Ettore Majorana meets his shadow (V)

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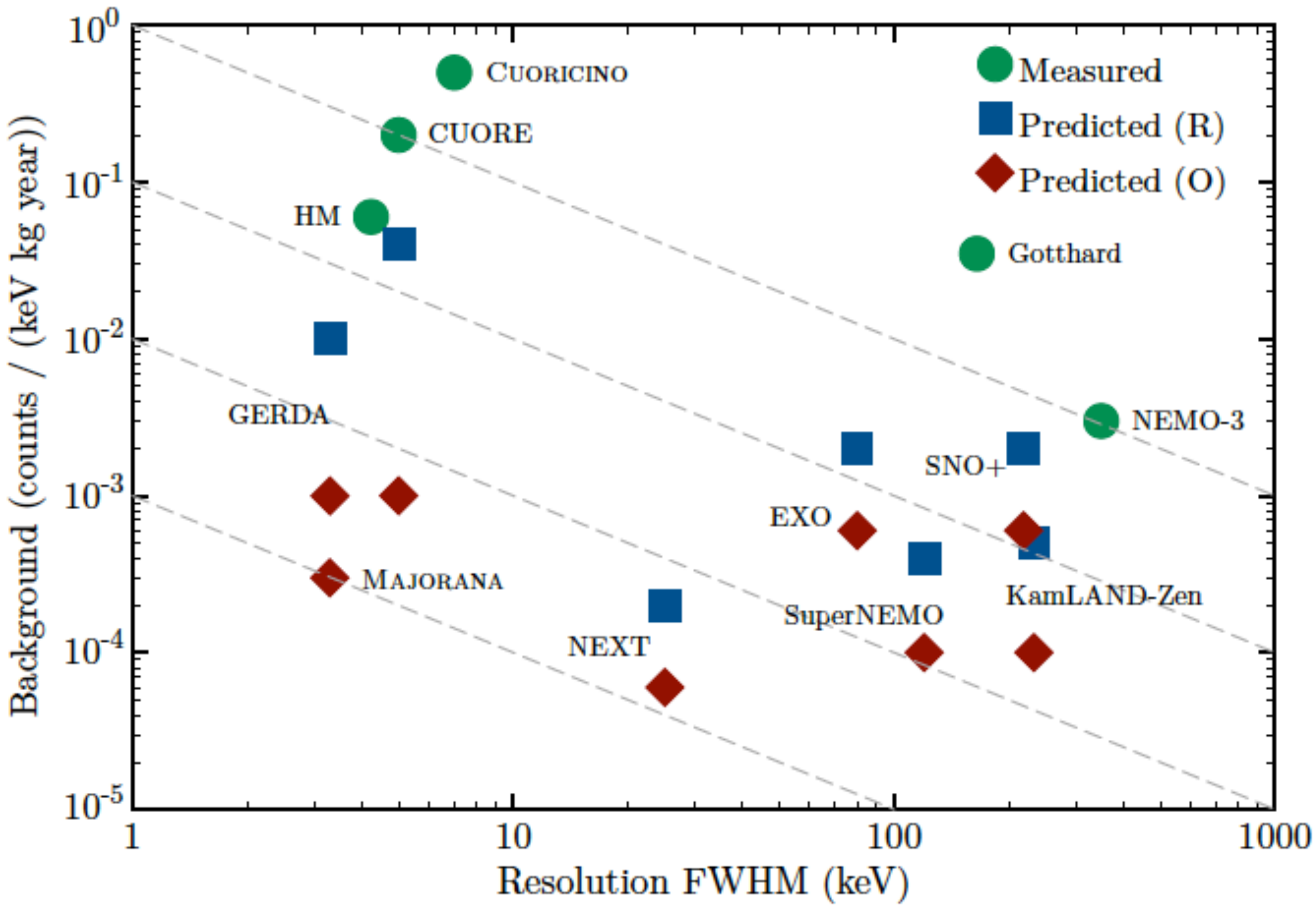
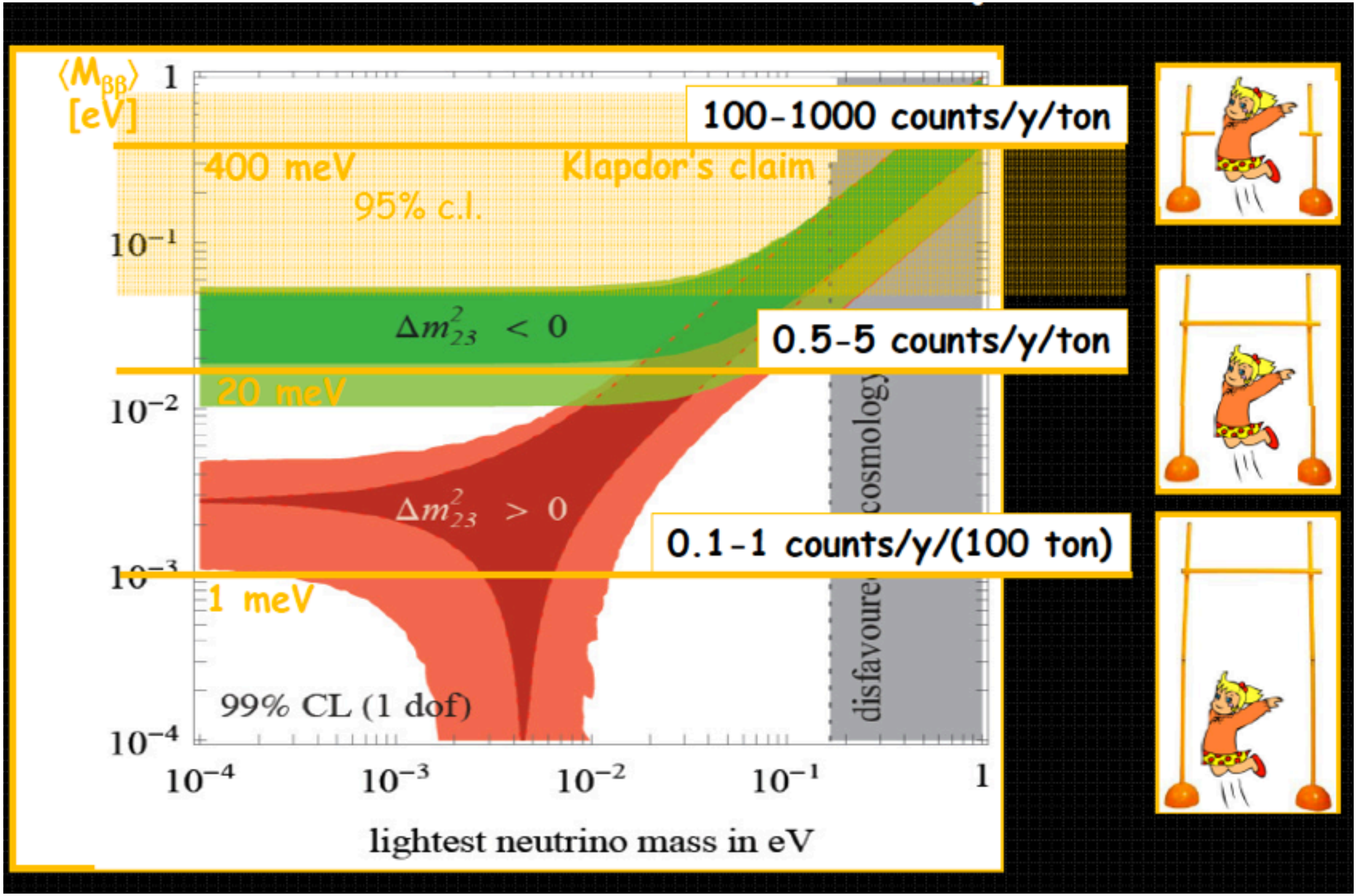
Proposals compared



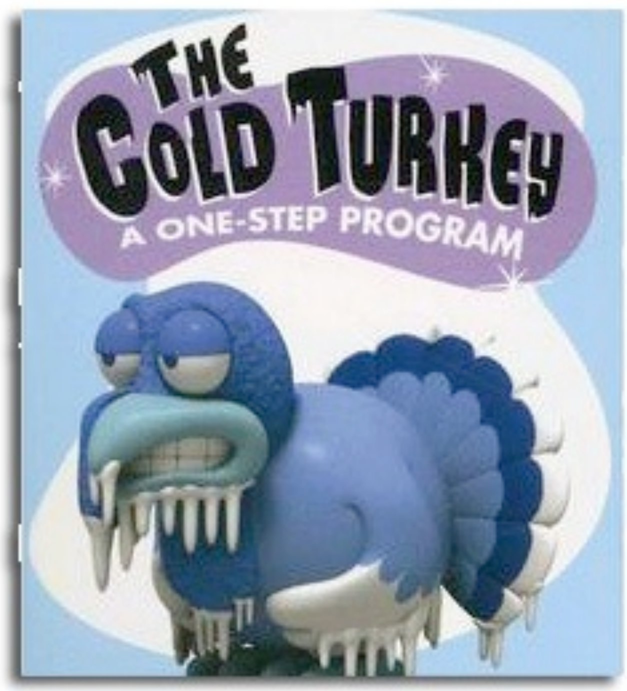
Three jumps ahead



Borrowed from A. Giuliani

Sensitivity

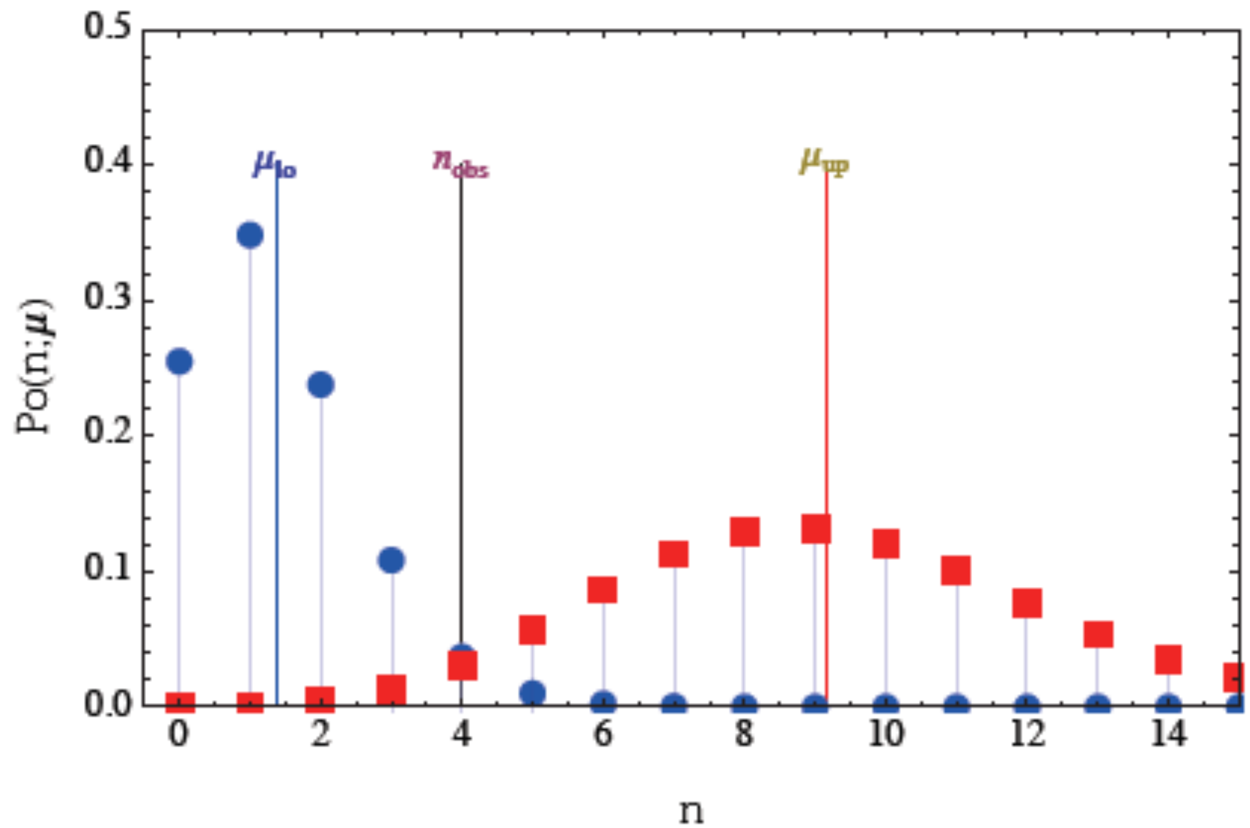
- A perverse way of expressing "cold turkey"
- Experiments who have not yet run try to convince funding agencies that they have a physics case by assuming failure in finding the signal!
- If the signal depends of some physics parameter, mbb, failure can be translated in a bound on the parameter (for DBD experiment an upper bound in mbb)
- The experiment who expects the lowest bound in mbb is the "best"



Describing DBD experiments

$$Po(n;\mu+b)=\frac{(\mu+b)^n}{n!}e^{-(\mu+b)}$$

Where mu is the true value of the signal (unknown) and b the expected background (known)



Example: An experiments observes 4 events (and expects b=0)

$$Po(n;\mu_{lo}=1.37)$$

90% of the blue dots are below n=4 (lower limit at 90% CL)

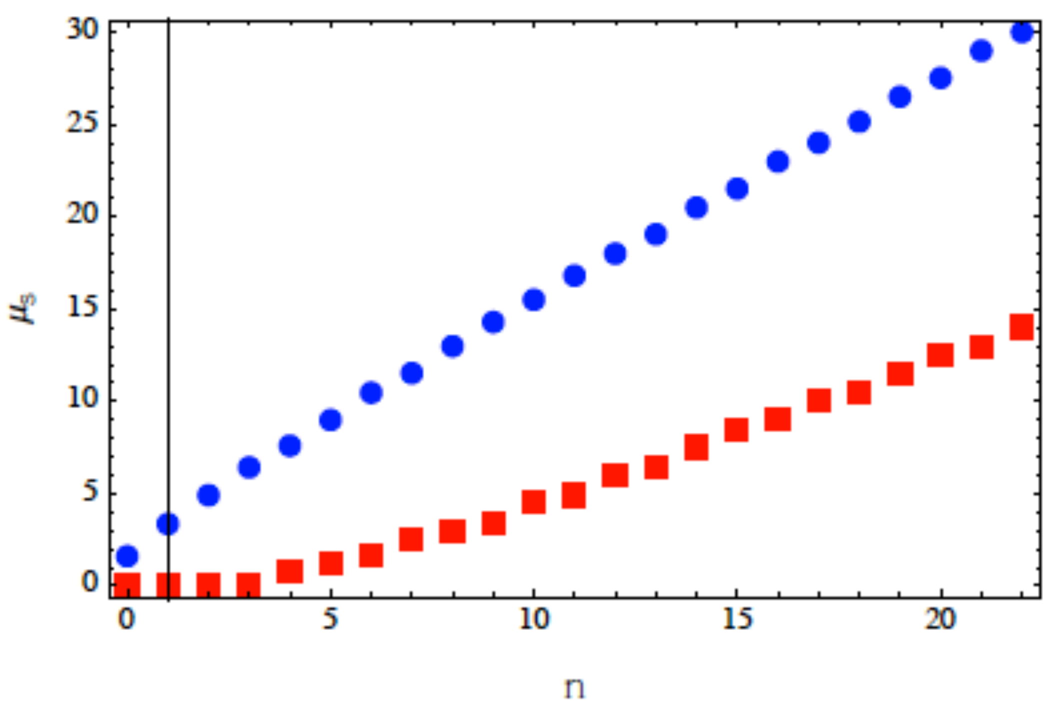
$$Po(n;\mu_{up}=9.15)$$

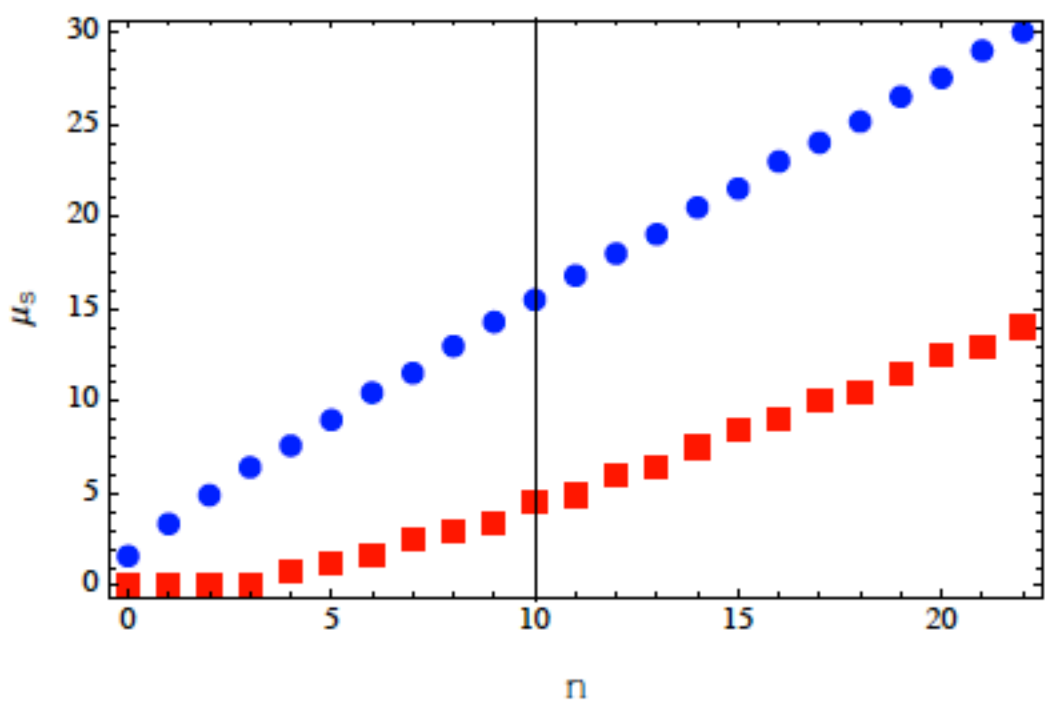
90% of the red dots are above n=4 (upper limit at 90% CL)

CONFIDENCE BELTS

$$\sum_{n=n_1}^{n_2} \frac{(\mu_{lo}+b)^n}{n!} e^{-(\mu_{lo}+b)} \geq CL$$

For a given value of b construct belts for all possible values of mu (example, b=1)





Construct horizontal: read vertical

The Unified Approach

$$\sum_{n=n_1}^{n_2} \frac{(\mu_{lo}+b)^n}{n!} e^{-(\mu_{lo}+b)} \geq CL$$

Acceptance interval constrained by equation but not fully specified by it.

Unified approach (a.k.a Feldman & Cousins)

ordering principle based on likelihood ratio

1) Compute the mean background expectation b (e.g, b=1)
2) Given b, compute the best estimator for the true value of the mean signal, mu_best for each possible measurement outcome, n. If mu is unconstrained, mu_best is found by maximizing the Poisson probability for any given b and n.

$$\left.\frac{dPo(n;\mu+b)}{d\mu}\right|_{n,b} = \frac{d}{d\mu}\frac{(\mu+b)^n}{n!}e^{-(\mu+b)} = n-b$$

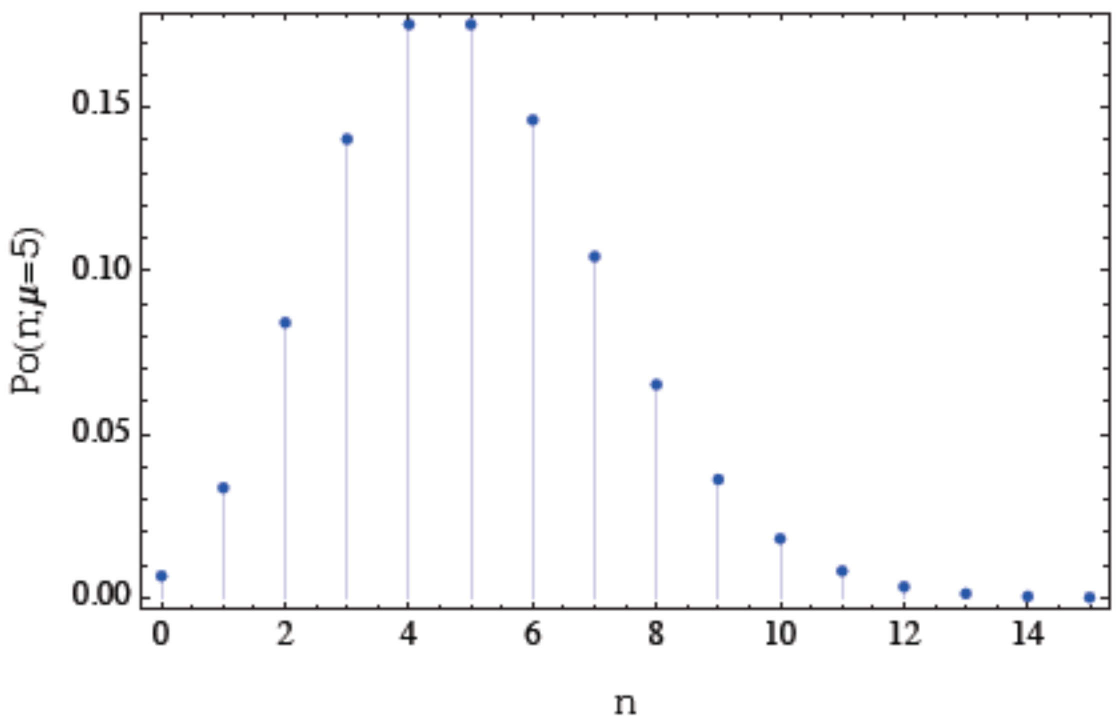
$$\mu_{best} = \max(0, n-b)$$

Since only non-negative values for mu are allowed

Sensitivity of an experiment with background

What is Sensitivity of an experiment with background b?

Average upper limit that would be obtained by an ensemble of identical replicas of such experiment, all of them expecting the same background and no true signal



Given the expected background b and assuming expected signal mu=0, the ensemble of experiments would be defined by Po(n;b)

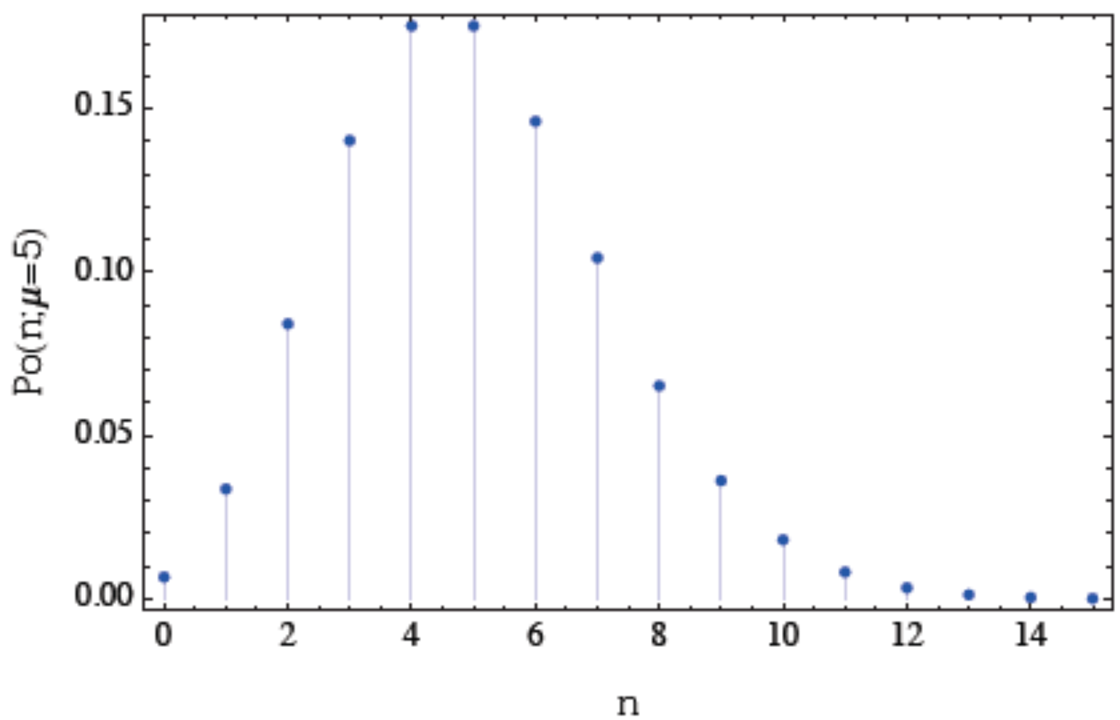
Example: Ensemble of experiments with b=5, mu=0

Sensitivity of an experiment with background

In the above example:

1) Compute the upper limit using F&C for each “experiment” (defined by n=0, 1, 2… defined by U(n;b)

2) Multiply by the probability of each experiment defined by Po(n;mu)



$$S(b) = \sum_{n=0}^{\infty} Po(n;b)U(n;b)$$

$$S(5) = \sum_{n=0}^{\infty} Po(n;5)U(n;5) = 4.99 \times 0.175 + 3.66 \times 0.175 + ... = 5.17$$

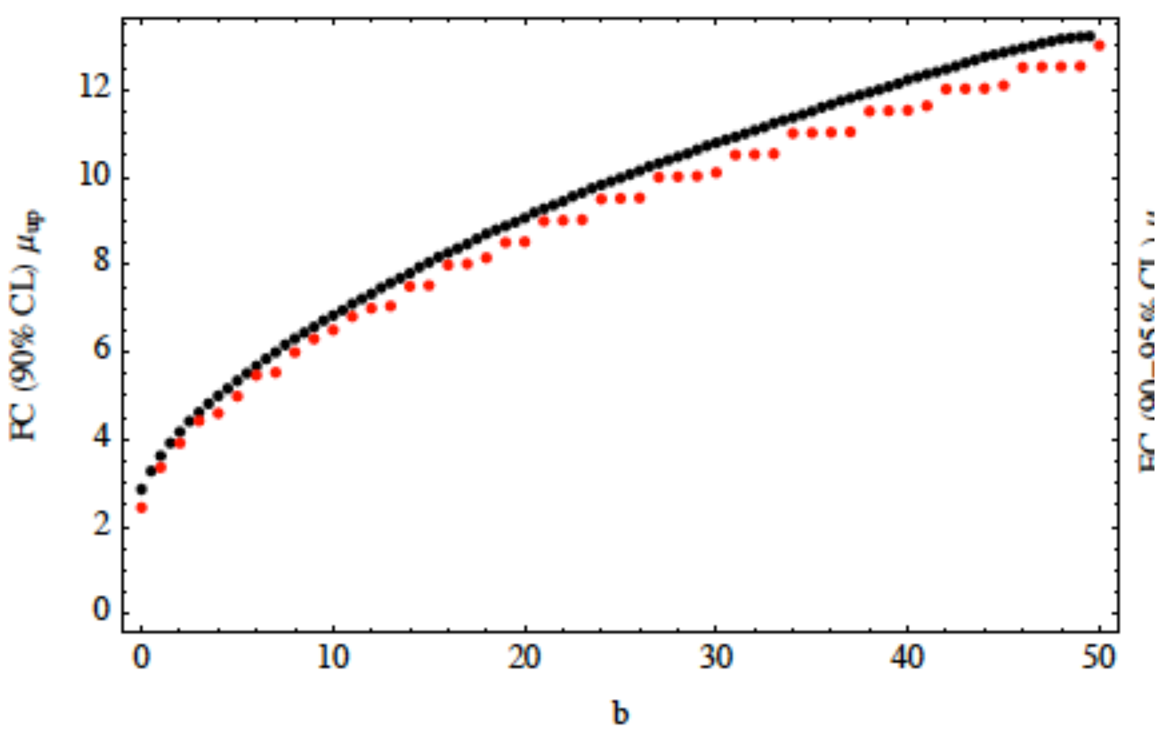
Example: Ensemble of experiments with b=5, mu=0

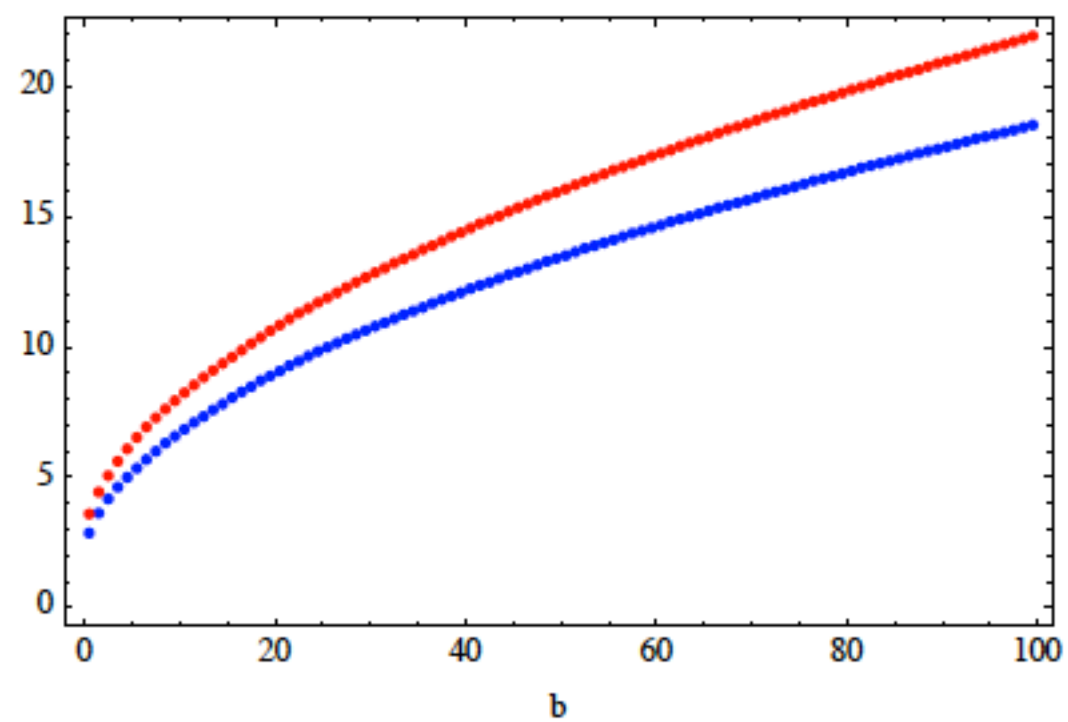
Sensitivity of an experiment with background

Notice that:
1) S(n;b) not the same that S(n;n)
2) In the large limit we recover the expected behavior

$S(b) \sim \sqrt{b} \Rightarrow$ for large n

$S(b) \sim$ 90% and 95% CL





$$m_{\beta\beta} = K_2 \sqrt{\frac{b^{1/2}}{\varepsilon M t}} \longrightarrow b = c \cdot Mt \cdot \Delta E \longrightarrow m_{\beta\beta} = K_2 \sqrt{1/\varepsilon} \left(\frac{c\, \Delta E}{Mt}\right)^{1/4}$$

Sensitivity of proposals

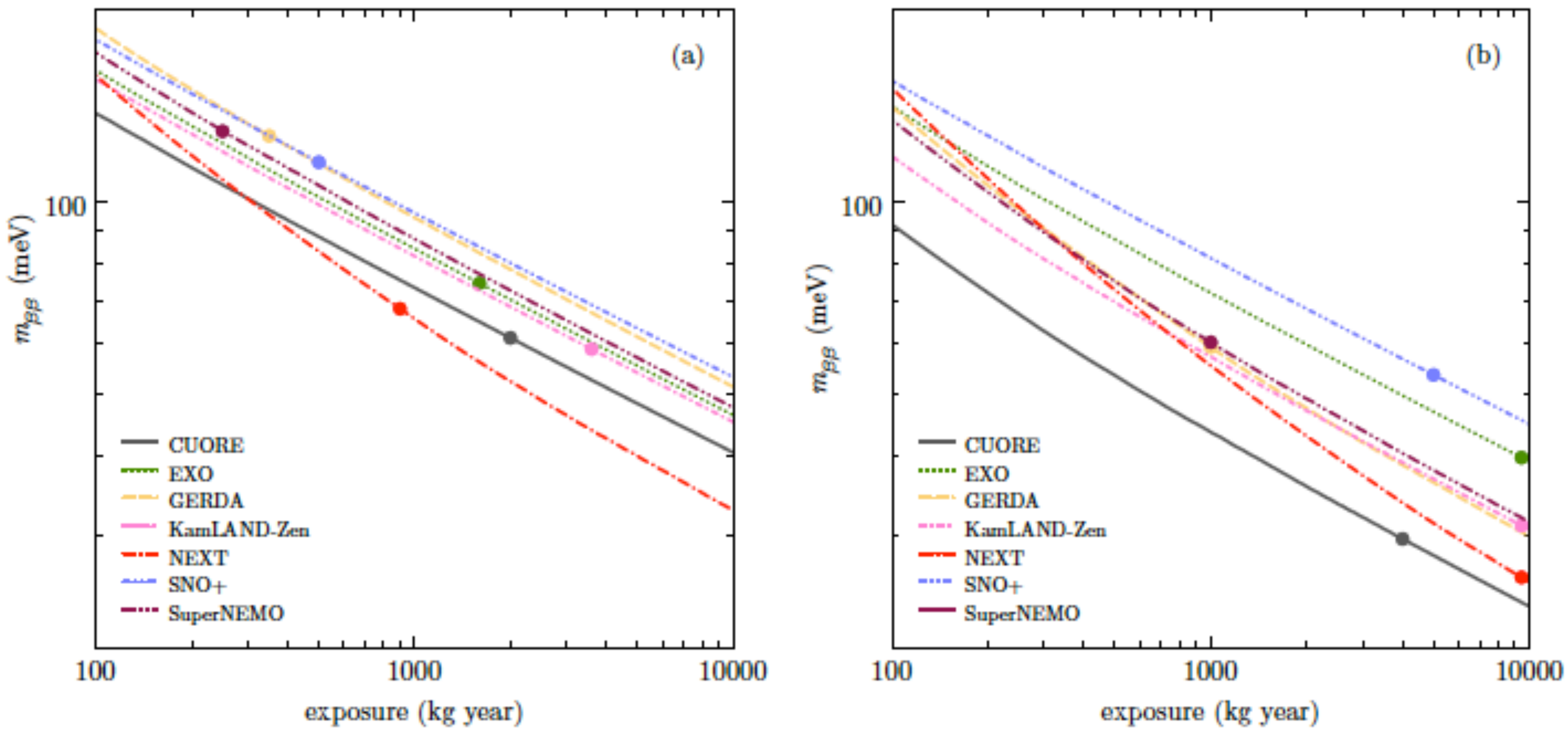
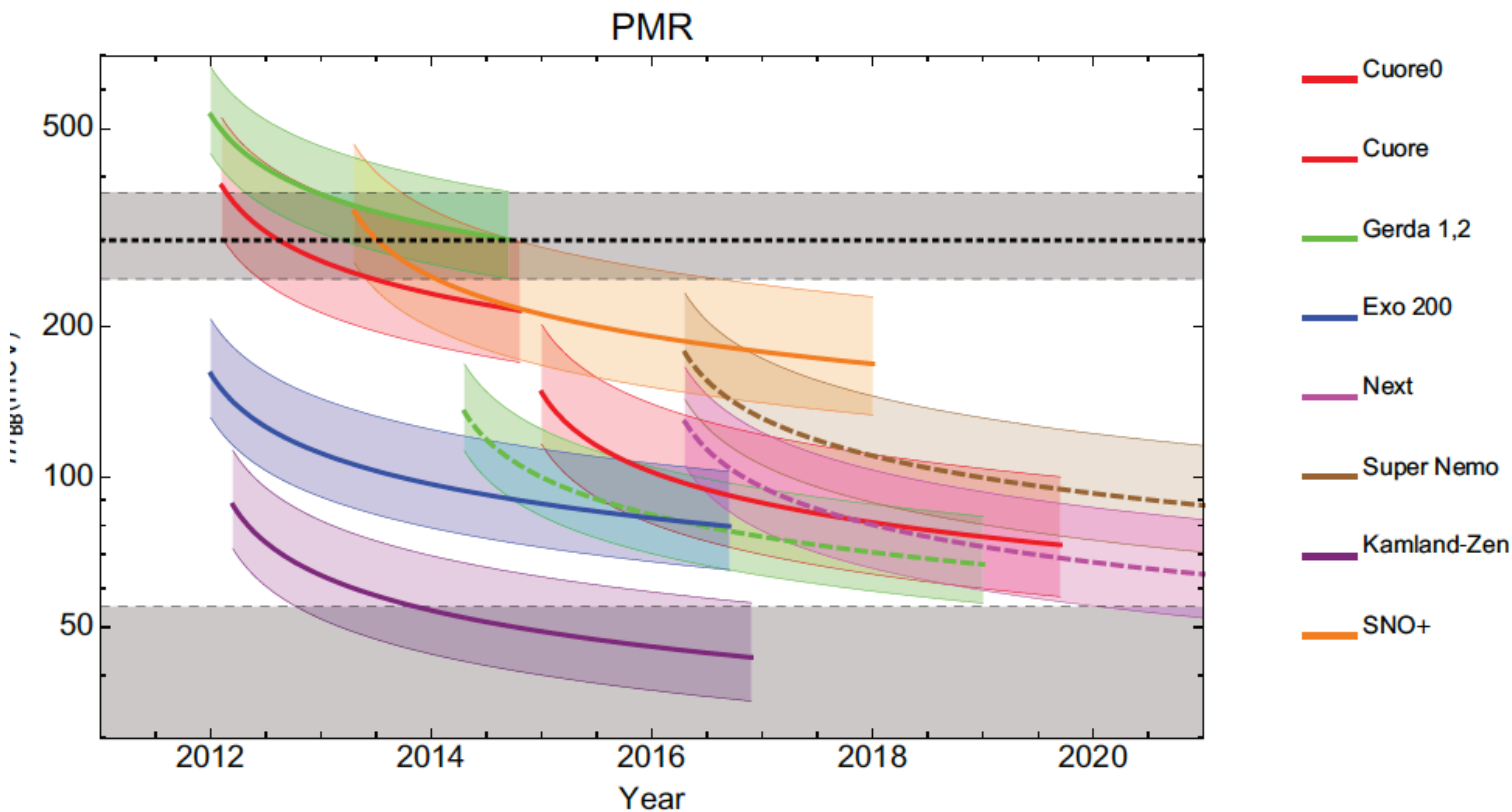
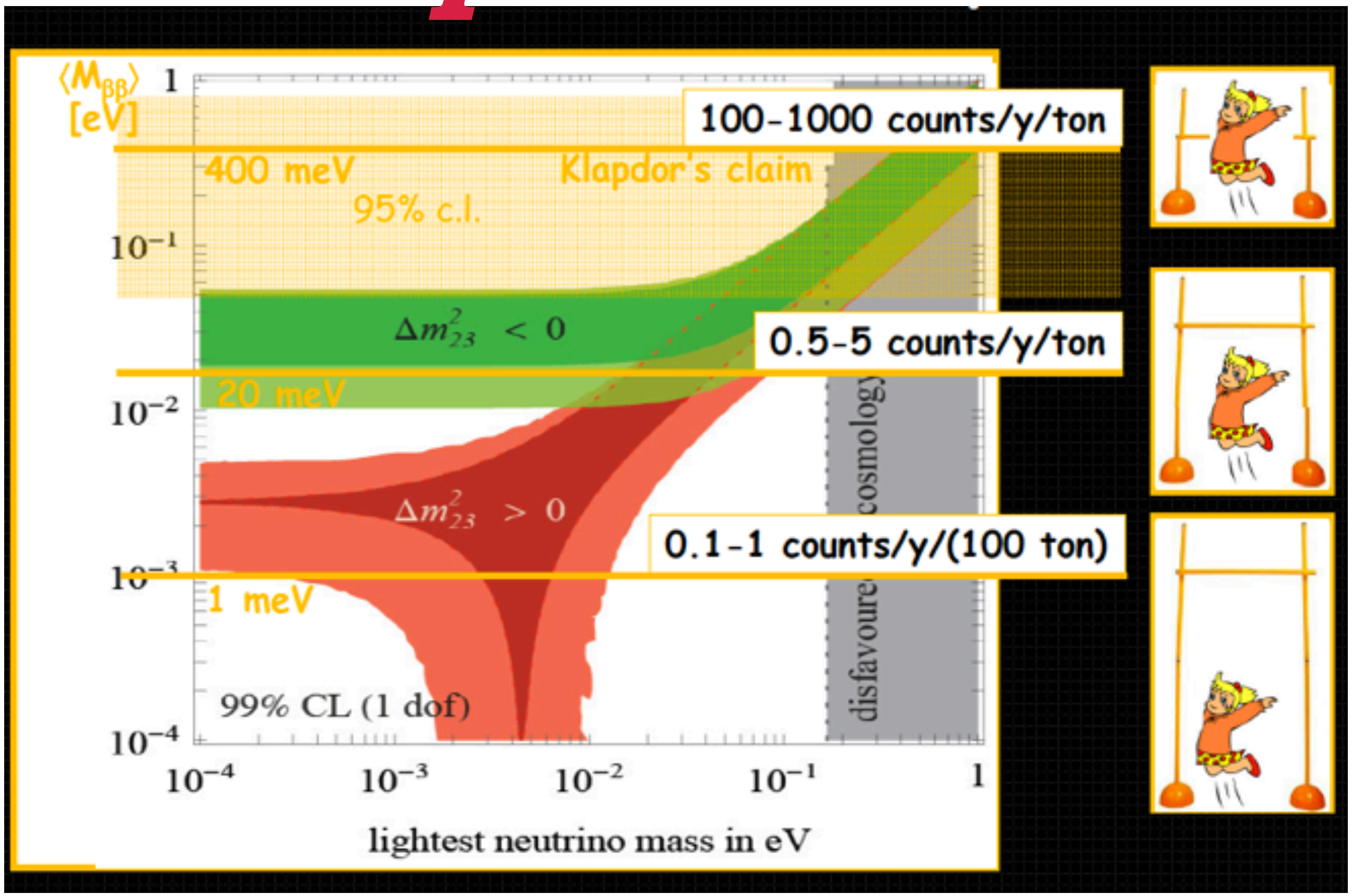


Figure 8. The $m_{\beta\beta}$ sensitivity (at 90% CL) as a function of exposure of the seven different $\beta\beta0\nu$ proposals considered. For each proposal, two detector performance scenarios are shown: (a) reference case (R), (b) optimistic case (O). For illustrative purposes, the filled circles indicate 10 yr exposures according to the reference and optimistic isotope mass assumptions in Table 2.

Sensitivity of proposals

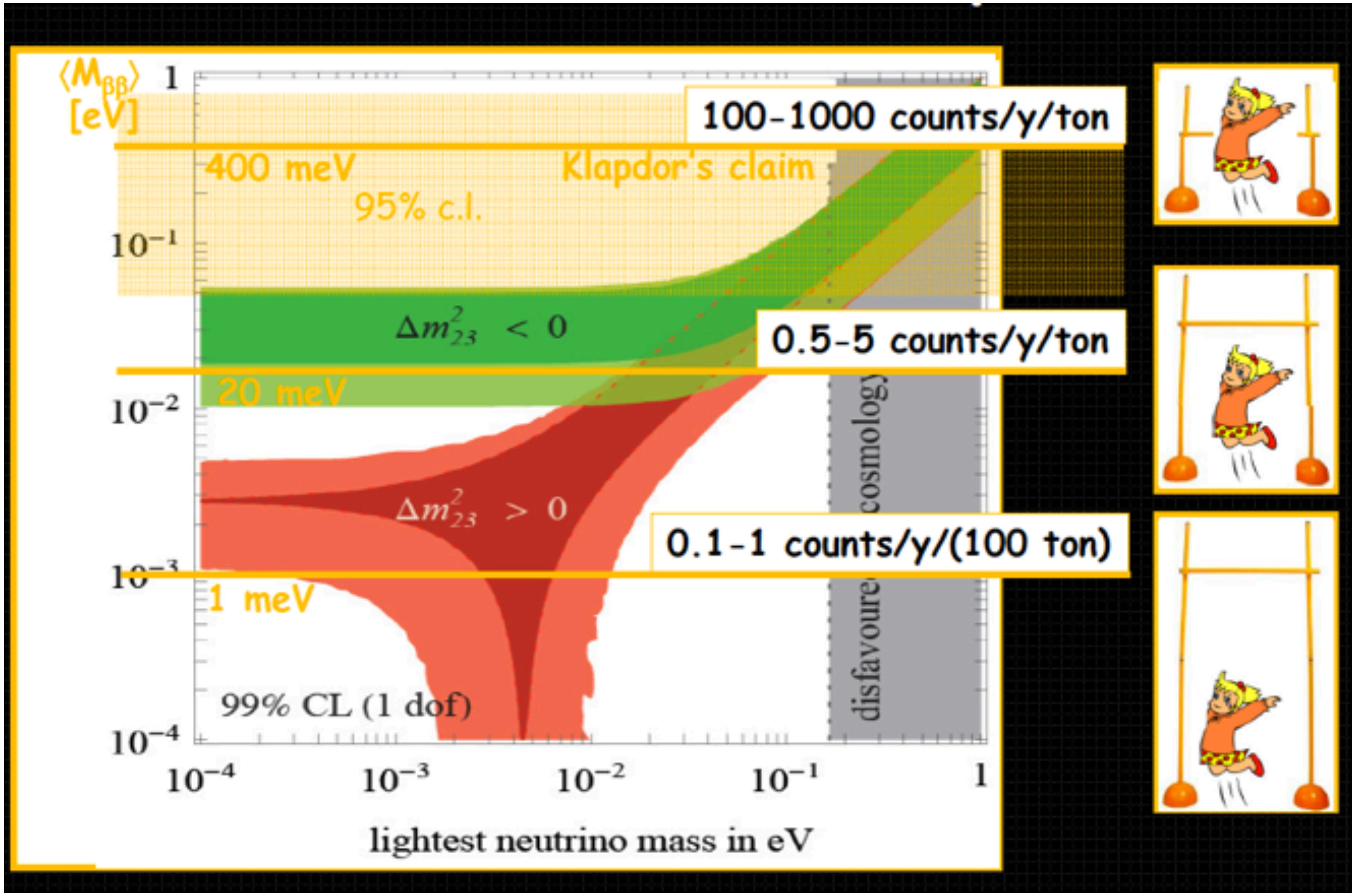


Two jumps perhaps possible



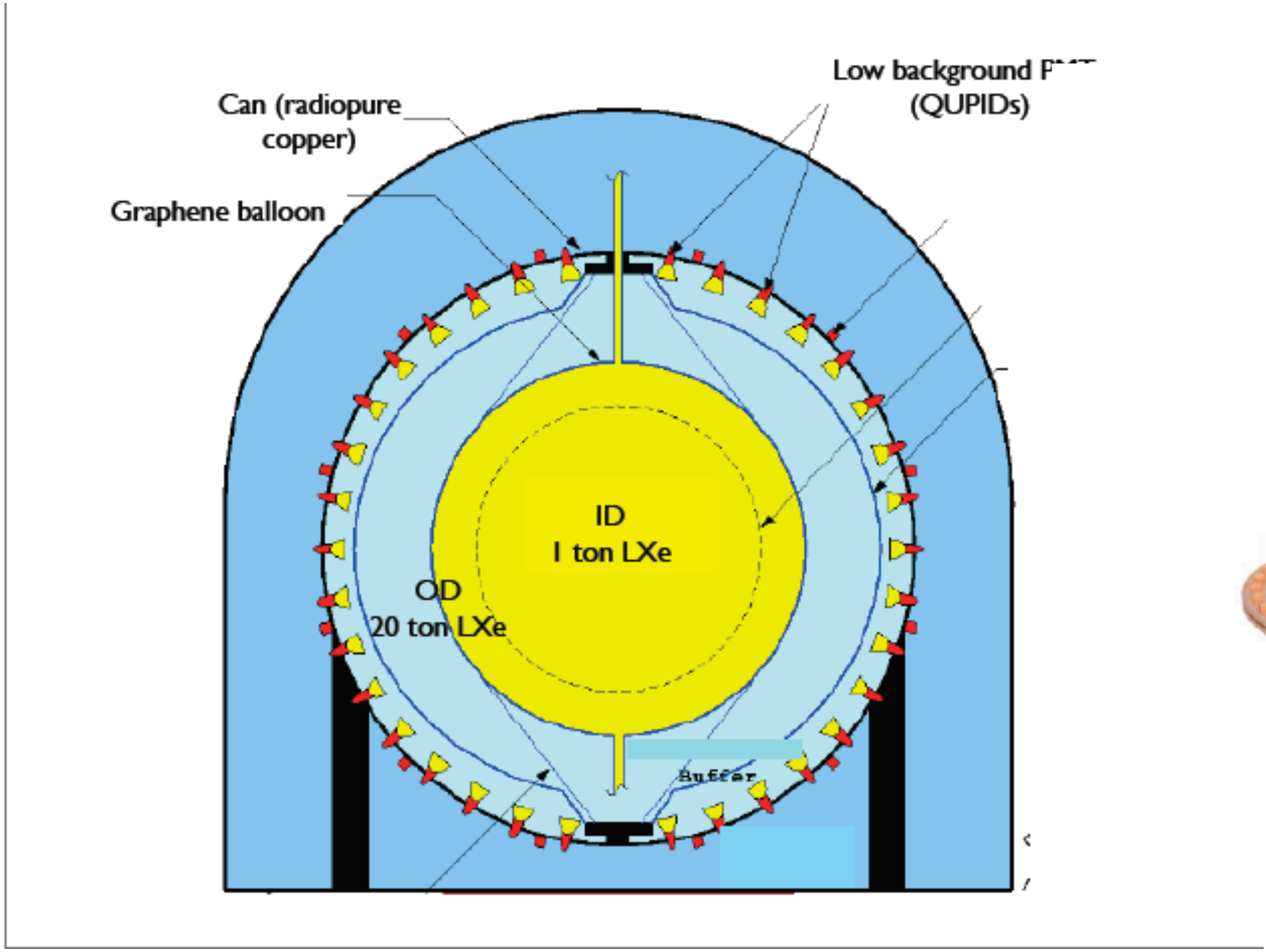
A number of next-generation experiments may reach 50 meV by 2020

And the third jump?

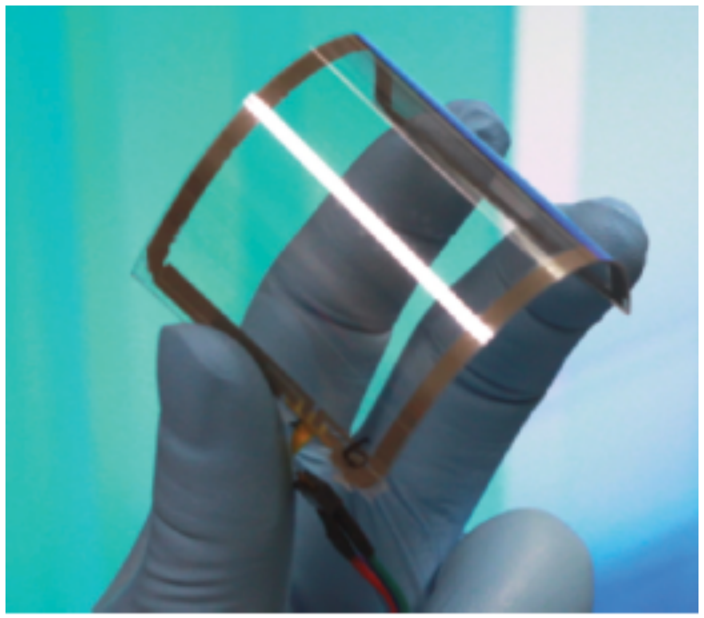


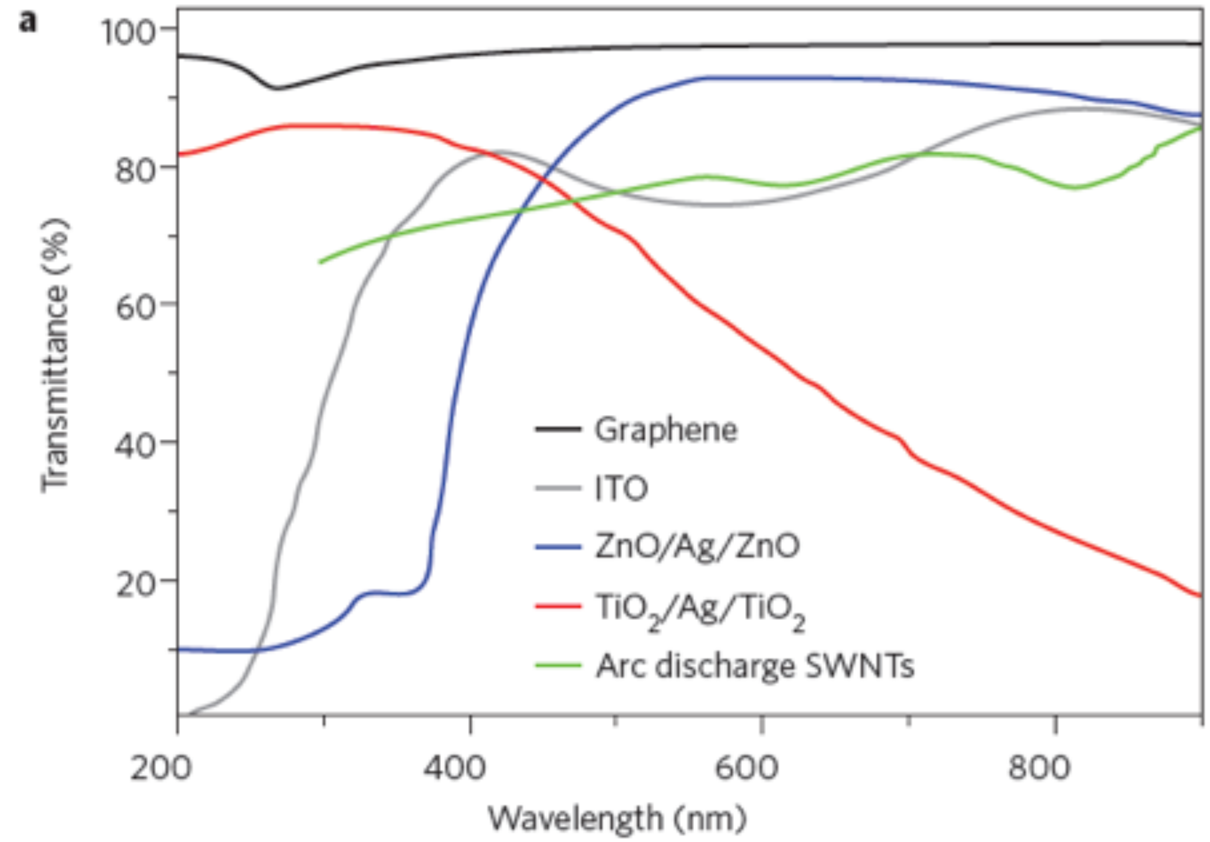
What is your favorite idea for an experiment that can explore beyond 50 meV?

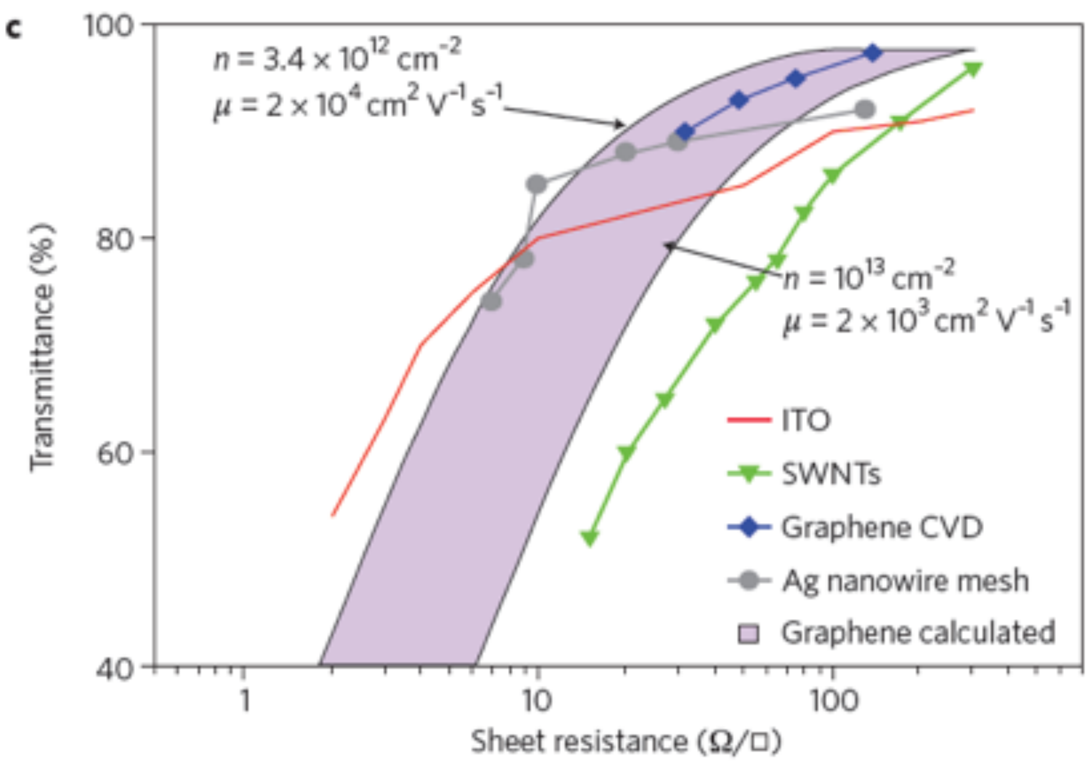
GraXe for DBD



GraXe for DBD







- Graphene is (very likely) transparent to Xenon light
- Strong, large area, "industrial" graphene sheets appear to be at reality.
- If one can manufacture a bag of Graphene to contain (liquid) Xenon and read the VUV light using external phototubes (shielded by natural Xenon) the experiment is virtually background free.

GraXe for DBD