

Single electron in the XENON100 direct dark matter search experiment

Maxime Le Calloch

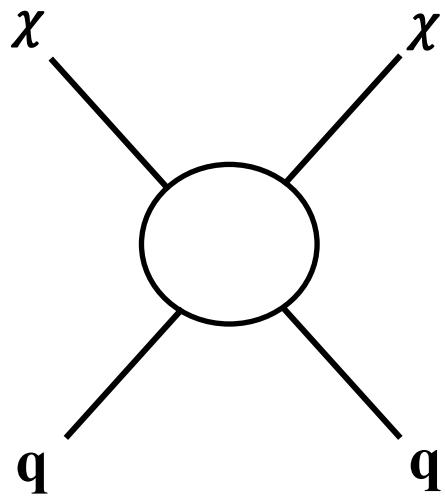
Dir. : Thierry Gousset

Sup. : Luca Scotto Lavina



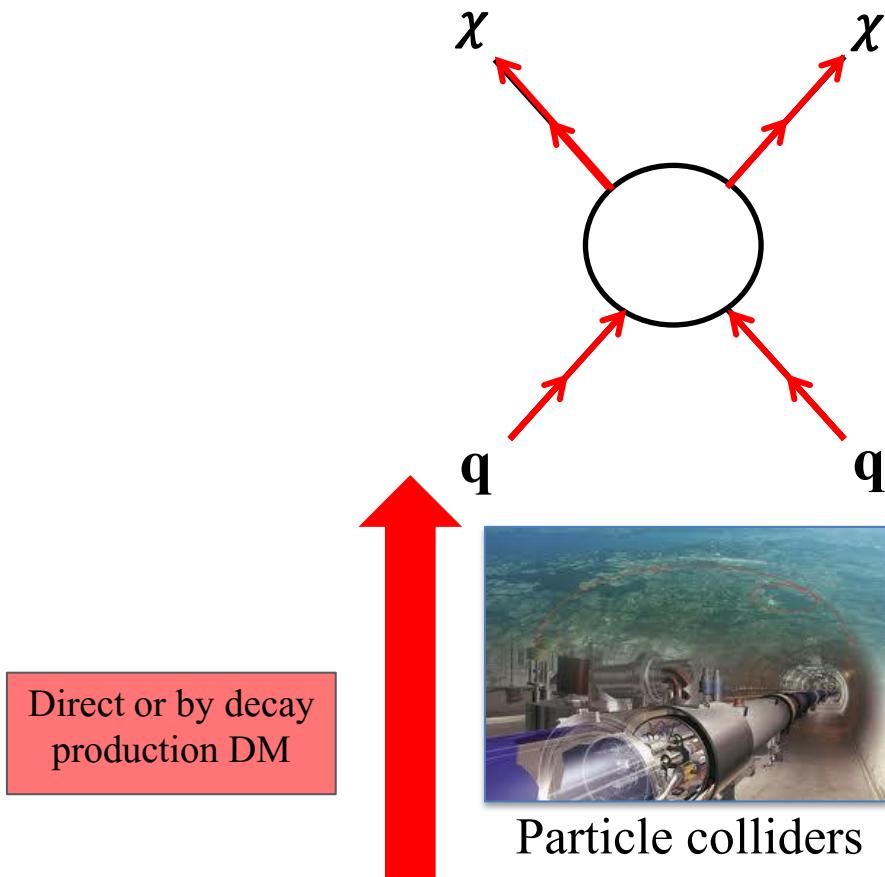
Dark Matter hunt

- **Dark matter hunt:**



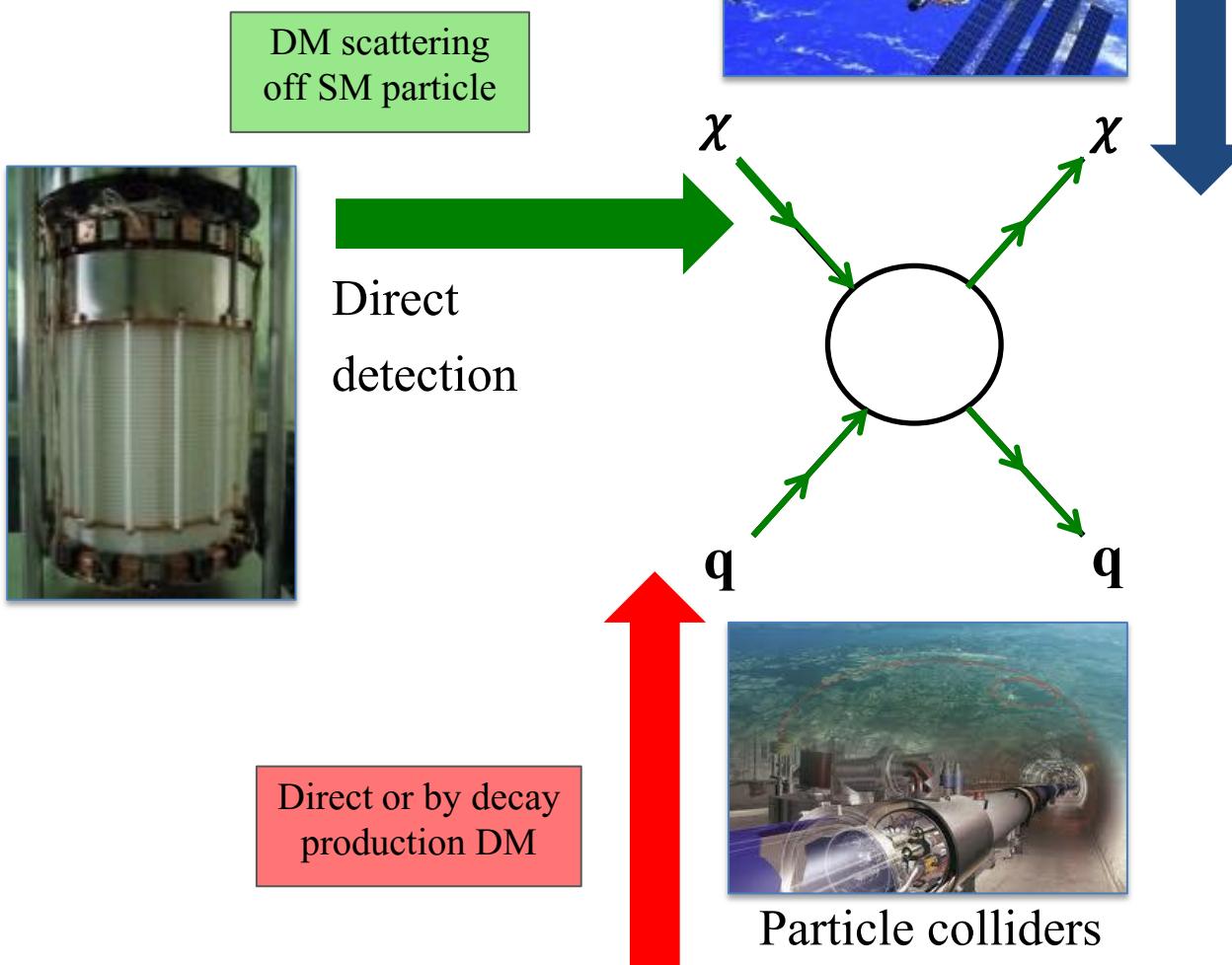
Direct detection principle

- **Dark matter hunt:**

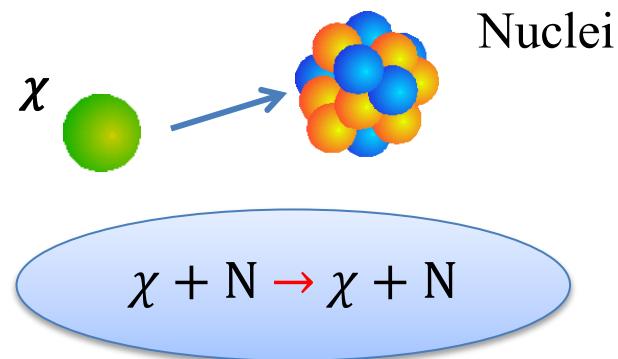


Direct detection principle

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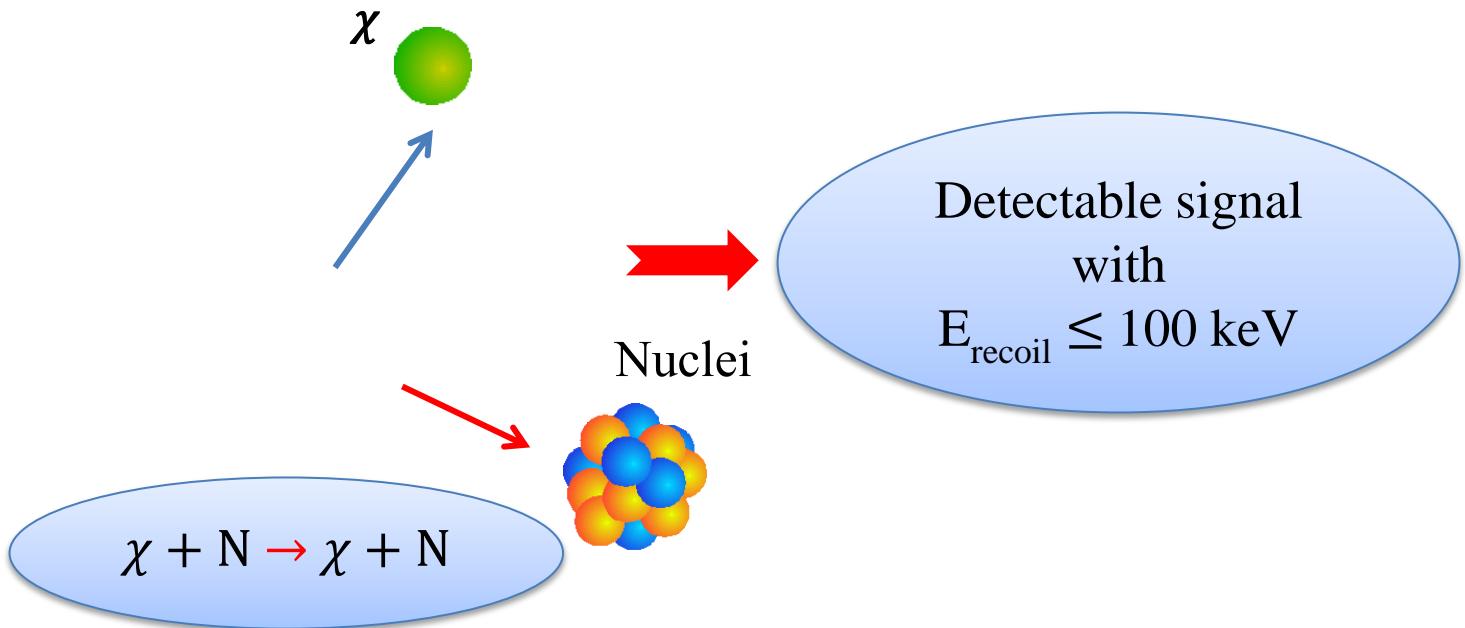


- Direct detection principle:



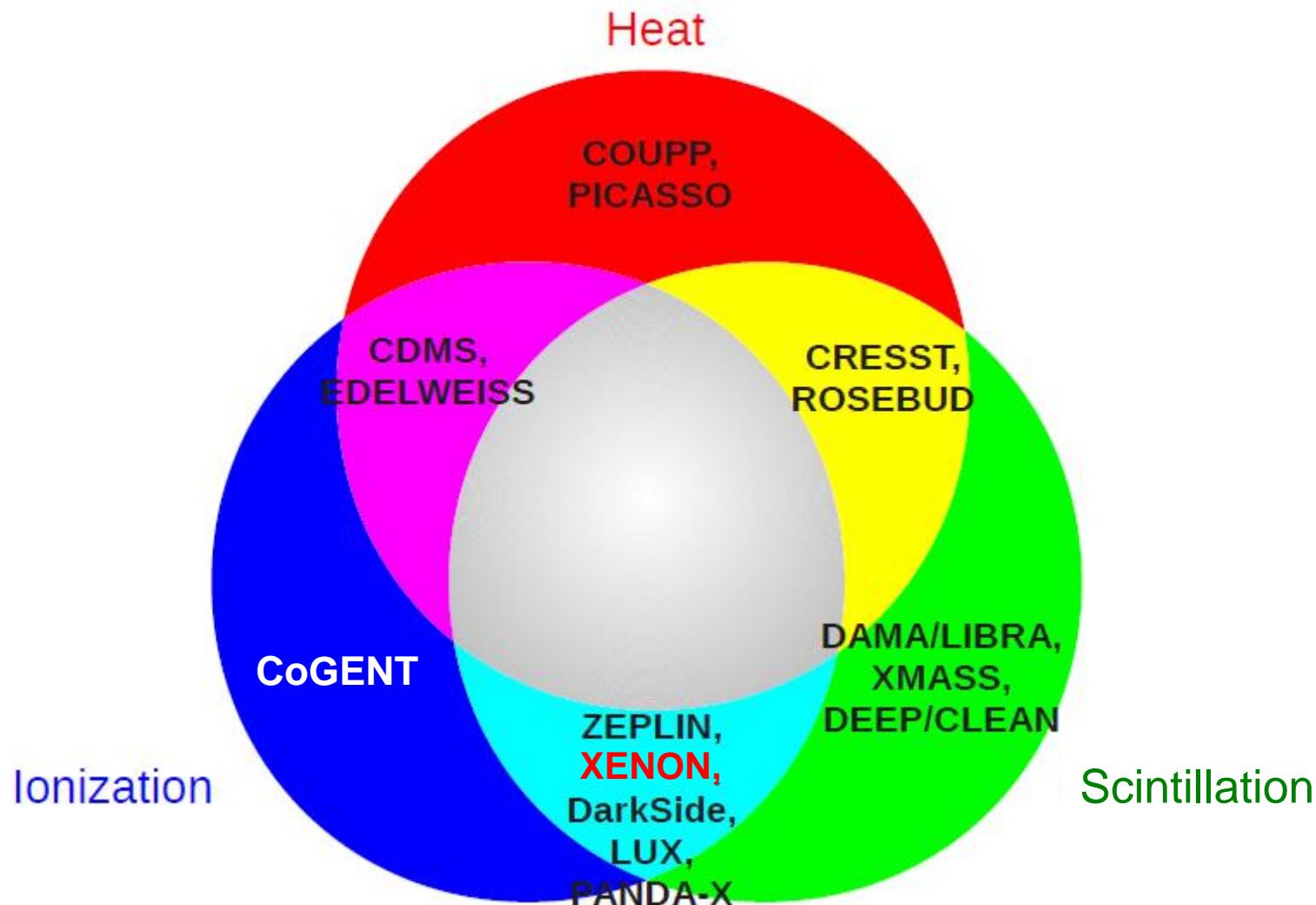
Direct detection principle

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Direct detection principle

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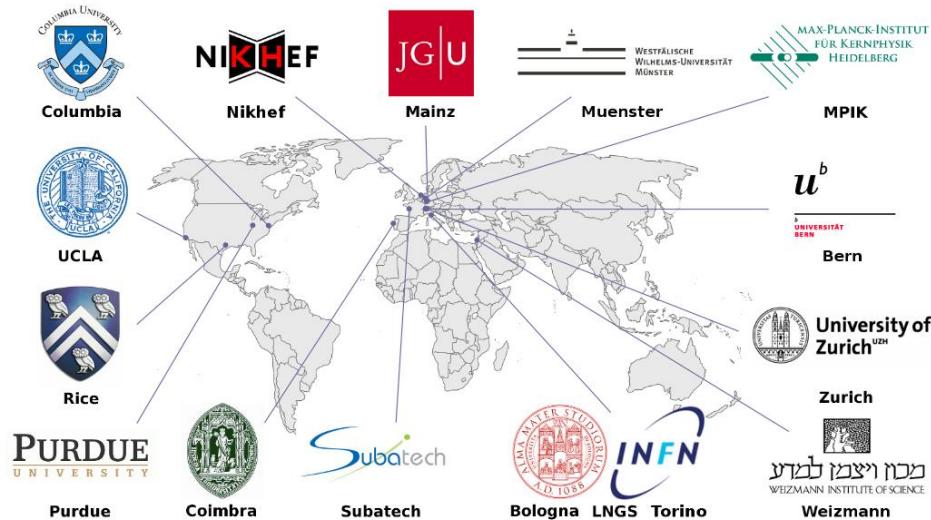


Direct detection principle

○ Direct detection with xenon:



○ Who are we?

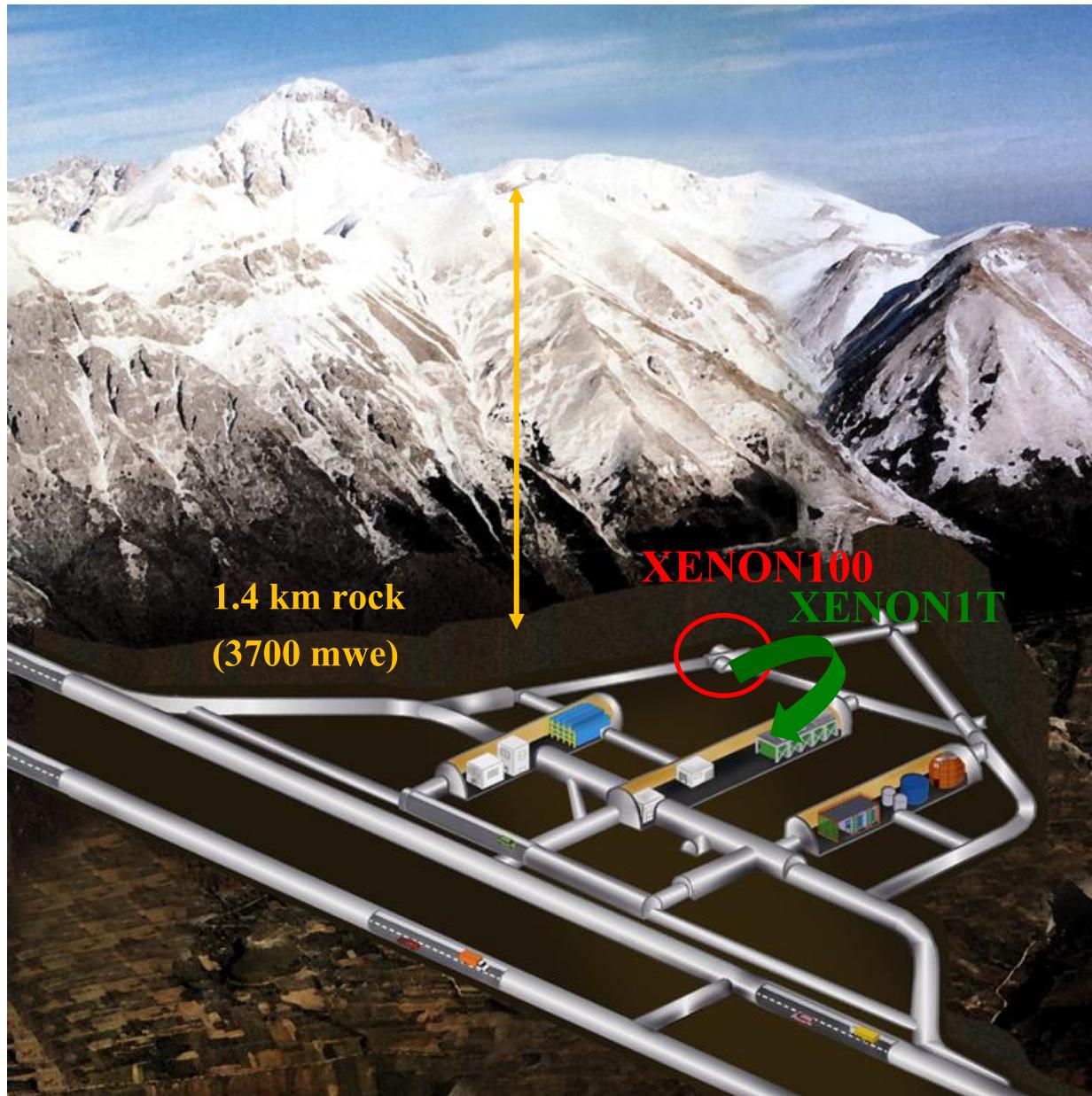


- 16 institutions over the world

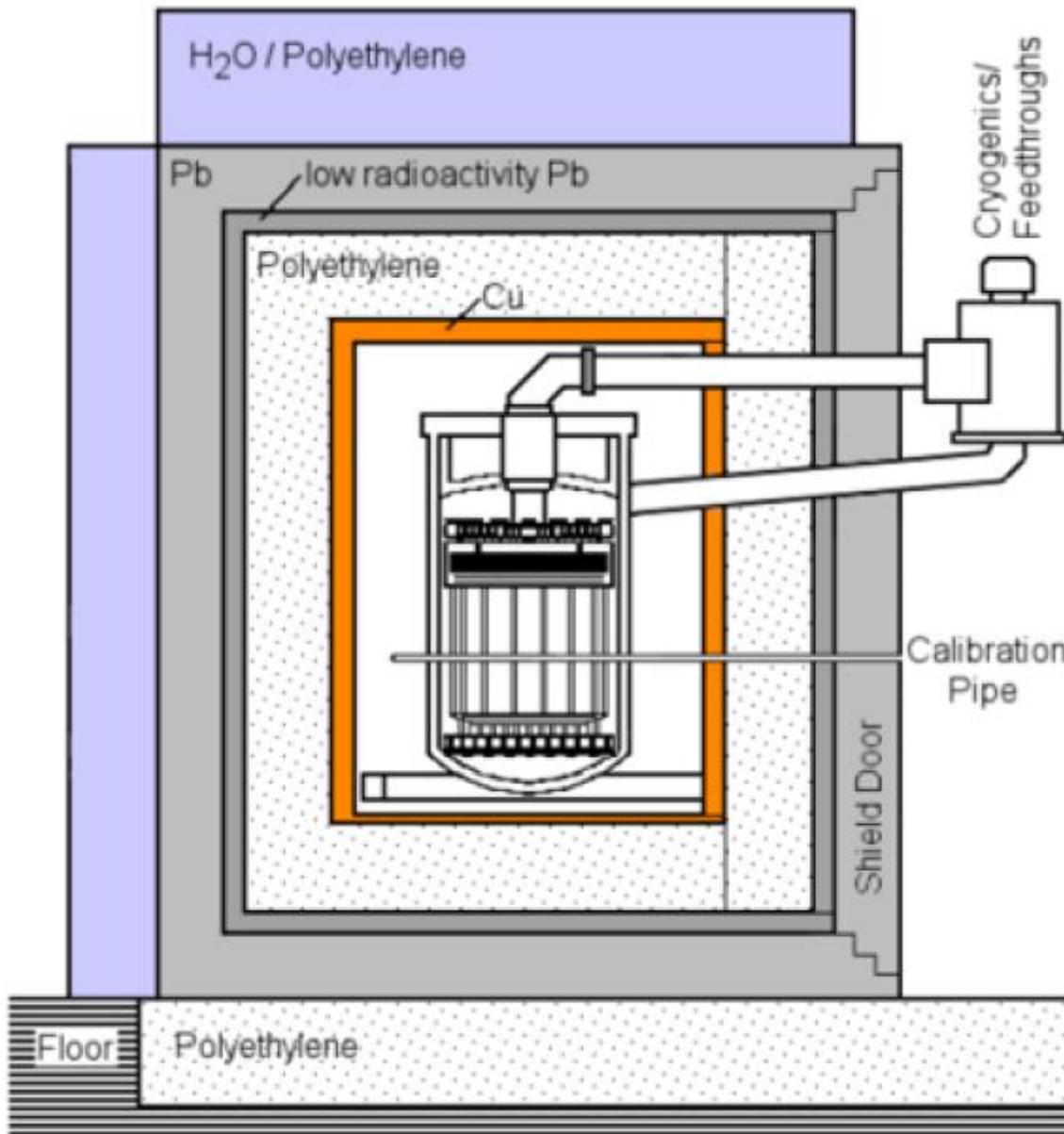
- More than 100 scientists:
~50% students (Master,
PhD stud.) or young
scientists



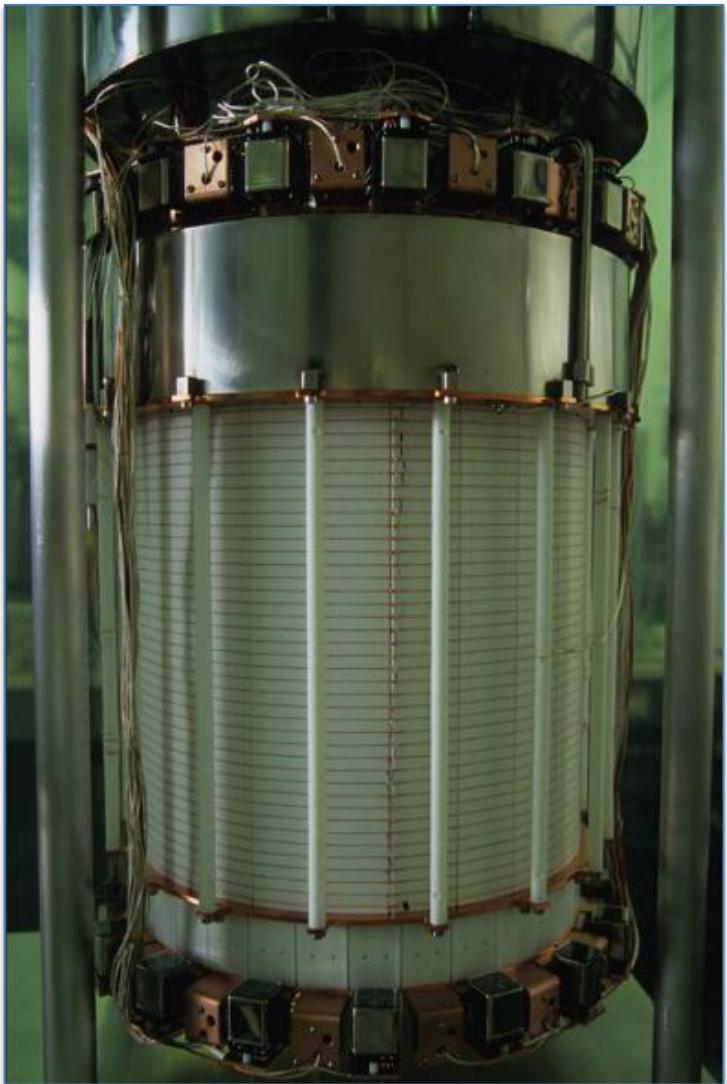
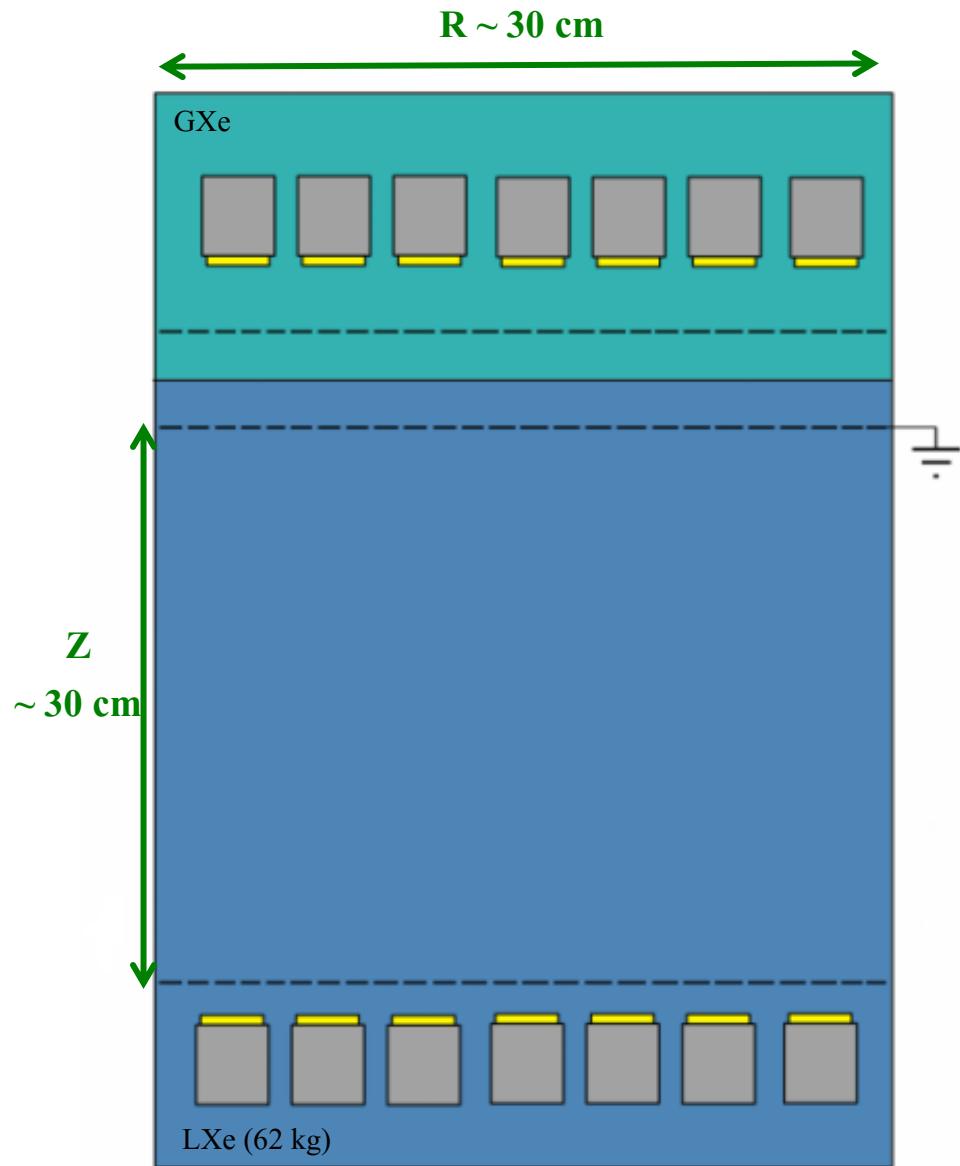
The Xenon100 Detector



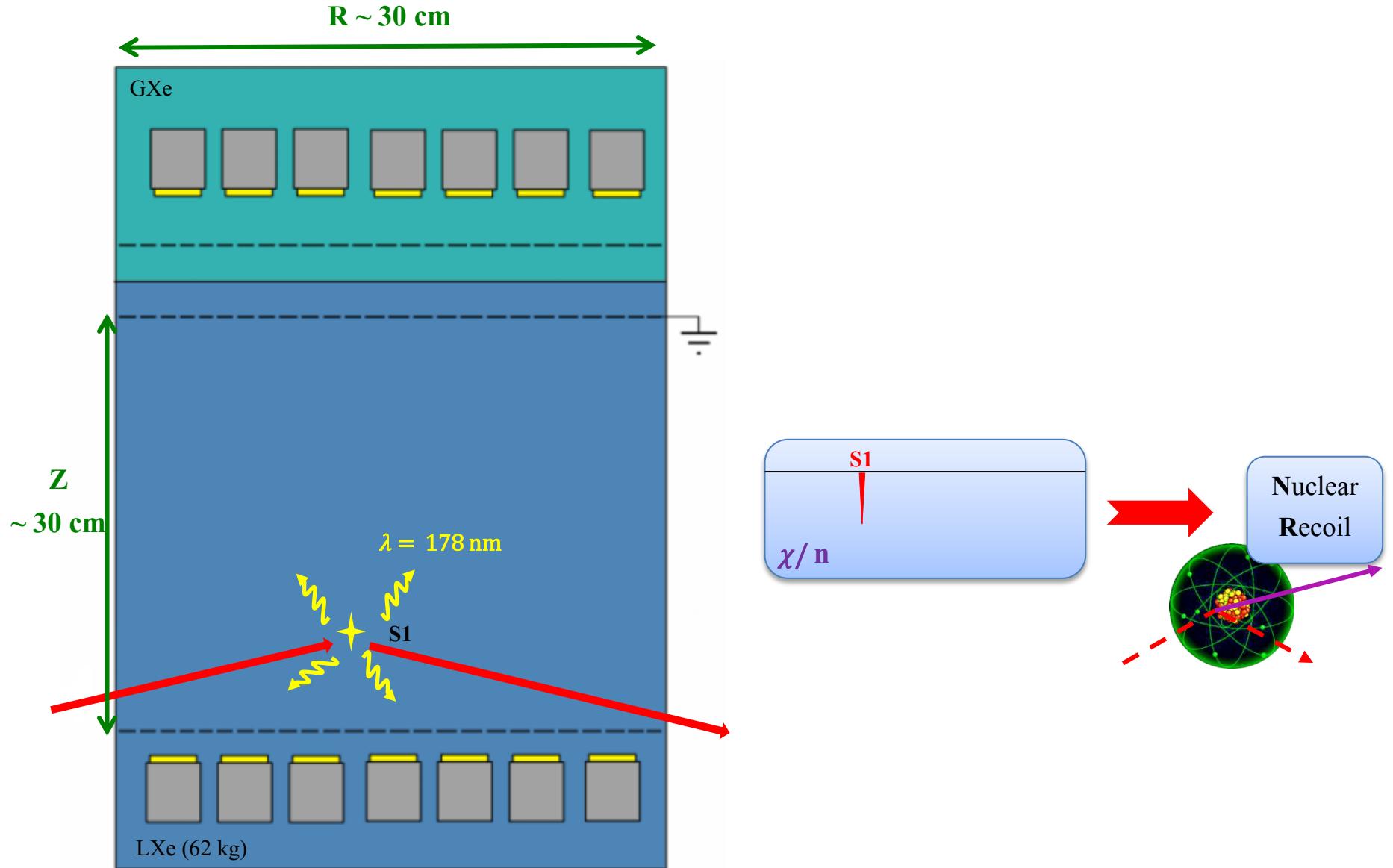
The Xenon100 Detector



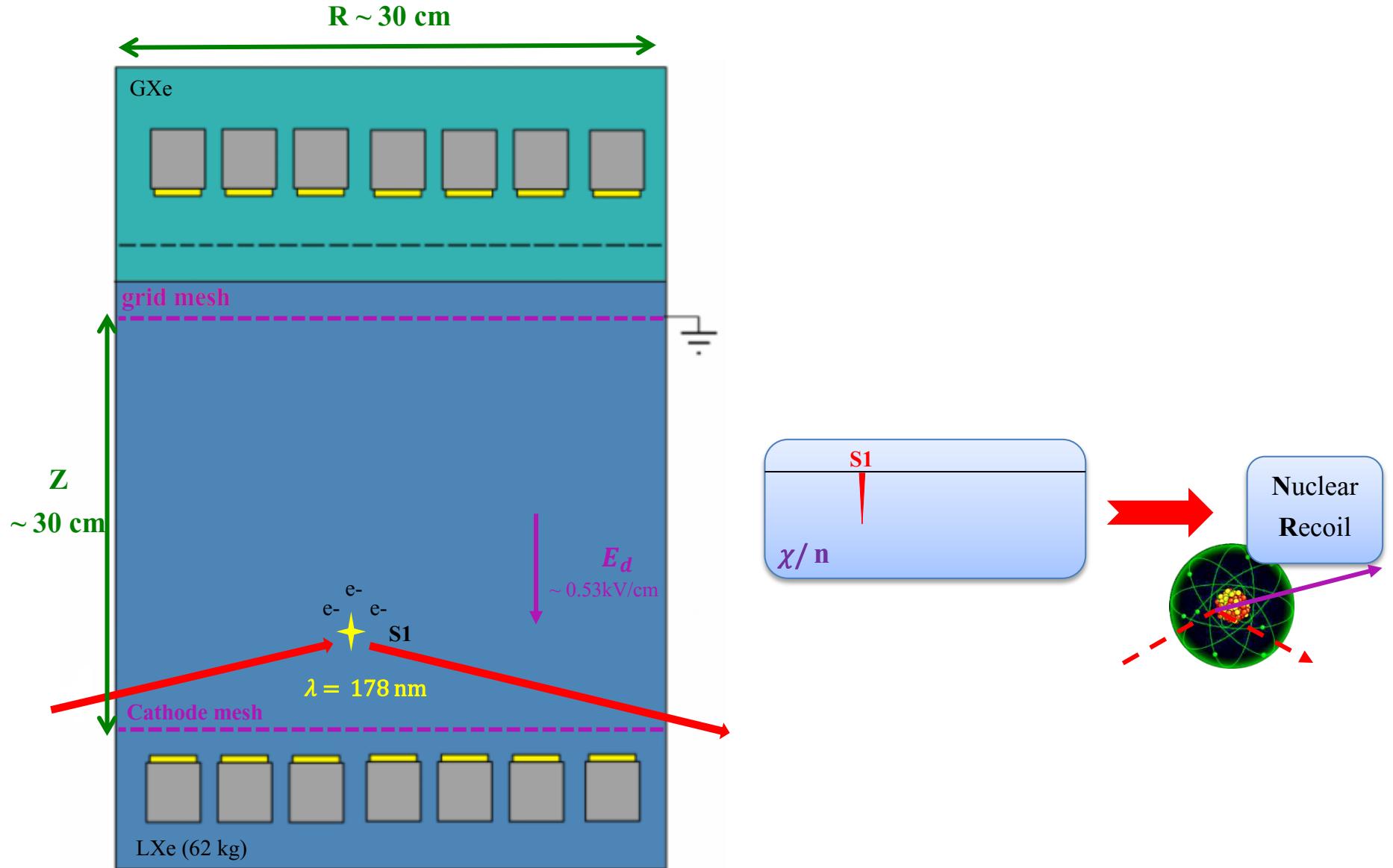
The Xenon100 Detector



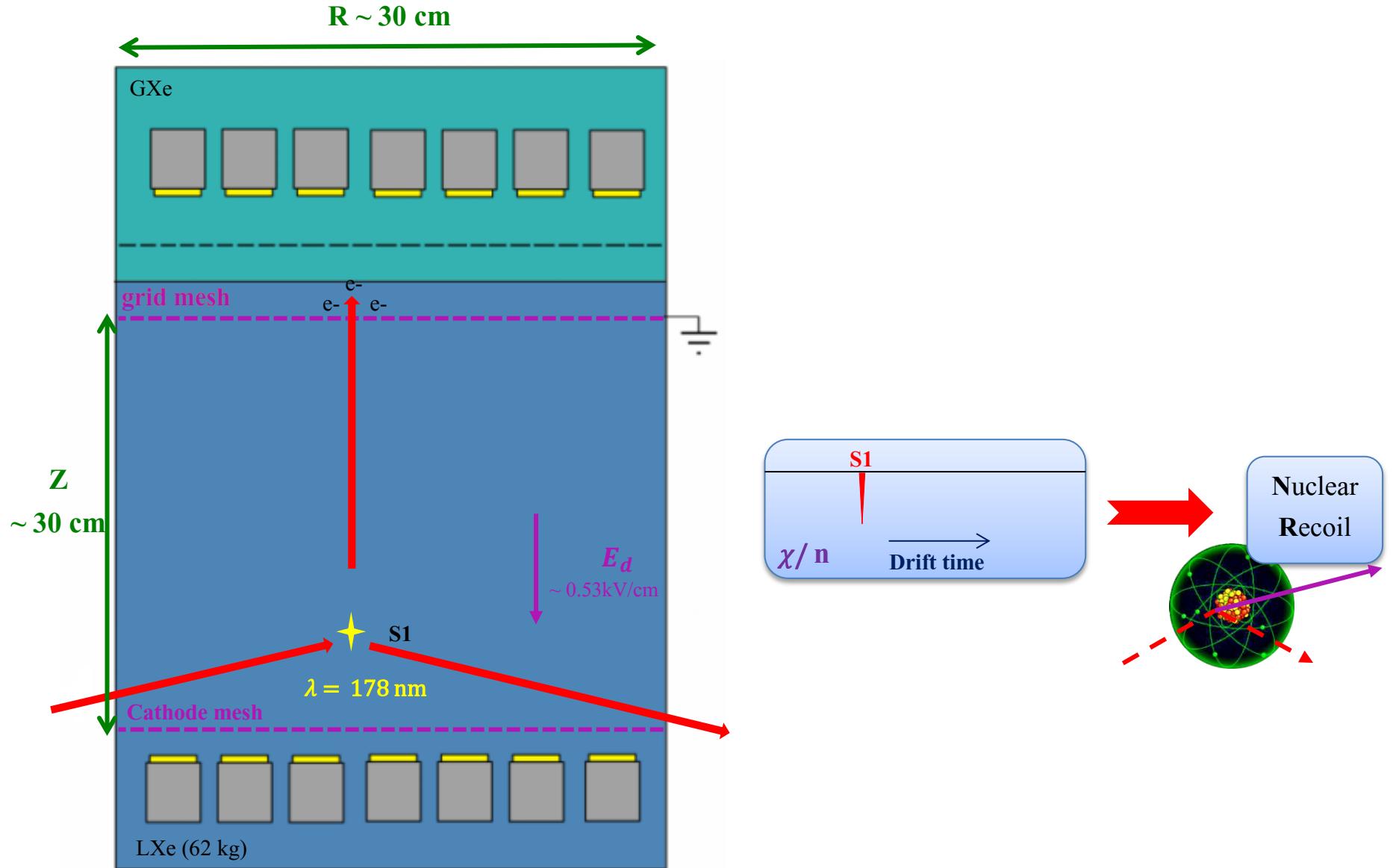
The Xenon100 Detector



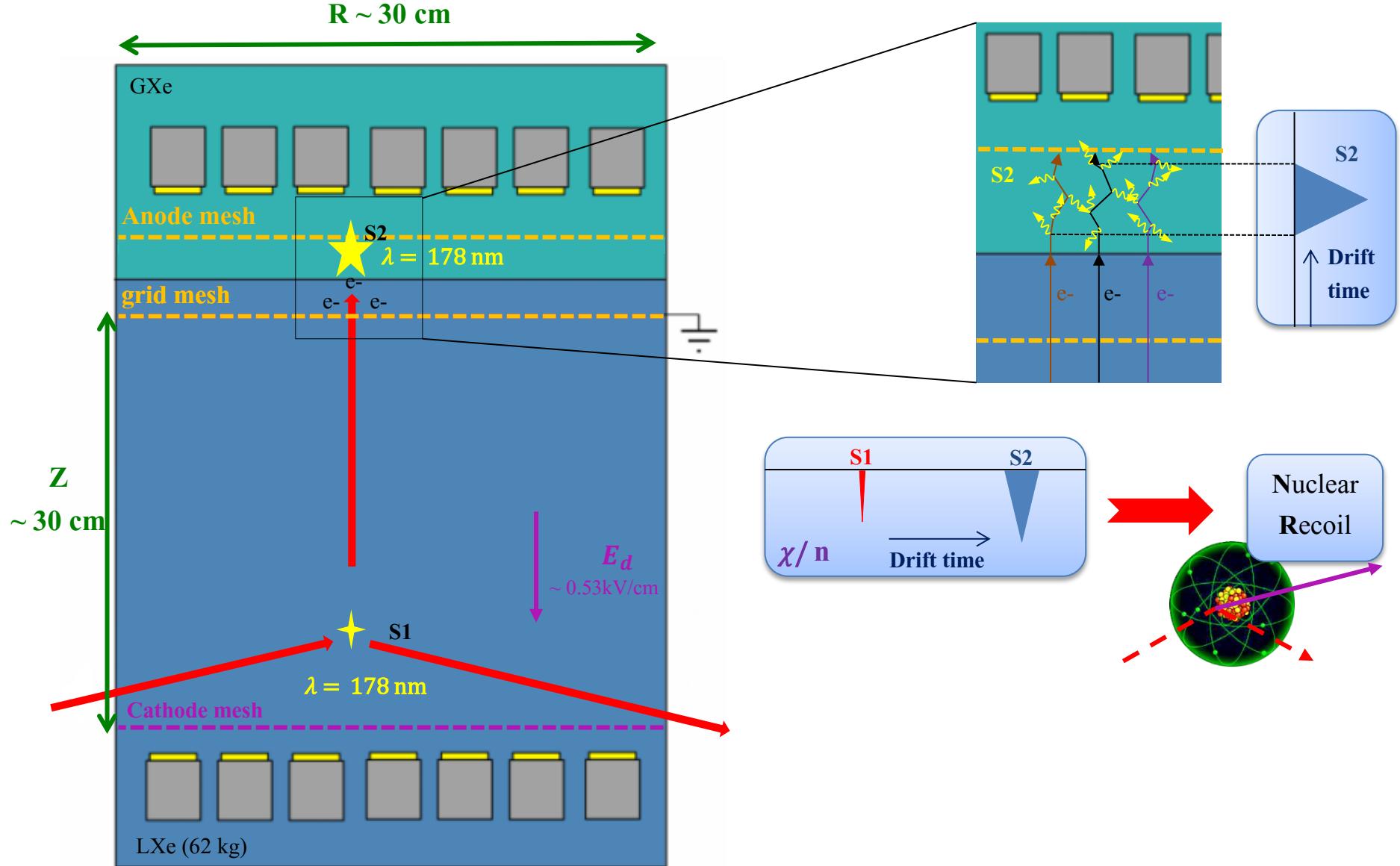
The Xenon100 Detector



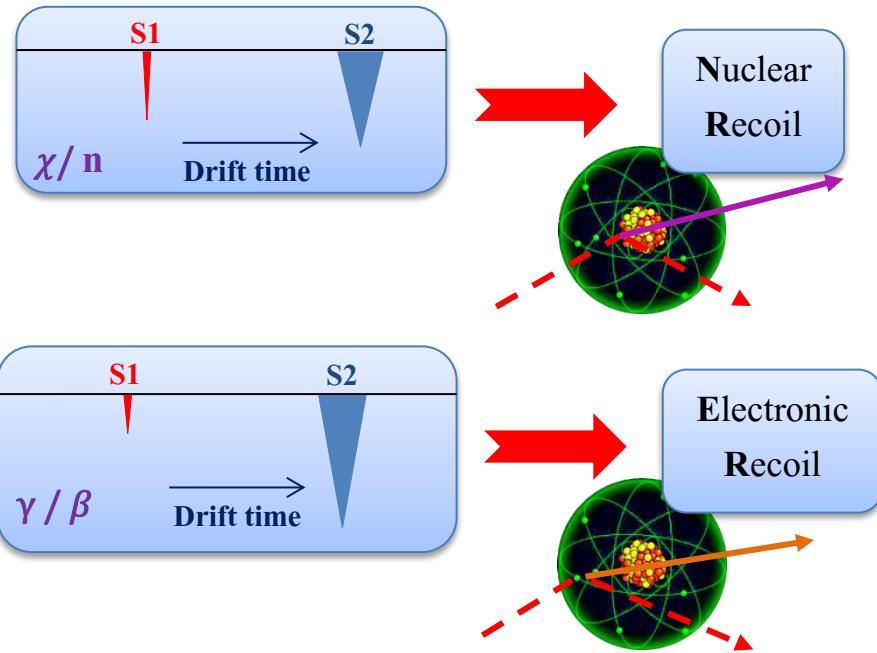
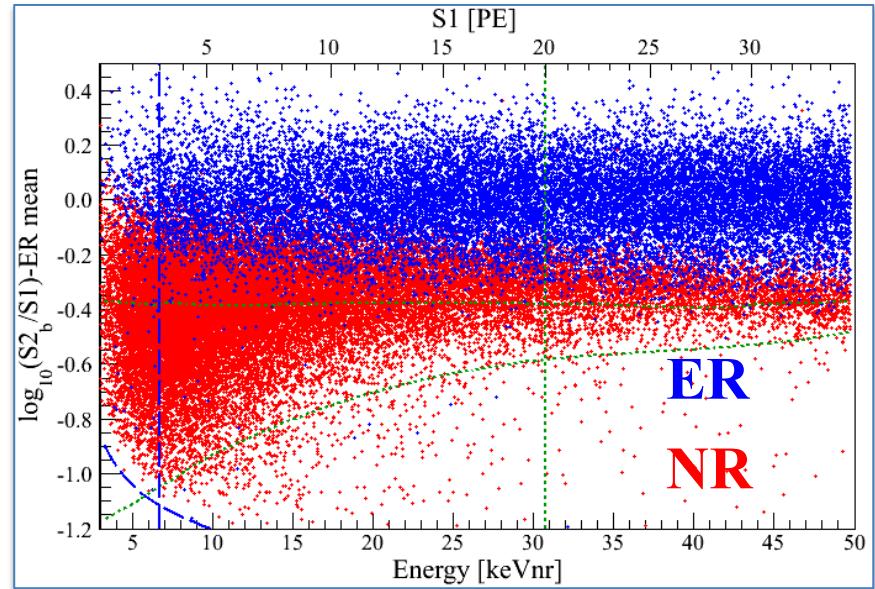
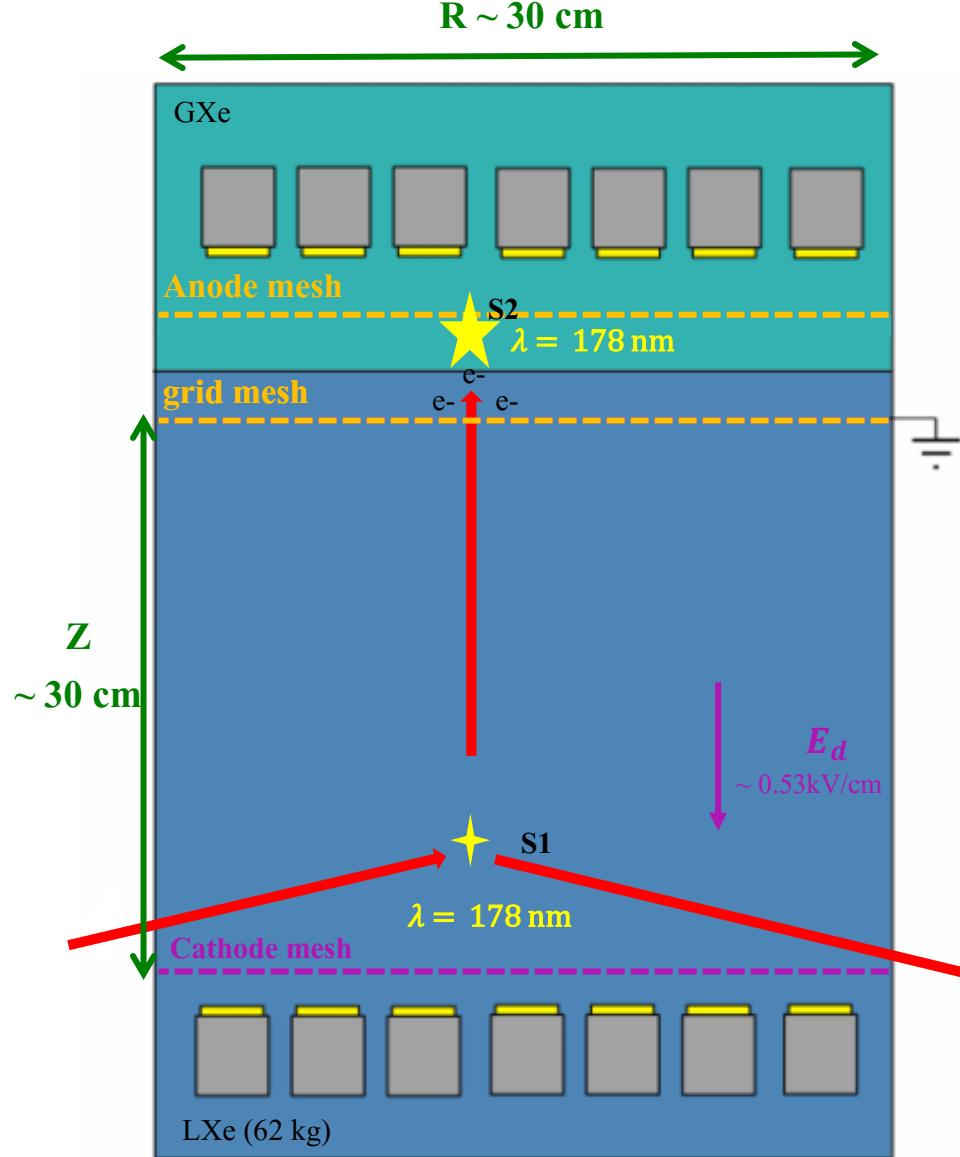
The Xenon100 Detector



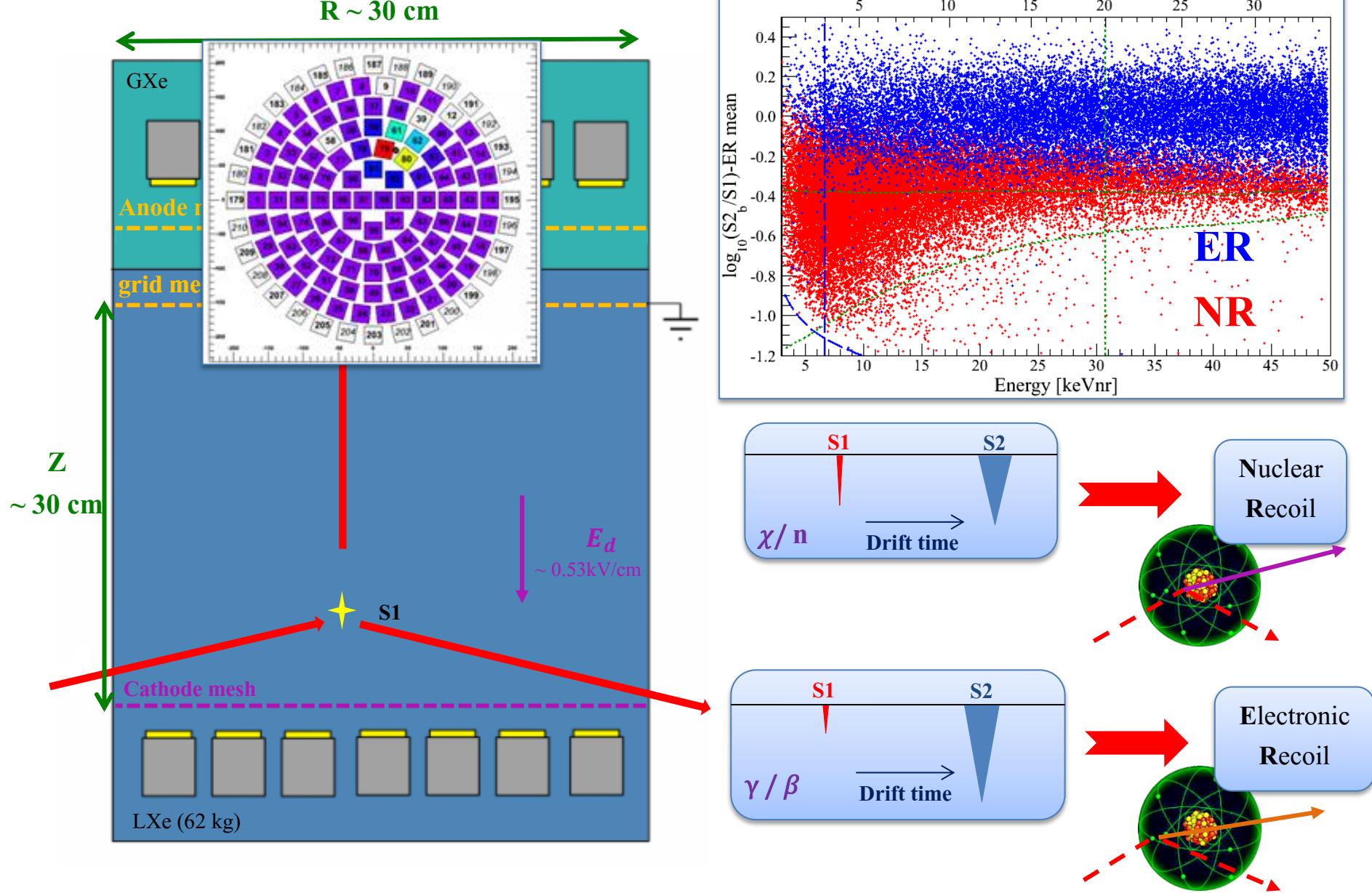
The Xenon100 Detector



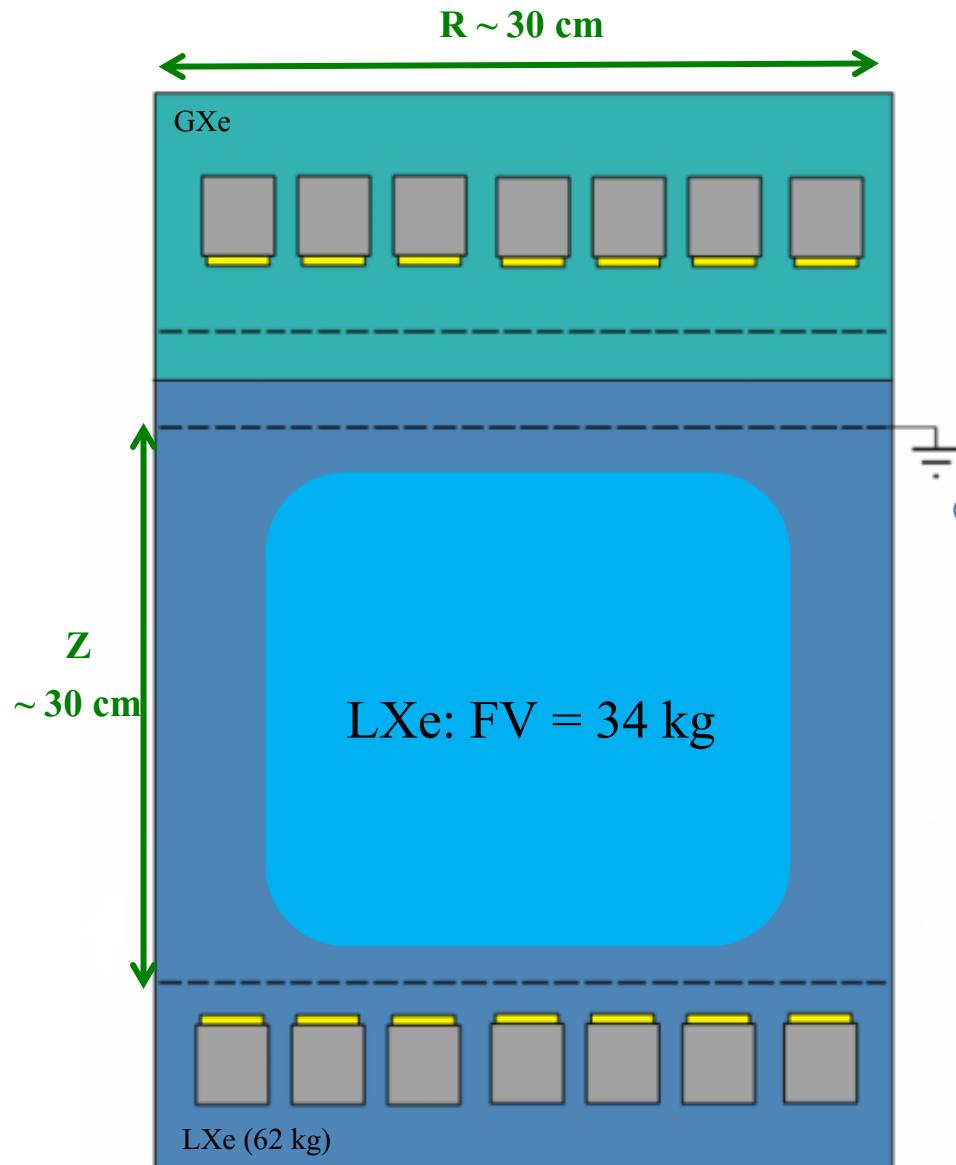
The Xenon100 Detector



The Xenon100 Detector



The Xenon100 Detector



- **Fiducial volume definition:**

= Final search volume

$$\left(\frac{|Z|}{Z_{max}}\right)^n + \left(\frac{R^2}{R_{max}^2}\right)^n < 1$$

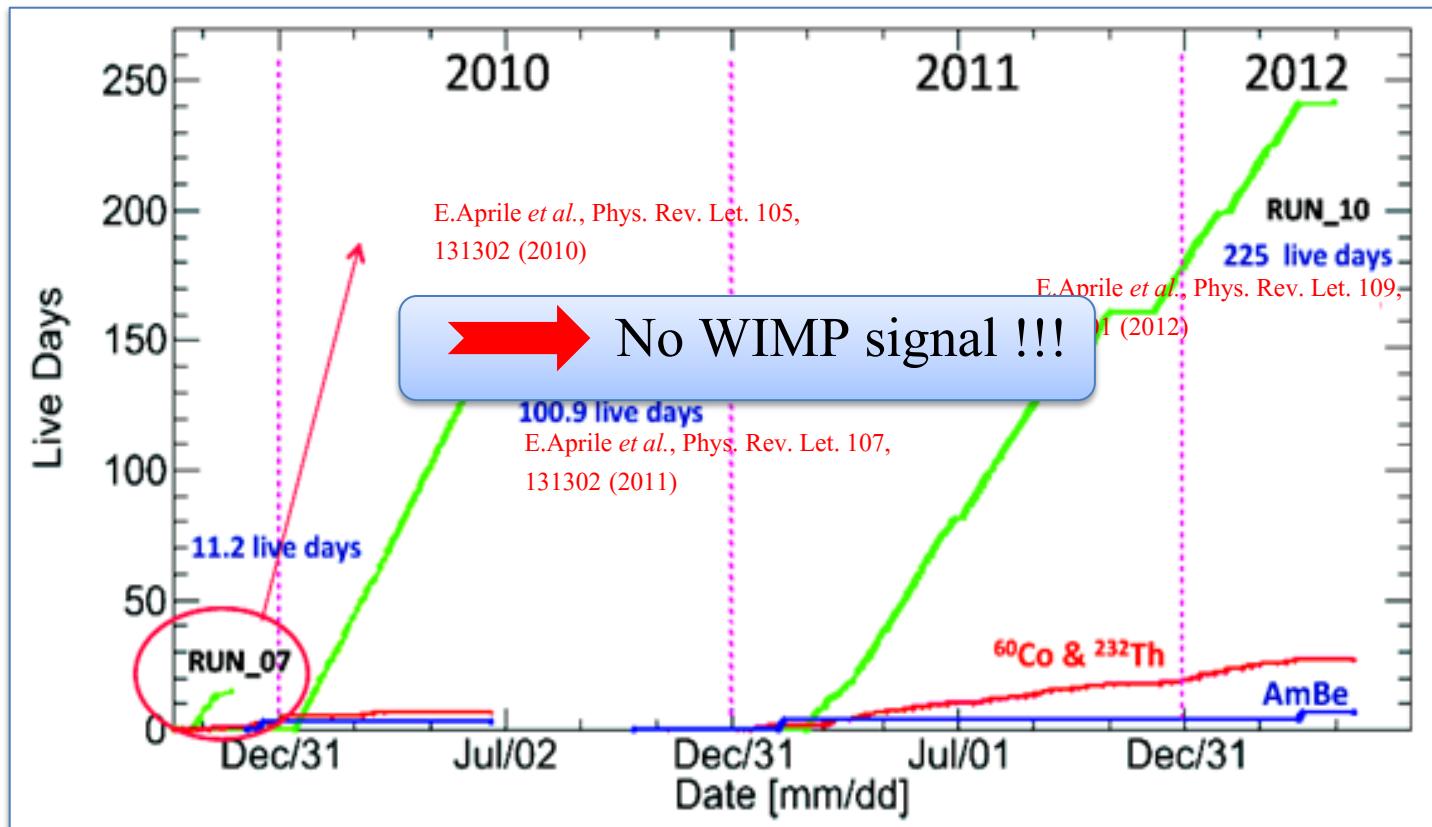
- TPC volume : 62 kg LXe
- Fiducial Volume : 34 kg LXe

Data collected

225 lives of data taking

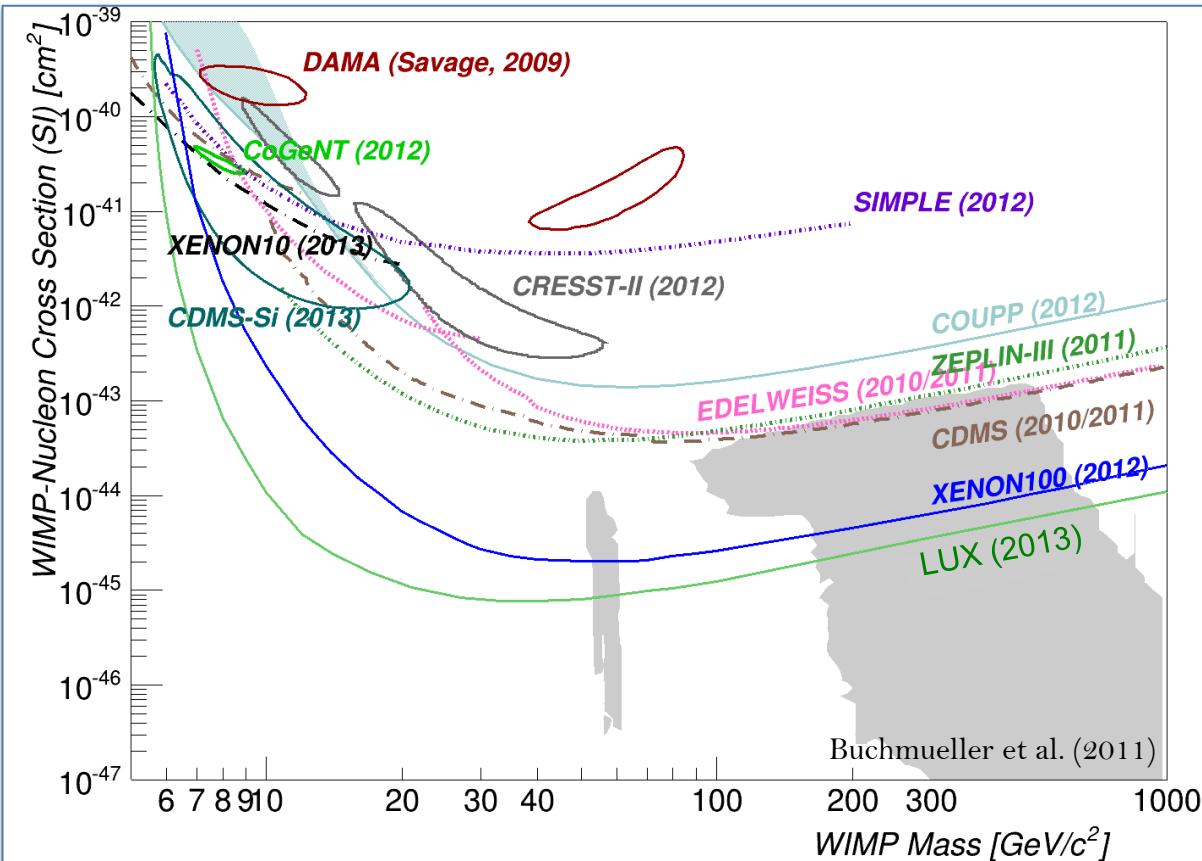
Exp. Background: 1.0 ± 0.2 event

Unblinding: 2 events found



Spin Independent results

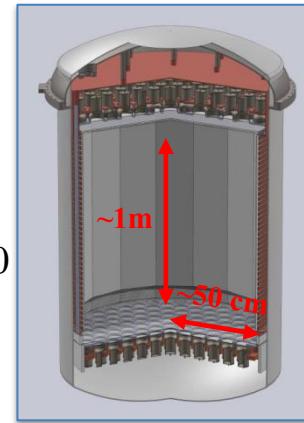
XENON100 lowest limit for $M_X = 55 \text{ GeV}/c^2$:
 $2.0 \cdot 10^{-45} \text{ cm}^2$ (90% C.L.)



LUX lowest limit for $M_X = 33 \text{ GeV}/c^2$: $7.6 \cdot 10^{-46} \text{ cm}^2$ (90% C.L.)

○ XENON1T Characteristics:

- **1 m** drift TPC with 2.4 ton LXe (**1 ton** fiducial)
 - ↳ 3x XENON100
 - ↳ 30x XENON100



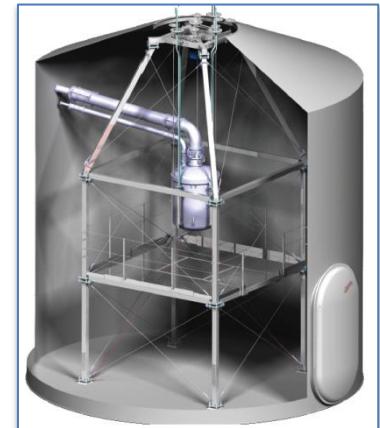
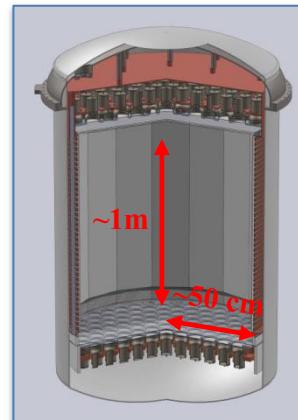
Next step: XENON1T (2015)

○ XENON1T Characteristics:

- **1 m** drift TPC with 2.4 ton LXe (**1 ton** fiducial)
- **10 m** water shield as Cerenkov Muon Veto
- Construction has **started**:



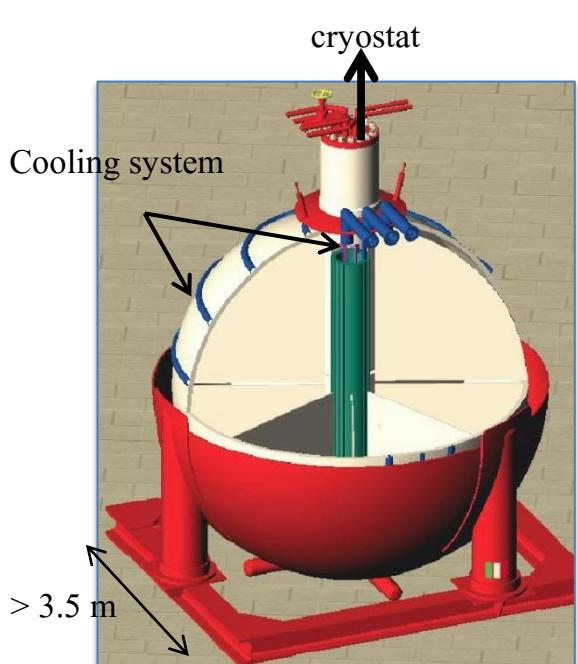
Water tank



To XENON1T



Infrastructure
building

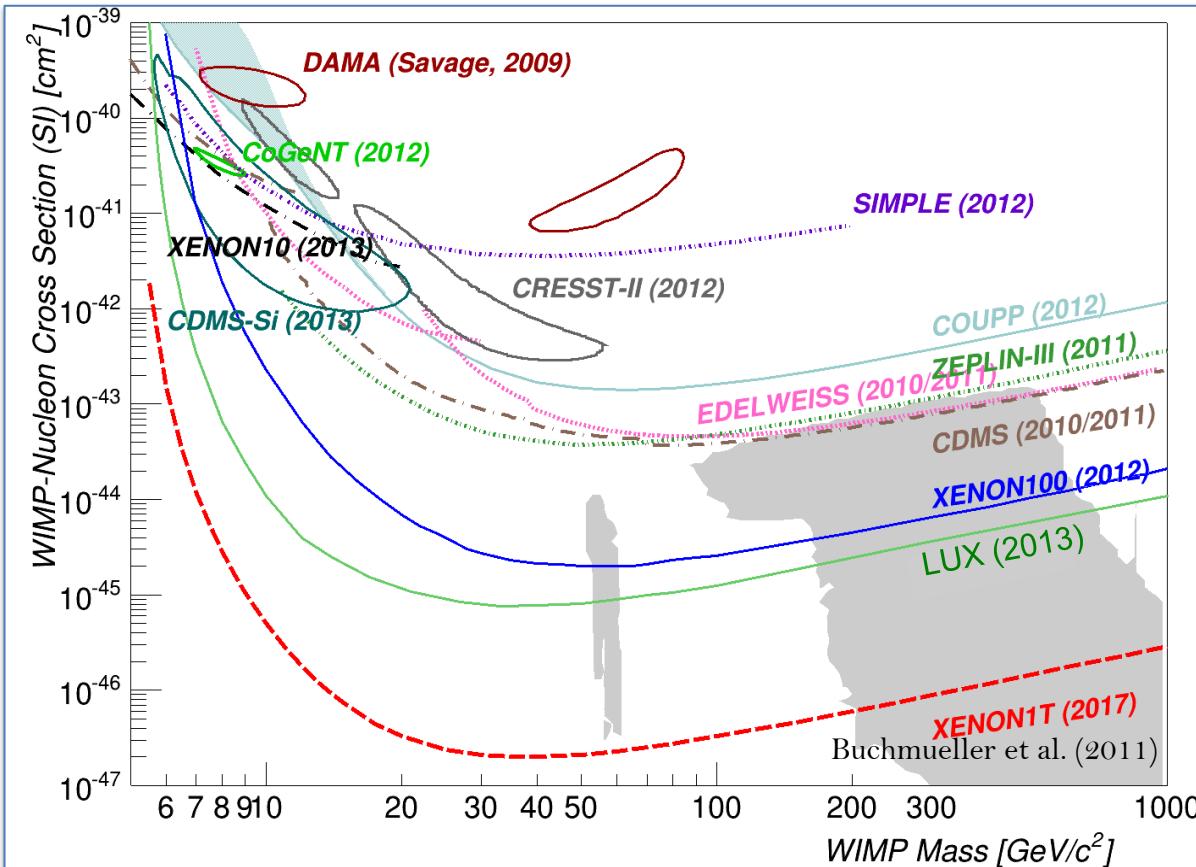


ReStoX
(Xenon storage)

Next step: XENON1T (2015)

Expected sensitivity:

$2 \cdot 10^{-47} \text{ cm}^2$ after 2 years of data taking

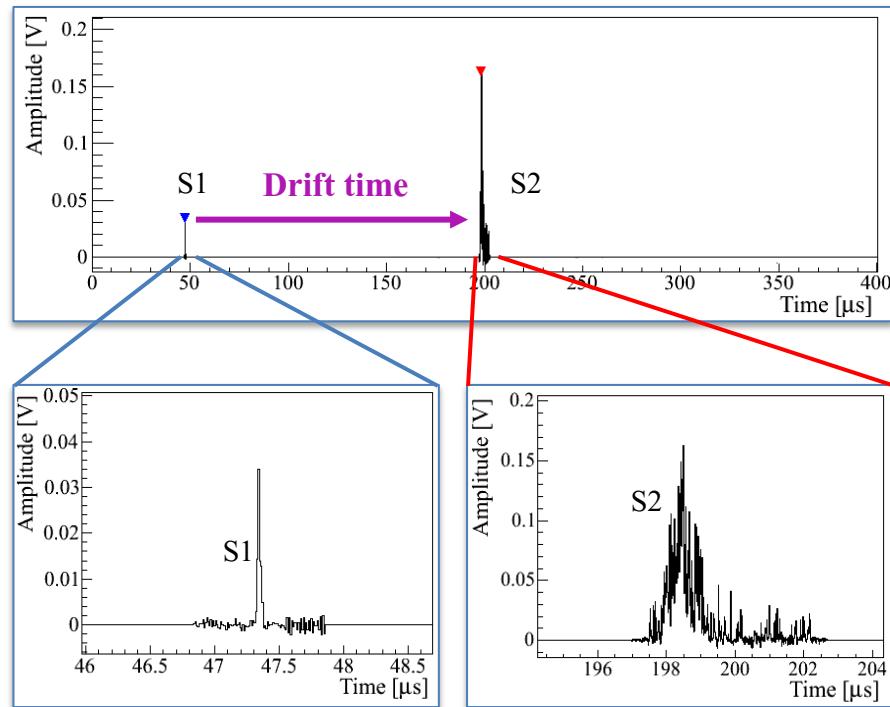
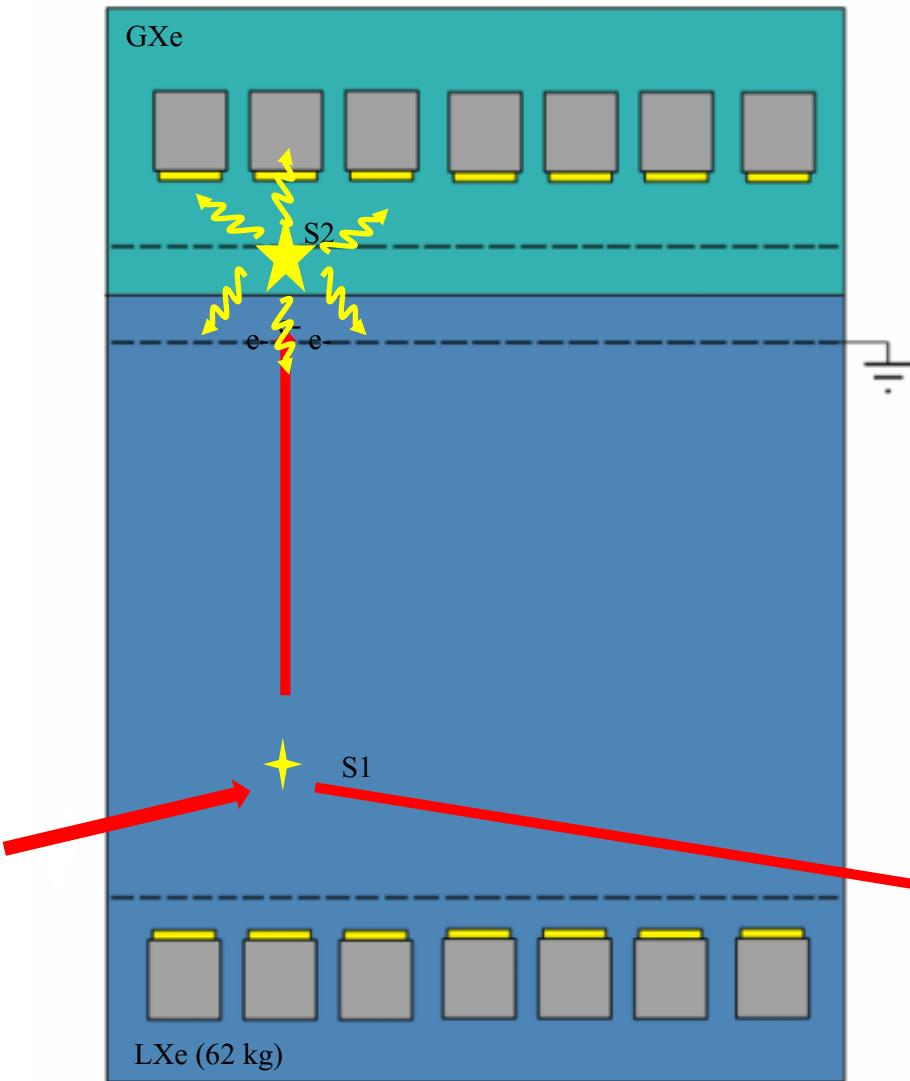


→ 100 x less background than XENON100

Single electrons analysis

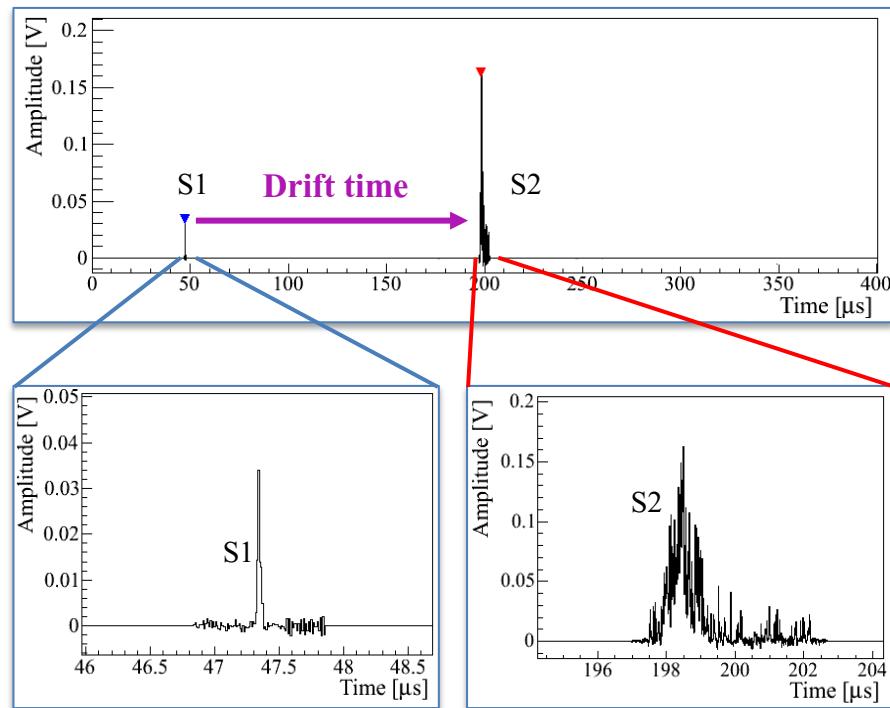
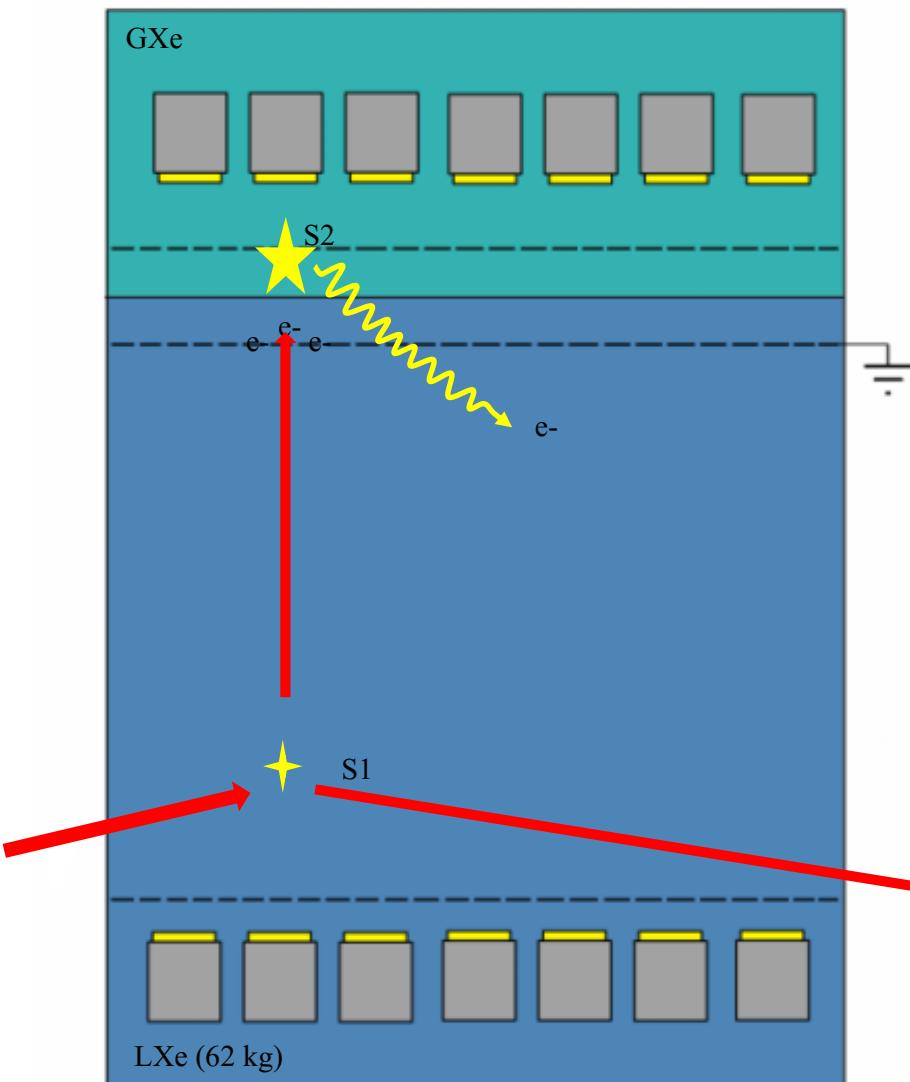
Single electron charge signal

○ Definition:



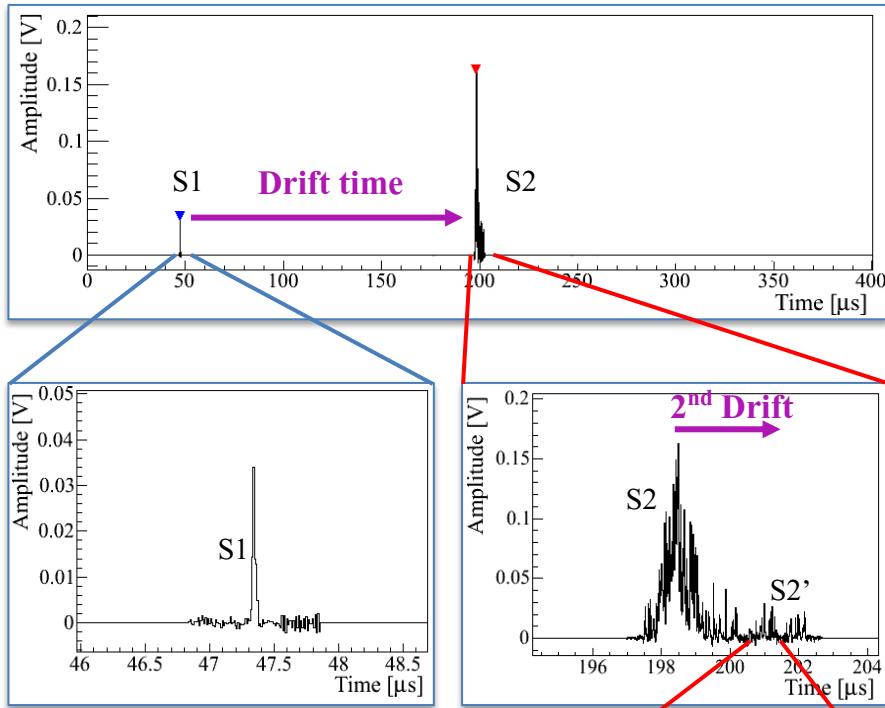
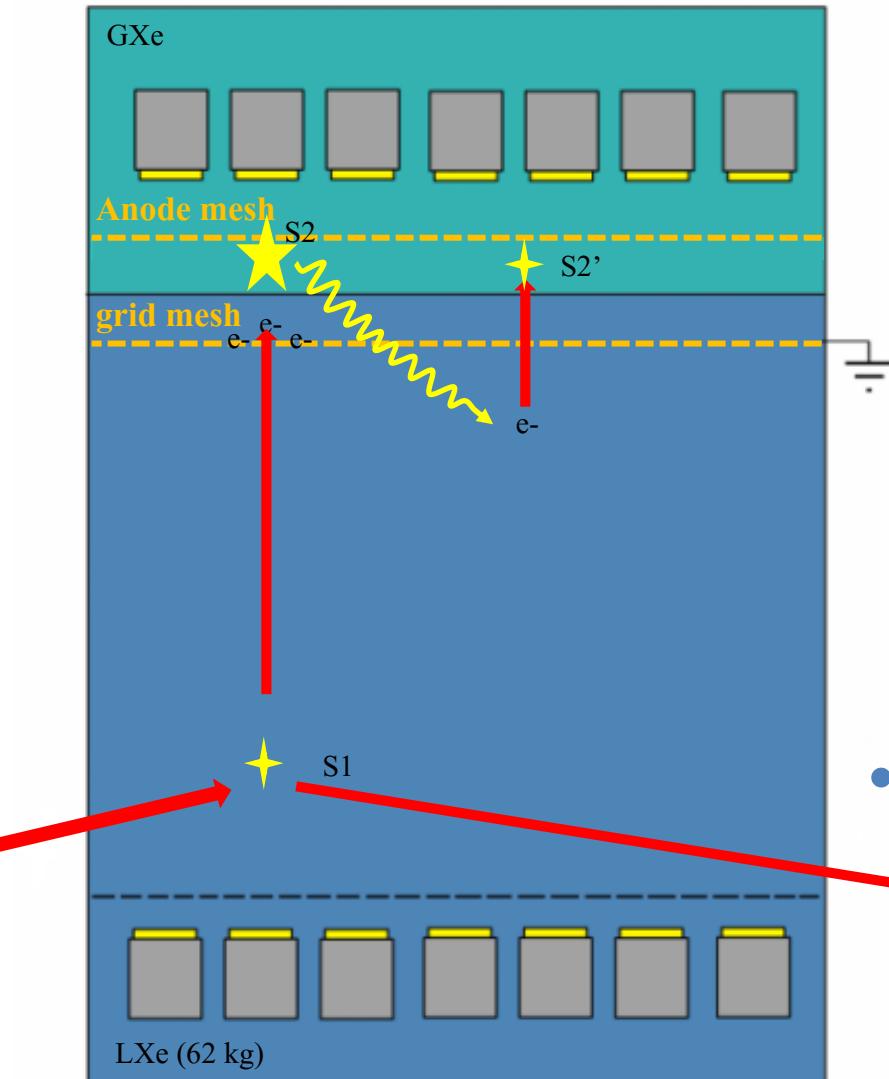
Single electron charge signal

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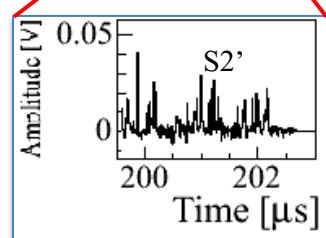


Single electron charge signal

○ Definition:



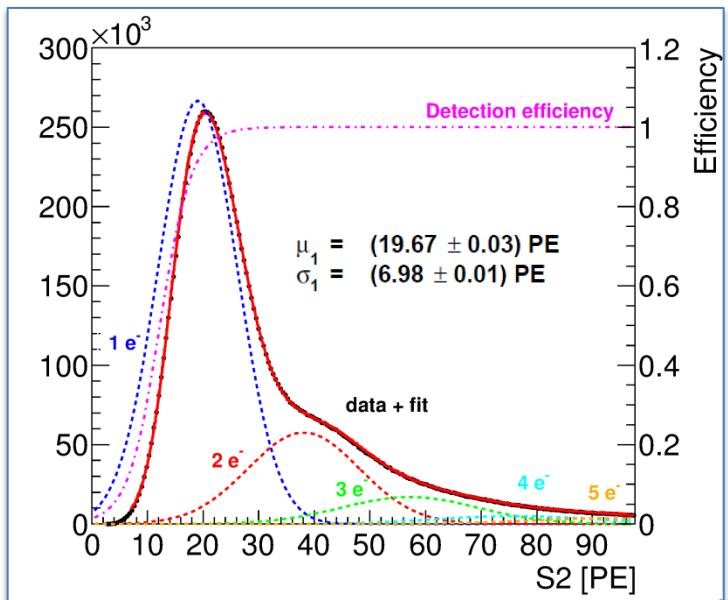
- **Single electron:**
 - **Photoelectric effect** on impurities
 - **Small charge signal** (~400 photons)



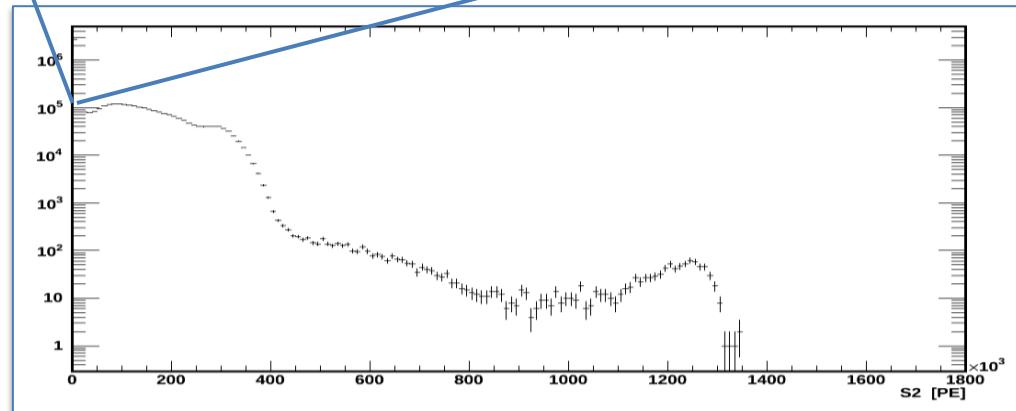
○ Secondary scintillation gain evaluation:

- S2 low energy spectrum
- Fit:
 - $\sum 5 \text{ Gaussians with } \mu_i = i \mu_1$
and $\sigma_i = \sqrt{i} \sigma_1$
 - Fermi-Dirac function
- $\mu_1 = \text{Secondary scintillation gain} \approx 20 \text{ PE}$

→ Sec. scint. gain = Average light for 1 e-

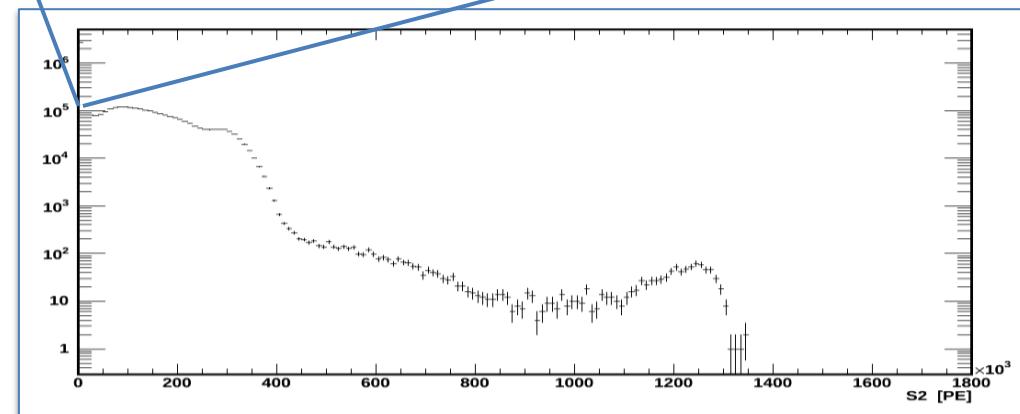
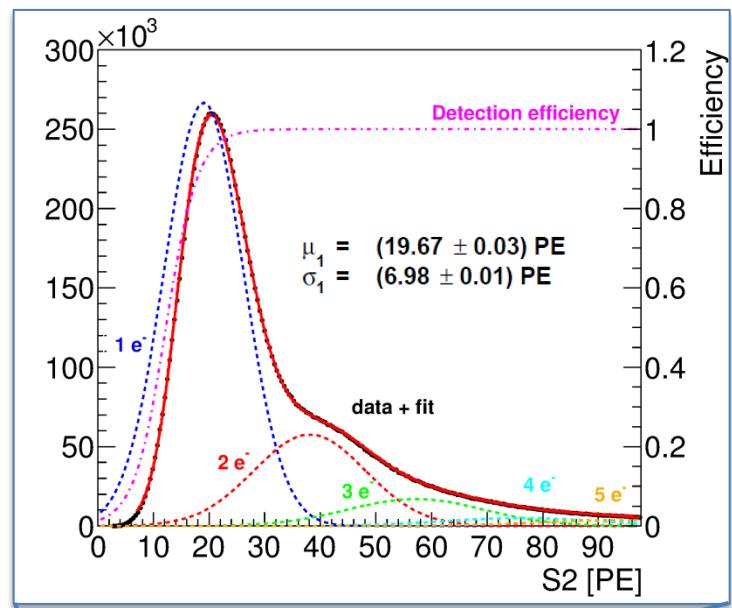


E. Aprile et al. (XENON100), arXiv:1311.1088, Submitted to J.Phys. G

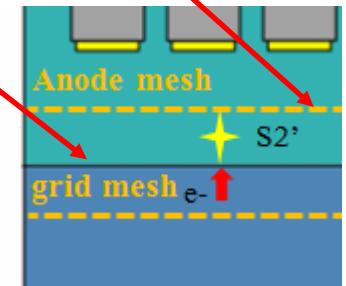


$$S2 (\text{PE}) = n_{ph/e^-} \cdot \varepsilon_{\text{extr}} \cdot \varepsilon_{\text{coll}} \cdot \varepsilon_{\text{quant}}$$

○ Secondary scintillation gain evaluation:

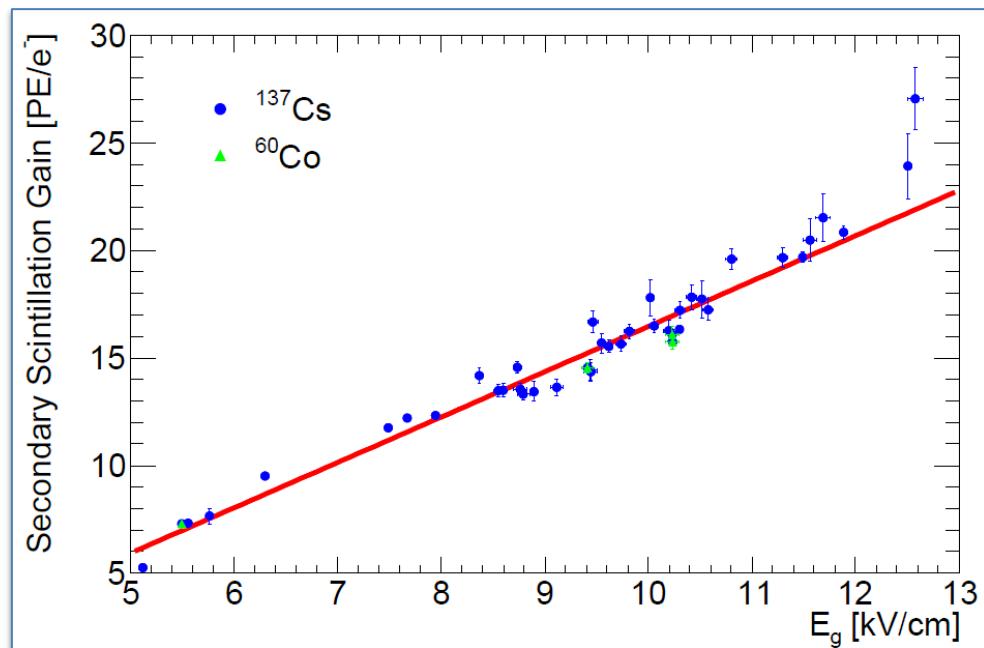


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 - $\mu_1 = \text{Secondary scintillation gain} \approx 20 \text{ PE}$
- Sec. scint. gain = Average light for 1 e⁻
- $E_{\text{gas}} = f(\text{Liquid Level, Anode voltage})$



$$S2 (\text{PE}) = n_{ph/e^-} \cdot \varepsilon_{\text{extr}} \cdot \varepsilon_{\text{coll}} \cdot \varepsilon_{\text{quant}}$$

- Evolution with the electric field:



- Data acquired during the three sciences runs
- Source independence
- Linear evolution
- Electron multiplication for $E_{\text{Gas}} > 11.9 \text{ kV/cm}$

$$G = \left(a \frac{E_g}{P_g} + b \right) h_g P_g \bar{\beta} \bar{\eta}$$

With:

E_g = Electric field in gas phase

P_g = Pressure in gas phase

h_g = drift length in gas phase

And :

$\bar{\beta}$ = PMTs Average photon collections efficiency (7–15 %)

$\bar{\eta}$ = PMTs Average quantum efficiency (25–32 %)

- **Interest on single electrons analysis:**

- Full understanding of the detector
- Optimization of running conditions
- Improvement of position reconstruction, and detector's low energy threshold
- Improvement of double scatters rejections
- Monte Carlo simulations
- ...

Thank you for your attention