Precision Measurements with (Anti)Neutrinos at LBNF

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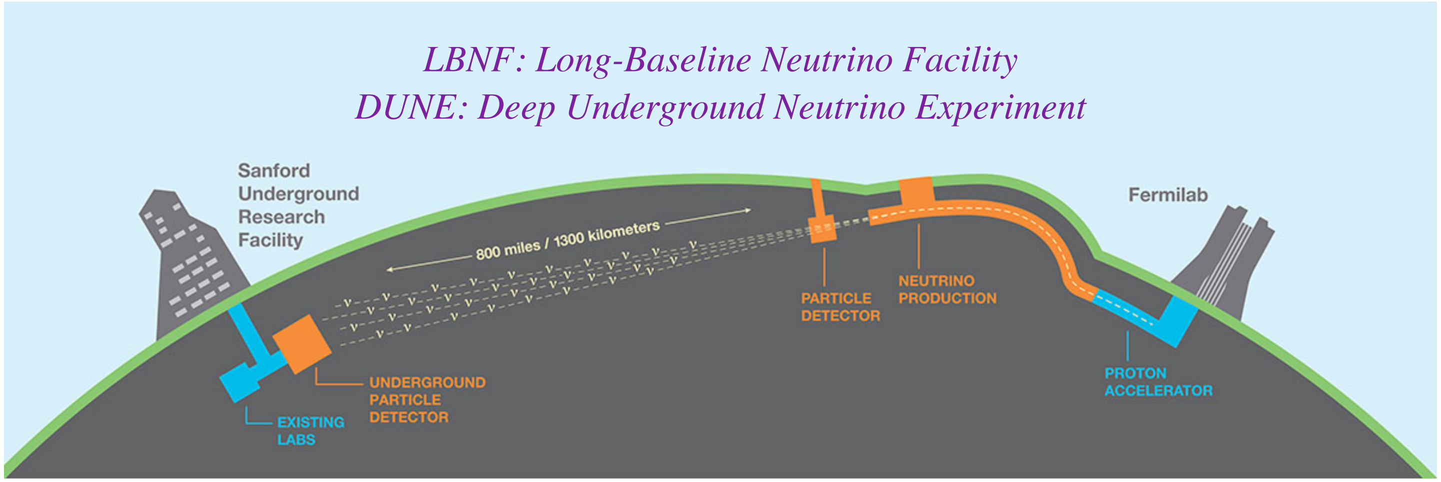
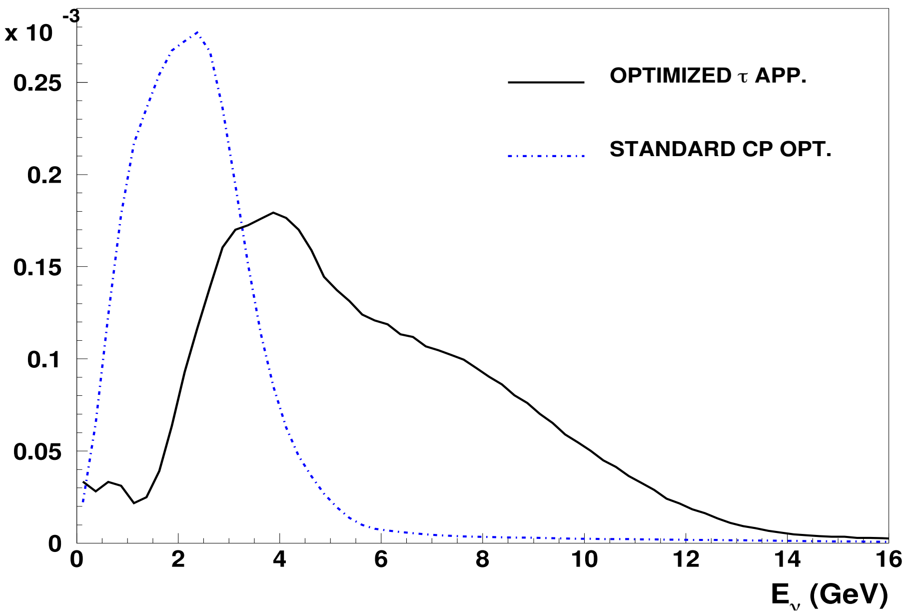
LBNF SPECTRA & STATISTICS

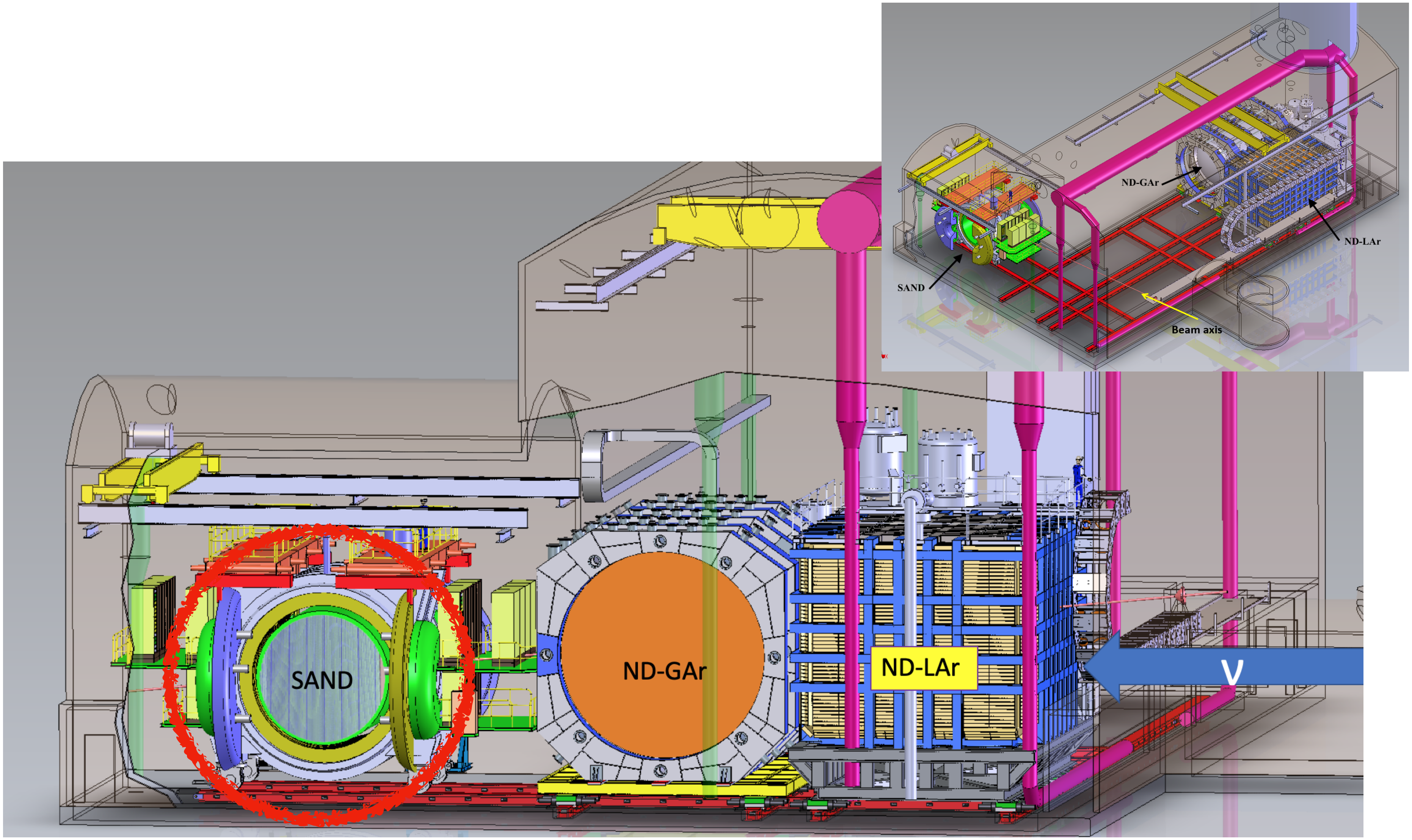




Interactions (ND 5 tons)	CH_2
Standard CP optimized (1.2 MW):	
ν_μ CC (ν beam, 5 y)	33×10^6
$\bar{\nu}_\mu$ CC ($\bar{\nu}$ beam, 5 y)	12×10^6
Optimized ν_τ appearance (2.4 MW):	
ν_μ CC (ν beam, 2 y)	62×10^6
$\bar{\nu}_\mu$ CC ($\bar{\nu}$ beam, 2 y)	22×10^6

$\Longrightarrow$ *Can collect $\sim 10^8$ CC events with compact high-resolution detector ($\Delta E_\mu \leq 0.2\%$)*

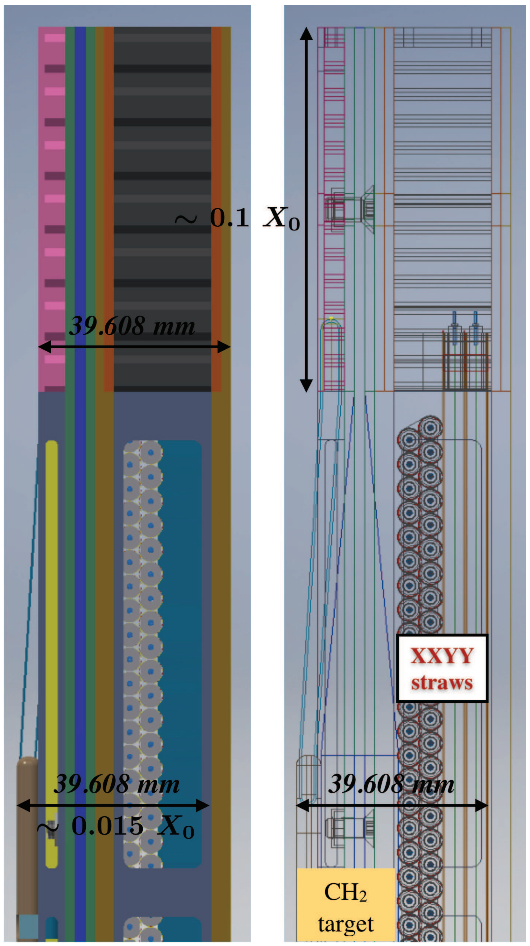
NEAR DETECTOR COMPLEX IN DUNE



CONTROL OF TARGETS

- *Straw Tube Tracker designed for a control of ν-target(s) similar to $e^{\pm}$ DIS experiments:*
  - *Typical ν-detectors: systematics from target composition & materials, limited target options;*
  - *Thin (1-2% X_0) passive target(s) separated from active detector (straw layers);*
  - *Target layers spread out uniformly within tracker by keeping low density* $0.005 \leq \rho \leq 0.18$ g/cm^3.

$\Longrightarrow$ *STT can be considered a precision instrument fully tunable/configurable*



- *Targets of high chemical purity give $\sim 97\%$ of STT mass (straws 3%)*
- *"Solid" hydrogen target from a model-independent subtraction of* CH_2 & C *after kinematic selection*
- *Thin targets can be replaced during data taking: C, Ca, Ar, Fe, Pb, etc.*

$\Longrightarrow$ *STT considered for inner tracker of SAND in DUNE ND*

GENERAL PURPOSE PHYSICS FACILITY

✦ *Possible to constrain systematics reducing the precision gap with electron experiments*

- *Relative ν_μ and $\bar{\nu}_\mu$ flux vs. E_ν to $< 1\%$ from exclusive processes on H at small energy transfer;*
- *Calibration of neutrino energy scale and nuclear smearing with H control sample.*

✦ *Turn the LBNF ND site into a general purpose $\nu \& \bar{\nu}$ physics facility with broad program complementary to ongoing fixed-target, collider and nuclear physics efforts:*

- *Measurement of $\sin^2 \theta_W$ and electroweak physics;*
- *Precision tests of isospin physics & sum rules (Adler, GLS);*
- *Measurements of strangeness content of the nucleon $(s(x), \bar{s}(x), \Delta s$, etc.);*
- *Studies of QCD and structure of nucleons and nuclei;*
- *Precision tests of the structure of the weak current: PCAC, CVC;*
- *Measurement of nuclear physics and (anti)-neutrino-nucleus interactions; etc. .....*
- *Precision measurements as probes of New Physics (BSM);*
- *Searches for New Physics (BSM): sterile neutrinos, NSI, NHL, etc.....*

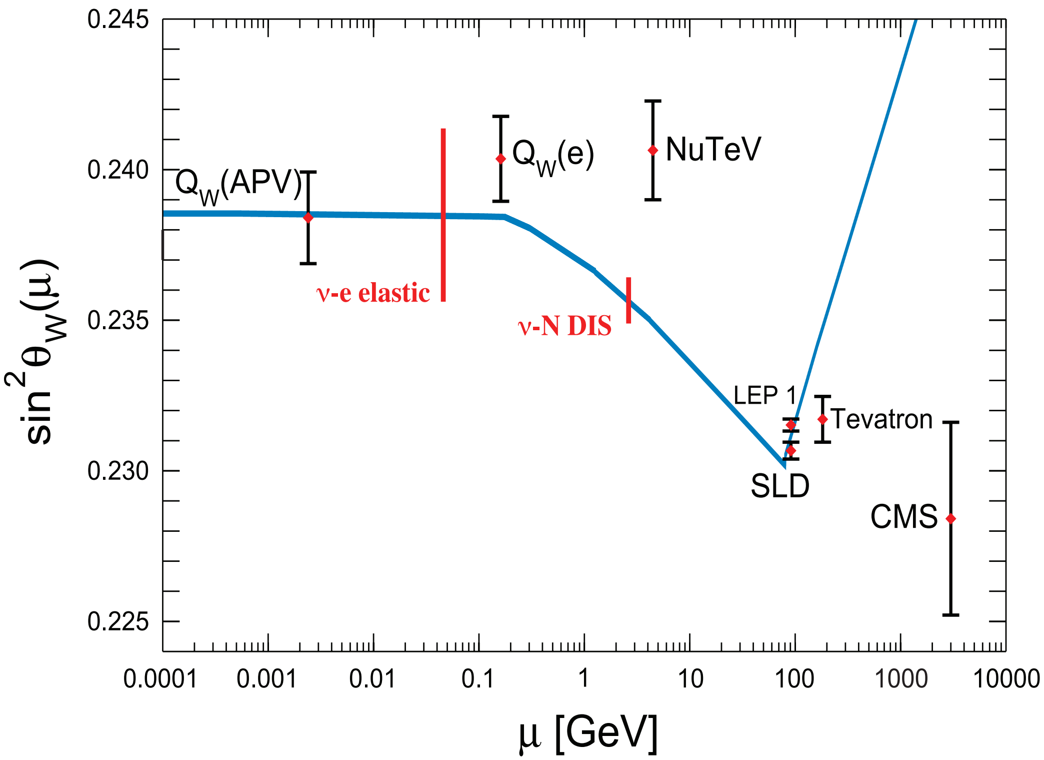
$\Longrightarrow$ *Hundreds of diverse physics topics offering insights on various fields*

✦ *No additional requirements: same control of targets & fluxes to study LBL systematics*

ELECTROWEAK MEASUREMENTS

✦ *Complementarity with colliders & low-energy measurements:*

- *Different scale of momentum transfer with respect to LEP/SLD (off Z^0 pole);*
- *Direct measurement of neutrino couplings to Z^0*
  $\Longrightarrow$ *Only other measurement LEP $\Gamma_{\nu\nu}$*
- *Single experiment to directly check the running of $\sin^2\theta_W$;*
- *Independent cross-check of the NuTeV $\sin^2\theta_W$ anomaly ($\sim 3\sigma$ in ν data) in a similar Q^2 range.*



✦ *Different independent channels:*

- $\mathcal{R}^\nu = \frac{\sigma^\nu_{\rm NC}}{\sigma^\nu_{\rm CC}}$ *in ν-N DIS (~0.35%)*
- $\mathcal{R}_{\nu e} = \frac{\sigma^{\bar\nu}_{\rm NC}}{\sigma^\nu_{\rm NC}}$ *in ν-e^- NC elastic (~1%)*
- *NC/CC ratio $(\nu p \to \nu p)/(\nu n \to \mu^- p)$ in (quasi)-elastic interactions*
- *NC/CC ratio ρ^0/ρ^+ in coherent processes*

$\Longrightarrow$ *Combined EW fits*

✦ *Achievable sensitivity depending upon HE beam exposure*

SUMMARY

- ✦ *The intensity and different $\nu(\bar{\nu})$ spectra available at the LBNF offer unique opportunities for neutrino physics, if coupled with a high resolution ND of a few tons*

- ✦ *STT instrumentation of SAND provides control of configuration, material & mass of neutrino targets similar to electron experiments & suite of various target materials.*

- ✦ *"Solid" hydrogen concept can provide high statistics $\mathcal{O}(10^6)$ samples of $\nu(\bar{\nu})$-hydrogen interactions, allowing precisions in the measurement of ν & $\bar{\nu}$ fluxes $< 1\%$.*

- ✦ *Turn the LBNF ND site into a general purpose ν & $\bar{\nu}$ physics facility with broad program complementary to ongoing fixed-target, collider and nuclear physics efforts*

- ✦ *Precision electroweak measurements using various independent channels characterized by different momentum scale*

  $\Longrightarrow$ *Study sensitivity vs. exposure and possible combination with other measurements*

Precision Measurements with (Anti)Neutrinos at LBNF

G. Adamov[1,10], L. Alvarez Ruso[2], I. Bagaturia[1], B. A. Bambah[30], P. Bernardini[3,4], S. Bertolucci[5,6], M. Bhattacharjee[7], B. Bhuyan[7], S. Biagi[8], B. Brahma[31], A. Caminata[9], A. Cervelli[5], A. Chatla[30], D. Chokheli[1,10], A. Chukanov[10], S. Davini[9], S. Di Domizio[9,11], C. Distefano[8], L. Di Noto[9,11], M.V. Diwan[13], H. Duyang[12], P. Evtoukhovitch[10], A. Falcone[14,15], O. Fedin[16], A. Ferrari[17], F. Ferraro[9,11], A. Gabrielli[5], Z. Ghorbani Moghaddam[9], A. Giri[31], M. Guerzoni[5], B. Guo[12], M.A. Iliescu[18,19], A. Jha[30], I. Kakorin[10], A.L. Kataev[20], A. Khvedelidze[1,10], B. Kirby[13], U. Kose[5,19], S.A. Kulagin[20], C. Kullenberg[10], C. Kuruppu[12], R. Lalnuathunga[31], I. Lomidze[1], G. Laurenti[5], R. Majhi[30], V. Maleev[16], S. Malhotra[24], G .Mandrioli[5], N. Mauri[5,6], P. Mehta[21], S.R. Mishra[12], N. Moggi[5,6], R. Mohanta[30], A. Montanari[5], S. Movchan[10], S. Nagu[22], A. Nandi[7], A. Nath[7], F. Olness[23], M. Pallavicini[9,11], R. Papaleo[8], L. Pasqualini[5,6], L. Patrizii[5], R. Petti[12], V. Pia[5,6], F. Poppi[5,6], M. Pozzato[5,6], G. Riccobene[8], P.R. Sala[25], O. Samoylov[10], P. Sapienza[8], F. H. Sawy[26,28], Ja. Singh[22], Jy. Singh[22], K. Singh[24], L. Singh[27], V. Singh[27], G. Sirri[5], L. Stanco[26], S. Sundar Rajan[24], A. Surdo[4], N. Talukdar[7], M. Tenti[5], V. Teotia[24], F. Terranova[14,15], G. Testera[9], M. Torti[14,15], N. Tosi[5], R. Travaglini[26], Z. Tsamalaidze[1,10], N. Tsverava[1,10], S. Vasina[10], M. Vicenzi[9,11], S. Zucchelli[5,6], and B. Wonsak[29]

Backup slides