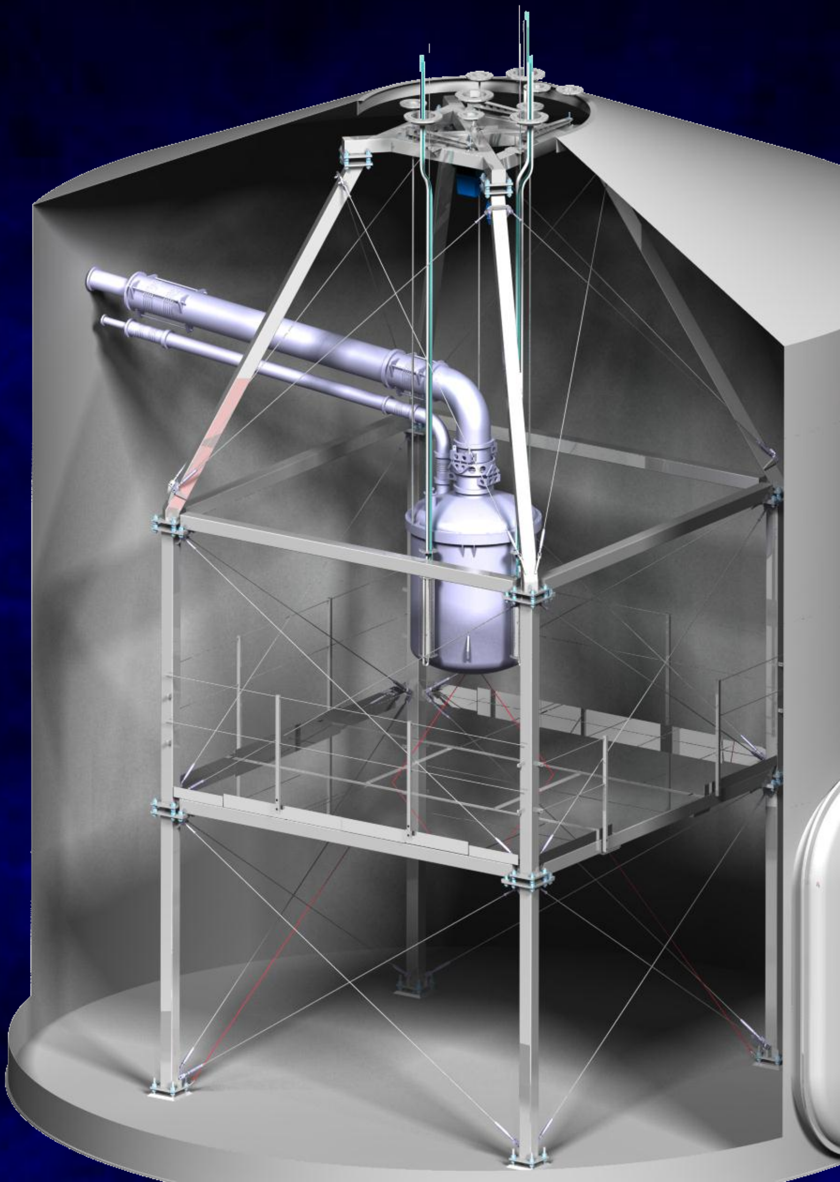
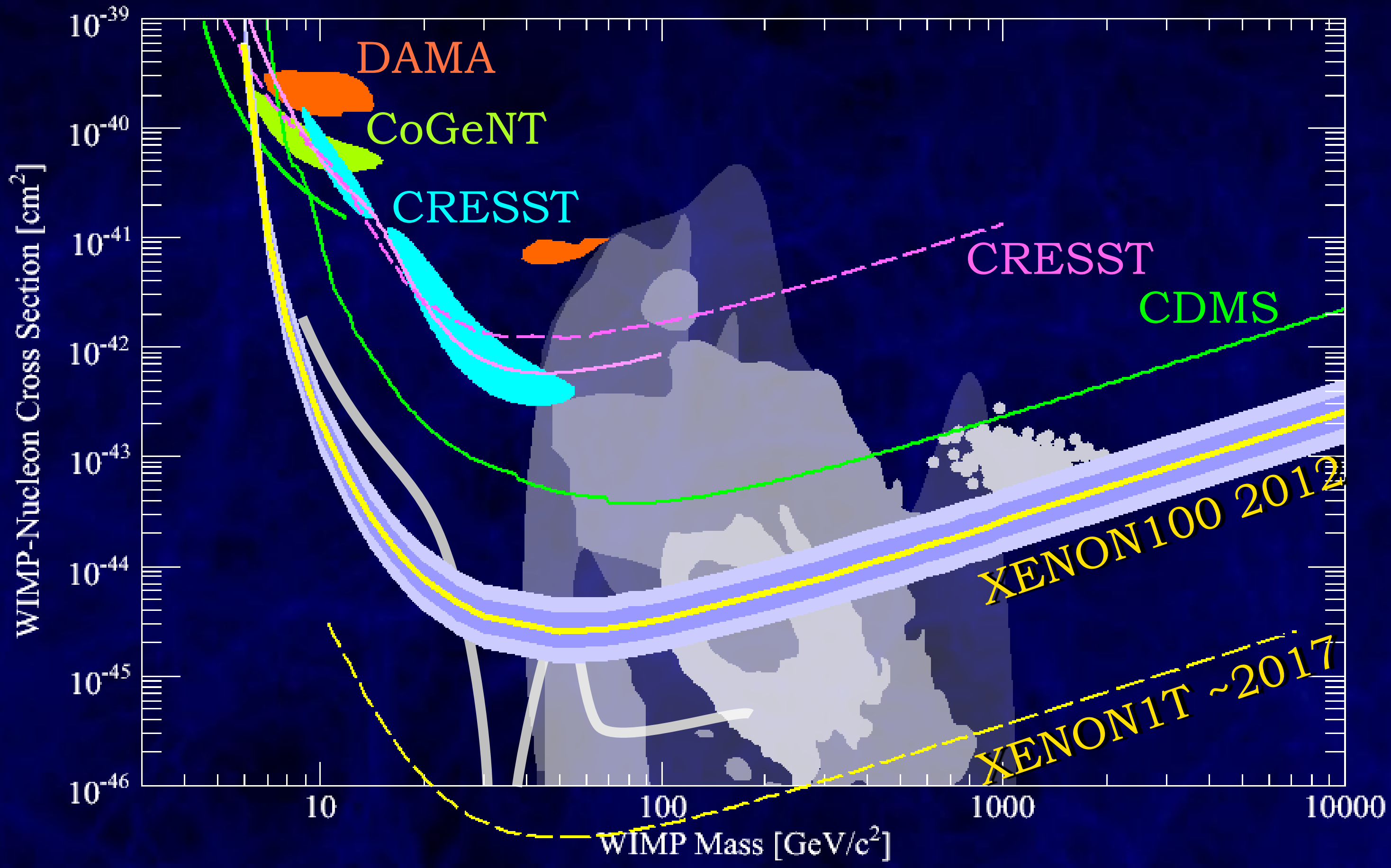
XENON1T



for the XENON collaboration
Rafael F. Lang
Purdue University
rafael@purdue.edu
Aspen, January 30, 2013

Key Points

- sensitivity 1 event/ton/year, $2 \cdot 10^{-47}$ cm^2
- data taking 2015 at Gran Sasso: approved & funded



The XENON Collaboration

50% of capital cost
from NSF – thanks!

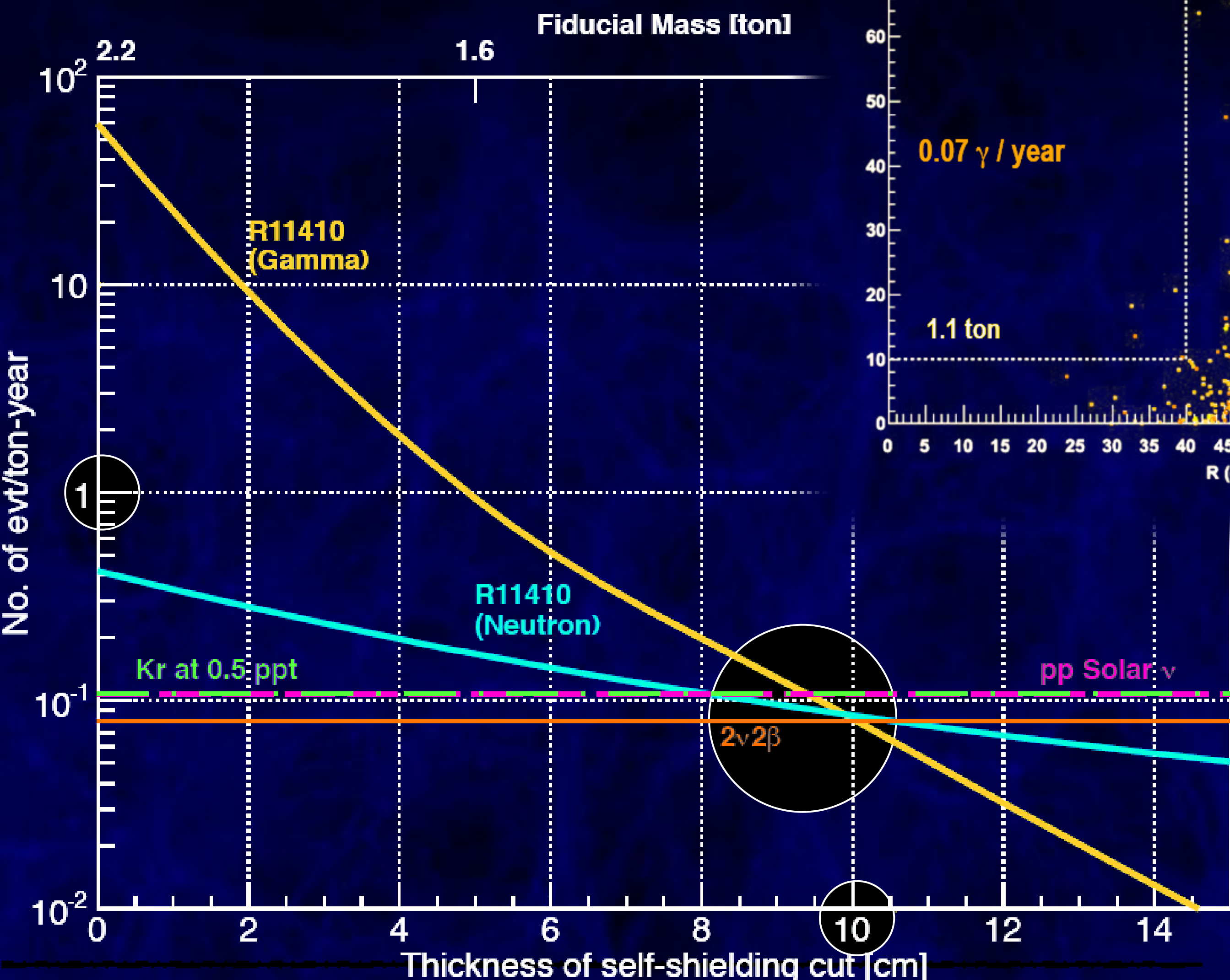
100 scientists from 16 institutions:

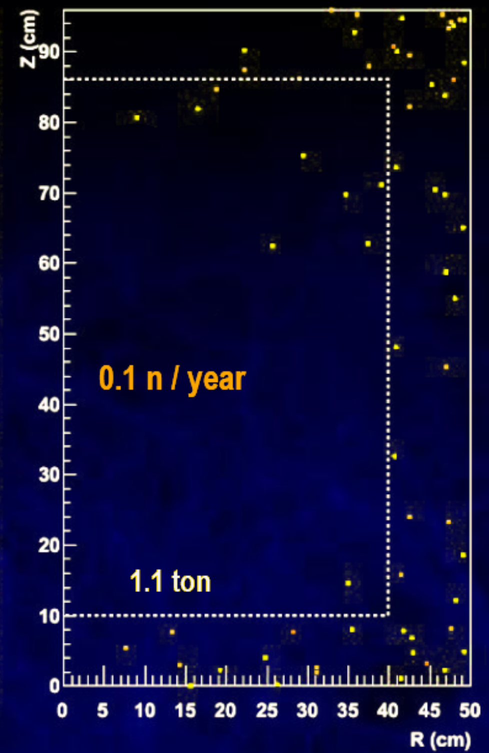
- University of California Los Angeles
- Rice University Houston
- Purdue University
- Columbia University New York
- Universidade de Coimbra
- Subatech Nantes
- NIKHEF Amsterdam
- Universität Bern
- Willhelms Universität Münster
- J. Gutenberg-Universität Mainz
- Max-Planck-Institut für Kernphysik
- Universität Zürich
- Laboratori Nazionali del Gran Sasso
- INFN e Università di Bologna
- Weizman Institute Rehovot

Key Challenges

	XENON100	XENON1T
• liquid xenon	161 kg	~3500 kg
• background	$5 \cdot 10^{-3}$ dru	$5 \cdot 10^{-5}$ dru
• krypton/xenon	(19±4) ppt	<0.5 ppt
• radon/xenon	~65 μBq/kg	~1 μBq/kg
• electron drift	30 cm	1 m
• cathode	-16 kV	-100 kV
• filling-to-search	several months	2 months

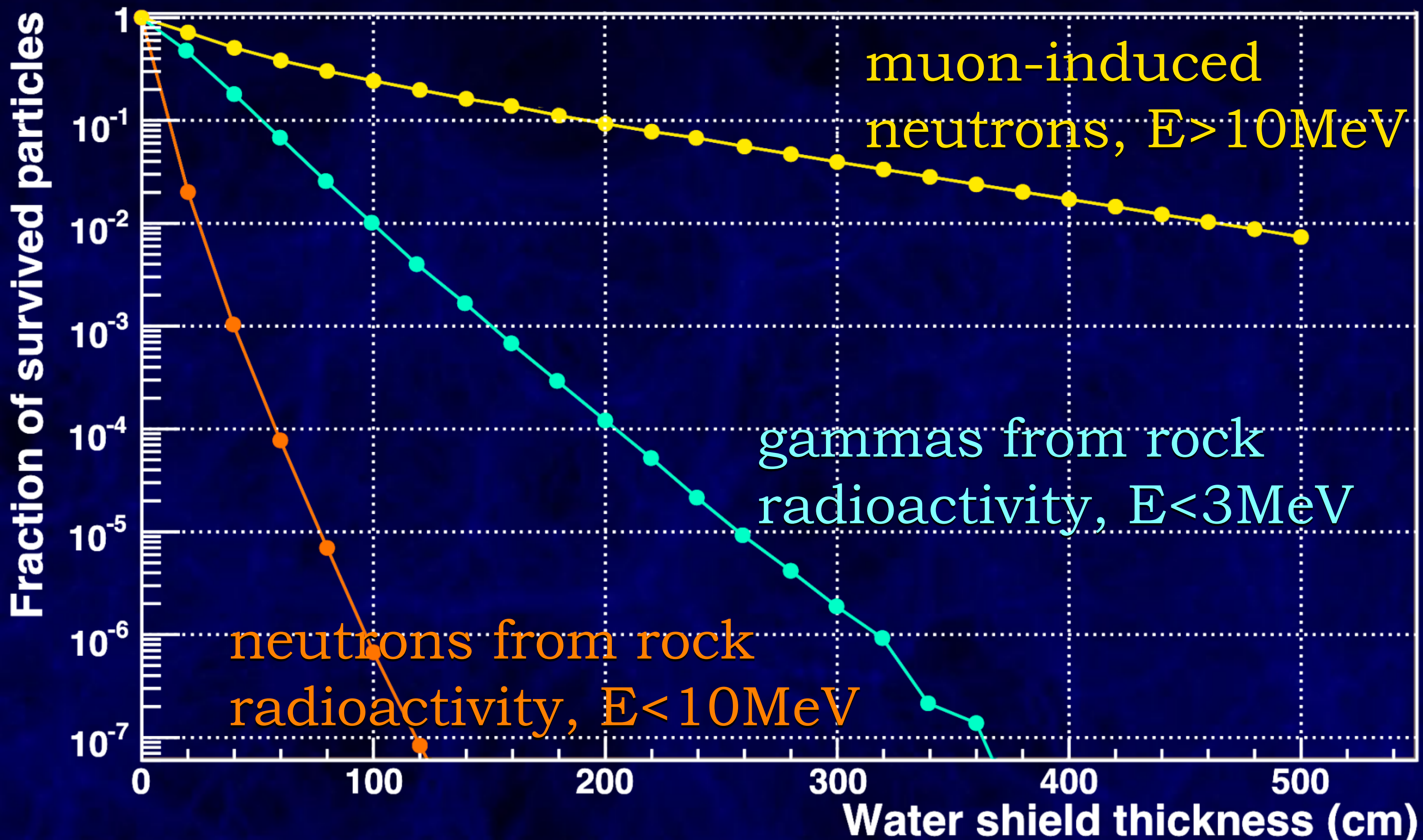
Backgrounds





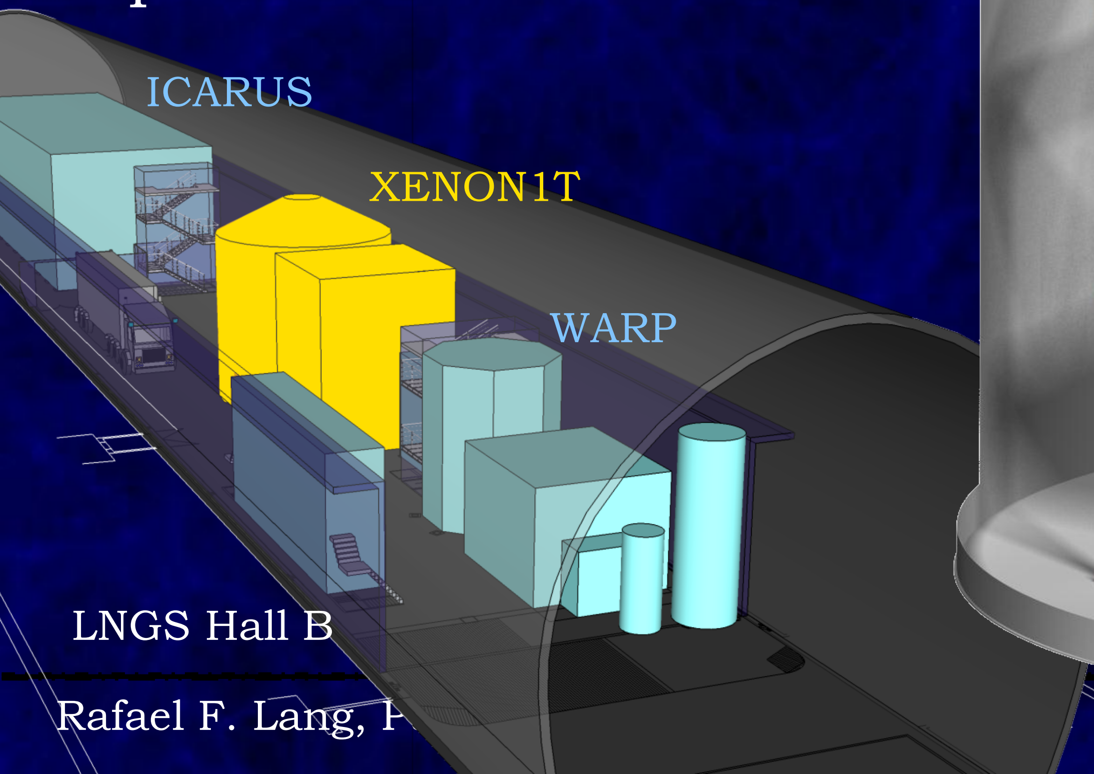
The Need for a Muon Veto

shielding of high-energy n insufficient: requires veto



Water Tank

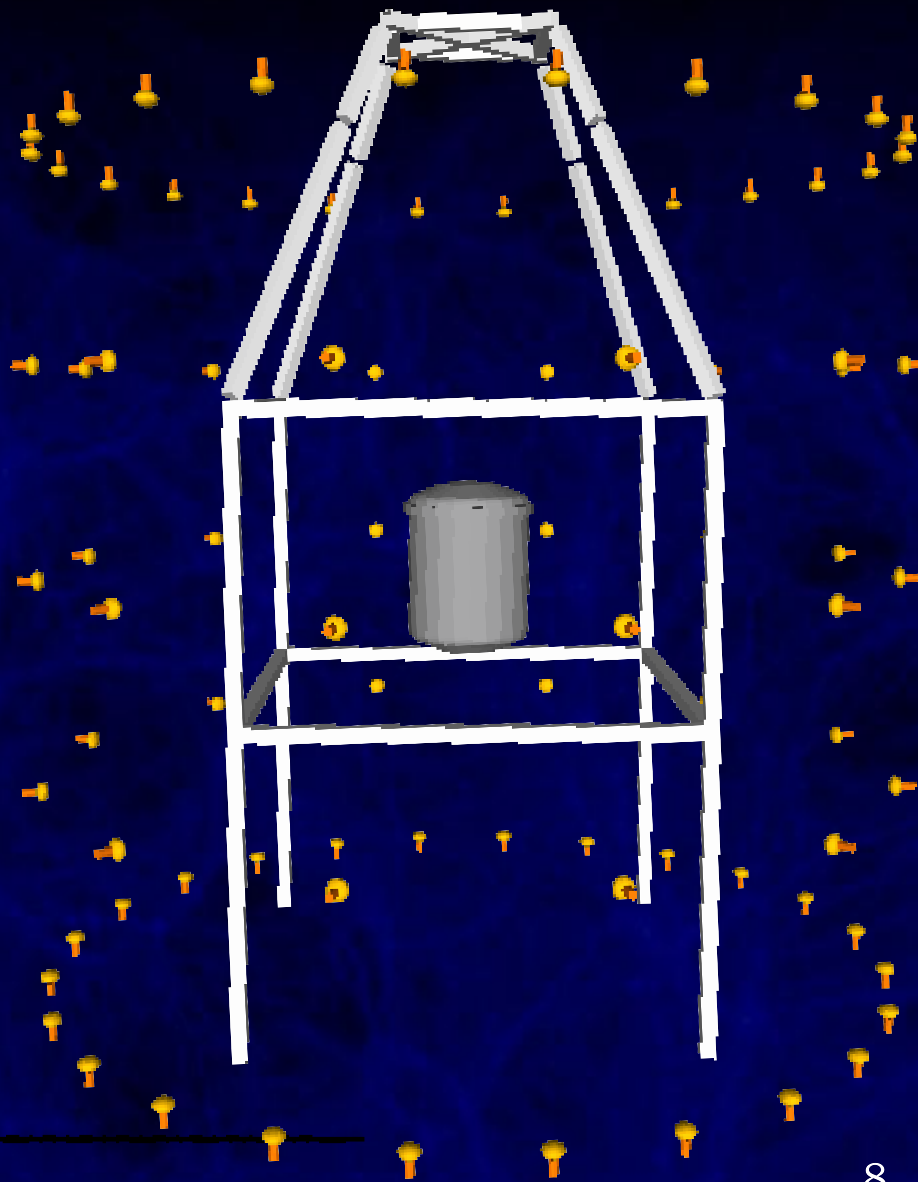
- 10m high, Ø 9.6m
- construction start April 1st
- ~5 m^3/h deionization, radon stripping, particulate removal



Water Черенков Muon Veto

- 84 high QE 8”
  Hamamatsu R5912 PMTs
- single PE trigger 4-fold
  coincident within 300ns

→ reject
  99.5% n with μ in veto
  78% n with μ outside



Bologna, Mainz, Torino

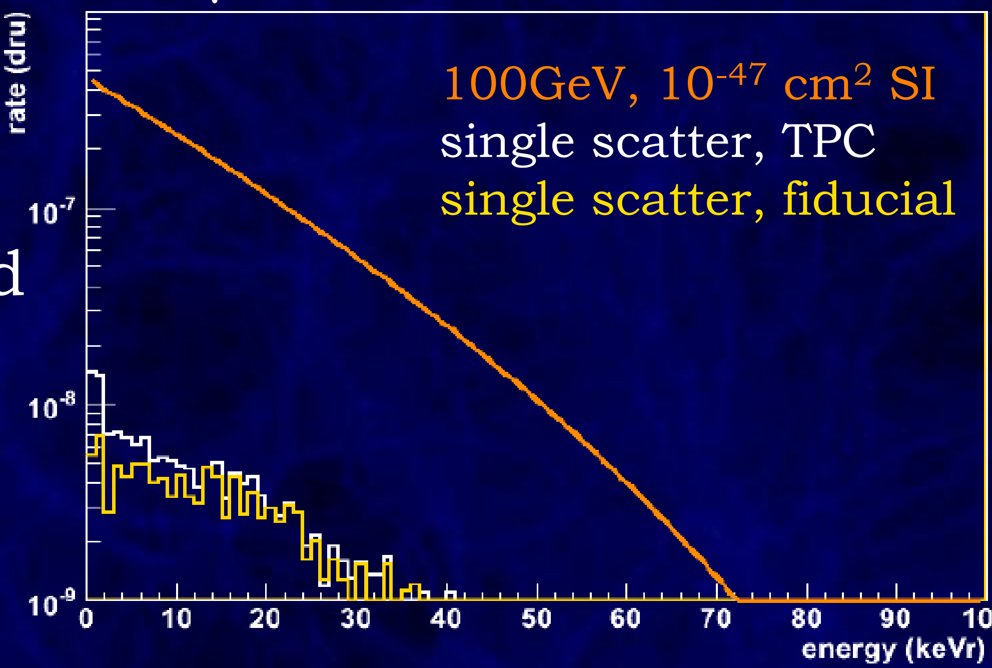
Water Черенков Muon Veto

- 84 high QE 8”
  Hamamatsu R5912 PMTs
- single PE trigger 4-fold
  coincident within 300ns

→ reject
  99.5% n with μ in veto
  78% n with μ outside

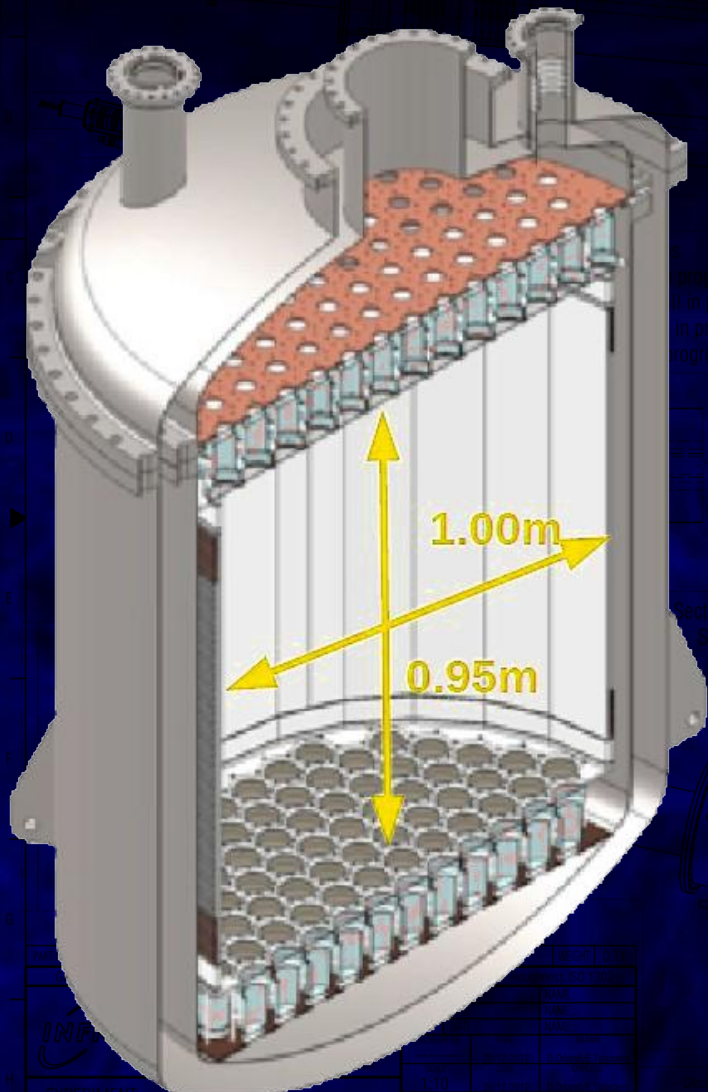
- μ-induced n background
  0.01 per year: negligible

μ induced n from rock

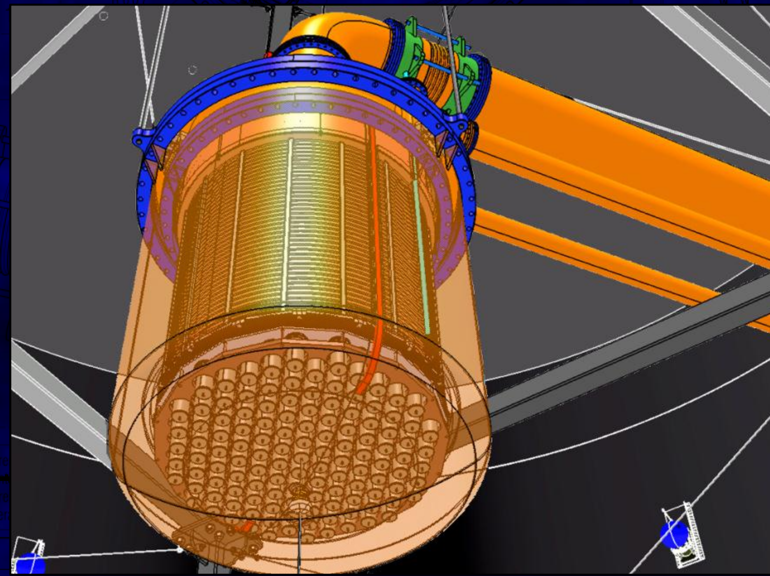


Bologna, Mainz, Torino

Cryostat & TPC



- SS 316Ti
- cryostat 1.5m high, Ø1.3m
- HV feedthrough demonstrated with grids up to 110kV



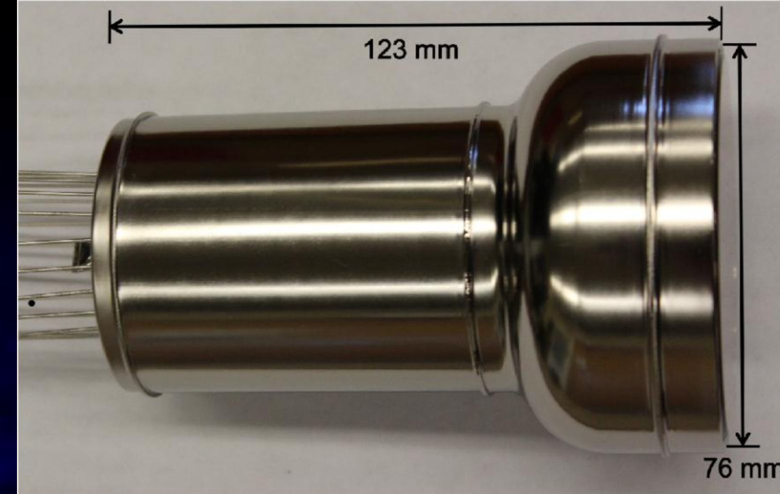
Materials Screening

- gamma-ray screening
  ~10 µBq/kg sensitivity
- ICPMS
- miniaturized proportional counter

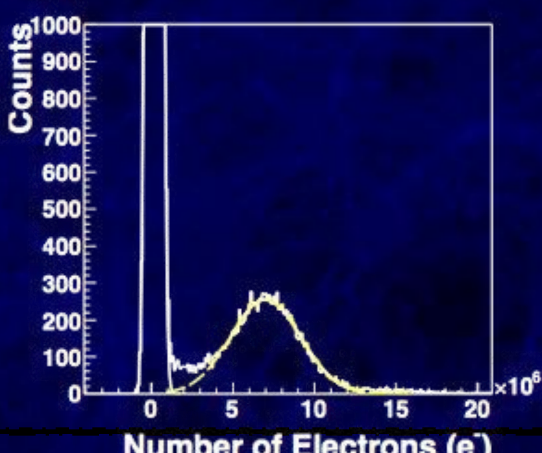
- ^{222}Rn emanation
  measurement
  few atom sensitivity
- Neutron Activation Analysis

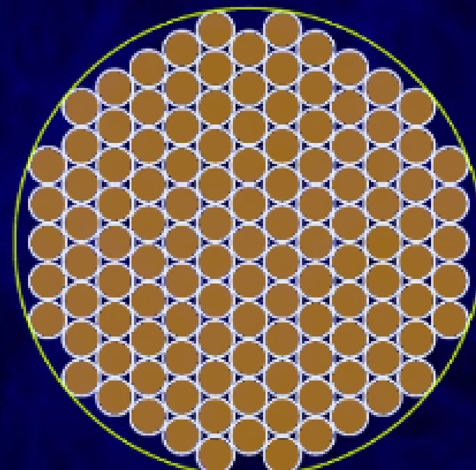
LNGS, Zürich, MPIK, UCLA, Mainz

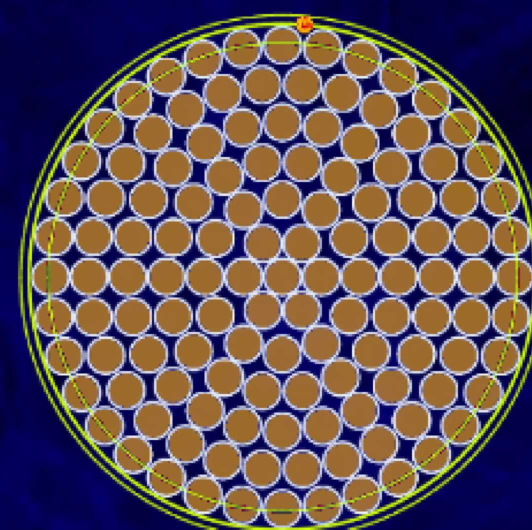
PMT Arrays



- scale up to 3” R11410
- 121+127 PMTs (~XENON100)
- quantum efficiency @178nm > 28%, average 32.5%
- gain $6 \cdot 10^6$
- screen individual components



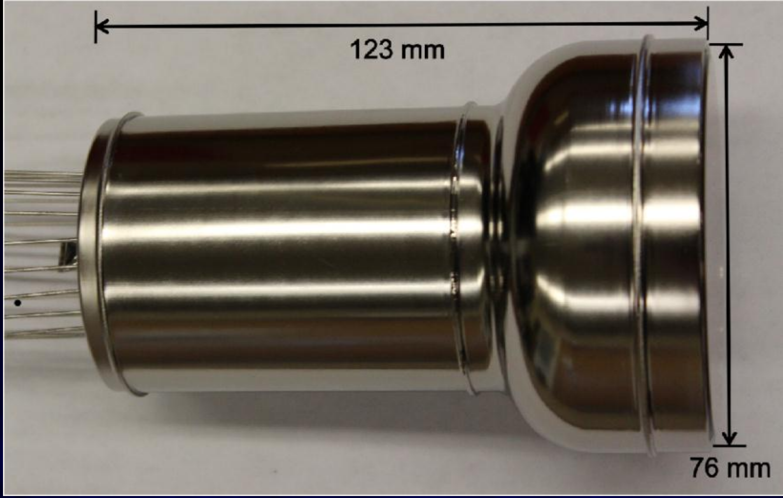


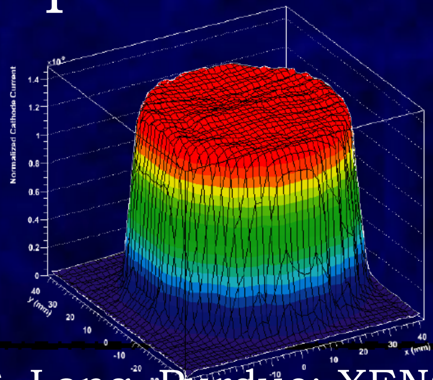


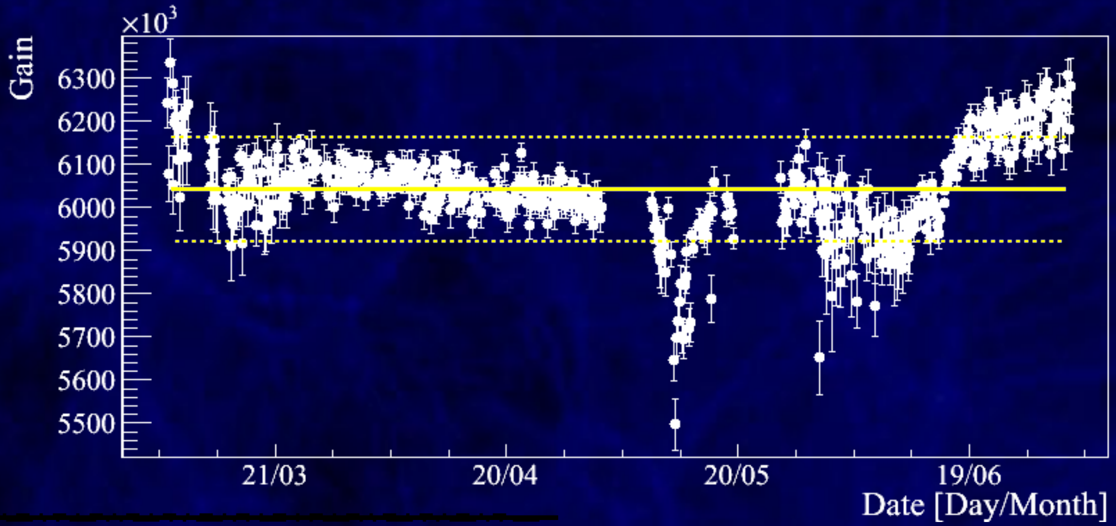
UCLA, Zürich, MPIK, Columbia

PMT Arrays

- scale up to 3” R11410
- 121+127 PMTs (~XENON100)
- quantum efficiency @178nm > 28%, average 32.5%
- gain $6 \cdot 10^6$
- screen individual components
- gain stability <2% in liquid xenon



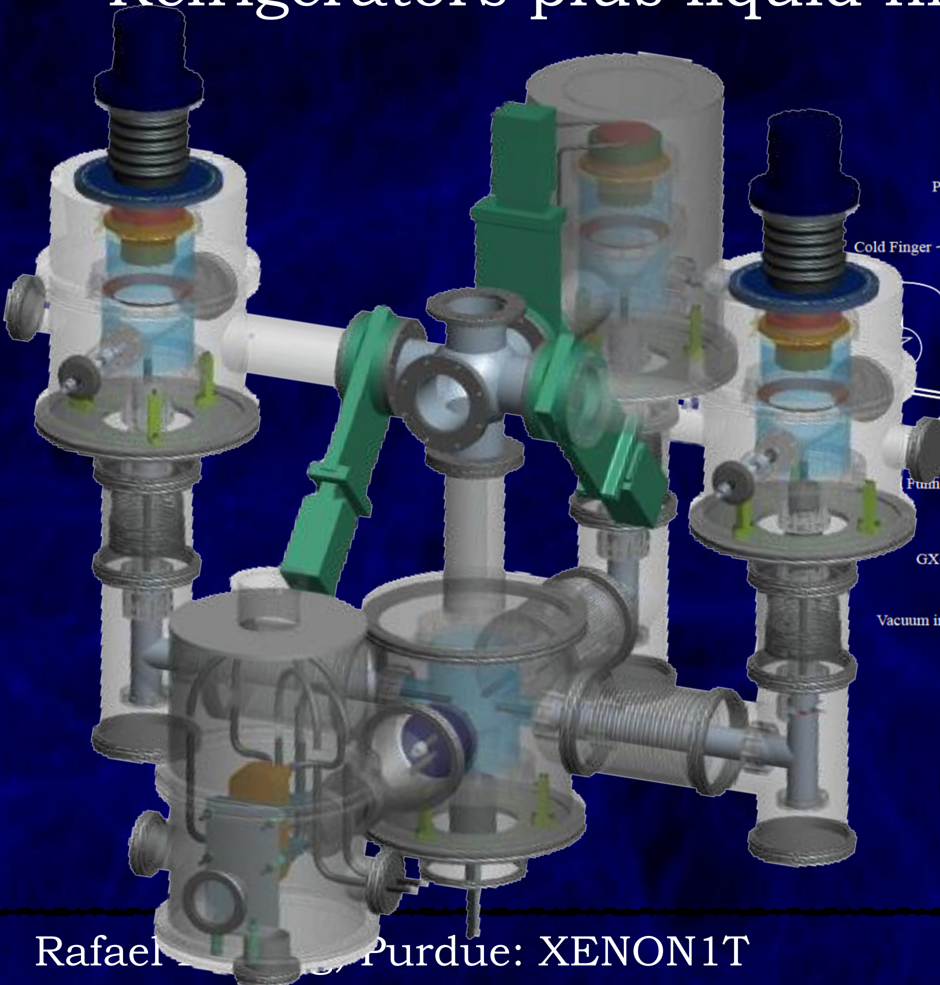


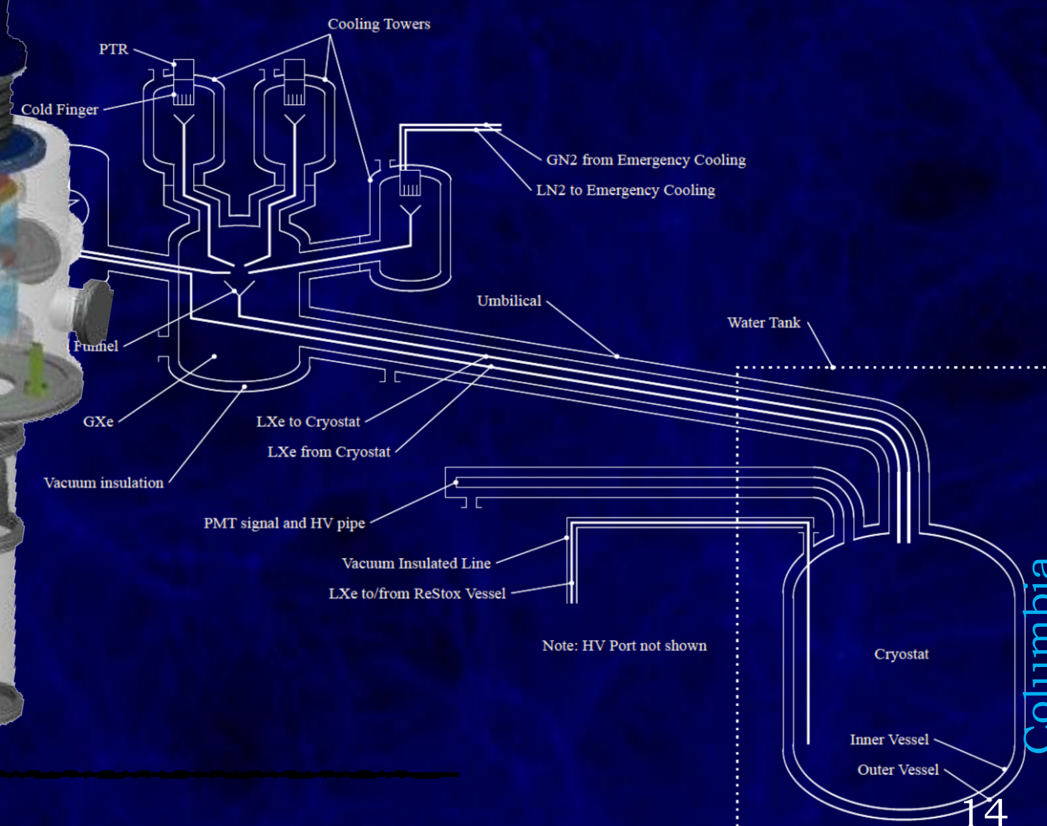


UCLA, Zürich, MPIK, Columbia

Cooling

- heat load <50W
- cooling outside tank: 2 redundant 200W Pulse Tube Refrigerators plus liquid nitrogen





Xenon Handling

very compact storage
(2.7 m x 3.2 m x 3.0 m)
3.6 ton storage capacity
500W available for cooling

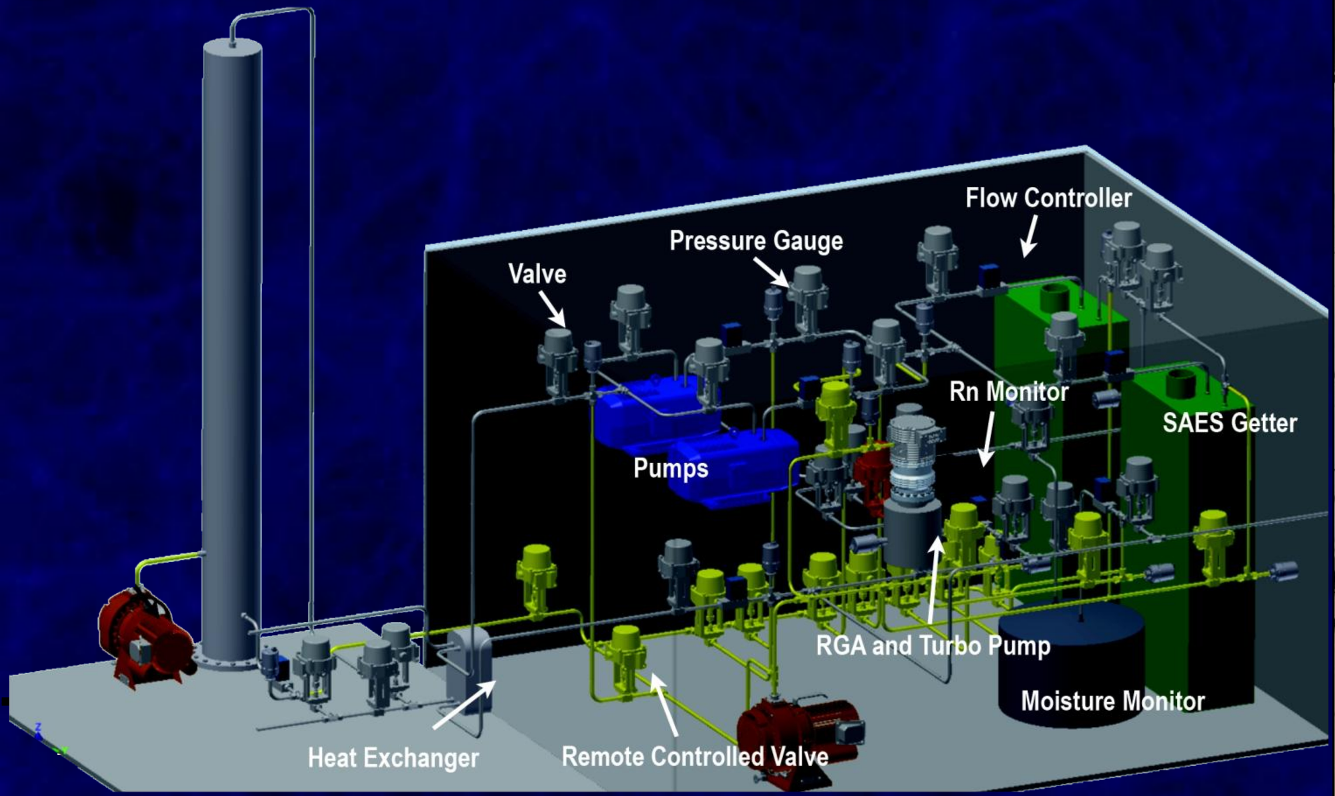
store both
liquid xenon (-108 °C)
or gaseous xenon (65 bar)
keep high purity

fill and recuperate liquid

Subatech

Xe Gas System

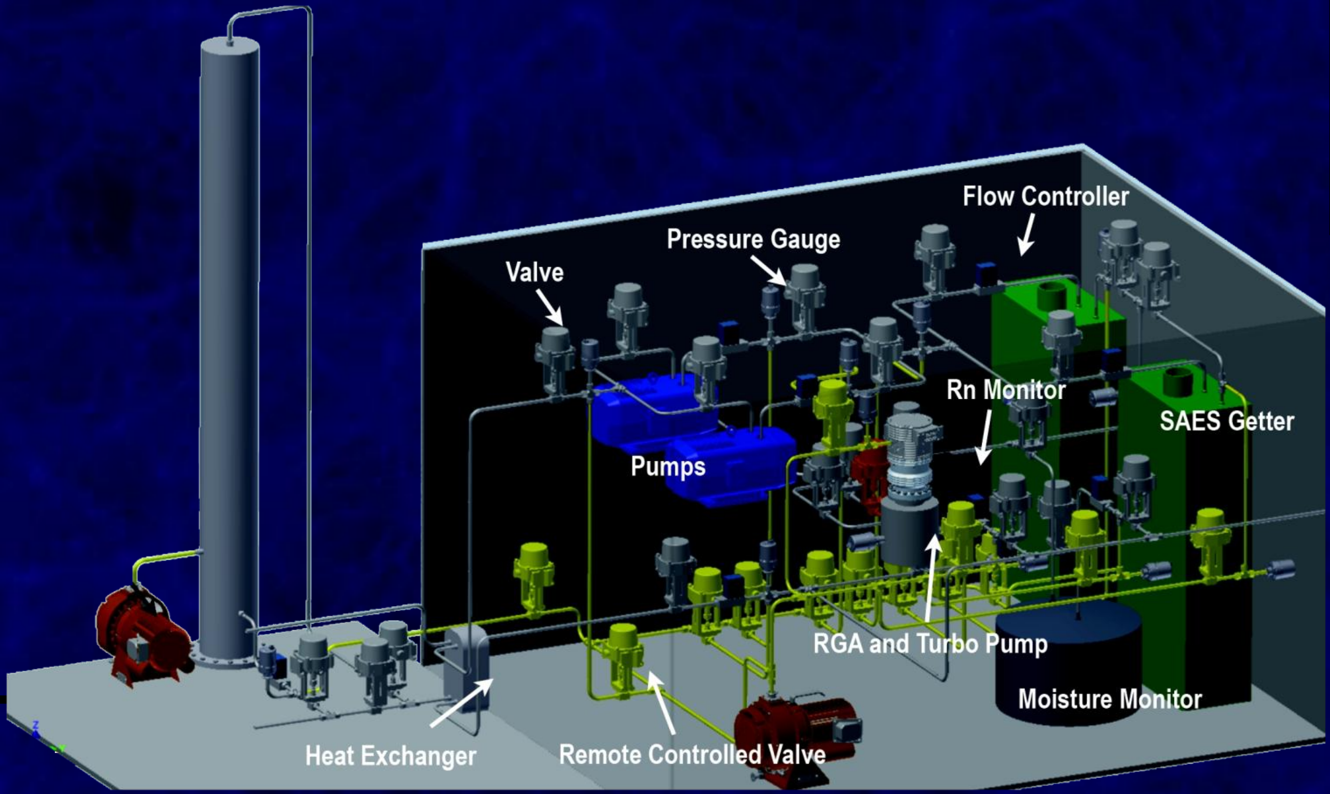
- continuously re-circulate and purify
- redundant setup
- online purity monitoring



Münster, Columbia

Radon in Xenon

- Goal: a few µBq/kg from ^{222}Rn in Xe
- avoid and minimize sources of Rn
- cryogenic adsorption of Rn on charcoal: slow down Rn sufficiently to decay ($t_{1/2}$ = 3.8 d) extensive R&D underway

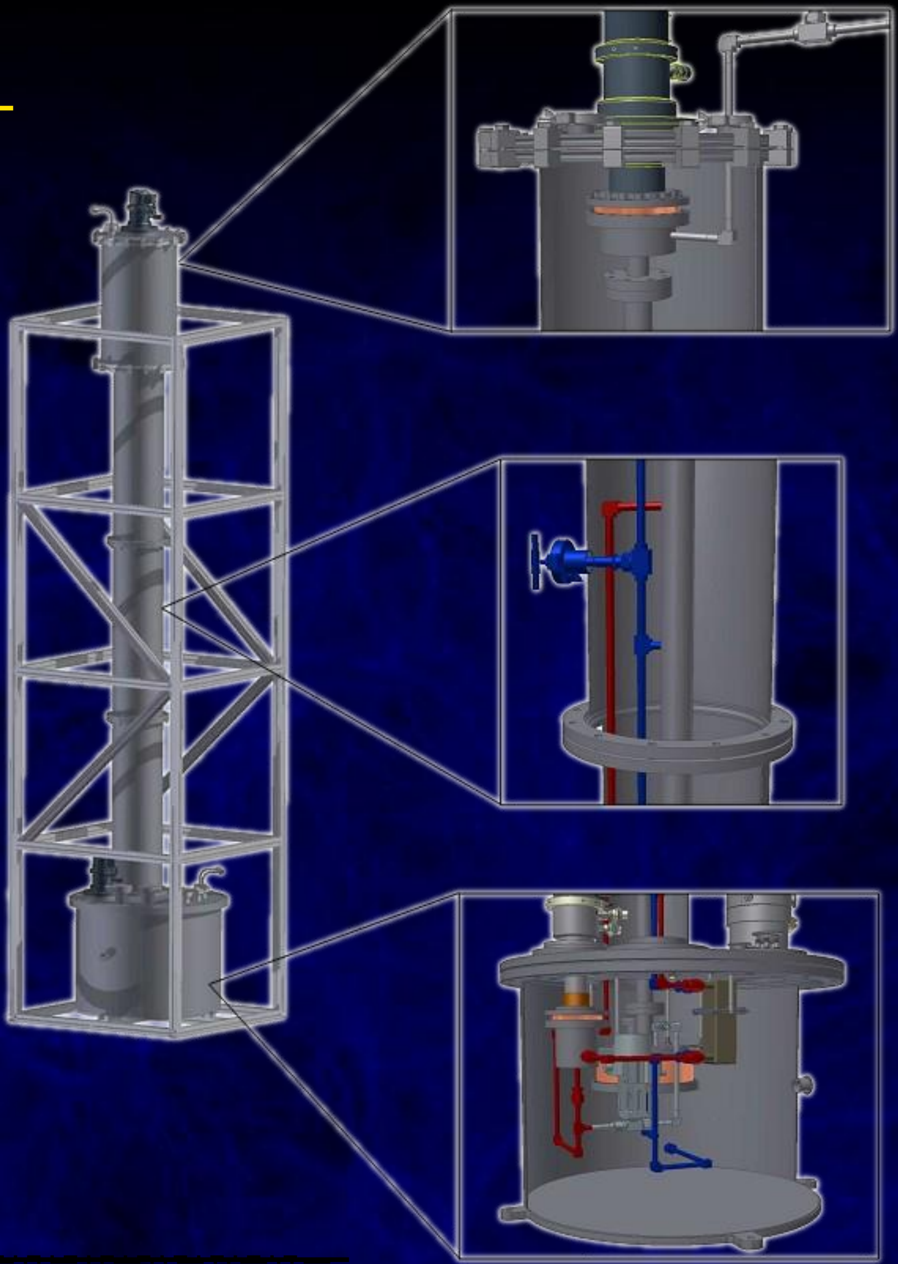


MPIK

Krypton Removal

^{85}Kr beta decays (687keV),
natural abundance
$^{85}Kr/Kr \sim 10^{-11}$

- target 0.5 ppt ^{nat}Kr in Xe (XENON100: (19±4) ppt)
- custom designed and build Kr distillation column
- throughput 3 kg/h @ 10^4 separation
- 3m version built

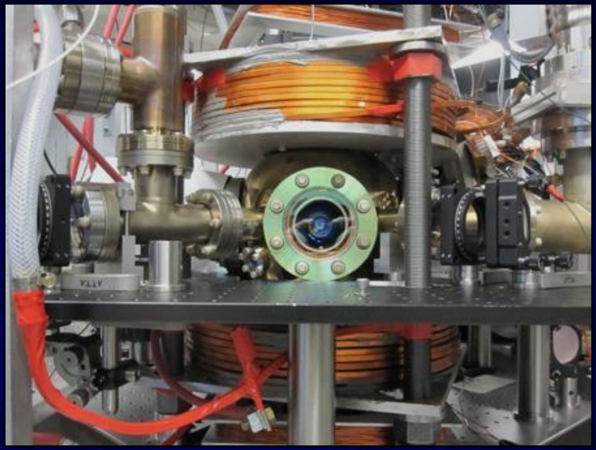


Münster

Krypton Analysis

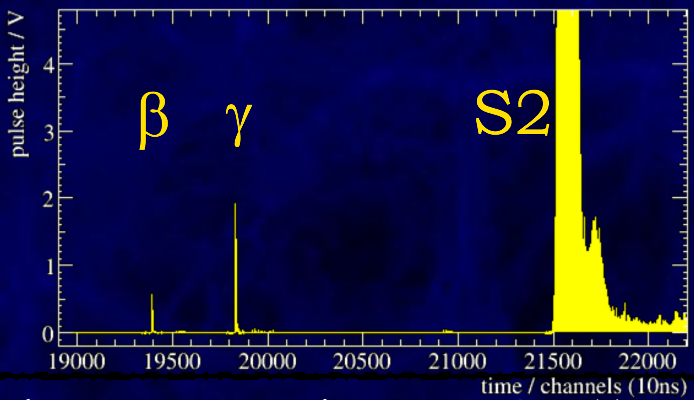
Rare Gas Mass Spectroscopy RGMS:
^{nat}Kr to ppt level

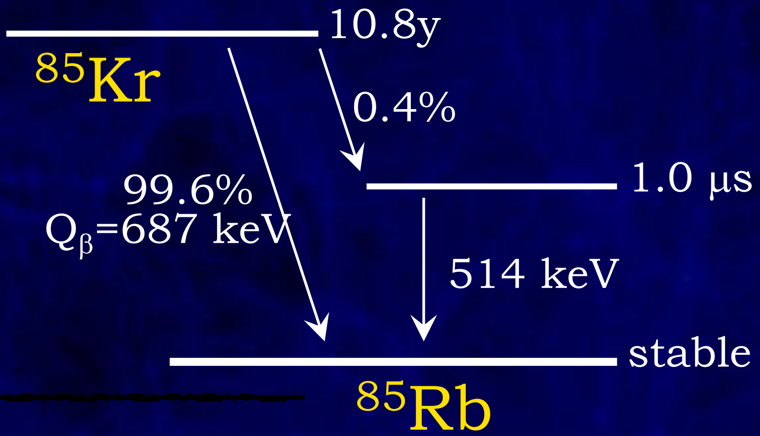
atomic trap ATTA:
^{84}Kr to ppt level



get ^{85}Kr from atmospheric abundance

in situ: delayed coincidences
branching 0.4%



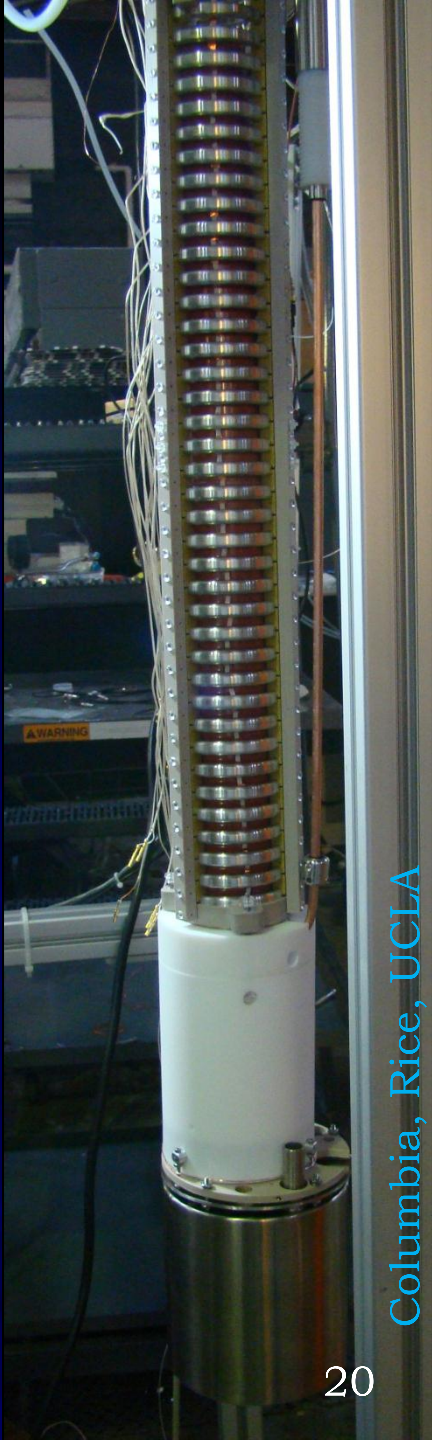


MPIK, Columbia

XENON1T Demonstrator

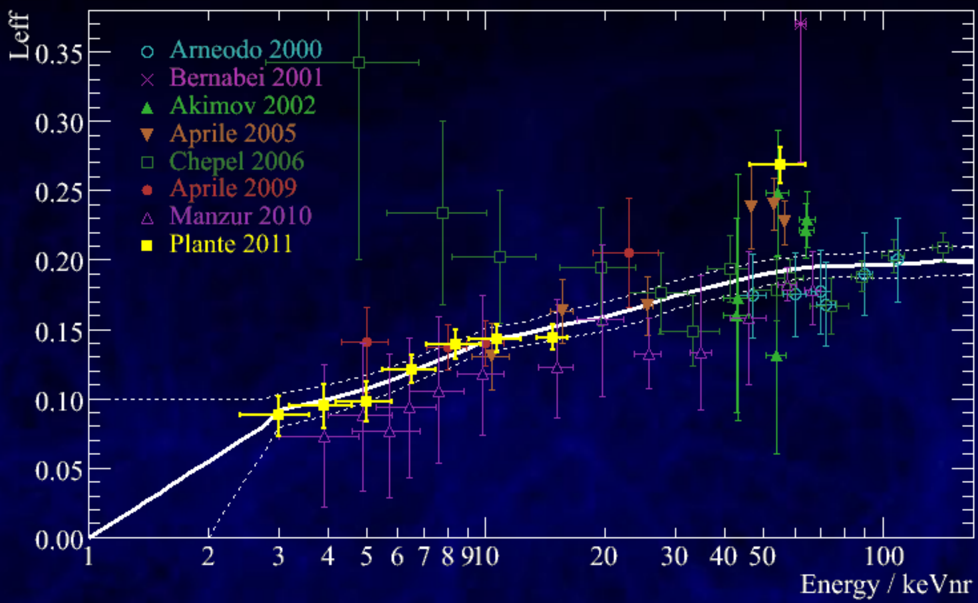
a vertical slice of XENON1T

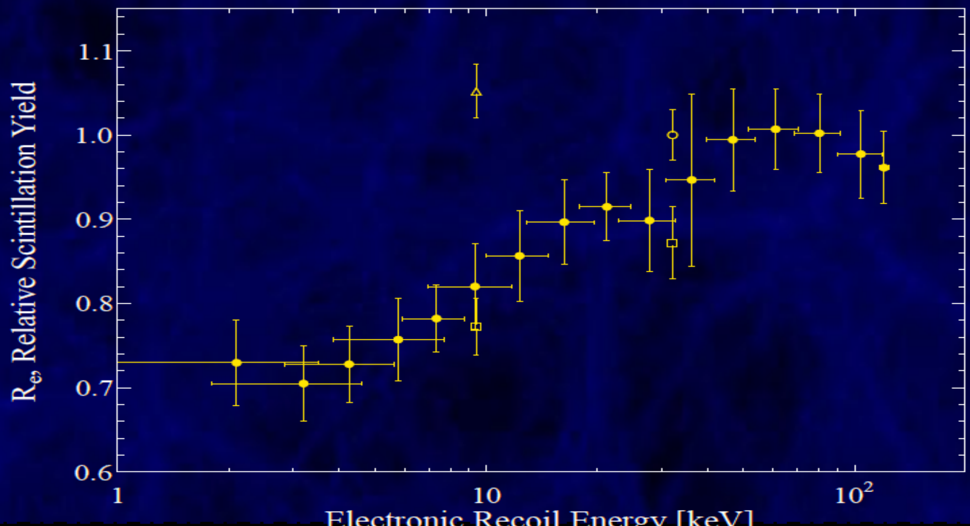
- cooling ✓
  >130W to spare
- e^- lifetime✓
  1 ms in 12 h
- purification ✓
- recirculation ✓
  >800kg/day
- HV✓
  100kV stable
- 1m drift



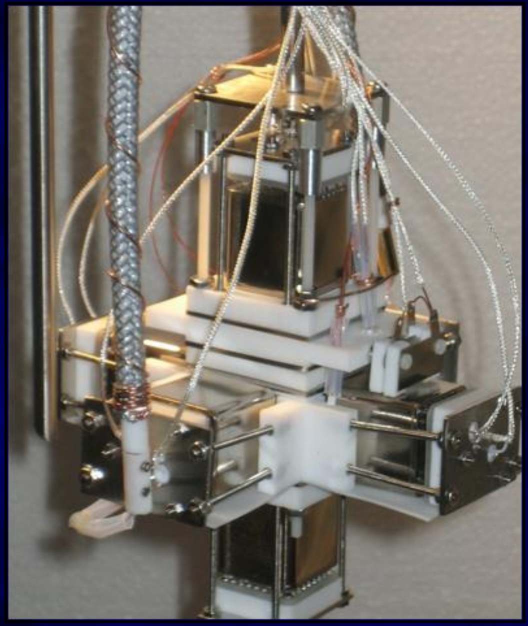
Columbia, Rice, UCLA

Dedicated Zero-Field Setups





$\mathcal{L}_{eff}$ no major systematic uncertainty anymore measured to $3keV_{nr}$

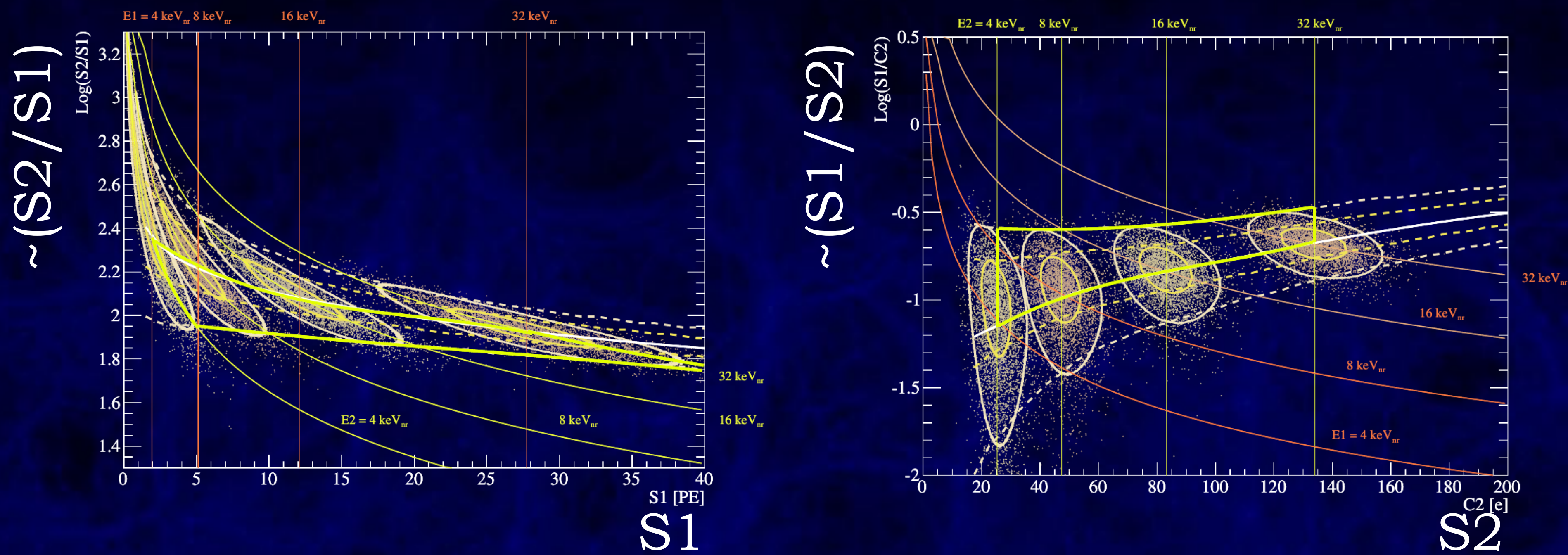


electronic recoils measured to $2keV_{ee}$

Columbia, arXiv:1104.2587 and 1209.3658

Reducing Systematics

charge-based energy scale much better defined:



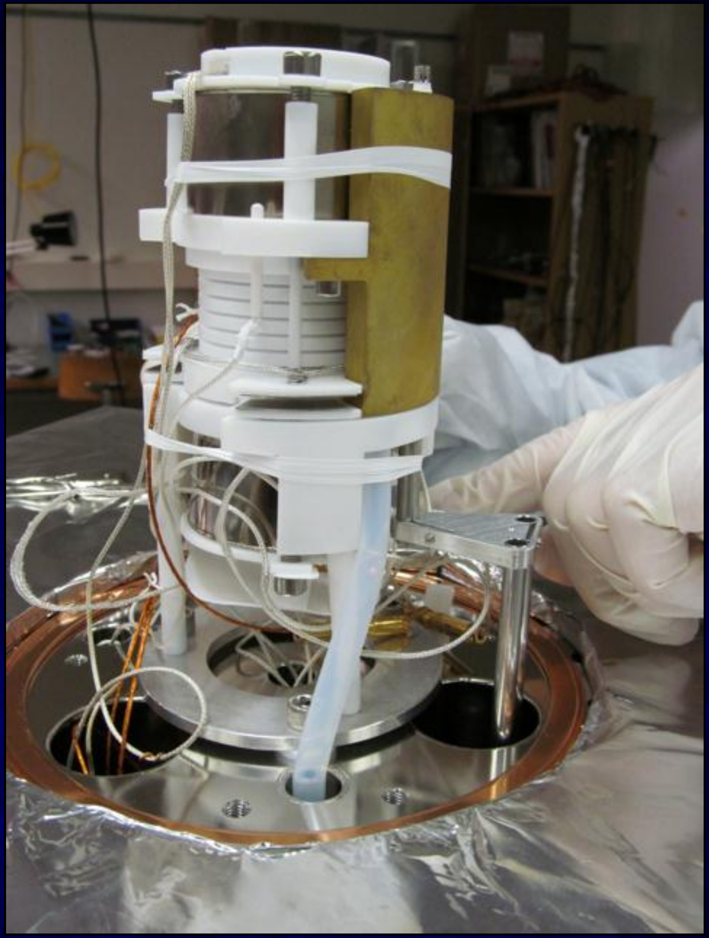
→ measure charge yield (and light yield of course)

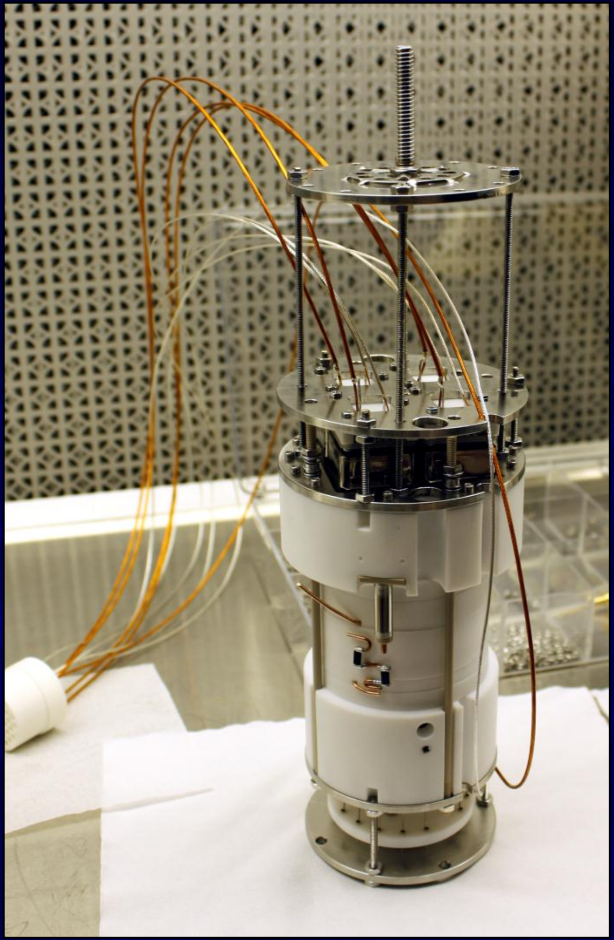
- more precisely
- for nuclear and electronic recoils
- in situ and in dedicated experiments

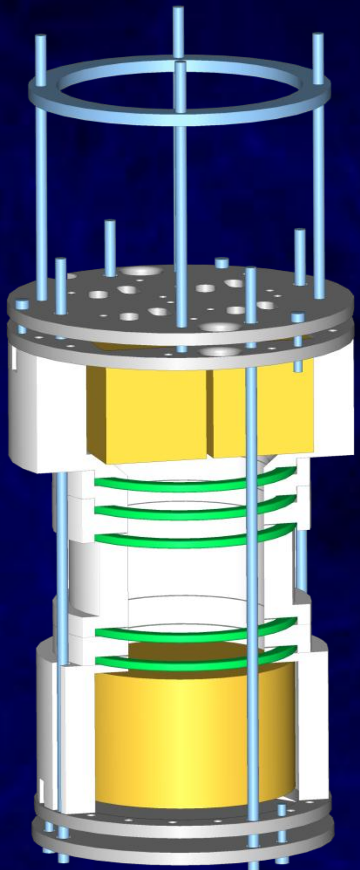
arXiv:1202.1924

Dedicated R&D @Columbia,Zürich

- optimized for <1mm position resolution
- Compton coincidence (γ) and neutron tagging (n)



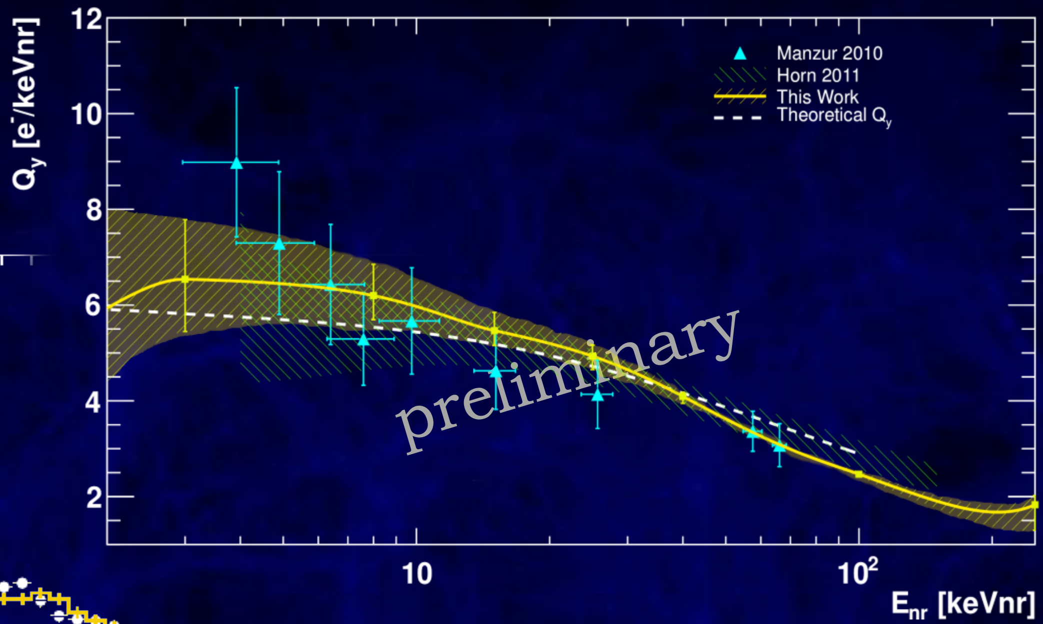


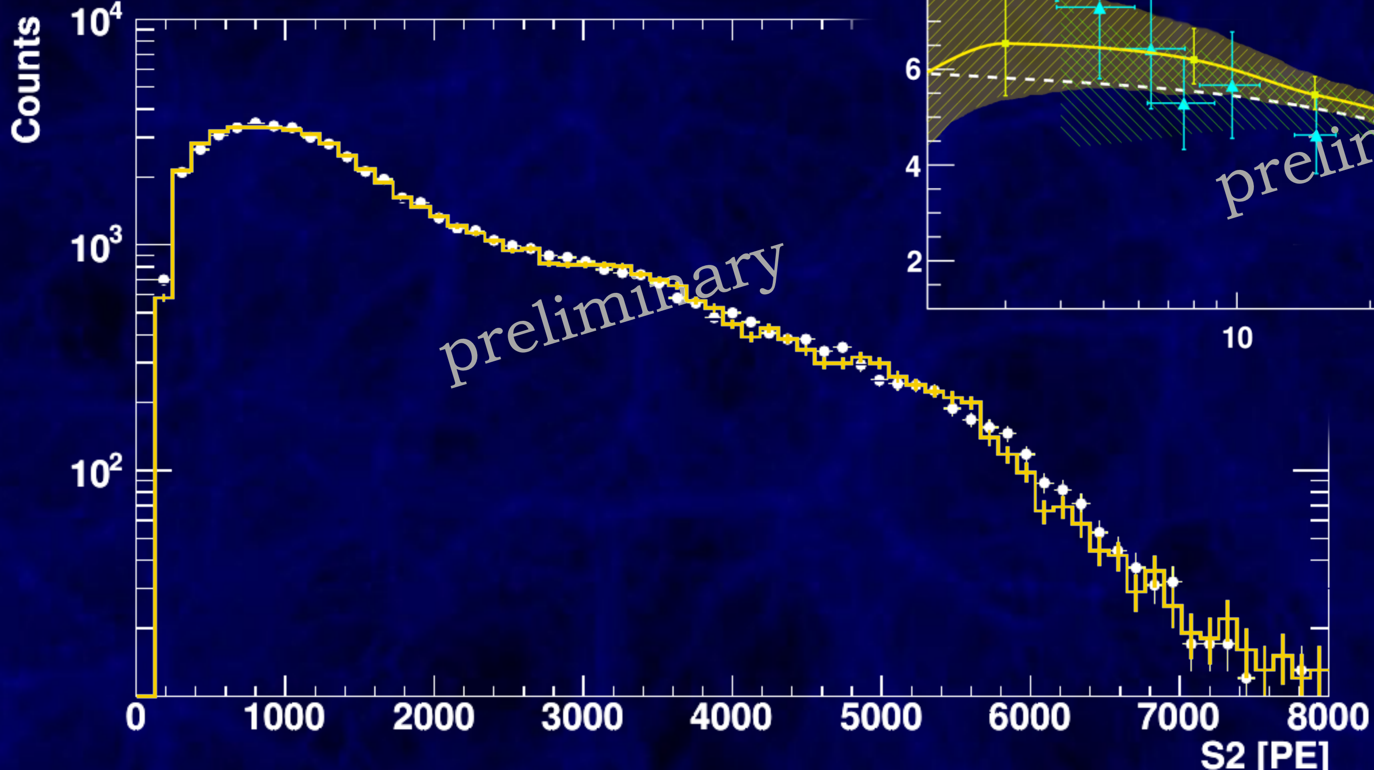


Columbia, Zürich

Absolute (!) Rate Matching

XENON100 AmBe calibration:
systematics ~% level...

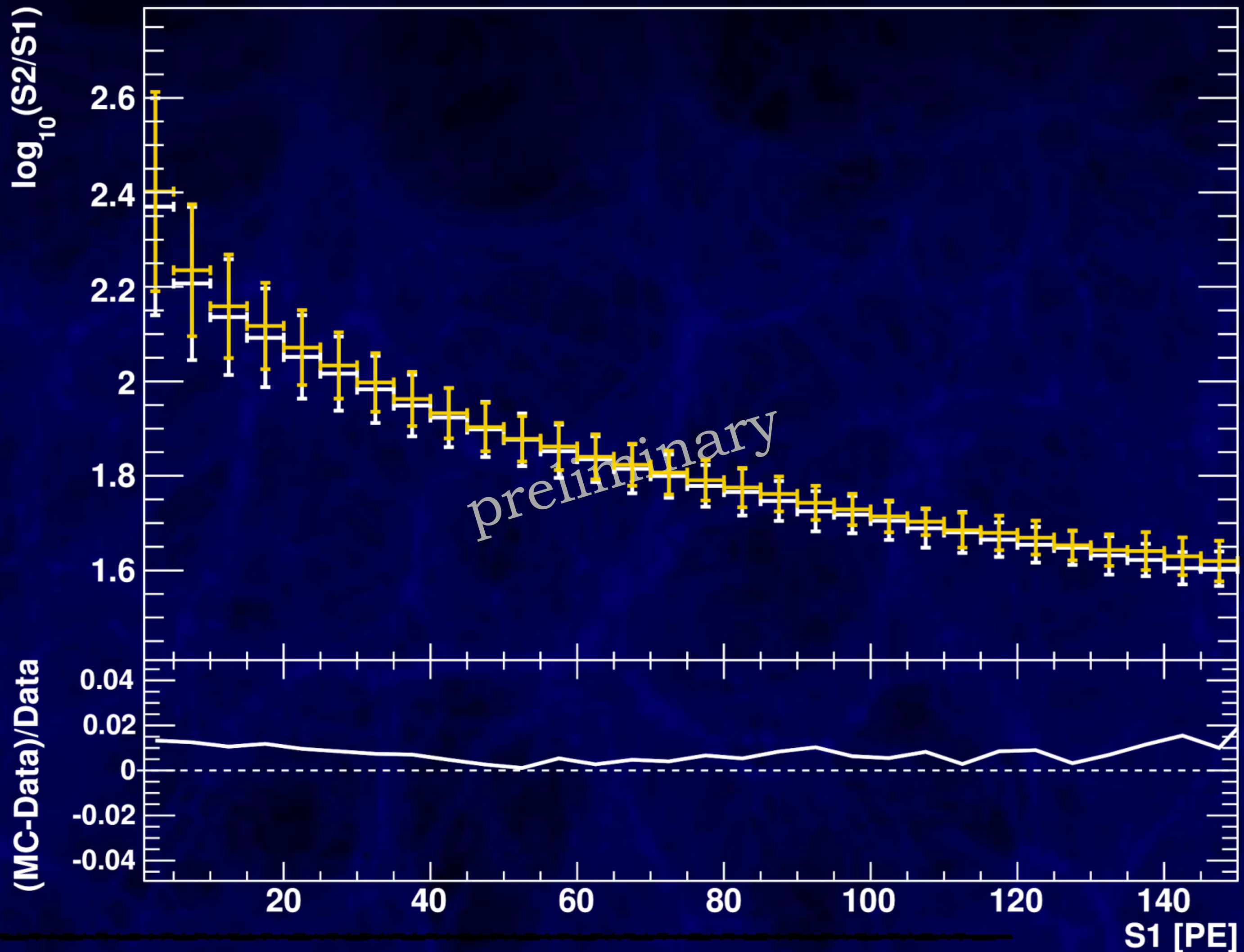




in preparation

Excellent Understanding Already

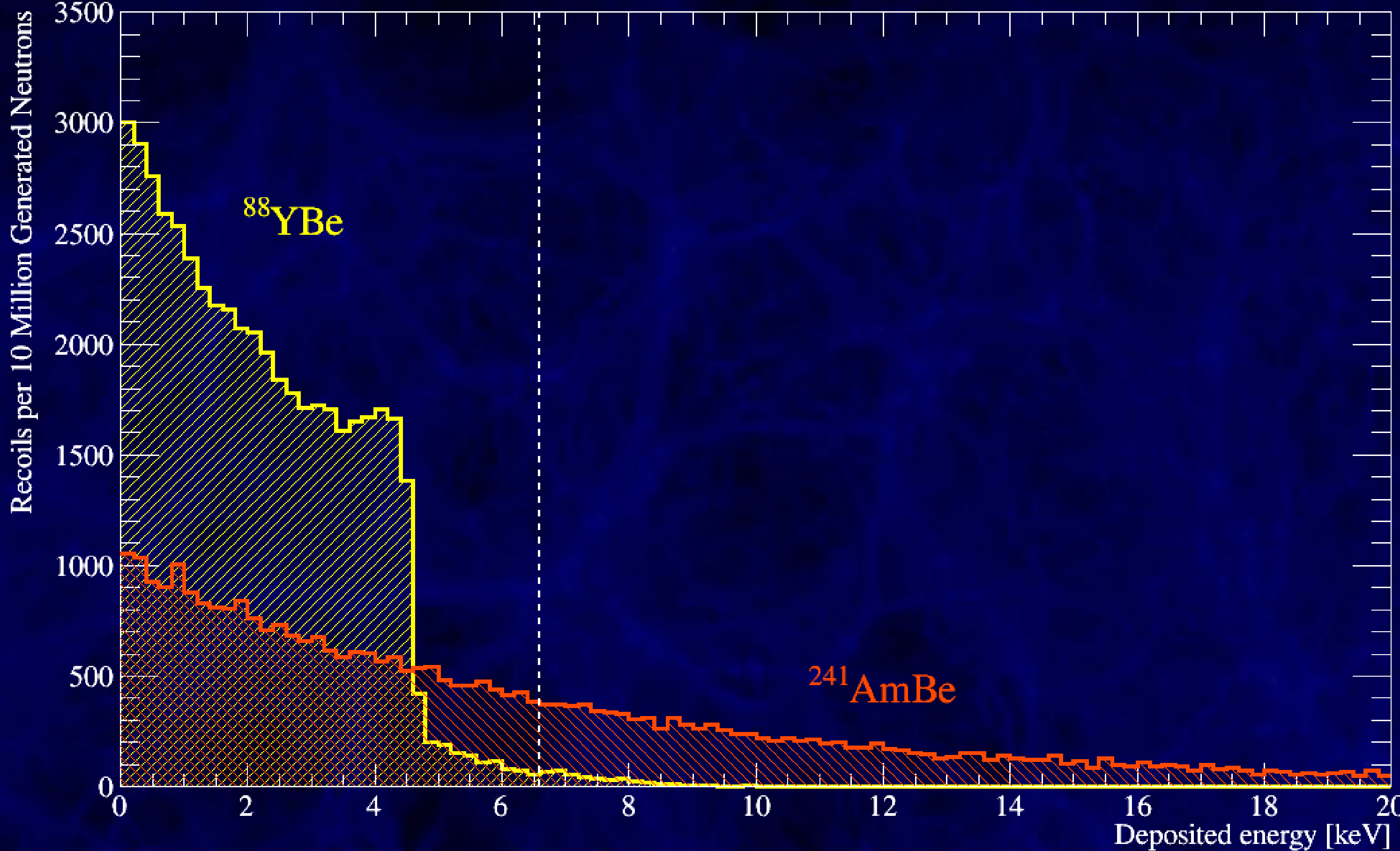
XENON100: maximum deviation <2%



in preparation

How To Measure Poisson Process?

so far: all effects assumed to give simple Poissonian, plus Gaussian PMT response (most conservative assumption)

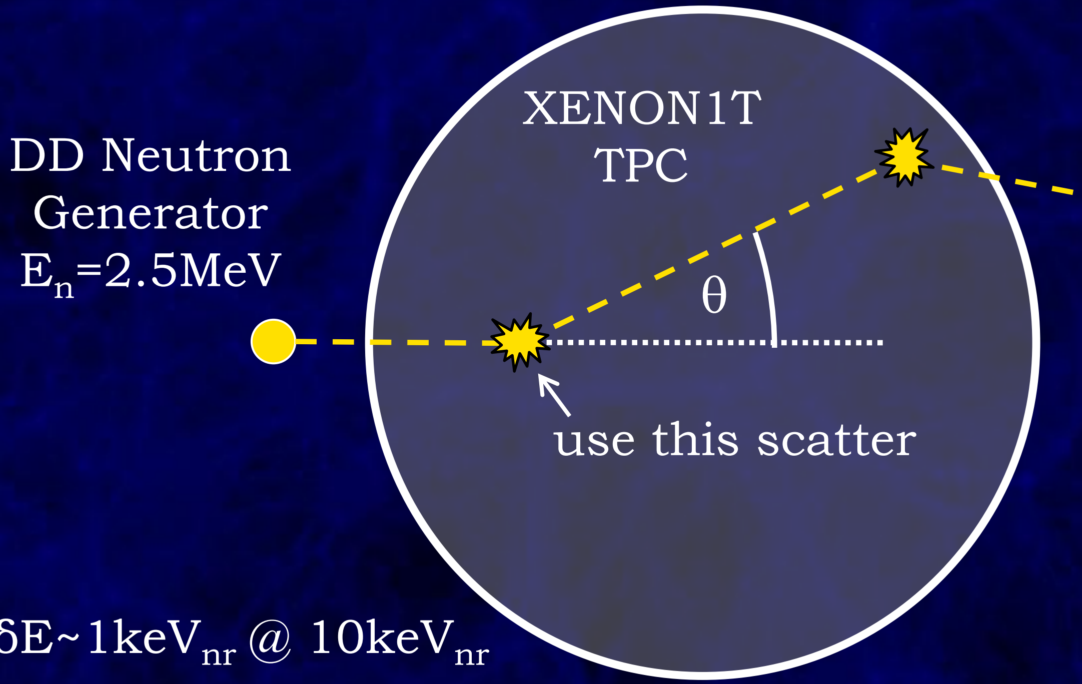


Purdue, Zürich

In Situ Nuclear Energy Calibration

water-proof deuterium-deuterium generator (NSD-Fusion) optimized for low fluxes

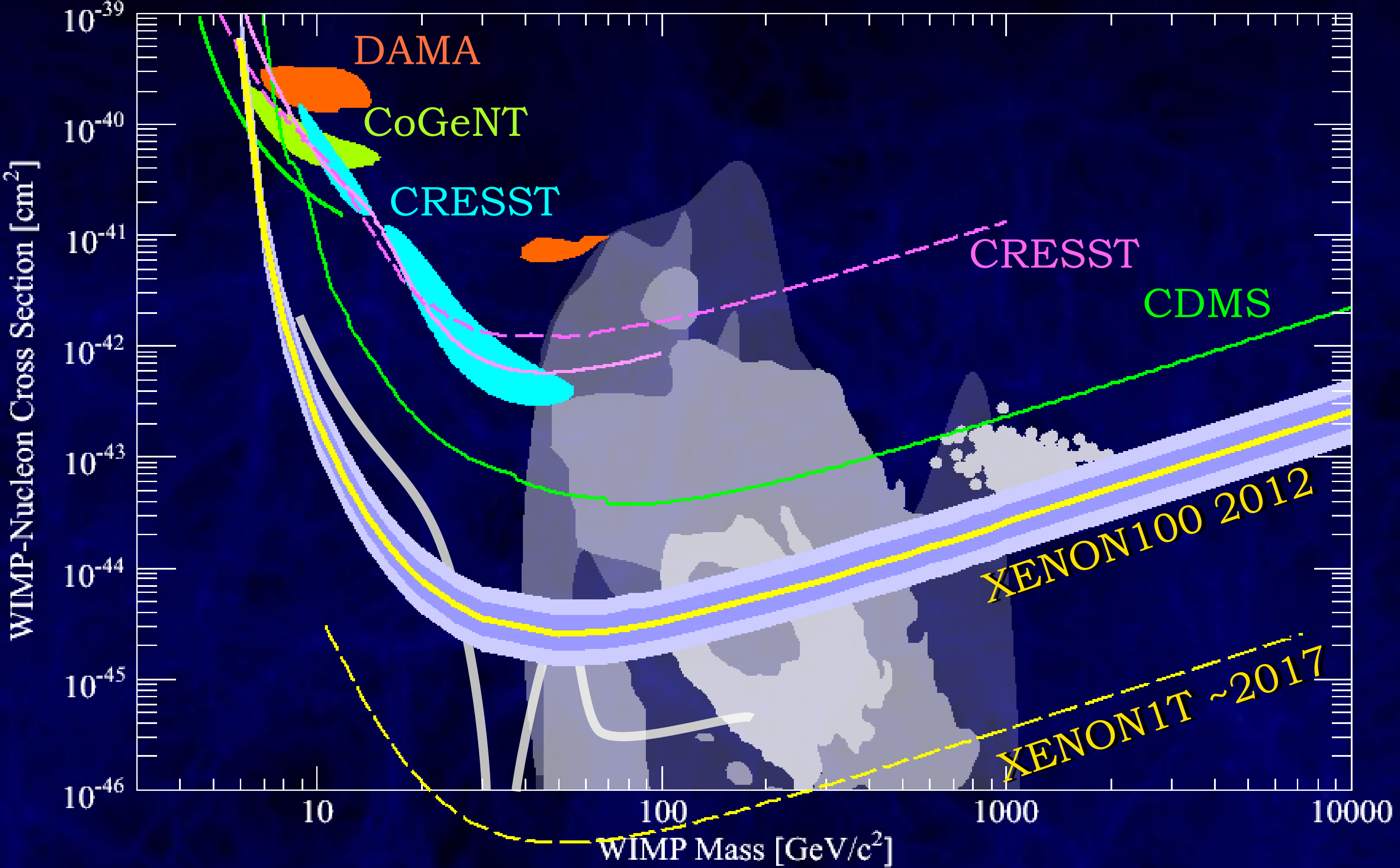
$$E = \frac{2E_n m_{\mathrm{Xe}}}{m_n \left(1 + \frac{m_{\mathrm{Xe}}}{m_n}\right)^2}(1 - \cos\theta^*)$$



$\delta E \sim 1\mathrm{keV_{nr}}$ @ $10\mathrm{keV_{nr}}$

XENON1T is Proven Technology

commissioning late 2014, data taking 2015, limit ~2017:



Calibration with ^{83m}Kr