Quentin ARNAUD

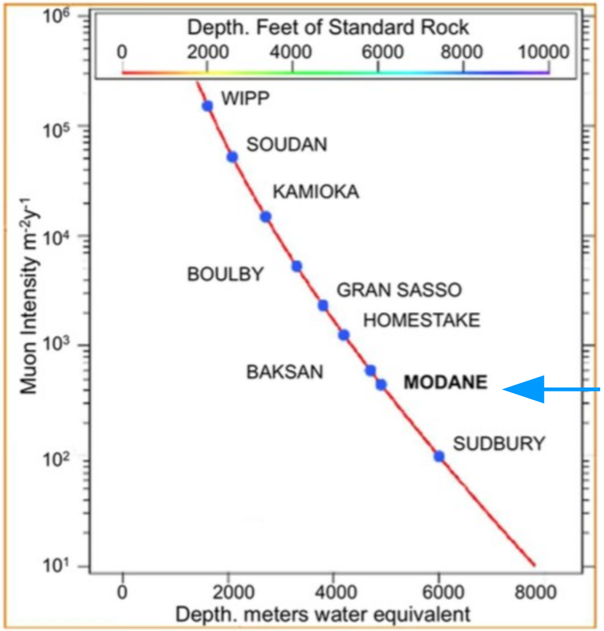
First results from the NEWS-G direct dark matter search experiment

CAP Conference, Kingston, ON

28/05/2017

New **E**xperiment **W**ith **S**pheres **- G**as

NEWS-G @ LSM - Experimental Setup



surface

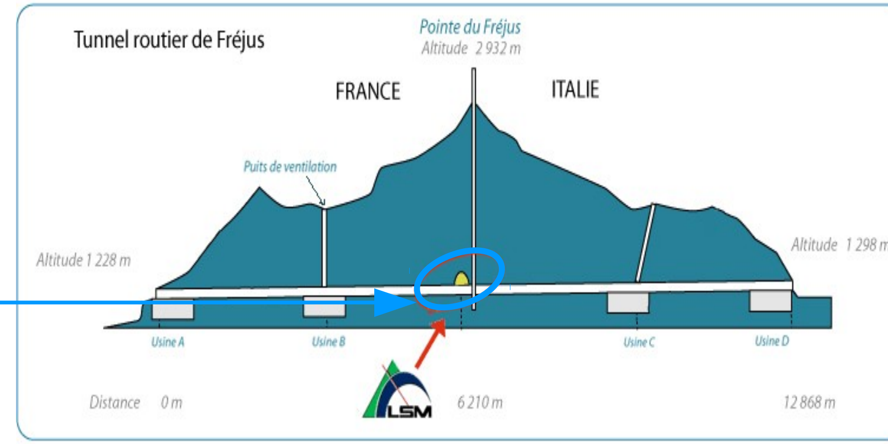
$10^6\ \mu/m^2/day$

Muon flux

4800 mwe

$5\ \mu/m^2/day$

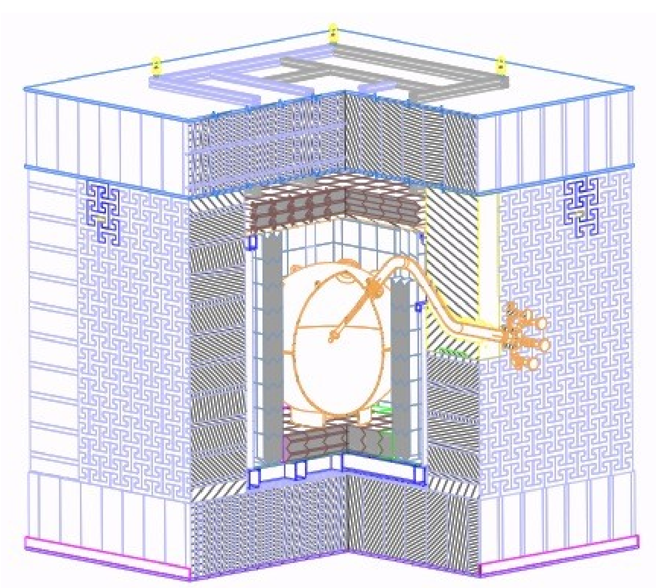
Laboratore Souterrain de Modane



Data taking conditions

9.7 kg.days of exposure with **Neon**+0.7 % **CH_4** @ **3.1 bars**

~280 g target mass, operated for **42.7 days** in **sealed mode**

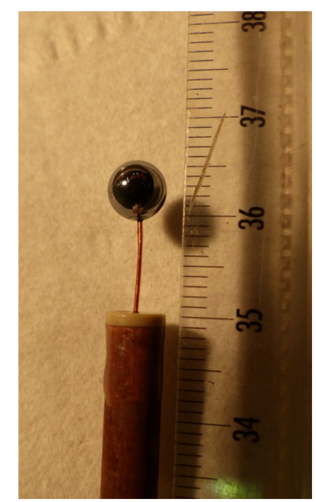


Shieldings

30 cm PE, **10-15 cm Pb**, [**3-8**] **cm Cu**

Vessel

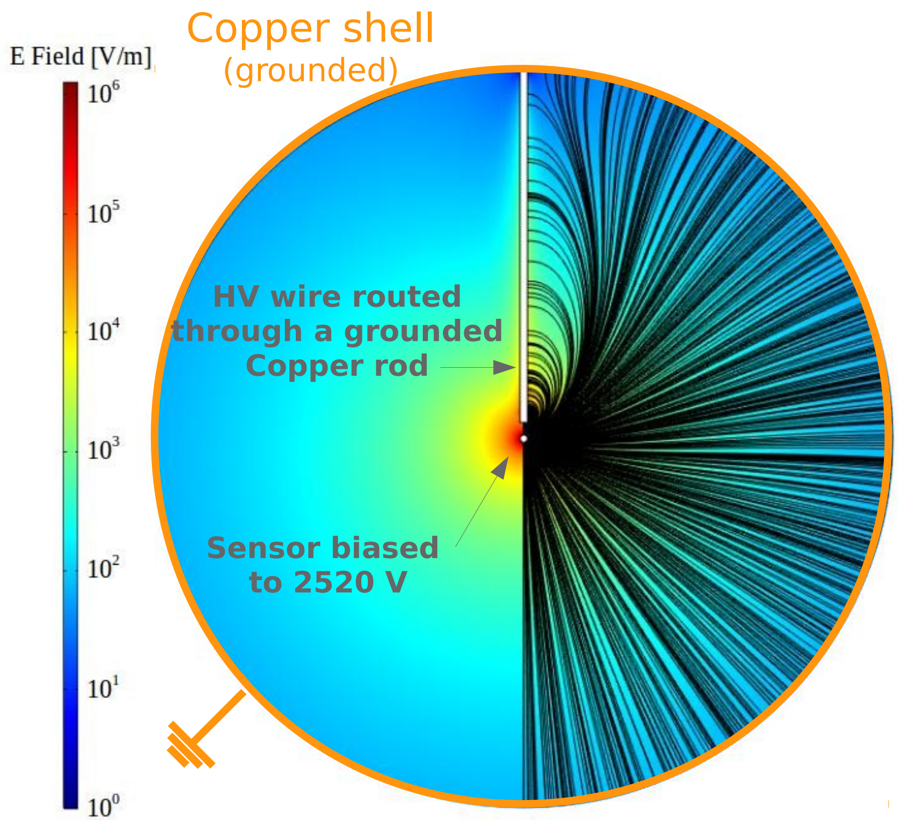
60 cm Ø NOSV Copper



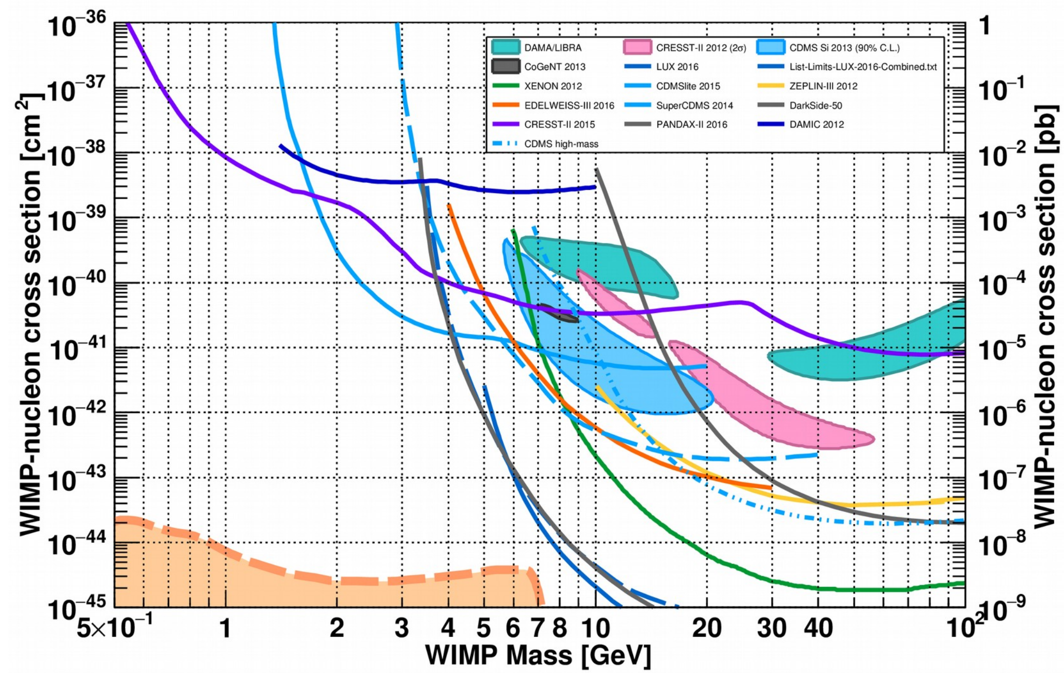
Sensor

6.3 mm Ø

Designed for low-mass WIMP search



search for low-mass WIMPs



with Spherical Proportional Counters

Low threshold 10-40 eVee

High amplification gain arising from

$$E(r) \propto \frac{1}{r^2}$$

And Low Capacitance

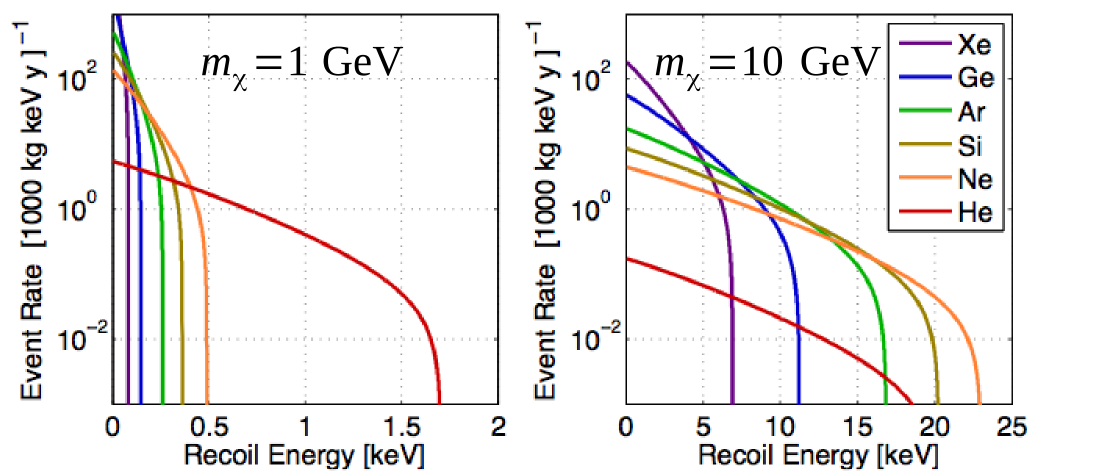
(doesn't depend on the size of the sphere)

$$C = \frac{4\pi\epsilon}{\left(\frac{1}{r_{sensor}} + \frac{1}{r_{vessel}}\right)} \approx 4\pi\epsilon r_{sensor} \approx 0.35\,\text{pF}$$

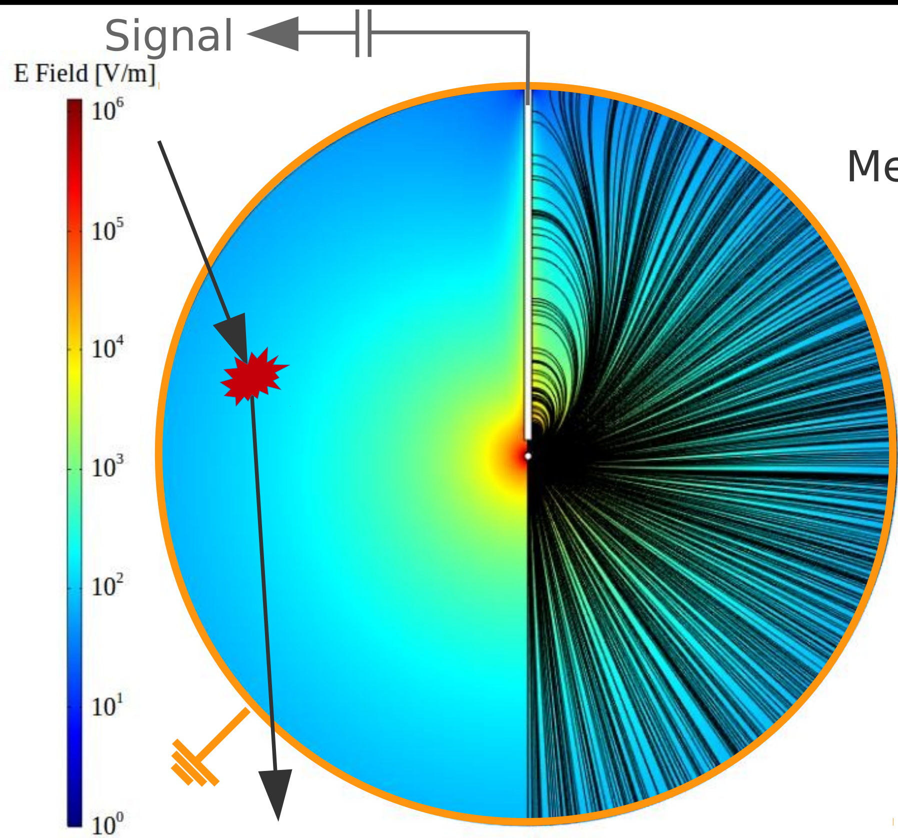
sensitivity to single electrons

Light Targets

Optimization of momentum transfers for low-mass particles



Operating Principle & Pulse Treatment



Primary Ionisation

Mean number of primary electrons created : $<N> = \frac{E_R}{\epsilon_j}$

With Neon : $\epsilon_\gamma = 36$ eV $\qquad \epsilon_n = \frac{\epsilon_\gamma}{Q(E_R)} \approx 5\,\epsilon_\gamma$

Drift of the electrons toward the sensor

Typical drift time surface → sensor : ~500 µs

Avalanche Process

Each primary electron leads to thousands of secondary ionisations

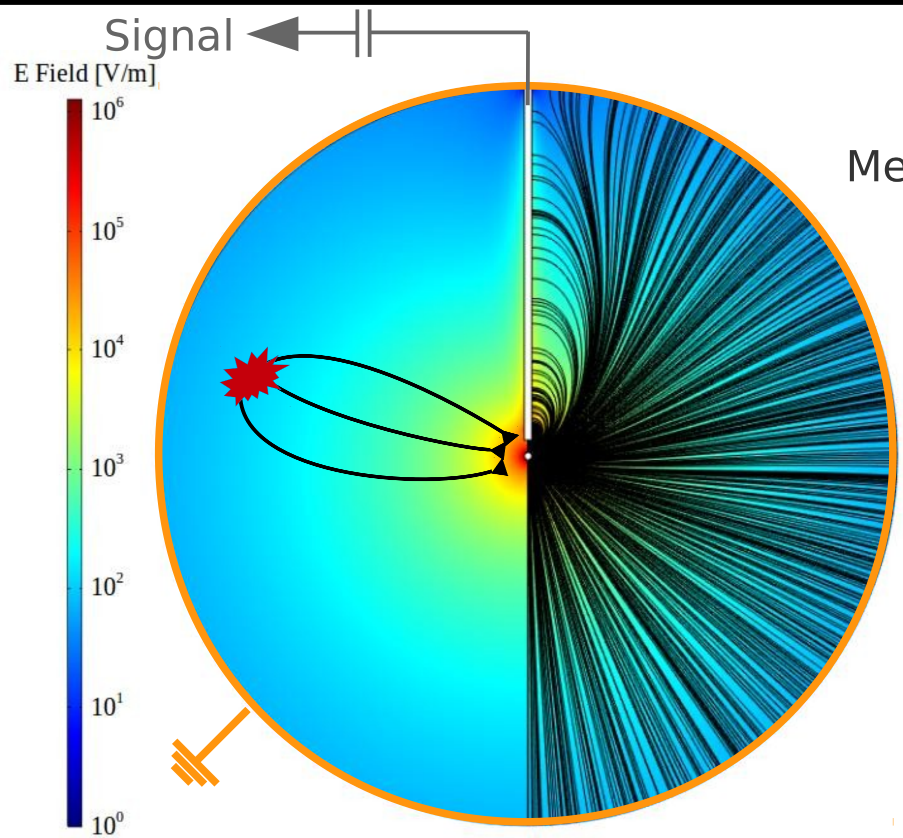
Signal Formation

Current induced by Secondary ions

Signal Read out

Induced current integrated by a resistive feedback charge sensitive pre-amplifier CAMBERRA (RC=50 µs) and digitized at 2.08 MHz

Operating Principle & Pulse Treatment



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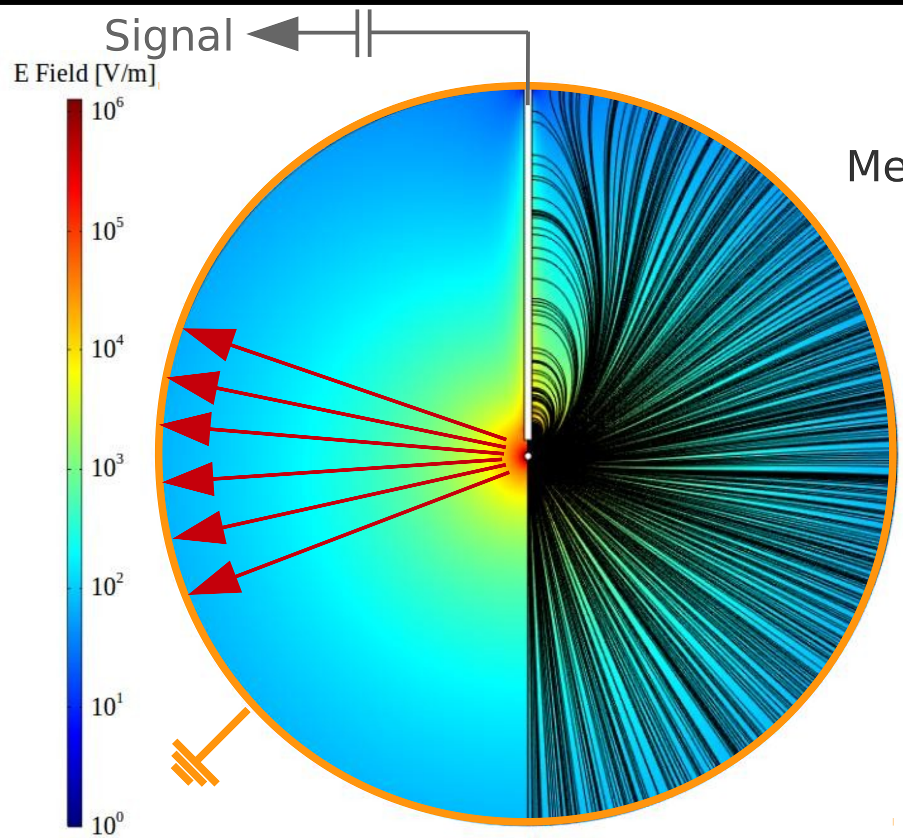

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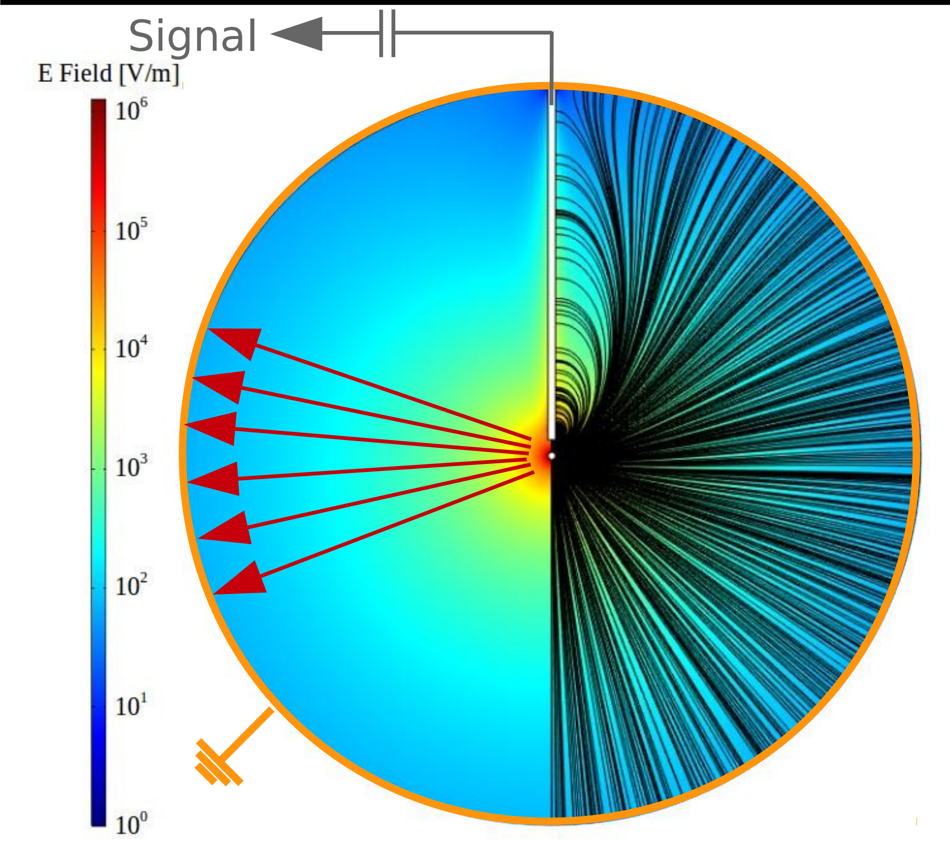

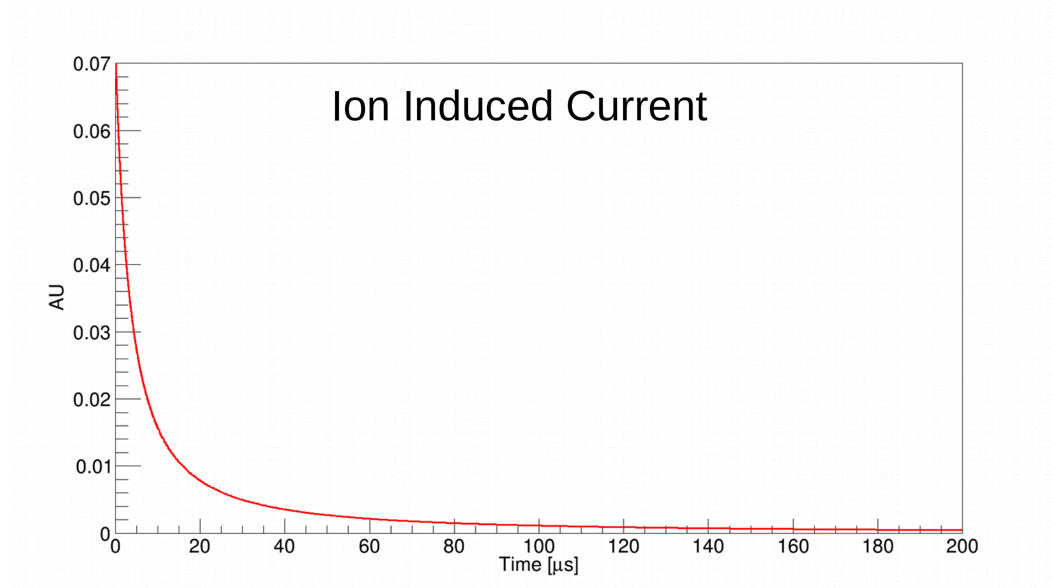

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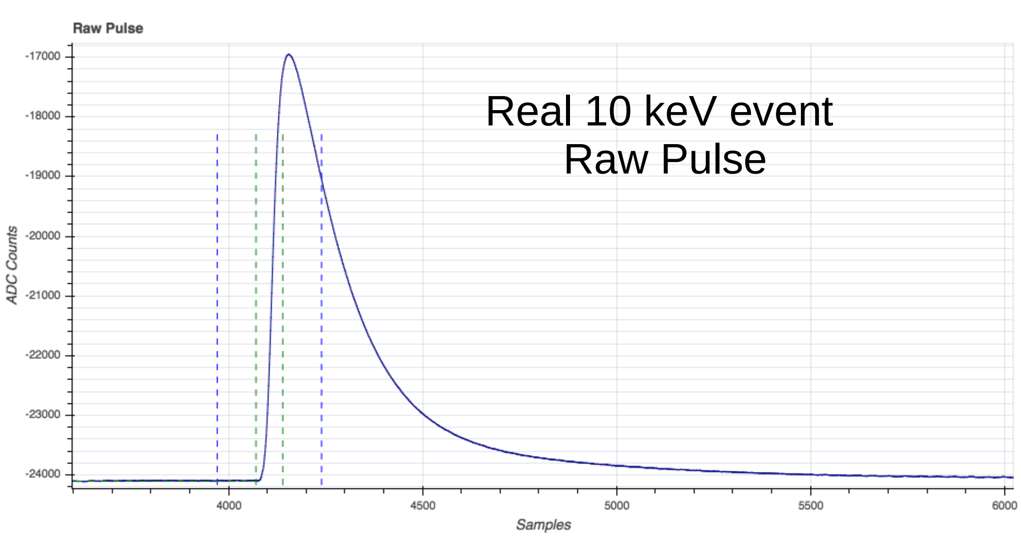

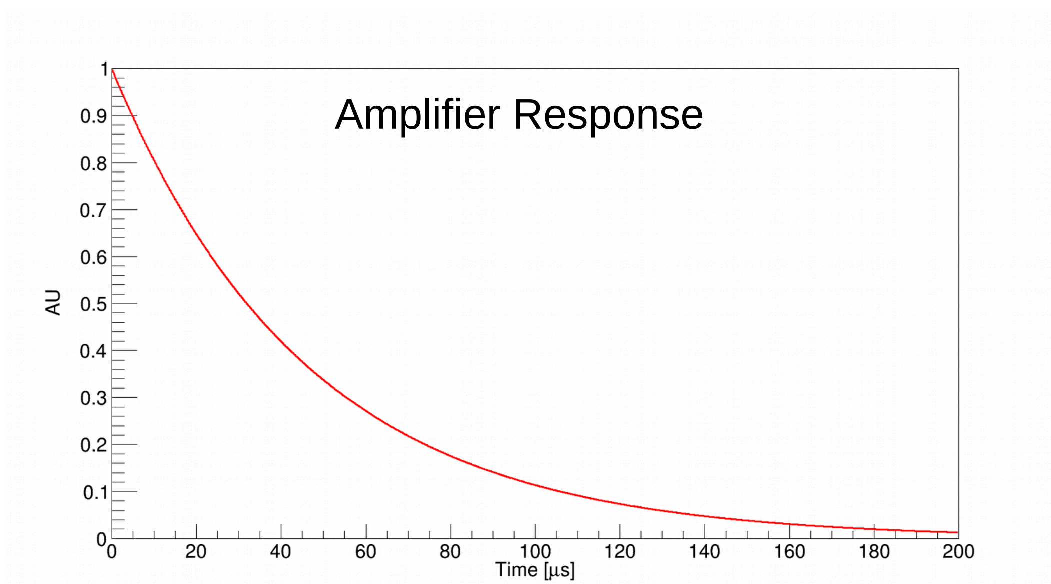

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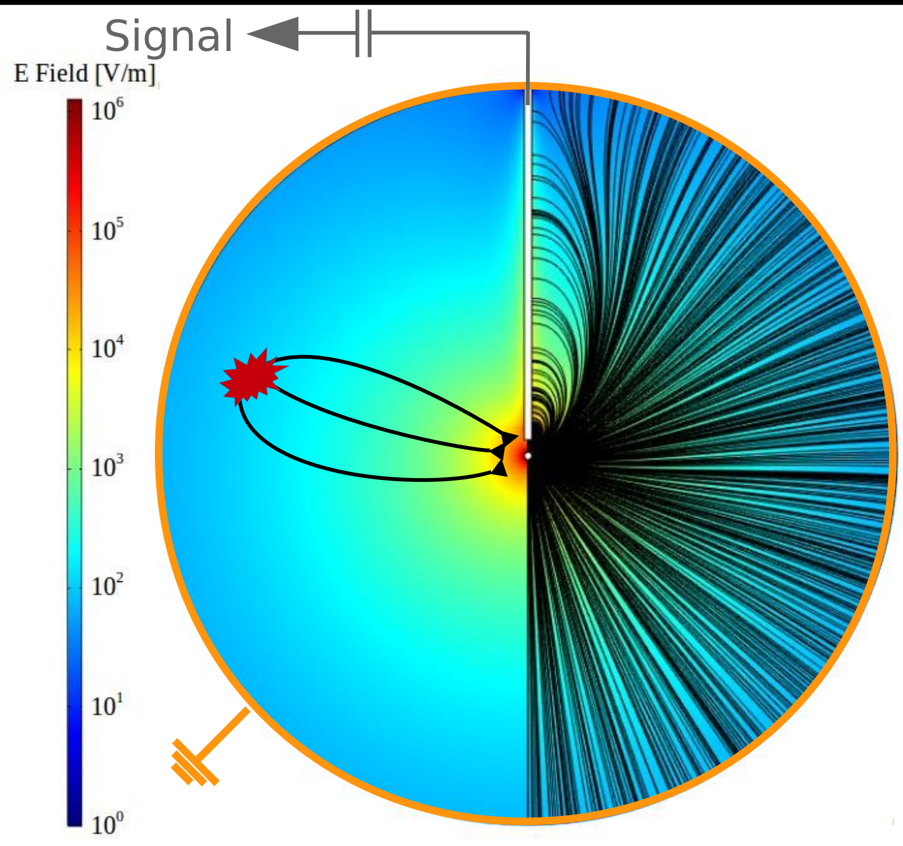


Drift of the electrons toward the sensor

Typical drift time surface → sensor

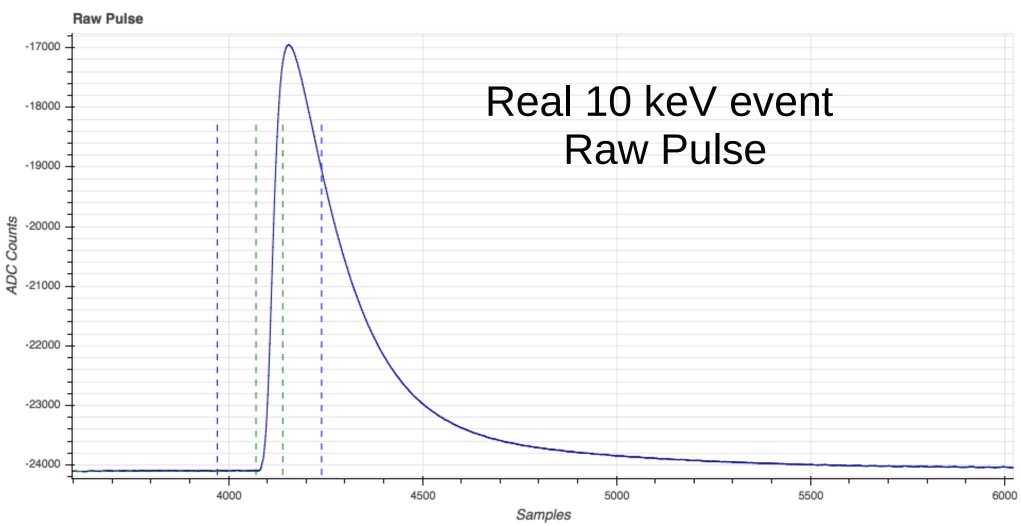
(500 ± 20) µs

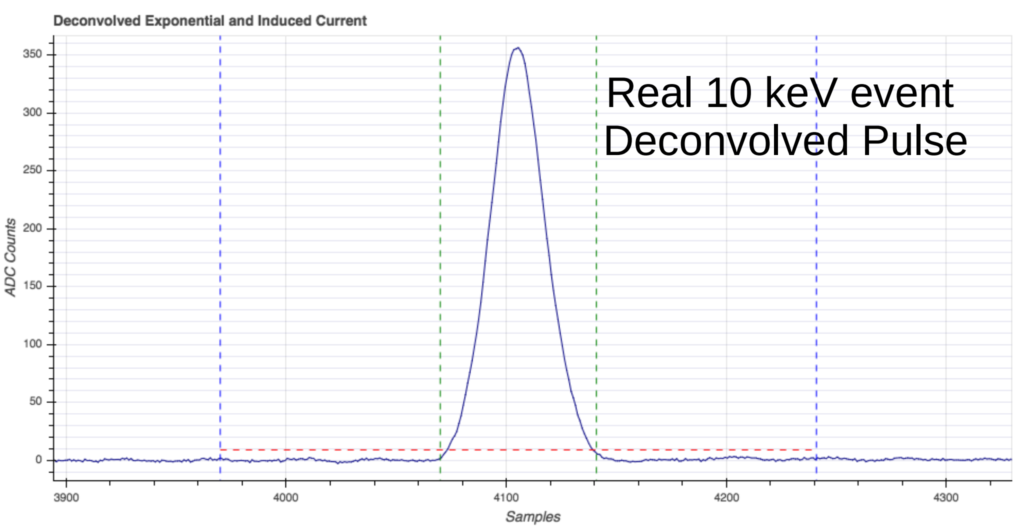
Gaussian dispersion in the arrival time of the primary electrons due to diffusion

whose standard deviation increases with the radial location of the event

$$\sigma(\boldsymbol{r}) = \left(\frac{\boldsymbol{r}}{r_{sphere}}\right)^3 \times\ 20\mu s$$

Fiducialisation





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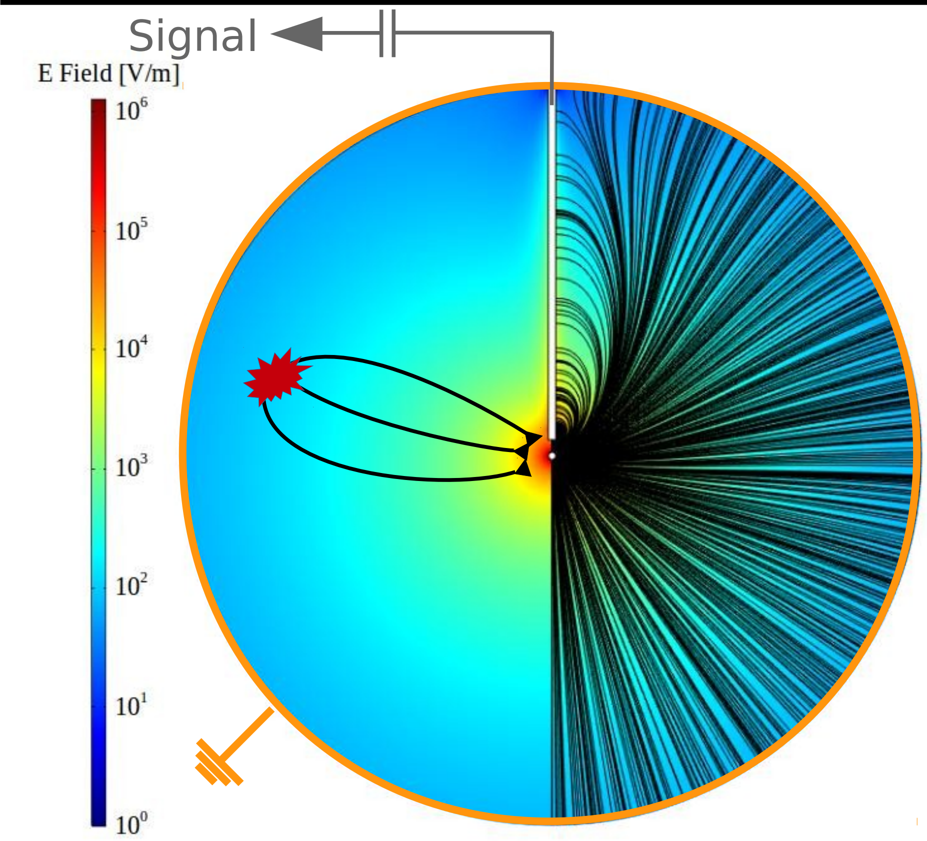
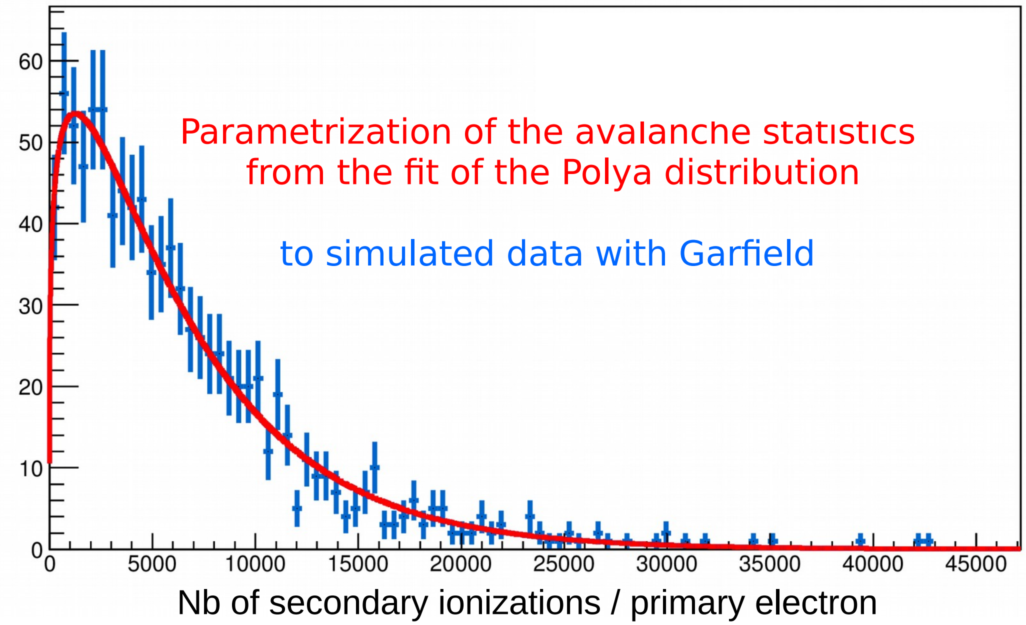
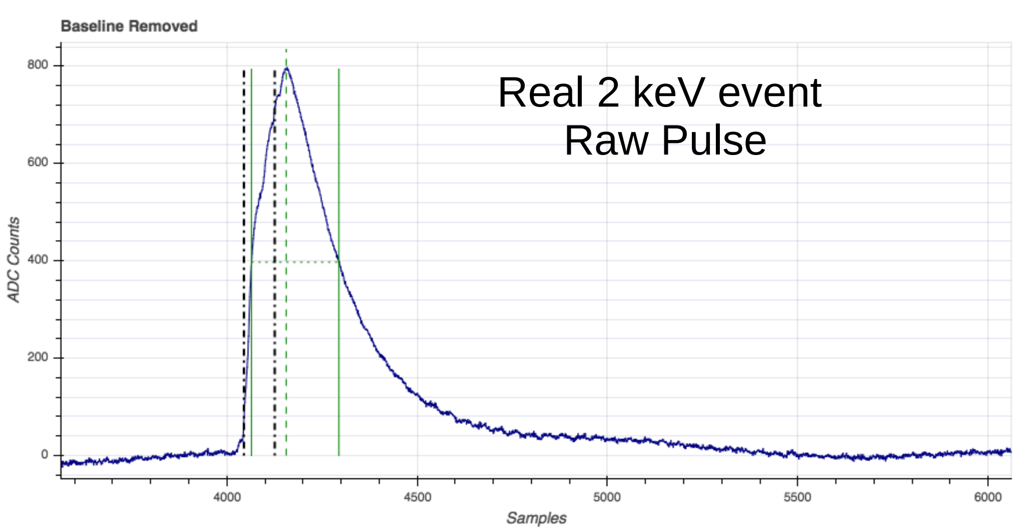
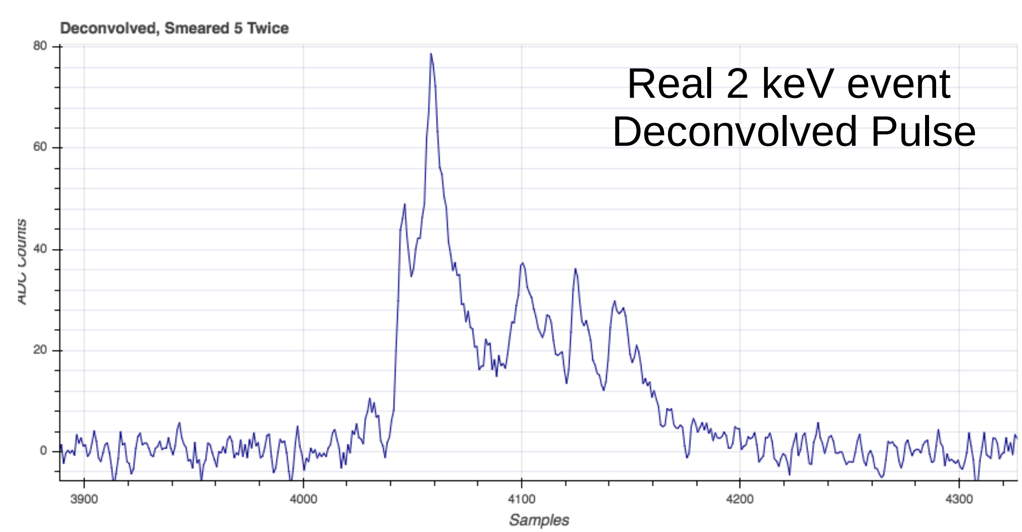


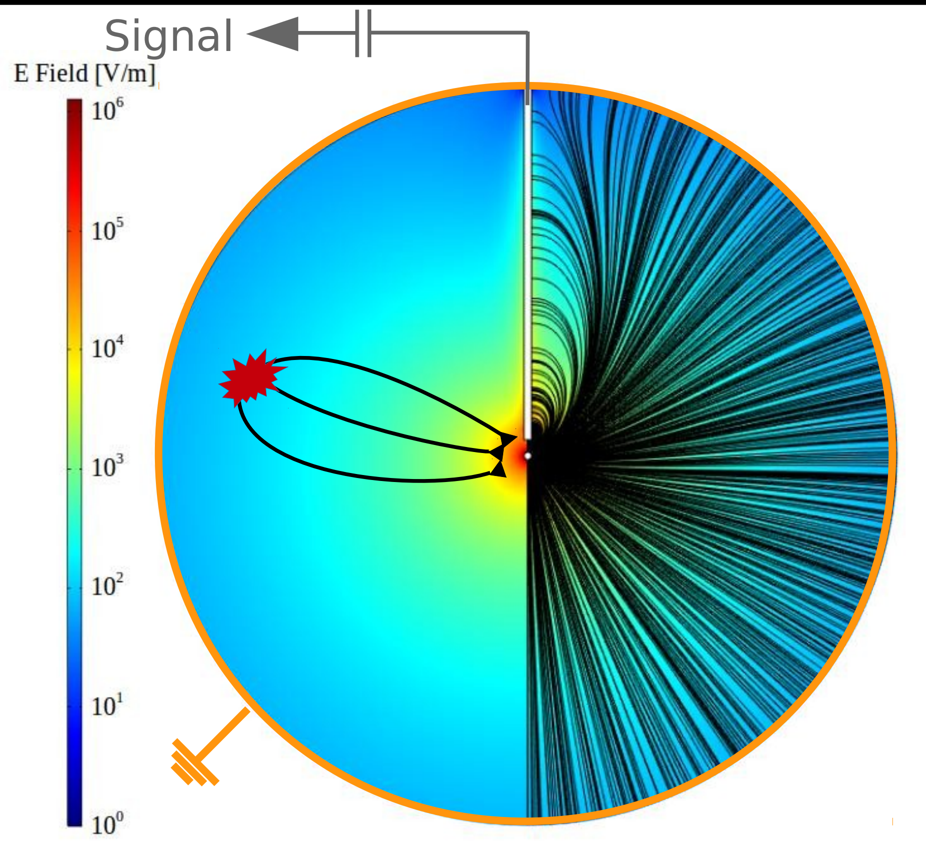
Avalanche Process

Each PE → <N> ~ 7000 secondary ionisations



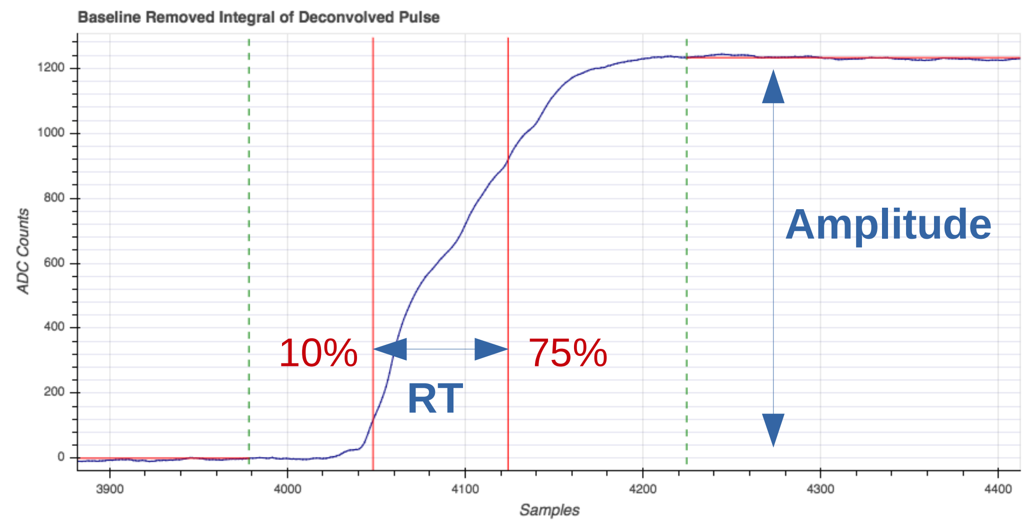


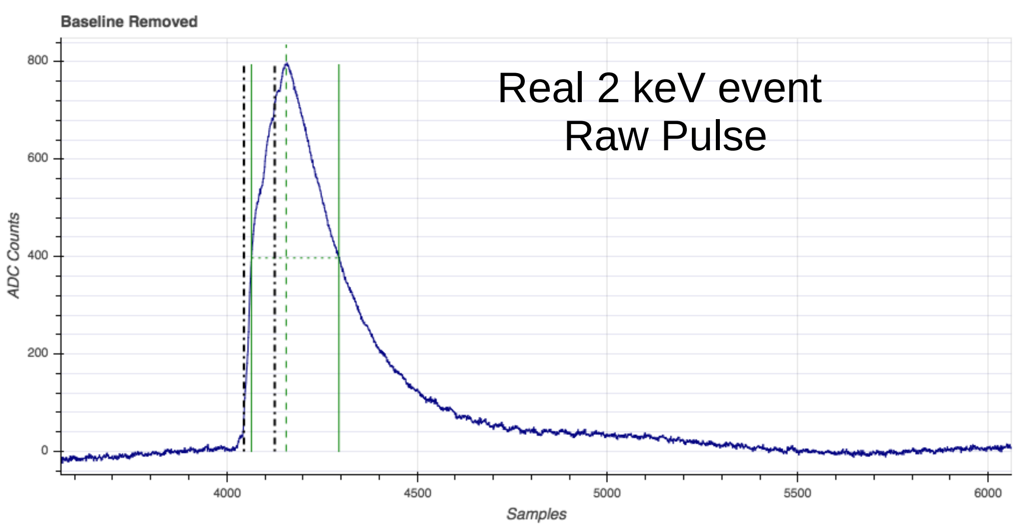


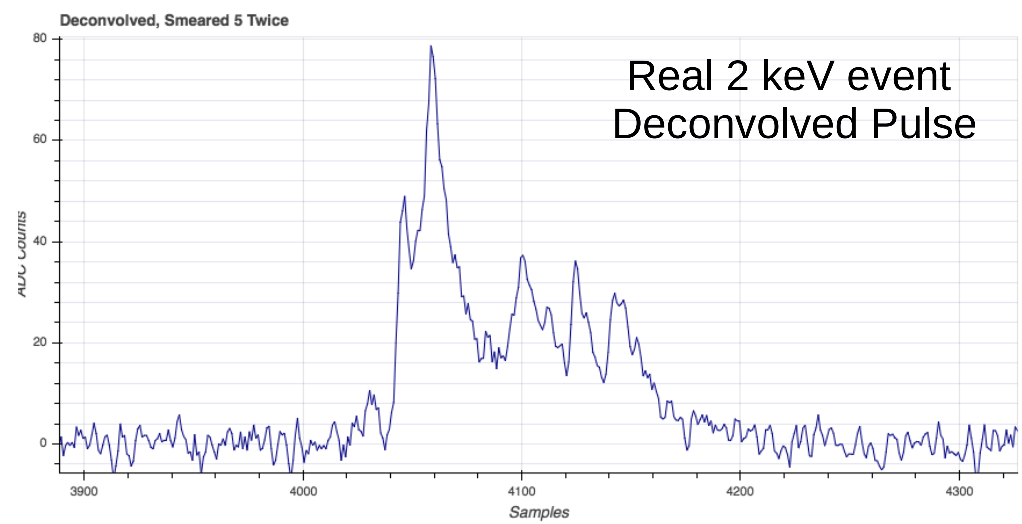


Energy and Diffusion Estimators

Real 2 keV event
Cumulative integration of the deconvolved pulse

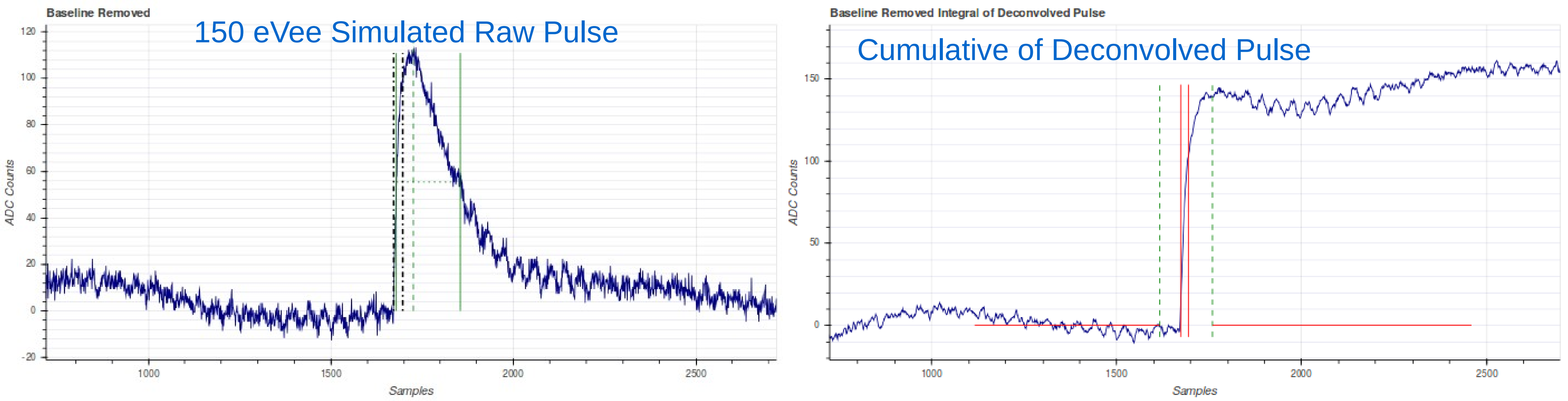




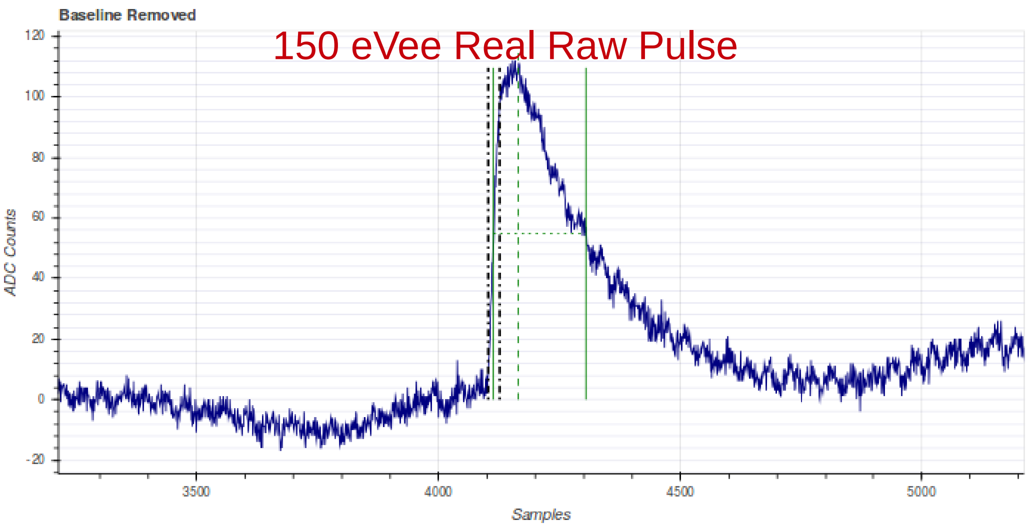


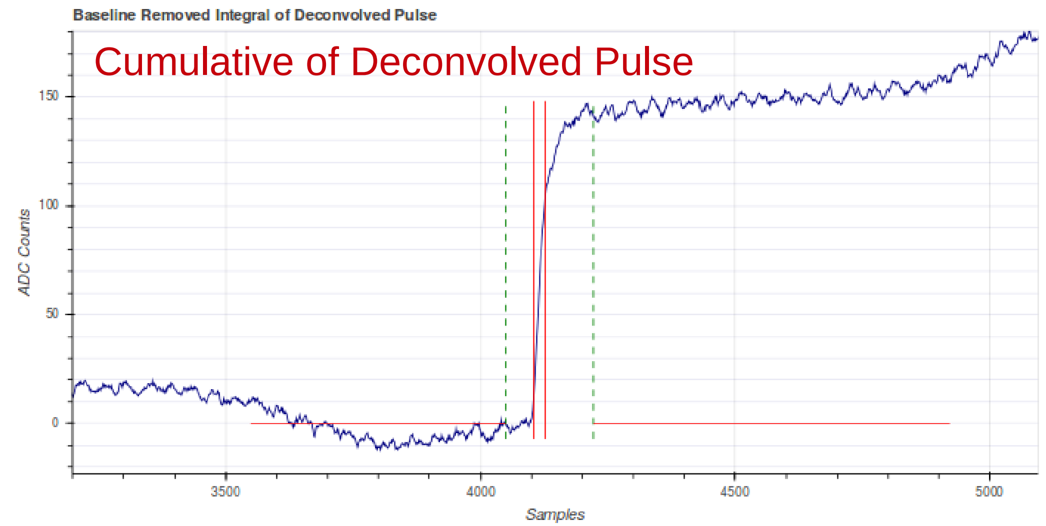
Simulations

- Field map computed with COMSOL
- Quenching parametrization $Q(E_R)$ derived from SRIM (Stopping and Range of Ions in Matter)
- Primary electrons are individually drifted using drift parameters from Magboltz
- Number of secondary electrons drawn from the Polya distribution (parametrized with Garfield)
- Simulated pulses : (Ion Induced current **X** Amplifier response)
- Noise templates taken from the pretraces of real pulses
- Same trigger algorithm and processing than for real pulses

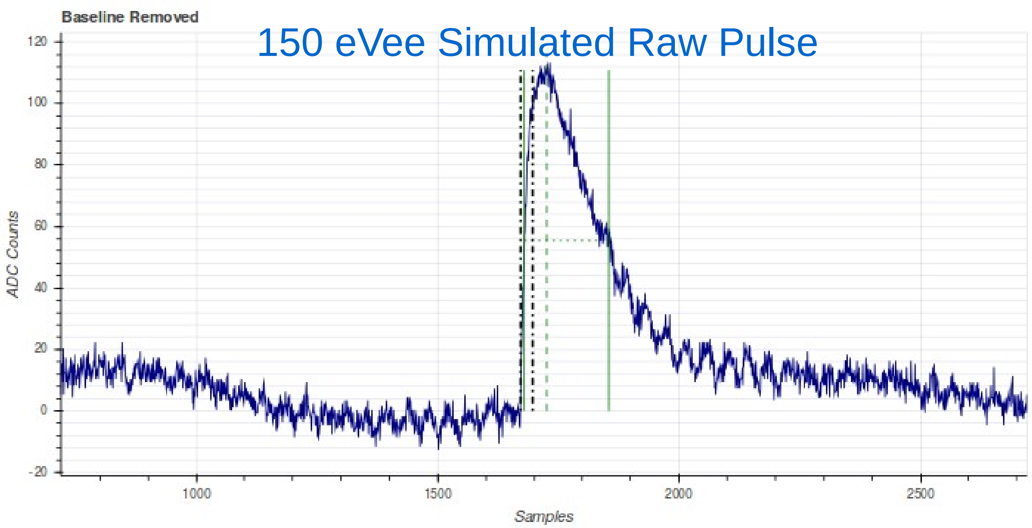


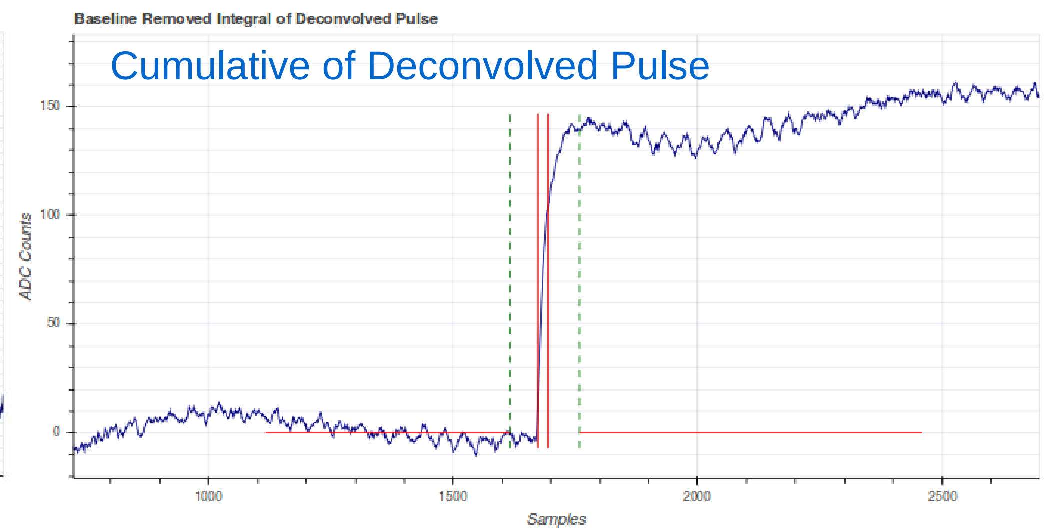
Data





Simulation

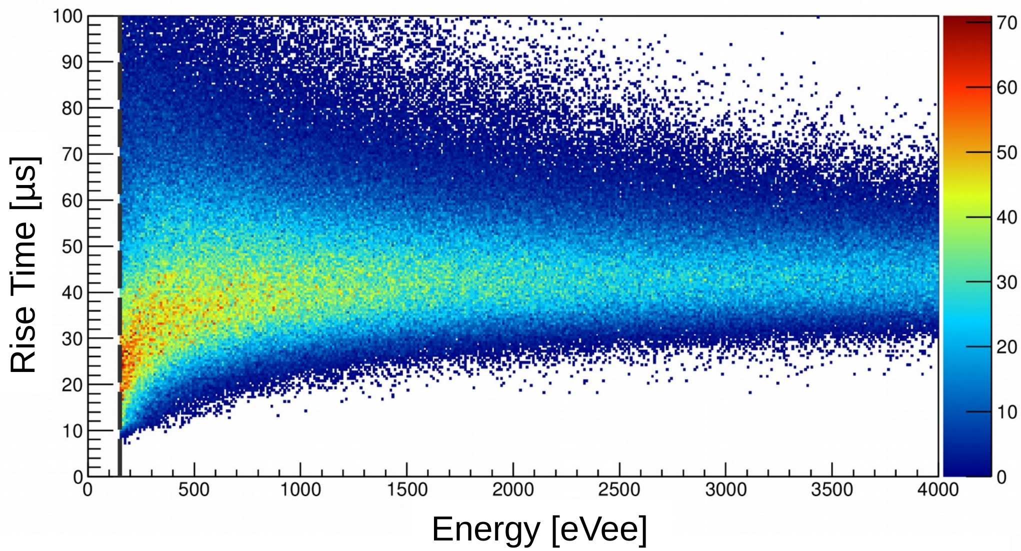




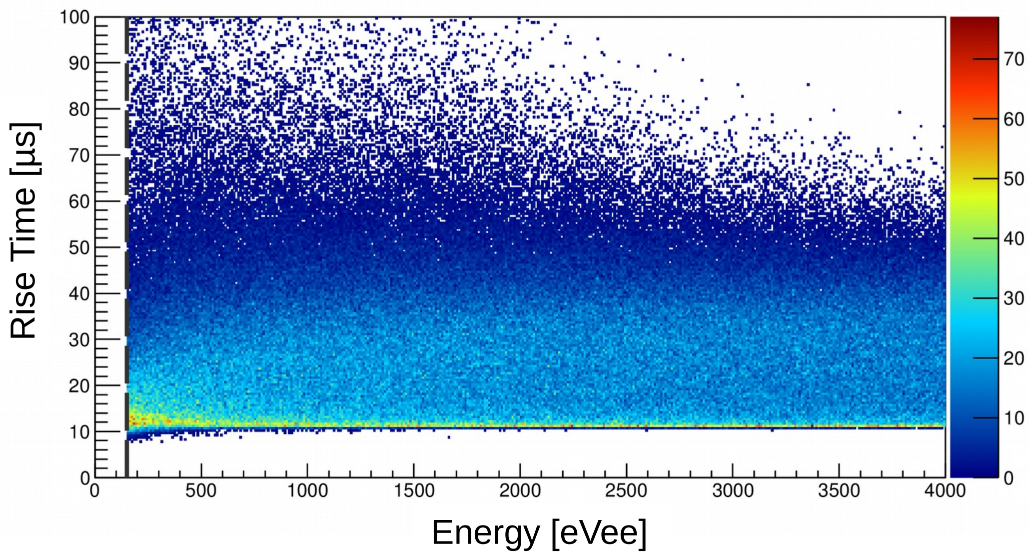
Physics-run data analysis

Simulations

Surface events



Volume events



Physics-run Data

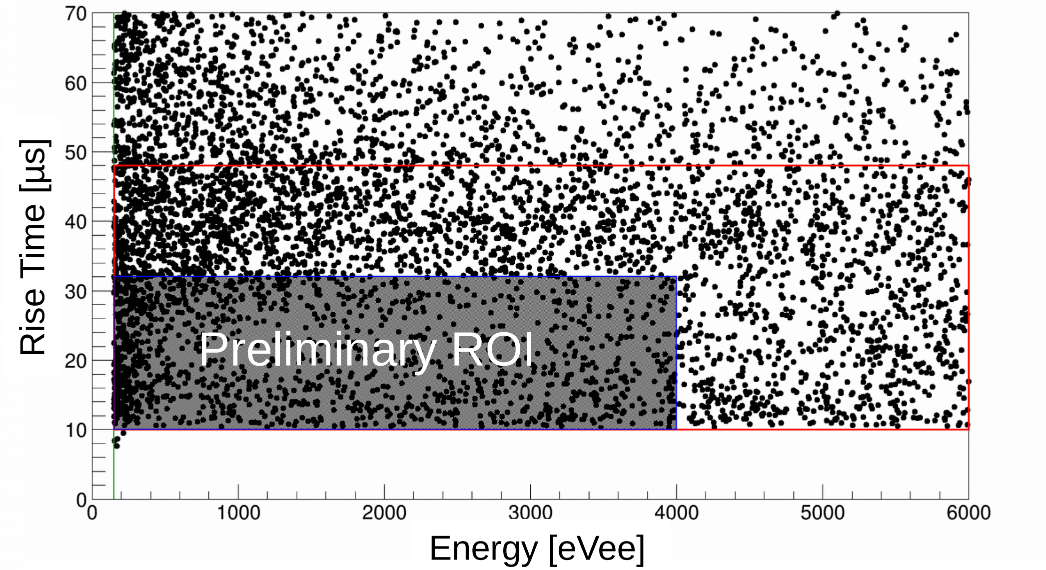
Quality cuts responsible for 20.1 % dead time

Total exposure = 34.1 live-days x 0.28 kg = **9.7 kg.days**

Analysis threshold : 150 eVee (~720 eVnr)

100% trigger efficiency (trigger threshold @ ~35 eVee)

WIMP search run



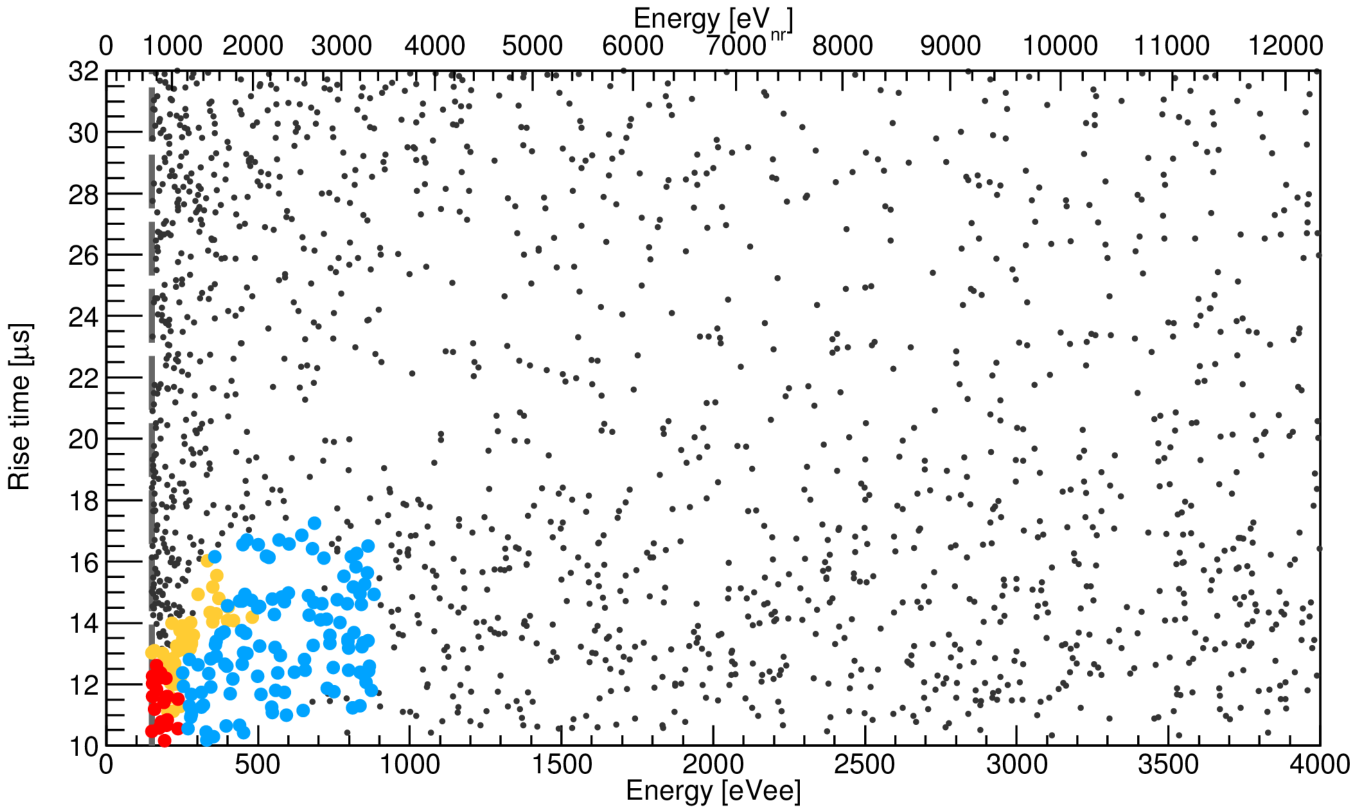
Side Band region used together with simulations to determine the number and distribution of background events expected in the **preliminary ROI**

Further tuning of the ROI performed with a Boosted Decision Tree (BDT)

Physics-run data analysis

We make use of a Boosted Decision Tree (BDT) algorithm that we train with our signal and background models to identify the fine-tuned ROI that maximizes our expected sensitivity for 8 different WIMP masses

We end with a WIMP-mass-dependent fine-tuned ROI in the rise time vs energy plane



1715 events recorded in the preliminary ROI :

- **Fail any of the BDT cuts**
- **pass the BDT cut for 0.5 GeV/c2**
- **pass the BDT cut fot 16 GeV/c2**
- **pass the BDT cut for other masses**

Robustness of the analysis methodology against background mis-modeling

If the BDT were to be trained with inaccurate background models, the fine-tuned ROI would just end to be non-optimized for signal/background discrimination

Still, an accurate modelisation of the signal is critical for the exclusion limit to be unbiased.

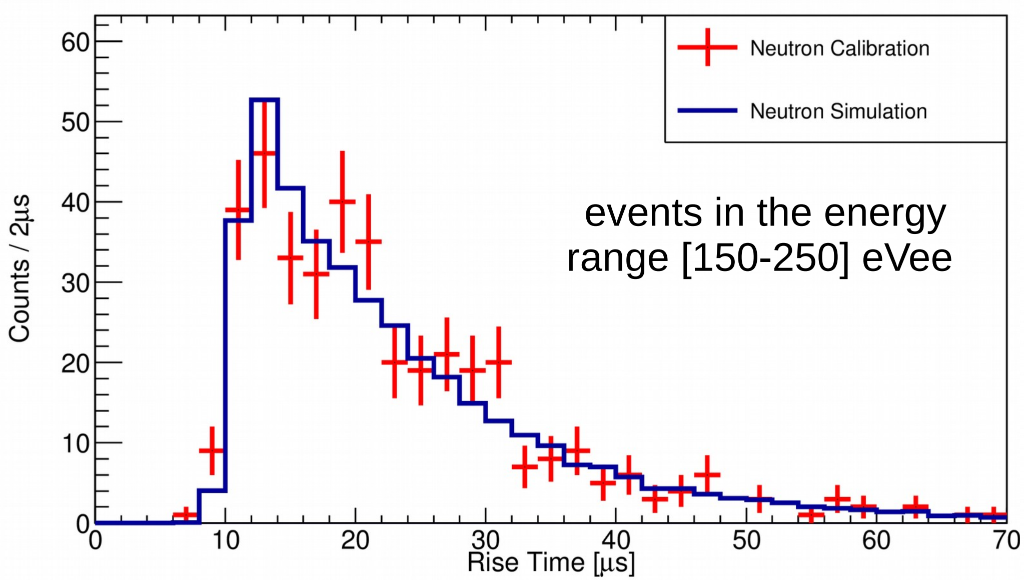
Comparison of Calibration data with Simulation

Validation of the simulation through its agreement with calibration Data

37Ar gas added to the mixture : 2.82 keV and 270 eV X-rays from the electron capture in the K- and L-shells respectively.

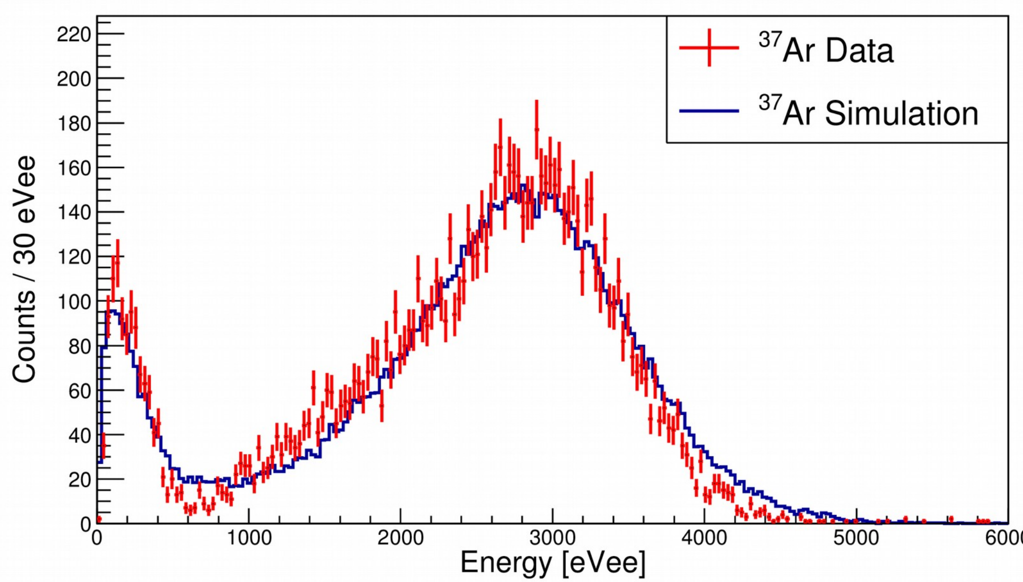
Am-Be neutron source : nuclear recoils homogeneously distributed in the volume.

Comparison of Neutron data with simulation



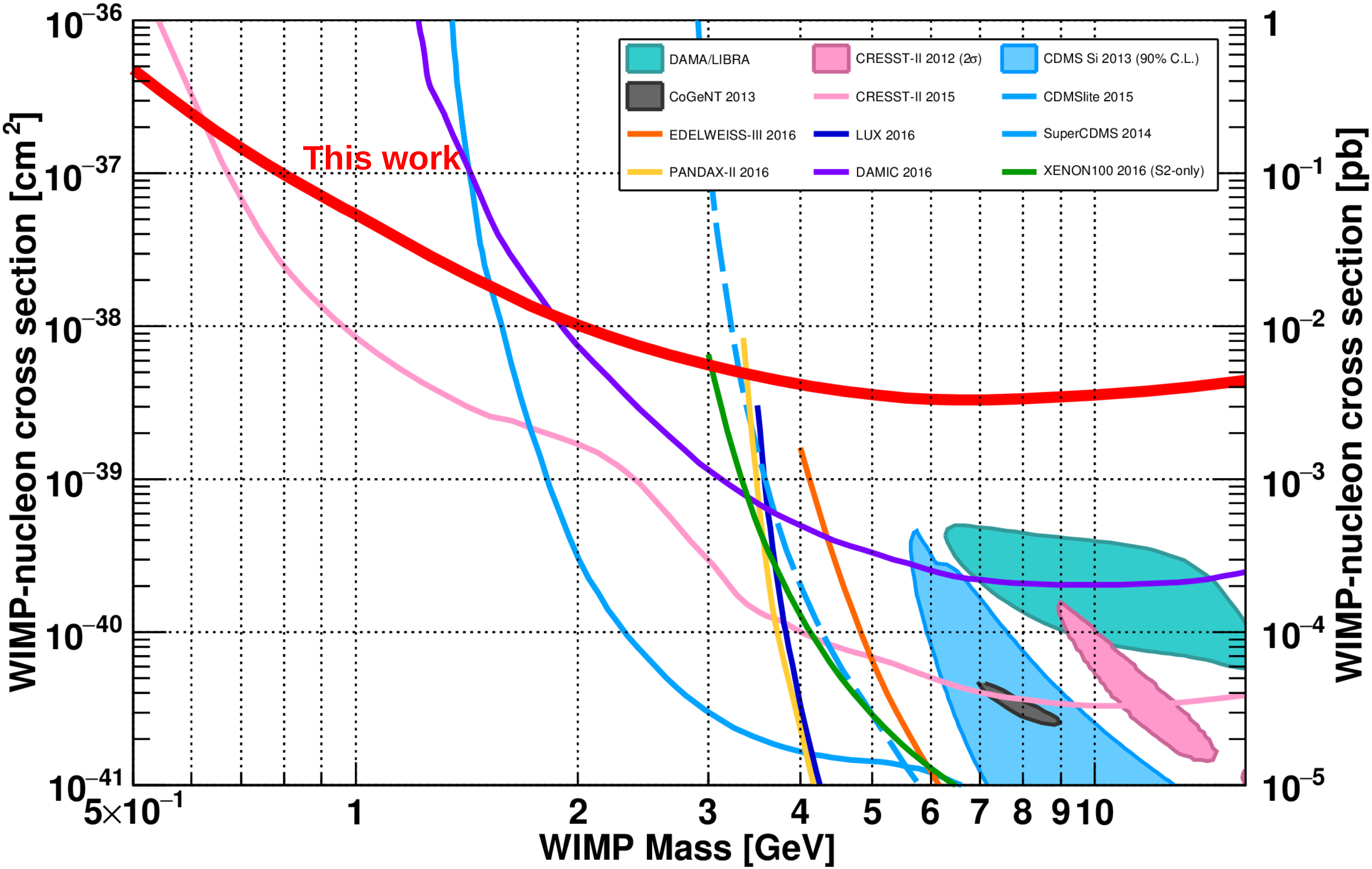
Response in rise time and drift parameters

Comparison of 37Ar data with simulation



Response in energy

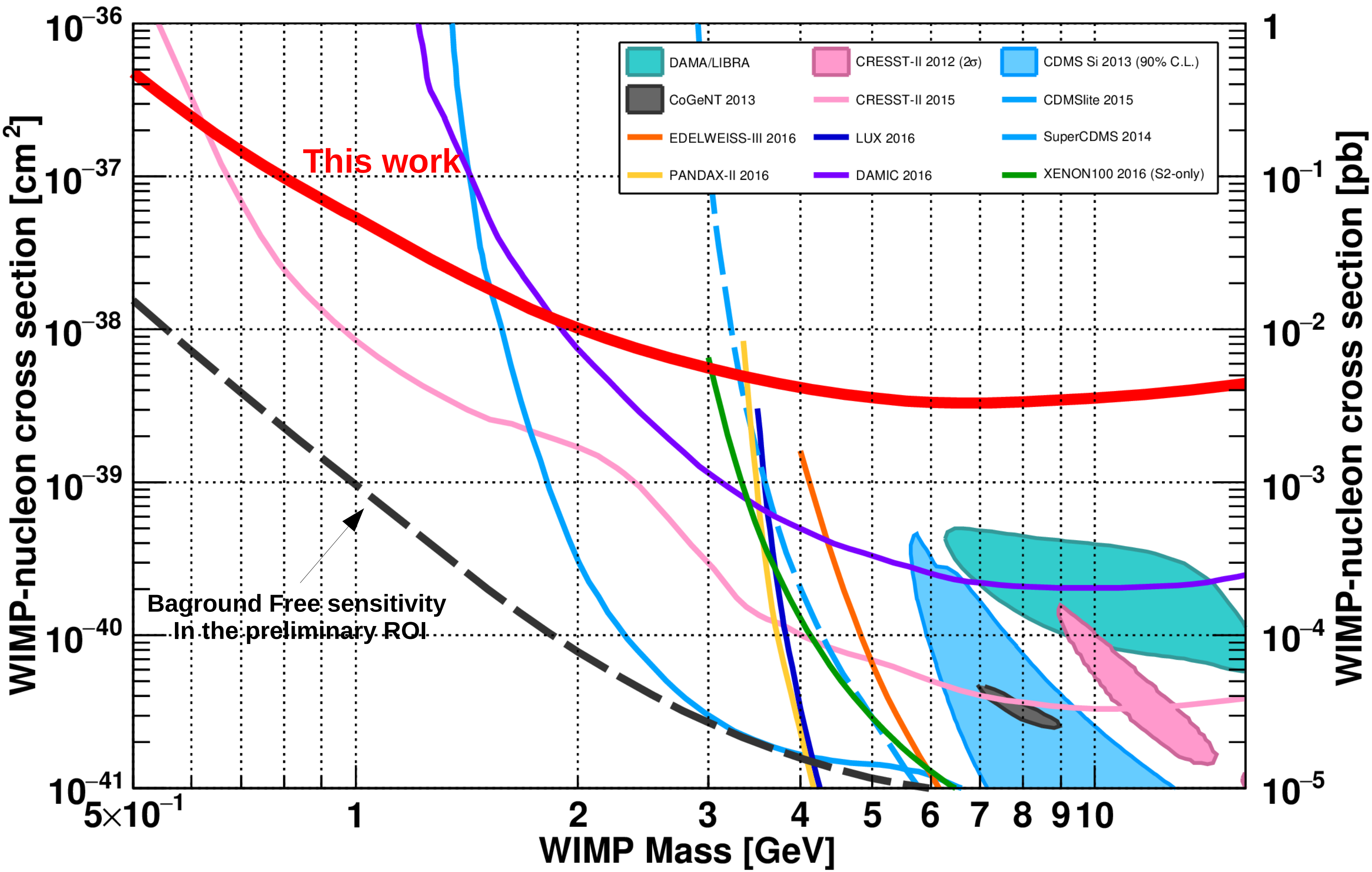
The overall agreement between the simulation and calibration data allows us to confidently derive our sensitivity from simulated WIMP events



90 % (CL) upper limit derived from Poisson statistics.

Standard halo model parameters : $\rho_{DM} = 0.3\ \mathrm{GeV/c^2/cm^3}$ $v_{esc} = 544\ \mathrm{km/s}$ $v_0 = 220\ \mathrm{km/s}$

Results



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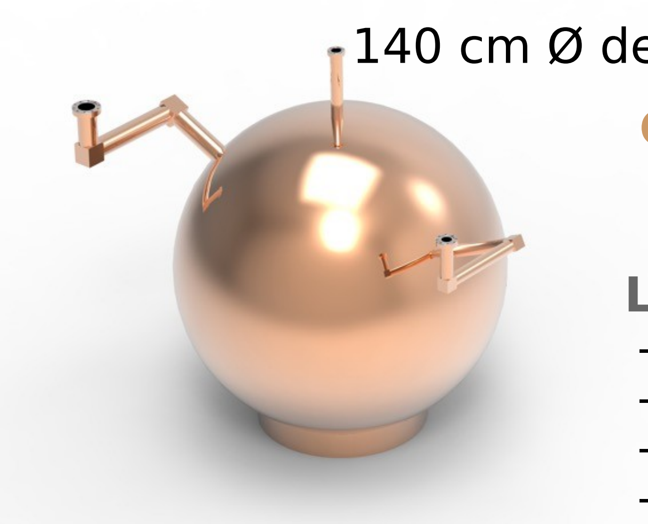
NEWS-G @ SNOLAB



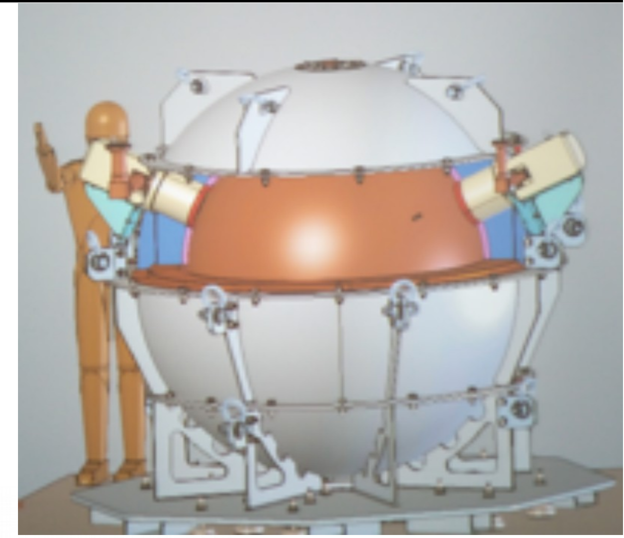
140 cm Ø detector @ 10 bars (Ne, He, CH_4)

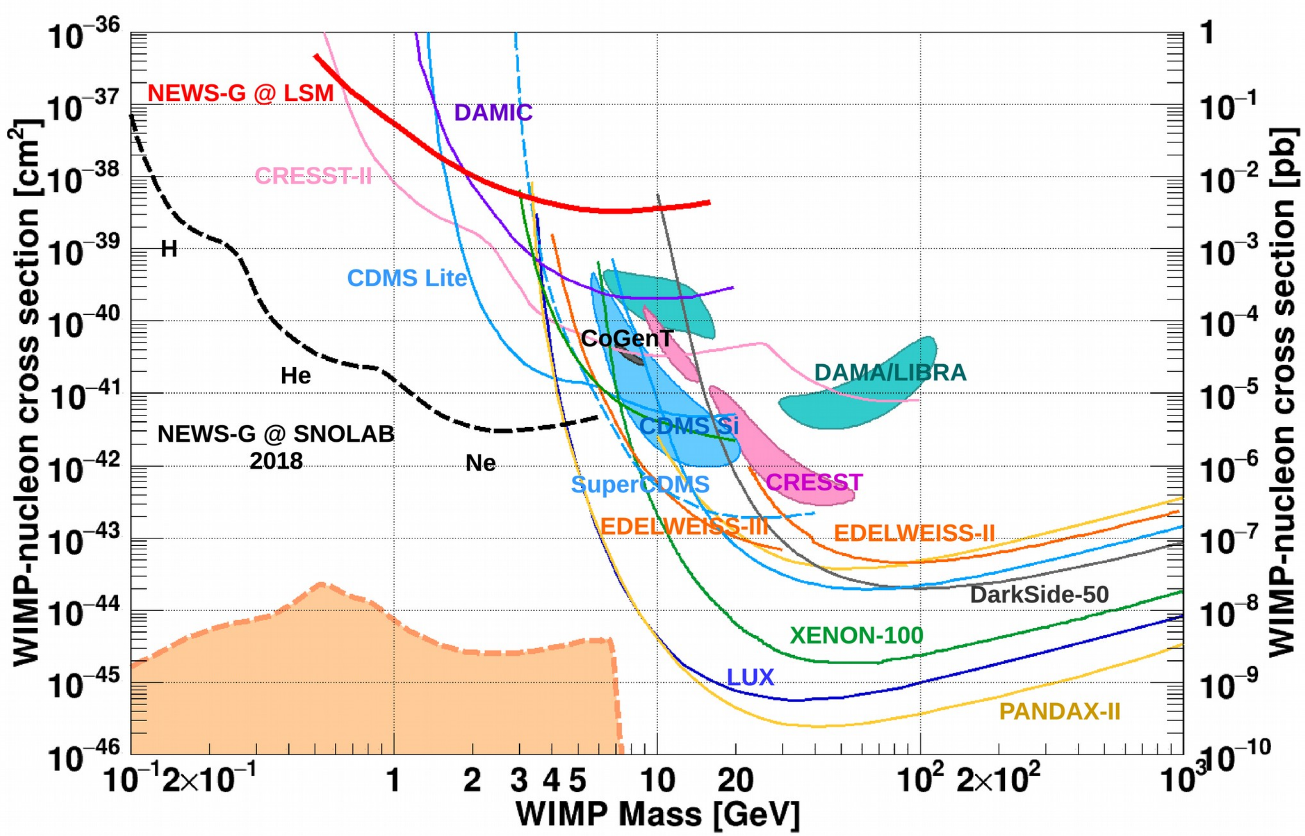
Copper vessel

- Thickness ~12 mm
- Electropolishing cleaning

Lead shield

- 40 cm PE + Boron sheet
- 22 cm VLA (1 Bq/kg 210Pb)
- 3 cm archeological lead
- Air tight SS envelope to flush pure N





See G. Gerbier talk on Thursday for more details

Conclusion and outlook

NEWS-G @ LSM

The NEWS-G experiment sets competitive constraints on the spin-independent WIMP-nucleon scattering cross section in the sub-GeV range.

Paper to be submitted to the Astroparticle Physics Journal and uploaded on ArXiv by the end of next week

NEWS-G @ SNOLAB

These results are very promising for the next phase of the NEWS-G experiment @ SNOLAB

See G. Gerbier ' s talk on Thursday for details

Talks from the NEWS-G collaboration all in the same room (Botterell B139)

Today at 4.15 pm

A. Brossard : “Sensor optimisation and gas quality analysis for spherical gas detector operation”

D. Durnford : “Calibration schemes for Spherical Gas Detectors”

Thursday at 1.30 pm

G. Gerbier : “Status of NEWS-G experiment”

P. Di Stefano : “Quenching measurements for a spherical detector at the COMIMAC facility”

THANK YOU for your attention

NEWS-G Collaboration

- **Queen's University Kingston –** G Gerbier, P di Stefano, R Martin, T Noble, D. Durnford A Brossard, A Kamaha, F Vazquez de Sola, Q Arnaud, K Dering, J Mc Donald, M Clark, M Chapellier
  - 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, 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, DM Asner
  - Low activity measurements, Copper electroforming
- **RMCC (**Royal Military College Canada**) Kingston –** D Kelly, E Corcoran
  - 37 Ar source production, sample analysis
- **SNOLAB –Sudbury –** P Gorel
  - Calibration system/slow control
- **University of Birmingham –** Kostas Nikolopoulos
  - Simulations, analysis, R&D

Associated lab : TRIUMF - F Retiere
- Future R&D on light detection, sensor