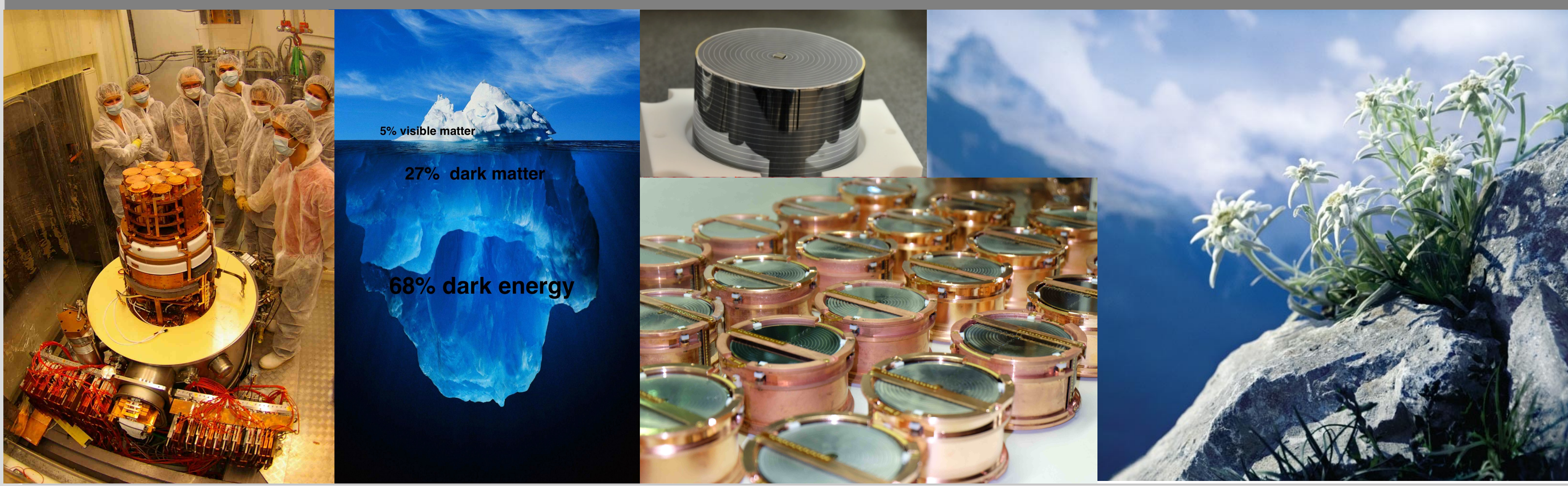
EDELWEISS-III Experiment

Status and First Low WIMP Mass Results

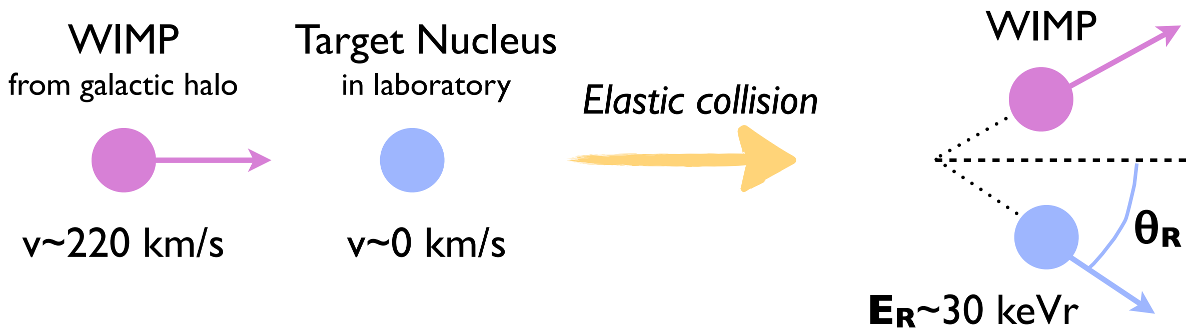
Silvia Scorza on behalf of the EDELWEISS collaboration

Institut für Kernphysik, Karlsruher Institut für Technologie

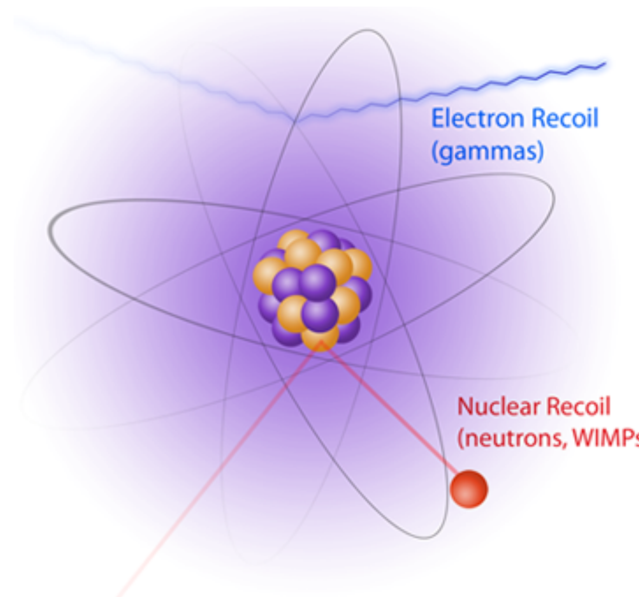


Direct Detection Principle

Detection of the energy deposited due to elastic scattering off target nuclei



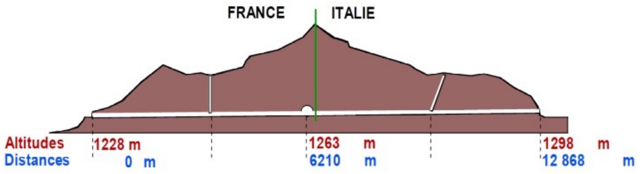
- Ge crystal: event ID from measurements of ionization and phonon energies
- Elastic scattering of a WIMP deposits small amount of energy into recoiling nucleus (~ few 10s of keV)
- Expected rate:
  < 1 interaction per kg per year
- Radioactive background of most materials gives higher rate

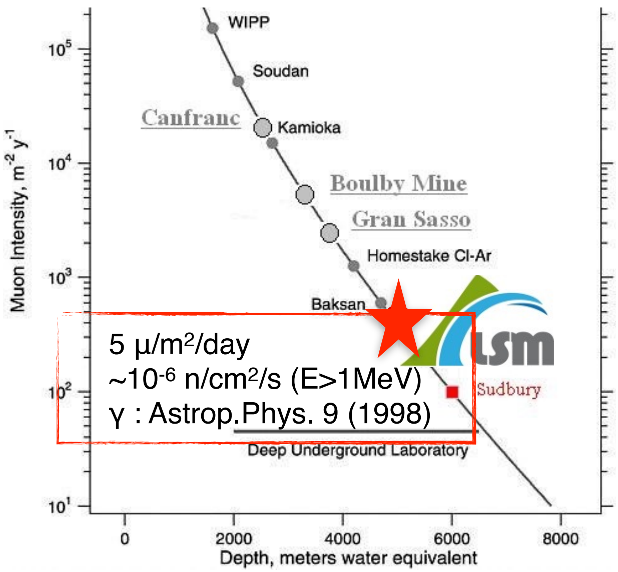


Edelweiss

Expérience pour DEtecter Les WIMPs En Site Souterrain

LSM @ *Fréjus* tunnel





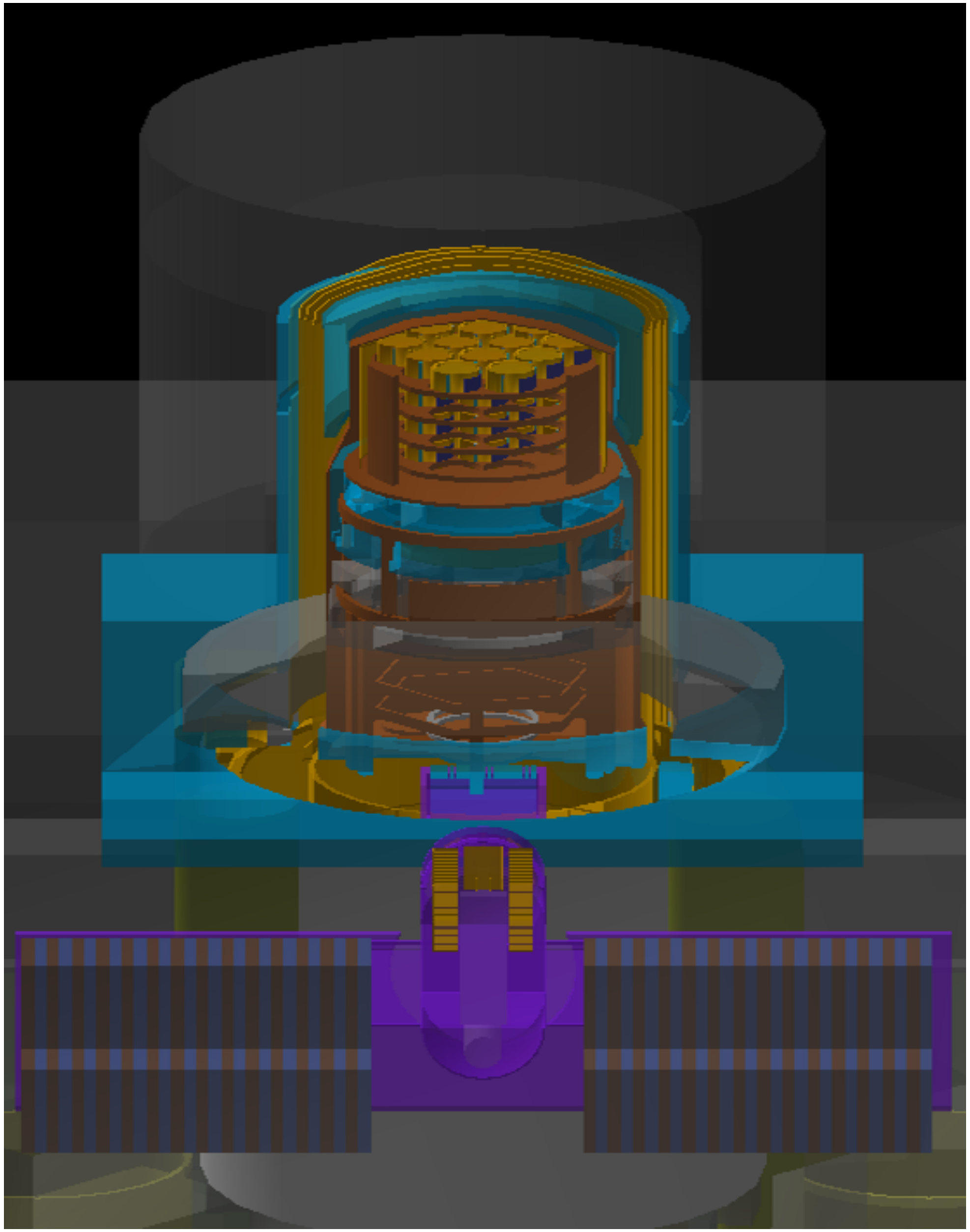
Clean room (Rn)
with deradonized air supply
(from 10 Bq/m^3 → ≈ 30 mBq/m^3)

Active muon veto (μ)
97.7% geometric coverage
$N^{\mu\text{-}n} = 0.6^{+0.7}_{-0.6}$ evts (90%CL, 3000kg.d)
Astropart. Phys. 44 (2013) 28

Polyethylene shielding (n)
50cm for moderation

Lead shielding (β, γ)
18cm + 2cm ancient lead

Copper cryostat (β, γ)
thermal shielding
- extra 10 cm below detectors PE shield
- extra 15 cm Roman Pb (1K)



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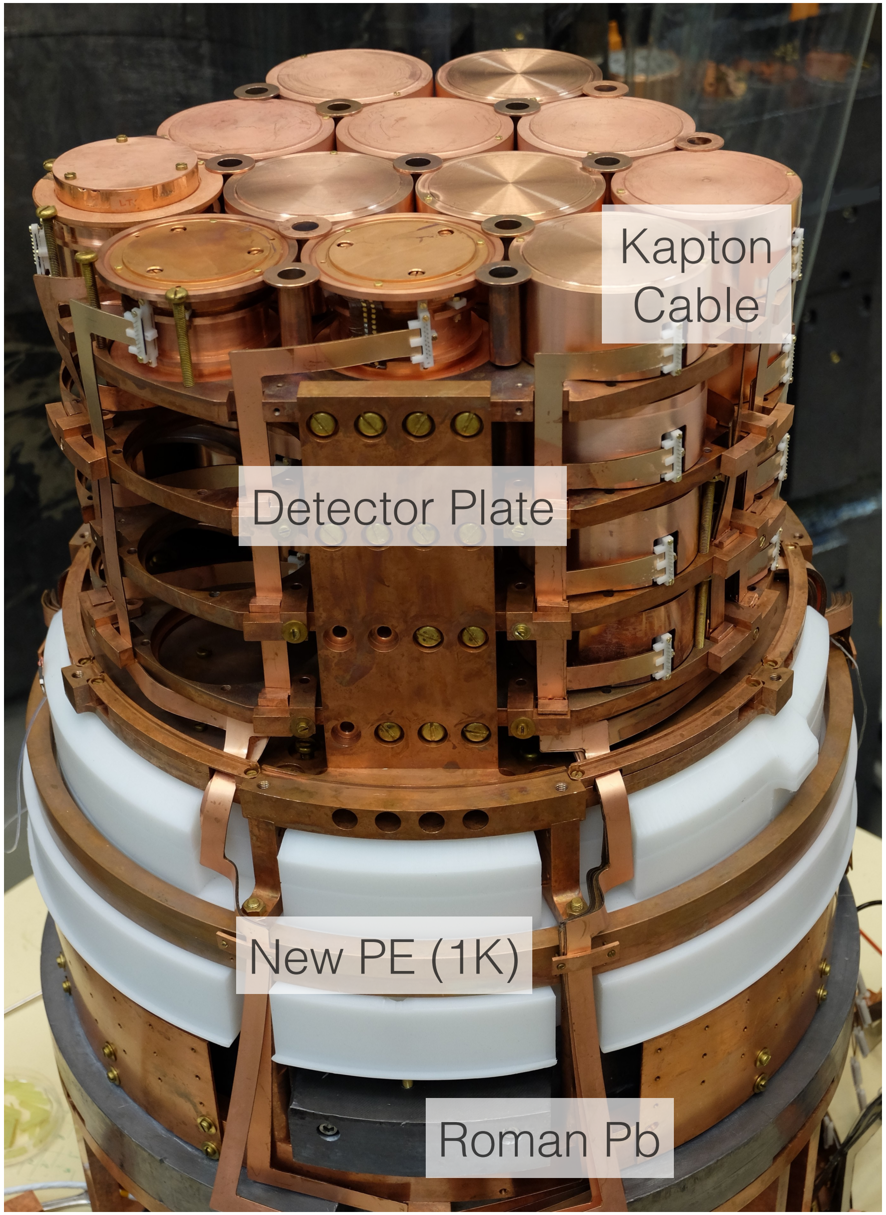

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Detectors within the Cryostat

Karlsruhe Institute of Technology

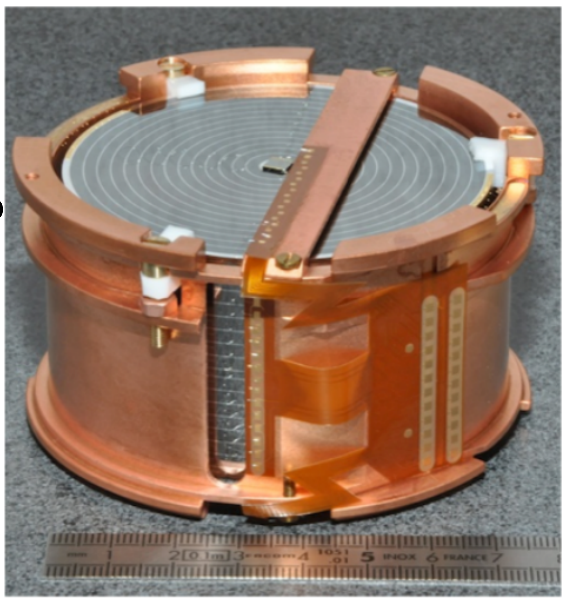
WIMP search

Full Inter-Digitized
800 g HP-Ge Detector

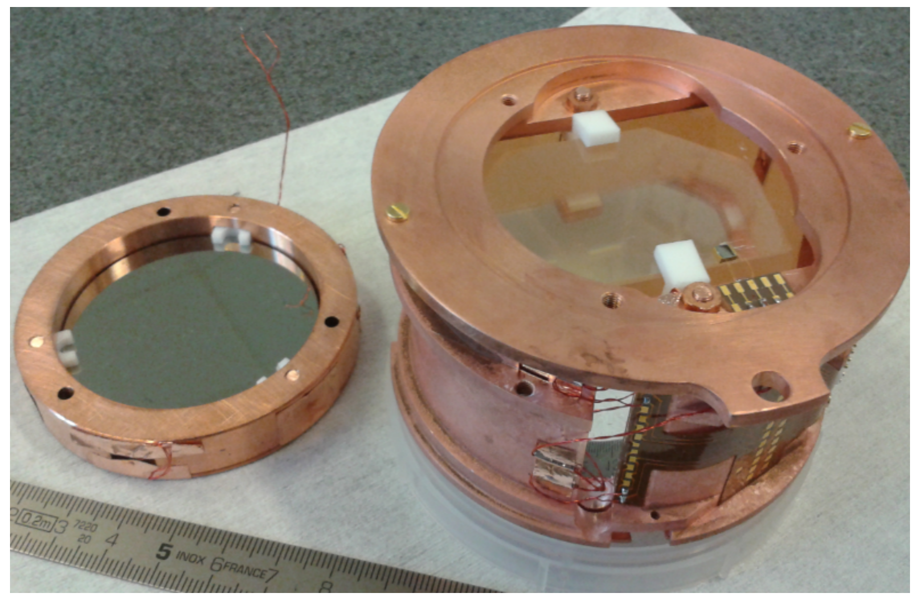
$0\nu\beta\beta$ of ^{100}Mo

313g ZnMo04 bolometer

Height: 4 cm



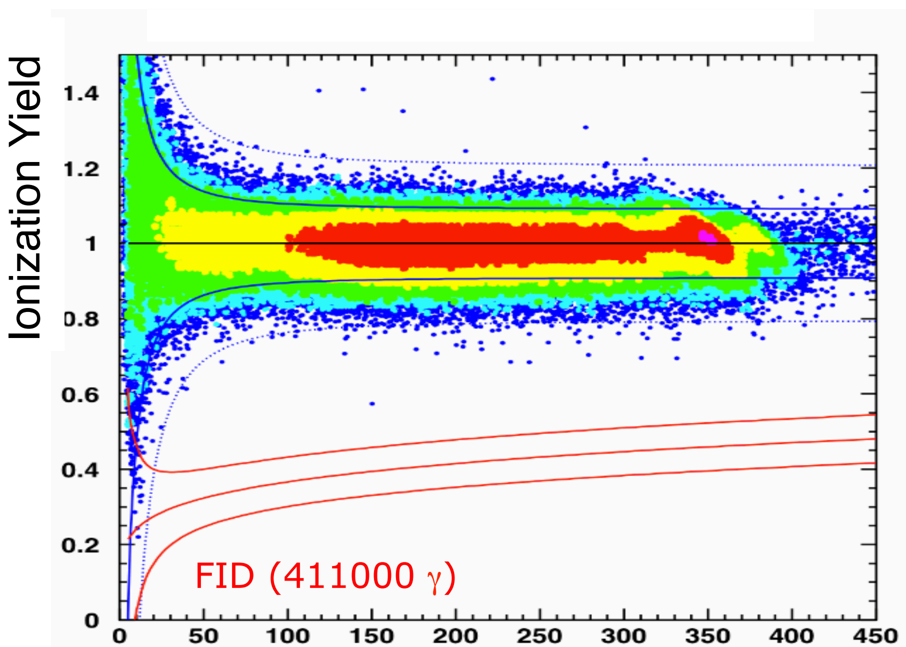
Diameter: 7 cm

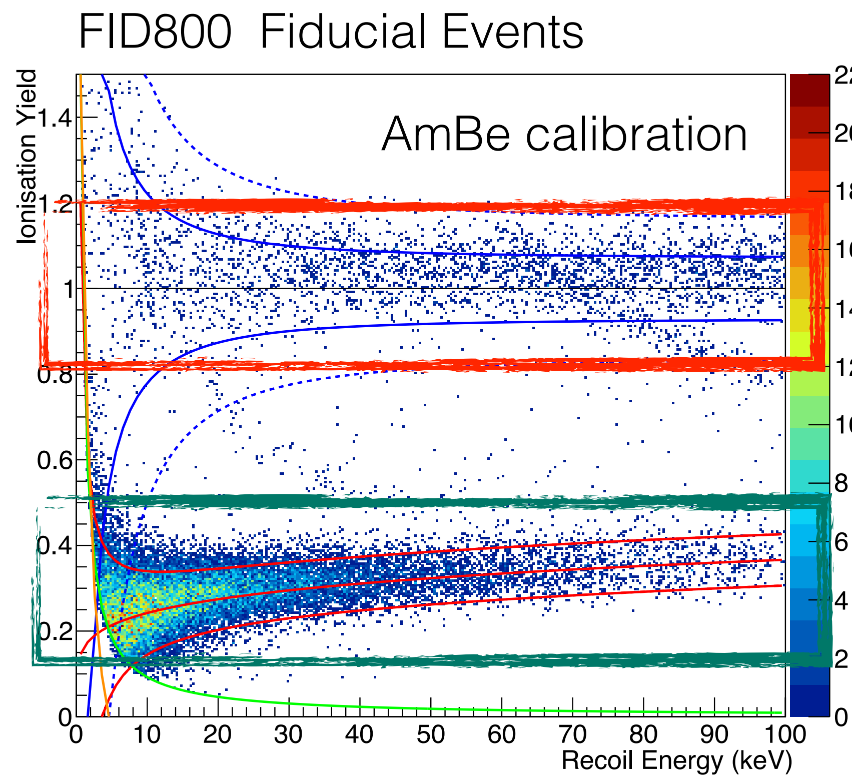


Background Rejection

Most backgrounds (e, γ) produce electron recoils
Yield (Ionization/recoil) ~1

WIMPs and neutrons produce nuclear recoils
Yield (Ionization/recoil) ~0.3





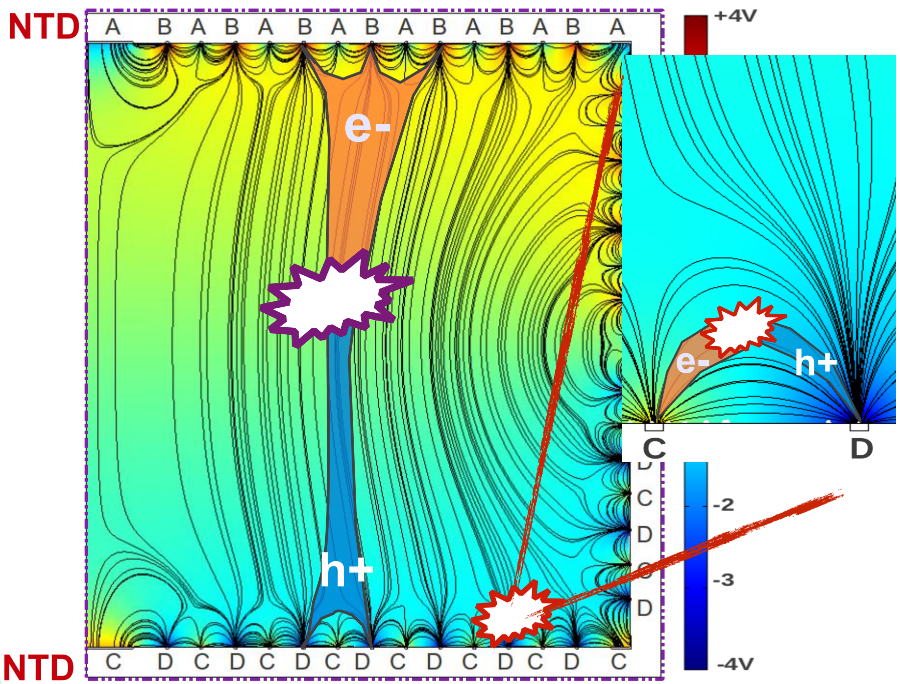
^{133}Ba Gamma Calibration:
no event in 4.1×10^5 γ leaks below ionization yield of 0.5
-> FID gamma's rejection factor < 6×10^{-6}

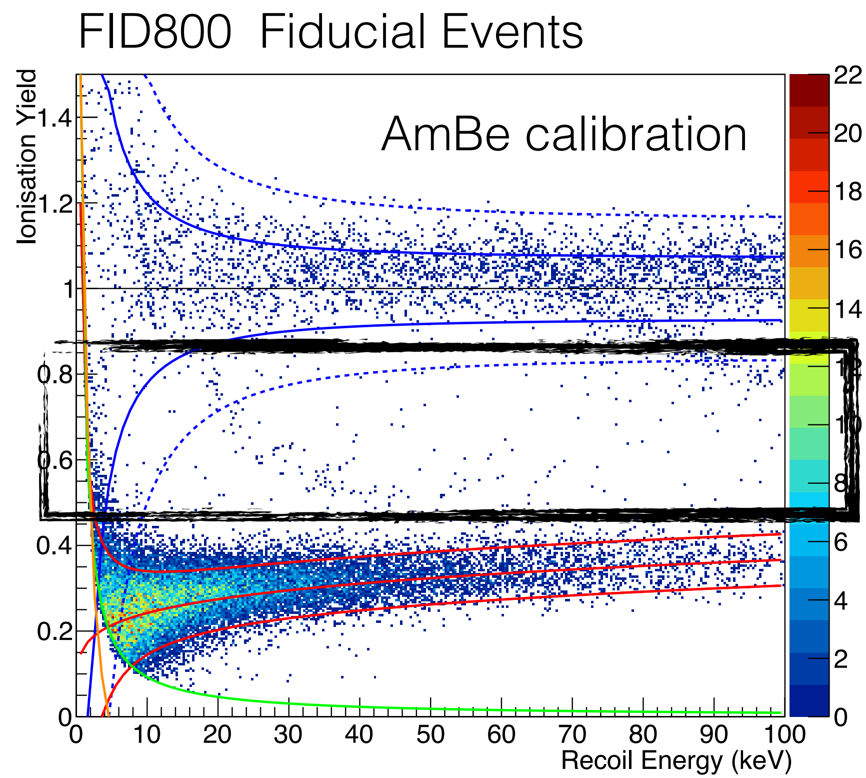
J Low Temp Phys (2012) 167:1056-1062

Background Rejection

Karlsruhe Institute of Technology

Particles that interact close to the "surface layer" result in reduced ionization yield.
Surface events can be identified via the ionization signal thanks to ID electrodes





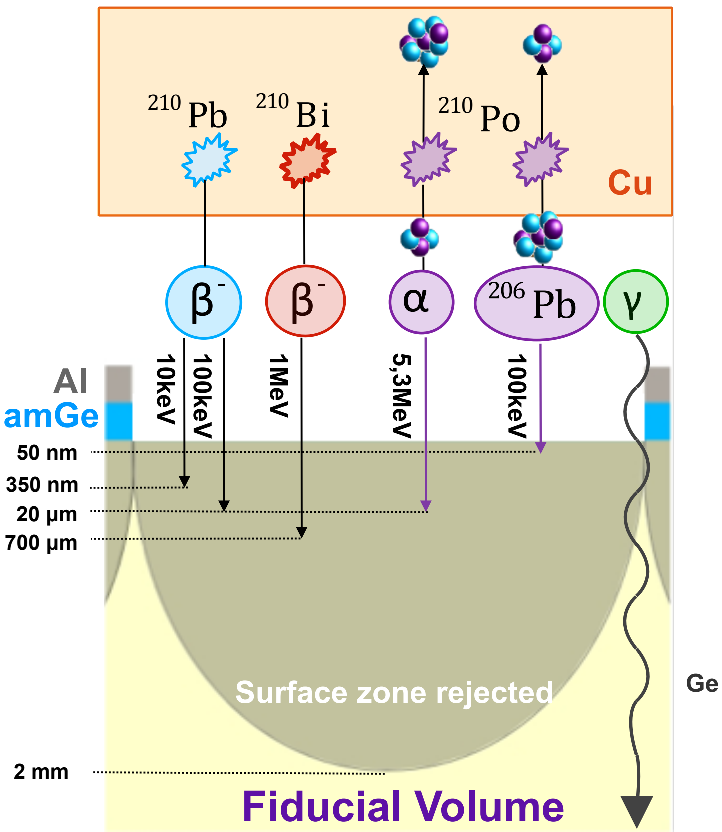
Surface Events
Charge collection shared between one veto and its neighbor fiducial electrodes, e.g. C & D

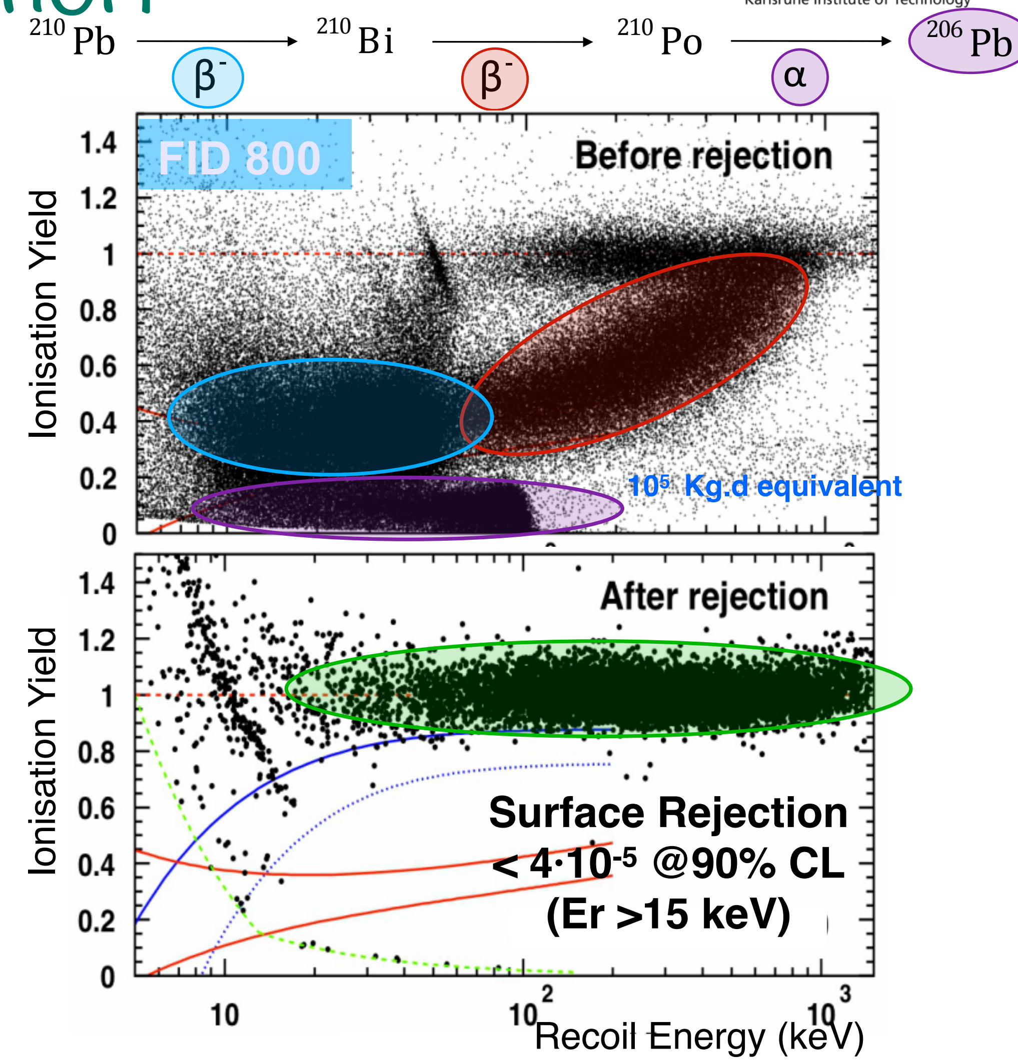
Bulk Event
Charge collected on fiducial electrodes B & D

Background Rejection

Installed ^{210}Pb implanted on Cu cover facing one detector

Allows performance verification of surface event identification





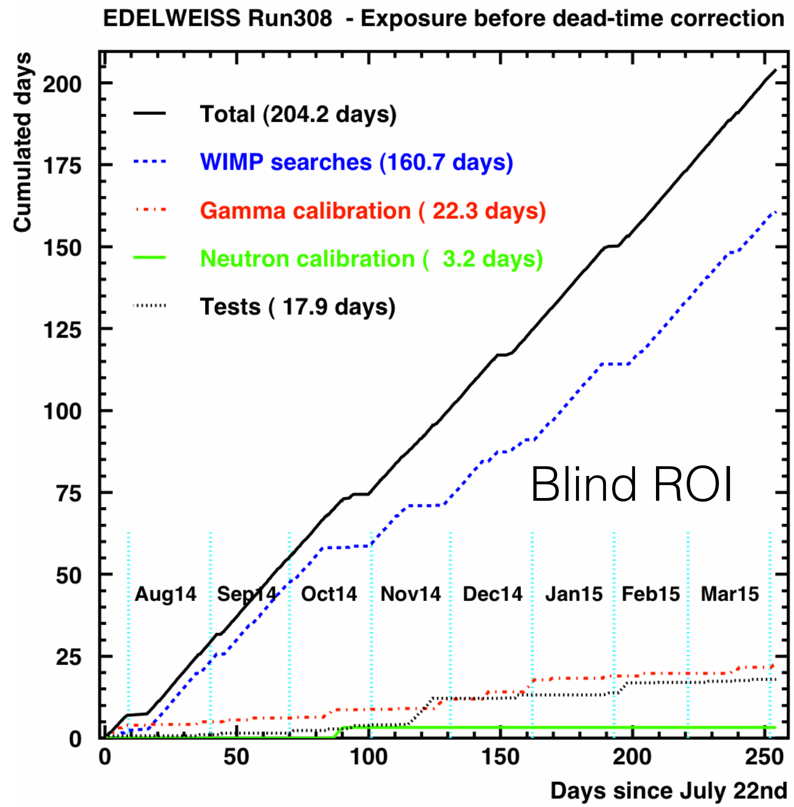
J Low Temp Phys (2014) 176:870-875
Phys Lett B 681 (2009) 305–309

R308 Status

Physics data since summer 2014: 36 x 800 g detectors installed in cryostat
24 x 800 g detectors cabled

Low WIMP mass search:

- Eight months of data taking
- Blind analysis
- Eight detectors with good baselines and low thresholds
- 582 kg·day (fiducial)
- **Boosted decision tree** (BDT) and a 2D profile likelihood analysis performed

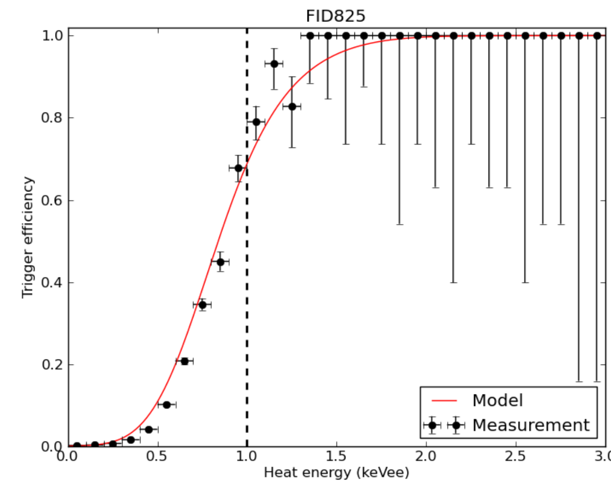


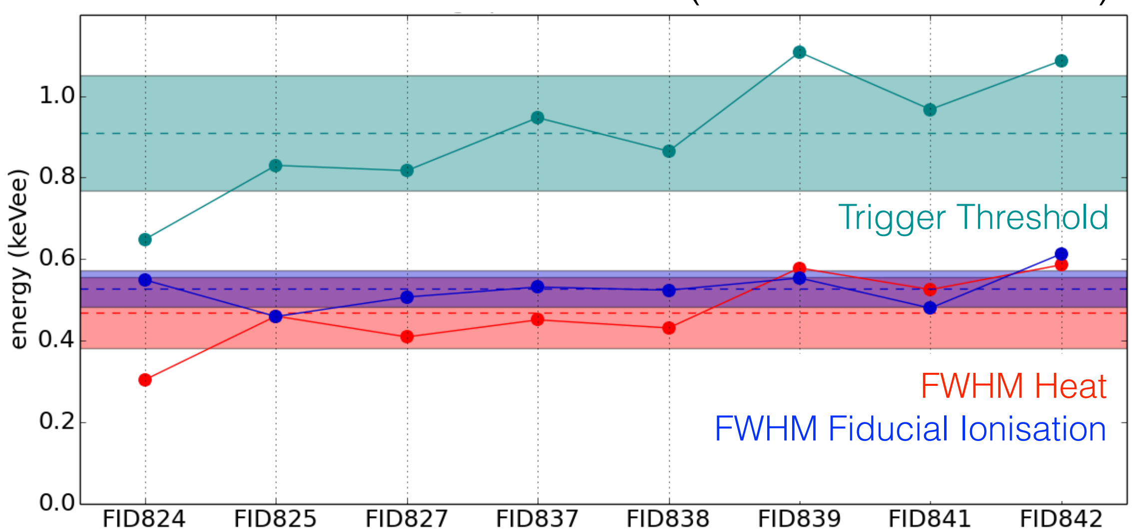
Data Selection

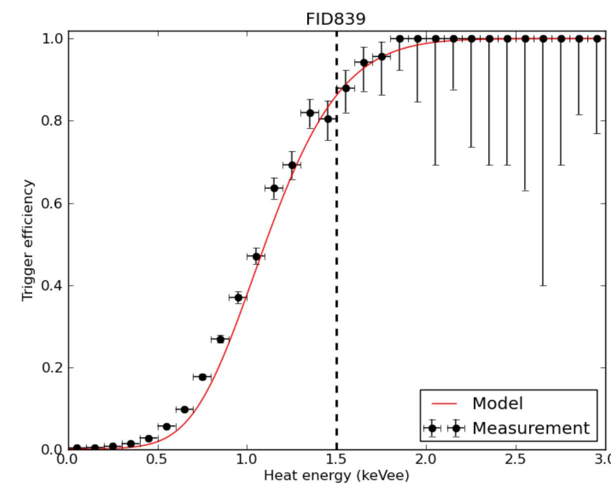
- High sensitivity to the lowest WIMP mass achievable
- Good sensitivity up to WIMP mass ~20 GeV
- Dataset as homogenous as possible

Trigger threshold is the dominating parameter strongly correlated to the heat baseline resolution

Analysis heat threshold:
4 FIDs @1keVee and 4 FIDs @1.5keVee
(1keVee = 2.4 keVnr)





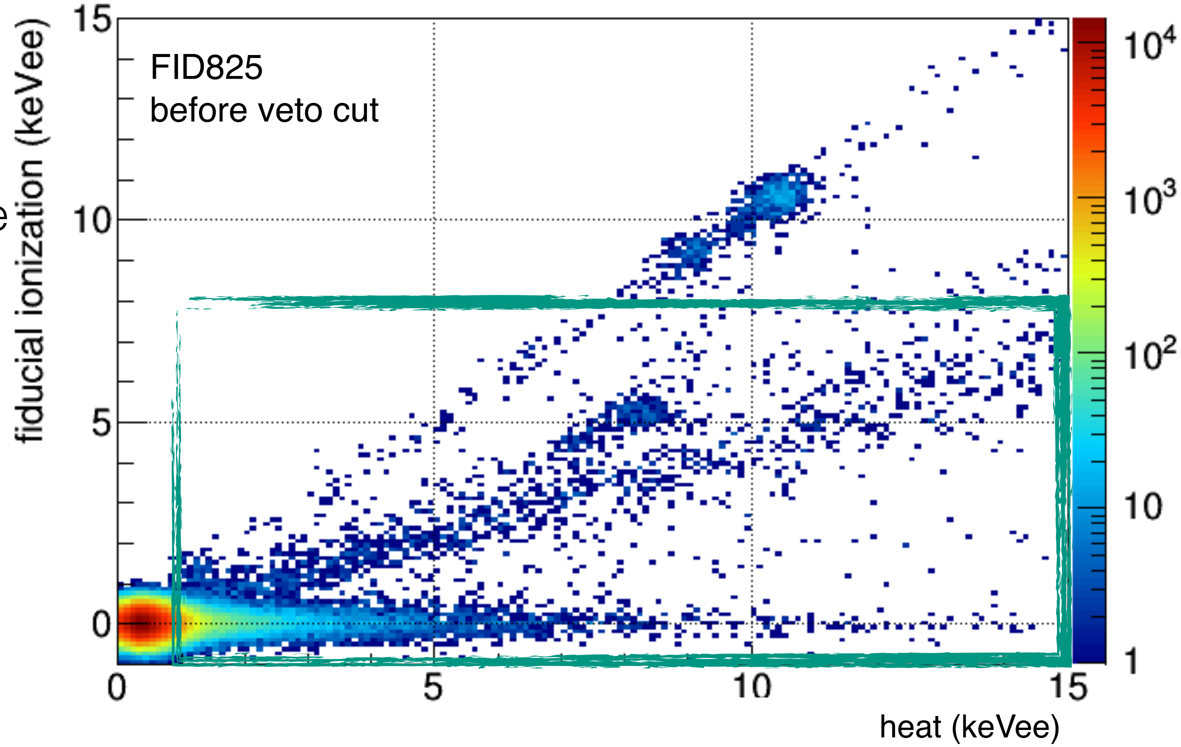


BDT Analysis

High statistics simulation for BDT training
- Include individual detector effects: trigger, time dependent noise.
- Six variables (4 ionization +1 heat + 1 heat-only event rate) for signal/background discrimination
- Model WIMP signal and backgrounds

WIMP box (ROI for training):
- Veto signal less than 5σ
- 0 < fiducial ionization < 8 keVee
- 1 (1.5) keVee < Heat < 15 keVee

Data driven bkg models:
- Bulk gammas, surface events, heat-only events, neutrons;
- Use regions without signal (sideband) to build the model (blinded data);
- Use calibrations as crosscheck



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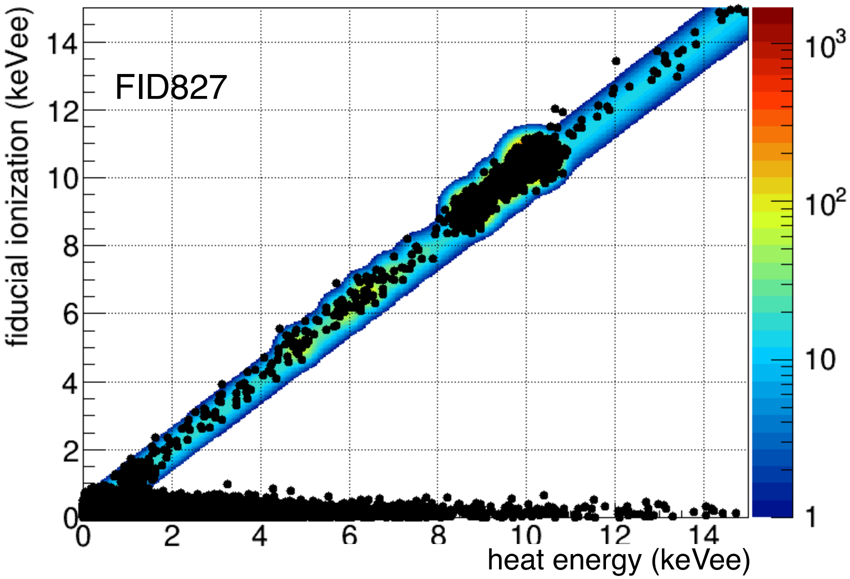
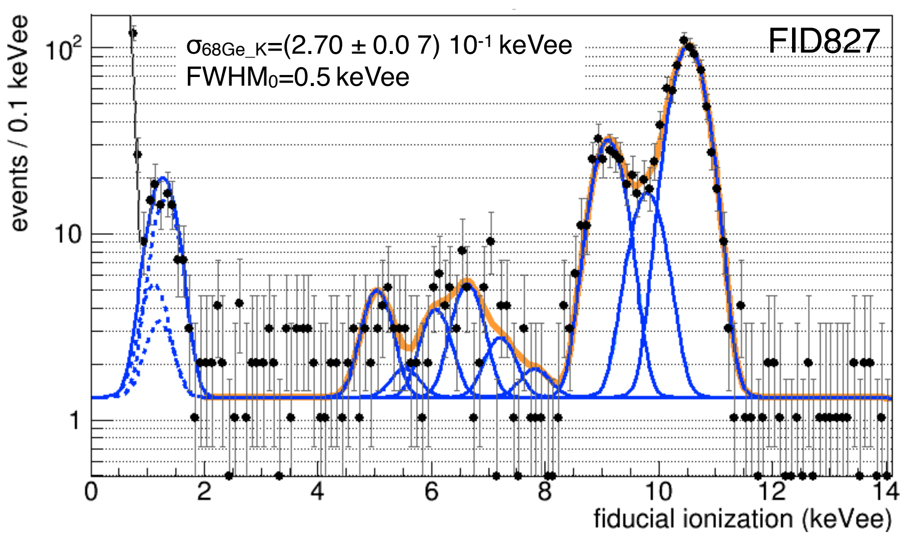
Bulk Gammas



- Fiducial selection

- Fit in [3,15] keVee heat and extrapolation of the flat component down to 0 keV

Lines @ **10.37**, **9.66**, **8.98**, 7.71, 7.11, 6.54, 5.99, 5.46, 4.97 keVee

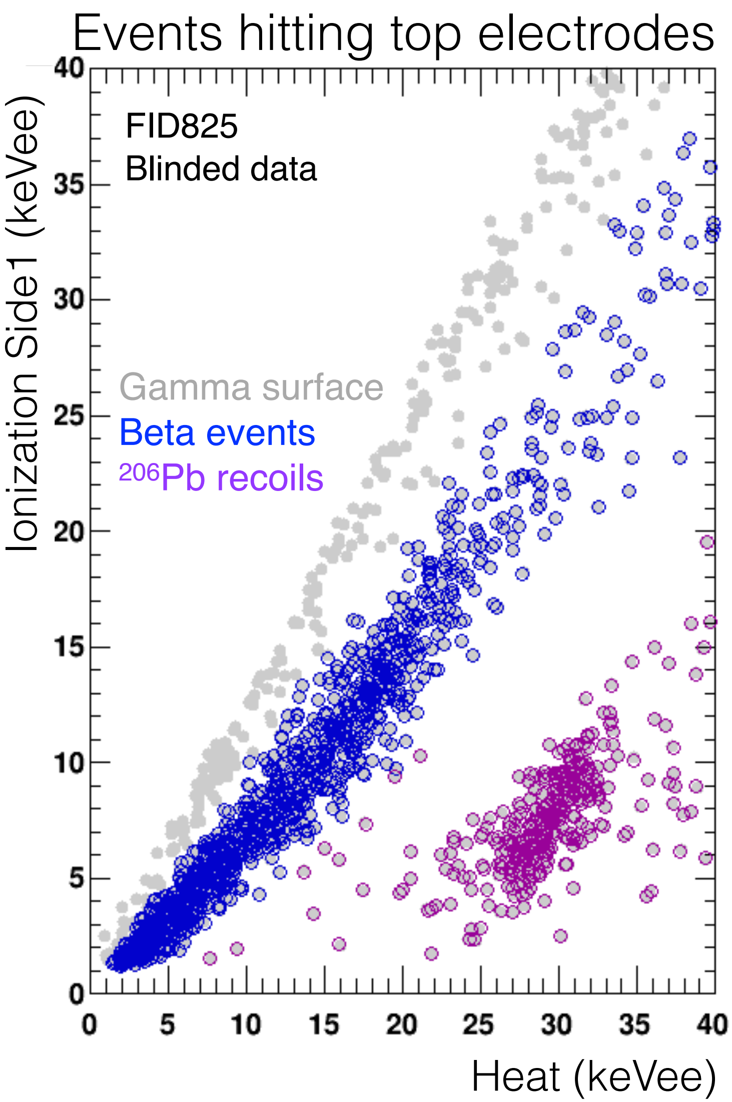


- L-shell cosmogenic lines with an intensity derived from the K-shell intensity

- The main lines considered are from ^{68}Ge, ^{68}Ga and ^{65}Zn with corresponding L-shell lines at 1.10, 1.19 and 1.30 keV, and a L/K relative intensity of 0.11*

*J. Bahcall, Phys. Rev. 132, 362 (1963)

Surface Events



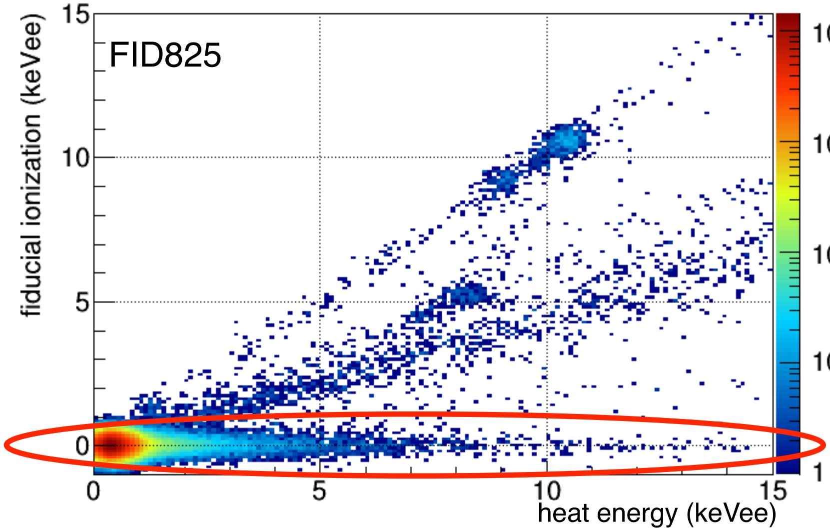
Background models for top and bottom sides:

- **Betas**: spline adjustment in the energy range [4,25] keVee and extrapolation down to 0 keV.

- **Lead**: adjust the data to a constant plus a gaussian peak in the [10,35] keVee heat energy range and extrapolation to lower energies.

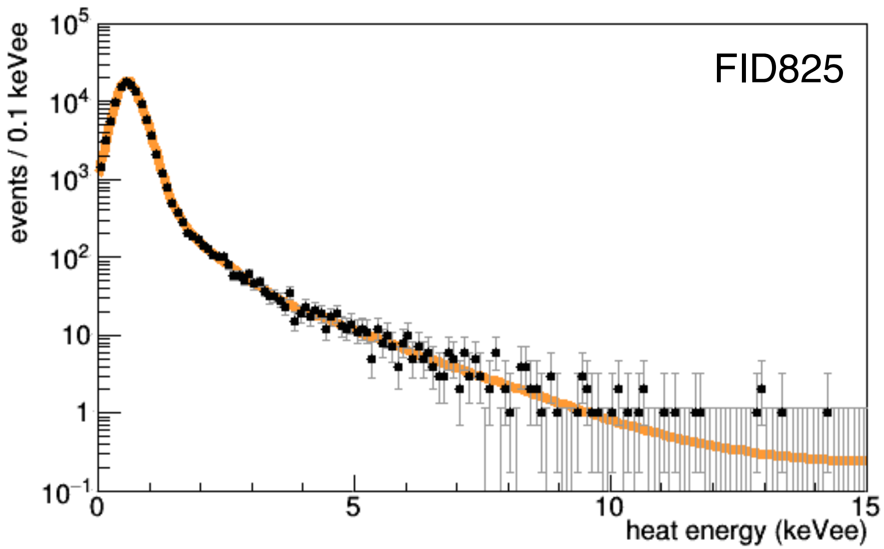
- **Surface Gammas**: fit in [3,15] keVee heat of a flat component + lines. The intensity of lines is scaled from intensity of corresponding fiducial lines w/ fiducial mass fraction.

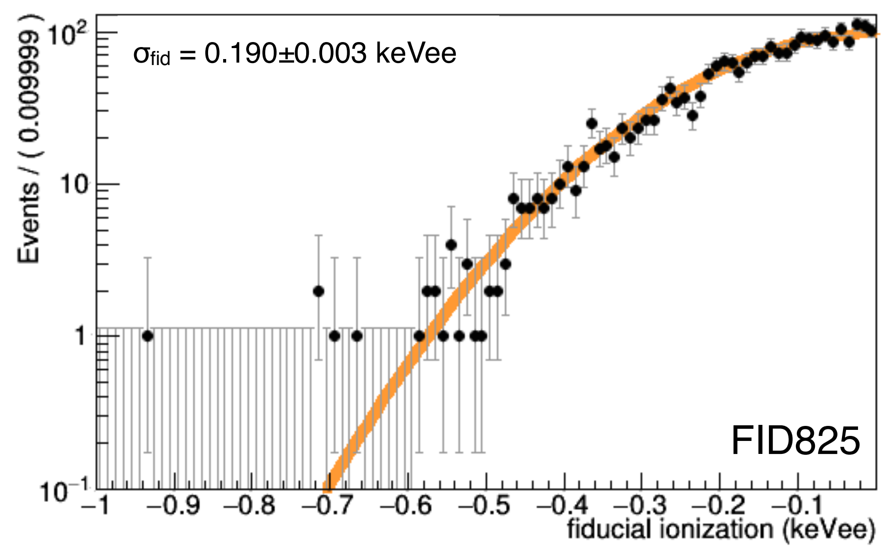
Heat-Only Events



Dominant background in our detectors (under investigation, probably mechanical origin)

- The heat-only distribution is symmetric w.r.t fiducial ionization=0
- We expect very few WIMPs for heat energy> 1keVee & fiducial ionization <0 keV
- Use region IonFid<0 as a sideband to model heat-only events

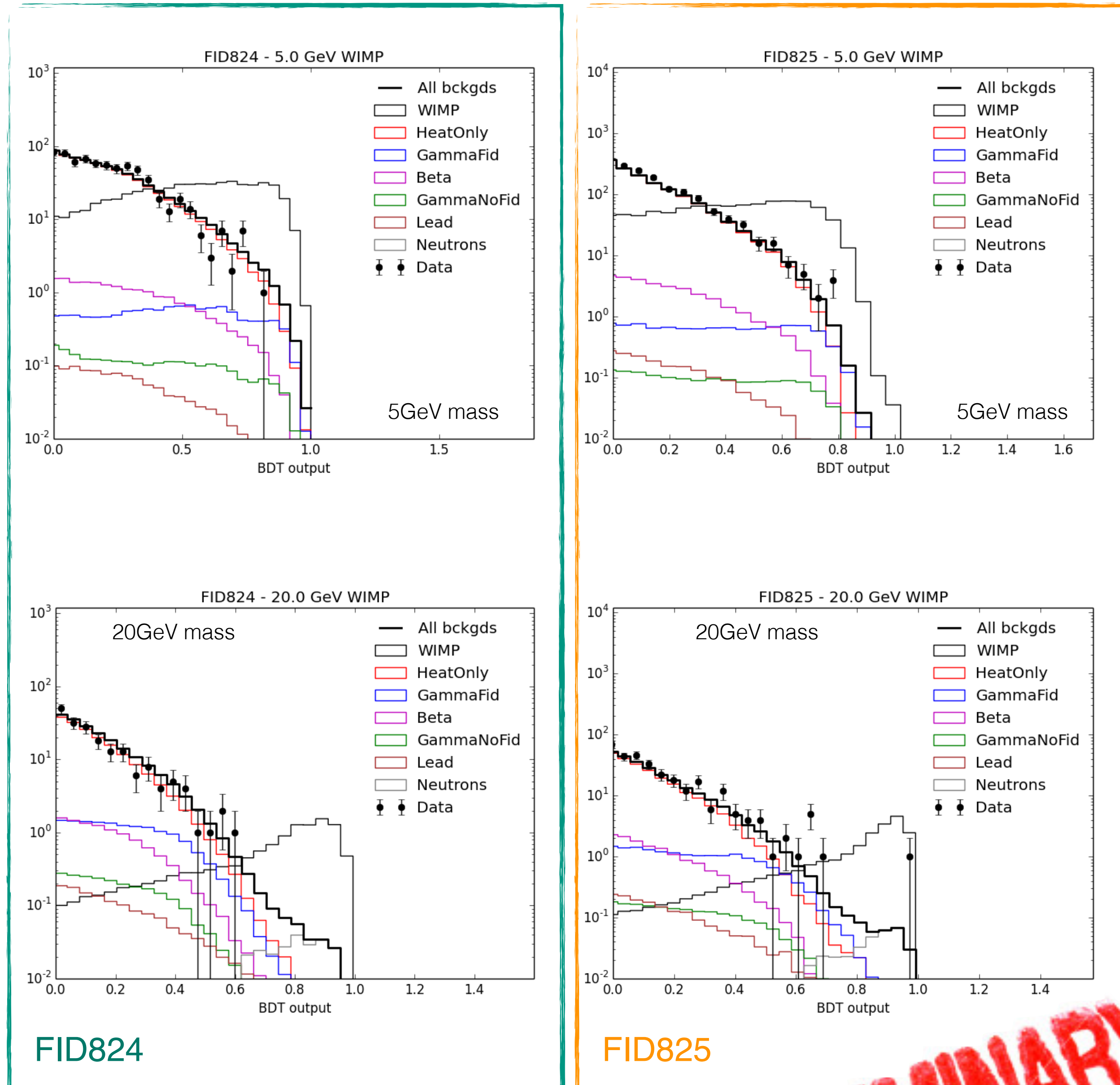




BDT Output

One BDT distribution per WIMP mass of 4, 5, 6, 7, 10, 15, 20 and 30.0 GeV.

Backgrounds are normalized to the expected number of events for that given detector and data selection.
WIMP signal not normalized.



PRELIMINARY

BDT Output

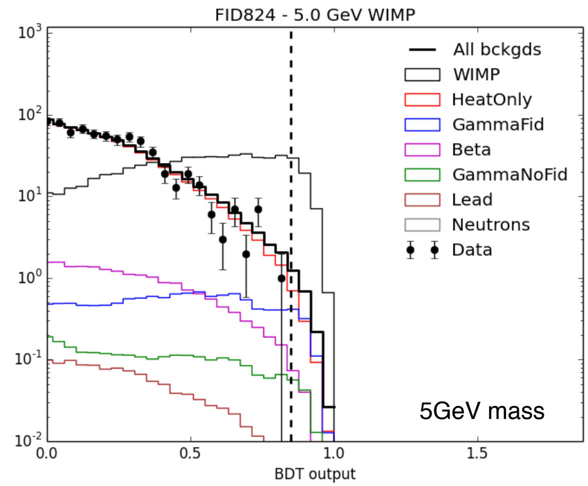
After BDT and WIMP box cut in 8 FIDs

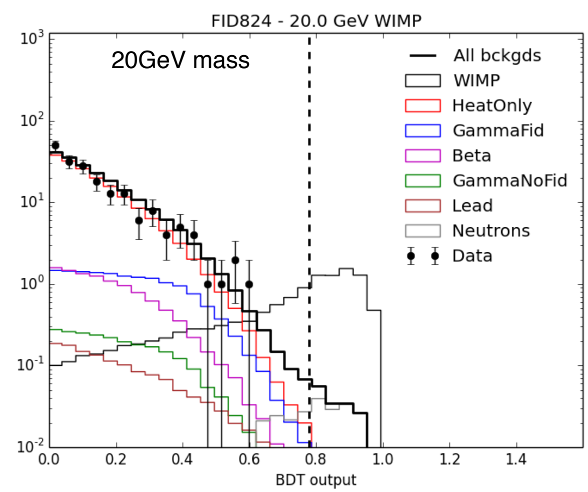
	N_bkg expected	N_bkg observed	p_value (stat only)
5GeV	6.14	9	0.17
20GeV	1.35	4	0.10

Dominant background:

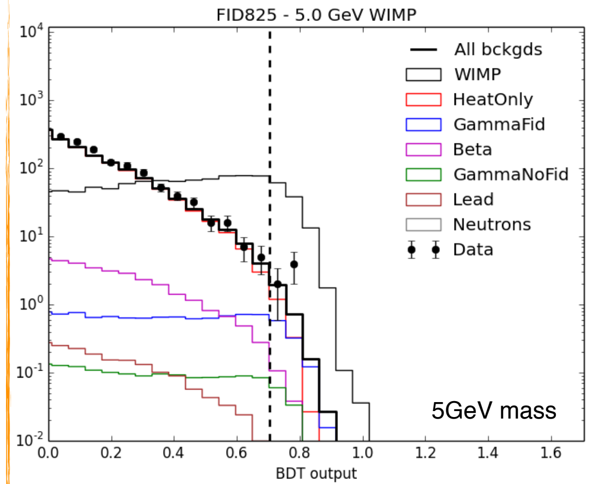
Low WIMP mass: heat-only events and cosmogenic gamma lines

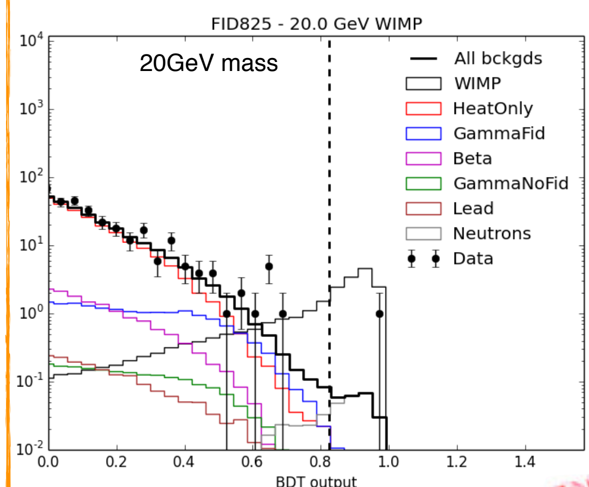
High WIMP mass: radiogenic neutrons (preliminary systematic of 45%)





FID824





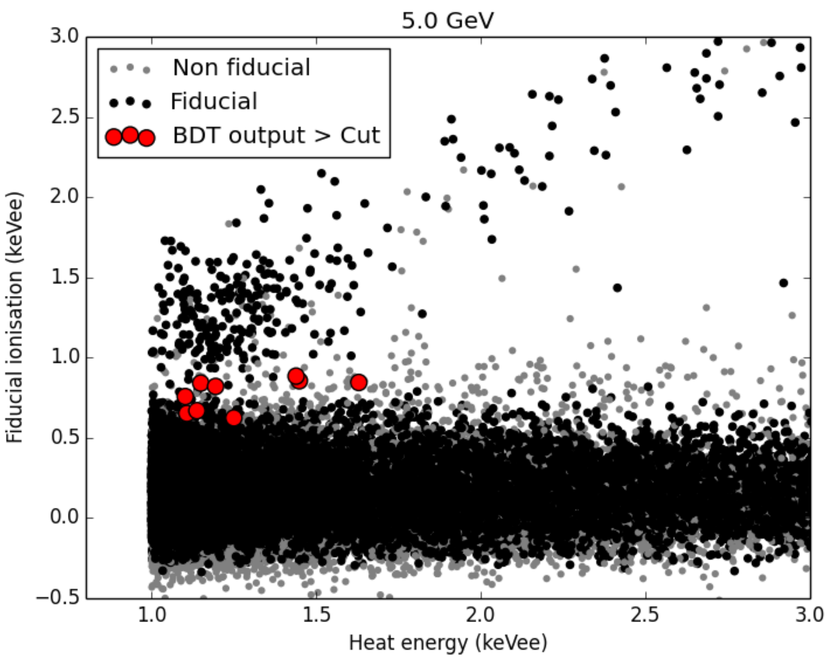
FID825

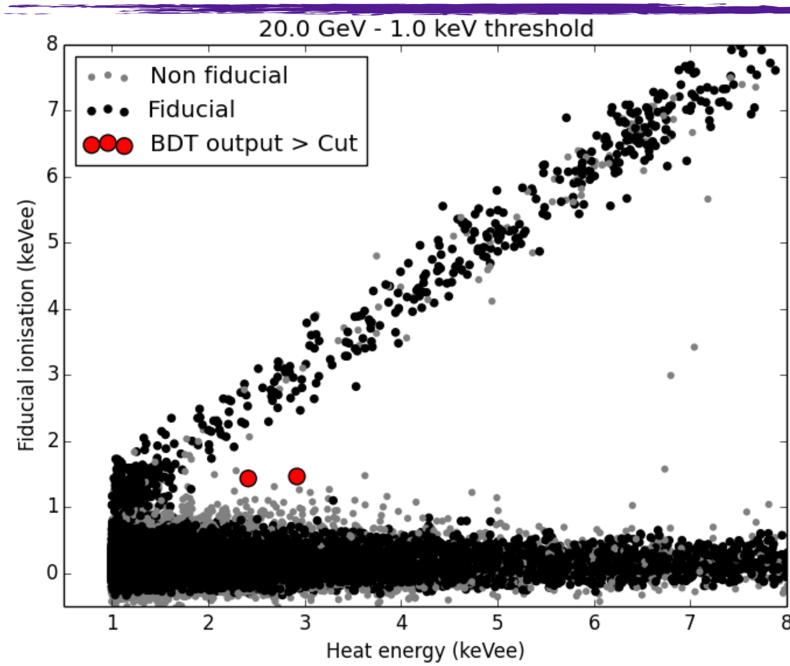
PRELIMINARY

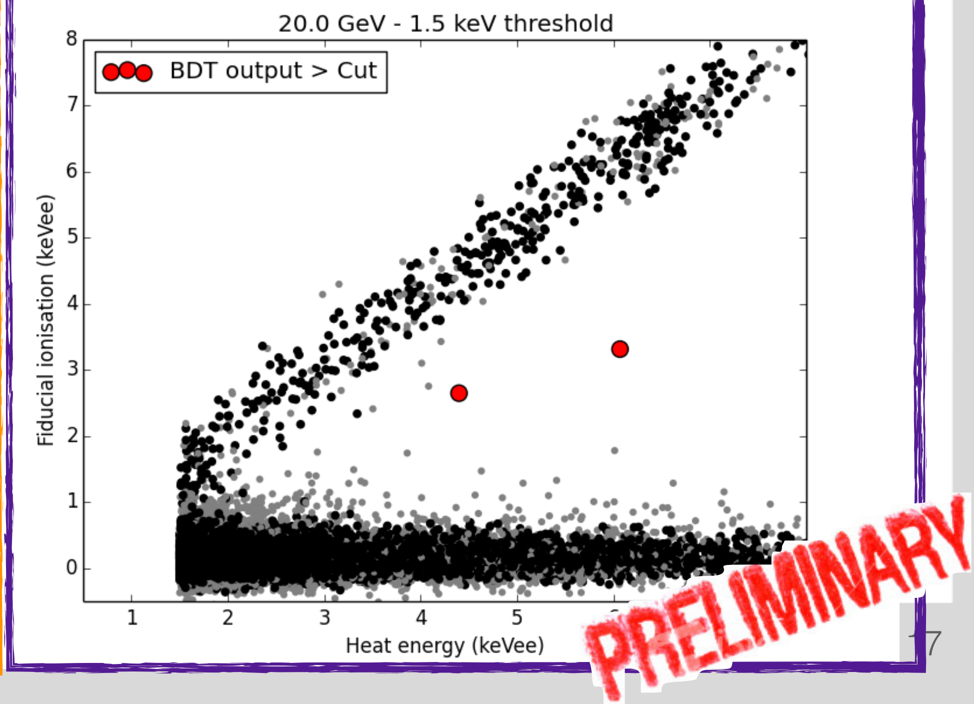
Candidates Events

@20GeV: all 8 detectors,
-> 4 events observed

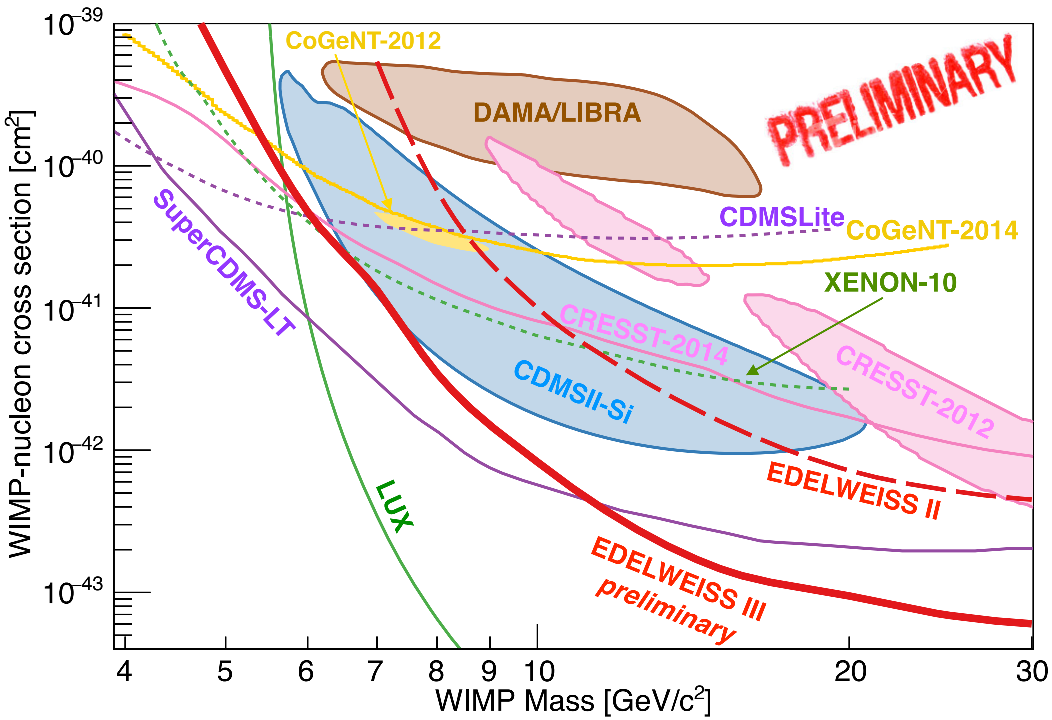
@5GeV: only 4 detectors @1keVee heat threshold
->9 events observed







Low Mass WIMP Limit



- Preliminary limit
- w/o background subtraction
- Poisson limit

The preliminary 90%CL limit achieved for spin-independent WIMP-nucleon varies from 4.6×10^{-40} cm² at 5 GeV/c² to 6.2×10^{-44} cm² at 30 GeV/c².

Cross checks with a 2D profile likelihood analysis is ongoing and already shown good agreement

Summary & Outlook

R308

- Low energy WIMP mass (4-30GeV) analysis performed for 582 kgd (fiducial).
    - A factor 40 (@5GeV) and 8 (@30GeV), w.r.t to the previous generation of ID detectors with an exposure of 113 kgd (fiducial).
    - Crosscheck w/ a 2D profile likelihood analysis is ongoing.
    - Post-unblinding checks are ongoing.
- High energy WIMP mass analysis results soon.

Current Run (R309)

DAQ resumed in June 2015:

23 FID800 (12 new)

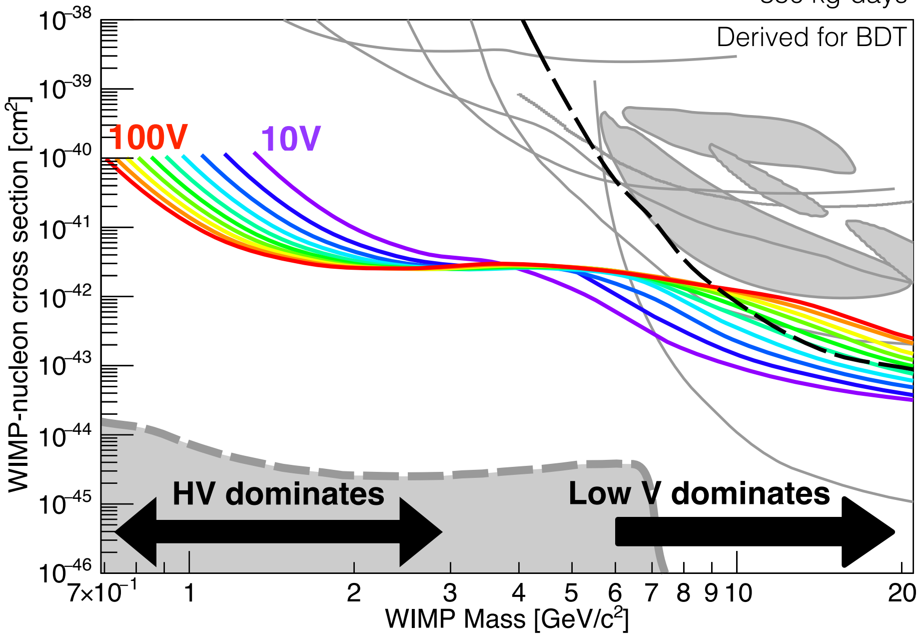
One FID200 for 'High-Voltage' R&D, i.e. Neganov-Luke amplification

HEMT R&D to lower ionization threshold down to σ_{ion} = 100 eV

R&D on heat sensor goal: σ_{heat}= 100 eV and HV (Luke-Neganov) to reduce recoil threshold

R&D to reduce heat-only events

Reduction of Heat-Only by x100
100 eV (RMS) ion & heat
350 kg-days



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Thanks!

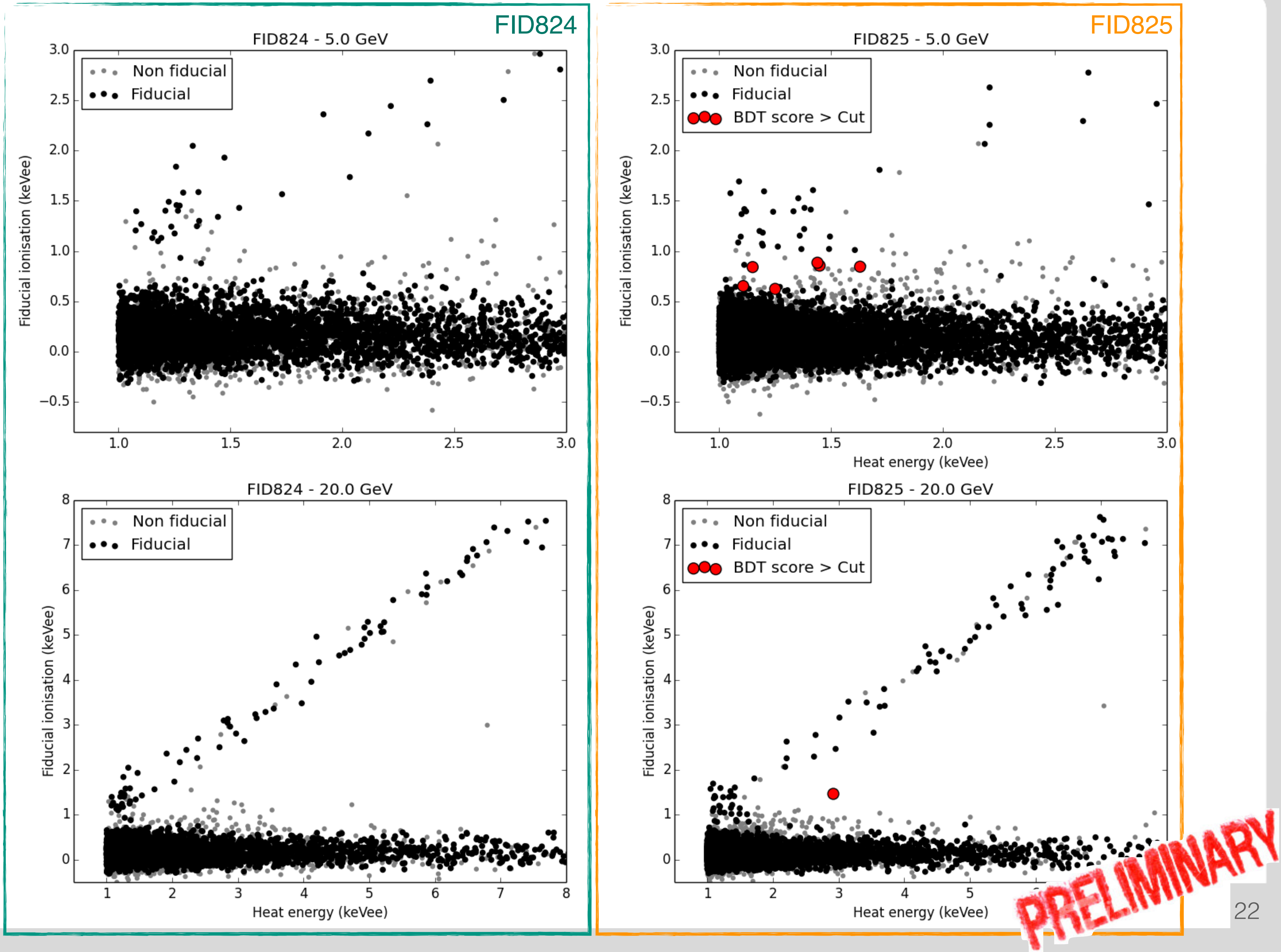
CEA Saclay (IRFU & IRAMIS)
CSNSM Orsay (CNRS/IN2P3 & Paris Sud)
IPNL Lyon (CNRS/IN2P3 & Univ. Lyon 1)
Néel Grenoble (CNRS/INP)
LPN Marcoussis (CNRS)

KIT Karlsruhe (IKP, EKP, IPE)

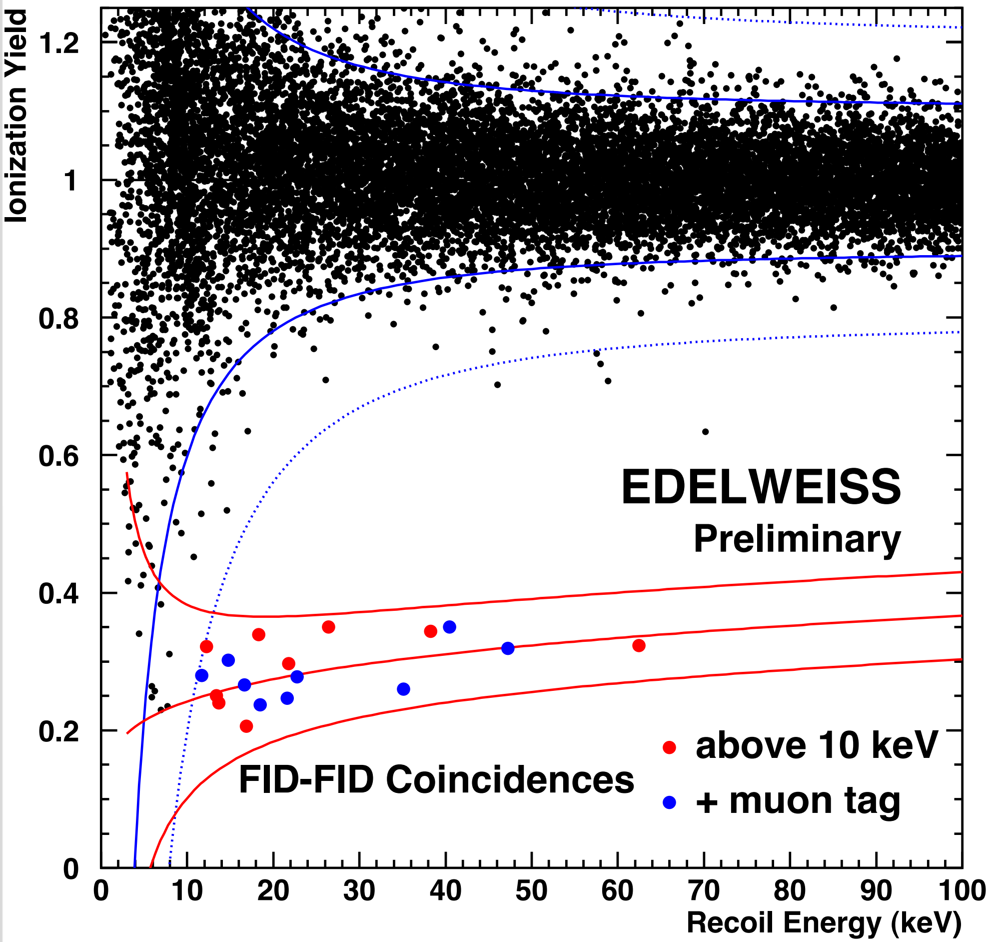
JINR Dubna

Oxford University
University of Sheffield

Back-up


FID824
FID825
FID824 - 5.0 GeV
FID825 - 5.0 GeV
FID824 - 20.0 GeV
FID825 - 20.0 GeV
Non fiducial
Fiducial
BDT score > Cut
Fiducial ionisation (keVee)
Heat energy (keVee)
PRELIMINARY

Neutrons

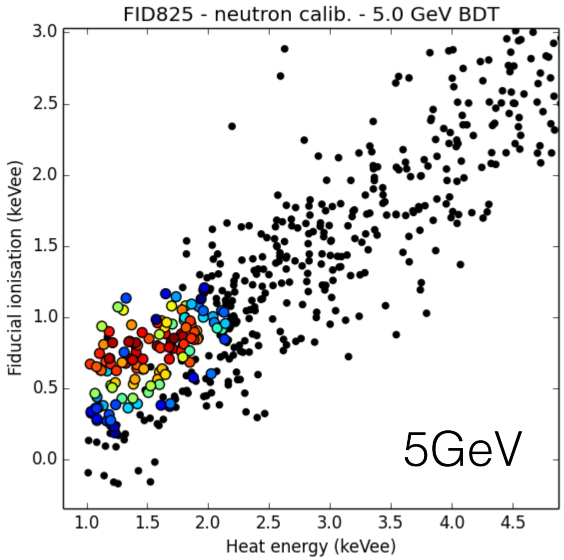


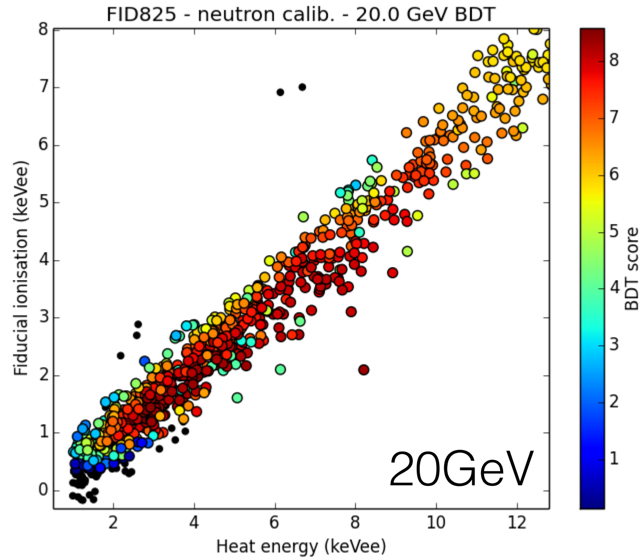
- During the WIMP search, we see 9 multiple nuclear recoil events (excluded from the search data set) after muon cut, in 17 detectors in 1300 kgdays
- It has been used as normalization factor in simulation, BDT training and BDT cut optimization along with the single-to-multiple ratio
- Single-to-multiple ratio from radiogenic neutron simulations varies between FIDs. An average has been considered

Systematics : sqrt(9) + large variation is single-to-multiple ratio

Neutrons

AmBe neutron calibration and BDT output

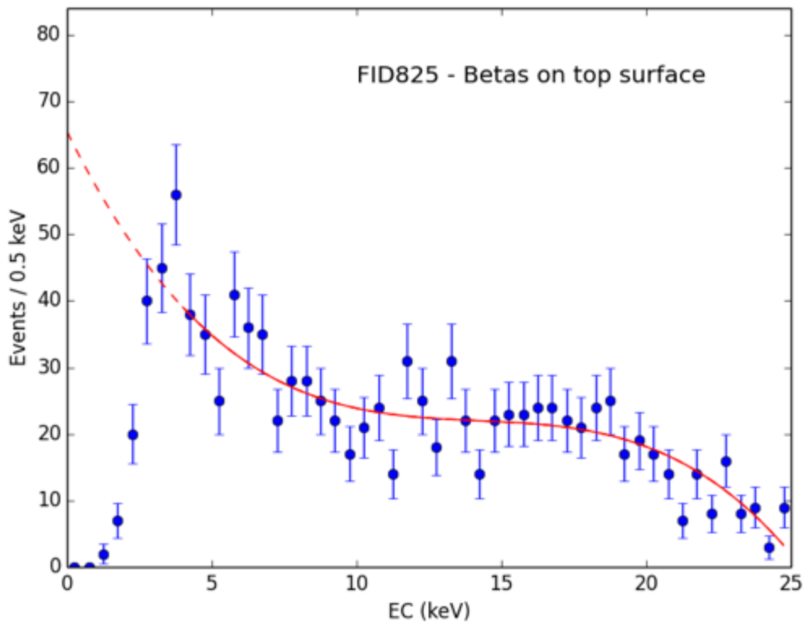


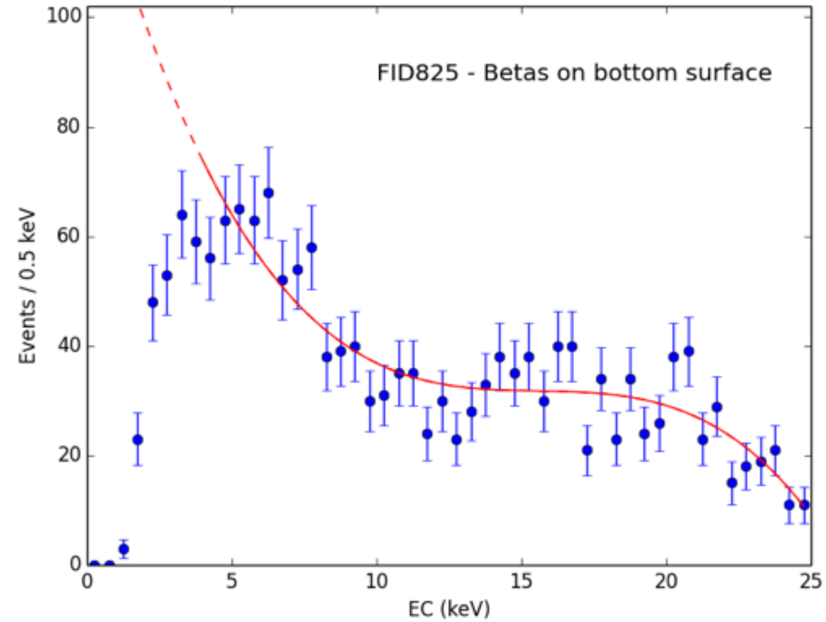


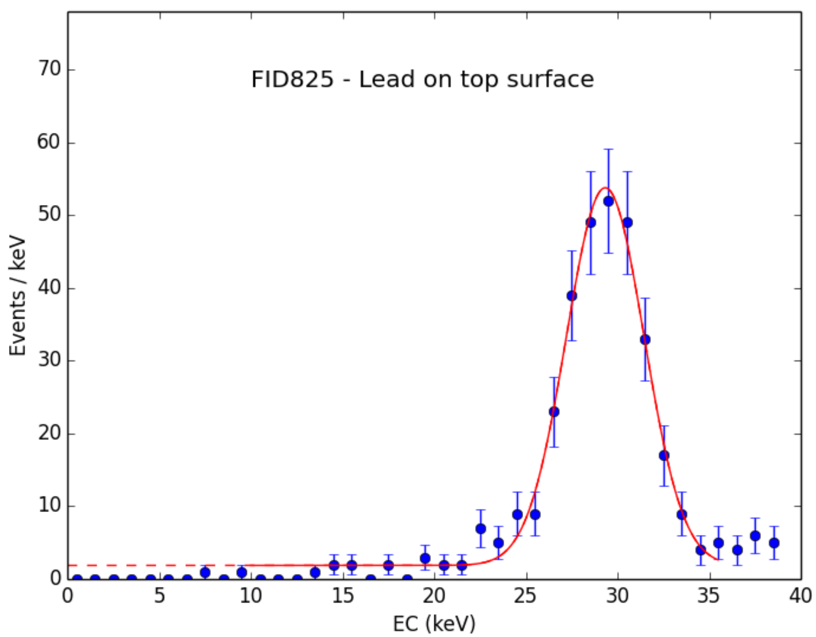
We can see NR at low energies with a good efficiency in the low mass WIMP analysis

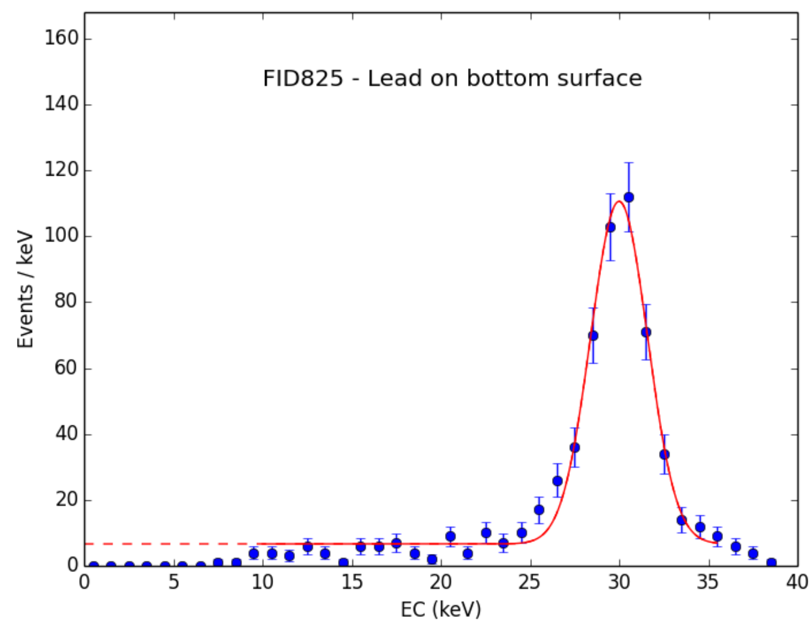
Low WIMP mass: neutron is a negligible background. Events passing the BDT cut are below 2keVee heat energy and we would expect radiogenic neutrons at higher energy

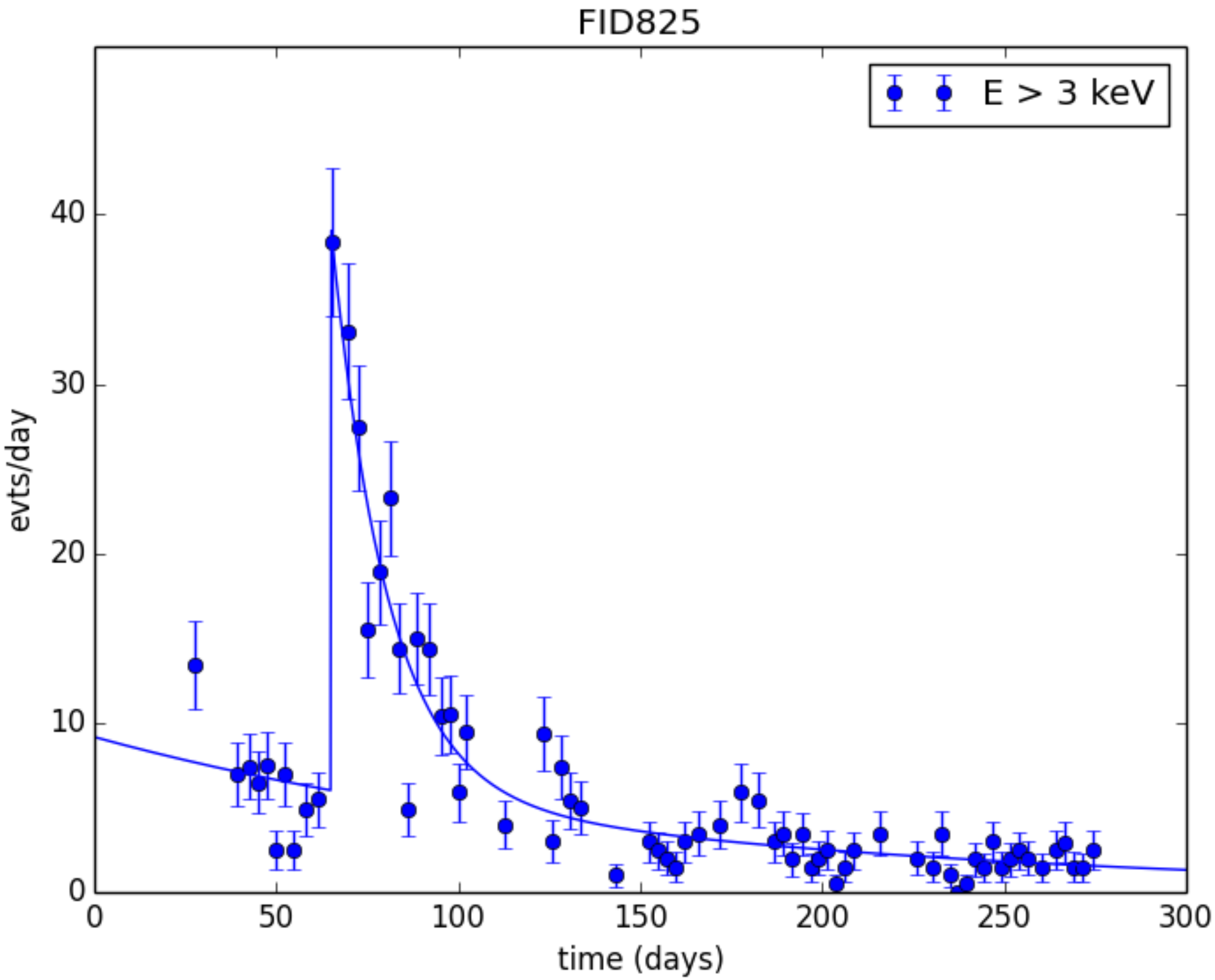
High WIMP mass: BDT cut at ~7, dark red events are passing the cut.


FID825 - Betas on top surface
Events / 0.5 keV
EC (keV)


FID825 - Betas on bottom surface
Events / 0.5 keV
EC (keV)


FID825 - Lead on top surface
Events / keV
EC (keV)


FID825 - Lead on bottom surface
Events / keV
EC (keV)


FID825
E > 3 keV
evts/day
time (days)
0
10
20
30
40
0
50
100
150
200
250
300