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E-1000 DarkSide 50-kg DAr

P-1001 MAX Multi-ton Argon & Xenon

FCPA Retreat 2010

Henning O. Back

North Carolina State University

(Princeton U.)

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DarkSide

UMass Amherst
Arizona State University
Augustana College
Black Hills State University
Fermilab
University of Houston
University of Notre Dame
Princeton University
Temple University
UCLA

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Liquid Argon Dark Matter arose from the program for developments in Liquid Argon aimed at large Neutrino Detectors.

Neutrino Argon program
- T-962 ArgoNeuT (0.25 tonne) TPC in NuMI beam - taken data under analysis
- E-974 MicroBooNE (200 tonne) TPC in Booster Neutrino beam (CD-1, CD-2 at end of 2010)
- LBNE (20 ktonne) TPC at DUSEL (Engineering studies – CD-1 at end of 2010)

Infrastructure
- Materials Test System – qualify detector materials (that do not contaminate Argon)
- TPC for electronics development – develop wire readout, HV feedthroughs, TPC field cage

Purity without Evacuation
- Liquid Argon Purity Demonstration (30 tonne Argon in a non-evacuable tank)

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Technical Issues for Multi-ton Argon Detector

Chemical purity of Argon to allow electron drift (10's ppt O2 equivalent),
Chemical purity of Argon to allow light propagation
Light collection and detection (photodetectors, wavelength shifters)
HV feedthroughs (>100 kV) in Argon gas
TPC design
Data Acquisition
Cryogenics (and associated safety issues)
Detector Materials Qualification
Shielding from environment radiation
Radio-purity of detector materials

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Technical Issues for Multi-ton Argon Detector

Chemical purity of Argon to allow electron drift (10's ppt O2 equivalent), ***(neutrino and DM)***

Chemical purity of Argon to allow light propagation (*DM*)

Light collection and detection (photodetectors, wavelength shifters) ***(neutrino and DM)***

HV feedthroughs (>100 kV) in Argon gas ***(neutrino and DM)***

TPC design ***(neutrino and DM)***

Data Acquisition ***(neutrino and DM)***

Cryogenics (and associated safety issues) ***(neutrino and DM)***

Detector Materials Qualification ***(neutrino and DM)***

Shielding from environment radiation *(DM)*

Radio-purity of detector materials *(DM)*

obvious overlaps => leverage for DM search => association with Princeton (Galbiati, Calaprice)

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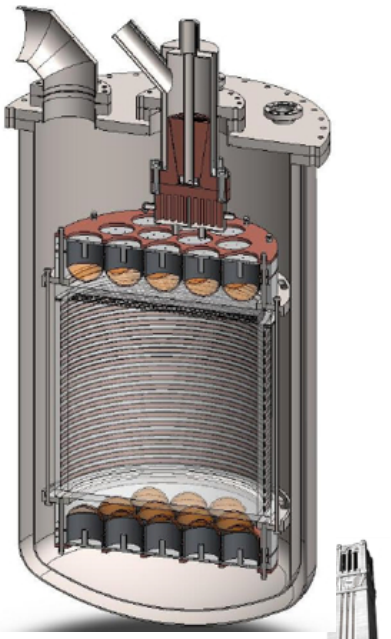
DarkSide 50

- Dual phase TPC
- 50 kg active volume, reach 10^{-45} cm^2
- A combination of technologies and techniques that maximize background characterization and rejection
- The goal: ~0 background detector in multi-ton•year exposure
- **Test bed for 3 new technologies to achieve zero background**
  - **Depleted argon**
  - **QuPID (hybrid photon detector)**
  - **Active neutron veto with n capture on boron-loaded liquid scintillator**



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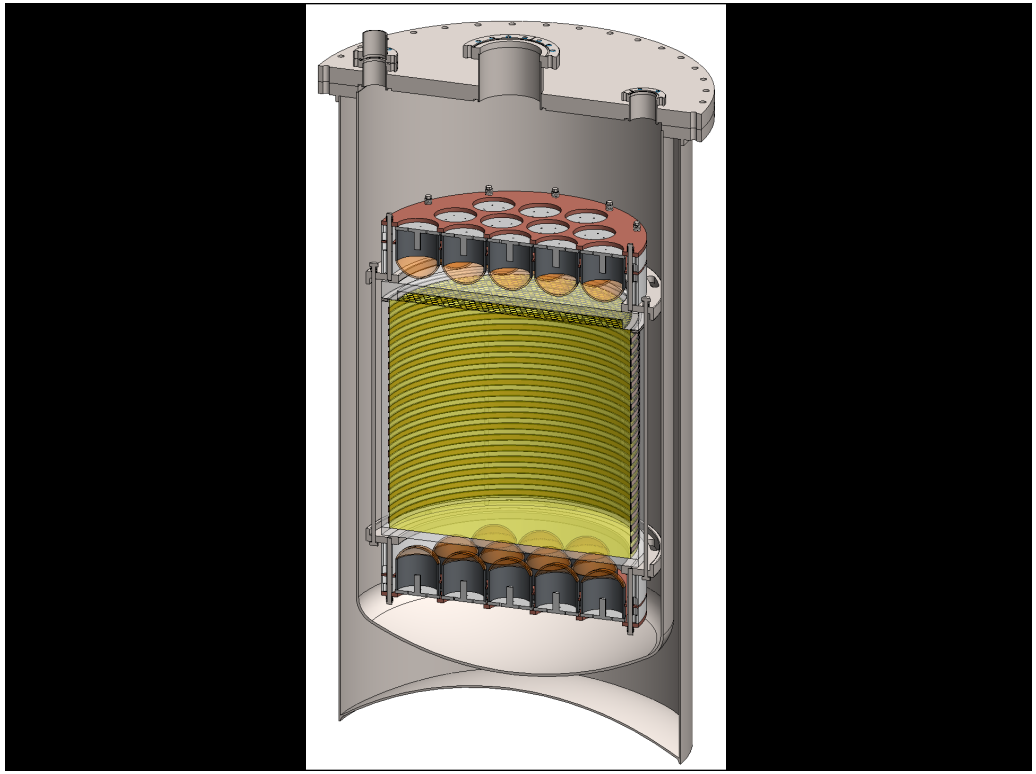

Here is how it would work. The DarkSide detector would be placed in a titanium sphere of 3.5 m diameter, to be filled with borated scintillator. The titanium sphere would be contained within the dimensions required for installation within the CTF tank, through the large opening on the top of the tank itself.

Interested European Groups

- INFN Laboratori Nazionali del Gran Sasso
- INFN and Università degli Studi Genova
- INFN and Università degli Studi Milano
- INFN and Università degli Studi Napoli
- Joint Institute for Nuclear Research, Dubna
- RRC Kurchatov Institute, Moscow
- St. Petersburg Nuclear Physics Institute
- Technische Universität München

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^{39}Ar: A limiting factor

- ^{39}Ar facts
  - **Beta emitter (q = 565 keV, $t_{1/2}$ = 269 years)**
  - Produced in the atmosphere through cosmic ray interactions (eg, ^{40}Ar(n, 2n)→^{39}Ar)
  - In the atmosphere
    - ^{39}Ar/^{40}Ar is 8×10^{-16} (0.8 ppq)
    - **Specific activity = 1 Bq/kg**
  - Is the limiting factor in size and sensitivity for argon detectors
    - Due to ^{39}Ar event pile-up
    - Detector size limited to 500-1000kg
- ^{39}Ar depleted argon gas
  - Available through isotopic purification (expensive)
  - ^{39}Ar production is strongly suppressed deep underground
  - Gas wells found with available argon (CO_2 and He)

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Underground Argon extraction

- Extracted from CO_2 well in southwestern Colorado
- CO_2 and O_2 absorbed and returned to company
- Starting from ~400 ppm of argon we produce gas ~6% argon
- Final gas = Ar, N_2, and He
- Live-time production rate – 1.2kg/day
- Collected ~35 kg so far, ~120 kg needed for E-1000

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VPSA plant at DOE Canyon facility in Colorado

Argon purification

- Method – cryogenic distillation
- Under construction at the PAB
  - Henning Back managing local Fermilab assembly
  - Large effort from Cary Kendziora and co.
  - Expected production running Aug. 2010
- Expected performance
  - Production – nearly 10 kg/day
  - Argon purity – 99.999%
  - Collection efficiency - 95%
- Funded - (NSF PHY-0811186 & FNAL)
- **Capable of purifying Xe from Kr at ppt levels! Crucial for ton-scale Xe searches**

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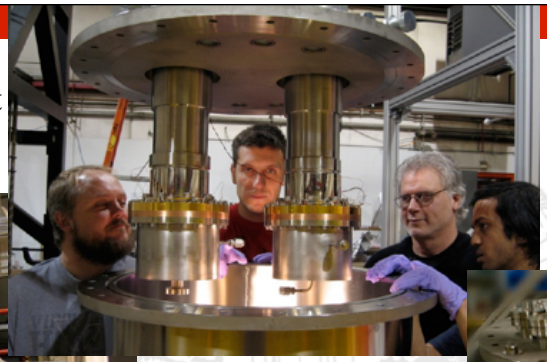
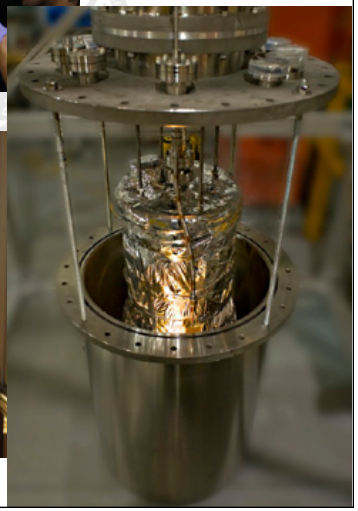
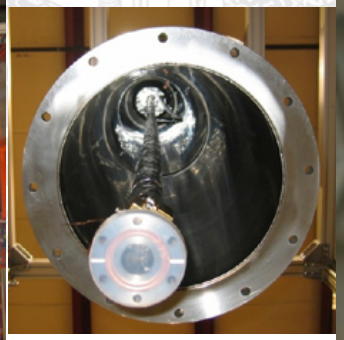
Vacuum Jacket



Column Head

Reboiler





Column

Production version 3” QuPID

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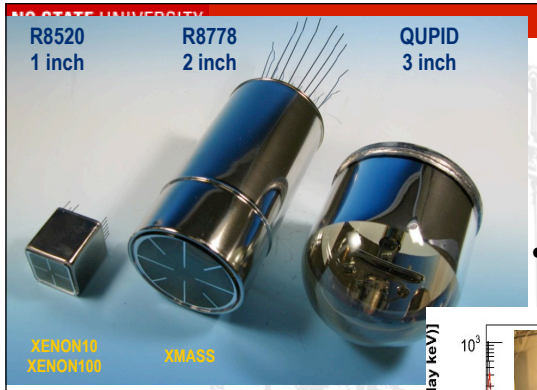
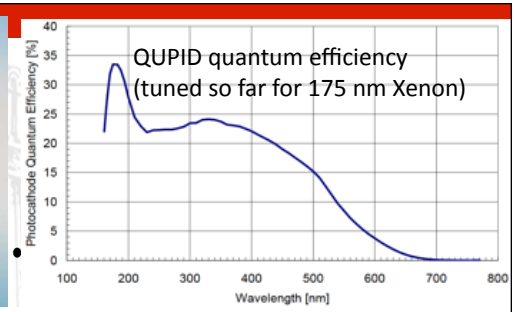
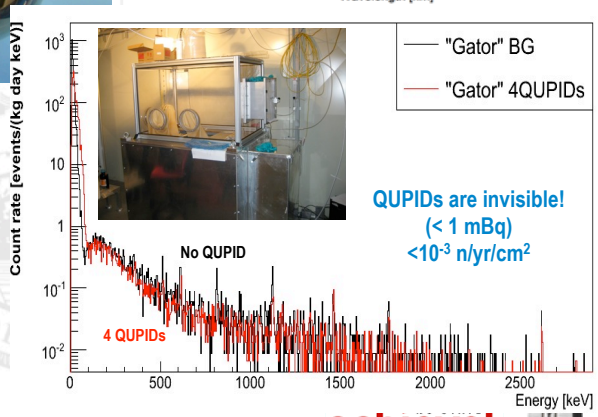




QUPID radioactivity
(not detectable above background)



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20kg detector

- Prototype for DarkSide using standard materials and equipment
- Science reach
  - 10^{-44} cm^2 for WIMP cross section
- R&D goals
  - **Light yield: achieved 4 pe/ keV**
  - Low energy threshold
  - Neutron background
- Total argon mass = 20 kg
- **Fermilab designed and built the 3" PMT bases**
- **Underground deployment Fall 2010**

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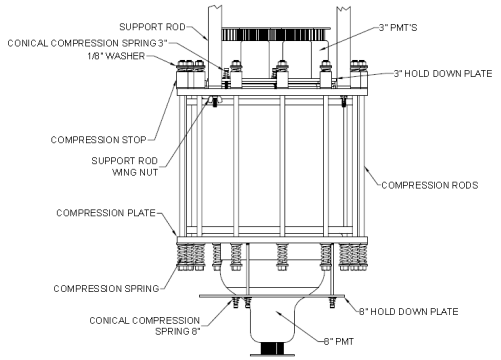
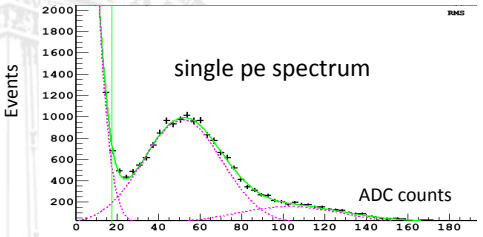
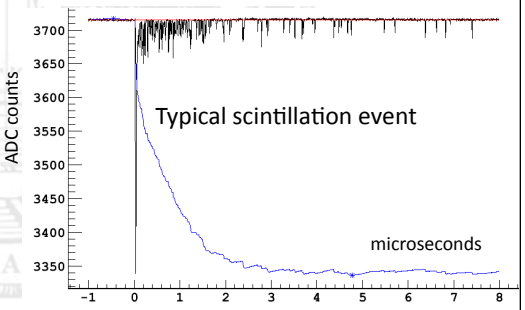


20 kg Vessel with upper PMTs.(PMT bases (circled) and HV feedthroughs (not shown) are from Fermilab. Running with no field





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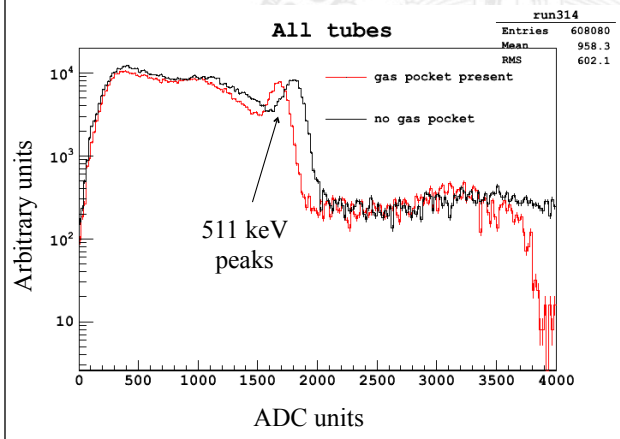
20 kg detector



- Assembled and running at Princeton
- Spectum
  - All PMTs combined
  - Source = ^{22}Na (β+ emitter)
  - 511 keV anihilation gammas are measured in coincidence with NaI detector

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DarkSide funding

- $1.7M estimated equipment costs
- Depleted Argon independently funded (NSF PHY-0811186)
- Proposal submitted to NSF Oct 2009 (Princeton, Temple, Houston, UCLA, UMass, Augustana) - requests 100% of equipment costs
- Proposal to DOE submitted by Princeton & UCLA
- **FWP to DOE submitted by Fermilab in March 2010**

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DarkSide-50

Manpower Request in E-1000 Proposal
- 1 Applications Physicist
- 0.5 Mechanical Engineer, 0.5 Electrical Engineering - would add 0.25 ME for distillation

Fermilab Contributions

- Cryogenic Simulations
- DAQ and Electronics (with Houston)
- Chemical Purification (with Temple)
- Passive Shielding and Muon Veto
- Storage of Depleted Argon
- Possible trial operation in NuMI tunnel

Present FNAL:participation: S. Pordes (1/2 time), H.Jostlein (1/4 time),
A. Sonnenschein & S. Brice have expressed continuing interest.

Fermilab resources presently used: PAB group (C. Kendziora) ~1 FTE, S. Hansen (EE, 0.1 FTE), Prepul PPD/EE assembly

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Field Work Proposal submitted in March 2010 for DarkSide-50

Item	FY10	FY11	FY12	Type	Provides
a & b	$285k	$285k	-	M & S	$500k
c	$40k	$30k	$13k	EE	19 wks
d	-	$10k	$10k	MT	8 wks
e	$6k	$5k	-	ME	2 wks
f	$15k	$15k	$10k	ME	9 wks
g	-	$55k	$80k	EP	33 wks
total	$346k	$400k	$113k		

Items a & b:The funds requested from DOE for items 1 & 2 are material costs.

Item c: We are requesting support for a total of ~ 4.5 months of electrical engineering (EE) for the design of the trigger and data-acquisition system.

Item d: We are requesting support for a total of 8 weeks of mechanical technician (MT)

Item e: We are requesting support for 2 weeks of mechanical engineering (ME) analysis, 1 week each at two different times.

Item f: We are requesting support for 9 weeks of mechanical engineering for the design of the passive shield and muon veto

Item g: We are requesting 33 wks total of technical physicist support.

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MAX - Multi-ton Argon & Xenon

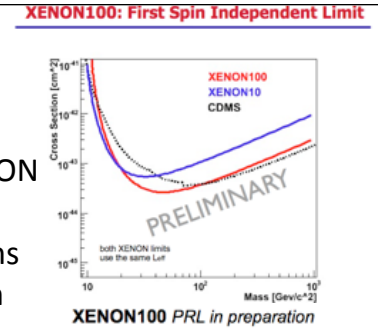
UMass Amherst
Arizona State University
Augustana College
Black Hills State University
Coimbra University
Columbia University
Fermilab
University of Houston
INAF
LNGS
MIT
University of Münster
University of Notre Dame
Princeton University
Rice University
Shanghai Jiao Tong University
Temple University
UCLA
University of Virginia
Waseda University
University of Zürich

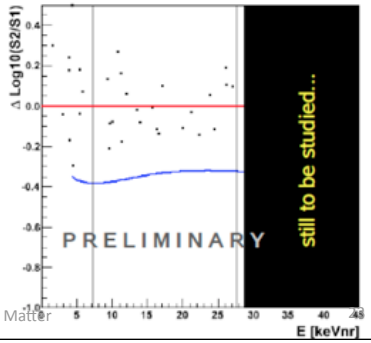
MAX collaboration S4 Proposal for engineering of a 5 ton Argon and 2 ton Xenon detector at DUSEL
Collaboration between DarkSide and XENON

Fermilab staff assigned important positions in electronics, cryogenics, and purification for the LAr detector.

Fermilab Directorate provided letter of support.
NSF has funded to $3.5M

Cryogenic distillation column has very important role in guaranteeing ultimate purify for DAr and Xe targets





DarkSide – 50 Challenges/Advantages/Risks

Challenges: Existing Dark Matter experiments

Advantages: Background-free multi-ton-year exposures

Risks: Funding schedule

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