nEXO: a multi-ton detector for neutrinoless double-beta decay

Karl Twelker (Stanford University)

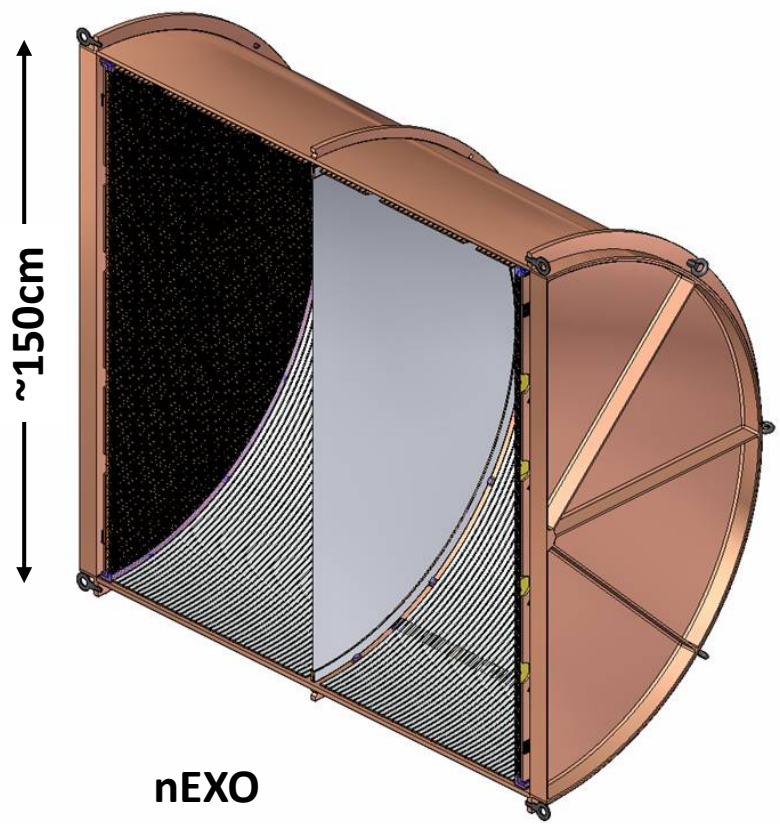
For the EXO Collaboration

TAUP 2013

The Next Generation: nEXO

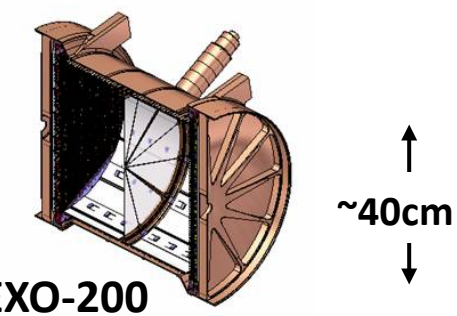
"as similar to EXO-200 as possible"

- Low-activity copper construction
- HFE thermal fluid buffer
- Continuous circulation and purification of xenon
- Water shield and muon veto
- Space and ports for barium tagging



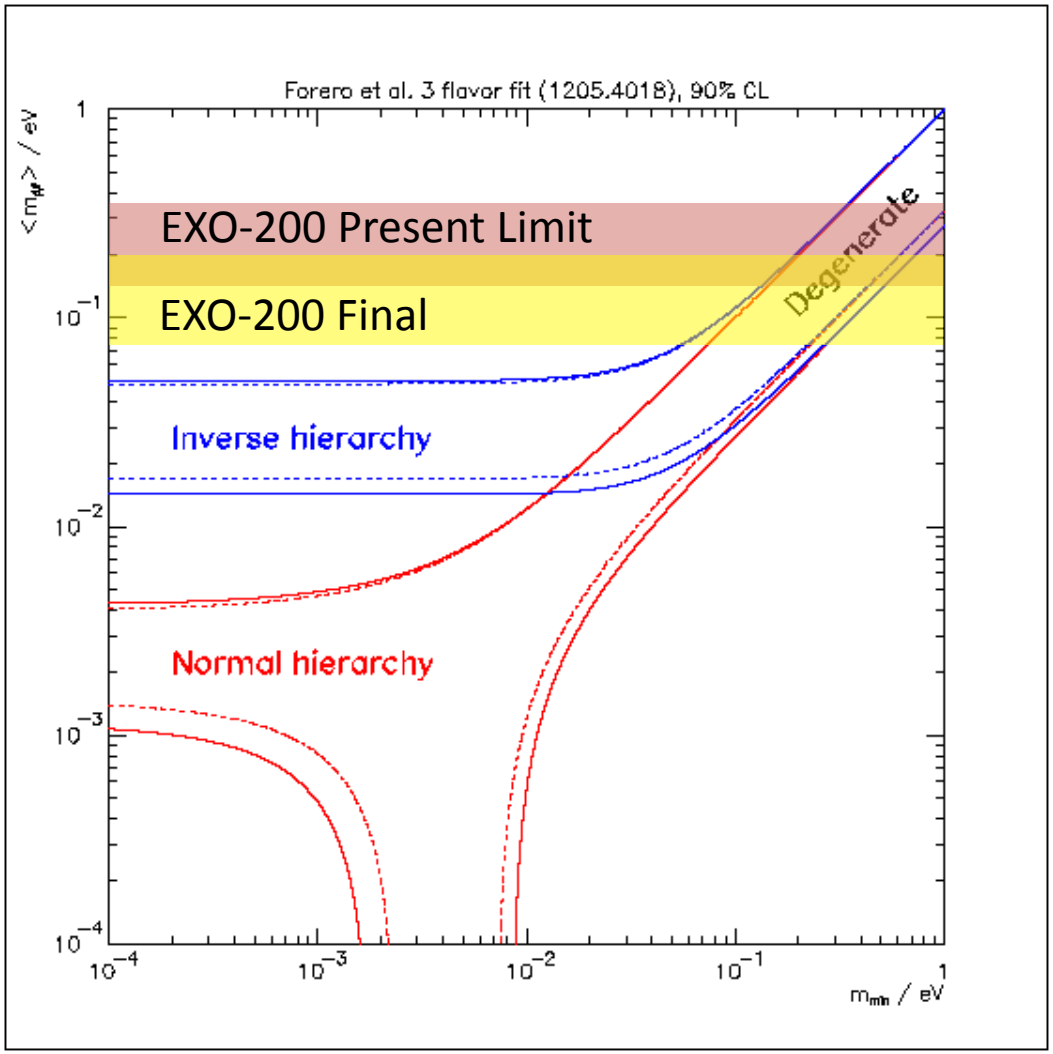
nEXO

Overall Mass: 5 tonnes, 90% enriched ^{136}Xe
Time Projection Chamber (TPC)
Running Time: 10 years
Baseline energy resolution: 1.5%
Preferred site: SNOLAB Cryopit
Final $T_{1/2}$ sensitivity (90% CL): 4.1×10^{27} yrs
With barium tagging: 2.1×10^{28} yrs



EXO-200

nEXO Sensitivity Projections

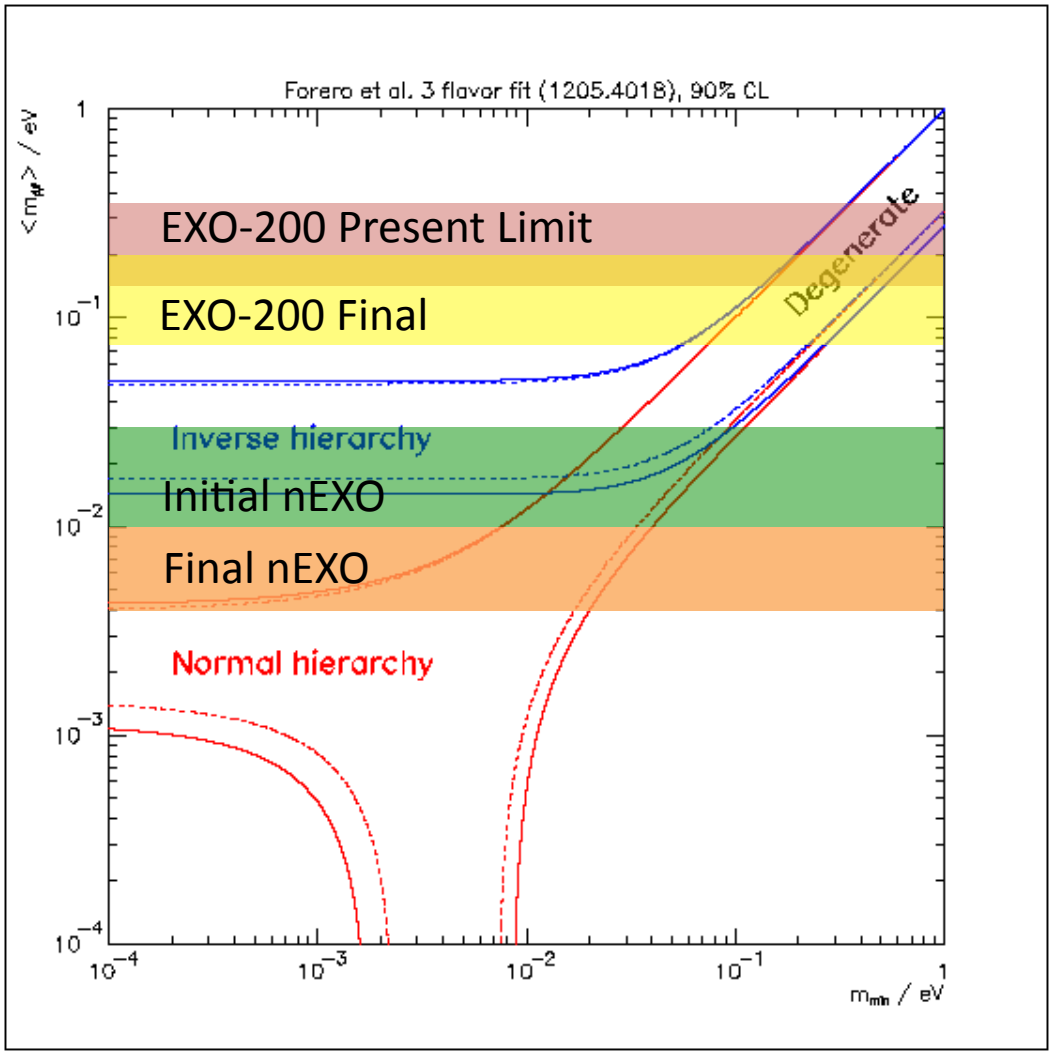


Bands are 90%CL from oscillation experiments for inverted and normal mass hierarchy

EXO-200 present limit is the 90%CL envelope of limits (for different NMEs) from PRL 109 (2012) 032505

EXO-200 ultimate sensitivity: 90%CL for no signal in 4 years livetime with new analysis and Rn removal

nEXO Sensitivity Projections



Bands are 90%CL from oscillation experiments for inverted and normal mass hierarchy

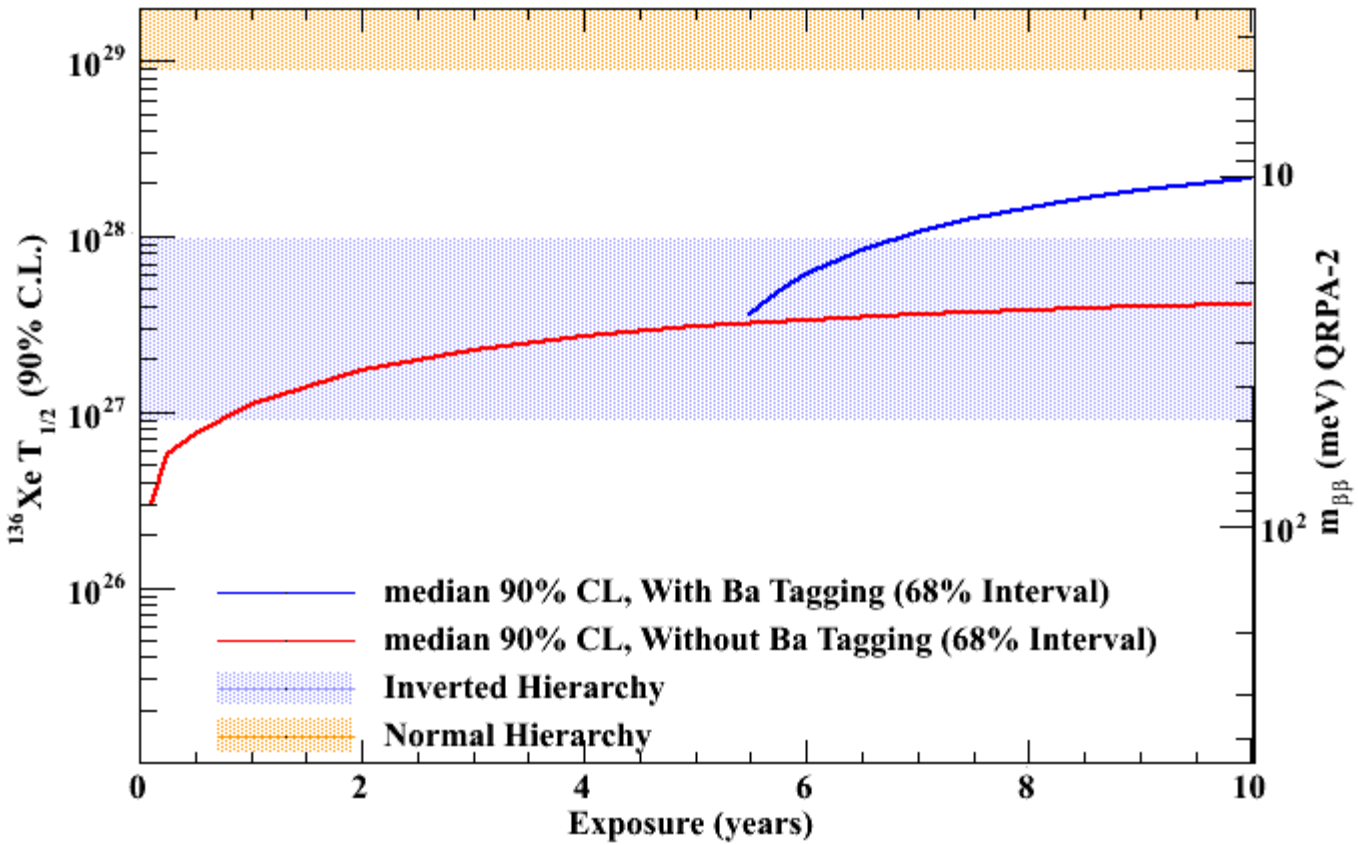
EXO-200 present limit is the 90%CL envelope of limits (for different NMEs) from PRL 109 (2012) 032505

EXO-200 ultimate sensitivity: 90%CL for no signal in 4 years livetime with new analysis and Rn removal

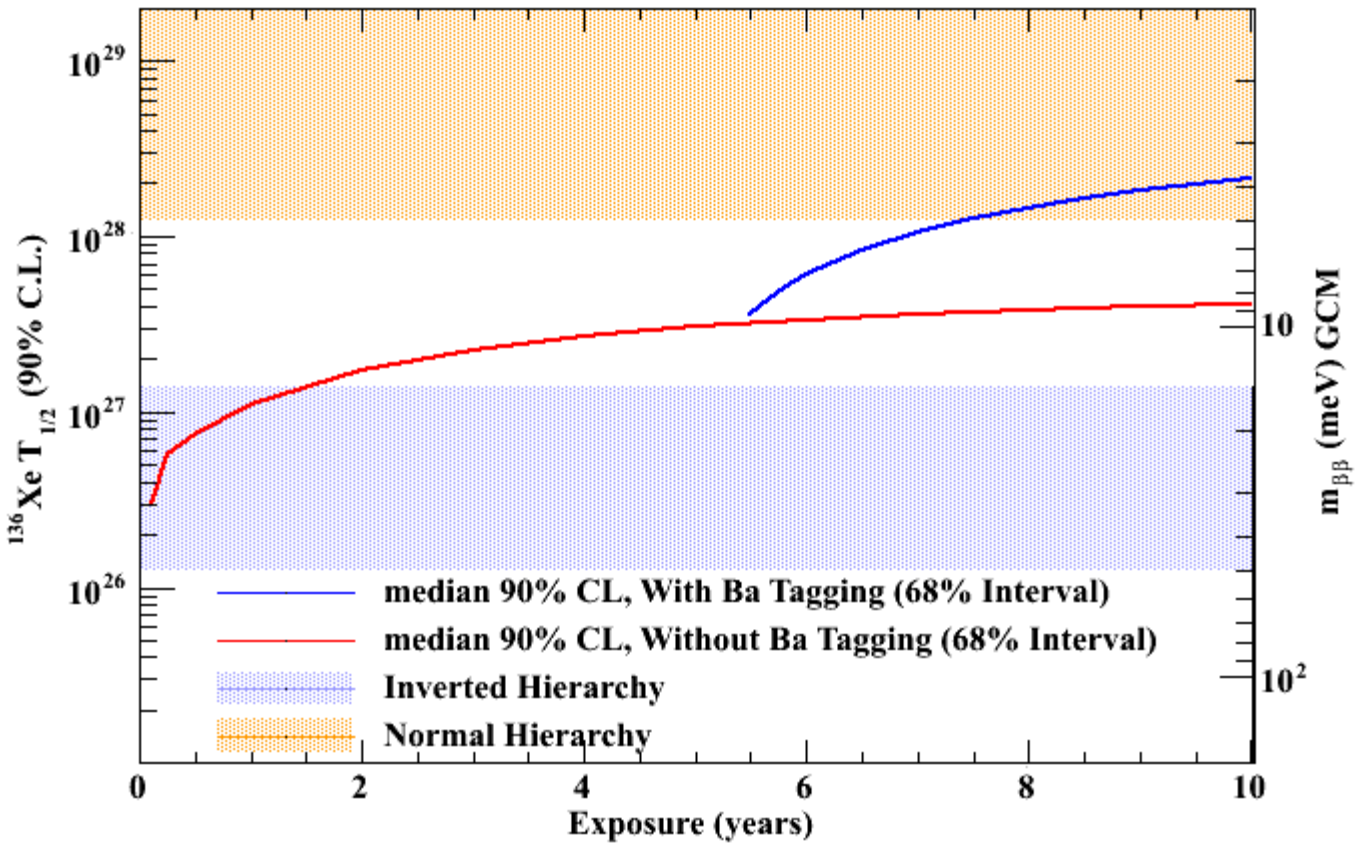
Initial nEXO band refers to a detector directly scaled from EXO-200, including its measured background and 10yr livetime.

Final nEXO band refers to the same detector and no background other than 2v

Sensitivity

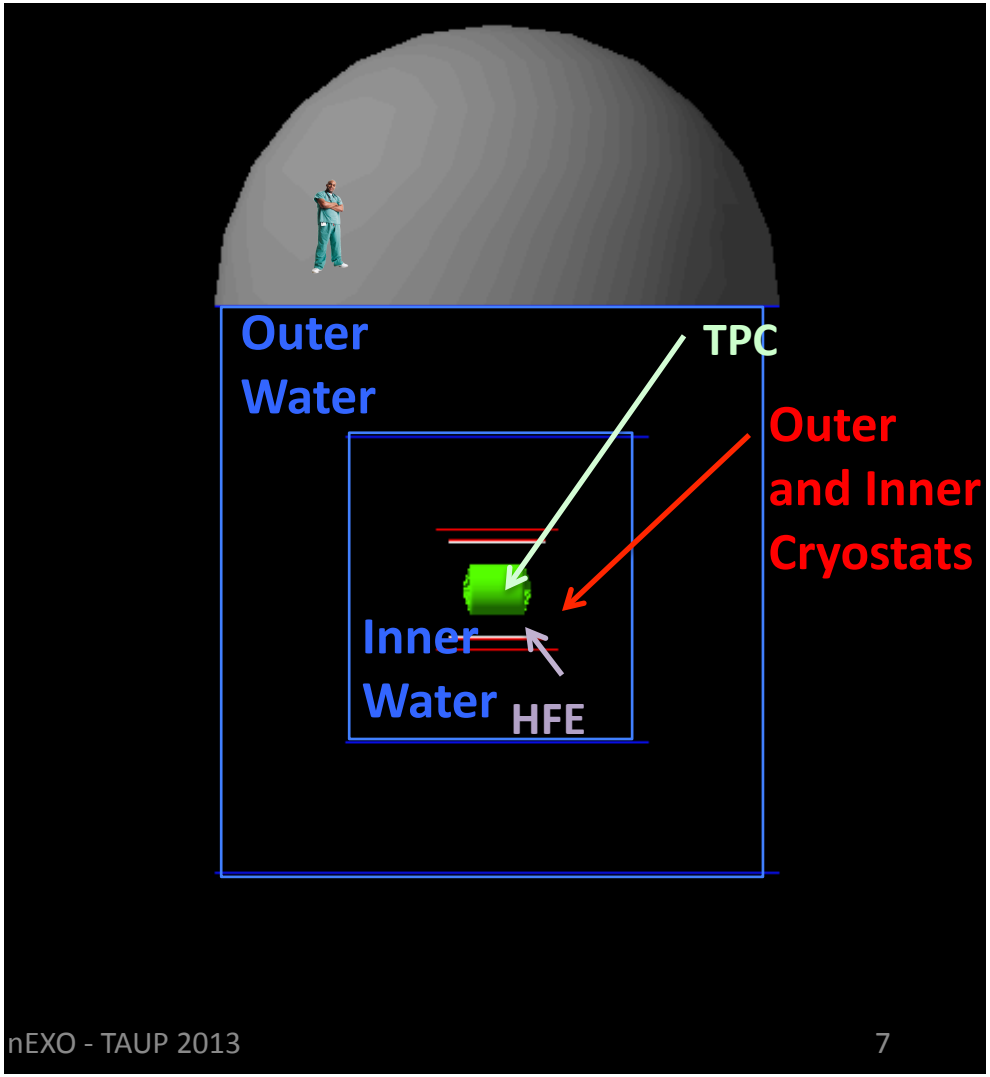


Sensitivity

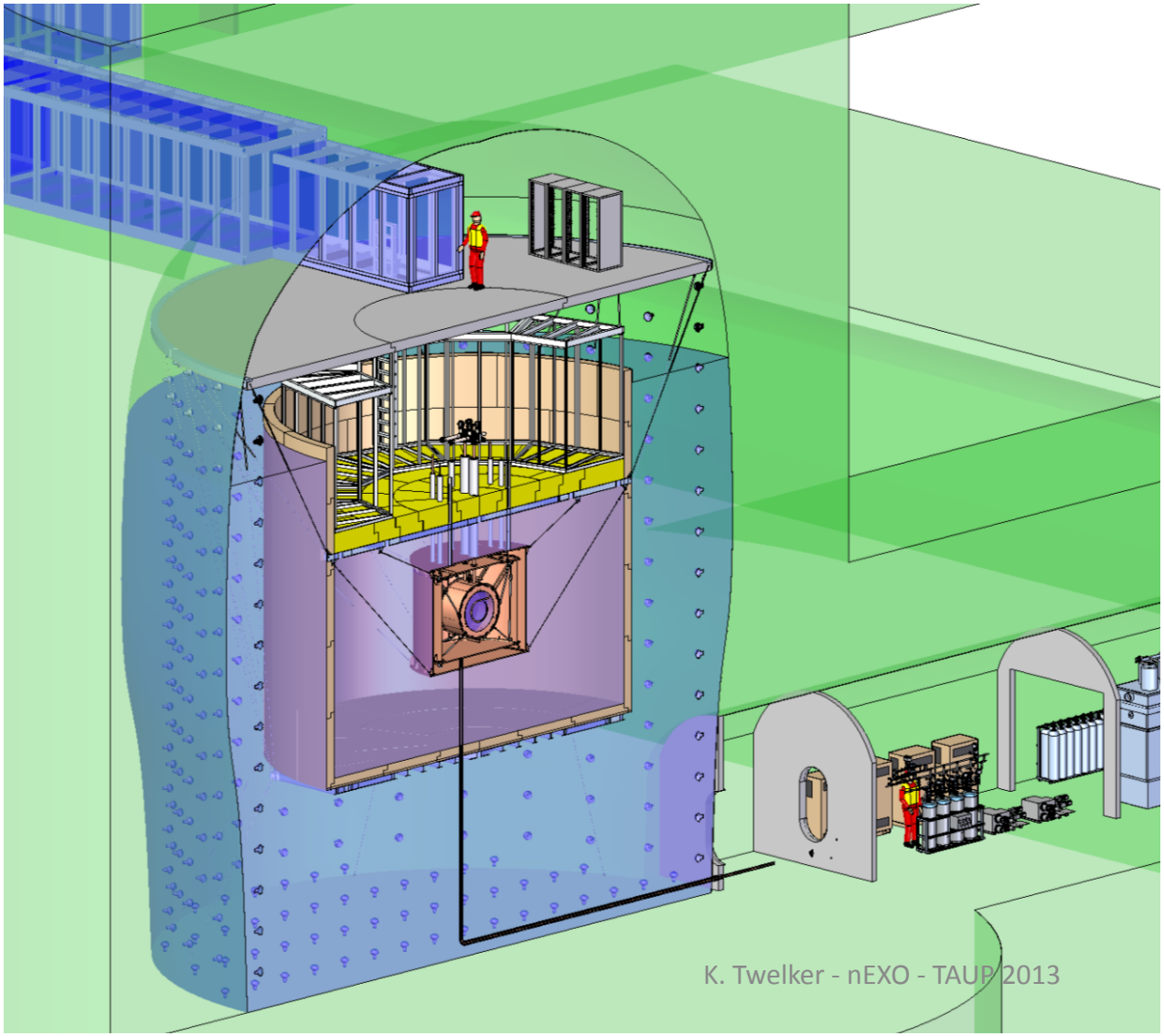


Sensitivity and Backgrounds

- We're constructing a Monte Carlo to assess the discovery potential.
- Gamma backgrounds and 2νββ have been incorporated into the sensitivity projections.
- We're restarting the material assay program that we used to great success for EXO-200.



nEXO at the SNOLAB Cryopit

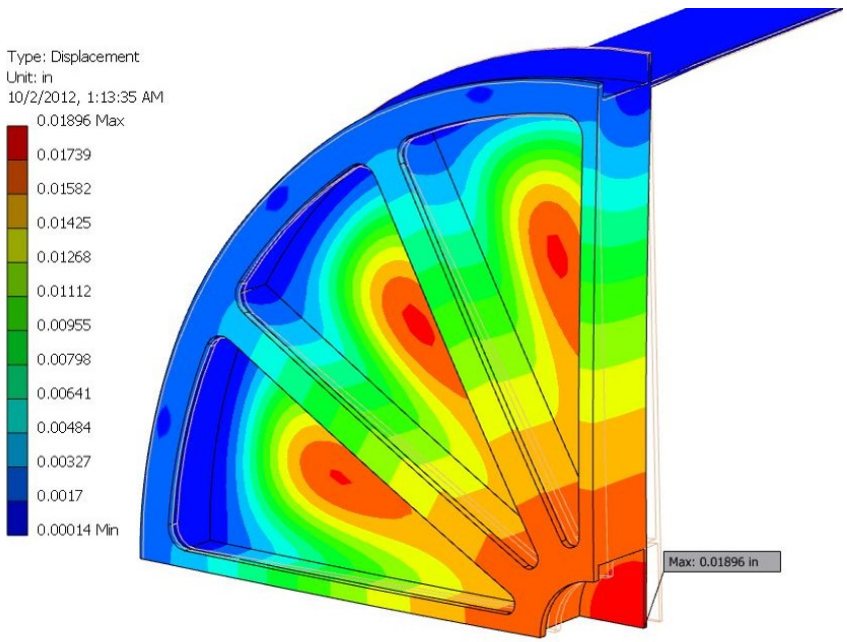


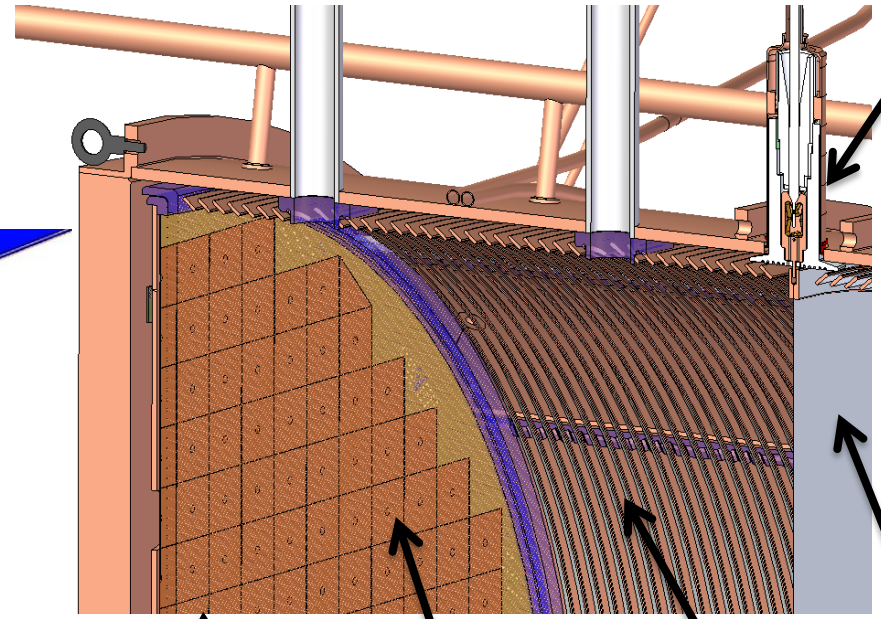
The cryostat will be surrounded by a water muon veto.

Xenon recirculation and repurification in the upper drift.

HFE storage and delivery in the lower drift.

TPC Design





HV feedthrough

Cathode

Wire planes SiPMs

Field shaping rings

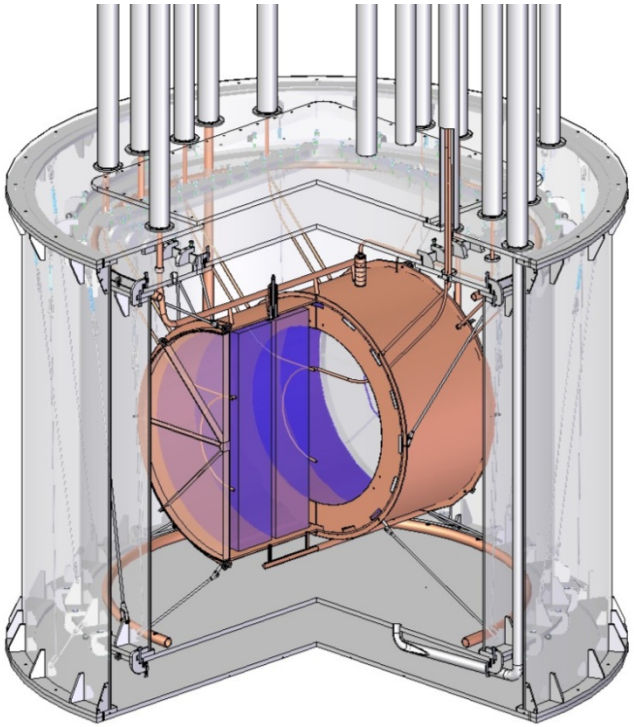
Initial TPC endplate FEA
To ensure minimal use of copper to reduce backgrounds

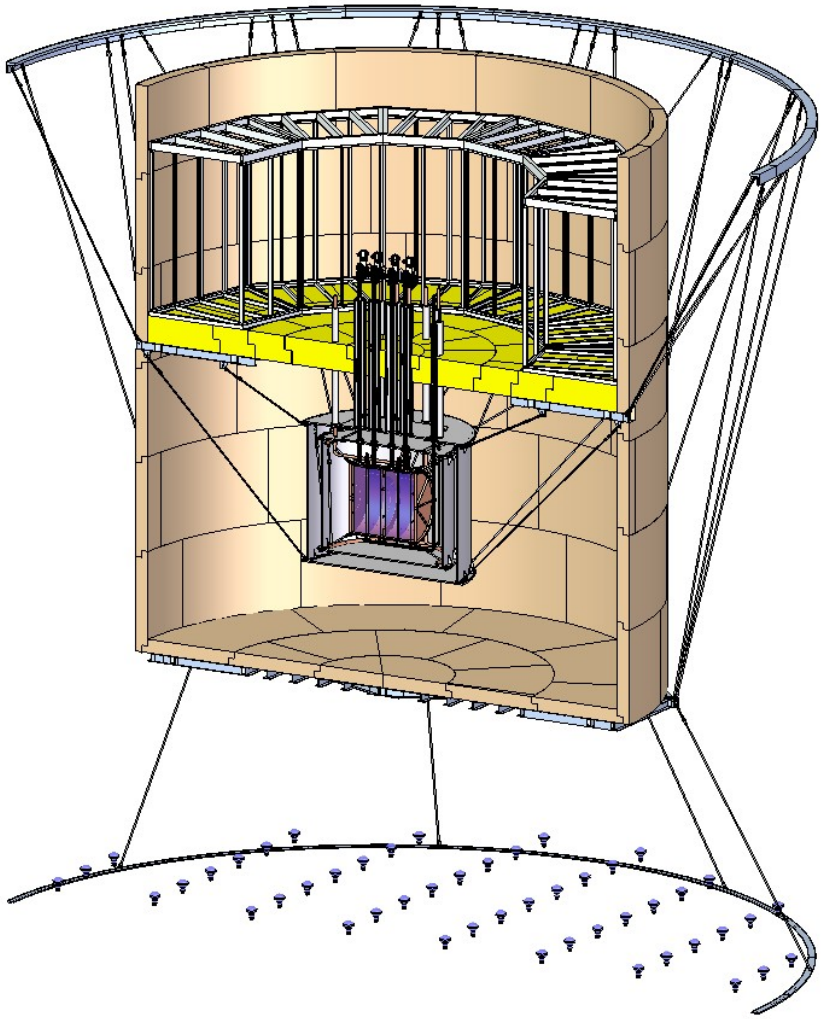
We are investigating other light & charge collection technologies.

Barium Tagging Facilities

The secondary vessel can be pumped dry for easy access to the cryostat.

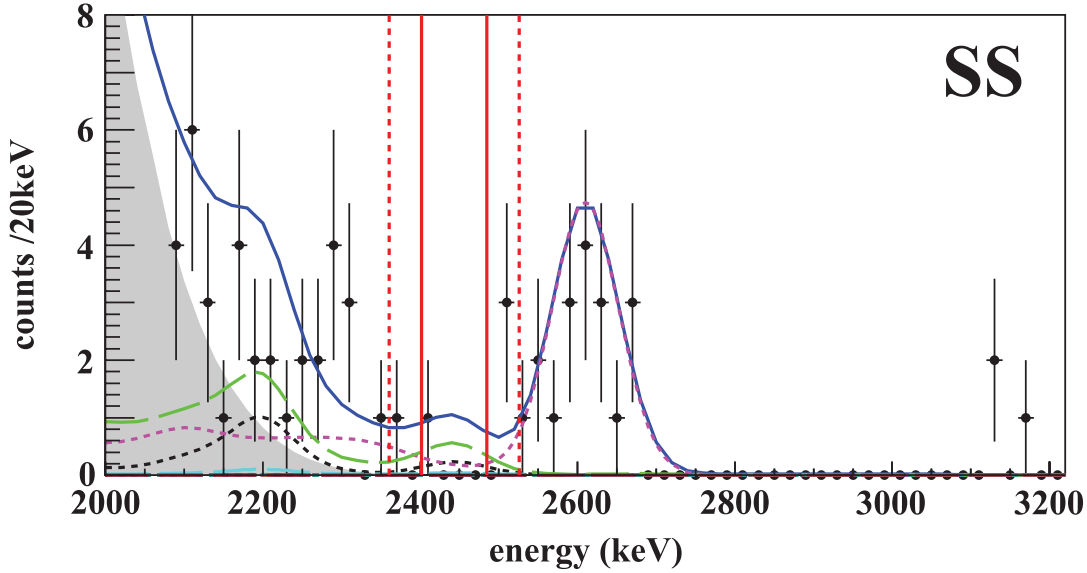
The barium tagging room will be on top of a thin lead shield.





Ba Tagging Motivation

- Goal: eliminate non ββ backgrounds
  - Measure candidate decay event positions, energies
  - Recover and identify Ba ion
  - Tag event-recovery coincidences as ββ
  - Reject untagged events



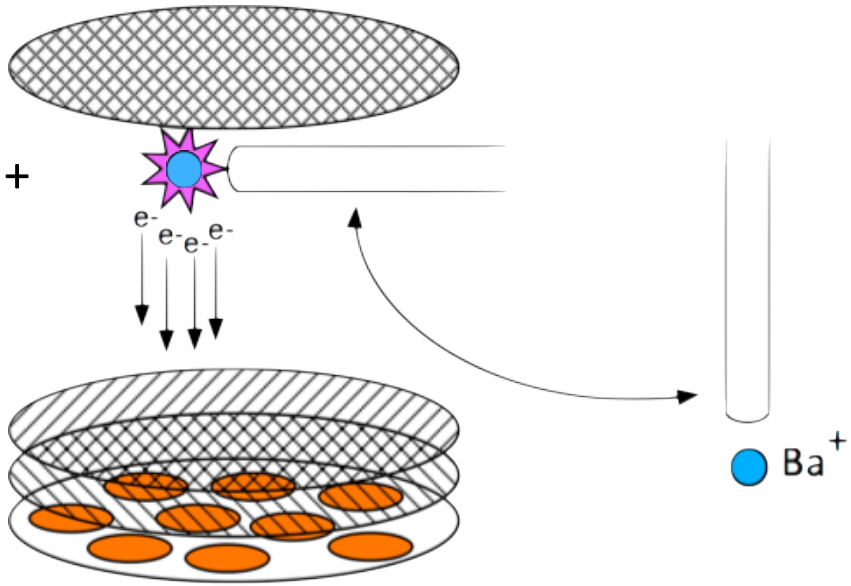
PRL 109, 32505 (2012)

With background: $\langle m_\nu \rangle \propto 1/\sqrt{T_{1/2}^{0\nu\beta\beta}} \propto 1/(Nt)^{1/4}$

Without background: $\langle m_\nu \rangle \propto 1/\sqrt{T_{1/2}^{0\nu\beta\beta}} \propto 1/\sqrt{Nt}$

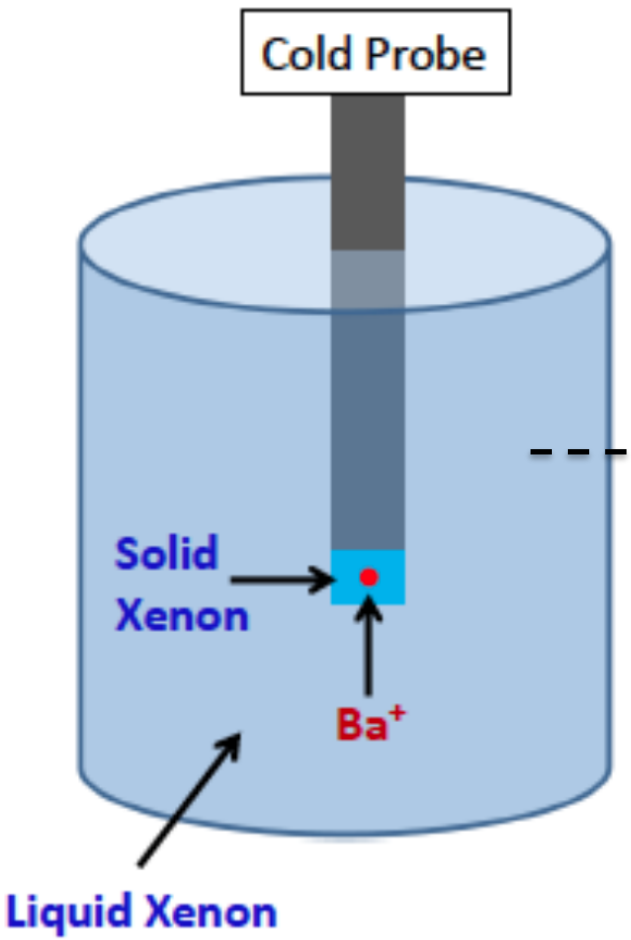
Tagging from Liquid Xenon

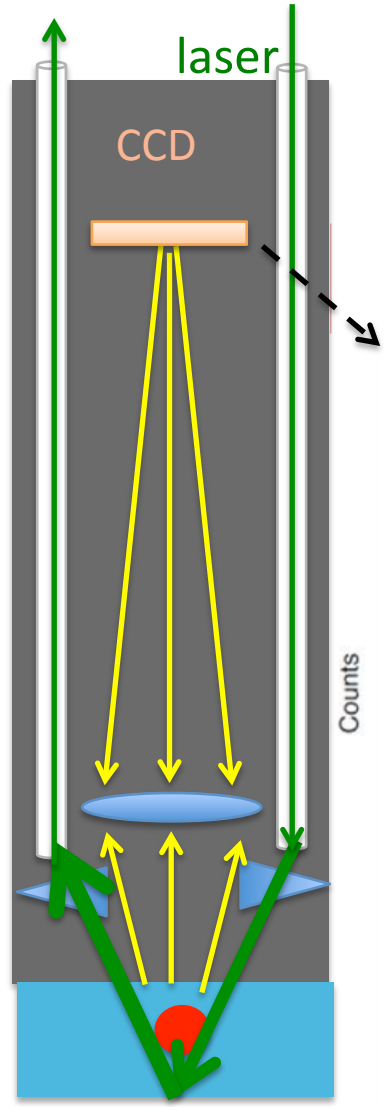
- Decay product in LXe is Ba^+
- Send probe into TPC, electrostatically deposit Ba^+ onto probe tip
- Remove probe to identification chamber
- Many tagging techniques are under development—I will talk about two of them



Spectroscopy in Solid Xe

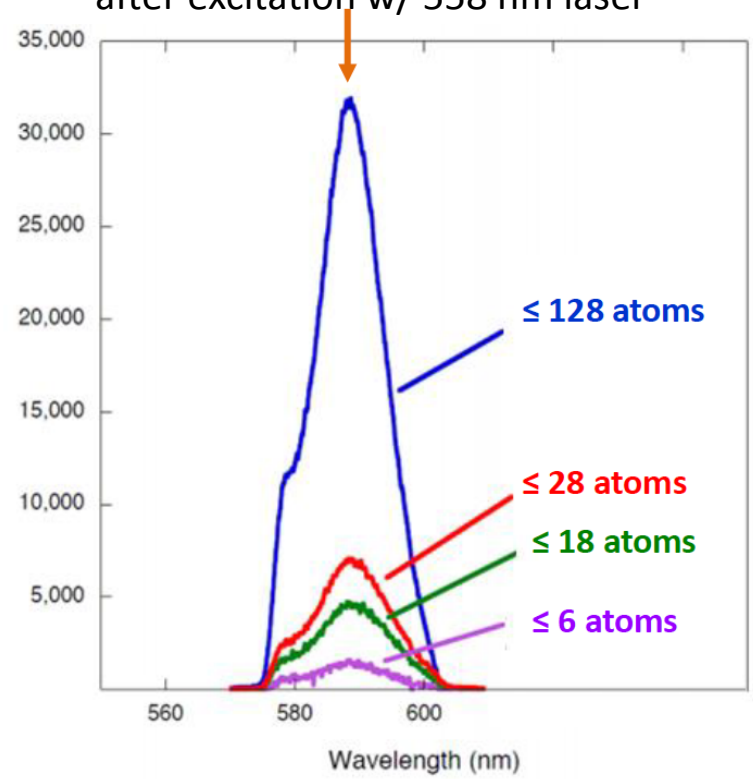
Trap barium daughter ion in solid xenon on a probe:



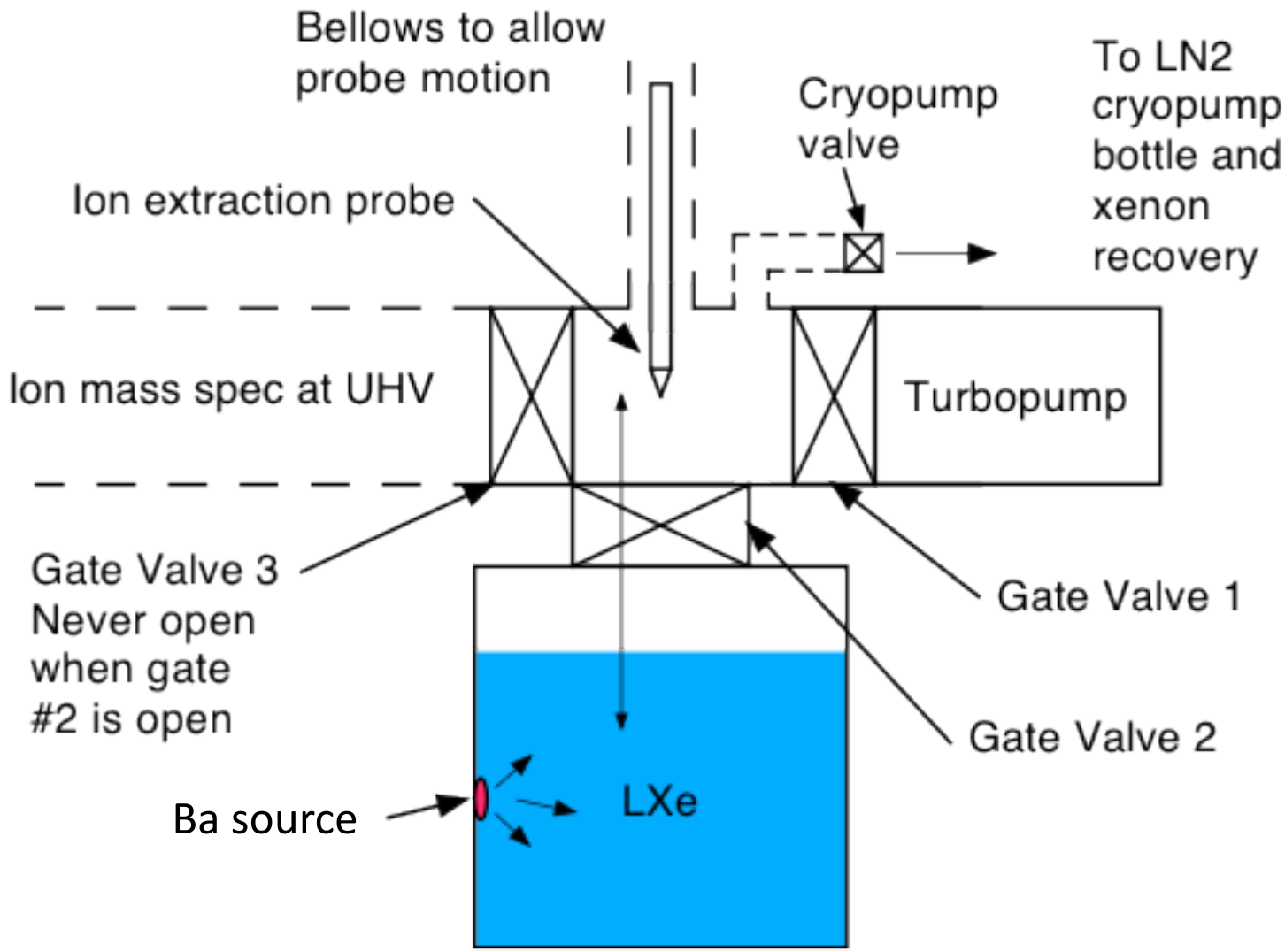


Detect single ion or atom on the probe with laser-induced fluorescence:

Fluorescence peak of Ba in SXe
after excitation w/ 558 nm laser

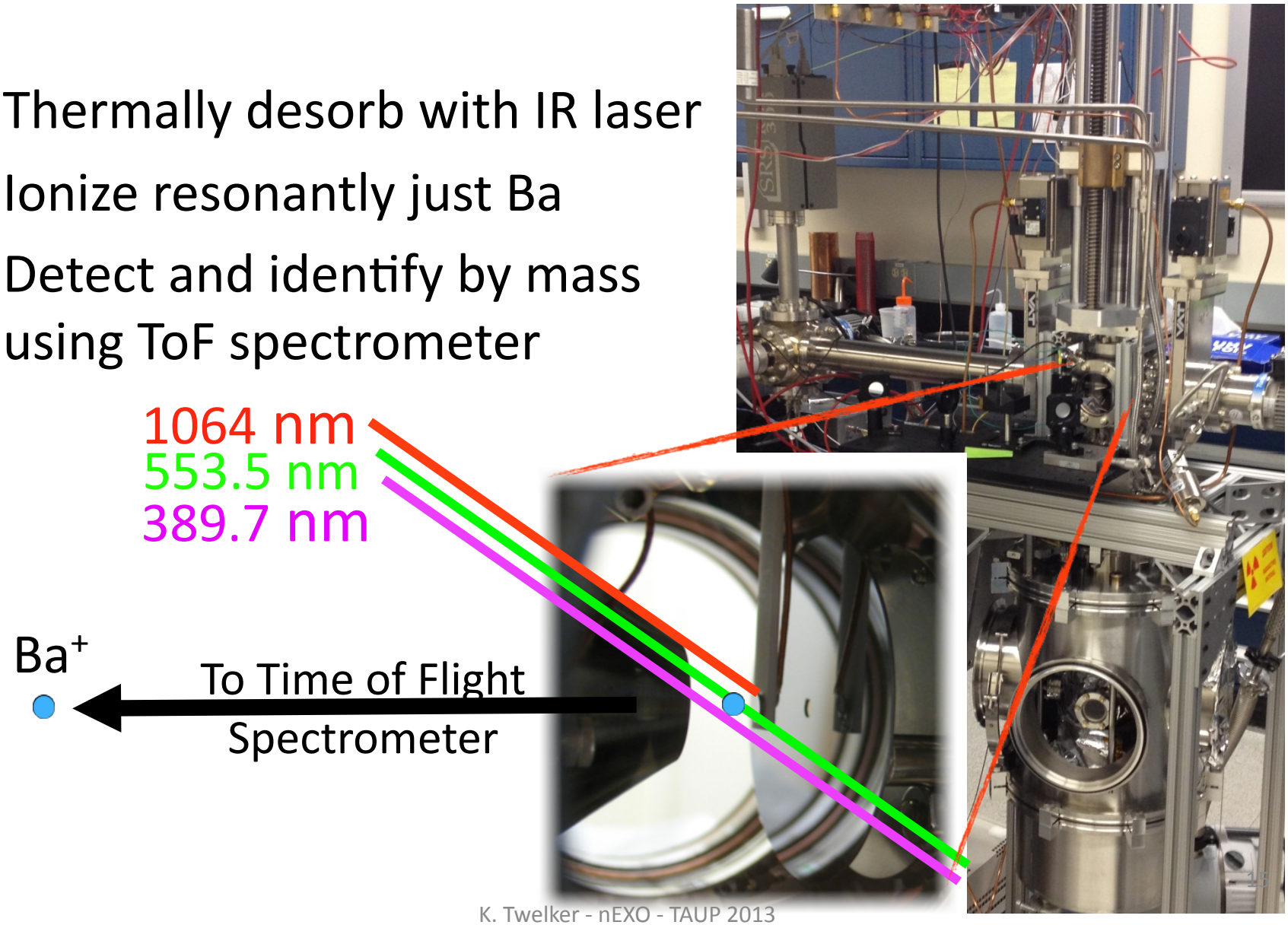


Liquid Tagging Setup Schematic



Resonance Ionization Spectroscopy

- Thermally desorb with IR laser
- Ionize resonantly just Ba
- Detect and identify by mass using ToF spectrometer

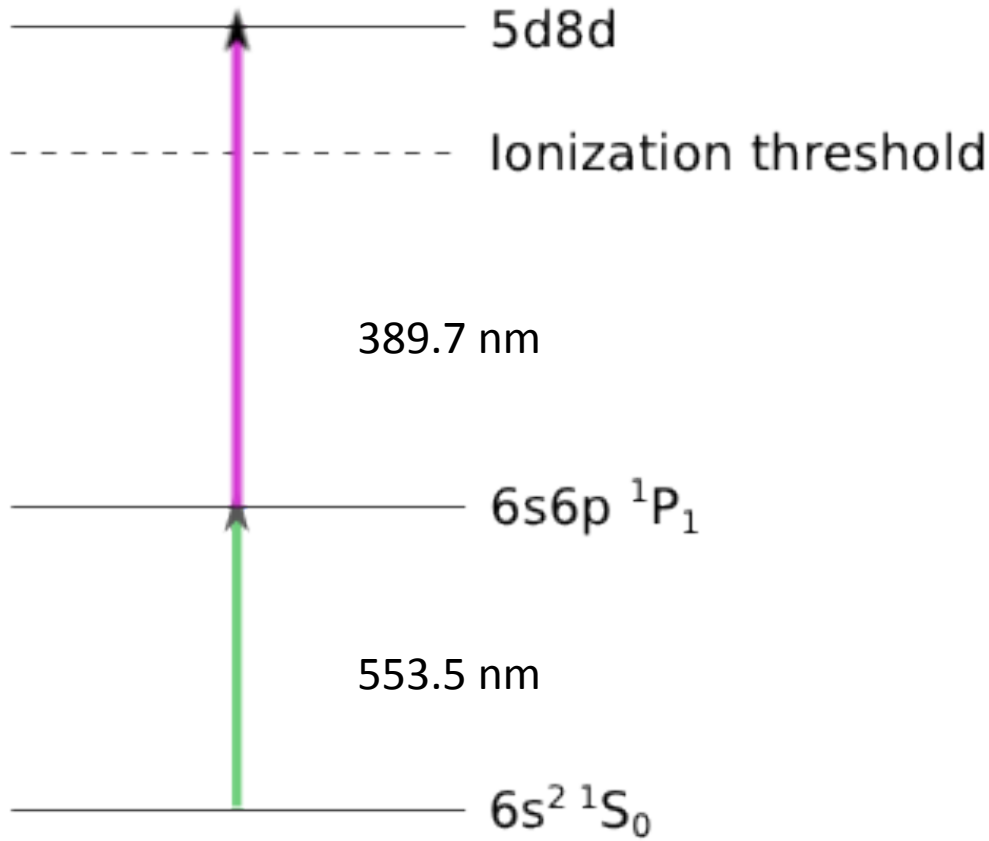


Resonance Ionization Spectroscopy

Challenge:
Recover and identify
single Ba, ignoring all other
elements

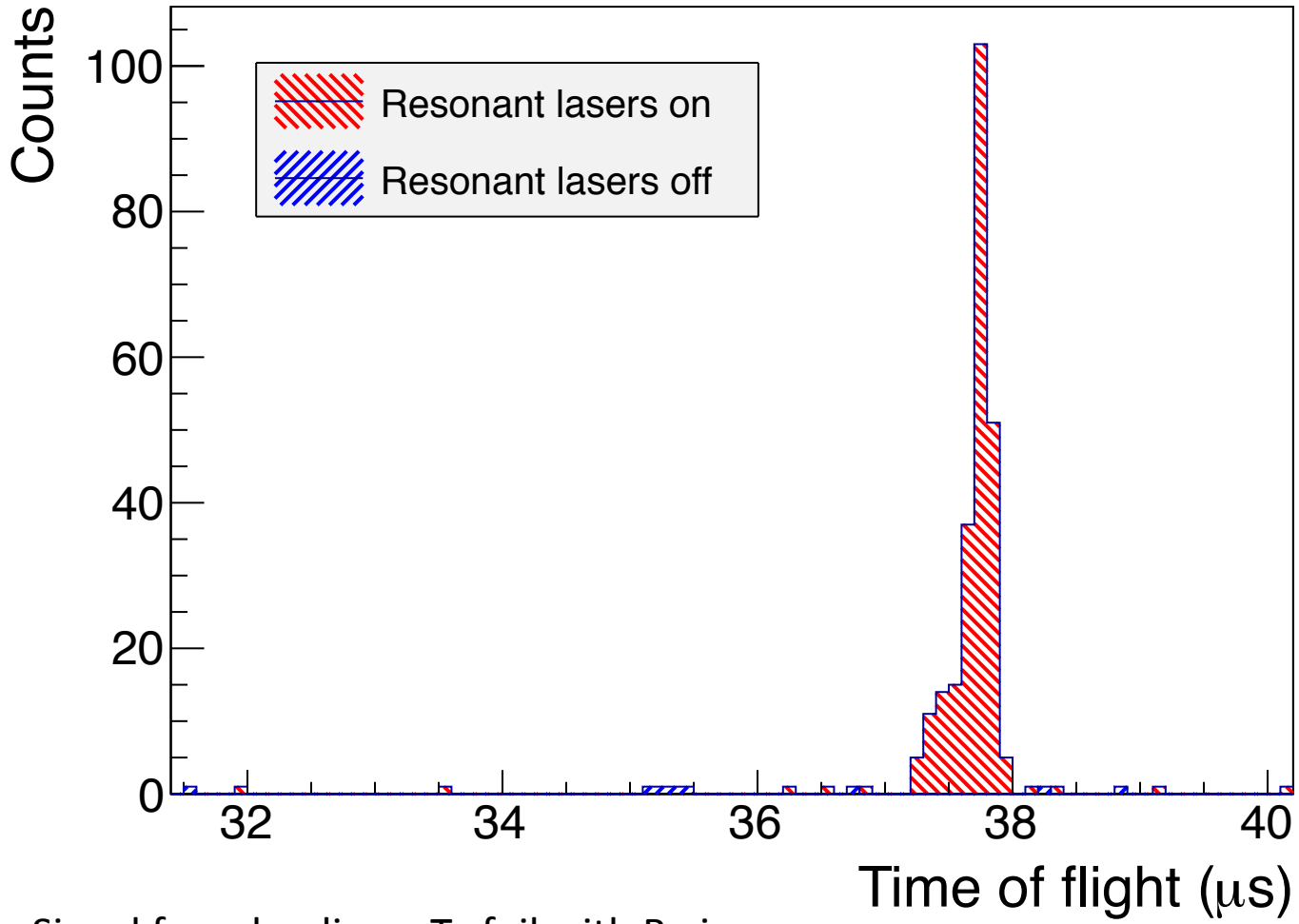
Solution:
Efficiently and *selectively*
re-ionize barium
using its atomic spectroscopy

RIS is sensitive to single ions



Neutral barium spectroscopy

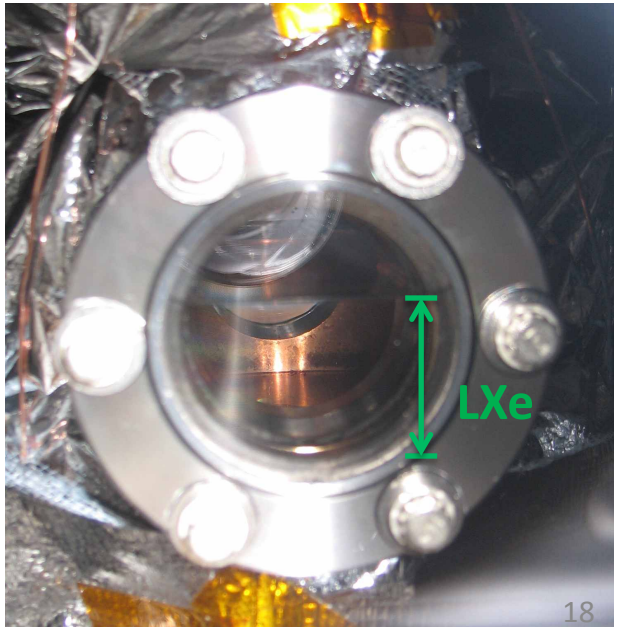
A Very Clean Signal from Vacuum



Signal from loading a Ta foil with Ba in vacuum.

Results and Next Steps

- Proper choice of material and surface prep produces a signal with almost no backgrounds
- Ideal conditions allow **5% efficiency** from deposition to final detection
- **Next:**
  - Continued work on improving repeatability, efficiency
  - Testing in LXe



Counts

The EXO Collaboration

University of Alabama, Tuscaloosa AL, USA - D. Auty, T. Didberidze, M. Hughes, A. Piepke

University of Bern, Switzerland - M. Auger, S. Delaquis, D. Franco, G. Giroux, R. Gornea, T. Tolba, J-L. Vuilleumier, M. Weber

California Institute of Technology, Pasadena CA, USA - P. Vogel

Carleton University, Ottawa ON, Canada - V. Basque, M. Dunford, K. Graham, C. Hargrove, R. Killick, T. Koffas F. Leonard, C. Licciardi, M. Rozo, D. Sinclair

Colorado State University, Fort Collins CO, USA - C. Benitez-Medina, C. Chambers, A. Craycraft, W. Fairbank, Jr., N. Kaufhold, T. Walton

Drexel University, Philadelphia PA, USA - M.J. Dolinski, M.J. Jewell, Y.H. Lin, E. Smith

Duke University, Durham NC, USA - P.S. Barbeau

University of Illinois, Urbana-Champaign IL, USA - D. Beck, J. Walton, M. Tarka, L. Yang

IHEP Beijing, People's Republic of China - G. Cao, X. Jiang, Y. Zhao

Indiana University, Bloomington IN, USA - J. Albert, S. Daugherty, T. Johnson, L.J. Kaufman

University of California, Irvine, Irvine CA, USA - M. Moe

ITEP Moscow, Russia - D. Akimov, I. Alexandrov, V. Belov, A. Burenkov, M. Danilov, A. Dolgolenko, A. Karelin, A. Kovalenko, A. Kuchenkov, V. Stekhanov, O. Zeldovich

Laurentian University, Sudbury ON, Canada - B. Cleveland, J. Farine, B. Mong, U. Wichoski

University of Maryland, College Park MD, USA - C. Davis, A. Dobi, C. Hall, S. Slutsky, Y-R. Yen

University of Massachusetts, Amherst MA, USA - T. Daniels, S. Johnston, K. Kumar, M. Lodato, C. Mackeen, K. Malone, A. Pocar, J.D. Wright

University of Seoul, South Korea - D. Leonard

SLAC National Accelerator Laboratory, Menlo Park CA, USA - M. Breidenbach, R. Conley, A. Dragone, K. Fouts, R. Herbst, S. Herrin, A. Johnson, R. MacLellan, K. Nishimura, A. Odian, C.Y. Prescott, P.C. Rowson, J.J. Russell, K. Skarpaas, M. Swift, A. Waite, M. Wittgen

Stanford University, Stanford CA, USA - J. Bonatt, T. Brunner, J. Chaves, J. Davis, R. DeVoe, D. Fudenberg, G. Gratta, S. Kravitz, D. Moore, I. Ostrovskiy, A. Rivas, A. Schubert, D. Tosi, K. Twelker, L. Wen

Technical University of Munich, Garching, Germany - W. Feldmeier, P. Fierlinger, M. Marino

TRIUMF, Vancouver BC, Canada – P.A. Amandruz, D. Bishop, J. Dilling, P. Gumplinger, R. Kruecken, C. Lim, F. Retiere, V. Strickland