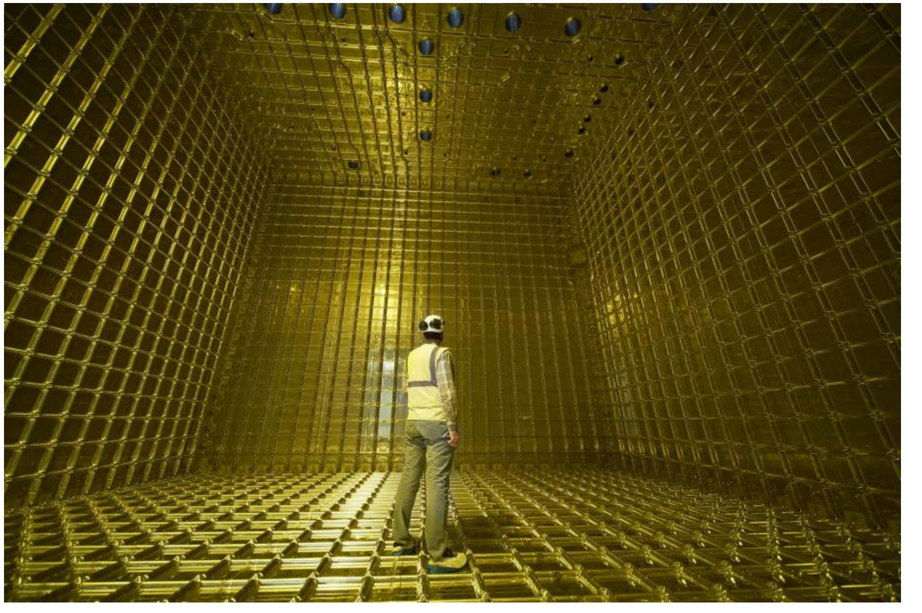
Dataflow and DAQ data challenges

Simon JM Peeters

Second UK-Latin America Workshop on DAQ and Data Selection
13 November 2018

Table of contents

- UK-LA project
- (Far) detector overview
- Physics requirements
  - *Supernova detection*
- Data challenges
- Electronics overview
- Summary of current data flow
- Challenges



In the interest of time / being concise / (my focus),
I focus on the single phase drift chamber readout.

UK – Latin America GCRF

Initiative of Prof. Trallero, director of the UNESCO-recognised Centro Latino-Americano de Física (CLAF), and Prof. Mark Thomson, the then spokesperson of the DUNE experiment. Current lead is Dr Andrezj Szelc (Manchester).

- Grant provides:
  - Travel money for workshops
  - Travel money for stays in the UK (3-6 months)
- Current grant until end 2018 - plus a few months “no cost extension”
- 18 month follow up grant requested *(Manchester, Sussex, Cambridge, Warwick, Lancaster, Edinburgh, Bristol, Oxford)*
- Purpose to prepare for a 10-year grant

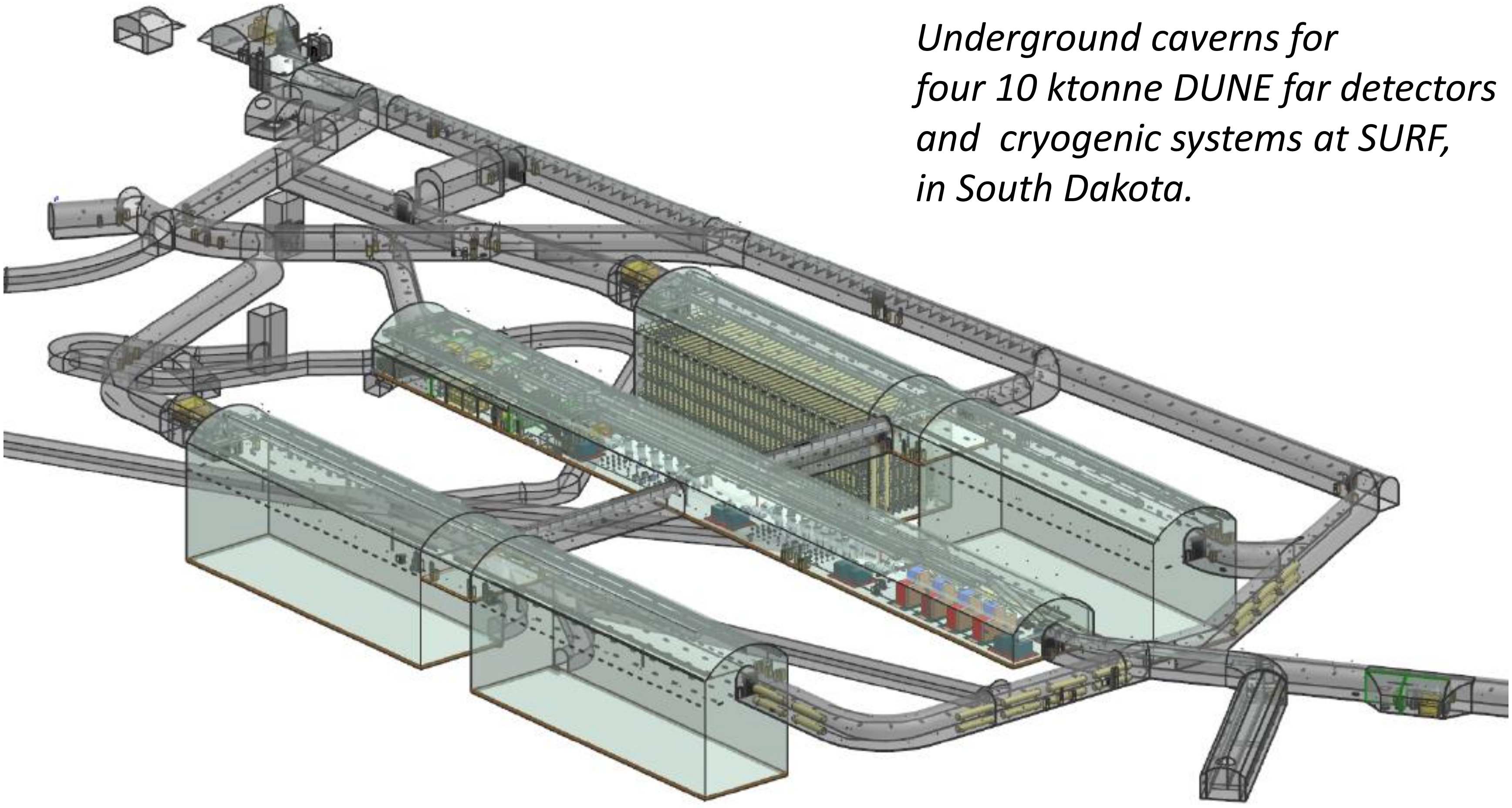
Main goals:

- **to develop ambitious LA-UK collaborative efforts in advanced computing/deep learning, highspeed electronics and light detection - cutting-edge areas of development in neutrino physics;**
- **to provide training opportunities for early career scientists in Latin America in these three areas;**

Argentina, Brazil, Colombia, Costa Rica, Ecuador, Mexico, Paraguay, Peru

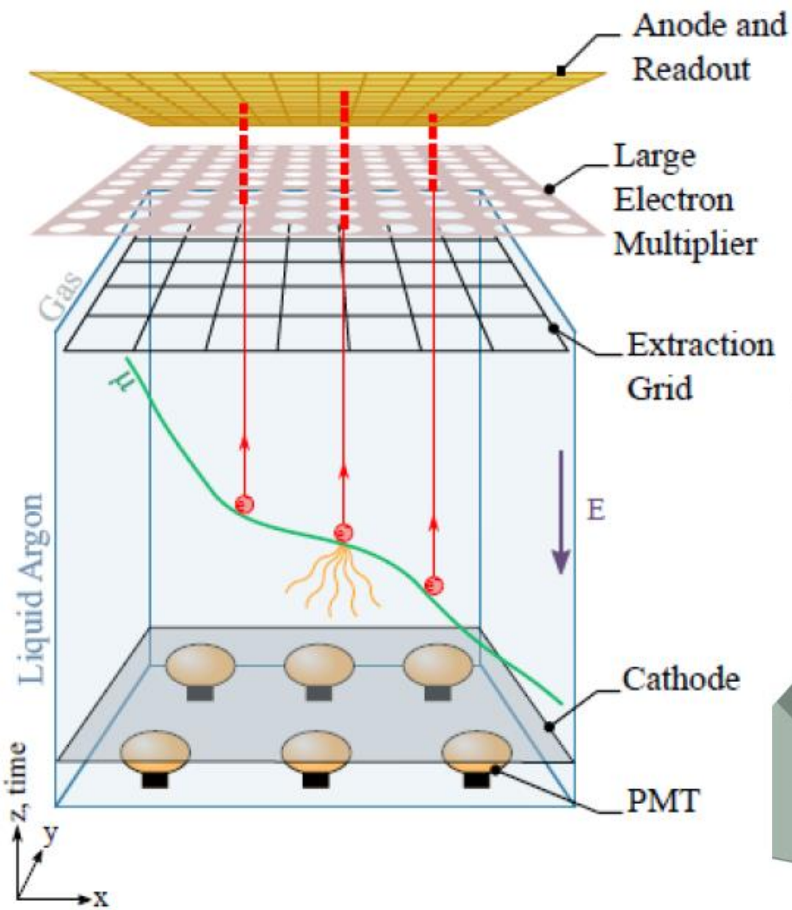
DUNE member states in orange

Far detector overview

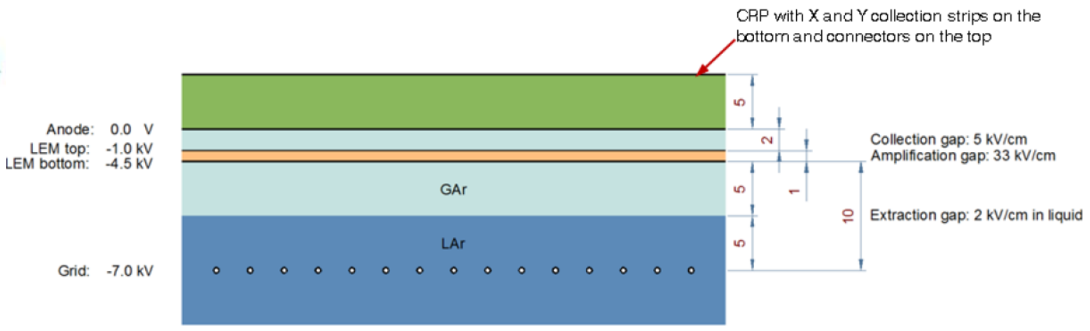


Underground caverns for four 10 ktonne DUNE far detectors and cryogenic systems at SURF, in South Dakota.

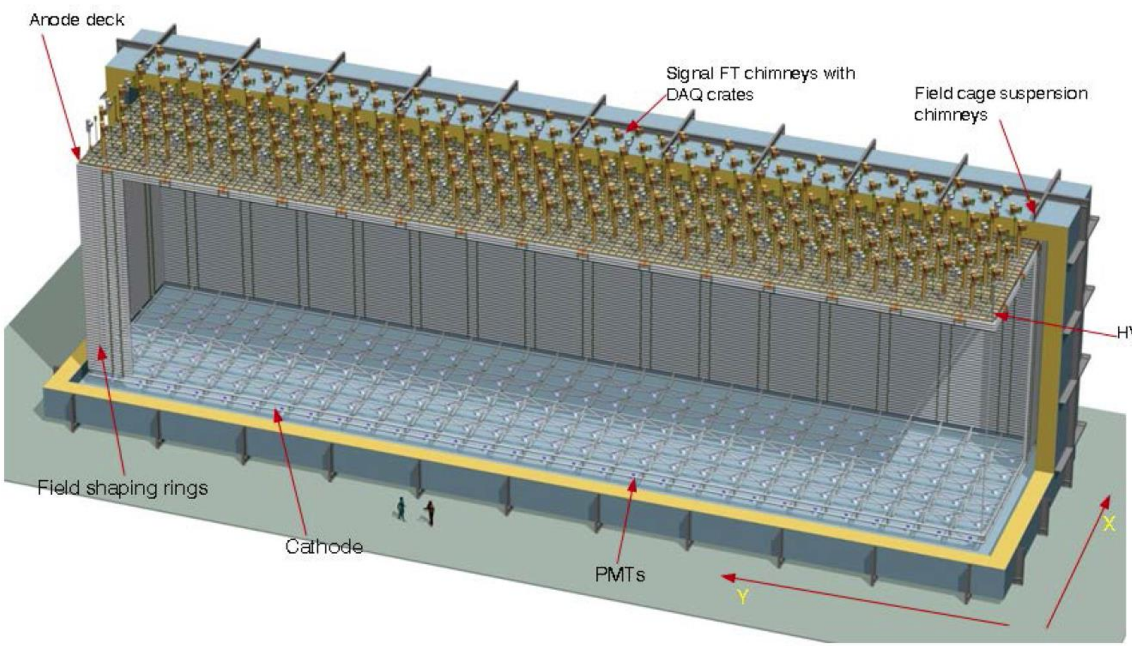
Dual Phase



Anode and Readout
Large Electron Multiplier
Extraction Grid
Cathode
PMT
Gas
Liquid Argon
E
z, time
y
x

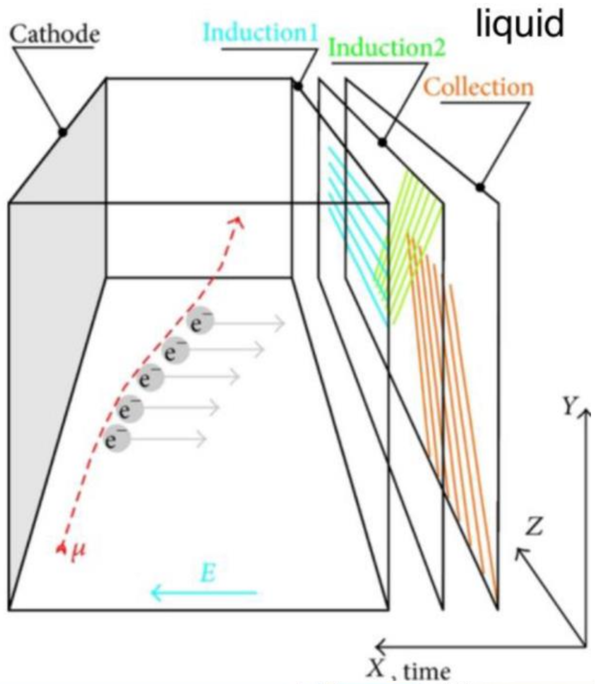


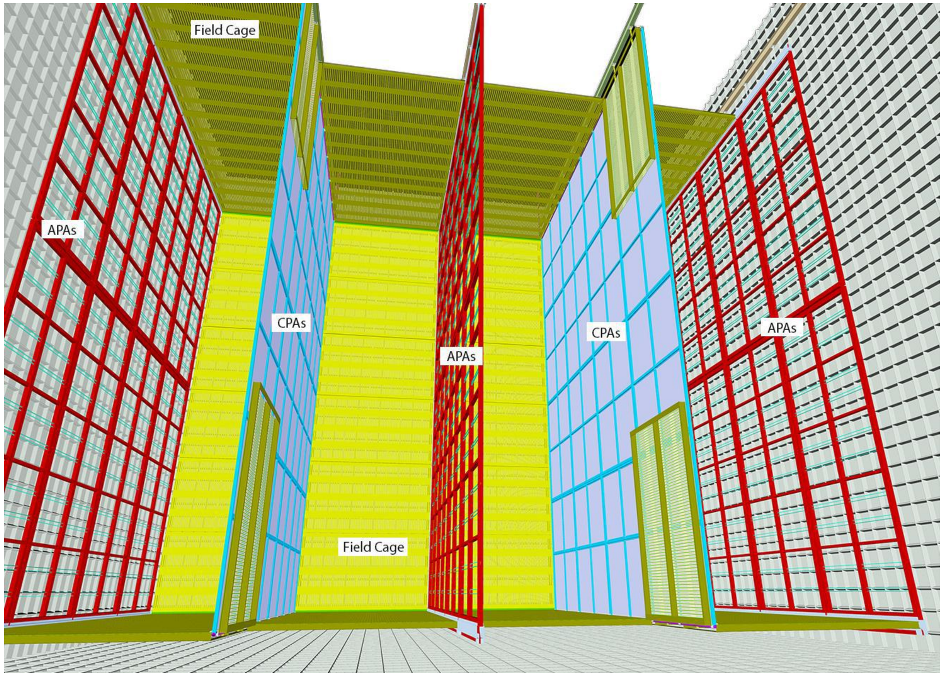
CRP with X and Y collection strips on the bottom and connectors on the top
Anode: 0.0 V
LEM top: -1.0 kV
LEM bottom: -4.5 kV
Grid: -7.0 kV
GAr
LAr
Collection gap: 5 kV/cm
Amplification gap: 33 kV/cm
Extraction gap: 2 kV/cm in liquid

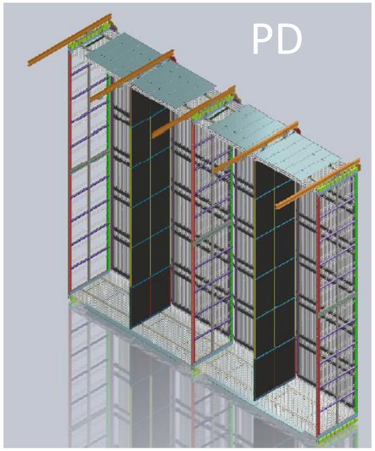


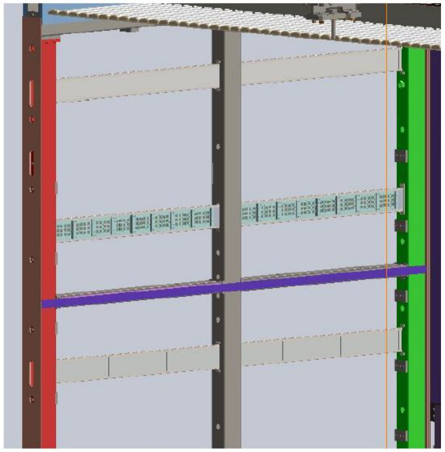
Anode deck
Signal FT chimneys with DAQ crates
Field cage suspension chimneys
HV
Field shaping rings
Cathode
PMTs
Y
X

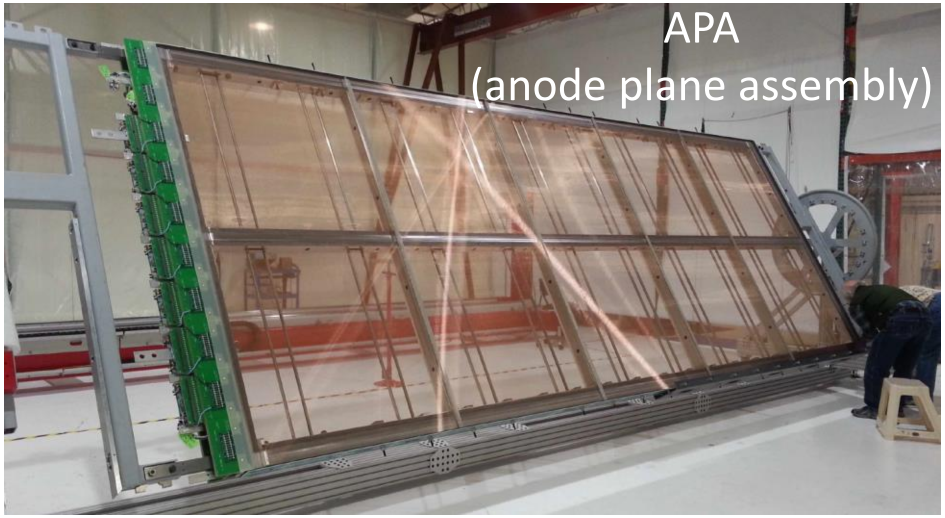
Single Phase



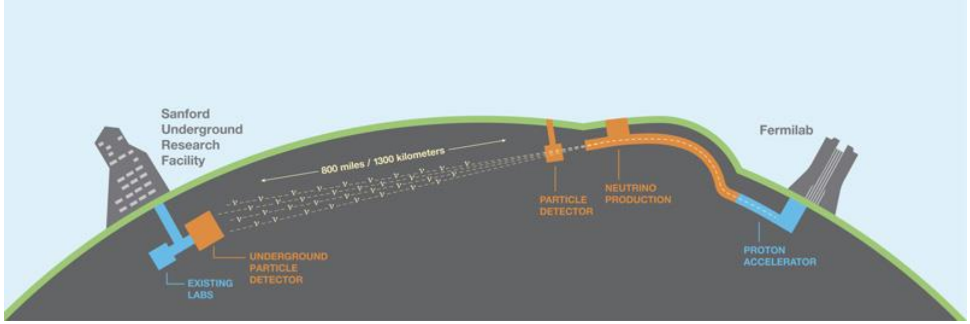








Physics overview



Primary science goals

- Beam neutrino oscillations
  Multi-GeV energy depositions
- Search for proton decay
- **Supernova neutrino detection**

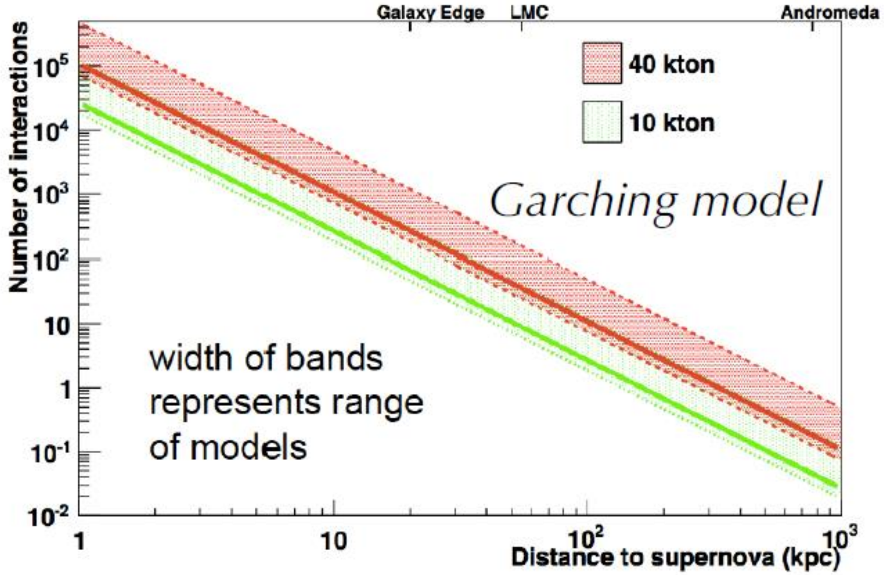
Ancillary science program

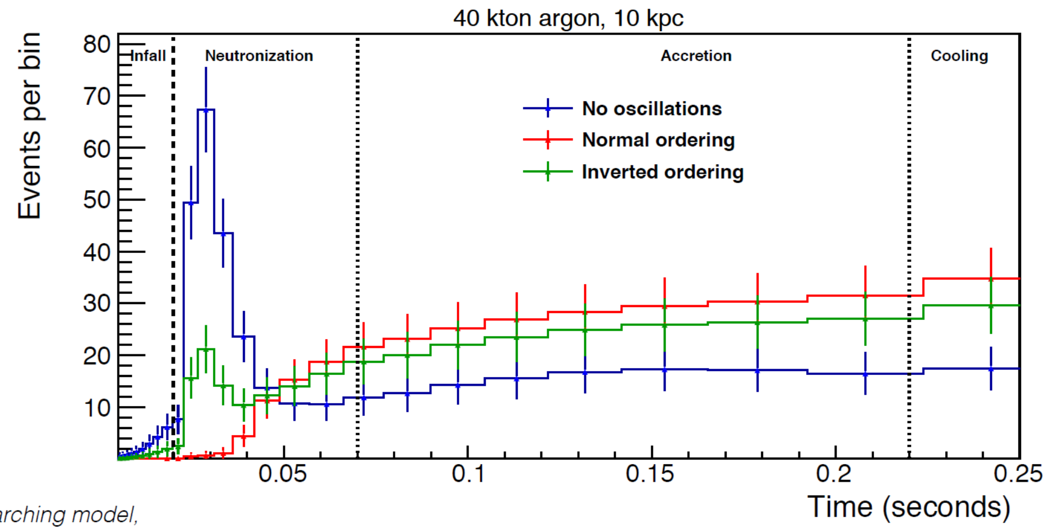
- Other accelerator neutrino physics
  (BSM, NSI, Lorentz violation, CPT violation, sterile neutrinos, large extra dimensions, heavy neutral leptons, tau appearance)
- Neutrino oscillation phenomena using atmospheric neutrinos
- Neutrino cross sections, nuclear effects
- Searches for dark matter
- And more, for example: solar neutrinos

Supernova νs

Loads of interesting physics

- Early alert
- Supernova physics
  core collapse mechanism, time evolution, cooling of supernova protostar, nucleosynthesis of heavy nuclei, black hole formation
- Neutrino physics
  flavour transformation in SN core/Earth, absolute mass, sterile, magnetic moment, axions, extra dimensions

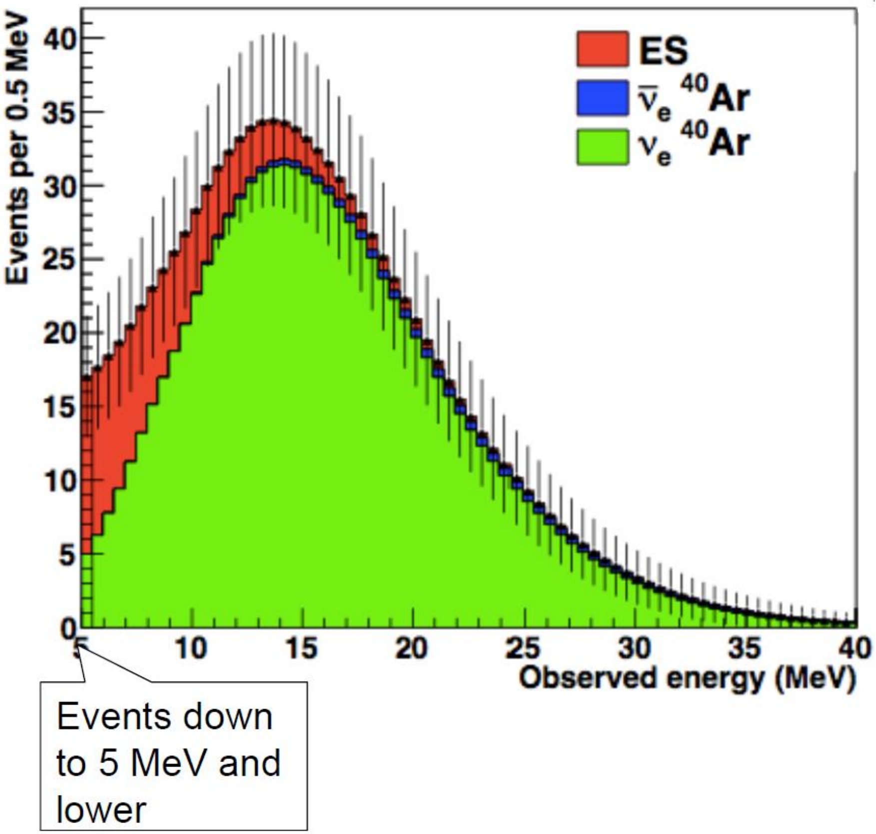


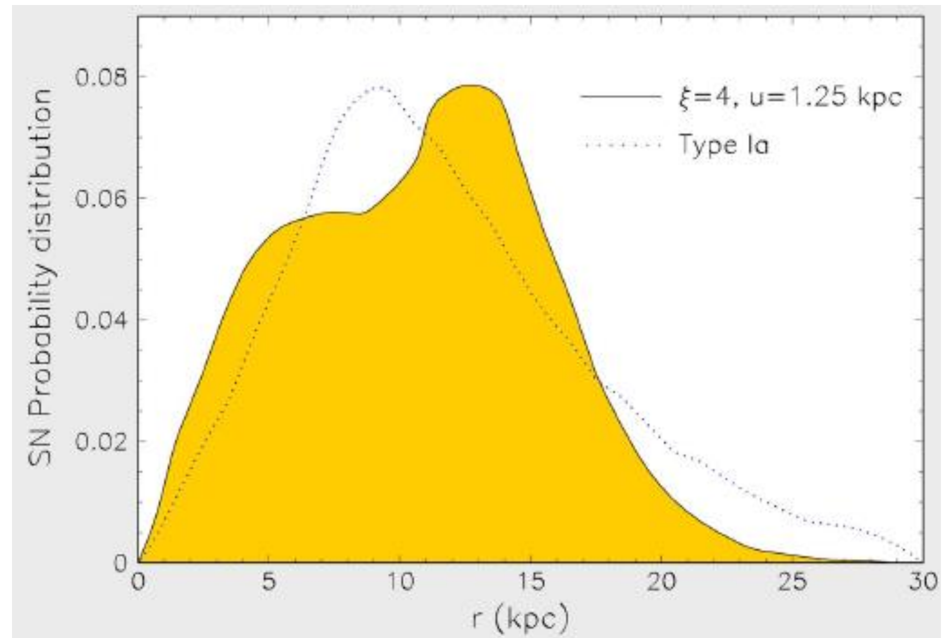


Garching model,
MSW transitions only,
total events (mostly ν_e)

Robust mass ordering signature

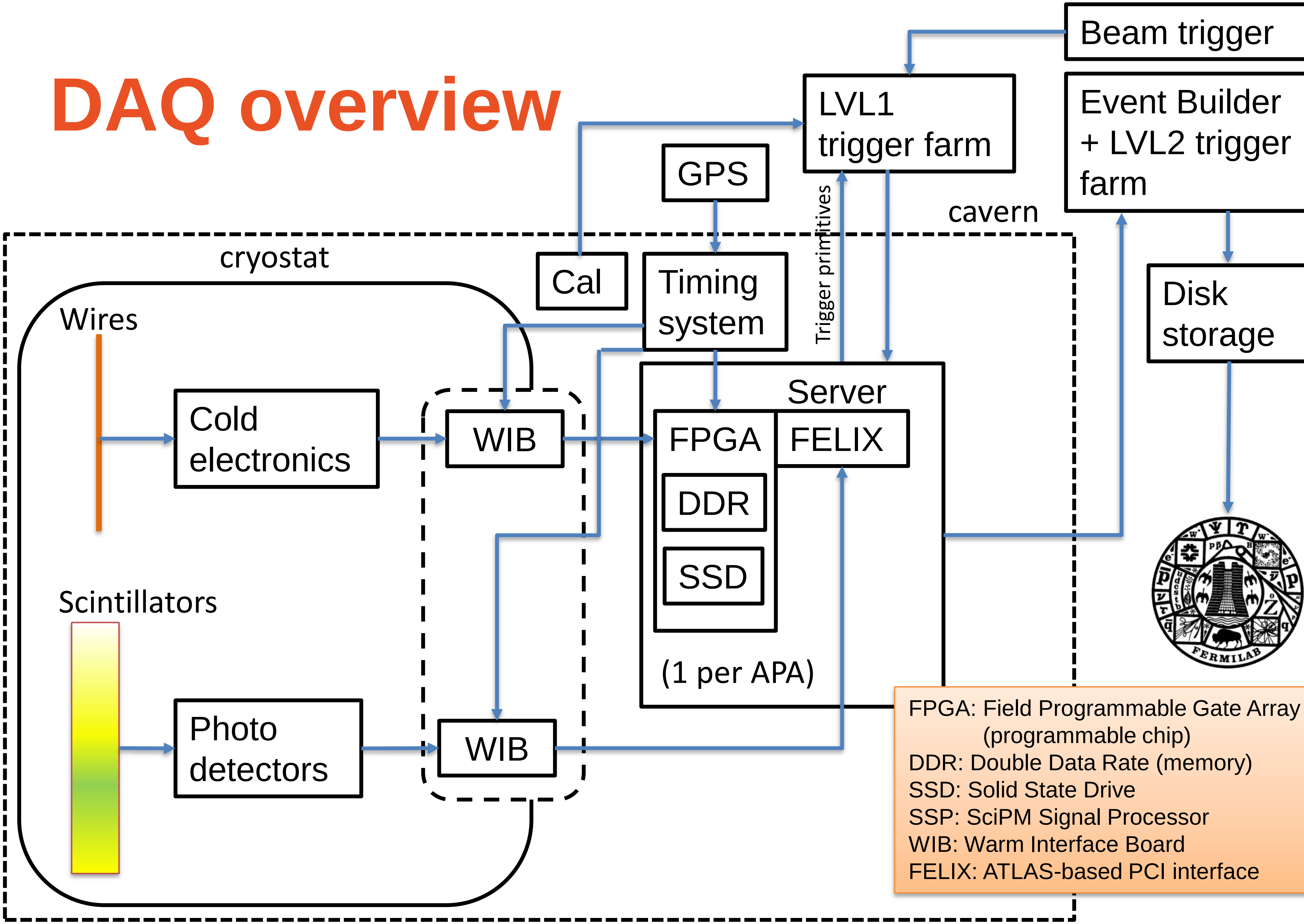
Supernova νs





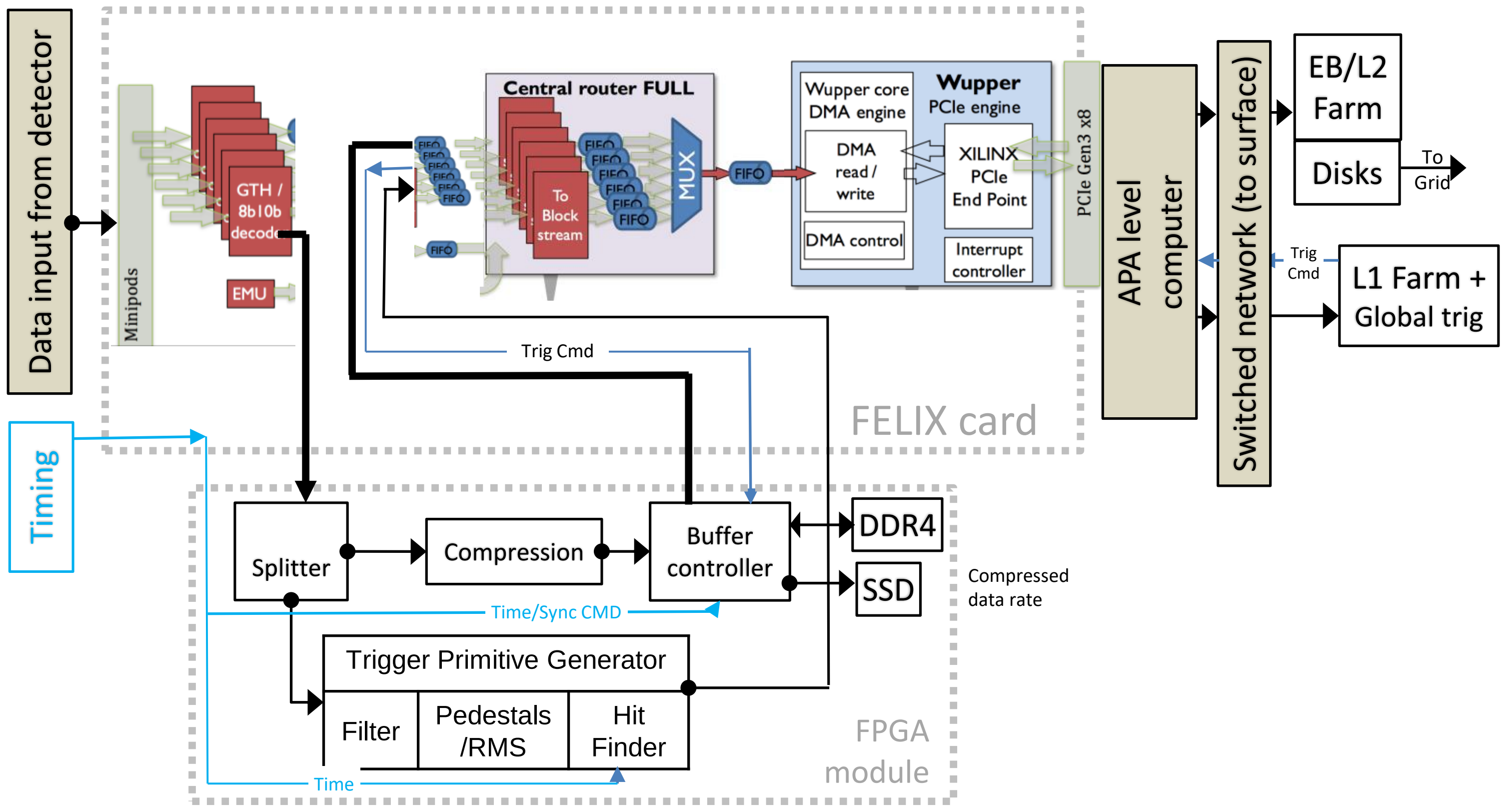
Mirizzi, Raffelt and Serpico , astro-ph/0604300

DAQ overview



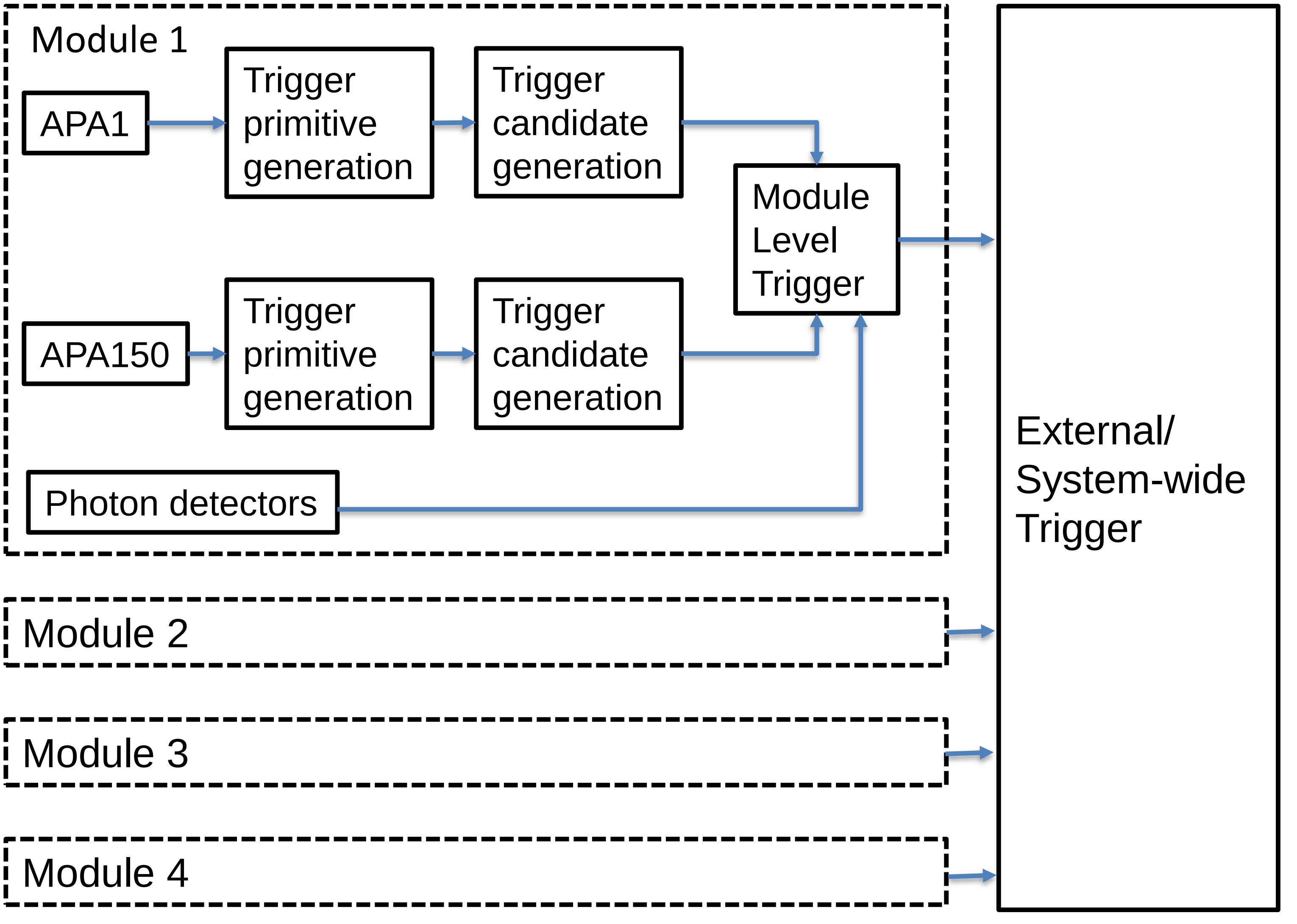
FPGA: Field Programmable Gate Array (programmable chip)
DDR: Double Data Rate (memory)
SSD: Solid State Drive
SSP: SciPM Signal Processor
WIB: Warm Interface Board
FELIX: ATLAS-based PCI interface

DAQ: detail FPGA + FELIX



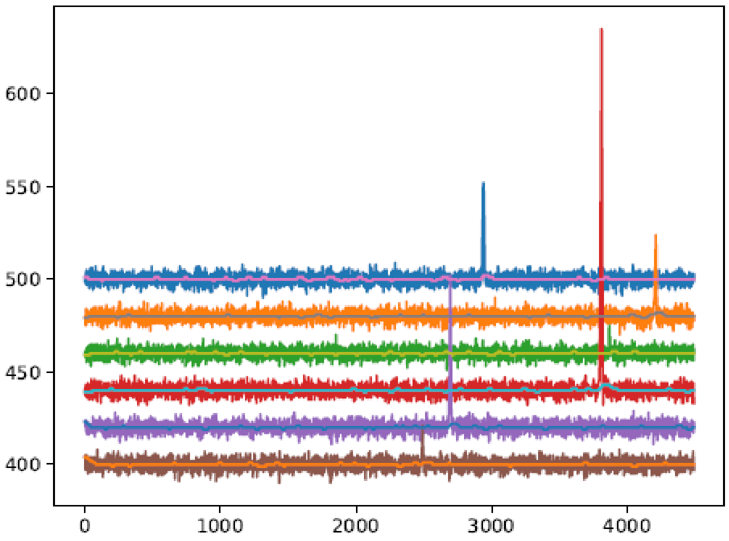
More detail / information in David Cussans' talk next

Data selection - overview



Some challenging numbers

- ADC dynamic range: 12 bits (say 2 bytes)
- ADC sampling rate: 2 MHz
- Number of channels / APA: 2,560
- Number of APAs / module: 150
- Number of channels / module : 384,000



Almost 10 GB / s / APA or 1.4 TB / s / module

One drift window: 2.2 ms – Readout window 5.4 ms (2.7 ms around trigger)

One DUNE event: 6.22 GB

Supernova burst readout window: 30 seconds

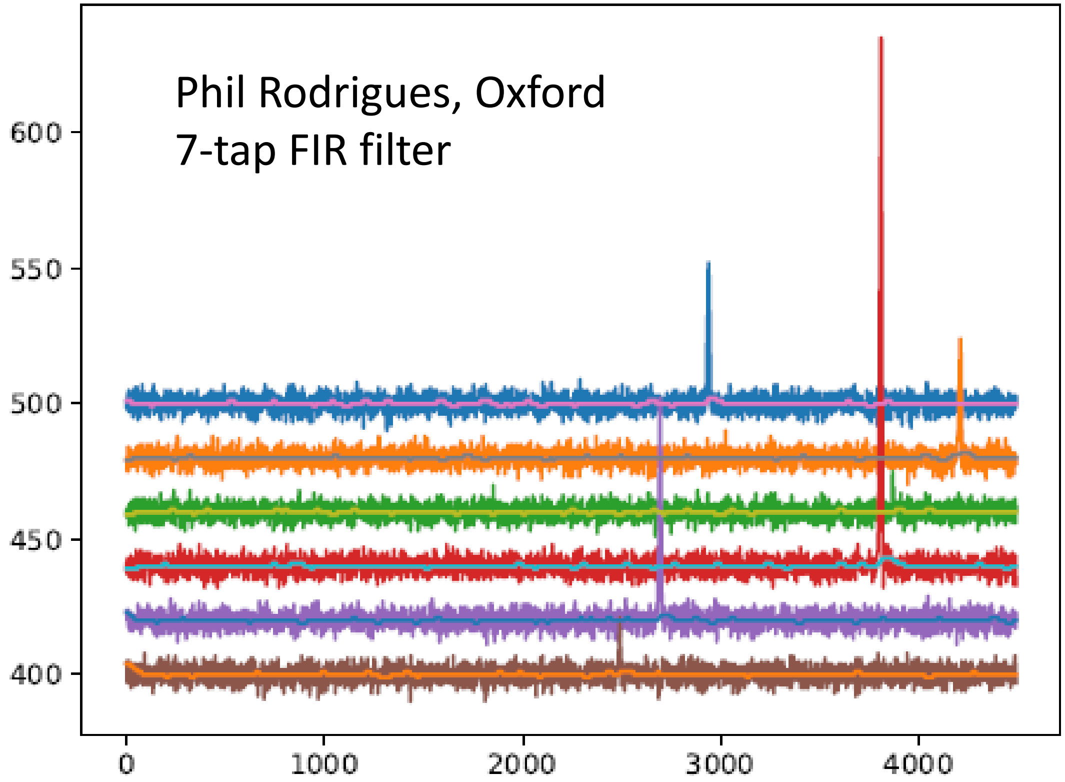
Requirement: Store less than 30 PT / yr after data compression

Sources of data

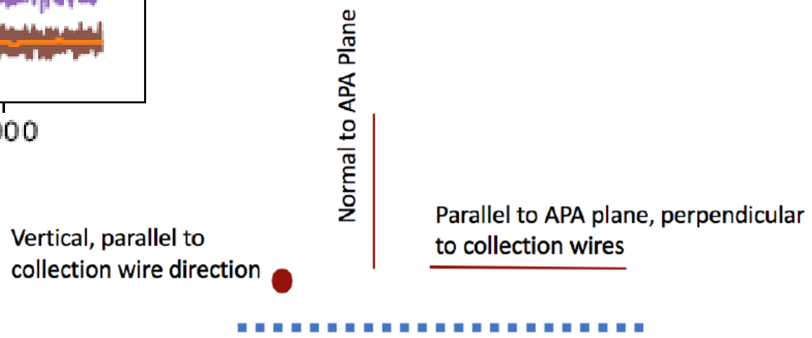
DocDB9240 (J.R. Klein)

- Cosmic rays: 4,200 / day or 10 PB / yr
- Trigger primitives: 2 PB / yr
- Supernova neutrinos: < 1 fake / month or 1.6 PB / yr
- Calibration sources: < 350 TB / yr
- “Random triggers” (pulser): 1% of cosmic, 100 TB / yr
- Solar neutrinos: 11,000 / module / yr or 68 TB / yr (upper limit)
- Noise, radioactive and inst. backgrounds: assumed to be negligible
- Beam related events: ~ 5,100 events / module / yr or 32 TB / yr
  - beam neutrinos <1,000 events / module / yr
  - rock muons: 1,400 events / module /year (large uncertainty)
  - Accidental cosmic rays: 2,800 / module / yr
- Atmospheric neutrinos: ~ 1,200 yr or 7.4 TB / yr

Generating trigger primitives



FPGA Algorithms:
- Data handling
- Compression
- Hit finding
- Trigger primitive generation



Trigger studies

The following steps have been studied
(see Pierre Lasorak's presentation at the last collaboration meeting)

- Hit finding
- Clustering
- Trigger algorithm (burst for SN)

For the overall background and minimal noise levels,
there is toolkit and studies have been done for wires & photons.
Needs to continue: for example, using different hit finders / clustering.

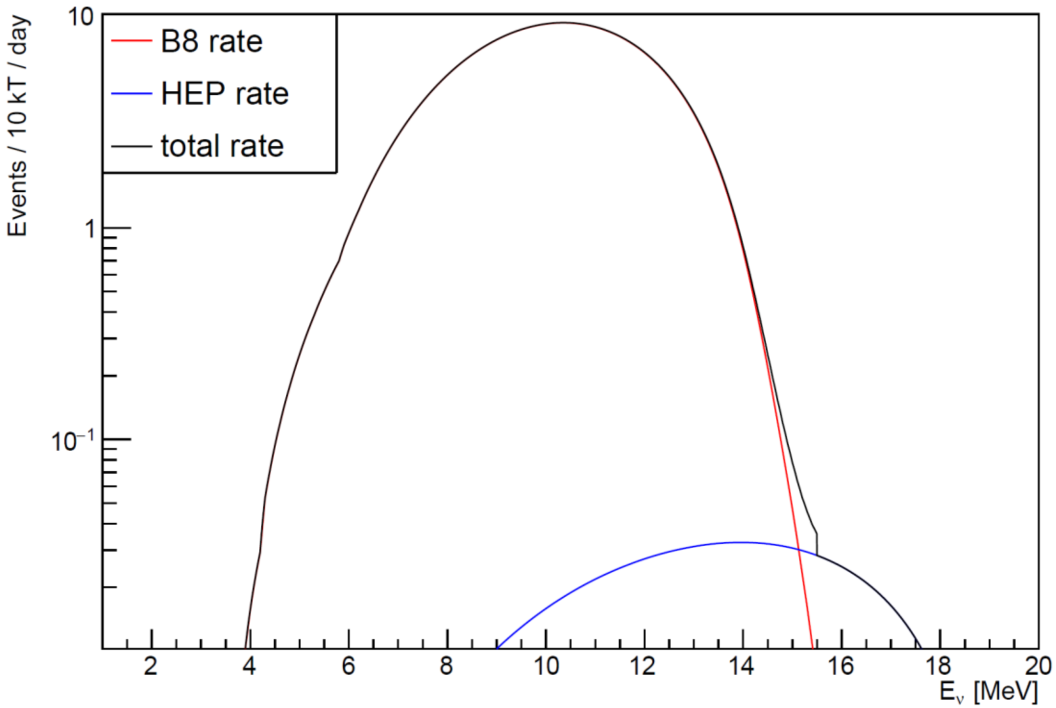
Most urgently:

- ^{222}Rn – currently approximated as single alphas (fix: Juergen)
- Neutrons – currently single neutron rate (fix: Aran Borkum) (but large fission comp)

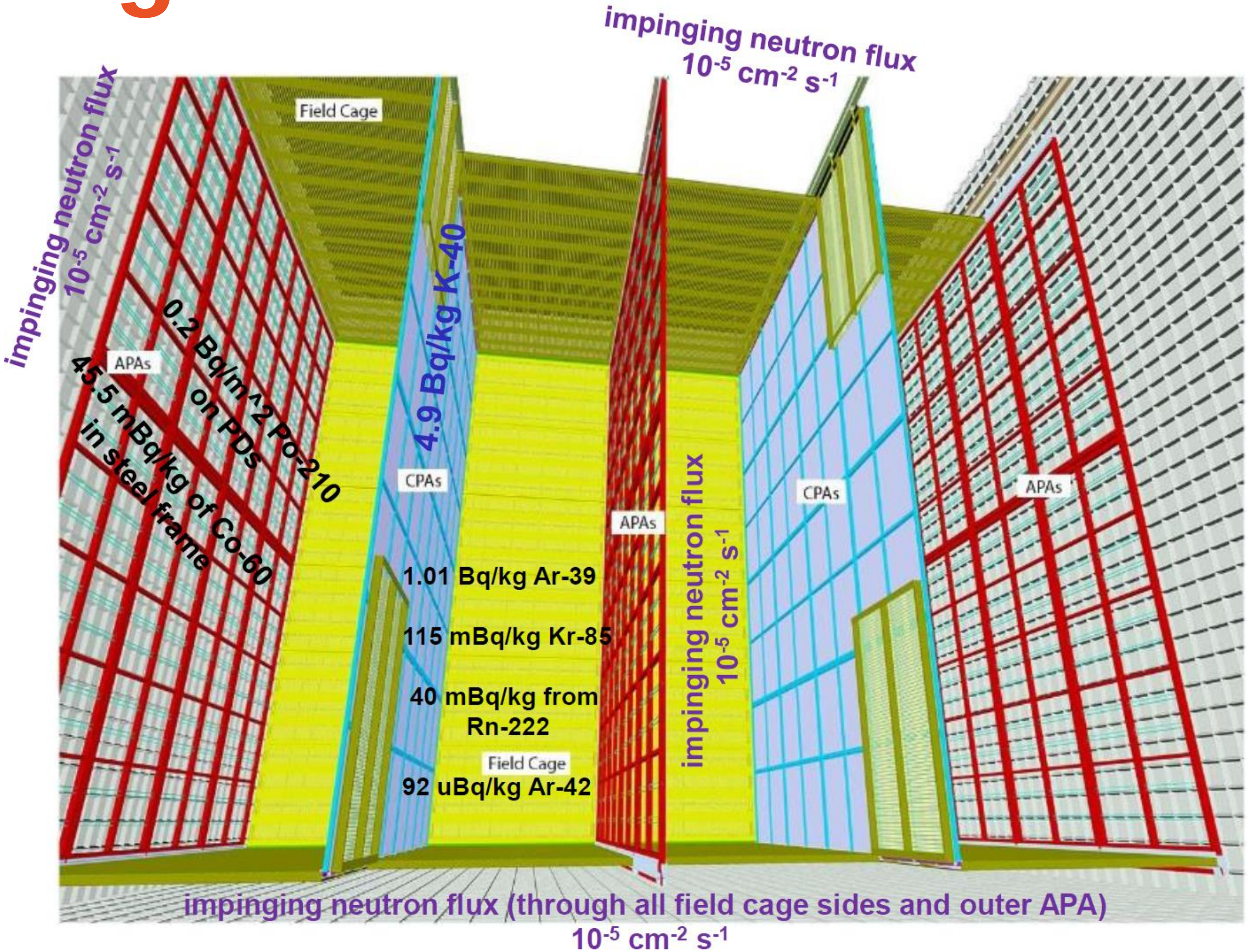
Requirements

- Supernovae:
  < 1 / month fake rate while > 95% efficient for galactic SNe
- Beam events:
  > 99% efficient for events with energy deposit of > 100 MeV
- Other events:
  > 50% efficiency for electrons with energy > 10 MeV

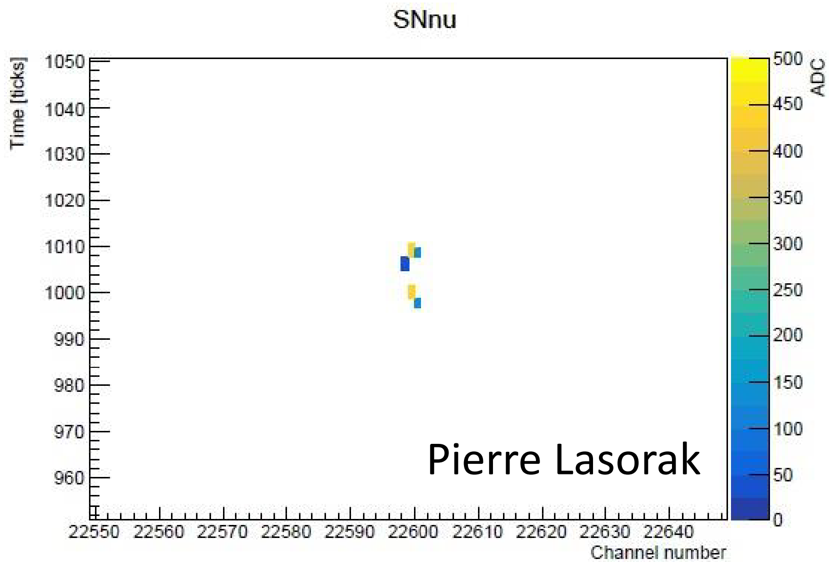
Solar neutrinos in DUNE (Pierre Lasorak)

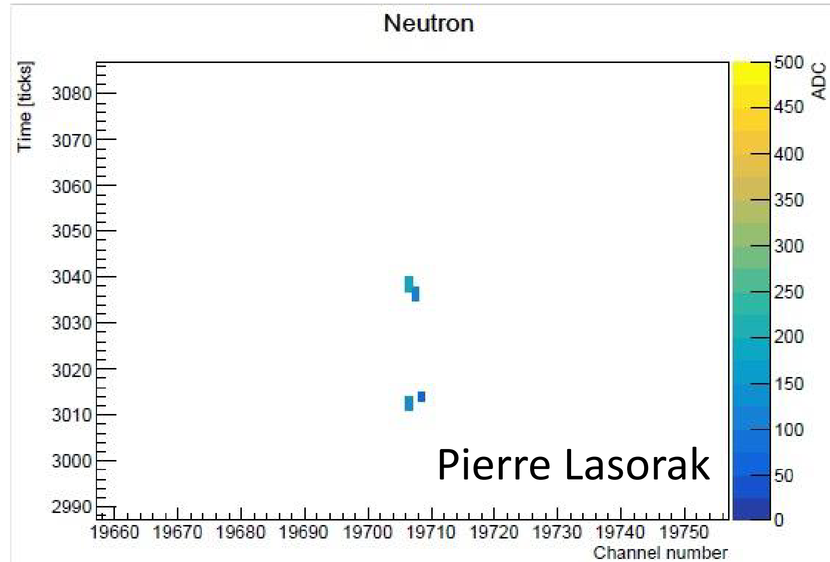


Background sources

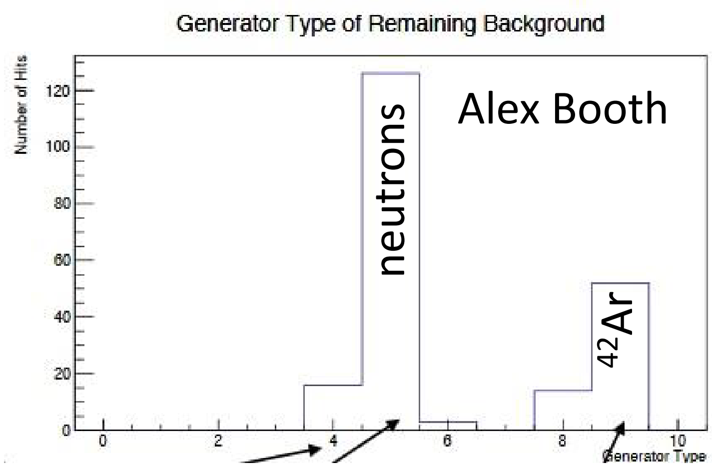


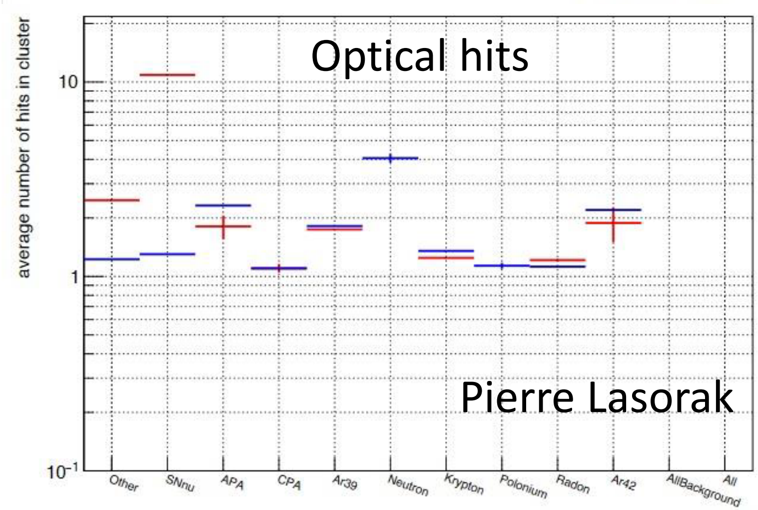
Clustering





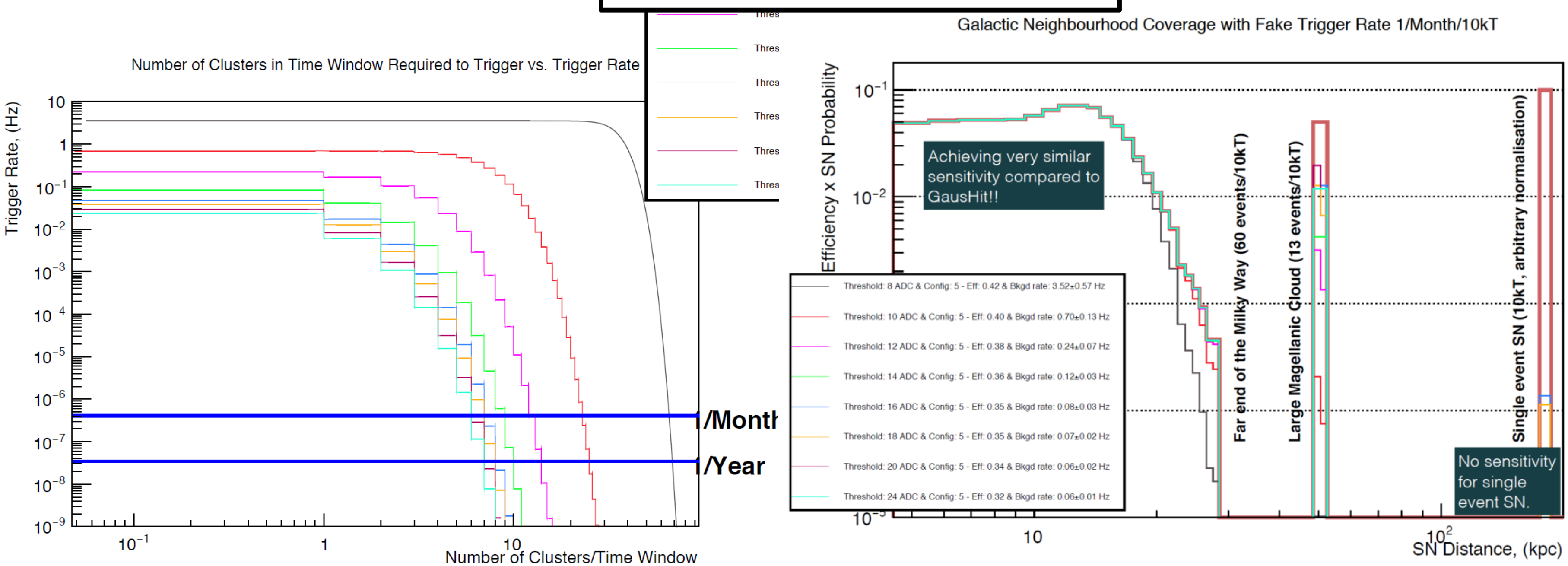
SN Efficiency: 81.2%, Bkgd: 0.19Hz





Supernova studies

Example of using different hit finding thresholds



Pierre Lasorak

Summary

1. Data selection (triggering) in DUNE is challenging
2. We need to get this right to get to the interesting and diverse aspects of the physics
3. Studies started and we have a good handle – however, more realism needed, more physics channels should be studied

We already had interesting discussions, and this workshop will continue those, to see how we can collaborate more intensly using the opportunities the GCRF funding scheme provides.