Status and Prospects of the NEWS Experiment

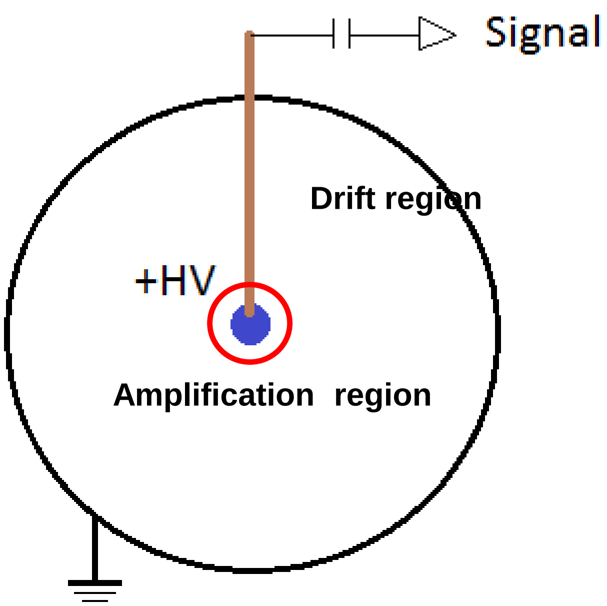
ICHEP 2016
August 05, 2016

Alvine Kamaha
for NEWS collaboration

Outline

- Description of spherical gaseous detectors
- Overview of the SEDINE prototype at LSM
  - WIMP search data taking conditions
- Preliminary data analysis and results
  - Pulse simulation & agreement with the data
  - Expected sensitivity using Boosted Decision Tree analysis
- Status of the project @ SNOLAB
  - Outlook and projected sensitivity
- R&D program

Description of spherical gaseous detector



Detector

- Large grounded metallic sphere
- Small sensor (1-16 mm) in the center
- Filled with gas mixture
- Particle interactions create e-ion pairs in the gas – drift and cause avalanches at center of detector
- Measured signal charge is proportional to particle energy

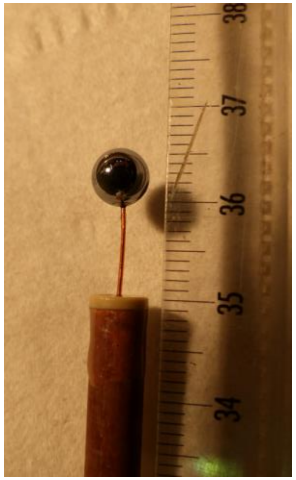
System advantages

- Simple detector design
- Low radioactivity
- Very low energy threshold, sensitive to low-mass WIMPs
- Low mass targets (H, He, Ne)
- Flexible gas pressure and interchangeable sensor size
- Good energy resolution

Overview of SEDINE (SphEre pour la DetectIon de Neutron)

Data taking condition

- NOSV Cu vessel (60 cm Ø) + sensor (6 mm Ø) +HV
- Ultrapure fill gas (Ne) + quencher (CH_4) @3.1 bar
  ➔310 g sensitive mass
- HV set to 2520 V ➔gain~ 3000
- Seal mode, no recirculation
- DAQ sampling frequency 2 MHZ + soft trigger
- Data taking continuously for 42 days for WIMP search
  ➔12.6 kgd
- Trigger threshold 50 eV➔No noise in stable conditions
- Loss of gain 4 % along 42 days monitored with ^{210}Po alpha line + variation on days scale of +- 4%

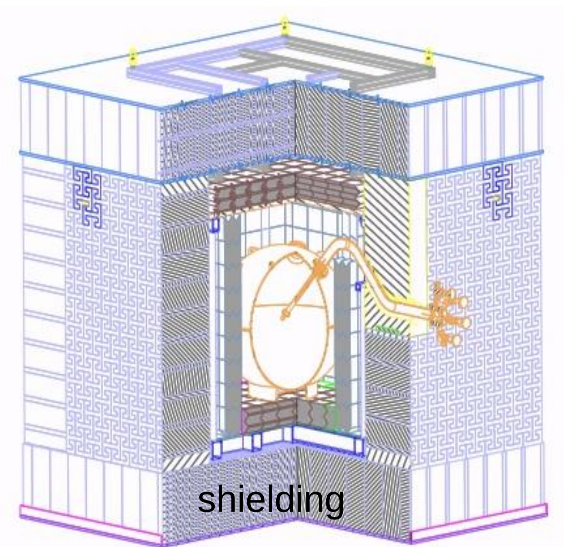


sensor

NOSV Cu vessel

Shielding:

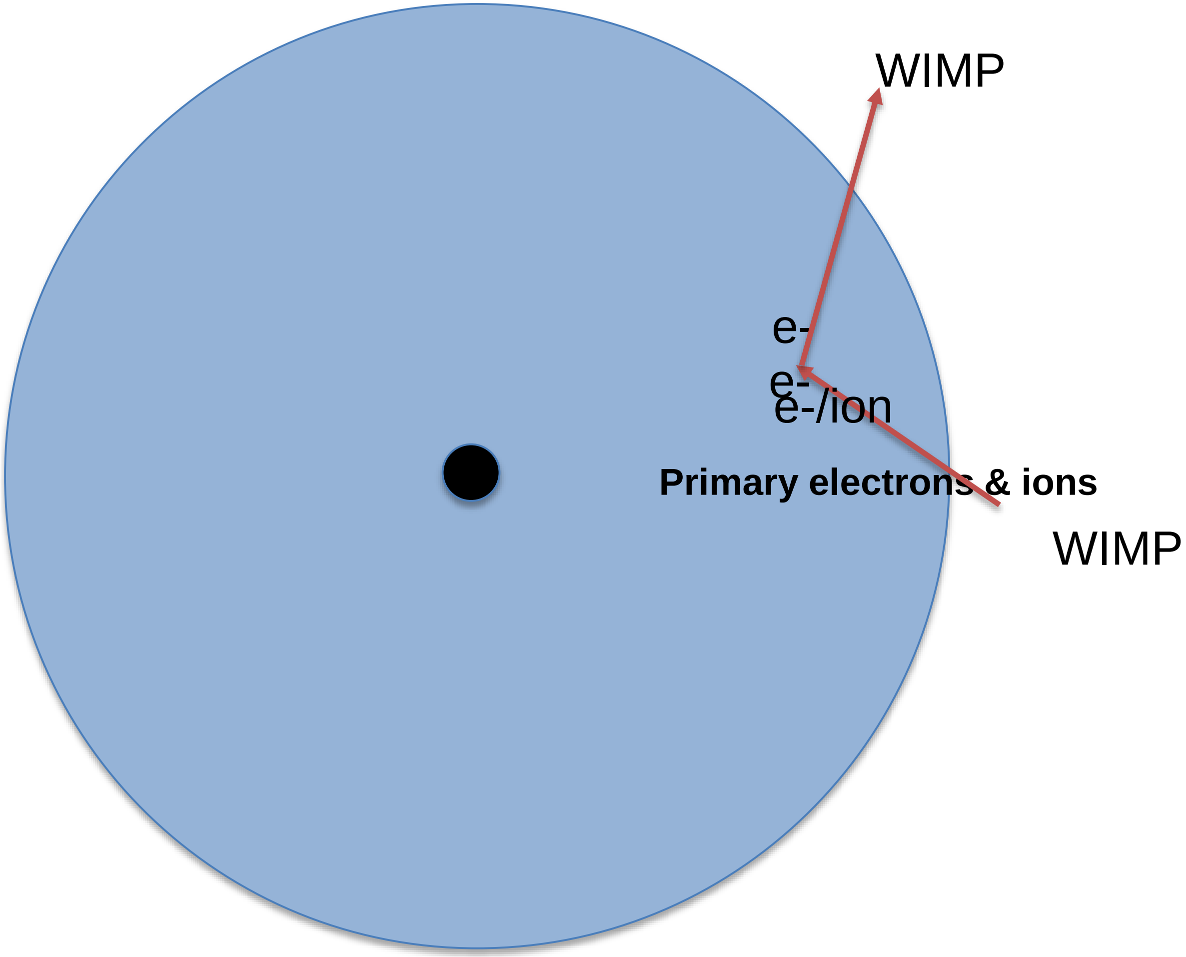
- Located @Laboratoire Souterain de Modane(4800mwe)
- Cu(4-7cm) + Pb(10cm) +PE(30cm) shielding



shielding

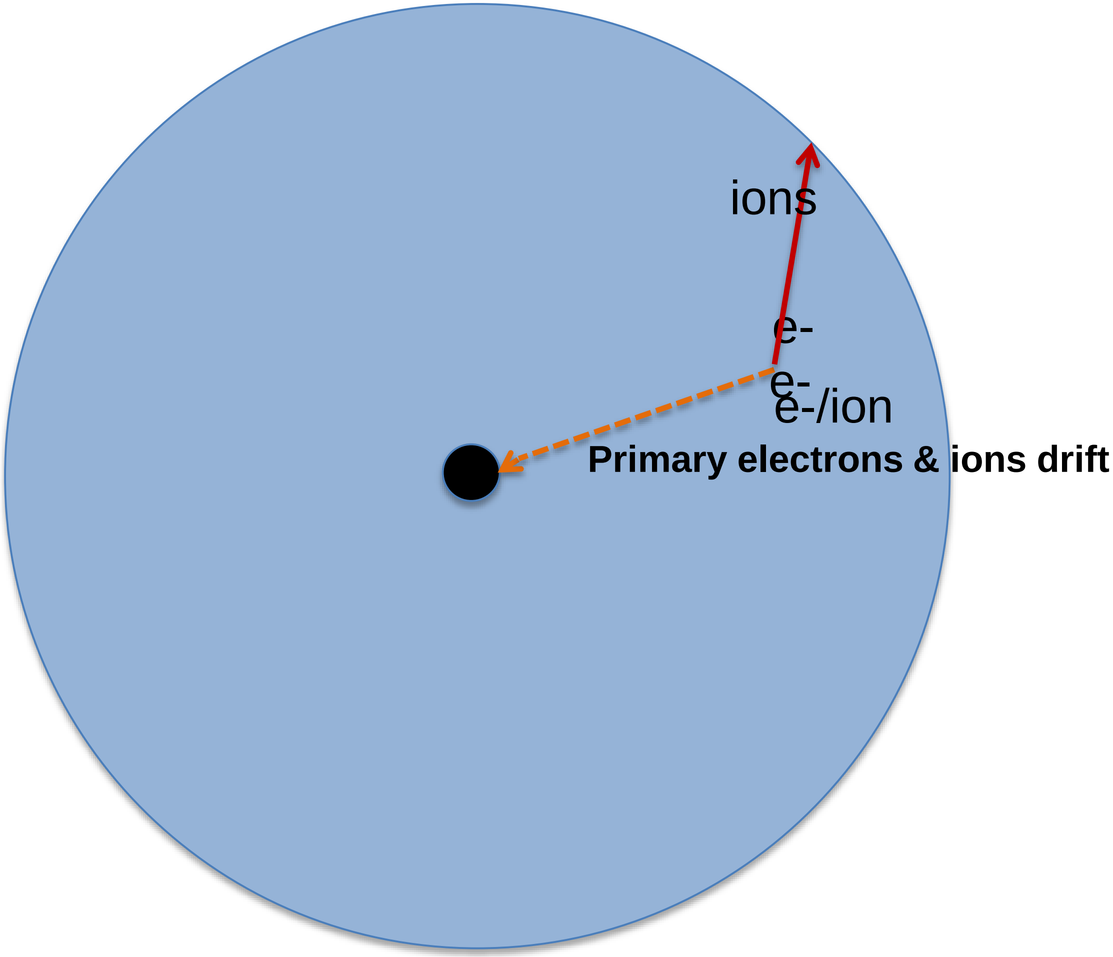
Data analysis

- Understanding and simulation of physical pulses (**ionization**, diffusion & avalanche)



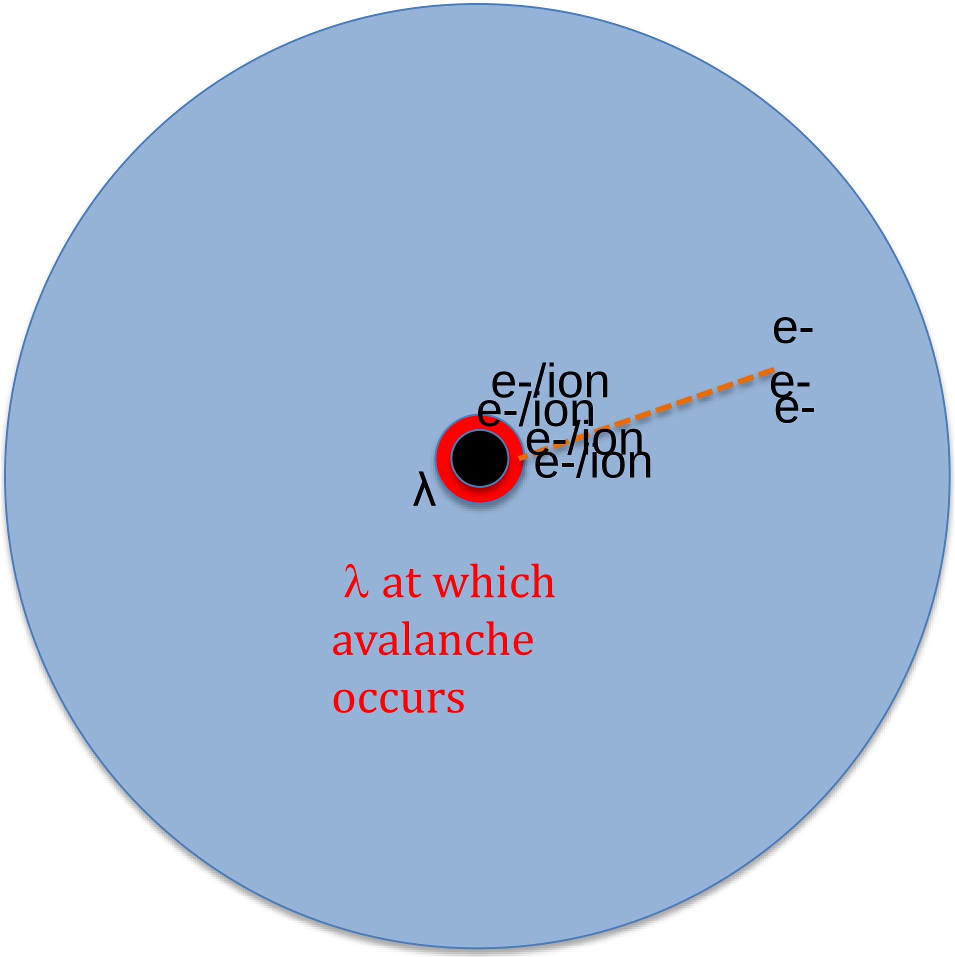
Data analysis

- Understanding and simulation of physical pulses (ionization, **diffusion** & avalanche)



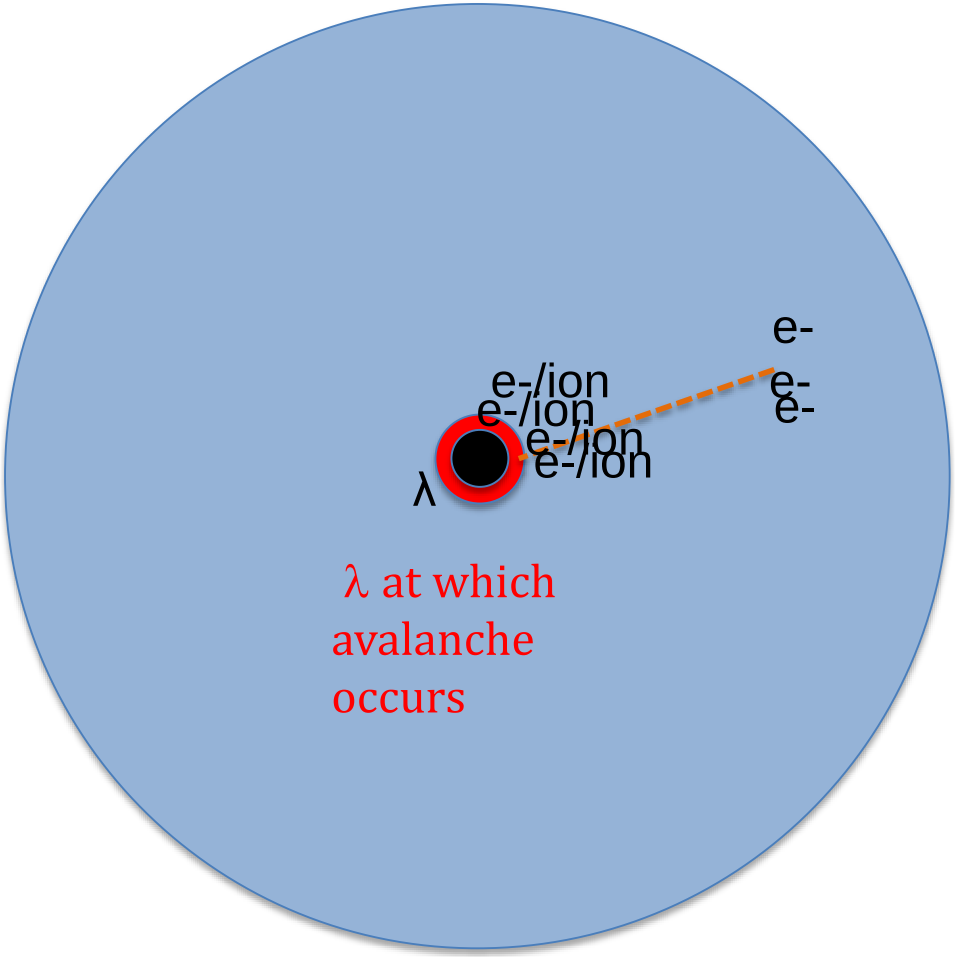
Data analysis

- Understanding and simulation of physical pulses (ionization, diffusion & **avalanche**)

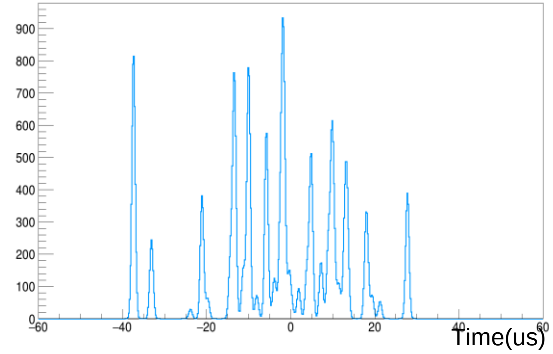


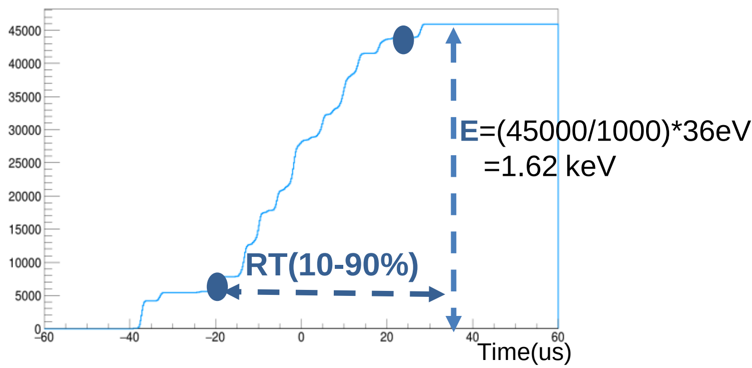
Data analysis

- Understanding and simulation of physical pulses (ionization, diffusion & avalanche)



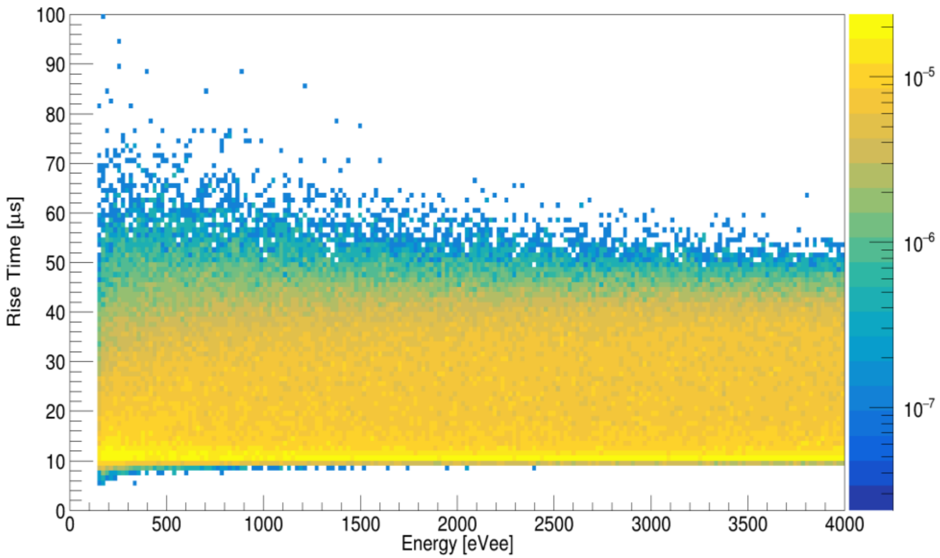
Example of a simulated pulse with 45 primary e-

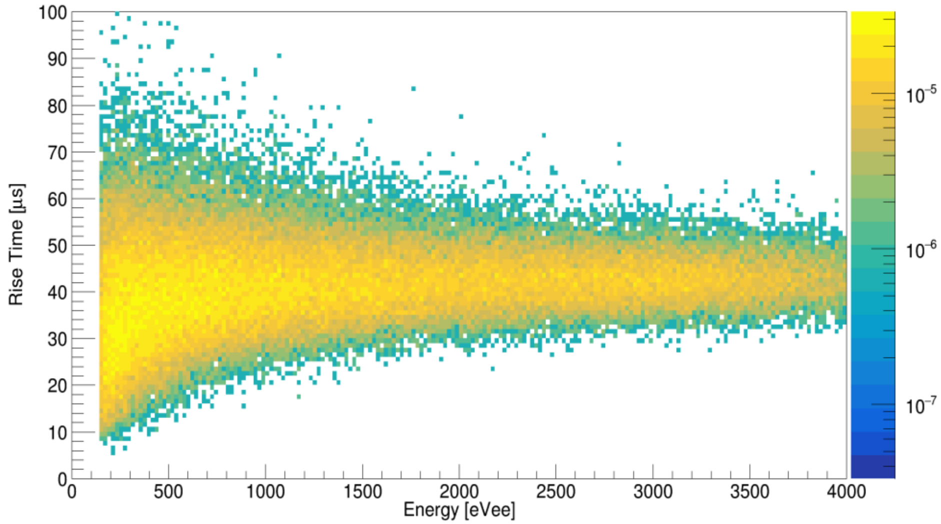




Simulated pulses in energy & risetime plane

- Understanding and simulation of physical pulses with assumption of homogeneous field

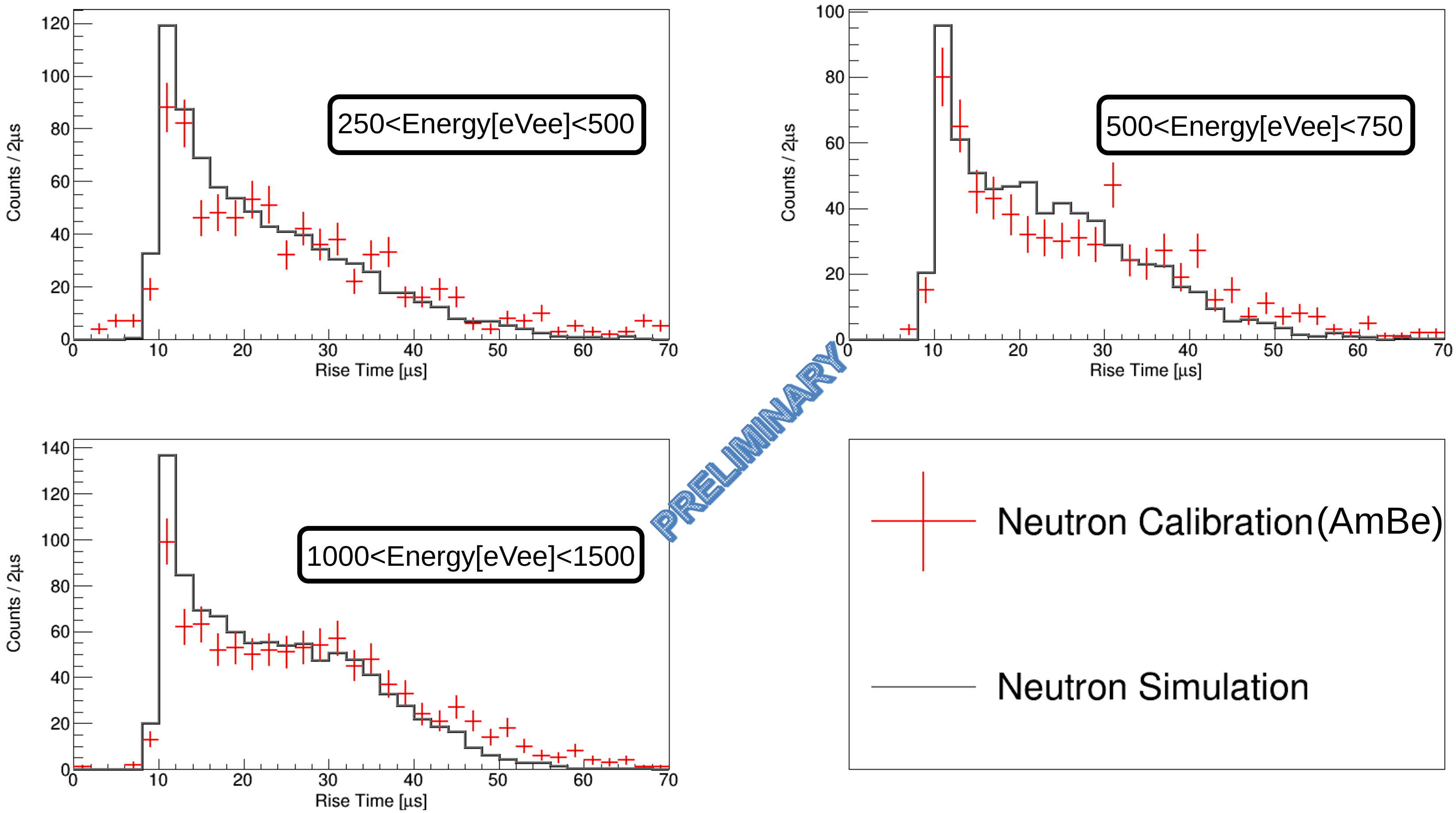




Volume events
Neutron/WIMP/Compton

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

Comparison with neutron (AmBe) calibration data



- Good agreement noticeable at different energy windows

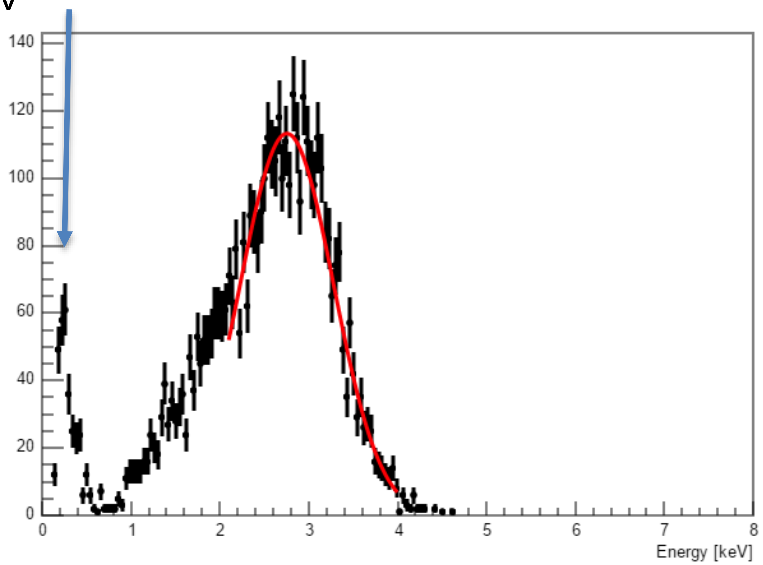
Energy calibration

- 2 ways (after run and during run)
  - Volume calibration with ^{37}Ar source obtained by irradiating ^{40}Ca with fast neutrons
  - Internal calibration with 8 keV peak from Cu fluorescence

- Agreement of both calibrations within 15 %

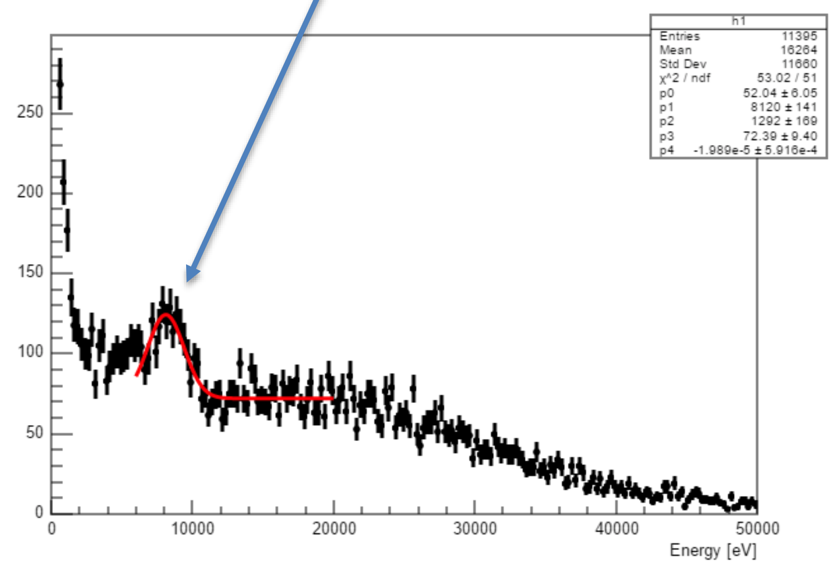
L capture, Auger e- /X
0.27 keV

K capture, Auger e- /X
2.82 keV



^{37}Ar X rays calibration

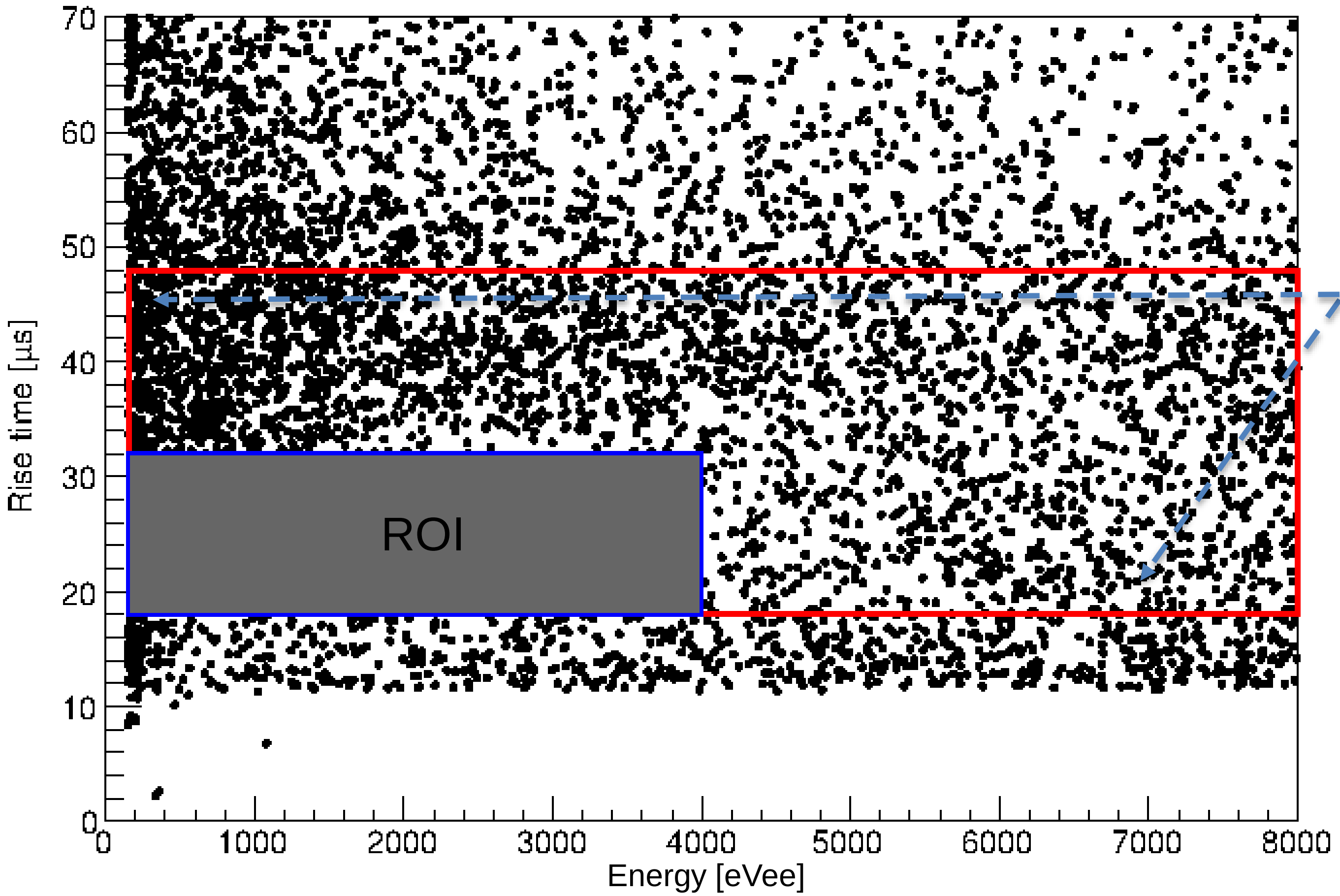
8 keV peak from Cu fluorescence



WIMP search data

Background events (surface & Compton) from WIMP search data

- WIMP search data in energy & risetime plane with ROI hidden

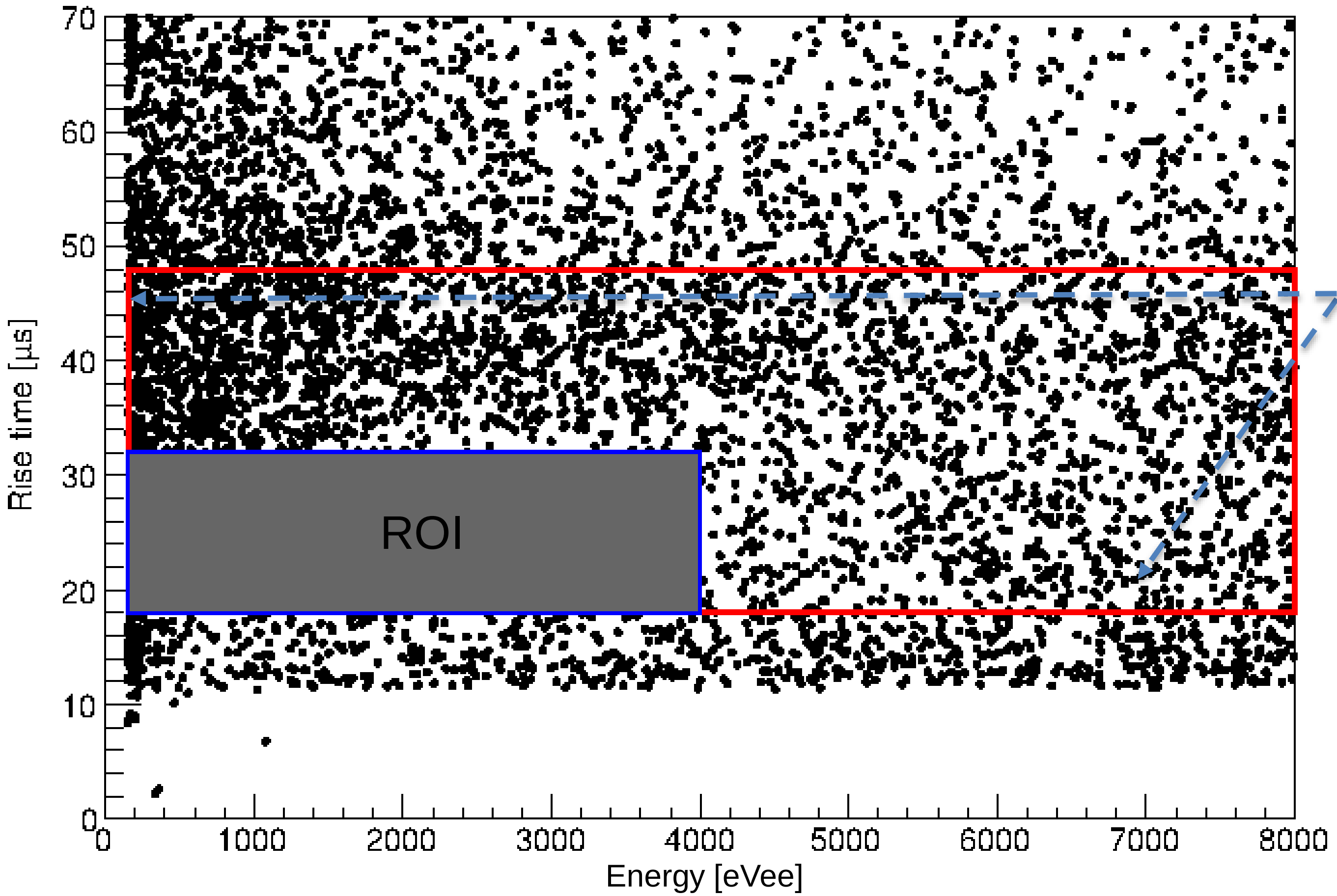


side bands for bckg (surface & Compton) used for preliminary analysis

- $E_{thresh} = 150\ eVee$ (trigeff > 90% preliminary) cuteff>85%

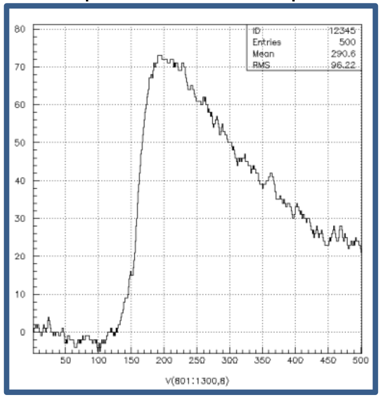
Background events (surface & Compton) from WIMP search data

- WIMP search data in energy & risetime plane with ROI hidden



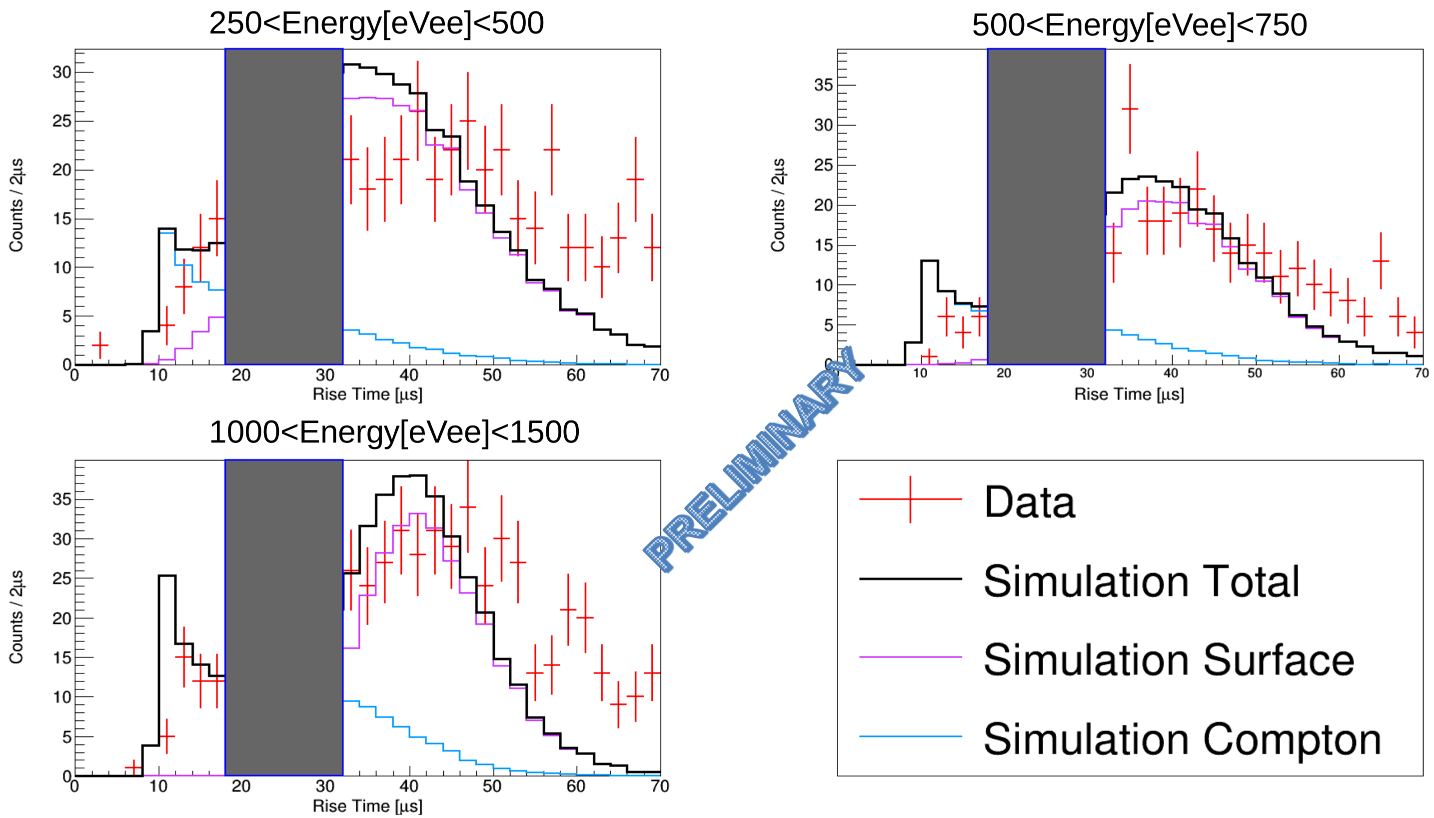
side bands for bckg (surface & Compton) used for preliminary analysis

Sample of a 150eVee pulse



- $E_{thresh} = 150\ eVee$ (trigeff > 90% preliminary) cuteff>85%

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



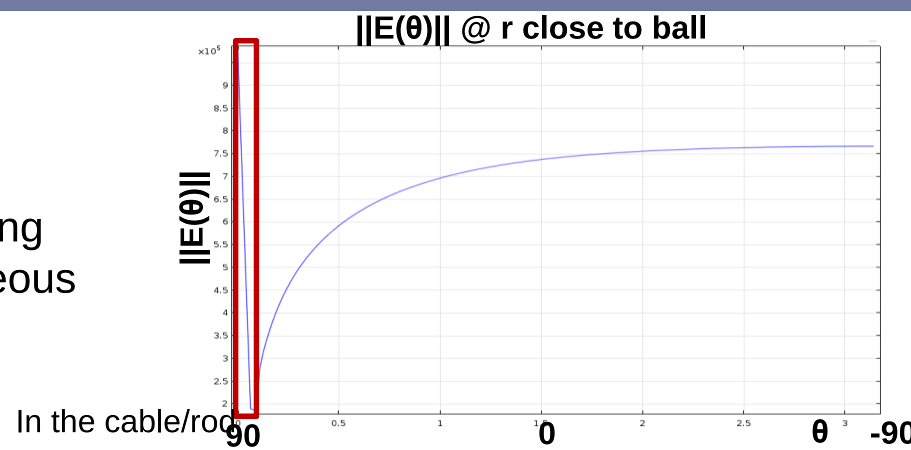
- Ongoing work to fully understand detector response to improve pulse simulation
  - ➢ Long risetime tail in data not reproduced by simulation.
  - ➢ Leakage in energy towards lower amplification region

- Conservative limits on WIMP-nucleon coupling using a Boosted decision tree analysis

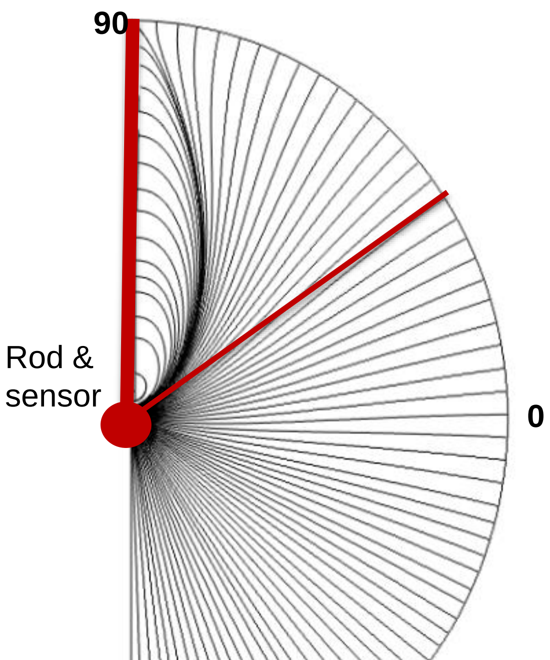
Improvement in simulation & background modeling

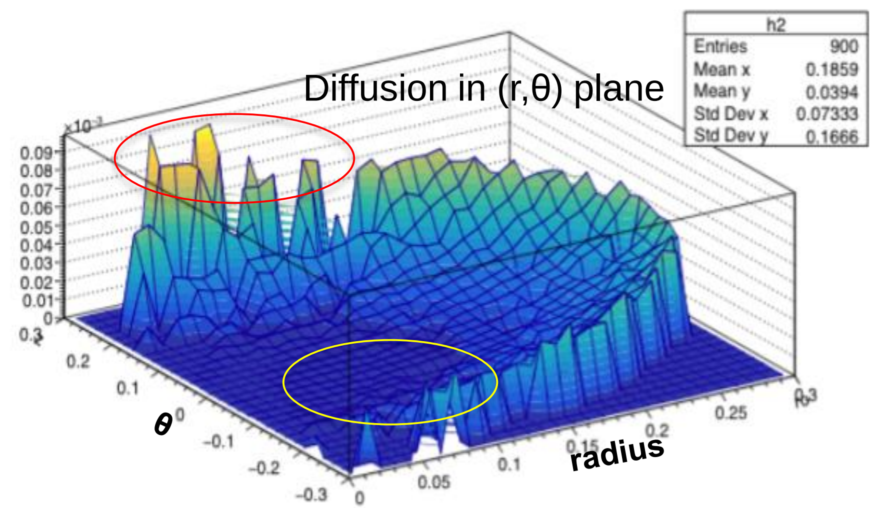
- Field map & simulation of e-/ions transport in real detector set up shows inhomogeneity of E field lines near rod leading to higher RT & lower gain

- 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

Conservative limits on WIMP coupling using a Boosted Decision Tree (BDT) analysis

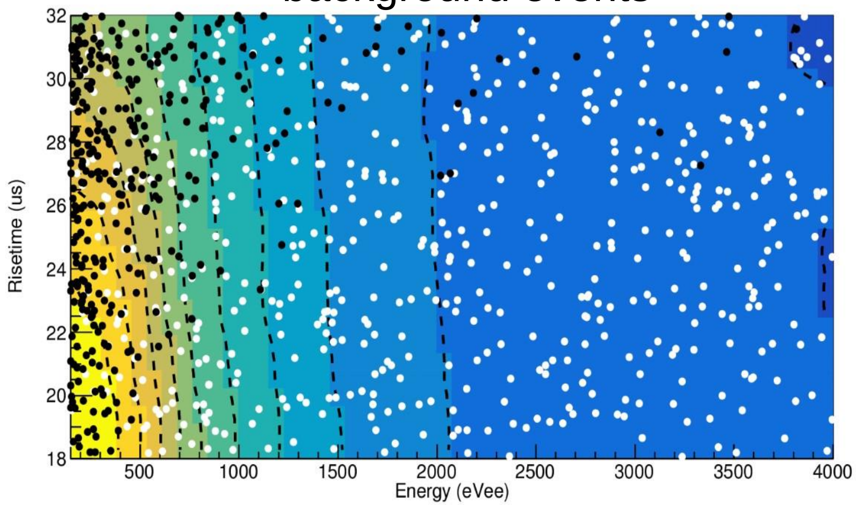
- Set of linear cuts in the multidimensional space (Risetime and Energy) in order to optimize the **signal** / **background** discrimination

- 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) and provides conservative limits

- Poisson limit derived with the remaining events above the BDT optimal cut

PDF of a 7GeV WIMP +background events



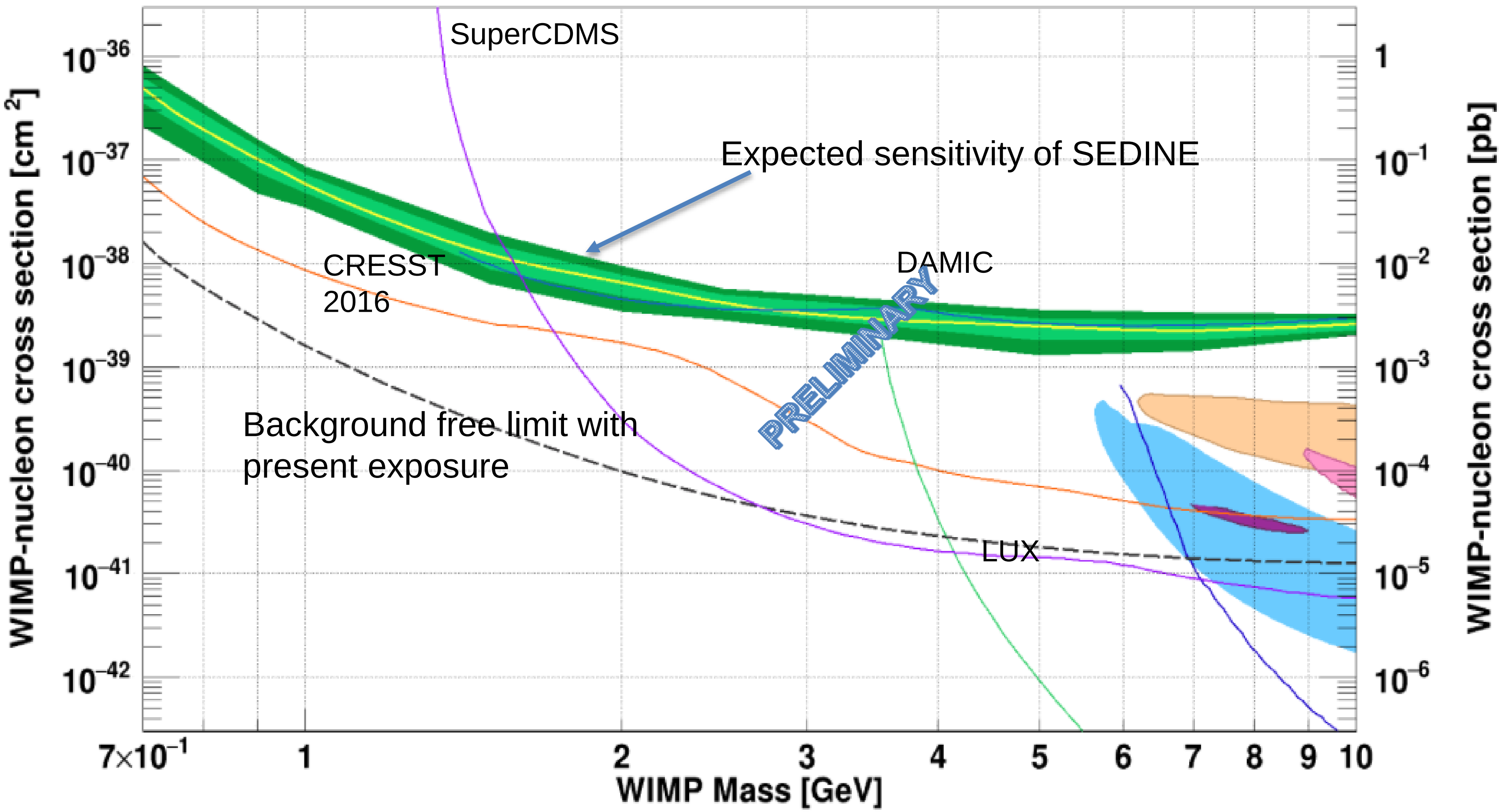
PDF of the signal for a WIMP of 7GeV

● Surface events

○ Compton events

- WIMP spectrum using standard assumption on WIMP velocities, escape velocity and with quenching factor (QF) calculated from SRIM simulation

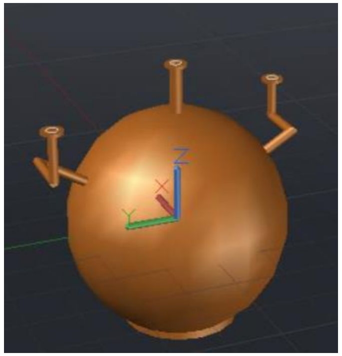
Spin Independent (SI) Limits



- Limits constrained by residual radioactivity

NewS @ SNOLAB

1) Detector design finalized

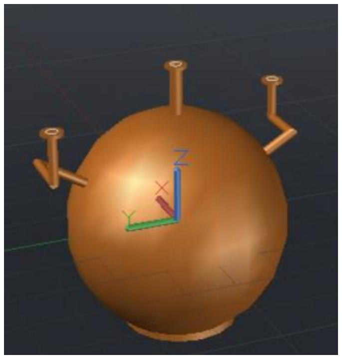


C10100 Cu vessel (140 cm Ø)
filled with 10 bars of He,Ne, Xe

2) Prototype machined & samples sent to PNNL for radioactivity measurements

VewS @ SNOLAB

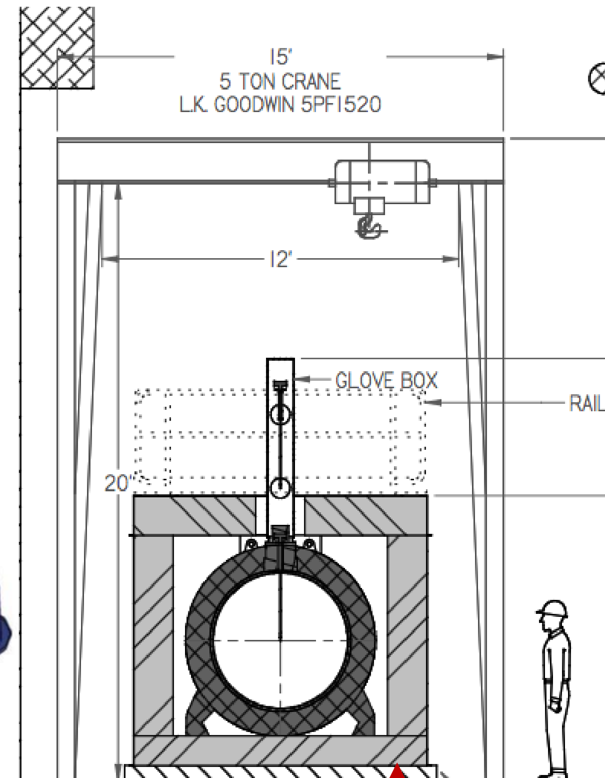
1) Detector design finalized

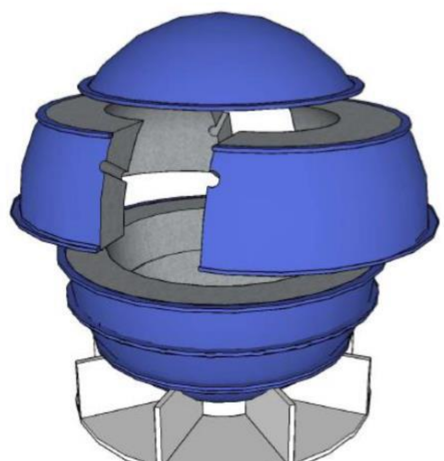


C10100 Cu vessel (140 cm Ø) filled with 10 bars of He,Ne, Xe

2) Prototype machined & samples sent to PNNL for radioactivity measurements

3) Shielding design finalized



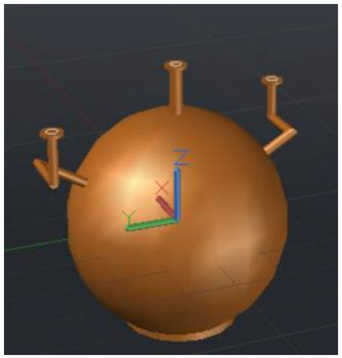


3cm of archeological lead (inner radius) + 22 cm normal lead

40 cm of borated PE shielding surrounding compact lead

NEWS @ SNOLAB

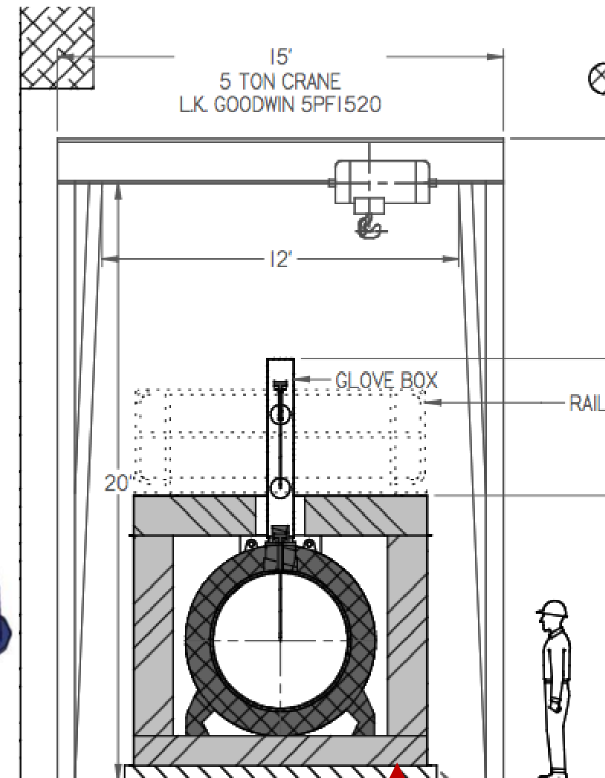
1) Detector design finalized

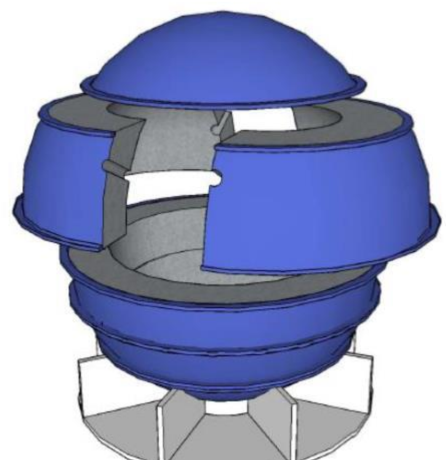


C10100 Cu vessel (140 cm Ø)
filled with 10 bars of He,Ne, Xe

2) Prototype machined & samples sent to PNNL for radioactivity measurements

3) Shielding design finalized

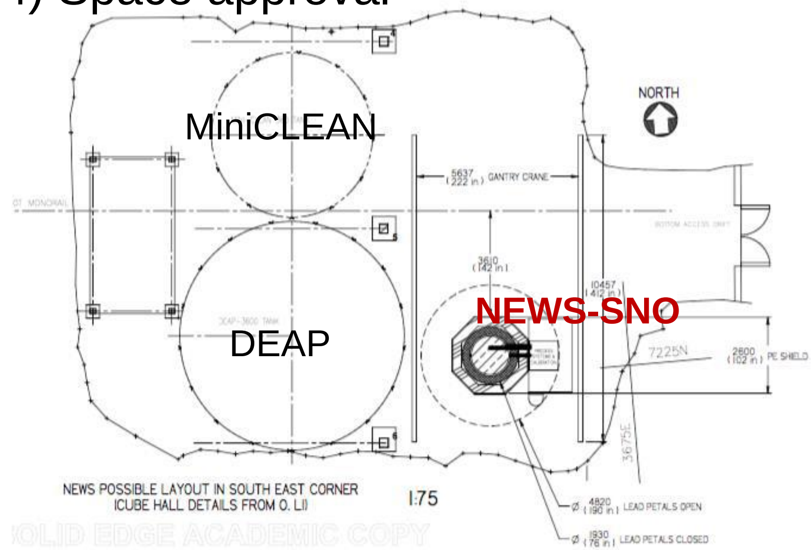




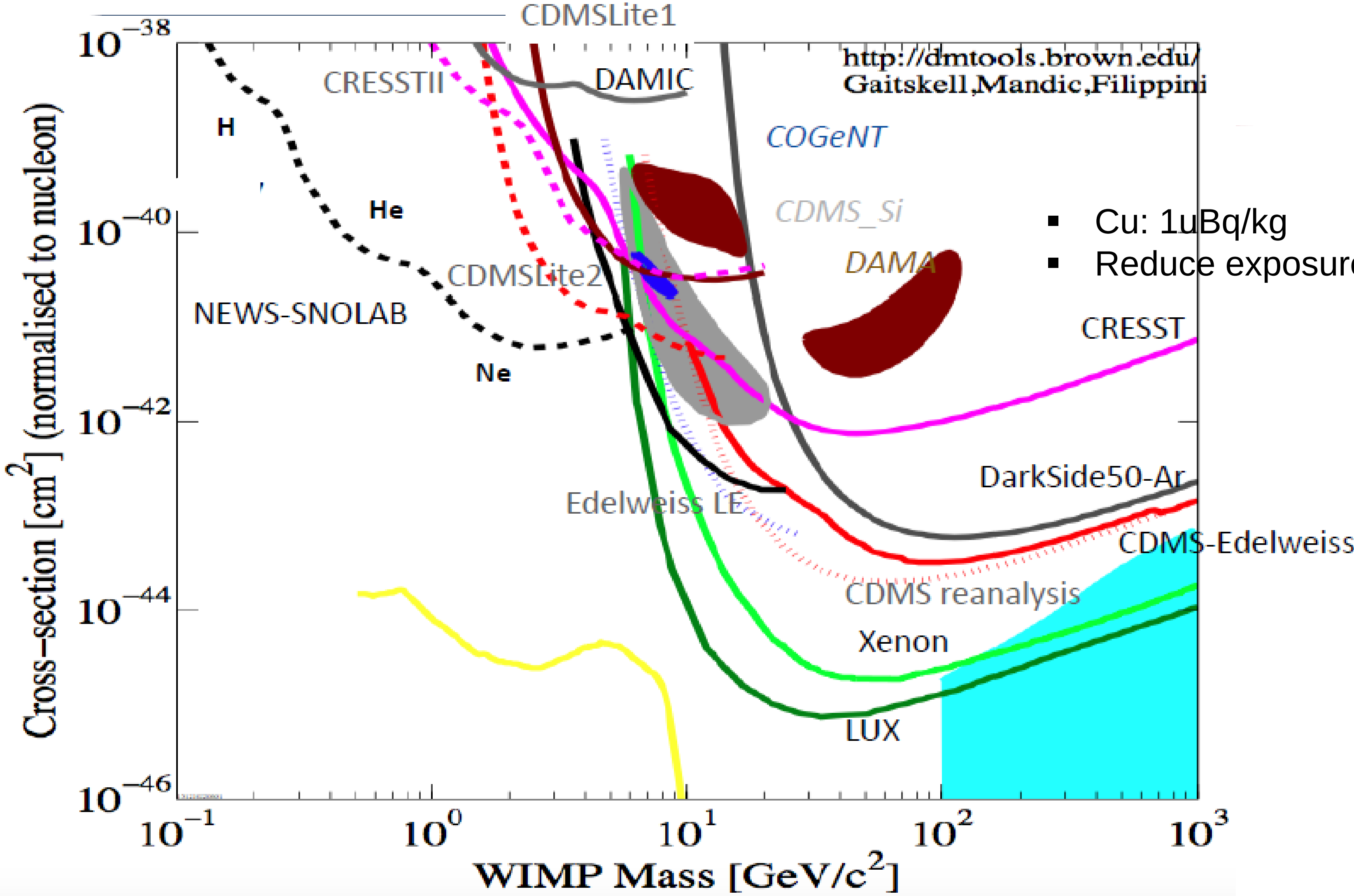
3cm of archeological lead (inner radius)
+ 22 cm normal lead

40 cm of borated PE shielding
surrounding compact lead

4) Space approval



Projected sensitivity (SI) of NEWS@SNOLAB



- Cu: 1uBq/kg
- Reduce exposure to air

R&D Program

Institutions	R&D activities
Queen's University	▪ Single electron response study ▪ Gain stability ▪ Drift time & diffusion measurements ▪ Surface bckg (implanted alpha sources) study ▪ Calibration system and source deployment testing
LSM	▪ Internal surface cleanliness using high pressure water jet ▪ Further data taking with He and H rich gas
Grenoble	▪ QF measurement with ion beams below 1keV
TUM	▪ Gas scintillation properties & Laser studies
PNNL	▪ Plan for electroforming of Cu vessel for future NEWS detector

Conclusion

- 12.6 kgd of data using a 60cm low radioactivity prototype currently being analyzed

- Development of full pulse shape simulation to model background
  - Pulse modeling/simulation using ideal homogeneous E field reproduce reasonably well the data (Calibration + WIMP search)
  - Improving 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 the way to the larger scale detector to be installed at SNOLAB

- SNOLAB space approval, detector vessel and shielding design finalized, construction in few months & installation @SNOLAB scheduled end of 2017

NewS Collaboration

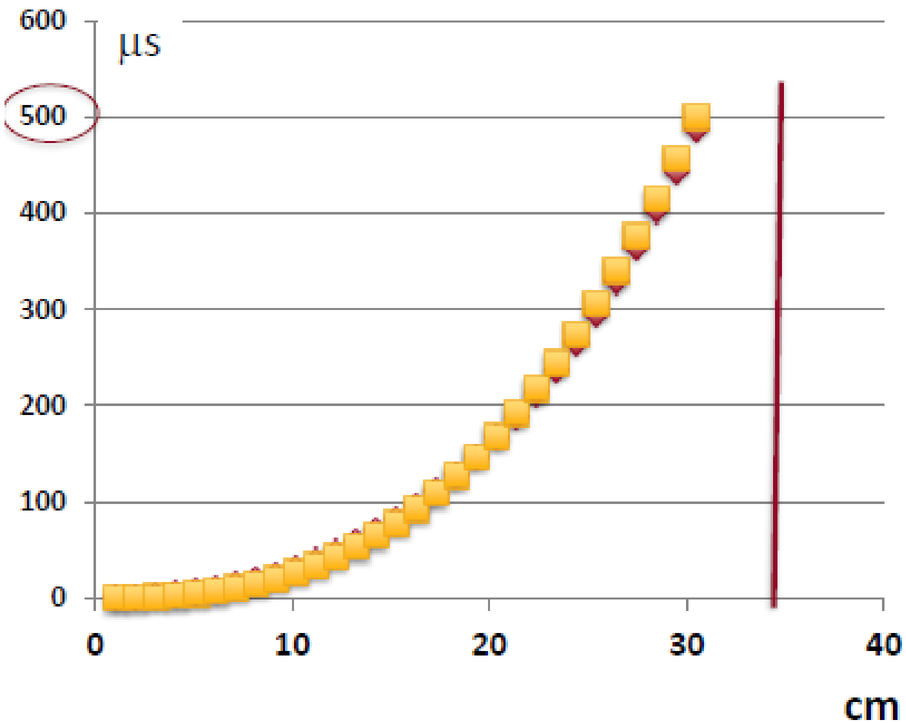
- **Queen's University Kingston** – G Gerbier, P di Stefano, R Martin, T Noble, B Cai, A Brossard, A Kamaha, P Vasquez dS, Q Arnaud, K Dering, J Mc Donald, M Clark, and summer students
  - Copper vessel and gas set-up specifications, calibration, project management
  - Gas characterization, laser calibration, on smaller scale prototype
  - Simulations/Data analysis
- **IRFU** (Institut de Recherches sur les Lois fondamentales de l'Univers)**/CEA Saclay** -I Giomataris, M Gros, C Nones, 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), IN2P3, U of Chambéry **-** F Piquemal, M Zampaolo, A DastgheibiFard
  - Low activity archeological lead
  - 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 (**Laboratoire de Physique Subatomique et Cosmologie) **Grenoble** - D Santos, JF Muraz, O Guillaudin
  - Quenching factor measurements at low energy with ion beams
- **Technical University Munich** – A Ulrich, T Dandl
  - Gas properties, ionization and scintillation process in gaz
- **Pacific National Northwest Lab**– E Hoppe, D Asner
  - Low activity measurements, Copper electroforming
- **Associated lab : TRIUMF** - F Retiere
  - Future R&D on light detection, sensor

June 2016

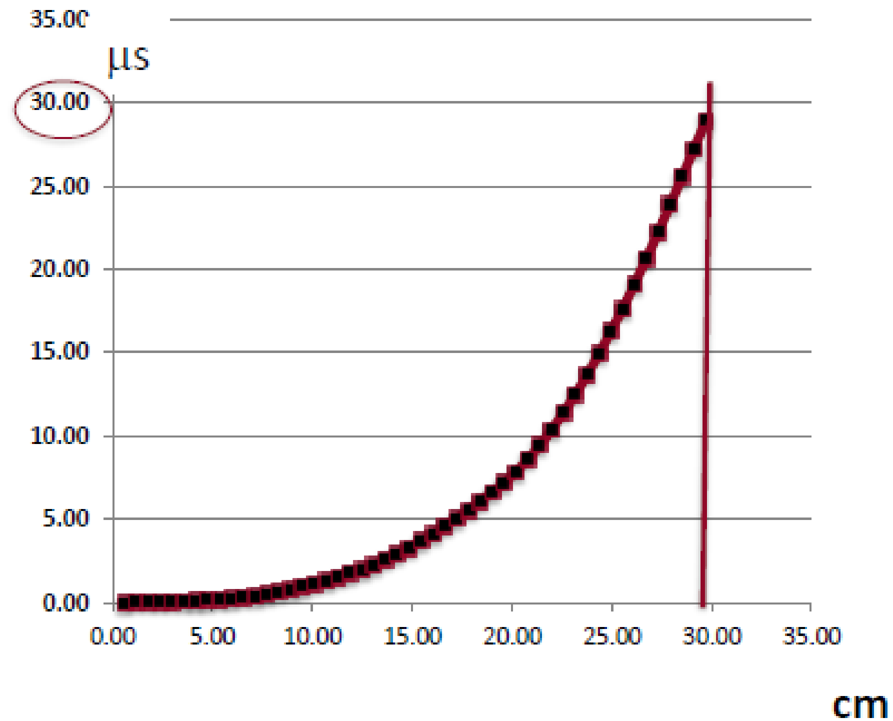
Back up

Drift time and diffusion vs radial position

Drift time vs radius of e deposition



Long diffusion vs radius of e deposition



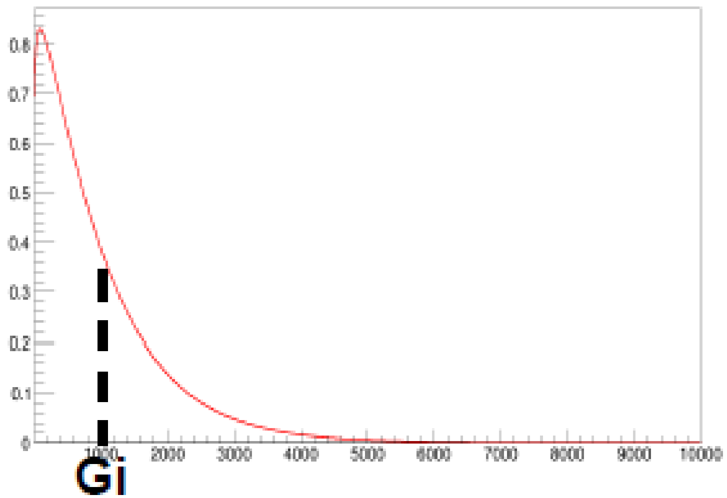
Example of Ne-CH_4 3 b for 60 cm diameter SEDINE

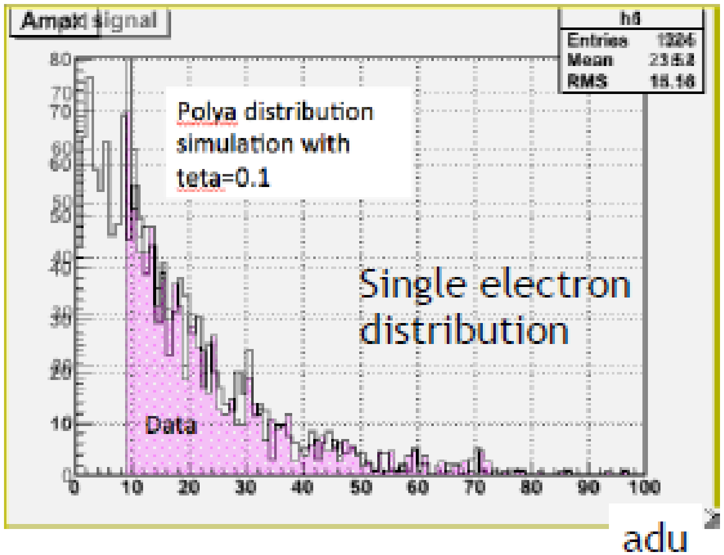
=> Discrimination track/point like if Deltatrift induced by length of track > diffusion

Pulse formation: avalanche

- Gain follows polya distribution

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





UV lamp calibration data

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

Boosted Decision Tree (BDT) analysis

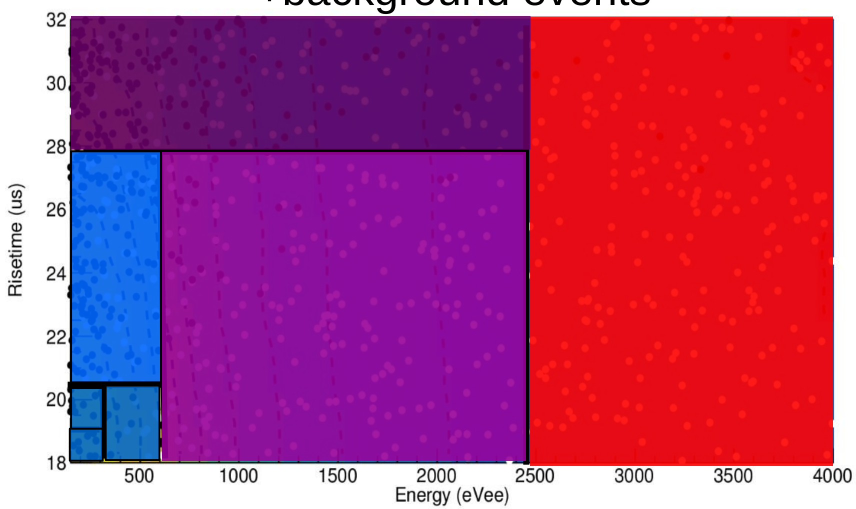
- Set of linear cuts in the multidimensional space (Risetime and Energy) in order to optimize the **signal** / **background** discrimination

- 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

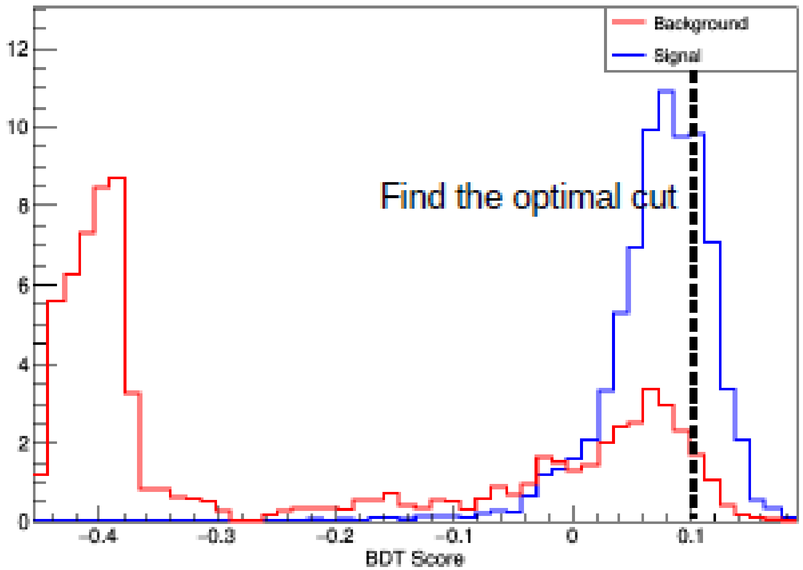
- Poisson limit derived with the remaining events above the BDT optimal cut

PDF of a 7GeV WIMP +background events



Background like : low BDT Score

Signal like : high BDT Score



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

Background budget (simulation) for NEWS @ SNOLAB

Radioactive background budget	Goal / estimation / measurement	Rate Ne ev/kg.keV.d in 0-1 keV in Neon 10b	Relative weight %	Rate He ev/kg.keV.d in 0-1 keV for He/CH4-90/10	Relative weight %	Rate H ev/kg.keV.d in 0-1 keV for He/CH4-90/10	Relative weight %
U Copper	1 µBq/kg	0,006	5,4	*0,006*	*5,9*	*0,055*	*5,9*
Th Copper	1 µBq/kg	0,004	4,0	*0,004*	*4,4*	*0,041*	*4,4*
Co60 Copper	30 µBq/kg integrated exposure to CR	0,046	45,3	*0,046*	*49,1*	*0,460*	*49,1*
External radiation from rock	208Tl and 40K flux underground	0,006	5,9	*0,002*	*2,1*	*0,020*	*2,1*
U/Th from shield	U/Th in low activ 22 cm Pb	0,025	24,6	*0,001*	*1,1*	*0,010*	*1,1*
Radon in gas	Rn emanation within sphere/pipes/ valve (0.3 mBq)	0,005	4,9	*0,005*	*5,3*	*0,050*	*5,3*
Rod/sensor	Max 0.01 mBq	0,005	4,9	*0,005*	*5,3*	*0,050*	*5,3*
Pb210 Surface	Max exposure= 2 Bq/m3*h	0,005	4,9	*0,025*	*26,7*	*0,250*	*26,7*
Total	dru	**0,102**	100,0	*0,094*	*100,0*	***0,936***	*100,0*
Nb evts in 0.2 keV	in 100 kg.d	**2,032**		***1,872***		***18,724***	

Run with Ar/CH_4 + 3g ^3He @ 200 mb SPC 130cm Ø @ LSM