液氙暗物质实验的计划和进展

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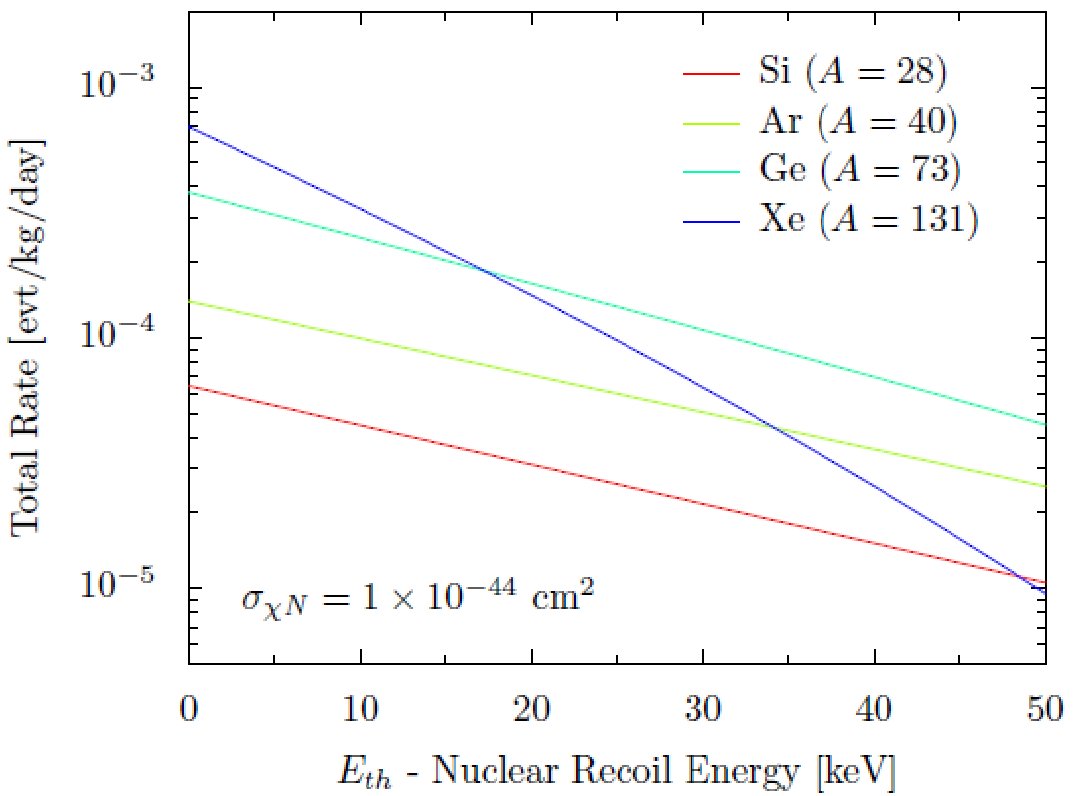
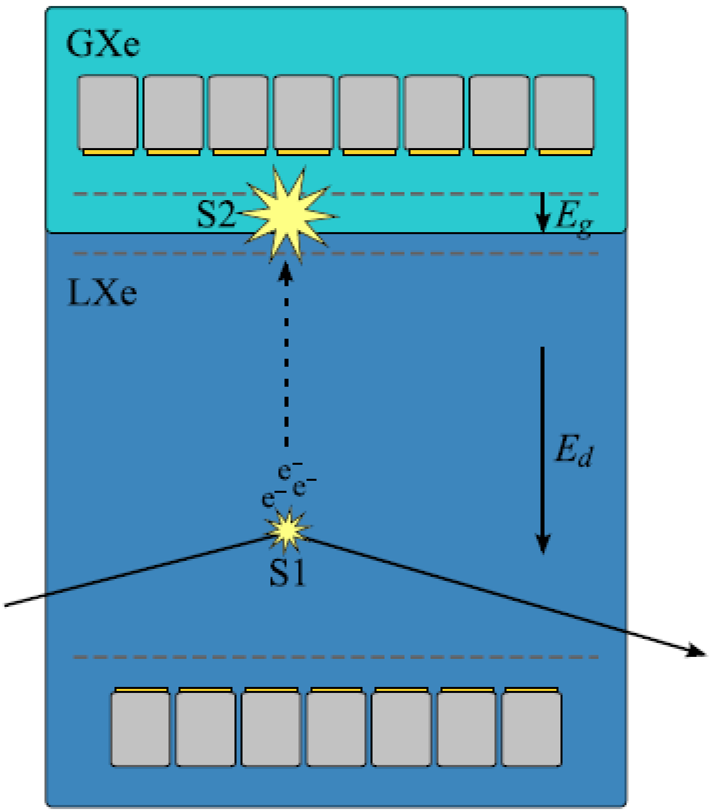
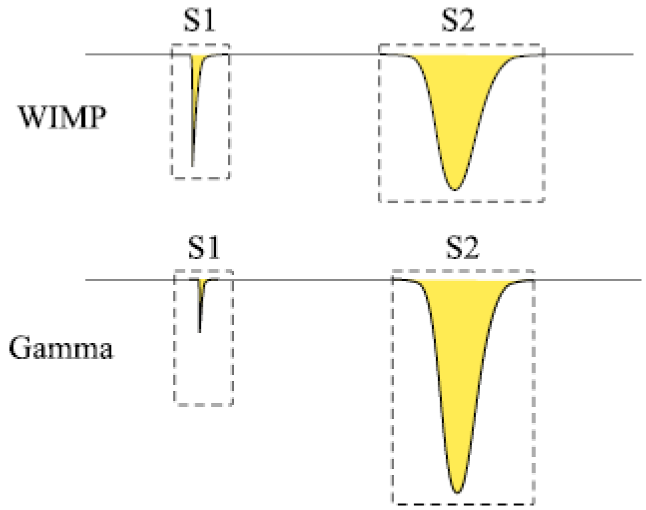
Why Xenon?

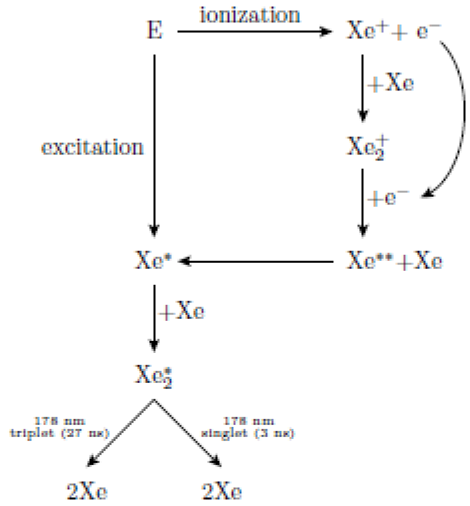
- Large mass number A (~131), expect high rate for SI interactions ($\sigma \sim A^2$) if energy threshold for nuclear recoils is low
- ~50% odd isotopes (^{129}Xe,^{131} Xe) for SD interactions
- No long-lived radioisotopes, Kr can be reduced to ppt levels
- High stopping power ($Z = 54$, $\rho = 3\,\mathrm{g\,cm^{-3}}$), active volume is self shielding
- Efficient scintillator (~80% light yield of NaI), fast response
- Nuclear recoil discrimination with simultaneous measurement of scintillation and ionization



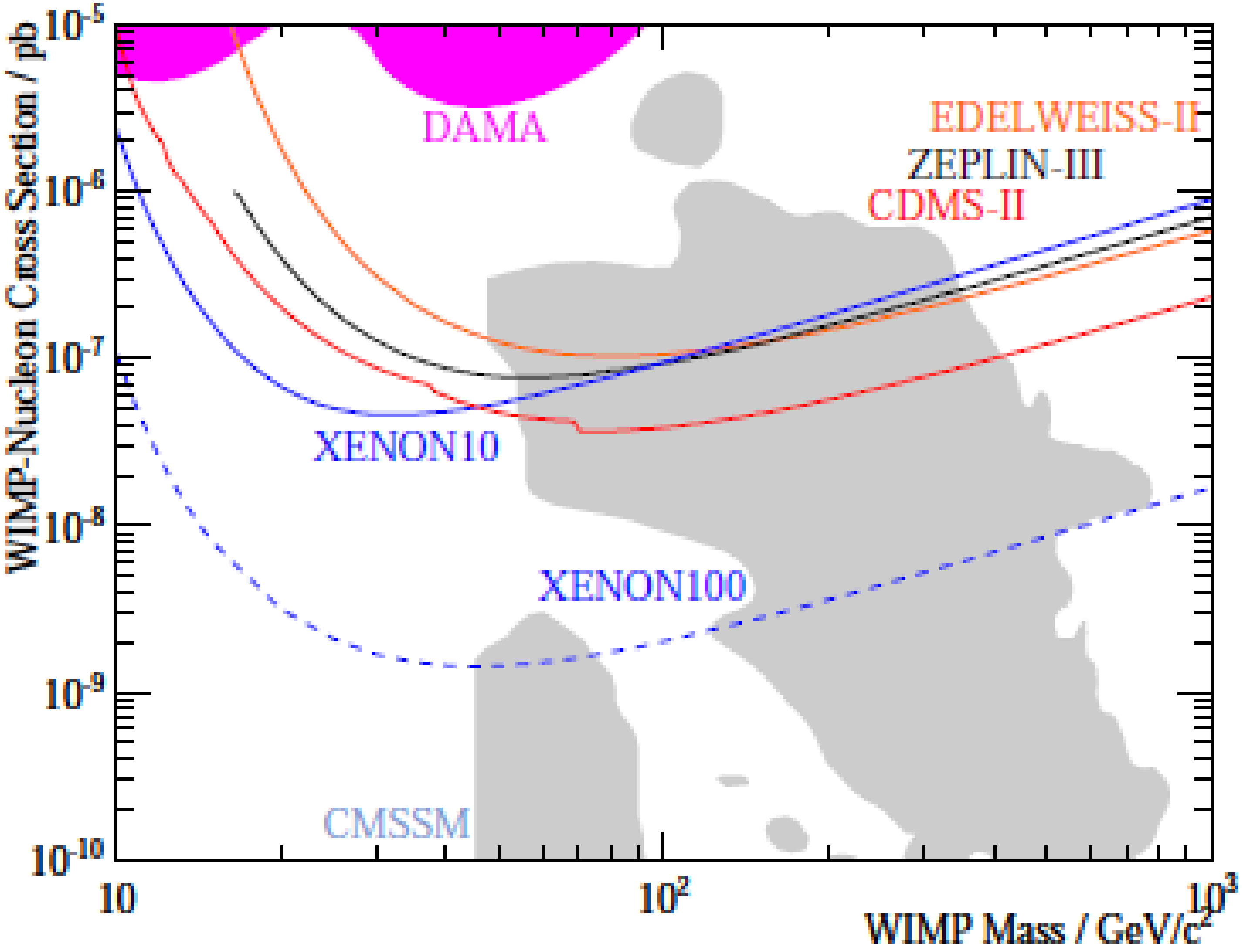
Principle





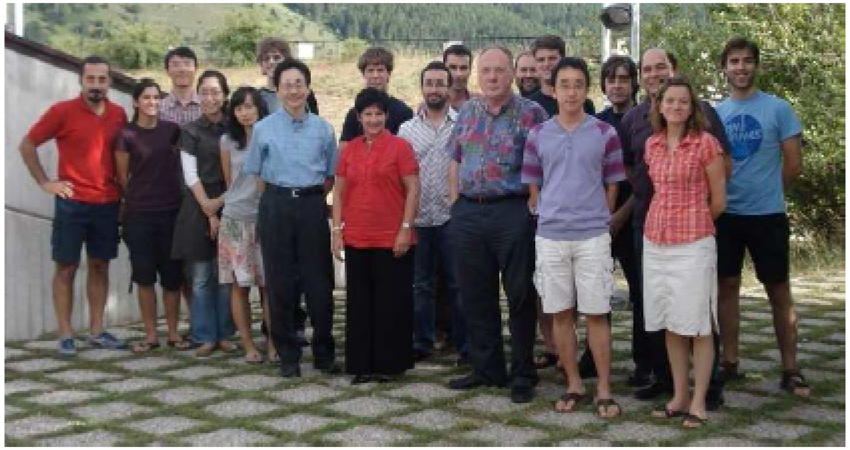


- Bottom PMT array below cathode, fully immersed in LXe to efficiently detect scintillation signal (S1).
- Top PMTs in GXe to detect the proportional signal (S2).
- Distribution of the S2 signal on top PMTs gives xy coordinates while drift time measurement provides z coordinate of the event.
- Ratio of ionization and scintillation (S2/S1) allows discrimination between electron and nuclear recoils.



WIMP-Nucleon Cross Section / pb
WIMP Mass / GeV/c²
10
10²
10³
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
DAMA
EDELWEISS-II
ZEPLIN-III
CDMS-II
XENON10
XENON100
CMSSM

XENON100 Collaboration



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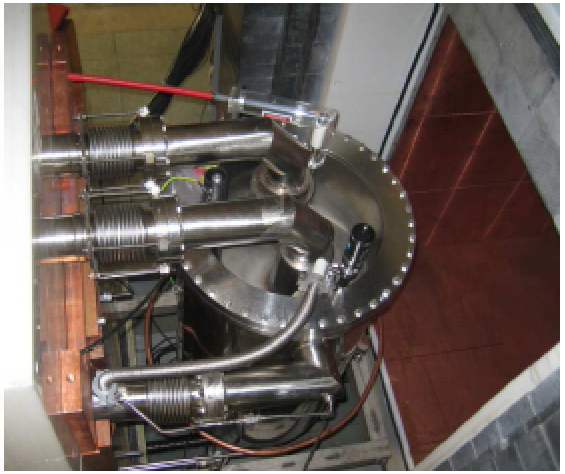
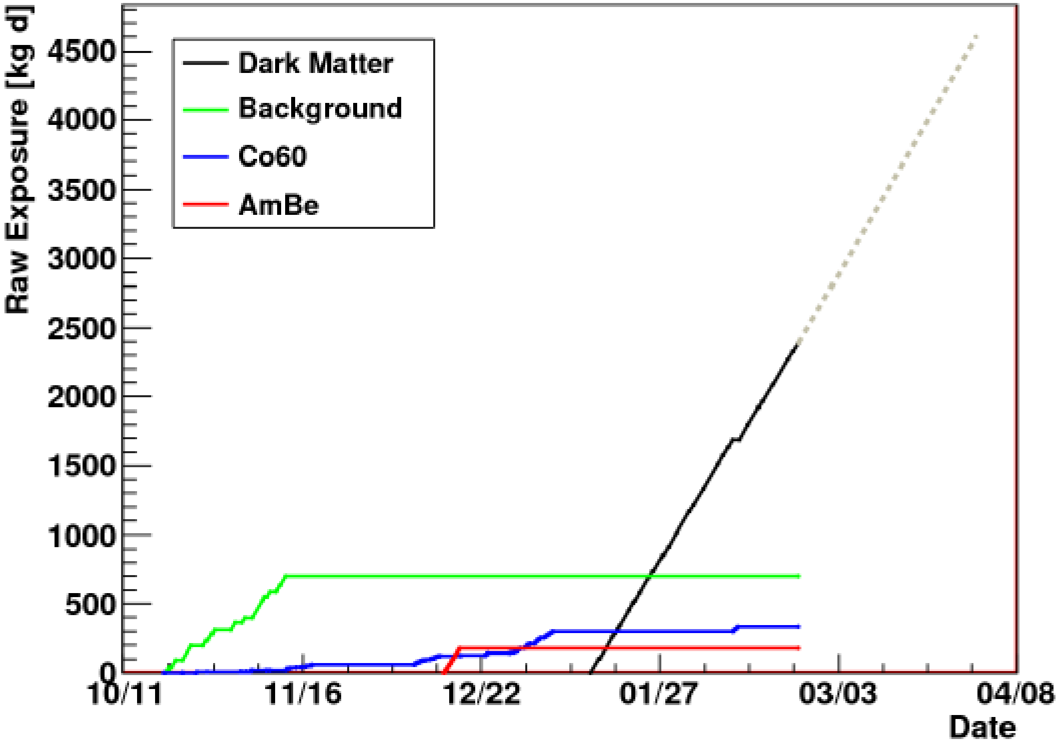
XENON100

- Reuse techniques and technologies developed for the XENON10 prototype to build a detector with a $\times 10$ increase in fiducial mass and a $\times 100$ reduction in background.
- Reduce the background from internal components
  - Pulse tube refrigerator and motor valve outside the shield,
  - All signal and HV feedthroughs also outside the shield,
  - Extensive material screening program to choose materials,
  - Kr distillation column to reduce Kr contamination in Xe.
- Reduce the background contribution from external sources
  - New 5 cm layer of copper to the XENON10 shield to reduce the contribution from the the polyethylene,
  - LXe Active veto surrounding the target.
- 170 kg LXe total mass consisting of a 65 kg target surrounded by a 105 kg active veto. 15 cm radius, 30 cm drift length active volume.



XENON100: Status

- XENON100 is operating reliably and stably underground at LNGS for the last 6 months.
- Neutron calibration was performed in mid-December.
- Gamma calibrations are being taken on a regular basis.
- Background level measured is consistent with a factor 100 reduction compared to XENON10.
- Started first blind Dark Matter Search run on January 13th.
- In this talk I will present some preliminary results of the neutron and gamma calibrations and unblind background data.



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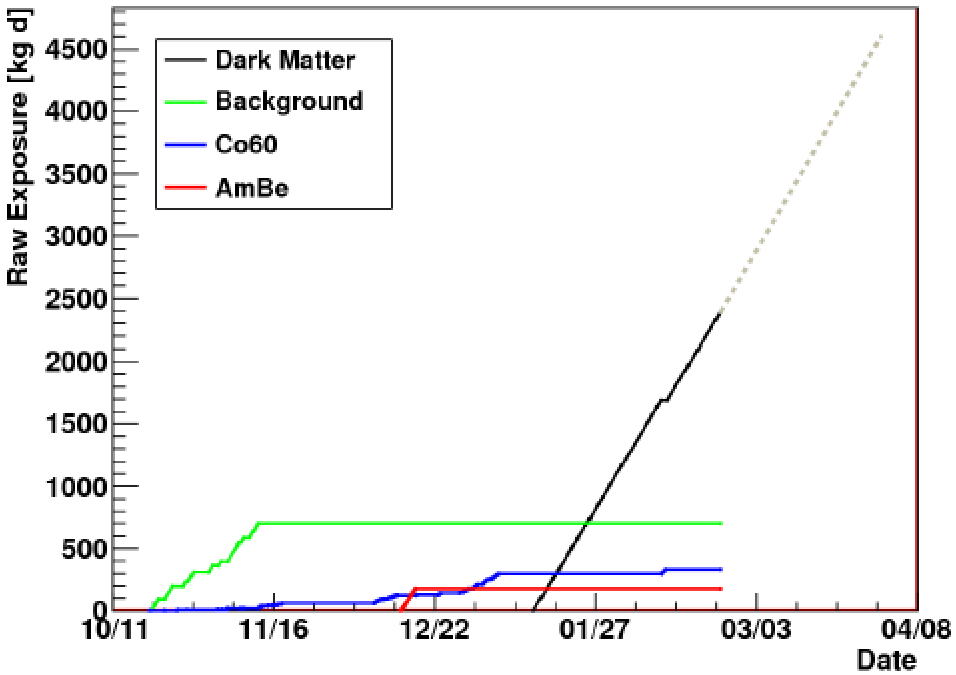
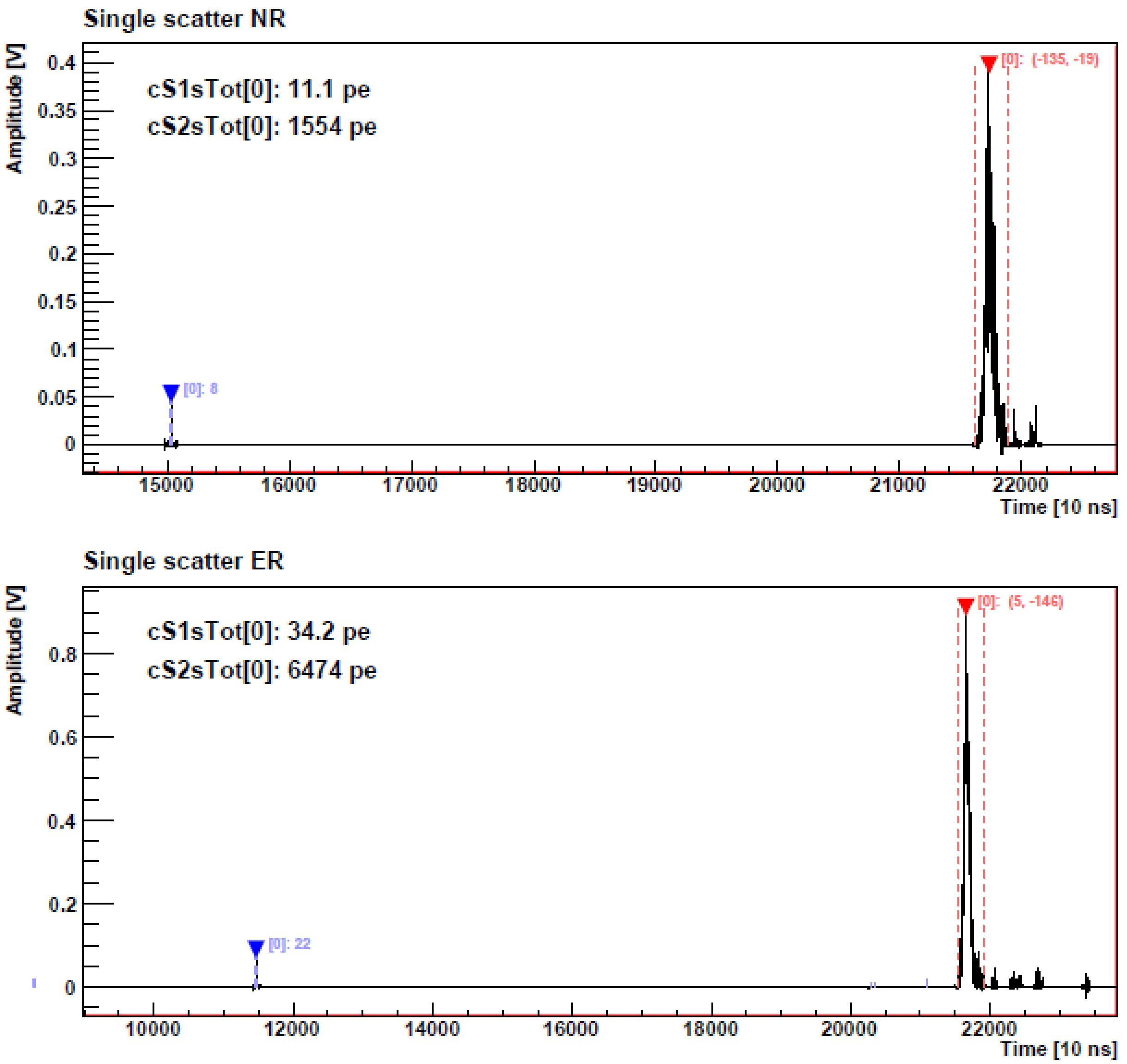


XENON100: Typical Low Energy Events



XENON100: Data Selection

Three levels of cuts are applied to the calibration data:

L0: Basic quality cuts

Designed to remove noisy events, events with unphysical parameters. Very high acceptance.

- S1 coincidence cut
- S2 threshold cut
- S2 saturation cut
- S2 width cut
- Signal/Noise cut

L1: Scatter cuts

Designed to remove events with multiple interactions (multiple S2s), with delayed coincidences (multiple S1s) or with misidentified S1s.

- S1 single peak cut
- S2 single peak cut

L2: Fiducial volume cuts

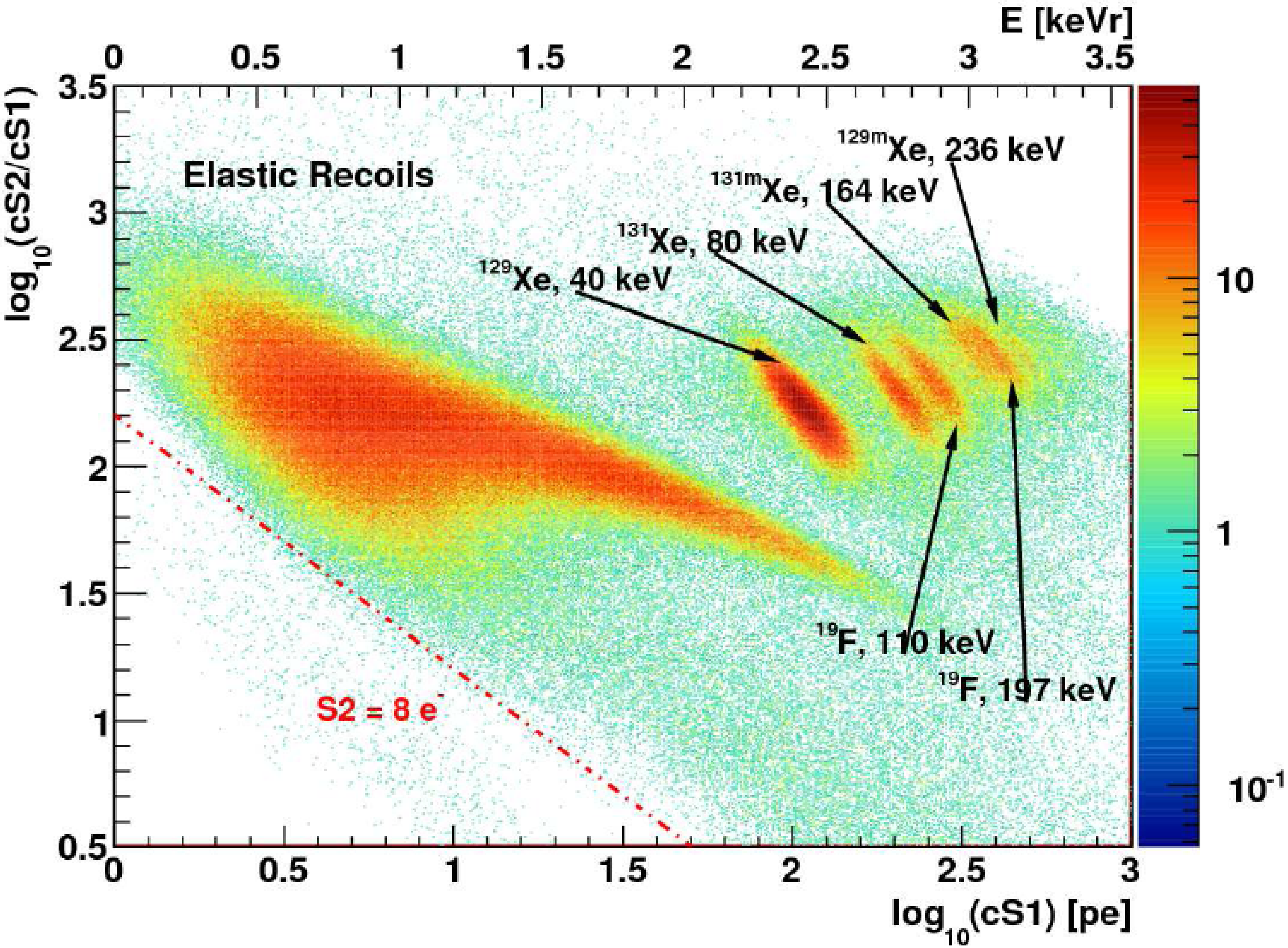
Because of the high stopping power of LXe, fiducialization is an extremely effective way of reducing background. Possible fiducial volumes:

- 50 kg
  - $r < 14$ cm
  - $2\,\text{cm} < z < 29\,\text{cm}$
- 30 kg
  - $r < 13$ cm
  - $4\,\text{cm} < z < 27\,\text{cm}$

XENON100: Neutron Calibration 1

- Calibration performed with a 3.7 MBq (220 n/s) AmBe source from 12/15/09 to 12/18/09.
- Accumulated 3×10^6 events in 3 days, 5×10^4 single scatter nuclear recoils <100 keVr. Much more statistics than for the XENON10 neutron calibration to be able to describe the nuclear recoil band up to higher energies.
- Since WIMPs are expected to elastically scatter off of nuclei understanding the behavior of single elastic nuclear recoils in Xe is essential.
- In addition, the neutron calibration gives gammas from inelastic recoils and activated Xe lines that can be used to infer the spatial dependence of S1 and S2 signals (analysis is ongoing).
- For the data presented here the spatial dependence of the S1 signal is corrected using factors obtained from Cs137 calibrations at uniform positions around the detector. The drift time dependence of the S2 signal is also infered from weekly Cs137 calibrations.

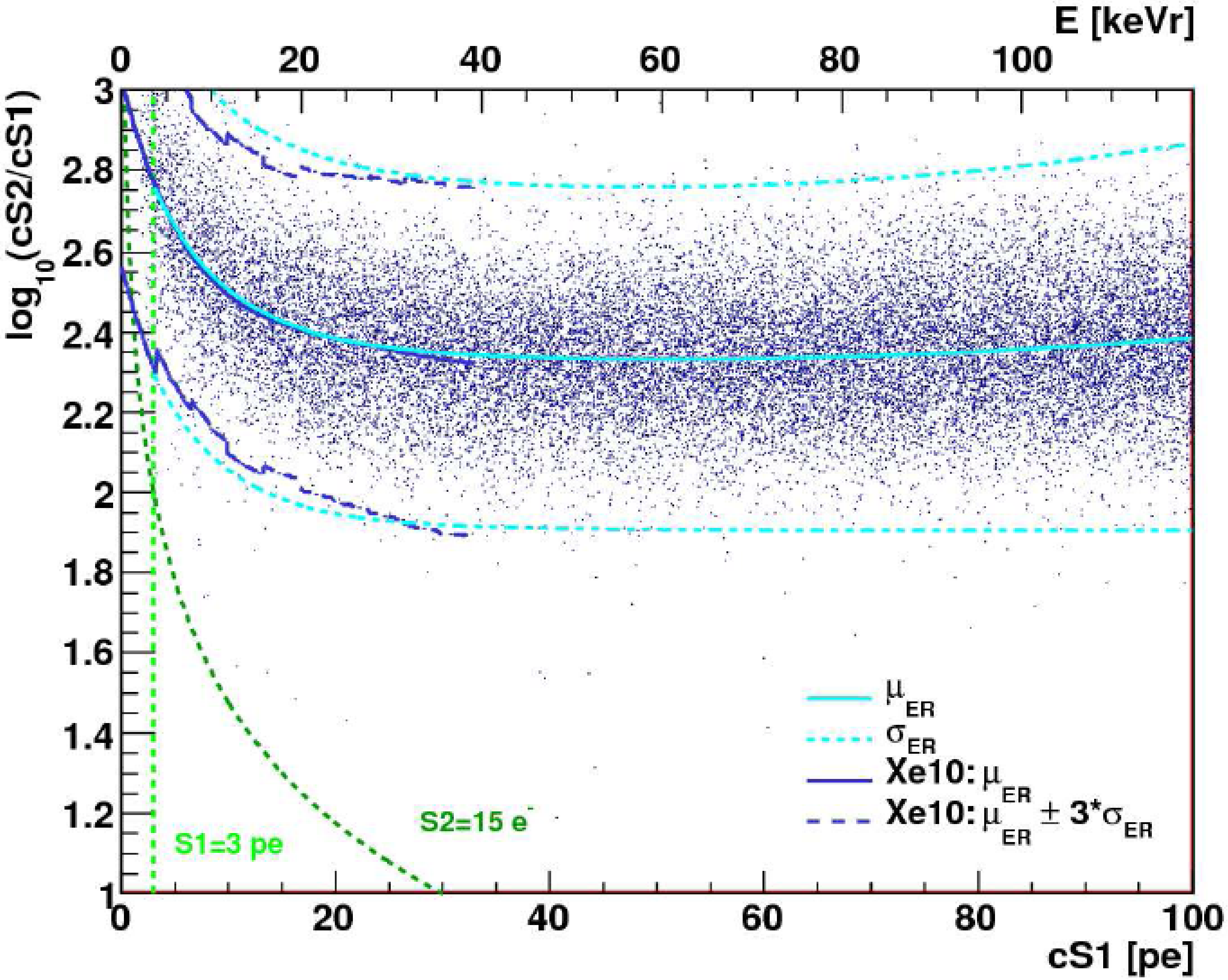
XENON100: Neutron Calibration 2



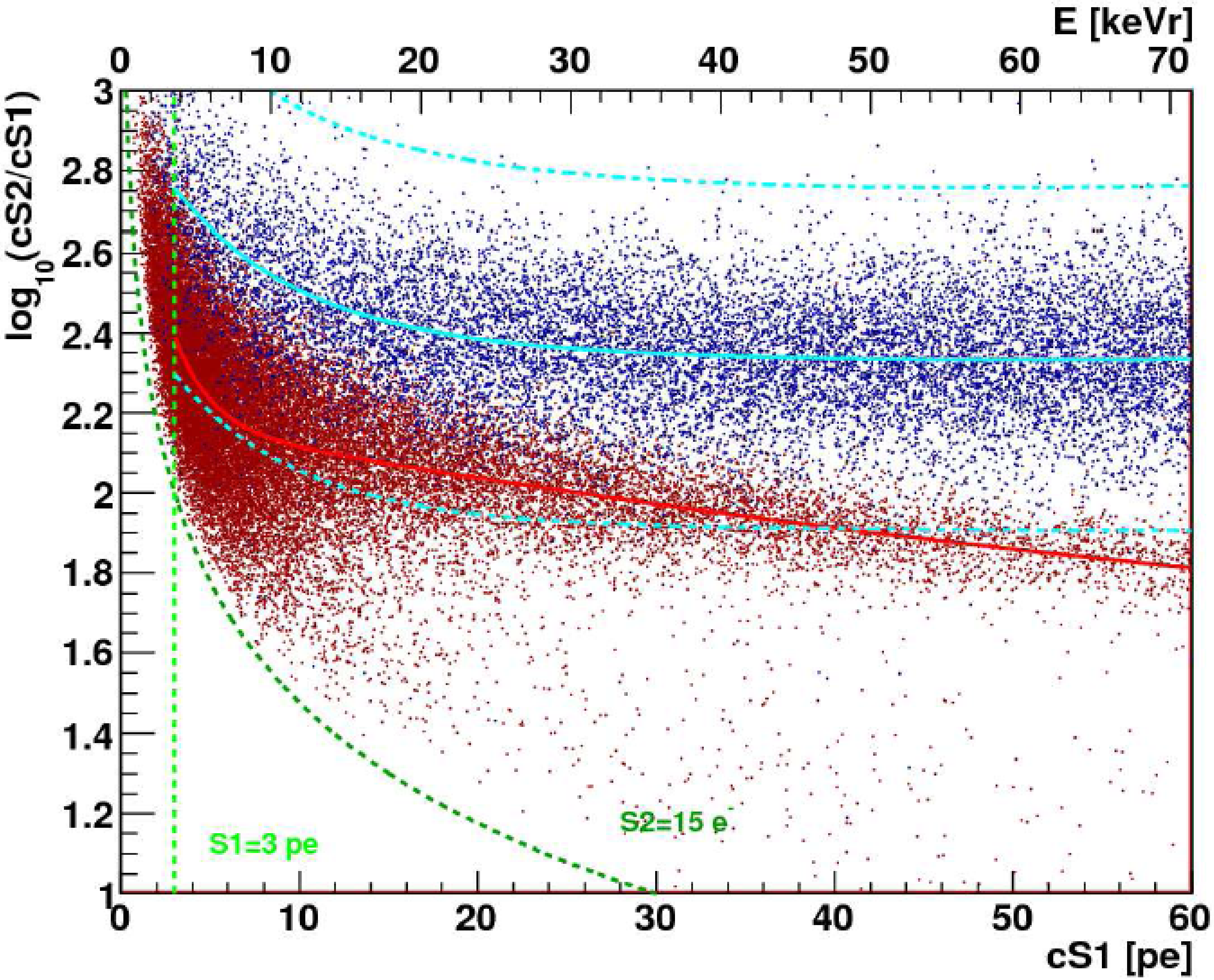
XENON100: Gamma Calibration

- A gamma calibration is performed on a regular basis with a 1 kBq Co60 source at different positions around the detector.
- High energy gammas from Co60 (1.17 Mev, 1.33 MeV) allow for an efficient low energy electron recoil band calibration due to their increased Compton mean free path.
- The data acquisition system (DAQ) was designed to allow calibration at high rate in order to accumulate much larger statistics for the electron recoil band compared to what was accumulated with XENON10.
- The ultimate limit is set by the inherently slow response of a large ionization detector (maximum drift time of 175 μs).
- DAQ/processing/storage system allows data taking at rates of 100 evts/keVee/liveday in a 30 kg fiducial volume with the Co60 source, a factor 1000 higher than the background.

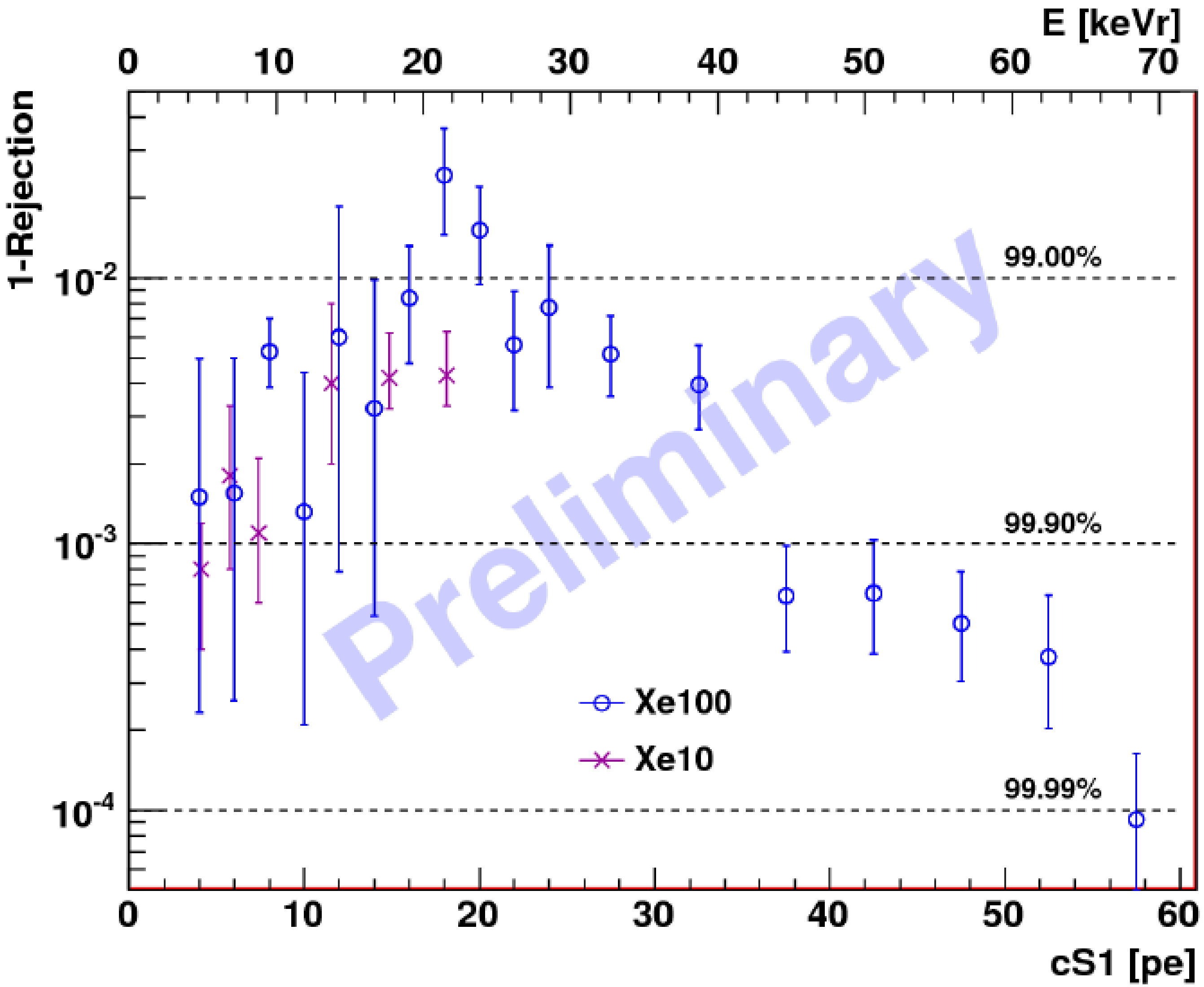
XENON100: Electron Recoil Band



XENON100: Rejection Power 1



XENON100: Rejection Power 2

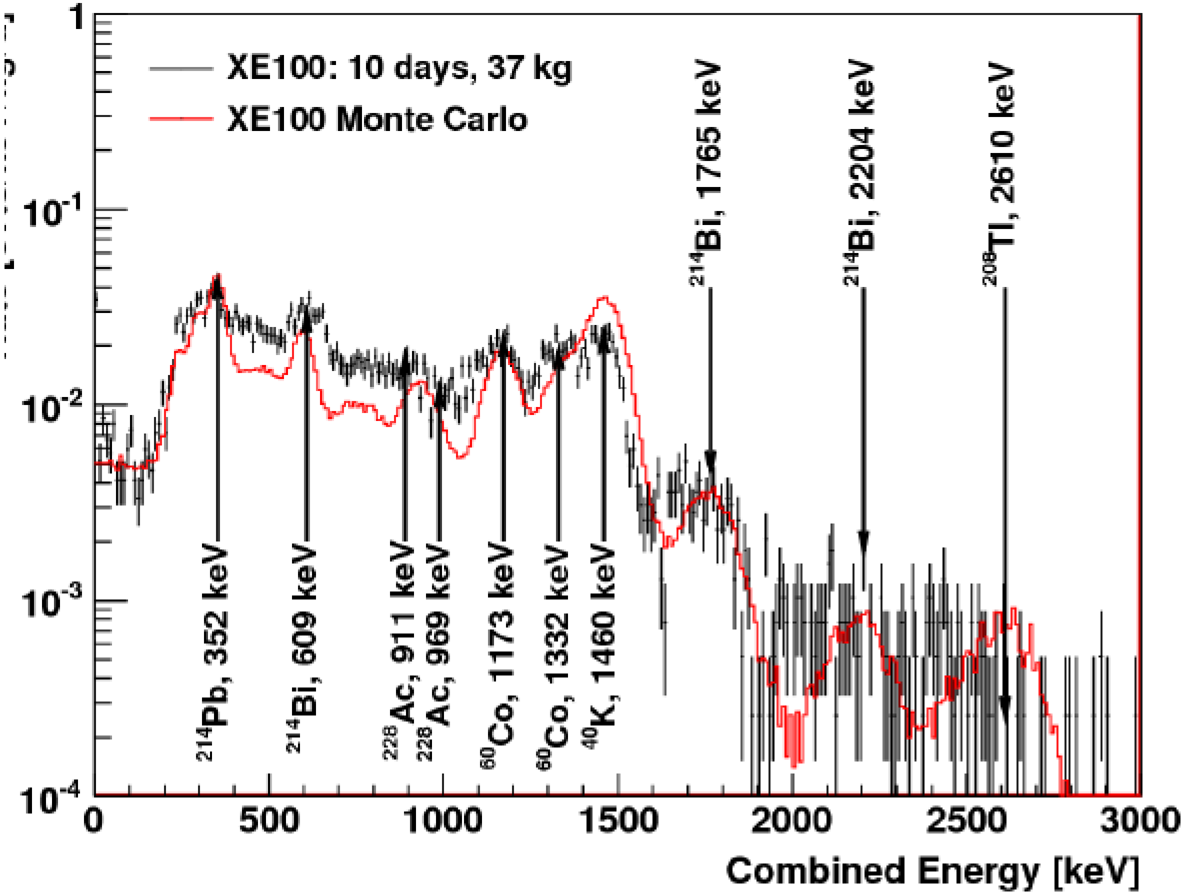


XENON100: Background 1

- Measured background is in good agreement with Monte Carlo predictions (no tuning).
- The measured single scatter rate below 100 keVee is

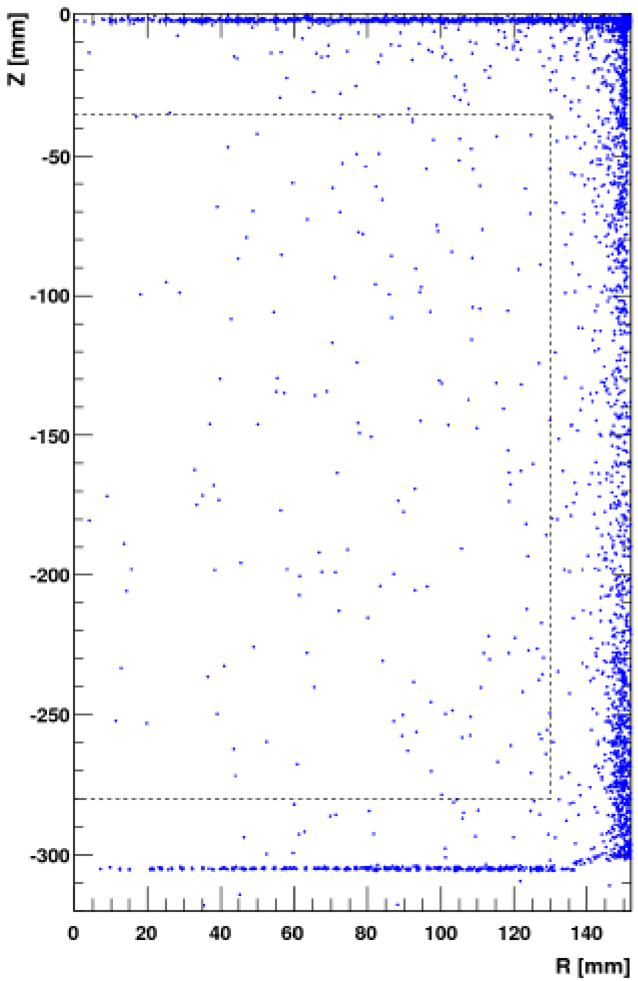
5×10^{-3} evts/kg/keV/d

- Background level in fiducial volume is a factor 100 lower than XENON10 (0.6 evts/kg/keV/d).

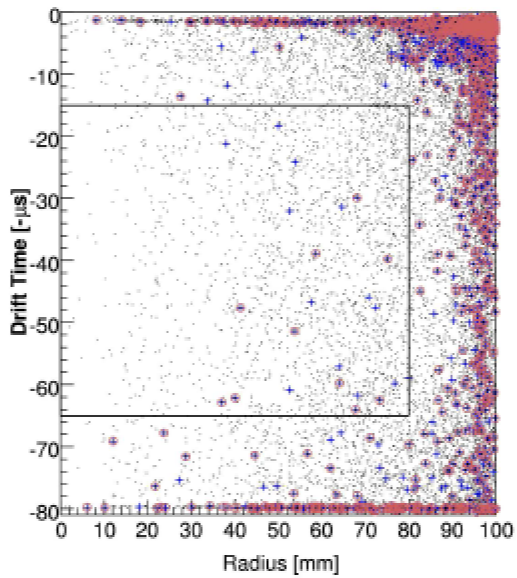


XENON100: Background 2

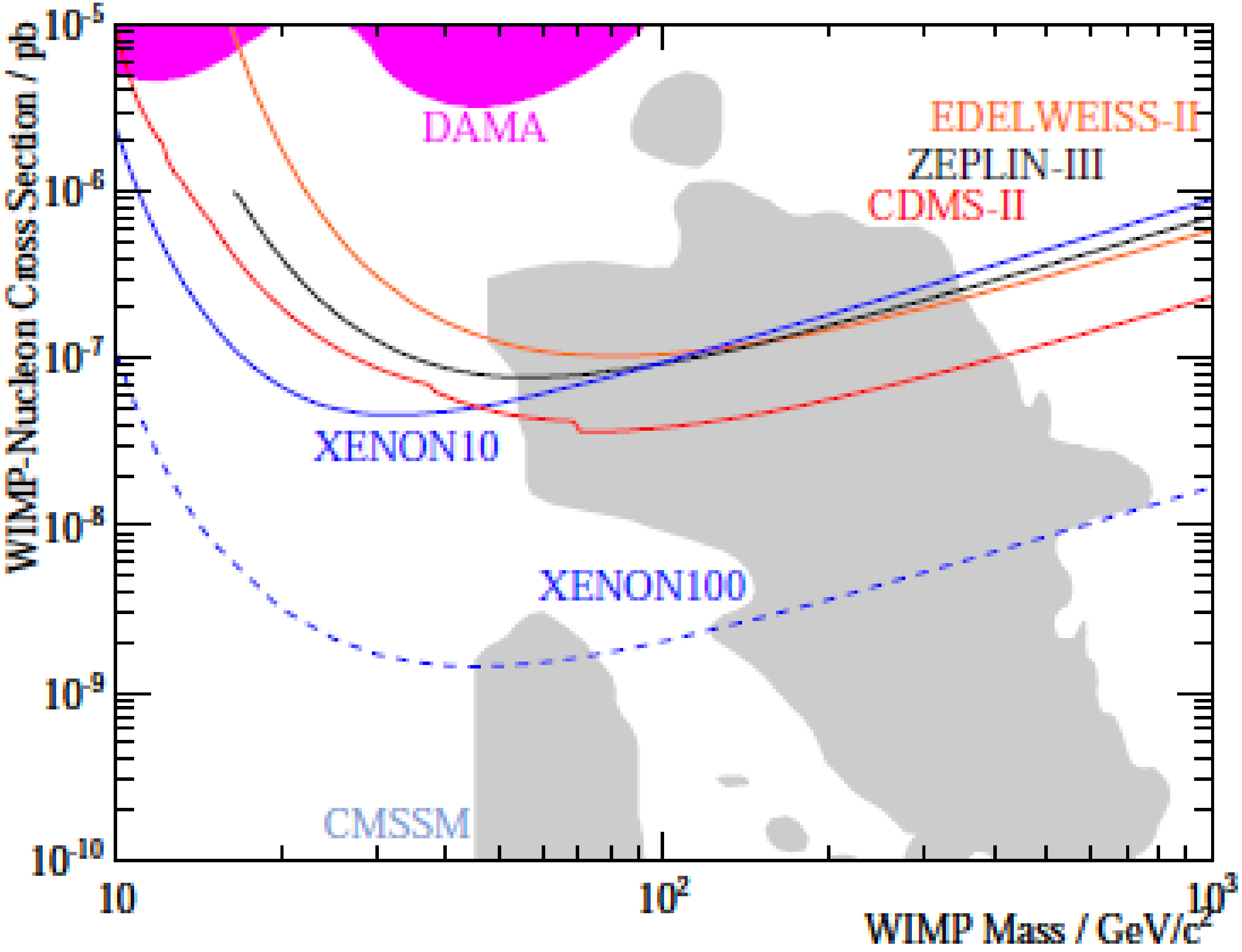
- Dramatic background reduction from XENON10 to XENON100 is evident by comparing the event distributions for similar exposures.
- With an ER/NR rejection power of 99.5% at 50% NR acceptance, XENON100 will be able to run background-free for 40 days with a fiducial volume of 50 kg or 200 days with a fiducial volume of 30 kg.



XENON100, 4-60 keVee
37 kg fiducial, 10 d



XENON10, 2-12 keVee
5 kg fiducial, 58 d



WIMP-Nucleon Cross Section / pb
WIMP Mass / GeV/c^2
DAMA
EDELWEISS-II
ZEPLIN-III
CDMS-II
XENON10
XENON100
CMSSM

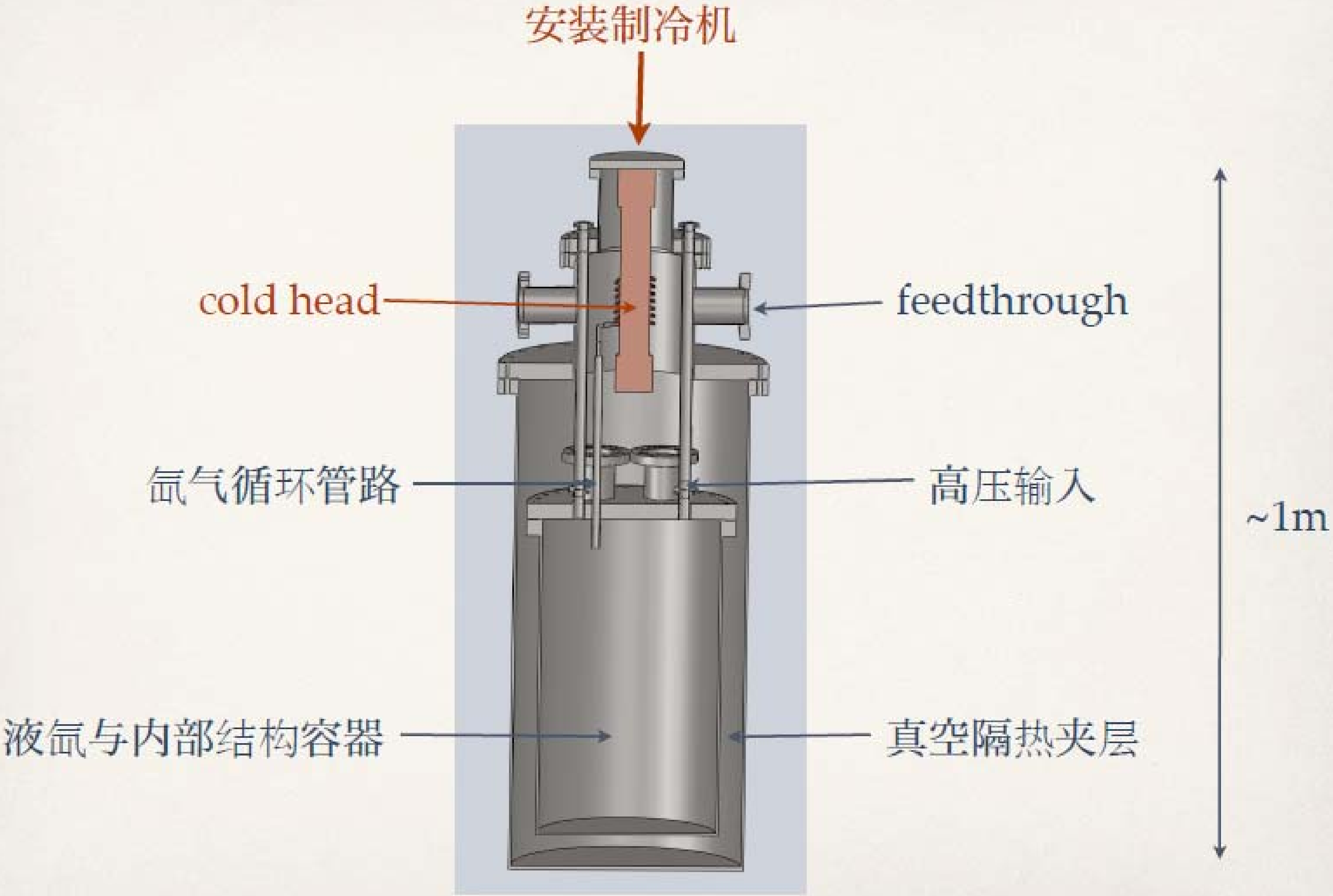
暗物质吨级液氙探测器的预研

- 我们将研制一个新型的25公斤的“二相型氙”探测器(CXO-25)，对该探测器运行所需的各类技术进行探索，在真空，制冷，高压，氙气提纯等方面开展研究，对在液氙中使用的光电管进行测试和信号获取，对氙探测器中产生的信号进行分析和辨别，对氙探测器对于伽马射线，中子等射线的反应以及辨别暗物质的方法进行实验研究。我们将利用CXO-25在地下实验室中运行并采取暗物质探测数据。在25公斤探测器模型的基础上，我们将设计建造一个200公斤的探测器。

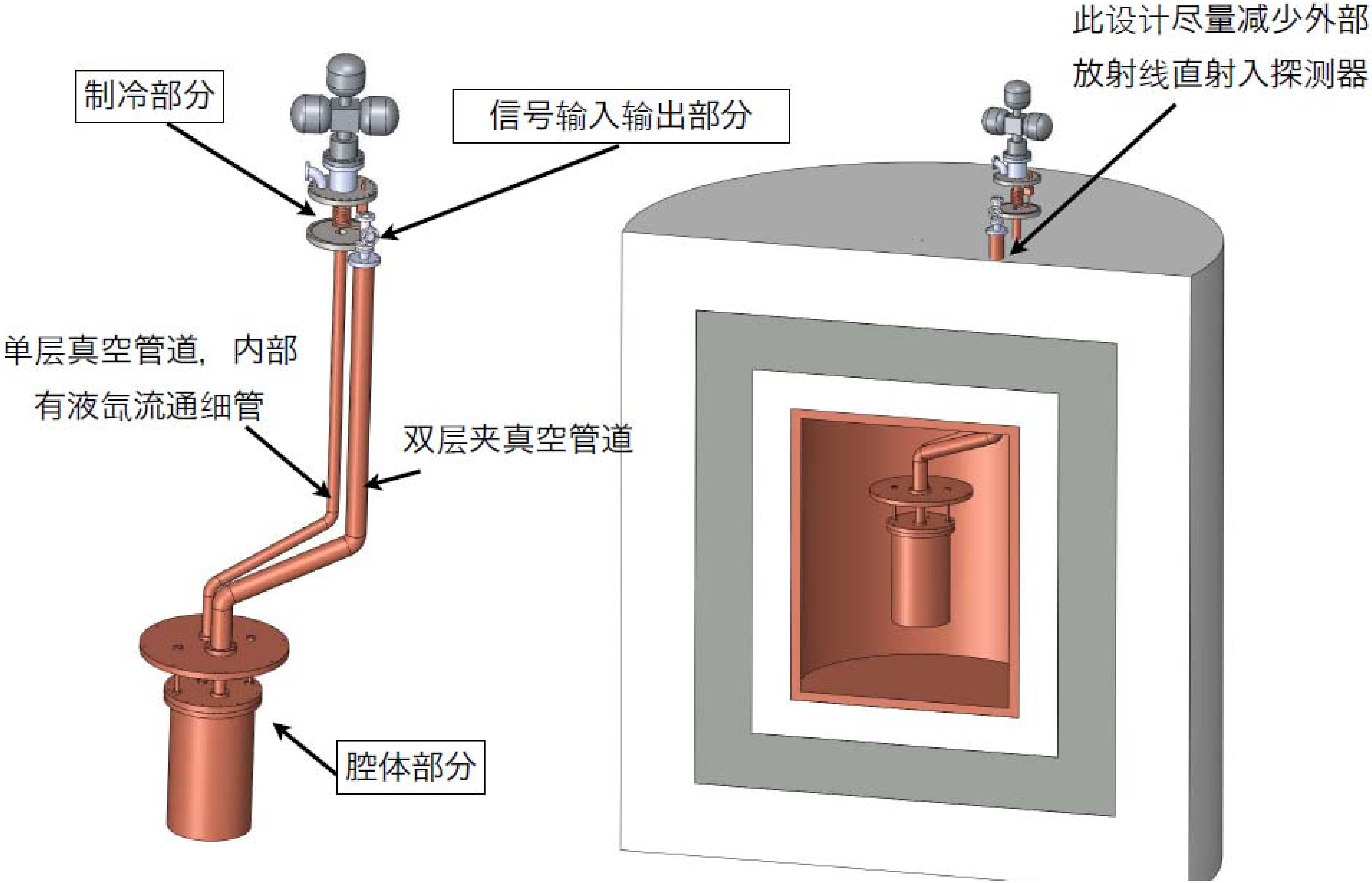
2010的任务

- 完成25公斤的探测器(CXO-25)的设计，并开始建造
- 完成氙气循环提纯系统的设计和建造
- 完成针对25公斤探测器的部分仪器和材料的购买（包括氙气、光电管、制冷机、提纯机等）
- 完成数据采集系统的设计和设备的购买
- 开始低本底测量设备的设计和建设
- 开始设计地下实验室中的屏蔽系统及材料选取
- 完成设计Kr移除系统

探测器真空及制冷系统设计



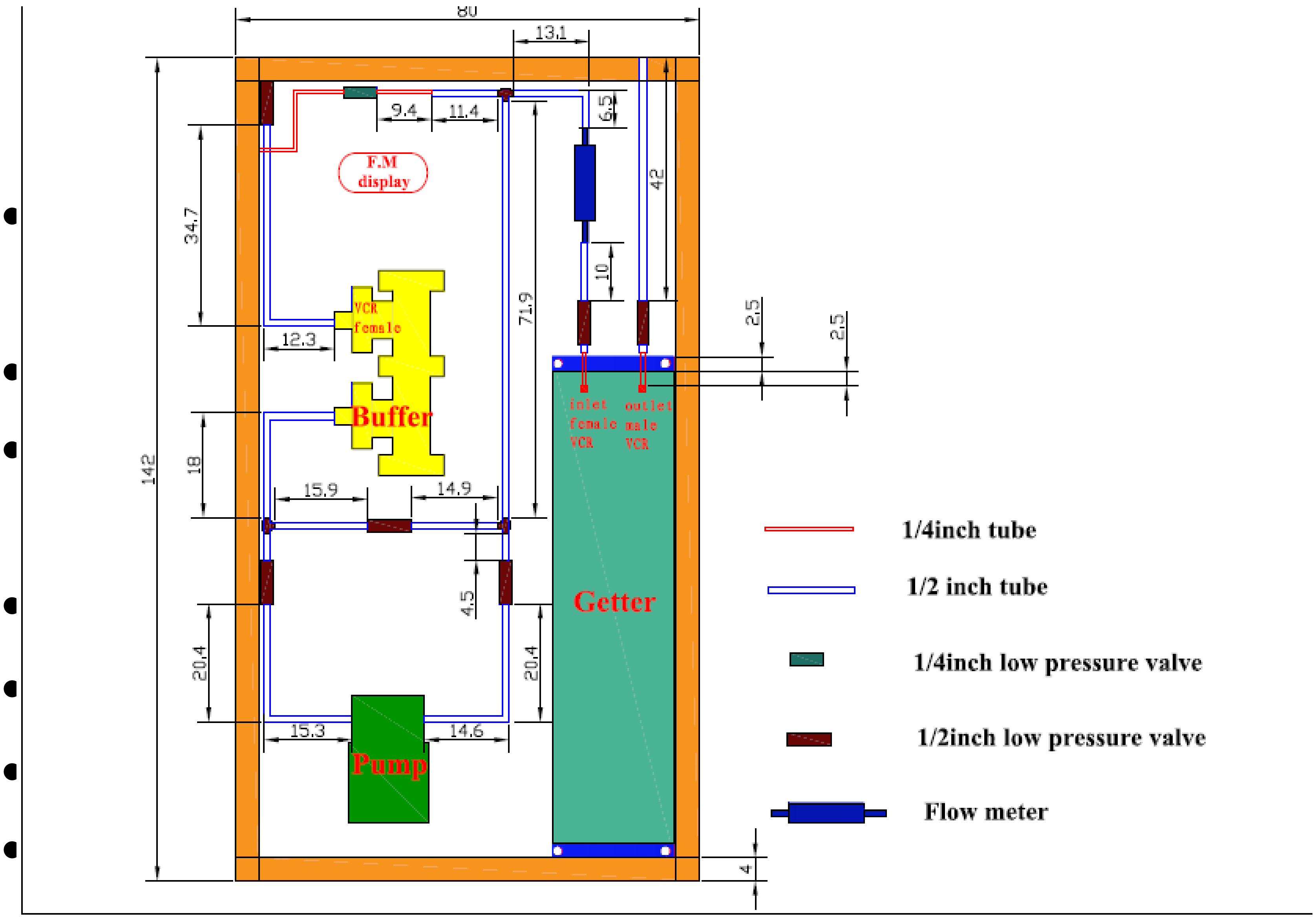
探测器整体及与屏蔽系统衔接



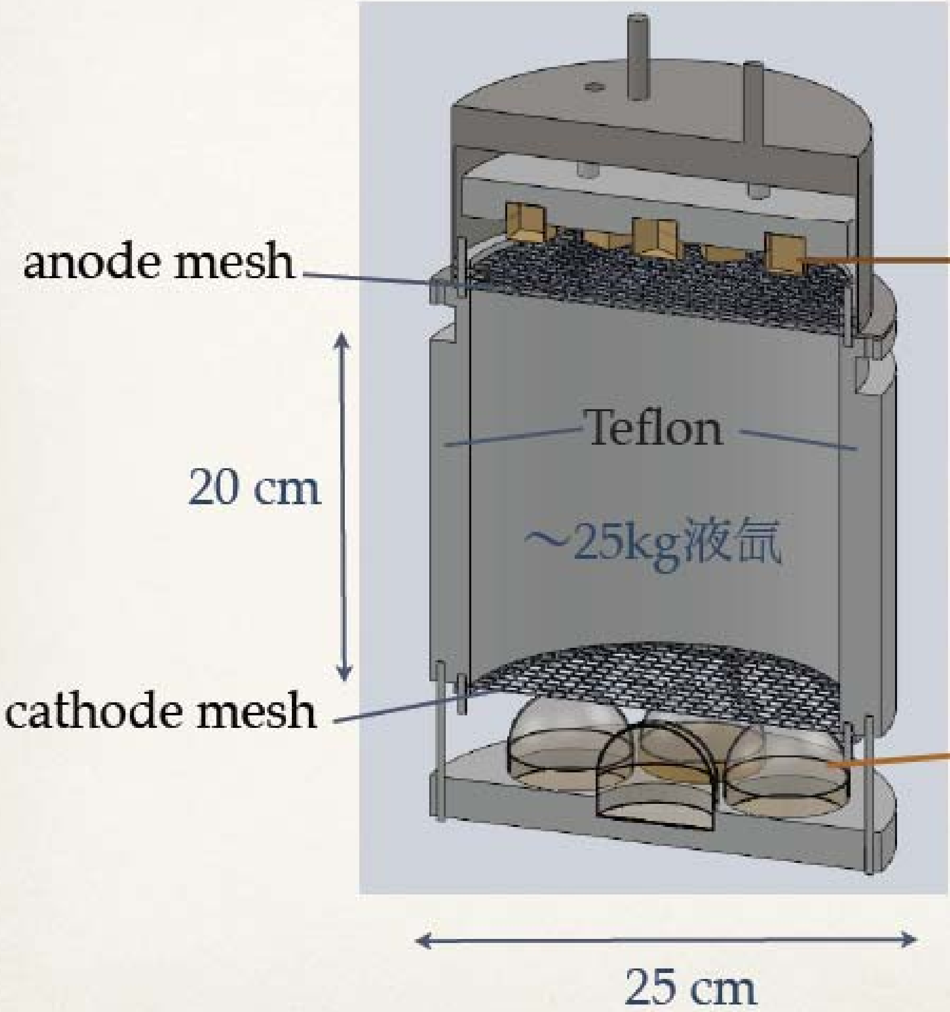
探测器材料放射性

	U	Th	K		reference
S.S.	<1.9	<1.0	10.5	8.5 (^{60}Co)	Alfredo
OFHC	<0.22	<0.16	<1.34	0.2 (^{60}Co)	Alfredo
Titanium	<0.3	<0.2	<1.6	2.5 (^{46}Sc)	lux best result

unit: mBq/kg


80
13.1
9.4
11.4
6.5
42
F.M
display
34.7
71.9
10
VCR
female
12.3
Buffer
2.5
2.5
inlet
female
VCR
outlet
male
VCR
142
18
15.9
14.9
4.5
Getter
20.4
20.4
15.3
14.6
Pump
4
1/4inch tube
1/2 inch tube
1/4inch low pressure valve
1/2inch low pressure valve
Flow meter

CXO25探测器内部漂移室细节介绍



顶部：20 R8520

（973经费购买）

(1″ x 1″)

底部：7个QUPID

(3″ diameter)

上海交大实验室建设情况（一）

屏蔽体设计

- Co-centric cylinder boxes with opening either on the top or on the side.
  - Open on top: need crane, harder to access
  - Open on the side: easier to access, with a pushing door (like XE100), hard to design the door.
- Layers of materials (from outside in)

50cm Poly, 20 cm Pb, 15 cm poly, 2cm A-Pb, 2cm Cu

The goal

- Less than one neutron event in the fiducial volume per year
- Less than one gamma event with nuclear recoil type of signature (S2/S1, ~10 keV)

Gamma ray

- Goal? 0.1-1 mdru = mili events/kgdaykeV before s2/s1 cut.
- From rocks and cement (small)
- Compare with XE100:

  PMT, Vessel, PTFE, grid, ??

  new PMT, Cu vessel, better cut for PTFE, grid

  135mdru reduces to 10 mdru

  a fiducial cut can reduce this by at least

  a factor of 10!
- Rn gas Could be problem..... sealed shield?
- Kr, U in Xe (10-12) scale with the target mass?

Neutrons from cosmic ray

- 100-300 muons/year/m^2
- Energy 300 GeV
- Generate high-energy neutrons which cannot be shielded effectively
- High-energy, multiple scattering, can be vetoed
- Singles: less than one neutron recoil in the right-energy range per year.
- Will be smaller at least a factor of 10 at JP Lab

XENON1T Collaboration

USA, Switzerland, Portugal, Italy, Germany, France, China, Netherlands

COLUMBIA	RICE	UCLA	ZURICH	COIMBRA
LNGS	INFN	MPIK	Bologna	SJTU
MUENSTER	SUBATECH	NIKHEF		