Fermilab U.S. DEPARTMENT OF ENERGY Office of Science

Status of the SpinQuest experiment and proposal of the DarkQuest upgrade

Nhan Tran on behalf of the SpinQuest and DarkQuest communities

June 2022 FNAL PAC meeting

June 23, 2022

Outline

SpinQuest and the DarkQuest upgrade

Dark sector searches at SpinQuest and DarkQuest

+ Snowmass framing

+ Recent progress

SpinQuest status and future nuclear/spin physics program

Collaboration and Outlook

Charge: We ask the PAC to review the status of the SpinQuest experiment and the proposal for its upgrade, referred to as DarkQuest.

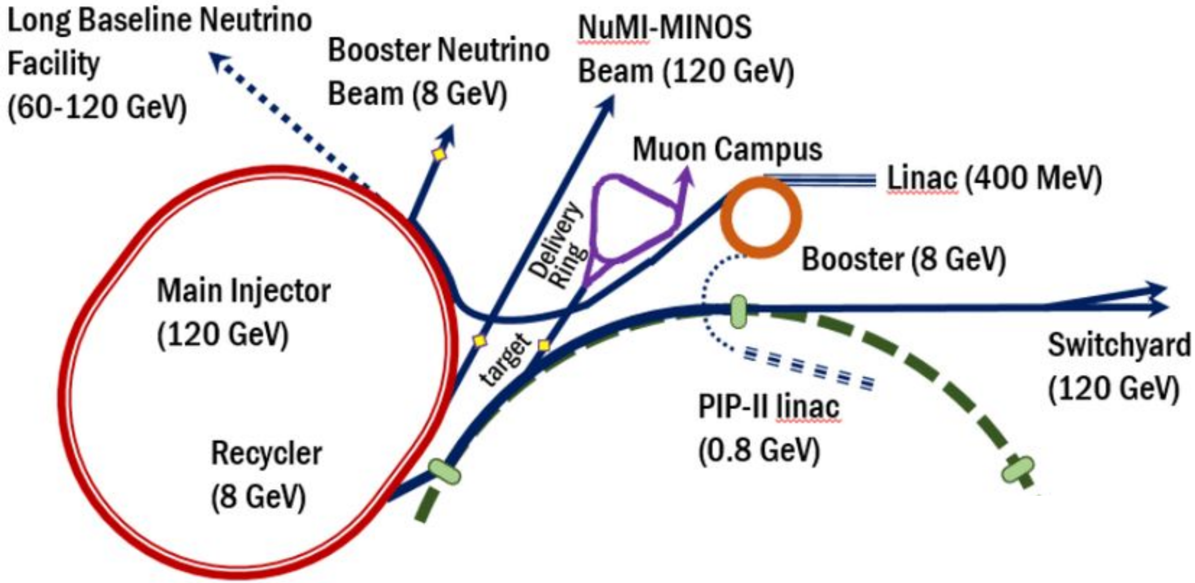
SpinQuest and the DarkQuest upgrade

SeaQuest (e906) - dimuon spectrometer

SpinQuest (e1039) - dimuon spectrometer + polarized target

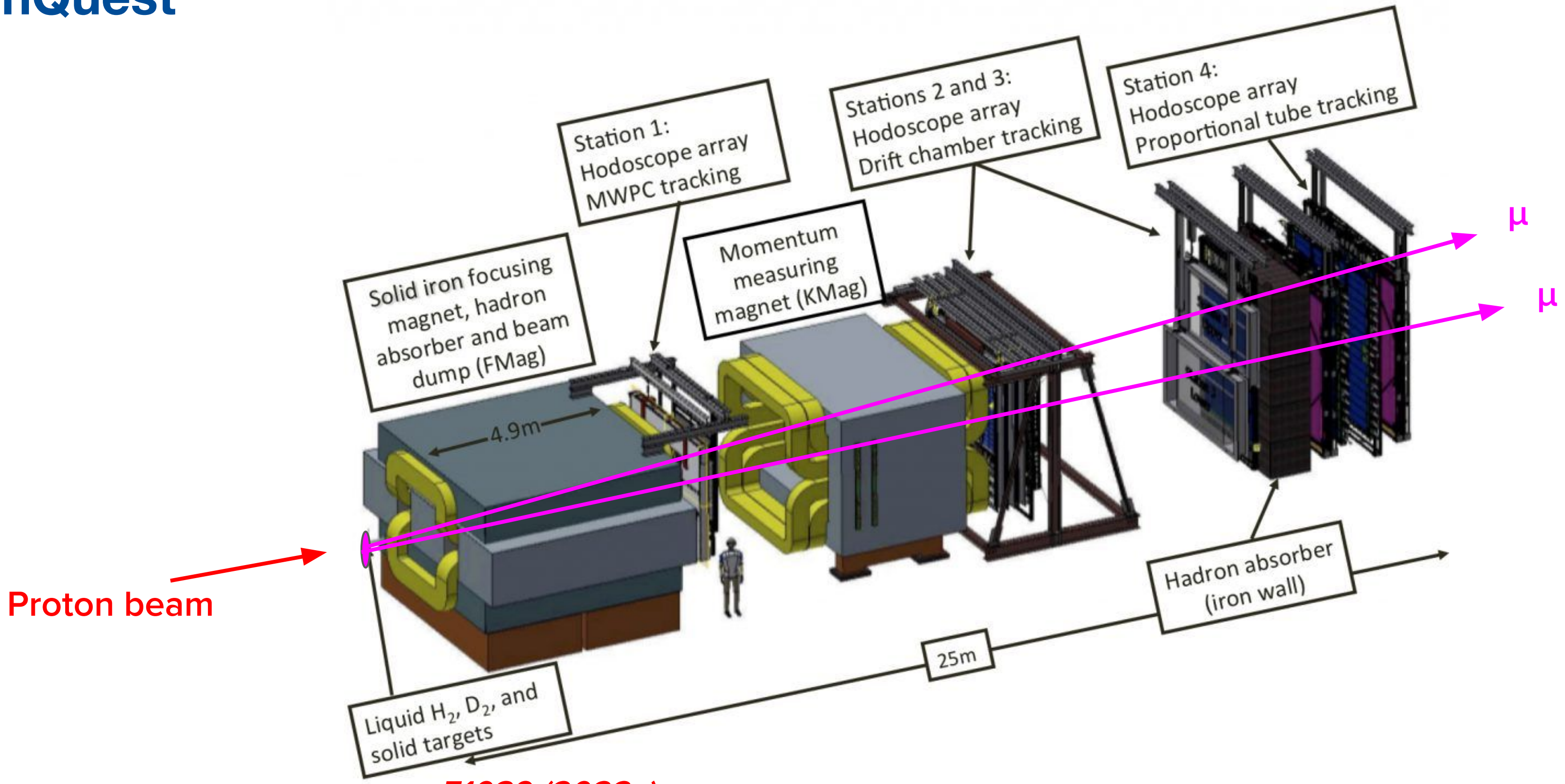
DarkQuest - EMCal/tracking/target upgrade to dimuon spectrometer

SpinQuest and DarkQuest



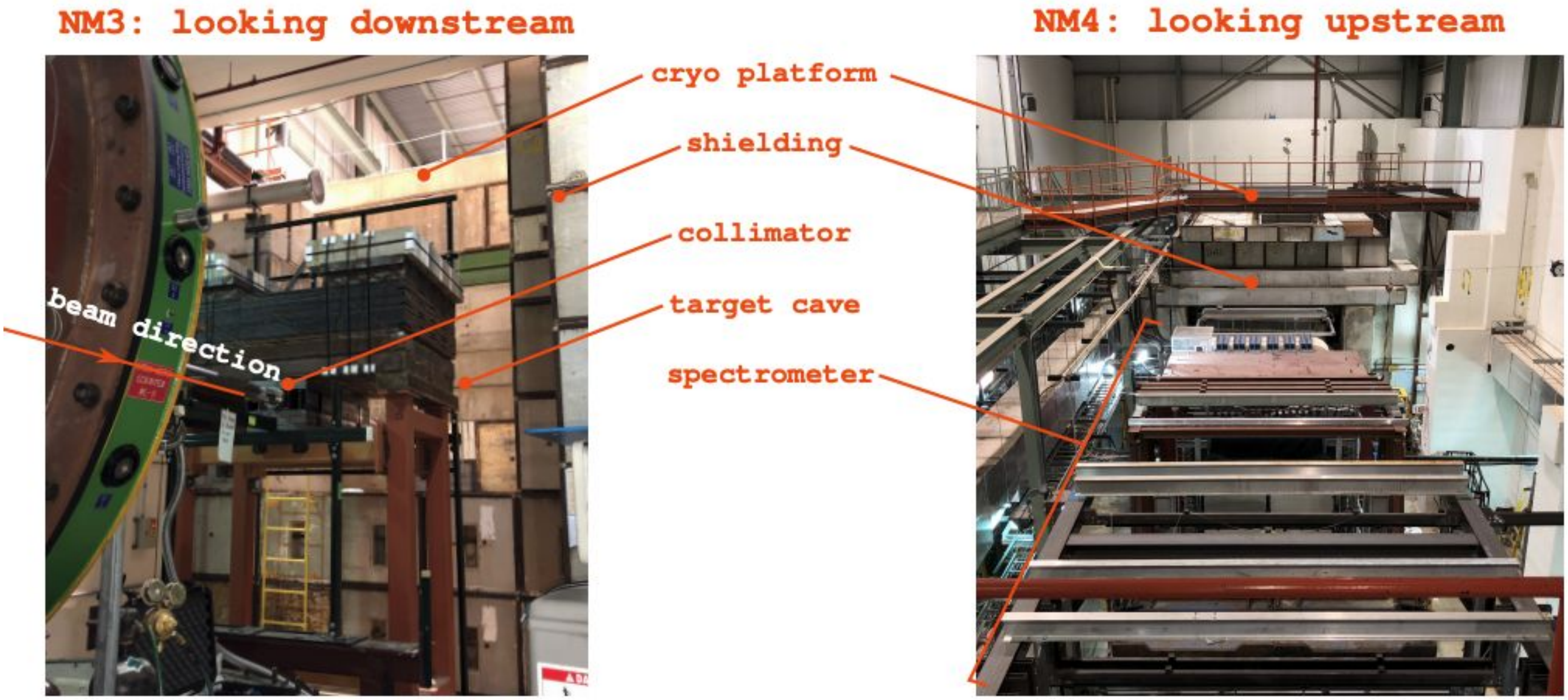
NM4 experimental hall

SpinQuest



E1039 (2022+):
Polarized NH_3 target

SpinQuest


NM3: looking downstream
NM4: looking upstream
cryo platform
shielding
collimator
target cave
spectrometer
beam direction

SpinQuest collaboration

About SpinQuest/E1039 Collaboration

https://spinquest.fnal.gov

INSTITUTION 20	FULL MEMBERS 53 Postdocs 7 Grad. Students 15	AFFILIATE MEMBERS
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2) Argonne National Laboratory	Paul Reimer (PI), Donald Geesaman	Kevin Bailey, Thomas O'Connor
3) Aligarh Muslim University	Huma Haider (PI)	
4) Boston University	David Sperka (PI), Zijie Wan	
5) Fermi National Accelerator Laboratory	Richard Tesarek (PI), Carol Johnstone	
6) KEK	Shin'ya Sawada (PI)	Shigeru Ishimoto
7) Los Alamos National Laboratory	Kun Liu (SP), Ming Liu, Astrid Morreale, Mikhail Yurov, Kei Nagai, Zongwei Zhang	Jan Boissevain, Melynda Brooks, Matt Durham, David Kleinjan, Sho Uemura, Cesar Da Silva, Patrick McGaughey, Andi Klein
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13) University of Colombo	Darshana Perera (PI), Harsha Sirilal, Vibodha Bandara	
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16) University of New Hampshire	Karl Slifer (PI), David Ruth	Maurik Holtrop
17) Tsinghua University	Zhihong Ye (PI)	
18) University of Virginia	Dustin Keller (SP), Kenichi Nakano, Ishara Fernando, Zulkaida Akbar, Waqar Ahmed, Liliet Diaz, Anchit Arora, Arthur Conover, Jay Roberts	Donal Day, Donald Crabb, Jixie Zhang, Oscar Rondon, Arthur Conover, Brandon Kriesten, Simonetta Liuti, Ellen Brown, Blaine Norum, Matthew Roberts
19) Yamagata University	Yoshiyuki Miyachi (PI), Norihito Doshita	Takahiro Iwata, Norihiro Doshita
20) Yerevan Physics Institute	Hrachya Marukyan (PI)	

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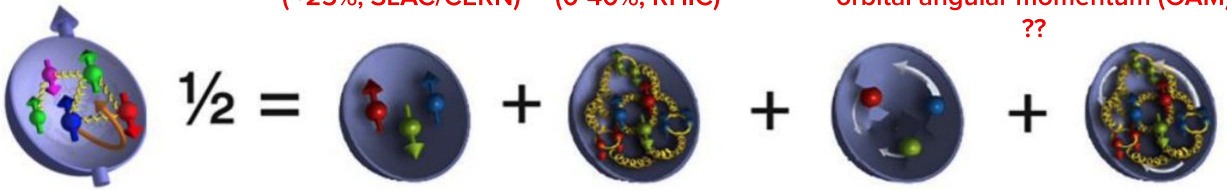
SpinQuest - proton spin puzzle

valence quark spin
(~25%, SLAC/CERN)

gluon spin
(0-40%, RHIC)

(sea) quark + gluon
orbital angular momentum (OAM)
??



Puzzle: EMC experiment (1987) measured only ~25% of proton spin comes from valence quarks (unexpected!)

Other potential contributions:
Orbital angular momentum (OAM) of the quarks and gluons

[Lattice QCD predicts non-zero quark OAM]

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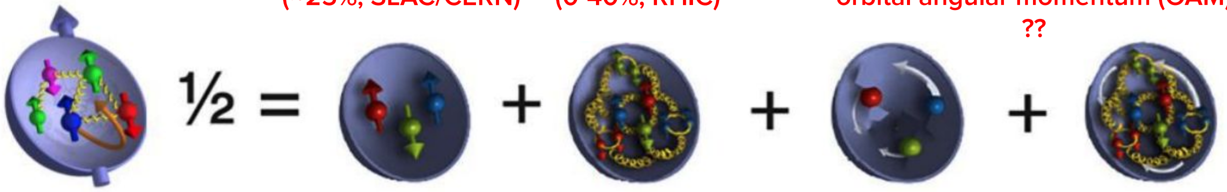
valence quark spin (~25%, SLAC/CERN) | gluon spin (0-40%, RHIC) | (sea) quark + gluon orbital angular momentum (OAM) ??



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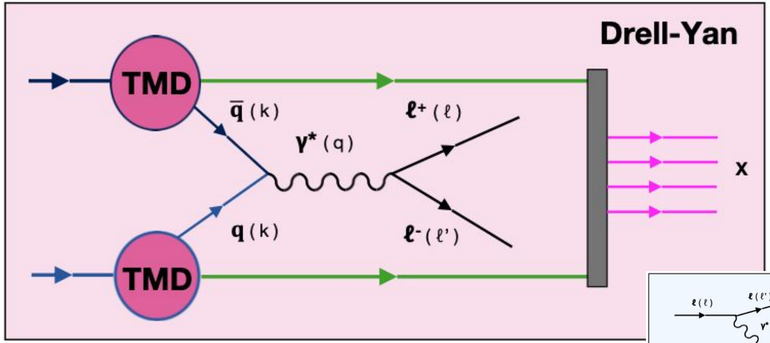
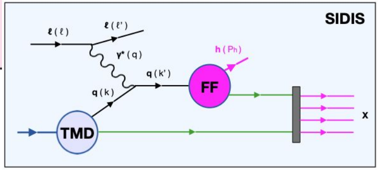
[Lattice QCD predicts non-zero quark OAM]

Drell-Yan is a critical complement to **SIDIS** (semi-inclusive deep inelastic scattering) for measuring the proton spin and testing QCD, *both are required*

Cleanest method with no fragmentation function, two parton TMDs, direct access to sea-quark distributions





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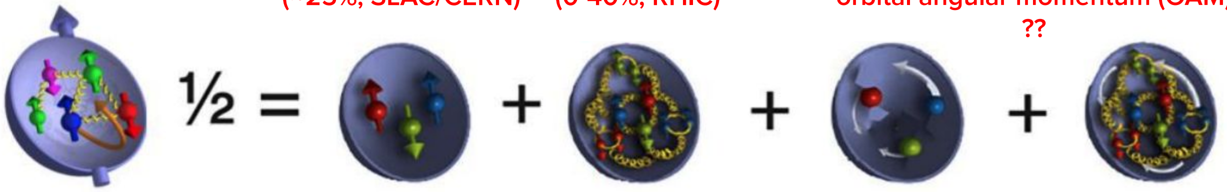
valence quark spin (~25%, SLAC/CERN) | gluon spin (0-40%, RHIC) | (sea) quark + gluon orbital angular momentum (OAM) ??



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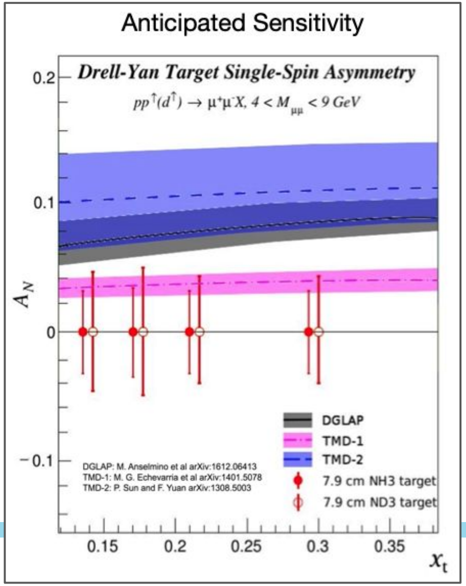
[Lattice QCD predicts non-zero quark OAM]

Measuring non-zero Sivers asymmetry at SpinQuest requires sea-quark OAM - observation would be a major discovery!

$$A_N(p_{\text{beam}} + p^{\uparrow}_{\text{trg}} \to \text{DY}) \propto \frac{N_L^{DY} - N_R^{DY}}{N_L^{DY} + N_R^{DY}} \propto \frac{f_{1T}^{\perp,\bar{u}}(x_t)}{f_1^{\bar{u}}(x_t)}$$



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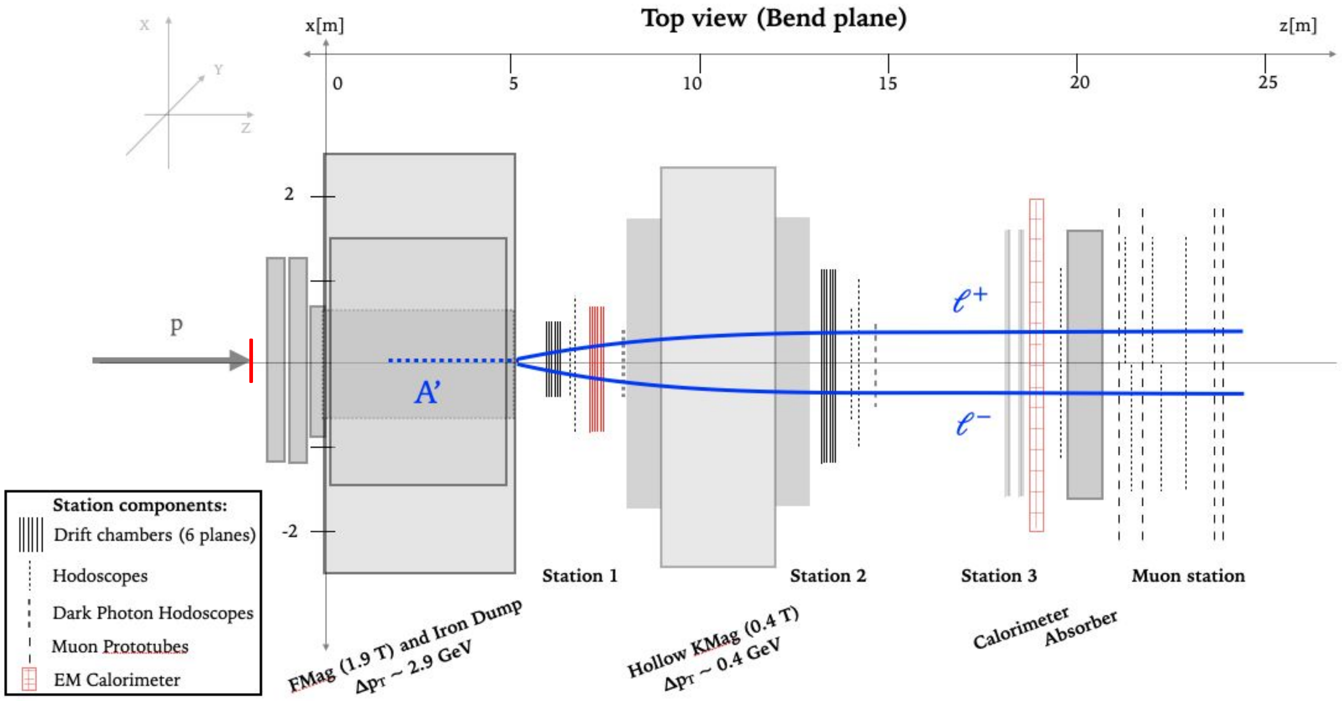
SpinQuest and DarkQuest upgrade



Dark sector signature

SpinQuest: muon final states

DarkQuest: e,γ,π,…

System upgrades

Existing EMCal from PHENIX

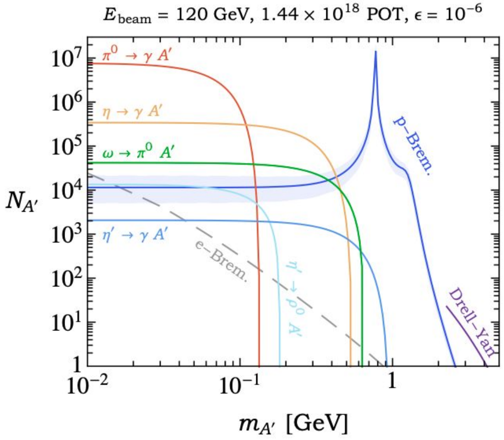
Tracking MWPC available

Tensor polarized deuteron target

Unique features of SpinQuest/DarkQuest for dark sectors

Berlin, Gori, Schuster, Toro
https://arxiv.org/abs/1804.00661

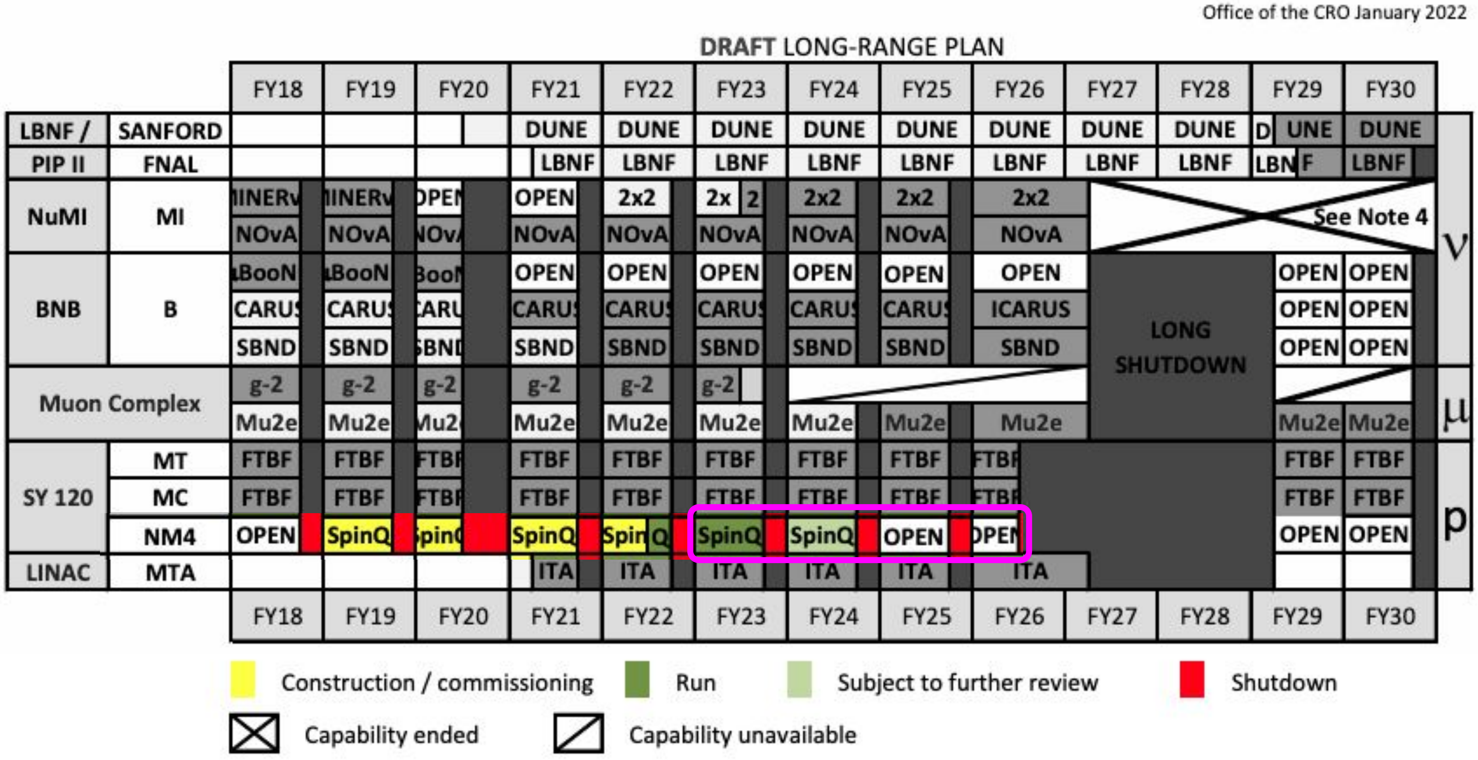
- Large putative dark sector production cross section with **120 GeV proton beam**
- 5m beam dump - geometry sensitive to **unique lifetime baseline**
- Spectrometer with KMAG provides good momentum measurement for forward decays
- EMCal opens up new final states distinct from large muon backgrounds



Existing experiment and infrastructure means we require modest investment - short time to high impact physics!

	E_{beam}	p_{min}	POT	z_{min}	z_{max}	z_{min}/E_{beam}
SeaQuest	120 GeV	10 GeV	$10^{18} - 10^{20}$	5 m	10 m	4 cm / GeV
NA62	400 GeV	-	10^{18}	100 m	250 m	25 cm / GeV
SHiP	400 GeV	100 GeV	10^{20}	65 m	125 m	16 cm / GeV
FASER	6500 GeV	1 TeV	$10^{16} - 10^{17}$	390 m	400 m	6 cm / GeV

Timelines



Near-term window of opportunity, including FY25-26

High level vision – SpinQuest and DarkQuest

A vibrant and powerful spin and dark sector program running together

SpinQuest Phase

- proton spin puzzle - measure Sivers asymmetry
- dark sectors in muon final states

DarkQuest Phase

- EMCal upgrade (no degradation of spin physics), enhanced tracking and targetry
- expanded spin physics program measuring transversity
- expanded dark sector program in e,γ,π final states

High impact HEP dark sectors and NP/spin physics; strong complementarity with Fermilab capabilities and timelines for modest resources

Dark sector searches at SpinQuest and DarkQuest

Snowmass framing *(also, see PAC talk from Alexey Petrov on Rare and Precision Frontier)*

Recent progress from the SpinQuest dark sector community

Physics drivers

- **Dark matter** exists
  - Thermal freeze-out DM narrows the mass range to ~MeV-TeV
    - Provides clear milestones
  - No discovery in WIMP searches thus far

- **Dark sectors** can solve many experimental/theoretical puzzles
  - Dark sectors mean SM-neutral forces (typically < ~GeV)
    - Can include dark matter
  - Visible (SM) final states important to explore for discovery

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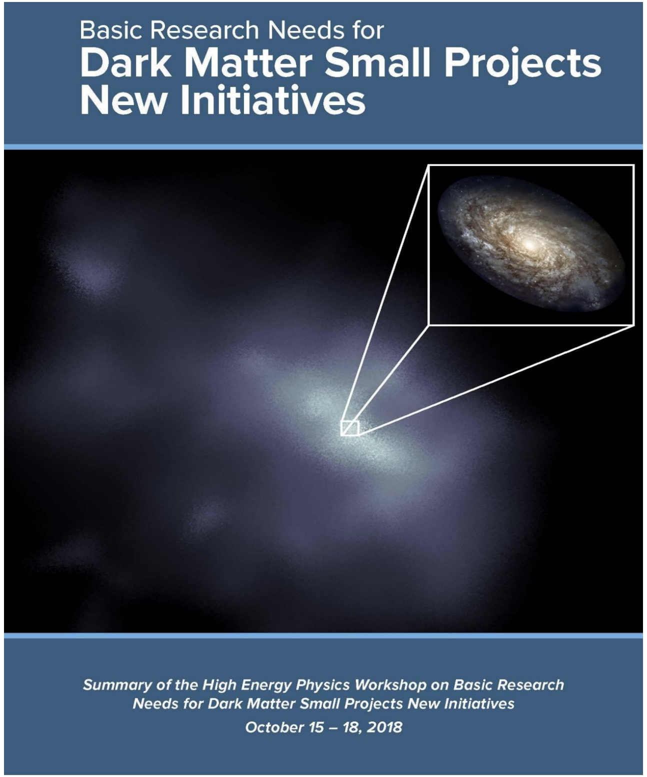
Setting the stage: dark sectors at accelerators

Dark Matter New Initiatives report



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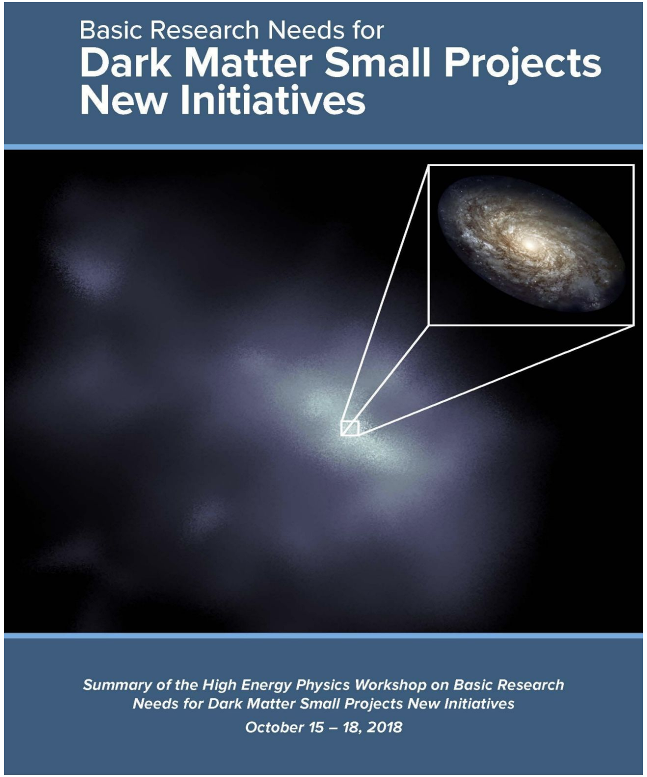
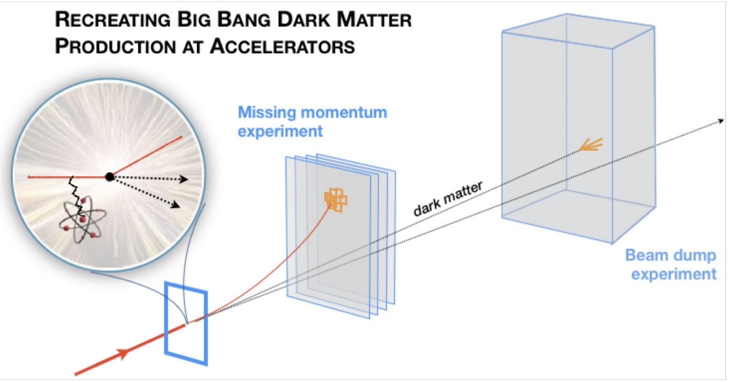
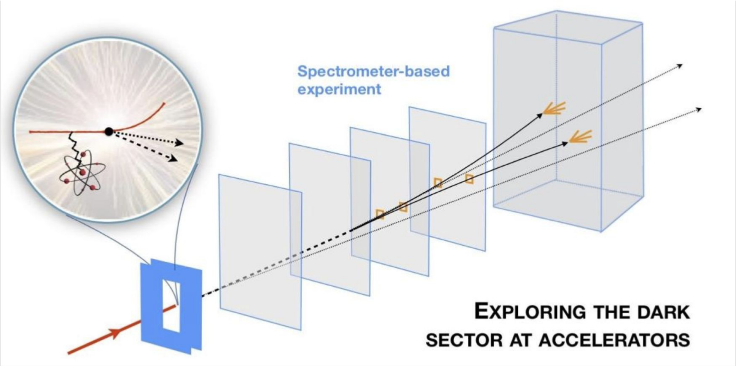




Thrust 1: target thermal dark matter milestones

Thrust 2: Exploration structure of dark sectors



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Snowmass RF6 Big Ideas

RF6 report (to appear)

Strong connection with NF03, EF10, AF5, CF6

Dark matter production at intensity frontier experiments

Benchmarks:
***dark photon*,**
scalar, neutrino portal,
millicharged

Exploring dark sector portals with high intensity experiments

Benchmarks:
***dark photon*,**
scalar, neutrino portal,
axion-like particle (ALPs)

New flavors and rich structures in dark sectors

Benchmarks:
***g-2*, SIMPs,**
inelastic DM,
non-minimal ALPs

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S. Gori, M. Williams

Dark matter production at intensity frontier experiments	Exploring dark sector portals with high intensity experiments	New flavors and rich structures in dark sectors
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G. Krnjaic, N. Toro	B. Batell, C. Hearty	P. Harris, P. Schuster, J. Zupan

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+ Experiments & Facilities (P. Ilten, N. Tran)

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high level frontier benchmarks

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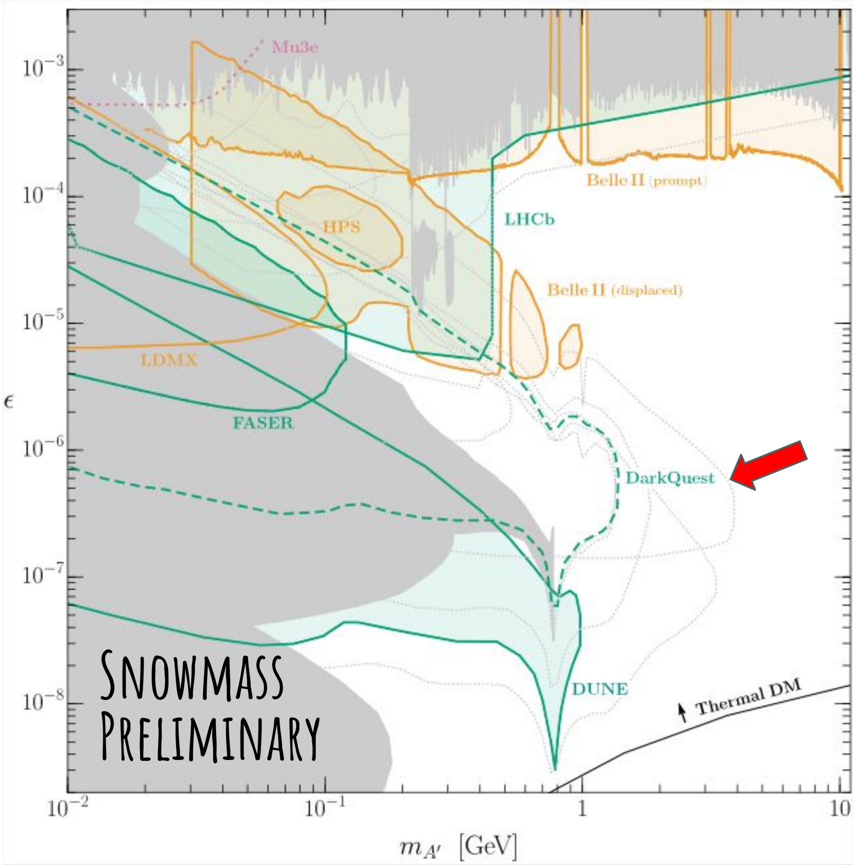
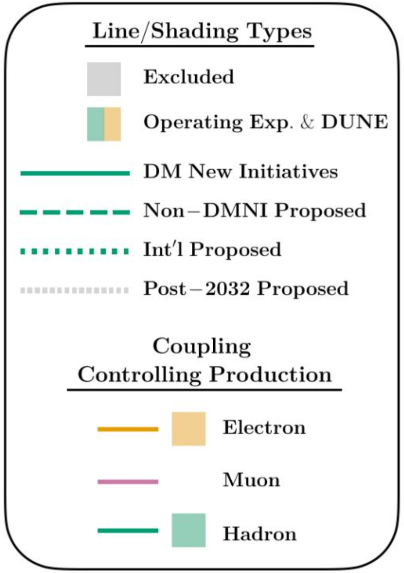
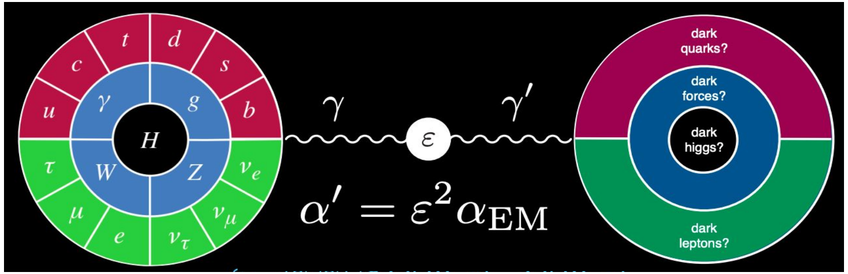
Dark photon benchmark scenario







muon g-2 benchmark scenario

A No-Lose Theorem for Discovering the New Physics of $(g-2)_\mu$ at Muon Colliders

Rodolfo Capdevilla,[a,b] David Curtin,[a] Yonatan Kahn,[c,d] Gordan Krnjaic[e,f]

(Paraphrasing 2101.10334...)

Step 1. Confirm g-2 anomaly

Step 2. Look for low-scale phenomenon < ~GeV at existing and new facilities

Step 3-5. Build successively higher energy muon colliders

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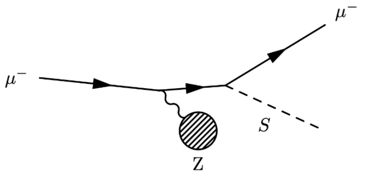

B. Batell

	Invisible			Visible			
final state/ mediator	Long-lived	neutrinos $\nu\nu$	DM $\chi\chi$	photons $\gamma\gamma$	electrons e^+e^-	muons $\mu^+\mu^-$	hadrons $\pi\pi,\ldots$
vector	no(?)	yes	yes	no	no(?)	yes* ($m_V > 2m_\mu$)	no(?)
	• $L_\mu - L_\tau$ gauge boson: UV complete, automatic coupling to neutrinos, easy to couple to DM. (* $m_V > 2m_\mu$ constrained by dedicated *BABAR* search) • Challenging to build viable models with sizable couplings of vector mediator to electrons or hadrons (gauge anomalies, constraints from neutrino physics)						
scalar	yes ($m_S < 2m_\mu$)	yes	yes	yes ($m_S < 2m_\mu$)	yes ($m_S < 2m_\mu$)	yes ($m_S > 2m_\mu$)	yes ($m_S > 2m_\pi$)
	• All minimal signatures can be realized in scalar simplified models. • UV complete models require new SM-charged states above weak scale with special flavor structure (such states can in principle affect (g-2) • More phenomenological studies needed to chart the parameter space						
signature	missing momentum			prompt or displaced resonance			

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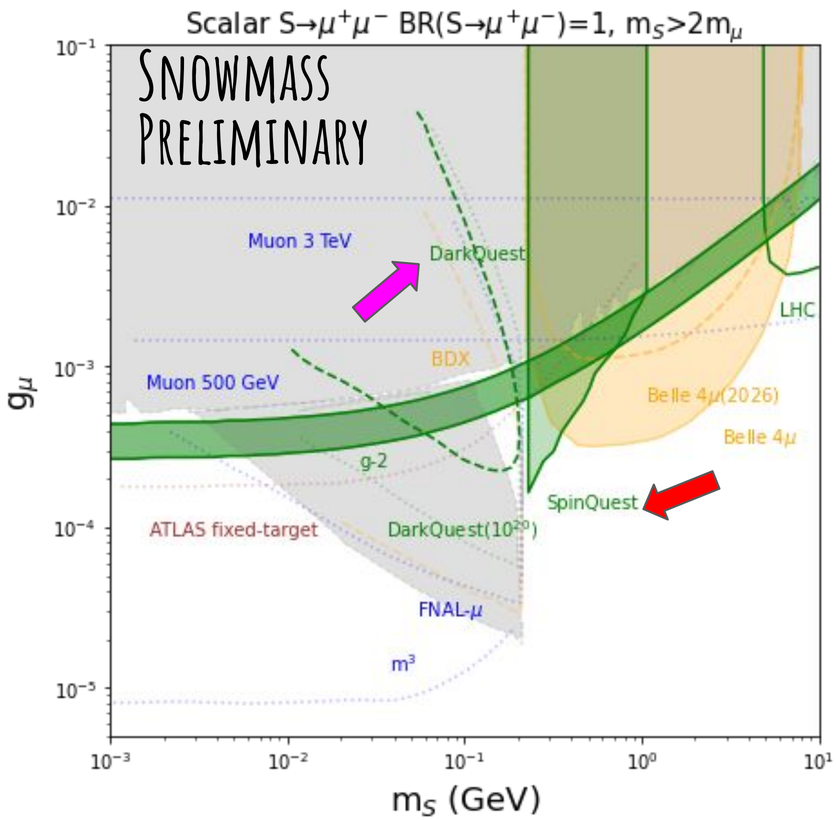
muon g-2 benchmark scenario

Forbes, Kahn, Krnjaic, et al (to appear)



SpinQuest/DarkQuest plays a key role in new physics models for g-2 < ~GeV

SpinQuest limits from FY23 data!

e.g. Belle II limits on full $30ab^{-1}$ (> 2030)

DarkQuest limits in ee,γγ channel below $2m_{\mu}$

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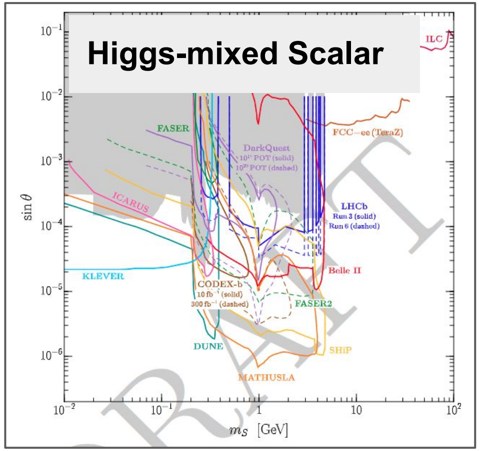
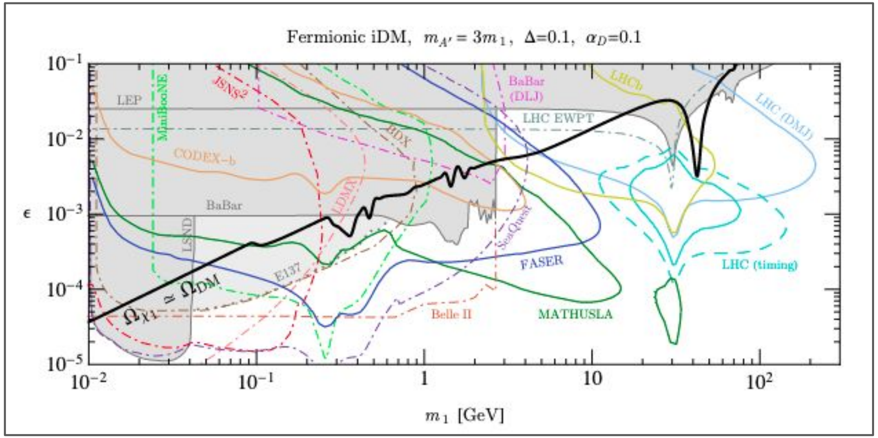
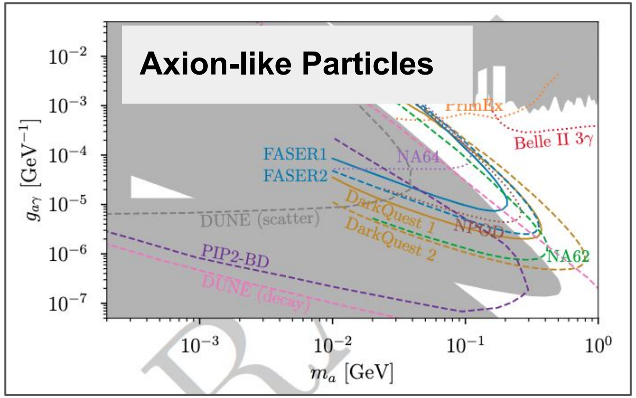
Sensitivity to other Snowmass benchmark scenarios

RF6 reports (to appear)
Berlin, Gori, Schuster, Toro: 1804.00661
Batell, Evans, Gori, Rai: 2008.08108
Blinov, Kowalczyk, Wynne: 2112.09814

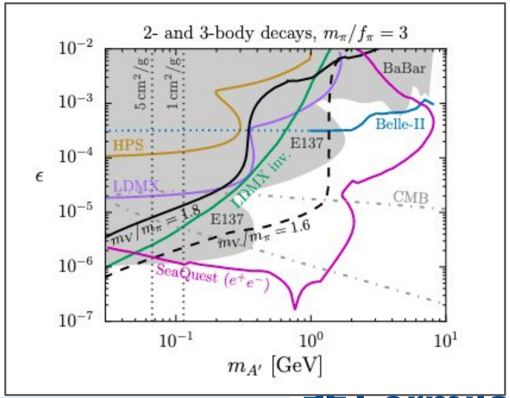


Inelastic Dark Matter
(DM candidate with *testable* targets)





Strongly-Interacting Massive Particles
(DM candidate with *testable* targets)



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Dark sectors at SpinQuest and DarkQuest

SpinQuest (now!)

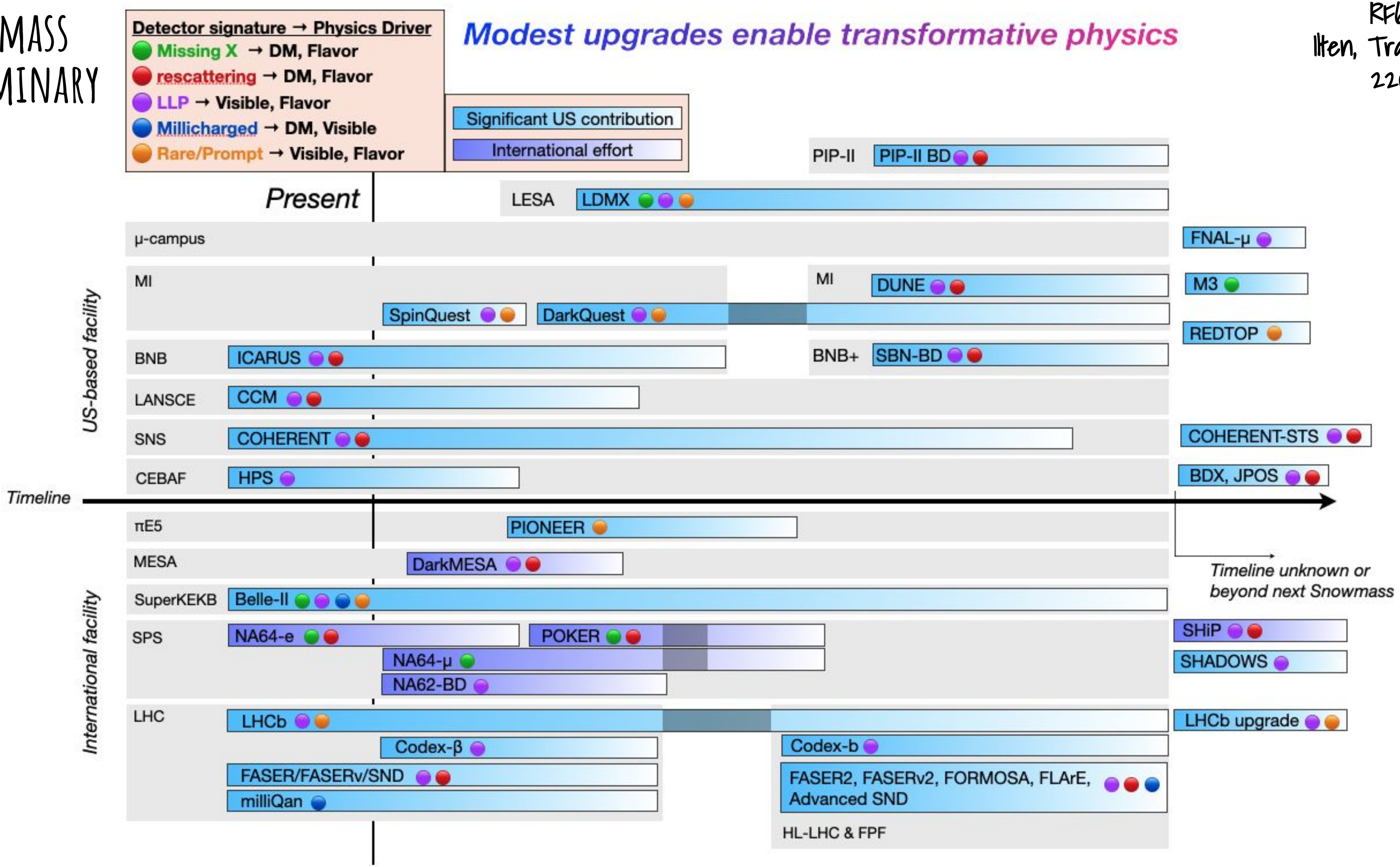
- Cover open g-2 phase space, prompt S/V → μμ
- Initial long-lived dark photon (μμ) searches, commission displaced tracking

DarkQuest (soon!)

- Large increase in sensitivity to dark photon phase space
- Cover open g-2 phase space, displaced S/V → ee,γγ
- Enable searches for inelastic DM, SIMPs, ALPs, etc.

Snowmass Preliminary

RF6 report
Ilten, Tran, et al
2206.04220



Dark Sectors @ SpinQuest/DarkQuest effort

Theory and experimental community come together over past 2 years - building physics case, detailed full simulation, coordinate with NP community

arXiv:2203.08322v1 [hep-ex] 16 Mar 2022

DarkQuest: A dark sector upgrade to SpinQuest at the 120 GeV Fermilab Main Injector

Aram Apyan[1], Brian Batell[2], Asher Berlin[3], Nikita Blinov[4], Caspian Chaharom[5], Sergio Cuadra[6], Zeynep Demiragli[5], Adam Duran[7], Yongbin Feng[3], I.P. Fernando[8], Stefania Gori[9], Philip Harris[6], Duc Hoang[6], Dustin Keller[8], Elizabeth Kowalczyk[10], Monica Leys[2], Kun Liu[11], Ming Liu[11], Wolfgang Lorenzon[12], Petar Maksimovic[13], Cristina Mantilla Suarez[3], Hrachya Marukyan[14], Amitav Mitra[13], Yoshiyuki Miyachi[15], Patrick McCormack[6], Eric A. Moreno[6], Yasser Corrales Morales[11], Noah Paladino[6], Mudit Rai[2], Sebastian Rotella[6], Luke Saunders[5], Shinaya Sawada[21], Carli Smith[17], David Sperka[5], Rick Tesarek[3], Nhan Tran[3], Yu-Dai Tsai[18], Zijie Wan[5], and Margaret Wynne[12]

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ABSTRACT

Expanding the mass range and techniques by which we search for dark matter is an important part of the worldwide particle physics program. Accelerator-based searches for dark matter and dark sector particles are a uniquely compelling part of this program as a way to both create and detect dark matter in the laboratory and explore the dark sector by searching for mediators and excited dark matter particles. This paper focuses on developing the DarkQuest experimental concept and gives an outlook on related enhancements collectively referred to as LongQuest. DarkQuest is a proton fixed-target experiment with leading sensitivity to an array of visible dark sector signatures in the MeV-GeV mass range. Because it builds off of existing accelerator and detector infrastructure, it offers a powerful but modest-cost experimental initiative that can be realized on a short timescale.

Submitted to the Proceedings of the US Community Study on the Future of Particle Physics (Snowmass 2021)

Dark Sectors @ SpinQuest/DarkQuest effort

Theory and experimental community come together over past 2 years - building physics case, detailed full simulation, coordinate with NP community

Contents

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arXiv:2203.08322v1 [hep-ex] 16 Mar 2022

ABSTRACT

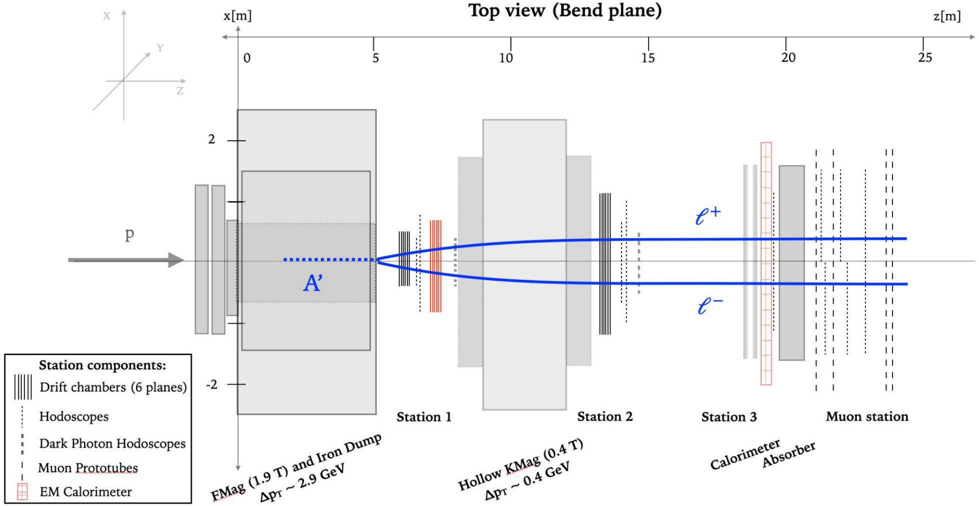
Expanding the mass range and techniques by which we search for dark matter is an important part of the worldwide particle physics program. Accelerator-based searches for dark matter and dark sector particles are a uniquely compelling part of this program as a way to both create and detect dark matter in the laboratory and explore the dark sector by searching for mediators and excited dark matter particles. This paper focuses on developing the DarkQuest experimental concept and gives an outlook on related enhancements collectively referred to as LongQuest. DarkQuest is a proton fixed-target experiment with leading sensitivity to an array of visible dark sector signatures in the MeV-GeV mass range. Because it builds off of existing accelerator and detector infrastructure, it offers a powerful but modest-cost experimental initiative that can be realized on a short timescale.

Submitted to the Proceedings of the US Community Study on the Future of Particle Physics (Snowmass 2021)

Dark Sectors @ SpinQuest/DarkQuest

Detailed study from HEP community to understand dark sector performance

- Trigger
- Tracking & Vertexing efficiency
- Calorimeter & Particle ID
- Mass reconstruction



A lot of progress in software and simulation:

- trigger hodoscope studies; new displaced tracking algorithm with speed-ups (for prompt too) and simulation improvements for upgrade and dark sector event generation

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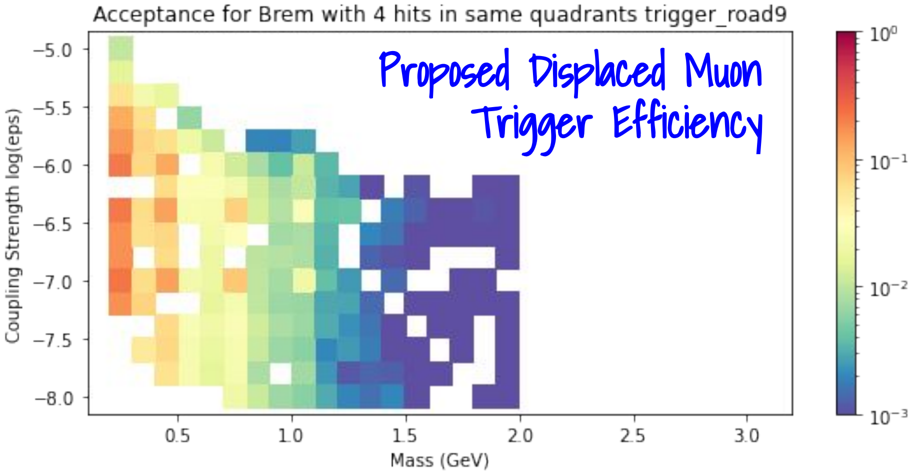
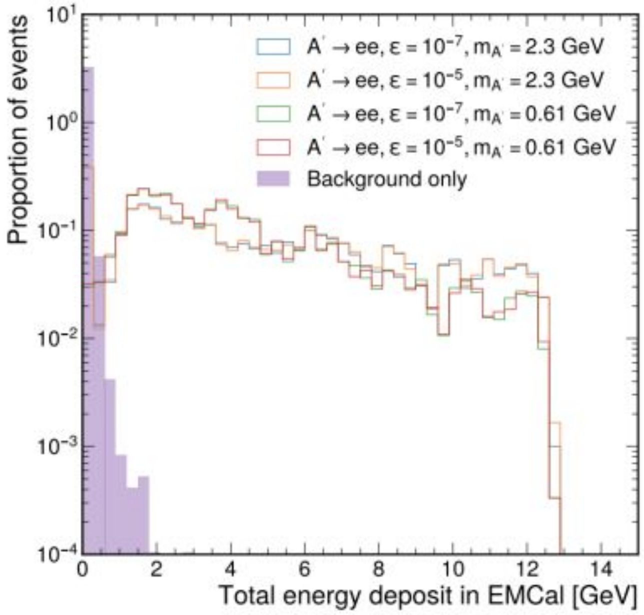


EMCal Energy Trigger



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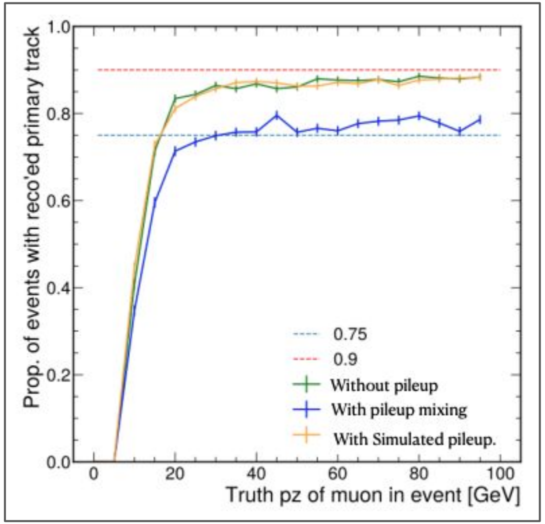
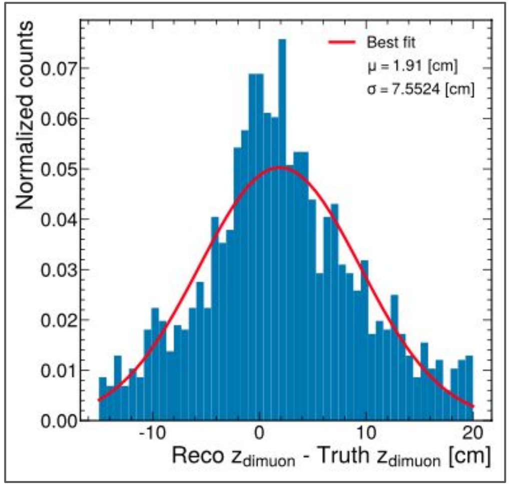
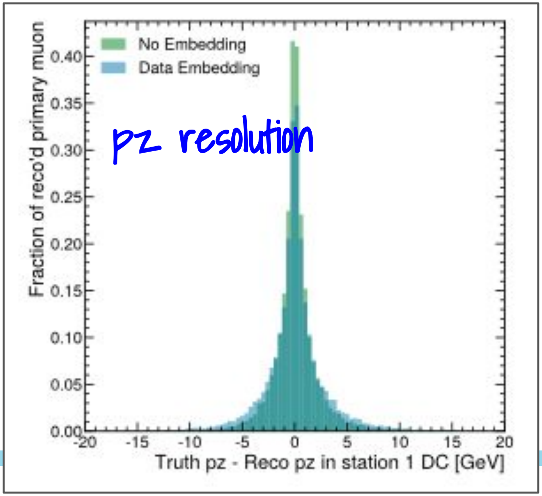


tracking efficiency

vertex resolution





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Dark Sectors @ SpinQuest/DarkQuest

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- **Calorimeter & Particle ID**
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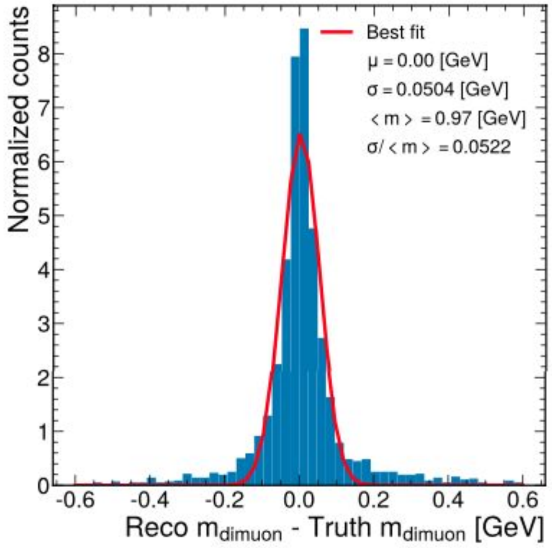
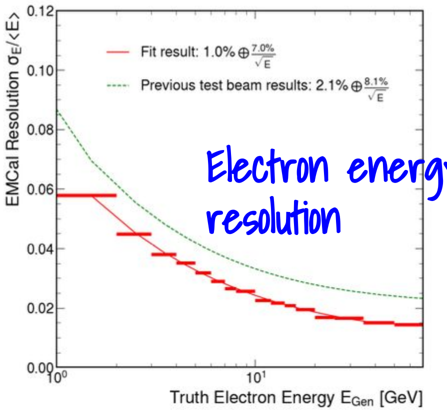
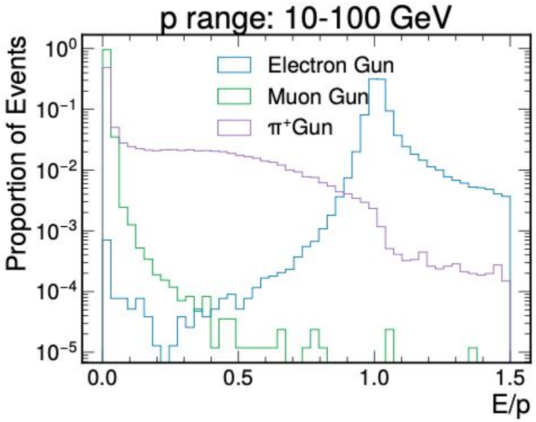
mass resolution





Electron energy resolution



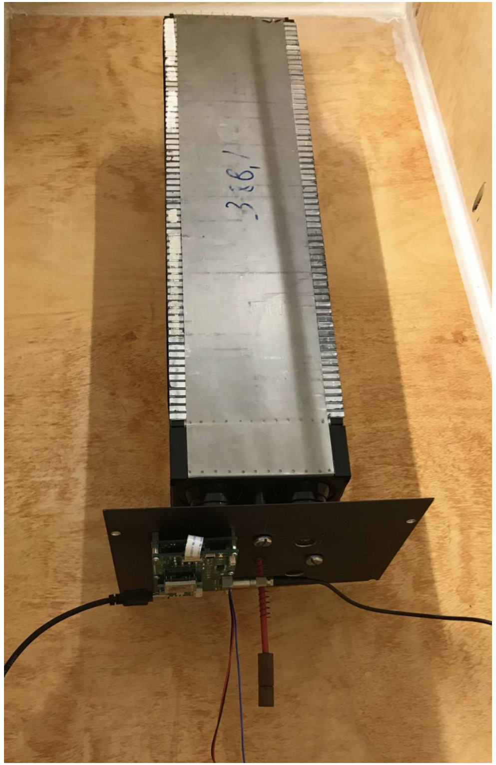
Particle ID

Dark Sectors @ SpinQuest/DarkQuest

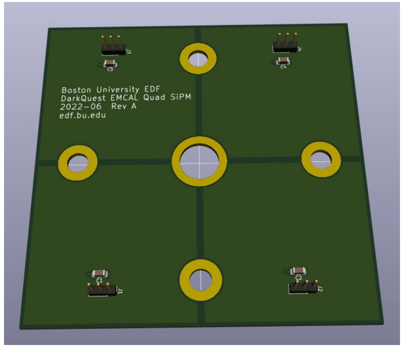
MIT/BU EMCal test stand has been developed for electronics studies

- Comparing different readout options (fully custom and generic system a la STAR, or dedicated off-the-shelf system from CAEN)
- CAEN FERS-5200 system a strong candidate: minimal design work, competitive price, and short lead time for integration
- Will be available to measure background rates in NM4 later this year

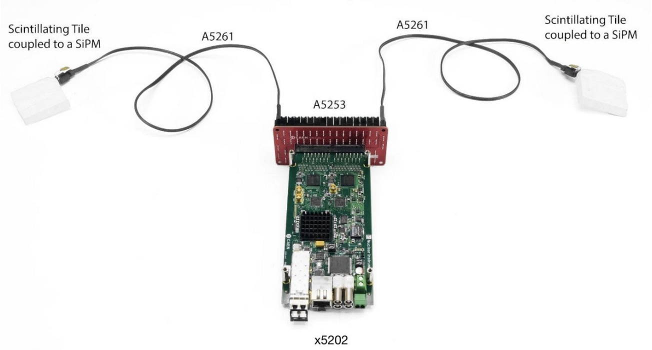
EMCal Test Stand at BU



Custom 4-ch SiPM Board



CAEN 64-ch A5202 ASIC Board



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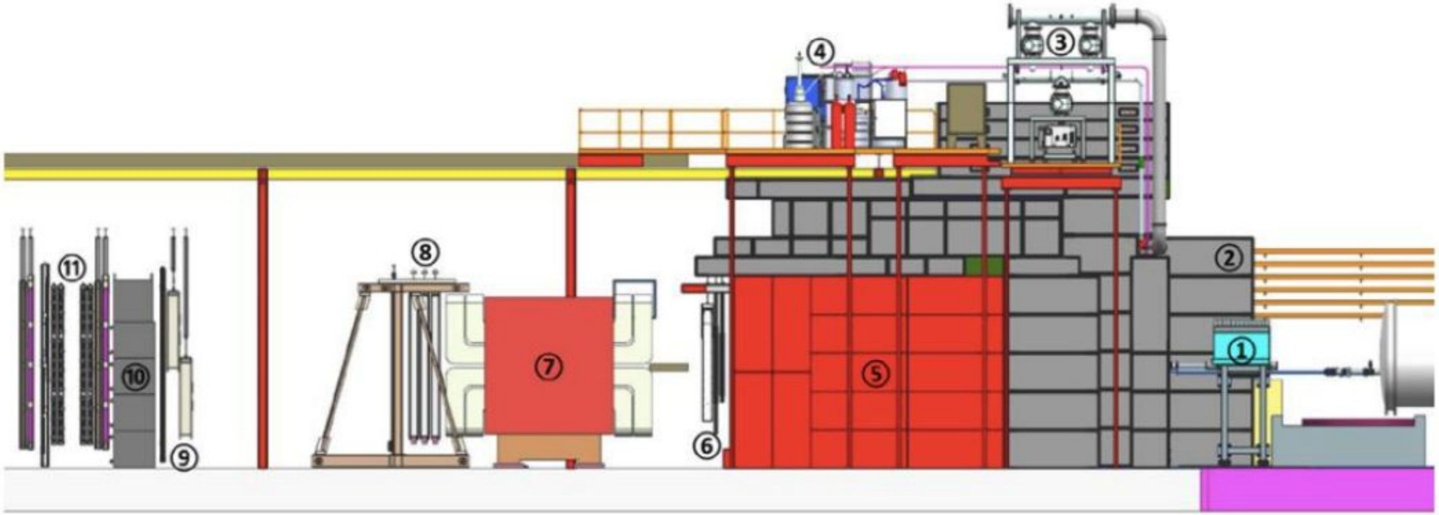
SpinQuest status and future nuclear/spin physics program

SpinQuest: construction and commissioning status



① Beam Collimator ② Target Shielding ③ ROOTS Vacuum Pump ④ Helium Liquefier
⑤ Beam Dump/FMag ⑥ Station-1 Hodoscope & Tracking ⑦ KMag
⑧ Station-2 hodoscope & tracking ⑨ Station-3 Hodoscope & Tracking ⑩ Absorber
⑪ Station-4 Hodoscope & Muon Identification

SpinQuest:
items #1-4

Inherited from SeaQuest:
items #5-11

SpinQuest: construction and commissioning status

- **Construction of all aspects of SpinQuest nearly complete**
  - New collimator installed
  - All cryo infrastructure piping installed
  - Cryogenic Safety Review now 98% complete (just a couple more weeks)
    - Pandemic and availability of lab resources cause of delays in completing these milestones
- **Target System Status**
  - Liquefaction plant installed, commissioning going well (*LHe storage dewars now full and ready*).
  - Target electronics and infrastructure ready to use
  - Software/monitors/subsystems all ready
- **Now under Accelerator Readiness Review**

SpinQuest: Moving Forward

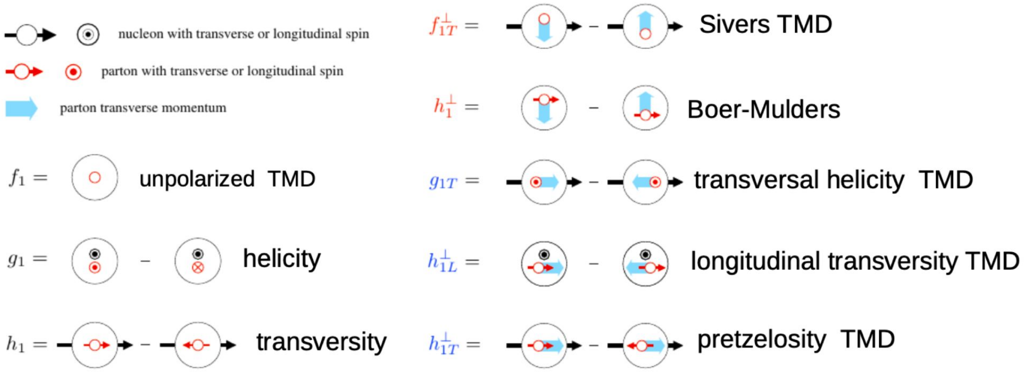
- **SpinQuest next few steps for target system**
  - Get Greenlight from Safety to run all parts
  - Test main transfer line (with LHe)
  - Have SC magnet cooldown (in July)
  - Start full cryogenic circulation commissioning
  - Polarize Target Material
- **Complete Cave Roof (shielding blocks)**
- **Complete Accelerator Readiness Review**
  - FNAL management has stepped in to ensure that this review takes place quickly and that SpinQuest has no further delays
- **Take beam in November**
  - Detector is ready for beam commissioning
  - Online monitoring is ready
  - Analysis framework is ready

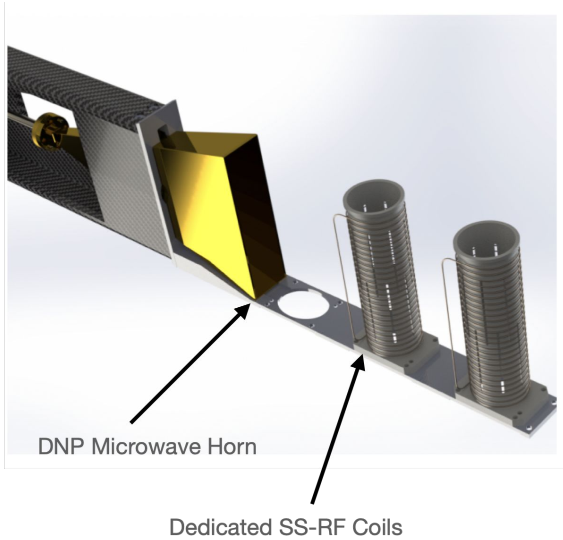
SpinQuest upgrade - future transversity program

Modest upgrade brings expanded nucleon transversity physics program

Beyond non-zero Sivers/OAM, see more at [Tranversity 2022 conference]

Primary focus is Gluon Transversity –
this would be the first experiment of its kind
on a very hot topic in Spin Physics





NIM 981, 21 (2020) 164504 (arxiv.org/abs/2008.09515)

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Modest upgrade brings expanded transversity physics program

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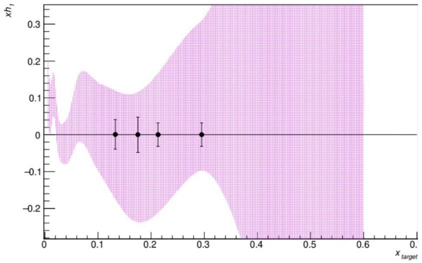
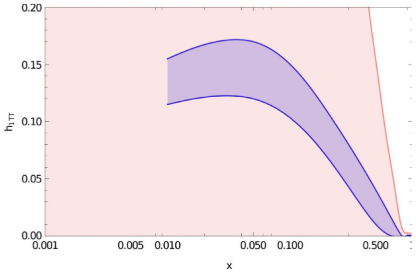
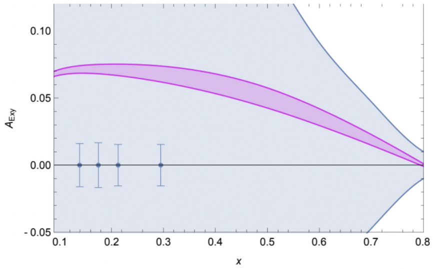
SeaQuark Transversity



Gluon Transversity



Gluon Tensor Transverse Asymmetry



The Transverse Structure of the Deuteron with Drell-Yan

The SpinQuest Collaboration[a]

We propose to measure neutron and deuteron transversity TMDs. The quark transversity distributions of the nucleon are decoupled from the deuteron gluon transversity in the Q^2 evolution due to the chiral-odd property in the transversely-polarized target. The gluon transversity TMD only exists for targets of spin greater or equal to 1 and does not mix with quark distributions at leading twist, thereby providing a particularly clean probe of gluonic degrees of freedom. This experiment would be the first of its kind and would probe the gluonic structure of the deuteron, investigating exotic glue contributions in the nucleus not associated with individual nucleons. This experiment can be performed with the SpinQuest polarized target recently assembled for experiment E1039 and the spectrometer already in place in NM4. This new experimental setup would require very minimal modification to the target system and no modification to the detector package. An additional RF-circuit and target coil are necessary to RF-modulate across the domain of the Larmor frequency to manipulate the solid-state target spin population densities. Dedicated beam-time with this novel target system is required to achieve our physics goals.

Spin/NP upgrade program

arXiv:2205.01249

- Very high proton luminosity from Main Injector
  - Large kinematic coverage overlaps with JLab and future EIC
  - Beam cycle allows target RF manipulations between spills
- No other facility can offer these two combinations allowing access to these sought after observables

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Collaboration and Outlook

Community and Collaboration

More collaboration between dark sector and NP members started > 1 year ago

- BU now a formal member, MIT associate members
- Build new Dark Sectors working group within SpinQuest
- Bringing mutually beneficial technical collaboration – e.g. shared generation of large data samples, improvements to displaced and prompt tracking

Work on-going to understand technical aspects of running concurrently

- Modest trigger bandwidth (~100 Hz) for displaced and e/γ final states
- Dedicated dark sector trigger menu with full bandwidth during target annealing

Community and Collaboration

A lot of interest in the dark sector program!

additional university HEP groups contributing students

Vibrant theory - experiment collaboration, large role in Snowmass

Theory students working closely with experimenters

Modest seed efforts have ***brought concept significantly forward***

FNAL LDRD for exploring accelerator-based dark sector concepts

(spread over 4 ideas)

URA visiting scholar award, NSF graduate fellowship

University startups to support students and hardware tests

… looking for support from PAC to expand our efforts!

High level vision – SpinQuest and DarkQuest

A vibrant and powerful spin and dark sector program running together

SpinQuest Phase

- proton spin puzzle - measure Sivers asymmetry
- dark sectors in muon final states: cover g-2 phase space, displaced dimuon

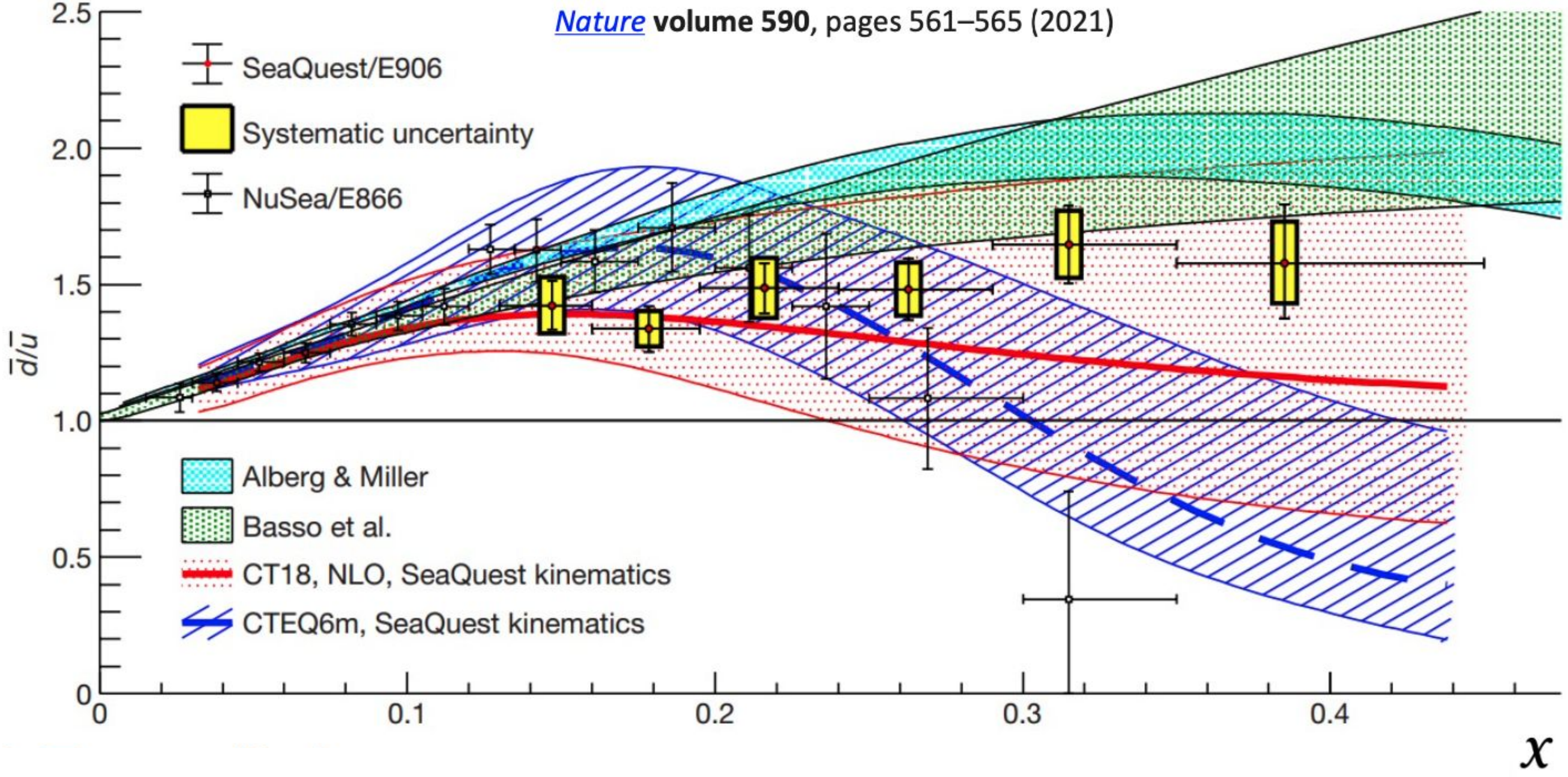
DarkQuest Phase

- Modest upgrade, ~order of magnitude less cost than contemporaries
  - EMCal upgrade (no degradation of spin physics), enhanced tracking and targetry
- World leading physics
  - Unique spin physics transversity program complementing EIC
  - significant increase in dark photon sensitivity, opens signatures for iDM, ALP, SIMPs, etc.

High impact HEP and NP/spin physics; leverage DOE and Fermilab capabilities; short timeline with modest resources

Extra material

SeaQuest



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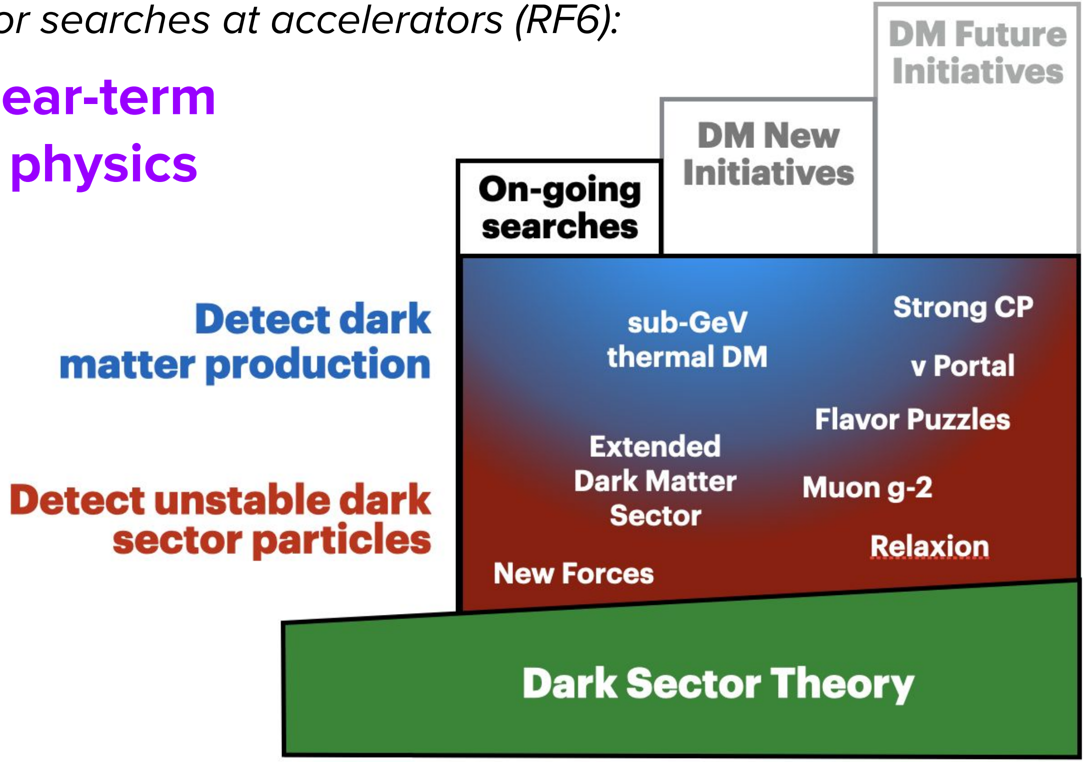
Setting the stage: dark sectors at accelerators

RF6 report (to appear)

Snowmass message from dark sector searches at accelerators (RF6):

Modest upgrades enable near-term transformative dark sector physics



Lanfranchi

Physics Beyond Colliders

PBC Experiments/projects able to produce results within 10 years

Experiment	Dataset assumed for sensitivities, beams	Tentative Timescale	References	Benchmarks	Comments
NA64-e	$3x10^{12}$ eot, electrons, 100 GeV	< LS3 (2025) (approved)	CERN-SPSC-2018-004 ; SPSC-P-348-ADD-2.	BC1, BC2, BC9	Extrapolation from data
FASER	150 fb^{-1}, pp@13 TeV	< LS3 (2025) (approved)	arXiv:1812.09139 ; CERN-LHCC-2018-036	BC1, BC9, BC9, BC11	Full simulation ? Bkg included?
NA62-dump	10^{18} pot, protons 400 GeV	< LS3 (2025) (approved)	CERN-SPSC-2019-039 ; SPSC-P-326-ADD-1	BC1, BC4, BC5, BC6, BC7, BC8, BC9, BC10, BC11	Full simulation, bkg from data
milliQan	3 ab^{-1}	First run: 2022		BC3	
nTOF	$6x10^{17}$ pot, protons, 20 GeV	2022-2023	INTC-I_233	BC1	New experiment
NA64-mu	Up to $2x10^{13}$ mot, muons, 160 GeV ~10^7 μ/spill	LS3 (2026) < run < LS4 (2031) Pilot run 11/2021	CERN-SPSC-2019-002 ; SPSC-P-359, CERN-SPSC-2018-024 ; SPSC-P-348-ADD-3 1903.07899, 2110.15111	BC2	Full simulation, Bkg included.
SHADOWS	Phase1: 10^{19} pot, protons , 400 GeV Phase2: 5 10^{19}, protons, 400 GeV	LS3 < run < LS4 (2031) LS4 < run < LS5 (2035)	EoI: 2110.08025	BC4, BC5, BC6, BC7, BC8, BC10, BC11	Fast simulation, bkg being estimated using dump data in ECN3

UNDER CONSTRUCTION

In green: already approved
In black: under consideration

Physics Beyond Colliders

PBC experiments/projects able to produce results between 10 and 20 years

Experiment	Dataset assumed for sensitivities, beams	Tentative Timescale	References	Benchmarks	Comments
SHiP	2x10^{20} pot, 400 GeV protons	2037+ ?	CDS: CERN-SPSC-2019-049 ; SPSC-SR-263 Progress Report: CERN-SPSC-2019-010	BC1, BC2, BC4, BC5, BC6, BC7, BC8, BC9, BC10, BC11	Full simulation, bkg included Based on MC sample: 1.8x10^{9} pot, with p>1 GeV from Progress Report, p. 24, CERN-SPSC-2019-010 ; SPSC-SR-248)
KLEVER/NA62 high intensity	A few 10^{19} pot/year	After LS4 ?	1901.03199	BC4, BC9, ….	Full simulation, bkg evaluated but not included in results?
CODEX-b	300 fb^{-1}, pp@14 TeV	2038 (end of HiLumi) CODEX-beta could start after LS3	EOI: 1911.00481 Background: 1912.03846	BC4, BC5, BC6, BC7, BC8, BC10, BC11	Fast simulation, background evaluated but not included in results?
MATHUSLA	3 ab^{-1}	2038 (end of HiLumi)	Physics case: 1806.07396 LoI: 1811.00927	BC4, BC5, BC6, BC7, BC8, BC10, BC11	Fast simulation, no bkg (bkg being evaluated with data)
FLArE@FPF	3 ab^{-1}	2038 (end of HiLumi)	2109.10905	DM via scattering (BC2)	Fast simulation, no bkg
FASER-2@FPF	3 ab^{-1}	2038 (end of HiLumi)	2109.10905	BC1, BC4, BC5, BC6, BC7, BC8, BC9, BC10, BC11	Fast simulation, no bkg
FORMOSA@FPF	3 ab^{-1}	2038 (end of HiLumi)	2109.10905, 2010.07941	BC3	Fast simulation, no bkg
Gamma Factory	Laser on stripped ions (LHC)	Still undefined.. PoP crucial to understand.	2105.10289 (DP)	BC1, BC6	Fast simulation, no bkg

UNDER CONSTRUCTION

7

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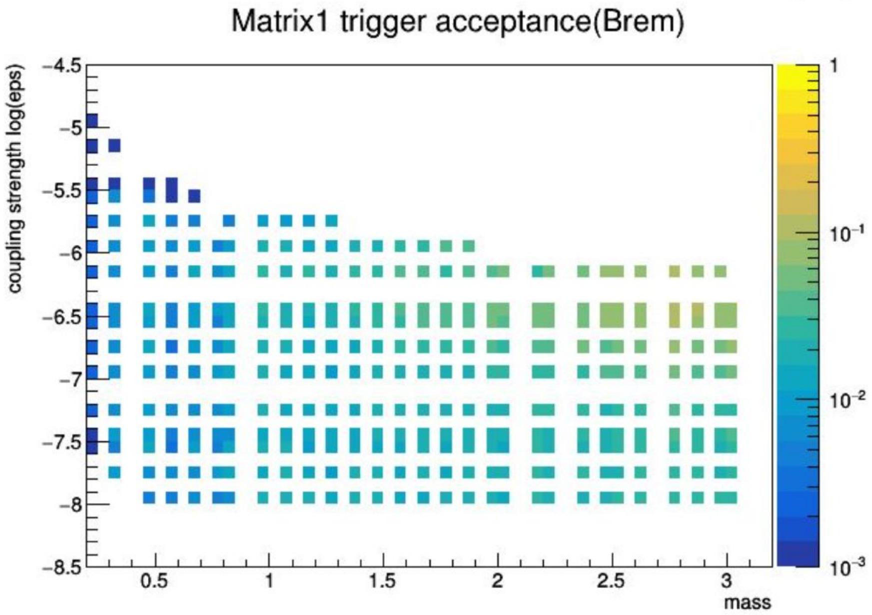
Dark Sector Snowmass effort

Detailed study from HEP community to understand dark sector performance

- **Trigger**
- Tracking & Vertexing efficiency
- Calorimeter & Particle ID
- Mass reconstruction

Current Muon Trigger Efficiency for displaced signatures



Proton vs. Electron Beams

Proton		Electron
• nuclear collision length ~ 10 cm	$L \sim n_{\text{atom}}\, \ell$	• radiation length ~ 1 cm
• QCD reactions	$\alpha_s \gg \alpha_{\text{em}}$	• EM reactions
• $\gamma + \pi + \mu + \cdots$	dark Higgs, axion, leptophilic scalar	• $\gamma + \cdots$
• Main Injector (FNAL), SPS and LHC (CERN)	$100\ \text{GeV} \gg 1\ \text{GeV}$	• LCLS (SLAC), CEBAF (JLab)

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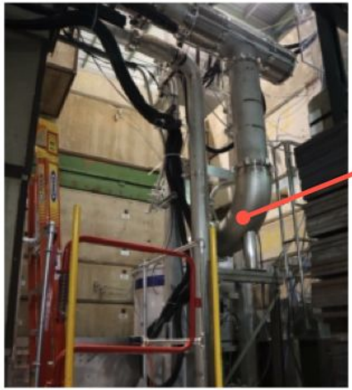
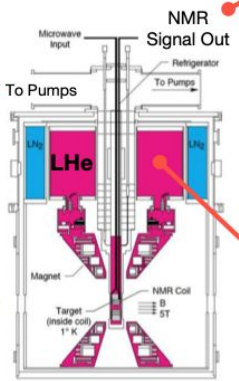
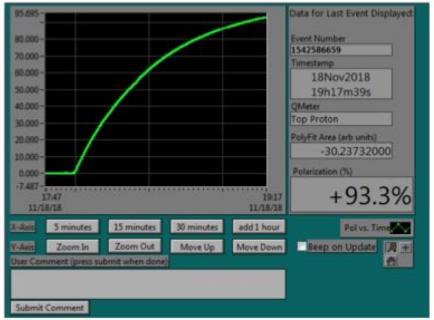
SpinQuest: construction and commissioning status

Target installation and full safety review will be completed within ~ 1 month



Target installed in cave with nearly complete connections to cryo-platform above





2018 UVA cooldown polarization data -
Cooldown at Fermilab next month

Quantum Technology Helium Recovery
200 L / day capacity – self sustaining

Target commissioning during summer shutdown, start data taking in late October / early November with protons