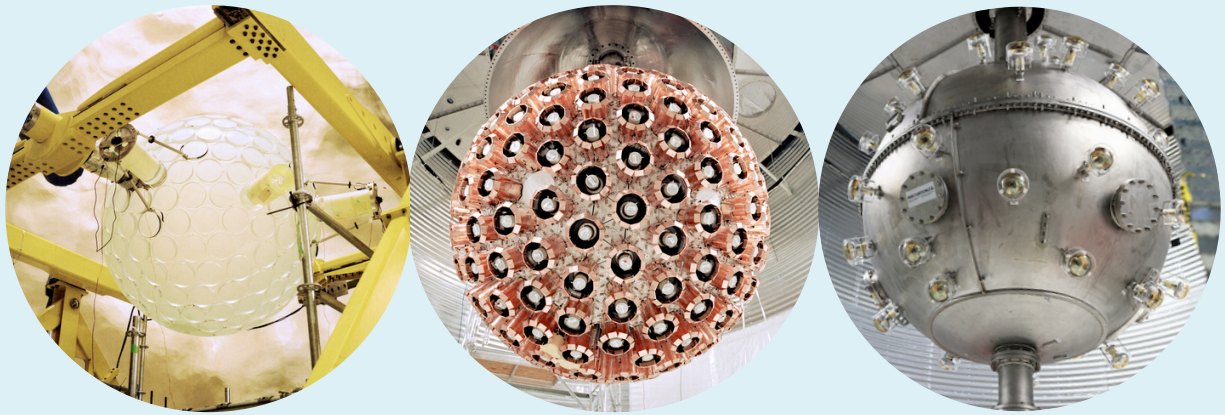
DEAP-3600 trigger: dark matter from light

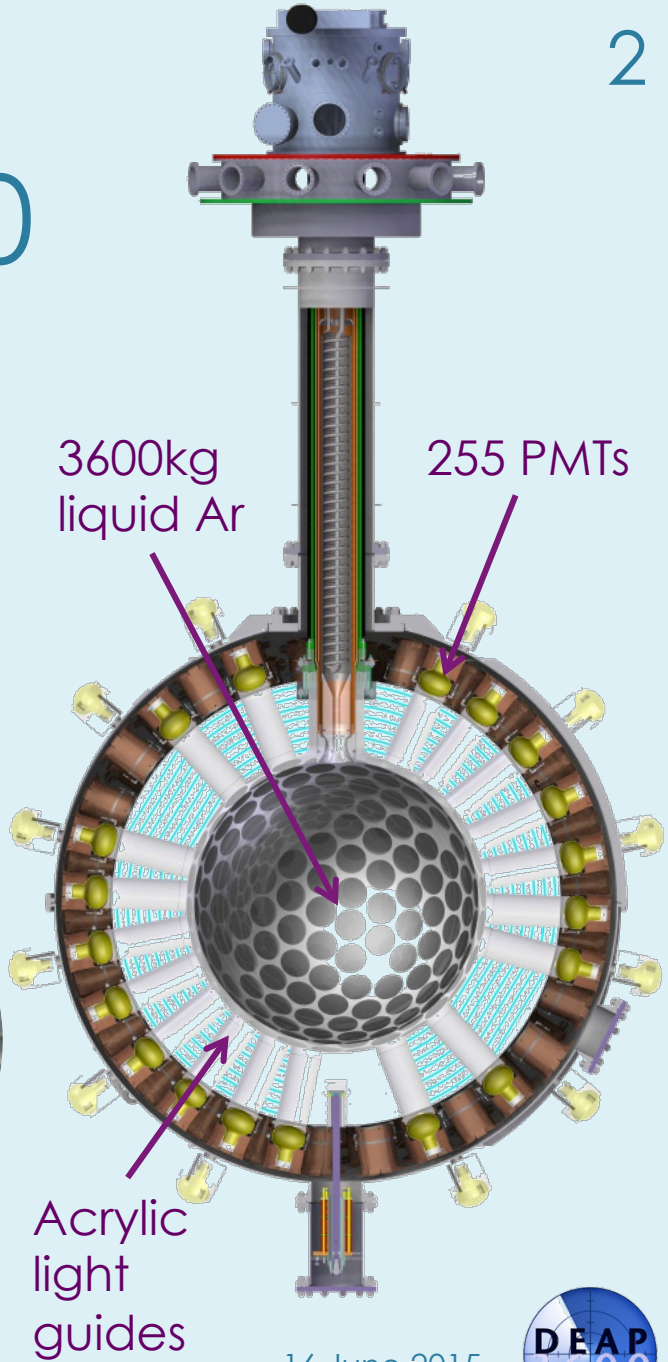
Ben Smith
TRIUMF
CAP – 16th June 2015

See detector hardware poster for more!

DEAP-3600

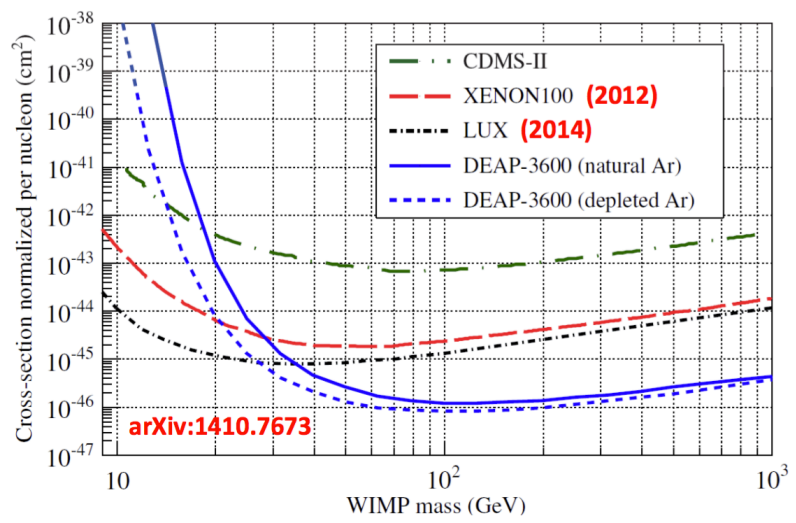
- 2km below Sudbury, ON
- Uses liquid Ar to search for WIMPs
- ~60 collaborators from Canada, UK and Mexico

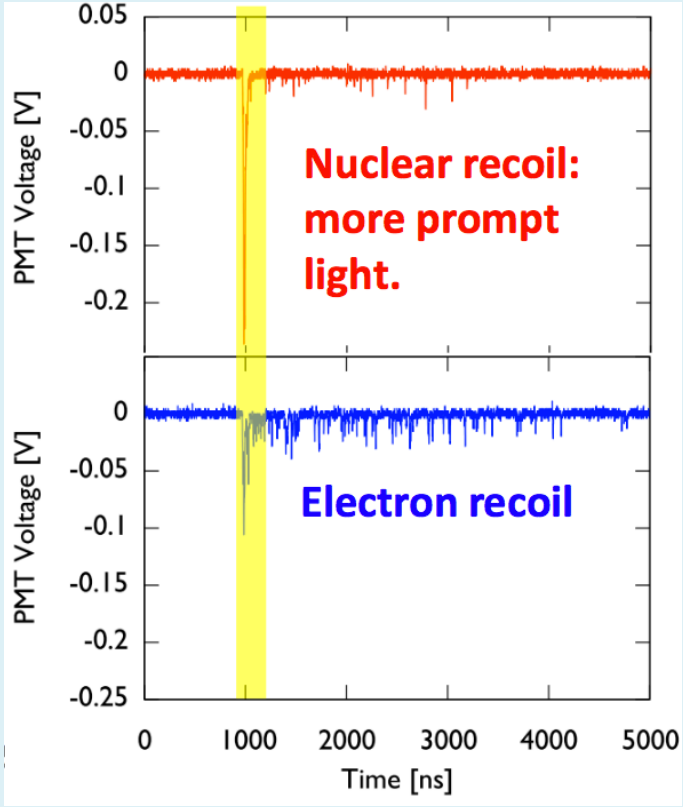




Detection principle

- Recoils in liquid argon cause scintillation
  - WIMPs cause nuclear recoils
  - Most backgrounds cause electron recoils
  - Pulse shapes are different!
- Expect world-leading sensitivity for 100GeV WIMPs



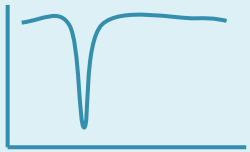


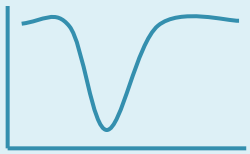
Expected event rates

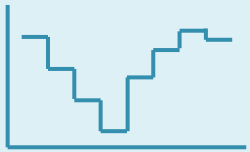
Event type	Trigger rate (Hz)
^{39}Ar β decay	**3600**
Surface backgrounds	$< 10^{-3}$
Cosmic muons	$< 10^{-3}$
WIMPs	**$< 10^{-5}$**
^{222}Rn decay	$< 5 \times 10^{-6}$
Neutrons in Ar	$< 10^{-6}$

- At least 10^8 β decays for each WIMP!
- Trigger needs to filter out most of these events, so offline analysis is feasible

Electronics setup







255 LAr PMTs

22 signal conditioning boards
(slow down the fast PMT pulses)

SUM

Trigger
(DTM)

Trigger signals

32 250MHz
digitizers

4 62.5MHz
digitizers

Readout
PCs

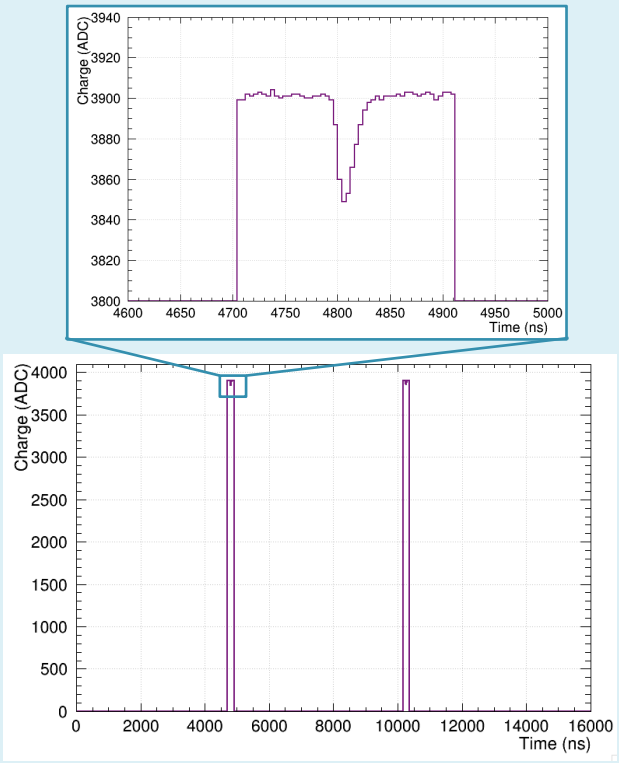
PMTs: Hammamatsu R5912
SCBs: Custom TRIUMF/Alberta
DTM: Custom TRIUMF
250MHz digitizers: CAEN V1720
62.5MHz digitizers: CAEN V1740

Digitizer and trigger module

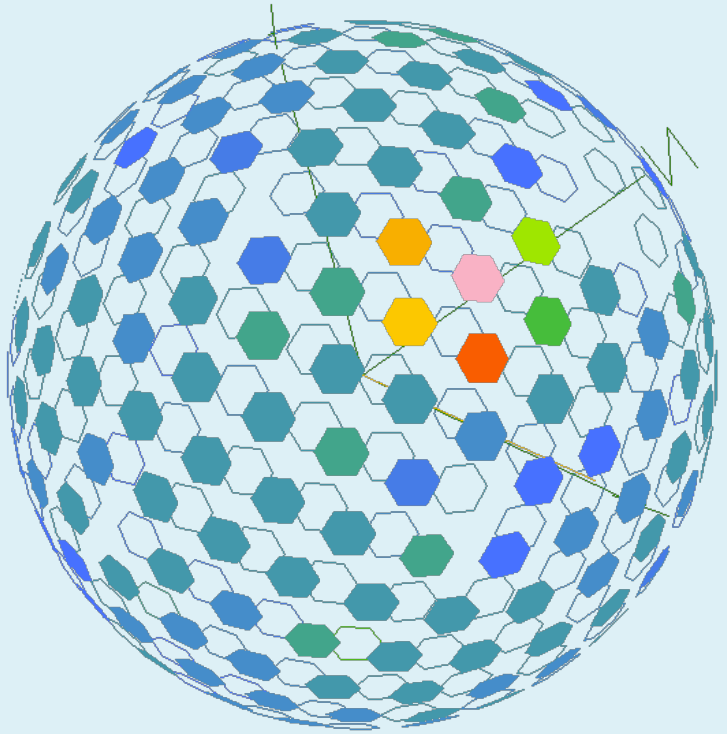
- Trigger is at the heart of the electronics
- Can trigger based on different *sources*
  - A timer (e.g. take data at 1kHz)
  - External signal (e.g. calibration system)
  - Analysing the PMT signals
- Each *source* is connected to one or more *outputs*
  - Which hardware to trigger
  - Whether to skip this event (to reduce trigger rate)
- This system is incredibly flexible and powerful
  - Can change the entire trigger scheme run-to-run

DEAP-3600 events

- Expect <1 pulse per PMT from a WIMP
- Digitizers configured to only save data near pulses



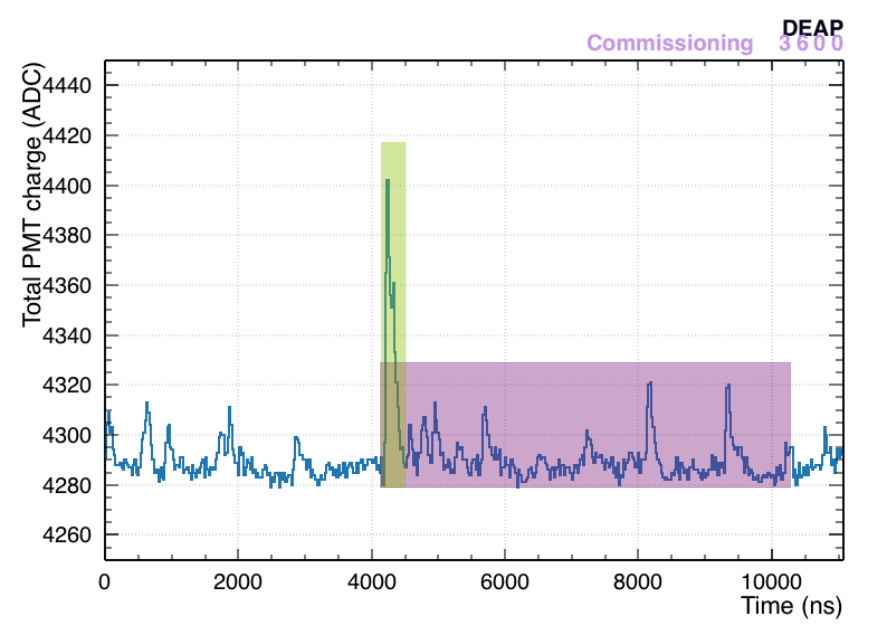
Waveform from one PMT in a light injection calibration run



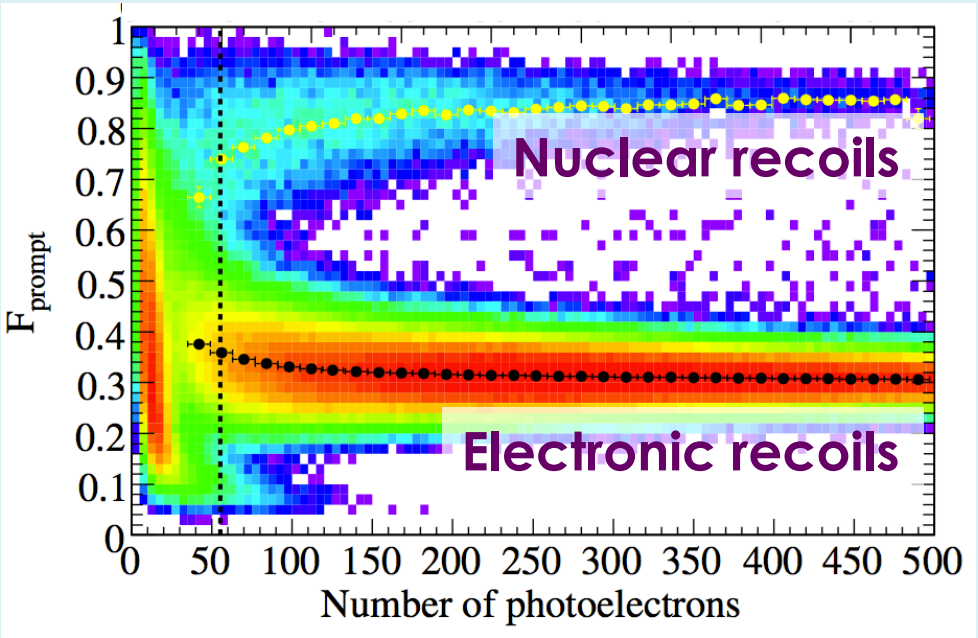
Average charge on each PMT from a light injection calibration run

Energy and Fprompt

- Trigger looks at sum of all 255 PMTs
- Can distinguish ^{39}Ar β decays and WIMP-like nuclear recoils using Fprompt



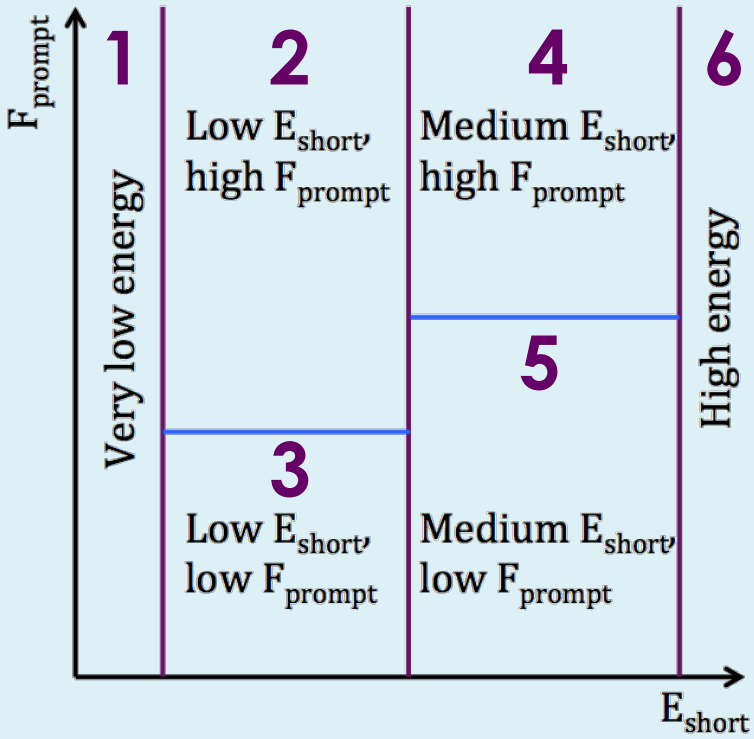
Eprompt = charge in prompt window
Fprompt = Eprompt / Ewide



Electronic and nuclear recoil calibration data from DEAP-1 (arXiv:0904.2930)

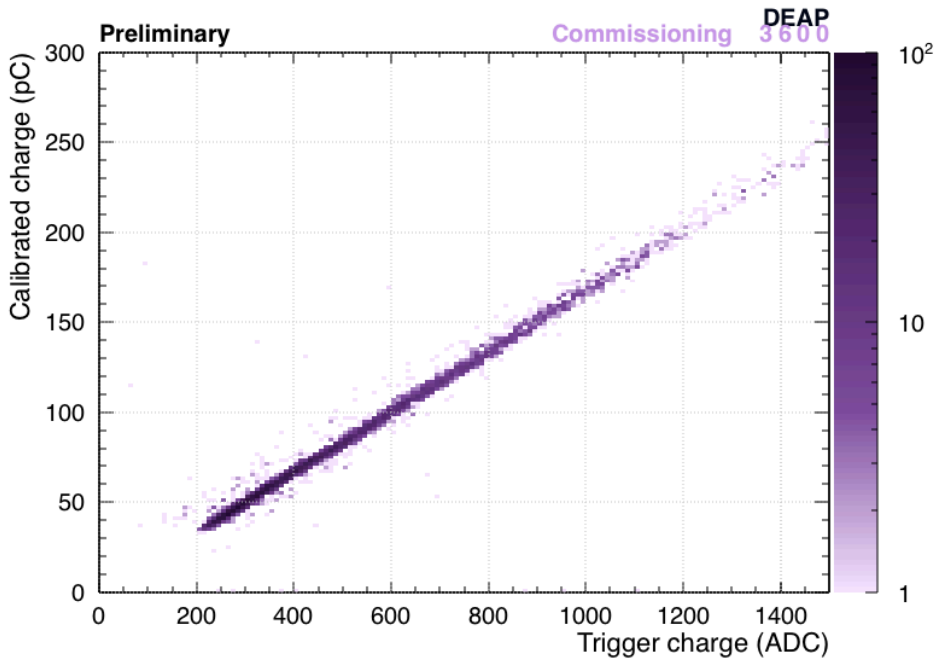
Energy and Fprompt

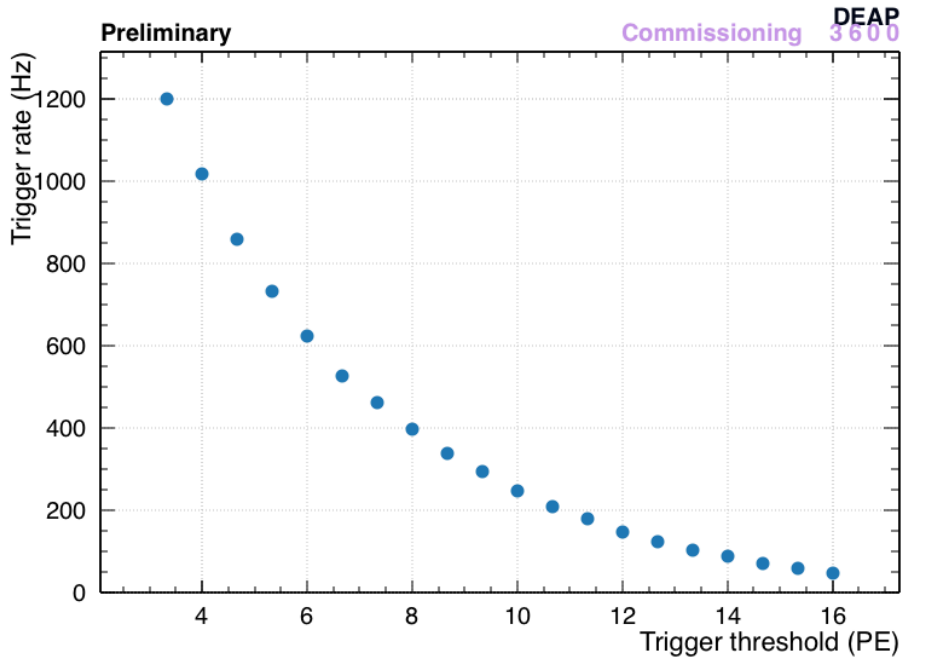
- The main physics trigger for DEAP-3600 will split up the energy/Fprompt phase-space into 6 regions
- Each region is connected to a different *output*
  - Keep all data for events in region 4 (WIMP-like!)
  - Ignore some events in region 5 (β decays)
  - Ignore almost all events in region 1 (noise)
- Thresholds are being tuned during commissioning



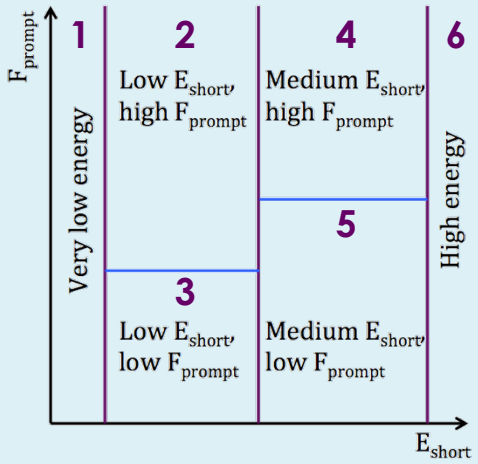
Latest commissioning results

- Trigger is calibrated
- Low-threshold data being used to tune MC noise model
- Lots of data taken to model trigger rates





The roadmap



- Need to optimize all the thresholds for the energy/Fprompt trigger
- Backgrounds change as the detector continues to be built
  - Add water to the veto tank – fewer "rock gammas"
  - Add wavelength-shifter – more α backgrounds
  - Install LAr flow guides in neck – more α backgrounds
  - Add gaseous Argon – start to understand β rate
- Step-wise approach gives us great insight to the different background sources
- Final goal: 5MB/s, don't miss a single WIMP-like event

Summary

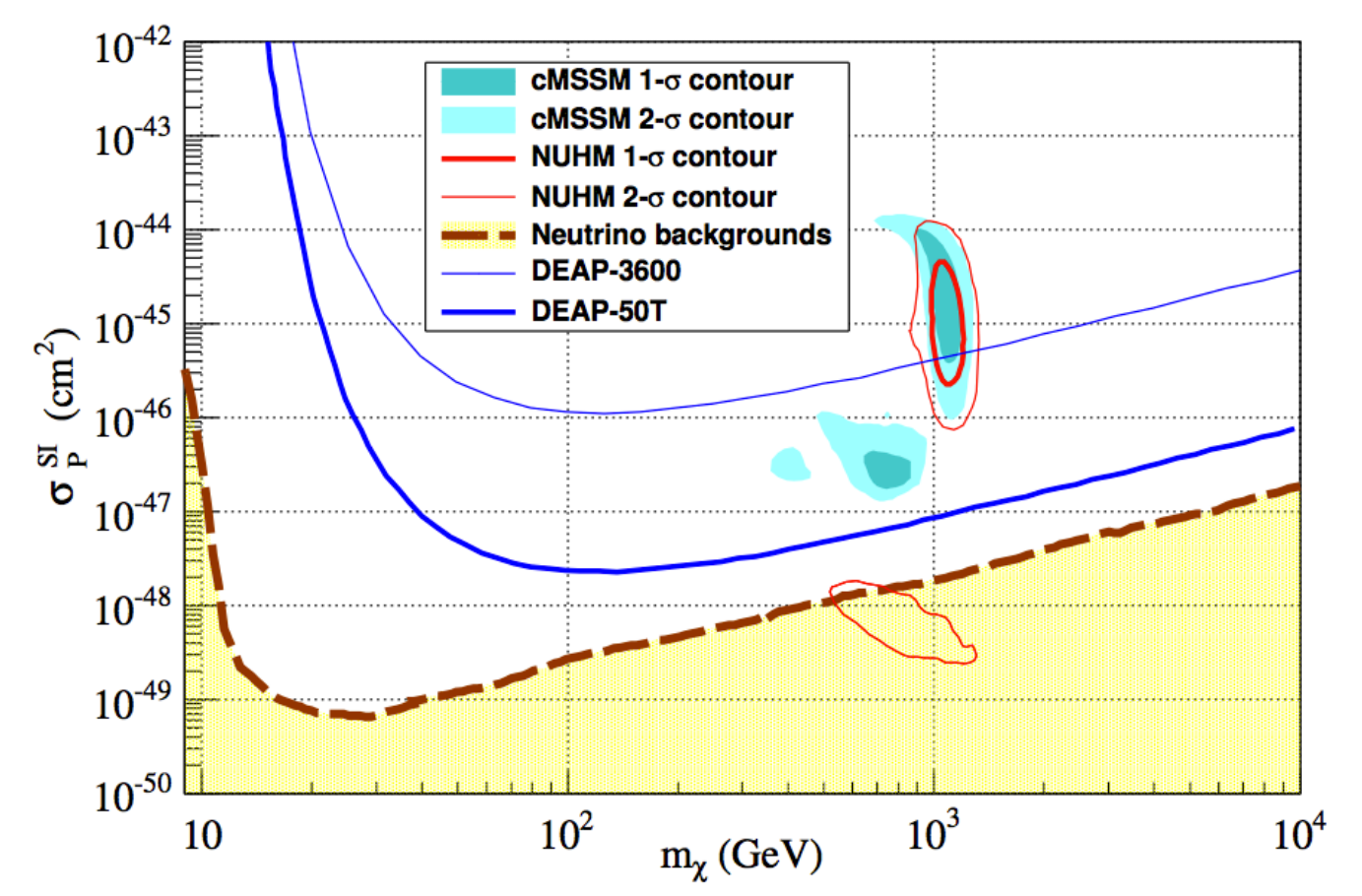
- DEAP-3600 expects to see at least 10^8 times more ^{39}Ar β decay events than WIMPs
- TRIUMF has developed a very flexible trigger module
- Trigger scheme will be refined and optimised as we learn more about our detector
- Aim to keep 100% of WIMP-like events, but greatly suppress β decays and other backgrounds

Backups

More about DEAP-3600

- Talks
  - Optical calibrations – Berta Beltran – next!
  - Photon counting – Thomas Mcelroy – this session!
  - Alpha backgrounds – James Bueno – today T3-4
  - Wavelength-shifter – Derek Cranshaw – today T3-4
  - Invited talk – Bei Cai – yesterday M2-7
- Posters – PPD poster session – tomorrow
  - Detector hardware – Pollman/Giampa/Dering
  - Resurfacer robot – Pietro Giampa
  - PMT calibration – Tina Pollman / Marcin Kuzniak
  - Neck alpha backgrounds - Courtney Mielnichuk
  - Energy calibration from beta decays – Connor Stone

SUSY


cMSSM 1-σ contour
cMSSM 2-σ contour
NUHM 1-σ contour
NUHM 2-σ contour
Neutrino backgrounds
DEAP-3600
DEAP-50T
σ_P^{SI} (cm^2)
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10
10^2
10^3
10^4
m_χ (GeV)

Commissioning

- Trigger system is being used to collect lots of commissioning data
  - Light injection
  - PMT dark noise
  - Background characterisation
- Trigger is also used to monitor the health of PMTs