Direct Dark Matter Searches

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La Thuile, AO

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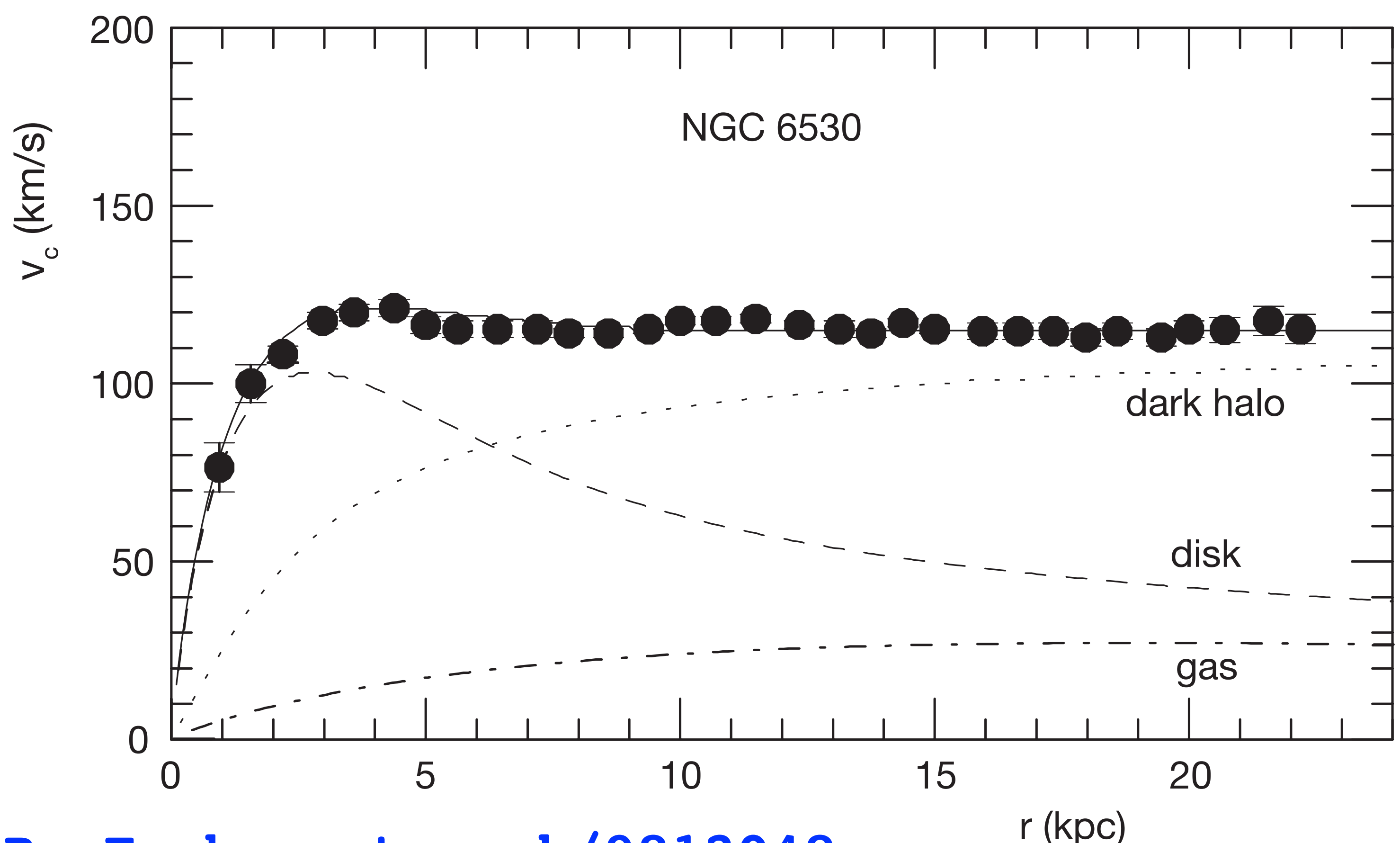
Plan of the Talk

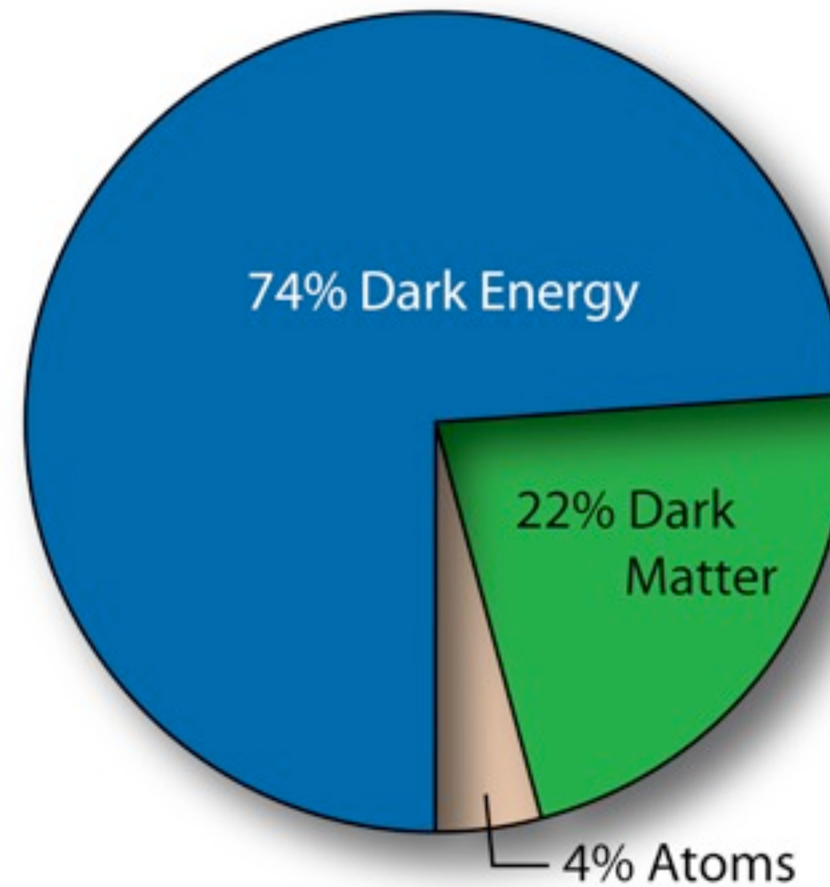
- Evidence for dark matter
- Present results and claims
- Future prospects

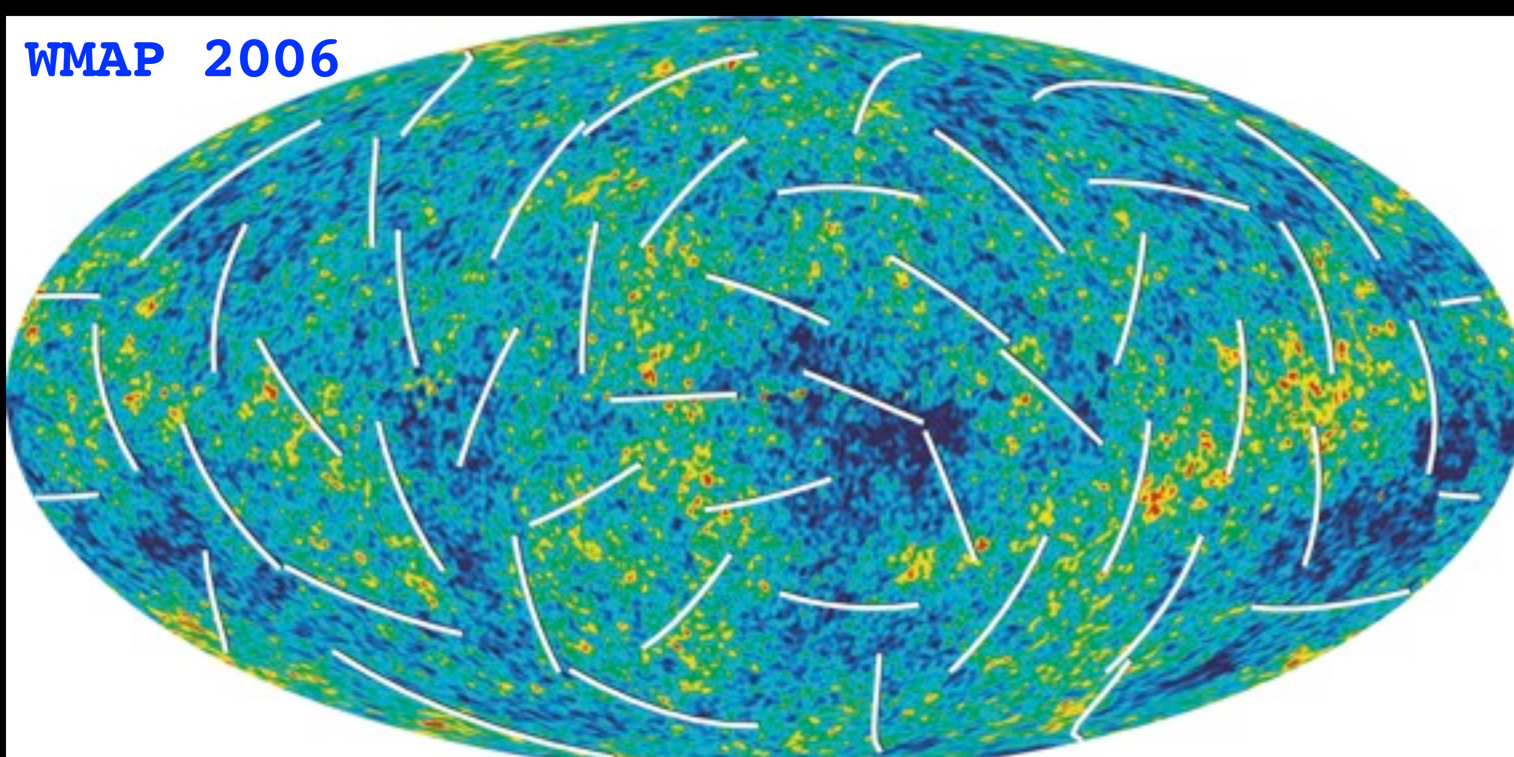
Dark Matter Evidence

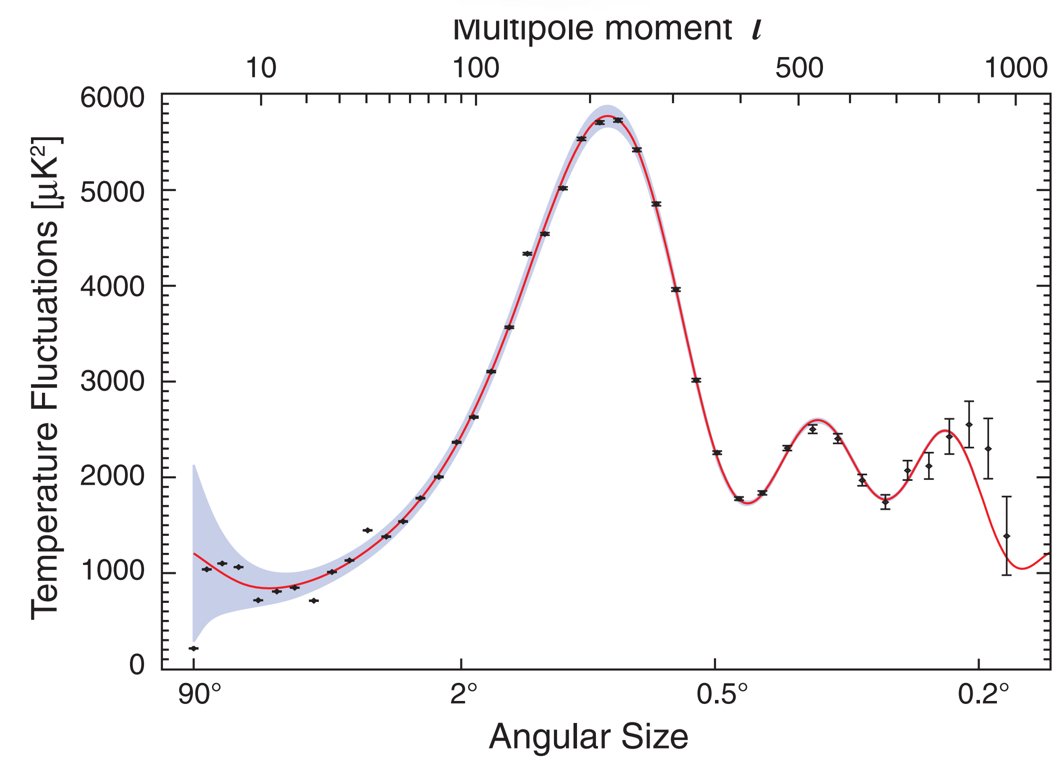


B. Fuchs astro-ph/9812048

WMAP 2006



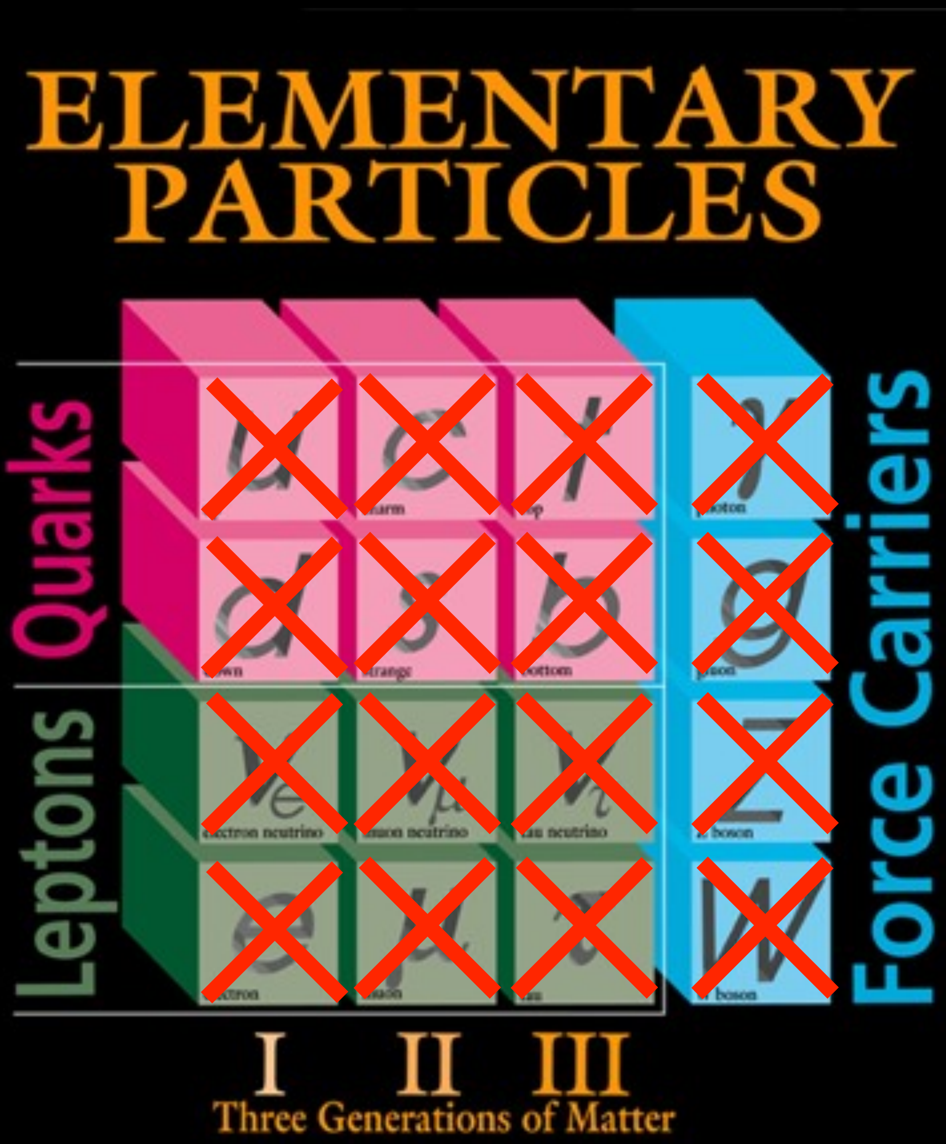




Bullet Cluster

NASA

Dark Matter



Known DM properties

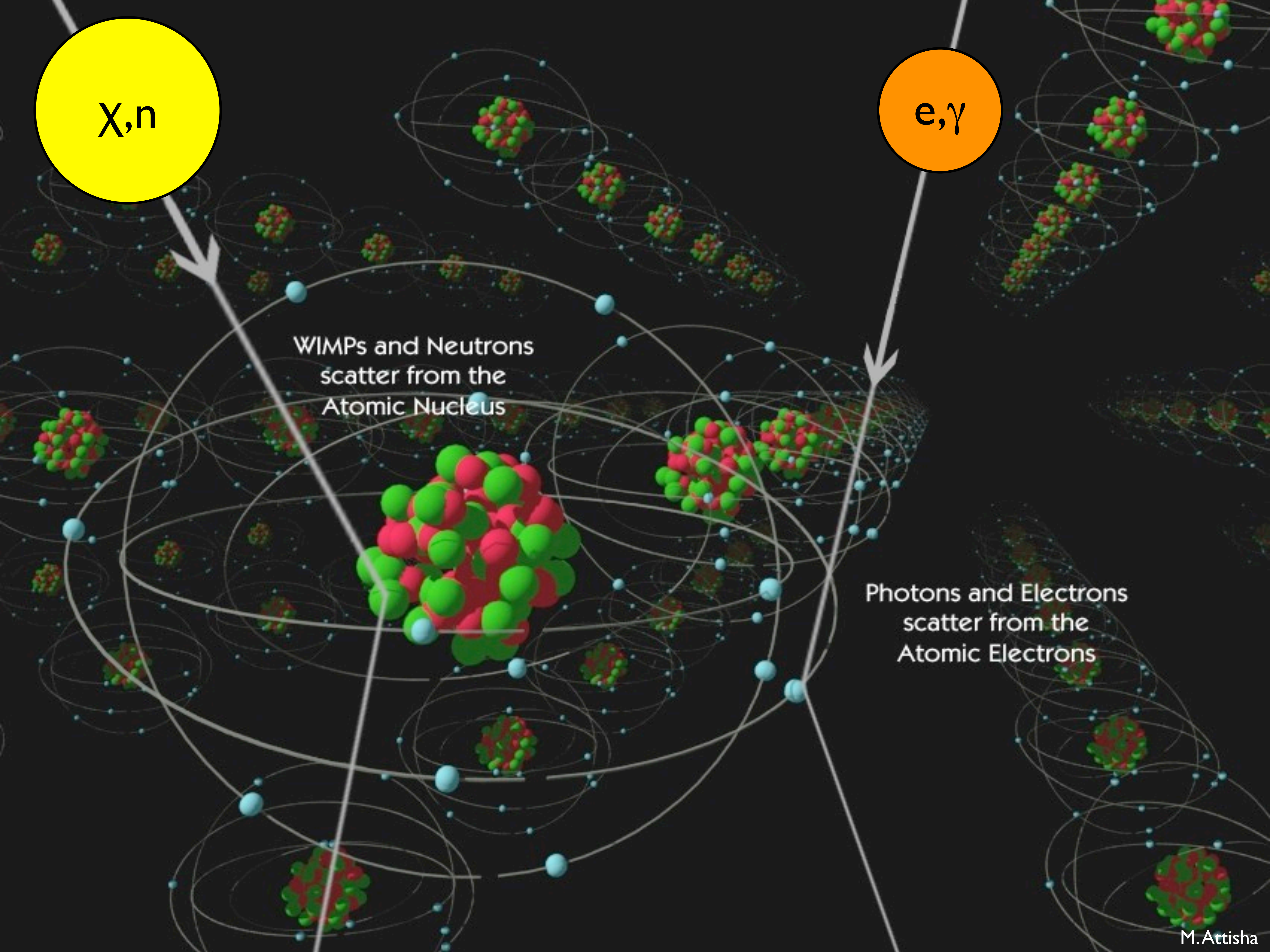
- Gravitationally interacting
- Not short-lived
- Not hot
- Not baryonic

Unambiguous evidence for new particles

J.L. Feng

Dark Matter

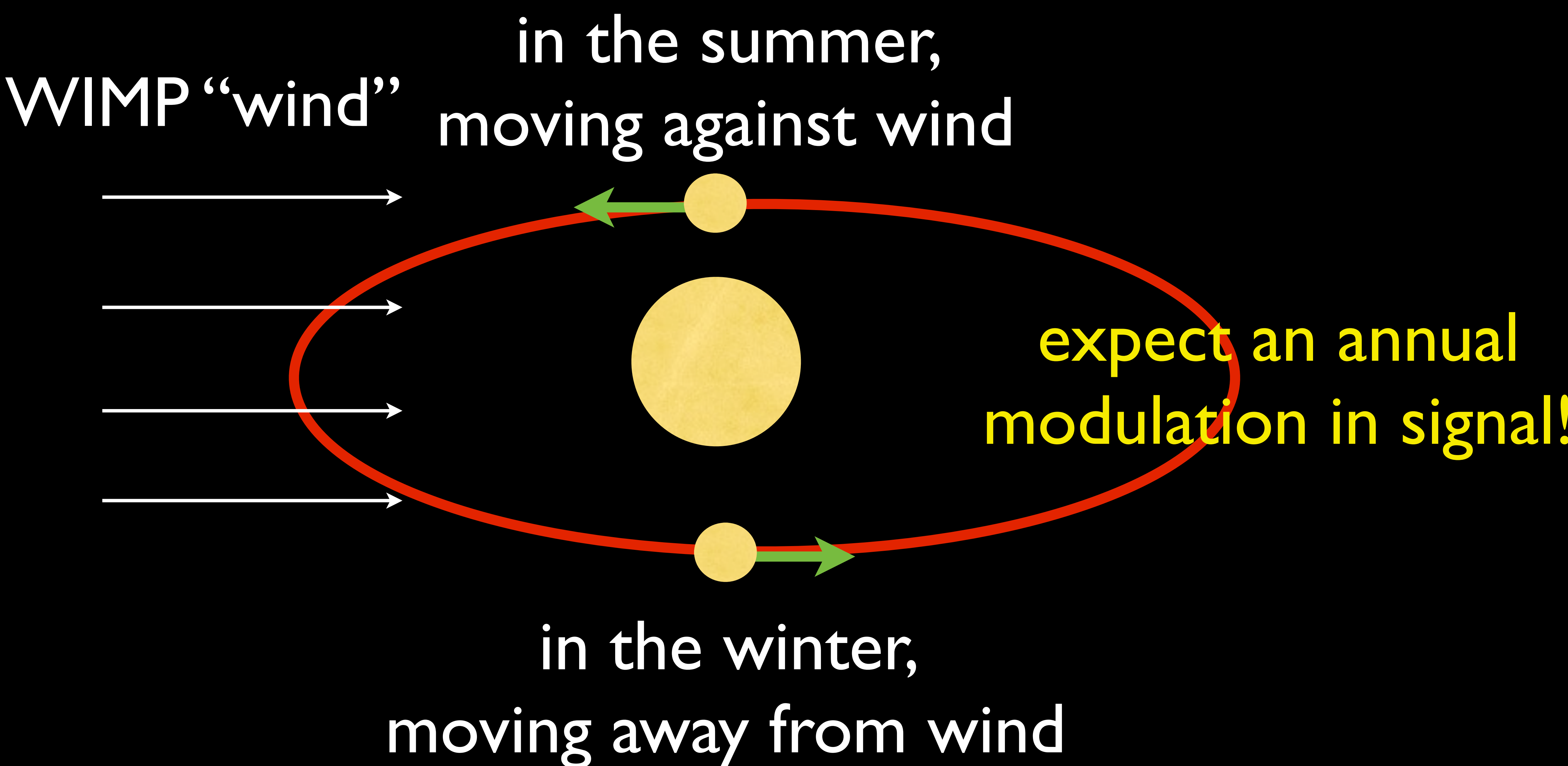
- New physics beyond Standard Model
  - Unambiguous evidence
  - Possibly connected with electroweak symmetry breaking, SUSY, and structure formation
- Very bright prospects for experimental observation
  - Astroparticle physics: direct and indirect searches
  - Particle physics: CMS and ATLAS at LHC
  - Cosmology: halo profiles, CMB, BBN
- Discovery of dark matter in nature with direct searches would be transformational for entire particle physics community


χ,n
e,γ
WIMPs and Neutrons scatter from the Atomic Nucleus
Photons and Electrons scatter from the Atomic Electrons
M. Attisha

Direct Detection Requirements

- Low energy nuclear recoils (< 100 keV)
- Low rate (~1 event/ton/yr for 10^{-47} cm^2)
- Background, background, background
- Detector designed for "Discovery"

WIMP Wind & Signatures



Drukier, Freese, and Spergel Phys.Rev. D **33**, 3495 (1986)

The second generation DAMA/LIBRA set-up ~250 kg ULB NaI(Tl) (Large sodium Iodide Bulk for RAre processes)

As a result of a second generation R&D for more radiopure NaI(Tl)
by exploiting new chemical/physical radiopurification techniques
(all operations involving crystals and PMTs - including photos - in HP Nitrogen atmosphere)

installing DAMA/LIBRA detectors

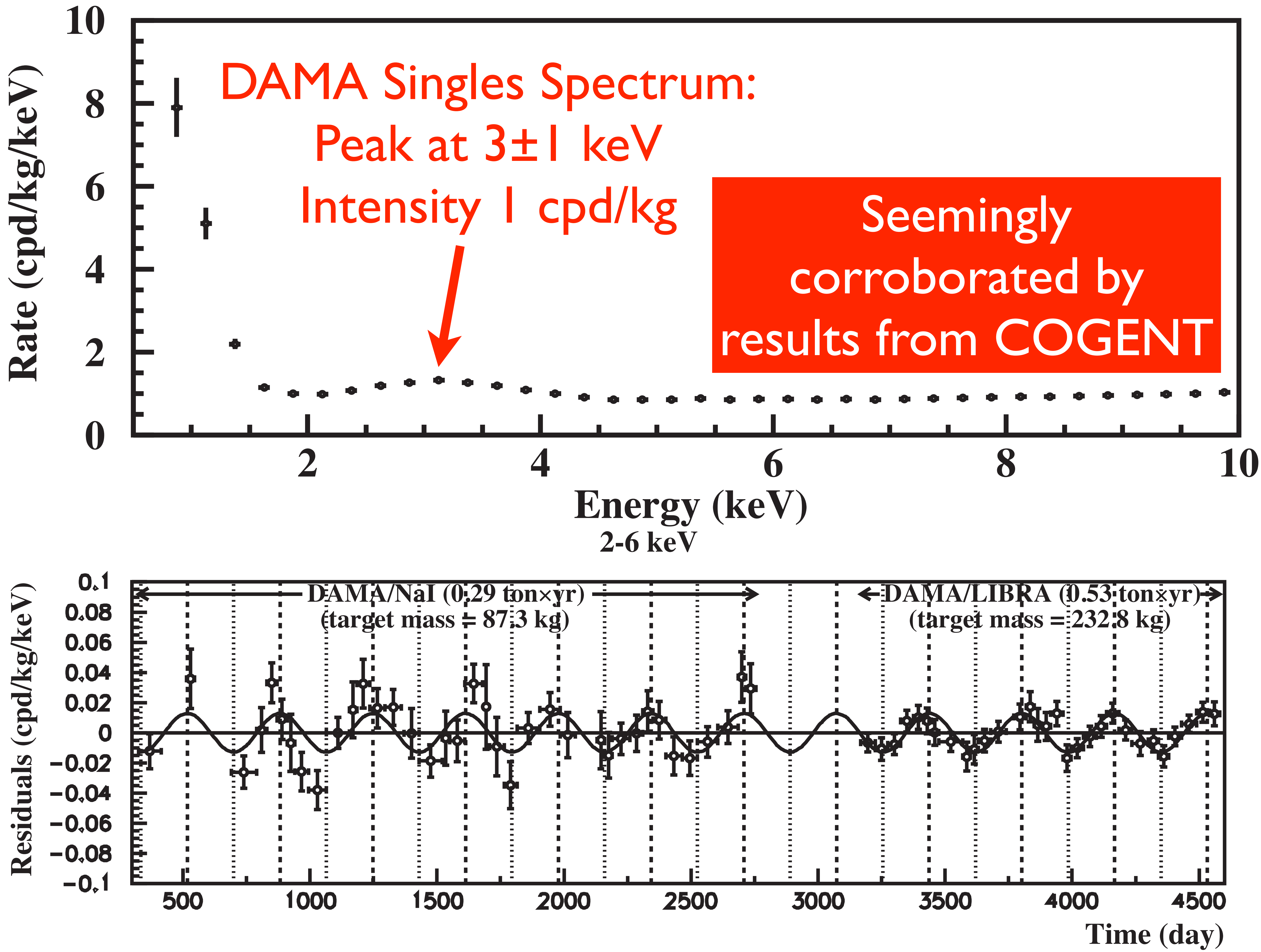
assembling a DAMA/ LIBRA detector

detectors during installation; in the central and right up detectors the new shaped Cu shield surrounding light guides (acting also as optical windows) and PMTs was not yet applied

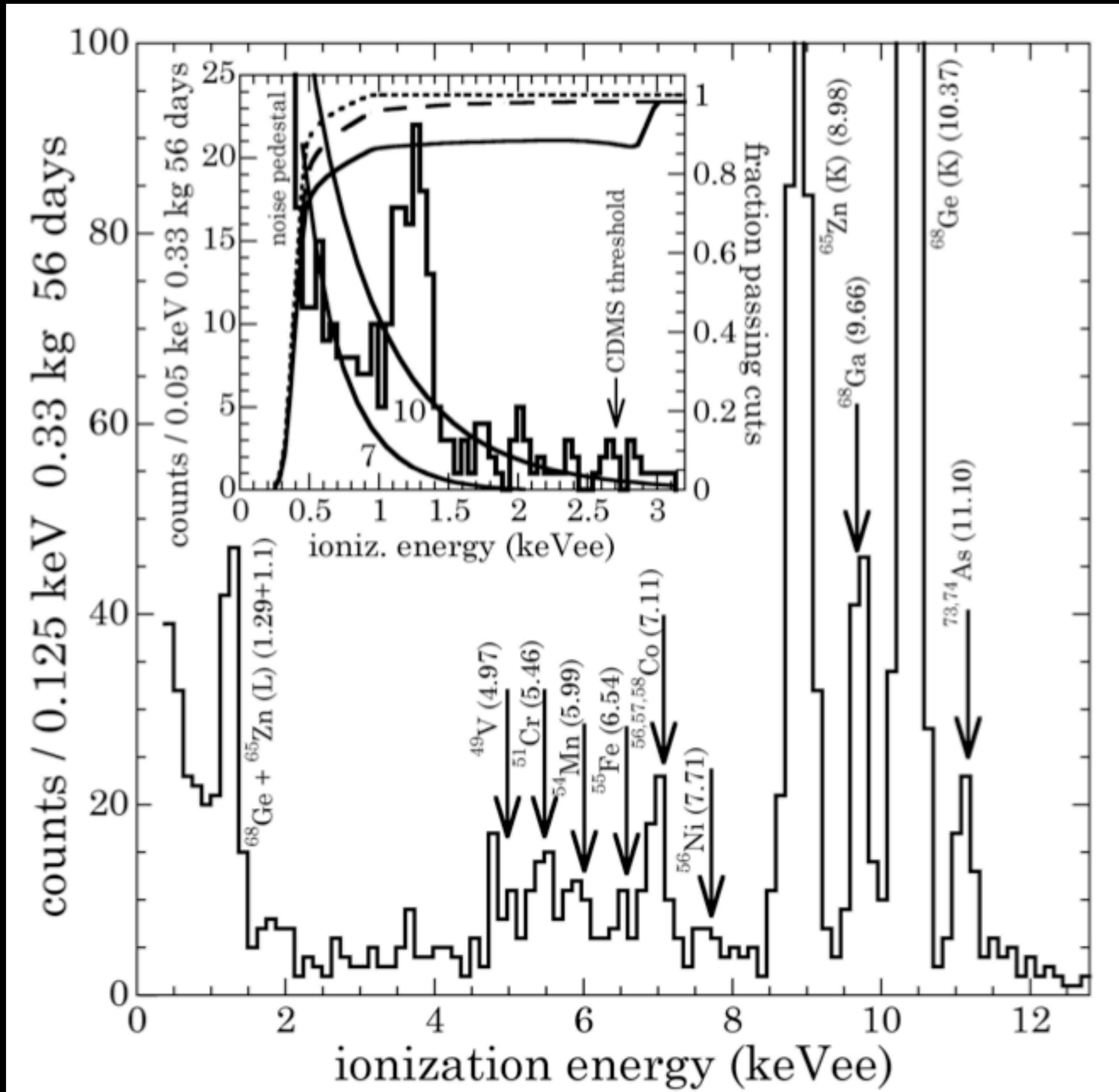
filling the inner Cu box with further shield

closing the Cu box housing the detectors

view at end of detectors' installation in the Cu box


DAMA Singles Spectrum:
Peak at 3±1 keV
Intensity 1 cpd/kg
Seemingly corroborated by results from COGENT
Rate (cpd/kg/keV)
Energy (keV)
2-6 keV
DAMA/NaI (0.29 ton×yr)
(target mass = 87.3 kg)
DAMA/LIBRA (0.53 ton×yr)
(target mass = 232.8 kg)
Residuals (cpd/kg/keV)
Time (day)

COGENT

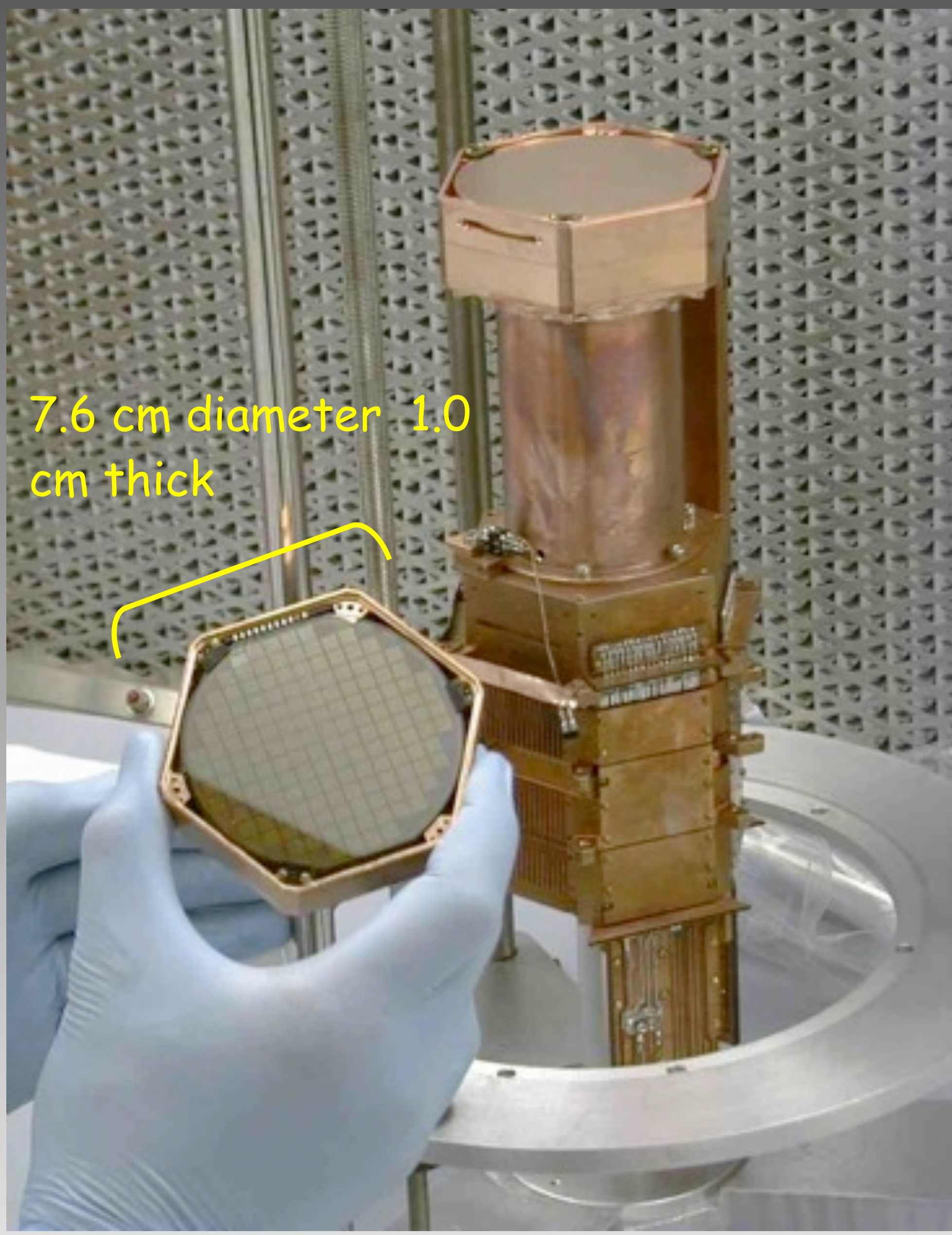


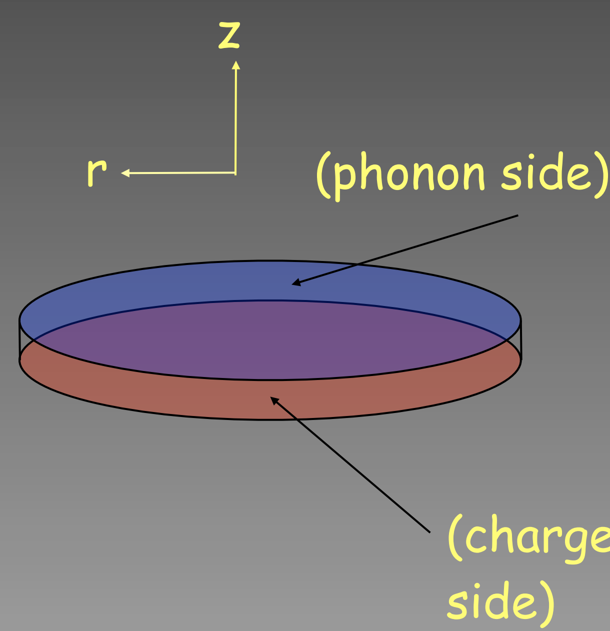
counts / 0.125 keV 0.33 kg 56 days
ionization energy (keVee)
counts / 0.05 keV 0.33 kg 56 days
fraction passing cuts
ioniz. energy (keVee)
noise pedestal
CDMS threshold
10
7
^{68}Ge + ^{65}Zn (L) (1.29+1.1)
^{49}V (4.97)
^{51}Cr (5.46)
^{54}Mn (5.99)
^{55}Fe (6.54)
^{56,57,58}Co (7.11)
^{56}Ni (7.71)
^{65}Zn (K) (8.98)
^{68}Ga (9.66)
^{68}Ge (K) (10.37)
^{73,74}As (11.10)

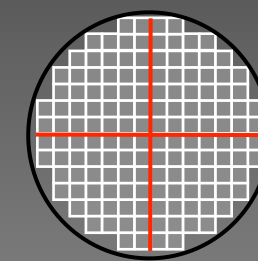
New Technologies

- Germanium crystals (CDMS iZips, Edelweiss)
- Bubble chamber (COUPP, PICASSO)
- Xenon
  - 1-Ph: XMASS
  - 2-Ph:LUX, XENON
- Argon
  - 1-Ph:DEAP,CLEAN
  - 2-Ph: DarkSide, WARP, ArDM

Z-sensitive Ionization and Phonon Detectors

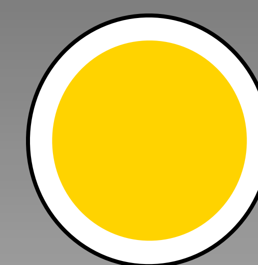




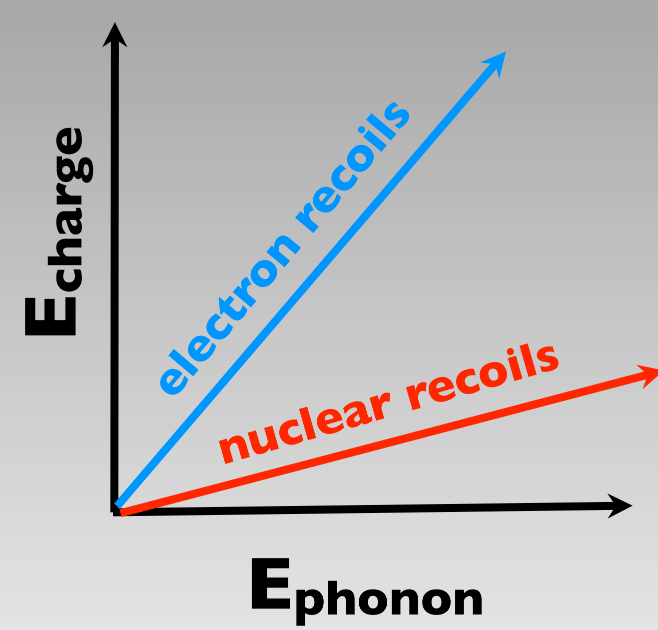


4 phonon channels

(each is 1036 TES sensors in parallel)



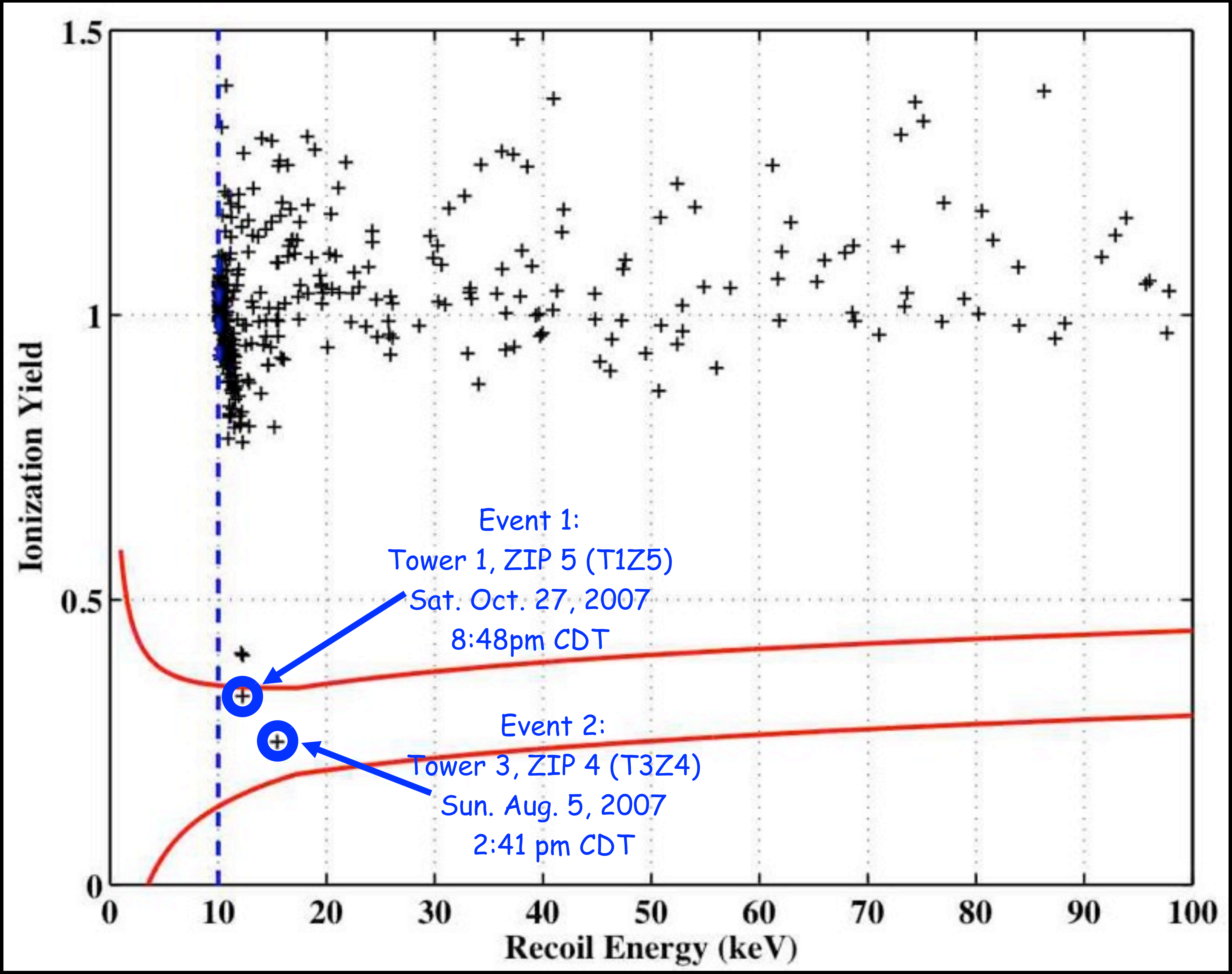
inner sensor
+
outer guard



Signature of a Nuclear Recoil

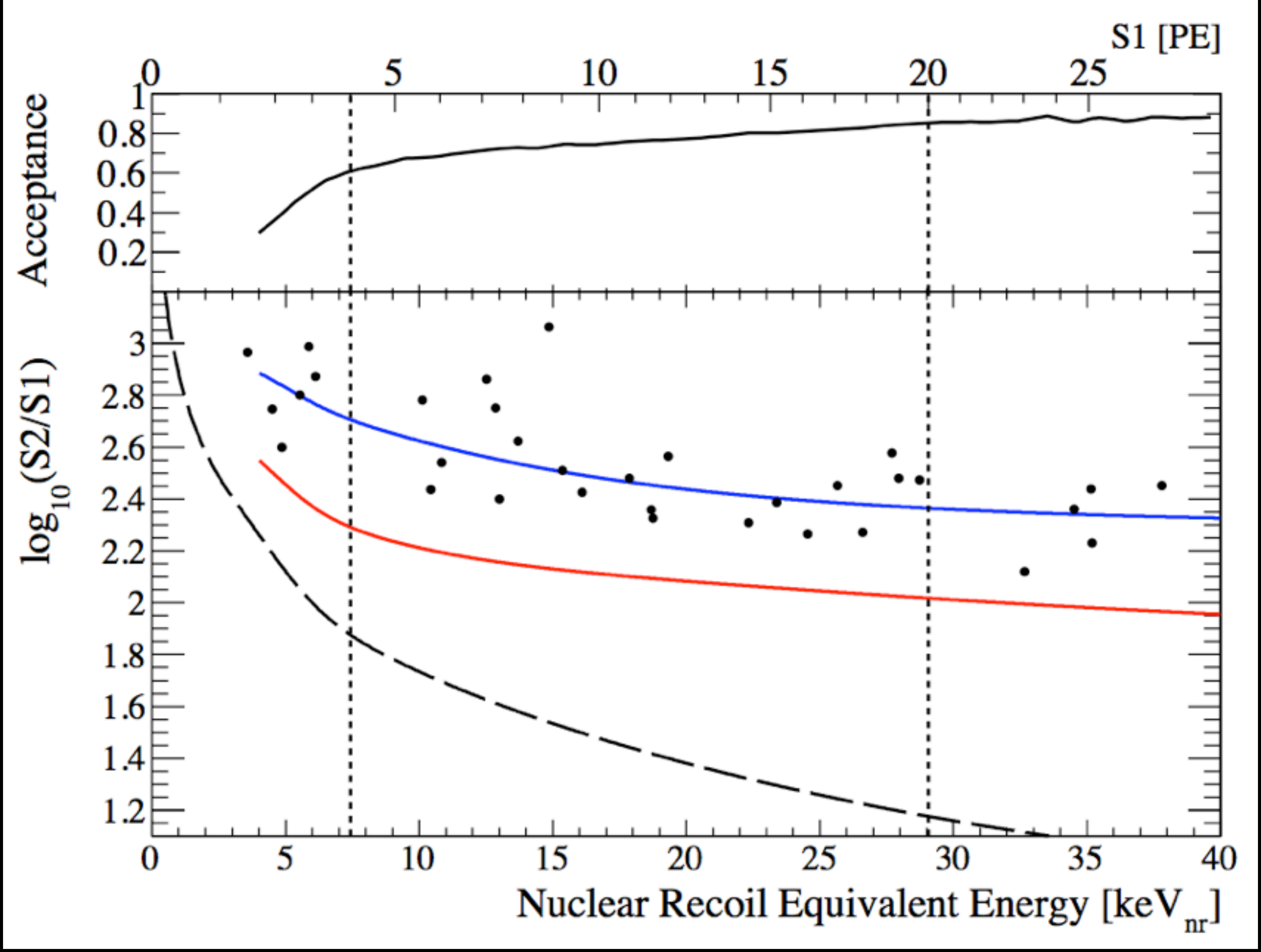
reduced ionization signal relative to phonon signal

CDMS



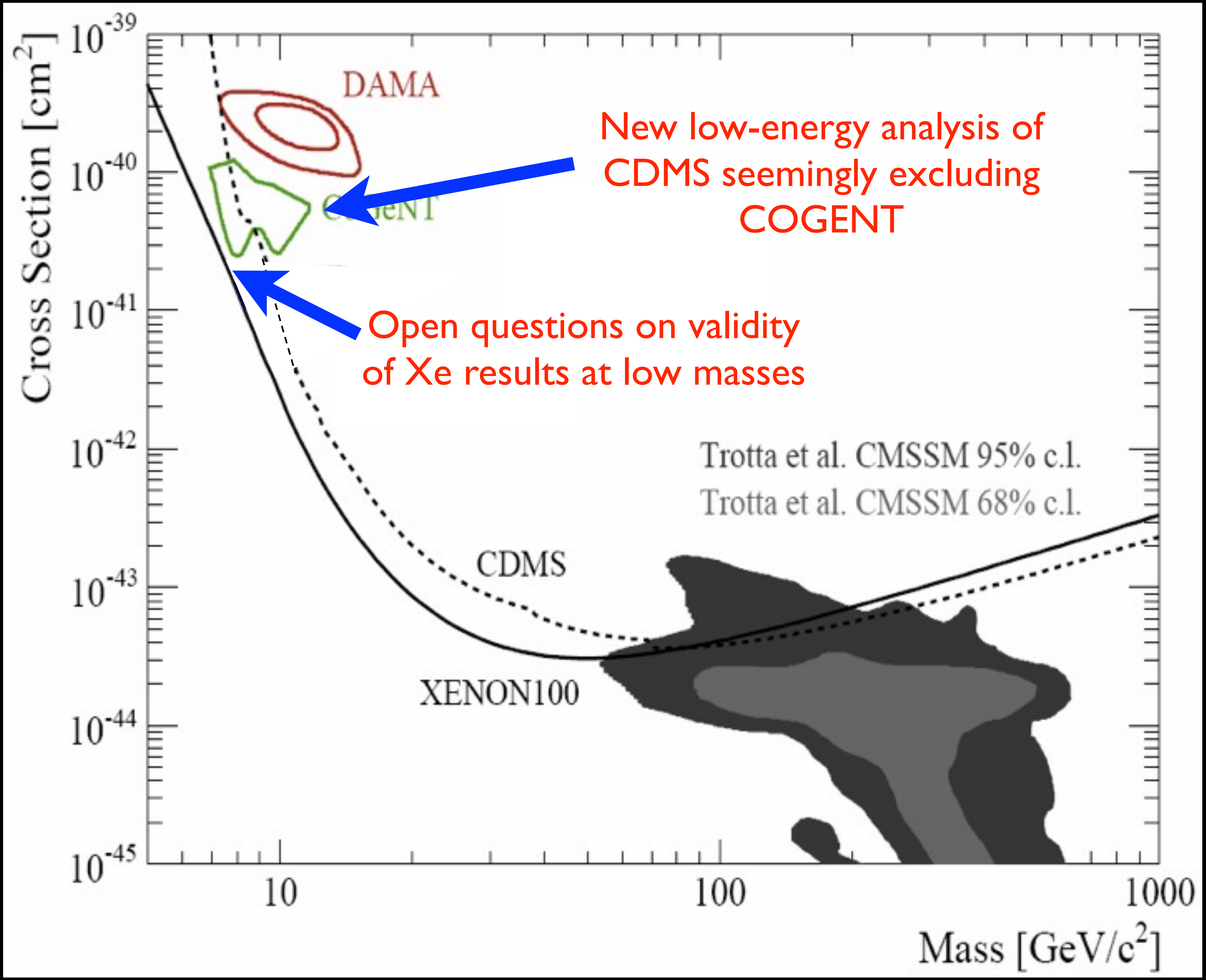
2 events in the NR band pass the timing cut!

XENON-100

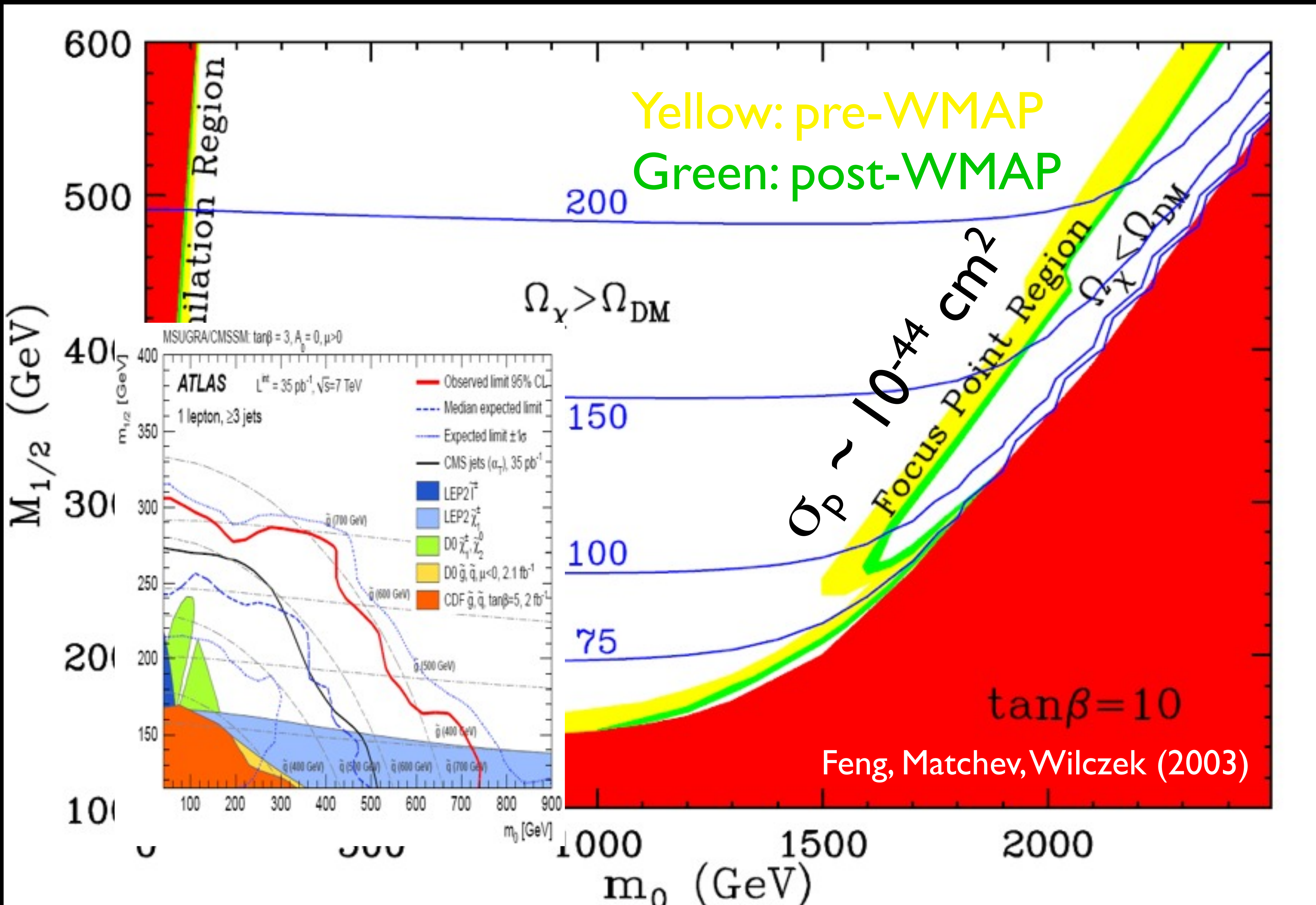


S1 [PE]
0
5
10
15
20
25
Acceptance
1
0.8
0.6
0.4
0.2
$\log_{10}(S2/S1)$
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
0
5
10
15
20
25
30
35
40
Nuclear Recoil Equivalent Energy [keV_{nr}]

Current Status

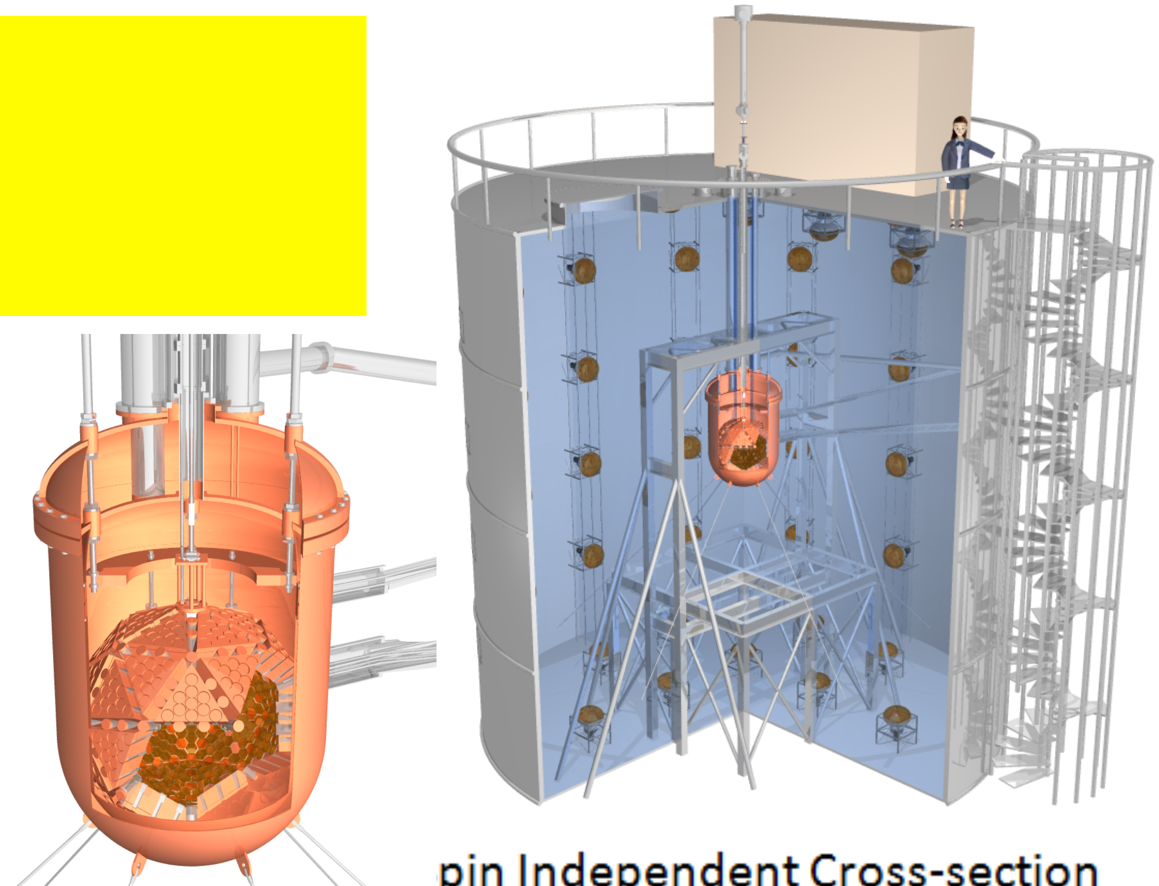


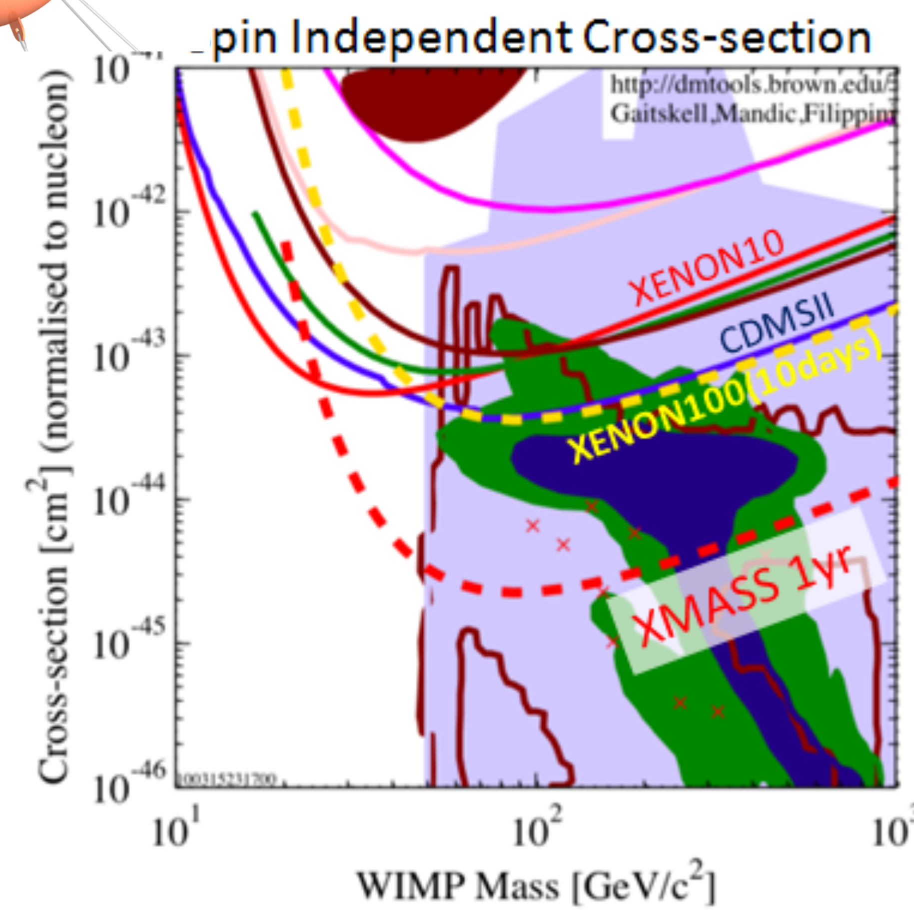
LHC may produce dark matter



XMASS
As of 20-Feb-2011

- Aim
  - Search for DM
    $\sigma_{SI} > 10^{-45}\ cm^2$
- Detector
  - 850 kg of liquid xenon
  - 100 kg fiducial volume
  - $E^{th}_{ee} = 5$ keV
  - 642 low BG PMTs
- Backgrounds
  - Various efforts to reduce
  - Aim: 10^{-4} events/kg/keV/day
- Status
  - Detector has been completed in October last year
  - Under commissioning untill March, 2011

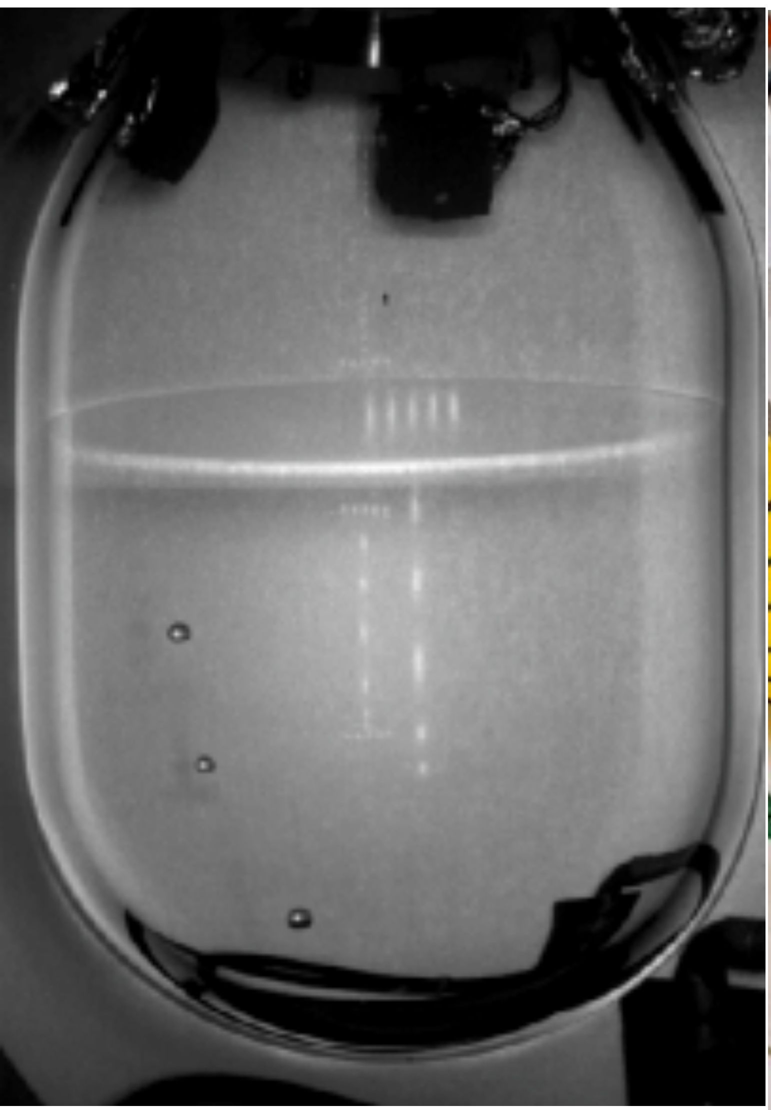




Searching for Dark Matter with Bubble Chambers (COUPP)

• Exploit physics of bubble nucleation to discriminate against background gammas and alphas: successful 2009 run of small chamber demonstrated potential to reach zero background.

• Scalable: 4-kg run in 2009, 60-kg being commissioned now; 500-kg and 16-ton (DUSEL) versions under discussion

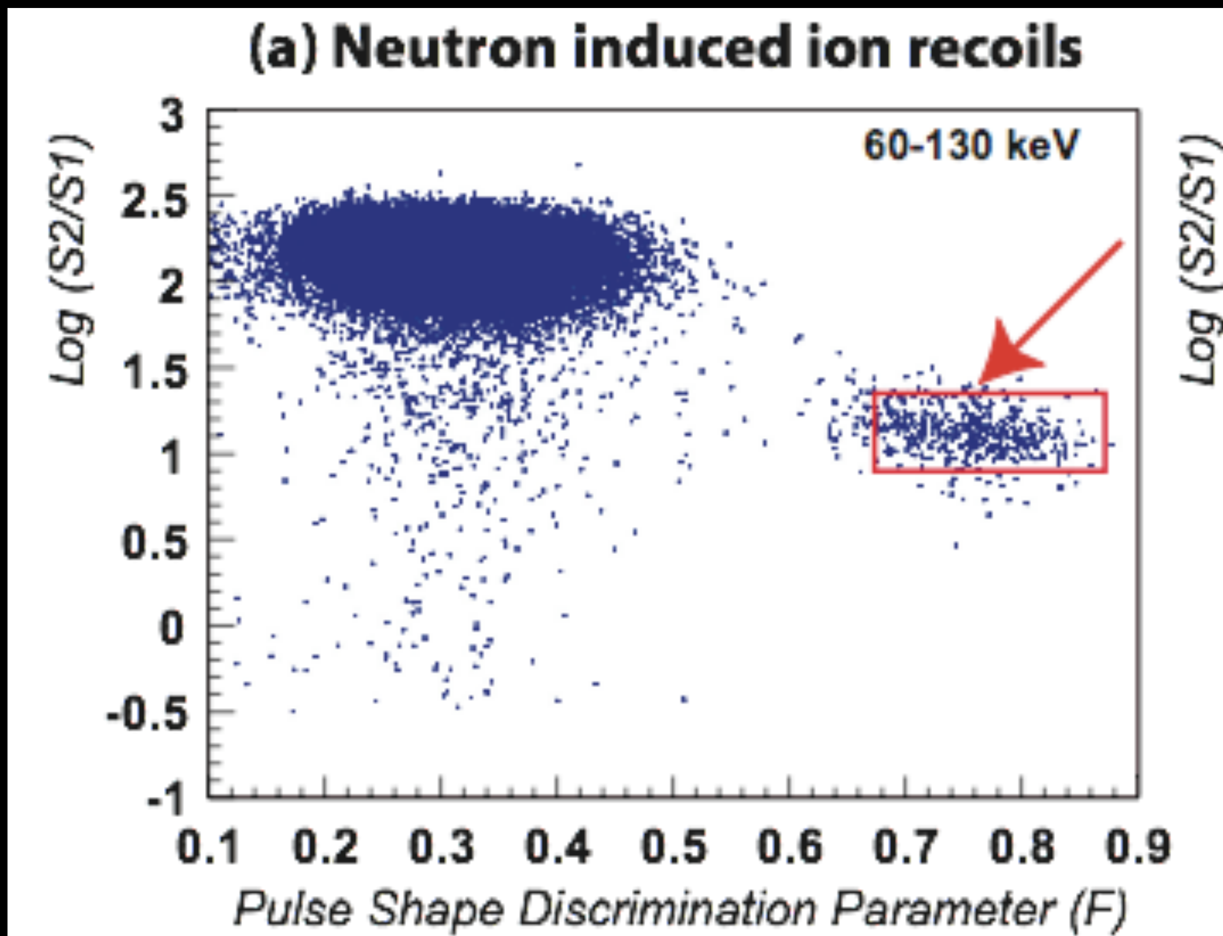


Neutron scattering background event in 4-kg chamber

Construction of 60-kg chamber

Fused silica inner vessel for 60-kg chamber. High purity construction techniques are used to reduce contamination by environmental radioisotopes

First Dark Matter Results



Selected events in the n-induced single recoils window during the WIMP search run: None

Astropart. Phys. **28**, 495 (2008)

WARP 140-kg Detector

The WARP 140-kg detector, currently under commissioning at LNGS

140 kg active target, to reach into 5×10^{-45} cm^2 and cover critical part of SUSY parameter space

Complete neutron shield!

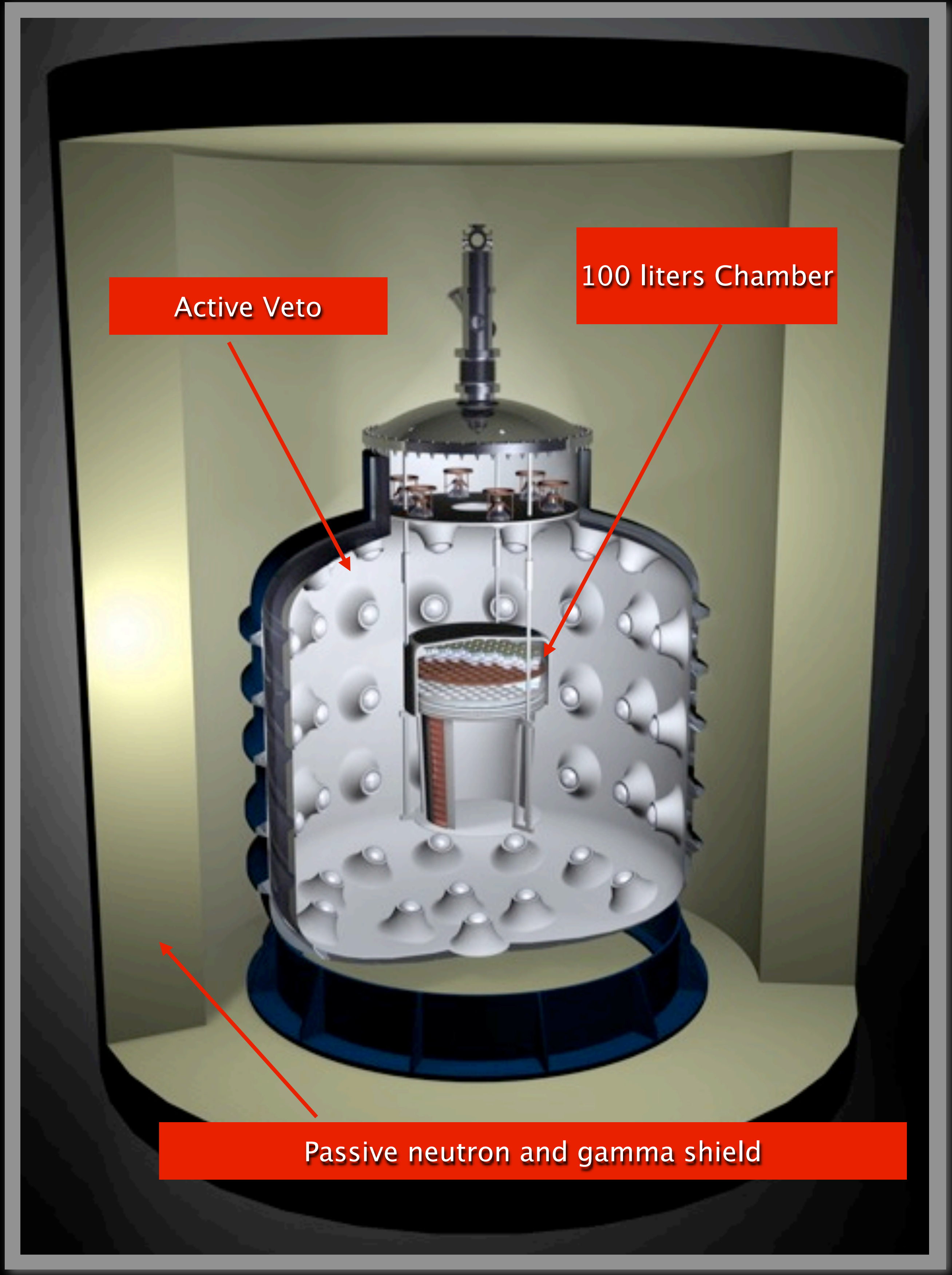
4π active neutron veto (9 tons Liquid Argon, 300 PMTs)

Active control on nuclide-recoil background, owing to unique feature (LAr active veto)

3D Event localization and definition of fiducial volume for surface background rejection

Detector designed for positive confirmation of a possible WIMP discovery

Cryostat designed to allocate a possible 1400 kg detector

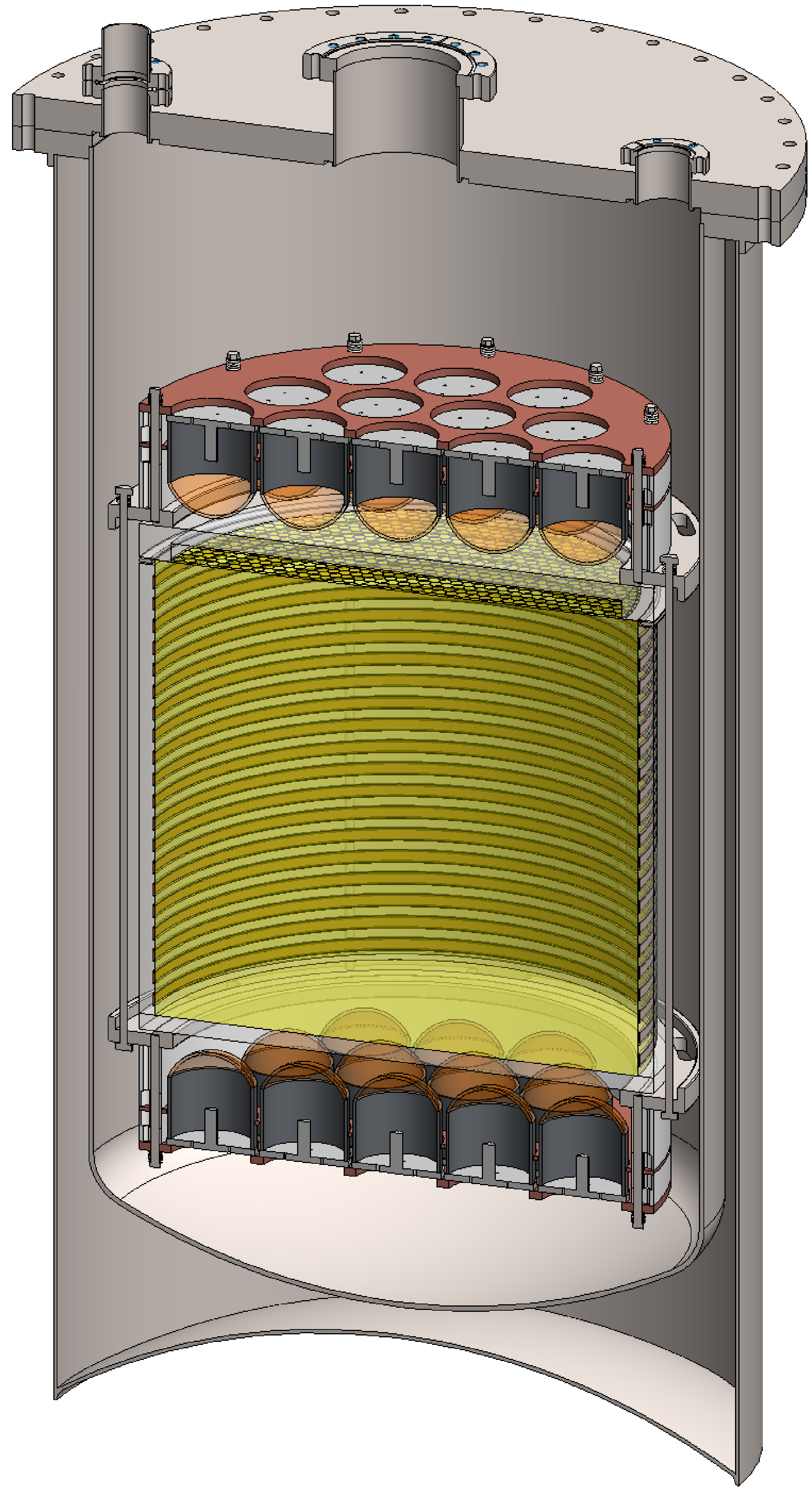


DarkSide-50

- first implementation of new technologies
  - depleted argon, QUPIDs, organic-scintillator-based neutron veto
- dual-phase TPC à la WARP
- 50 kg DAr active mass

sensitivity 10^{-45} cm^2 in 3-yrs background-free operation

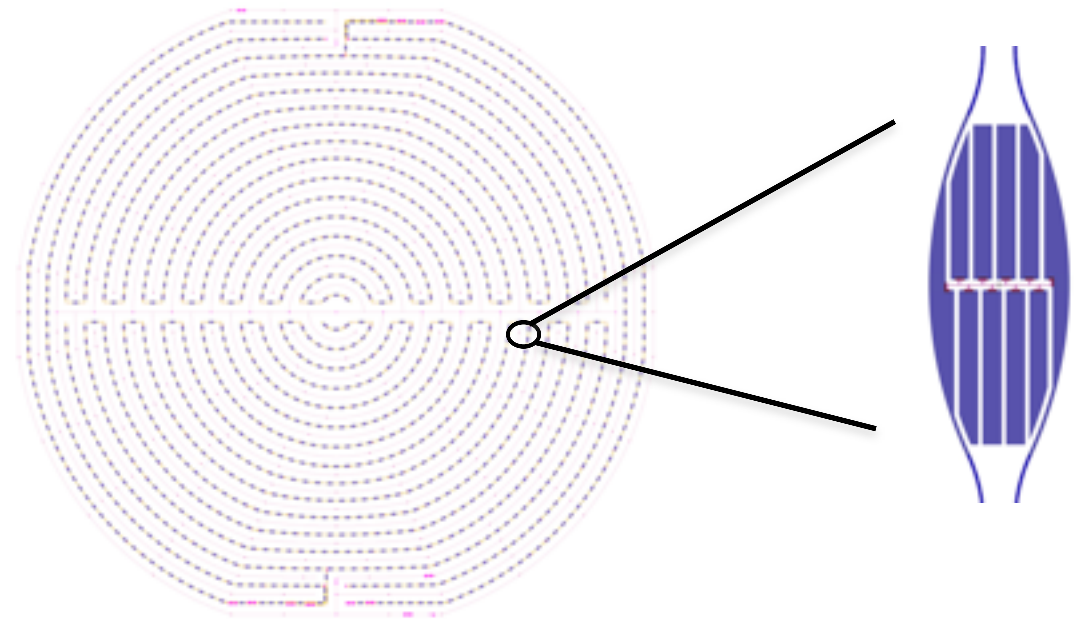
demonstrate potential of the technology for multi-ton year background-free sensitivity

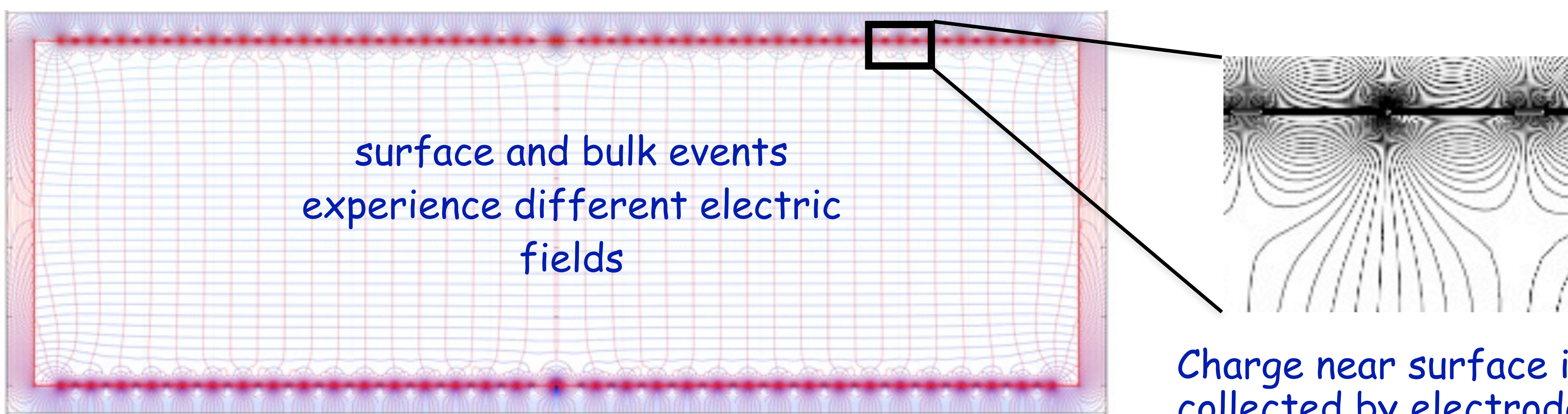


Breakthrough in detector technology

iZIP = interleaved charge and phonon channels

- rejection of surface events X10 better than CDMSII style detectors !
- efficiency for neutrons passing charge cut is ~55%





Charge near surface is collected by electrodes on only one side

Like the jelly beans in this jar, the Universe is mostly dark: 96 percent consists of dark energy (about 70%) and dark matter (about 26%). Only about four percent (the same proportion as the lightly colored jelly beans) of the Universe - including the stars, planets and us - is made of familiar atomic matter.

The End