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Experiment: Preliminary results from a 60cm prototype run with Neon for dark matter search

CAP CONGRESS
OTTAWA
June 16, 2016

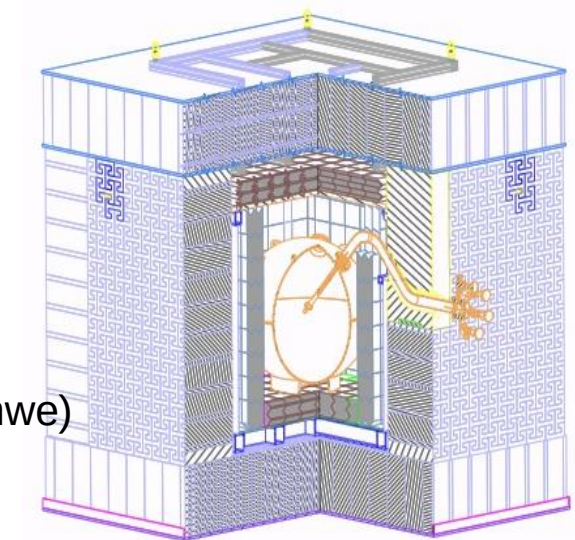
Queen's University

Alvine Kamaha for NEWS collaboration

Overview of the prototype SEDINE

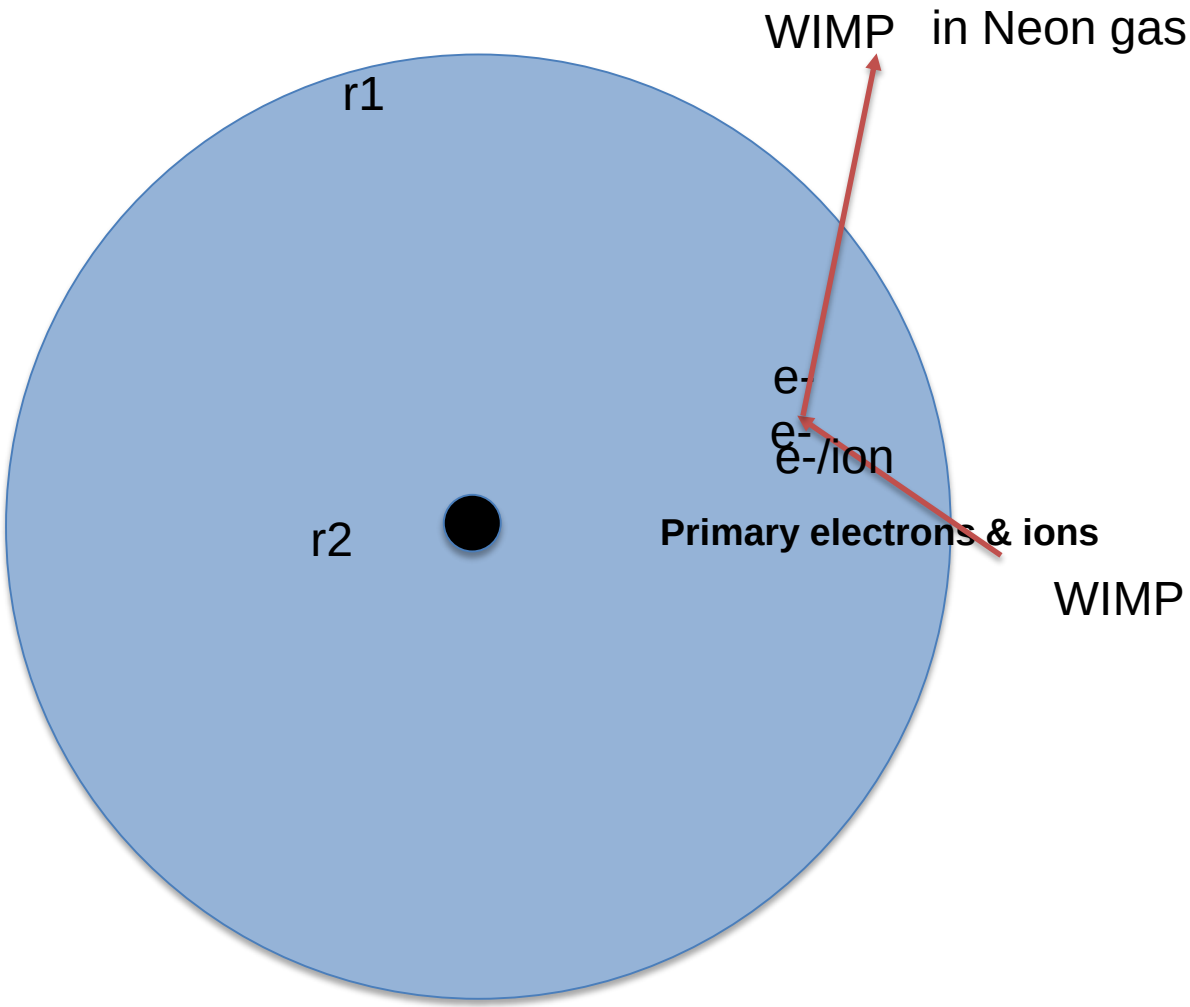
- **Operation & data taking conditions**
- NOSV Cu sphere vessel (60 cm Ø) + sensor (6 mm Ø) +HV
- Fill gas Ne (6N:99.3%) + quencher CH4 (5.5N:0.7%) @3.1 bar
  - ➔ 310 g sensitive mass
- HV set to 2520 V
  - no sparks & gain~ 3000
- Seal mode, no recirculation
- DAQ sampling frequency 2 MHZ + soft trigger
- Data taking continuously for 42 days for WIMP search
- Calibration : 5000 ADU@ 8.1 keV
- Threshold @30ADU ➔50 eV
  - ➔No noise in sable conditions
- Loss of gain 4 % along 42 days monitored with ^{210}Po line + variation on days scale of +- 4%
- Mode of operation: Point like energy deposition

- **Shielding:**
  - Located @Laboratoire Souterain de Modane(4800mwe)
  - Cu(4-7cm) + Pb(10cm) +PE(30cm) shielding

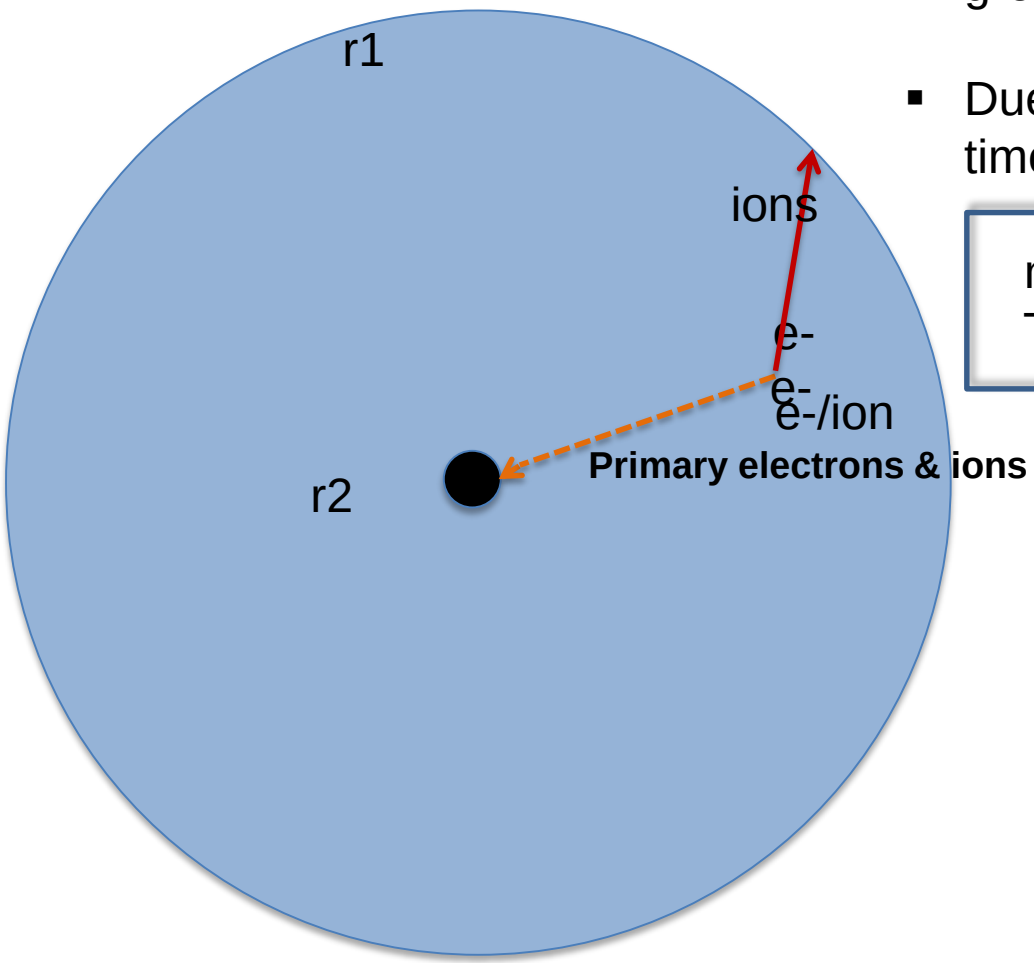


Pulse modeling/simulation: ionisation

- Energy deposited produces e-/ions pairs in Neon gas (36eV/pairs)



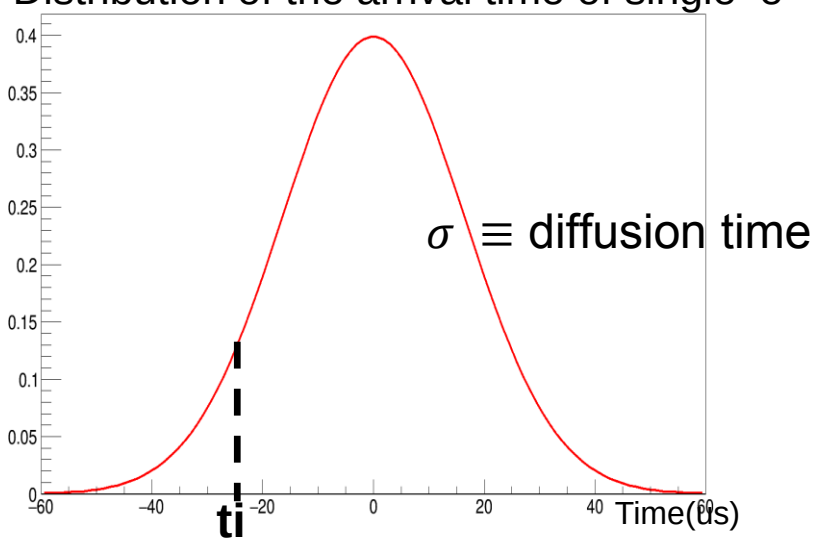
Pulse modeling/simulation: diffusion



- Primary e- drift to sensor while ions drift to ground
- Due to diffusion, each e- arrives at distinct times at the sensor

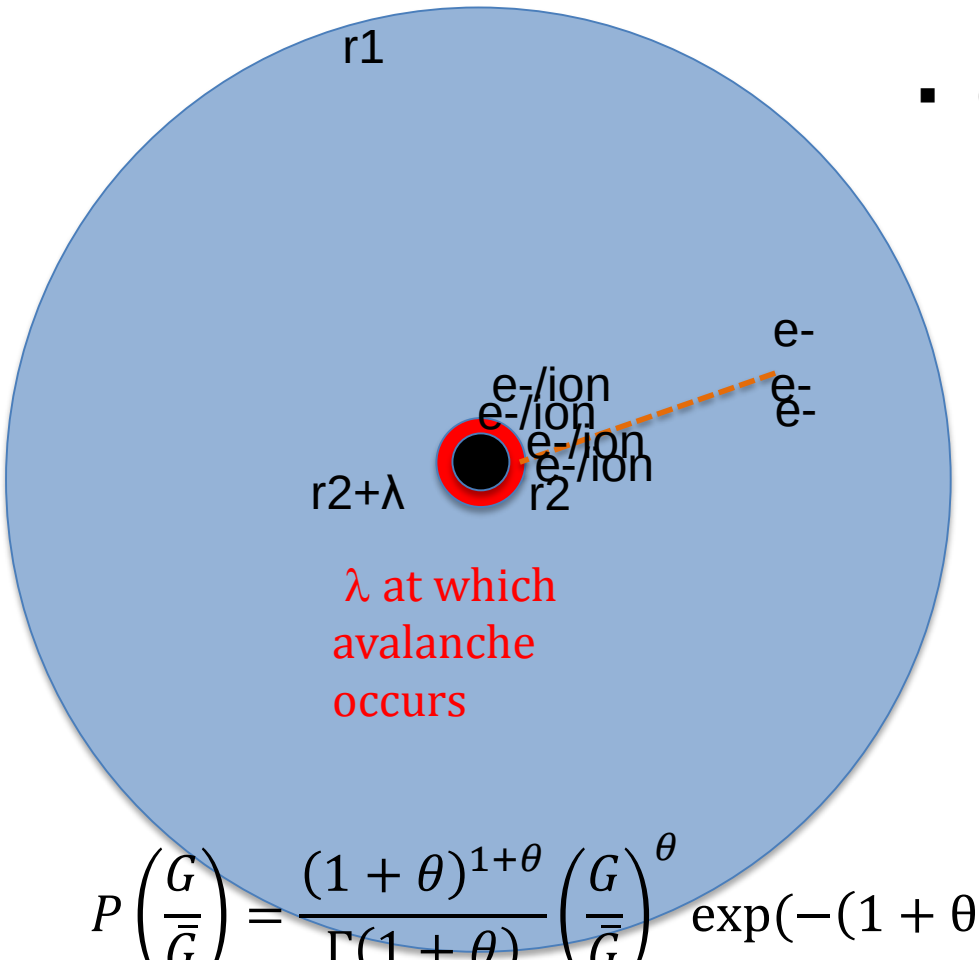
max diffusion time:20us
Total drift time (max):500us

Distribution of the arrival time of single e-



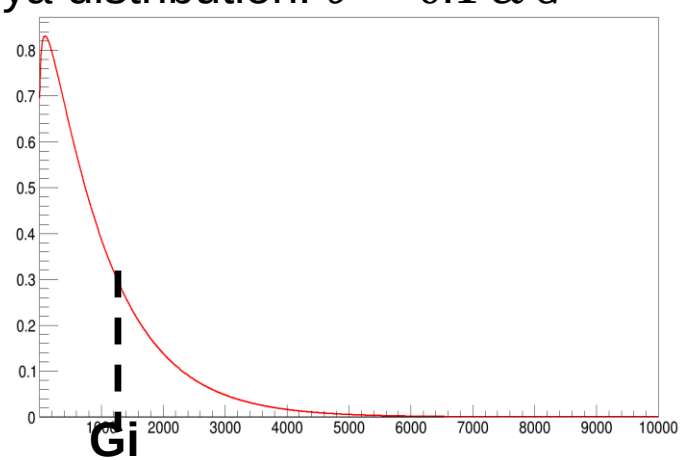
Pulse modeling/simulation: avalanche

- Primary e- arrive at the avalanche region near the sensor & get multiplied
- Gain modelled by a polya distribution.



~3000 e-/ions pairs in average

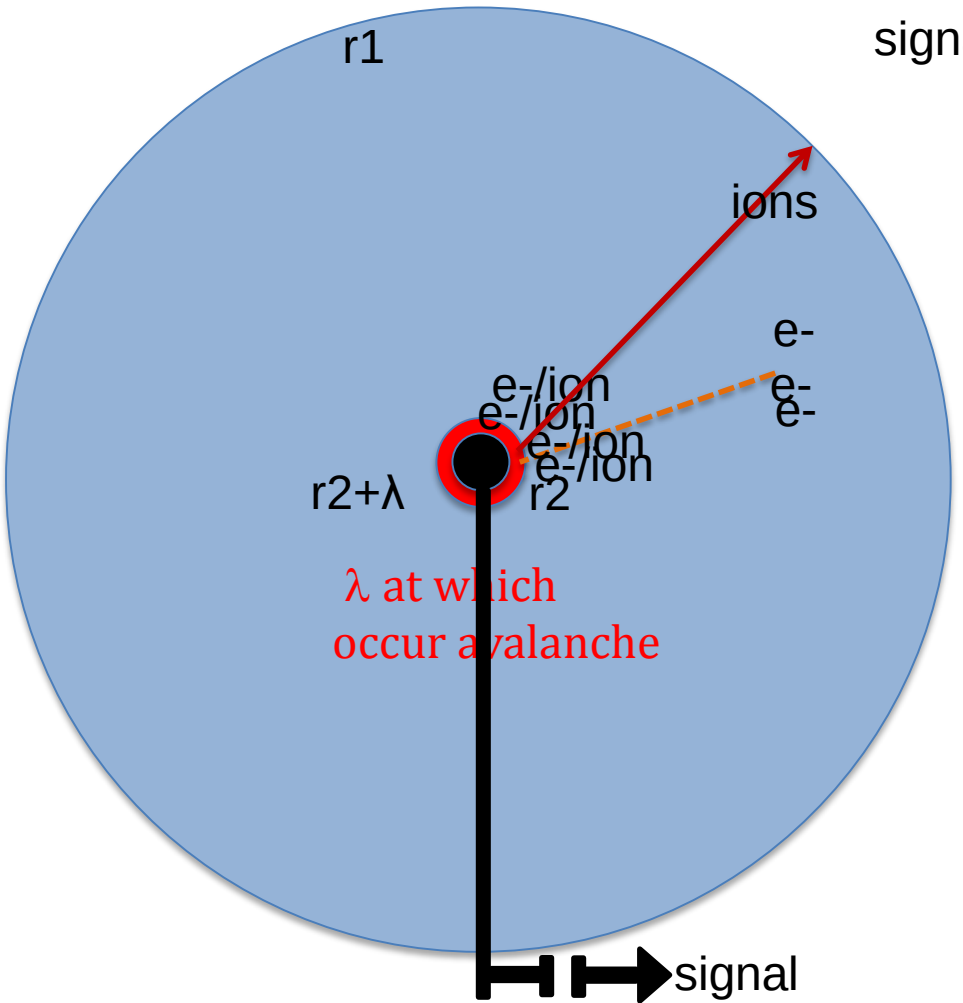
Polya distribution: $\theta = 0.1$ & $\bar{G}$

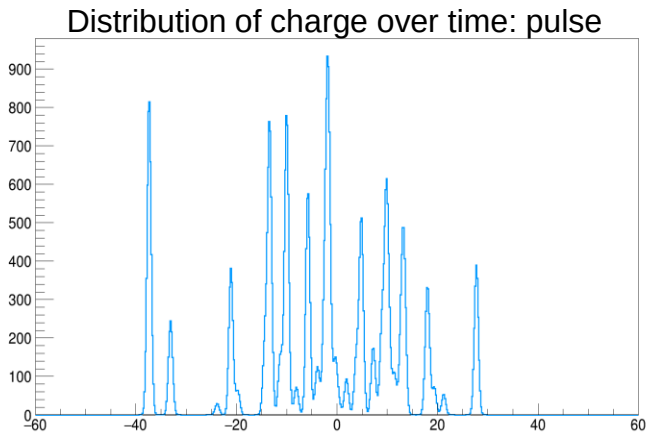


$$P\left(\frac{G}{\bar{G}}\right) = \frac{(1+\theta)^{1+\theta}}{\Gamma(1+\theta)}\left(\frac{G}{\bar{G}}\right)^{\theta} \exp\left(-(1+\theta)\frac{G}{\bar{G}}\right)$$

Pulse modeling/simulation: signal

- Primary e- arrive at the avalanche region near the sensor, get multiplied and induce a signal on the sensor





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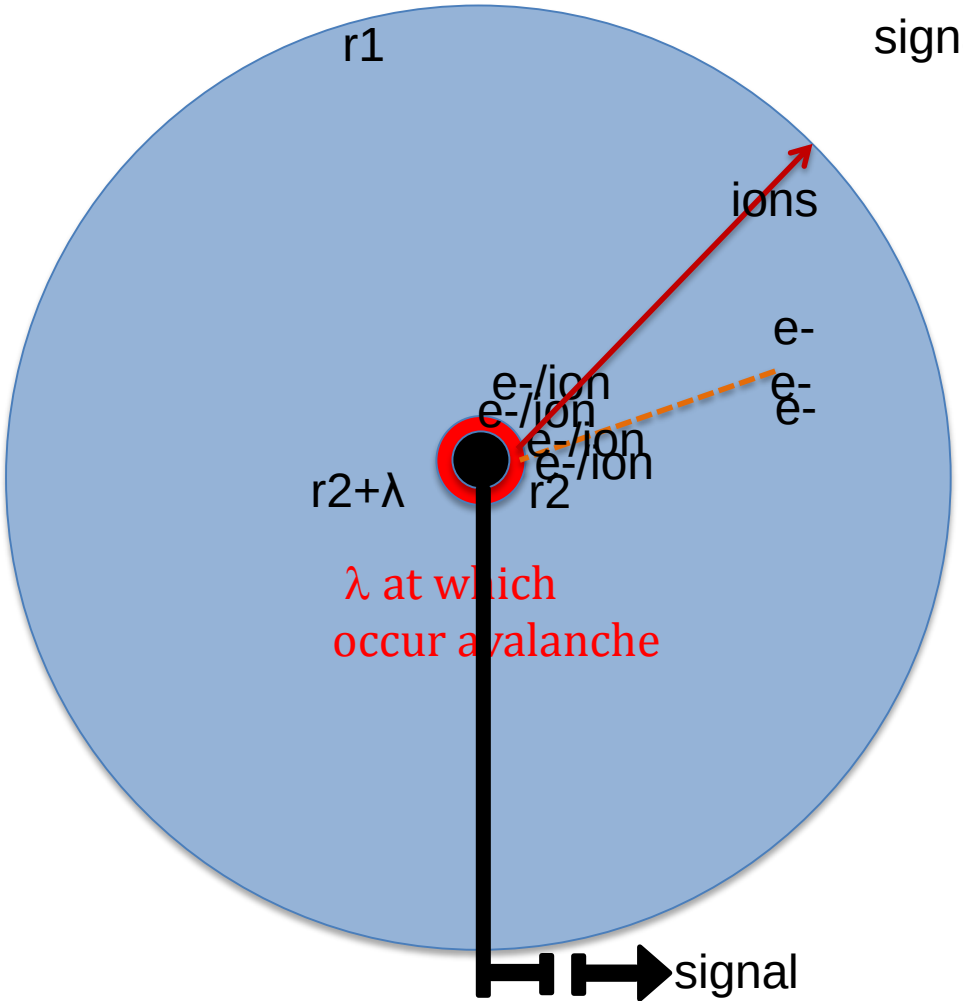
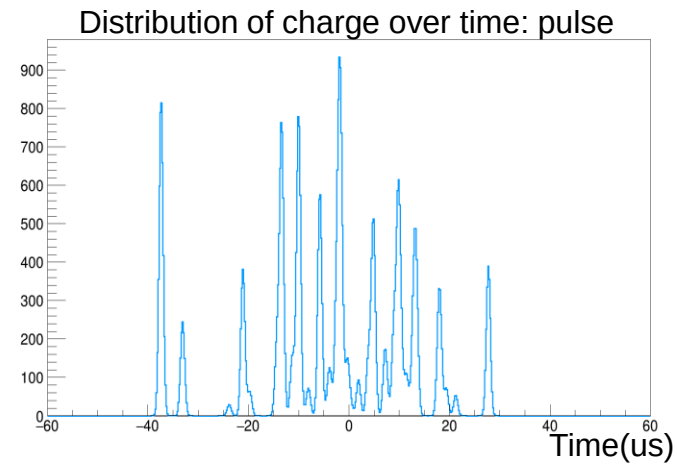
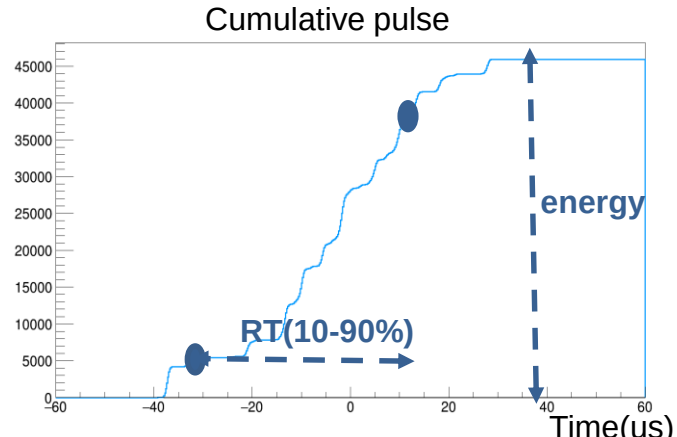
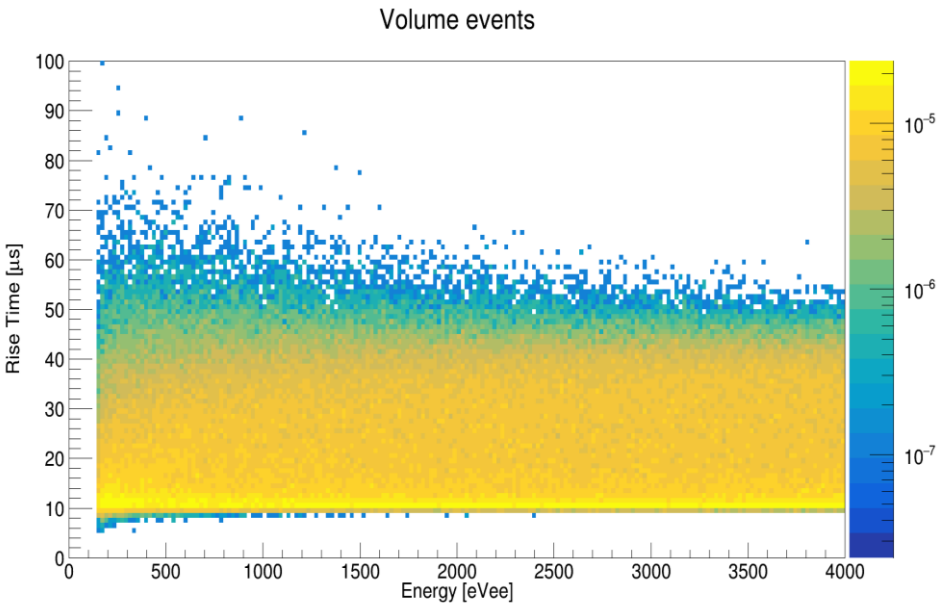


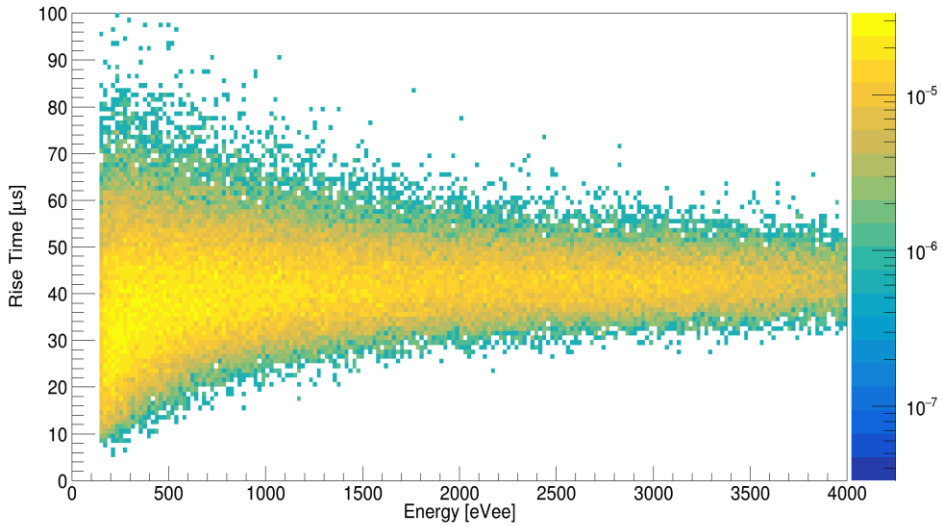




Simulated pulses

- Risetime calibration





Volume events
Neutron/WIMP/Compton

Surface events
^{210}Po decay products(α,^{206}Pb)

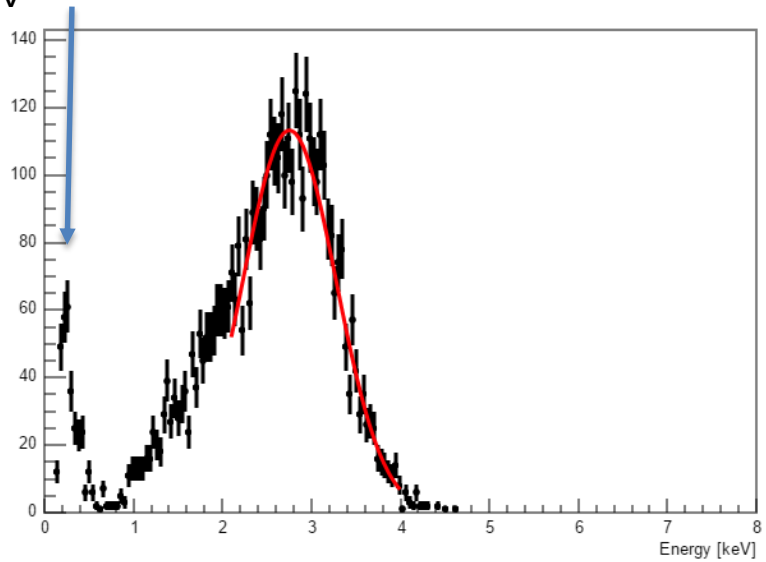
Energy calibration

- 2 methods
  - Volume calibration with ^{37}Ar source (after end of run), obtained from $^{40}Ca(n,\alpha)^{37}Ar$
  - internal calibration with 8 keV peak from Cu fluorescence

- Match of both calibrations within 15 %

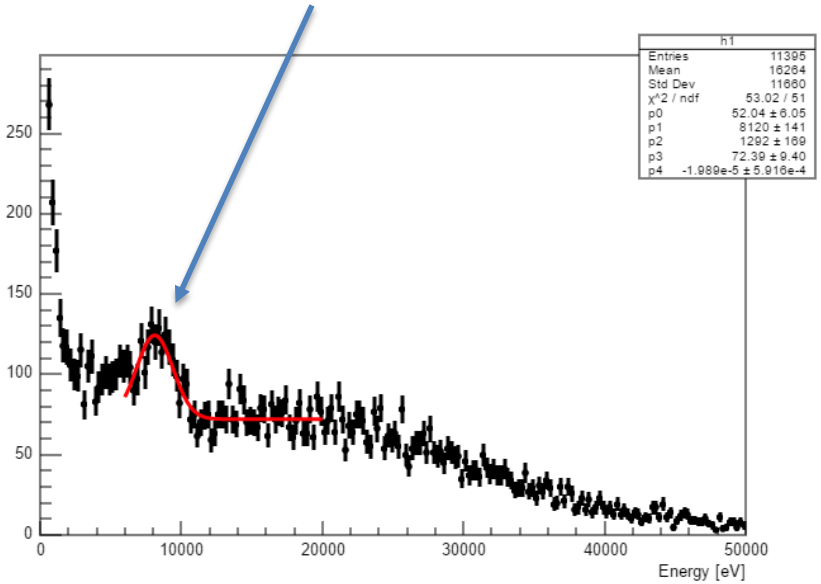
L capture, Auger e- /X
0.27 keV

K capture, Auger e- /X
2.82 keV



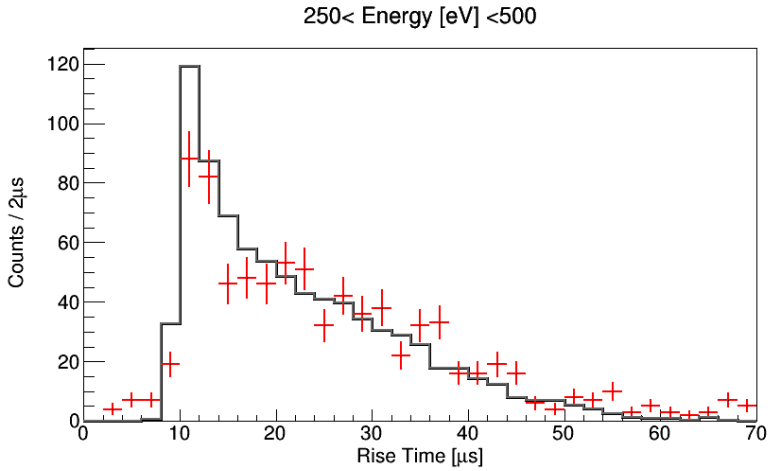
^{37}Ar X rays calibration

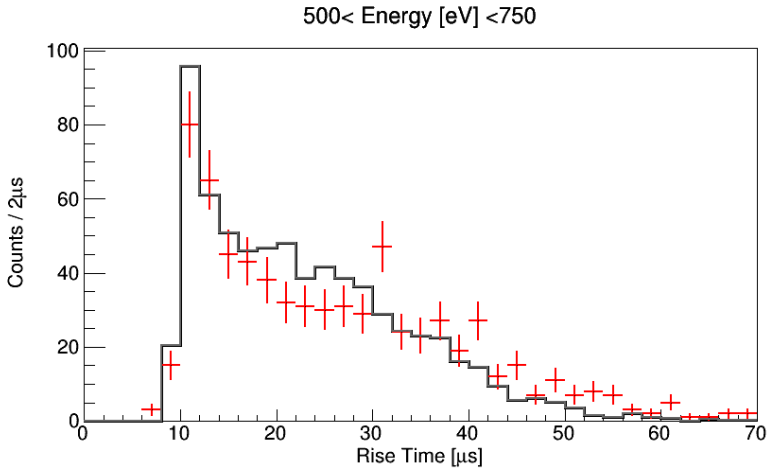
8 keV peak from Cu fluorescence

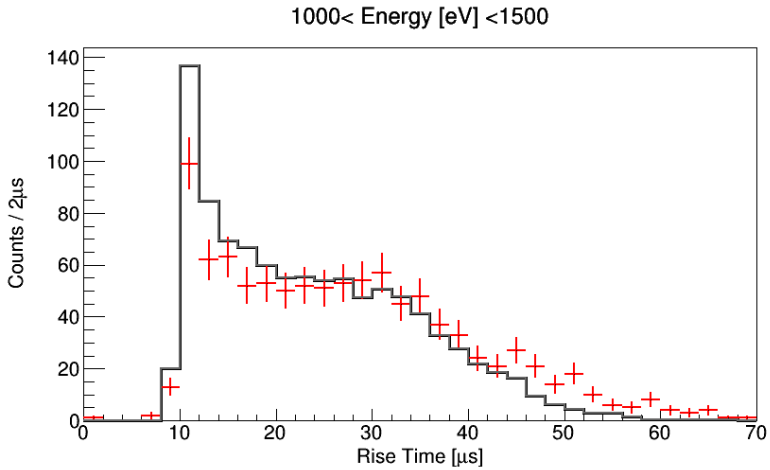


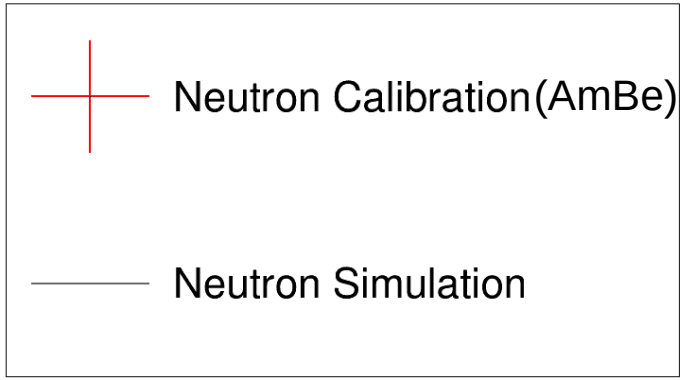
WIMP search data

Comparison of simulation with neutron calibration (AmBe) data



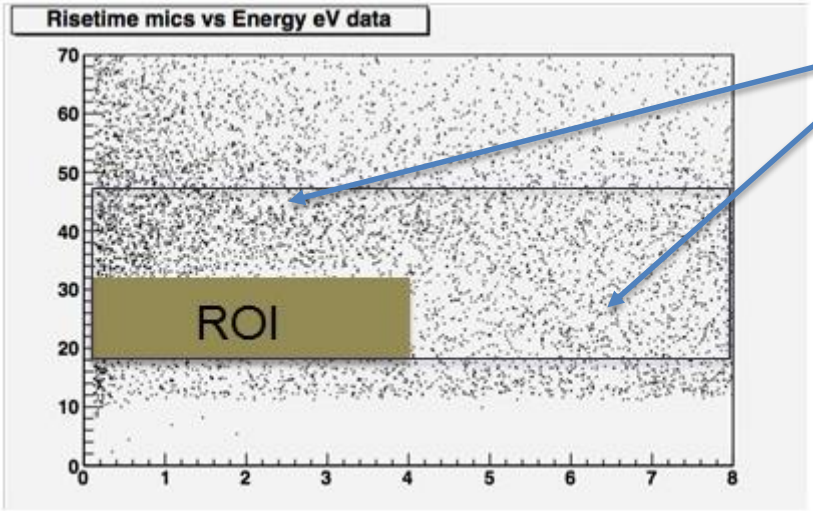






- Good agreement noticeable

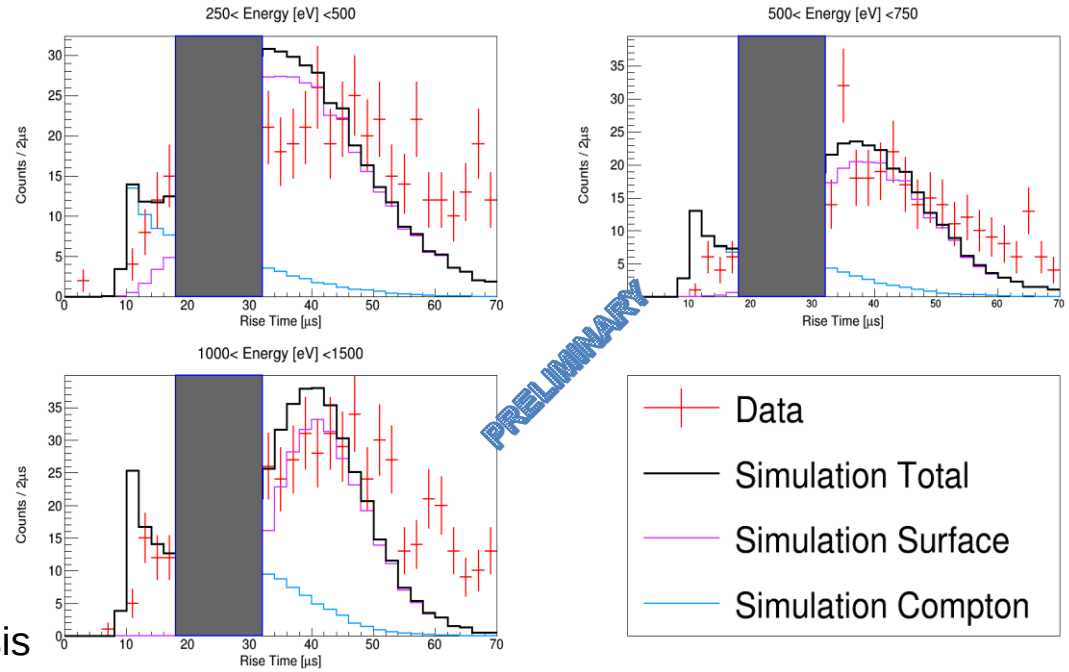
Comparison of simulation with bckg events (surface & Compton) from WIMP search data



Data: side bands for bckg events (surface & Compton)

- Side bands used to normalize volume/Compton and surface event populations in ROI

➢ $E_{thresh} = 150\ eV$ (eff >85 %)



1) Ongoing work to fully understanding the detector response to optimize simulation

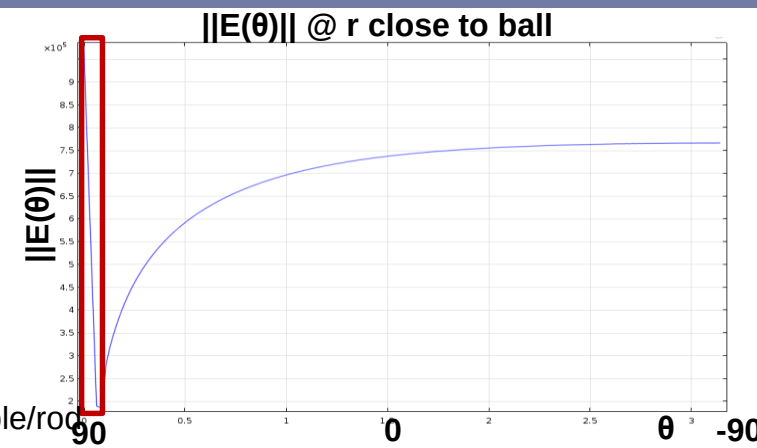
2) Apply a Boosted Decision Tree (BDT) analysis to provide conservative limits.

- Fair agreement close to the ROI
- Long risetime tail in data not reproduced by simulation

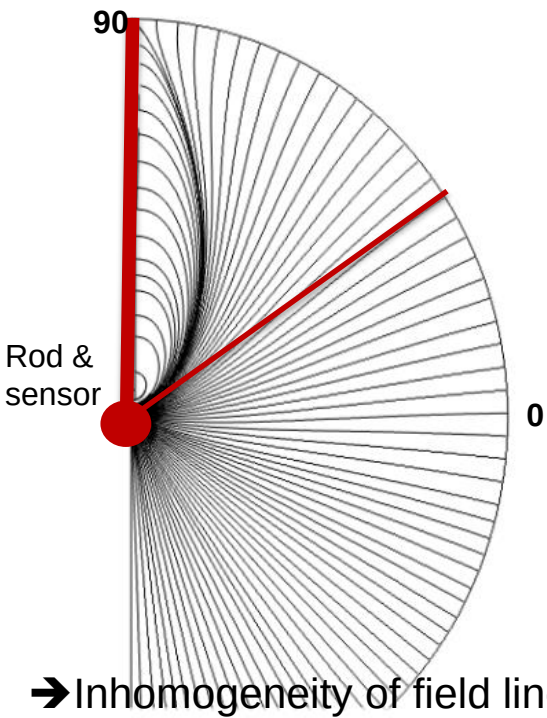
Improvement in simulation & background modeling

- Field map & simulation of e-/ions transport in real detector set up shows inhomogeneity of E field lines near rod leading to higher RT & lower gain

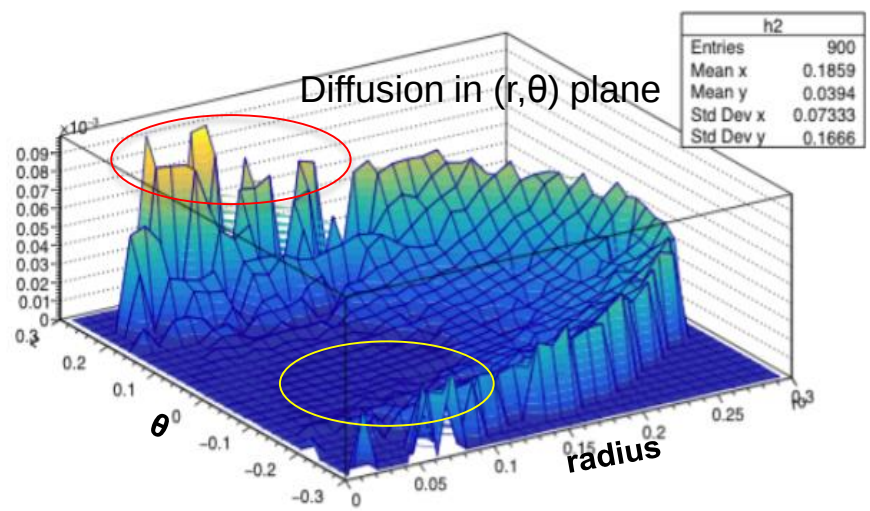
- Studies under way to simulate expected tails of long diffusion time and drop in gain due to inhomogeneous field
- About 25 % of volume expected to be affected



➔anisotropic gain



➔Inhomogeneity of field lines near rod

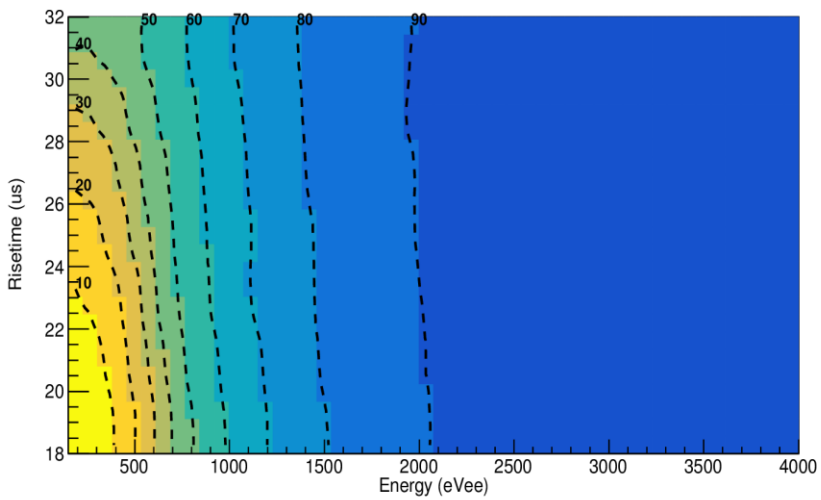


➔anisotropic diffusion/RT

Boosted Decision Tree (BDT) analysis

- Set of linear cuts in the multidimensional space (Risetime and Energy) in order to optimize the **signal** / **background** discrimination
- BDT trained to classify events using simulated events from our **signal** and **background** models
- Reduces the parameters space to only one variable : the BDT score
- Poisson limit derived with the remaining events above the BDT optimal cut

PDF of a 7GeV WIMP



PDF of the signal for a WIMP of 7GeV

Contour at X % of the total signal, X from 10 to 90 %

- WIMP spectrum using standard assumption on WIMP velocities, escape velocity and with quenching factor (QF) of Neon nuclear recoils in neon calculated from SRIM simulation

➔QF measurement below 1keV scheduled to start in Grenoble in the next month.

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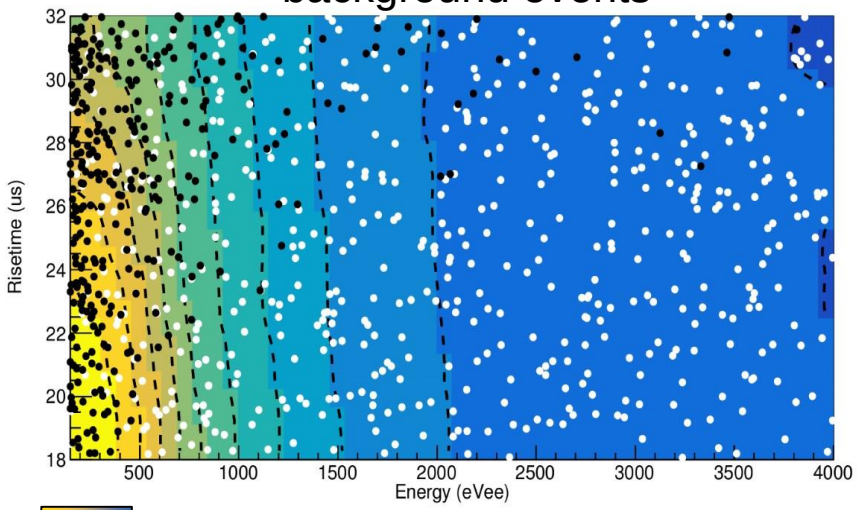
PDF of a 7GeV WIMP
+background events



PDF of the signal for a WIMP of 7GeV

● Surface event

○ Compton event

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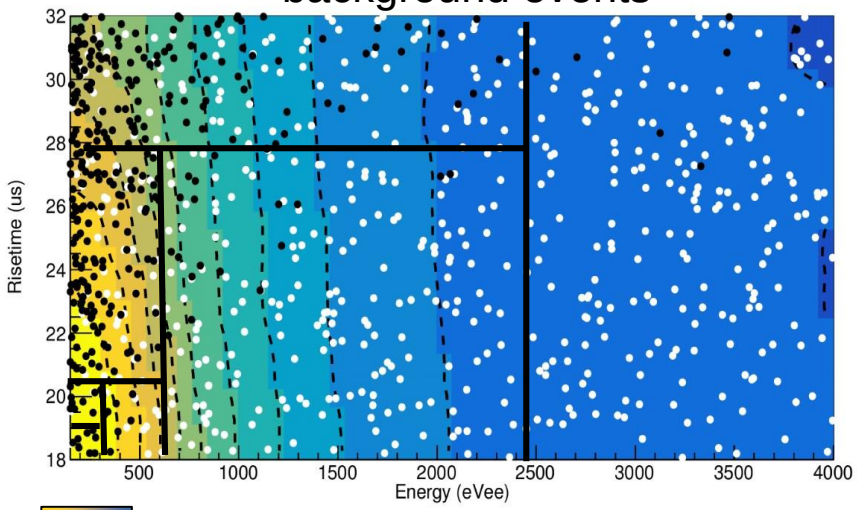

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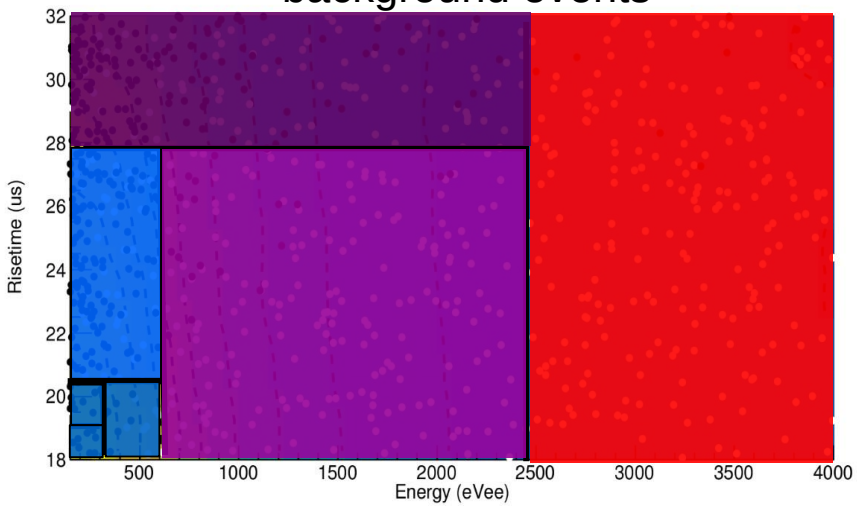
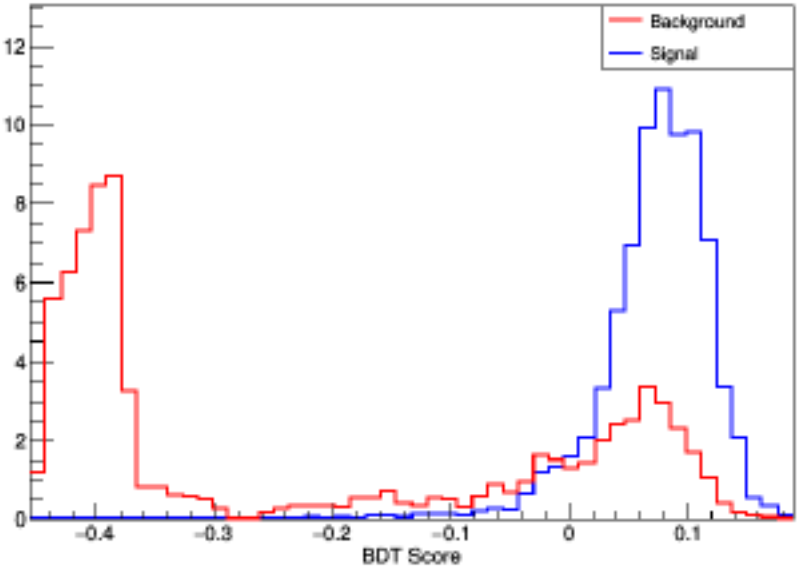
PDF of a 7GeV WIMP +background events



Background like : low BDT Score

Signal like : high BDT Score



Distribution of simulated **signal** / **background** events in BDT Score

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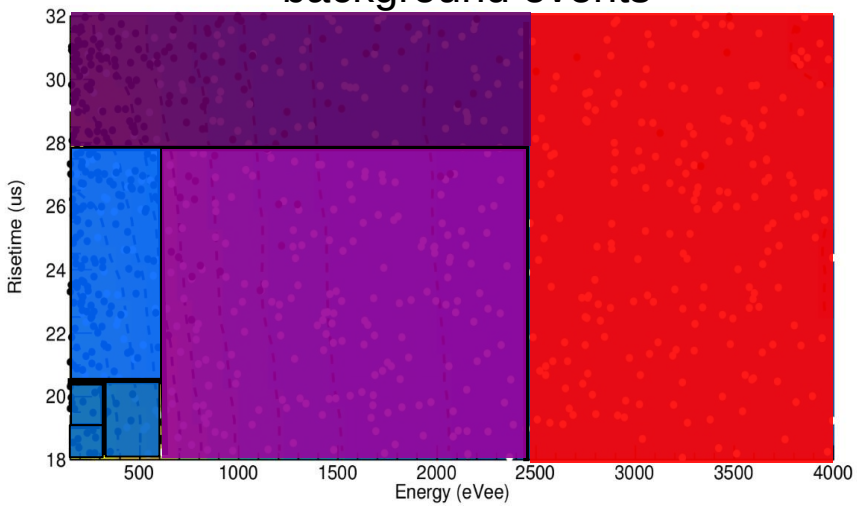

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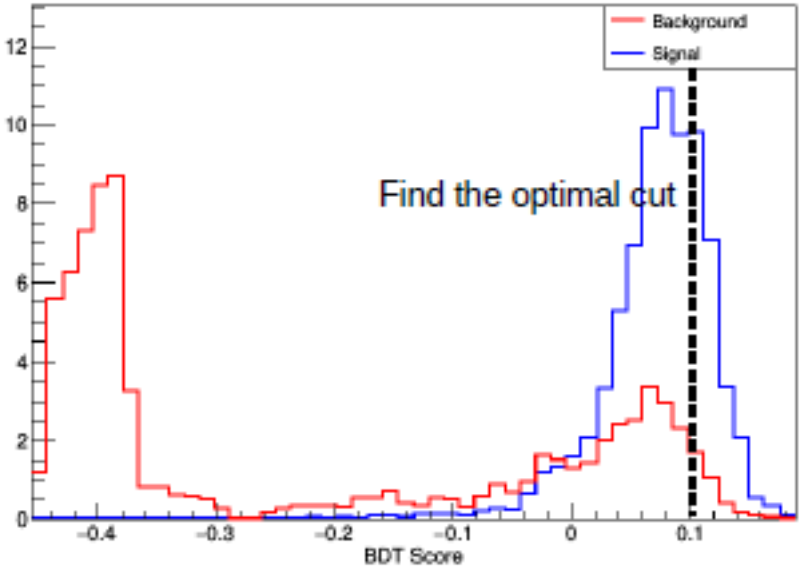
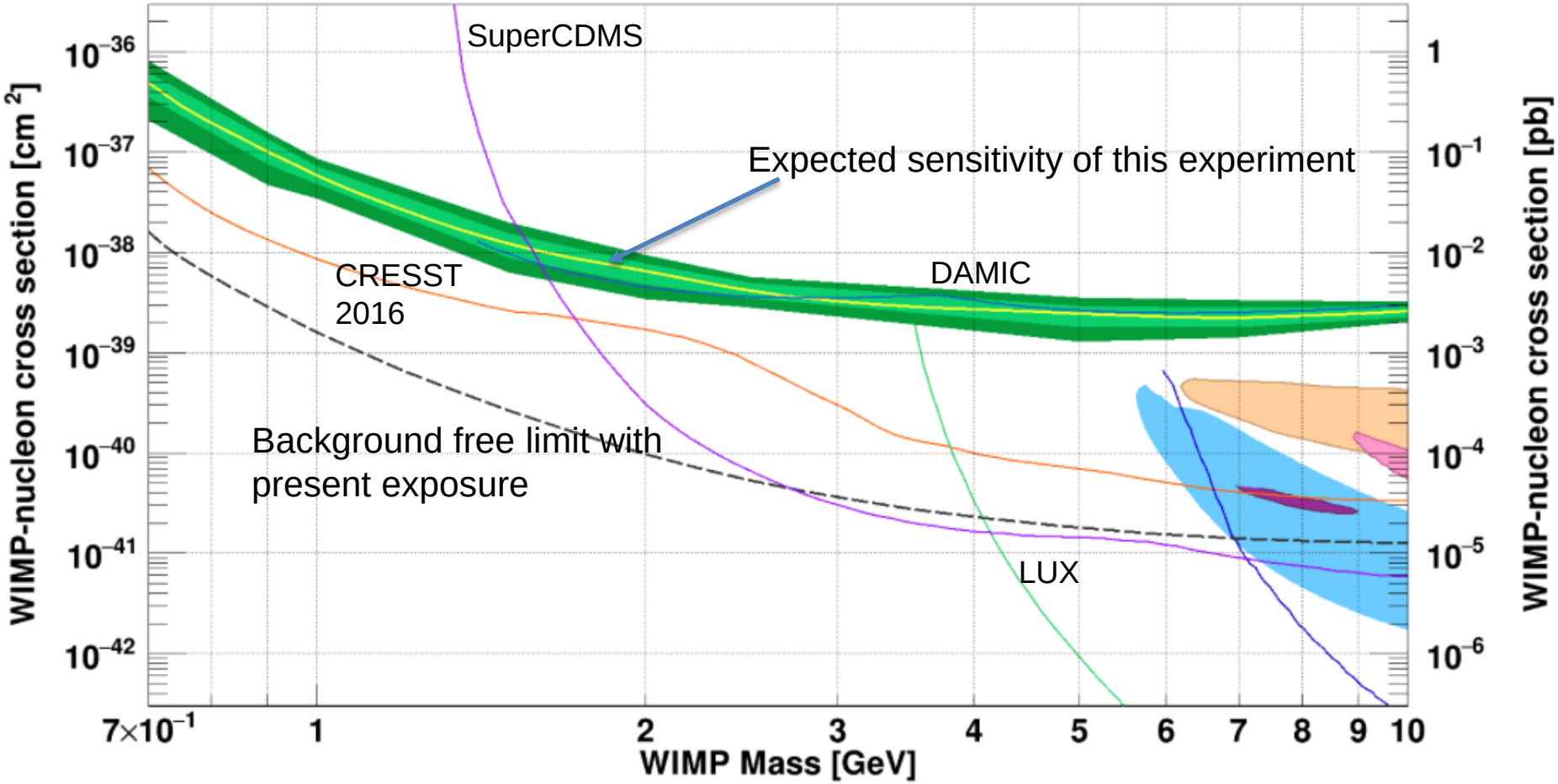


Distribution of simulated **signal** / **background** events in BDT Score

Preliminary: Expected sensitivity of SEDINE assuming events in ROI are pure background and behave in ROI as expected from sidebands



- Limit set on spin independent coupling.

Conclusion

- 12.6 kgd of data using a 60cm prototype currently being analyzed and finalized

- Good pulse treatment and understanding

- Pulse modeling/simulation using ideal homogeneous E field reproduce reasonably well the data (Calibration + WIMP search)
    - Fine tuning of pulse simulation to account for E field and charge transport in real detector set up is underway

- Preliminary analysis results for WIMP sensitivity (using conservative BDT analysis) are promising and pave a way to the larger scale detector to be installed at SNOLAB

Collaboration

- **Queen's University Kingston – GG,** P di Stefano, R Martin, T Noble, B Cai, A Brossard, A Kamaha, P Vasquez dS, Q Arnaud, K Dering, J Mc Donald, M Clark, and summer students
  - Copper vessel and gas set-up specifications, calibration, project management
  - Gas characterization, laser calibration, on smaller scale prototype
  - Simulations/Data analysis
- **IRFU/Saclay** -I Giomataris, M Gros, I Katsioulas, T Papaevangelou, A Gigagnon, JP Bard, JP Mols, XF Navick,
  - Sensor/rod (low activity, optimization with 2 electrodes)
  - Electronics (low noise preamps, digitization, stream mode)
  - DAQ/soft
- **LSM** (Laboratoire Souterrain de Modane) **-** F Piquemal, M Zampaolo, A DastgheibiFard
  - Low activity archeological lead for close electronics/valve shield
  - Coordination for lead/PE shielding and copper sphere
- **Thessaloniki University** – I Savvidis, A Leisos, S Tzamarias, C Elefteriadis, L Anastasios
  - Simulations, neutron calibration
  - Studies on sensor
- **LPSC Grenoble** - D Santos, JF Muraz, O Guillaudin
  - Quenching factor measurements < 1 KeV with ion beams
- **TU Munich** – A Ulrich
  - Gas properties and ionisation process for Pening mixtures
- **Pacific National Northwest Lab**– E Hoppe
  - Low activity measurements, Copper electroforming
- **Associated lab : TRIUMF** - Fabrice Retiere
  - light detection, sensor

June 2016

Back up slide

Discussion on trigger efficiency at threshold

Trigger efficiency (~100%)
➔Example of 150eV raw pulse