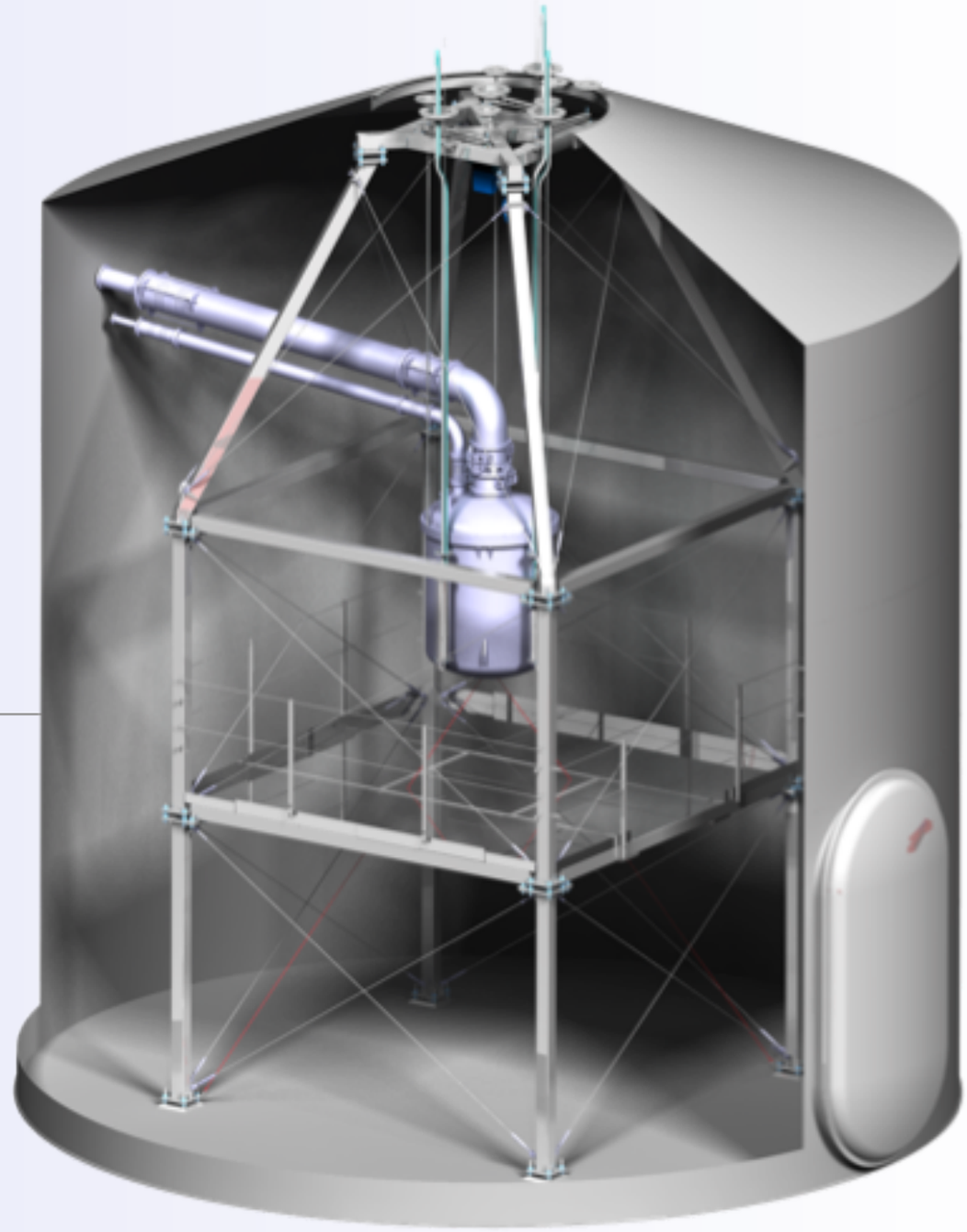
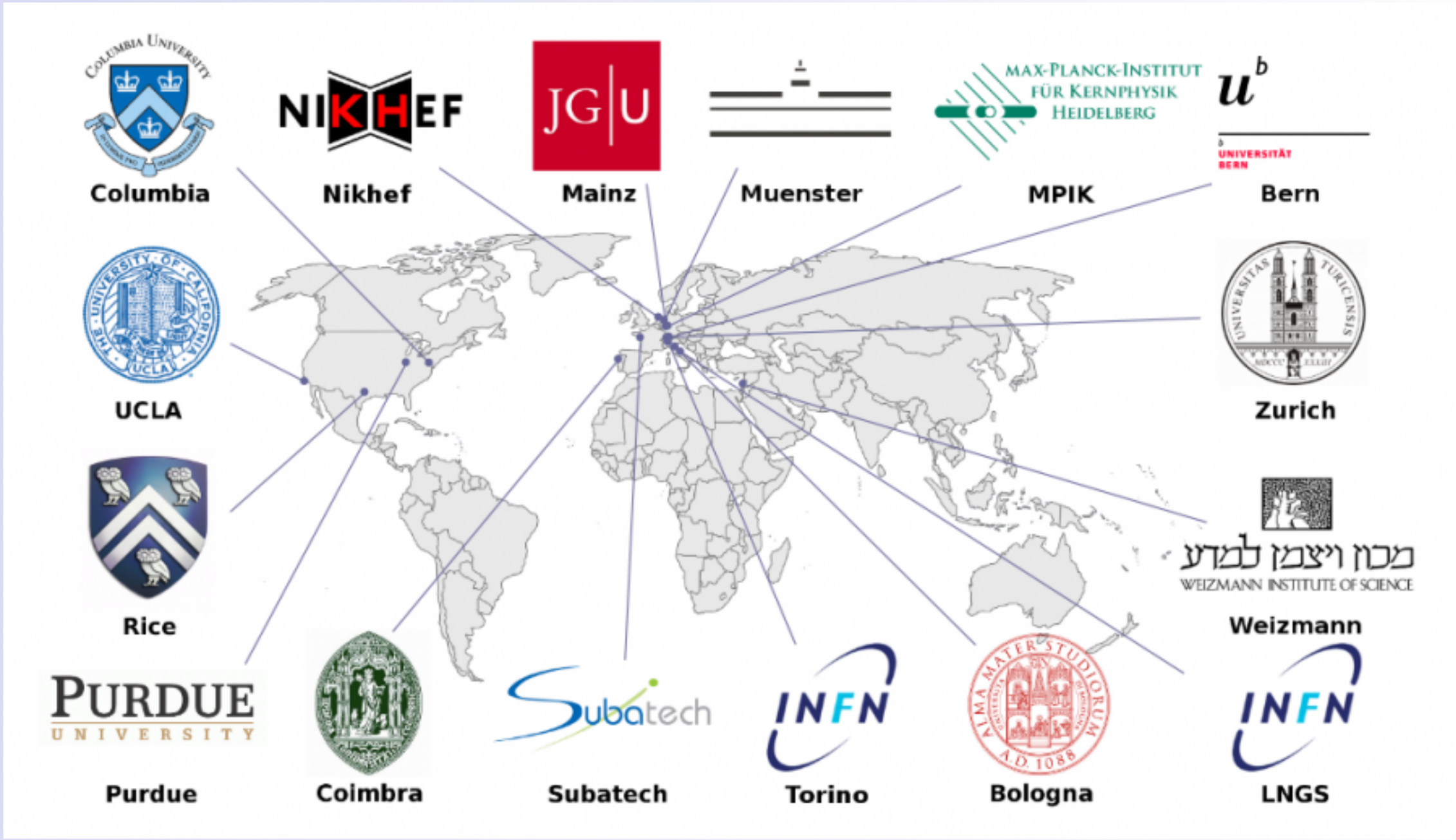
The XENON1T experiment



SUSY 2013
Trieste Italy

A.P.Colijn for the XENON collaboration
colijn@nikhef.nl

XENON collaboration



XENON1T:Two orders of magnitude more sensitive

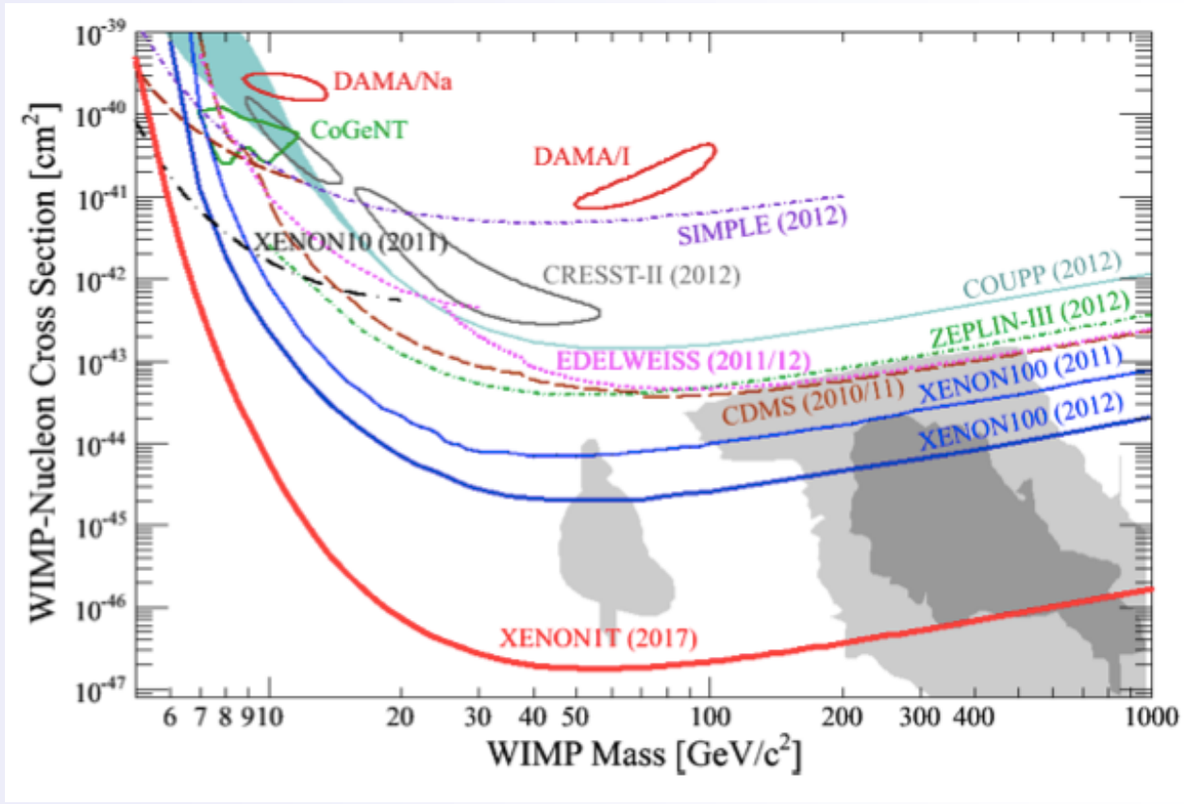
- **Goal:**

  ➡find dark matter particle

  ➡(improve the XENON100 limits by factor 100)

- Rate for spin-independent coupling

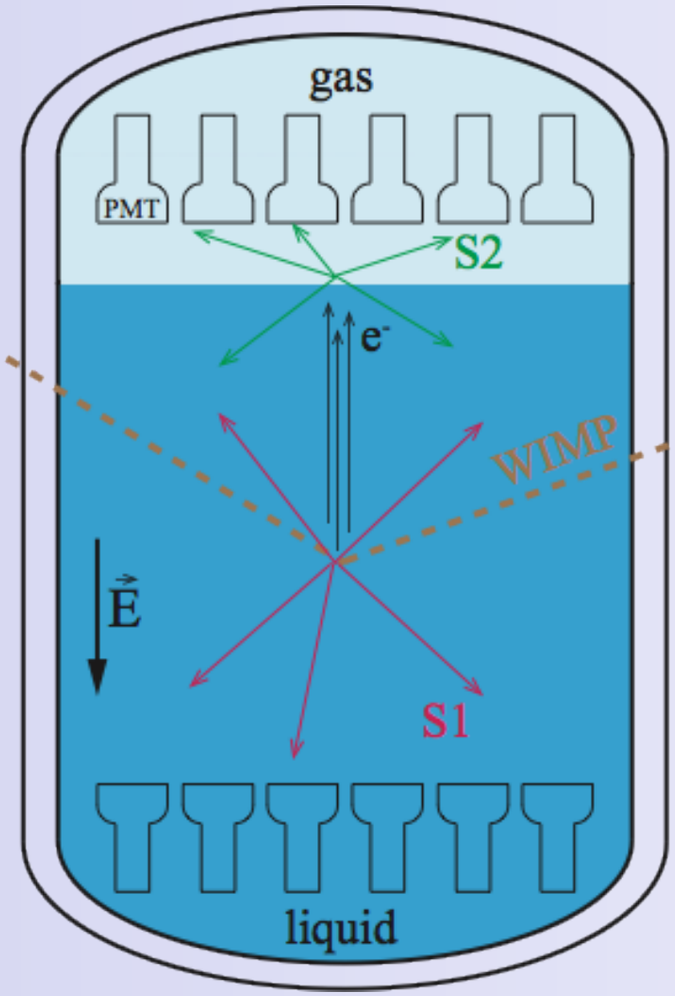
$$\frac{dR}{dE_{NR}} = \frac{M_{det}}{m_N}\frac{\rho_\chi}{m_\chi}\int_{v_{min}}^{v_{esc}} dv\, v f(v) \frac{d\sigma_N}{dE_{NR}}$$



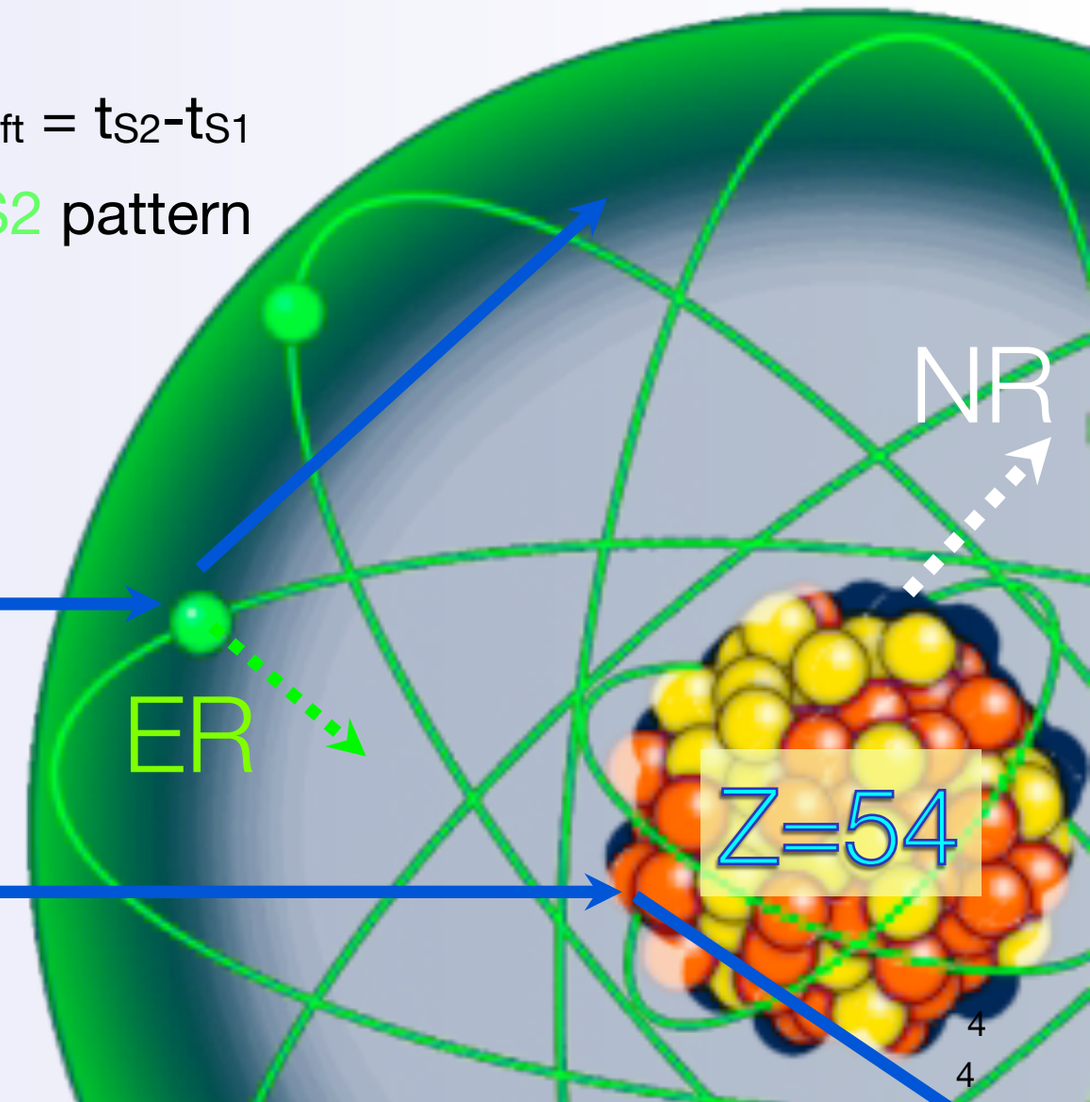
- M_{target} ~2200 kg (XENON100 62kg)

- Background < 1 event in 2 ton-year exposure (~100x lower than XENON100)

XENON: Calorimeter & 3D position detector



- From “any” recoil in xenon:
  - ➡S1 = scintillation
  - ➡S2 = ionization
- Energy from S1 and/or S2
- 3D position:
  - ➡ z-coordinate from $t_{drift} = t_{S2}-t_{S1}$
  - ➡ xy-coordinate from S2 pattern

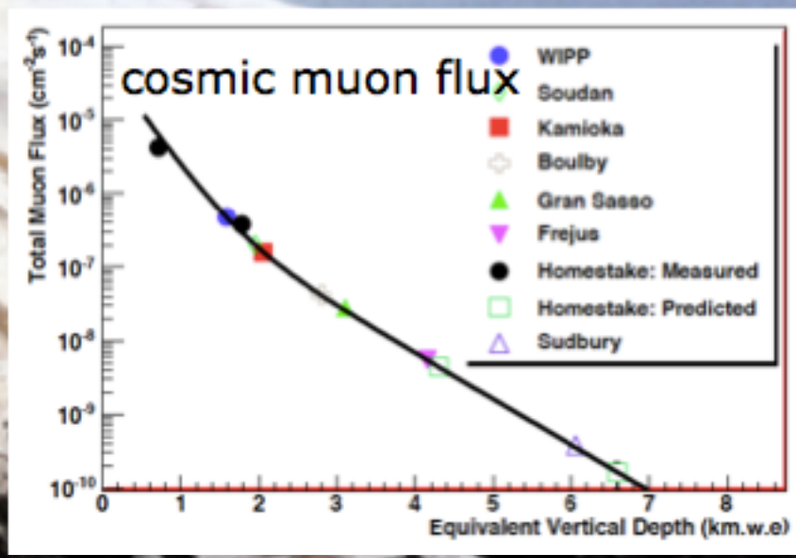


$(S2/S1)_{ER} > (S2/S1)_{NR}$

In XENON100 99.75% of electronic recoils (ER) are rejected, while keeping 50% of the nuclear recoils (NR).

Laboratori Nazionali del Gran Sasso, Italy

LNGS 1400 m Rock (3100 w.m.e)



ICARUS

XENON1T

WARP

XENON10 / XENON100

LVD

ICARUS

WARP

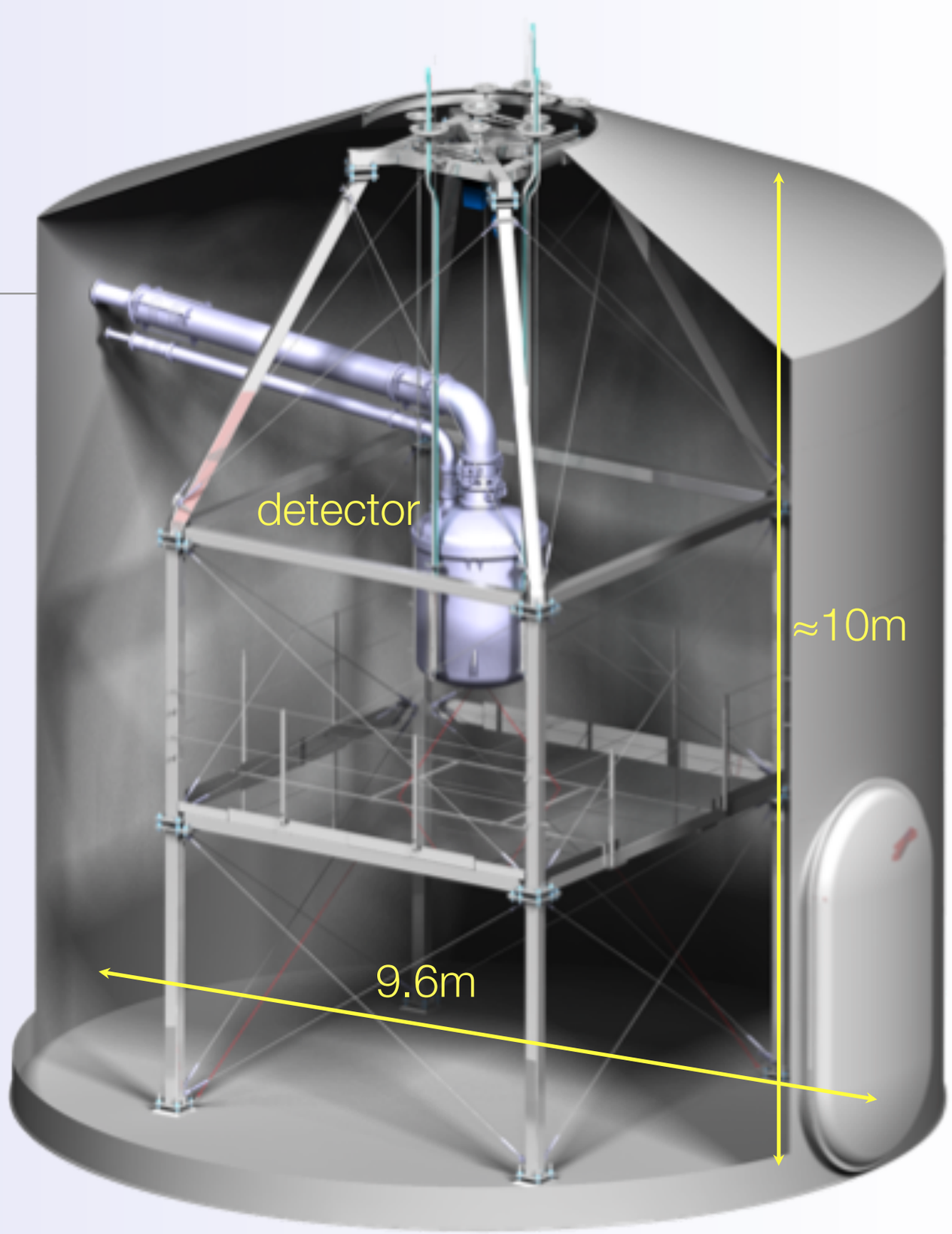
OPERA

XENONIT

XENON1T: Design

- Dark matter detector inside cryostat
- Surrounded by 10m diameter Cerenkov active shield
- Cryostat suspended from 3 rods, like a marionette

- <u>Infrastructure outside water shield</u>
  - ➡DAQ + HV + slow control
  - ➡Cryogenics system
  - ➡Xenon purification and handling




XENON100 on same scale

XENON1T: Cryostat & Cryogenics

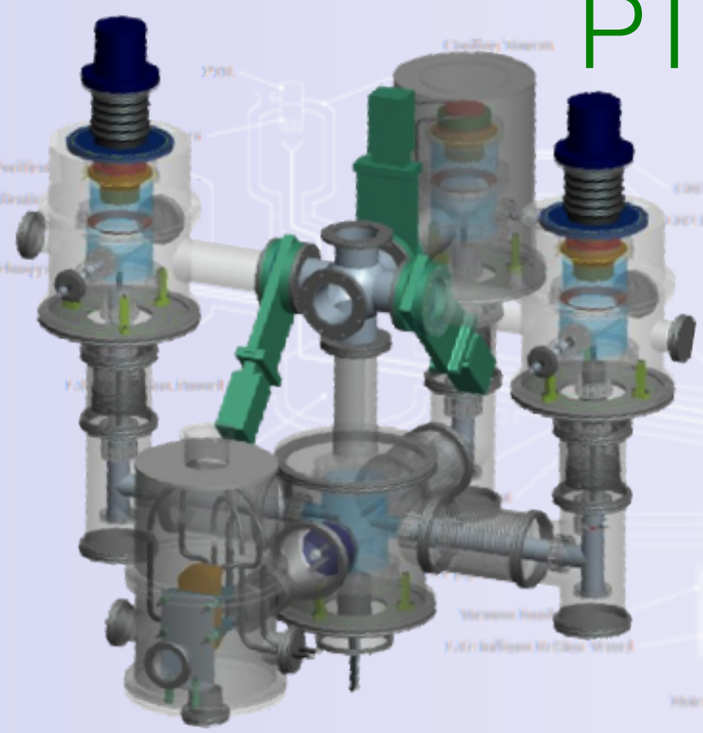
Cryogenics

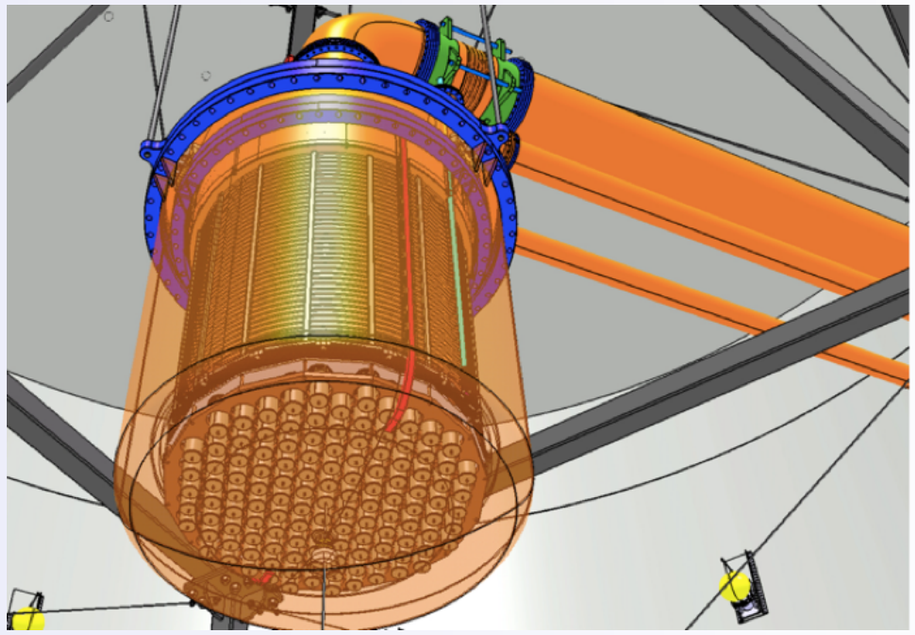
➡200W pulse tube refrigerator plant

➡Liquid N_2 backup for safety

PTR2

PTR1





Cryostat

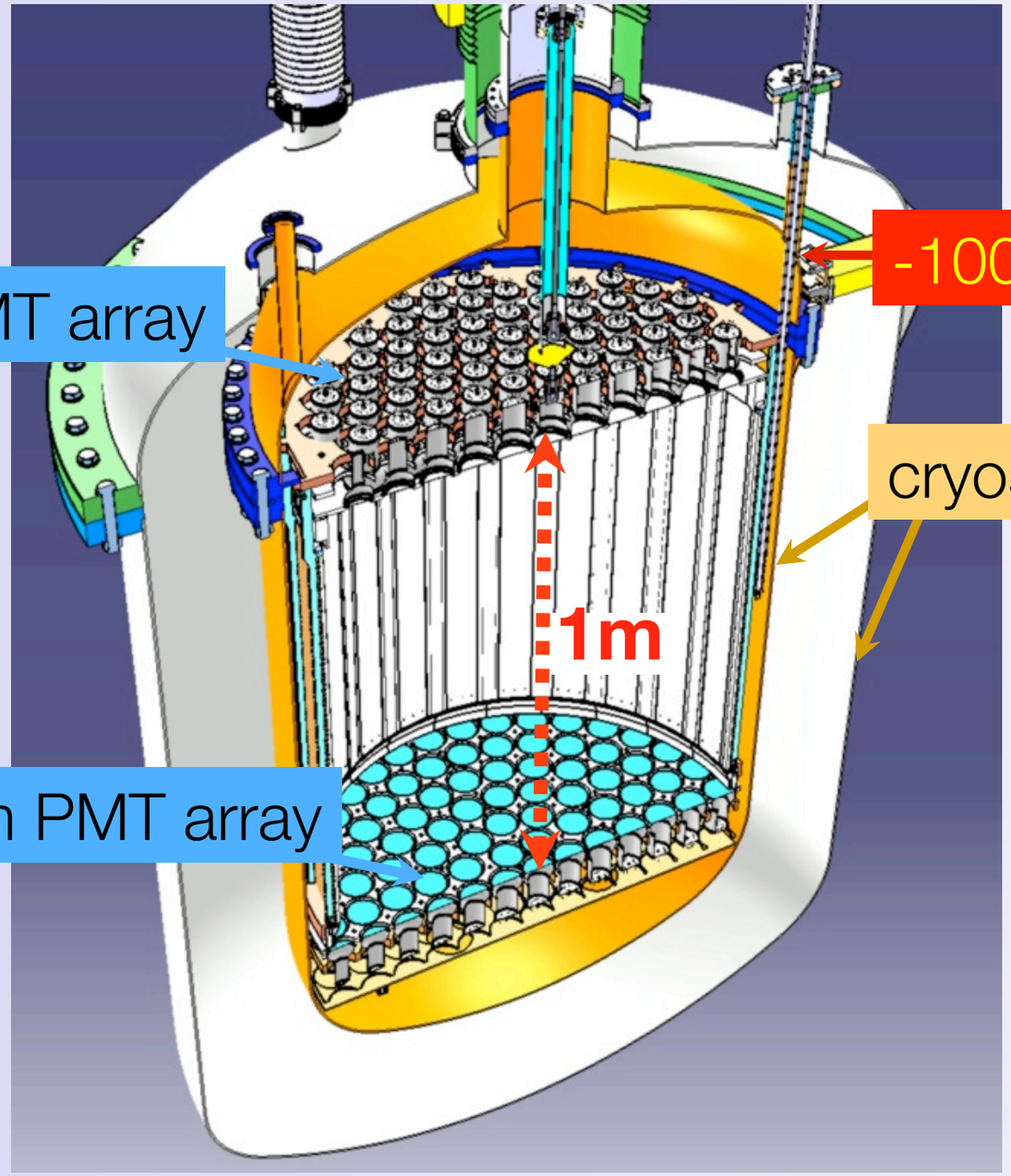
➡Two stainless steel vessels with vacuum insulation

➡Feedthroughs for PMT signal/HV, detector HV, LXe recovery

➡Connected to cryogenic system through big-pipe

➡Heat leak <50W

XENON1T: Time Projection Chamber

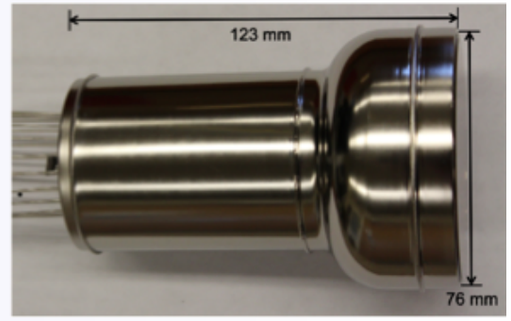


Xenon

➡>2 ton liquid xenon @ -100°C

➡>1.1 ton fiducial

➡~1m drift



Photomultipliers

➡3” R11410 from Hamamatsu

➡127 in top array

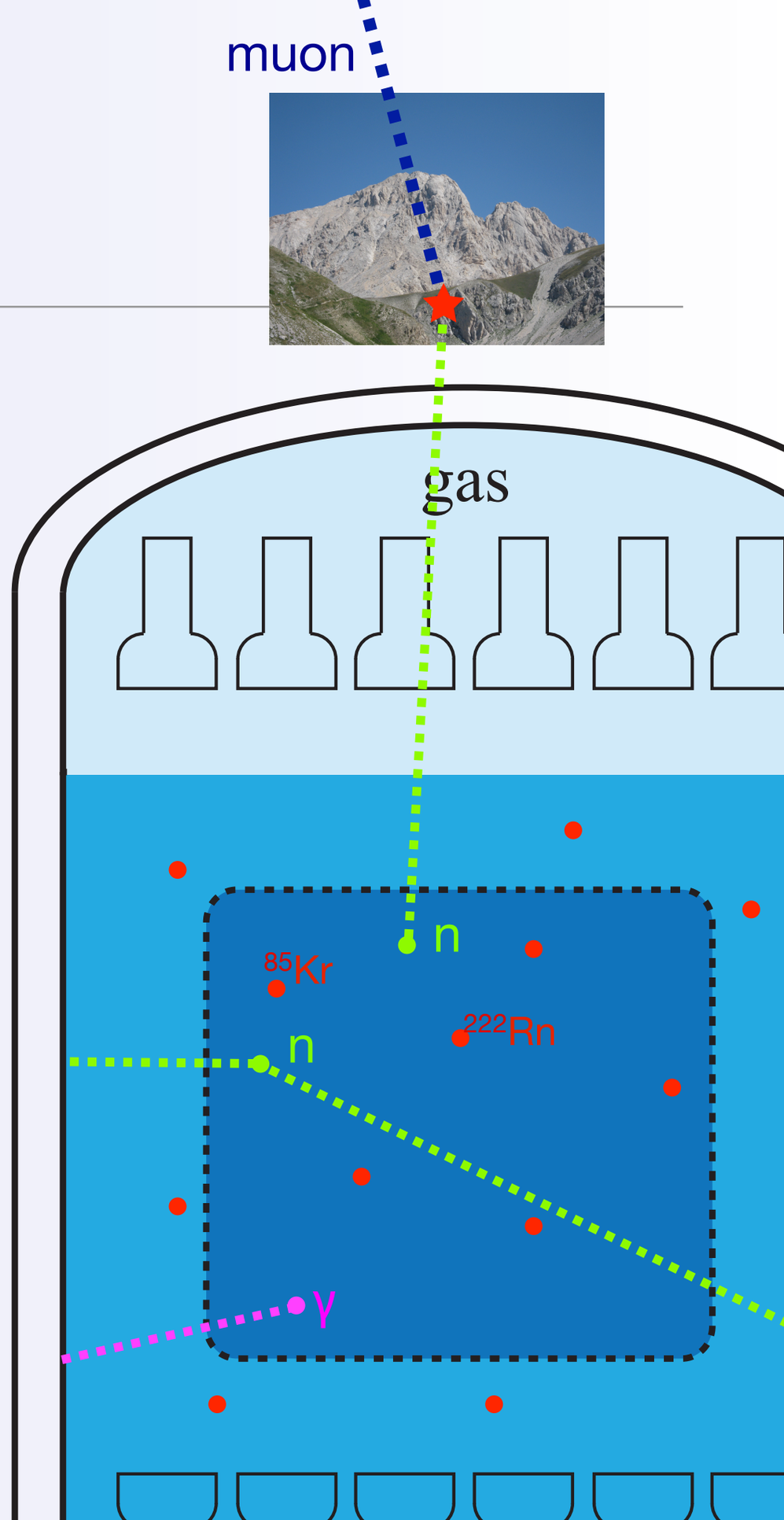
➡121 in bottom array

HV = -100kV (-16kV for XENON100)

Backgrounds

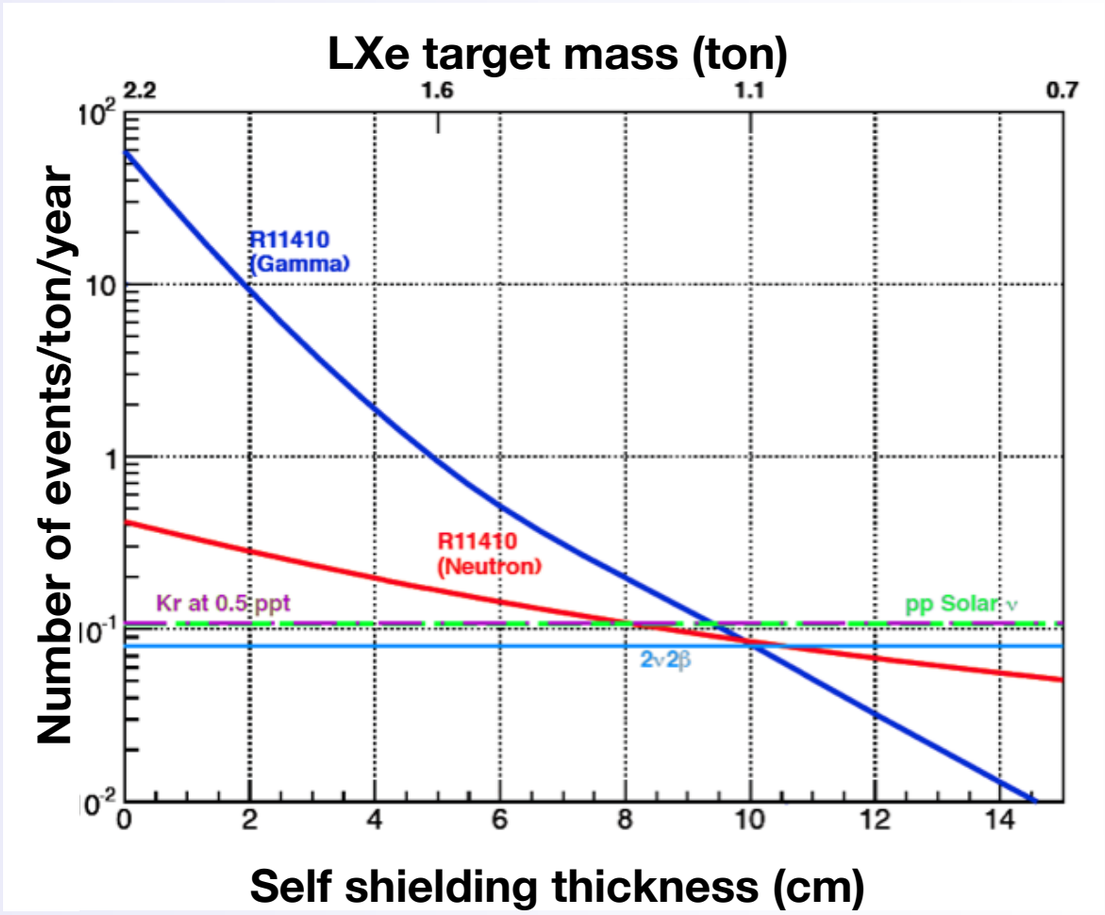
- External backgrounds
  - ➡cosmic muons
  - ➡neutrons induced by cosmic muons
  - ➡U and Th in any material
    - neutrons from (α, n) reactions
    - γ's
  - ➡neutrinos not a major background (yet)

- Internal backgrounds
  - ➡^{85}Kr
  - ➡^{222}Rn
  - ➡2ν2β decay of ^{136}Xe



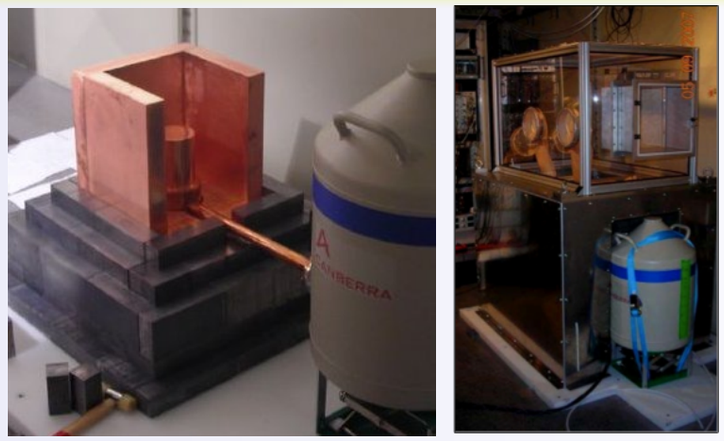
... and how to 'eliminate' them

- **Strategy**
  1. **External backgrounds**: Use self-shielding of LXe to reduce external backgrounds (Z=54, ρ_{LXe}=3 g/cm^3)
  2. **Internal backgrounds:** Reduction of background atoms in LXe
  3. "Screen everything"



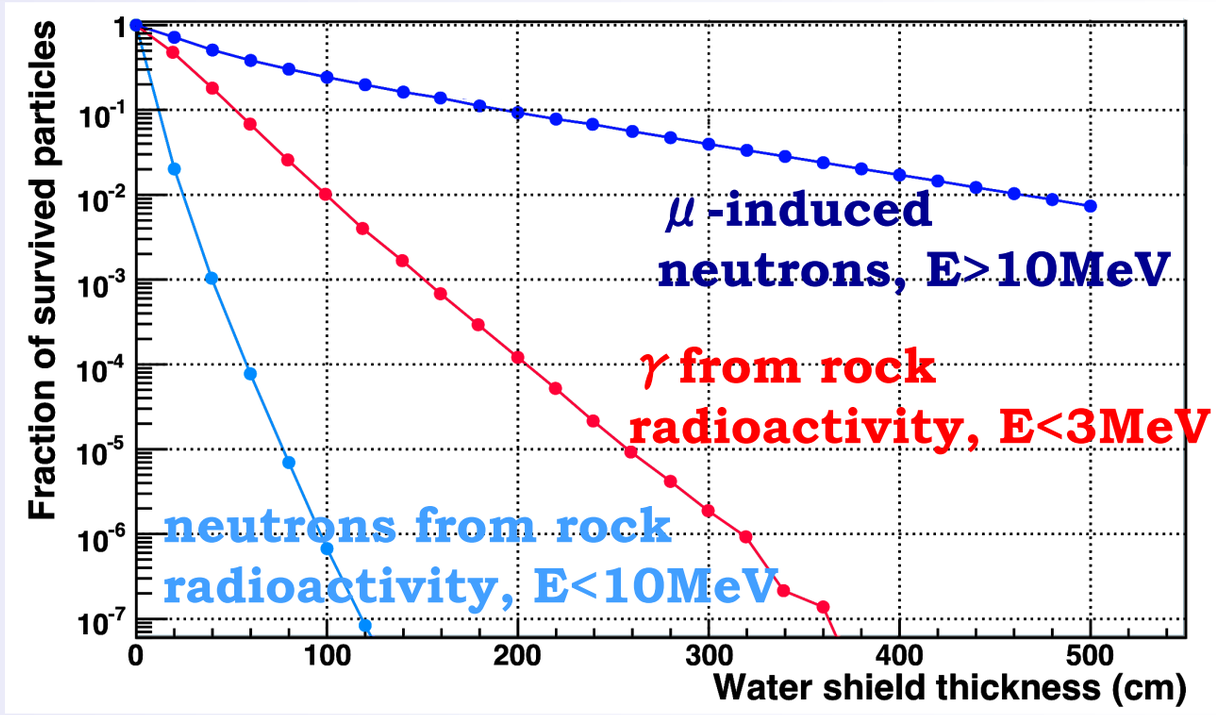
- Advantage in **BIG** detector
  - ➡can afford more self-shielding
  - ➡extra neutron suppression

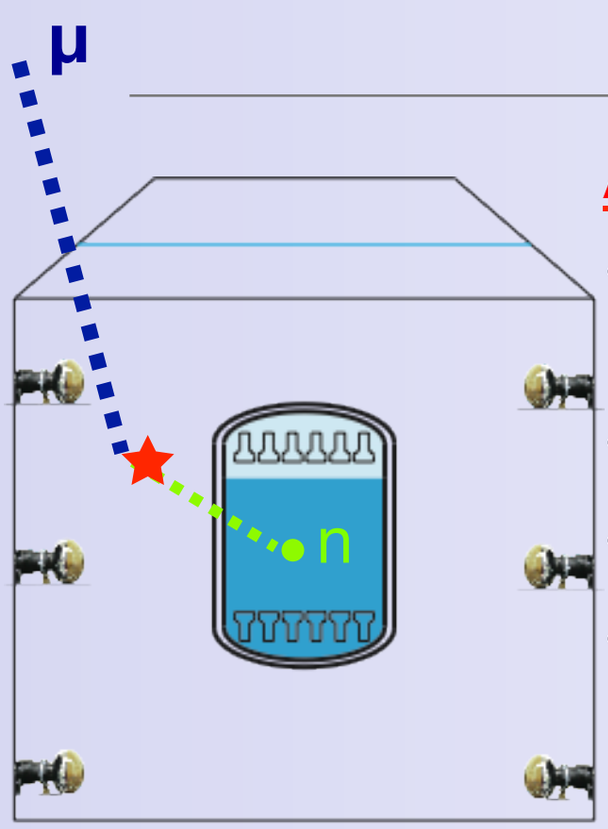
High purity Ge detector for screening



BG reduction: cosmic muon induced

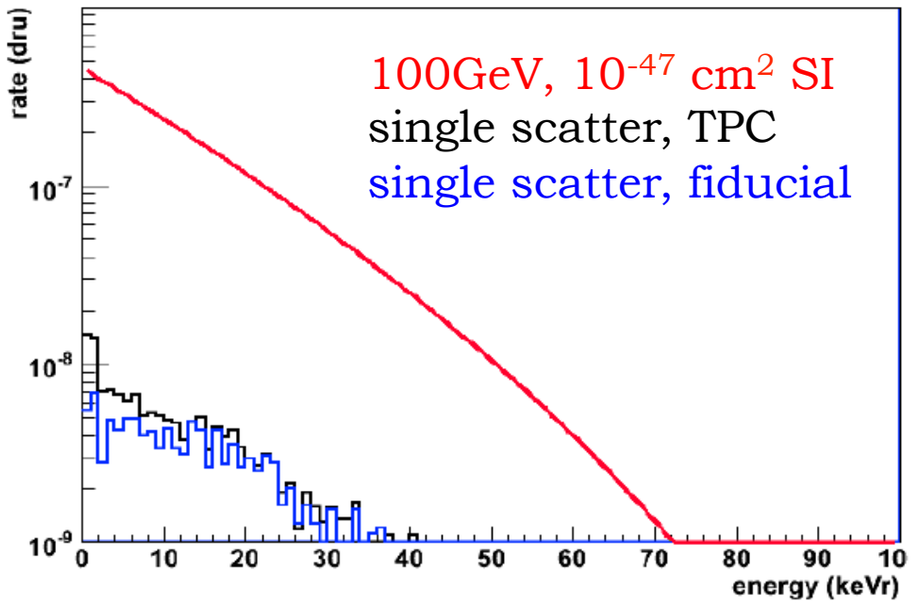
- **Water shield**
  - ➡Big difference / complication with respect to XENON100 is the ~4.5 m water shield surrounding the XENON1T cryostat
  - ➡Passive shield alone insufficient to reduce the high energy neutron flux



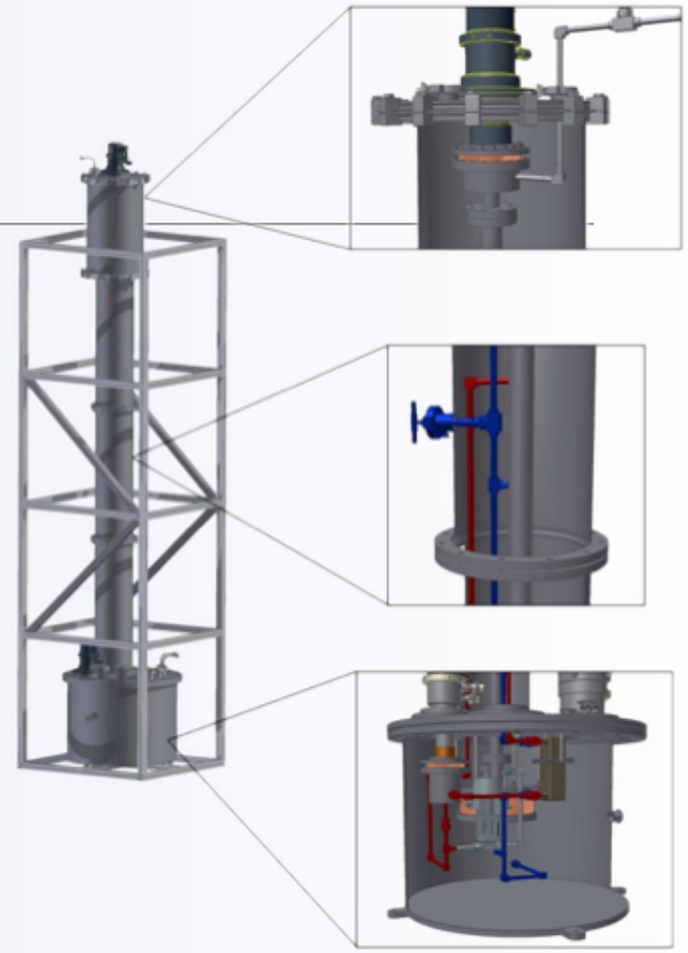


Active Cerenkov VETO

- 84 high QE Hamamatsu R5912 PMTs
- Reject 99.5% of n with μ in veto
- Reject 78% of n with μ outside veto
- μ induced n background<0.05 ev/yr

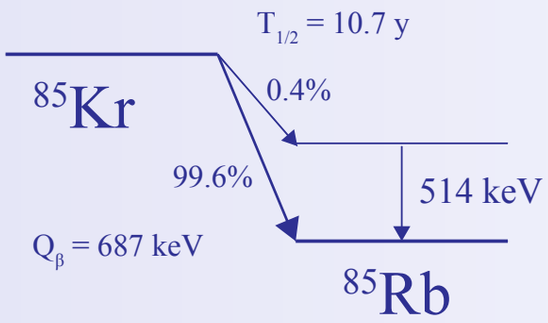


BG reduction: ^{85}Kr and ^{222}Rn



^{85}Kr

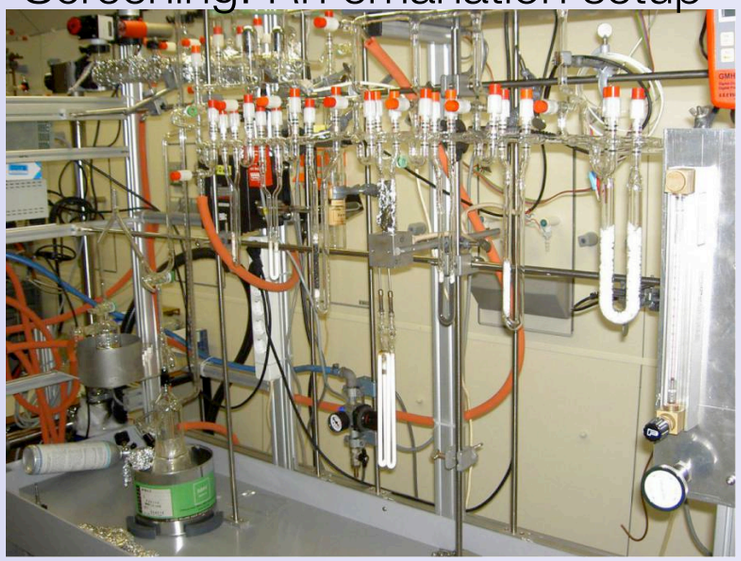
- ^{85}Kr : ^{nat}Kr ~ 10^{-11}
- beta / gamma emitter:



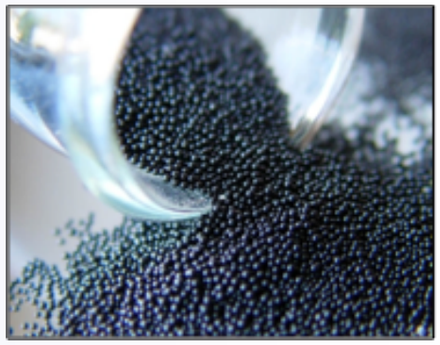
- reduce ^{nat}Kr to < 0.5 ppt < 25 atoms ^{85}Kr per kg xenon
- custom built distillation column
- 3kg / h @ 10^{-4} separation
- diagnostics: RGMS / atom trap < 1 ppt level Kr/Xe

^{222}Rn

Screening: Rn emanation setup



- Noble gas produced in the ^{238}U decay chain.
  - ➡ can originate from any surface (in unpredictable way)
  - ➡ dissolves well in LXe
  - ➡ $t_{1/2}$ = 3.8 days, with shortlived daughters and longlived ^{210}Pb
- Strategy for elimination
  - ➡ avoid surfaces that emanate a lot-> screening
  - ➡ ^{222}Rn removal necessary



BG: XENON1T summary

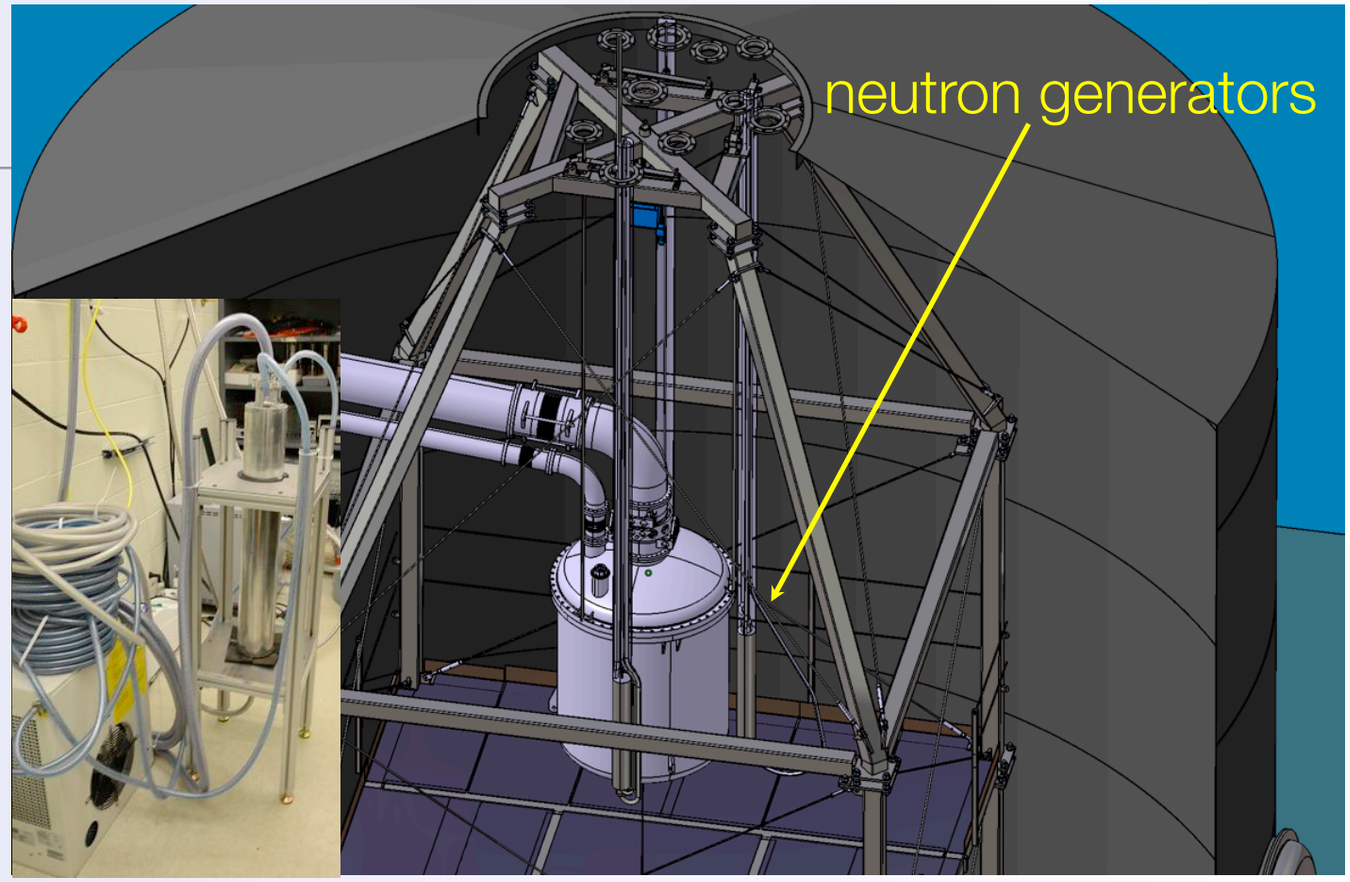
- Fiducial 1.1ton of xenon
- Exposure 2 years

1 dru = 1 event / keV / kg /day

	ER (10^{-3} dru_{ee})	NR (10^{-7} dru_{nr})
^{85}Kr	0.01	-
pp solar neutrino	0.01	-
^{136}Xe 2νββ	0.008	-
n from rock and μ induced	-	0.05
PMT with base	0.006	0.05
PTFE	0.0001	0.02
Cryostat	0.0002	0.0007
Total BG	0.03	0.12
Total BG after **S2/S1** cut	<0.0001	
expected BG events	**0.8**	**0.2**

Calibration: strategy

- Response of detector
  - ➡Energy scale
  - ➡Position reconstruction
- Strategy
  - ➡Use neutron + gamma sources
- Challenge
  - ➡calibrate interior of the TPC

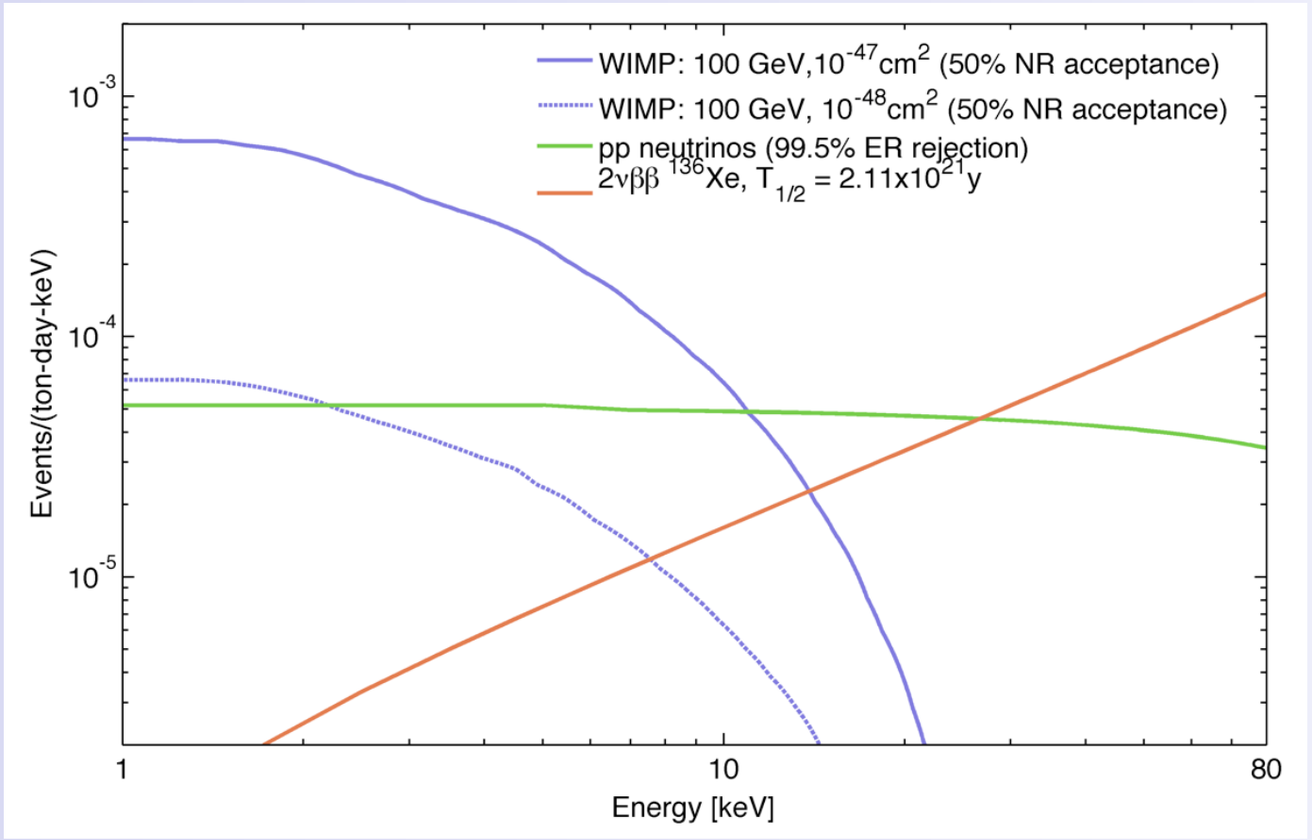


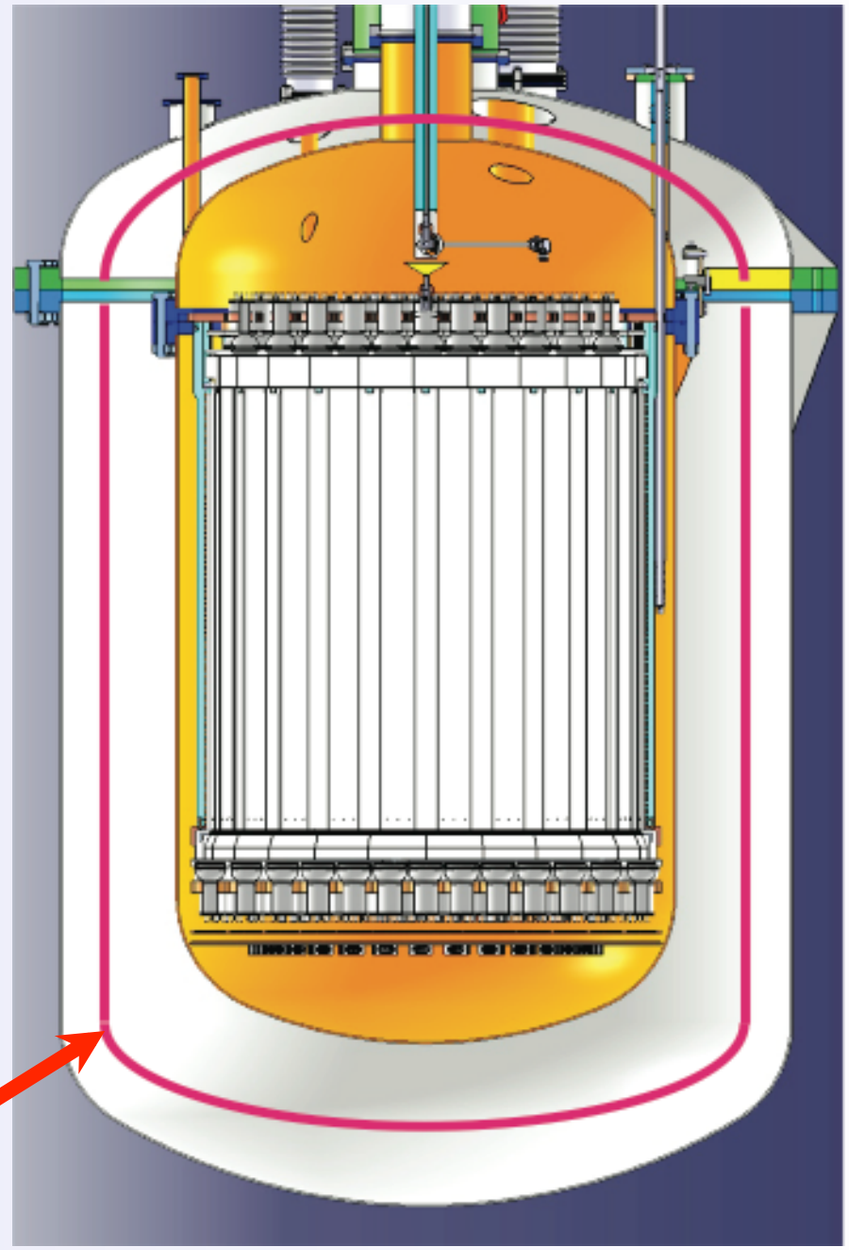
Impact on data-acquisition

- ➡need dead-time less readout
- ➡no trigger decision in hardware
- ➡continuous feeding of data to trigger farm
- ➡starts to look like HEP triggers

XENONnT: The ultimate detector?

- If WIMPs / no WIMPs found with XENON1T, we could build a completely new detector…..

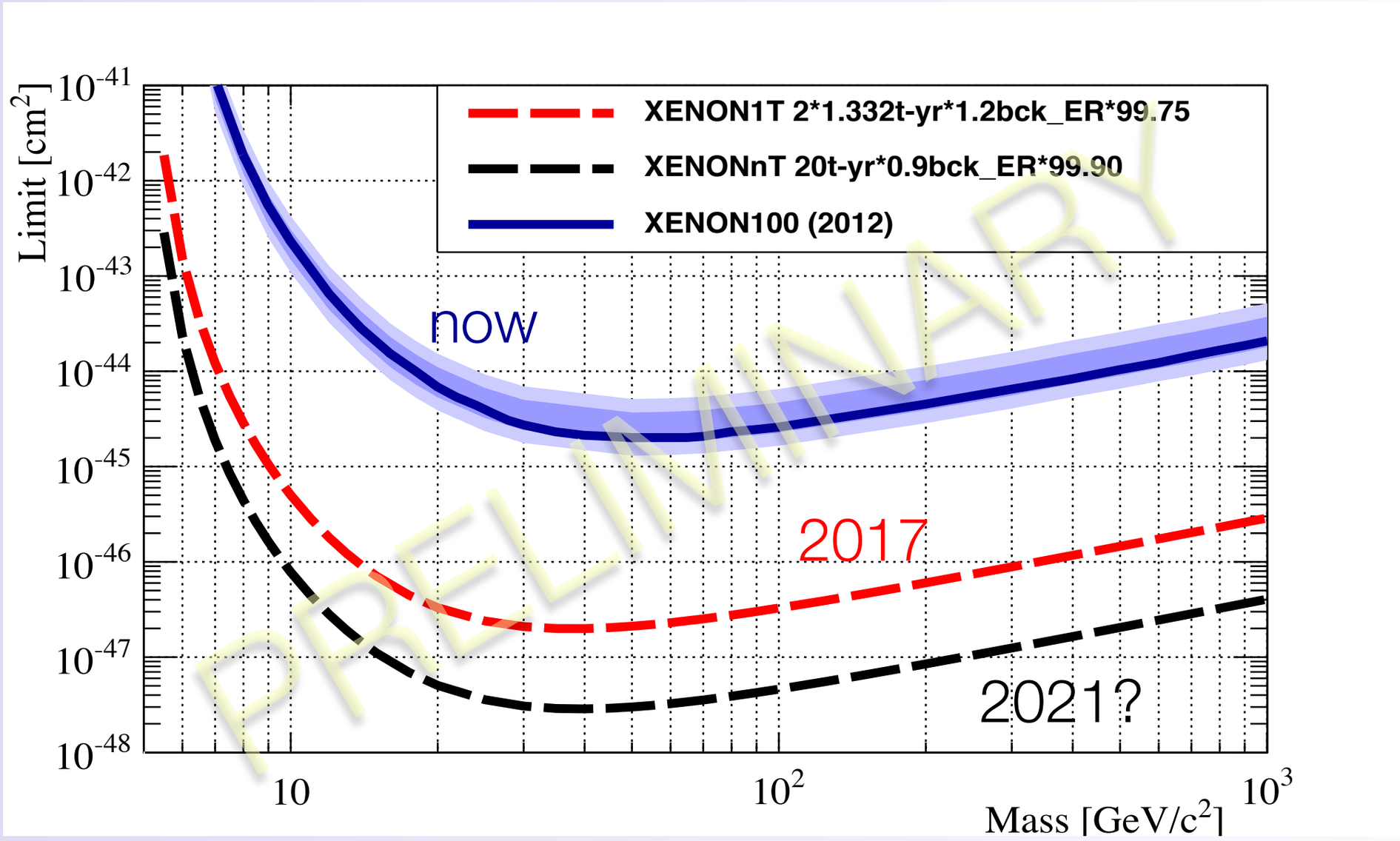




- or ... XENON**n**T = XENON1T + bigger inner cryostat + bigger TPC

XENONnT: 202x

	XENON100	XENON1T	XENONnT
status	running	construction	design
xenon	161 kg	3500 kg	6000 kg
Kr/Xe	(19±4) ppt	0.5 ppt	0.2 ppt
Rn/Xe	≈ 65 μBq/kg	≈ 1 μBq/kg	≈0.5 μBq/kg
drift	0.3 m	1m	1m
HV	-16 kV	-100 kV	-100 kV



Construction @ LNGS

preparing the foundation

structural elements for service building

Construction started:
now low-tech, soon high-tech

Conclusion (6x)

1. XENON1T detector design phase has been finished

2. XENON1T construction has started

3. XENON1T will be completed end 2014

4. XENON1T dark matter run starts in 2015

5. XENON1T dark matter discovery or limits 2015-2017

6. XENONnT ..... n=f(€,$)? 2017-2021