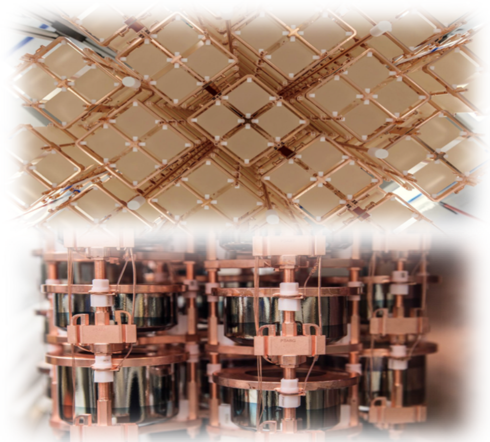
NSD: State of the Division

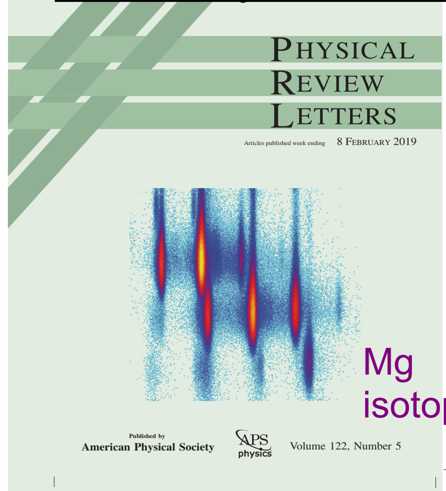
- Overview
- Our science
- Our people
- An important safety reminder
- State of our funding

Major Programs in the NSD

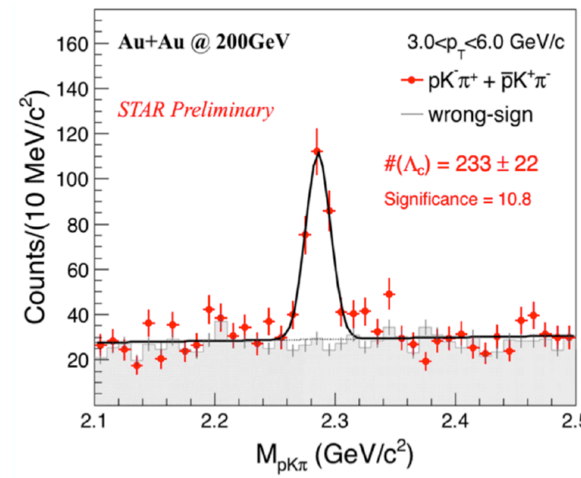
Fundamental Symmetries and Neutrinos



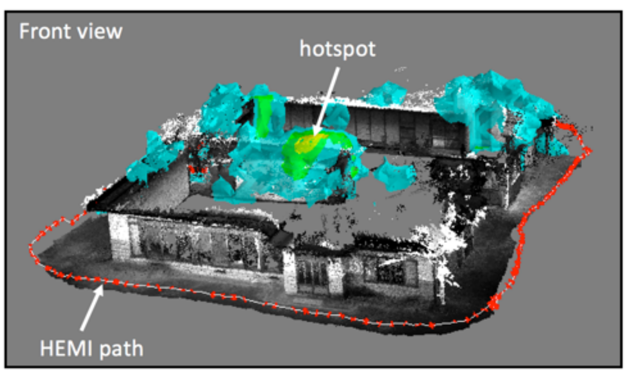
Nuclear Structure and Heavy Elements



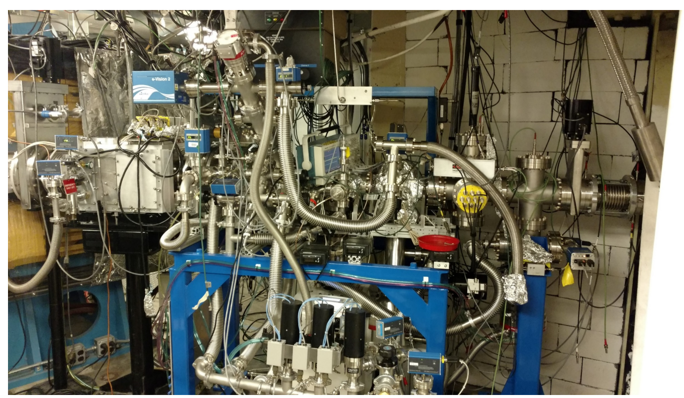
Relativistic Nuclear Collisions



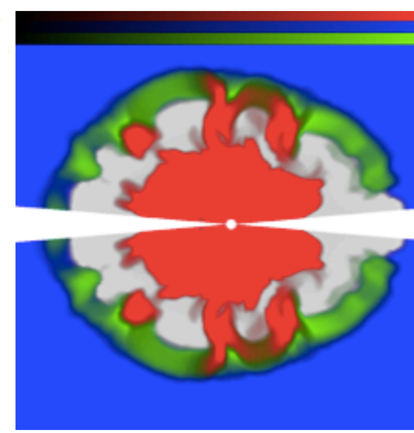
Applied Nuclear Physics



88-Inch Cyclotron



Nuclear Theory



NSD Organization

Operations Management
Division Deputy: **Alan W. P. Poon**
Program Manager: **Tom Gallant**

Financial Management
Pr. Financial Analyst: **Ting Liu**
Pr. Financial Analyst: **Brad Jacobs**

Safety Management
Safety Coordinator/
Chair, ES&H Committee: **Dave Rodgers**

Human Resources
Sr. HR Partner: **Carolyn Charles**
HR Partner: **Sylvia Garcia**
HR Assistant: **Kelly Rushing**

NUCLEAR SCIENCE DIVISION
Division Director: **Barbara V. Jacak**
Division Deputy: **Alan W. P. Poon**

Executive Support: **Sandra Ritterbusch**
Finance Support: **Ting Liu**

Nuclear Science Division Projects:

CUORE
Y. KOLOMENSKY
Spokesperson
S. ZIMMERMANN
Project Lead

Admin Support: **Jane McCall**
Finance Support: **Ting Liu**

GRETA
P. FALLON
S. ZIMMERMANN
Project Leads

Admin Support: **Dorothy Kenlow**
Finance Support: **Ting Liu**

Neutrinos
W. HAXTON
Program Head

- KamLAND, CUORE — **B. K. FUJIKAWA**, *Group Leader*
- Majorana Demonstrator, KATRIN, Low Background Counting — **A. W. P. POON**, *Group Leader*
- SNO+ — **G. OREBI GANN**, *Group Leader*

Admin Support: **Jane McCall**
Finance Support: **Brad Jacobs**

Accerlerator Based Low Energy Research
P. FALLON
Program Head

- Nuclear Data — **L. BERNSTEIN**, *Group Leader*
- Nuclear Structure — **A. MACCHIAVELLI**, **R. M. CLARK**, *Group Leaders*
- Heavy Elements — **J. GATES**, *Group Leader*

Admin Support: **Dorothy Kenlow**
Finance Support: **Ting Liu**

Relativistic Nuclear Collisions
G. ODYNIEC
Program Head

- STAR Analysis — **X. DONG**, *Group Leader*
- Instrumentation — **L. GREINER**, *Group Leader*
- ALICE — **M. PLOSKON**, *Group Leader*
- Computing — **J. PORTER**, *Group Leader*

Admin Support: **Lady Bonifacio**
Finance Support: **Ting Liu**

88-Inch Cyclotron
L. W. PHAIR
Program Head

- Mechanical Engineering — **A. HODGKINSON**, *Group Leader*
- Electrical Engineering — **M. KIREEFF-COVO**, *Group Leader*
- Research Coordination — **M. JOHNSON**, *Group Leader*
- Accelerator ECR Physics — **D. XIE**, *Group Leader*
- Operations — **B. NINEMIRE**, *Group Leader*

Admin Support: **Kymba A'Hearn**
Finance Support: **Ting Liu**

Nuclear Theory
F. YUAN
Program Head

ASupportdmin : **Jane McCall**
Finance Support: **Ting Liu**

Applied Nuclear Physics
K. VETTER
Program Head

- Semiconductor Detector Laboratory — **P. BARTON**, *Group Leader*
- Instrumentation and Data Integration — **R. COOPER**, *Group Leader*
- Imaging Systems and Algorithms — **L. MIHAILESCU**, *Group Leader*
- Gamma-ray Imaging — **B. QUITER**, *Group Leader*

Program Ops: **Erika Suzuki**
Admin Support: **Dorothy Kenlow**
Finance Support: **Brad Jacobs**

Applied Nuclear Physics

Approximately $8.8M. Funding from NNSA, DNDO, DTRA, DARPA, JAEA

16 grad students, 3 undergrad, 1.5 postdocs, 15 scientists

Led by Kai Vetter (joint LBNL & UCB Nuclear Engineering)

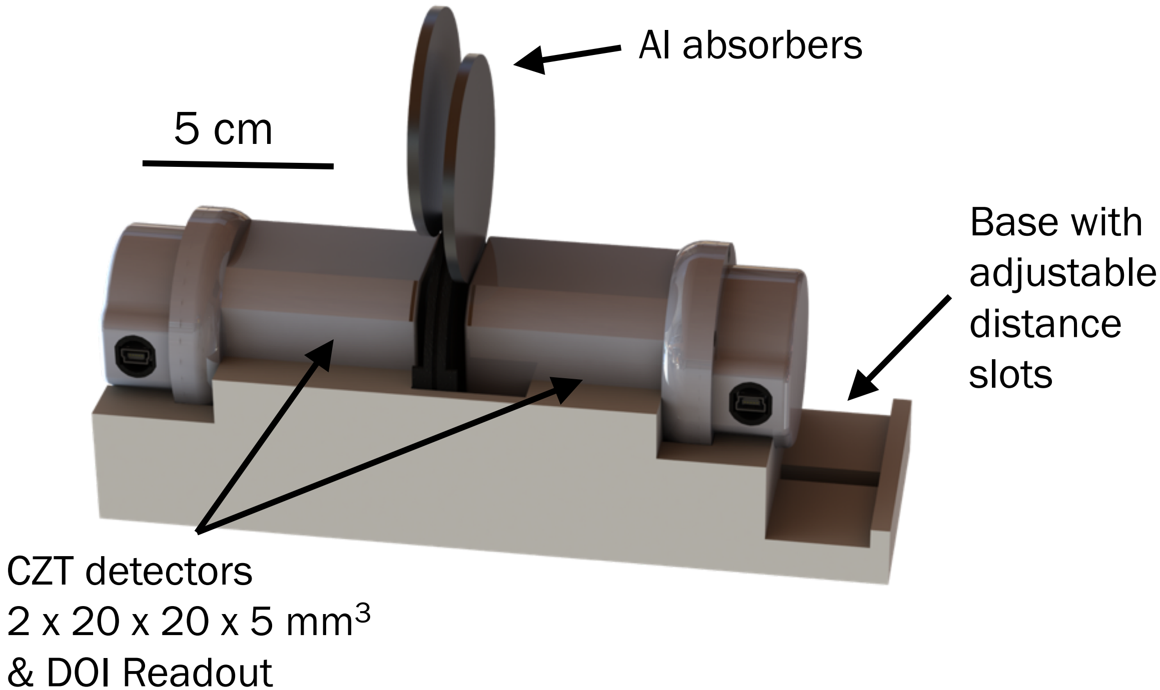
QUOTE at Director's Review: We could have written the entire LRP Applications chapter based on this group's work!

In-Situ Sr-90 detection and quantification

Utilizing Compact Coplanar Grid CdZnTe Detector

NNSA/NA84

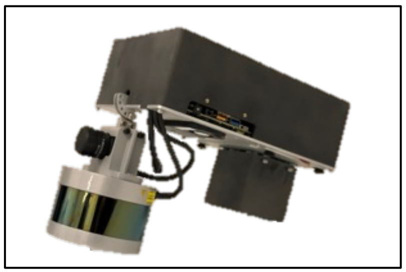
- CdZnTe detectors in co-planar grid implementation provides ability to detect Sr-90 to < 1uCi/m^2 (10% of DRL) in <60 minutes in a mobile lab.

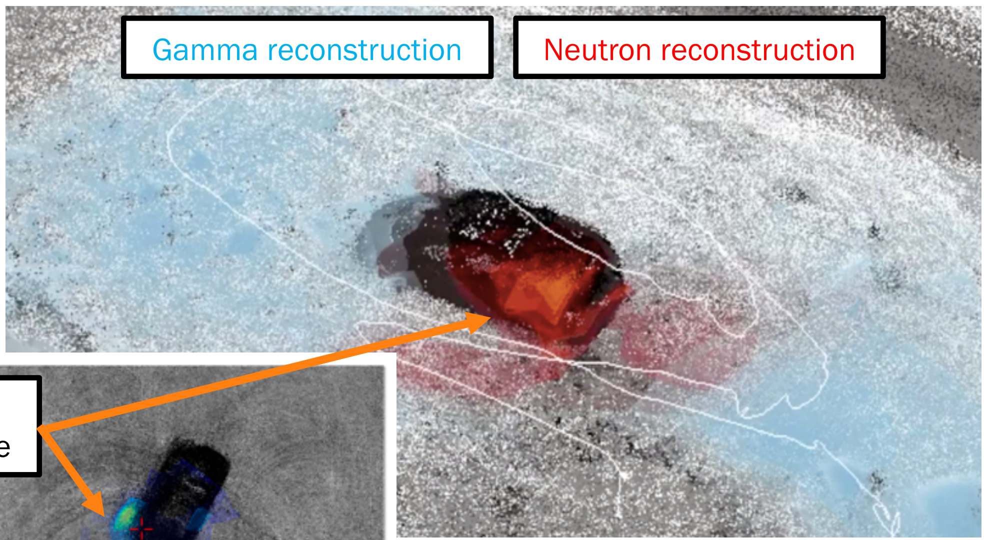


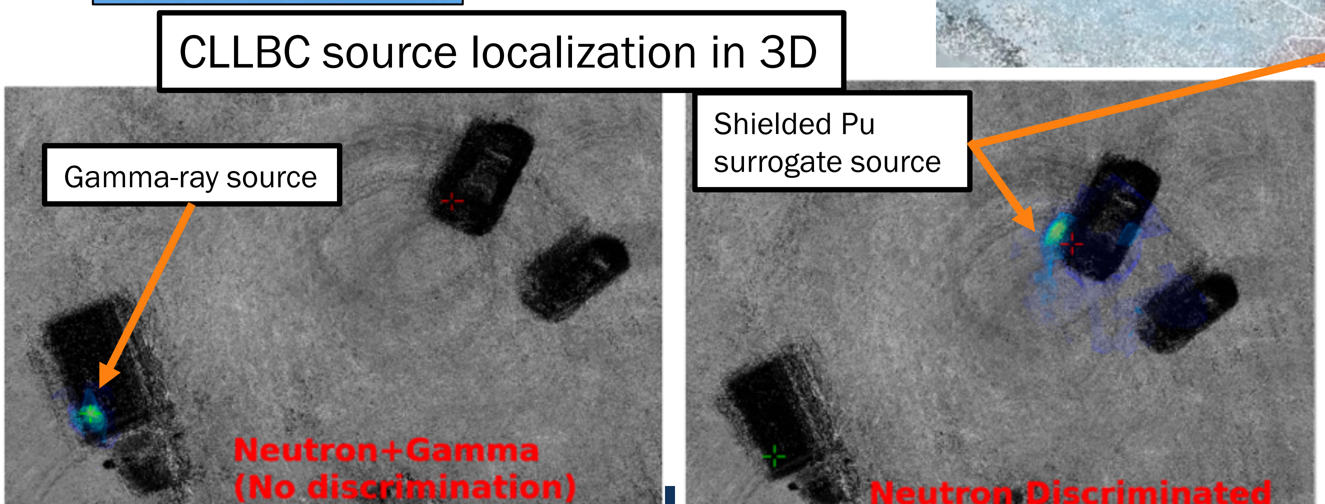
- Combination of gamma- and beta- measurements enable effective means to differentiate and estimate gamma- and beta-emitting isotopes such as Cs-134/137 and beta-only emitting isotopes such as Sr-90/90.
- Assessment of Sr-90 can be done in the field not requiring lengthy process;

Localizing and visualizing neutron sources in 3D

- CLLBC ($Cs_2LiLa(Br,Cl)_6$:Ce scintillator) enables the accurate detection and identification of gamma-ray sources and the efficient detection of neutron sources, relevant in the detection and mapping of SNM, such as Pu-239;
- The combination with SDF enables the ***3D localization of neutron sources*** in a hand-portable format or on sUAS;

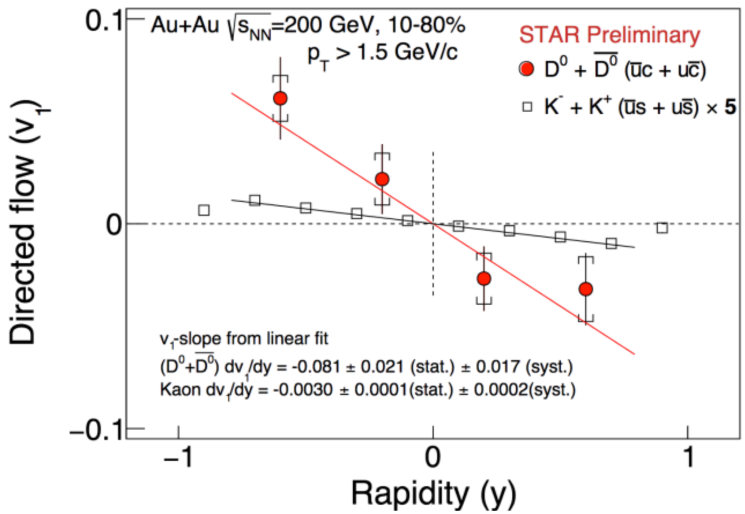


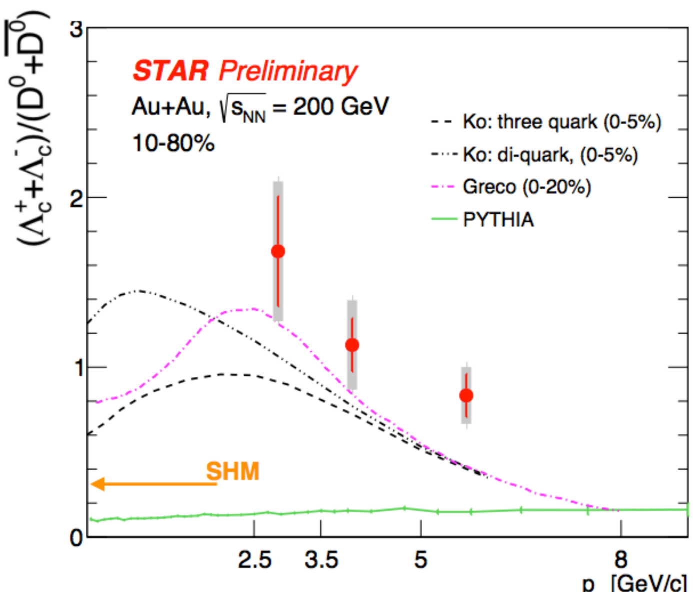




- Detection and 3D localization of shielded SNM in real time!

STAR probes quark gluon plasma with charm quarks





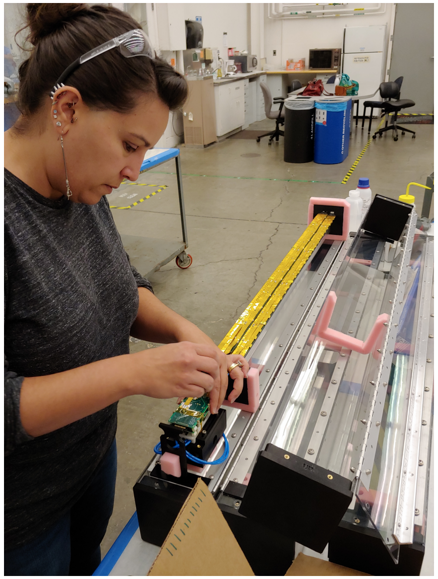
New Heavy Flavor results from STAR HFT:

1. Significant D^0/D^0bar v_1 at RHIC
   - *probing QGP longitudinal properties*
   - *probing initial magnetic field*

2. Significant enhancement in Λ_c^+/D^0 in HI coll.
   - *coalescence hadronization for charm quarks*
   - *significance of Λc contribution to total charm cross section*

ALICE is upgrading the inner tracker

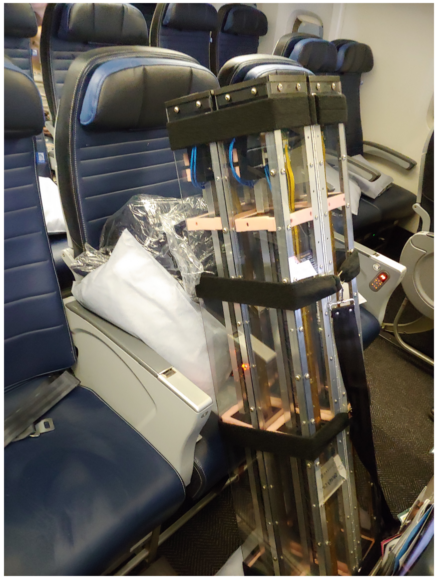
Intermediate layers are assembled at LBNL:
- Stave production in progress
- Staves arriving at CERN every two weeks with minimal casualties
- We are on schedule!



finishing touches

ready to go

leaving LBNL

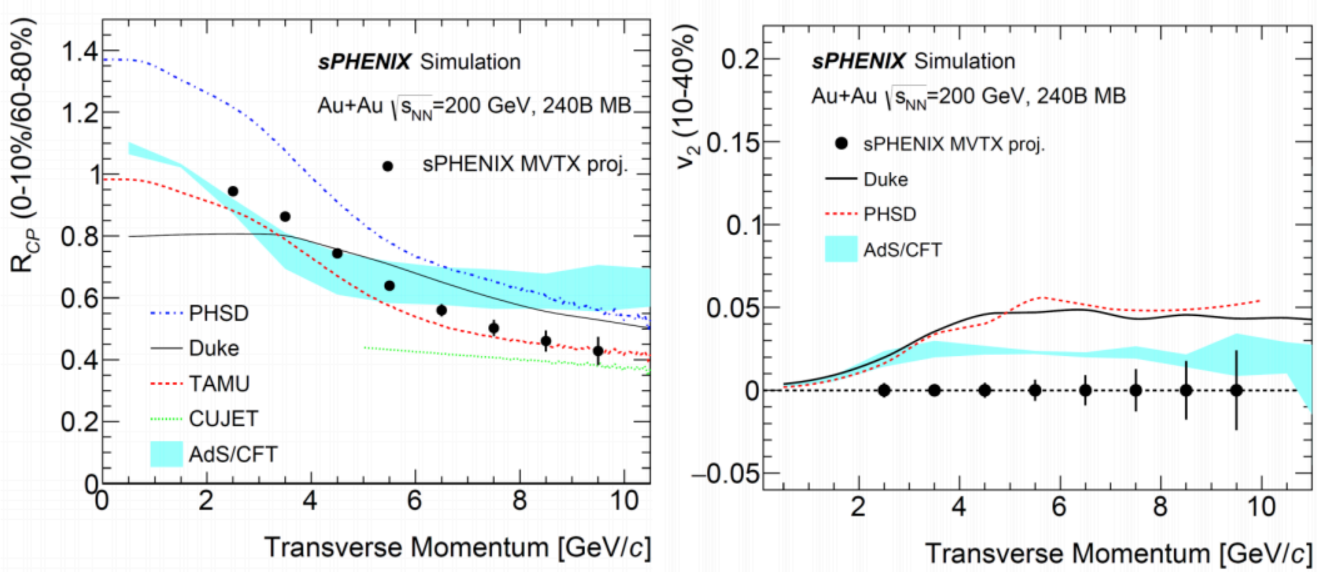


on board UNITED

MVTX inner tracker in sPHENIX

Physics goals: precision measurement of open bottom mesons

- *heavy quark diffusion coefficient*
- *mass hierarchy of parton energy loss*

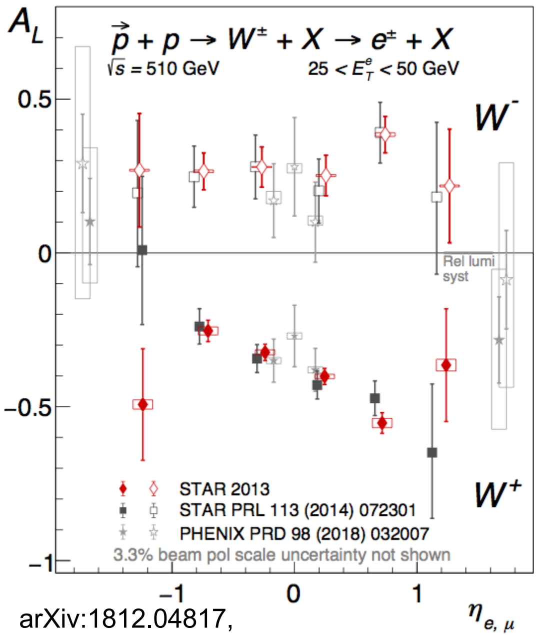


We have seen that the heavy charm quark loses energy & flows
What about the even heavier bottom quark???
What changes with the temperature of the plasma?

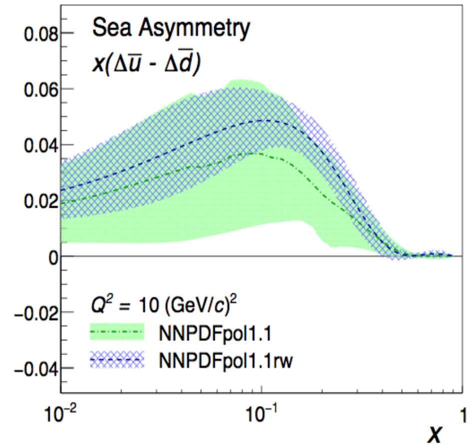
X.Dong co-convener of Heavy Flavor PWG in sPHENIX
G.Odyniec – deputy project manager for the MVTX

Medium Energy Physics

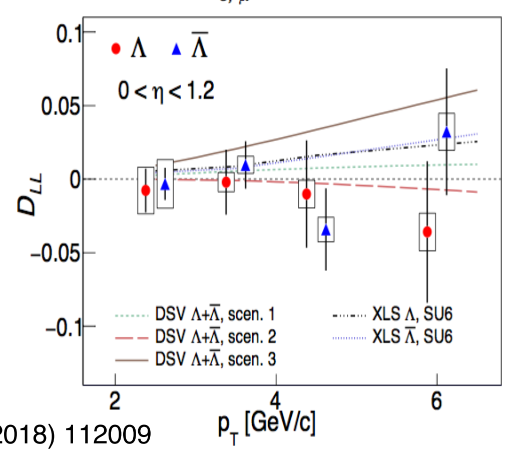
Ernst Sichtermann + Maria Zurek (+Kolomensky, Mei)



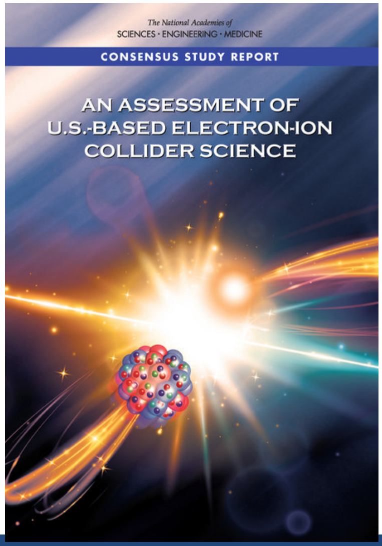
arXiv:1812.04817,
Accepted in PRD(R)



arXiv:1808.07634,
Accepted in PRD



Phys. Rev. D 98 (2018) 112009



* W for polarized sea asymmetry program completed (milestone HP8)

* $\Delta\bar{u} > \Delta\bar{d}$ opposite from unpolarized sea

* hyperon D_{LL} published

EIC:

- Scientific goals and measurement design underway

JLAB:

- *Moller experiment joined, together with Kolomensky (UCB) and Mei*
- *Postdoc search now*

California Consortium

Build part of EIC detector in California!

Berkeley

UCLA

UC RIVERSIDE

BERKELEY LAB

UCDAVIS
UNIVERSITY OF CALIFORNIA

Lawrence Livermore National Laboratory

Los Alamos NATIONAL LABORATORY

Expertise in tracking & calorimetry

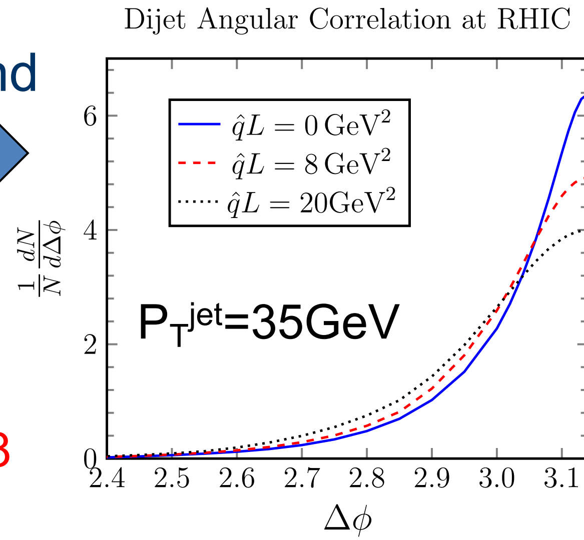
Just received UC MRPI funding to get started!

Funding is “not much, but hard to get”

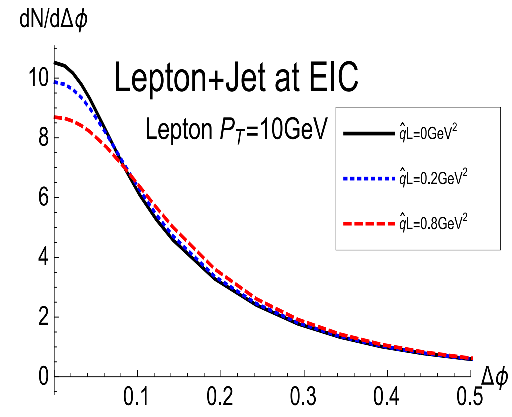
– 2 grad students for 2 years to work on EIC simulations + 2 workshops/yr

Also plan joint postdoc hire with Stony Brook CFNS

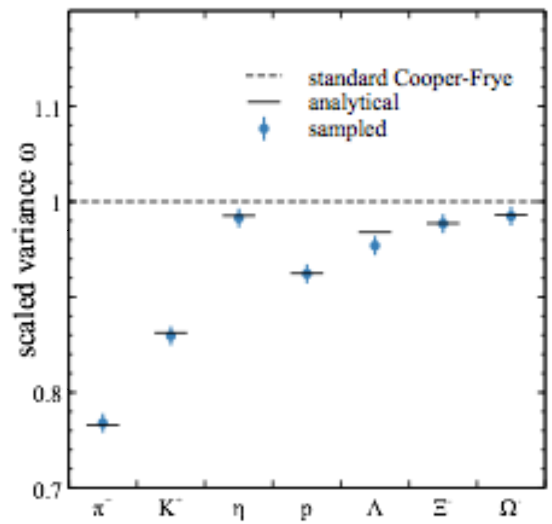
- Jet correlations to probe hot and cold QCD Matter



Yuan et al, 1812.08077



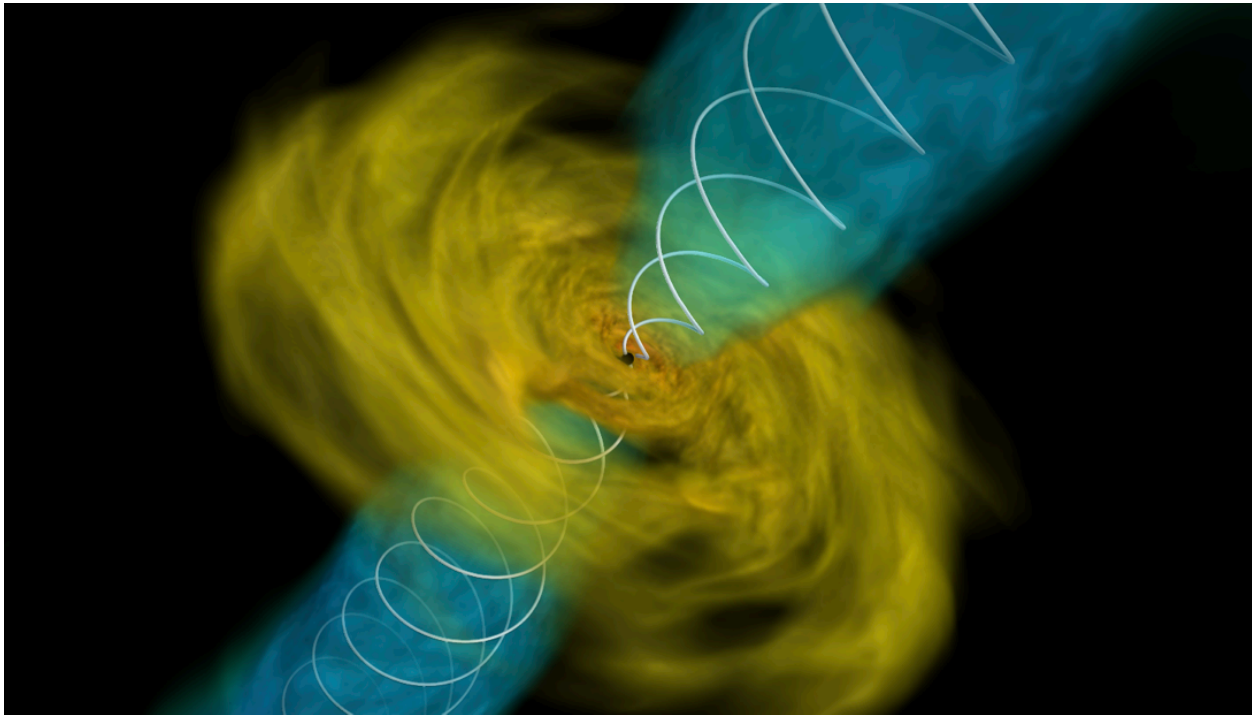
- Machine Learning of EoS in Heavy-ion Collisions
  - Wang et al, Nature Comm. 2018
- Fluctuations in beam energy scan experiment at RHIC
- Better understanding of neutron stars mergers through a 3D simulation
  - Kasen et al, MNRAS, 2019



Scaled variance of hadron yields

Koch et al, 2019

The merger aftermath



In this simulation, the collision of two neutron stars has left behind a newly formed black hole and a whirlpool of magnetized gas orbiting around it. While some gas is eaten by the black hole, some matter emerges in energetic jets and winds, within which heavy elements will be synthesized and flashes of detectible light emitted

Another theoretical topic

Snowballs in Hell: Explaining Light Ion Production in High-Energy Collisions

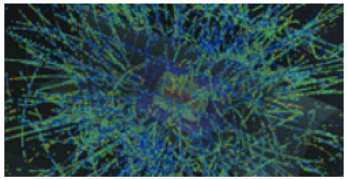
Featured in Physics | Editors' Suggestion

Microscopic study of deuteron production in PbPb collisions at $\sqrt{s} = 2.76\ \mathrm{TeV}$ via hydrodynamics and a hadronic afterburner

Dmytro Oliinychenko, Long-Gang Pang, Hannah Elfner, and Volker Koch

Phys. Rev. C **99**, 044907 (2019) – Published 11 April 2019

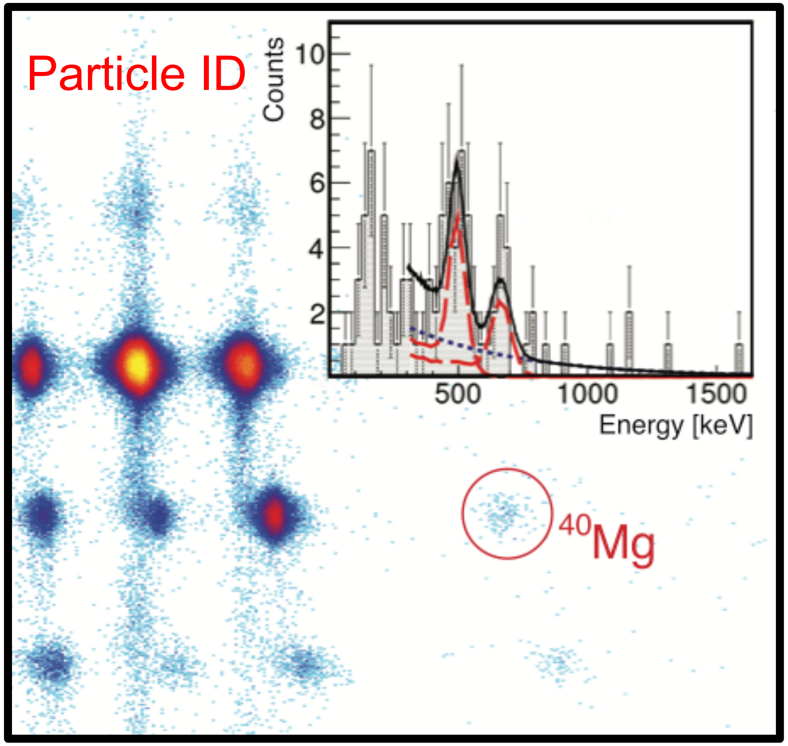
Physics Synopsis: Explaining Light Ion Production in High-Energy Collisions



Pions could catalyze reactions between protons and neutrons, allowing the stable production of Deuterons in high-energy ion-ion collisions.

Show Abstract +

First Spectroscopy of the Near-Drip-Line Nucleus ^{40}Mg



- First gamma-ray spectroscopy of near-drip-line (weakly bound) nucleus ^{40}Mg was performed at RIBF, RIKEN
- Gamma-ray spectrum is very different to neighboring ^{36,38}Mg
  - ➢ First dramatic change in nuclear structure near dripline
  - ➢ not reproduced by theory
  - ➢ evidence for a modification of structure due to weak binding

Editors' Suggestion

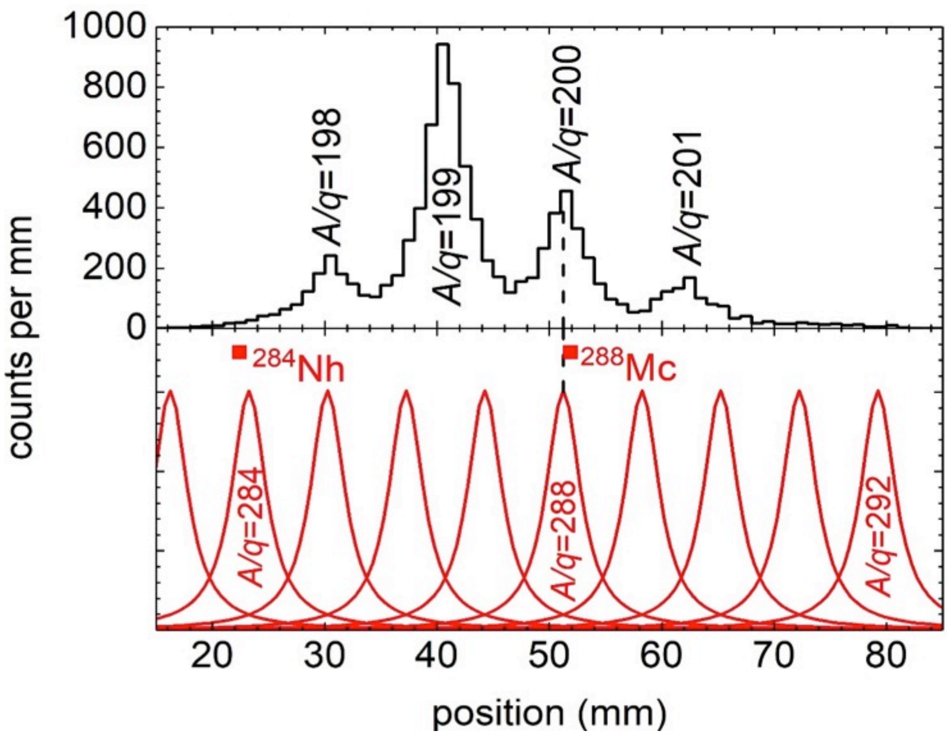
PRL Editors Suggestion

First Spectroscopy of the Near-Drip-Line Nucleus ^{40}Mg

H. L. Crawford,[1,*] P. Fallon,[1] A. O. Macchiavelli,[1] P. Doornenbal,[2] N. Aoi,[3] F. Browne,[2] C. M. Campbell,[1] S. Chen,[2] R. M. Clark,[1] M. L. Cortés,[2] M. Cromaz,[1] E. Ideguchi,[3] M. D. Jones,[1,†] R. Kanungo,[4,5] M. MacCormick,[6] S. Momiyama,[7] I. Murray,[6] M. Niikura,[7] S. Paschalis,[8] M. Petri,[8] H. Sakurai,[2,7] M. Salathe,[1] P. Schrock,[9] D. Steppenbeck,[9] S. Takeuchi,[2,10] Y. K. Tanaka,[11] R. Taniuchi,[7] H. Wang,[2] and K. Wimmer[7]

First Mass Number Identification of Mc (Z=115) with FIONA

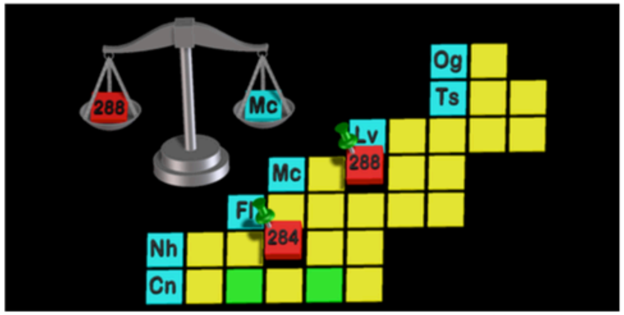
Observed two alpha decay chains, one from $^{288}115$ and one from $^{284}113$



Synopsis: Pinning Down Superheavy Masses

November 28, 2018

A new measurement technique directly determines the masses of two superheavy isotopes, providing confirmation that previous indirect measurements were correct.



J. Gates and J. Pore/Lawrence Berkeley National Laboratory

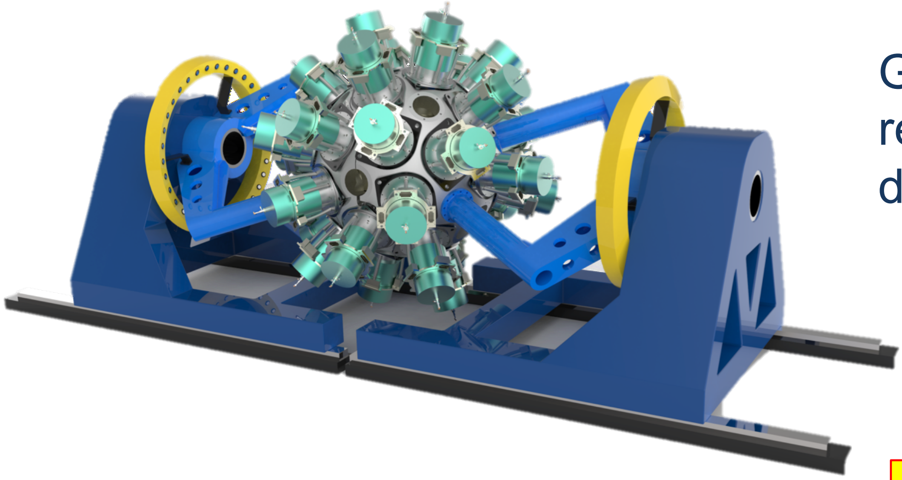
PRL Editors Suggestion

Also highlighted in: nature International journal of science

c&en PHYSICS TODAY

CHEMISTRY WORLD

The Gamma-Ray Energy Tracking Array: GRETA



GRETA is a 4π tracking detector capable of reconstructing the energy and three-dimensional position of γ-ray interactions

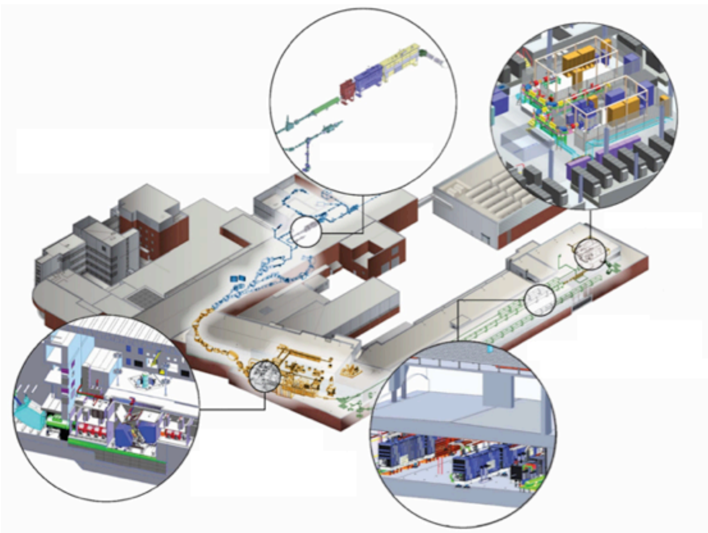
Key Properties
- *full solid angle coverage and high efficiency*
- *excellent energy and position resolution*
- *good background rejection (peak-to-total)*

Design & module procurement underway!

GRETA Project

- 18 Quad Modules (*+12 from GRETINA*)
- Electronics, Computing, Mechanical Systems for 30 Quad Modules
- Tailored for CD-4A – phased approach for early physics @ FRIB

A **key detector** for FRIB



Search for Element 120 at 88" Cyclotron?

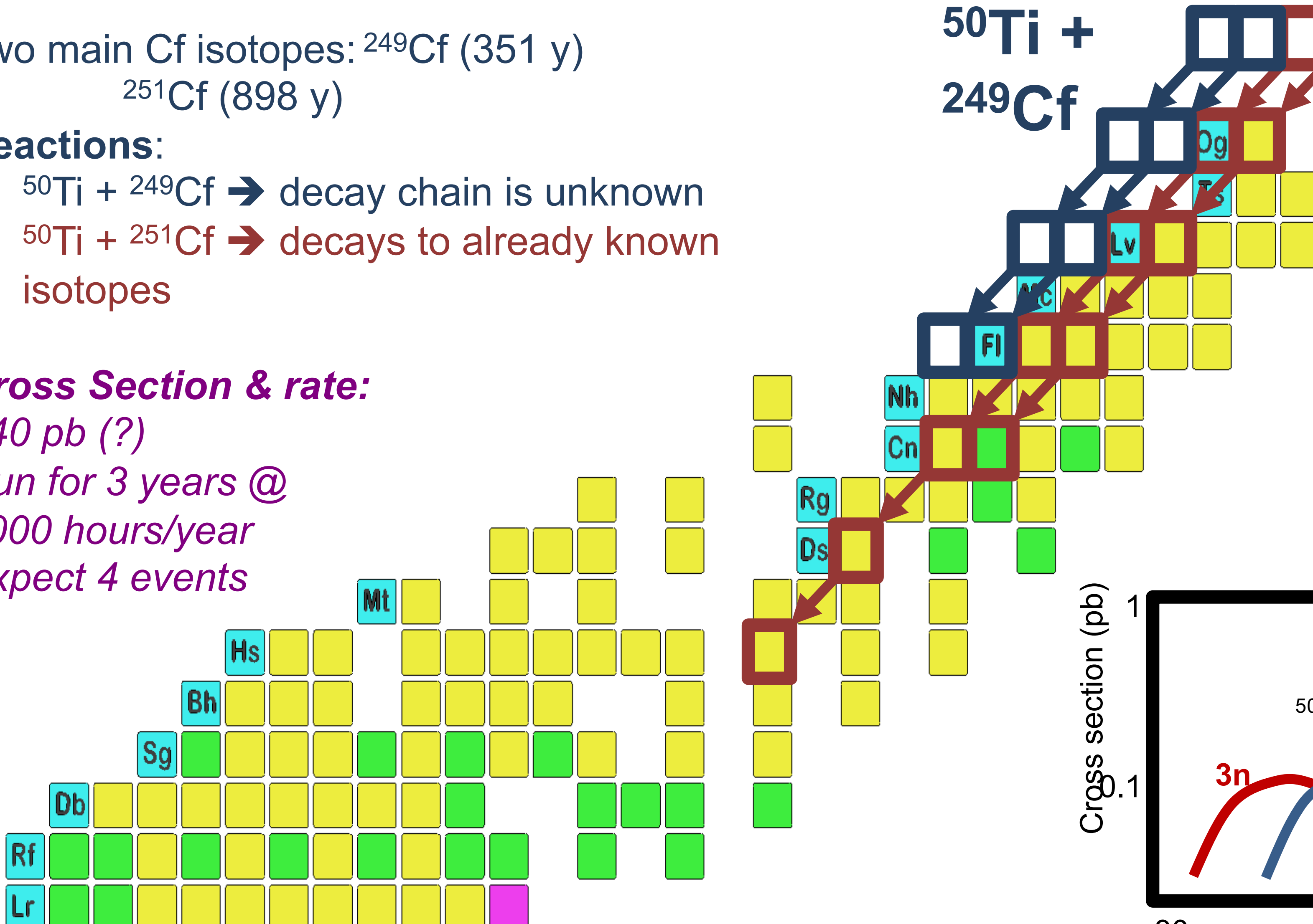
Two main Cf isotopes: ^{249}Cf (351 y)
^{251}Cf (898 y)

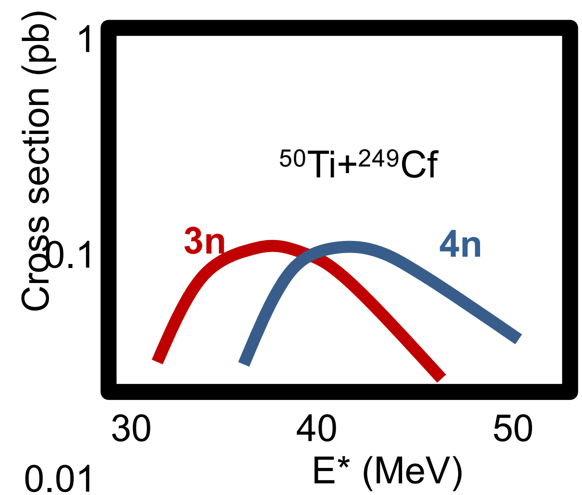
Reactions:

- ^{50}Ti + ^{249}Cf ➔ decay chain is unknown
- ^{50}Ti + ^{251}Cf ➔ decays to already known isotopes

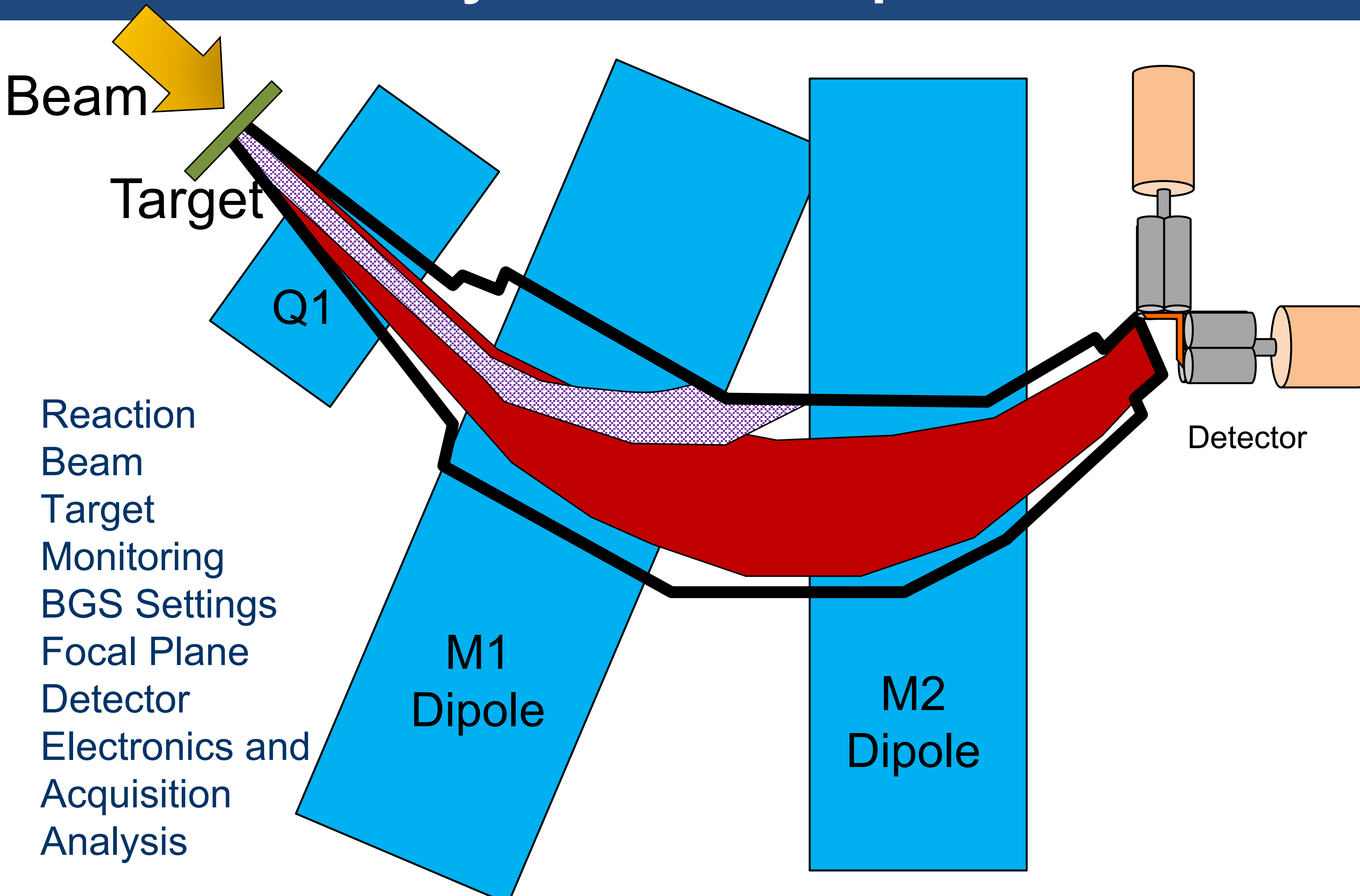
Cross Section & rate:

~40 pb (?)
Run for 3 years @
2000 hours/year
Expect 4 events





Berkeley Gas-filled Separator

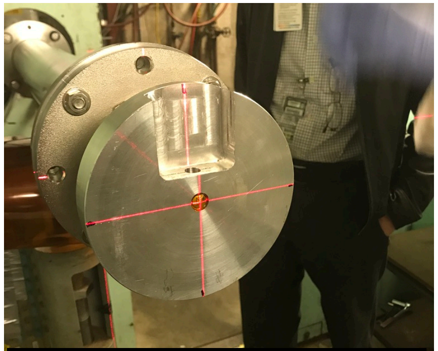


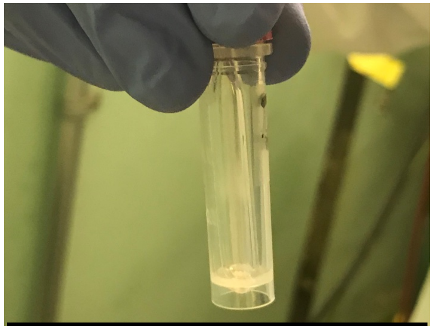
1. Reaction
2. Beam
3. Target
4. Monitoring
5. BGS Settings
6. Focal Plane Detector
7. Electronics and Acquisition
8. Analysis

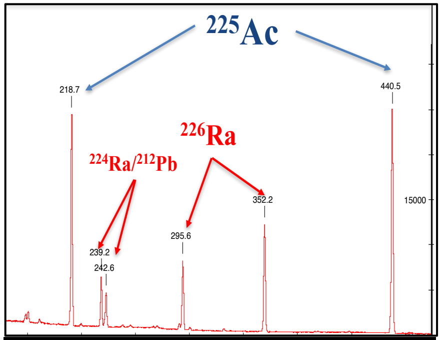
A new production route for ^{225}Ac using secondary neutrons

- We are developing a new production mode for ^{225}Ac via the $^{226}Ra(n,2n)^{225}Ra \xrightarrow{\beta-decay} {}^{225}Ac$ using deuteron break-up neutrons that is free of contamination from long-lived ^{227}Ac and La fission fragments
- ^{225}Ac is a promising therapeutic radionuclide, but its production is difficult and radiochemical contaminants could limit its use.
- Our approach could provide a clean production route for many more diagnostic and therapeutic radionuclides.


UC student-led effort


HEIFER target holder

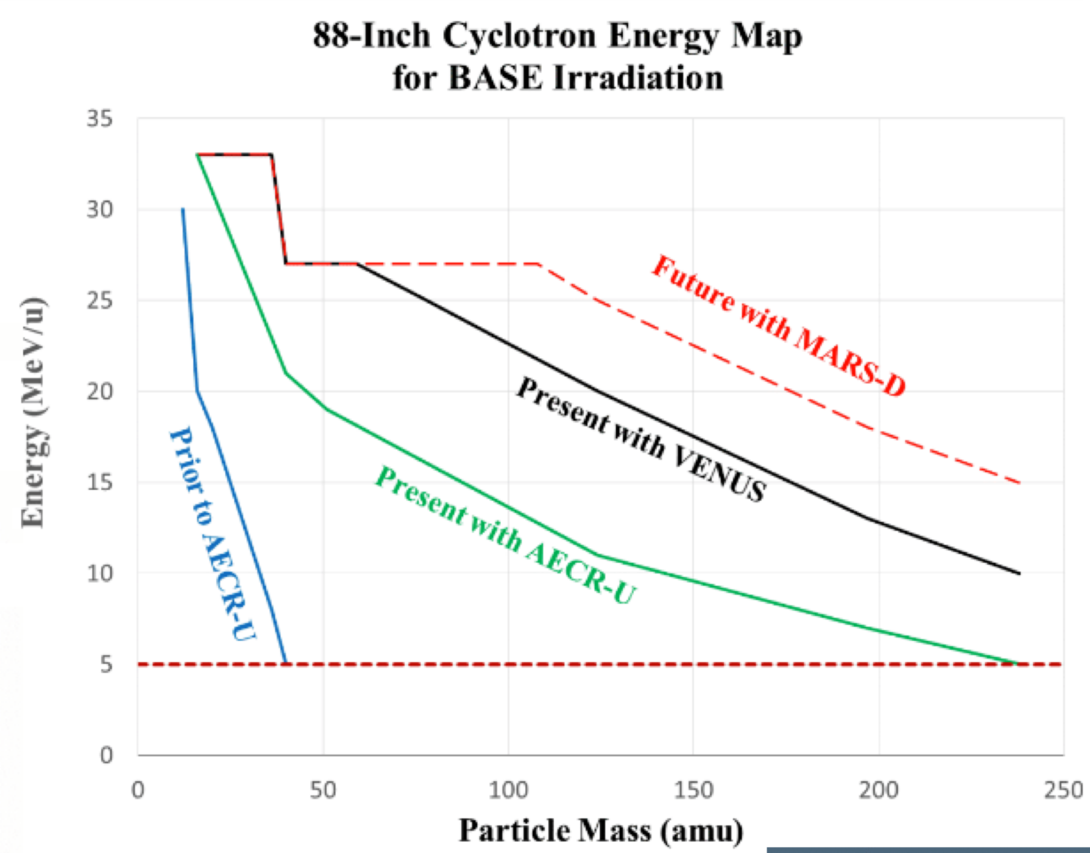

^{226}Ra sample (ORNL)



γ-spectroscopic assay

Patent Application Underway

New Ion Source proposed

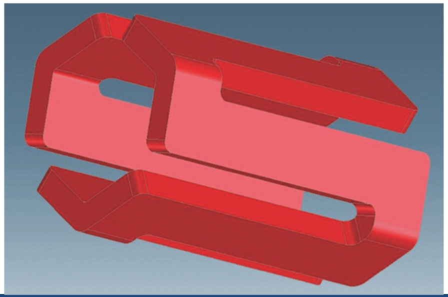


↑ ↑

$E/A = k\,(q/A)^2$

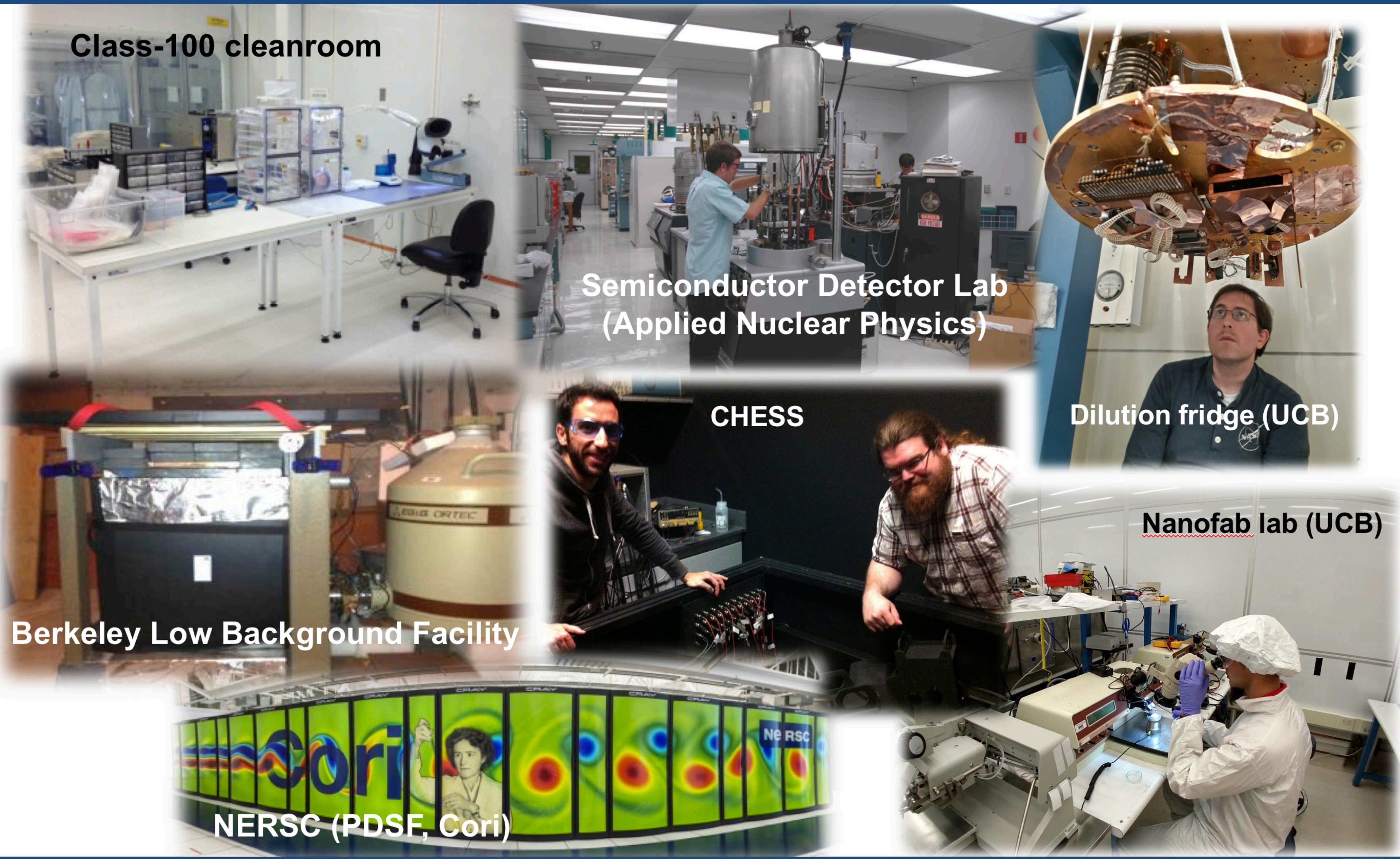
- Higher charge-state ions going into the cyclotron means higher energy beams at the output
- MARS allows for higher beam intensities than previous ion sources by a factor of 5 (for ions with the same charge state)
- An additional ion source adds redundancy, which reduces failure time

MARS will have NbTi closed-loop sextupole windings



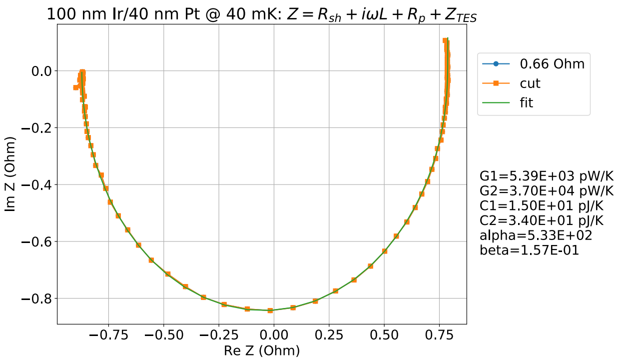
3D view of MARS windings

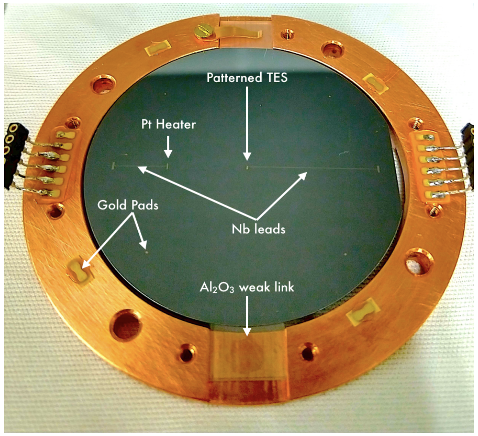
We bring a lot to the search for neutrinoless ββ decay



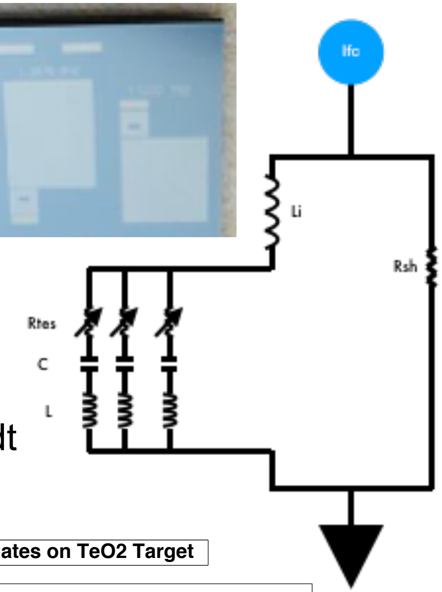
CUPID – LBNL is US lead lab!

TES characterization, LD calibration - B. Welliver, B. Schmidt (NSD), ANL, UCB

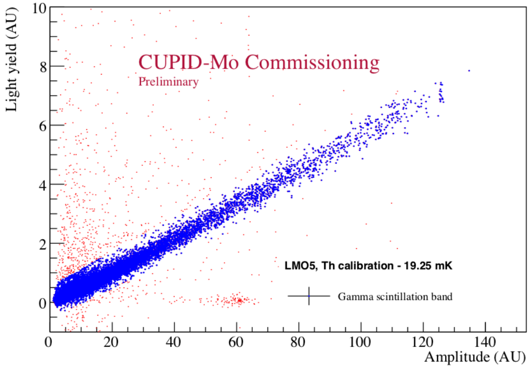




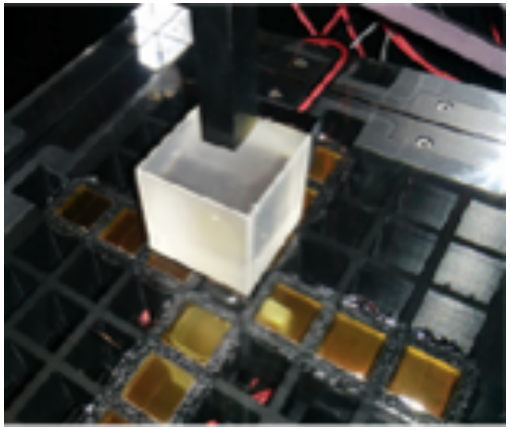
TES multiplexing - B. Welliver (NSD), A. Suzuki (PD), S. Zimmermann (ENG)

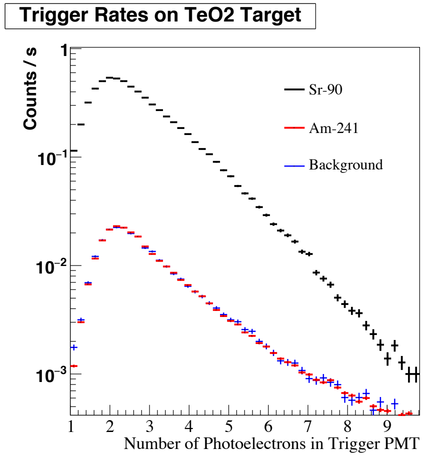


CUPID-Mo data analysis at NERSC
B. Schmidt



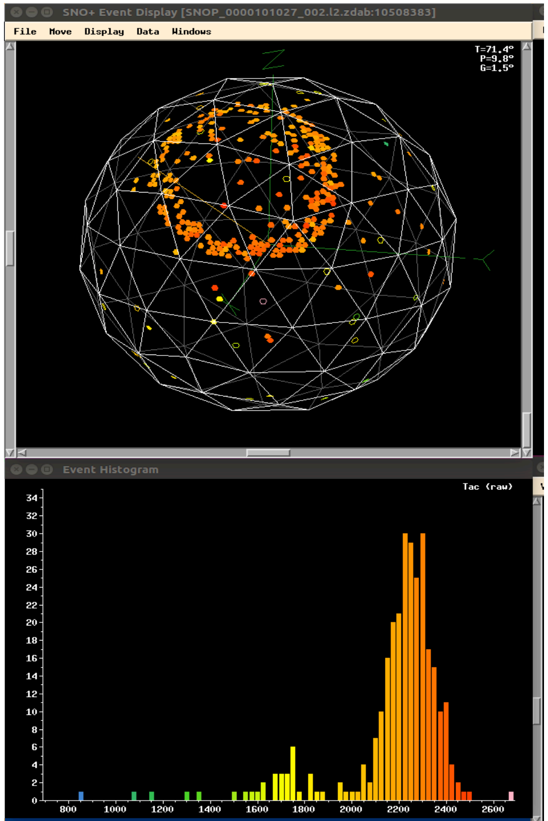
TeO_2 crystal optical properties - B. Schmidt (NSD), R. Huang (UCB), G. Orebi Gann (NDS/UCB) & CHESS team





SNO+

Physics data-taking since May 4th, 2017



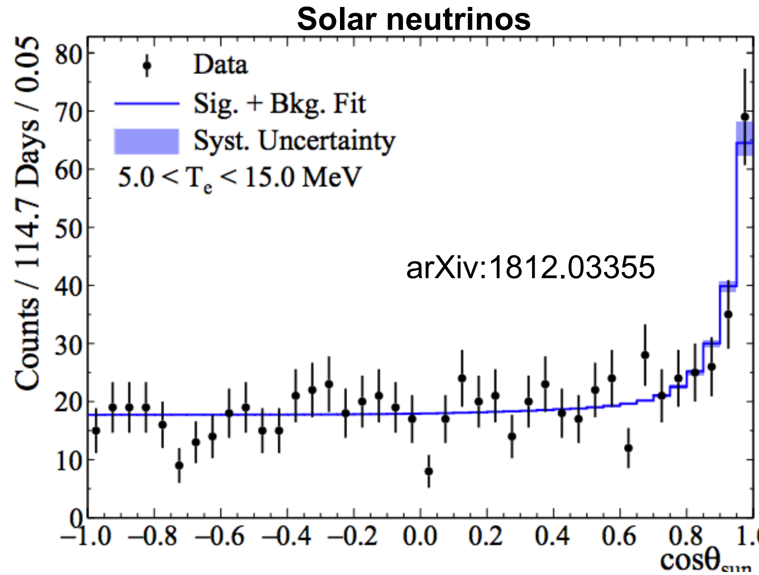
Arrival time

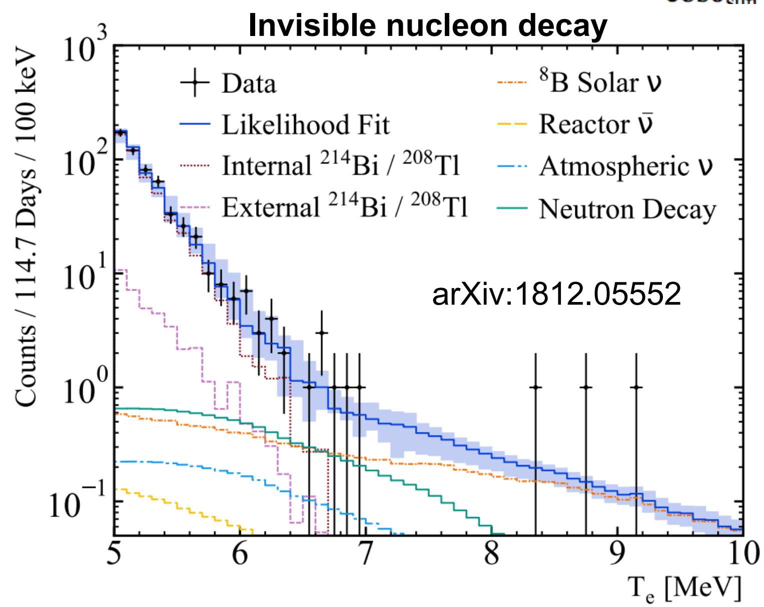
New measurement of flux & spectrum of solar neutrinos

↵ Atmospheric ν candidate

New limit on p lifetime for invisible decay modes:

3.6×10^{29} years





Quantum information science: NP call for proposals

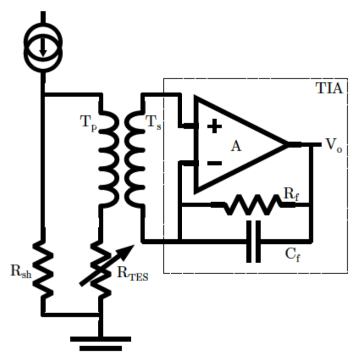
RIKEN-Berkeley QIS conference

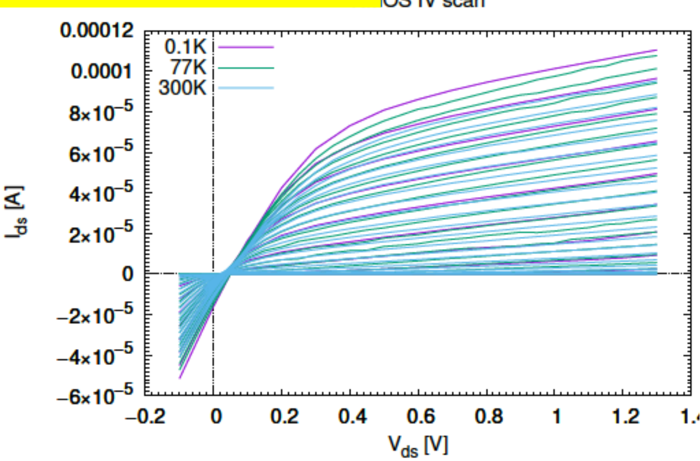
Theory

Quantum annealing for polynomial systems of equations

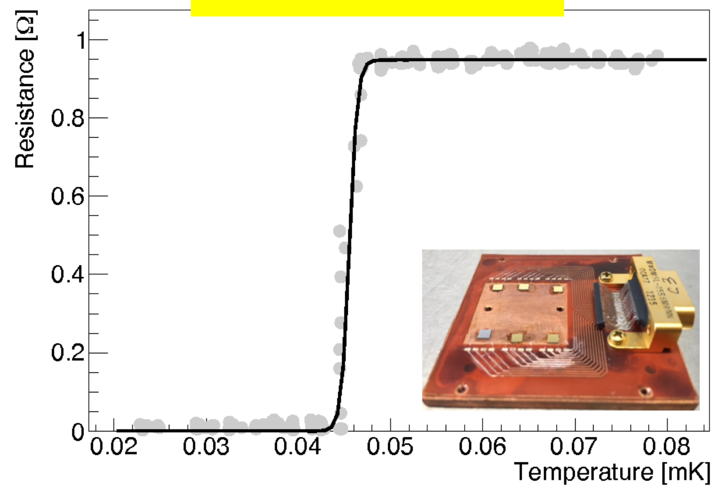
Chia Cheng Chang (張家丞),[1,2,3,*] Arjun Gambhir,[4] Travis S. Humble,[5] and Shigetoshi Sota[6]
[1] *Interdisciplinary Theoretical and Mathematical Sciences Program (iTHEMS), RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan*
[2] *Department of Physics, University of California, Berkeley, California 94720, USA*
[3] *Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA*
[4] *Physics Division, Lawrence Livermore National Laboratory, Livermore, CA 94550, USA*
[5] *Quantum Computing Institute, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA*
[6] *Computational Materials Science Research Team, RIKEN Advanced Institute for Computational Science (AICS), Kobe, Hyogo 650-0047, Japan*

Low power TIA (to replace SQUID?)





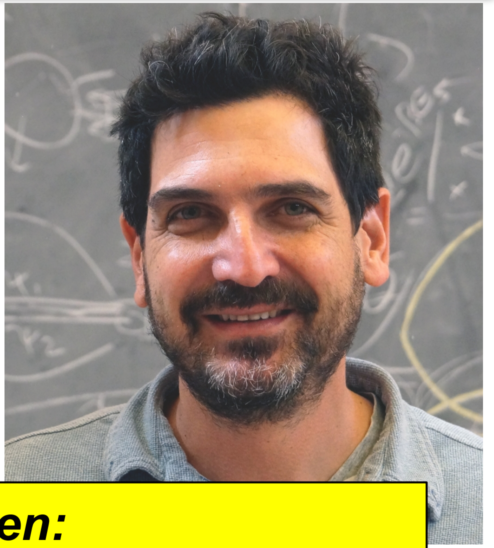
CUPID TES R&D



Award Winners

Kathryn Meehan:
Gertrude Goldhaber Prize

Grazyna Odyniec:
APS Fellow
and
Women @The Lab 2018



Dan Kasen:
Bruno Rossi Prize of the High Energy Astrophysics Division, AAS, 2019

Lynen Fellows from Humboldt Foundation:
Christian Drischler,
Christopher Körber
Michael Willers

Barbara Jacak
Bonner Prize

Welcome

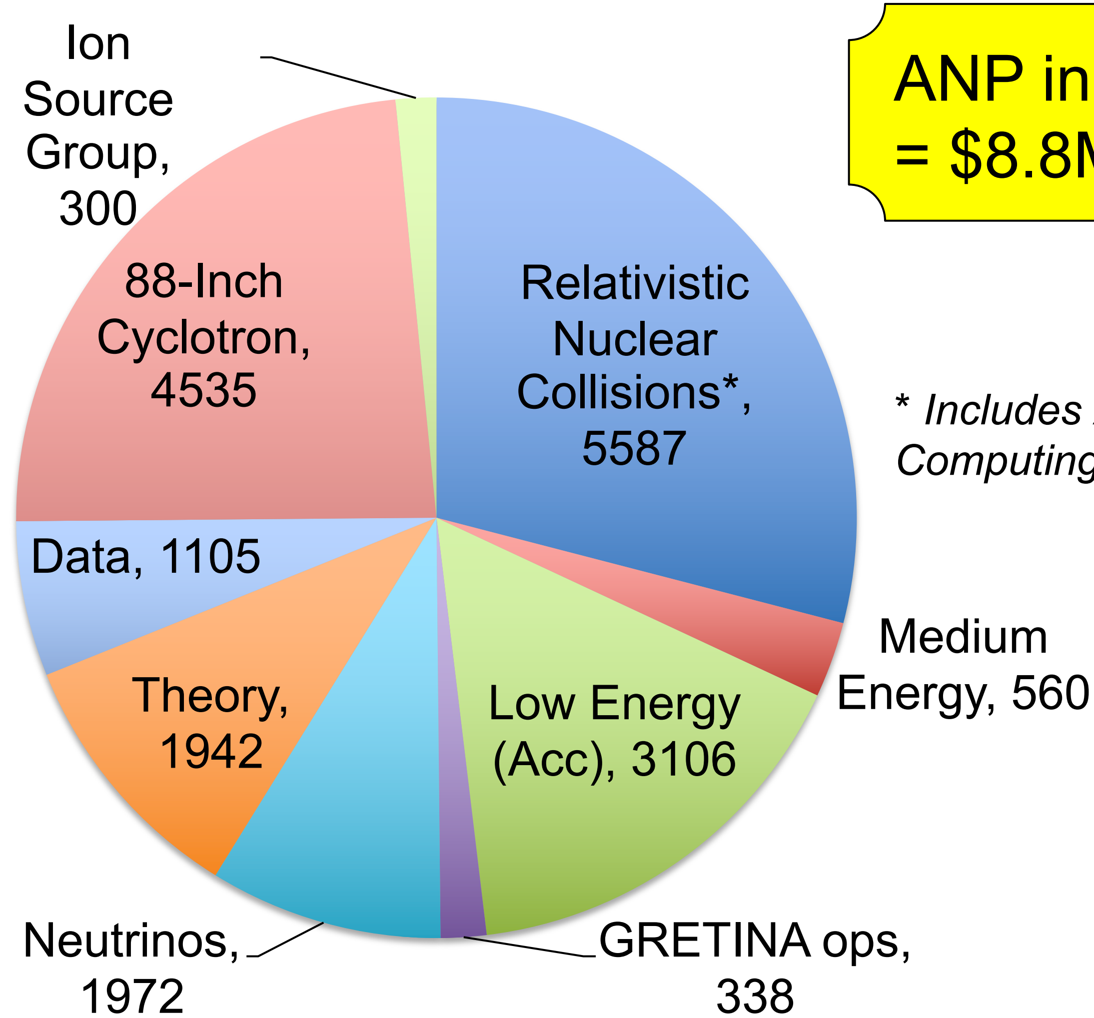
To our new NSD members!

- New postdocs
- New graduate students
- Summer students

A quick safety note

- We have a two-person rule for work in the lab by students
- Postdocs should also follow this rule
- Best for staff, also, not to work alone

Funding by Program FY19 ($K)



ANP in FY18 = $8.8M

** Includes ALICE Computing*

COL increase in FY19

Established a new Ion Source Group!

FY2020 outlook

House proposed budget

- Looks good for NP (increase; follows Long Range Plan)
- FRIB construction tailing off (generates some funds)

Uncertainties remain

- Senate mark is awaited
- Guidance is to expect a continuing resolution

Applications funding looks robust

- ANP group is looking for postdocs!

Science enabled by LBNL LDRD

Recent Scientific outcomes

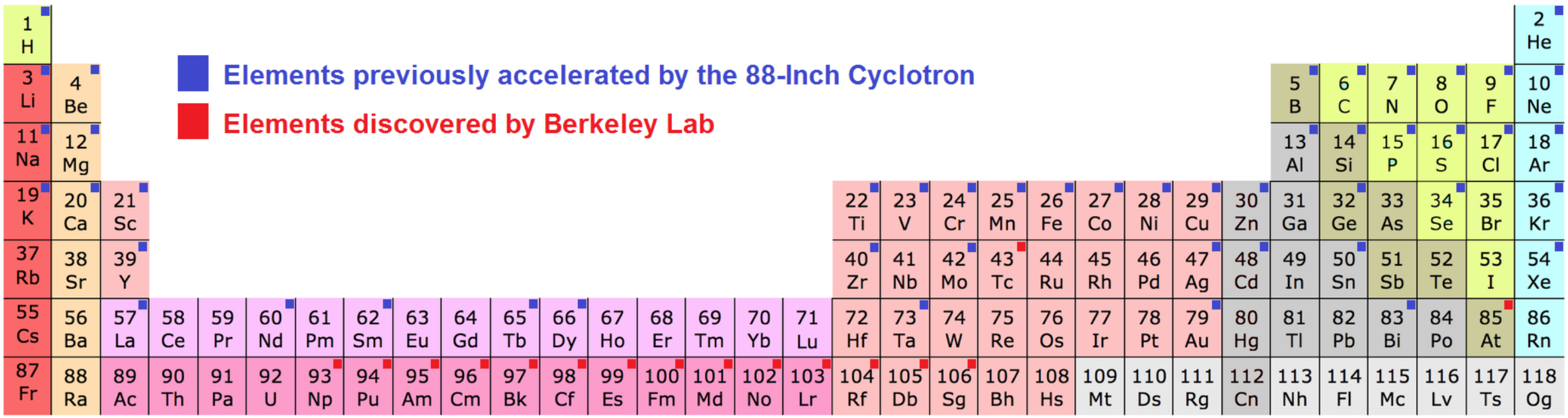
- Mass measurements of Mc, Nh
- Key roles in LEGEND $0\nu\beta\beta$ collaboration
- Heavy element production in neutron star mergers
- New program at Jefferson Lab
- New eSTARlight Monte Carlo event generator
- Jet physics at EIC

Future Scientific outcomes

- Next generation Ge detectors & low noise electronics in basic and applied research
- LQCD short range correlations for $0\nu\beta\beta$ decay studies
- Light collection techniques for LEGEND veto
- Machine learning applied to heavy ion collisions

Thank you

Elements

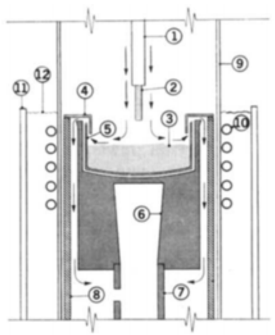


Elements previously accelerated by the 88-Inch Cyclotron
Elements discovered by Berkeley Lab
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
37 Rb
38 Sr
39 Y
40 Zr
41 Nb
42 Mo
43 Tc
44 Ru
45 Rh
46 Pd
47 Ag
48 Cd
49 In
50 Sn
51 Sb
52 Te
53 I
54 Xe
55 Cs
56 Ba
57 La
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
72 Hf
73 Ta
74 W
75 Re
76 Os
77 Ir
78 Pt
79 Au
80 Hg
81 Tl
82 Pb
83 Bi
84 Po
85 At
86 Rn
87 Fr
88 Ra
89 Ac
90 Th
91 Pa
92 U
93 Np
94 Pu
95 Am
96 Cm
97 Bk
98 Cf
99 Es
100 Fm
101 Md
102 No
103 Lr
104 Rf
105 Db
106 Sg
107 Bh
108 Hs
109 Mt
110 Ds
111 Rg
112 Cn
113 Nh
114 Fl
115 Mc
116 Lv
117 Ts
118 Og

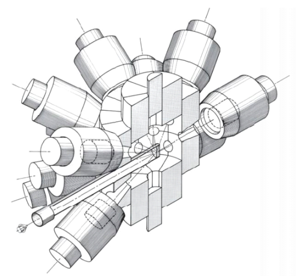
Semiconductor Lab

Key Technologies

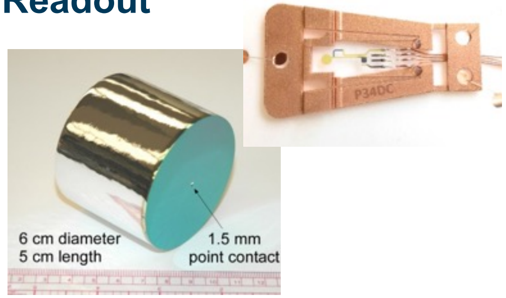
Birth of HPGe



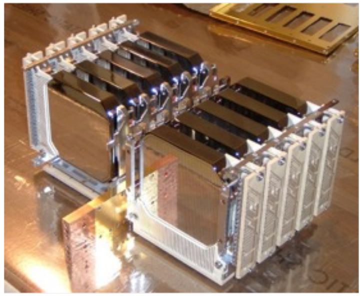
HPGe Arrays



P-type Point Contact HPGe, Low Mass Front End Readout

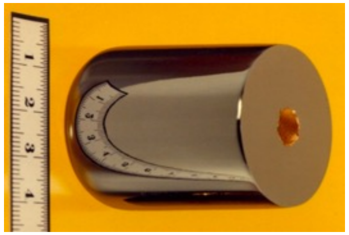


Segmented HPGe Detectors



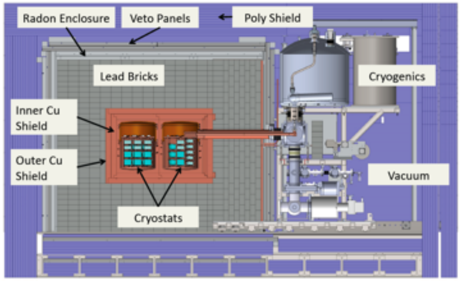
Instruments & Applications

High Resolution γ-ray Spectrometers



Gammasphere

MAJORANA DEMONSTRATOR



GRETA/GRETINA In-beam Spectroscopy *FIONA, FRIB*

Performance Drivers

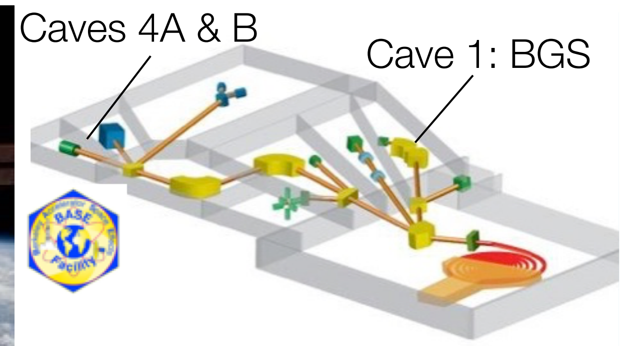
- Energy Resolution
- Efficiency

- Efficiency

- Electronic noise
- Efficiency
- Background rejection

- Position resolution
- Count rate
- Efficiency

88-Inch Cyclotron: Dual Mission



BASE Users: ~ 350

Light Ions: Protons up to 55 MeV

^{3}He up to 170 MeV

Heavy Ions: 5 To 32 AMeV

- National center for Superheavy element research
- Key provider of Nuclear Data supporting work in energy, medicine & security

  Student education/workforce development in both areas
- Leading facility for space effects measurements for US and commercial space & aeronautics communities: Air Force/NASA/industry
- *Ion Source development is a core capability!*

VENUS performance leading, but…

FRIB needs very high intensity high-charge-state beams.

Collaboration with MSU

$^{238}U^{33+}$: 430 μA

Low emittance beams for high intensity transmission (super heavy studies)

- Next generation ECR ion source at "older" facilities could be a path forward for increased heavy ion use
  - UC Davis
  - TAMU