# 1-minute Zoom Colloquium
# Oct 7, 2021

## University of Hawaii at Manoa
## Physics & Astronomy Department



and about 20 more

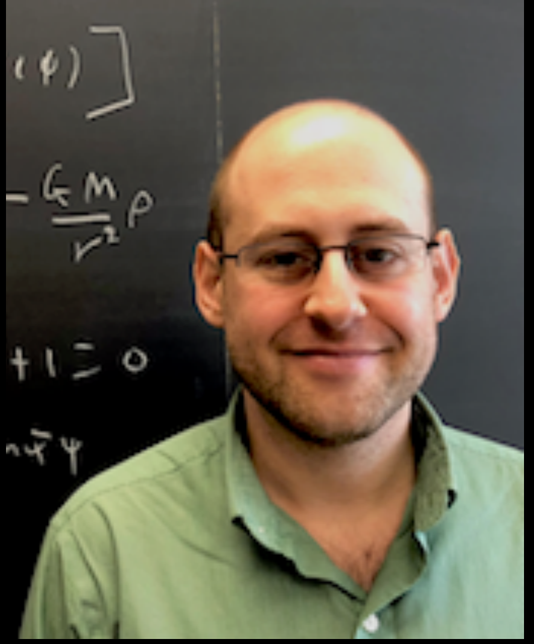
# Jason Kumar

HEP theory group, jkumar@hawaii.edu


- **I work on *dark matter* theory**
  - **with <u>Brad Boucher</u>, *Jacob Christy*, <u>Van Le</u>, *Jack Runburg*, <u>Aleczander Paul</u>**
- **since the 1930's, astronomical evidence has suggested that most of the mass in the universe (~80%) is of a type different than found here**
  - **dark matter ... doesn't interact (much) with light**
  - **the idea I focus on → it is a *new particle***

**Sculptor, believed to be a dark matter-dominated dwarf galaxy**

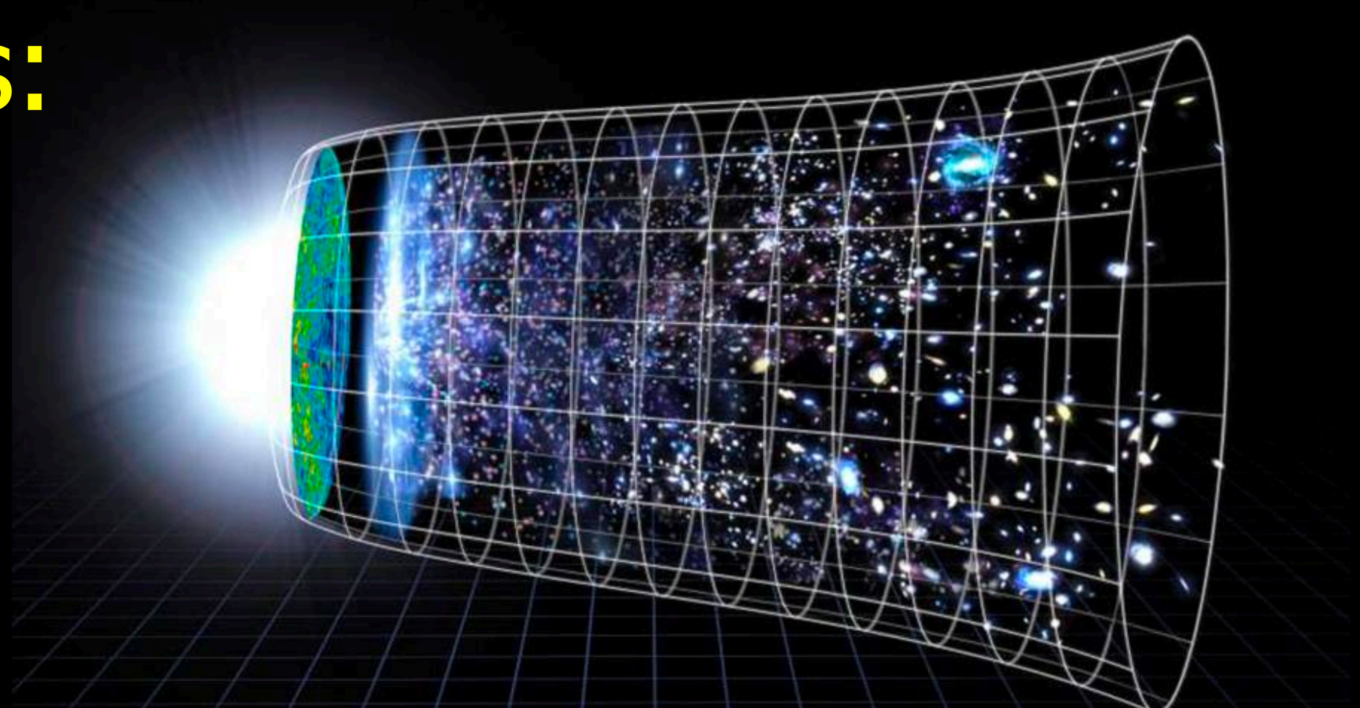
- **my work mostly focused on two prongs**
  - **developing new models for what dark matter could be**
  - **developing new ways of testing with experiments**
- **this field has great overlap between theory, experiment and observation, and between cosmology, particle physics and astrophysics**



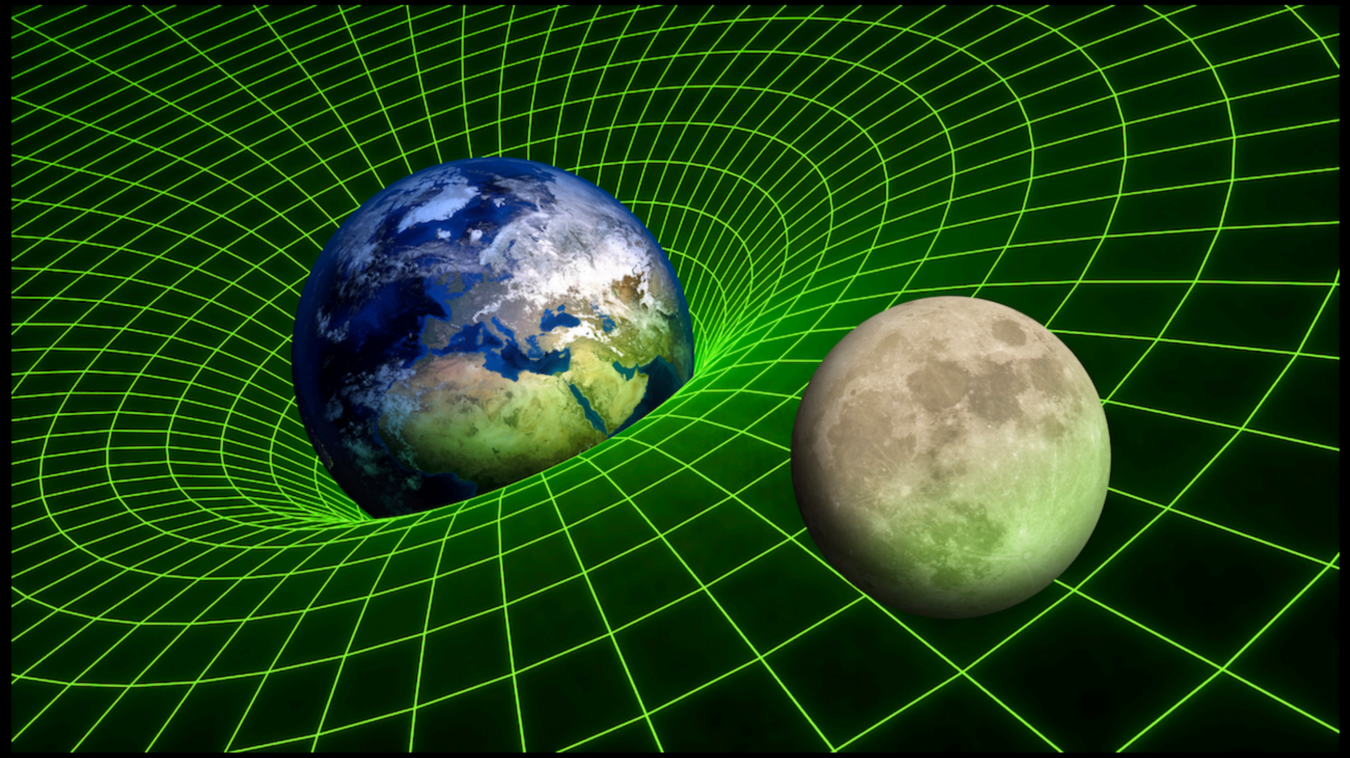
# Jeremy Sakstein
## Theoretical Cosmology, Gravitation & Astrophysics

sakstein@hawaii.edu
www.jeremysakstein.com

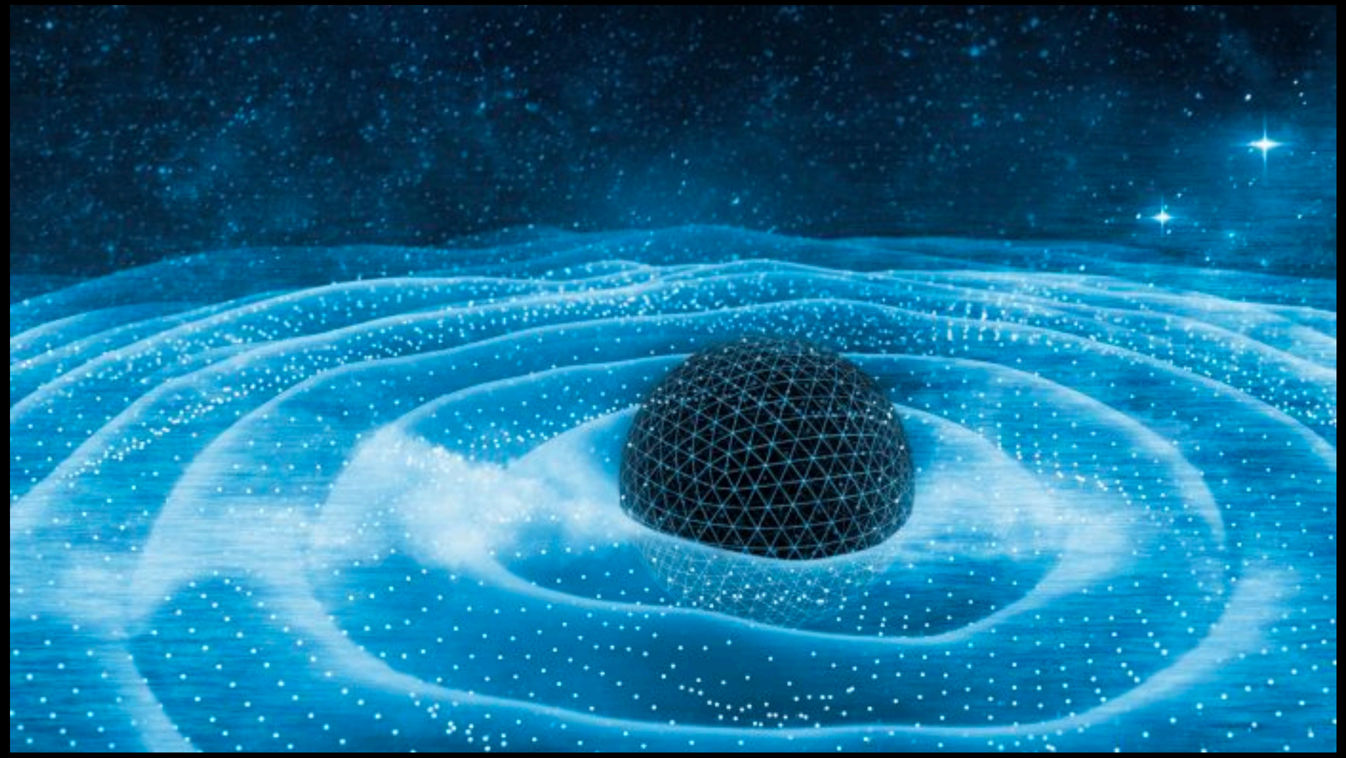
## Interests:



Cosmology
Dark Energy, Dark Matter



Gravitation
Modified Gravity, Tests of Gravity in Space



High Energy Astrophysics
Black Holes, Neutron Stars, Gravitational Waves

## Research Group:

Ben Elder
Quantum Mechanical Tests of Gravity

Omar Ramadan
Cosmology/Hubble Tension

Chris Reyes
Neutron Stars/Gravitational Waves

Mitchell Dennis (IfA)
Machine learning in
stellar astronomy & dark matter

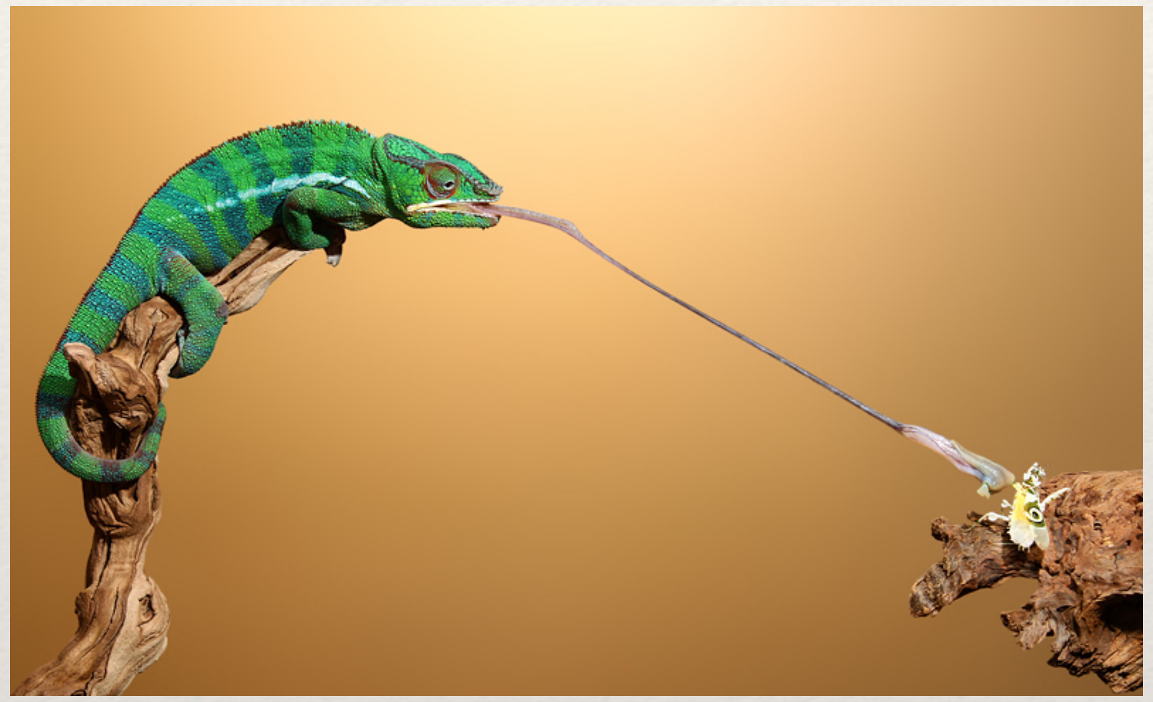
bcelder@hawaii.edu

# Benjamin Elder

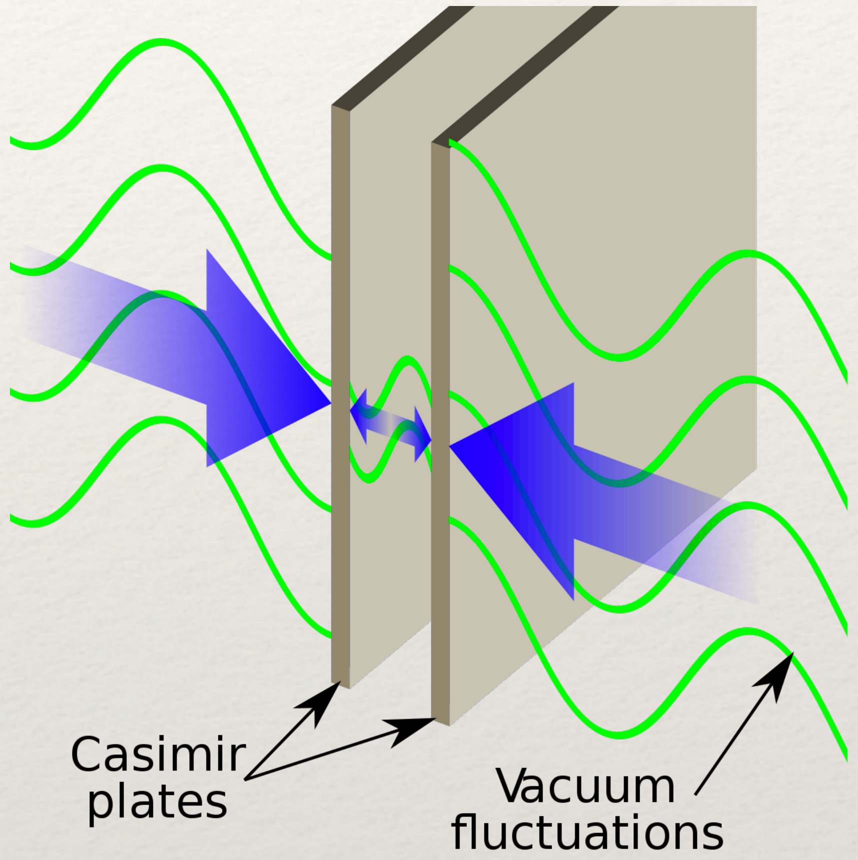
*Quantum mechanical tests of dark energy, dark matter, and modified gravity*

New **particles** mediate new **forces**, which can be detected in:

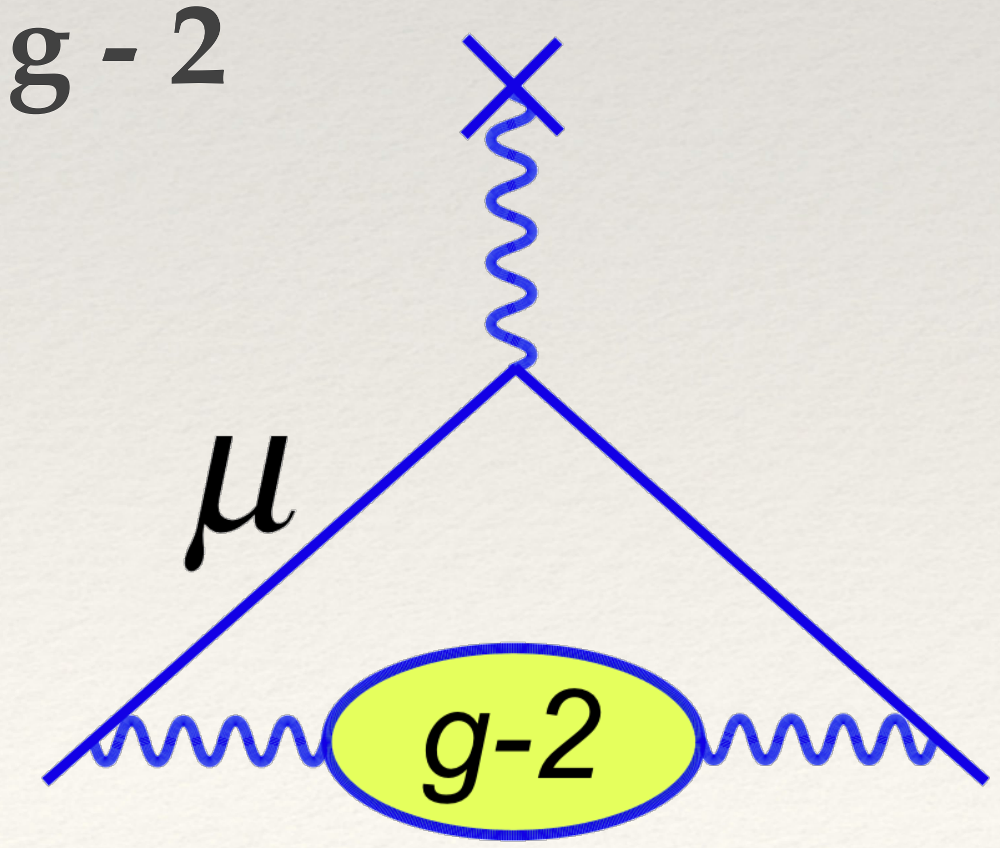
- **Atom interferometry**

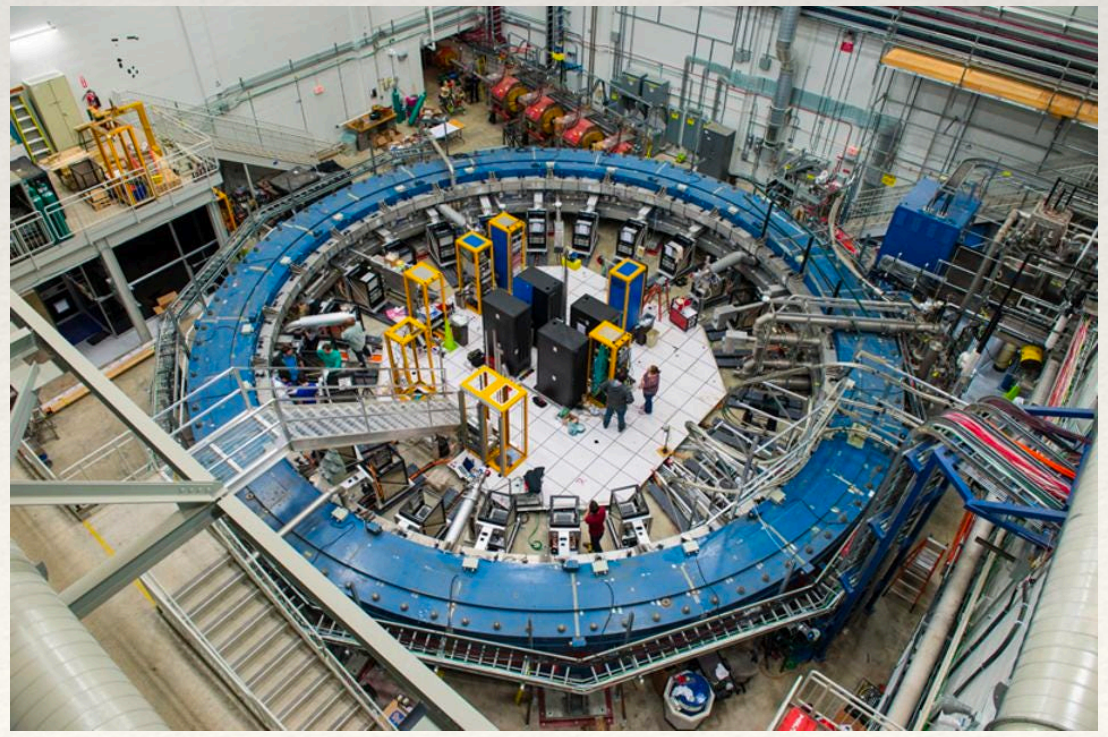


- Casimir

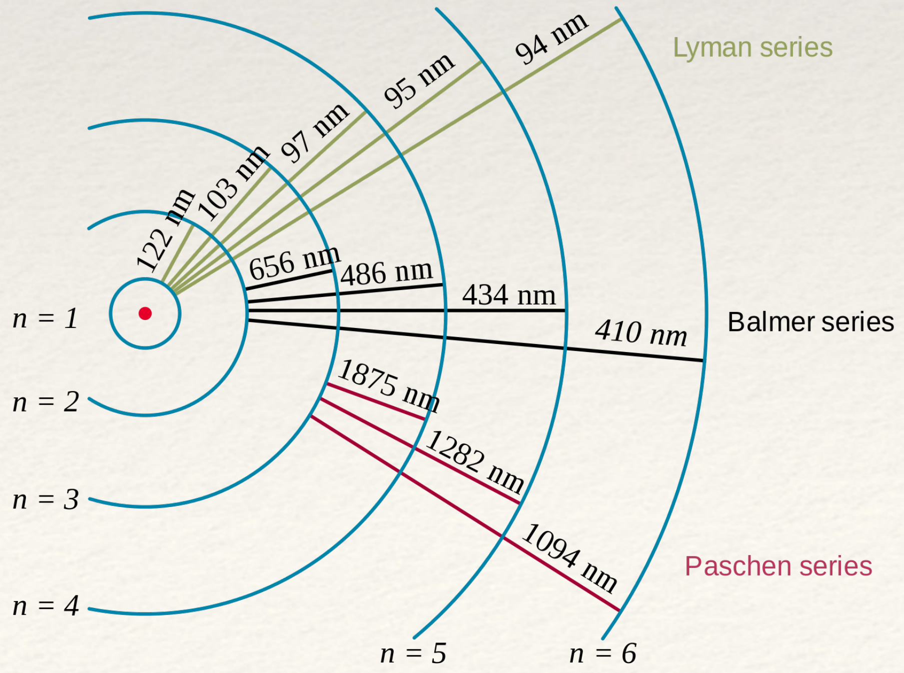



- **g - 2**

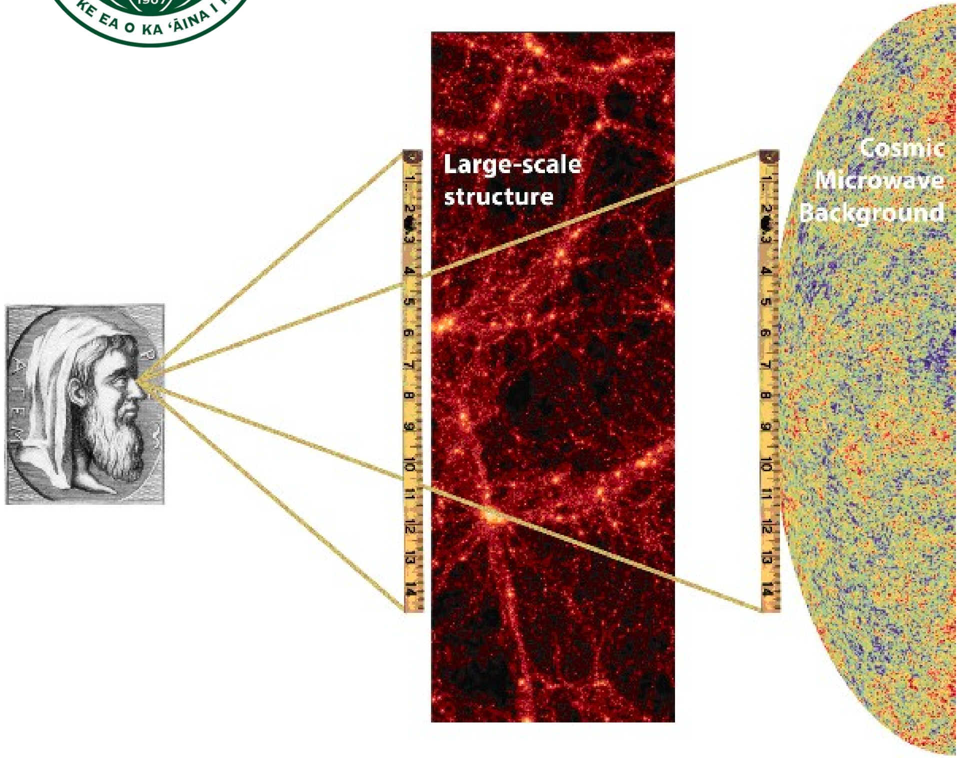


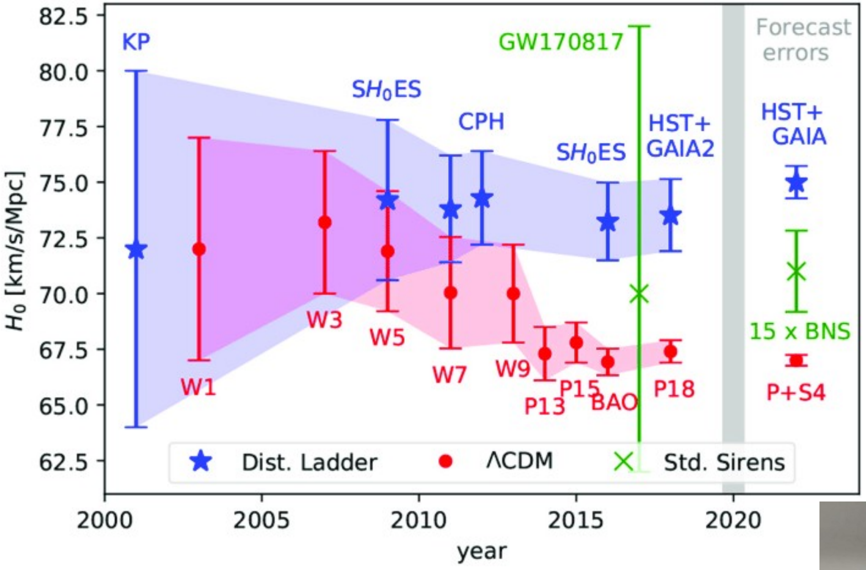



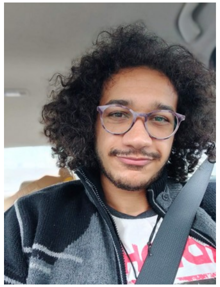
- Hydrogen spectroscopy



# Dynamical EDE to Resolve the Hubble Tension



*Omar Ramadan*
*Physics and Astronomy*
*oramadan@hawaii.edu*

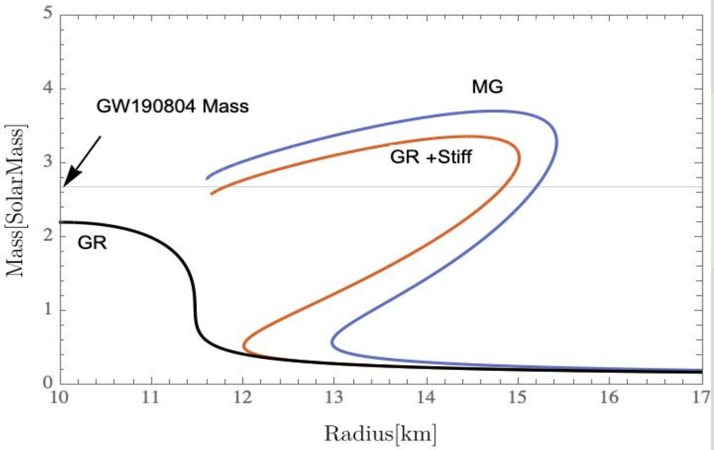
# Christopher Reyes

Recently, Ligo/Virgo observed an object (2.50-2.67 solar masses) that is too heavy to be a neutron star and too light to be a black hole.

I'm currently working on try to understand what this object is.

I am doing this by:
Stiffer equations of state (EOS) in the core.
Modify Gravity

Important Results:
GW190814 can be accounted for it if the EOS stiffens in the core.
Modify gravity theories can generally account for this object





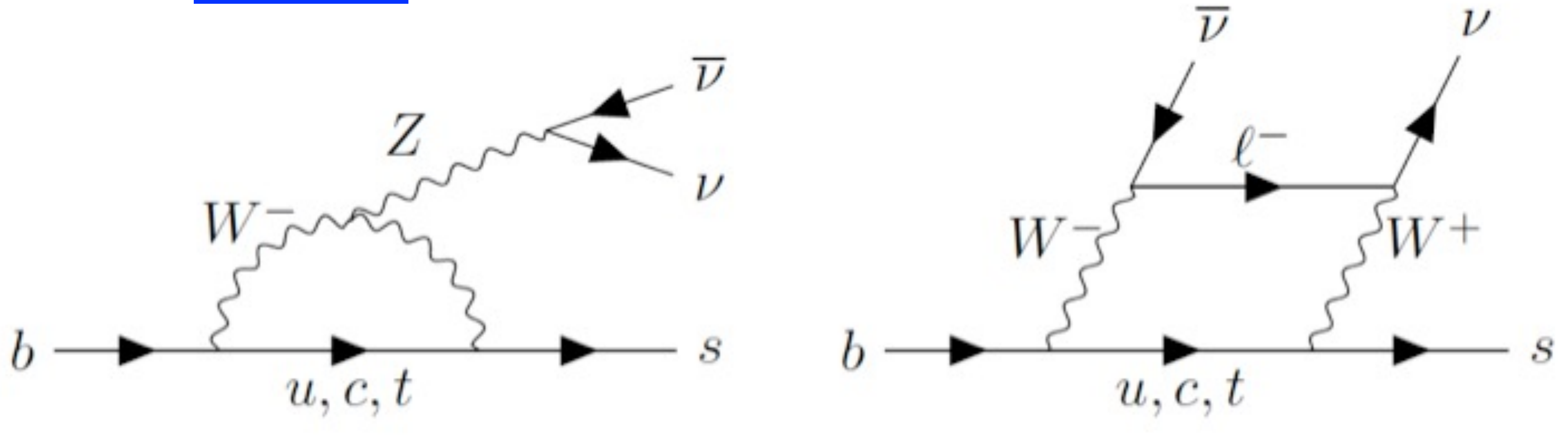
Graduate Student
Email:
cmreyes3@hawaii.edu

Tom Browder

# B→K ν νbar: NP without hadronic uncertainties

Also working on New Physics MC Generators with Alexei Sibidanov (UH) and preparing Belle II/SuperKEKB White Papers for Snowmass

(See Belle II Physics Mind Map Below)

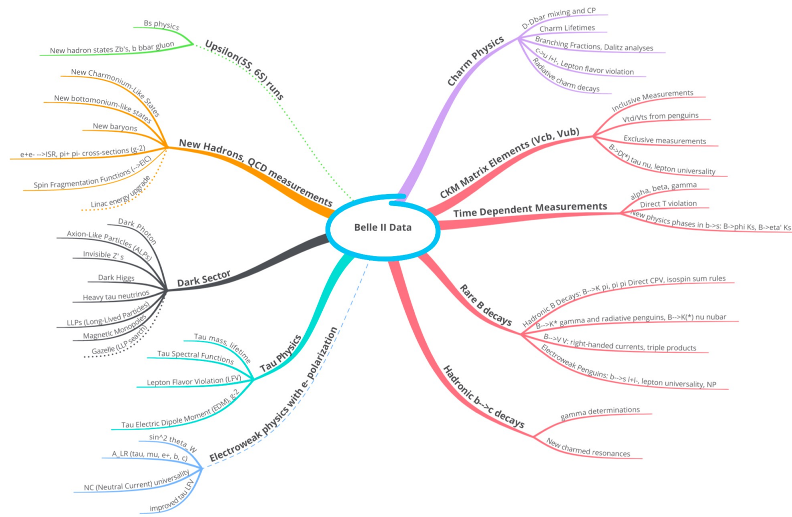



(a) Penguin diagram (b) Box diagram

Note that in contrast to $B \to K^{(*)} l^+ l^-$ angular asymmetries, there are NO long distance (charm annihilation) contributions from $B \to J/\psi K^{(*)}$ and $B \to \psi(2S) K^{(*)}$

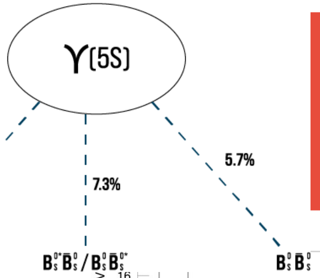
This is the most likely way that Belle II could discover NP.

More details in this theory paper (TEB, N.G. Deshpande, R. Mandal, R.Sinha): https://arxiv.org/abs/2107.01080, published as **Phys. Rev. D. 104, 053007 (2021)**

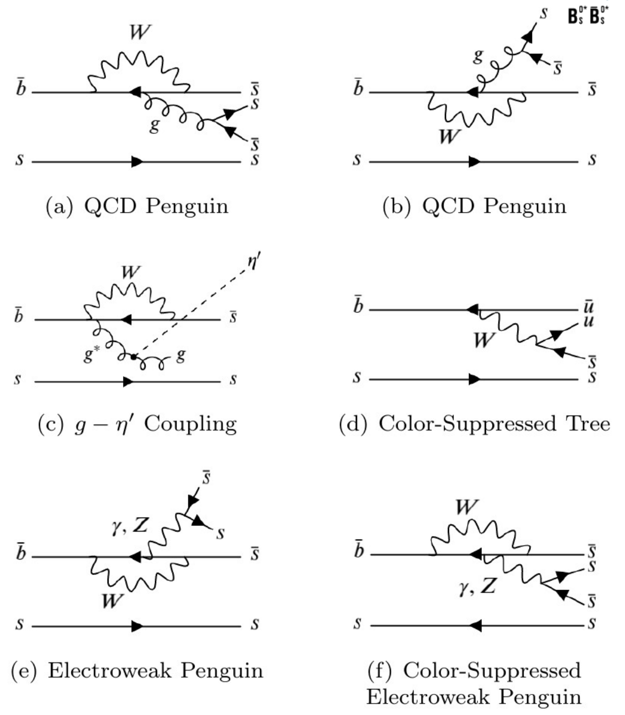


# $B_s^0 \to \eta' X_{s\bar{s}}$

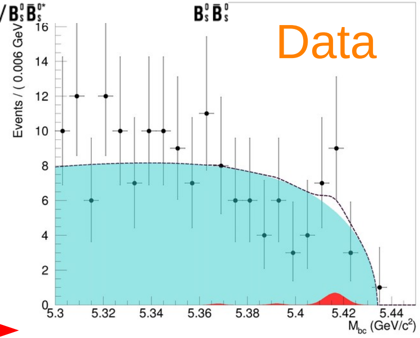
# PENGUIN HUNTER

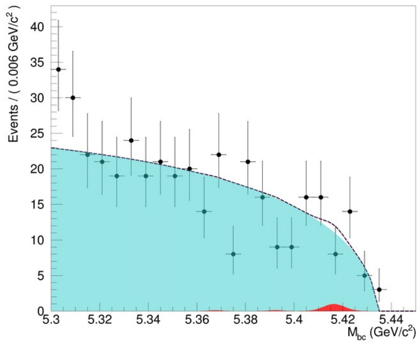



$$M_{\rm bc} = \sqrt{E_{\rm beam}^2/c^4 - p_{B_s}^2/c^2} \quad E_{\rm beam} = \sqrt{s}/2$$



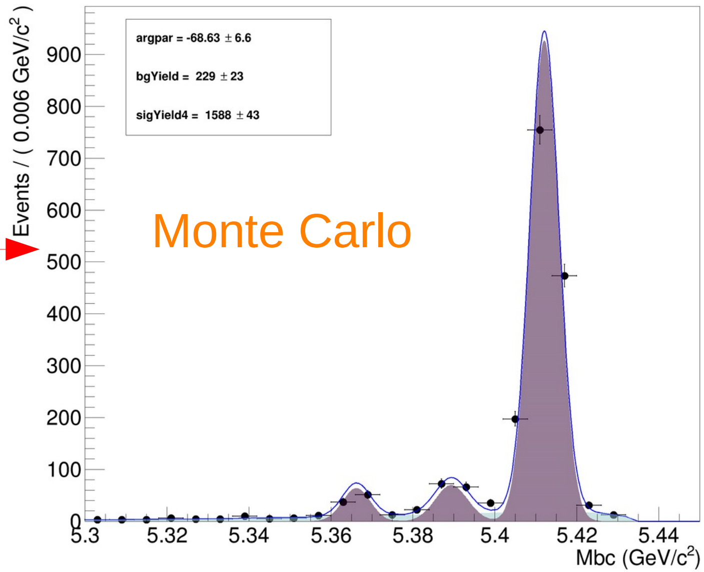

Data




$B_s^0 \to \eta'(\to \eta\pi^+\pi^-)X_{s\bar{s}}$

Monte Carlo



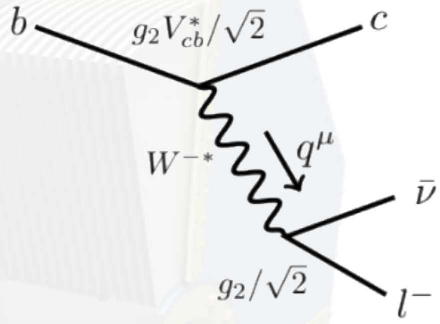

$B_s^0 \to \eta'(\to \rho^0\gamma)X_{s\bar{s}}$



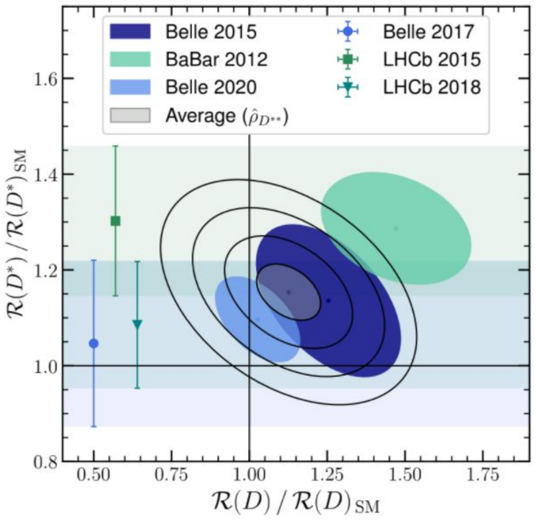
Phys. Rev. D 104, 012007 (2021): $90\%$ CL UL :$\mathcal{B}(B_s^0 \to \eta' X_{s\bar{s}}) < 1.4 \times 10^{-3}$

S. Dubey

**Boyang Zhang, PhD student**
**[zhangboy@hawaii.edu](mailto:zhangboy@hawaii.edu)**
**WAT 202**

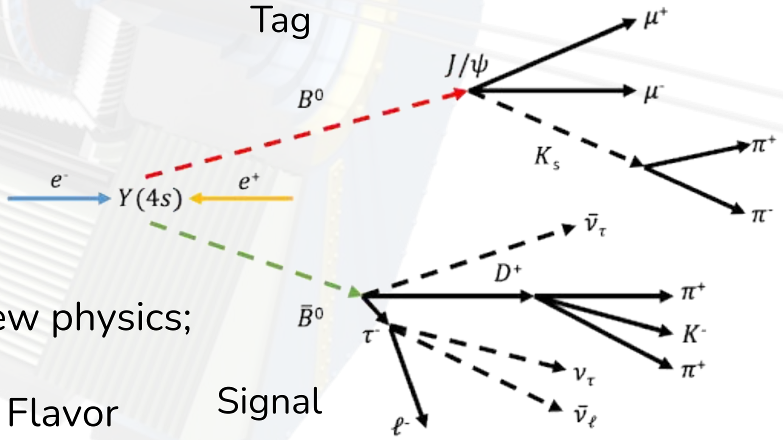



# Measurement of R(D) and R(D*) using an inclusive tagging method at Belle II (Novel)




$$R(D) = \frac{\mathcal{B}(\bar{B} \to D\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D\ell^-\bar{\nu}_\ell)}$$

$$R(D^*) = \frac{\mathcal{B}(\bar{B} \to D^*\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D^*\ell^-\bar{\nu}_\ell)}$$




1. Sensitive probes for new physics;
2. Direct tests for Lepton Flavor Universality

# Monte Carlo Studies of Decay of $B^+$ in Search for Violation of Lepton Universality

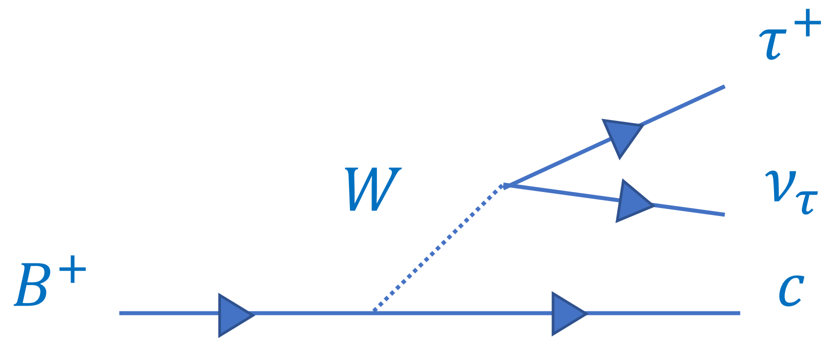
$$B^+ \to \tau^+ \nu_\tau D^0$$

$\tau^+ \to e^+ \nu_e \bar{\nu}_\tau$

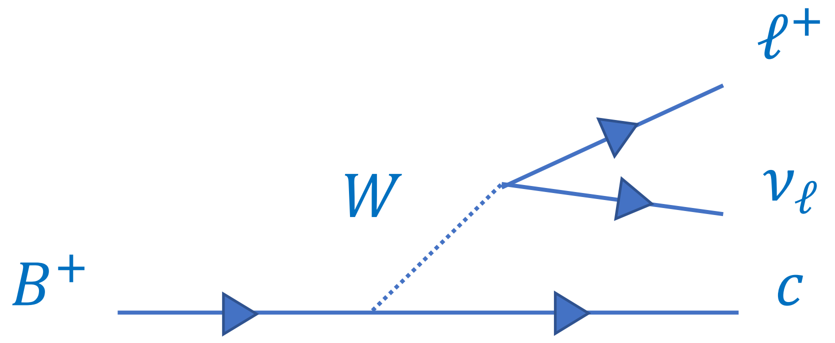
$\tau^+ \to \mu^+ \nu_\mu \bar{\nu}_\tau$

$R_D =$

$BR$




$BR$

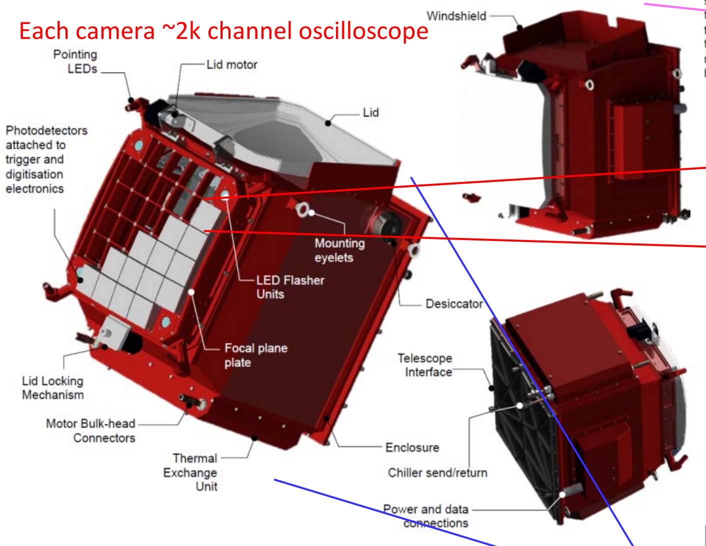


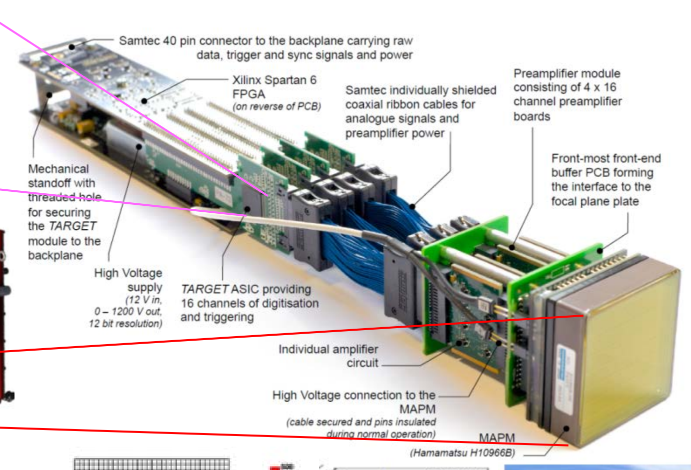
# Cherenkov Telescope Array

Gary Varner (varner@hawaii.edu)

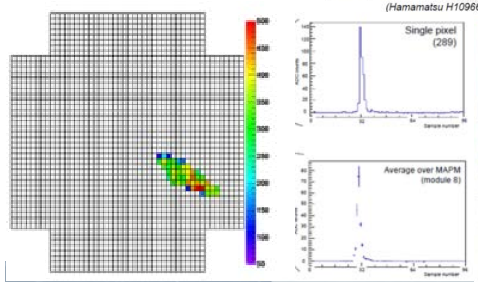
CTC (sampler)
CT5TEA (trigger)
Gang Liu

Each camera ~2k channel oscilloscope

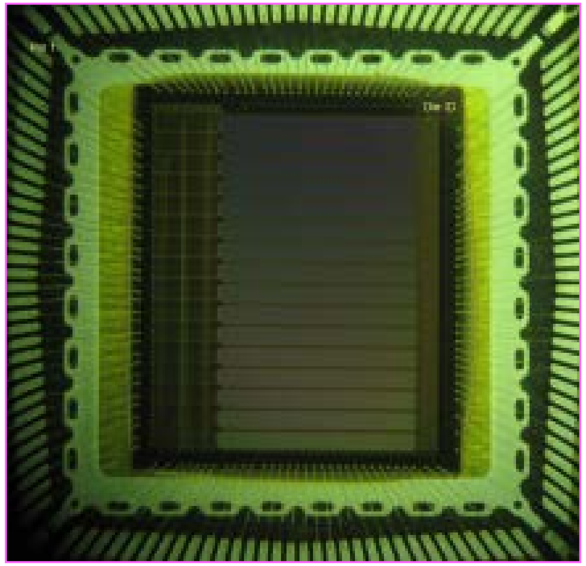


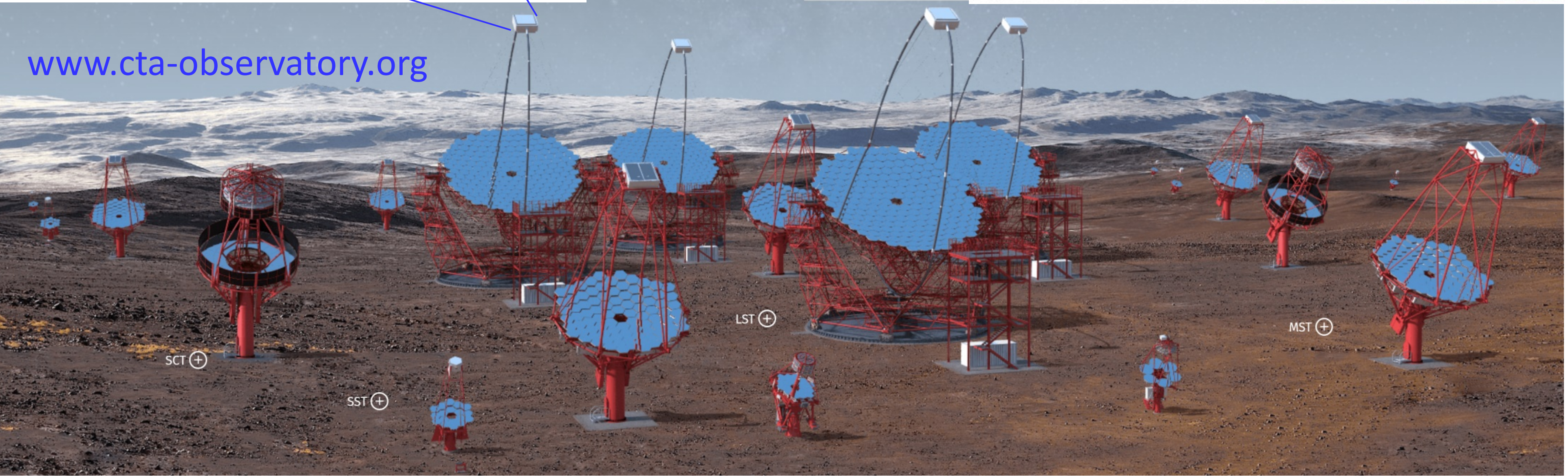






www.cta-observatory.org




- First production batch of 6k ASICs (~100k chan) started
- ALPHA configuration baseline approved, construction started
- 2023 first light (2026 complete) – though eruption in north

İlknur Köseoğlu-Sarı
Postdoc
Turkish

koseoglu@hawaii.edu

Optimizing the performance and operation of the imaging Time-Of-Propagation particle identification detector of Belle-II experiment.

- Master the expert operations of the existing readout electronics
- Developing prototype upgrade electronics
- TOP expert shifts, Belle-II Operational shifts

Ph.D. : University of Giessen, Germany, June 2021.

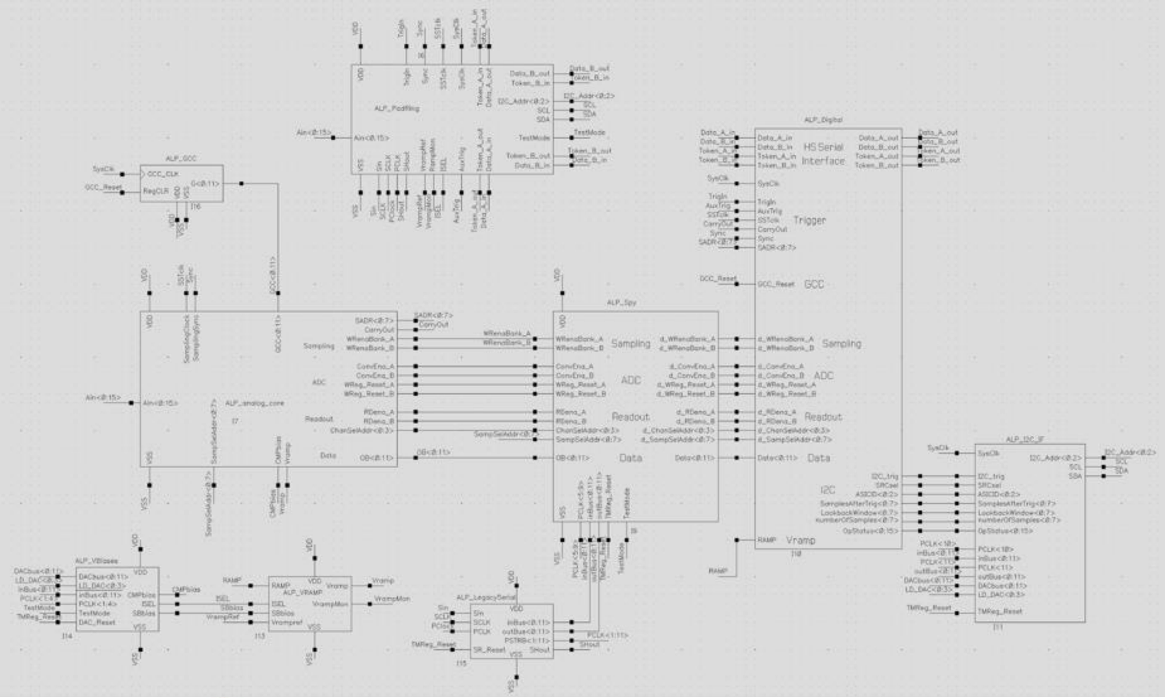
"Title: Development of a fast readout system for the DISC DIRC prototype of PANDA"

Currently: In Turkey, remotely working for UH.

Hopefully, I will be in Hawaii in a month.

# Advanced Low Power Hybrid Acquisition (ALPHA) ASIC

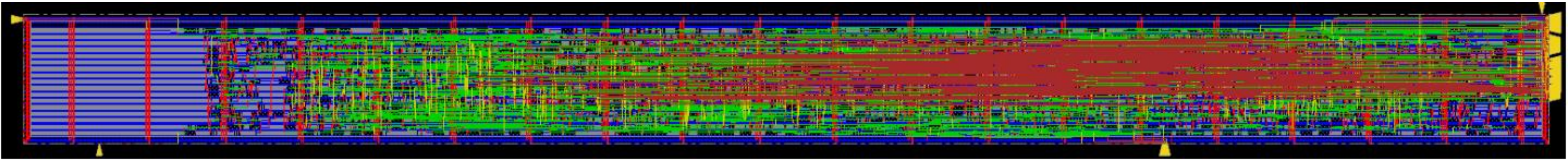
- Readout of the **Advanced Particle Telescope (APT)** sensor elements
- Novel in this architecture is the **daisy-chaining** and **token passing** of the readout, as well as sharing of clocking resources, all to reduce power.
- Digital design (Makiko) / Analog design (Gang)



1. **(Programming) VHDL**: Write text models that express logic circuits
2. **(Synthesize) Cadence Genus**: Register transfer level (RTL) is turned into a design implementation in terms of logic gates
3. **(Simulation) Cadence Xcelium**: Simulate the synthesized output file of Genus
4. **(Place and Route) Cadence Innovus**: Deciding where to place all logic elements in a limited amount of space. This is followed by routing, which decides the exact design of all the wires needed to connect the placed components.

- Design v_1 was sent for manufacturing on Sep 18, 2021
- Next task is to make simulation board using **Xilinx PYNQ**


**Makiko Kuwahara: makikoku@hawaii.edu**
**Ph.D. student of Electrical and Computer Engineering**
**IDL : advisor Professor Gary Varner**

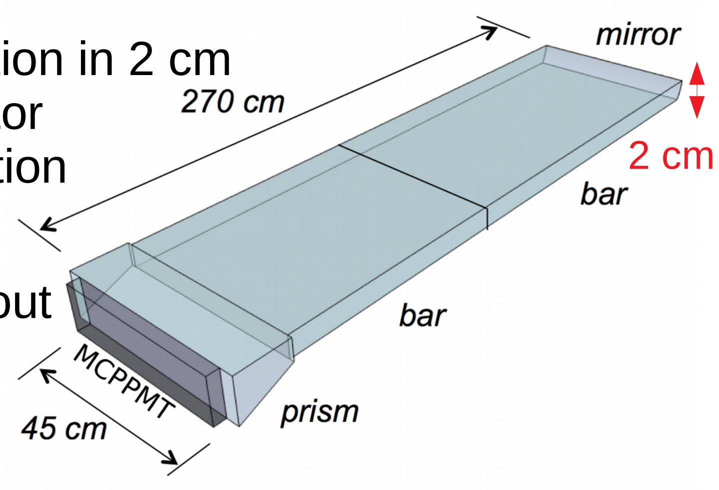


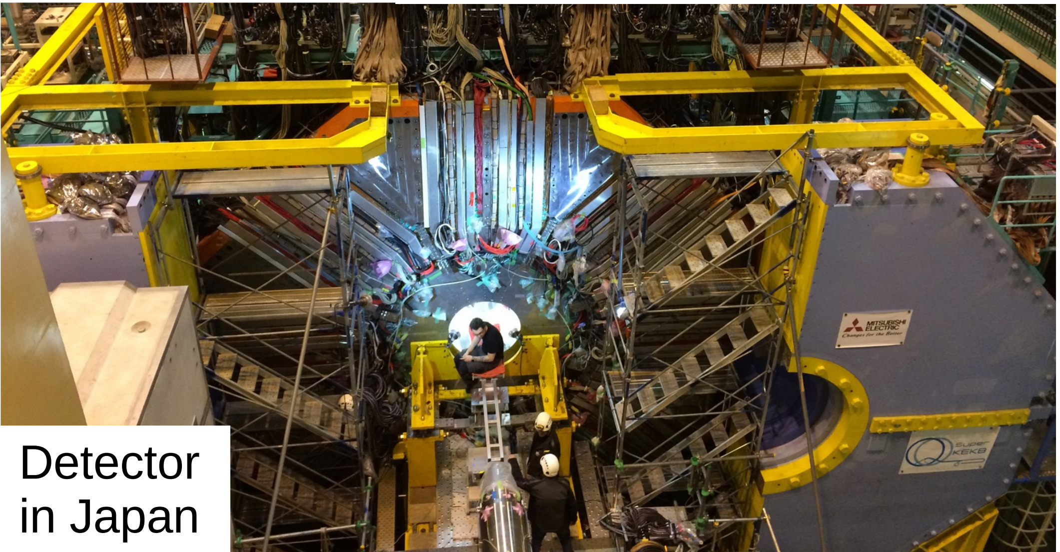
Martin Bessner
bessner@hawaii.edu

# TOP in Belle II

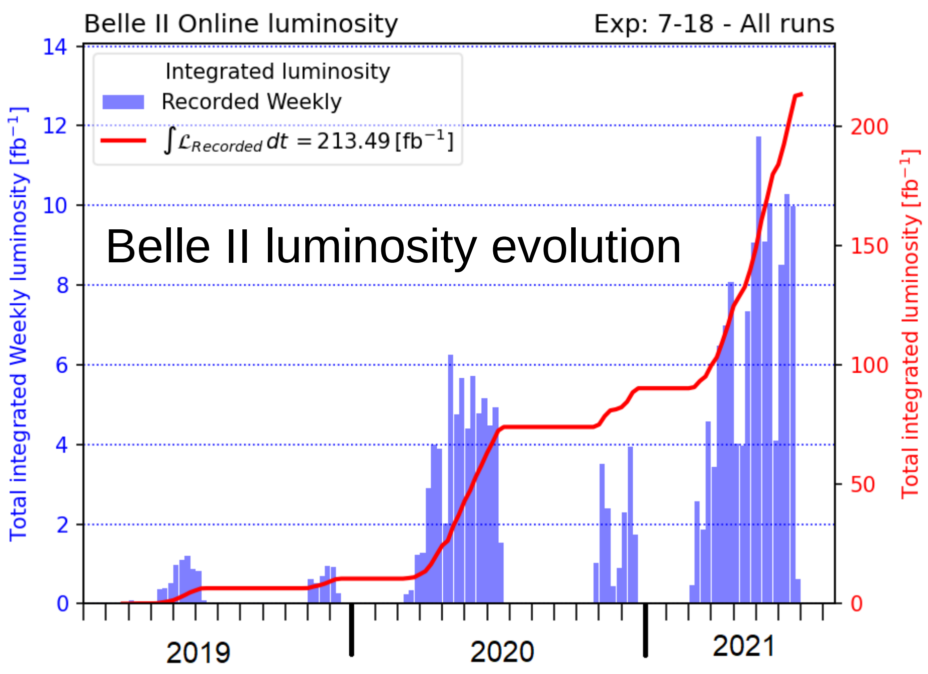
Particle identification in 2 cm
Cherenkov detector
Time Of Propagation

Readout



Detector
in Japan




Minimal contact shifter scheme
accelerator and detector kept running

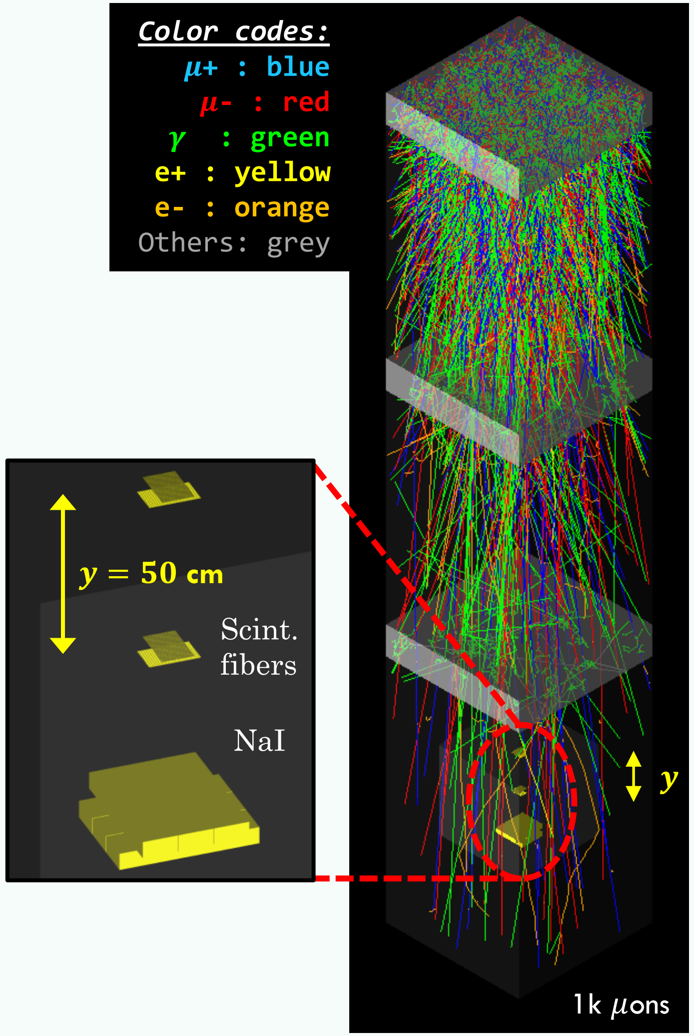
Major upgrade/replacement work in summer 2022

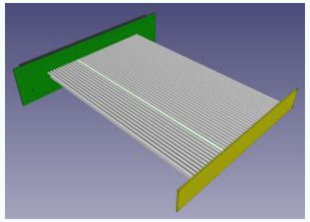
Join our group!

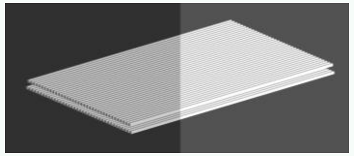
# Harsh Purwar – HMB Geant4 simulations

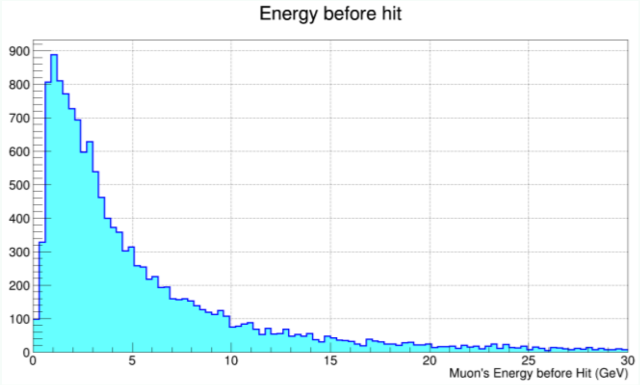
purwar@hawaii.edu

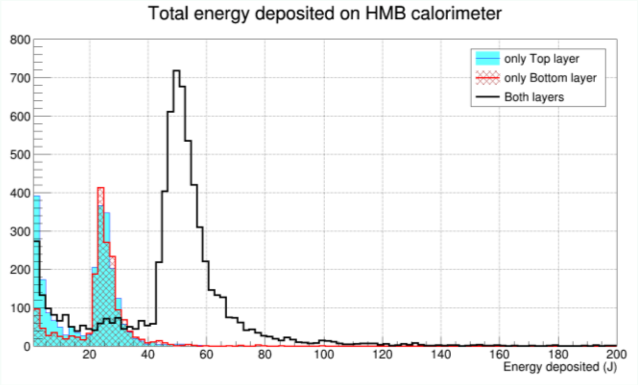
- Joined HEP Group in Oct. 2019, working with Prof. Varner
- For general info on **H**awaii **M**uon **B**eamline – stay tuned to other ppts
- **GE**ometry **AN**d **T**racking, a platform (toolkit) for simulation of the passage of particles through matter using MC methods
- *Why Geant4?*
  - Extensively used in Particle Phys, Nuclear Phys, Acc. Design, Space Engineering, Optical Phys, & Medical Phys.
  - Provides a complete range of functionality: tracking, geometry, physics models and hits.
  - Toolkit includes several inbuilt physics processes: HEP, EM, Optical, etc.
- More info: https://www.phys.hawaii.edu/~idlab/taskAndSchedule/HMBv3/HMBv3.html





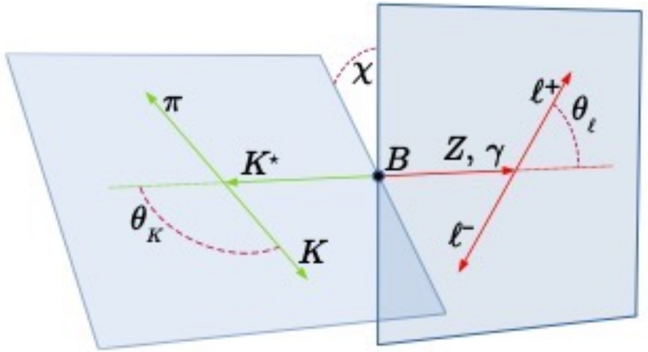


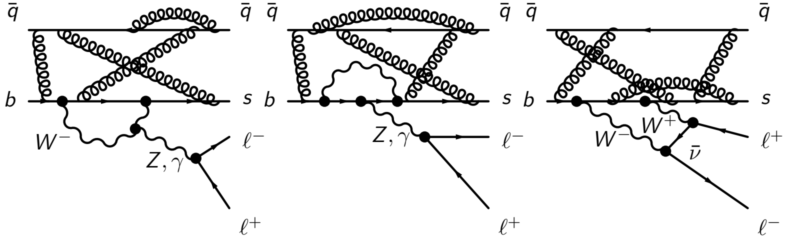



# Rare B Decays: $B \to K^* l^+ l^-$

*Shahab Kohani (kohani@hawaii.edu)*

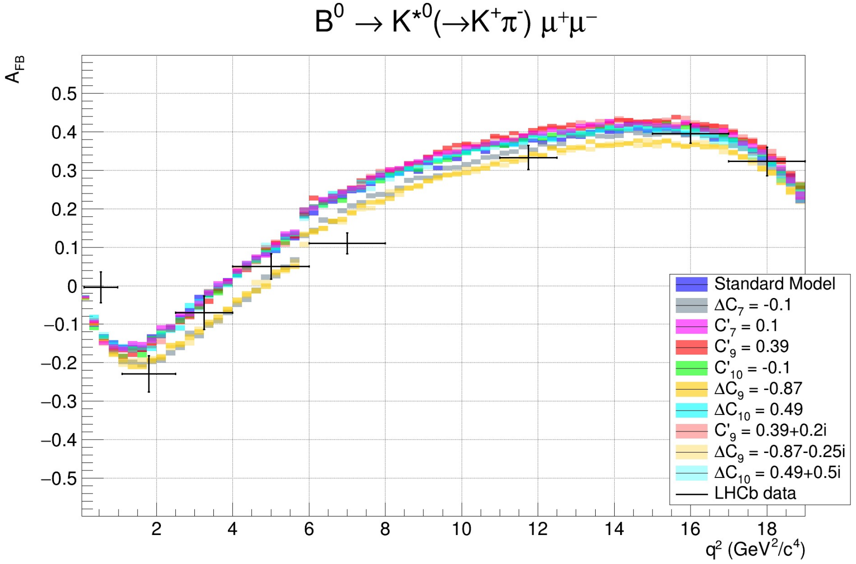
- These rare decays are sensitive to possible contributions from new physics (NP) heavy mediators.
- Experimental studies of branching fractions, angular distributions and ratios of branching fractions between decays with different flavors of lepton pairs all show discrepancies from the standard model.

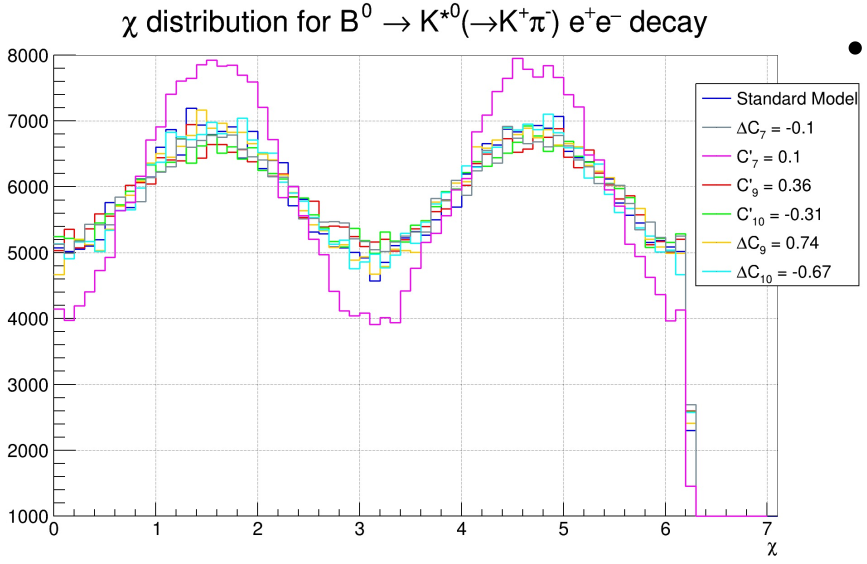



$$
\begin{aligned}
\mathcal{M} = & \frac{G_F \alpha}{\sqrt{2}\pi} V_{tb} V_{ts}^* \Big\{ \Big[ \langle K\pi | \bar{s}\gamma^\mu (C_9^{\text{eff}} P_L + C_9^{\prime\text{eff}} P_R) b | \bar{B} \rangle \\
& - \frac{2m_b}{q^2} \langle K\pi | \bar{s} i \sigma^{\mu\nu} q_\nu (C_7^{\text{eff}} P_R + C_7^{\prime\text{eff}} P_L) b | \bar{B} \rangle \Big] (\bar{\ell}\gamma_\mu \ell) \\
& + \langle K\pi | \bar{s}\gamma^\mu (C_{10}^{\text{eff}} P_L + C_{10}^{\prime\text{eff}} P_R) b | \bar{B} \rangle (\bar{\ell}\gamma_\mu\gamma_5 \ell) \\
& + \langle K\pi | \bar{s}(C_S P_R + C_S' P_L) b | \bar{B} \rangle (\bar{\ell}\ell) + \langle K\pi | \bar{s}(C_P P_R + C_P' P_L) b | \bar{B} \rangle (\bar{\ell}\gamma_5 \ell) \Big\}
\end{aligned}
$$

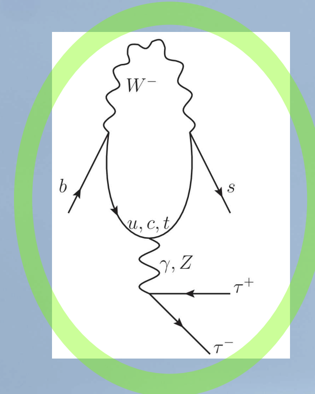
- The new physics here can be modeled as different values of Wilson coefficients.
- We are using a new generator by Alexei Sibidanov.
- I'm looking at the effects of varying Wilson coefficients on different Kinematic variables and Observables.

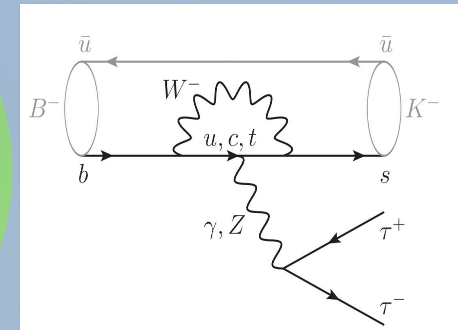


# Chris Ketter

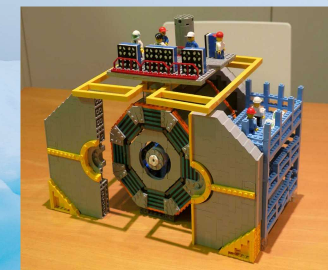
ckketter@hawaii.edu




within the $772\times10^6$ $B\bar{B}$ pairs saved on

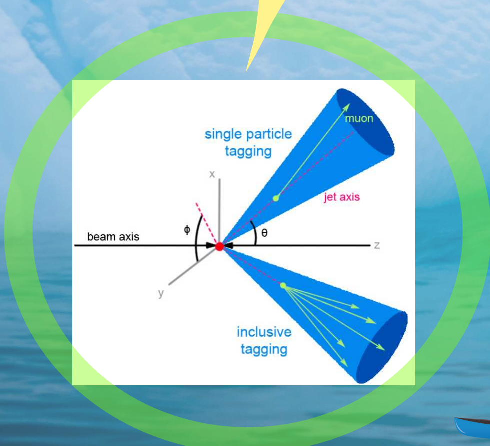

from the



part of

using novel tools like

basf2


made possible by

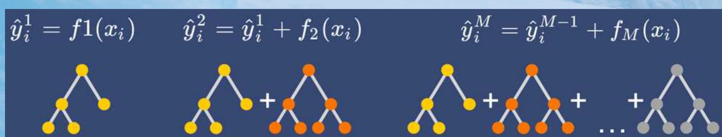
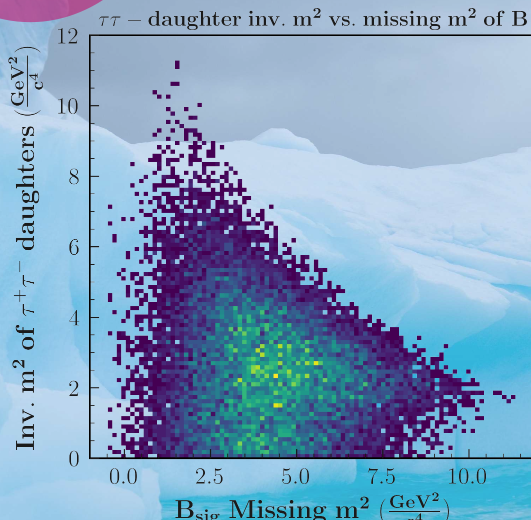



Figure Source: Tal Peretz

and currently looking to fit



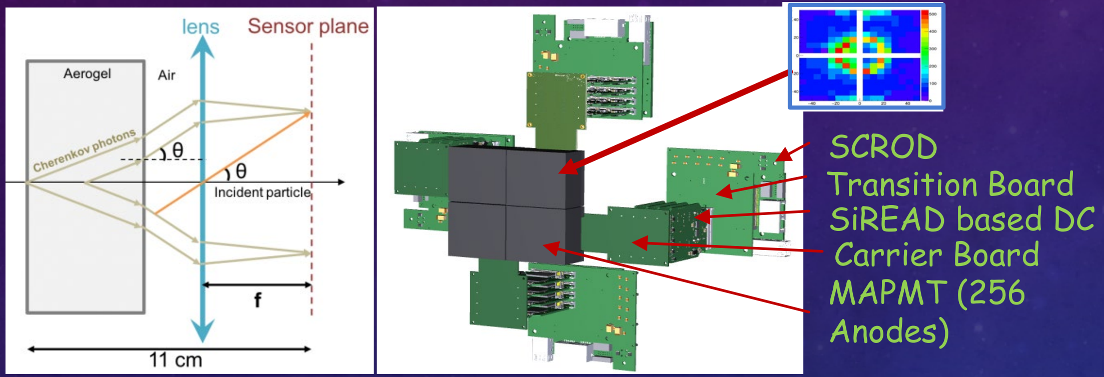

Shivang Tripathi, Postdoc (shivang@hawaii.edu)
Instrumentation & Development Lab

with Prof. Gary Varner

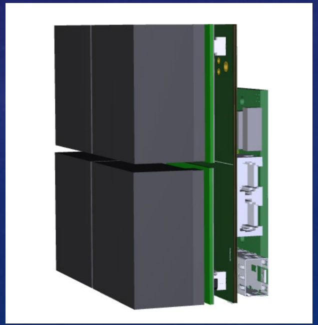

## Readout Electronics for the EIC-PID (eRD14)

- Readout solution for various photosensors being considered for the RICH & DIRC detectors
- Firmware & Software Development for SiRead based R.E.

Modular RICH (mRICH)




- Board, FW & SW development for Nalu Scientific's next gen HDSoC ASIC

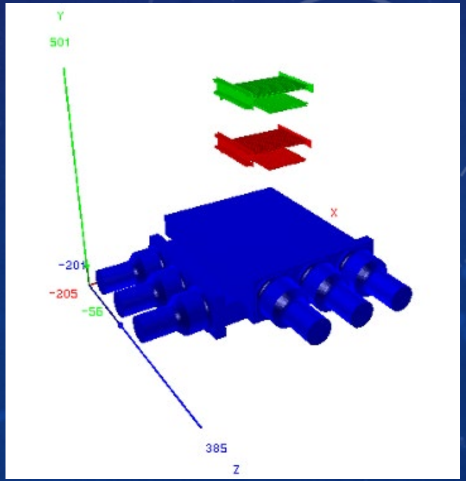



## HMBv3 Calorimeter Readout

- 6U VME and Zynq based readout for the HMBv3 calorimeters
- Hands-on with Xilinx's Vivado, Vitis SDK and Zynq SoC

## Detector Description for High Energy Physics (DD4hep)

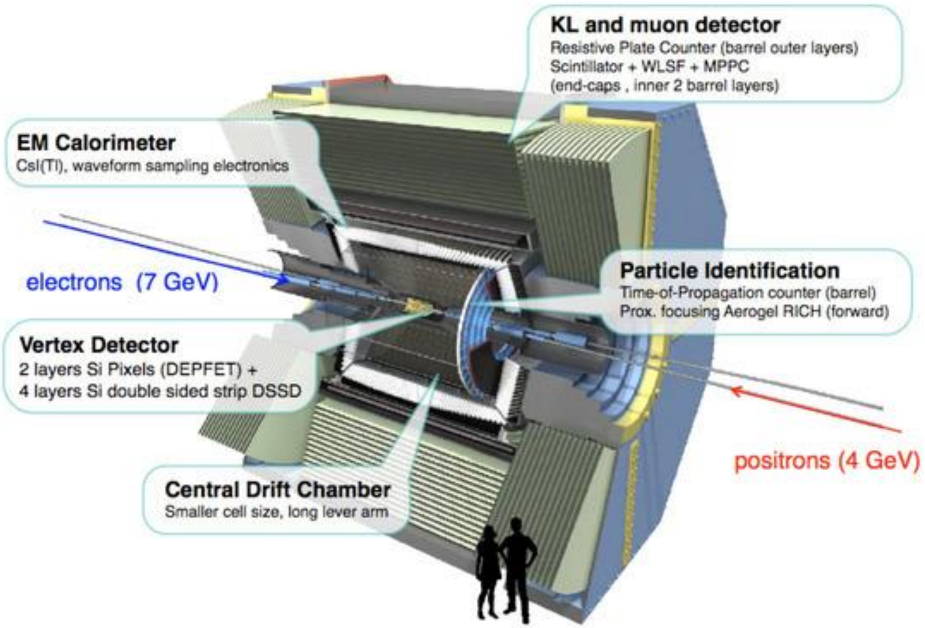
- Toolkit framework for detector description from single source of information
- Geometry description of the HMB



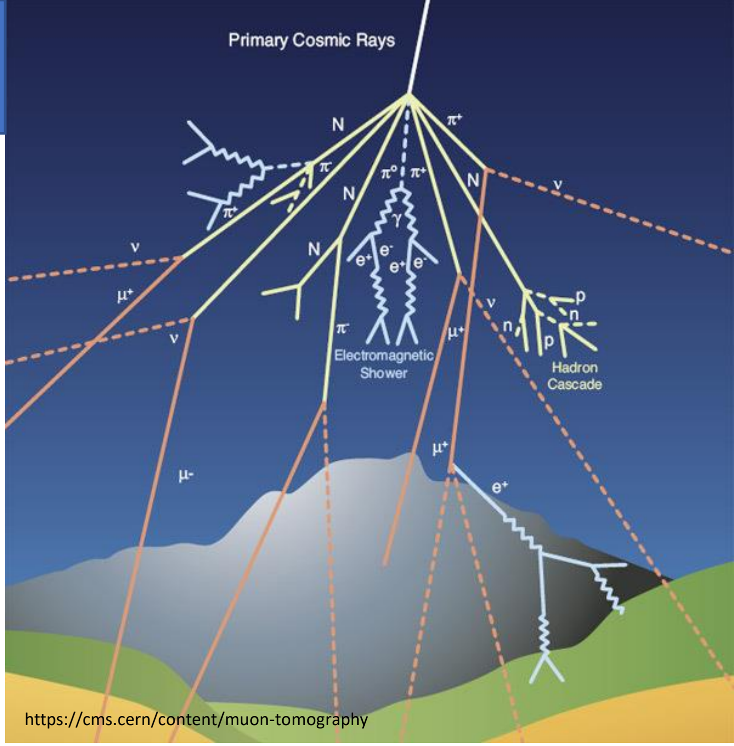

6th Annual 1-minute colloquium, Oct 7, 2021

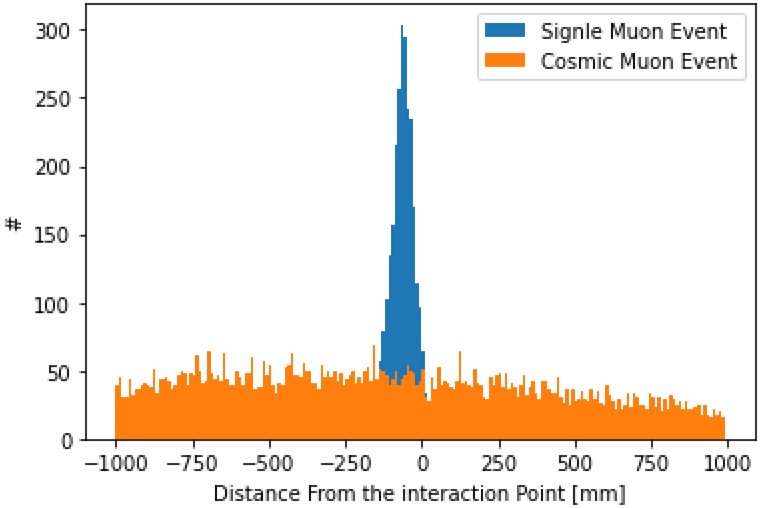
# BELLE2 - KLM – MUON TRIGGER UPGRADE

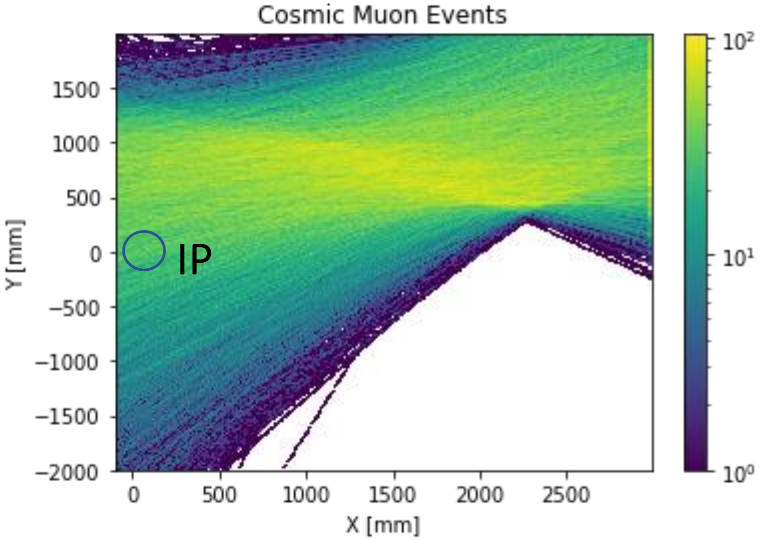
Richard Peschke | rp40@hawaii.edu

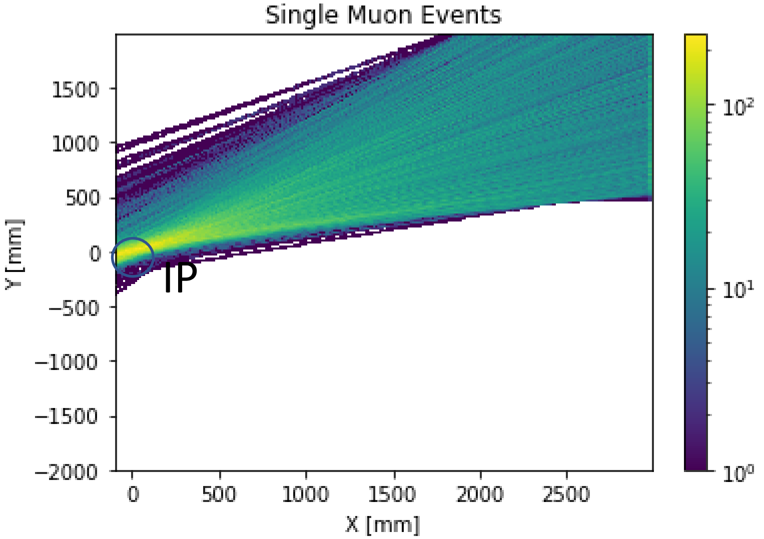



- Studying the possible upgrade of the KLM Muon Trigger
- Trigger should successfully identify muon events and simultaneously suppress cosmic muons
- Implementing track fitting algorism on the FPGA
- Muon events converge around the interaction point
- Cosmic muons are (more or less) uniform distributed



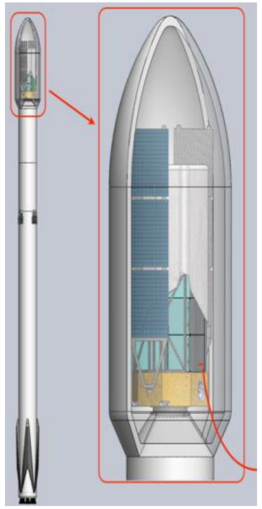
Instrumentation Development Lab

**ASIC Design - *A*pplication *S*pecific *I*ntegrated *C*ircuit**

Gang Liu : liugang@hawaii.edu

## APT The *A*dvanced *P*article-astrophysics *T*elescope

**- Space-based high-energy γ-ray and cosmic-ray explorer**



### ALPHA *A*dvanced *Low-Power Hybrid Acquisition*

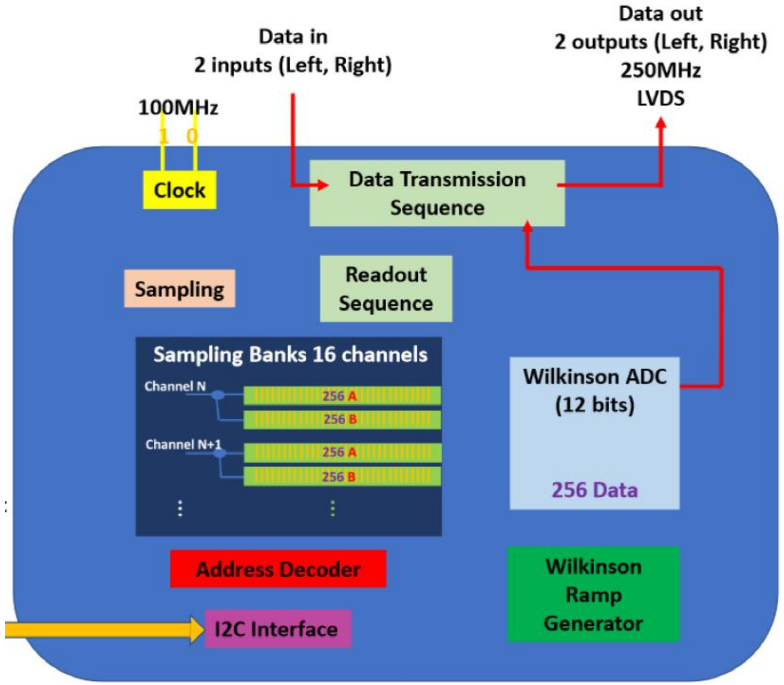
**- Data Transmission Sequence**

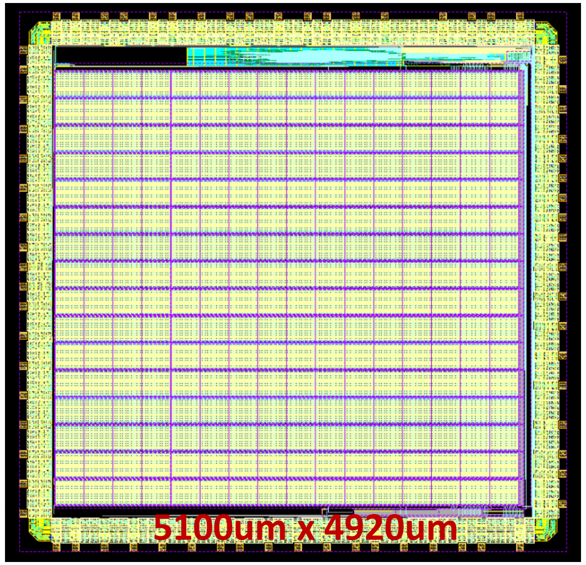
**- Readout Sequence**

**- Two Operating Modes:**

- **Calorimeter (100MSPS)**
- **Tracker (250MSPS)**

**- Mix-signal design (analog & digital) with our own pad and standard cell library**



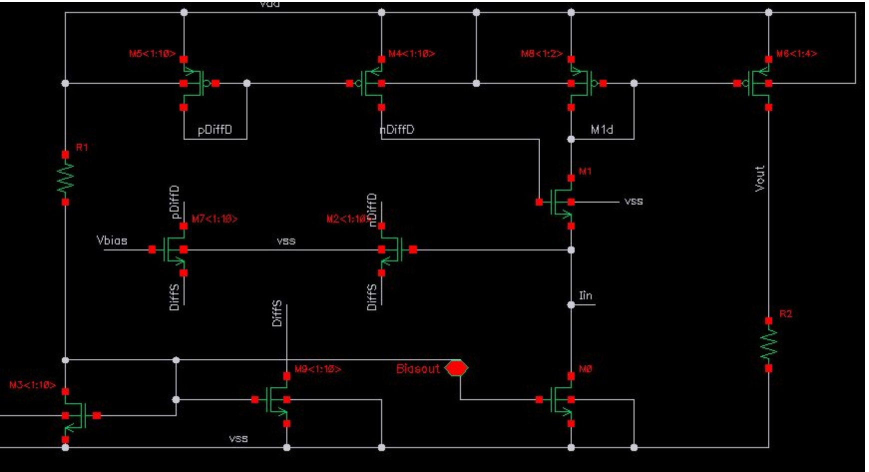



# Analog Signal Circuit Design in the Instrumentation Development Lab

What Analog Circuit Designers Do:

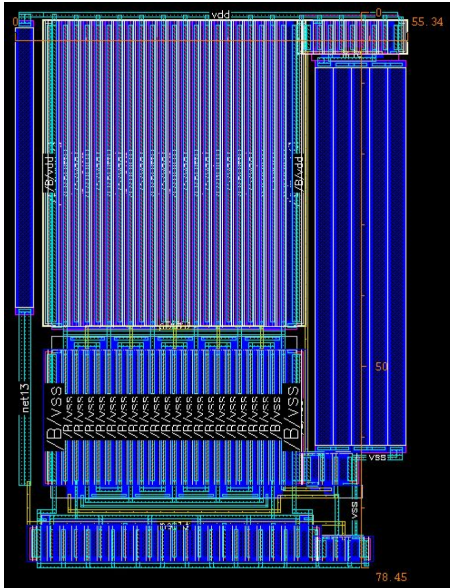
- ➢ Analyze output Specifications from Analog Sensors which output signals in a continuous time
  - ○ These can be sensors like microphones or light detectors in the ID Lab the HDSOC chip is trying to detect one photon.
- ➢ With Analog Specifications derived we try to fit a combination of MOSFET’s (Metal Oxide Field Effect Transistors) to analyze the analog signal without interfering with the input signal and increasing the output in a way which can be digitized and evaluated with more advanced methods.

In Effect - Analog Designers make circuits which record physical observations for further analysis or alter the signal in real time for further analysis with other methods.




Circuit which converts and amplifies a SiPM signal for further analysis

The silicon wafer layout for the circuit which measures 78 by 55 microns. -The width of hair is between 10 to 180 microns

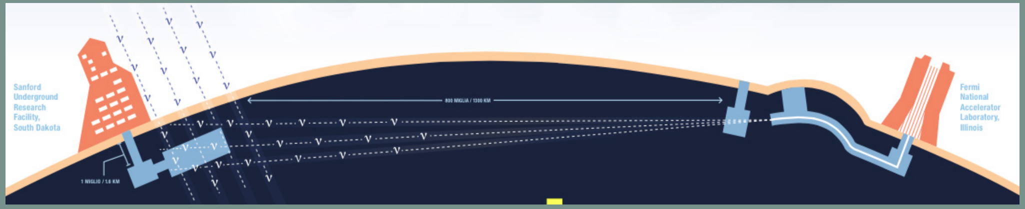



Charles White
whitece6@hawaii.edu

# The digital component for Q-Pix pixilated readout concept.

Vasily Shebalin, postdoc
professors : Kurtis Nishimura, Gary Varner
e-mail:shebalin@hawaii.edu

## DUNE: the next big thing in ν physics

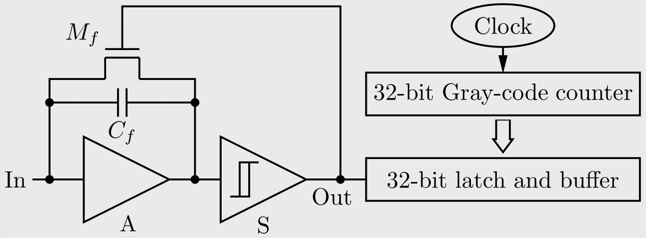


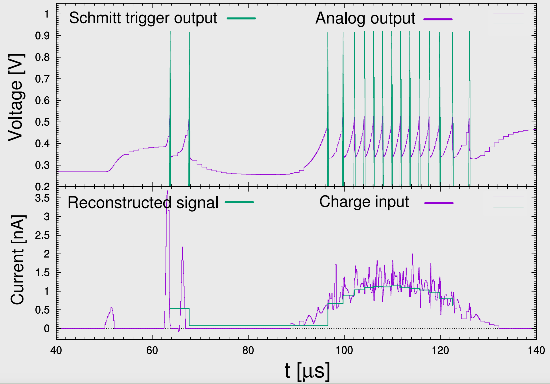

Far detector : LAr TPC + pixelated readout to help with track reconstruction.

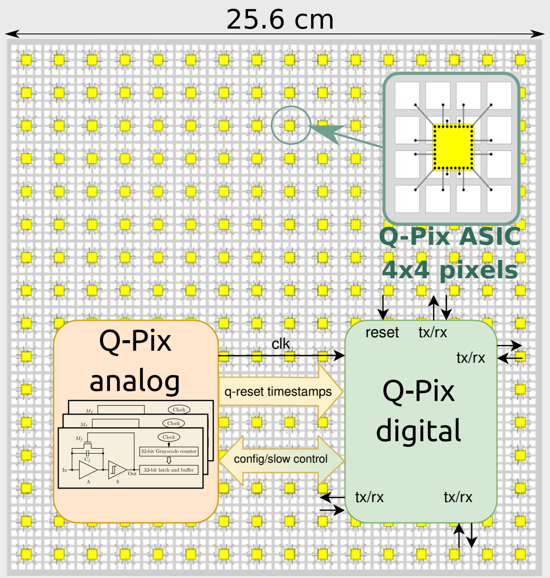
Novel QPix concept - an option under development.

## Q-Pix concept

Self-triggering charge integrate-reset (CIR) blocks generate reset pulses for a fixed amount of input charge => detect pulses, reconstruct charge.

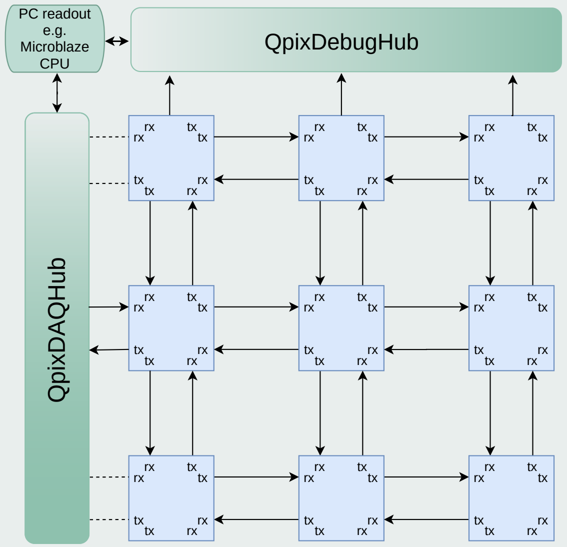


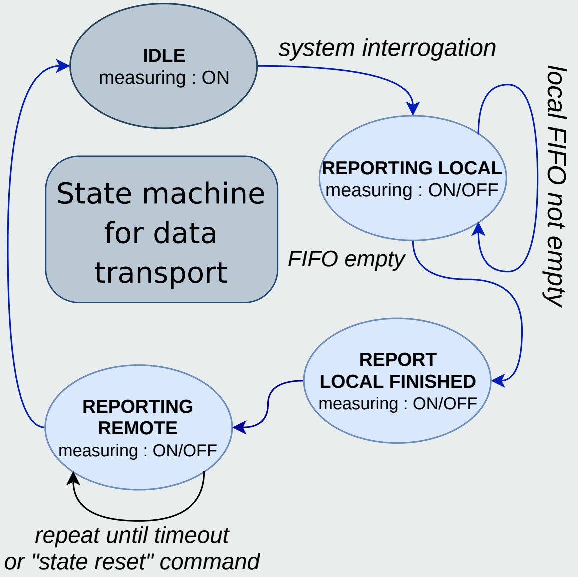




A "tile" as a basic unit of 16x16 ASICS (4096 4mmx4mm pixels)

## Our part : QPix digital component



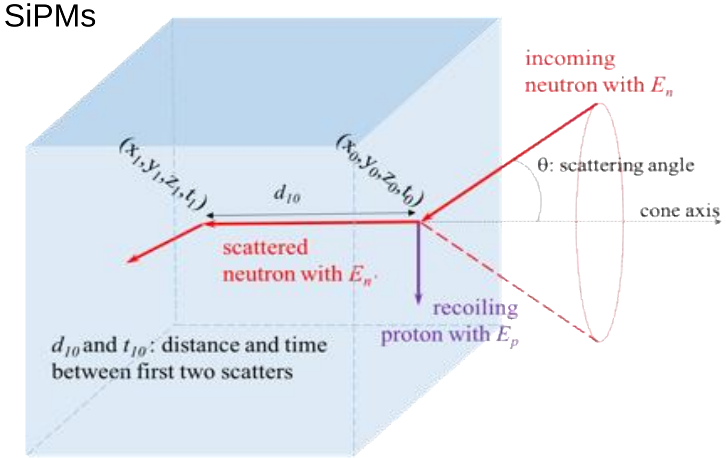




- The design utilizes synthesised logic.
- Reconfigurable inter-ASIC communication.
- Data transfer to the DAQ node through neighbour ASICs.
- Slow control and monitoring data flow.

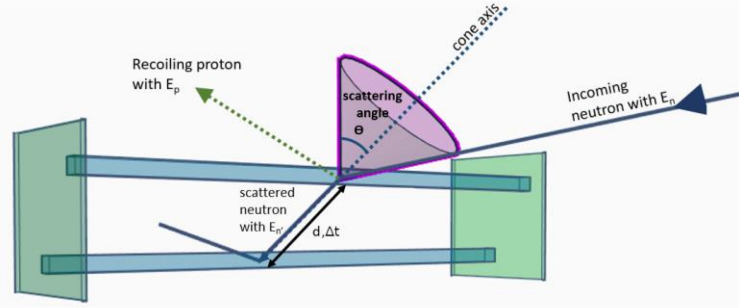
- A full design of the Q-Pix digital component has been implemented in a Xilinx Zynq-7 FPGA including multiple ASIC blocks arranged in an array to emulate ASIC-to-ASIC functionality.
- First version of Q-Pix analog and digital are planned as separate submission.
- FPGA-based board prototype for the digital component with low-power Lattice Semiconductor chips is under development by UH team.

# Single Volume Scatter Camera:

Reconstruct double neutron scatters
- Fast timing to reconstruct energy
- Require spatial resolution O(~1cm) to reconstruct and overlay cones
- Fast scintillators coupled to SiPMs




"Monolithic" Design
- Complicated algorithms
- "Simple" Mechanical Design

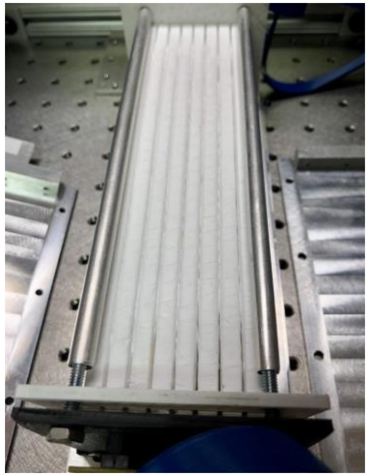


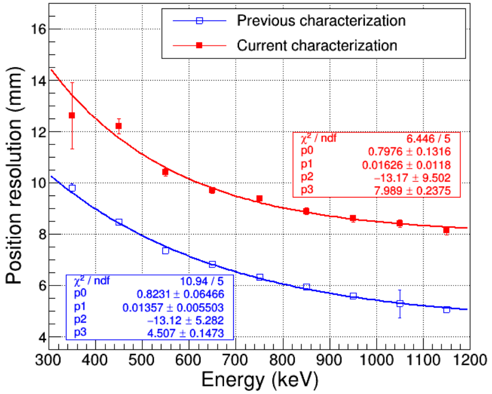

"OS" Design
- "Simple" algorithms
- Complicated Mechanical Design

# Optically Segmented (OS) Implementations:

## OS 1:

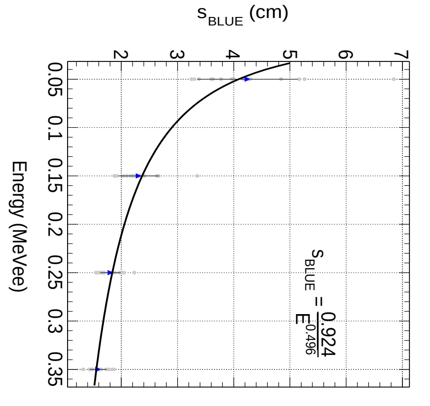
- Constructed at UH
- 128 channels (64 bars)
- Large electrical crosstalk motivated design of second prototype
- Overall resolution limited by timing






## OS 2:

- Constructed at Sandia National Labs
- "Simple" 32 channel (16 bar) Modular Design
- Improves interaction time resolution by nearly a factor of 2 (400 ps ~ 250 ps)





Kevin Keefe
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# David Rubin: Observational Cosmology

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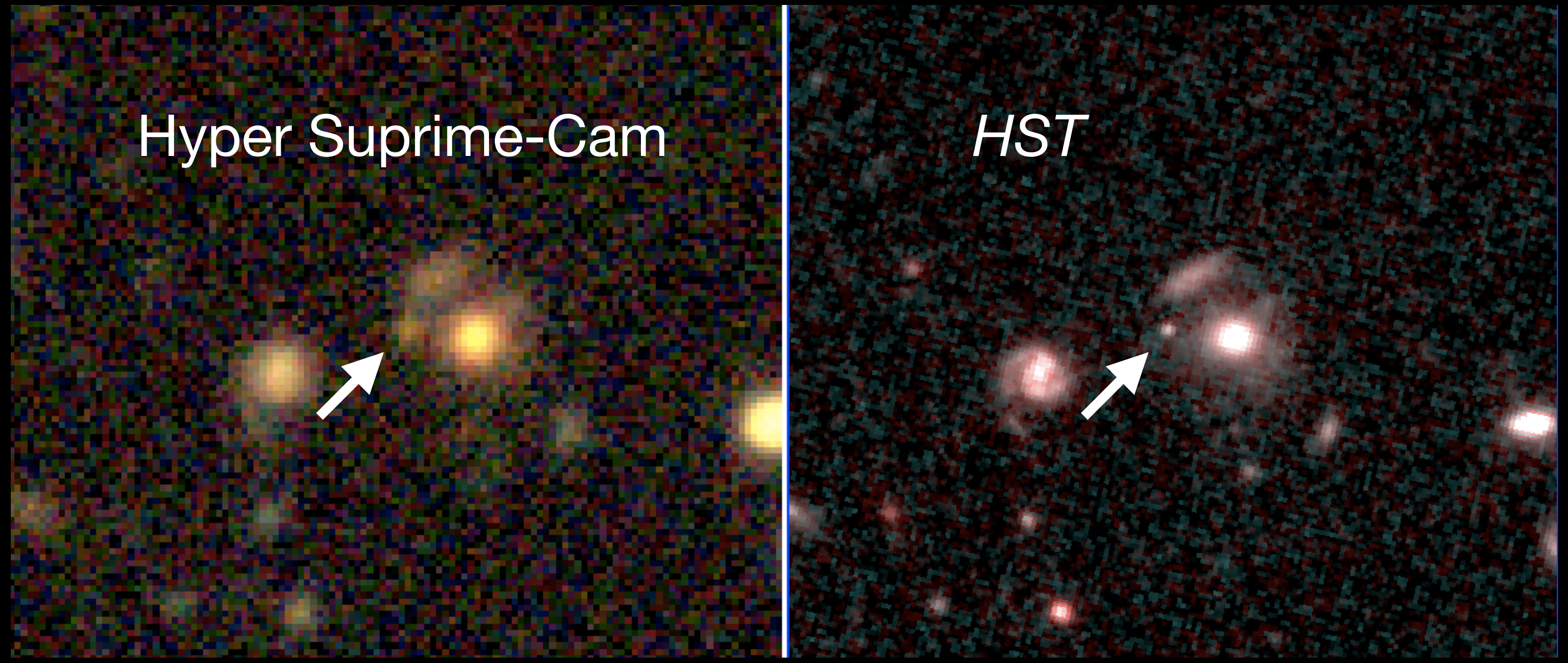
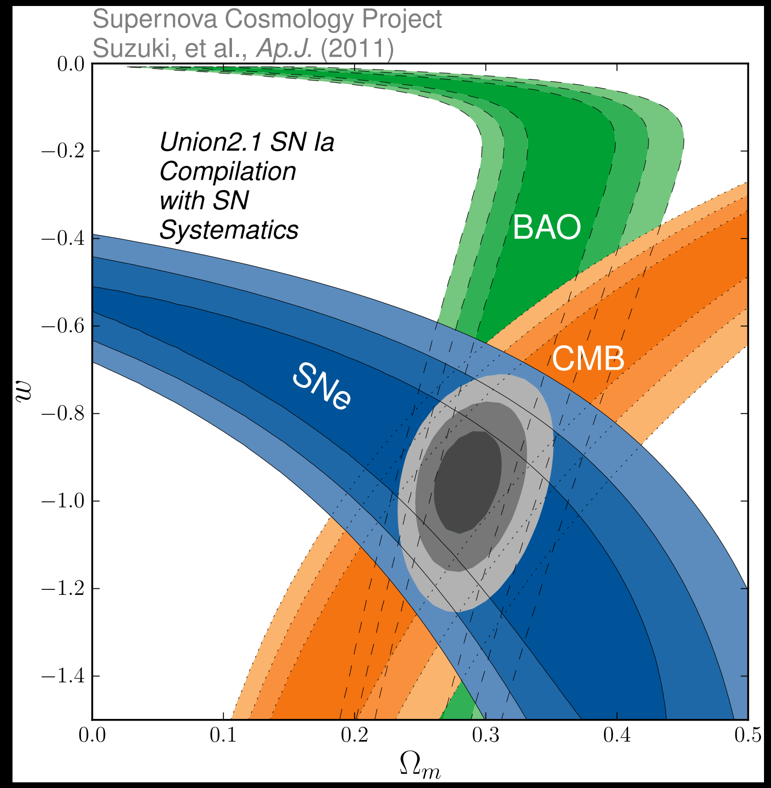
**Now Hiring!**

## Cosmology Surveys

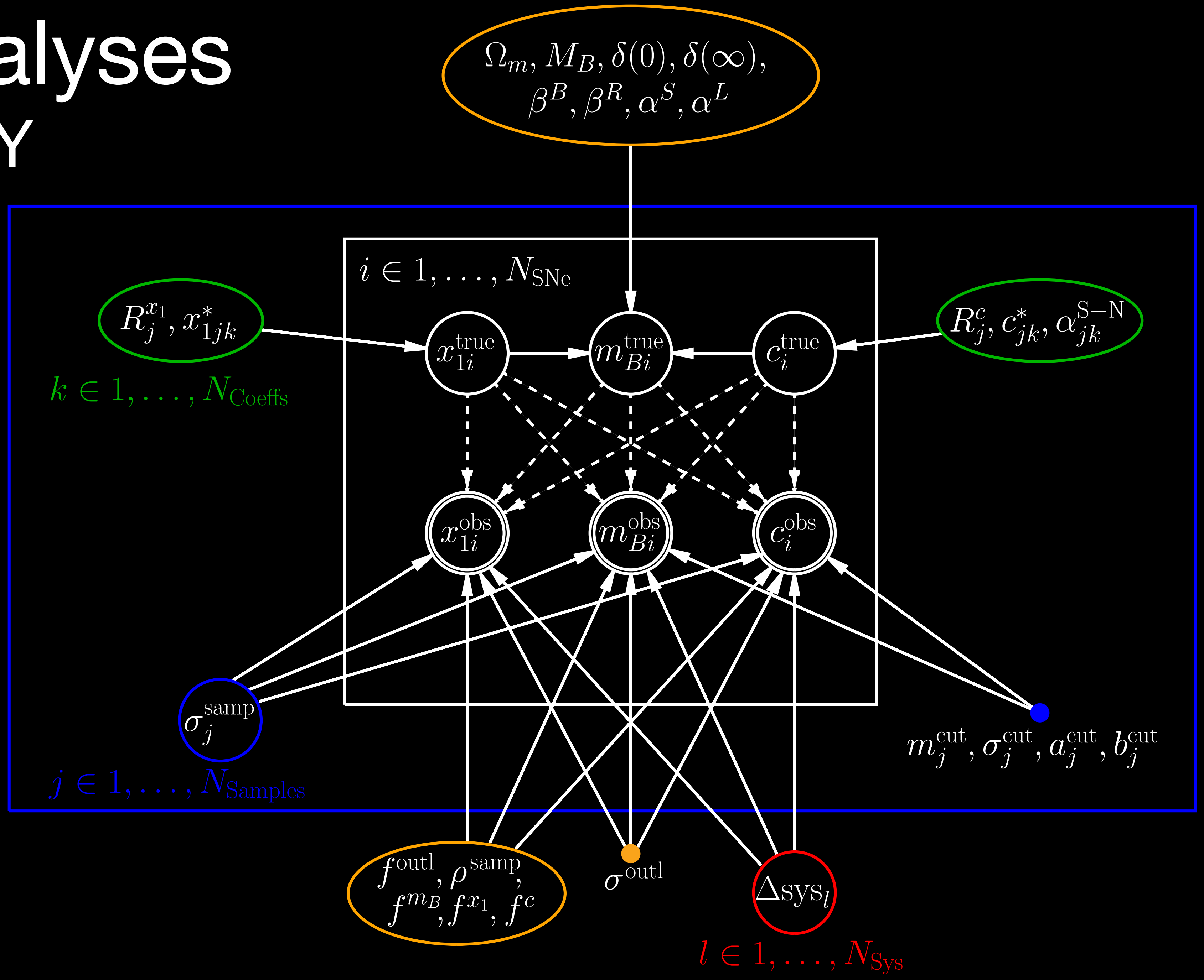
- Measuring gravity and dark energy
- SUbaru Supernovae with *Hubble* Infrared, (SUSHI)
- Nearby SN surveys with the 2.2m, UKIRT, VYSOS, IRTF, and others



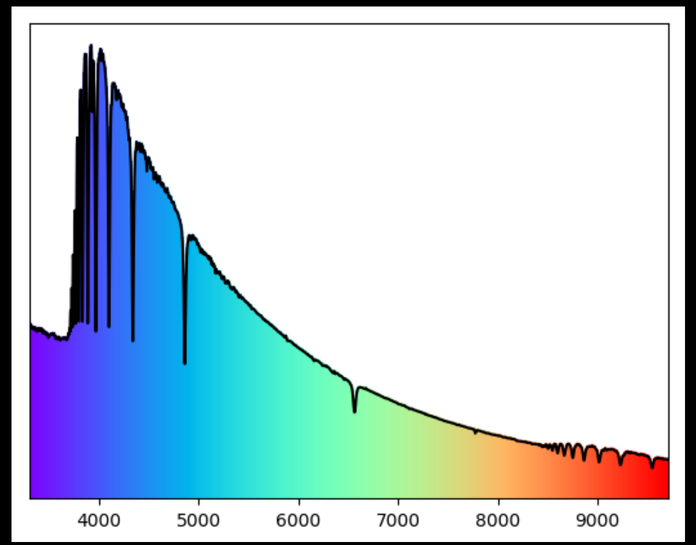

## SN Standardization and Cosmology Analyses

- Unified Nonlinear Inference for Type Ia cosmologY
- Twin SN Statistics
- Union Cosmology Analyses
- Hubble constant measurements
- Blinded analyses




## Calibration

- Photometry methods
- Calibration methods
- Flux scale



# Cosmic-Ray Antinuclei

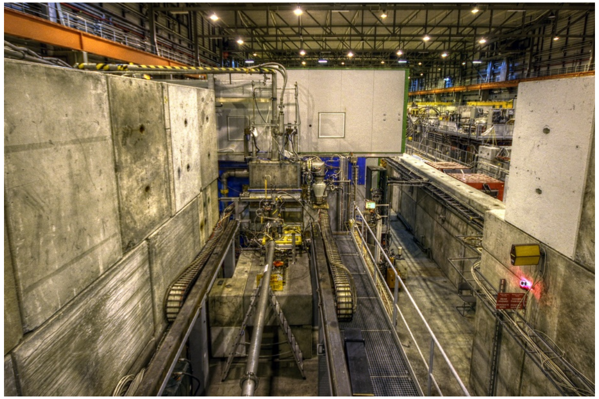
# CR$\bar{A}$

Philip von Doetinchem (PI), Cory Gerrity (G), Diego Gomez (PD), Bobby Lyon (G), Jesus Negrete (G) , Anirvan Shukla (G), Achim Stoessl (PD), Hershel Weiner (UG)

- Measurement of cosmic-ray antinuclei is a promising way to search for “new” physics

- Detection of cosmic-ray antinuclei is experimentally challenging
  → **multiple experiments needed**
  - AMS-02 on the ISS since 2011
  - GAPS first balloon flight planned for 2022

- cross section measurements needed to improve understanding of antinuclei production:



Ground-based measurements with NA61/SHINE


Review article: JCAP08 035 (2020), arXiv:2002.04163
GAPS AR app: http://go.hawaii.edu/rK3

Diego Gomez
Jesus Negrete

Philip von Doetinchem
Associate Professor

## Search for Cosmic-Ray Antinuclei

Indirect detection of Dark Matter or other exotic sources

## Cosmic-Ray Nuclei (Deuteron)

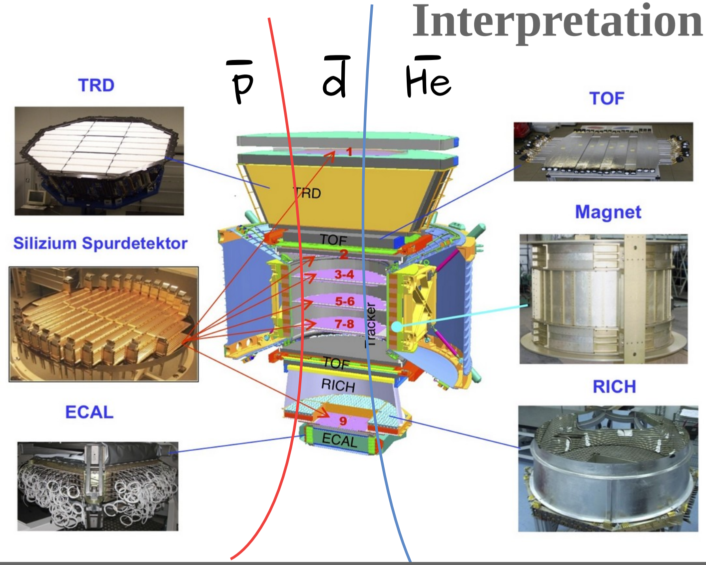
Information about cosmic-ray propagation in the Galaxy

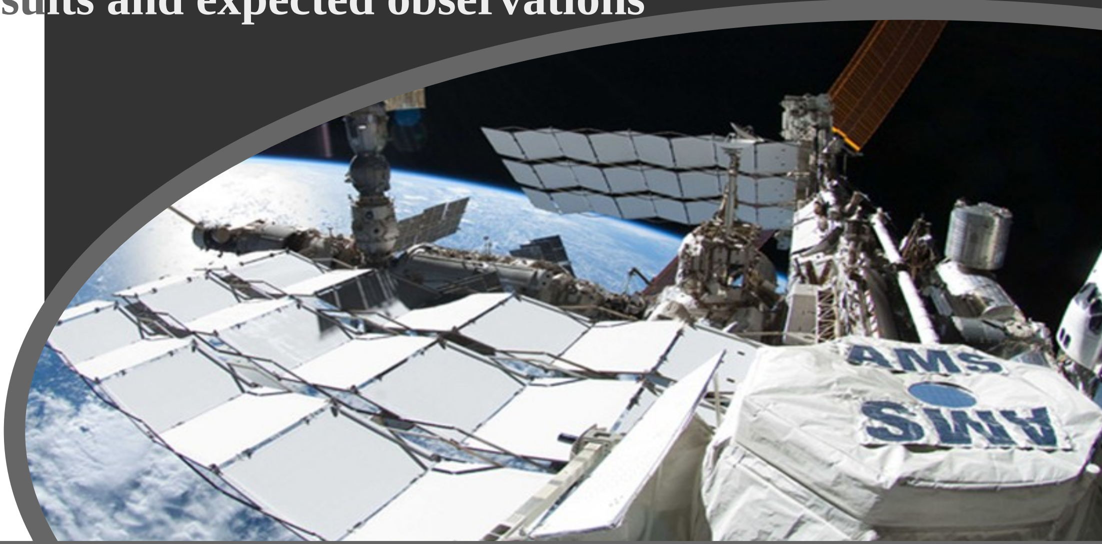
## AMS Experiment

Nuclei and Antinuclei are identified by measuring their masses and charge sign

## Modeling antinuclei and nuclei production

Interpretation of new results and expected observations

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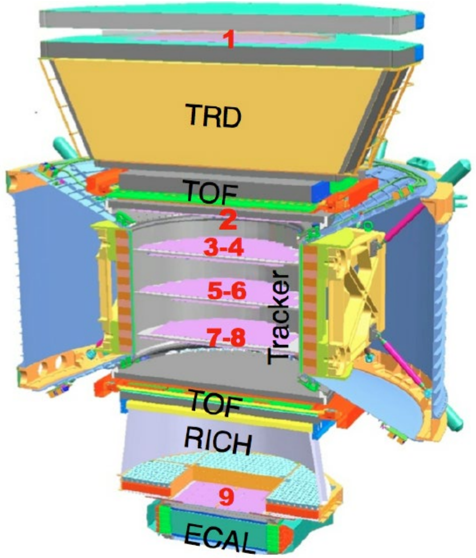
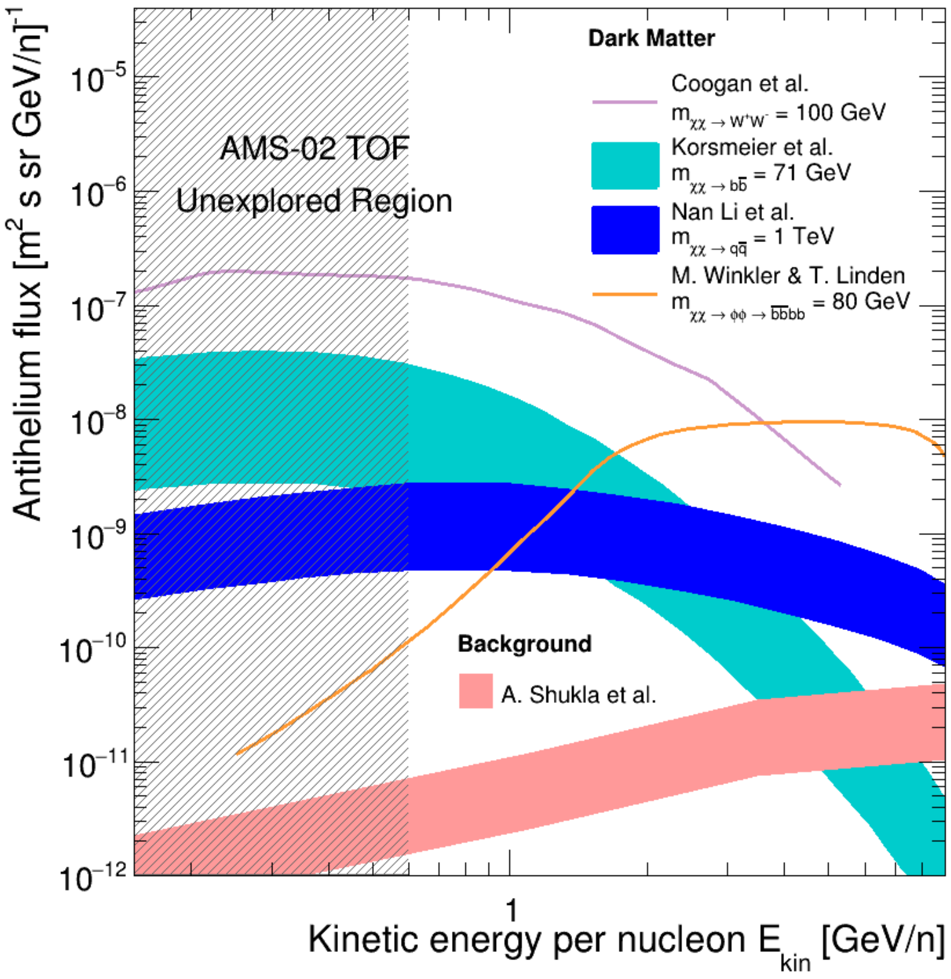
# Jesus Negrete
# Bridge Student

P. von Doetinchem

- Searching for Antihelium at low Energies
  - Learn about Antimatter asymmetry
  - Indirect detection for Dark matter
- Analysis with AMS-02
  - Using the TOF ($\beta$) and Tracker/ Magnet (R, Z)

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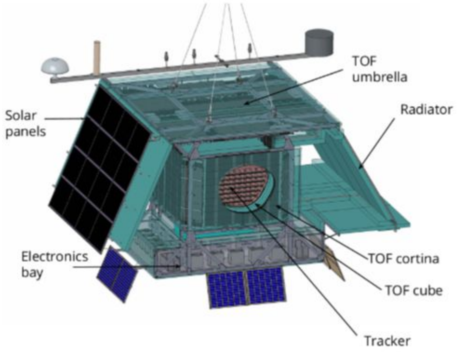
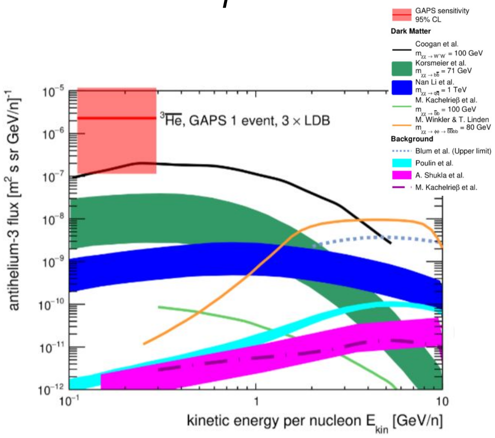
# Achim Stoessl

Postdoctoral researcher, GAPS experiment, Philip von Doetinchem

stoessl@hawaii.edu




*GAPS experiment*




GAPS - *General AntiParticle Spectrometer*
Balloon experiment to study antinuclei in cosmic rays, smoking gun signal for dark matter.

<u>Work at UH:</u>
Characterizing and testing Si(Li) tracker detectors.(→ Cory)

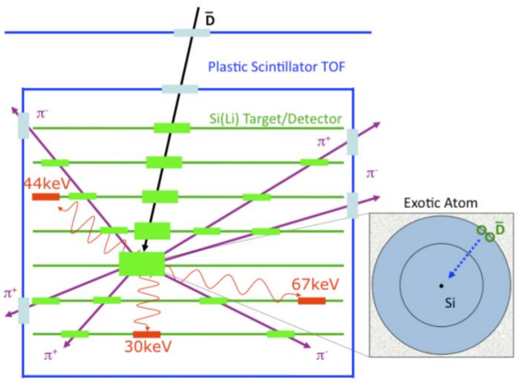
Support for prototype and integration

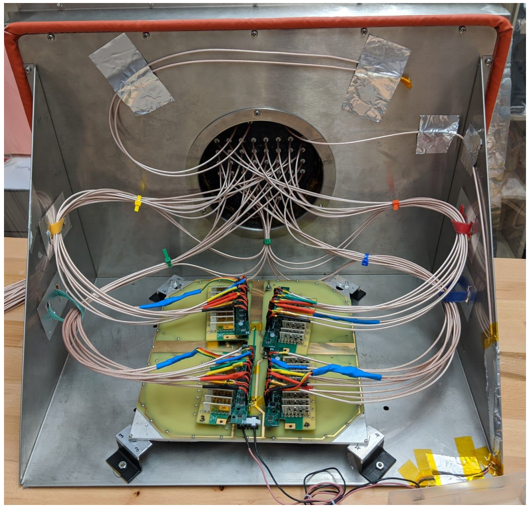
Simulation: High precision geometry modeling

Analysis:
E.g studying of anti-He3 capabilities [ICRC proceedings]

***First 6 flight modules Arranged for GAPS prototype at MIT***

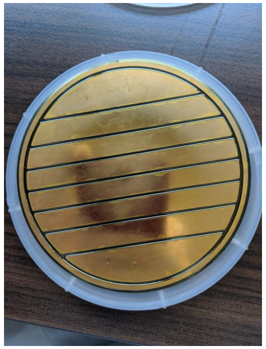
# General Anti-Particle Spectrometer (GAPS) Cory Gerrity (von Doetinchem Group)



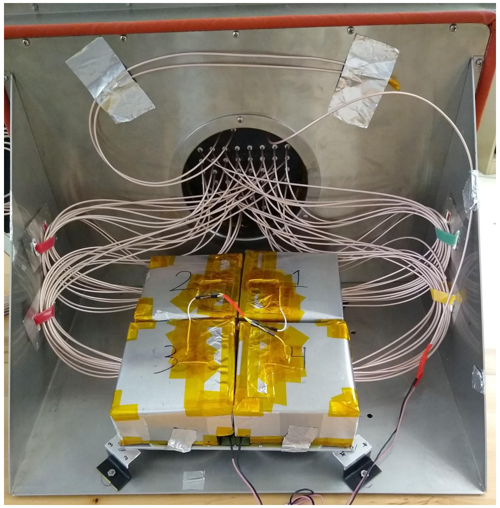



4-Detector module mounted to door.

Our “clean-er room,” humidty controlled for module mounting



A single GAPS Si(Li) 8-strip detector wafer



w/ Faraday cages

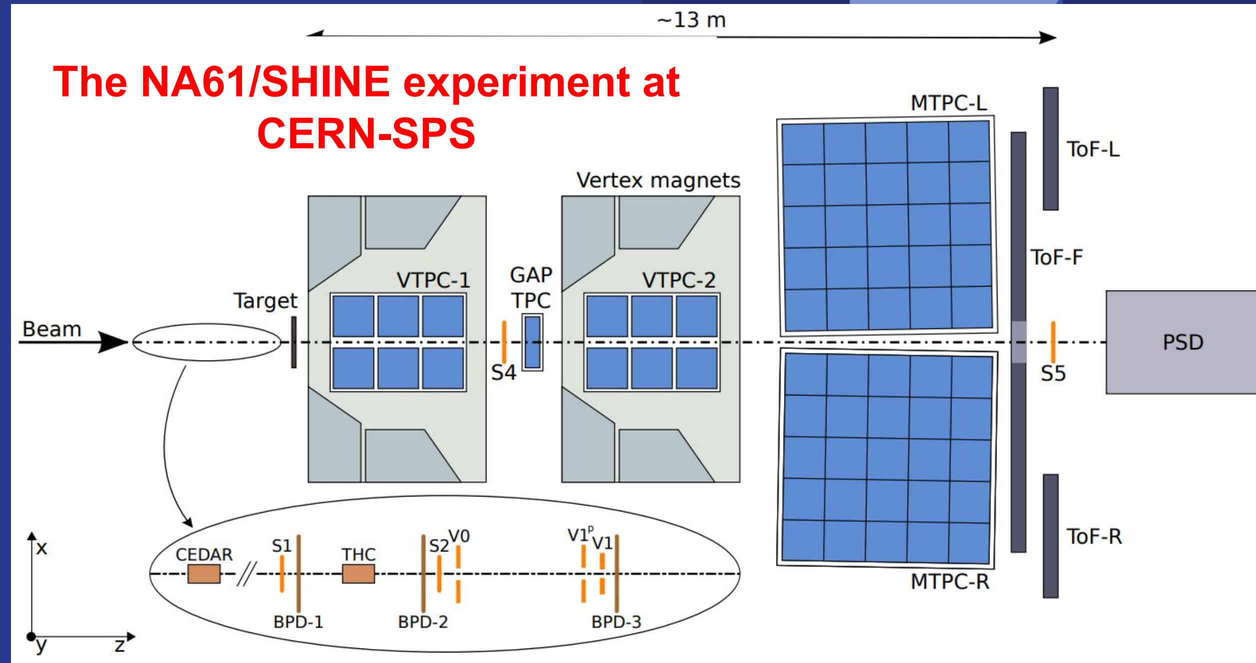
Cold-chamber/readout electronics

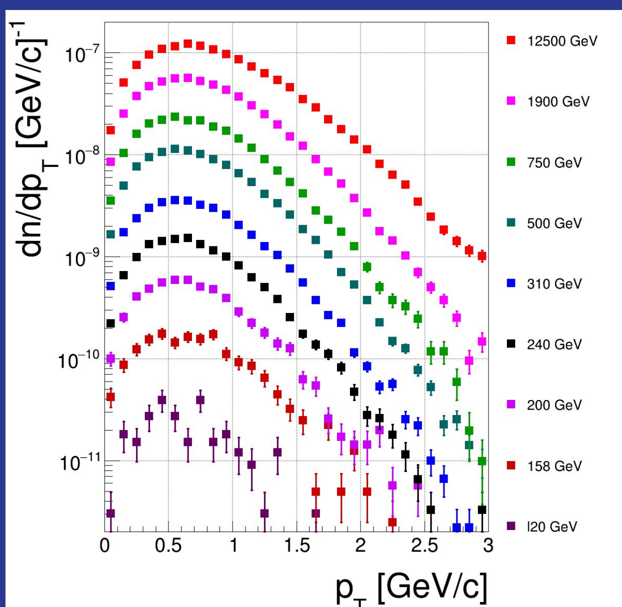
# Anirvan Shukla

anirvan@hawaii.edu

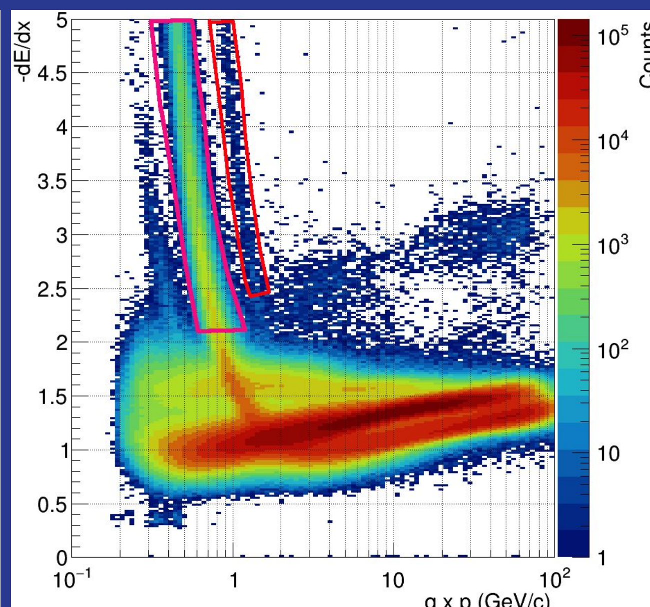
I am a graduate student, and I work with Philip on:

- Understanding the production of light nuclei in p-p collisions at the NA61 experiment at CERN.
- Simulating the production of light antiparticles in the interstellar medium, and their propagation through our galaxy.

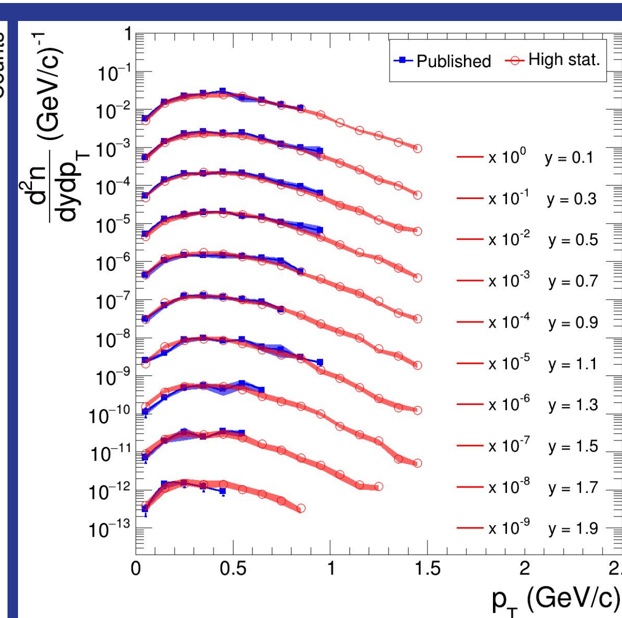



5000 CPU-years of simulations to produce this AntiHe-3 spectra




Energy deposition in NA61 TPCs as function of momentum

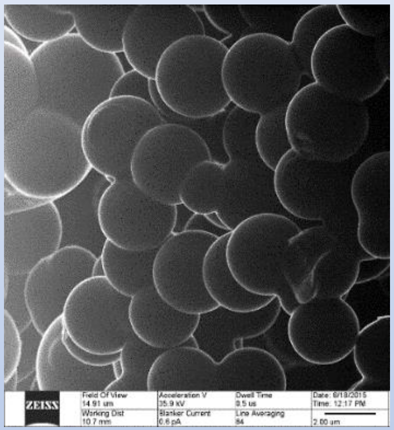


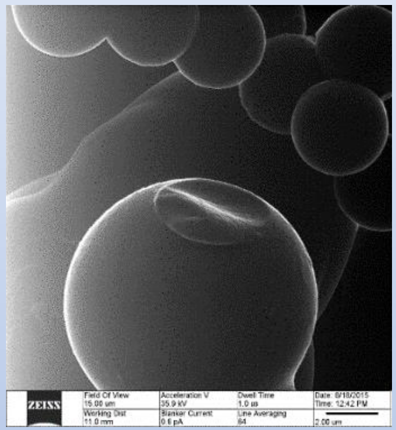

Antiproton spectra as function of rapidity and $p_T$

# Nanophysics Klaus Sattler sattler@hawaii.edu

Website: https://sites.google.com/a/hawaii.edu/klaus-sattler-lab/

## Ultralight Carbon Nanofoam

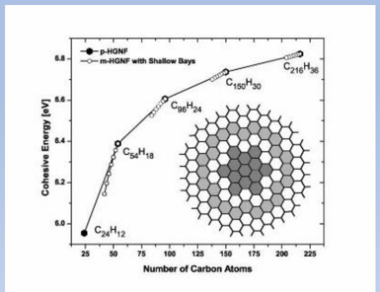


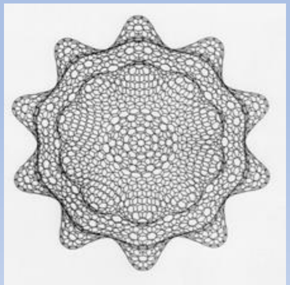




- Density ~5% of graphite density
- Micropearls; 2D-3D Network
- Highly porous on the nanoscale
- Very high storage capacity
- Study of fluid dynamics in nanochannels
- Produced by hydrothermal carbonization
- Analytic methods used:
- SEM, TEM, HIM, XPS, Raman, FTIR, DLS
- Applications in Nanomedicine,….

## Graphene Quantum Dots (Materials Design with the Computer)

- Nanoflakes, and search for new types of 5-,6-,7- networks
- Determine structure-activity relationships (SAR), magic numbers,...

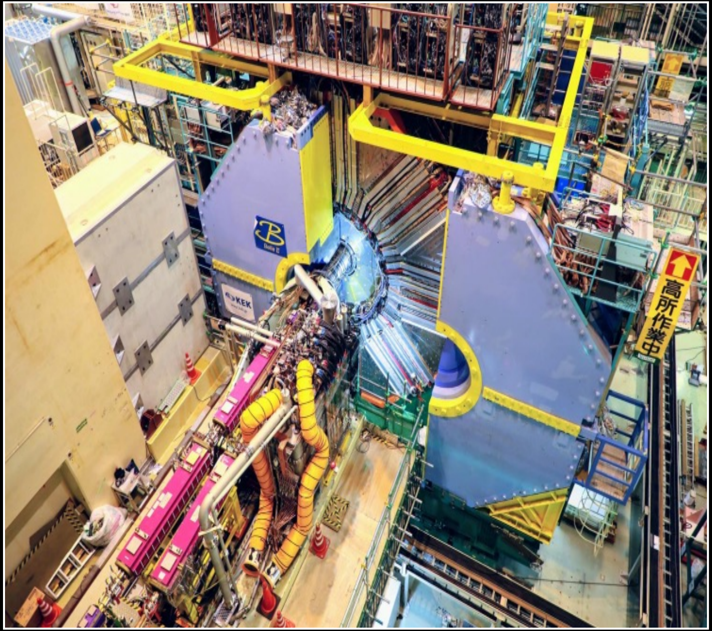


# Belle II Experiment

*Search for new physics at world's brightest particle collider*

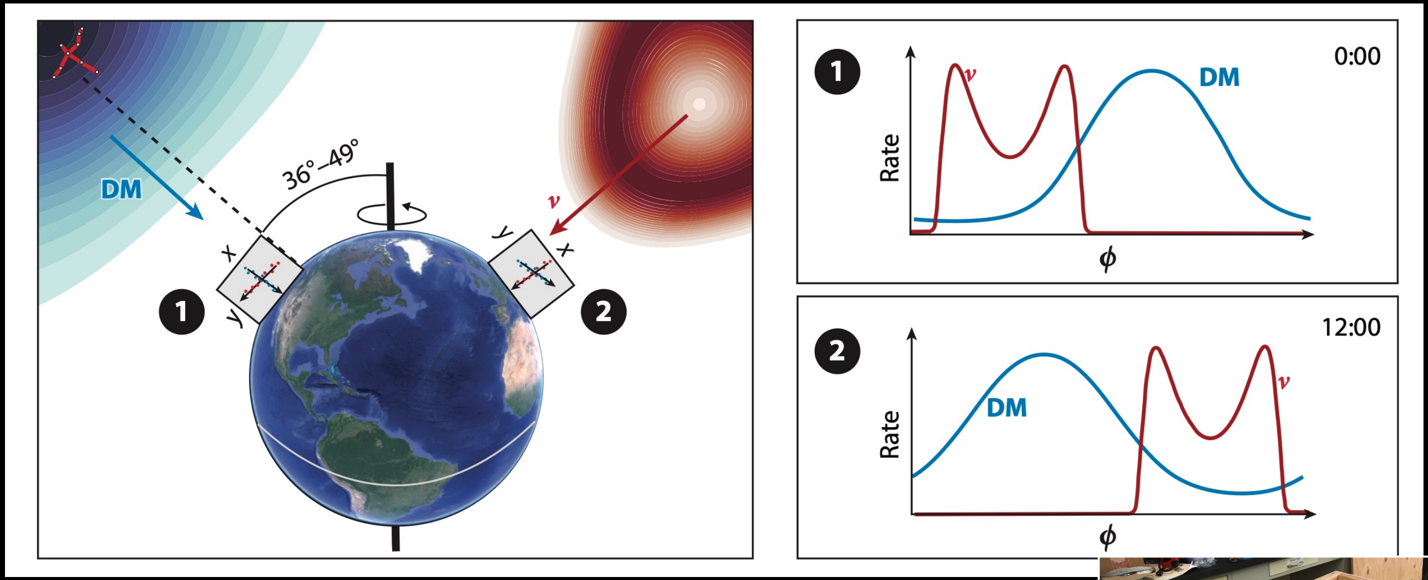
- *Are we seeing physics beyond the standard model in B-meson decays?*
- *Are there measurable limits of quantum entanglement?*



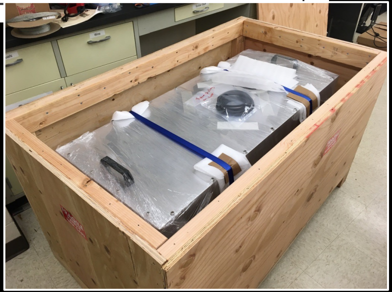
https://www.belle2.org

# CYGNUS Experiment

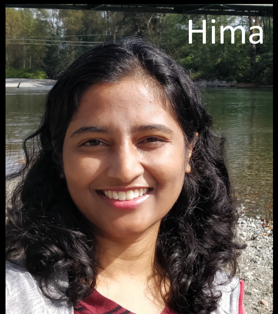
*Proposed directional experiment that will search for dark matter particles and measure solar neutrinos*




https://doi.org/10.1146/annurev-nucl-020821-035016



*New detector prototypes under construction!*
Looking for motivated undergrads to help!
Contact Sven Vahsen, sevahsen@hawaii.edu

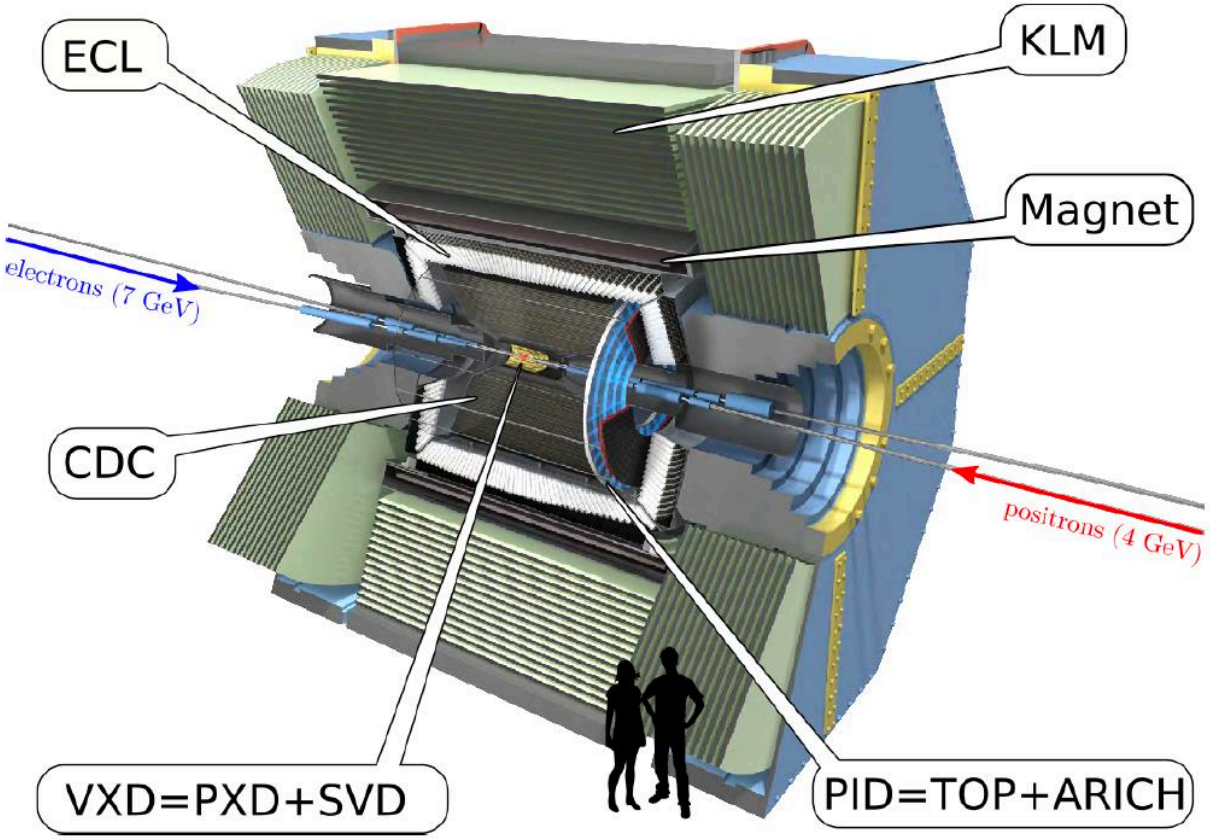







# Analyze B meson decays

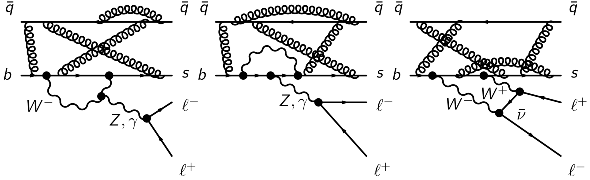
$$B^+ \rightarrow K^{*+} + l^+ + l^-$$
$$\hookrightarrow K_L^0 + \pi^+$$




Hima Korandla Email: korandla@hawaii.edu
PI: Sven Vahsen Email: sevahsen@hawaii.edu

# Dr Alexei Sibidanov, e-mail: sibid@hawaii.edu

- Full time postdoctoral fellow at the University of Hawaii, December 2020 till present time.
  - Introduction of New Physics contributions into the EvtGen particle decay generator framework, particularly $B \to K^* \ell^+ \ell^-$ and $B \to D^* \ell^+ \nu$ to test Belle II sensitivity to them.
- Full time postdoctoral fellow at the University of Victoria, June 2015 – November 2020.
  - Belle II software development, mainly ECL
  - Precision test of Lepton Flavor Universality in the leptonic decays of the $\Upsilon(3S)$ resonance with the BaBar data, Phys. Rev. Lett. 125, 241801 (2020).
  - Efficient random number generator RANLUX++, Comput.Phys.Commun. 221 (2017) 299-303.
- Full time postdoctoral research associate at the University of Sydney, October 2010 – May 2015.
  - Search for $B \to \mu\nu$ at Belle – first time the null hypothesis is excluded with 90% CL, Phys.Rev.Lett. 121 (2018) 3, 031801
  - Study of charmless semileptonic decays of $B$ with Belle data and $V_{\rm ub}$ determination, Phys.Rev.D 88 (2013) 3, 032005




- Full time researcher at Budker Institute of Nuclear Physics and part time at Laboratori Nazionali di Frascati, 2003–2010
  - Design of a drift chamber for the CMD-3 detector as well as its software support.
  - Precise MC generator with radiative corrections for processes in $e^+e^-$ annihilation ($<$ 0.2 % accuracy), Eur. Phys. J. C **46**, 689 (2006), Eur.Phys.J.C 71 (2011) 1597 – part of my PhD
  - Precision measurement of the $e^+e^- \to \pi^+\pi^-$ cross section, JETP Lett. **84**, 413 (2006) – part of my PhD
  - First observation of quantum interference in the neutral kaon system, Phys. Lett. B **642**, 315 (2006)
  - Precision measurement of $K^- \to e^-\bar{\nu}_e$, Eur.Phys.J.C 64 (2009) 627-636
  - Study of $K_L$ decay properties, and $V_{\rm us}$, Phys.Lett.B 632 (2006) 43-50

Majd Ghrear
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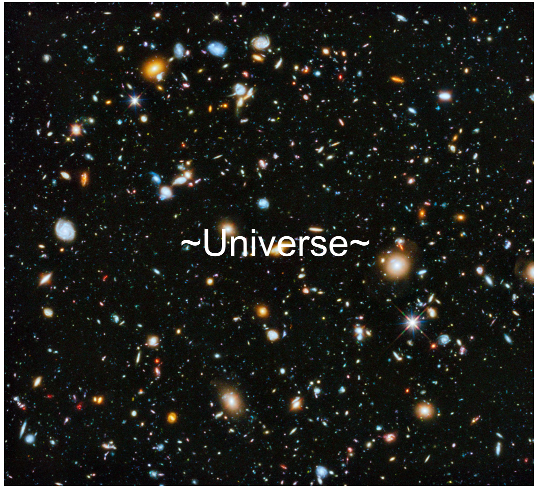
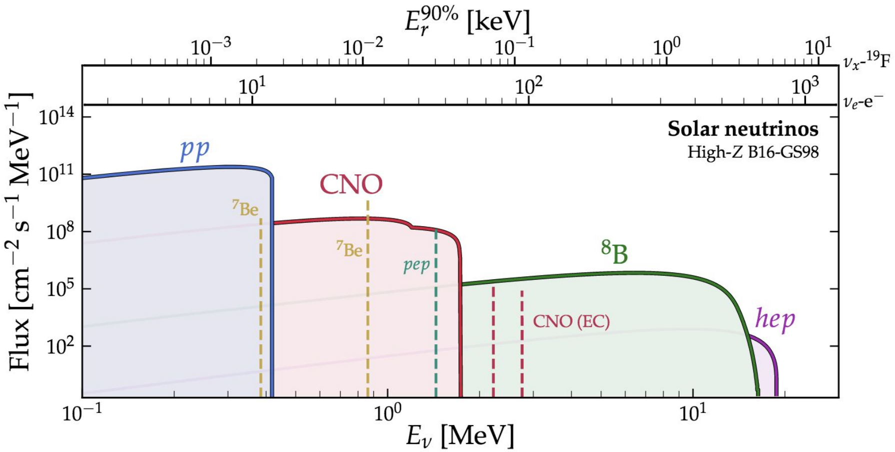
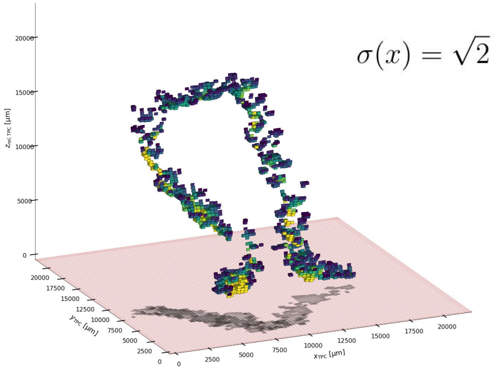



Source: CYGNUS for Neutrinos



$$\sigma(x) = \sqrt{2}\left[a^2 x(1+0.058\ln\frac{x}{b})^2 + c^2 x^{-3}\right]^{1/2}$$

$$a \equiv \frac{1}{\sqrt{3}}\frac{13.6\text{MeV}}{\beta c p\sqrt{X_o}}$$

$$b \equiv X_o\beta^2$$

$$c \equiv \sigma_y\sqrt{\frac{12W}{dE/dx}}$$

Dr. Andrii Natochii
natochii@hawaii.edu
Based at KEK, Japan
PI: Prof. Sven. E. Vahsen

## Current research field

- ❖ Beam-induced background simulation and measurements in Belle II
- ❖ SuperKEKB collimation system operation and optimization

UNIVERSITY of HAWAIʻI MĀNOA

## SuperKEKB Collider

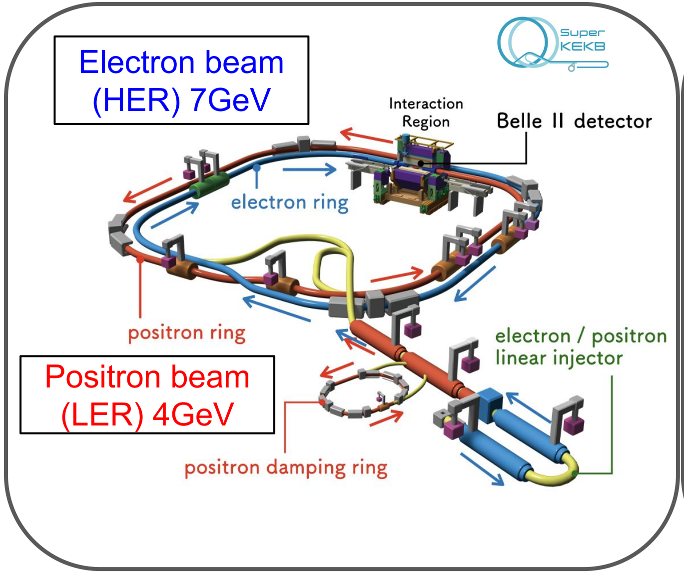
In 2021, achieved the world's highest instantaneous luminosity of $3 \times 10^{34}$ $cm^{-2}s^{-1}$

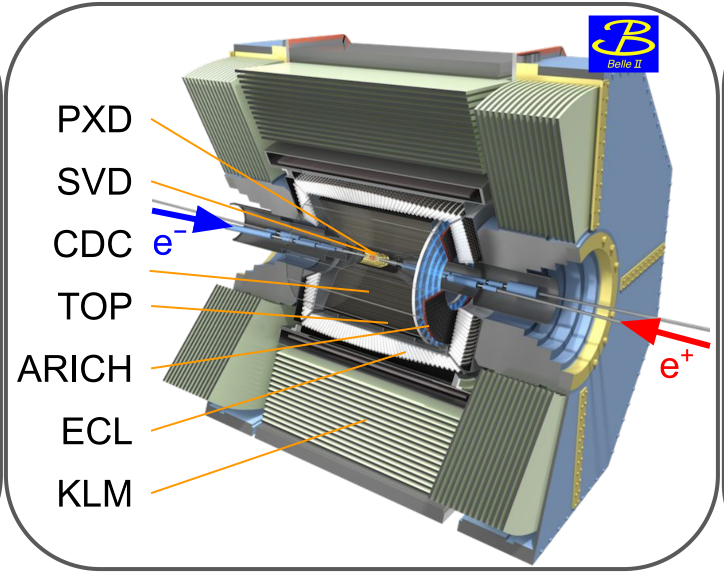
## Belle II Detector

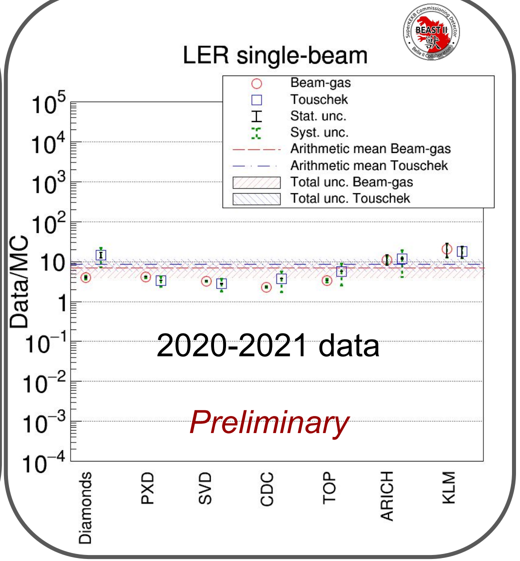
Is expected to collect around 50 times more data than its predecessor

## Data/MC Ratio

The current status of the single-beam background understanding in Belle II

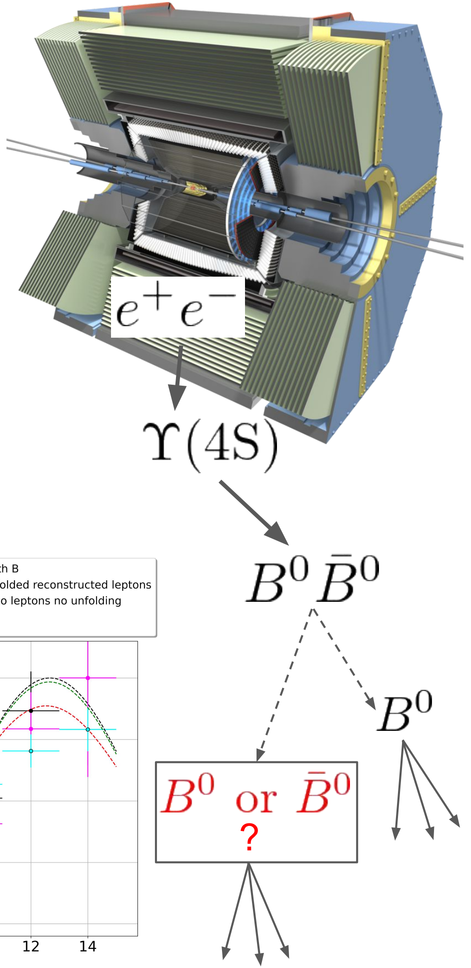


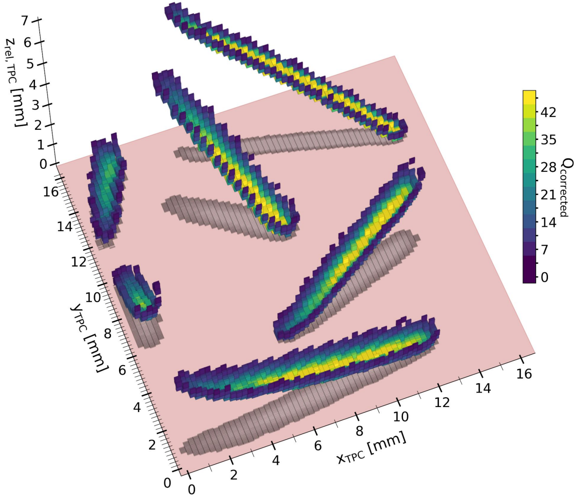
# Neutron backgrounds and tests of quantum decoherence at Belle II

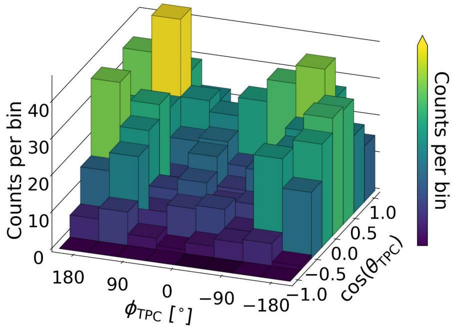

Jeff Schueler
jschuel@hawaii.edu

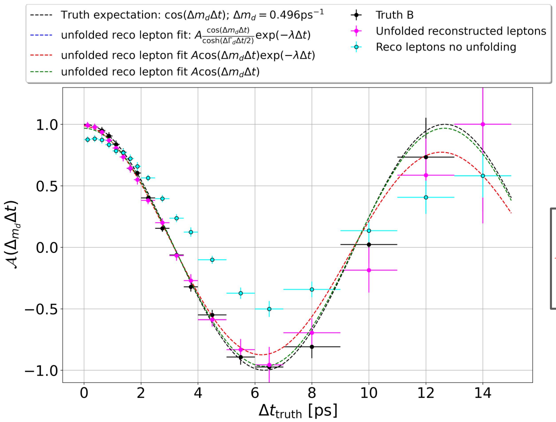


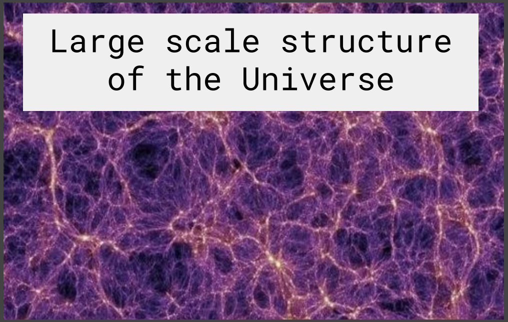

**Directional detection of neutron backgrounds at SuperKEKB**

**Flavor mixing in neutral B-meson pairs can be used to measure decoherence**



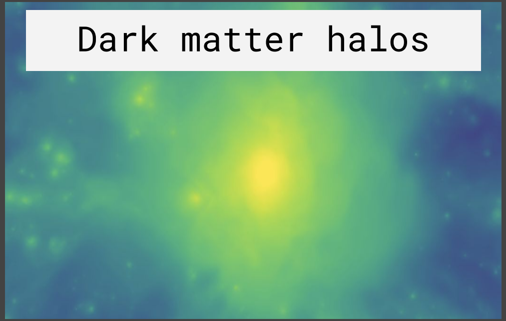






* Does the cosmological constant + cold dark matter model describe our Universe?

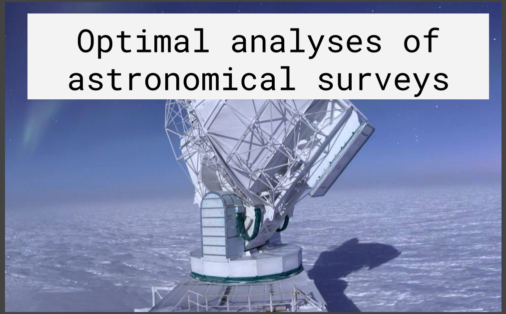
* Are late-time measurements of structure consistent with early-time measurements?

(with the Dark Energy Survey, South Pole Telescope, and Atacama Cosmology Telescope collaborations)




* How does accretion change the boundaries of dark matter halos?  (with DES, SPT and ACT)

* Can we detect signals from dark matter annihilation? (with Jason Kumar, Jack Runburg, Jacob Christy)




* How can we combine data from galaxy and CMB surveys to probe structure? (with DES, SPT, ACT)

* How can we use techniques such as approximate Bayesian computation and neural networks to extract information from astronomical datasets?
(with Jason Kumar, Jacob Christy, David Krejcik)

# Eric Baxter

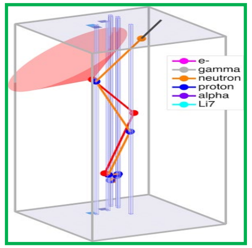
Email:
ebax@hawaii.edu

Faculty at IfA

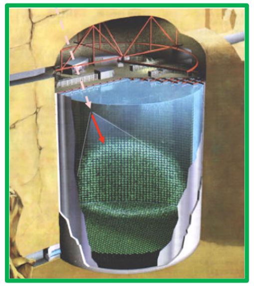
*If you're interested in joining weekly cosmology meetings, let me know!*

**Watchman:** deep mine in UK, neutrino detector 2026

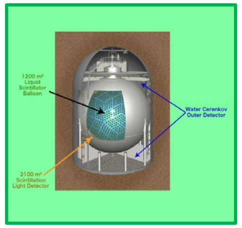
**Double Scatter Neutron camera:** UH and Sandia concluding



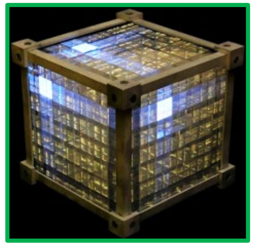

**SuperKamiokande:** continuing, Nobel in 2015 discovery of nu osc, now neutrons via Gadolinium



**KamLAND:** continuing, now best double beta limits, Korean reactors

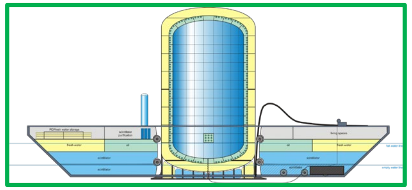


**NuLat:** Protoype in testing at VT, reactor nest year.



**Neutrino physics & astrophysics:** continue studies, writing and talks

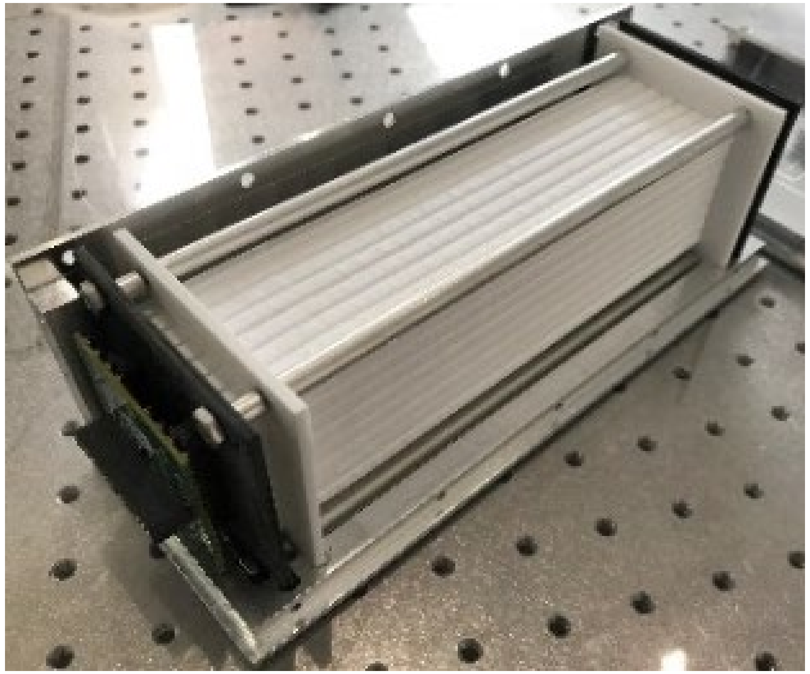
**Japanese Hanohano:** Under development with Tohoko U & JAMSTEC



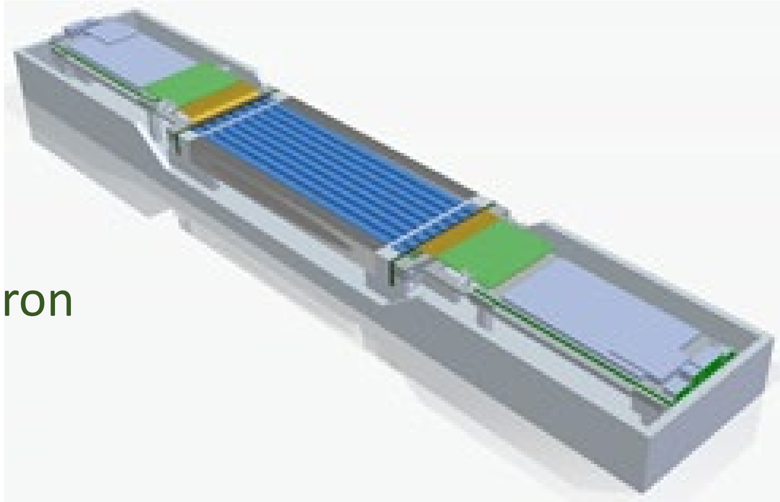
**UH Neutrino Team:** collabs Profs. Kurtis Nishimura, Jelena Maricic, Gary Varner; project manager Andrew Druetzler; departing post docs Aline Tellez and Salvador Ventura; grads Brian Crow, Jack Borusinski; 5 undergrads; recent grads Slava Li, Ryan Dorrill & Kevin Croker on postdoc

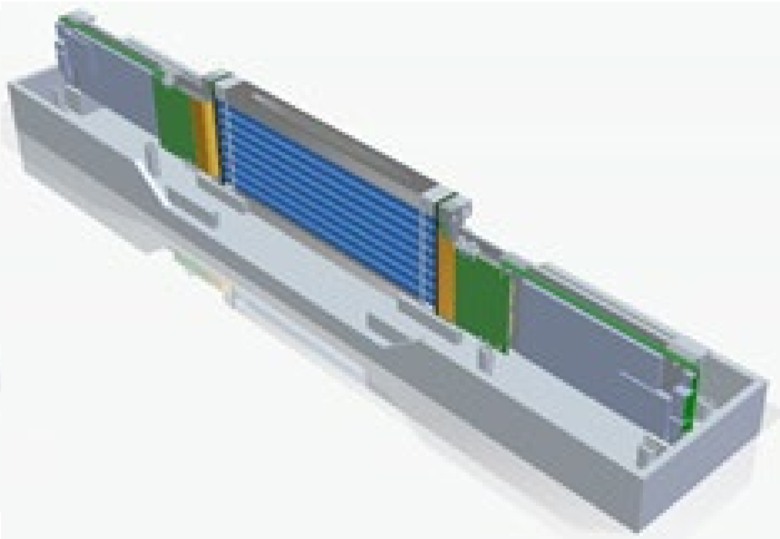
Andrew Druetzler – adruetzl@hawaii.edu

# SVSC COMING TO AN END!



- SVSC = Single Volume Scatter Camera
- Collaboration led by Sandia Labs in Livermore, CA
- 4 year program aiming to reconstruct neutron multi-scatters using compact detectors/imagers
- 18 UH team members over the years
    - 8 undergrads
    - 3 grads
    - 2 postdocs
    - 4 staff*
    - 2 faculty
- Two prototypes developed
- One last ditch effort to reconstruct neutron scatters





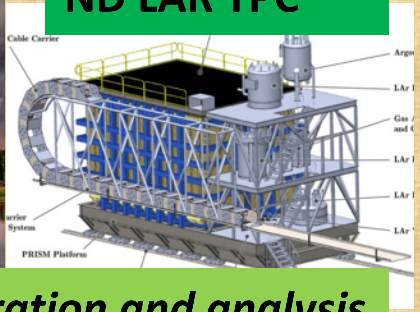
# NEUTRINOS
# DARK MATTER

Group members:
Jelena Maricic, PI
(jelena@phys.hawaii.edu)
Radovan Milincic
**Postdocs:** Ranjan Dharmapalan, John Koblanski

**Grads**: Alex Dvornikov, Victor Goicoechea Casanueva, Andrew Meyer

***Looking for grad students***

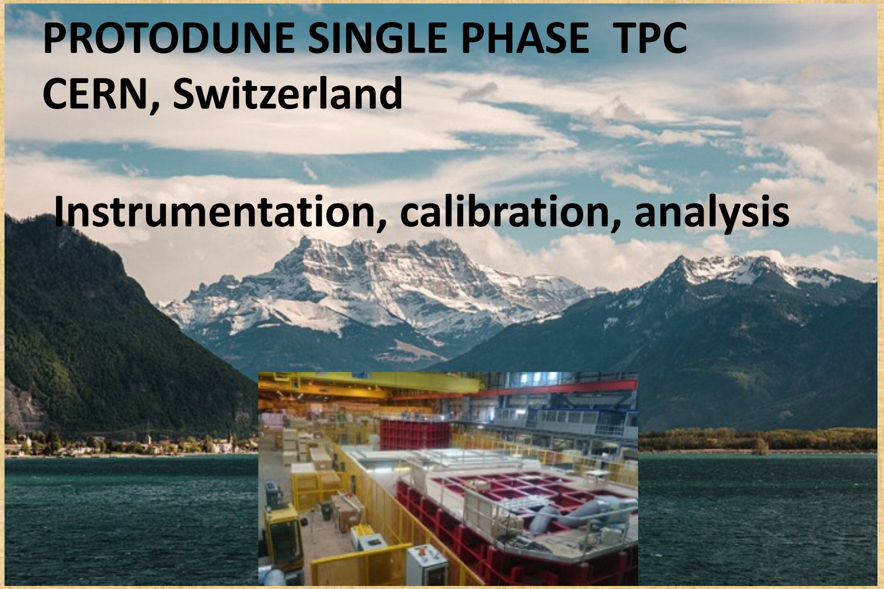

**ND LAR TPC**



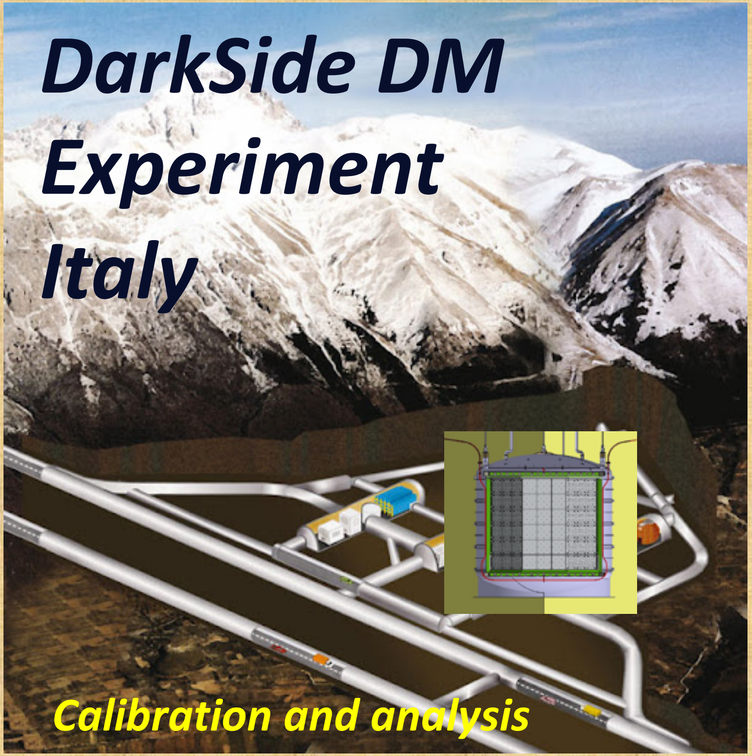

***PE Laser calibration and analysis***

**PROTODUNE SINGLE PHASE TPC**
**CERN, Switzerland**

**Instrumentation, calibration, analysis**

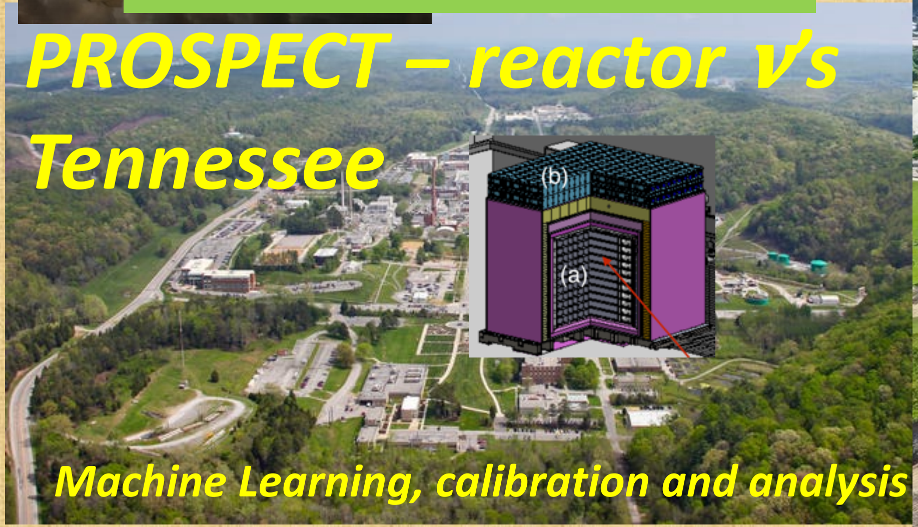


***DarkSide DM Experiment***
***Italy***



***Calibration and analysis***

***PROSPECT – reactor νs***
***Tennessee***




***Machine Learning, calibration and analysis***

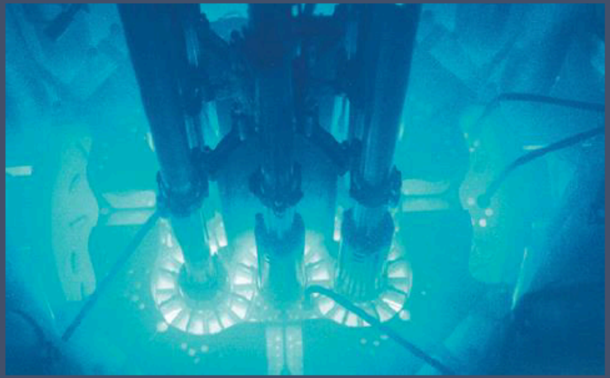
***DUNE***
***South Dakota***

**Long baseline *ν***

# Precision Reactor Oscillation and Spectrum Experiment (PROSPECT)

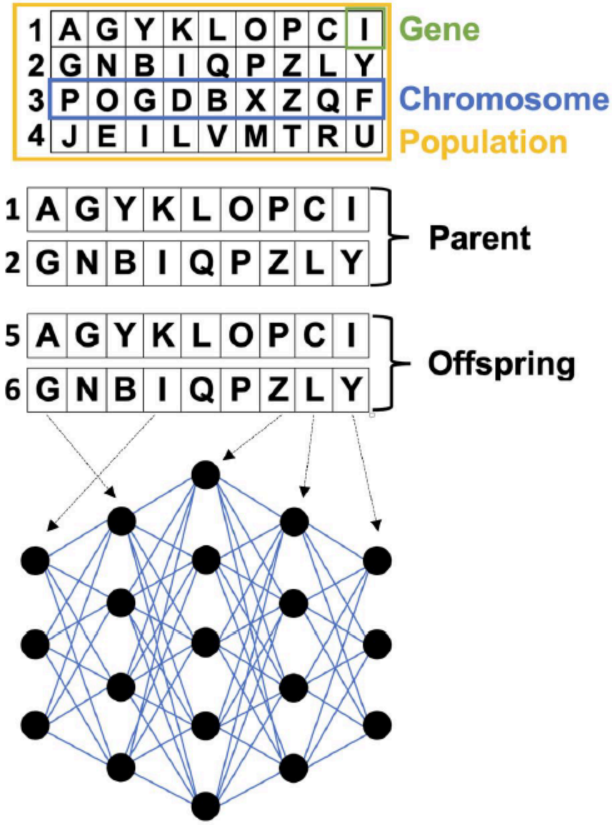
- PROSPECT is a Neutrino Experiment at Oak Ridge National Laboratory (ORNL)
- Detector is an 11x14 grid of Lithium-loaded Liquid Scintillators
- PROSPECT seeks to explain the anomaly between predicted models of reactor neutrino flux and observations
- Maybe Sterile Neutrinos?
- I'm working on calibration for an upgraded PROSPECT-II detector and measurements for absolute reactor flux

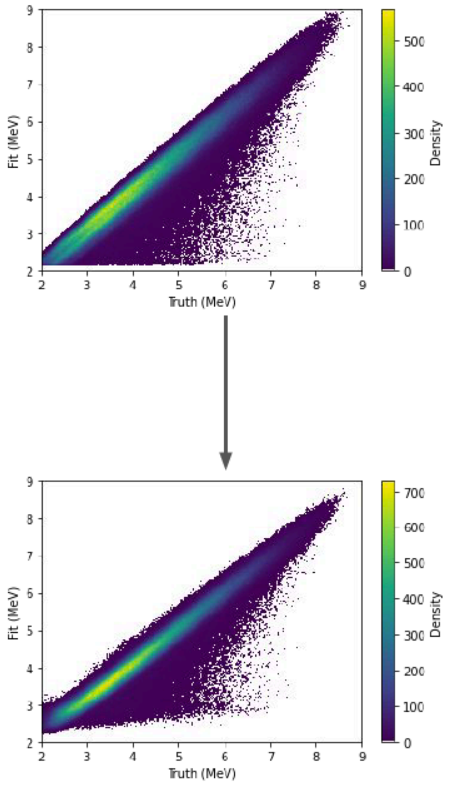
PROSPECT



Andrew Meyer andrewm9@hawaii.edu

# Precision Reactor Oscillation And Spectrum Experiment




- designed to make both a precise measurement of the antineutrino spectrum and probe ev-scale sterile neutrinos via neutrino oscillations.
- Li-doped liquid scintillator detector for both efficient detection of reactor antineutrinos through the inverse beta decay reaction and excellent background discrimination.
- Currently working to increase antineutrino position and energy resolution using a novel approach which uses deep learning model blueprints nested from within a genetic algorithm.
- Paper near completion

John Koblanski johnk2@hawaii.edu

Ranjan Dharmapalan (Postdoc)
Neutrino group working with Prof. Jelena Maricic
and Alex Dvornikov

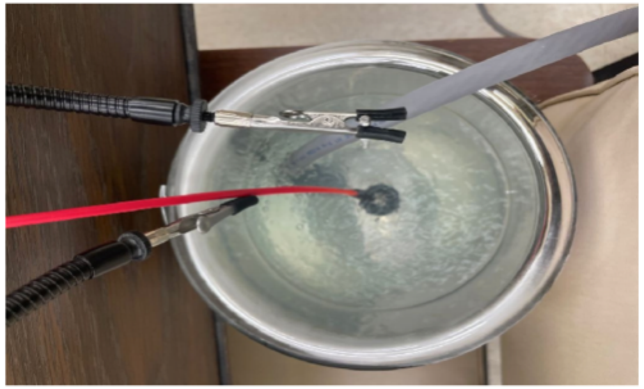
Previously:
- PhD work on MiniBooNE experiment. Neutrino cross sections and searching for sub-GeV dark matter
- Long baseline neutrino oscillations on NOvA experiment and Large Area Picosecond Photodetectors

Current work at Hawai’i:
Deep Underground Neutrino Experiment (DUNE). Answer questions like:
- Why is universe made up of matter rather than antimatter?
- Do protons decay?
- What can we learn from neutrinos produced in SuperNovae?

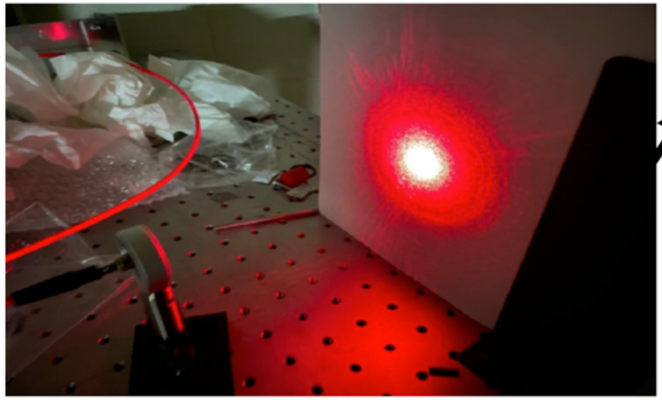
How to make sure the largest Liquid Argon Time Projection Chamber (LArTPC) to be built works and we understand the data?
- New ideas for detector calibration
- Design and test prototypes at our lab in Hawai’i
- Analyze the results from prototype experiments to guide the final design

Vacuum pump and test chamber

Electronics setup in the lab



Testing prototypes in LN2

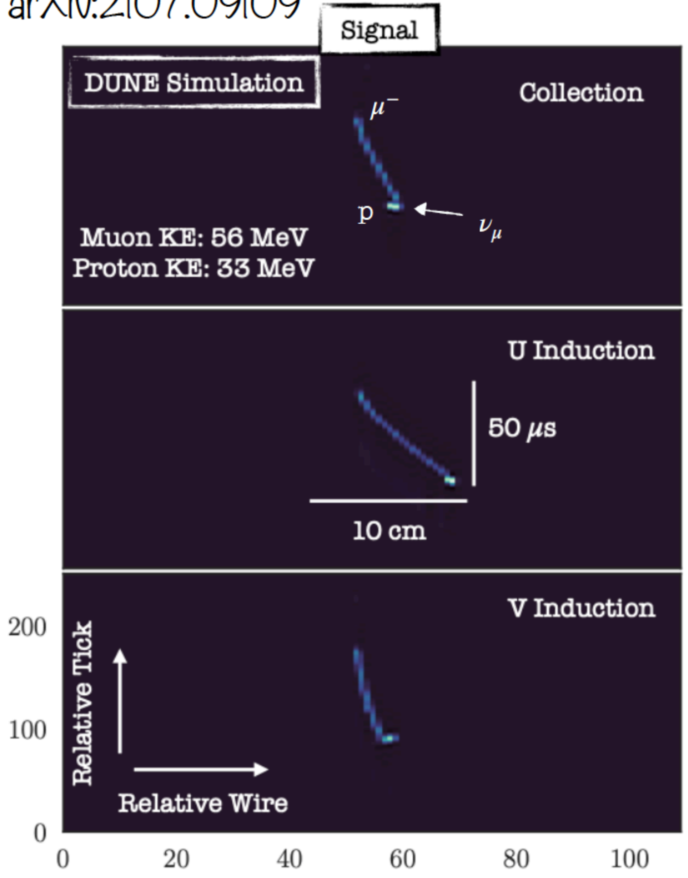


Testing light output from a fiber


Laser setup

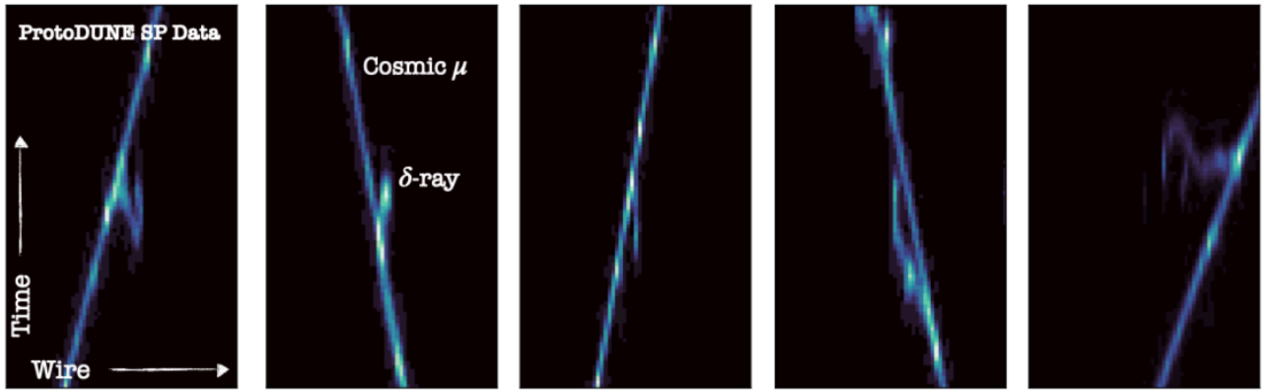
# DM Searches and $\nu$ Astrophysics at DUNE*

arXiv:2107.09109




If DM accumulates in the Sun and annihilates to standard matter, perhaps $\nu$'s are a beacon.
Turns out, $\nu$ observatories are sensitive to this hypothetical signal (simulation above) and can test DM models outside the grasp of current direct detection experiments.

**$\delta$-rays:** 8 cm x 30 cm Snippets (Axes stretched for easier viewing)




$\delta$-rays are secondary $e^-$s that have sufficient energy to leave ionization trails. They are often seen as backgrounds accompanying cosmic muons at $\nu$ observatories.

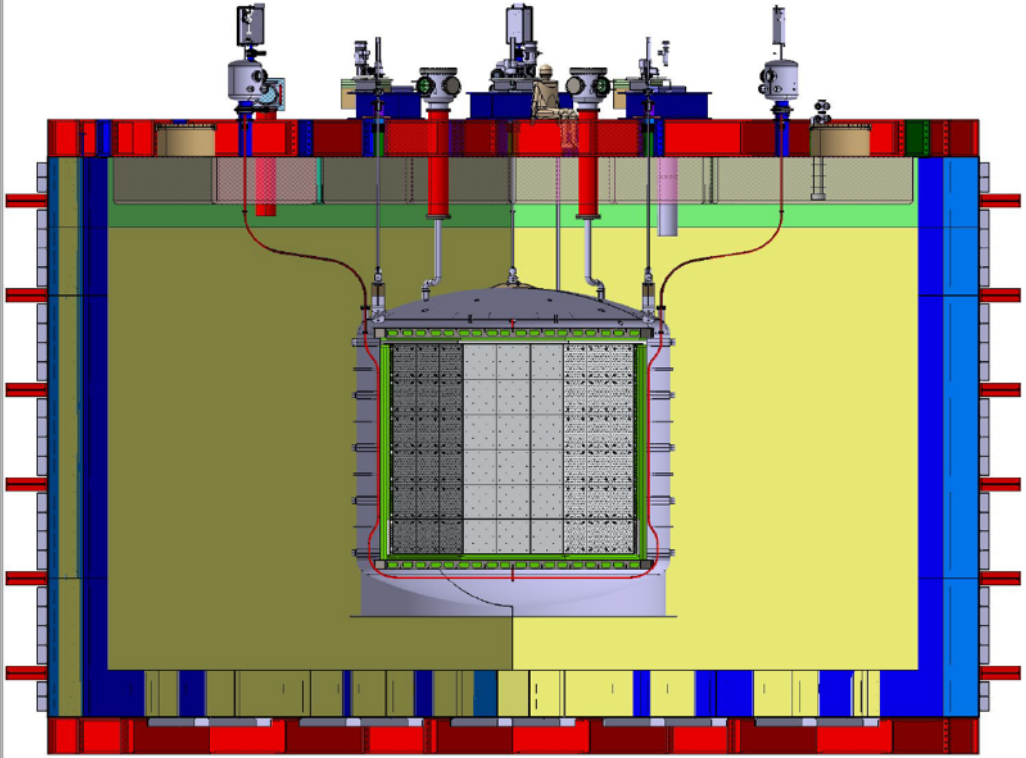
The solar and supernova $\nu$ spectra overlap with the $\delta$-ray spectrum.
Meaning that the $e^-$s liberated at detectors by rare astrophysical $\nu$'s are of similar energies to the ever-present $\delta$-rays.
$\delta$-rays can be a "standard candle" for extraterrestrial $\nu$'s.

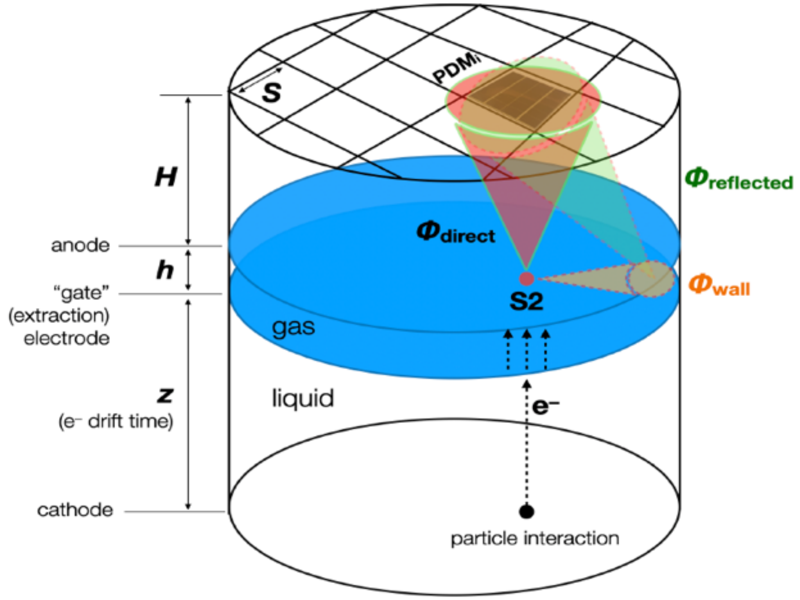
* DUNE (Deep Underground Neutrino Experiment) - Under Construction
ProtoDUNE SP (Single Phase Prototype for DUNE) - Operational

# DarkSide -20k

Victor Goicoechea Casanueva - victorgc@hawaii.edu

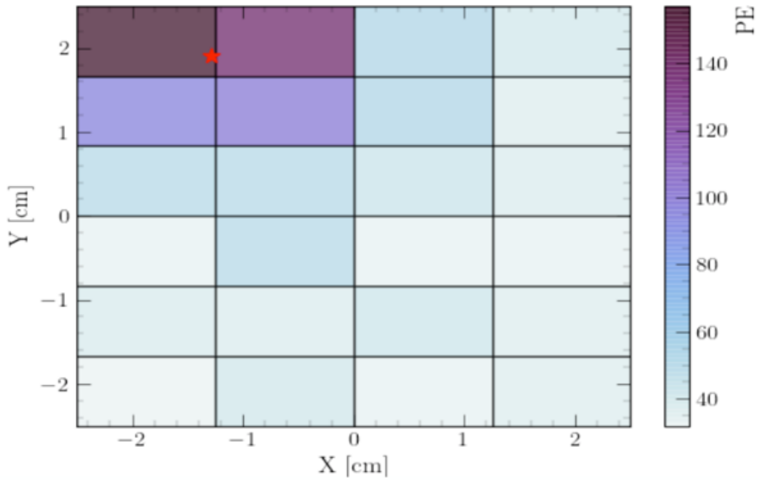
- Latest experiment of the DarkSide Project @ Gran Sasso
- Two phase Time Projection Chamber filled with liquid Argon for dark matter (WIMP) direct detection
- 20 ton of fiducial volume, projected sensibility in the order of $10^{-47}$ cm$^2$ for WIMP mass of 1 TeV/c$^2$
- Argon extracted from underground (Urania) and depleted for higher purity (Aria)
- Background free






<u>Current work:</u>

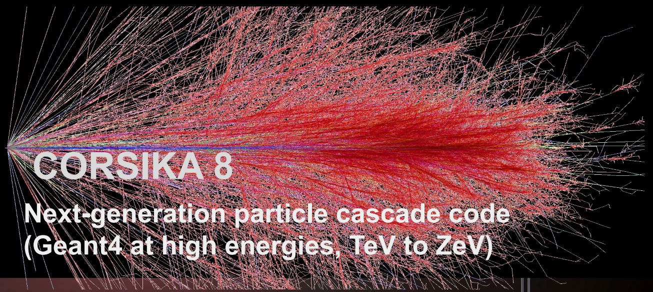
- Event position reconstruction using machine learning
- Calibration studies focused on recent changes of detector geometry



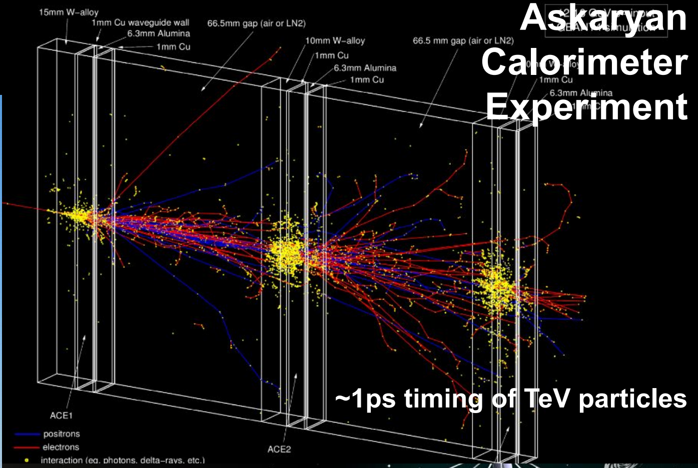
# Radio & Microwave Detection of High Energy Particles

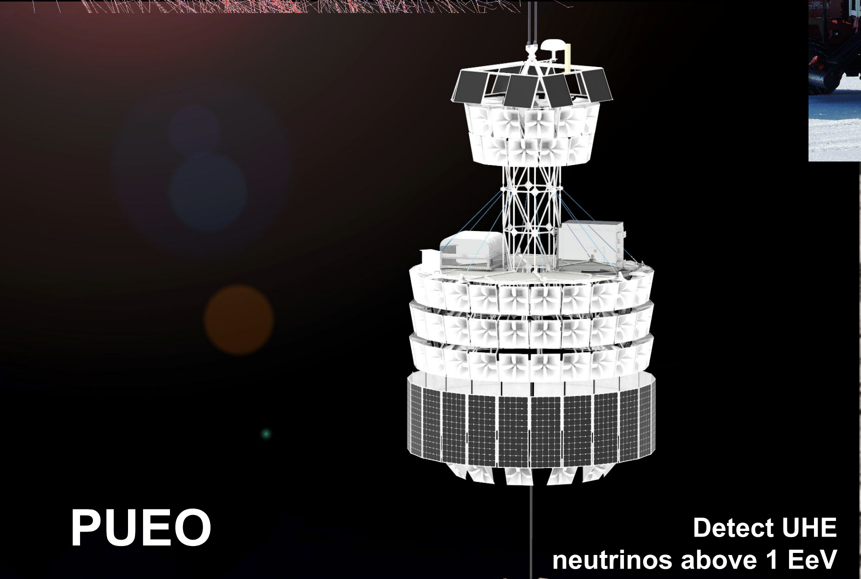
*(plus using these particles to do cool science!)*

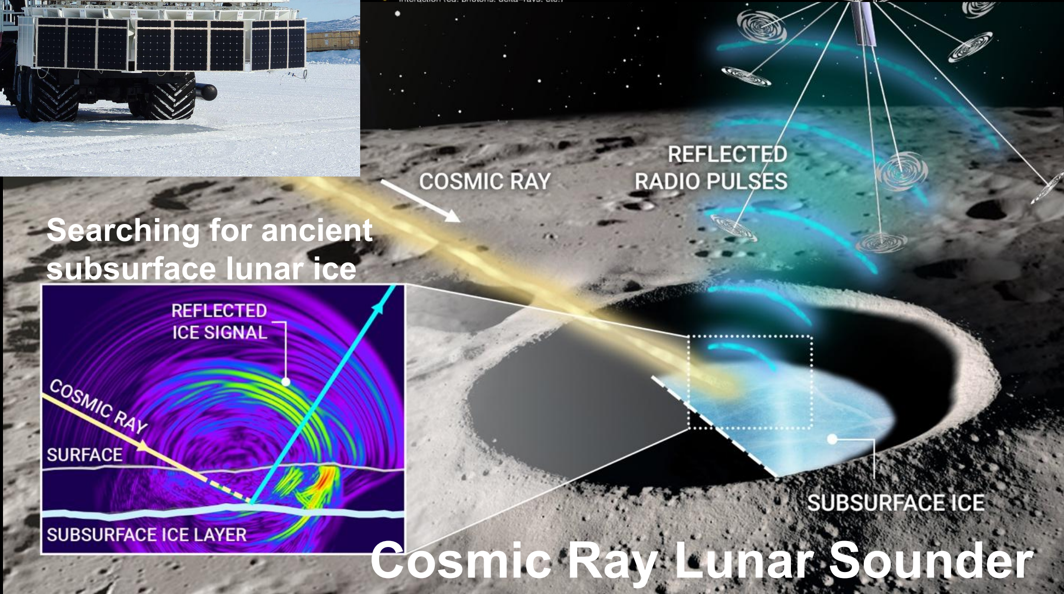
## Remy Prechelt (Gorham Group)

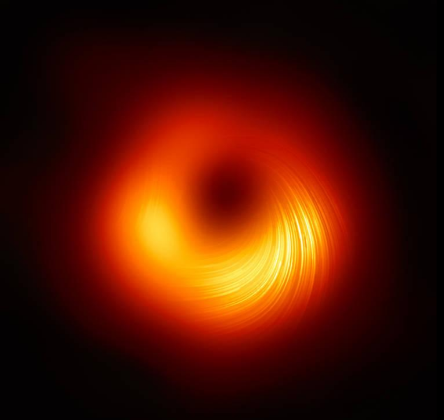








# Cosmological Coupling in Strong Gravity

**Interdisciplinary:** Physics, Mathematics (Differential geometry), Astronomy

**Multiscale:** Cosmology (Mpc+), Compact binaries (AU), Stellar collapse remnants (km)

**Recent results:**

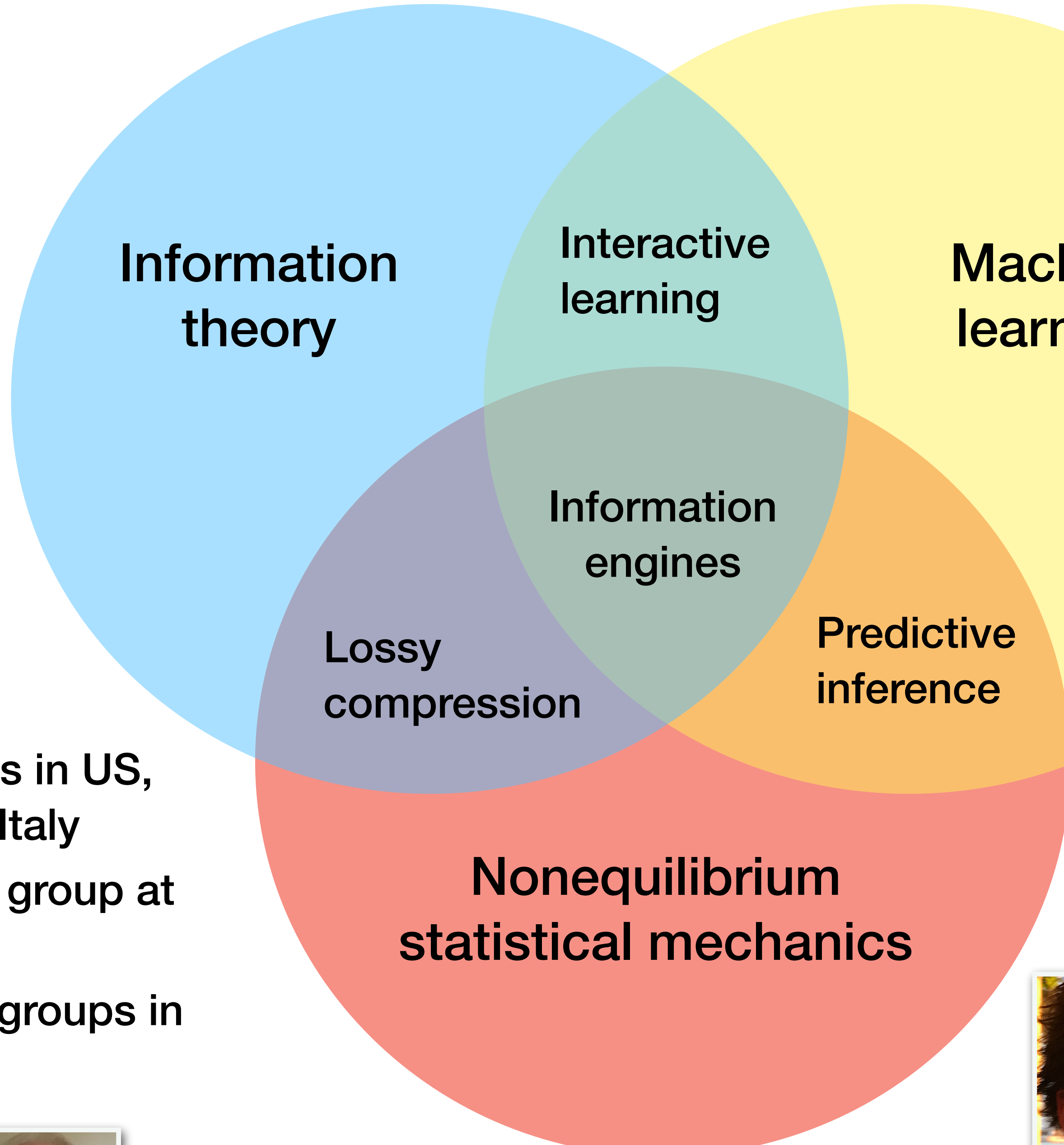
- **LIGO-observed population reproduced with a single parameter**
  Croker, Zevin, Farrah, Nishimura & Tarle 2021, 2109.08146 revised at ApJL
- **Viable accelerated late-time expansion without a cosmological constant**
  Croker, Runburg & Farrah 2020 *ApJ* **900** 57
- **Predicted BBH within the upper mass gap (7 weeks before detection)**
  Croker, Nishimura & Farrah 2020 *ApJ* **889** 115

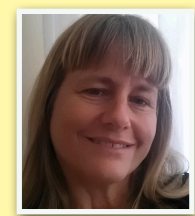
**In preparation:**

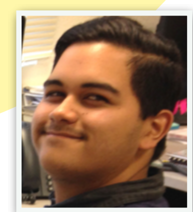
- **Integrated Sachs-Wolfe (ISW) with anisotropic stress (FL21)**
- **Black hole merger rate vs. stellar formation rate (FL21)**
- **Primordial star formation rate predictions for James-Webb (SP22)**

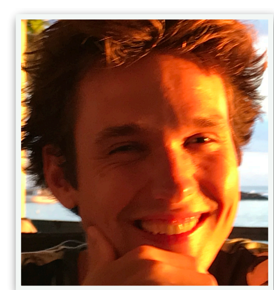
Kevin Croker, kcroker@phys.hawaii.edu

# Physics of Information Processing and Machine Learning Laboratory





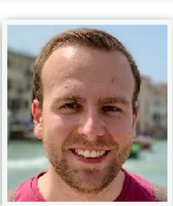


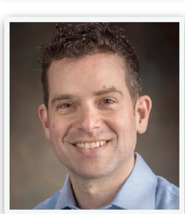
Application areas:

- Reinforcement Learning
- Evolution
- Origin of life
- Data analysis
- Econophysics
- Thermodynamic Computing

Collaborations

- Theory groups in US, Canada, UK, Italy
- Experimental group at SFU, Canada
- Applied / CS groups in Canada, UK

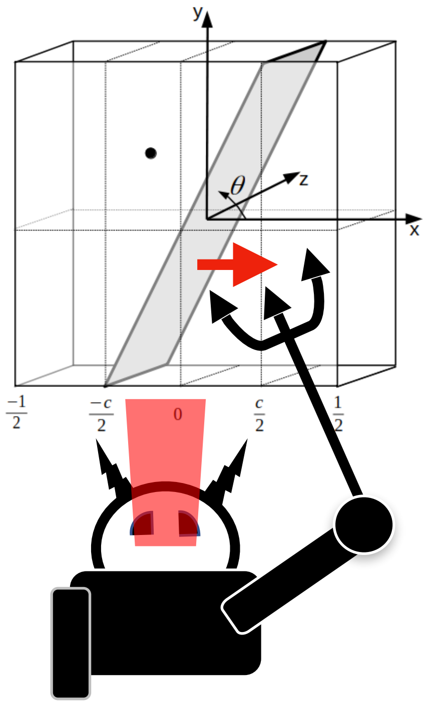


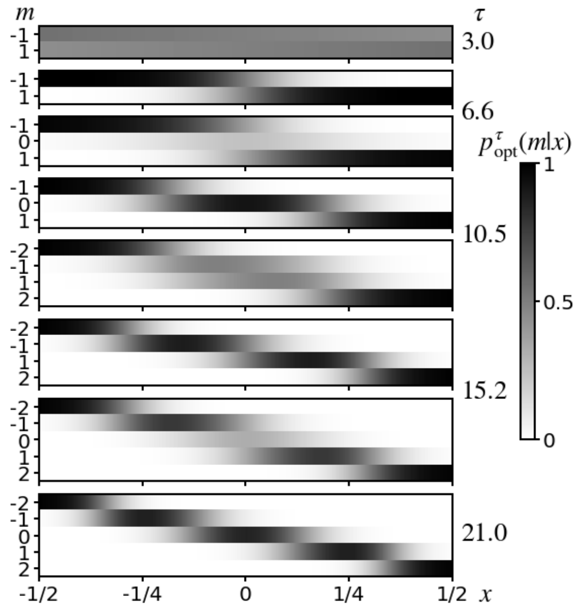


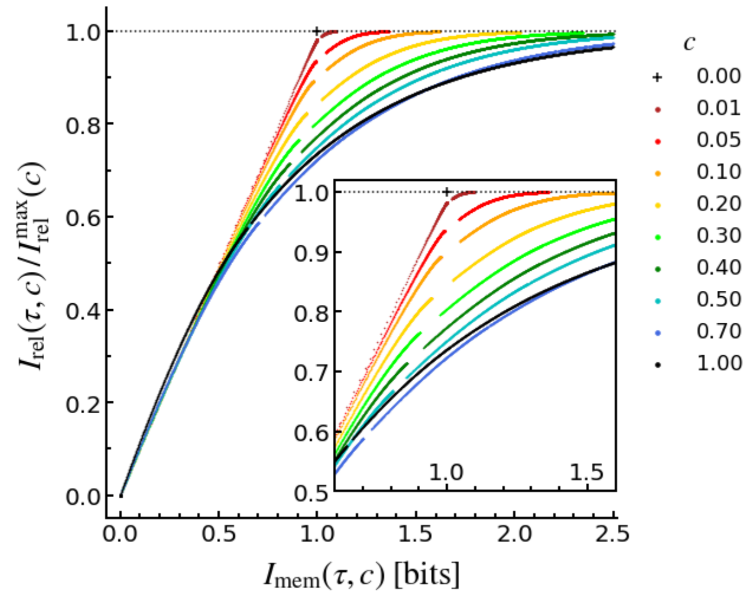
FQXi
FOUNDATIONAL QUESTIONS INSTITUTE

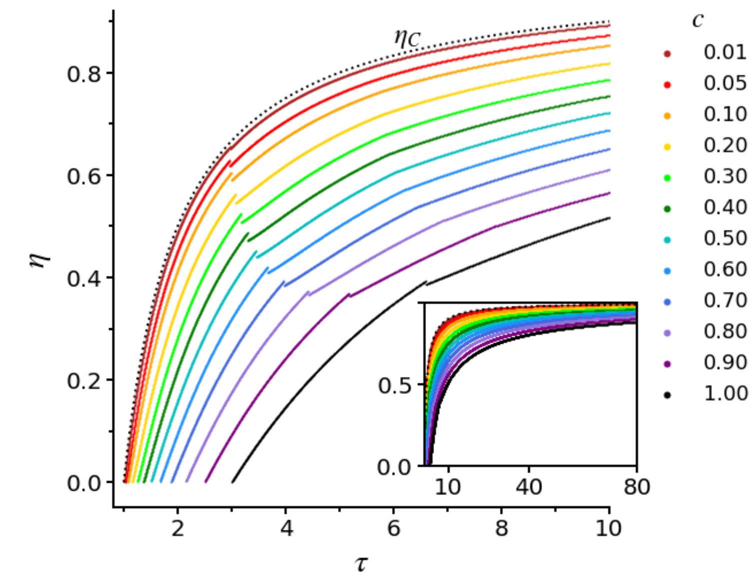
Fetzer Franklin Fund
Exploring Frontiers. Breakthroughs. Science.

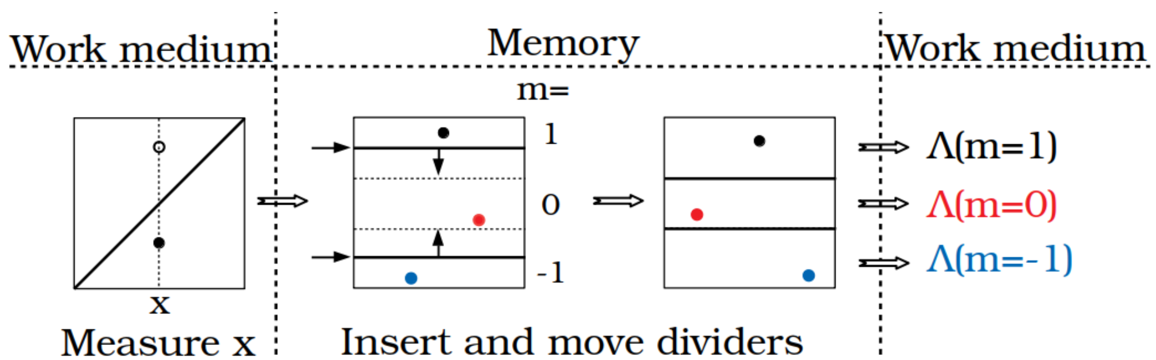
# Generalized Partially Observable Szilard Engines





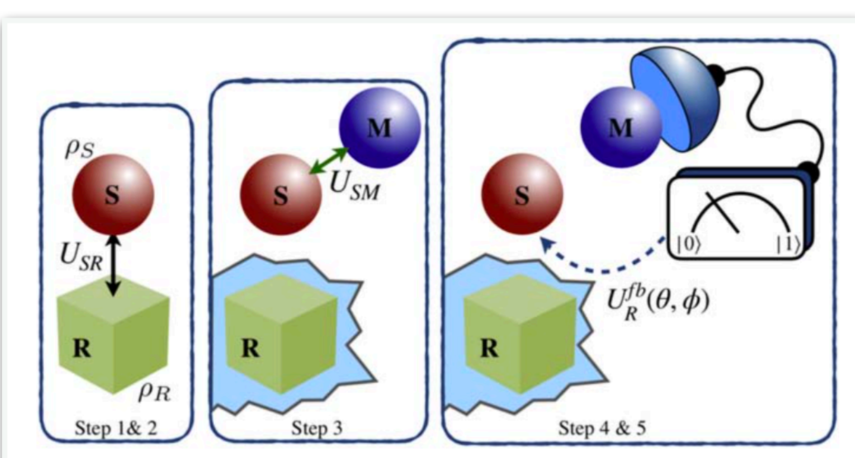

Observable — Memory — Actionable variable

$$W_{\rm diss} \geq kT I[x, m] - kT' I[m, u]$$

Total information kept — Useful information

Useless information memorized sets lower bound on dissipation

- **Work in progress: *partial observability in quantum systems***




$$U_{SM} \equiv U_{\rm CNOT}(\tau_m) = \cos(\tau_m)\mathbb{1} \otimes \mathbb{1} - i\sin(\tau_m){\rm CNOT},$$

$$U^{fb}_R(\nu) = e^{i\gamma}\begin{pmatrix} \cos\frac{\alpha}{2} - i\cos\theta\sin\frac{\alpha}{2} & -i\sin\frac{\alpha}{2}\sin\theta e^{-i\phi} \\ -i\sin\frac{\alpha}{2}\sin\theta e^{i\phi} & \cos\frac{\alpha}{2} + i\cos\theta\sin\frac{\alpha}{2} \end{pmatrix}$$

Abah & Paternostro, *J. Phys. Comm.* *4*(8) 085016, 2020