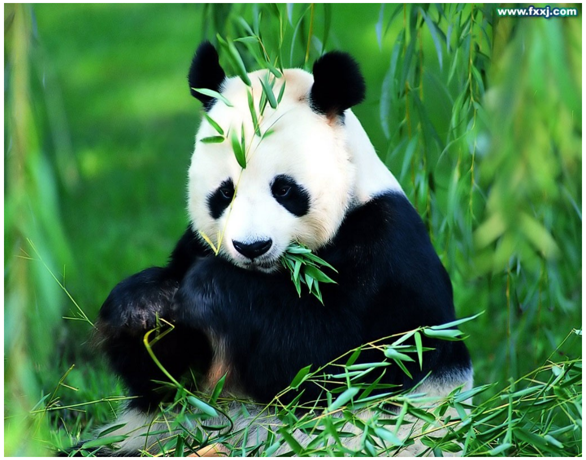
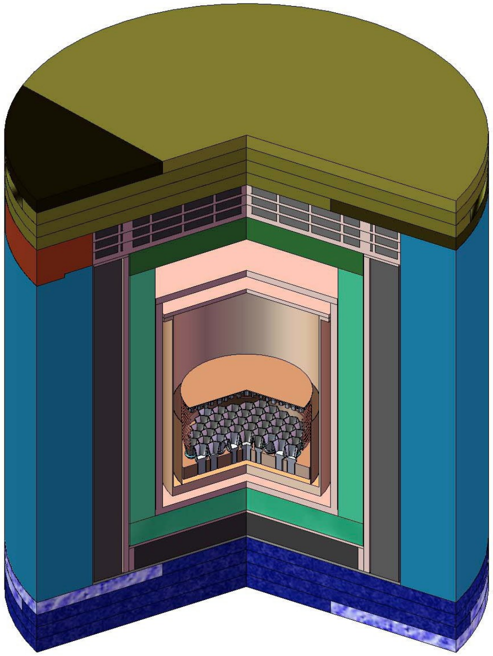
The PANDAX Experiment
Particle AND Astroparticle Xenon Observatory





刘湘
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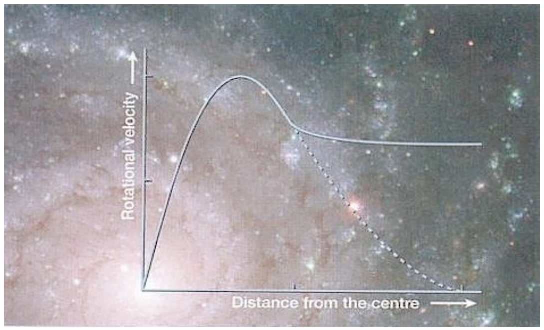
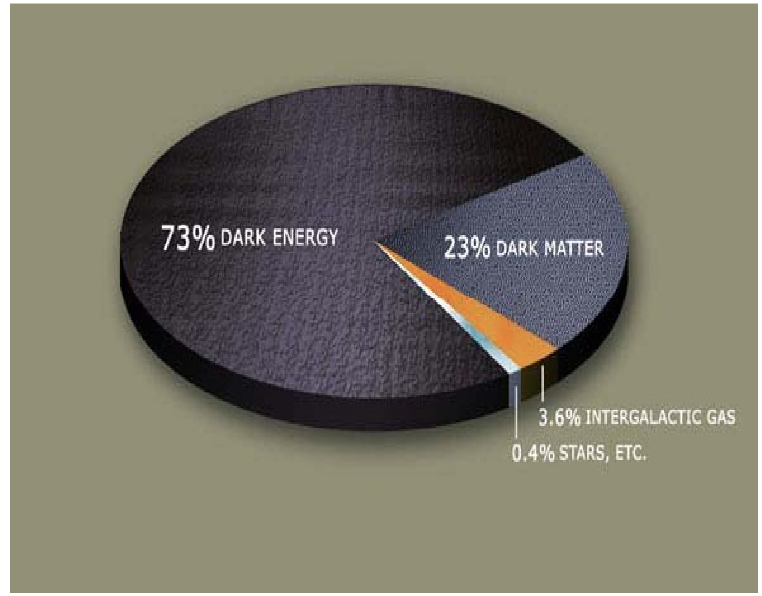
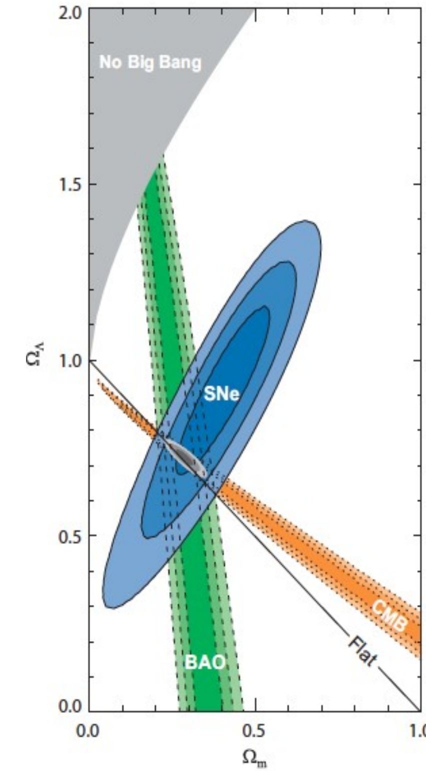
粒子物理宇宙学研究所

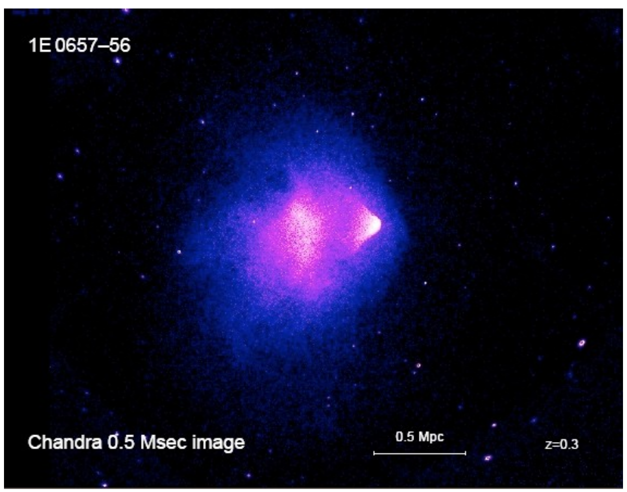
中国科学院理论物理研究所冬季研讨会
2010。 12。 13 - 15

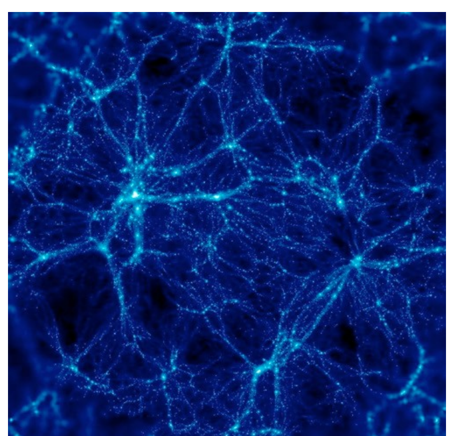
Existing evidence of dark matter

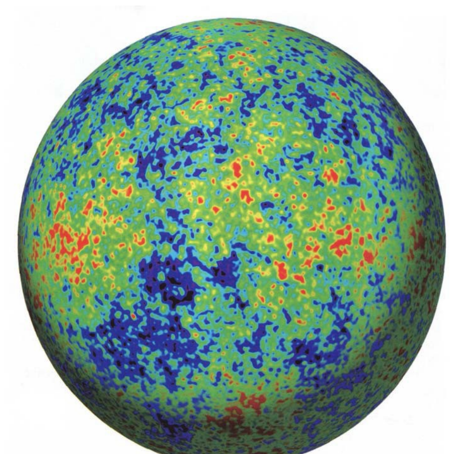


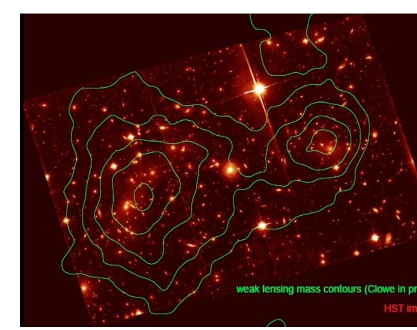






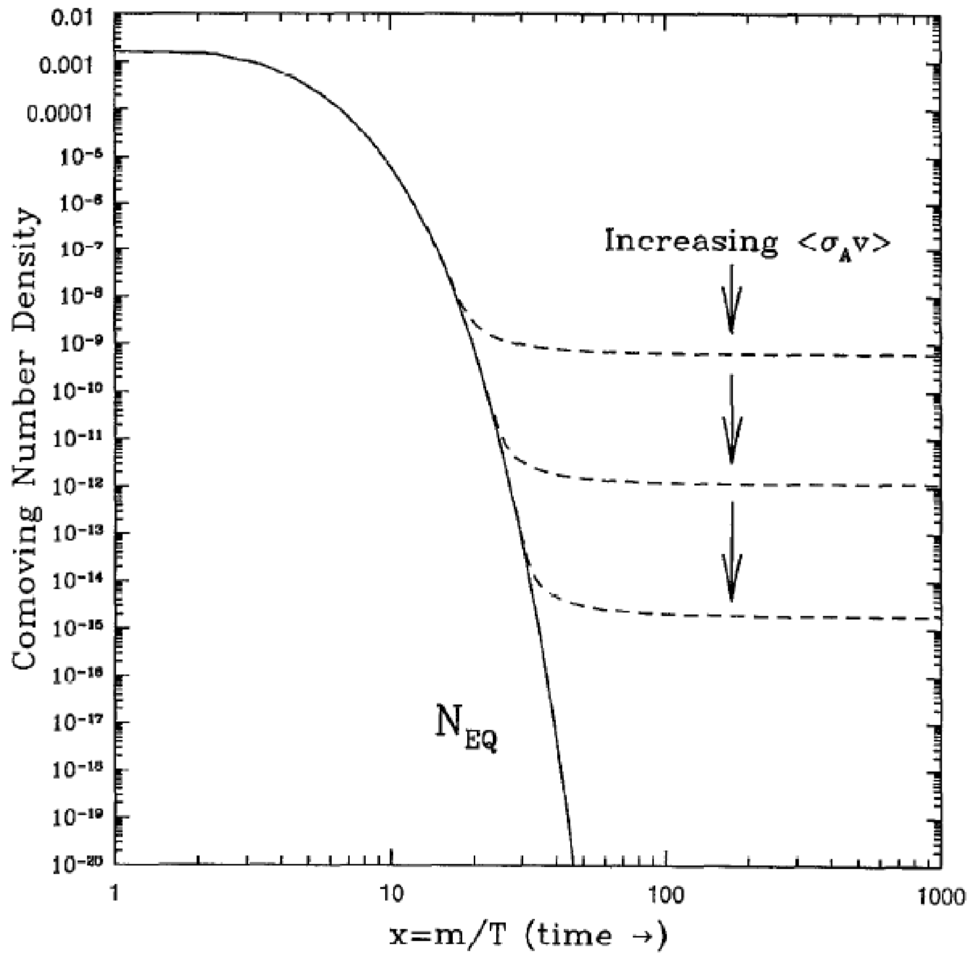






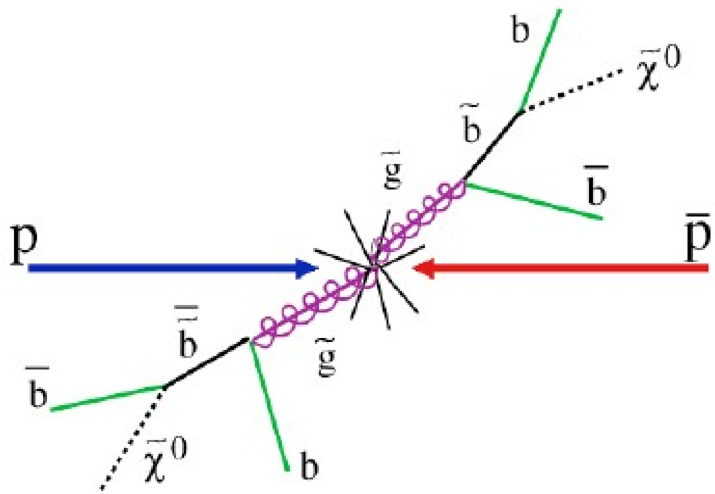
Favorite candidate: WIMP

LSP Neutralino
with weak coupling
→ WIMP Miracle

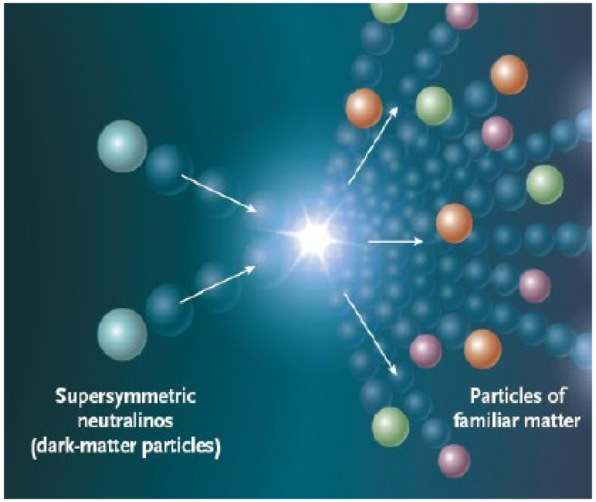


Phys. Rep. 267(1996) 195-273

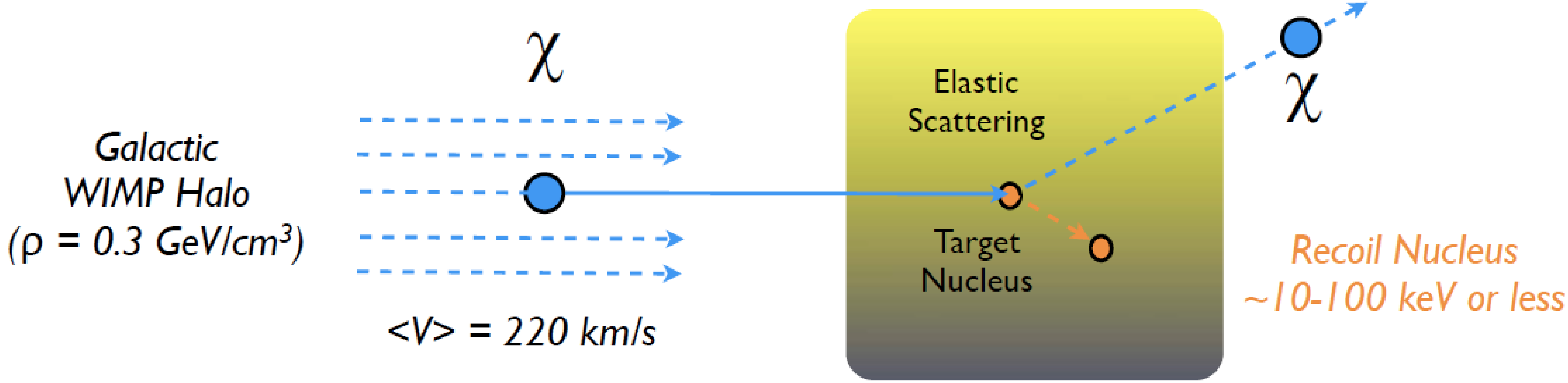
Methods to search LSP



production at collider

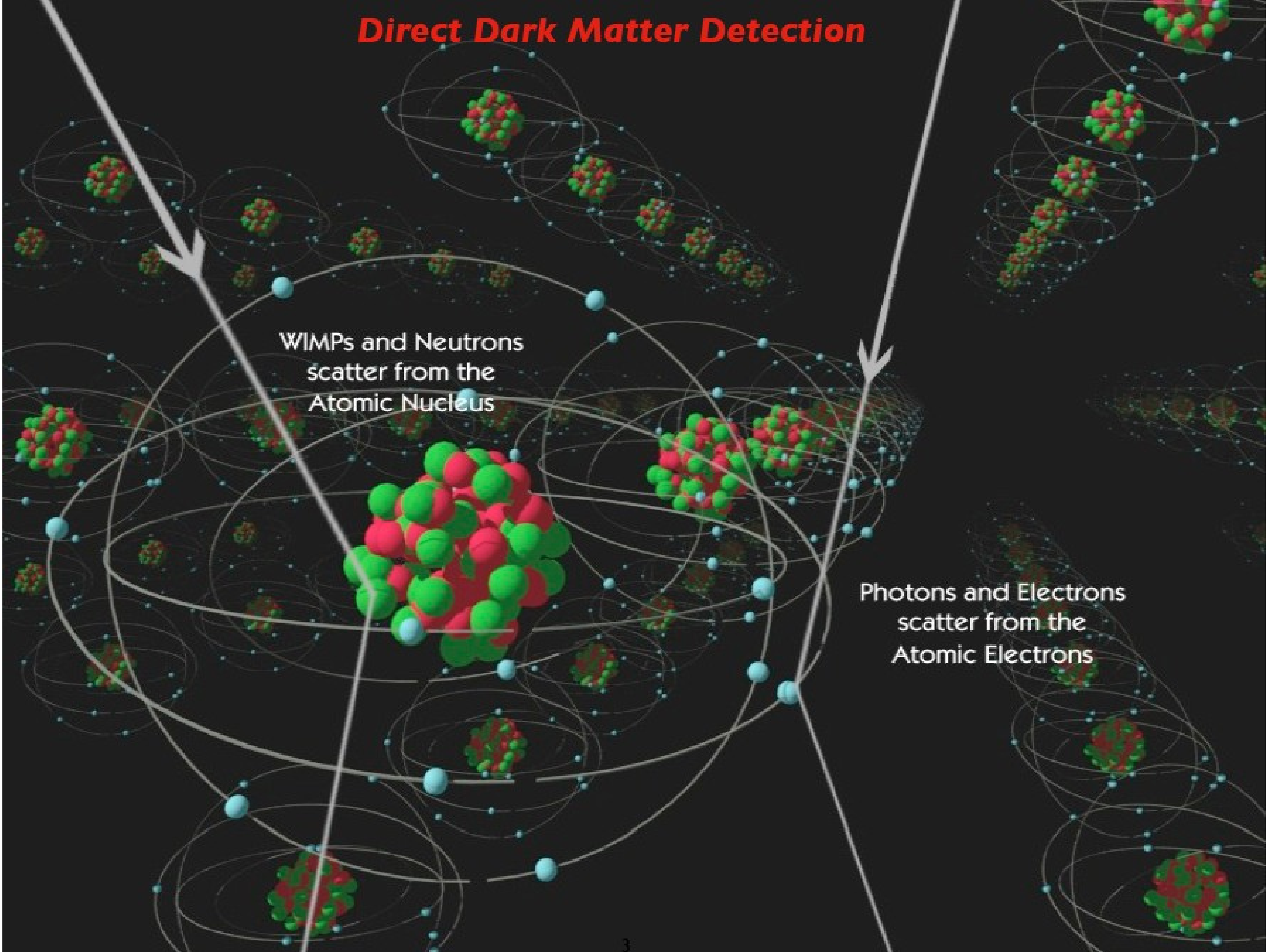


annihilation particle detection (indirect)

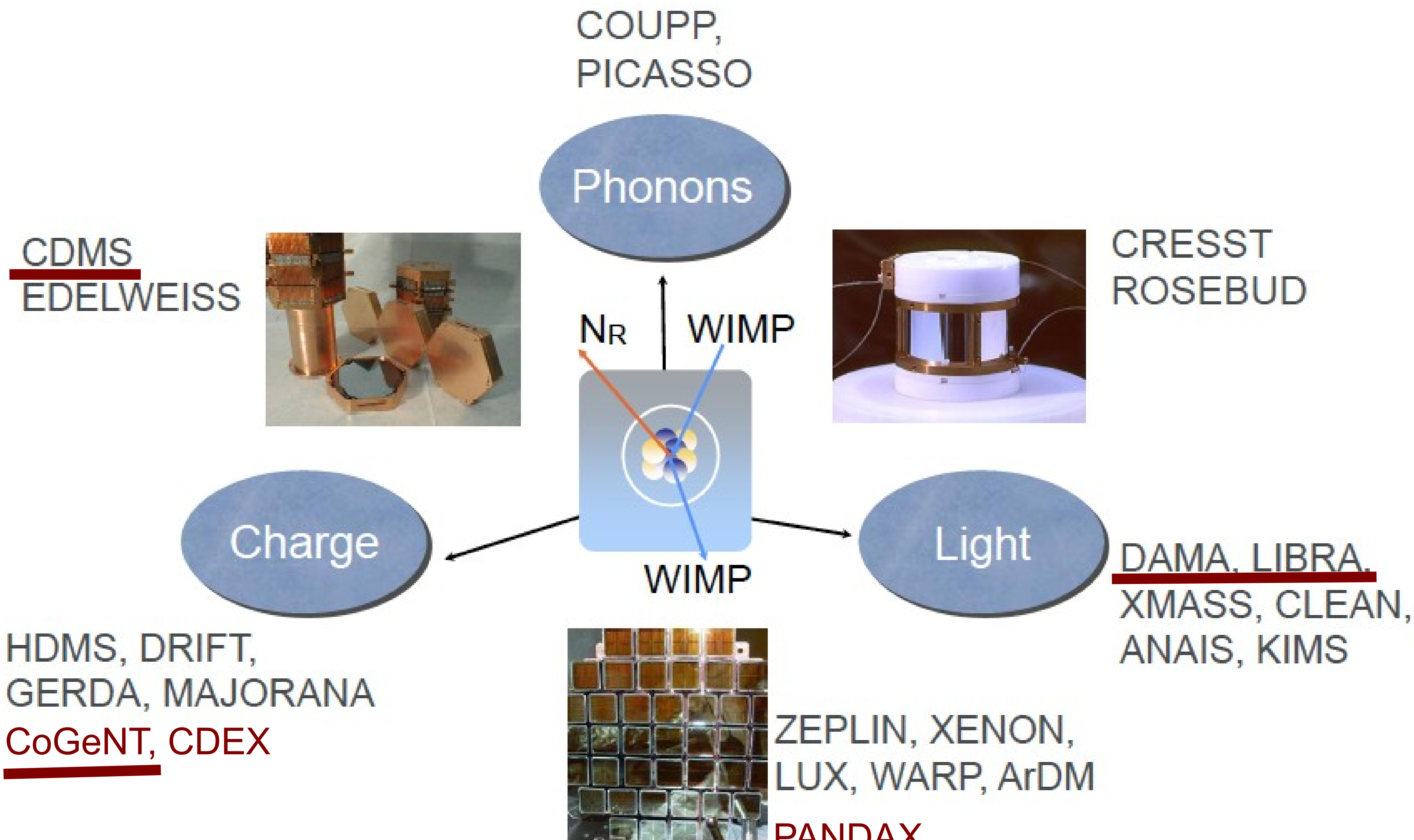


nuclear recoil (direct)

Direct Dark Matter Detection



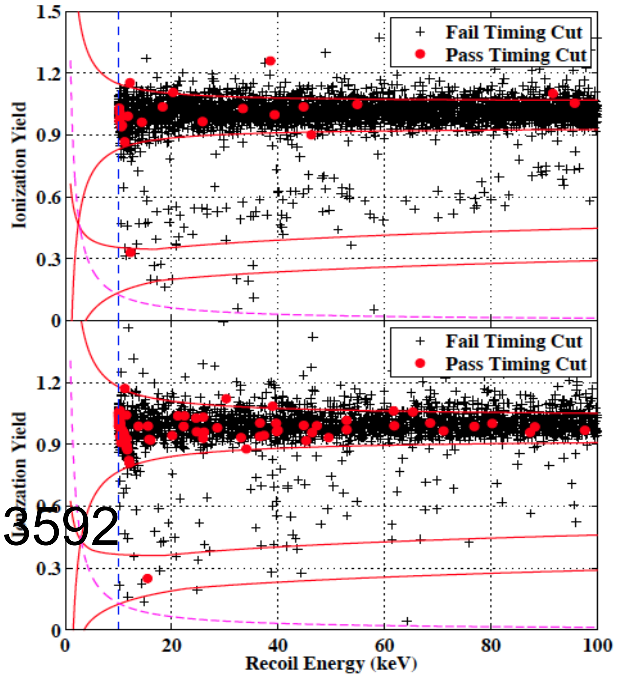
Direct detection technique

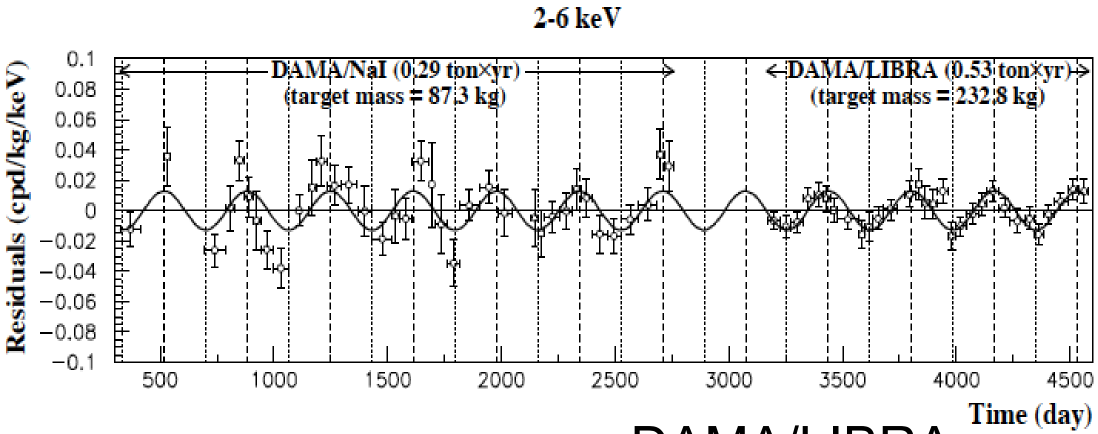


Direct detection results

CDMS

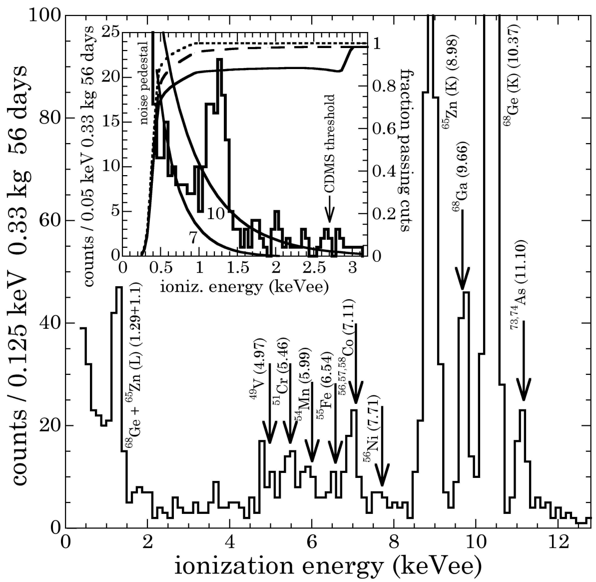
arXiv:0912.3592

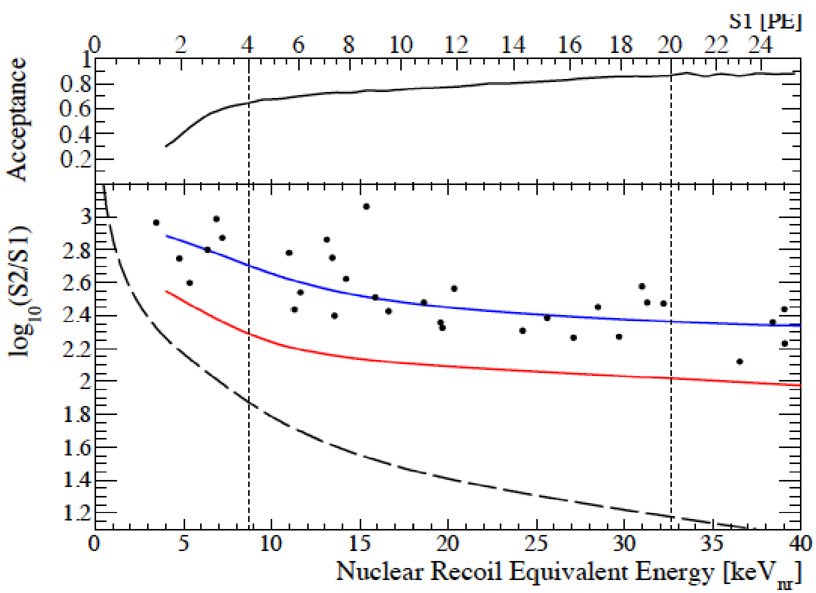




DAMA/LIBRA

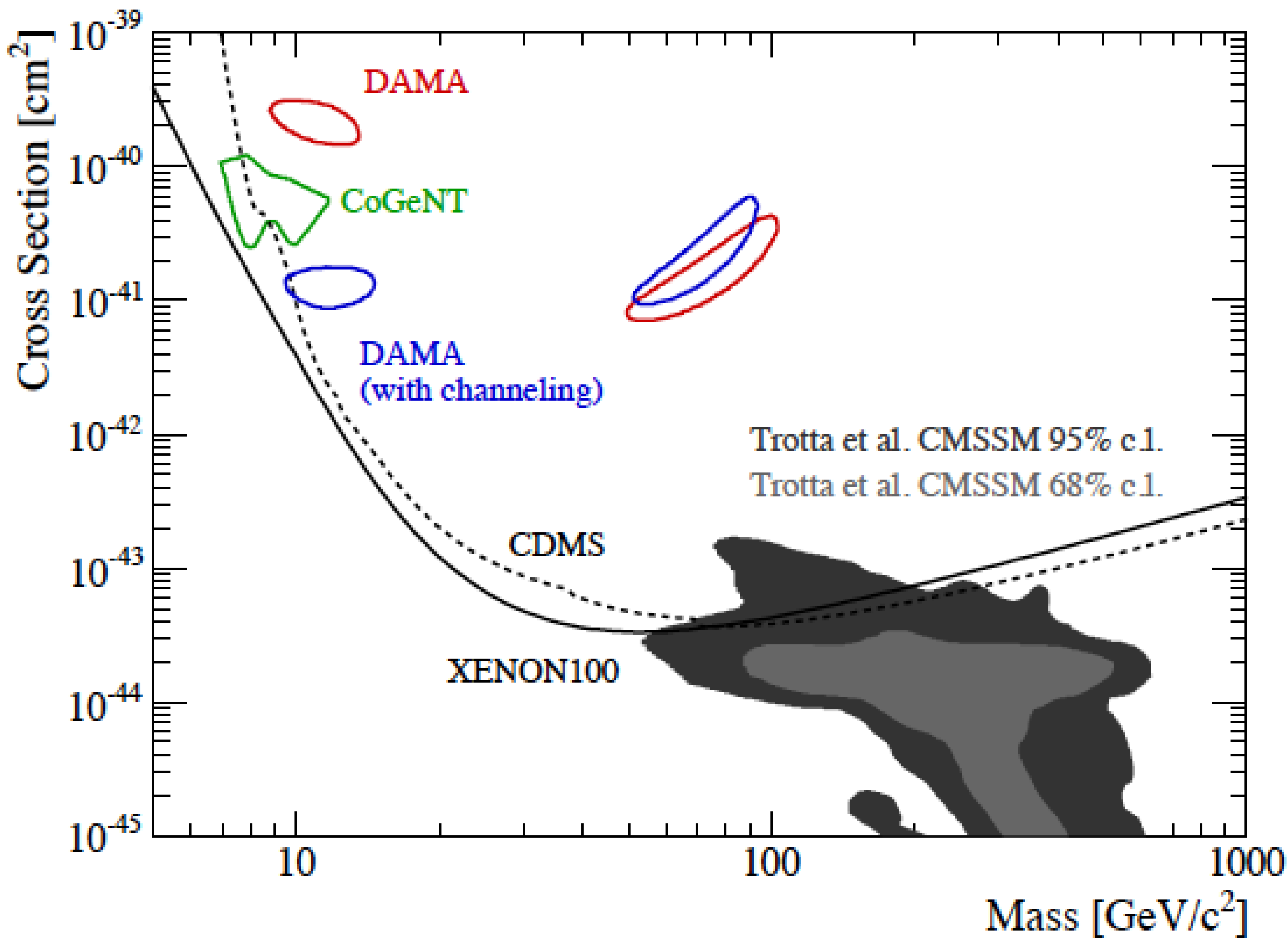
CoGeNT





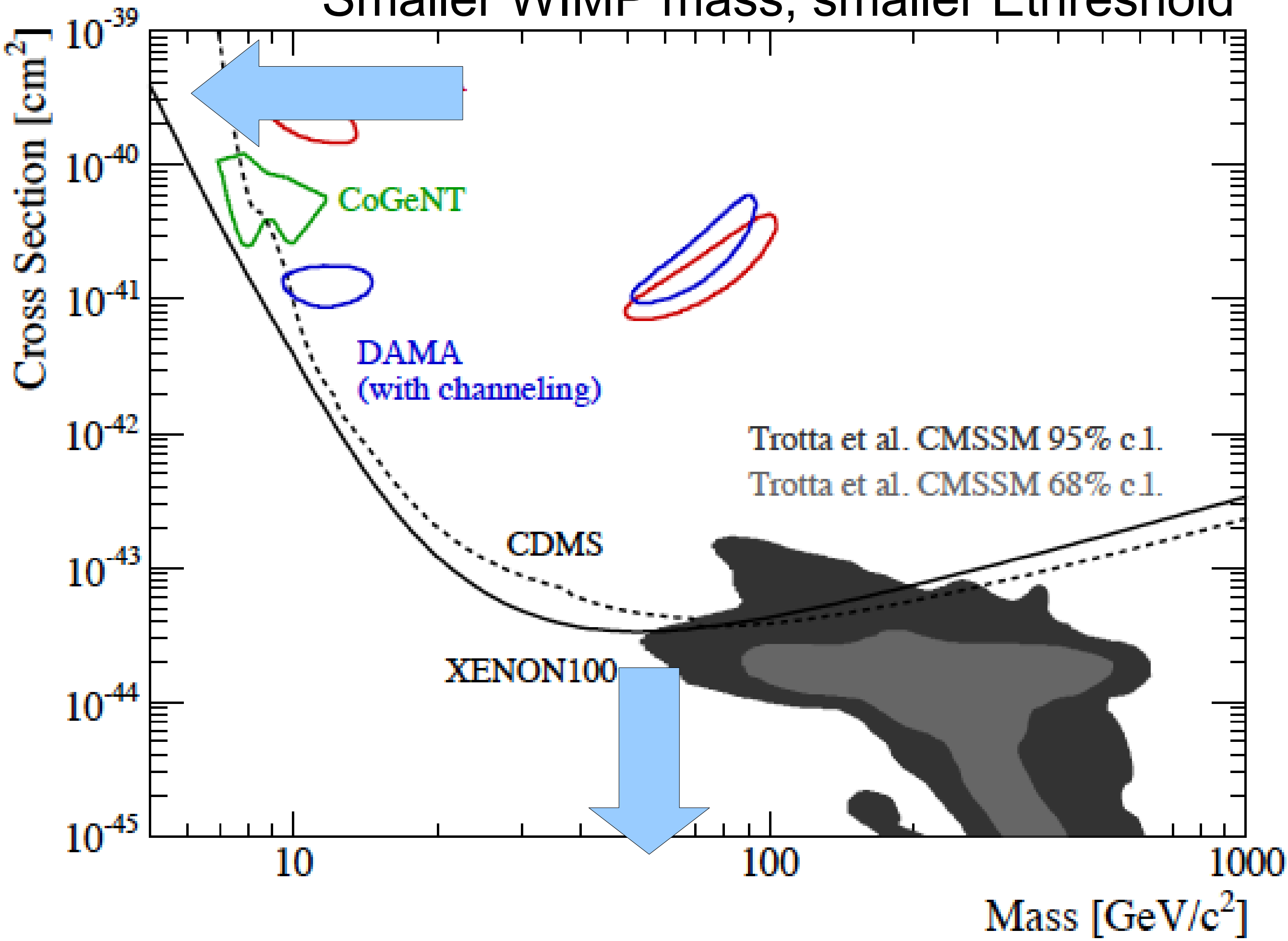
arXiv:1002.4703 XENON100 arXiv:1005.0380

Direct detection status



Direct detection status

Smaller WIMP mass, smaller Ethreshold



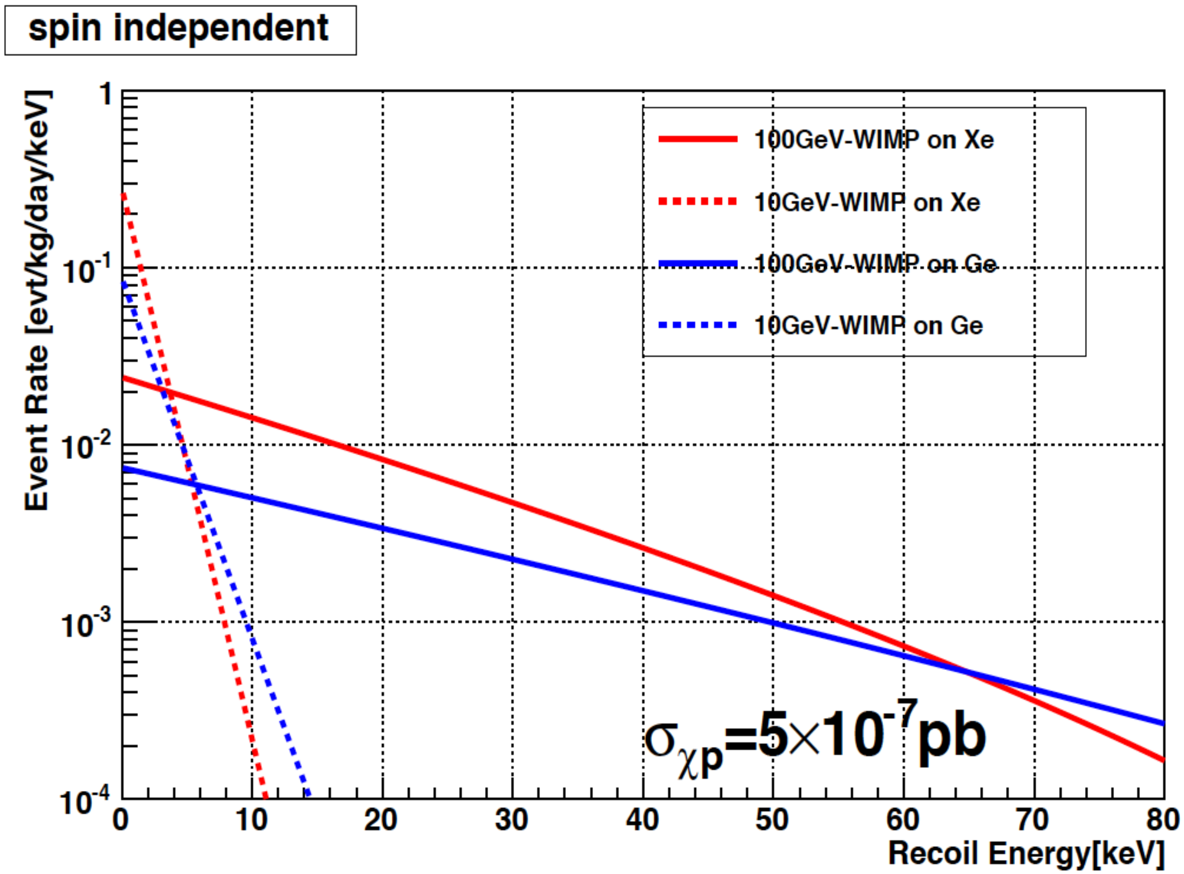
Smaller σ, larger detector mass, lower bg rate.

Direct detection challenge

WIMP signal: <0.1/kg day (bg 10^6/kg day)
<100keV
no feature

Signal collection

Background rejection



Xenon advantage

Signal collection

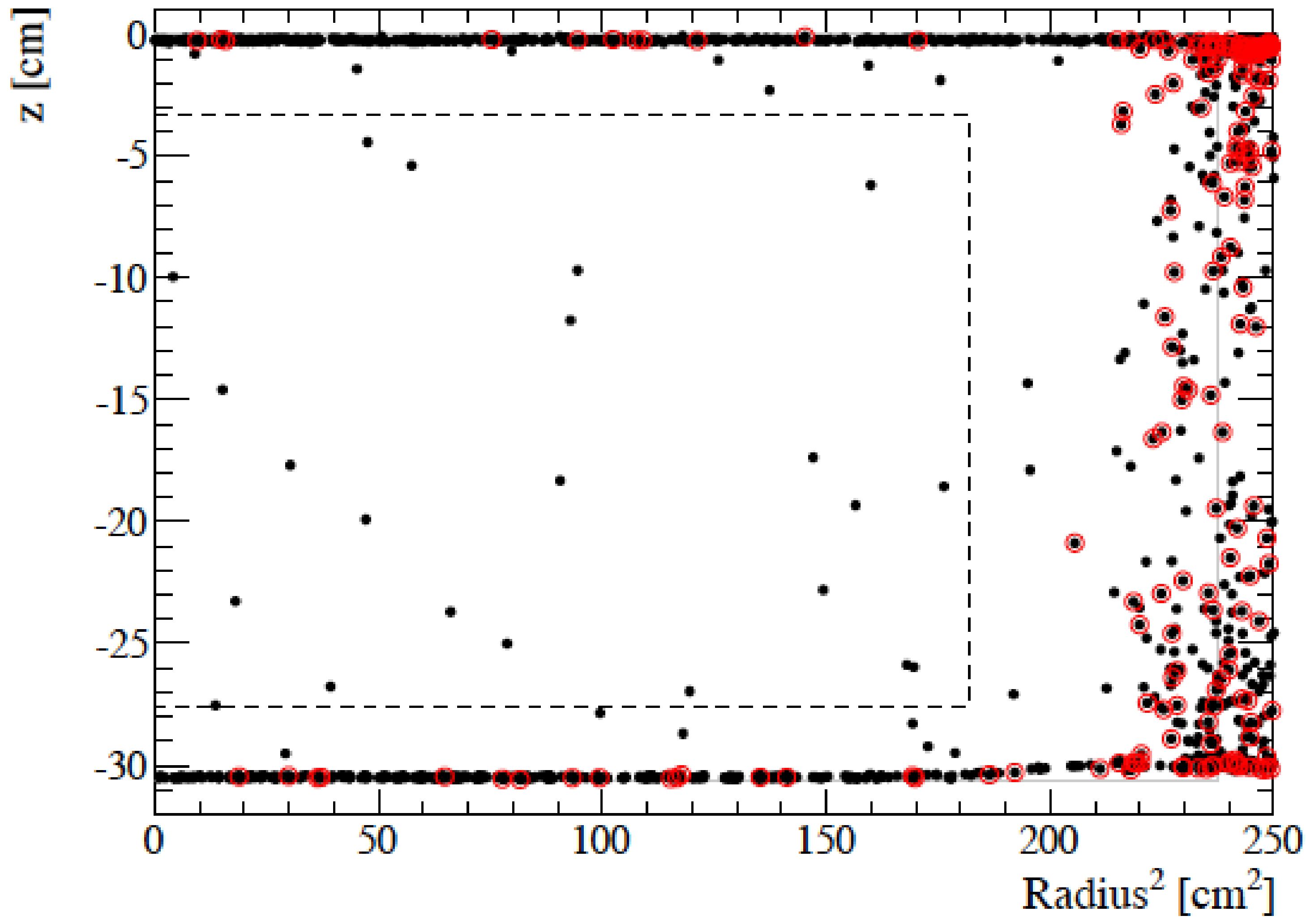
- large A: $\sigma_{SI} \sim A^2$
- easy scale-up, larger mass
- efficient scintillation (80% of NaI), 178nm, no WS
- Xe131 sensitive to spin-dependent

Background rejection

- self-shielding, 3g/cm^3
- no long-life radioactive isotopes
- easy to remove Kr (distillation)
- dual phase

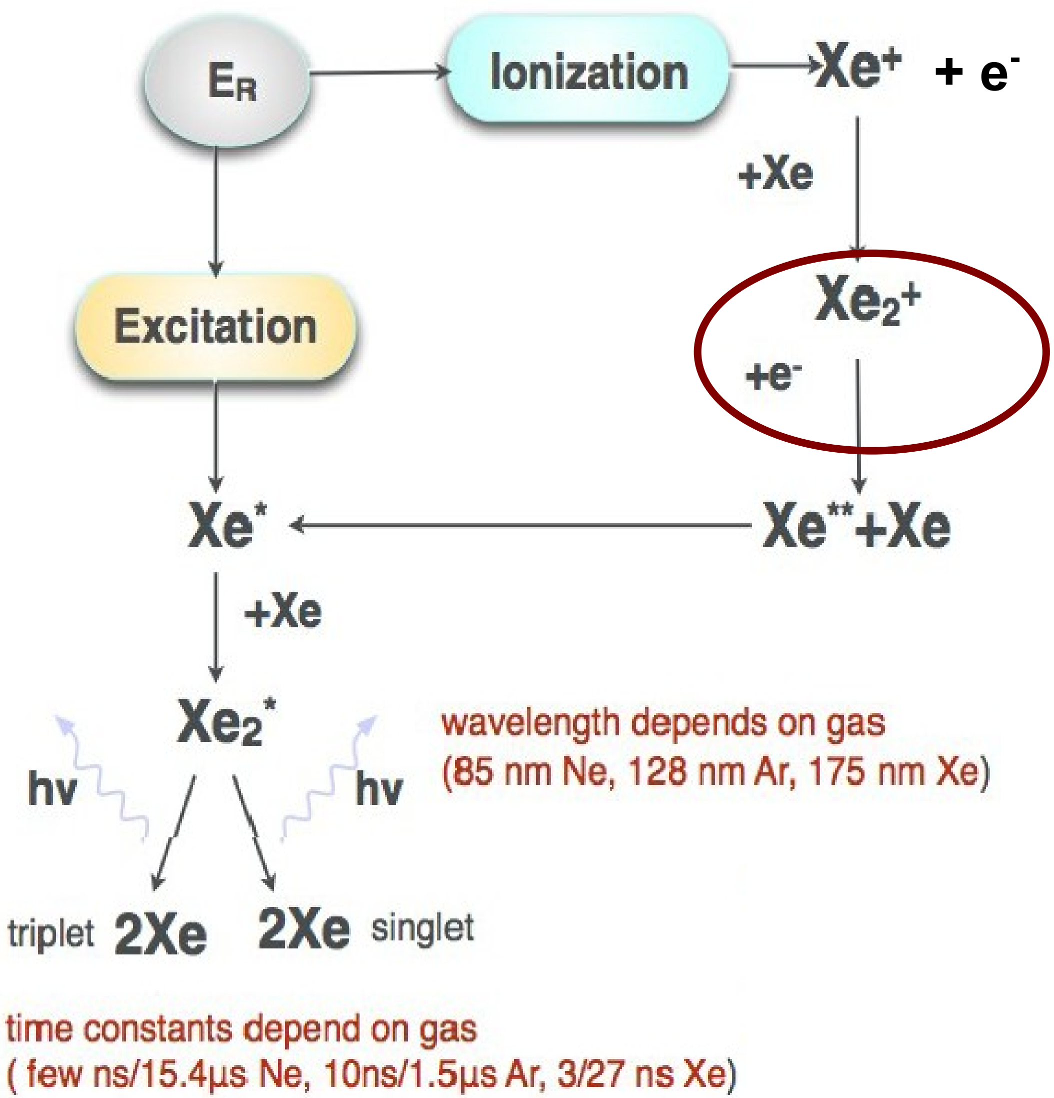
- noble gas, -100°C, easy to handle

Xenon self-shielding



XENON100 arXiv1005.0380

Xenon light & charge



Recombination:
Nuclear Recoil >> Elec. Recoil

→

NR light >> ER light
NR charge << ER-charge

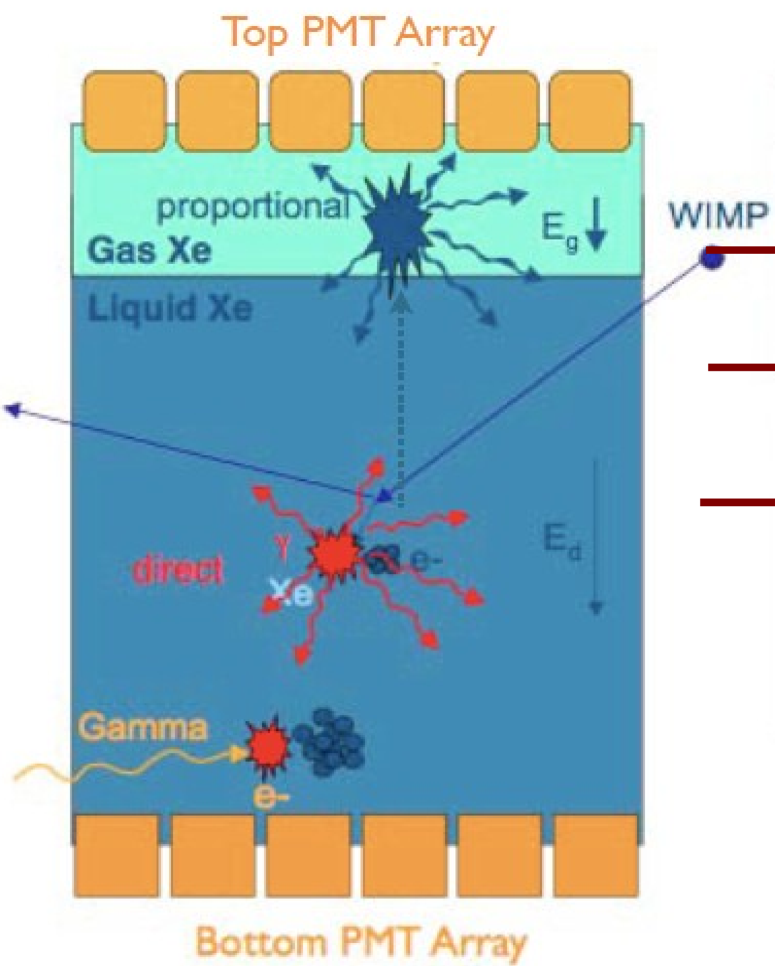
Two-Phase Xenon TPC

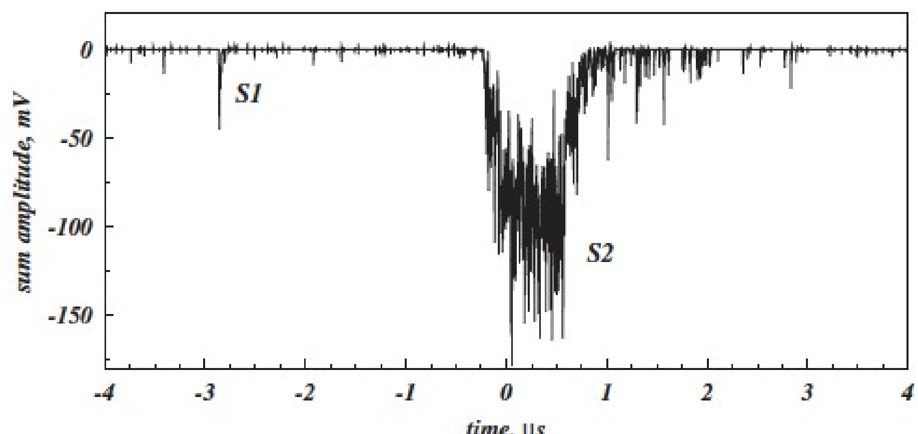
10keV

x100, 400K gamma (S2=charge)

4000 electrons drift

400 gamma (S1=photon)

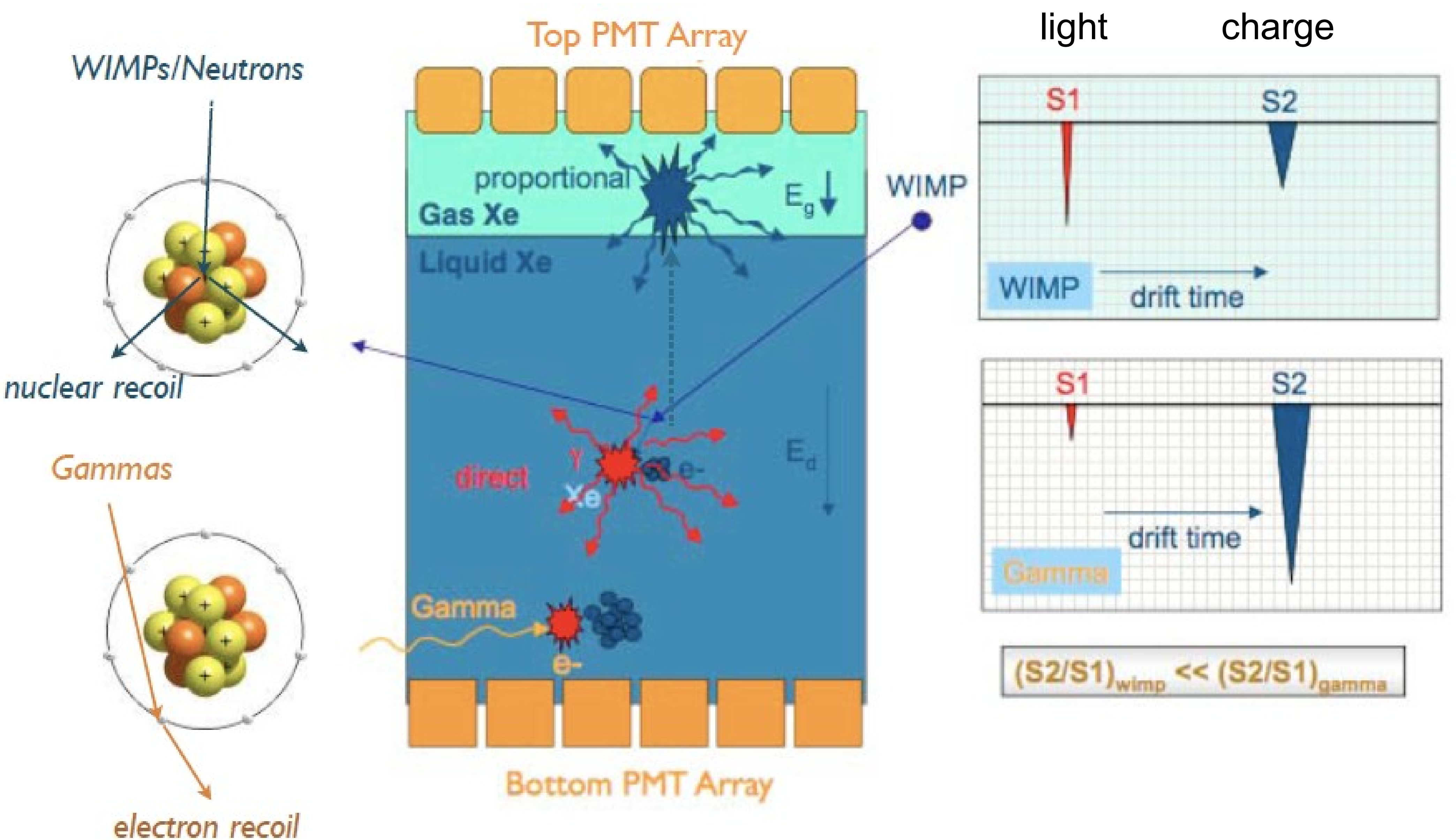




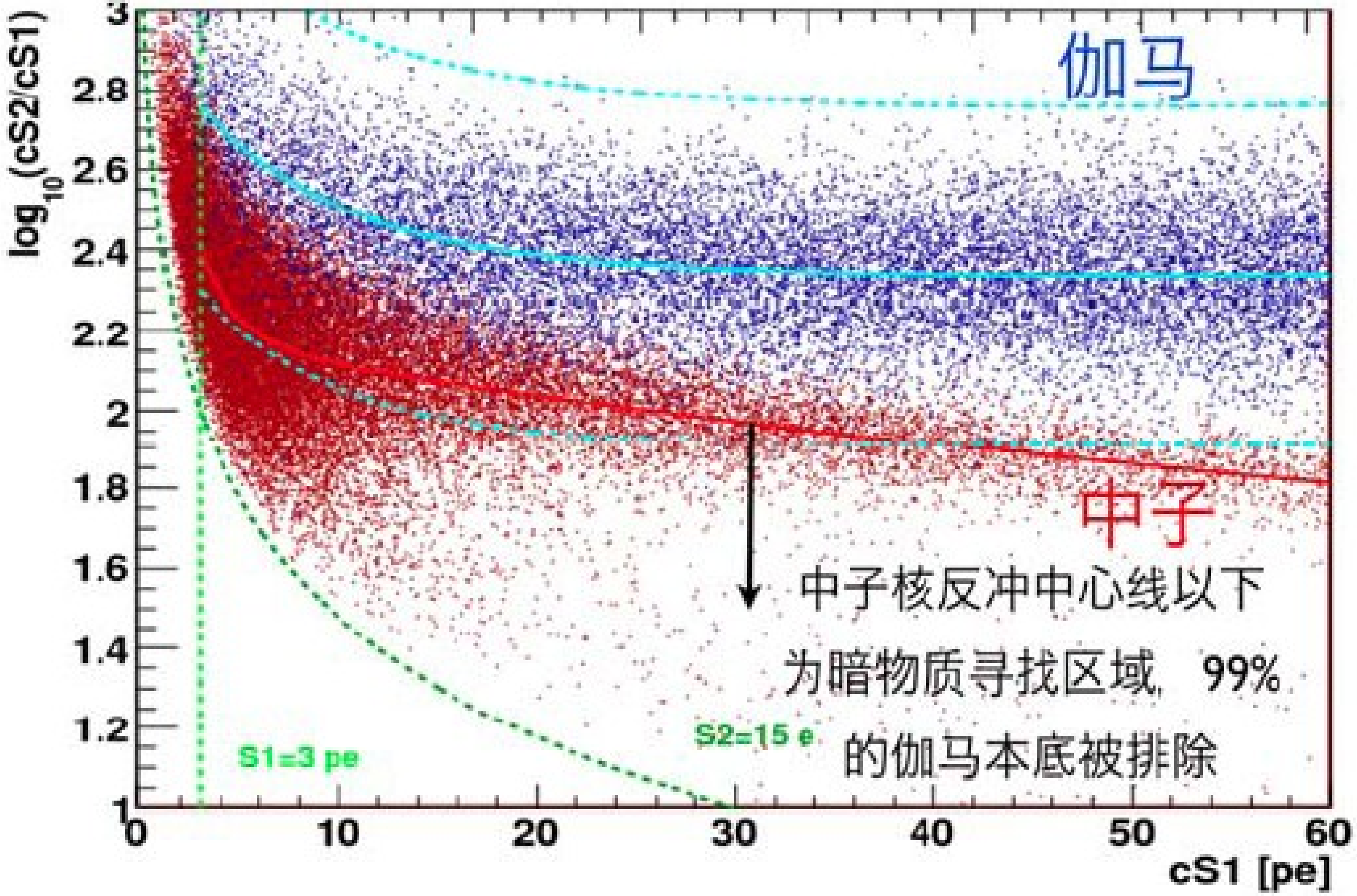
(ZEPLIN-III)

σ_E (S1+S2) can reach5%

Advantage of two-phase TPC I

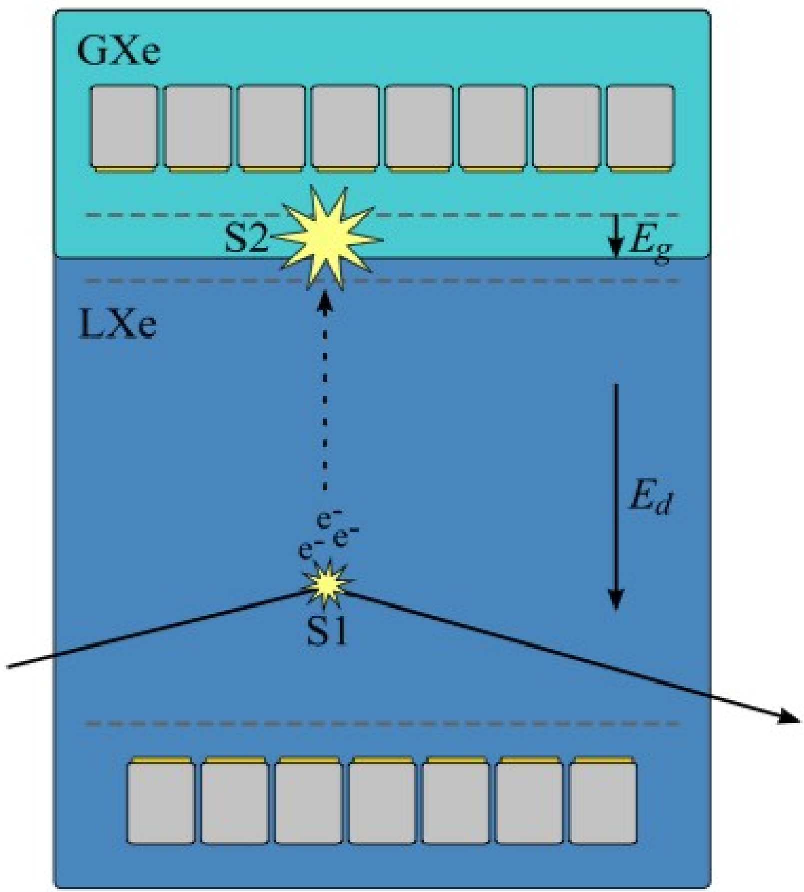


Advantage of two-phase TPC I

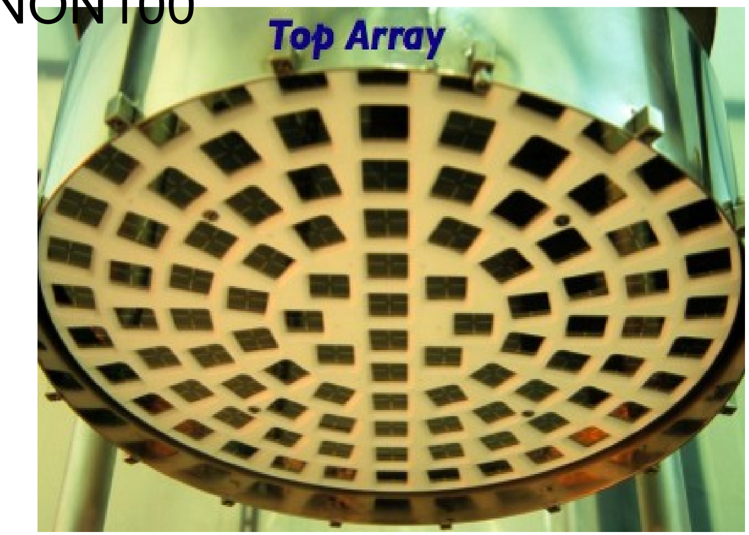


Advantage of two-phase TPC II

Excellent 3D position σ, 2mm



XENON100

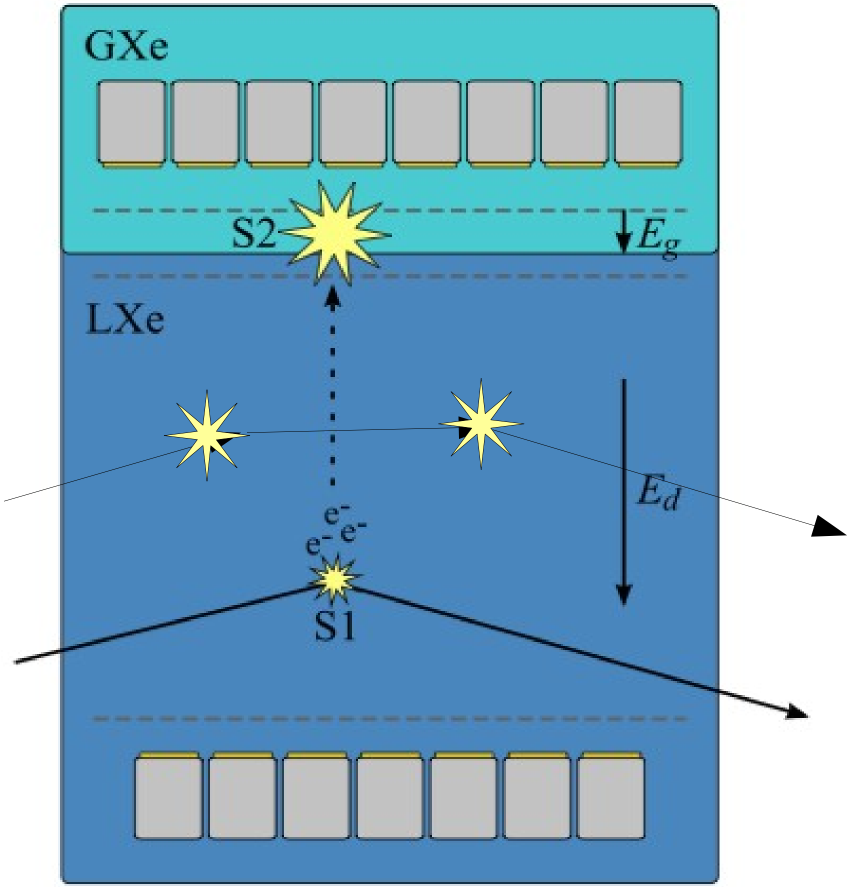


gamma event localized

Top PMT array

Advantage of two-phase TPC II

Excellent 3D position σ, 2mm

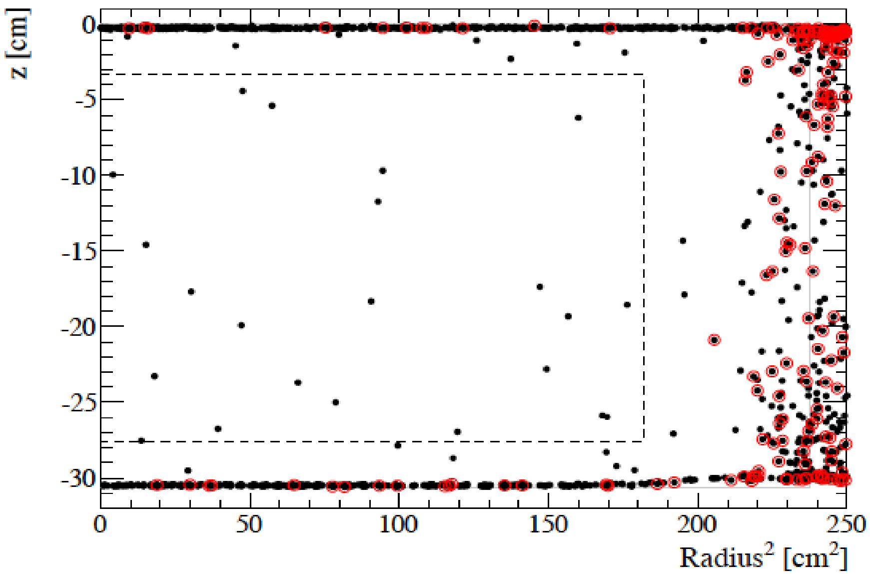


Mean-free-path
MeV gamma: ~3cm
MeV neutron: ~30cm

gamma/neutron , multiple hits

WIMP, single hit

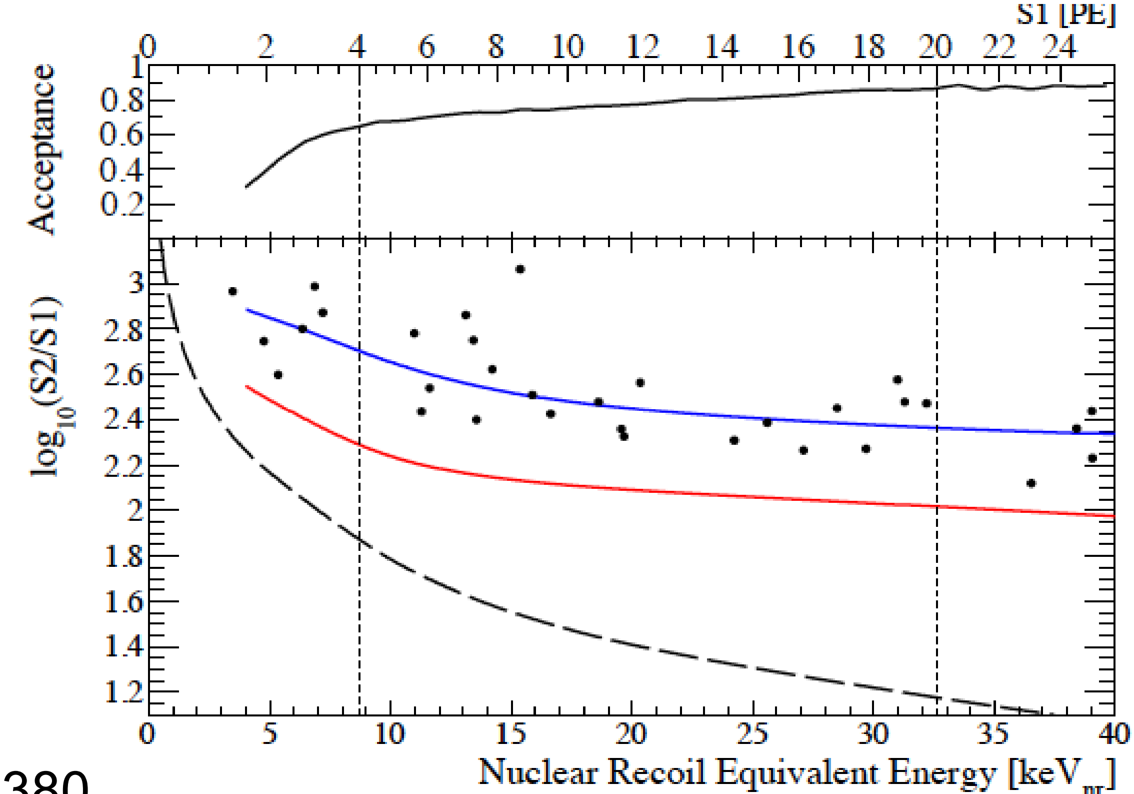
XENON100 as example



all 22 events in fiducial volume failed S2/S1 and single-hit cut

→

Zero background achieved



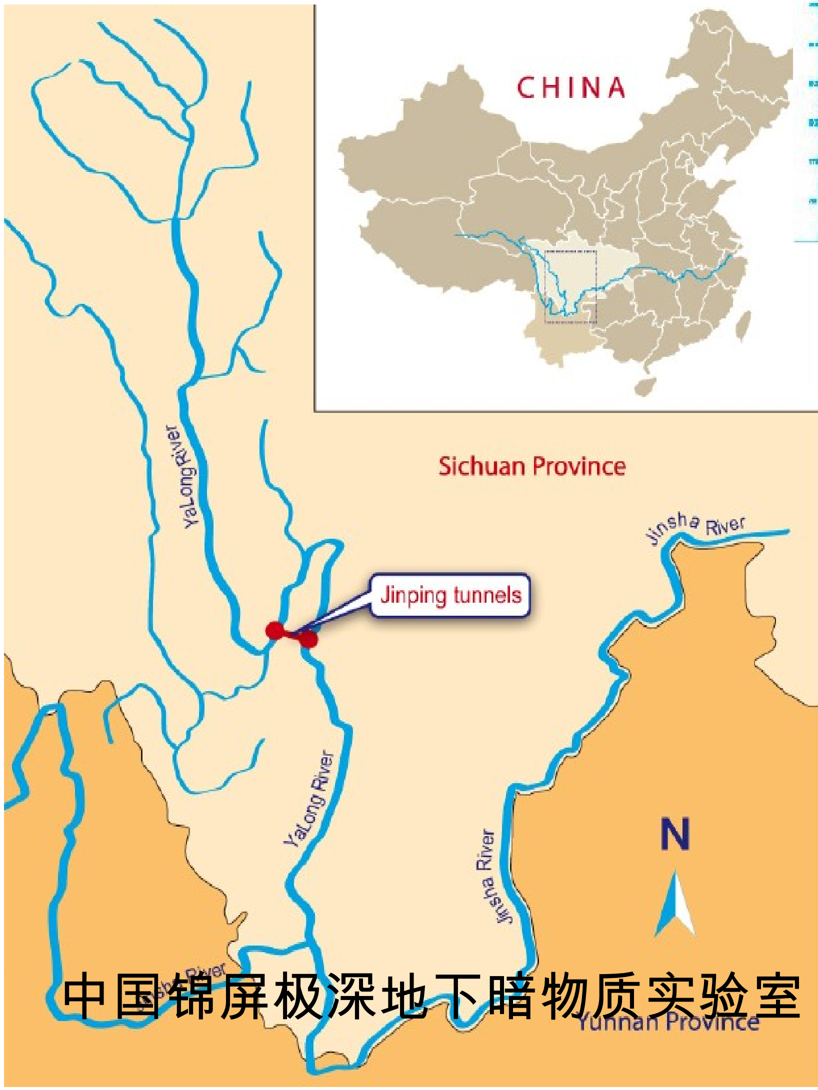
XENON100 arXiv1005.0380

PANDAX collaboration

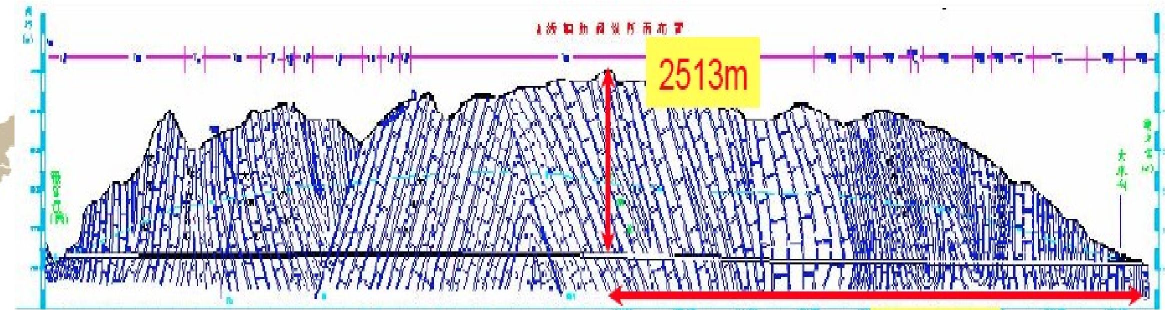
Particle AND Astro-particle Xenon Observatory
since 2009

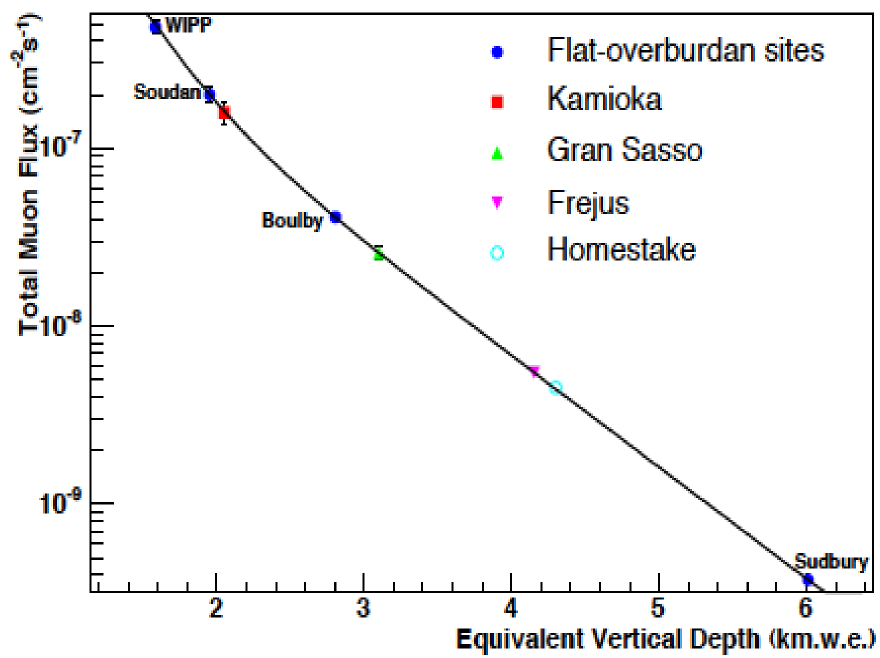
上海交通大学
上海应用物理研究所
山东大学

PANDAX in Sichuan (of course)



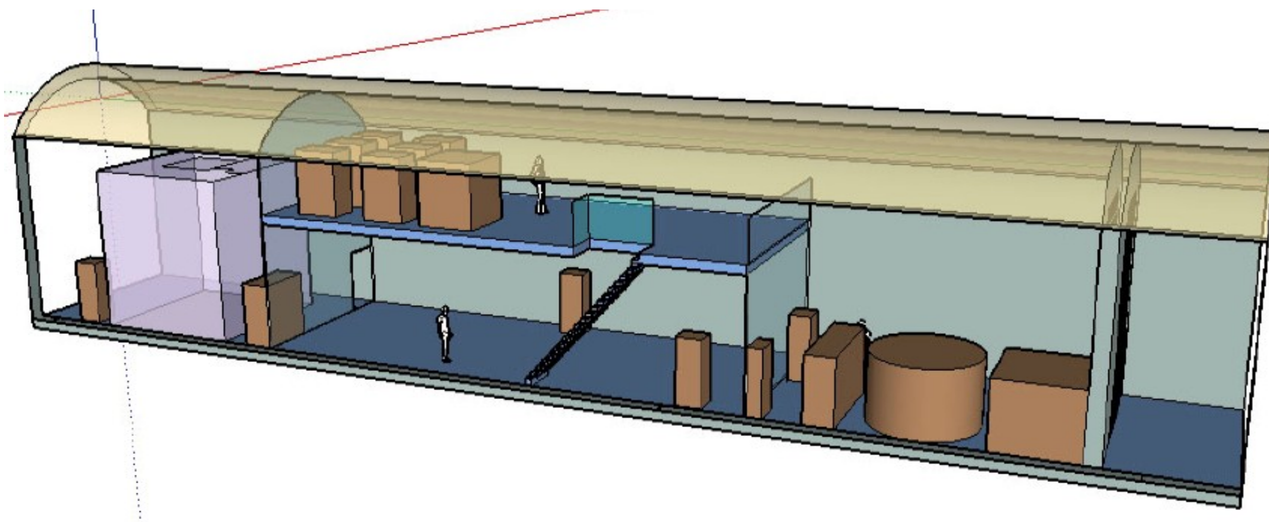
中国锦屏极深地下暗物质实验室

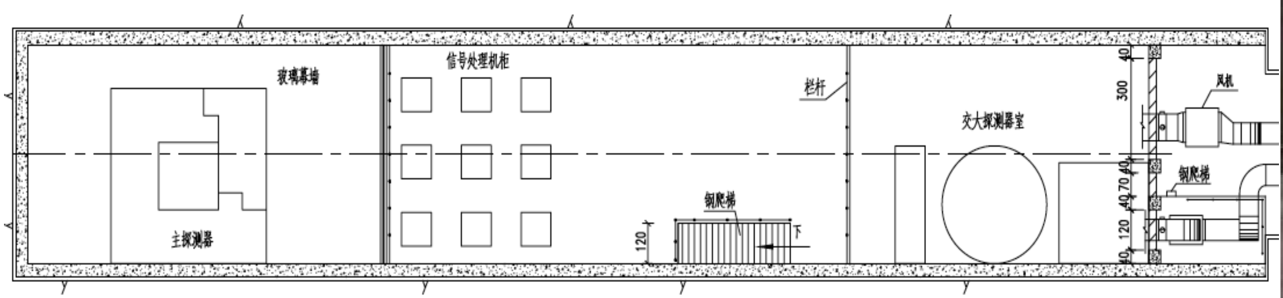


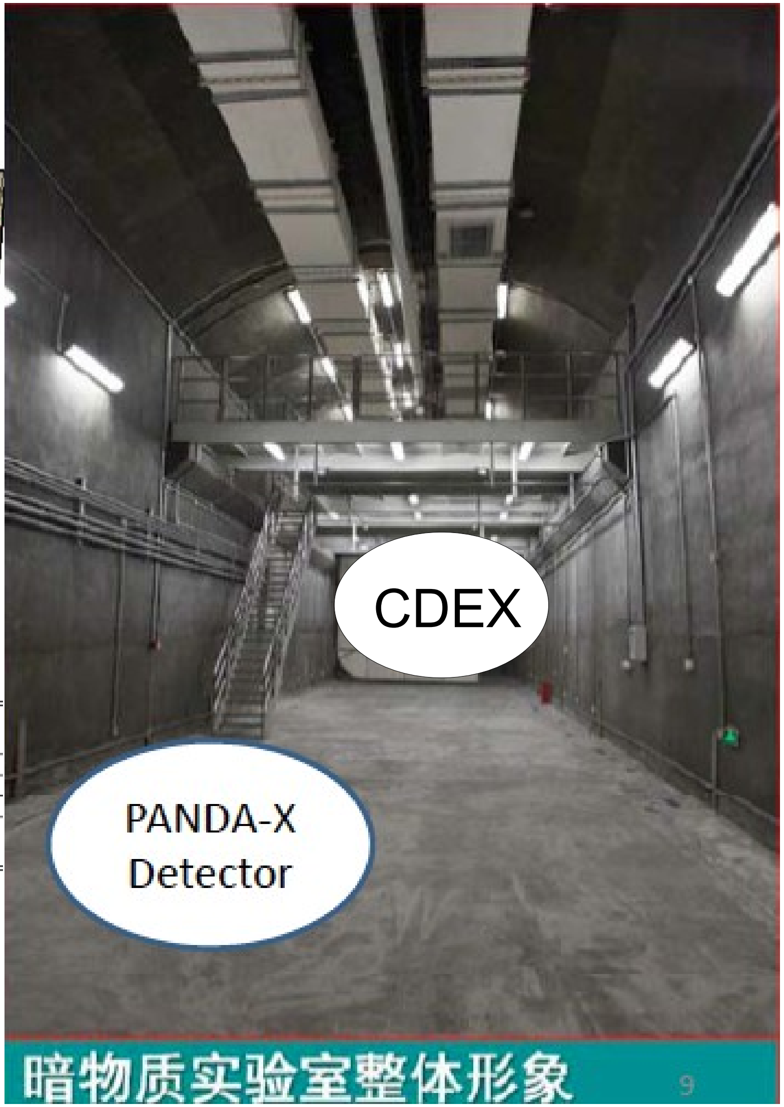


Cosmic muon 25-50/m^2 year

PANDAX in Sichuan (of course)

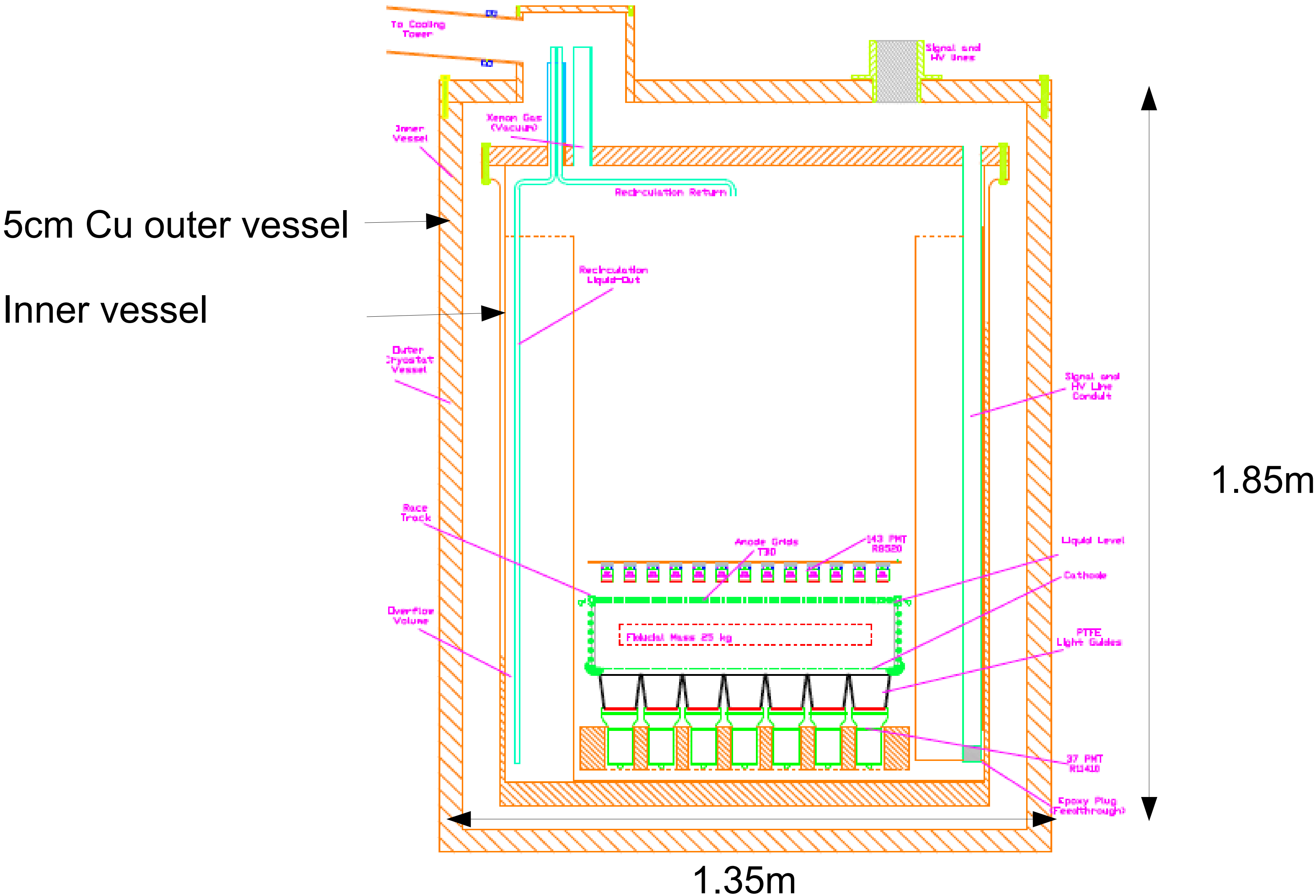




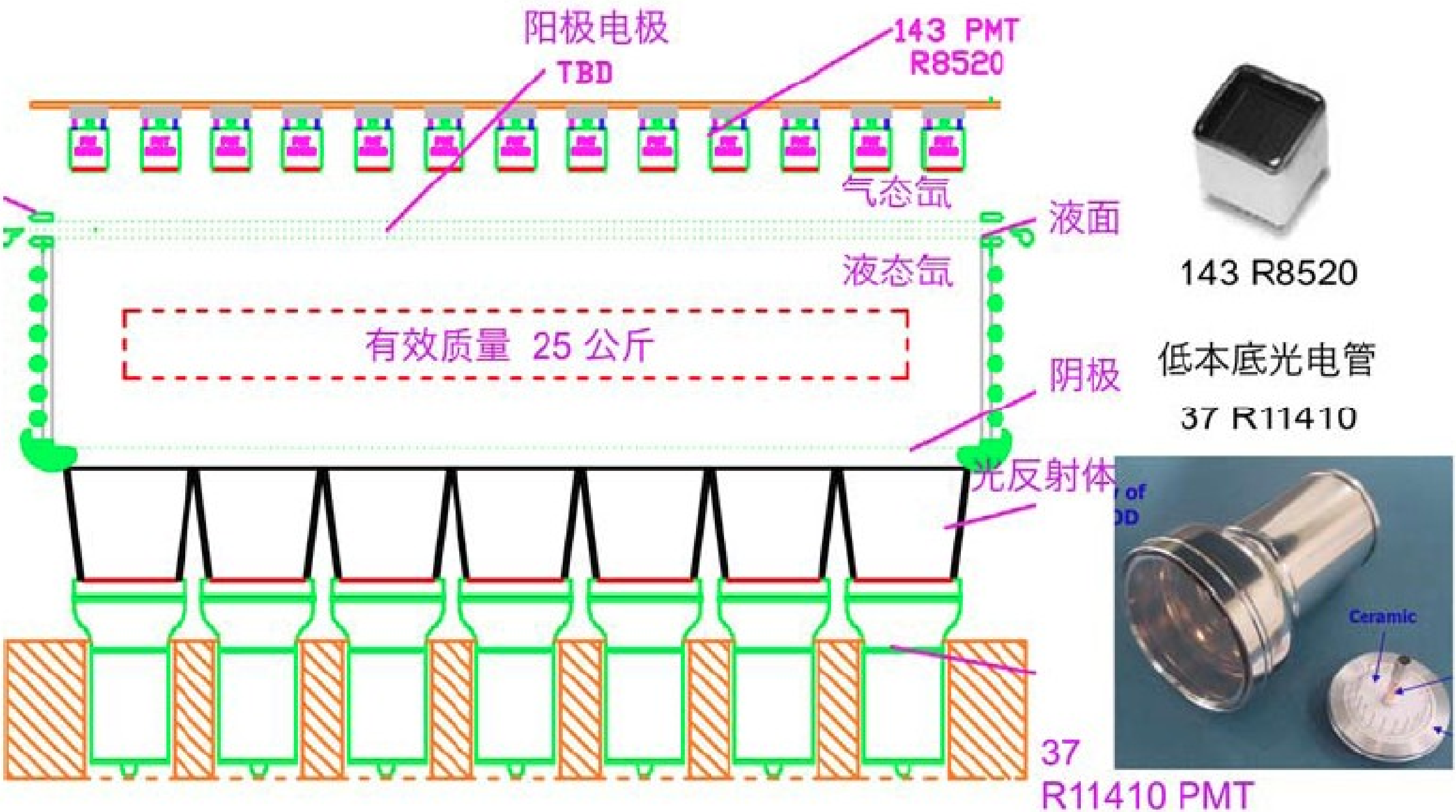


Many thanks to Tsinghua colleagues and Ertan company!

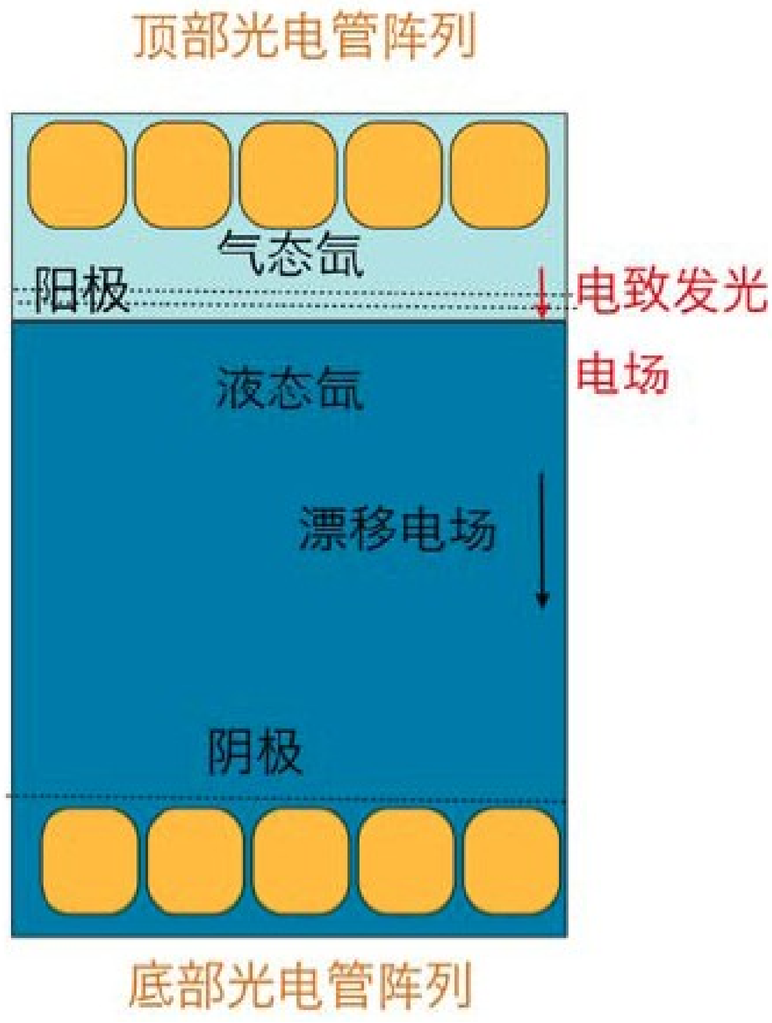
Detector overview



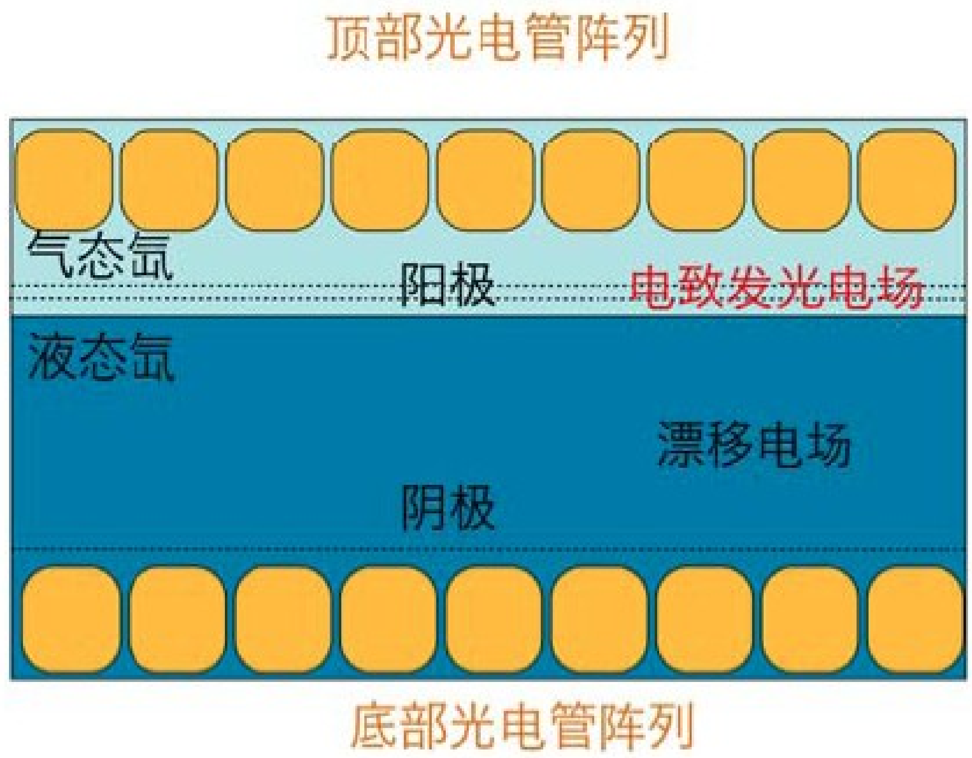
Inner detector



Disk-like Xenon TPC



XENON10/100



PANDAX

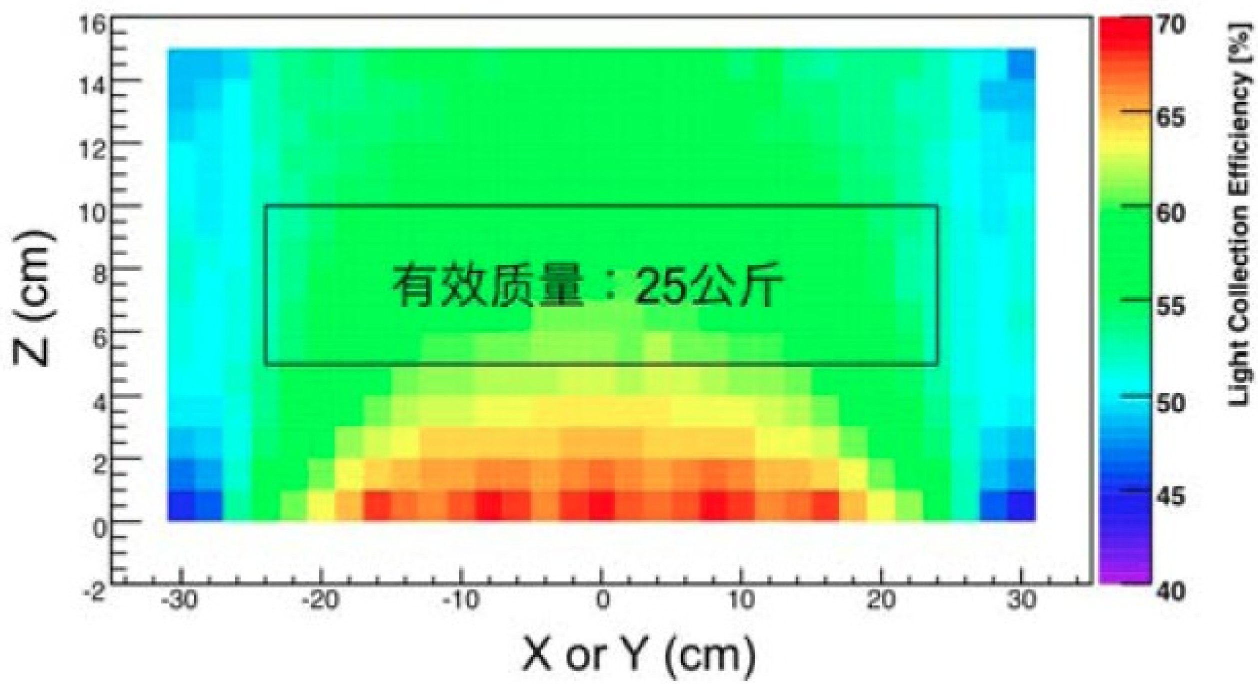
PANDAX vs. Xenon100

Parameter	XENON100	PANDA-X
LXe ID (m)	0.3	0.6
Drift distance (m)	0.3	0.15
Cathode voltage (kV)	-16	-75
Drift field (kV/cm)	0.53	5
Fiducial mass (kg)	40	25
# of R8520	242	143
# of R11410	0	37
S1 collection efficiency	24%	57%

Disk-like LXe

Disk-like advantage I

S1 light collection efficiency ε



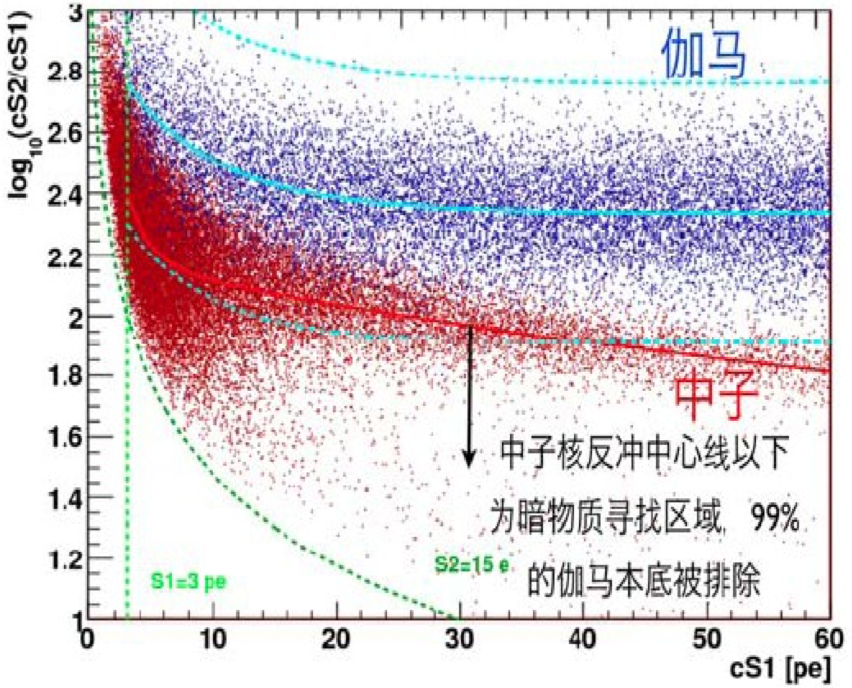
E_{NR} = S1 / ε / Fraction_E_in_scintillation

ε↑, E threshold ↓, { WIMP event rate ↑ / low-mass WIMP sensitivity ↑ }

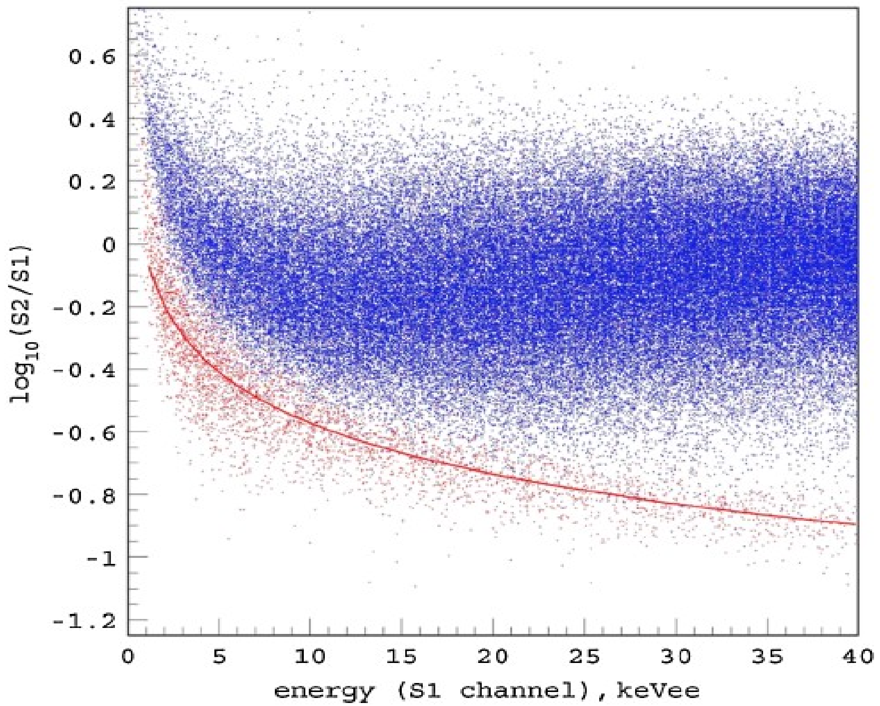
Xenon100, 4-20p.e. S1 signal, 8.7-32.6keV E_{NR}

PANDAX, 5keV E_{ER}

Disk-like advantage II



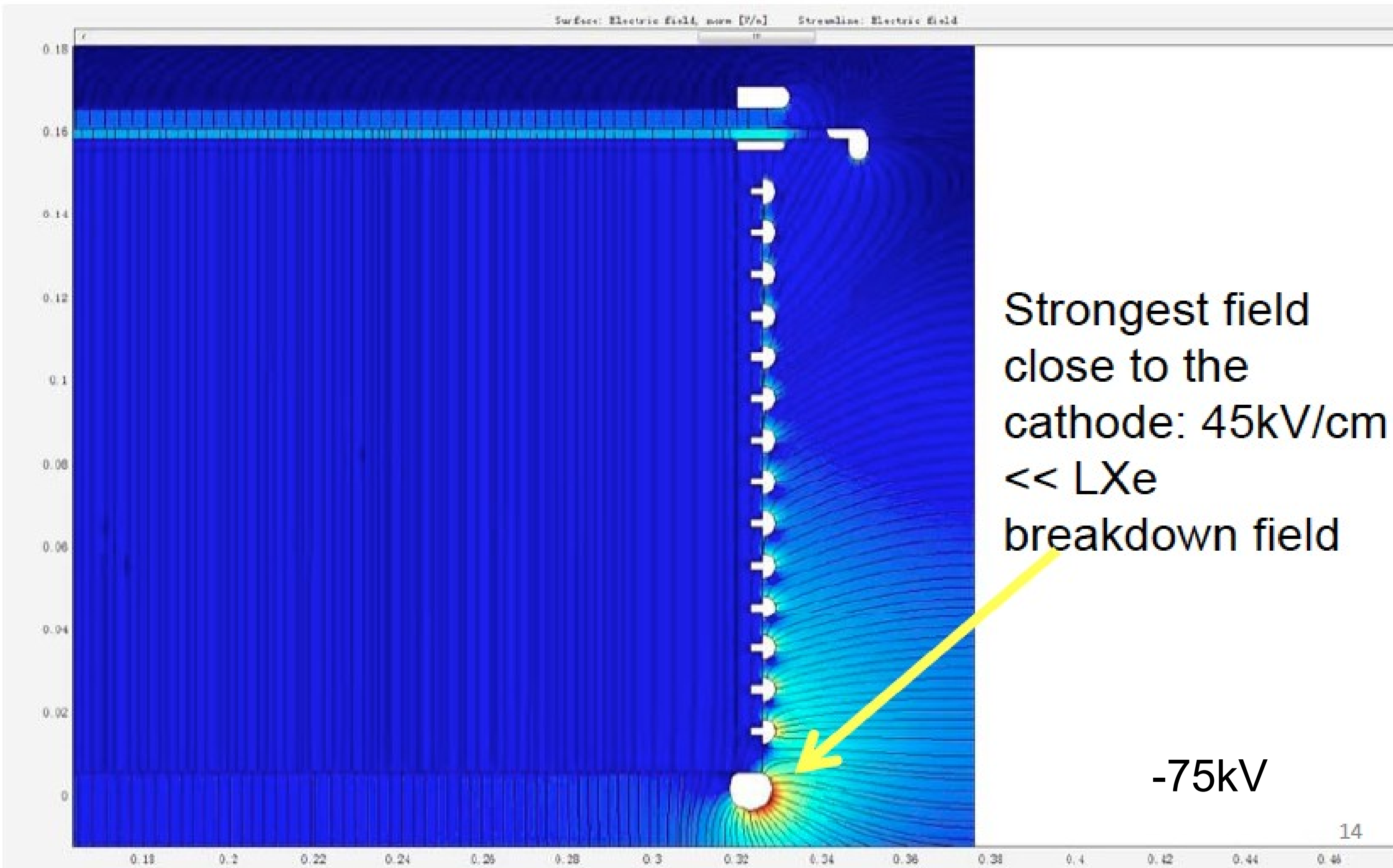
XENON100 E_{drift}=0.5kV/cm
99% gamma rejected



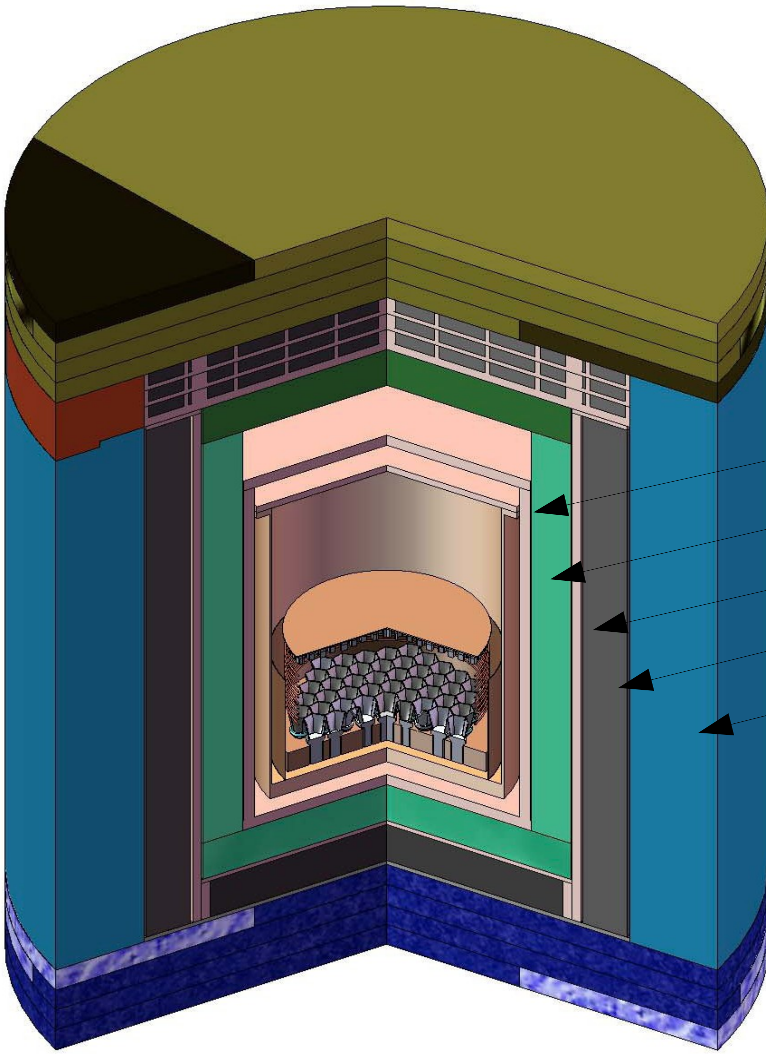
ZEPLIN-III E_{drift}=3.9kV/cm
99.9% gamma rejected

PRD 80, 052010 (2009)

Strong E field achievable



PANDAX Shielding



直径 3 米，高 3.6 米

从内向外：
5cm 铜
20cm 聚乙烯
5cm 铜
20cm 铅
40cm 聚乙烯

内部容积
高 160cm
直径 120cm

Goal set for ton-scale: external bg event in 5-15keV, < 1/ton year

External background

1, n/gamma from rock & concrete

材料	放射性元素含量[Bq/kg]		
	Ra226	Th232	K40
岩石	1.8 ± 0.2	< 0.27	< 1.1
水泥骨料	≈ 2	≈ 0.7	低于探测极限
水泥	≈ 60	≈ 25	≈ 130

2, cosmic muon and induced neutron

3, n/gamma from shielding material

4,

表 2，XENON100 实验屏蔽体材料的放射性元素含量，单位 mBq/kg。

材料	U238	Th232	Co60	K40	Pb210
铜	<0.07	<0.03	<0.0045	<0.06	
内层聚乙烯	0.23±0.05	<0.094	<0.89	0.7±0.4	
铅	<0.92	<0.72	<0.12	14±3	530±70

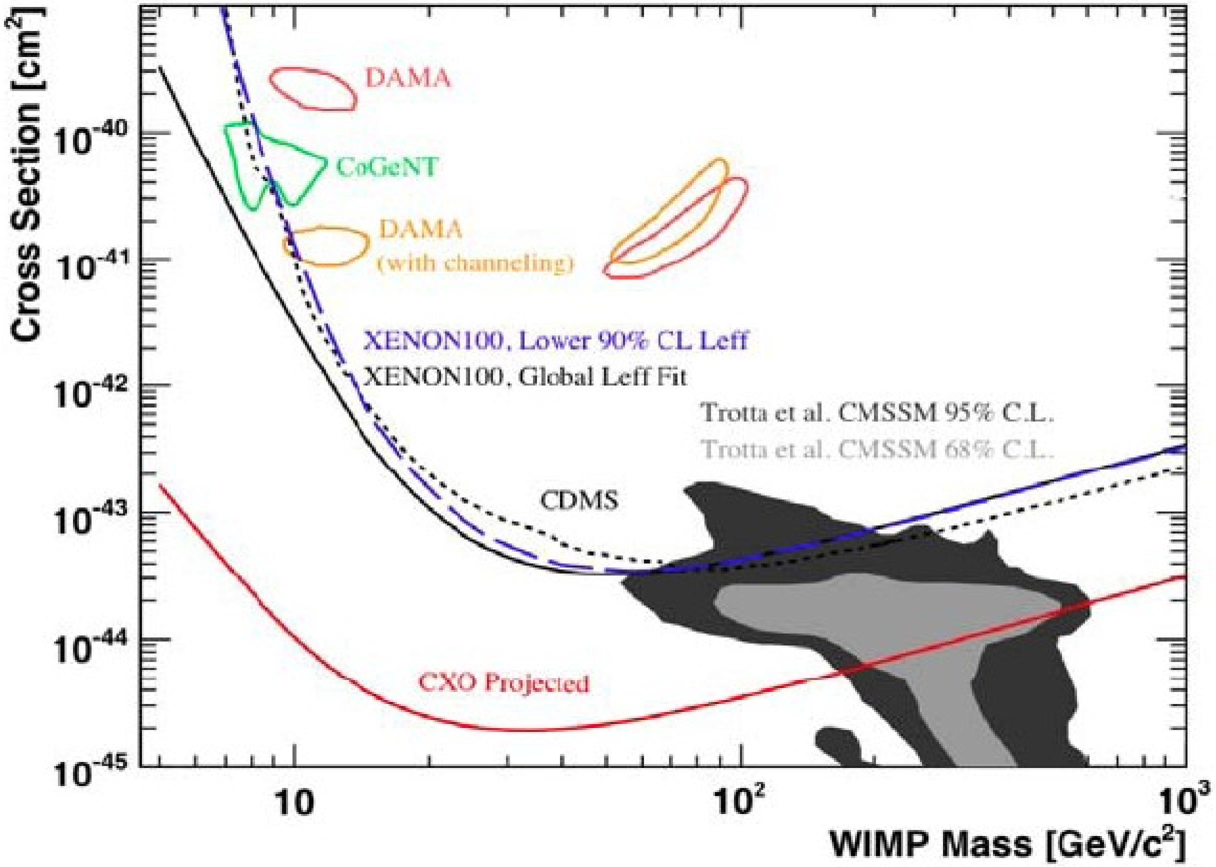
Shielding simulation results

Simulation based on Gean4.9.3
~1.15 event in 5-15keV / ton year
  0.5 from rock+concrete gamma
  0.6 from Cu gamma
  0.03 from Cu neutron

实验	所在地下实验室/探测器材料	铜（厘米）	铅（厘米）	聚乙烯（厘米）	屏蔽体内本底事例率（mdru）	内部容积（立方米）
XMASS	Kamioka / Xe	-	-	2 米水	0.1*** [6]	0.27
XENON100	LNGS / Xe	5	20	20	0.006**** [7]	0.67
LUX	DUSEL / Xe	-	-	3 米水	0.0005**** [8]	0.12
PANDAX	CJPL / Xe	>10	20	20+40	0.0002****	1.9

PANDAX projected sensitivity

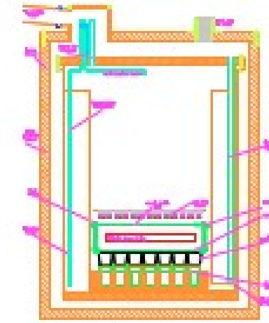
assume:
- light yield 5.5 p.e./keV
- energy range 3-30 p.e.
- 25kg x 200 days exposure



Comparison with other Xe-based DM exp.

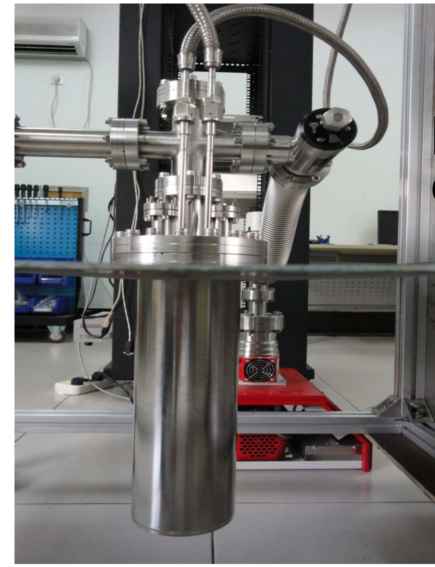






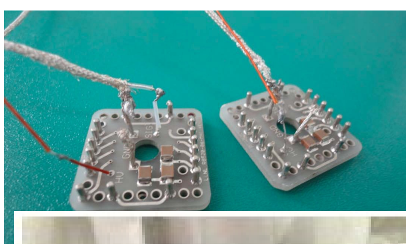
	ZEPLIN III	XENON100	XMASS	LUX	PandaX
active target mass (kg)	12	~60	~800 (100)	~300	~120
electron recoil rejection	99.9%	99%	0	99%	99.9%
energy threshold (keVr)	10	9	20	10	5
sensitivity at 100 GeV (cm^2)	$\sim 10^{-44}$	2×10^{-45}	1×10^{-45}	3×10^{-46}	4×10^{-45}
sensitivity at 10 GeV (cm^2)	$>10^{-42}$	3×10^{-43}	$> 10^{-42}$	4×10^{-44}	1×10^{-44}
status	science run	science run	operation	surface testing	construction

Current activities



prototype detector

PMT base



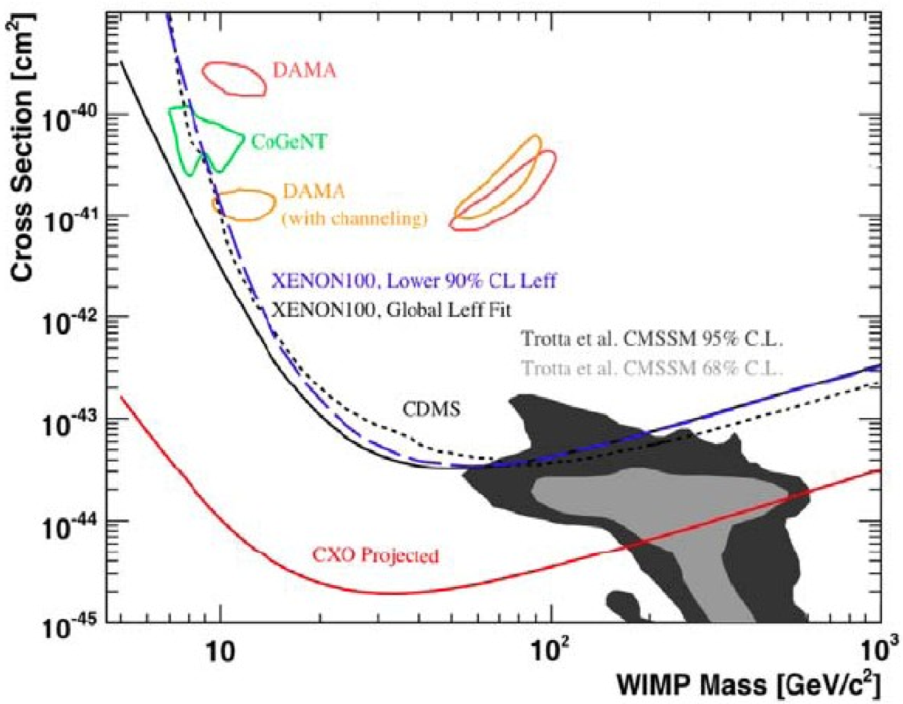
测量低本底材料放射性的探测器

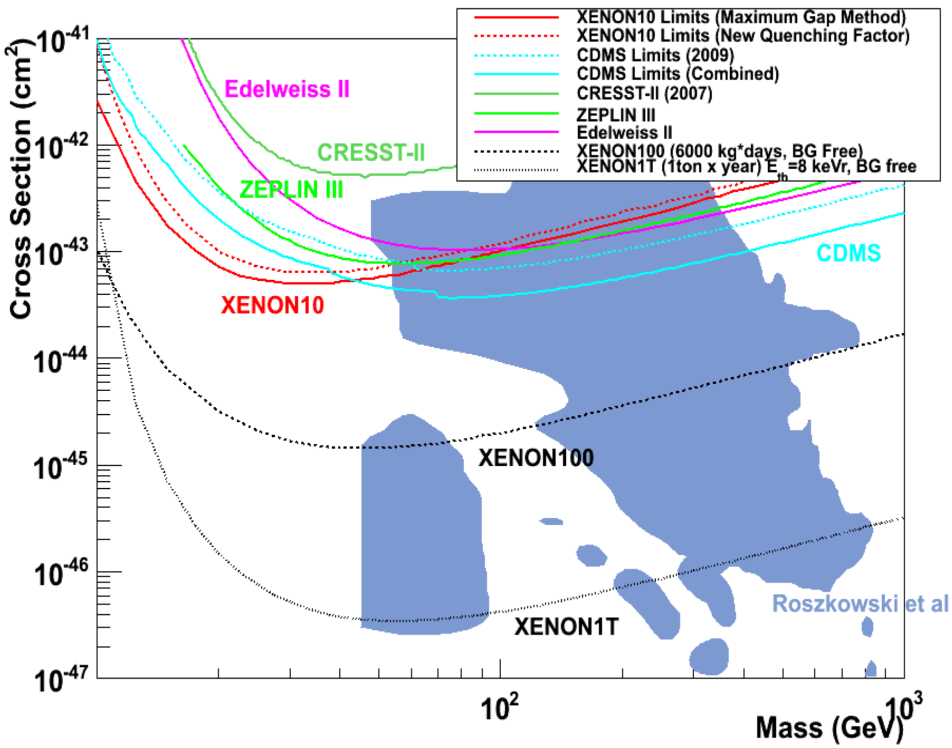
cryogenic testing

PMT testing facility

Summary

- exciting physics, strong competition.
- We must move forward fast.





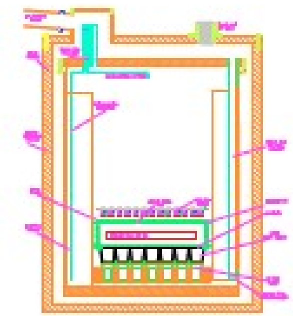
Thank you!

backup

Comparison with other Xe-based exp.







	ZEPLIN III	XENON100	XMASS	LUX	PandaX
technique	two-phase	two-phase	single-phase	two-phase	two-phase
active target mass (kg)	12	~60	~800 (100)	~300	~120

Energy Calibration: determine the energy of nuclear recoils

energy of nuclear recoils (NRs)

measured signal in # of pe

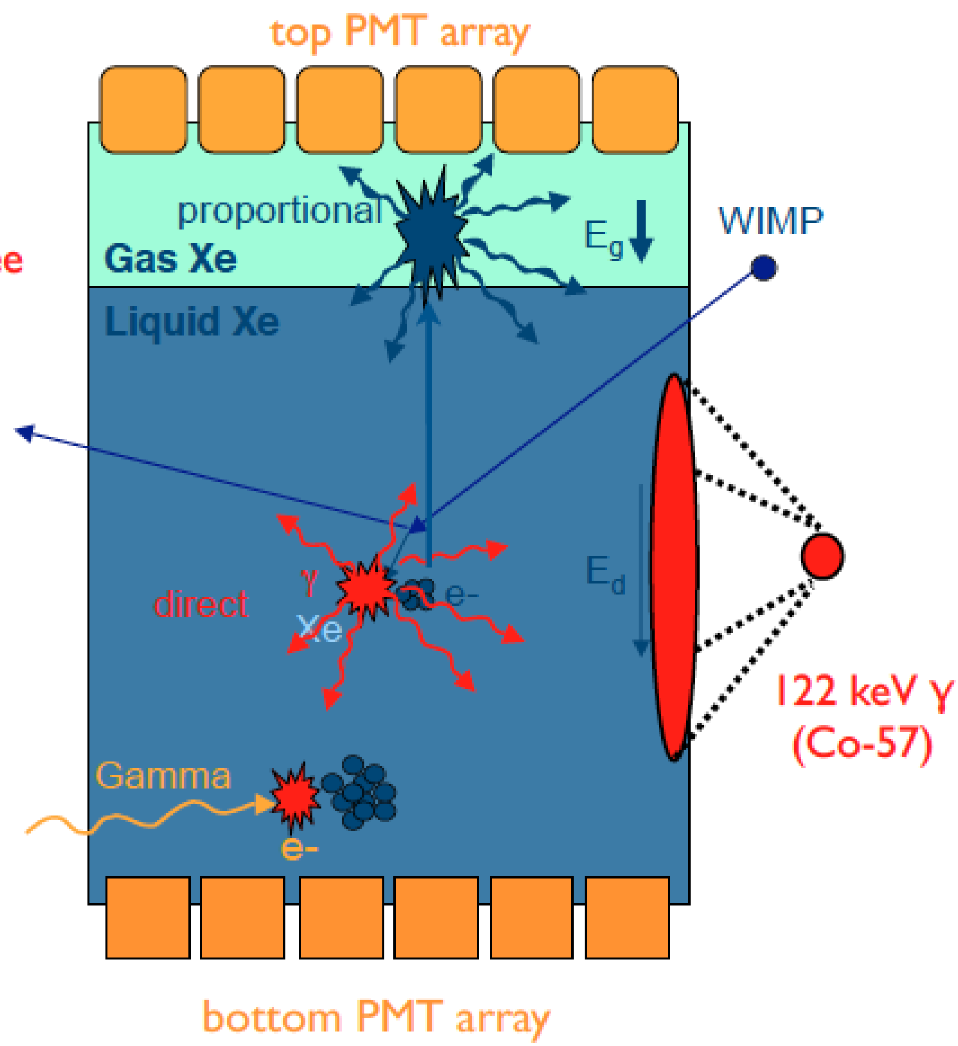
light yield for 122 keV γ in pe/keVee (detector dependent)

$$E_{nr} = S1/L_y/\mathcal{L}_{eff} \cdot S_{er}/S_{nr}$$

relative scintillation efficiency of NRs to 122 keV γ's at zero field (large uncertainty at low energy)

quenching of scintillation yield for 122 keV γ's due to drift field

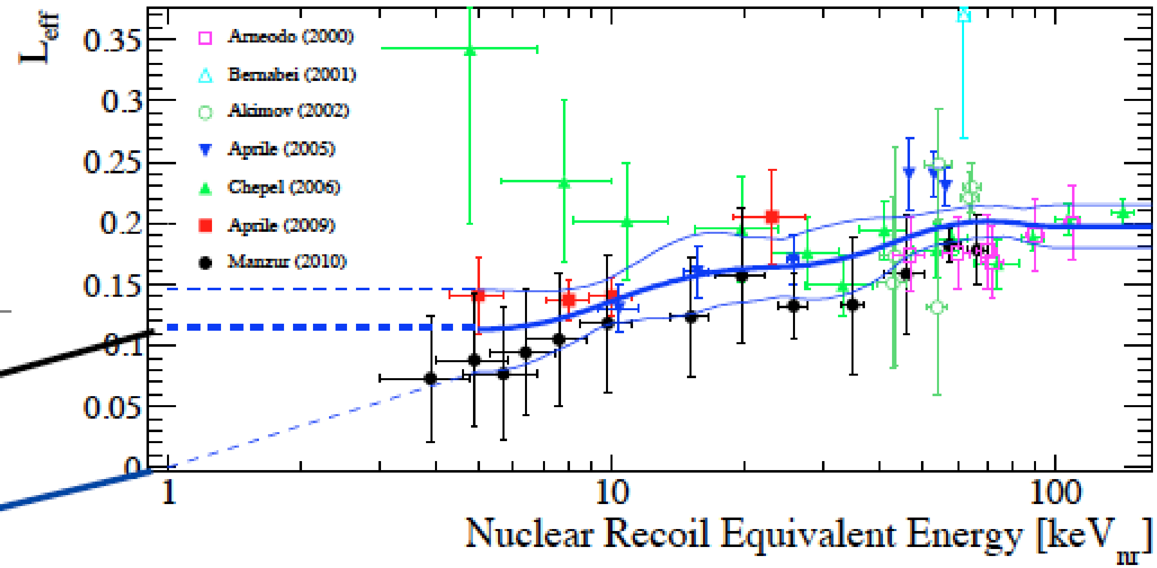
quenching of scintillation yield for NRs due to drift field

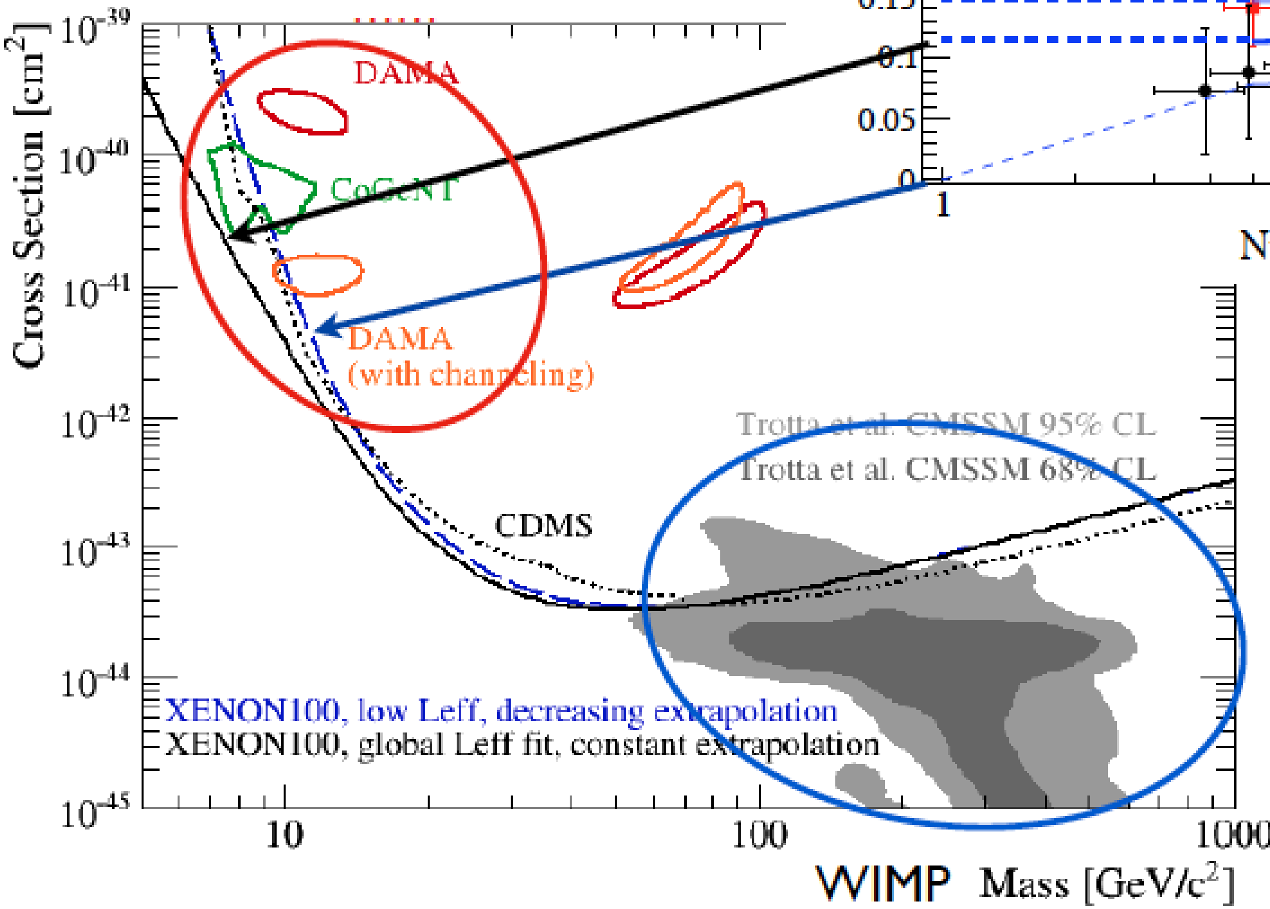


Achieved upper limits

“hot” low-mass wimps and debates:

1002.4703, 1005.0838, 1005.2615
1005.3723, 1006.0972, 1006.2031
1007.1005, 1009.0549, 1010.5187
......





achieved competing sensitivity for “normal” mass WIMPs

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