

Updates from FLArE

Forward Liquid Argon Experiment at the LHC

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ASTROCENT



FLArE & far-forward searches at the LHC

Selected (preliminary) design details:

BNL team & Milind Diwan

- Membrane cryostat

Inner volume $\sim 36\text{m}^3$ (2m x 2m x 9m inner dimensions), LAr mass $\sim 20\text{-}50$ ton

- Time Projection Chamber

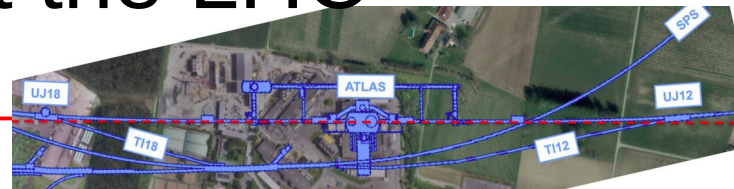
Fiducial volume 7m^3 (1m x 1m x 7m), LAr mass ~ 10 ton

- Photon Detection System

200 PMTs in total, total window area of the PMT on array ~ 0.45 m²

- Simulations **Jianming Bian & Wenjie Wu (UCI)**

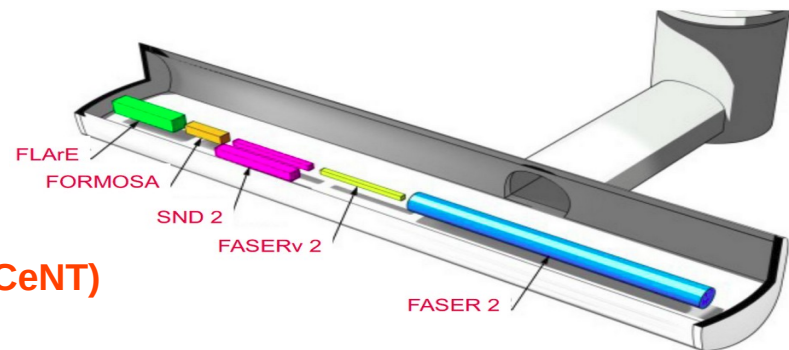
FPF
(FLArE,...)



Forward Physics Facility (FPF), talks: Jamie Boyd

FASER (2): Jonathan L. Feng

FORMOSA: Matthew Citron



Credit: John Osborne, Kincso Balazs, Jonathan Gall

Physics goals

Standard Model

Neutrino measurements (>100k events)

Implications for QCD, cosmic rays...

Talk: Mary Hall Reno

Beyond the Standard Model

Light dark matter,

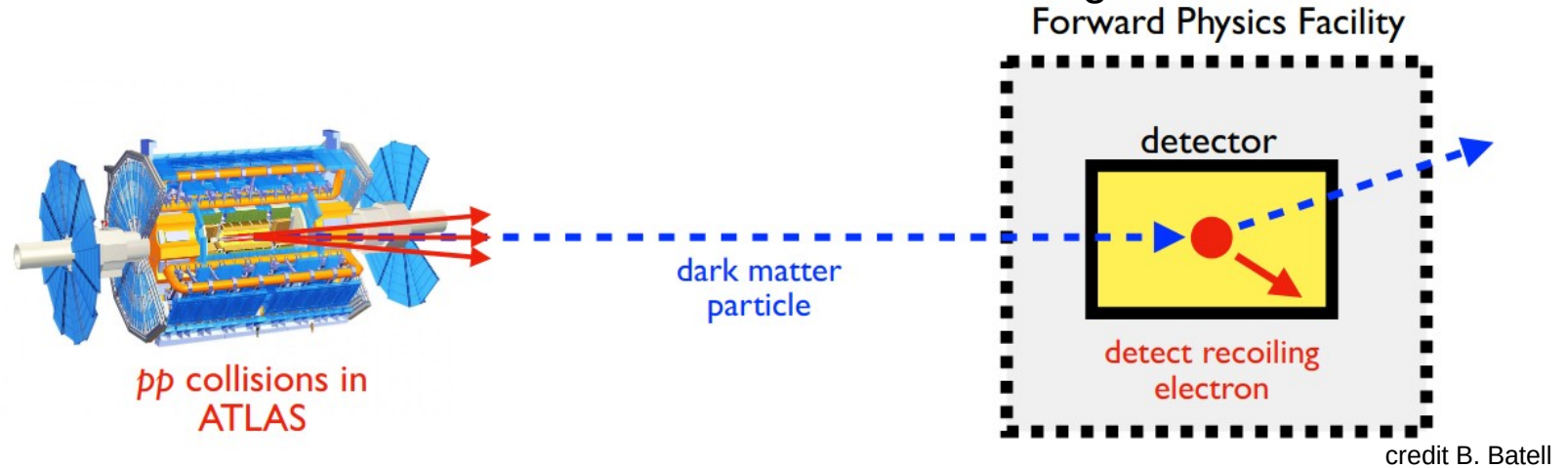
THIS TALK

Neutrino BSM interactions,

Milli-charged particles,...

Direct dark matter detection at the LHC

- Light DM search: DM particles produced in the far-forward region of the LHC & their scattering in a distance detector

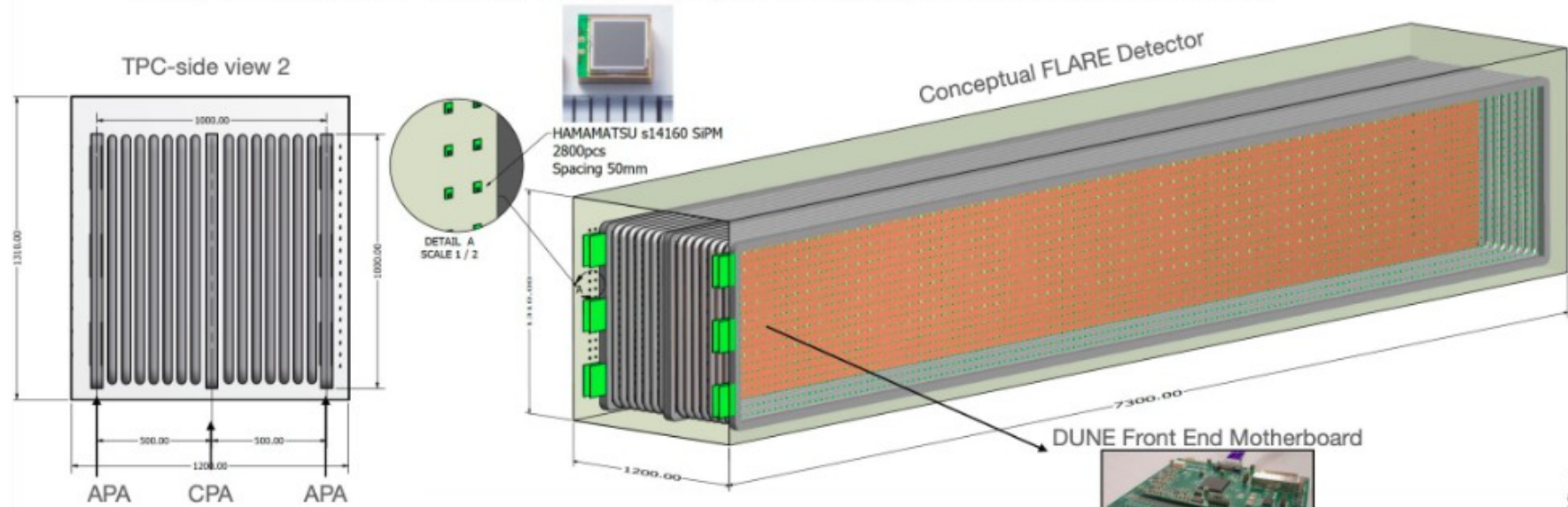


- This search is highly complementary to the traditional DM direct detection searches:
 - probe of relativistic interaction rates of LDM (DM energy ~ a few hundred GeV) [collider-boosted DM]
 - the search is not sensitive to the precise abundance of χ DM component (possible variations in cosmological scenario) [collider-produced DM]

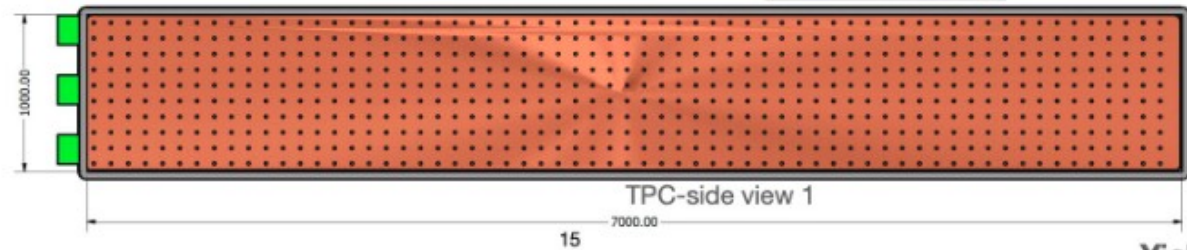
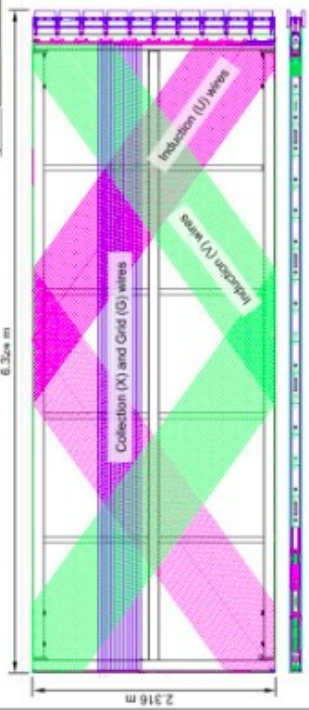
FLArE Detector Preliminary Drawings

- All dimensions are in millimeter (this is not a design, just a sketch)**
- ▶ In particular, the GTT cryostat has corrugations which need to be considered (Bo Yu)
 - ▶ The gap needed for safety is inspired by NeXO design with similar HV needs

Volume	11.5 m³
LAr	16 ton
LKr	27.5 ton
membran	0.5 m
heat loss	290 W



DUNE APA for scale only



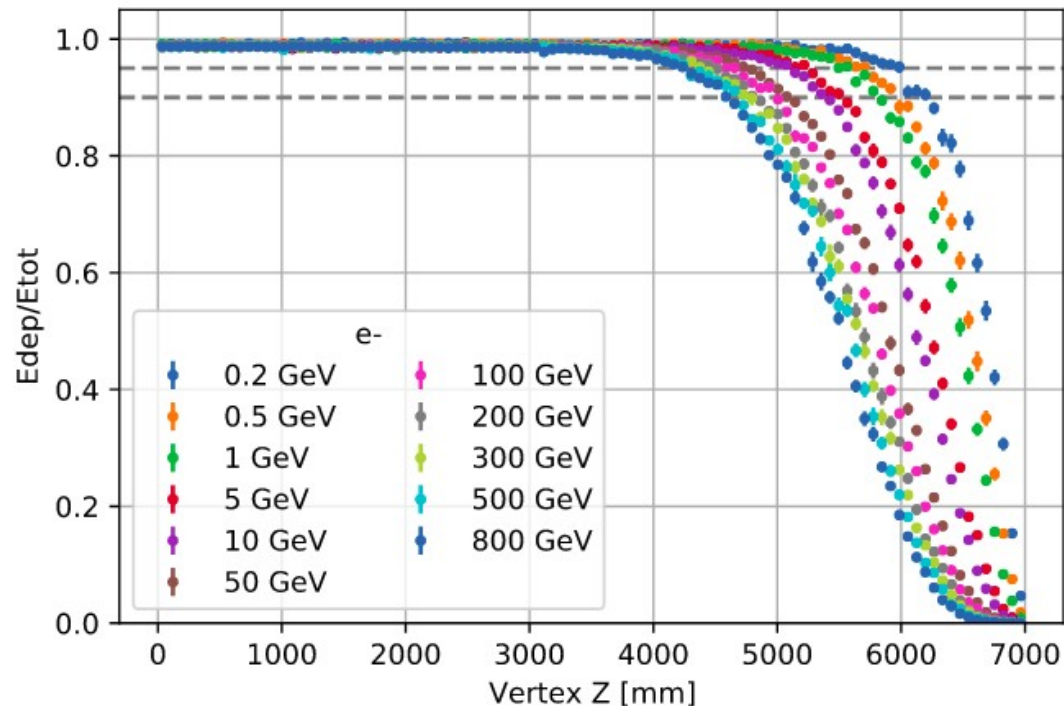
Energy Containment



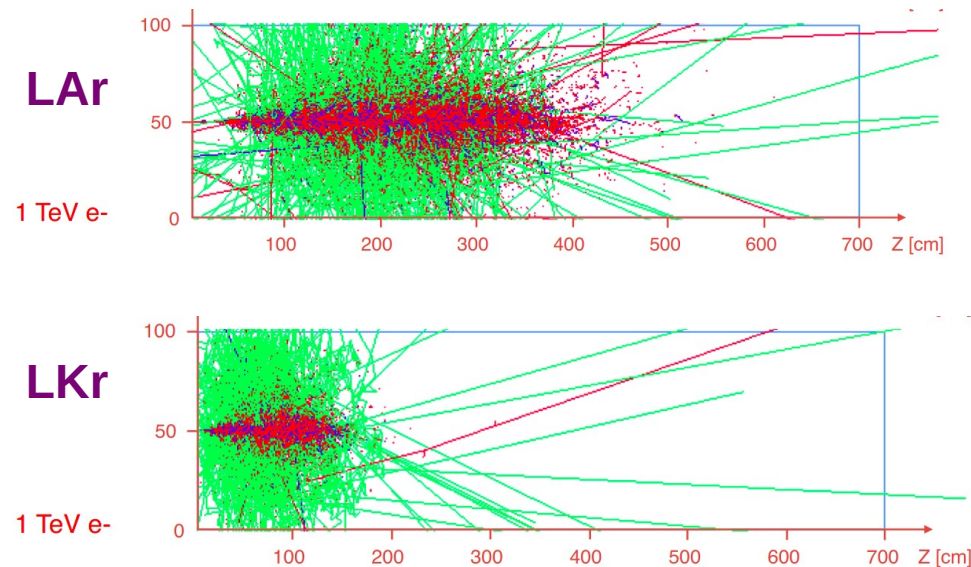
Credit: Wenjie Wu
Jianming Bian

- Electron shower in LAr

DM search: low-energy showers,
good containment



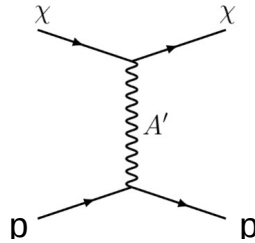
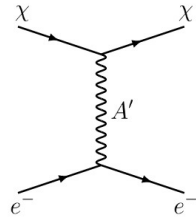
Currently also considered: LKr
(better high-energy shower containment)



Dark matter signatures

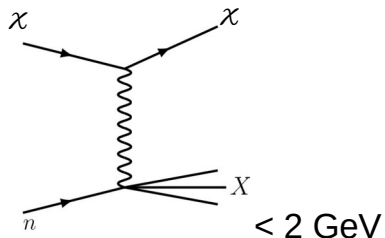
- Scattering off electrons

Light vector mediator favors low momentum exchange

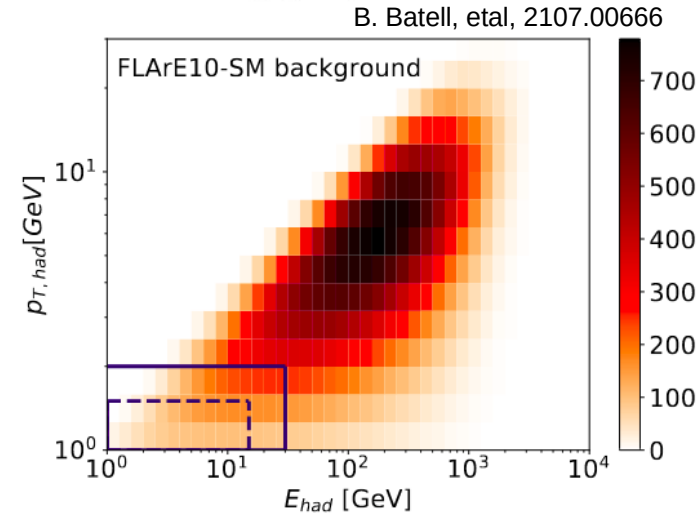
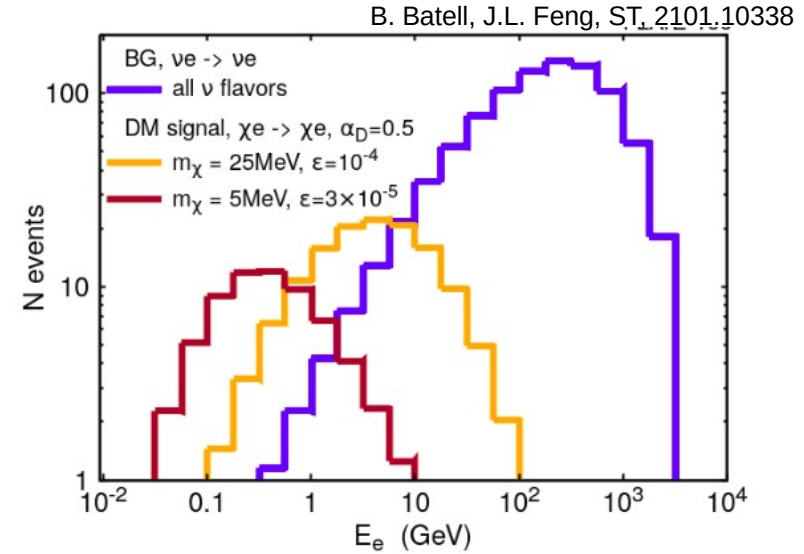
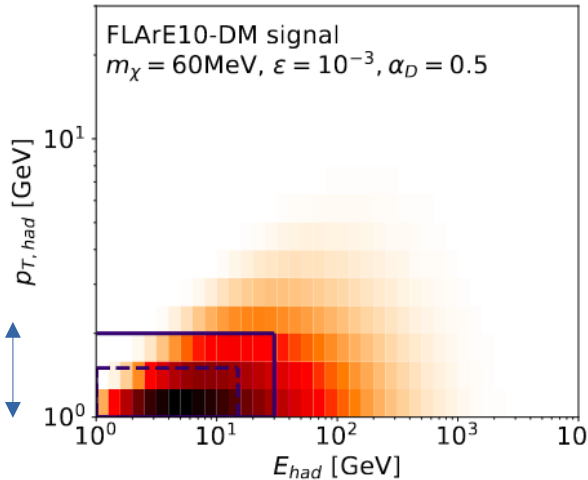


- Elastic scattering off protons

- single proton track with $p_p < 500$ MeV
- we require $E_{k,p} > 20$ or 50 MeV
- impact of Final State Interactions (FSI) taken into account



- DIS regime



Dark matter relic target

Benchmark scenario: dark vector portal to scalar DM

$$\mathcal{L} \supset A'_\mu (\epsilon e J_{EM}^\mu + g_D J_D^\mu) \quad \mathcal{L} \supset |\partial_\mu \chi|^2 - m_\chi^2 |\chi|^2 \quad J_D^\mu = i\chi^* \overleftrightarrow{\partial}_\mu \chi$$

Relic target line: (thermal) $\Omega_\chi h^2 = 100\%$ DM

- above relic target line:
underabundant χ DM
- below relic target line:
too much χ DM
(non-standard cosmology needed)

Other targets:

- Majorana DM (suppressed DD rates)

B. Batell, etal, 2101.10338, 2107.00666

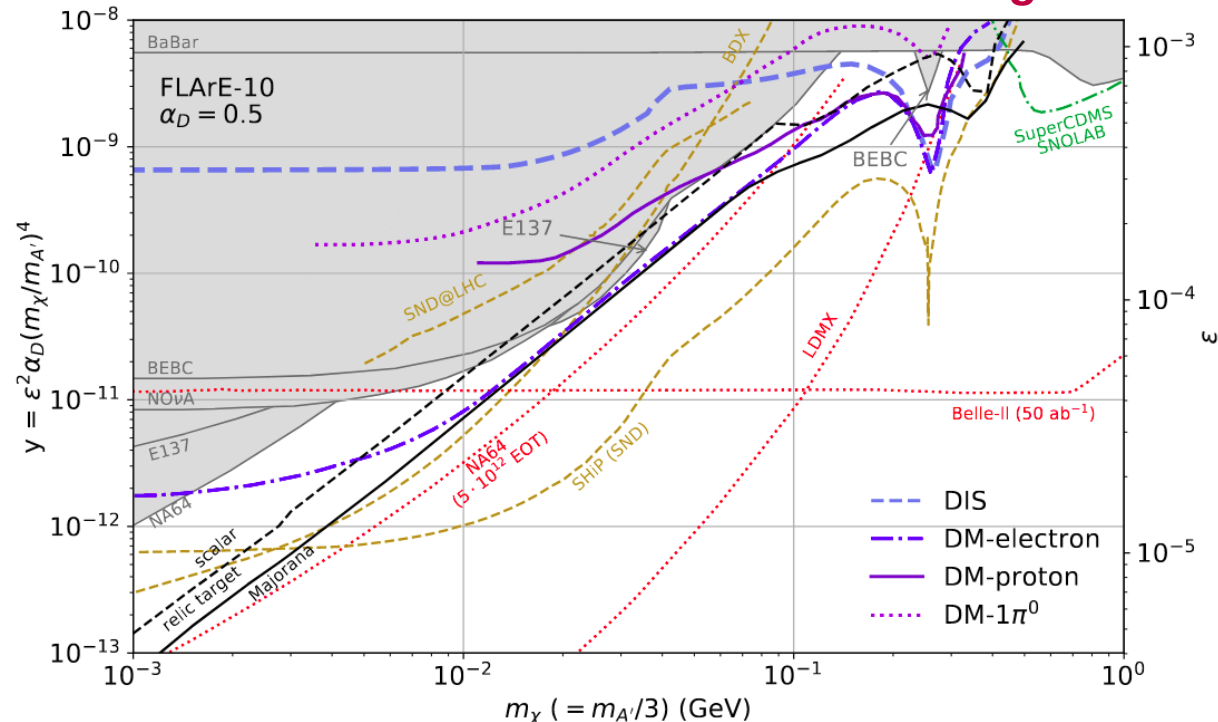
- Hadrophilic DM

B. Batell, etal, 2111.10343

- Neutrino-portal DM

K.J. Kelly, etal, 2111.05868

Includes ν -induced backgrounds



Conclusions

- far-forward searches at the LHC starts now (Run 3), exciting opportunity for HL-LHC
- scattering detector needed (neutrino physics, light DM, ...)
- FLArE: Forward Liquid Argon Experiment (possibility Lar+LKr)

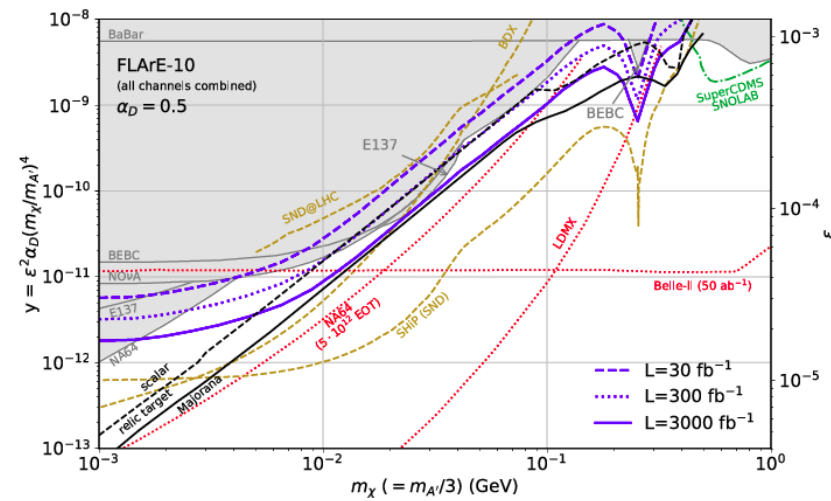
– **multipurpose scattering detector**

DM search:

- Opportunity to directly detect DM scattering at the LHC in the relativistic regime
- Neutrino-induced backgrounds to be rejected based on typical energy depositions
- Muon-induced backgrounds: veto/time info + sweeping magnet

Talk: Jamie Boyd

Further studies ongoing + work on detector design



BACKUP (credit BNL team & Milind Diwan, BNL)

▸ **Preliminary conceptual design for LAR Detector**

- Membrane Cryostat reference to DUNE design

- Inner volume $\sim 36\text{m}^3$ (2m x 2m x 9m inner dimensions), LAr mass ~ 50 ton
- Membrane insulation thickness ~ 0.5 m
- Heat leak into cryostat from wall ~ 58 W (assuming 7.2 W/m² heat flux)

- TPC reference to ICARUS design

- Fiducial volume 7m^2 (1m x 1m x 7m), LAr mass ~ 10 ton
- Perforated metal plate CPA in the middle with main bias voltage
- Two identical APAs on both sides with 50 cm drift distance
- APA with wrapping wires following DUNE APA arrangement, Single-end readout
- ~ 1200 readout wires on one APA with DUNE wrapping method, could be more with other wire arrangement
- HV required for the common 0.5kV/cm is 25kV , can go for higher drift field
- Readout with DUNE front end electronics

- Photon Detection System

- 100x Hamamatsu R11410 PMT(3-inch window) array at the back of each APA, 200 PMTs in total
- Total window area of the PMT of on array ~ 0.45 m²