DarkSide-50 and DarkSide-20k experiments: computing model and evolution of infrastructure

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on behalf of the **DarkSide Collaboration**
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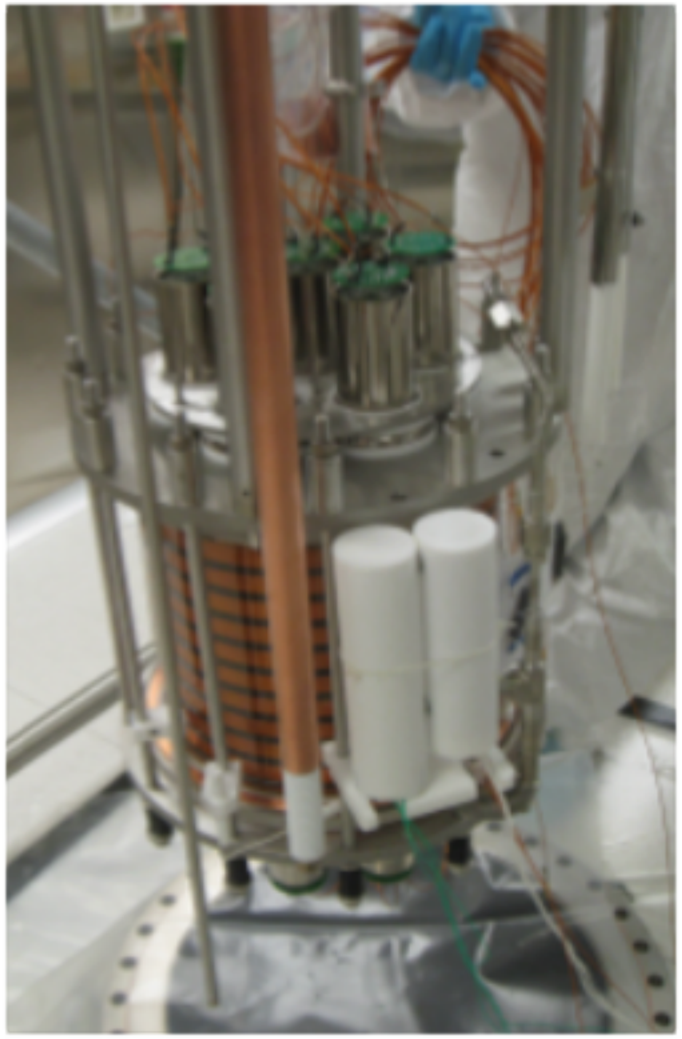
Outlook

- The DarkSide project:
  - DarkSide-50 first results;
  - Future perspectives;
- DarkSide-50 computing scheme;
- DarkSide-20k computing scheme;
- Final remarks and conclusions.

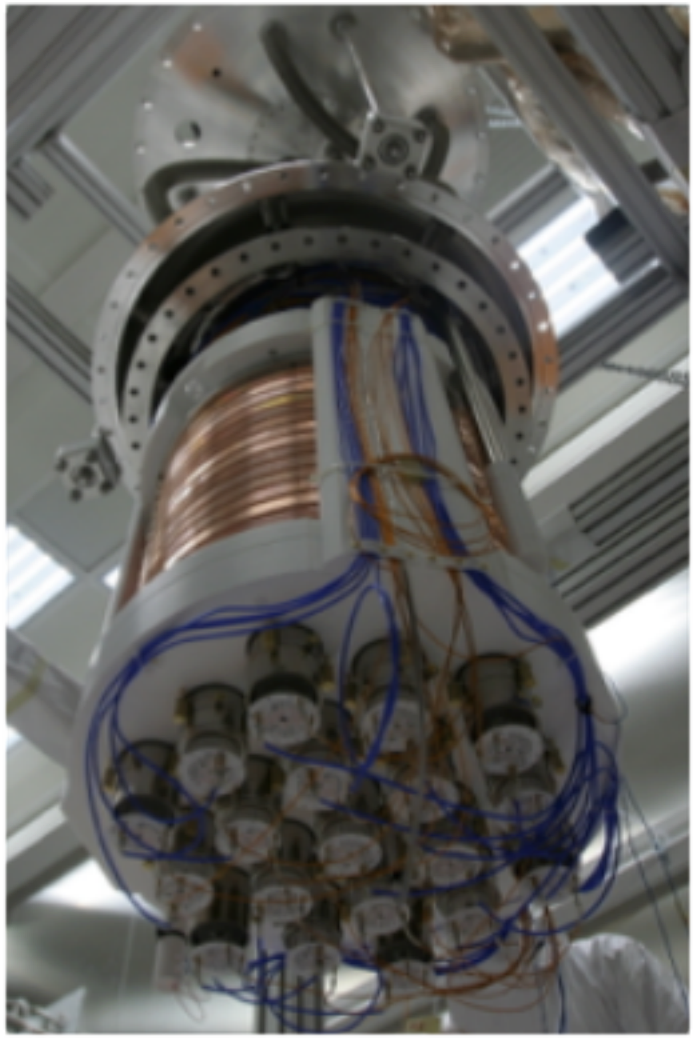
The DarkSide Project

- **Aim**: direct dark matter detection looking for nuclear recoils possibly induced by WIMPs;
- **How**: usage of liquid argon (*LAr*) as detector media in a dual-phase *TPC* which:
  - has very low background thanks to be housed in the underground laboratory at LNGS and usage of low background material, including the target itself,
  - has powerful background rejection thanks to effective PSD, ionization to scintillation ratio and 3D position reconstruction,
  - has an active neutron and muon veto, allowing *in situ* background measurement.

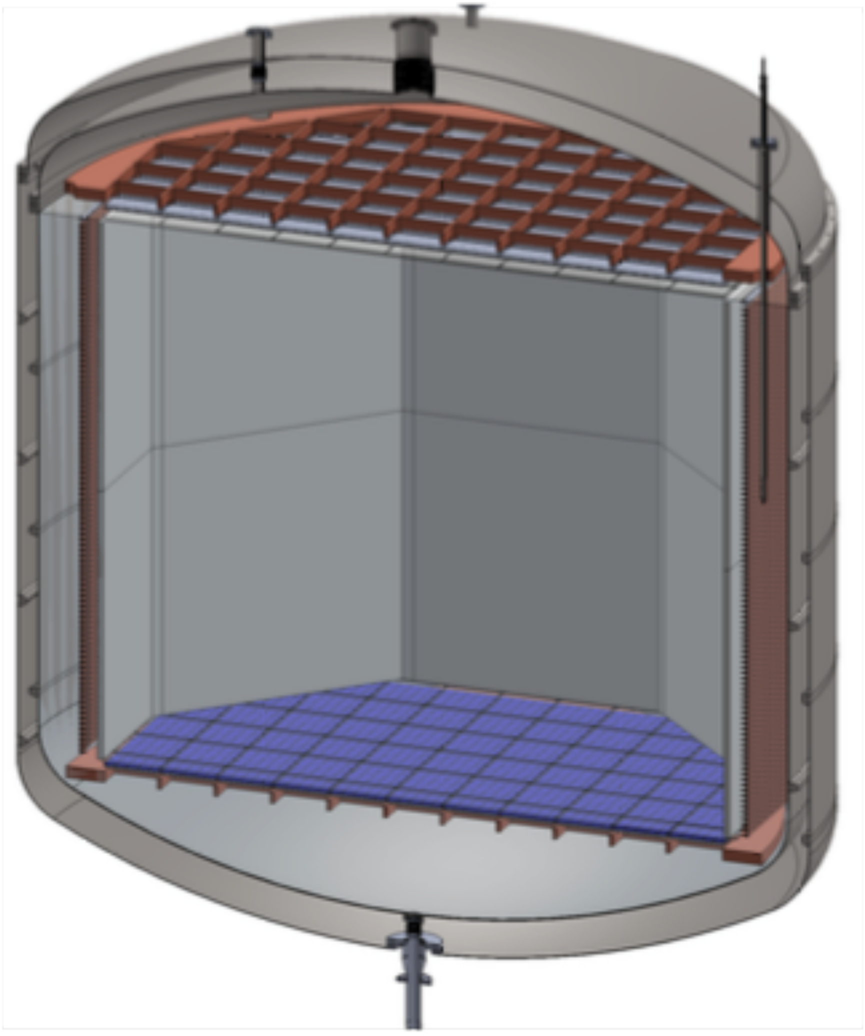
DarkSide: a multi-stage program



DarkSide-10
Prototype Detector

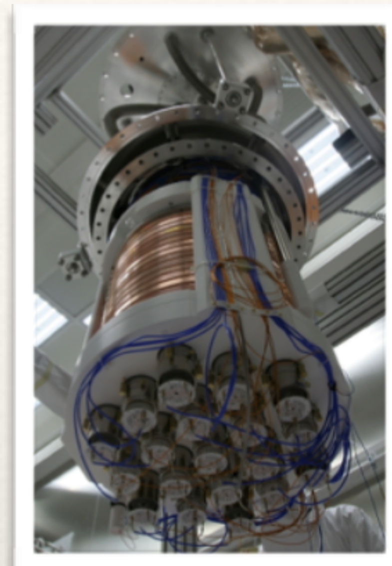


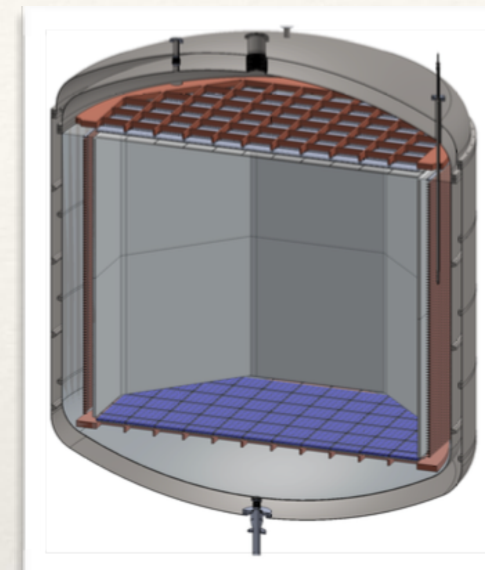
DarkSide-50
First physics detector
$\sim 10^{-45}$ cm^2 @ 100 GeV



DarkSide-20k
Future multi-ton detector
$\sim 10^{-47}$ cm^2 @ 100 GeV

DarkSide: the timetable

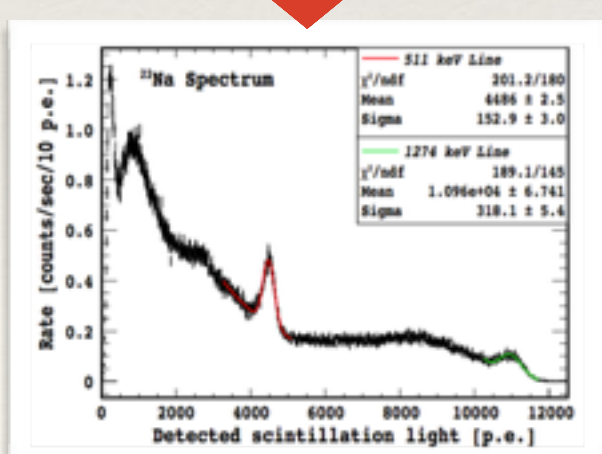


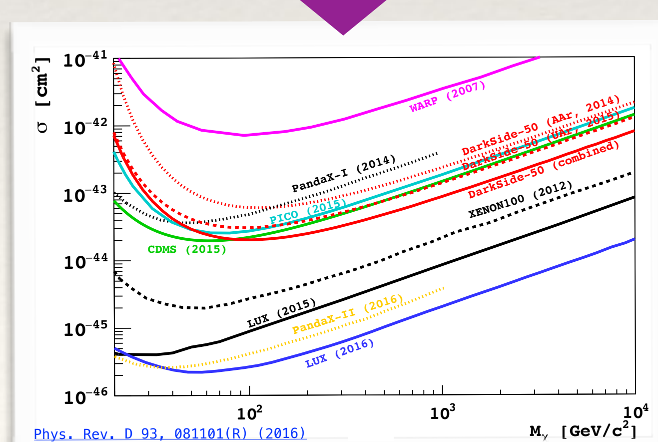


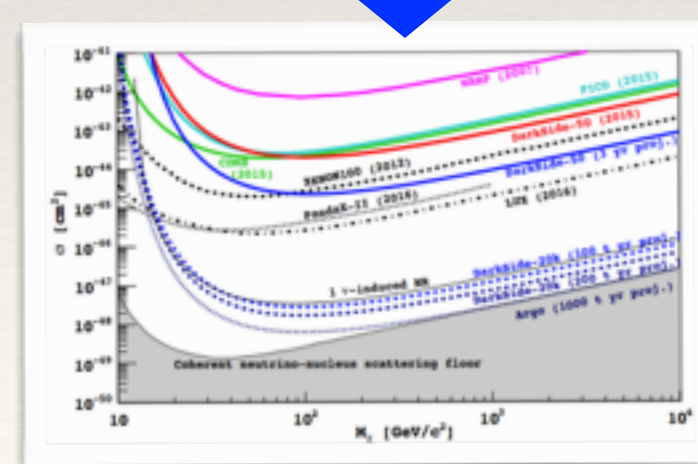
DarkSide-10
Operating from
Dec. 2010 to Jan. 2013

DarkSide-50
Still ongoing
from Apr. 2015

DarkSide-20k
Will be operational
from ~ 2020

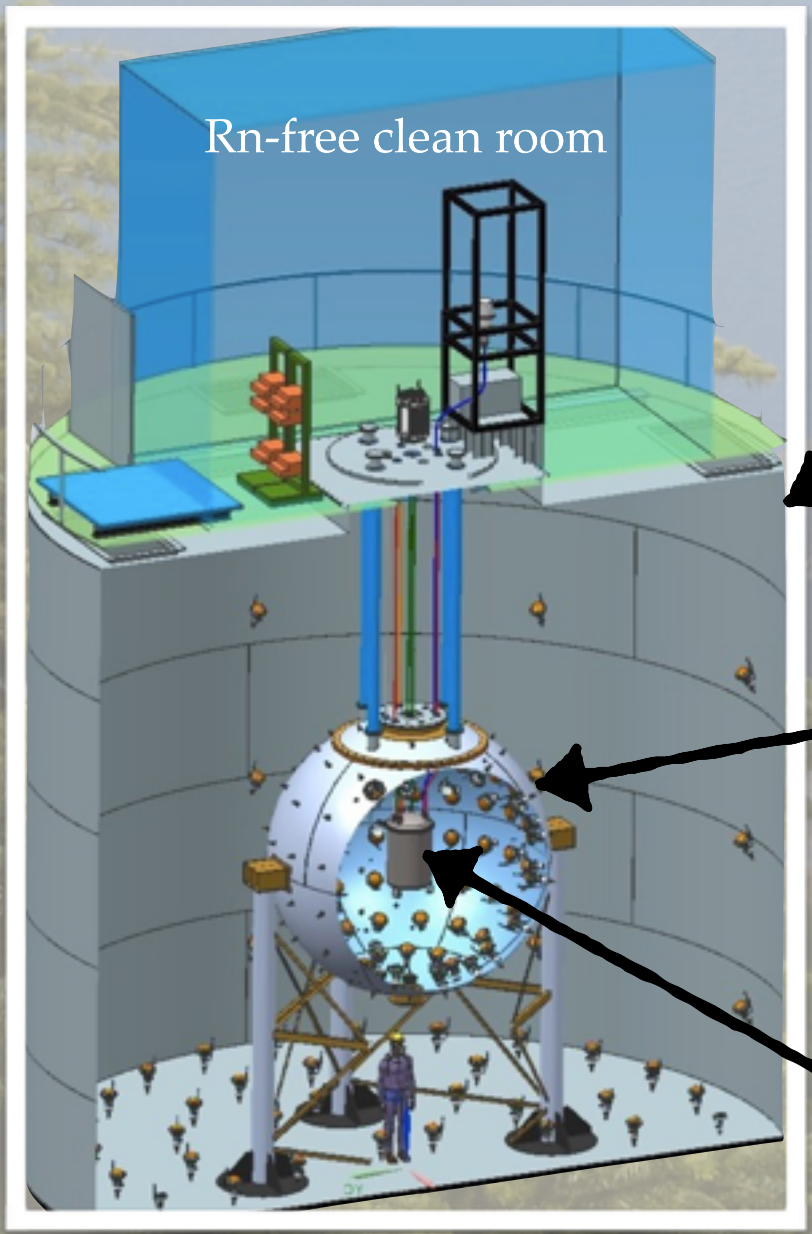






DarkSide-50

The current ongoing stage of the DarkSide project!



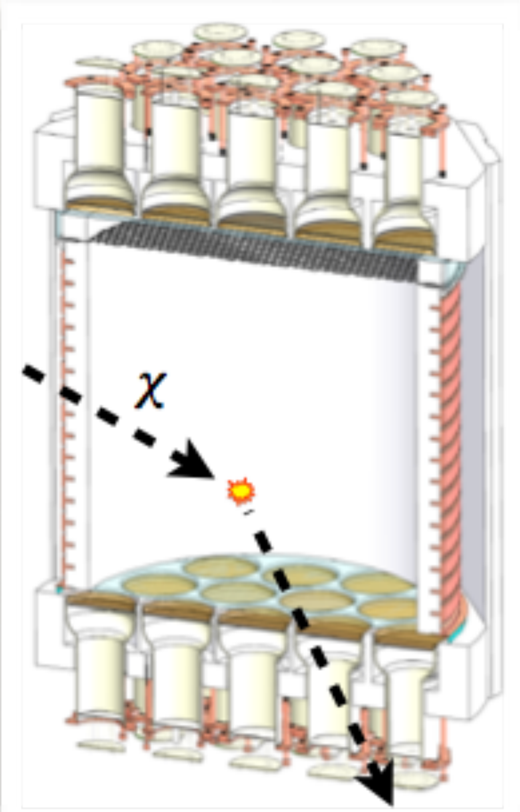
Corno Grande of the Gran Sasso massif (pictured) provides 3800 m.w.e. passive shielding against cosmic rays

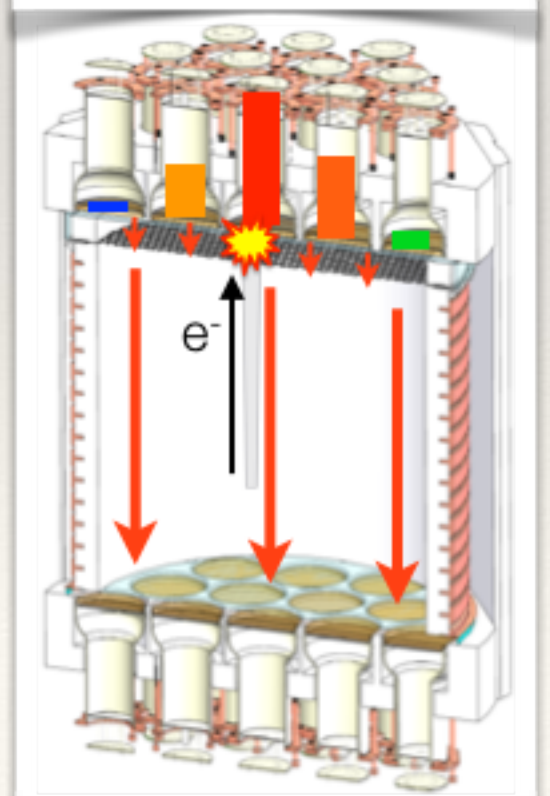
11m-diameter, 10m-tall, 1 kt Water Čerenkov Detector (WCD) instrumented with 80 8″-PMTs provides active shielding against μ's

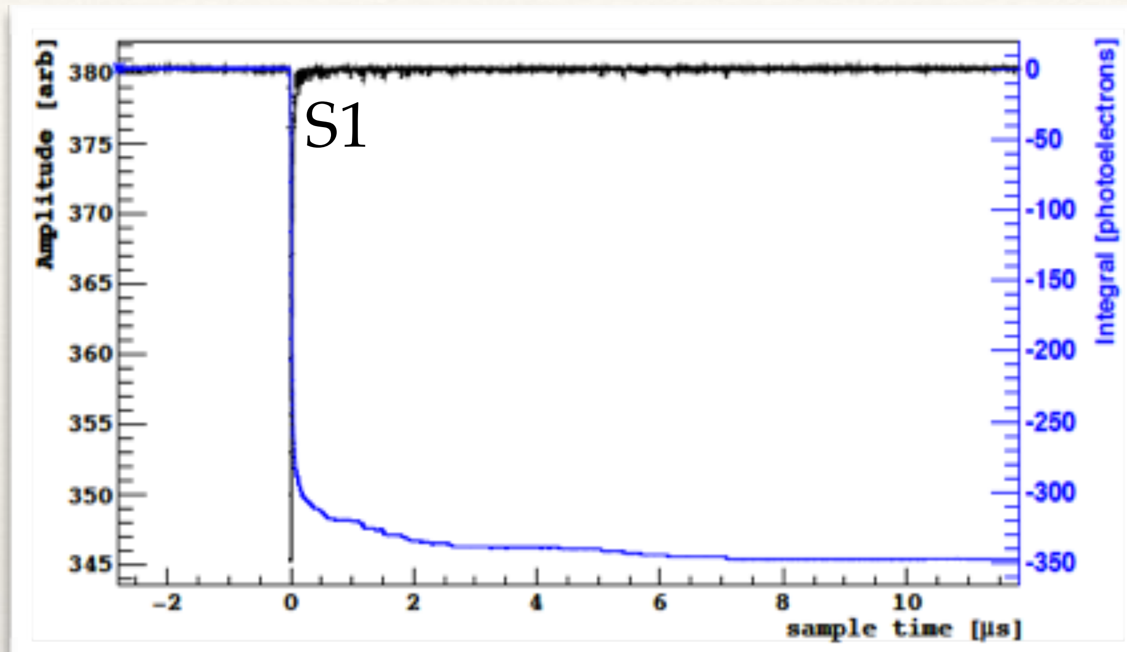
4m-diameter 30 t borated Liquid Scintillator Veto (LSV) instrumented with 110 8″-PMTs provides additional active shielding against γ's, n's and μ's

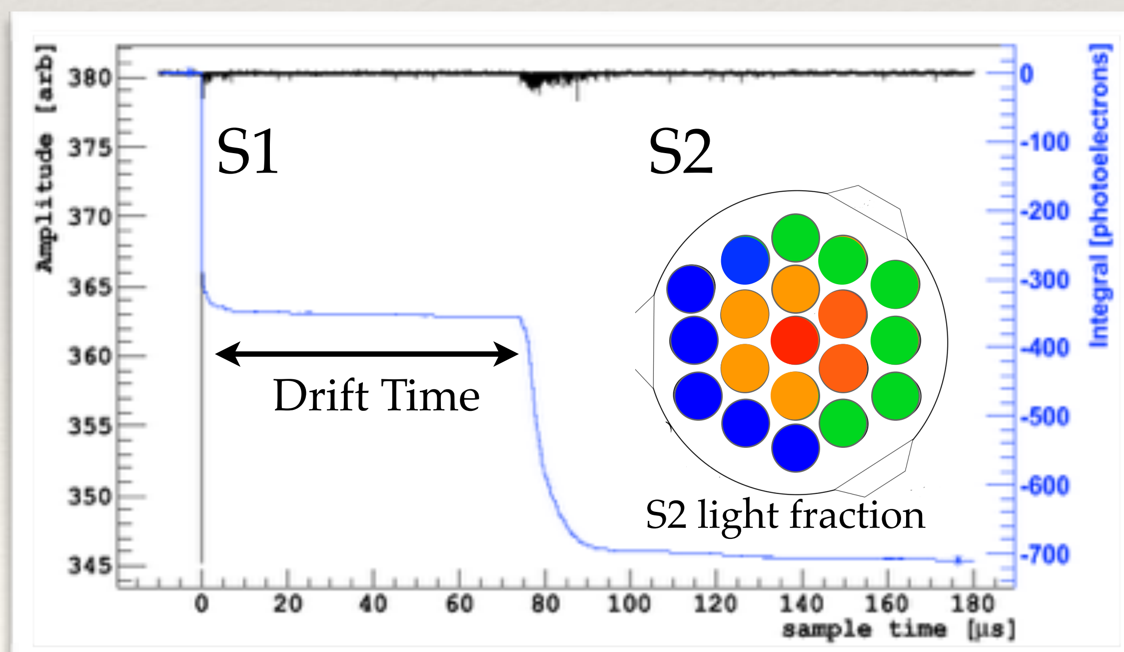
…these all surround the inner detector, the Time Projection Chamber (TPC)

Two Phase Argon TPC





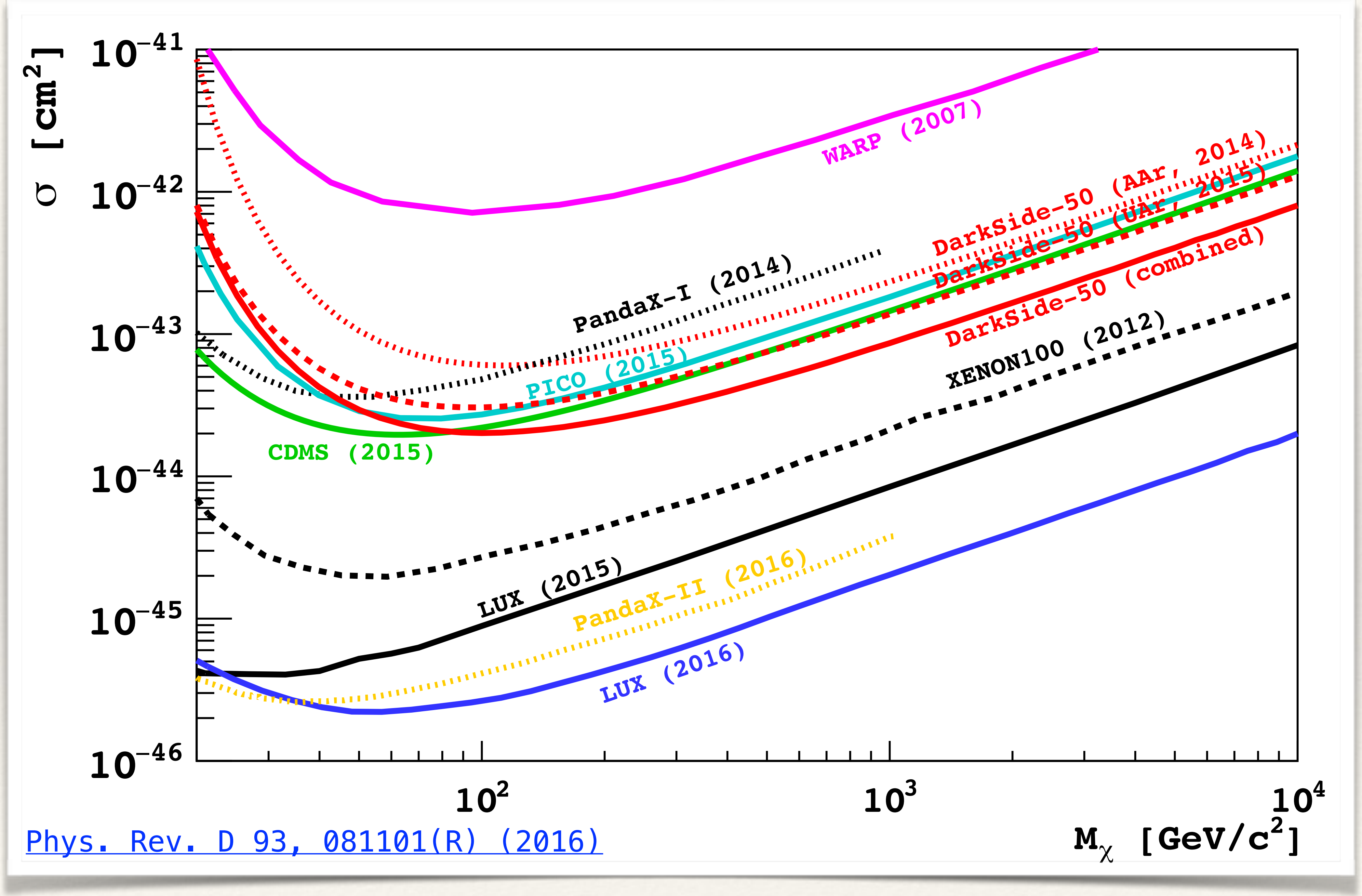




- A recoil **excites** and **ionizes** the liquid argon, producing **scintillation** light (S1) that is detected by the photomultipliers
- The electrons are extracted into the gas region, where they induce **electroluminescence** (S2)
- The time between the S1 and S2 signals gives the vertical position.
- x-y position of events are reconstructed from fraction of S2 in each PMT.

Electron drift lifetime > 5 ms, compared to max. drift time of ~ 375 µs.
Electron drift speed = 0.93 mm/µs

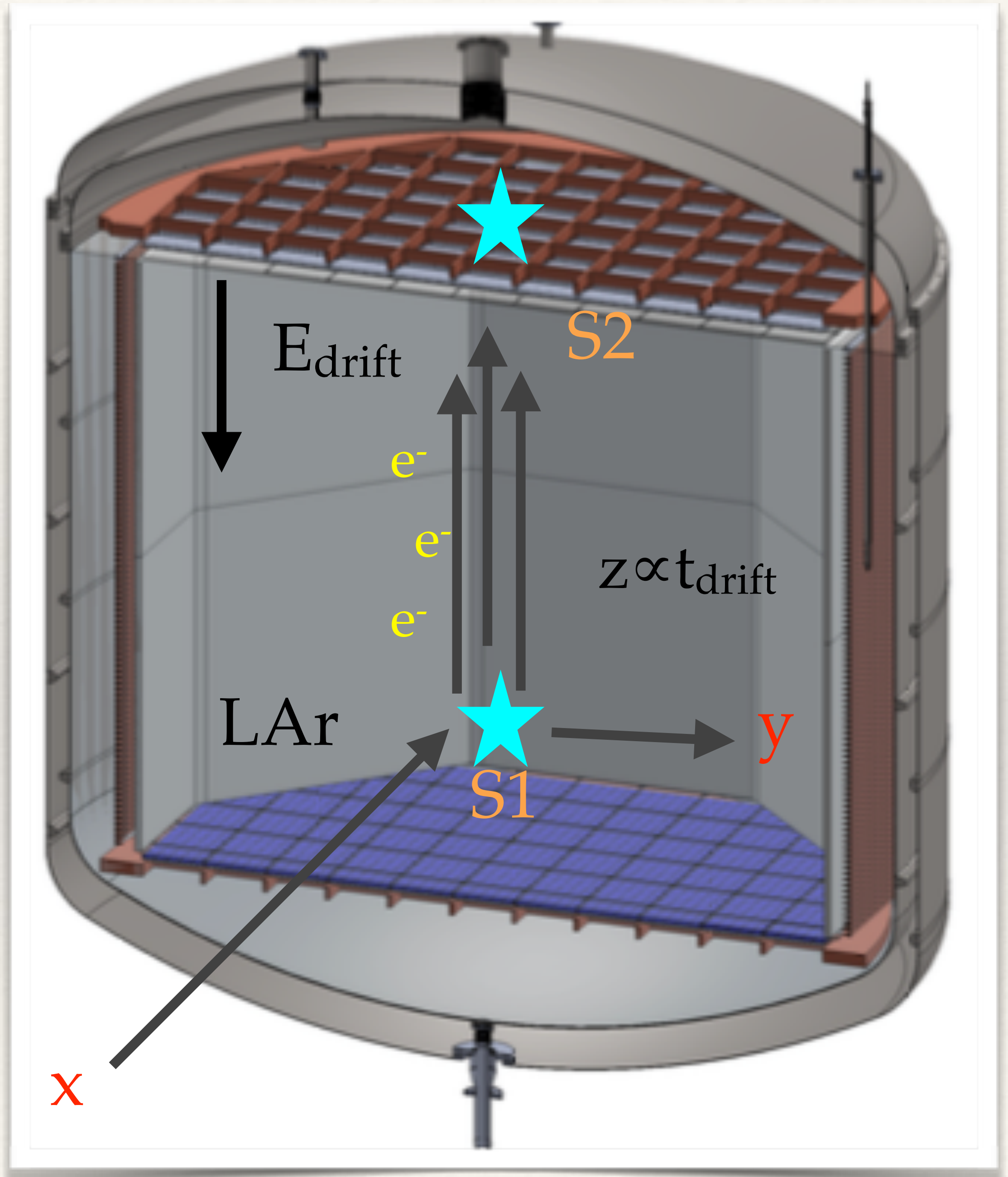
DarkSide-50 Results



Best limit to date, with argon target, third best limit behind LUX & Xenon100 at high mass WIMP range.

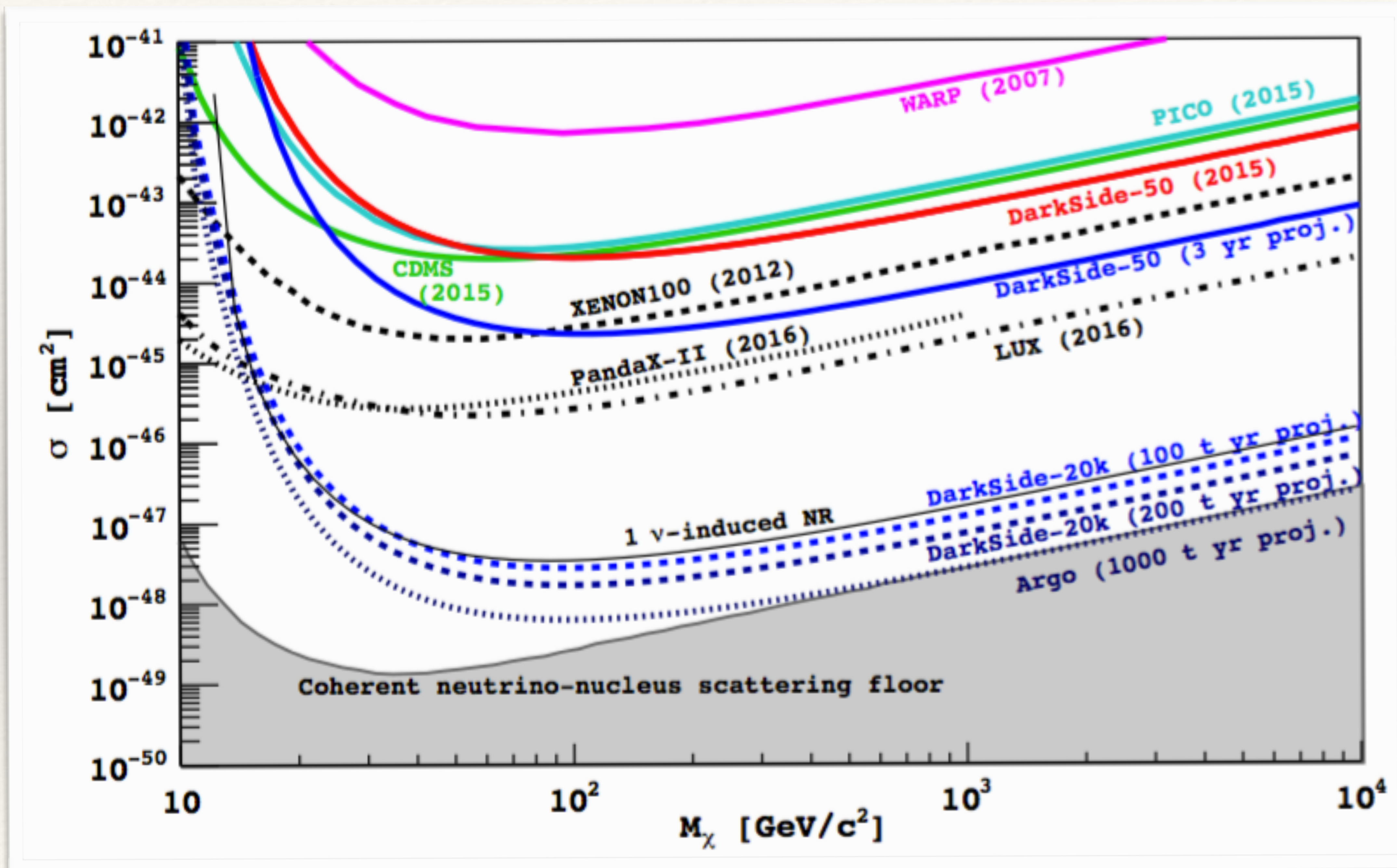
Future perspectives

- Collaboration planned to build big volume detectors [DS-20k (20t), Argo (200t)];
- R&D on going to produce radio pure SiPM;
- plans for massive UAr production (Urania project: ~100 kg/d) and purification (Aria project: ~300 m tall column for isotope separation).



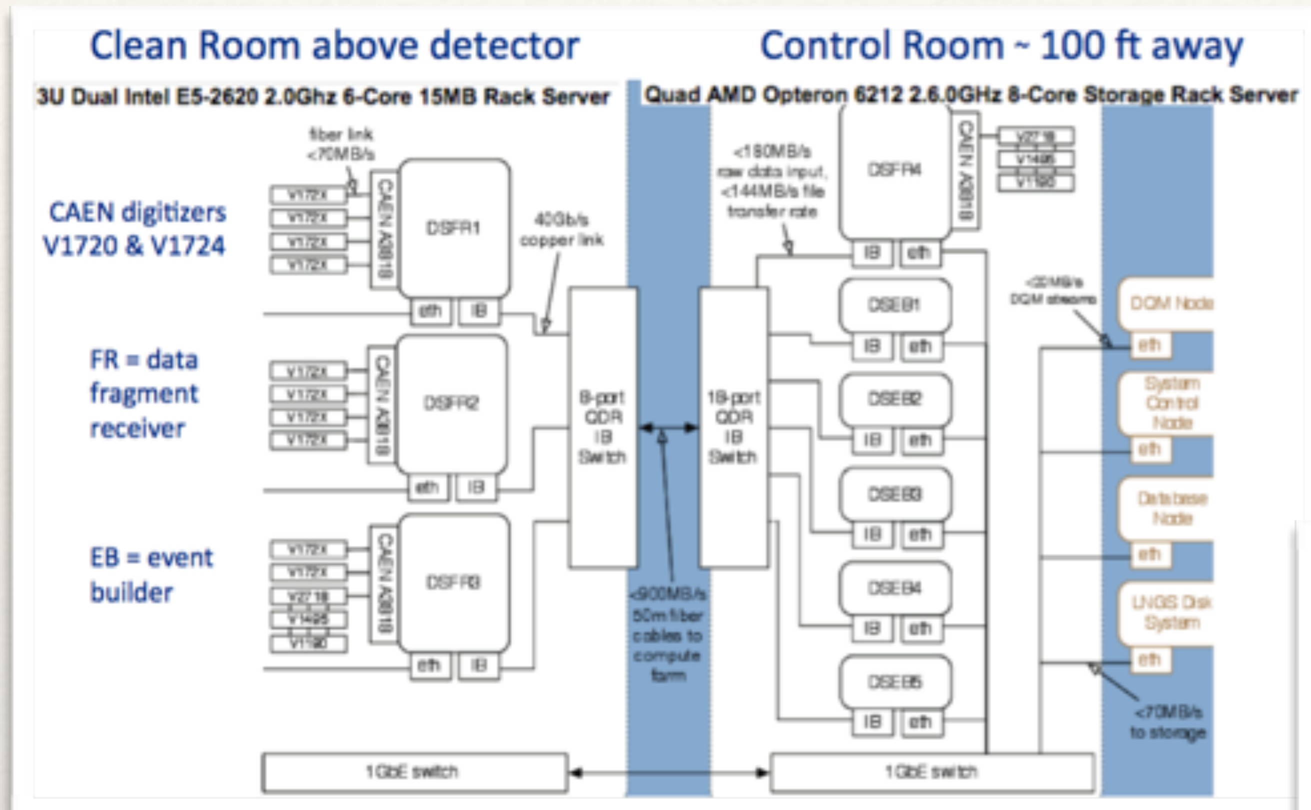
DarkSide-20k

DarkSide-20k projected limits

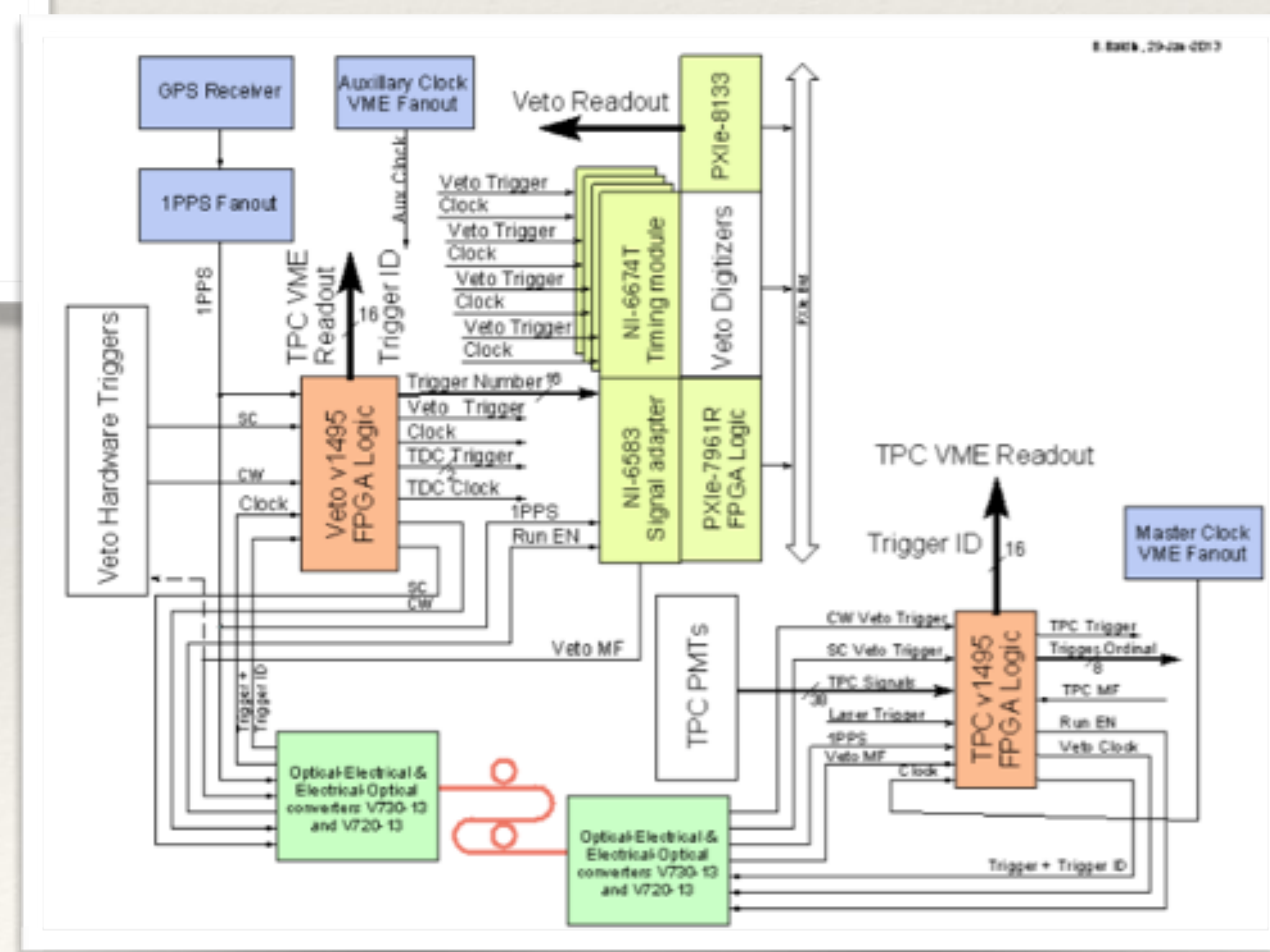


The DarkSide-20k Yellow Book / Technical Proposal (2016).

DarkSide-50 Data Acquisition schematic @ LNGS



- Caen V1720 module:
  - 8 channel 12bit 250 MS/s ADC;
  - Pulse Shape Discrimination;
  - Memory buffer: 1.25 or MS/ch, up to 1024 events.
- Caen V1724 module:
  - 8 channel 14bit 100 MS/s ADC;
  - Pulse Height Analysis



- Global Trigger logic provides mechanism to synchronize TPC DAQ and Veto DAQ events;
- Common 50 MHz high accuracy clock allows GPS based timing synchronization of the events;
- Both systems can run independently with their own triggers in local mode.

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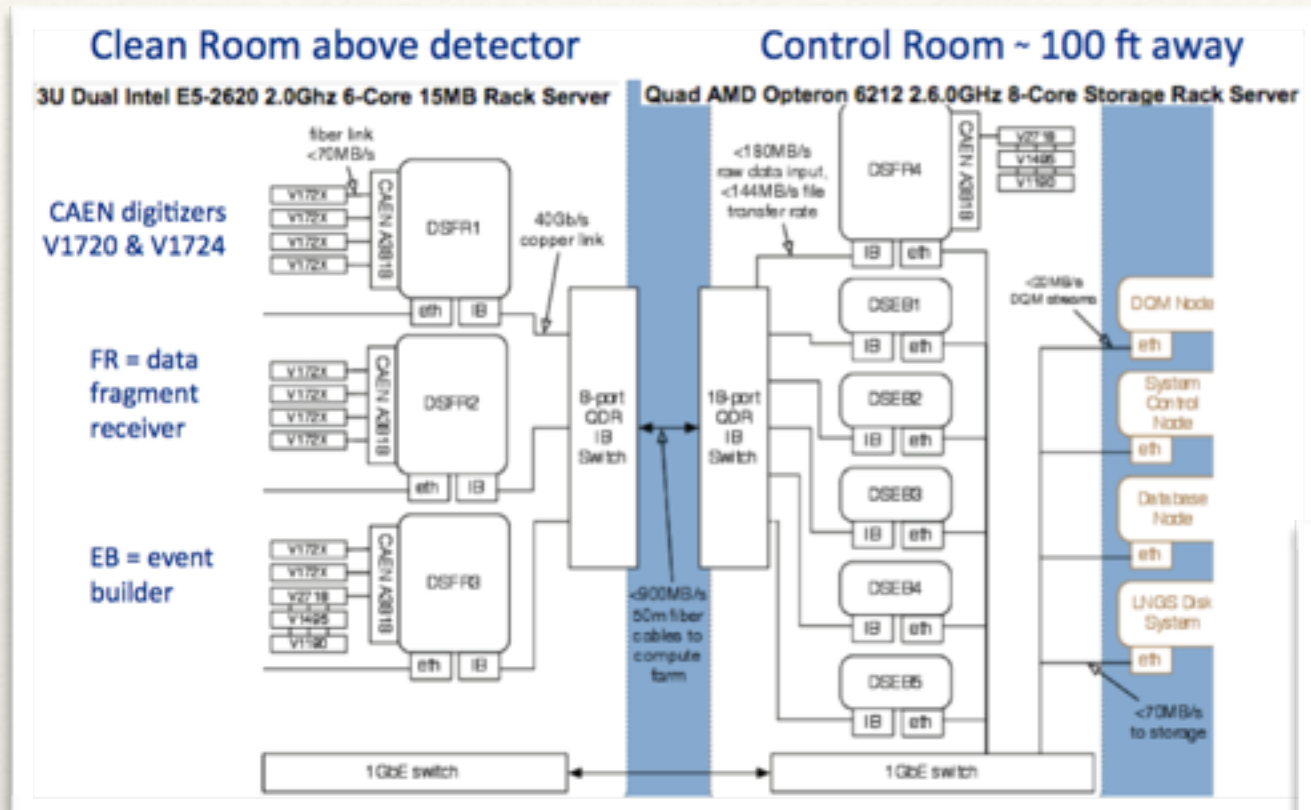

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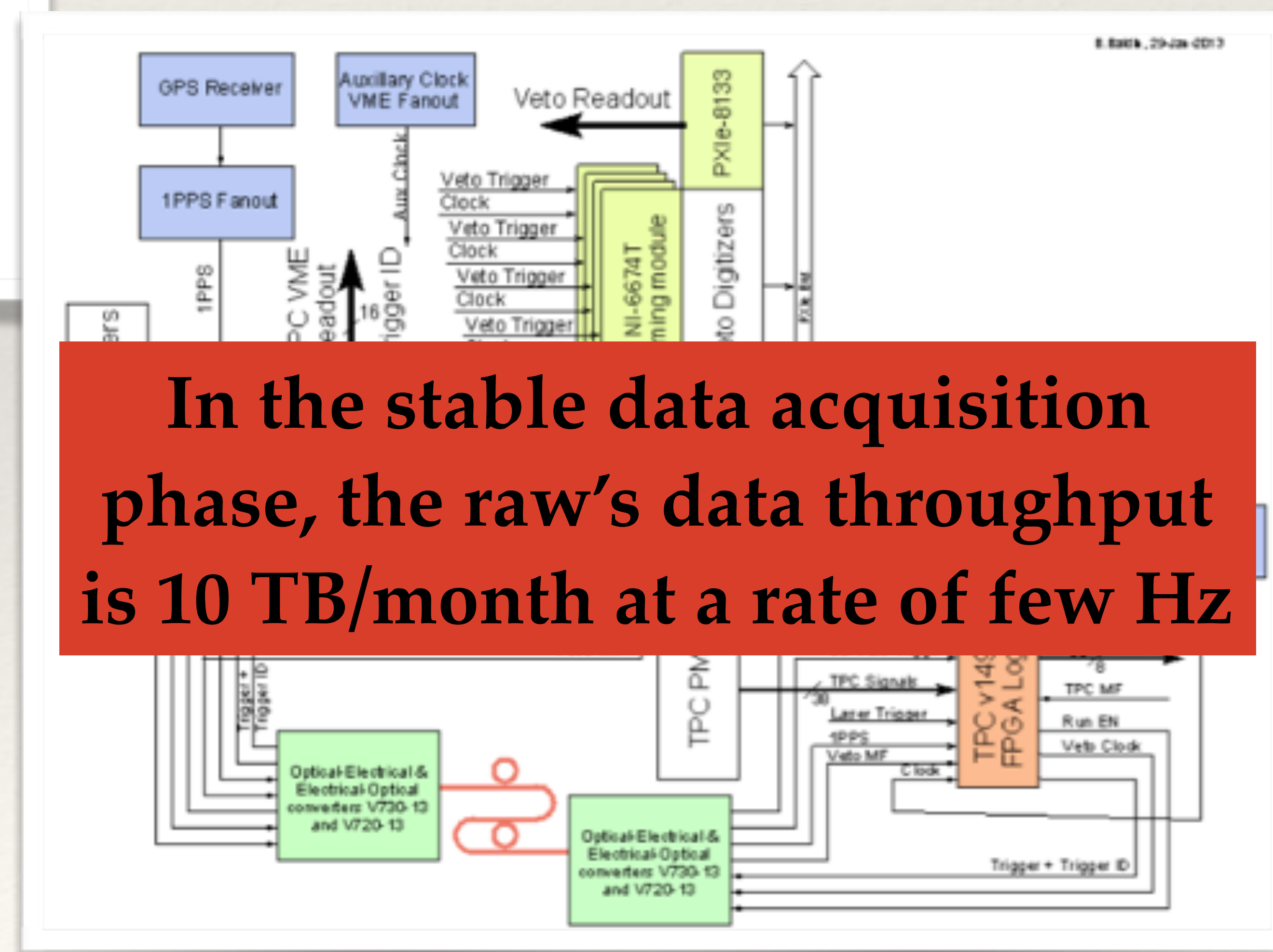

In the stable data acquisition phase, the raw's data throughput is 10 TB/month at a rate of few Hz

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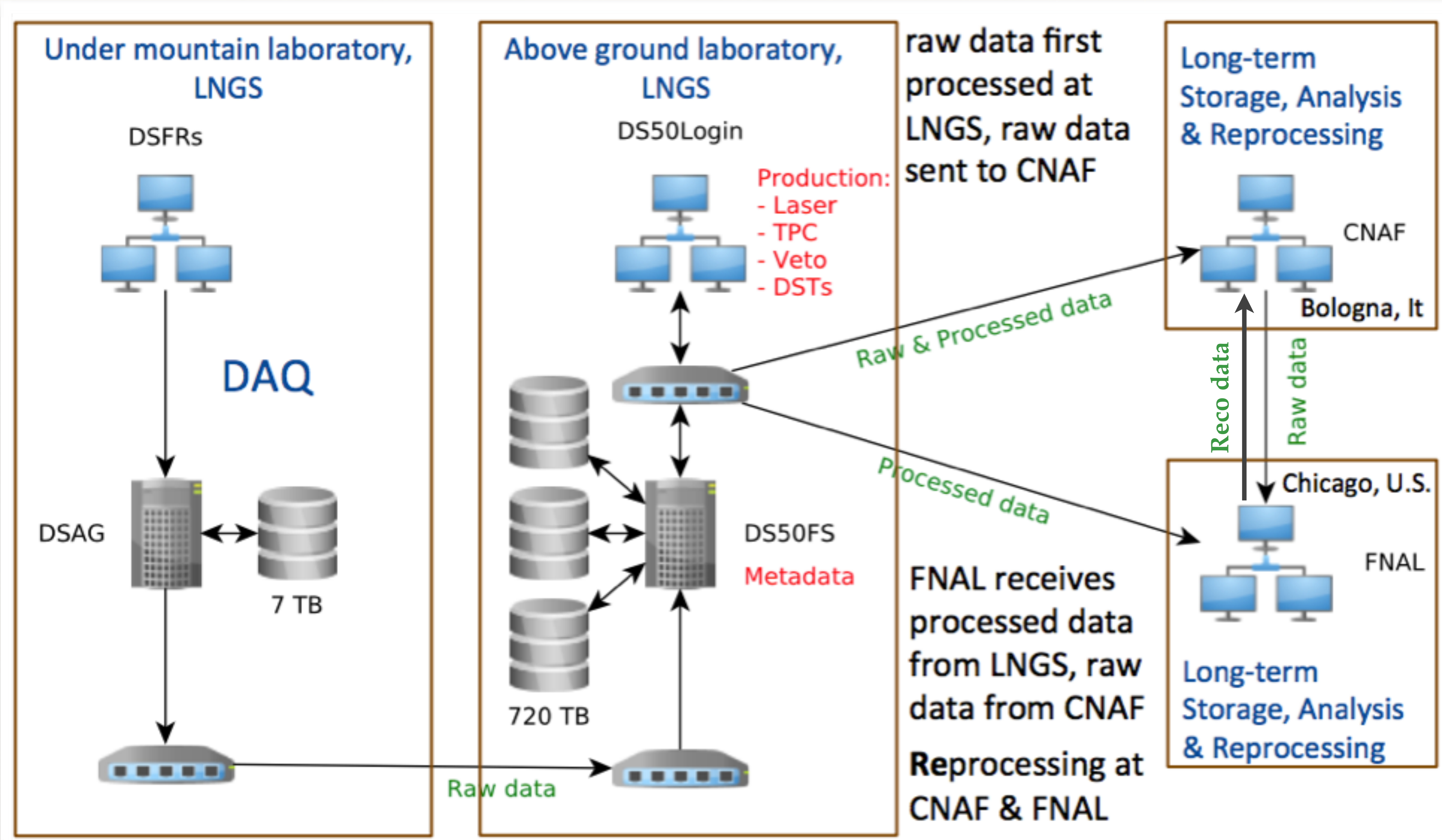
DarkSide-50 computing model

- DarkSide-50 has two main offline sites: CNAF and Fermilab (FNAL);
- DAQ transfers (temporary) data to LNGS Offline Farm via a 2 Gbit optical link;
- Raw data are automatically (men supervised) copied to CNAF Farm via a 10 Gbit optical link (almost with approx. 7 hours delay);
- Raw data are semi-automatically copied from CNAF to FNAL via a 100 Gbit optical link;
  - Part of them are processed at CNAF, stored in it (SLAD files), and copied to FNAL;
- FNAL processes data and send them back to CNAF via the same link as before with a rate of 0.5 TB/month (RECO files);
- LNGS, CNAF and FNAL provide infrastructures to store and process data;
- Major effort in order to let collaborators use the same environment and tools on the two sides of the Ocean.

DarkSide-50 data distribution scheme



DarkSide-50 @ CNAF

- CNAF officially support 30 High Energy Physics experiments (HEP): 4 LHC and 27 non-LHC (i.e. DarkSide);
- INFN-Tier 1 provide more than 120 racks and several tape libraries:
  - 1300 server with about 10000 cores available;
  - about 10 PBytes of disk space;
  - 80 KHS06;
  - about 14 PBytes on tapes;
- DarkSide-50 in this moment is using:
  - 1 PByte of disk space;
  - 1 KHS06;
  - about 0.3 PBytes on tapes.

Software for DS-50 @ CNAF

- DarkSide software area is located @ bastion.cnaf.infn.it in the ui-darks.cr.cnaf.infn.it machine;
- Depending on your job it is possible to configure the working environment in three possible ways:
  - Data analysis:
    - source /opt/exp_software/darkside/ds50/app/ds50/setup_highlevel
  - Montecarlo codes:
    - source /opt/exp_software/darkside/ds50/app/ds50/setup_g4ds
  - To use DarkArt:
    - /opt/exp_software/darkside/ds50/app/ds50/setup_ds50
- All of the recorded data are converted in *ROOT* format in order to be easily analyzed by the collaborators.

DarkSide-50 @ CNAF: conclusions

- High professionalism and performances from the CNAF staff members;
- Very good technical support up to the needs of the DarkSide Collaboration;
- DarkSide-50 is a “drop” in the ocean of the computing needs of the CNAF:
  - in almost 3 years of data taking in wimp search mode we used “only”:
    - 1 PByte of disk space;
    - 1 KHS06;
    - about 0.3 PBytes on tapes;
- Plans for future: DarkSide-50 will be online until 2020.

DarkSide-20k: Computing Strategy

build on knowledge acquired in the construction and operations of the DS-50 system

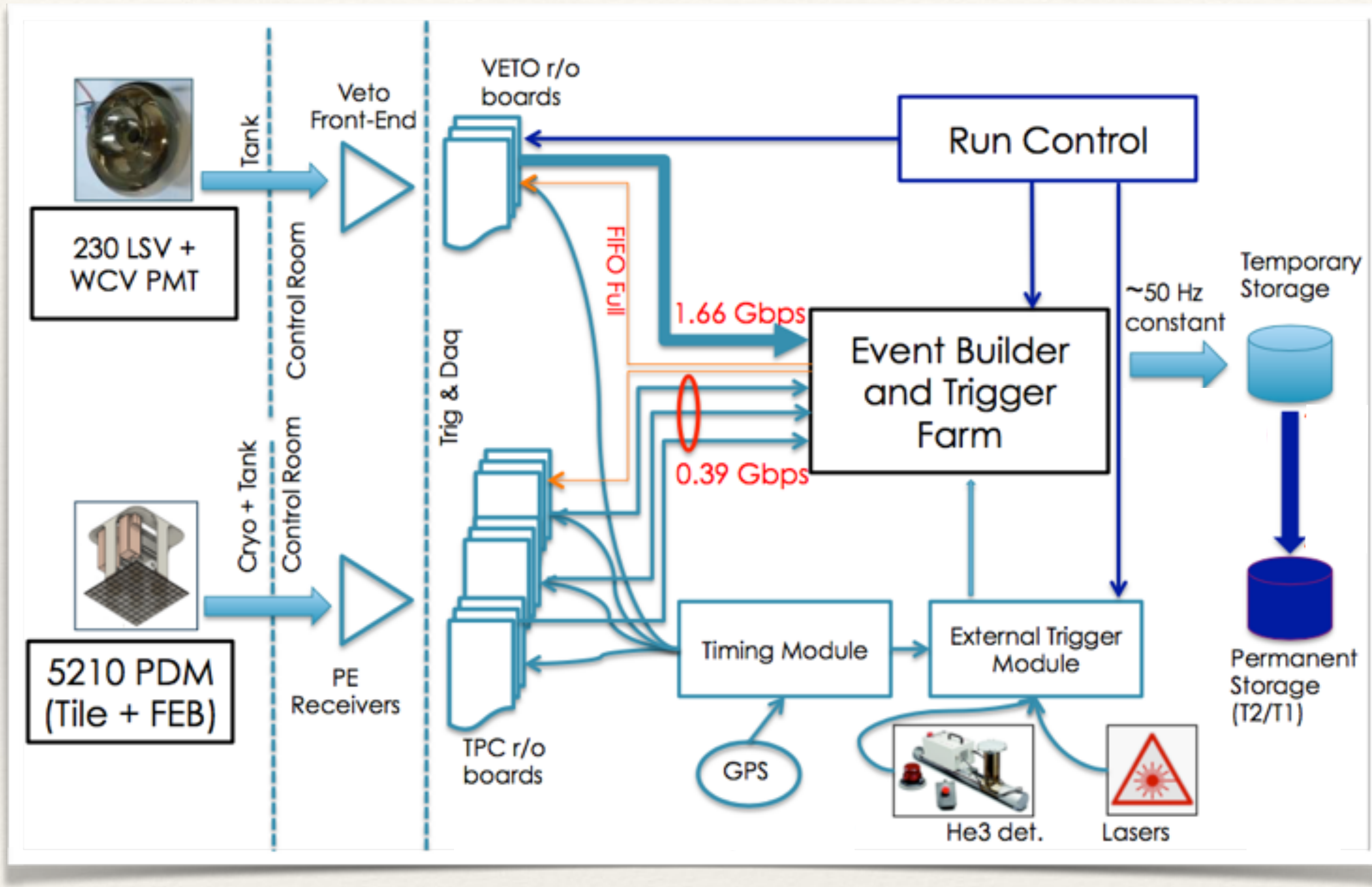
+

take advantage of competences, infrastructures, resources, manpower developed and used for LHC computing

(DarkSide-20k computing: a first attempt to optimise resources connecting competences in csn2 and csn1)

- hierarchical computing model to optimise use of resources and access to data
- exploit DS-20k software trigger farm that allows to perform online part of the reconstruction and data compression that today is done offline in DS-50
- raw/pre-processed data from trigger farm will be sent to a T1 computing center (CNAF or RM1 T2) for processing, re-processing, permanent storage and automatic/on-demand distribution of analysis-format data to other centers (EU and non-EU)
- MC simulation done in the same T1 computing center exploiting grid/cloud/HPC resources
- we are evaluating possible advantages in designing the software for multi-threading/parallel processing to exploit HPC resources
- batch&interactive analysis: analysers expected to analyse small reduced samples (mini-ntuples) both in local computers and on grid

DarkSide-20k DAQ Scheme



- raw data rate from High Level Software Trigger: 3.8 (S2/Veto waveforms) to 16.5 (+S1 waveform) TB/day
- waveform compression algorithms expected to reduce the data rate on disk to: 1 to 2 TB/day

DarkSide-20k Computing Requirements

- Inputs:
  - physics events rate: 50 Hz sustained ⇒ 4.32 Mevents/day
  - raw-data event size (after online compression): 0.5 to 1 MB/ev
  - simulation event size: 2.5 MB/ev to 0.7 MB/ev (compressed)

  - CPU processing time (std INFN grid CPU core):
    - raw-event reconstruction: 1.2 sec/ev
    - re-processing of a reconstructed event: 0.1 sec/ev
    - simulation+rec. of a DS20k event: 2.5 s /ev
- Assumptions:
  - 5 years DS-20k data-taking: 2021-2026
  - offline reconstruction in real-time at the T1/T2 computing center of all the events logged by the high level software trigger
  - re-process two times per year in 1/2 month all physics events collected in one year
  - simulation samples ≥10x the physics data events

DarkSide-20k Computing Requirements

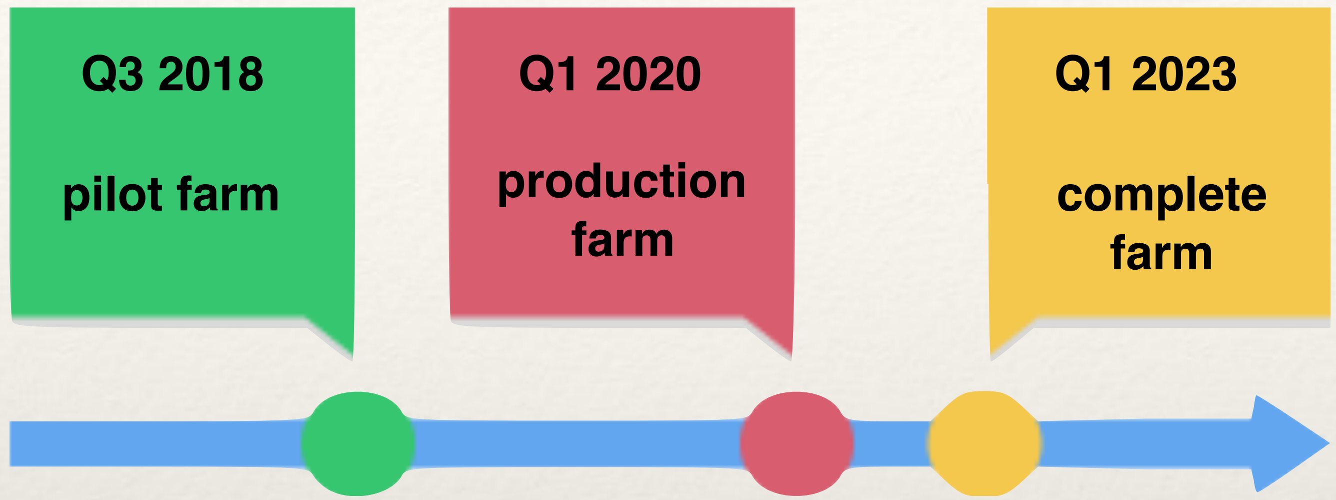
- CPU processing power needed at T1/T2:
  - raw-data reconstruction: 4.3 Mevents / day can be processed in real time with ≥60 std INFN grid cores
  - raw-data re-processing: 1.6 Gevents / year can be processed in 1/2 month with ≥1460 cores (to be done 2 x year)
  - MC simulation: 10x 1.6 Gevents / year can be produced in one year with ≥1250 cores
- summary: a system with O(1500) cores would cover the DarkSide-20k needs in terms of CPU processing power

- Network bandwidth needed between LNGS and T1/T2: 2 TB / day ⇒ 250 Mbit ⇒ already available both at CNAF and RM1 T2

- Storage needed at T1/T2:
  - raw-data (after online compression): 1-2 TB / day x 5 years: 2-4 PB
  - reconstructed data: 10% of raw-data: 0.2-0.4 PB
  - calibration data: ~10% of raw-data: 0.2-0.4 PB
  - simulation (after compression and saving only reconstructed samples): 2-4 PB
- summary: total storage 4.4 PB to 8.8 PB in 5 years

- With current systems the whole needed system: ~1500 CPUs cores with ~4 PB storage should fit in 1/1.5 full-size rack for a cost of the order of 500-700 kEuro

DarkSide-20k Computing Timeline



2018

pilot farm 10% of the whole system in the CNAF T1 or RM1 T2 site

- for development of offline/grid code&tools
- test system reliability & performances
- start production and storage of MC samples

2020

production farm for first 2-years of data-taking

- 50% of cpu cores / 50% of disk/tape storage
- full dress rehearsal planned in 2020

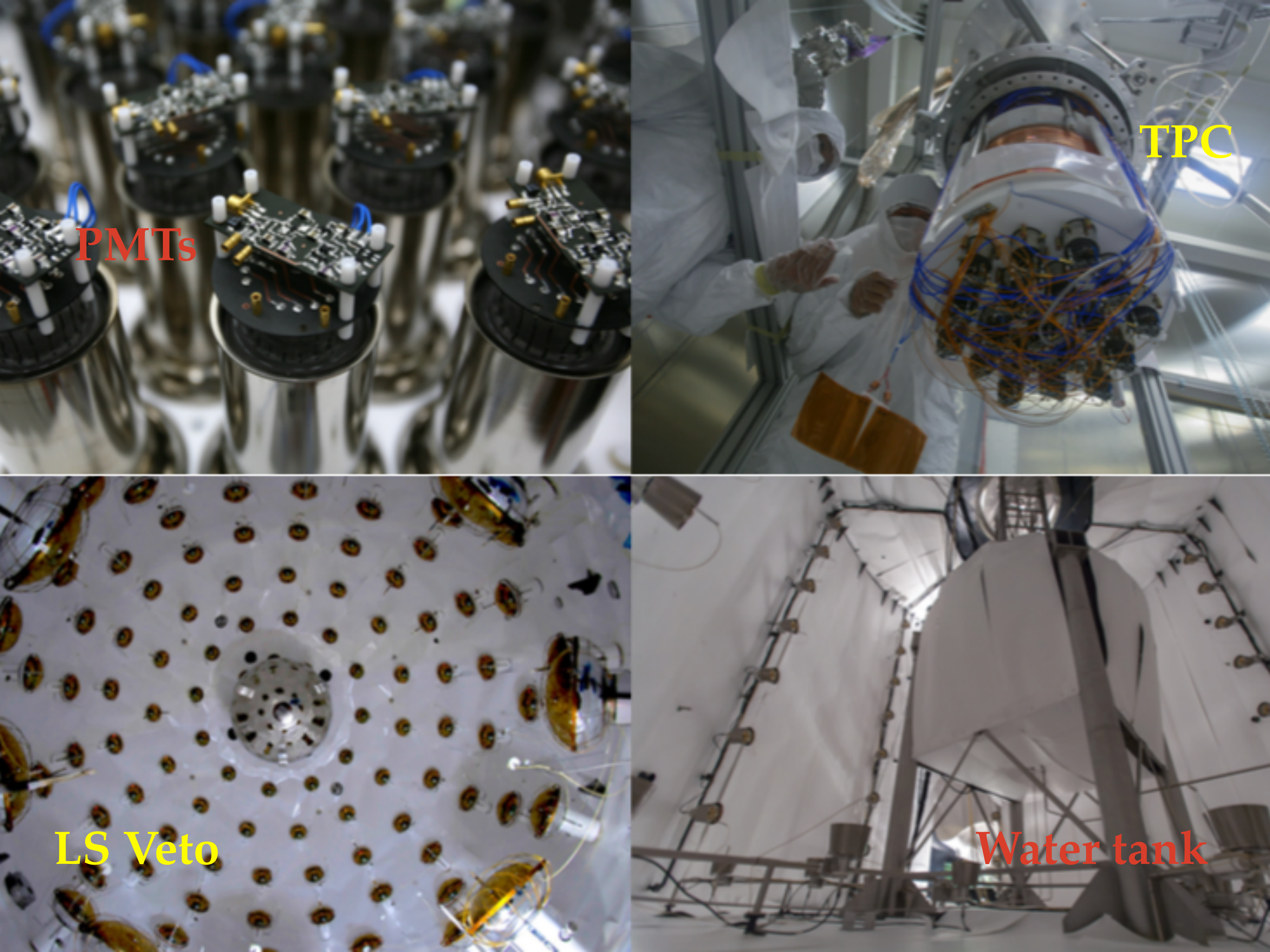
2023

complete farm

- staged integration to maximise cpu&storage per Euro

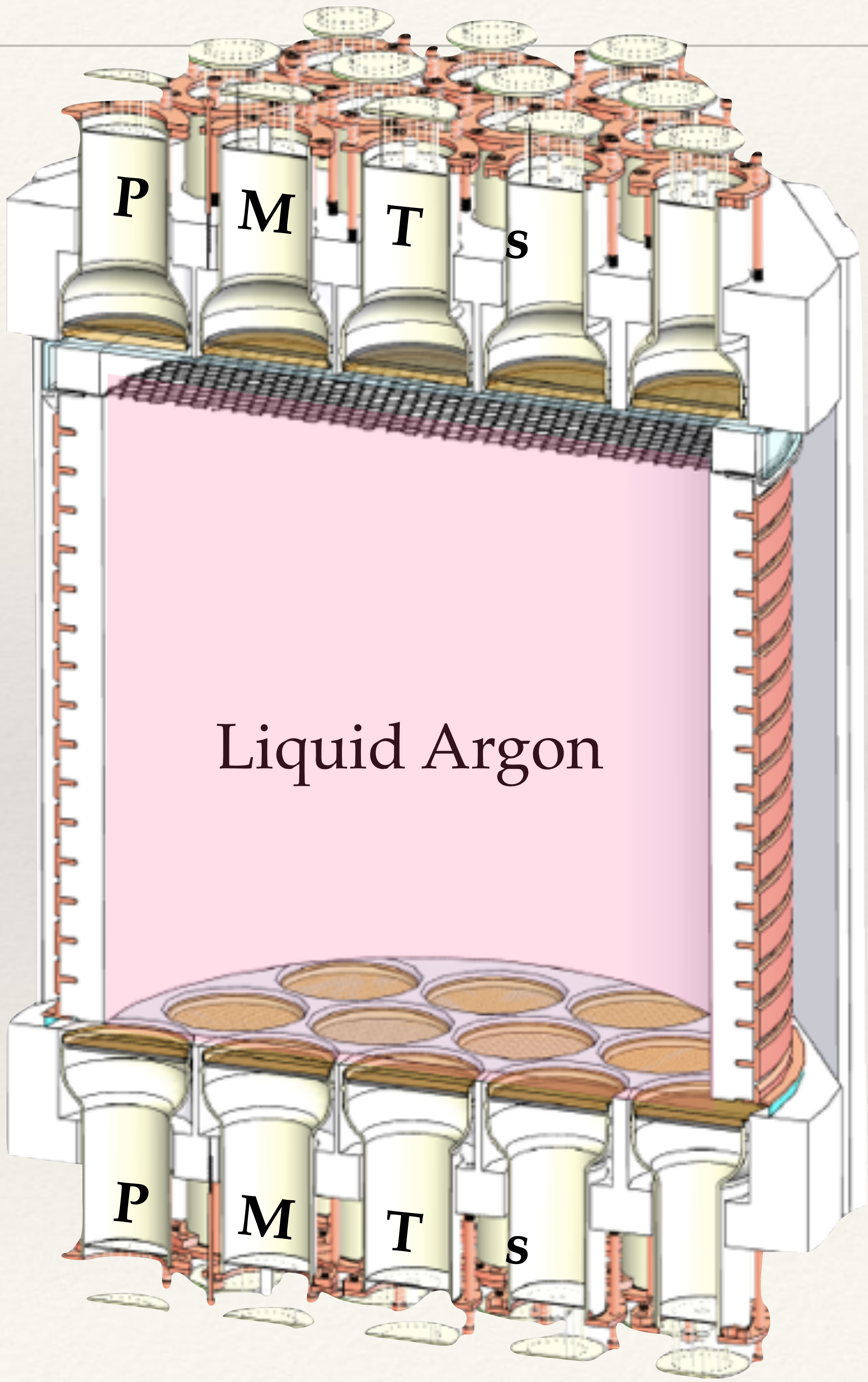
ENJOY THE DARK SIDE!

Backup


PMTs
TPC
LS Veto
Water tank

Dual-phase LAr Time Projection Chamber

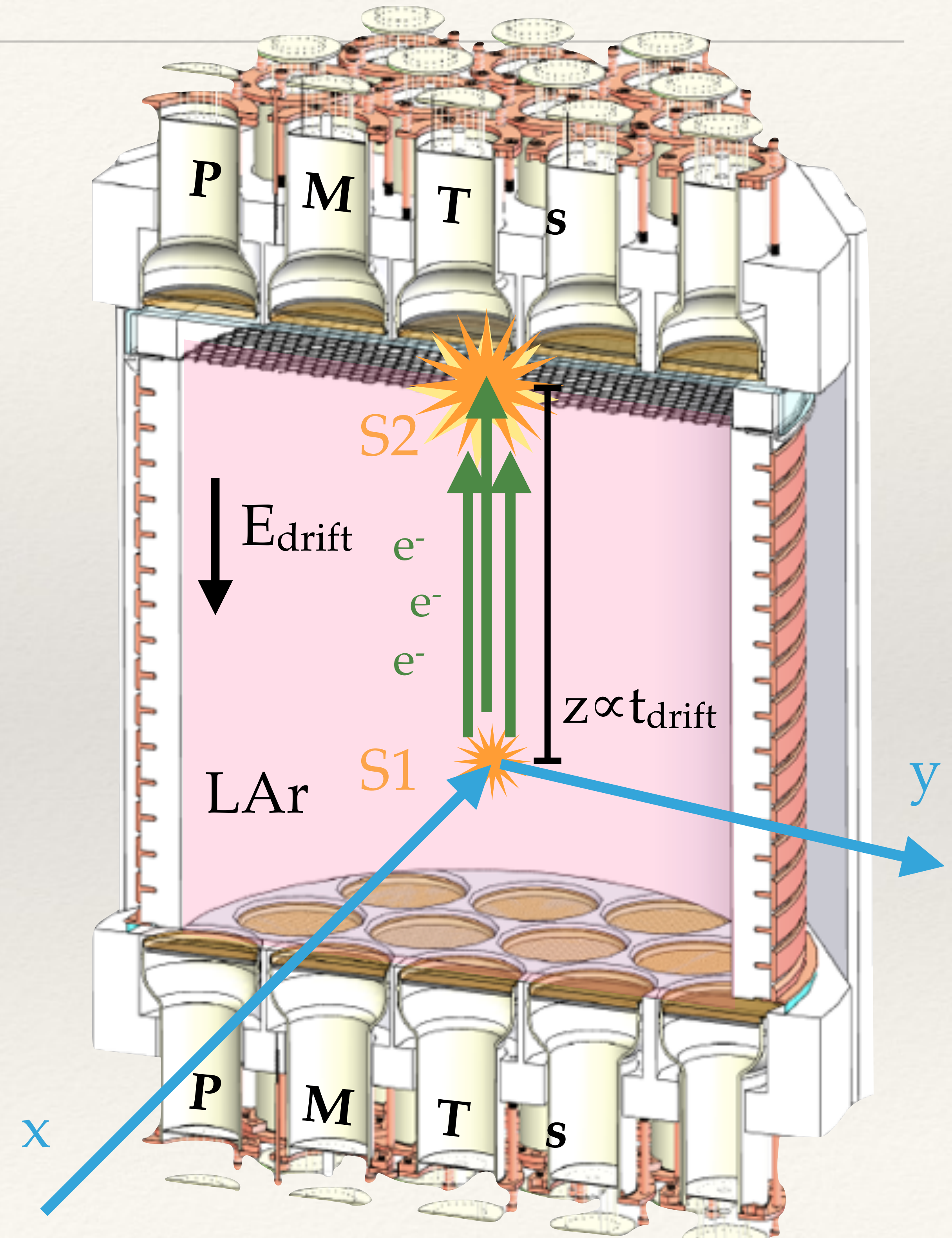
- Cylindrical shape of 35.6 cm radius x 35.6 cm height x 2.54 cm thick with PTFE reflector walls;
- TetraPhenyl Butadiene (TPB) wavelenght shifter on the walls;
- 19 3”-PMTs in the top and 19 on the bottom with cold amplifiers;
- Drift Field: 0.2 kV/cm
- Extraction Field: 2.8 kV/cm



The DarkSide-50 signal

X, Y position through S2 light on top PMTs

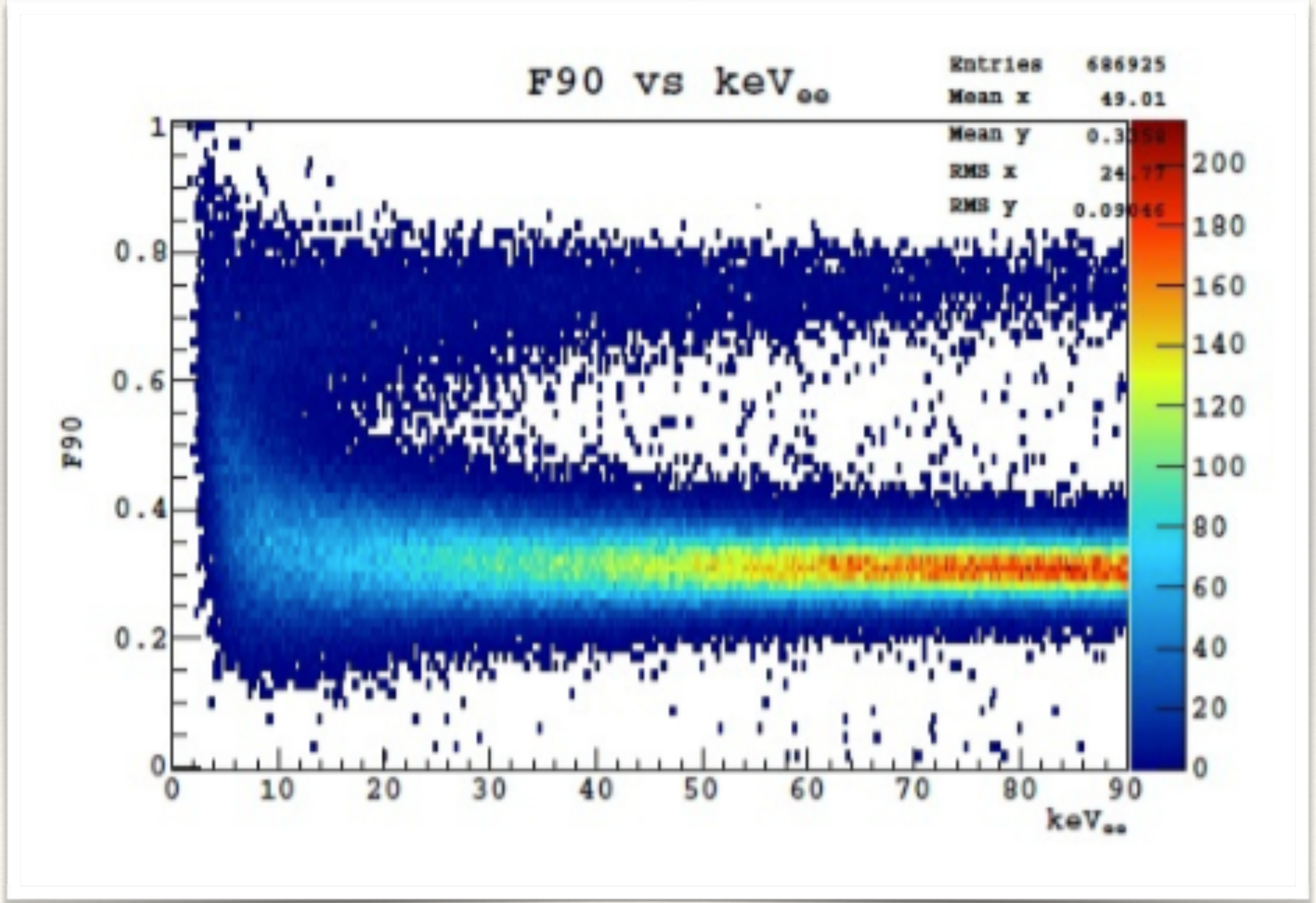
Z position through S1-S2 drift time



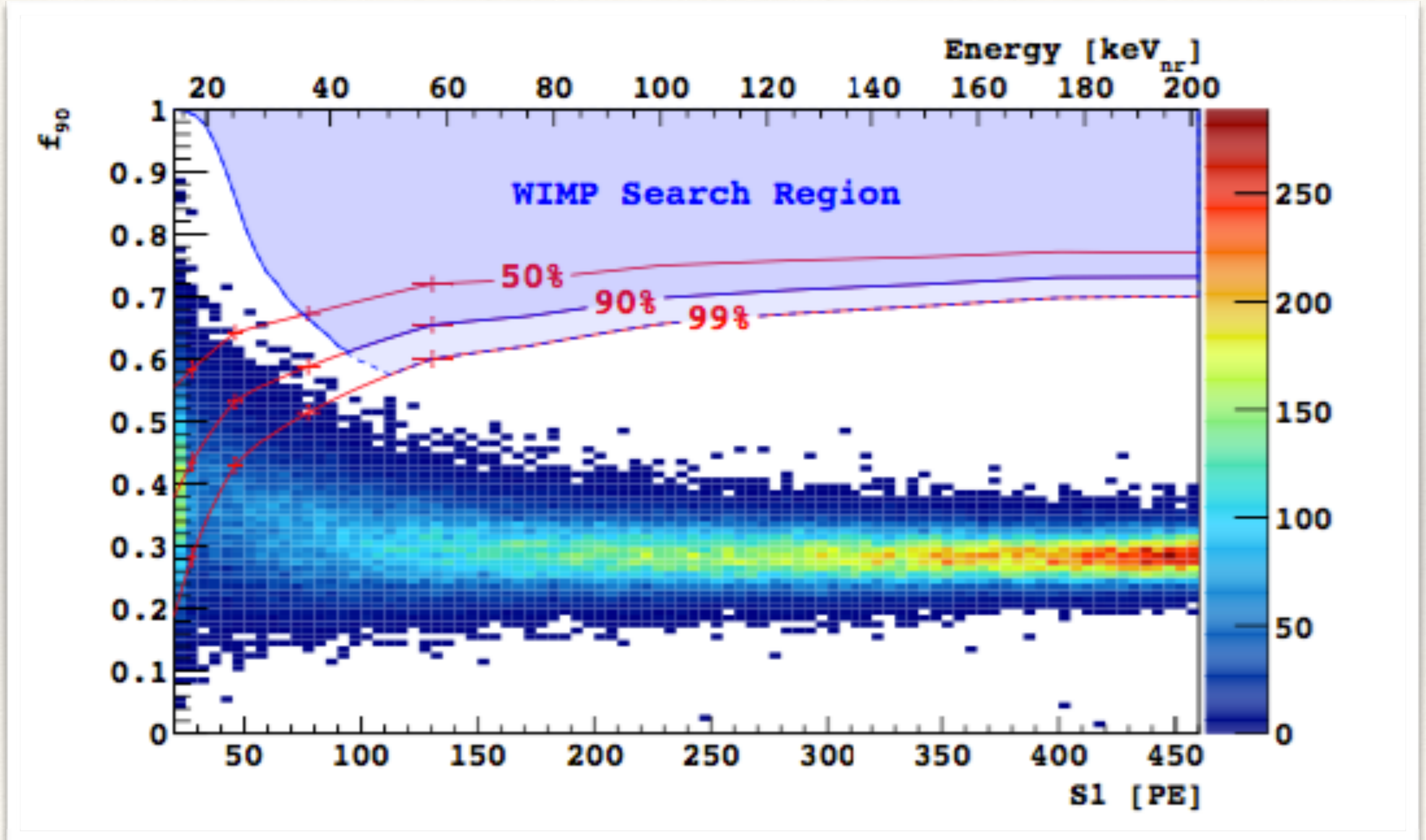
Discrimination through:

- S1 pulse shape (F90)
- S2/S1 ratio

DarkSide-50: signal processing

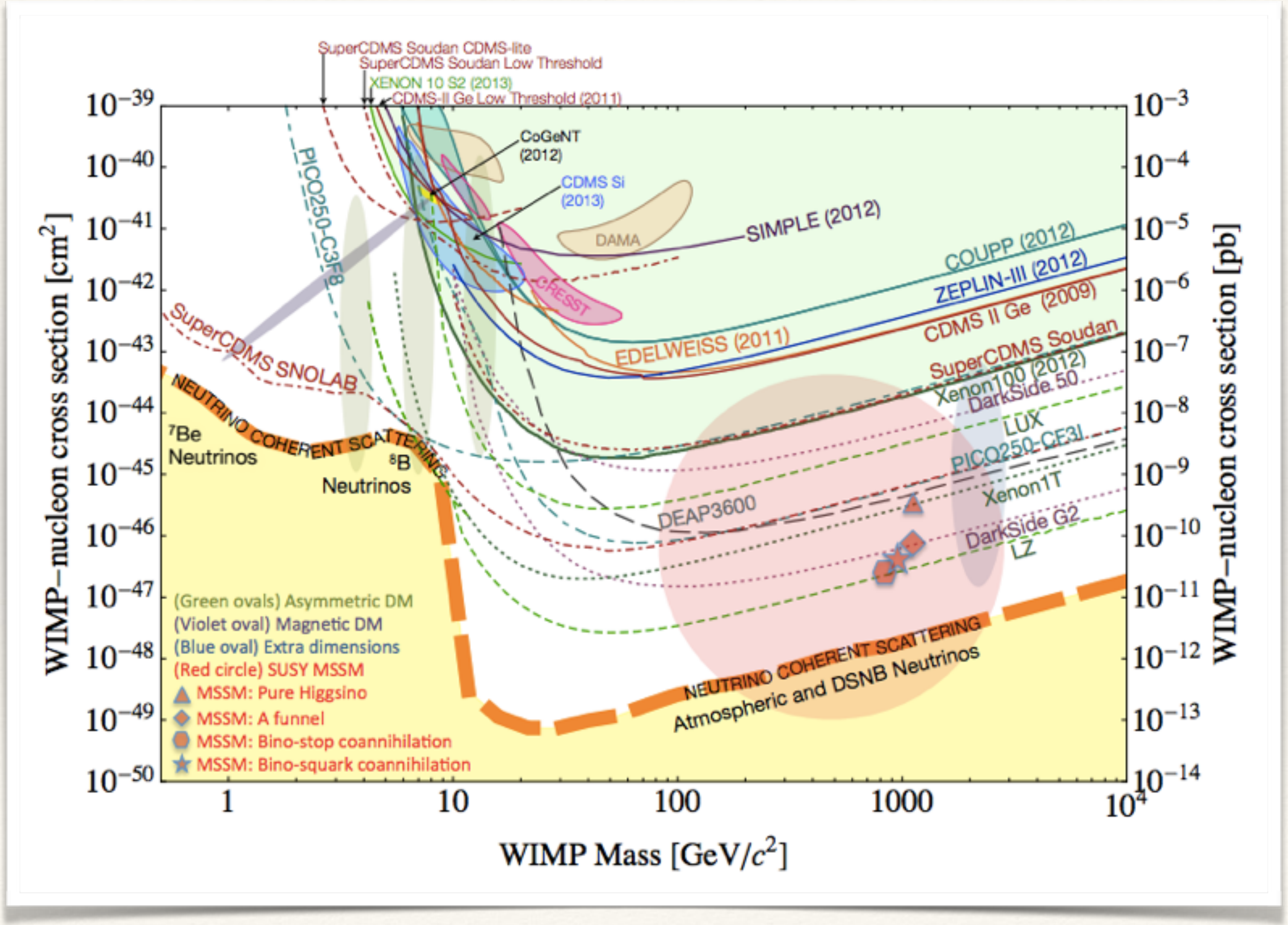


DarkSide-50 Results (1/2)

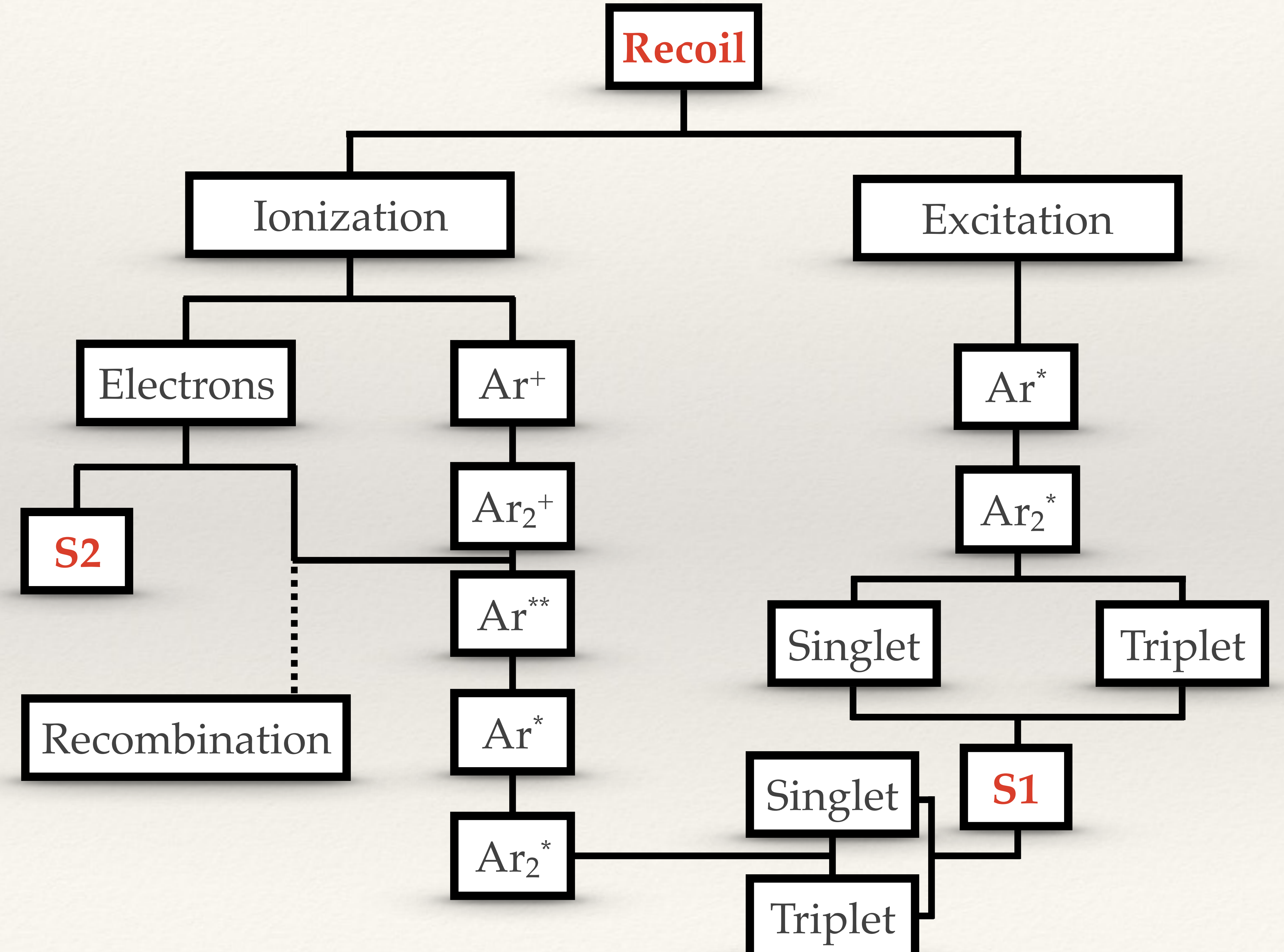


Agnes et al., Phys. Rev. D 93, 081101 (R) (2016)

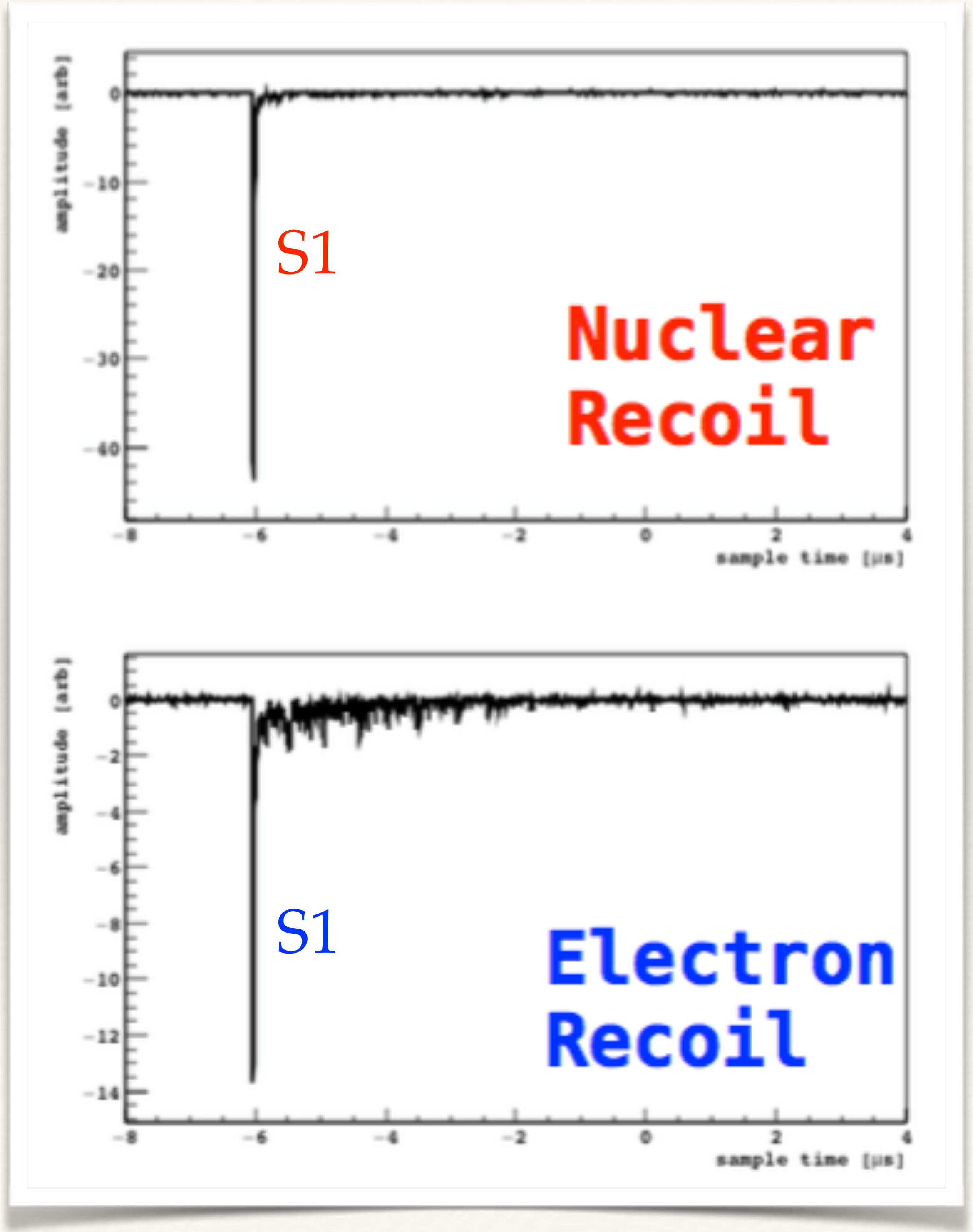
Direct Detection State-of-the-Art

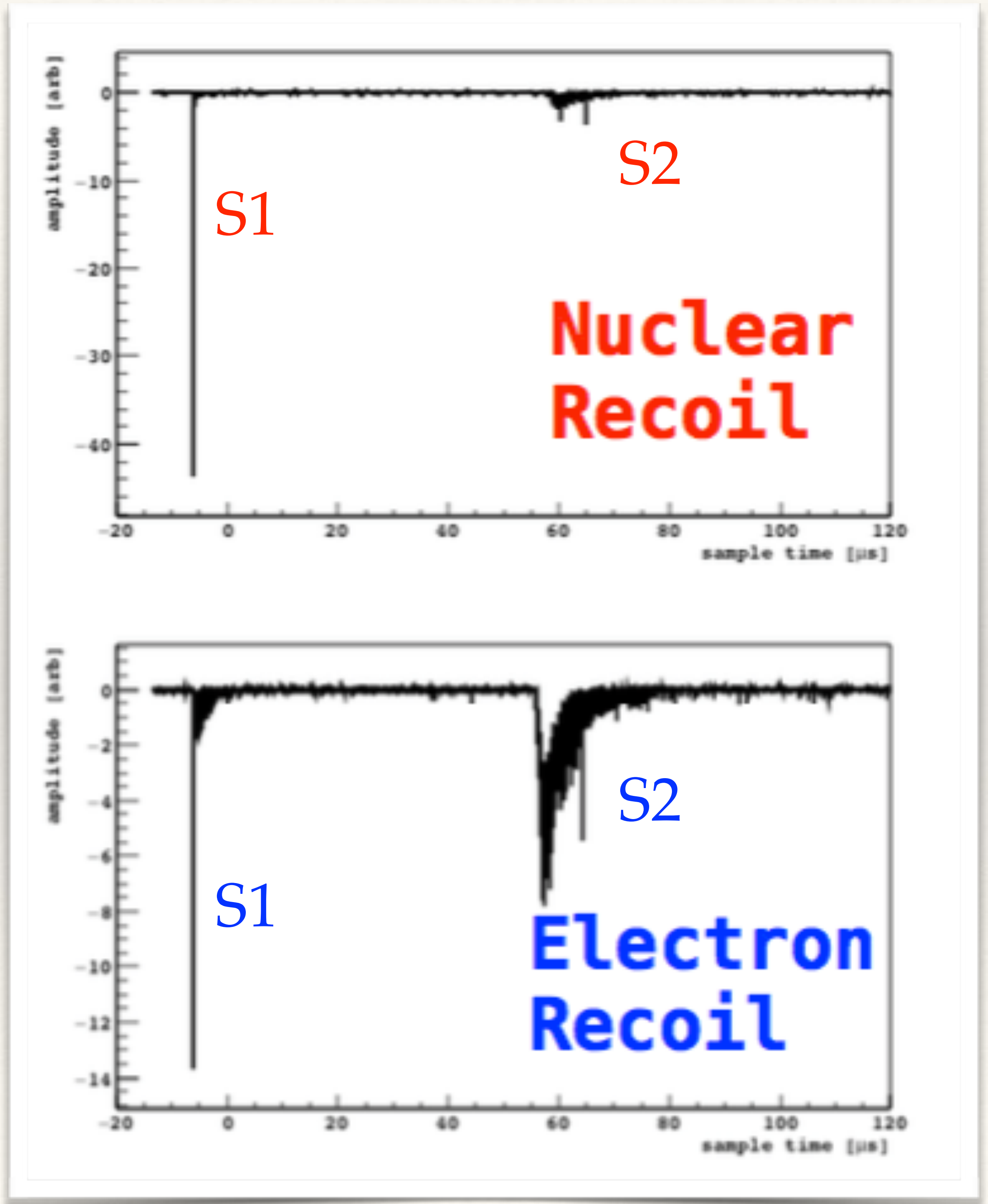


Ionization and Scintillation branches

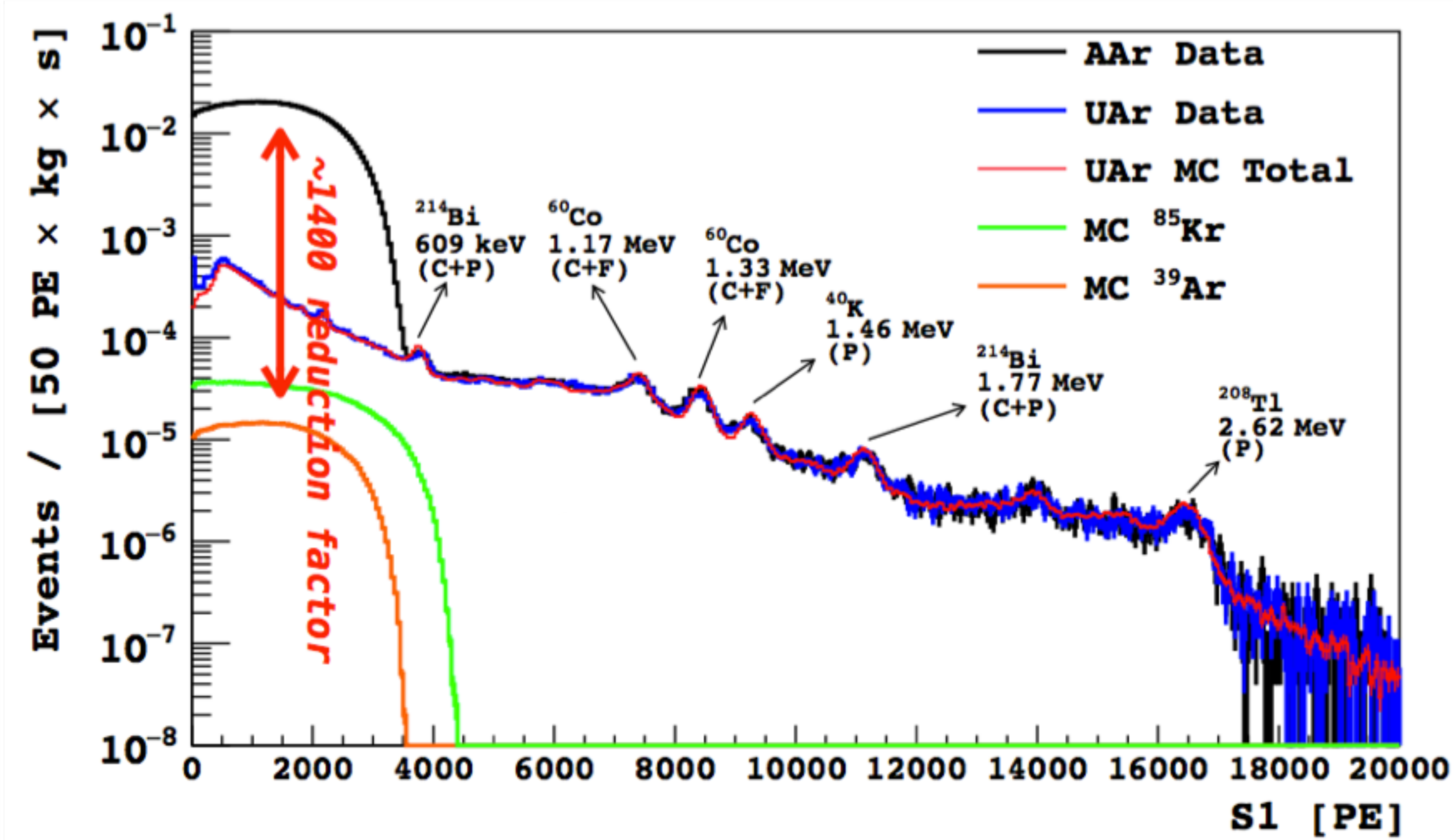


Nuclear vs Electron recoil





Underground Ar vs Atmospheric Ar



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