the physics beyond the *then-Standard Model* !

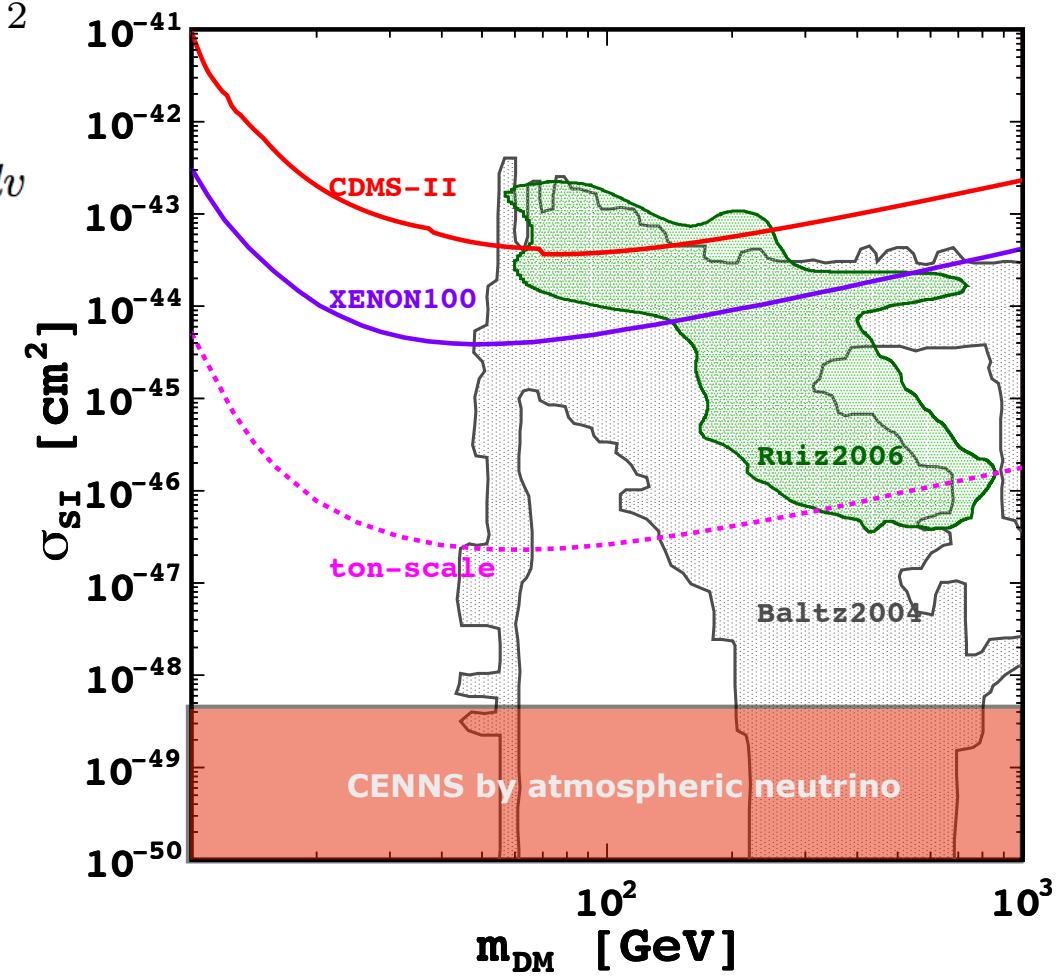
Irreducible Backgrounds of Dark Matter Search



$$\sigma_{\chi N} \simeq \frac{4}{\pi}\mu^2[Zf_p + (A-Z)f_n]^2$$

$$\frac{dR}{dE} = \frac{\sigma_0}{m_\chi}\frac{A^2}{2\mu_n^2}F_A^2(E) \times \rho_0 \int_{v_m} \frac{f(v)}{v}dv$$

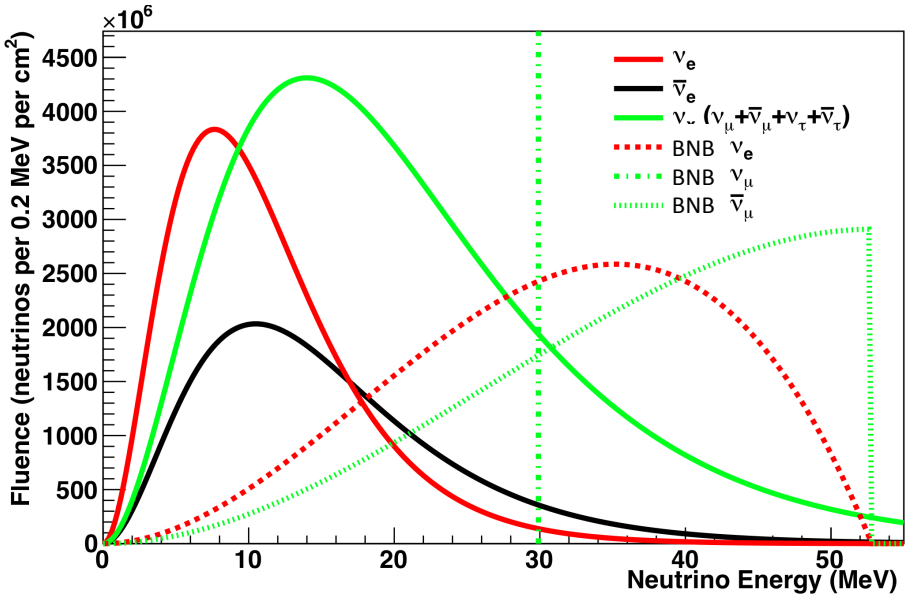




- Coherent scattering of atmospheric neutrino is an irreducible background in future *O*(10 ton) scale dark matter experiments (see Strigari, arXiv:0903.3630)

Sensitivity of dark matter detectors will be saturated out by irreducible neutrino backgrounds

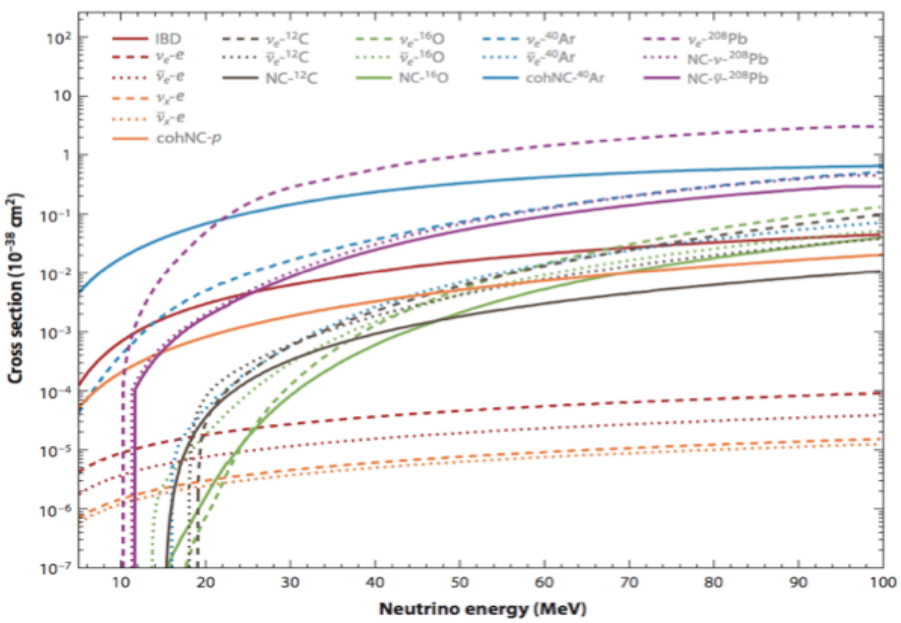
Supernova Physics



Neutrinos are intimately involved in the post-collapse explosion, which is not fully understood

- Explosion mechanism
- proto-neutron star cooling
- black hole formation
- nucleosynthesis

Supernova spectrum overlaps very nicely with pion decay at rest neutrino spectrum

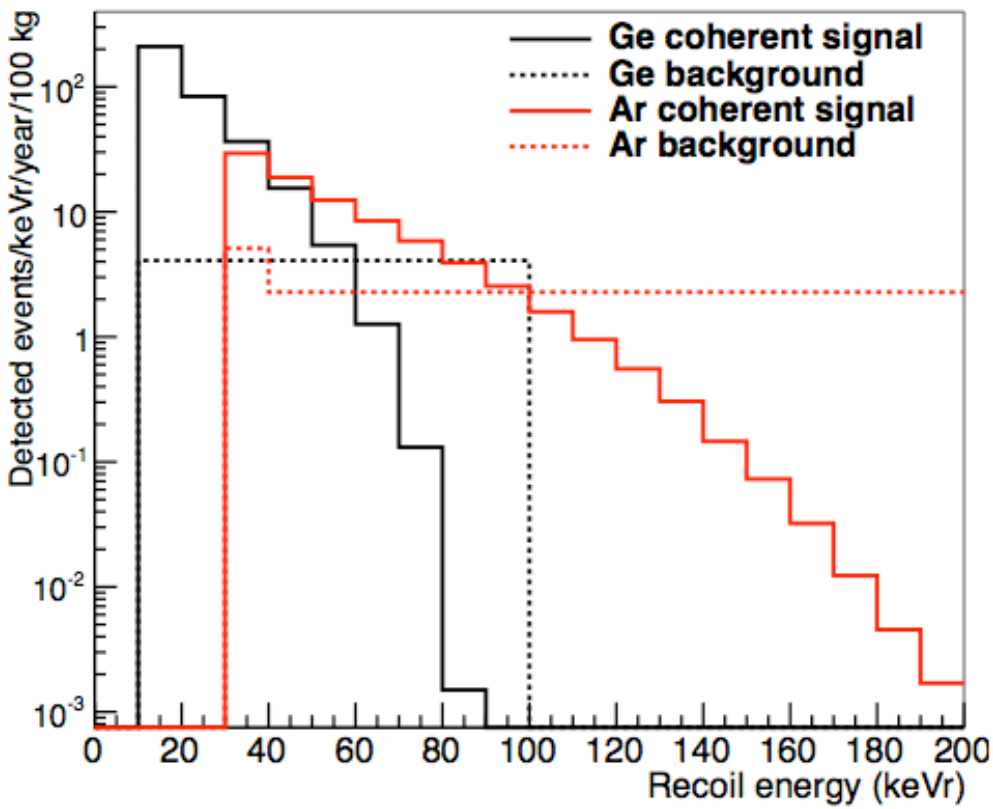


Neutrino Interaction at SN neutrino energy range is very poorly measured

Only IBD and ν-e elastic scatterings are known in a few % level. It's important to understand SN explosion process and SN neutrino detection

K. Scholberg at Coherent NCνAs mini-workshop at FNAL
Horowitz, Coakley, McKinsey Phys Rev D 68 (2003) 023005

Neutrino Oscillation Physics

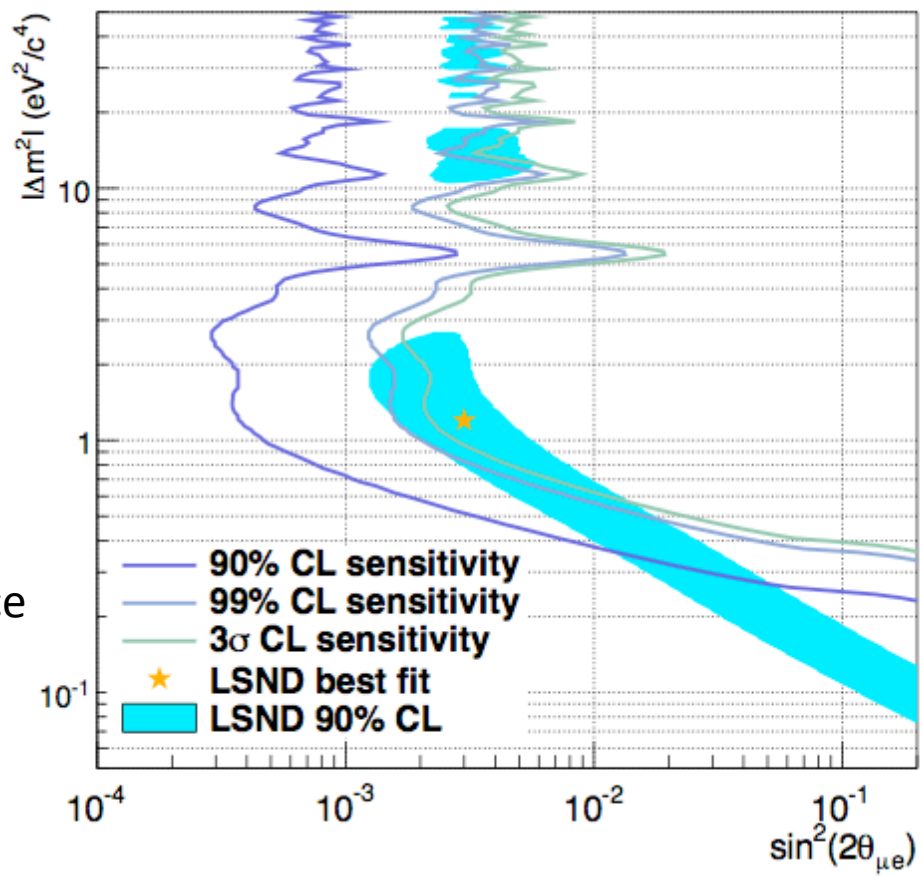


J. Anderson et al, Phys. Rev. D86, 013004 (2012)

$$P(\nu_\alpha \rightarrow \nu_{\alpha'}) = 4|U_{\alpha 4}|^2(1-|U_{\alpha 4}|^2)\sin^2(1.27\Delta m^2_{41}L/E)$$

Active to sterile neutrino oscillation search

Neutral Current is the best way for sterile neutrinos searches

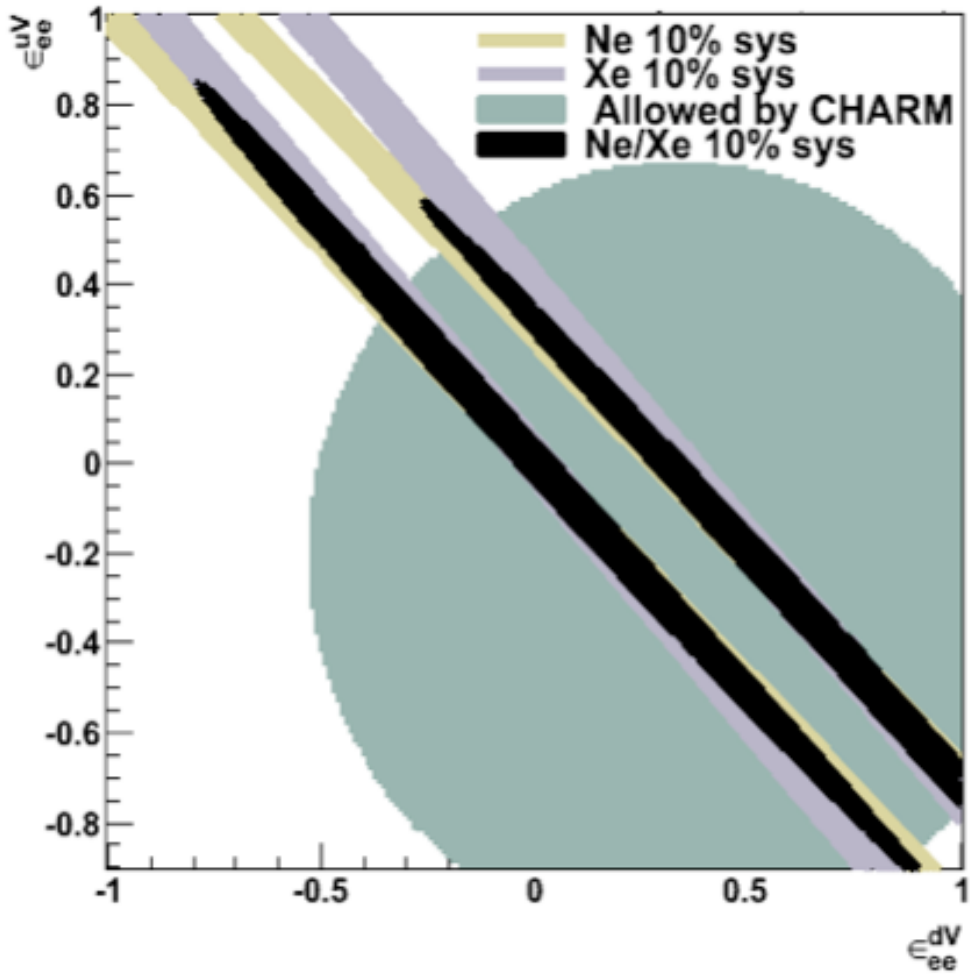


This particular study is based on DAEδULAS configuration of pion decay at rest neutrino source

A similar experiment is possible with improved beam condition and large scale CENNS detector

The key to these physics cases is to discover CENNS first!

- **Non-Standard Interaction**



For flavor α, spin-0 nucleus

$$\left(\frac{d\sigma}{dE}\right)_{\nu_\alpha A} = \frac{G_F^2 M}{\pi} F^2(2ME)\left[1-\frac{ME}{2k^2}\right]\times$$
$$\{[Z(g_V^p+2\varepsilon_{\alpha\alpha}^{uV}+\varepsilon_{\alpha\alpha}^{dV})+N(g_V^n+\varepsilon_{\alpha\alpha}^{uV}+2\varepsilon_{\alpha\alpha}^{dV})]^2$$
$$+\sum_{\alpha\neq\beta}[Z(2\varepsilon_{\alpha\beta}^{uV}+\varepsilon_{\alpha\beta}^{dV})+N(\varepsilon_{\alpha\beta}^{uV}+2\varepsilon_{\alpha\beta}^{dV})]^2\}$$
$$g_V^p = (\frac{1}{2}-2\sin^2\theta_W),\quad g_V^n = -\frac{1}{2}$$
$$\varepsilon_{\alpha\beta}^{qV} = \varepsilon_{\alpha\beta}^{qL}+\varepsilon_{\alpha\beta}^{qR}$$

NSI affect total cross-section

The effect depends on N and Z

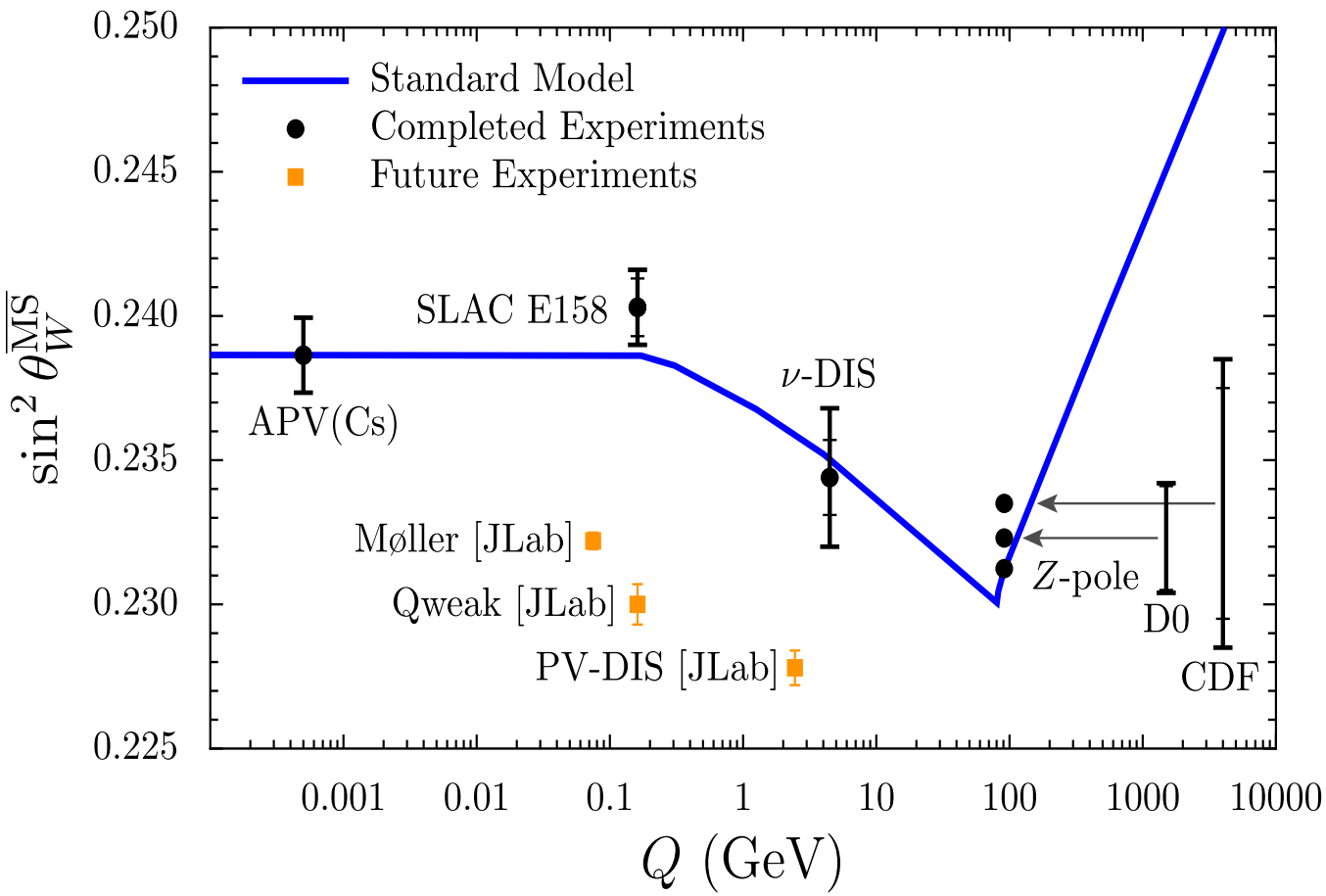
If this effect observed, Dark Matter interaction cross-section calculation should be revisited

Physics Cases for CENNS

- **Measuring $\sin^2\theta_W$**

$$\sigma_{\nu N} \simeq \frac{4}{\pi} E_\nu^2 \left[Z\omega_p + (A-Z)\omega_n \right]^2$$

$$g(Z_0 u) = \frac{1}{4} - \frac{2}{3}\sin^2\theta_W, \qquad g(Z_0 d) = -\frac{1}{4} + \frac{1}{3}\sin^2\theta_W$$

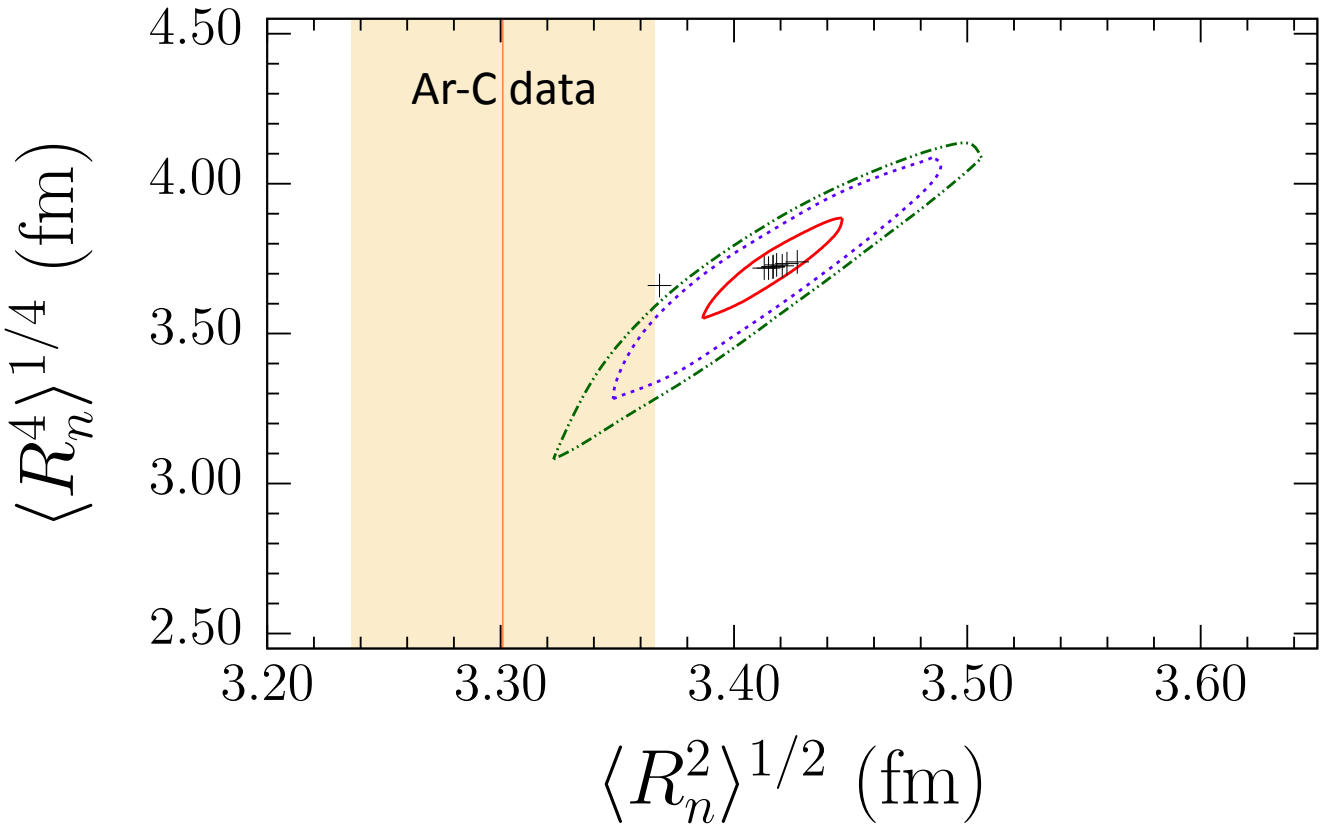


Bentz et al., Phys Lett B 693 (2010) 462-466
see also Scholberg, Phys Rev D 73 (2006) 033005

- **Form Factor Moments**

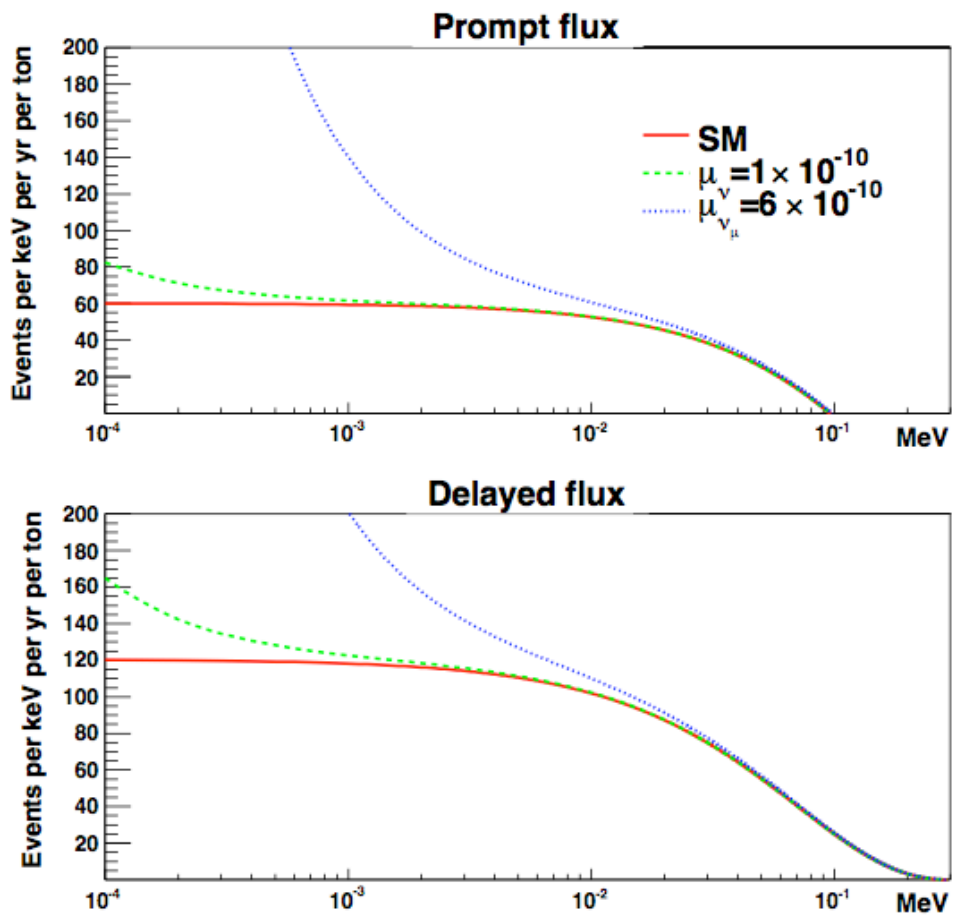
$$F(Q^2) = \frac{1}{Q_W}\left[F_n(Q^2) - (1 - 4\sin^2\theta_W)F_p(Q^2)\right]$$

$$F_n(Q^2) \approx \int \rho_n(r)\left(1 - \frac{Q^2}{3!}r^2 + \frac{Q^4}{5!}r^4 - \frac{Q^6}{7!}r^6 + \cdots\right) r^2 dr$$



Patton et al., arXiv/1207.0693

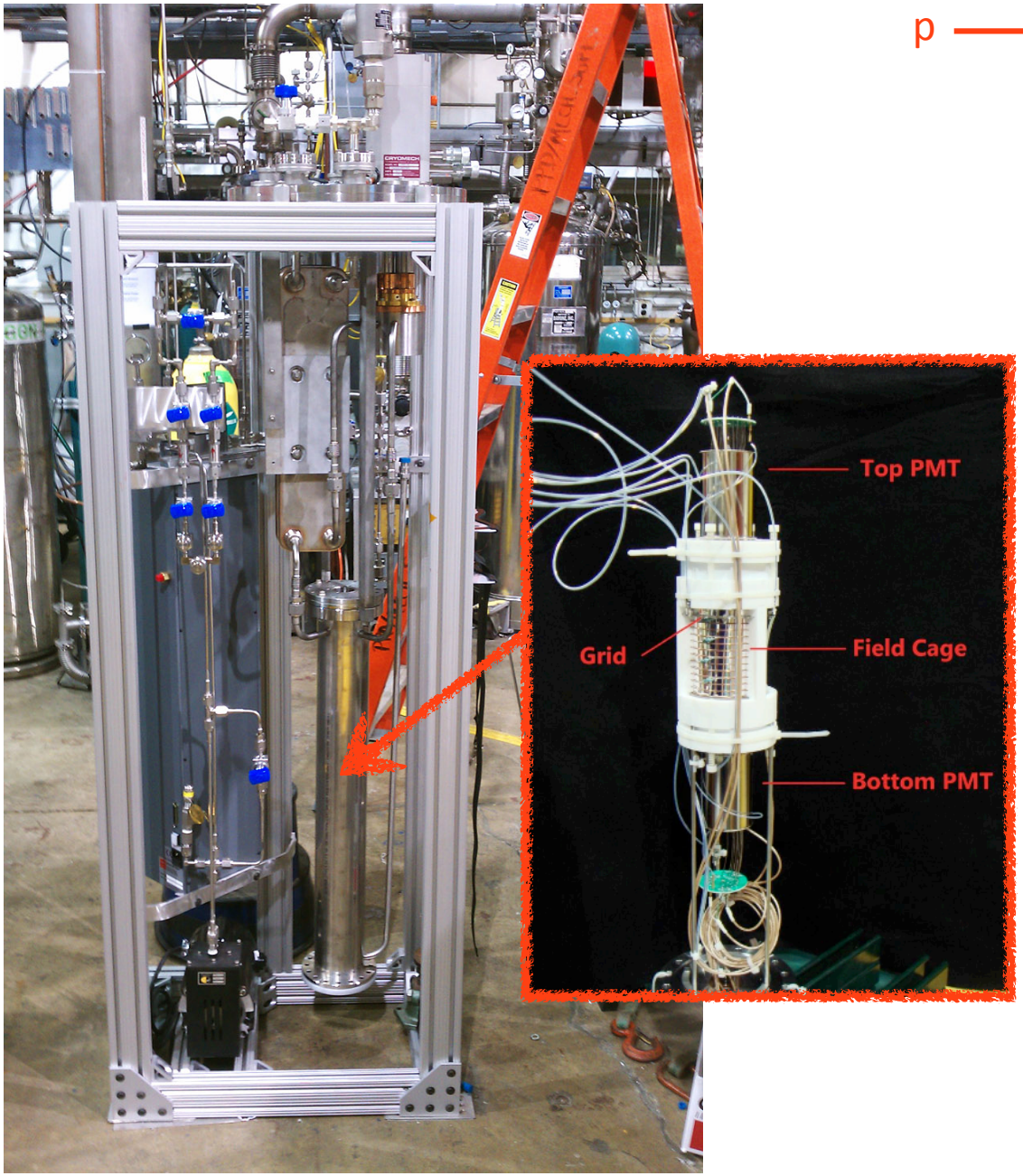
- **Neutrino Magnetic Moments**

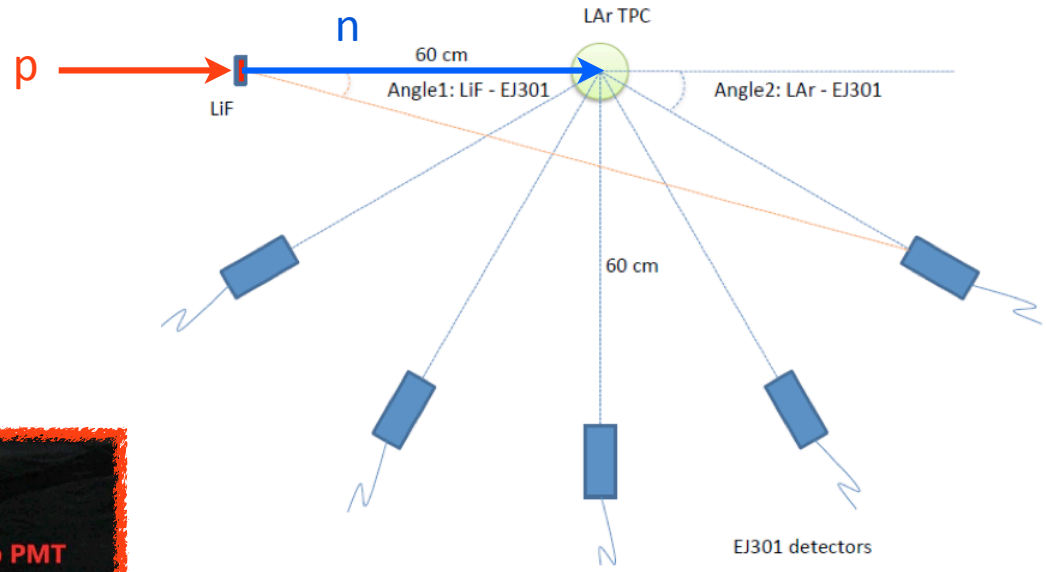


- Differential yield as a function of nuclear recoil energy. (pion decay-at-rest neutrino source on neon target)
- Requires intensive neutrino flux (project-X era)

Scholberg., PRD73, 033005, 2006 (hep-ex/0511042v2)

1-kg LAr Detector



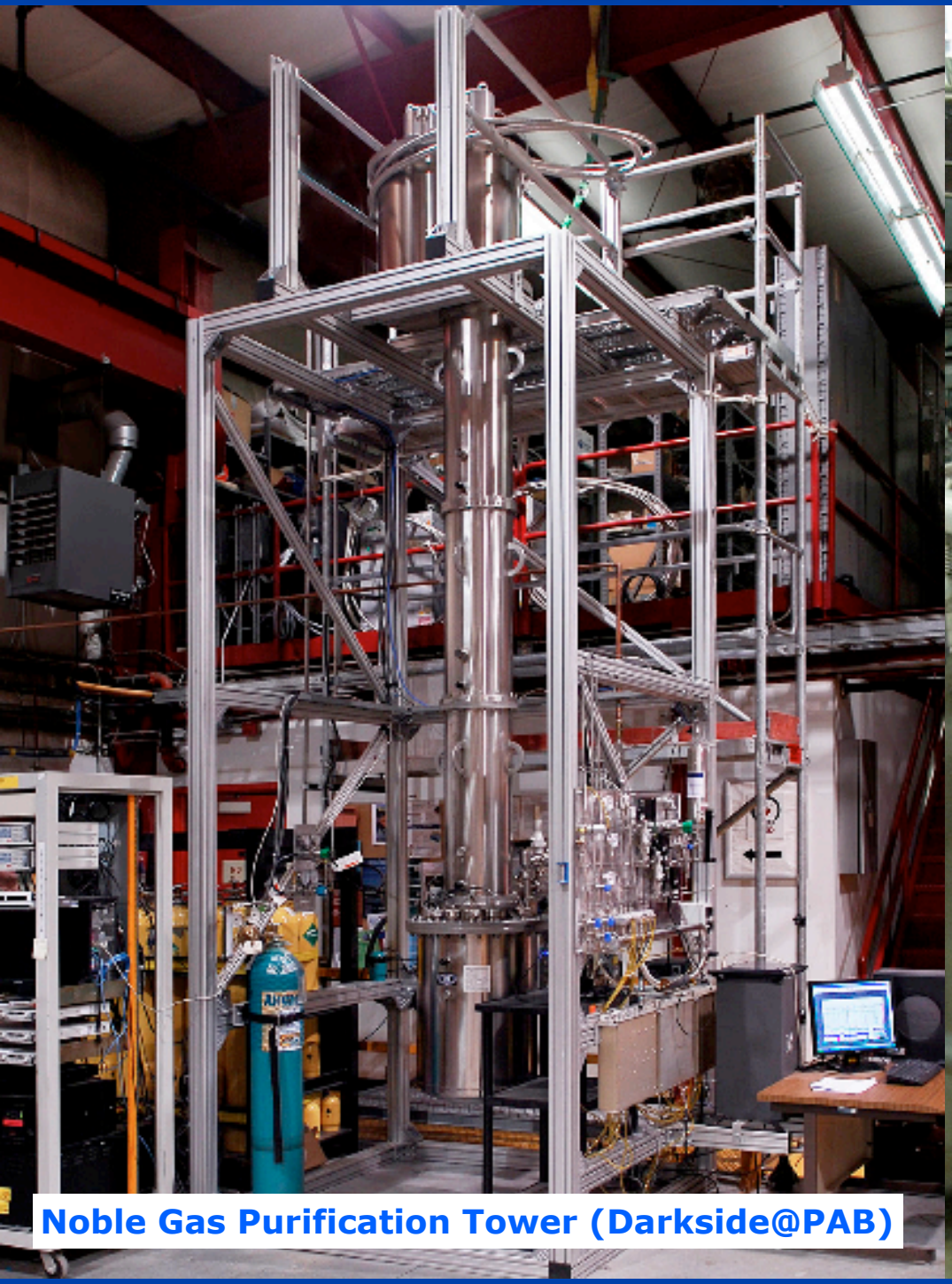


1-kg LAr prototype detector

- **SCENE Collaboration**: (CENNS+DarkSide)
  SCintillation Efficiency of Noble Elements
- Goals:
  Measure scintillation light yield
  in low-energy (<50 keV) nuclear recoils
- Can run in single-phase mode
  or dual phase TPC mode
- Use pulsed neutron beam
  at University of Notre Dame
- **Strong support by Detector R&D Group**

Fermilab Noble Gas Detector R&D Facility

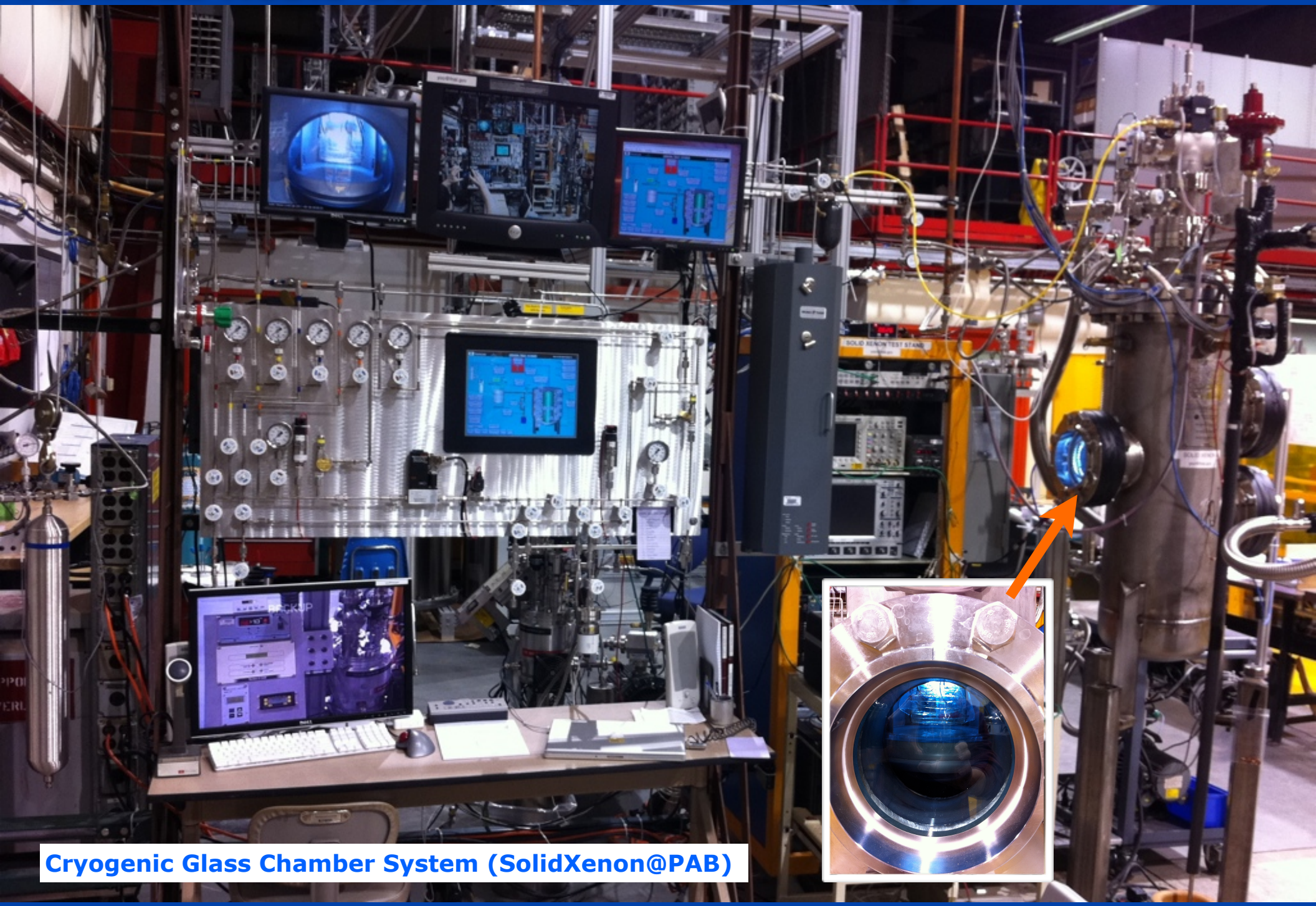
Fermilab Noble Gas Detector R&D Facility



Noble Gas Purification Tower (Darkside@PAB)

Liquid Argon Purity Demonstrator (LAPD@PC4)

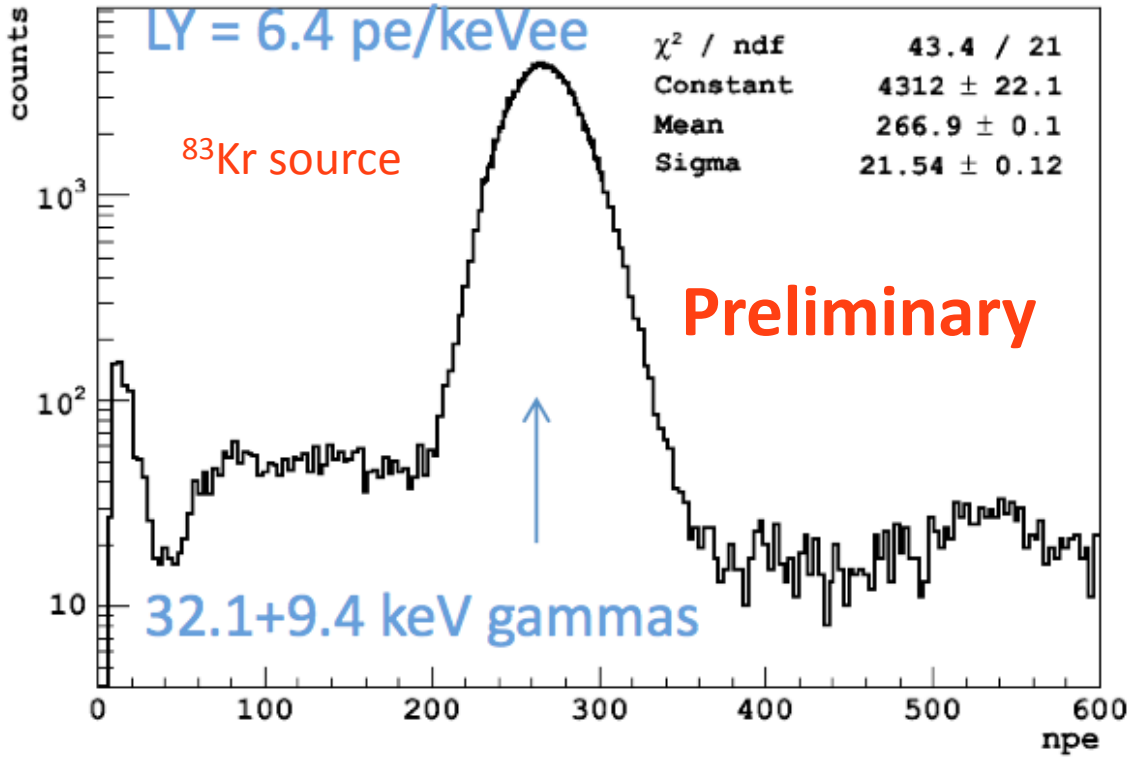
Fermilab Noble Gas Detector R&D Facility



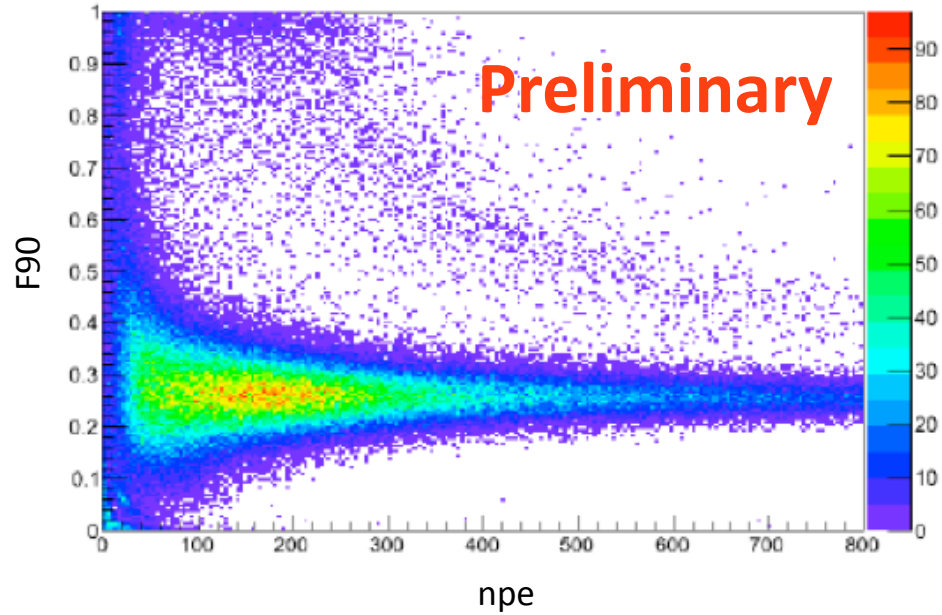
Cryogenic Glass Chamber System (SolidXenon@PAB)

1-kg Detector Performance

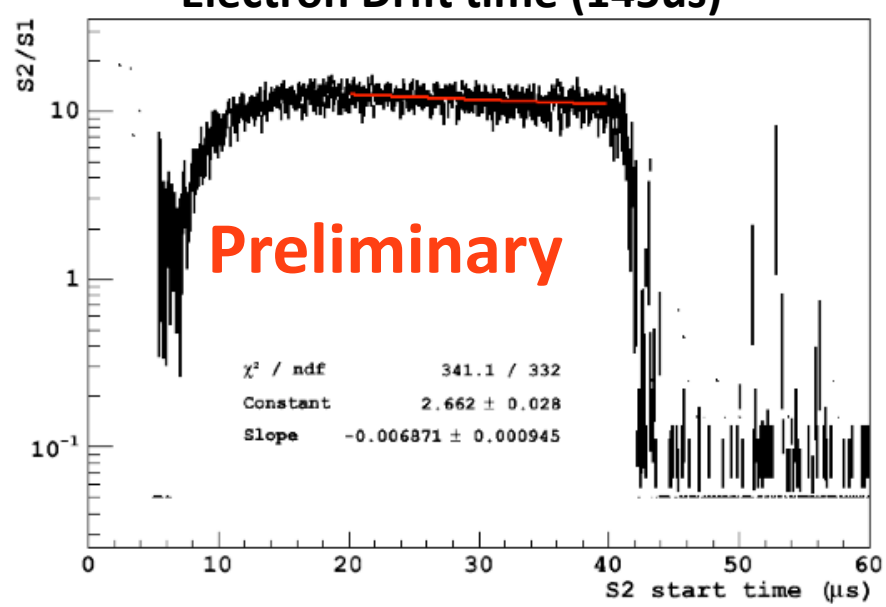
Gamma Light Yield (single phase)



Pulse Shape Discrimination



Electron Drift time (145us)



- Detector performance is good enough to carry out in-beam measurement
- Date taking at the end of 2012 and early 2013

10-kg Detector

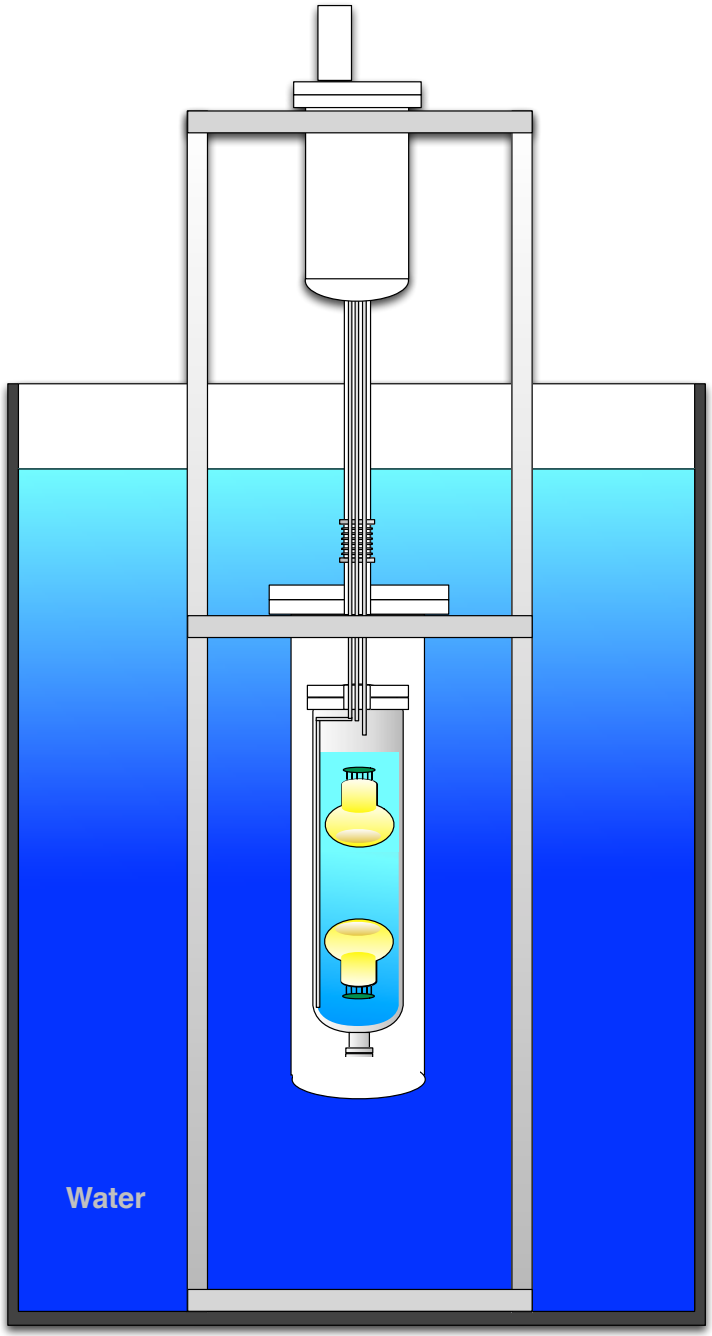
10-kg prototype detector

- Goals:
  - Neutron background study at BNB site
  - Demonstrate detector performance
  - Light collection efficiency R&D
    (energy threshold study)

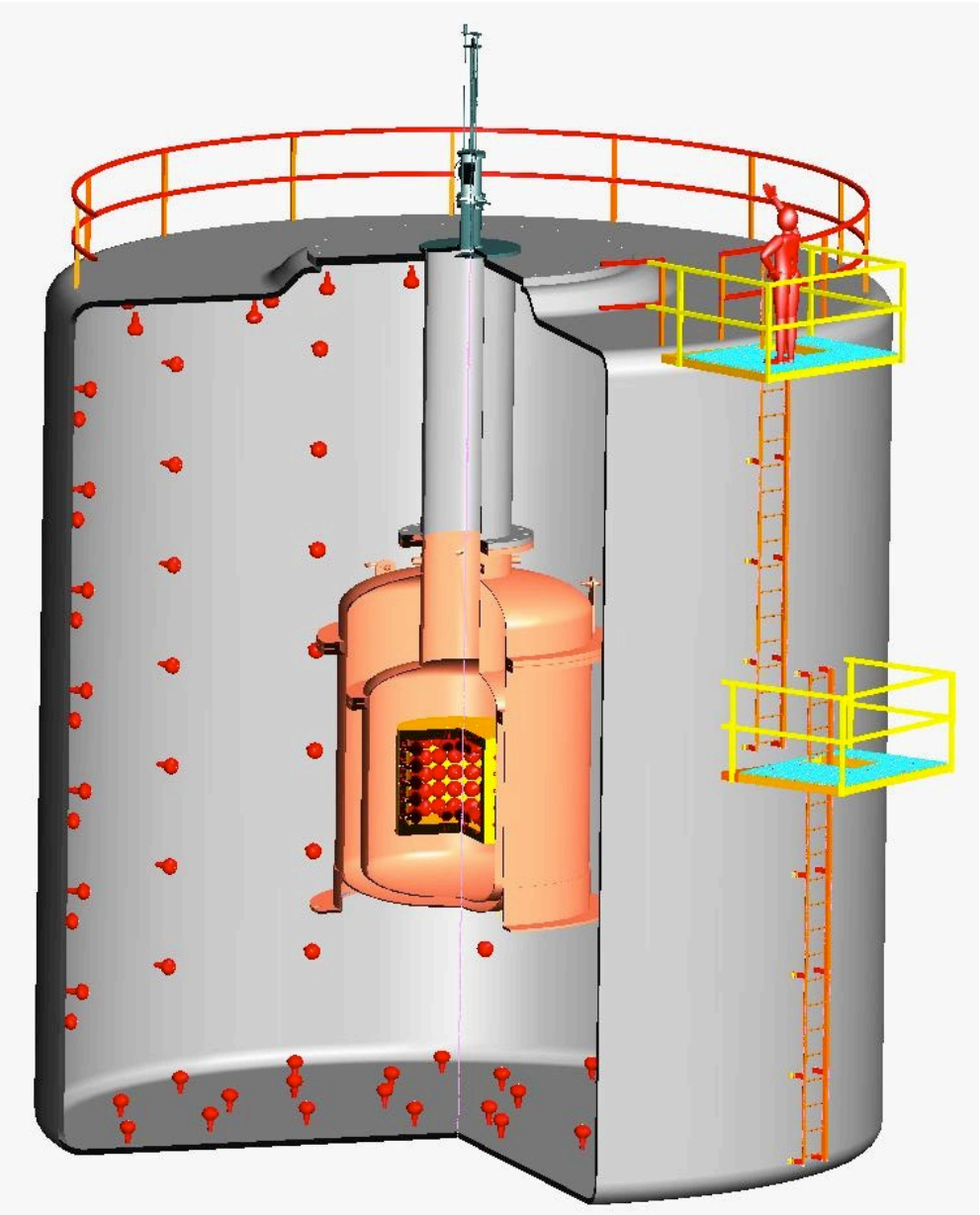
- Parts are ordered and purchased

- Initial phase will use two R5912-02MOD 8” PMTs (Hamamatsu)

- To be ready in 2013

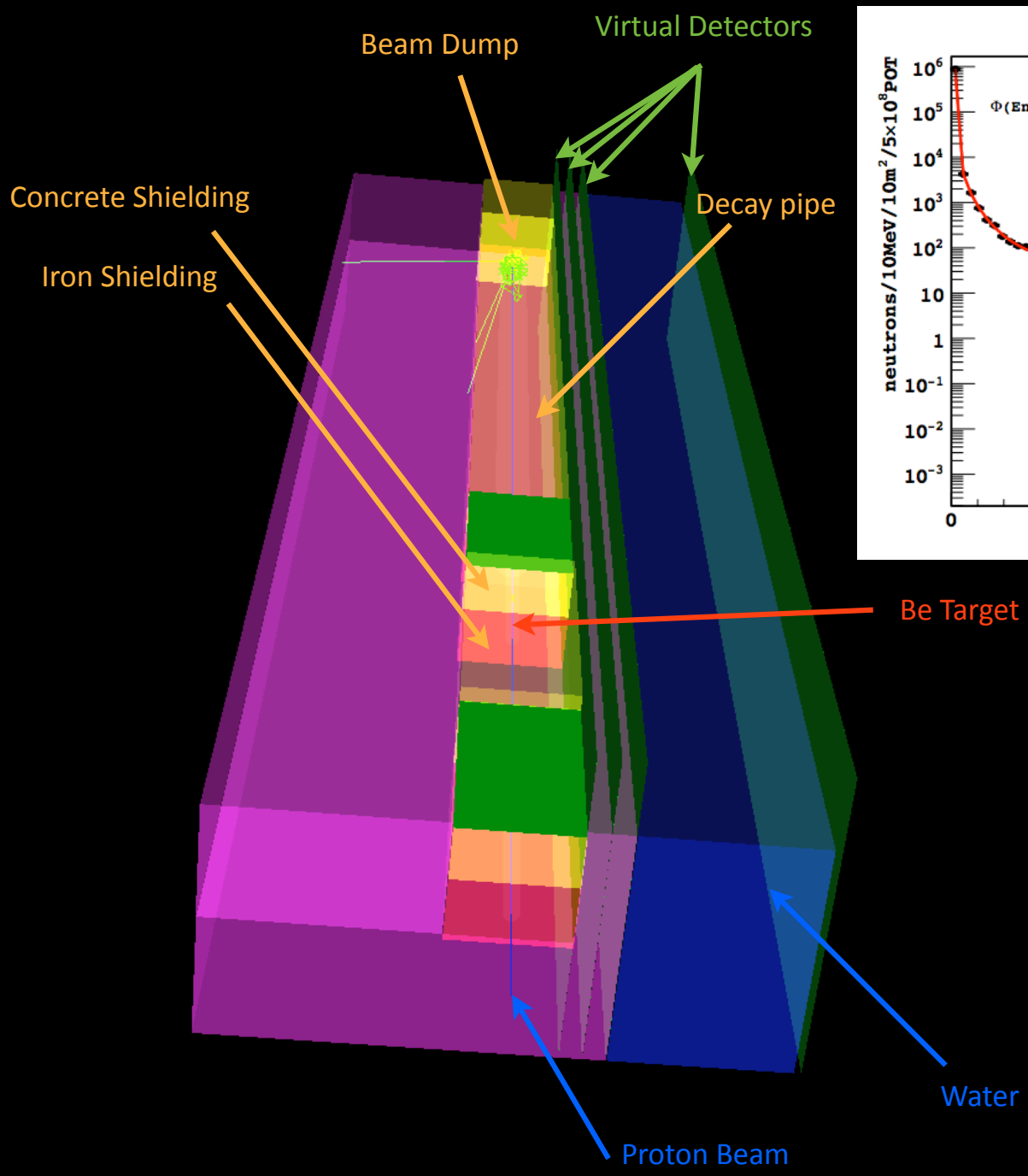


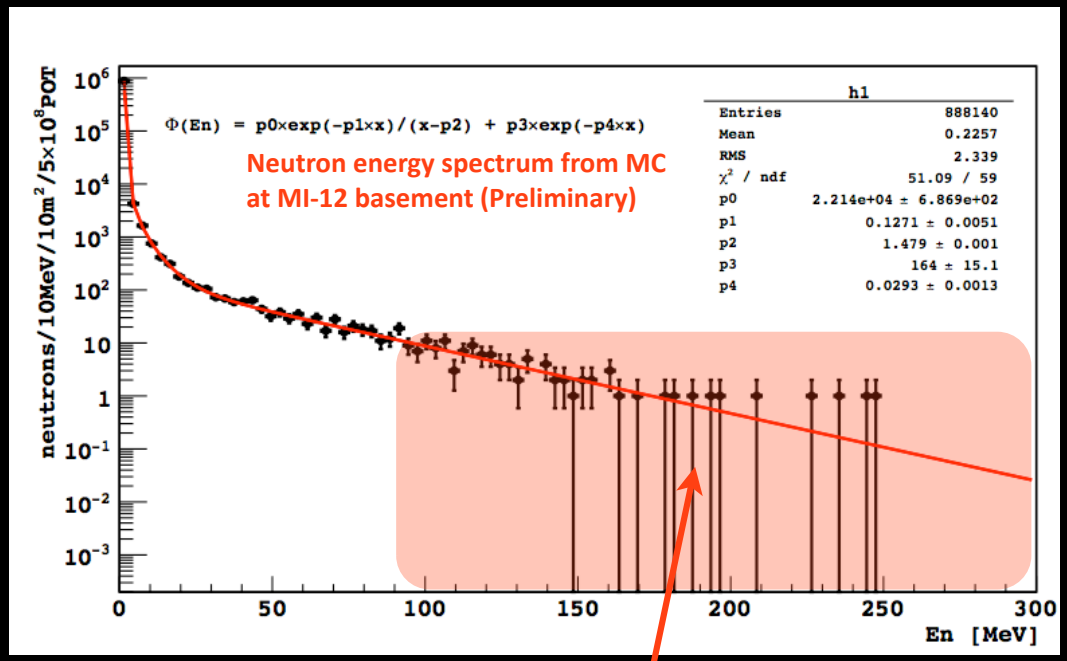
Ton-Scale CENNS Detector



- Single-phase LAr detector
  - Ton-scale fiducial volume
  - Viewed by ~100 PMTs
  - Energy threshold < 30keV
- ^{39}Ar backgrounds (beta)
  - kHz/ton × 10^{-5}(duty factor)
  - Pulse Shape Discrimination
- Neutron veto (water or concrete) determined by 10-kg detector study
- If cosmogenic BG are significant, the water veto can be instrumented as an active moun-veto

Beam Background Simulation



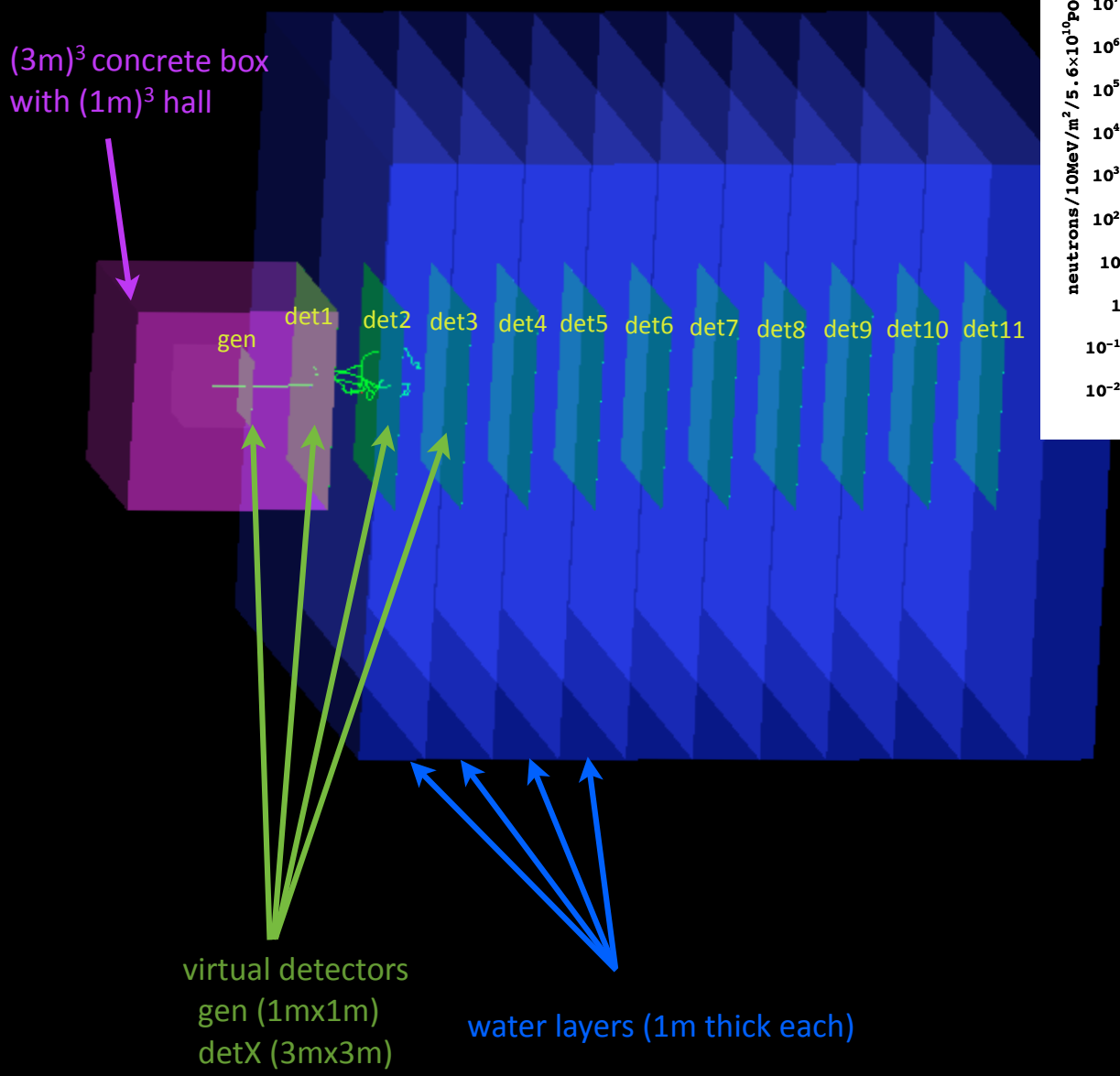


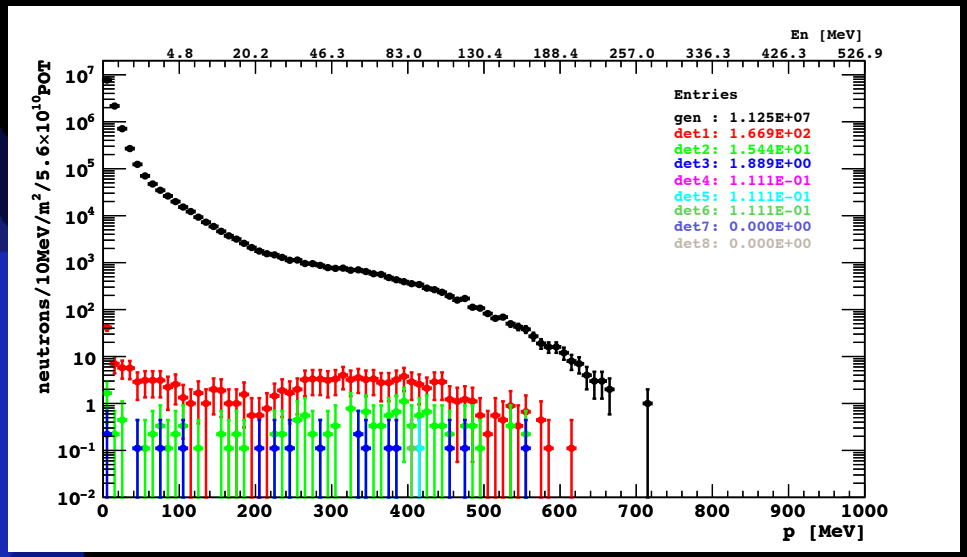
These fast neutrons are notorious ones

Fast Neutrons
- meters of shielding needed
- often counterintuitive
- need for different layers
  (steel, concrete, water, poly …)

Experiment doesn't have to be zero BG
- trade offs between neutrino flux, background rate and live time

Neutron Shielding Study with Toy MC



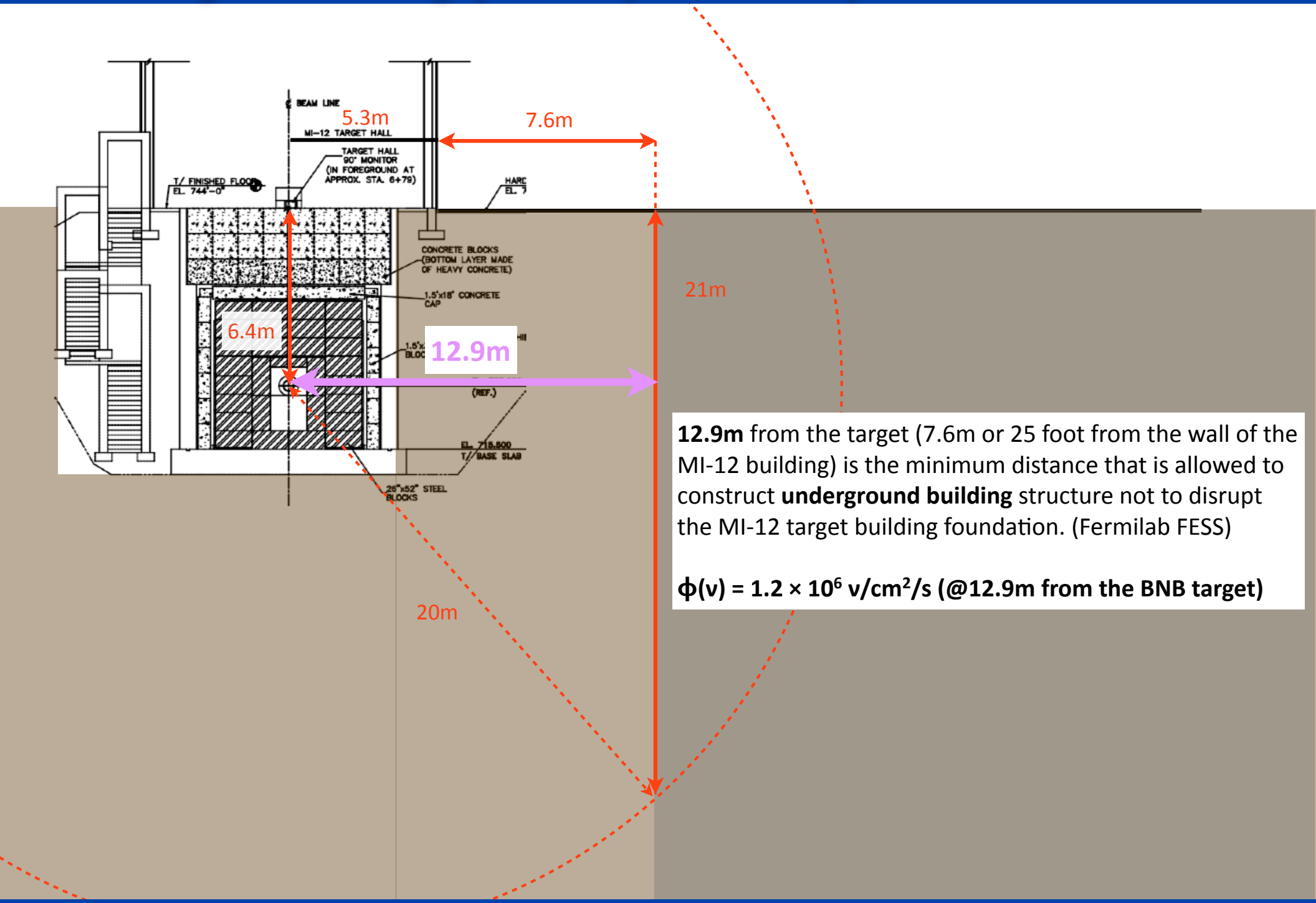


Neutron beams are simulated in 1m^2 surface area
Momentum distribution are taken from the primary neutron distributions of the full simulation (with statistical enhancement & extrapolation)

We are forming a team with NCSU and LANL neutronics group to carry out MC study of neutron shielding

Best way is to measure the neutron shielding effects at the experimental site.

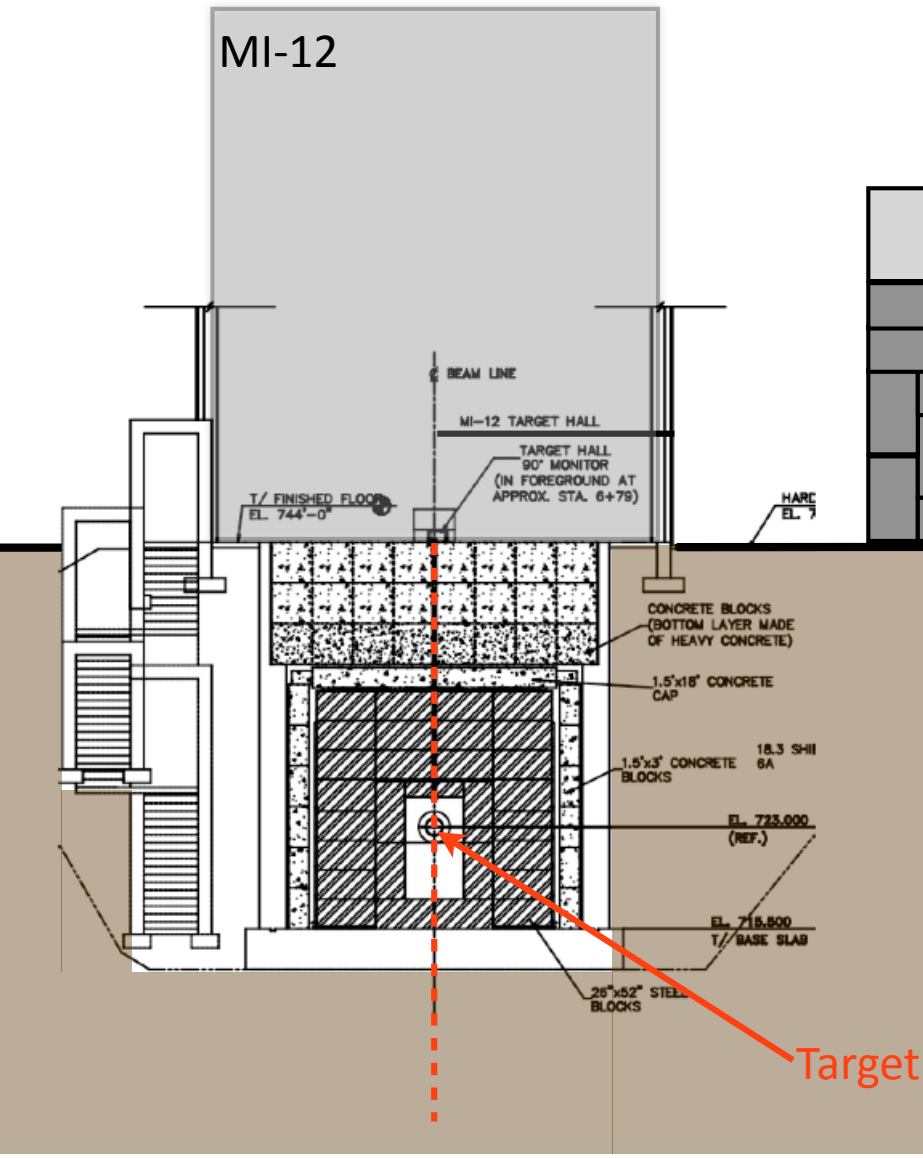
BNB Target Building (MI-12) Geometry



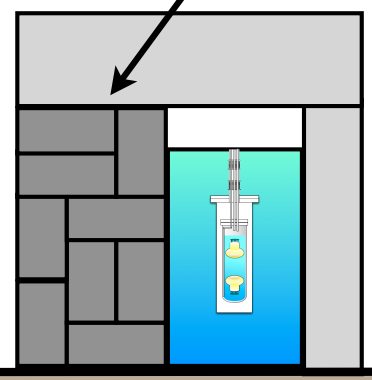
12.9m from the target (7.6m or 25 foot from the wall of the MI-12 building) is the minimum distance that is allowed to construct **underground building** structure not to disrupt the MI-12 target building foundation. (Fermilab FESS)

$\phi(\nu) = 1.2 \times 10^6$ $\nu/cm^2/s$ (@12.9m from the BNB target)

Neutron Shielding Test Option



Concrete blocks
or other shielding material

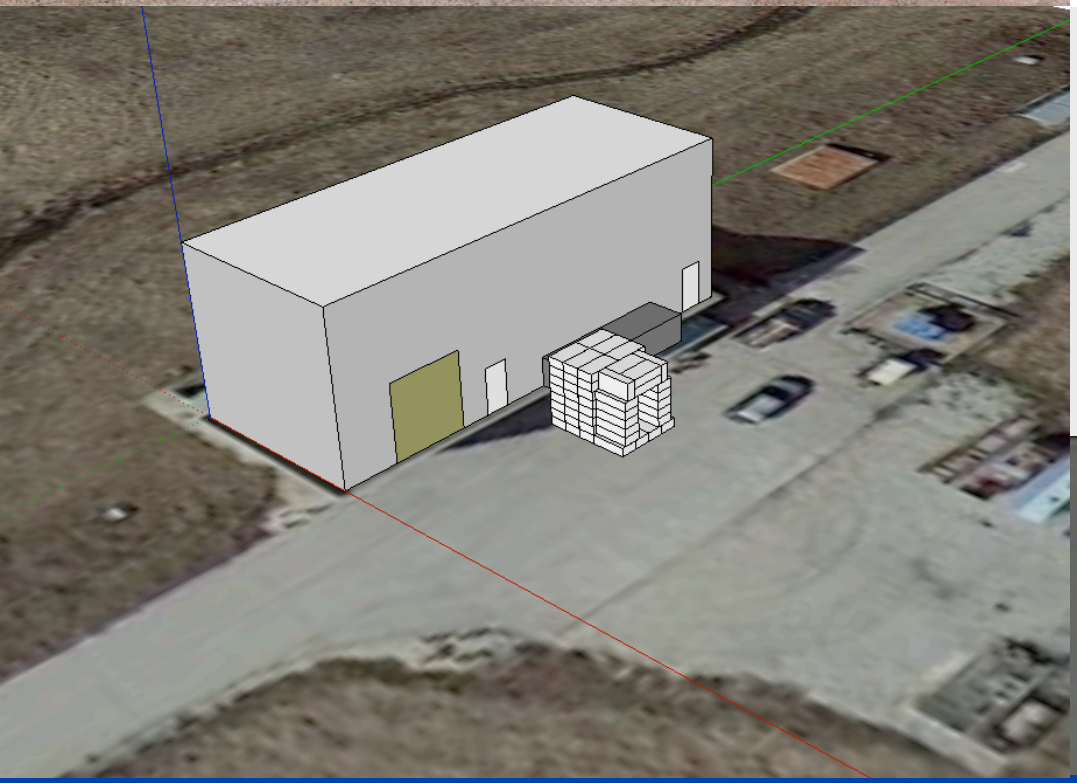


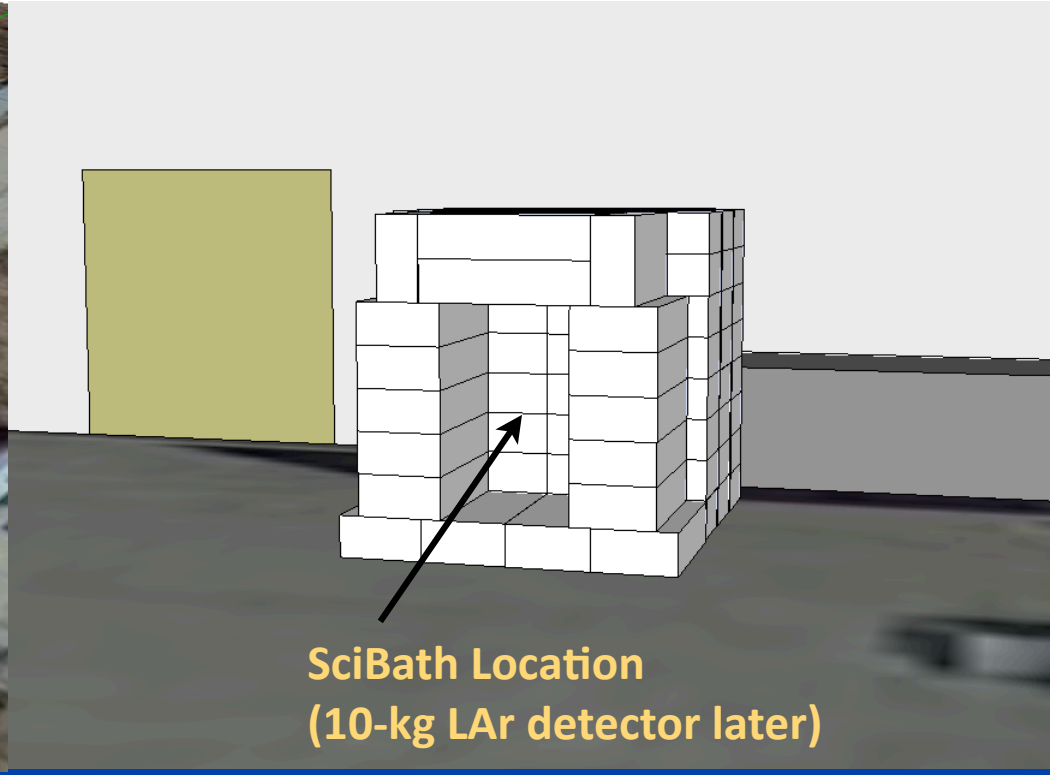
- Conceptually easy to build
- Fermilab has a lot of concrete blocks
- Easy to test shielding effects
- Need advices from AD safety team
- FESS consider this is possible options

Ground

Shielding Ideas

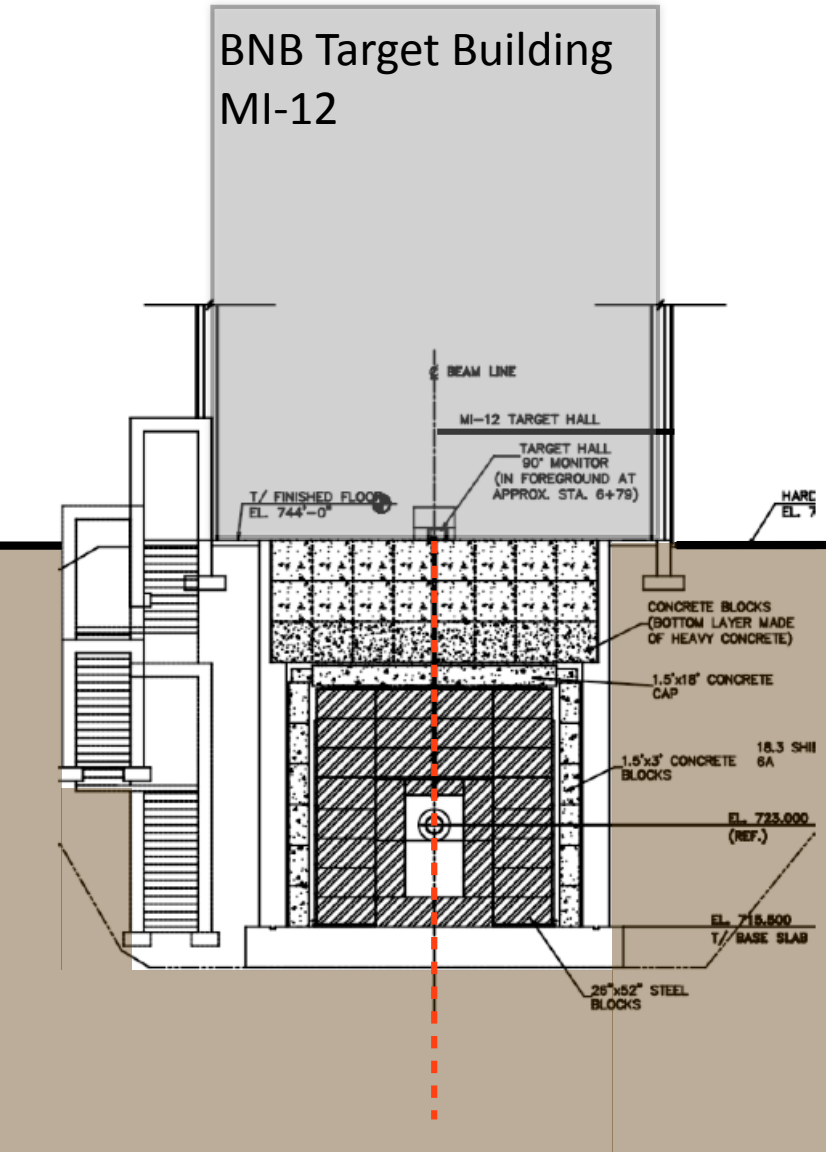
- Many shielding concrete blocks around Fermilab yards (typical size: 1.5’ x 3’ x 5’)
- Renting crane $4K/day (x how many days?)
- Various shielding condition need to be tested
  - Direction of neutrons
  - Shielding effects

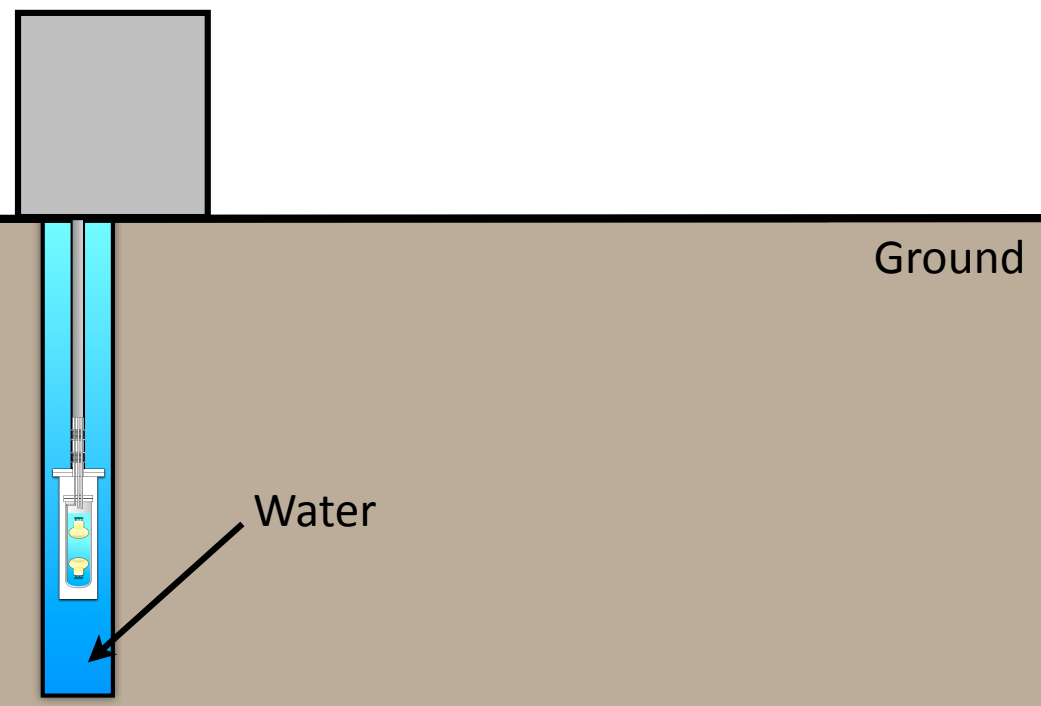




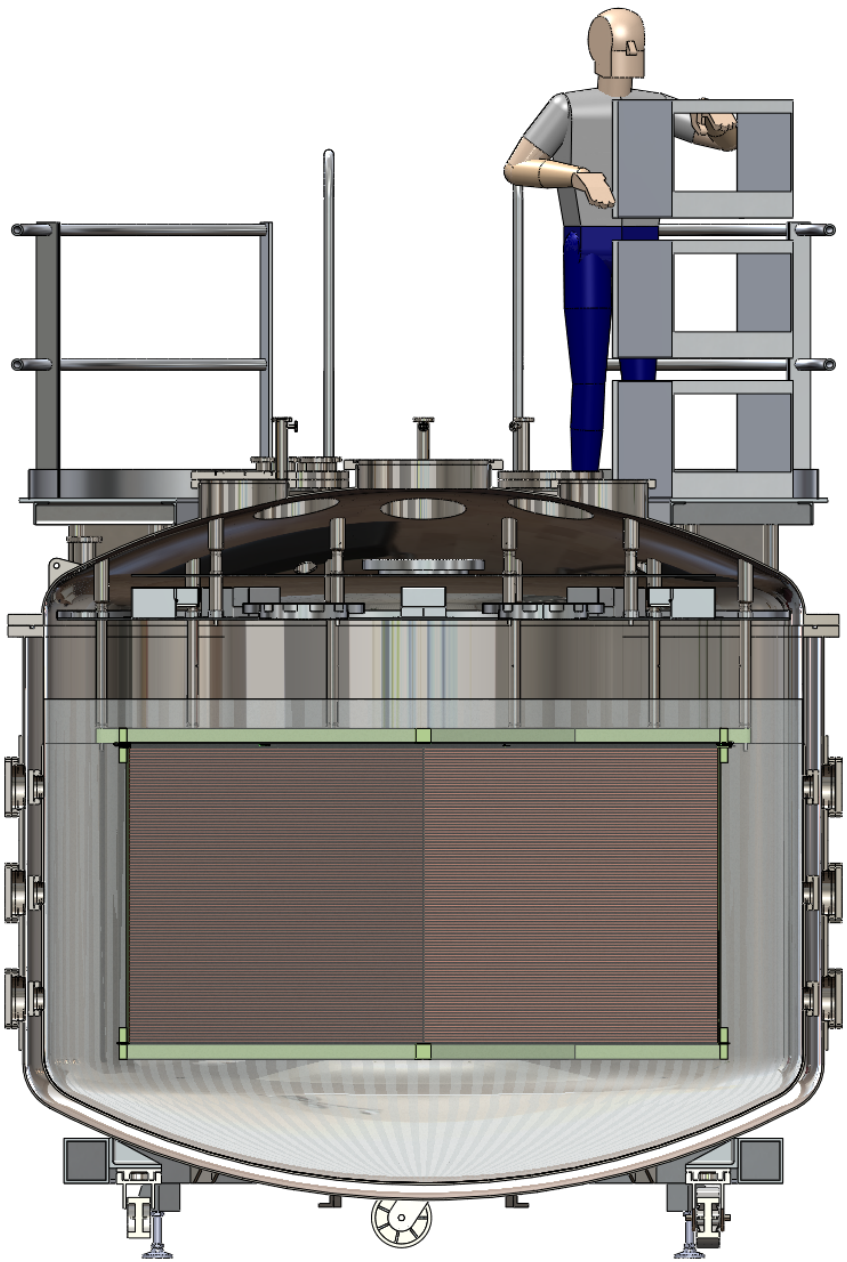
Neutron Shielding Test Option

- Not very difficult to make pits: Fermilab FESS
- Safety, environmental issue need to be understood
- Test can start in 2013 -- in earliest scenario



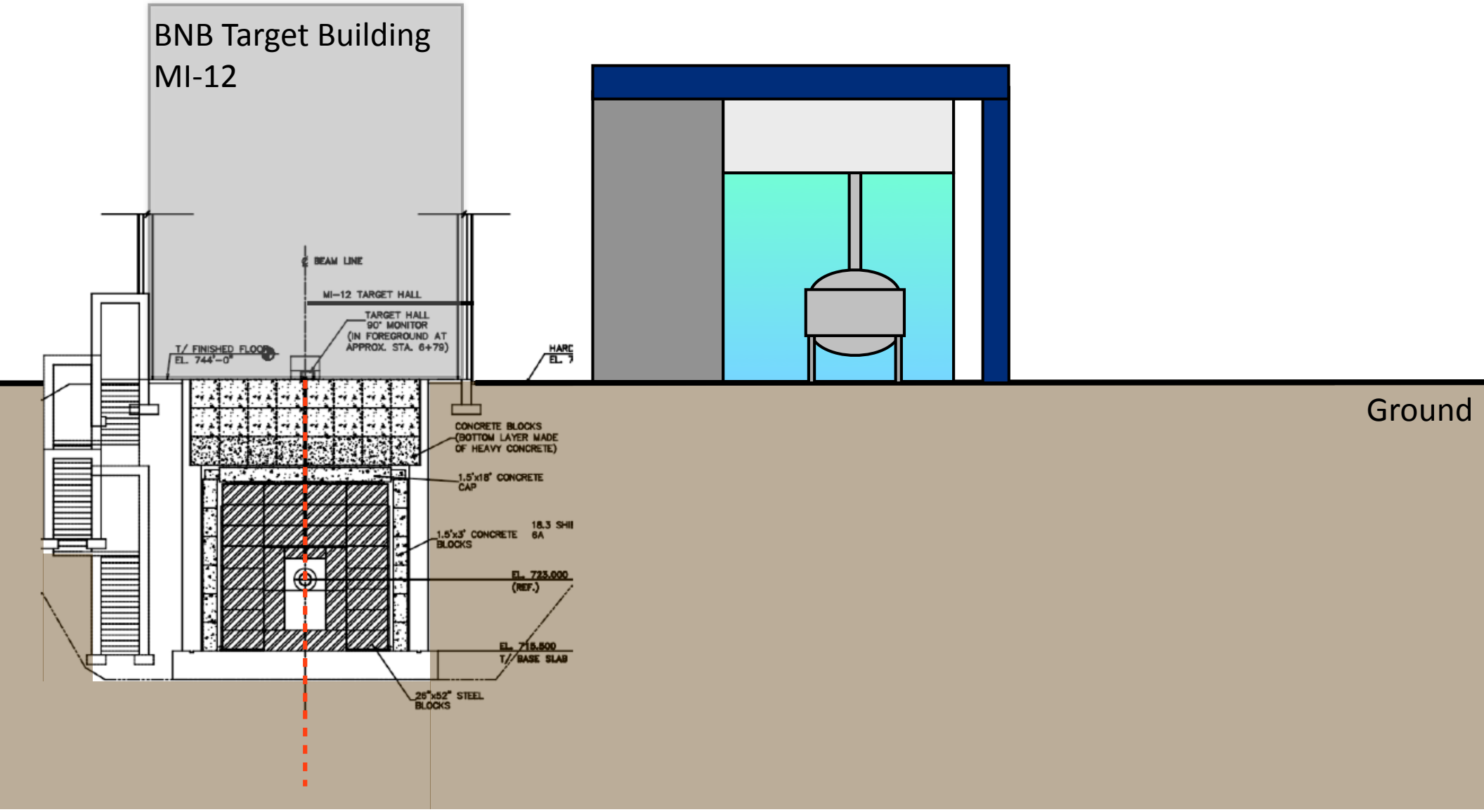


LANL LAr Cryostat

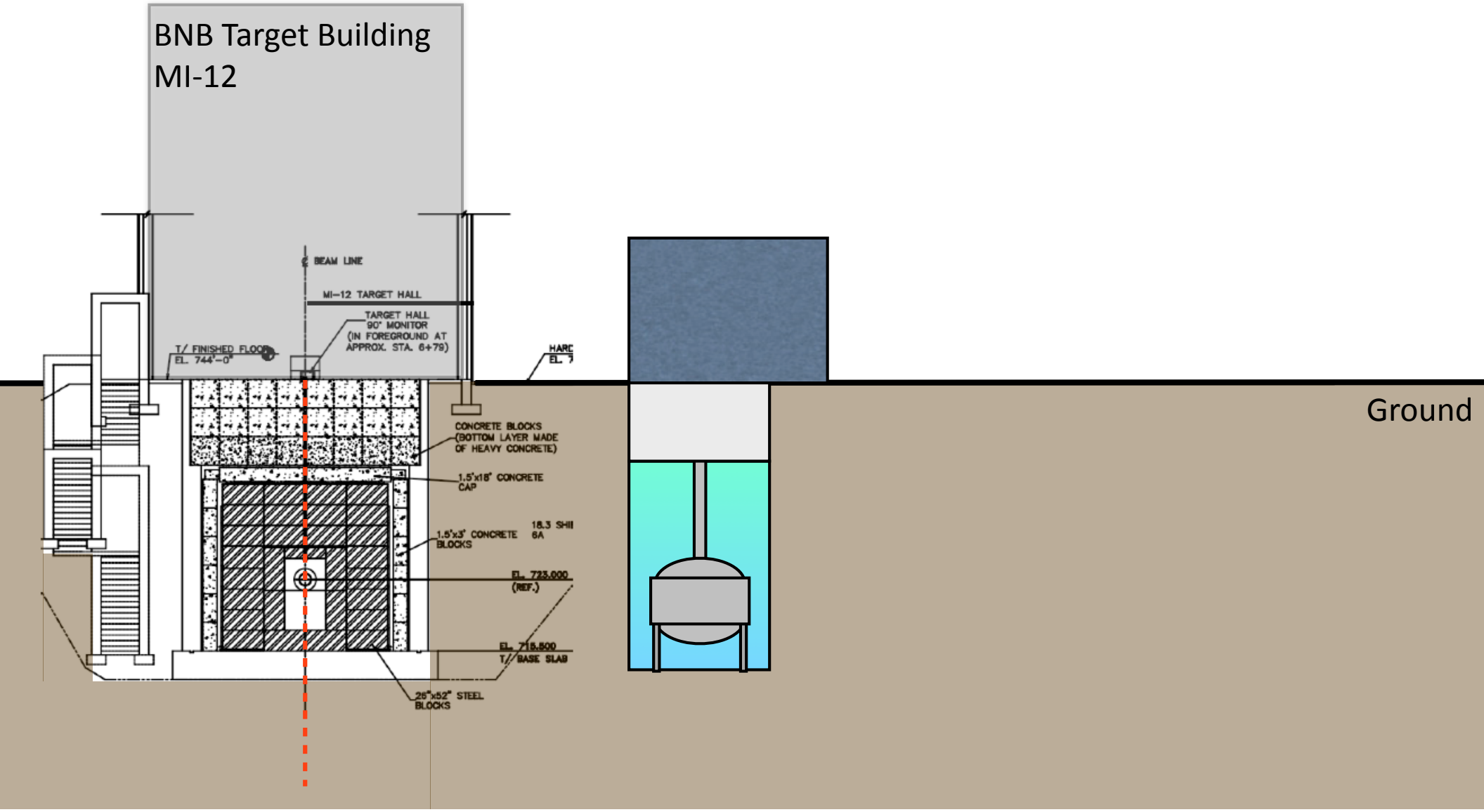


- LANL LDRD project
  - Initial phase will be LArTPC
  - R&D for particle interactions in TPC
  - Designed for easy transportation (LANL and Fermilab beam test)
  - TPC commissioning scheduled by the end of the 2013
- Cryostat
  - Capacity: ~7700L (10ton full LAr) ~5ton LArTPC active region
  - All cryogenic and instrumentation connections made through top head
  - Expected chamber delivery by the end of August 2013
- Cryostat is to be available for CENNS after its TPC mission completed! (C.Mauger LANL)

CENNS Experiment Setup Option 1

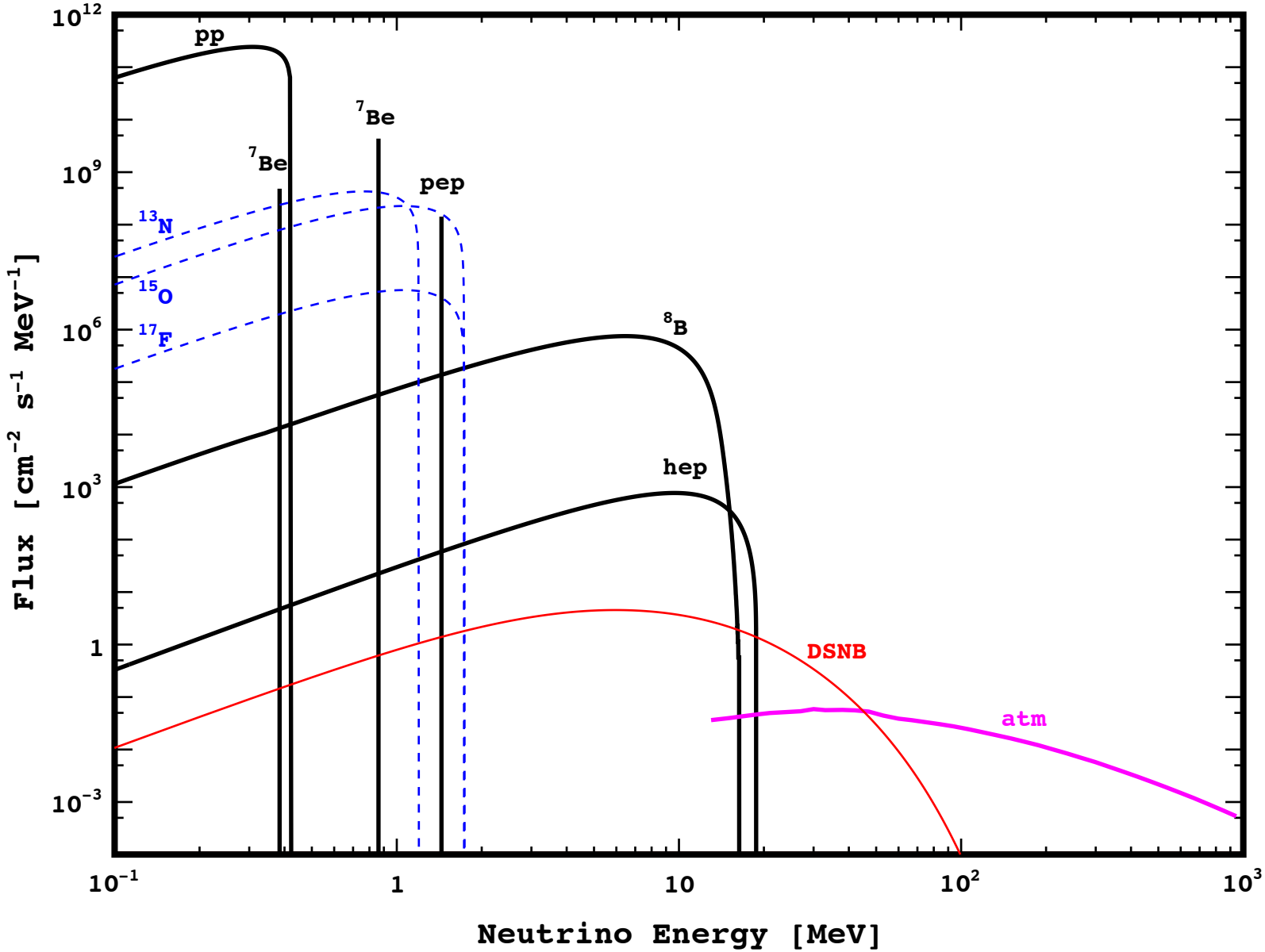


CENNS Experiment Setup Option 2

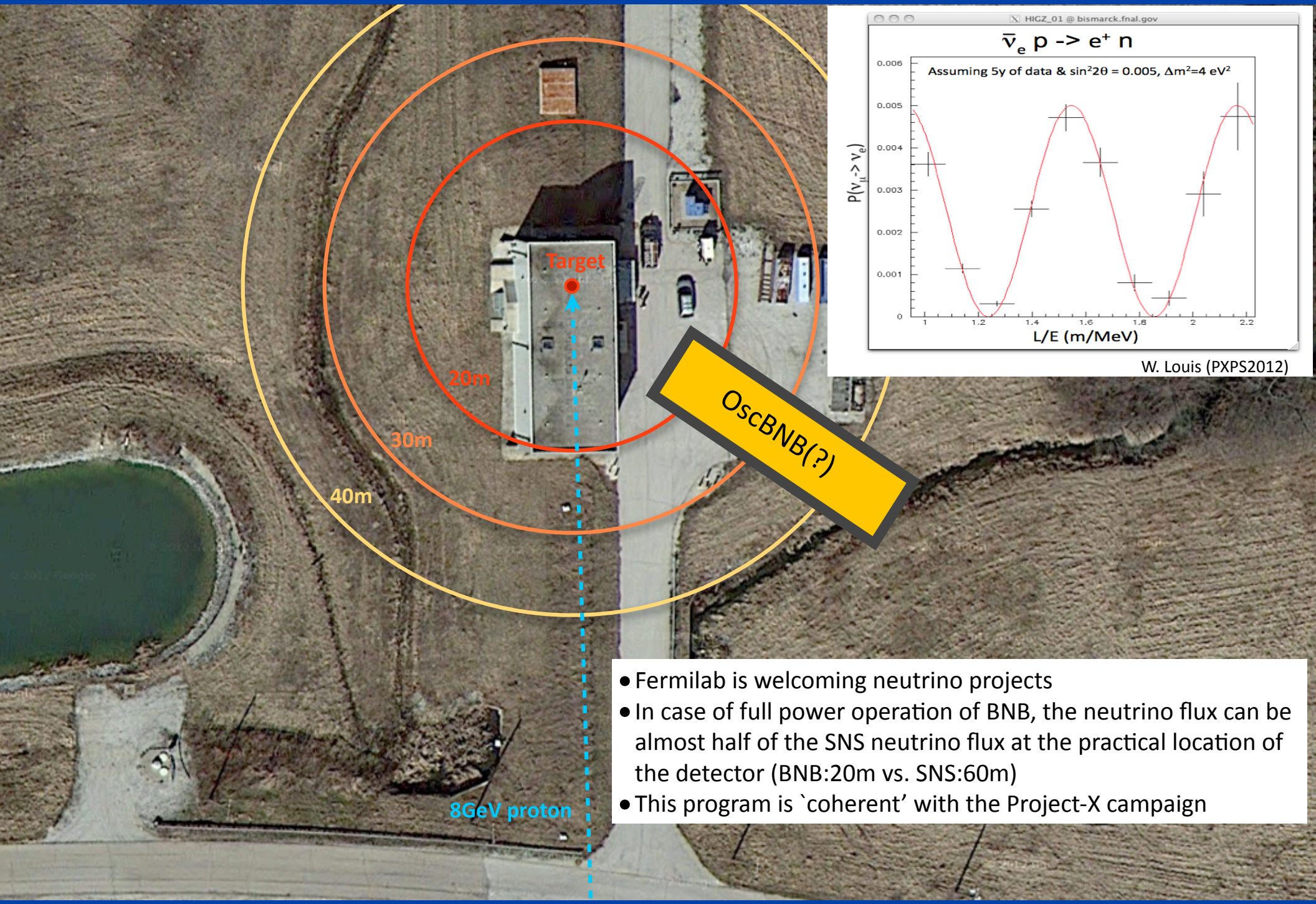


Irreducible Backgrounds

Neutrinos from astrophysical origin



OscBNB?



W. Louis (PXPS2012)

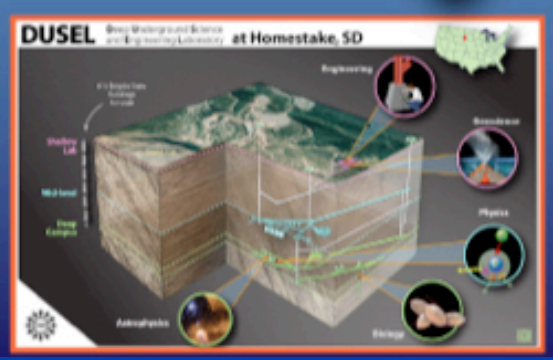
- Fermilab is welcoming neutrino projects
- In case of full power operation of BNB, the neutrino flux can be almost half of the SNS neutrino flux at the practical location of the detector (BNB:20m vs. SNS:60m)
- This program is `coherent' with the Project-X campaign

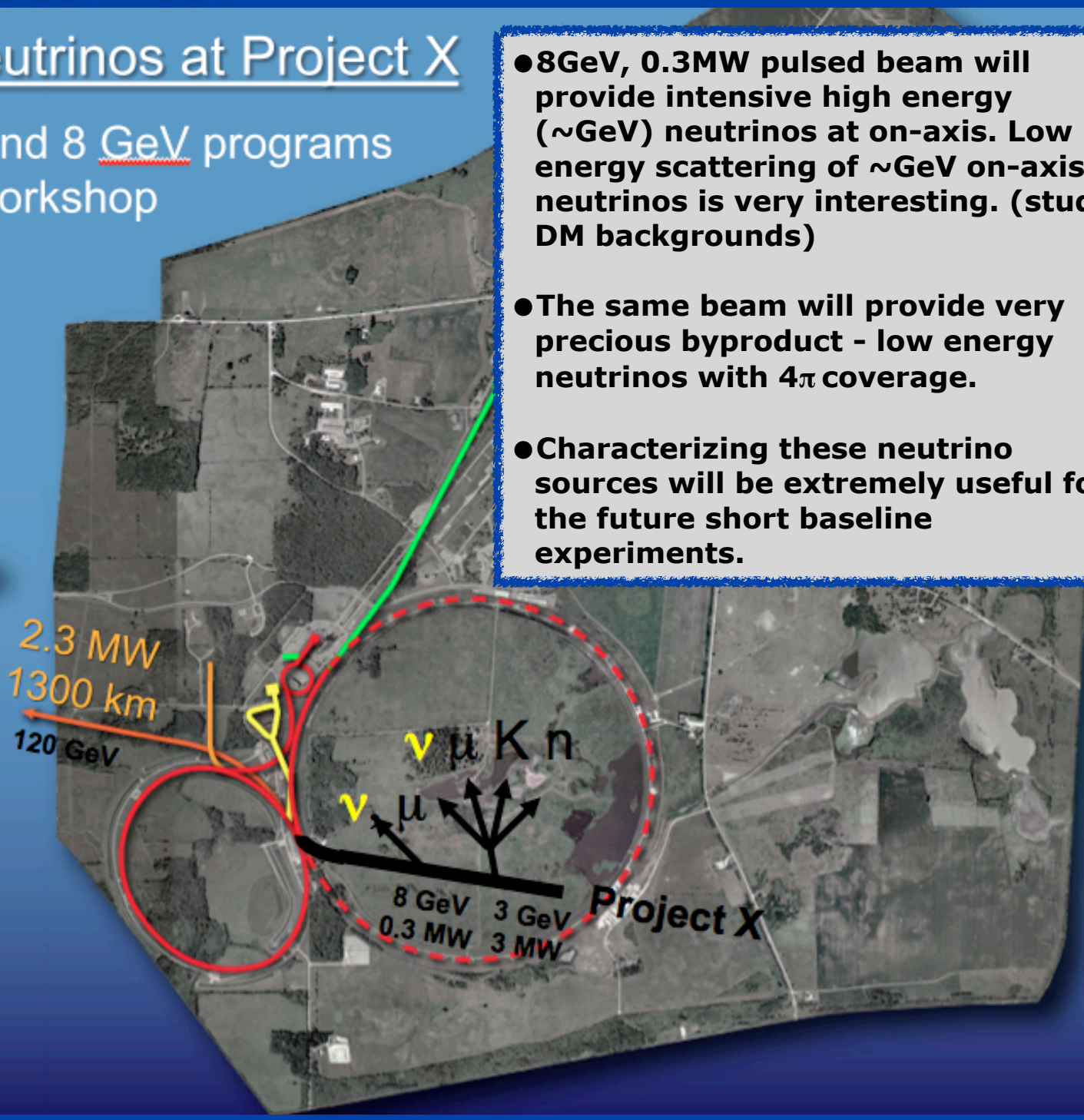
Future of FOX neutrinos?

Short Baseline Neutrinos at Project X

Exploring 3 GeV and 8 GeV programs
This workshop

- **8GeV, 0.3MW pulsed beam will provide intensive high energy (~GeV) neutrinos at on-axis. Low energy scattering of ~GeV on-axis neutrinos is very interesting. (study DM backgrounds)**
- **The same beam will provide very precious byproduct - low energy neutrinos with 4π coverage.**
- **Characterizing these neutrino sources will be extremely useful for the future short baseline experiments.**





Project-X Stages

← Project X Campaign →

Program:	Onset of NOvA operations in 2013	Stage-1: 1 GeV CW Linac driving Booster & Muon, n/edm programs	Stage-2: Upgrade to 3 GeV CW Linac	Stage-3: Project X RDR	Stage-4: Beyond RDR: 8 GeV power upgrade to 4MW
MI neutrinos	470-700 kW**	515-1200 kW**	1200 kW	2450 kW	2450-4000 kW
8 GeV Neutrinos	15 kW +0-50kW**	0-42 kW* + 0-90 kW**	0-84 kW*	0-172 kW*	3000 kW
8 GeV Muon program e.g, (g-2), Mu2e-1	20 kW	0-20 kW*	0-20 kW*	0-172 kW*	1000 kW
1-3 GeV Muon program, e.g. Mu2e-2	-----	80 kW	1000 kW	1000 kW	1000 kW
Kaon Program	0-30 kW** (<30% df from MI)	0-75 kW** (<45% df from MI)	1100 kW	1870 kW	1870 kW
Nuclear edm ISOL program	none	0-900 kW	0-900 kW	0-1000 kW	0-1000 kW
Ultra-cold neutron program	none	0-900 kW	0-900 kW	0-1000 kW	0-1000 kW
Nuclear technology applications	none	0-900 kW	0-900 kW	0-1000 kW	0-1000 kW
# Programs:	4	8	8	8	8
Total max power:	735 kW	2222 kW	4284 kW	6492 kW	11870kW

* Operating point in range depends on MI energy for neutrinos.

** Operating point in range depends on MI injector slow-spill duty factor (df) for kaon program.

Budget Request

item	M&S	FTE#	etc
Neutron Shielding*	$40K	0.1 ME 0.5 MT	
Electric Power**	$35K	0.1 ET	
SciBath Operation	$20K	0.2 MT	
LAr Detector Operation	$40K	0.5 MT	
Other Structures***	$30K	0.1 ME 0.5 MT	
Contingency	30%		
Total	$215K	1.7MT, 0.4ME, 0.1ET	

* $4K/configuration (crane, truck rental) x 10
** SciBath: 2 x 20A x 120VAC, 10-kg LAr: 3 x 20A x 120VAC + 230VAC; 3 phase 25A (requires power upgrade at MI-12)
*** SciBath and LAr detector protect structures, safety structure and crane etc.
# MT: Mechanical Tech, ME: Mechanical Engineer, ET: Electric Tech