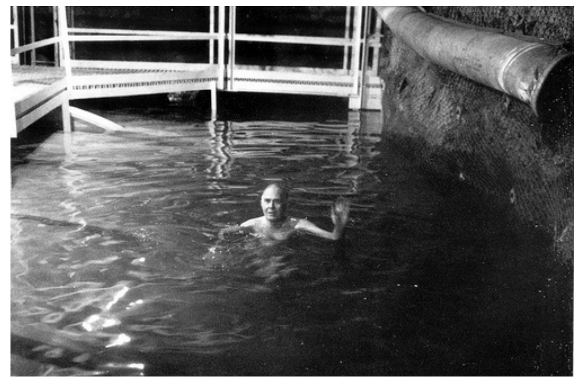
Survey of Facilities for Fundamental Symmetries and Neutrinos

Brad Plaster, University of Kentucky

+ thanks to innumerable members of the community (U.S. and international) !



NSAC Fundamental Symmetries and Neutrinos Workshop

Chicago – August 11, 2012

Goals For This Talk: "Where" ?

What are the facilities here in the U.S. ?

Physics programs (broad)

Current and envisioned future status

What is the international competition ?

Broadly, where are U.S. nuclear physics people working ?

Should address the four NSAC Subcommittee questions

Neutron Physics	Underground Labs (– Sanford; *K. Lesko*)	JLab 12 GeV: PVES *K. Paschke*
Muon Physics	"Other" : Nuclear β-Decay, EDM R&D, Kaons, …	*Focus on "nuclear physics"* *Disclosure: I work in neutron physics*

I. Neutron Physics Facilities

Facilities: Cold vs. Ultracold Neutrons

"Cold Neutrons"
~50 μeV – ~25 meV

↓

Moderation of Flux From Reactor / Spallation Source

↓

Transported Along Guides
Pros: High Rates

↓

Hadronic PV, β-decay, Interferometry, n-nbar

"Ultracold Neutrons" **"UCN"**
< 350 neV

↓

Downscattering of (Cold) Neutron Flux in Moderator "Source"

↓

Stored in Bottles or Magnetic Traps
Pros: Systematics

↓

nEDM, β-decay, Gravity/Exotic Forces

U.S. Neutron Facilities

NIST (NCNR):
Cold Beamlines

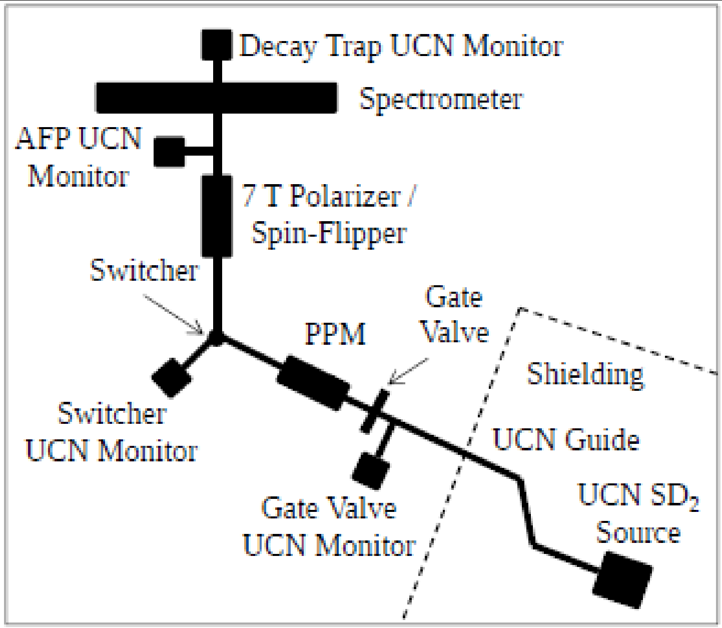
NCSU (PULSTAR):
UCN Source

LANL:
UCN Source

SNS (FNPB):
Cold Beamline(s)

LANL: UCN Source

see A.R. Young talk



LANSCE 800 MeV proton beam (~6 μA)

Shared beamline with Proton Radiography

W Spallation target + cold H moderator

Downscattering to UCN in solid deuterium (~2 L)

Density at shield wall UCN guide exit of ~58/cm^3

1997–2000: Prototyping

2001–2005: Construction/Commissioning

2005– : Operation (per LANSCE cycle)

Key Physics Results :

UCN production mechanism in SD_2 $\rightarrow$ Crucial for PSI, Munich UCN sources

UCNA: First measurements of neutron β-asymmetry A_0 with UCN (g_A/g_V)

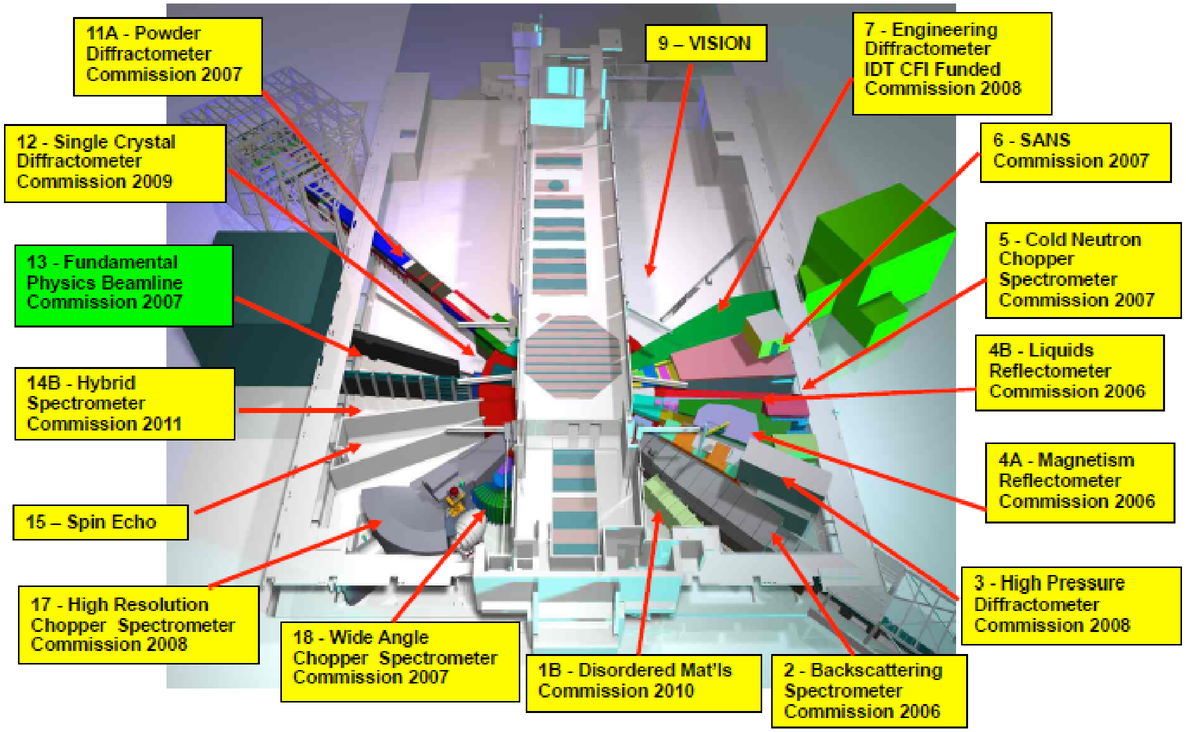
Test bed for nEDM Experiment R&D

Currently only operating UCN source in the U.S.

Large amount of floor space (~15 m × 10 m) for experiments (crane access)

SNS: FnPB

see J. Nico talk



SNS: 1.4 MW proton beam on Hg target

Fundamental Neutron Physics Beamline (#13)

CD-0: 2003

CD-4 achieved on schedule in 2008

Beamline 13 original design, split into :

wavelength selection needed for UCN production

"Cold Beamline" : Hadronic PV and β-decay

"UCN Beamline" : nEDM (8.9 Å selection via monochromator)

UCN beamline 8.9 Å flux below design goal (monochromator efficiency)

nEDM Experiment proposed to move to Cold Beamline (beam choppers)

SNS: FnPB

Envisioned Facility Timeline for Cold Beamline Experiments :

Hadronic PV: $n + p \rightarrow d + \gamma$

Running (LH_2 target operated w/o incident Feb – June)

Rates ~$O(10^2)$ higher than at LANSCE

- Statistics already better than previously published
- Goal: 10 ppb in the next year

↓

Hadronic PV: $n + {}^3He \rightarrow p + T$

Significant progress on hardware construction

↓

Nab: β-decay "a", "b"

Project approved (CD-2 equivalent) by DOE NP

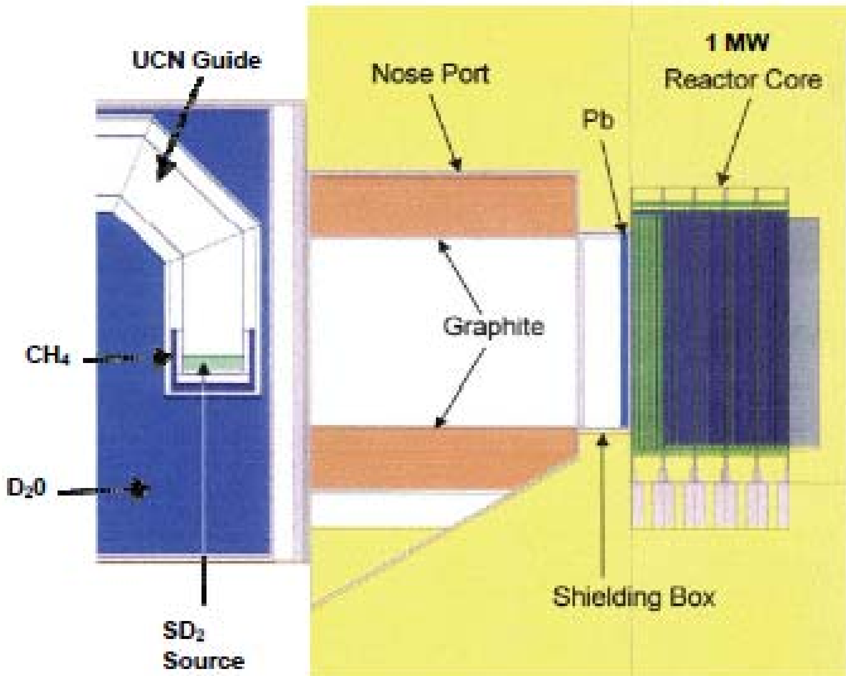
NSF MRI to U. of Virginia for magnetic spectrometer

↓

nEDM Experiment

FnPB out-year schedule somewhat uncertain due to nEDM Experiment status (see B. Filippone talk)

NCSU PULSTAR UCN Source



1 MW research reactor on NCSU campus

UCN source: Solid Deuterium
Initially funded by NSF

Complete: shielding, heavy water system, deuterium gas system, liquid helium system, assembly of source cryostat

In progress: cryogenic testing, UCN guides

Physics program :

Test-bed for nEDM Experiment development (minus the electric field)

Longer-term: Has the footprint for a small- to medium-scale experiment

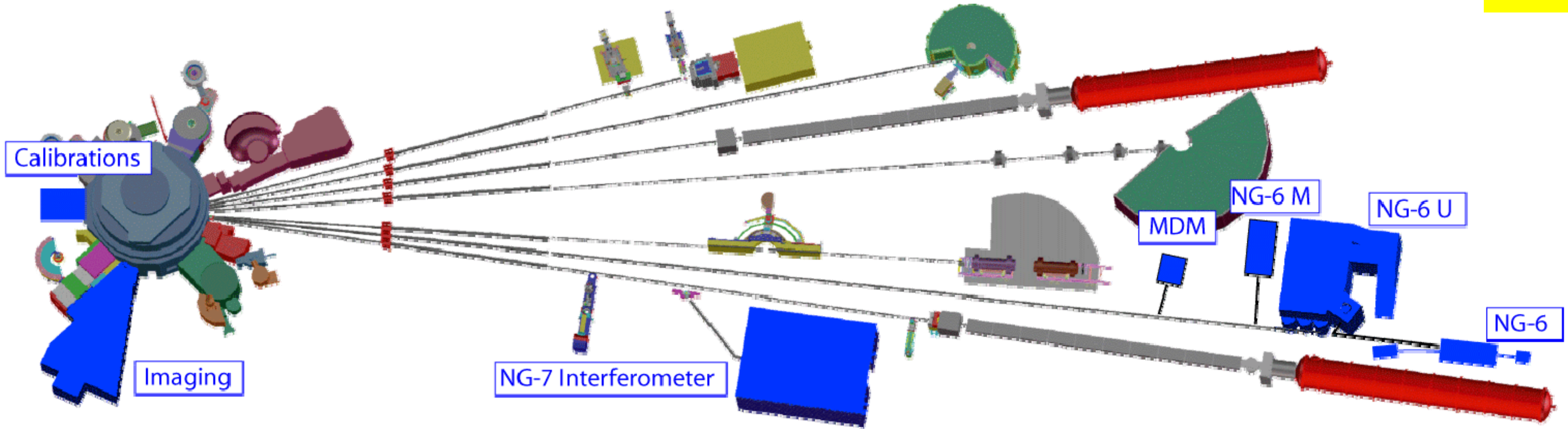
NIST Center for Neutron Research

20 MW research reactor (Dept. of Commerce/NIST), currently LH_2 cold source

Cold neutron beamlines for nuclear physics (DOE/NSF funded collaborations)

Recently: NG-6, NG-7

see J. Nico talk



NG-6: Beam Neutron Lifetime, Time-Reversal Asymmetry, Radiative Decay, PV spin-rotation in Helium, *a*CORN ("*a*" correlation in β-decay)

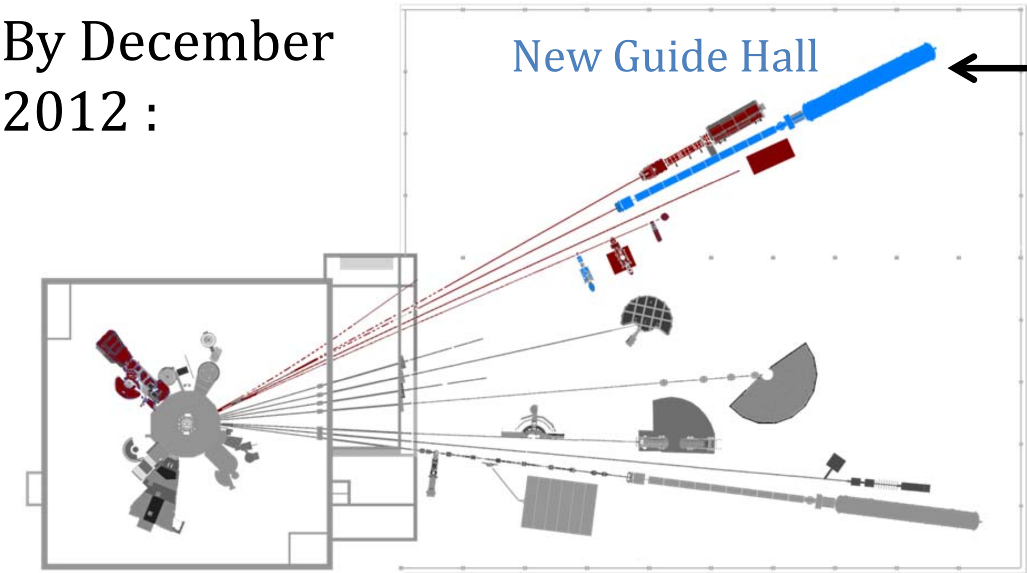
NG-6U: Cold line for UCN production in superfluid ^{4}He, Neutron lifetime

NG-6M: Neutron fluence, Polarized ^{3}He neutron spin filters

NG-7: Interferometry (scattering lengths, neutron charge radius, etc.)

NIST Center for Neutron Research

By December 2012 :



New high-flux beam NG-C

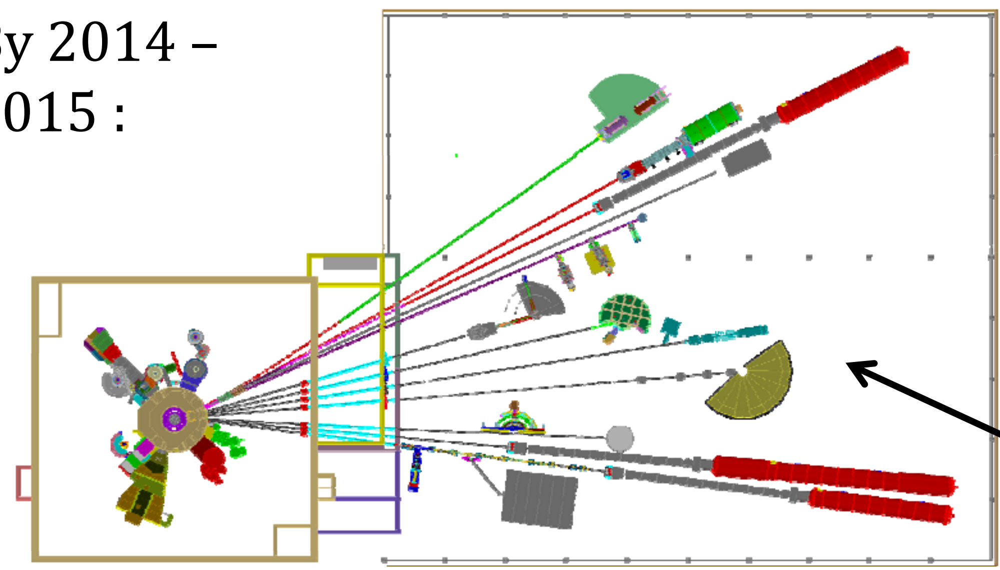
Focusing ballistic guide

11×11 cm^2 area

Comparable to best worldwide

Also: NG-7A, second interferometer

By 2014 – 2015 :



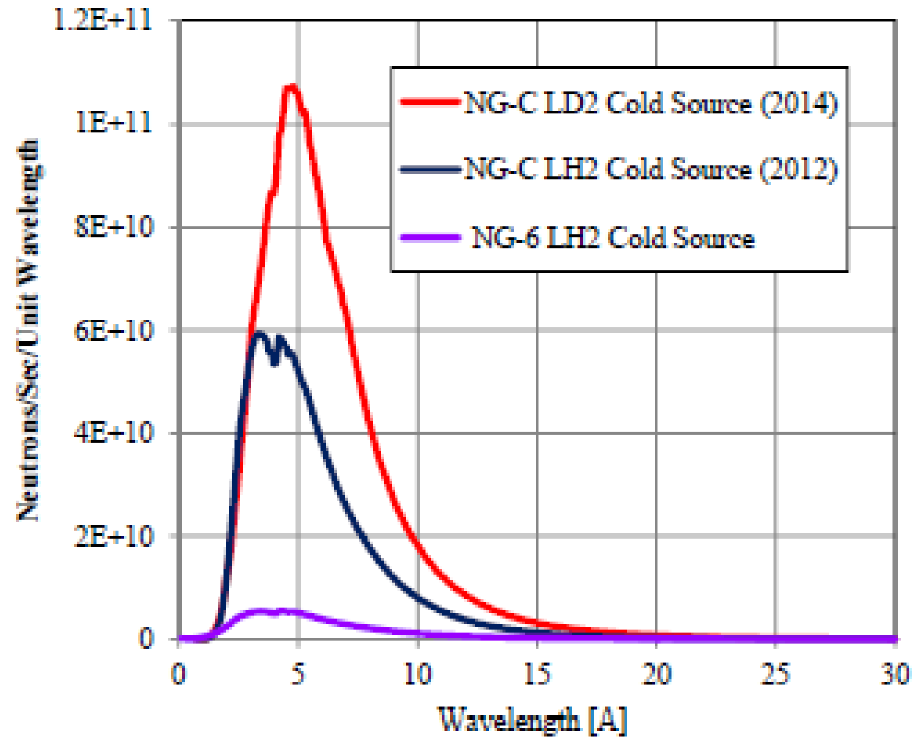
Liquid Deuterium Cold Source Installation Complete

Increased flux

NG-6 neutron physics moves to NG-3

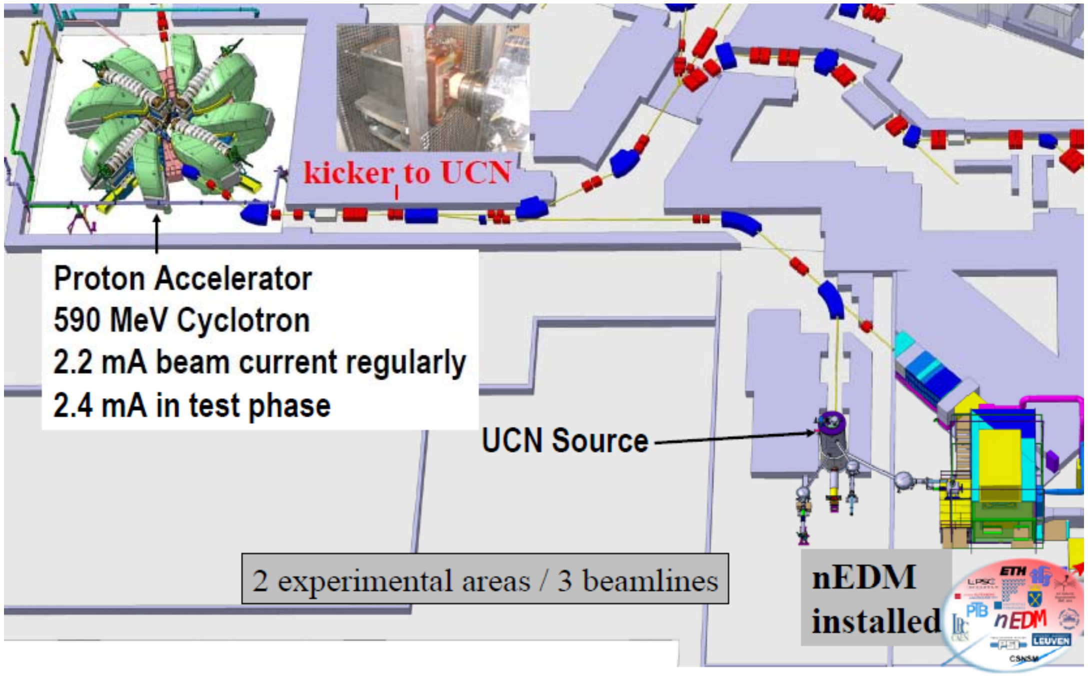
NIST Center for Neutron Research

New Guide Hall



Physics program: aCORN, Beam Lifetime, PV Spin Rotation

PSI: UCN Source



1% duty cycle proton beam

Up to 2.4 mA

Pb/Zr spallation target (~8 n/p)

Heavy-water moderator

UCN moderator

~30 L SD_2 (relatively LARGE)

Construction and commissioning completed 2010

One day of "parasitic" UCN production in December 2010

First beam on target: August 2011

At the end of 2011, only factor of 30–50 from design intensity (~1000/cm^3)

Operation: July 2012 – December 2012

Future physics: PSI nEDM

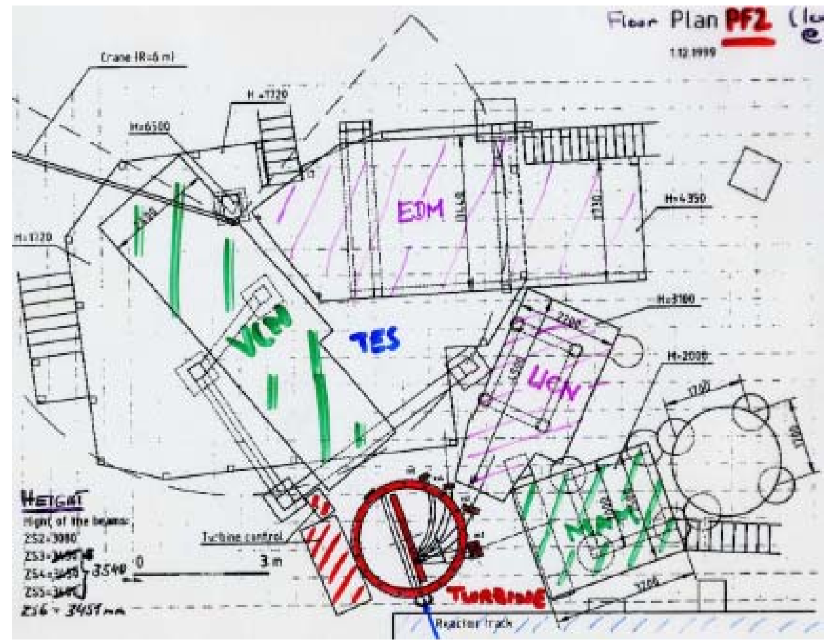
Longer term: UCNA ?

ILL Cold Neutron Beams and UCN Sources

ILL: 58 MW reactor

<u>Cold Neutron Beams</u>: PF1B Facility

- Flux: $2 \times 10^{10}/(\text{cm}^2\text{-s})$ over 120 cm^2
- PERKEO II/III (neutron β-asymmetry A_0)

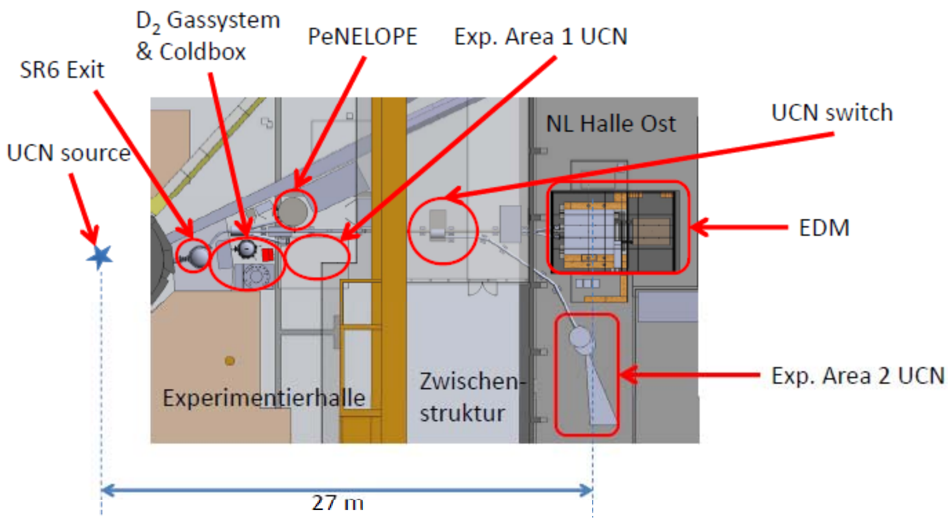


<u>UCN Beams/Production</u>:

- PF2 Beam Facility (vertical guide + turbine)
  - Four UCN ports, ~ few/cm^3 – 10/cm^3
  - nEDM, τ_n, gravity
- H53 Cold Beamline: cryoEDM (at present)
- H172a/H127b: He-II Production (SUN)
  - 8.9 Å via Bragg reflection off intercalated graphite
  - SUN-I (GRANIT), SUN-2 (R&D) : 55/cm^3
  - SuperSUN: SUN-2 + magnetic reflector ($\tau_{storage}\uparrow$) : > 1000/cm^3

Munich, TRIUMF Beams and Sources

Munich :



FRM-II Reactor (~20 MW)

MEPHISTO: Cold beams, $2 \times 10^{10}/(\text{cm}^2\text{-s})$

PERC: neutron β-decay correlations

UCN production in SD_2 (starting 2012)

Projected: UCN densities ~ $10^3/\text{cm}^3$

Physics: Neutron Lifetime, nEDM

RCNP (Osaka) / TRIUMF :

Now – 2014: Second-generation UCN source

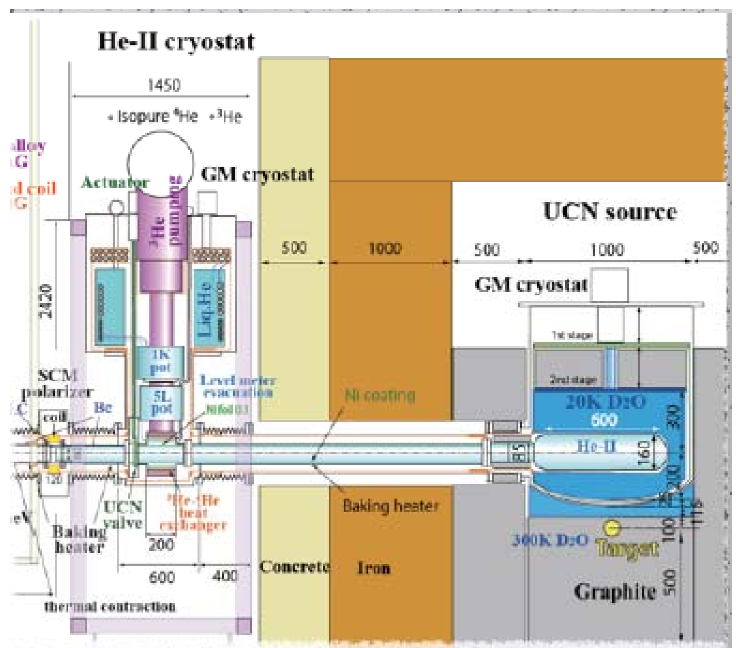
superfluid ^{4}He

2015: Move to TRIUMF

40 μA, 500 MeV proton beam

Project 12000 UCN/cm^3 at valve exit

Primary physics program: nEDM, other (?)



II. Underground Lab Facilities

Underground Labs in North America

Waste Isolation Pilot Plant

DOE Facility (Carlsbad, NM)

2150 feet underground in salt deposit
~1600 mwe

EXO-200 physics result: Viable scientific facility

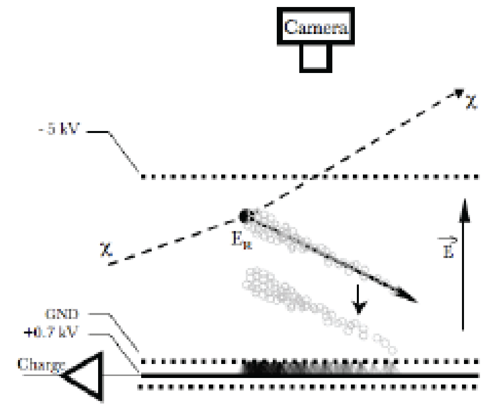
See A. Piepke talk

Continue operation 4+ years at WIPP
Keep the facility available !

Current footprint ~fills up space

DMTPC

(CF_4)



HEP (MIT, Boston U., Brandeis U., London)

1 m^3 (2013), 5+ years at WIP

Background limited > 10 m^3
[but mitigated with active shielding]

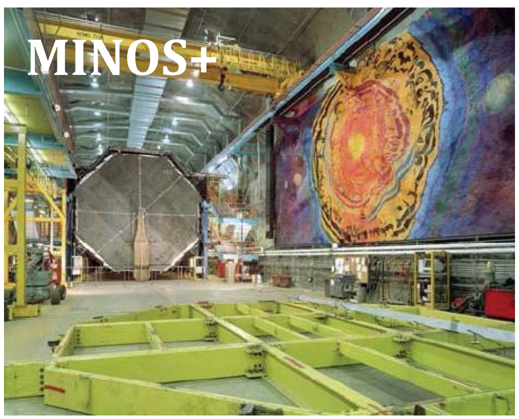
Soudan

Operated by U. Minnesota

Overburden of 700 m of rock (~2090 mwe)

In addition to experimental areas, has a Low Background Counting Facility

M. Marshak: 50,000 m^3 usable volume;
Quick and efficient testing / prototyping

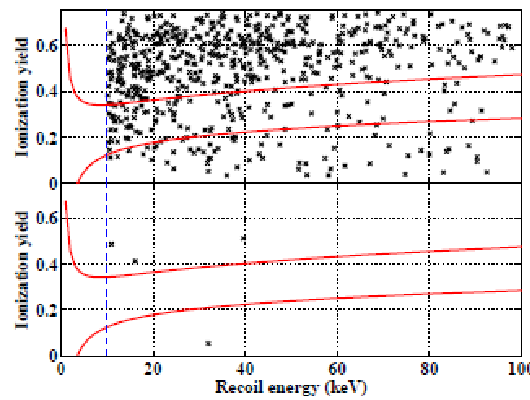


MINOS complete

Detector to run as MINOS+ for 3+ years

1230 m^2 of floor space

CDMS



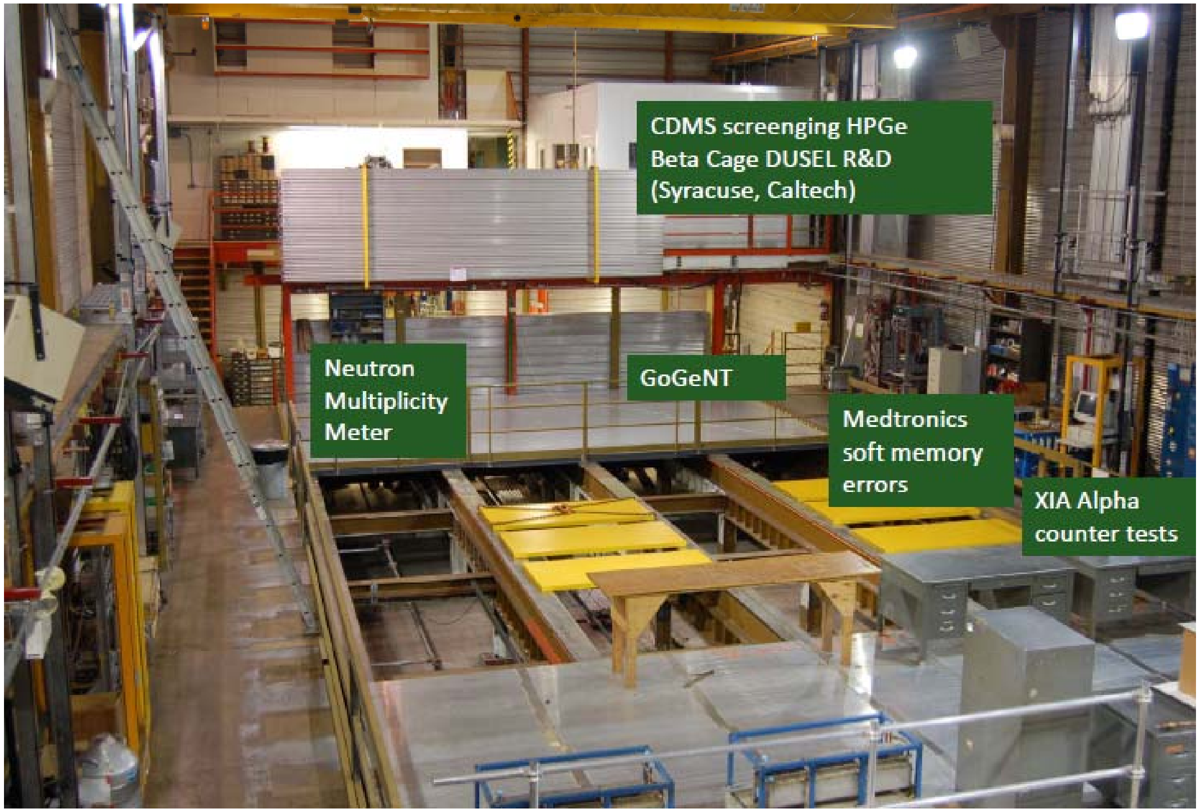
Super-CDMS at Soudan (10 kg Ge)

2-3 yrs (n-limited), 3-5 yrs (μ-limited)

→ Super-CDMS at SNOLAB (100 kg Ge)

Soudan

Muon-Shielded Experimental Hall (35′ x 40′ x 100′)
Picture before installation of the following experiments .



Low Background Counting Facility

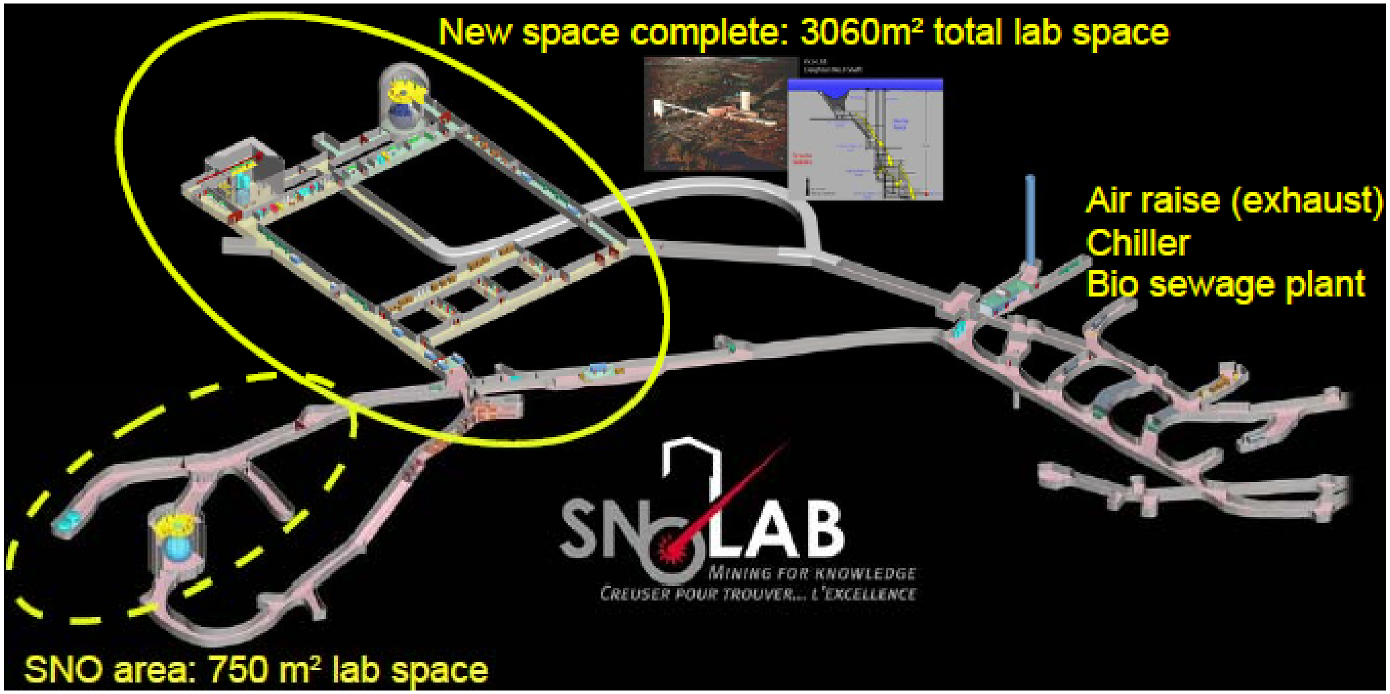
Room lined with proportional tubes (muon tracking)

Neutron detectors: cross-correlate with muon showers to study cosmogenic neutron production underground

(U. South Dakota, Syracuse, U. California-Santa Barbara)

Also, CoGeNT dark matter search
    Continue for at least ~3–4 years

SNOLAB



Original SNO cavity 200 m^2; significant expansion to 3060 m^2 for experiments

6000 mwe

Broad international program on nuclear, particle, and astroparticle physics

Hosts kton scale experiments

Significant available unallocated space: "Cryopit" (50' diameter × 50' high)

Also: space available for fast deployment small prototype/R&D scale apparatuses

SNOLAB

see G. Orebi Gann talk

Experiment	Solar ν	0νββ	Dark Matter	Super nova	GeoNu	Other	Space Allocated	Status	Expt Lead
SNO+	X	X		X	X		SNO Cavern	Construction	
PICASSO			X				Ladder Labs	Running	
DEAP-1			X				J-Drift	Running	
DEAP-3600			X				Cube Hall	Construction	
MiniCLEAN			X				Cube Hall	Construction	
COUPP-4			X				J-Drift	Running	
COUPP-60			X				Ladder Labs	2011	
SuperCDMS			X				Ladder Labs	2012	
HALO				X			Phase III Stub	Construction	
PUPS						Seismic	Various Locations	Completed	

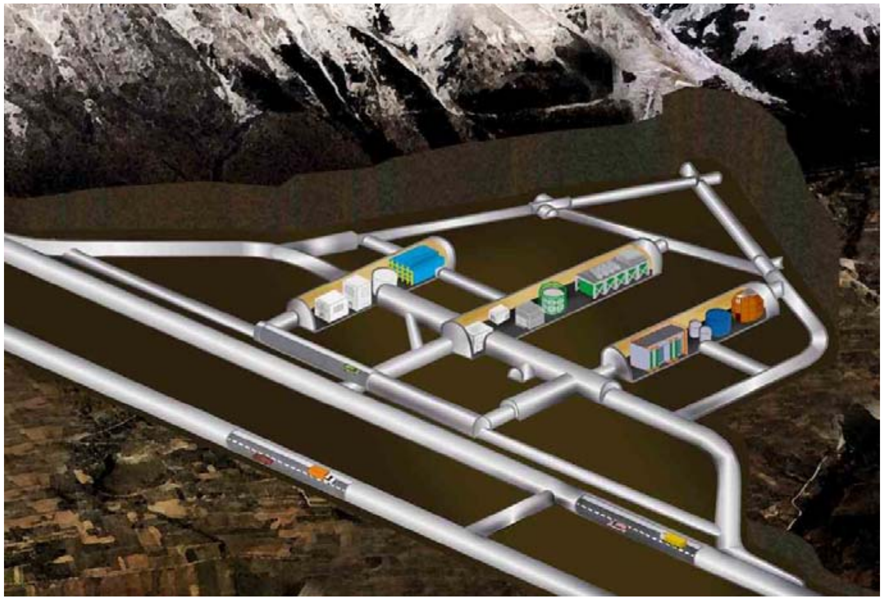
SNO+ : "nuclear physics"

solar neutrinos, ^{150}Nd $0\nu\beta\beta$, geoneutrinos, etc.

BNL, U. Penn, U.C.-Berkeley, U. Washington

LANL and LBNL: "in kind" hardware donations to SNO+

Gran Sasso



~3500 mwe (μ-reduction ~10^6)
~180,000 m^3 (3 halls + tunnels)

Neutrino beams: OPERA, ICARUS

Dark Matter: LIBRA, CRESST2, XENON, WARP

$0\nu\beta\beta$: COBRA, CUORE, GERDA

Solar Neutrinos: Borexino

CUORE

$0\nu\beta\beta$ ^{130}Te

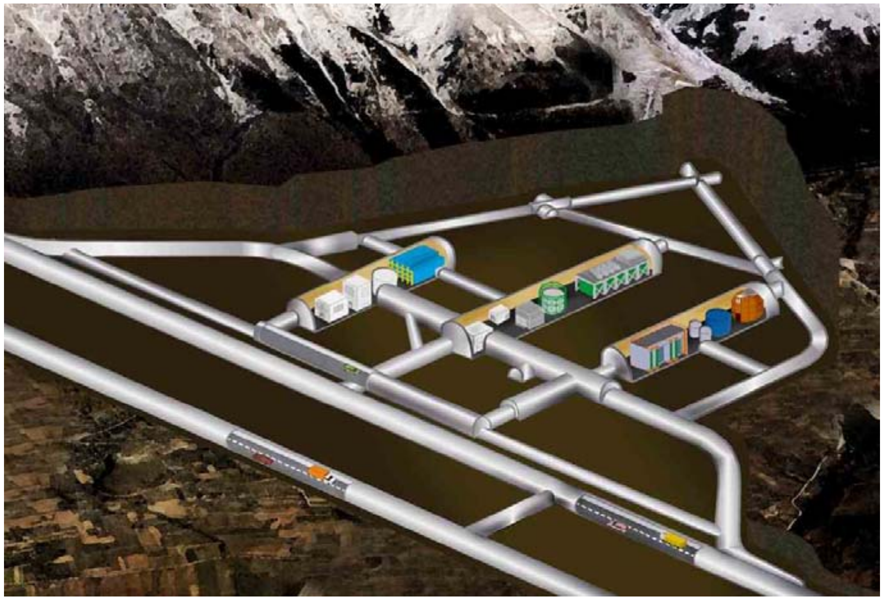
TeO_2 Bolometers

Ton Scale : LNGS maybe not deep enough

U.S. Collaborators:
Cal Poly, LBNL, LLNL, UC-Berkeley, UCLA, U. South Carolina, U. Wisconsin,

Major contributions/responsibilities :
anti-radon system; purchased half of crystals; developed thermistors; calibration system; electronics; DAQ support; assembly, integration, commissioning

Gran Sasso



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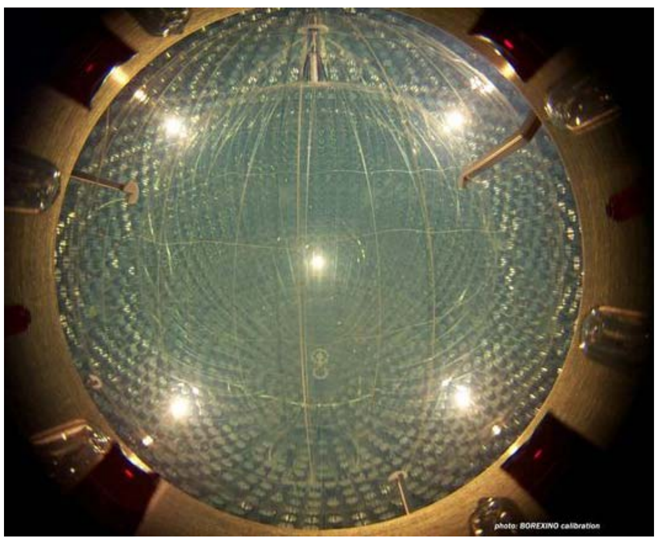


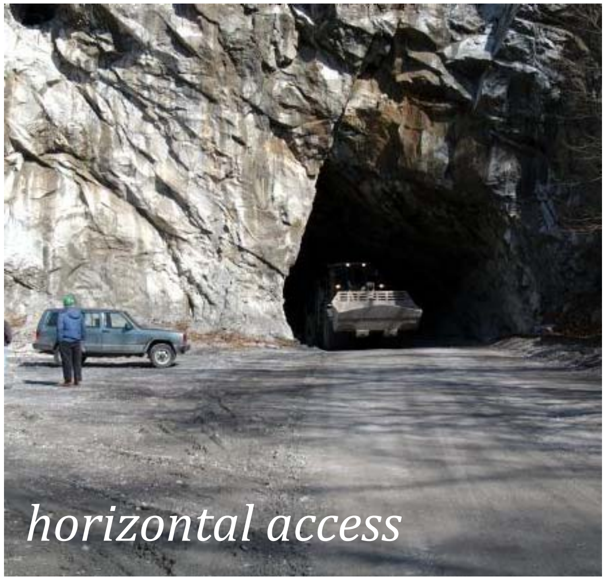
Borexino

^{7}Be, pep, pp, CNO

Princeton, Virginia Tech, U. Massachusetts,
U. Houston, UCLA

→ DarkSide-50 (Borexino CTF)

Kimballton Underground Research Facility



30 minutes from V. Tech

Limestone mine, 1450 mwe

Vast space: 50+ miles of drifts
(20' w × 20'–100' h)

Current space built for < $200k
(VT funded)

KURF physics program (all DOE- or NSF-funded) :

- mini-LENS
- Neutron Spectrometer
- ββ-decay to excited states
- HPGe Low Background Screening
- MALBEK (Majorana 0νββ)
- ^{39}Ar Depleted Argon

Kimballton proponents proposed KURF as host location for DIANA
(Deep Ion-Accelerator for Nuclear Astrophysics)

Washington State: Old Cascade Tunnel

Near Stevens Pass (~1.5 hrs from Seattle)

Former railway tunnel: 4.2 km long, 650 m deep (granite), concrete lined

~1430 mwe

Operated in the 1970s by UW and Boeing for experiments

Not considered for DUSEL due to depth requirements

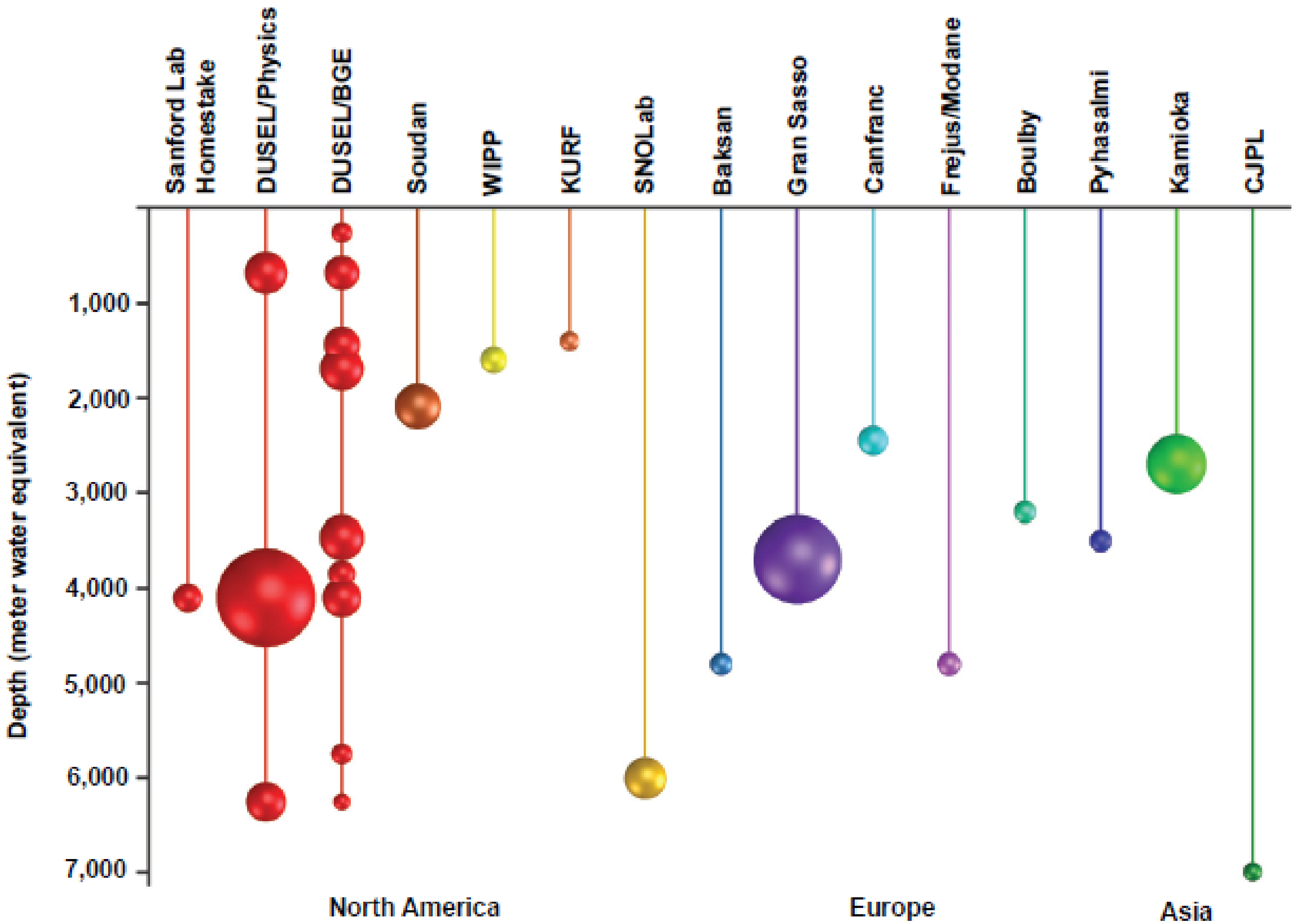
However, potentially ideal for experiments with modest depth requirements

- Near term: DIANA
- Long term: Neutrino target (bi-magic baseline to FNAL; magic baselines to CERN/KEK)

DOE HEP expressed interest during preparations for Intensity Frontier Workshop

- W. Haxton prepared report, but no DOE response yet

International Underground Labs



Outsider Worry: Will labs in North America be deep/large enough 5 years from now? What happens if have to move U.S. expt's to international labs? Recall NRC report ...

Neutrino Facility at the SNS

Pions → Stop in target → Decay at rest

Monochromatic 29.8 MeV ν_μ

O(2.2 μs): $\bar{\nu}_\mu$ and ν_e from μ decay (~tens of MeV)

Expected Flux: $\sim 10^7$ / cm^2 / s

SNS small duty factor reduces backgrounds, discriminates ν_μ from $\bar{\nu}_\mu$ and ν_e

"Two-pagers" posted on website :

- ν-nucleus cross sections (supernovae processes)
- Nuclear recoils from coherent elastic ν-nucleus scattering (supernova processes)
- OscSNS: sterile neutrinos (detected based on LSND and MiniBooNE detectors)

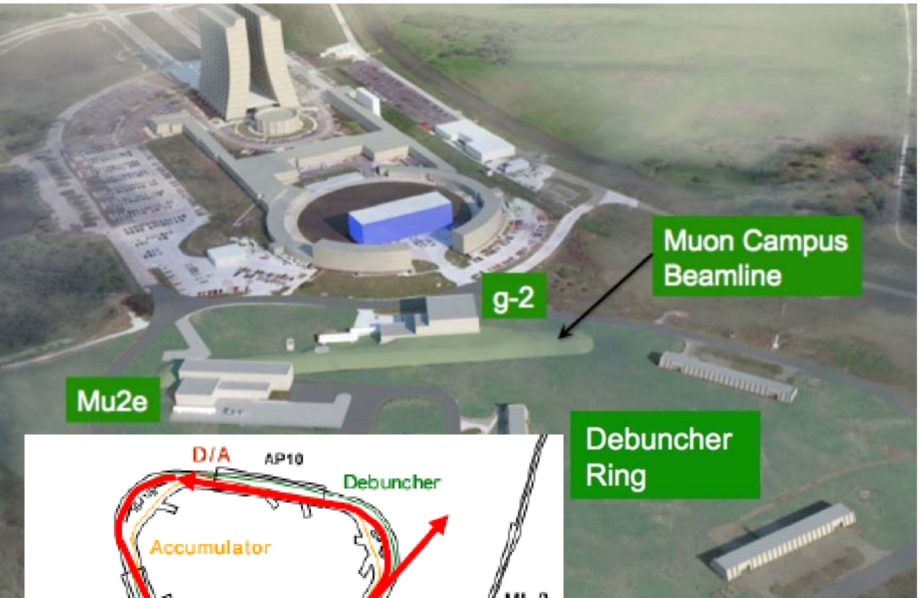
see W. Louis and K. Scholberg talks

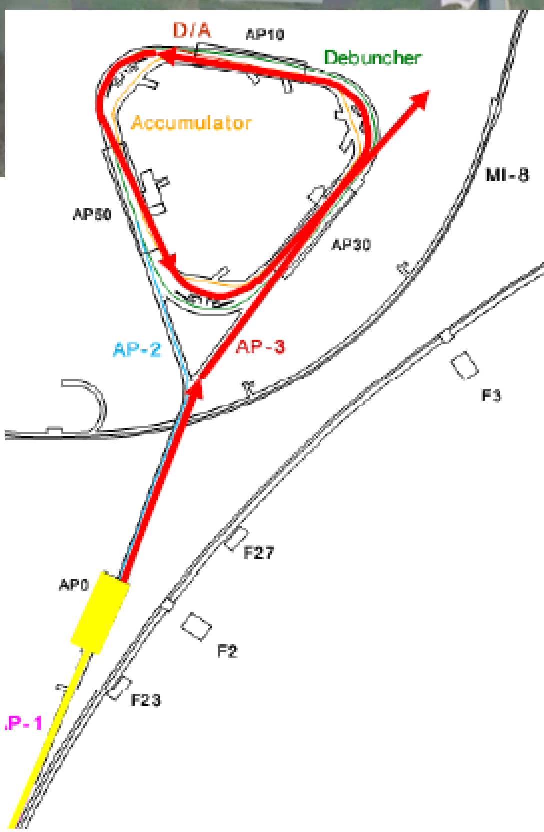
Notes:

- SNS receives no operational support from DOE NP
- Construction/Installation/Operation must have no impact on accelerator and neutron scattering program

III. Muon Physics Facilities

New Facility: Muon Campus at FNAL





FNAL has committed to a "Muon Campus"

→ HEP-funded (~\$300M)

Result of optimizing program plan to simultaneously meet the requirements of g–2 and Mu2e (coordinated effort)

↓

tens of M\$ savings

Ground breaking this fall

Completed by 2016–17

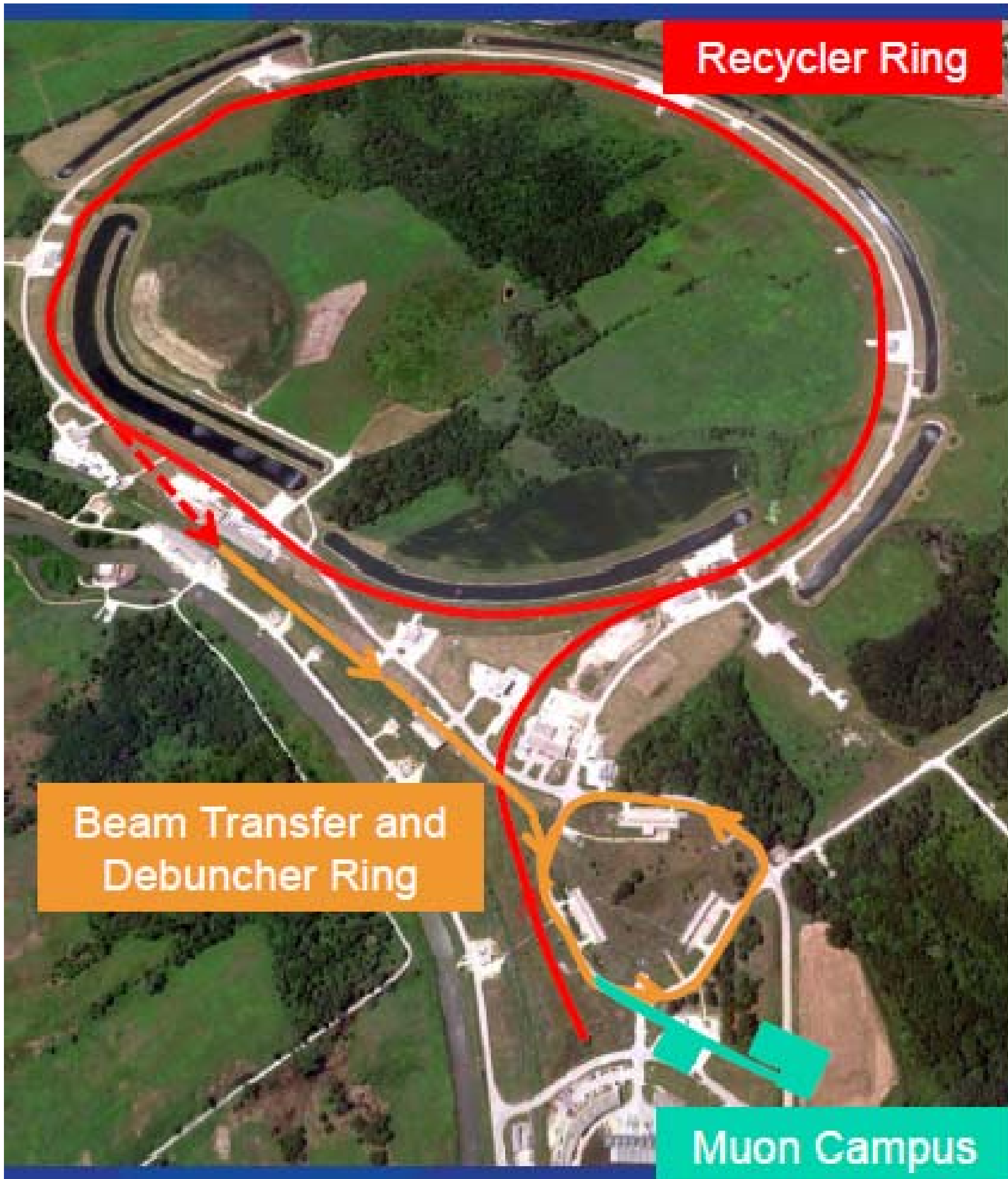
(1) Booster: 8 GeV proton bunches at 15 Hz → Recycler

(2) Bunches split into 4 smaller bunches (new RF)

(g–2) Bunches extracted to existing $\bar{p}$ target (AP0), 3.1 GeV π's → μ's → "Delivery Ring" → g–2 ring

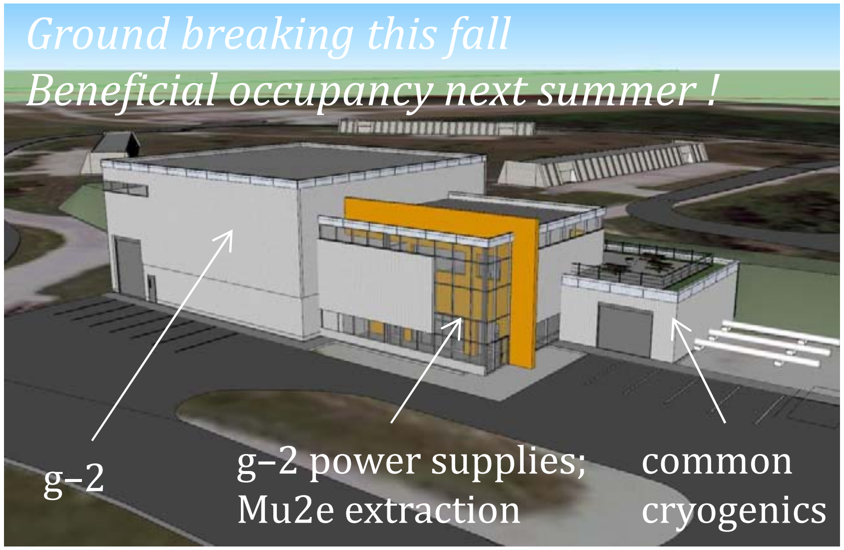
(Mu2e) proton bunches stored in DR → resonant extraction (1.6 μs) to μ→e "Production Solenoid"

Muon Campus: g–2 and Mu2e Overlaps



- Areas of overlap…
  - → Recycler upgrades
    - RF capability
    - Connection to former pbar complex
  - → Debuncher modifications
    - Beam transport to and injection into Debuncher
    - Proton abort system
    - Removal of TeV equipment
  - → Muon Campus
    - MC-1 Building (GPP)
    - MC Cryo Plant (AIP)
    - MC Beamline Enclosure (GPP)

Muon Campus at FNAL: Collaborations



Although "HEP" facility, leadership from nuclear physics

g–2: D. Hertzog, B.L. Roberts

Mu2e: B. Bernstein, J. Miller

g–2 Nuclear Physics Groups:

Boston U., James Madison, U. Kentucky, U. Massachusetts, U. Michigan, Regis U., U. Virginia, U. Washington

NSF Nuclear:
Detectors, Electronics, DAQ

Mu2e Nuclear Physics Groups:

Boston U., U. California-Berkeley, U. Massachusetts, U. Virginia, U. Washington

Muon Physics: PSI

HIPA: 590 MeV Ring Cyclotron

2.2 – 2.4 mA → 1.3 – 1.4 MW

πM1: FAST, stopped π for τ_μ

μE4: μSR

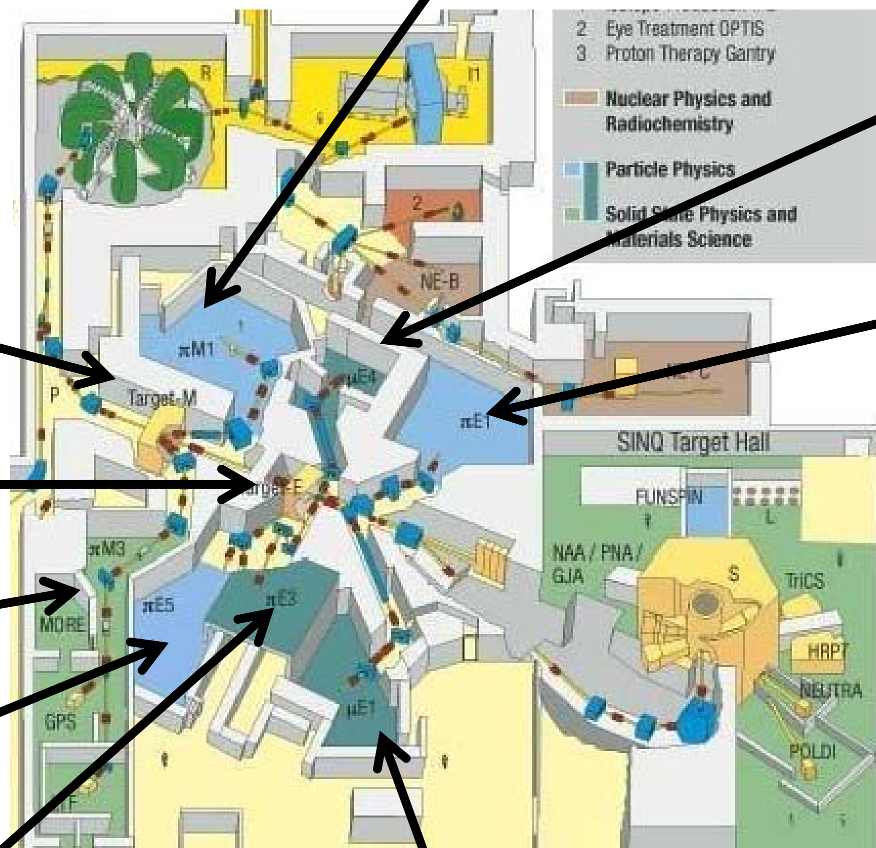
Thin Target M Station
5 mm graphite

πE1: MuSun
(moving, running)

U.S. : Boston U., Regis U., U. Kentucky, U. South Carolina, U. Washington

Formerly PIBETA

Thick Target E Station
~50 mm graphite



πM3: μSR

πE5: MEG
$\sim 10^8\ \mu^+/s$, running

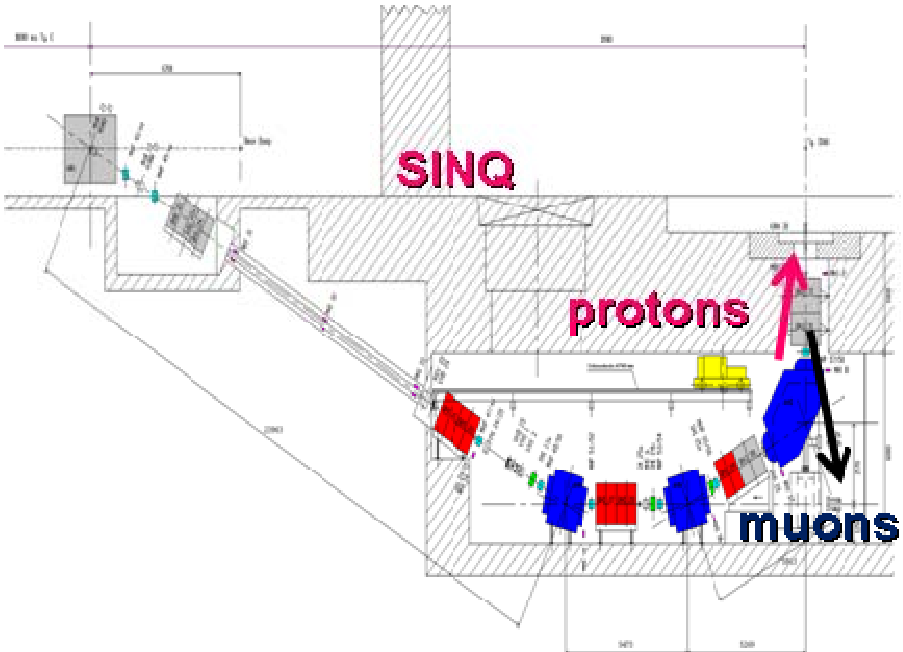
πE3: MuLan, MuCap, MuSun, $\sim 10^7\ \mu^+/s$

μE1: $\sim 10^7\ \mu^-/s$, μEDM ?

Muon Physics: PSI

At present, μ^+ beam intensities up to $\sim 10^8$/s (MEG uses $\sim 3 \times 10^7$/s)

Ultra-High Intensity Muon Beamline: Up to $\sim 3 \times 10^{10}\ \mu^+$/s (under study!)



Basic Idea :

Use SINQ spallation target as muon source

(a) Increased number of primary p interactions

(b) Increase in π production for backward production

(c) Higher Z $\rightarrow$ Increased π production cross sections

(d) Increase from "usefulness" of high-energy pions that stop in target window

Experimental Program :

$\mu \rightarrow eee$ to $\sim 10^{-16}$ (Letter of Intent, 2020)

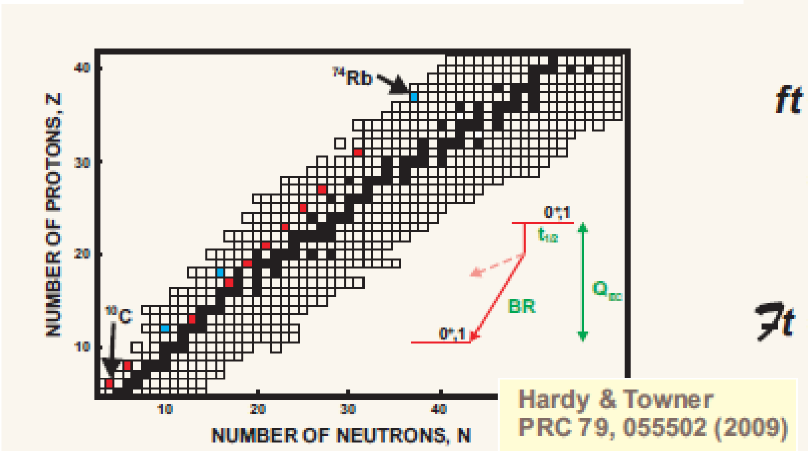
But … as far as I can tell, no significant U.S. involvement …

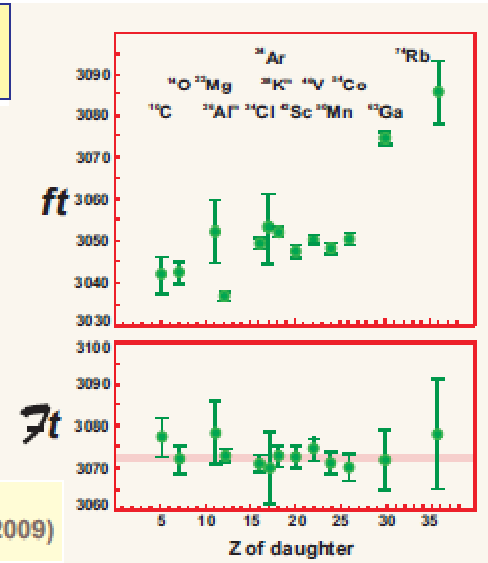
IV. “Other” Facilities

Nuclear β-Decay

SUPERALLOWED $0^+ \rightarrow 0^+$ BETA DECAY

$$\mathcal{F}t = ft\,(1 + \delta_R')[1 - (\delta_C - \delta_{NS})] = \frac{K}{2G_V^2\,(1 + \Delta_R)}$$





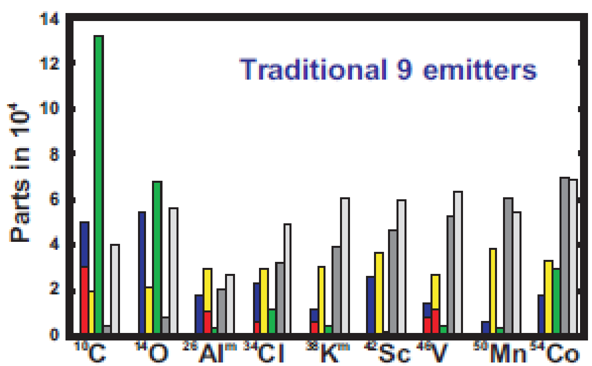
- CVC verified
- V_{ud} = 0.97425(22)

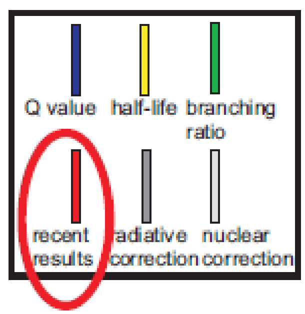
CKM unitarity test:

$V_{ud}^2 + V_{us}^2 + V_{ub}^2$
= 0.9999(6)

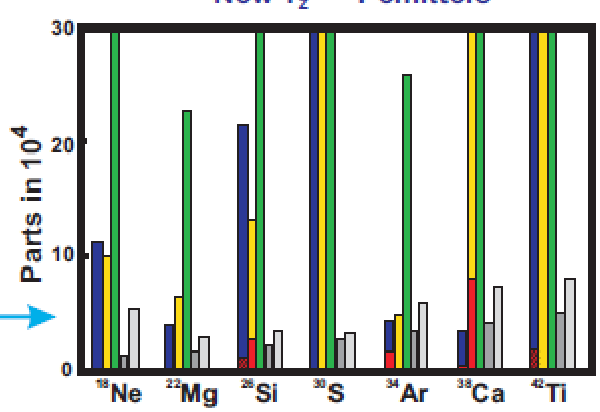
Improvements since 2009

(Most done at, or in collaboration with TAMU)





Uncertainty budgets



Nuclear β-Decay

Many smaller-scale experiments :

TRIUMF

Argonne

NSCL/FRIB

U. Washington

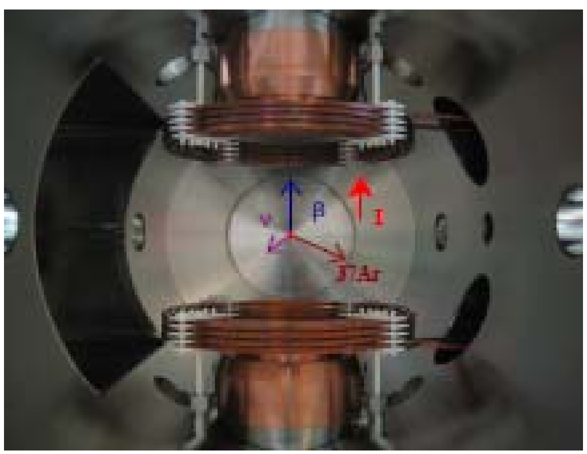
LBNL / UC-Berkeley

Texas A&M

Nuclear β-Decay: TRIUMF

Collaboration/Facility	Nucleus	Physics Goals	Timeline
TRINAT at TRIUMF; Isotope separator; Double MOT *TAMU, Manitoba, Tel Aviv, et al.*	^{37}K ^{38m}K ^{37}K	A_β, B_ν β-ν D (emiT level)	Starting 2012 2014 Conceptual
TRIUMF Francium Trapping *TRIUMF, William & Mary, Manitoba, TAMU, U. Maryland, Stony Brook, et al.*	*Fr	Anapole moment, etc.	Starting 2012

MOT for ^{37}K



EM shielded room for Fr trapping facility

Nuclear β-Decay: U. Washington

Collaboration/Facility	Nucleus	Physics Goals	Timeline
U. Washington tandem Van de Graaff *Argonne, Michigan State, U. Washington*	^{6}He	$\Delta a/a < 10^{-3}$ $\Delta b/b < 10^{-3}$ ↓ $(C_T + C_T')/C_A < 10^{-3}$ $(C_T - C_T')/C_A < 5 \times 10^{-2}$ } Tensor currents (direct sensitivity unlike neutron)	5 years

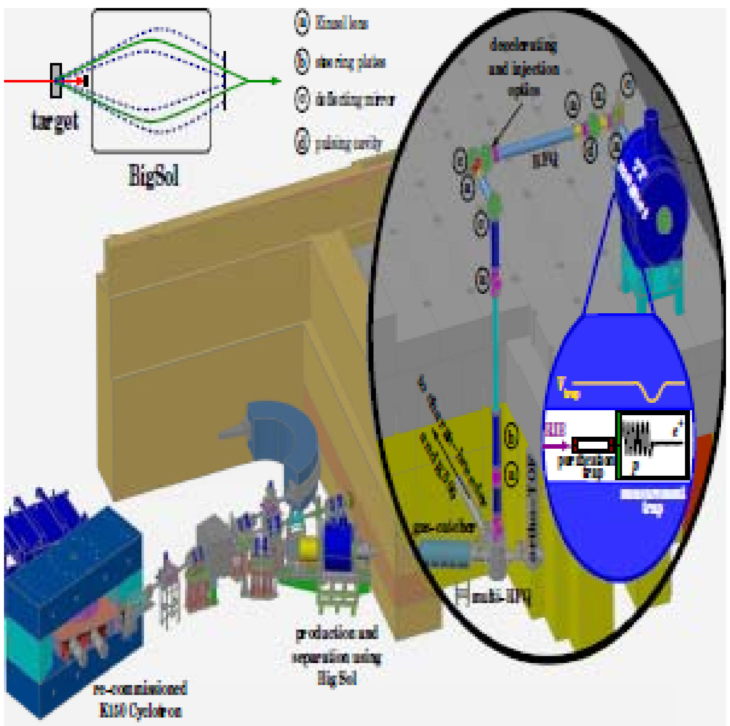
Copious ^{6}He production: 10^{9}/s

MOT: for electron-antineutrino correlation
Achieved trapping of ~500 ^{6}He atoms

Shape of beta spectrum (without laser trap)

Nuclear β-Decay: Texas A&M

Collaboration/Facility	Nucleus	Physics Goals	Timeline
TAMU Double Penning Trap (TAMUTRAP) Cyclotron TREX upgrade	^{32}Ar, ^{20}Mg, ^{24}Si, ^{28}S, ^{36}Ca, ^{44}Cr, ^{40}Ti	Superallowed ft values (new *p* emitters), $a_{\beta\nu}$	Online tests by end of 2013



TREX: High-intensity light and heavy ion beams, re-commissioning K150 cyclotron, etc.

React with target in front of "BigSol" (7 T)

Gas catcher collect and transport to
low-energy beamline to TAMUTRAP

Ions cooled, bunched, transported to
Penning trap

7 T spectrometer, largest diameter
(180 mm) of any existing Penning trap

Nuclear β-Decay: Argonne

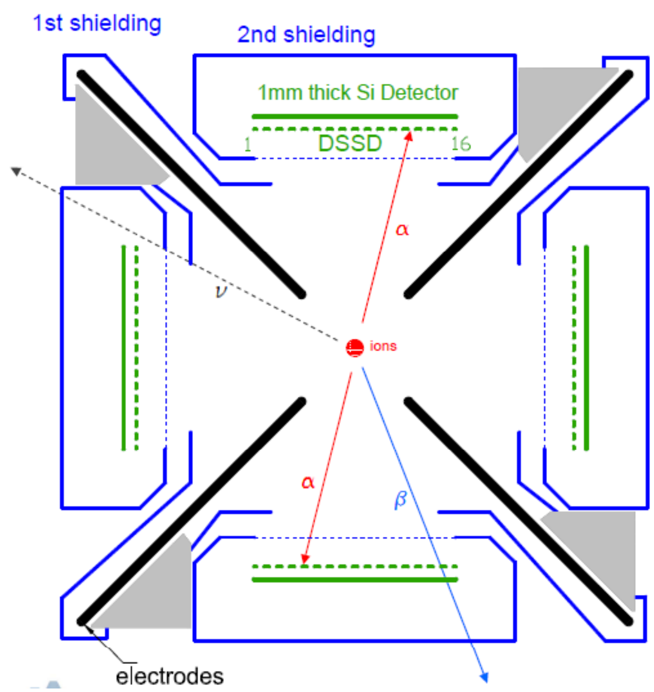
Collaboration/Facility	Nucleus	Physics Goals	Timeline
Argonne: β-decay Paul trap, connected to gas-catcher-based system at ATLAS	^{8}Li, ^{8}B	CVC, tensor currents, second class currents	^{8}Li: ran, expect best tensor limit ^{8}B: CVC, SCC (2013)

β-decay Paul trap:
- DC axial potential
- RF quadrupole

High collection efficiency

No scattering in source

Buffer gas ion cooling to LN_2



Nuclear β-Decay: NSCL, FRIB

Collaboration/Facility	Nucleus	Physics Goals	Timeline
NSCL / BECOLA	^{37}K	GT/F ratio for V_{ud}	2 years
	^{21}Na	GT/F ratio for V_{ud}	3 years
U. Leuven, U. Mainz, U. Michigan, Michigan State, U. North Carolina, TRIUMF, TAMU	^{21}Na	Test of max P-violation	4 years
	^{23}Mg	Test of max P-violation	4 years
	^{36}K	T-violation	5 years
FRIB	β-decay experiments from NSCL, EDMs, ^{6}He exp't from UW (if 10–100× intensities), TAMU MOT (^{37}K, ^{38m}K)		

Beam Cooler and Laser Spectroscopy Endstation: Polarized Nuclei

Experiments with low-energy radioactive beams at NSCL

High-energy fragments "stopped", transported to BECOLA beamline, polarized via optical pumping

p/d EDM: Work at International Facilities

U.S.-led (Y. Semertzidis et al.) proton
and deuteron EDM storage-ring experiments :

Polarized proton beams at BNL

10^{-29} e-cm $\rightarrow$ 10^{-30} e-cm

Followed by the deuteron

Proposal submitted to DOE NP for pEDM
Experiment at BNL (Nov 2011)

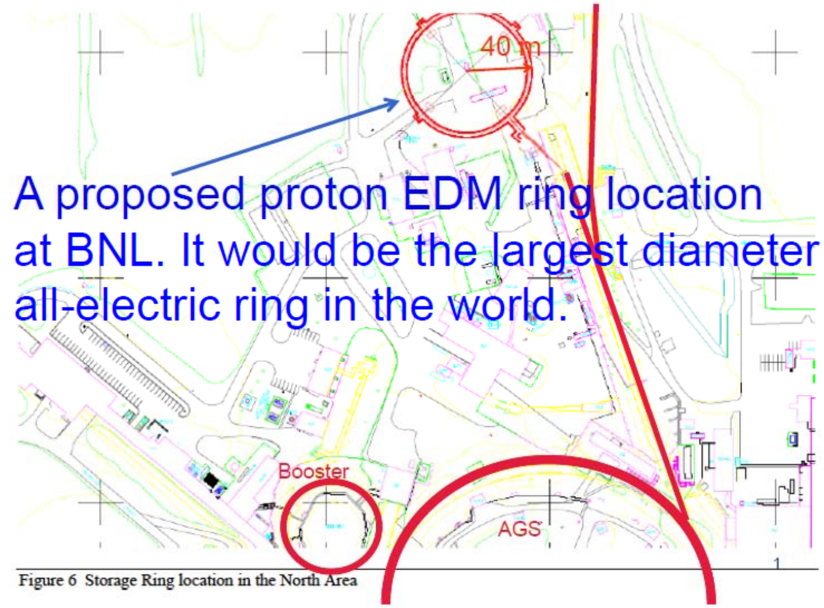


Figure 6 Storage Ring location in the North Area

10^{11} protons/pulse
spin coherence times $\rightarrow$ 10^{3} s storage
prospects for longer SCTs

Other possible facilities:

COSY: Already, common R&D collaboration !

FNAL: Would need polarized proton source
(use old accumulator ring?)

COSY Collaboration: dEDM: 10^{-24} e-cm (pre-cursor), then dedicated ring for 10^{-29} e-cm

Common R&D Storage Ring Collaboration

BNL: Beam Position Monitor Magnetometers

COSY: Polarimetry, Spin Coherence Times

Counter-rotating beams; splitting tells radial magnetic field (main systematic error)

FNAL Project X

← 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 + 0-50 kW**	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.

13 R. Tschirhart - PXPS Charge June 14th 2012 Fermilab

2-pager on website :

Stage 1:
New superconducting CW 1 GeV linac (replace conventional 400 MeV)

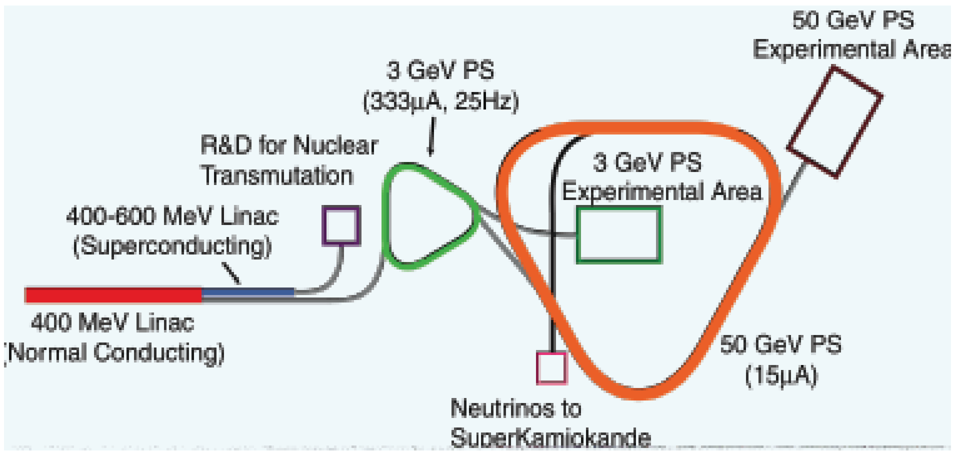
Construction later this decade; operation early next decade

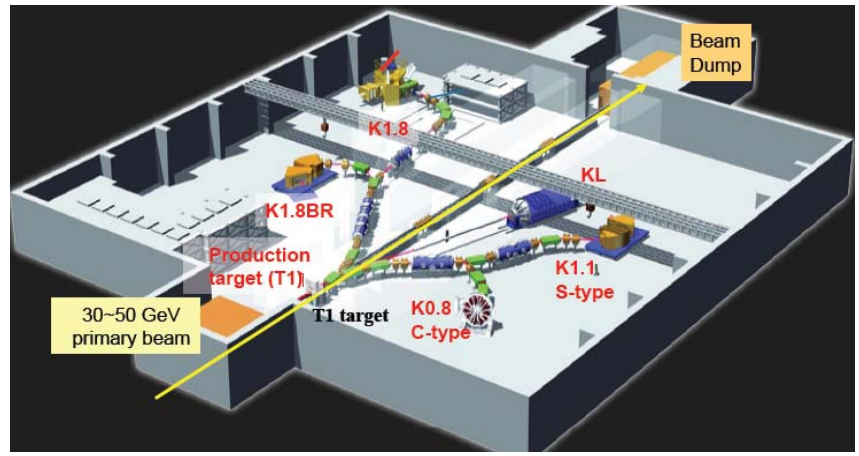
June 2012: Project X Physics Study

"Nuclear Physics": Neutrino physics, Kaon physics, pEDM, UCN source, nEDM, n-nbar, neutron β-decay, …

T-Violating Kaon Physics at J-PARC

Hadron Facility at J-PARC for TREK program
(Time Reversal Violation Experiment with Kaons)





TREK: ~9 μA @ 30 GeV (270 kW) → 2×10^6 K/s

Planned Experiments :

P36: Lepton Universality and Heavy Neutrino Search (will receive approval soon)

$\Gamma(K^+ \to e^+\nu)/\Gamma(K^+ \to \mu^+\nu)$; using the TREK detector system

E06: TREK: Measurement of muon P_T in $K^+ \to \pi^0 \mu^+\nu$

Approved since July 2006 (Hampton U., JLab, MIT, U. South Carolina, Iowa State)

But now spatial conflict with COMET; possibly at J-PARC or elsewhere (FNAL)?

Summary of Findings

Neutron Physics Facilities in the U.S.

Cold Neutron Beams: Premier physics programs at SNS and NIST, Beams comparable to best worldwide

Ultracold Neutrons: Only operating UCN source for neutron β-decay correlations at LANL; Test-bed for nEDM Experiment at NCSU

Underground Labs

WIPP: EXO physics result → Viable scientific facility
Must operate for at least 4+ more years

Soudan: Significant space; background counting facility

Kimballton: DOE- and NSF-funded experiments currently running

Washington state: initial study

Major U.S. involvement at SNOLAB and Gran Sasso (also Daya Bay)

Outsider worry: In 5 years, will there be sufficient space / depths ?

Summary of Findings

Muon Physics

Major (impressive) HEP commitment to FNAL Muon Campus

Nuclear physics is leading g–2 and Mu2e

Significant U.S. involvement at PSI: MuLan, MuCap, MuSun, MEG

U.S.-led proposal for elastic μ-p scattering (proton charge radius)

Also significant pion physics program: PIBETA (past), PEN (ongoing)

"Other"

Broad nuclear β-decay program with U.S. involvement at:

Texas A&M, TRIUMF, NSCL/FRIB, Argonne, U. Washington, LBNL

Significant proton/deuteron EDM R&D program at COSY

Project X: Construction late this decade, beams early next decade ?

Significant opportunities for neutrinos, UCN source, n-nbar, EDMs

Apologies to pion physics, etc. and everything else not discussed …