CENNS @ BNB with LAr

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Pacific Northwest National Laboratory

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PHYSICAL REVIEW D **89**, 072004 (2014)

A method for measuring coherent elastic neutrino-nucleus scattering at a far off-axis high-energy neutrino beam target

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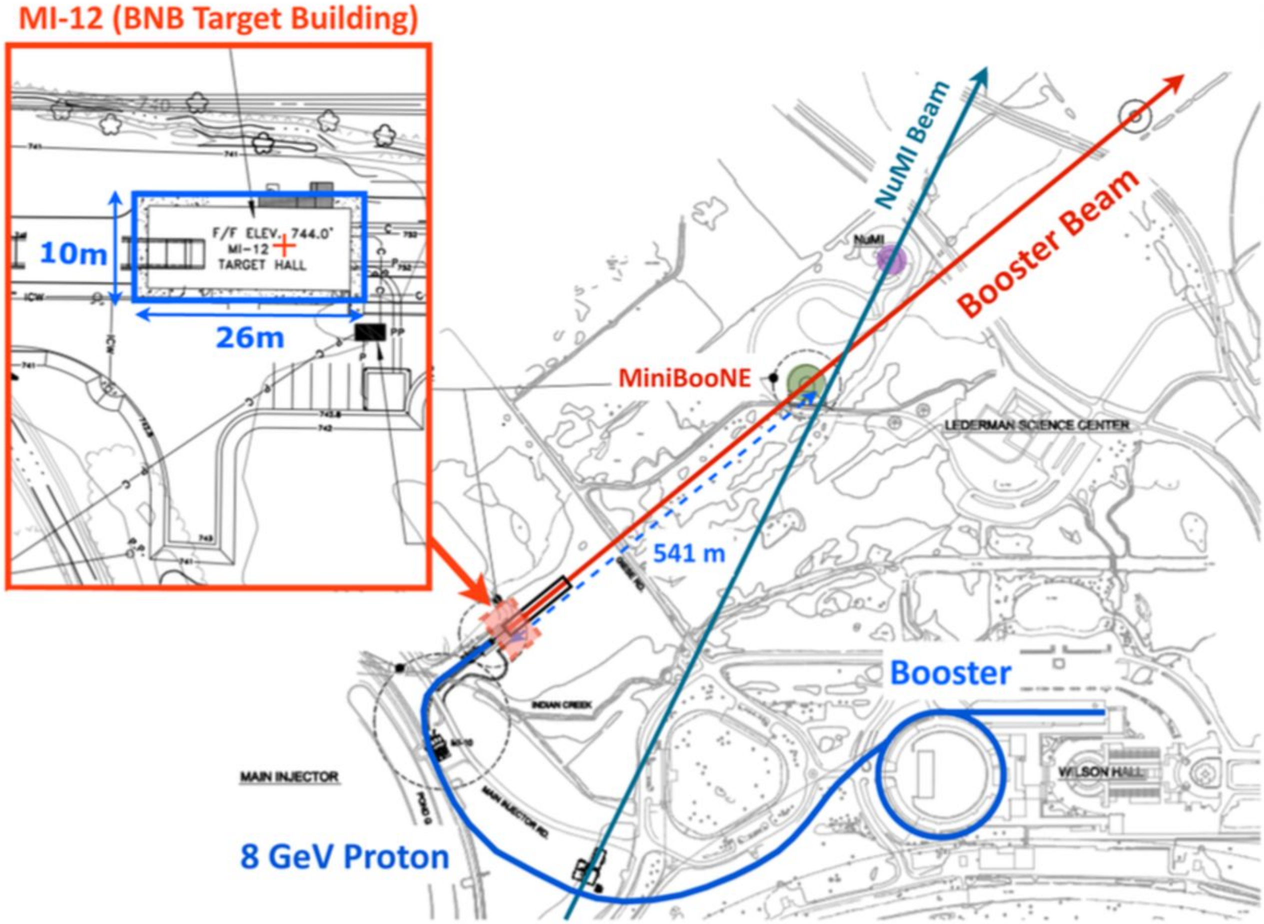
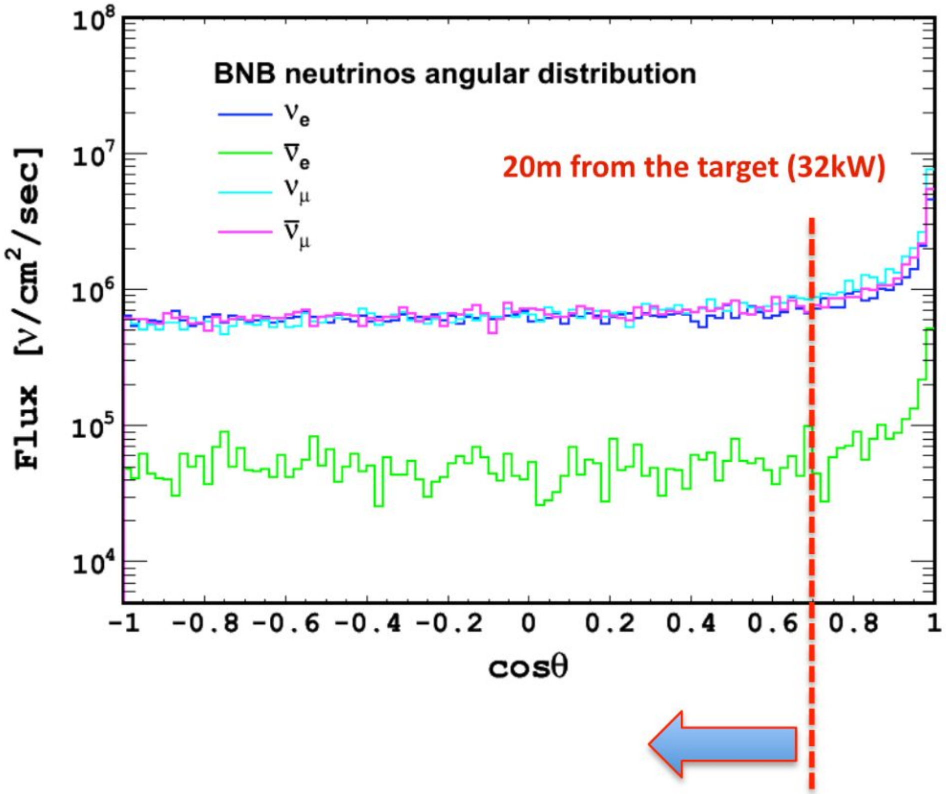
Exploit BNB @ Fermilab



Get Close to the Source

Neutron Production & Angular Distribution

CENNS Collaboration, PRD **89**, 072004 (2014)



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

$E_\nu < \frac{1}{R_N} \simeq 50\ \mathrm{MeV}$ to satisfy coherence condition

Off-Axis Neutrinos at Fermilab BNB

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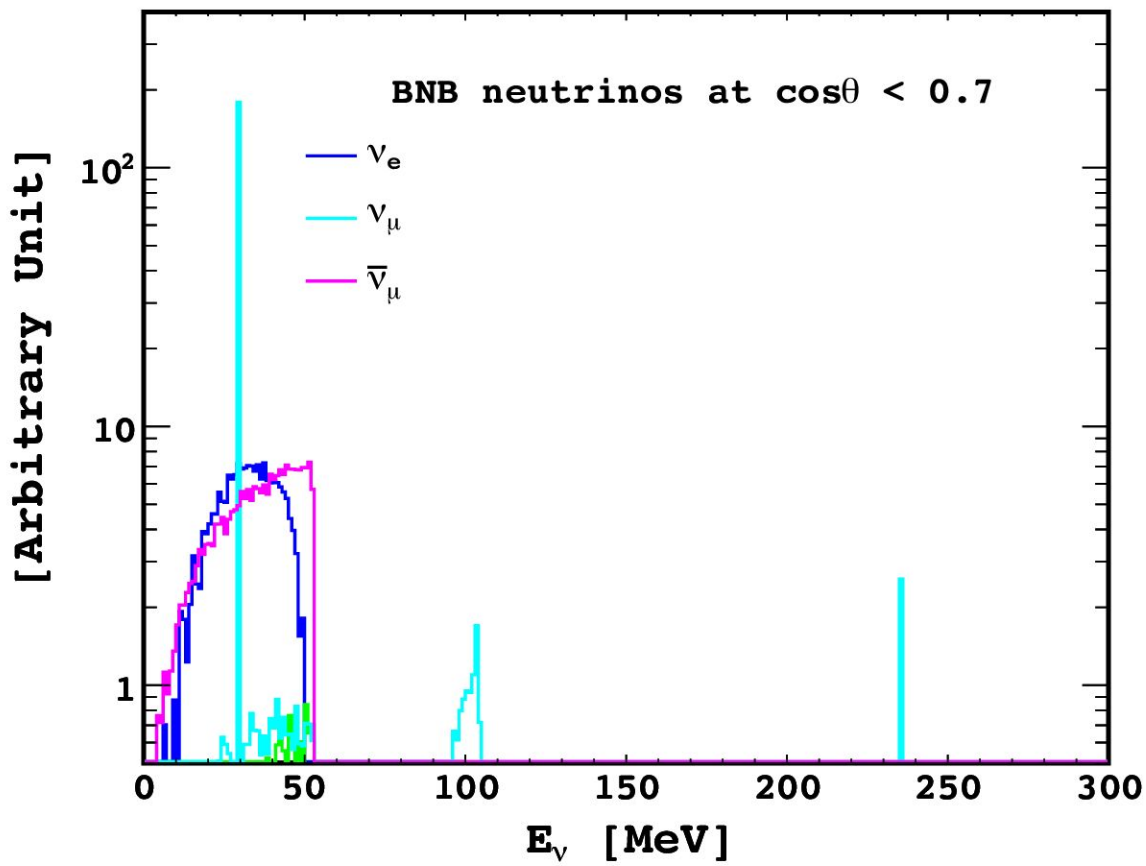
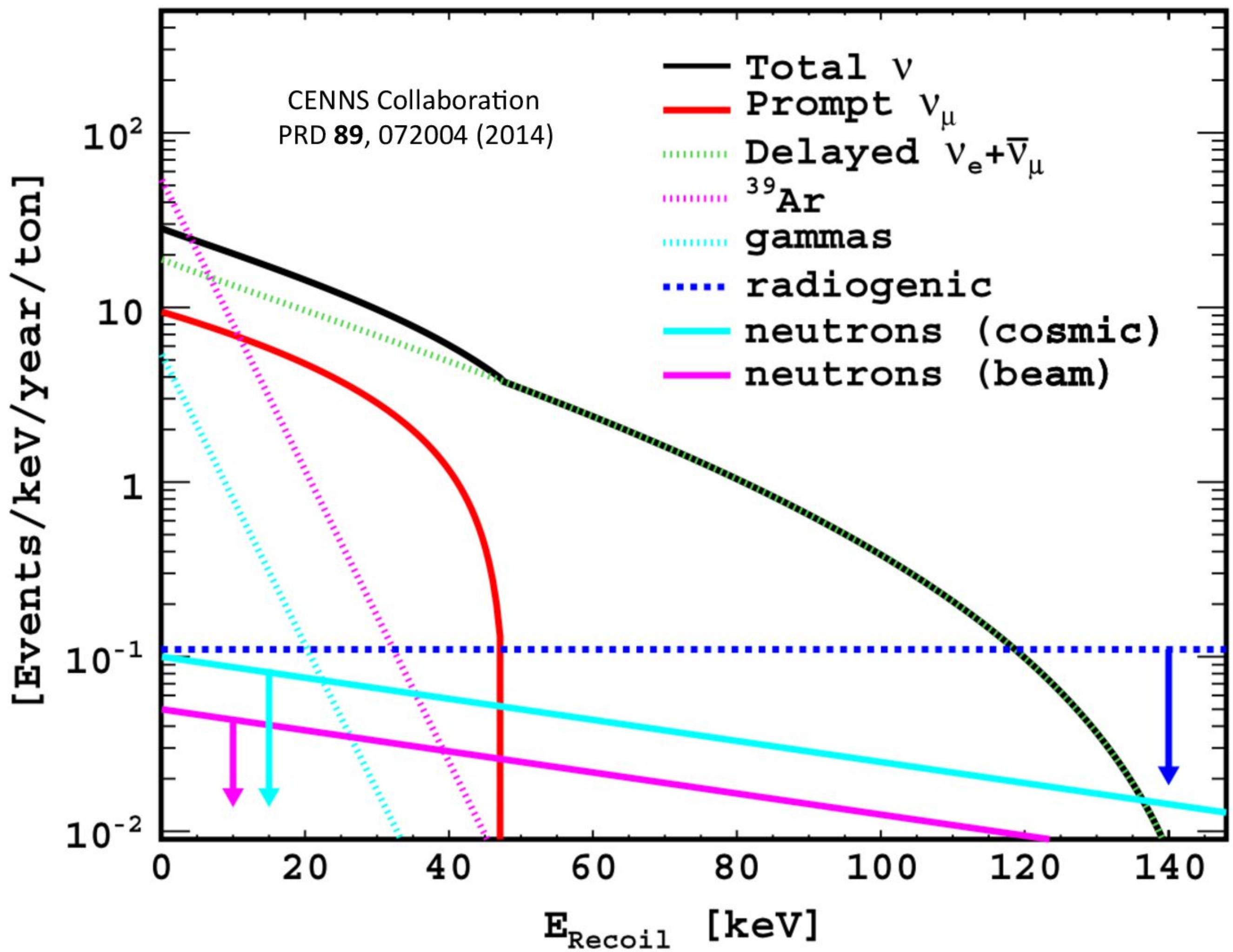


ϕ(BNB) ≅ 5×10^5 ν/cm²/s @20m, or 2×10^6 ν/cm²/s @10m (cosθ<0.5)

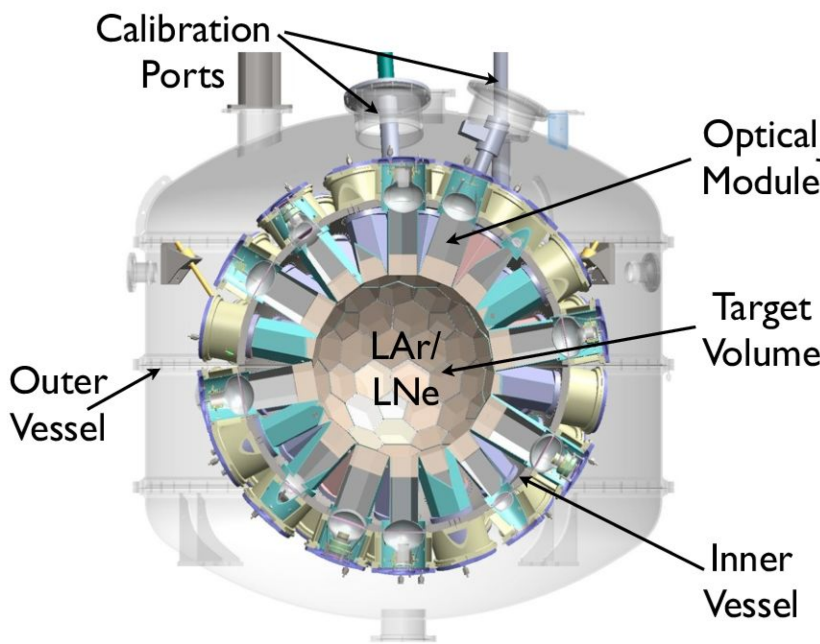
(cf. ϕ(SNS)= 2×10^6ν/cm²/s @46m, or 4.7×10^6ν/cm²/s @30m)

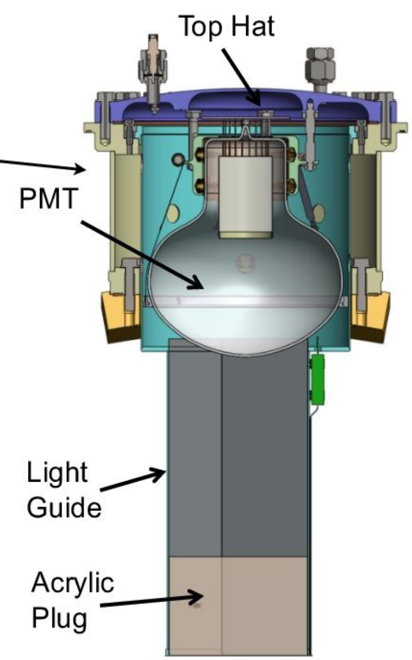
Signals & Background in "tonne-year" LAr Exposure



Consider MiniCLEAN at BNB in 1'rst Generation Experiment

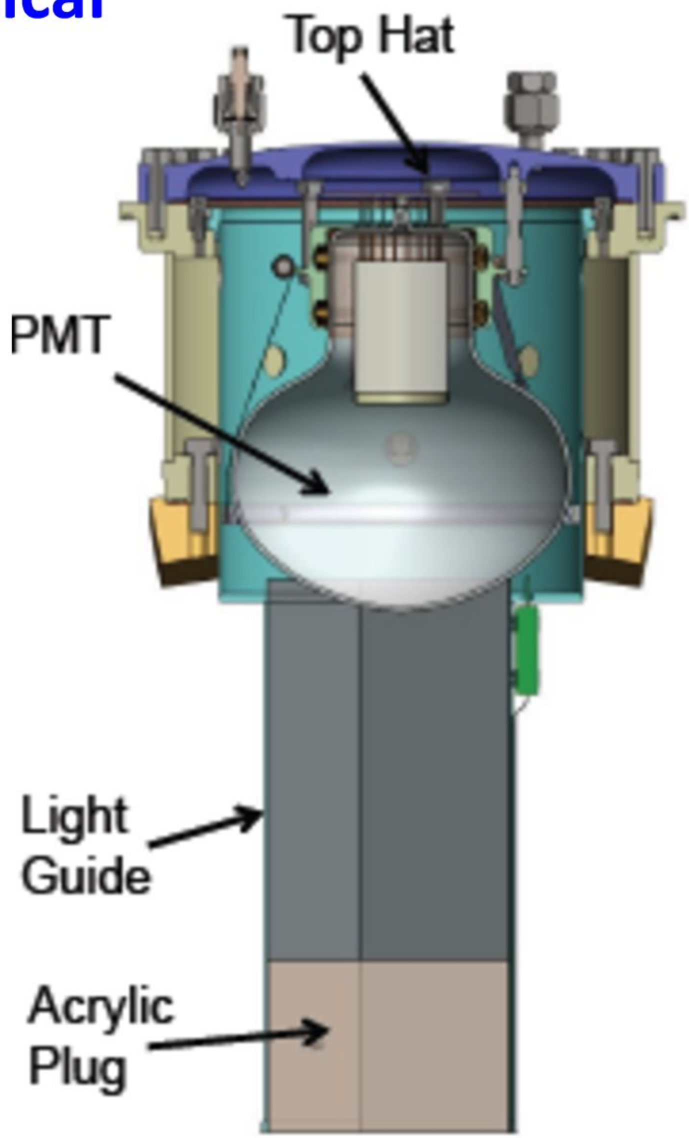
- 4π coverage to maximize light-yield at threshold …
  - 3D Position Reconstruction
  - Particle-ID via Pulse-Shape Discrimination
- "Cold" design allows both LAr & LNe … 500 kg Target
- No electric fields … PMTs only active component …

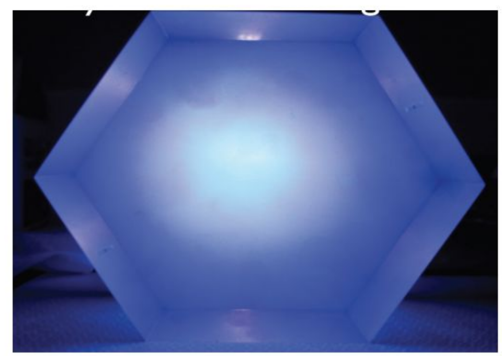




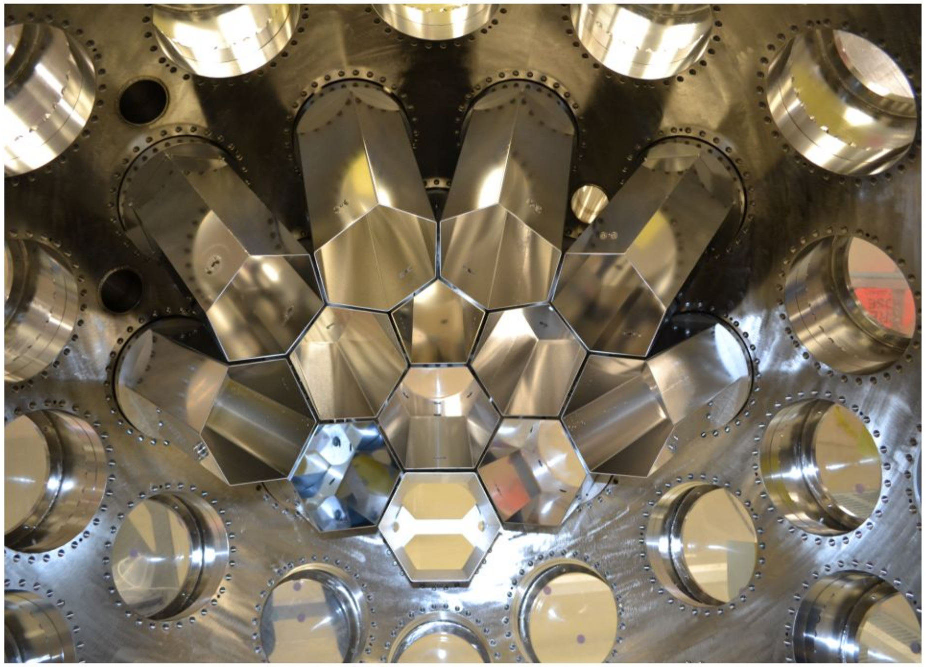
AH, arXiv:1110.1005

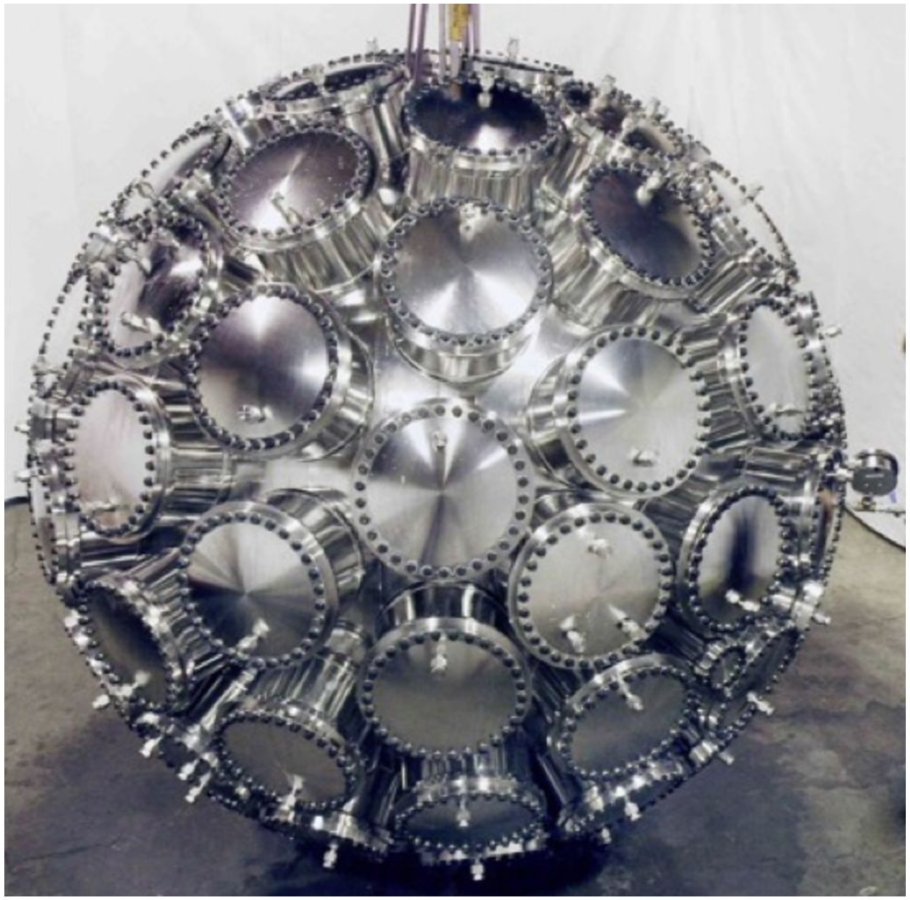
MiniCLEAN Optical Modules





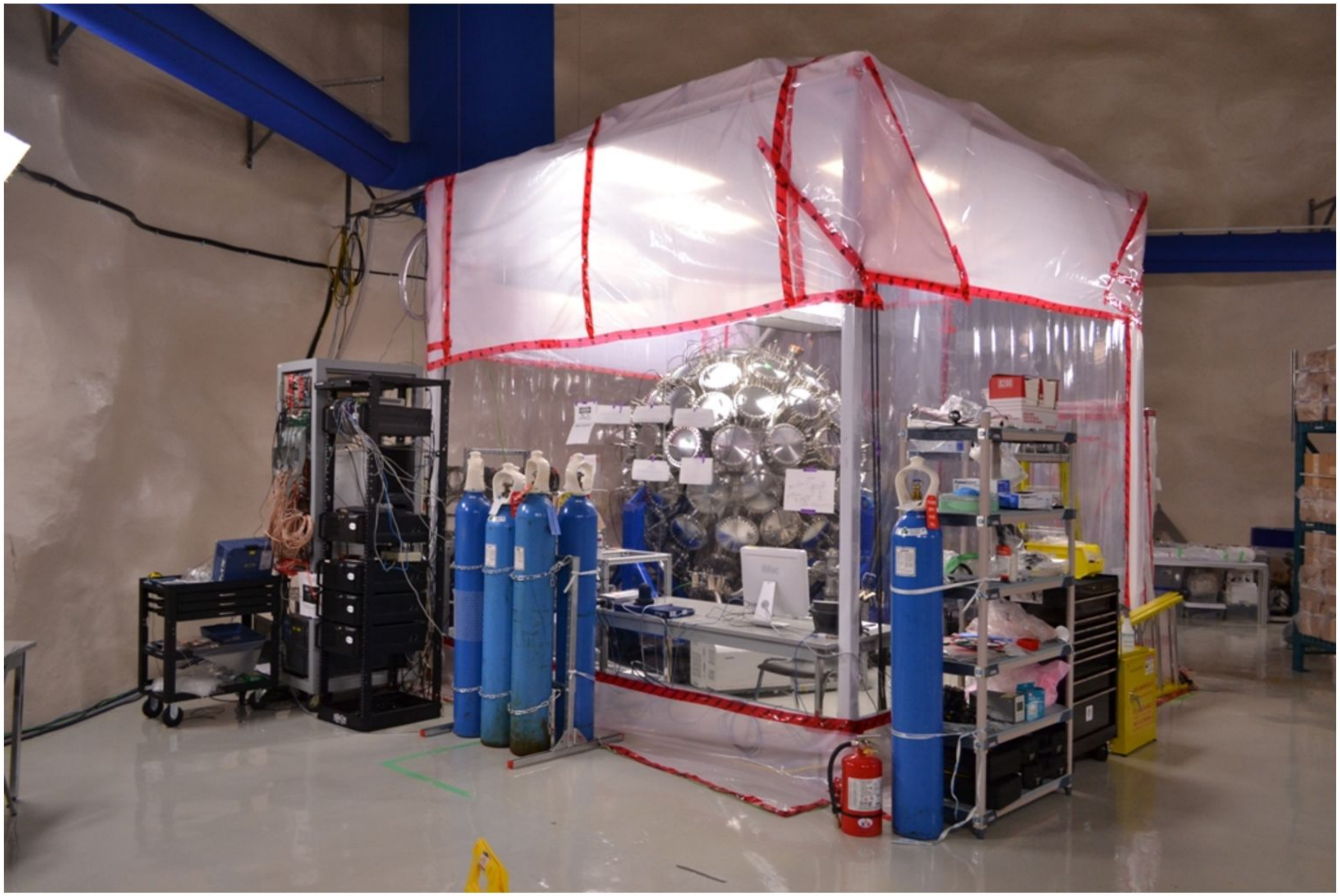
MiniCLEAN Inner Vessel



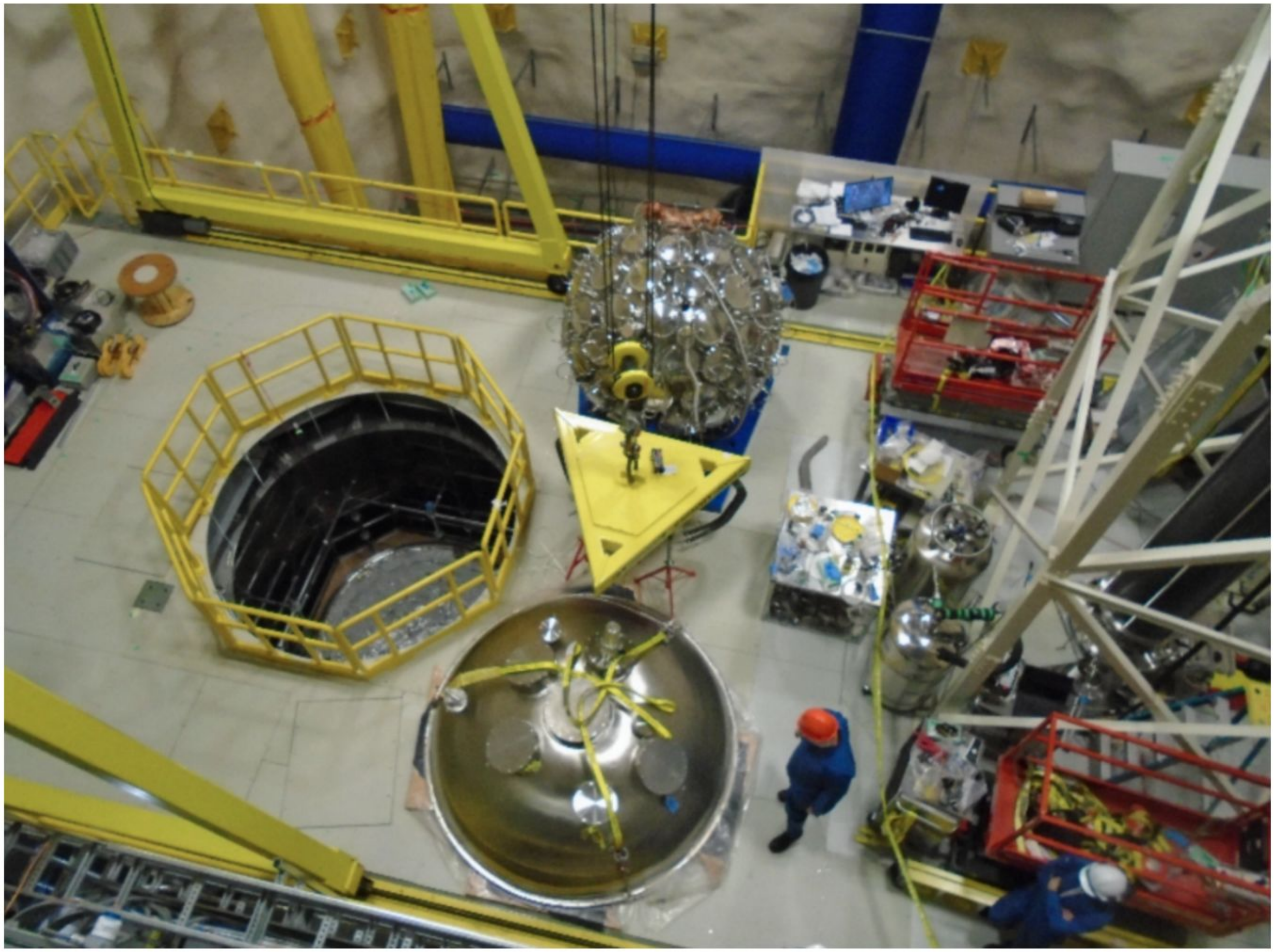


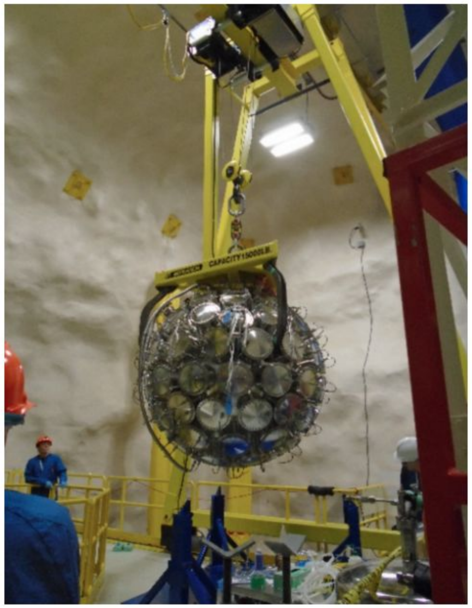
MiniCLEAN Radon-Reduced Assembly

MiniCLEAN Inner Vessel Assembly

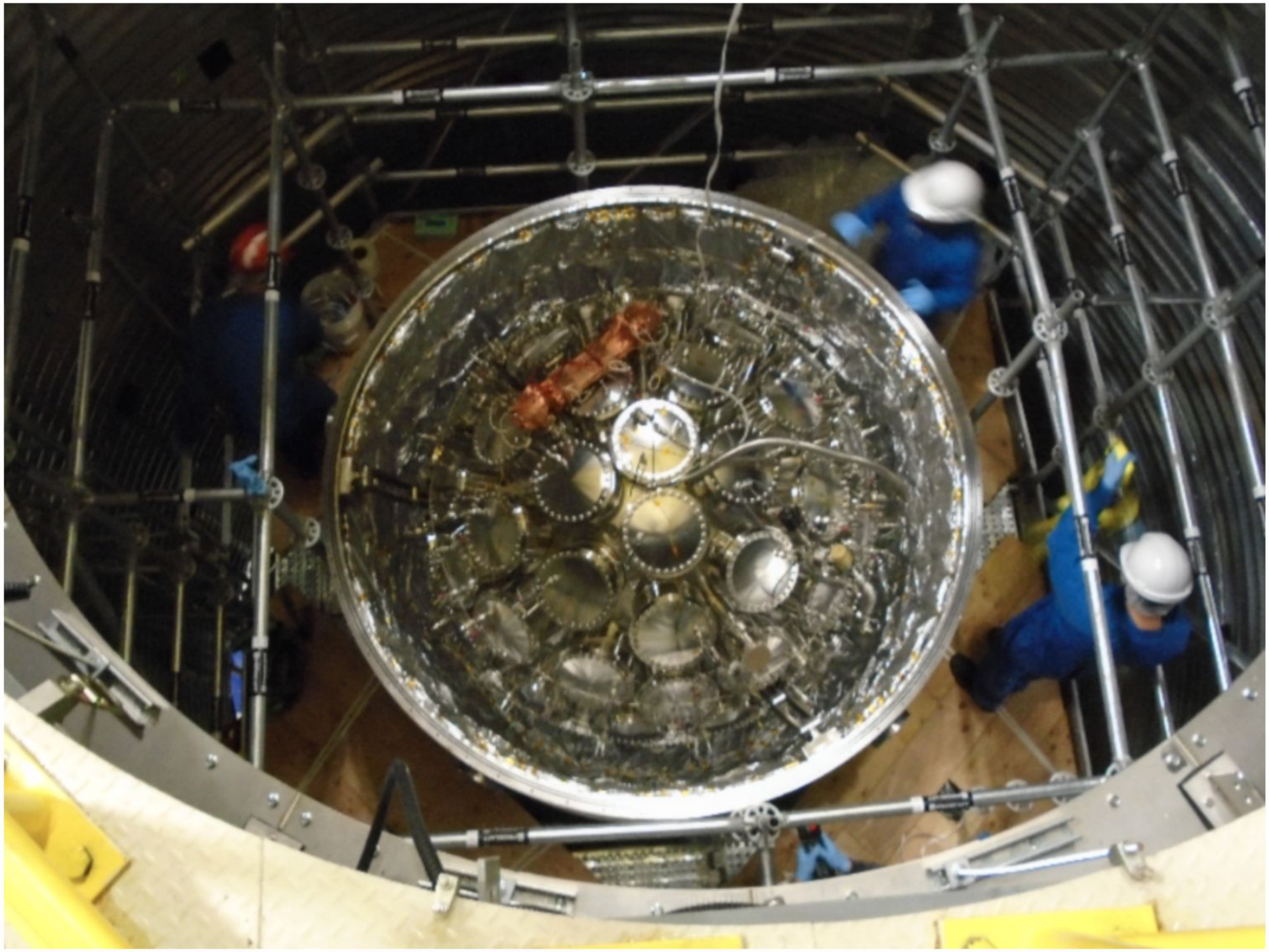


MiniCLEAN Installation in SNOLAB Cube Hall





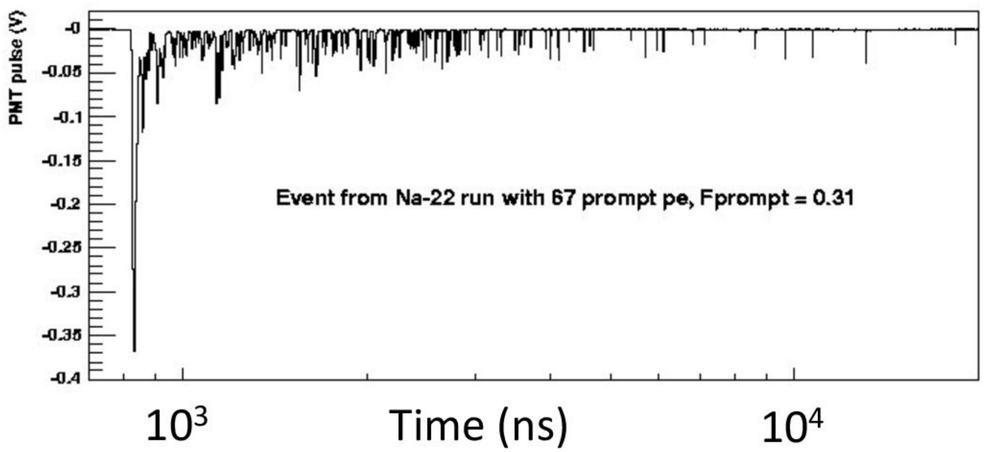
MiniCLEAN Installation in SNOLAB Cube Hall

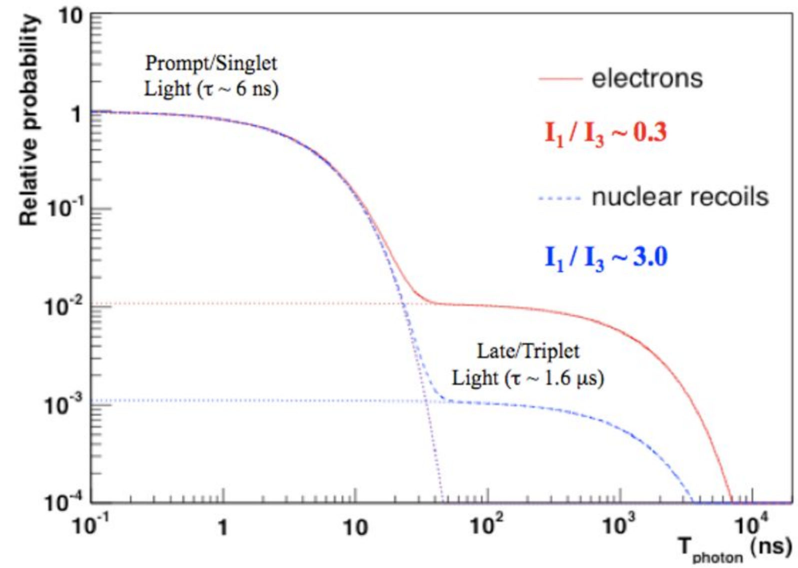


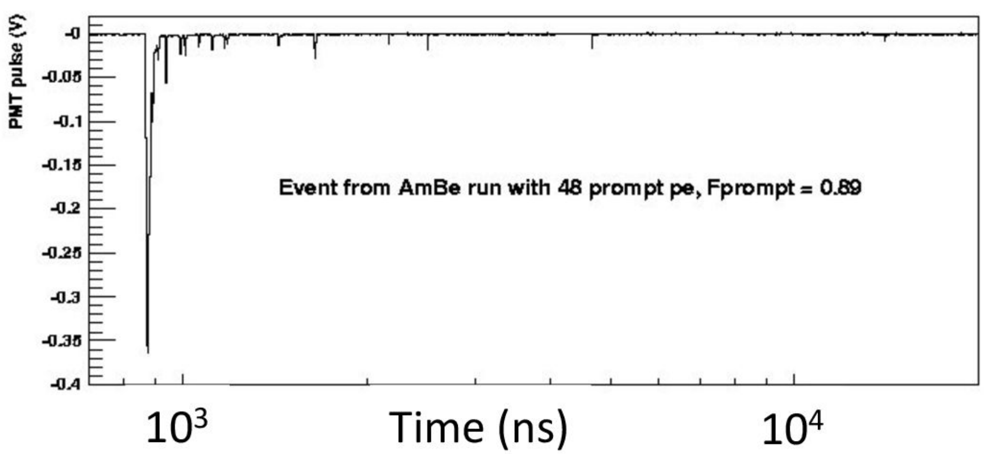
M.G. Boulay and A. Hime, Astroparticle Physics **25**, 179 (2006)

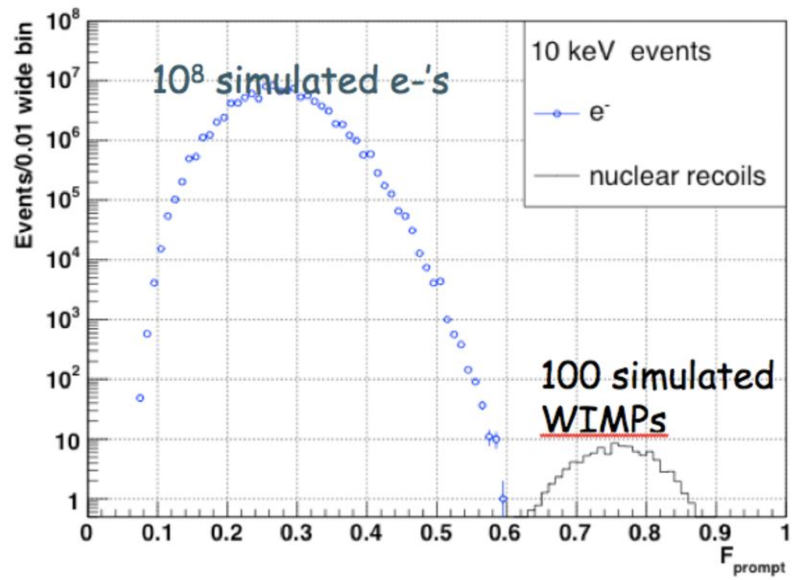
Pulse-Shape Discrimination in LAr

Example Pulses from DEAP-0 at LANL

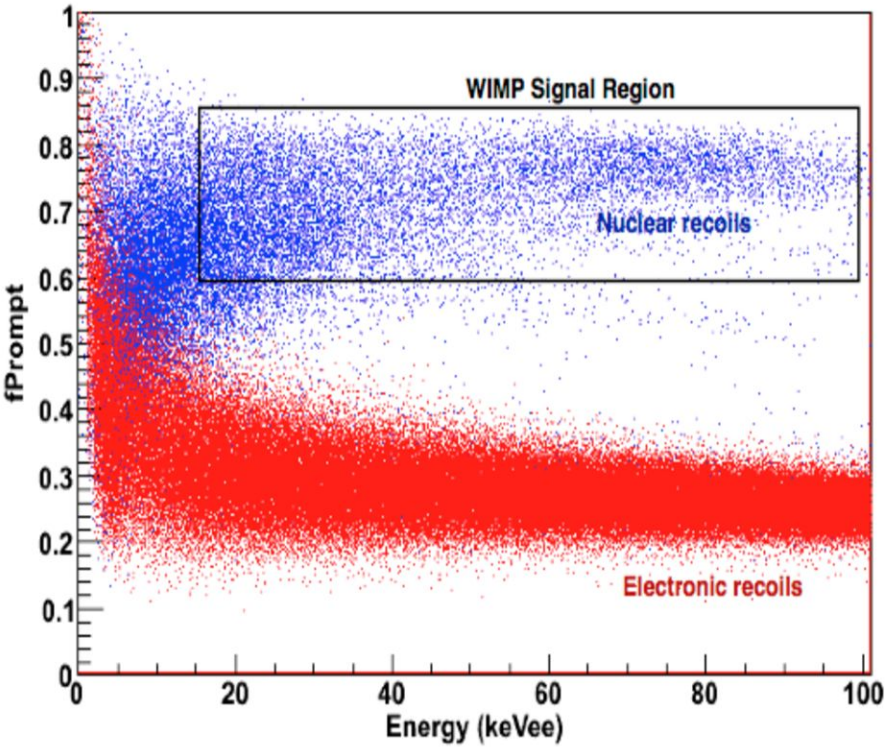






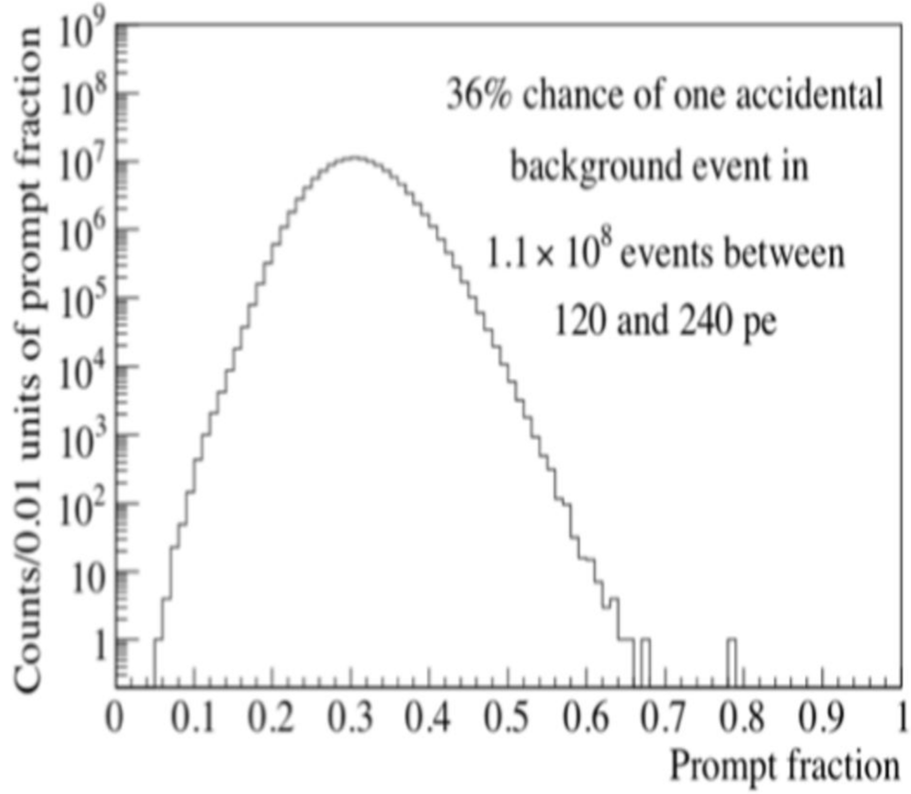


microCLEAN



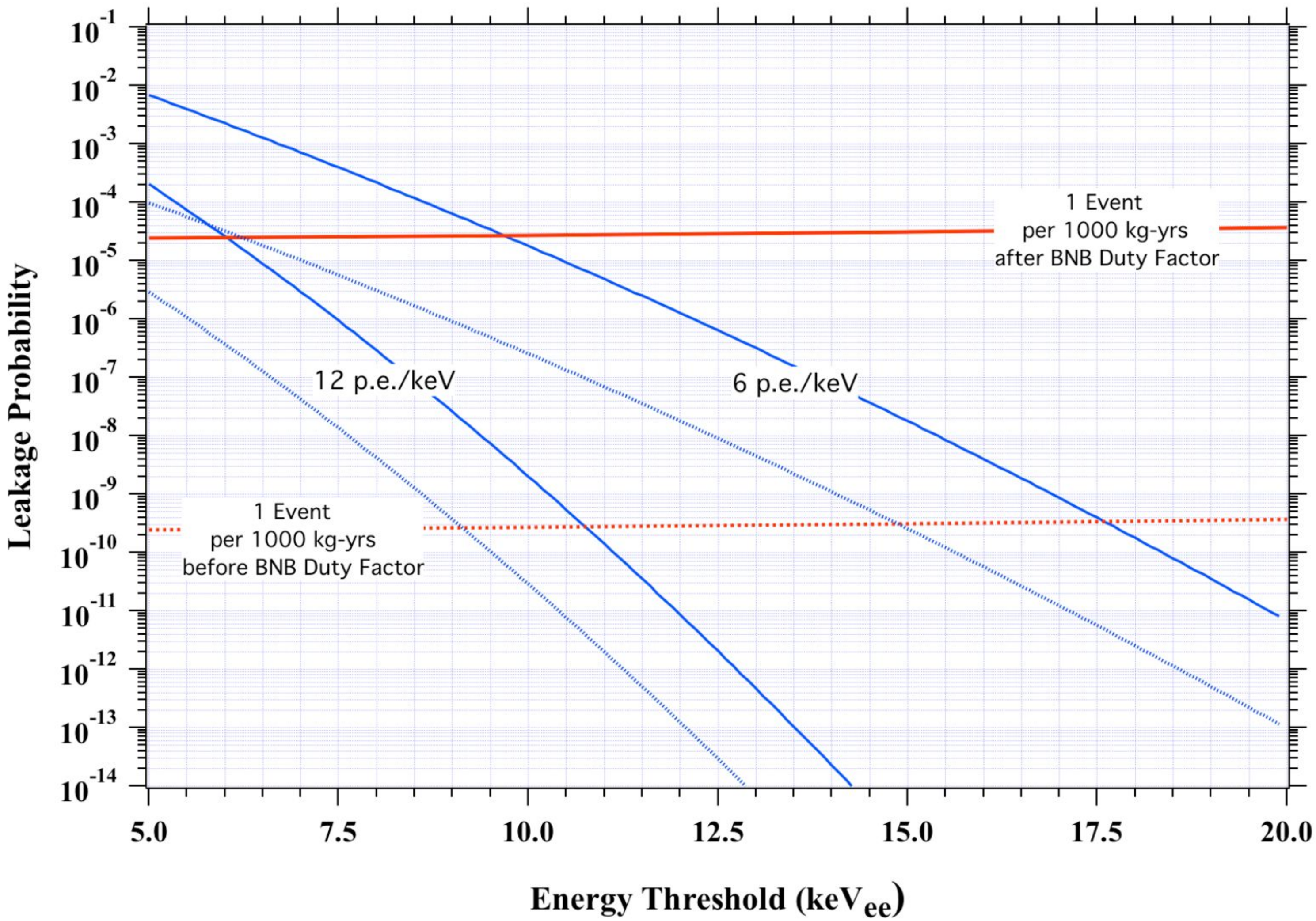
Phys. Rev. C**78**, 035801 (2008)

DEAP-1



arXiv:0904.2903 (2009)
TAUP - 2011

^{39}Ar Background Leakage



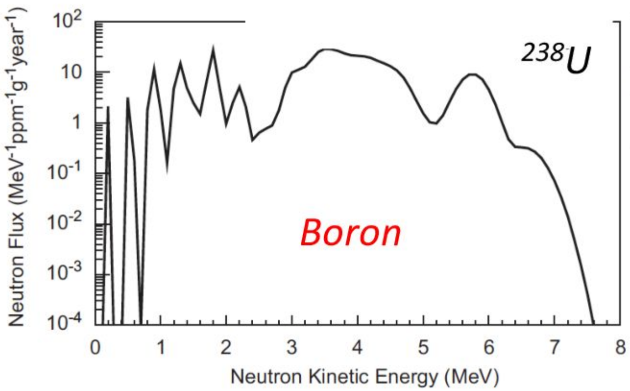
Light Yield

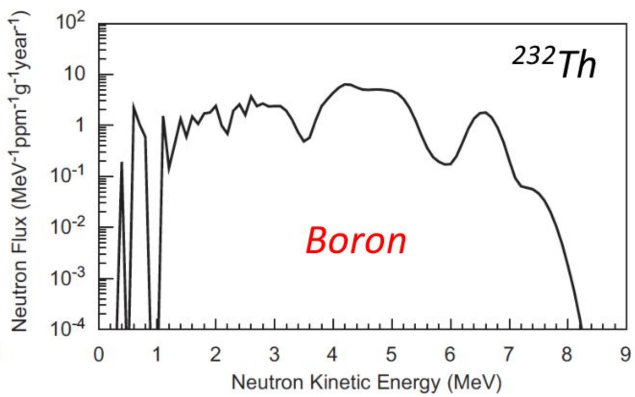
MiniCLEAN

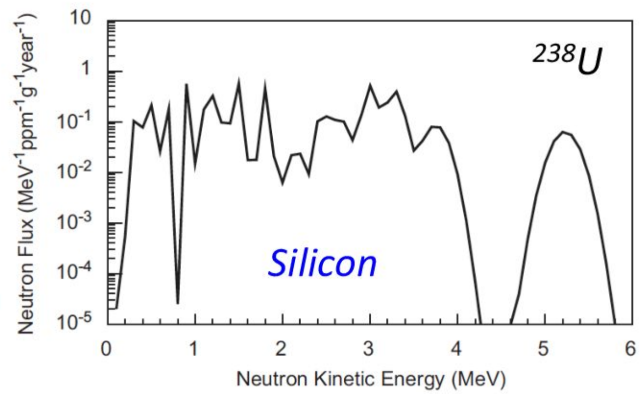
Hamamatsu R5912-02MOD
TPB
3M Foil in 30 cm Light Guides & 10 cm Acrylic Plug
Reflective Baffles in 6.5% of "Coverage" Gap

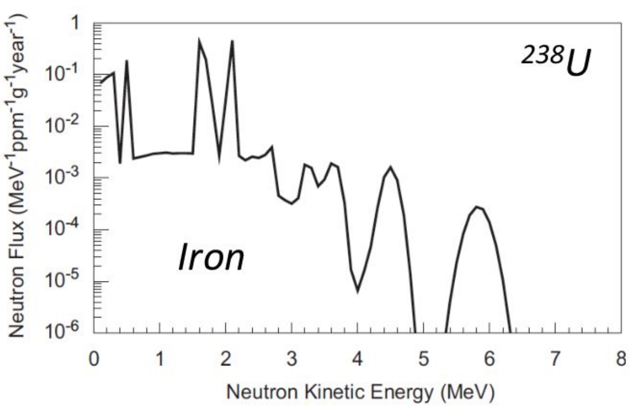
Parameter	Value	Light Yield p.e. / keVee	Note
Scintillation Yield (photons/keVee)	41±2	41±2	100% Efficiency
PMT Efficiency	18±2 %	7.4±1.1	R5912-02MOD
TPB Coverage	93.5	6.9±1.0	Viewing 500 kg Target
TPB Re-Emission Efficiency	1.2±0.1	8.3±1.2	128 nm
Reflectivity & Absorption in TPB	2 to 20 %	7.5±1.9	Deposition Technique
Absorption in Acrylic	11.5 %	6.6±1.7	Attenuation Length is 1.2 m at 420 nm
Absorption in Light Guide	12.5 %	5.8±1.5	Reflectivity is 98% at 420 nm
Resulting Light Yield		5.8±1.5	15% Efficiency

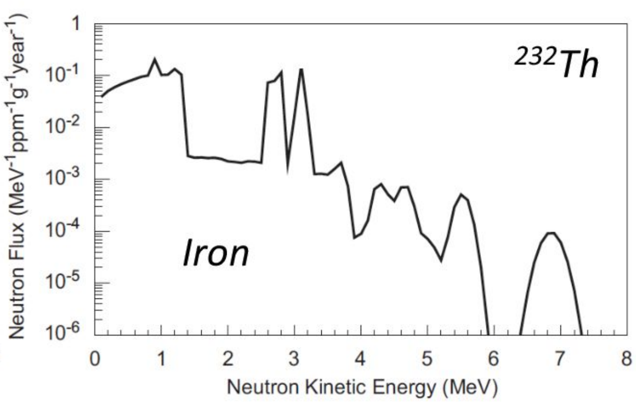
PMT (α,n) Backgrounds











Borated Silica Glass

Hamamatsu
R5912-02MOD

D.-M. Mei, C. Zhang and A. Hime
*NIM A**606**, 651 (2009)*

Detector Related Nuclear Recoil Background

- The intrinsically low background in MiniCLEAN combined with BNB duty factor allows Usage of full 500 kg LAr target for CENNS measurements.

Source	Production Rate (/ton/year)	Detection Rate (events/ton/year)	$E < 25$ keV$_{ee}$	$12.5 < E < 25$ keV$_{ee}$
PMT(α, n)	66,700	11,340	1520	710
Steel(α, n)	3680	495	65	30
Total(α, n)	70,380	11,835	1585	740
Total(α, n) $\times$ duty factor	3.5	0.6	0.08	0.04
Radon	15,880	7,147 ($25 < E < 100$ keV$_{nr}$)		
Radon $\times$ duty factor	0.8	0.36		

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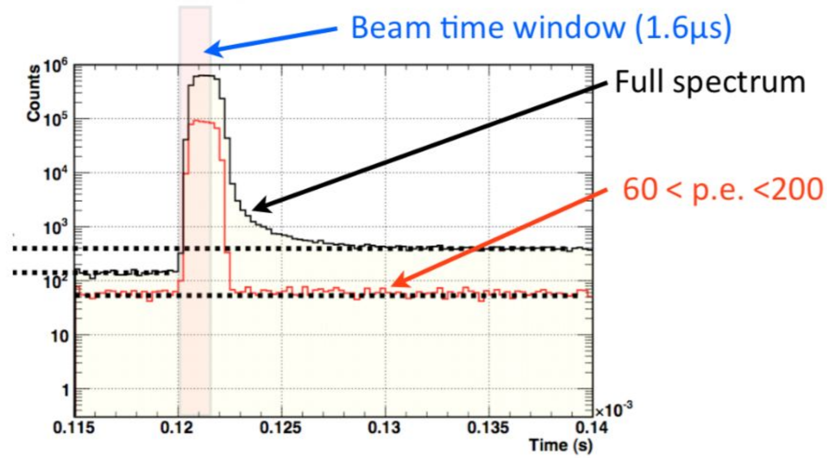
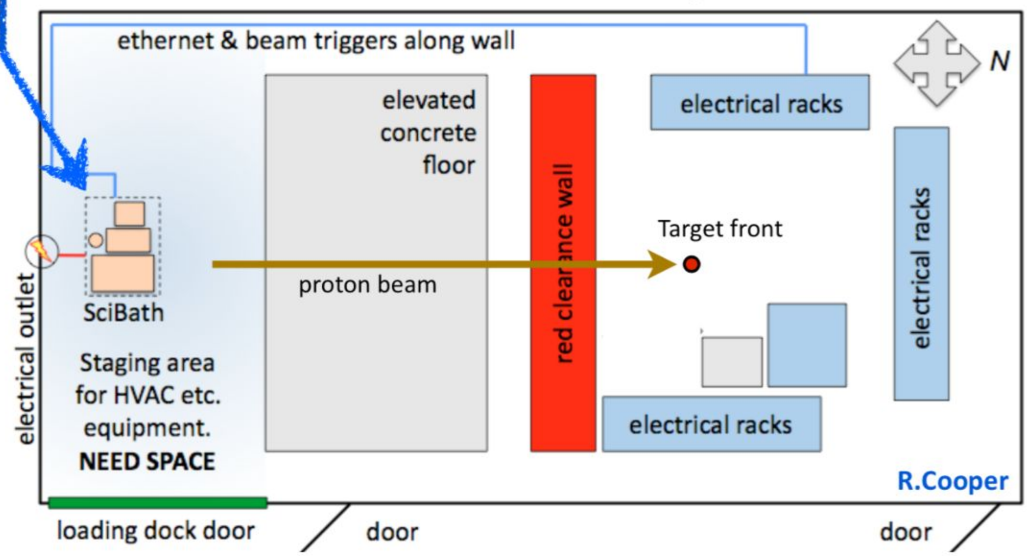
Beam Induced Neutron Background Measured with SciBath

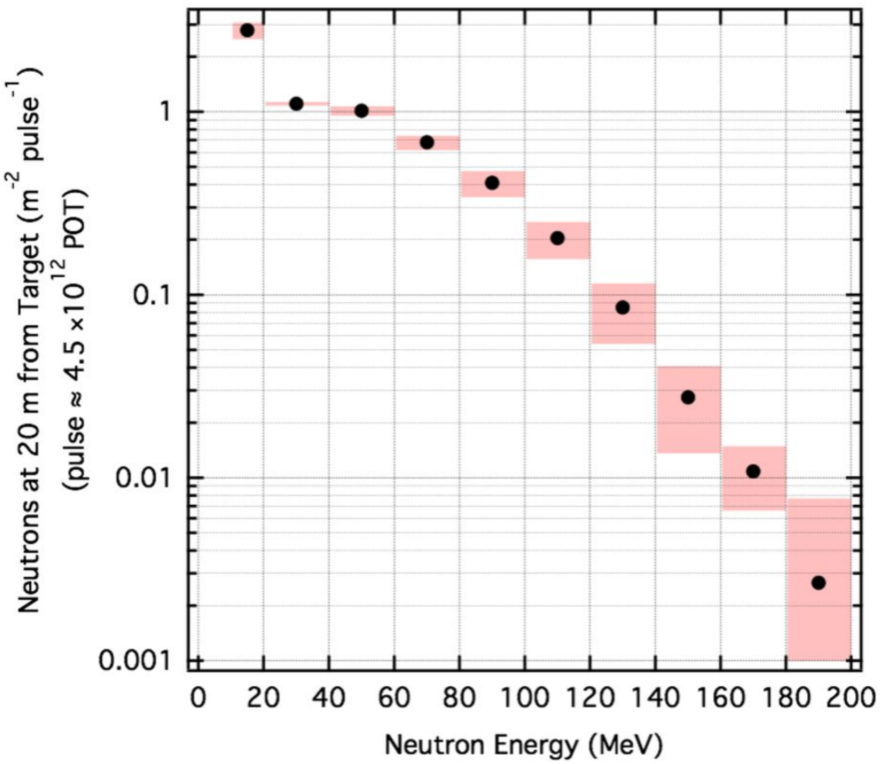


- Detector located in the target building (MI-12 @20m away from the target)
- Pre-beam, in-beam, off-beam backgrounds measurements
- Data taking: Feb~Apr 2012

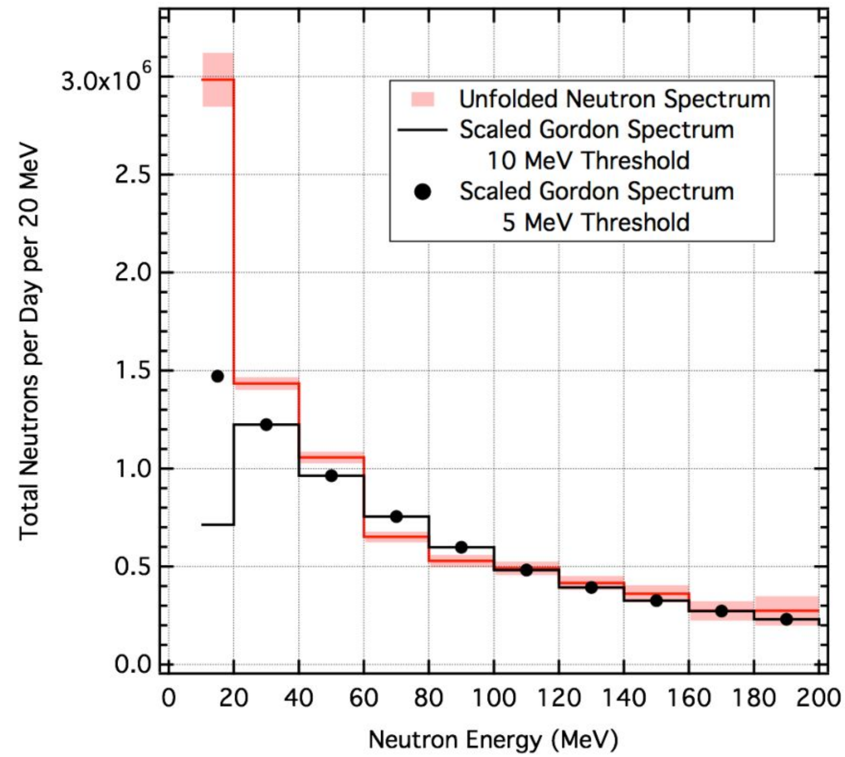


Beam Induced Neutron Backgrounds

Measured Spectrum

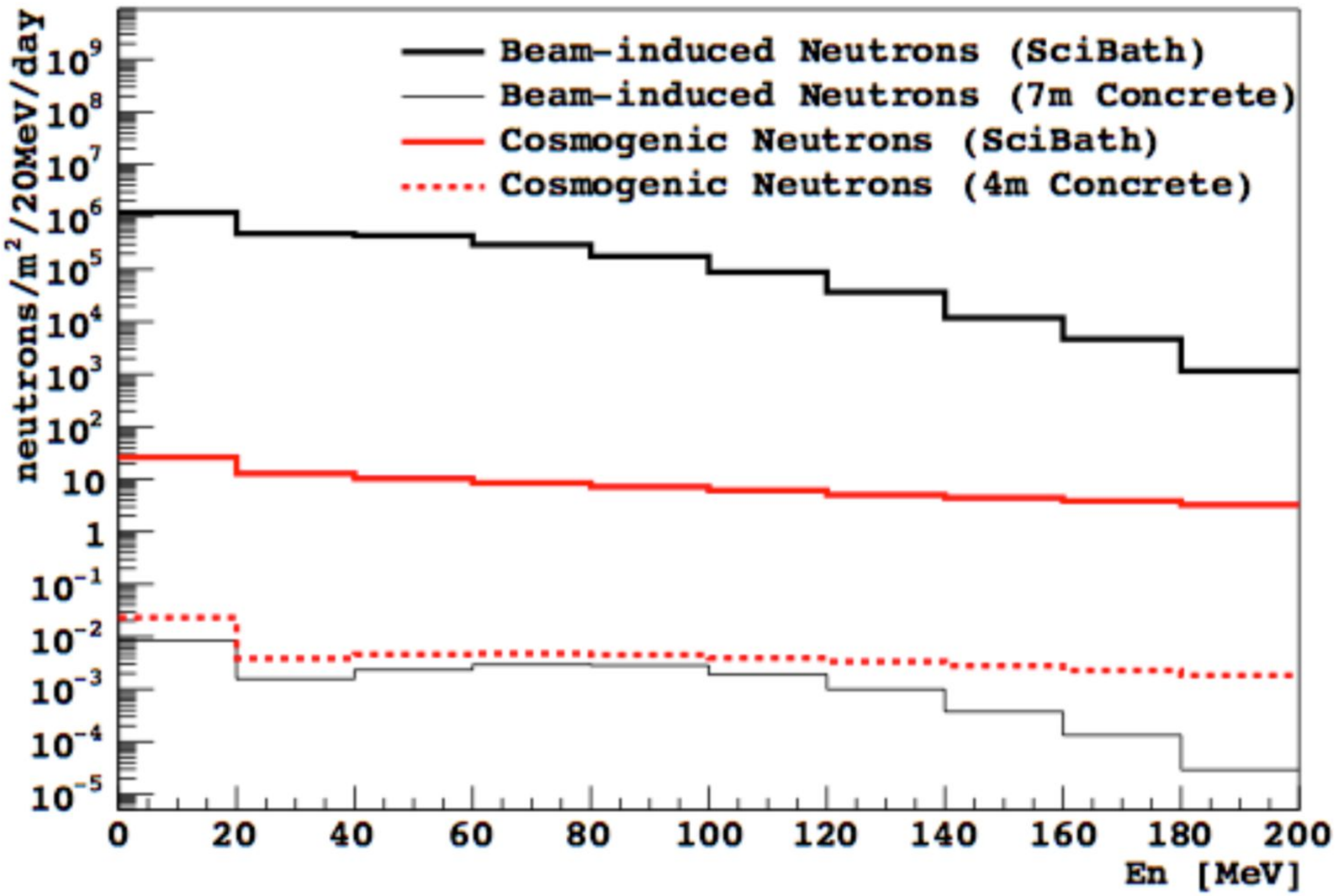


Unfolded Spectrum



CENNS Collaboration, PRD **89**, 072004 (2014)

MC Study for Shielding Beam Induced Neutrons



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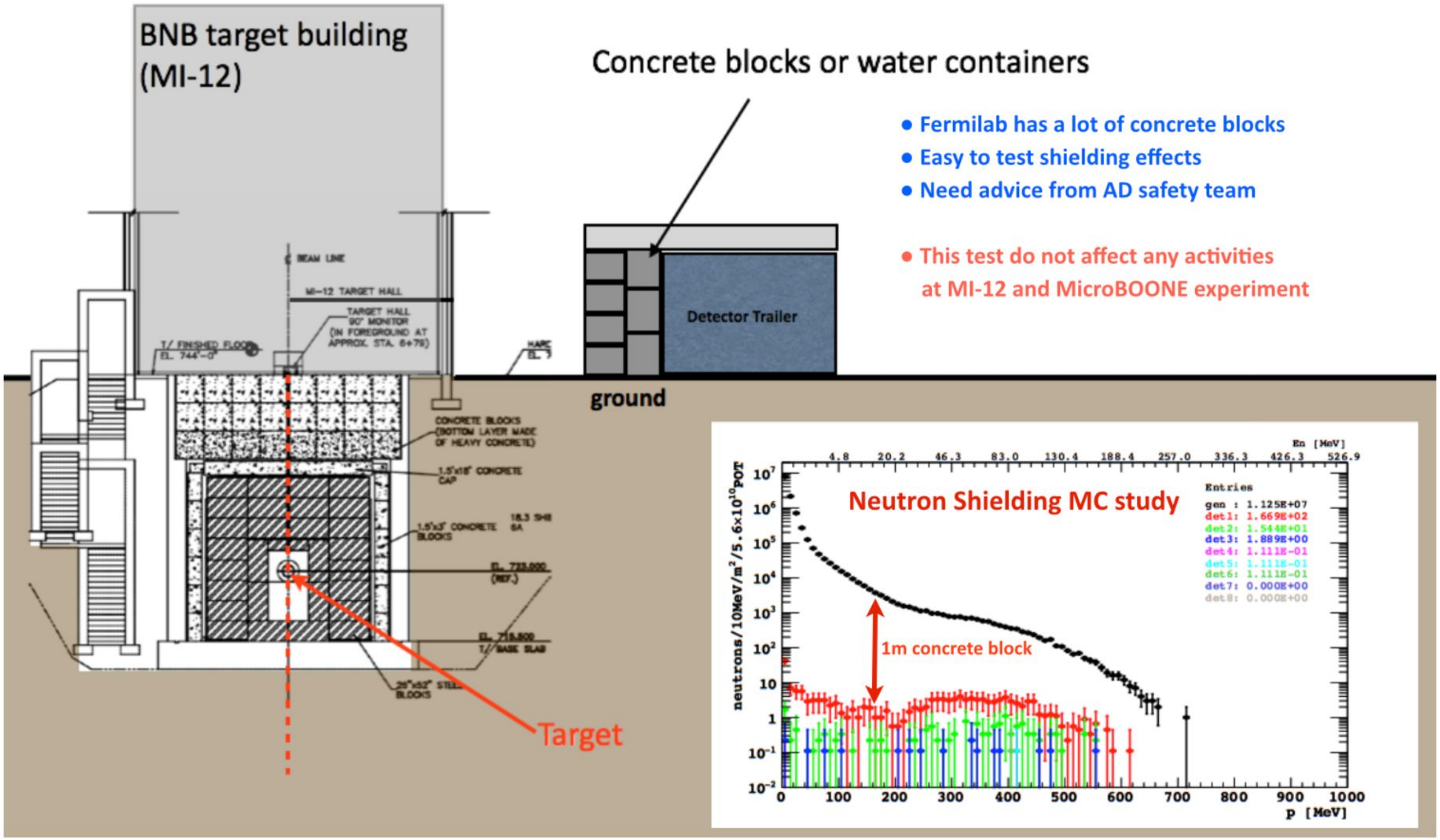
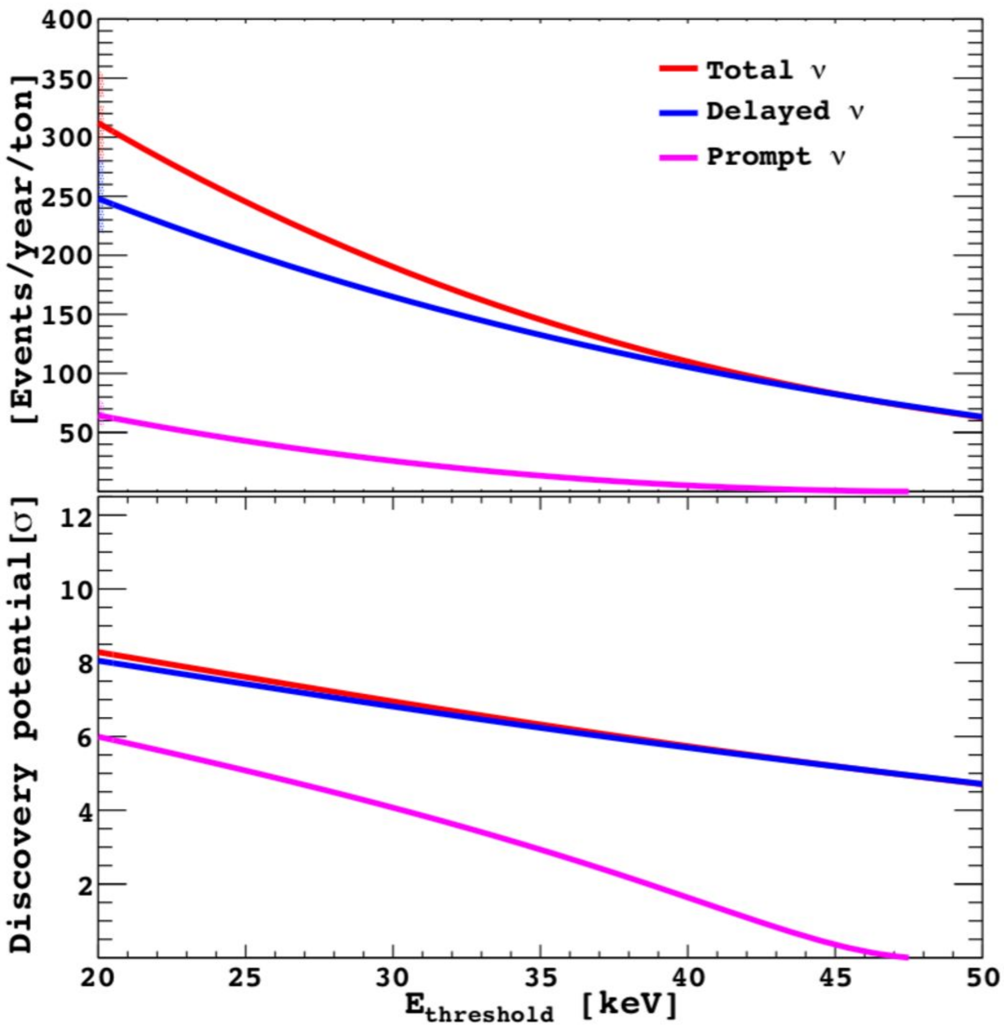
Planning New Measurements of Beam Induced Neutrons



- Fermilab has a lot of concrete blocks
- Easy to test shielding effects
- Need advice from AD safety team

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

“Discovery” Potential for CENNS @ BNB



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Error Budget

	Uncertainty
Neutrino flux	9%
Leff of LAr	7.5%
High-energy neutrinos	$< 1\%$
Beam-induced neutrons	$< 1\%$
Cosmogenic neutrons	$< 1\%$
^{39}Ar and gammas	$< 1\%$
Radiogenic backgrounds	$< 1\%$
Total uncertainty	**12%**

BGNDS
Under Control

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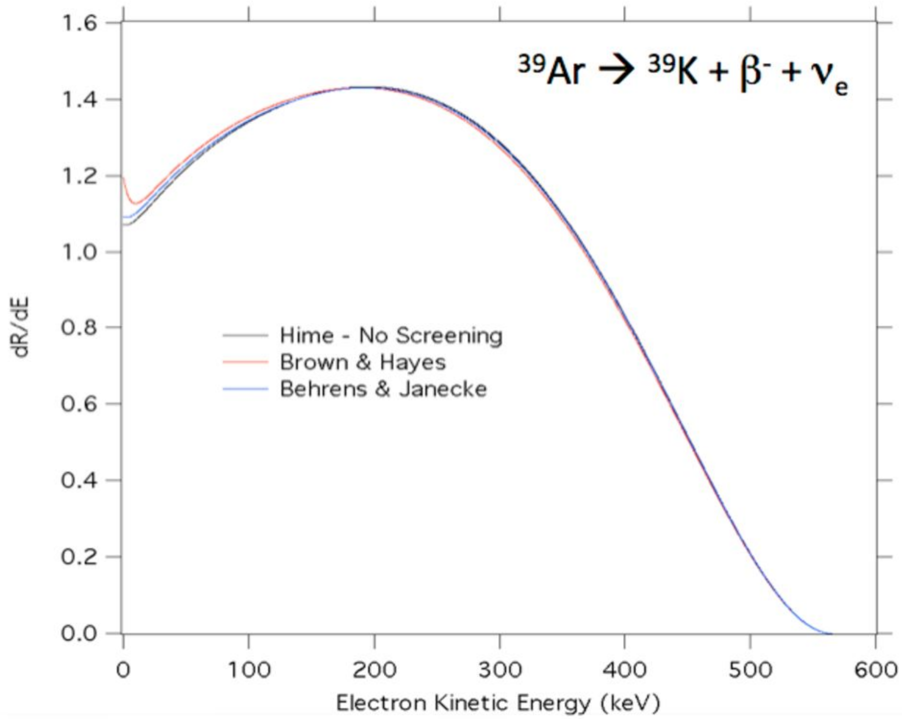
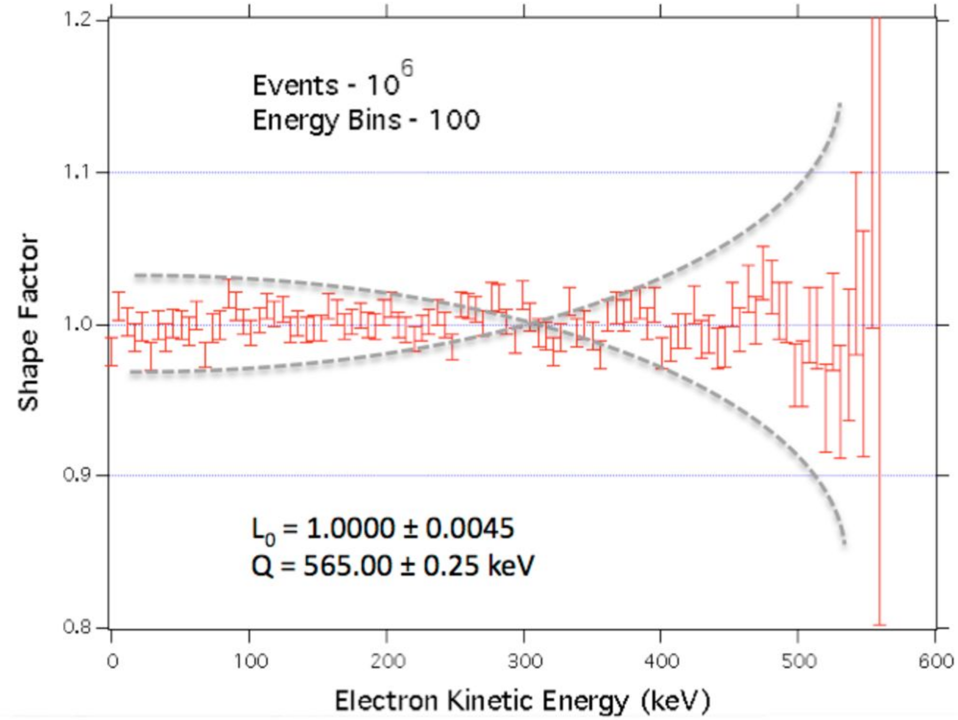
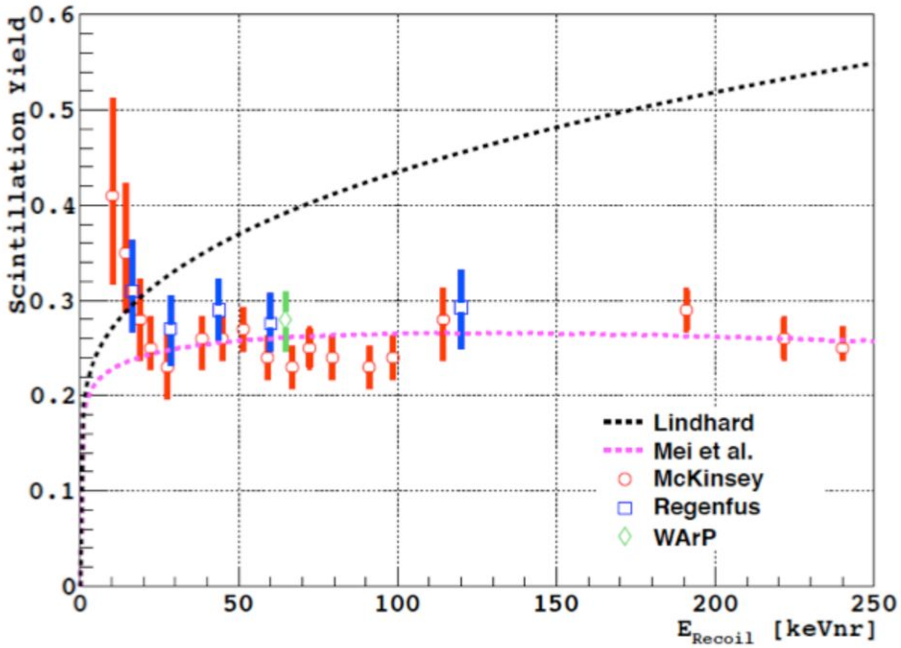
Measure Energy Scale with ^{39}Ar Spectrum

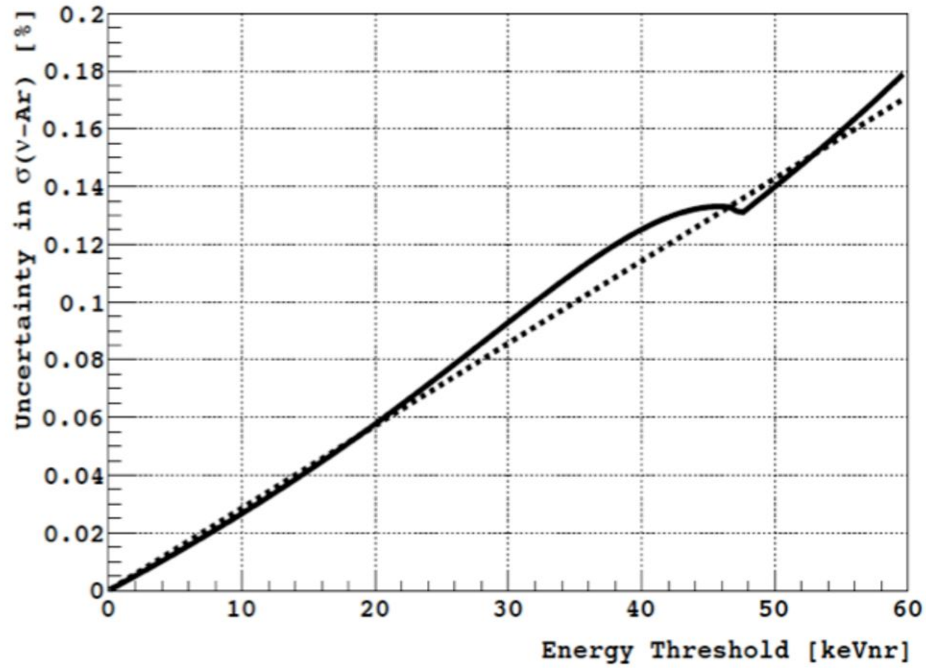




AH, arXiv:1110.1005

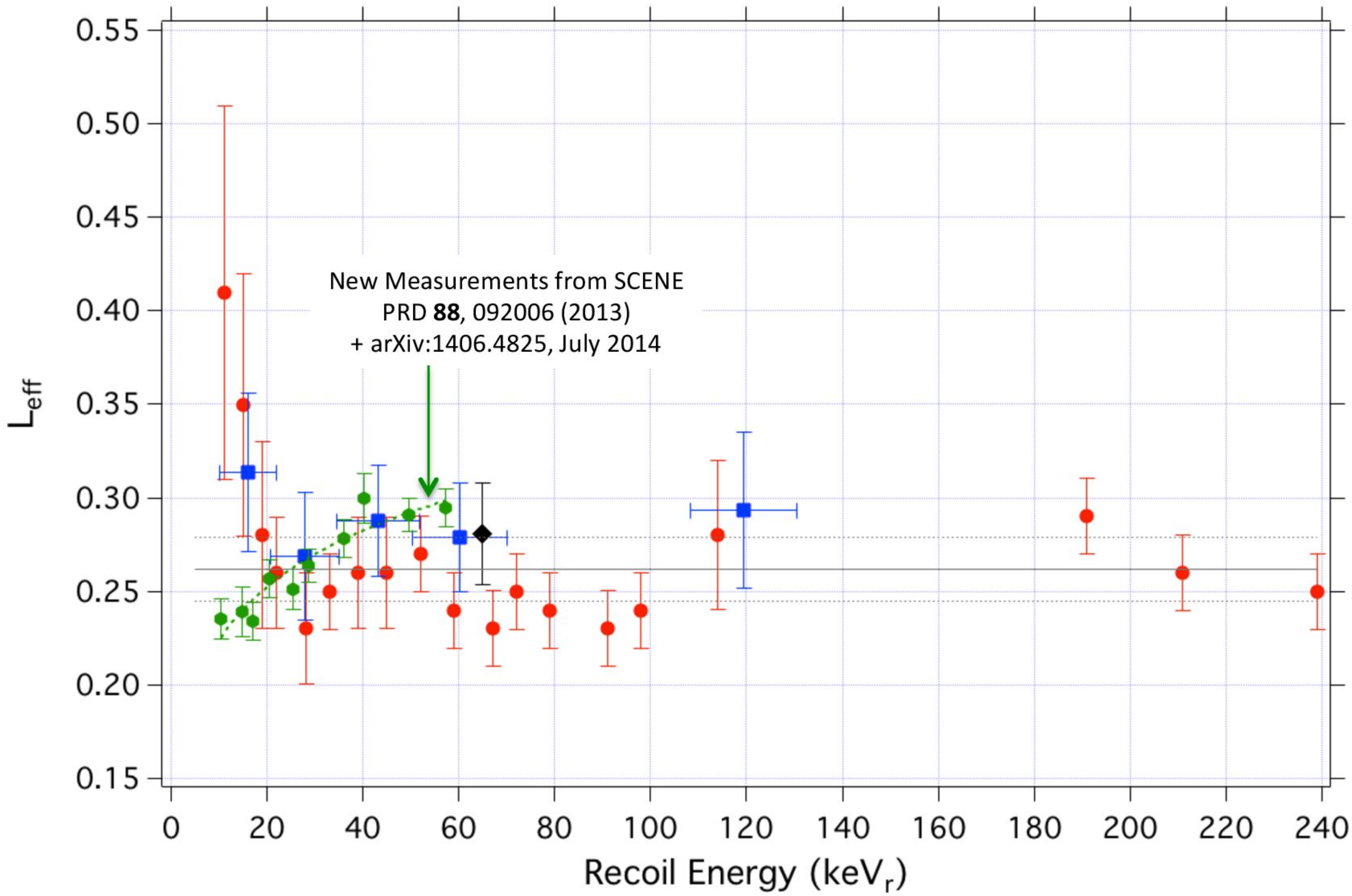
Uncertainties from Nuclear Recoil Scintillation Yield





CENNS Collaboration
PRD **89**, 072004 (2014)

Uncertainties from Nuclear Recoil Scintillation Yield



Comparing Potential Sites

	BNB(FNAL)	SNS(ORNL)	MLF(JPARK)
proton beam power	32 kW (max)	1.4 MW (max)	1MW (max)
proton energy	8 GeV	1 GeV	3 GeV
ν flux at 20m from the target	5e5 ν/cm2/s	1e7 ν/cm2/s	4e6ν/cm2/s
ν flux at closest practical location	2e6 ν/cm2/s (@10m)	2e6 ν/cm2/s (@47m)	6e6ν/cm2/s(@17m)
repetition rate	5 Hz	60 Hz	25 Hz
duty factor	5.00E-06	6.00E-04	1.20E-06
beam induced n-background	measured	under study	under study
CENNS event rate (Er>30keVr)	~700 ev/yr/1ton LAr	~700 ev/yr/1ton LAr	~2100 ev/yr/1ton LAr
Institution	US. DOE. HEP	US. DOE. BS	JPN. Material Science

A Perspective

A phased program for CENNS measurements at the Fermilab BNB is both timely and strategic. On the one hand, the existing BNB can provide the low-energy neutrino source to carry out a Phase-I scientific program using the MiniCLEAN detector. It is pertinent to note that the design and construction of the MiniCLEAN detector was at a capital Cost of ~$10M. Furthermore, with accelerator upgrades at Fermilab anticipated in the near future, the substantial increase in neutrino intensity (following upgrade from ~32 kW to ~1.2 MW) would allow a Phase-II Experiment with a factor of 6 in statistics and maintaining use of the MiniCLEAN detector. This would poise the collaboration well for a proposal to stage a massive LAr detector at the BNB for a future Phase-III campaign.

Thank You