The 29th International Workshop on Weak Interactions and Neutrinos

The progress of ALHETHIA

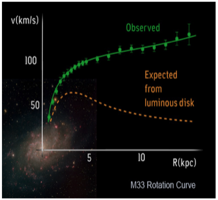
Outline

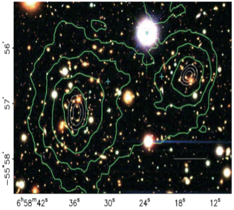
1. DM "review" (kind of)
   - DM should be there: astrophysicist and cosmologist
   - Particle physicists: where is the damn DM?
2. The challenges DM particle physicists face
   - Theoretically: Two many models → resources split
   - Experimentally, too many backgrounds → some dramas (if not jokes)
3. The opportunities for DM particle physicists
   - New thoughts/actions worldwide
   - My thoughts
4. The progress of the ALETHEIA project
   - ALETHEIA Introduction
   - ALETHEIA prototype detector: the 30g-V1 LHe
   - ALETHEIA prototype detector: TPB coating on a PTFE chamber
   - ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
   - Ongoing tests at CIAE
5. Summary

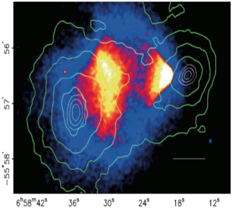
Outline

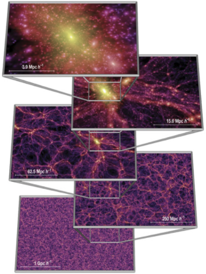
1. DM “review” (kind of)
   - DM should be there: astrophysicist and cosmologist
   - Particle physicists: where is the damn DM?
2. The challenges DM particle physicists face
   - Theoretically: Two many models → resources split
   - Experimentally, too many backgrounds → some dramas (if not jokes)
3. The opportunities for DM particle physicists
   - New thoughts/actions worldwide
   - My thoughts
4. The progress of the ALETHEIA project
   - ALETHEIA Introduction
   - ALETHEIA prototype detector: the 30g-V1 LHe
   - ALETHEIA prototype detector: TPB coating on a PTFE chamber
   - ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
   - Ongoing tests at CIAE
5. Summary

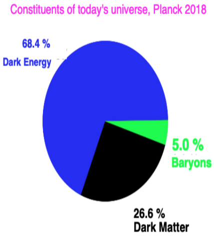
Astrophysical and cosmological evidence of DM existence.

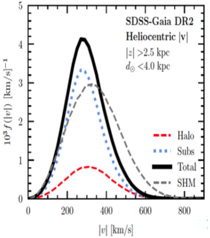










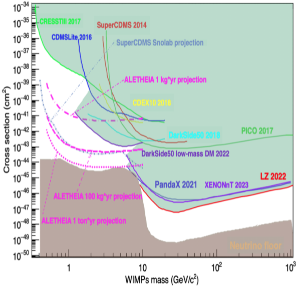


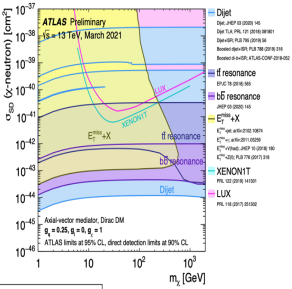
Astrophysicists and cosmologists working on DM (“缺口”官方MV).

Outline

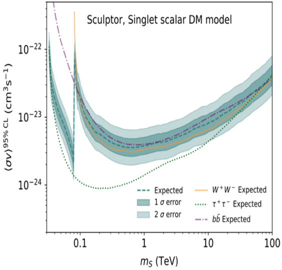
1. DM “review” (kind of)
   - DM should be there: astrophysicist and cosmologist
   - Particle physicists: where is the damn DM?
2. The challenges DM particle physicists face
   - Theoretically: Two many models → resources split
   - Experimentally, too many backgrounds → some dramas (if not jokes)
3. The opportunities for DM particle physicists
   - New thoughts/actions worldwide
   - My thoughts
4. The progress of the ALETHEIA project
   - ALETHEIA Introduction
   - ALETHEIA prototype detector: the 30g-V1 LHe
   - ALETHEIA prototype detector: TPB coating on a PTFE chamber
   - ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
   - Ongoing tests at CIAE
5. Summary

No any convincing DM signals from each and every hunting strategy.





ATL-PHYS-PROC-2022-003



arXiv: 2210.01220

Particle physicists working in DM. DM = Damn?

Research on DM: cosmologists V.S. particle physicists

- Left picture: Cosmologists working on DM.

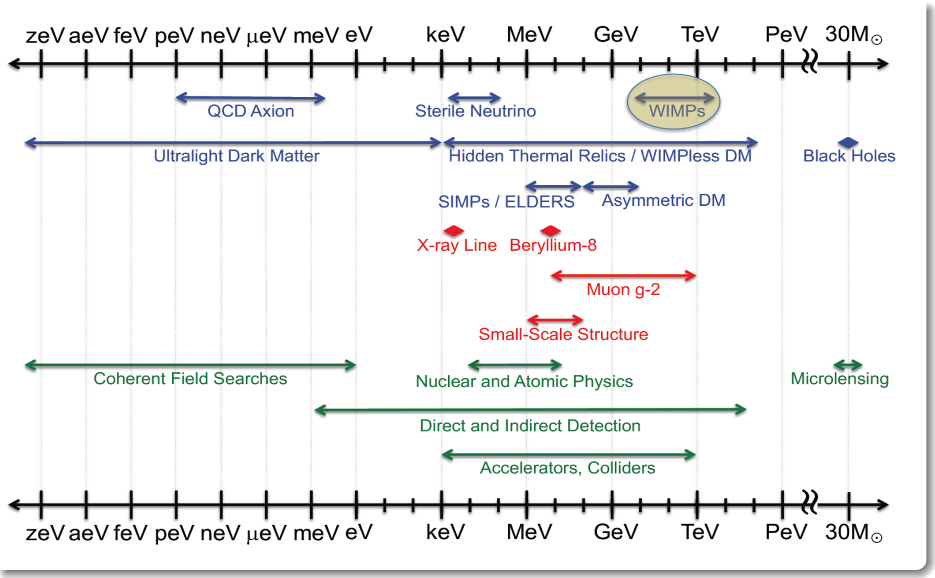
Research on DM: cosmologists V.S. particle physicists

- Left picture: Cosmologists working on DM.
- Right picture: Particle physicists working on DM.

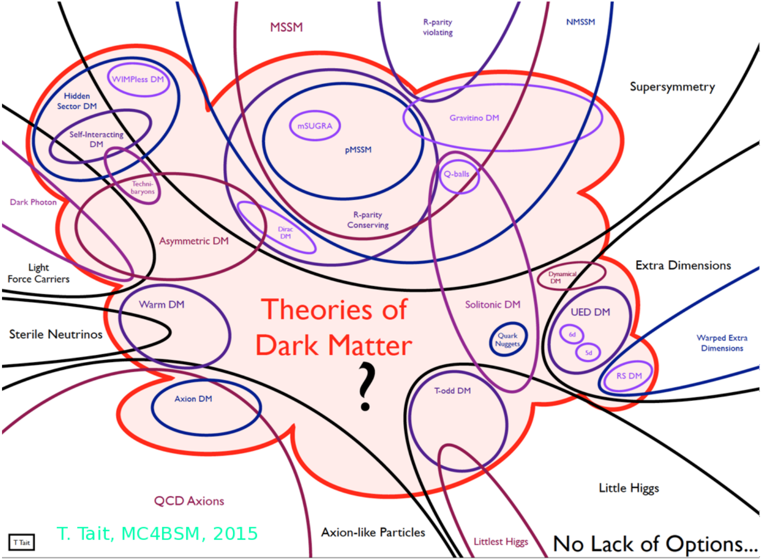
Outline

1. DM "review" (kind of)
   - DM should be there: astrophysicist and cosmologist
   - Particle physicists: where is the damn DM?
2. The challenges DM particle physicists face
   - Theoretically: Two many models → resources split
   - Experimentally, too many backgrounds → some dramas (if not jokes)
3. The opportunities for DM particle physicists
   - New thoughts/actions worldwide
   - My thoughts
4. The progress of the ALETHEIA project
   - ALETHEIA Introduction
   - ALETHEIA prototype detector: the 30g-V1 LHe
   - ALETHEIA prototype detector: TPB coating on a PTFE chamber
   - ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
   - Ongoing tests at CIAE
5. Summary

DM mass range: 100 orders (arxiv:2212.02479)



Too many models, mainly on particle DM.



Even for the WIMPs model, under EFT, there are 20 interactions.

N. Anard etc, arXiv: 1308.6288

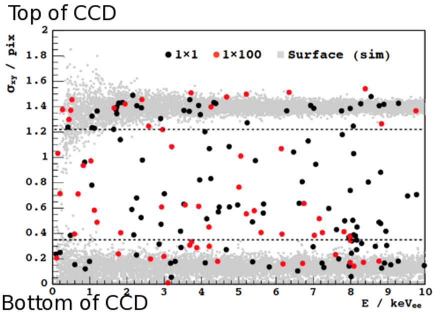
j	$\mathcal{L}^j_{\rm int}$	Nonrelativistic reduction	$\sum_i c_i \mathcal{O}_i$	P/T
1	$\bar\chi\chi\bar N N$	$1_\chi 1_N$	$\mathcal{O}_1$	E/E
2	$i\bar\chi\chi\bar N\gamma^5 N$	$i\frac{\vec q}{m_N}\cdot\vec S_N$	$\mathcal{O}_{10}$	O/O
3	$i\bar\chi\gamma^5\chi\bar N N$	$-i\frac{\vec q}{m_\chi}\cdot\vec S_\chi$	$-\frac{m_N}{m_\chi}\mathcal{O}_{11}$	O/O
4	$\bar\chi\gamma^5\chi\bar N\gamma^5 N$	$-\frac{\vec q}{m_\chi}\cdot\vec S_\chi\frac{\vec q}{m_N}\cdot\vec S_N$	$-\frac{m_N}{m_\chi}\mathcal{O}_6$	E/E
5	$\bar\chi\gamma^\mu\chi\bar N\gamma_\mu N$	$1_\chi 1_N$	$\mathcal{O}_1$	E/E
6	$\bar\chi\gamma^\mu\chi\bar N i\sigma_{\mu\alpha}\frac{q^\alpha}{m_M}N$	$\frac{\vec q^{\,2}}{2m_N m_M}1_\chi 1_N + 2(\frac{\vec q}{m_\chi}\times\vec S_\chi + i\vec v^\perp)\cdot(\frac{\vec q}{m_M}\times\vec S_N)$	$\frac{\vec q^{\,2}}{2m_N m_M}\mathcal{O}_1 - 2\frac{m_N}{m_M}\mathcal{O}_3$ $+2\frac{m_N^2}{m_M m_\chi}(\frac{q^2}{m_N^2}\mathcal{O}_4 - \mathcal{O}_6)$	E/E
7	$\bar\chi\gamma^\mu\chi\bar N\gamma_\mu\gamma^5 N$	$-2\vec S_N\cdot\vec v^\perp + \frac{2}{m_\chi}i\vec S_\chi\cdot(\vec S_N\times\vec q)$	$-2\mathcal{O}_7 + 2\frac{m_N}{m_\chi}\mathcal{O}_9$	O/E
8	$i\bar\chi\gamma^\mu\chi\bar N i\sigma_{\mu\alpha}\frac{q^\alpha}{m_M}\gamma^5 N$	$2i\frac{\vec q}{m_M}\cdot\vec S_N$	$2\frac{m_N}{m_M}\mathcal{O}_{10}$	O/O
9	$\bar\chi i\sigma^{\mu\nu}\frac{q_\nu}{m_M}\chi\bar N\gamma_\mu N$	$-\frac{\vec q^{\,2}}{2m_\chi m_M}1_\chi 1_N - 2(\frac{\vec q}{m_N}\times\vec S_N + i\vec v^\perp)\cdot(\frac{\vec q}{m_M}\times\vec S_\chi)$	$-\frac{\vec q^{\,2}}{2m_\chi m_M}\mathcal{O}_1 + \frac{2m_N}{m_M}\mathcal{O}_5$ $-2\frac{m_N}{m_M}(\frac{\vec q^{\,2}}{m_N^2}\mathcal{O}_4 - \mathcal{O}_6)$	E/E
10	$\bar\chi i\sigma^{\mu\nu}\frac{q_\nu}{m_M}\chi\bar N i\sigma_{\mu\alpha}\frac{q^\alpha}{m_M}N$	$4(\frac{\vec q}{m_M}\times\vec S_\chi)\cdot(\frac{\vec q}{m_M}\times\vec S_N)$	$4(\frac{\vec q^{\,2}}{m_M^2}\mathcal{O}_4 - \frac{m_N^2}{m_M^2}\mathcal{O}_6)$	E/E
11	$\bar\chi i\sigma^{\mu\nu}\frac{q_\nu}{m_M}\chi\bar N\gamma^\mu\gamma^5 N$	$4i(\frac{\vec q}{m_M}\times\vec S_\chi)\cdot\vec S_N$	$4\frac{m_N}{m_M}\mathcal{O}_9$	O/E
12	$i\bar\chi i\sigma^{\mu\nu}\frac{q_\nu}{m_M}\chi\bar N i\sigma_{\mu\alpha}\frac{q^\alpha}{m_M}\gamma^5 N$	$-[i\frac{\vec q^{\,2}}{m_\chi m_M} - 4\vec v^\perp\cdot(\frac{\vec q}{m_M}\times\vec S_\chi)]\frac{\vec q}{m_M}\cdot\vec S_N$	$-\frac{m_N}{m_\chi}\frac{\vec q^{\,2}}{m_M^2}\mathcal{O}_{10} - 4\frac{\vec q^{\,2}}{m_M^2}\mathcal{O}_{12} - 4\frac{m_N^2}{m_M^2}\mathcal{O}_{15}$	O/O
13	$\bar\chi\gamma^\mu\gamma^5\chi\bar N\gamma_\mu N$	$2\vec v^\perp\cdot\vec S_\chi + 2i\vec S_\chi\cdot(\vec S_N\times\frac{\vec q}{m_N})$	$2\mathcal{O}_8 + 2\mathcal{O}_9$	O/E
14	$\bar\chi\gamma^\mu\gamma^5\chi\bar N i\sigma_{\mu\alpha}\frac{q^\alpha}{m_M}N$	$4i\vec S_\chi\cdot(\frac{\vec q}{m_M}\times\vec S_N)$	$-4\frac{m_N}{m_M}\mathcal{O}_9$	O/E
15	$\bar\chi\gamma^\mu\gamma^5\chi\bar N\gamma^\mu\gamma^5 N$	$-4\vec S_\chi\cdot\vec S_N$	$-4\mathcal{O}_4$	E/E
16	$i\bar\chi\gamma^\mu\gamma^5\chi\bar N i\sigma_{\mu\alpha}\frac{q^\alpha}{m_M}\gamma^5 N$	$4i\vec v^\perp\cdot\vec S_\chi\frac{\vec q}{m_M}\cdot\vec S_N$	$4\frac{m_N}{m_M}\mathcal{O}_{13}$	E/O
17	$i\bar\chi i\sigma^{\mu\nu}\frac{q_\nu}{m_M}\gamma^5\chi\bar N\gamma_\mu N$	$2i\frac{\vec q}{m_M}\cdot\vec S_\chi$	$2\frac{m_N}{m_M}\mathcal{O}_{11}$	O/O
18	$i\bar\chi i\sigma^{\mu\nu}\frac{q_\nu}{m_M}\gamma^5\chi\bar N i\sigma_{\mu\alpha}\frac{q^\alpha}{m_M}N$	$\frac{\vec q}{m_M}\cdot\vec S_\chi[i\frac{\vec q^{\,2}}{m_N m_M} - 4\vec v^\perp\cdot(\frac{\vec q}{m_M}\times\vec S_N)]$	$\frac{\vec q^{\,2}}{m_M^2}\mathcal{O}_{11} + 4\frac{m_N^2}{m_M^2}\mathcal{O}_{15}$	O/O
19	$i\bar\chi i\sigma^{\mu\nu}\frac{q_\nu}{m_M}\gamma^5\chi\bar N\gamma_\mu\gamma^5 N$	$-4i\frac{\vec q}{m_M}\cdot\vec S_\chi\vec v_\perp\cdot\vec S_N$	$-4\frac{m_N}{m_M}\mathcal{O}_{14}$	E/O
20	$i\bar\chi i\sigma^{\mu\nu}\frac{q_\nu}{m_M}\gamma^5\chi\bar N i\sigma_{\mu\alpha}\frac{q^\alpha}{m_M}\gamma^5 N$	$4\frac{\vec q}{m_M}\cdot\vec S_\chi\frac{\vec q}{m_M}\cdot\vec S_N$	$4\frac{m_N^2}{m_M^2}\mathcal{O}_6$	E/E

Outline

1. DM “review” (kind of)
   - DM should be there: astrophysicist and cosmologist
   - Particle physicists: where is the damn DM?
2. The challenges DM particle physicists face
   - Theoretically: Two many models → resources split
   - Experimentally, too many backgrounds → some dramas (if not jokes)
3. The opportunities for DM particle physicists
   - New thoughts/actions worldwide
   - My thoughts
4. The progress of the ALETHEIA project
   - ALETHEIA Introduction
   - ALETHEIA prototype detector: the 30g-V1 LHe
   - ALETHEIA prototype detector: TPB coating on a PTFE chamber
   - ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
   - Ongoing tests at CIAE
5. Summary

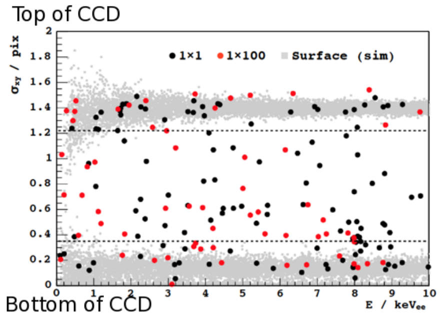
Bkgs in DAMIC and SuperCDMS.

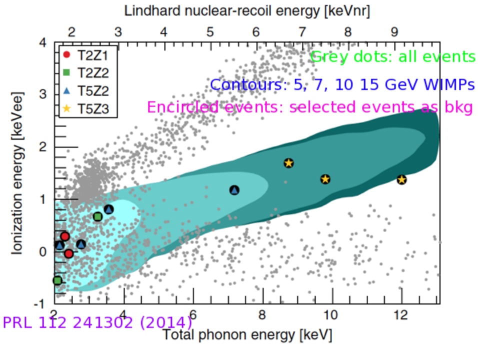
- Left plot : DAMIC data, the survived events are in between two dotted lines. CCD thickness on the plot: ~ 300 μm.



Bkgs in DAMIC and SuperCDMS.

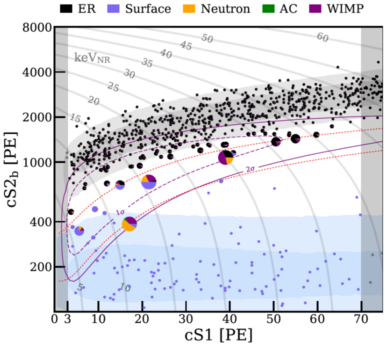
- Left plot : DAMIC data, the survived events are in between two dotted lines. CCD thickness on the plot: ~ 300 μm.
- Right plot : SuperCDMS events. The 11 colorful events have been picked up as the desired backgrounds, among survived events sea (grey).





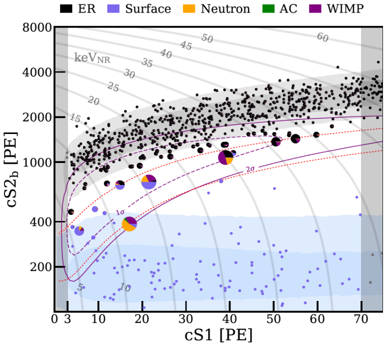
Bkgs in XENON-1T and LUX

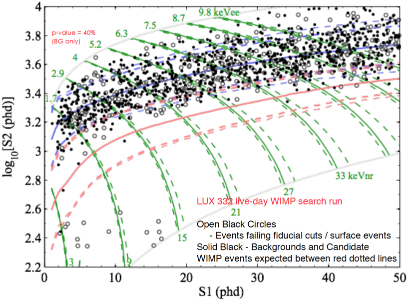
- Left plot : XENON-1T, arXiv: 1805.12562; PRL 121, 111302(2018).



Bkgs in XENON-1T and LUX

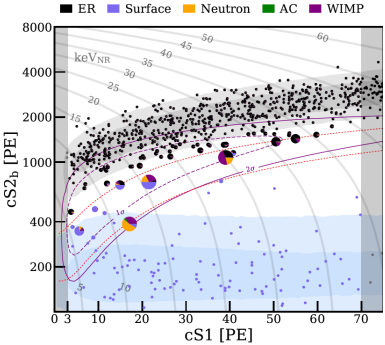
- Left plot : XENON-1T, arXiv: 1805.12562; PRL 121, 111302(2018).
- Right plot : LUX, PRL 118, 021303 (2017).

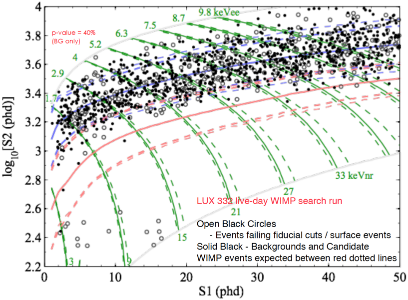




Bkgs in XENON-1T and LUX

- Left plot : XENON-1T, arXiv: 1805.12562; PRL 121, 111302(2018).
- Right plot : LUX, PRL 118, 021303 (2017).





- LUX and XENON-1T are both LXe TPC.

Outline

1 DM “review” (kind of)
- DM should be there: astrophysicist and cosmologist
- Particle physicists: where is the damn DM?

2 The challenges DM particle physicists face
- Theoretically: Two many models → resources split
- Experimentally, too many backgrounds → some dramas (if not jokes)

3 The opportunities for DM particle physicists
- New thoughts/actions worldwide
- My thoughts

4 The progress of the ALETHEIA project
- ALETHEIA Introduction
- ALETHEIA prototype detector: the 30g-V1 LHe
- ALETHEIA prototype detector: TPB coating on a PTFE chamber
- ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
- Ongoing tests at CIAE

5 Summary

- EU: Direct detection of dark matter – APPEC committee report, arXiv: 2104.07634.

- EU: Direct detection of dark matter – APPEC committee report, arXiv: 2104.07634.
- US: the Snowmass 2021 meeting (P5). arXiv: 2211.09978, 2203.07700, 2209.07426, 2203.08297, ...

- EU: Direct detection of dark matter – APPEC committee report, arXiv: 2104.07634.
- US: the Snowmass 2021 meeting (P5). arXiv: 2211.09978, 2203.07700, 2209.07426, 2203.08297, ...
- LXe community, LZ + XENON → a new LXe collaboration;
  LAr, DEAP + DS20k + ArDM + ... → a new LAr collaboration.

- EU: Direct detection of dark matter – APPEC committee report, arXiv: 2104.07634.
- US: the Snowmass 2021 meeting (P5). arXiv: 2211.09978, 2203.07700, 2209.07426, 2203.08297, ...
- LXe community, LZ + XENON → a new LXe collaboration; LAr, DEAP + DS20k + ArDM + ... → a new LAr collaboration.
- China: CEDX 50 kg HPGe, PandaX-30T (?), DS-1ton for low-mass DM (?); ALETHEIA, R&D stage

- EU: Direct detection of dark matter – APPEC committee report, arXiv: 2104.07634.
- US: the Snowmass 2021 meeting (P5). arXiv: 2211.09978, 2203.07700, 2209.07426, 2203.08297, ...
- LXe community, LZ + XENON → a new LXe collaboration;
  LAr, DEAP + DS20k + ArDM + ... → a new LAr collaboration.
- China: CEDX 50 kg HPGe, PandaX-30T (?), DS-1ton for low-mass DM (?); ALETHEIA, R&D stage
- ALETHEIA progressed significantly since 2020: demonstrated the viability of single-phase LHe TPCs;
  R&D underway: dual-phase LHe TPCs.

Outline

1 DM "review" (kind of)
- DM should be there: astrophysicist and cosmologist
- Particle physicists: where is the damn DM?

2 The challenges DM particle physicists face
- Theoretically: Two many models → resources split
- Experimentally, too many backgrounds → some dramas (if not jokes)

3 The opportunities for DM particle physicists
- New thoughts/actions worldwide
- My thoughts

4 The progress of the ALETHEIA project
- ALETHEIA Introduction
- ALETHEIA prototype detector: the 30g-V1 LHe
- ALETHEIA prototype detector: TPB coating on a PTFE chamber
- ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
- Ongoing tests at CIAE

5 Summary

A search with no model bias: ER is not necessary to be bkgs.

- Considering tens of elementary particles in the SM, reasonable to assume there are more than one type of DM particle; some generate ER, some NR $\Longrightarrow$ ER and NR could co-exist in a DM detector's same dataset.

A search with no model bias: ER is not necessary to be bkgs.

- Traditionally, WIMPs suppose to generate NR events; actually, it could generate ER events also, PRD 85.076007 $\Rightarrow$
  Even if DM is all made of WIMPs, it could generate both ER and NR events.
- Considering tens of elementary particles in the SM, reasonable to assume there are more than one type of DM particle; some generate ER, some NR $\Rightarrow$
  ER and NR could co-exist in a DM detector's same dataset.

A search with no model bias: ER is not necessary to be bkgs.

- Traditionally, WIMPs suppose to generate NR events; actually, it could generate ER events also, PRD 85.076007 $\Rightarrow$
  Even if DM is all made of WIMPs, it could generate both ER and NR events.
- Considering tens of elementary particles in the SM, reasonable to assume there are more than one type of DM particle; some generate ER, some NR $\Rightarrow$
  ER and NR could co-exist in a DM detector's same dataset.
- From a DM detector's point of view: there could exist three possible excesses: (a) ER excess only, (b) NR excess only, or (c) ER and NR excesses co-existening.

A search with no model bias: ER is not necessary to be bkgs.

- Traditionally, WIMPs suppose to generate NR events; actually, it could generate ER events also, PRD 85.076007 ⇒
  Even if DM is all made of WIMPs, it could generate both ER and NR events.
- Considering tens of elementary particles in the SM, reasonable to assume there are more than one type of DM particle; some generate ER, some NR ⇒
  ER and NR could co-exist in a DM detector's same dataset.
- From a DM detector's point of view: there could exist three possible excesses: (a) ER excess only, (b) NR excess only, or (c) ER and NR excesses co-existening.
- To be able to handle the three possible excesses, single-digit numbers of ER and NR background events are desired ← ALETHEIA can do that.

A search with no model bias: ER is not necessary to be bkgs.

- Traditionally, WIMPs suppose to generate NR events; actually, it could generate ER events also, PRD 85.076007 ⇒
  Even if DM is all made of WIMPs, it could generate both ER and NR events.
- Considering tens of elementary particles in the SM, reasonable to assume there are more than one type of DM particle; some generate ER, some NR ⇒
  ER and NR could co-exist in a DM detector's same dataset.
- From a DM detector's point of view: there could exist three possible excesses: (a) ER excess only, (b) NR excess only, or (c) ER and NR excesses co-existening.
- To be able to handle the three possible excesses, single-digit numbers of ER and NR background events are desired ← ALETHEIA can do that.
- For more details, arXiv: 2302.12406.

Outline

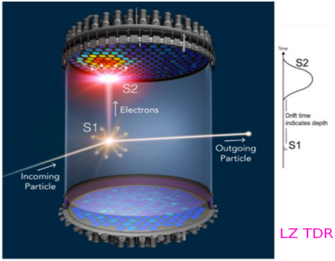
1. DM "review" (kind of)
   - DM should be there: astrophysicist and cosmologist
   - Particle physicists: where is the damn DM?
2. The challenges DM particle physicists face
   - Theoretically: Two many models → resources split
   - Experimentally, too many backgrounds → some dramas (if not jokes)
3. The opportunities for DM particle physicists
   - New thoughts/actions worldwide
   - My thoughts
4. The progress of the ALETHEIA project
   - ALETHEIA Introduction
   - ALETHEIA prototype detector: the 30g-V1 LHe
   - ALETHEIA prototype detector: TPB coating on a PTFE chamber
   - ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
   - Ongoing tests at CIAE
5. Summary

ALETHEIA

- ALETHEIA: A Liquid hElium Time projection cHambEr In dArk matter.

ALETHEIA

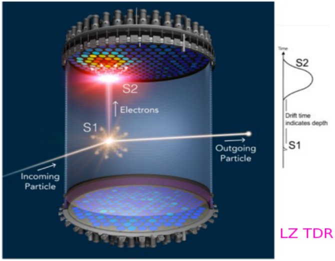
- ALETHEIA: A Liquid hElium Time projection cHambEr In dArk matter.
- TPC is arguably the best technology in the community: LZ, PandaX, XENON; DarkSide, DEAP.



LZ TDR

ALETHEIA

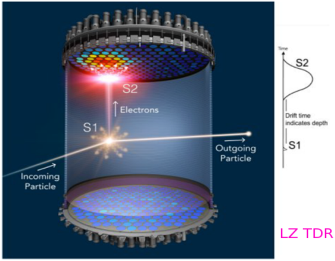
- ALETHEIA: A Liquid hElium Time projection cHambEr In dArk matter.
- TPC is arguably the best technology in the community: LZ, PandaX, XENON; DarkSide, DEAP.
- LHe is arguably the cleanest bulk material: nothing is solvable in LHe except ^{3}He, which is extremely rare in nature.



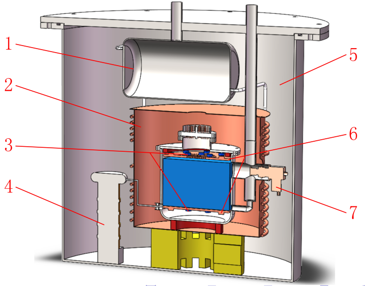
LZ TDR

ALETHEIA

- ALETHEIA: A Liquid hElium Time projection cHambEr In dArk matter.
- TPC is arguably the best technology in the community: LZ, PandaX, XENON; DarkSide, DEAP.
- LHe is arguably the cleanest bulk material: nothing is solvable in LHe except ^{3}He, which is extremely rare in nature.
- A 1.5-m LHe TPC with 1 ton* yr exposure only has 11 ER and 0.5 NR events. Applying 99.5% ER cut and 50% NR cut, only 0.3 events for 1 ton*yr exposure.

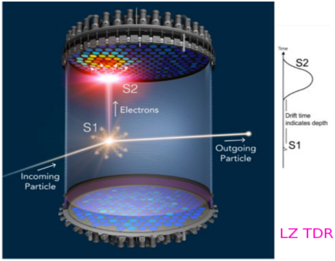


LZ TDR

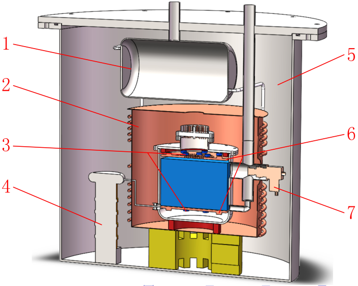


ALETHEIA

- ALETHEIA: A Liquid hElium Time projection cHambEr In dArk matter.
- TPC is arguably the best technology in the community: LZ, PandaX, XENON; DarkSide, DEAP.
- LHe is arguably the cleanest bulk material: nothing is solvable in LHe except ^{3}He, which is extremely rare in nature.
- A 1.5-m LHe TPC with 1 ton* yr exposure only has 11 ER and 0.5 NR events. Applying 99.5% ER cut and 50% NR cut, only 0.3 events for 1 ton*yr exposure.
- For details: Eur. Phys. J. Plus (2023) 138:128.

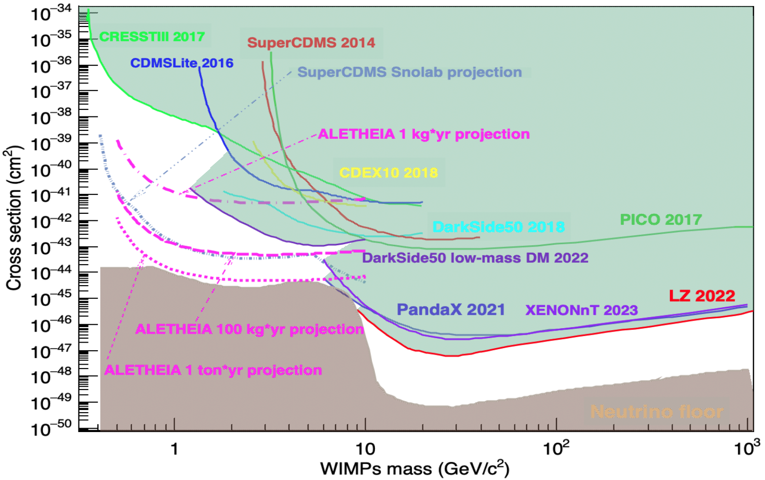


LZ TDR



ALETHEIA NR channel: Projected sensitivities

- 1 ton*yr ALETHEIA can "touch down" the ^{8}B solar ν fog (Assuming IBF, 50% Eff.).



ALETHEIA review, Oct 2019.

ALETHEIA review, Oct 2019.

- *"It is possible that liquid helium could enable especially low backgrounds because of its powerful combination of intrinsically low radioactivity, ease of purification, and charge/light discrimination capability."*

ALETHEIA collaborators so far

5 institutions (increasing), ~ 20 members

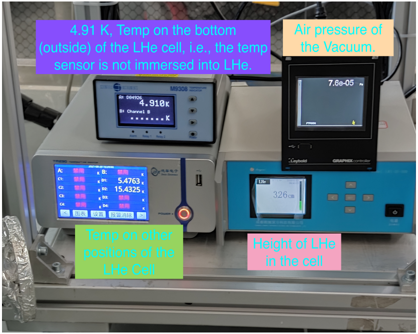
- CIAE (China Institute of Atomic Energy), ~ 10 researchers.
- Peaking University, 1 + 2 (?) researchers.
- University of South China, 1 + 1(?) researchers.
- China Southern Power Grid Electric Power Research Institute, 5 researchers.
- SCRI (Shanghai Cable Research Institute), 3 researchers.

Outline

1. DM “review” (kind of)
   - DM should be there: astrophysicist and cosmologist
   - Particle physicists: where is the damn DM?
2. The challenges DM particle physicists face
   - Theoretically: Two many models → resources split
   - Experimentally, too many backgrounds → some dramas (if not jokes)
3. The opportunities for DM particle physicists
   - New thoughts/actions worldwide
   - My thoughts
4. The progress of the ALETHEIA project
   - ALETHEIA Introduction
   - ALETHEIA prototype detector: the 30g-V1 LHe
   - ALETHEIA prototype detector: TPB coating on a PTFE chamber
   - ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
   - Ongoing tests at CIAE
5. Summary

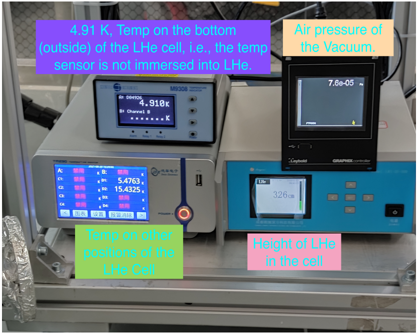
The R&D of the 30g-V1 LHe prototype.

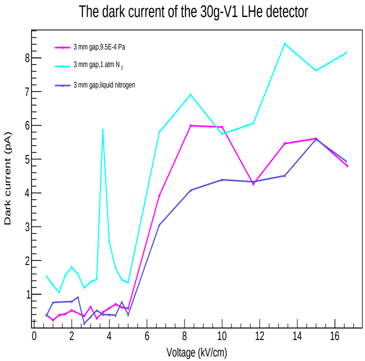
- Left picture: the detector successfully cooled to 4 K.



The R&D of the 30g-V1 LHe prototype.

- Left picture: the detector successfully cooled to 4 K.
- Right plot: dark current is less than 10 pA under several circumstances.



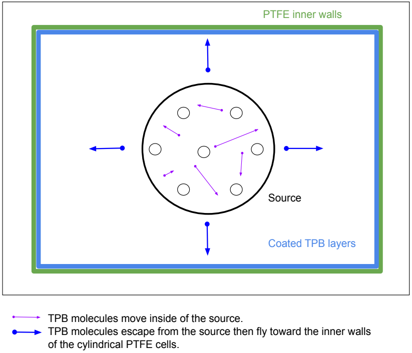


Outline

1. DM "review" (kind of)
   - DM should be there: astrophysicist and cosmologist
   - Particle physicists: where is the damn DM?
2. The challenges DM particle physicists face
   - Theoretically: Two many models → resources split
   - Experimentally, too many backgrounds → some dramas (if not jokes)
3. The opportunities for DM particle physicists
   - New thoughts/actions worldwide
   - My thoughts
4. The progress of the ALETHEIA project
   - ALETHEIA Introduction
   - ALETHEIA prototype detector: the 30g-V1 LHe
   - ALETHEIA prototype detector: TPB coating on a PTFE chamber
   - ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
   - Ongoing tests at CIAE
5. Summary

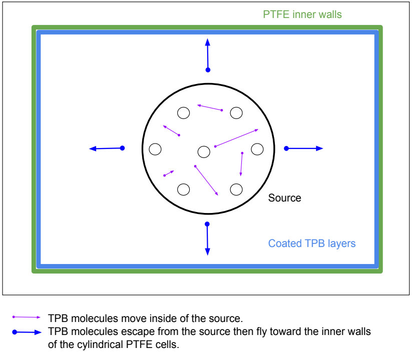
LHe light peaked 80 nm, TPB to convert into visible light.

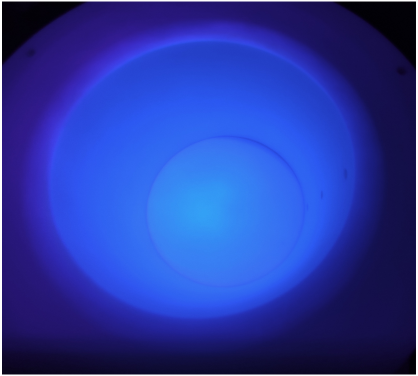
- Left picture: the principle of TPB coating.



LHe light peaked 80 nm, TPB to convert into visible light.

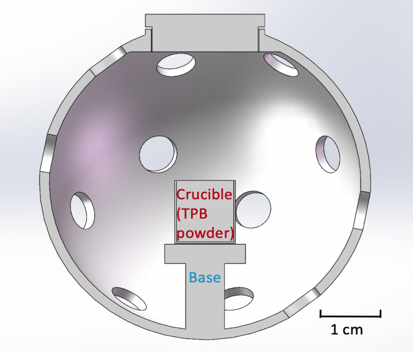
- Left picture: the principle of TPB coating.
- Right plot: top view of the coated 10-cm size PTFE chamber.
- Published: Acta Phys. Sin. Vol. 71, No. 22 (2022) 229501





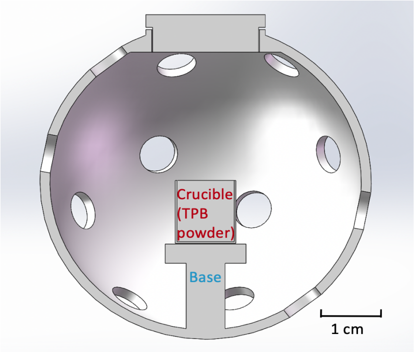
The coating source.

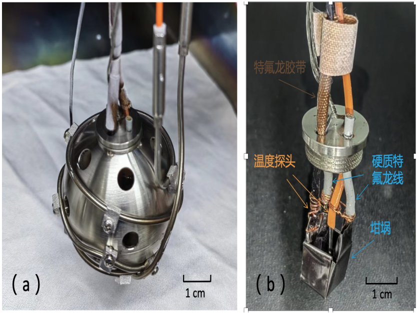
- Left picture: The source's drawing.



The coating source.

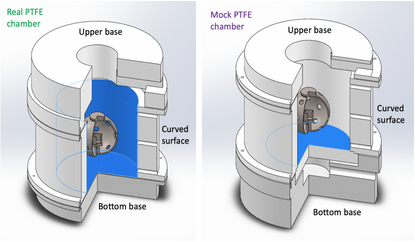
- Left picture: The source's drawing.
- Right plot: The image of the source.





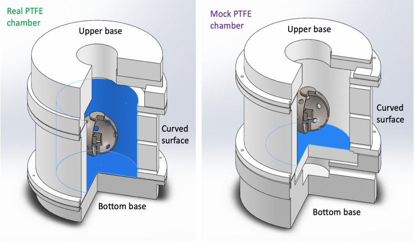
Coating process.

- Left picture: Coating into steps.



Coating process.

- Left picture: Coating into steps.
- Right plot: real time monitoring on TPB thickness.



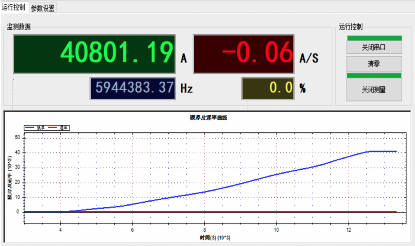


Figure out the TPB coating thickness.

- Left picture: sample films inside of the chamber.

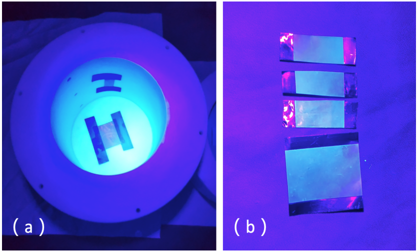
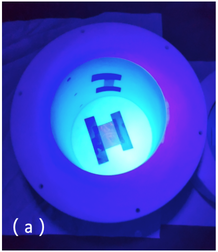


Figure out the TPB coating thickness.

- Left picture: sample films inside of the chamber.
- Right plot: calculate TPB's thickness based on the mass difference.



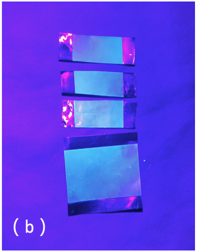


表 1　根据涂覆前后的质量差计算的 TPB 涂覆厚度

Table 1.　TPB coating thickness calculation based on the mass difference before and after coating on the aluminum plates.

编号	测试面积/cm^2	铝片安装位置	试验前后增加质量/mg	膜厚/μm
1	2	工装内壁	0.75 ± 0.02	3.48 ± 0.11
2	2	工装内壁	0.46 ± 0.04	2.13 ± 0.17
3	2	小室桶壁	0.87 ± 0.04	4.03 ± 0.16
4	6	小室底面	2.54 ± 0.02	3.92 ± 0.03

Figure out the TPB coating thickness.

- Left picture: sample films inside of the chamber.
- Right plot: calculate TPB's thickness based on the mass difference.
- The third method to figure out TPB's thickness is based on the TPB mass consumed, 0.2 g.
- All of the three methods returned consistent thickness.

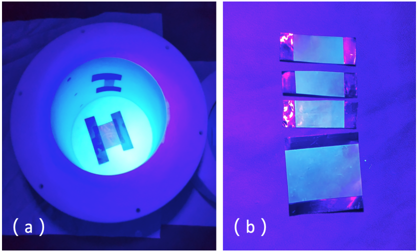


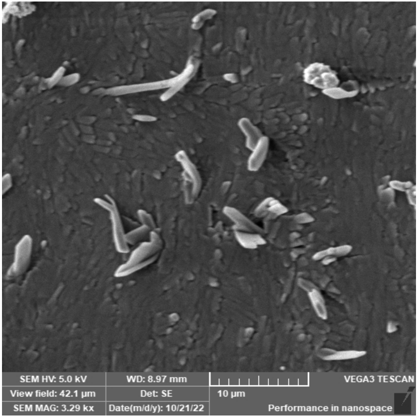
表 1　根据涂覆前后的质量差计算的 TPB 涂覆厚度

Table 1.　TPB coating thickness calculation based on the mass difference before and after coating on the aluminum plates.

编号	测试面积/cm^2	铝片安装位置	试验前后增加质量/mg	膜厚/μm
1	2	工装内壁	0.75 ± 0.02	3.48 ± 0.11
2	2	工装内壁	0.46 ± 0.04	2.13 ± 0.17
3	2	小室桶壁	0.87 ± 0.04	4.03 ± 0.16
4	6	小室底面	2.54 ± 0.02	3.92 ± 0.03

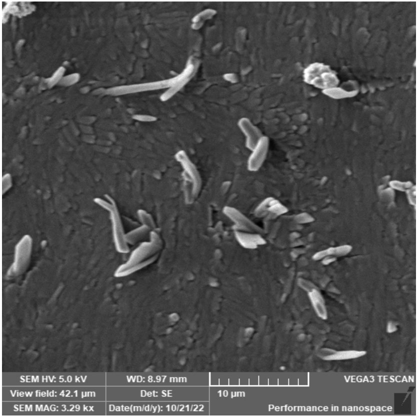
TPB coating film, exposed at 4 K.

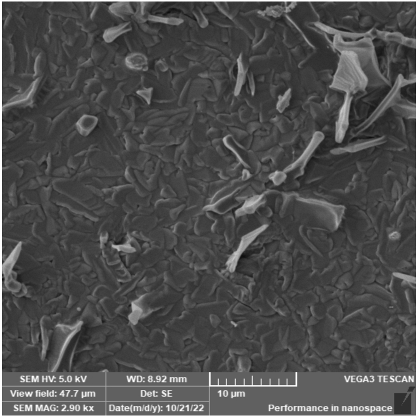
- Left picture: SEM scanning imagine on TPB coated film experienced at 4 K.



TPB coating film, exposed at 4 K.

- Left picture: SEM scanning imagine on TPB coated film experienced at 4 K.
- Right plot: SEM scanning imagine on TPB coated film W/O cryogenic experience.
- Published in JINST, 2022 JINST 17 P12001.



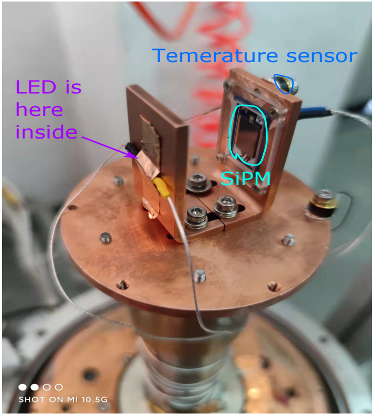


Outline

1. DM “review” (kind of)
   - DM should be there: astrophysicist and cosmologist
   - Particle physicists: where is the damn DM?
2. The challenges DM particle physicists face
   - Theoretically: Two many models → resources split
   - Experimentally, too many backgrounds → some dramas (if not jokes)
3. The opportunities for DM particle physicists
   - New thoughts/actions worldwide
   - My thoughts
4. The progress of the ALETHEIA project
   - ALETHEIA Introduction
   - ALETHEIA prototype detector: the 30g-V1 LHe
   - ALETHEIA prototype detector: TPB coating on a PTFE chamber
   - ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
   - Ongoing tests at CIAE
5. Summary

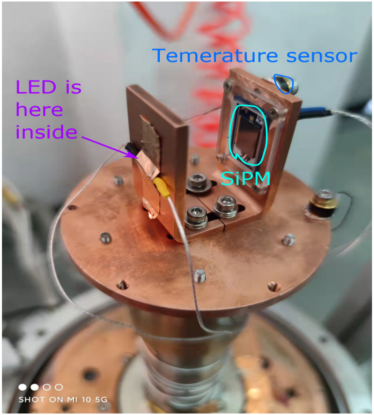
SiPMs tests at 4 K, with a LED

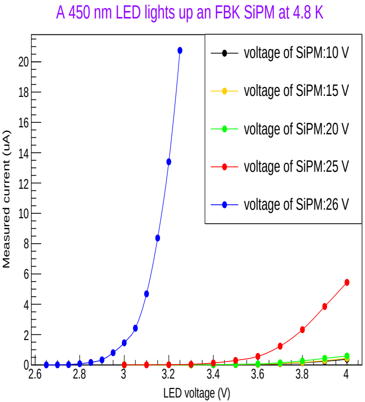
- Left picture: experimental setup (Inside of the G-M cryocooler).



SiPMs tests at 4 K, with a LED

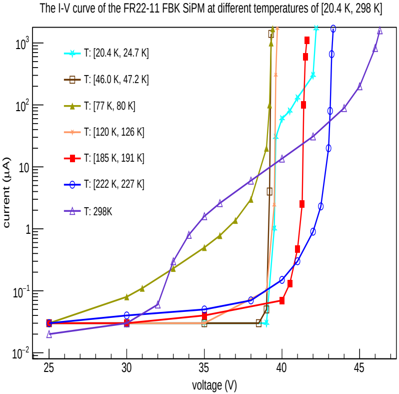
- Left picture: experimental setup (Inside of the G-M cryocooler).
- Right plot: Preliminary results.





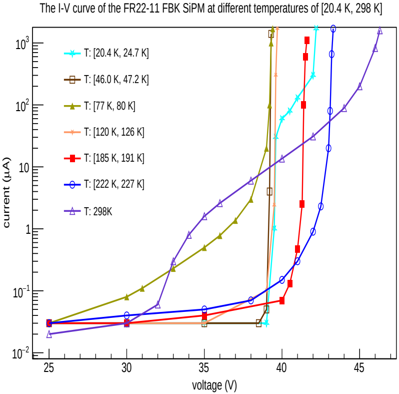
SiPMs test at 4 K, IV curve measurement

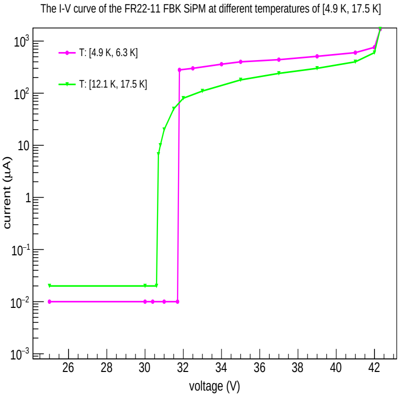
- Left picture: SiPMs IV curve tests, 20 K - RT.



SiPMs test at 4 K, IV curve measurement

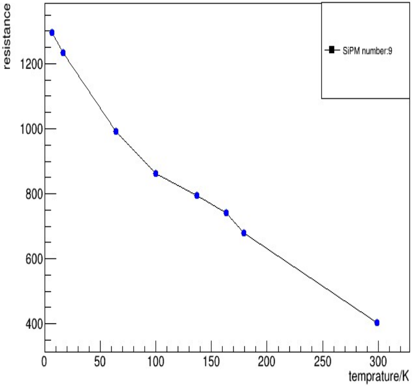
- Left picture: SiPMs IV curve tests, 20 K - RT.
- Right plot: SiPMs IV curve tests, (4 - 20) K, 10 V plateau existed.





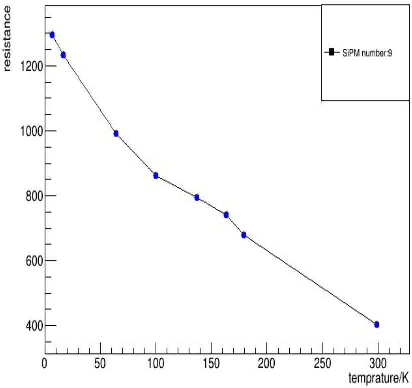
FBK SiPM: resistance VS temp, and Drop voltage VS Temp.

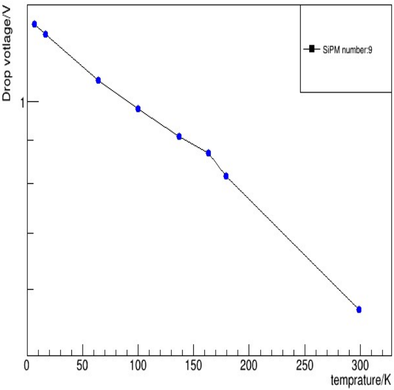
- Left picture: FBK SiPM, resistance VS temp.



FBK SiPM: resistance VS temp, and Drop voltage VS Temp.

- Left picture: FBK SiPM, resistance VS temp.
- Right plot: FBK SiPM, voltage VS temp.





FBK SiPM @ 4 K, typical analog signal.

SiPMs tests at 4 K, resistance and voltage upon $R_s@V_BD$.

- 38 FBK SiPMs tested. Most (36/38) of FBK SiPMs are functional at 4 K. More detailed: Eur. Phys. J. Plus (2023) 138:128.

SiPM 编号	暗噪声测试实验			
	测试温度（K）	暗噪声信号	正向电阻（Ω）	导通电压（V）
FR21-5	7.7	正常	1214	1.184
FR21-6	7.5	正常	1546	1.357
FR21-8	7.9	正常	1122	1.132
FR22-1	4.5	正常	1176	1.165
FR22-2	4.3	正常	1241	1.18
FR22-3	4.2	正常	1234	1.198
FR22-4	4.4	正常	1234	1.197
FR22-5	4.6	正常	1199	1.177
FR22-6	5	异常	1650	1393

Outline

1. DM “review” (kind of)
   - DM should be there: astrophysicist and cosmologist
   - Particle physicists: where is the damn DM?
2. The challenges DM particle physicists face
   - Theoretically: Two many models → resources split
   - Experimentally, too many backgrounds → some dramas (if not jokes)
3. The opportunities for DM particle physicists
   - New thoughts/actions worldwide
   - My thoughts
4. The progress of the ALETHEIA project
   - ALETHEIA Introduction
   - ALETHEIA prototype detector: the 30g-V1 LHe
   - ALETHEIA prototype detector: TPB coating on a PTFE chamber
   - ALETHEIA prototype detector: (preliminary) SiPMs tests at 4 K.
   - Ongoing tests at CIAE
5. Summary

A 10-cm chamber, ~ 100 g LHe prototype detector is assembling.

A 10-cm chamber, ~ 100 g LHe prototype detector is assembling.

Summary

- DM sector might have more than one elemental particle. DM signals not necessary to show up as NR recoil only: ER only and ER&NR coexistence also possible.
- ALETHEIA project is supposed to only have single-digit number of ER and NR backgrounds with a 1 ton*yr exposure, therefore, be sensitive to any kinds of DM signal combinations.
- We demonstrated the viability of a single-phase LHe TPC. The R&D on a dual-phase LHe TPC is underway.

Summary

- DM sector might have more than one elemental particle. DM signals not necessary to show up as NR recoil only: ER only and ER&NR coexistence also possible.
- ALETHEIA project is supposed to only have single-digit number of ER and NR backgrounds with a 1 ton*yr exposure, therefore, be sensitive to any kinds of DM signal combinations.
- We demonstrated the viability of a single-phase LHe TPC. The R&D on a dual-phase LHe TPC is underway.

Summary

- DM sector might have more than one elemental particle. DM signals not necessary to show up as NR recoil only: ER only and ER&NR coexistence also possible.
- ALETHEIA project is supposed to only have single-digit number of ER and NR backgrounds with a 1 ton*yr exposure, therefore, be sensitive to any kinds of DM signal combinations.
- We demonstrated the viability of a single-phase LHe TPC. The R&D on a dual-phase LHe TPC is underway.