Dark Side
and its perspectives

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Conseil Scientifique de l'IN2P3
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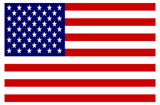
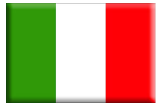
The Collaboration



Augustana College, SD
Black Hills State University, SD
Drexel University, PA
Fermi National Accelerator Laboratory, IL
Princeton University, NJ
Temple University, PA
University of Arkansas, AR
University of California, Los Angeles CA
University of Houston, TX
University of Massachusetts, Amherst, MA
Virginia Tech, VA

Joint Institute for Nuclear Research, Dubna
Skobeltsyn Institute for Nuclear Physics, Moscow
National Research Centre Kurchatov Institute, Moscow
St. Petersburg Nuclear Physics Institute, Gatchina



Laboratori Nazionali del Gran Sasso, Assergi
Universita' degli Studi and INFN, Genova
Universita' degli Studi and INFN, Milano
Universita' degli Studi and INFN, Perugia
Universita' degli Studi and INFN, Napoli

Smoluchowski Institute of Physics, Krakow

Institute of High Energy Physics, Beijing

Institute of Nuclear Research, Kiev

University College London, London

Guidelines

Double phase Argon time projection chamber
- Liquid argon is a great dark matter target
- Good scintillation (~40,000 photons/MeV)
- Transparent to its own scintillation light
- Easy to purify

Background identification
- Argon pulse shape discrimination
- S1/S2 discrimination
- Neutron with borate scintillator

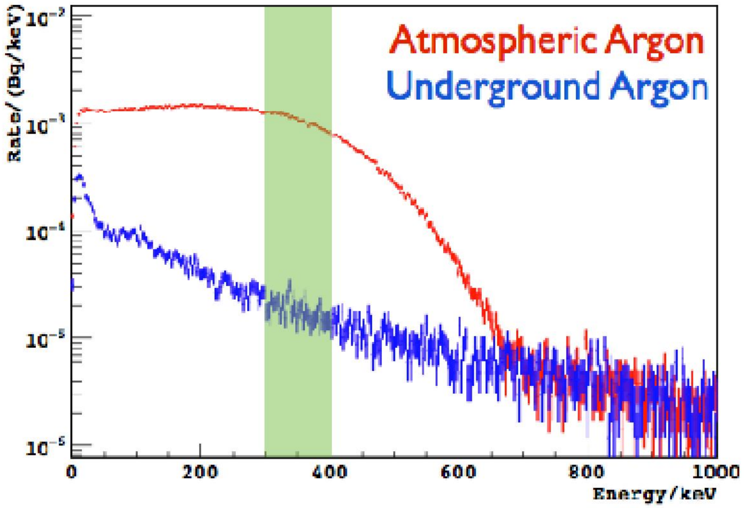
Active shields
- Water Cherenkov against muons
- Borate scintillator against mu and n
- Multiple scattering with the TPC

Three stage approach program
- DS-10 kg: full prototype
- DS-50 kg: physics goal 10^{-45} cm^2
- DS-G2: physics goal 10^{-47} cm^2

Ultra-low background materials
- Depleted liquid argon
- Low background photo-detectors
- (…)

The ^{39}Ar Problem

Depleted in ^{39}Ar
Depletion factor: < 0.65% (90%CL)



Cryogenic Distillation
0.9 kg/day production
70 - 81% efficiency
~ 19 kg produced so far
arXiv:1204.6061

VPSA system (Cortez)
0.5 kg/day production - 125 kg produced so far (150 kg needed)
arXiv:1204.6024

Relatively inexpensive technology, could be scaled to multi-ton detectors

DarkSide and DEAP will collaborate to expand the argon extraction facility in Cortez

- ✓ 5000 kg for DarkSide
- ✓ 4000 kg for DEAP
- ✓ Aim for **50 kg/day** argon collection rate

Upgrade begin in 2013

The Detector

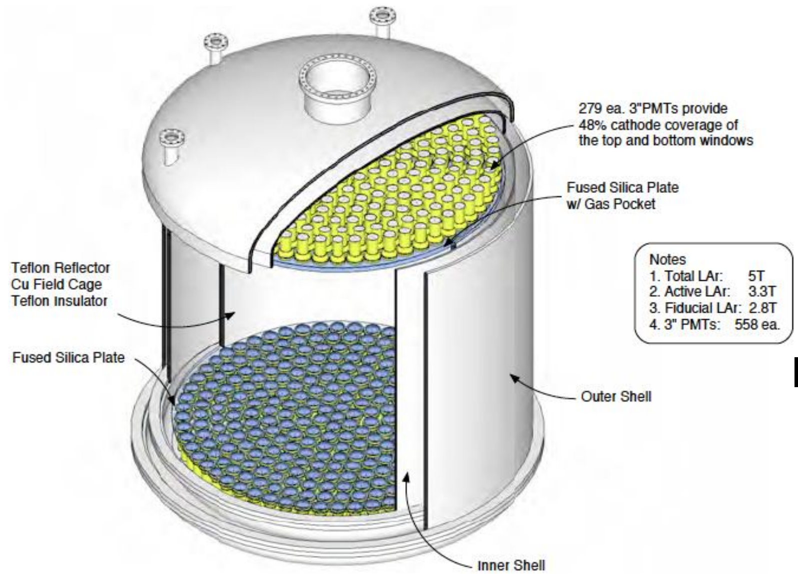
Dark Side 50

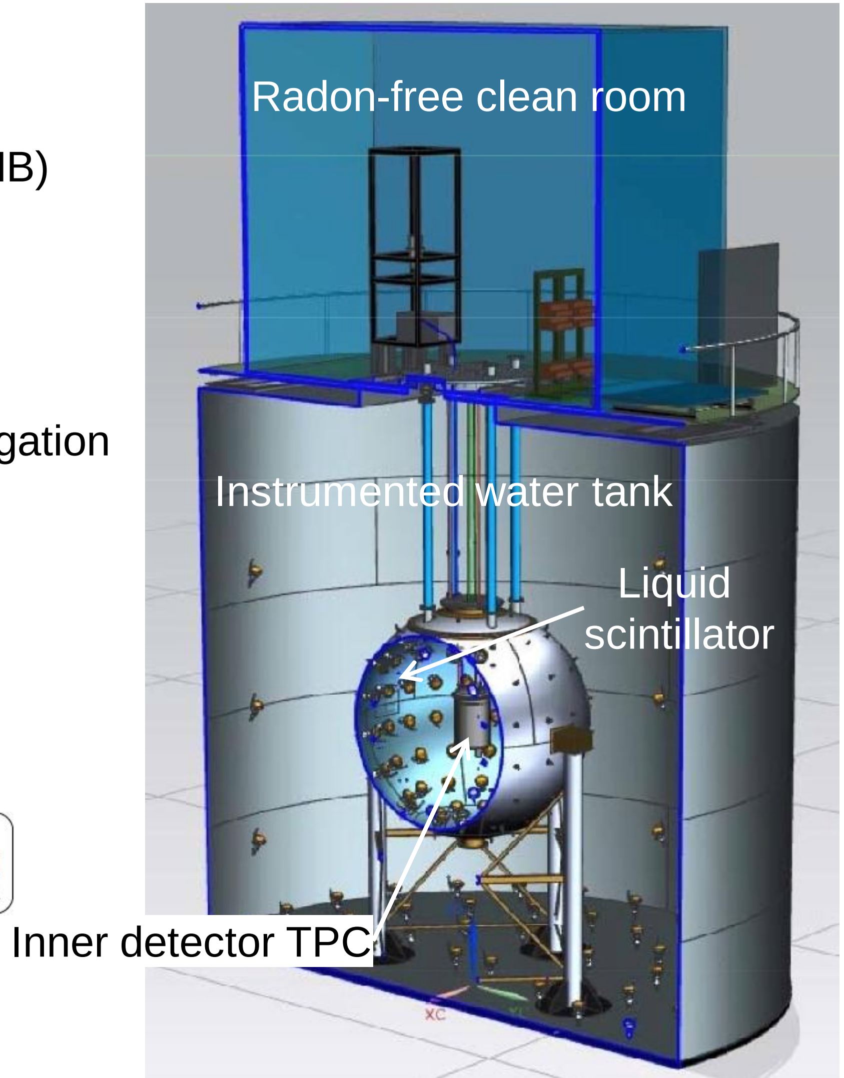
External water tank
5.5 m radius – 10 m high
80 PMTs 8-inches

Neutron veto
2 m radius
110 PMTs 8-inches
Borate scintillator (PC+TMB)

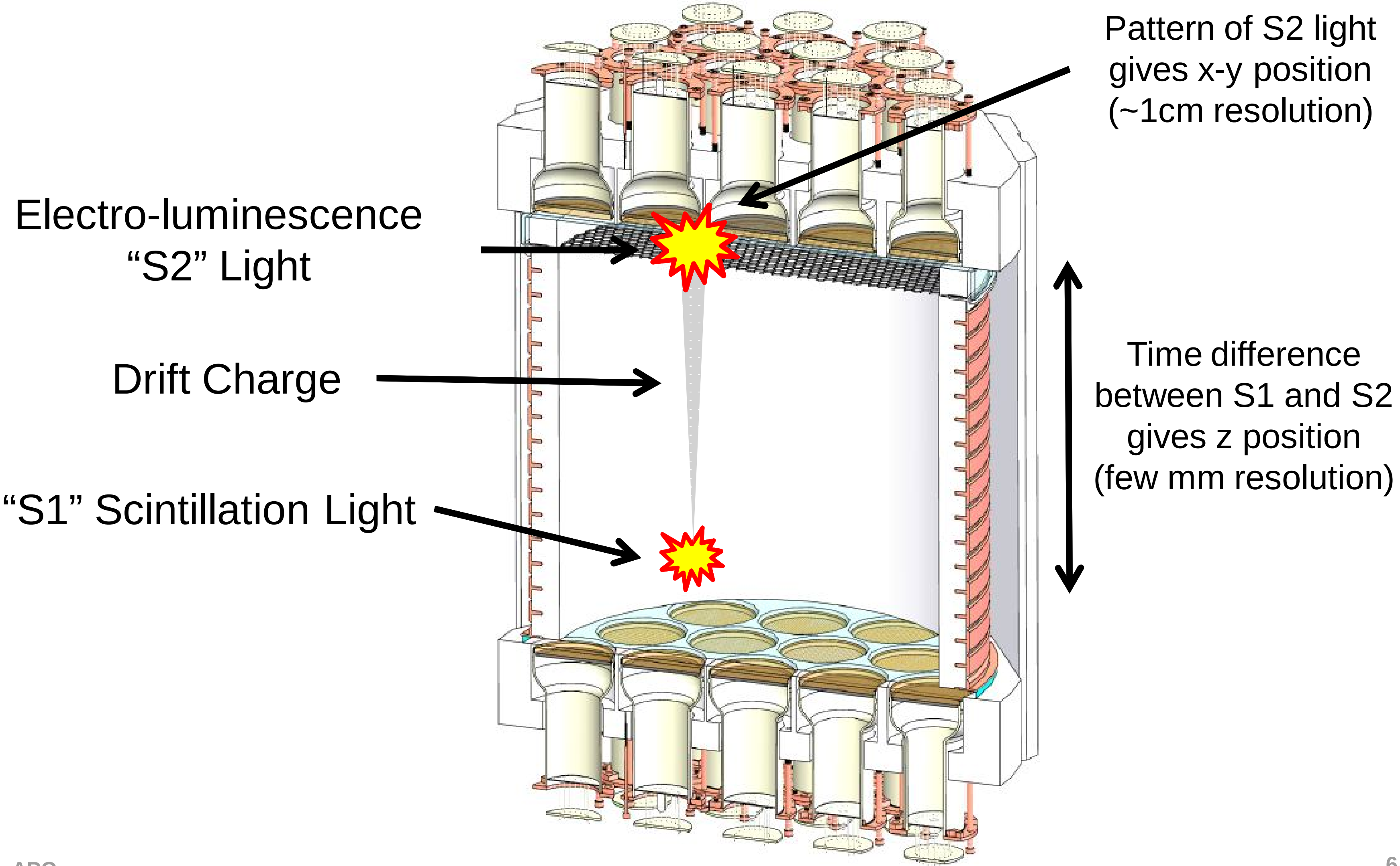
TPC-50kg
38x3 inches PMTs
Wavelength shifter
Extraction field: ~3 kV/cm
Drift field: ~1 kV/cm

TPC-3 tons
~ 550 3’’ PMTs
Design under investigation





Two Phase Argon TPC



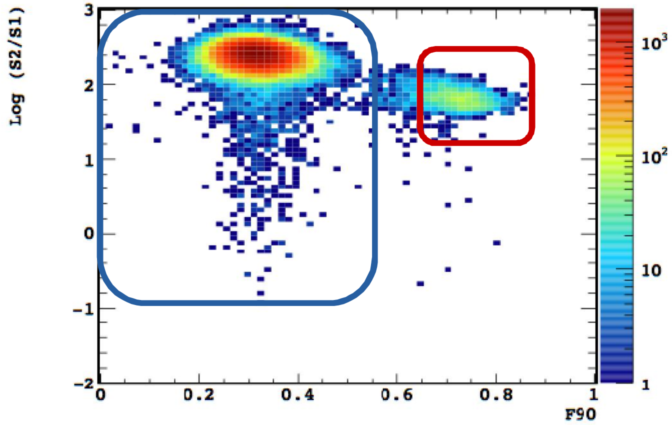
Discrimination Power

Very powerful **rejection capability** for electron recoil background

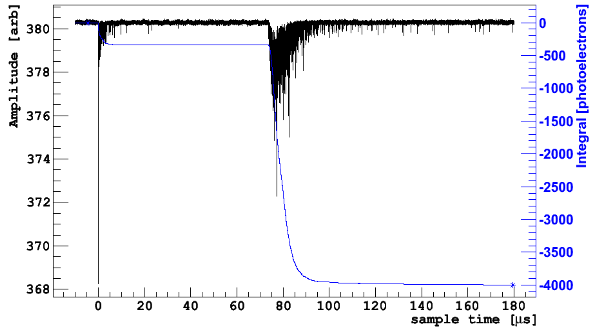
The recombination probability (and hence the ratio of **S2/S1** light) also depends on ionization density **10^2-10^3** additional discrimination

The ratio of light from singlet (**~7 ns** decay time) and triplet (**1.6 μs** decay time) depends on ionization density
>10^8 discrimination factor
Xenon singlet and triplet decay times are comparable

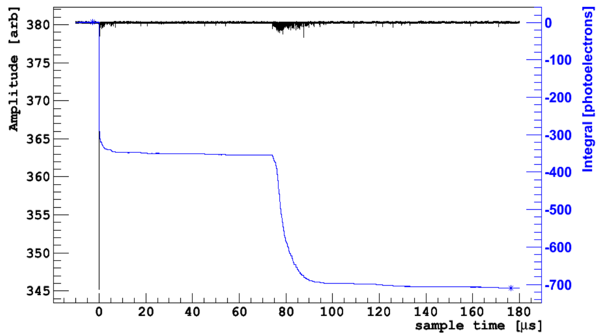
>10^{10} total electron recoil rejection



AmBe neutron calibration



Electro magnetic events



Nuclear recoils

The Vetos

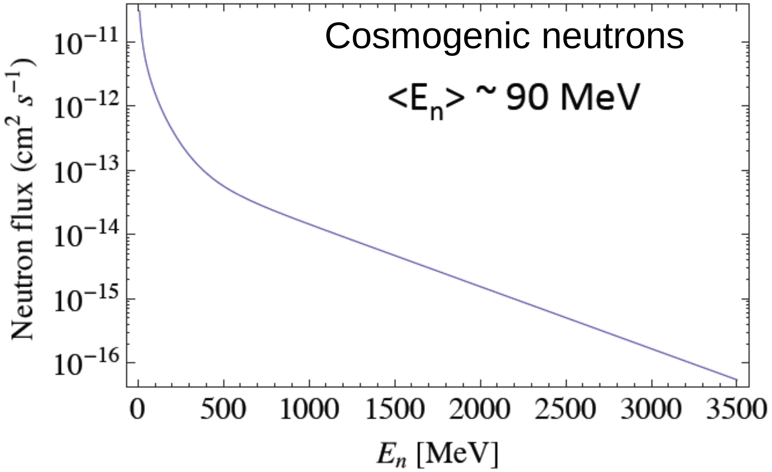
Neutrons from natural radioactivity

Radiogenic neutrons

• from (α,n) and spontaneous fission (e.g. U and Th)
• energy ~ a few MeV (<10 MeV)

Source in DarkSide:

• PMTs (low background PMTs ~ few n/year/PMT)
• Steel in cryostat and support structures



Cosmogenic neutrons

Flux at LNGS: 2.4 m^{-2} day^{-1}

• Expected rate ~ 3×10^{-33} /s/atom
• WIMPS rate ~ 10^{-34} /s/atom (@ 50 GeV s~10^{-45})

Passive shielding

neutrons from surrounding rocks

• 3 m of water rej. factor **~10^3**
• 1.5 m of liquid scintillator: rej. factor **~20**

Boron-loaded radio-pure liquid scintillator

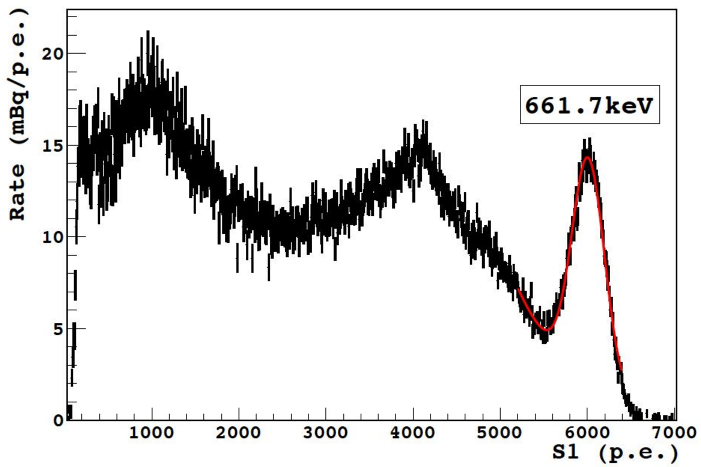
• ^{10}B+n -> ^{7}Li+α(1.474MeV)+γ(0.478MeV) (93.7%)
• **σ=3837b** and capture time ~ 3μs
• 1m thick veto: **rejection factor ~10^3** against external neutrons

Water Tank muon veto + neutron veto reduces total cosmogenic background by **>> 10^3**

Neutrons are identified in the borate scintillator: **measurement of the residual rate**

The Stages

Dark Side 10 kg
installed in Hall C of LNGS
10 kg active mass of atmospheric argon
Operating at LNGS since summer 2011
Measured light yield **9 p.e./keVee**.
Proved **discrimination** power and **HHV feedthrough stability** demonstrated over 8 months of data taking at full value of the fields

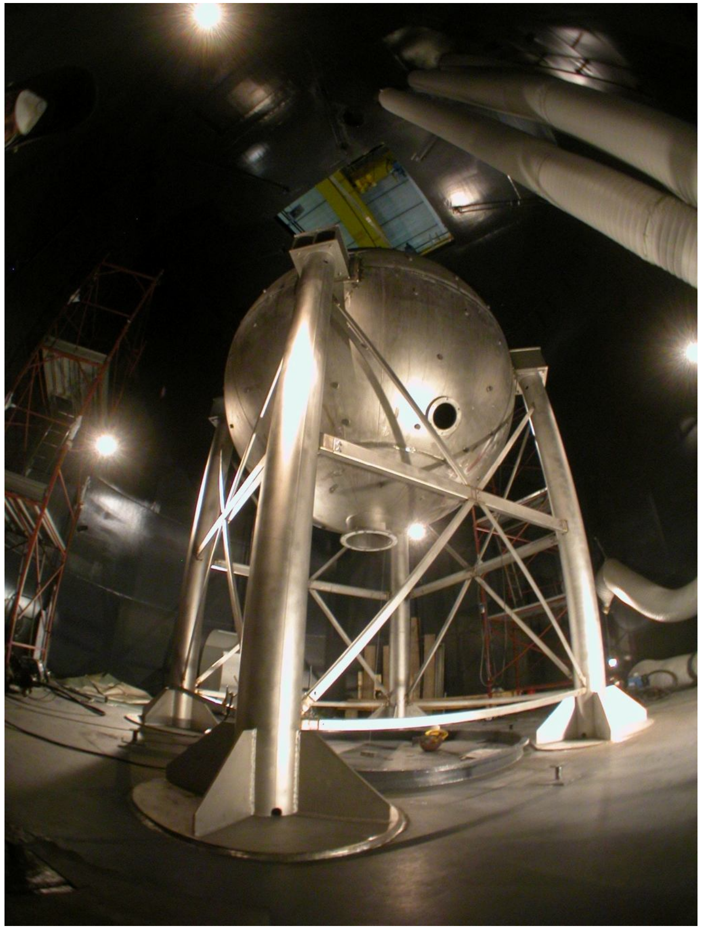


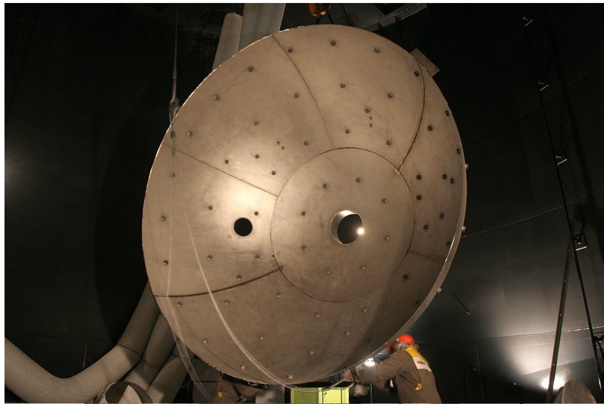
Dark Side 50 kg
funded by INFN DOE NSF
in phase of installation (Hall C)
Ready in spring 2013
Test active veto performance and low background procedure
Sensitivity 10^{-45} cm^2 at 100 GeV

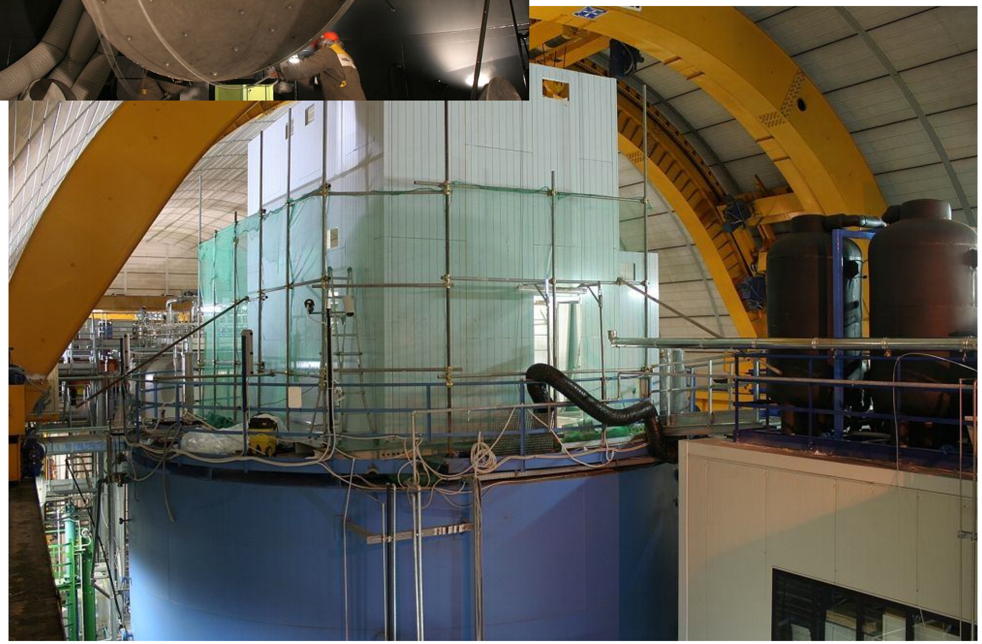
Dark Side G2 (3 tons)
R&D funded NSF
Sensitivity 10^{-47} cm^2 at 100 GeV
2015 construction
2016 data taking

The Status

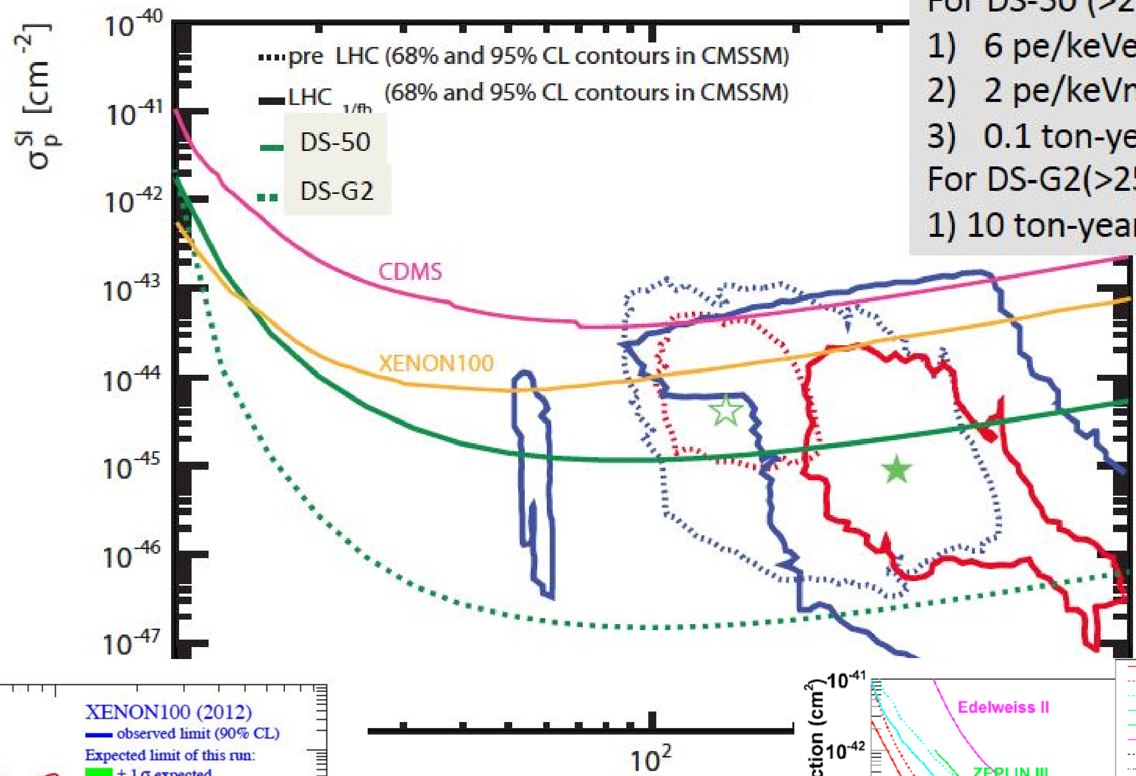
- **CTF tank: emptied and adapted**
- **Liquid scintillator sphere: installed and cleaned (class 50)**
- **Rn-suppressed clean rooms (~10 mBq/m3): top in phase of installation, bottom installed (Rn-scrubbed supply demonstrated < 1 mBq/m^3)**







The Sensitivity

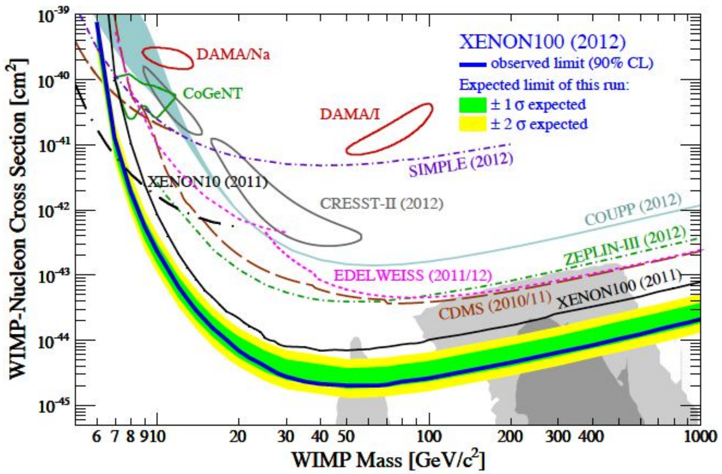


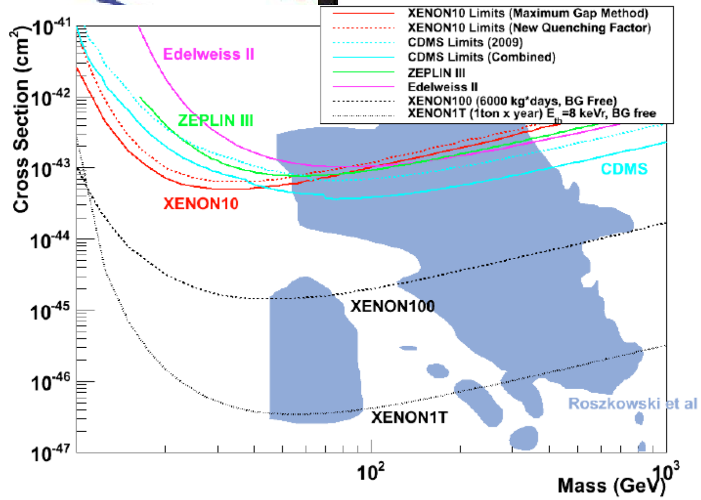
For DS-50 (>20keVnr):

1) 6 pe/keVee
2) 2 pe/keVnr
3) 0.1 ton-year

For DS-G2(>25keVnr):

1) 10 ton-year





Why Dark Side

Xenon100 (and Xenon 1ton in the near future) is unambiguously the present leading experiment in direct dark matter search

Bolometers (and hence Edelweiss) are a wonderful technology, but difficult to scale to the ton mass

What are our reasons for Dark Side?

(1) Cross check with different nuclear targets – **complementary** to Xenon
(2) **Competitive** sensitivity
(3) **Scalable** (and relatively less expensive) technology to the ton mass
(4) **Discrimination** (stronger then in Xenon)
(5) Particle **identification** (TPC and borate scintillator)
(6) Efficient double **shielding**
(7) Very robust **expertise's** on liquid scintillator (Borexino community) and liquid Argon (WARP community + GERDA engineers)
(8)Large interest in the community on liquid Argon **technology**

APC and IPHC expressed interest for Dark Side

Moreover: LAr Technology

General interest to **acquire expertise** in LAr technology for future activities in Neutrino Physics and Direct Dark Matter Search

Fitting time schedule:
R&D ➔ Dark Side ➔ LAGUNA-LBNO

Synergies with the LAGUNA-LBNO framework at APC and with R&D at IPNL

Good opportunity to strength the LAr community in **France**

Photodetection In Dark Side

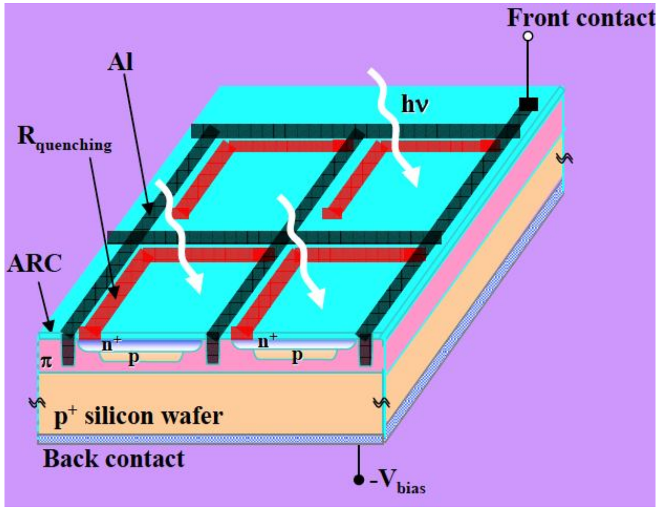
Dark Side G2 investigated options

Low background PMTs
- + known technology
- - cost

QUPIDS
- + low background – QE ~ 30%
- - not on the market
- - problem with HV

Our Dark Side G2 option: SiPMs

Advantages
Available on the market
Highest possible QE
Large size matrix
Low voltage
Low background
High gain

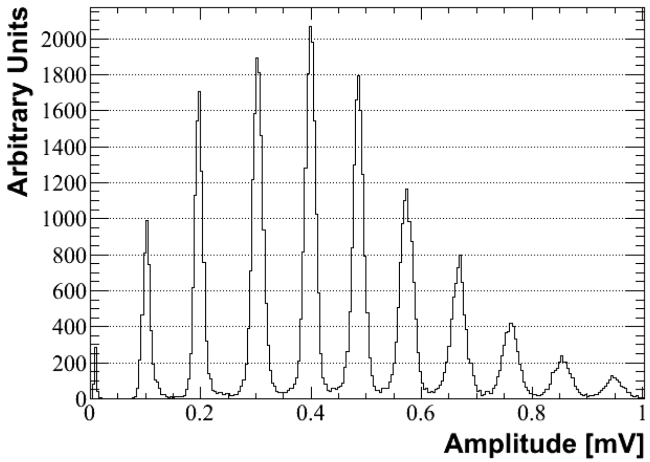


Silicon Photomultiplier

Geiger Mode Avalanche Photo-diode

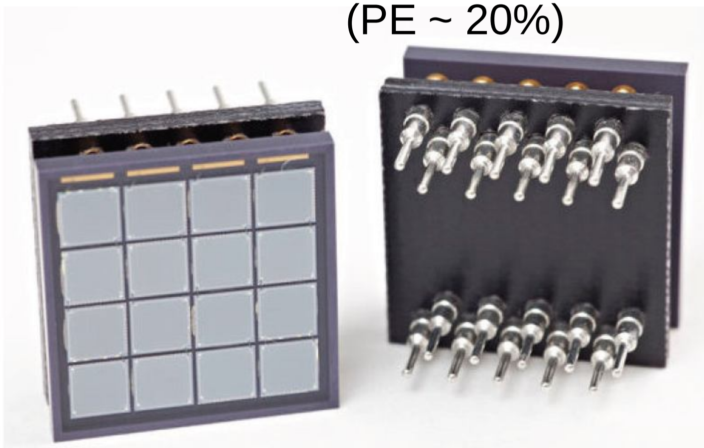
- ✓ solid state technology: robust, compact
- ✓ high detection efficiency: $e = QE \times e_{geo} \times e_{avalanche}$
- ✓ high internal gain of $10^5 \div 10^6$
- ✓ high sensitivity for single photons
- ✓ excellent timing even for single photo electrons
- ✓ good temperature stability
- ✓ devices operate in general < 100V

Questions
Mass production?
Larger pixel size or higher density?
Multi channel readout?
Working in cryogenic?
Radiopurity tested?
Reduced gain summing channels?



Hamamatsu

SENSL Array – 5x5 cm^2
(PE ~ 20%)

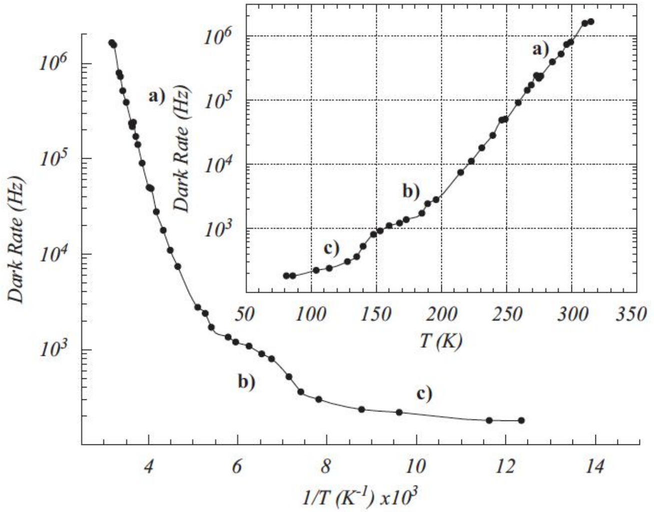


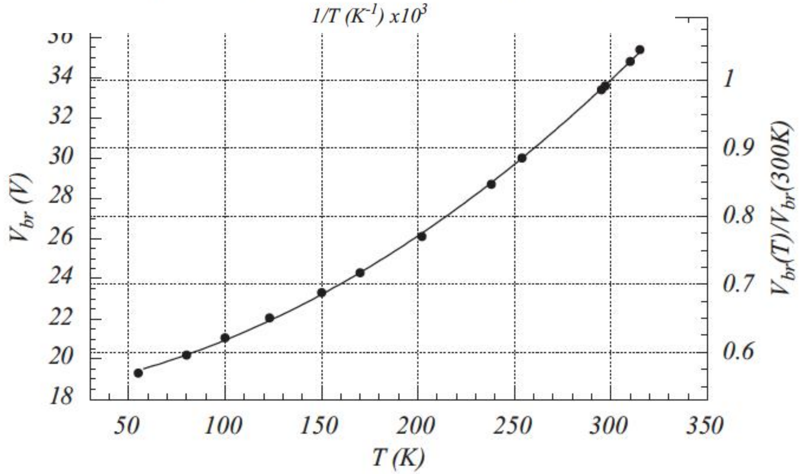
SiPM Dark Rate At Low Temperature

FBK-IRST T6-V1-PD

625 square cells (40x40mm^2), fillfactor of 20%
Breakdown voltage 33V (T_{room})

NIM A 628 (2011) 289

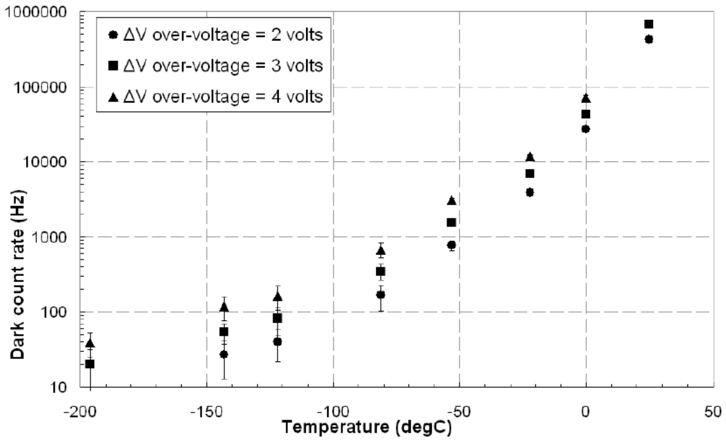


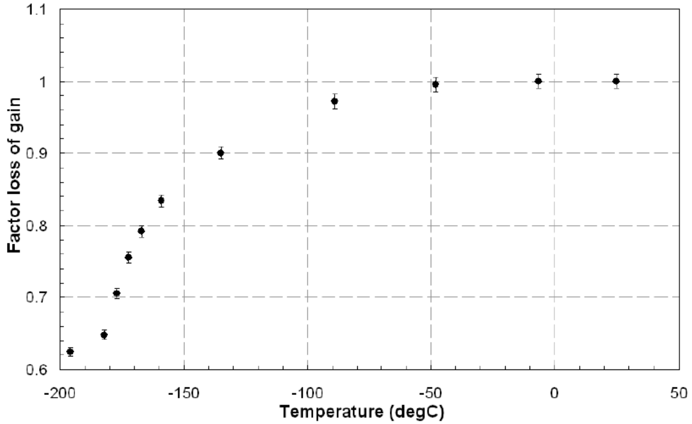


SensL1 Series 1000

848 cell array (20x20mm^2), fillfactor 43%
Breakdown voltage 28.2V (T_{room})

JINST 3 (2008) P10001





LAr and SiPM in France

APC Neutrino + **IPHC Neutrino** groups interested in Dark Side and LAGUNA-LBNO

APC Cosmology group interested in Dark Side

IPNL Neutrino group (LabEx in LAr) interested in the SiPM R&D

ToDoList

(1)Read out electronics
(2)Increased PD efficiency
(3)Radiopurity
(4)Characterization in cryogenics
(5)Wavelength shifter

Presently at APC

(1)Characterization at room temperatures (SENSL and Hamamatsu)
(2)Contacts with FBK: defining the collaboration and the R&D
(3)Installing setup for characterization in cryogenics

Promising technologies + several research interests:

joining the efforts?

The financial prospect of DS

R&D already funded by **NSF** and answer by **DOE** is coming soon (end of October)
INFN R&D within the DS50 program

Dark Side G2

Item	Capital Cost	Capital Cost+ +Contingency
Photosensors	$4,900,000	$6,370,000
Electronics, Feedthroughs, and Cables	$1,820,000	$2,366,000
TPC	$400,000	$600,000
Cryostat, Cryogenics, and Argon Recovery System	$1,000,000	$1,430,000
UAr Extraction and Purification	$1,325,000	$1,722,500
Possible neutron veto upgrade	-	$500,000
Computing	$300,000	$390,000
Total	$9,745,000	$13,378,500
DOE		$1,990,000
INFN		$2,756,000
NSF		$8,632,500

Dominant component (Photosensors)

Preliminary split of funding among agencies (DOE, INFN, NSF)

N.B.: shieldings are not included because already installed for DS50

A possible French budget profile

Identified Tasks
photodetection + Monte Carlo (long term experience in APC and IPHC)

Ideal France participation in Dark Side

	2013	2014	2015	2016	2017	Total
Equipment		300 kE	300 kE			**600 kE**
CDD		100 kE	100 kE	100 kE	50 kE	**350 kE**
Mission	5 kE	30 kE	30 kE	30 kE	20 kE	**115 kE**
Total	**5 kE**	**430 kE**	**430 kE**	**130 kE**	**70 kE**	**1065 kE**

Preparing the future

let's go to
a common R&D on LAr and SiPM

In Conclusion

Dark Side:
Competitive in sensitivity
Complementary to Xenon
Powerful in discriminating particles
Double shielded
Depleted Argon
Experienced collaboration

→ Strong interest at APC and IPHC

LAr technology:
Promising for future experiments

→ We need experience: Dark Side is on the way to LAGUNA-LBNO

SiPM:
High QE
Low voltage
Working in cryogenics

→ Attractive for noble liquid based experiments (Dark Side, Xenon, LAGUNA-LBNO, …)