Project-X Research Program

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U.S. DEPARTMENT OF ENERGY

Fermilab

Project-Y: Origins…

- **The Origin of Mass:**

  How do massless chiral fermions become matter particles?
  (buzzword: "Higgs")

- **The Origin of Matter:**

  Why are there so many different kinds of matter particles with different properties?
  (buzzword: "Flavor")

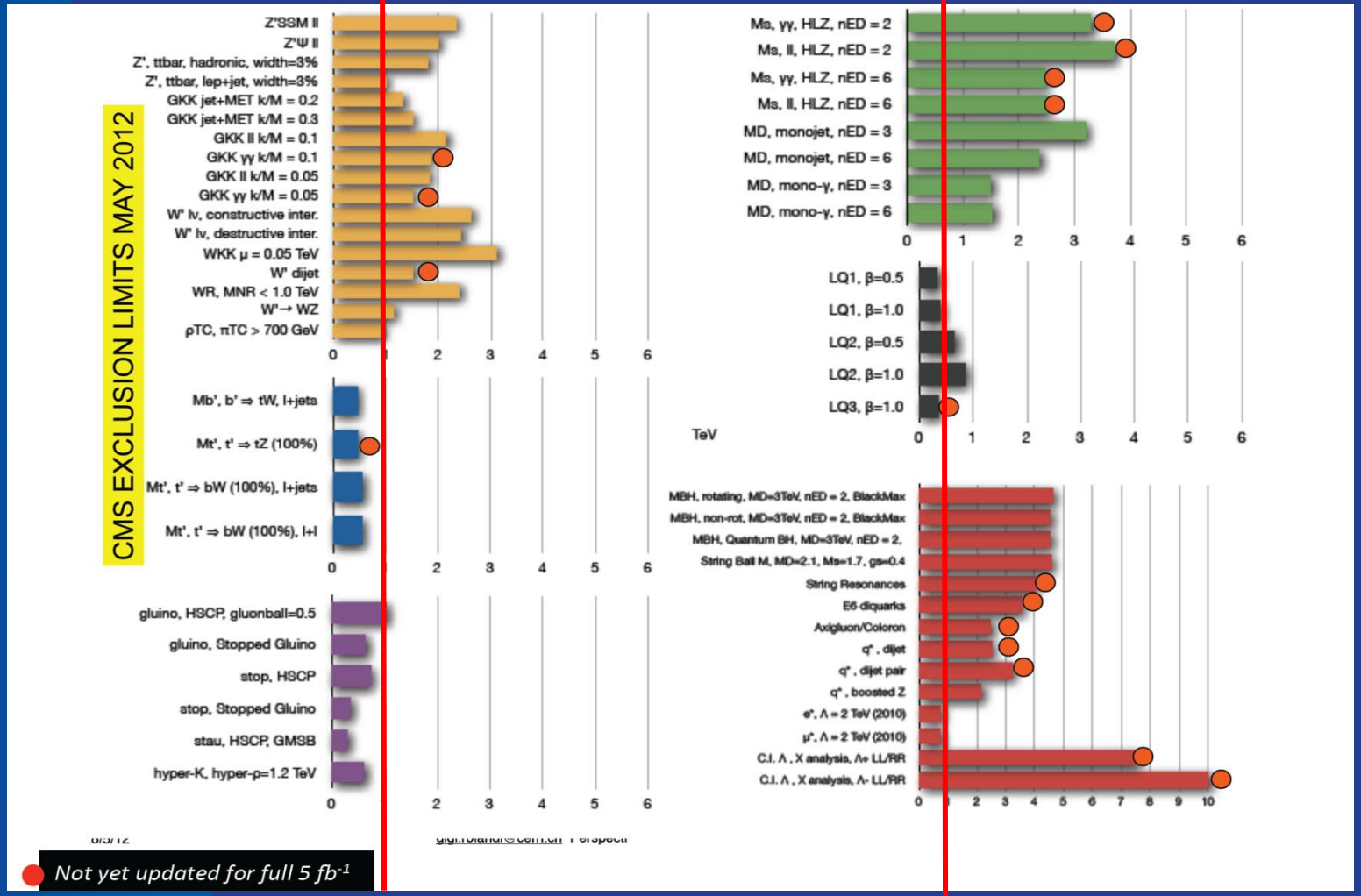
- **The Origin of the Universe:**

  Where did matter come from in the first place and why didn't it all annihilate with antimatter?
  (buzzwords: "Baryogenesis", "Leptogenesis")

-Joe Lykken

Direct Challenges from the Energy Frontier to Models Beyond the Standard Model

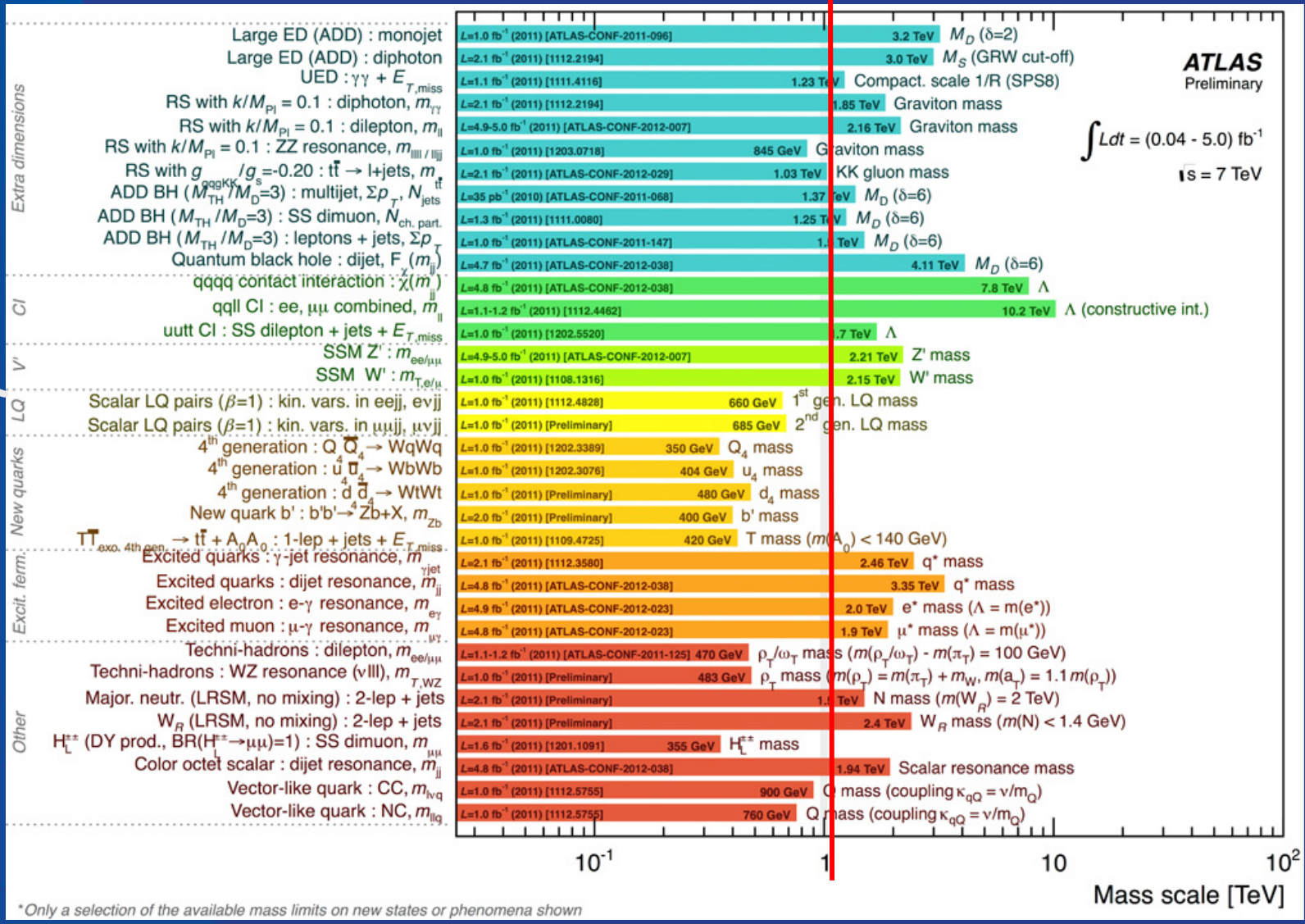
New Physics



Courtesy Tulika Bose, BU

Direct Challenges from the Energy Frontier to Models Beyond the Standard Model

New Physics



The Project-X Research Program

- ***Neutrino experiments***

A high-power proton source with proton energies between 1 and 120 GeV would produce intense neutrino sources and beams illuminating near detectors on the Fermilab site and massive detectors at distant underground laboratories.

- ***Kaon, muon, nuclei & neutron precision experiments***

These could include world leading experiments searching for muon-to-electron conversion, nuclear and neutron electron dipole moments (edms), precision measurement of neutron properties and world-leading precision measurements of ultra-rare kaon decays.

- ***Platform for evolution to a Neutrino Factory and Muon Collider***

Neutrino Factory and Muon-Collider concepts depend critically on developing high intensity proton source technologies.

- ***Nuclear Energy Applications***

Accelerator, spallation, target and transmutation technology demonstration which could investigate and develop accelerator technologies important to the design of future nuclear waste transmutation systems and future thorium fuel-cycle power systems.

Detailed discussion on Project X website

EDMs: New CPV?

In units of e cm, selected EDM limits are:

Particle	EDM limit	System	SM Prediction	New Physics
e	10.5×10^{-28}	YbF	10^{-38}	10^{-27}
μ	1.1×10^{-19}	rest frame E	10^{-35}	10^{-22}
τ	3.1×10^{-16}	$e^+e^- \to \tau^+\tau^-\gamma$	10^{-34}	10^{-20}
p	6.5×10^{-23}	TlF molecule	10^{-31}	10^{-26}
n	2.9×10^{-26}	UCN	10^{-31}	10^{-26}
^{199}Hg	3.1×10^{-29}	atom cell	10^{-33}	10^{-28}

- *SM "background" well below new CPV expectations*
- *New expts: 10^2 to 10^3 more sensitive*

A non-exhaustive list:

Leptonic EDMs		Hadronic EDMs	
System	Group	System	Group
GdIG (solid)	Amherst	^{213,225}Ra (trapped)	KVI
GGG (solid)	Yale/Indiana	^{223}Rn (trapped)	TRIUMF
muon (ring)	J-PARC	Proton (ring)	BNL

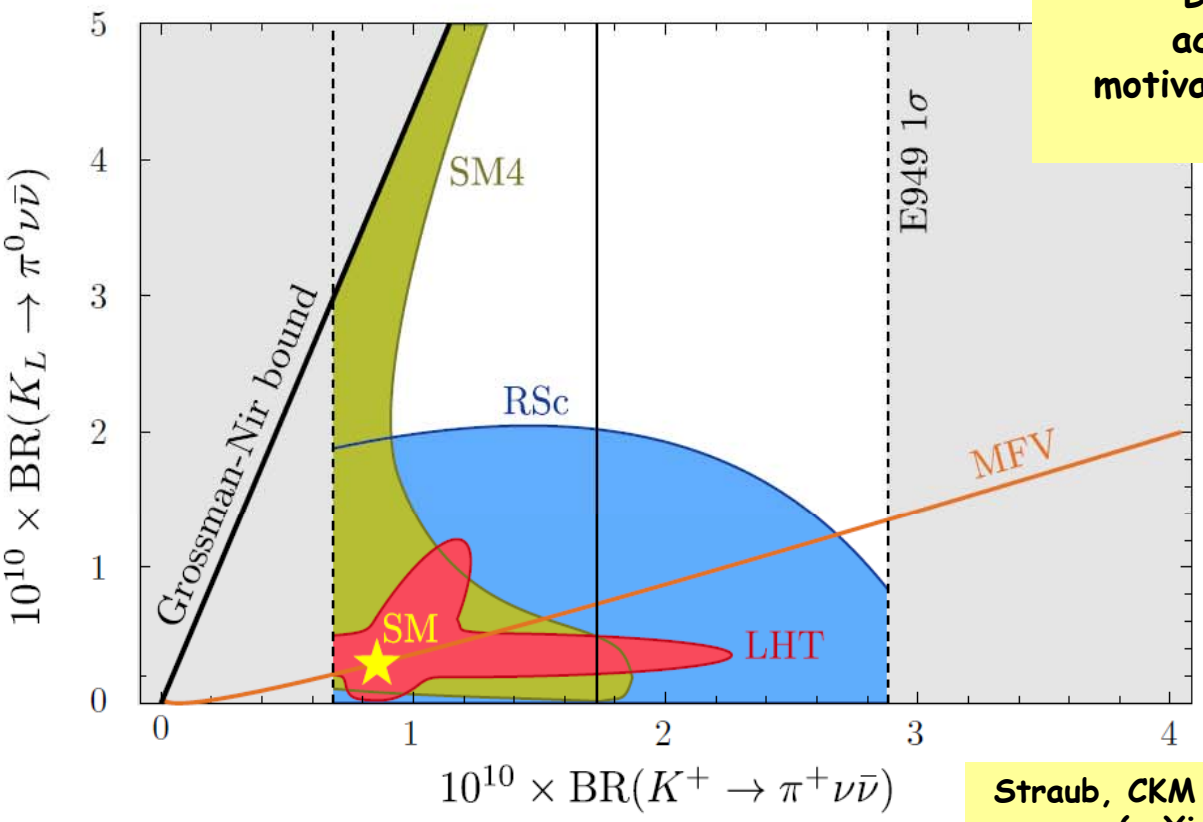
IUMF

+ COSY (deuteron)

"n-EDM has killed more theories than any other single experiment"

-J.M. Pendlebury, Review of Particle Electric Dipole Moments

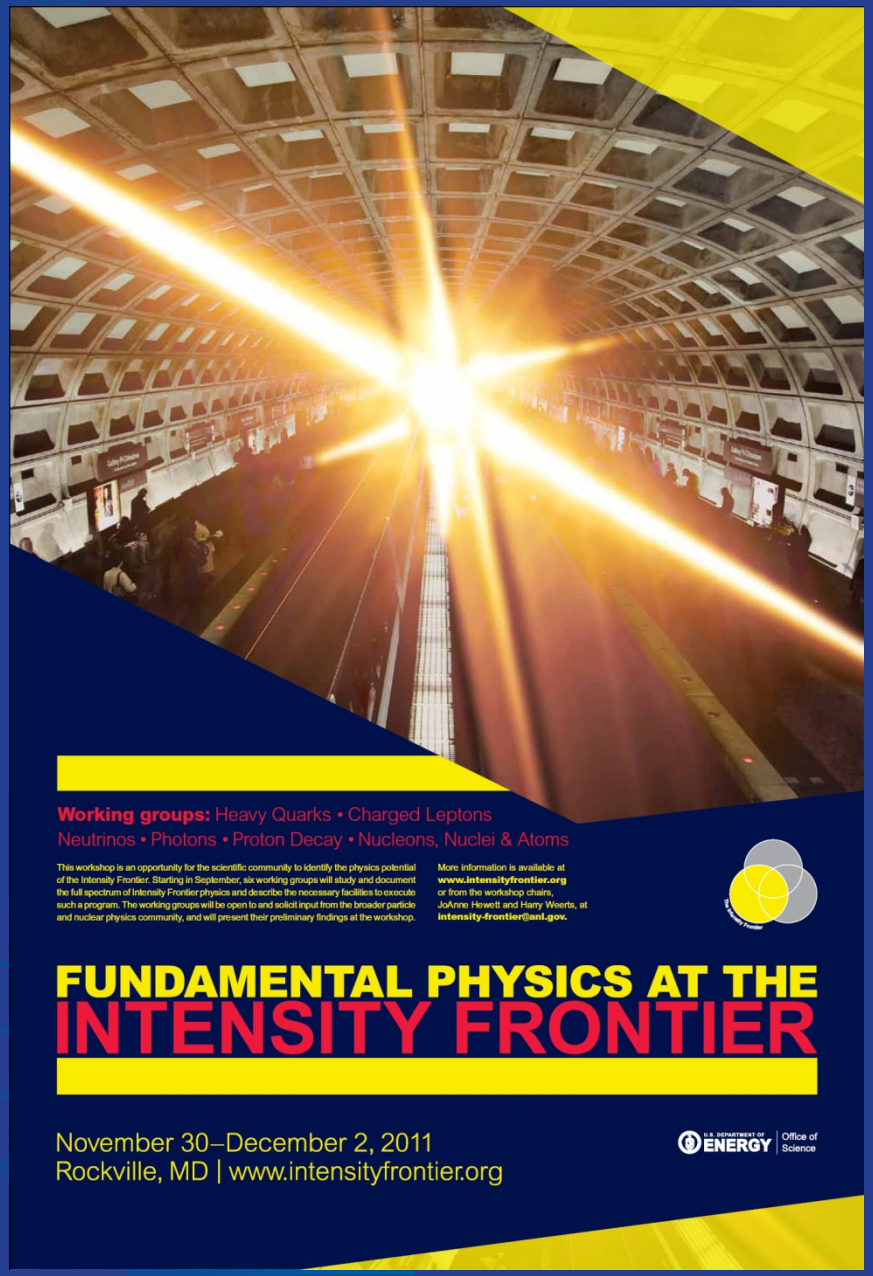
Rare processes sensitive to new physics…
e.g. Warped Extra Dimensions as a Theory of Flavor??



Buras et al. SM accuracy of <5%, motivates 1000-event experiments

Straub, CKM 2010 workshop (arXiv:1012.3893v2)

Figure 1: Correlation between the branching ratios of $K_L \to \pi^0 \nu\bar{\nu}$ and $K^+ \to \pi^+ \nu\bar{\nu}$ in MFV and three concrete NP models. The gray area is ruled out experimentally or model-independently by the GN bound. The SM point is marked by a star.



(http://www.intensityfrontier.org/)

- 500+ Attendees
- Six very active working groups:
- Charged leptons
- Heavy Quarks
- Hidden Sector
- Neutrinos
- Nucleons/Nuclei/Atoms
- Proton Decay
- Project X potential discussed in each group

A Partial Menu of World Class Science Enabled by Project-X

Neutrino Physics: **LBNE campaign is a candidate Day-1 program**

- **Mass Hierarchy**
- **CP violation**
- **Precision measurement of the θ_{23} (atmospheric mixing). Maximal??**
- Anomalous interactions, e.g. $\nu_\mu \rightarrow \nu_\tau$ probed with target emulsions (Madrid Neutrino NSI Workshop, Dec 2009)
- Search for sterile neutrinos, CP & CPT violating effects in next generation $\nu_e, \bar{\nu}_e \rightarrow X$ experiments….x3 beam power @ 120 GeV, **x10-x20 power @ 8 GeV**.
- Next generation precision cross section measurements.

A Partial Menu of World Class Science Enabled by Project-X

Muon Physics: **Mu2e upgrade is a candidate Day-1 experiment**

- **Next generation muon-to-electron conversion experiment, new techniques for higher sensitivity and/or other nuclei.**
- Next generation $(g\text{-}2)_\mu$ if motivated by next round, theory, LHC. New techniques proposed to JPARC that are beam-power hungry…
- μ edm
- $\mu \rightarrow 3e$
- $\mu^+ e^- \rightarrow \mu^- e^+$
- $\mu^- A \rightarrow \mu^+ A'$; $\mu^- A \rightarrow e^+ A'$; $\mu^- e^-(A) \rightarrow e^- e^-(A)$
- Systematic study of radiative muon capture on nuclei.

A Partial Menu of World Class Science Enabled by Project-X

Kaon Physics: **ORKA is a candidate Day-1 experiment**

- **$K^+ \to \pi^+ \nu\bar{\nu}$: >1000 events, Precision rate and form factor.**
- $K_L \to \pi^0 \nu\bar{\nu}$: 1000 events, enabled by high flux & precision TOF.
- $K^+ \to \pi^0 \mu^+ \nu$: Measurement of T-violating muon polarization.
- $K^+ \to (\pi,\mu)^+ \nu_x$: Search for anomalous heavy neutrinos.
- $K^0 \to \pi^0 e^+ e^-$: <10% measurement of CP violating amplitude.
- $K^0 \to \pi^0 \mu^+ \mu^-$: <10% measurement of CP violating amplitude.
- $K^0 \to X$: Precision study of a pure K^0 interferometer: Reaching out to the Plank scale ($\Delta m_K/m_K \sim 1/m_P$)
- $K^0, K^+ \to$ LFV: Next generation Lepton Flavor Violation experiments

...and more

A Partial Menu of World Class Science Enabled by Project-X

Nuclear Enabled Particle Physics: Candidate Day-1

- **Production of Ra, Rd, Fr isotopes for nuclear edm experiments that are uniquely sensitive to Quark-Chromo and electron EDM's. Production of Very-cold and Ultra-cold neutrons for EDM and n-nbar.**

Hadron and Baryon Physics:

- **Next generation QCD probes (e.g. evolution of Seaquest)**
- $pp \rightarrow \Sigma^+ K^0 p^+$; $\Sigma^+ \rightarrow p^+ \mu^+ \mu^-$ (HyperCP anomaly, and other rare Σ^+ decays)
- $pp \rightarrow K^+ \Lambda^0 p^+$; Λ^0 ultra rare decays
- $\Lambda^0 \leftrightarrow \bar{\Lambda}^0$ oscillations (Project-X operates below anti-baryon threshold)

Science Enabled with Stage-1

- Promotes the Main Injector to a Mega-Watt class machine for neutrinos, and increases the potential beam power for possible slow-spill experiments (e.g. ORKA).
- Unshackles the $\mu \rightarrow e$ (Mu2e) experiment from the Booster complex: Potentially increases sensitivity of Mu2e by x10 - x100 with 1-GeV CW drive beam.
- World class ultra-cold neutron and ISOL-edm programs optimized for particle physics: e.g. edms & neutron$\Leftrightarrow$anti-neutron oscillations.
- Increases the available integrated 8 GeV power for other experiments (e.g. short-baseline neutrinos) from the Booster complex by liberating Mu2e.

Broad World-class Program in Neutrinos and Rare Processes

A spallation target facility dedicated to particle physics

- The pursuit of edms induced by physics beyond the Standard Model has been a long term interest of US science agencies: NIST, NSF, DOE/NP*, DOE/HEP…***this is core particle physics.***
- Project X presents an opportunity for a spallation target facility optimized for particle physics: ISOL production of edm-enhanced isotopes and ultra-cold neutrons for edm research, n-nbar oscillations, etc.
- Leaders in the nuclear physics community are intrigued.
- The spallation facility is excellent leadership-share opportunity for our Indian colleagues in accelerator science and particle physics, ***and for our field to learn new techniques (e.g. AMO).***
- Much infrastructure can be shared with energy and materials technology development.

*http://science.energy.gov/~/media/np/nsac/pdf/docs/NSAC_NeutronReport.pdf

Science Enabled with Stage-2

- World leading kaon physics program: Megawatt power (x10 over competing facilities) can drive multiple experiments.
- World class muon physics program: Mu2e descendant migrates to a higher power campus. Megawatt power for conversion experiments (x10 over competing $\mu \rightarrow e$ facilities), opportunities for major next steps in other channels (e.g. $\mu \rightarrow 3e$).
- Maintains Main Injector beam power at lower energies (e.g. 60 GeV) enhancing the neutrino spectrum for long baseline experiments.

Science Enabled with Stage-3 (RDR)

- Main Injector power upgrade to >2 Mega Watts for 60-120 GeV beam, doubling power to long baseline Main Injector Neutrinos and Main Injector near-detector neutrino physics.
- 8 GeV beam power for experiments is doubled to now x10 the MiniBooNE era, which will support a new generation of short-baseline neutrino physics.

Science Enabled with Stage-4 (Beyond RDR)

- 4000kW @ 8 GeV and 4000kW at 60 GeV for the ultimate super beams.
- Double beam super-beam technique can tune illumination of the first and second maxima of long-baseline experiments of very massive next generation long-baseline detectors.
- Driver for an extremely powerful muon storage ring neutrino source, driving detectors based existing large magnetized neutrino detector technologies (MINOS), and possibly LAr in the future.

Example Research Program, definitive space on PXPS website.

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.

Particle Physics Research Program Activities Since the 2011 June PAC meeting

- July 2011: Indian Intensity Frontier research proposal submitted
- Sept 2011: Project X scope broadened to include targetry concerns
- Oct 2011: Interaction with Intensity Frontier Workshop conveners
- Jan 2012: Development of staging scenarios
- Feb 2012: Kaon and Muon targetry R&D established
- Mar 2012: Project X Forum on Spallation Sources for Particle Physics
- Mar 2012: Interaction with SBL Neutrino Focus Group
- April 2012: Engagement in LBNE staging discussion
- June 2012: Project X Physics Study

Project X In-reach & Out-reach since last PAC retreat

- July 2011: Indian VIPs, Dr. Kakodkar and Dr. Grover
- Aug 2011: DPF meeting
- Sept 2011: SLAC seminar, BLV workshop, OHEP Briefing
- Nov 2011: Intensity Frontier Workshop
- Jan 2012: FNAL-STFC workshop, Briefing to OHEP where staging is introduced
- Feb 2012: PNNL briefing
- Mar 2012: Spallation target forum.
- April 2012: Project-X meeting@ LBNL
- May 2012: Fermilab-In-reach trifecta, IPAC mtg, CIPANP mtg
- June 2012: Heavy Quarks & Leptons (HQL) mtg
- July 2012: ICHEP mtg, BEACH mtg
- Aug 2012: NuFact mtg

The Project X Physics Study

June 2012 Physics Study:
June 14th-22nd

Summer 2012 through Spring 2013:

Continue to evolve existing white papers into a comprehensive staged program with compelling physics at each stage.

October 11th-13th 2012:

US particle physics town meeting at Fermilab preparing for “Snowmass”, summer 2013.

Snowmass, summer 2013:

June 9th-23rd

Event to develop US strategies.

PXPS Overview*

- The Physics Study will engage theorists, experimenters, and accelerator scientists in establishing and documenting a comprehensive vision of the physics opportunities at Project X, and integrating these opportunities within a coherent plan for development of detector capabilities and the accelerator complex.

*(https://indico.fnal.gov/conferenceDisplay.py?confId=5276)

Experimental and Theory Thrusts to Develop (15 conveners)

- Neutrino experiments
- Kaon experiments
- Muon experiments
- Electric dipole moments
- Neutron-antineutron oscillations
- Hadronic physics

Conveners for Experimental Concepts and Sensitivities

Neutrinos:

A. de Gouvea (Northwestern University), P. Huber (Virginia Tech) , G. Mills (LANL)

K. Nishikawa (KEK, FNAL), Steve Geer (FNAL)

Muon Experiments:

R. Bernstein (Fermilab), Graham Kribs, (University of Oregon)

Kaon Experiments:

K. Pitts (University of Illinois UC), V. Cirigliano (LANL)

EDMs:

T. Chupp (Univ. of Michigan) , Susan Gardner (University of Kentucky), Zheng-Tian Lu (ANL)

n-nbar oscillations:

C. Quigg (FNAL), A. Young (North Carolina State University)

Hadron physics:

Stephen Godfrey (TBC), Paul Reimer (TBC)

Detector & Theory Technology Thrusts to Develop (16 conveners)

- Lattice QCD
- EM calorimetry
- Tracking
- Time of flight
- Neutrino detectors
- Large-area, cost-effective detectors

Conveners for Enabling Technologies and Techniques

High rate Precision Photon Calorimetry:

D. Hitlin (Caltech), M. Diwan (BNL)

Very Low-Mass High-Rate Charged Particle Tracking:

R. Lipton (FNAL), J. Ritchie (University of Texas, Austin)

Time-of-Flight System Performance below 10 psec:

M. Albrow (FNAL), R. Wagner (ANL)

High Precision Measurement of Neutrino Interactions:

K. McFarland (Rochester), Jonghee Yoo (FNAL), Rex Tayloe (Indiana)

Large Area Cost Effective Detector Technologies:

M. Sanchez (Iowa State University), Y. Kamyshkov (University of Tennessee)

Lattice QCD:

Ruth Van de Water (BNL), Tom Blum (University of Connecticut)

2012 PXPS Deliverables

- Brainstorming, work!
- Succinct summary (<5pages) of physics opportunities for each stage.
- Outline and roadmap of work required for Project X to reach science goals for each stage in the following thrusts:
  - **-Experiment concept development**
  - **-Detector R&D**
  - **-Theory development**

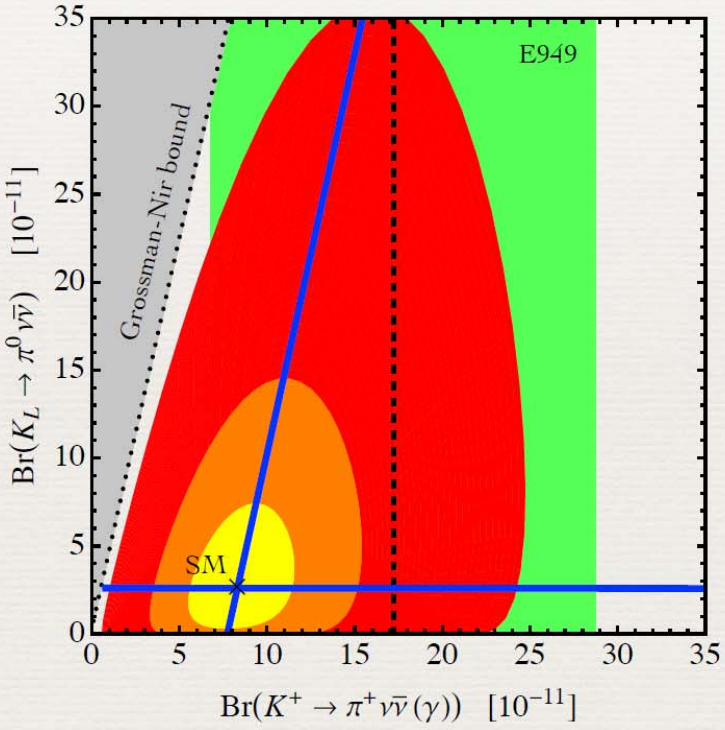
PXPS Meeting scope

- 220 registrants
- 210 presentations
- 2 days of plenary, 4 days of parallel, 2 days of summary.
- Both vigorous and stimulating discussions.

  (heat & light)
- Mean residency of registrants was 2-3 days, ~500 researcher-days on the Project-X research program. Instantaneous population of 75-100, 150+ at Wine & Cheese seminar.

Some heat and light…

ε_K & Rare K Decay Link Cont'd



$|C_{\rm NP}| \leq 0.5\,|\lambda_t C_{\rm SM}|$

$|C_{\rm NP}| \leq |\lambda_t C_{\rm SM}|$

$|C_{\rm NP}| \leq 2\,|\lambda_t C_{\rm SM}|$

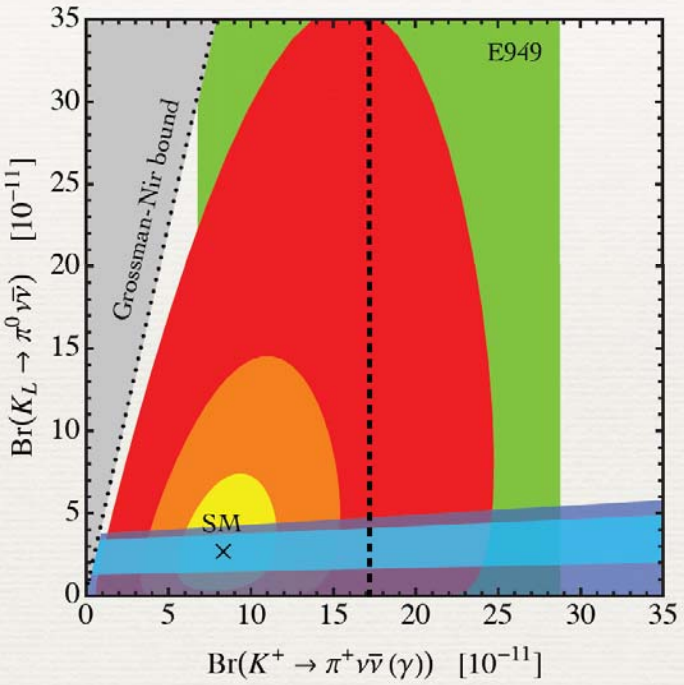
— LH currents only

but pattern not generic & absent in MSSM, RS, ..., as Q_{LR}^{sd} renders dominant effect in ε_K

U. Haisch, PXPS

Some heat and light…

ε'/ε Strikes Back



$|C_{\rm NP}| \leq 0.5\,|\lambda_t C_{\rm SM}|$

$|C_{\rm NP}| \leq |\lambda_t C_{\rm SM}|$

$|C_{\rm NP}| \leq 2\,|\lambda_t C_{\rm SM}|$

$C_{\rm NP} = |C_{\rm NP}|\, e^{i\phi_C}$

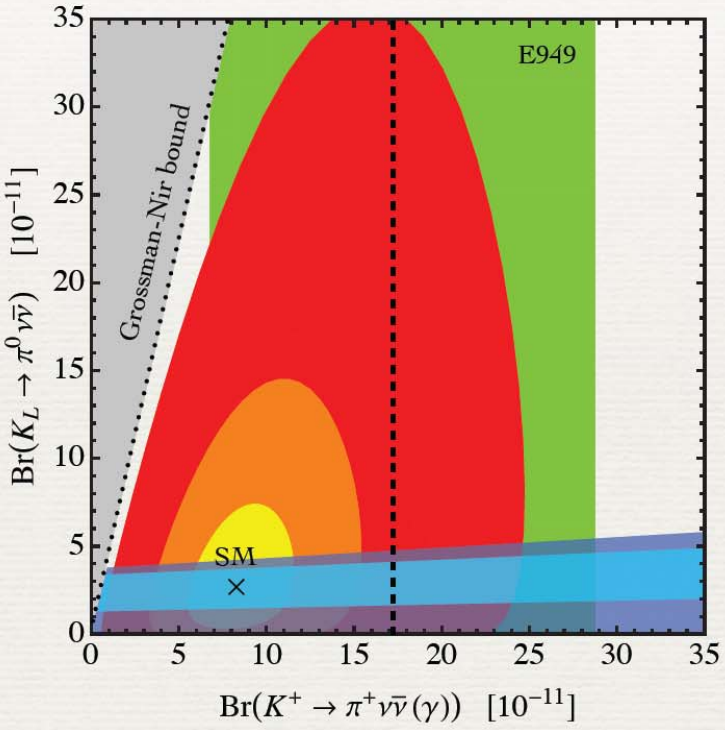
$\epsilon'/\epsilon \in [0.5, 2]\,(\epsilon'/\epsilon)_{\rm SM}$

$\epsilon'/\epsilon \in [0.2, 5]\,(\epsilon'/\epsilon)_{\rm SM}$

U. Haisch, PXPS

Some heat and light…

ε′/ε Strikes Back



stringent correlation between CP-violating kaon observables present in MSSM, RS, compositeness, ...

ε′/ε "sleeping beauty" of flavor physics: when will lattice's kiss wake her?

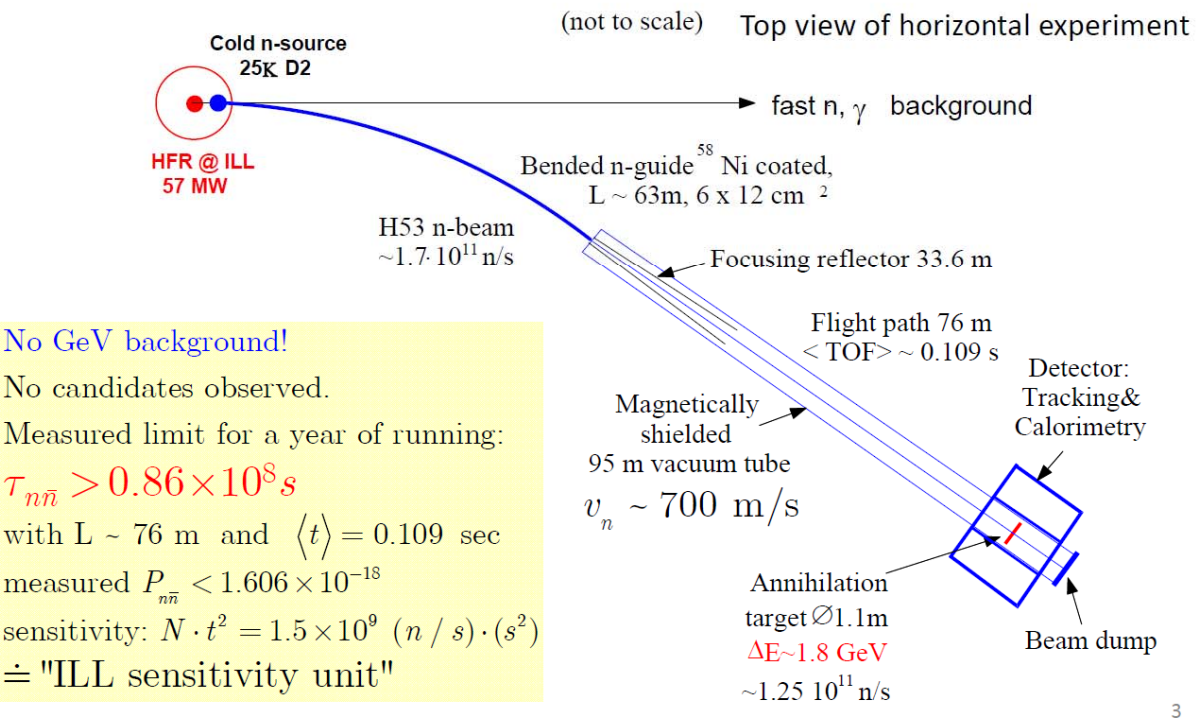
U. Haisch, PXPS

Opportunities for In-kind contributions…

Previous n-nbar search experiment with free neutrons

At ILL/Grenoble reactor in 89-91 by Heidelberg-ILL-Padova-Pavia Collaboration

Z. Phys., C63 (1994) 409



No GeV background!

No candidates observed.

Measured limit for a year of running:

$\tau_{n\bar{n}} > 0.86 \times 10^8 s$

with L ~ 76 m and $\langle t \rangle = 0.109$ sec

measured $P_{n\bar{n}} < 1.606 \times 10^{-18}$

sensitivity: $N \cdot t^2 = 1.5 \times 10^9 \ (n/s) \cdot (s^2)$

≐ "ILL sensitivity unit"

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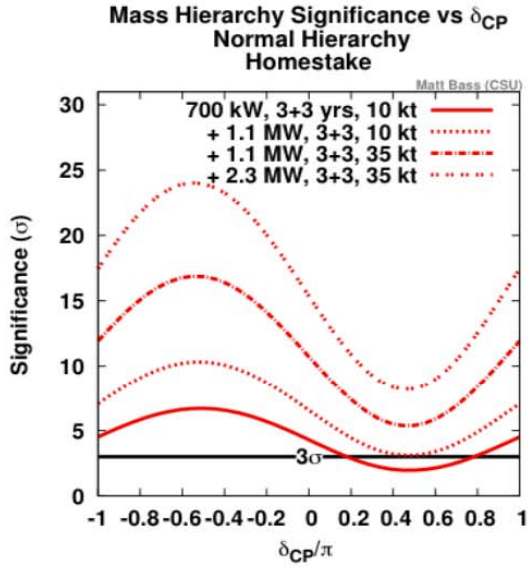
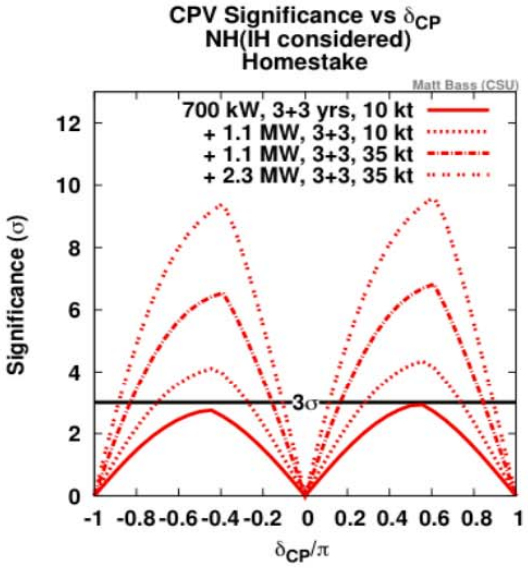
Kamyshkov, Dubbers PXPS

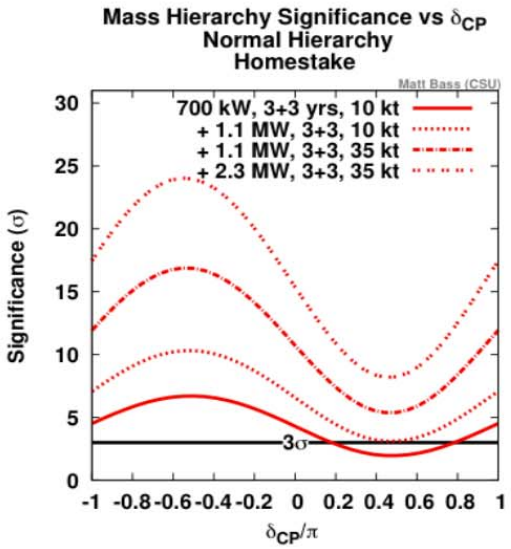
LBNE Phase 2 + Project X Stage 1

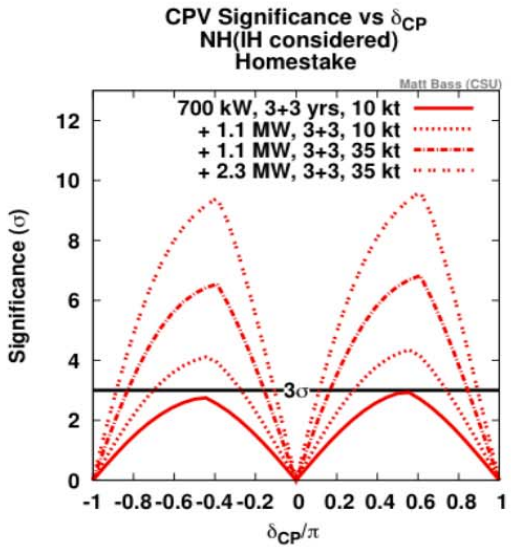




- Stage 1 of PX increases the MI beam power to MW range
- LBNE/Homestake Phase 2 + PX Phase 1 = **Discovery (>5σ) CPV**

LBNE Phase 2 + Project X Stage 1



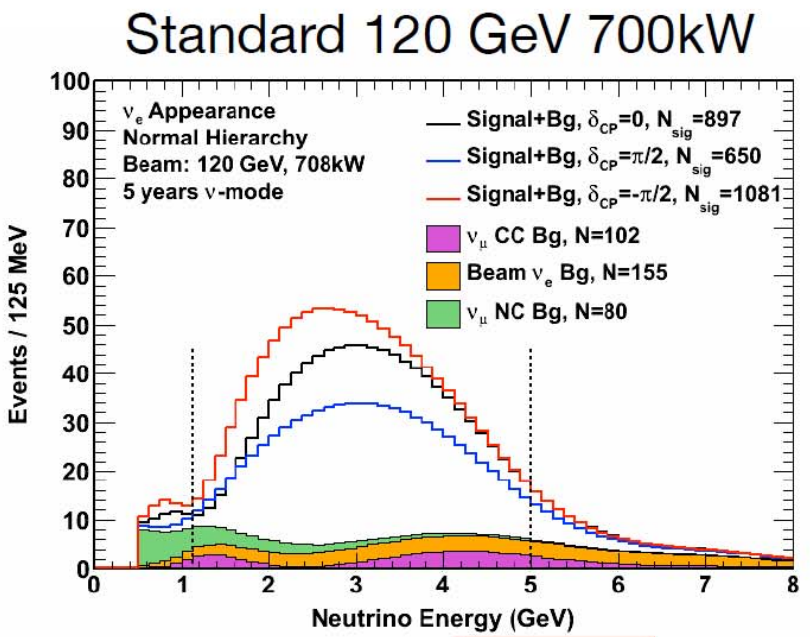


- Stage 1 of PX increases the MI beam power to MW range
- LBNE/Homestake Phase 2 + PX Phase 1 = **Discovery (>5σ) CPV**

Project X Stage 2 Possibilities

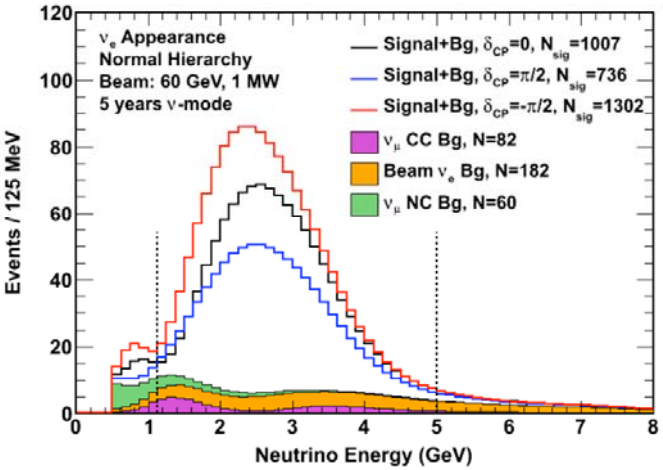
- Stage 2 will allow MW-power lower energy beams
- Can we gain low energy flux (at long baselines) by going to lower energies?
- This can populate the second maximum and improve the signal/background in the CPV-sensitive region.
- Consider 30, 60, 90 GeV energies and 1MW beam power
- Separation power figure of merit:

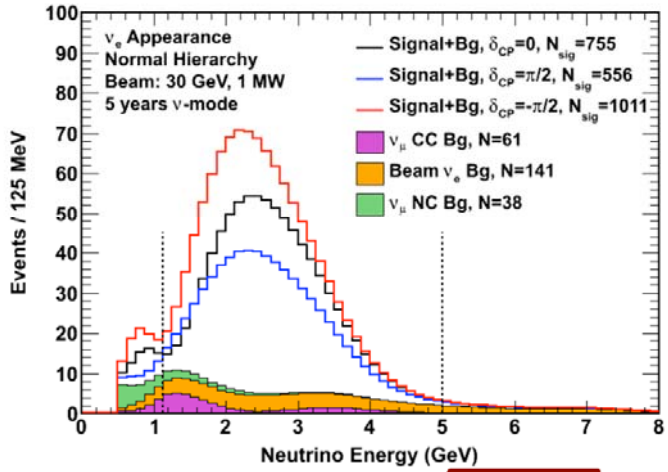
$$\frac{N_{-\pi/2} - N_{\pi/2}}{\sqrt{B}} = 23.5$$



δ_{CP}	N	N_{second}	N_{first}	$N/\sqrt{B}$	$N_{second}/\sqrt{B}$	$N_{first}/\sqrt{B}$
0	897	14	817	48.86	2.27	57.34
$\pi/2$	650	5	597	35.41	0.81	41.90
$-\pi/2$	1081	24	994	58.89	3.89	69.77

60 GeV 1MW, 30 GeV 1MW





δ_{CP}	N	N_{second}	N_{first}	$N/\sqrt{B}$	$N_{second}/\sqrt{B}$	$N_{first}/\sqrt{B}$
0	1007	26	955	55.94	3.92	64.83
$\pi/2$	736	10	707	40.89	1.51	47.99
$-\pi/2$	1302	45	1231	72.33	6.78	83.57

$$\frac{N_{-\pi/2} - N_{\pi/2}}{\sqrt{B}} = 31.4$$

δ_{CP}	N	N_{second}	N_{first}	$N/\sqrt{B}$	$N_{second}/\sqrt{B}$	$N_{first}/\sqrt{B}$
0	755	30	716	48.74	4.93	55.08
$\pi/2$	556	11	538	35.89	1.81	41.38
$-\pi/2$	1011	51	951	65.26	8.38	73.15

$$\frac{N_{-\pi/2} - N_{\pi/2}}{\sqrt{B}} = 29.4$$

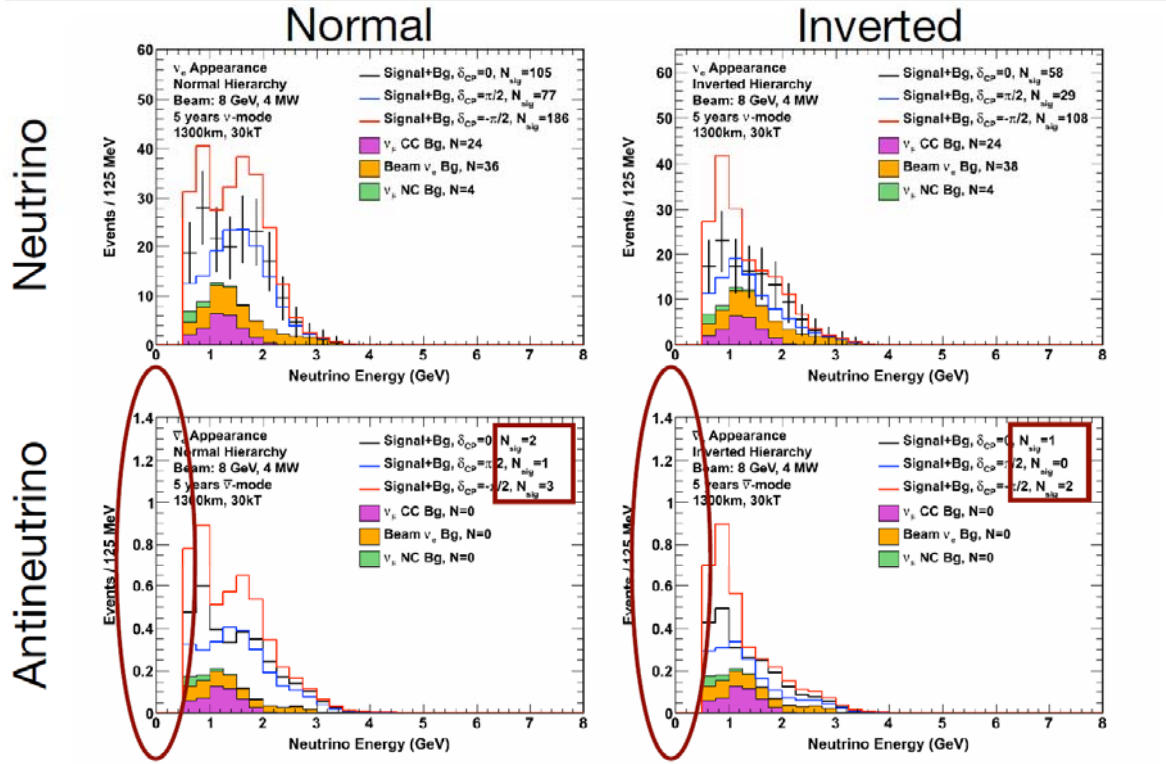
- Can do better CPV than 120 GeV with the same amount of running
- Technical: High density graphite target inserted into horn 1 unlike standard NuMI LE at z=-30cm

Zeynep Isvan (BNL) 6/19/2012 PXPS 12

Zeynep Isvan (BNL) PXPS

Stage-4: LBL physics with 8 GeV beam!

Matter vs CP effect with 8 GeV



- Mass hierarchy and CP asymmetry non-degenerate - they're completely disentangled!

Zeynep Isvan (BNL) 6/19/2012 PXPS

Zeynep Isvan (BNL) PXPS

PXPS relationship to upcoming proposals and reviews

- Recent DOE OHEP FOA

  (**DE-FOA-0000733)**

- Laboratory KA15 Detector R&D reviews.

- Open phone call with Glen Crawford Wednesday afternoon (6/20) on funding guidance.

Feedback and Interaction with "Snowmass"

"The Intensity Frontier Workshop" exercise

2011 working groups and conveners

Topic	Experiment	Theory	Observer
Heavy Quarks	Joel Butler, Jack Ritchie	Zoltan Ligeti	Ritchie Patterson
Charged leptons	Brendan Casey	Yuval Grossman	Aaron Roodman
Neutrinos	Sam Zeller, Kate Scholberg	Andre deGouvea	Kevin Pitts
Hidden Sector Photons, Axions & WISPs	John Jaros	Rouven Essig	Juan Collar
Proton decay	Chang-Kee Jung	Carlos Wagner	Chip Brock
Nucleons, Nuclei & Atoms	Zheng-Tian Lu	Michael Ramsey-Musolf	Wick Haxton
Topic	Experiment	Theory	Observer

Physics: *s,c* & *b* quarks final states

Muons, taus

All experiments for properties of neutrinos. Accelerator & non-accel.

"Dark" photons, paraphotons, axions, WISPs

Proton decay

Properties of nucleons, nuclei or atoms (EDM)

H. Weerts, PXPS

Thinking after June 14, 2012 meeting:

Intensity Frontier

Proposed working groups for 2012/2013

Intensity Frontier working groups

13-Jun-12

Under Construction				
Topic	**Experiment**	**Theory**	**Observer**	**Overlap**
Heavy Quarks				
Charged leptons				
Neutrinos				Cosmic Frontier
New light, weakly coupled particles	**Get input**			Cosmic Frontier
Proton decay				keep
Nucleons, Nuclei & Atoms				Nuclear Physics
Hadronic Structure	*Proposed new group*			Nuclear Physics
Topic	**Experiment**	**Theory**	**Observer**	

This will be on Web site.

Request for **feedback** on groups & suggestions for conveners

Note:
if no feedback , a default is to go with 2011 conveners-- proven team and worked very well
Some may already be demand other places.

Liaison(s): with experiments proposed for Project-X ? Project-X?
Other experiments ?

H. Weerts, PXPS

Evolution at face-to-face meeting yesterday

No subgroup structure was/is on the “Snowmass” web site.

After initial proposal, quite a bit of discussion.

Initial sub groups organized by “beam type”: neutrinos, charged leptons, colliders etc

This does not underscore a facility, with many “secondary” beams like Project-X.

Subgroup structure will change and reflect this == watch website & DPF announcements.

PLEASE: comment on subgroup structures, suggest improvements and suggest conveners.

Each subgroup: plan is to have three conveners.

Liaisons & connections; maintain

H. Weerts, PXPS

A Few of the opportunities for growth identified at the PXPS

- Driving the Mu2e experiment with 1 GeV beam.
- Common target station for n-nbar and n-edm experiments
- Substantial infrastructure from previous ILL n-nbar experiment may be available.
- Importance of 1000 event $K_L \rightarrow \pi^0 \nu\nu$ amplified.
- Importance of 60 GeV Main-Injector running at Stage 2 quantified, value of 8 GeV drive beam in Stage-4 explored.

Opportunities for pruning identified at the PXPS

- Pursuing a pion Decay-at-Rest (DAR) experiment with Stage-1 will not compete or distinguish from Osc-SNS at the SNS.
- Pursuing the use of PXIE to drive an “IsoDAR” type experiment* (~1 kTon IBD detector) near or on the surface does not appear feasible.
- Pursuing a <100 event sensitivity experiment for $K_L \rightarrow \pi^0 \nu\nu$.

***arXiv:1205.4419v1 May 2012**

Challenges to developing the Project X Research Program

- Communicating plausible schedules
- Relationship with LBNE
- Developing a smooth interface with the program this decade
- Building partnerships between funding agencies & offices

Research program priorities for the coming year

- Complete the concept study of LBNE/Project-X staging interplay.
- Concept study of scheme to drive Mu2e with 1 GeV proton beam.
- Guest and visitor support to develop 1-GeV spallation target designs to drive next generation cold-neutron experiments.
- Continued effort on developing high power targetry.
- Continued outreach into the community

Summary-
The High Intensity Horizon…

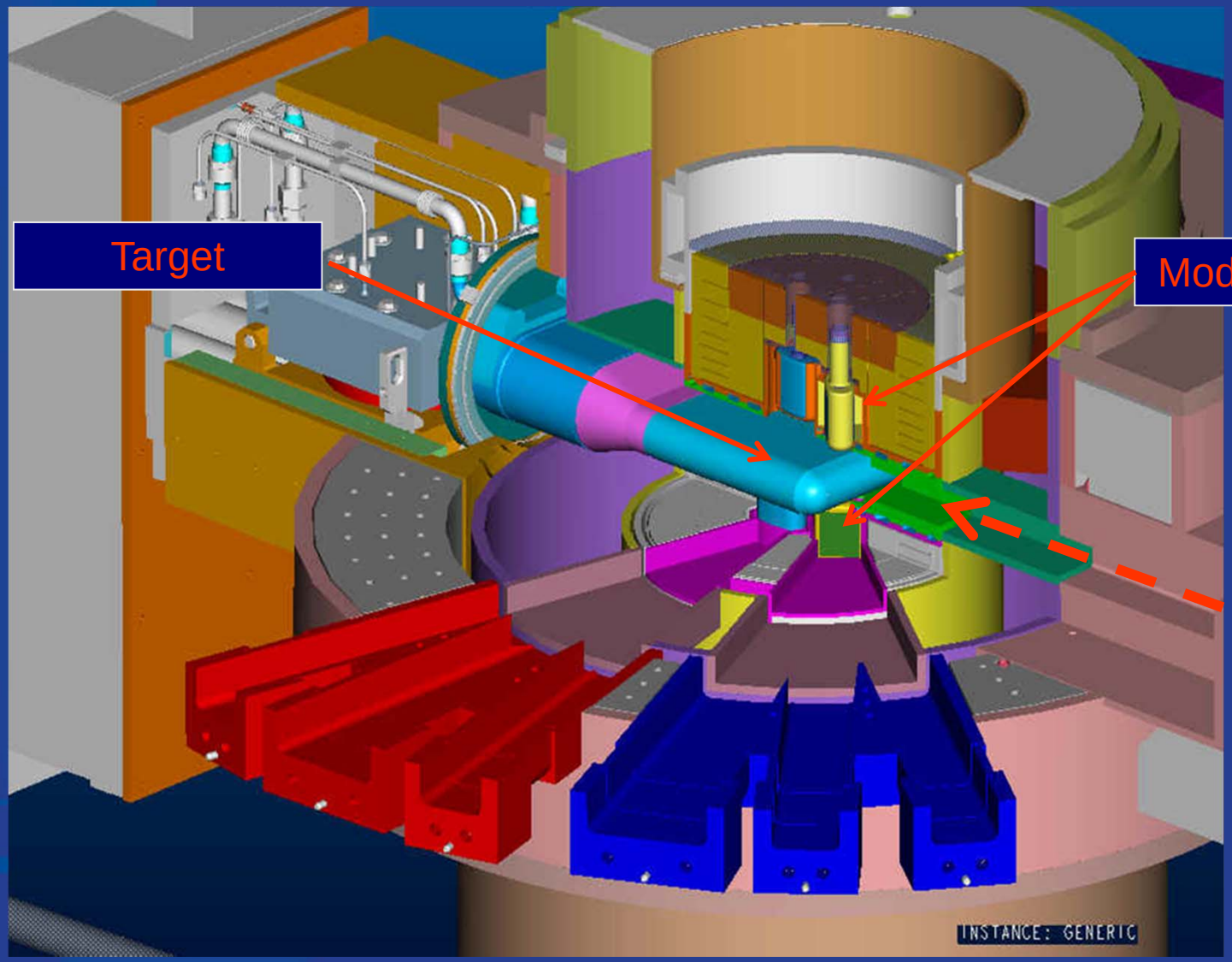
- Project-X is a staged evolution of the best assets of the Fermilab accelerator complex with the revolution in super-conducting RF technology.
- Each Stage of Project-X will raise many boats of the Intensity Frontier in particle physics, with a program scope of more than 20 world-leading particle physics experiments and an associated robust user community.
- The near term focused R&D for Project X is PXIE, and this effort in parallel with continuing critical SRF development could support a staged construction start for Project X as early as 2017.

Spare Slides

Research Program Budget in the Indian 12th and 13th Budget Proposals

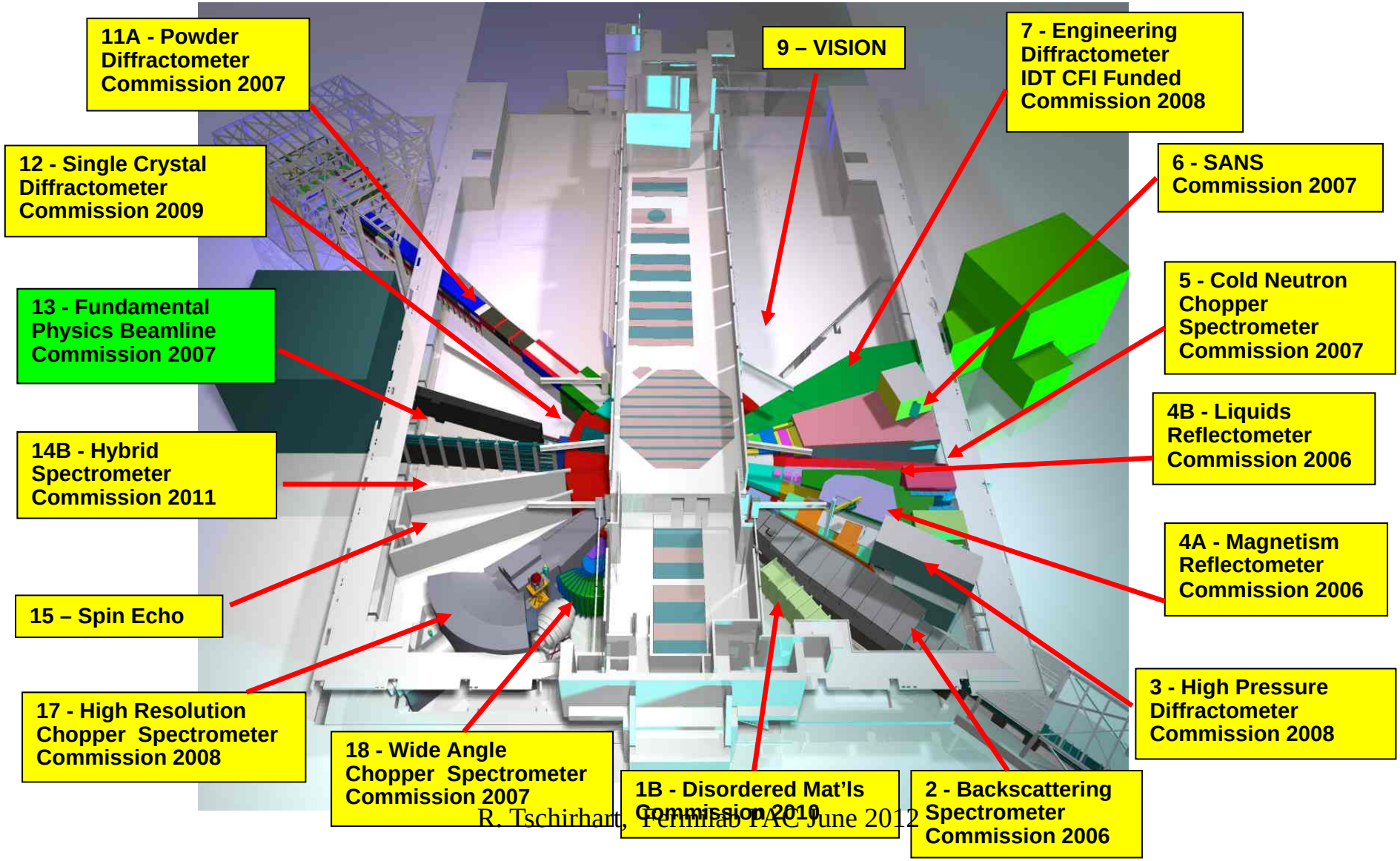
Sub-Projects	12th Plan (Rs. Crores)	13th Plan (Rs. Crores)
Indian Infrastructure and Manpower Development	100	50
Neutrino Physics	150	100
Particle Production and Hyper Nuclei Experiments	60	30
Nuclear Physics	75	75
Rare Decay	25	25
Nuclear Energy	100	100
Detector	100	100
	~$125M	~$100M

ORNL SNS Spallation target



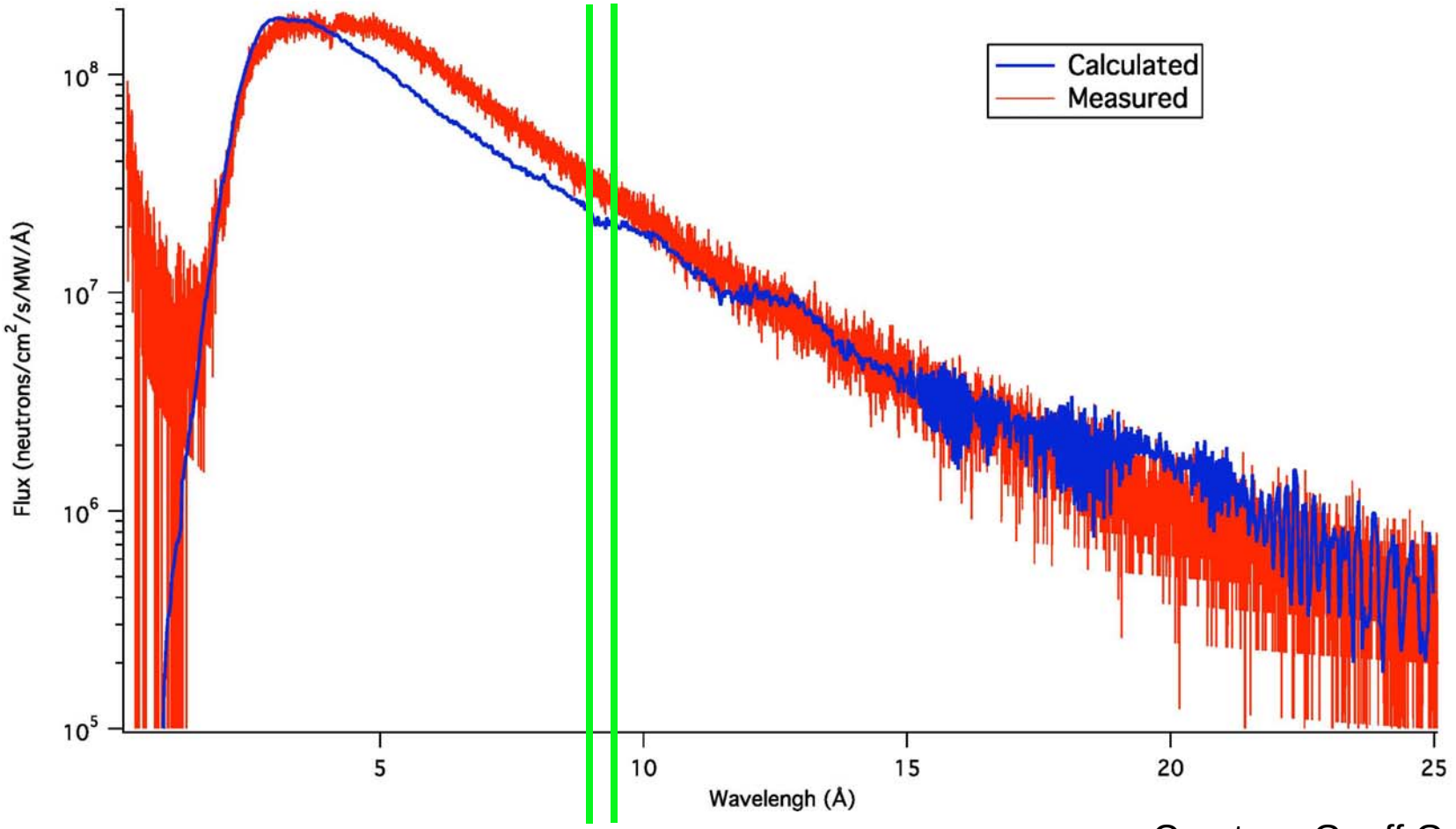
Courtesy Geoff Greene

Beamline 13 Has Been Allocated for Nuclear Physics



Courtesy Geoff Greene

nEDM requires a very narrow wavelength slice at 8.9Å



Courtesy Geoff Greene

Only neutrons in this band are efficiently downs-scattered by superfluid ^{4}HE to give UCN