Dark Matter Searches with sub-keV Germanium Detector

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- Overview (Collaboration, Programs)
- Laboratories : KSNL
- Analysis, Bulk/Surface, Results [arXiv:1303.0925, PRL13]
- Summary

TEXONO-CDEX Collaboration

TEXONO Taiwan EXperiment On NeutrinO (since 1997)

Neutrino Physics at Kuo-Sheng Reactor Neutrino Laboratory (KSNL)

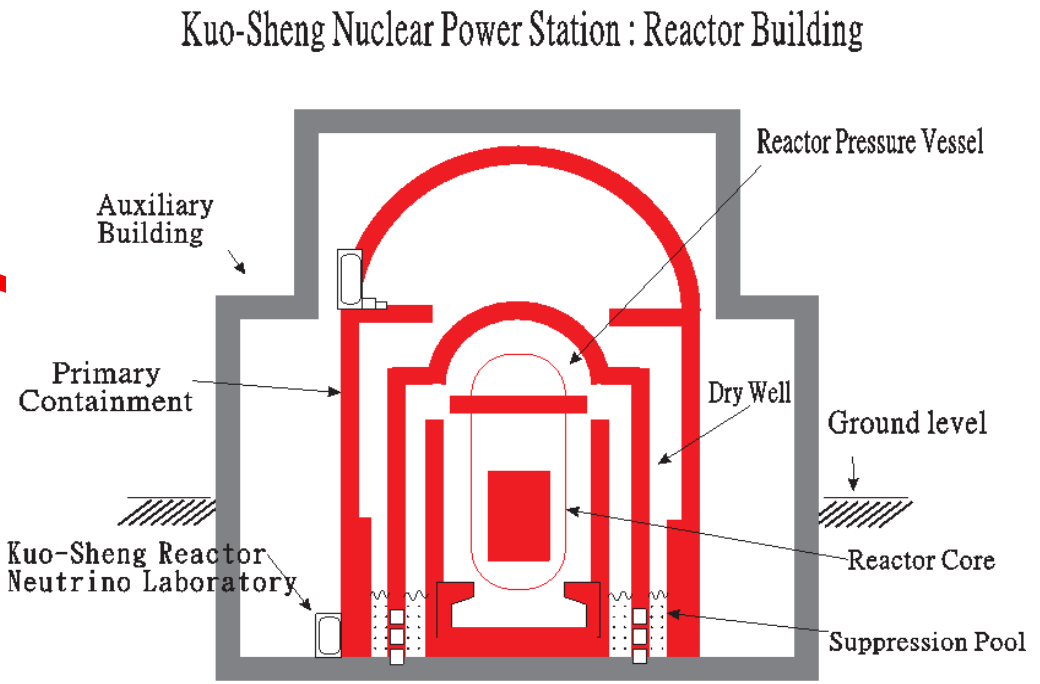
- **Taiwan** (AS, NTHU, INER, KSNPS)
- **Turkey** (METU)
- **India** (BHU)

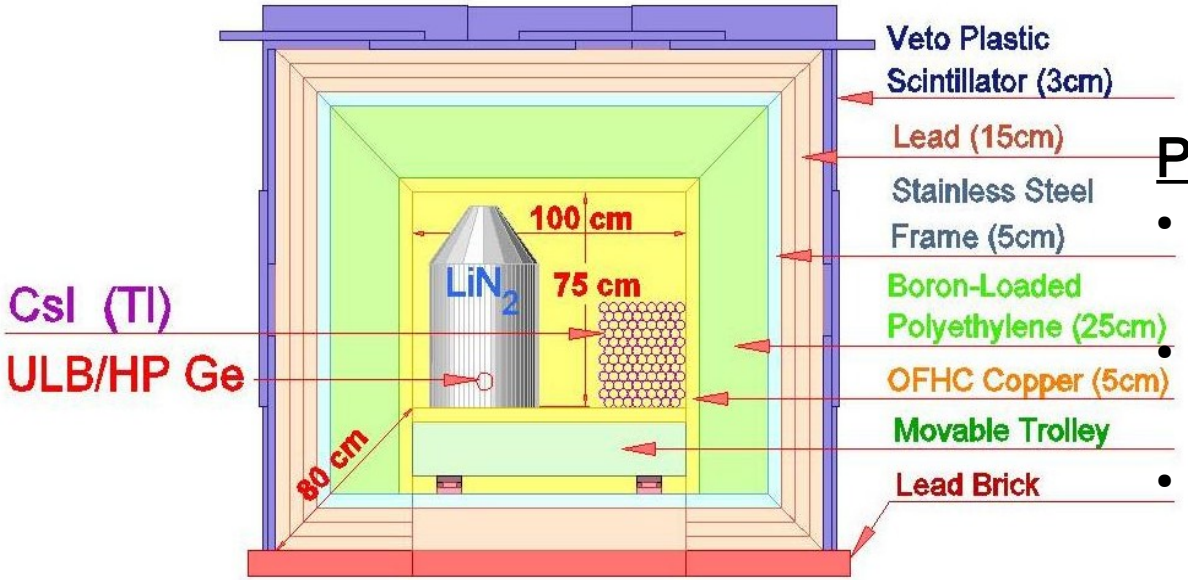
CDEX China Dark Matter Experiment (birth 2009)

Dark Matter Searches at China Jin-Ping Underground Laboratory (CJPL)

- **China** (THU, CIAE, NKU, SCU,EHDC)

Kuo Sheng Reactor Neutrino Laboratory

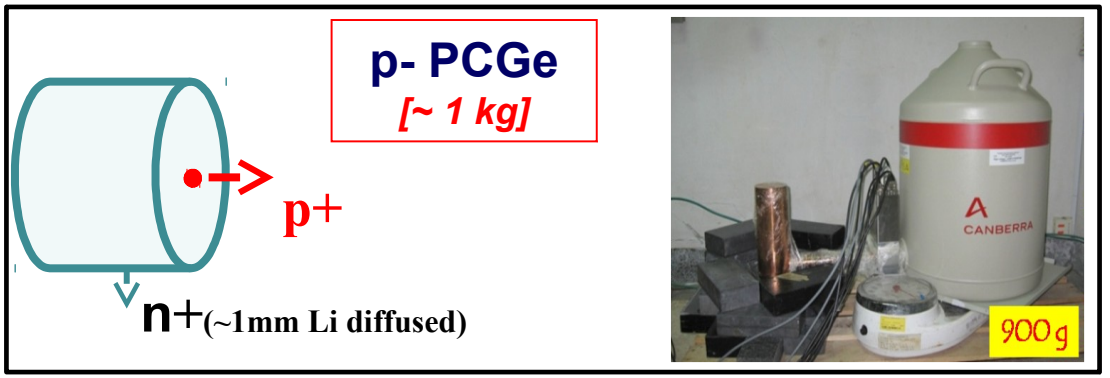




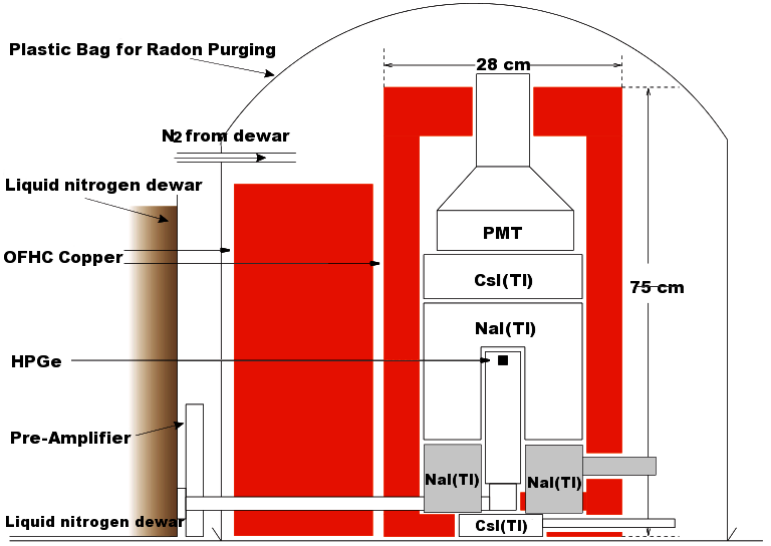
Physics Programs

- Neutrino Magnetic Moment
  PRL03, PRD05, PRD07
- neutrino-electron scattering(SM/BSM)
  PRD10x2, PRD12
- →Dark Matter Search PRD-RC09, this report

Detectors shielding goals/challenge



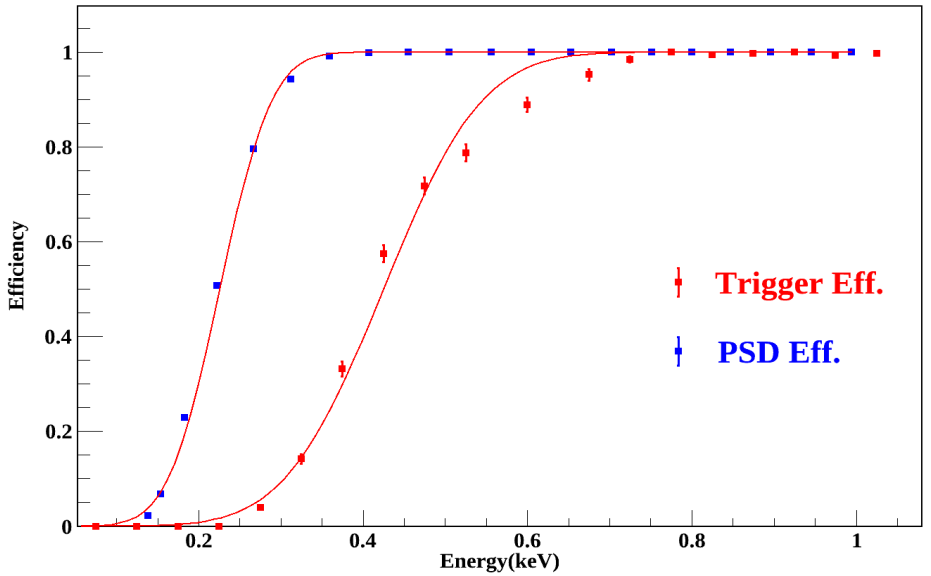
PCGe : ~kg, threshold ~300 eV



Low-mass WIMP searches.

- mass ~1kg : threshold ~few×100 eV : bgk ~few cpkkd
- Quenching Factors : adopted TRIM
- Energy Definition & Calibration.
- Trigger Efficiencies near threshold.
- Physics vs. Noise Pulse-Shape Selection : algorithms & efficiencies.
- Bulk vs. Surface Events Selection : algorithms & efficiencies.
- Background understanding

PCGe : the data



Trigger Eff. from background data & pulser.

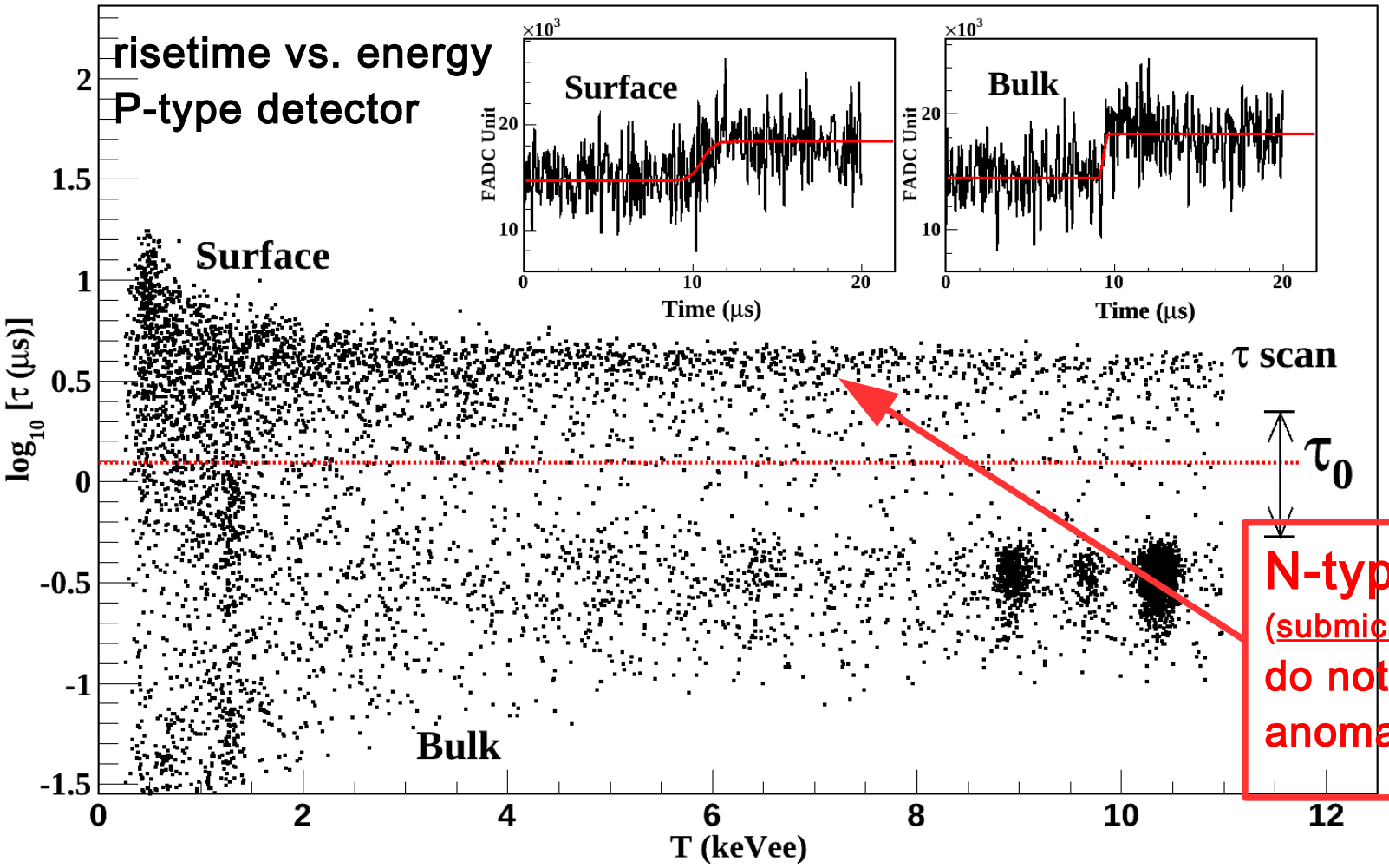
- **Trigger threshold (Eff. = 50%) ~ 200 eV**
- **PN threshold (Eff. = 50%) ~ 420 eV**

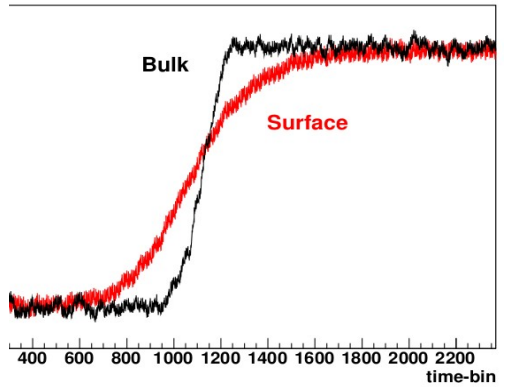
- 39.5 kg-days of data at KSNL
- Baseline design with NaI(Tl) AC & active CR vetos
- PPCGe , 840 g fiducial mass
- Noise-edge : 400 eV. Analysis above 500 eV.

Selection Criteria:

- Physics Vs Electronics Noise (PN) – pulse shape
- Anti-Compton vetos (ACV) – NaI(Tl)
- Cosmic-Ray vetos (CRV) – plastic scintillators
- Bulk Vs Surface Cut (BS) – pulse shape

Bulk/Surface : the cut





N-type detector
(submicron inactive surface layer)
do not show these anomalous surface events

- n+ inactive surface layer is not totally dead, deposit partial charge.
- **efficiency ε**(probability of bulk events identified as bulk)
- **leakage 1-λ**(probability of surface events identified as bulk)

Bulk/Surface : efficiencies

$$Bulk_{measure} = \varepsilon Bulk_{real} + (1-\lambda)Surface_{real}$$

$$Surface_{measure} = (1-\varepsilon)Bulk_{real} + \lambda Surface_{real}$$

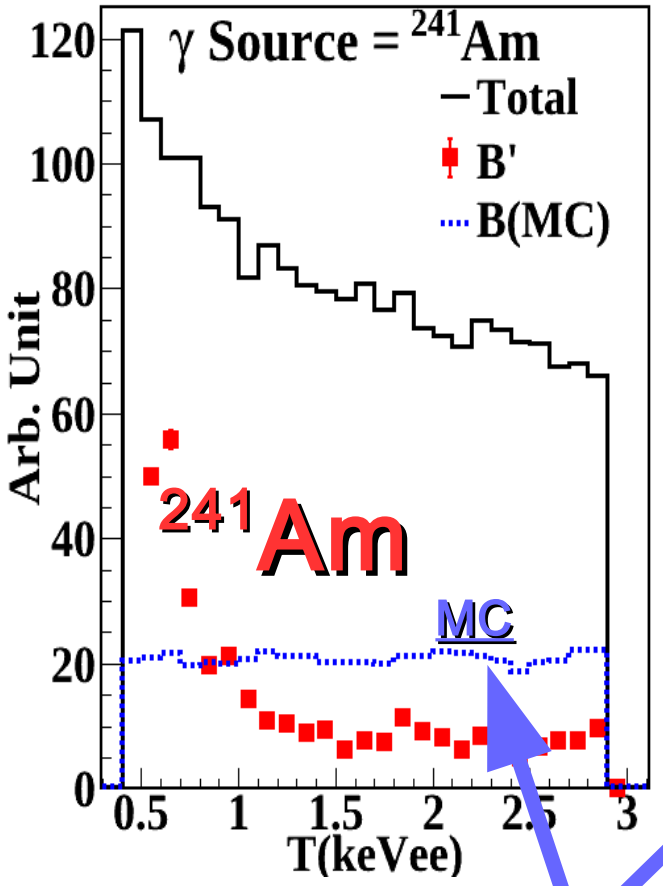
→ solve equation.

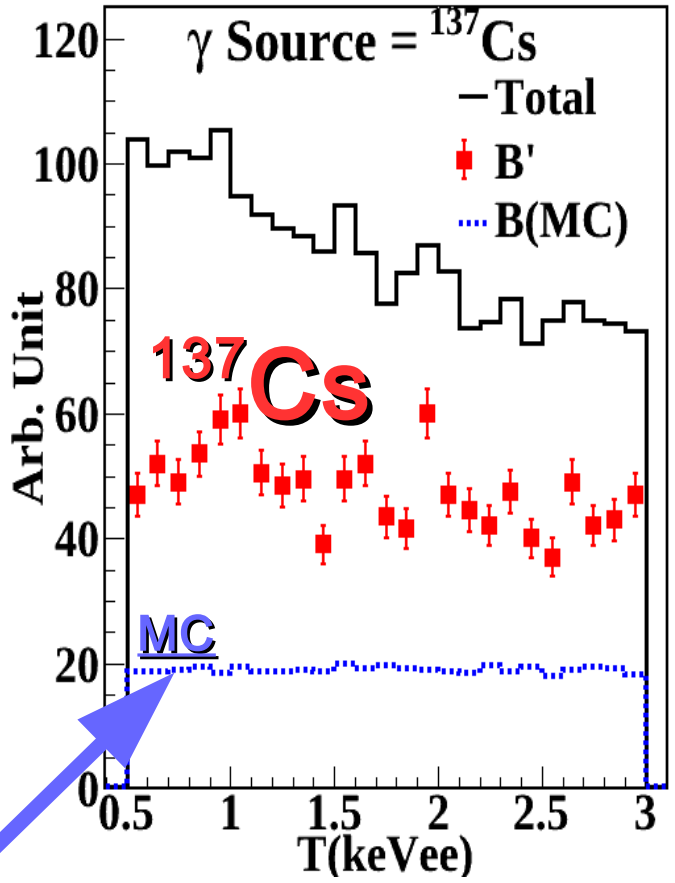
- 3 Bulk/Surface calibration sources(known $Bulk_{real}$):

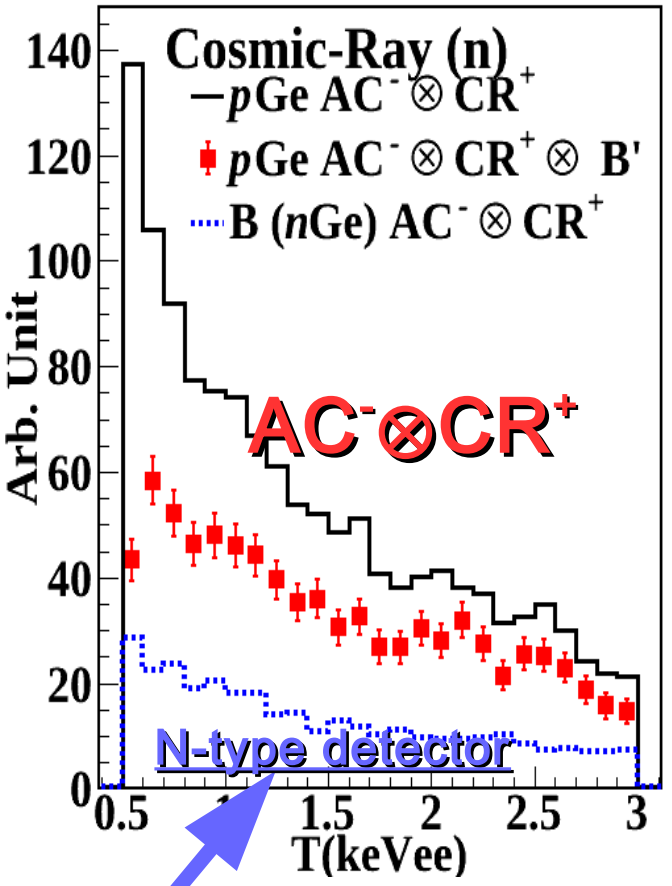
1. ^{241}Am (Surface-rich), $Bulk_{real}$ from Monte-Carlo.
2. ^{137}Cs (Surface-rich with more Bulk events), $Bulk_{real}$ from Monte-Carlo.
3. Cosmic-induced without anti-Compton signal ($AC^{-}\otimes CR^{+}$, Bulk-rich), $Bulk_{real}$ from N-type detector(w/o anomalous surface events).

- risetime distrubution : independent of sources' energy and location.

Bulk/Surface : calibration sources





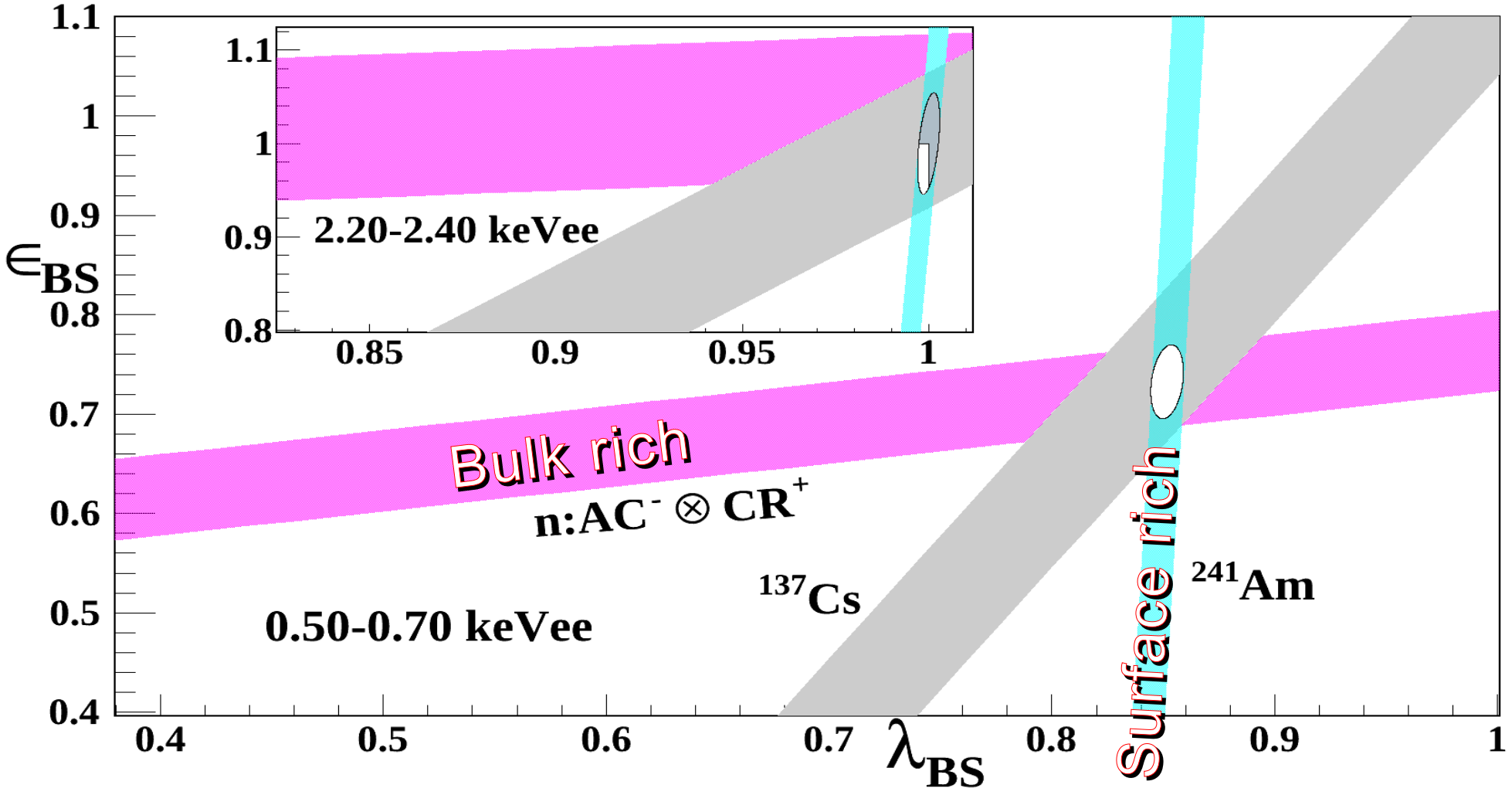


Surface rich sources, flat bulk spectrum by MC

Normalize → Solve equation

Bulk rich, cosmic induced without anti-Compton signal($AC^{-}\otimes CR^{+}$), know spectrum shape from N-type detector

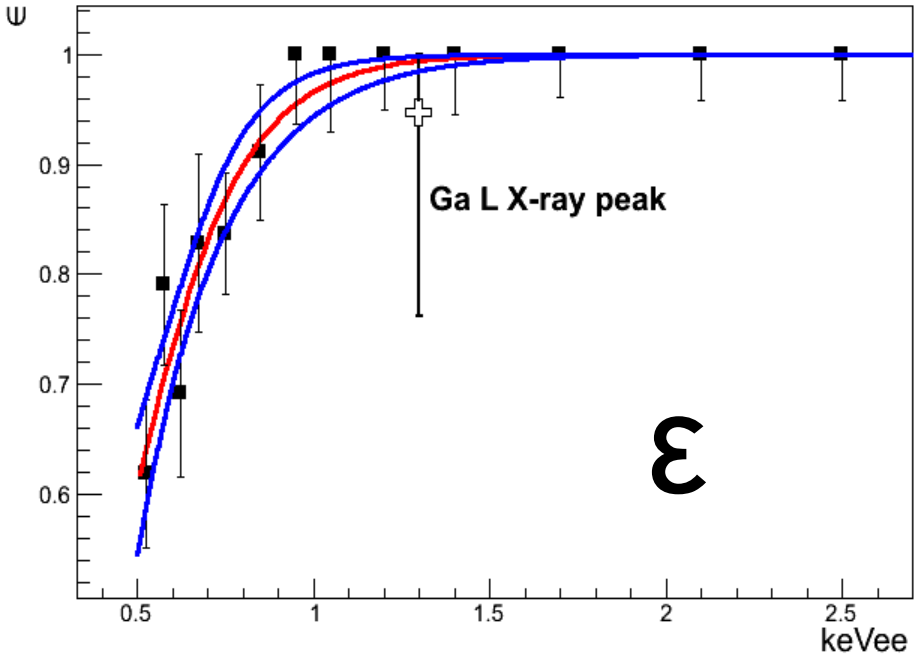
Bulk/Surface : efficiencies

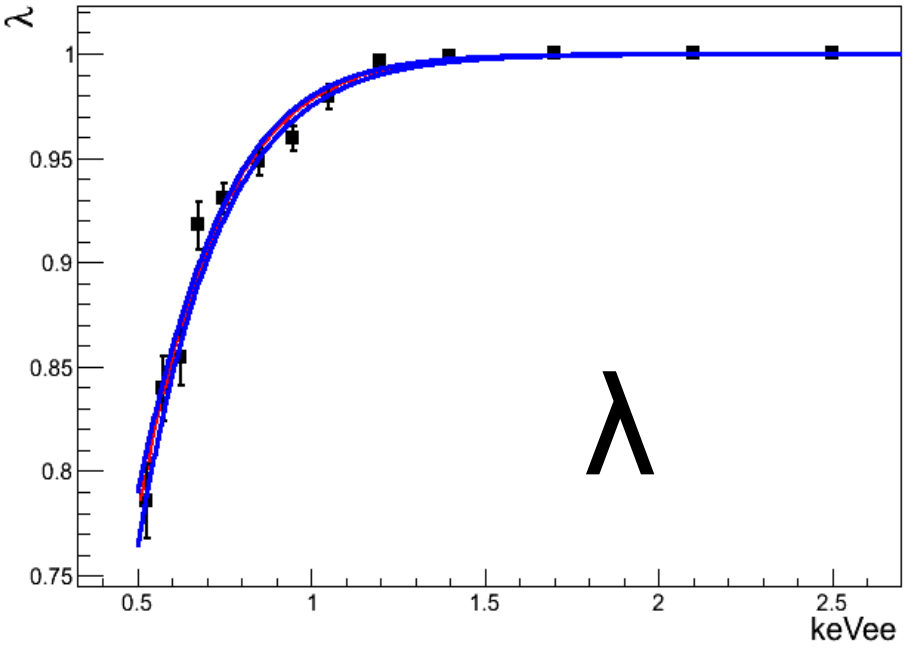


Surface-rich sample(^{241}Am) : determine λ

Bulk-rich sample(cosmic w/o anti-Compton): determine ε

Bulk/Surface : efficiencies

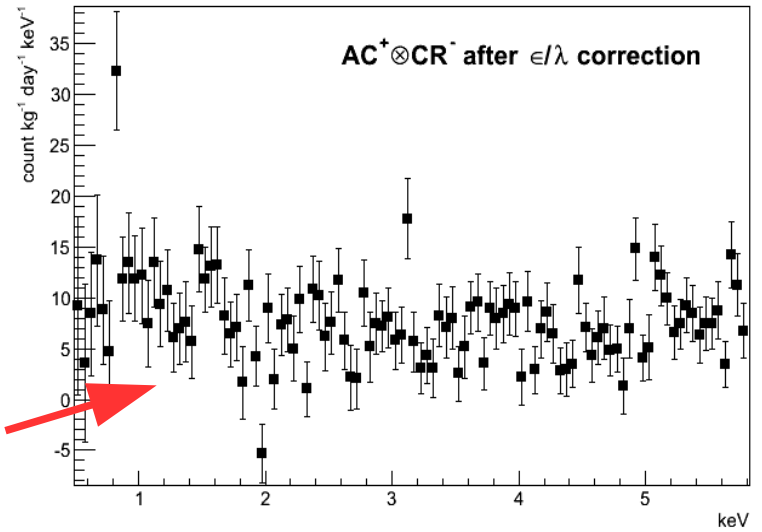




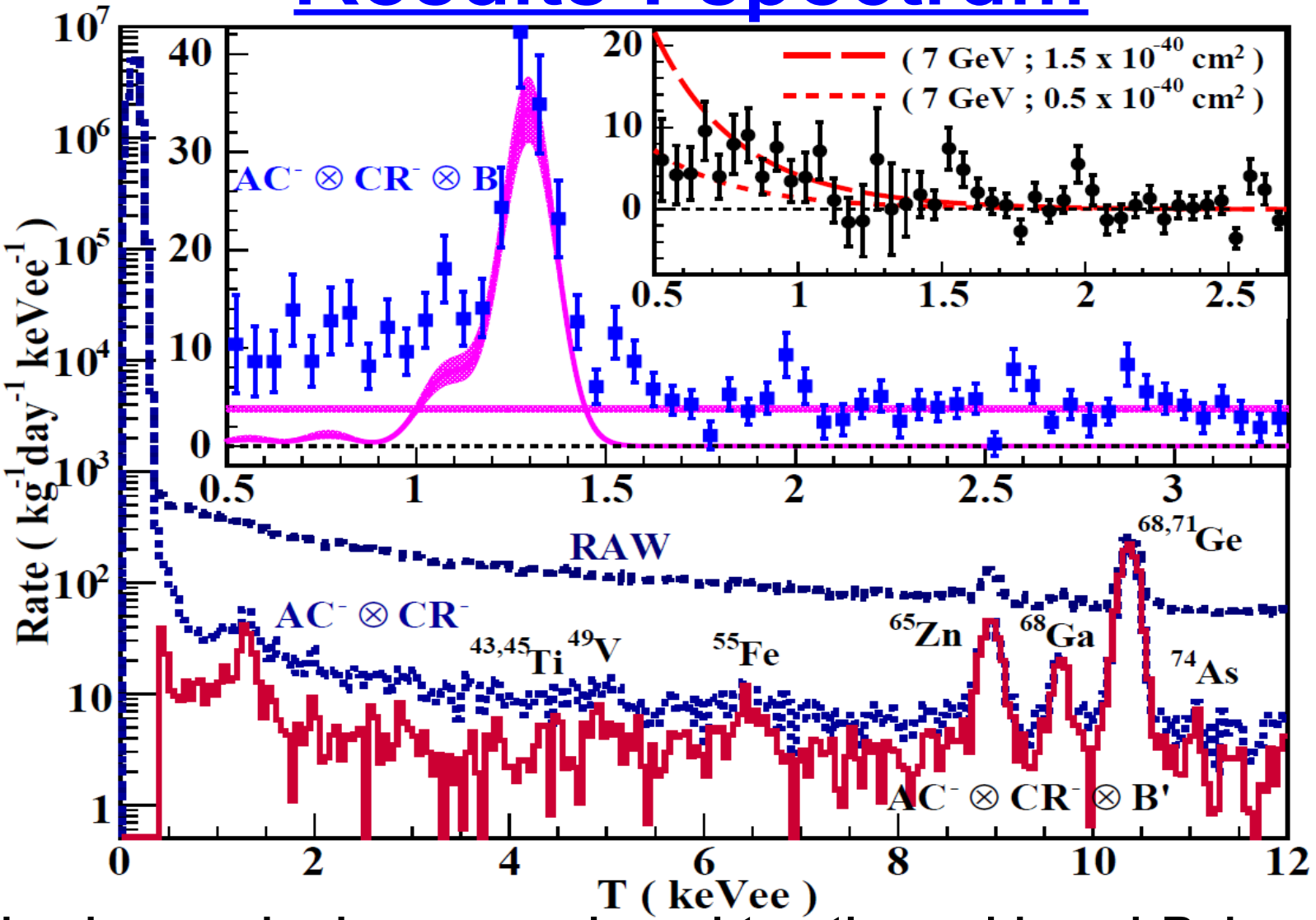
$$\text{total error} \sim \frac{\text{stat. error}}{(\varepsilon+\lambda-1)} + \text{error from } \Delta\varepsilon,\ \Delta\lambda + \text{sys.}$$

main contributor of errors at low evergy.

correctly reconstruct flat γ-rich spec



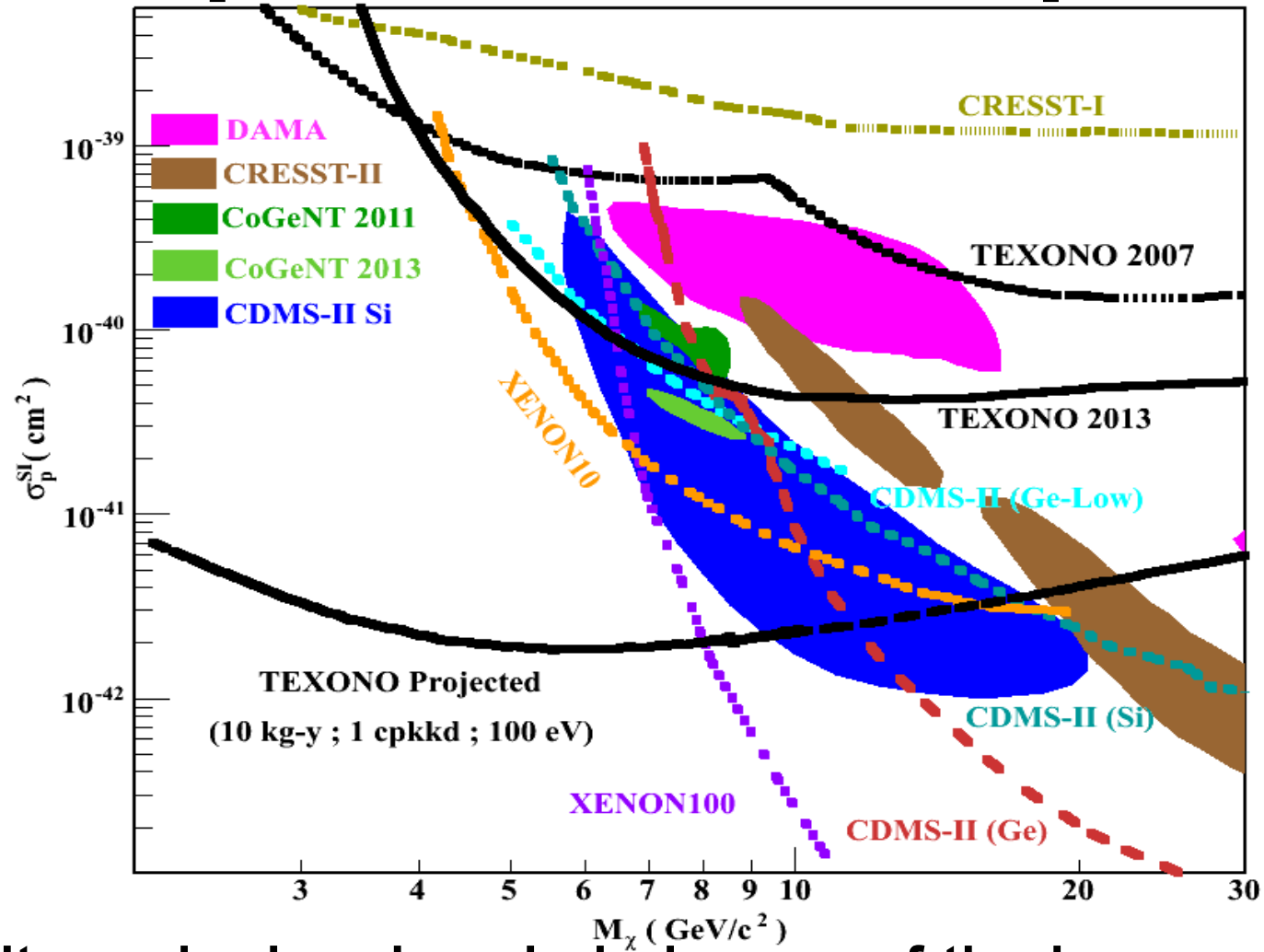
Results : spectrum



- Flat background + known peaks subtraction → binned-Poisson.
- unaccounted sub-keV excess.
- Stable within different B/S cut, normalization scheme :
  contribute to <5 % of total errors.

Results : spin-independent

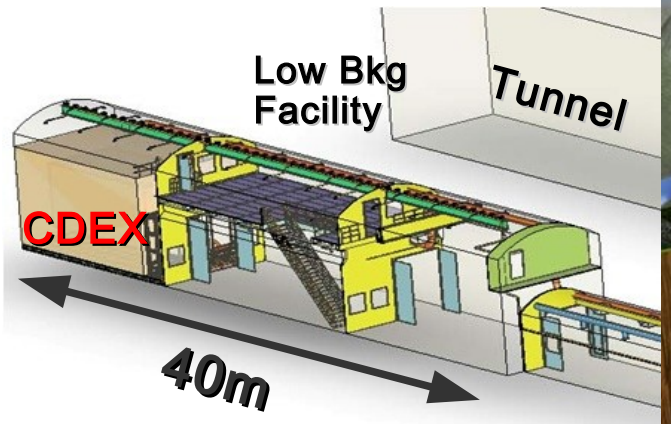
[arXiv:1303.0925, PRL13]

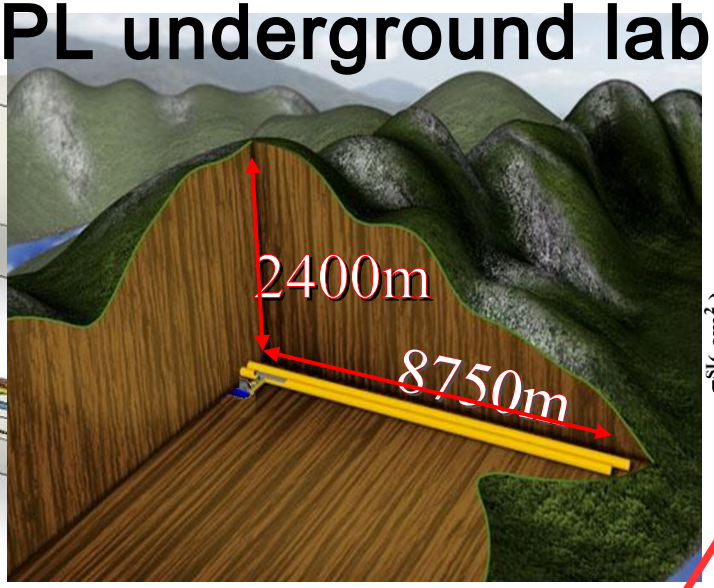


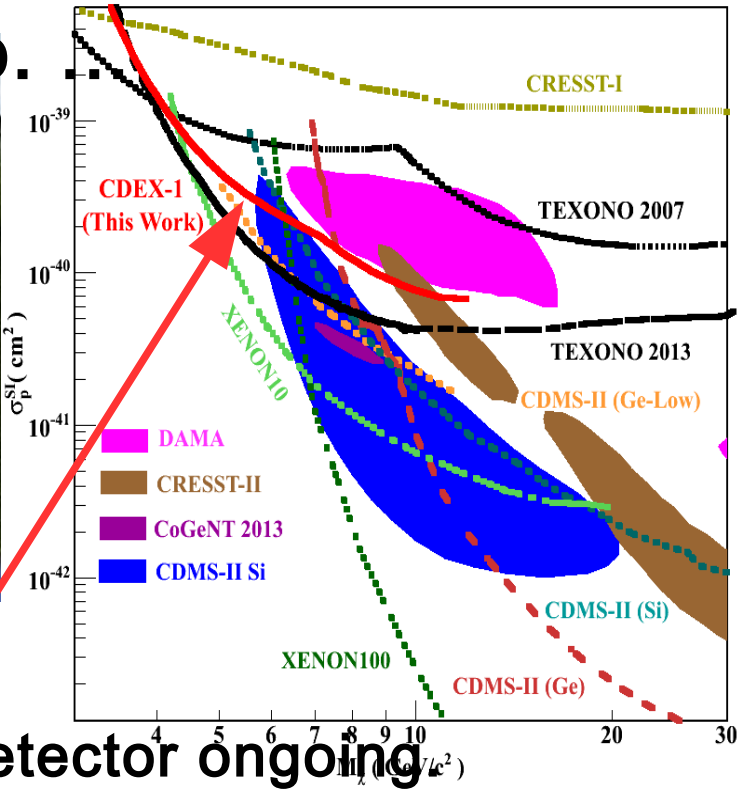
- New limits probed and excluded some of the low-mass WIMP allowed regions implied by other experiments.

Plans at CJPL & KSNL

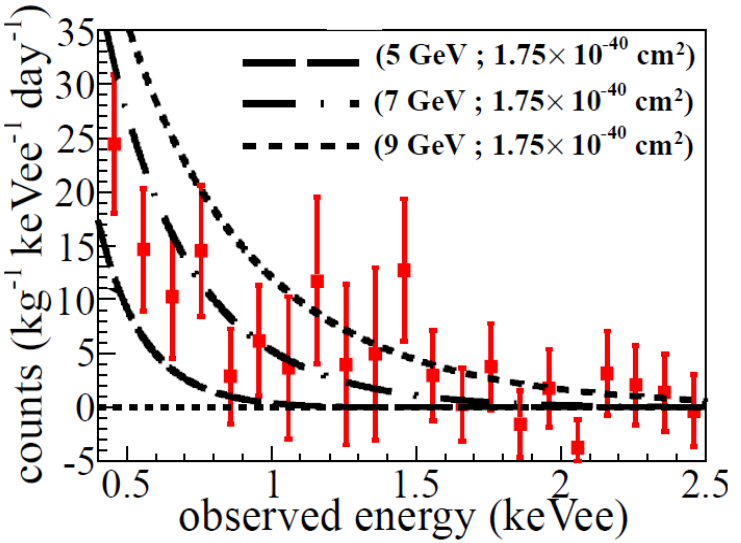
meanwhile at CJPL underground lab. ..







- data taking and analysis for 20 g and 1 kg detector ongoing
  achieve similar sensitivities without anti-Compton & Bulk/Surface cut.
  [arXiv : 1306.4135]



and ...

- data taking for lower threshold detectors ongoing (analysis threshold ~ 300 eV)

Summary

- TEXONO new results with PPCGe at KSNL with 500 eV physics threshold probed and excluded part of allowed light-WIMPs regions, in particular CoGeNT-2011.
- Devised calibration schemes to characterize bulk-Vs-surface cuts in PPCGe ; demonstrated that leakage of surface background to bulk signals is important.
- There exists residual excess at sub-keV not-accounted-for by present analysis ; intense work on their understanding.
- Continue data taking with upgraded PPC & NPC at KSNL & CJPL ; lowering physics threshold :
  Goals → 300 eV → 100 eV

Thank You